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PS Count-Down Checklist Worksheet

PX # from figure 2	Count down days	This is a list of the most likely sequence of events based on user chosen end date. Use this pole shift count-down checklist worksheet template to keep track of your observations and to help predict expected results. Enter the estimated date for pole shift in cell D2 and the rest of the dates will be auto-calculated. The sequence of events is a human understanding of the clues left by the Zetas of http://www.Zetatalk.com/.	Expected Date	Your Observed Date
1		Put your estimated Pole Shift date into the blank on the right. For example: 28 May 18, etc.	28-May-18	
1		Note: These sequences do not include any of the un-predictable warning times when the ET's are exaggerating the Earth wobble, producing high tides, and sloshing of the ocean. This done like a diner bell, to wake up those on the planet that a Pole shift is coming and is near at hand.		
1		Two years after the PS (pole shift), due to melting polar caps, and many other factors, sea levels will rise, an estimate some 675 feet above current levels. Choose your location with this in mind.		
1	52	PX will get to be almost the size of the moon at the time of passage at 14 million miles away. At all times, it is expected to be red to deep red, and may never be a distinct image due to all of the red iron oxide dust around it.	6-Apr-18	
1	51	7.3 weeks the before pole shift, **PX is starting to be visible to naked eye**: First as faint reddish blur, later to look like a cross, then eventually as a winged globe with comet like tail and swirling moons.	7-Apr-18	
1	50		8-Apr-18	
1	49	Its now 7 weeks before PS. During this time frame many more will start to see PX for the first time. Look for it just as soon as it is dark and in the direction of the sunset near the ecliptic (path of sun and planets along an east west direction).	9-Apr-18	
1	48		10-Apr-18	
1	47		11-Apr-18	
1	46		12-Apr-18	
1	45		13-Apr-18	
1	44		14-Apr-18	
1	43	Expect most will be able to see PX with the naked eye around this date.	15-Apr-18	
1	42		16-Apr-18	
1	41		17-Apr-18	
1	40		18-Apr-18	
1	39		19-Apr-18	
1	38		20-Apr-18	
1	37		21-Apr-18	
1	36		22-Apr-18	
1	35		23-Apr-18	
1	34		24-Apr-18	
1	33		25-Apr-18	
1	32		26-Apr-18	
1	31		27-Apr-18	
1	30	.	28-Apr-18	
1	29		29-Apr-18	
1	28		30-Apr-18	
1	27		1-May-18	
1	26		2-May-18	
2	25	**Start of 18 day of Earth Slowing Rotation.** This is the start of a 270 degree roll of earth's axis that ends with rotation stoppage and the pole shift.	3-May-18	
2	24	**Look for PX to be close to the sun**. PX passes close to the sun on or near this date	4-May-18	
2	23		5-May-18	
2	22		6-May-18	
3	21		7-May-18	
3	20		8-May-18	
3	19	At some point the **sun appears to rise in the North east, and set in the south west**.	9-May-18	
3	18	Earth's north axis tilts a bit back toward the sun.	10-May-18	

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3	17		11-May-18	
4	16	**9 days of Severe Wobble**. Strong winds, and sloshing water (oceans) result.	12-May-18	
4	15	**Start of 3 Days of darkness for the Northern hemisphere. PX crosses ecliptic to make Zeta triangle.** PX's tale sweeps across earth, red dusting, waters turn red.	13-May-18	
4	14	The Earth changes will increase dramatically. Devastating quakes, collapsing cities, monstrous tidal waves, and disruption of services - power, gas, water, and phone. Bridges will be down, roadways torn, the atmosphere so volatile that planes cannot be safely lofted.	14-May-18	
5	13		15-May-18	
6	12	**6 days of Sunrise West**. Earth is upside down continuing to rotate in the same direction.	16-May-18	
6	11	For near side of the sun **Venus orbit crossing,** if it is predicted to occur for this date, look in the direction of Venus. PX should be close to it as it passes by on or near this date.	17-May-18	
6	10		18-May-18	
6	9		19-May-18	
6	8		20-May-18	
6	7	Slowing rotation will be such that over two days, one will notice minutes lost, then hours then stopped. The most probable stopped orientation would be with Earth's south direction, or southern hemisphere pointed toward the sun with the Atlantic trench facing PX. The Northern hemisphere would be mostly in twilight and/or darkness.	21-May-18	
7	6	**Stopped: 6 (5.9) days of NO earth rotation on its axis**. Earth is groaning, and making noises as geological changes take place throughout the world. The core is trying to turn and the curst is held magnetically at the Atlantic trench facing PX. Plate slippage is taking place in a direction away from the Atlantic trench.	22-May-18	
7	5	All travel and traffic will be stopped, all communications down, the world frozen in horror, waiting for the next blow. The Earth is stopped in it's orbit around the sun, now being drawn in closer to PX.	23-May-18	
7	4	Cities imploding, bridges and roadways and rail lines distorted, all the infrastructure of man's civilized existence rupturing.	24-May-18	
7	3	Earth is hot on sun side and cold on the dark side. Increased wind helps stabilize temperature.	25-May-18	
7	2	Endless moaning and a continuously trembling Earth. Strong and unusual windstorms.	26-May-18	
7	1	**Red dusting is a countdown clue**, that only hours remain. Hailstones and firestorms may follow the red dusting (Iron oxide) and are another clue of only hours to the shift.	27-May-18	
8	0	**The Pole shift** with high magnitude earthquakes (9-10+), and hurricane winds (approximate 100 MPH) is over in slightly less than 1 hrs time. New north pole is just off the cost of Brazil. New south pole is off the cost of India. At first there is a vibration of sorts, a jiggling, as the crust separates in various places from the core. Then there is a Slide, where the crust is dragged, over minutes, to a new location, along with the core. During the slide, tidal waves move over the Earth along the coast lines, as the water is not attached and can move independently. The water and the atmosphere tends to stay where it is, the crust moving under it, essentially. When the core finds itself aligned, it churns about somewhat, settling, but the crust, more solid and in motion, proceeds on. This is in fact where mountain building and massive earthquakes occur, just as car crashes do their damage on the point of impact, when motion must stop. See shallow trench covered with sheet metal (http://www.zetatalk2.com/poleshft/p177.htm) as a recommended way to survive.	28-May-18	
9	1		29-May-18	
9	2	Earth's rotation starts as PX rapidly moves on out.	30-May-18	
		For more details on what to do read Zetatalk preparation help http://www.zetatalk.com/index/help.htm**, safe locations advice** http://www.zetatalk.com/info/tinfo242.htm **and pole shift** http://www.zetatalk.com/poleshft/p00.htm		
		See Zetatalk after-time http://www.zetatalk.com/xtime/x00.htm **and transformation** http://www.zetatalk.com/transfor/t00.htm **files for details of what happens next.**		
		See TT (Troubled Times) http://www.zetatalk.com/thub00.htm **and** http://www.pssurvival.com/ **for long term survival information.**		

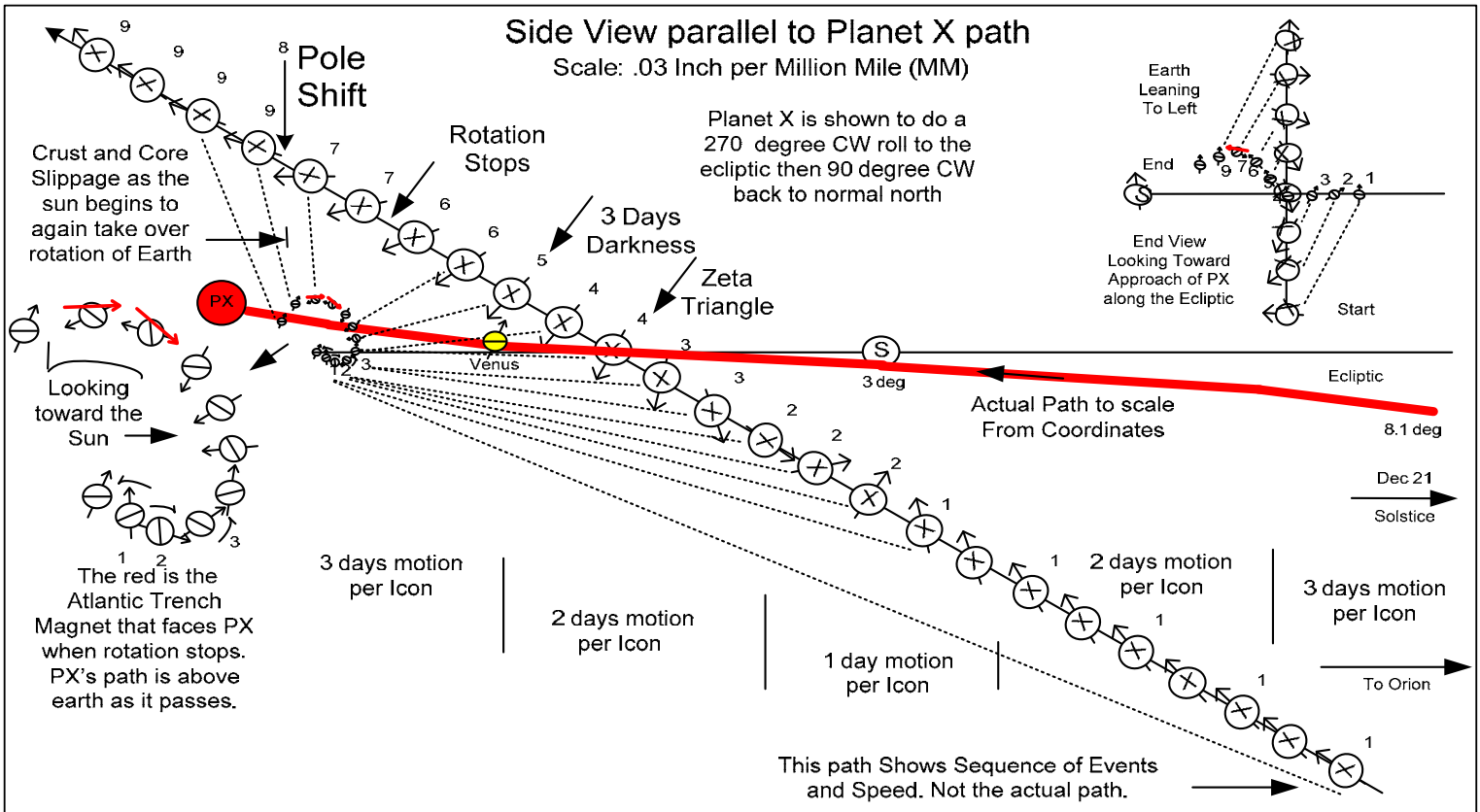

Figure 1: **Side View of Sequence of Events**

Figure 1 Shows a side, and end view of the sequence of events. The red path for PX is drawn roughly to scale, to show how close Venus, and PX come to each other, and how close PX gets to earth. Earth is expected to be pulled around a bit in its orbit, as show in the expanded view of earth's movement. The diagram shows PX passing though earth's motion icons. This is not true to scale. It was't able shrink it down enough on this diagram and still see where the stages are. Consider this much smaller in motion and that PX passes over the top and to the left side of earth (facing the sun). Figure 5 and 6 show this better. Note the red arrow pointing in the opposite direction from earth's poles. This represents the magnetized iron in the Atlantic trench, that cause a shift in earth's orientation (180 degree end for end flip of the earth) during the 6 days the planet has stopped rotating. The sequence of events line, shows functionally what happens with coupling magnetic fields for earth and PX (X). It also shows the effect of the suns magnetic field on PX. PX speeds up as it gets close to the sun, and slows down after the sun. .

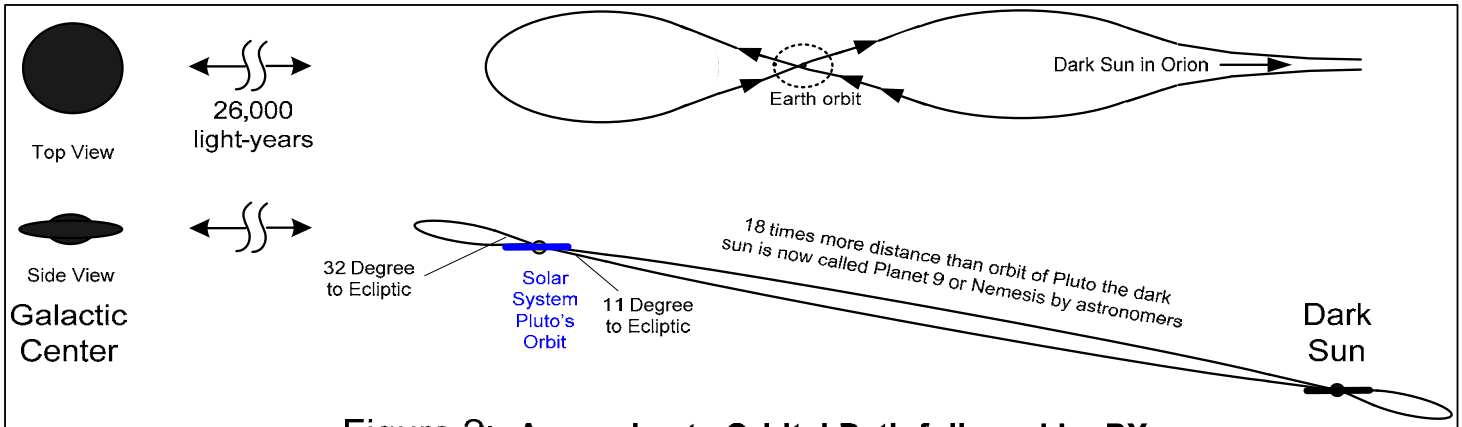

Figure 2: **Approximate Orbital Path followed by PX**

Figure 2 shows the overview orbit of PX between our sun and the dark twin star. According to the Zetas we are a two star or binary system with one lit an one dark or not lit star of about equal size. The blue orbit is Pluto. The orbit of PX crosses over the return obit, just after passing the sun on it's approach.

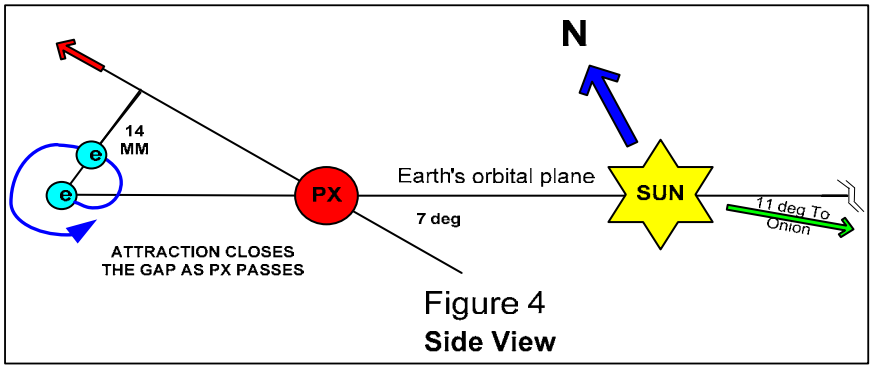

Figure 4
Side View

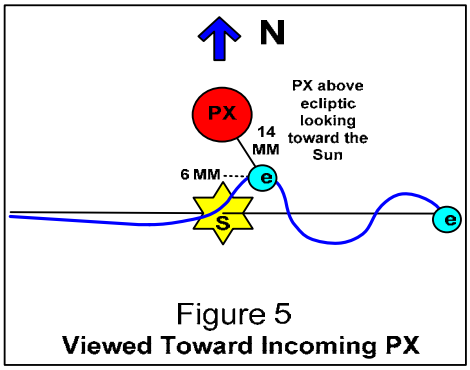

Figure 5
Viewed Toward Incoming PX

Figure 4 and 5 shows the path of PX as it comes in from Orion. The earth's dark twin is pulled toward PX, or further along in its orbit around the sun, nearer to incoming PX path as PX approaches earth's orbit. This speeds the twin up, so it can come closer to Earth latter on. PX passes the sun, and goes on to make the Zeta triangle at the ecliptic, and then passes Venus resulting in a Pole Shift as it passes earths orbit. There are lots of forces and timings in play beyond what can be estimated at, at this time, thus the date is given plus or minus a week or so. Figure 4 and 5 also shows how the earth is pulled out of it's orbit from various views.

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Construction Manual for 12PU350 and 12PU500 Windmills

by Niek Van de Ven

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CONSTRUCTION MANUAL

OF 12 PU350 AND 12 PU500 WINDMILLS BY NIEK VAN DE VEN

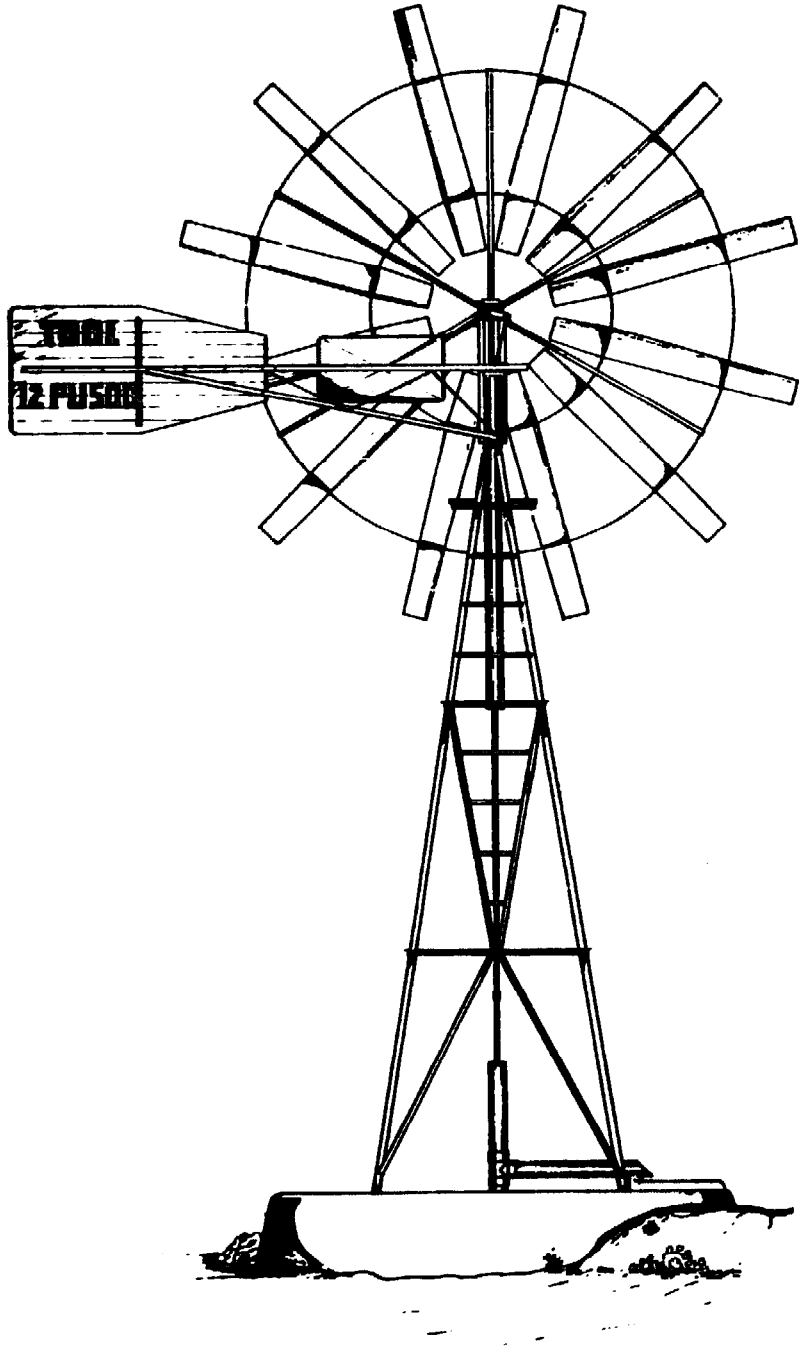

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Acknowledgement

The Netherlands assistance in the windmill projects in Ghazipur and Allahabad officially stoppéd at the end of March 1981. It was recognized by the project management committee that the experiences of the experts in these projects should be recorded. Finally it was agreed that the financing of this activity took place trough the Steering Committee Windenergy Developing countries (SWD). This is a government financed organisation promoting the interest for wind energy in developing countries and aims at helping governments, institutions and private parties in the Third World with their efforts to utilize wind energy.

The author is very grateful to all parties concerned that the experiences could be materialized in this publication. It is hoped that it will contribute to the extention of development in many countries.

NIEK VAN DE VEN

TOOL is a Dutch foundation participating in the global process of renewable development and application of socially appropriate technologies.

The broad objective is to promote greater freedom for groups which are deprived of full opportunities for local, self-programmed and self-sustained development.

The strategy is to provide and support information resource links among the practitioners, users and generators of appropriate technology for development.

The operations of TOOL are designed to match need and resource:
- technical advice and support
- research and development
- publications
- documentation systems and services
- applicstion projects
- education and training
- organisational linkages.

WOT is a non-profit organisation at the Twente University of Technology and gives technical advice in the field of wind energy, solar energy and water supply. The broad objective is to improve the position of the weaker sections in society and the advice should be appropriate to the local situations and circumstances. To support the technical advice the WOT has a testing field where various designs are being developed and tested. The WOT is mainly a voluntary organisation and consists mainly of students of the university. Several staffmembers take care for the administrative and technical support.

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Material requirement; 12PU350 Appendix I

Material requirement; 12PU500 Appendix II

Introduction

No doubt a lot of research is going on nowadays in the field of windmill technology: fuel prices are still driven up day-by-day changing the economic feasibility of many machines and equipment.
Moreover we become more and more aware that the current fuel resources like gas, coal and crude oil are rapidly depleting while their exploitation encounters increasing practical constraints.

This brief introduction is not meant to create the impression that the application of wind energy will be the final answer to future energy problems. On the contrary: the common energy consumption per head in the West has reached such a level that for example in the Netherlands thousands of huge windmills are to be installed at the windy shore of the country, necessary just to cover a few percent (say 5 or so) of the actual need of energy.
Moreover it will be doubtful whether the initial energetic investment in such an enterprise will ever be "paid back" during the actual lifetime of such remarkable generators.

Does it mean that there is no future for the windmill? Of course there is, which can be illustrated by the fact that in the past and still at the present windmills proved to serve their purpose very well as far as limited power conversion is concerned, especially in places where power distribution is poor, fuel is too expensive or even not available at all. In spite of the recent low fuel prices the windmill has never been defeated totally and as a matter of fact a great revival of the windmill is at the doorstep now since the use of its competitors becomes less attractive due to scarcity of the conventional fuels and their price politics in particular.

The latter development (though partly expected, but not fully foreseen) has strengthened some people who have taken up the windmill technology for further development and especially concerning its adoption in local circumstances.
This manual resulted from the developing process of windmills which was initiated by experts of the Dutch TOOL - foundation in close cooperation with the Organisation of the Rural Poor (ORP) in Ghazipur and the Allahabad Polytechnic Allahabad (U.P.) India.

From December 1977 on a 12-bladed Pumping Unit of 500 cm rotor-dia (12 PU 500) evolved overthere and in later stages also designs of the 12 PU 350, 12 PU 250 and 12 PU 700 have been derived. These windmills are supposed to be fabricated locally with a minimum of advanced equipment.

This building manual deals with the 12 PU 350 and 12 PU 500 windmills while the 12 PU 250 and 12 PU 700 are still under development.

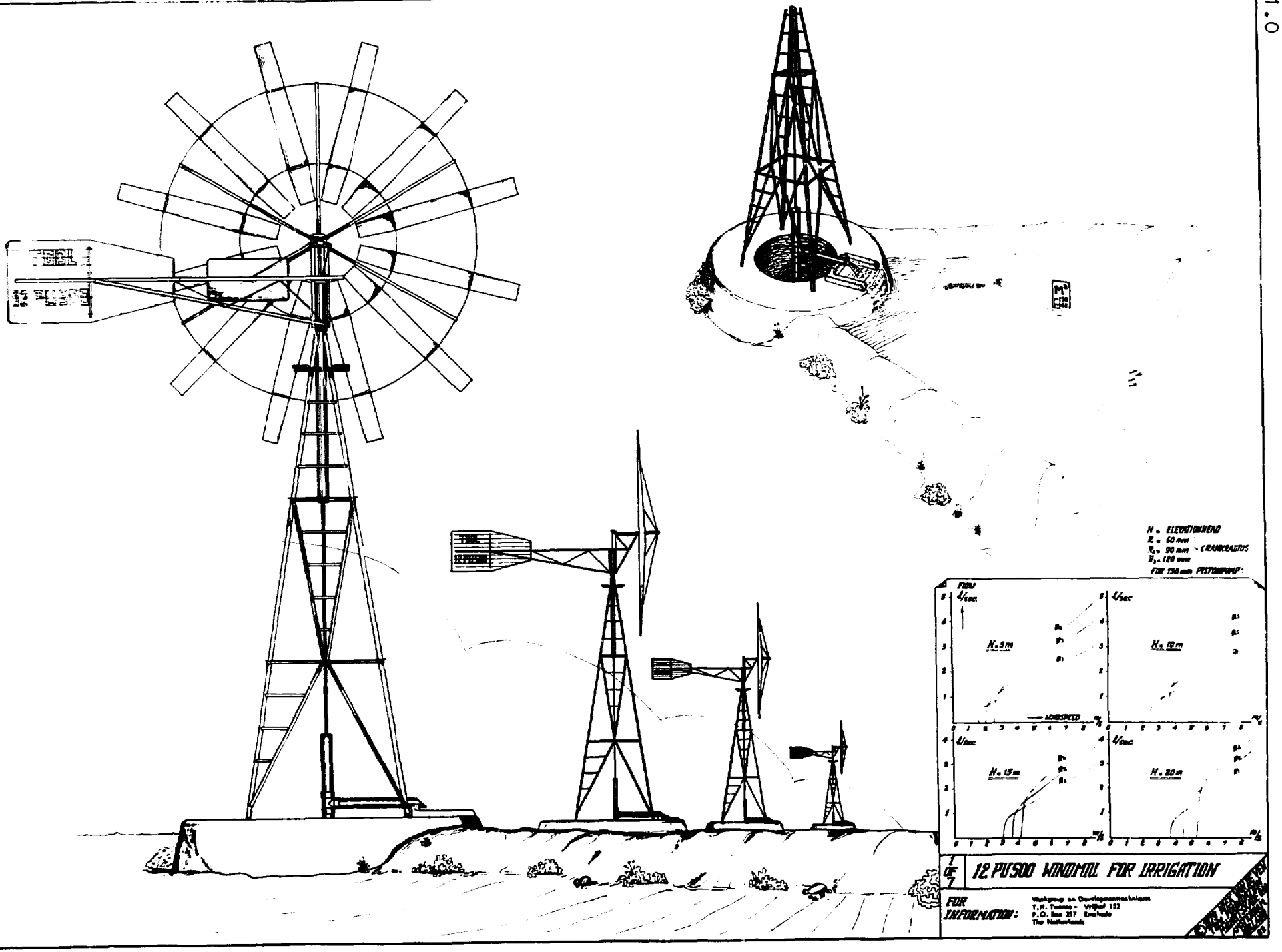
H = ELEVATION HEAD
Z = 60 mm
Y1 = 90 mm
Y2 = 120 mm
CRANKRADIUS
FOR 150 mm PISTONPUMP:
FLOW
l/sec
H = 5 m
H = 10 m
H = 15 m
H = 20 m
m/s
1 OF 7
12 PU500 WINDMILL FOR IRRIGATION
FOR INFORMATION:
Workgroup on Development Techniques
T.H. Twente - Vrijhof 152
P.O. Box 217 Enschede
The Netherlands

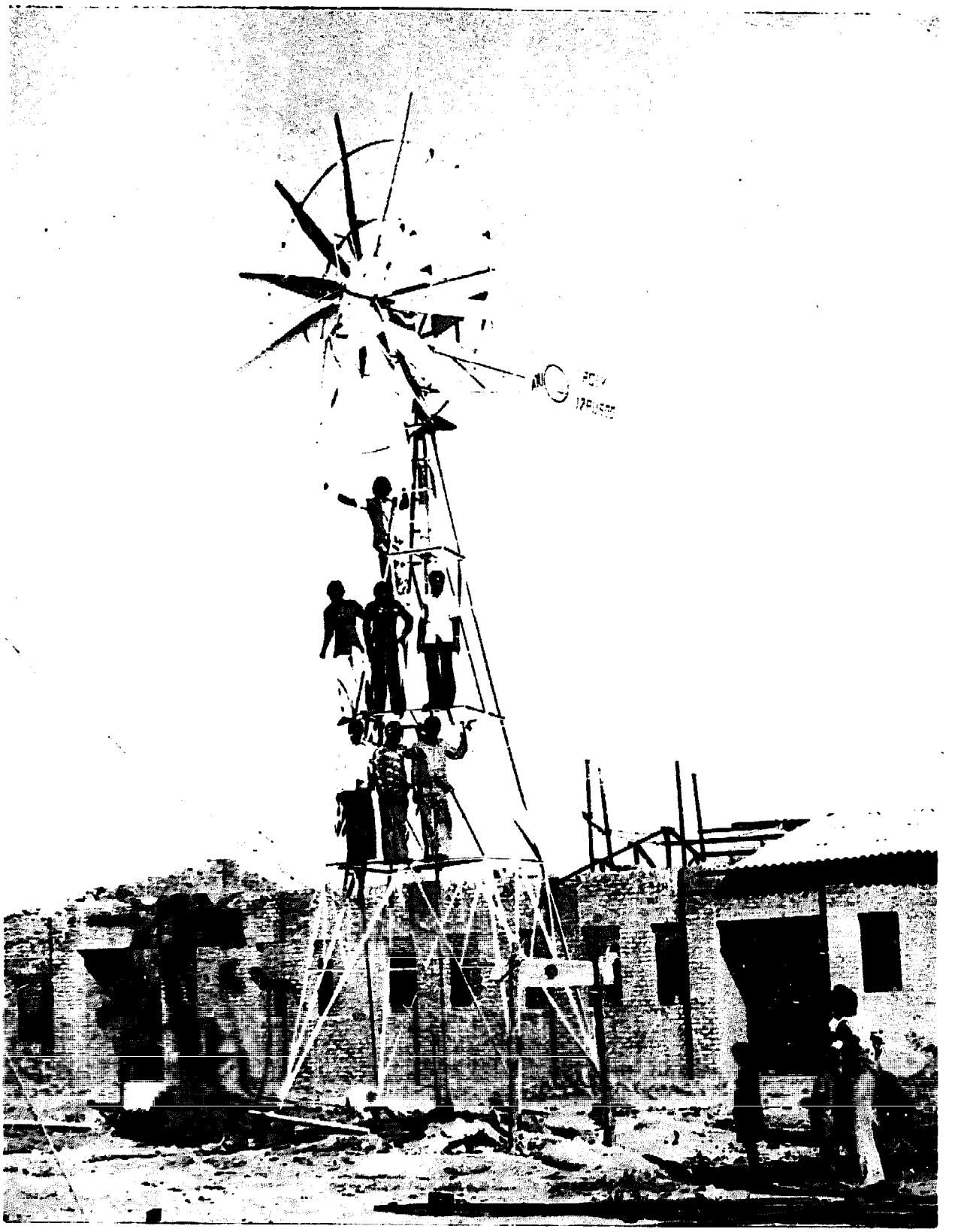

A 12 PU 500-windmill being installed for drinking water supply (February 1980, Gohri near Allahabad, U.P. India).

1. The 12 PU 350 and 12 PU 500 windmill for irrigation

These windmills have been developed especially for irrigation purposes. They operate in windy places and convert a certain part of the offered windenergy into mechanical power.
This mechanical power is led via a crankmechanism to a single-acting piston pump, which lifts the water from shallow wells or tube wells to ground level. Generally the lifted water is stored in a basin in order to save it during day-time so a regular flow can be obtained for an increased efficiency. Usually the irrigation is carried out during sunset, since the evaporation of the irrigation water is less than in daytime. The amount of irrigation water needed depends on the climatological conditions, the soil structure and the crop pattern, so the size of the command area is restricted by these and the capacity of the windmill.

The construction of the windmill is that simple that it can be prefabricated by blacksmiths using the materials and equipment which are available locally in India.
Maintenance is restricted to greasing some essential moving parts from time to time, which can be carried out by the owner (farmer) himself. The windmill is secured automatically against storms: if severe storms appear the windmill turns out of the wind and will remain in that position till it is reset manually. Meanwhile it is a great opportunity to inspect and lubricate the moving parts.

1.1. Capacity of the windmill

Since the capacity of the windmill depends on the availability of the wind the latter is very important in order to make estimates of the output. Therefore it is preferred to study the wind data of the area which have been measured in former years. Probably these data can be obtained from local institutes or

airports.

The essential thing of these winddata is the duration in hours of certain windspeed ranges during a year in the form of histograms, in order to estimate the capacity of the windmill. The figure shows an example of these histograms.

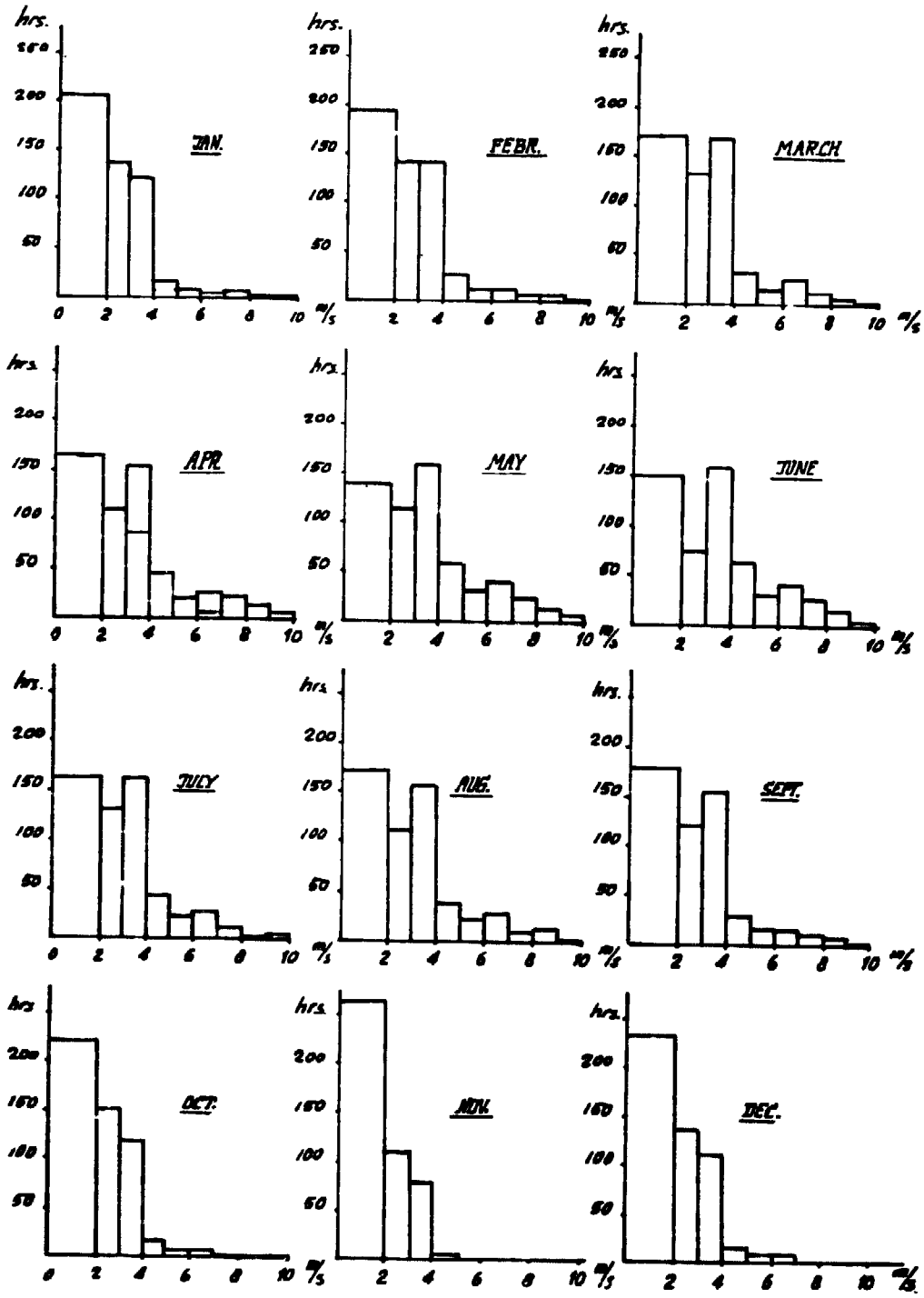

Since there are various power-losses due to some properties of the windmill-pistonpump combination the extracted windpower will be converted partly into a nett delivered water flow. Next figures show the quantity of water delivery in litres per second in case of four different elevation heads (5 m, 10 m, 15 m and 20 m) if the windmill concerned is fitted with the standard piston pump (see chapter 6).

12 PU 350

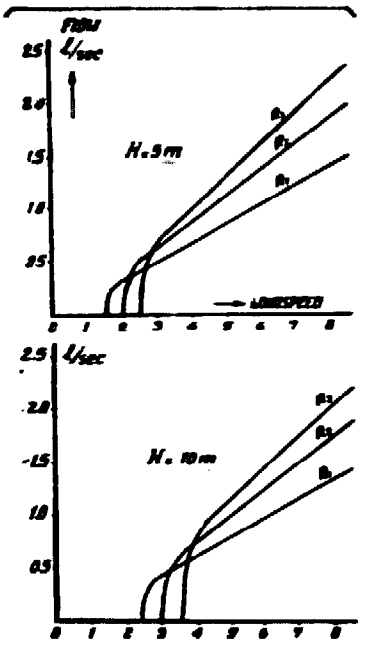

12 PU 500

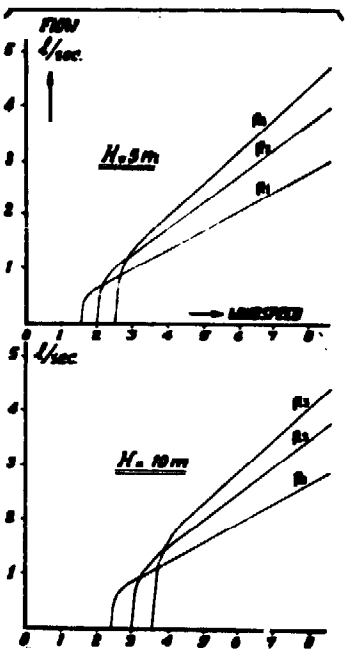

The adjustable crank radius provides three different stroke volumes of the piston pump, so the windmill can be loaded suitably within the actual circumstances. It will be evident that a higher chosen value of the crank radius will influence the starting wind speed and the output as well.

Considering the wind data obtained the monthly number of hours of certain ranges of wind speeds (0-1 m/sec, 1-2 m/sec, 2-3 m/sec. etc.) are calculated: this is done for all the ranges up to 12 m/sec. since the windmill stops operating above this value of wind speeds due to the automatic security device.
In relation with the flow-windspeedgraphs the expected water delivery per month can be estimated. Since fluctuations in wind speed and wind direction will cause a lower result, the estimated monthly delivery can be multiplied by a factor 0.7

or 0.8 in order to achieve a more valid estimation.

Now it is possible to define the crop pattern and the maximum size of the command area which will be under windmill irrigation.

1.2. The well and the storage tank

One has to be sure, whether the capacity of the well will be sufficient with regard to the expected peak windmill capacity. As far as just a shallow well is going to be applied the windmill pump will start sucking air if the well is not able to deliver the amount of water needed. This effect will not harm the pump; only airbulbs will be transported through the water column which is kept in the pump and delivery pipe. But if a tube-well is "overdrawn", much sand will be transported by the lifted water and a quickly worn out pump will be the result due to aggressive sand particles. Therefore one has to be sure, whether a tube well can deliver the peak capacity of the windmill.

Generally the pump section is installed near or below the water level in order to maintain a low suction head. In practice this suction head must not be higher than appr. 7 m. in order to prevent cavitation.

Applying a narrow tube-well (e.g. 4") in combination with an existing shallow well (see chapter 6) sufficient space is available for a proper installation of the tube well section near or even below the static water level. In this case the existing well casing provides a solid foundation for the windmill and pump anchors. The exhaust aperture of the pump is preferably situated in such a way that people can easily do the wash or tap some (drinking) water, since this will be done definitely. A simple accomodation, which is built from bricks, will prevent people from damaging the outlet pipe. Also a struc-

ture of bricks is demanded for an erosion-free guidance and a proper entrance of the water flowing into the tank.

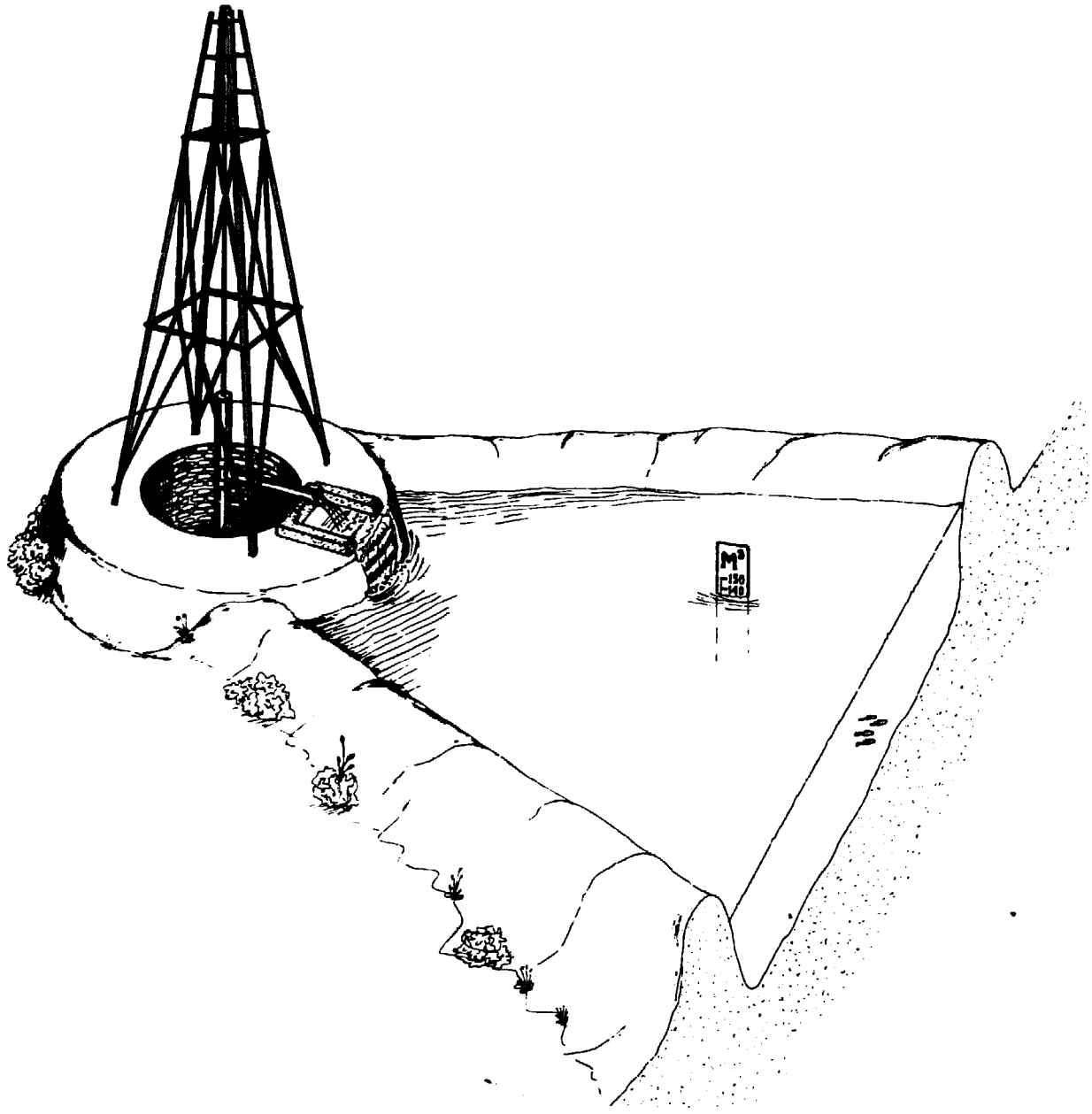

Usually the tank is composed of walls of appr. 1 m high, which are built from the surrounding soil. The contents of a storage tank amount from 50 to 150 m^3 depending on the expected need and area available which can be suitably occupied by the tank.

If the soil has sufficiently high clay content no extra provisions are required with regard to the expected seepages, but if these seepages are not to be neglected it is advisable to plaster the mud-walls with bricks. Under certain conditions the application of a plastic-foil will decrease the seepage definitely.

Due to erosion the unmasoned walls will be damaged in the environment of the water-line which can be prevented by growing grass in these particular places. Of course an overflow will be necessary in connection with the erosion mentioned before.

To release the water out of the tank an outlet pipe, fitted with a valve, will serve the purpose but the disadvantage is that people or playing children may open the valve and release the water which flows to the field uncontrolled. Using a 2½" hose as a siphon the released water can be tapped in any place of the tank and is guided into one of the several irrigation-ditches. As mentioned before this irrigation is carried out during sunset in order to limit the evaporation of the irrigation-water.
In certain cases fish-rearing or growing waterlilies (for cattle-feeding) can be attractive in order to make the total windmill installation more profitable.

1.3. Required skill, equipment and materials.

This simple windmill construction can be realized easily with the local skills, machines and materials. Therefore the required machines are restricted to a turning-lathe, a drilling machine and an electrical weldingset. The construction materials consist of angle iron, flat iron, gas pipe, ball bearings, leather, some wooden parts, bolts, nuts and washers.

WALL THICKNESS TOWERPIPE NOT LESS THAN 3.5 MM

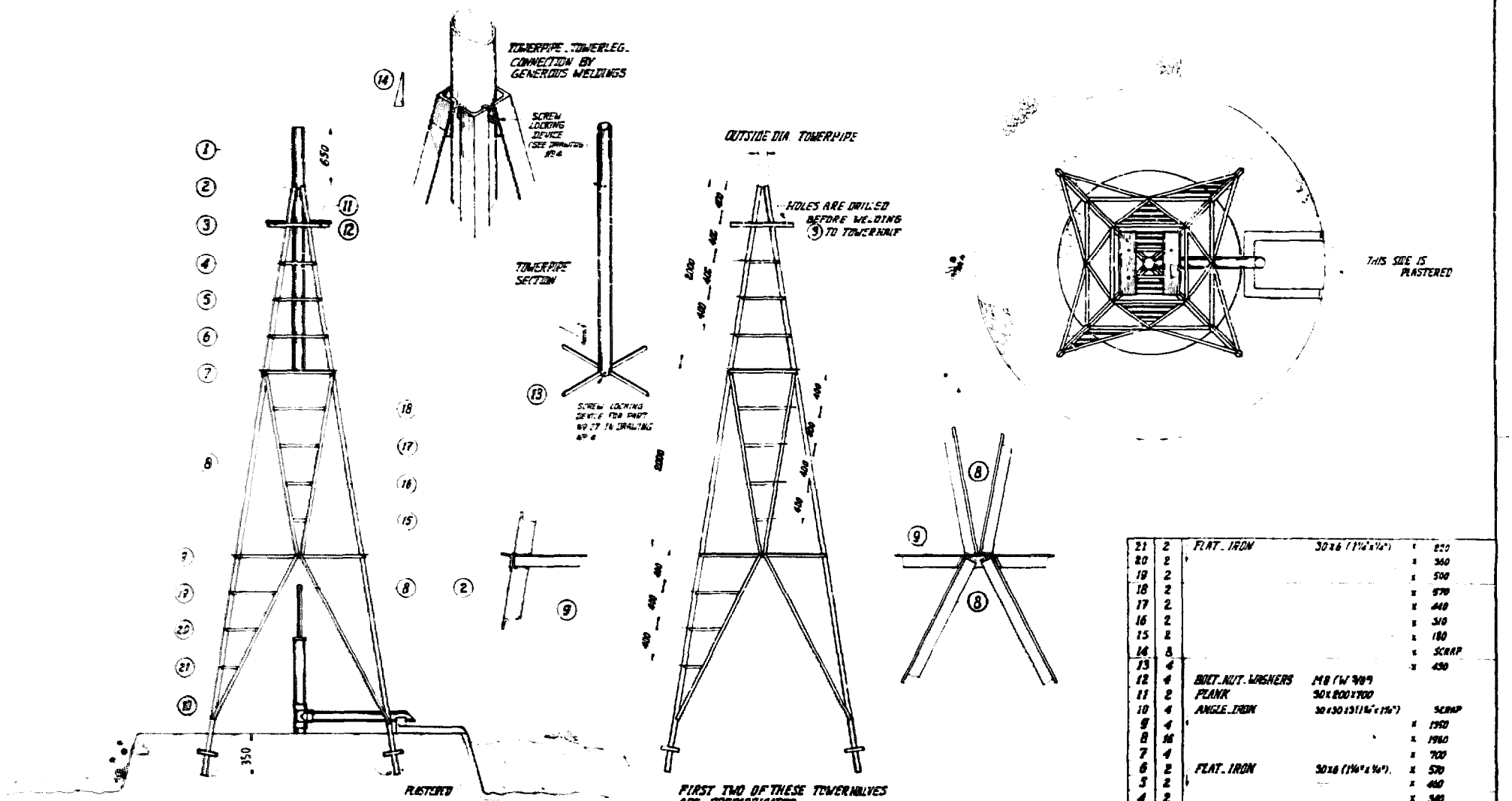

IF DESIRED THE LATTICE MEMBERS CAN BE POSITIONED AND WELDED INSIDE THE TOWER LEGS RESULTING IN A MORE ATTRACTIVE APPEARANCE OF THE TOWER. HOWEVER THE FLANGES AT THE ENDS OF THE ANGLE-IRON MEMBERS Nº 7 AND Nº 8 SHOULD BE CUT AT ANGLES OF 45 DEGREES.

FIRST TWO OF THESE TOWERHALVES ARE PREFABRICATED BOTH HALVES ARE COMPOSED AND THE TOWERPIPE-SECTION IS SHIFTED IN AND A COMPLETE TOWER RESULTS

Nº	NUMBER	MATERIAL / NAME / REMARKS / MEASUREMENTS		
21	2	FLAT-IRON	30x6 (1¼"x¼")	x 820
20	2			x 360
19	2			x 500
18	2			x 970
17	2			x 440
16	2			x 310
15	2			x 180
14	8			x SCRAP
13	4			x 430
12	4	BOLT-NUT-WASHERS	M8 (W 3/8")	
11	2	PLANK	50x200x700	
10	4	ANGLE-IRON	30x30x3 (1¼"x1¼")	SCRAP
9	4			x 1950
8	16			x 1960
7	4			x 700
6	2	FLAT-IRON	30x6 (1¼"x¼")	x 570
5	2			x 460
4	2			x 340
3	2	ANGLE-IRON	50x50x3 (1¾"x1¾")	x 660
2	4		40x40x4 (1½"x1½")	x 6500
1	1	TOWERPIPE	4" GASPIPE	x 2650

2 OF 7

12 PU500 - TOWERCONSTRUCTION

FOR INFORMATION: Werkgroep ter Ontwikkelingssamenwerking T.H. Twente - Vrijhof 152 P.O. Box 217 Enschede - The Netherlands

In various developing countries such equipment and materials are available everywhere and due to the simplicity of the design no advanced engineering is required.
However, some of the labourers have to be trained in reading drawings (here: English), handling the machines and carrying out some measurements, while others have to do the simple things like cutting, painting etc. In the next chapter of the booklet the most essential matters, with regard to measurements, order of machining and constructing are fully described.

Generally first all the materials are purchased and transported to the workshop. There the production of the mainparts starts according to the sequence of the next chapters (tower, headconstruction, etc.).
The prefabrication of all these parts takes about 200 manhours (100 skilled and 100 unskilled manhours appr.), depending on the local circumstances like shortage of material, power-cuts etc. After completing the mainparts they are transported to the site (see chapter 7), where the windmill will be erected.

In case of large scale production of the 12 PU 350 and 12 PU 500 windmills their production will be facilitated and streamlined by means of the application of welding fixtures, drilling guides and manipulators. Some small alternations in the designs are introduced as well in order to optimize the transportation of these remarkable products.

2. The towerconstruction

The tower is the simplest part of the windmillconstruction. It can be fabricated in a few hours only.

First two tower-half are composed as follows.
The angles 2 are positioned on the floor in such a way, that the top of the towerhalve clamps around the 4" towerpipe 1. By means of chalk-marks the position of the angles 3 , 7 and 9 and flats 4 , 5 and 6 are marked and these parts are welded to the tower legs. Do not forget to drill the holes into the angles 3 for the connection of the platform planks. Now the angles 8 are positioned and welded. Some scrap, e.g. angle iron, is welded to the bottom side of the tower legs, providing simple anchors.

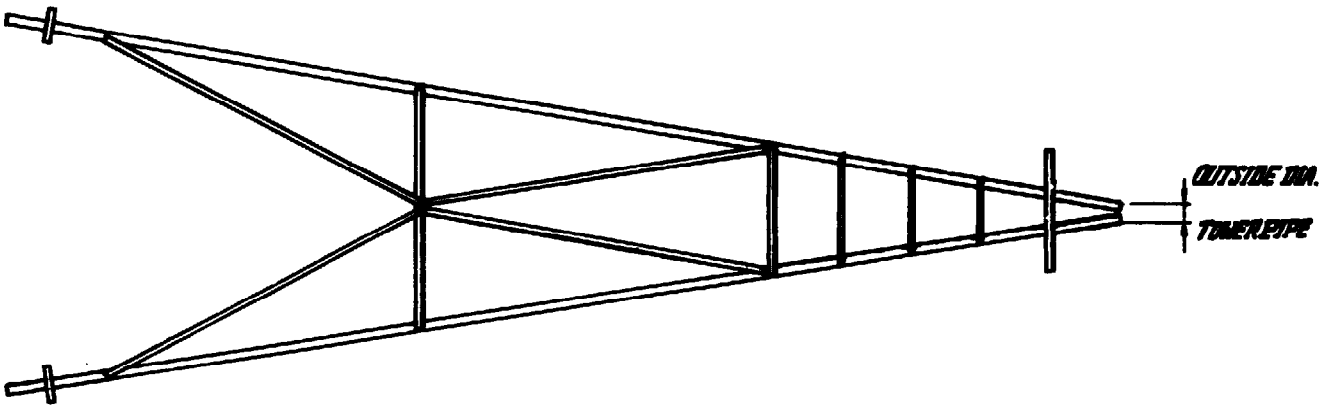

After completing the two equal halves, the tower is composed on the floor while the two tower halves are kept upright. See that the tips of the two tower halves just touch each other and secure this position temporarily by means of small spot-weldings.
Now the angles 7 and 8 are positioned and welded as far as possible and the tower construction becomes more and more rigid. In this phase the temporary spot-weldings in the tower top can be opened and the tower pipe section can be shifted in.

This section is composed by the tower-pipe and the four flats 13 by welding the flats exactly straight to the bottomside of the pipe. See that the flats 13 are inclined sufficiently so that the cross fits exactly into the inside of the tower in the plane of the four angles 7 .

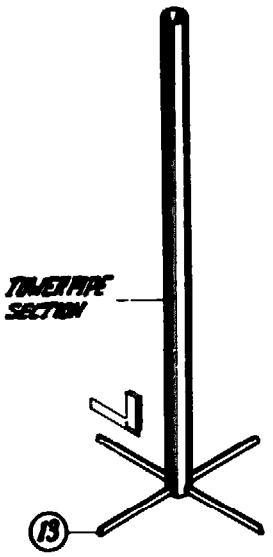

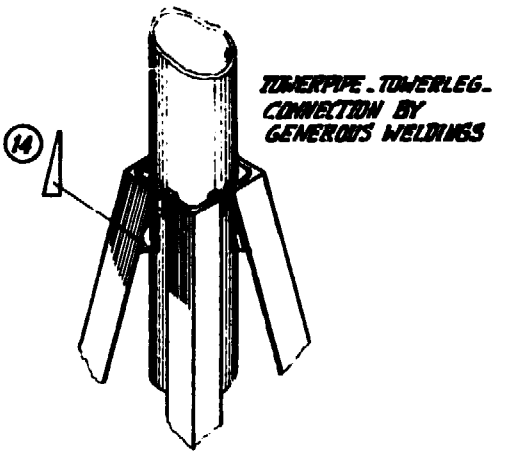

Now the entire tower pipe section is shifted into the tower positioned precisely and welded to the inside of the tower legs. The upper section is surrounded by the ends of the tower-legs. In order to ensure a strong and reliable connection eight cut pieces of flat 14 are welded in as filler metal. These triangular pieces can be cut simply from flat.

Now the tower has become strong enough to handle it by rolling it from side to side in order to finish all the weldings. See that the top of the tower pipe will not be damaged during these transactions since the headconstruction should fit properly around this pipe (see next chapter).

All the carbon of the weldings can be removed and the entire structure must be cleaned by brush before the tower is painted (first primer).

The holes in the planks are defined and just drilled: the planks will be mounted to the tower later on if it is erected on the site. This is done in order to prevent damage to the platform during transport.

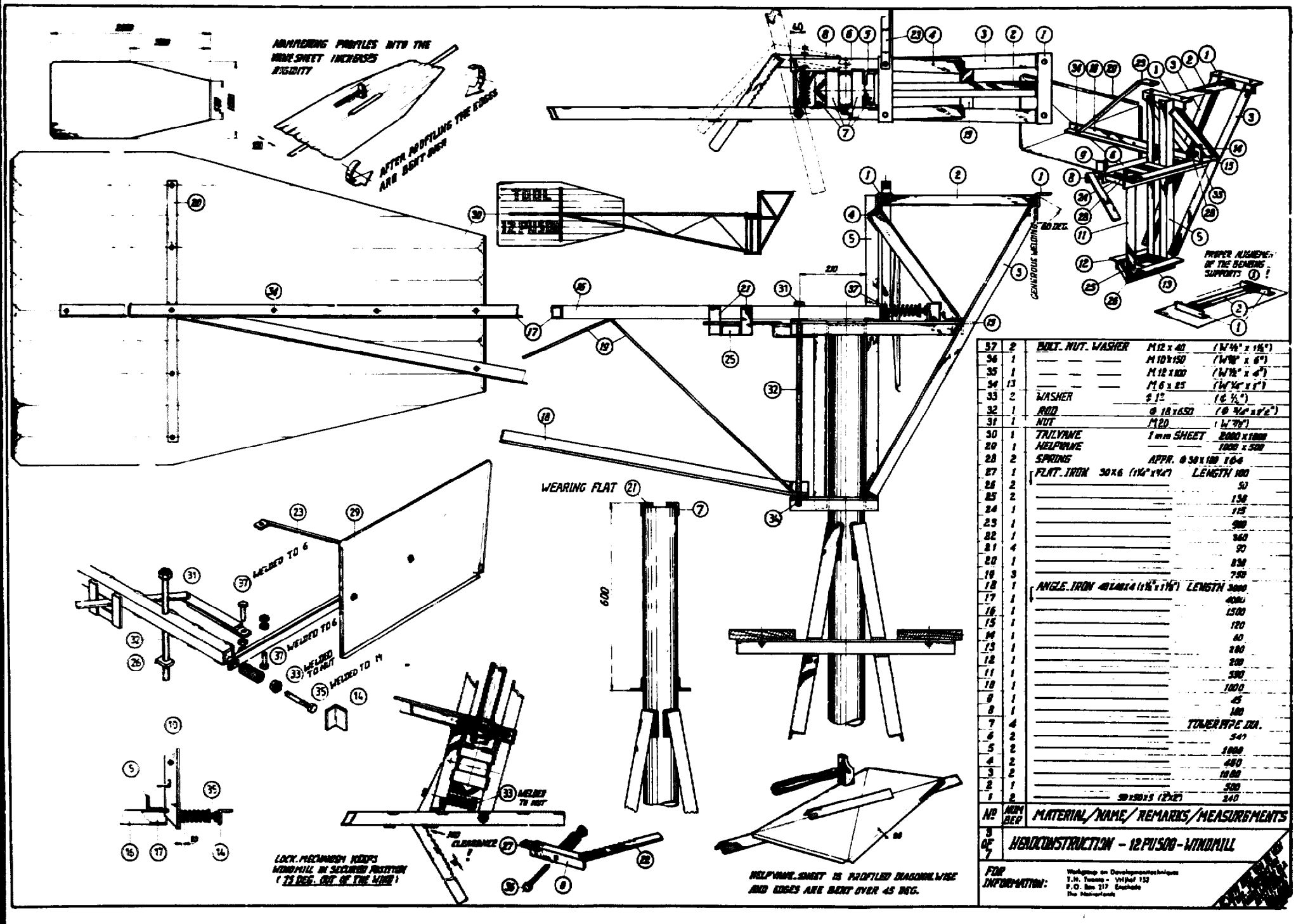

37	2	BOLT. NUT. WASHER	M12 x 40	(1/2" x 1 1/2")
36	1	— — —	M10 x 150	(3/8" x 6")
35	1	— — —	M12 x 100	(1/2" x 4")
34	13	— — —	M6 x 25	(1/4" x 1")
33	2	WASHER	ø 12	(ø 1/2")
32	1	ROD	ø 18 x 650	(ø 3/4" x 26")
31	1	NUT	M20	(3/4")
30	1	TAILVANE	1 mm SHEET	2000 x 1000
20	1	HELPVANE		1000 x 500
28	2	SPRING	APPR. ø 30 x 100	ø 6
27	1	FLAT. IRON 50 x 6 (1 3/4" x 1/4")		LENGTH 100
26	2			50
25	2			150
24	1			115
23	1			500
22	1			960
21	4			90
20	1			830
19	3			750
18	1	ANGLE. IRON 40 x 40 x 4 (1 1/2" x 1 1/2")		LENGTH 3000
17	1			4000
16	1			1500
15	1			120
14	1			40
13	1			280
12	1			200
11	1			590
10	1			1000
9	1			45
8	1			100
7	4			TOWER PIPE 1 1/4"
6	2			540
5	2			1000
4	2			450
3	2			1000
2	1			500
1	2		50 x 50 x 5 (2" x 2")	240
Nº	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS		

3 OF 7

HOLDCONSTRUCTION – 12 PU500 – WINDMILL

FOR INFORMATION: Werkgroep en Ontwikkelingstechniek T.H. Twente – Vrijhof 132 P.O. Box 217 Enschede The Netherlands

A 12 PU 500-tower half is composed and welded.

Positioning the tower halves and composing the tower.

3. The head construction

The head construction is the most important part of the entire windmill construction. It provides a suitable framework for carrying the rotor construction and the moving parts and moreover it contains the automatic security device.

In mounted condition the head construction can rotate around the tower pipe by the steering function of the windvane. The latter keeps the wind-wheel in front of the wind unless the windmill is in secured position; then the windwheel is kept out of the wind automatically.

If the windspeed exceeds a certain value the auxiliary vane unlocks the front part of the head construction from the tail structure and the head turns approximately 75 degrees out of wind backwards. In this position the entire windmill is secured against severe damage caused by storms.

The head construction is composed by angle-irons and flats, which are assembled quite accurately. Machining is just restricted to drilling some holes.

Generally the production is started in the following sequence: frontsection, tail, vane and security device and it will be discovered that a lot of time will be spent in obtaining a smooth operation of the security device,

3.1. The front section

This section is rather difficult to build and the right sequence of composing the parts is important. First three sections are prefabricated in order to simplify the composition:

section 1:

Angles 7 will surround the towerpipe and the length of these is very important. Two angles 7 are welded to angle 11 and this section defines the position of the other two angles 7 in section 2.

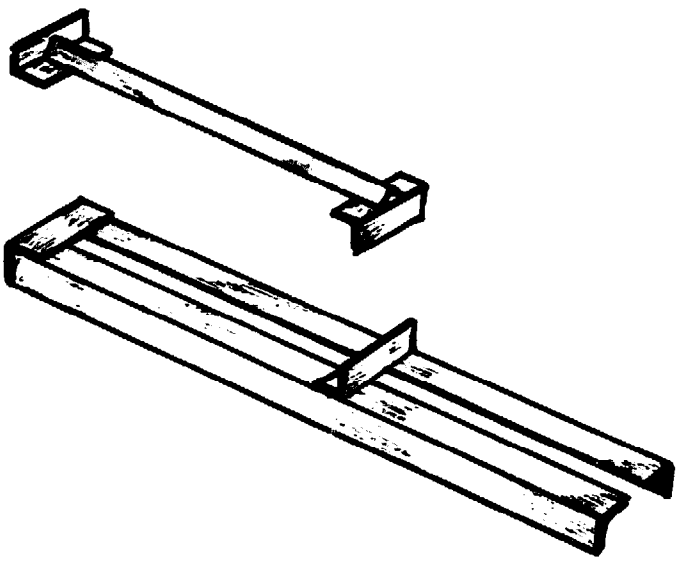

section 2:

Two angles 7 are welded to the two angles 5 ,which are positioned in parallel. See that the width of the two composed angles 5 near the welded parts 7 does not exceed the outside tower pipe diameter. Later on it will become clear, that this measure is rather essential with regard to the fitting of the head construction over the tower pipe.

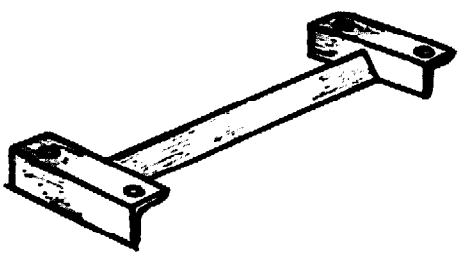

section 3:

Now angles 1 and 2 are composed. It is preferable to drill the holes in the angles 1 first ; the pitch is taken over from the bearing houses.

Now the moment comes to assemble the three sections. First section 3 is connected to the top of section 2 by spotweldings according to the drawings. To make both sections perpendicular to each other the angles 3 can be positioned and spotwelded after the top of each is inclined to 60 degrees .
It is essential to apply spotweldings first, since many mistakes can be made in this phase, so correction can be carried out easily.

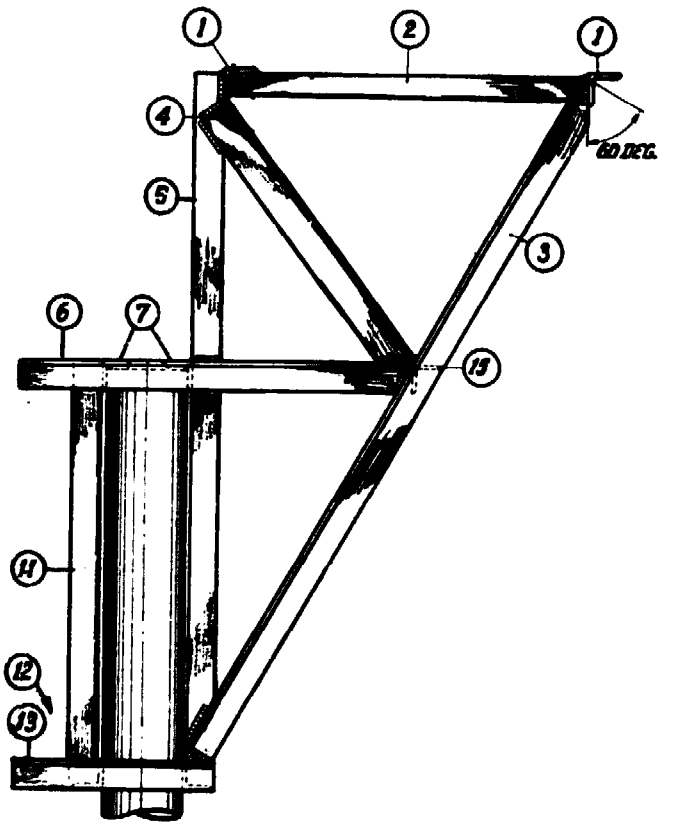

Now the section 1 will be built in in such a way, that the structure fits properly around the tower-pipe. Therefore it is preferable to use a piece of 4" pipe with the equal outside measure, which is enclosed in the framework temporarily.
The angles 6 , 12 and 13 are positioned and fixed by means of some spotweldings after the required holes of the pivot are determined and drilled.
The pieces of flat 26 have to be positioned and welded after which the holes are drilled. It should be checked whether your drilling machine reaches sufficient height for this workpiece. If not, better drill the holes first in the angles before the latter are welded in the head construction. Besides an other kind of tail-pivot arrangement will be suitable which is described further on.

With regard to the positioning of the angles 6 there is no need to incline the ends on the frontside since the vertical flanges have an overlap with the angles 3 . Do not weld yet near the overlap where angle 15 will be positioned and welded later on.
Angles 4 are jointed; also here the vertical flanges will overlap angle 6 so an inclination of it will not be required either. The fit of angle 15 between angles 3 may not be quite proper, but since this part of the frame is rather elastic angle 15 can be hammered in or clamped temporarily during its positioning.
All the spotweldings and connections can be finished now and a strong and rigid frame is obtained. An extra reinforcement is provided by welding in the flats 24 and 25 .

It will be clear, that the weight of the entire head construction and the pumprod forces are going to be carried by the edge of the tower pipe and there in particular some wearing may be expected after some time of operation. Therefore two wearing flats 21 are spotwelded at the inside of the angles 7 .

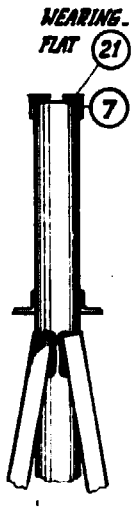

The fit of the head construction over the tower pipe is checked and corrected by filing, since change in measure is to be expected after the welding procedure. Moreover the unroundness of the 4" tower-pipe may result in a seizing fit

at some positions of the headconstruction so the need of filing (or grinding) may be expected.
Some clearance of approximately 0.5 mm between the surrounding angle frame and tower pipe is acceptable.

If a rod is applied for the hinge according to the drawings the distance-plates 26 are made and welded to the head construction. As mentioned before there is an easier way to realize the pivot for the tail. Instead of drilling, two sufficiently strong and long bolts are welded in these places. The rod 32 and two plates 26 are superfluous then, while the number of the rather big holes, which have to be drilled, is restricted to two only.

Now just the frame work of the front part of the head construction is finished: later on the mechanism of the safety device will be assembled, after completing the tail construction

3.2. The tail construction

The upper-tail angle 17 is reinforced over a specific length at the frontside by means of the extra angle 16 . Both are connected by means of a number of weldings with a length of 25 mm and a mutual pitch of appr. 150 mm. Then the hole for the pivot is drilled through the reinforced section in such a place that the front part of this double tail angle has a 5 mm overhang of the angle 5 of the head construction. This is necessary with regard to the unlock system of the safety device (see next paragraph). The pivot hole in the lower tail angle is also drilled.

Now the head construction is put in vertical position while the upper tail angle is connected by means of the pivot and is kept horizontally
The end of the lower tail angle 18 is bent over after first cutting a triangular opening in the upright flange. If the desired angle is obtained the remaining cut can be closed by welding.

The lower angle is shifted over the pivot and jointed to the upper tail angle while the latter is still kept horizontally (or better: perpendicular to the centre line of the tower pipe). In this joint also the vertical flanges of the angles 17 and 18 have an overlap preventing a laborious inclination.

Now the three flats 19 are jointed between angles 17 and 18 one by one starting nearby the bent end of the lower angle and a rigid lattice is obtained
The tail can be taken off from the pivot and flat 20 is welded perpendicular to angle 17 nearby the joint of 17 and 18 .

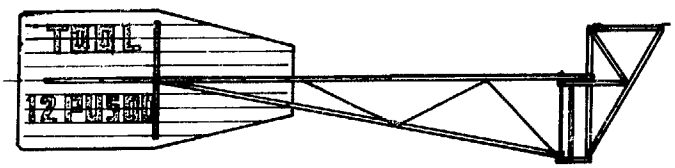

This flat defines the position of the middle of the vane which is bolted by means of twelve M 6x25 (W $\frac{1}{4}$"x1") bolts. The holes in the tail angles are drilled according to the given position in the drawings while the five holes in the upright flat have a pitch accordingly to the "up- and down-profile" of the tail vane

3.3. The tail vane and the help vane

Since a large sheet is not rigid at all it will be advisable to increase its rigidity by hammering some profiles into it. For small sheets a cross of two hammered diagonals will suffice, but this is just applied for the small help vane.

Due to the large dimensions of the tail vane a sufficient rigidity must be obtained by hammering profiles alternately to one side and to the other and appr. 20 or 30 mm deep. After profiling the front- and rear edge (appr. 40 mm) are bent over to a hollow profile on the right hand side.

This is achieved by hammering these edges over a rod or angle which provides a temporary gauge.

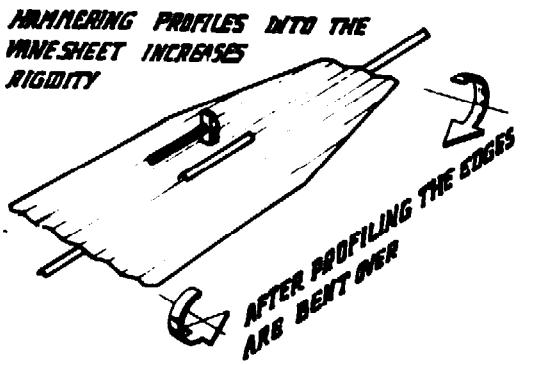

One will discover that the vane became very rigid without increasing its weight. Now the vane is laid down on the floor and the tail is positioned on it and the holes can be taken over by marking or drilling directly if a hand-drilling-machine is available.

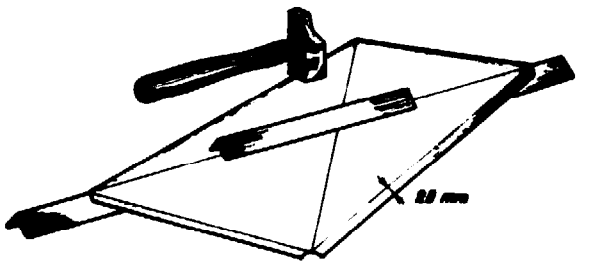

HELPVANE-SHEET IS PROFILED DIAGONALWISE
AND EDGES ARE BENT OVER 45 DEG.

As mentioned before the profiling of the small help vane is done simply by hammering profiles into it diagonally. Therefore the four corners of the sheet are cut first, so that the diagonals as well as the edges can be hammered.

3.4. The safety-device

Actually there are two devices: first the spring-adjusted-help-vane-mechanism initiates the security movement by opening the lock between the head and the tail.
Secondly: a toothed handle prevents that the tail will turn back and keeps it locked at the end of the movement which is really necessary during heavy storms.

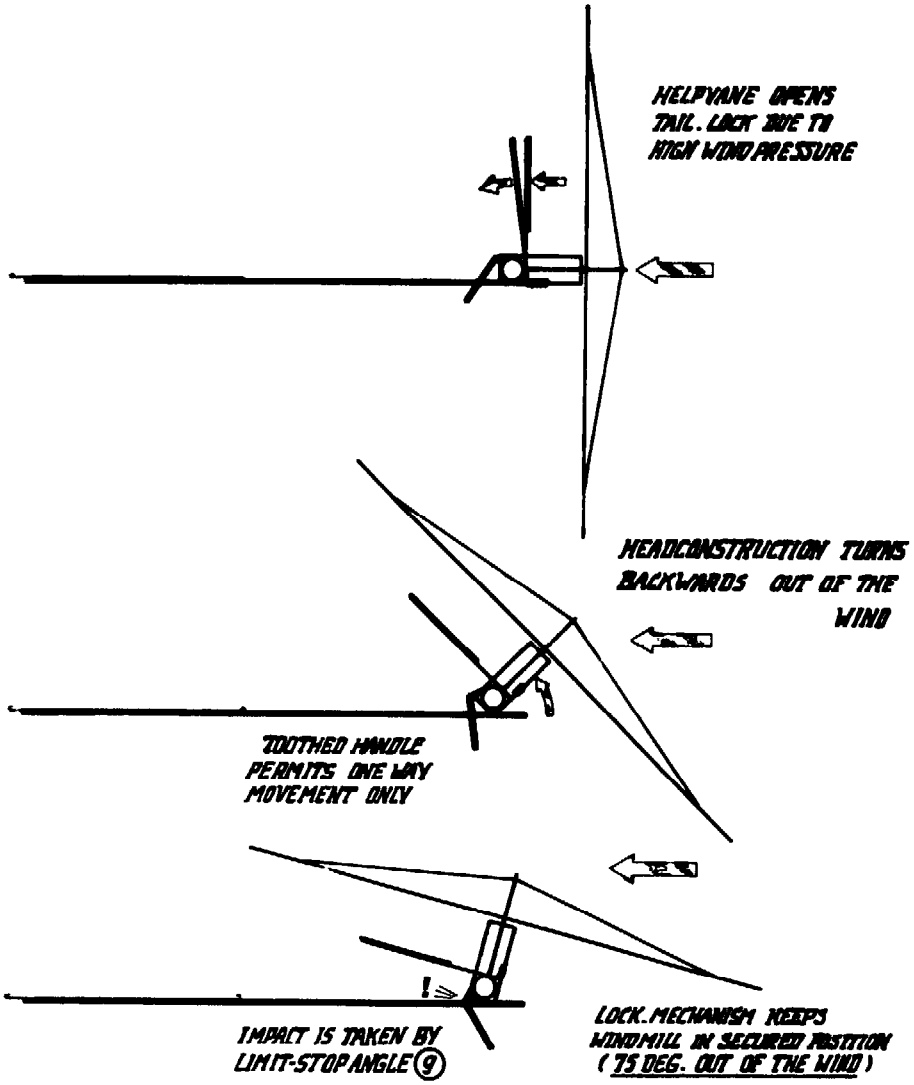

The help-vane-lock-mechanism is made as follows:
Bolt 37 is welded to the horizontal flange of angle 6 in such a way that this bolt can act as a simple pivot for angle 10 . In mounted condition the edge of the horizontal flange of angle 10 just touches the edges of the upright angles 5 while the pivot hole is drilled in such a place that the end at lock-side does not protrude from the frame. Now a filling piece is required between the bolt head of 37 and angle 10 so that the lock, which will be made in the horizontal flange of the latter, can engage the upper tail angle 17 (See drawings). Generally one nut will serve this purpose.

In order to reinforce the suspension of the help vane arrangement a second pivot has to be created: an extra long bolt applied for the fixation of the rear-bearing house provides this. Flat 23 is drilled and bent and welded finally to

angle 10 while the latter is kept horizontally. It is evident that the bearing house has been mounted already (temporarily or permanently) in order to achieve a properly positioned help vane structure.

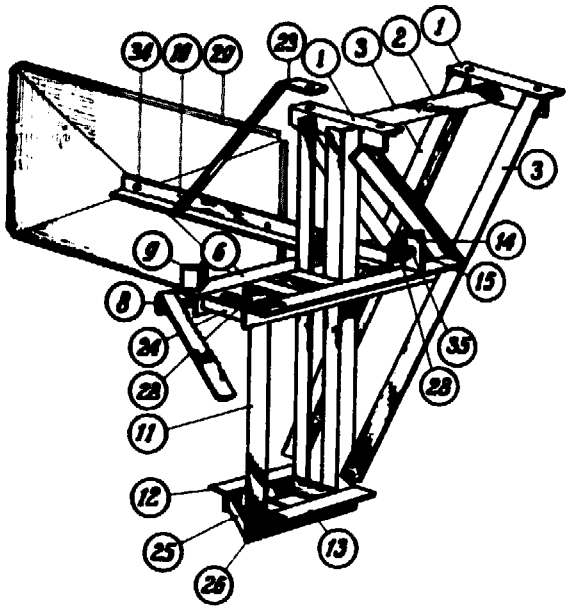

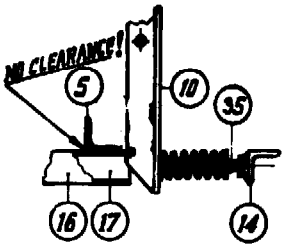

The most accurate job is making a smooth operating lock, which keeps the upper tail angle 17 pressed to angle 5 of the head construction in locked position. Therefore a simple cut-out is made by sawing and filing which will not be deeper than 5 mm(!) while the sliding edge of the cut is inclined a little. This inclination is done in order to obtain a wedging-effect resulting in a clearance-free lock between head and tail.
Inclination of the run-on side of the lock is required for smooth manual handling if the windmill will be put into action later on.
The movement in rotation of the help vane structure is limited to a maximum of 10 mm by the top of the bolt 35 which provides a limit stop and a possibility of spring-adjusting as well.

First the head of this bolt is welded perpendicularly to the small angle 14 and this section is positioned and welded in the head construction so that the help vane struc-

ture can just rotate within its permitted travel of 10 mm. Generally a suitable spring is obtained from the valve arrangement of a diesel- or petrol-engine. To centre the spring between the adjusting nut 31 and angle 10 two different washers are welded to these (see drawing).

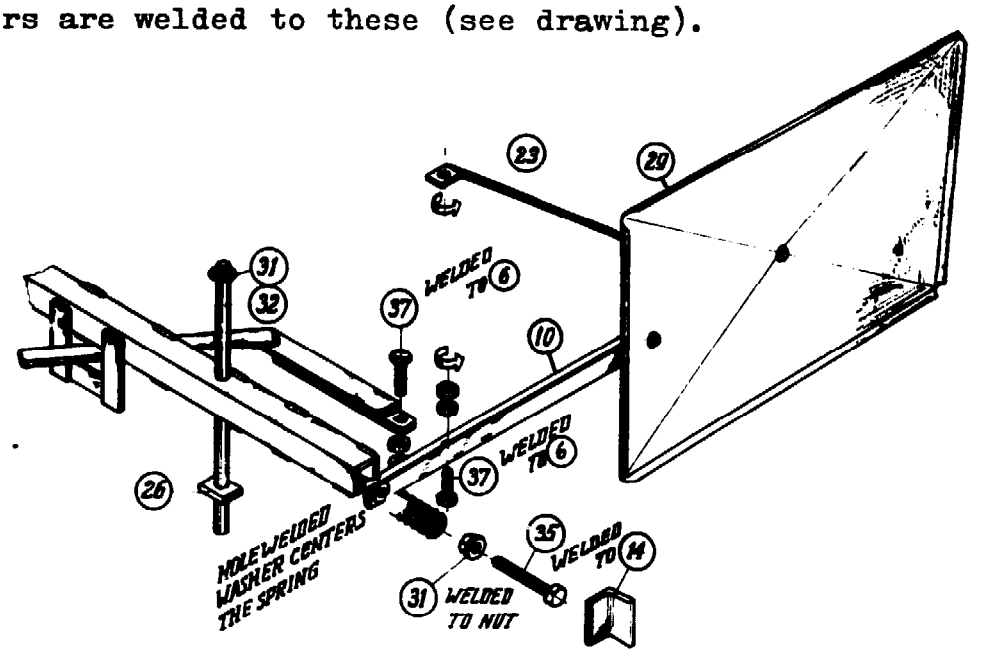

The holes can be drilled in angle 10 according to the given positions in the drawing for mounting the help vane by means of M 6 (W ¼") bolts and nuts. The unlock mechanism is finished now, proper adjustment of the spring is carried out after assembling the entire windmill on the site.

Now the second part of the securing-mechanism is going to be assembled. First the limit-stop-angle 9 is positioned and welded to angle 6 of the head so that the measured angle between head and tail amounts to appr. 75 degrees. Pivot bolt 37 is welded with its head to the inside of angle 6 of the head construction and the pivot-hole is drilled in flat 27 . The latter is welded to angle 8 according to the specifications given in the drawings, but the flat 22 is not yet connected.
Now this section is fixed temporarily to its pivot. Later on the right position of the toothed handle 22 will be defined. First flat 21 is positioned to the upper tail-

angle 16 with its sliding on line of the edge of angle 6 .(see drawings) and now flat 22 (still untoothed) is positioned at the horizontal flange of 8 in such a way that the edge of flat 22 always touches the edge of 21 See that angle 8 moves free of the inside of angle 6 so that the spring, if it is mounted later on, can always maintain a pressed contact between 21 and 22 even if the latter is toothed ! The complete handle is taken out now and the teeth can be made accurately by grinding or filing (the direction of the teeth is taken into account!).

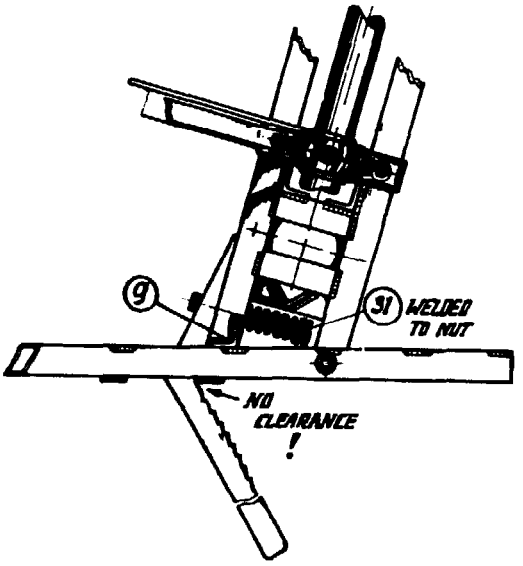

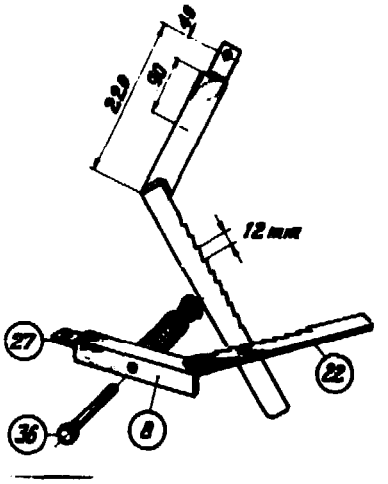

After this is done the handle is built in again; the hole for the spring-loaded bolt 36 is drilled and the latter is mounted, including spring, washer, etc. The mechanism is checked now.
No clearance is permitted in it.
In secured position tail and head both should be kept strongly together, in order to avoid their mutual movements during storms.

By means of filing or grinding a self-wedging lock is obtained which keeps the head and tail together without clearance. If this is not succesful and the clearance persists,a filling between stop angle 9 and the tail can be applied. Generally a small piece of sheet will serve this purpose.

The other two flats 21 will complete the entire security-mechanism. These flats surround the handle in order to prevent that the lever is bent down during transport or is operating in a wrong place.

The total head construction is finished now and ready for painting.

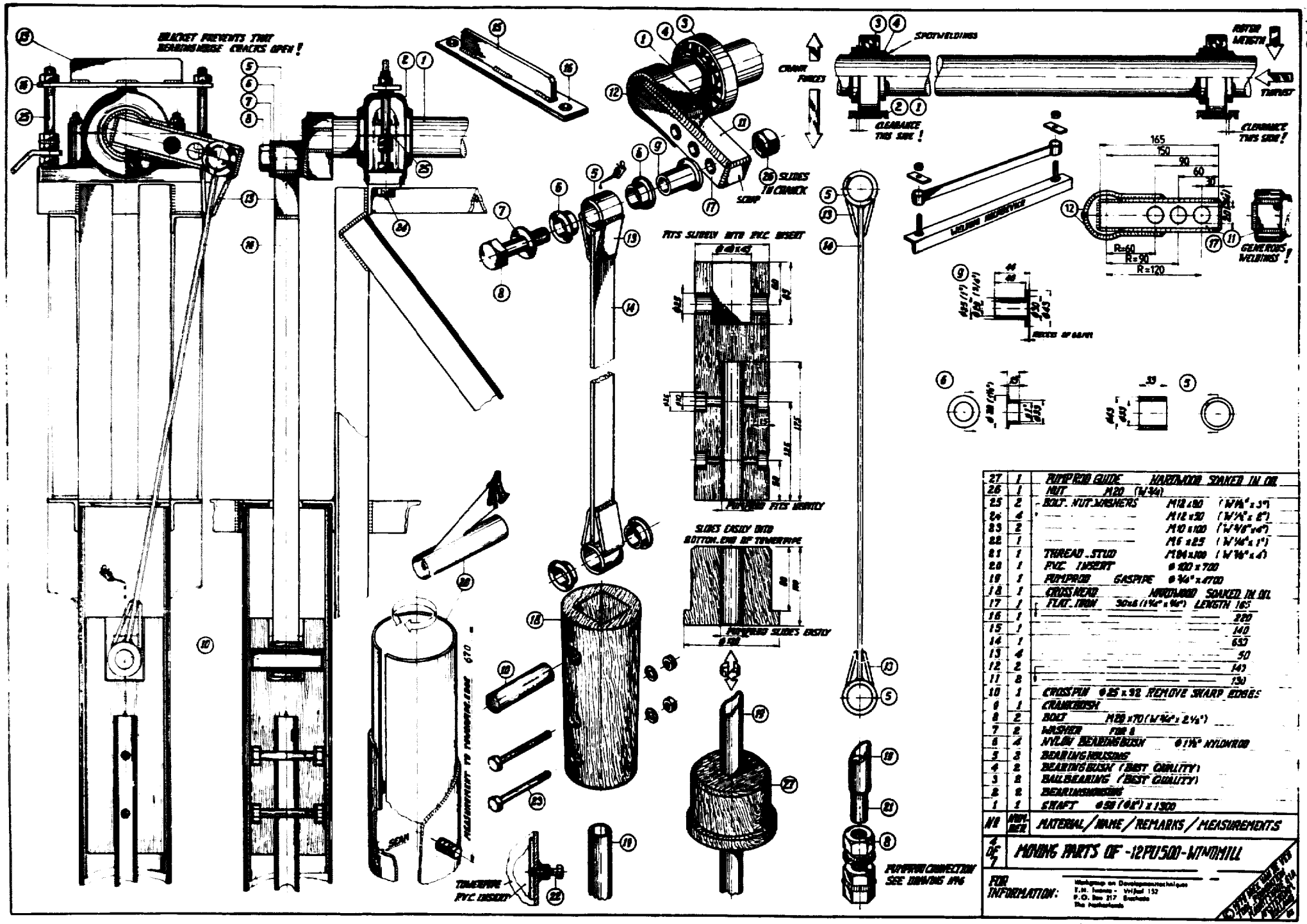

Nº	NUMBER	MATERIAL / NAME / REMARKS / MEASUREMENTS
27	1	PUMPROD GUIDE HARDWOOD SOAKED IN OIL
26	1	NUT M20 (W¾")
25	2	BOLT. NUT. WASHERS M12 x 90 (W½" x 3")
24	4	— M12 x 50 (W½" x 2")
23	2	— M10 x 100 (W⅜" x 4")
22	1	— M6 x 25 (W¼" x 1")
21	1	THREAD. STUD M14 x 100 (W½" x 4")
20	1	PVC INSERT ø 100 x 700
19	1	PUMPROD GASPIPE ø ¾" x 4700
18	1	CROSSHEAD HARDWOOD SOAKED IN OIL
17	1	FLAT. IRON 30 x 6 (1¼" x ¼") LENGTH 165
16	1	220
15	1	140
14	1	650
13	4	50
12	2	140
11	8	130
10	1	CROSSPIN ø 25 x 92 REMOVE SHARP EDGES
9	1	CRANKSHAFT
8	2	BOLT M20 x 70 (W¾" x 2½")
7	2	WASHER FOR 8
6	4	NYLON BEARINGBUSH ø 1½" NYLONROD
5	3	BEARINGHOUSING
4	2	BEARINGBUSH (BEST QUALITY)
3	2	BALLBEARING (BEST QUALITY)
2	2	BEARINGHOUSING
1	1	SHAFT ø 50 (ø 2") x 1900

4 OF 7

MOVING PARTS OF -12PU500-WINDMILL

FOR INFORMATION: Werkgroep en Ontwikkelingstechniek T.H. Twente - Vrijhof 152 P.O. Box 217 Enschede The Netherlands

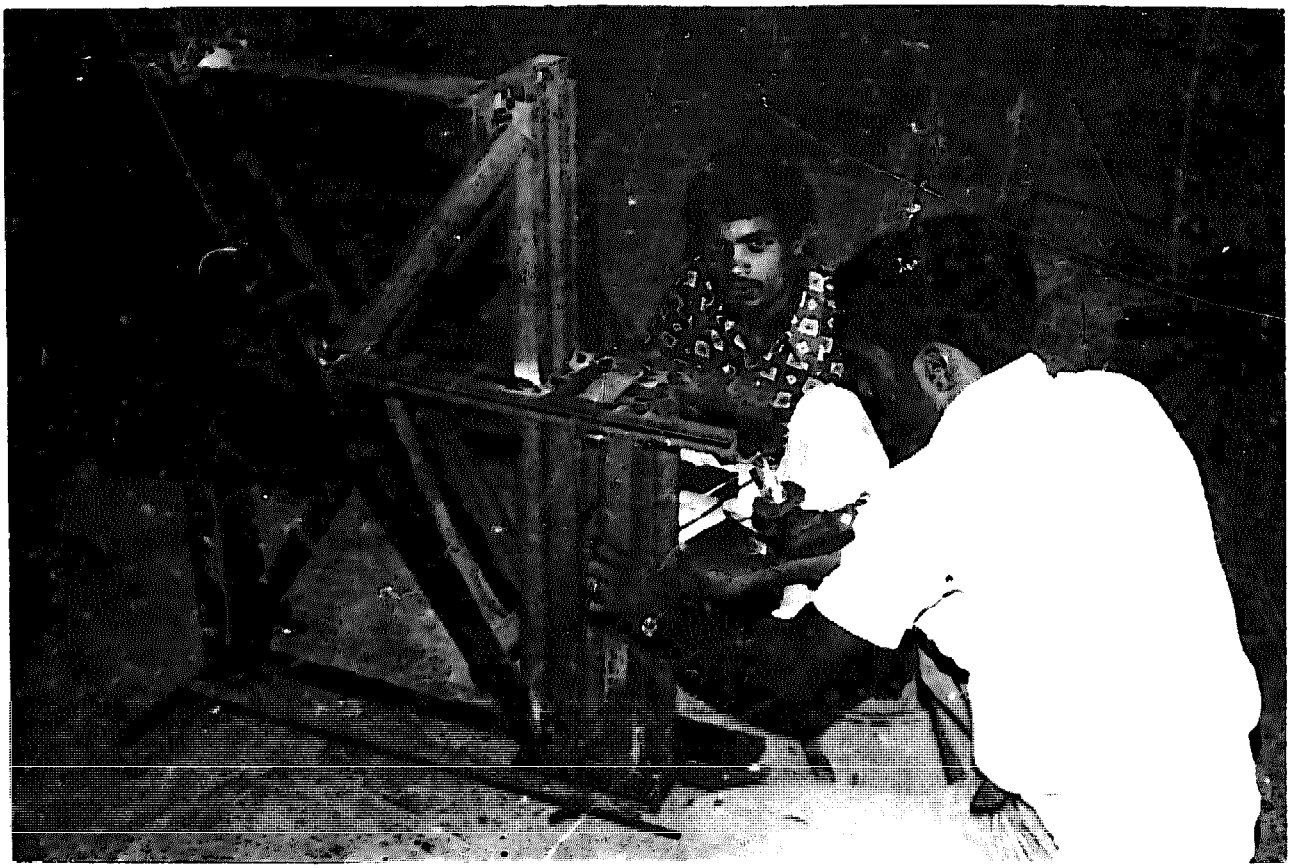

Composing and spot welding the head construction is facilitated by applying a welding fixture

Checking the fit of the head over the tower pipe.

4.0. Moving parts

The rotation of the mill shaft is converted into an up- and down movement of the pumprod by means of a crank-connecting rod-mechanism. The crosshead is guided by the inside tower-pipe so if the head construction turns around the towerpipe, due to a change of wind-direction , the cross head, pump rod and piston as well will also turn.

The mill shaft rotates in ball bearings, while both the crank-pin bearings and cross-pin-bearings are made of nylon. If no nylon is available bronze will be a good choice, but still nylon is preferred with regard to lubrication and maintenance. The cross head is made of wood since field testings proved that its lifetime will be remarkably long depending of course on the applied lubrication.

Generally the gas pipe which is applied as tower pipe has a seam inside which cannot be removed easily, so it is fitted with an insert in order to provide a smooth guidance to the crosshead. This insert can be realized by cutting a strip from a PVC-pipe, so that the circumference-measure will be little less than the one inside the tower pipe. The opening just provides enough space for the seam and the latter is countersunk now. On its bottom side a M 6 (W ¼") bolt locks this PVC-insert in axial sense (see drawings).

4.1. Mill shaft bearings

Two kinds of load actuate on the two bearings. It is assumed that the front bearing carries the radial load due to the total weight of the rotor and the axial forces (thrust-load) caused by the windpressure acting on the rotor. The

rear bearing carries the alternating crank forces.
It will be clear that the best quality of bearings and bearingbushes (sleeve-type) will be applied. If a proper fixation of the bearings to the shaft is not assured entirely, the shaft will start rolling and shifting in the bearing bushes definitely. This rolling will increase after some time of operation, while the shaft shifts backwards due to the thrust and the sharp edges of the rotorhub (angle irons) will scrape at the front of the cast-iron bearing house. A few thousand revolutions are sufficient to destroy this bearing house completely and the ball bearing (due to the scraping-dust).

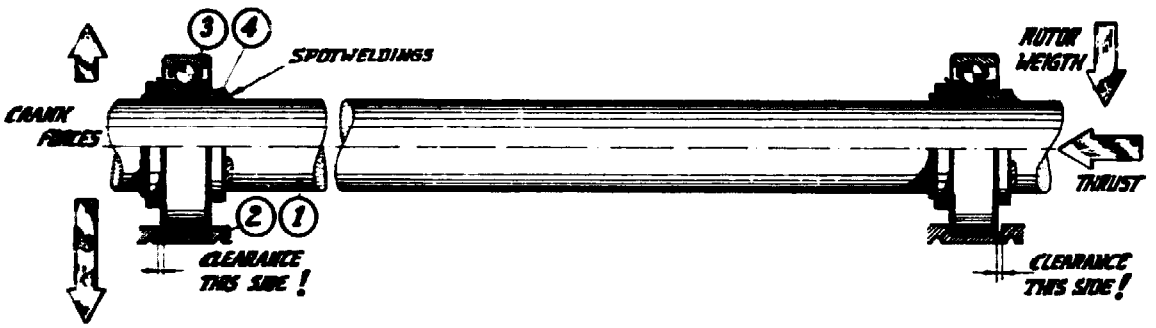

This is prevented by locking the bearing bushes to the shaft by means of some small spot weldings (!) so that the shaft cannot roll and shift.
Proper positioning of the bearings with regard to the axial clearances between the bearings and the inside edges of the bearing houses defines which bearing is going to carry which load.
With regard to the bearings themselves: self-aligning bearings of double roller type are most attractive provided one goes for the best quality. Single rollers can be loaded more due to the bigger contact surface of the balls but extra attention has to be paid to the alignment.
In many cases complete one-piece bearing blocks are available which are self-aligning and of excellent quality.
Since the rear bearing is loaded by reciprocating forces the bearing house top also has to carry some load. A crack of this cast iron top may be occur then which leads

to a disastrous damage of the rotor, because it will tumble forward and hit the tower! To prevent this a simple security device is applied which supports the housing in carrying upwards forces.
Therefore bolts 24 have to be extended which can be obtained simply by welding nuts to the heads of bolts 25 resulting in easily removable extensions.

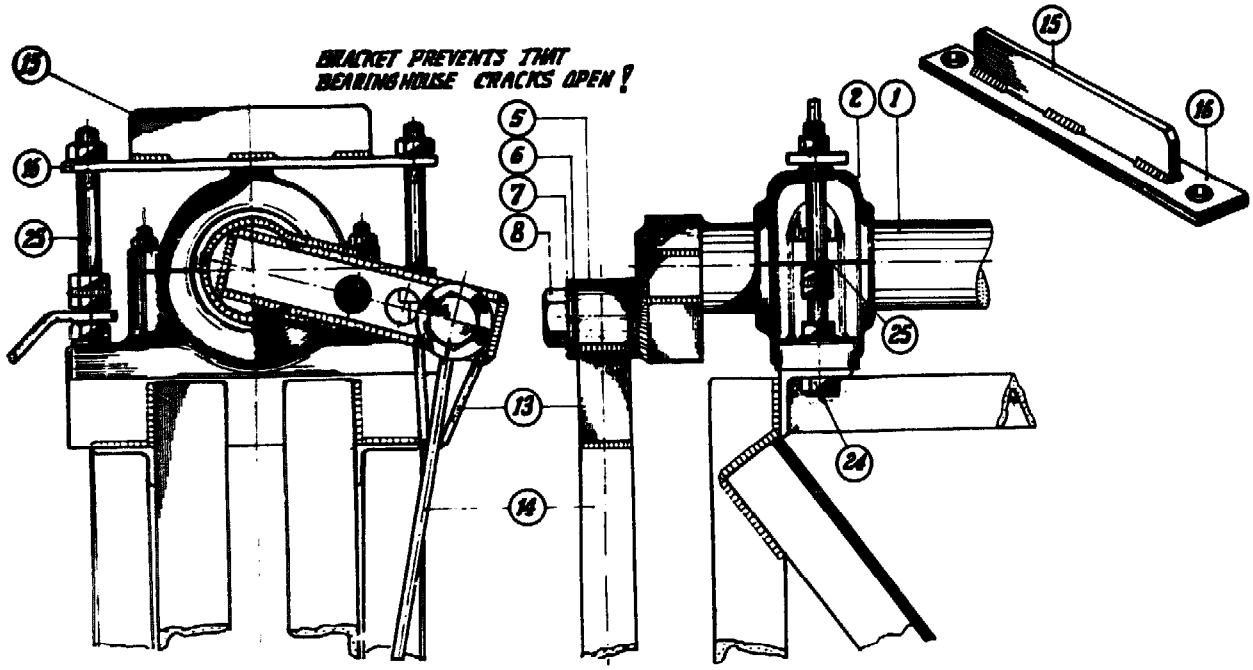

4.2. Crank and crank pin

The crank is composed of flats 11 , 12 and 17 . First the holes are drilled in flat 17 and the latter is positioned according to the drawings and spotwelded perpendicularly to the rear end of the mill shaft.

Now the flats 11 are positioned planparallelly so that the inside measure is equal to the width of the applied crankpin nut. This nut will be trapped now between the flats 11 preventing that it will turn during fastening the crank pin later on. It will be evident that inside weldings are not permitted near the places, where the nut will be positioned in future.

During finishing the weldings one will see that 17 will remain perpendicular to the shaft while the weldings between flats 11 and the shaft are made double. Now flat 12 is bent, positioned and welded. The latter will be necessary in carrying over the generous forces.

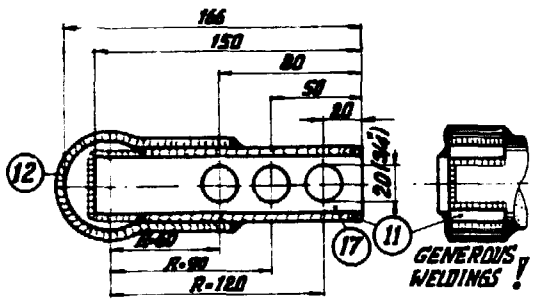

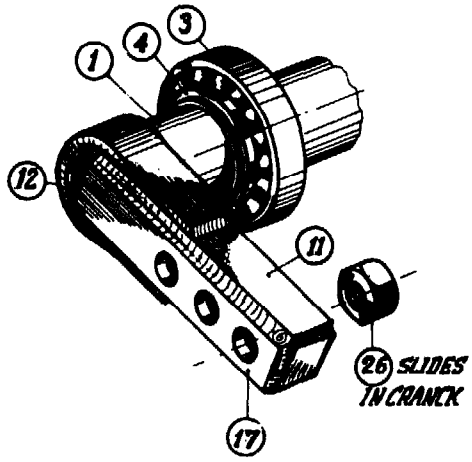

It will be clear that the surface of flat 17 should be perfectly plane in order to achieve a proper bearing joint with the collar of a crank bush. As a matter of fact all alternating forces and moments acting on the bush are supposed to be transmitted via this collar to the crank plane merely by means of friction. One can imagine what is going to happen if the central crank bolt runs loose, so a proper tightening of it is most essential.

4.3. Connecting rod and bearing bushes

The essential thing is to weld two bushes 5 mutually parallel to the flat 14 . This is achieved by using a simple welding help device which is composed of an angle and two bolts with nuts and washers (or flats). These bolts are welded

at the needed pitch to one of the flanges of the angle and now the bushes 5 can be fixed parallel while flat 14 is kept between them and welded. After it is taken out flats 13 will be positioned and welded providing extra strength to the connecting rod.

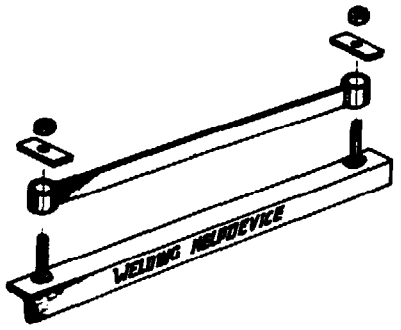

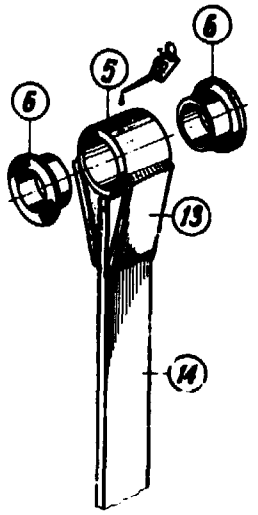

The nylon bearing bushes fit with a slight oversize into the welded bushes of the connecting rod but the inside measure still will be oversized with regard to the fit over the crank pin. The unroundness of the bushes,caused by the welding procedure, does not affect a smooth function of the bearings which fit around the pin with a clearance of 0.2 - 0.3 mm in radial sense. An axial clearance of appr. 1 to 2 mm is permitted and usual.

For lubrication only the top bush is furnished with a lubricating hole which ends up in the groove between the two nylon bearing bushes. At bottom side the nylon bearings will be situated in oil since the cross head is oil-containing.

4.4. Cross head and pump rod guide

These parts are made of wood so expansion is to be expected due to oil absorption. Generally the rough material is kept in (expired) oil during a few days so that the wood will be soaked and expanded if it is machined.

The simplest way in making the cross head is to start with drilling the central hole but so that the pump rod (gas pipe) fits into it heavily. Actually there is no need to make this hole through the crosshead. The depth as is stated in the drawings will be sufficient for a proper fixation of the pump-rod.

Now a piece of gaspipe is forced in temporarily which provides a mandrel in order to fixate the rectangular block to the chuck of the lathe-machine. The other end is supported by the centre.

First the outside diameter is turned at the right measure so that a slide fit is obtained in the (inserted) tower pipe. Then the centre is removed and a central hole is drilled and turned carefully at the top of the cross head. The lathework is done now and the mandrel is removed.

Now the holes for the crosspin are drilled exactly through and perpendicular to the centre line of the cross head. The fit of the cross pin into these holes must be tight; see to it that the wood will not split if the cross pin is hammered in.

The rectangular hole is marked while its position with regard to the cross-pin is taken into account! The hole is made easily by chisel. The fit of the lower part of the connecting rod over the cross-pin and in the hole is checked. See that the top of the connecting-rod can deflect sufficiently in both directions.

The pump rod is mounted by forcing its ends into the central hole of the cross head. Take care that its fixation will be done once: the bolt holes are drilled now through the cross head and pumprod in which the countersunk bolts 23 fit without clearance.
See that the bolt heads, nuts and bolt- tails do not project from the surface.

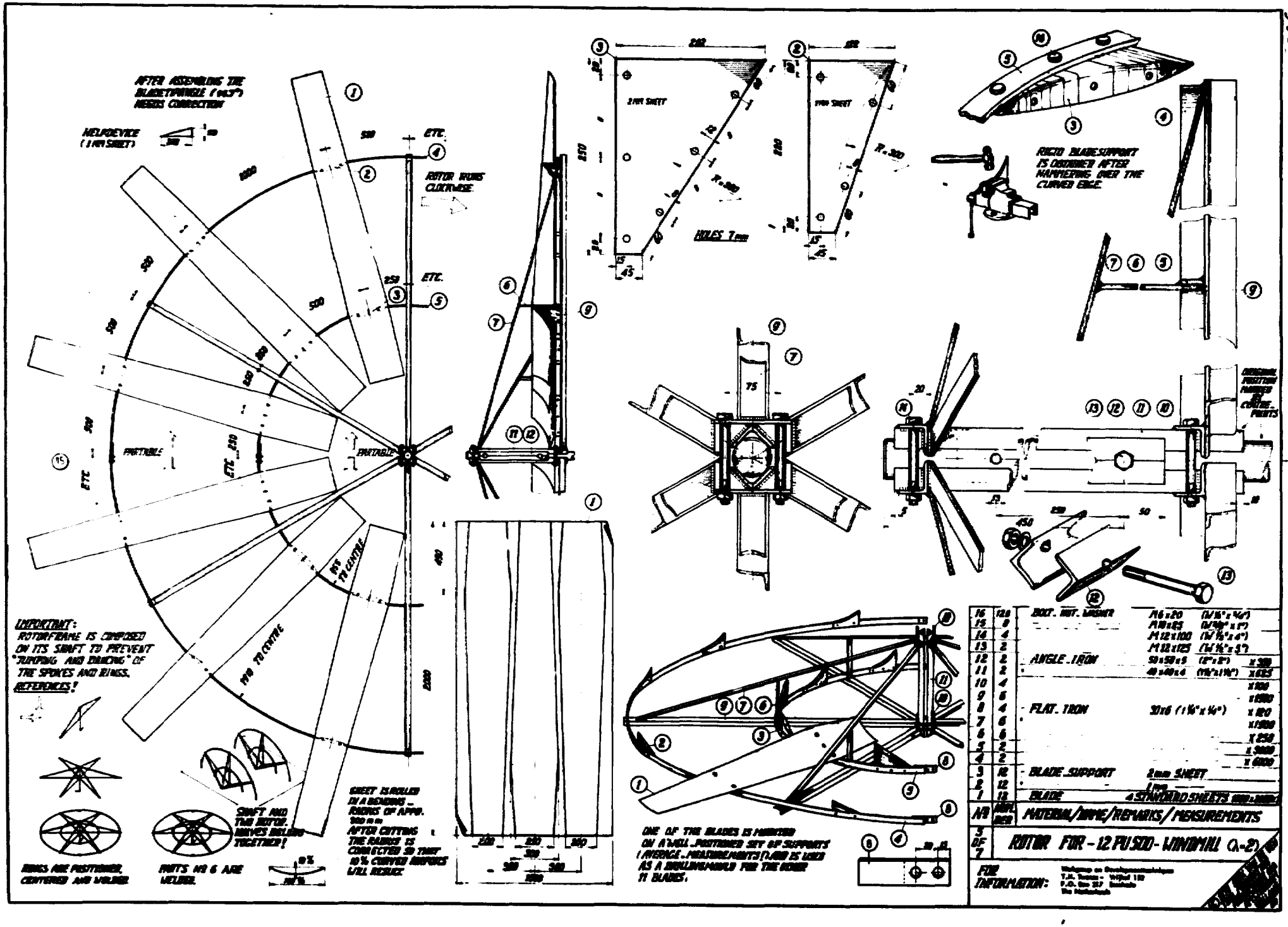
AFTER ASSEMBLING THE BLADETRIANGLE (NO.7) MAKES CORRECTION
HELPDEVICE (1 MM SHEET)
ROTOR TURNS CLOCKWISE
ETC.
PARTABLE
1 MM SHEET
HOLES 7mm
RECTO BLADESUPPORT IS OBTAINED AFTER HAMMERING OVER THE CURVED EDGE
ORIGINAL POSITION MARKED BY CENTRE-PUNTS
IMPORTANT:
ROTORFRAME IS COMPOSED ON ITS SHAFT TO PREVENT "JUMPING AND DANCING" OF THE SPOKES AND RINGS.
REFERENCES!
RINGS ARE POSITIONED, CENTERED AND WELDED
PARTS NR 6 ARE WELDED
SHAFT AND THE ROTOR MOVES BELOW TOGETHER!
SHEET IS ROLLED IN A BENDING-RADIUS OF APPR. 900 mm
AFTER CUTTING THE RADIUS IS CORRECTED SO THAT 10% CURVED ARCS WILL REDUCE
ONE OF THE BLADES IS MADE ON A WELL-POSITIONED SET OF SUPPORTS (AVERAGE-MEASUREMENTS) AND IS USED AS A BOILERMAKER FOR THE OTHER 11 BLADES.
BOLT, NUT, WASHER
ANGLE-IRON
FLAT-IRON
BLADE SUPPORT
BLADE
4 STANDARD SHEETS
MATERIAL/NAME/REMARKS/MEASUREMENTS
ROTOR FOR - 12 PU 500 - WINDMILL (λ=2)
FOR INFORMATION:

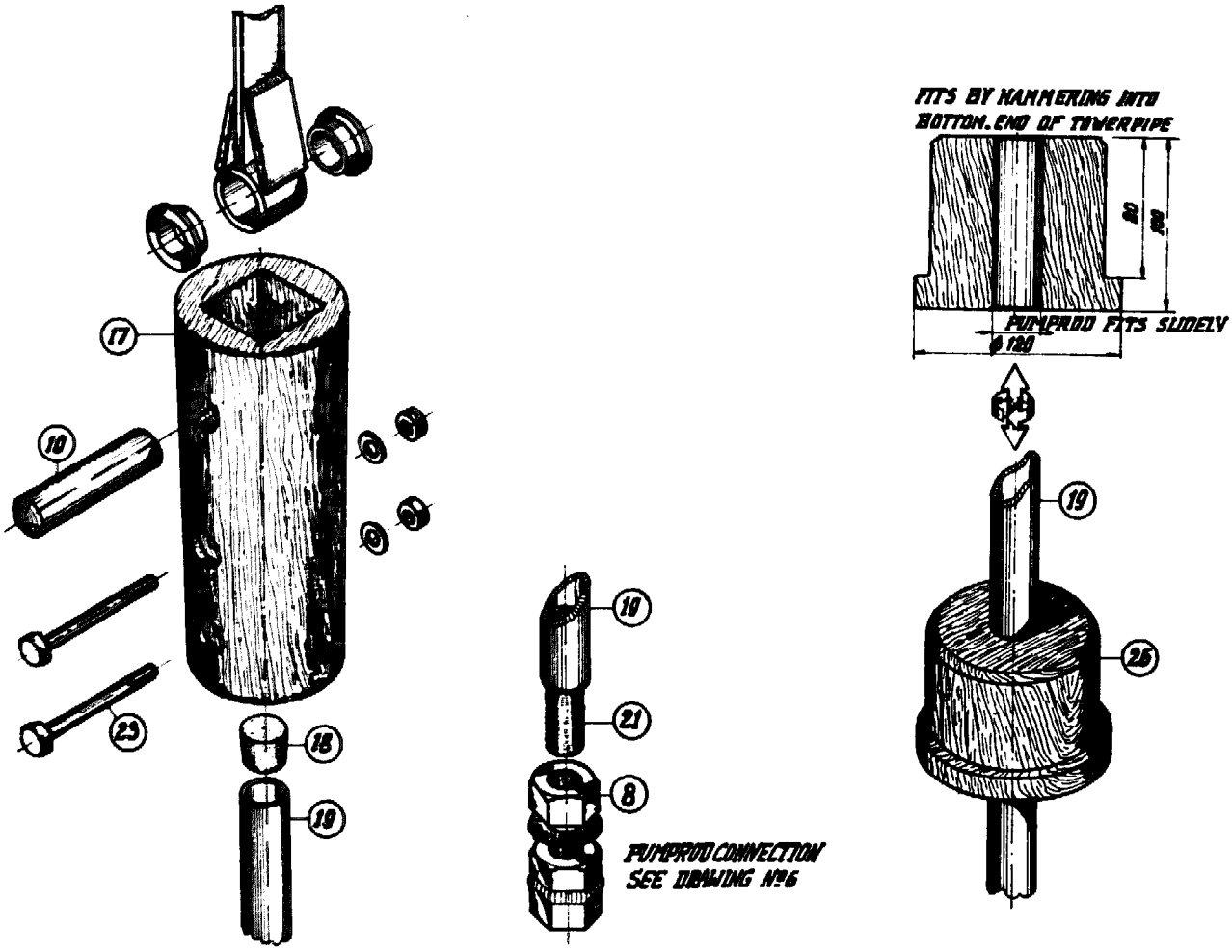

The lower end of the pump-rod is furnished with a thread-stud which is hammered into it and welded. For further details see chapter and drawing 6.

The pump rod is guided by the wooden pumprod guide which is situated in the lower end of the tower pipe where it is locked by means of a 1/4" (6 mm) bolt (See drawings.) The pump rod can slide and rotate in it easily with a clearance of approx. 0.5 mm.

5. Rotor

The shape and setting of the blades of this 12-bladed rotor has been designed especially according to a scientific approach. The blades are defined by the blade-supports which connect the blades to the inside-and outside-ring. These rings in combination with the spokes, tie flats and hub compose the rotorframe which carries the forces acting on the rotor.

It will be evident, that the rotor is made very accurate in order to obtain a balanced and smoothly running rotor.

5.1. In- and outside-rings.

With regard to transport it will be attractive to construct the rotor frame in two halves ,which seems to be obtained easily since the hub is partable, but a proper connection of the ring halves must be achieved then!
Therefore it is advisable to take the following order of constructing into account.

First the holes for the blade supports are drilled very acrate in the flats 4 and 5 according to the measures provided in the drawings.

Then the flats 8 are cut and drilled and these are clamped or spotwelded temporarily to one of the ends of the flats 4 and 5 so that the holes can be taken over by drilling.
Then these connecting flats are bolted to the flat-end concerned.
Now the flats (still straight) are laid down in line at the floor and the connecting flat 8 is positioned and welded to the other flat-ends.

One can start hammering the flats 4 and 5 in a circular shape; but see that the flats 8 are positioned at the <u>inside</u> of the ring halves.

A half circular line made at the floor by using a rope and a piece of chalk supports the labour in shaping the ring halves.

If both halves are bent they are bolted together which must result in two circular rings in which the position of the blade supports are divided perfectly. It will be evident that the twelve blades will be divided perfectly in the rotor provided that the rings are welded in right position to the spokes 9 which will be done later on.

5.2. Building the rotor frame

First the hub is prefabricated. In the four angles 10 the holes are drilled and the triangular cut-outs are made so that these angles fit over angles 11.

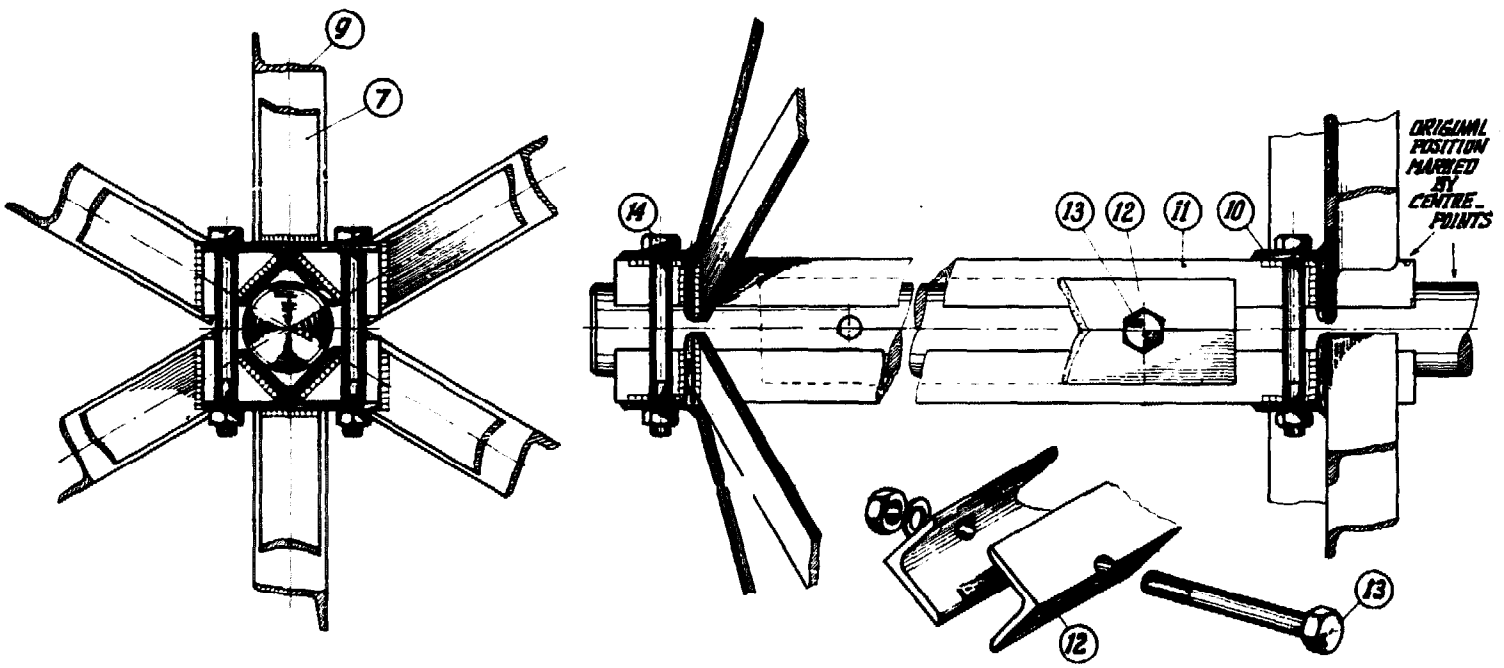

The hub is composed now by the four angles 10, two angles 11 and bolts 14 and is shifted temporarily over the shaft. See that the position of the angles 10 is taken into account (drawings) before welding is started . This welding is just

done at inside the flanges of angles 10 since in the other places the spokes 9 and tie rods 7 will be positioned and welded there later on.

The clamping angles 12 can also be cut and drilled while the hole positions are taken over to the shaft and these holes are drilled as well (See that the rear-edges of the hub just do not touch the front of the front bearing house).

Now the most important phase in rotor fabrication: how to connect the angles 9 and tierods 7 to the hub so that they will be divided exactly in the rotor frame and run in one plane without "jumping and dancing".

Therefore the entire head construction, bearings and mill-shaft are needed in order to create a support during the construction of the rotorframe . The tail is laid down on the floor while the head construction is put in secured position (remove toothed lever), so the mill shaft stands more or less vertical.
See that the head is supported sufficiently for a stable position while the shaft can rotate freely.

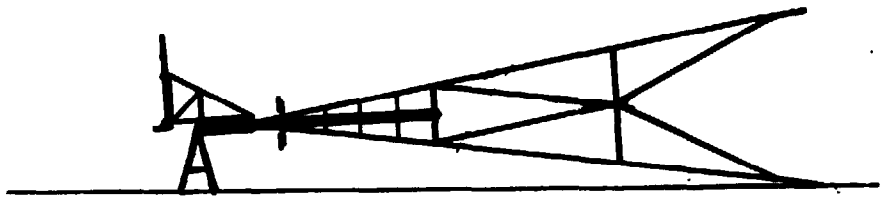

The hub is mounted to the shaft in its position which must always be maintained in future: the rotor frame is made on its "own" shaft in order to eliminate unstraightness of the shaft. Therefore this original position is marked by two centerpoints (see drawings).

IMPORTANT:

Before starting to weld: do not connect the minus-pole of the welding-equipment with the head, since the current will flow through the bearings and they will be spoiled definitely! Prevent this by making this contact with the hub itself!

Now the first angle 9 is positioned with its end behind angle 10 of the hub and just touching the top of angle 11 and is welded perpendicularly to 10. The first tie flat 7 is positioned and welded in a similar way to angle 10 at the front of the hub and its other end is now welded to 9 so that the latter is supported in such position that 9 is perpendicular to the hub-assembly.

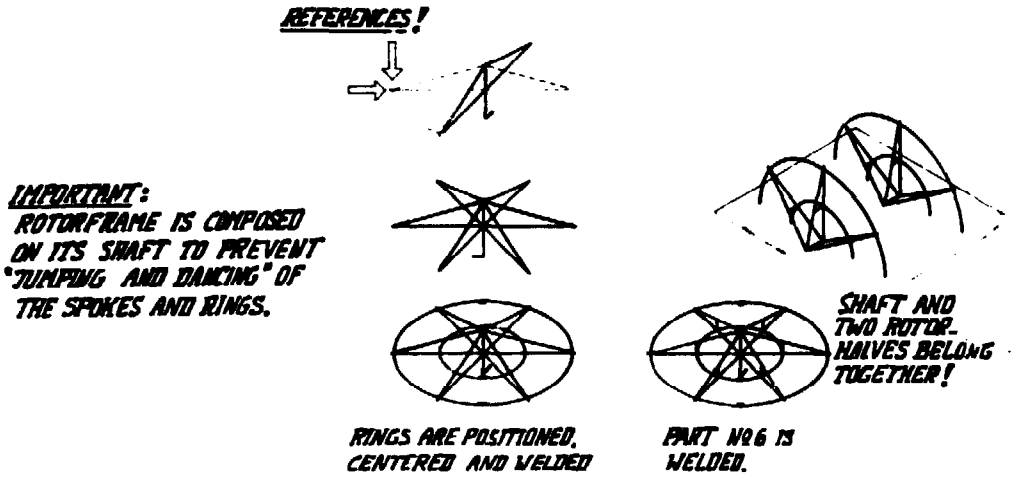

Apply a reference by using a case or a chair or something similar in order to take over the position of the tip in radial and axial sense as well of this very first spoke.

Now the shaft is rotated a half revolution and the next spoke and tieflat are welded in the above mentioned way while the tip position is taken into account.

Be consequent in positioning the angles 9 with regard to its "downward" flange: this is always kept on the right. The connections of the spokes and tieflats with the hub will seem more complicated now since the mutual angle of 60° between the spokes must be obtained.
Remember that the inside tip distance of the spokes is almost equal to the spoke length itself. Using one of these angles 9 for rough defining of the tip- distances while spot welding connections are made to the hub. It will be discovered that every set can be corrected easily with regard to this mutual angle.

If the sets are completed all the mutual tip distances are measured: the average distance is calculated and the sets are corrected. With regard to accuracy it is mentioned that a final tolerance of ± 30 mm in these distances is acceptable since the sets are rather elastic in this phase. On the other hand the tips of the angles 9 must run in one plane within a small tolerance of appr. 5 mm and this is checked simply by rotating the rotor slowly so that the tip will pass nearby a reference-point.

If necessary: a correction can be carried out yet since the connections are just spot welded: then the welds will be finished and the prefabricated inner- and outer ring can be built in as follows.

First the positions of the rings at spokes 9 will be determined by taking measurements from the shaft centre and making chalk marks at the top flange of the spokes. This is done easily by means of a measuring tape which is kept as zero-reference. Of course half the shaft thickness is deducted of the radius to be marked at the poles.

Then at both rings 6 chalk marks are made in the right places between the blade supports concerned (see drawings!). These marks are kept in the middle of the width of the top flange of the spokes during positioning.

First the inside ring is positioned and spot-welded to the spokes, while the positions of the connections of the ring halves (flats 8 are taken into account with regard to the hub!(Rotor is partable!). Do not weld on the inside of the inside ring, since flat 6 will be positioned there later on. A check by means of a few rotations of the rotor will detect unroundness or mistakes.

The outside ring is positioned and welded according to the same procedure. Now the flats 6 are positioned and welded in order to provide an extra support to the slender tie rods.

The rotorframe is opened and dismantled carefully in order to finish all the welds. This is carried out easily since the two halves are easy to manipulate. Then the rotor halves are ready for painting (first primer!), provided that the carbon of the welds have been removed thoroughly!

5.3. Blade supports

The blade supports provide strong connections of the blades to the rotor frame and both are important with regard to blade setting and carrying over the forces. In practice the major part of the axial forces actuate on the outside ring while the centrifugal forces are taken by the inside ring via the blade supports. Since these last mentioned can be rather considerable the inside ring blade supports are made from 2 mm sheet iron.
For 12 PU 350 one mm-sheet serves the purpose.
In fact the inside and outside blade supports do not differ in the way of fabrication . First the sheets (2x12) are cut and the first one of both sets will be used as a sample for drilling in order to obtain two sets of twelve equal blade-supports. Then the circular bending lines (see drawings) for both supports (do not mix them up!) and the edges can

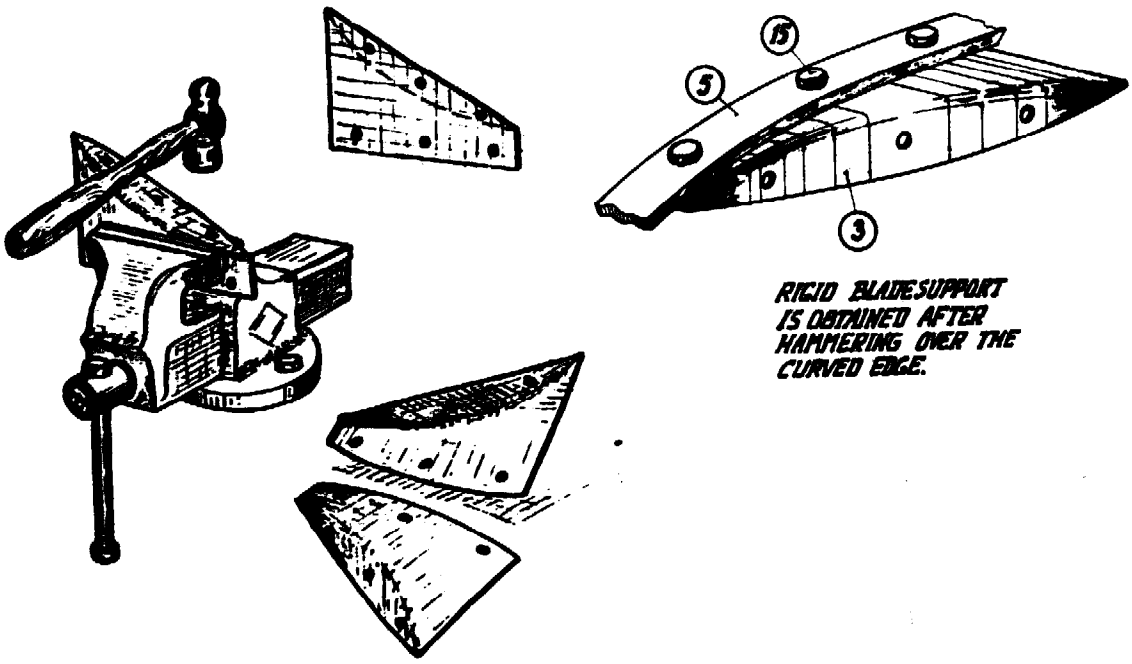

be hammered over now (windwheel runs clockwise!).This procedure is really enjoyable: use the bench vice and keep the bending line just tangential to the grips of the bench vice and start a uniform hammering. Do not be surprised that the unhammered part cambers too: it provides an extra rigidity and moreover this shape will be useful for a proper fit in the rotor ring. It will be experienced that the holes in the hammered part have been damaged due to the hammering procedure. Therefore these holes are drilled again afterwards in order to obtain an easy bolting of the blades to these support later on.
After painting the supports, they are mounted to the inside of the rotor rings.

5.4. Blades

The blades will have a 10% circular camber (see drawings) at any cross section, providing efficient airfoils having attractive aerodynamic properties.

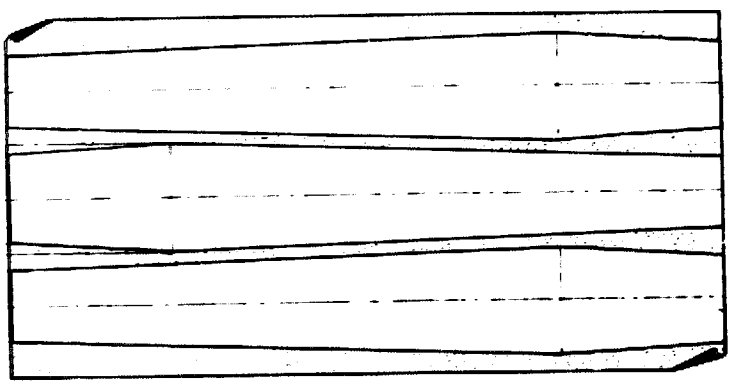

Since the blades are cut from sheet it is advisable to apply a stripe of scrap between the blade edges. This because cutting by means of hand-shearing tools always cause plastic deformation of one of the cut edges.

It seems to be simple to camber the entire sheet in the required minimum radius first and cut out the blades afterwards. However in practice it proved that cutting the blades first and then rolling them one by one is easier to be done. The disadvantage of the last system is that the edges of the blades will not be rolled properly due to the existing distance of the rolls in the rolling machine, but still these edges can be corrected by hammering (use a rubber or wooden hammer!).
If no rolling machine is available the blades are bent over a pipe (e.g. 4") by hammering which is a more time-consuming process.

Concerning the definition of the blade-holes for the connection to the supports first one of the blades will be used as a sample in order to obtain the demanded equality in blade positions. To obtain this, first a representative set of mounted blade supports is found for which the mutual distance of both rotor rings is quite accurate. Then the blade is positioned and clamped temporarily in its future position.
See that the distance of the blade tip to the shaft centre represents the rotor radius while the width of the blade is devided properly in the supports.

The hole positions of the supports are taken over now to the back of this blade by means of a pencil or scriber and the holes can be drilled.
Still using this first blade as a sample the holes are taken over to the other eleven blades which result in twelve equal products. This procedure is very essential with regard to the demanded positions of the blades in the rotor and for proper balancing.

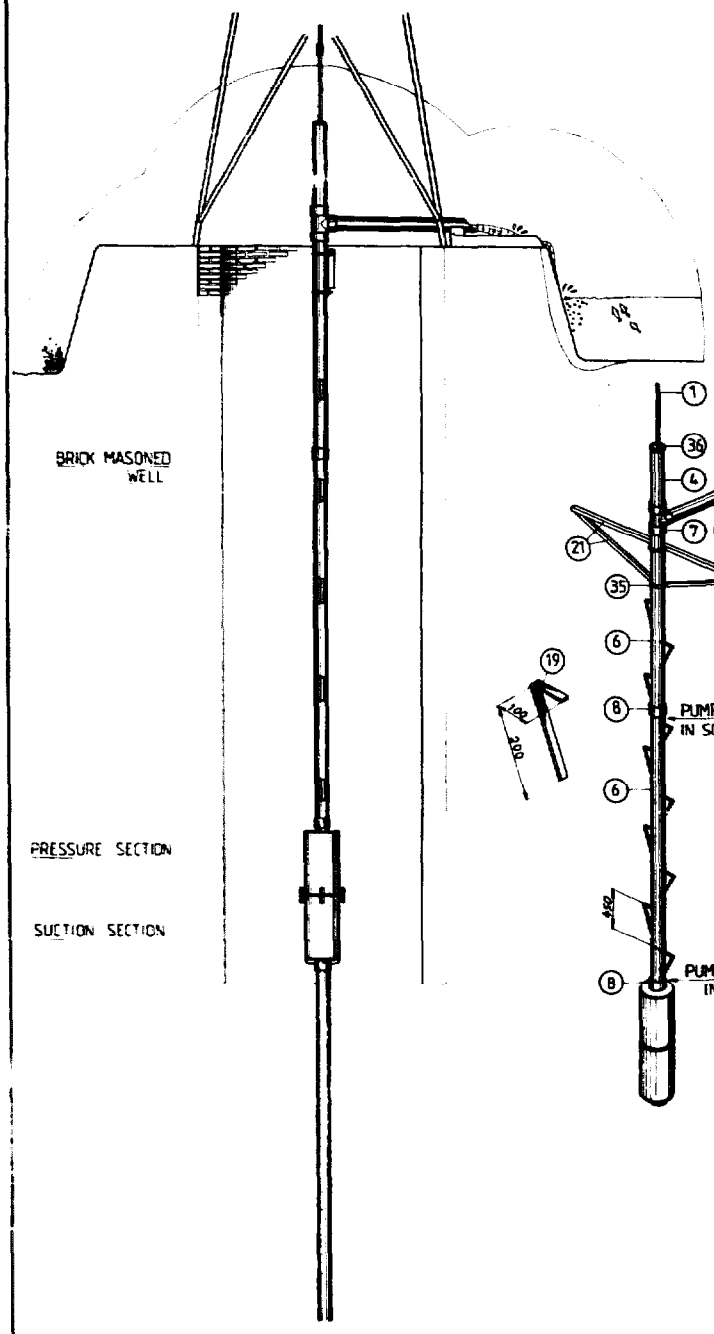

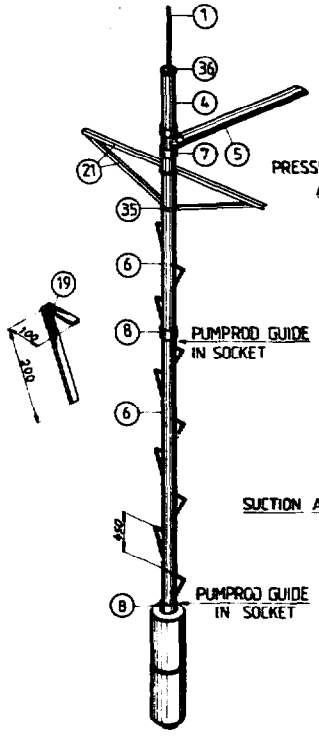

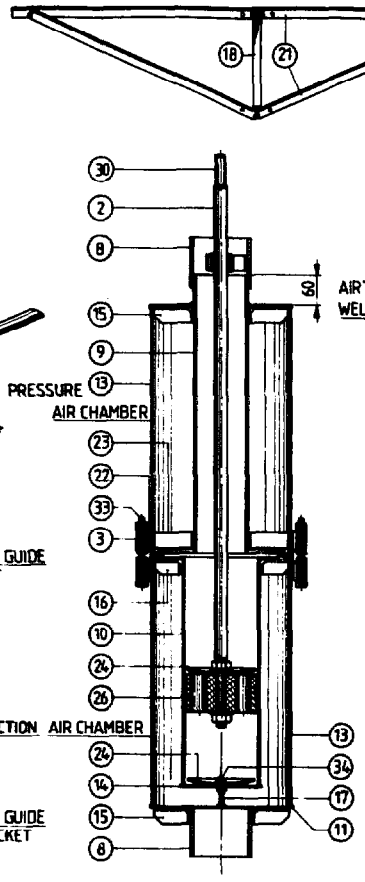

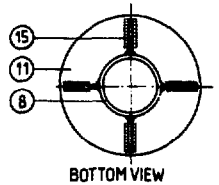

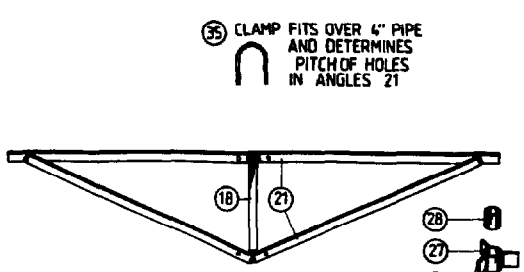

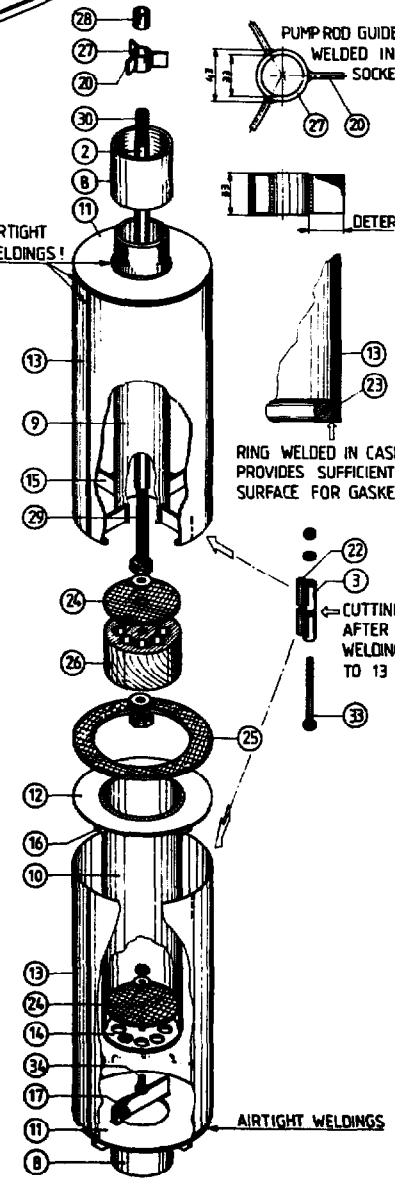

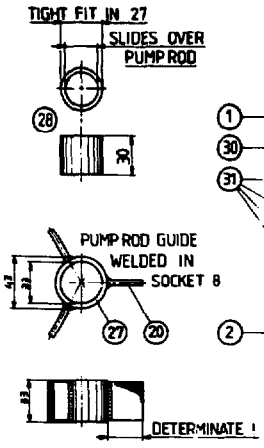

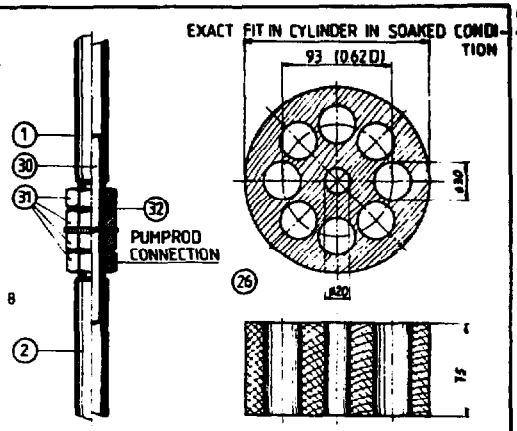

✱ AMOUNT OR SIZE DEPEND ON CIRCUMSTANCES

NO	NUMBER	MATERIAL / NAME / REMARKS / MEASUREMENTS
36	1	WOODEN PUMPROD GUIDE 27 IN DRAWING NO 4
35	2	CLAMP ROD Φ 12 (½") × 370
34	1	BOLT - NUT - WASHER M 12 × 20 (W ½" × ¾")
33	4	BOLT NUT WASHER M 12 × 125 (W ½" × 5")
32	✱	SPRING WASHERS M 24 (W 7/8")
31	✱	NUTS M 24 (W 7/8")
30	✱	THREAD STUD M 24 × 100 (W 7/8" × 4")
29	1	THREAD STUD M 24 × 150 (W 7/8" × 6")
28	✱	GUN METAL BUSH Φ 33 × 30
27	✱	STEEL BUSH Φ 43 × 33
26	1	PISTON TEAK WOOD
25	1	GASKET SOLE LEATHER Φ 290 × 6
24	2	VALVE Φ 150 × 6
23	1	RING ROD Φ 8 (5/16") × 870
22	9	FILLING PIECE × 40
21	2	ANGLE IRON 40×40×4 (1½×1½") × ✱
20	3	FLAT IRON 30 × 6 (1⅛" × ¼") × ✱
19	✱	× 300
18	1	× 450
17	1	× 180
16	4	× 60
15	12	× 85
14	1	FOOTVALVE 2 mm SHEET Φ 170
13	2	CASING 500 × 900
12	1	CASING FLANGE Φ 290
11	2	CASING FLANGE Φ 290
10	1	CYLINDER SEAMLESS 6" GASPIPE × 460
9	1	DELIVERY PIPE 4" × 560
8	✱	SOCKET FOR 4"
7	1	T - SOCKET 4"
6	✱	DELIVERY PIPE (EXTENSION) 4" × ✱
5	1	EXHAUST PIPE 4" × ✱
4	1	TOPPIPE 4" × 750
3	4	PIPE ½" × 100
2	1	PUMPROD ¾" × 950
1	✱	PUMPROD EXTENSION ¾" × ✱

6 OF 7

PISTONPUMP FOR 12 PU500 WINDMILL

FOR INFORMATION: Werkgroep en Ontwikkelingstechniek T.H. Twente - Vrijhof 152 P.O. Box 217 Enschede The Netherlands

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ALT. 1-3-1982 WA

Welding the first two spokes of the rotor frame (Here the procedure is facilitated by applying a help device).

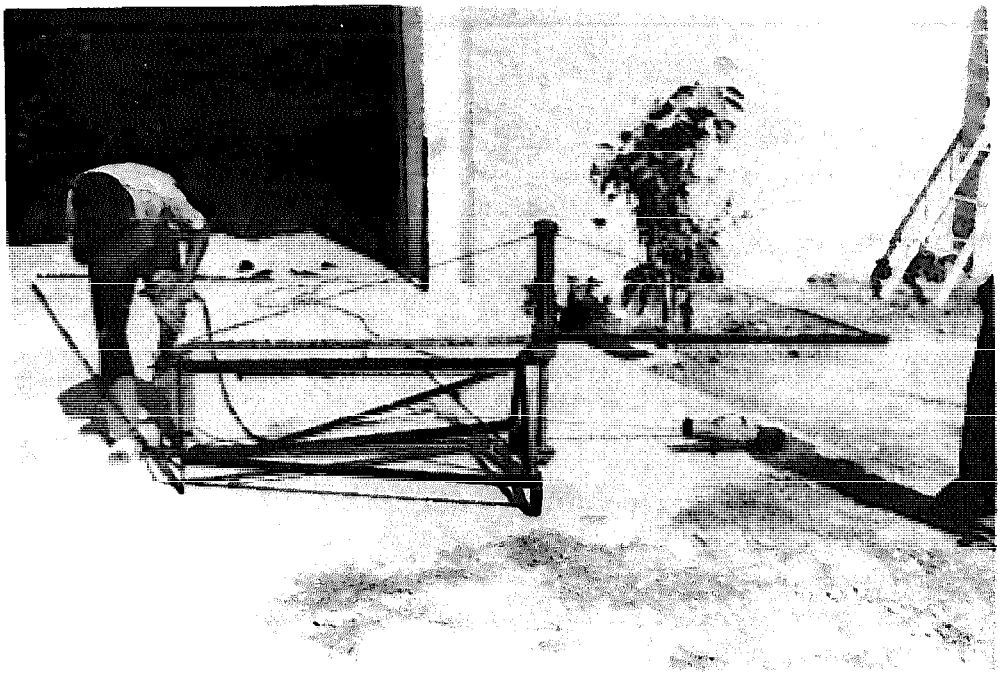

Rings are perfectly centred and spot welded to the spokes.

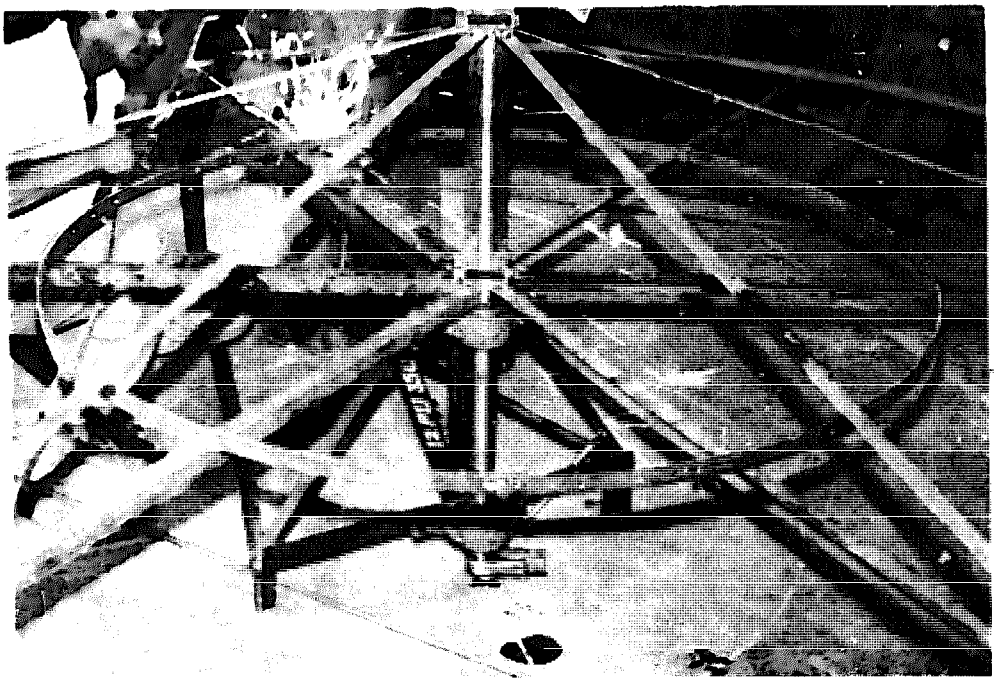

Final weldings are easily made after parting the rotor frame.

6. Piston pump

Apparently the piston pump seems to be a simple and insignificant part of the total windmill installation, which is situated just below ground level. However, in the past experiences have shown that this particular part is most virtually the heart of the entire installation. If not made properly the entire enterprise must end in a failure. For instance, air leakage, loose pump-rod connections, leaking piston and valves or a complete loose or "elastic" suspension of the pump section will cause lots of problems, loss of time and waste of labour and material. In short, do not underrate the fabrication of the pump and its fixation.

6.1 The functioning of the pump

Just considering the bottom part of the pump we recognise the piston and the footvalve both having 8 holes and a leather disk on top which covers these holes.

During upward stroke the leather disk (piston valve) of the piston is pressed to the top surface and as a result the water column is moved upwards by the piston. Due to the underpressure created on bottom side of the piston the leather disk of the foot valve is pressed upwards providing a flow through just in upward direction.

During down-ward stroke the actions of both the leather disks reverse: the piston valve opens and the footvalve prevents the freshly sucked water to flow back.
Since the water delivery just occurs during the upward stroke, this process is known as single acting. A double acting pump seems to be more attractive; people expect that the output will be double, but that is not true!
Of course a double-acting pump will provide a more continuous flow as in every stroke it delivers a certain amount of water. On the other hand the single acting pump delivers the double amount in one stroke only while the result of next stroke is

zero again. This single acting process will cause a more irregular drive, but is preferred since the pump-rod transmission is able to carry considerable pulling forces but not the pushing forces occurring during double acting pump drive.

As far as the irregular drive is concerned a flywheel is needed: the rotor provides a huge flywheel. Still the major disadvantage of the single acting pump driven by windmill is the high starting torque demanded since the entire water column causes full pressure on the piston. Therefore one will note that the windmill needs some extra strong windgusts in order to pull the piston in top position first after which the rotor is accelerated in rotation during the unloaded downward stroke. Then the windmill picks up a more continuous rotation.
To improve this starting feature of the windmill a small but permitted leakage over the piston is applied. Then the windmill is able to pull the piston in top position, while the pressure over the piston is considerably less since the water column remains "standing" statically on the footvalve Such leakage can be created by drilling a hole in a piston which has been equipped with a perfect sealing, but one can imagine that this will lead to a contradiction. Applying a piston without any sealing a leakage is achieved and moreover friction does not occur, so wear and tear in the piston and cylinder combination are reduced as well.

Experiments have shown that pistons made of hard wood (teak, sesam, iroko) have longer life than those made of e.g. aluminium. Therefore, in design, the combination of a wooden piston and steel cylinder has been preferred. As far as the "permitted" leakage is concerned a nice sliding fit without any clearance of the piston in the cylinder will provide the needed minimum leakage. The desired effect is obtained after the initial wear occuring during the "run-in" period.

Due to the irregularity in acceleration of the lifted water column the forces acting on the piston and footvalve appear as "hammer beats" resulting in damage to the moving parts and pump suspension in the long run.

Air vessels at suction- and pressure-side of the pump prevent these sudden impacts since each air-chamber provides a "kind of airspring". Moreover, the water flow is more or less equalized at suction- and pressure-side as well allowing the application of rather narrow suction- and delivery-pipelines. In the designs these air-chambers have been created by spaces enclosed by the several concentrically placed cylindrical parts. This central formation of the air-chambers has the advantage above excentrically situated air-chambers (by means of T-piece and elbow-connections) since now all the unpredictable forces and jumping of the mass of water and air bulbs are acting in symmetry without causing any sideward vibration.

The pump exists of two main sections: the top- and bottom-section:

<u>top section:</u>

Actually this section is just a big airchamber made from 2mm sheet, partly reinforced by flat iron ribs. The delivery pipe reaches to the bottom, near the cylinder. In the socket of this pipe a pump rod guide, furnished with a bronze bush, provides the needed support to the pump-rod. Both the delivery pipe and pump rod are extended by means of standardized screw connections.

<u>bottom-section:</u>

Enclosed by the cylinder and outside-casing the suction air chamber exists. Also this casing is composed of 2mm sheet and some reinforcing flat iron ribs. At the bottom of the cylinder the footvalve arrangement is situated. In the steel cylinder itself the wooden piston, equipped with leather washer and bolted to the pumprod, slides accurately without any play.

Both the sections are jointed by means of four bolts while the gasket assures a water-sealed connection.

6.2 Preparation of the steel cylinder

Preferably the cylinder is made from seamless gas pipe. If not available it is possible to apply "seamed" - pipe provided that the seam is removed accurately. This is done either by grinding or by means of a simple scraping tool which can be made easily from a piece of suitable metal (hard, e.g. piece of broken file), which is welded at right angle to the end of the rod. Once shaped by grinding according to the inside cylinder radius, surprisingly good scraping effect is achieved and the removal of the seam is just a matter of a few minutes.
The finishing touch is given by some filing and honing.

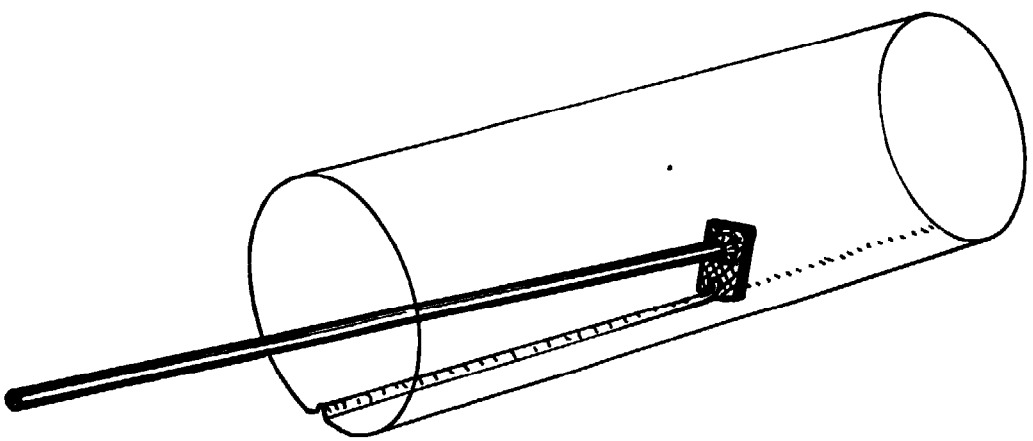

It will be evident that causing any unroundness of the cylinder should be avoided during vice-clamping since then an inside-machining on a lathe machine is needed definitely. This might be inconvenient and cause extra complications.

Inside facing of the cylinder by honing is advisable. A simple honing device is made from a cylindrical piece of wood in which three grooves are chiseled at its circumference, so that three whet stones have an easy slide in these. A piece of 3/4" gas pipe of approx. one metre length is fitted into the central hole, which has been drilled into the wooden cylinder. Two circular sheets are pulled together by three bolts and enclose

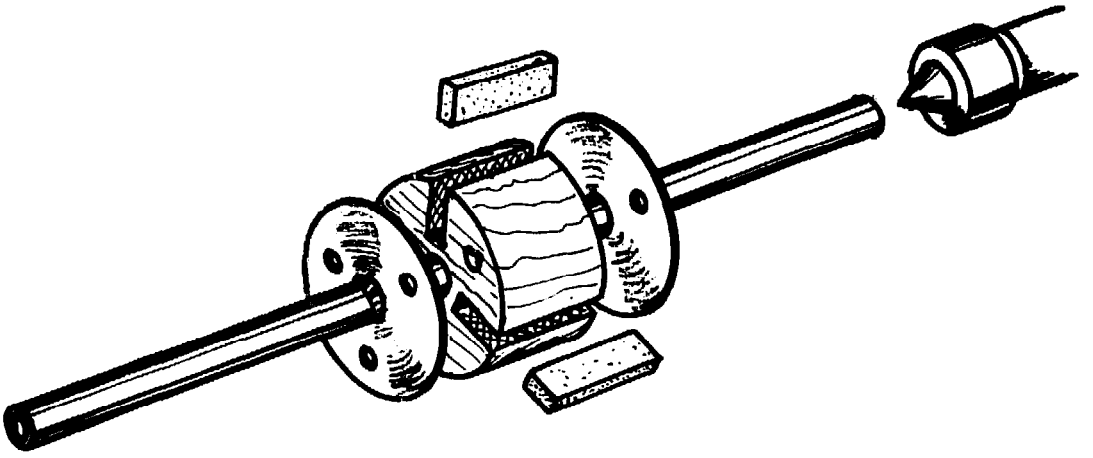

the wooden body and so the whet-stones in longitudinal sense. This set is situated in the centre of the gas-pipe and one of the sheet disks is welded to it to carry the torque. One end of the gas pipe is clamped in the chuck of the lathe machine. The cylinder (to be honed) is slided over the device and the end of the pipe is supported by the tail stock center of the lathe. Hold the cylinder by hand and try to find the most suitable RPM-number of the lathe for which the whet-stones,as a result of the acting centrifugal forces, serve their purpose best. Move the cylinder to and fro regularly and add some cooling oil from time to time.

Important : See that after completing this procedure the bed and settles of the lathe are cleaned properly from the abrassive grinding particles.

6.3 Footvalve arrangement and pre-machining of the piston

The foot valve is made of a 2 mm steel disk in which the large holes in combination with the leather washer allow the "one-way flow" of the water.

The disk chiselled out from the casing flange 12 will provide the material for the foot valve body. Very accurately the pitch circle (0.6 D) is drawn and the eight hole centres are derived by compass. After accurate center punching the holes are predrilled first with a small drill, say 6 mm.

It is clear that drilling the big holes into this rather thin sheet can be complicated. (Holes become more or less triangular.) However, the same holes should be drilled into the thick wooden block of the piston and at the same pitch. Therefore it is advisable to put the disk on top of the piston block (centred and fixed by means of a ½" bolt) and to drill both the workpieces at once. Do this in a careful manner: see that the tiny ribs in between the holes are not going to crack during the drilling procedure. After this the piston is kept in water again till it is machined to its final shape in a later stage of pump fabrication. (see 6.4.3)

The sharp edges of the holes in the footvalve disk are removed (so that the leather valve will not be damaged in future) and the footvalve disk is positioned and welded to the bottom part of the steel cylinder. See that the nicely honed inside surface of the cylinder is not going to be spoiled due to welding drops and sparks, so cover the inside temporarily or close the valve-holes. Actually, the cylinder is complete to be built in into the bottom section of the pump.

6.4.1 The top section

At its bottom part the edge of the casing is made broader in order to create sufficient surface to press the gasket (if not, the gasket will be cut definitely). It is the best to get the ring 23 made first. Do not weld it yet, but see that it is perfectly circular and plane. Position it in the casing so that the ring neither protrudes nor is sunken down too deep. Check this by rule and give some spot weldings to secure its position.

Stepwise the welding is made now, but very moderately since protruding welding material has to be removed later on (by filing) in order to achieve a plane gasket flange.

The casing is put on the floor with its bottom facing downwards. Put the delivery pipe 9 in its centre and slide the 2mm disk 11 over it. Give some spot weldings to connect the

latter mentioned and take this set out to check the rectangularity. Weld the 4 ribs 15 and correct the shape of the sheet iron disk by means of some hammering.
Put the arrangement in the casing again and secure it by means of some spot weldings (do not finish the weldings yet). Turn the top section upside down and install the other 4 flats 15 to ensure alignment of delivery pipe in the casing . Now all the welds are finished air-tight and the top section is ready for the assembly of the pump-rod guide and anchor bolt arrangement which is done in a later stage.

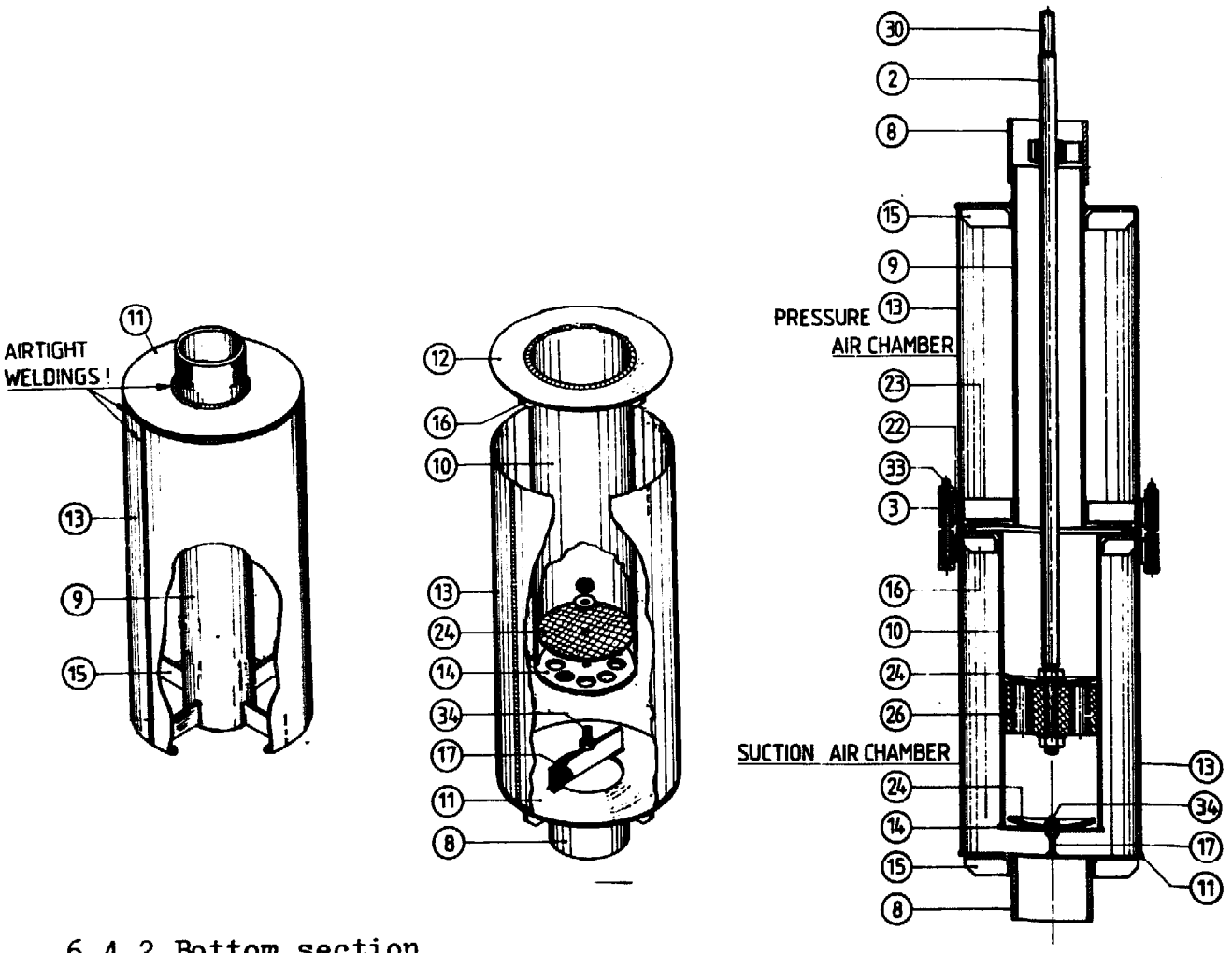

6.4.2 Bottom section

The socket 8 is welded to the disk 11. Then the central bolt 34 and its support flat 17 are composed and welded too. This bottom portion is positioned to the outside casing and secured by means of 8 spot weldings. To be sure to achieve a perfect alignment of bottom casing (so the entire pump) and suction pipe, a pipe is screwed into the socket and the alignment is

checked and corrected. Then the four outside ribs 15 are positioned and welded and all the weldings are completed.

Put the cylinder into the casing; its bottom is centered by means of the footvalve and its centre bolt. Slide disk 12 over the cylinder and connect them by means of 8 spot weldings. Take the set out; position and weld the 4 inside ribs 16 and give some correction by hammering. Then the section is installed again into the casing and connected to it by means of 8 spot weldings first after which final weldings are made stepwise. It will be evident that the air-tight weldings between disk 12 and the outside casing are moderate in order to prevent a great deal of filing there.

6.4.3 The piston

The wood for the piston (rectangular block) is kept in water for at least one week. This is done in order to allow the wood to "grow" so that the size of the piston, which is given to it by machining, will not increase later resulting in a jamming fit in the steel cylinder. This should be prevented at any price!

Preferably the holes in the pistons are taken over from the footvalve sheet when it is drilled as mentioned earlier.

The block is put on a rod (preferably the pump rod itself) in between two nuts, in order to get it clamped in the chuck of the lathe machine. The outside diameter is turned approx 1mm in oversize of the inside diameter of the steel cylinder. Both sides of the piston are faced nicely after which the piston is taken off from the screw rod and final assembling to the pump rod is done. See that the smooth side of the leather washer (piston valve) faces the smoothest plane of the wooden piston. Of course, the burred edges of the steel washers are situated in such way that they do not harm the leather washer and the wood. Screw the nut and lock it either by means of an extra nut or by applying a locking bolt.

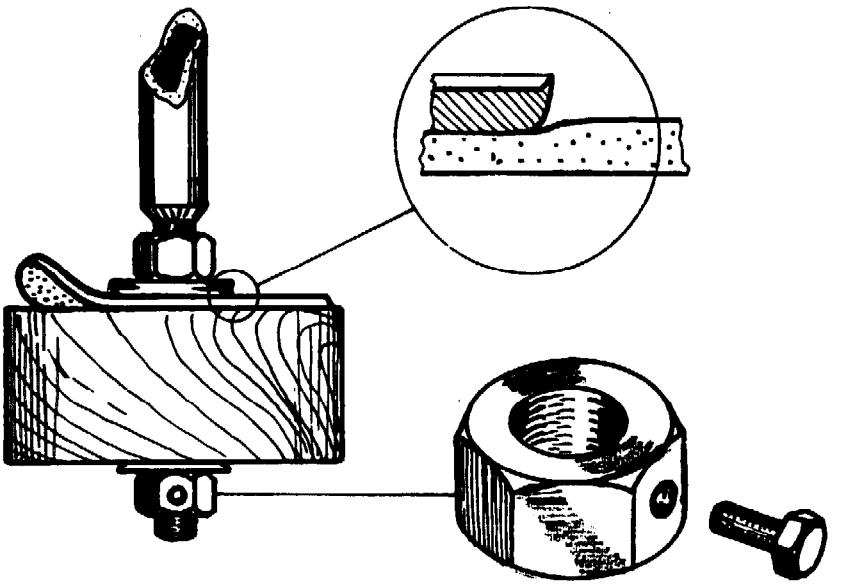

Final machining to the piston is done now so that it has a nice sliding fit in the steel cylinder.

6.5 Final assembly

First of all the 4 clamping devices and pumprod guide are composed. The piston is slipped into the cylinder and the top section of the pump is situated on the bottom section. See that the outside welds of both the casings are aligned which defines the correct mutual position of Top-and Bottom-section of the pump. Weld the clamping devices to the casing (their position at the circumference are given automatically by the inside joints of the 4 ribs 15 to the bottom portion of the Top section.)

Slide the pump rod guide over the pump rod into the pipe socket which is screwed to the delivery pipe. The presence of the pump rod is essential: now we are sure that the guide is going to be positioned and welded correctly. These welds are made carefully without damaging the screw thread of the socket.

The clamping devices are cut open now by hand hacksaw and both the sections as well as the piston are parted and cleaned. In order to prevent corrosion of the pump it is advisable to put some thin tar into the casings, roll them over and over and let the surplus drip out again. Painting of the outside might be advisable too (no tar, please!) in order to prolong the life-time of the pump.

Of course the piston is going to start drying out as long as it is not in its future environment. However, is is advisable to put the assembled piston and leather valve under oil (e.g. expired motor oil) instead of water since the leather should not yet be soaked in water as long as the pump is not installed on the windmill site. (Leather, once soaked in water, becomes brittle and fatigue-sensitive if it has got the opportunity to dry!).

Doing this the oil provides preservation and prevents shrinking of the piston and gives a corrosion protective coating to the cylinder.

The footvalve, piston, gasket and top section are assembled and the 4 bolts are tightened up cross-wise and regularly so that the gasket is compressed nicely and providing a leakage-free connection. Final paint coating is given now.

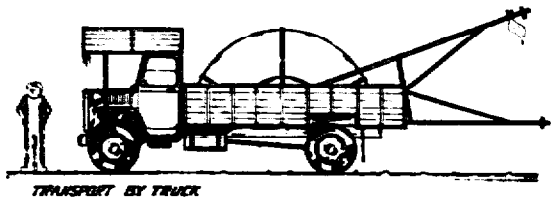

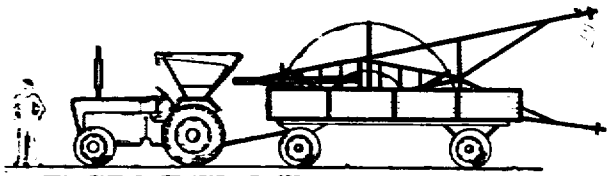

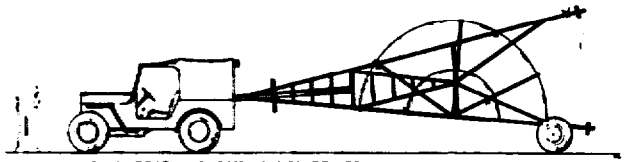

THREE WAYS OF WINDMILL TRANSPORT

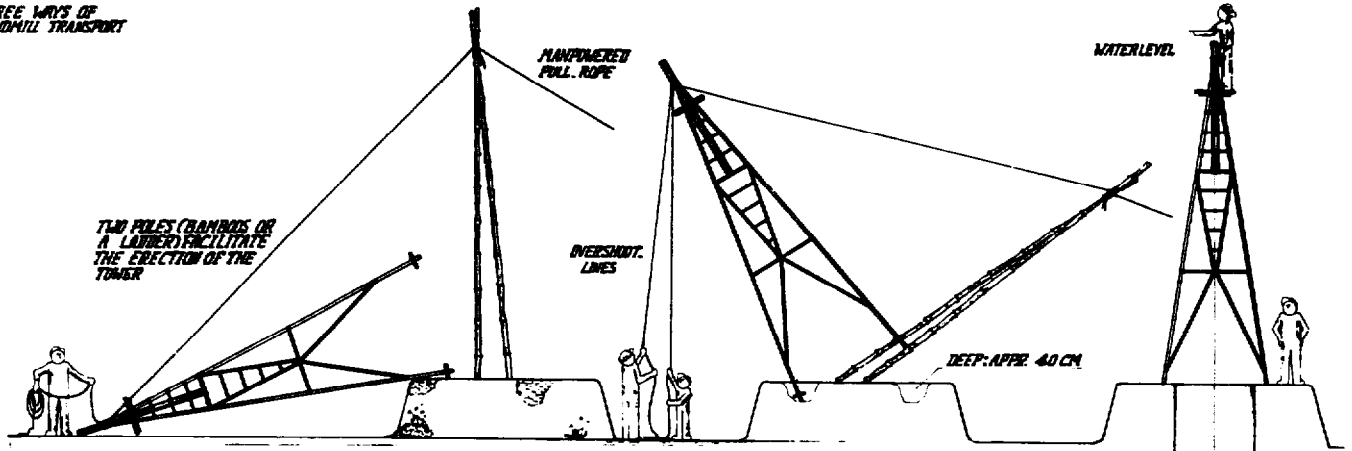

IMPORTANT: AFTER PLACING THE TOWER THE TOWERLEGS ARE POURED IN WITH CONCRETE AND AFTER APPR. 5 DAYS THE HEAD- AND ROTOR- CONSTRUCTION CAN BE INSTALLED SAFE AND QUICK BY MEANS OF LIFTING DEVICES. DURING THE DRYING PERIOD OF THE CONCRETE FUNDATION THE PISTON-PUMP IS FIXED INTO THE WELL ACCORDING TO THE SPECIFICATIONS!

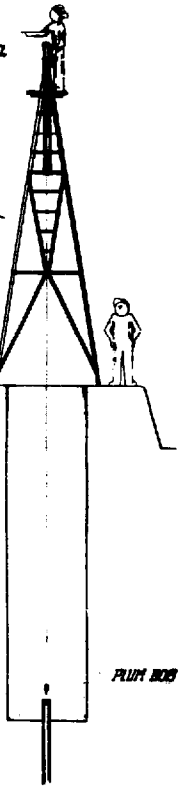

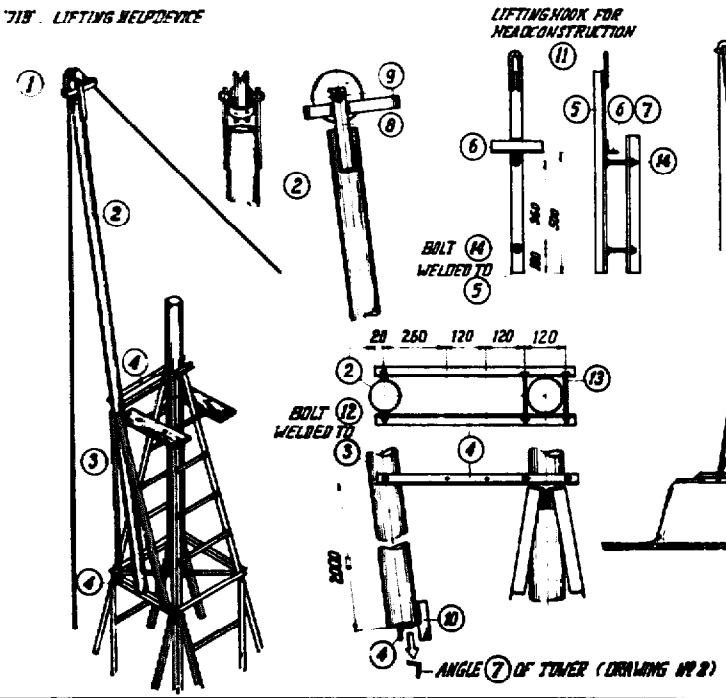

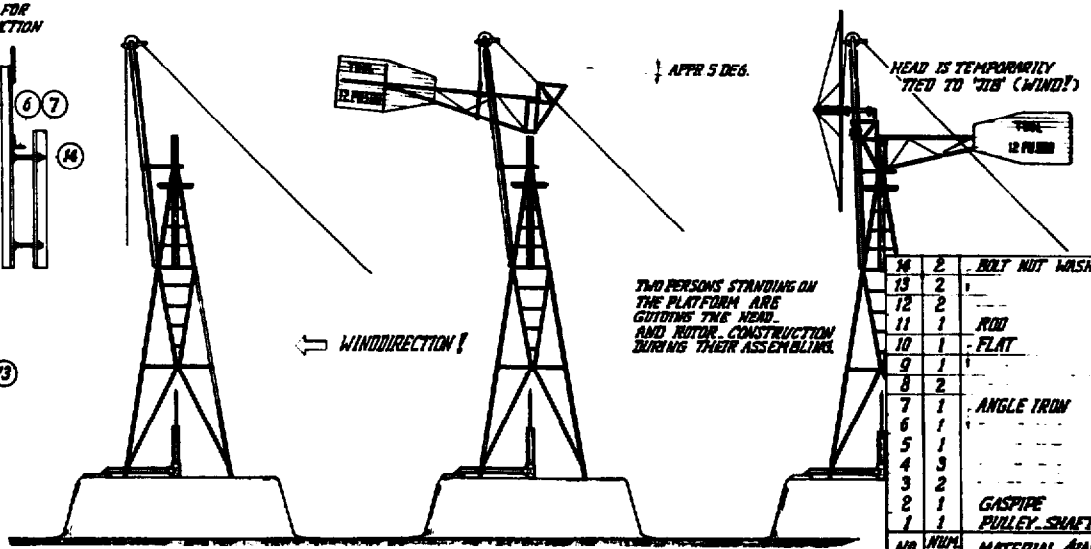

SINCE THE CENTRE OF GRAVITY OF THE HEAD-CONSTRUCTION IS SITUATED ABOVE THE UPPER TAIL ANGLE A SPECIAL LIFTING HOOK IS APPLIED. A SMOOTH SLIDING OVER THE TOWERPIPE IS ACHIEVED IF THE FRONT IS OUT OF BALANCE APPR 5 DEGR.

ROTOR IS LIFTED WITH THE SHAFT COMPLETE WITH BEARINGS FIXED IN THE ROTORHUB IN ITS ORIGINAL POSITION (CENTRE POINTS!) AND FIXED ON THE HEAD CONSTRUCTION. NOW THE "718" CAN BE REMOVED AND THE BLADES, SAFETY DEVICE AND MOVING PARTS ARE ASSEMBLED.

Nº	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS
14	2	BOLT NUT WASHER — M12 x 75 (W½" x 3")
13	2	" — M12 x 150 (W½" x 6")
12	2	" — M12 x 50 (W½" x 2")
11	1	ROD — Ø 10 (Ø ⅜") x 200
10	1	FLAT — 30 x 6 (1¼" x ¼") x 100
9	1	" — x 600
8	2	" — x 200
7	1	ANGLE IRON — 40 x 40 x 4 (1½" x 1½") x 550
6	1	" — x 200
5	1	" — x 800
4	3	" — x 600
3	2	" — x 2000
2	1	GASPIPE — Ø 3" x 4500
1	1	PULLEY, SHAFT AND ROPE OR STEELCABLE (30 M)

7 BF 7

INSTALLING THE WINDMILL — 12 PU 500 —

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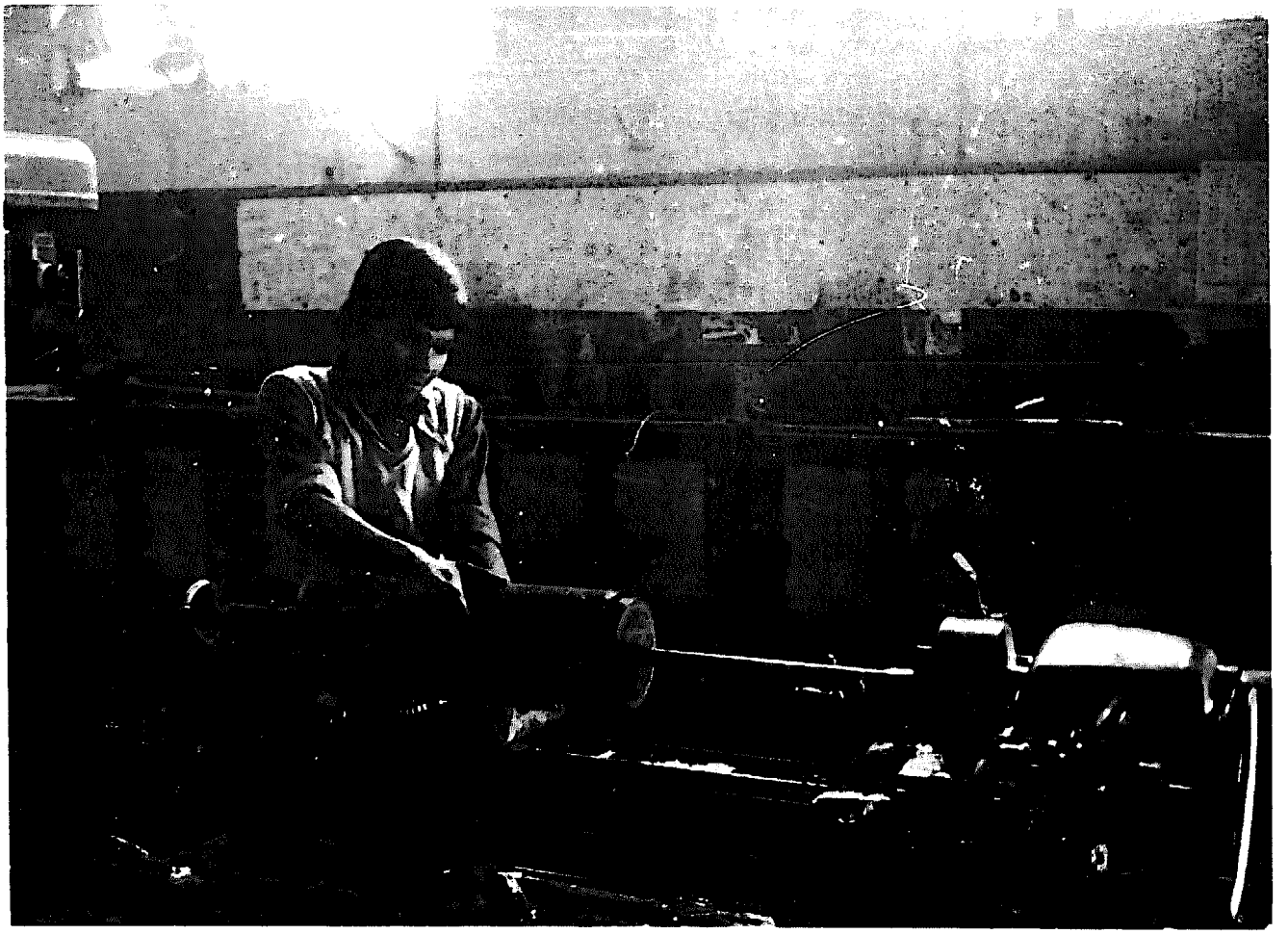

Honing the steel cylinder.

Windmill pump production.

7. Installing the windmill

Till so far the following windmill parts are supposed to be prefabricated: tower, headconstruction, moving parts, rotor frame and blades, and the pump section. However, this does not mean that the job has been done. On the contrary: quite a deal of essential steps are to be undertaken yet.
First of all the parts are composed partly in order to check the fit. Therefore put the headconstruction on the tower in order to find out whether it rotates smoothly over the tower pipe. Also install the moving parts (mainshaft, crosshead and connecting rod) temporarily and check the functioning. Also check the fit of some blades (at random). Until and unless these checks are confirmed the windmill is ready for transport. One can imagine what inconvenience will be felt on the site if needed corrections should be carried out over there.
Another important thing with regard to windmill installation should not be forgotten. Help devices like the jib crane and lifting hook, which are represented in the drawing, are not merely helpful but a must! This from a safety point of view.

The use of the jib crane is really necessary for lifting the head construction and rotor both. If this help device is made (see drawing) see that the pulling rope runs nicely in a pulley and cannot run off!
The lifting hook is a help device which provides a suitable attachment to the head construction which is situated above the point of gravity of the latter. One can imagine what happens if no lifting hook is applied: the head construction tumbles over and nobody will be able to handle it during the procedure of lifting and installing. (See paragraph 7.4).

If all these required precautions have been taken the windmill is ready for transport.

The drawing presents three ways of transport of the windmill in order to reach its destination. See that all the parts are hand-

led with care and tie them up in order to prevent shifts and mutual movement. It will be evident that for proper transportation some sloth-flags are applied to get the other traffic attended of this remarkable transport.

7.1 Erection of the tower

The holes for the foundation are dug at the desired pitch. Make them of equal depth and wide enough to provide sufficient space for the towerleg anchors and to enable the tower to shift to a certain extent. The tower is laid in position and a rope is connected to the top portion. A ladder (or a set of bamboes) is kept vertically over which the rope is led. Before pulling the tower upright one has to be sure whether the ladder (bamboes) as well as the tower itself cannot fall sidewards. Some extra people can prevent this by guiding and supporting them.
After the erection procedure the tower is placed vertically. This is checked by means of a water level gauge which is kept aside the towerpipe (not at top of the towerpipe edge!) Some filling material (e.g. bricks) are wedged under the towerleg angles during the adjustement in vertical sence. Now the desired position of the centre is checked by means of a rope and plumb-bob, this with regard to the alignment of the tower with the centre of the well or the centre of the tubewell. Again the vertical position is checked and if both positions are satisfactory the towerlegs are grouted by means of cement and stone- or brick chips.

Unfortunately for this job the application of a simple plumb-bob proves to be sometimes unreliable due to the influence of the wind. However by visual means the centring of the tower can be checked by looking through the tower pipe along its centre-line.

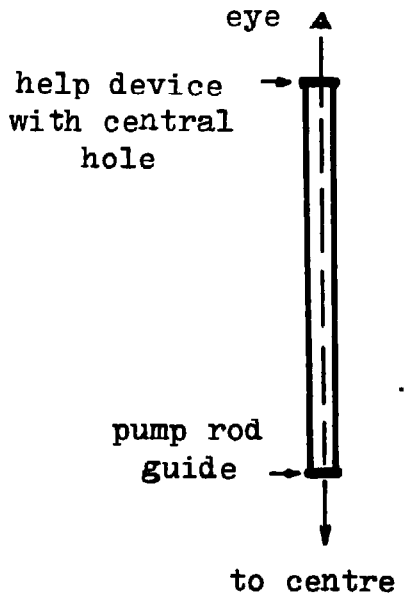

The harding-out procedure of the foundation needs at least 5 days,but in the meantime the time-consuming fixation of the pump is carried out. As far as grouting is needed (for pump fixation, washing place etc.) the needed mortar is made available during grouting the towerlegs.

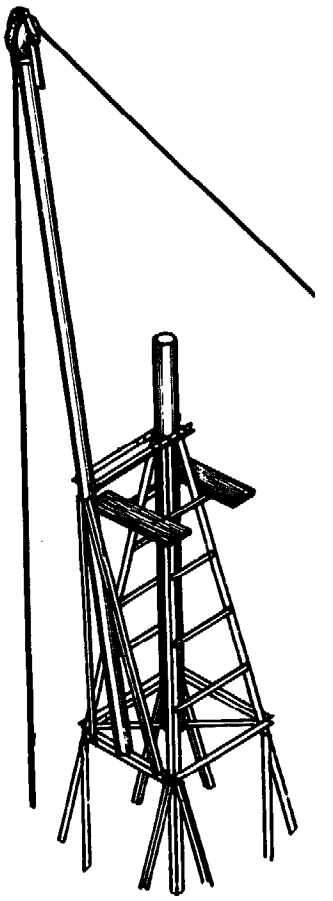

7.2 Installing the headconstruction

Now the jib crane is going to prove its worth. It is pulled and pushed up aside the tower and finally set on angle 7 of the tower. See that the jib is installed at the "windshadow"-side of the tower, (See drawing) while its two clamping angle-iron arms 4 enclose the tower-pipe in most outward positon.

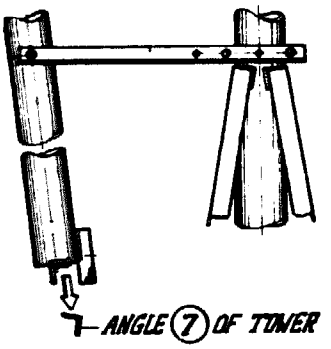

Now the complete headconstruction without help vane is brought under the jib. The lifting hook is bolted to the tail at about 1.5 metres distance from the tail hinge. The head tends to turn towards the tail, since the lock mechanism of the help vane is kept out which makes the entire headconstruction difficult to handle. Arrange a locking device temporarily either by roping the upper tail-beam to the headconstruction or by putting a clamp overthere. Also a pin, stuck through the head and ending up in the upper tail-beam,serves the purpose very well. Lock it

The rope is connected to the lifting hook and balancing of the headconstruction is tried out. Balancing in the sense that the front part of the head is out of balance! (say: 5 degrees). This is a must in order to prevent that the framing of the headconstruction, which is going to surround the towerpipe, will grip and throttle it. (This is a most essential precaution which seams to be even contradictional: further on it will be explained).

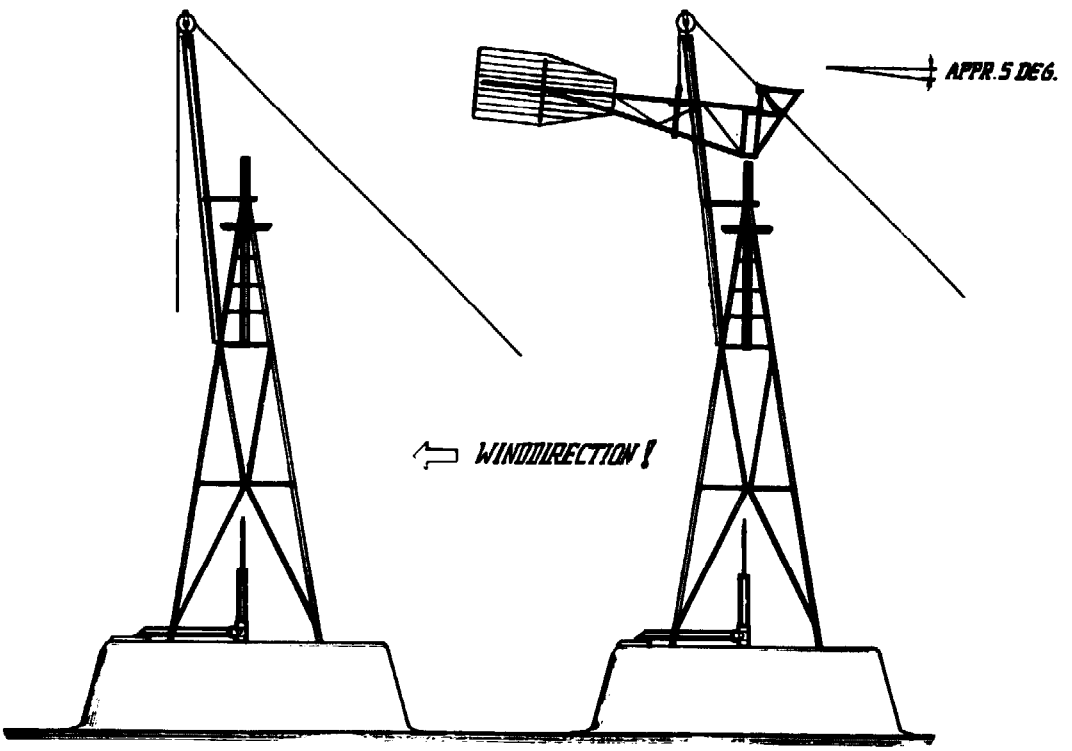

Now the head is lifted slowly by pulling the rope (by approx. 6 persons) and two persons guide the head while climbing the tower. Let the head seek its position in the wind, do not force it and lift it till it floats just above the tower pipe. Both persons, each standing on the platform now, guide the bottom part of the head just over the towerpipe. The head is lowered down very slowly and the persons keep the head pressed down over the towerpipe. Actually they should maintain the "5 degrees out of balance" state of the head while the head itself is lowered down stepwise. The last few centimetres might be bothersome as the inside angles 7 of the head might touch the towerpipe edge and so obstruct a further sliding over of the

head. If extra attention is paid to a proper centration no problems appear and the head sinks into its final position. Loosen the rope and remove the lifting hook and preparations are undertaken now to install the rotor frame.

7.3 Installing the Rotor

First of all the position of the jib crane should be adjusted. Therefore the jib crane is put in the most upright position. Now the headconstruction is turned 180 degrees so that the front part of the head is touching the jib crane. For security reasons we make a rope connection overthere so that the head on which the rotor, shaft and bearing blocks are going to be bolted, should remain under the pulley of the jib crane. This is really necessary as appearing wind might turn the headconstruction suddenly.

The two rotor halves are connected now and the shaft is put into the hub and of course in its original position (the centre points! see chapter 5). The hub bolts are tightened stepwise as well as securing clamping angle irons. Carefully the rotorframe is carried to the tower where it is put in vertical position, standing on one of its six spokes right under the jib crane. Be aware that the extruding shaft points into the lattice of the tower construction and problems will arise during the lifting procedure.

The rope is lowered down now from the jib crane and it is connected to the hub of the rotor frame, but so that the rope passes both the inside - and outside - ring from the back of the rotor!
Carefully and slowly the rotor is lifted and two persons guide it while climbing the tower. Extra attention is paid to the extruding shaft which tends to stick into the lattice of the tower. Finally reaching the level of the platform it is seen that the shaft is positioned on the correct side of the jib crane, since the latter itself will be an obstacle.

The entire rotor and shaft are hovering over the head now. With some effort the bearing blocks are positioned above their supports and the rotor is lowered very slowly then. Quickly the bolts are put and nuts are screwed by hand first. The position is secured now and the rope is removed from the rotor and the jib crane is lowered down. Revolve the rotor during some revolutions in order to enable the bearing blocks to settle on their supports and tighten the bolts of them finally.

Put the windmill in secured position and bolting of the blades can start. Therefore one person sits on the platform and another stands on angle 7 of the tower. Bolts, nuts and the tools can be kept conveniently in a basket which is hung temporarily to the platform during this intensive bolting activity. It will be evident that the blades are mounted in cross wise sequence e.g. 1-7, 8-2, 3-9, 10-4 etc.

After this the crosshead, assembled with both connection rod and pump rod now, is slided into the towerpipe and the crank bush and central bolt are assembled. See that locking bolt of the P.V.C. - towerpipe insert is removed temporarily in order to allow the crosshead to pass by. Also important is to install the crank bush with its collar facing the crank plane and do not forget to apply the washer in between its bolt head and the bush edge. The crank bolt is tightened up strongly and of course the locking screw for the P.V.C. - towerpipe insert is re-installed (and should not be forgotten!). Also the wooden pump rod guide is installed on bottom side of the towerpipe and locked with the bolt.

Now the helpvane arrangement is built in and the windmill can be put into the wind enjoying the wind for the first time.

7.4 Installing the pump

As expressed earlier in chapter 6 the suspension of this very essential part should not be underrated as many difficulties are felt regarding the alignment and fixation in the well.

The reciprocating forces, which act on this section, can be considerable and of course a minor play in the suspension, either in axial- or in radial sense, will lead to a "noisy dancing and swinging" performance of the pump. One can imagine what is going to happen then in the long run: play increases to the extent that grouted parts of the suspension come out, bolts and nuts run loose and hammer their way through their counterparts. In short, this is not the way windpower should be utilized and no doubt; such a clumsy performance creates a wrong impression concerning your windmill.

So, better pay a lot of attention to the proper alignment and strong suspension of the pump and delivery pipe in order to prevent the above mentioned malfunctioning.

Though the wells for windmill-sites differ in depth of water table, diameter and structure, at least some prescriptions can be given to obtain suitable suspension:

- In case of centrally situated installation of the windmill above the well it is advisable to apply at least one "bridge construction" which is represented in drawing no. 6. This structure really provides the needed suspension, provided that its legs have been grouted thoroughly in the well casing. Centration at the bottom part of the pump section is obtained either by the tubewell (if applied) or by the application of a similar "bridge construction" which supports the suction pipe to which the pump has been screwed.

  In the latter case grouting the bridge into the well casing might be complicated since preferably the bottom part of the pump is situated under the water table in order to make the pump selfpriming and to ensure the desired minimum suction head. This problem is overcome either by grouting the bridge-legs during a period for which the lowest water level exists (dry season, after excessive water removal by another pumping device) or by using an expanding clamp mechanism.

Provided that the well casing is of proper construction the entire pump arrangement can be fixed suitably by means of an expanding clamping device. The latter is composed of 1"gas pipes which are welded at right angle either to the bottom section of the pump or to the suction pipe. Mutual braces (angle iron) ensure a rigid construction. The clamping arrangement is obtained by fitting longthreaded bolts or screw studs into the extruding pipe ends. Tightening their nuts causes the expansion and fixation of the frame. In order to prevent damage to the bricks of the well casing it is necessary to enlarge the bearing surface by means of pieces of angle iron.

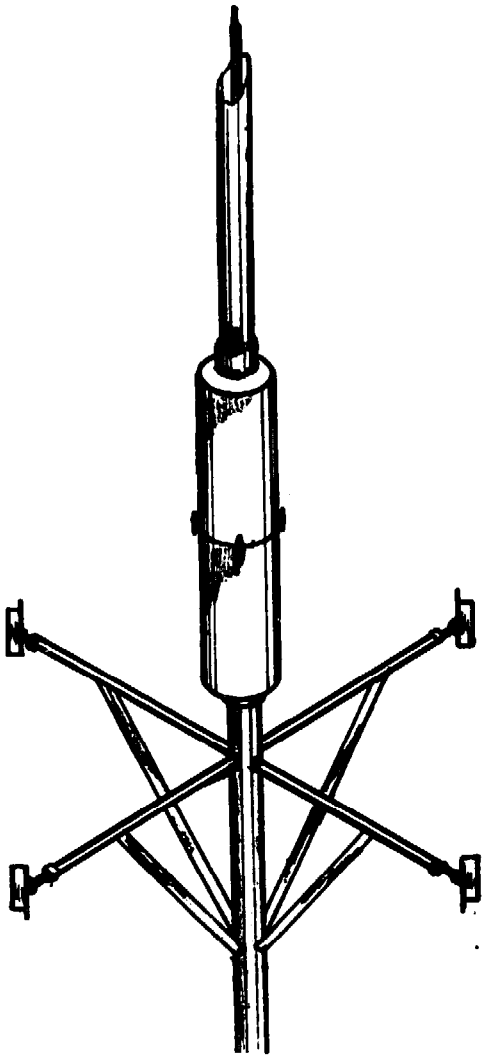

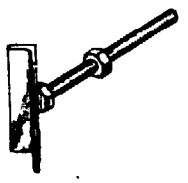

Such clamping device proved its worth in combination with the "bridge" construction.

In case of an excentrical position of the windmill no choice is left. Clamps, extended with strong anchors, are grouted in the well casing.

In such cases of pump suspension all forces, acting in vertical sense, should be taken directly by a connection between the pump-section and tower-pipe.
This connection is achieved by means of two parallel angle irons of which ends are welded to the halves of the clamps which embrace the tower pipe and delivery pipe.

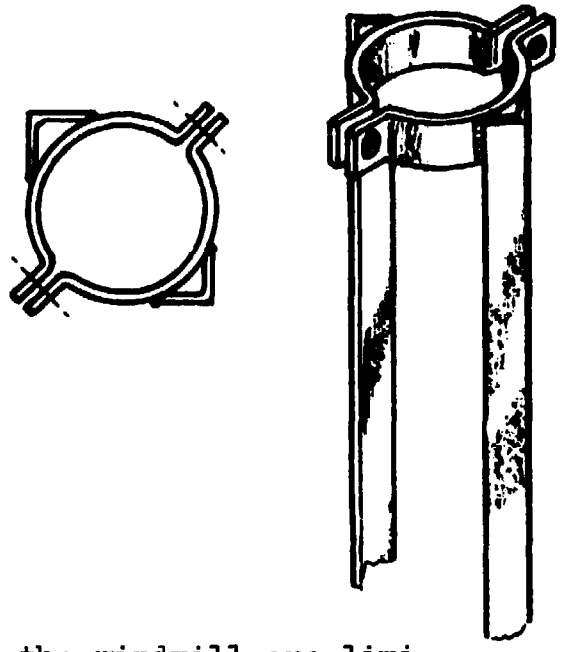

7.5 Maintenance of the windmill

Though the number of moving parts in the windmill are limited yet certain regular check-ups and lubrication services should be undertaken from time to time. Also, in the long run, some moving parts might wear out and are to be replaced then. Fortunately in this design, such parts are cheap in material costs, easy to make and easy to replace.
Due to this the maintenance costs of the windmill are minor and make the application of the windmill attractive. Moreover it is independent of fuel supply. In next paragraph the required maintenance of the windmill is described stepwise.

7.5.1 The overall structure

Actually corrosion of the steel structure is the greatest enemy of the windmill. If the corrosion problem is tackled in the right way the technical lifetime of the windmill is expected to reach at least 15 years and probably far beyond that figure.
Therefore it is advisable to have the structure painted thoroughly by means of at least one primer-coating and two finish coatings (do not forget to chip off the weldingslag).
Especially in areas where the air is humid or even: saline (coastal areas) it is advisable to have the best anti-corrosive paint (zinc-based) applied. No doubt, that will be a costly affair but we should realize that it will be paid back in the long run. This is illustrated by the fact that shipowners are too eager to spend huge amounts of money to get their sea-going vessels protected by means of the rather costly anti-

corrosive zinc-compounded paints.
This enemy (corrosion) is certainly always present in the pump section of your windmill and the most excessive attacks might be expected in there first. Of course, the tar- and paint-preparation, given to the pump earlier (see chapter 6), might provide considerable precaution against excessive corrosion. Yet the lifetime is restricted rather by the corrosion than the actual wear and tear of the pump and in a saline environment in particular.

In this regard also some know what is drawn from the "tackle of sea-vessel corrosion". To prevent excessive dissolvement of the steel body in this very strong corrosive environment some "anodes" are sacrified. Zinc blocks, connected to the steel body, are bound to be dissolved first as zinc is more inferior than steel.
In short: as long as the zinc-anode is available in the active environment, the steel-parts are protected from corrosion provided that a proper electric contact is maintained in between both materials.

This "anodic-protection" can be applied very usefully in our steel pump-section in order to protect it from corrosion. A zinc block is cast around a piece of (clean and not corroded) flat-iron and the extruding ends of the flat are welded to the inside casing of the pump; there where it will always be surrounded by the corrosive water. Suitable places are the inside of the bottom portions of the casings of either the suction-air chamber or the pressure-airchamber of the pump. This system is the only remedy against corrosion of the "underwater" parts of the windmill besides, of course, the overall zinc-plating of the entire construction.

7.5.2 Tower

Generally it is expected that the tower will not need a specific attention with regard to wear and tear since it concerns a static structure here. However one should realise that the tower-pipe serves multiple functions:

- It carries the headconstruction on the edge (this is in axial sense).

- It provides support by its outside to the headconstruction, which encloses it at top- and bottom-part as well. (This in radial sense.)

- Its inside provides the guidance to the crosshead via the contact of the P.V.C.-insert.

No doubt, the "steel to steel" joint of the towerpipe and headconstruction needs some lubrication (grease) from time to time. However as long as the stubborn grease is present no excessive wear is going to occur over there. Also, as long as the P.V.C.-insert remains locked in the tower pipe also the P.V.C.-insert will serve its purpose very persistently. (see 7.5.4)

However, corrosion of the tower as prescribed earlier, has to be taken into account and check-ups and remedies should be undertaken.

7.5.3 Headconstruction

Besides its joint to the towerpipe only a few moving parts of this structure need some attention for maintenance. Especially the locks of the security-device should remain free of any play. The functioning of the hinges of the helpvane and tail vane both should be checked from time to time since they might have the tendency either to run loose or to corrode! The first will lead to loose and noisy (so clumsy) joints and the latter lead to a reluctant and hesitating functioning of the mechanism Best remedy is to apply some oil drops there (very moderately) from time to time.

If, unfortunately, the helpvane-lock or the final-lock are worn out better take it out, apply some welding and reshaping (the

latter by filling) and get it re-installed properly. There is no need to explain the necessity of a proper functioning storm-security device (see chapter 3).

7.5.4 Moving Parts

It is assumed that the main bearings have been positioned, tightened up, and greased and then locked up into their houses. Generally the lubrication is sufficient for millions of revolutions and as long as no dust-particles are going to enter this "greasy environment" (in order to form a very destructive grinding paste then) no complications are expected. However one can imagine that in the course of time the grease is "rolled out" of the bearing and will change its lubrication properties. So, though this is a matter of years, sooner or later new grease should be applied (no oil!) and therefore it will be most convenient if a greasing-nipple is present at the bearing house. However, if no nipple is there, the bearing house has to be opened now to apply the fresh greasing. In that case be aware that the rotor tends to tumble over if you are going to open the rear bearing house with such disastrous effects as mentioned in chapter 4. Prevent this by roping the rear-end of the mainshaft to angle 2 of the headconstruction.

Generally the nylon (or bronze) bearings of the connecting-rod keep their lubricant very well. Some fresh oil drops from time to time will serve the purpose satisfactorily. The same counts for the wooden cross head and pumprod guides. Properly soaked in oil as they are, they contain the lubricant themselves and from safety point of view it is the best to keep them in that condition! Generally a "generous filling up" of the square hole in top of the cross head by means of oil, provides the best guarantee that these essential wooden parts will maintain their excellent functioning. The appearing play in these parts after some time of functioning might seem to be bother-some, but realize that they have a long way to go before replacement is really necessary. In short: the wear is acceptable as long as no noisy and clumsy malfunctioning of them oc-

cur. Then their replacement will be cheap and easy to be carried out especially as far as the wooden pumprod guides are concerned. With regard to replacement of the cross head it is advisable to drill completely new holes for the pumprod/cross-head connection so in the same manner as has been described in chapter 4.
It will be evident that in case of replacement of a worn-off cross head the replacement of the P.V.C.-insert is recommended also. Maintain the origional pumprod length.

7.5.5 The Rotor

Besides protection, concerning corrosion, the rotor does not need any maintenance. However in some cases bolts and nuts will run loose due to the alternating character of load on them. A "cracky" noise is the indication for this evil and the best remedy is to check-up all bolt- and nut-connections, especially at the start of the new life of your windmill.
In very rare cases some fatigue cracks are going to appear either in the outside blade supports (shearing-fatigue) and/or in the blades somewhere near the outside supports. This is due to poor quality of the sheet iron (mainly its structure) so this is a good reason to apply materials which answer the standard specifications (for mild steel in this case).
If, unfortunately this fatigue occurs, only one remedy exists: get the supports and/or blades replaced by new material and avoid a mispurchase this time. If still doubts remain better go for sheet material which is slightly thicker (1.25 mm for 12 PU 500).

7.5.6 The Piston Pump

No doubt, in a good windmill the pump section remains the most bothersome part of it. Besides the checks of its suspension also checks are to be made with regard to its delivery.
Namely, depending on the purity of the lifted water the piston is going to wear sooner or later resulting in a poor delivery which means that it should be replaced then. Replacement just concerns the cheap and simple piston here since the steel cylinder of the pump remains the toughest and survives many pistons.

If this time has come for the change of the piston better replace the leather valves too. Then guarantee will be there that the newly overhauled pump will serve its purpose for the next period of time without any failure. The span of that time fully depends on the purity of the water which is pumped from the source. No doubt the presence of sand particles play a significant role in the life time of the piston and if possible precautions should be undertaken. Therefore at least, in case of water delivery from a tube well, a proper "washing" procedure is necessary (see chapter 1) otherwise the windmill will do it, with the above mentioned consequence.

7.6 Monitoring of the windmill performance

Though in most of the cases windmills will be put up for their actual purpose (here: water pumping) it might be interesting to yield some data from their functioning For example costbenefit analysis of it in comparison with those of its "competitors" (diesel pumpset, electric motor pumpsets, waterlifting by bullocks, or even water lifting by means of human power) may provide information with regard to its feasibility. Of course, this water lifting device depends fully on the wind and will fail it the latter does not supply the required energy. This drawback should be taken into account before one starts with a well meant large-scale application of the windmill. Therefore a proper study and monitoring of the "behaviour" of your windmill should be undertaken in order to draw right conclusions. On the other hand the future developments in fuel supply and electrical power supply should be considered as well and certainly not forgotten.

Anyway, collecting data from the windmill is desirable and as far as the technical features of the windmill are concerned the derivation of the delivered water flow versus the occuring wind speeds will be interesting. According to the wind data, valid for the region (see chapter 1) in which the windmill is going to function, the expected delivery can be estimated.

No doubt, it will be really interesting and useful to figure out the capacity and prospects of your windmill while knowing that the wind persists blowing even beyond our time.

Chiseling the square hole in the crosshead

APPENDIX I

MATERIAL REQUIREMENTS & COST PRICE ANALYSES OF THE 12 PU 350 WINDMILL

With the pump 6m below ground level & a 4" steel pump

	Tower (m)	Head + tail & help - vane	Rotor (m)	Trans mission (m)	Pump (m)	Deli-very part (m)	Total length (m)	kg/m kg/each	Rs/kg Rs/m	Total weight (kg)	Cost price Sept. 1980 (Rs)
Angle 1¼" x ¼"	40.3	13.22	9.95	-	7.6	-	71.1	1.78	4.50	126.56	456.40
Flat 1" x ¼"	6.86	3.78	22.2	1.53	-	3.62	38.0	1.25	4.50	47.5	213.75
Pipe ø 5/8"	-	-	-	4.0	1.1	6.5	11.6	-	7.80	-	90.50
ø 1"	-	-	-	-	2.4	-	2.4	-	18.00	-	43.20
ø 3"	2.15	-	-	-	0.575	7.0	9.7	-	54.00	-	523.80
ø 4"	-	-	-	-	0.475	-	0.5	9.33	73.00	4.7	36.50
Rod ø ½"	-	0.47	-	-	-	-	0.5	0.96	4.15	0.5	2.10
ø 3/8"	-	-	-	-	0.6	-	0.6	0.56	4.15	0.4	1.70
Shaft ø 1½"	-	-	-	1.0	0.06	-	1.1	-	60/m	-	66.00
ø 20"mm	-	-	-	0.2	-	-	0.2	-	20/m	-	4.00
Sheet 1mm	-	1.25m2	2.2m2	-	-	-	3.5m2	7.8m2	5.77/kg	27.3	157.50
2mm	-	-	-	-	0.75m2	-	0.8m2	15.6m2	5.77/kg	12.5	72.10
Wood 1" x 8"(mango)	1.2	-	-	-	-	-	1.2	-	10/m	-	12.00
4" x 4"(sesam)	-	-	-	0.22	-	-	0.25	-	50/m	-	12.50
3½"x3½"(sesam)	-	-	-	0.1	-	0.1	0.2	-	130/m	-	26.00
4½"x2½"(teak)	-	-	2.12	-	0.13	-	0.2	-	40/m	-	8.00
Leather ø 220	-	-	-	-	1x	-	1x	0.4	34/kg	-	13.60
(6 mm) ø 100	-	-	-	-	2x	-	2x	0.1	34/kg	-	3.40
Nylon 1½"	-	-	-	0.06	-	-	0.06	-	62/ft	-	12.40
Gun metal 1"	-	-	-	-	0.06	-	0.06	4.44	40/kg	-	10.65
Pillow blocks 1½"	-	-	-	2x	-	-	2x	-	250	-	500.00

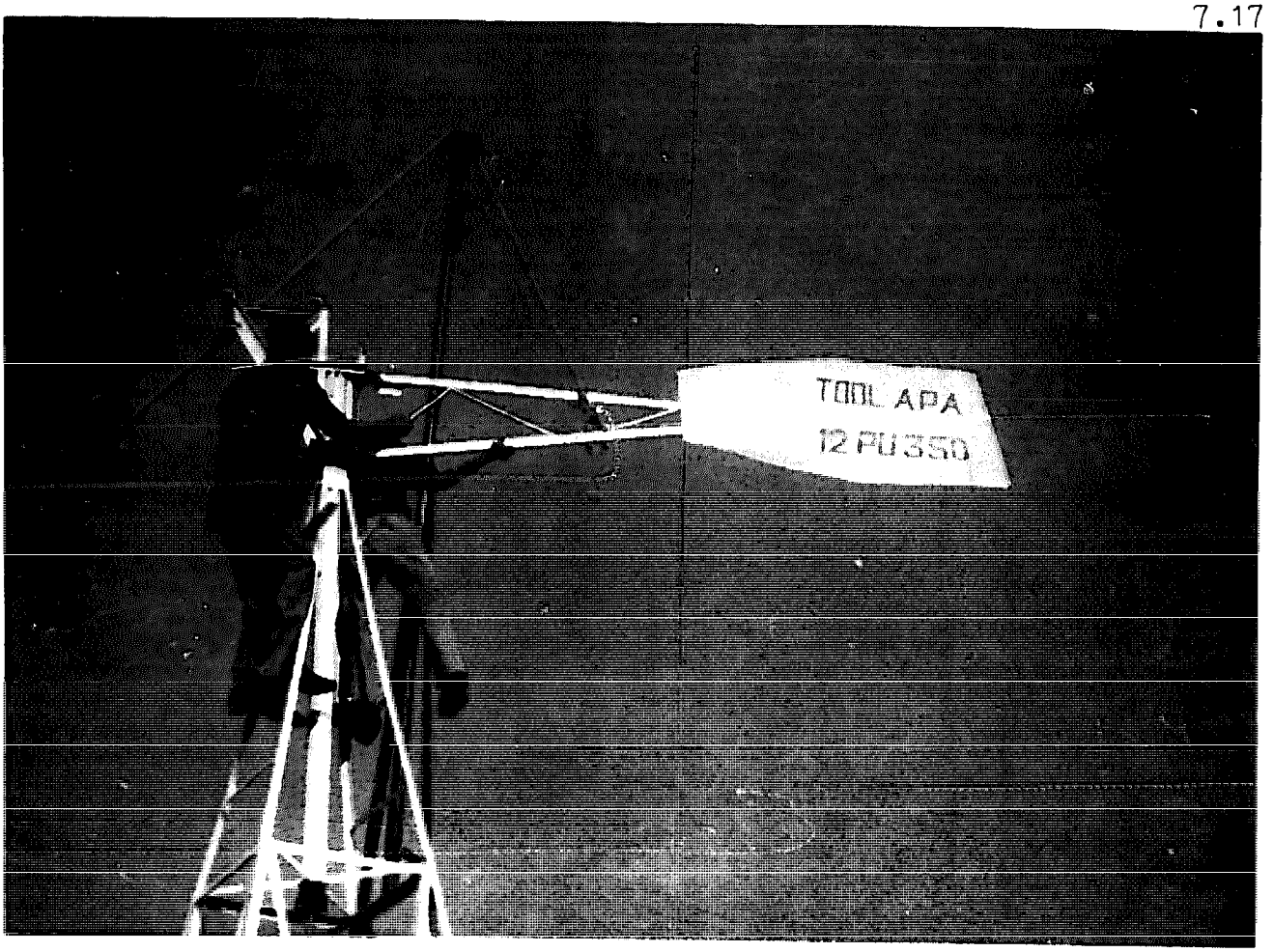

Installing a 12 PU 350 head construction

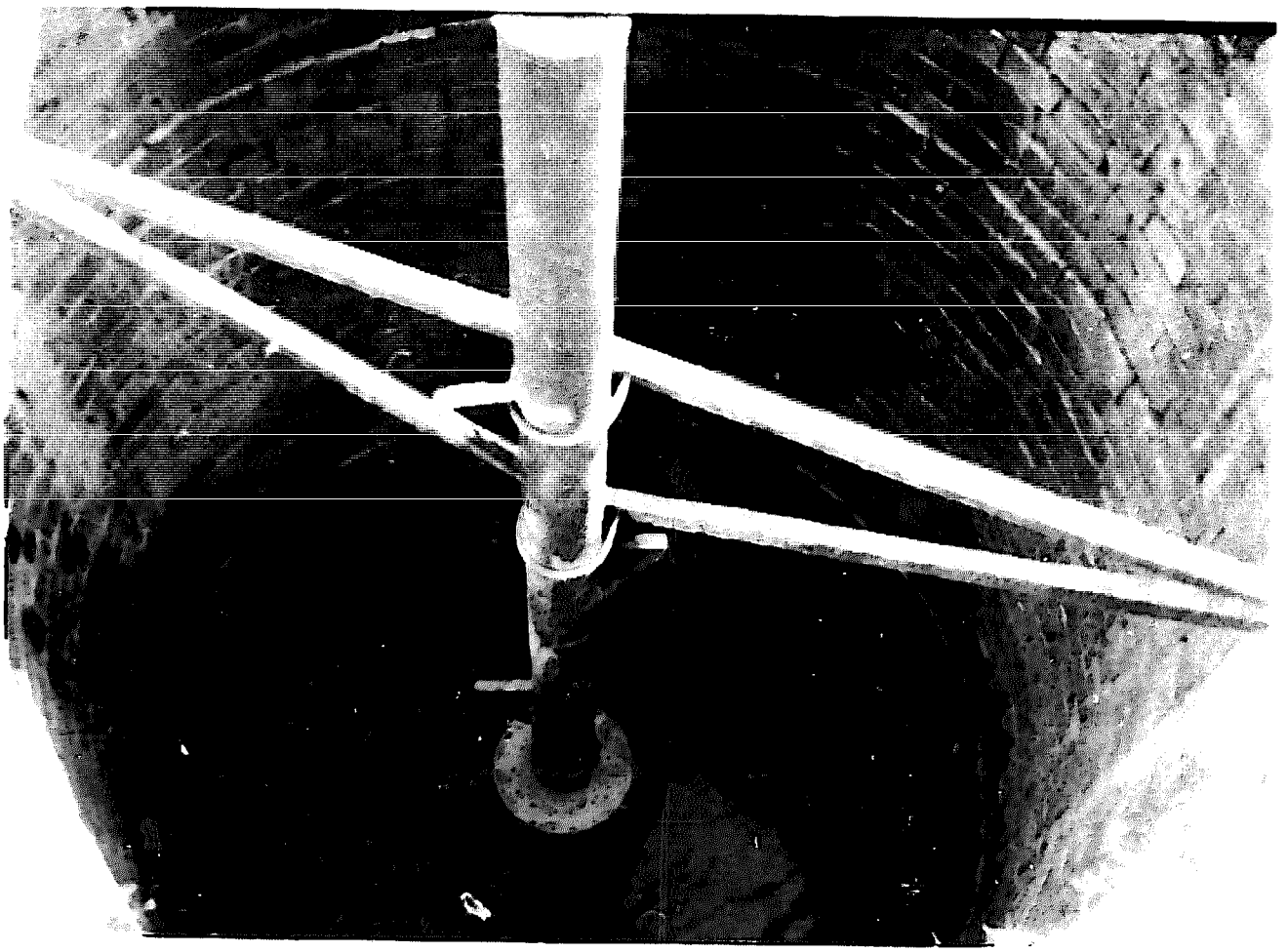

Typical bridge-suspension.

APPENDIX II

MATERIAL REQUIREMENTS AND COST PRICE ANALYSES OF THE 12 PU 500 WINDMILL

With the pump 6 m below ground level and a 6" steel pump (tube well flange6m below ground level - well diameter 1,50m)

	Tower (m)	Head + Tail & help vane (m)	Rotor	Trans-mission (m)	Pump steel pump (m)	Deli-very part (m)	Total length (m) (no's)	Kg/m kg/each	Rs/kg Rs/m	Total weight	Cost price Sept.1980
Angle 1¼" x 1¼"	41.53	-	-	-	-	-	41.5	1.78	4.50	73.9	332.55
Angle 1½" x 1½"	26.00	18.1	13.5	-	-	4	61.2	2.97	4.50	181.8	818.10
Angle 2" x 2"	-	0.48	0.7	-	-	-	1.2	4.47	4.50	5.4	24.30
Flat 1" x ¼"	-	-	-	0.54	-	-	0.6	1.25	4.50	0.8	3.60
Flat 1¼" x ¼"	7.82	5.28	31.38	0.85	-	4.64	50.0	1.50	4.50	80	360.00
Flat 1½" x 3/8"	-	-	-	0.17	-	-	0.2	2.40	4.50	0.5	2.25
Pipe 5/8"	-	-	-	-	0.4	-	0.4	-	7.80/m	-	3.10
Pipe 3/4"	-	-	-	4.7	0.9	6.5	12.1	2.01	12.30/m	24.3	148.80
Pipe 4"	2.65	-	-	-	0.56	7.0	10.2	9.33	73.00/m	95.2	744.60
Pipe 6"	-	-	-	-	0.46	-	0.5	-	105.00/m	-	52.50
Rod 3/8"	-	-	-	-	0.77	-	0.8	0.56	4.15	0.5	2.10
Rod ½"	-	-	-	-	-	0.74	0.8	0.96	4.15	0.8	3.30
Rod ¾"	-	0.65	-	-	-	-	0.7	2.22	4.15	1.6	6.60
Shaft 1"	-	-	-	0.2	-	-	0.2	3.95	25.00	0.8	5.00
Shaft 2"	-	-	-	1.37	0.04	-	1.41	15.8	90.00	22.3	126.90
Sheet 1mm-1 x 2.5m	-	1x	4x	-	-	-	5x	19.5	5.77	97.5	568.60
Sheet 2mm 1 x 2.5m	-	-	1/3x	-	½x	-	5/6x	39.0	5.77	32.5	187.50
Wood 1" x 12" (mango)	1.4	-	-	-	-	-	1.4	-	10.00	-	14.00
Wood 5" x 5" (sesam)	-	-	-	0.1	-	0.1	0.2	-	50/m	-	10.00
Wood 3" x 7" (teak)	-	-	-	-	0.17	-	0.2	-	130.00	-	26.00
Wood 4½"X 4½" (sesam)	-	-	-	0.3	-	-	0.3	-	40.00	-	12.00
Leather ø 29 cm	-	-	-	1x	1x	1x	1x	0.4	34.00	-	13.60
6mm ø 15cm	-	-	-	-	2x	-	2x	0.2	34.00	-	6.80

(12 PU 350)

PVC pipe 3"	-	-	-	0.55	-	-	0.55	-	23/m	-	12.65
MS T - socket 3"	-	-	-	-	1x	-	1x	-	30	-	30.00
MS Socket 3"	-	-	-	-	1x	1x	2x	-	8	-	16.00
MS Flange 3"	-	-	-	-	1x	-	1x	-	24	-	24.00
MS Flange 4"	-	-	-	-	2x	-	2x	-	34	-	68.00
Primer	-	-	-	-	-	-	2L	-	20/L	-	40.00
Thinner	-	-	-	-	-	-	2L	-	21.50/L	-	43.00
Paint	-	-	-	-	-	-	4L	-	35/L	-	140.00
Bolts/nuts/Washers/ Spring/Washers/Springs	-	-	-	-	-	-	-	-	13/kg	10	130.00
Welding rods	-	-	-	-	-	-	-	-	-	-	100.00

TOTAL 2987.36

(12 PU 500)

Nylon 1½" Gun metal	- -	- -	- -	0.8 -	- 0.04	- -	0.08 0.04	- 10kg	62.00 40.00	- 0.4	16.50 16.00
Pillow blocks	-	-	-	2x	-	-	2x	-	365/each	-	730.00
PVC pipe 4"	-	-	-	0.7	-	-	0.7	-	32.75/m	-	23.00
MS Steel socket 4" MS Steel T socket 4"	- -	- -	- -	- -	1x -	1x 1x	2x 1x	- -	14/each 50/each	- -	28.00 50.00
Primer Thinner Paint	- - -	- - -	- - -	- - -	- - -	- - -	4L 4L 8L	- - -	20.00/L 21.50/L 35.00/L	- - -	80.00 86.00 280.00
Bolts/nuts/washer/ springs 1"-¾"-3/8"-½"- ¾" - 7/8"	-								13.00/kg	12	156.00
Welding Rods											200.00

TOTAL 5137.70

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Technical Report 1982

by Niek Van de Ven

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TECHNICAL REPORT 1982

by NIEK VAN DE VEN

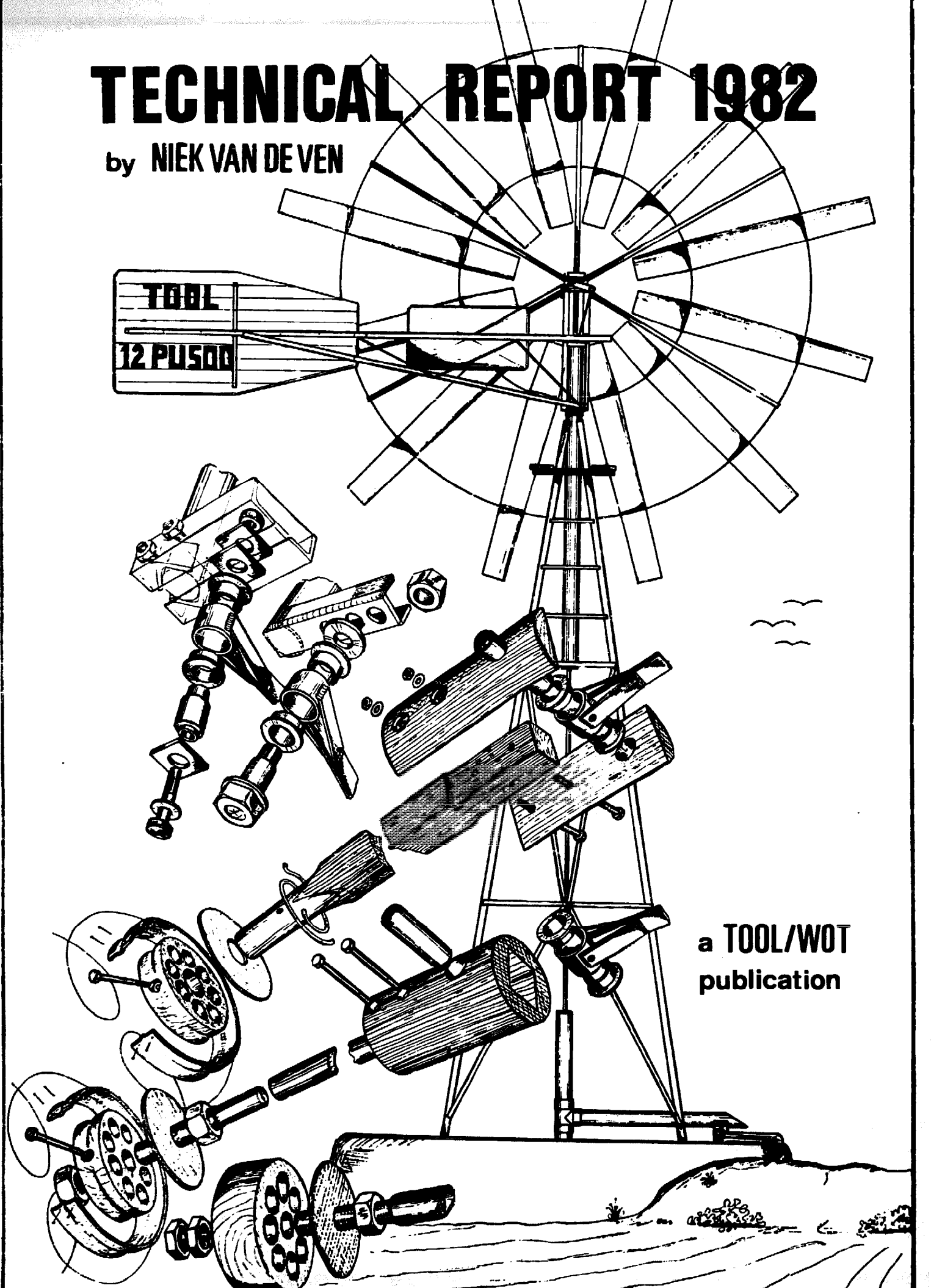

a TOOL/WOT publication

TECHNICAL REPORT

by NIEK VAN DE VEN

dealing with the

TOOL WINDMILLPROJECTS

over the period

AUGUST 1977 - MARCH 1981

TOOL TECHNICAL DEVELOPMENT WITH DEVELOPING COUNTRIES
MAURITSKADE 61 a, 1092 AD AMSTERDAM, THE NETHERLANDS

WOT WORKING GROUP ON DEVELOPMENT TECHNIQUES
T.H. TWENTE, VRIJHOF 152, P.O. BOX 217,
7500 AE ENSCHEDE, THE NETHERLANDS

Acknowledgement

The Netherlands assistance in the windmill projects in Ghazipur and Allahabad officially stopped at the end of March 1981. It was recognized by the project management committee that the experiences of the experts in these projects should be recorded.
Finally it was agreed that the financing of this activity took place through the Steering Committee Windenergy Developing countries (SWD). This is a government financed organisation promoting the interest for wind energy in developing countries and aims at helping governments, institutions and private parties in the Third World with their efforts to utilize wind energy.

The author is very grateful to all parties concerned that the experiences could be materialized in this publication. It is hoped that it will contribute to the extention of development in many countries

NIEK VAN DE VEN

TOOL is a Dutch foundation participating in the global process of renewable development and application of socially appropriate technologies.

The broad objective is to promote greater freedom for groups which are deprived of full opportunities for local, self-programmed and self-sustained development.

The strategy is to provide and support information resource links among the practitioners, users and generators of appropriate technology for development.

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- publications
- documentation systems and services
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- education and training
- organisational linkages.

WOT is a non-profit organisation at the Twente University of Technology and gives technical advice in the field of wind energy, solar energy and water supply. The broad objective is to improve the position of the weaker sections in society and the advice should be appropriate to the local situations and circumstances. To support the technical advice the WOT has a testing field where various designs are being developed and tested. The WOT is mainly a voluntary organisation and consists mainly of students of the university. Several staffmembers take care for the administrative and technical support.

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Short History

In 1975 the Organization of the Rural POOR (ORP) in Ghazipur (India, U.P.) wanted to support small and marginal farmers in growing an extra crop during summer season by means of irrigation. As rather high wind speeds occur during summers the idea was born to use wind energy as the power source for pumping the irrigation water from the wells.

In cooperation with the TOOl-foundation in the Netherlands some feasibility studies have been carried out and eventually a proposal for a pilot windmill project has been granted both by the Government of India and the Netherlands. The latter sponsored the pilot project which started in August of 1977.

The project was extended year by year while the 12 PU 500 Windmill design improved step by step. Expansion of the project occurred in 1979 when the newly built ORP-TOOL-Windmill workshop was inaugurated and the Windmill Research and Developments activities were taken up at the Allahabad Polytechnic Allahabad (APA). In the course of 1980 another Windmill project started in Trichy (South India) where the Workshop for Rehabilitation and Training of Handicapped (WORTH) also adopted the same windmills for irrigation as one of its products.(The latter has been financed by HIVOS.)

In January of 1981 the Allahabad Polytechnic Allahabad started the "National Windmill Demonstration Project" which was initiated and sponsored by the Department of Science and Technology (DST) of the Government of India. During the first three months thirty 12 PU 500 windmills have been succesfully distributed all over India attended with trainingcourses for mechanics and engineers, after which the TOOL-project ran to its end.

The following year three hundred 12 PU 500 windmills have been

built by the Allahabad Polytechnic by order of the Department of Science and Technology while plans exist regarding a windmill production of several thousands during the next year.

1. The design criteria and first developments.

Previous to the introduction of the new waterlifting device sufficient knowledge concerning its feasibility and acceptance should be gathered in order to obtain relevant input for a proper set up of a pilot project.
Therefore short term missions were undertaken to Ghazipur to gather information about materials, equipments and expertise. Also information on winddata of the eastern part of Uttar Pradesh gave important information in order to calculate the size of the windmill which had to be designed.

Since the windspeeds in the Ghazipur district are rather low, rough calculations pointed out that even in the windy season a windmill applied for irrigation of a command area of two and a half acres (1 ha) needs a rotor diameter of at least 7 metres. This calculation was based on the assumption that the average water requirement of the irrigated plots amounts to ± 7 mm a day, the total pumping head increases to 14 metres (dry season) and that the windmill starts pumping with a total efficiency of 0.10 (if the windspeed exceeds 2.5 m/s.).

Other calculations also led to smaller windwheel diametres, very high starting windspeeds and extremely huge storage tanks on the one hand and a large rotor diameter, moderate tank-capacities and low starting windspeeds on the other.
An optimum must exist depending on material- and labourcosts and the loss of agricultural area in order to realize the needed storage tank. All these matters were taken into account to approach this unknown ideal of windmill size and storage capacity, but still a lot of uncertain aspects and doubts remained.

Moreover in 1977 the availability of expertise and successful designs of cheap, reliable and appropriate windmills were

rather limited in spite of the fact that many efforts had been undertaken already to develop windmills in other developing countries.
Such experiences always showed that the introduction of the windmill is easily underrated. First the technology has to be developed and implemented successfully under the local circumstances after which a process of transfer of technology should take place.

Due to the above mentioned lack of sufficient experience, it was decided to design and develop first a proto-type windmill in the Netherlands which should be completely constructed with the materials, expertise and implements which are locally available in Ghazipur. The total material-costs should amount to Dfl. 1000.-- (Rs 3000.-- up to Rs 4000.-- 1977).
Materials like gas-pipe, angle-irons, flat- and sheet-irons, ball-bearings, bolts & nuts etc. would be available in plenty there according to the information obtained.
The local blacksmiths in India are able to construct simple implements from these, like wheat-threshers and many other agricultural equipment. Moreover the electrification of several villages sparks off more or less sufficiently equipped blacksmiths and small industries. So welding and simple machining, like drilling- and lathe-work, are rather current.

In comparison with steel (1977: angle iron RS 2.20/Kg) wood is very costly and later on it proved not to be available in required size and quality. For example wood for the construction material for building a tower-structure would not be attractive as far as the lifetime is concerned. Moreover the Indian Government stimulates application of other construction-material rather than wood in order to prevent the severe erosion of the country due to deforestation.

Such considerations and restrictions led to new ideas and alternative designs of some essential parts of the windmill. In September 1977 the construction of the first proto-type windmill was carried out at the testing field of the Working

Group on Developing Techniques (WOT) which is a member of the TOOL-foundation.

1.1 The construction of the first proto-type

This first proto-type windmill was fitted with a 4m diameter 16 bladed rotor which was left after an education program of the WOT in which it was constructed. It seemed to be a fruitful opportunity to integrate it in the design which had to be developed at that time, but afterwards it turned out that this rotor was too weak, too complicated and too expensive. Moreover according to the estimation a 4 m. diameter-windmill is rather small to serve the purpose. So after some trouble-shooting during the months of September-November, the experience with the very first proto-type caused a complete re-designing. This resulted in a set of drawings of the tower construction, head construction, moving parts and the windwheel of a new 5 m. dia. 12-bladed proto-type. Besides also a small building manual of the new proto-type has been edited, but actually the total set was not yet completed. Still the design and the drawings of the most important and essential part of this wind-powered water-lifting device, the pump, failed. In the next chapters extra attention will be paid to the pump designs which followed.

Basic designs

The expected rotor efficiency of the newly designed windmill amounts 0.38 theoretically if the windmill is loaded at a tip-speed ratio ($\lambda = \frac{\Omega R}{V}$: tipspeed divided by the windvelocity) of two. Via a simple crank-connecting rod-crosshead mechanism the rotation of the millshaft is converted into an up- and downmovement of the pumprod which drives the single-acting reciprocating piston-pump.

The tail of the headconstruction carries a windvane which turns the headconstruction around the towerpipe in order to keep the windwheel perpendicular to the wind.

In case of severe storm a simple security-mechanism will dislock automatically the headconstruction from the tailstructure after

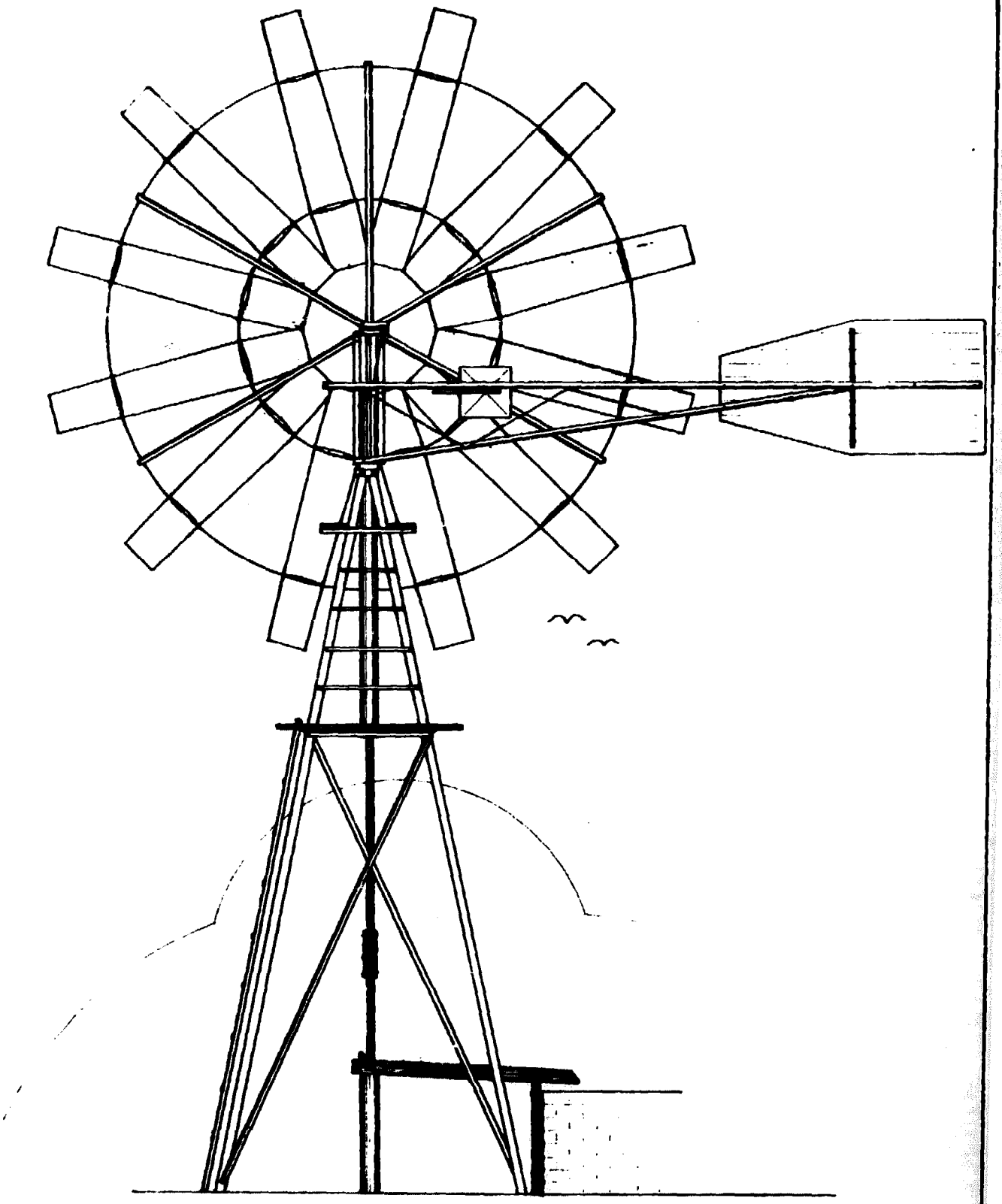

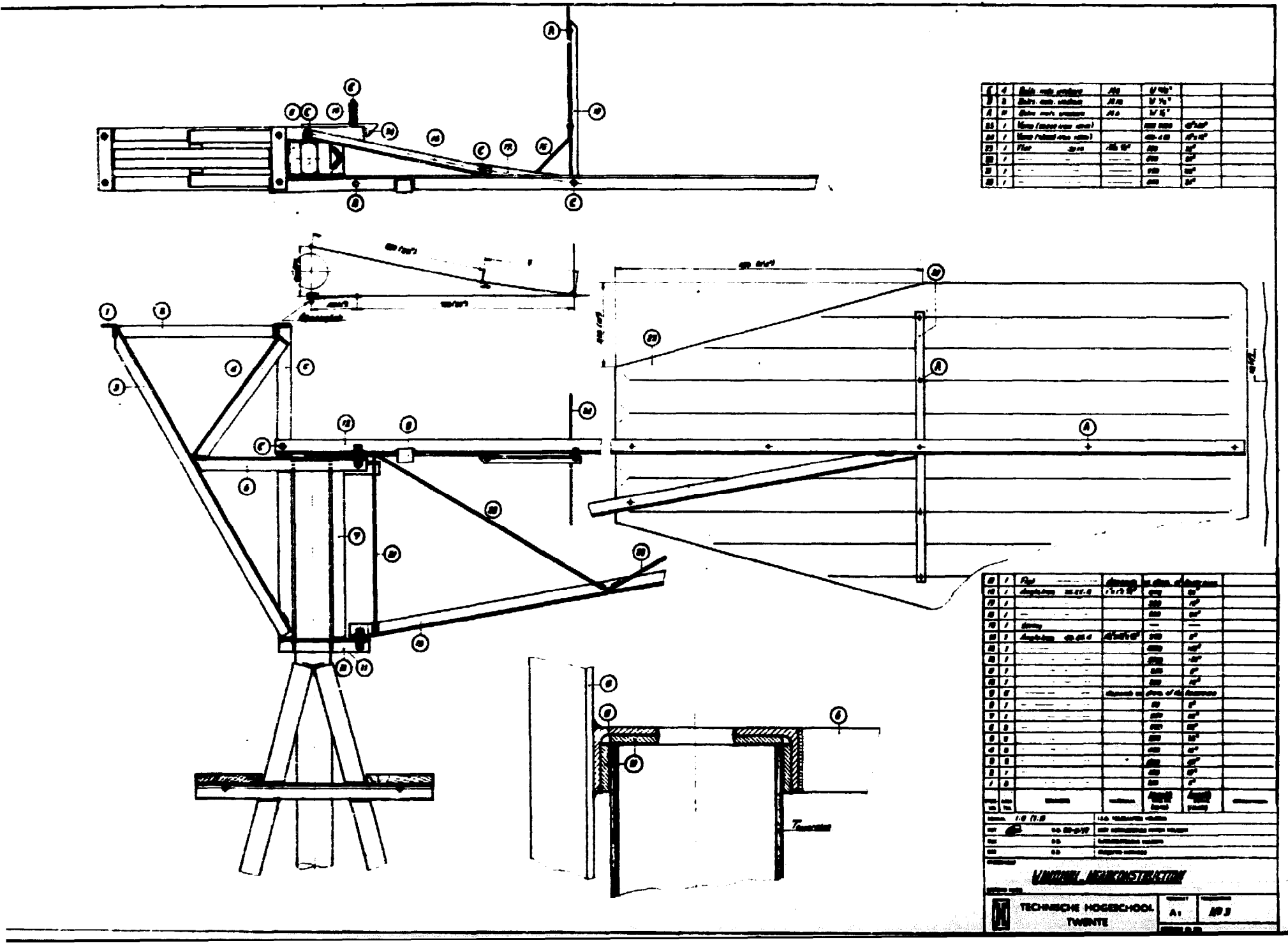
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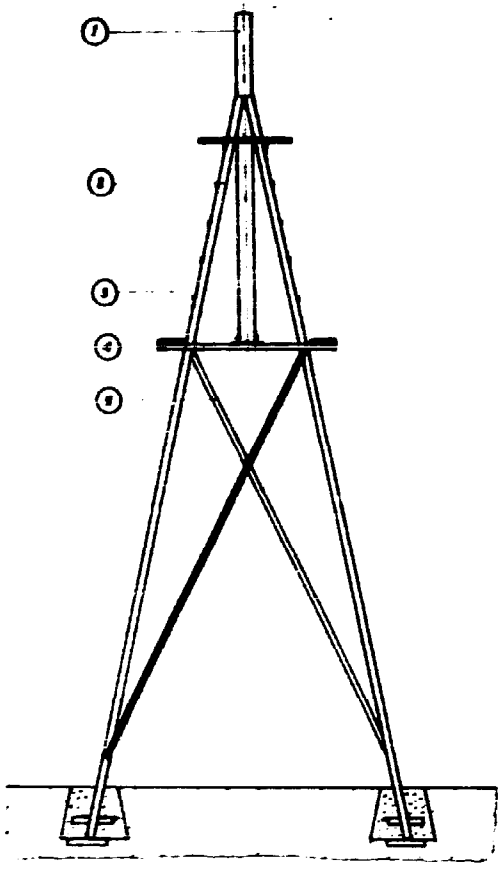

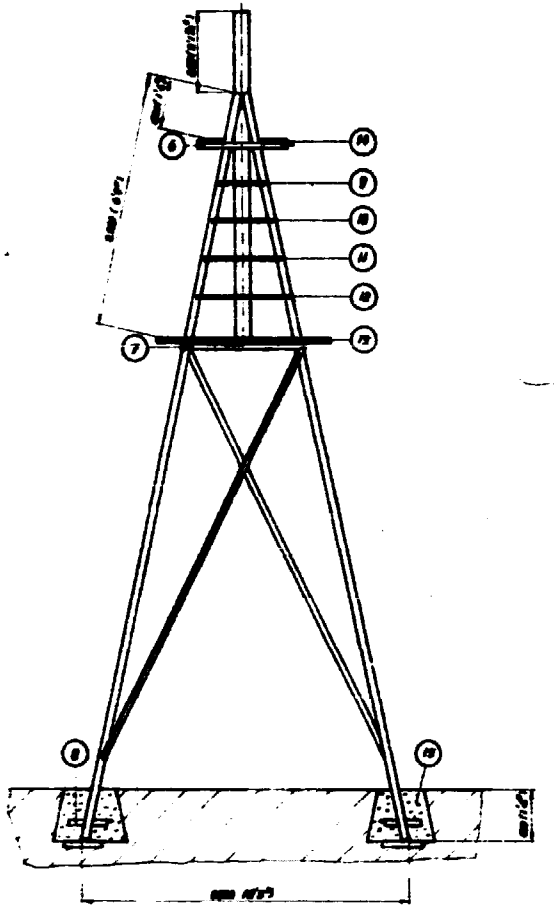

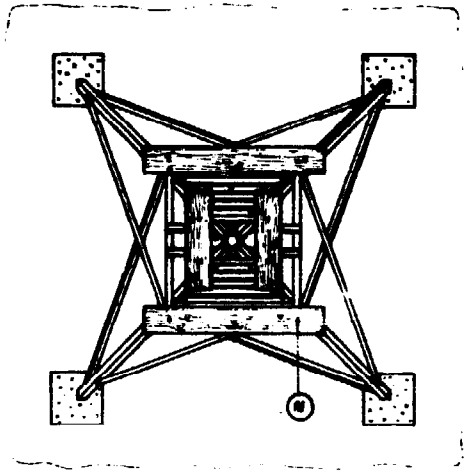

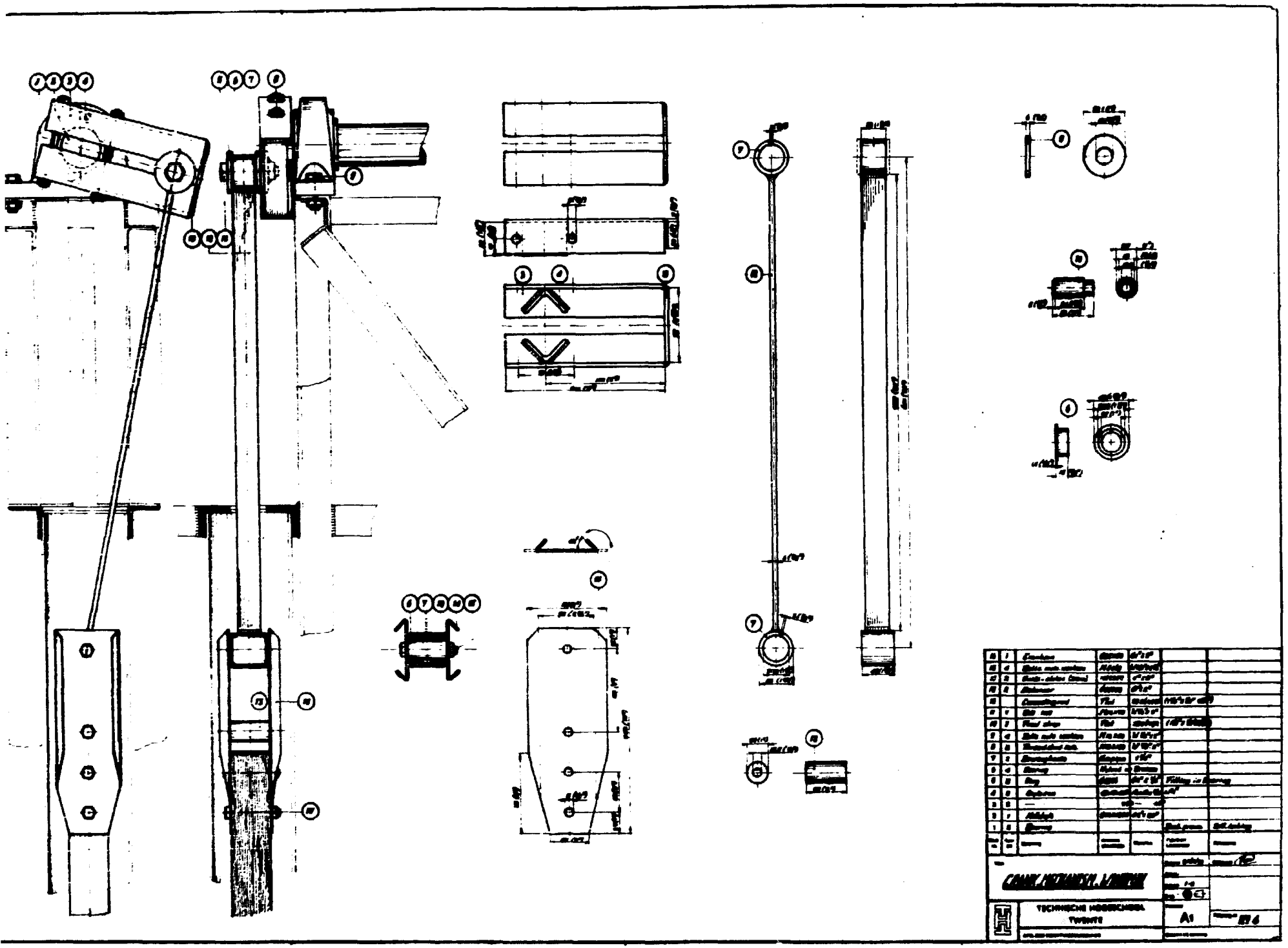
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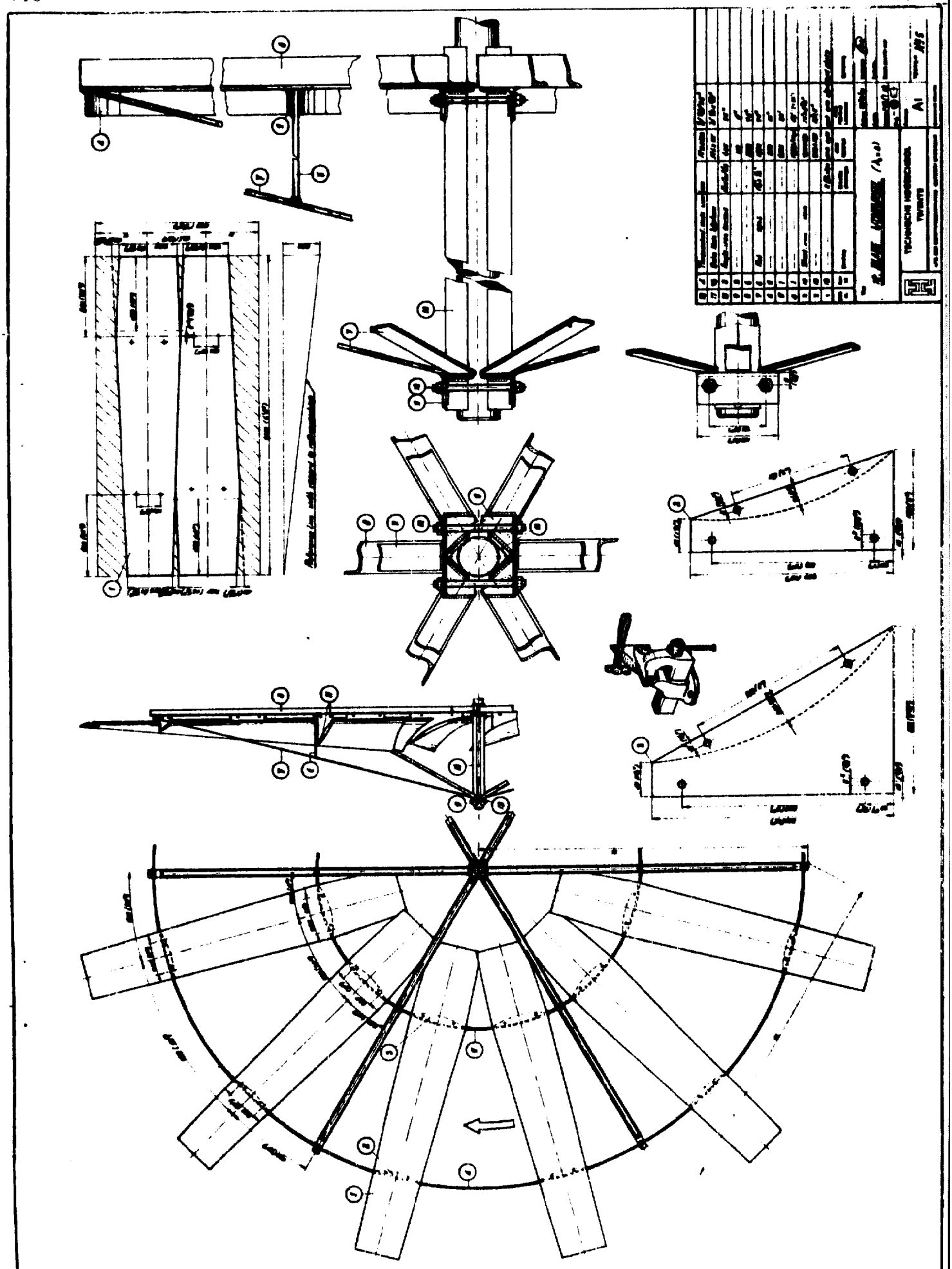

which the head (and so the windwheel) turns 90^0 degrees out of the wind. In drawing No 1 the windmill has been drawn in that secured position.
The rotor-, head- and towerconstruction have been composed of parts of angle-iron of 1.5" (except the four towerlegs: 2") and flat-iron, 1.25" which are jointed by means of electric weldings. The application of bolt and nut connections is limited just to the mounting of sheet-iron parts and some connections like hinges, pumprod-connection etc.
The millshaft (50 mm.) rotates in dustproof self-adjusting bearings which are considerably oversized according to the S.K.F.-specifications. The crankpin- and crosspin-bearings are preferably furnished with nylon bearing-bushes, but bronze bearings can also serve the purpose if lubrication is applied from time to time. Also the crosshead which is composed of two specially shaped sheets needs the lubrication (see next chapters).
Characteristic of the headconstruction is the surrounding of the towerpipe by its framework of angle-iron which acts as a bearing. In radial sense some tolerance is permitted, and is even necessary due to the unroundness of the towerpipe.
Positive experience has been achieved already by applying this remarkable joint of the head and tower-construction in a wooden sail-wing windmill which has been designed and constructed in May 1976. Axial forces can be carried-over directly to the top-edge of the towerpipe, so the radius of coulomb's friction acts very near to the centre.
The total structure has been designed for maximum windspeeds of at least 20 m/sec and even the blade tips (free length of appr. 60 cm.) can in theory stand the forces which should act on it if the windwheel runs free of load under static conditions at a windspeed of 65 m/sec.
It is expected that the rotor is not the constraint factor of strength of the total structure. However dynamic forces (e.g. due to rotor unbalance) probably cause vibration in the natural frequency of several parts which may even lead to fatigue cracks! For example the natural frequency of the headconstruction situated around the towerpipe comes to 4.35 rad/sec (theoretically) which means that during operation of the windmill at a R.P.M.

number of approx. 45, resonance may occur. Also the slender parts like the long angle-irons of the tower- and tail-construction are free to vibrate within a scale of R.P.M.-numbers of the windmill if unbalances exist in the rotor construction. The single-acting piston pump applied in combination with the first prototype windmill consisted of a 6" p.v.c. pipe in which a wooden footvalve and piston with leather washers and sealing were acting. This kind of pump, which also was applied in combination with the former mentioned wooden sailwing windmill, seemed to be very reliable as far as resistance against wearing and tearing of the sealings and washers were concerned.

1.2. The first experiments in the Netherlands.

Due to shortage of time the prototype windmill was not yet kept up to date according to the new designs, so the first experiments have been undertaken with a rotordesign which was not representative of the prototype which would be introduced in India. Moreover the elevation head in India was expected to be considerably more than the 4.0 meter head which appears in the Netherlands. In spite of that the first experience turned out already that a proper fixing of the pump in the well as well as jointing the wooden pumprods are rather difficult, especially if high R.P.M.-numbers occurred. The entire pump-construction jumped in its suspension and the pump-rod joints got loose caused by the reciprocating forces after some time during operation. The cross-head, constructed of two shaped sheets, started wearing out and making noise. Neither did the connection of the crank to the mill shaft turn out to be reliable. Although the security mechanism functioned rather well, its critical adjustment did not remain and demanded re-tightening of the adjusting bolt from time to time.
Especially its required and accurate hinges cause that this sensitive mechanism may never be successful, so other possibilities had to be considered and developed in order to obtain a simple and reliable security device.

A rather remarkable aspect has been discovered in those days. Depending on the R.P.M. number the amount of water, delivered

per stroke of the piston pump exceeded the stroke-volume in a percentage of more than 30 %. Later on this effect was recognised as an inertia-effect: the kinetic energy of the accelerated water column is converted into an extra delivery. Even after introduction of a small but permitted leakage in the piston sealing, which is done in order to decrease the starting torque of the pistonpump, this inertia effect still persisted. Also some experiments with sealingless pistons has been carried out but unfortunately the required time for a proper investigation failed and the TOOL- windmill experts travelled to India at the end of November 1977.

2.1. The first experiences with the 5 m. dia. windmills.

As mentioned above the experiences with the first prototype windmill in the Netherlands were rather poor and still a new and unknown security-mechanism and a complete new and untested rotor was to be applied. In spite of that the realization of the first windmill at the Technical School in Ghazipur progressed smoothly. Also a quick prefabrication of the next two prototypes in the R.T.I. workshop, later on, has been achieved by using welding- drilling- and shaping-moulds. Small changes in the original designs were caused by slight differences in quality and size of the materials which are available locally.

Transport of the entire windmills to the site proved to be rather uncomplicated. A truck or tractor with lorry can easily contain all the separate parts (tower,head, windwheel) of a complete windmill. Local people are always prepared to carry the unloaded parts, lying on the roadside, to the site where the windmill is going to be erected.
In general the windmill is built above an existing well, from which water was drawn previously for irrigation purposes by using bullocks as an energy-source. Since the maximum pumping capacity of the windmill amounts to appr. 30 m^3/h the water-supply to these wells is often insufficient.
In order to increase this capacity a tubewell has to be applied at the bottom of the well. The length of these tubewells varies between 12 to 15 meters depending on the depth of the aquifers.
The erection of the tower is achieved simply by pulling and pushing it upwards by means of offered manpower of the local people.
After the tower has been positioned(exactly in the centre above the tubewell)the towerlegs are poured in with concrete in the 40 cm deep holes which have been made in advance.
After a five-days period the concrete is sufficiently hardened out to stand the extra load acting on it during lifting and positioning of the headconstruction and windwheel. Next page

2. Technical developments of the windmills

In the beginning of December 1977 the windmill-project started in Ghazipur. Although a workshop was not at the disposal of the counterpart organization: The Organization of the Rural Poor (O.R.P.), the facilities seemed to be sufficient in Ghazipur-village.
Several blacksmiths and institutes proved to be interested in the windmill-technology (there was no windmill-history in the rather remote Ghazipur-area) and it was decided to construct the first windmill in cooperation with the teachers and students of the local Technical School.
On Friday the 20th of December, the first windmill (KK I) was erected near the Kusumih Kalan village beside the national-highway Ghazipur-Benares and it was baptised by local villagers and authorities. During the month of January two other windmills have been prefabricated in the workshop of the Rural Trainings Institute (R.T.I.) where agricultural implements like plows and threshers are manufactured by trainees and staff members.

In the course of 1979 a newly built workshop, situated at the ORP-campus, came at the disposal of the windmill project. A complete set up of windmill production,maintenance and training facilities has taken place in this workshop. At the same time all research- and development activities were taken up at the Allahabad Polytechnic Allahabad (APA) where already a modest windmill production was sparking off as well. During the period of November 1979 up to March 1981 an intensive program of pumpdesign, pumptesting, redesigning of windmillparts and training was carried out over there.

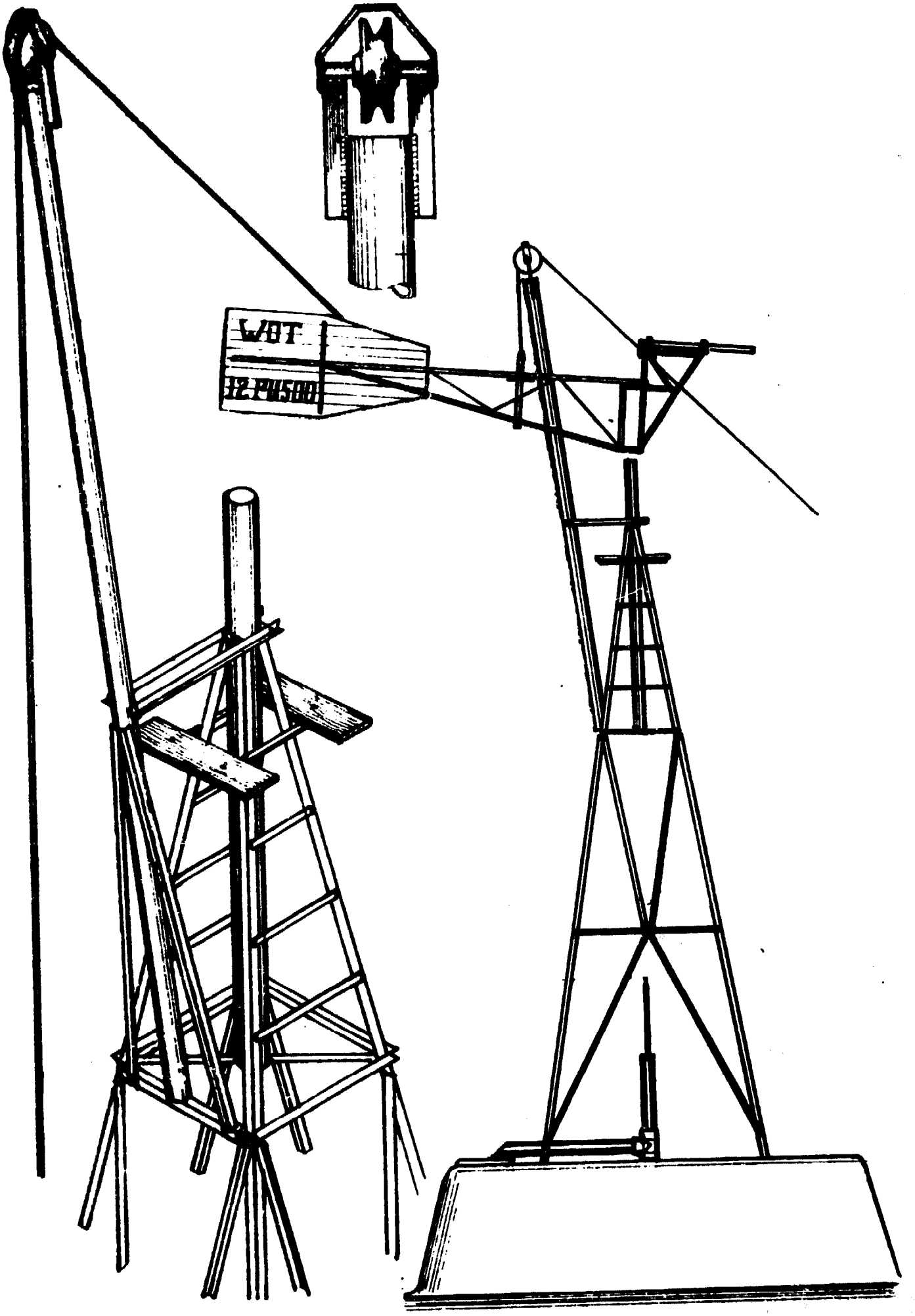
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shows how these can be carried out quickly and safely by means of a simple lifting device.

The needed storage tank is constructed from mud-made walls of about 1 metre high, which are partly bricklined and plastered in places where erosion or seapage is expected. The content of a storage-tank amounts 50 up to 150 m^3, depending on the expected need and the available area which can suitably be occupied by the tank. An overflow pipe is masoned into the wall in order to prevent that overflowing water will damage the mudwalls (if the tank is full).
Since the local people often utilize the fresh water(delivered by the windmill) for domestic purposes, like drinking, bathing and doing the wash, the mudwalls in the environment of the delivery pipe definitely will be damaged. Therefore a simple washing accomodation is provided by means of some masonry.

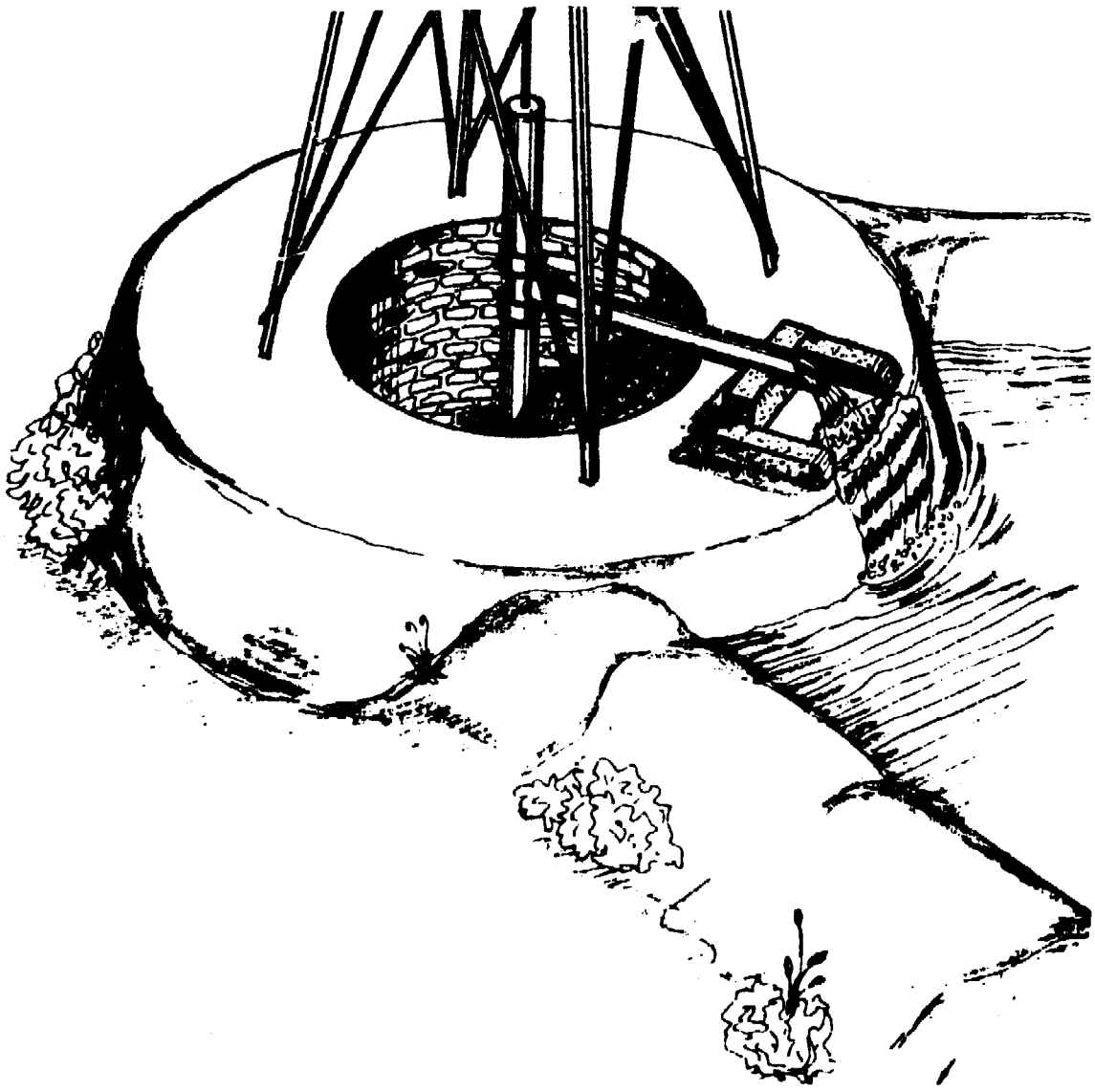

The water can be released from the tank by the farmer(s), using a 2.5" hose, which acts as a siphon. Since this device is easy to handle the water can be tapped at any place from the tank and can be led to the plot(s), via one of the several irrigation canals. The farmers have to be well-informed in handling the windmills. During storms the windmills stop automatically, so afterwards the farmers have to climb on their windmills in order to reset the windmill into the wind. At the same time it is an opportunity to inspect and lubricate the moving parts. However, soon after the introduction of the first windmills several breakdowns and long windless periods proved to be a draw back for this particular technology. In spite of this the farmers involved remained rather enthousiastic and local agencies and Institutions developed interest as well.

2.2 The prototypes under development.

During field-tests some parts of the windmill components needed redesigning in order to achieve a higher reliability on the one hand and a costprice reduction on the other.

Although this seems to be more or less contradictory it is proved that both demands mentioned can partly be conceded by surging for the most simple solutions and alternatives which can be realized with the local means and materials. Therefore it is a must to know the local market and the means of production to which the designs have to be adapted.

In practise still unknown factors like the extent of wear, corrosion , vibration etcetera will remain and just a thorough fieldtesting will provide the answers in the long run and broaden the experience. This disadvantage of such research is that failures can cause the distrust of the local people in the windmill technology. To avoid this it was decided to carry out the research and development as much as possible under "laboratory" conditions. For this

reason a testing machine has been designed and built (see chapter 3) in order to speeden up the developement of the windmill.

These experiments as well as the field experiences led to the stepwise evolution of several windmill components which is described in the following paragraphs.

2.2.1. The towerconstruction.

The fabrication of the tower is very simple. The two prefabricated halves are composed: the towerpipe is pushed in, positioned and welded. In three hours the tower is completed with the help of three persons.(including the cutting and straightening of the materials).
The first and second platform are rather safe and comfortable to stand on but actually the first platform is superfluous: lubrication and repairs will always be carried out standing on the top platform.
Climbing on the tower is not done by means of a ladder: by coincidence the diagonals of the lower tower section just provide an adult the needed facilities to reach the first platform. For esthetic reasons the base-measurement of the tower has been reduced from 2.50 to 2.00 meters and still its foundation can surround the opening of the well which is seldom more than 1.8 meters in diameter.
Previously the total material costs of the tower amounted to ± 1/3 of the total material costs of the windmill, so a reduction in tower weight has been undertaken. Applying 1.5" instead of 2" angle-iron for the four towerlegs decreases the weight considerably but the legs became too slender which means that extra compartments in the structure must be applied in order to achieve sufficient strenght in the entire construction.
Also some minor modifications, like guiding the towerpipe by flats instead of angles and cancelling the first platform decreased the weight and costs. It was also proposed to reduce the length of the towerpipe,but extra angles and flats will be necessary to fix it properly and to provide sufficient rigidity to the tower-top structure.

However the original simplicity of the construction will turn over in an extra complicated one appearing during fabrication and defenitely resulting in loss of time due to mistakes.
Due to these above mentioned modifications the towerweight has been reduced from appr. 225 to 125 kg. Also another advantage is that the tower is easier to handle during transport and installation while the strength is almost the same. Climbing the tower is facilitated by applying some welded flats in the lattice.

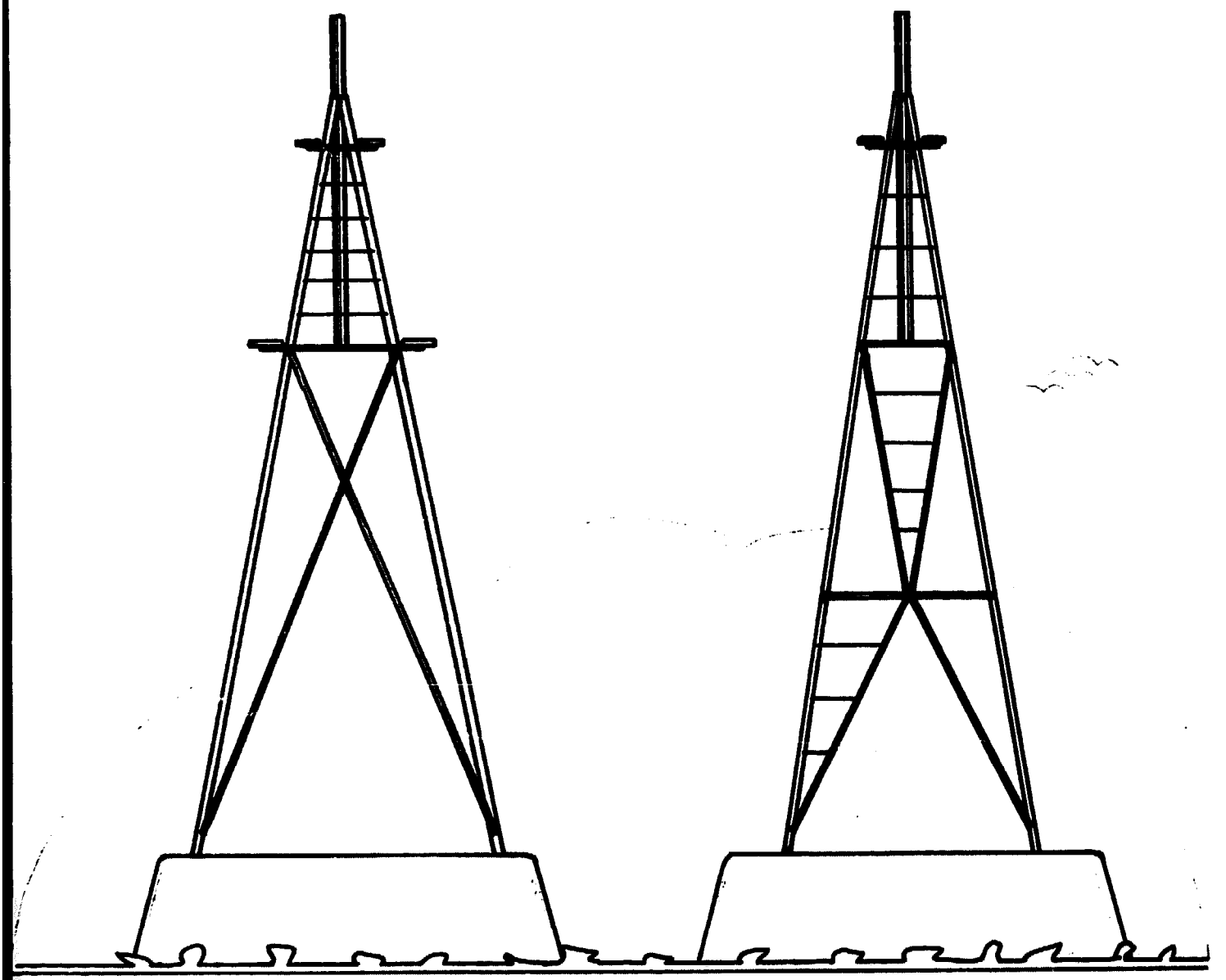

OLD TOWERDESIGN NEW TOWERDESIGN

2.2.2. The headconstruction.

Some minor parts in the framework of the headconstruction have been changed. The most important and valuable change was reduction of the total length of the tail. This has been done in order to obtain a better balanced structure; the length amounts to 0.8 D and a better steering resulted. Since the bearinghouses, which are available in India, are rather wide some extra space had to be created for the support of the rear-bearing. The flange of this support (angle-iron 2" x 2") is pointing to the front of the headconstruction in order to achieve that.
Worthmentioning is that using a simple fixture for welding the head saves time and moreover accurate work results.

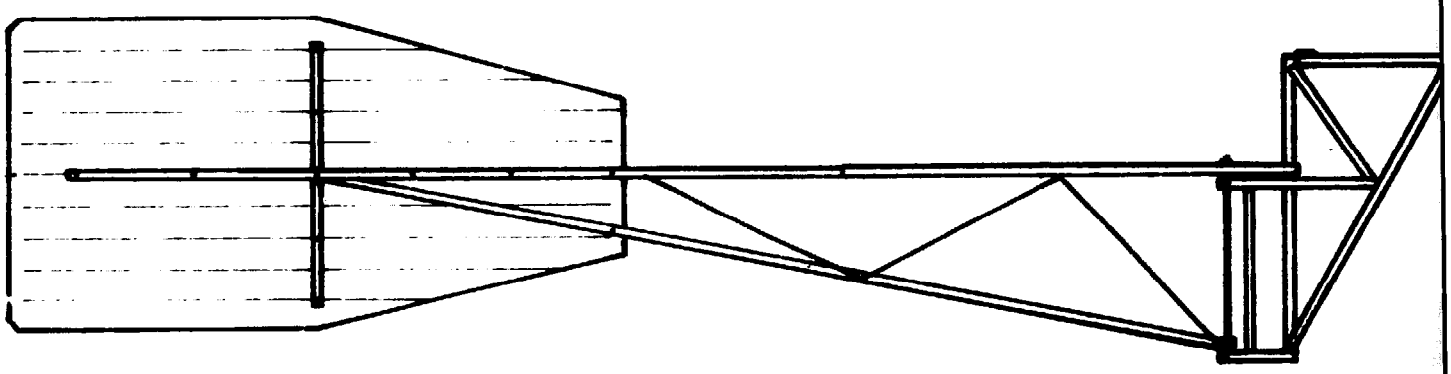

The security mechanism

In the very first designs the required accurate hinges of the security-mechanism caused lots of problems concerning its adjustment which did not remain constant. Initially a new design has been introduced in all the Indian prototypes which proved to be very simple and reliable. A helpvane, situated behind the rotor and besides the headconstruction, is pushed backwards by the wind if the adjusted preload of a spring is exceeded. Due to that the achieved displacement unlocks the headconstruction from the tailstructure by opening a simple lockmechanism. The moment, caused by the windpressure acting on the helpvane, initiates a small rotation of the head (and so the windwheel) with regard to the tail and winddirection.

The windpressure acting on the windwheel provides a further rotation of the headconstruction until the windwheel is turned 90 degrees out of the wind and a lock-system finally fixates the head to the tail.

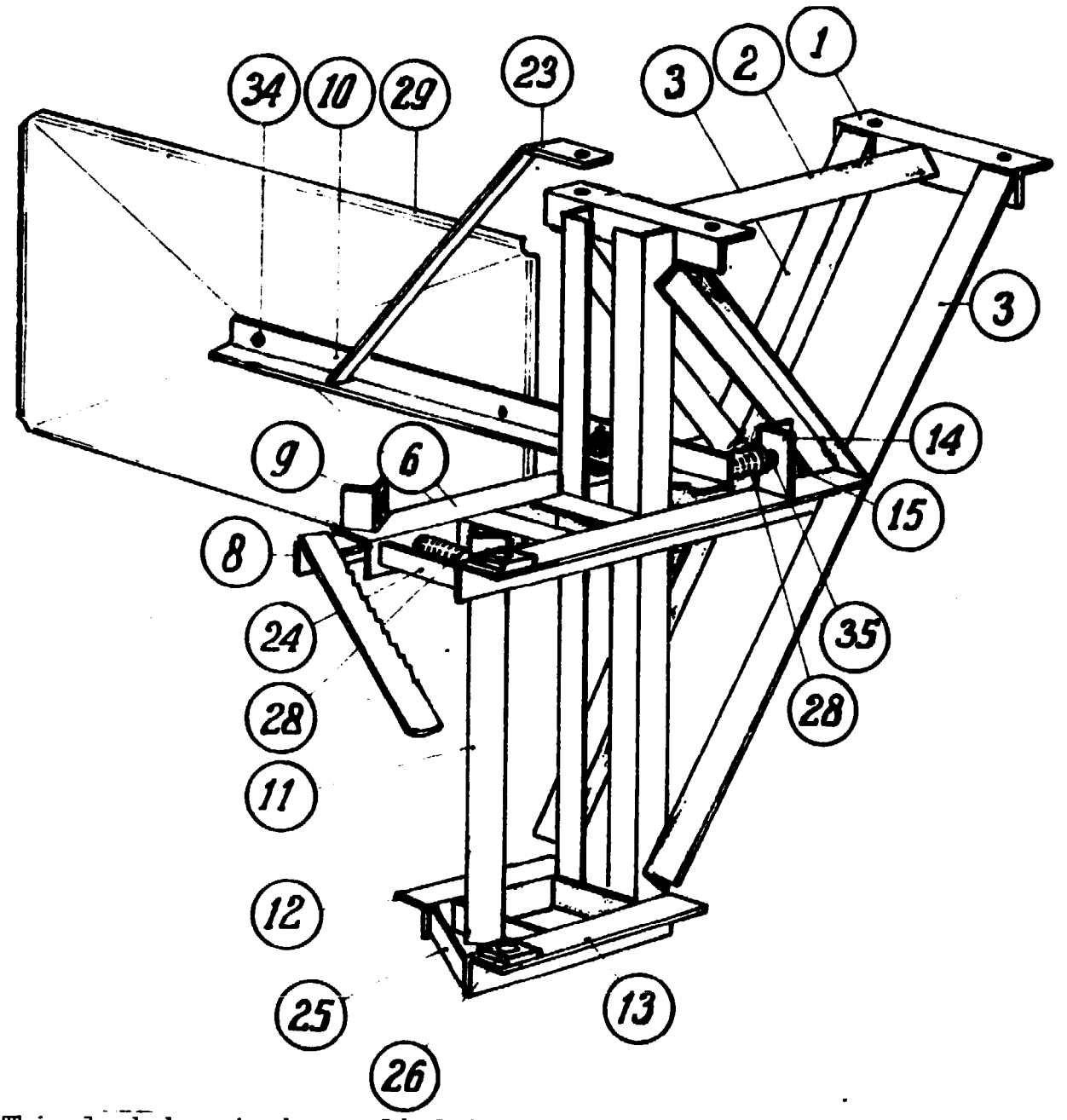

This lock has to be applied in order to prevent that during storms, accompanied by sudden changes of wind direction, the tail and head will move separately which can result in very high impacts in case of concussion of both parts. During this securing motion a toothed handle prevents such separate movements and it will not allow the headconstruction to turn back with regard to the tailconstruction.
Since there is almost no damping in the entire security system the kinetic energy, stored by the wind into the rotating

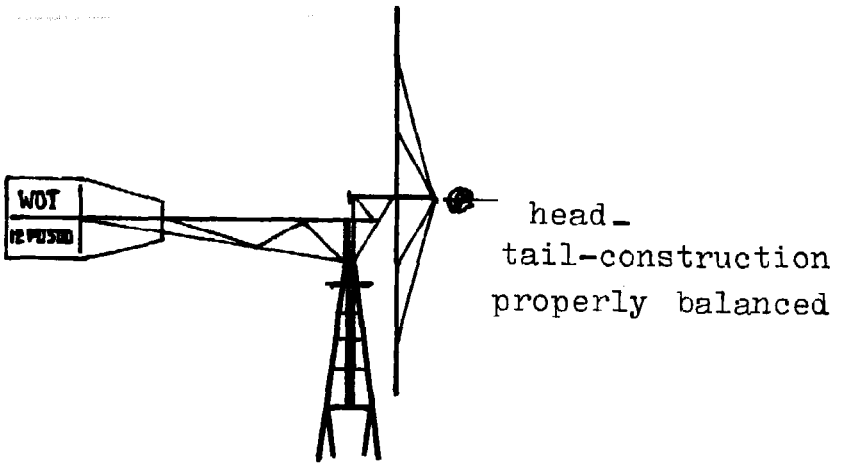

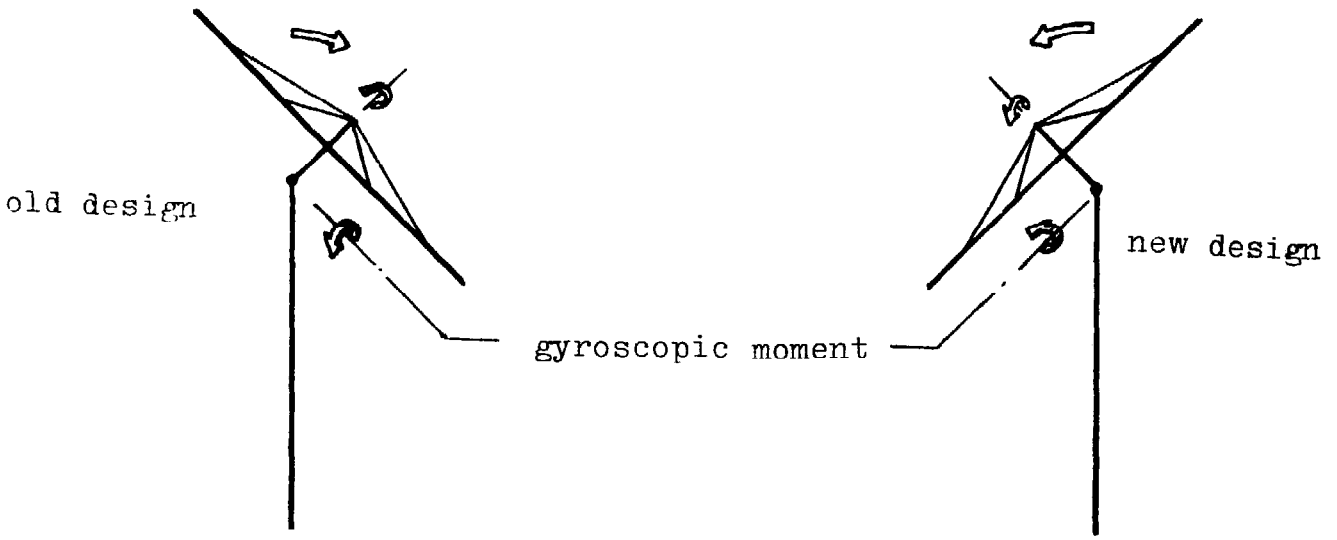

headconstruction, has to be dissipated. The impact taken by the final lock, proved to be considerable at the end of such movement of securing. Although there is the Coulomb's friction, its dissipation capacity is too less and moreover its friction is eliminated more or less by the gyroscopic moment which appears during this security movement. So even this damping can be neglected. In order to use this gyroscopic effect an extra generated Coulomb's friction could be added in positive sense by changing e.g. the direction of rotation of the windwheel. Since the windwheel runs clockwise in connection with the bolted crank pin, it is preferable to maintain this, but inverting the direction of turning of the headconstruction with regard to the tail will also lead to the same achievement.
Nowadays the headconstruction turns anti-clockwise out of the wind (topview!), in order to obtain the extra needed friction for damping caused by the gyroscopic moment. The impact is reduced considerably and hardly audible.

Although the windwheel is kept out of the wind by the steering-function of the tail, it will still be hit by the gusts during storms. This is caused by the inertia of the total secured structure: during stormy weathers it was observed that the rotor changes its direction of rotation continuously : clockwise-anticlockwise, etc, which means that it is also attacked by these gusts from the back. This resulted several times in a forward bending of the blade-tips because its rigidity is low in forward direction.

In order to prevent such damage it was proposed to increase the rigidity by hammering a profile in the blades in the environment of the outside-ring blade-support. However, in this way the airfoil will be spoiled and so the efficiency will decrease.

Another possibility is keeping the windwheel slightly into the wind in such a way that it will just not be attacked from the back. This is achieved if the windwheel is turned out of the wind less than 90 degrees: the rotor maintains clockwise running too.

Nowadays the final lock of the security mechanism is situated in such way that the windwheel turns appr. 75 degrees out of the wind and forward bendings of the blade tips do not occur any more.

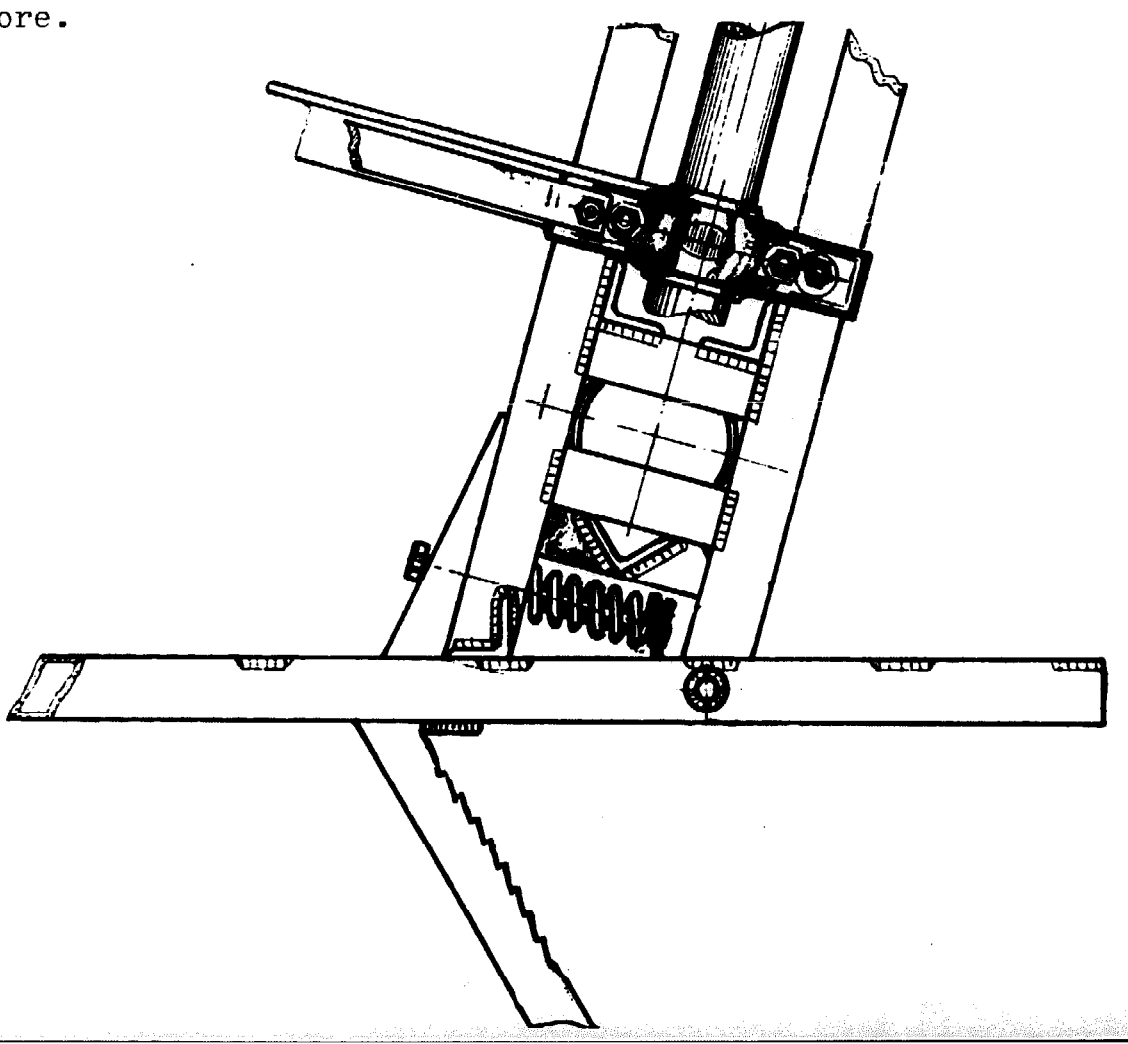

Though this automatic security device never failed the required reset procedure proved not to be practical in places where wind speeds fluctuate too much. Therefore efforts have been undertaken to develop systems in order to tackle this reset problem.

For instance a rope connected with the reset lever and led via the tail end to ground level facilitates a reset possibility which excludes the need of climbing the tower. However this system still demands the presence of an operator so it is not a great improvement.

As a matter of fact several fully automatic security devices are common in commercial windmills which principle is based on the momentum equilibrium of head and inclined hinged tail. However such mechanism demands a frictionless rotation of the head over the towertop which does not apply for the simple windmill design described here.

Therefore it was tried to derive a fully automatic security device from the existing mechanism which finally led to the following designs:

a. ratchet system
b. stepless system

Both new systems have in common that the helpvane releases the fixation between head and tail in order to allow the head to turn backwards out of the wind. This process continues till the helpvane does not detect any exceeding windpressure anymore with the result that fixation between head and tail is restored in that particular position. This fixation is achieved by means of a ratchet- and a stepless friction mechanism respectively in these systems.

Minor changes in wind direction cause minor oscillations of the tailvane which are most essential in order to return the head and rotor more or less facing the wind again if the storm decreases. This return motion is possible due to the "one way" character of the ratchet and stepless friction me-

chanism as long as the helpvane does not detect any overpressure in its newly found position.

So both the systems allow the head and rotor to turn out of the wind to a certain extent depending on the actual windforces. The oscillating tail vane will see for the automatic reset. However for the simple ratchet system a minimum oscillation of the tail vane is required during the automatic reset procedure in order to reach for the next tooth of the ratchet. In case of rapidly fluctuating wind directions impacts on the teeth will occur which may lead to wear of the ratchet and its counterpart in the long run. Also an impact occurs at the end of the securing motion if suddenly the helpvane puts the ratchet in action again. Observations made during field tests just partly confirmed these disadvantages and presently the ratchet devices are still observed.

The "stepless" system, as the word suggests, responds to very minor oscillations in a less hesitating manner than the "ratchet" does. The pivoted catch induces sufficient high friction between the disk (jointed to tailbeam) and contact surface (jointed to head) resulting in a tight grip. In this system also the sudden impact exists at the end of the security motion. This disadvantge has been eliminated by allowing slip in between the disk and tail beam in order to dissipate severe shocks.

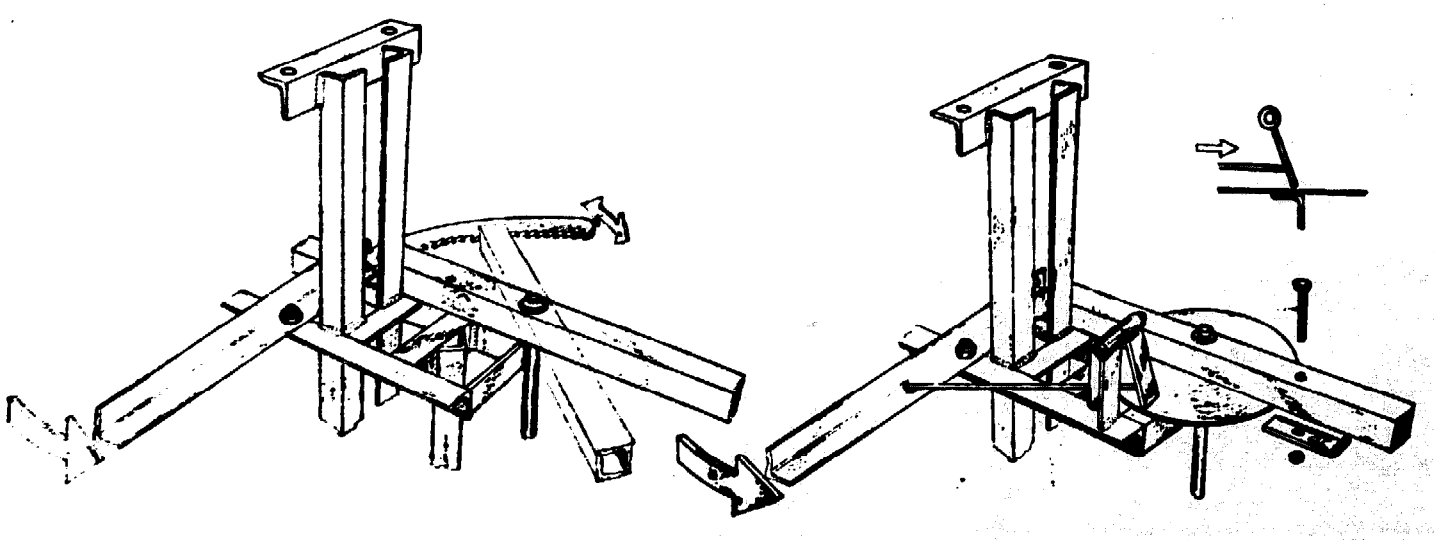

2.2.3 The moving parts: Crank-mechanism, bearings, etc.

Although the principle of converting the millshaft rotation into the up-and down-movement of the pumprod was still maintained, the bearings as well as the simple crank-mechanism have been changed a lot. Many thousands of revolutions of the windmill were necessary to indicate and to eliminate the weak components which finally resulted in a complete redesigning of these essential parts which are still simple in manufacturing and assembling.

The mainshaft bearings

Two kinds of loads actuate on the two main-bearings.
The front bearing carries a radial load of appr. 1000 N (rotor-weight) and a thrust-load upto 7000 N, while the rear-bearing takes the alternating forces carried out on the crank-mechanism. If these bearings are nicely adjusted the above mentioned assumption will be actual but unfortunately there are constraints in practice.
Due to considerable unroundness of the shaft and poor quality of the bearing-bushes (sleeve-type) a proper fixing of the bearings to the shaft often led to complications. After some time the bearing-bushes got loose and the shaft started rolling and sliding in them. This rolling effect will increase while the shaft slides backwards by the windpressure acting on the rotor

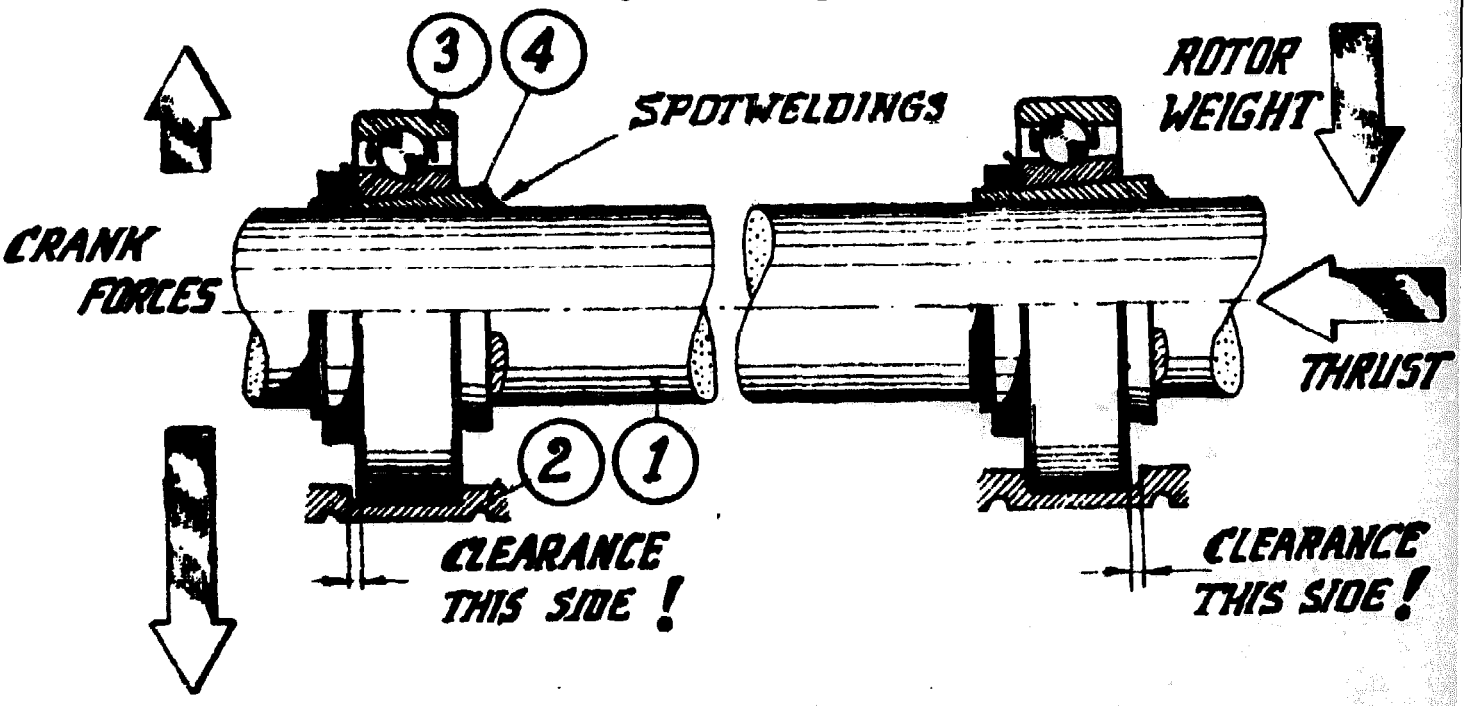

and the sharp edges of the angle iron hub start scraping at the front of the bearinghouse. Of course, few thousands of revolutions are sufficient to destroy the bearing-house completely and the ball-bearing (due to the scraping-dust). This problem is solved by locking the bearing-bush to the shaft by a short spotweld so that the shaft cannot roll and slide. Proper position of the bearings to the shaft with regard to the axial clearance of the bearings between the inside edges of the bearing-housings will assure which bearing is going to carry which load.

Besides, there were the problems with the bearings themselves. Since the bearinghousings are bolted to a welded framework self-aligning bearings (double-roller type) have to be applied.

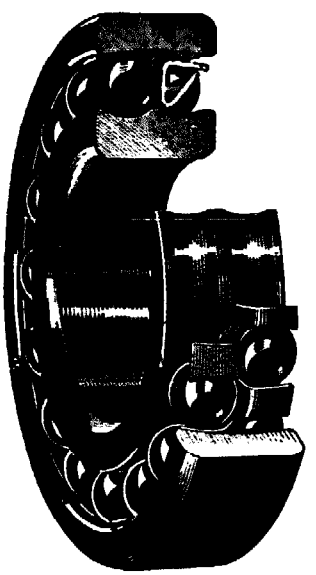

double-roller selfadjusting

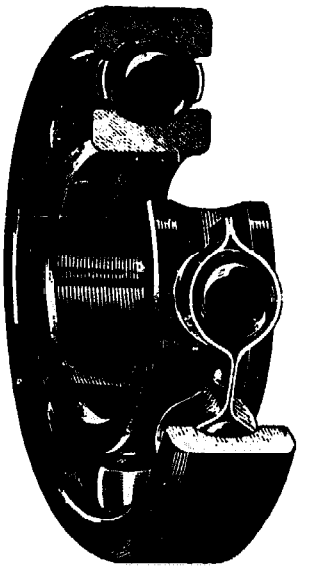

single-roller

Although these bearings are rather oversized, according to the S.K.F.-specifications, the lifetime proved to be too short (appr. 1 ÷ 5 millions of revolutions). This means that these specifications are not representative of the bearings available in the local markets. Many bearings of several trademarks are offered but specifications are unknown and the quality is not guaranteed. Often these bearings are "repaired" old ones: the rollersurfaces have been lightly ground and oversize balls are applied. The result is surprising; only insiders can detect the minor differences from the new ones. Since these bearings are not able to stand the loads and S.K.F. is not easily

available one has to go for the best qualified trade mark like N.B.C. The latter really offers good quality bearings and sleeved bushes. Unfortunately the costs are considerable.
The same counts for the "one piece" bearing blocks (imported) which are of excellent quality but also quite costly.

Another possibility is to apply single roller bearings which can be loaded more than the double roller type due to the bigger contact surface. But a proper alignment of the housings is absolutely necessary and moreover the rotorshaft should be greatly straight.

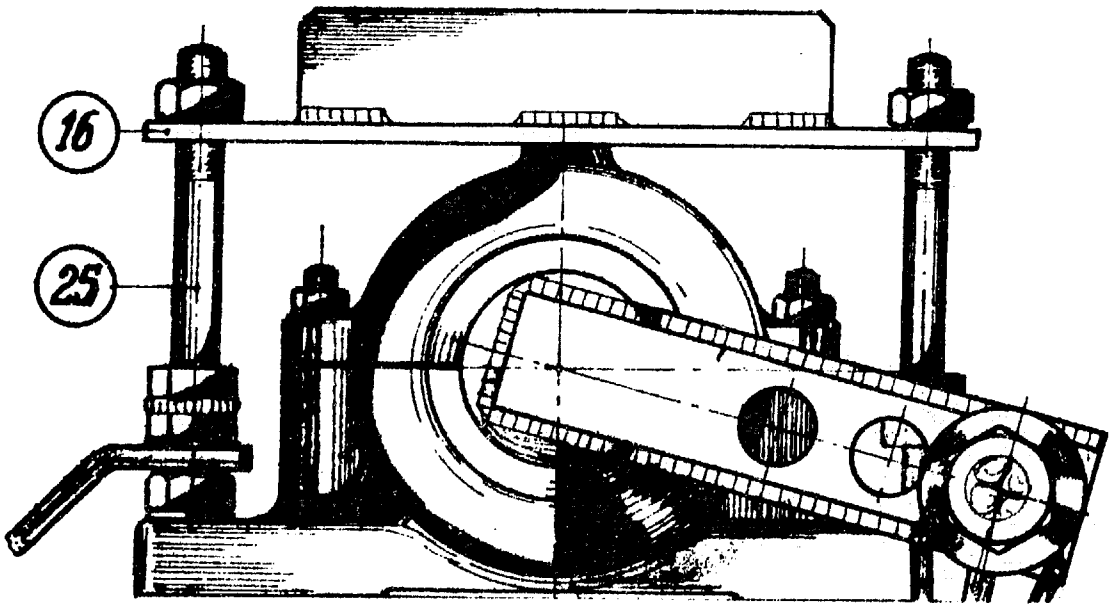

Since the rear bearing is loaded by alternating forces a crack of the weak bearing-housing-top might occur. This leads to a disastrous damage of the rotor, because it will tumble forward and hit the tower. To avoid this a simple supporting bracket is applied which supports the housing-tops in carrying upward forces.

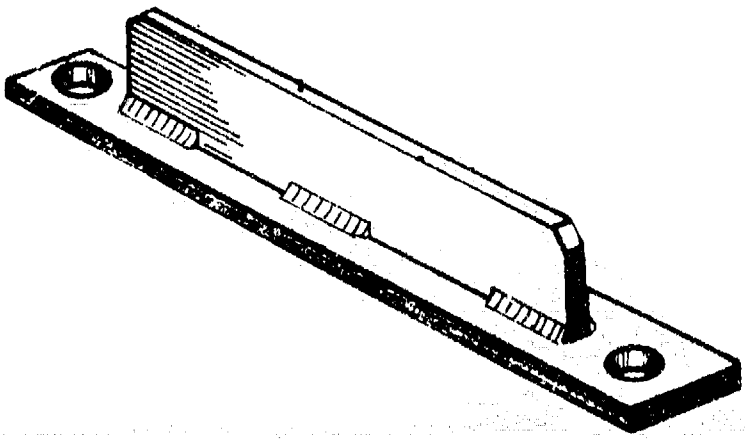

The crank

In the previous designs an "open" crank has been preferred to a "closed" one. The advantage of the application of an open crank is that the radius of the crankpin can be adjusted easily. Moreover the assembly of the connectingrod is very simple because there is no need of a partable construction of its bearing-housing and bearing.

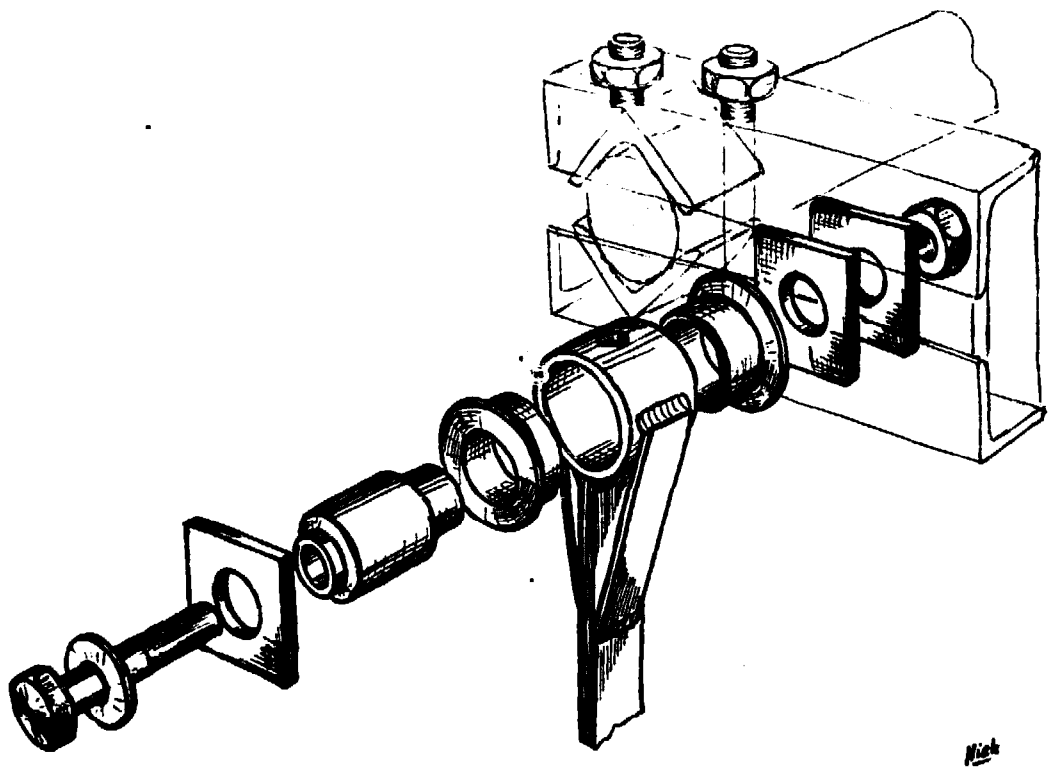

An adjustable crankradius always creates the opportunity to "match" the windmill to the pump, depending on the actual windspeed and the elevationhead. Therefore the first windmills have been provided with a slotted crank in which the crankpin can be positioned at any radius between 50 and 125 mm (2" and 5"). This slotted crank, composed of angleiron (1.5"), was clamped, just like the hubconstruction of the windwheel at the end of the mainshaft but this unkeyed connection proved not to be reliable. Slipping led to fretting and the end of the shaft as well as the crankhub were spoiled. Several efforts have been undertaken (central bolts, keys), but a 100% reliable clamping-device has never been achieved.
Welding of the crank to the shaft-end solved the problem as long as replacing of the mainbearings of the millshaft was not required. In general welding to a shaft is not advisable, because

straigthening is difficult to maintain., but also the metal-structure will be affected or even spoiled due to the enormous heat. Since this welding takes place at the end of the shaft which un-straightning of it will occur in the rear section of the shaft which can be eliminated in the crank itself. Also the affected metal-structure is situated behind the rear bearing, so if a fatique-crack will appear in this place the rotor remains and a further damage is avoided.
Although the slotted crank served its purpose very well,it needs a very tight fixing of the central crankpin-bolt in order to prevent that it gets loose and starts sliding in the slot. This was a result of experiments with 8" dia pumps (normal pump-dia 6"). Moreover in practice only two of the infinite adjusting facilities were used: maximum and minimum position! This led to the idea to introduce a new crank with three or even two crank radia only.

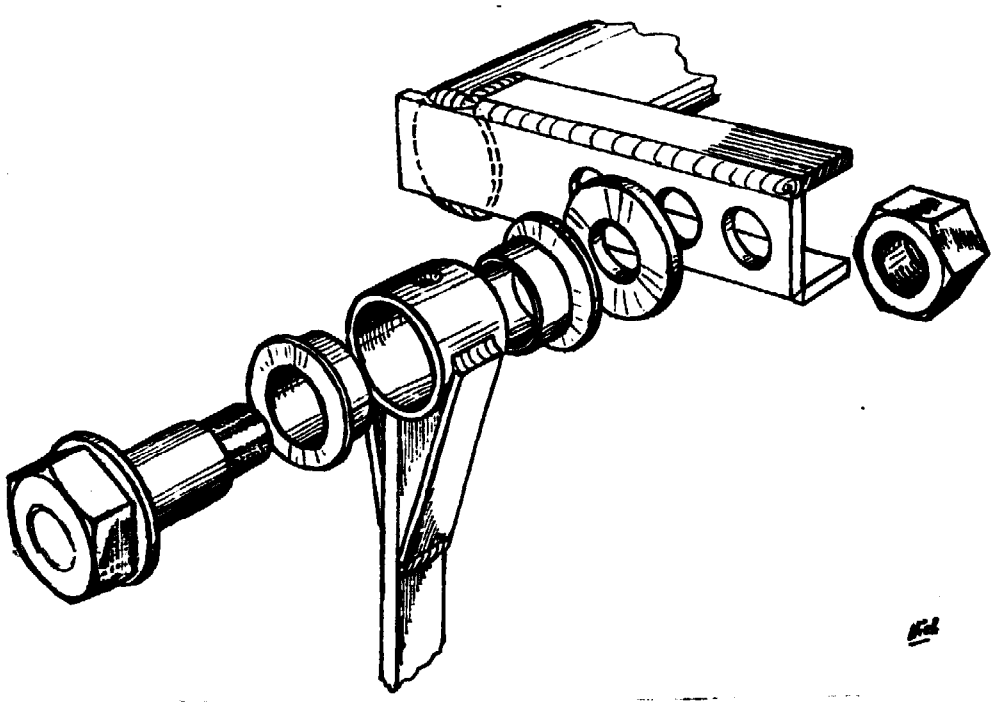

The crank is composed of several pieces of flat iron which are welded to the shaft end. Later on it proved to be necessary to create reinforcement by applying an extra flat situated near the shaft in order to obtain sufficient strength. The U-shaped crank provides a sliding fixation of

the crank pin nut which facilates assembling. For aesthetical and safety reasons the sharply edged tip of the crank is closed by welding a small piece of flat to it.

A crank made of a solid steel block, directly screwed to the shaft, showed also satisfactory results especially regarding the revision to the rear bearing. However, generally, the less sophisticated construction of the composed crank, as described sofar, is preferred.
The bearing surface of the bolt-type crank pin loading the crank plane proved to be too small for yield of the material occurred resulting in a loosening crank pin- One can imagine that this leads to disastrous damage of all the components concerned (including the connecting rod and its bearings).

Improvement has been achieved by applying a collar bush combined with a central crank bolt which latter ensured a sufficient strong connection of the bush to the crank plane. No indication of yield or loose crank pins have been discovered so far.

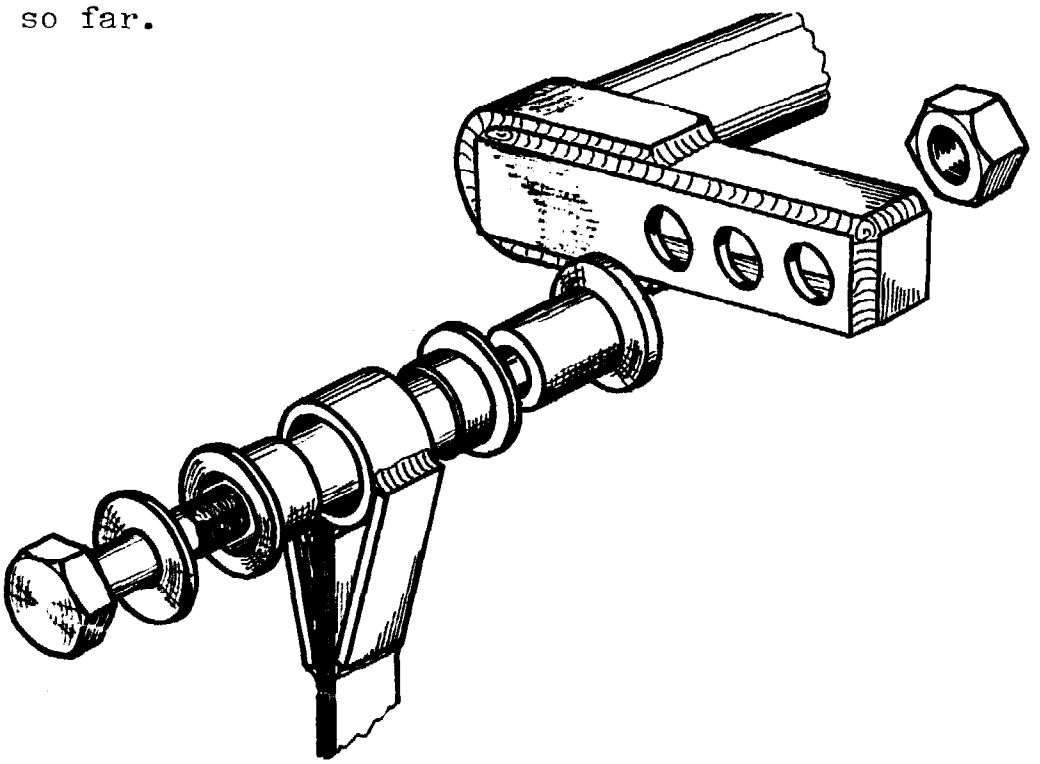

The connecting rod

To the upper-and lower-end of the connecting rod (flat iron) cylindrical steel-bushes are welded which enclose the flanged nylon bearing-bushes. In the beginning these steel-bushes have

been made of 1.5" gaspipe sockets after the screwthreads have been removed by turning. The remaining thickness in combination with the poor metal properties lead to unroundness and even cracks of these bearing houses, in spite of the fact that reinforcement-flats have been applied. Therefore it was decided to apply stronger bushes machined of scrap which remains from the millshaft if it is sawed on the right length. Nowadays the thickness of the bushes amounts to ± 6 mm. During composing and welding the connecting rod, a simple device is applied in order to obtain a correct parallelism of both bushes. The unroundness of the bushes,

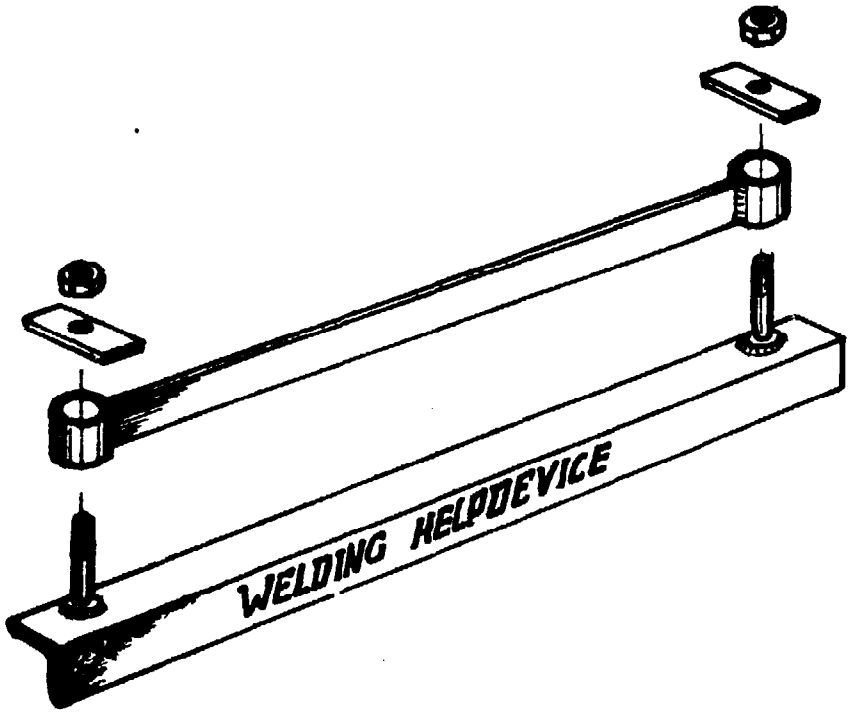

caused by the welding-procedure, does not affect a smooth function of the nylon bearings which fit nicely over the crankpin with 0.2 ÷ 0.3 mm. clearance in radial sense. An axial clearance of appr. 1 ÷ 2 mm. is usual. Up till now no nylon-bearingbushes wore out ,and were replaced accordingly.

The crosshead

The crosshead is situated and guided in the towerpipe. As mentioned before a rather high rate of wear of the very first crosshead has been noted, so another one had to be designed. Since the towerpipe (gas pipe) always has a seam inside a proper guidance of the crosshead is impossible unless the entire seam is removed. This can only be done by grinding, but the

required grinding equipment is rather advanced, not always available and moreover the resulting surface remains rough.
Efforts undertaken in obtaining an inside surface of an acceptable roughness were not succesful during constructing the first prototype (KK I) in India.
The idea was born to install a P.V.C. insert inside the towerpipe. This insert is made of a 4" P.V.C.-pipe of sufficient length from which a strip is cut in such a way that the circumference measure is a little less than the inside-one of the towerpipe. The opening just provides enough space for the seam which is completely counter-sunk then. At the bottom a small bolt, screwed through the towerpipe,locks the insert in axial sense. Since P.V.C. is rather soft the crosshead must have a sufficient wide contact surface in order to prevent high specific loads. Also sharp and hard edges must be avoided (scraping!). It was decided to compose the crosshead of hardwood because this material was expected to be a better counterpart for the P.V.C.lining than e.g. steel.

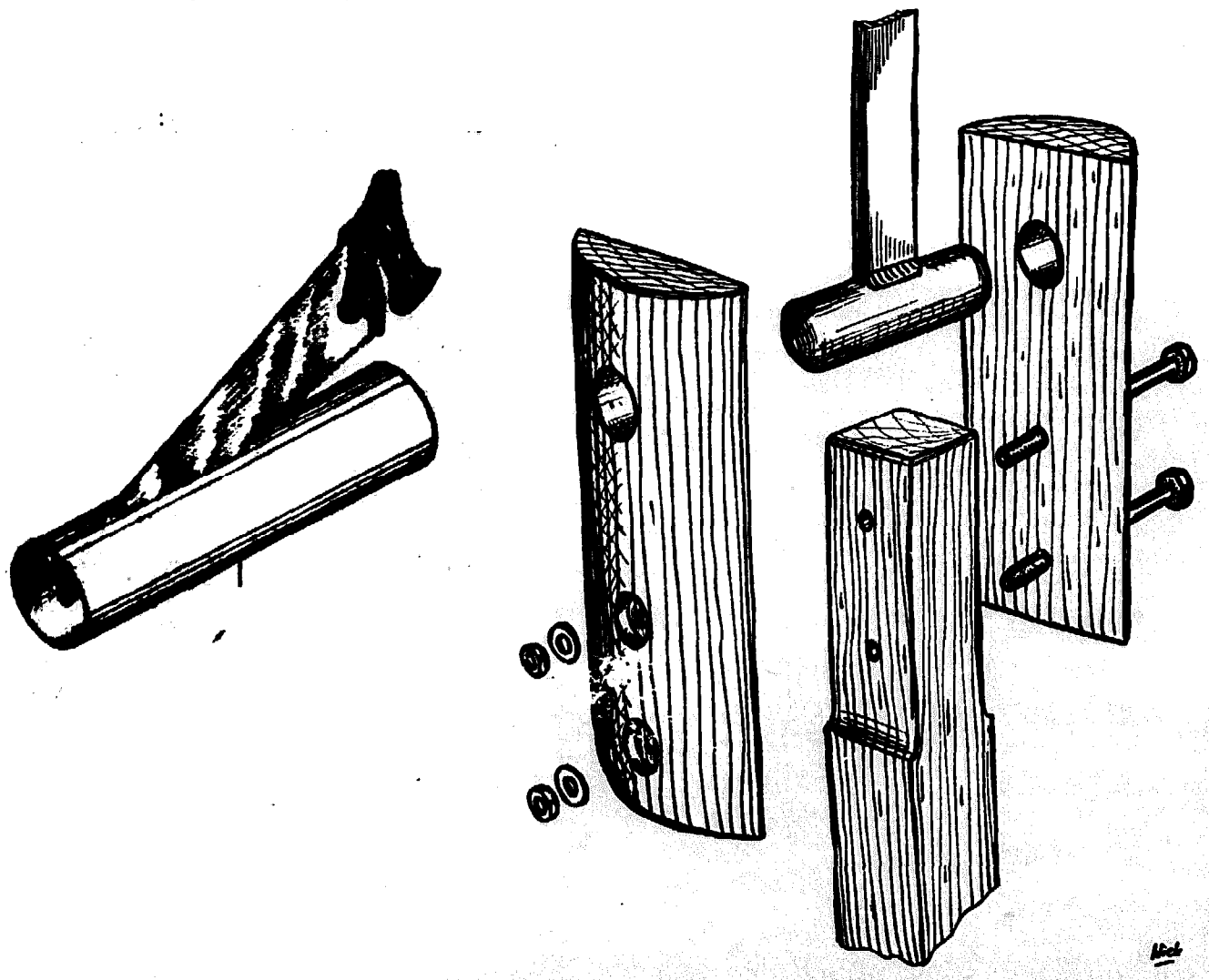

Previously the first pumprods also consisted of wood (ϕ 1.5"; see next chapter) and the first crosshead had been composed of two parts of sesam-wood which clamped the pumprod by tightening two 3/8" countersunk bolts. The first experiments seemed to be satisfactory but after some time the upper-portion of the two halves started wearing due to the gap of bearing-surface between both parts and the crosshead became more or less conical. Later on the steel pumprod has been introduced, which caused a complete redesigning of this crosshead. After some trouble-shooting the crosshead evolved, in a simple cylindrical wooden part in which the steel pumprod is hammered and clamped by two 3/8" bolts at the bottom side. In the top a square hole is made by chiseling in which the lower-section of the connecting-rod is enclosed.

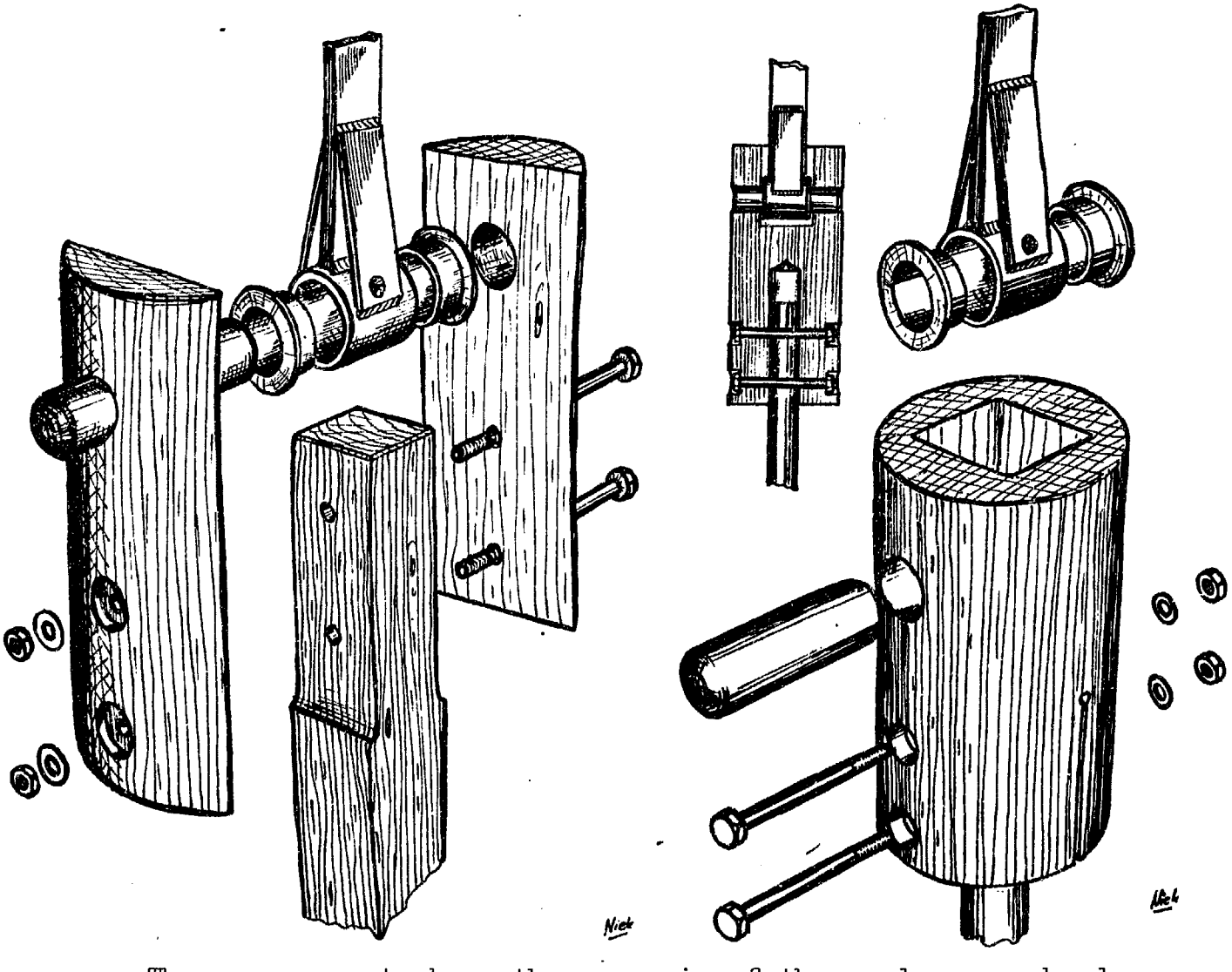

The measurement above the crosspin of the wooden crosshead amounts to appr. 2" in order to obtain sufficient strength.

Lubrication is applied by grease from time to time, but also soaking in expired motoroil before assembling assures a smooth motion, and oil in the square hole provides a continuous lubrication

2.2.4. The rotor

The twelve-bladed rotor is composed by the rotorframe, bladesupports and blades which are completely prefabricated in the workshop. During installation of the windmill the rotorframe is lifted and installed first and the blades are fixed afterwards.

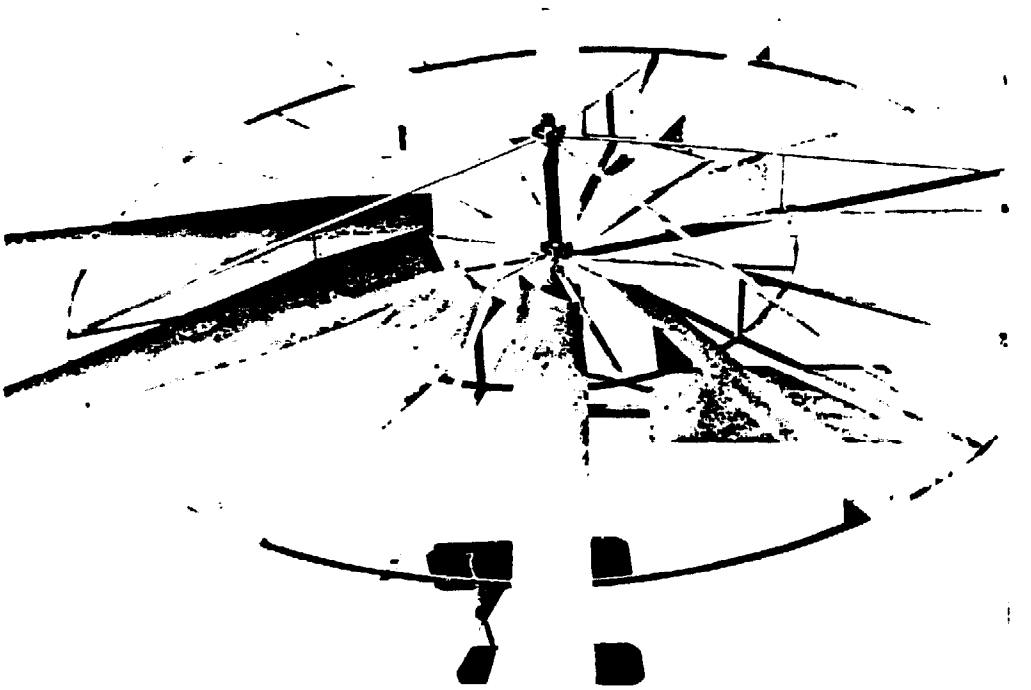

The rotorframe.

Using the shaft, bearings and headconstruction as basement during composing and welding of the rotorframe the latter is composed very accurately. However the disadvantage was felt during transportation: the diameter of the rotorframe amounts to : 3.8 m, so its transport can be complicated. Nowadays the rotorframe is composed of two halves: which can be obtained easily due to the fact that the hub is partable.

In the beginning there were some doubts concerning the strength of the inside ring which is supposed to carry the centrifugal forces acting on the blades. Although no deformation has been indicated the rotorframe of the next four prototypes have been reinforced by extra flats which provide extra support to the inner-ring. Later on this precaution proved to be superfluous bacause an overhaul of the KKI-windmill pointed out that the inner-ring still was perfectly circular . Since the rotorframe proved its reliability in combination with the broad blades of the old design no doubts remain concerning its strength in combination with the smaller blades. Nowadays the rotors are constructed without these extra reinforcement flats.

The hub.

During the introduction of the bigger pumps (6" and 8" dia)

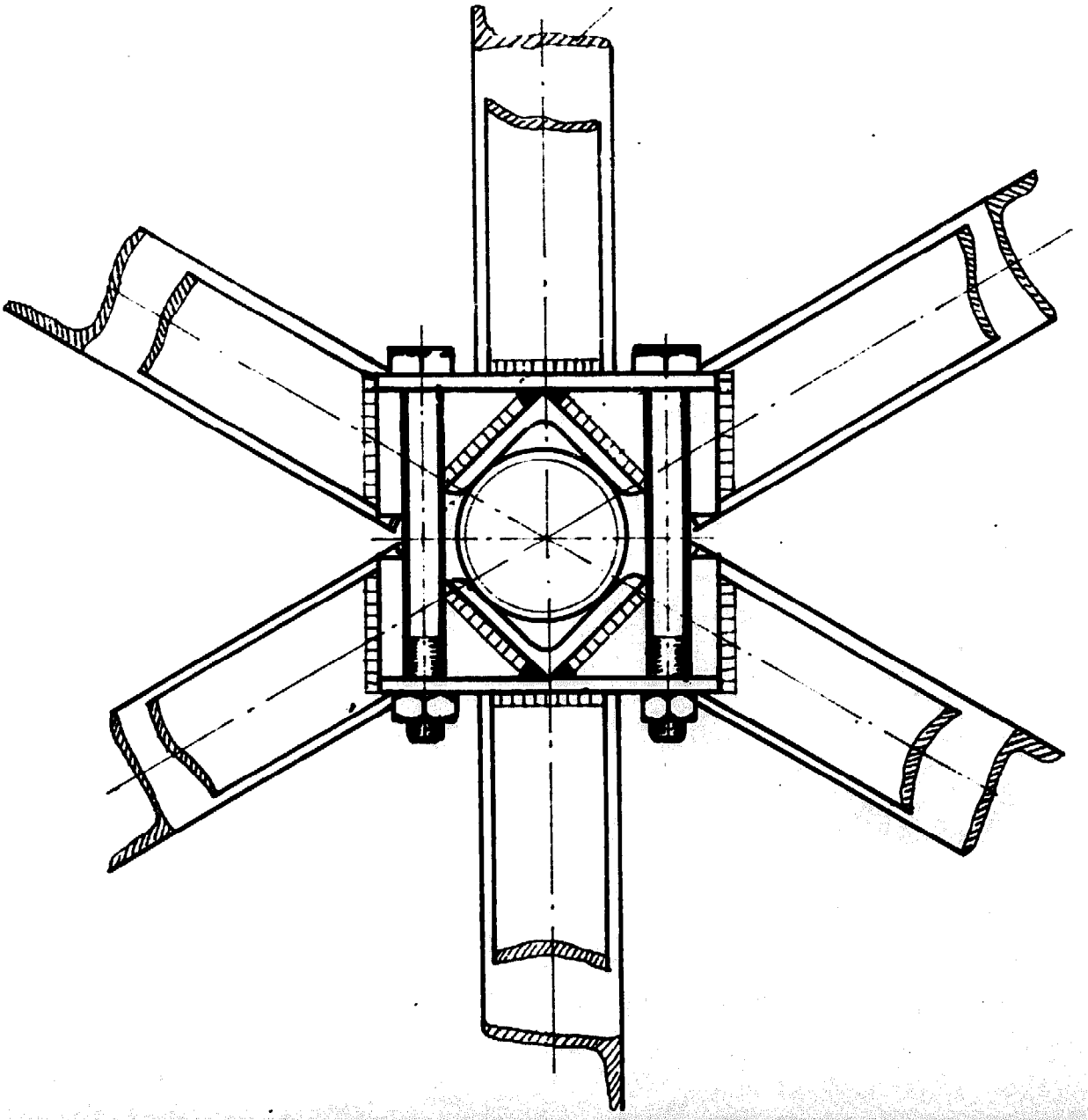

and allowing the windmill to run in windspeeds higher than 12 m/s the hub of the rotor started slipping and screwed backwards over the shaft.
Obviously the clamping of the hub was not sufficient in order to prevent the rotor from slipping which results in wrong position with regard to the shaft (Rotorframe is fabricated on its shaft to eliminate unstraightness) Defenitely a "shaking" windwheel will result,which leads to vibrations and wearing and tearing will result of several parts like the security-lock, head/tail-hinge and head/towerpipe-joint, so avoiding this is a must.
Practice proved that just a bolt through the shaft acting as a key is not sufficient: if slipping occurs the two hub-halves (angle-iron) will be bent open and the entire hub- and rotor-construction is spoiled.
Finally an acceptable solution for this problem was found by applying two extra clamping angle-irons clamped firmly by two 1/2" bolts.

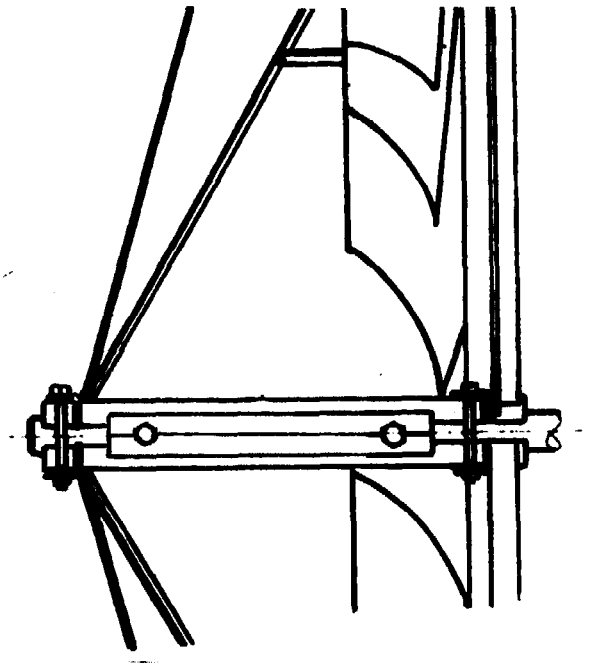

Blade-supports.

The blade-supports are manufactured from sheet-iron and if one is able to prefabricate two sets of twelve equal blade-supports an accurate running windwheel will result. This is achieved by making the supports in sets of twelve,while the

first of each set is used temporarily as a simple shape during cutting and drilling of the other eleven supports. After marking and hammering nice blade supports result in satisfactory shape and sufficient strength. However, in the first prototype windmills the inside blade supports proved to be not fatigue-resistant as cracks developed at the bolt-hole edges, near the inside ring. This problem was solved by applying 2mm sheet iron for the fabrication of the inside blade supports. The outside blade supports served their purpose best and are still made of 1mm sheet.

Some efforts have been undertaken to compose the blade supports of pre-drilled and curved flats which are welded to the rings. Unfortunately this experiment turned into a failure. Obviously due to the rigidity of these supports the forces setting of the blades in them was often accompanied by initial stresses resulting in increase of fatigue sensitivity of the blades

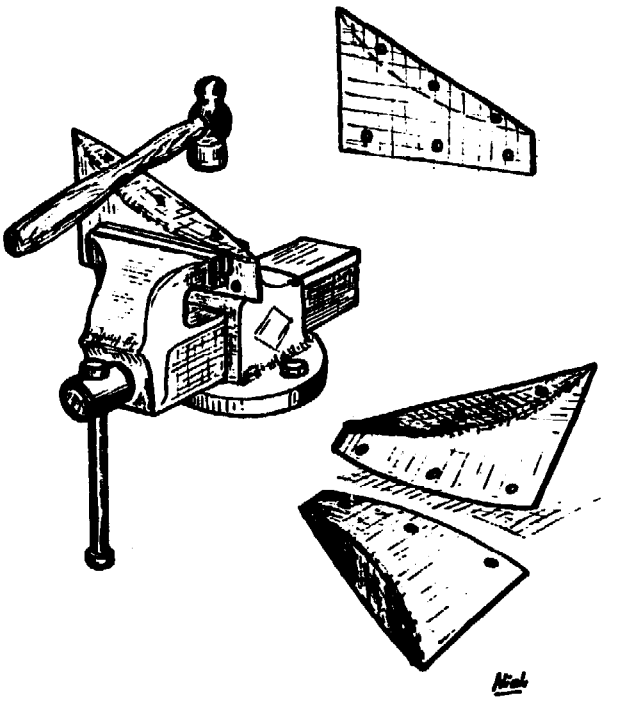

in places near the bolt holes. Such complications do not occur if the sheet iron blade supports are applied for these show "elastic" properties which are stress-relieving.

The blades.

The first three prototypes (KKI, KKII and RTI) have been equipped with sheet-iron blades which were curved 10%.

Due to a mistake in the assumption the blade-shape was calculated for 7% airfoils which resulted in broader blades than was actually needed. The production of the blades from 1 metre wide standard-sheets proves to be rather

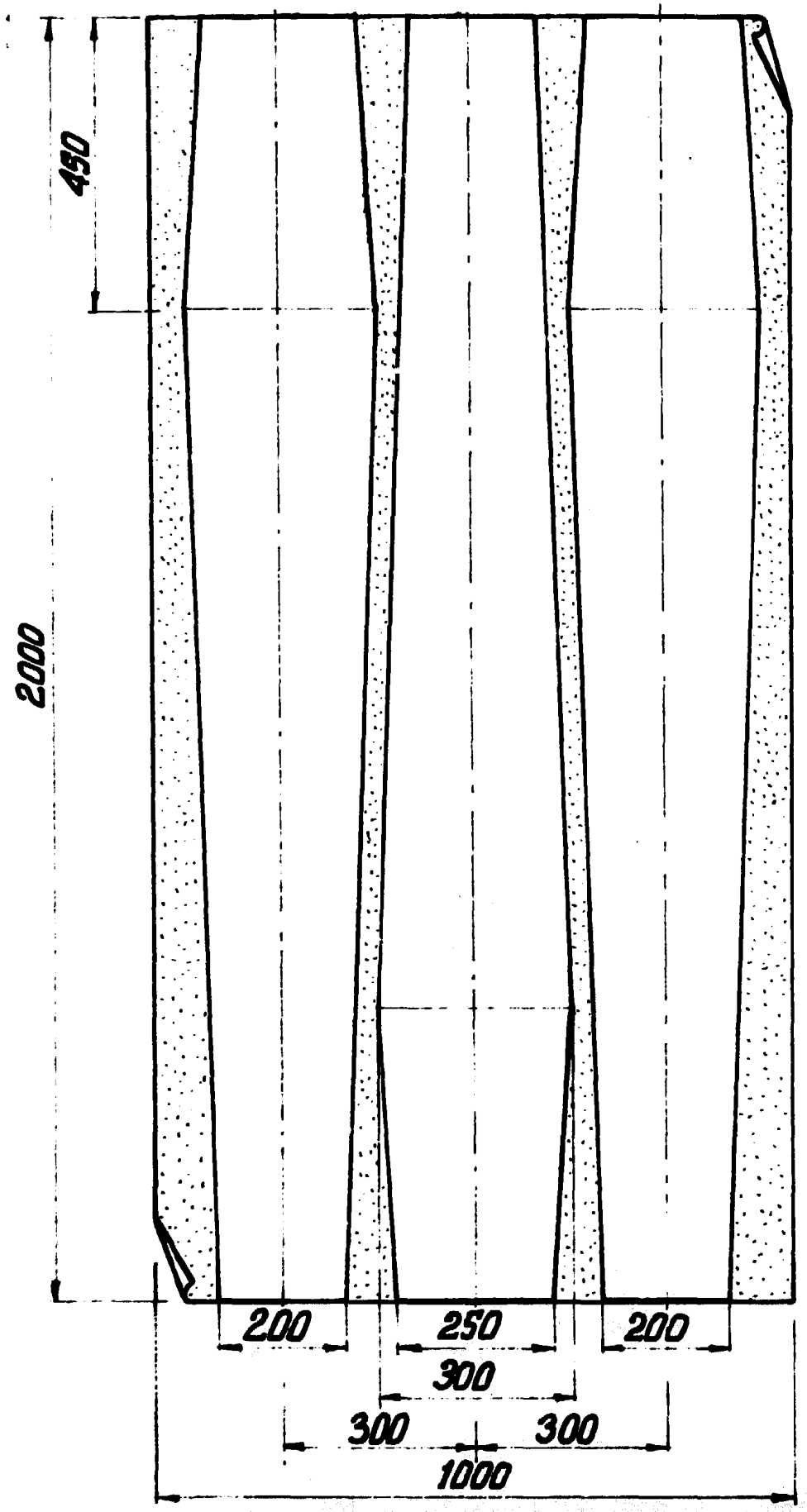

uneconomical (two blades per sheet). It was decided to narrow the blades by applying the properties of the 10% airfoils which resulted in a new blade-shape: three blades can be cut from one standardsheet.
Unfortunately the starting torque coefficient of the rotor decreased from 0.19 to 0.14 but the advantage of costprice-reduction made this quite acceptable.
It was also proposed to cut the blade tips in a circular shape which might increase the efficiency by appr. 2.5 %.
Although wind tunnel tests on this topic did not show any significant improvement. Some of the 12 PU 500 - windmills have been fitted with blades of circularly shaped blade tips and are accepted (more or less) for aesthetic reasons.

2.2.5. The pistonpump.

From the beginning the major part of the time and energy spent in developing the windmill-installation has been required for the evolution of the pumpsection.
Many problems had to be solved concerning the fixation of the pumps and delivery-pipes into the wells and also the design of the pistonpump changed from time to time.

Since the windmill drives the pistonpump with R.P.M-numbers of 15 up to 120 the application of air-chambers proved to be necessary in order to decrease the acceleration-forces acting in the pumprod, pump suspension and transmission. These forces were always underrated and several times cracks of the pumprod-connections and loose pump suspensions resulted. In some cases even the entire tubewell was pulled out and led to damage of the pump and pumprod as well.

The pump rod and pump rod connections

As mentioned before the first windmills have been fitted with wooden pump rods which proved not to be successful.

The wooden rods, if available, do not exceed the length of appr. 2 m and they are always unstraigth. Since the length of a total pumprod is at least 10 meters many connections have to be applied.

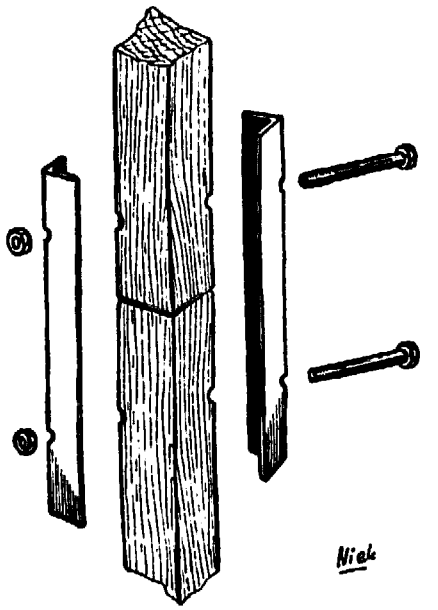

These connections are realized by using simple clamping devices of angle iron. These seemed to be very strong but sooner or later, due to the reverse of pumprod forces, these connection got loose. Actually these failures resulted in applying steel-pipe as a pumprod. In order to minimise the total weight the first steel-pumprod has been composed of 1" pipe with 1 mm. thickness only, but still the problem of simple joints persisted.

A simple rod connection, made by two bolts through it, did not serve the purpose. Such joints also got loose, worn out and finally cracked. Flanges made of flats which have been welded to the pump rod ends offered a strong and reliable joint after bolting them.

The disadvantages of such connections were that the pump rod sections were difficult to align and moreover the assembling of the pump-rod guides became complicated. The latter had to be partable. Moreover the thin walled pump rods needed many guides in order to prevent collapse during downward motions. Therefore normal 3/4" gaspipe has been applied for all the pumprods and the introduction of a new and simple joint solved all the pump-rod troubles.

3/4" screw-threaded rods are hammered into the 3/4" pump rod and welded to it. Two or three nuts provide a simple threaded-bush in which the threaded ends of the pump rods, with a spring-washer in between, are locked by an extra nut.
These pump rods and its joints serve the purpose very satisfactorily and no complications, concerning alignment, cracks or looseness, appeared anymore.

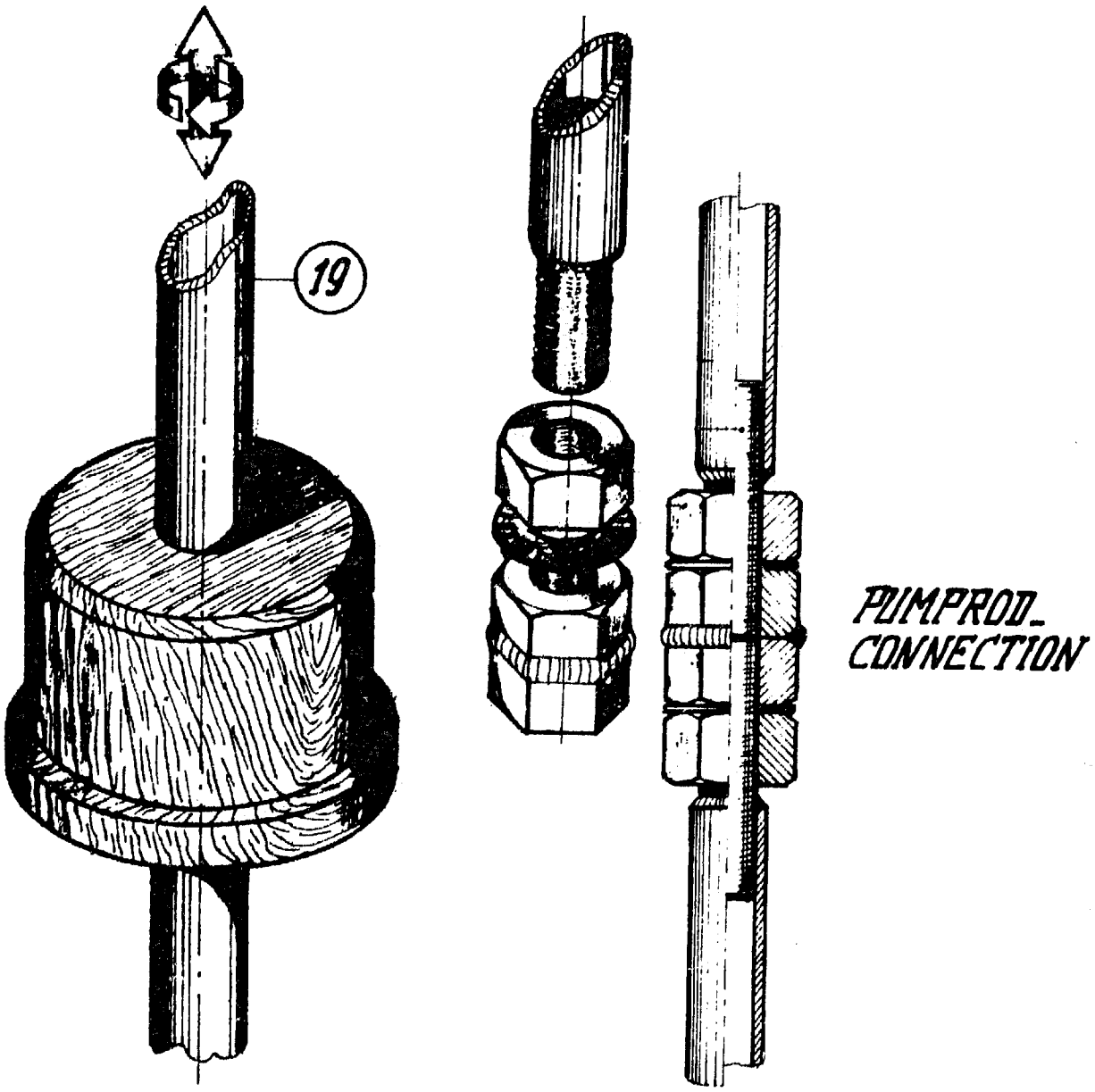

The first prototype-pistonpump

The first prototype existed of a set of P.V.C. pipes of 5" dia in which the wooden footvalve and wooden piston with leather sealing were situated near the watertable.

Besides the developing of the pumprod and its connections the piston became the bottle-neck when the stronger pumprods were introduced. Since the piston is made out of wood its strength was improved by increasing the thickness from 1.5" up to 3". The leather piston sealing proved to be very suitable as far as wearing and tigthening were concerned, but due to the high friction coefficient of the leather/P.V.C.-combination

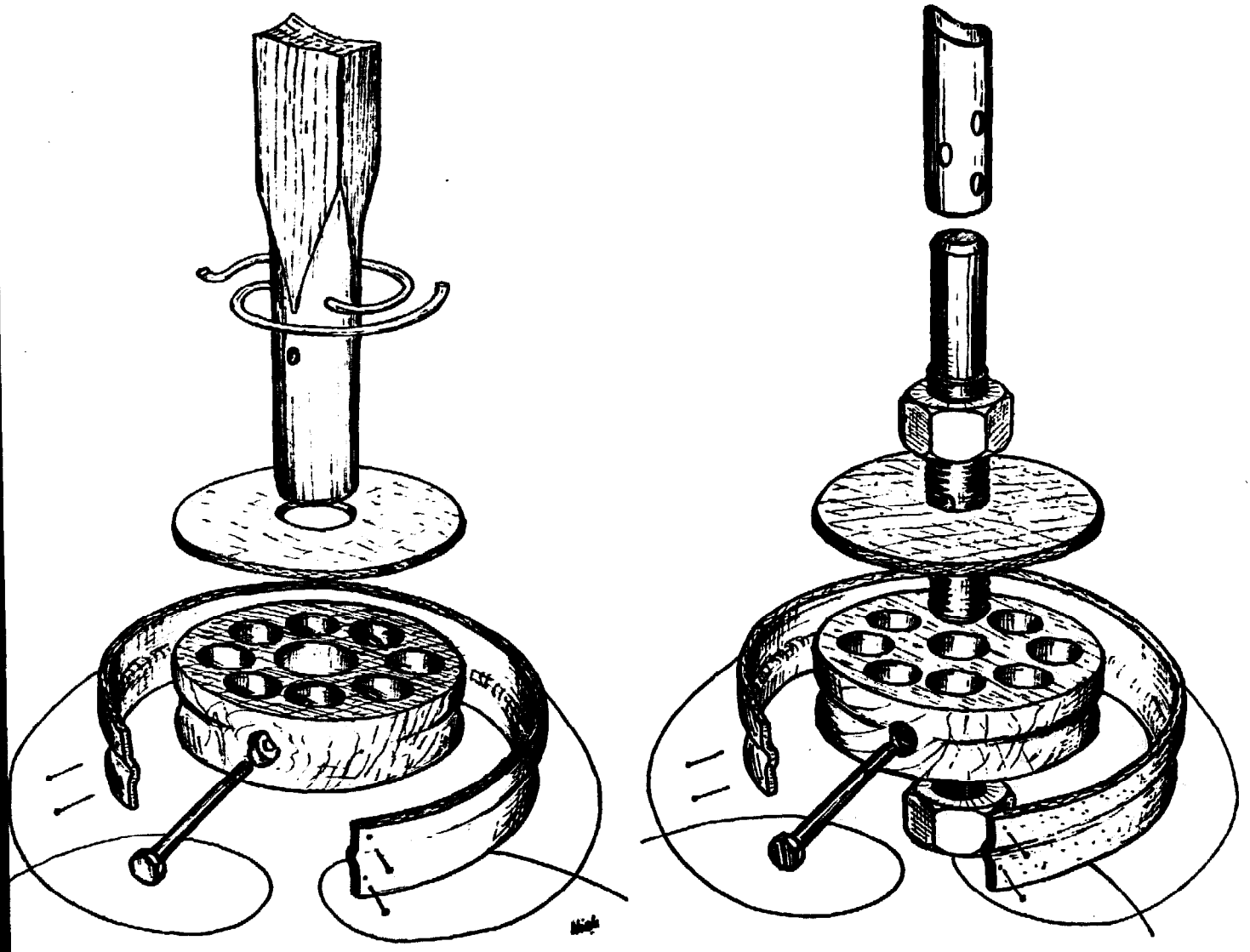

and the high static pressure the leather sealing set up and caused a sticking slide of the piston in the cylinder resulting in a very high startingtorque. First a rather high windgust (upto 6 or 7 m/sec) was required to start the windmill while the minimum runningspeed amounted to 3 m/sec. The idea was born to apply a small but permitted leakage in the piston in

such a way that the windmill can slowly move the piston in the top-position and is able to start running unloaded during the first half revolution. Probably the stored kinetic energy in the rotor might maintain the rotation so the starting-windspeed can be reduced.

During these experiments the inducted friction due to the set up of the leather sealing still persisted and just a small improvement has been noted.

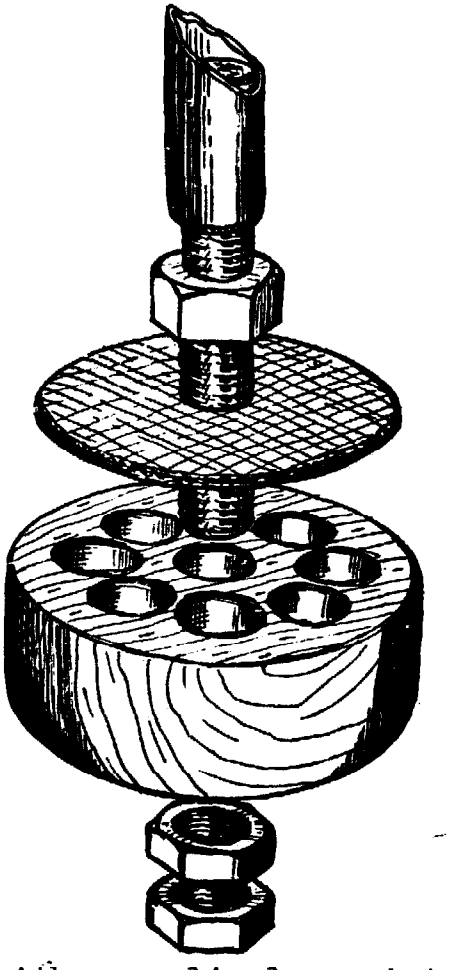

A new experiment with a sealingless piston showed a considerable improvement due to the absence of the Coulomb's friction acting on the P.V.C.-leather-surface. In spite of the fact that the volumetric efficiency is badly affected at very low R.P.M.-numbers this efficiency seemed not to be influenced if higher R.P.M.-numbers are actual. Although the expected lifetime was quite uncertain concerning the increasing of leakage (decreasing of volumetric efficiency) sooner or later this sealing-less piston has been fitted in the existing prototypes. The experience with the sealingless pistons in practice is rather positive: depending on the sliding-fit at the beginning, the purity of the lifted water and the actu-

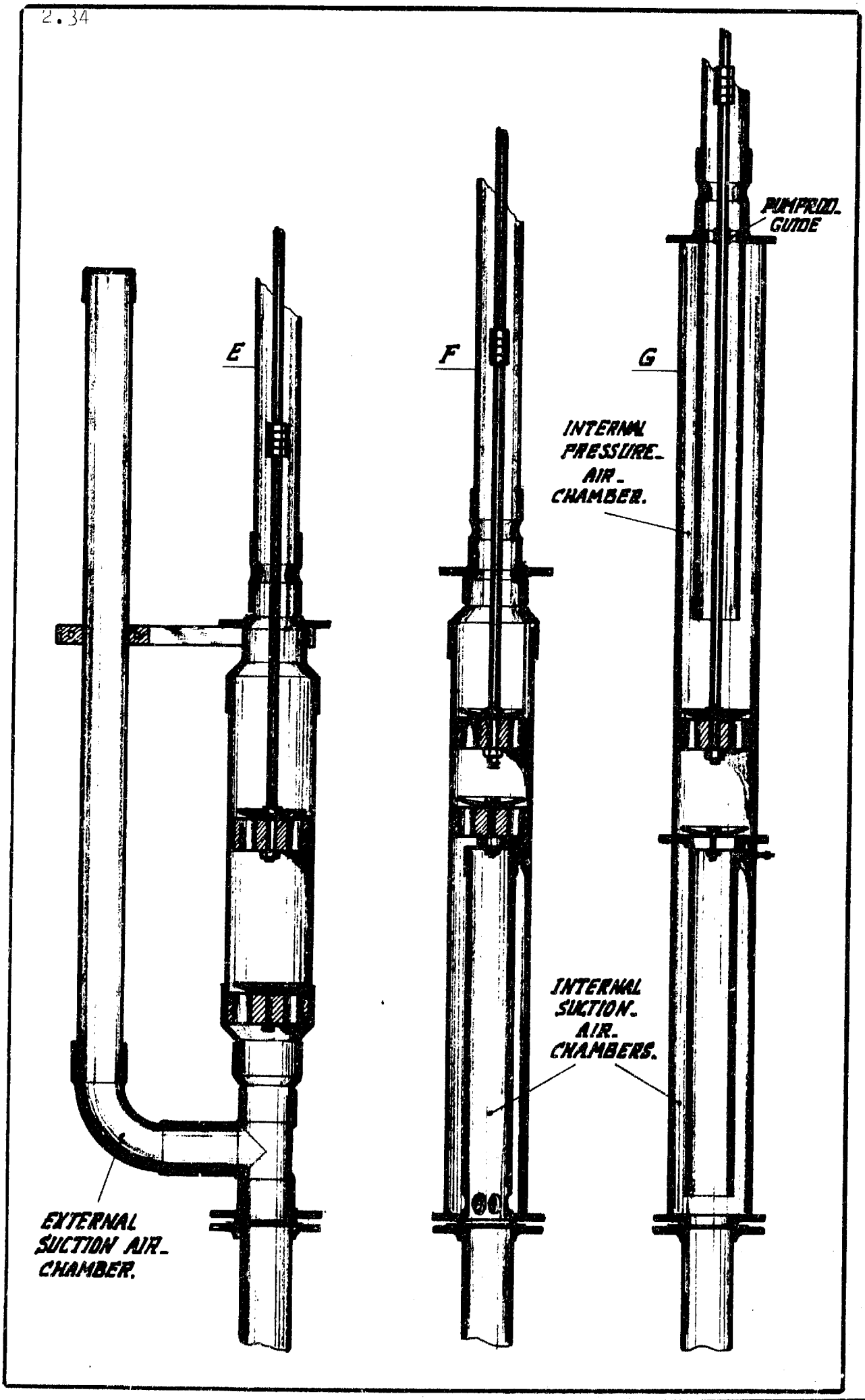
E
F
G
PUMPROD.
GUIDE
INTERNAL
PRESSURE.
AIR.
CHAMBER.
INTERNAL
SUCTION.
AIR.
CHAMBERS.
EXTERNAL
SUCTION AIR.
CHAMBER.

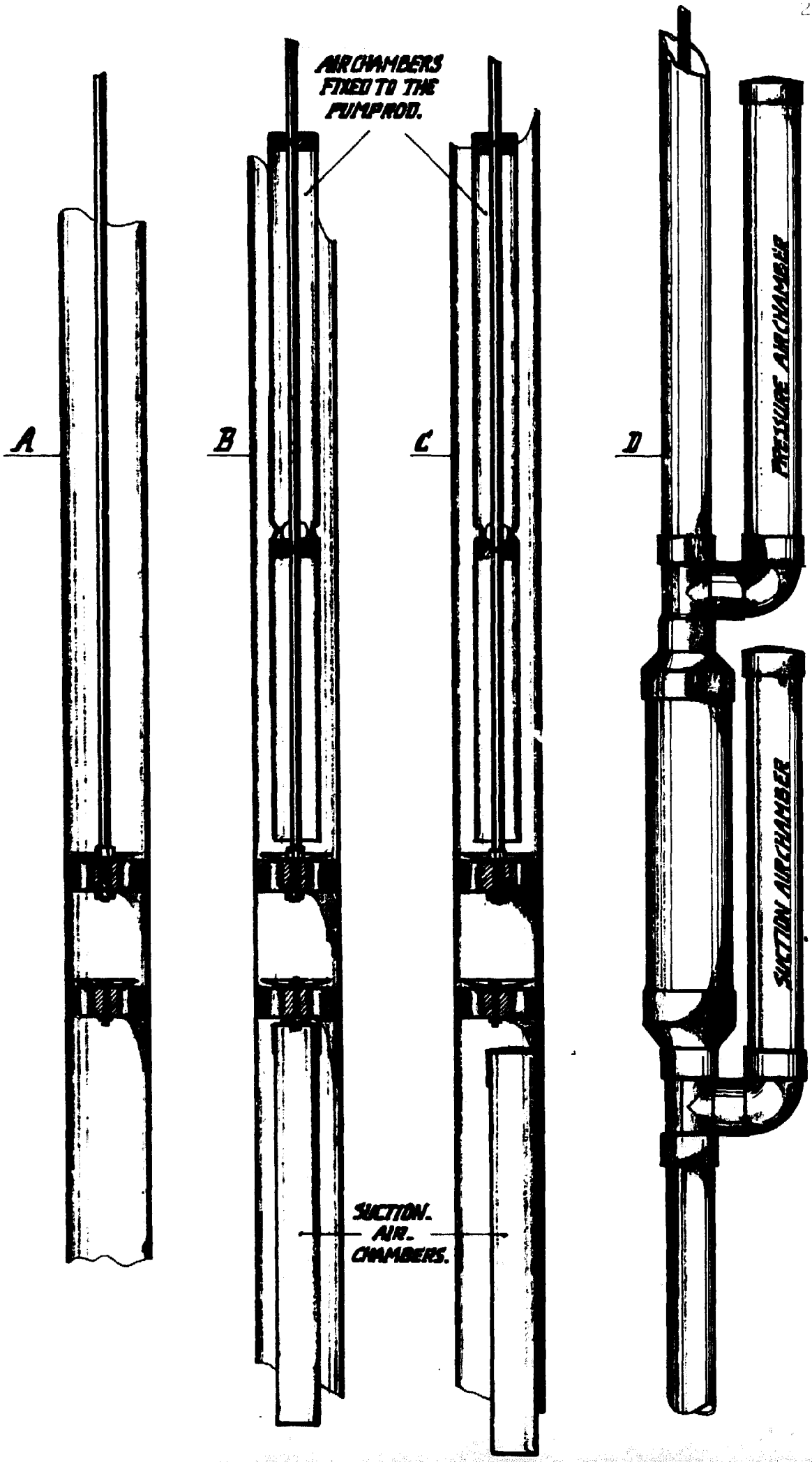
AIR CHAMBERS FIXED TO THE PUMP ROD.
A
B
C
D
PRESSURE AIR CHAMBER
SUCTION AIR CHAMBER
SUCTION. AIR. CHAMBERS.

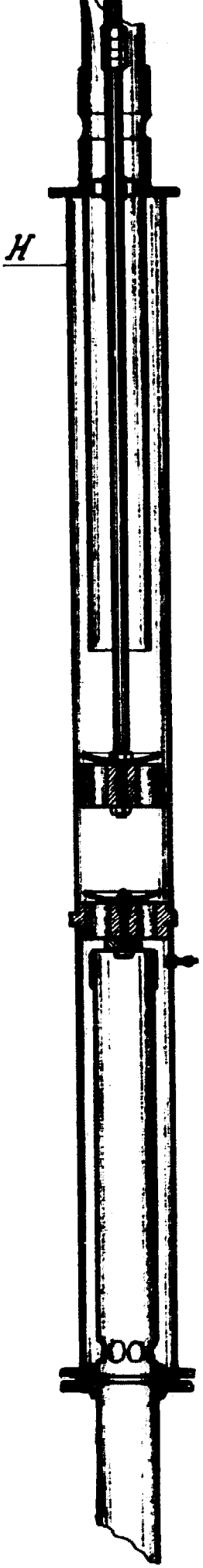

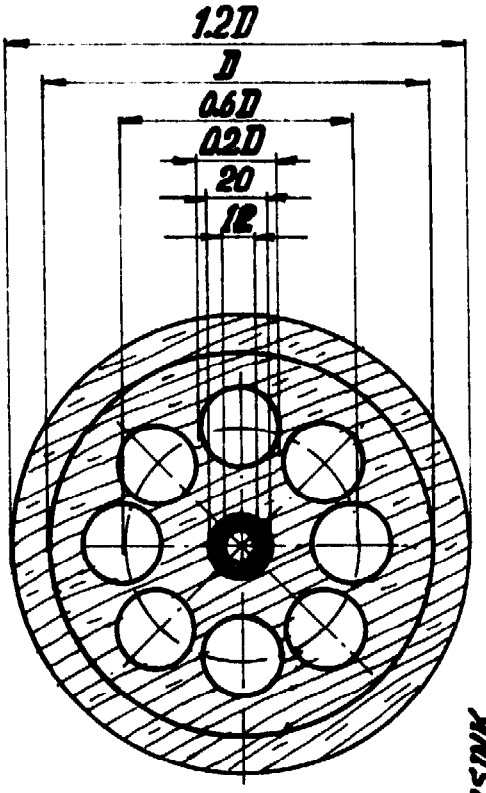

D ≙ 150

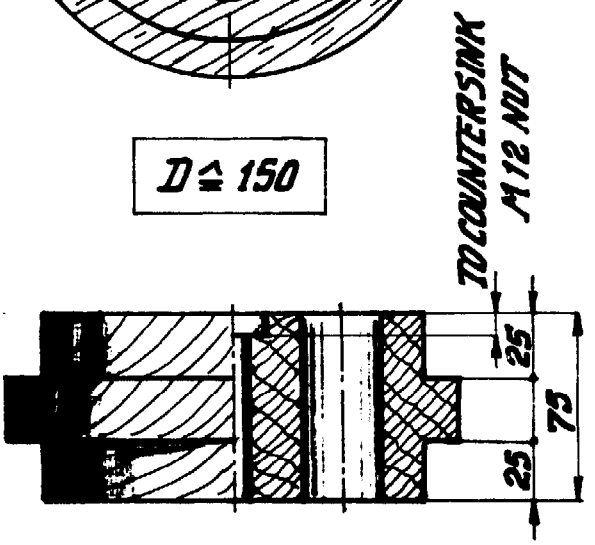

MEASUREMENTS IN WET CONDITION!

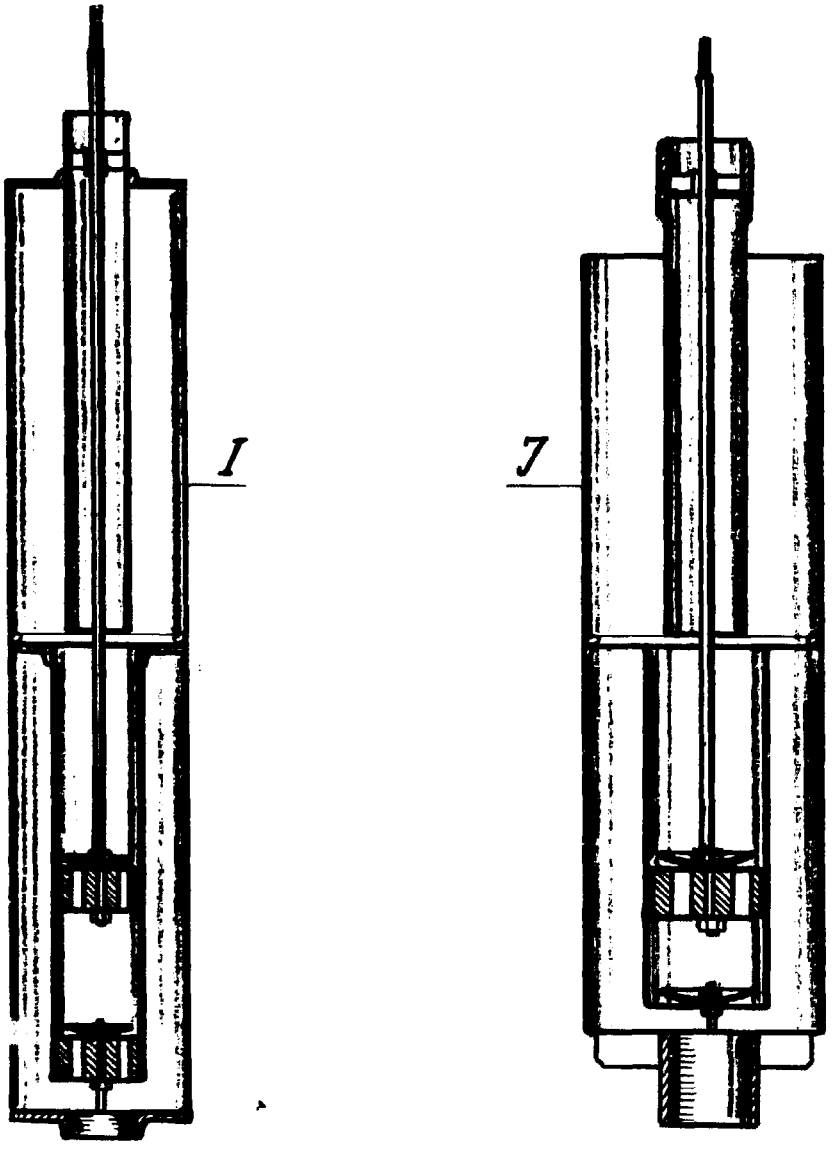
I
7

al accuracy of the pump-rod guidance (!) the lifetime varies considerably.
A worn-out piston/cylinder-combination still operates, but the efficiency becomes unacceptably low. Therefore maintenance and repair must be carried out, and if possible in a quick and uncomplicated way.
Since the leather valves need inspection and repair too the above mentioned demands had to be taken into account with regard to the pump designs. Finally the required airchambers and the materials available determinated this pump design.
Right from the beginning the development of the piston pump reached many stages resulting in type (A upto J) and still the way of developing by trial- and error detected the weaker sections in these designs. Time, wind, patience, optimism and invention in particular proved to be the most required tools in order to develop the piston-pump step by step. Briefly types A up to J will be described.

A — Basic type; very simple and reliable (handpumps) as far as no high frequencies actuate!

B and C — The need of air chambers were felt. Forces acting on the internal chambers were underrated. Complete chamber sections got loose and caused damage to foot-valve and piston. Especially the airtightness of the pressure chambers was difficult to achieve.

D — When the P.V.C.-sockets, elbows and T-connections were available, external air chambers have been composed and applied. But action-reaction effects in the external pipes caused vibrations while the presence of air in the pressure section remained doubtful after some time of operation. (Air solves into the water under high pressure conditions.)

E — Suitable for moderate elevation head (no pressure chamber). In this stage 7/8" pump rod and 7/8" connection have been introduced.

F Cheaper and simpler construction; by applying an internal suction-air chamber several reducing sockets, T-connection and elbow were superfluous. Total section is clamped between two flanges.

G Similar type but suitable for higher elevation head. Air in pressure chamber is maintained due to small but permitted leakage in suction section (by bicycle tube-valve). Due to the location of the suction-air chamber a foot valve with central supply has been applied. The latter did not operate satisfactorily in combination with the sole-leather valve disk which deformed in such a way that leakage resulted. The pump is simple to open and to inspect.

H The "combination pump" combines the advantages of pumptypes F and G resulting in the following properties of the pump:

- double air-chambers (reduces pump-rod forces)
- reliable valves (self-priming)
- proper pumprod guidance (life-time piston)
- "automatic air injector"(pressure chamber remains full)
- total pump sections can be replaced easily (quicker repair, maintenance)
- pump is opened quickly (repair, maintenance is normally carried out in the workshop).

I This pump is completely composed of steel components which are jointed by weldings. The pump is easy to open in order to carry out maintenance and repairs. The cylinde is made of gaspipe from which the inner seam is removed by means of a simple cutting device and final finishing is done by honing. Though its construction is more advanced than those of the other pumps its reliability proved to be better. (See chapter 4).

J. Same type but the footvalve is made of sheet iron. This allows a shorter cylinder which facilitates removing the seam. Moreover no doubts remain whether leakage occurs between valve-body and cylinder as sometimes seemed in the foregoing pumptype. Also this pump has been tested thoroughly as described in chapter 4.

The air-injection system in both the pumptypes I and J has been abandoned as pumptests showed (by means of waterlevel gauge) that the air in the pressure vessel still remained. Results of thorough tests of the pumps latter mentioned are described in chapter 4.

2.2.6 Pump suspension

Practice showed that fixation of the windmill pump can be rather complicated. Especially during stormy weather considerable forces are acting on all moving parts and the pump structure in particular. One can imagine what happens if the suspension shows some play. In some cases the entire tube-well got loose and was simply pulled up till the piston started hammering on the foot valve!

Besides the need of an adequate fixation in vertical sense supports are also necessary to keep the long pipe lines centered. Previously this was achieved by means of wooden crosses which have been wedged in the well by means of keys. Though such arrangements served the purpose some danger exists as people tend to stand on the crosses during climbing into the well. A simple tripod-"umbrella", combined with the pipe-line socket, proved to be very useful. Centring is done simply by adjusting the "pods" and locking them in the brick wall by means of a few hammer blows.

Proper fixation of the entire pump sections have been achieved by applying the following constructions:

- Anchors masoned in the well
- Expanding clamping-devices
- Tower-pipe connection
- "Bridge"

Anchors masoned in the well

In case of an excentrically placed tower, which is often done in order to facilitate waterlifting by means of other devices, the well-structure itself provides attachments for the pump section. Anchors are masoned into the wall so that the delivery pipe-line can be fitted.

Expanding clamping device

Provided that the well casing is of proper construction the entire pump arrangement can be fixed suitably by means of an expanding clamping device. The latter is composed of 1"gas pipes which are welded at right angle either to the bottom section of the pump or to the suction pipe. Mutual braces (angle iron) ensure a rigid construction. The clamping arrangement is obtained by fitting longthreaded bolts or screw studs into the extruding pipe ends. Tightening their nuts causes the expansion and fixation of the frame.

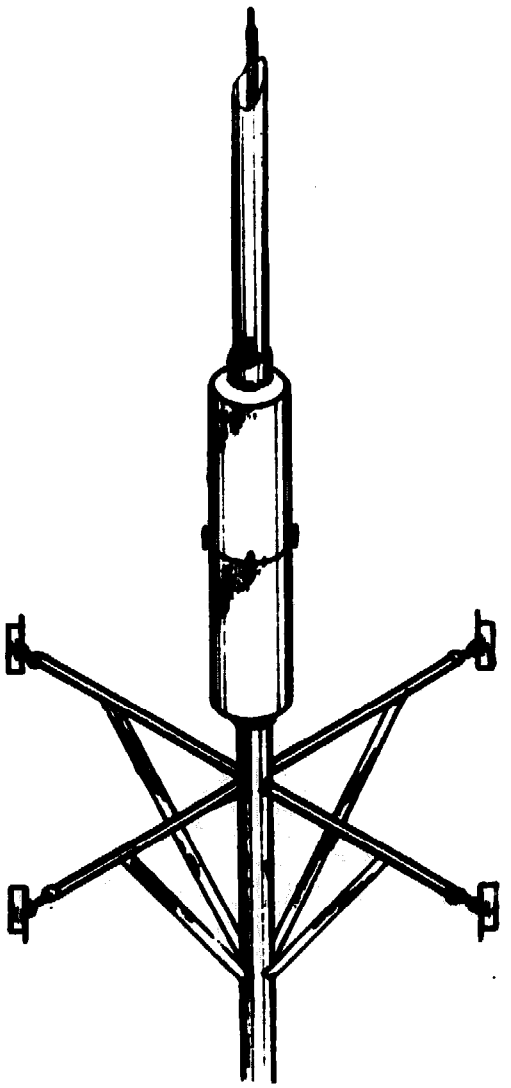

In order to prevent damage to the bricks of the well casing it is necessary to enlarge the bearing surface by means of pieces of angle iron.

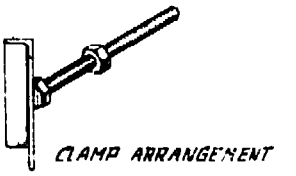

Such clamping device proved its worth in combination with the "bridge" construction.

Tower pipe connection

In cases of weak or brittle well casings the pump rod forces are hardly carried by masoned anchors and other devices to such well-casings. Therefore it is preferable to carry over the forces directly via a tower-pipe extension, which is composed of two long angle irons and some clamps. As a matter of fact the entire pump section hangs from the tower pipe and all acting forces are led through this suspension instead of through tower structure, fundation, well casing and the pump suspension respectively.

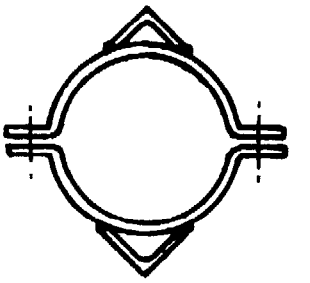

Sideward vibration hardly occur and if so,retaining of the pump section is simply achieved by means of applying the "tripod umbrella" (as mentioned earlier), masoned anchors or the "bridge".

"Bridge"-suspension

If a strong and proper well casing is available the simple bridge construction provides a rigid suspension of the pump section in horizontal and vertical sense both.

The delivery pipe is clamped to the bridge by means of two clamps. By opening these clamps, and the pumprod-connection, the entire topsection of the pump (including delivery line) can be lifted in order to facilitate repair and maintenance the moving parts of the pump.

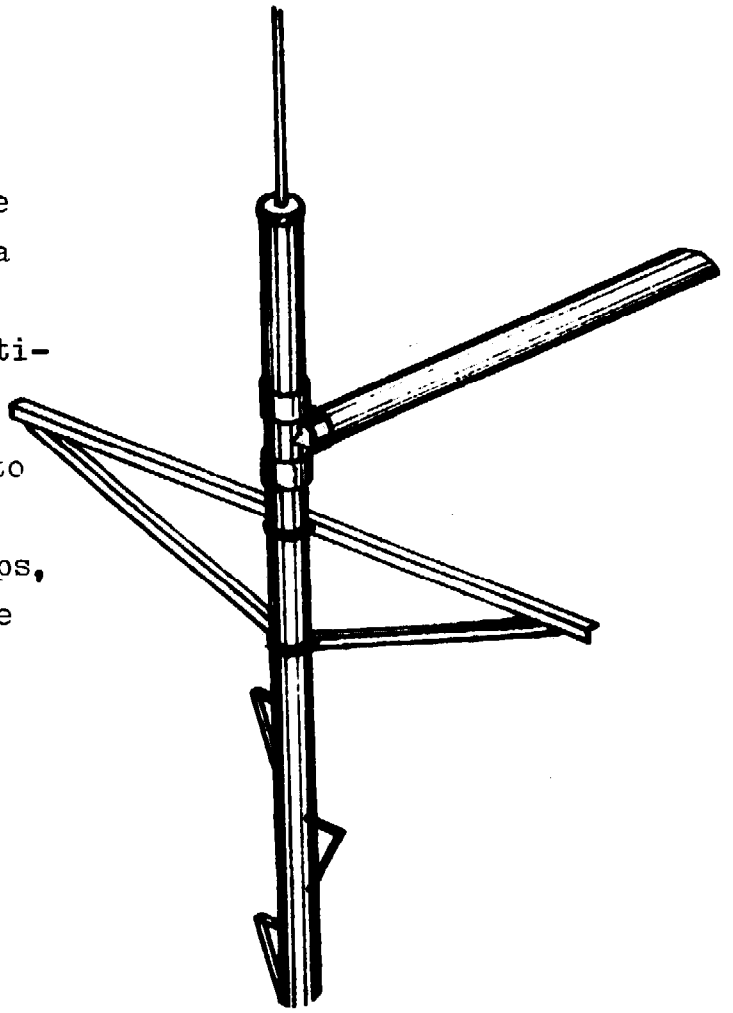

2.3. The 4-bladed 2.50 m. dia. windmill for low-water-lifting.

In winterseason surface water, which remained from the rain-season, is used in some cases for the irrigation of the winter-crops. Several small farmers lift this surface water by manpower to their fields; the idea was born to develop a small and cheap windmill which can do this job.
Although this low-waterlifting was not planned in the project-schedule and its need was not actual, some time has been spent by the Dutch windmillengineers in developing this windmill. Therefore some attention is paid to this subject.

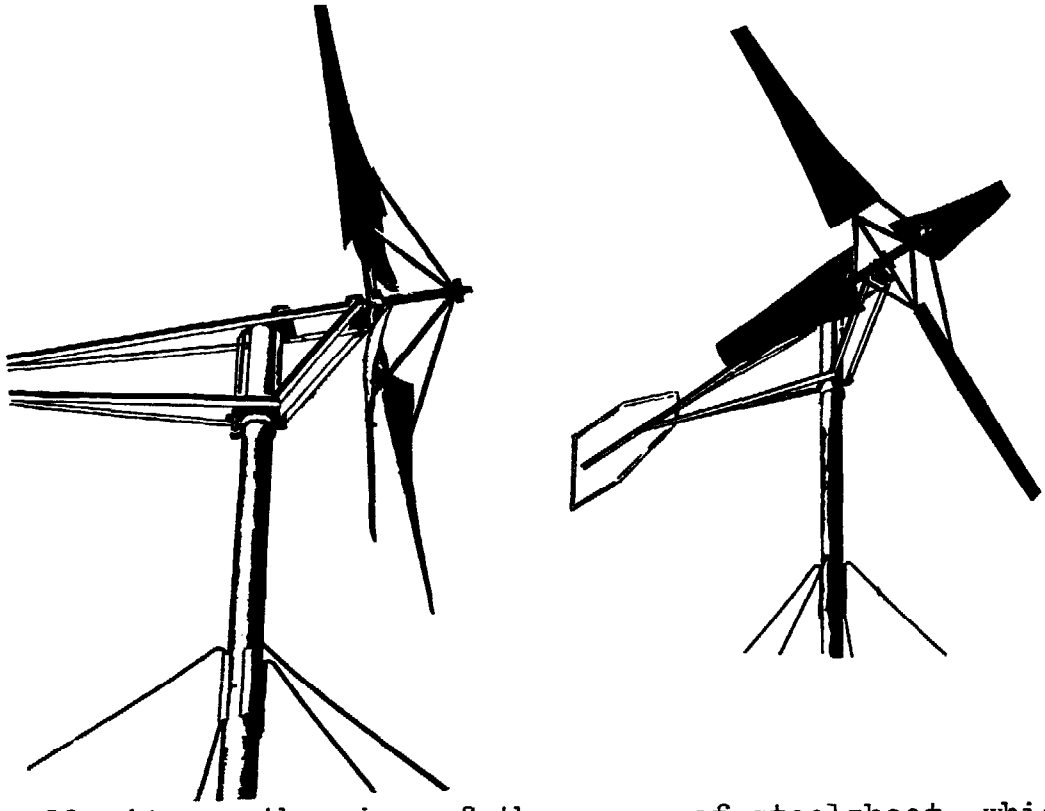

Actually it was the size of the scrap of steelsheet, which was left from the production of the big windmills which determined the dimensions of this small windmill. The first prototype has been fitted with a 4" pistonpump combined with a 3" towerpipe. The total structure stands on its pump-section and is held in position by guys. The latter are simply made of 3/8" steel rods and anchored by pegs to the ground. The conversion of the millshaft-rotation into the up-and downward -motion of the pumprod is obtained by means of a crank-pumprod-mechanism. The elasticity of the rod allows its outward bending besides the up-and down-movement so a

connecting-rod and crosshead are superfluous. Two wooden guides, situated in the tower, provide a further support to the 6 m.-long pumprod. The piston is made sealingless in order to enable the windmill to start almost unloaded. This is necessary since the starting-torque of the 4-bladed windmill is very low. The measure of leakage is determined by trial and error and a clearance of the piston in the cylinder of appr. 1/2 % of the piston-diameter proved to lead to satisfactory results. In spite of this leakage the volumetric efficiencies are reasonable and even the value of 100% is exceeded due to the inertia-effects in the watercolumn if high R.P.M.-numbers occur.
In 1978 the total material-costs of the small windmill amounted to less than Rs. 500,- while the required manpower for building it is estimated at appr. 50 manhours.

Later on 3 other small windmills have been built and installed. These were slightly different in size and design (3.2 m. dia., tip-speed ratio 5) and consequently more costly.
In the longer run some technical problems (e.g. fatigue-cracks in the blades) in combination with the low windspeeds made it clear that the use of these small windmills was not quite succesful in the Ghazipur district, but on the other hand its simplicity and costprice caused that it was adopted by the WOT (TOOL-member in The Netherlands). Developing and testing there, proved that this small windmill can still be attractive for low-waterlifting purposes while the basic design is maintained and applied in other WOT windmill types.
In the framework of these windmilltypes the small windmill is coded: 4 PU 250 (4-bladed pumping unit of 250 cm. dia.)
Applying some small modifications the windmill can be fitted with a transmission to groundlevel by means of a rotating shaft for multi-purposes (4 MP 250). Also generating electricity is possible by applying this basic design and a 4 EG 250 will result.

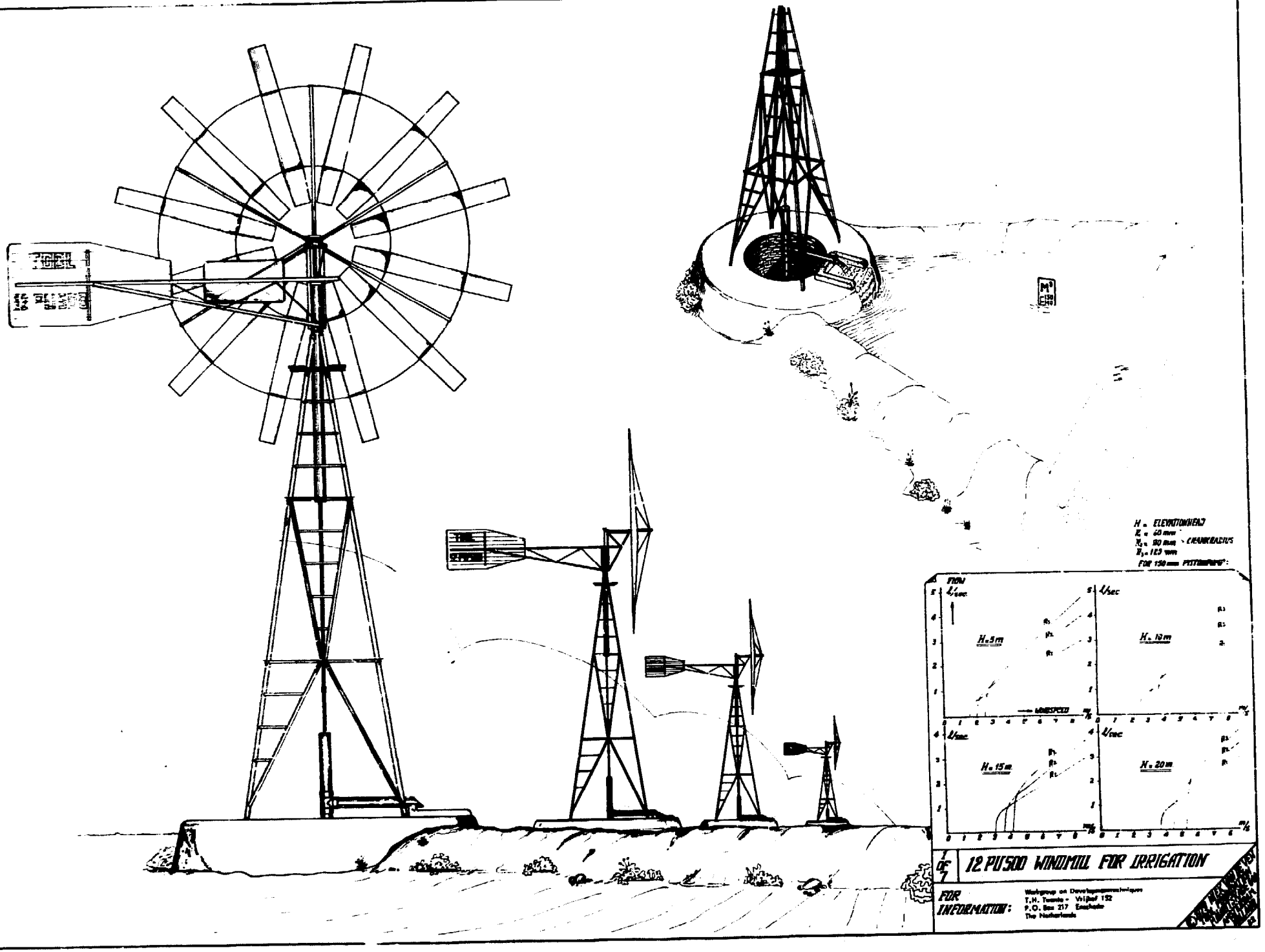
H = ELEVATION (M)
FOR 150 mm PISTON PUMP:
H = 5 m
H = 10 m
H = 15 m
H = 20 m
l/sec
m/s
1 OF 7
12 PU500 WINDMILL FOR IRRIGATION
FOR INFORMATION:
Workgroup on Development Techniques
T.H. Twente - Vrijhof 122
P.O. Box 217 Enschede
The Netherlands

WALLTHICKNESS TOWERPIPE NOT LESS THAN 3.5 MM

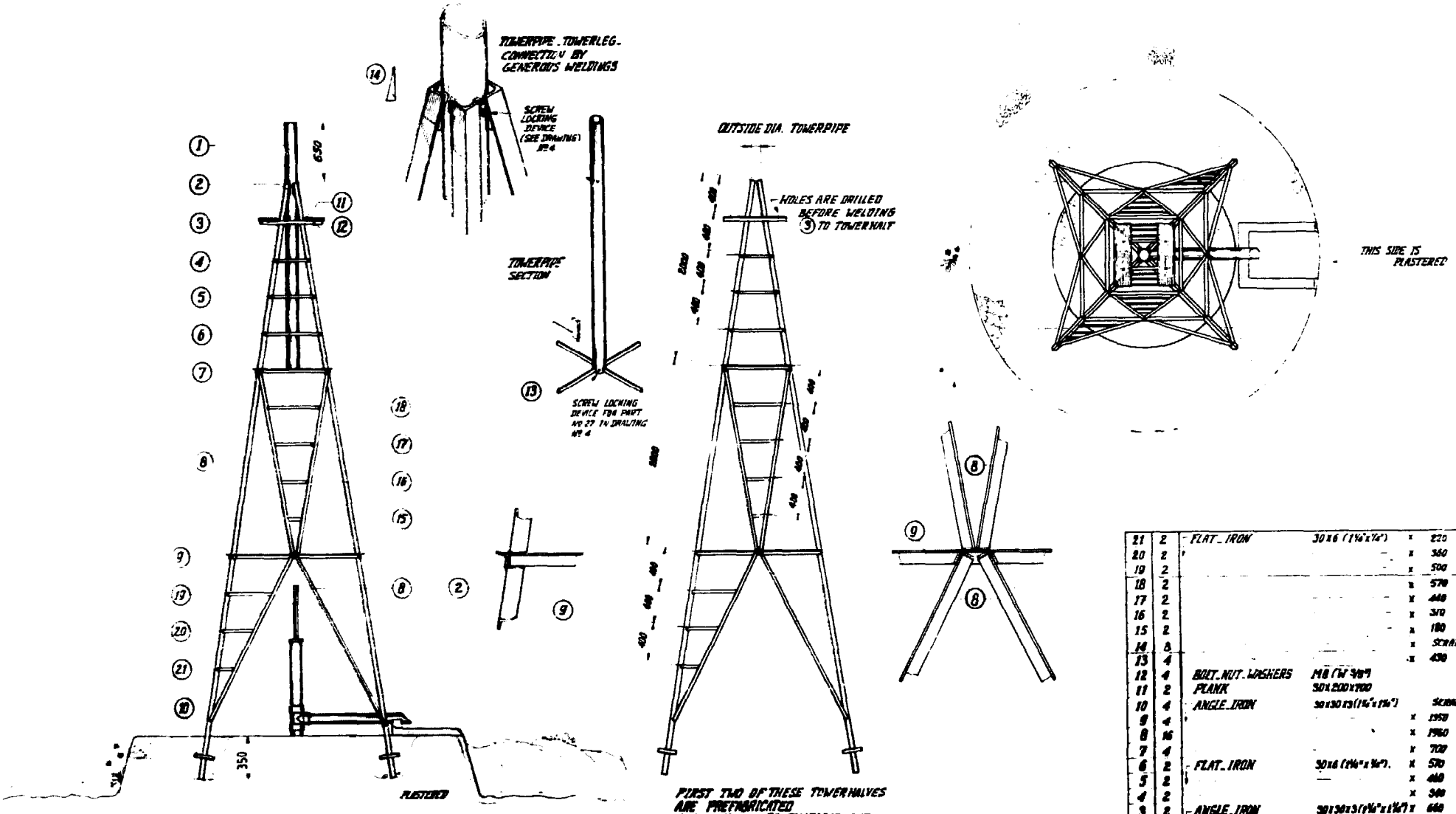

IF DESIRED THE LATTICE MEMBERS CAN BE POSITIONED AND WELDED INSIDE THE TOWER LEGS RESULTING IN A MORE ATTRACTIVE APPEARANCE OF THE TOWER. HOWEVER THE FLANGES AT THE ENDS OF THE ANGLE-IRON MEMBERS Nº 7 AND Nº 9 SHOULD BE CUT AT ANGLES OF 45 DEGREES.

FIRST TWO OF THESE TOWERHALVES ARE PREFABRICATED. BOTH HALVES ARE COMPOSED AND THE TOWERPIPE-SECTION IS SHIFTED IN AND A COMPLETE TOWER RESULTS

21	2	FLAT-IRON	30 x 6 (1¼" x ¼")	x	220
20	2			x	360
19	2			x	500
18	2			x	570
17	2			x	440
16	2			x	310
15	2			x	180
14	8			x	SCRAP
13	4			x	450
12	4	BOLT-NUT-WASHERS	M8 (¼" x ⅜")		
11	2	PLANK	50 x 200 x 900		
10	4	ANGLE-IRON	50 x 50 x 5 (1¼" x 1¼")		SCRAP
9	4			x	1950
8	16			x	1960
7	4			x	700
6	2	FLAT-IRON	30 x 6 (1¼" x ¼").	x	570
5	2		—	x	440
4	2			x	300
3	2	ANGLE-IRON	50 x 50 x 5 (1¼" x 1¼")	x	660
2	4		40 x 40 x 4 (1⅝" x 1⅝")	x	6500
1	1	TOWERPIPE	4" GASPIPE	x	8650
Nº	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS			

2 OF 7

12 PU500 - TOWERCONSTRUCTION

FOR INFORMATION: Werkgroep on Ontwikkelingstechniek T.H. Twente - Vrijhof 153 P.O. Box 217 Enschede The Netherlands

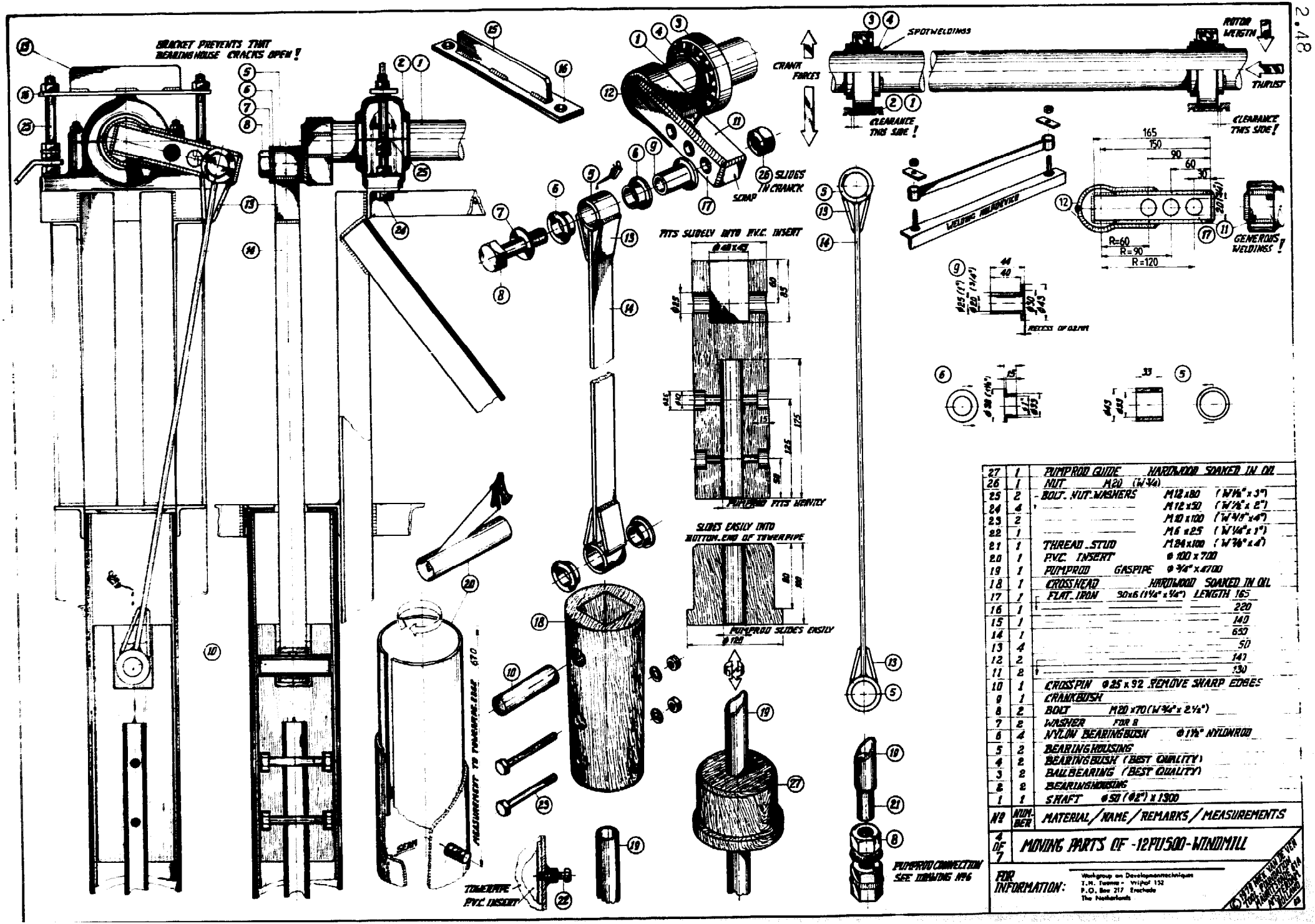

Nº	NUMBER	MATERIAL / NAME / REMARKS / MEASUREMENTS
27	1	PUMPROD GUIDE HARDWOOD SOAKED IN OIL
26	1	NUT M20 (W¾")
25	2	BOLT. NUT. WASHERS M12 x 80 (W½" x 3")
24	4	M12 x 50 (W½" x 2")
23	2	M10 x 100 (W⅜" x 4")
22	1	M6 x 25 (W¼" x 1")
21	1	THREAD. STUD M24 x 100 (W¾" x 4")
20	1	PVC INSERT ø 100 x 700
19	1	PUMPROD GASPIPE ø ¾" x 4700
18	1	CROSSHEAD HARDWOOD SOAKED IN OIL
17	1	FLAT. IRON 30x6 (1¼" x ¼") LENGTH 165
16	1	220
15	1	140
14	1	650
13	4	50
12	2	147
11	2	130
10	1	CROSSPIN ø 25 x 92 REMOVE SHARP EDGES
9	1	CRANKBUSH
8	2	BOLT M20 x 70 (W¾" x 2½")
7	2	WASHER FOR 8
6	4	NYLON BEARINGBUSH ø 1½" NYLONROD
5	2	BEARINGHOUSING
4	2	BEARINGBUSH (BEST QUALITY)
3	2	BALLBEARING (BEST QUALITY)
2	2	BEARINGHOUSING
1	1	SHAFT ø 50 (ø 2") x 1300

4 OF 7

MOVING PARTS OF -12PU500-WINDMILL

FOR INFORMATION: Werkgroep en Ontwikkelingstechnieken
T.H. Twente - Wijhof 152
P.O. Box 217 Enschede
The Netherlands

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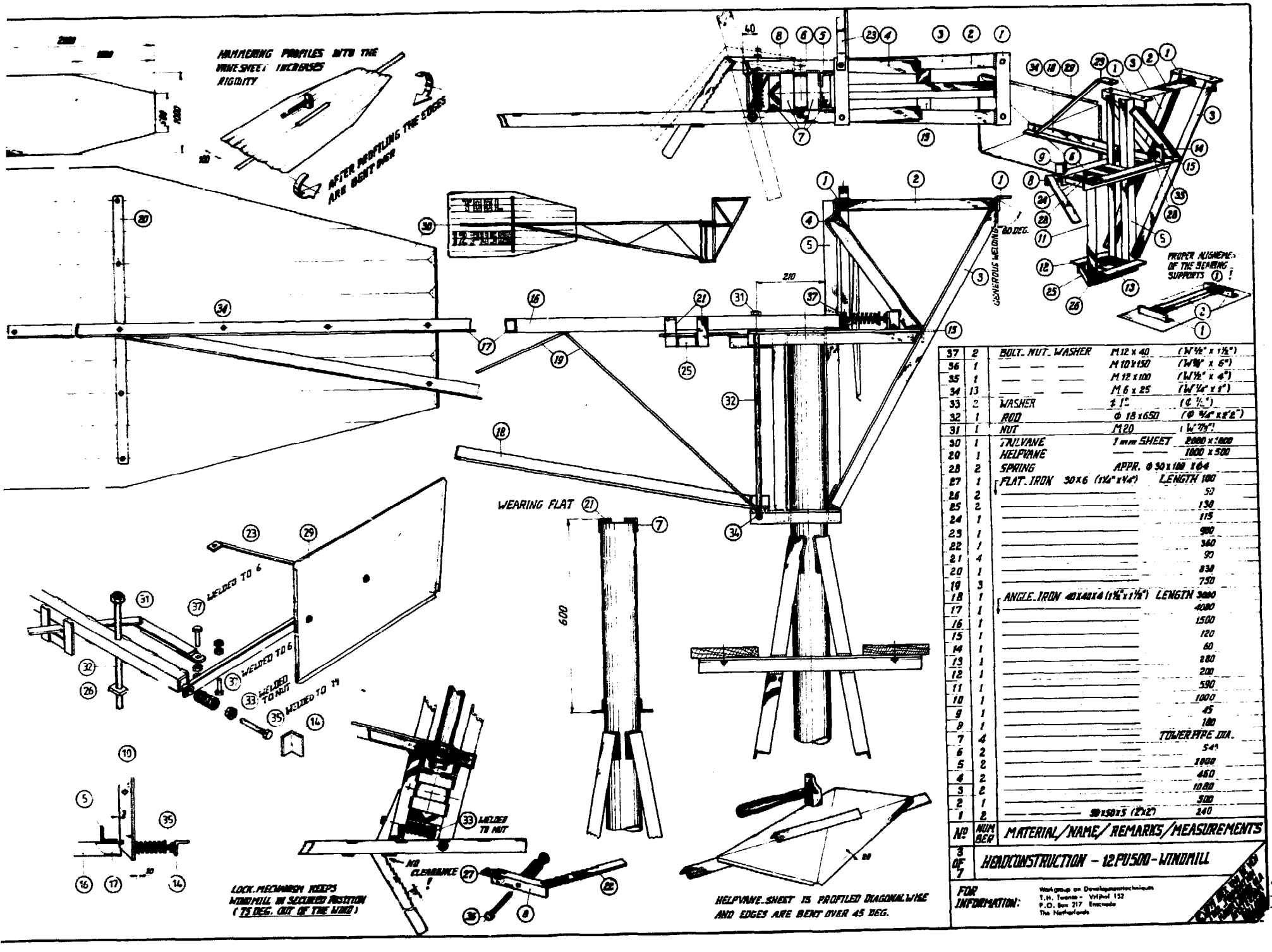

Nº	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS		
37	2	BOLT NUT WASHER	M12 x 40	(W½" x 1½")
36	1	— — —	M10 x 150	(W⅜" x 6")
35	1	— — —	M12 x 100	(W½" x 4")
34	13	— — —	M6 x 25	(W¼" x 1")
33	2	WASHER	⌀ 1"	(⌀ ½")
32	1	ROD	⌀ 18 x 650	(⌀ ¾" x 2'2")
31	1	NUT	M20	(W ⅞")
30	1	TAILVANE	1 mm SHEET	2000 x 1000
29	1	HELPVANE	— —	1000 x 500
28	2	SPRING	APPR. ⌀ 30 x 100 ⌀ 4	
27	1	FLAT IRON 30x6 (1¼" x ¼")	LENGTH 100	
26	2		50	
25	2		130	
24	1		115	
23	1		980	
22	1		340	
21	4		90	
20	1		830	
19	3		750	
18	1	ANGLE IRON 40x40x4 (1½" x 1½")	LENGTH 3000	
17	1		4080	
16	1		1500	
15	1		120	
14	1		60	
13	1		280	
12	1		200	
11	1		590	
10	1		1000	
9	1		45	
8	1		100	
7	4		TOWER PIPE DIA.	
6	2		540	
5	2		1000	
4	2		460	
3	2		1080	
2	1		500	
1	2	50x50x5 (2"x2")	240	

3 OF 7

HEADCONSTRUCTION - 12PU500 - WINDMILL

FOR INFORMATION: Werkgroep on Ontwikkelingstechniek T.H. Twente - Vrijhof 152 P.O. Box 217 Enschede The Netherlands

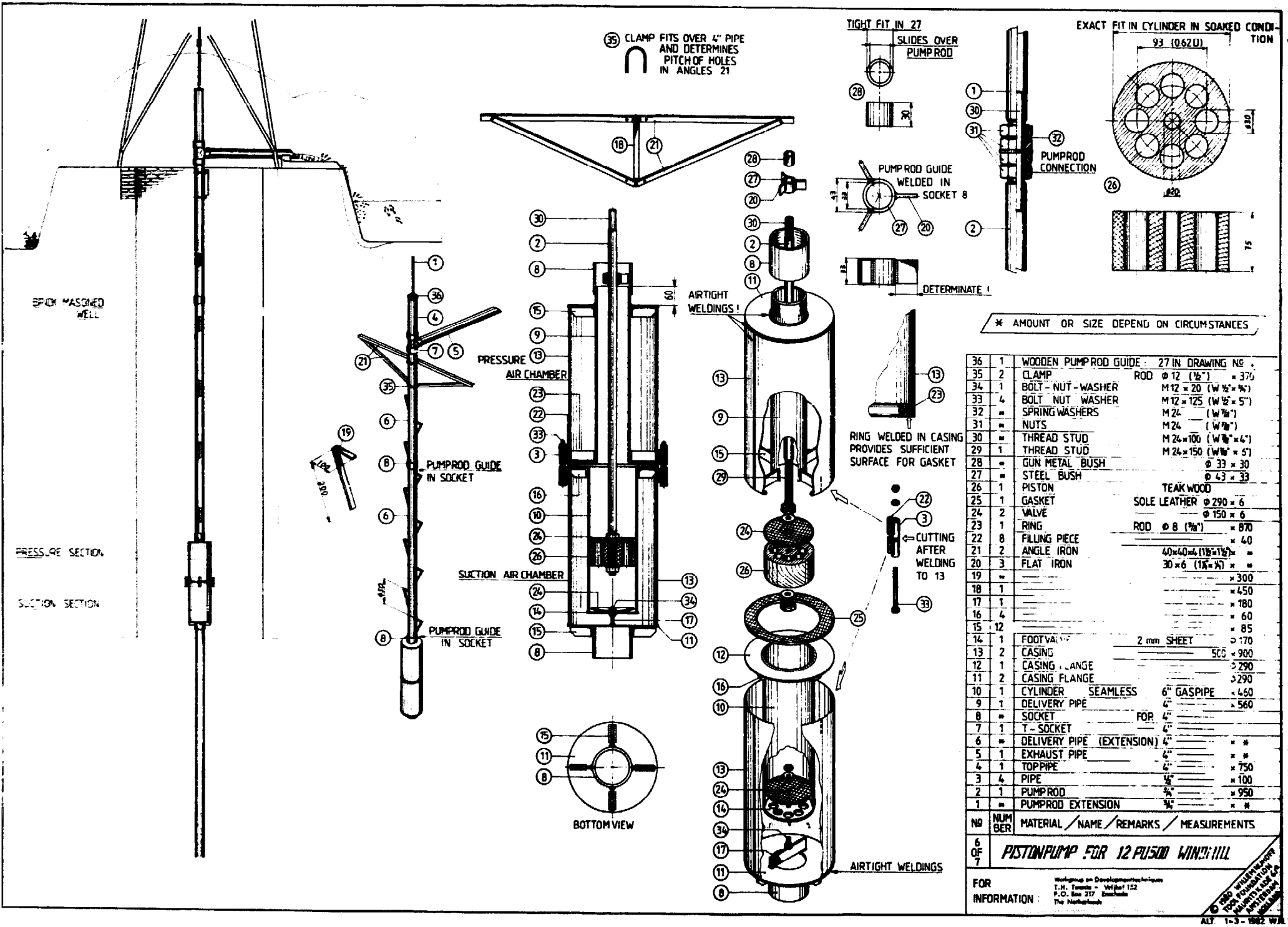

* AMOUNT OR SIZE DEPEND ON CIRCUMSTANCES

Nº	NUMBER	MATERIAL / NAME / REMARKS / MEASUREMENTS		
36	1	WOODEN PUMPROD GUIDE : 27 IN DRAWING Nº		
35	2	CLAMP	ROD Φ 12 (½")	× 370
34	1	BOLT - NUT - WASHER	M 12 × 20 (W ½" × ¾")	
33	4	BOLT NUT WASHER	M 12 × 125 (W ½" × 5")	
32	*	SPRING WASHERS	M 24 (W ⅞")	
31	*	NUTS	M 24 (W ⅞")	
30	*	THREAD STUD	M 24 × 100 (W ⅞" × 4")	
29	1	THREAD STUD	M 24 × 150 (W ⅞" × 6")	
28	*	GUN METAL BUSH	Φ 33 × 30	
27	*	STEEL BUSH	Φ 43 × 33	
26	1	PISTON	TEAK WOOD	
25	1	GASKET	SOLE LEATHER	Φ 290 × 6
24	2	VALVE		Φ 150 × 6
23	1	RING	ROD Φ 8 (⅜")	× 870
22	8	FILLING PIECE		× 40
21	2	ANGLE IRON	40×40×4 (1½"×1½")	× *
20	3	FLAT IRON	30 × 6 (1⅛" × ¼")	× *
19	*			× 300
18	1			× 450
17	1			× 180
16	4			× 60
15	12			× 85
14	1	FOOTVALVE	2 mm SHEET	Φ 170
13	2	CASING	500	× 900
12	1	CASING FLANGE		Φ 290
11	2	CASING FLANGE		Φ 290
10	1	CYLINDER SEAMLESS	6" GASPIPE	× 460
9	1	DELIVERY PIPE	4"	× 560
8	*	SOCKET	FOR 4"	
7	1	T - SOCKET	4"	
6	*	DELIVERY PIPE (EXTENSION)	4"	× *
5	1	EXHAUST PIPE	4"	× *
4	1	TOPPIPE	4"	× 750
3	4	PIPE	½"	× 100
2	1	PUMPROD	¾"	× 950
1	*	PUMPROD EXTENSION	¾"	× *

6 OF 7

PISTONPUMP FOR 12 PU500 WINDMILL

FOR INFORMATION : Werkgroep en Ontwikkelingstechniek
T.H. Twente - Wijhof 152
P.O. Box 217 Enschede
The Netherlands

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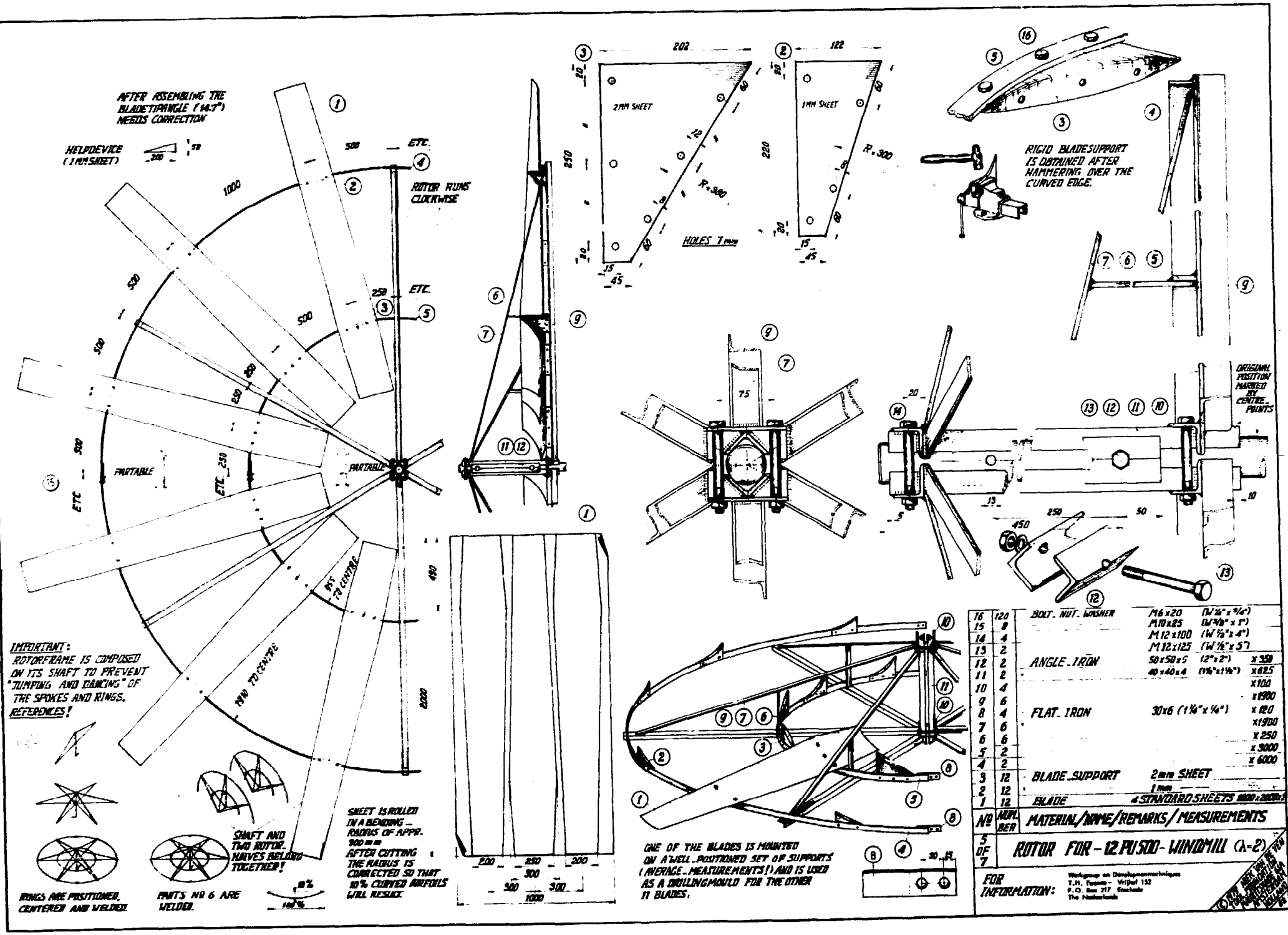

Nº	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS		
16	120	BOLT-NUT-WASHER	M6x20	(W 1/4" x 3/4")
15	8		M10x25	(W 3/8" x 1")
14	4		M12x100	(W 1/2" x 4")
13	2		M12x125	(W 1/2" x 5")
12	2	ANGLE-IRON	50x50x5	(2"x2") x 350
11	2		40x40x4	(1 9/16"x1 9/16") x 625
10	4			x 100
9	6			x 1900
8	4	FLAT-IRON	30x6 (1 1/8"x 1/4")	x 120
7	6			x 1900
6	6			x 250
5	2			x 3000
4	2			x 6000
3	12	BLADE-SUPPORT	2mm SHEET	
2	12		1mm	
1	12	BLADE	4 STANDARD SHEETS 1000x2000x1	

5 OF 7

ROTOR FOR-12 PU500-WINDMILL (λ-2)

FOR INFORMATION: Werkgroep en Ontwikkelingstechniques T.H. Twente - Vrijhof 152 P.O. Box 217 Enschede The Netherlands

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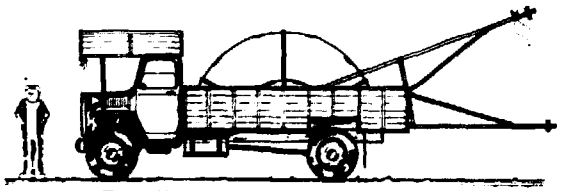

TRANSPORT BY TRUCK

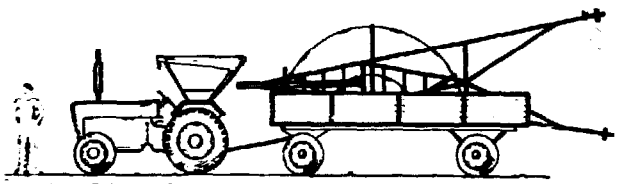

TRANSPORT BY TRACTOR AND LORRY

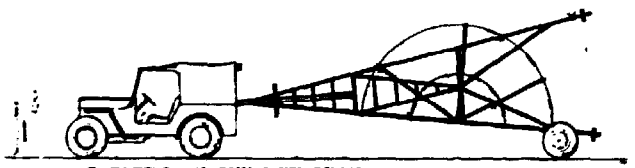

TRANSPORT BY JEEP AND ROLLING HELPDEVICE

THREE WAYS OF WINDMILL TRANSPORT

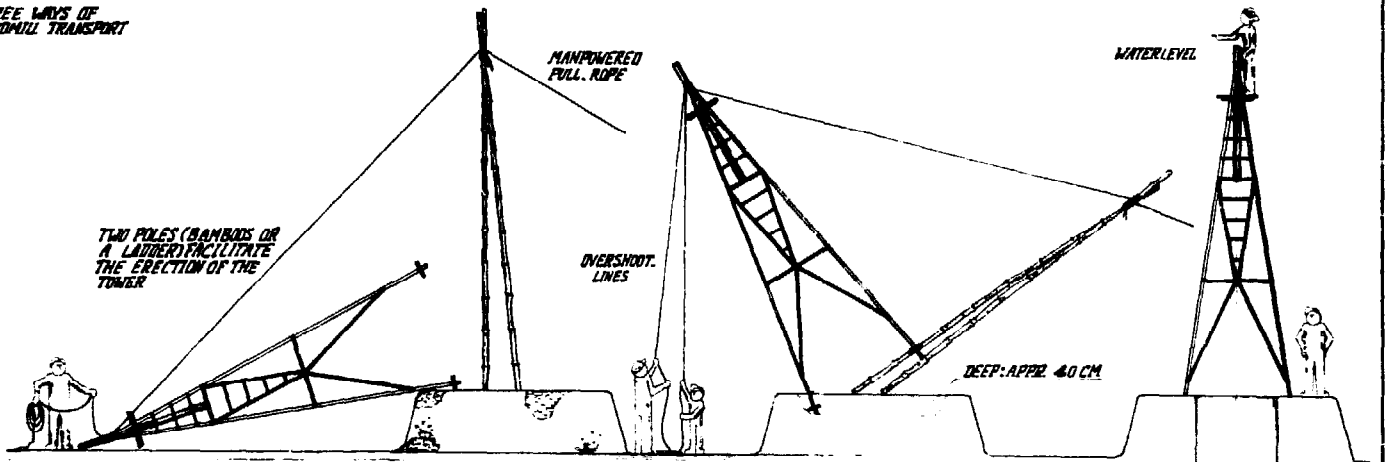

IMPORTANT: AFTER PLACING THE TOWER THE TOWERLEGS ARE POORED IN WITH CONCRETE AND AFTER APPR. 5 DAYS THE HEAD- AND ROTOR- CONSTRUCTION CAN BE INSTALLED SAFE AND QUICK BY MEANS OF LIFTINGDEVICES. DURING THE DRYINGPERIOD OF THE CONCRETE-FUNDATION THE PISTON-PUMP IS FIXED INTO THE WELL ACCORDING TO THE SPECIFICATIONS!

PUMP ROD

"718". LIFTING HELPDEVICE

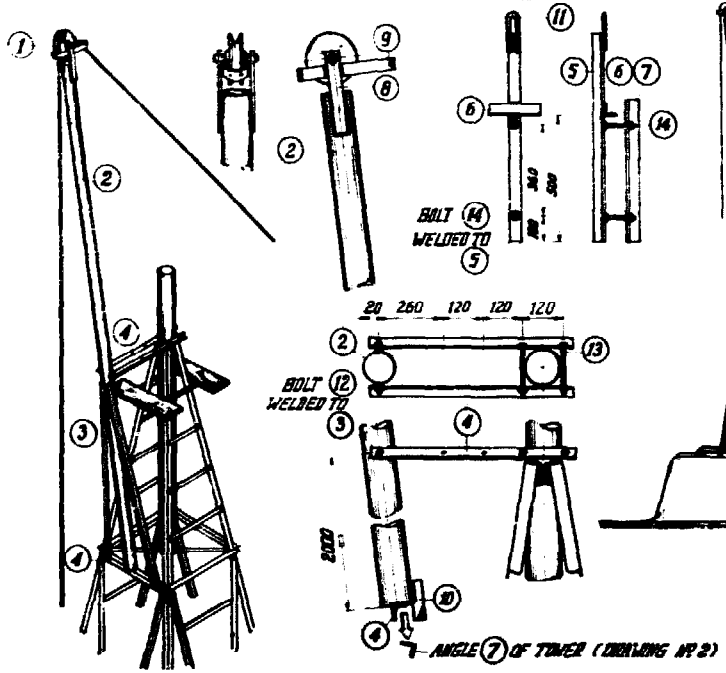

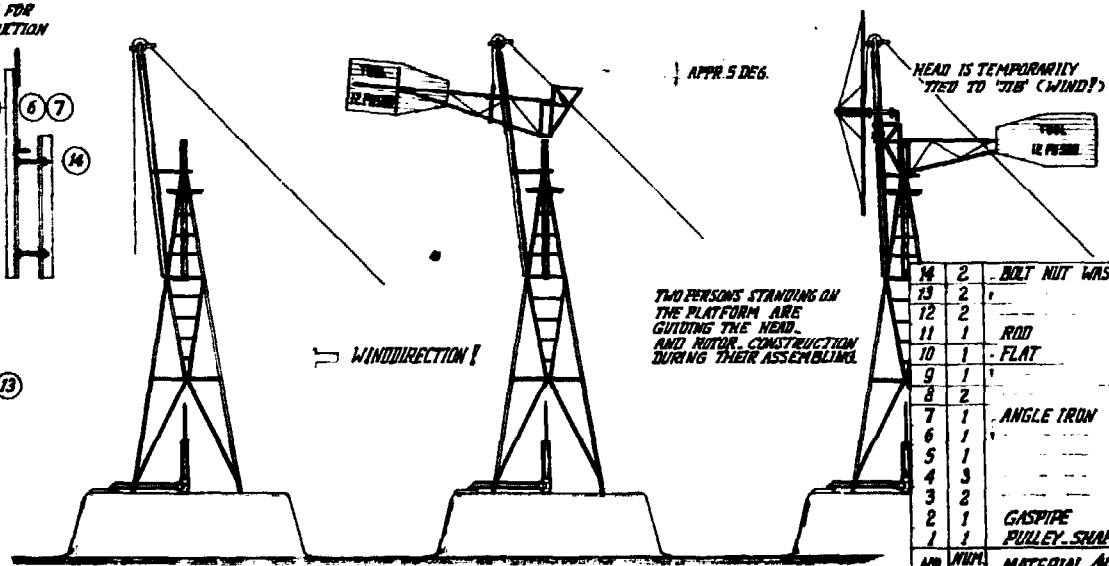

SINCE THE CENTRE OF GRAVITY OF THE HEAD-CONSTRUCTION IS SITUATED ABOVE THE UPPER TAIL-ANGLE A SPECIAL LIFTINGHOOK IS APPLIED. A SHOOTK SLIDING OVER THE TOWERPIPE IS ACHIEVED IF THE FRONT IS OUT OF BALANCE APPR. 5 DEGR.

ROTOR IS LIFTED WITH THE SHAFT COMPLETE WITH BEARINGS FIXED IN THE ROTORHUB IN ITS ORIGINAL POSITION (CENTRE POINTS!) AND FIXED ON THE HEAD CONSTRUCTION. NOW THE "718" CAN BE REMOVED AND THE BLADES, SAFETY DEVICE AND MOVING PARTS ARE ASSEMBLED.

Nº	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS
14	2	BOLT NUT WASHER — M.12 x 75 (W 1½", 3")
13	2	" — M.12 x 150 (W 1½" x 6")
12	2	— M.12 x 50 (W 1½" x 2")
11	1	ROD — Ø 10 (Ø 3/8") x 200
10	1	FLAT — 30 x 16 (1¼" x ⅝") x 100
9	1	" — x 600
8	2	— x 200
7	1	ANGLE IRON — 40 x 40 x 4 (1½" x 1½" x 550)
6	1	" — x 200
5	1	— x 800
4	3	— x 600
3	2	— x 2000
2	1	GASPIPE — Ø 3" x 4500
1	1	PULLEY-SHAFT AND ROPE OR STEELCABLE (30 M)

7 OF 7

INSTALLING THE WINDMILL — 12 PU 500 —

FOR INFORMATION: Werkgroep ten Ontwikkelingstechniqum T.H. Twente - Vrijhof 152 P.O. Box 217 Enschede The Netherlands

2.51

3. Test-Rig for 12 PU 500 Windmill

In the past the development of windmills took place on the site itself where they have been installed which created a lot of inconvenience with regard to breakdowns and repairs. It will be evident that such a procedure of technical development takes a lot of time and moreover the image and popularity of the technology might be degenerated due to failures. Therefore it is advisable to simulate the practical conditions in such way that the development-process is done in a shorter time and under heavy conditions without being dependent on the fluctuating and unreliable wind. So the idea was born to get a Test-Rig developed in which the essential parts of the windmill can be tested thoroughly. This activity was carried out in the Research and Development section at the Polytechnic in Allahabad.

3.1 Demanded features of the Test-Rig

Since the 12 PU 500 Windmill (12 blades Pumping Unit of 500 cm Rotordia) proved to be the most applied windmill so far the urgency of developing its essential components is favourable. On the other hand results extracted from these tests can be extrapolated usefully for other windmill types like 12 PU 250, 12 PU 350 and 12 PU 700 Windmills which are under development too. Therefore it has been decided to get the Test-Rig developed for testing the parts of the 12 PU 500 Windmill. Considering the structure of the essential moving parts and Pump of this particular windmill, testing of the following parts should be carried out with regard to wear and tear:

- Main shaft bearings
- Crank Pin
- Cross Pin
- Cross head / P.V.C. - insert tower pipe
- Wooden pump-rod guide situated in the lower end of the towerpipe.
- Pump-rod guide (Bronze and Nylon).
- Leather sealing / pump rod
- Piston / Cylinder

- Leather valves (Piston-Foot-Valve).
- Joint between tower pipe and rotating head construction.

Actually there is no need of testing the rotor with regard to wear and tear, though fatigue cracks might occur. Field experiences showed that fatigue cracks had been developed right in the inner ring bladesupports which were made according to the first designs. The improved bladesupport proved to be sufficiently resistant with regard to fatigue and no failures appeared anymore. In this context there is no need to have the rotor tested.

Actually a normal 12 PU 500 Windmill installation provides the entire structure for a Test-Rig. Instead of the rotor a flywheel, which is driven by an electric motor, should be installed in order to obtain a regular drive to the fluctuating loaded mainshaft.

3.1.1 Drive of the Test-Rig

To estimate the required R.P.M.-number for the Test-Rig we consider the 12 PU 500 Windmill under extreme conditions. In practice the maximum R.P.M.-number does not exceed the value of 120 since the windmill is locked in secured position automatically by means of its automatic security device. This R.P.M.-number represents a reasonable value for testing pumps and the moving parts of the windmill.

Applying an electric motor for the drive a reduction of 1:12 is needed in the transmission. This is simply achieved by applying a V-belt transmission (directly) from motor pulley to the circumference of the flywheel. In practice the nominal diametres of pulley and flywheel turned out in 70 and 850 mm respectively while three V-belts (B-type) completed the transmission. The required power of the electric motor has been estimated at 4 K W.

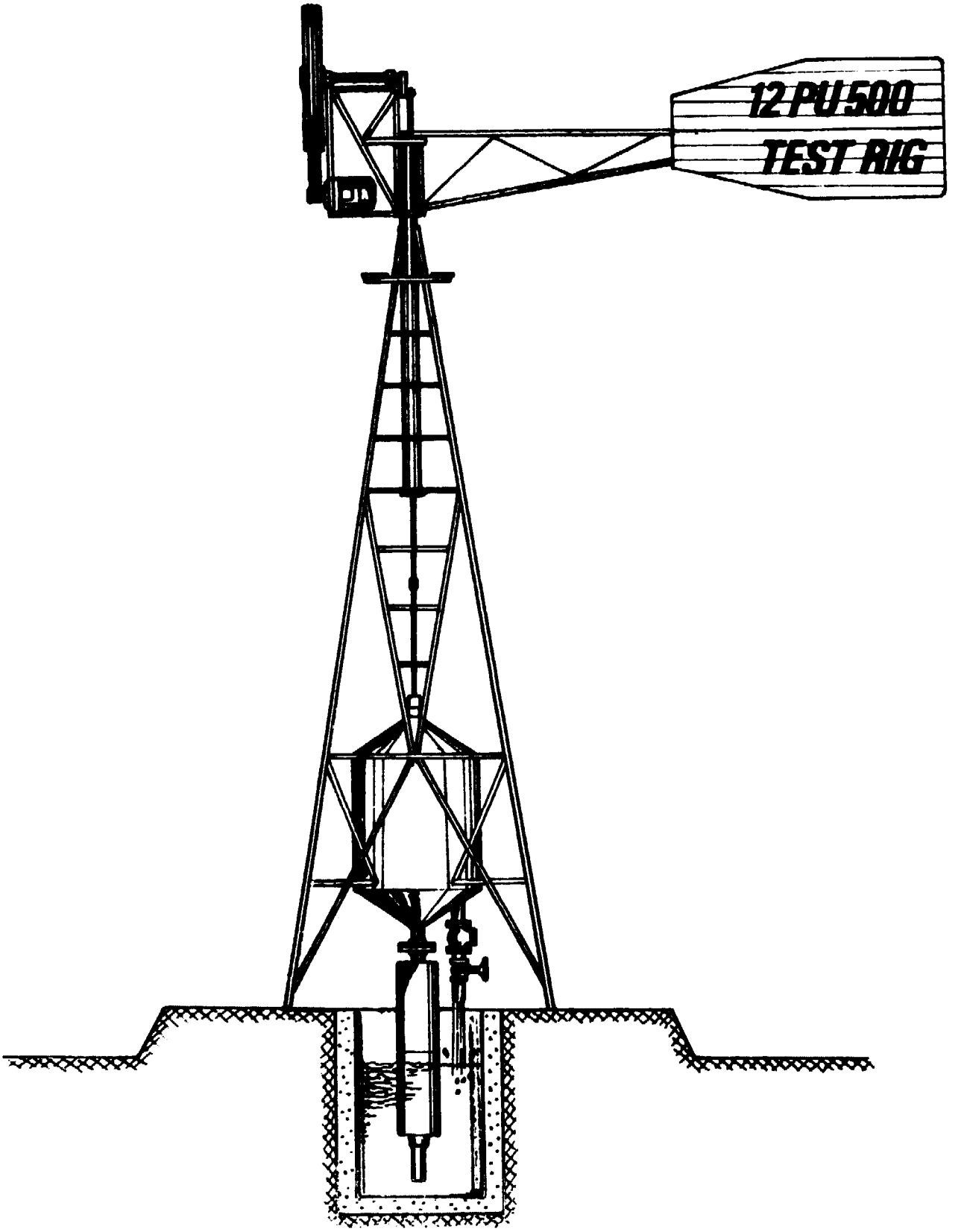
12 PU 500
TEST RIG

3.1.2 Selfmoving head construction

In normal condition the head just rotates if the wind-direction changes which means that in the long run wear and tear might be expected in the joint of the tower-pipe and head-construction. This rotation is made by piston and cross-head as well.

However, the tests should be carried out under laboratory conditions independently from appearing winds and wind directions. This implies that the rotation of the head construction should be simulated by forcing the head to carry out this movement regularly.

In practice it is very rare that the head rotates more than 180 degrees while in most of the cases swinging movements within a certain range of some degrees occur for a certain wind direction. Actually this is the worst condition from point of view of wear and tear since still the same part of the bearing surface (here: tower-pipe) is carrying the load.

So an attractive simulation seems to be achieved by forcing the head to swing to and fro around the tower pipe within a certain range, of degrees. This cycle should be carried out not too quickly and not too slowly but in such a way that the lubrication properties of the bearing are the same as under normal field conditions. However, it is quite difficult to quantify and to extract the required movement from the latter mentioned: wind patterns are different from place to place and from time to time.

As a compromise it has been decided to swing the head construction to and fro within the range of plus and minus 45 degrees (total swing 90 degrees). In order to obtain this movement a small crank is driven by a worm-wormwheel-transmission (1:80). The latter is fed by the main shaft (120 R.P.M.) on which the worm is fitted.
The crank is linked to a joint of the tower by means of a con-

necting rod. This mechanism forces the head construction to swing over the tower pipe. One cycle is completed in 40 seconds while this motion appears to be quite "natural".

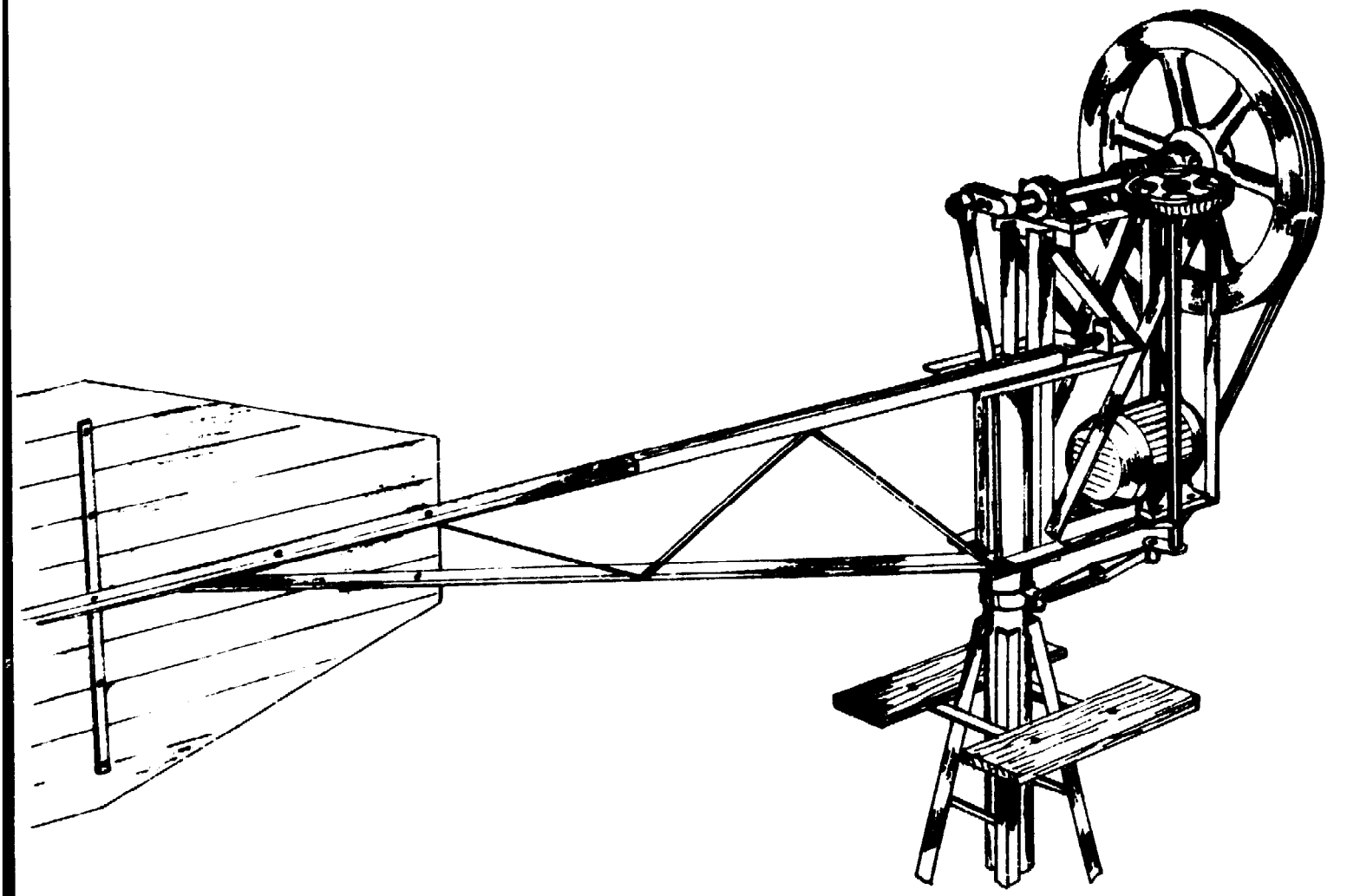

3.1.3 Simulation of the elevation head

In practice the windmills lift water over several elevation heads up to 20 metres or even more. Then the dimension of the pump applied depends on the actual head. Pump dimensions in the 12 PU 500 serie are: 3", 4", 5", 6" and 8" (piston diameters.) It is expected that, as far as pump-testing is concerned, this range of elevation heads should be applied during these tests.

In laboratory conditions it will be possible to simulate the elevation -heads by applying long pipe-lines leading to an overhead tank which should be situated on several levels.

This method is expensive and it creates quite a lot of inconvenience with regard to installation and of course it will not be practical.

Simulation can be carried out in a simpler way by pumping the water from a sump (bottom basin) and getting it delivered into an air-tight vessel where a static pressure persists. This pressure simulates the elevation head and it is built up by compressing the existing air which remained above the water table in this vessel. The latter is achieved by restricting the exhaust opening at its bottom-side by means of an adjustable valve over there. Its resistance causes the required pressure to get the actual water flow forced through it, back into the sump.

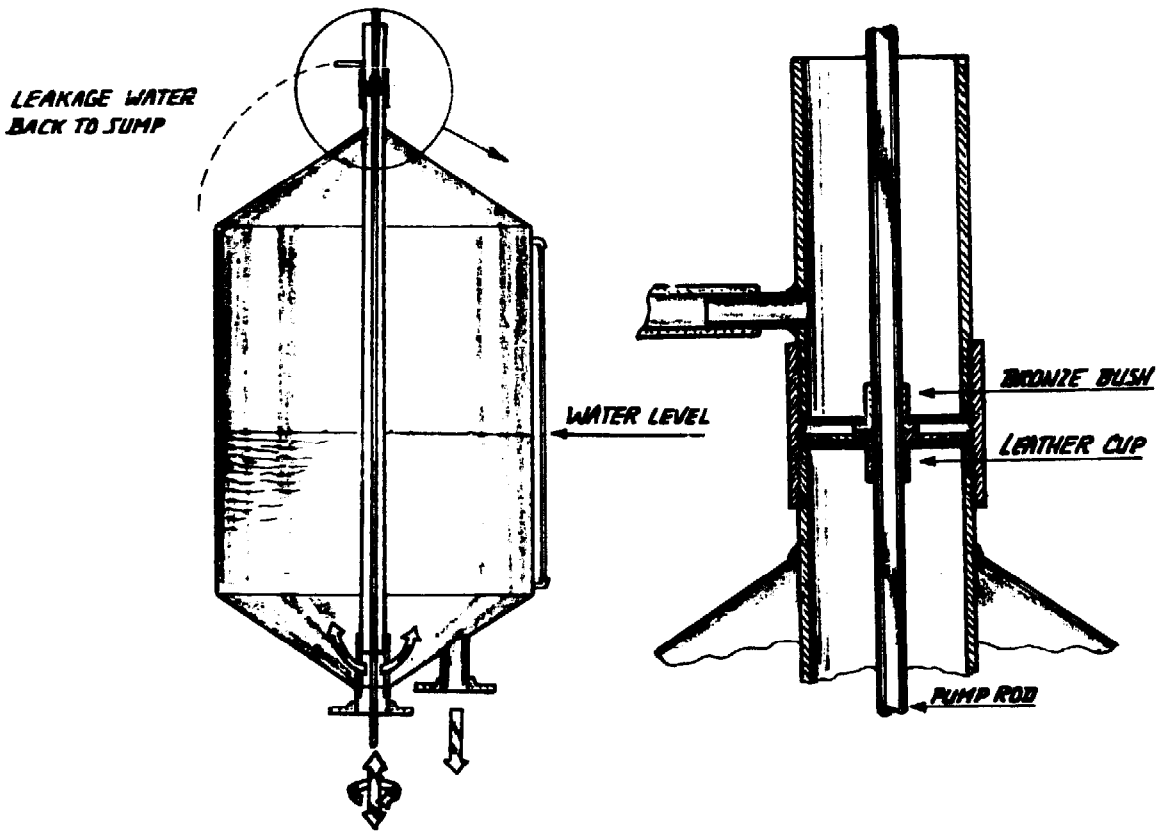

The main advantage of this system is that it is compact to be built. However its disadvantage is that the inertia-effects and pressure losses, which normally appear in long and narrow pipelines, are not simulated since they are not there. Instead the colossal vessel with compressed air is there which provides a huge air receiver which acts as an capacitor

equalizing the irregular waterdelivery from the single acting piston pump. Therefore it is advisable to consider this air pressure not to be the static elevation head (geodetic head) but the actual hydraulic head! The latter is known as static head plus the pressure losses.

The pressure vessel is situated in center of the Test Rig-tower in order to integrate it with the entire structure. The tower provides suitable attachments for the suspension to the several lattice joints.However a practical problem has to be solved with regard to the leading of the pump rod through the centre of the tank since its airtightness is most essential. This implies the application of a pump rod sealing which should not permit any leakage of air. The latter is achieved by applying a pipe in centre of the tank which bottom ends under water surface. On its topportions the pump rod sealing is situated. In this way air leakage is avoided in case the sealing proves not to be perfect since in that case only water-leakage will appear without any effect to the functioning of the airchamber.

3.1.4 Instruments

In order to run the Test Rig in a proper and safe way and to gather information with regard to lifetime and efficiency of the pumps to be tested, several instruments have to be applied. These instruments are:

- Switch and relais box
- Amps meter and KWH-meter
- Water meter
- Revolution counter
- Pressure gauge
- Water level gauge

Switch and relais box

Besides the application of a main switch box it is preferable to have a relais box installed. Purposes of this device are:

- Switching-off the remaining phases if one of the phases is lacking due to power cuts. (If this is not done in time the electric motor will burn definitely.)

- Switching-off the electric motor in case one (or more) of the phase-currents exceeds an unacceptable value. (By means of thermo-elements.)

- To enable the operator to start and stop the Test Rig by a "simple push of the button". The actual switch is made by the relais.

The relais box is attached to the head construction of the Test Rig in order to obtain a short multi wired connection to the electric motor. This also means extra safety since the Test Rig can only be started by the operator which is at the machine itself; so the machine can not be started from ground level while an operator is carrying out some job at the top of the Test Rig. In case of emergency the machine can always be stopped at ground level by using the main switch.

Amps meter / KWH-meter

It is advisable to have an Amps meter installed in order to detect any overload. Moreover the Amps-meter provides information to what extent the machine is loaded.
The same applies for the KWH-meter (3-phase) which counts the amount of energy which has been consumed to drive the test pumps under different conditions.
Till a certain extent this power consumption can be derived for the specific pump under the specific conditions.

Water-meter

This instrument measures the total amount of water which has been delivered during the pump tests. This reading is most essential in order to calculate the volumetric efficiency of the test pump. The Water-meter is situated in between the pressure tank and the adjustable valve through which the water is

flown back into the sump.

Revolution counter

The revolution counter registrates each revolution of the main shaft. Its counting is essential for calculating volumetric efficiency and judging lifetime features of the test pump and moving parts as well.

Pressure gauge

As mentioned before the pressure in the tank represents the total hydraulic head, which is indicated by the pressure gauge.

Waterlevel gauge

It is advisable to indicate the actual waterlevel in the pressure vessel. This in order to detect any leakage of air which will lead to a decrease of the capacitor effect of the air-chamber resulting in a "hammering" run of the machine. Under static conditions the waterlevel gauge also provides a (rough) indication of the actual pressure in the tank.

3.1.5 Way of testing

Running the Test-Rig is done in day-time (working hours) in order to have a close look at the experiments. Day by day the following readings are taken and noted:

- Water passed through water-meter.
- Number of revolutions indicated by counting device.

These readings provide the information for calculating the volumetric efficiency. (See next chapter.)
Pumps to be tested (4" - 5" - 6") are run at 15, 10 and 7 metres head respectively simulating the hydraulic heads. Adjustment of this head is achieved by tuning the adjustable valve situated in the return-flow. One should be aware that this adjustment is "tricky" for the following reasons:

- Its initial adjustment is quite a time-consuming procedure which is achieved by regularly made check - ups and re-

adjustments of the valve.

- After some time the features of the test pump change resulting in higher out-put (setting of valves) or lower output (wear) with the effect that the equilibrium of the system is going to be disturbed. Hence the regular check-ups are necessary too in order to give re-adjustments if needed.

The pumps are tested for at least one million revolutions while recording wear and tear and calculating volumetric efficiencies is done at certain intervals. The out-come of these will provide the information to base conclusions on.

3.2 Pumps to be tested

Since the completion of the Test Rig (March 1980) four types of pumps have been tested each for one million revolutions.
The test pumps were:

---- 4" S 500
---- 5" SS 500
---- 6" P.V.C. 500
---- 6" S 500

Each pump has been tested turn by turn during cycles of 250,000 revolutions loaded at hydraulic heads of 15, 10 and 7 metres respectively. At the end of each experiment of 250,000 revolutions the pumps have been checked up (and revised, if necessary).

In these check-ups the qualification of wear proved to be rather complicated. This in the sense that e.g. play of piston/cylinder and pumprod/pumprod guide are difficult to measure and to define due to unroundness of the several parts. Although initial unroundness exists in the cylinder (black pipe, P.V.C. pipe) and pump rod (gas pipe) which are acceptable (from the point of view of Appropriate Technology) wear and tear seem to cause an extra unroundness to these

particular parts. No doubt that the latter develops due to improper alignment of the structure and slight bends in the pumprod sections, (which is always the case in practice). In order to judge the extent of wear of the parts in such cases the non-measurable qualifications have to be expressed in degrees.

3.2.1 The 4" S 500 (Type I, see chapter 2)

This type of pump has been designed and introduced in the beginning of 1980 as a deepwell-pump. (Applied for the first time at Gohri.)

It consists of two main sections as follows:

- Topsection: composed of 2 mm steel casing, delivery pipe, top flange and pumprod guide.
  The latter contains a brass guide bush.
  The space between the delivery pipe and the casing provides the air pressure chamber.

- Bottom section: Composed of 2 mm steel casing, steel cylinder, top- and bottom-flange, wooden foot valve body and leather foot valve.
  The wooden sealingless piston has a proper fit in the cylinder which has been honed by means of a simple honing device.

Though the nominal cylinder diameter is given in 4" the exact diameter amounts 106.6 mm. (Actually such deviations also exist for 5" and 6" pumps.)

The eight holes in piston and footvalve body are situated at a pitch circle of 0.65 D and the diameters are 0.2 D. This has been standardized for all the pumps.

3.2.2 The 5" SS 500

Basically this pump is of the same construction as the former though the construction of the footvalve differs and the piston has been fitted with a P.V.C. piston ring. These special arrangements provided the "special" label to this test pump hence an extra S has been taken up in its code number.

Its foot valve arrangement consists of a wooden footvalve body and a 2 mm steel disk which has been lined with leather. This disk contains a steel hub which slides over the central bolt of the valve arrangement and is pressed to the valve body by a spring.

Since the rigidity of this valve disk does not provide the "Umbrella-effect", if opened like the elastic leather valves have, extra "flow round" space had to be created. This has been achieved by constructing a wider bottom part (of 6") to the 5" cylinder. Hence the outside dia of the wooden foot valve body has been made at the nominal dia of 6" but of course the hole-arrangement (dia, and pitch) refers to the actual 5" cylinder dia.

As an experiment the piston has been fitted with a PVC-ring which should act as a sealing. This 8 mm wide ring has been cut from a 6"PVC-pipe and is situated in a groove in the wooden piston. This experiment could provide lifetime information of such a sealing.

3.2.3 The 6" P.V.C. 500 (Type H, see chapter 2)

This pump, known as the "combination pump", has been developed in Ghazipur (1979) and proved to be of a quite satisfactory design. It consists of a Top - and a bottom - section.

- Top section : Composed of a 6" PVC-pipe (1.20 m long), top flang and delivery pipe. The latter carries the pumprod guide (nylon). Here

also the space between delivery pipe and PVC cylinder creates the airchamber. The wooden sealingless piston runs in the PVC-cylinder with a proper fit.

- Bottom section: Composed of a 6" PVC-pipe (0.75 long), wooden footvalve body and leather valve, PVC (4") airchamber and bottom flange.

Both sections are jointed by means of 4 anchor rods.

3.2.4 The 6" S 500. (Type J, see chapter 2)

As a matter of fact this pump is basically the same as the other steelpumps. Only the foot valve differs:
which is made of a sheet-iron disk in stead of wood. Therefore this pump is shorter in total length resulting in a more economical use of sheet materials during its fabrication.

3.3 Test results

The schemes given on the next pages show results of the check-ups made after each interval of 250,000 revolutions.
As mentioned earlier quantifying the extent of wear proves to be quite difficult with the result that judgements are given in degrees of wear.

The first 250.000 revolutions

During this test interval it is found that the brass pumprod guide showed a better performance than the nylon one. The latter already wore out in an oval shape which was already visable. The leather valves functioned without any breakdown and developed a good setting to their wooden counter-parts. In contradiction with the expectation the disk-valve of the 5" SS 500 developed a good setting too, though its "steel to steel" slide of its disk-hub over the central bolt showed some wear. The fit of the wooden pistons in the steel cylinder remained proper in the sense that some jerking fit in

some positions persisted. In the PVC-pump the fit already got so loose that some play between cylinder and piston could be seen.

The PVC piston ring,applied in the 5" SS 500, wore rather seriously. The tips of the ring became sharp like a razor blade. Moreover the wear was not uniform; the thickest portion of the ring (4.0 mm)hardly showed any wear (approx. 0.2 mm) while the thinnest portion measured 1.4 mm. It has been decided to stop the experiments with the PVC ring for the time being till the cylinder surface has been polished thoroughly by the plain piston after some newly undertaken experiments. Probably a longer life of the ring would be achieved then.

After the first 500.000 revolutions

Still the brass pump-rod guides show a good sliding fit as well as the piston / steel cylinder combinations. All these moving parts showed nicely polished surfaces.
The fit of the piston in the PVC-pump showed an increased play. Though difficult to measure, its play is estimated at 2mm while a clear edge in the PVC is detected at the end and beginning of the track of the piston. Most problably due to the initial unroundness of this PVC-cylinder the piston seemed also to be worn off which is proved by a loose fit of it in an unused part of the cylinder.
The nylon pumprod guide showed increased wear. Estimated play of pumprod 1÷2 mm.
The valves continued functioning well. Though once the central nut of the leather foot-valve of the PVC-pump ran loose (due to poor fixation). Obviously the hub of the steel disk-valve as well as its central bolts showed no increase in wear. Probably its combination developed a good "run-in".

After the first 750,000 revolutions

The brass pumprod guide still shows an acceptable fit while the nylon guide wore out in an oval shape causing an estimated play of 2 mm.
All valves are in good condition except the leather foot-valve of the PVC pump which developed cracks due to fatigue so it had to be replaced.

The piston / steel cylinder combinations are about to show the first wear, though not simple to quantify (say 0.5 mm play). It is assumed that wear in the steel cylinders (if any) is to be neglected: the inside surfaces just show nice polishing.

The experiment with the PVC piston ring failed again : at approx. 650,000 revolutions (so this ring just run approx. 150,000 revolutions) the ring wore off that much that it slipped in between the piston and cylinder.
This caused that the wedged piston has been pulled up to its upward position with such a force that a cleavage fracture occurred in the cross-head and the connection rod had to collaps during the downward stroke. (Fortunately the Test-Rig could be stopped immediately.)

The experiments have been continued again after removing the badly deformed ring.

After the first 1,000,000 revolutions

The brass bushes show detectable wear which is still acceptable, but the clearance between pumprod and nylon guide was increased up to 3 mm.

All the piston valves as well as the foot-valves were still in good condition. However, in the 5" SS 500 the spring, applied at the top of the disk-foot valve, broke (after approx. 860,000 revolutions) and had to be replaced.

Clearance in the piston / steel cylinder combinations was detected now and it had been estimated at approx. 1 mm. On the other hand the clearance in the 6" PVC 500 increased to more than 2 mm.

3.4 Volumetric efficiencies

All the pumps showed a decreasing volumetric efficiency with increasing number of revolutions. Obviously this is due to wear of piston and/or cylinder. Although in two cases (5" SS 500 and 6" PVC 500) considerable wear has been detected still the volumetric efficiencies exceed 75% for the 4" S 500, 80% for the 5" SS 500 and 80% for the 6" PVC 500 and 6" S 500 respectively.
In all cases the decreasing behaviour of the volumetric efficiency does not seem to be due to malfunctioning of valves, since their condition did not change during the 1-million revolution tests.

It is hard to make a comparison between the pumps based upon the registered volumetric efficiencies since relative leakage will depend upon size and pressure.
Moreover taking this in consideration, it seems that the steel cylinders show better performance than the PVC cylinder as far as volumetric efficiency is concerned. Next pages show the testresults, which are calculated from the readings during 50,000 revolutions in intervals of 100,000 revolutions.

3.5 Conclusions with regard to life time- features of the test pumps

It will be clear that pumptesting to one million of revolutions just provide modest information with regard to lifetime features of the pumps.
Though further testing should be applied, yet some conclusions can be drawn as far as the test results have provided obvious information.

- The combination of a wooden piston and PVC-cylinder can not compete with the wooden piston/steel cylinder combination.

- Nylon Pumprod guides show a much quicker wear than those made of brass.

- A PVC-ring hardly covers a life of 250,000 revolutions while it creates risks for the moving parts of the windmill (here: Test Rig) if it slips in between the piston and cylinder.

- The application of a spring on top of the foot-valve (here: 5" SS 500) might fail due to fatigue (crack of the spring), causing damage to piston/cylinder combination.

- Leather valves, as applied so far, proved to be quite reliable though one should apply a good quality of processed leather (sole-leather). The main disadvantage of leather is that after it has been dried its elasticity is gone and fatigue sensitivity increases.

After testing four pumps (each during one million revolutions) the Test Rig completed another one and a half millions revolutions which should provide some significant information. As a matter of fact it drove pistons up and down covering a total distance of almost 3000 kilometres. The head construction was forced to swing to and fro more than 65,000 times in order to create the possibility to study the wear between tower pipe and head.
In this stage the following conclusions are drawn with regard to life time features of the moving components of the 12 PU 500 windmill.

- No visible wear has been noticed in radial sense in the joint of tower-pipe and head. In axial sense the head just sank approx. 0.5 mm during the run-in period. Obviously after setting of the contact surfaces no additional wear appeared.

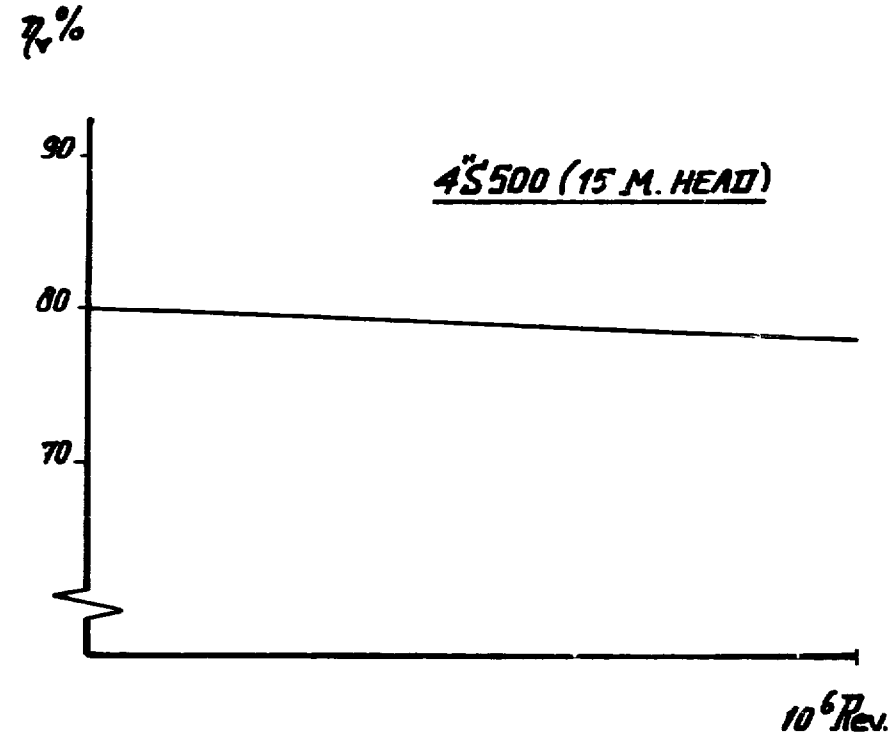
η_v %
90
80
70
4"S500 (15 M. HEAD)
10^6 Rev.

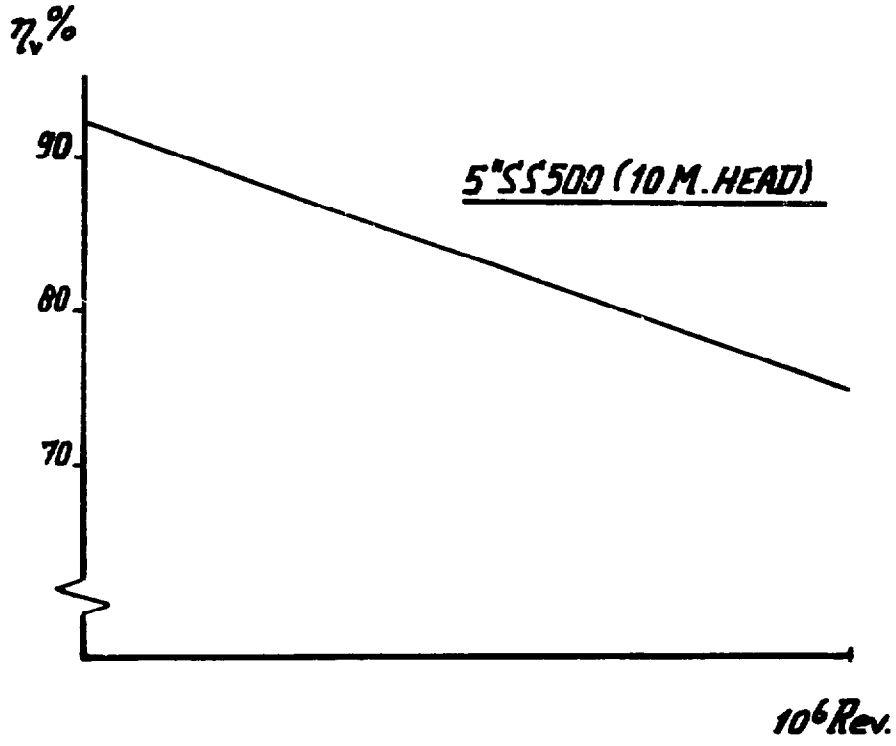
η_v %
90
80
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5"SS500 (10 M. HEAD)
10^6 Rev.

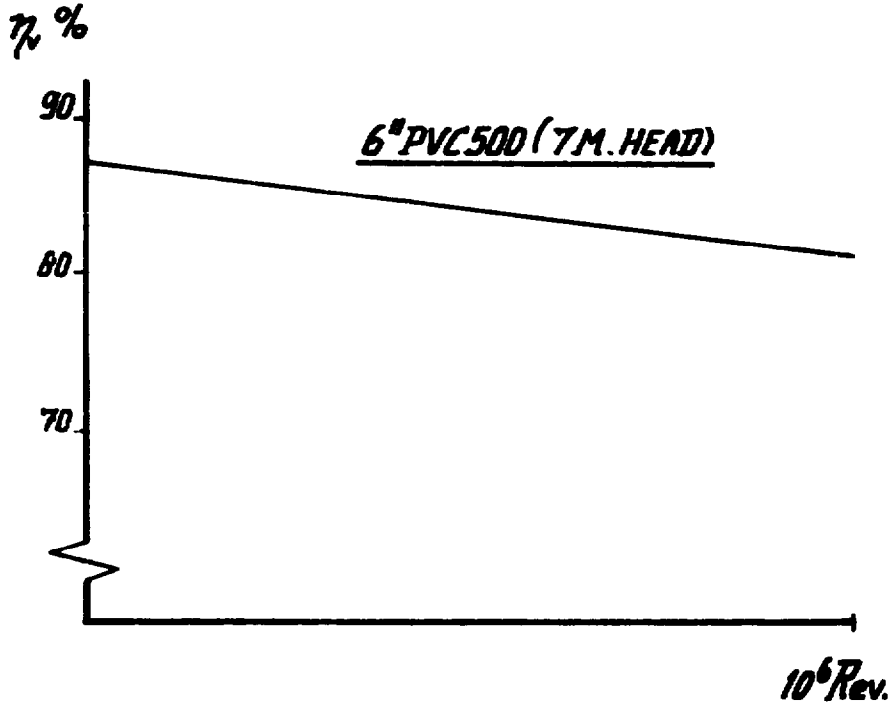
η_v %
90
80
70
6"PVC500 (7M. HEAD)
10^6 Rev.

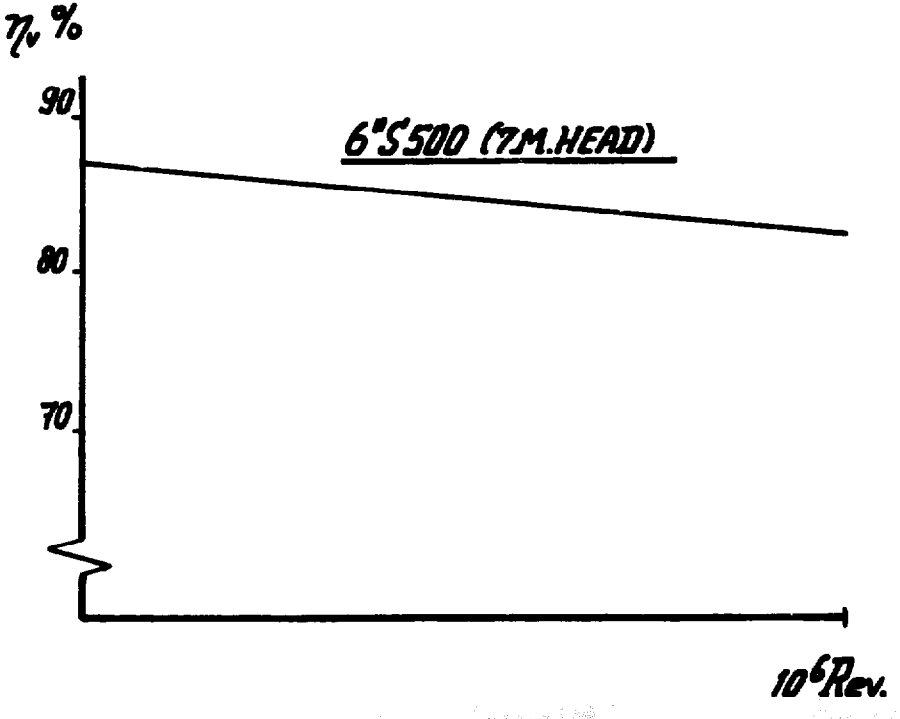
η_v %
90
80
70
6"S500 (7M. HEAD)
10^6 Rev.

It is concluded that the joint will serve the purpose persistently.

- The bearings of the mainshaft (N.B.C.-double roller, self-aligning) did not show any defects or play, while no additional lubrication was applied.
- Though once, the crosshead had to be replaced (cleavage due to jerking piston) its bearing properties in combination with the P.V.C.-towerpipe-lining seemed to be excellent. However, still the tests should be continued in order to find out to what extent wear will develop in the long run.
- The nylon bearing bushes in the connecting rod did not show any wear of relevance. Neither did the cross- and crank pin.

Though these results appear to be promising it is understood that in a suitable windy area the 12 PU 500 windmill runs in the range of 500,000 up to 1,000,000 revolutions per month. Hence the experiences, gathered so far, just represent such a windmill during the first three up to six months of its lifetime. In this regard these achievements should not be seen as a milestone, but rather a beginning.

4. Properties and characteristics of the 12 PU 500.

As mentioned in the first chapter the windspeeds in Ghazipur are rather low and actucally the windmill should be sufficiently adapted to these circumstances in order to utilize the little available windpower in the most efficient way. The size of the piston pump (piston dia. and stroke) as well as the elevation head are the most important parameters in the windmill installation which define the starting windspeed (cut-in windspeed) and the design windspeed. The latter is the windspeed for which the maximum overall efficiency is obtained.

4.1. Input-Output relations, volumetric- and overall-efficiency.

Considering the total windmill installation as a converting-system the relationship of input and output is interesting with regard to its efficiency, its capacity and the economics. The applied measurement equipment at the R.T.I.-windmill was not suitable for the definition of the input-output relationship since the windspeed is monitored interval-wise while the R.P.M.-number and output of the windmill was fluctuating continuously due to changings in the windspeed.
Accurate readings can just be taken if the circumstances are stationary which means that the windspeed as well as the R.P.M.-number are constant while the flow measurement is taken. These data will provide a relation between input and output and the required instruments are:

- anemometer
- R.P.M. counter
- flowmeter

Although these instruments were available the above mentioned measuring could not be carried out satisfactorily. In particular the flow measurements proved to be rather inaccurate due to the irregularity of the waterdelivery of the single-acting piston pump.

Therefore some efforts have been undertaken in developing a simple flowmeter and finally two flowmeters resulted. The first one consisted of a simple 1-gallon oilcan. The flowing water enters the open bottomside and is released through the screw-top-opening. The static waterlevel in the can will represent the actual flow which is indicated by a "gauge-glass" simply made from a plastic hose. These oilcans are standardized so a similar flowmeter can be made in any place of the world, but its use is restricted to a maximum flow of approx. 7 m^3/hr. Moreover an irregular flow causes considerable errors since this instrument reacts rather slow and airbulbs spoil the readings depending on the way of entrance of the water.

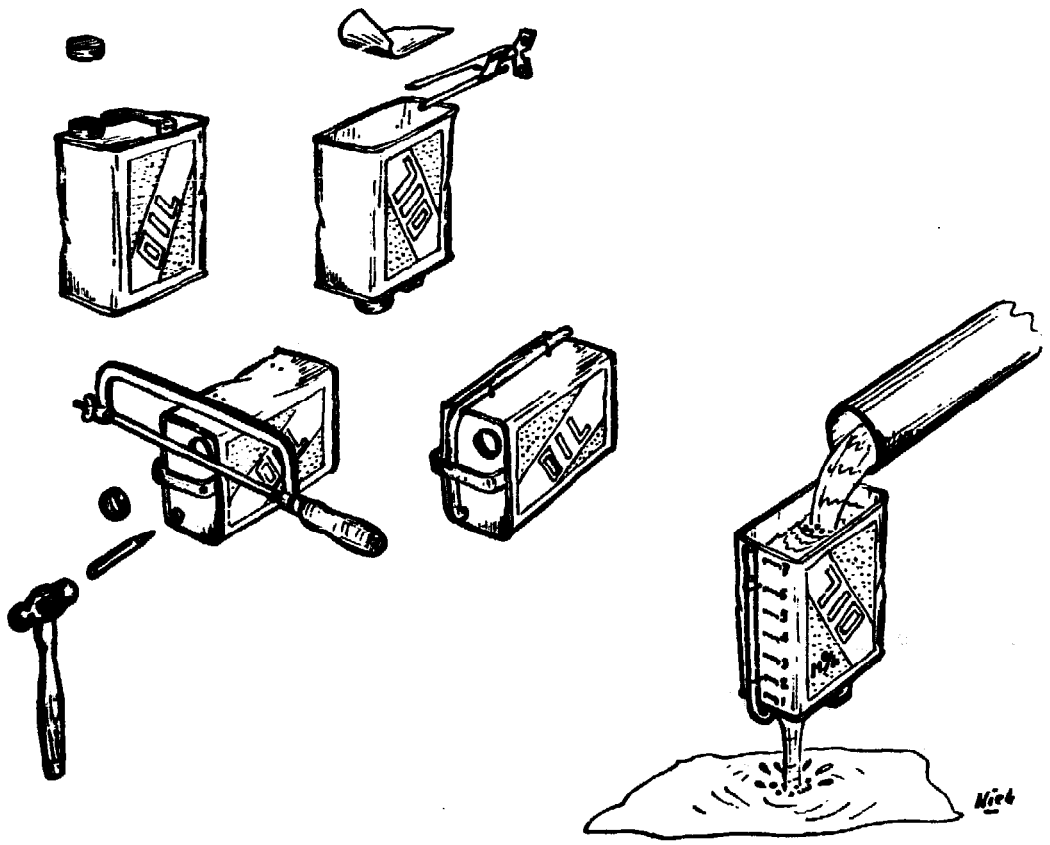

The second device of flowmeasuring consisted of a shallow basin in which the flow enters the back-side and leaves this basin on the other side via a V-notch. The static waterlevel in the basin also represents the actual flow according to several theoretically defined tables. Unfortunately this equipment did not serve the purpose very well. The phenomenon of slowness, due to the large volume, caused that this device acts too late in order to determine the actual output.

So both measuring devices failed because the slowness in indicating made these "instruments" unsuitable for direct flow registration.
Due to this another way of flowmeasuring has been developed: in a period of constant windspeed and constant R.P.M.-number (audible) a 20 l. drum is shifted under the output opening of the pistonpump during the downward -stroke (no output!). At the same time a stopwatch is switched on and from that moment on the number of strokes is counted (e.g. four or five). Then during the downwards-stroke again, the drum is removed quickly and its contents will amount to the delivery of four (or five) strokes. The timespan, registrated by the stopwatch, the windspeed and the amount of water delivered will provide sufficient information in order to calculate respectively the input-output relation, the volumetric efficiency and the overall efficiency.
The above mentioned method proved to be the most accurate and reproductive way of measuring.
In the following table the results (screened) are printed of the first measurement which have been carried out in May 1978.

Dia. pump: 132 mm.
Stroke: 254 mm. (10")
Elevation head: 6.5 m.
Pumptype: A (see pistonpumps)

V (m/sec.)	n (R.P.M.)	ϕ (dm^3/sec.)	η_v —	η_{tot} —
2.5	14	0.6	0.74	0.21
3.0	25	1.2	0.83	0.24
3.5	31	1.6	0.90	0.20
4.0	37.5	2.0	0.93	0.16
4.5	43	2.4	0.96	0.14
5.0	49	2.8	0.98	0.12
5.5	55	3.2	1.00	0.11
6.0	61	3.6	1.02	0.09
6.5	68	4.0	1.01	0.08
7.5	76	4.4	1.00	0.07

The maximum overall-efficiency amounts to 0.24 for a wind speed of 3 m/sec. For higher values of the windspeed the overall-efficiency is decreasing up to a few per cent only. Improvements have been obtained later when the blades of the rotor were replaced by the narrow ones and the pumpsize was increased from 132 mm. to 150 mm. New measurements were carried out in May 1979. The condition of the piston was rather bad; wear of the piston caused a considerably affected output due to internal leakage, but in spite of that higher overall-efficiences have been extracted from these measurements:

Dia. pump: 150 mm. (clearance appr. 3.5 mm.)
Stroke: 240 mm.
Elevation head: 6.5 m.
Pumptype: E (see pistonpumps)

V (m/sec.)	n (R.P.M.)	ϕ (dm^3/sec.)	η_v —	η_{tot} —
2.5	21	1.0	0.67	0.32
3.0	26	1.3	0.71	0.24
3.5	31	1.5	0.68	0.18
4.0	36	1.7	0.67	0.13
4.5	42	2.0	0.67	0.11
5.0	47	2.5	0.75	0.10
5.5	55	3.0	0.77	0.09
6.0	63	3.5	0.78	0.08
6.5	70	4.0	0.81	0.07
7.0	78	4.5	0.82	0.07
7.5	86	5.0	0.82	0.06
8.0	96	5.5	0.81	0.05
8.5	105	6.0	0.81	0.05

Although these results are not quite representative (low volumetric efficiency) one can conclude that overall-efficiencies of acceptable value can be obtained even if the pistonpump is not in proper condition. After replacing the piston new measurements have been carried out with respectively 0.5 mm. and 1.0 mm clearance between piston and cylinder. The difference in these measuring data proved to be insignificant so both data have been combined:

Dia. pump: 150 mm. (0.5 ÷ 1 mm. clearance)
Stroke: 240 mm.
Elevation head: 6.5 m.
Pumptype: E (see pistonpumps)
"Cut-in" windspeed 2.5 m/sec.

V (m/sec.)	n (R.P.M.)	ϕ (dm^3/sec.)	η_v —	η_{tot} —
3.0	25	1.5	0.85	0.30
3.5	31	1.8	0.82	0.23
4.0	36	2.2	0.87	0.19
4.5	42	2.6	0.88	0.15
5.0	47	3.0	0.90	0.13
5.5	54	3.5	0.92	0.11
6.0	60	4.0	0.94	0.10
6.5	67	4.6	0.97	0.09
7.0	77	5.2	0.96	0.08

Decreasing the stroke from 240 to 160 mm. reduces the output and "cut-in" windspeed.

Dia. pump: 150 mm. (0.5 ÷ 1 mm. clearance)
Stroke: 160 mm.
Elevation head: 6.5 m.
Pumptype: E (see pistonpumps)
Cut-in windspeed 2.2 m/sec.

V (m/sec.)	n (R.P.M.)	ϕ (dm^3/sec.)	η_v —	η_{tot} —
2.5	26	0.9	0.74	0.31
3.0	31	1.1	0.76	0.22
3.5	37	1.3	0.75	0.16
4.0	43	1.5	0.74	0.13
4.5	49	1.7	0.74	0.10
5.0	55	1.9	0.74	0.08
5.5	61	2.2	0.77	0.07
6.0	69	2.4	0.74	0.06
6.5	76	2.7	0.76	0.05
7.0	85	3.0	0.75	0.05

In the next paragraphs extra attention will be paid to the windmill-pump-combination.

4.2. The powercharacteristics of the windmill.

By means of the former described way of measuring several properties of the windmill-pump combination can be defined but still the power characteristics of the windmill as well as the pump are completely unknown. In order to investigate this also torque-measurements must be carried out. In practice many complications will be met in order to realize a reliable torque-measuring because the actual torque will fluctuate considerably due to the irregular drive of the pistonpump. Knowing the characteristics of the rotor the conversion of windpower into useful mechanical power can be calculated then for any windspeed and R.P.M.-numbers. This characteristic is known as the $C_P - \lambda$ curve; C_P is here the power coefficient (the rate of power conversion) while λ stands for the tip-speed ratio. Both dimensionless ratios are defined as follows:

$$\boxed{C_P = \frac{P}{\frac{1}{2}\rho V^3 \pi R^2}}$$

$$\boxed{\lambda = \frac{\Omega R}{V}}$$

Besides a dimensionless torque-coefficient is defined as follows:

$$\boxed{C_T = \frac{T}{\frac{1}{2}\rho V^2 \pi R^3}}$$

The symbols are representing:

P	= useful converted power	[Watts]
T	= useful converted torgue	[Nm]
ρ	= density of air	[1.2 Kg./m^3]
V	= windspeed	[m/sec.]
R	= radius of the rotor	[m]
Ω	= rotor angular velocity	[rad/sec]

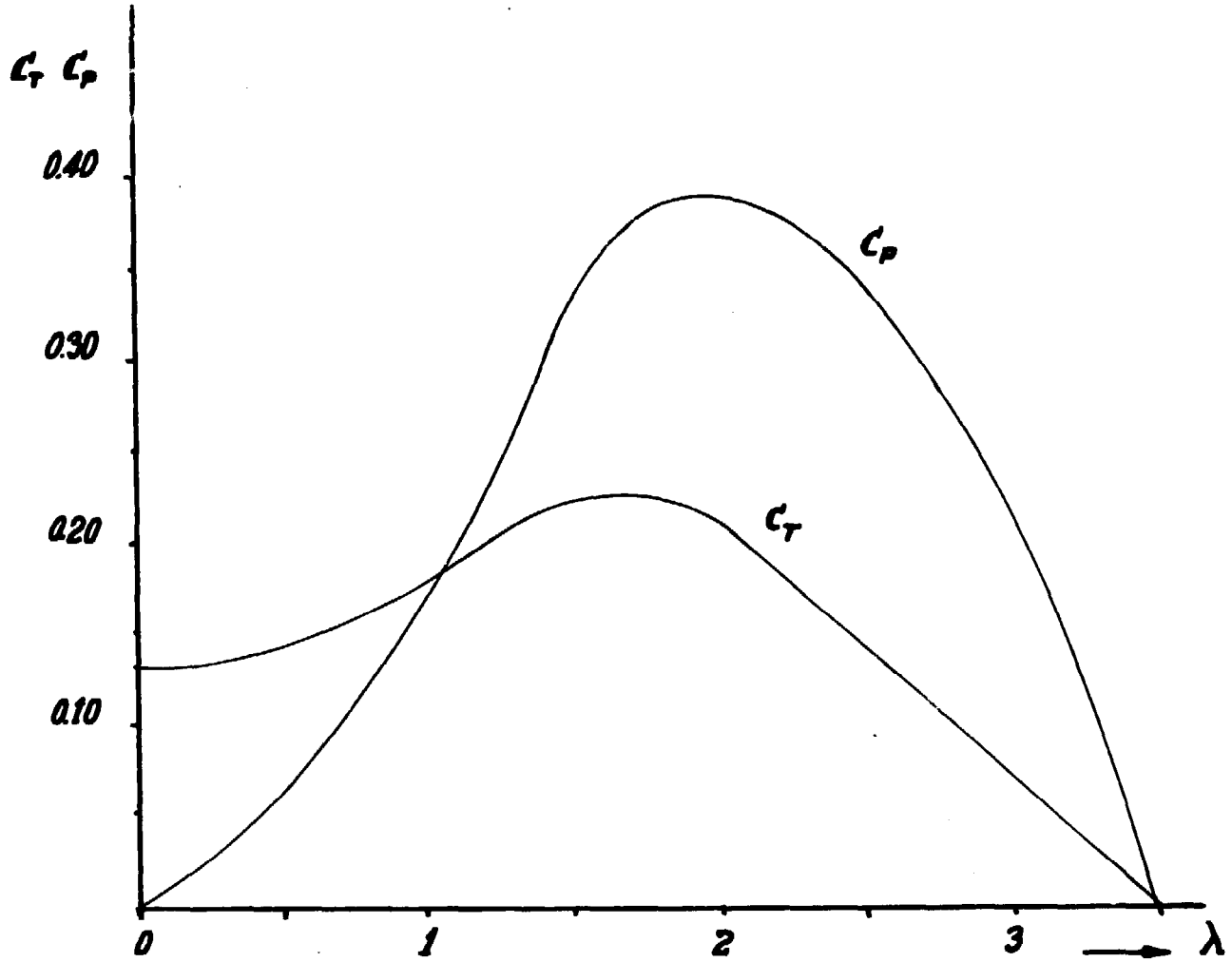

Both the $C_T - \lambda$ curve and the $C_P - \lambda$ curve will represent the main properties of the rotor in a certain range of Reynolds numbers (Re). Since 10% arched steel plate airfoils are applied the curves will be valid if Reynolds-numbers appear which exceed the critical Re-number of 10^4 since the applied airfoil properties, which determined the blade design, are just valid under this condition ($RE > 10^4$). By the help of some SWD-members (SWD= Steering Committee for Windenergy in Developing Countries) the C_T-λ and C_P-λ curves of a scale-model (1.5 m. dia.) resulted from windtunnel-tests. In these tests the influence of the presence of several disturbing parts in the rotorframe has been investigated. Also the presence of the helpvane of the safety-device proved to affect the C_P - curve resulting in lower efficiencies.
The assumption that this C_P-λ curve will represent the 5 m. dia. windmill provides a lot of information with regard to the actual generated power and torque. Also the powercharacteristic(s) of the pistonpump can be derived then. It is

12 PU 500

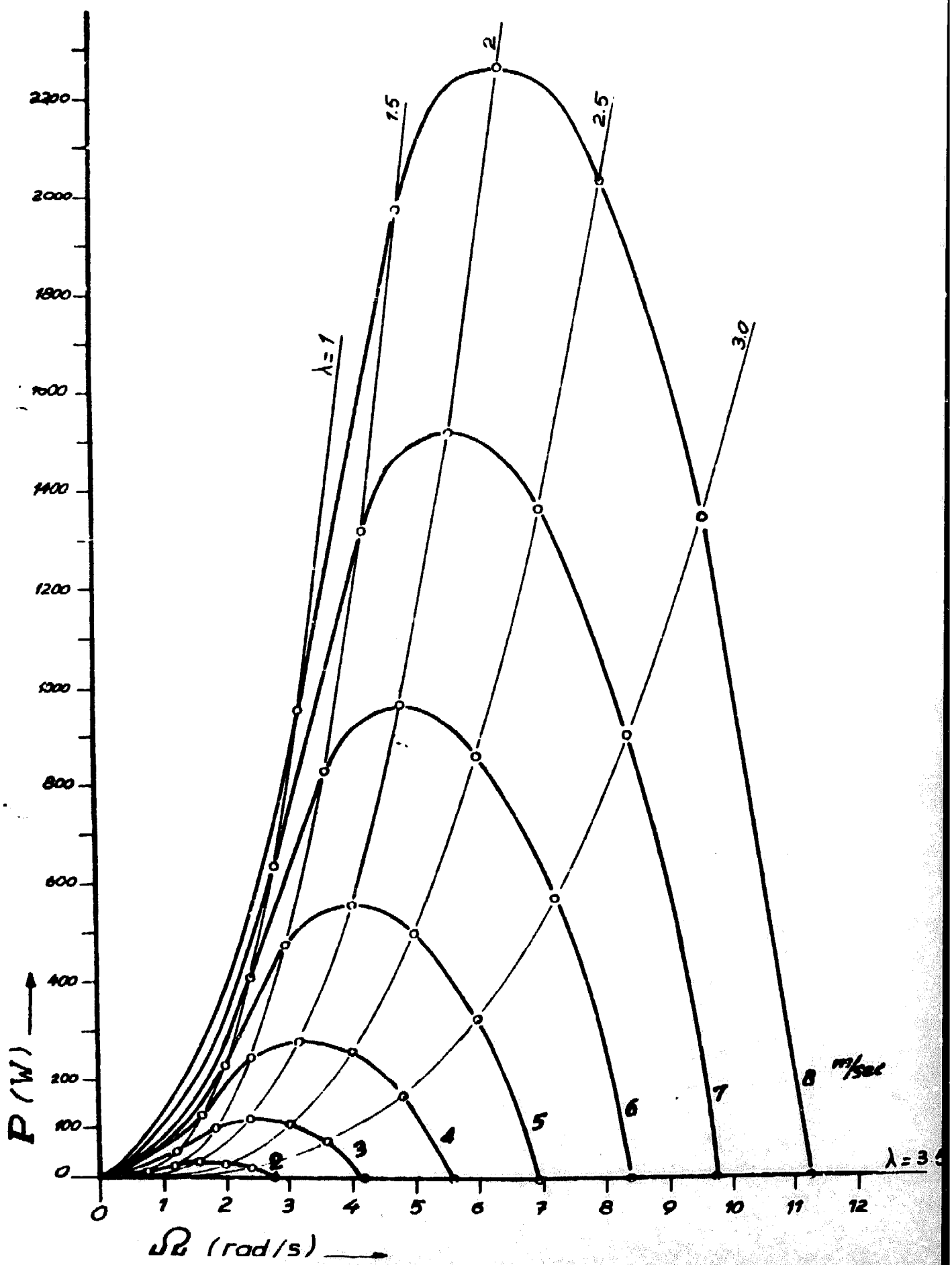
P (W)
Ω (rad/s)
λ=1
1.5
2
2.5
3.0
λ=3.5
2
3
4
5
6
7
8 m/sec
0
100
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
0
1
2
3
4
5
6
7
8
9
10
11
12

evident that the mechanical losses of power must be taken into account. An acceptable value of a mechanical efficiency will be 0.90. Probably a part of mechanical loss is related to the angular velocity of the system, but is supposed to be constant in a certain range of R.P.M.-numbers. These assumptions led to the approximation of the power-curves of the 5 m. dia. windmill. The cubic influence of the windspeed is clearly visible while the most attractive load-curve should cover the cube-curve for $\lambda = 2$.

4.3. Analysis of the windmill-pistonpump-combination.

Since the R.P.M.-number in relation with the windspeed is known, the load characteristics of the pump(s) can be drawn into the former derived powercurves. Considering this it can be concluded that the transmitted power to the pump depends on the pump-performance and the crank radius. The considerable

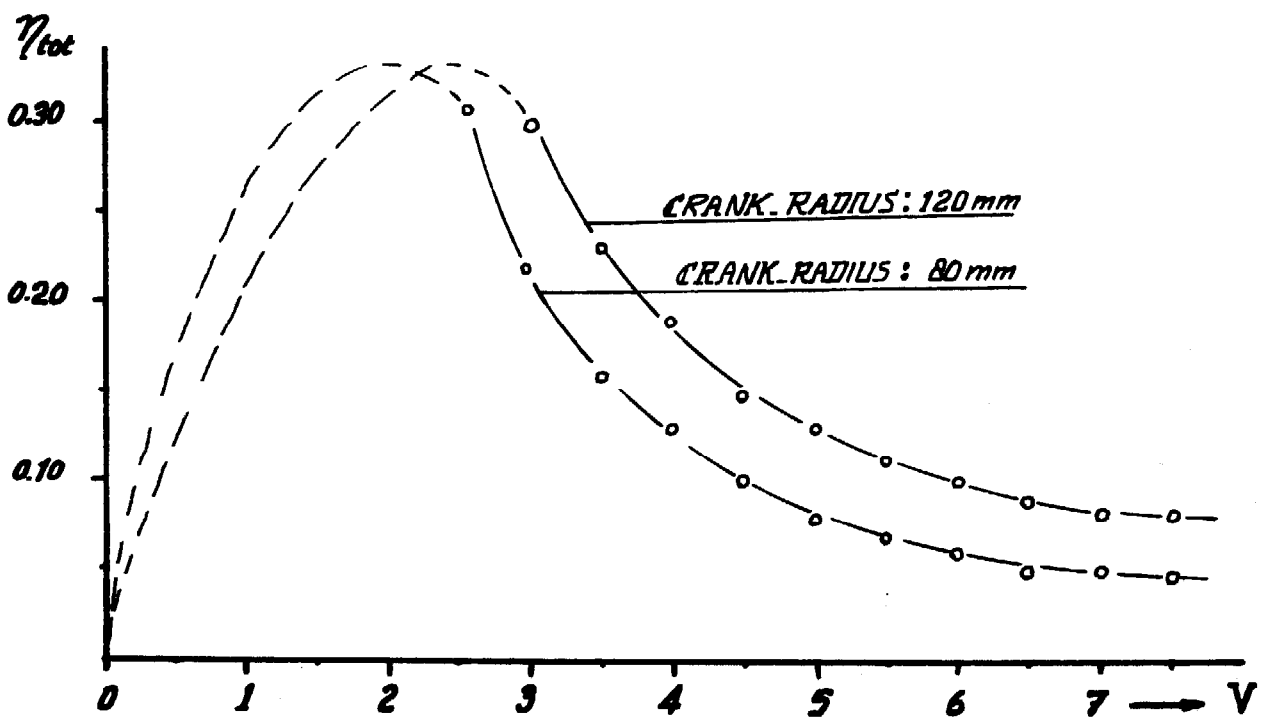

reduction of the overall-efficiency can be explained as follows: for increasing windvelocities the combination operates at increasing values of the tip speed ratio so the rate of the windpowerconversion drops. The mechanical efficiency and the efficiency of the pistonpump affects the overall-efficiency as follows:

$$\eta_{tot} = C_{p(\lambda)} \cdot \eta_{mech.} \cdot \eta_{pump}$$

Since the mechanical efficiency is fixed at 0.9 and the C_p-value does not reach values below 0.15÷0.20 the low total efficiencies (e.g. 0.05 for V= 8m/sec.) must be caused by a low efficiency of the pump. This assumption can be proved simply by considering the power-curve of the pistonpump.

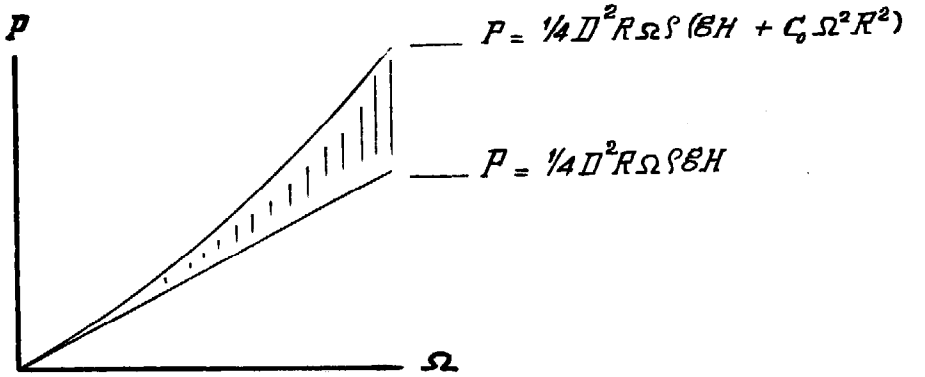

In case of higher angular velocities the losses in power increase considerably due to friction and all kinds of hydraulic losses.

The determinated powercurves can suitably be approached by the following expression:

$$P = \frac{1}{4} D^2 R \Omega \rho (gH + C_0 \Omega^2 R^2)$$

<u>Symbols</u>:

P	= Power	[Watt]
D	= Diameter of piston	[m]
R	= Crank radius	[m]
Ω	= Angular velocity	[rad/sec]
ρ	= Density of water	[kg/m^3]
g	= Gravity-acceleration	[m/sec^2]
H	= Elevation head	[m]

The symbol C_0 stands for the coefficient of loss. As far as just the hydraulic losses are concerned the hydraulic efficiency is defined by:

$$\eta_H = \frac{\Phi \rho g H}{\Phi \rho (gH + C_0 \Omega^2 R^2)} = \frac{1}{1 + C_0 \frac{\Omega^2 R^2}{gH}}$$

while the total efficiency of the pistonpump is found by:

$$\eta_p = \eta_H * \eta_V$$

(η_V = volumetric efficiency)

In general the total windmill-pistonpump-installation can be represented schematically in case of fixed parameters like elevation head,pistondiameter and crank radius.

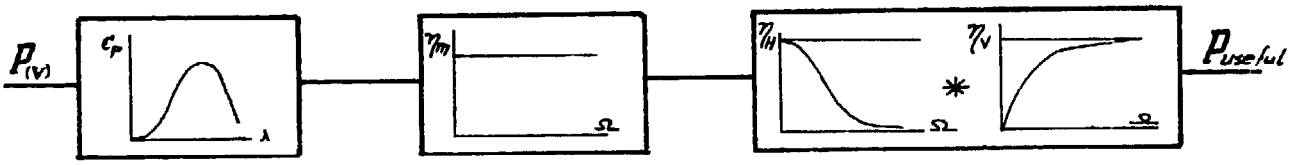

From this scheme it can be concluded that the total efficiency is badly affected by the influence of hydraulic efficiency since the measured tipspeed ratio (λ) in practice seldom exceeds the value of 3.0 while C_p maintains reasonable values.
From the two last mentioned measuring-data the value for C_0 can be derived so an approach of powercharacteristics in case of different elevationheads and crank radia will result. For C_0= 200,rather "pessimistic" but acceptable powercurves can be drawn through the powercurves of the windmill in order to define the meetingpoints and the actual angular velocity of the system. Assuming the volumetric efficiency be 0.8 the input-output relation is found by the calculated output for all combinations of elevationhead and crank radia.
Although this determination is not quite valid the results will provide a rather good impression concerning the output which can be expected. One can conclude that in case of higher elevation the output is hardly affected,but the starting wind speed is higher.

12 PU 500

CRANKRADIUS 60 mm.

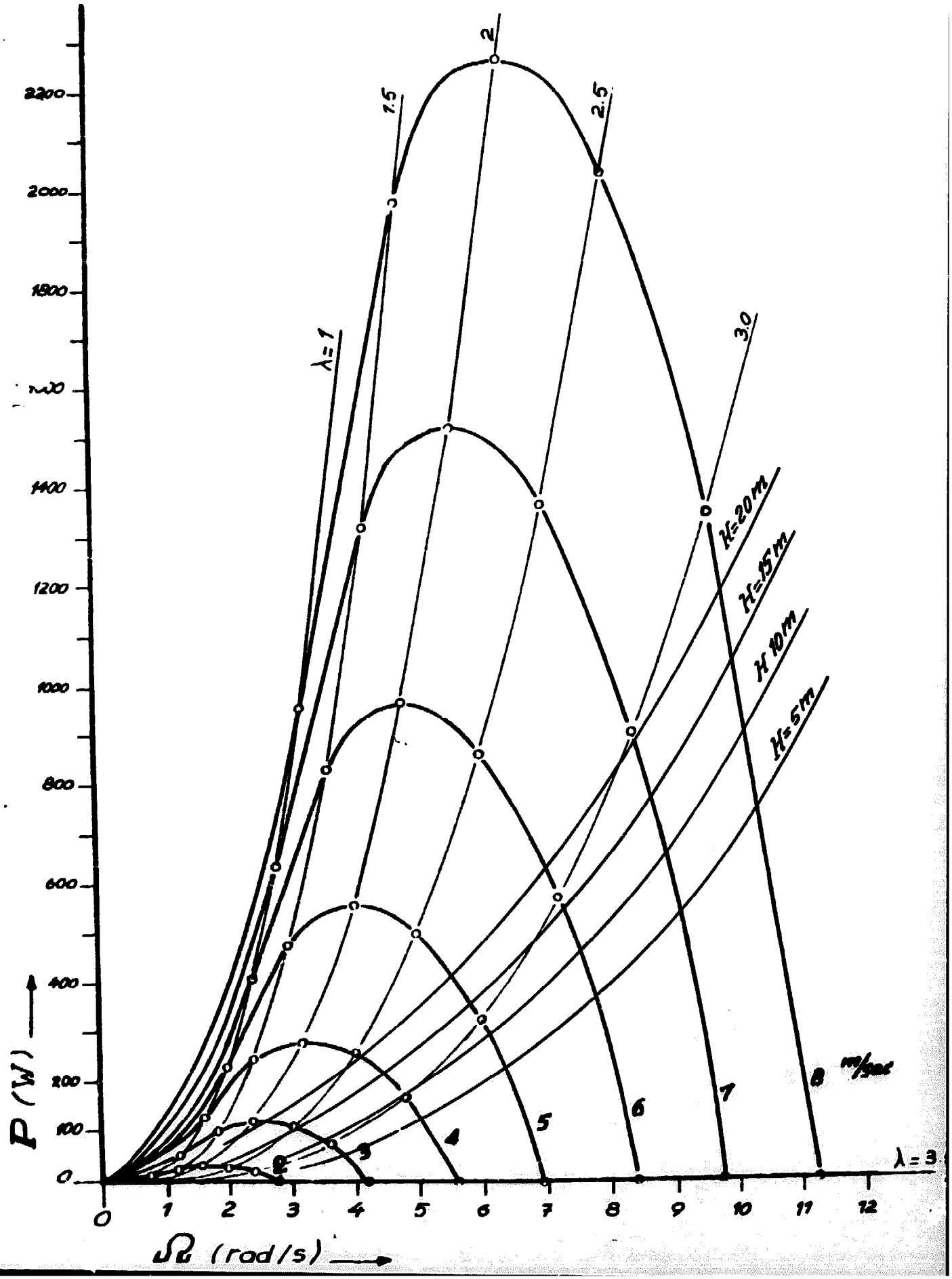

12 PU 500

CRANKRADIUS 90 mm

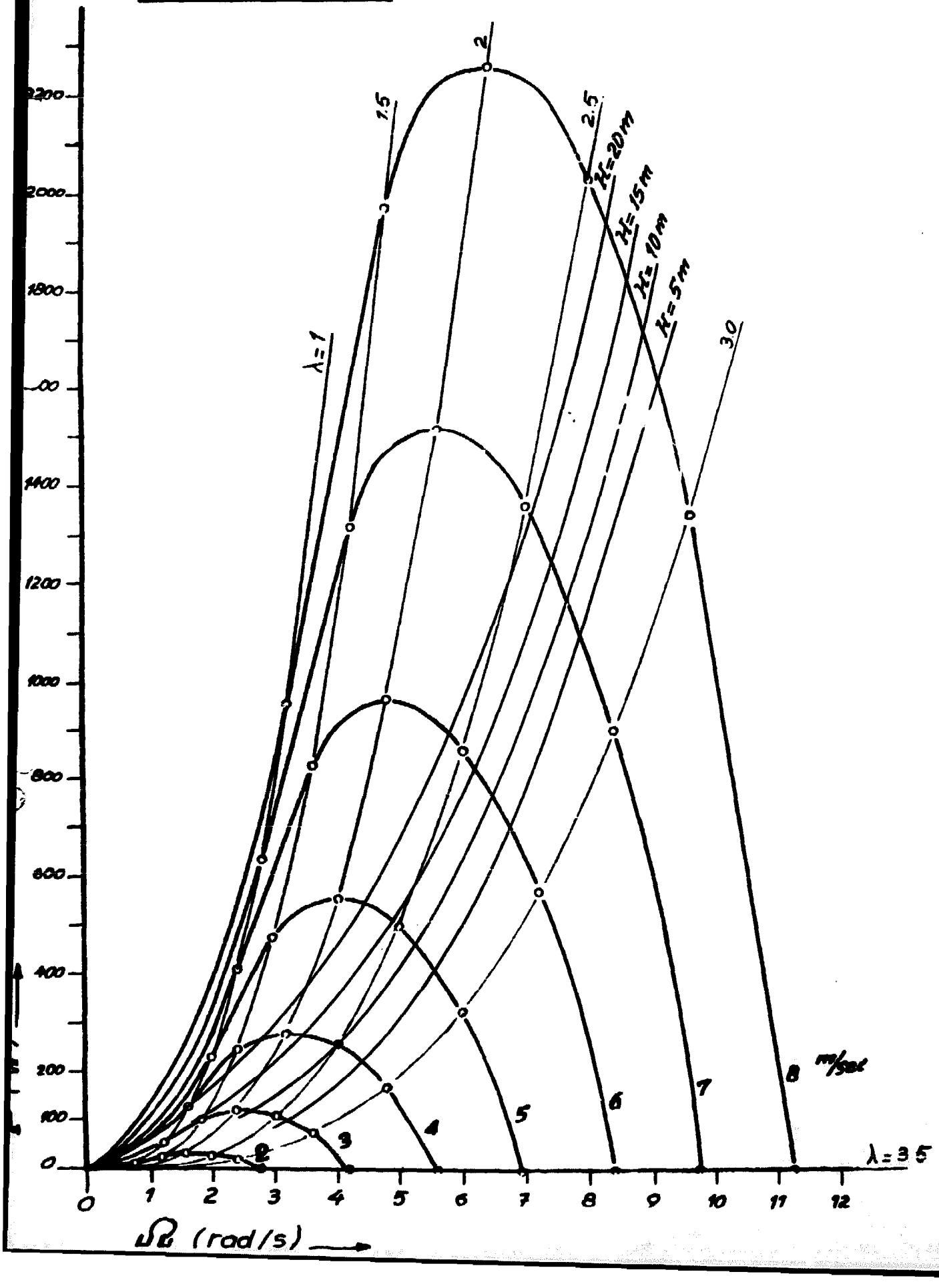

12 PU 500

CRANKRADIUS 120 mm

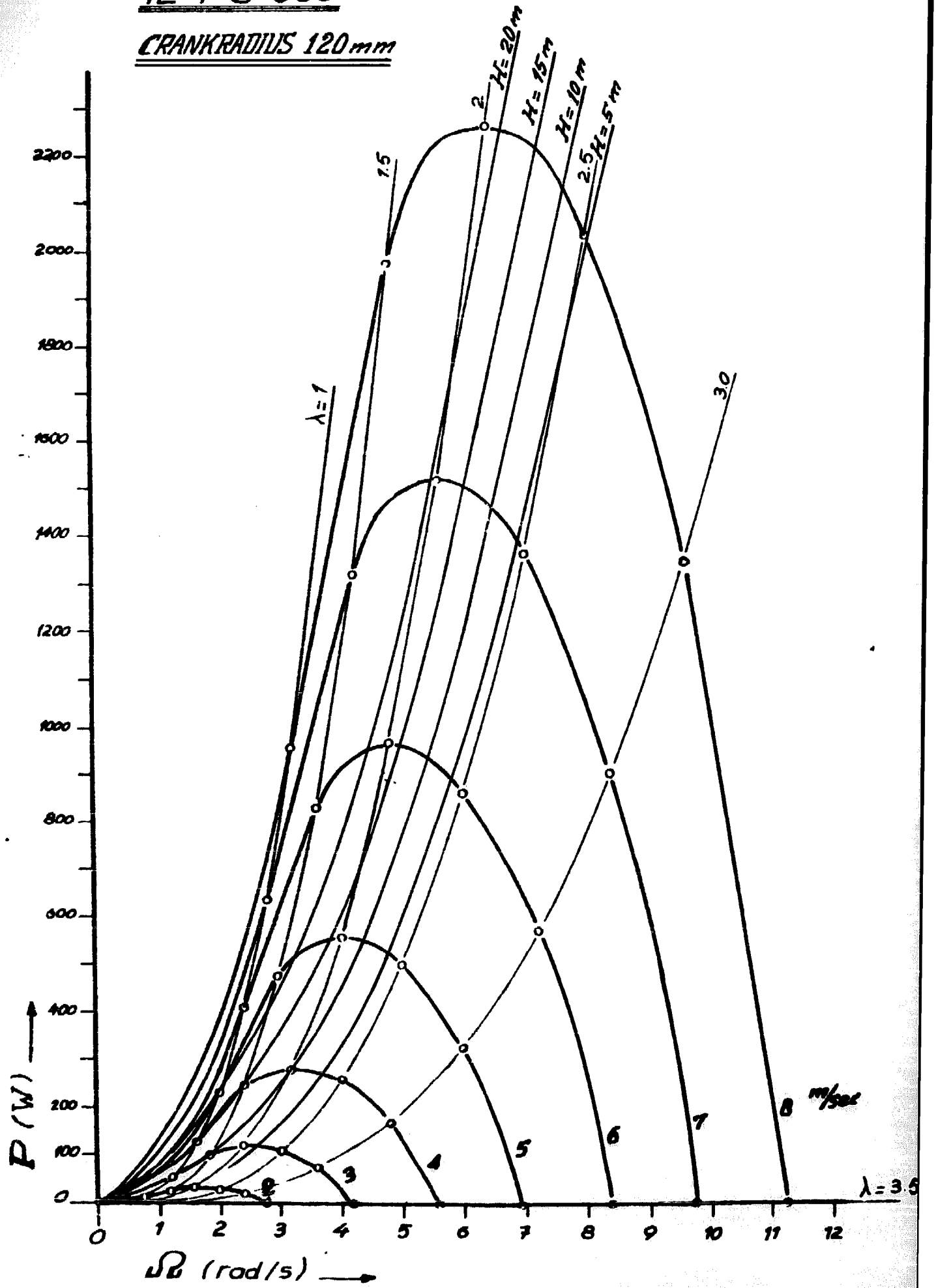

INPUT_OUTPUT_RELATIONS (150 mm PUMP)

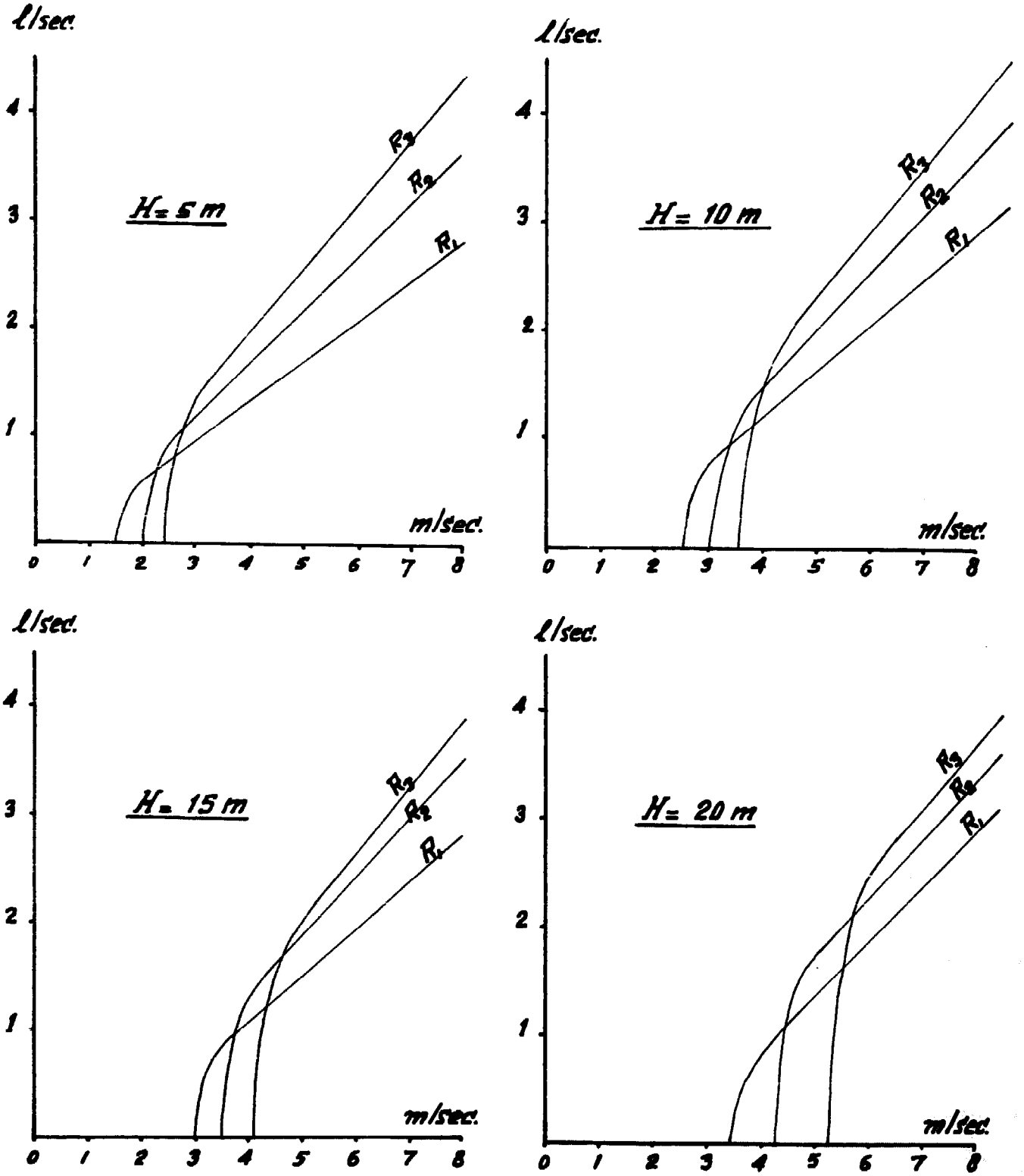

H = ELEVATION HEAD

R_1 = 60 mm
R_2 = 90 mm
R_3 = 120 mm

CRANKRADIUS

5. Defining optimal starting windspeed, windmill- and pump dimensions

In the former chapter the "mis-match" of the windmill and single-acting piston pump has been fully described for the 12 PU 500 windmill. As a matter of fact the same applies for the other members of 12 PU-family (250, 350 and 700) for their C_p-λ curves are the same.

Apart from the problem which windmill type should be applied also the starting windspeed to be chosen is most essential with regard to the way the windmill is going to perform. To illustrate this we consider the following extreme situations which often occur in practice:

Too low starting windspeed:

Too small a pump applied. Windmill is almost always running (psychologically attractive). Poor output: too low quantity in the long run.

Too high starting windspeed:

Too big a pump applied. Windmills is almost never running (psychologically unattractive.) Impressive output, but too low a quantity in the long run.
Somewhere in between an optimum exists for which the most optimal starting windspeed occurs for which the best windmill-pump combination can be composed. To derive this optimal combination there is a need for a simple and systematic procedure by which the following can be calculated:

- starting windspeed
- rotor diameter (250-350-500-700)
- pump dimension (3"-4"-5"-6"-8")

Whether such optimizing contradicts for instance social acceptance or required storage capacity cannot be foreseen as yet. However, as all components are available

in a finite number of sizes a certain deviation occurs. The latter provides a margin to create a compromise if necessary.

5.1 Deriving the optimal starting windspeed:

The essential point in power conversion by the windmill, combined with the single acting piston pump, is that the highest efficiency (η) occurs for the optimal (design) windspeed V_o. The starting windspeed V_s is found slightly less. Further the usefull output of the system is almost proportional to the windspeed and as a matter of fact the total output curve can be suitably approached as follows:

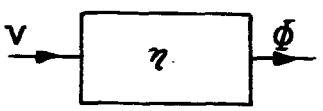

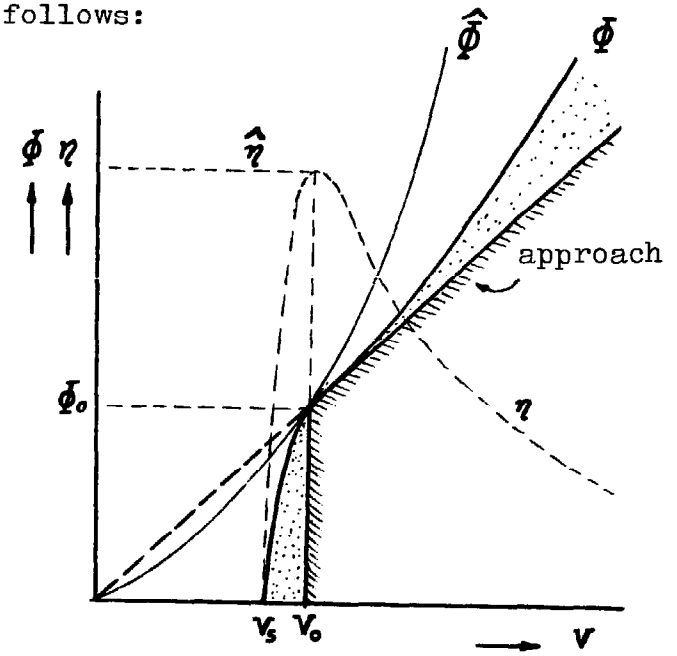

$$
\begin{array}{lcl}
V_s & \approx & V_o \\
V & < & V_o \;:\; \Phi = 0 \\
V & = & V_o \;:\; \Phi = \Phi_o \\
V & \geq & V_o \;:\; \Phi = \frac{\Phi_o}{V_o} * V
\end{array}
$$

Of course some deviations occur particularly about the interval V_s-V_o and in case of higher windspeeds but these are supposed to be neglected.

Symbols:

A	= rotor area	$[m^2]$
Φ	= flow (water delivery)	$[m^3/s]$
V	= actual windspeed	$[m/s]$
V_o	= optimal (design) windspeed	$[m/s]$
H	= elevation head	$[m]$
$\hat{\eta}$	= peak-efficiency	$[-]$
P	= power	$[W]$
ρ_a	= specific density of air	$[kg/m^3]$
ρ	= specific density of water	$[kg/m^3]$
g	= gravity acceleration	$[m/s^2]$

P (windmill) $= \eta * \frac{1}{2} \rho_o V_o^2 A$

P (pump) $= \rho g H * \Phi_o$

After equalization:

$$\hat{\eta} * \tfrac{1}{2} \rho_a V_o^2 A = \rho g H * \Phi_o$$

for $V = V_o$:

$$\boxed{\Phi_o = \frac{\hat{\eta} * \frac{1}{2} \rho_a V_o^3 * A}{\rho g H}} \quad [m^3/s] \qquad (5.1)$$

for $V > V_o$:

$$\boxed{\Phi_o = \frac{\hat{\eta} * \frac{1}{2} \rho_a V_o^2 A * V}{\rho g H}} \quad [m^3/s] \qquad (5.2)$$

for:

$$\left.\begin{array}{ll} \hat{\eta} = 0.30 & (12\,PU\text{-}Serie) \\ \rho_a = 1.3 & kg/m^3 \\ \rho = 10^3 & kg/m^3 \\ g = 9.81 & m/s^2 \end{array}\right\} \quad \boxed{\Phi = 2.10^{-5} \frac{A}{H} V_o^2 * V} \quad [m^3/s]$$

$$(V \geq V_o)$$

In this expression the influence of elevation head, rotor area and windspeeds are quite evident.
We are interested in a maximum total water delivery during the time period considered $t_1 - t_2$: (e.q. January or a critical season):

$$Q = \int_{t_1}^{t_2} \Phi dt = \int_{t_1}^{t_2} 2.10^{-5} \frac{A}{H} V_o^2 * V dt = 2.10^{-5} \frac{A}{H} V_o^2 \int_{t_1}^{t_2} V dt$$

$$(V \geq V_o)$$

It is noted that as far as optimizing is concerned the expression $V_0^2 \int_{t_1}^{t_2} V dt \quad (V \geq V_0)$ should reach a maximum. However, the actual windspeed is not presented in continuous functions although Histograms provide time durations of windspeeds belonging to certain ranges. Therefore it is advisable to rewrite the expression in order to facilitate an interval-wise calculation as follows:

$$\boxed{V_0^2 \int_{t_1}^{t_2} V dt} \quad \Rightarrow \quad \boxed{V_0^2 \sum_{t_1}^{t_2} V_i t_i}$$

Windspeed V_i represents the mean windspeed of a certain interval (e.g. 5-6; V_i = 5.5) and t_i is the time of which windspeeds, belonging to the interval concerned, actually occur during the time span:
Note that the expression indicates the extent of useful energy conversion. For convenience it is written in short as E.

As a matter of fact the optimizing problem can be suitably shown by means of this picture:

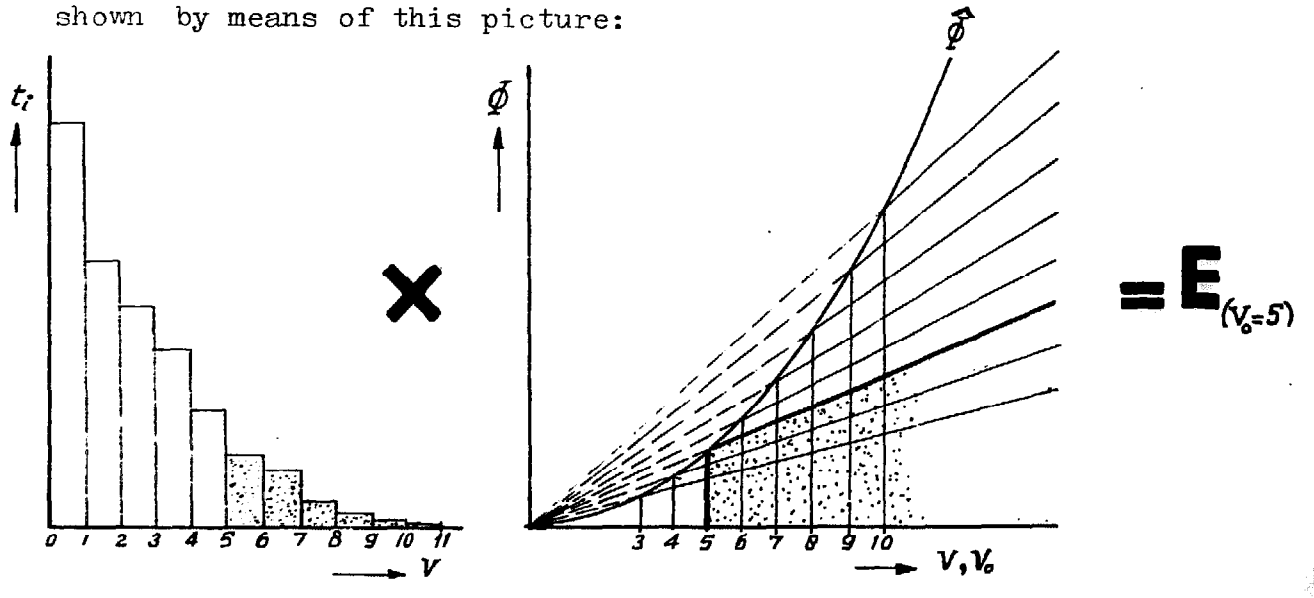

Many boring multiplications carried out again and again for an other starting windspeed V_0 (as a parameter) are needed

to figure out for which value of V_0 a maximum is found for the expression:

$$E = V_0^2 \sum V_i * t_i \quad (V \geq V_0)$$

Such a process can suitably be computerized, but a systematical calculation is simply carried out in a few minutes only without using any advanced calculation machines. This is done table-wise as follows:

V_0	V_i	t_i	$V_i * t_i$	$\sum V_i * t_i$	V_0^2	E
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						

<u>V_0-column</u>

Here the whole numbers of the potential starting windspeeds V_0 are filled out, while these correspond with each start value of the intervals given by the histogram.
The required length of this column depends on relevant duration of intervals of high windspeeds and whether the windmill still functions as the security mechanism might have switched off the windmill. Generally no relevant contribution to the total addition is found for windspeeds which exceed values of 10 up to 12 m/sec.

V_i-column

As mentioned before V_i represents the mean value of the windspeeds which are represented in the interval concerned.

t_i-column

Time duration of windspeeds represented in the interval are preferably filled out in hours.

$V_i * t_i$ -column

Values of the two foregoing columns are multiplied and printed here.

$\Sigma V_i * t_i$ -column

Here starts a tricky procedure! This column is filled out starting from the bottom adding the value of the foregoing column.

V_o^2-column

Print values of the first column in square.

$E = V_o^2 \Sigma V_i * t_i$-column

Multiply the figures of the last two columns to find a maximum and so the optimal starting windspeed V_o as a round figure.

Of course a real optimum is found for a value of V_o which is slightly more or less but as mentioned before the components of the windmill installation are bound to certain series of fixed dimensions.
Therefore better continue the calculations with the "round figure" found sofar but knowing where the real optimum exists. (This saves time and calculations.)

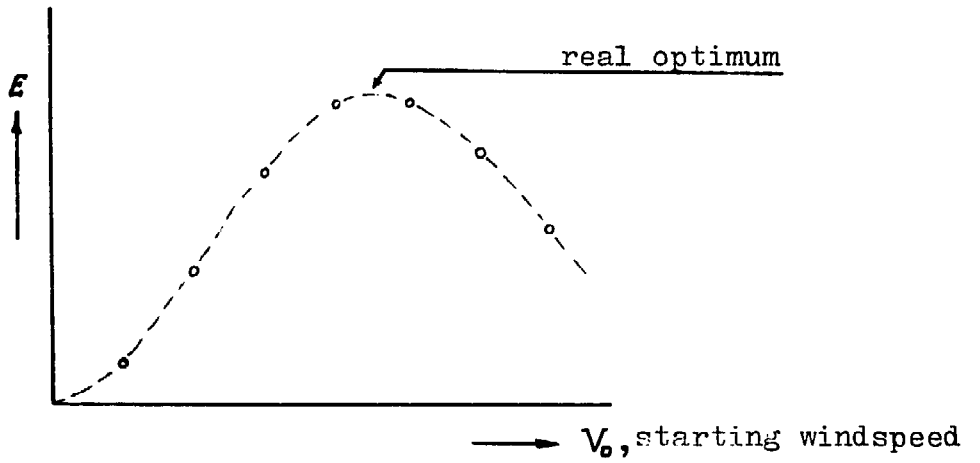

The expected total delivery is calculated as follows:

$$\boxed{Q_{t_1 \div t_2} = 2 \cdot 10^{-5} \frac{A}{H} * E} \quad [m^3] \qquad (5.3)$$

which is only valid if time (t_1) has been expressed in seconds. In practice winddata are given in hours so far the practical case the foregoing formule turns into:

$$\boxed{Q_{t_1 \div t_2} = 7.2 \cdot 10^{-2} \frac{A}{H} * E} \quad [m^3] \qquad (5.4)$$

5.2 Deriving required rotor dia:

Depending on water requirement and actual elevationhead the minimum rotor area is simply derived by applying the formula:

$$\boxed{A = \frac{QH}{7.2\ 10^{-2}\ E}} \quad [m^2] \qquad (5.5)$$

But in practice only a few windmill designs are at our disposal which means that each choice to be made will be a compromise:

type	rotor area	power
12 PU 250	4.9	P
12 PU 350	9.6	2P
12 PU 500	19.6	4P
12 PU 700	38.5	8P

One should realize that a generous rotor area always provides some margins which, of course, is more attractive than a very critically chosen windmill which will hardly cover the need.

5.3 Pump dimensions

So far we are able to extract the optimal starting windspeed and windmill type to be applied under certain circumstances (winds, waterdepth, water requirement). The final match of pump and windmill should prove the demanded properties of starting behaviour and output.
To find out the optimal pump dimension the equilibrium is to be considered for

Windmill: $\Omega_o = \frac{\lambda_o V_o}{R}$ (5.6)

Pump: $\Phi_o = \frac{\Omega_o}{2\pi} 2r \frac{\pi}{4} d^2 \eta_v$ (5.7)

Ω_o	= angular velocity for $V = V_o$	$[1/s]$
r	= crank radius	$[m]$
d	= pump dia	$[m]$
η	= volumetric efficiency (0,85)	$[-]$
λ_o	= tipspeed ratio (2)	$[-]$
R	= rotor radius	$[m]$

(5.6) substituted into (5.7):

$$\boxed{\Phi_o = 1/2\, V_o \frac{r}{R} d^2 \eta_v} \quad [m^3] \qquad (5.8)$$

In paragraph 5.1 was found for $V = V_o$: $\Phi_o = \frac{\hat{\eta}\, 1/2\, \rho_a V_o^3 A}{\rho g H}$ (5.1)

after equalization of : (5.8) and (5.1)

$$\boxed{H = 4.68 * 10^{-5} \frac{A}{d^2} \cdot \frac{R}{r} * V_o^2} \quad [m] \qquad (5.9)$$

It will be useful to create a graphical representation of the forementioned equation which is achieved as follows:

H is proportional to V_o^2 while A, d^2 and $\frac{R}{r}$ (which are fixed figures) can be applied as parameters. As well known the 12 PU - windmills have three crank radia(r) so the ratio leads to:

$$\frac{R}{r_1} = 41.66$$
$$\frac{R}{r_2} = 27.78$$
$$\frac{R}{r_3} = 20.83$$

The graphical representation will be:

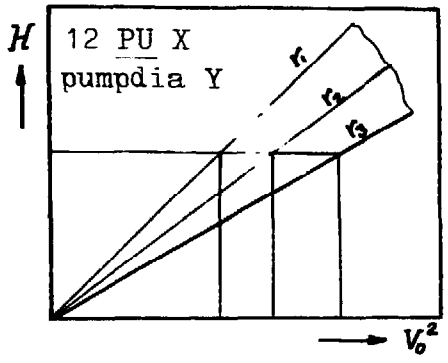

More pump types can be involved, so the H-V_0-plane will contain several overlapping fan-shaped figures representing the pump size and crank-radius concerned.
Though in principle the choice is made for the biggest radius r_3 an extra possibility is available to give an additional change in the starting windspeed. This is done by re-adjustment of the crank which might be necessary during critical periods.

Next pages show the graphs which are valid for the 12 PU 250-350 and 500 windmills respectively. By means of these graphs the most optimal pump is chosen and of course, most probably, a compromise has to be made. However, in many cases an overcapacity of the windmill will be applied which allows us to deviate from the round figure of V_0, which was found so far. Preferably the "match point" is chosen which lies just on left side of the V_0 which should be obtained. The reasons for this are:

- A lower starting windspeed proved to be more attractive with regard to social acceptance of the windmill.
- As the windmill is running during a higher percentage of time its delivery will be more regular, which requires a smaller storage tank in case of regular consumption.

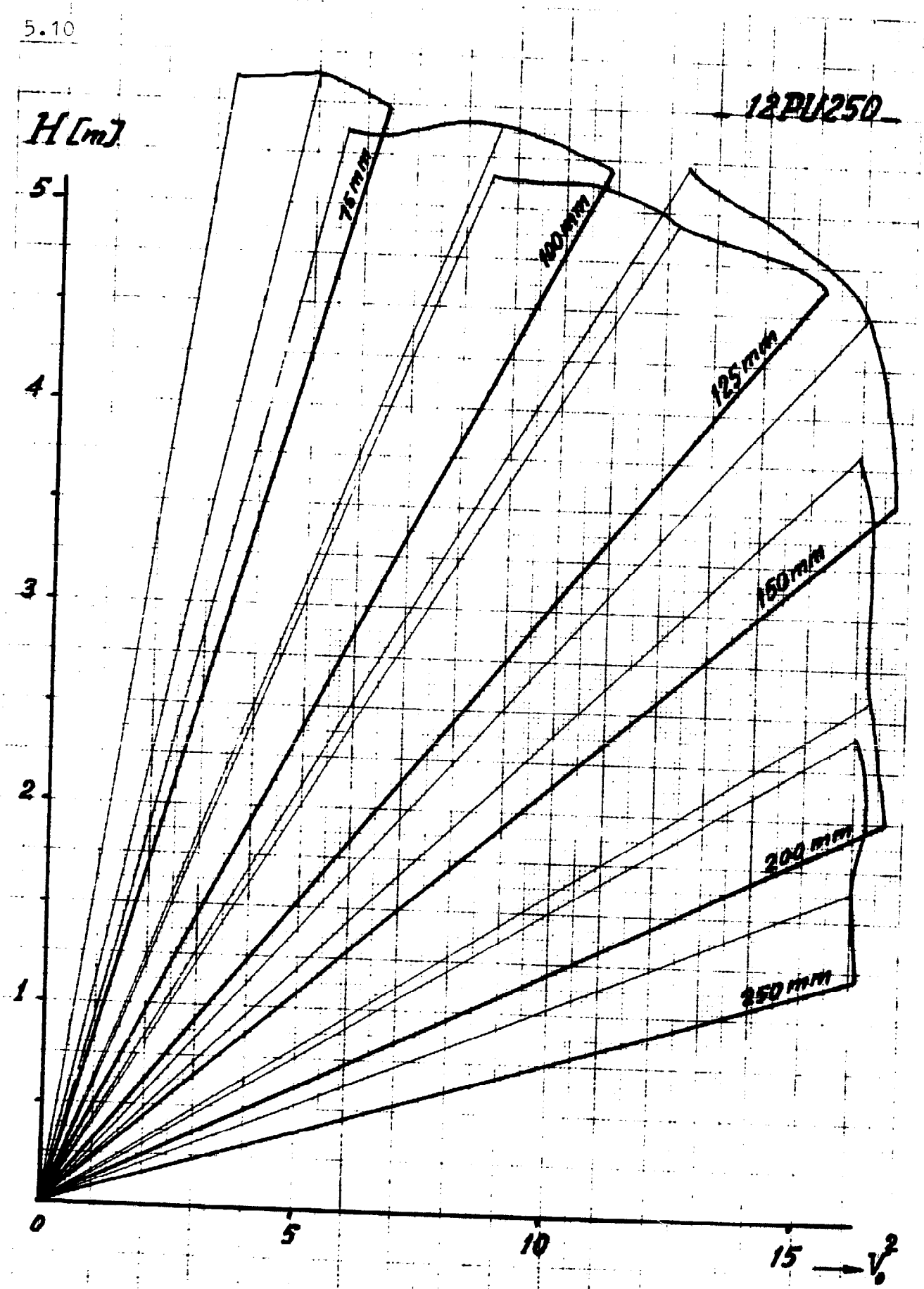
12PU250
H [m]
5
4
3
2
1
0
5
10
15
V_0^2
75 mm
100 mm
125 mm
150 mm
200 mm
250 mm

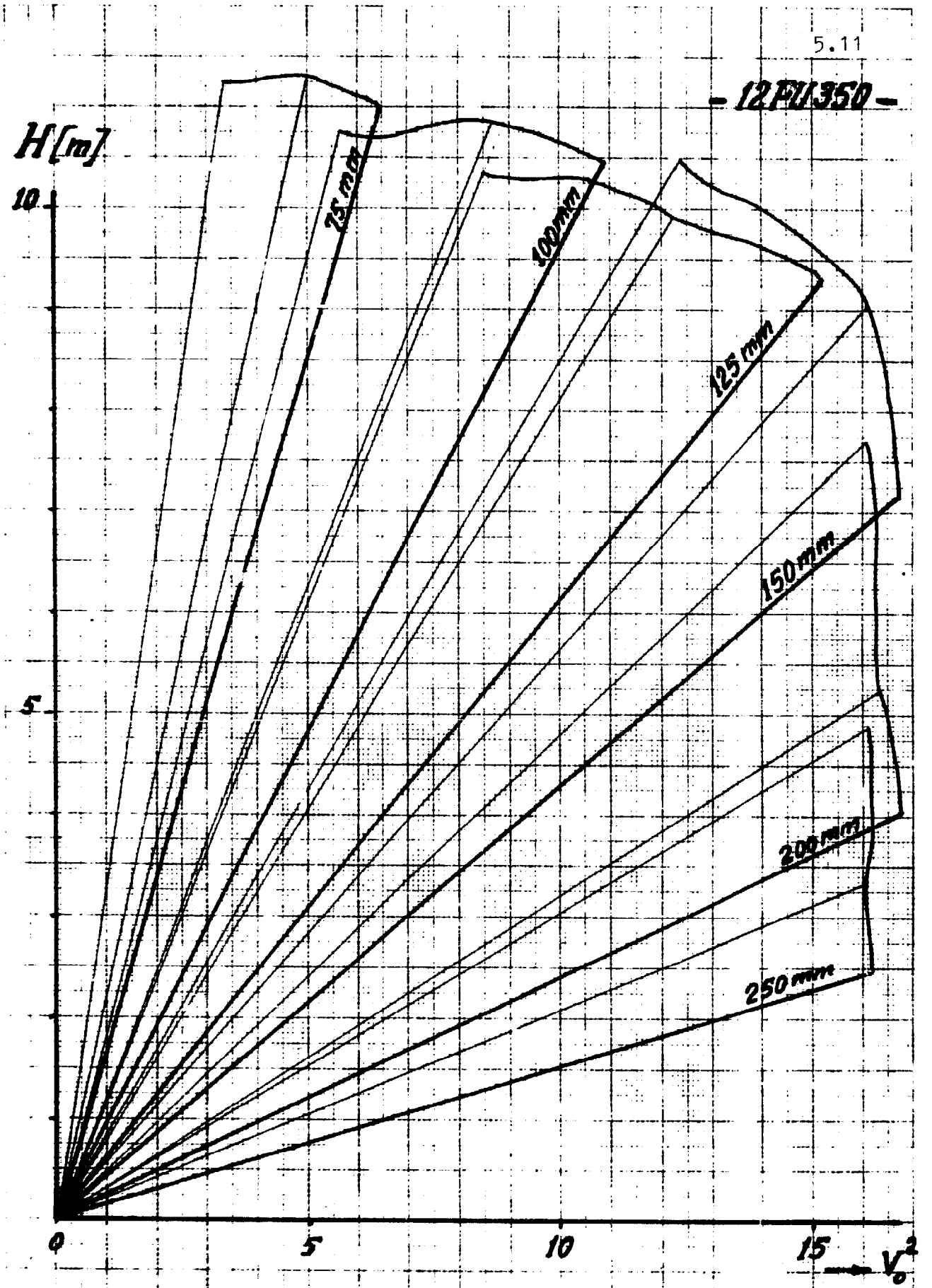
- 12FU350 -
H[m]
10
5
0
5
10
15
V_0^2
75 mm
100 mm
125 mm
150 mm
200 mm
250 mm

5.12

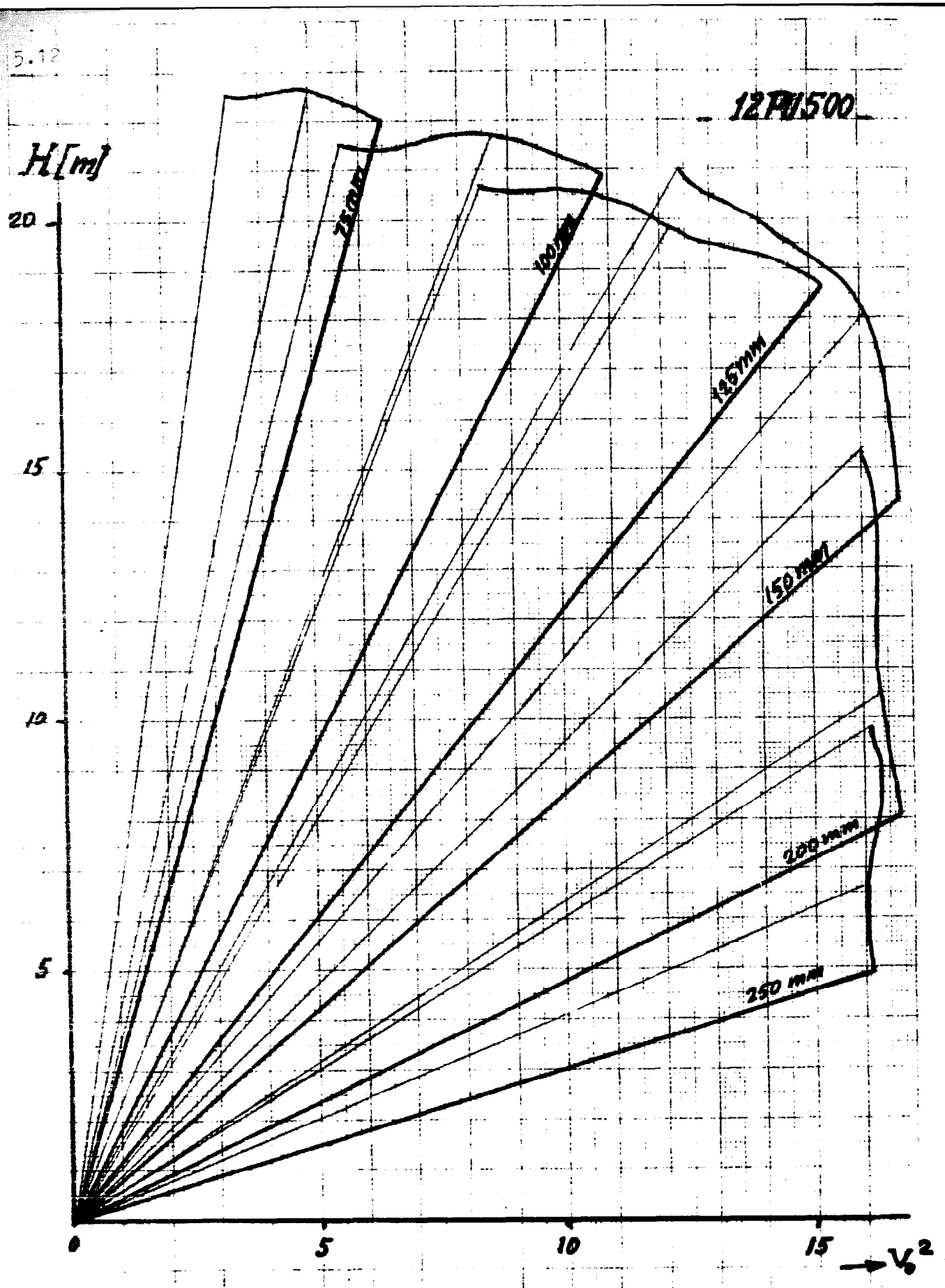
12PU500
H[m]
20
15
10
5
0
5
10
15
V_0^2
75 mm
100 mm
125 mm
150 mm
200 mm
250 mm

- The forces transmitted acting on the moving parts are less in case of lower starting windspeeds. To a certain extent a less quicker wear of such components and a lower probability of breakdowns occur.
  This might seem contradictional for the windmill has a higher degree of running, but such indications have been noticed in practice.

5.4 Numerical example

In a certain project area the following winds appear during the most critical period of water requirement.

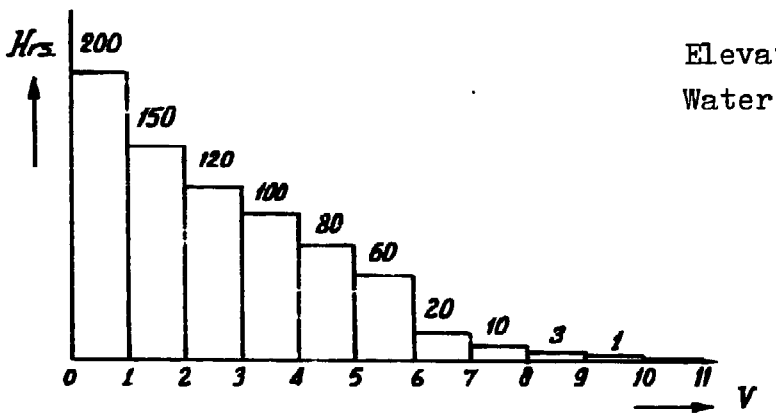

Elevation head = 10 m
Water requirement = 1,500 m^3

1. What is the optimal starting windspeed (round figure)?
2. Which windmill is applied to cover the water requirement?

3a. Which pump dia should be applied to approach the maximum output possible?

3b. What will be the starting windspeed?

3c. What is the maximum output to be expected?

3d. How many running- hours and -percentage are expected?

4a. Which minimum pump dia is possible to obtain at least the required output and what will be the starting windspeed then?

4b. How many running- hours and -percentage are expected?

1.

V_o	V_i	t_i	$V_i * t_i$	$\Sigma V_i * t_i$	V_o^2	E
0	0.5	200	-	-	-	-
1	1.5	150	225	1805	1	1,805
2	2.5	120	300	1580	4	6,320
3	3.5	100	350	1280	9	11,520
4	4.5	80	360	930	16	14,880
5	5.5	60	330	570	25	14,250
6	6.5	20	130	240	36	8,640
7	7.5	10	75	110	49	5,390
8	8.5	3	25.5	35	64	2,240
9	9.5	1	9.5	9.5	81	770
10	10.5	-	-	-	100	-
11	11.5	-	-	-	121	-

⇦ maximum

The optimal starting windspeed amounts to 4 (round figure)

2. $Q = 7.2 * 10^{-2} * \frac{A}{H} * E = 7.2 * 10^{-2} * \frac{A}{10} * 14880 = 1500 \Longrightarrow A = 14.0\ m^2$

$\Longrightarrow$ 12PU500

3a/3b.

By graphs: H = 10m

(pump dia = 150) $V_o^2 = 11.7 \longrightarrow V_o = 3.42\ m/s$

(pump dia = 200) $V_o^2 = 21^* \longrightarrow V_o = 4.58\ m/s$

* Actually this figure is not represented at the V_o^2-scale, but the graph reads half the value of V_o^2 for half the value of H.

Though the second match (pump dia = 200) is not desirable as explained before it is considered here to illustrate the consequences of such a choice.

3c. Recalculation of E by means of proportional interpolation.

$E_{(150)} \geqslant 11520 + (14880-11520)(3.42-3) = 12931.2$

$E_{(200)} \geqslant 14250 + (14880-14250)(5-4.58) = 14514.6$

Obviously the second match is closest to the optimum.

$Q_{(150)} \geqslant 7.2 * 10^{-2} * \frac{19.6}{10} * 12931.2 = 1825\ m^3$

$Q_{(200)} \geqslant 7.2 * 10^{-2} * \frac{19.6}{10} * 14514.6 = 2048\ m^3$

3d. <u>Total hours of functioning:</u> (from table)

$T_{(150)} = 1+3+10+20+60+80+(4-3.42)100 = 232$ *hrs.*

$T_{(200)} = 1+3+10+20+60+(5-4.38)80 = 127.6$ *hrs.*

<u>Percentages:</u>

$P_{(150)} = \frac{232}{744} * 100\% = 31\%$

$P_{(200)} = \frac{127.6}{744} * 100\% = 17\%$

4a. $Q = 7.2 * 10^{-2} * \frac{A}{H} * E = 7.2 * 10^{-2} * \frac{19.6}{10} * E = 1500$

$E = 10629 \Longrightarrow V_o^2 \approx 9$ (see table)

pump dia = 125 mm (see graphs)

with $V_o^2 = 8.2$ and $V_o = 2.86$ m/s

<u>Recalculation for E:</u> (from table)

$E_{(125)} \geqslant 6320 + (11520-6320)(2.86-2) = 10792$

This is slightly more than was demanded:

$Q_{(125)} \geqslant 7.2 * 10^{-2} * \frac{19.6}{10} * 10792 = 1523\ m^3$

A 125 mm pump will serve the purpose so the starting windspeed of 2.86 m/s is confirmed.

4b. <u>Running hours:</u> (from table)

$T_{(125)} = 1+3+10+20+60+80+100+120*(3-2.86) = 288.4$ hrs

<u>Running percentage:</u>

$P_{(125)} = \frac{288.4}{744} * 100\% = 39\%$

WOT 12 PU 500 Windmill Construction Project Saighanchi Afghanistan

Australian Council of Churches

let us consider the design, development and production of windmills. The windmills as produced in industrialised countries use high technology, requiring well-developed associated technologies to assist the design. Some of the complex blades used in certain windmills are actually the result of complicated computor programmes, complex materials and sophisticated presses to fashion the shapes. It would be inappropriate to introduce to a developing country a technology which is either static, or too advanced for manufacture in the country. In other words, a starting point has to be established which is compatible with technological skills available in the country at that particular time, so that as and when the country acquires high technology, a linkage can be readily created whereby products or equipment are naturally and automatically improved through the use of that high technology. The drawings supplied in Figures 6.8 to 6.23 for the manufacture of windmills take into account that 'starting point', fully utilising available skills and technology, while leaving ample room for further development and improvement.

The windmill designated 12 PU 500 Windmill for Irrigation has been designed by Niek van de Ven for the Working Group on Development Technology (WOT), Twente University of Technology, Vrijhof 152, P.O. Box 217, 7500 AE ENSCHEDE, The Netherlands. Any technical assistance or further information needed will be gladly supplied by the Working Group on request.

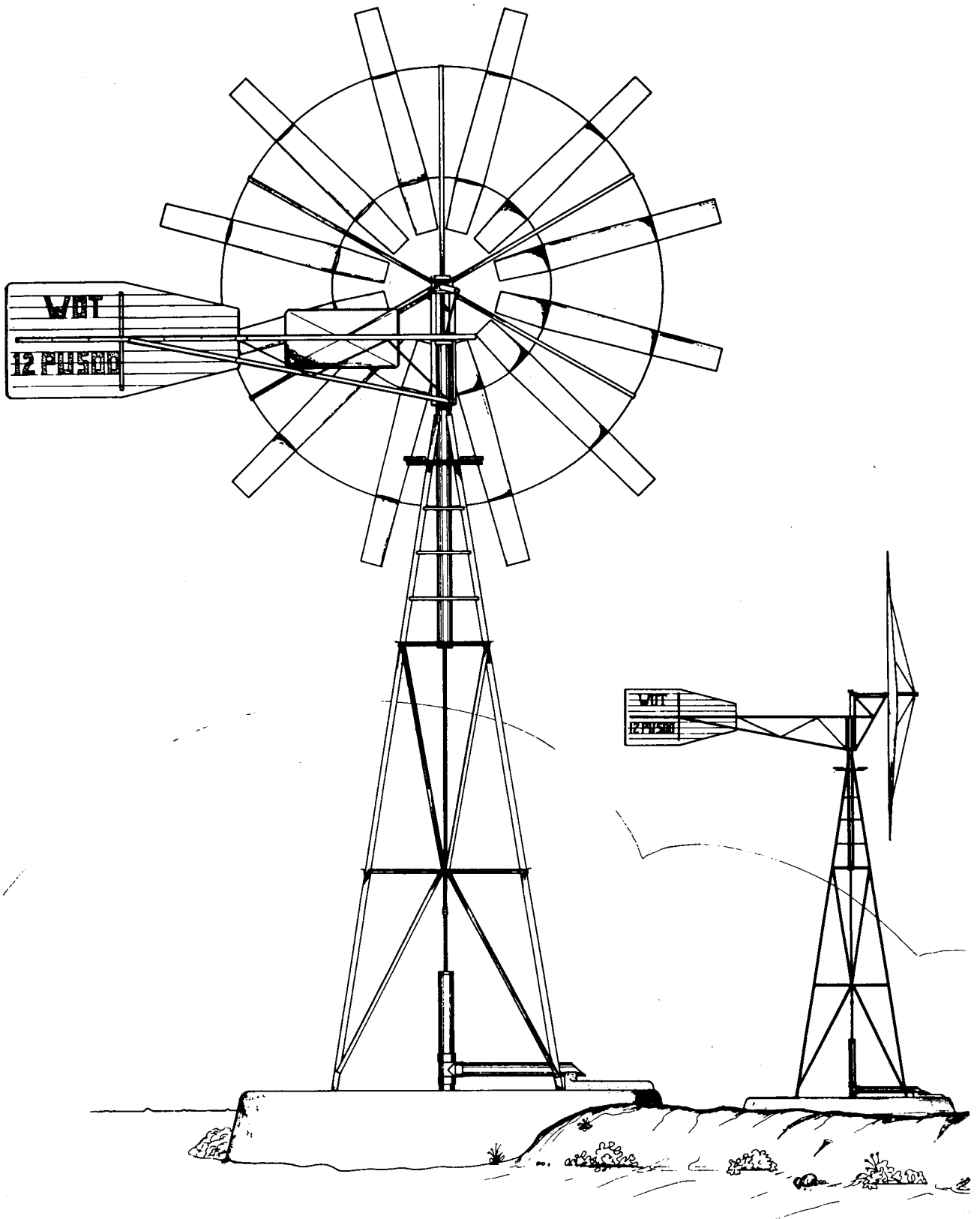
WBT
12 PU500
WBT
12 PU500

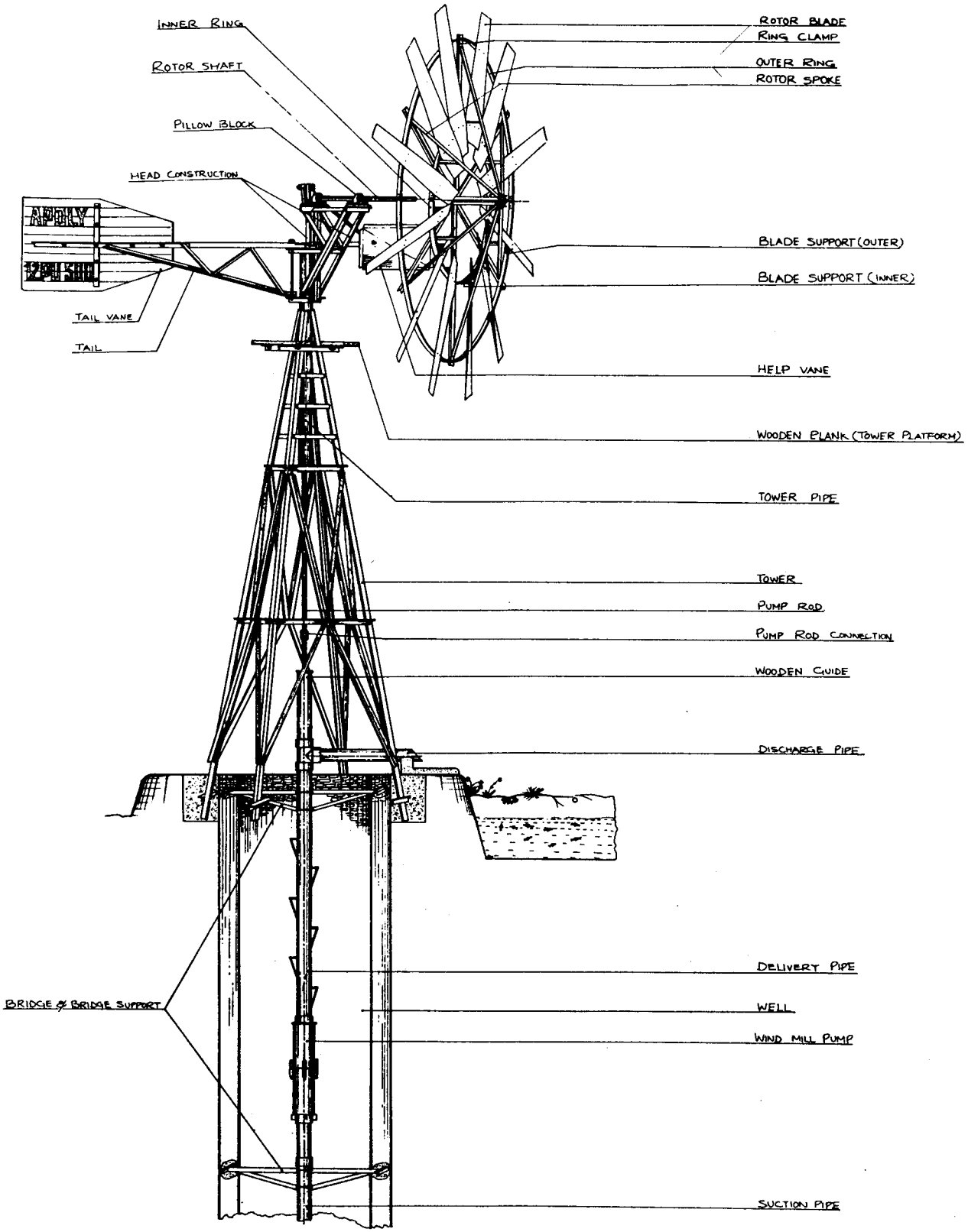

Fig. 5 12 P U 500 Water Pumping Windmill

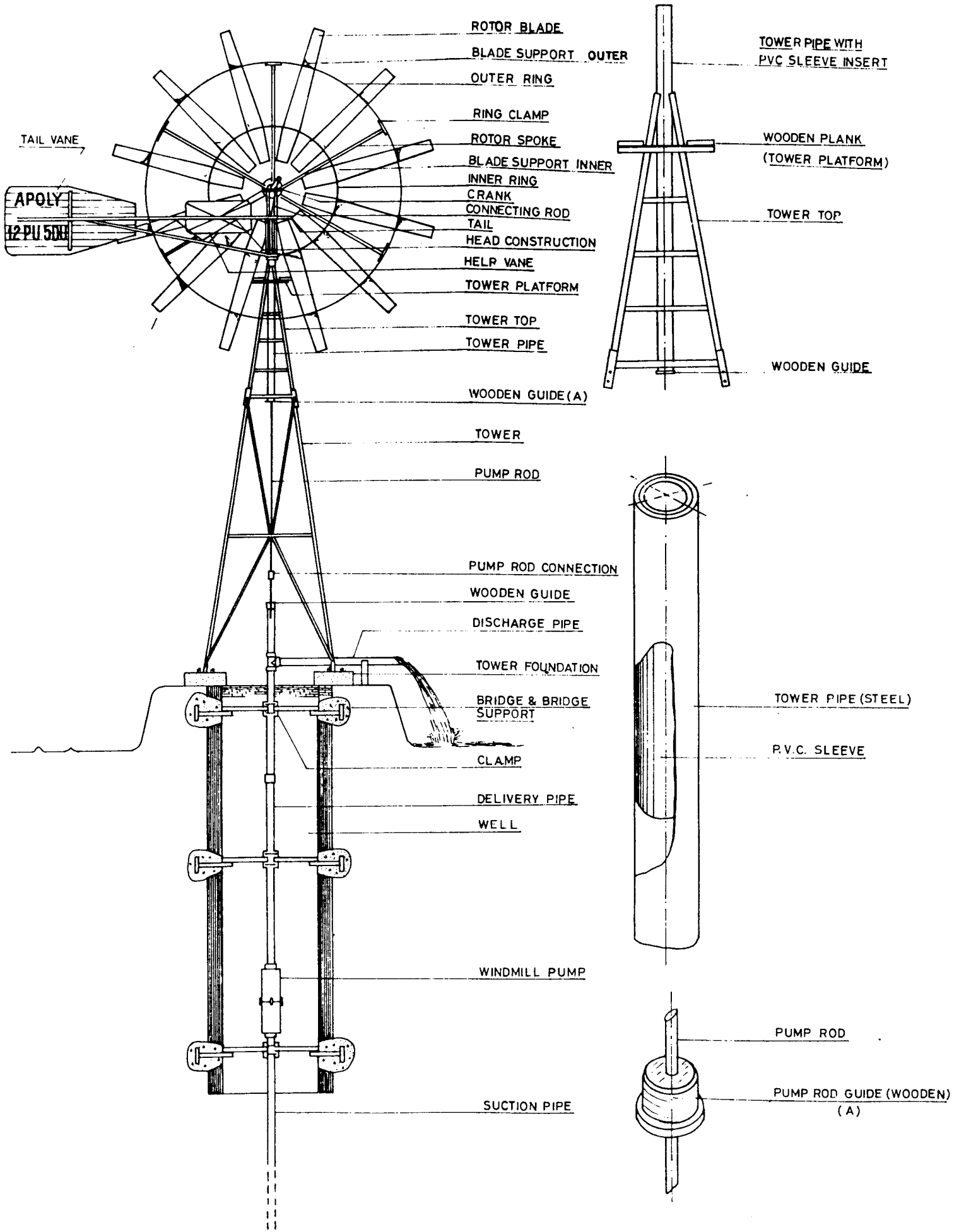
ROTOR BLADE
BLADE SUPPORT OUTER
OUTER RING
RING CLAMP
ROTOR SPOKE
BLADE SUPPORT INNER
INNER RING
CRANK
CONNECTING ROD
TAIL
HEAD CONSTRUCTION
HELP VANE
TOWER PLATFORM
TOWER TOP
TOWER PIPE
WOODEN GUIDE (A)
TOWER
PUMP ROD
PUMP ROD CONNECTION
WOODEN GUIDE
DISCHARGE PIPE
TOWER FOUNDATION
BRIDGE & BRIDGE SUPPORT
CLAMP
DELIVERY PIPE
WELL
WINDMILL PUMP
SUCTION PIPE
TAIL VANE
APOLY
12 PU 500
TOWER PIPE WITH PVC SLEEVE INSERT
WOODEN PLANK (TOWER PLATFORM)
TOWER TOP
WOODEN GUIDE
TOWER PIPE (STEEL)
P.V.C. SLEEVE
PUMP ROD
PUMP ROD GUIDE (WOODEN) (A)

Water output graphs

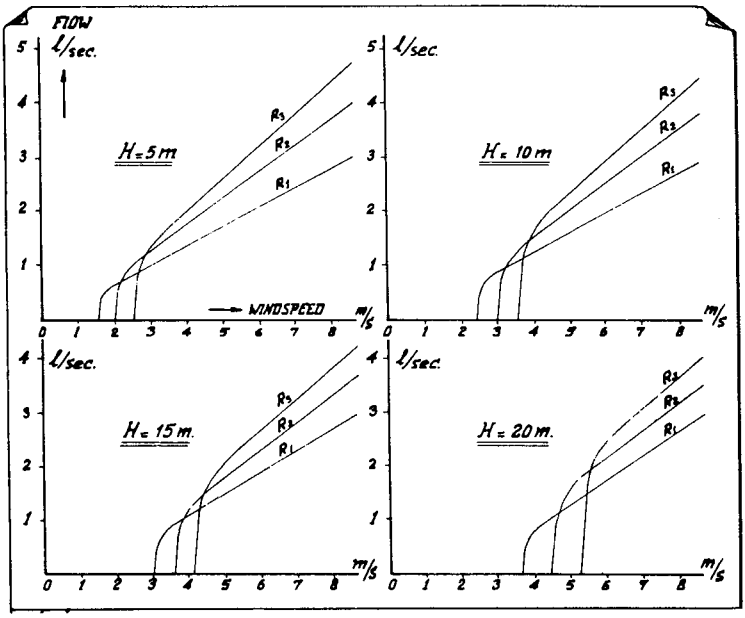

H = elevation head
R_1 = 60 mm
R_2 = 90 mm
R_3 = 120 mm
crank radius
for 150 mm piston pump

Materials for a tower

No	Number required	Materials, particulars and measurements		
1	1	Tower pipe	4″ gaspipe	× 2650
2	4	Angle iron	40 × 40 × 5 (1½″ × 1½″)	× 6500 ÷ 7000
3	2	,,	30 × 30 × 4 (1¼″ × 1¼″)	× 660
4	2	Flat iron	30 × 6 (1¼″ × ¼″)	× 360
5	2	,,	,,	× 480
6	2	,,	,,	× 600
7	4	Angle iron	30 × 30 × 4 (1¼″ × 1¼″)	× 750
8	16	,,	,,	× 2000
9	4	,,	,,	× 1350
10	4	,,	,,	× scrap
11	2	Plank	30 × 200 × 700	
12	4	Bolt, nut, washers	M 8 (W ⅜″)	
13	4	Flat iron	30 × 6 (1¼″ × ¼″)	× 460
14	8	Flat scrap		

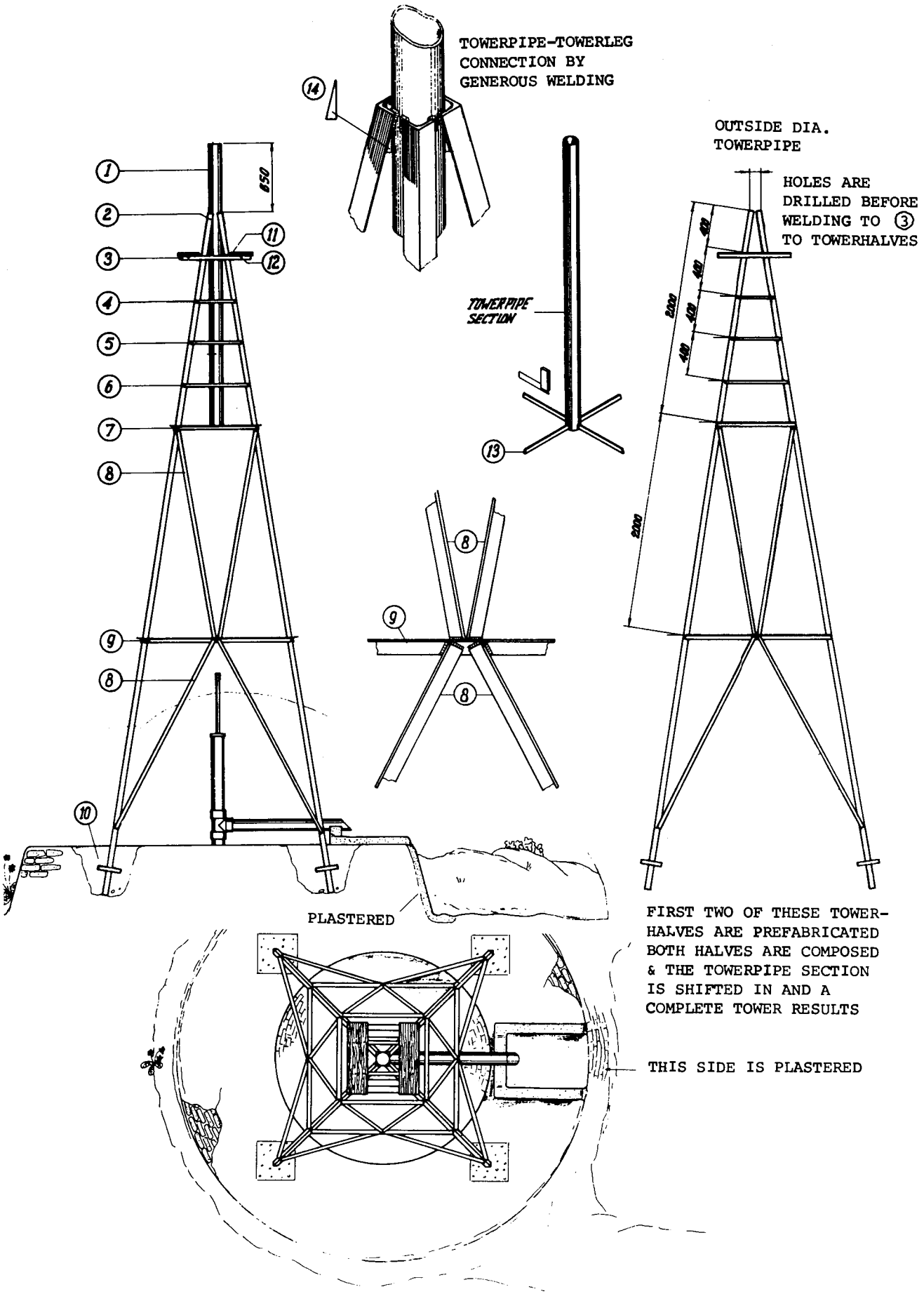
TOWERPIPE-TOWERLEG
CONNECTION BY
GENEROUS WELDING
OUTSIDE DIA.
TOWERPIPE
HOLES ARE
DRILLED BEFORE
WELDING TO 3
TO TOWERHALVES
TOWERPIPE
SECTION
850
400
400
400
400
2000
2000
PLASTERED
FIRST TWO OF THESE TOWER-
HALVES ARE PREFABRICATED
BOTH HALVES ARE COMPOSED
& THE TOWERPIPE SECTION
IS SHIFTED IN AND A
COMPLETE TOWER RESULTS
THIS SIDE IS PLASTERED

Head Construction

No	Number required	Materials, particulars and measurements		
1	2	Angle iron	50 × 50 × 5 (2″ × 2″)	Length 220
2	1	,,	40 × 40 × 4 (1½″ × 1½″)	500
3	2	,,	,,	1080
4	2	,,	,,	460
5	2	,,	,,	1000
6	2	,,	,,	550
7	4	,,	,,	tower pipe dia.
8	1	,,	,,	Length 180
9	1	,,	,,	45
10	1	,,	,,	1000
11	1	,,	,,	580
12	1	,,	,,	200
13	1	,,	,,	280
14	1	,,	,,	60
15	1	,,	,,	120
16	1	,,	,,	1500
17	1	,,	,,	4000
18	1	,,	,,	3000
19	3	Flat iron	30 × 6 (1¼″ × ¼″)	Length 750
20	1	,,	,,	830
21	5	,,	,,	80
22	1	,,	,,	360
23	1	,,	,,	900
24	1	,,	,,	115
25	1	,,	,,	130
26	2	,,	,,	40
27	1	,,	,,	100
28	2	Spring	Appr. ϕ30 × 1000 × ϕ4	
29	1	Helpvane	1 mm sheet 1000 × 500	
30	1	Tailvane	1 mm sheet 2000 × 1000	
31	3	Washer	ϕ18 inside	
32	1	Rod	ϕ18 × 650 (ϕ¾″ × 2′2″)	
33	1	Split pin	ϕ6 (ϕ¼″)	
34	12	Bolt, nut, washer	M 6 × 25 (W ¼″ × 1″)	
35	1	,,	M 12 × 100 (W ½″ × 4″)	
36	1	,,	M 10 × 150 (W ⅜″ × 6″)	
37	2	,,	M 12 × 40 (W ½″ × 1½″)	

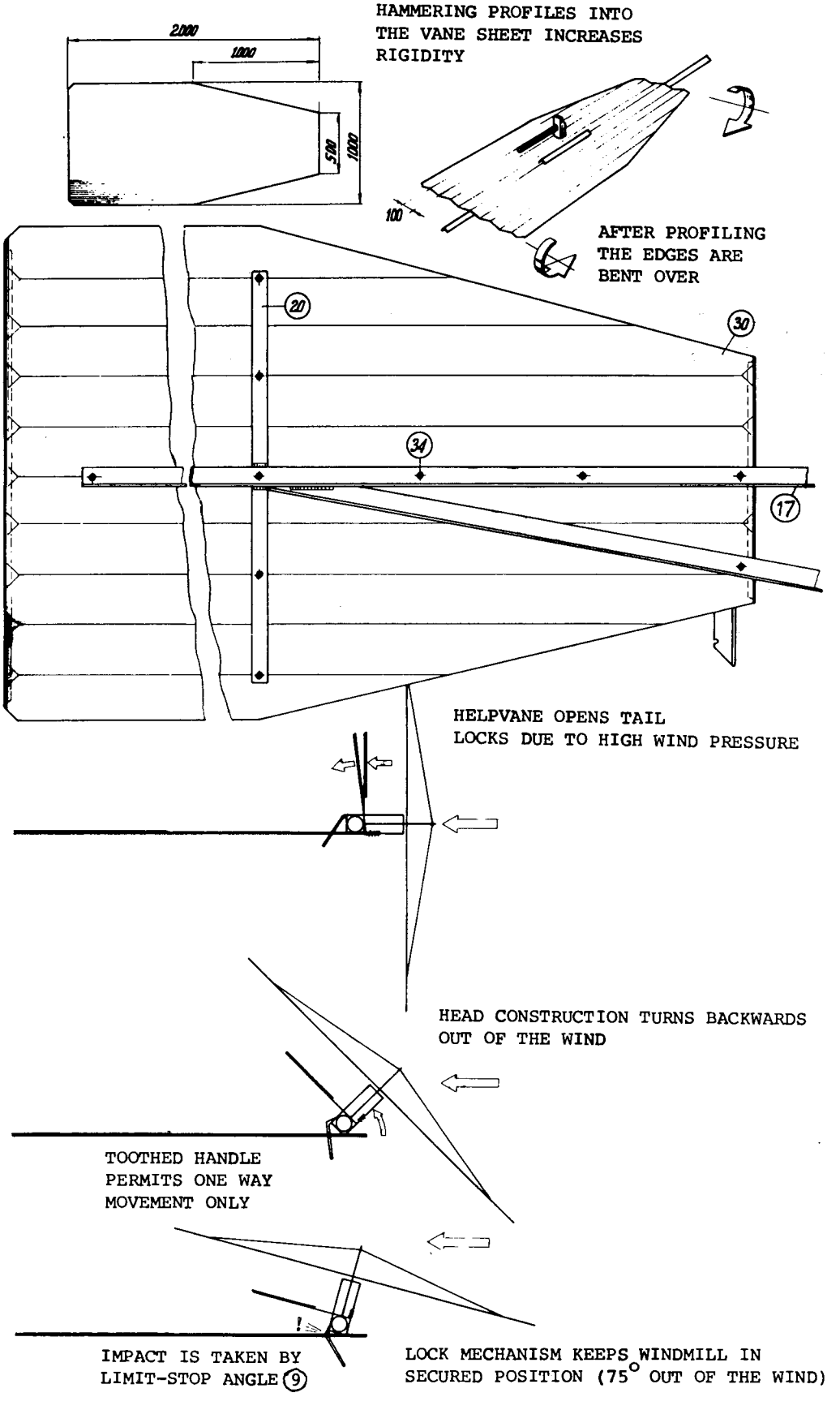
HAMMERING PROFILES INTO THE VANE SHEET INCREASES RIGIDITY
2000
1000
500
1000
100
AFTER PROFILING THE EDGES ARE BENT OVER
20
30
34
17
HELPVANE OPENS TAIL LOCKS DUE TO HIGH WIND PRESSURE
HEAD CONSTRUCTION TURNS BACKWARDS OUT OF THE WIND
TOOTHED HANDLE PERMITS ONE WAY MOVEMENT ONLY
IMPACT IS TAKEN BY LIMIT-STOP ANGLE 9
LOCK MECHANISM KEEPS WINDMILL IN SECURED POSITION (75° OUT OF THE WIND)

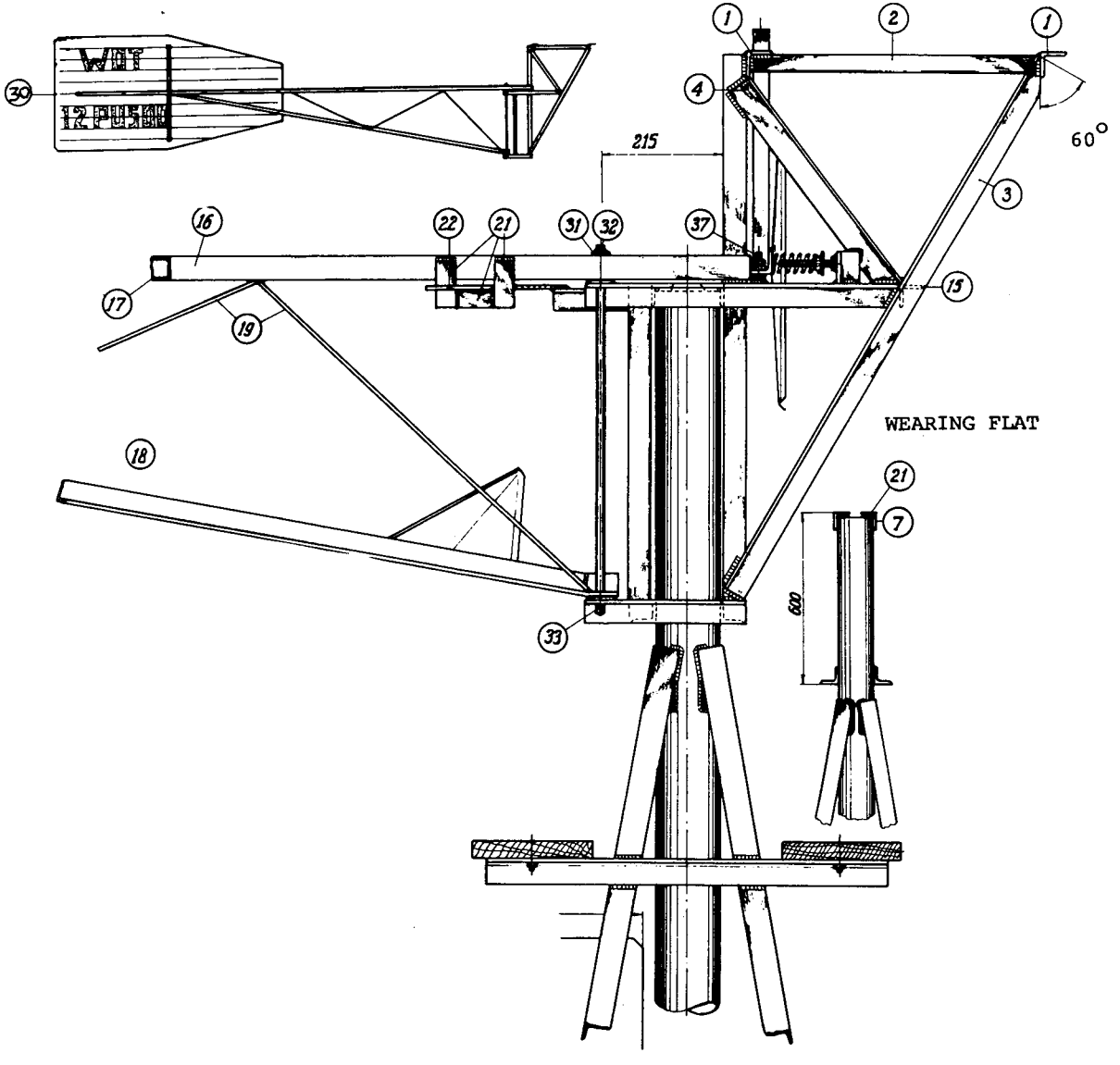
WOT
12 PUSH
39
1
2
1
4
60°
215
3
16
22
21
31
32
37
15
17
19
18
WEARING FLAT
21
7
600
33

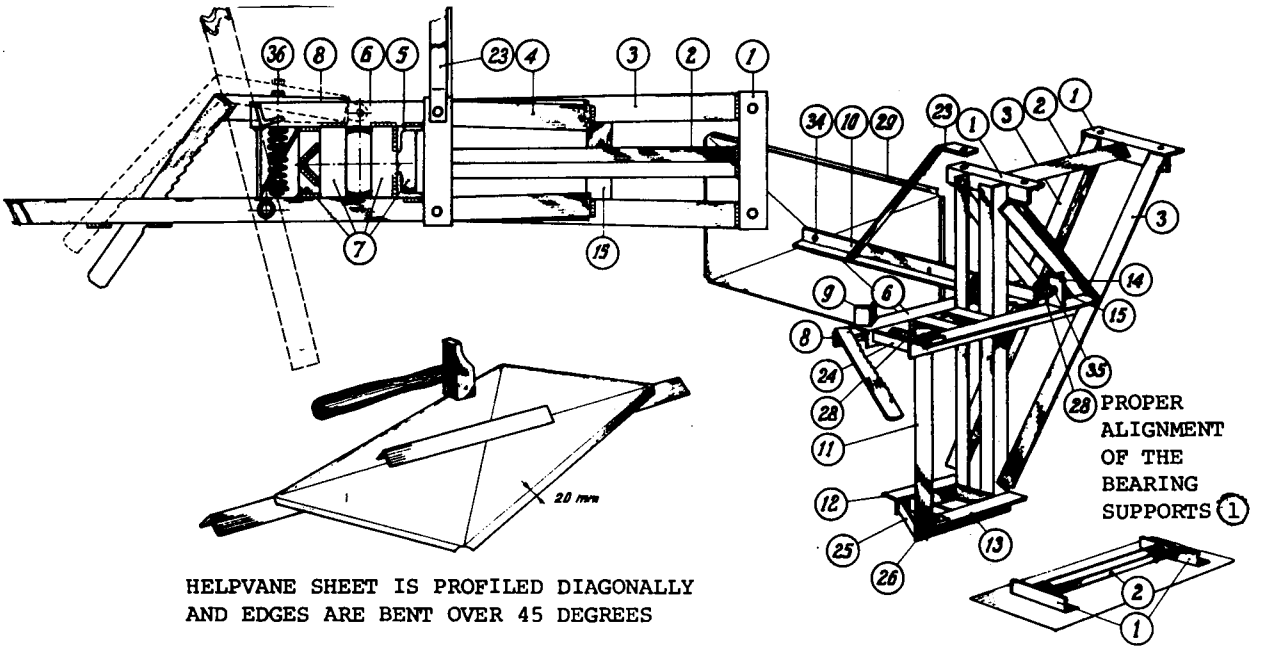

HELPVANE SHEET IS PROFILED DIAGONALLY AND EDGES ARE BENT OVER 45 DEGREES

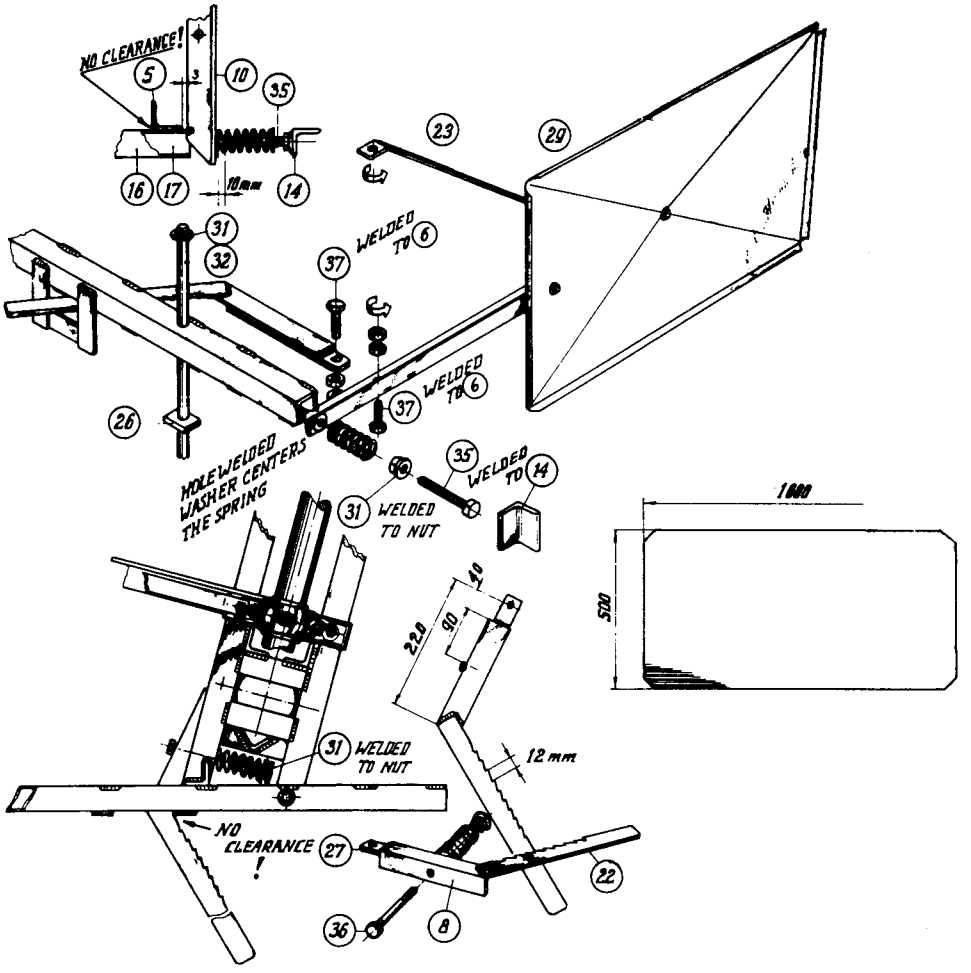

Moving parts

No	Number required	Materials, particulars and measurements	
1	1	Shaft	ϕ50 (ϕ2″) × 1250
2	2	Bearing housing	
3	2	Ball bearing (best quality)	
4	2	Bearing bush (best quality)	
5	2	Bearing housing	
6	4	Nylon bearing bush	ϕ1½″ nylon rod
7	2	Washer	
8	3	Nut M 20 (W ¾″)	
9	1	Crank pin ϕ25 (ϕ1″)	
10	1	Cross pin ϕ25 (ϕ1″) remove sharp edges	
11	2	Flat iron 30 × 6 (1¼″ × ¼″)	Length 120
12	1	,,	150
13	4	,,	50
14	1	,,	600
15	1	,,	140
16	2	,,	220
17	1	Cross head	Sesam wood soaked in oil
18	1	Cork	
19	1	Pump rod	Gaspipe ϕ¾″ × 4700
20	1	PVC insert	ϕ100 × 700
21	1	Thread, stud	M 24 × 75 (W ⅞″ × 4″)
22	2	Bolt, nut, washers	M 6 × 25 (W ¼″ × 1″)
23	1	,,	M 10 × 100 (W ⅜″ × 4″)
24	4	,,	M 12 × 50 (W ½″ × 2″)
25	2	,,	M 12 × 80 (W ½″ × 3″)
26	1	Pump rod guide	Sesam wood soaked in oil

BRACKET PREVENTS CRACK-
OPENING OF BEARING HOUSE

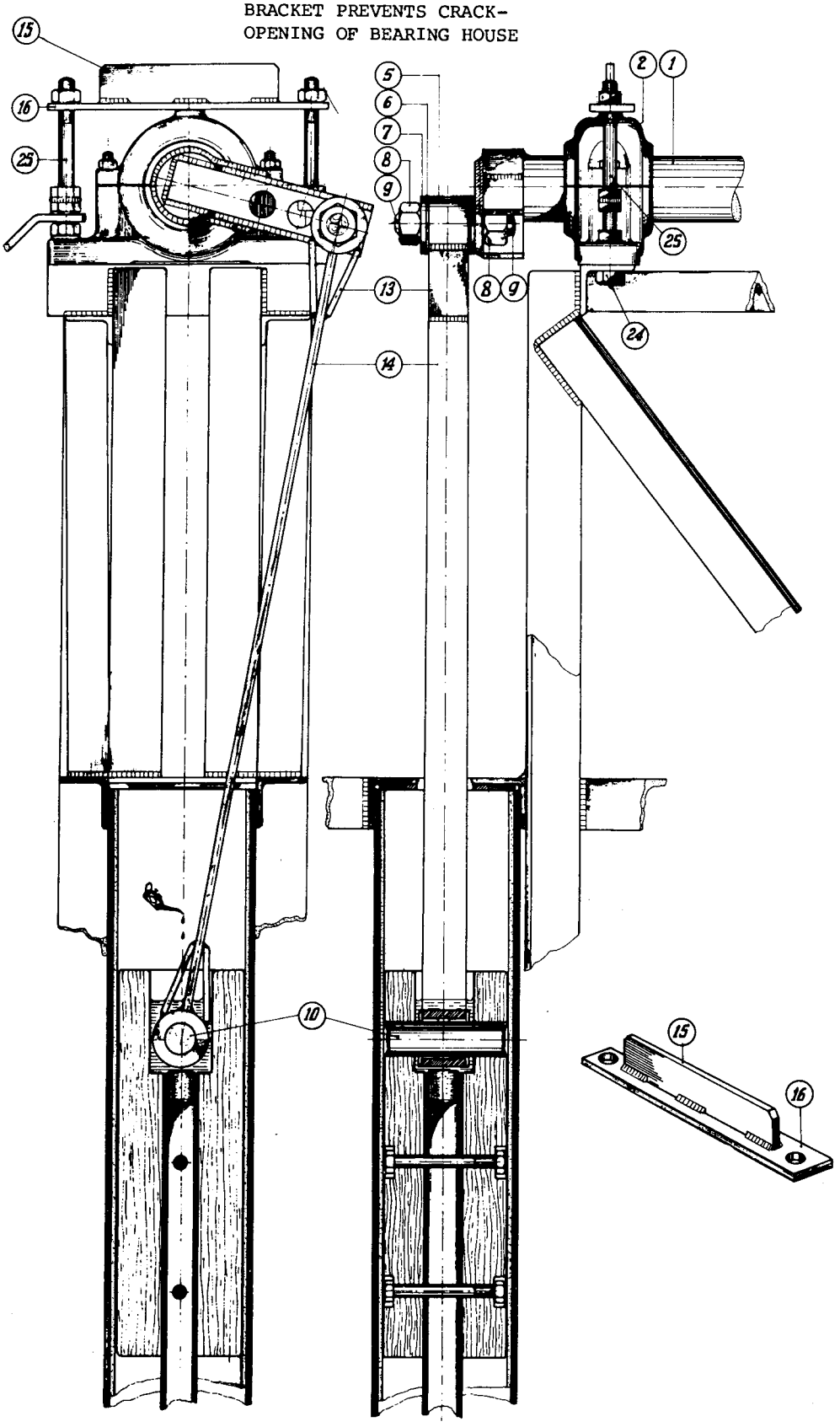

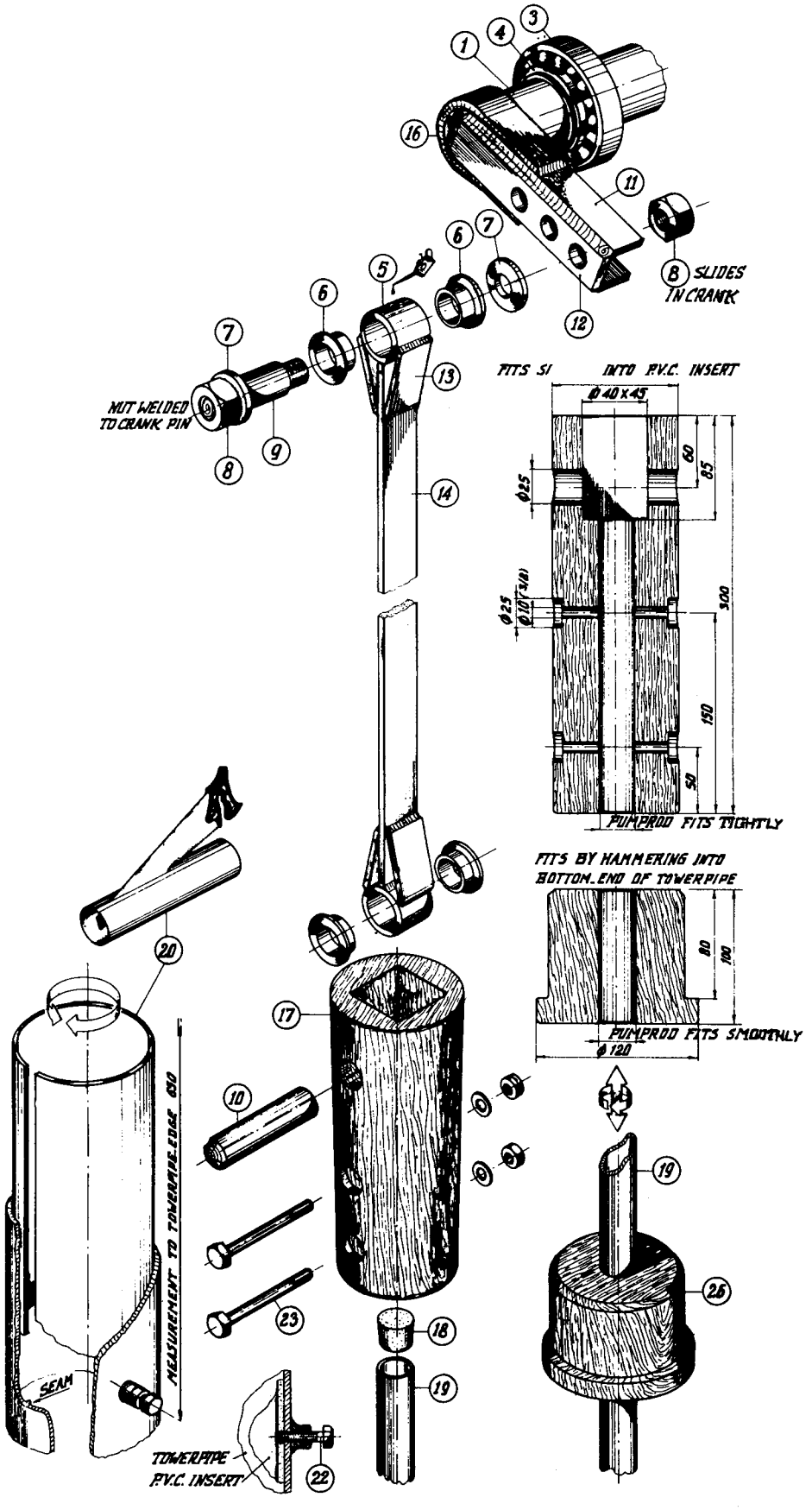
1
4
3
16
11
8 SLIDES IN CRANK
12
6
7
5
6
7
13
NUT WELDED TO CRANK PIN
8
9
14
FITS SI INTO P.V.C. INSERT
Ø 40 X 45
60
85
Ø25
Ø25
Ø10 (3/8)
100
150
50
PUMPROD FITS TIGHTLY
FITS BY HAMMERING INTO BOTTOM END OF TOWERPIPE
80
100
PUMPROD FITS SMOOTHLY
Ø 120
20
17
10
23
18
19
22
19
26
MEASUREMENT TO TOWERPIPE EDGE 610
SEAM
TOWERPIPE P.V.C. INSERT

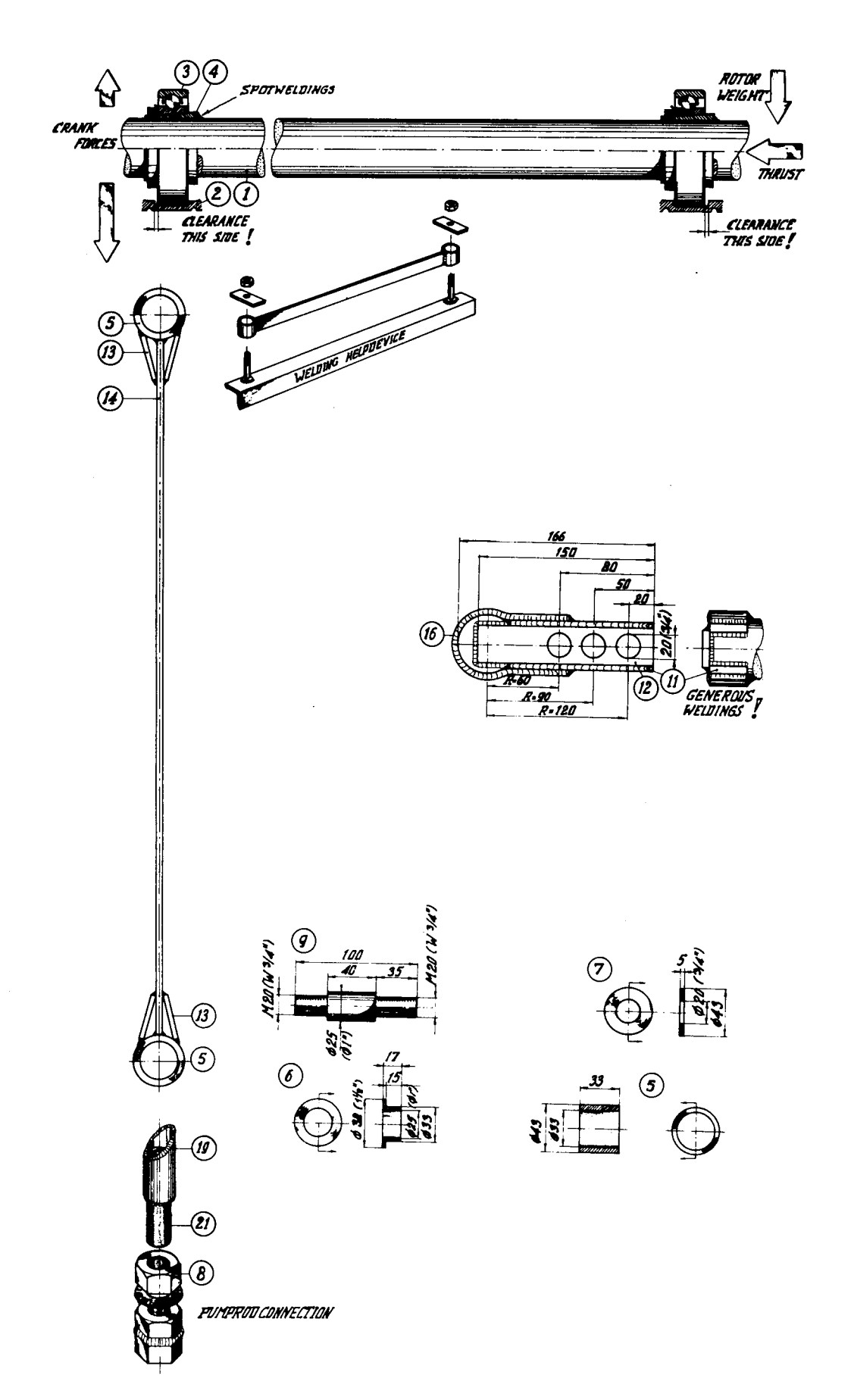
SPOTWELDINGS
CRANK FORCES
ROTOR WEIGHT
THRUST
CLEARANCE THIS SIDE !
CLEARANCE THIS SIDE !
WELDING HELPDEVICE
166
150
80
50
20
20 (3/4")
R=60
R=90
R=120
GENEROUS WELDINGS !
100
40
35
M20 (W 3/4")
M20 (W 3/4")
Ø25 (Ø1")
17
15
Ø 38 (1½")
Ø25
Ø33
5
Ø20 (3/4")
Ø43
33
Ø43
Ø33
PUMPROD CONNECTION

Rotor

No	Number required	Materials, particulars and measurements		
1	12	Blade	4 standard sheets 1000 × 2000 × 1	
2	12	Blade support	2 mm sheet	
3	12	,,	,,	
4	1	Flat iron	30 × 6 (1¼″ × ¼″)	2 × 6000
5	1	,,	,,	2 × 3000
6	6	,,	,,	× 250
7	6	,,	,,	× 1900
8	4	,,	,,	× 120
9	6	Angle iron	40 × 40 × 4 (1½″ × 1½″)	× 1900
10	4	,,	,,	× 100
11	2	,,	,,	× 625
12	2	,,	,,	× 350
13	2	Bolt, nut, washer	M 12 × 125 (W ½″ × 5″)	
14	4	,,	M 12 × 100 (W ½″ × 4″)	
15	120	,,	M 6 × 20 (W ¼″ × ¾″)	

AFTER ASSEMBLING THE
BLADE TIP ANGLE (14.7°)
NEEDS CORRECTION

HELP DEVICE
(1mm SHEET)

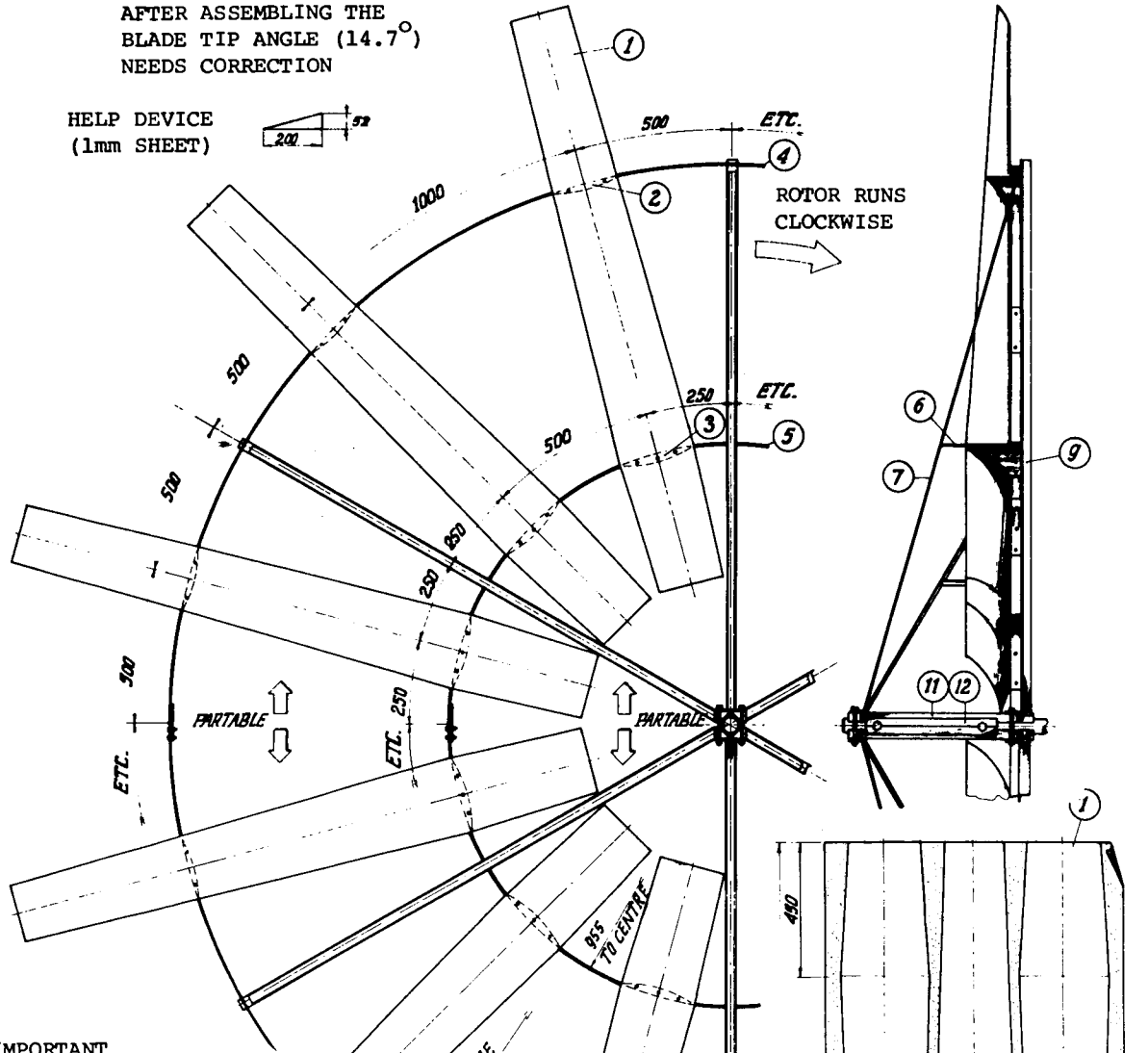

IMPORTANT
ROTOR FRAME IS COMPOSED
ON ITS SHAFT TO PREVENT
'JUMPING & DANCING'
OF SPOKES & RINGS

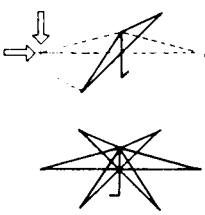

SHAFT &
TWO ROTOR-
HALVES
BELONG
TOGETHER

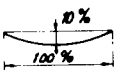

SHEET IS
ROLLED IN
A BENDING
RADIUS OF
APPROX.
300mm. AFTER
CUTTING THE
RADIUS IS
CORRECTED SO
THAT 10% CURVED
AIRFOILS WILL
RESULT

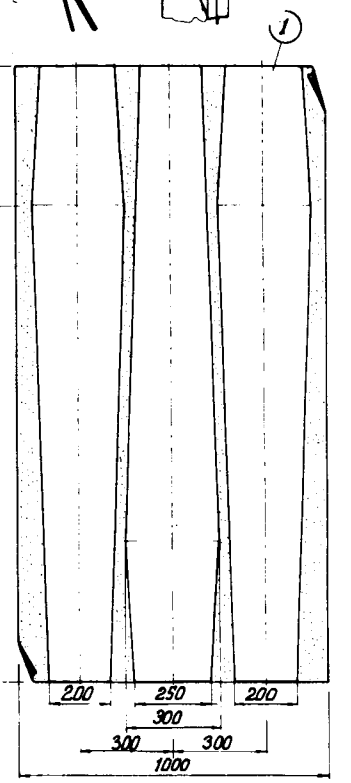

RINGS ARE POSITIONED,
CENTRED AND WELDED

PART No.6
IS WELDED

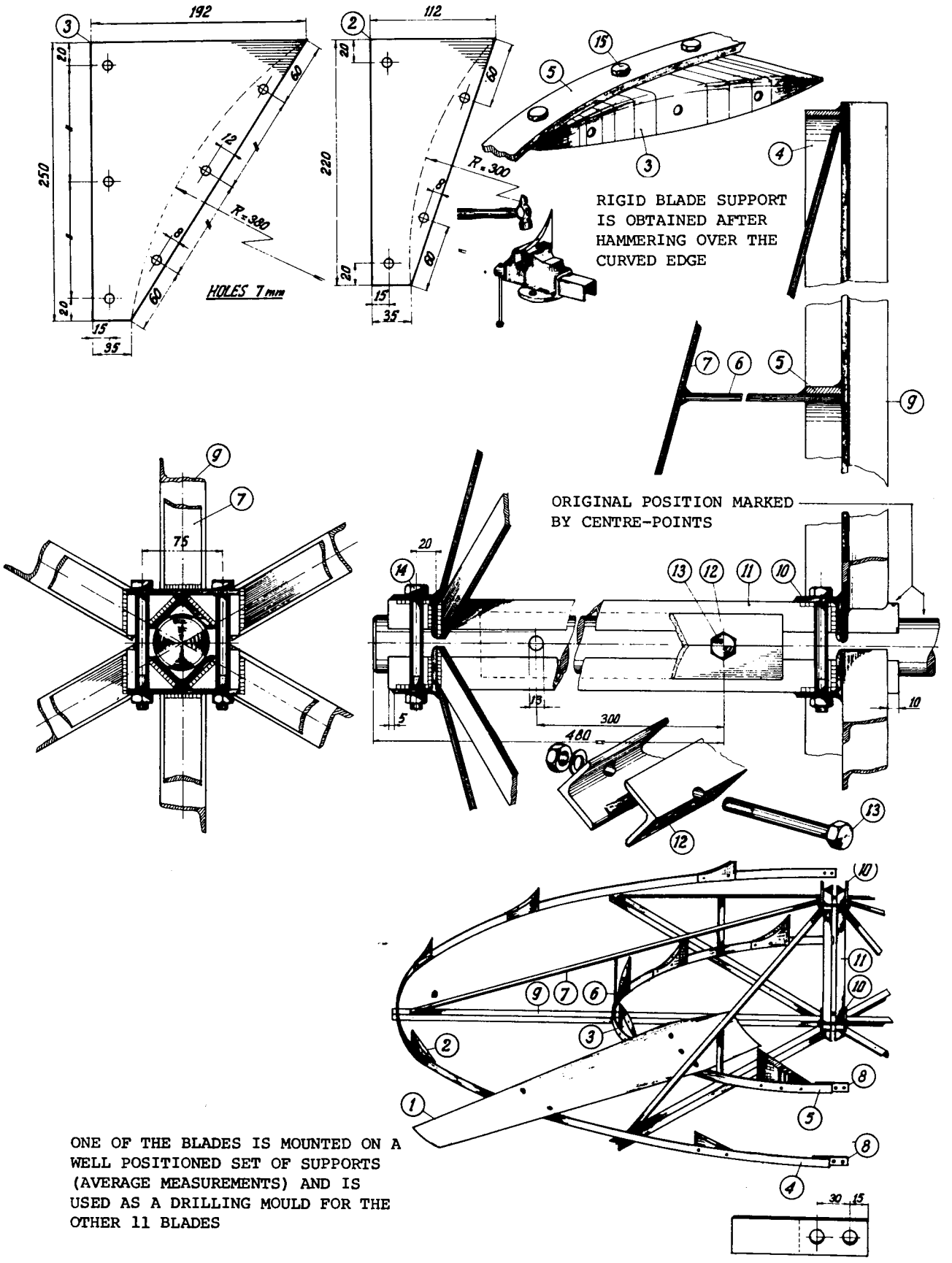

ONE OF THE BLADES IS MOUNTED ON A WELL POSITIONED SET OF SUPPORTS (AVERAGE MEASUREMENTS) AND IS USED AS A DRILLING MOULD FOR THE OTHER 11 BLADES

Piston pump

No	Number required	Materials, particulars and measurements		
1	*	Pump rod extension	ϕ¾″ gaspipe	*
2	1	Wooden pump rod guide: 26 in Fig. 6.14		
3	1	T-socket	4″ gaspipe Length 750	
4	1	Delivery pipe	,,	
5	1	,,	4″ gaspipe or PVC pipe	*
6	*	,,	,,	*
7	1	PVC pipe	ϕ4″ × 700	
8	1	Gaspipe (threaded)	ϕ4″ × 800	
9	*	Steel socket	G 4″	
10	1	PVC end cap		
11	2	Flange (blind):	four 12 mm holes at 190 mm pitch	
12	1	PVC pipe	ϕ150 (ϕ6″) × 1250	
13	1	,,	,, × 740	
14	1	Piston	teakwood	
15	1	PVC socket		
16	1	Foot valve	teakwood	
17	3	Flat iron	25 × 5 (1″ × ¼″)	
18	*	,,	30 × 6 (1¼″ × ¼″)	
19	*	Angle iron	40 × 40 × 4 (1½″ × 1½″)	*
20	2	Sole-leather valve	ϕ150 × at least 6 mm	
21	4	,, packing	ϕ140 × ϕ200 × 4	
22	1	Steel bush		
23	1	Nylon bearing bush		
24	*	Pump rod gaspipe	ϕ¾″ × 1300	
25	*	Thread stud	M 24 (W ⅞″) × 75	
26	*	,,	,, × 150	
27	*	Nut		
28	*	Spring washer		
29	4	Rod	ϕ12 (ϕ½″) × 2100	
30	1	Bolt, nut, washer	M 12 (W ½″) × 150	
31	*	,,	,, × 30	
32	1	Bicycle tube valve	(apply rubber washers)	
33	1	Distancer	steel ϕ50 × 50 (ϕ2″ × 2″)	

** Amount and size depend upon total elevation head*

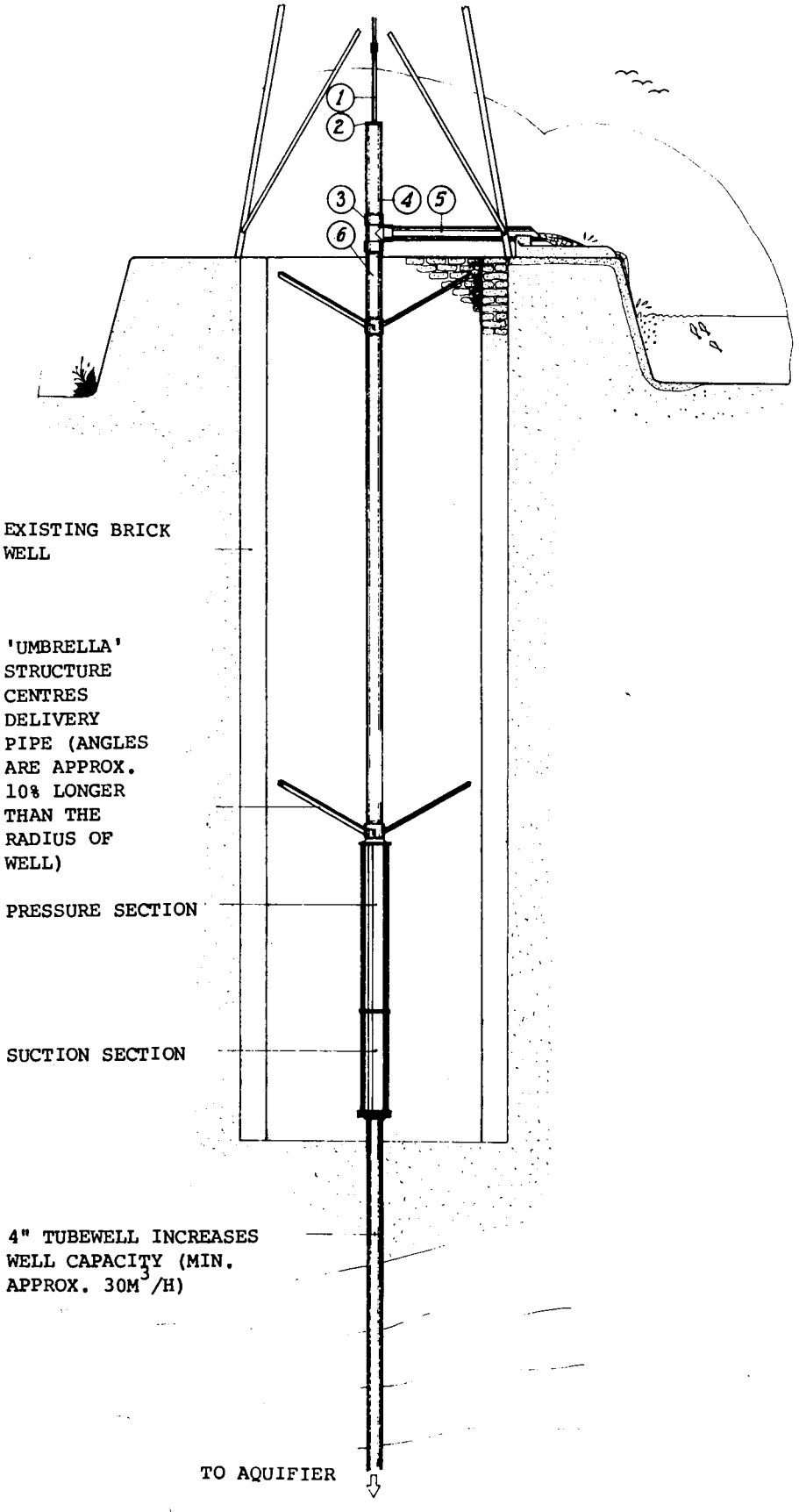
1
2
3
4
5
6
EXISTING BRICK WELL
'UMBRELLA' STRUCTURE CENTRES DELIVERY PIPE (ANGLES ARE APPROX. 10% LONGER THAN THE RADIUS OF WELL)
PRESSURE SECTION
SUCTION SECTION
4" TUBEWELL INCREASES WELL CAPACITY (MIN. APPROX. 30M3/H)
TO AQUIFIER

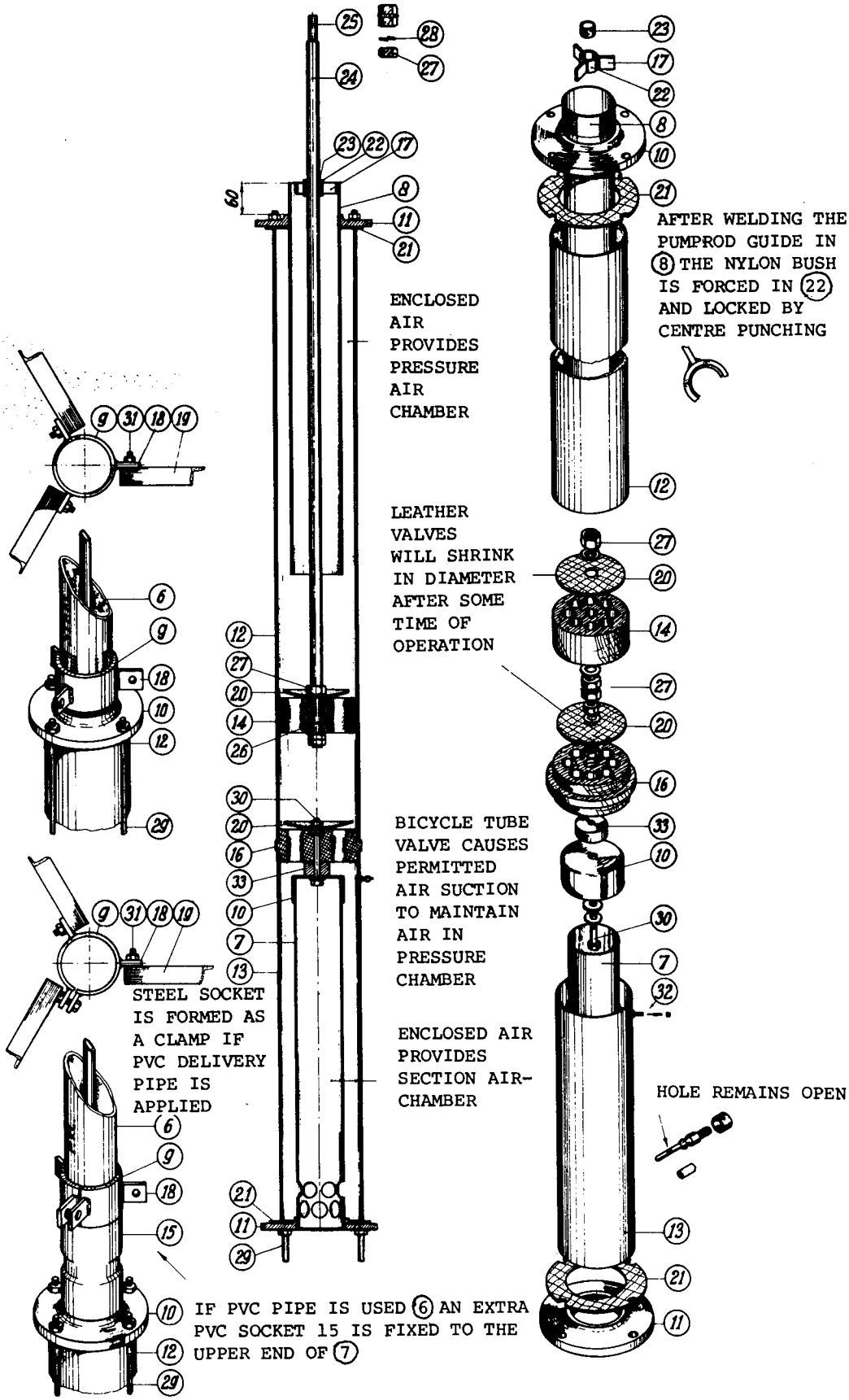
AFTER WELDING THE PUMPROD GUIDE IN (8) THE NYLON BUSH IS FORCED IN (22) AND LOCKED BY CENTRE PUNCHING
ENCLOSED AIR PROVIDES PRESSURE AIR CHAMBER
LEATHER VALVES WILL SHRINK IN DIAMETER AFTER SOME TIME OF OPERATION
BICYCLE TUBE VALVE CAUSES PERMITTED AIR SUCTION TO MAINTAIN AIR IN PRESSURE CHAMBER
ENCLOSED AIR PROVIDES SECTION AIR-CHAMBER
HOLE REMAINS OPEN
STEEL SOCKET IS FORMED AS A CLAMP IF PVC DELIVERY PIPE IS APPLIED
IF PVC PIPE IS USED (6) AN EXTRA PVC SOCKET 15 IS FIXED TO THE UPPER END OF (7)

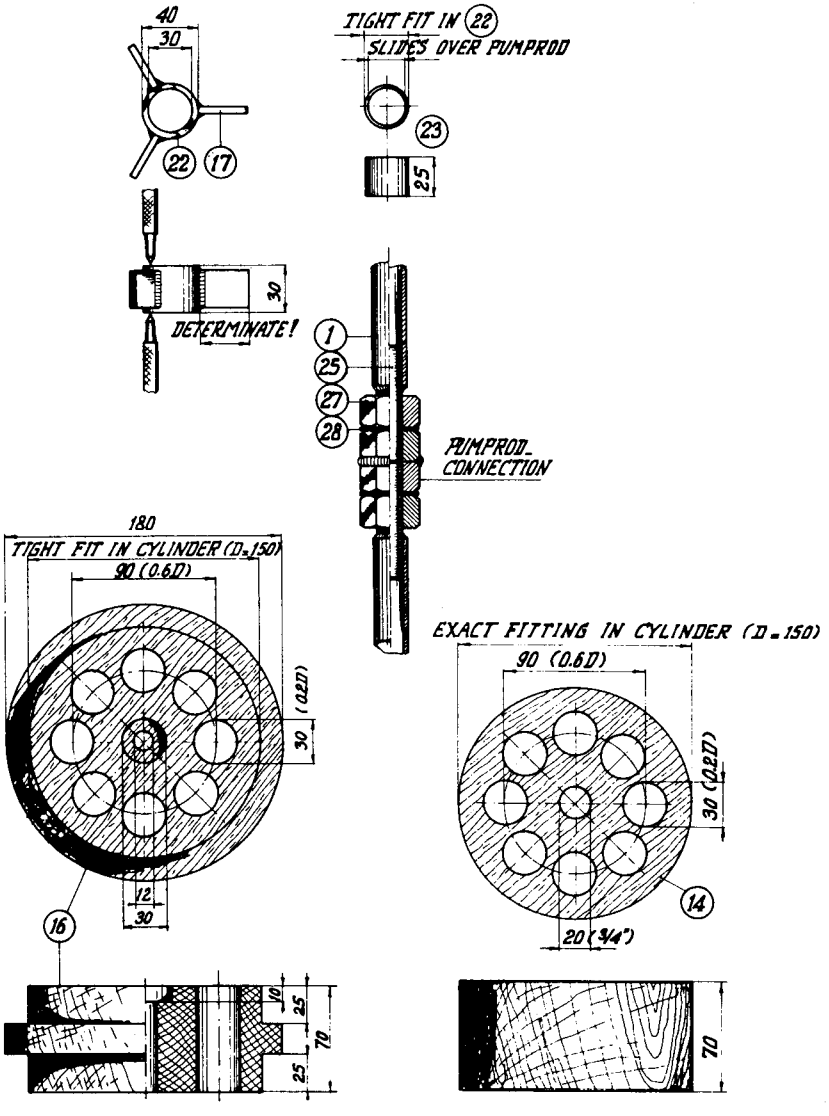

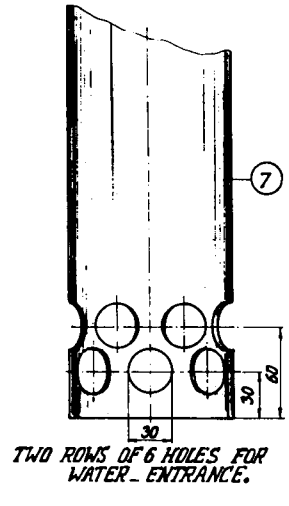

AFTER SOAKING THE WOOD IN WATER FOR AT LEAST ONE WEEK, THE PISTON IS MACHINED TO A PERFECT SLIDING FIT.

THE SEALINGLESS PERFORMANCE DECREASES STARTING TORQUE REQUIRED DUE TO ACCEPTABLE LEAKAGE SO THE WINDMILL BEGINS TO MOVE AT LOW WIND SPEEDS

Installing the windmill

No	Number required	Materials, particulars and measurements		
1	1	Pulley shaft and rope or steel cable (30 M)		
2	1	Gaspipe	ϕ3″ × 4500	
3	2	Angle iron	40 × 40 × 4 (1½″ × 1½″)	× 2000
4	3	,,	,,	× 750
5	1	,,	,,	× 800
6	1	,,	,,	× 200
7	1	,,	,,	× 550
8	3	Flat iron	30 × 6 (1¼″ × ¼″) × 200	
9	1	,,	,, ≙ tower pipe dia.	
10	1	,,	30 × 6 (1¼″ × ¼″) × 100	
11	1	Rod	ϕ10 (ϕ⅜″) × 200	
12	2	Bolt, nut, washer	M 12 × 50 (W ½″ × 2″)	
13	1	,,	M 12 × 150 (W ½″ × 6″)	
14	2	,,	M 12 × 75 (W ½″ × 3″)	

Three methods of transporting the windmill

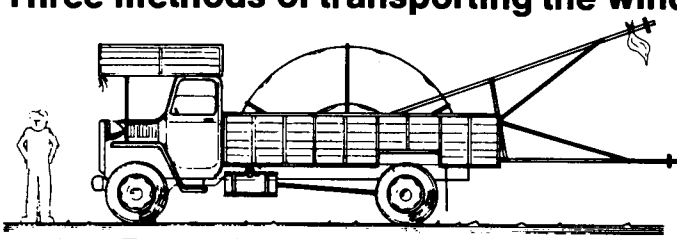

TRANSPORT BY TRUCK

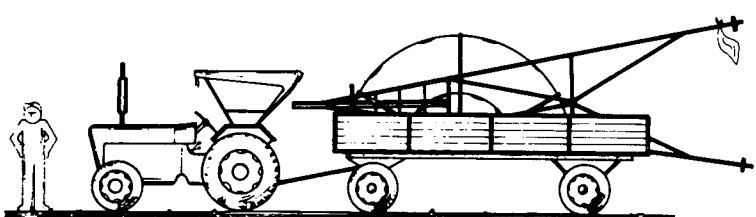

TRANSPORT BY TRACTOR AND LORRY

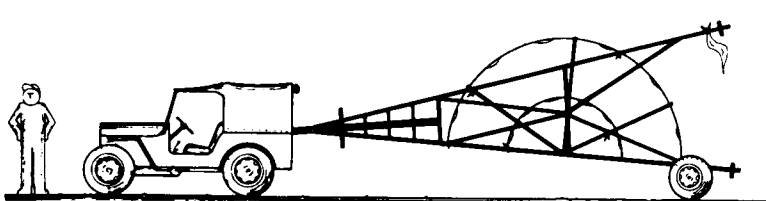

TRANSPORT BY JEEP AND ROLLING HELPDEVICE

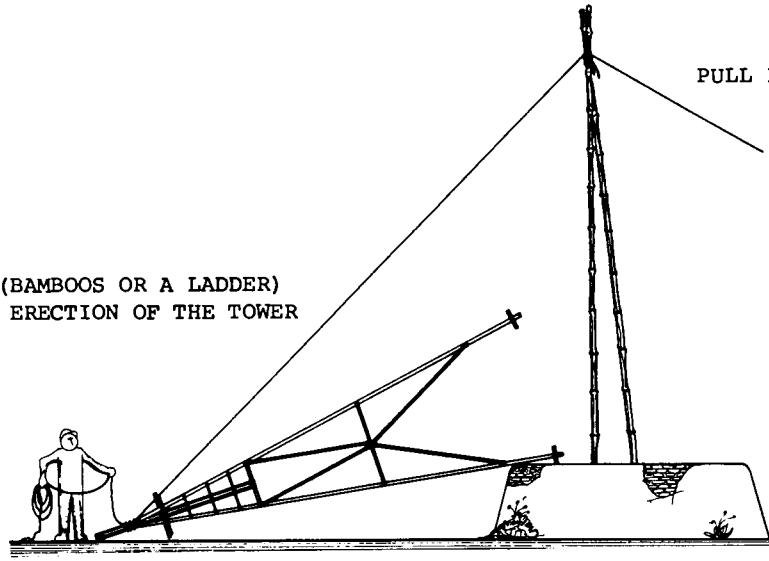

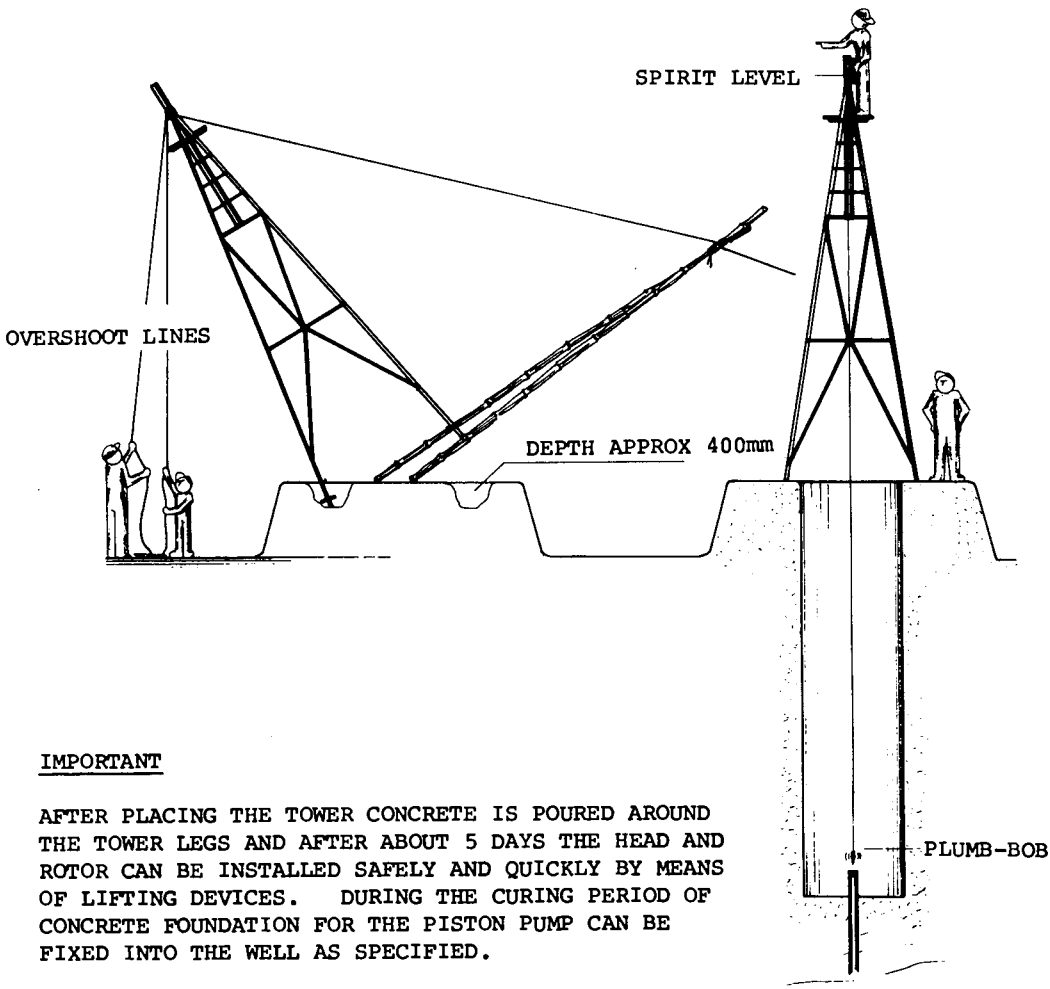

IMPORTANT

AFTER PLACING THE TOWER CONCRETE IS POURED AROUND THE TOWER LEGS AND AFTER ABOUT 5 DAYS THE HEAD AND ROTOR CAN BE INSTALLED SAFELY AND QUICKLY BY MEANS OF LIFTING DEVICES. DURING THE CURING PERIOD OF CONCRETE FOUNDATION FOR THE PISTON PUMP CAN BE FIXED INTO THE WELL AS SPECIFIED.

'JIB' LIFTING HELP-VANE

LIFTING HOOK FOR HEAD CONSTRUCTION

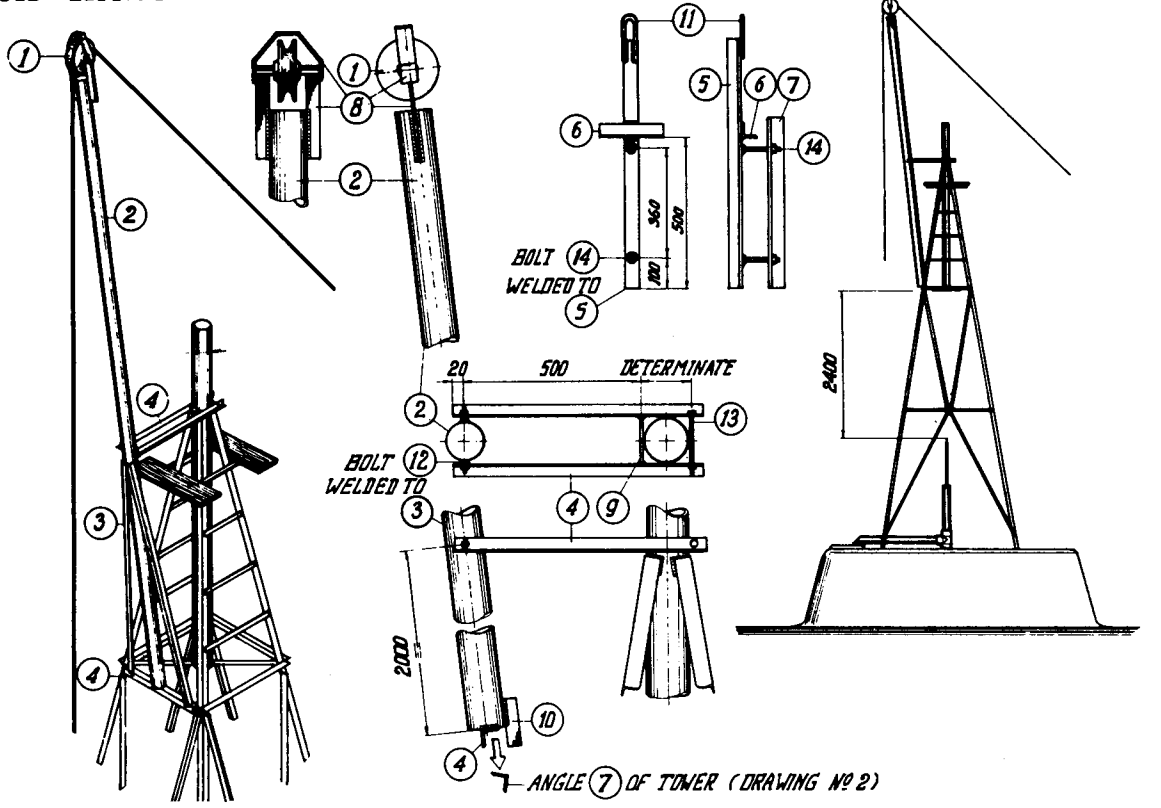

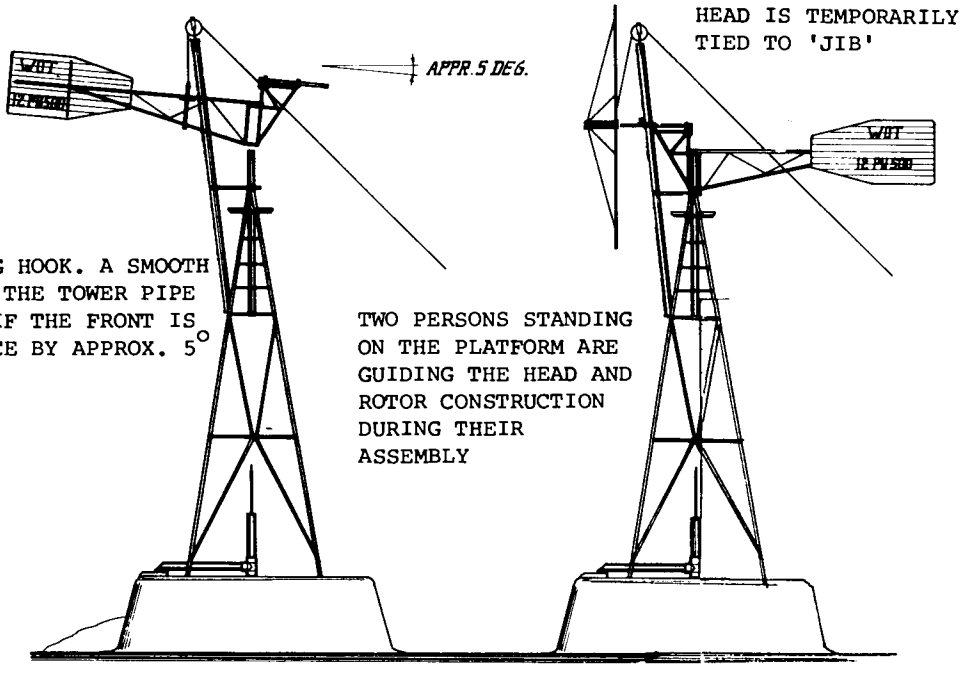

HEAD IS TEMPORARILY TIED TO 'JIB'

USE A LIFTING HOOK. A SMOOTH SLIDING OVER THE TOWER PIPE IS ACHIEVED IF THE FRONT IS OUT OF BALANCE BY APPROX. 5°

TWO PERSONS STANDING ON THE PLATFORM ARE GUIDING THE HEAD AND ROTOR CONSTRUCTION DURING THEIR ASSEMBLY

ROTOR IS LIFTED AND POSITION AT THE TOP OF ITS SHAFT AND SHIFTED IN ITS ORIGINAL POSITION AND FIXED. REMOVE 'JIB' AND ASSEMBLE BLADES, SAFETY DEVICE AND MOVING PARTS.

Irrigation in Saighanchi

Irrigation of reclaimed land near Saighanchi consists of the following:

Windmill constructed in Saighanchi
Australian Southern Cross Pump with check valves and air chambers. Type: Piston, Capacity: 4 litres
Pipeline from the well to the fields, approximate distance 1000 metres. Diameter 50 mm

To irrigate land there has to be an adequate supply of water available. After finding a drinking water supply in the village, we then had to find water for irrigation outside the village. Instead of using drilling rig, we decided to dig a well by traditional methods. The position for the well was determined and a team of professional well-diggers was hired to do the job.

The diggers continued digging for a few days and, at about three metres below the ground, water began to seep through the walls of the well. Once the water was discovered, the diggers did not dig any deeper. However, for our purpose, the water discharged was not sufficient, so we obtained a motor-driven pump to enable us to dig deeper. As the villagers dug deeper, the pump kept the well dry enough to enable them to dig to a depth of six metres. At this point the inflow of water was so great that the motor pump could not keep up with it. We now had sufficient water to irrigate as much land as we wanted to, and our only limitation was that we had only one windmill and pump.

The walls of the well were secured by lining it with concrete pipes of 900 mm diameter which were manufactured on the site.

The windmill was sited adjacent to the well with the tower located above the perimeter of the stone wall housing the pump, which was located directly under the windmill. The pump inlet consisted of a 50 mm diameter galvanised iron pipe with a check valve at the bottom end. The pipe reached a depth of five metres into the well.

The piston pump was fitted with two air chambers, one on the inlet side and the other on the outlet side, to ensure maximum water output. The outlet was then connected to the pipeline with a check valve in between.

The pipeline, 50 mm in diameter, was buried underground and climbs to a height of eighteen metres within a length of about 350 metres. From that point onward the pipeline was laid on a slope of about two metres in 650 metres, being the remaining distance to the fields. The total length of the pipeline was about 1000 metres, mostly buried underground with a minimum depth of one metre. Where the pipeline could not be buried, when crossing the road through a bridge and a culvert, galvanised iron pipes were used. The remaining pipeline was made from PVC with a diameter of 50 mm. At the terminal, on the edges of the fields, there are five outlets to enable controlled irrigation of plots as required.

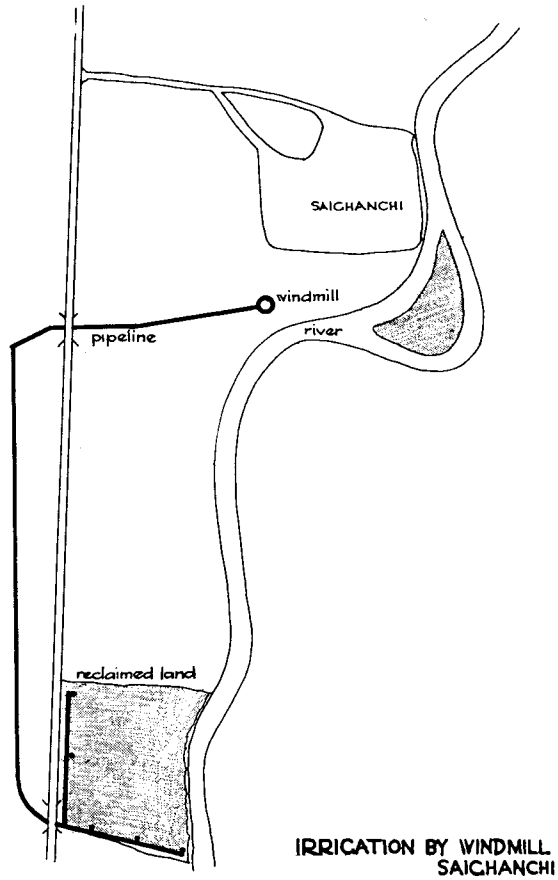

Fig. 6.24

Plate 51 *Laying the pipeline*

let us consider the design, development and production of windmills. The windmills as produced in industrialised countries use high technology, requiring well-developed associated technologies to assist the design. Some of the complex blades used in certain windmills are actually the result of complicated computor programmes, complex materials and sophisticated presses to fashion the shapes. It would be inappropriate to introduce to a developing country a technology which is either static, or too advanced for manufacture in the country. In other words, a starting point has to be established which is compatible with technological skills available in the country at that particular time, so that as and when the country acquires high technology, a linkage can be readily created whereby products or equipment are naturally and automatically improved through the use of that high technology. The drawings supplied in Figures 6.8 to 6.23 for the manufacture of windmills take into account that 'starting point', fully utilising available skills and technology, while leaving ample room for further development and improvement.

The windmill designated 12 PU 500 Windmill for Irrigation has been designed by Niek van de Ven for the Working Group on Development Technology (WOT), Twente University of Technology, Vrijhof 152, P.O. Box 217, 7500 AE ENSCHEDE, The Netherlands. Any technical assistance or further information needed will be gladly supplied by the Working Group on request.

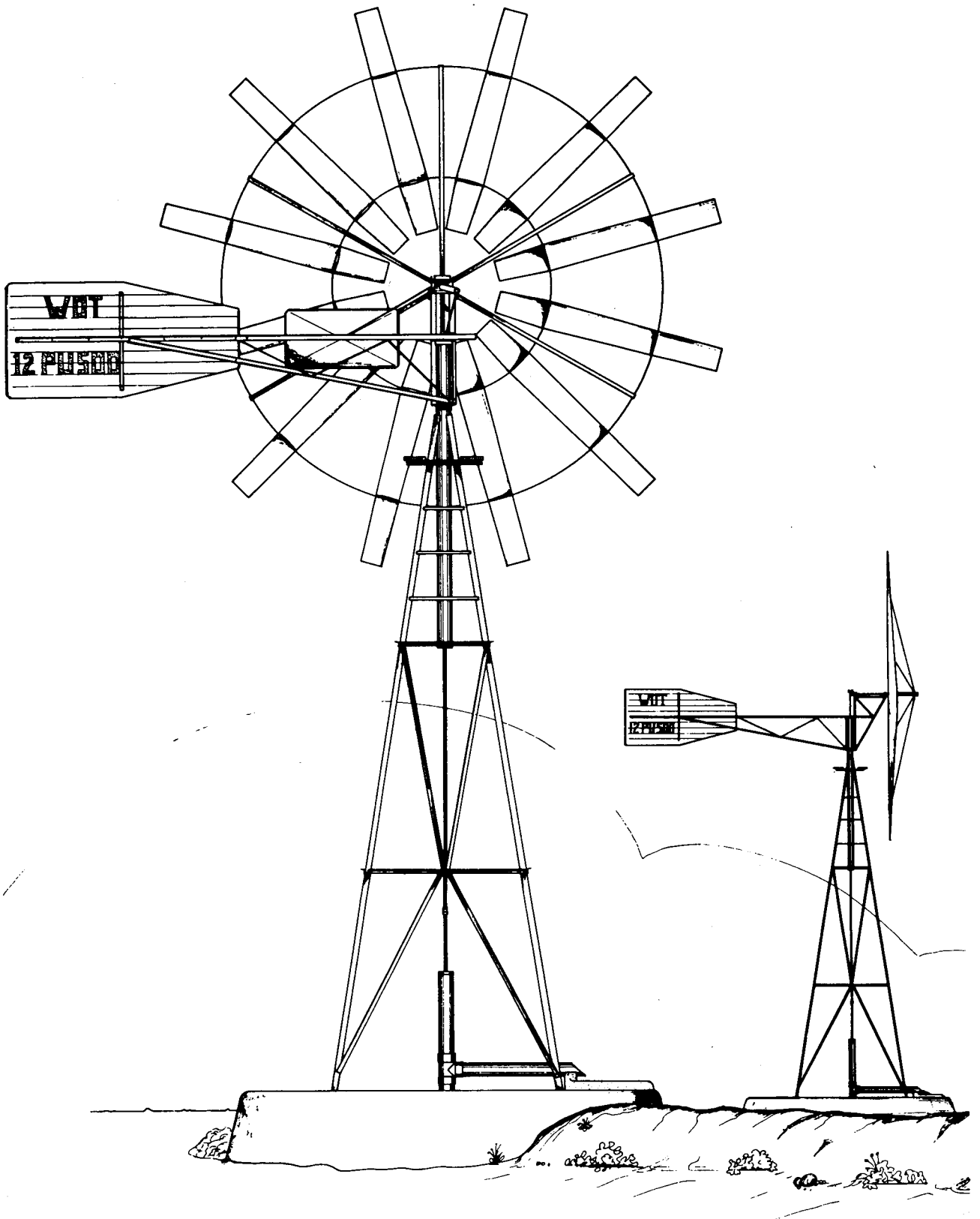
WBT
12 PU500
WBT
12 PU500

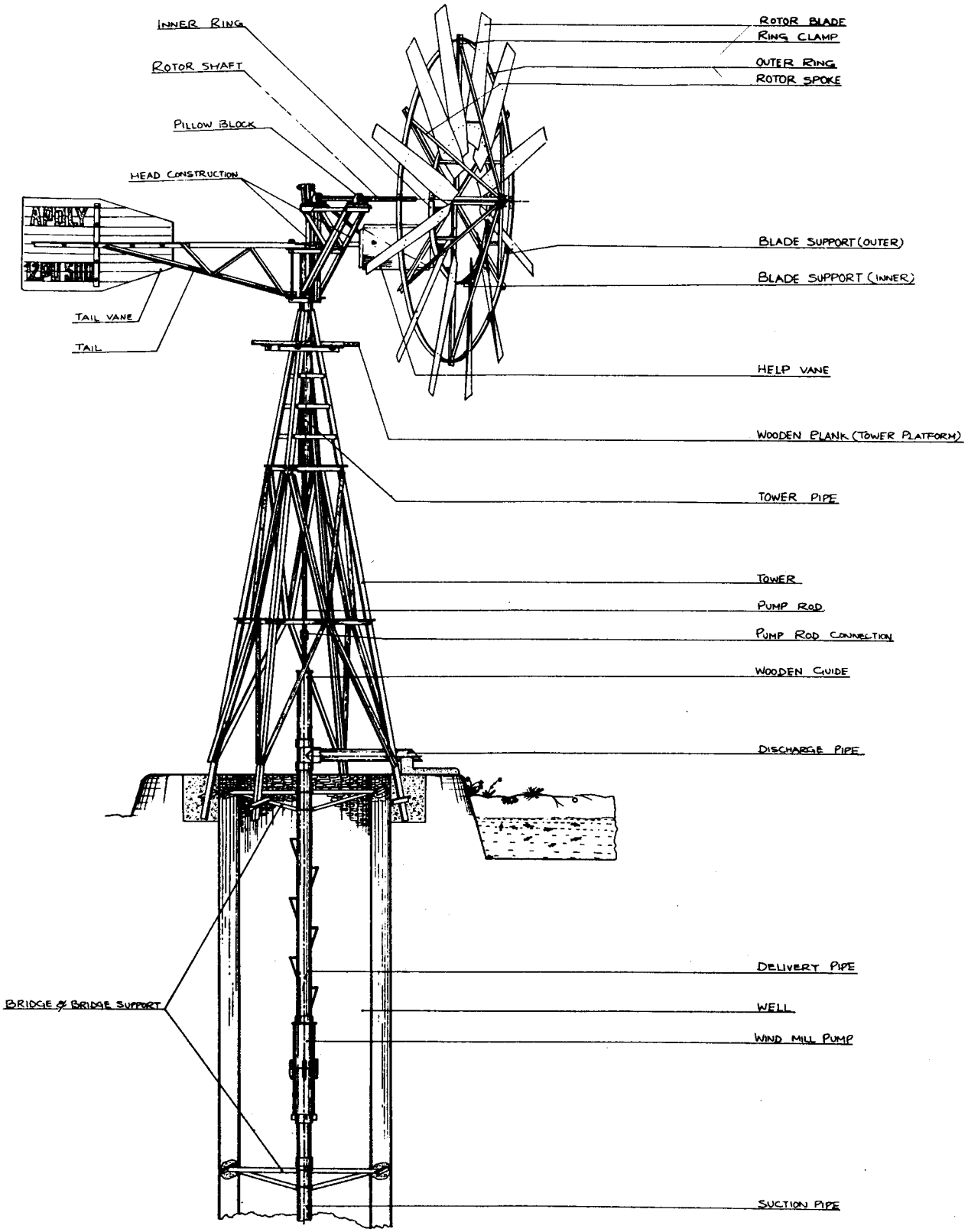

Fig. 5 12 P U 500 Water Pumping Windmill

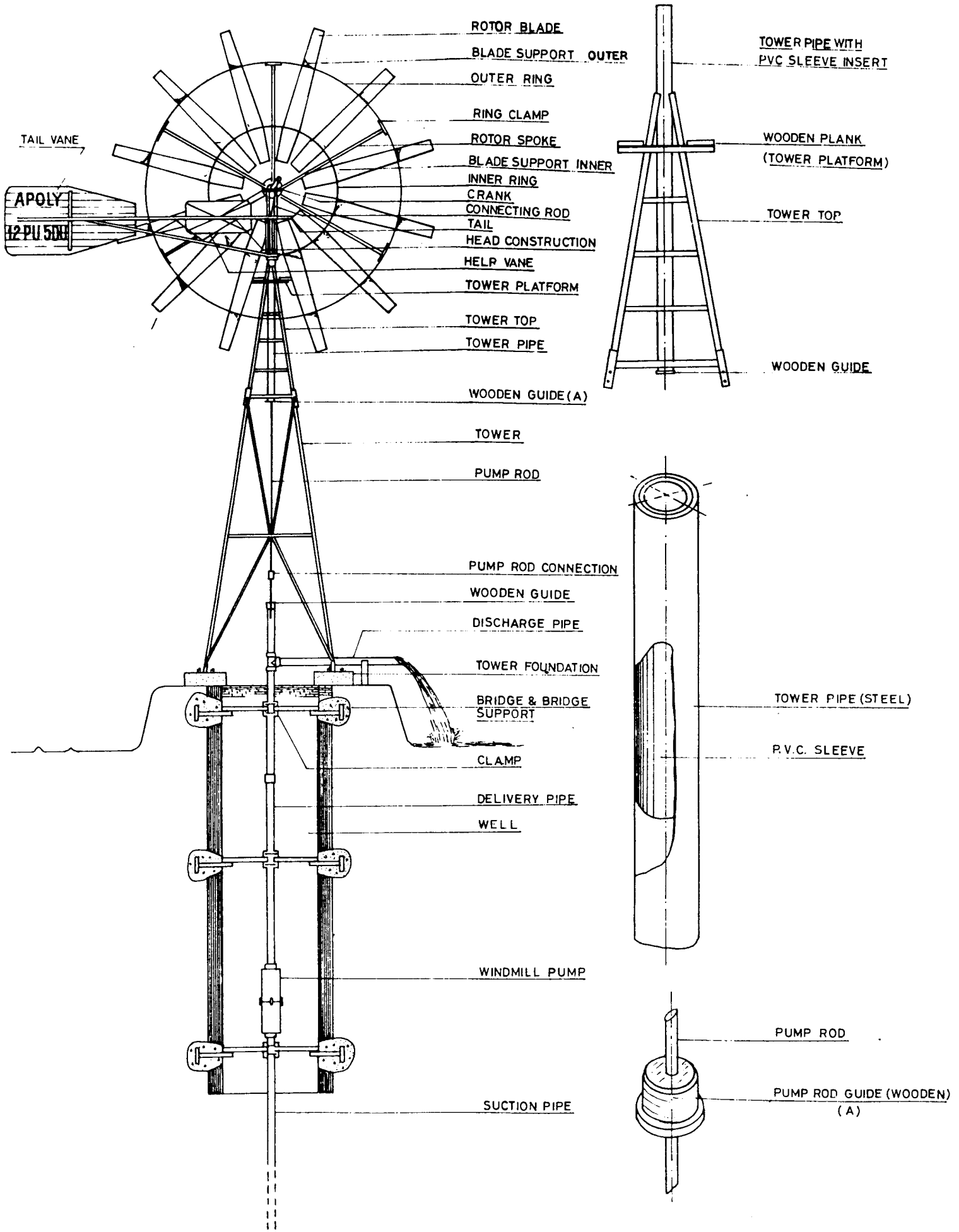
ROTOR BLADE
BLADE SUPPORT OUTER
OUTER RING
RING CLAMP
ROTOR SPOKE
BLADE SUPPORT INNER
INNER RING
CRANK
CONNECTING ROD
TAIL
HEAD CONSTRUCTION
HELP VANE
TOWER PLATFORM
TOWER TOP
TOWER PIPE
WOODEN GUIDE (A)
TOWER
PUMP ROD
PUMP ROD CONNECTION
WOODEN GUIDE
DISCHARGE PIPE
TOWER FOUNDATION
BRIDGE & BRIDGE SUPPORT
CLAMP
DELIVERY PIPE
WELL
WINDMILL PUMP
SUCTION PIPE
TAIL VANE
APOLY
12 PU 500
TOWER PIPE WITH PVC SLEEVE INSERT
WOODEN PLANK (TOWER PLATFORM)
TOWER TOP
WOODEN GUIDE
TOWER PIPE (STEEL)
P.V.C. SLEEVE
PUMP ROD
PUMP ROD GUIDE (WOODEN) (A)

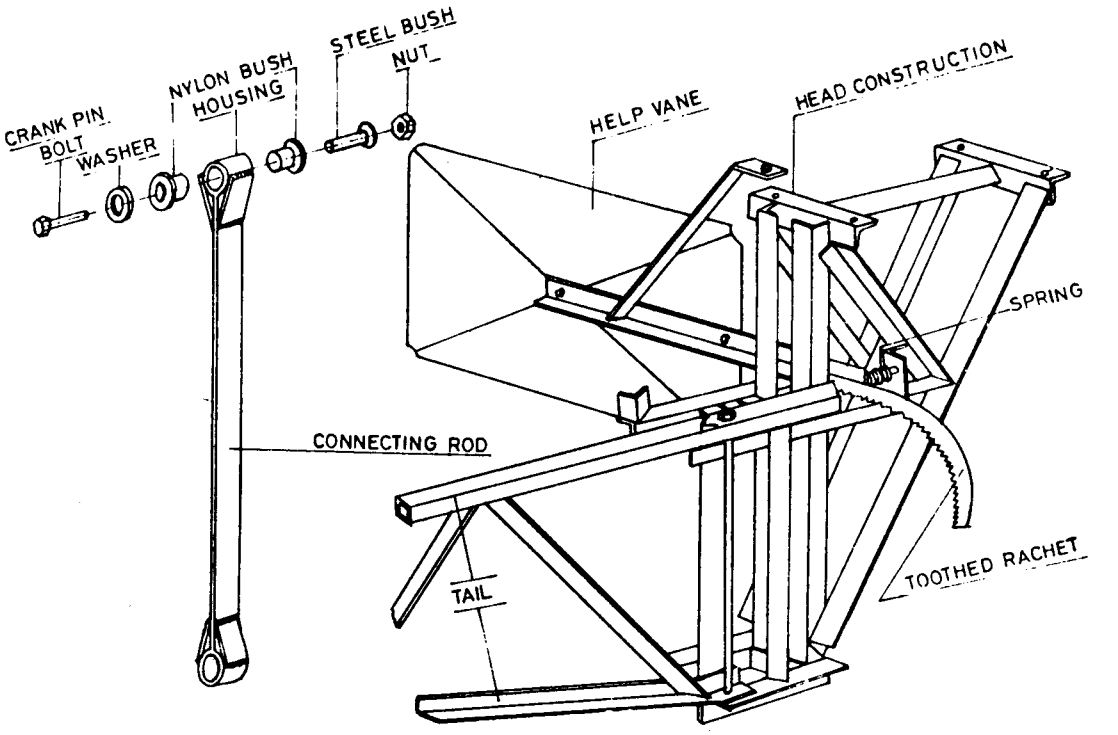

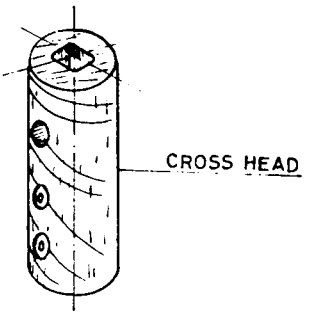

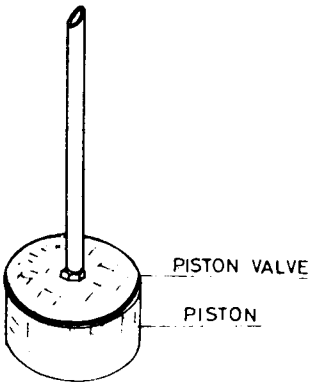

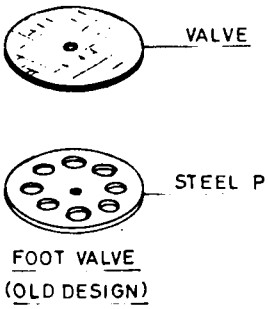

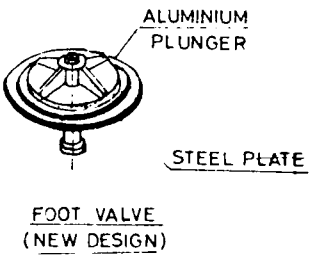

SCHEMATIC OF

12 PU 500 WATER PUMPING WINDMILL

INSTALLATION

WIND ENERGY R & D CENTRE
INSTITUTE OF ENGG. & RURAL TECHNOLOGY

ALLAHABAD
211002

7. Guidelines for Site Selection for 12-PU-500 Water Pumping Windmill

GUIDELINES FOR SITE SELECTION

7.0 General

Water pumping windmills can be installed on an open well, a tube well, or near a canal, stream, pond, creak etc.

7.1 Surroundings of the Site

Taking the site as the centre there should not be any obstacle of more than 4 meter high height within an area of 100 m radius. If any such obstacle is there it should be cleared before the installation of the windmill. Alternatively, the height of the tower has to be increased suitably.

7.2 Well and Boring

(a) If the diameter of the well is not small enough to accommodate "tower leg pitch", some modification has to be carried out in the tower design. In case the well is of a larger diameter than the tower, the legs have to be increased in length. Two legs then will be supported over a steel bridge or a ginder spanning over the well and the remaining two legs will be outside the well.

(b) The well should be in proper condition, otherwise repairs in the masonry work and cleaning of the well should be carried out before the installation.

(c) The refilling capacity of the well should be about 25 cubic metre/hr. otherwise cleaning/ boring of well has to be done. If it is a cavity boring, it should be cleaned preferably by compressor unit so as to achieve a discharge rate not less than 35 cubic metre/hr.

(d) When the installation has to be done over a borewell, a masonry pit is prepared. The diameter of the pit may be 1.5 m, and its depth shall be the same as spring water level below the ground.

(e) The total head over which the water is to be pumped should preferably be within 15 m and not more than 20m in any case.

7.3 Water Storage Tank

Before the construction of water storage tank near the windmill, it is necessary to test or evaluate the soil characteristics, specially its permeability. This will help in deciding whether the tank be an earthen one or lined by a suitable material.

A proforma has been designed to collect relevant site information to select a suitable installation site.

7.4 Proforma for Site Selection

1. (i) Name and address of the organisation. .....

   (ii) Name and address of the representative of the organisation. .....

2. Exact location of the place where the windmill is to be erected .....

3. End use of the windmill

   (a) If drinking water supply, population to be served .....

   (b) If minor irrigation, cultivated area in hectares with cropping pattern .....

   (c) If brine pumping, quantity of salt water to be pumped in litres. .....

4. Distance of the windmill site from the collaborating organisation (please mention the details of the route to the windmill site. .....

5. Surroundings of the site :

   (a) Obstacle, if any, within metre radius (taking site as centre) :

      (i) Nature of the obstacle .....

      (ii) Distance of the obstacle from the windmill site .....

      (iii) Height of the obstacle .....

   (b) Whether it can be removed or not .....

   (c) Whether it should be removed or not (considering main wind direction) .....

6. Available sources for water pumping

Open well/pond/river/sea/tube well/ canal/any other. .....

(a) If open well -

(i) Inside diameter/size/depth Please give dimensions A,B,C,D,E and F on figure 7. .....

(ii) Average depth of water table in summer season .....

(iii) Average depth of water table in rainy season .....

(iv) Refilling capacity of well/tube well .....

(v) Whether the capacity can be increased or not .....

(b) If bore well -

(i) Depth of boring .....

(ii) Size of tube well .....

(iii) Position of the boring at the centre/out of centre .....

(iv) Age of the boring/well .....

(v) Whether the boring has been cleaned. .....

(vi) Date of boring .....

Type of system used for cleaning. .....

(vii) Vertical distance between the top of bore pipe and the water table. .....

(ix) Height of the boring pipe above water level. .....

In rainy season .....

In summer season .....

Approximate value of soil bearing capacity of the soil .....

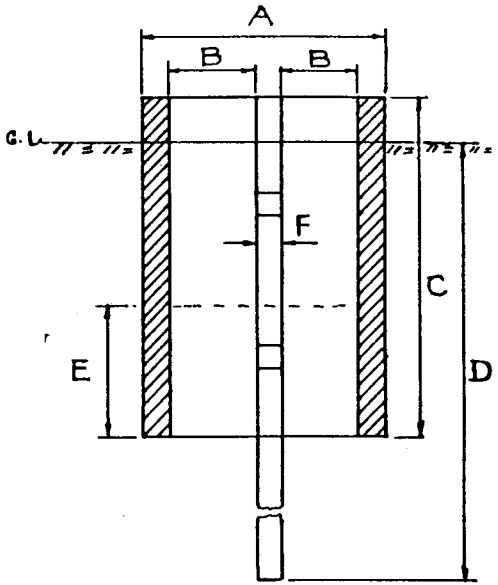

Fig. 7 Dimensions of Well and boring to be measured and recorded

8. Approximate value of soil permeability (in view of water retention in storage tank built at the ground level) .....

9. Whether auxiliary structures are to be made in view of windmill errection like masonry pit boring in the open well, special foundation for the tower legs open wells or some odd situation .....

10. Further details, if any .....

11. Remarks .....

Signature of representative of organisation

Signature with seal of head of organisation.

8.0 Installation
12-PU-500
Water Pumping Windmill

INSTALLATION OF WINDMILL:

8.1 General

The following windmill parts are supposed to be prefabricated: tower, head construction, moving parts, rotor frame and blades, and the pump section. In addition to these, some more essential steps to be taken are listed here. First of all the parts are composed partly in order the check the fit. The head construction may be put on the tower to find out if it rotates smoothly over the crosshead and the connecting rod. The fit of some blades is also to be checked (at random). Until and unless these checks are confirmed the windmill is not ready for transport. Another important thing with regard to windmill installation should not be forgotten. Help devices like the jib crane and lifting hook, which are represented in the drawing, are not only helpful but are a must from the safety point of view.

The use of the jib crane is really necessary for lifting the head construction and rotor both. While fabricating the jib crane care should be taken to see that the pulling rope runs nicely in the pulley and cannot run off:

The lifting hook is a help device which provides a suitable attachment to the head construction which is situated above the point of gravity of the latter. One can imagine what happens if no lifting hook is applied: the head construction tumbles over and nobody will be able to handle it during the procedure of lifting and installing it.

8.2 Tools & tackle required during installation:

1.	Spirit level	1
2.	Plumb with 20 m fisher nets string	1
3.	Steel tape (15 metre)	1
4.	Manila rope 1½" x 30 metre long	one
5.	Manila rope 3/4" x 20 metre long	one
6.	Mason's tool kit set	one set
7.	Jib crane	1
8.	Winch and wire rope 20 metres long x ½" or (chain pulley with chain 1½" size x 20 metres long)	one
9.	Chain wrench (4" pipe size)	1
10.	Chain wrench (4" B.S.P. pipe size)	2
11.	Pipe wrench (2" pipe size)	1
12.	Ball pin hammer 2 lb. with handle	1
13.	Hand hacksaw with 6 spare blades	1
14.	Double ended spanner set	1 set
15.	Ring spanner set	1 set
16.	Adjustable slide wrench 12" long	1
17.	Bastered double cut flat file 12"	1
18.	Round file rough 10" x 3/8" Dia.	1
19.	Wood file 12"	1
20.	Small grease gun	1

21.	Chisel 6" (Flat)	1
22.	Water Pump Plier	1
23.	Screw Driver 6"	1
24.	Screw driver 8"	1
25.	Centre Punch	1
26.	Hand drill with drilling capacity 1/2" Dia.	1
27.	Drill bits (Straight Shank) 1/2"	1
28.	Drill bits 3/8" Dia.	3
29.	Drill bits 5/8" Dia. with reduced shank	1

* Hand tools should be of standard make such as Gedore, Taparia, Everest or equivalent.

8.3 Illustration showing the position of Tower Foundation Bolts. (Refer. Fig. 8)

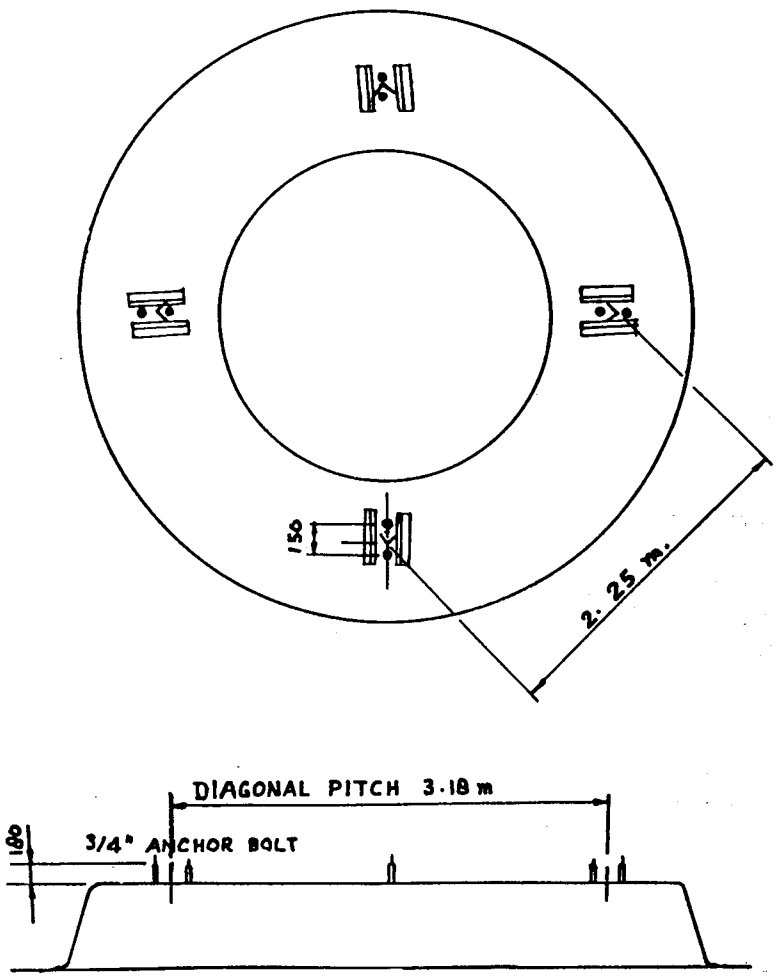

Fig. 8 Position of Tower Foundation Bolt

8.4 Details of Infra-structure to be prepared before the erection of the windmill. (Refer Fig. 9, 10 & 11)

8.5 Details of Sub-structure and Puca alignment fixture of 12-PU-500 Water Pumping Windmill (Refer Fig. 12)

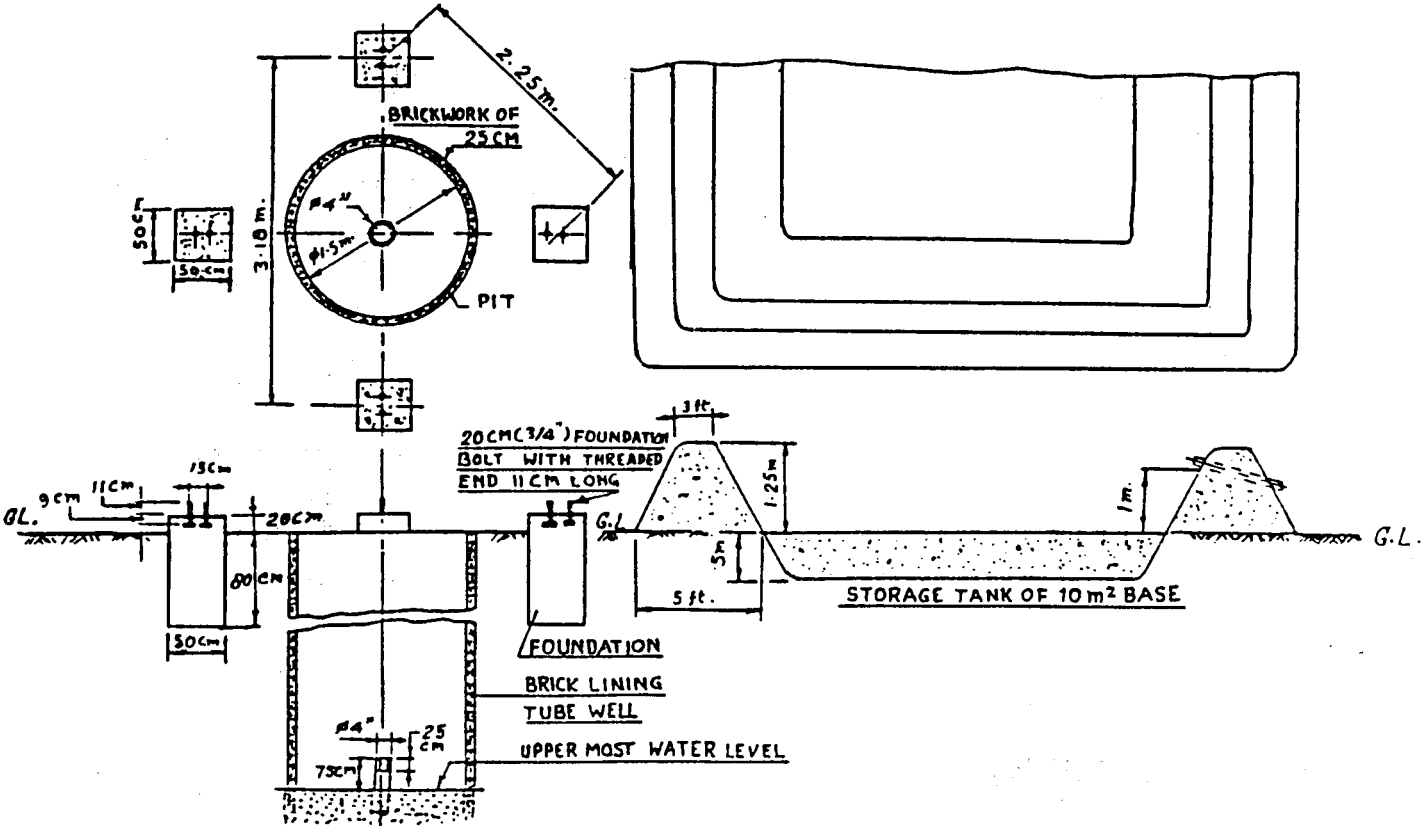

Fig. 9 Details of infrastructure to be prepared before erection of windmill

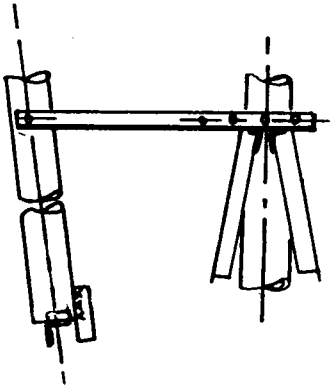

Fig. 10

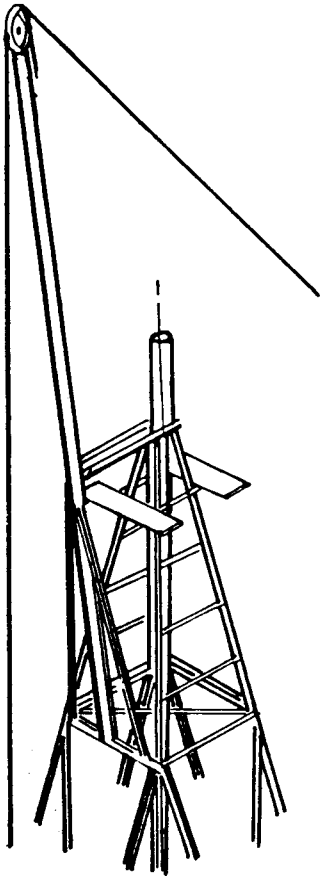

Fig. 11

Fixing of Jibcrane on the Tower

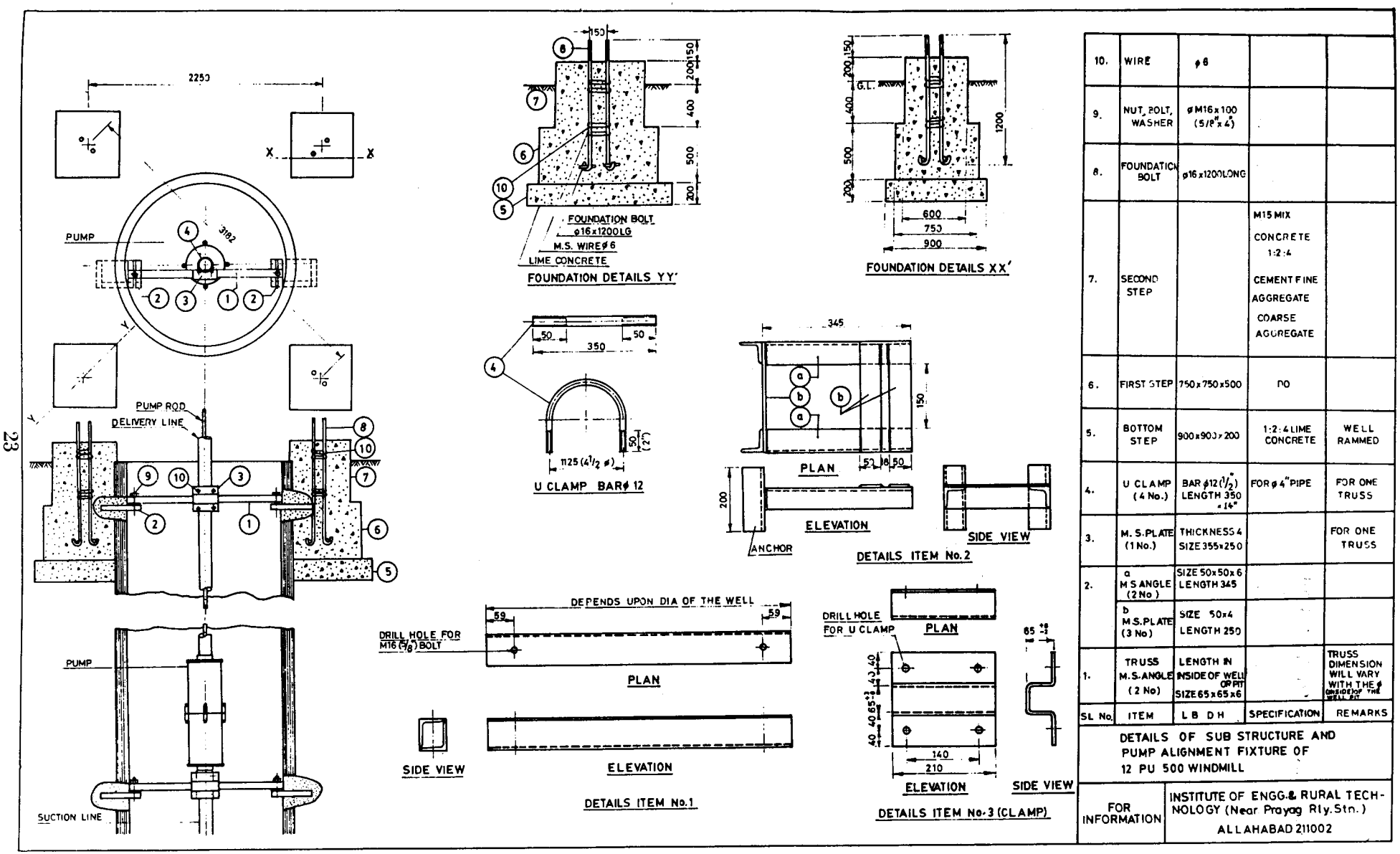

SL No.	ITEM	L B D H	SPECIFICATION	REMARKS
10.	WIRE	ø 6		
9.	NUT, BOLT, WASHER	ø M16 x 100 (5/8" x 4")		
8.	FOUNDATION BOLT	ø16 x 1200 LONG		
7.	SECOND STEP		M15 MIX CONCRETE 1:2:4 CEMENT FINE AGGREGATE COARSE AGGREGATE	
6.	FIRST STEP	750 x 750 x 500	DO	
5.	BOTTOM STEP	900 x 900 x 200	1:2:4 LIME CONCRETE	WELL RAMMED
4.	U CLAMP (4 No.)	BAR ø12 (1/2") LENGTH 350 x 14"	FOR ø 4" PIPE	FOR ONE TRUSS
3.	M. S. PLATE (1 No.)	THICKNESS 4 SIZE 355 x 250		FOR ONE TRUSS
2.	a M S ANGLE (2 No)	SIZE 50 x 50 x 6 LENGTH 345		
	b M.S. PLATE (3 No)	SIZE 50 x 4 LENGTH 250		
1.	TRUSS M.S. ANGLE (2 No)	LENGTH IN INSIDE OF WELL OR PIT SIZE 65 x 65 x 6		TRUSS DIMENSION WILL VARY WITH THE ø OR SIDE OF THE WELL PIT

DETAILS OF SUB STRUCTURE AND PUMP ALIGNMENT FIXTURE OF 12 PU 500 WINDMILL

FOR INFORMATION

INSTITUTE OF ENGG.& RURAL TECHNOLOGY (Near Prayag Rly.Stn.)
ALLAHABAD 211002

Fig. 12

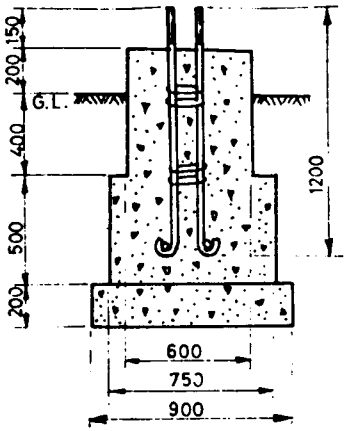

FOUNDATION DETAILS XX'

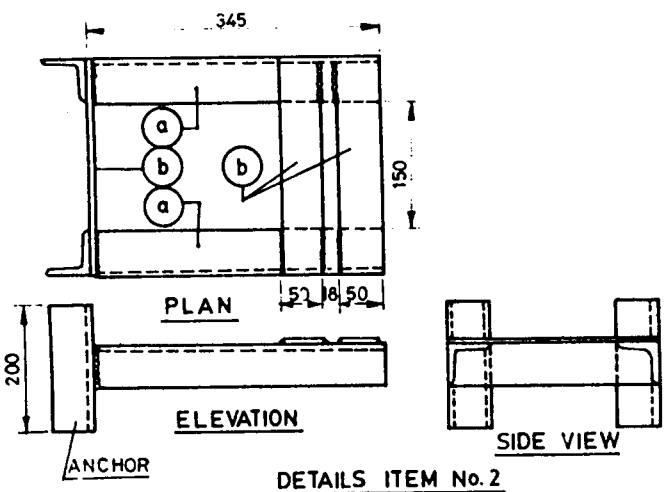

DETAILS ITEM No. 2

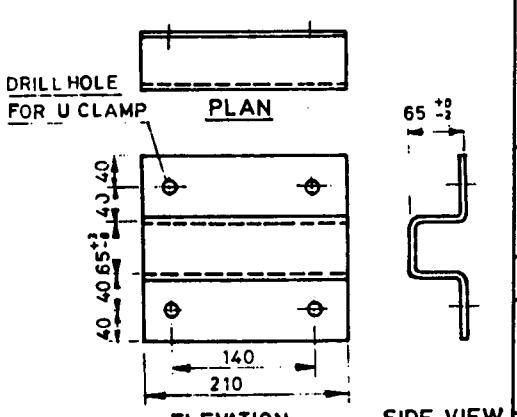

DETAILS ITEM No. 3 (CLAMP)

SL No.	ITEM	L B D H	SPECIFICATION	REMARKS
10.	WIRE	ϕ 6		
9.	NUT, BOLT, WASHER	ϕ M16 x 100 (5/8" x 4")		
8.	FOUNDATION BOLT	ϕ16 x 1200 LONG		
7.	SECOND STEP		M15 MIX CONCRETE 1:2:4 CEMENT FINE AGGREGATE COARSE AGGREGATE	
6.	FIRST STEP	750 x 750 x 500	DO	
5.	BOTTOM STEP	900 x 900 x 200	1:2:4 LIME CONCRETE	WELL RAMMED
4.	U CLAMP (4 No.)	BAR ϕ12 (1/2") LENGTH 350 = 14"	FOR ϕ 4" PIPE	FOR ONE TRUSS
3.	M. S. PLATE (1 No.)	THICKNESS 4 SIZE 355 x 250		FOR ONE TRUSS
2.	a M S ANGLE (2 No)	SIZE 50 x 50 x 6 LENGTH 345		
	b M.S. PLATE (3 No)	SIZE 50 x 4 LENGTH 250		
1.	TRUSS M.S. ANGLE (2 No)	LENGTH IN INSIDE OF WELL OR PIT SIZE 65 x 65 x 6		TRUSS DIMENSION WILL VARY WITH THE ϕ (INSIDE) OF THE WELL PIT

DETAILS OF SUB STRUCTURE AND PUMP ALIGNMENT FIXTURE OF 12 PU 500 WINDMILL

FOR INFORMATION	INSTITUTE OF ENGG. & RURAL TECHNOLOGY (Near Prayag Rly. Stn.) ALLAHABAD 211002

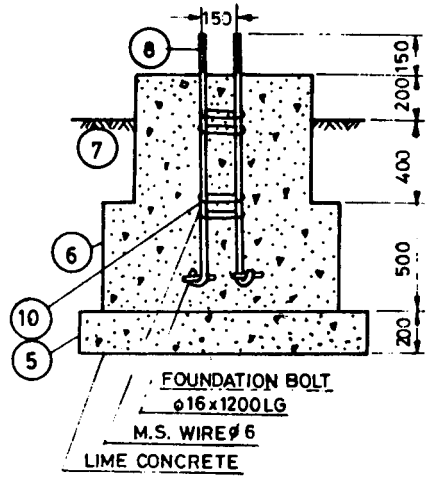

FOUNDATION DETAILS YY'

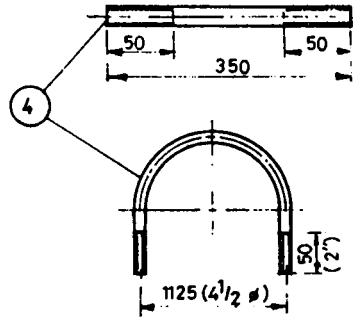

U CLAMP BAR ϕ 12

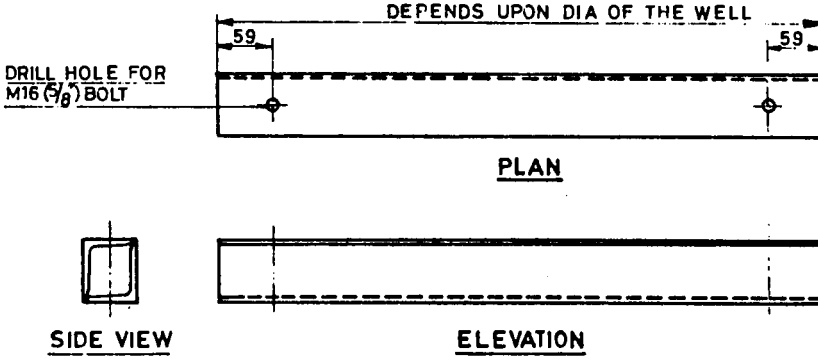

DETAILS ITEM No.1

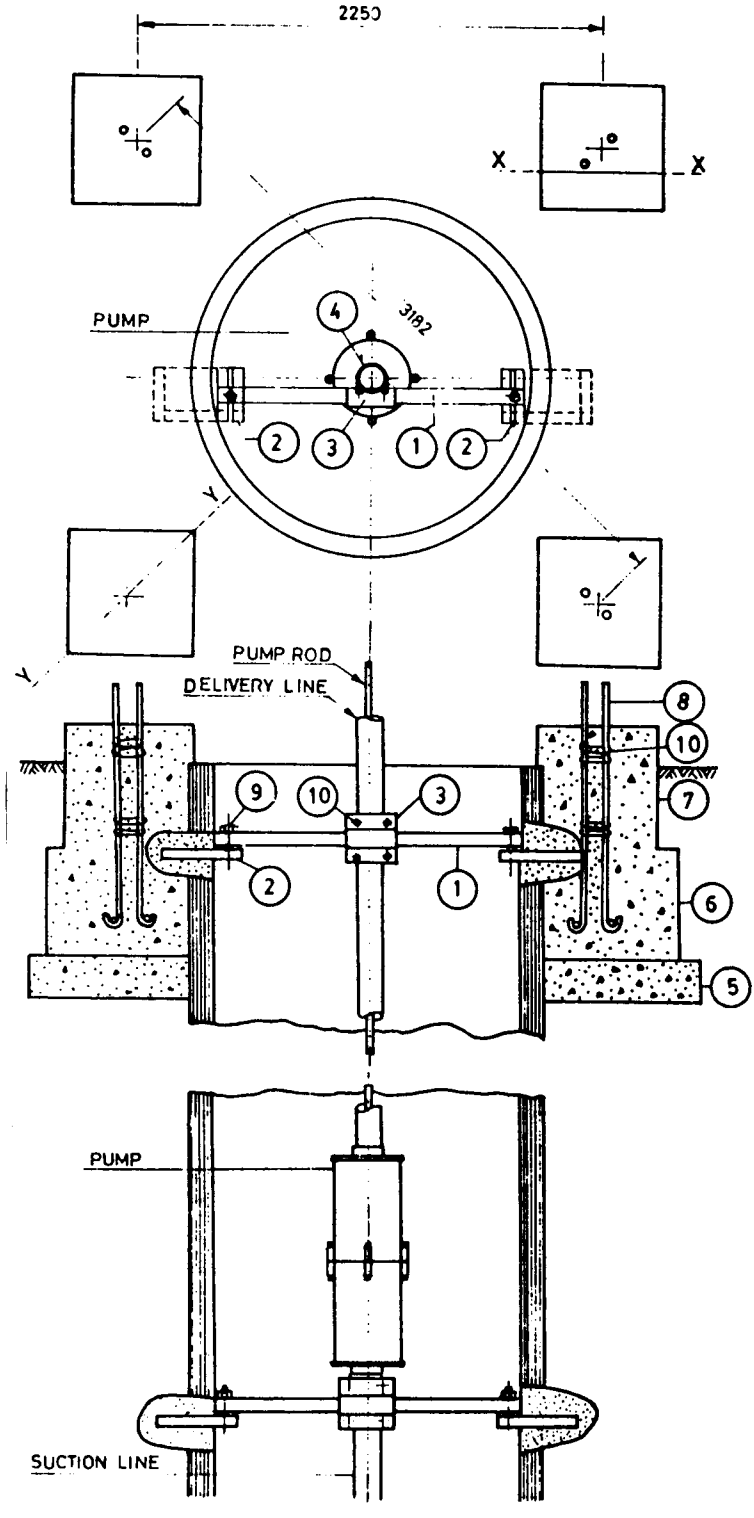
2250
X
X
PUMP
4
3182
2
3
1
2
Y
Y
PUMP ROD
DELIVERY LINE
8
10
9
10
3
7
2
1
6
5
PUMP
SUCTION LINE

8.6 INSTALLATION OF THE TOWER

The Tower is supplied in a knocked-down state and has to be assembled. The holes for the foundation are dug at the desired pitch. They are made of equal depth and wide enough to provide sufficient space for the towerleg anchors and to enable the tower to shift to a certain extent. The tower is laid in position and a rope is connected to the top portion. A ladder (or some bamboos) are kept vertically over which the rope is laid. Before pulling the tower upright one has to be sure that the ladder (bamboos) as well as the tower itself will not fall sidewards. Some extra hands can prevent this by guiding and supporting them with ropes. After the erection procedure the tower is placed vertically. This is checked by means of water level gauge which is kept beside the tower pipe (not at top of the tower pipe edge). Some filling material (e.g. bricks) are shifted under the tower leg angles temporarily during the adjustment in vertical sense. The desired position of the centre is checked by means of a rope and plumb bob with reference to the alignment of the tower with the centre of the well or the tubewell. The vertical position is checked again, and if both the positions are satisfactory the tower legs are grouted by means of cement and stone or brickchips.

The curing of the foundation needs at least 5 days, meanwhile, the time consuming fixation of the pump is carried out. For the grouting needed for pump fixation, the required mortar is made available during grouting the tower legs.

8.7 INSTALLING THE HEAD CONSTRUCTION

The jib crane is pulled and pushed up beside the tower and is finally set on angle of the tower. The jib is installed on the 'wind shadow' side of the tower (see drawing) while its two clamping angle-iron arms enclose the tower pipe on most outward position.

Now the complete head construction without the help vane is brought under the jib. The lifting hook is bolted to the tail at about 1.5 metres distance from the tail hinge. the head tends to turn towards the tail, since the lock mechanism of the help vane is kept out which makes the entire head construction difficult to handle. A locking device is arranged temporarily either by roping the upper tail-beam to the head construction or by putting a clamp overthere. A pin stuck through the head and ending up in the upper tail-beam may also serve the purpose very well.

The rope is connected to the lifting hook and 'balancing' of the head construction is tried out in such a way that the front part of the head is out of balance; (say: 5 degrees). This is essential to ensure that the framing of the head construction, which is going to surround the tower pipe, will grip and throttle it. (This is a most essential precaution which seems to be even contradictional).

The head is now lifted slowly by pulling the rope (by about 6-persons) and two persons guide the head while climbing the tower. The head is allowed to seek its position in the wind (do not force it and lift it till it floats just above the tower pipe). The two persons, each standing on the platform now, guide the bottom part of the head just over the tower pipe. The head is lowered down very slowly and the persons keep the head pressed down over the tower pipe. Actually they should maintain the '5 degrees out of balance' state of the head while the head itself is lowered down stepwise. The last few centimetres may be difficult as the inside angles of the head might touch the tower pipe edge and so obstruct a further sliding over of the head. If extra attention is paid to a proper centering, no problems appear and the head sinks into its final position. Loosen the rope and remove the lifting hook, and preparations are undertaken now to install the rotor frame.

8.8 INSTALLING THE ROTOR

First of all the position of the jib crane is adjusted. The jib crane is put in the most upright position, and the head construction is turned 180 degrees so that the front part of the head is touching the jib crane. For security reasons a rope connection is made overthere so that the head on which the rotor, shaft and bearing blocks are going to be placed, remains under the pulley of the jib crane. This is necessary as appearing wind might turn the head construction.

Both the rotor halves are connected now and the shaft is slid into the hub to take its normal position. The hub bolts are tightened stepwise as well as the securing clamping angle iron, care-

fully the rotor frame is lifted and carried to the tower where it is put in vertical position, standing on one of its six spokes. Now it sets against the tower, right under the jib crane. Care should be taken of the extending shaft pointing into to lattice of the tower construction, as this may cause problems.

The rope is lowered down now from the jib crane and it is connected to the hub of the rotor frame, so that the rope passes both the inside and outside ring from the back of the rotor.

Carefully and slowly the rotor is lifted and two persons guide it while climbing the tower. Extra attention is paid to the extending shaft which tends to get stuck in the lattice of the tower. Finally, reaching the level of the platform it is seen that the shaft is positioned on the correct side of the jib crane, since the latter itself will be an obstacle.

The entire rotor and shaft are hovering above the head now. With some effort the bearing blocks are positioned above their supports and the rotor is lowered down very slowly. The bolts are put quickly and the nuts are screwed on by hand first. The position is secured now and the rope is removed from the rotor and jib crane and the latter is lowered down. The rotor is revolved through a few revolutions in order to enable the bearing blocks to settle on their supports. The bolts of these bearing blocks are tightened.

The windmill is put in a secured position and the mounting of the blades can start now. One person sits on the platform and the other stands on angle 6 of the tower. The bolts, nuts and the tools can be kept conveniently in a basket which is hung temporarily from the platform during this bolting activity. It is necessary that the blades are mounted in crosswise sequence e.g. 1-7, 8-2, 3-9, 10-4 etc.

After this the crosshead, assembled with connecting rod and the pump rod both, is pushed into the tower pipe and the crank bush and central bolt are assembled. It is to be seen that the locking bolt of the PVC tower pipe insert is removed temporarily in order to allow the crosshead to pass in. Also important is to install the crank bush with its collar facing the crank plane and the application of the washer in between the bolt head and the bush edge is to be removed. The bolt is tightened up strongly and the locking screw for the PVC tower pipe insert is reinstalled. The wooden pump rod guide is fitted on the bottom side of the tower pipe and locked with the bolt.

Now the help vane arrangement is assembled and the windmill can be put to face the wind.

8.9 INSTALLING THE PUMP

It is preferable to have the pump section installed and completed by the time the windmill itself has been assembled.

As expressed earlier the installation of this very essential part should not be underrated as many difficulties are felt with regard to the alignment and fixation in the well. The reciprocating forces, which act on this section, can be considerable and a minor play in the suspension, either in axial or in radial sense, can lead to a "noisy dancing and swinging" performance of the pump. In the long run the grouted parts of the suspension will come out, the nuts and bolts will run loose and hammer their way through their counterparts.

A good deal of attention, therefore, is to be paid to the proper alignment and strong fixation of the pump and delivery pipe in order to prevent the above mentioned malfunctioning.

Though the wells for windmill sites differ in depth of water table, diameter and structure, at least some general guidance can be given to obtain suitable suspension :

In case of centrally situated installation of the windmill above the well it is advisable to fix at least one "bridge construction". This structure lends the needed suspension, provided of course, that its legs are grouted thoroughly in the well casing.

Centralisation at the bottom part of the pump section is provided by the tube well (if applied) or by the application of a similar "bridge construction" which embraces the suction pipe on which the pump has been screwed.

In the latter case grouting of the bridge into the well casing might be complicated since the bottom part of the pump is situated preferably under the water table in order to make the pump

self priming and to assure the desired minimum suction head. The problem is overcome either by grouting the bridge legs during a period for which the lowest water level exists (dry season, after excessive water removal by another pumping device) or by using and expanding clamp mechanism in the bridge legs themselves. This can be obtained by applying at each leg a bolt/nut combination in such a way that by screwing out the bolt the expanding effect occurs.

In case of an off-centre installation of the windmill not much choice is left and clamps, equipped with strong anchors which are grouted into the well casing, prove to be the best solution.

As far as the fixation under the waterline is concerned (in case of no tube well) it is advisable to apply a connection in the well casing based on key-wedge principle.

IMPORTANT NOTE

After the completion of the erection the installation should be checked with reference to the check list, and a record of all readings taken, be maintained.

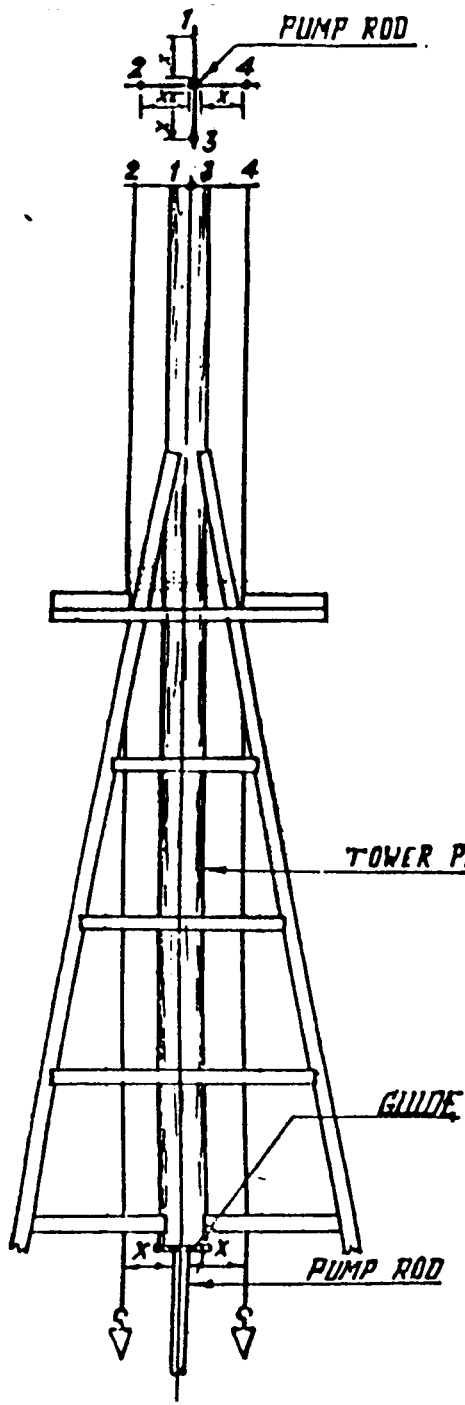
PUMP ROD
1
2
4
3
2 1 3 4
TOWER PM
GUIDE
X
X
PUMP ROD

8.10 Check List for Installation of Windmill

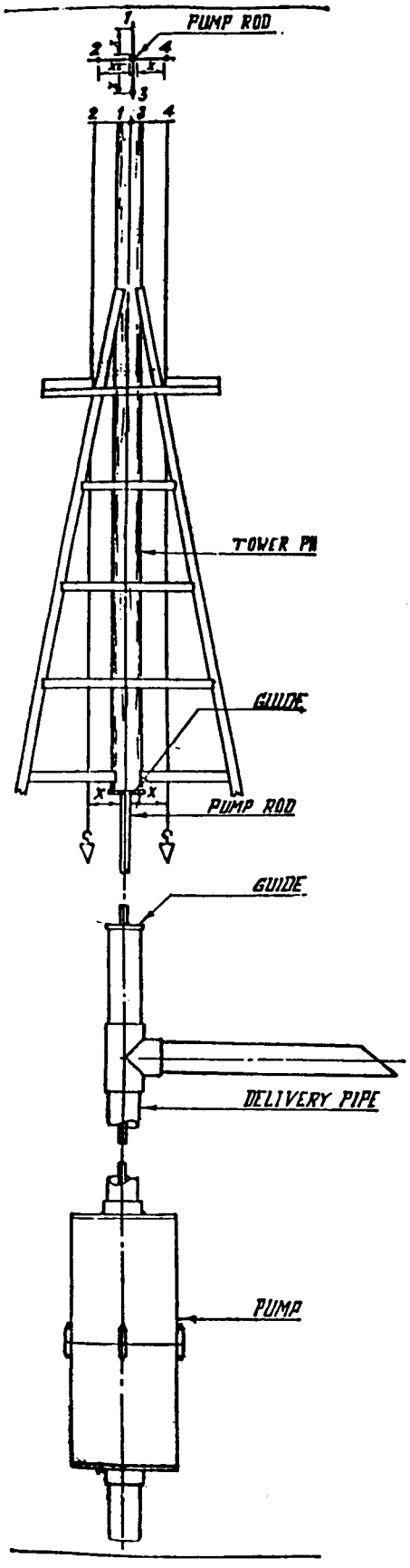

CHECKS IN WINDMILL INSTALLATION

पवन चक्की स्थापना के समय निरीक्षण

(A) **Verticality (Sahul, Scale Try-square, Spirit Level)**

(अ) **लम्बवत निरीक्षण (साहुल, स्केल, गुनिया, स्प्रीट लेवल)**

(a) Tower pipe
(take 4 readings)

(१) टावरपाईप (चार रीडिंग लीजिए)

(b) Pump rod with reference to tower pipe
(about 150 mm below the upper wooden guide)

(२) टावर पाईप के सापेक्ष पम्प राड का निरीक्षण (टावर पाईप से गाइड १५० मि० मी० नीचे)

(c) Perpendicularity of tower top Face with reference to the side of the pipe.
If the distance between the two wooden guides is more than 3 metres then.

(३) टावर टाप सतह की लम्बवता पाईप के चारों ओर के सापेक्ष ।
अगर पम्प राड की लम्बाई दोनों गाइड के मध्य तीन मीटर से अधिक हो तब ।

(d) Measure perpendicularity of pump rod at a distance of about 150 mm above the lower guide.

(४) पम्पराड की लम्बवता निचली गाईड से १५० मि० मी० ऊपर निरीक्षण कीजिए ।

(e) Measure verticality of delivery pipe.

(५) डिलीवरी पाईप लम्बवता का निरीक्षण कीजिए ।

1	2	3	4

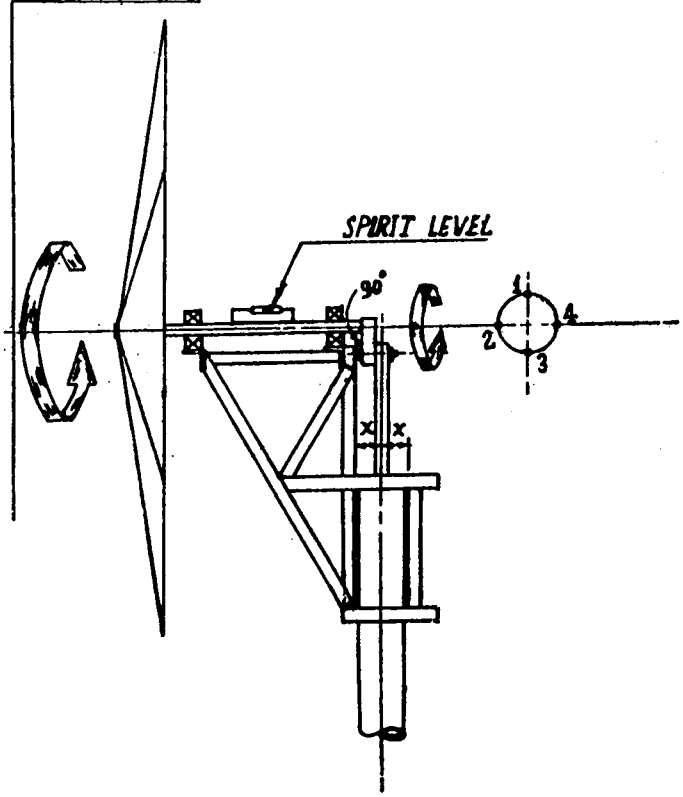

(B) SHAFT (Spirit level & Scale)

(ब) साफ्ट (स्प्रीट लेबल और स्केल)

		Position स्थिति	Reading प्रेक्षण
(a)	Turn the rotor around tower axis, meassure level in rotor facing North, West, South & East (NWSE) w. e. at 4 positions.	1.	mm मि॰ मी॰
		2.	mm मि॰ मी॰
(१)	टावर के अक्ष के चारों तरफ रोटर घुमाइये एवं सतह का निरीक्षण कीजिए । (पूरब, पश्चिम, उत्तर, दक्षिण) चारों स्थितियों में ।	3.	mm मि॰ मी॰
		4.	mm मि॰ मी॰
		I II	
(b)	Rotate rotor around the axis of the shaft and measure perpendicularity of the crank with reference to the shaft. (Measure distance between the connecting rod and head construction X).	1.	mm मि॰ मी॰
		2.	mm मि॰ मी॰
(२)	साफ्ट के अक्ष के चारों ओर रोटर को घुमाइये और क्रैंक की लम्बवता ज्ञात कीजिए ।	3.	mm मि॰ मी॰
		4.	mm मि॰ मी॰
(c)	Measure clearance between the head construction & towertop pipe surface.		gauge / mm
(३)	(हैड कन्सट्रक्शन एवं कनैक्टिंग राड के बीच की दूरी नापिये)		गेज / मि॰मी॰

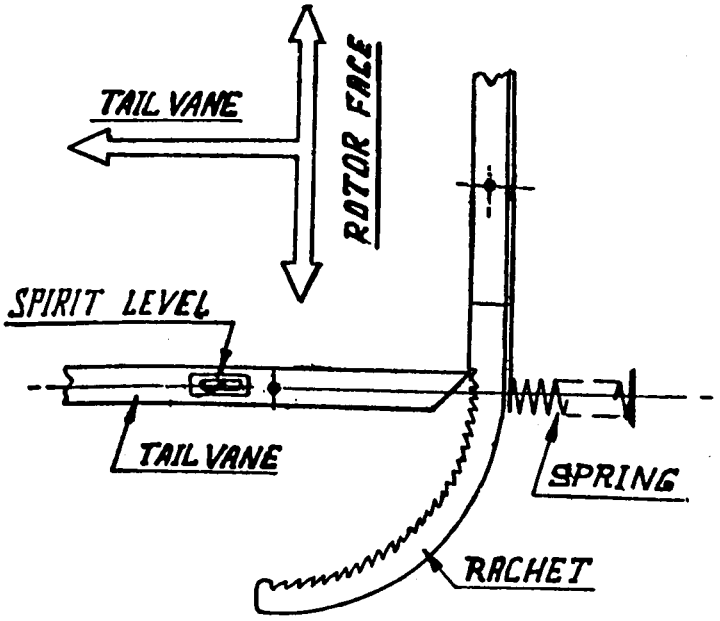

(B) Measure spring tension of the tail with the help of spring balance. ... ... kg.

(१) स्प्रींग बैलेंस की सहायता से टेल स्प्रींग का तनाव ज्ञात कीजिए ।

(C) (a) Check meshing of the tail with toothed sector.
(b) Measure horizontality of the tail with the help of spirit level & scale. ... . mm.

(२) टुपेड रेचेट भाग का टेल के साथ मैचिंग का निरीक्षण कीजिए ।
टेल की क्षेतिजता स्प्रोट लेबल एवं स्केल की सहायता से ज्ञात कीजिए ।

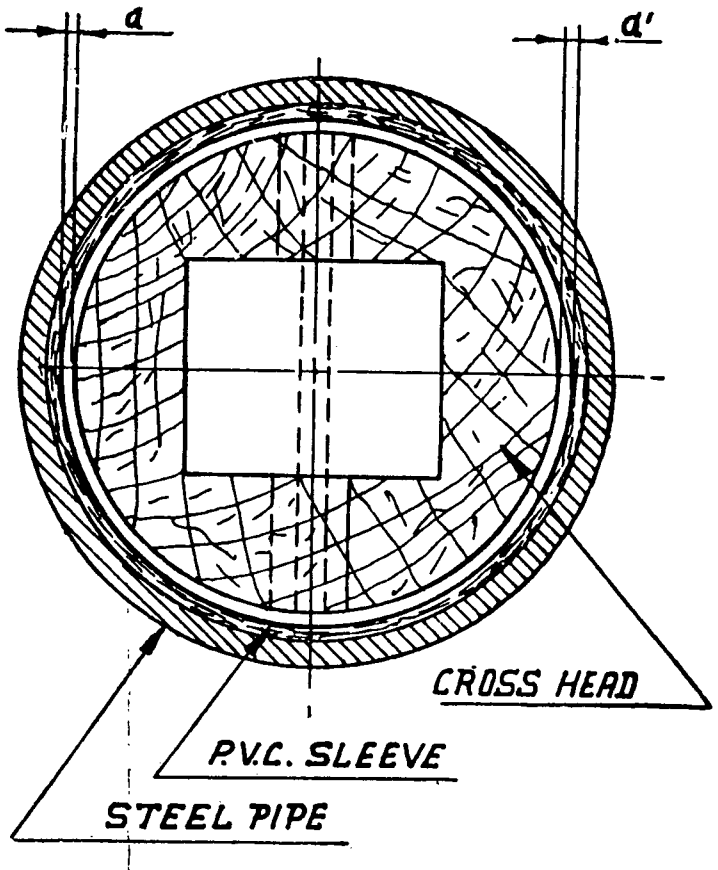

(E) Measure clearance d x d between the PVC sleeve & cross head. ... ... gauge/mm.

(१) पी० वी० सी० स्लीव एवं क्रासहेड के बीच अन्तराल डी एवं डी, नापिए। गेज/मि० मी०

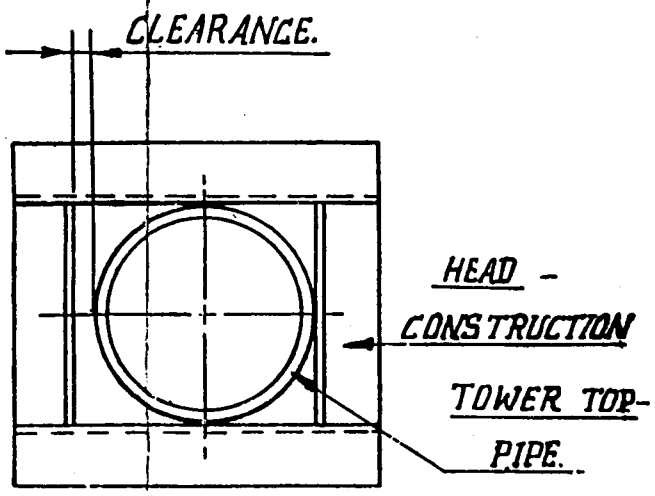

(D) Measure clearance between the head construction & towertop pipe surface. ... ... gauge/mm.

(१) हेड कन्सट्रक्शन एवं टावर टाप पाइप सतह के बीच अन्तराल ज्ञात कीजिए। गेज/मि० मी०

9. MAINTENANCE OF THE WINDMILL

Though the number of moving parts in the windmill is limited yet certain regular checkups and lubrication services should be undertaken from time to time. Also, in the long run some moving parts might wear out and need replacement. Fortunately, in this design, such parts are cheap in the material costs. They can be made easily and replaced.

9.1 THE OVERALL STRUCTURE

Actually corrosion of the steel structure is the greatest enemy of the windmill. If the corrosion problem is tackled in the right way the technical lifetime of the windmill is expected to reach at least 15 years and probably far beyond this figure.

It is advisable, therefore, to have the structure painted thoroughly with one coat of primer and two coats of finish, after chipping off the weldings. The need for these preventive measures is more in areas where the air is humid or saline as along a coast-line. The best anticorrosive zinc-based paints should ba applied.

9.2 TOWER

Generally it is expected that the tower will not need any specific attention with regard to wear and tear, since it is a static structure. One should realise however, that the tower pipe serves multiple functions:-

- It carries head construction the edge (this is in axial sense).
- Its outside provides support to the head construction by enclosing it at the top and bottom parts (in radial sense).
- Its inside provides the guidance to the crosshead via the contact of PVC insert.

The 'steel to steel' contact of tower pipe and head construction needs some lubrication (grease) from time to time. As long as the grease is present no excessive wear is going to occur there. Also, as long as the PVC insert remains locked in the tower pipe, the insert will serve its purpose well.

However, corrosion of the tower has to be taken into account and check-ups should be undertaken at half yearly intervals.

9.3 HEAD CONSTRUCTION

Besides its contact with the tower pipe only a few moving parts of this structure need attention for maintenance. It should be ensured that the locks of the security device remain free of any play. The functioning of the hinges of the help vane and tail vane both should be checked up from time to time since they have the tendency either to run loose or to corrode: The former will lead to loose and noisy, and hence clumsy joints, and the latter to a struggling and faultering functioning of the mechanism. The best remedy is to apply a few oil drops from time to time.

If, the help vane lock or the final lock is worn out. It would be better to take it out, apply some welding and reshape it by filing, and get it re-installed properly. There is no need to explain the necessity of a proper functioning of storm security device.

9.4 MOVING PARTS

It is assumed that the main bearings have been positioned and tightened properly. Generally the lubrication is sufficient for millions of revolutions and as long as no dust particles enter the "grease" no complications are expected. However, in course of time the grease is "rolled out" of the bearing and will change its lubricating properties. This takes years, though, to happen, but moment it is noticed, new grease (not oil) should be applied. If no grease nipple is there, the bearing housing has to be opened to apply fresh grease.

Generally the nylon (or bronze) bearings of the connecting rod keep their lubricant well. Some fresh oil drops from time to time will serve the purpose satisfactorily. The same counts for the wooden cross-head and pump rod guides. Properly soaked in oil they contain the lubricant themselves and from safety point of view it is best to keep them in that condition. Generally a "generous filling up" of the square hole in top of the crosshead with oil, provides the best guarantee that these essential wooden parts will maintain their functioning. The appearance of play in these parts after some time of functioning might seem to be bothersome, but they have a long way to go before replacement is really necessary. In short, the wear is acceptable as a long as no noisy and clumsy malfunctioning occurs. The replacement is cheap and easy to carry out specially, as far as the wooden pump rod guides are concerned. With regard to replacement of the crosshead it is advisable to drill complete new holes for the pump rod crosshead connection. It will be evident that in case of replacement of worn out crosshead the replacement of the PVC insert is also recommended.

9.5 THE ROTOR

Besides maintenance concerning corrosion, the rotor does not need any maintenance. However, in some cases bolts and nuts become loose due to the alternating character of the load on them. A "cracky" noise indicates such fault.

The remedy is to chek-up all bolt and nut connections, especially at the start. In a fair number of cases some fatigue cracks appear either in the outside blade supports (shearing fatigue) and/or in the blades somewhere at their edge. If it happens, supports and/or blades should be replaced by new ones.

9.6 THE PISTON PUMP

In the windmill the pump section remains the most bothersome part. Besides the checks of its suspension, checks are to be made with regard to its delivery. Depending on the purity of the lifted water the piston wears out sooner of later, resulting in a poor delivery. It should be replaced then.

If time has come to change the piston, it is better to replace the valves too. This will ensure that the newly overhauled pump will serve its purpose for the next period of time without any failure. The span of this time will depend on the purity of the water which is pumped from the source. Presence of sand particles play a significant role in the life of the piston and precautions should be taken. In case of water delivery from a tube well, a proper "washing" procedure is necessary.

Maintenance checks as given in the following pages should be carried out at half yearly intervals.

9.7 Preventive Maintenance Schedule
Water Pumping Windmill
12-PU-500

Sl. No.	Major Parts	Sub Components	Insepction Schedule				Suggested Remedial measures.
			D	M	Q	Y	
1.	Rotor	Hub bolts			✓		If loose, tighten
		Hub clamp bolt			✓		-do-
		All the Rotor Fasteners			✓		-do-
		Upper and lower tips of the blades	✓				If bent, remove the blades with bent tips, straighten and fix again, If badly damaged, replace it.
		Condition of paint				✓	Retouch/Repaint
		Blade supports			✓		If cracked, replace
		Inner and outer rings			✓		Repair/Replace
		Blades	✓				If damaged badly, replace.
2.	Head Construction Tail and the security mechanism	All the fasteners and joints			✓		If loose, tighten
		Condition of security lock in both secured and operational positions.			✓		If functioning is improper and it suffers from vibration check the ratchet arm and spring and the locking edge of the tail, replace the worn out part.
		Movement of head construction aroundthe tower pipe.		✓			If the rotation around the tower pipe is not smooth, lubricate with grease. if the clearance between the tower pipe and head construction is abnormal put a shim in the gap.

Sl. No.	Major Parts	Sub Components	Insepction Schedule				Suggested Remedial measures.
			D	M	Q	Y	
3.	Mechanical Power Transmission system.	Condition of the bearing block		✓			If cracked replace the complete bearing with housing immediately.
		Condition of the bearing for any unusual sound axial movement or play.		✓			If running dry, lubricate, if sound still persist or there is axial movement or play then replace the complete bearing.
		Bearing fixing bolts.		✓			If loose, tighten firmly.
		Rear bearing safety bracket		✓			If loose, tighten firmly.
		Hub screw of bearing		✓			If loose, tighten firmly.
		Condition of crank holes		✓			If holes are enlarged, remove the shaft with crank repair by welding and drilling repairing and reinstall properly.
		Welding joint of the crank with main shaft.		✓			If cracked or deformed remove the shaft with the crank, repair and refix properly.
		Crank bolt		✓			If loose tighten firmly.
		Collar Bush			✓		If sign of wear appears change and lubricate with grease.
		Connecting rod		✓			If broken, bent or crack appears on any joint, replace.
		Nylon bushes at both ends of connecting rod			✓		If play has developed or bushes have worn out replace them.
		Crosshead			✓		If unusual sound or play appears, replace.
		PVC Sleeve			✓		If worn out replace.
		Pump rod joints			✓		If loose, tighten firmly.
		Wooden/Polypropelene guides			✓		If wornout, replace.

Sl. No.	Major Parts	Sub Components	Insepction Schedule				Suggested Remedial measures.
			D	M	Q	Y	
4.	Piston Pump	Pipe line joints	✓				If there is any leakage check the flange and socket joints, repair.
		Coupling bolts			✓		If there is any leakage from middle section through the rubber gasket, replace the gasket, open the pump and check.
		Abnormal noise from the pump	✓				The complete assembly consisting of the piston rod, nut, brass guide, foot valve, piston barrel, replace the faulty component.
5.	Tower	All the fasteners of joints		✓			If loose, tighten firmly.
		Condition of tower pipe				✓	If bent change the tower top.
		Welded joint of tower pipe with stand legs.				✓	If cracked remove the tower top, repair and reinstall.
		Condition of protective coating.				✓	If peeled off, carry out touching with primer and paint.
6.	Foundation and Aux. Structure	Physical insp. of work	✓				If any vibrations have caused cracks, stop the windmill and repair the civil constructions.
		Supporting bridges & clamps		✓			If the clamps are loose tighten them.
		Delivery pipe bracket		✓			If fitting is disturbed, fix it correctly.

D = Daily; M = Monthly; Q = Quarterly; Y = Yearly

9.8 PART LIST OF 12-PU-500 WINDMILL

TOWER :

Sl.No.	Item	Material	Size mm	Measurements mm	No. Regd.
T/1	ANGLE IRON	M.S.	35x35x5	250	8
T/2	ANGLE IRON	M.S.	40x40x5	4500	4
T/3	ANGLE IRON	M.S.	35x35x5	1940	16
T/4	ANGLE IRON	M.S.	35x35x5	1400	4
T/5	ANGLE IRON	M.S.	50x50x6	250	4
T/6	ANGLE IRON	M.S.	35x35x5	700	4
T/7	ANGLE IRON	M.S.	40x40x5	2000	4
T/8	ANGLE IRON	M.S.	35x35x5	660	2
T/9	FLAT IRON	M.S.	32x6	580	2
T/10	FLAT IRON	M.S.	32x6	460	2
T/11	FLAT IRON	M.S.	32x6	340	2
T/12	WOODEN PLANK	WOOD	30x200	700	2
T/13	PIPE (SLEEVE)	PVC	4" BORE	710	1
T/14	TOWER PIPE	M.S.	4" N.B.	2650	1
T/15	FLAT	M.S.	32x6	410	4
T/16	PLATE	M.S.	170x160x6		4
T/17	NUT,BOLT,WASHERS	M.S.	M12x40(W½"x1½")		52
T/18	MACHINE SCREW		½" Ø x 2" long		4
T/19	MACHINE SCREW		½" Ø x 1" long		4

HEAD CONSTRUCTION :

Sl.No.	Item	Material	Size mm	Measurement mm	No. Regd.
HC/1	ANGLE IRON	M.S.	40x40x5	200	1
HC/2	ANGLE IRON	M.S.	40x40x5	200	1
HC/3	ANGLE IRON	M.S.	40x40x5	155.5	4
HC/4	ANGLE IRON	M.S.	40x40x5	555	2
HC/5	ANGLE IRON	M.S.	40x40x5	590	1
HC/6	ANGLE IRON	M.S.	40x40x5	1000	2
HC/7	ANGLE IRON	M.S.	40x40x5	1110	2
HC/8	ANGLE IRON	M.S.	40x40x5	540	2
HC/9	ANGLE IRON	M.S.	40x40x5	460	2
HC/10	ANGLE IRON	M.S.	40x40x5	500	1
HC/11	ANGLE IRON	M.S.	65x65x6	250	2
HC/12	ANGLE IRON	M.S.	40x40x5	1500	1
HC/13	ANGLE IRON	M.S.	40x40x5	4000	1
HC/14	ANGLE IRON	M.S.	40x40x5	3000	1
HC/15	ANGLE IRON	M.S.	40x40x5	125	1
HC/16	ANGLE IRON	M.S.	40x40x5	60	1
HC/17	ANGLE IRON	M.S.	40x40x5	45	1
HC/18	ANGLE IRON	M.S.	40x40x5	1000	1
HC/19	FLAT IRON	M.S.	32x6	115.3	2
HC/20	FLAT IRON	M.S.	32x6	65	2
HC/21	FLAT IRON	M.S.	32x6	150	1
HC/22	FLAT IRON	M.S.	32x6	115.5	1
HC/23	FLAT IRON	M.S.	32x6	830	1
HC/24	FLAT IRON	M.S.	32x6	750	3
HC/25	FLAT IRON	M.S.	32x6	200	1
HC/26	RACHET (FLAT, HARDENED)	M.S.		480	1
HC/27	TAIL VANE (1mm SHEET)	M.S.		2000x1000	1
HC/28	HELP VANE (1mm SHEET)	M.S.		1000x500	1
HC/29	ROD	M.S.		30Diax650	1
HC/30	WASHER	M.S.		M12(½" Dia.)	1
HC/31	NUT	M.S.		M22(W 7/8")	1
HC/32	BOLT,NUT,WASHER	M.S.		M12x40(W½"x1½")	1
HC/33	BOLT,NUT,WASHER	M.S.		M12/100(W½"x4")	1
HC/34	BOLT,NUT,WASHER	M.S.		M6x25-(W¼"x1")	12
HC/35	SPRING	SPRING STEEL	App. 30Dia.x1000x14		1

MOVING PARTS

Sl.No.	Item	Materials	Size mm	Measurements mm	No.
MP/1	MAIN SHAFT	M.S.	ϕ 50(ϕ2")	1300	1
MP/2	PILLOW BLOCK (BEARING)-FYH & NTN		P210J-50±0.01 bore		2
MP/3	BUSH	M.S.	33x43x33		2
MP/4	BUSH (MOULDED)	NYLON	ϕ 25xϕ38x18		4
MP/5	BUSH	M.S.	ϕ20xϕ40x44		1
MP/6	WASHER	M.S.	ϕ20x40ϕx3		1
MP/7	CRANK BOLT (GKW MAKE)	M.S.	M20x75(W3/4"x3")		1
MP/8	NUT	M.S.	M20(W3/4")		1
MP/9	BOLT,NUT,WASHER	M.S.	M12x50(W1/2"x2")		2
MP/10	BOLT,NUT,WASHER	M.S.	M10x100(W3/8"x4")		2
MP/11	CROSS PIN	M.S.	ϕ 25x92		1
MP/12	CROSS HEAD	WOOD (SEASONED In OIL)	ϕ97x5x300		1
MP/13	CONNECTING ROD (FLAT)	M.S.	30x6	650	1
MP/14	FLAT	M.S.	30x6	50	4
MP/15	FLAT	M.S.	15x6	300	2
MP/16	FLAT	M.S.	40x10	165	1
MP/17	FLAT	M.S.	25x6	135	2
MP/18	FLAT	M.S.	25x6	250	2
MP/19	GREASE CUP				1
MP/20	PIPE (Q.S.T. MAKE) CLASS 'A' G.I.		ϕ1"	(Amount or size depend upon - circumstances)	*
MP/21	PUMP ROD GUIDE	(TEAK WOOD)	ϕ120x100		1

ROTOR:

Sl.No.	ITEM	MATERIAL	SIZE mm	MEASUREMENTS mm	NO. REQD.
R/1	PLATE	M.S.	260Dia.x6		2 (Two piece in one)
R/2	ANGLE IRON	M.S.	50x50x5	625	2
R/3	ANGLE IRON	M.S.	50x50x5	100	4
R/4	ANGLE IRON	M.S.	50x50x5	350	2
R/5	ANGLE IRON	M.S.	40x40x5	1880	6
R/6	FLAT IRON	M.S.	30x5	1880	6
R/7	FLAT IRON	M.S.	30x5	495	6
R/8	FLAT IRON	M'S'	30x5	275	6
R/9	RING CLAMP (FFLAT)	M.S.	40x10	150	12
R/10	OUTER RING (FLAT)	M.S.	30x5	2000	6
R/11	INNER RING (FLAT)	M.S.	30x5	3000	2
R/12	ROTOR BLADE (SHEET)	M.S.	2000x300x1.5		12
R/13	OUTER BLADE SUPPORT (SHEET)	M.S.	220x157x2.65		12
R/14	INNER BLADE SUPPORT (SHEET)	M.S.	250x247x2.65		12
R/15	BOLT, NUT, WASHER	M.S.	M16x100(W5/8"x4")		12
R/16	BOLT, NUT, WASHER	M.S.	M16x125(W5/8"x5")		2
R/17	BOLT, NUT, WASHER	M.S.	M10x25(W3/8"x1")		64
R/18	BOLT, NUT, WASHER	M.S.	M6x25(W1/4"x1")		120

PISTON PUMP

Sl.No.	Item	Material	Size mm	No. Reqd.
PP/1	PUMP ROD EXTENSION	G.I. PIPE	3/4"——————x*	*
PP/2	PUMP ROD	G.I. PIPE	3/4"——————x900	1
PP/3	PIPE	G.I. PIPE	5/8"——————x100	4
PP/4	TOP PIPE	BLACK PIPE	4"——————x750	1
PP/5	EXHAUST PIPE	BLACK PIPE	4"——————x*	1
PP/6	DELIVERY PIPE	BLACK PIPE	4"x——————x*	*
PP/7	T-SOCKET	G.I.	4"——————	1
PP/8	SOCKET	BLACK	4"——————	*
PP/9	DELIVERY PIPE	BLACK PIPE	4"——————	1
PP/10	CYLINDER	SEAMLESS BLACK PIPE	6" GASPIPE X 460	1
PP/11	CASING FLANGE	M.S.	ϕ 290	2
PP/12	CASING FLANGE	M.S.	ϕ 290	1
PP/13	CASING	C.R. SHEET	500x900	2
PP/14	FOOT VALVE	8 mm M.S. SHEET	ϕ 170	1
PP/15	FLAT IRON		——————35	12
PP/16	FLAT IRON		——————80	4
PP/17	FLAT IRON		——————x180	1
PP/18	FLAT IRON		——————x450	1
PP/19	FLAT IRON		——————x300	*
PP/20	FLAT IRON		40x6(1½"x¼")	3
PP/21	ANGLE IRON		40x40x4(1½"x1½")	2
PP/22	FILLING PIECES	M.S. ROD	ϕ 8mm x 10mm	8
PP/23	RING	M.S. ROD	ϕ 8(0 3/8")x870	1
PP/24	VALVE	NITRILE RUBBER WITH NYLON FABRIC INSERT/ LEATHER	ϕ 150 x 5	2
PP/25	GASKET	NITRILE RUBBER SOLE LEATHER	ϕ 290 x 6 mm	1
P/26	PISTON	POLYPROPELENE/ TEAK WOOD POLYPROPELENE		1
PP/27	STEEL BUSH		ϕ 43 x 33	*
PP/28	GUNMETAL BUSH		ϕ 33 x 30	*
PP/29	THREADED STUD	C.I.	M24x150(W7/8"x65)	1
PP/30	THREADED STUD	C.I.	M24x100(W7/8"x4")	*
PP/31	NUTS	G.I.	M24x(W7/8")	*

Sl.No.	Item	Material	Size mm	No. Reqd.
PP/32	SPRING WASHER	G.I.	M24(W7/8")	*
PP/33	BOLT,NUT,WASHER *	G.I.	M12x125(W½"x5")	4
PP/34	BOLT,NUT,WASHER *	G.I.	M12x120(W½"x3/4")	1
PP/35	CLAMP (U BOLT)	M.S.	ϕ 12 (½") x370	
PP/36	TEAK WOOD/POLYPRO—PELENE GUIDE	TEAK WOOD	(5"x5"x4")	1

**Nylock bolts x nuts are preferred to avoid their frequent loosening.*

9.9 INVENTORY OF MINIMUM SPARES OILS AND LUBRICANTS

Sl. No.	Component	Qty.	Reference of fabrication drawing	Part number on the drawing
1.	Help vane spring	1	Head construction 12-PU-500	35
2.	Help vane frame with ratchet	1	"	18,25,26
3.	Tail pin	1	"	29
4.	Connecting rod	2	Moving parts	3,13,14,15,19
5.	Nylon bush (4 nos. at a time	8	"	4
6.	Crank pin	2	"	5
7.	Crank pin bolt and nut	1	"	7 & 8
8.	Cross head with cross pin	1 st.	"	11 & 12
9.	Wooden guides	2 pairs	"	21
10.	Pillow blocks N.T.N. Japan	1 pairs	"	2
11.	PVC sleeve for tower pipe	1	Tower 12-PU-500	13
12.	Blades coated with 90% zinc rich primer and enamel paint	3	Rotor & blade	12
13.	Blade supports (inner & outer)	3 pairs	"	13 & 14
14.	Piston valve & suction valves	3 each	Windmill pump	18,37,38,4
15.	Pump gasket	1	"	17
16.	Piston (polypropelene)	2	"	27
17.	Pump rod guide (brass)	2	"	25
18.	Pump rod guide bush	2	"	23
19.	Pump rod connection	1	"	30,32
20.	Galvanised fasteners with nylock nuts and plain washers (¼" x ϕ x 1" long)	10	"	-
21.	Galvanised fasteners with nuts and plain washers (3/8" ϕ x 1½")	40	"	-
22.	Galvanised fasteners with nylock nuts and plain washers ½" ϕ x 1½" long)	10	"	-
23.	Galvanised fasteners with nylock nuts and plain washers 5 $^{1}/_{8}$" 0 x 1½" long)	10	"	-
24.	Grease for bearings	½ Kg.	"	-
25.	SAE 40 mobile oil	1 Lit.	"	-

9.10 SOURCES OF AVAILABILITY OF SPARES

(a) State Nodal Agencies:

1.	Andhra Pradesh	(BHEL)	Bharat Heavy Electricals Ltd. Vikas Nagar, Hyderabad-500 593.
2.	Andhra Pradesh	(NEDCAP)	Non-Conventional Energy Development Corporation 10-2-318/1/A/5/1, Indranagar Colony Hyderabad-500 457.
3.	Bihar		Executive Engineer, Solar Division, Sone Bhawan, Beer Chand Patel Marg, Patna.
4.	Delhi	(DEDA)	Delhi Energy Development Agency, 11, Lancer Road, Timarpur, Delhi-110 007.
5.	Gujarat	(GEDA)	Gujarat Energy Development Agency, P.N. Chambers, 3rd Floor, Vadodra- 390 005.
6.	Himachal Pradesh	(HPSEB)	Himachal Pradesh State Electricity Board, Shimla, H.P.
7.	Madhya Pradesh	(MRUVN)	Madhya Pradesh Urja Vikas Nigam, B-Block, G.B.T. Complex, T.T. Nagar, Bhopal, M.P.
8.	Maharashtra	(MEDA)	Maharasthra Energy Development Agency, 3rd Floor, Mantralaya, Bombay-400 023.
9.	Orissa	(OREDA)	Orissa Renewable Energy Development Agency, 5-57, Mancheswar, Industrial Estate, Bhubaneswar-751 010.
10.	Rajasthan	(REDA)	Rajasthan State Agro Industries Corporation Ltd. O.I. Subhash Nagar, Ghotwara Road, Jaipur-6.
11.	Tamilnadu	(TEDA)	Tamil Nadu Energy Development Agency, Jhaver Plaza, IVth Floor, 1-Nungambhakkam High Road, Madras.
12.	Uttar Pradesh	(NEDA)	Non-Conventional Energy Development Agency, B-46, Mahanagar Extension, Lucknow-226 006.

9.11 FABRICATING AGENCIES

(b) Fabricating Agencies:

(Involved during demonstration Programme)

1.	Andhra Pradesh	Non-Conventional Energy Development Corporation, 10-2-3/8/1/A/5/1, Indranagar Colony, Hyderabad-500 457.
2.	Gujarat	Principal, Community Polytechnic Wing, Government Polytechnic, Porbhandar, Gujarat-360 577.
3.	Madhya Pradesh	Principal, Government Polytechnic, Khurai, Distt. Sagar-470 117, M.P.
4.	Orissa	Chief Executive, Orissa Renewable Development Agency, 5-57, Mancheshwar Industrial Estate, Bhubaneswar-751 010.
5.	Punjab	Principal, Ramagarthia Polytechnic Phagwara P.O. Satnampura-144 402.
6.	Uttar Pradesh	Works Manager, Training-Cum-Production-Centre, Institute of Engineering & Rural Technology, 26, Chatham Lines, Allahabad-211002, U.P. LORP (TOOL-ORP Project) Kusumikalan, Gazipur, U.P.
7.	Tamilnadu	Principal, Murugappa Polytechnic Satyamurthy Nagar, Avadi, Madras-600 062.

10.1 POLYPROPELENE CROSS HEAD

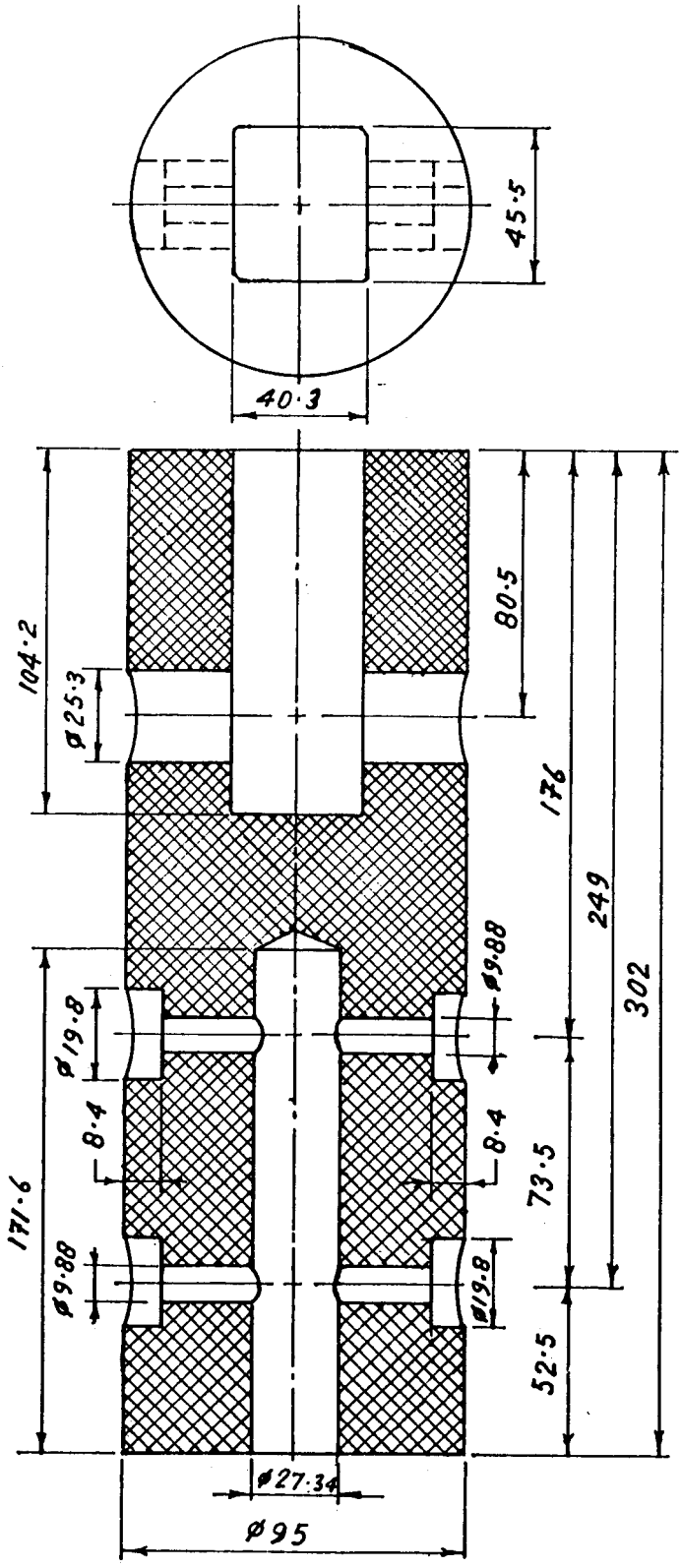

Fug, 13 Polypropelene cross head

10.2 BALL & SOCKET JOINT

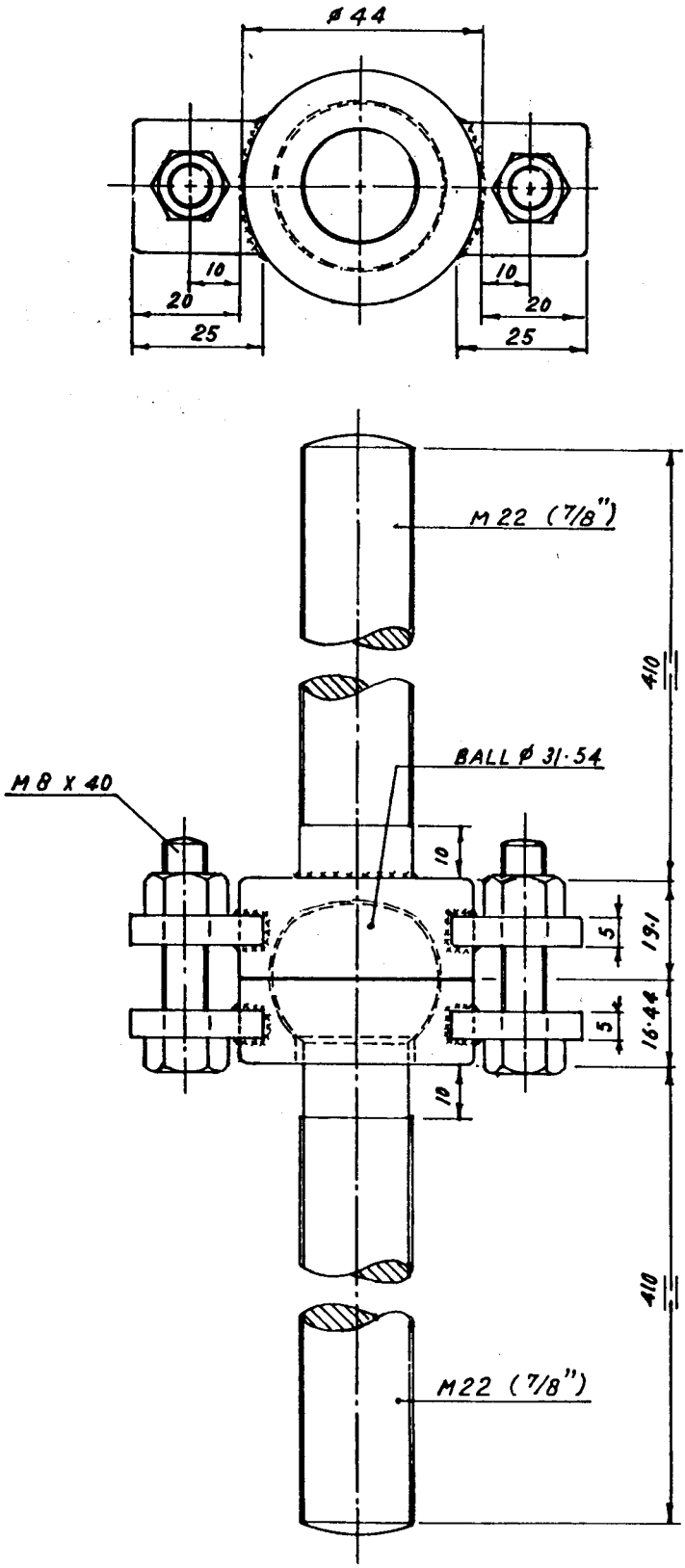

Fig. 14 Ball & Socket joint

10.3 NYLON BUSH FABRICATED AND NYLON BUSH MOULDED

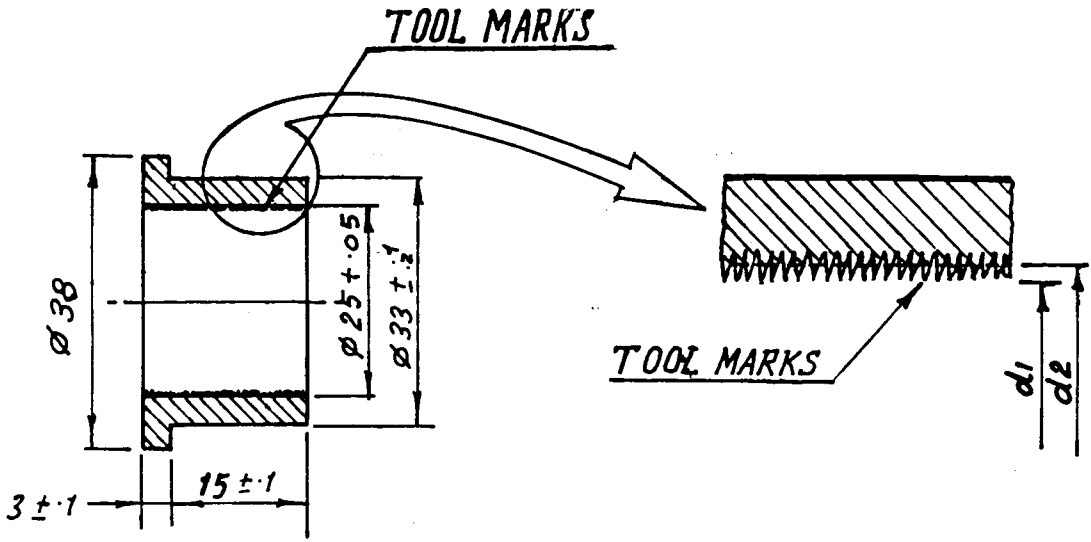

Nylon Bush (fabricated)

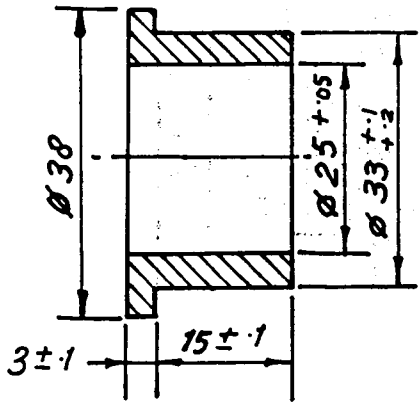

Nylon Bush (Moulded)

Fig. 15

10.4 NEOPRENE VALVE WITH NYLON FABRIC INSERT

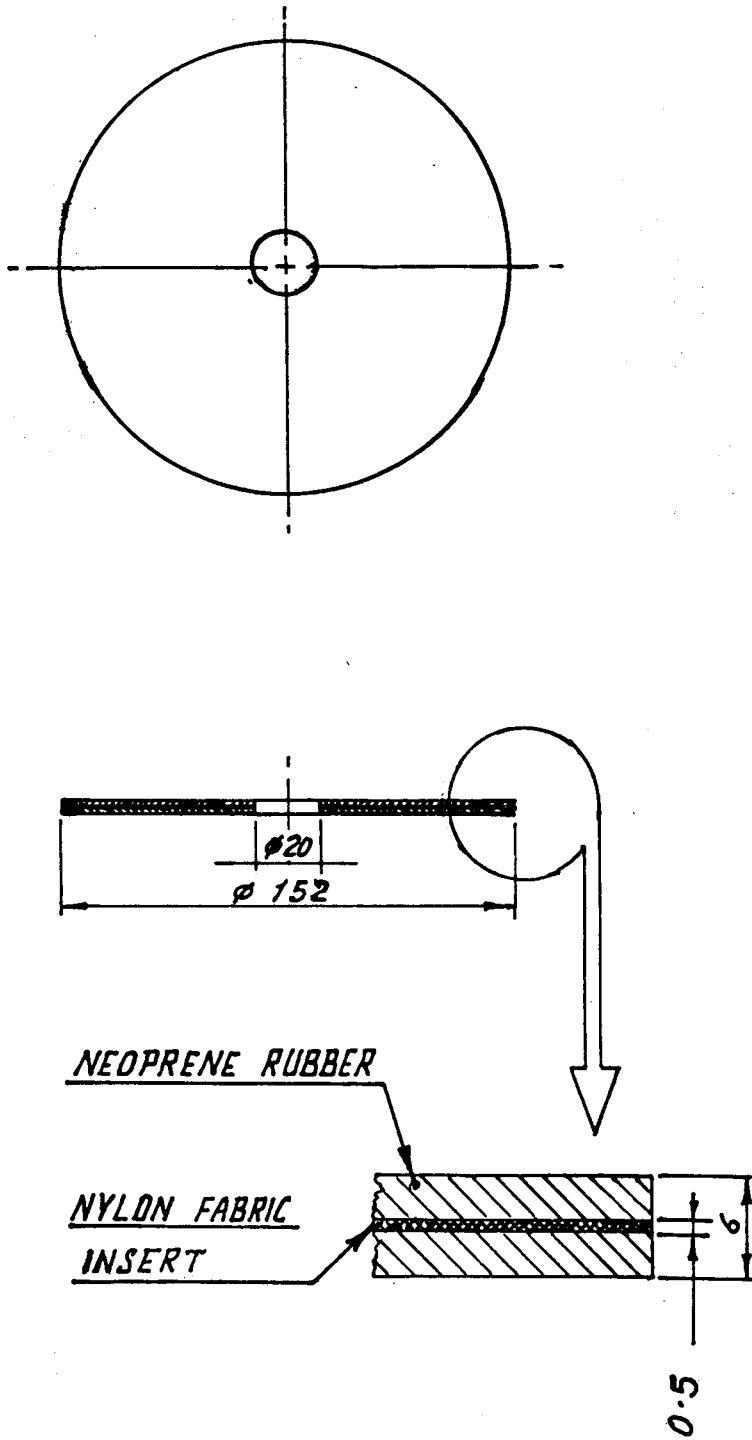

Fig. 16 Neoprene Valve with Nylon Fabric Insert

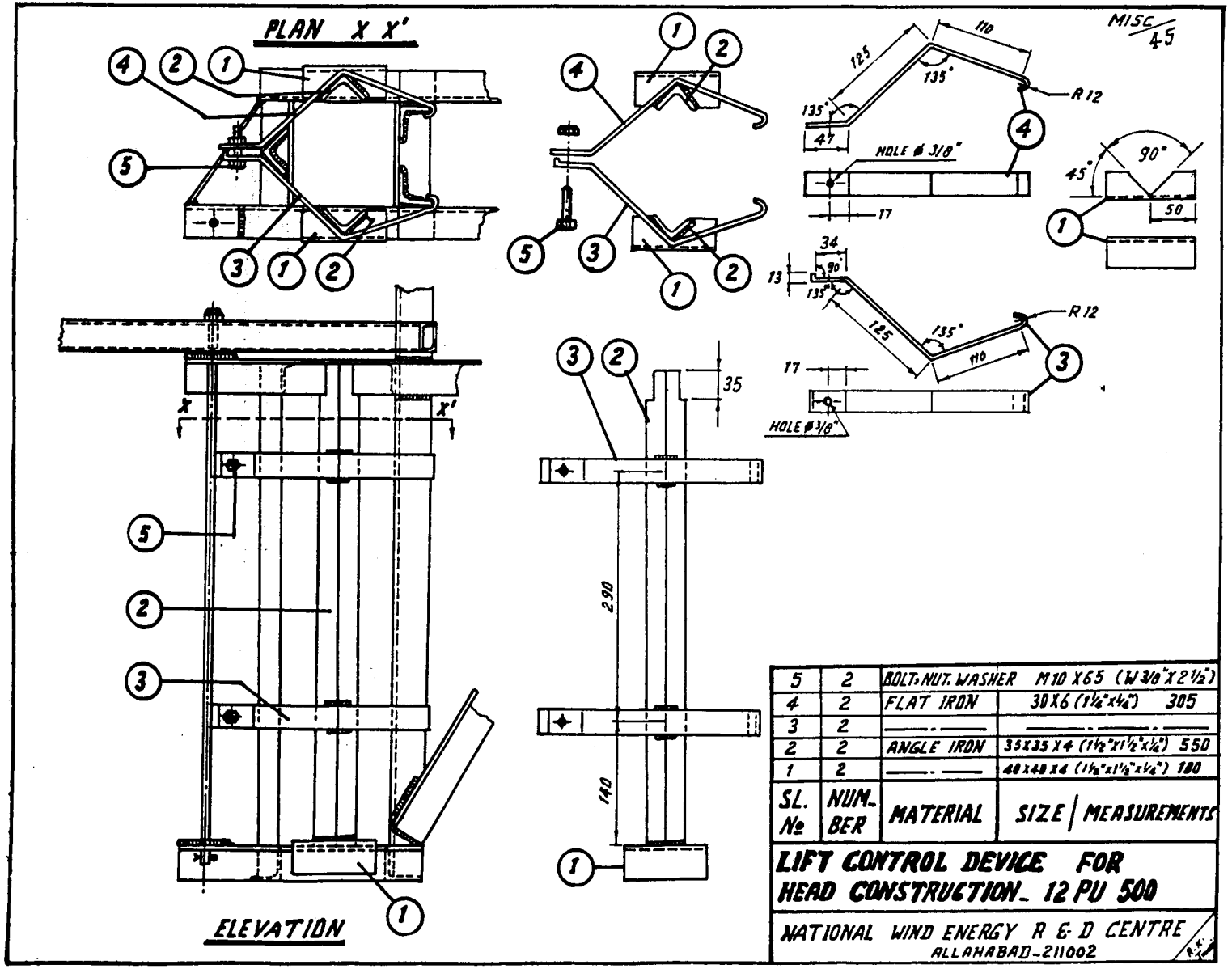
PLAN X X'
ELEVATION
MISC 45
HOLE ø 3/8"
R 12
125
110
135°
47
17
34
13
90°
45°
50
35
290
140
X
X'
5 2 BOLT, NUT, WASHER M10 X65 (W 3/8" X 2 1/2")
4 2 FLAT IRON 30X6 (1 1/2" x 1/4") 305
3 2
2 2 ANGLE IRON 35X35 X4 (1 1/2" x 1 1/2" x 1/4") 550
1 2 40X40 X4 (1 1/2" x 1 1/2" x 1/4") 180
SL. № NUM-BER MATERIAL SIZE / MEASUREMENTS
LIFT CONTROL DEVICE FOR HEAD CONSTRUCTION_ 12 PU 500
NATIONAL WIND ENERGY R & D CENTRE
ALLAHABAD-211002

Fig. 17

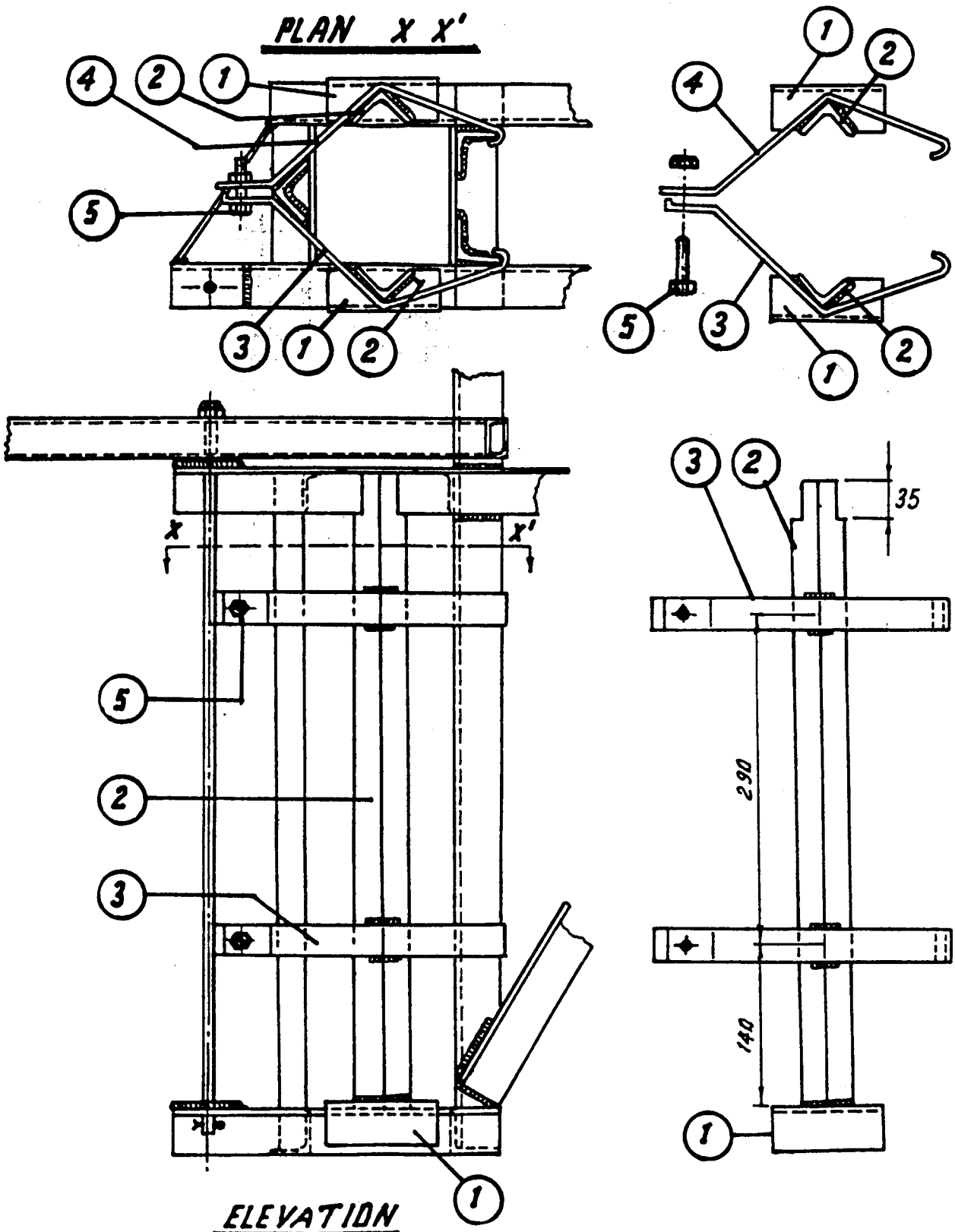
PLAN X X'
ELEVATION
X
X'
35
290
140
1
2
3
4
5

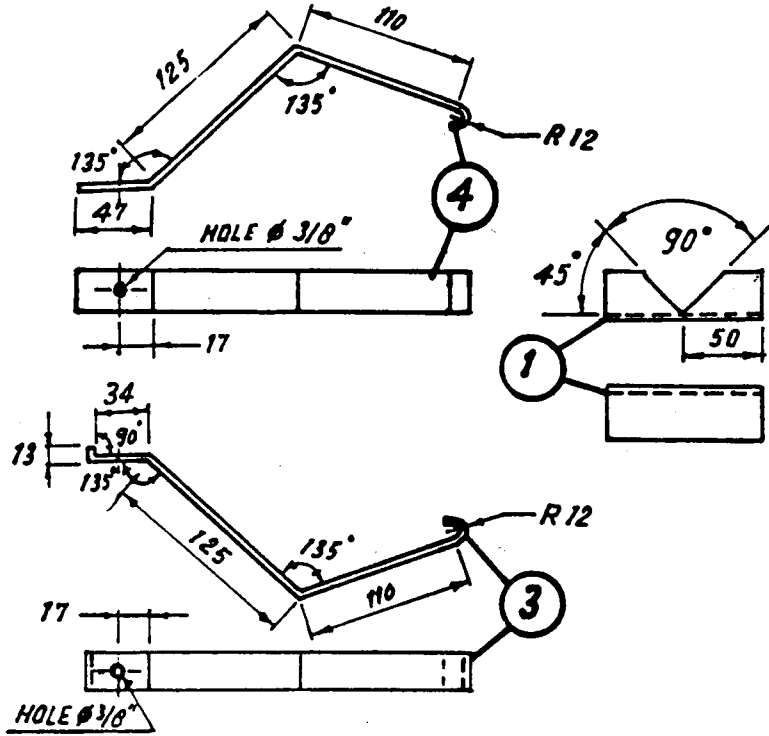
110
125
135°
135°
R 12
4
47
HOLE ø 3/8"
17
90°
45°
50
1
34
90°
13
135°
125
135°
R 12
110
3
17
HOLE ø 3/8"

10.6 WOODEN CROSS HEAD WITH STEEL REINFORCEMENT

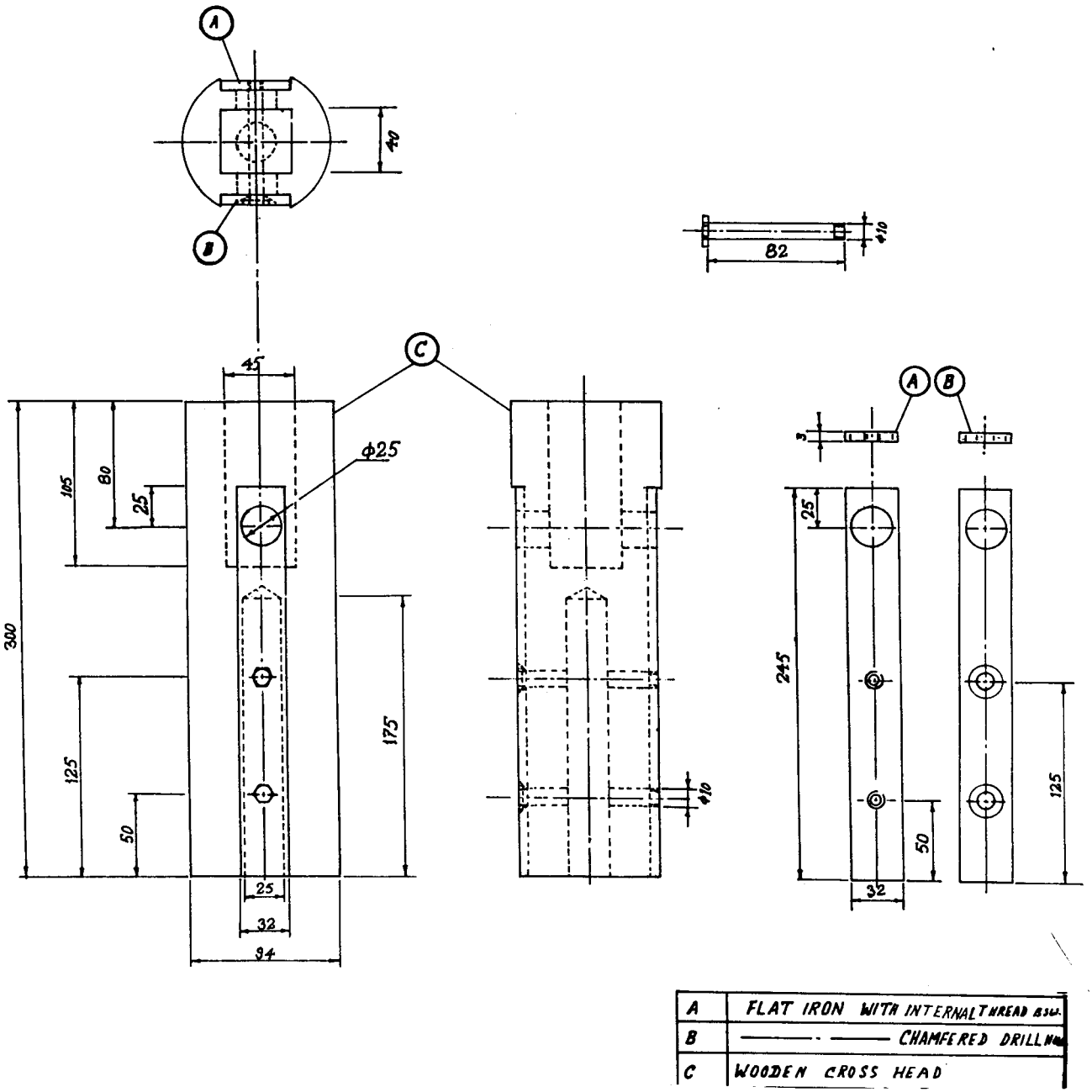

Fig. 23 Wooden Cross Head with Steel Reinforcement

11. MERITS OF THE NEW PUMP "A RECIPROCATING PUMP WITH C.I. CYLINDER"

NEW WINDMILL PUMP WITH CAST IRON CYLINDER:

(Special features over the old pump of Nick design).

(1) Volumetric efficiency is comparable. It is as high as 95.00 percent as compared to 69.00 percent of old pump of Nick design.

(2) Can be installed above the well, integrated with tower structure, so that pump axis coincides with the axis of the tower pipe thus eliminating the problem of misalignment which has hitherto being treated as difficult to achieve practically. This is because of the fact that the suction valve is all metallic (brass) and does not contain leather or rubber washers.

(3) Accurately machined and honed cylinder gives uniform bore and eliminates the ovality which is almost impracticable in the case of cylinders made out of M.S. pipes.

(4) Clearance between the bore and the piston has also been reduced to 0.1 mm uniformly. (The minimum achievable clearance in case of old pump of Nick design is 0.75 mm) with further decrease in clearance, the cylinder wall which is made of M.S. pipe, becomes too thin. The corrosion sets in the thin wall which leads to leakage within a short period.

The cylinder made of cast iron, ensures longer operational life and makes it rust resistant.

(5) Spherical suction valve makes it priming free provided, of course, the water is free from substances, like coarse grit, pebbles, floating leaves, twigs etc.

(6) Light in weight, fully galvanised pump body ensures corrosion and rust free service in adverse atmospheric conditions.

(7) Totally metallic suction valve assembly offers long life and trouble free service.

(8) Detachable suction valve of the pump makes the inspection of the suction valve and the piston of the pump easier and simplifies the replacement if necessary, unlike the old system where the complete heavy pump is to be taken out of the well for even petty repairs.

(9) Inspection and repairs can be further simplified because of convenience in installation of the pump above the well.

SL. No	No REQD.	MATERIAL NAME / SIZE / MEASUREMENTS	Wt. IN KG.
18	120	NYLOCK NUT, BOLT, WASHER, M6 X 25 (W 1/4" x 1")	
17	64	NUT, BOLT, WASHER, M10 X 25 (W 3/8" X 1")	
16	2	" " " M16 X 125 (W 5/8" x 5")	
15	4	" " " M16 X 100 (W 5/8" x 4")	
14	12	'I' BLADE SUPPORT M.S. SHEET 11 B.G. 2.80 MM. THICK	9.00
13	12	'O' BLADE SUPPORT " " " " " " "	5.04
12	12	ROTOR BLADE " " 16 B.G. 1.6 MM " "	90.00
11	2	INNER RING M.S. FLAT 30x5 3000	7.2
10	6	OUTER RING " " " " 2000	14.4
9	12	RING CLAMP " " 40x10 150	5.58
8	6	M.S. FLAT ———— 30x5 275	2.22
7	6	" " ———— " " 495	3.6
6	6	" " ———— 1880	13.56
5	6	ANGLE IRON ———— 40x40x5 1880	8.8
4	2	" " ———— 50x50x5 350	2.6
3	4	" " ———— " " 100	1.52
2	2	" " ———— " " 625	4.5
1	2	M. S. PLATE ———— φ 260 x 6	2.4

ROTOR-FOR-12 PU 500 WINDMILL

	DESIGNED BY	DRAWN BY	CHECKED BY	APPROVED BY	SCALE
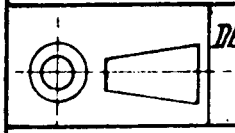		(R.K. Tiwari) TRD. - Man Singh.	PRATAP SINGH		N.T.S.

FOR INFORMATION

WIND ENERGY R-&-D CENTRE
I. E. R. T. ALLAHABAD-211002 INDIA

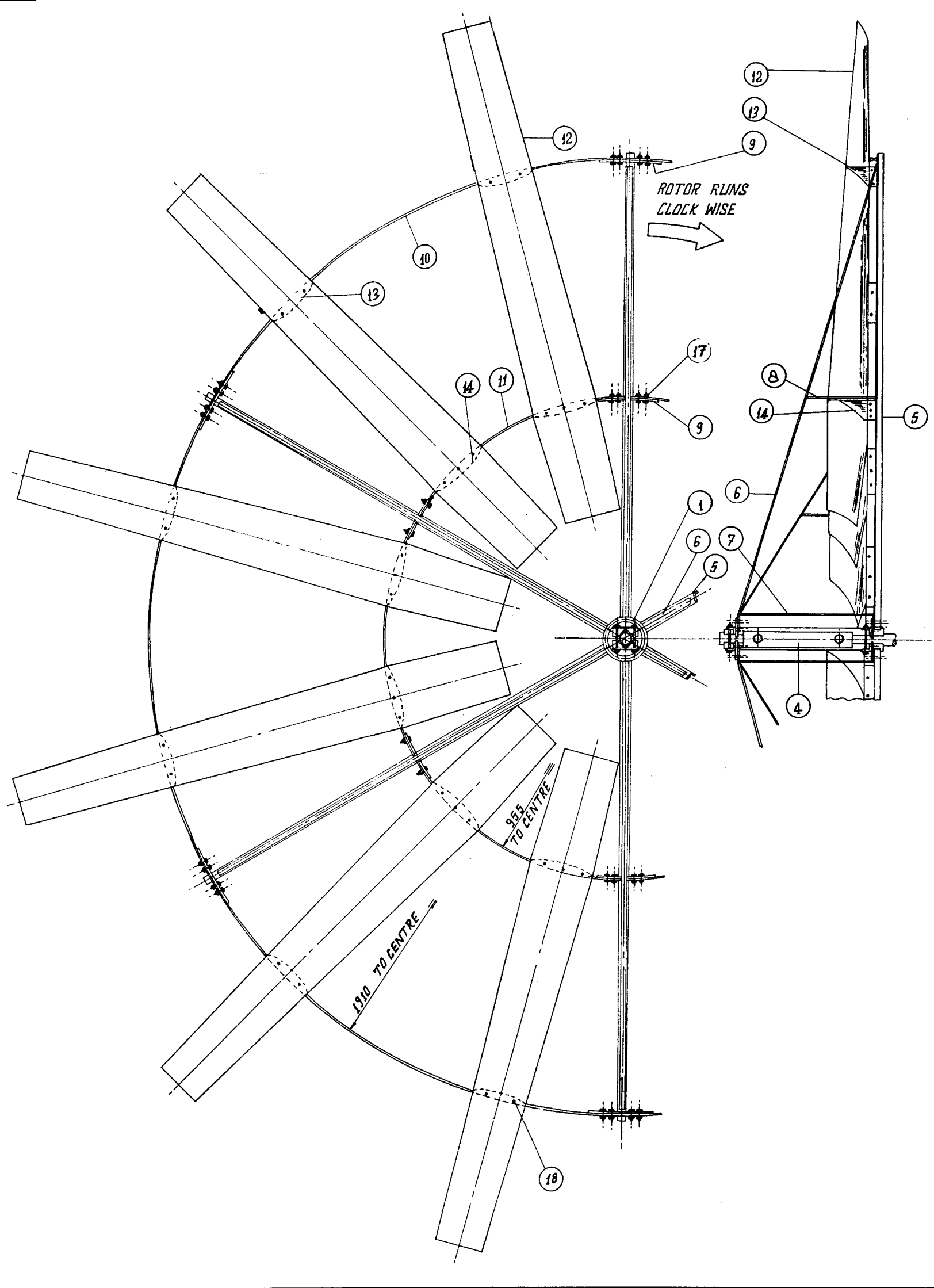
ROTOR RUNS
CLOCK WISE
955
TO CENTRE
1910 TO CENTRE
1
4
5
6
7
8
9
10
11
12
13
14
17
18

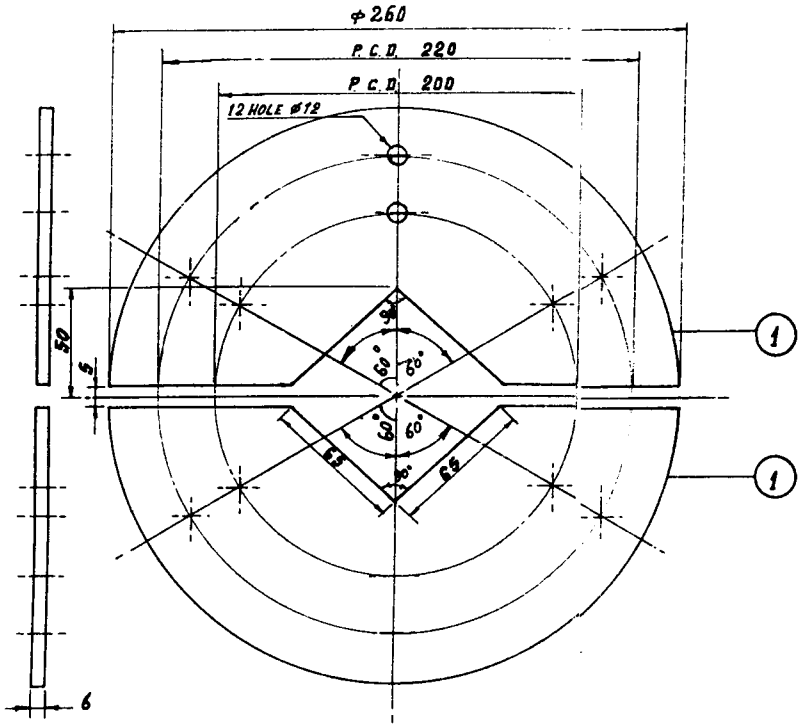

DETAIL ITEM No 1 (HUB PLATE)

DETAIL ITEM No 2 & 3 ROTOR (HUB)

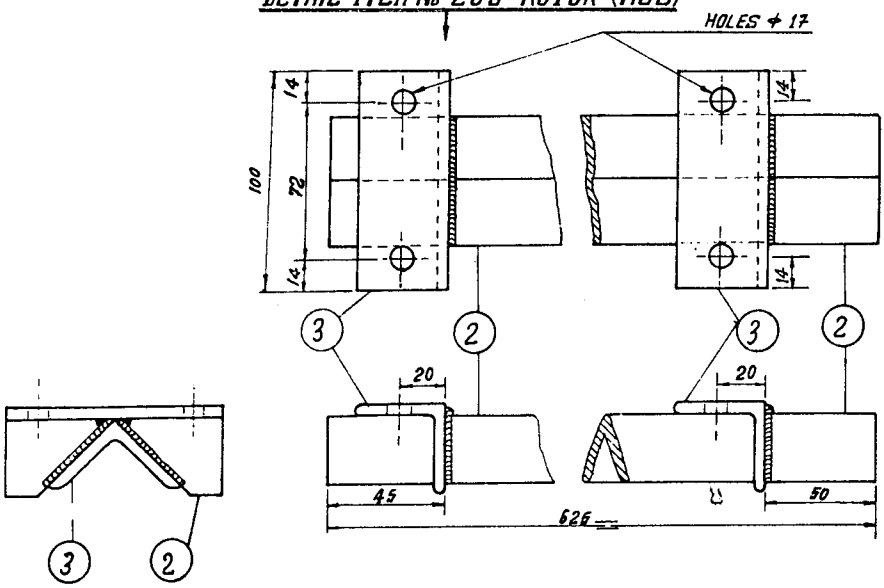

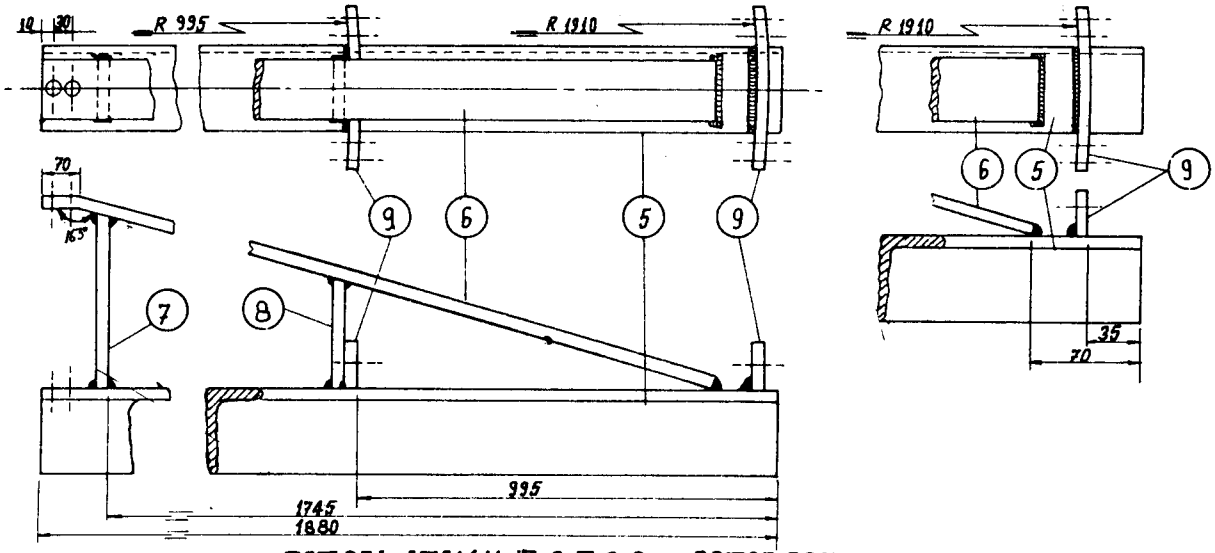

DETAIL ITEM No 5, 6, 7, 8, 9, ROTOR SPOKE

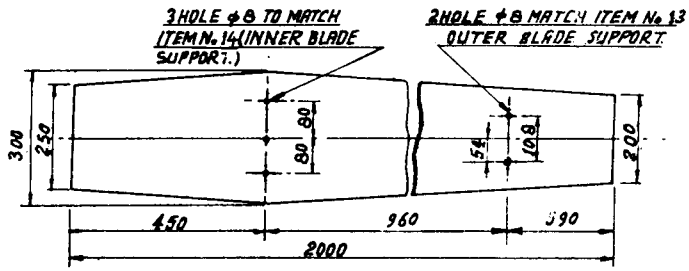

DETAIL ITEM No 12 (ROTOR BLADE)

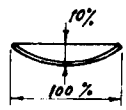

SHEET IS ROLLED IN A BENDING RADIUS OF APPR. 200 mm.

AFTER CUTTING THE RADIUS IS CORRECTED SO THAT 10% CURVED AIRFOILS WILL RESULT.

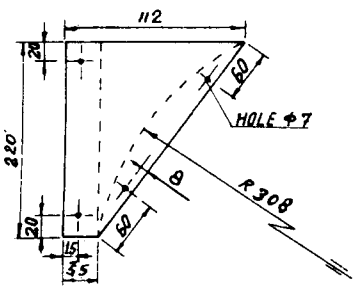

DETAIL ITEM No 13
OUTER BLADE SUPPORT

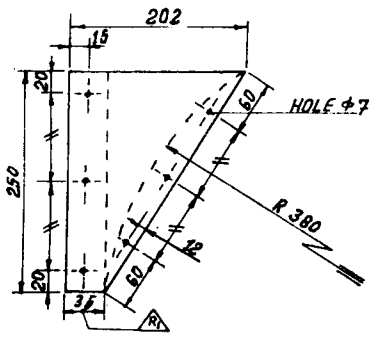

DETAIL ITEM No 14
INNER BLADE SUPPORT

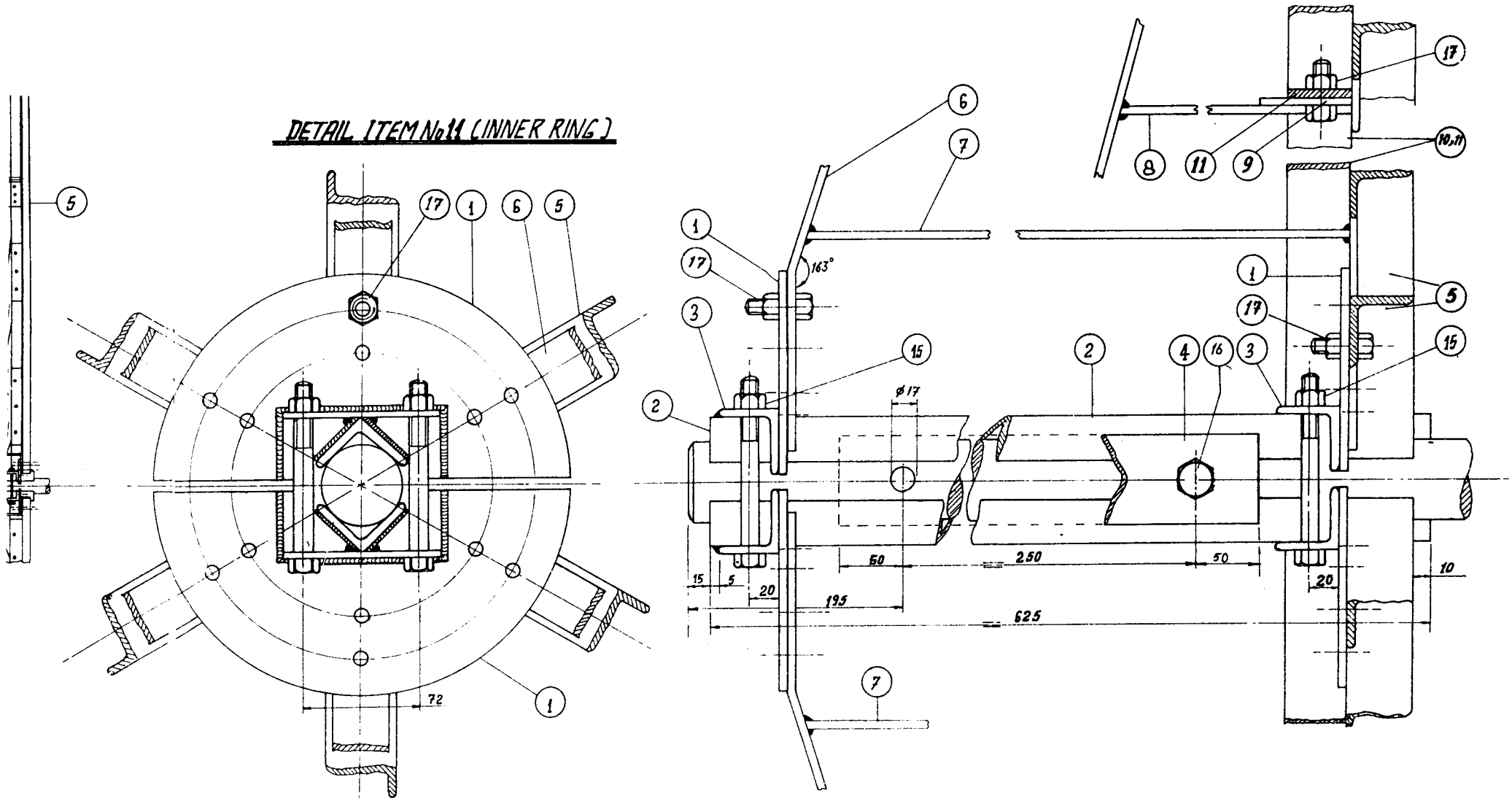
DETAIL ITEM No 11 (INNER RING)
5
17
1
6
5
72
1
6
7
1
17
163°
3
15
2
ø17
7
17
8
11
9
10,11
1
5
17
2
4
16
3
15
60
250
50
15
5
20
195
625
20
10

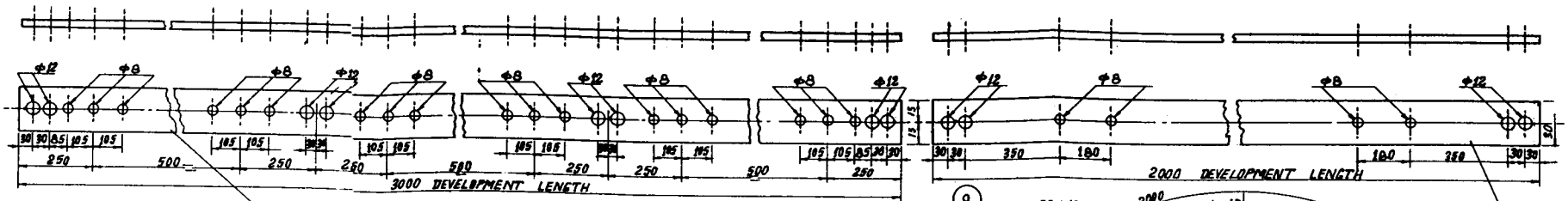

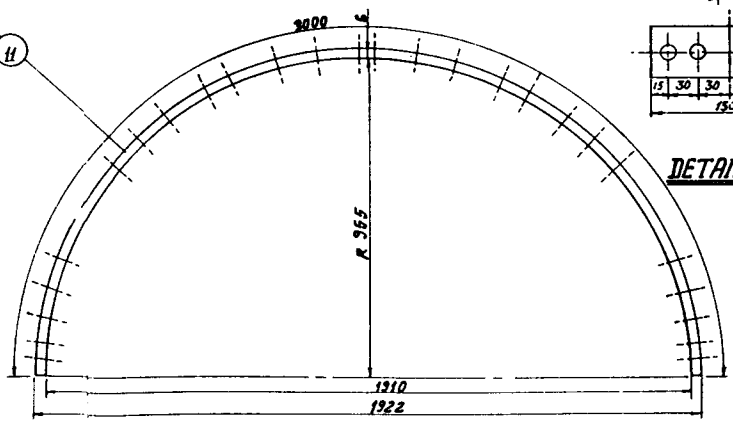

DETAIL ITEM No 11 (INNER RING)

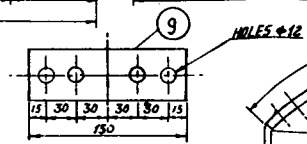

DETAIL ITEM No 9

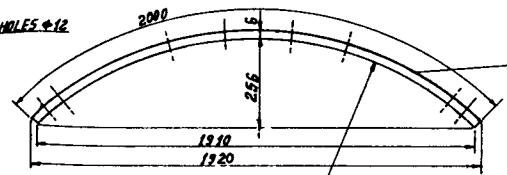

DETAIL ITEM No 10 (OUTER RING)

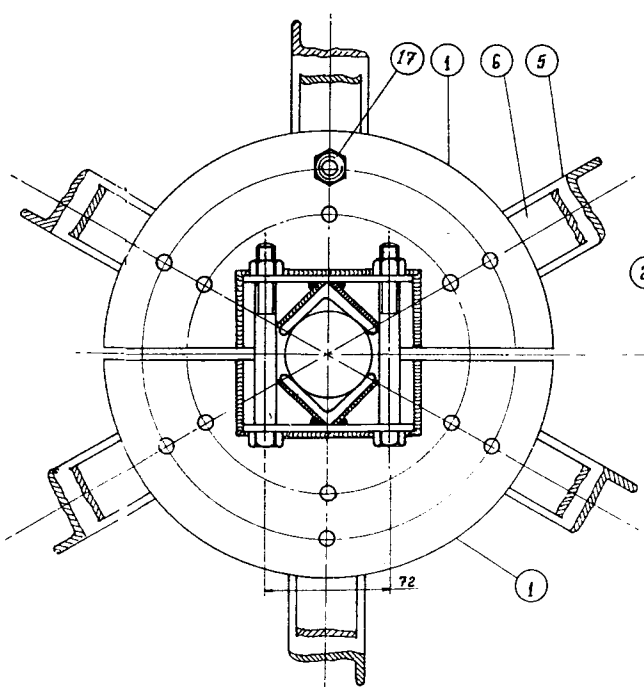

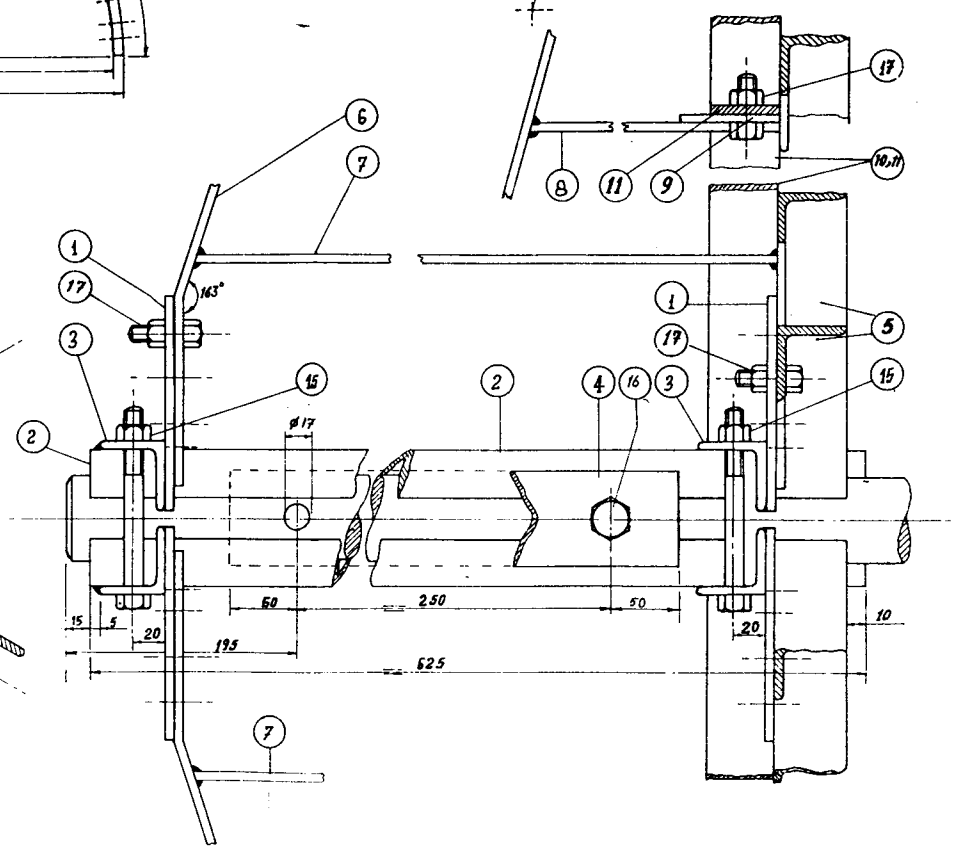

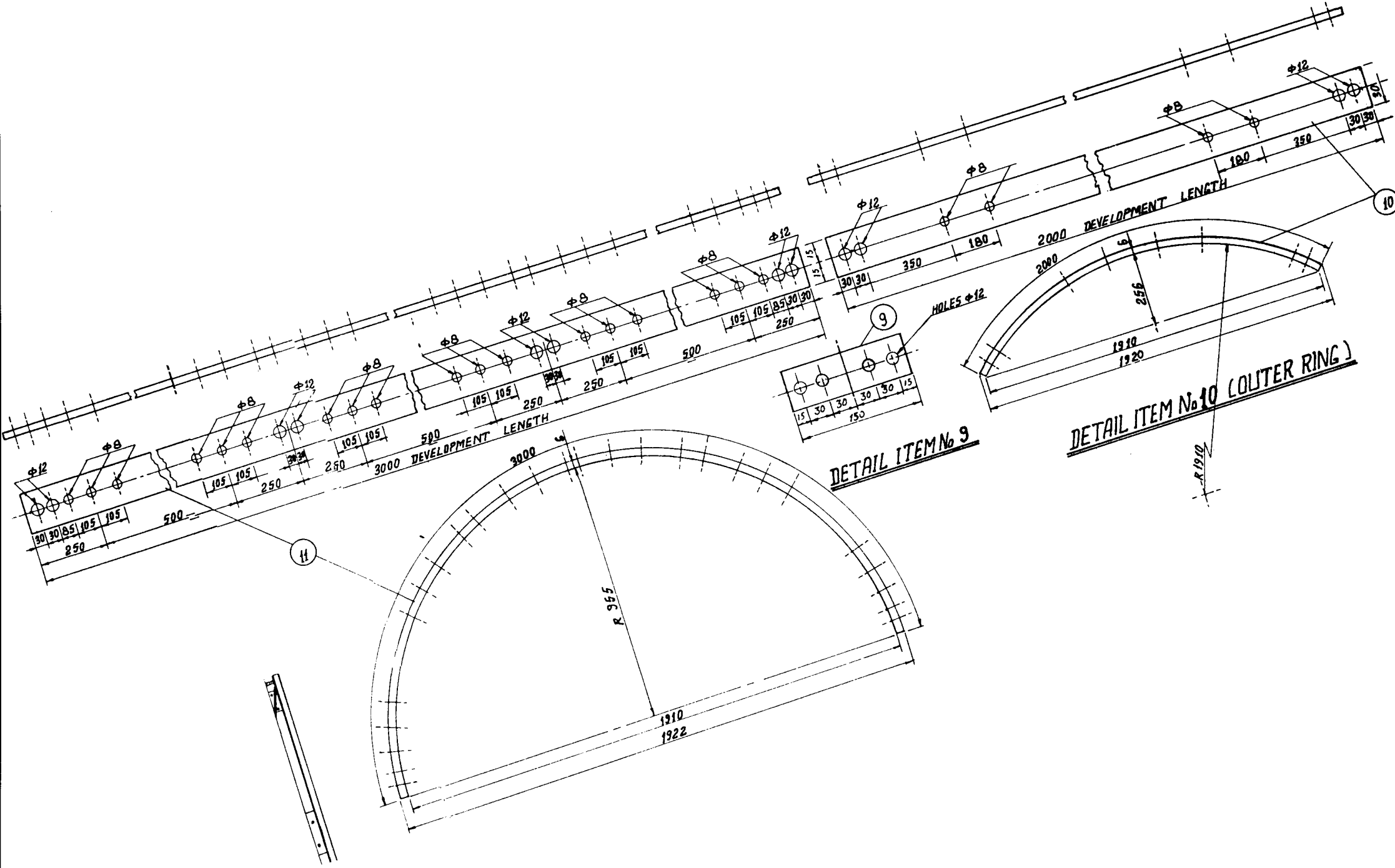
DETAIL ITEM No 9
HOLES Φ12
DETAIL ITEM No 10 (OUTER RING)
DEVELOPMENT LENGTH
3000 DEVELOPMENT LENGTH
2000 DEVELOPMENT LENGTH
R 955
R 1910
1910
1922
1910
1920
256
Φ8
Φ12
9
10
11

SL. No	No REQD	MATERIAL NAME / SIZE / MEASUREMENTS	REMARKS
17	52	NUT, BOLT, WASHER, M 12 x 40 (W ½" x 1½")	
16	4	M.S PLATE — 170 x 160 x 6	
15	4	FLATE IRON — 32 x 6 — 410	
14	1	TOWER PIPE — (4" N.B) B-GRADE — 2650	
13	1	P. V. C SLEVE PIPE — (4" BORE) — 710	
12	2	PLANK — 30 x 200 x 700	
11	2	FLATE IRON — 32 x 6 — 340	
10	2	" " — " " — 460	
9	2	" " — " " — 580	
8	2	ANGLE IRON — 35 x 35 x 5 — 660	
7	4	" " — 40 x 40 x 6 — 2000	
6	4	" " — 35 x 35 x 5 — 700	
5	4	" " — 50 x 50 x 6 — 250	
4	4	" " — 35 x 35 x 5 — 1400	
3	16	" " — " " " — 1940	
2	4	" " — 40 x 40 x 5 — 4500	
1	8	" " — 35 x 35 x 5 — 250	

TOWER-FOR 12 PU 500 WIND MILL

	DESIGNED BY	DRAWN BY	CHECKED BY	APPROVED BY	SCALE
		S.N. SRIJEEVAN SINGH	PRATAP SINGH		N.T.S.

FOR INFORMATION

WIND ENERGY R-&-D CENTRE
I.E.R.T. ALLAHABAD - 211002 INDIA.

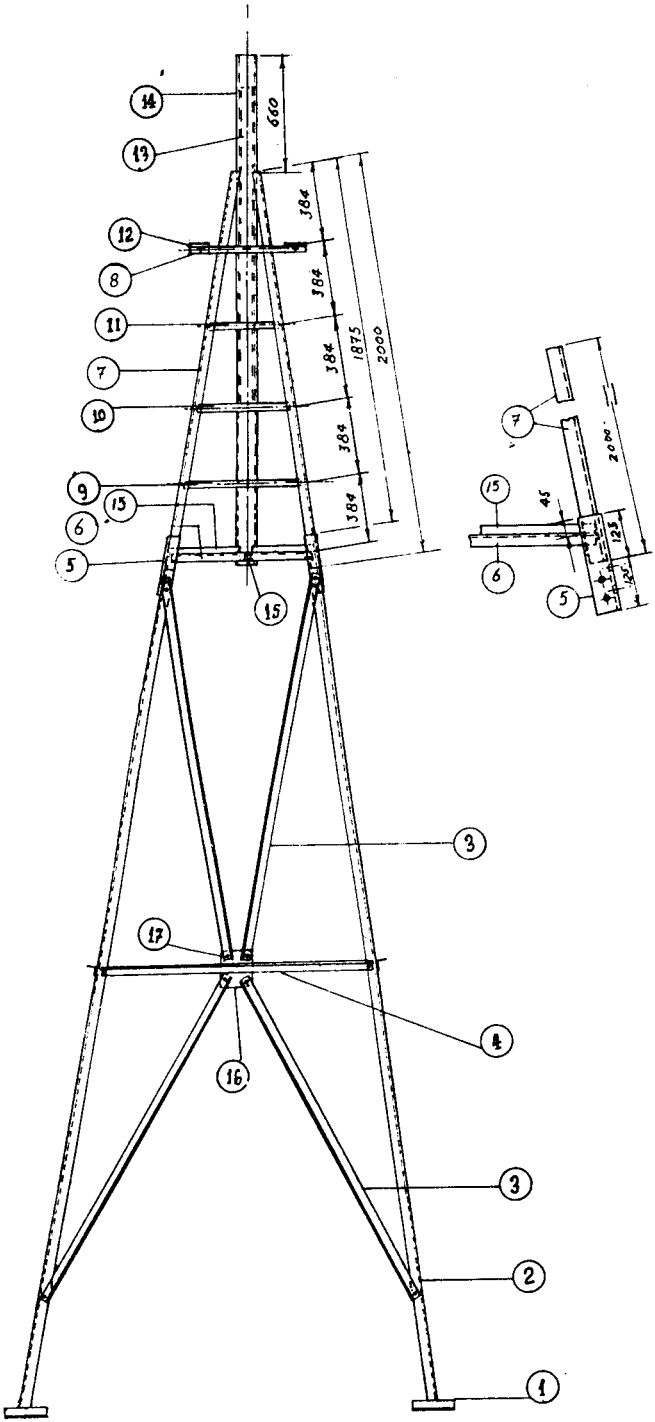
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13
660
384
12
8
384
11
384
1875
2000
7
10
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3
2
1

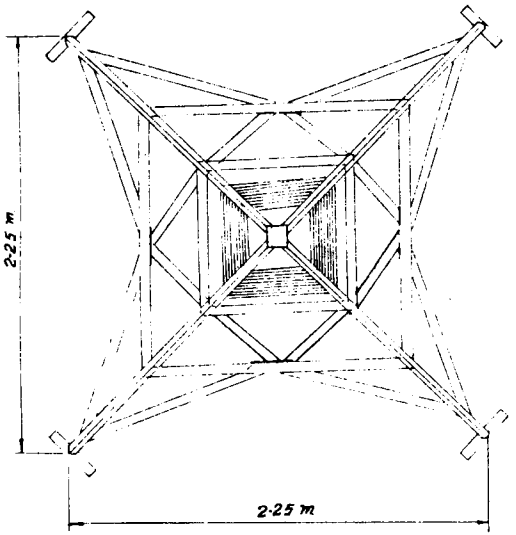

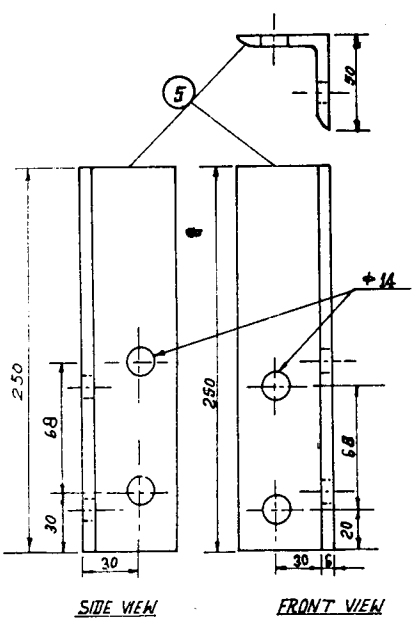

TOWER TOP & TOWER LEG JOINTER (OUTER)

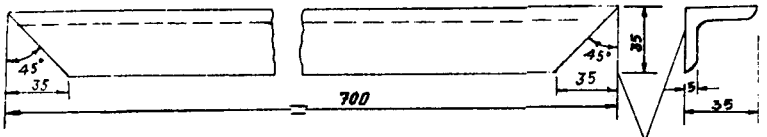

TOWER TOP BASE (HORIZONTAL)

6

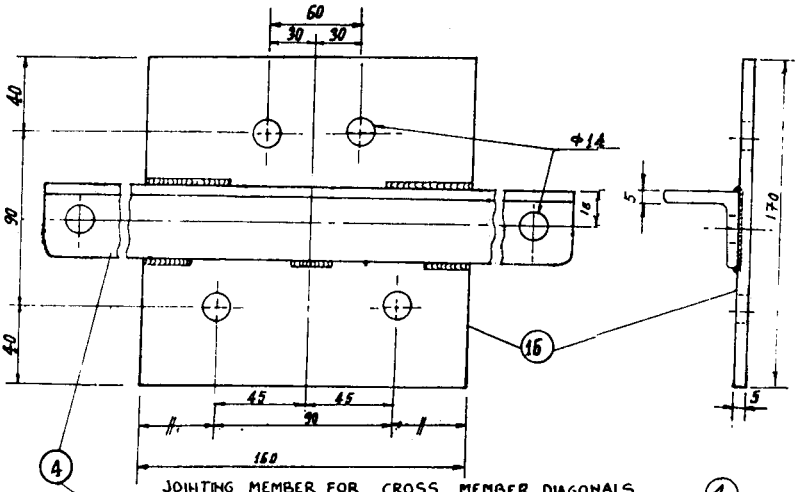

JOINTING MEMBER FOR CROSS MEMBER DIAGONALS

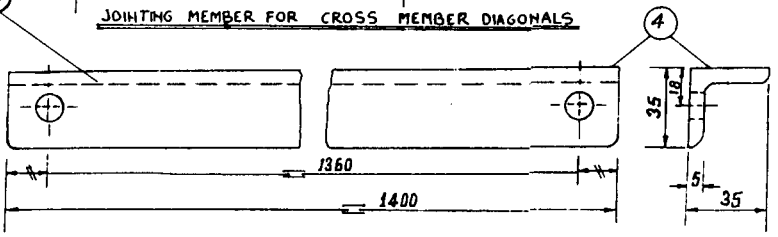

CROSS MEMBER FOR TOWER LEG

DETAIL ITEM No 4

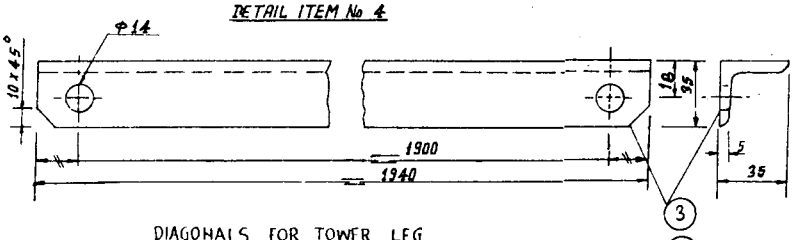

DIAGONALS FOR TOWER LEG

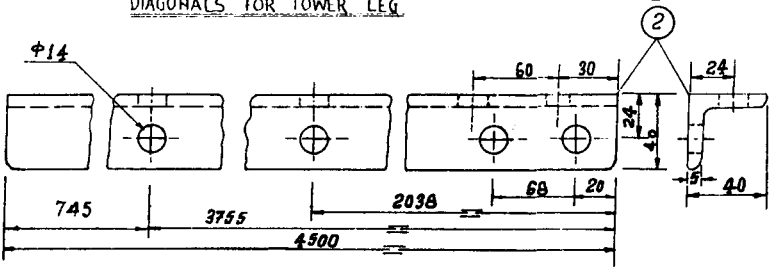

TOWER LEG

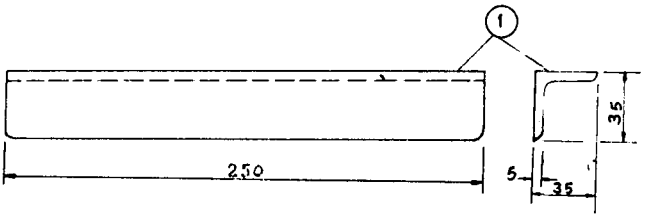

TOWER LEG FOUNDATION PIECE

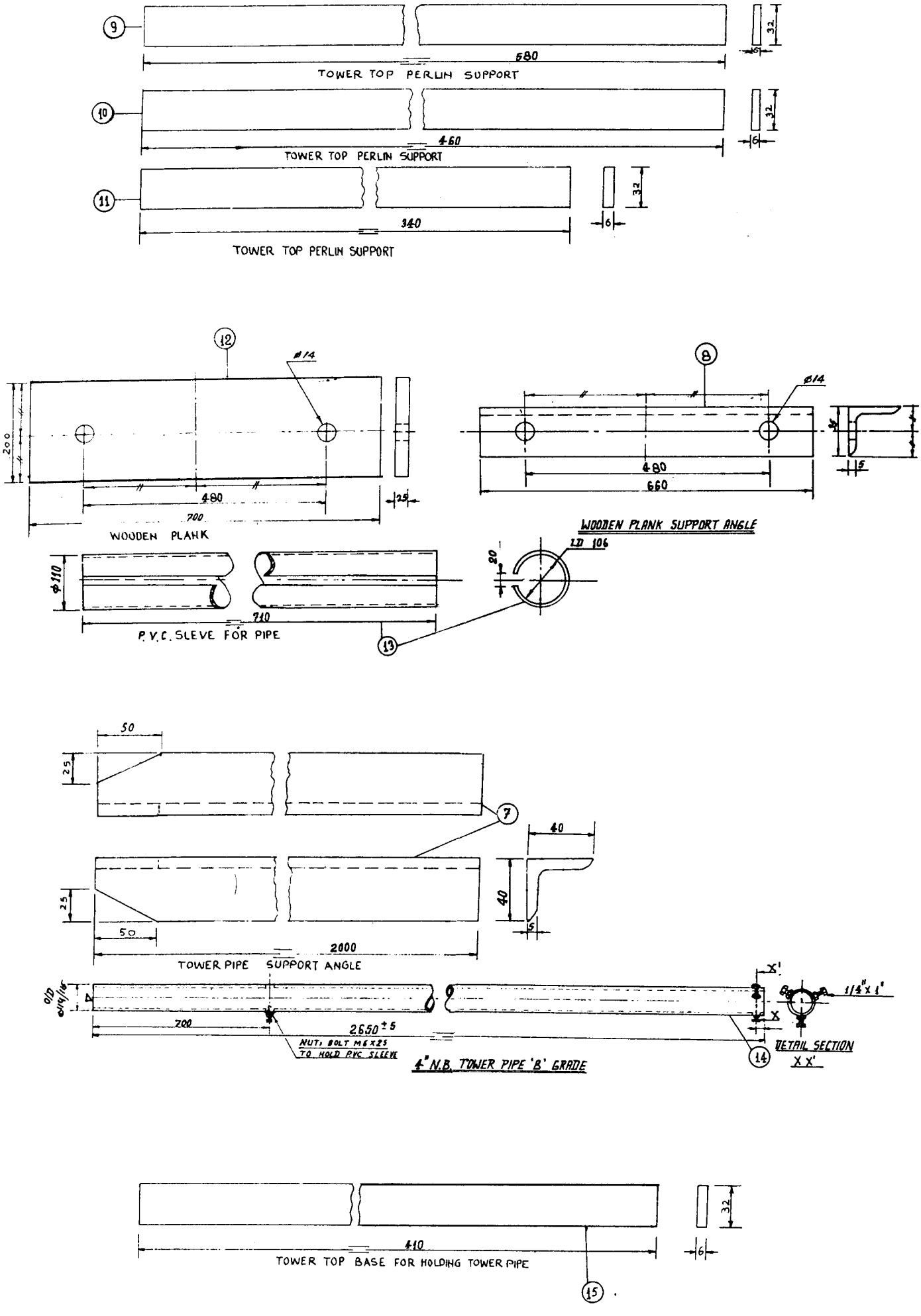
9
580
32
6
TOWER TOP PERLIN SUPPORT
10
460
32
6
TOWER TOP PERLIN SUPPORT
11
340
32
6
TOWER TOP PERLIN SUPPORT
12
ø14
200
480
700
25
WOODEN PLANK
8
ø14
480
660
36
15
WOODEN PLANK SUPPORT ANGLE
ø110
710
P.V.C. SLEVE FOR PIPE
20
ID 106
13
50
25
7
40
40
5
25
50
2000
TOWER PIPE SUPPORT ANGLE
OD 6 1/16
4
700
2650 ± 5
NUT, BOLT M6 X 25
TO HOLD PVC SLEEVE
4" N.B. TOWER PIPE 'B' GRADE
14
X'
X
1 1/4" x 1"
DETAIL SECTION
X X'
410
32
6
TOWER TOP BASE FOR HOLDING TOWER PIPE
15

SL. No	No REQD	MATERIAL NAME / SIZE / MEASUREMENTS	REMARKS
35	1	SPRING APP Φ 30 x 100 x Φ 4	
34	12	M.S. BOLT, NYLOCK NUT, WASHER M 6 X 25 (W ¼" x 1")	
33	1	M.S. BOLT, " " " M12 x 100 (W ½" x 4")	
32	1	M.S. BOLT, " " " M12 X 40 (W ½" x 1½")	
31	1	M.S NYLOCK NUT M22 (W 7/8")	
30	1	M.S. WASHER M 12 (W 1/2")	
29	1	M.S. ROD Φ 20 x 690	
28	1	HELP VANE 1 M.M SHEET 1000 x 500	
27	1	TAIL VANE 2000 x 1000	
26	1	RACHET FLAT IRON HARDEND 32 x 6 LENGTH — 480	
25	1	FLAT IRON 32 x 6 " — 900	
24	3	" " " " — 750	
23	1	" " " " — 830	
22	1	" " " " — 115.5	
21	1	" " " " — 130	
20	2	" " " " — 60	
19	2	" " (WEARING FLATE) " " — 115.5	
18	1	ANGLE IRON 40 x 40 x 5 — 1000	
17	1	" " " " — 45	
16	1	" " " " — 60	
15	1	" " " " — 125	
14	1	" " " " — 3000	
13	1	" " " " - 4000	
12	1	" " " " - 1500	
11	2	" " 65 x 65 x 6 — 250	
10	1	" " 40 x 40 x 5 — 500	
9	2	" " " " — 460	
8	2	" " " " — 540	
7	2	" " " " — 1110	
6	2	" " " " — 1000	
5	1	" " " " — 590	
4	2	" " " " — 555	
3	4	" " " " — 155.5	
2	1	" " " " — 280	
1	1	" " " " — 200	

HEADCONSTRUCTION-12PU500 - WINDMILL

DESIGNED - BY	DRAWN - BY	CHECKED - BY	APPROVED - BY	SCALE
	Trd. By - Mon Singh	PRATAP SINGH		N. T. S.

FOR INFORMATION

WIND ENERGY R-&-D CENTRE
I.E.R.T. ALLAHABAD - 211002-INDIA

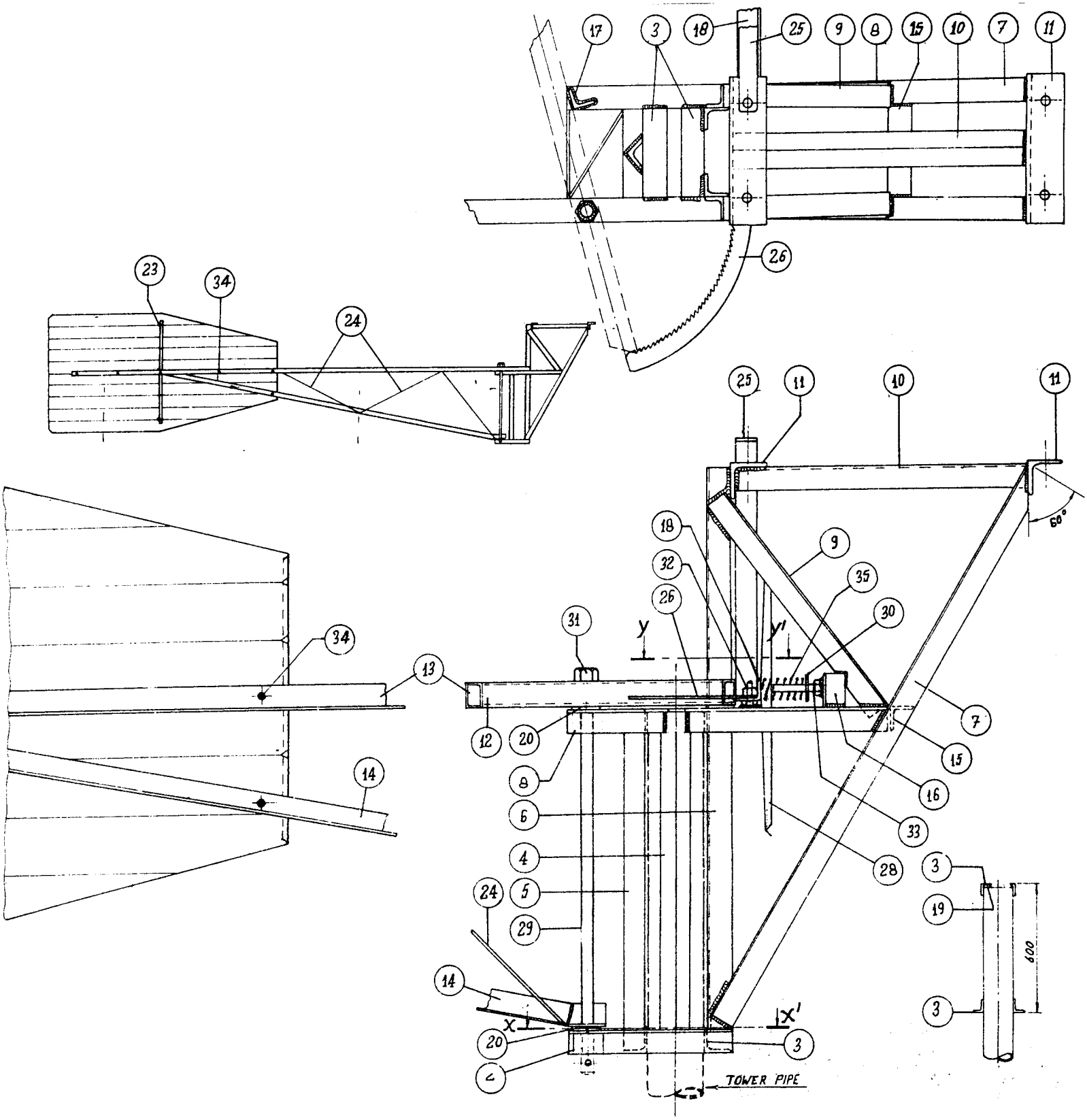
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3
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9
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15
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7
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26
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25
11
10
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32
35
26
30
31
y
y'
34
13
12
20
8
6
4
5
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x
x'
20
3
2
TOWER PIPE

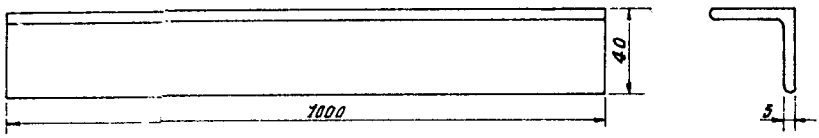

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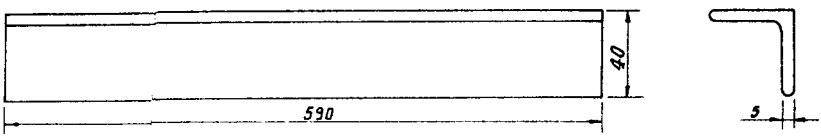

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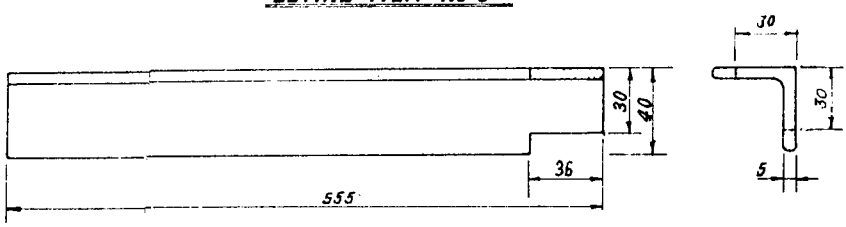

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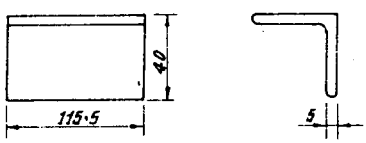

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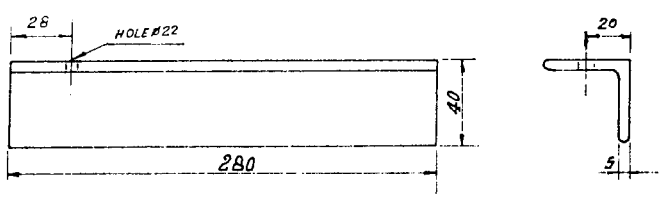

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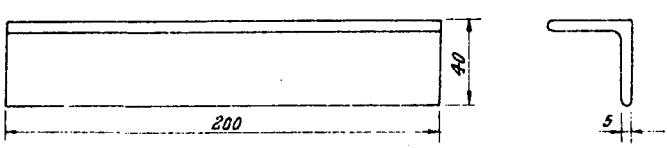

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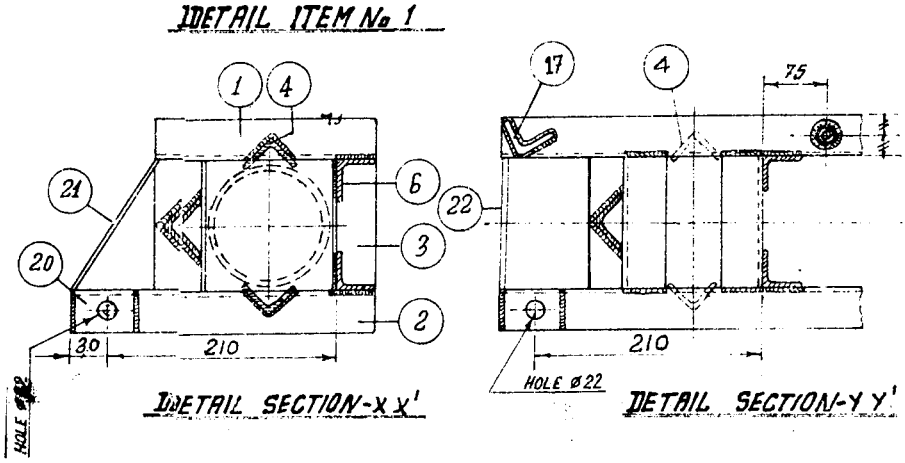

DETAIL SECTION-X X'

DETAIL SECTION-Y Y'

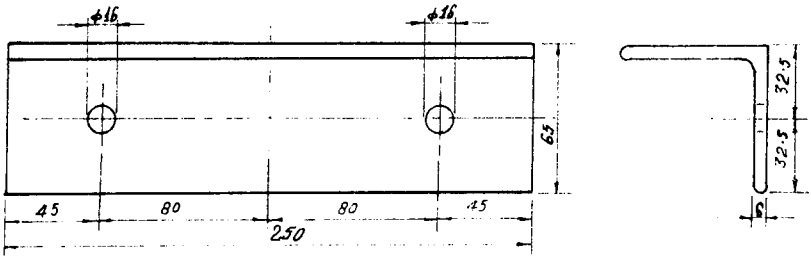

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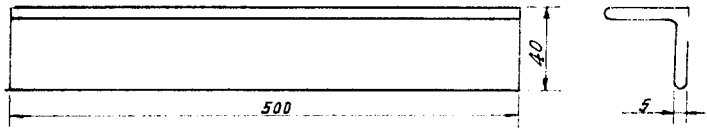

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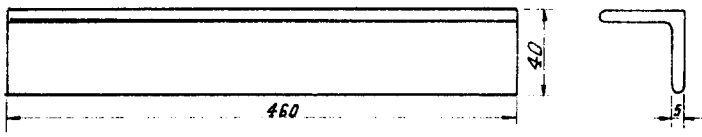

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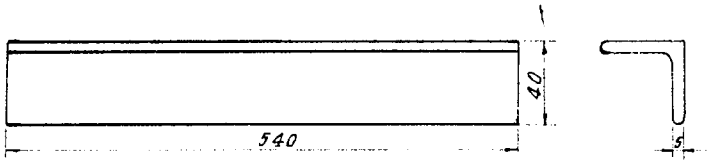

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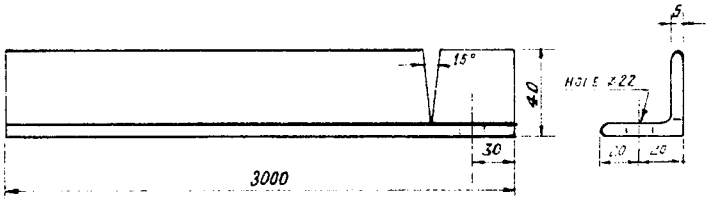

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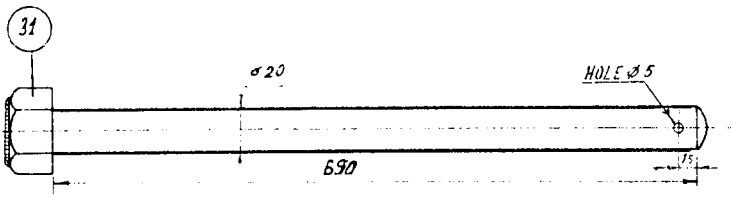

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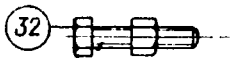

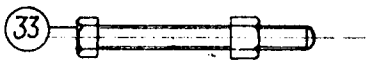

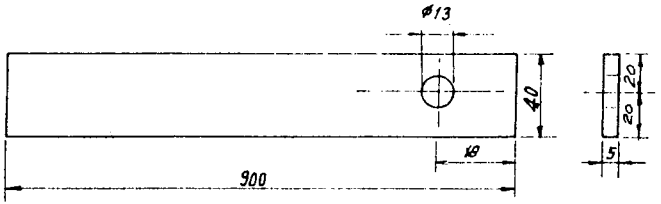

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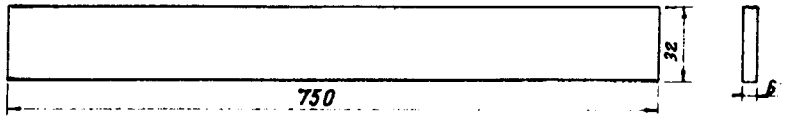

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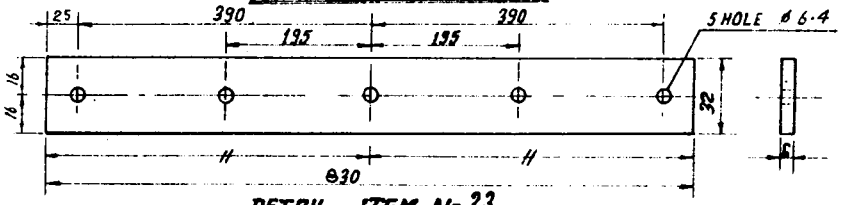

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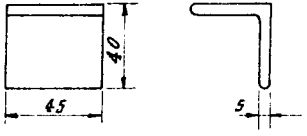

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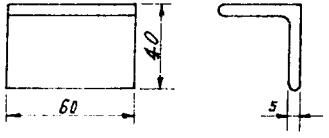

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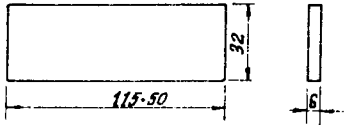

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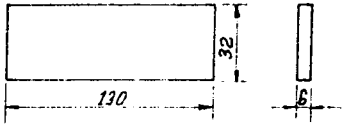

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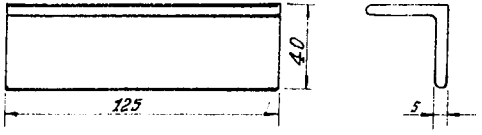

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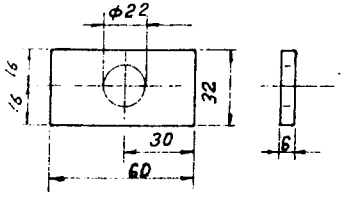

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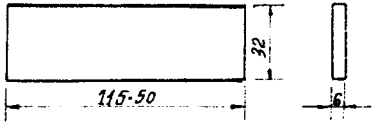

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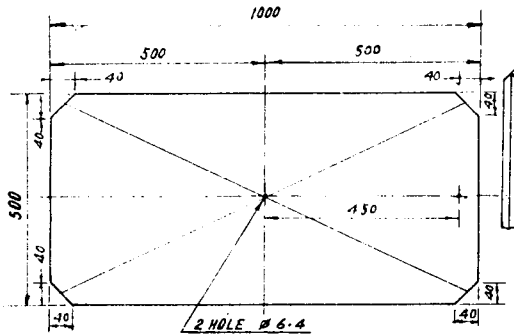

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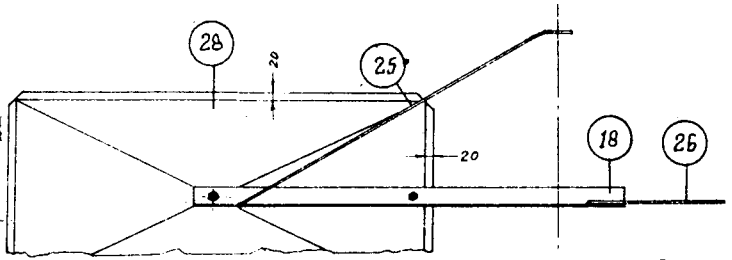

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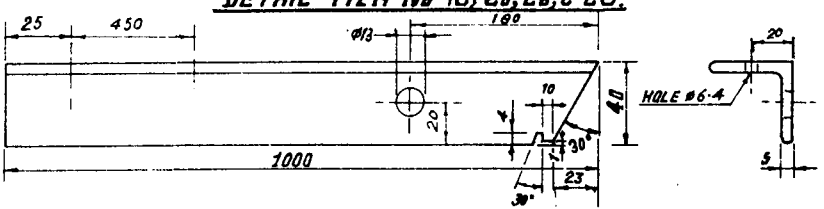

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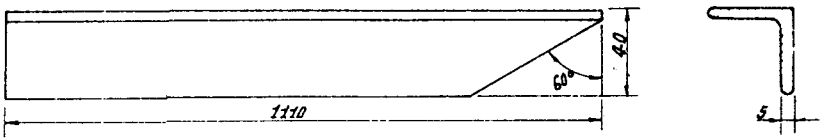

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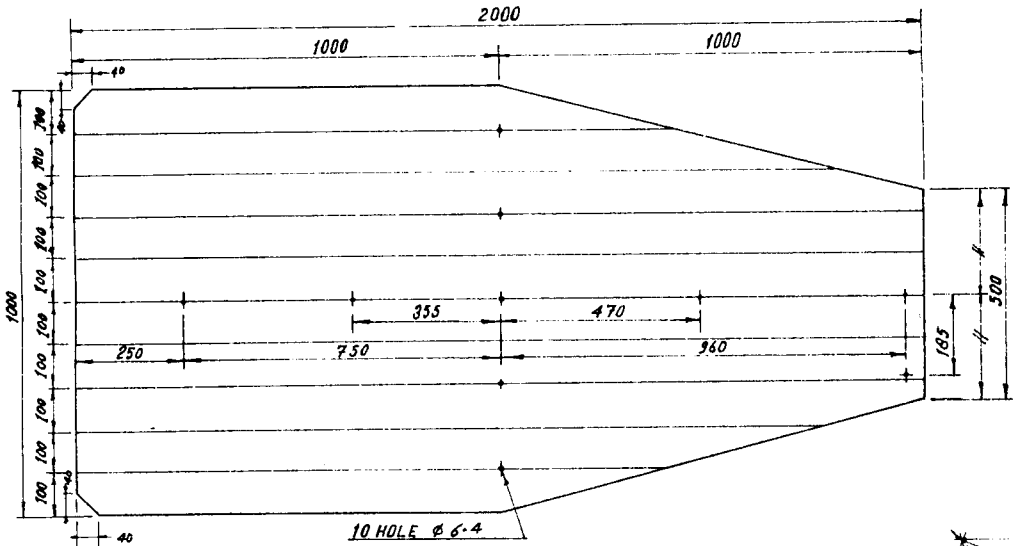

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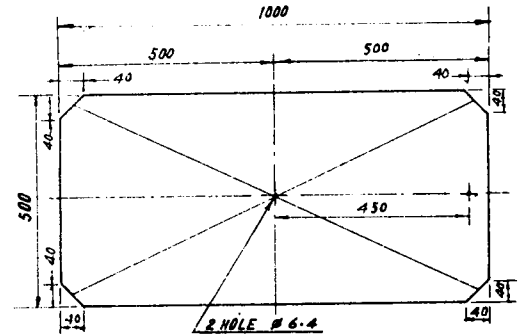

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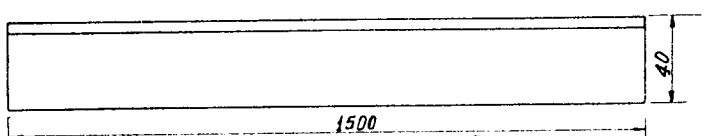

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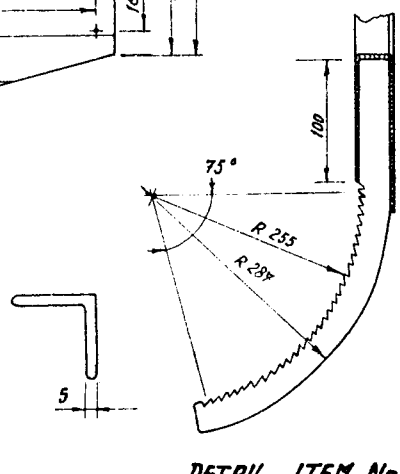

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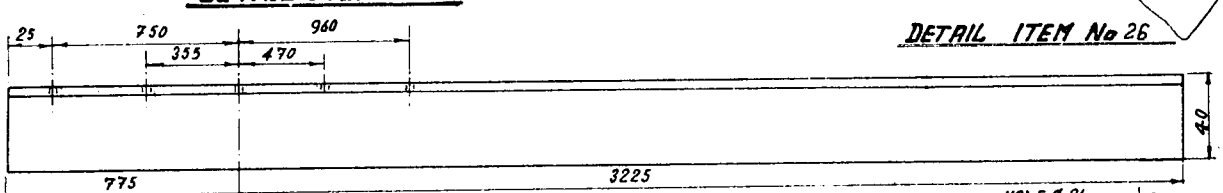

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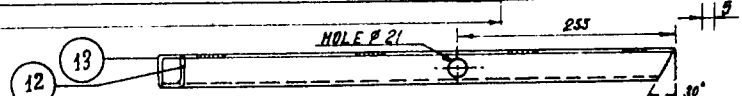

* LENGTH DEPEND UPON CIRCUMSTANCES.

SL No	N.REQD.	MATERIAL NAME / SIZE / MEASUREMENTS	REMARKS.
21	2	TEAK WOOD PUMP ROD GUIDE	
20	*	G.I. PIPE (G.S.T. MAKE) CLASS 'A'	
19	1	GREASE CUP	
18	1	FLAT IRON. 25x6 250	
17	2	" " " 135	
16	1	" " 40x10 165	
15	2	" " 15x6 300	
14	4	" " 30x6 50	
13	1	" " CONNECTING ROD:-30x6 650	
12	1	POLYPROPELENE CROSS HEAD.	
11	1	M.S. CROSS PIN. φ25 92	
10	2	M.S. BOLT, NUT, WASHER M10x100 (W 3/8"x4")	
9	4	M.S. BOLT, NUT, WASHER. M12x50 (W 1/2"x2)	
8	1	M.S. NUT. M20 (W 3/4")	
7	1	M.S. CRANK BOLT (G.K.W MAKE):-M20x75 (W 3/4"x3")	
6	1	M.S. WASHER φ20xφ40x3mm	
5	1	M.S. BUSH φ20xφ40x44	
4	4	NYLON BUSH (MOULDED) φ25xφ38x18	
3	2	M.S. BUSH φ33xφ43x33	
2	2	PILLOW BLOCK (BEARING) φ50 (FYH & NTN P 210J 50mm ±0.01 BORE	
1	1	M.S. MAIN SHAFT φ50x1300	

MOVINGPARTS OF 12 PU 500 WINDMILL

DESIGNED BY	DRAWN BY	CHECKED BY	APPROVED BY	SCALE
	TRD. BY	PRATAP SINGH		N.T.S.

FOR INFORMATION

WIND ENERGY R.&D CENTRE
INSSTT. OF ENGINEERING AND RURAL TECHNOLOY
ALLAHABAD - 211002

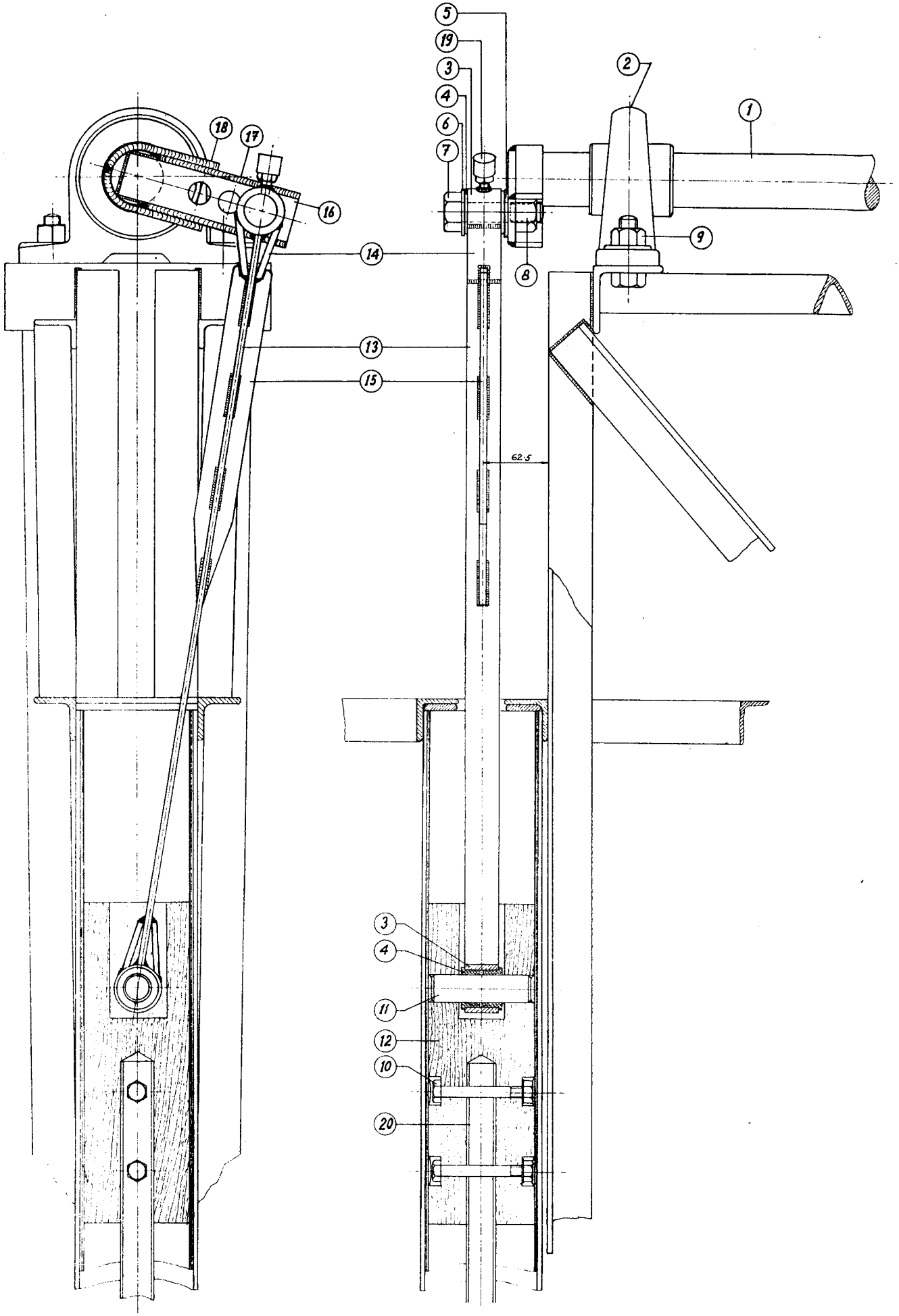
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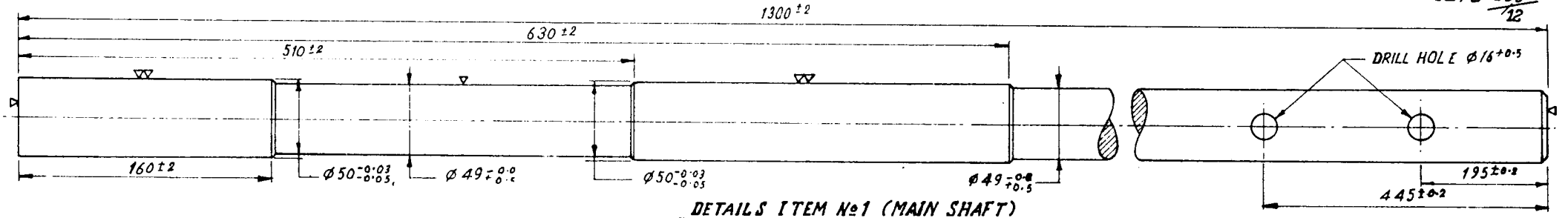

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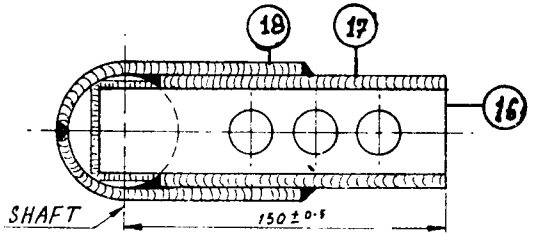

SIDE VIEW

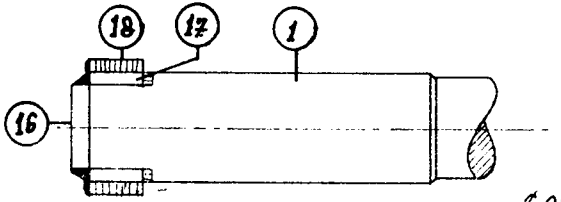

FRONT VIEW

(CRANK) DETAILS ITEM № 16, 17 & 18 WITH SHAFT ASSY. (WELDING)

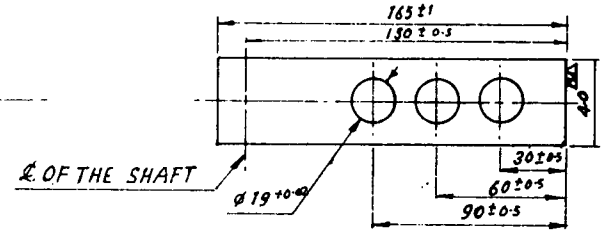

DETAILS ITEM № 16

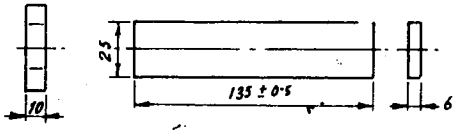

DETAIS ITEM № 17

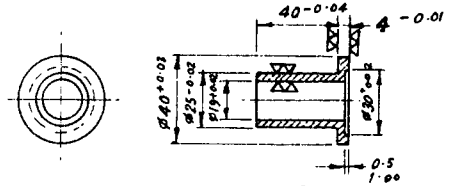

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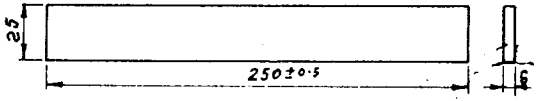

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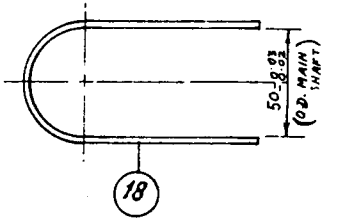

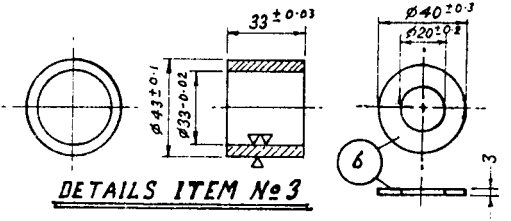

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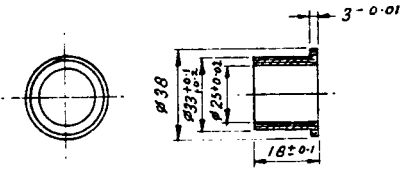

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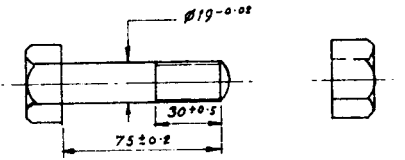

DETAILS ITEM № 7, 8

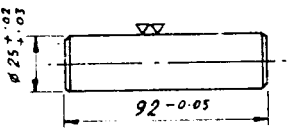

DETAILS ITEM № 11

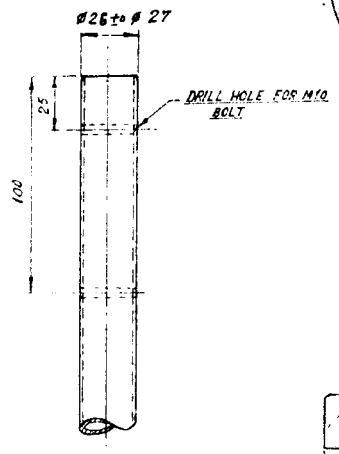

PUMPROD & PISTON ROD

ITEM № 20

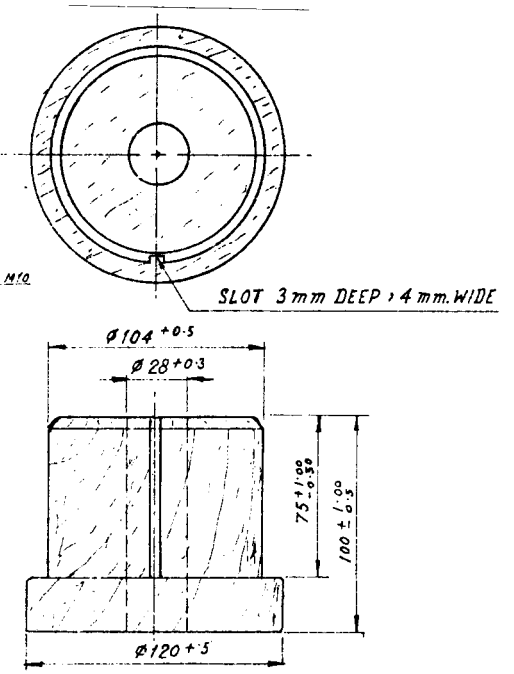

PUMPROD WOODEN GUIDE

(SL. № 42 ON 12 PU 500 PUMP DESIGN)

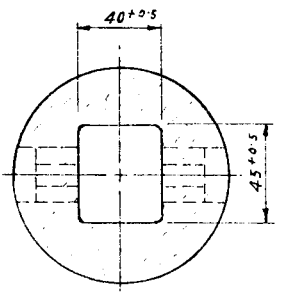

TOP VIEW

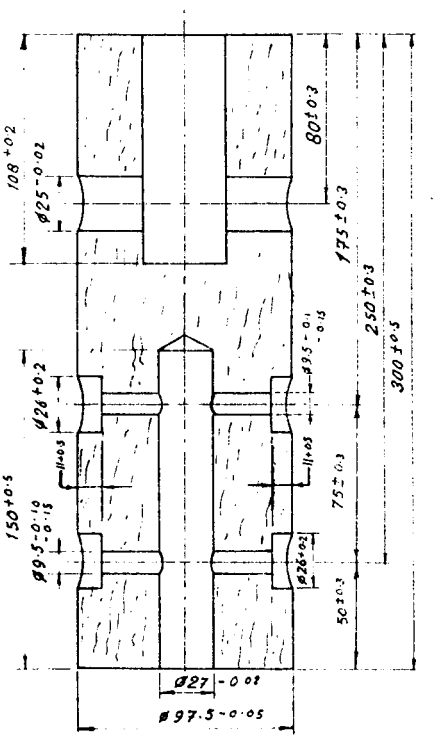

SECTIONAL FRONT VIEW

(CROSSHEAD). DETAILS ITEM № 12

NOTE :—

* MARKED THUS INDICATES THAT LENGTH OR QUANTITY WILL VARY ACCORDING TO CIRCUMSTANCES

SL.No	No.REQD	MATERIAL NAME / SIZE / MEASUREMENTS / REMARKS
36	1	TEAK WOOD / POLYPROPELENE — TEAK WOOD — 5"X5"X4"
35	2	CLAMP ROD ø12 (1/2")X370 mm.
34	1	BOLT, NUT, WASHER M12 X 20 (W 1/2" X 3/4")
33	4	BOLT, NUT, WASHER M12 X 125 (W 1/2" X 5")
32	*	SPRING WASHERS M24 (W 7/8")
31	*	NUTS M24 (W 7/8")
30	*	THREADED STUD M24 X 100 (W 7/8" X 4")
29	1	THREADED STUD M24 X 125 (W 7/8" X 5")
28	*	GUN METAL BUSH ø 33 X 30 mm.
27	*	STEEL BUSH ø 43 X 33 mm.
26	1	PISTON TEAK WOOD / POLYPROPELENE
25	1	GASKET NITRILE RUBBER / SOLE LEATHER ø290 X 6 mm
24	2	VALVE ø 150 X 6
23	1	RING ROD ø 8 (3/8") — 870 mm.
22	8	FILLING PIECE ROD ø 8 (3/8") — 40 mm.
21	2	ANGLE IRON 40 X 40 X 4 (1 1/2" X 1 1/2") — *
20	3	FLAT IRON 30 X 6 (1 1/4" X 1/4")
19	*	" " " " — 700 mm.
18	1	" " " " — 450 mm.
17	1	" " " " — 180 mm.
16	4	" " " " — 60 mm.
15	12	" " " " — 85 mm.
14	1	FOOT VALVE 3mm. SHEET ø170 mm.
13	2	CASING 500 X 900 mm.
12	1	CASING FLANGE ø 290 mm.
11	2	CASING FLANGE ø 290 mm.
10	1	CYLINDER SEAMLESS 6" GAS PIPE — 460 mm.
9	1	DELIVERY PIPE 4" " " — 560 mm.
8	*	SOCKET FOR 4" " "
7	1	T- SOCKET " " " "
6	*	DELIVERY PIPE 4" " " — *
5	1	EXHAUST PIPE 4" " " — *
4	1	TOP PIPE 4" " " — 750 mm.
3	4	PIPE 5/8" " " — 100 mm.
2	1	PUMP ROD 3/4" " " — 900 mm.
1	*	PUMP ROD EXTENSION 3/4" " " — *

PISTON PUMP FOR 12 PU 500 WIND MILL

DRN. BY	TRD. BY	CHD. BY	APPVD. BY	SCALE
Tiwari (R. K. Tiwari)	Tiwari (R.K. Tiwari)			NTS

FOR INFORMATION

WIND ENERGY R. & D. CENTRE
I.E.R.T. ALLAHABAD - 211002 - INDIA

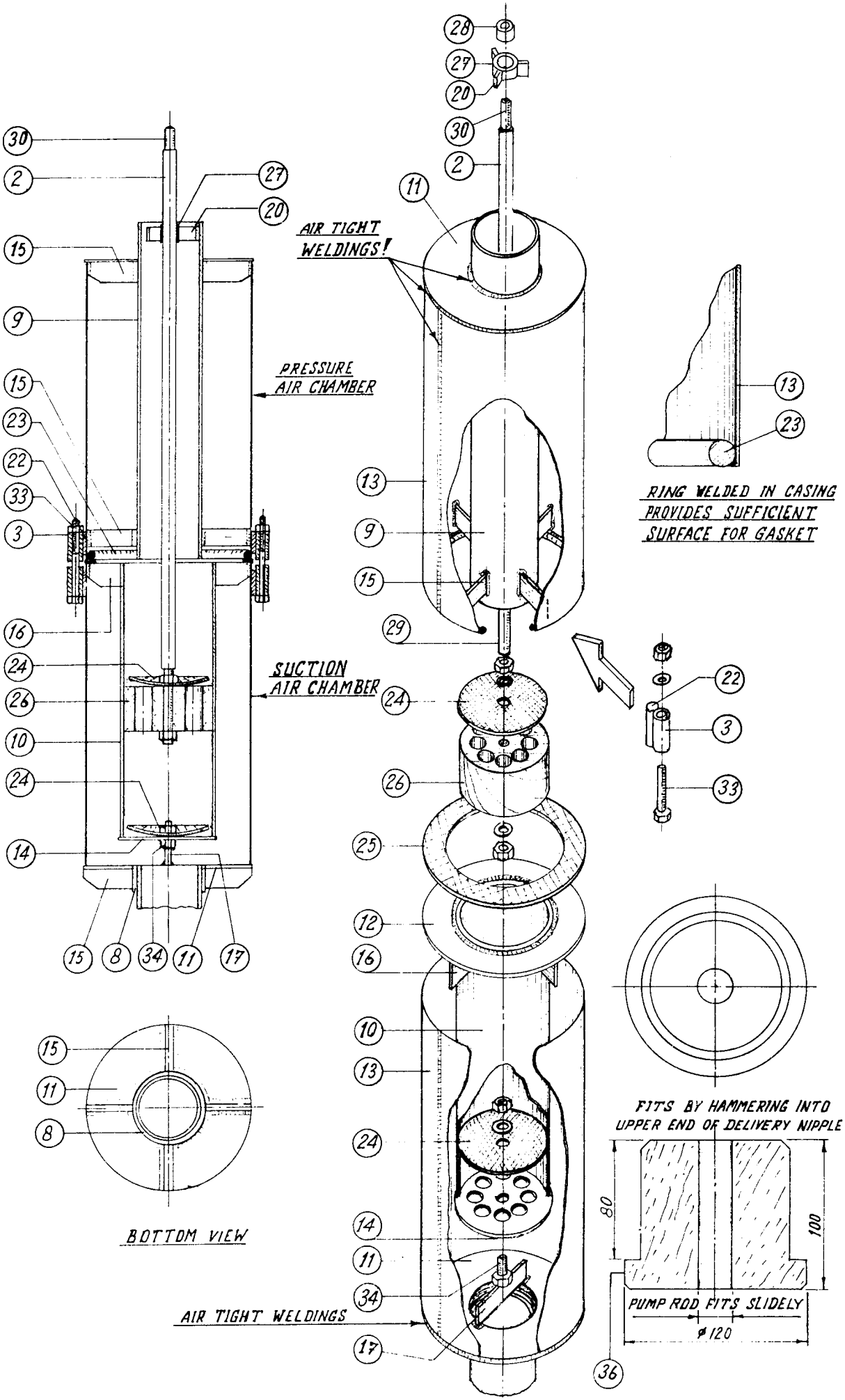
AIR TIGHT WELDINGS!
PRESSURE AIR CHAMBER
SUCTION AIR CHAMBER
RING WELDED IN CASING PROVIDES SUFFICIENT SURFACE FOR GASKET
BOTTOM VIEW
FITS BY HAMMERING INTO UPPER END OF DELIVERY NIPPLE
80
100
PUMP ROD FITS SLIDELY
ø 120
AIR TIGHT WELDINGS

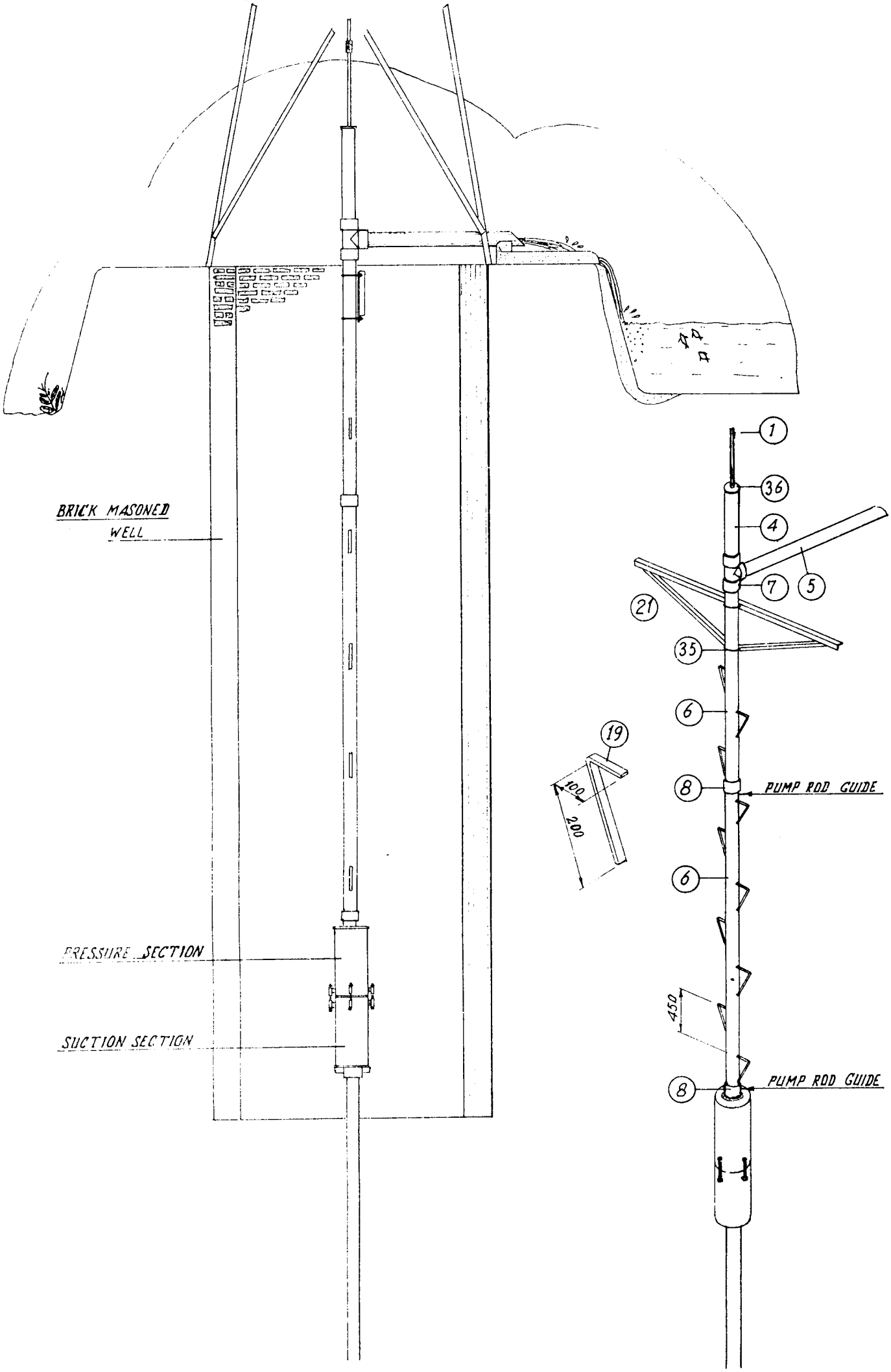
BRICK MASONED WELL
PRESSURE SECTION
SUCTION SECTION
1
36
4
5
7
21
35
6
19
100
200
8
PUMP ROD GUIDE
6
450
8
PUMP ROD GUIDE

let us consider the design, development and production of windmills. The windmills as produced in industrialised countries use high technology, requiring well-developed associated technologies to assist the design. Some of the complex blades used in certain windmills are actually the result of complicated computor programmes, complex materials and sophisticated presses to fashion the shapes. It would be inappropriate to introduce to a developing country a technology which is either static, or too advanced for manufacture in the country. In other words, a starting point has to be established which is compatible with technological skills available in the country at that particular time, so that as and when the country acquires high technology, a linkage can be readily created whereby products or equipment are naturally and automatically improved through the use of that high technology. The drawings supplied in Figures 6.8 to 6.23 for the manufacture of windmills take into account that 'starting point', fully utilising available skills and technology, while leaving ample room for further development and improvement.

The windmill designated 12 PU 500 Windmill for Irrigation has been designed by Niek van de Ven for the Working Group on Development Technology (WOT), Twente University of Technology, Vrijhof 152, P.O. Box 217, 7500 AE ENSCHEDE, The Netherlands. Any technical assistance or further information needed will be gladly supplied by the Working Group on request.

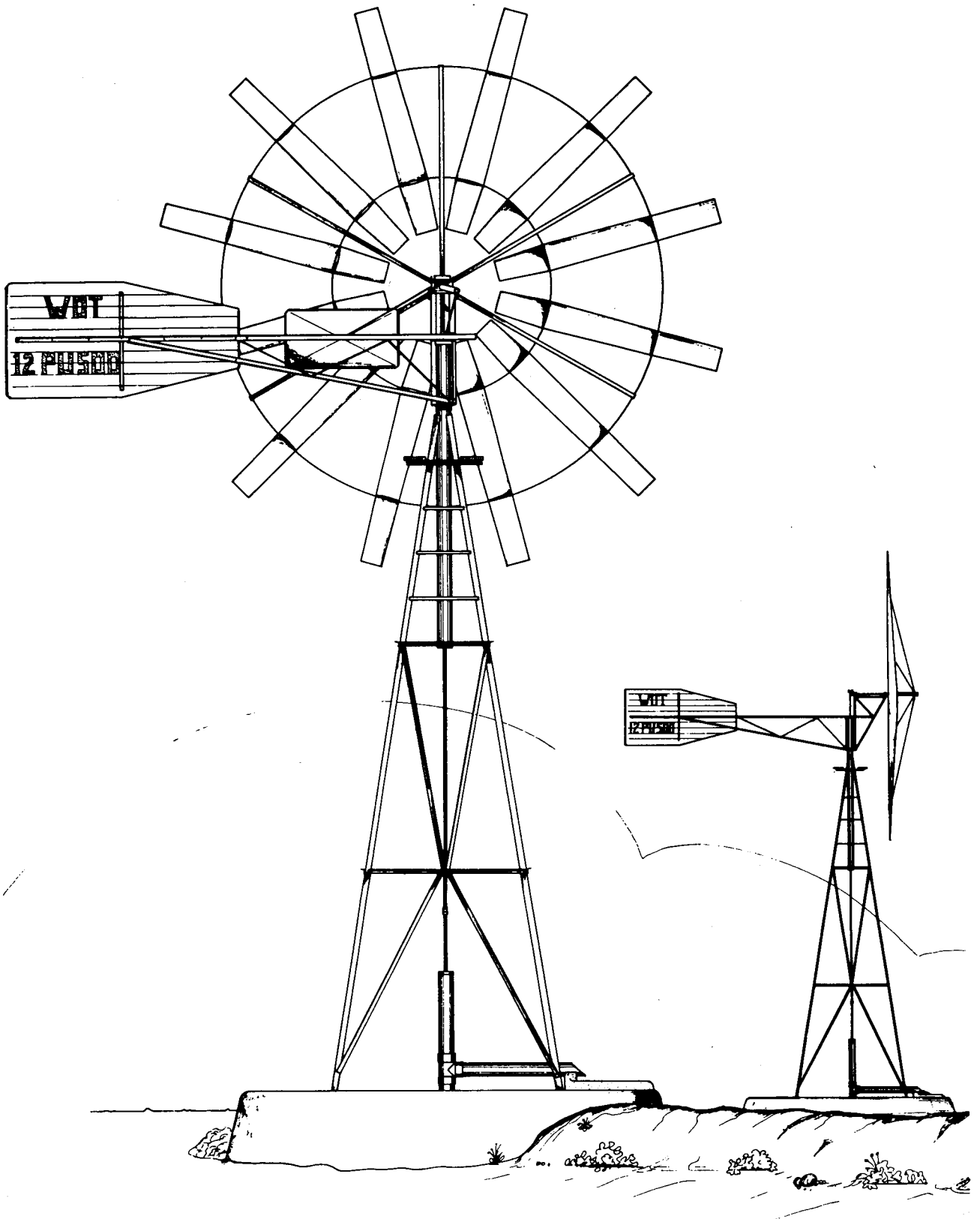
WBT
12 PU500
WBT
12 PU500

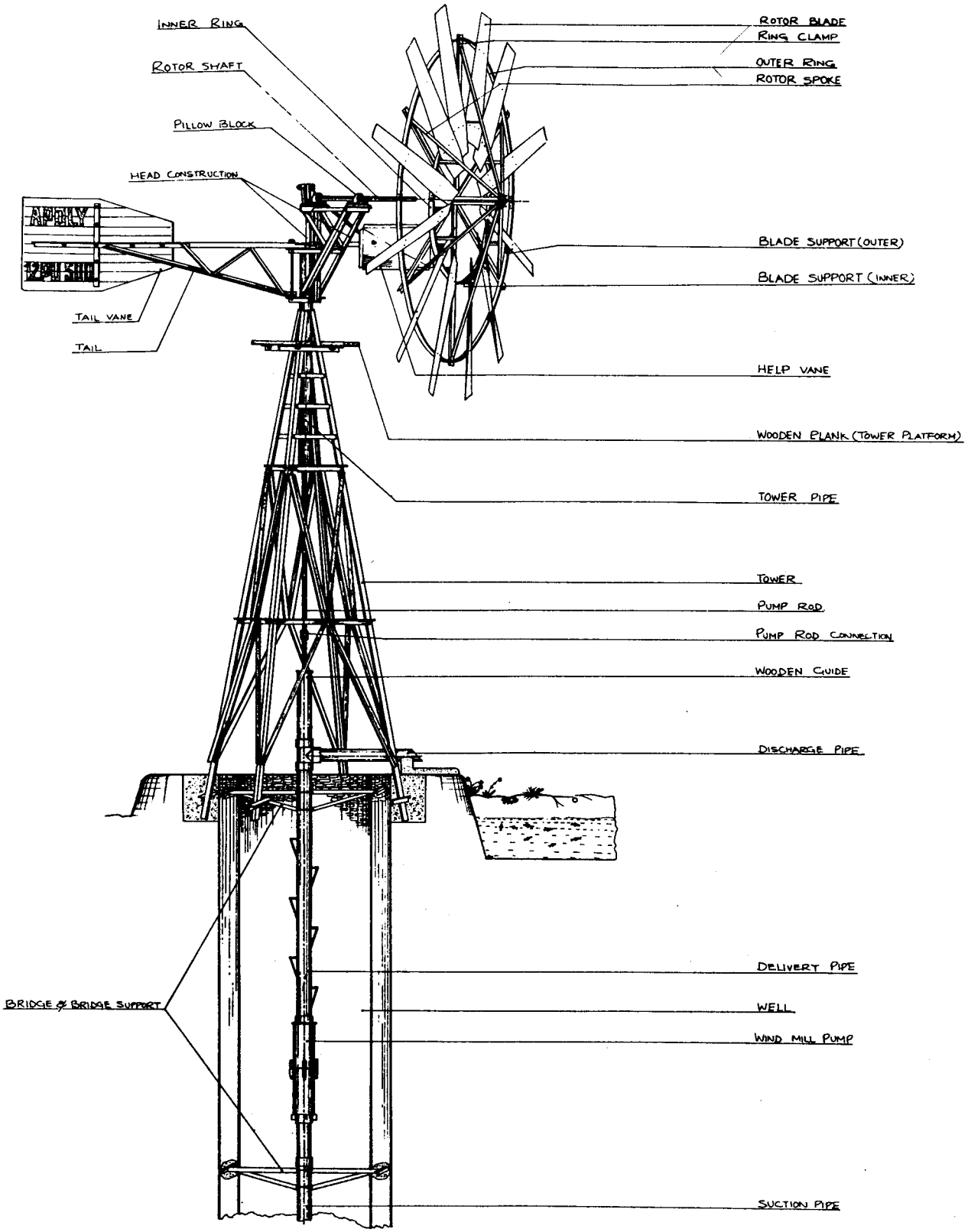

Fig. 5 12 P U 500 Water Pumping Windmill

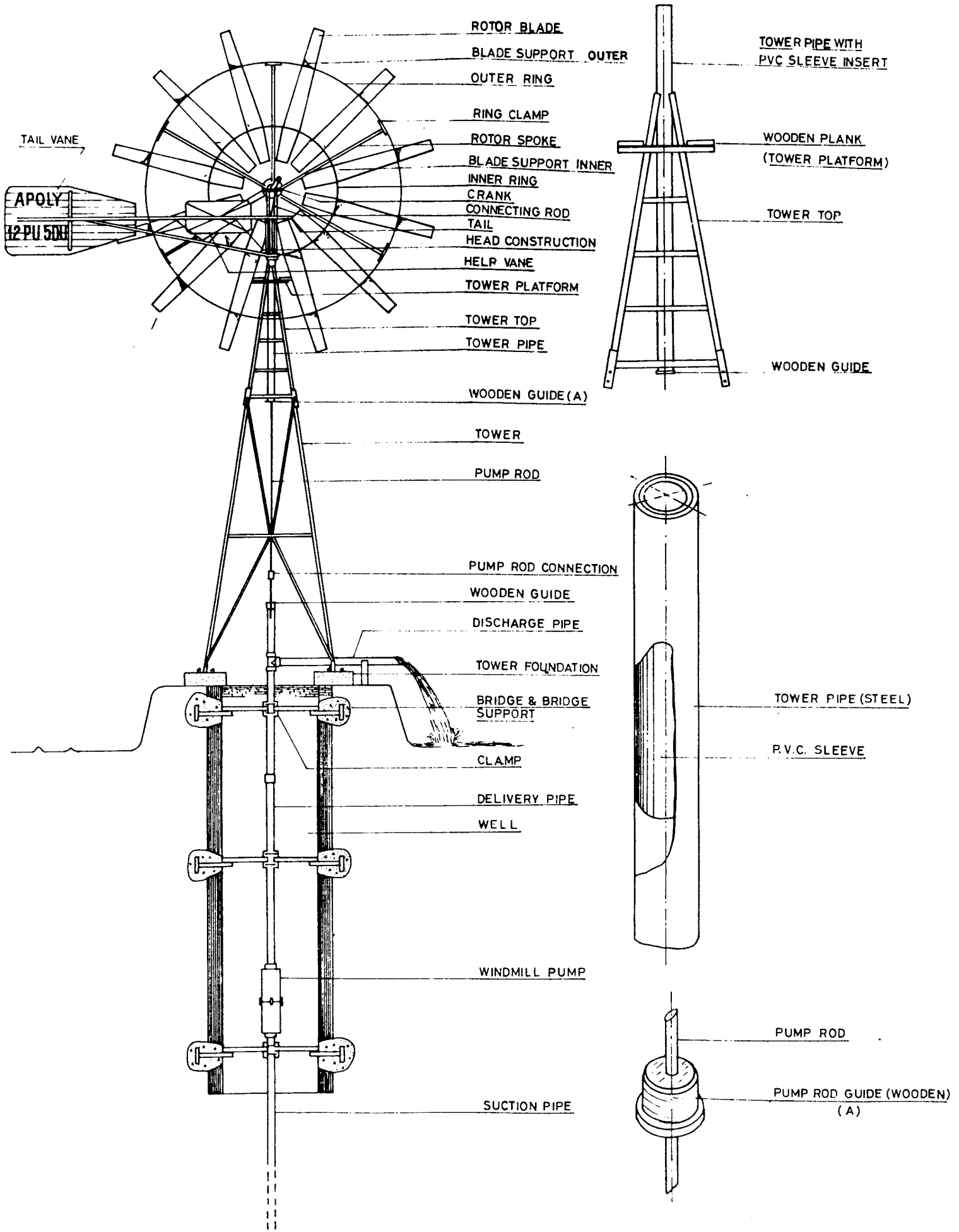
ROTOR BLADE
BLADE SUPPORT OUTER
OUTER RING
RING CLAMP
ROTOR SPOKE
BLADE SUPPORT INNER
INNER RING
CRANK
CONNECTING ROD
TAIL
HEAD CONSTRUCTION
HELP VANE
TOWER PLATFORM
TOWER TOP
TOWER PIPE
WOODEN GUIDE (A)
TOWER
PUMP ROD
PUMP ROD CONNECTION
WOODEN GUIDE
DISCHARGE PIPE
TOWER FOUNDATION
BRIDGE & BRIDGE SUPPORT
CLAMP
DELIVERY PIPE
WELL
WINDMILL PUMP
SUCTION PIPE
TAIL VANE
APOLY
12 PU 500
TOWER PIPE WITH PVC SLEEVE INSERT
WOODEN PLANK (TOWER PLATFORM)
TOWER TOP
WOODEN GUIDE
TOWER PIPE (STEEL)
P.V.C. SLEEVE
PUMP ROD
PUMP ROD GUIDE (WOODEN) (A)

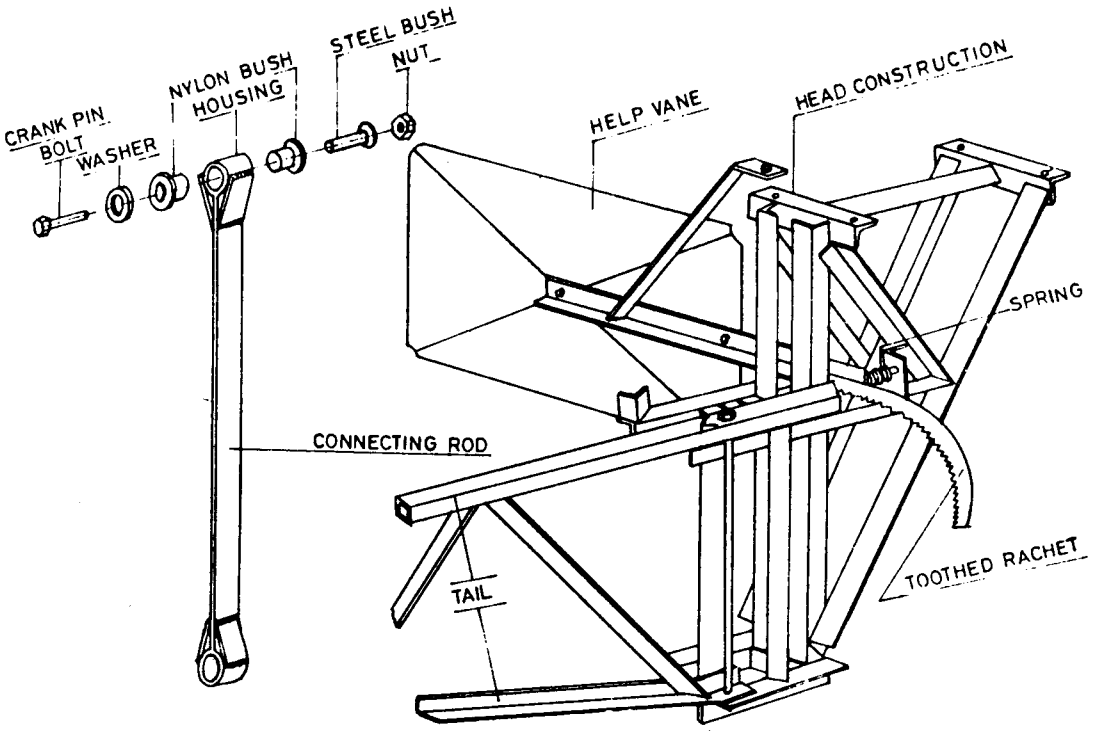

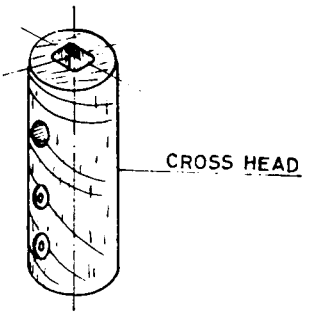

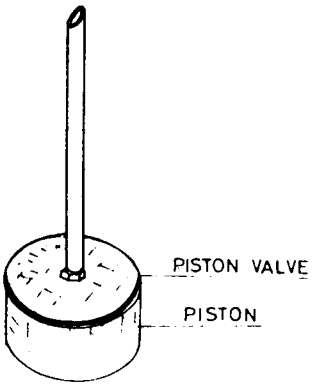

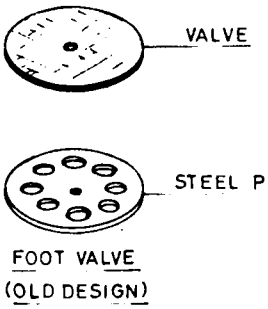

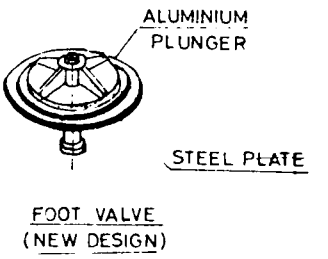

SCHEMATIC OF

12 PU 500 WATER PUMPING WINDMILL

INSTALLATION

WIND ENERGY R & D CENTRE
INSTITUTE OF ENGG. & RURAL TECHNOLOGY

ALLAHABAD
211002

7. Guidelines for Site Selection for 12-PU-500 Water Pumping Windmill

GUIDELINES FOR SITE SELECTION

7.0 General

Water pumping windmills can be installed on an open well, a tube well, or near a canal, stream, pond, creak etc.

7.1 Surroundings of the Site

Taking the site as the centre there should not be any obstacle of more than 4 meter high height within an area of 100 m radius. If any such obstacle is there it should be cleared before the installation of the windmill. Alternatively, the height of the tower has to be increased suitably.

7.2 Well and Boring

(a) If the diameter of the well is not small enough to accommodate "tower leg pitch", some modification has to be carried out in the tower design. In case the well is of a larger diameter than the tower, the legs have to be increased in length. Two legs then will be supported over a steel bridge or a ginder spanning over the well and the remaining two legs will be outside the well.

(b) The well should be in proper condition, otherwise repairs in the masonry work and cleaning of the well should be carried out before the installation.

(c) The refilling capacity of the well should be about 25 cubic metre/hr. otherwise cleaning/ boring of well has to be done. If it is a cavity boring, it should be cleaned preferably by compressor unit so as to achieve a discharge rate not less than 35 cubic metre/hr.

(d) When the installation has to be done over a borewell, a masonry pit is prepared. The diameter of the pit may be 1.5 m, and its depth shall be the same as spring water level below the ground.

(e) The total head over which the water is to be pumped should preferably be within 15 m and not more than 20m in any case.

7.3 Water Storage Tank

Before the construction of water storage tank near the windmill, it is necessary to test or evaluate the soil characteristics, specially its permeability. This will help in deciding whether the tank be an earthen one or lined by a suitable material.

A proforma has been designed to collect relevant site information to select a suitable installation site.

7.4 Proforma for Site Selection

1. (i) Name and address of the organisation. .....

   (ii) Name and address of the representative of the organisation. .....

2. Exact location of the place where the windmill is to be erected .....

3. End use of the windmill

   (a) If drinking water supply, population to be served .....

   (b) If minor irrigation, cultivated area in hectares with cropping pattern .....

   (c) If brine pumping, quantity of salt water to be pumped in litres. .....

4. Distance of the windmill site from the collaborating organisation (please mention the details of the route to the windmill site. .....

5. Surroundings of the site :

   (a) Obstacle, if any, within metre radius (taking site as centre) :

      (i) Nature of the obstacle .....

      (ii) Distance of the obstacle from the windmill site .....

      (iii) Height of the obstacle .....

   (b) Whether it can be removed or not .....

   (c) Whether it should be removed or not (considering main wind direction) .....

6. Available sources for water pumping

Open well/pond/river/sea/tube well/ canal/any other. .....

(a) If open well -

(i) Inside diameter/size/depth Please give dimensions A,B,C,D,E and F on figure 7. .....

(ii) Average depth of water table in summer season .....

(iii) Average depth of water table in rainy season .....

(iv) Refilling capacity of well/tube well .....

(v) Whether the capacity can be increased or not .....

(b) If bore well -

(i) Depth of boring .....

(ii) Size of tube well .....

(iii) Position of the boring at the centre/out of centre .....

(iv) Age of the boring/well .....

(v) Whether the boring has been cleaned. .....

(vi) Date of boring .....

Type of system used for cleaning. .....

(vii) Vertical distance between the top of bore pipe and the water table. .....

(ix) Height of the boring pipe above water level. .....

In rainy season .....

In summer season .....

Approximate value of soil bearing capacity of the soil .....

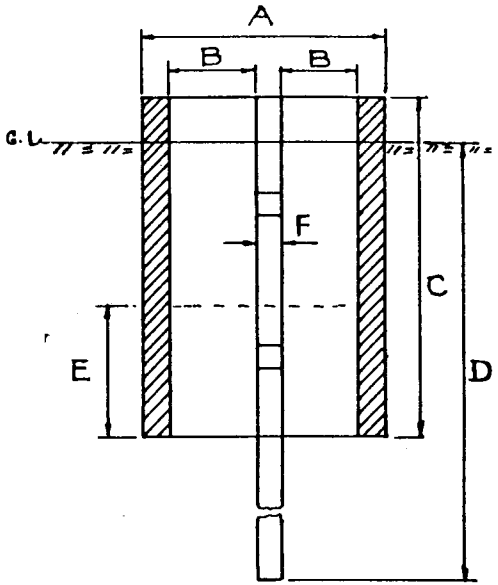

Fig. 7 Dimensions of Well and boring to be measured and recorded

8. Approximate value of soil permeability (in view of water retention in storage tank built at the ground level) .....

9. Whether auxiliary structures are to be made in view of windmill errection like masonry pit boring in the open well, special foundation for the tower legs open wells or some odd situation .....

10. Further details, if any .....

11. Remarks .....

Signature of representative of organisation

Signature with seal of head of organisation.

Water output graphs

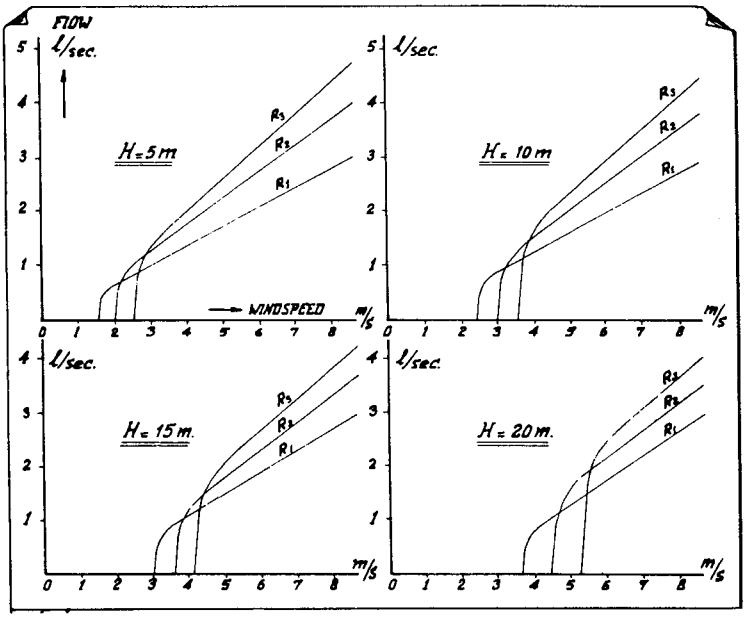

H = elevation head
R_1 = 60 mm
R_2 = 90 mm
R_3 = 120 mm
crank radius
for 150 mm piston pump

Materials for a tower

No	Number required	Materials, particulars and measurements		
1	1	Tower pipe	4″ gaspipe	× 2650
2	4	Angle iron	40 × 40 × 5 (1½″ × 1½″)	× 6500 ÷ 7000
3	2	,,	30 × 30 × 4 (1¼″ × 1¼″)	× 660
4	2	Flat iron	30 × 6 (1¼″ × ¼″)	× 360
5	2	,,	,,	× 480
6	2	,,	,,	× 600
7	4	Angle iron	30 × 30 × 4 (1¼″ × 1¼″)	× 750
8	16	,,	,,	× 2000
9	4	,,	,,	× 1350
10	4	,,	,,	× scrap
11	2	Plank	30 × 200 × 700	
12	4	Bolt, nut, washers	M 8 (W ⅜″)	
13	4	Flat iron	30 × 6 (1¼″ × ¼″)	× 460
14	8	Flat scrap		

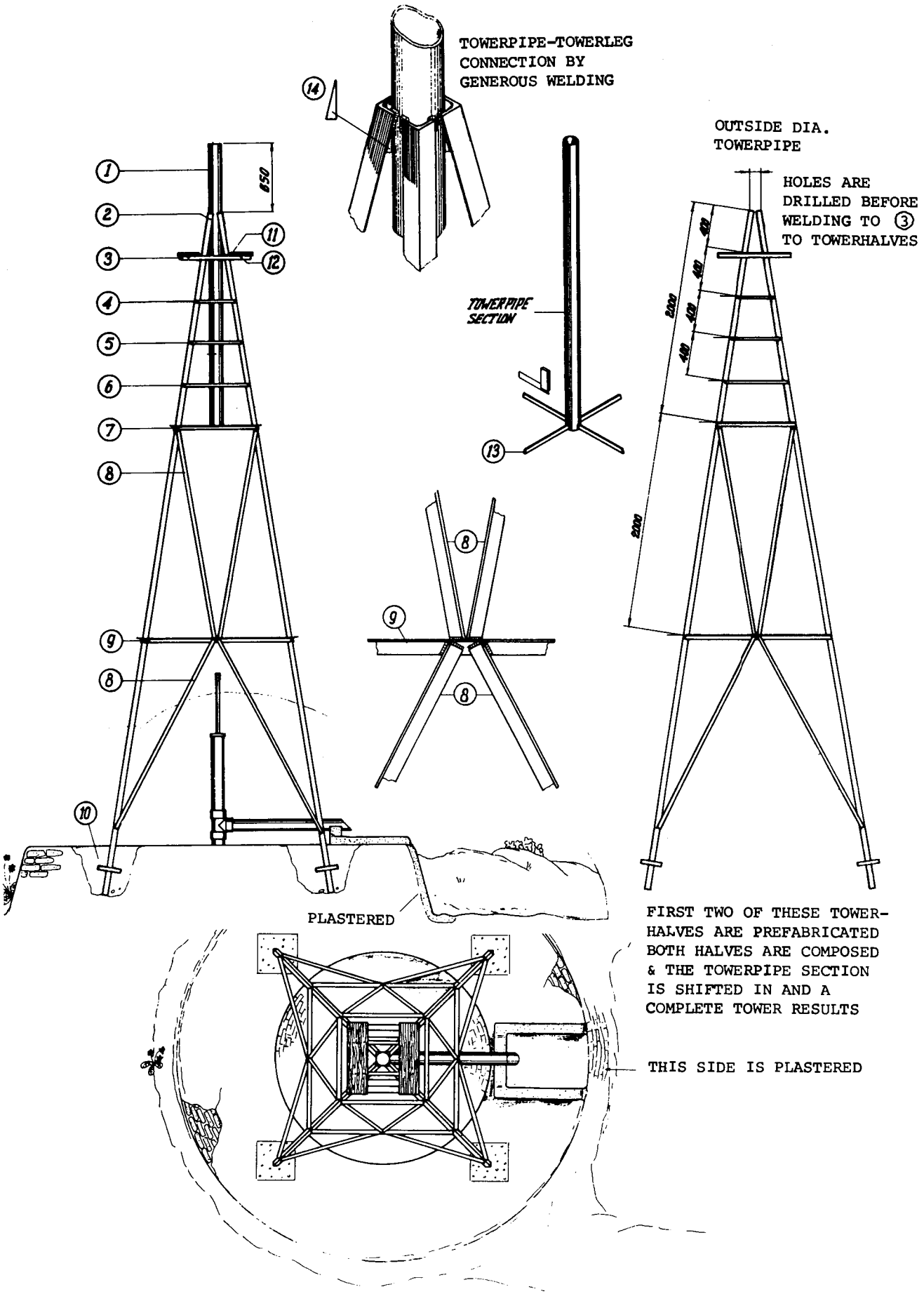
TOWERPIPE-TOWERLEG
CONNECTION BY
GENEROUS WELDING
OUTSIDE DIA.
TOWERPIPE
HOLES ARE
DRILLED BEFORE
WELDING TO 3
TO TOWERHALVES
TOWERPIPE
SECTION
850
400
400
400
400
2000
2000
PLASTERED
FIRST TWO OF THESE TOWER-
HALVES ARE PREFABRICATED
BOTH HALVES ARE COMPOSED
& THE TOWERPIPE SECTION
IS SHIFTED IN AND A
COMPLETE TOWER RESULTS
THIS SIDE IS PLASTERED

Head Construction

No	Number required	Materials, particulars and measurements		
1	2	Angle iron	50 × 50 × 5 (2″ × 2″)	Length 220
2	1	,,	40 × 40 × 4 (1½″ × 1½″)	500
3	2	,,	,,	1080
4	2	,,	,,	460
5	2	,,	,,	1000
6	2	,,	,,	550
7	4	,,	,,	tower pipe dia.
8	1	,,	,,	Length 180
9	1	,,	,,	45
10	1	,,	,,	1000
11	1	,,	,,	580
12	1	,,	,,	200
13	1	,,	,,	280
14	1	,,	,,	60
15	1	,,	,,	120
16	1	,,	,,	1500
17	1	,,	,,	4000
18	1	,,	,,	3000
19	3	Flat iron	30 × 6 (1¼″ × ¼″)	Length 750
20	1	,,	,,	830
21	5	,,	,,	80
22	1	,,	,,	360
23	1	,,	,,	900
24	1	,,	,,	115
25	1	,,	,,	130
26	2	,,	,,	40
27	1	,,	,,	100
28	2	Spring	Appr. ϕ30 × 1000 × ϕ4	
29	1	Helpvane	1 mm sheet 1000 × 500	
30	1	Tailvane	1 mm sheet 2000 × 1000	
31	3	Washer	ϕ18 inside	
32	1	Rod	ϕ18 × 650 (ϕ¾″ × 2′2″)	
33	1	Split pin	ϕ6 (ϕ¼″)	
34	12	Bolt, nut, washer	M 6 × 25 (W ¼″ × 1″)	
35	1	,,	M 12 × 100 (W ½″ × 4″)	
36	1	,,	M 10 × 150 (W ⅜″ × 6″)	
37	2	,,	M 12 × 40 (W ½″ × 1½″)	

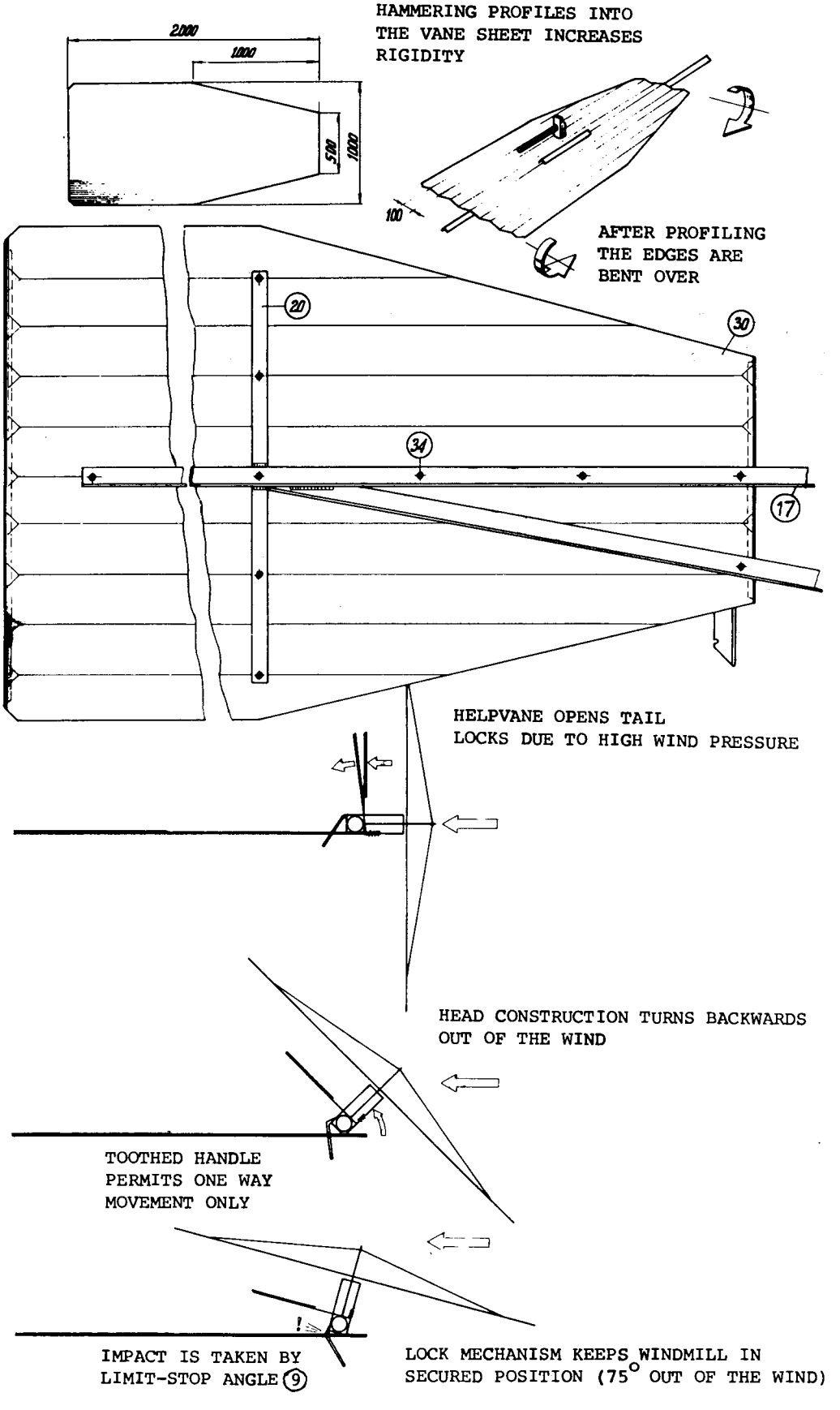
HAMMERING PROFILES INTO THE VANE SHEET INCREASES RIGIDITY
2000
1000
500
1000
100
AFTER PROFILING THE EDGES ARE BENT OVER
20
30
34
17
HELPVANE OPENS TAIL LOCKS DUE TO HIGH WIND PRESSURE
HEAD CONSTRUCTION TURNS BACKWARDS OUT OF THE WIND
TOOTHED HANDLE PERMITS ONE WAY MOVEMENT ONLY
IMPACT IS TAKEN BY LIMIT-STOP ANGLE 9
LOCK MECHANISM KEEPS WINDMILL IN SECURED POSITION (75° OUT OF THE WIND)

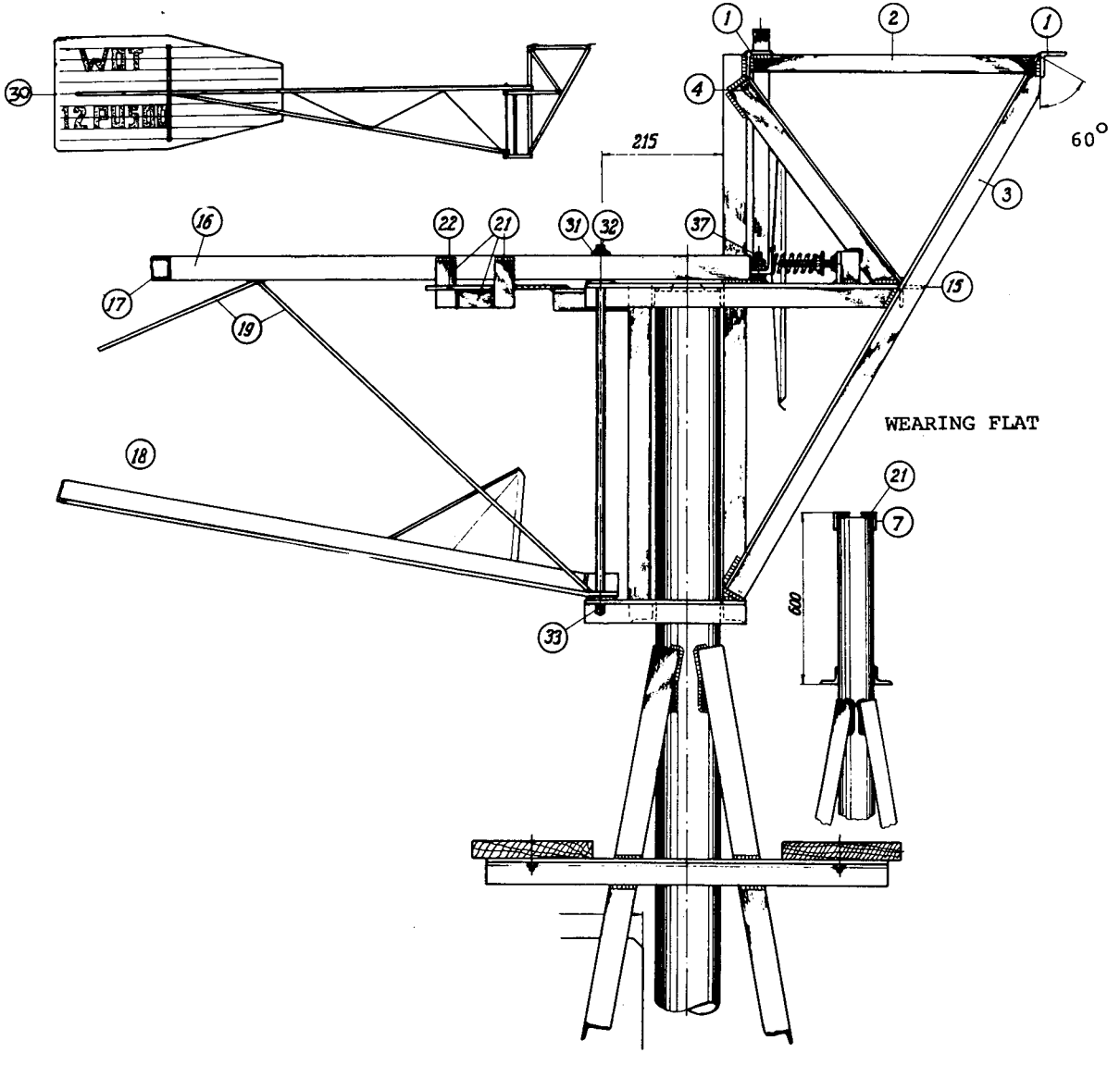
WOT
12 PUSH
39
1
2
1
4
60°
215
3
16
22
21
31
32
37
15
17
19
18
WEARING FLAT
21
7
600
33

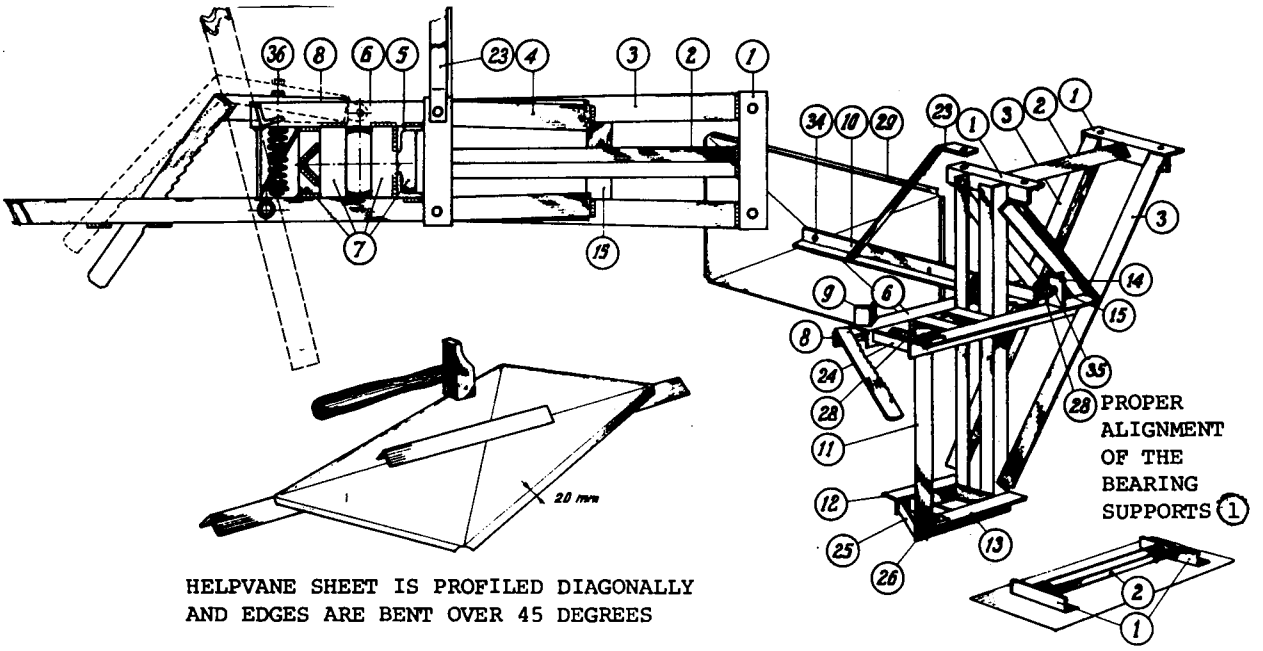

HELPVANE SHEET IS PROFILED DIAGONALLY AND EDGES ARE BENT OVER 45 DEGREES

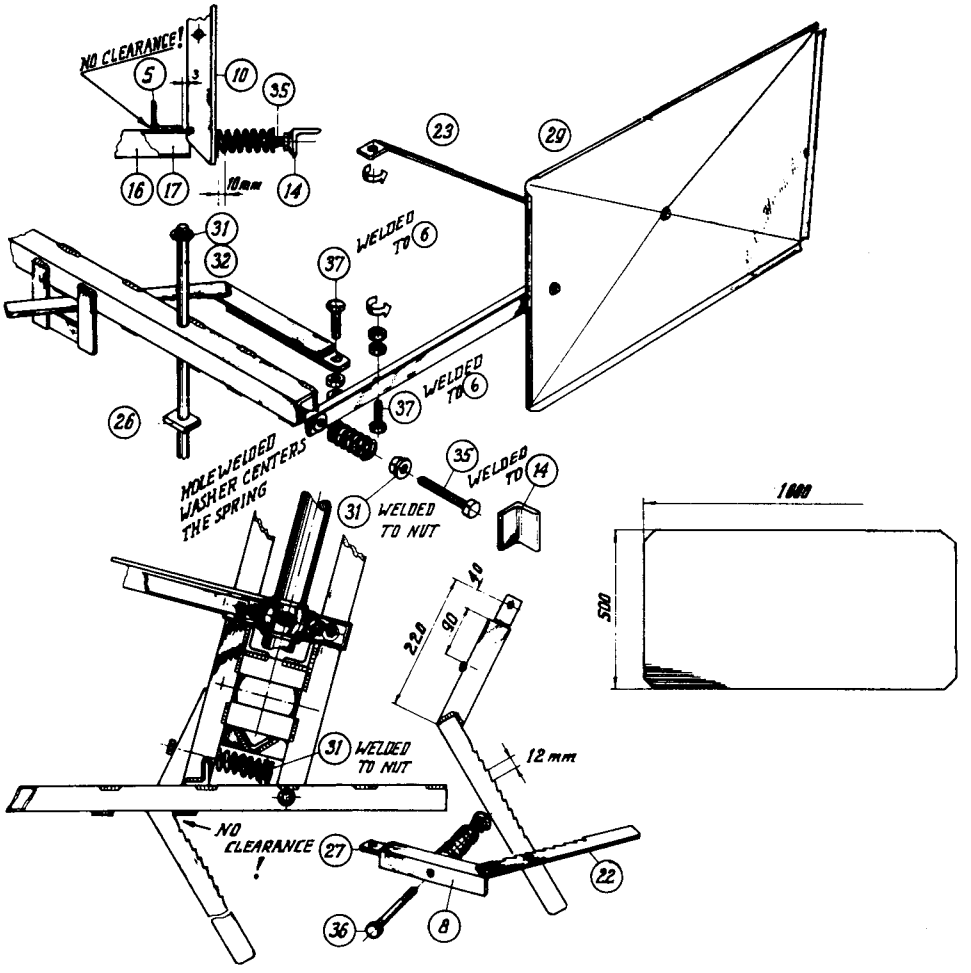

Moving parts

No	Number required	Materials, particulars and measurements	
1	1	Shaft	ϕ50 (ϕ2″) × 1250
2	2	Bearing housing	
3	2	Ball bearing (best quality)	
4	2	Bearing bush (best quality)	
5	2	Bearing housing	
6	4	Nylon bearing bush	ϕ1½″ nylon rod
7	2	Washer	
8	3	Nut M 20 (W ¾″)	
9	1	Crank pin ϕ25 (ϕ1″)	
10	1	Cross pin ϕ25 (ϕ1″) remove sharp edges	
11	2	Flat iron 30 × 6 (1¼″ × ¼″)	Length 120
12	1	,,	150
13	4	,,	50
14	1	,,	600
15	1	,,	140
16	2	,,	220
17	1	Cross head	Sesam wood soaked in oil
18	1	Cork	
19	1	Pump rod	Gaspipe ϕ¾″ × 4700
20	1	PVC insert	ϕ100 × 700
21	1	Thread, stud	M 24 × 75 (W ⅞″ × 4″)
22	2	Bolt, nut, washers	M 6 × 25 (W ¼″ × 1″)
23	1	,,	M 10 × 100 (W ⅜″ × 4″)
24	4	,,	M 12 × 50 (W ½″ × 2″)
25	2	,,	M 12 × 80 (W ½″ × 3″)
26	1	Pump rod guide	Sesam wood soaked in oil

BRACKET PREVENTS CRACK-
OPENING OF BEARING HOUSE

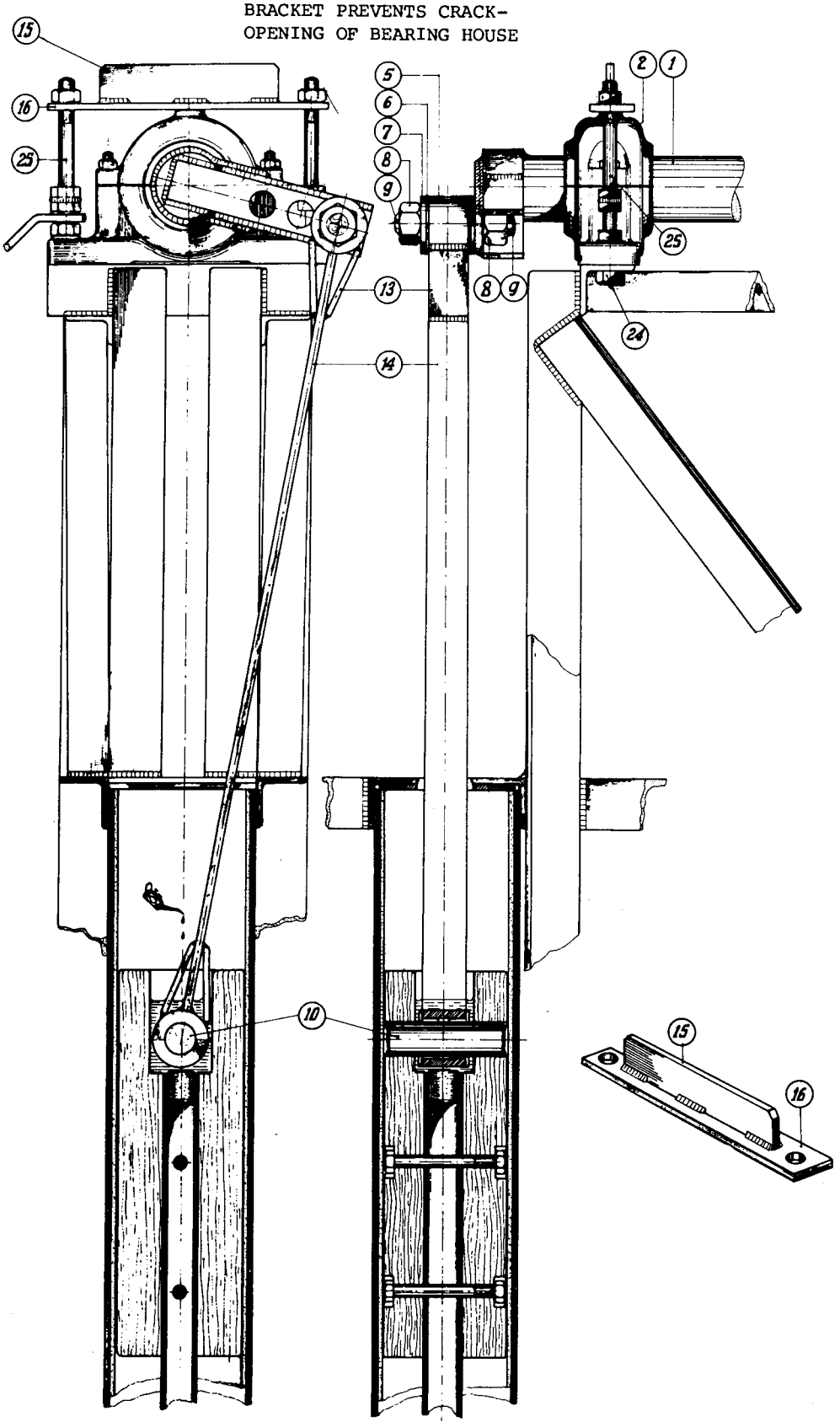

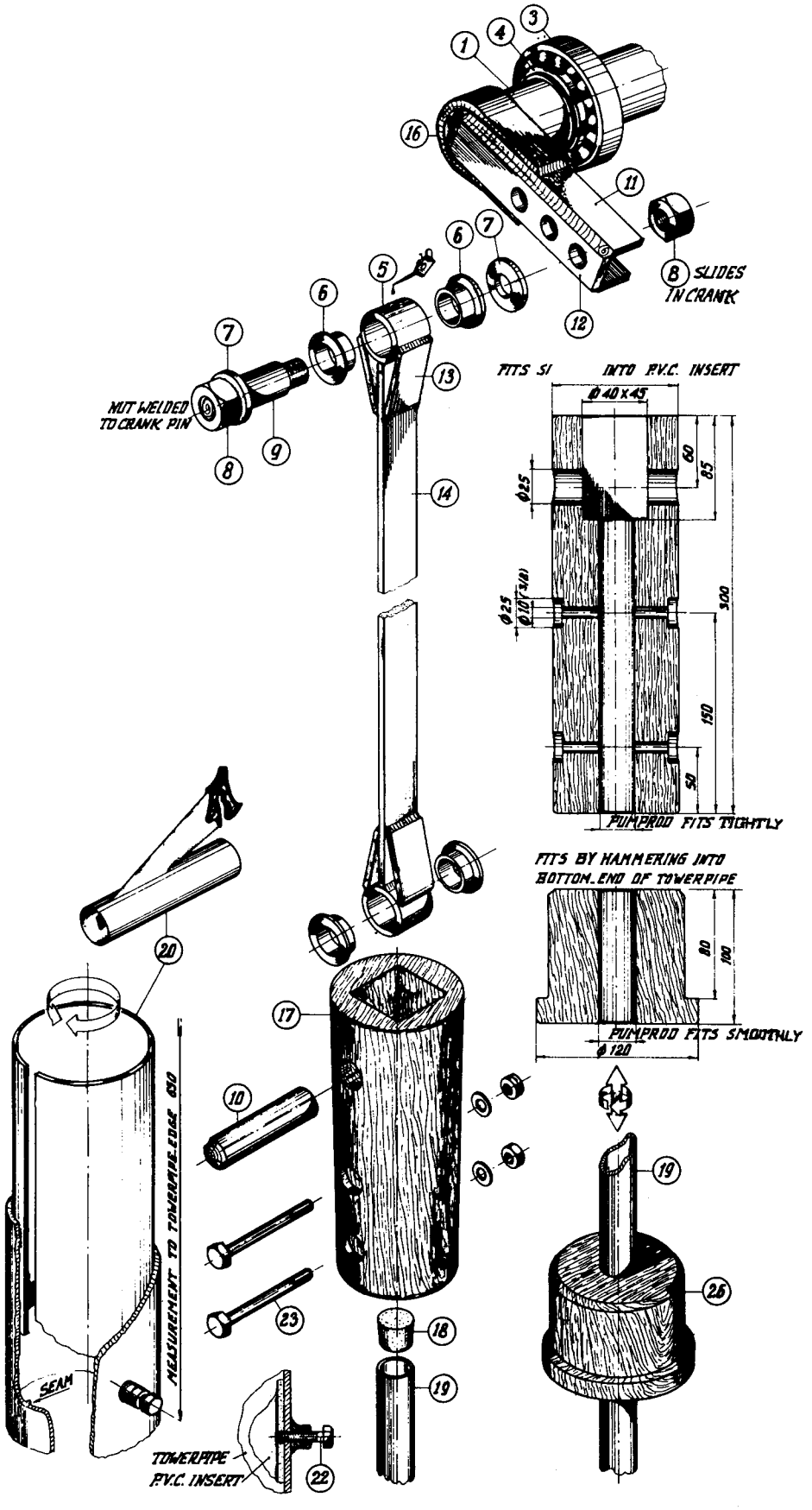
1
4
3
16
11
8 SLIDES IN CRANK
12
6
7
5
6
7
13
NUT WELDED TO CRANK PIN
8
9
14
FITS SI INTO P.V.C. INSERT
Ø 40 X 45
60
85
Ø25
Ø25
Ø10 (3/8)
100
150
50
PUMPROD FITS TIGHTLY
FITS BY HAMMERING INTO BOTTOM END OF TOWERPIPE
80
100
PUMPROD FITS SMOOTHLY
Ø 120
20
17
10
23
18
19
22
19
26
MEASUREMENT TO TOWERPIPE EDGE 610
SEAM
TOWERPIPE P.V.C. INSERT

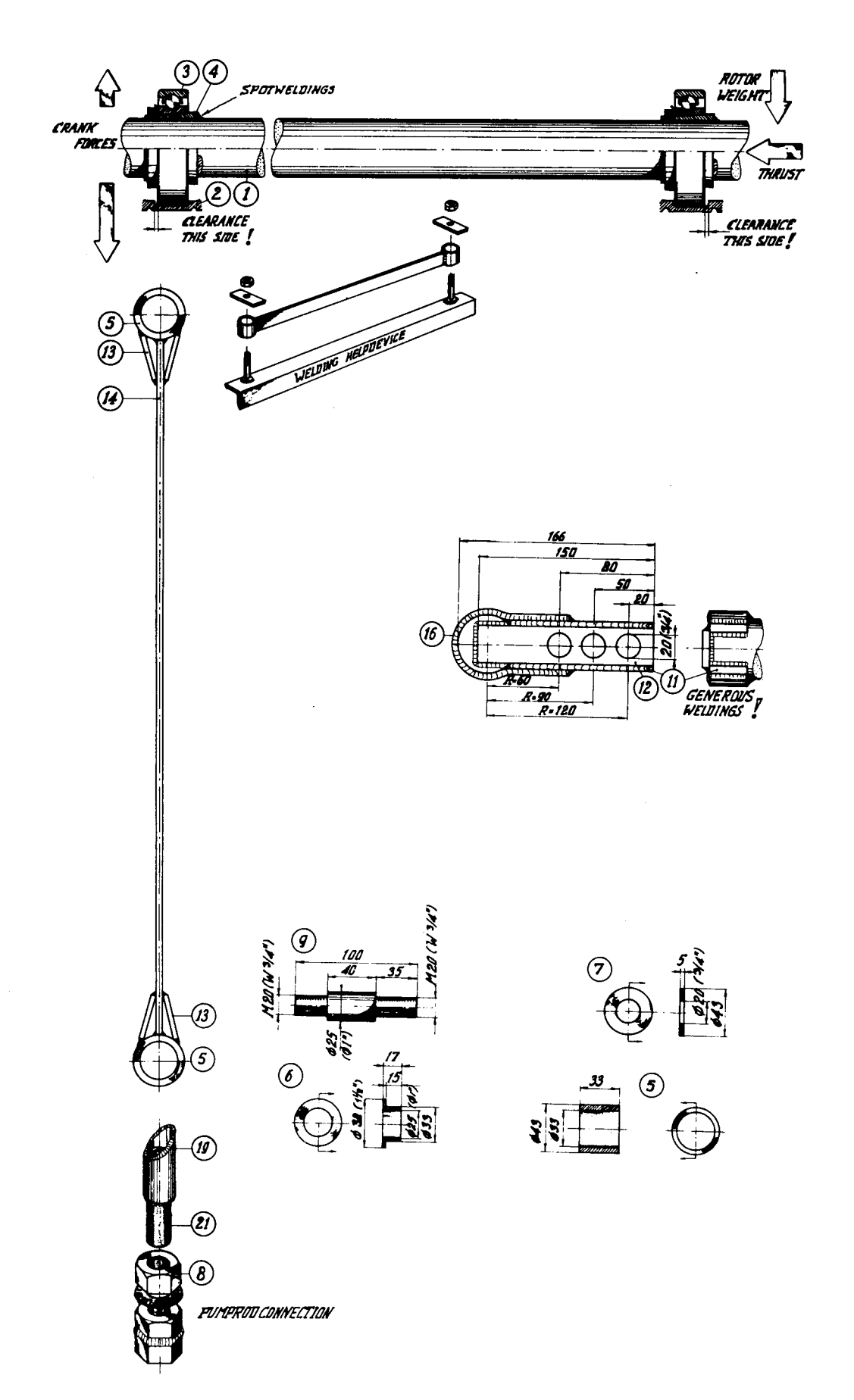
SPOTWELDINGS
CRANK FORCES
ROTOR WEIGHT
THRUST
CLEARANCE THIS SIDE !
CLEARANCE THIS SIDE !
WELDING HELPDEVICE
166
150
80
50
20
20 (3/4")
R=60
R=90
R=120
GENEROUS WELDINGS !
100
40
35
M20 (W 3/4")
M20 (W 3/4")
Ø25 (Ø1")
17
15
Ø 38 (1½")
Ø25
Ø33
5
Ø20 (3/4")
Ø43
33
Ø43
Ø33
PUMPROD CONNECTION

Rotor

No	Number required	Materials, particulars and measurements		
1	12	Blade	4 standard sheets 1000 × 2000 × 1	
2	12	Blade support	2 mm sheet	
3	12	,,	,,	
4	1	Flat iron	30 × 6 (1¼″ × ¼″)	2 × 6000
5	1	,,	,,	2 × 3000
6	6	,,	,,	× 250
7	6	,,	,,	× 1900
8	4	,,	,,	× 120
9	6	Angle iron	40 × 40 × 4 (1½″ × 1½″)	× 1900
10	4	,,	,,	× 100
11	2	,,	,,	× 625
12	2	,,	,,	× 350
13	2	Bolt, nut, washer	M 12 × 125 (W ½″ × 5″)	
14	4	,,	M 12 × 100 (W ½″ × 4″)	
15	120	,,	M 6 × 20 (W ¼″ × ¾″)	

AFTER ASSEMBLING THE
BLADE TIP ANGLE (14.7°)
NEEDS CORRECTION

HELP DEVICE
(1mm SHEET)

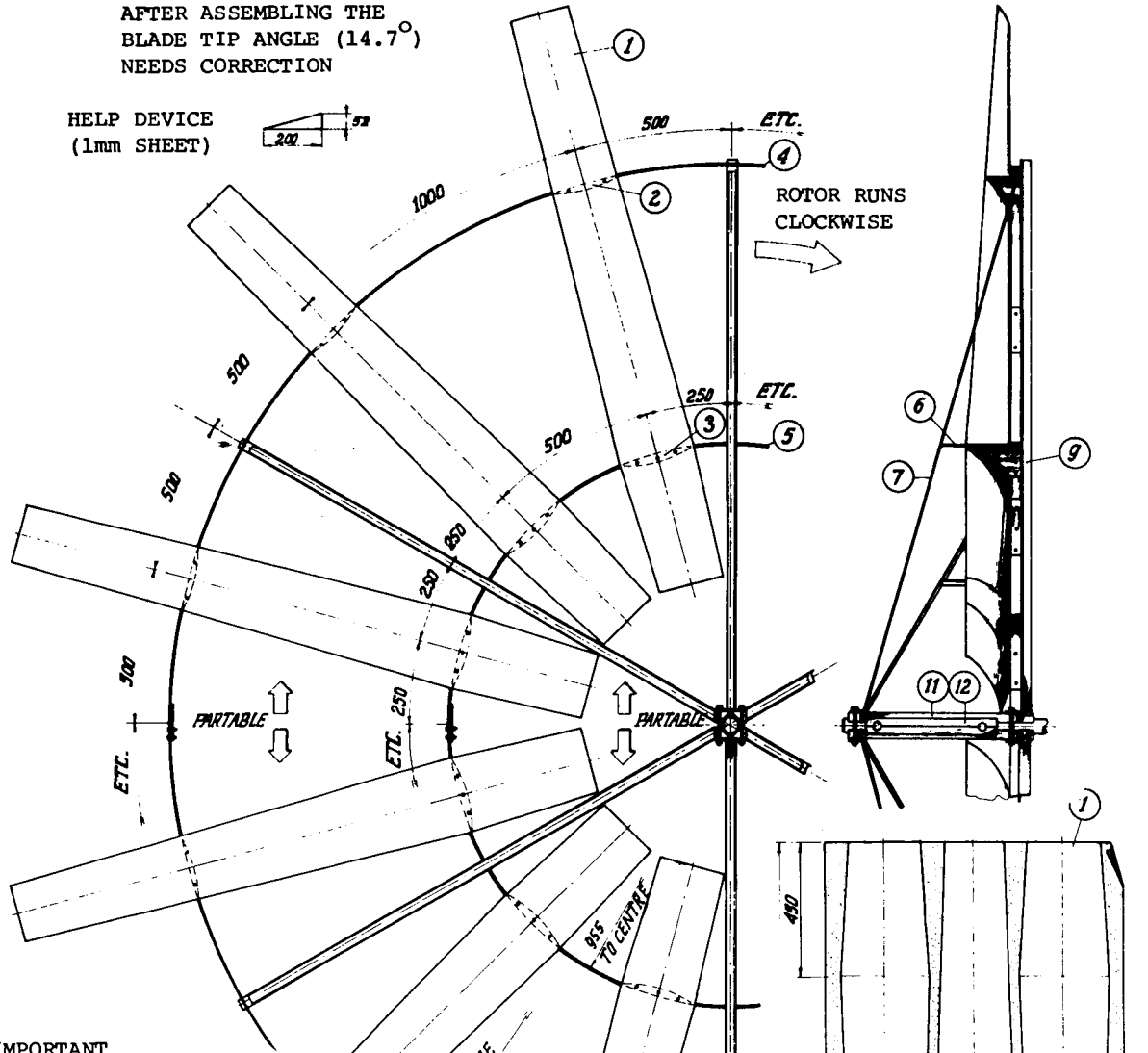

IMPORTANT
ROTOR FRAME IS COMPOSED
ON ITS SHAFT TO PREVENT
'JUMPING & DANCING'
OF SPOKES & RINGS

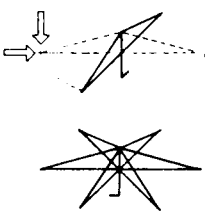

SHAFT &
TWO ROTOR-
HALVES
BELONG
TOGETHER

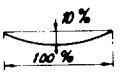

SHEET IS
ROLLED IN
A BENDING
RADIUS OF
APPROX.
300mm. AFTER
CUTTING THE
RADIUS IS
CORRECTED SO
THAT 10% CURVED
AIRFOILS WILL
RESULT

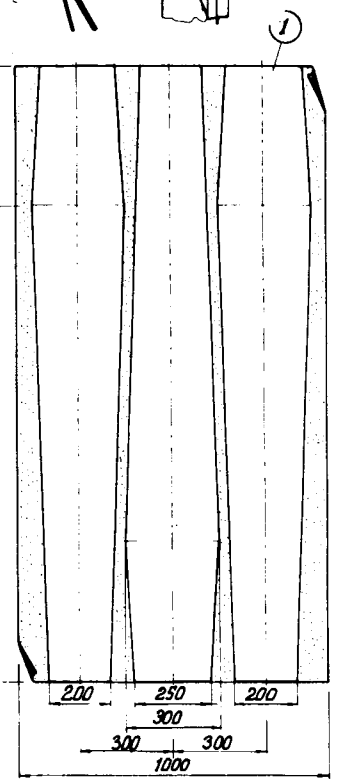

RINGS ARE POSITIONED,
CENTRED AND WELDED

PART No.6
IS WELDED

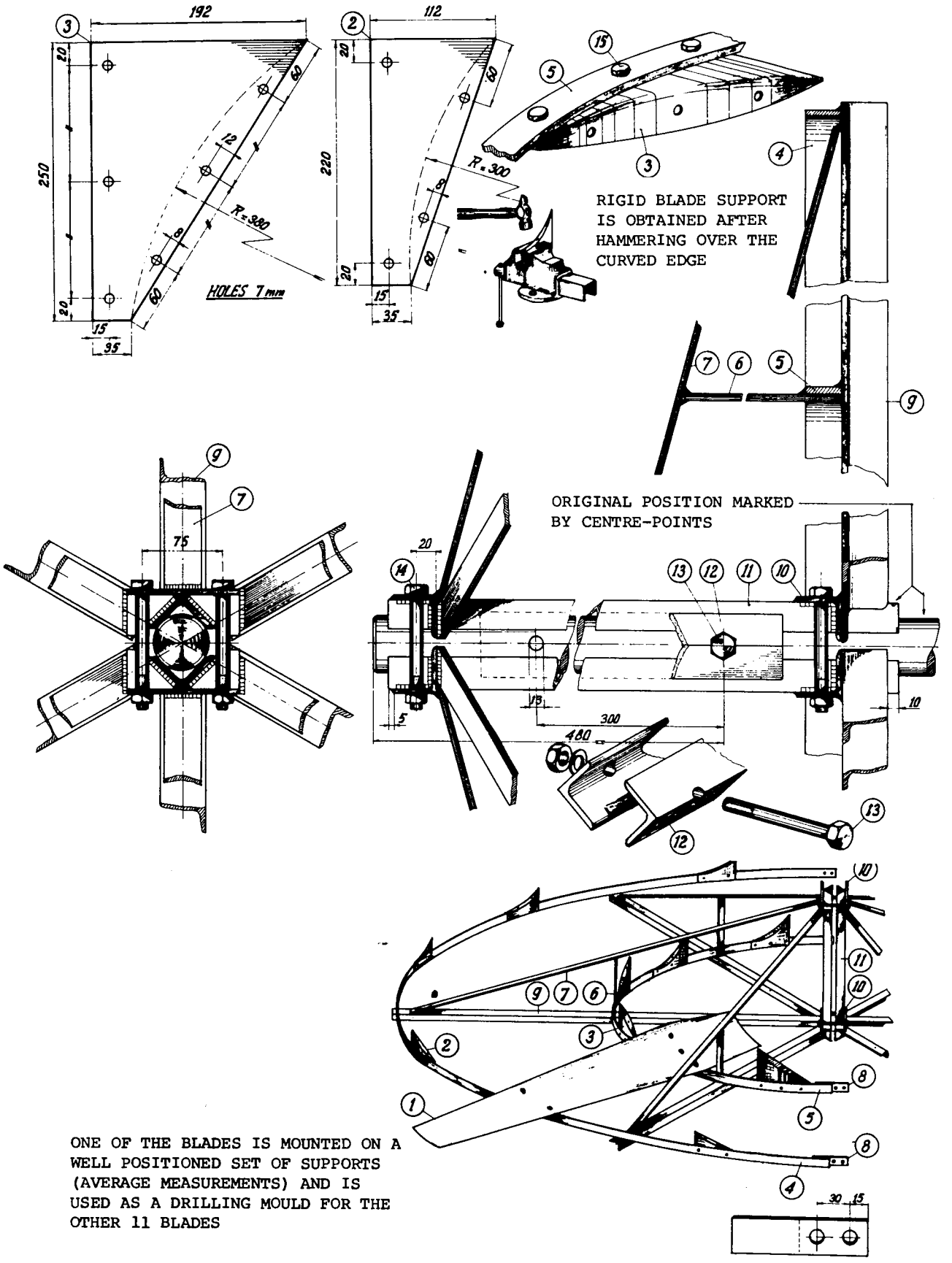

ONE OF THE BLADES IS MOUNTED ON A WELL POSITIONED SET OF SUPPORTS (AVERAGE MEASUREMENTS) AND IS USED AS A DRILLING MOULD FOR THE OTHER 11 BLADES

Piston pump

No	Number required	Materials, particulars and measurements		
1	*	Pump rod extension	ϕ¾″ gaspipe	*
2	1	Wooden pump rod guide: 26 in Fig. 6.14		
3	1	T-socket	4″ gaspipe Length 750	
4	1	Delivery pipe	,,	
5	1	,,	4″ gaspipe or PVC pipe	*
6	*	,,	,,	*
7	1	PVC pipe	ϕ4″ × 700	
8	1	Gaspipe (threaded)	ϕ4″ × 800	
9	*	Steel socket	G 4″	
10	1	PVC end cap		
11	2	Flange (blind):	four 12 mm holes at 190 mm pitch	
12	1	PVC pipe	ϕ150 (ϕ6″) × 1250	
13	1	,,	,, × 740	
14	1	Piston	teakwood	
15	1	PVC socket		
16	1	Foot valve	teakwood	
17	3	Flat iron	25 × 5 (1″ × ¼″)	
18	*	,,	30 × 6 (1¼″ × ¼″)	
19	*	Angle iron	40 × 40 × 4 (1½″ × 1½″)	*
20	2	Sole-leather valve	ϕ150 × at least 6 mm	
21	4	,, packing	ϕ140 × ϕ200 × 4	
22	1	Steel bush		
23	1	Nylon bearing bush		
24	*	Pump rod gaspipe	ϕ¾″ × 1300	
25	*	Thread stud	M 24 (W ⅞″) × 75	
26	*	,,	,, × 150	
27	*	Nut		
28	*	Spring washer		
29	4	Rod	ϕ12 (ϕ½″) × 2100	
30	1	Bolt, nut, washer	M 12 (W ½″) × 150	
31	*	,,	,, × 30	
32	1	Bicycle tube valve	(apply rubber washers)	
33	1	Distancer	steel ϕ50 × 50 (ϕ2″ × 2″)	

** Amount and size depend upon total elevation head*

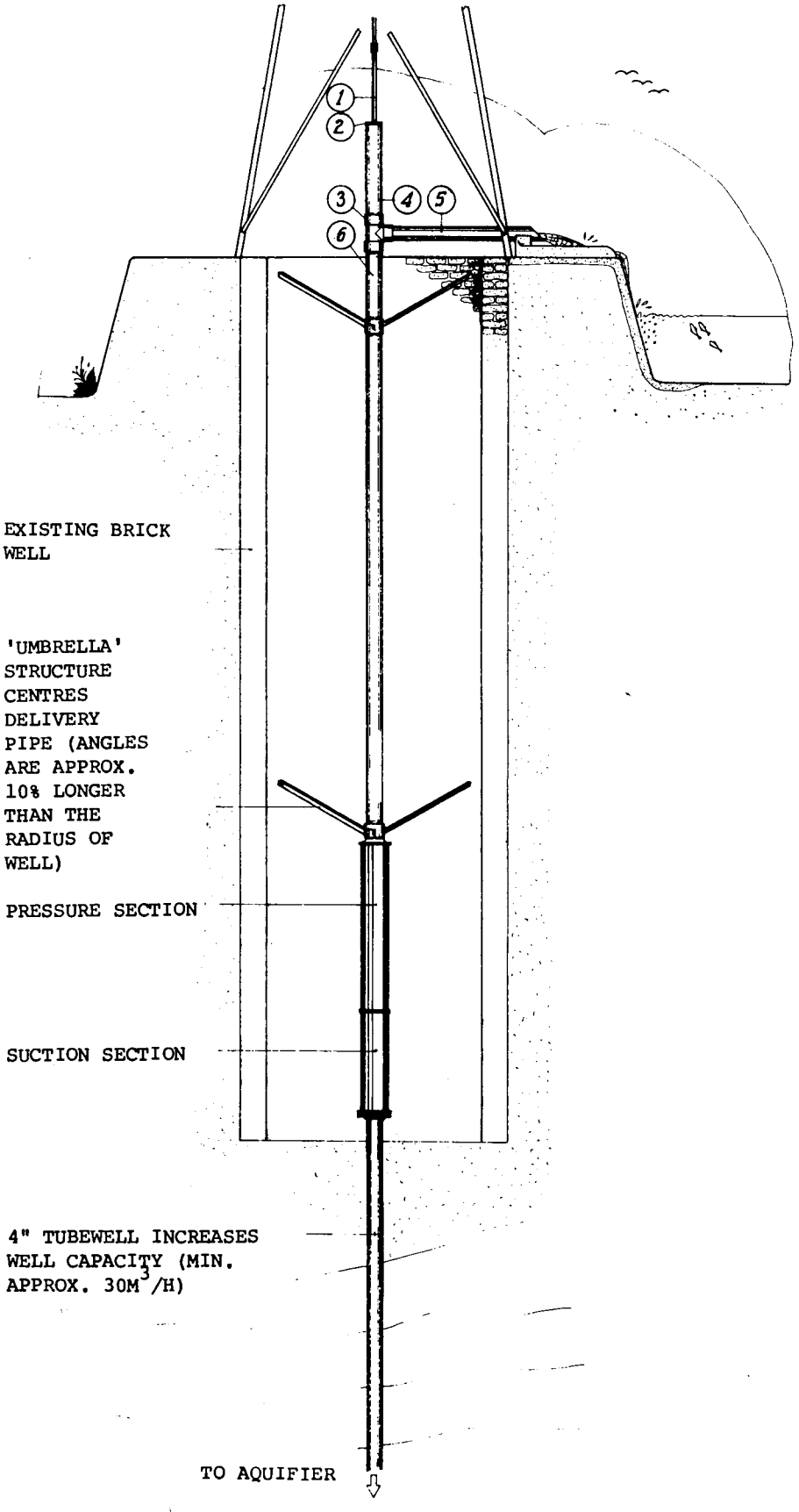
1
2
3
4
5
6
EXISTING BRICK WELL
'UMBRELLA' STRUCTURE CENTRES DELIVERY PIPE (ANGLES ARE APPROX. 10% LONGER THAN THE RADIUS OF WELL)
PRESSURE SECTION
SUCTION SECTION
4" TUBEWELL INCREASES WELL CAPACITY (MIN. APPROX. 30M3/H)
TO AQUIFIER

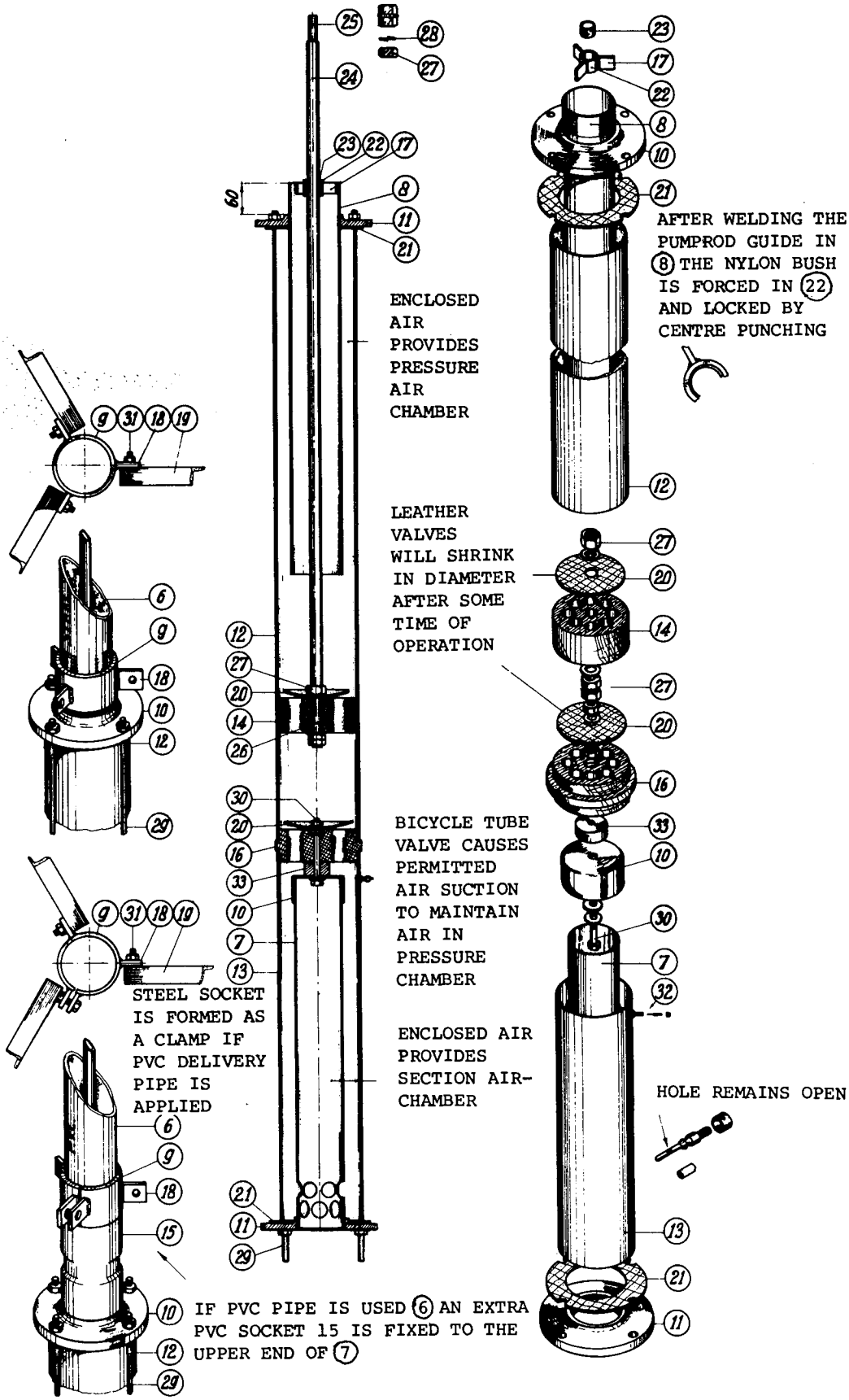
AFTER WELDING THE PUMPROD GUIDE IN (8) THE NYLON BUSH IS FORCED IN (22) AND LOCKED BY CENTRE PUNCHING
ENCLOSED AIR PROVIDES PRESSURE AIR CHAMBER
LEATHER VALVES WILL SHRINK IN DIAMETER AFTER SOME TIME OF OPERATION
BICYCLE TUBE VALVE CAUSES PERMITTED AIR SUCTION TO MAINTAIN AIR IN PRESSURE CHAMBER
ENCLOSED AIR PROVIDES SECTION AIR-CHAMBER
HOLE REMAINS OPEN
STEEL SOCKET IS FORMED AS A CLAMP IF PVC DELIVERY PIPE IS APPLIED
IF PVC PIPE IS USED (6) AN EXTRA PVC SOCKET 15 IS FIXED TO THE UPPER END OF (7)

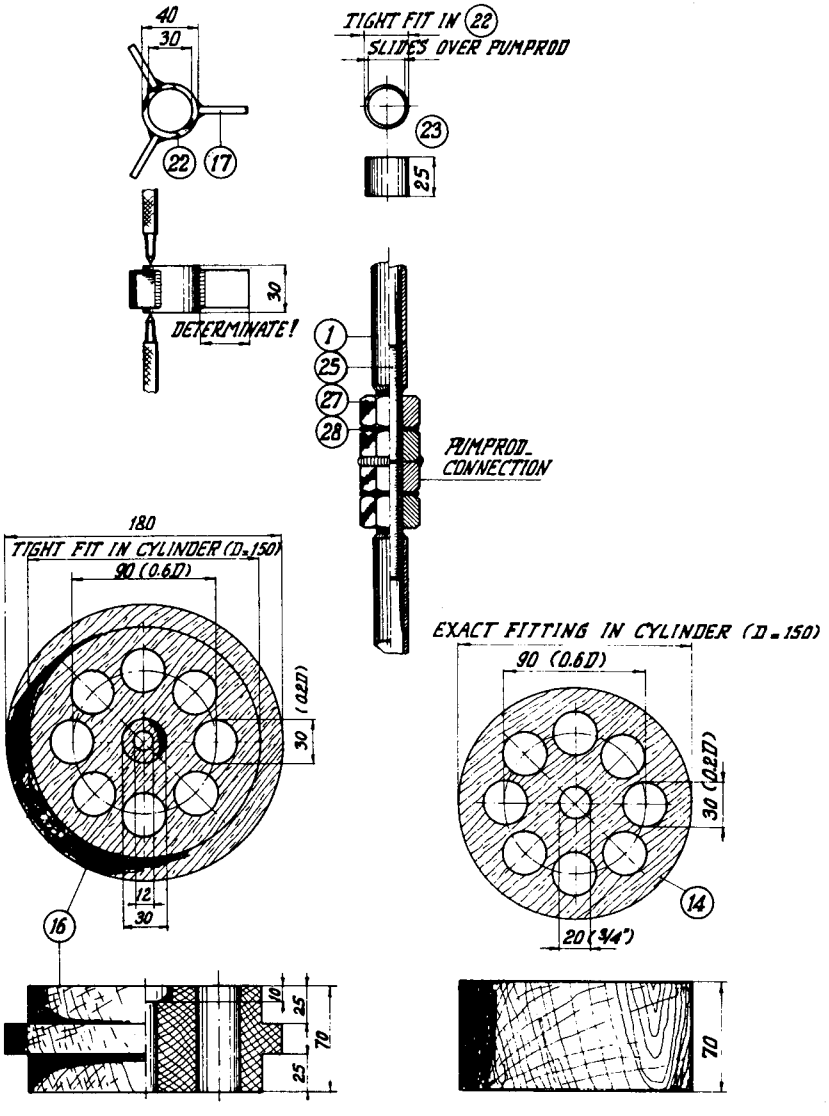

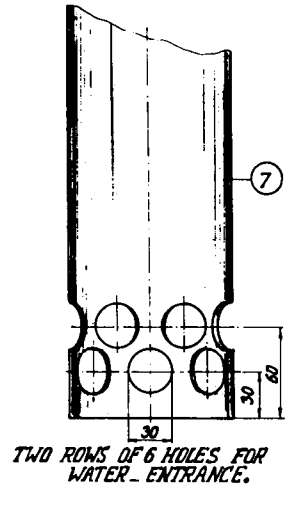

AFTER SOAKING THE WOOD IN WATER FOR AT LEAST ONE WEEK, THE PISTON IS MACHINED TO A PERFECT SLIDING FIT.

THE SEALINGLESS PERFORMANCE DECREASES STARTING TORQUE REQUIRED DUE TO ACCEPTABLE LEAKAGE SO THE WINDMILL BEGINS TO MOVE AT LOW WIND SPEEDS

Installing the windmill

No	Number required	Materials, particulars and measurements		
1	1	Pulley shaft and rope or steel cable (30 M)		
2	1	Gaspipe	ϕ3″ × 4500	
3	2	Angle iron	40 × 40 × 4 (1½″ × 1½″)	× 2000
4	3	,,	,,	× 750
5	1	,,	,,	× 800
6	1	,,	,,	× 200
7	1	,,	,,	× 550
8	3	Flat iron	30 × 6 (1¼″ × ¼″) × 200	
9	1	,,	,, ≙ tower pipe dia.	
10	1	,,	30 × 6 (1¼″ × ¼″) × 100	
11	1	Rod	ϕ10 (ϕ⅜″) × 200	
12	2	Bolt, nut, washer	M 12 × 50 (W ½″ × 2″)	
13	1	,,	M 12 × 150 (W ½″ × 6″)	
14	2	,,	M 12 × 75 (W ½″ × 3″)	

Three methods of transporting the windmill

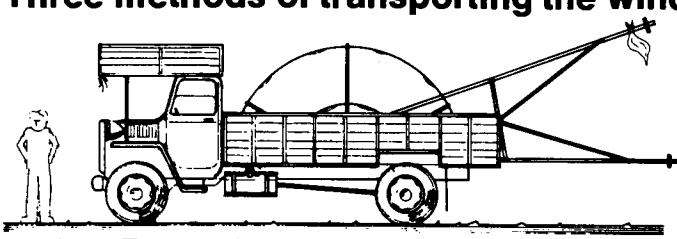

TRANSPORT BY TRUCK

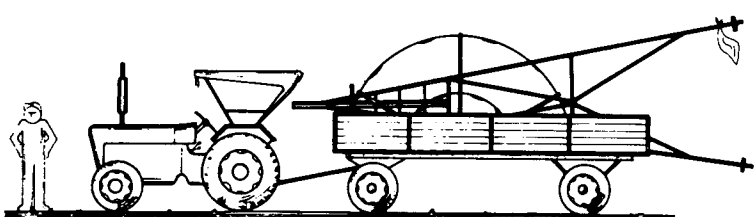

TRANSPORT BY TRACTOR AND LORRY

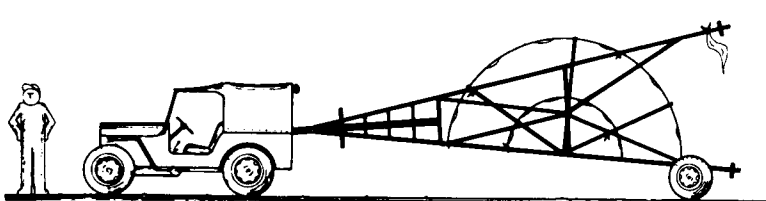

TRANSPORT BY JEEP AND ROLLING HELPDEVICE

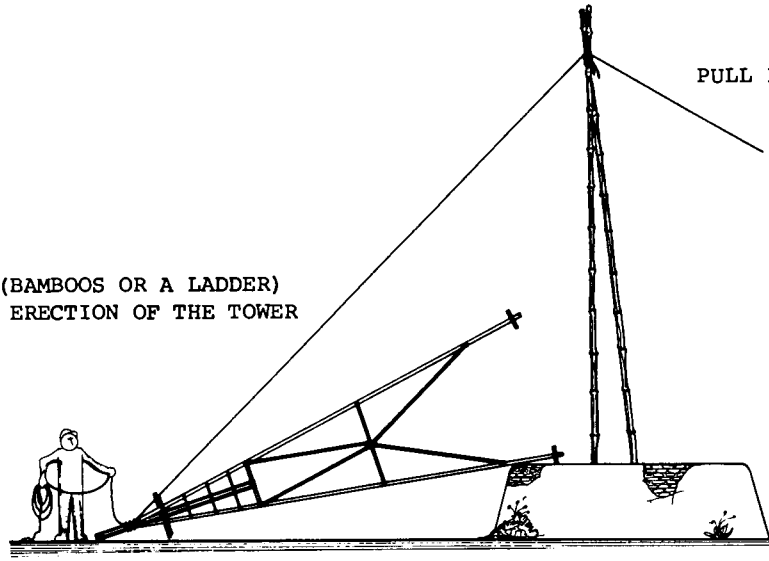

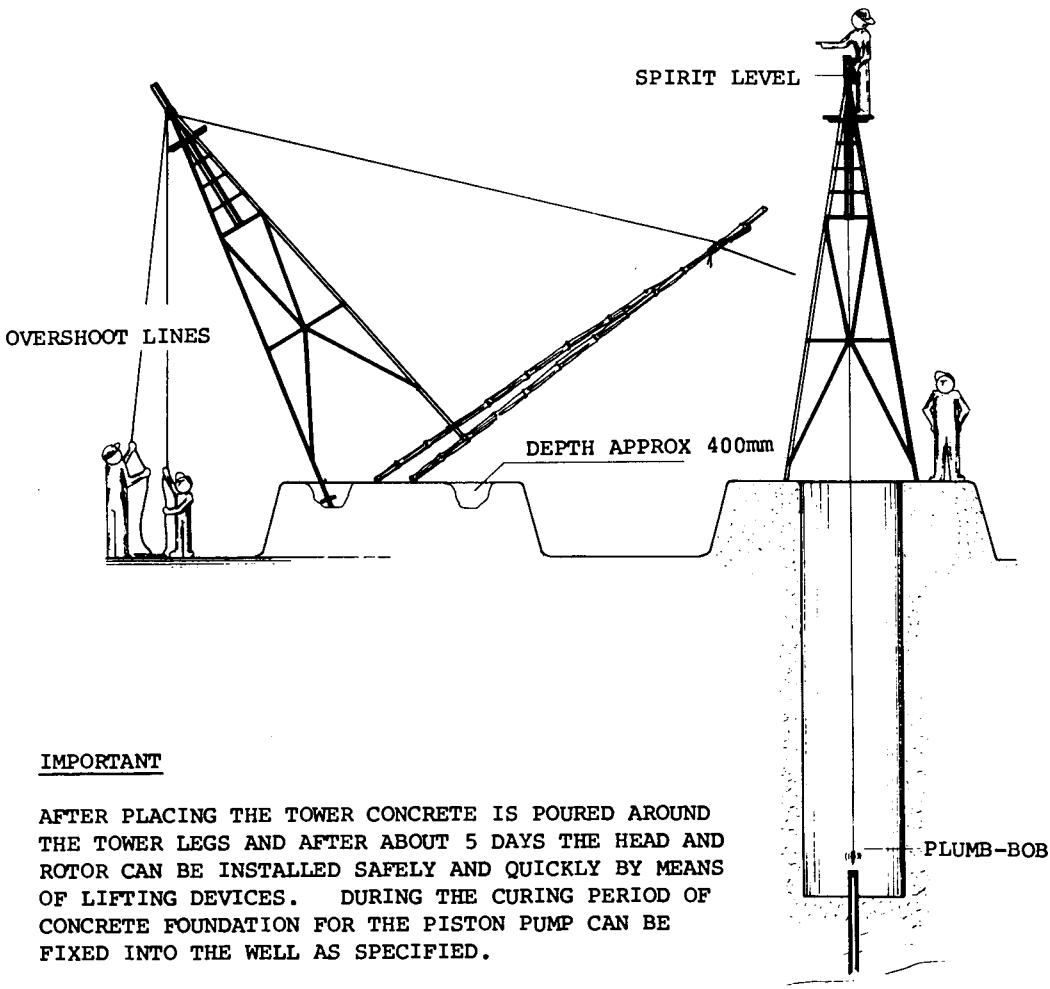

IMPORTANT

AFTER PLACING THE TOWER CONCRETE IS POURED AROUND THE TOWER LEGS AND AFTER ABOUT 5 DAYS THE HEAD AND ROTOR CAN BE INSTALLED SAFELY AND QUICKLY BY MEANS OF LIFTING DEVICES. DURING THE CURING PERIOD OF CONCRETE FOUNDATION FOR THE PISTON PUMP CAN BE FIXED INTO THE WELL AS SPECIFIED.

'JIB' LIFTING HELP-VANE

LIFTING HOOK FOR HEAD CONSTRUCTION

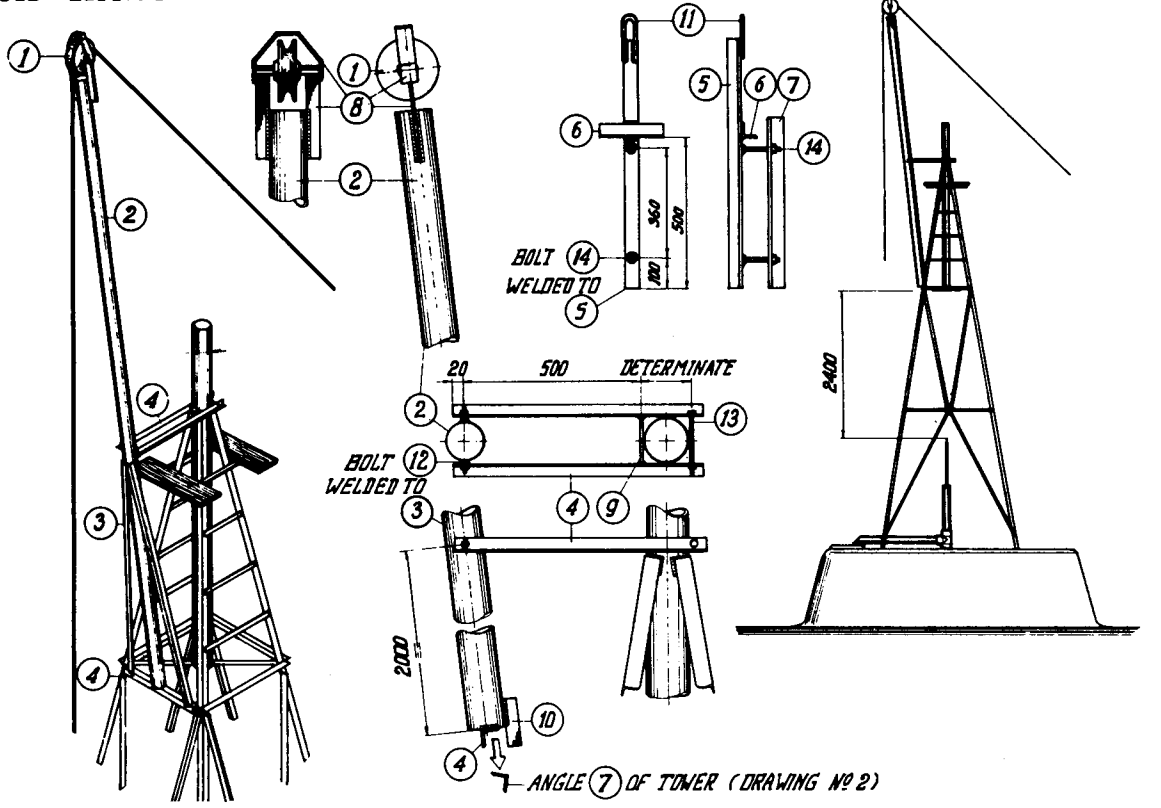

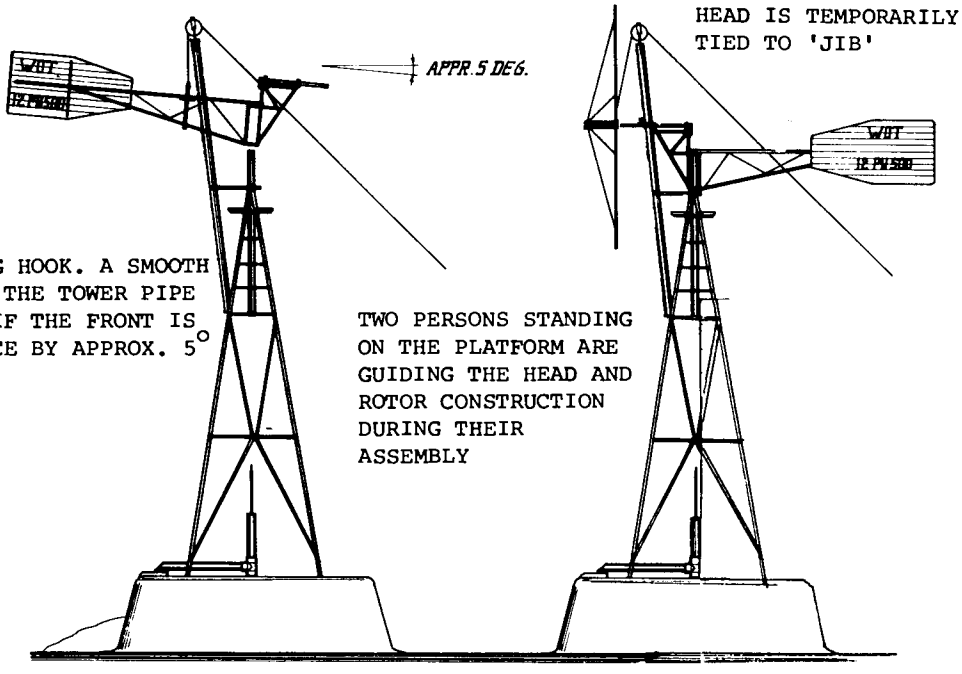

HEAD IS TEMPORARILY TIED TO 'JIB'

USE A LIFTING HOOK. A SMOOTH SLIDING OVER THE TOWER PIPE IS ACHIEVED IF THE FRONT IS OUT OF BALANCE BY APPROX. 5°

TWO PERSONS STANDING ON THE PLATFORM ARE GUIDING THE HEAD AND ROTOR CONSTRUCTION DURING THEIR ASSEMBLY

ROTOR IS LIFTED AND POSITION AT THE TOP OF ITS SHAFT AND SHIFTED IN ITS ORIGINAL POSITION AND FIXED. REMOVE 'JIB' AND ASSEMBLE BLADES, SAFETY DEVICE AND MOVING PARTS.

8.0 Installation
12-PU-500
Water Pumping Windmill

INSTALLATION OF WINDMILL:

8.1 General

The following windmill parts are supposed to be prefabricated: tower, head construction, moving parts, rotor frame and blades, and the pump section. In addition to these, some more essential steps to be taken are listed here. First of all the parts are composed partly in order the check the fit. The head construction may be put on the tower to find out if it rotates smoothly over the crosshead and the connecting rod. The fit of some blades is also to be checked (at random). Until and unless these checks are confirmed the windmill is not ready for transport. Another important thing with regard to windmill installation should not be forgotten. Help devices like the jib crane and lifting hook, which are represented in the drawing, are not only helpful but are a must from the safety point of view.

The use of the jib crane is really necessary for lifting the head construction and rotor both. While fabricating the jib crane care should be taken to see that the pulling rope runs nicely in the pulley and cannot run off:

The lifting hook is a help device which provides a suitable attachment to the head construction which is situated above the point of gravity of the latter. One can imagine what happens if no lifting hook is applied: the head construction tumbles over and nobody will be able to handle it during the procedure of lifting and installing it.

8.2 Tools & tackle required during installation:

1.	Spirit level	1
2.	Plumb with 20 m fisher nets string	1
3.	Steel tape (15 metre)	1
4.	Manila rope 1½" x 30 metre long	one
5.	Manila rope 3/4" x 20 metre long	one
6.	Mason's tool kit set	one set
7.	Jib crane	1
8.	Winch and wire rope 20 metres long x ½" or (chain pulley with chain 1½" size x 20 metres long)	one
9.	Chain wrench (4" pipe size)	1
10.	Chain wrench (4" B.S.P. pipe size)	2
11.	Pipe wrench (2" pipe size)	1
12.	Ball pin hammer 2 lb. with handle	1
13.	Hand hacksaw with 6 spare blades	1
14.	Double ended spanner set	1 set
15.	Ring spanner set	1 set
16.	Adjustable slide wrench 12" long	1
17.	Bastered double cut flat file 12"	1
18.	Round file rough 10" x 3/8" Dia.	1
19.	Wood file 12"	1
20.	Small grease gun	1

21.	Chisel 6" (Flat)	1
22.	Water Pump Plier	1
23.	Screw Driver 6"	1
24.	Screw driver 8"	1
25.	Centre Punch	1
26.	Hand drill with drilling capacity 1/2" Dia.	1
27.	Drill bits (Straight Shank) 1/2"	1
28.	Drill bits 3/8" Dia.	3
29.	Drill bits 5/8" Dia. with reduced shank	1

* Hand tools should be of standard make such as Gedore, Taparia, Everest or equivalent.

8.3 Illustration showing the position of Tower Foundation Bolts. (Refer. Fig. 8)

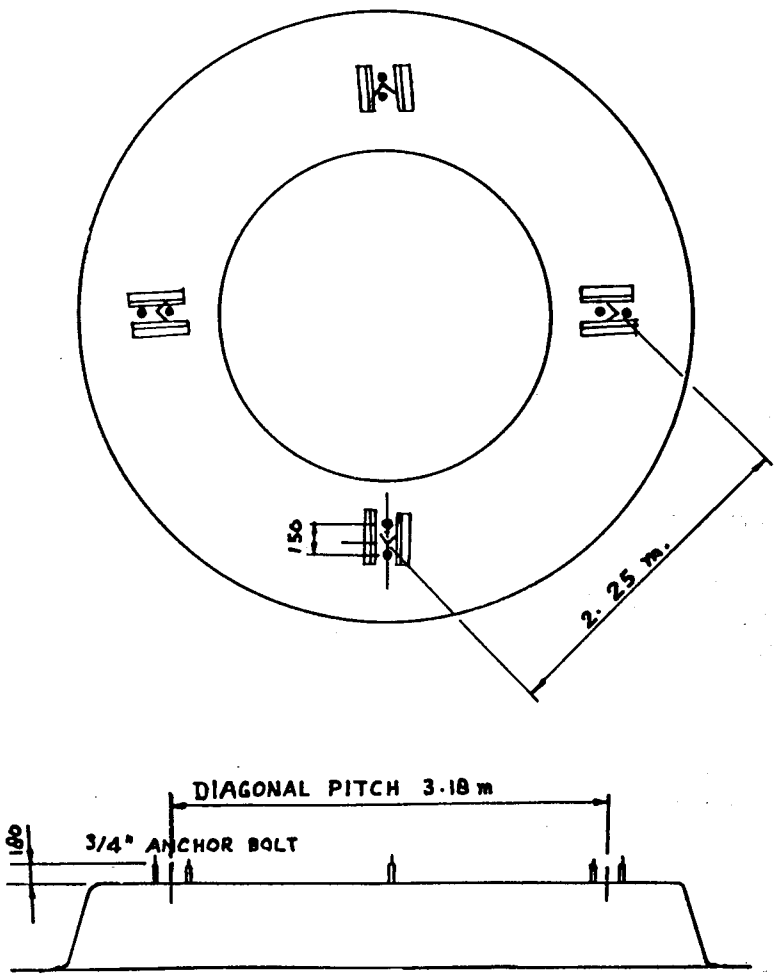

Fig. 8 Position of Tower Foundation Bolt

8.4 Details of Infra-structure to be prepared before the erection of the windmill. (Refer Fig. 9, 10 & 11)

8.5 Details of Sub-structure and Puca alignment fixture of 12-PU-500 Water Pumping Windmill (Refer Fig. 12)

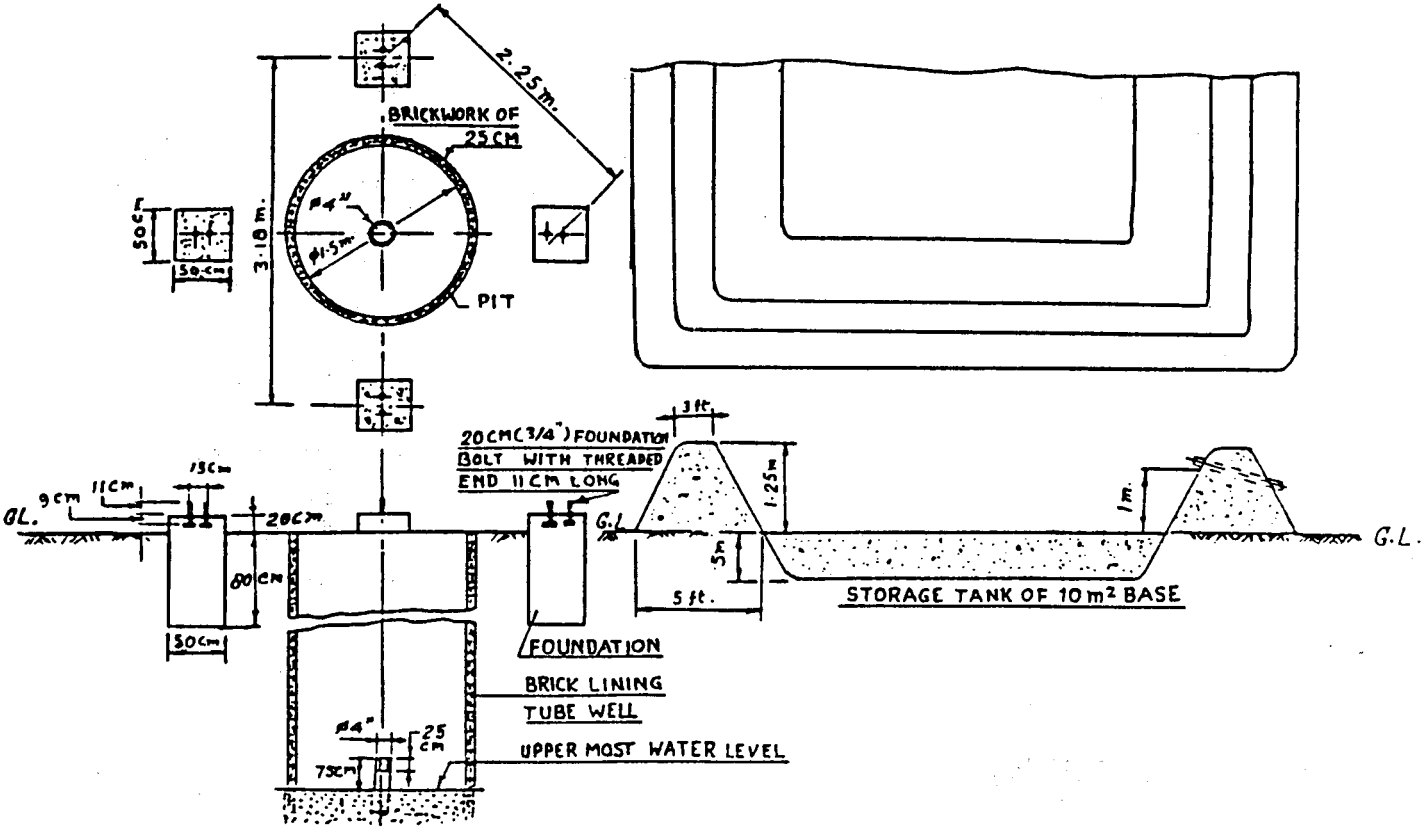

Fig. 9 Details of infrastructure to be prepared before erection of windmill

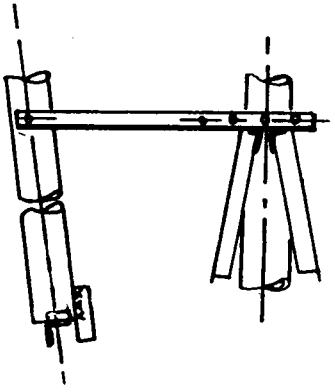

Fig. 10

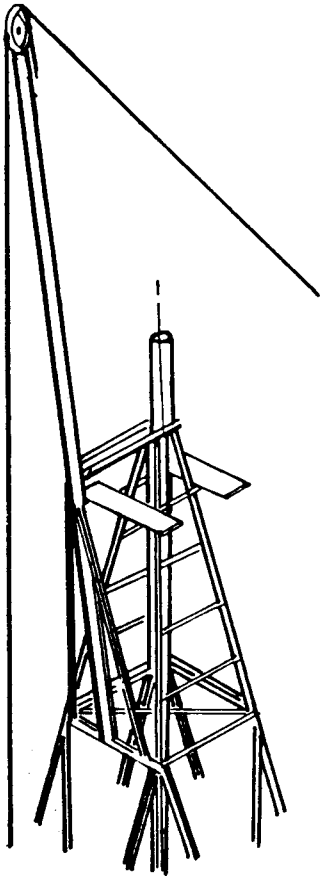

Fig. 11

Fixing of Jibcrane on the Tower

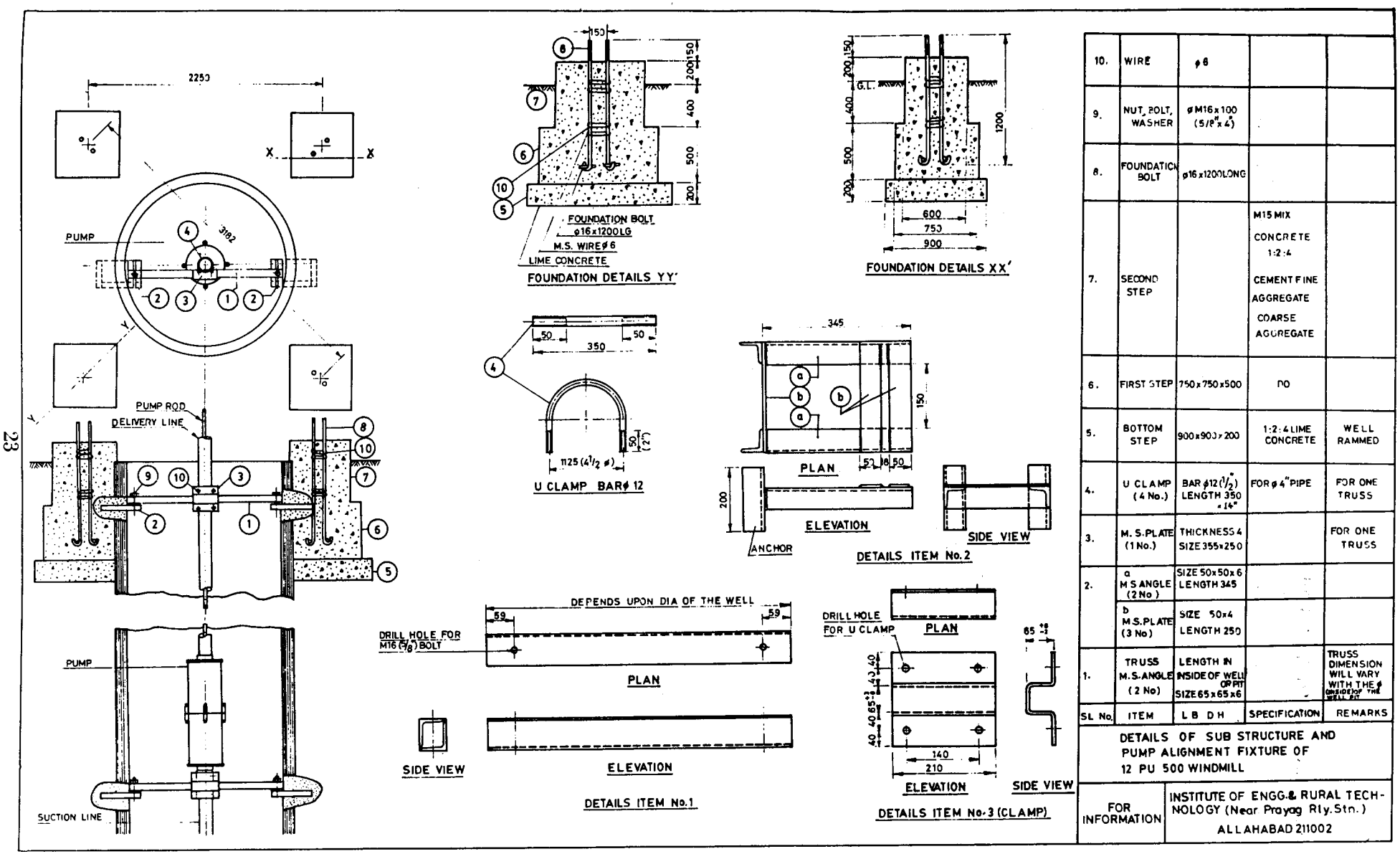

SL No.	ITEM	L B D H	SPECIFICATION	REMARKS
10.	WIRE	ø 6		
9.	NUT, BOLT, WASHER	ø M16 x 100 (5/8" x 4")		
8.	FOUNDATION BOLT	ø16 x 1200 LONG		
7.	SECOND STEP		M15 MIX CONCRETE 1:2:4 CEMENT FINE AGGREGATE COARSE AGGREGATE	
6.	FIRST STEP	750 x 750 x 500	DO	
5.	BOTTOM STEP	900 x 900 x 200	1:2:4 LIME CONCRETE	WELL RAMMED
4.	U CLAMP (4 No.)	BAR ø12 (1/2") LENGTH 350 x 14"	FOR ø 4" PIPE	FOR ONE TRUSS
3.	M. S. PLATE (1 No.)	THICKNESS 4 SIZE 355 x 250		FOR ONE TRUSS
2.	a M S ANGLE (2 No)	SIZE 50 x 50 x 6 LENGTH 345		
	b M.S. PLATE (3 No)	SIZE 50 x 4 LENGTH 250		
1.	TRUSS M.S. ANGLE (2 No)	LENGTH IN INSIDE OF WELL OR PIT SIZE 65 x 65 x 6		TRUSS DIMENSION WILL VARY WITH THE ø OR SIDE OF THE WELL PIT

DETAILS OF SUB STRUCTURE AND PUMP ALIGNMENT FIXTURE OF 12 PU 500 WINDMILL

FOR INFORMATION

INSTITUTE OF ENGG.& RURAL TECHNOLOGY (Near Prayag Rly.Stn.)
ALLAHABAD 211002

Fig. 12

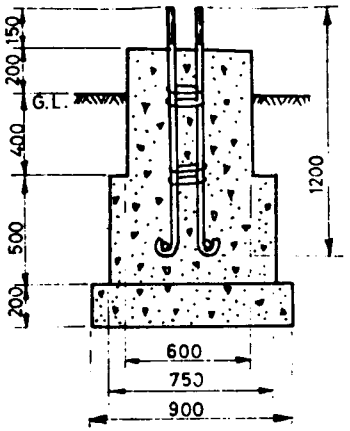

FOUNDATION DETAILS XX'

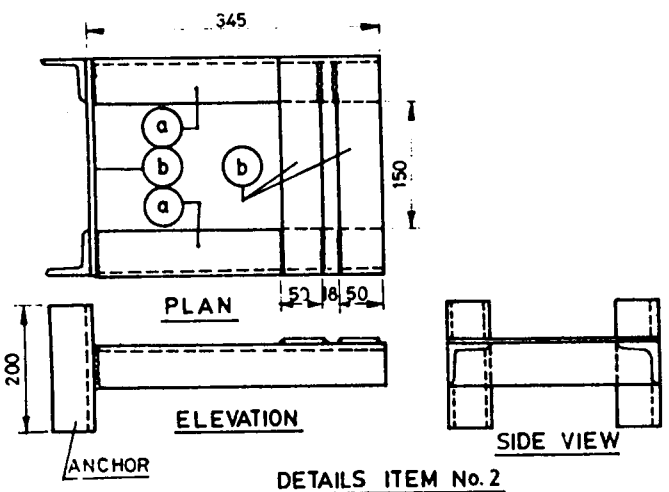

DETAILS ITEM No. 2

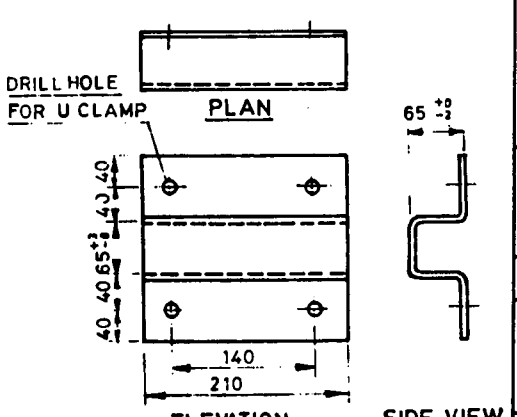

DETAILS ITEM No. 3 (CLAMP)

SL No.	ITEM	L B D H	SPECIFICATION	REMARKS
10.	WIRE	ϕ 6		
9.	NUT, BOLT, WASHER	ϕ M16 x 100 (5/8" x 4")		
8.	FOUNDATION BOLT	ϕ16 x 1200 LONG		
7.	SECOND STEP		M15 MIX CONCRETE 1:2:4 CEMENT FINE AGGREGATE COARSE AGGREGATE	
6.	FIRST STEP	750 x 750 x 500	DO	
5.	BOTTOM STEP	900 x 900 x 200	1:2:4 LIME CONCRETE	WELL RAMMED
4.	U CLAMP (4 No.)	BAR ϕ12 (1/2") LENGTH 350 = 14"	FOR ϕ 4" PIPE	FOR ONE TRUSS
3.	M. S. PLATE (1 No.)	THICKNESS 4 SIZE 355 x 250		FOR ONE TRUSS
2.	a M S ANGLE (2 No)	SIZE 50 x 50 x 6 LENGTH 345		
	b M.S. PLATE (3 No)	SIZE 50 x 4 LENGTH 250		
1.	TRUSS M.S. ANGLE (2 No)	LENGTH IN INSIDE OF WELL OR PIT SIZE 65 x 65 x 6		TRUSS DIMENSION WILL VARY WITH THE ϕ (INSIDE) OF THE WELL PIT

DETAILS OF SUB STRUCTURE AND PUMP ALIGNMENT FIXTURE OF 12 PU 500 WINDMILL

FOR INFORMATION	INSTITUTE OF ENGG. & RURAL TECHNOLOGY (Near Prayag Rly. Stn.) ALLAHABAD 211002

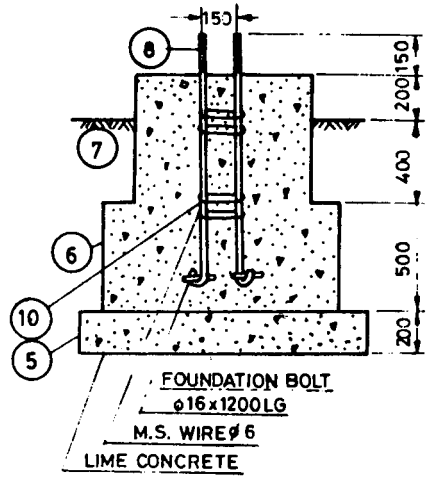

FOUNDATION DETAILS YY'

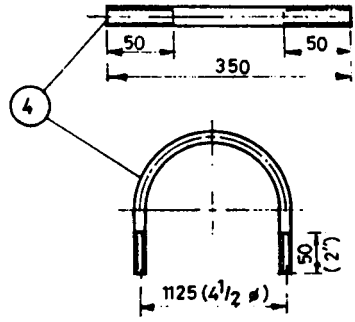

U CLAMP BAR ϕ 12

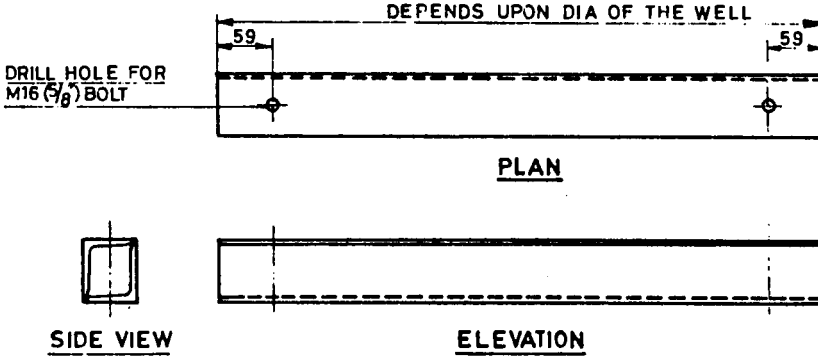

DETAILS ITEM No.1

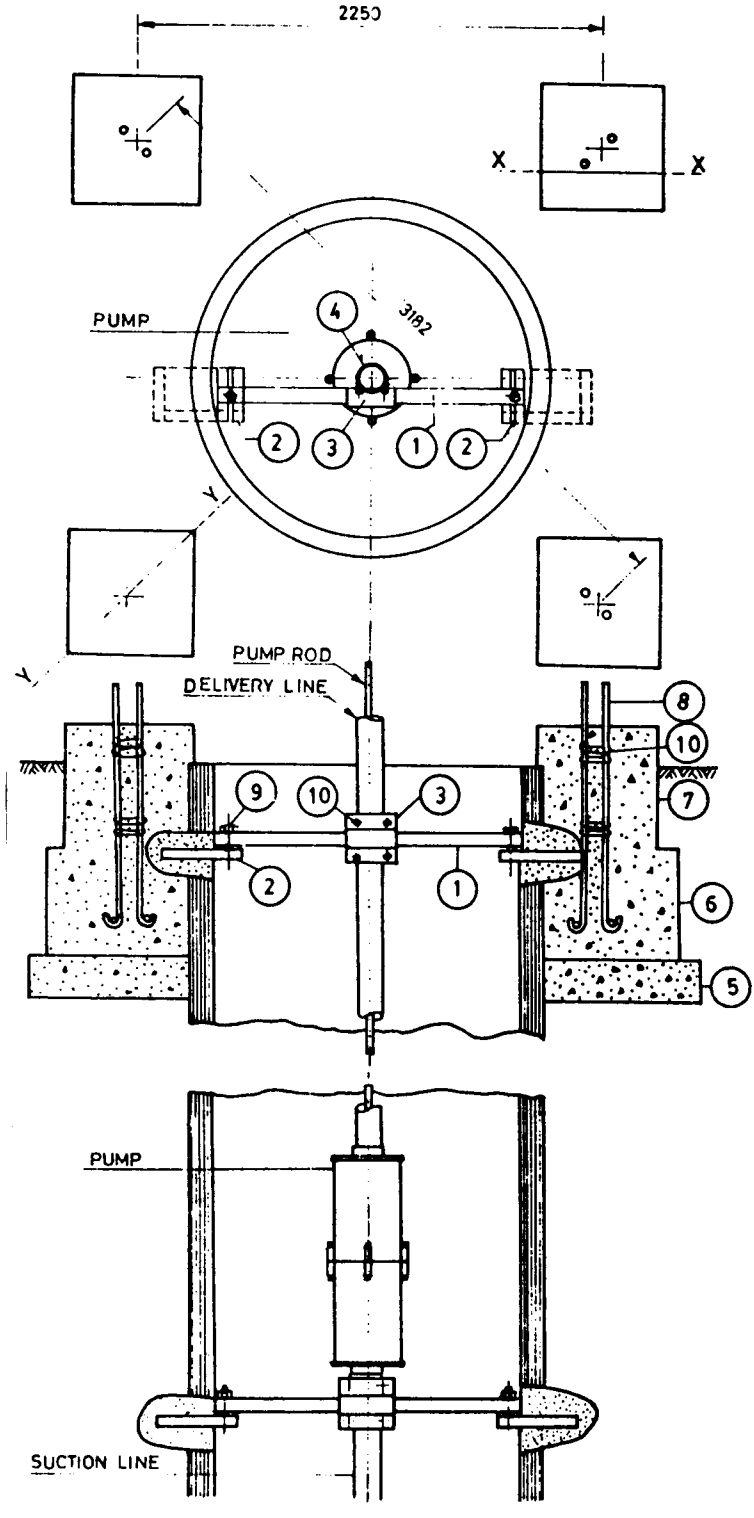
2250
X
X
PUMP
4
3182
2
3
1
2
Y
Y
PUMP ROD
DELIVERY LINE
8
10
9
10
3
7
2
1
6
5
PUMP
SUCTION LINE

8.6 INSTALLATION OF THE TOWER

The Tower is supplied in a knocked-down state and has to be assembled. The holes for the foundation are dug at the desired pitch. They are made of equal depth and wide enough to provide sufficient space for the towerleg anchors and to enable the tower to shift to a certain extent. The tower is laid in position and a rope is connected to the top portion. A ladder (or some bamboos) are kept vertically over which the rope is laid. Before pulling the tower upright one has to be sure that the ladder (bamboos) as well as the tower itself will not fall sidewards. Some extra hands can prevent this by guiding and supporting them with ropes. After the erection procedure the tower is placed vertically. This is checked by means of water level gauge which is kept beside the tower pipe (not at top of the tower pipe edge). Some filling material (e.g. bricks) are shifted under the tower leg angles temporarily during the adjustment in vertical sense. The desired position of the centre is checked by means of a rope and plumb bob with reference to the alignment of the tower with the centre of the well or the tubewell. The vertical position is checked again, and if both the positions are satisfactory the tower legs are grouted by means of cement and stone or brickchips.

The curing of the foundation needs at least 5 days, meanwhile, the time consuming fixation of the pump is carried out. For the grouting needed for pump fixation, the required mortar is made available during grouting the tower legs.

8.7 INSTALLING THE HEAD CONSTRUCTION

The jib crane is pulled and pushed up beside the tower and is finally set on angle of the tower. The jib is installed on the 'wind shadow' side of the tower (see drawing) while its two clamping angle-iron arms enclose the tower pipe on most outward position.

Now the complete head construction without the help vane is brought under the jib. The lifting hook is bolted to the tail at about 1.5 metres distance from the tail hinge. the head tends to turn towards the tail, since the lock mechanism of the help vane is kept out which makes the entire head construction difficult to handle. A locking device is arranged temporarily either by roping the upper tail-beam to the head construction or by putting a clamp overthere. A pin stuck through the head and ending up in the upper tail-beam may also serve the purpose very well.

The rope is connected to the lifting hook and 'balancing' of the head construction is tried out in such a way that the front part of the head is out of balance; (say: 5 degrees). This is essential to ensure that the framing of the head construction, which is going to surround the tower pipe, will grip and throttle it. (This is a most essential precaution which seems to be even contradictional).

The head is now lifted slowly by pulling the rope (by about 6-persons) and two persons guide the head while climbing the tower. The head is allowed to seek its position in the wind (do not force it and lift it till it floats just above the tower pipe). The two persons, each standing on the platform now, guide the bottom part of the head just over the tower pipe. The head is lowered down very slowly and the persons keep the head pressed down over the tower pipe. Actually they should maintain the '5 degrees out of balance' state of the head while the head itself is lowered down stepwise. The last few centimetres may be difficult as the inside angles of the head might touch the tower pipe edge and so obstruct a further sliding over of the head. If extra attention is paid to a proper centering, no problems appear and the head sinks into its final position. Loosen the rope and remove the lifting hook, and preparations are undertaken now to install the rotor frame.

8.8 INSTALLING THE ROTOR

First of all the position of the jib crane is adjusted. The jib crane is put in the most upright position, and the head construction is turned 180 degrees so that the front part of the head is touching the jib crane. For security reasons a rope connection is made overthere so that the head on which the rotor, shaft and bearing blocks are going to be placed, remains under the pulley of the jib crane. This is necessary as appearing wind might turn the head construction.

Both the rotor halves are connected now and the shaft is slid into the hub to take its normal position. The hub bolts are tightened stepwise as well as the securing clamping angle iron, care-

fully the rotor frame is lifted and carried to the tower where it is put in vertical position, standing on one of its six spokes. Now it sets against the tower, right under the jib crane. Care should be taken of the extending shaft pointing into to lattice of the tower construction, as this may cause problems.

The rope is lowered down now from the jib crane and it is connected to the hub of the rotor frame, so that the rope passes both the inside and outside ring from the back of the rotor.

Carefully and slowly the rotor is lifted and two persons guide it while climbing the tower. Extra attention is paid to the extending shaft which tends to get stuck in the lattice of the tower. Finally, reaching the level of the platform it is seen that the shaft is positioned on the correct side of the jib crane, since the latter itself will be an obstacle.

The entire rotor and shaft are hovering above the head now. With some effort the bearing blocks are positioned above their supports and the rotor is lowered down very slowly. The bolts are put quickly and the nuts are screwed on by hand first. The position is secured now and the rope is removed from the rotor and jib crane and the latter is lowered down. The rotor is revolved through a few revolutions in order to enable the bearing blocks to settle on their supports. The bolts of these bearing blocks are tightened.

The windmill is put in a secured position and the mounting of the blades can start now. One person sits on the platform and the other stands on angle 6 of the tower. The bolts, nuts and the tools can be kept conveniently in a basket which is hung temporarily from the platform during this bolting activity. It is necessary that the blades are mounted in crosswise sequence e.g. 1-7, 8-2, 3-9, 10-4 etc.

After this the crosshead, assembled with connecting rod and the pump rod both, is pushed into the tower pipe and the crank bush and central bolt are assembled. It is to be seen that the locking bolt of the PVC tower pipe insert is removed temporarily in order to allow the crosshead to pass in. Also important is to install the crank bush with its collar facing the crank plane and the application of the washer in between the bolt head and the bush edge is to be removed. The bolt is tightened up strongly and the locking screw for the PVC tower pipe insert is reinstalled. The wooden pump rod guide is fitted on the bottom side of the tower pipe and locked with the bolt.

Now the help vane arrangement is assembled and the windmill can be put to face the wind.

8.9 INSTALLING THE PUMP

It is preferable to have the pump section installed and completed by the time the windmill itself has been assembled.

As expressed earlier the installation of this very essential part should not be underrated as many difficulties are felt with regard to the alignment and fixation in the well. The reciprocating forces, which act on this section, can be considerable and a minor play in the suspension, either in axial or in radial sense, can lead to a "noisy dancing and swinging" performance of the pump. In the long run the grouted parts of the suspension will come out, the nuts and bolts will run loose and hammer their way through their counterparts.

A good deal of attention, therefore, is to be paid to the proper alignment and strong fixation of the pump and delivery pipe in order to prevent the above mentioned malfunctioning.

Though the wells for windmill sites differ in depth of water table, diameter and structure, at least some general guidance can be given to obtain suitable suspension :

In case of centrally situated installation of the windmill above the well it is advisable to fix at least one "bridge construction". This structure lends the needed suspension, provided of course, that its legs are grouted thoroughly in the well casing.

Centralisation at the bottom part of the pump section is provided by the tube well (if applied) or by the application of a similar "bridge construction" which embraces the suction pipe on which the pump has been screwed.

In the latter case grouting of the bridge into the well casing might be complicated since the bottom part of the pump is situated preferably under the water table in order to make the pump

self priming and to assure the desired minimum suction head. The problem is overcome either by grouting the bridge legs during a period for which the lowest water level exists (dry season, after excessive water removal by another pumping device) or by using and expanding clamp mechanism in the bridge legs themselves. This can be obtained by applying at each leg a bolt/nut combination in such a way that by screwing out the bolt the expanding effect occurs.

In case of an off-centre installation of the windmill not much choice is left and clamps, equipped with strong anchors which are grouted into the well casing, prove to be the best solution.

As far as the fixation under the waterline is concerned (in case of no tube well) it is advisable to apply a connection in the well casing based on key-wedge principle.

IMPORTANT NOTE

After the completion of the erection the installation should be checked with reference to the check list, and a record of all readings taken, be maintained.

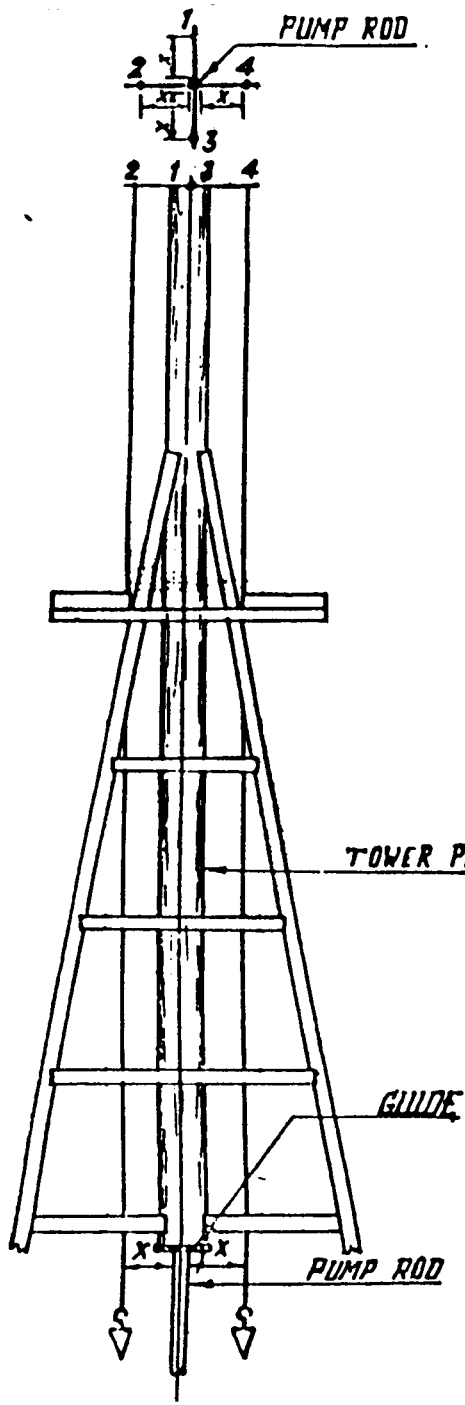
PUMP ROD
1
2
4
3
2 1 3 4
TOWER PM
GUIDE
X
X
PUMP ROD

8.10 Check List for Installation of Windmill

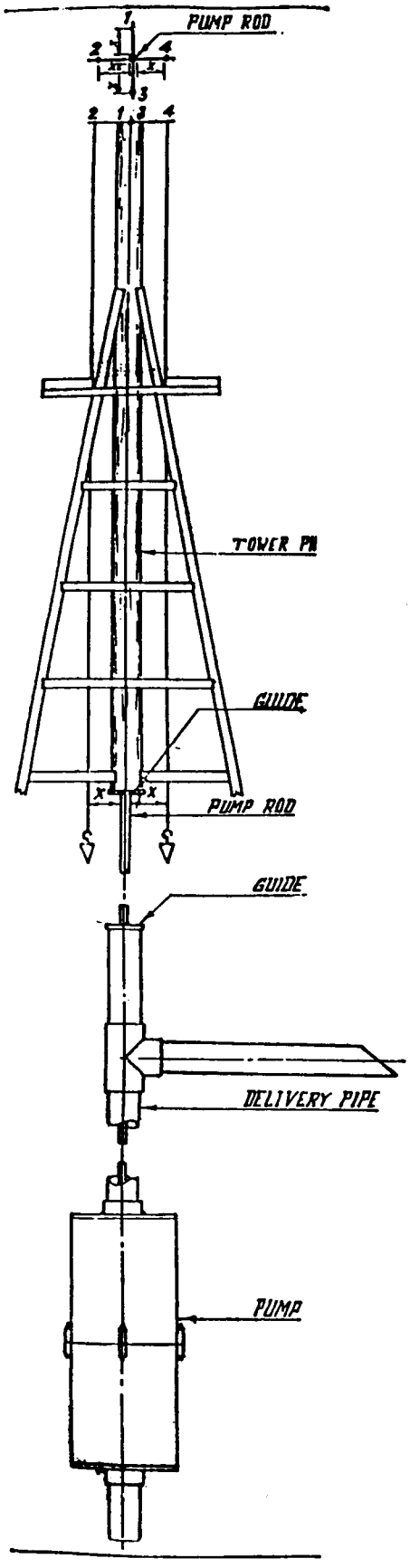

CHECKS IN WINDMILL INSTALLATION

पवन चक्की स्थापना के समय निरीक्षण

(A) **Verticality (Sahul, Scale Try-square, Spirit Level)**

(अ) **लम्बवत निरीक्षण (साहुल, स्केल, गुनिया, स्प्रीट लेवल)**

(a) Tower pipe
(take 4 readings)

(१) टावरपाईप (चार रीडिंग लीजिए)

(b) Pump rod with reference to tower pipe
(about 150 mm below the upper wooden guide)

(२) टावर पाईप के सापेक्ष पम्प राड का निरीक्षण (टावर पाईप से गाइड १५० मि० मी० नीचे)

(c) Perpendicularity of tower top Face with reference to the side of the pipe.
If the distance between the two wooden guides is more than 3 metres then.

(३) टावर टाप सतह की लम्बवता पाईप के चारों ओर के सापेक्ष ।
अगर पम्प राड की लम्बाई दोनों गाइड के मध्य तीन मीटर से अधिक हो तब ।

(d) Measure perpendicularity of pump rod at a distance of about 150 mm above the lower guide.

(४) पम्पराड की लम्बवता निचली गाईड से १५० मि० मी० ऊपर निरीक्षण कीजिए ।

(e) Measure verticality of delivery pipe.

(५) डिलीवरी पाईप लम्बवता का निरीक्षण कीजिए ।

1	2	3	4

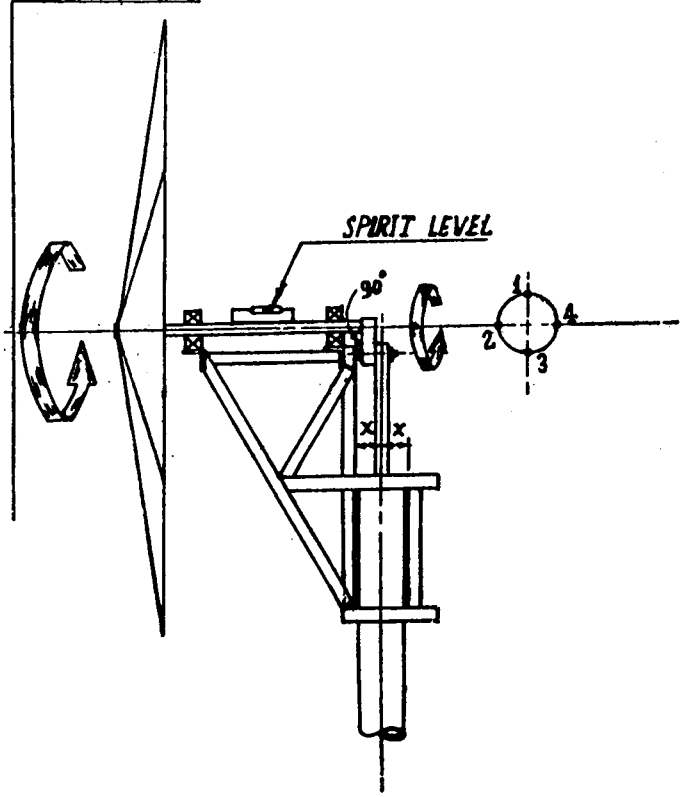

(B) SHAFT (Spirit level & Scale)

(ब) साफ्ट (स्प्रीट लेबल और स्केल)

		Position स्थिति	Reading प्रेक्षण
(a)	Turn the rotor around tower axis, meassure level in rotor facing North, West, South & East (NWSE) w. e. at 4 positions.	1.	mm मि॰ मी॰
		2.	mm मि॰ मी॰
(१)	टावर के अक्ष के चारों तरफ रोटर घुमाइये एवं सतह का निरीक्षण कीजिए । (पूरब, पश्चिम, उत्तर, दक्षिण) चारों स्थितियों में ।	3.	mm मि॰ मी॰
		4.	mm मि॰ मी॰
		I II	
(b)	Rotate rotor around the axis of the shaft and measure perpendicularity of the crank with reference to the shaft. (Measure distance between the connecting rod and head construction X).	1.	mm मि॰ मी॰
		2.	mm मि॰ मी॰
(२)	साफ्ट के अक्ष के चारों ओर रोटर को घुमाइये और क्रैंक की लम्बवता ज्ञात कीजिए ।	3.	mm मि॰ मी॰
		4.	mm मि॰ मी॰
(c)	Measure clearance between the head construction & towertop pipe surface.		gauge / mm
(३)	(हैड कन्सट्रक्शन एवं कनैक्टिंग राड के बीच की दूरी नापिये)		गेज / मि॰मी॰

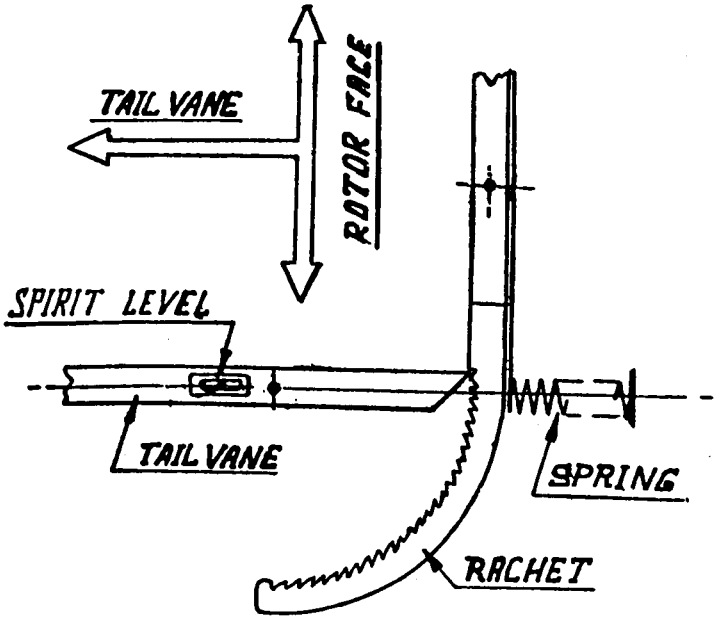

(B) Measure spring tension of the tail with the help of spring balance. ... ... kg.

(१) स्प्रींग बैलेंस की सहायता से टेल स्प्रींग का तनाव ज्ञात कीजिए ।

(C) (a) Check meshing of the tail with toothed sector.
(b) Measure horizontality of the tail with the help of spirit level & scale. ... . mm.

(२) टुपेड रेचेट भाग का टेल के साथ मैचिंग का निरीक्षण कीजिए ।
टेल की क्षेतिजता स्प्रोट लेबल एवं स्केल की सहायता से ज्ञात कीजिए ।

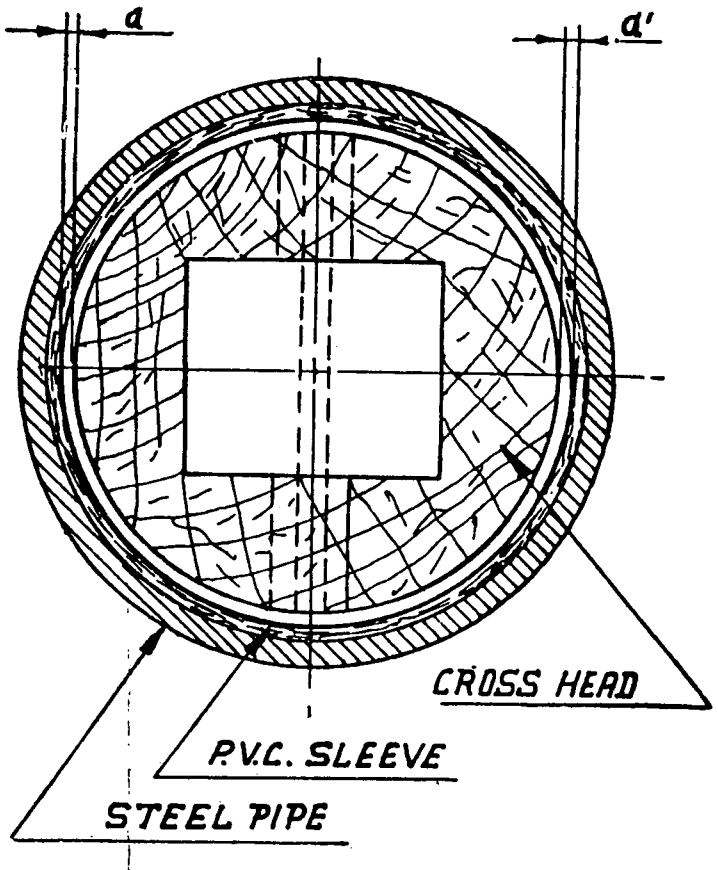

(E) Measure clearance d x d between the PVC sleeve & cross head. ... ... gauge/mm.

(१) पी० वी० सी० स्लीव एवं क्रासहेड के बीच अन्तराल डी एवं डी, नापिए। गेज/मि० मी०

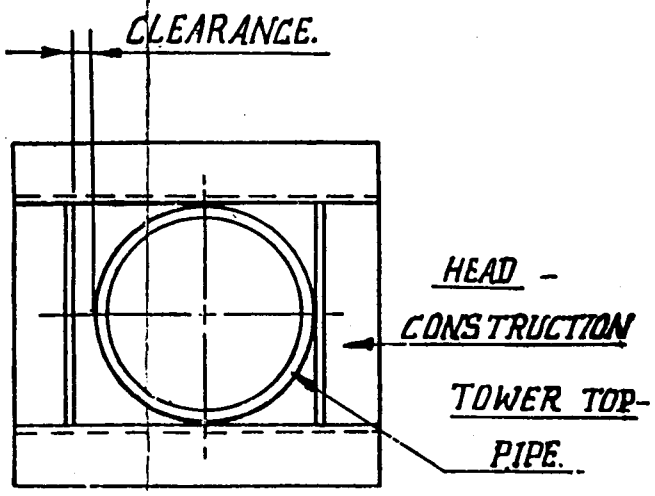

(D) Measure clearance between the head construction & towertop pipe surface. ... ... gauge/mm.

(१) हेड कन्सट्रक्शन एवं टावर टाप पाइप सतह के बीच अन्तराल ज्ञात कीजिए। गेज/मि० मी०

9. MAINTENANCE OF THE WINDMILL

Though the number of moving parts in the windmill is limited yet certain regular checkups and lubrication services should be undertaken from time to time. Also, in the long run some moving parts might wear out and need replacement. Fortunately, in this design, such parts are cheap in the material costs. They can be made easily and replaced.

9.1 THE OVERALL STRUCTURE

Actually corrosion of the steel structure is the greatest enemy of the windmill. If the corrosion problem is tackled in the right way the technical lifetime of the windmill is expected to reach at least 15 years and probably far beyond this figure.

It is advisable, therefore, to have the structure painted thoroughly with one coat of primer and two coats of finish, after chipping off the weldings. The need for these preventive measures is more in areas where the air is humid or saline as along a coast-line. The best anticorrosive zinc-based paints should ba applied.

9.2 TOWER

Generally it is expected that the tower will not need any specific attention with regard to wear and tear, since it is a static structure. One should realise however, that the tower pipe serves multiple functions:-

- It carries head construction the edge (this is in axial sense).
- Its outside provides support to the head construction by enclosing it at the top and bottom parts (in radial sense).
- Its inside provides the guidance to the crosshead via the contact of PVC insert.

The 'steel to steel' contact of tower pipe and head construction needs some lubrication (grease) from time to time. As long as the grease is present no excessive wear is going to occur there. Also, as long as the PVC insert remains locked in the tower pipe, the insert will serve its purpose well.

However, corrosion of the tower has to be taken into account and check-ups should be undertaken at half yearly intervals.

9.3 HEAD CONSTRUCTION

Besides its contact with the tower pipe only a few moving parts of this structure need attention for maintenance. It should be ensured that the locks of the security device remain free of any play. The functioning of the hinges of the help vane and tail vane both should be checked up from time to time since they have the tendency either to run loose or to corrode: The former will lead to loose and noisy, and hence clumsy joints, and the latter to a struggling and faultering functioning of the mechanism. The best remedy is to apply a few oil drops from time to time.

If, the help vane lock or the final lock is worn out. It would be better to take it out, apply some welding and reshape it by filing, and get it re-installed properly. There is no need to explain the necessity of a proper functioning of storm security device.

9.4 MOVING PARTS

It is assumed that the main bearings have been positioned and tightened properly. Generally the lubrication is sufficient for millions of revolutions and as long as no dust particles enter the "grease" no complications are expected. However, in course of time the grease is "rolled out" of the bearing and will change its lubricating properties. This takes years, though, to happen, but moment it is noticed, new grease (not oil) should be applied. If no grease nipple is there, the bearing housing has to be opened to apply fresh grease.

Generally the nylon (or bronze) bearings of the connecting rod keep their lubricant well. Some fresh oil drops from time to time will serve the purpose satisfactorily. The same counts for the wooden cross-head and pump rod guides. Properly soaked in oil they contain the lubricant themselves and from safety point of view it is best to keep them in that condition. Generally a "generous filling up" of the square hole in top of the crosshead with oil, provides the best guarantee that these essential wooden parts will maintain their functioning. The appearance of play in these parts after some time of functioning might seem to be bothersome, but they have a long way to go before replacement is really necessary. In short, the wear is acceptable as a long as no noisy and clumsy malfunctioning occurs. The replacement is cheap and easy to carry out specially, as far as the wooden pump rod guides are concerned. With regard to replacement of the crosshead it is advisable to drill complete new holes for the pump rod crosshead connection. It will be evident that in case of replacement of worn out crosshead the replacement of the PVC insert is also recommended.

9.5 THE ROTOR

Besides maintenance concerning corrosion, the rotor does not need any maintenance. However, in some cases bolts and nuts become loose due to the alternating character of the load on them. A "cracky" noise indicates such fault.

The remedy is to chek-up all bolt and nut connections, especially at the start. In a fair number of cases some fatigue cracks appear either in the outside blade supports (shearing fatigue) and/or in the blades somewhere at their edge. If it happens, supports and/or blades should be replaced by new ones.

9.6 THE PISTON PUMP

In the windmill the pump section remains the most bothersome part. Besides the checks of its suspension, checks are to be made with regard to its delivery. Depending on the purity of the lifted water the piston wears out sooner of later, resulting in a poor delivery. It should be replaced then.

If time has come to change the piston, it is better to replace the valves too. This will ensure that the newly overhauled pump will serve its purpose for the next period of time without any failure. The span of this time will depend on the purity of the water which is pumped from the source. Presence of sand particles play a significant role in the life of the piston and precautions should be taken. In case of water delivery from a tube well, a proper "washing" procedure is necessary.

Maintenance checks as given in the following pages should be carried out at half yearly intervals.

9.7 Preventive Maintenance Schedule
Water Pumping Windmill
12-PU-500

Sl. No.	Major Parts	Sub Components	Insepction Schedule				Suggested Remedial measures.
			D	M	Q	Y	
1.	Rotor	Hub bolts			✓		If loose, tighten
		Hub clamp bolt			✓		-do-
		All the Rotor Fasteners			✓		-do-
		Upper and lower tips of the blades	✓				If bent, remove the blades with bent tips, straighten and fix again, If badly damaged, replace it.
		Condition of paint				✓	Retouch/Repaint
		Blade supports			✓		If cracked, replace
		Inner and outer rings			✓		Repair/Replace
		Blades	✓				If damaged badly, replace.
2.	Head Construction Tail and the security mechanism	All the fasteners and joints			✓		If loose, tighten
		Condition of security lock in both secured and operational positions.			✓		If functioning is improper and it suffers from vibration check the ratchet arm and spring and the locking edge of the tail, replace the worn out part.
		Movement of head construction aroundthe tower pipe.		✓			If the rotation around the tower pipe is not smooth, lubricate with grease. if the clearance between the tower pipe and head construction is abnormal put a shim in the gap.

Sl. No.	Major Parts	Sub Components	Insepction Schedule				Suggested Remedial measures.
			D	M	Q	Y	
3.	Mechanical Power Transmission system.	Condition of the bearing block		✓			If cracked replace the complete bearing with housing immediately.
		Condition of the bearing for any unusual sound axial movement or play.		✓			If running dry, lubricate, if sound still persist or there is axial movement or play then replace the complete bearing.
		Bearing fixing bolts.		✓			If loose, tighten firmly.
		Rear bearing safety bracket		✓			If loose, tighten firmly.
		Hub screw of bearing		✓			If loose, tighten firmly.
		Condition of crank holes		✓			If holes are enlarged, remove the shaft with crank repair by welding and drilling repairing and reinstall properly.
		Welding joint of the crank with main shaft.		✓			If cracked or deformed remove the shaft with the crank, repair and refix properly.
		Crank bolt		✓			If loose tighten firmly.
		Collar Bush			✓		If sign of wear appears change and lubricate with grease.
		Connecting rod		✓			If broken, bent or crack appears on any joint, replace.
		Nylon bushes at both ends of connecting rod			✓		If play has developed or bushes have worn out replace them.
		Crosshead			✓		If unusual sound or play appears, replace.
		PVC Sleeve			✓		If worn out replace.
		Pump rod joints			✓		If loose, tighten firmly.
		Wooden/Polypropelene guides			✓		If wornout, replace.

Sl. No.	Major Parts	Sub Components	Insepction Schedule				Suggested Remedial measures.
			D	M	Q	Y	
4.	Piston Pump	Pipe line joints	✓				If there is any leakage check the flange and socket joints, repair.
		Coupling bolts			✓		If there is any leakage from middle section through the rubber gasket, replace the gasket, open the pump and check.
		Abnormal noise from the pump	✓				The complete assembly consisting of the piston rod, nut, brass guide, foot valve, piston barrel, replace the faulty component.
5.	Tower	All the fasteners of joints		✓			If loose, tighten firmly.
		Condition of tower pipe				✓	If bent change the tower top.
		Welded joint of tower pipe with stand legs.				✓	If cracked remove the tower top, repair and reinstall.
		Condition of protective coating.				✓	If peeled off, carry out touching with primer and paint.
6.	Foundation and Aux. Structure	Physical insp. of work	✓				If any vibrations have caused cracks, stop the windmill and repair the civil constructions.
		Supporting bridges & clamps		✓			If the clamps are loose tighten them.
		Delivery pipe bracket		✓			If fitting is disturbed, fix it correctly.

D = Daily; M = Monthly; Q = Quarterly; Y = Yearly

9.8 PART LIST OF 12-PU-500 WINDMILL

TOWER :

Sl.No.	Item	Material	Size mm	Measurements mm	No. Regd.
T/1	ANGLE IRON	M.S.	35x35x5	250	8
T/2	ANGLE IRON	M.S.	40x40x5	4500	4
T/3	ANGLE IRON	M.S.	35x35x5	1940	16
T/4	ANGLE IRON	M.S.	35x35x5	1400	4
T/5	ANGLE IRON	M.S.	50x50x6	250	4
T/6	ANGLE IRON	M.S.	35x35x5	700	4
T/7	ANGLE IRON	M.S.	40x40x5	2000	4
T/8	ANGLE IRON	M.S.	35x35x5	660	2
T/9	FLAT IRON	M.S.	32x6	580	2
T/10	FLAT IRON	M.S.	32x6	460	2
T/11	FLAT IRON	M.S.	32x6	340	2
T/12	WOODEN PLANK	WOOD	30x200	700	2
T/13	PIPE (SLEEVE)	PVC	4" BORE	710	1
T/14	TOWER PIPE	M.S.	4" N.B.	2650	1
T/15	FLAT	M.S.	32x6	410	4
T/16	PLATE	M.S.	170x160x6		4
T/17	NUT,BOLT,WASHERS	M.S.	M12x40(W½"x1½")		52
T/18	MACHINE SCREW		½" Ø x 2" long		4
T/19	MACHINE SCREW		½" Ø x 1" long		4

HEAD CONSTRUCTION :

Sl.No.	Item	Material	Size mm	Measurement mm	No. Regd.
HC/1	ANGLE IRON	M.S.	40x40x5	200	1
HC/2	ANGLE IRON	M.S.	40x40x5	200	1
HC/3	ANGLE IRON	M.S.	40x40x5	155.5	4
HC/4	ANGLE IRON	M.S.	40x40x5	555	2
HC/5	ANGLE IRON	M.S.	40x40x5	590	1
HC/6	ANGLE IRON	M.S.	40x40x5	1000	2
HC/7	ANGLE IRON	M.S.	40x40x5	1110	2
HC/8	ANGLE IRON	M.S.	40x40x5	540	2
HC/9	ANGLE IRON	M.S.	40x40x5	460	2
HC/10	ANGLE IRON	M.S.	40x40x5	500	1
HC/11	ANGLE IRON	M.S.	65x65x6	250	2
HC/12	ANGLE IRON	M.S.	40x40x5	1500	1
HC/13	ANGLE IRON	M.S.	40x40x5	4000	1
HC/14	ANGLE IRON	M.S.	40x40x5	3000	1
HC/15	ANGLE IRON	M.S.	40x40x5	125	1
HC/16	ANGLE IRON	M.S.	40x40x5	60	1
HC/17	ANGLE IRON	M.S.	40x40x5	45	1
HC/18	ANGLE IRON	M.S.	40x40x5	1000	1
HC/19	FLAT IRON	M.S.	32x6	115.3	2
HC/20	FLAT IRON	M.S.	32x6	65	2
HC/21	FLAT IRON	M.S.	32x6	150	1
HC/22	FLAT IRON	M.S.	32x6	115.5	1
HC/23	FLAT IRON	M.S.	32x6	830	1
HC/24	FLAT IRON	M.S.	32x6	750	3
HC/25	FLAT IRON	M.S.	32x6	200	1
HC/26	RACHET (FLAT, HARDENED)	M.S.		480	1
HC/27	TAIL VANE (1mm SHEET)	M.S.		2000x1000	1
HC/28	HELP VANE (1mm SHEET)	M.S.		1000x500	1
HC/29	ROD	M.S.		30Diax650	1
HC/30	WASHER	M.S.		M12(½" Dia.)	1
HC/31	NUT	M.S.		M22(W 7/8")	1
HC/32	BOLT,NUT,WASHER	M.S.		M12x40(W½"x1½")	1
HC/33	BOLT,NUT,WASHER	M.S.		M12/100(W½"x4")	1
HC/34	BOLT,NUT,WASHER	M.S.		M6x25-(W¼"x1")	12
HC/35	SPRING	SPRING STEEL	App. 30Dia.x1000x14		1

MOVING PARTS

Sl.No.	Item	Materials	Size mm	Measurements mm	No.
MP/1	MAIN SHAFT	M.S.	ϕ 50(ϕ2")	1300	1
MP/2	PILLOW BLOCK (BEARING)-FYH & NTN		P210J-50±0.01 bore		2
MP/3	BUSH	M.S.	33x43x33		2
MP/4	BUSH (MOULDED)	NYLON	ϕ 25xϕ38x18		4
MP/5	BUSH	M.S.	ϕ20xϕ40x44		1
MP/6	WASHER	M.S.	ϕ20x40ϕx3		1
MP/7	CRANK BOLT (GKW MAKE)	M.S.	M20x75(W3/4"x3")		1
MP/8	NUT	M.S.	M20(W3/4")		1
MP/9	BOLT,NUT,WASHER	M.S.	M12x50(W1/2"x2")		2
MP/10	BOLT,NUT,WASHER	M.S.	M10x100(W3/8"x4")		2
MP/11	CROSS PIN	M.S.	ϕ 25x92		1
MP/12	CROSS HEAD	WOOD (SEASONED In OIL)	ϕ97x5x300		1
MP/13	CONNECTING ROD (FLAT)	M.S.	30x6	650	1
MP/14	FLAT	M.S.	30x6	50	4
MP/15	FLAT	M.S.	15x6	300	2
MP/16	FLAT	M.S.	40x10	165	1
MP/17	FLAT	M.S.	25x6	135	2
MP/18	FLAT	M.S.	25x6	250	2
MP/19	GREASE CUP				1
MP/20	PIPE (Q.S.T. MAKE) CLASS 'A' G.I.		ϕ1"	(Amount or size depend upon - circumstances)	*
MP/21	PUMP ROD GUIDE	(TEAK WOOD)	ϕ120x100		1

ROTOR:

Sl.No.	ITEM	MATERIAL	SIZE mm	MEASUREMENTS mm	NO. REQD.
R/1	PLATE	M.S.	260Dia.x6		2 (Two piece in one)
R/2	ANGLE IRON	M.S.	50x50x5	625	2
R/3	ANGLE IRON	M.S.	50x50x5	100	4
R/4	ANGLE IRON	M.S.	50x50x5	350	2
R/5	ANGLE IRON	M.S.	40x40x5	1880	6
R/6	FLAT IRON	M.S.	30x5	1880	6
R/7	FLAT IRON	M.S.	30x5	495	6
R/8	FLAT IRON	M'S'	30x5	275	6
R/9	RING CLAMP (FFLAT)	M.S.	40x10	150	12
R/10	OUTER RING (FLAT)	M.S.	30x5	2000	6
R/11	INNER RING (FLAT)	M.S.	30x5	3000	2
R/12	ROTOR BLADE (SHEET)	M.S.	2000x300x1.5		12
R/13	OUTER BLADE SUPPORT (SHEET)	M.S.	220x157x2.65		12
R/14	INNER BLADE SUPPORT (SHEET)	M.S.	250x247x2.65		12
R/15	BOLT, NUT, WASHER	M.S.	M16x100(W5/8"x4")		12
R/16	BOLT, NUT, WASHER	M.S.	M16x125(W5/8"x5")		2
R/17	BOLT, NUT, WASHER	M.S.	M10x25(W3/8"x1")		64
R/18	BOLT, NUT, WASHER	M.S.	M6x25(W1/4"x1")		120

PISTON PUMP

Sl.No.	Item	Material	Size mm	No. Reqd.
PP/1	PUMP ROD EXTENSION	G.I. PIPE	3/4"——————x*	*
PP/2	PUMP ROD	G.I. PIPE	3/4"——————x900	1
PP/3	PIPE	G.I. PIPE	5/8"——————x100	4
PP/4	TOP PIPE	BLACK PIPE	4"——————x750	1
PP/5	EXHAUST PIPE	BLACK PIPE	4"——————x*	1
PP/6	DELIVERY PIPE	BLACK PIPE	4"x——————x*	*
PP/7	T-SOCKET	G.I.	4"——————	1
PP/8	SOCKET	BLACK	4"——————	*
PP/9	DELIVERY PIPE	BLACK PIPE	4"——————	1
PP/10	CYLINDER	SEAMLESS BLACK PIPE	6" GASPIPE X 460	1
PP/11	CASING FLANGE	M.S.	ϕ 290	2
PP/12	CASING FLANGE	M.S.	ϕ 290	1
PP/13	CASING	C.R. SHEET	500x900	2
PP/14	FOOT VALVE	8 mm M.S. SHEET	ϕ 170	1
PP/15	FLAT IRON		——————35	12
PP/16	FLAT IRON		——————80	4
PP/17	FLAT IRON		——————x180	1
PP/18	FLAT IRON		——————x450	1
PP/19	FLAT IRON		——————x300	*
PP/20	FLAT IRON		40x6(1½"x¼")	3
PP/21	ANGLE IRON		40x40x4(1½"x1½")	2
PP/22	FILLING PIECES	M.S. ROD	ϕ 8mm x 10mm	8
PP/23	RING	M.S. ROD	ϕ 8(0 3/8")x870	1
PP/24	VALVE	NITRILE RUBBER WITH NYLON FABRIC INSERT/ LEATHER	ϕ 150 x 5	2
PP/25	GASKET	NITRILE RUBBER SOLE LEATHER	ϕ 290 x 6 mm	1
P/26	PISTON	POLYPROPELENE/ TEAK WOOD POLYPROPELENE		1
PP/27	STEEL BUSH		ϕ 43 x 33	*
PP/28	GUNMETAL BUSH		ϕ 33 x 30	*
PP/29	THREADED STUD	C.I.	M24x150(W7/8"x65)	1
PP/30	THREADED STUD	C.I.	M24x100(W7/8"x4")	*
PP/31	NUTS	G.I.	M24x(W7/8")	*

Sl.No.	Item	Material	Size mm	No. Reqd.
PP/32	SPRING WASHER	G.I.	M24(W7/8")	*
PP/33	BOLT,NUT,WASHER *	G.I.	M12x125(W½"x5")	4
PP/34	BOLT,NUT,WASHER *	G.I.	M12x120(W½"x3/4")	1
PP/35	CLAMP (U BOLT)	M.S.	ϕ 12 (½") x370	
PP/36	TEAK WOOD/POLYPRO—PELENE GUIDE	TEAK WOOD	(5"x5"x4")	1

**Nylock bolts x nuts are preferred to avoid their frequent loosening.*

9.9 INVENTORY OF MINIMUM SPARES OILS AND LUBRICANTS

Sl. No.	Component	Qty.	Reference of fabrication drawing	Part number on the drawing
1.	Help vane spring	1	Head construction 12-PU-500	35
2.	Help vane frame with ratchet	1	"	18,25,26
3.	Tail pin	1	"	29
4.	Connecting rod	2	Moving parts	3,13,14,15,19
5.	Nylon bush (4 nos. at a time	8	"	4
6.	Crank pin	2	"	5
7.	Crank pin bolt and nut	1	"	7 & 8
8.	Cross head with cross pin	1 st.	"	11 & 12
9.	Wooden guides	2 pairs	"	21
10.	Pillow blocks N.T.N. Japan	1 pairs	"	2
11.	PVC sleeve for tower pipe	1	Tower 12-PU-500	13
12.	Blades coated with 90% zinc rich primer and enamel paint	3	Rotor & blade	12
13.	Blade supports (inner & outer)	3 pairs	"	13 & 14
14.	Piston valve & suction valves	3 each	Windmill pump	18,37,38,4
15.	Pump gasket	1	"	17
16.	Piston (polypropelene)	2	"	27
17.	Pump rod guide (brass)	2	"	25
18.	Pump rod guide bush	2	"	23
19.	Pump rod connection	1	"	30,32
20.	Galvanised fasteners with nylock nuts and plain washers (¼" x ϕ x 1" long)	10	"	-
21.	Galvanised fasteners with nuts and plain washers (3/8" ϕ x 1½")	40	"	-
22.	Galvanised fasteners with nylock nuts and plain washers ½" ϕ x 1½" long)	10	"	-
23.	Galvanised fasteners with nylock nuts and plain washers 5 $^{1}/_{8}$" 0 x 1½" long)	10	"	-
24.	Grease for bearings	½ Kg.	"	-
25.	SAE 40 mobile oil	1 Lit.	"	-

9.10 SOURCES OF AVAILABILITY OF SPARES

(a) State Nodal Agencies:

1.	Andhra Pradesh	(BHEL)	Bharat Heavy Electricals Ltd. Vikas Nagar, Hyderabad-500 593.
2.	Andhra Pradesh	(NEDCAP)	Non-Conventional Energy Development Corporation 10-2-318/1/A/5/1, Indranagar Colony Hyderabad-500 457.
3.	Bihar		Executive Engineer, Solar Division, Sone Bhawan, Beer Chand Patel Marg, Patna.
4.	Delhi	(DEDA)	Delhi Energy Development Agency, 11, Lancer Road, Timarpur, Delhi-110 007.
5.	Gujarat	(GEDA)	Gujarat Energy Development Agency, P.N. Chambers, 3rd Floor, Vadodra- 390 005.
6.	Himachal Pradesh	(HPSEB)	Himachal Pradesh State Electricity Board, Shimla, H.P.
7.	Madhya Pradesh	(MRUVN)	Madhya Pradesh Urja Vikas Nigam, B-Block, G.B.T. Complex, T.T. Nagar, Bhopal, M.P.
8.	Maharashtra	(MEDA)	Maharasthra Energy Development Agency, 3rd Floor, Mantralaya, Bombay-400 023.
9.	Orissa	(OREDA)	Orissa Renewable Energy Development Agency, 5-57, Mancheswar, Industrial Estate, Bhubaneswar-751 010.
10.	Rajasthan	(REDA)	Rajasthan State Agro Industries Corporation Ltd. O.I. Subhash Nagar, Ghotwara Road, Jaipur-6.
11.	Tamilnadu	(TEDA)	Tamil Nadu Energy Development Agency, Jhaver Plaza, IVth Floor, 1-Nungambhakkam High Road, Madras.
12.	Uttar Pradesh	(NEDA)	Non-Conventional Energy Development Agency, B-46, Mahanagar Extension, Lucknow-226 006.

9.11 FABRICATING AGENCIES

(b) Fabricating Agencies:

(Involved during demonstration Programme)

1.	Andhra Pradesh	Non-Conventional Energy Development Corporation, 10-2-3/8/1/A/5/1, Indranagar Colony, Hyderabad-500 457.
2.	Gujarat	Principal, Community Polytechnic Wing, Government Polytechnic, Porbhandar, Gujarat-360 577.
3.	Madhya Pradesh	Principal, Government Polytechnic, Khurai, Distt. Sagar-470 117, M.P.
4.	Orissa	Chief Executive, Orissa Renewable Development Agency, 5-57, Mancheshwar Industrial Estate, Bhubaneswar-751 010.
5.	Punjab	Principal, Ramagarthia Polytechnic Phagwara P.O. Satnampura-144 402.
6.	Uttar Pradesh	Works Manager, Training-Cum-Production-Centre, Institute of Engineering & Rural Technology, 26, Chatham Lines, Allahabad-211002, U.P. LORP (TOOL-ORP Project) Kusumikalan, Gazipur, U.P.
7.	Tamilnadu	Principal, Murugappa Polytechnic Satyamurthy Nagar, Avadi, Madras-600 062.

10.1 POLYPROPELENE CROSS HEAD

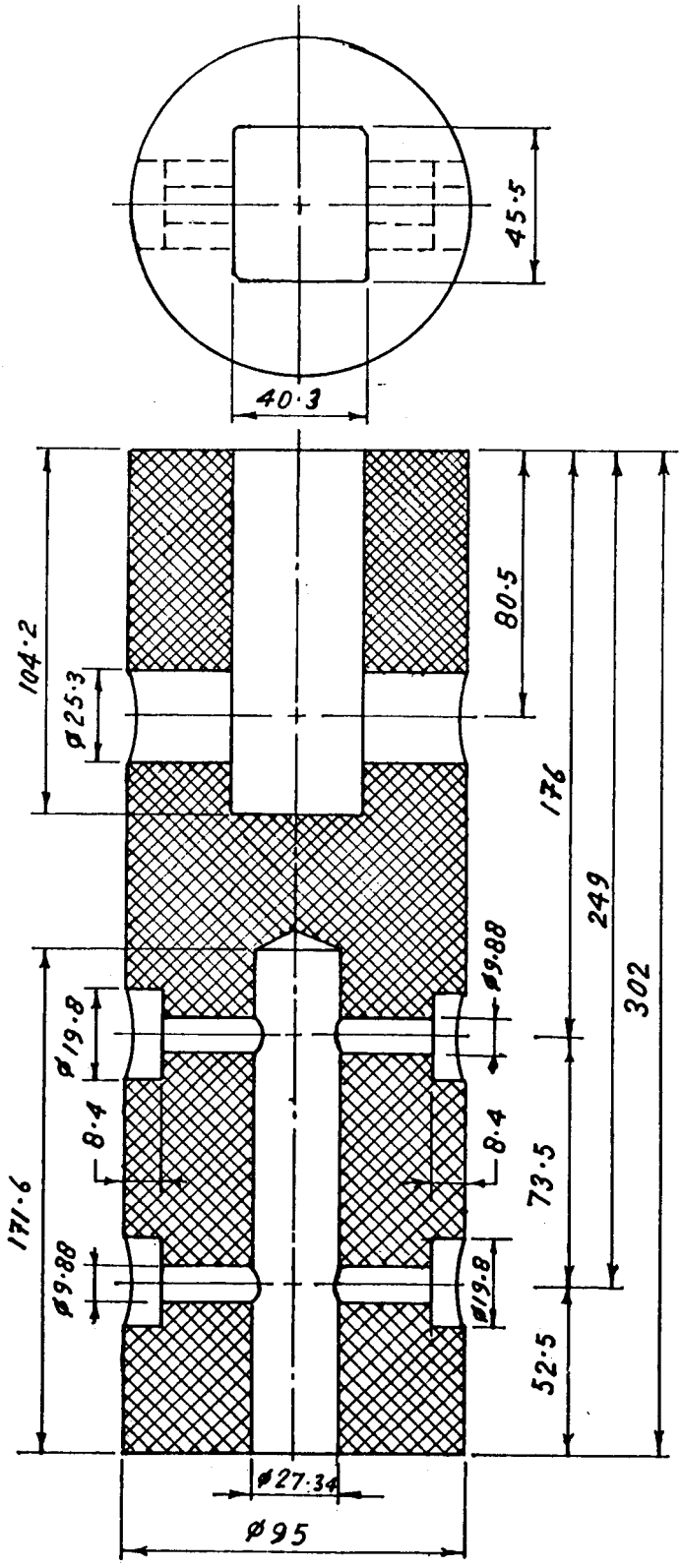

Fug, 13 Polypropelene cross head

10.2 BALL & SOCKET JOINT

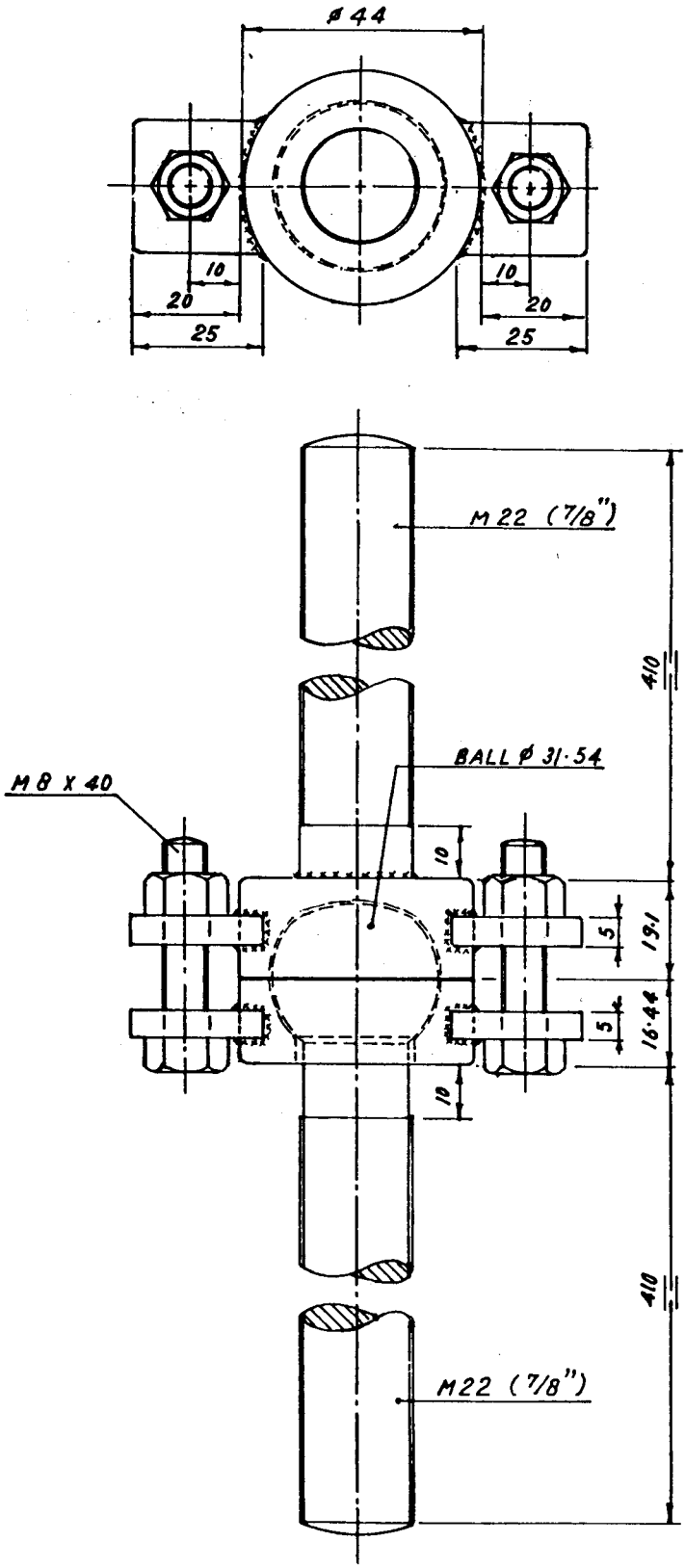

Fig. 14 Ball & Socket joint

10.3 NYLON BUSH FABRICATED AND NYLON BUSH MOULDED

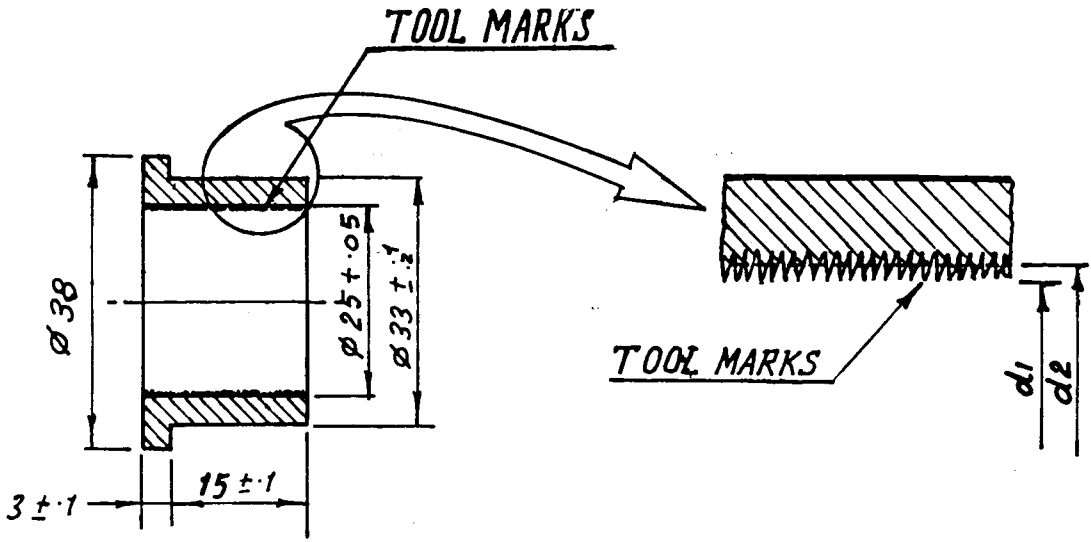

Nylon Bush (fabricated)

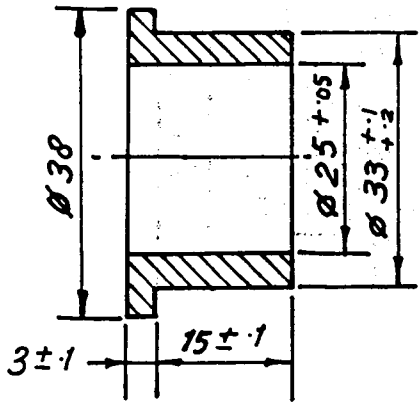

Nylon Bush (Moulded)

Fig. 15

10.4 NEOPRENE VALVE WITH NYLON FABRIC INSERT

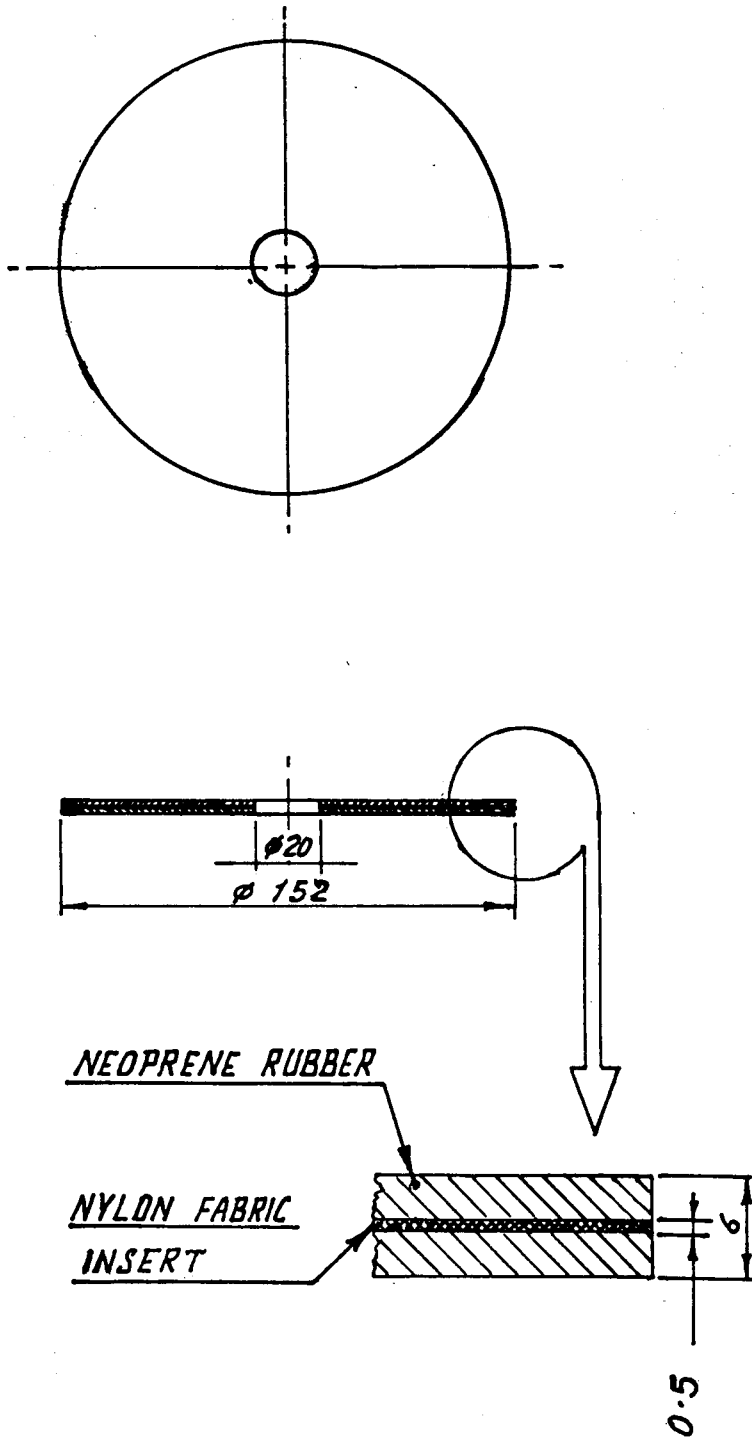

Fig. 16 Neoprene Valve with Nylon Fabric Insert

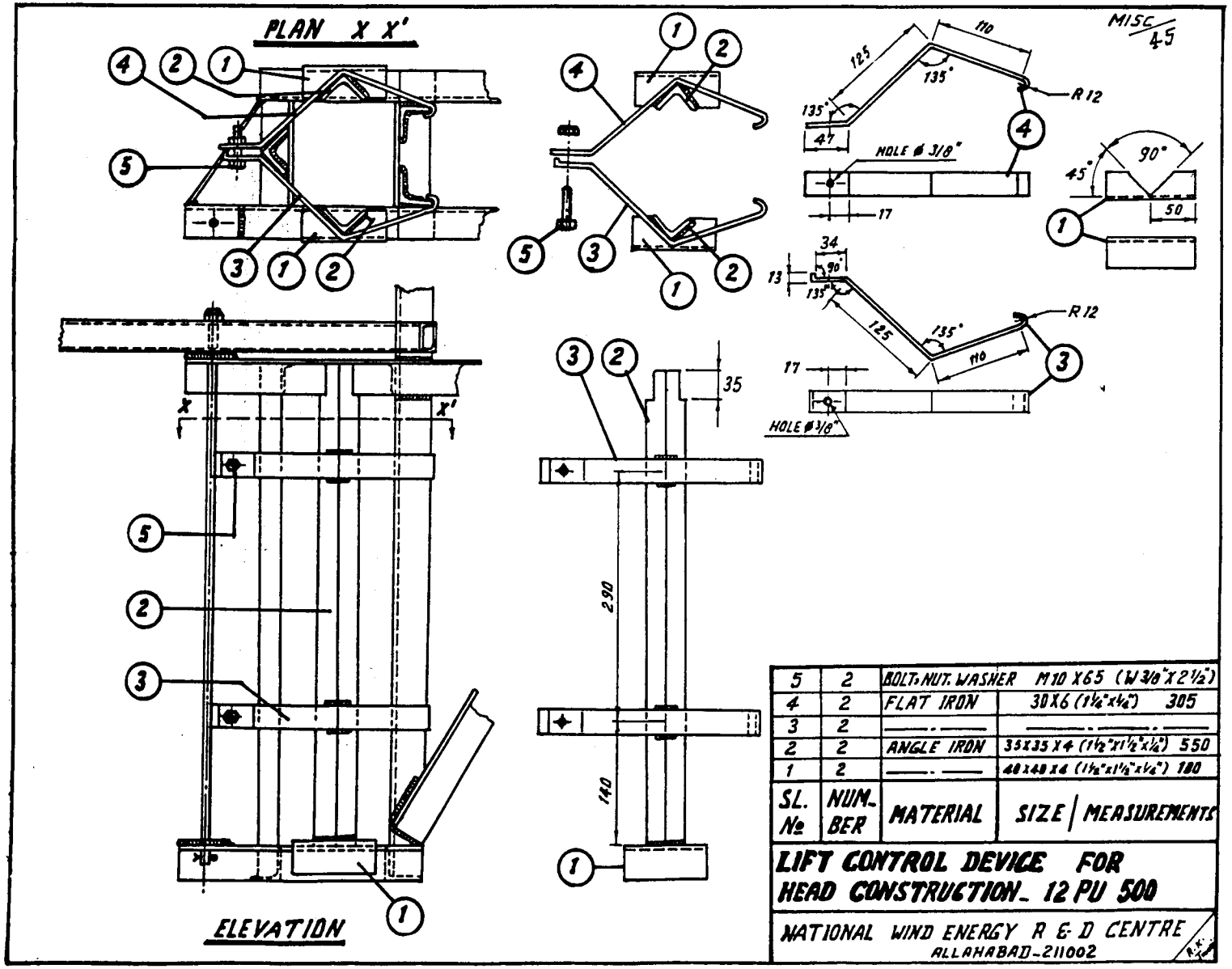
PLAN X X'
ELEVATION
MISC 45
HOLE ø 3/8"
R 12
125
110
135°
47
17
34
13
90°
45°
50
35
290
140
X
X'
5 2 BOLT, NUT, WASHER M10 X65 (W 3/8" X 2 1/2")
4 2 FLAT IRON 30X6 (1 1/2" x 1/4") 305
3 2
2 2 ANGLE IRON 35X35 X4 (1 1/2" x 1 1/2" x 1/4") 550
1 2 40X40 X4 (1 1/2" x 1 1/2" x 1/4") 180
SL. № NUM-BER MATERIAL SIZE / MEASUREMENTS
LIFT CONTROL DEVICE FOR HEAD CONSTRUCTION_ 12 PU 500
NATIONAL WIND ENERGY R & D CENTRE
ALLAHABAD-211002

Fig. 17

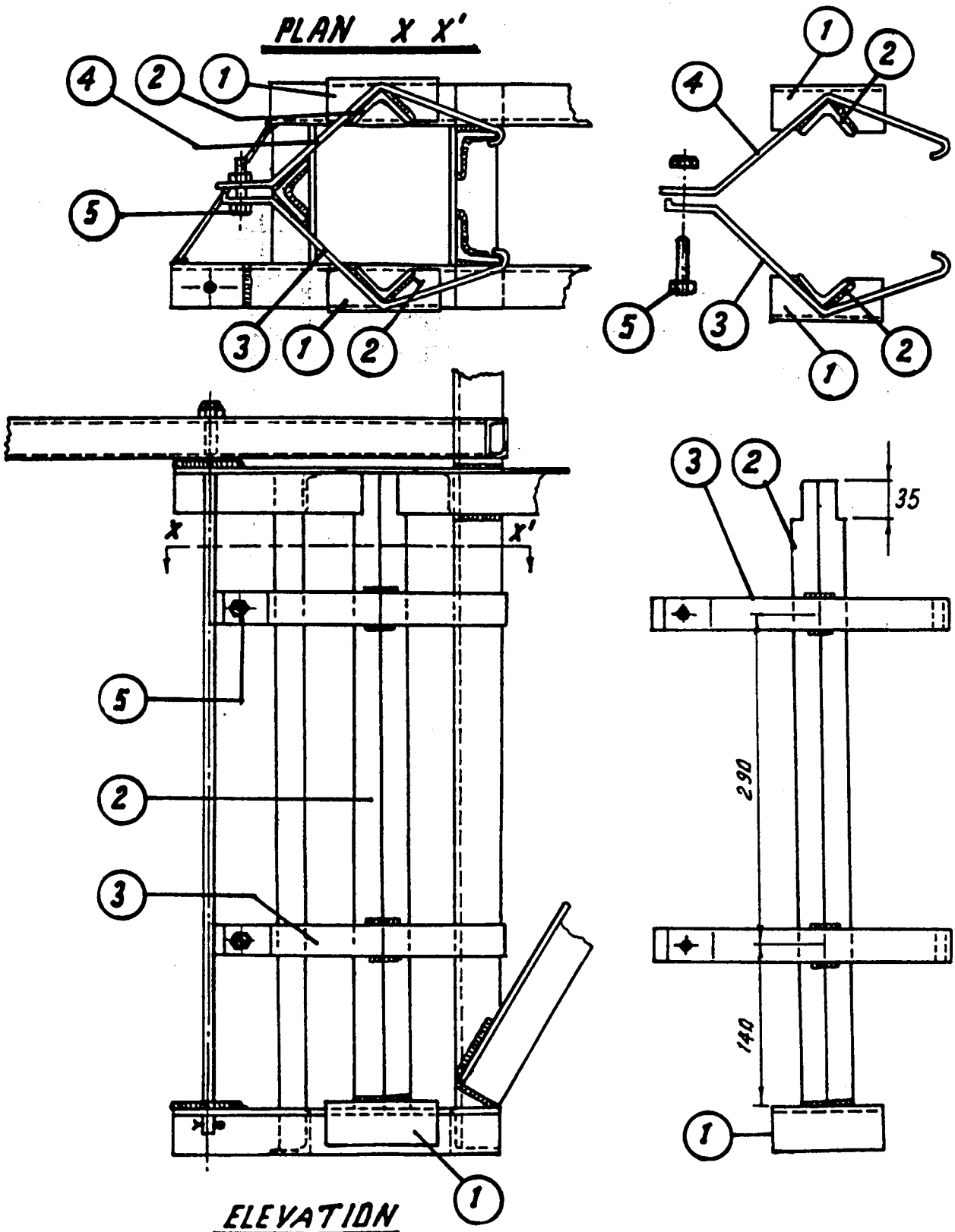
PLAN X X'
ELEVATION
X
X'
35
290
140
1
2
3
4
5

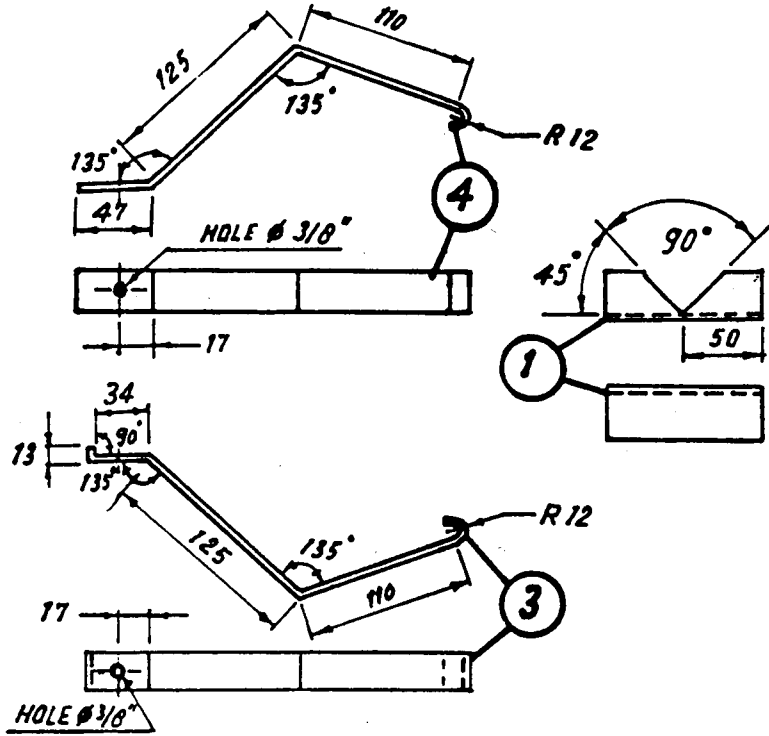
110
125
135°
135°
R 12
4
47
HOLE ø 3/8"
17
90°
45°
50
1
34
90°
13
135°
125
135°
R 12
110
3
17
HOLE ø 3/8"

10.6 WOODEN CROSS HEAD WITH STEEL REINFORCEMENT

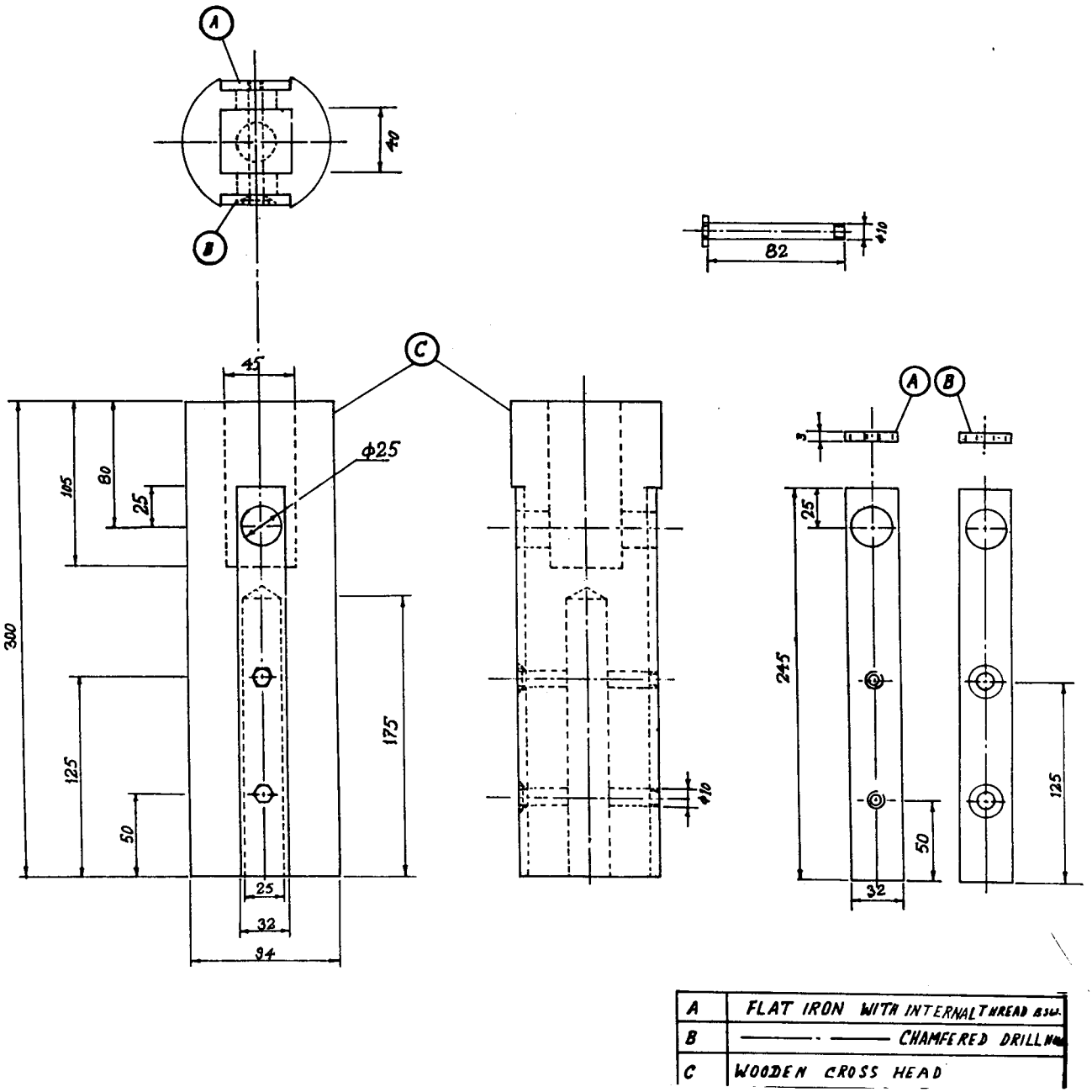

Fig. 23 Wooden Cross Head with Steel Reinforcement

11. MERITS OF THE NEW PUMP "A RECIPROCATING PUMP WITH C.I. CYLINDER"

NEW WINDMILL PUMP WITH CAST IRON CYLINDER:

(Special features over the old pump of Nick design).

(1) Volumetric efficiency is comparable. It is as high as 95.00 percent as compared to 69.00 percent of old pump of Nick design.

(2) Can be installed above the well, integrated with tower structure, so that pump axis coincides with the axis of the tower pipe thus eliminating the problem of misalignment which has hitherto being treated as difficult to achieve practically. This is because of the fact that the suction valve is all metallic (brass) and does not contain leather or rubber washers.

(3) Accurately machined and honed cylinder gives uniform bore and eliminates the ovality which is almost impracticable in the case of cylinders made out of M.S. pipes.

(4) Clearance between the bore and the piston has also been reduced to 0.1 mm uniformly. (The minimum achievable clearance in case of old pump of Nick design is 0.75 mm) with further decrease in clearance, the cylinder wall which is made of M.S. pipe, becomes too thin. The corrosion sets in the thin wall which leads to leakage within a short period.

The cylinder made of cast iron, ensures longer operational life and makes it rust resistant.

(5) Spherical suction valve makes it priming free provided, of course, the water is free from substances, like coarse grit, pebbles, floating leaves, twigs etc.

(6) Light in weight, fully galvanised pump body ensures corrosion and rust free service in adverse atmospheric conditions.

(7) Totally metallic suction valve assembly offers long life and trouble free service.

(8) Detachable suction valve of the pump makes the inspection of the suction valve and the piston of the pump easier and simplifies the replacement if necessary, unlike the old system where the complete heavy pump is to be taken out of the well for even petty repairs.

(9) Inspection and repairs can be further simplified because of convenience in installation of the pump above the well.

SL. No	No REQD.	MATERIAL NAME / SIZE / MEASUREMENTS	Wt. IN KG.
18	120	NYLOCK NUT, BOLT, WASHER, M6 X 25 (W 1/4" x 1")	
17	64	NUT, BOLT, WASHER, M10 X 25 (W 3/8" X 1")	
16	2	" " " M16 X 125 (W 5/8" x 5")	
15	4	" " " M16 X 100 (W 5/8" x 4")	
14	12	'I' BLADE SUPPORT M.S. SHEET 11 B.G. 2.80 MM. THICK	9.00
13	12	'O' BLADE SUPPORT " " " " " " "	5.04
12	12	ROTOR BLADE " " 16 B.G. 1.6 MM " "	90.00
11	2	INNER RING M.S. FLAT 30x5 3000	7.2
10	6	OUTER RING " " " " 2000	14.4
9	12	RING CLAMP " " 40x10 150	5.58
8	6	M.S. FLAT ———— 30x5 275	2.22
7	6	" " ———— " " 495	3.6
6	6	" " ———— 1880	13.56
5	6	ANGLE IRON ———— 40x40x5 1880	8.8
4	2	" " ———— 50x50x5 350	2.6
3	4	" " ———— " " 100	1.52
2	2	" " ———— " " 625	4.5
1	2	M. S. PLATE ———— φ 260 x 6	2.4

ROTOR-FOR-12 PU 500 WINDMILL

	DESIGNED BY	DRAWN BY	CHECKED BY	APPROVED BY	SCALE
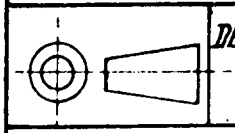		(R.K. Tiwari) TRD. - Man Singh.	PRATAP SINGH		N.T.S.

FOR INFORMATION

WIND ENERGY R-&-D CENTRE
I. E. R. T. ALLAHABAD-211002 INDIA

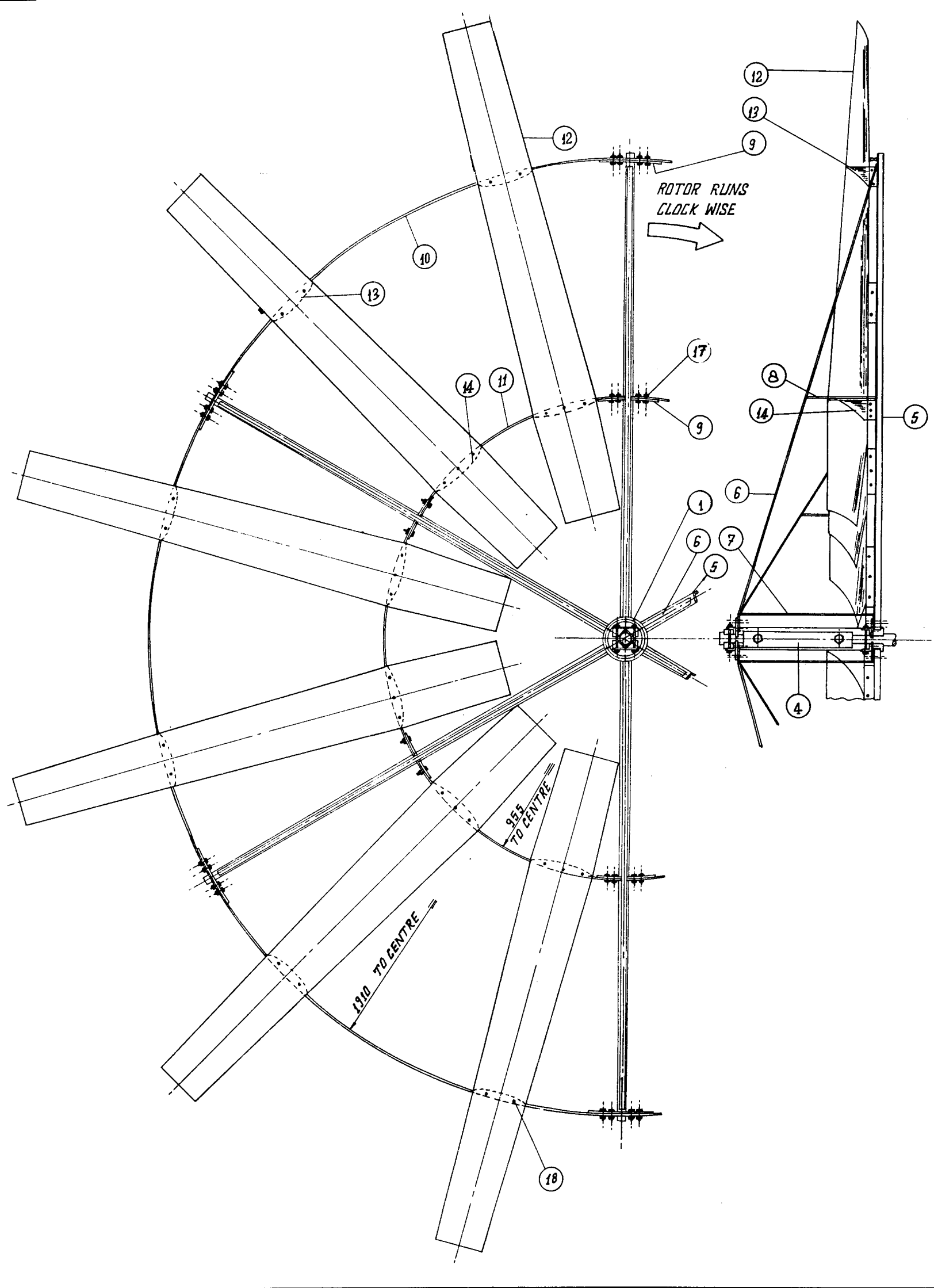
ROTOR RUNS
CLOCK WISE
955
TO CENTRE
1910 TO CENTRE
1
4
5
6
7
8
9
10
11
12
13
14
17
18

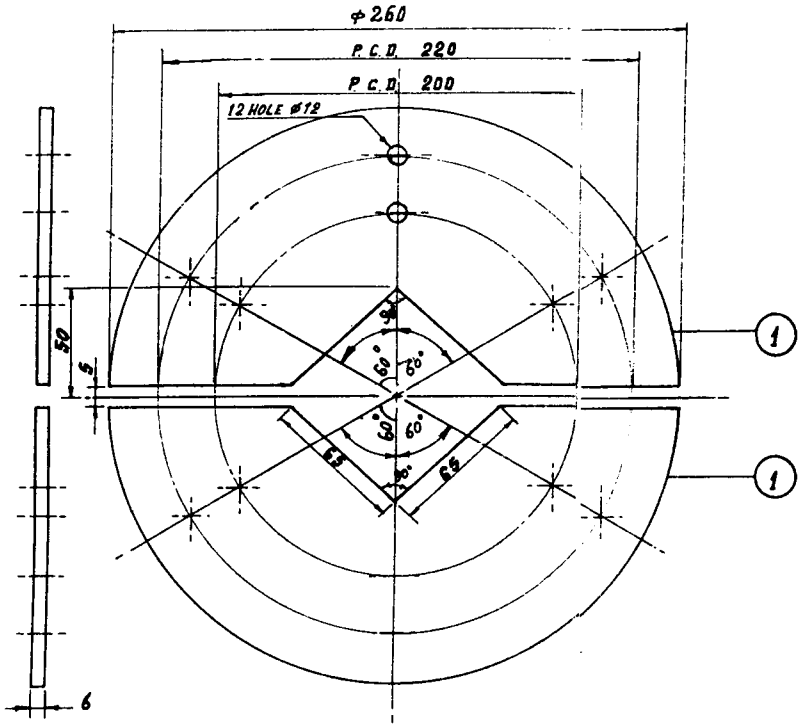

DETAIL ITEM No 1 (HUB PLATE)

DETAIL ITEM No 2 & 3 ROTOR (HUB)

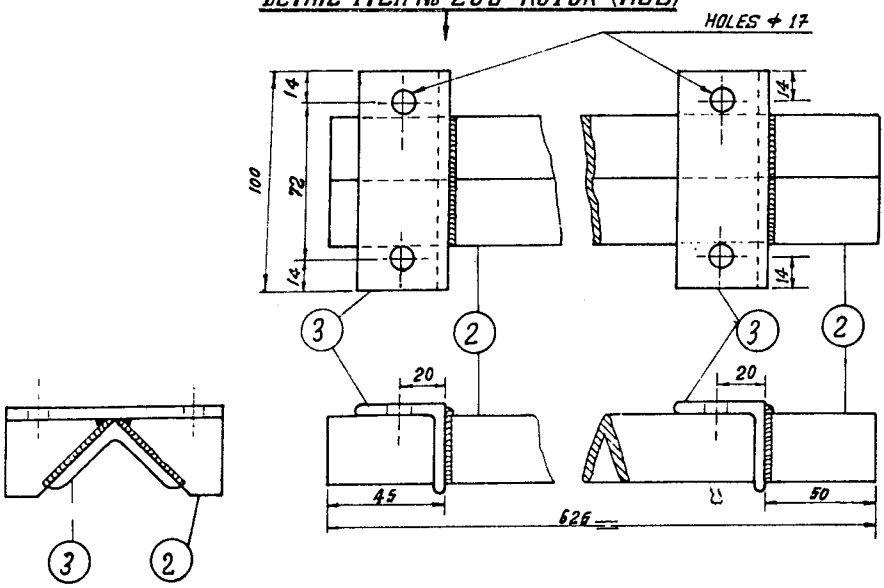

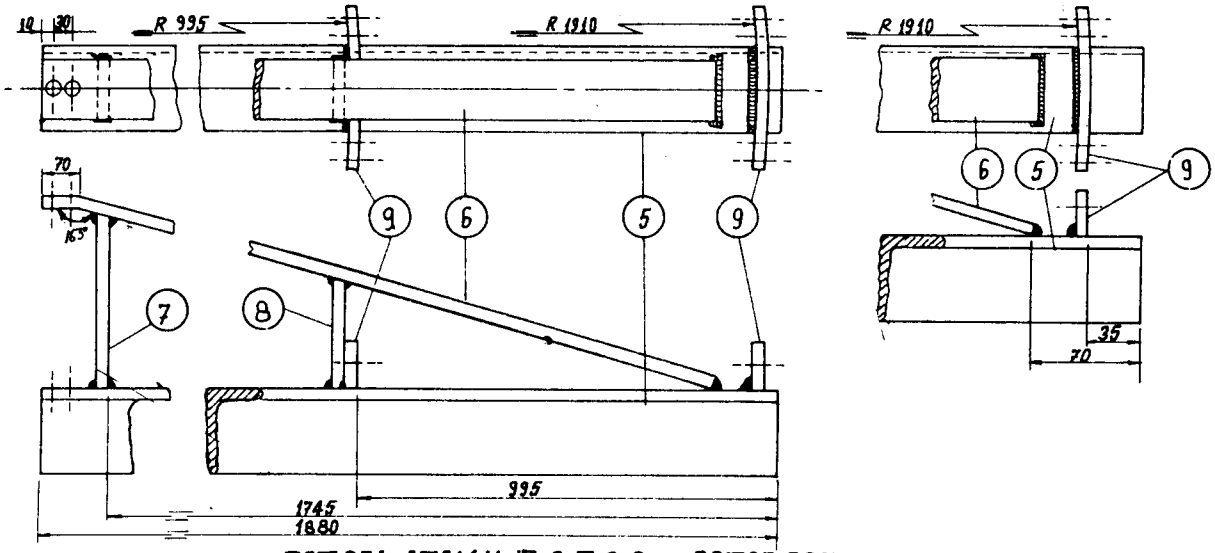

DETAIL ITEM No 5, 6, 7, 8, 9, ROTOR SPOKE

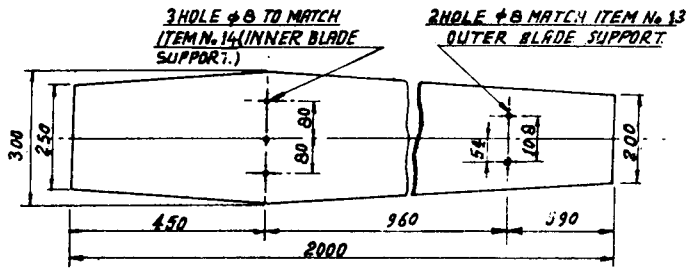

DETAIL ITEM No 12 (ROTOR BLADE)

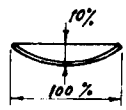

SHEET IS ROLLED IN A BENDING RADIUS OF APPR. 200 mm.

AFTER CUTTING THE RADIUS IS CORRECTED SO THAT 10% CURVED AIRFOILS WILL RESULT.

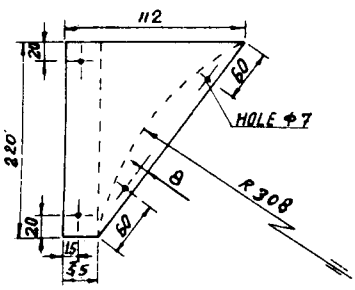

DETAIL ITEM No 13
OUTER BLADE SUPPORT

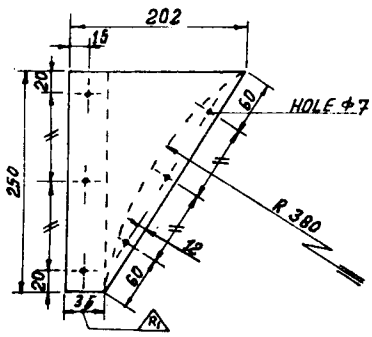

DETAIL ITEM No 14
INNER BLADE SUPPORT

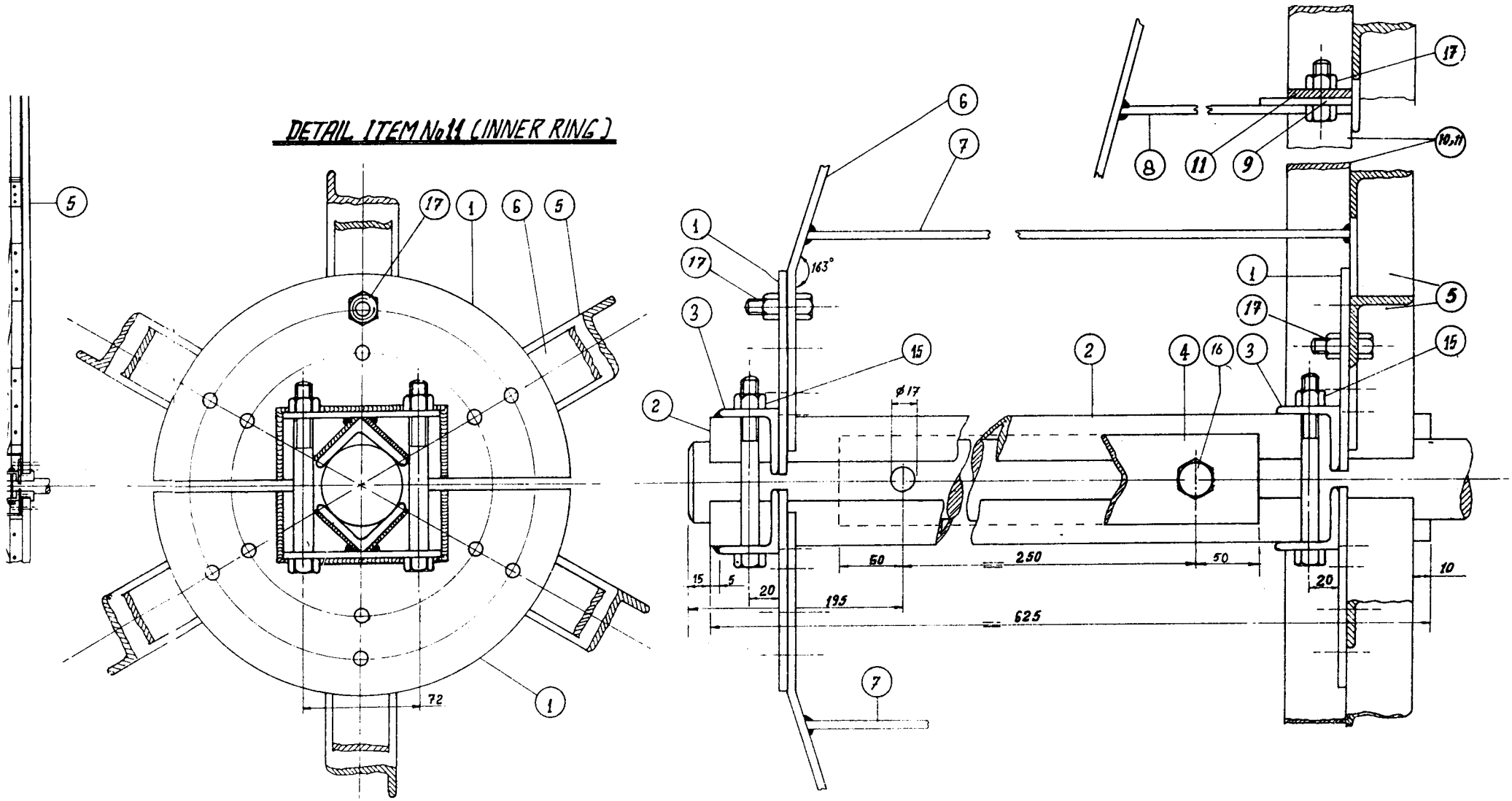
DETAIL ITEM No 11 (INNER RING)
5
17
1
6
5
72
1
6
7
1
17
163°
3
15
2
ø17
7
17
8
11
9
10,11
1
5
17
2
4
16
3
15
60
250
50
15
5
20
195
625
20
10

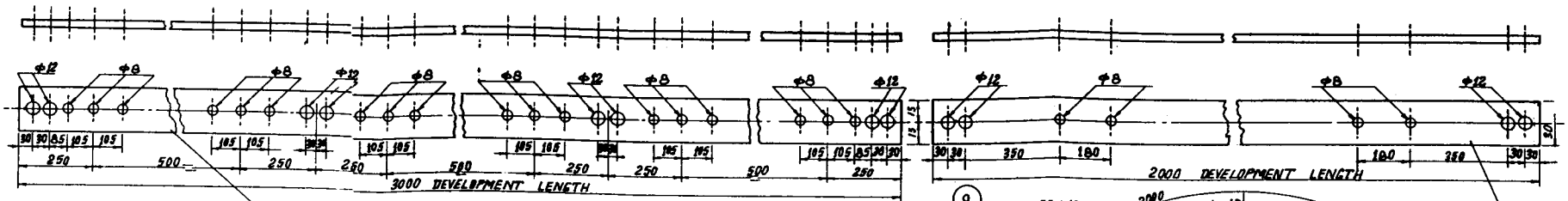

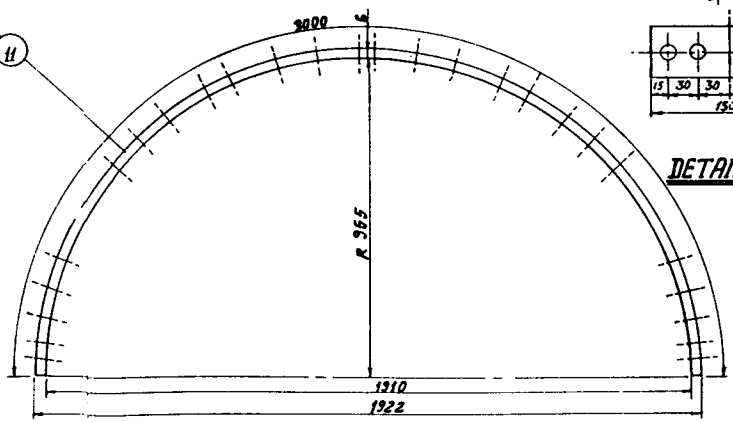

DETAIL ITEM No 11 (INNER RING)

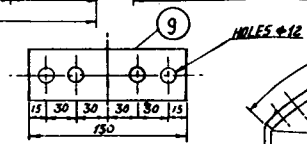

DETAIL ITEM No 9

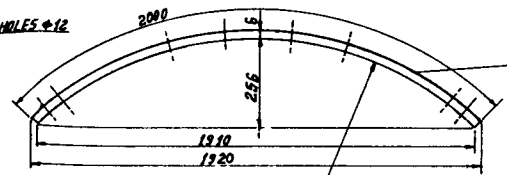

DETAIL ITEM No 10 (OUTER RING)

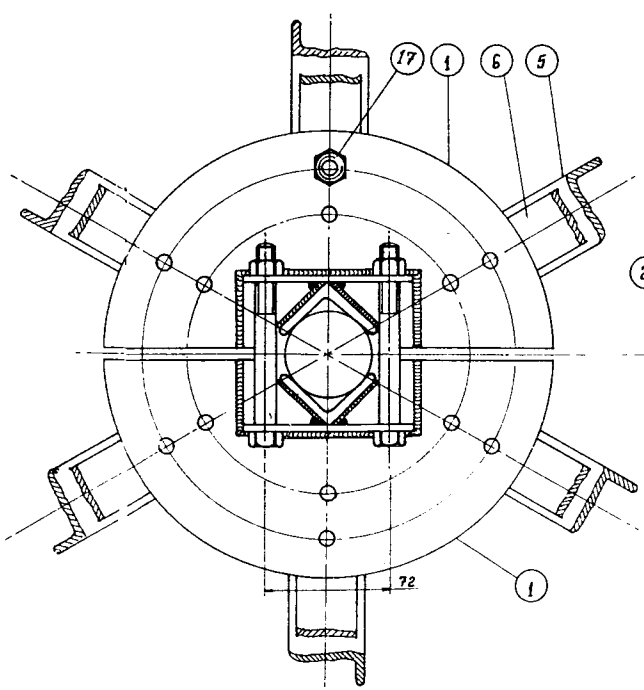

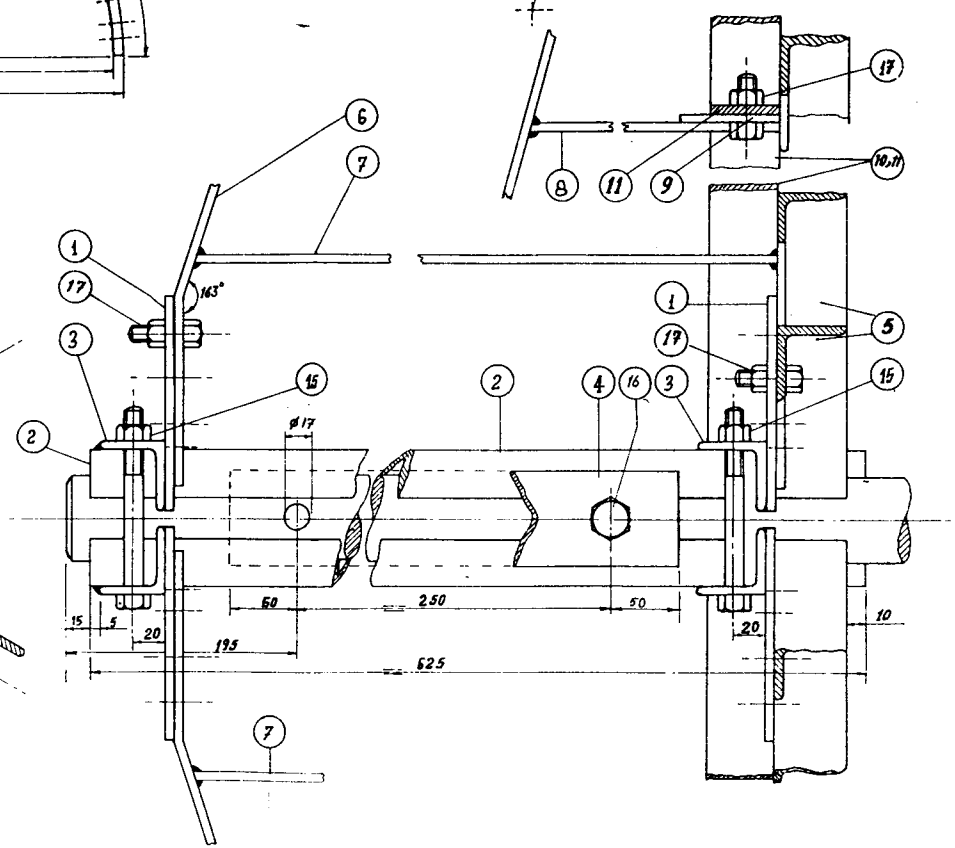

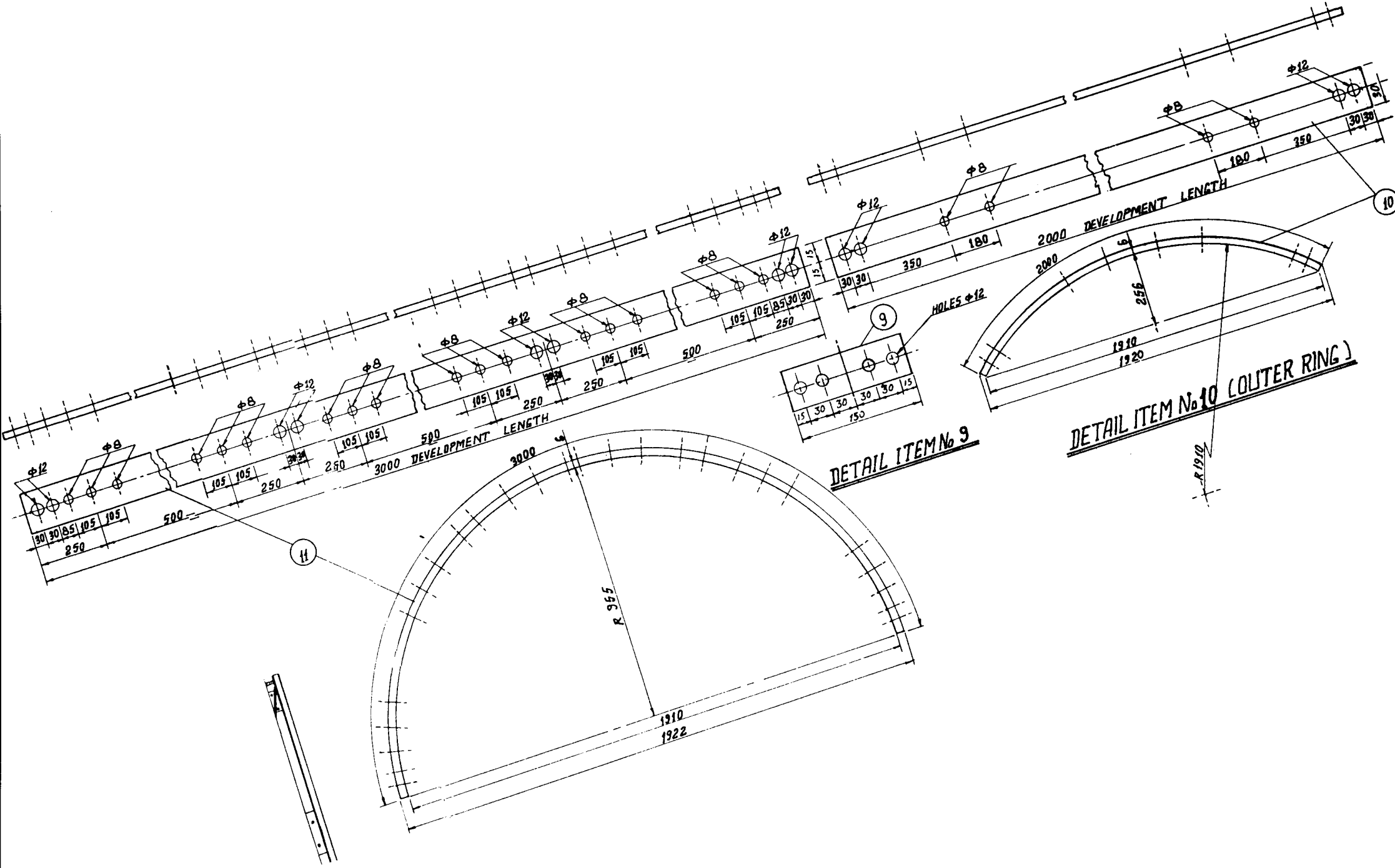
DETAIL ITEM No 9
HOLES Φ12
DETAIL ITEM No 10 (OUTER RING)
DEVELOPMENT LENGTH
3000 DEVELOPMENT LENGTH
2000 DEVELOPMENT LENGTH
R 955
R 1910
1910
1922
1910
1920
256
Φ8
Φ12
9
10
11

SL. No	No REQD	MATERIAL NAME / SIZE / MEASUREMENTS	REMARKS
17	52	NUT, BOLT, WASHER, M 12 x 40 (W ½" x 1½")	
16	4	M.S PLATE — 170 x 160 x 6	
15	4	FLATE IRON — 32 x 6 — 410	
14	1	TOWER PIPE — (4" N.B) B-GRADE — 2650	
13	1	P. V. C SLEVE PIPE — (4" BORE) — 710	
12	2	PLANK — 30 x 200 x 700	
11	2	FLATE IRON — 32 x 6 — 340	
10	2	" " — " " — 460	
9	2	" " — " " — 580	
8	2	ANGLE IRON — 35 x 35 x 5 — 660	
7	4	" " — 40 x 40 x 6 — 2000	
6	4	" " — 35 x 35 x 5 — 700	
5	4	" " — 50 x 50 x 6 — 250	
4	4	" " — 35 x 35 x 5 — 1400	
3	16	" " — " " " — 1940	
2	4	" " — 40 x 40 x 5 — 4500	
1	8	" " — 35 x 35 x 5 — 250	

TOWER-FOR 12 PU 500 WIND MILL

	DESIGNED BY	DRAWN BY	CHECKED BY	APPROVED BY	SCALE
		S.N. SRIJEEVAN SINGH	PRATAP SINGH		N.T.S.

FOR INFORMATION

WIND ENERGY R-&-D CENTRE
I.E.R.T. ALLAHABAD - 211002 INDIA.

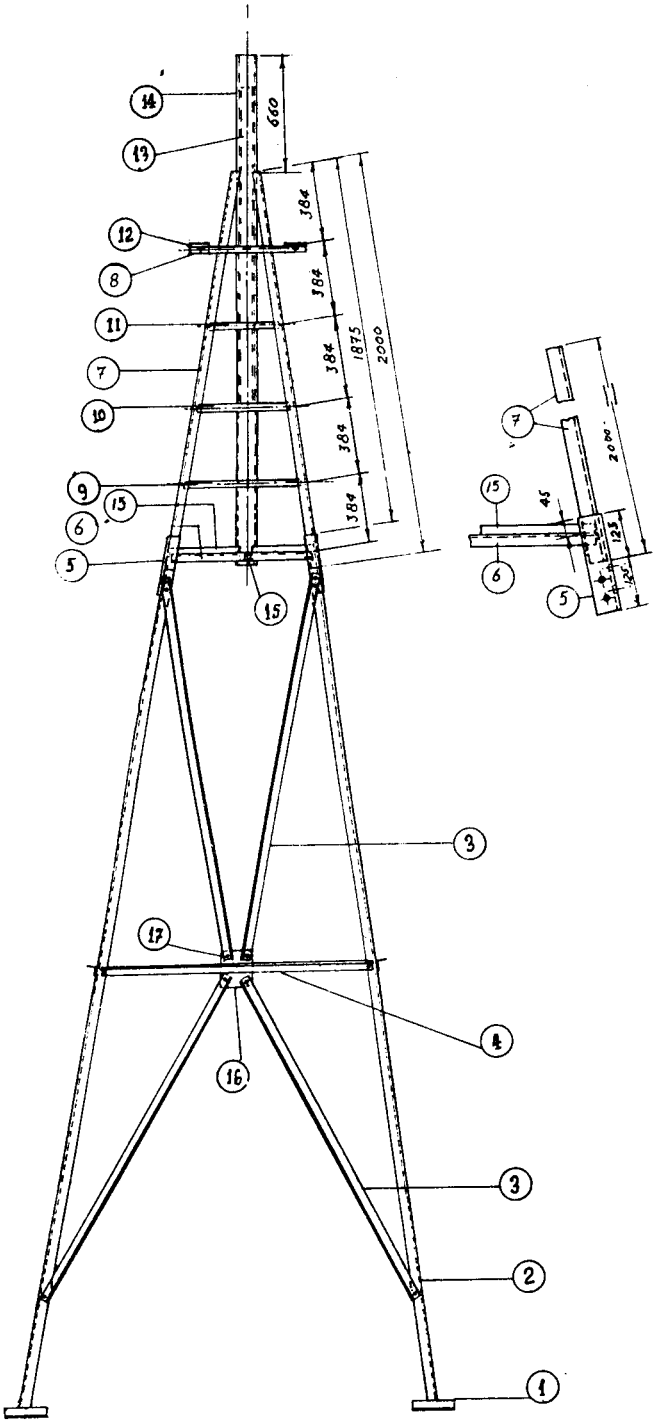
14
13
660
384
12
8
384
11
384
1875
2000
7
10
384
9
15
384
6
5
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16
3
2
1

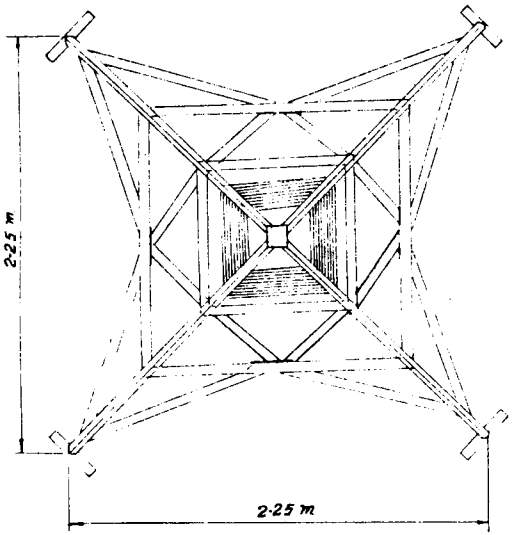

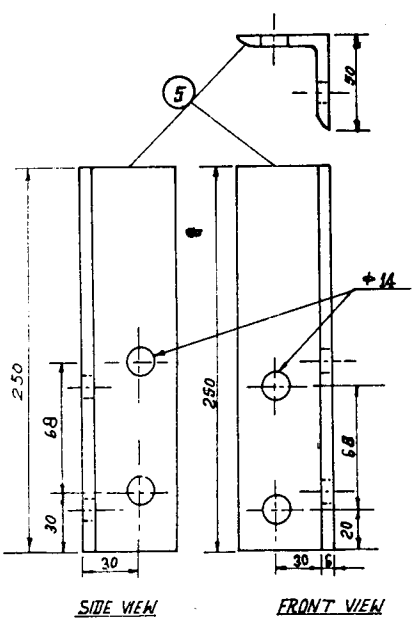

TOWER TOP & TOWER LEG JOINTER (OUTER)

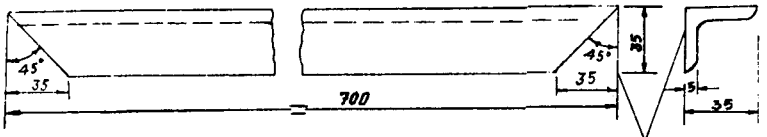

TOWER TOP BASE (HORIZONTAL)

6

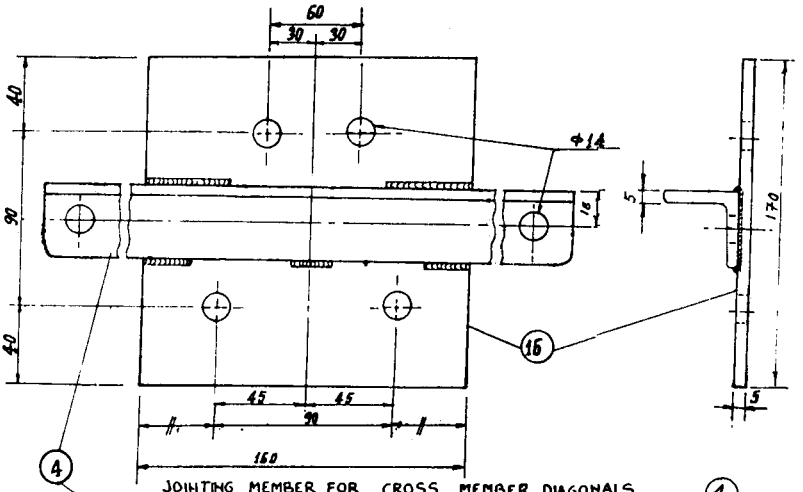

JOINTING MEMBER FOR CROSS MEMBER DIAGONALS

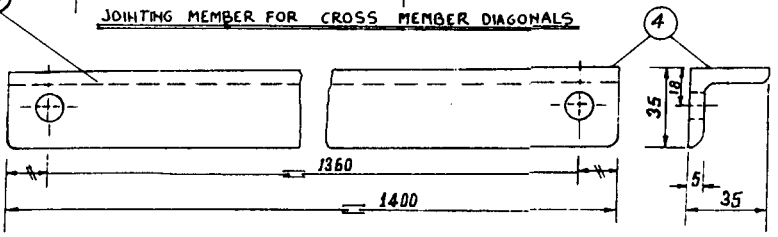

CROSS MEMBER FOR TOWER LEG

DETAIL ITEM No 4

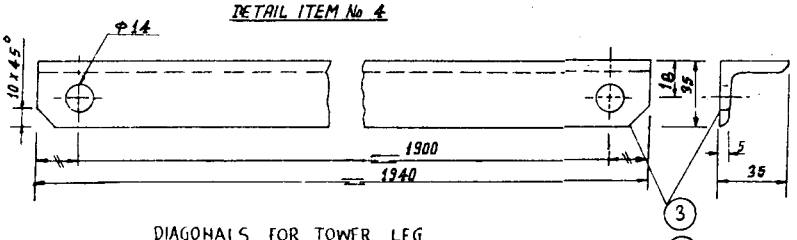

DIAGONALS FOR TOWER LEG

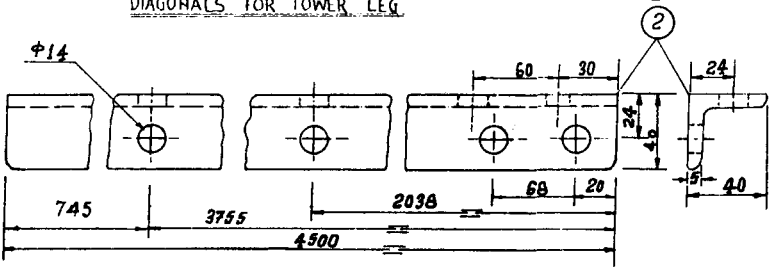

TOWER LEG

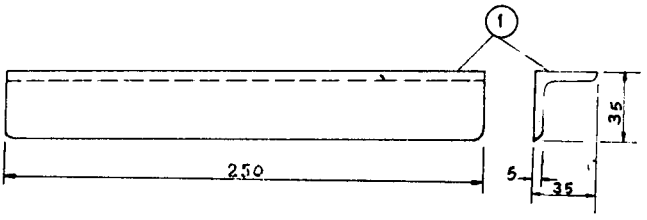

TOWER LEG FOUNDATION PIECE

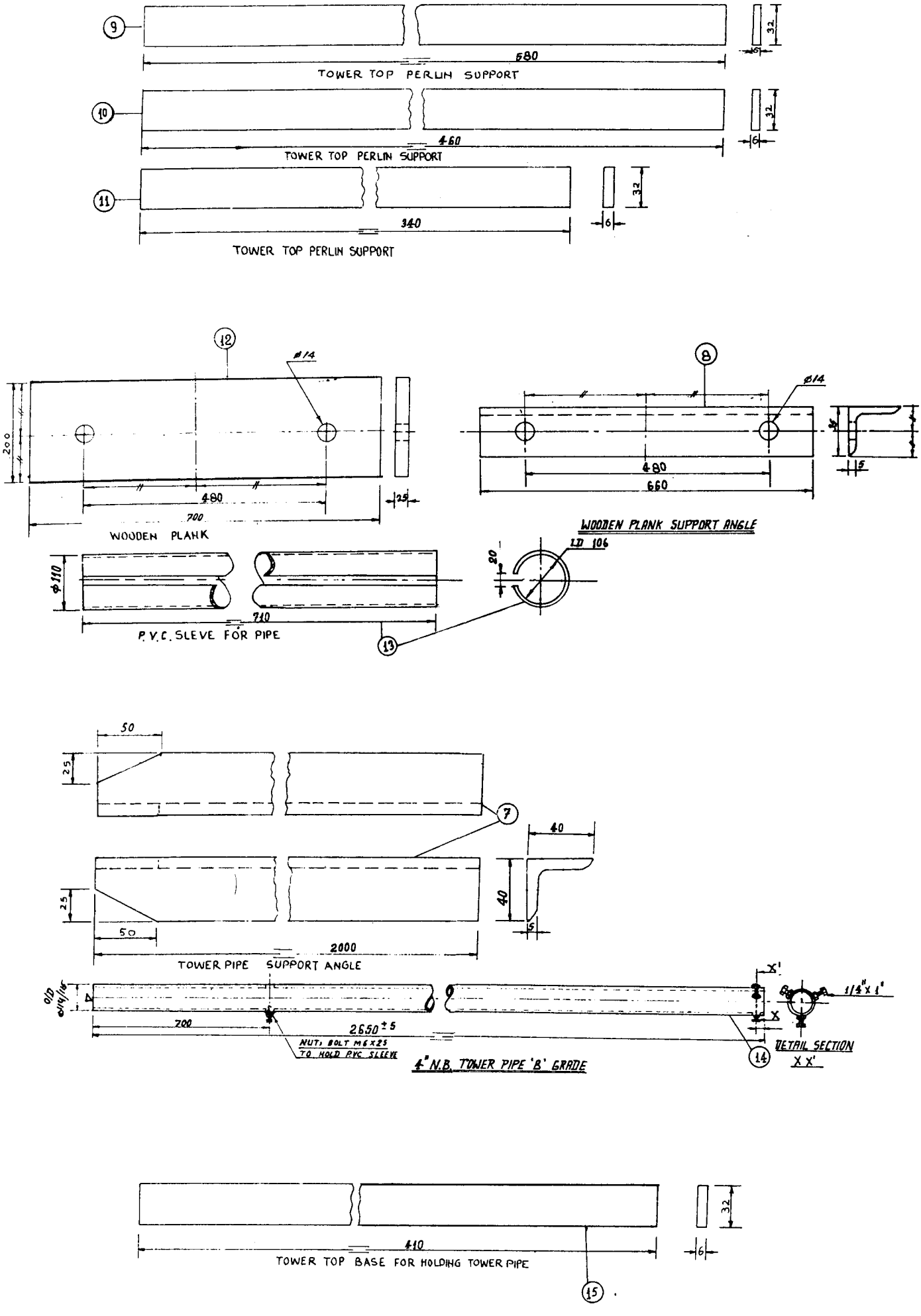
9
580
32
6
TOWER TOP PERLIN SUPPORT
10
460
32
6
TOWER TOP PERLIN SUPPORT
11
340
32
6
TOWER TOP PERLIN SUPPORT
12
ø14
200
480
700
25
WOODEN PLANK
8
ø14
480
660
36
15
WOODEN PLANK SUPPORT ANGLE
ø110
710
P.V.C. SLEVE FOR PIPE
20
ID 106
13
50
25
7
40
40
5
25
50
2000
TOWER PIPE SUPPORT ANGLE
OD 6 1/16
4
700
2650 ± 5
NUT, BOLT M6 X 25
TO HOLD PVC SLEEVE
4" N.B. TOWER PIPE 'B' GRADE
14
X'
X
1 1/4" x 1"
DETAIL SECTION
X X'
410
32
6
TOWER TOP BASE FOR HOLDING TOWER PIPE
15

SL. No	No REQD	MATERIAL NAME / SIZE / MEASUREMENTS	REMARKS
35	1	SPRING APP Φ 30 x 100 x Φ 4	
34	12	M.S. BOLT, NYLOCK NUT, WASHER M 6 X 25 (W ¼" x 1")	
33	1	M.S. BOLT, " " " M12 x 100 (W ½" x 4")	
32	1	M.S. BOLT, " " " M12 X 40 (W ½" x 1½")	
31	1	M.S NYLOCK NUT M22 (W 7/8")	
30	1	M.S. WASHER M 12 (W 1/2")	
29	1	M.S. ROD Φ 20 x 690	
28	1	HELP VANE 1 M.M SHEET 1000 x 500	
27	1	TAIL VANE 2000 x 1000	
26	1	RACHET FLAT IRON HARDEND 32 x 6 LENGTH — 480	
25	1	FLAT IRON 32 x 6 " — 900	
24	3	" " " " — 750	
23	1	" " " " — 830	
22	1	" " " " — 115.5	
21	1	" " " " — 130	
20	2	" " " " — 60	
19	2	" " (WEARING FLATE) " " — 115.5	
18	1	ANGLE IRON 40 x 40 x 5 — 1000	
17	1	" " " " — 45	
16	1	" " " " — 60	
15	1	" " " " — 125	
14	1	" " " " — 3000	
13	1	" " " " - 4000	
12	1	" " " " - 1500	
11	2	" " 65 x 65 x 6 — 250	
10	1	" " 40 x 40 x 5 — 500	
9	2	" " " " — 460	
8	2	" " " " — 540	
7	2	" " " " — 1110	
6	2	" " " " — 1000	
5	1	" " " " — 590	
4	2	" " " " — 555	
3	4	" " " " — 155.5	
2	1	" " " " — 280	
1	1	" " " " — 200	

HEADCONSTRUCTION-12PU500 - WINDMILL

DESIGNED - BY	DRAWN - BY	CHECKED - BY	APPROVED - BY	SCALE
	Trd. By - Mon Singh	PRATAP SINGH		N. T. S.

FOR INFORMATION

WIND ENERGY R-&-D CENTRE
I.E.R.T. ALLAHABAD - 211002-INDIA

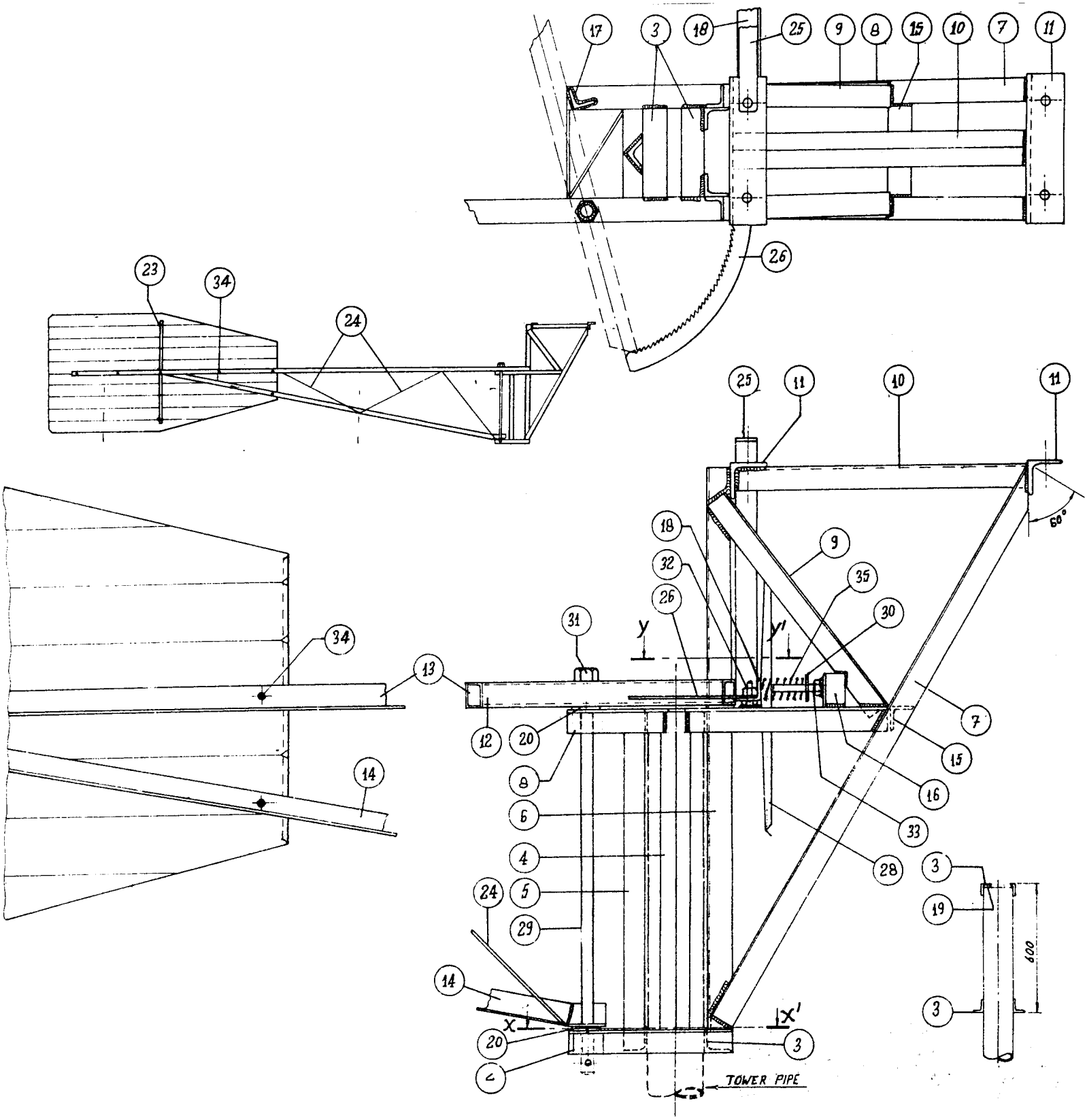
17
3
18
25
9
8
15
10
7
11
26
23
34
24
25
11
10
11
60°
18
9
32
35
26
30
31
y
y'
34
13
12
20
8
6
4
5
29
24
14
7
15
16
33
28
3
19
600
3
14
x
x'
20
3
2
TOWER PIPE

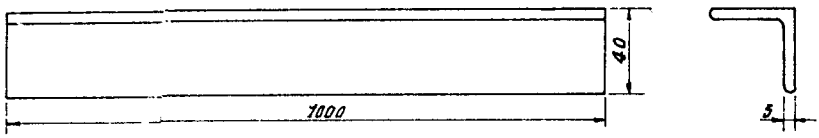

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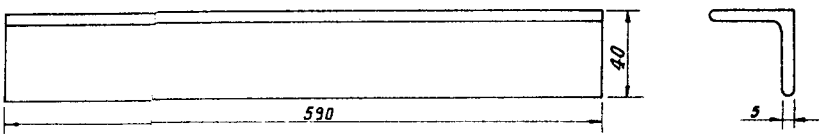

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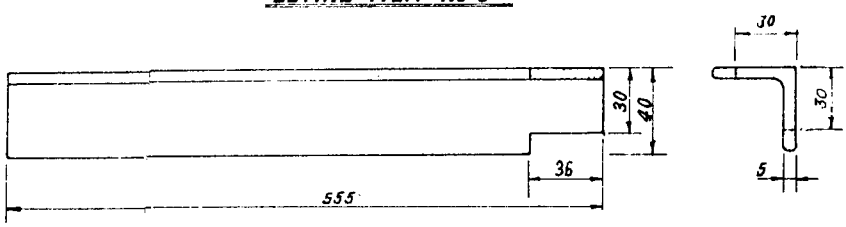

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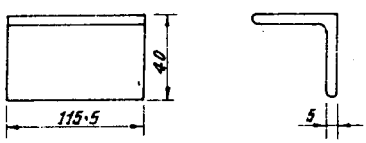

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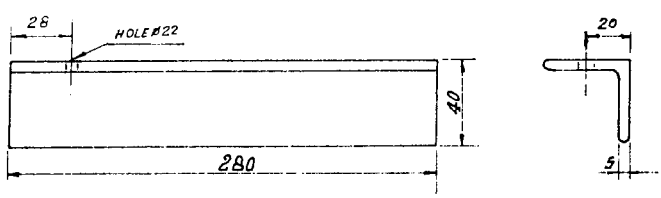

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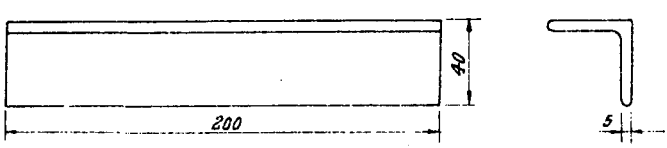

DETAIL ITEM No 1

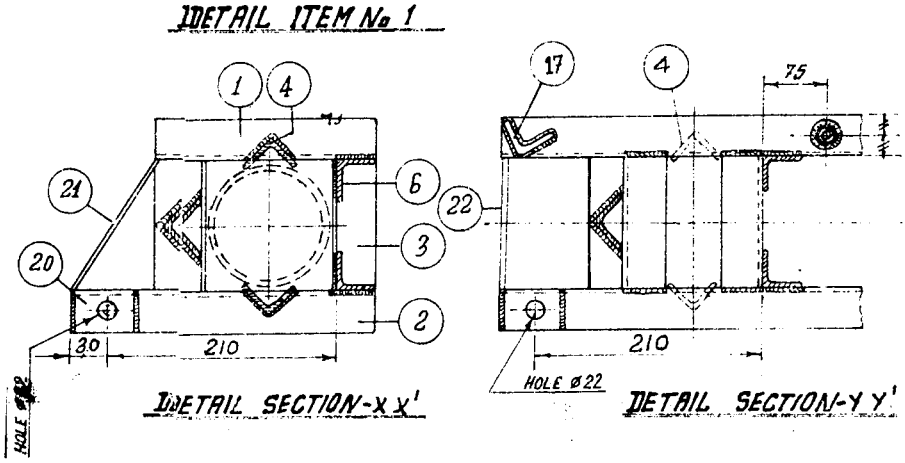

DETAIL SECTION-X X'

DETAIL SECTION-Y Y'

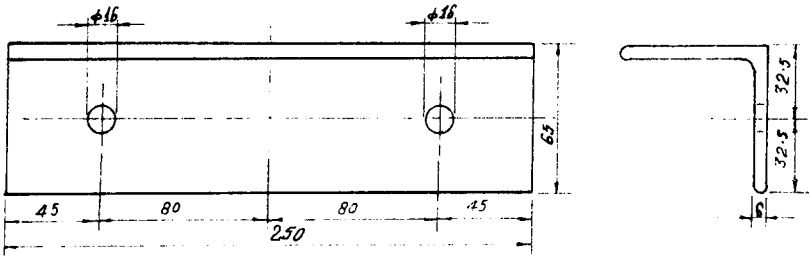

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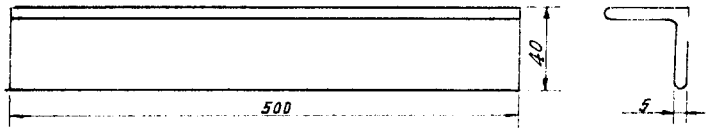

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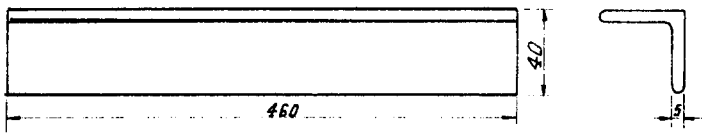

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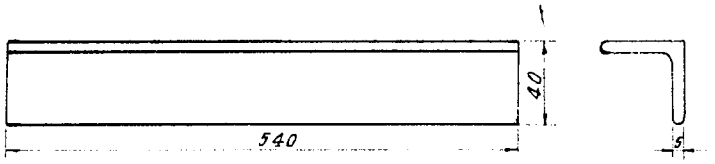

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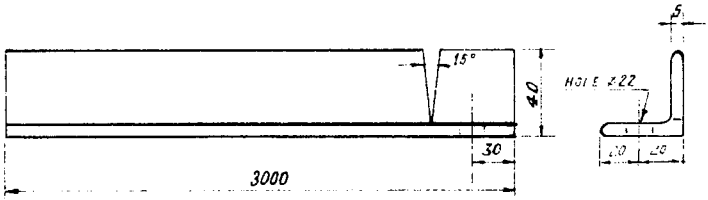

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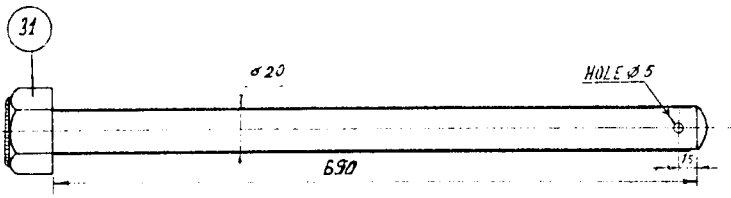

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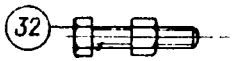

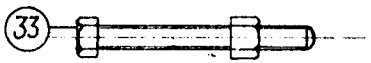

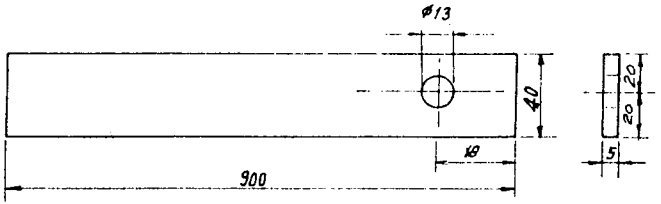

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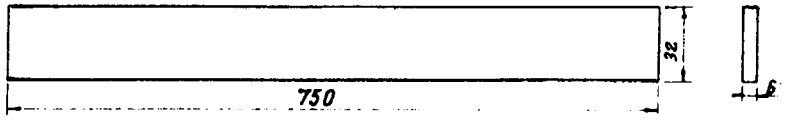

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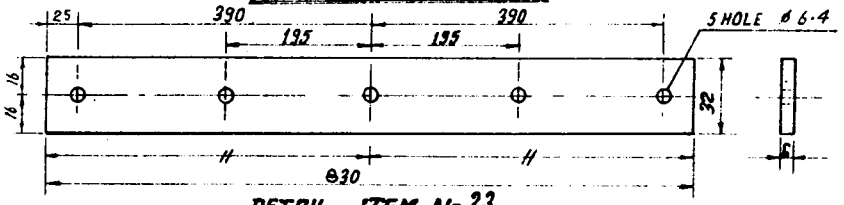

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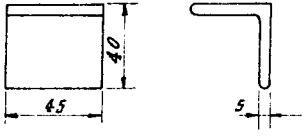

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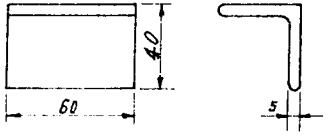

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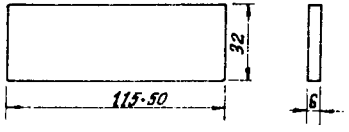

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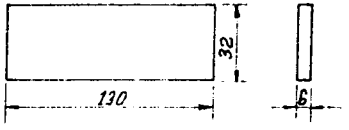

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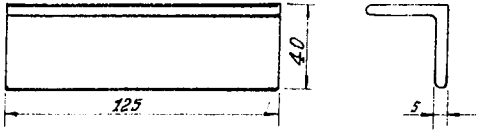

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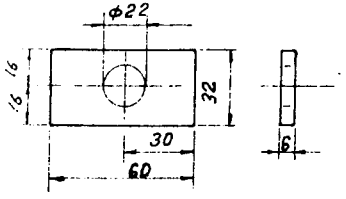

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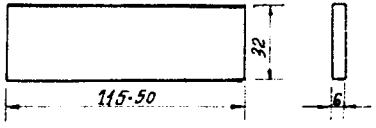

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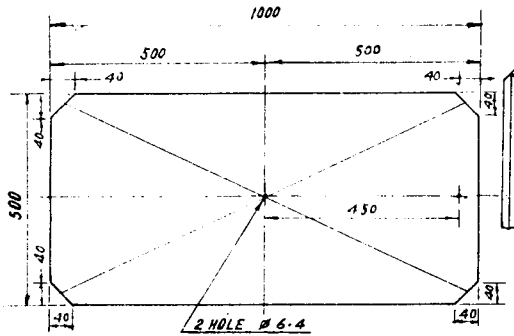

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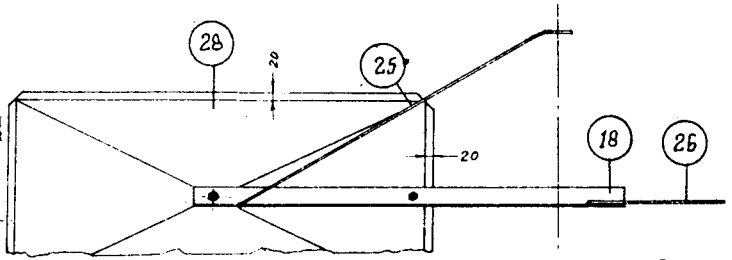

DETAIL ITEM No 18, 25, 26, & 28.

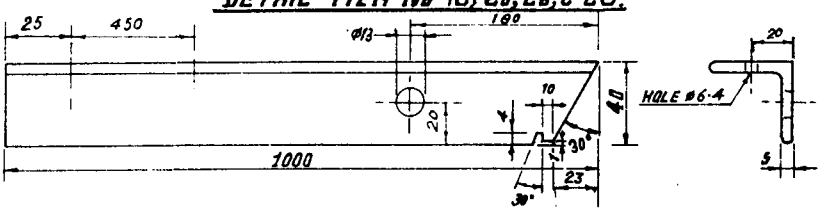

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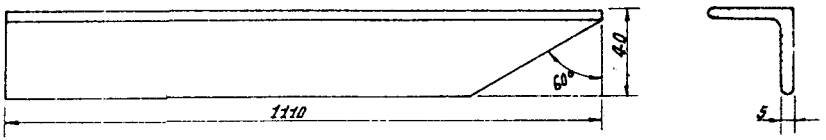

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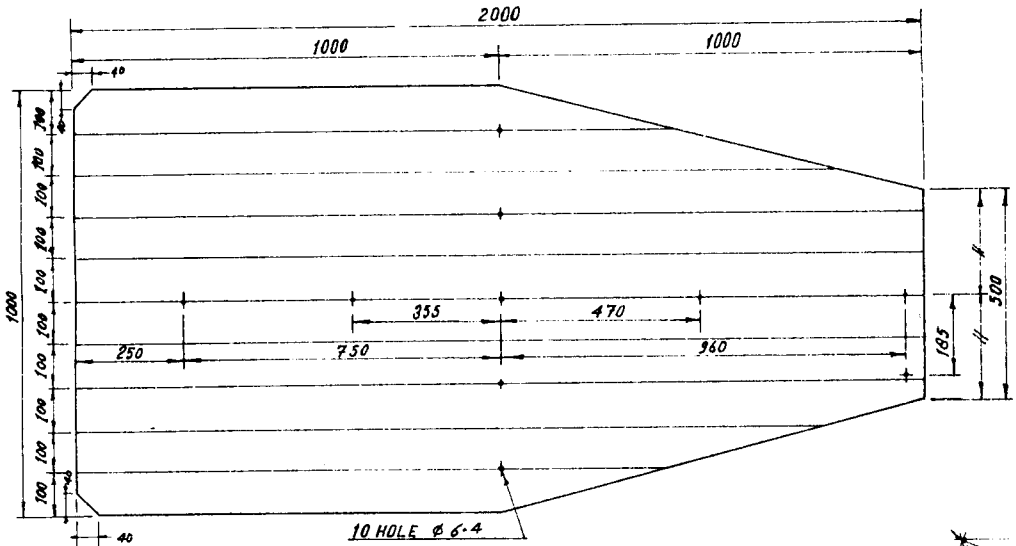

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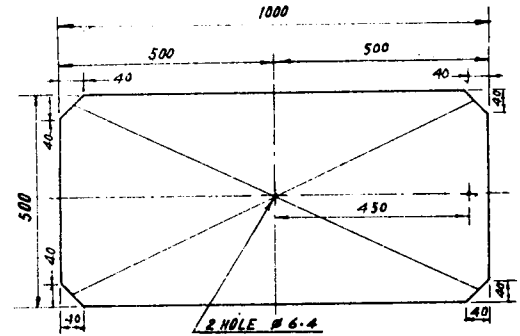

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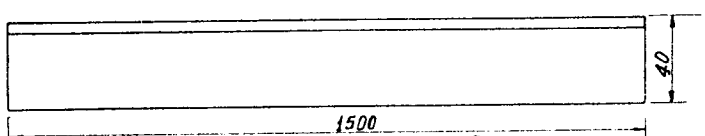

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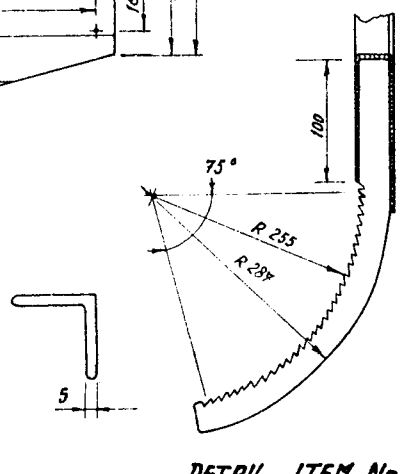

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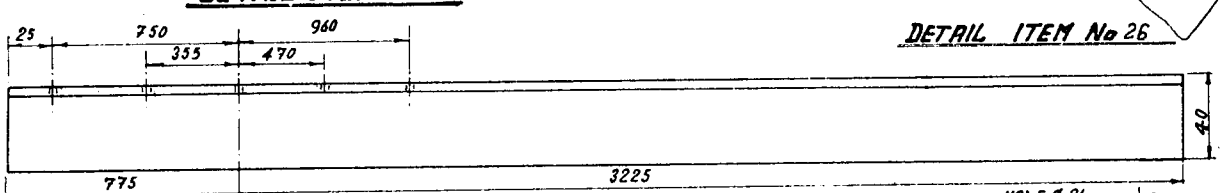

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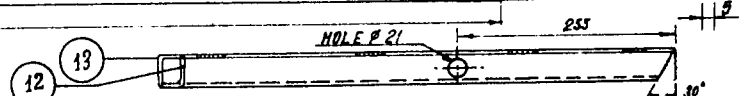

* LENGTH DEPEND UPON CIRCUMSTANCES.

SL No	N.REQD.	MATERIAL NAME / SIZE / MEASUREMENTS	REMARKS.
21	2	TEAK WOOD PUMP ROD GUIDE	
20	*	G.I. PIPE (G.S.T. MAKE) CLASS 'A'	
19	1	GREASE CUP	
18	1	FLAT IRON. 25x6 250	
17	2	" " " 135	
16	1	" " 40x10 165	
15	2	" " 15x6 300	
14	4	" " 30x6 50	
13	1	" " CONNECTING ROD:-30x6 650	
12	1	POLYPROPELENE CROSS HEAD.	
11	1	M.S. CROSS PIN. φ25 92	
10	2	M.S. BOLT, NUT, WASHER M10x100 (W 3/8"x4")	
9	4	M.S. BOLT, NUT, WASHER. M12x50 (W 1/2"x2)	
8	1	M.S. NUT. M20 (W 3/4")	
7	1	M.S. CRANK BOLT (G.K.W MAKE):-M20x75 (W 3/4"x3")	
6	1	M.S. WASHER φ20xφ40x3mm	
5	1	M.S. BUSH φ20xφ40x44	
4	4	NYLON BUSH (MOULDED) φ25xφ38x18	
3	2	M.S. BUSH φ33xφ43x33	
2	2	PILLOW BLOCK (BEARING) φ50 (FYH & NTN P 210J 50mm ±0.01 BORE	
1	1	M.S. MAIN SHAFT φ50x1300	

MOVINGPARTS OF 12 PU 500 WINDMILL

DESIGNED BY	DRAWN BY	CHECKED BY	APPROVED BY	SCALE
	TRD. BY	PRATAP SINGH		N.T.S.

FOR INFORMATION

WIND ENERGY R.&D CENTRE
INSSTT. OF ENGINEERING AND RURAL TECHNOLOY
ALLAHABAD - 211002

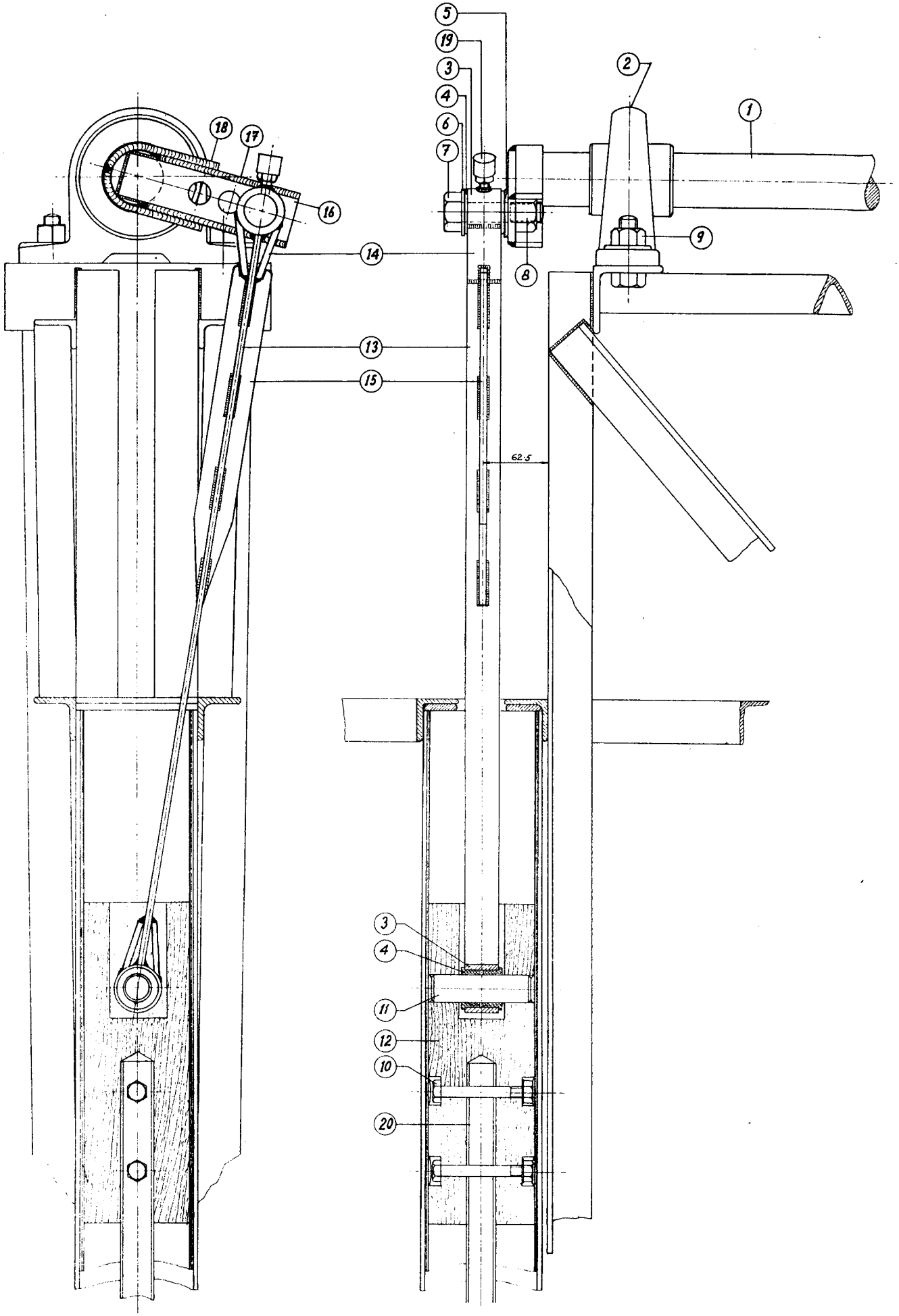
5
19
3
4
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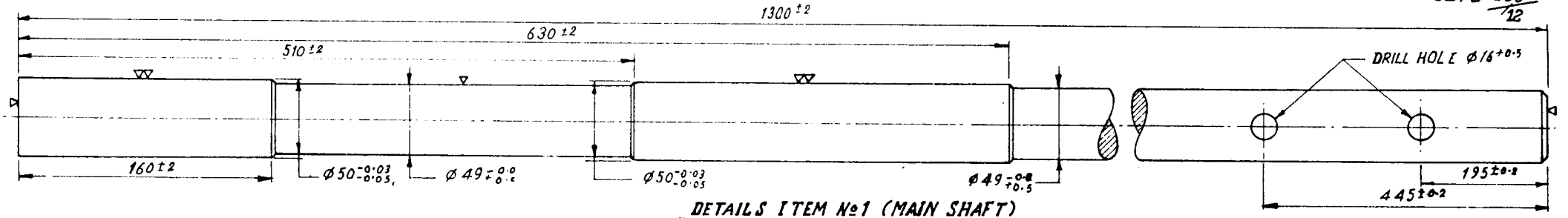

DETAILS ITEM №1 (MAIN SHAFT)

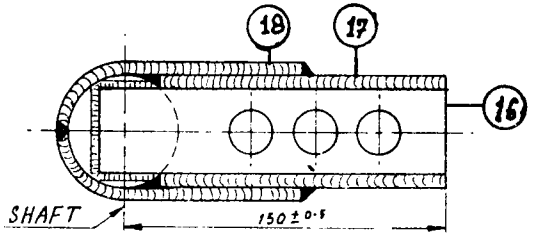

SIDE VIEW

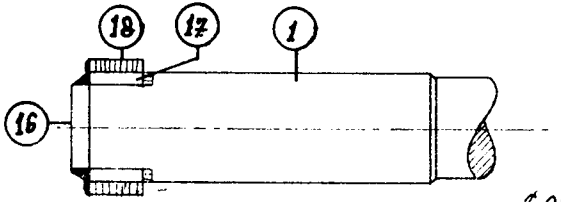

FRONT VIEW

(CRANK) DETAILS ITEM № 16, 17 & 18 WITH SHAFT ASSY. (WELDING)

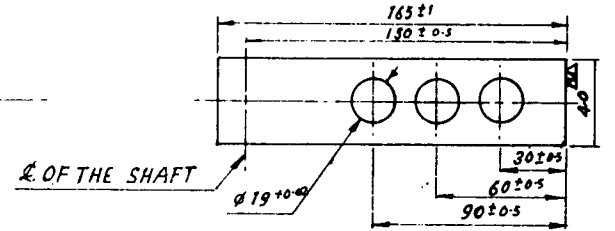

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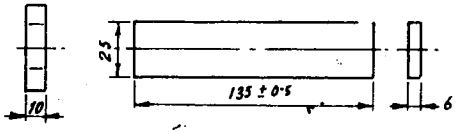

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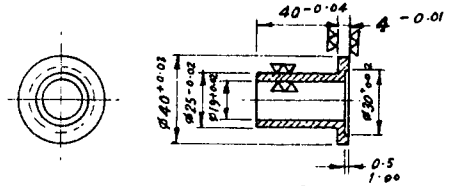

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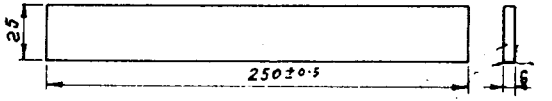

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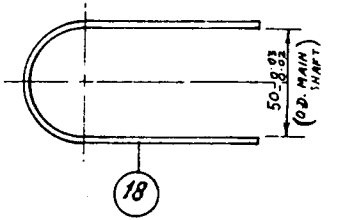

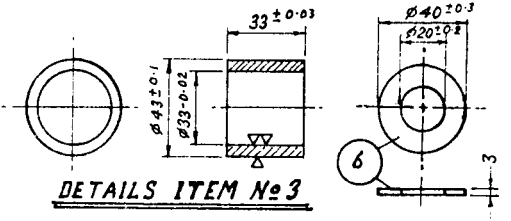

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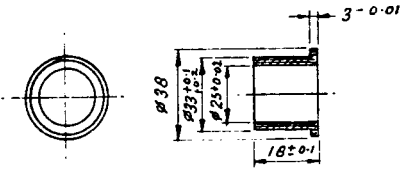

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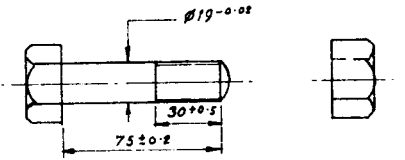

DETAILS ITEM № 7, 8

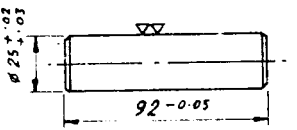

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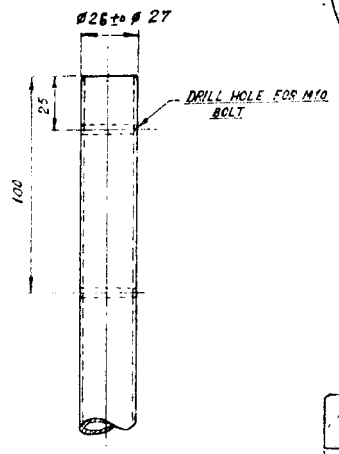

PUMPROD & PISTON ROD

ITEM № 20

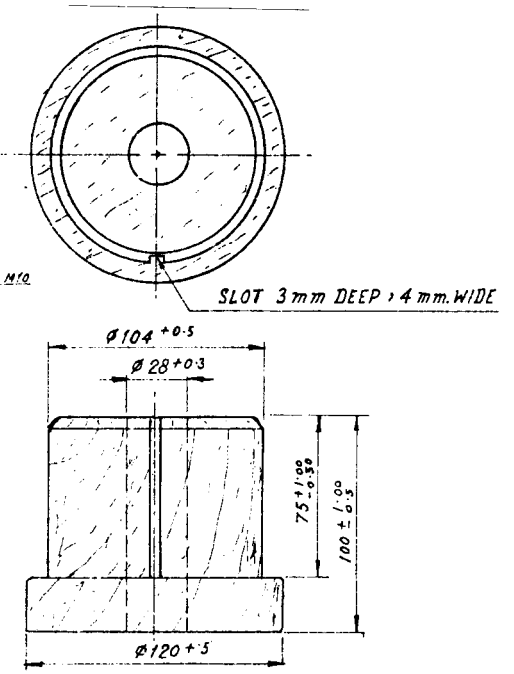

PUMPROD WOODEN GUIDE

(SL. № 42 ON 12 PU 500 PUMP DESIGN)

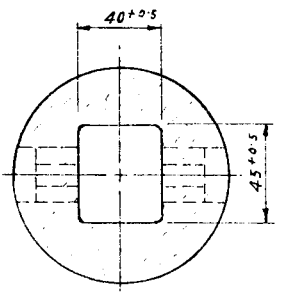

TOP VIEW

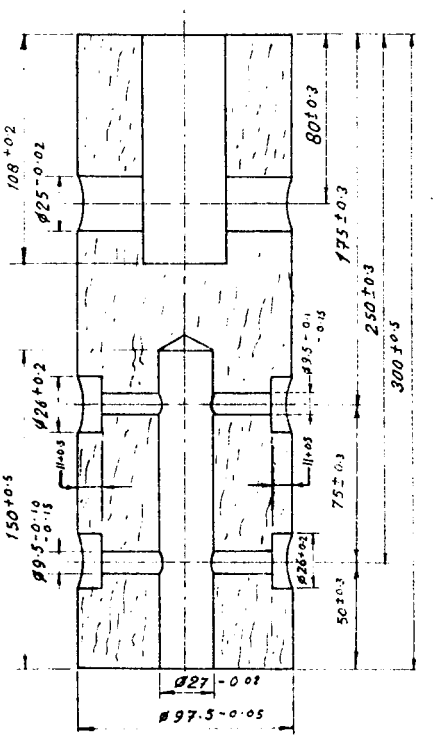

SECTIONAL FRONT VIEW

(CROSSHEAD). DETAILS ITEM № 12

NOTE :—

* MARKED THUS INDICATES THAT LENGTH OR QUANTITY WILL VARY ACCORDING TO CIRCUMSTANCES

SL.No	No.REQD	MATERIAL NAME / SIZE / MEASUREMENTS / REMARKS
36	1	TEAK WOOD / POLYPROPELENE — TEAK WOOD — 5"X5"X4"
35	2	CLAMP ROD ø12 (1/2")X370 mm.
34	1	BOLT, NUT, WASHER M12 X 20 (W 1/2" X 3/4")
33	4	BOLT, NUT, WASHER M12 X 125 (W 1/2" X 5")
32	*	SPRING WASHERS M24 (W 7/8")
31	*	NUTS M24 (W 7/8")
30	*	THREADED STUD M24 X 100 (W 7/8" X 4")
29	1	THREADED STUD M24 X 125 (W 7/8" X 5")
28	*	GUN METAL BUSH ø 33 X 30 mm.
27	*	STEEL BUSH ø 43 X 33 mm.
26	1	PISTON TEAK WOOD / POLYPROPELENE
25	1	GASKET NITRILE RUBBER / SOLE LEATHER ø290 X 6 mm
24	2	VALVE ø 150 X 6
23	1	RING ROD ø 8 (3/8") — 870 mm.
22	8	FILLING PIECE ROD ø 8 (3/8") — 40 mm.
21	2	ANGLE IRON 40 X 40 X 4 (1 1/2" X 1 1/2") — *
20	3	FLAT IRON 30 X 6 (1 1/4" X 1/4")
19	*	" " " " — 700 mm.
18	1	" " " " — 450 mm.
17	1	" " " " — 180 mm.
16	4	" " " " — 60 mm.
15	12	" " " " — 85 mm.
14	1	FOOT VALVE 3mm. SHEET ø170 mm.
13	2	CASING 500 X 900 mm.
12	1	CASING FLANGE ø 290 mm.
11	2	CASING FLANGE ø 290 mm.
10	1	CYLINDER SEAMLESS 6" GAS PIPE — 460 mm.
9	1	DELIVERY PIPE 4" " " — 560 mm.
8	*	SOCKET FOR 4" " "
7	1	T- SOCKET " " " "
6	*	DELIVERY PIPE 4" " " — *
5	1	EXHAUST PIPE 4" " " — *
4	1	TOP PIPE 4" " " — 750 mm.
3	4	PIPE 5/8" " " — 100 mm.
2	1	PUMP ROD 3/4" " " — 900 mm.
1	*	PUMP ROD EXTENSION 3/4" " " — *

PISTON PUMP FOR 12 PU 500 WIND MILL

DRN. BY	TRD. BY	CHD. BY	APPVD. BY	SCALE
Tiwari (R. K. Tiwari)	Tiwari (R.K. Tiwari)			NTS

FOR INFORMATION

WIND ENERGY R. & D. CENTRE
I.E.R.T. ALLAHABAD - 211002 - INDIA

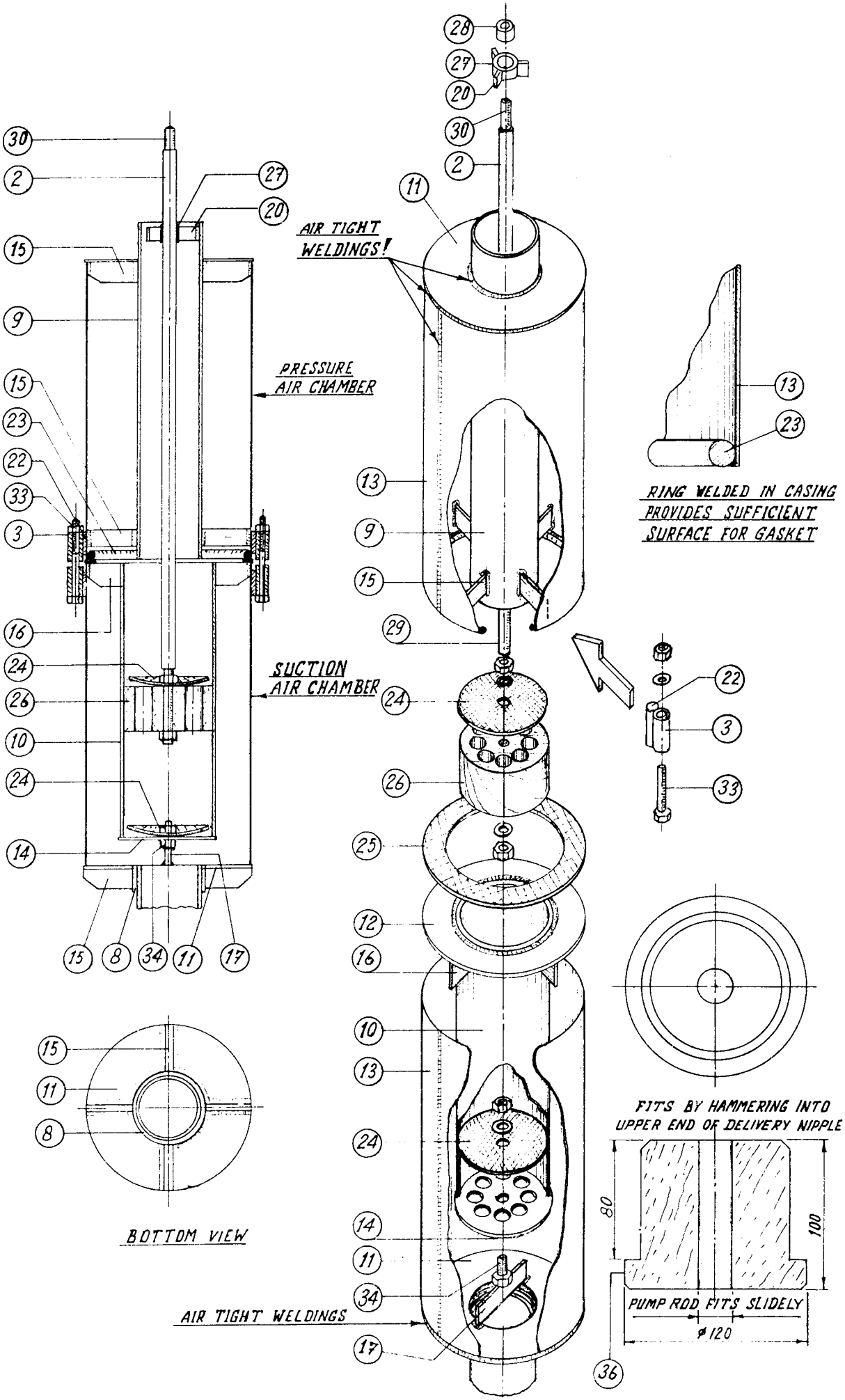
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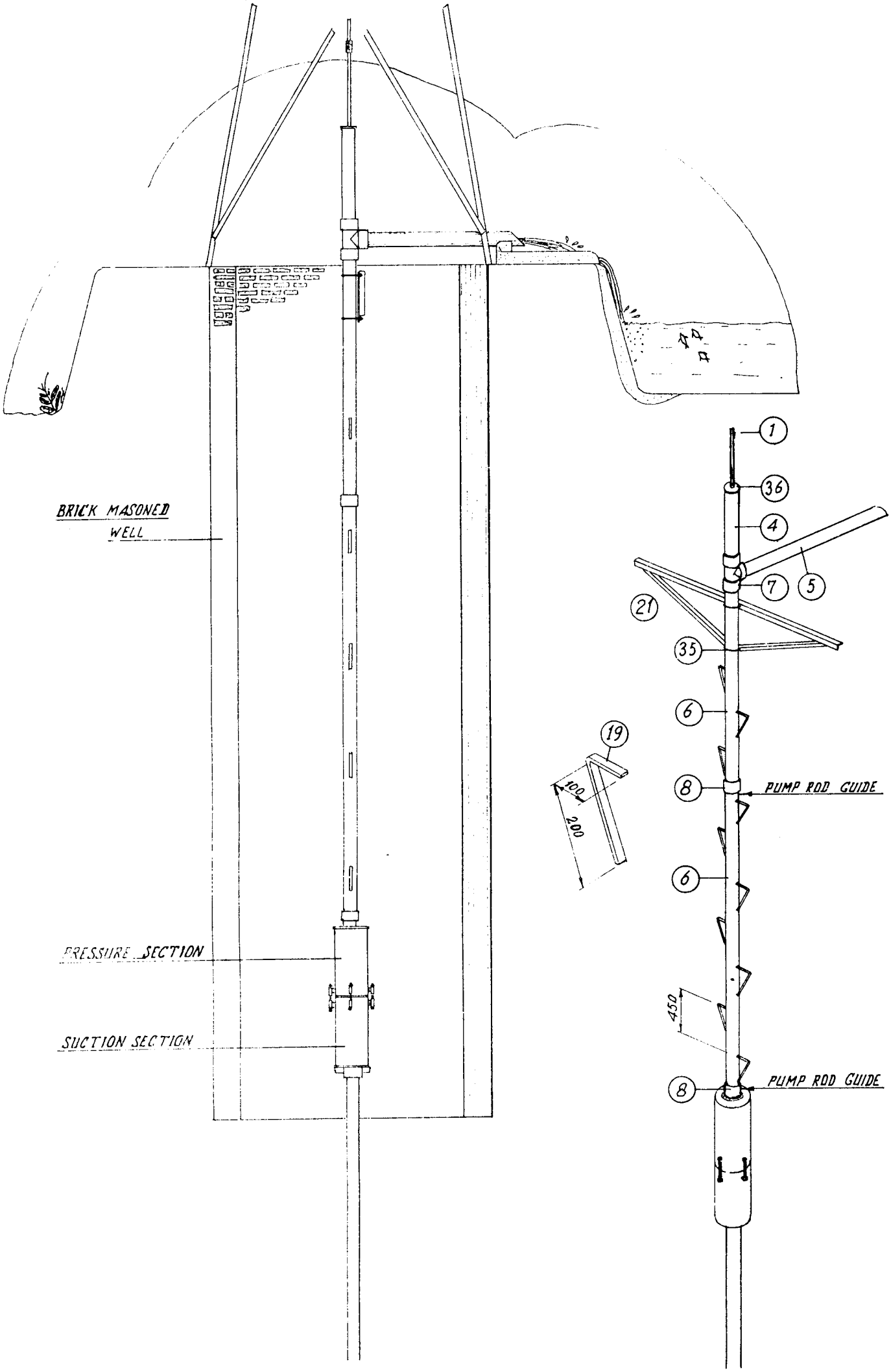
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PUMP ROD GUIDE

Puberty

From Wikipedia, the free encyclopedia

Puberty is the process of physical changes through which a child's body matures into an adult body capable of sexual reproduction. It is initiated by hormonal signals from the brain to the gonads: the ovaries in a girl, the testes in a boy. In response to the signals, the gonads produce hormones that stimulate libido and the growth, function, and transformation of the brain, bones, muscle, blood, skin, hair, breasts, and sex organs. Physical growth—height and weight—accelerates in the first half of puberty and is completed when an adult body has been developed. Until the maturation of their reproductive capabilities, the pre-pubertal physical differences between boys and girls are the external sex organs.

On average, girls begin puberty around ages 10–11; boys around ages 11–12.[1][2] Girls usually complete puberty around ages 15–17,[2][3][4] while boys usually complete puberty around ages 16–17.[2][3][5] The major landmark of puberty for females is menarche, the onset of menstruation, which occurs on average between ages 12–13;[6][7][8][9] for males, it is the first ejaculation, which occurs on average at age 13.[10] In the 21st century, the average age at which children, especially girls, reach puberty is lower compared to the 19th century, when it was 15 for girls and 16 for boys.[11] This can be due to any number of factors, including improved nutrition resulting in rapid body growth, increased weight and fat deposition,[12] or exposure to endocrine disruptors such as xenoestrogens, which can at times be due to food consumption or other environmental factors.[13][14] Puberty which starts earlier than usual is known as precocious puberty. Puberty which starts later than usual is known as delayed puberty.

Notable among the morphologic changes in size, shape, composition, and functioning of the pubertal body, is the development of secondary sex characteristics, the "filling in" of the child's body; from girl to woman, from boy to man. Derived from the Latin *puberatum* (age of maturity), the word *puberty* describes the physical changes to sexual maturation, not the psychosocial and cultural maturation denoted by the term *adolescent development* in Western culture, wherein adolescence is the period of mental transition from childhood to adulthood, which overlaps much of the body's period of puberty.[15]

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Differences between male and female puberty

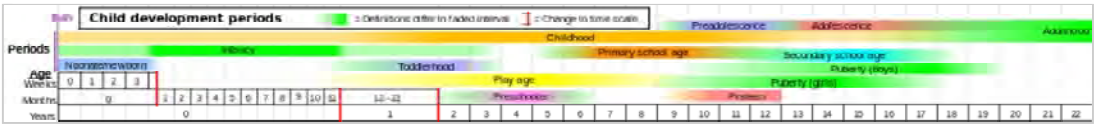

Approximate outline of development periods in child and teenager development. Puberty is marked in green at right.

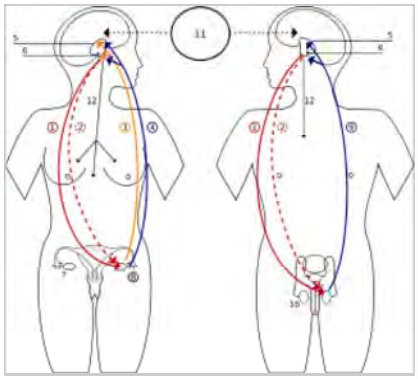

1 Follicle-stimulating hormone - FSH
2 Luteinizing hormone - LH
3 Progesterone
4 Estrogen
5 Hypothalamus
6 Pituitary gland
7 Ovary
8 Pregnancy - hCG (Human chorionic gonadotropin)
9 Testosterone
10 Testicle
11 Incentives
12 Prolactin - PRL

Two of the most significant differences between puberty in girls and puberty in boys are the age at which it begins, and the major sex steroids involved, the testosterones and the estrogens.

Although there is a wide range of normal ages, girls typically begin the process of puberty at age 10 or 11; boys at ages 11–12.[1][2] Girls usually complete puberty by ages 15–17,[2][3][4] while boys usually complete puberty by ages 16–17.[2][3][5] Girls attain reproductive maturity about four years after the first physical changes of puberty appear.[4] In contrast, boys accelerate more slowly but continue to grow for about six years after the first visible pubertal changes.[16] Any increase in height beyond the post-pubertal age is uncommon.

For boys, an androgen called testosterone is the principal sex hormone. While testosterone is produced, all boys' changes are characterized as virilization, a substantial product of testosterone metabolism in males is estradiol. The conversion of testosterone to estradiol depends on the amount of body fat and estradiol levels in boys are typically much lower than in girls. The male "growth spurt" also begins later, accelerates more slowly, and lasts longer before the epiphyses fuse. Although boys are on average 2 centimetres (0.8 in) shorter than girls before puberty begins, adult men are on average about 13 centimetres (5.1 in) taller than women. Most of this sex difference in adult heights is attributable to a later onset of the growth spurt and a slower progression to completion, a direct result of the later rise and lower adult male levels of estradiol.[17]

The hormone that dominates female development is an estrogen called estradiol. While estradiol promotes growth of the breasts and uterus, it is also the principal hormone driving the pubertal growth spurt and epiphyseal maturation and closure.[18] Estradiol levels rise earlier and reach higher levels in women than in men.

The hormonal maturation of females is considerably more complicated than in boys. The main steroid hormones, testosterone, estradiol, and progesterone as well as prolactin play important physiological functions in puberty. Gonadal steroidgenesis in girls starts with production of testosterone which is typically quickly converted to estradiol inside the ovaries. However the rate of conversion from testosterone to estradiol (driven by FSH/LH balance) during early puberty is highly individual, resulting in very diverse development patterns of secondary sexual characteristics. Production of progesterone in the ovaries begins with the development of ovulatory cycles in girls (during the lutheal phase of the cycle), before puberty low levels of progesterone are produced in the adrenal glands of both boys and girls.

Puberty onset

Puberty is preceded by adrenarche, marking an increase of adrenal androgen production between ages 6–10. Adrenarche is sometimes accompanied by the early appearance of axillary and pubic hair. The first androgenic hair resulting from adrenarche can be also transient and disappear before the onset of true puberty.

The onset of puberty is associated with high GnRH pulsing, which precedes the rise in sex hormones, LH and FSH.[19] Exogenous GnRH pulses cause the onset of puberty.[20] Brain tumors which increase GnRH output may also lead to premature puberty.[21]

The cause of the GnRH rise is unknown. Leptin might be the cause of the GnRH rise. Leptin has receptors in the hypothalamus which synthesizes GnRH.[22] Individuals who are deficient in leptin fail to initiate puberty.[23] The levels of leptin increase with the onset of puberty, and then decline to adult levels when puberty is completed. The rise in GnRH might also be caused by genetics. A study[24] discovered that a mutation in genes encoding both Neurokinin B as well as the Neurokinin B receptor can alter the timing of puberty. The researchers hypothesized that Neurokinin B might play a role in regulating the secretion of Kisspeptin, a compound responsible for triggering direct release of GnRH as well as indirect release of LH and FSH.

Effects of early and late puberty onset

Several studies about puberty have examined the effects of an early or a late onset of puberty in males and females. In general, girls who enter puberty late experience positive outcomes in adolescence and adulthood while girls who enter puberty early experience negative outcomes. Boys who have earlier pubertal timing generally have more positive outcomes in adulthood but more negative outcomes in adolescence, while the reverse is true for later pubertal timing.[25]

Girls

Outcomes have generally indicated that early onset of puberty in girls can be psychologically damaging. The main reason for this detrimental effect is the issue of body image. As they physically develop, gaining weight in several areas of the body, early-maturing girls usually look larger than girls who have not yet entered puberty. A result of the social pressure to be thin, the early-maturing girls develop a negative view of their body image. In addition, boys may tease the girls about their visible breasts, forcing the early-maturing girl to hide her breasts by dressing differently. Embarrassment about a more developed body may also result in the refusal to undress for gym. These experiences lead to lower self-esteem, more depression and poorer body image in these early-maturing girls.[25]

Furthermore, as physical and emotional differences set them apart from people in their same age group, early-maturing girls develop relationships with older people. For instance, some early-maturing girls have older boyfriends, "attracted to the girls' womanly figure and girlish innocence."[25] While having an older boyfriend might improve popularity among peers, it also increases the risk of alcohol and drug use, increased sexual relations (often unprotected), eating disorders and bullying.[25]

Generally, later onset of puberty in girls produces positive outcomes. They exhibit positive behaviors in adolescence that continue to adulthood.[25]

Boys

In the past, early onset of puberty in boys has been associated with positive outcomes, such as leadership in high school and success in adulthood.[26] However, recent studies have revealed that the risks and problems of early maturation in males might outweigh the benefits.[25]

Early-maturing boys develop "more aggressive, law-breaking, and alcohol abusing" behaviors, which result in anger towards parents and trouble in school and with the police. Early puberty also correlates with increased sexual activity and a higher instance of teenage pregnancy, both of which can lead to depression and other psychosocial issues.[25] However, early puberty might also result in positive outcomes, such as popularity among peers, higher self-esteem and confidence, as a result of physical developments, such as taller height, developed muscles, and better athletic ability.

On the other hand, late-maturing boys develop lower self-esteem and confidence and generally have lower popularity among peers, due to their less-developed physiques. Also, they experience problems with anxiety and depression and are more likely to be afraid of sex than other boys.[25]

Changes in males

Size and virility

In boys, testicular enlargement is the first physical manifestation of puberty (and is termed gonadarche).[27] Testes in prepubertal boys change little in size from about 1 year of age to the onset of puberty, averaging about 2–3 cm in length and about 1.5–2 cm in width. The size of the testicles is among the parameters of the Tanner scale for male genitals, from stage I which represents a volume of less than 1.5 ml, to stage V which represents a testicular volume of greater than 20 ml. Testicular size reaches maximal adult size about 6 years after the onset of puberty. After the boy's testicles have enlarged and developed for about one year, the length and then the breadth of the shaft of the penis will increase and the glans penis and corpora cavernosa will also start to enlarge to adult proportions.[28] While 18–20 cm^3 is an average adult size, there is wide variation in testicular size in the normal population.[29]

The testes have two primary functions: to produce hormones and to produce sperm. The Leydig cells produce testosterone, which in turn produces most of the male pubertal changes. Most of the increasing bulk of testicular tissue is spermatogenic tissue (primarily Sertoli and Leydig cells). Sperm can be detected in the morning urine of most boys after the first year of pubertal changes, and occasionally earlier. On average, potential virility (or fertility) in boys is reached at 13 years old, but full virility will not be gained until 14–16 years of age.

Erections

Erections during sleep or when waking up are medically known as nocturnal penile tumescence and colloquially referred to as *morning wood*.[30] The penis can regularly get erect during sleep and men or boys often wake-up with an erection.[31] Once a boy reaches his teenage years, erections occur much more frequently due to puberty.[32] Erections can occur spontaneously at any time of day, and if clothed may cause a bulge or "hump". This can be disguised or hidden by wearing close-fitting underwear, a long shirt and baggier clothes.[33] Erections are common for male children and infants, and can even occur before birth.[34] Spontaneous erections are also known as involuntary or unwanted erections and are normal. Such erections can be embarrassing if they happen in public, such as a classroom or living room.[35][36]

Foreskin retraction

During puberty, if not before, the tip and opening of a boy's foreskin becomes wider, progressively allowing for retraction down the shaft of the penis and behind the glans, which ultimately should be possible without pain or difficulty. The membrane that bonds the inner surface of the foreskin with the glans disintegrates and releases the foreskin to separate from the glans. The foreskin then gradually becomes retractable.

Research by Øster (1968) found that with the onset and continuation of puberty, the proportion of boys able to pull back their foreskins increased. At ages 12–13, Øster found that only 60% of boys were able to retract their foreskins; this increased to 85% by ages 14–15, and 95% by 16–17. He also found that 1% of those unable to fully retract experienced phimosis at ages 14–17, the remainder were partially able to.[37] The findings were supported by further research by Kayaba *et al* (1996) on a sample of over 600 boys,[38] and Ishikawa and Kawakita (2004) found that by age 15, 77% of their sample of boys could retract their foreskins.[39] Beaugé (1997) reports that boys may assist the development of retractile foreskin by manual stretching.[40]

Once a boy is able to retract his foreskin, penile hygiene should become an important feature of his routine body care. Although the American Academy of Pediatrics states there is "little evidence to affirm the association between circumcision status and optimal penile hygiene",[41] various studies suggest that boys be educated about the role of hygiene, including retracting the foreskin while urinating and rinsing under it and around the glans at each bathing opportunity. Regular washing under the foreskin was found by Krueger and Osborn (1986) to reduce the risk of numerous penile disorders.[42]

Pubic hair

Pubic hair often appears on a boy shortly after the genitalia begin to grow. The pubic hairs are usually first visible at the dorsal (abdominal) base of the penis. The first few hairs are described as stage 2. Stage 3 is usually reached within another 6–12 months, when the hairs are too many to count. By stage 4, the pubic hairs densely fill the "pubic triangle." Stage 5 refers to the spread of pubic hair to the thighs and upward towards the navel as part of the developing abdominal hair.

Body and facial hair

In the months and years following the appearance of pubic hair, other areas of skin that respond to androgens may develop androgenic hair. The usual sequence is: underarm (axillary) hair, perianal hair, upper lip hair, sideburn (preauricular) hair, periareolar hair, and the beard area.[43] As with most human biological processes, this specific order may vary among some individuals. Arm, leg, chest, abdominal, and back hair become heavier more gradually. There is a large range in amount of body hair among adult men, and significant differences in timing and quantity of hair growth among different racial groups. Facial hair is often present in late adolescence, but may not appear until significantly later.[44][45] Facial hair will continue to get coarser, darker and thicker for another 2–4 years after puberty.[44] Some men do not develop full facial hair for up to 10 years after the completion of puberty.[44] Chest hair may appear during puberty or years after. Not all men have chest hair.

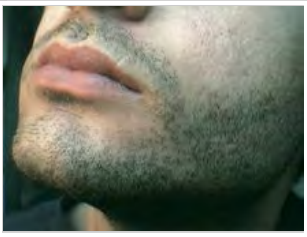
Facial hair of a male.

Voice change and Adam's apple

Under the influence of androgens, the voice box, or larynx, grows in both sexes. This growth is far more prominent in boys, causing the male voice to drop and deepen, sometimes abruptly but rarely "overnight," about one octave, because the longer and thicker vocal folds have a lower fundamental frequency. Before puberty, the larynx of boys and girls is about equally small.[46] Occasionally, voice change is accompanied by unsteadiness of vocalization in the early stages of untrained voices. Most of the voice change happens during stage 3-4 of male puberty around the time of peak growth. Adult pitch is attained at an average age of 15 years, although the voice may not fully settle until early twenties. It usually precedes the development of significant facial hair by several months to years.

Male musculature and body shape

By the end of puberty, adult men have heavier bones and nearly twice as much skeletal muscle. Some of the bone growth (e.g. shoulder width and jaw) is disproportionately greater, resulting in noticeably different male and female skeletal shapes. The average adult male has about 150% of the lean body mass of an average female, and about 50% of the body fat.

This muscle develops mainly during the later stages of puberty, and muscle growth can continue even after boys are biologically adult. The peak of the so-called "strength spurt", the rate of muscle growth, is attained about one year after a male experiences his peak growth rate.

Often, the fat pads of the male breast tissue and the male nipples will develop during puberty; sometimes, especially in one breast, this becomes more apparent and is termed gynecomastia. It is usually not a permanent phenomenon.

Body odor and acne

Rising levels of androgens can change the fatty acid composition of perspiration, resulting in a more "adult" body odor. As in girls, another androgen effect is increased secretion of oil (sebum) from the skin and the resultant variable amounts of acne. Acne can not be prevented or diminished easily, but it typically fully diminishes at the end of puberty. However, it is not unusual for a fully grown adult to suffer the occasional bout of acne, though it is normally less severe than in adolescents. Some may desire using prescription topical creams or ointments to keep acne from getting worse, or even oral medication, due to the fact that acne is emotionally difficult and can cause scarring.

Changes in females

Breast development

The first physical sign of puberty in girls is usually a firm, tender lump under the center of the areola of one or both breasts, occurring on average at about 10.5 years of age.[47] This is referred to as thelarche. By the widely used Tanner staging of puberty, this is stage 2 of breast development (stage 1 is a flat, prepubertal breast). Within six to 12 months, the swelling has clearly begun in both sides, softened, and can be felt and seen extending beyond the edges of the areolae. This is stage 3 of breast development. By another 12 months (stage 4), the breasts are approaching mature size and shape, with areolae and nipples forming a secondary mound. In most young women, this mound disappears into the contour of the mature breast (stage 5), although there is so much variation in sizes and shapes of adult breasts that stages 4 and 5 are not always separately identifiable.[48]

Pubic hair

Pubic hair is often the second noticeable change in puberty, usually within a few months of thelarche.[49] It is referred to as pubarche. The pubic hairs are usually visible first along the labia. The first few hairs are described as Tanner stage 2.[48] Stage 3 is usually reached within another 6–12 months, when the hairs are too numerous to count and appear on the pubic mound as well. By stage 4, the pubic hairs densely fill the "pubic triangle." Stage 5 refers to spread of pubic hair to the thighs and sometimes as abdominal hair upward towards the navel. In about 15% of girls, the earliest pubic hair appears before breast development begins.[49]

Vagina, uterus, ovaries

Perineal skin keratinizes due to effect of estrogen increasing its resistance to infection. The mucosal surface of the vagina also changes in response to increasing levels of estrogen, becoming thicker and duller pink in color (in contrast to the brighter red of the prepubertal vaginal mucosa).[50] Mucosa changes into a multilayered structure with superficial layer of squamous cells. Estrogen increase glycogen content in vaginal epithelium, which in future plays important part in maintaining vaginal pH. Whitish secretions (physiologic leukorrhea) are a normal effect of estrogen as well.[47] In the two years following thelarche, the uterus, ovaries, and the follicles in the ovaries increase in size.[51] The ovaries usually contain small follicular cysts visible by ultrasound.[52][53] Before puberty, uterine body to cervix ratio is 1:1; which increases to 2:1 or 3:1 after completion of pubertal period.

Menstruation and fertility

The first menstrual bleeding is referred to as menarche, and typically occurs about two years after thelarche.[49] The average age of menarche is 12.5 in the United States.[7] Most American girls experience their first period at 11, 12 or 13, but some experience it earlier than their 11th birthday and others after their 14th birthday. In fact, anytime between 8 and 16 is normal. In Canada, the average age of menarche is 12.72,[8] and in the United Kingdom it is 12.9.[9] The time between menstrual periods (menses) is not always regular in the first two years after menarche.[54] Ovulation is necessary for fertility, but may or may not accompany the earliest menses.[55] In postmenarchal girls, about 80% of the cycles were anovulatory in the first year after menarche, 50% in the third year and 10% in the sixth year.[54] Initiation of ovulation after menarche is not inevitable. A high proportion of girls with continued irregularity in the menstrual cycle several years from menarche will continue to have prolonged irregularity and anovulation, and are at higher risk for reduced fertility.[56]

Body shape, fat distribution, and body composition

During this period, also in response to rising levels of estrogen, the lower half of the pelvis and thus hips widen (providing a larger birth canal).[48][57] Fat tissue increases to a greater percentage of the body composition than in males, especially in the typical female distribution of breasts, hips, buttocks, thighs, upper arms, and pubis. Progressive differences in fat distribution as well as sex differences in local skeletal growth contribute to the typical female body shape by the end of puberty. On average, at 10 years, girls have 6% more body fat than boys.[58]

Body odor and acne

Rising levels of androgens can change the fatty acid composition of perspiration, resulting in a more "adult" body odor. This often precedes thelarche and pubarche by one or more years. Another androgen effect is increased secretion of oil (sebum) from the skin. This change increases the susceptibility to acne, a skin condition that is characteristic of puberty.[59] Acne varies greatly in its severity.[59]

Visual and other effects of hormonal changes

In girls, estradiol (the primary female sex hormone) causes thickening of lips and oral mucosa as well as further development of the vulva. In the vulva and vagina, estradiol causes thickening (stratification) of the skin and the growth of both the myoepithelial layer and the smooth muscle of the vagina. Typically estradiol will also cause pronounced growth of the labia minora and to a lesser degree of the labia majora.

Estradiol is also responsible for the increased production of pheomelanin, resulting in the characteristic red color of the lips, labia minora and sometimes labia majora. Estradiol together with other ovarian steroids also cause the darker coloration of the areola.

Testosterone will cause an enlargement of the clitoris and possibly has important effects on the growth and maturation of the vestibular bulbs, corpus cavernosum of the clitoris and urethral sponge.[60]

Changes of the vulva initiated by estradiol as well as its direct effects also appear to influence the functioning of the lower urinary tract.[61][62]

Variations

Timing of onset

The definition of the onset of puberty may depend on perspective (e.g., hormonal versus physical) and purpose (establishing population normal standards, clinical care of early or late pubescent individuals, etc.). A common definition for the onset of puberty is physical changes to a person's body.[4] These physical changes are the first visible signs of neural, hormonal, and gonadal function changes.

The age at which puberty begins varies between individuals; usually, puberty begins between 10 and 13 years of age. The age at which puberty begins is affected by both genetic factors and by environmental factors such as nutritional state and social circumstances.[63] An example of social circumstances is the Vandenbergh effect; a juvenile female who has significant interaction with adult males will enter puberty earlier than juvenile females who are not socially overexposed to adult males.[64]

The average age at which puberty begins may be affected by race as well. For example, the average age of menarche in various populations surveyed has ranged from 12[7][8][9] to 18 years. The earliest average onset of puberty is for African-American girls and the latest average onset for high altitude subsistence populations in Asia. However, much of the higher age averages reflect nutritional limitations more than genetic differences and can change within a few generations with a substantial change in diet. The median age of menarche for a population may be an index of the proportion of undernourished girls in the population, and the width of the spread may reflect unevenness of wealth and food distribution in a population.

Researchers have identified an earlier age of the onset of puberty. However, they have based their conclusions on a comparison of data from 1999 with data from 1969. In the earlier example, the sample population was based on a small sample of white girls (200, from Britain). The later study identified as puberty as occurring in 48% of African-American girls by age nine, and 12% of white girls by that age.[65]

One possible cause of a delay in the onset of puberty past the age 14 in girls and 15 in boys is Kallmann syndrome, a form of hypogonadotropic hypogonadism (HH). Kallmann syndrome is also associated with a lack of sense of smell (anosmia). Kallmann syndrome and other forms of HH affect both men and women. It is caused by a failure in HPG axis at puberty which results in low or zero gonadotropin (LH and FSH) levels with the subsequent result of a failure to commence or complete puberty, secondary hypogonadism and infertility.[66][67]

Historical shift

The average age at which the onset of puberty occurs has dropped significantly since the 1840s.[68][69][70] In every decade from 1840 to 1950 there was a drop of four months in the average age of menarche among Western European females. In Norway, girls born in 1840 had their menarche at an average age of 17 years. In France, the average in 1840 was 15.3 years. In England, the average in 1840 was 16.5 years. In Japan the decline happened later and was then more rapid: from 1945 to 1975 in Japan there was a drop of 11 months per decade.

A 2006 study in Denmark found that puberty, as evidenced by breast development, started at an average age of 9 years and 10 months, a year earlier than when a similar study was done in 1991. Scientists believe the phenomenon could be linked to obesity or exposure to chemicals in the food chain, and is putting girls at greater long-term risk of breast cancer.[71]

Genetic influence and environmental factors

Various studies have found direct genetic effects to account for at least 46% of the variation of timing of puberty in well-nourished populations.[72][73][74][75] The genetic association of timing is strongest between mothers and daughters. The specific genes affecting timing are not yet known.[72] Among the candidates is an androgen receptor gene.[76]

Researchers[77] have hypothesized that early puberty onset may be caused by certain hair care products containing estrogen or placenta, and by certain chemicals, namely phthalates, which are used in many cosmetics, toys, and plastic food containers.

If genetic factors account for half of the variation of pubertal timing, environment factors are clearly important as well. One of the first observed environmental effects is that puberty occurs later in children raised at higher altitudes. The most important of the environmental influences is clearly nutrition, but a number of others have been identified, all which affect timing of female puberty and menarche more clearly than male puberty.

Hormones and steroids

There is theoretical concern, and animal evidence, that environmental hormones and chemicals may affect aspects of prenatal or postnatal sexual development in humans.[78] Large amounts of incompletely metabolized estrogens and progestagens from pharmaceutical products are excreted into the sewage systems of large cities, and are sometimes detectable in the environment. Sex steroids are sometimes used in cattle farming but have been banned in chicken meat production for 40 years. Although agricultural laws regulate use to minimize accidental human consumption, the rules are largely self-enforced in the United States. Significant exposure of a child to hormones or other substances that activate estrogen or androgen receptors could produce some or all of the changes of puberty.

Harder to detect as an influence on puberty are the more diffusely distributed environmental chemicals like PCBs (polychlorinated biphenyl), which can bind and trigger estrogen receptors.

More obvious degrees of partial puberty from direct exposure of young children to small but significant amounts of pharmaceutical sex steroids from exposure at home may be detected during medical evaluation for precocious puberty, but mild effects and the other potential exposures outlined above would not.

Bisphenol A (BPA) is a chemical used to make plastics, and is frequently used to make baby bottles, water bottles, sports equipment, medical devices, and as a coating in food and beverage cans. Scientists are concerned about BPA's behavioral effects on fetuses, infants, and children at current exposure levels because it can affect the prostate gland, mammary gland, and lead to early puberty in girls. BPA mimics and interferes with the action of estrogen—an important reproduction and development regulator. It leaches out of plastic into liquids and foods, and the Centers for Disease Control and Prevention (CDC) found measurable amounts of BPA in the bodies of more than 90 percent of the U.S. population studied. The highest estimated daily intakes of BPA occur in infants and children. Many plastic baby bottles contain BPA, and BPA is more likely to leach out of plastic when its temperature is increased, as when one warms a baby bottle or warms up food in the microwave.[79]

Nutritional influence

Nutritional factors are the strongest and most obvious environmental factors affecting timing of puberty.[72] Girls are especially sensitive to nutritional regulation because they must contribute all of the nutritional support to a growing fetus. Surplus calories (beyond growth and activity requirements) are reflected in the amount of body fat, which signals to the brain the availability of resources for initiation of puberty and fertility.

Much evidence suggests that for most of the last few centuries, nutritional differences accounted for majority of variation of pubertal timing in different populations, and even among social classes in the same population. Recent worldwide increased consumption of animal protein, other changes in nutrition, and increases in childhood obesity have resulted in falling ages of puberty, mainly in those populations with the higher previous ages. In many populations the amount of variation attributable to nutrition is shrinking.

Although available dietary energy (simple calories) is the most important dietary influence on timing of puberty, quality of the diet plays a role as well. Lower protein intakes and higher dietary fiber intakes, as occur with typical vegetarian diets, are associated with later onset and slower progression of female puberty.

Obesity influence and exercise

Scientific researchers have linked early obesity with an earlier onset of puberty in girls. They have cited obesity as a cause of breast development before nine years and menarche before twelve years.[80] Early puberty in girls can be a harbinger of later health problems.[81]

The average level of daily physical activity has also been shown to affect timing of puberty, especially in females. A high level of exercise, whether for athletic or body image purposes, or for daily subsistence, reduces energy calories available for reproduction and slows puberty. The exercise effect is often amplified by a lower body fat mass and cholesterol.

Physical and mental illness

Chronic diseases can delay puberty in both boys and girls. Those that involve chronic inflammation or interfere with nutrition have the strongest effect. In the western world, inflammatory bowel disease and tuberculosis have been notorious for such an effect in the last century, while in areas of the underdeveloped world, chronic parasite infections are widespread.

Mental illnesses occur in puberty. The brain undergoes significant development by hormones which can contribute to mood disorders such as major depressive disorder, bipolar disorder, dysthymia and schizophrenia. Girls aged between 15 and 19 make up 40% of anorexia nervosa cases.[82]

Stress and social factors

Some of the least understood environmental influences on timing of puberty are social and psychological. In comparison with the effects of genetics, nutrition, and general health, social influences are small, shifting timing by a few months rather than years. Mechanisms of these social effects are unknown, though a variety of physiological processes, including pheromones, have been suggested based on animal research.

The most important part of a child's psychosocial environment is the family, and most of the social influence research has investigated features of family structure and function in relation to earlier or later female puberty. Most of the studies have reported that menarche may occur a few months earlier in girls in high-stress households, whose fathers are absent during their early childhood, who have a stepfather in the home, who are subjected to prolonged sexual abuse in childhood, or who are adopted from a developing country at a young age. Conversely, menarche may be slightly later when a girl grows up in a large family with a biological father present.

More extreme degrees of environmental stress, such as wartime refugee status with threat to physical survival, have been found to be associated with delay of maturation, an effect that may be compounded by dietary inadequacy.

Most of these reported social effects are small and our understanding is incomplete. Most of these "effects" are statistical associations revealed by epidemiologic surveys. Statistical associations are not necessarily causal, and a variety of covariables and alternative explanations can be imagined. Effects of such small size can never be confirmed or refuted for any individual child. Furthermore, interpretations of the data are politically controversial because of the ease with which this type of research can be used for political advocacy. Accusations of bias based on political agenda sometimes accompany scientific criticism.

Another limitation of the social research is that nearly all of it has concerned girls, partly because female puberty requires greater physiologic resources and partly because it involves a unique event (menarche) that makes survey research into female puberty much simpler than male. More detail is provided in the menarche article.

Variations of sequence

The sequence of events of pubertal development can occasionally vary. For example, in about 15% of boys and girls, pubarche (the first pubic hairs) can precede, respectively, gonadarche and thelarche by a few months. Rarely, menarche can occur before other signs of puberty in a few girls. These variations deserve medical evaluation because they can occasionally signal a disease.

Conclusion

In a general sense, the conclusion of puberty is reproductive maturity. Criteria for defining the conclusion may differ for different purposes: attainment of the ability to reproduce, achievement of maximal adult height, maximal gonadal size, or adult sex hormone levels. Maximal adult height is achieved at an average age of 15 years for an average girl and 18 years for an average boy. Potential fertility (sometimes termed *nubility*) usually precedes completion of growth by 1–2 years in girls and 3–4 years in boys. Stage 5 typically represents maximal gonadal growth and adult hormone levels.

Neurohormonal process

The endocrine reproductive system consists of the hypothalamus, the pituitary, the gonads, and the adrenal glands, with input and regulation from many other body systems. True puberty is often termed "central puberty" because it begins as a process of the central nervous system. A simple description of hormonal puberty is as follows:

1. The brain's hypothalamus begins to release pulses of GnRH.
2. Cells in the anterior pituitary respond by secreting LH and FSH into the circulation.
3. The ovaries or testes respond to the rising amounts of LH and FSH by growing and beginning to produce estradiol and testosterone.
4. Rising levels of estradiol and testosterone produce the body changes of female and male puberty.

The onset of this neurohormonal process may precede the first visible body changes by 1–2 years.

Components of the endocrine reproductive system

The **arcuate nucleus** of the **hypothalamus** is the driver of the reproductive system. It has neurons which generate and release pulses of GnRH into the portal venous system of the pituitary gland. The arcuate nucleus is affected and controlled by neuronal input from other areas of the brain and hormonal input from the gonads, adipose tissue and a variety of other systems.

The **pituitary gland** responds to the pulsed GnRH signals by releasing LH and FSH into the blood of the general circulation, also in a pulsatile pattern.

The **gonads** (testes and ovaries) respond to rising levels of LH and FSH by producing the steroid sex hormones, testosterone and estrogen.

The **adrenal glands** are a second source for steroid hormones. Adrenal maturation, termed adrenarche, typically precedes gonadarche in mid-childhood.

Major hormones

- **Neurokinin B** (a tachykinin peptide) and **kisspeptin** (a neuropeptide), both present in the same hypothalamic neurons, are critical parts of the control system that switches on the release of GnRH at the start of puberty.[83]
- **GnRH** (gonadotropin-releasing hormone) is a peptide hormone released from the hypothalamus which stimulates gonadotrope cells of the anterior pituitary.
- **LH** (luteinizing hormone) is a larger protein hormone secreted into the general circulation by gonadotrope cells of the anterior pituitary gland. The main target cells of LH are the Leydig cells of testes and the theca cells of the ovaries. LH secretion changes more dramatically with the initiation of puberty than FSH, as LH levels increase about 25-fold with the onset of puberty, compared with the 2.5-fold increase of FSH.
- **FSH** (follicle stimulating hormone) is another protein hormone secreted into the general circulation by the gonadotrope cells of the anterior pituitary. The main target cells of FSH are the ovarian follicles and the Sertoli cells and spermatogenic tissue of the testes.
- **Testosterone** is a steroid hormone produced primarily by the Leydig cells of the testes, and in lesser amounts by the theca cells of the ovaries and the adrenal cortex. Testosterone is the primary mammalian androgen and the "original" anabolic steroid. It acts on androgen receptors in responsive tissue throughout the body.
- **Estradiol** is a steroid hormone produced by aromatization of testosterone. Estradiol is the principal human estrogen and acts on estrogen receptors throughout the body. The largest amounts of estradiol are produced by the granulosa cells of the ovaries, but lesser amounts are derived from testicular and adrenal testosterone.
- **Adrenal androgens** are steroids produced by the zona reticulosa of the adrenal cortex in both sexes. The major adrenal androgens are dehydroepiandrosterone, androstenedione (which are precursors of testosterone), and dehydroepiandrosterone sulfate which is present in large amounts in the blood. Adrenal androgens contribute to the androgenic events of early puberty in girls.
- **IGF1** (insulin-like growth factor 1) rises substantially during puberty in response to rising levels of growth hormone and may be the principal mediator of the pubertal growth spurt.
- **Leptin** is a protein hormone produced by adipose tissue. Its primary target organ is the hypothalamus. The leptin level seems to provide the brain a rough indicator of adipose mass for purposes of regulation of appetite and energy metabolism. It also plays a permissive role in female puberty, which usually will not proceed until an adequate body mass has been achieved.

Endocrine perspective

The endocrine reproductive system becomes functional by the end of the first trimester of fetal life. The testes and ovaries become briefly inactive around the time of birth but resume hormonal activity until several months after birth, when incompletely understood mechanisms in the brain begin to suppress the activity of the arcuate nucleus. This has been referred to as maturation of the prepubertal "gonadostat," which becomes sensitive to negative feedback by sex steroids. The period of hormonal activity until several months after birth, followed by suppression of activity, may correspond to the period of infant sexuality, followed by a latency stage, which Sigmund Freud described.[84]

Gonadotropin and sex steroid levels fall to low levels (nearly undetectable by current clinical assays) for approximately another 8 to 10 years of childhood. Evidence is accumulating that the reproductive system is not totally inactive during the childhood years. Subtle increases in gonadotropin pulses occur, and ovarian follicles surrounding germ cells (future eggs) double in number.

Normal puberty is initiated in the hypothalamus, with de-inhibition of the pulse generator in the arcuate nucleus. This inhibition of the arcuate nucleus is an ongoing active suppression by other areas of the brain. The signal and mechanism releasing the arcuate nucleus from inhibition have been the subject of investigation for decades and remain incompletely understood. Leptin levels rise throughout childhood and play a part in allowing the arcuate nucleus to resume operation. If the childhood inhibition of the arcuate nucleus is interrupted prematurely by injury to the brain, it may resume pulsatile gonadotropin release and puberty will begin at an early age.

Neurons of the arcuate nucleus secrete gonadotropin releasing hormone (GnRH) into the blood of the pituitary portal system. An American physiologist, Ernst Knobil, found that the GnRH signals from the hypothalamus induce pulsed secretion of LH (and to a lesser degree, FSH) at roughly 1-2 hour intervals. The LH pulses are the consequence of pulsatile GnRH secretion by the arcuate nucleus that, in turn, is the result of an oscillator or signal generator in the central nervous system ("GnRH pulse generator").[85] In the years preceding physical puberty, Robert M. Boyar discovered that the gonadotropin pulses occur only during sleep, but as puberty progresses they can be detected during the day.[86] By the end of puberty, there is little day-night difference in the amplitude and frequency of gonadotropin pulses.

Some investigators have attributed the onset of puberty to a resonance of oscillators in the brain.[87][88][89][90] By this mechanism, the gonadotropin pulses that occur primarily at night just before puberty represent beats.[91][92][93]

An array of "autoamplification processes" increases the production of all of the pubertal hormones of the hypothalamus, pituitary, and gonads.

Regulation of adrenarche and its relationship to maturation of the hypothalamic-gonadal axis is not fully understood, and some evidence suggests it is a parallel but largely independent process coincident with or even preceding central puberty. Rising levels of adrenal androgens (termed adrenarche) can usually be detected between 6 and 11 years of age, even before the increasing gonadotropin pulses of hypothalamic puberty. Adrenal androgens contribute to the development of pubic hair (pubarche), adult body odor, and other androgenic changes in both sexes. The primary clinical significance of the distinction between adrenarche and gonadarche is that pubic hair and body odor changes by themselves do not prove that central puberty is underway for an individual child.

Hormonal changes in boys

Early stages of male hypothalamic maturation seem to be very similar to the early stages of female puberty, though occurring about 1–2 years later.

LH stimulates the Leydig cells of the testes to make testosterone and blood levels begin to rise. For much of puberty, nighttime levels of testosterone are higher than daytime. Regularity of frequency and amplitude of gonadotropin pulses seems to be less necessary for progression of male than female puberty.

However, a significant portion of testosterone in adolescent boys is converted to estradiol. Estradiol mediates the growth spurt, bone maturation, and epiphyseal closure in boys just as in girls. Estradiol also induces at least modest development of breast tissue (gynecomastia) in a large proportion of boys. Boys who develop mild gynecomastia or even developing swellings under nipples during puberty are told the effects are temporary in some male teenagers due to high levels of estradiol.

Another hormonal change in males takes place during the teenage years for most young men. At this point in a male's life the testosterone levels slowly rise, and most of the effects are mediated through the androgen receptors by way of conversion dihydrotestosterone in target organs (especially that of the bowels).

Hormonal changes in girls

As the amplitude of LH pulses increases, the theca cells of the ovaries begin to produce testosterone and smaller amounts of progesterone. Much of the testosterone moves into nearby cells called granulosa cells. Smaller increases of FSH induce an increase in the aromatase activity of these granulosa cells, which converts most of the testosterone to estradiol for secretion into the circulation. The remaining testosterone, together with adrenal androgens is responsible for the typical androgenic changes of female puberty: pubic hair, other androgenic hair as outlined above, body odor, acne. The bioactivity of testosterone is to a large degree limited by SHBG which in turn is mainly controlled by estradiol and prolactin levels (estradiol stimulates, prolactin decreases SHBG synthesis).

Rising levels of estradiol produce the characteristic estrogenic body changes of female puberty: growth spurt, acceleration of bone maturation and closure, breast growth, increased fat composition, growth of the uterus, increased thickness of the endometrium and the vaginal mucosa, and widening of the lower pelvis.

As the estradiol levels gradually rise and the other autoamplification processes occur, a point of maturation is reached when the feedback sensitivity of the hypothalamic "gonadostat" becomes positive. This attainment of positive feedback is the hallmark of female sexual maturity, as it allows the mid cycle LH surge necessary for ovulation.

Growth hormone levels rise steadily throughout puberty. IGF1 levels rise and then decline as puberty ends. Growth finishes and adult height is attained as

the estradiol levels complete closure of the epiphyses.

Stages

- adrenarche (approximately age 7)
- gonadarche (approximately age 8)
- thelarche (approximately age 11 in females)
- pubarche (approximately age 12)
- menarche (approximately age 12.5 in females)
- spermarche (in males)

See also

- Adolescent sexuality
- Child sexuality
- Delayed puberty
- Eunuch
- Hebephilia
- Precocious puberty
- Secondary sex characteristic
- Puberphonia
- Kallmann syndrome

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External links

Wikisource has the text of the 1911 *Encyclopædia Britannica* article ***Puberty***.

- Support for teens (http://www.theteencentre.com/forums)
- University of Maryland guide to puberty and adolescence (http://umm.edu/health/medical/ency/articles/puberty-and-adolescence)
- Growing Up Sexually: A World Atlas (http://www.sexarchive.info/GESUND/ARCHIV/GUS/INDEXATLAS.HTM)
- Pictures and detailed information about breast development during puberty (http://www.007b.com/breast_development.php)
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- Puberty in boys: interactive animation of Tanner stages (http://www.aboutkidshealth.ca/En/HowTheBodyWorks/SexDevelopmentAnOverview/SexualDifferentiation/Pages/PubertyinBoys.aspx)

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Categories: Puberty | Adolescence | Human development | Sexuality and age | Human female endocrine system

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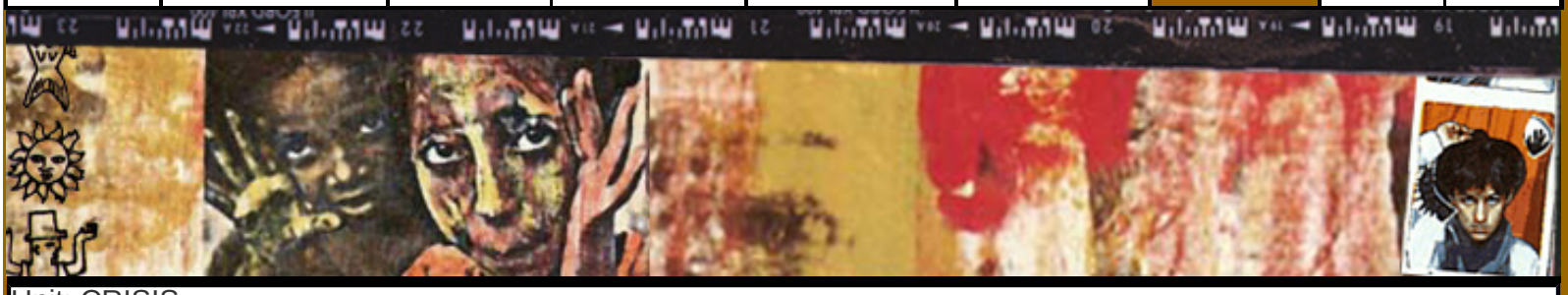

Unit: CRISIS
Lesson: **Public Health in the Sprawl**

Answer Key: Health Issues

Malaria

- Definition: A parasitic disease characterized by fever, chills, and anemia.
- Causes: Malaria is caused by a parasite that is transmitted from one human to another by the bite of infected mosquitoes. In humans, the parasites migrate to the liver where they mature and release another form. These enter the bloodstream and infect the red blood cells. The parasites multiply inside the red blood cells, which then rupture within 48 to 72 hours, infecting more red blood cells. The symptoms occur in cycles of 48 to 72 hours. Malaria can also be transmitted congenitally (from a mother to her unborn baby) and by blood transfusions. Malaria can be carried by mosquitoes in temperate climates, but the parasite disappears over the winter.
- Effects & Symptoms: The disease is a major health problem in much of the tropics and subtropics. More than 200 million people in the world have malaria. It presents the greatest disease hazard for travelers to warm climates. Falciparum malaria, one of four different types, can be fatal within a few hours of the first symptoms. Symptoms include: chills, fever, headache, nausea and vomiting, muscle pain, anemia, bloody stools, and jaundice.
- Treatment and Prevention: Malaria, especially Falciparum malaria, is a medical emergency requiring hospitalization. Chloroquine is the most frequently used antimalarial medication. Most people living in malaria-prevalent areas have acquired some immunity to the disease. In some areas of the world, mosquitoes that carry malaria have developed resistance to insecticides, while the parasites have developed resistance to antibiotics. This has led to difficulty in controlling both the rate of infection and spread of this disease.

Malnutrition (especially of children and mothers)

- Definition: A general term that indicates a lack of some or all nutritional elements. Causes: Malnutrition is caused by inadequate intake or inadequate digestion of nutrients.
- This can occur because of deficiencies in the diet. Single vitamin deficiencies are a form of malnutrition just as starvation is a form of malnutrition. Malnutrition can also occur when nutrients are adequately consumed in the diet, but one or more nutrients are not digested or absorbed properly.
- Effects & Symptoms: Malnutrition may be mild enough to show no symptoms or so severe that the damage it has done is irreversible even though the individual may be kept alive. Worldwide, malnutrition continues to be a significant problem, especially among children who cannot fend adequately for themselves. Symptoms vary based on kind of nutrition deficiency but include weakened heart, psychosis, fatigue, abdominal pain, numbness in limbs, shortness of breath, diarrhea, skin sores, loss of hair, and growth failure.
- Treatment & Prevention: Treatment usually consists of replacement of missing nutrients; and treatment of symptoms as necessary. Eating a good, well-balanced diet helps to prevent most forms of malnutrition. In infants, the breast milk of a healthy mother is the best source of nutrients possible.

HIV/AIDS

- Definition: a fatal transmissable disorder of the immune system.
- Causes: The Human Immunodeficiency Virus (HIV) causes AIDS. AIDS is the final and most serious stage of HIV disease. The virus attacks the immune system and leaves the body vulnerable to a variety of life-threatening illnesses.

Common bacteria, yeast, and viruses that would not cause disease in people with a fully functional immune system often cause these illnesses. HIV has been found in saliva, tears, nervous system tissue, blood, semen, breast milk, and female genital tract secretions. Transmission of the virus occurs: 1) through sexual contact including oral, vaginal, and anal sex, 2) through blood via blood transfusions or needle sharing, 3) from mother to child: when a woman is pregnant, she can passively transmit the virus to her fetus or a nursing mother can transmit it to her baby. Other transmission methods are rare and include accidental needle injury, artificial insemination through donated semen, and organ transplantation through the donated organ.

- Effects & Symptoms: Since the onset of the HIV/AIDS epidemic 15 years ago, the virus has infected more than 47 million people in the world. With more than 2.2 million deaths in 1998, HIV/AIDS has now become the fourth leading cause of mortality and its impact is going to increase. Over 95% of all cases and 95% of AIDS deaths occur in the developing world, mostly among young adults and increasingly in women. In East Africa, between one of every seven to one of every nine adults is infected in most countries. Symptoms of AIDS are primarily the result of infections that do not normally develop in individuals with healthy immune systems. These infections are termed opportunistic infections. The general symptoms associated with most infections are fevers, sweats, chills weakness, and weight loss. Initial infection may produce no symptoms. Some people with HIV infection remain without symptoms for years between the time of exposure and development of AIDS.
- Treatment & Prevention: No vaccine or cure has yet been developed that can prevent HIV infection. Therapy was initially limited to treatment of the individual opportunistic infections as they arose. However, several drugs, such as AZT, 3TC, and dideoxyinosine are now used to slow the development of AIDS once an individual has become infected with HIV. These drugs target the reverse transcriptase enzyme, inhibiting its activity and thereby curbing reproduction of the virus. A new class of pharmaceuticals, called protease inhibitors, has been developed that shows promise in combating HIV. These compounds prevent the final processing of a number of important HIV proteins carried out by the enzyme HIV protease. Protease inhibitors have been shown to block the development of AIDS, at least temporarily. Protease inhibitors are most effective in stemming the progression of the disease when used in conjunction with two different reverse transcriptase inhibitors-the so-called "triple-drug therapy." Efforts at prevention have been focused primarily on changes in sexual behavior such as abstinence, monogamy, the use of barrier contraceptives, and other "safe sex" methods. Attempts to reduce intravenous drug use and to discourage the sharing of hypodermic needles have also led to a reduction in infection rates in some areas. Since mothers can pass HIV to their fetuses, positive women are counseled to consider avoiding pregnancy and pregnant women are often advised against breast feeding.

Family Planning/ Population Control

- Family Planning is the conscious effort of couples to regulate the number and spacing of births through artificial and natural methods of contraception. Population control is a broad concept that addresses the relationship between fertility, mortality, and migration, but is most commonly used to refer to efforts to slow population growth through action to lower fertility.
- Causes: Overpopulation in an area is linked to several factors, especially: cultural values regarding sexuality, reproduction, and family size; and access to, understanding of, and financing for safe family planning methods.
- Effects & Symptoms: (1) Family planning saves lives. By spacing births, family planning lowers mortality among both women and children. Just by increasing the time between births or the age of first motherhood, family planning can reduce infant and child mortality by up to 25%- about three million lives a year. (2) Use of family planning can also help reduce the toll of repeated pregnancy and childbirth on women's health. Currently an estimated 600,000 women die annually from pregnancy-related causes. (3) Family planning also helps stem the spread of HIV/AIDS - directly, by making condoms available, and indirectly, by teaching women how to better negotiate condom use by their male partners. (4) It lowers the number of deaths from unsafe abortions. (5) Slower population growth can help alleviate environmental stress. Access to fresh water, the conservation of forests, and the preservation of species-rich habitats can all benefit from slower population growth. (6) Many women and girls in developing countries do not receive the same level of education as men, and they marry at a very young age. Postponing childbirth among young women increases their chances of receiving a good education, which is vital to social, political, and economic empowerment.
- Treatment & Prevention: Prevention of overpopulation and complications/hazards to women and children brought on by too many births, spaced too close together is family planning. Family planning includes education of people in their childbearing years about reproduction, sexuality issues, and contraception, as well as access to contraceptives (e.g., the pill, diaphragm, condoms, etc.) that are reasonably priced and safe.

Dysentery

- Definition: An infectious disease of the colon.
- Causes: Although several organisms can cause dysentery, *Shigella* are the most important. *Shigella* dysenteriae type 1 (Sd1), also known as the Shiga bacillus, is the most virulent of the four serogroups of Shigella. Sd1 is the only cause of epidemic dysentery.
- Effects & Symptoms: In addition to bloody diarrhea, the illness caused by Sd1 often includes abdominal cramps, fever and rectal pain. Symptoms include bloody, mucus-filled diarrhea; abdominal pain; fever; and loss of fluids from the body. Approximately 5-15% of Sd1 cases are fatal. In Africa, epidemic dysentery due to Sd1 appeared in eastern Zaire in 1979 and has subsequently been confirmed in Angola, Burundi, Equatorial Guinea, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Sao TomÈ and Principe, South Africa, Swaziland, Tanzania, Uganda, Zambia, and Zimbabwe.
- Treatment & Prevention: During an epidemic, all dysentery patients should receive an antibiotic to which Sd1 from local cases has been shown to be sensitive. (A major obstacle to the control of Sd1 is its resistance to many antimicrobial drugs. In one central African country the bacillus was resistant to all oral antibiotics that were locally available.) Dehydration should be treated with oral rehydration salts or, if severe, with intravenous fluids. Early detection and notification of epidemic dysentery, especially among adults, allows for timely mobilization of resources needed for appropriate case management and control.

Cholera

- Definition: Cholera is an acute intestinal infection caused by the bacterium *Vibrio cholerae*.
- Causes: Cholera is spread by contaminated water and food. Sudden large outbreaks are usually caused by a contaminated water supply. Only rarely is cholera transmitted by direct person-to-person contact. In highly endemic areas, it is mainly a disease of young children.
- Effects & Symptoms: When cholera occurs in an unprepared community, case-fatality rates may be as high as 50% -- usually because there are no facilities for treatment, or because treatment is given too late. In contrast, a well-organized response in a country with a well established diarrheal disease control program can limit the case-fatality rate to less than 1%. It has a short incubation period, from less than one day to five days, and produces an enterotoxin that causes a copious, painless, watery diarrhoea that can quickly lead to severe dehydration and death if treatment is not promptly given. Vomiting also occurs in most patients.
- Treatment & Prevention: Most cases of diarrhea caused by *V. cholerae* can be treated adequately by giving a solution of oral re-hydration salts. During an epidemic, 80-90% of diarrhea patients can be treated by oral re-hydration alone, but patients who become severely dehydrated must be given intravenous fluids. In severe cases, an effective antibiotic can reduce the volume and duration of diarrhea, although resistance is increasing to the most common antiobiotic. When cholera appears in a community it is essential to ensure three things: hygienic disposal of human faeces, an adequate supply of safe drinking water, and good food hygiene. Effective food hygiene measures include cooking food thoroughly and eating it while still hot; preventing cooked foods from being contaminated by contact with raw foods, including water and ice, contaminated surfaces or flies; and avoiding raw fruits or vegetables unless they are first peeled. Washing hands after defecation, and particularly before contact with food or drinking water, is equally important.

Yellow fever

- Definition: An insect-borne tropical disease
- Causes: Yellow fever is caused by an arbovirus (Flaviviridae), a small RNA virus that is transmitted by the bite of mosquitoes.
- Effects & Symptoms: The acute form of the disease causes headache, muscle aches, fever, loss of appetite, and vomiting. The infected person may also develop a red tongue, flushed face, and reddening of the eyes. By the fifth day, jaundice, stomach pain, and bleeding (which may appear as bloody vomiting) develops. Delirium and seizures followed by coma are common. Death occurs at the end of the first week of symptoms and as many as half of the infected people may die.
- Treatment & Prevention: There is no specific treatment for yellow fever. The present treatment is supportive. Intravenous fluids are given to treat dehydration, low blood pressure, and hypoglycemia (low blood sugar). Antacids and H2 histamine blockers are often prescribed to protect the stomach from bleeding. Medications such as acetaminophen are used for fever control. Dialysis may be needed if kidney failure develops. Transfusions of fresh blood, or plasma transfusion, may be needed to control severe bleeding disorders. Vaccination is the only sure prevention for yellow fever. Use of mosquito repellents, full covering clothing and screened housing will decrease

exposure risk. Mosquito control has decreased the risk in countries where the disease was once prevalent. The risks remain however, because the mosquito has increasing resistance to insecticides.

Measles

- Definition: A highly contagious viral illness
- Causes: Rubeola, or measles, is caused by the paramyxovirus. The infection is spread by droplets from the nose, mouth or throat of an infected person. The incubation period is 7 to 14 days before symptoms generally appear. An immunity to the disease occurs after vaccination, after active infection, and passive immunity of an infant whose mother is immune lasts most of the first year of life. Densely populated urban areas are particularly at risk, where the virus may be kept circulating by numerous pockets of susceptibles, despite a relatively high overall level of coverage. The urban poor usually have less access to immunization services, as well as frequently having ethnic or cultural reasons which might hinder their accepting immunization.
- Effects & Symptoms: An estimated 700,000 thousand deaths occur annually in developing countries from measles; these are mainly children. Symptoms include: sore throat, runny nose, cough, muscle pain, fever, bloodshot eyes, tiny white spots in mouth, light sensitivity, rash.
- Treatment & Prevention: There is no specific treatment of measles. Symptomatic relief may be achieved from bed rest, acetaminophen - oral, and humidified air.

Tuberculosis

- Definition: A contagious bacterial infection
- Causes: Like the common cold, TB spreads through the air. Only people who are sick with pulmonary TB are infectious. When infectious people cough, sneeze, talk or spit, they propel TB germs, known as bacilli, into the air. A person needs only to inhale a small number of these to be infected. Left untreated, each person with active TB will infect on average between 10 and 15 people every year. But people infected with TB will not necessarily get sick with the disease. The immune system 'walls off' the TB bacilli which, protected by a thick waxy coat, can lie dormant for years. When someone's immune system is weakened, such as with HIV/AIDS, the chances of getting sick are greater. Untreated TB spreads quickly in crowded refugee camps and shelters, which is a problem since the number of refugees and displaced people in the world is increasing. It is difficult to treat mobile populations, as treatment takes at least six months. As many as 50% of the world's refugees may be infected with TB.
- Effects & Symptoms: Tuberculosis kills 2 million people each year; over 1.5 million TB cases per year occur in sub-Saharan Africa. This number is rising rapidly as a result of the HIV/AIDS epidemic. The breakdown in health services, the spread of HIV/AIDS and the emergence of multidrug-resistant TB are contributing to the worsening impact of this disease. It is estimated that between 2000 and 2020, nearly one billion people will be newly infected, 200 million people will get sick, and 35 million will die from TB - if control is not further strengthened. Symptoms include cough, fever, fatigue, weight loss, and coughing up blood.
- Treatment & Prevention: Drug-resistant TB is caused by inconsistent or partial treatment, when patients do not take all their drugs regularly for the required period because they start to feel better, doctors and health workers prescribe the wrong treatment regimens or the drug supply is unreliable. From a public health perspective, poorly supervised or incomplete treatment of TB is worse than no treatment at all. When people fail to complete standard treatment regimens, or are given the wrong treatment regimen, they may remain infectious.

Hepatitis B

- Definition: An inflammation of the liver
- Causes: In the general population, hepatitis B is considered primarily a sexually-transmitted disease. It is also transmitted in blood and, prior to the availability of hepatitis B vaccine, health care professionals such as doctors and nurses were at risk for contracting hepatitis B. Because it is very easily transmitted by blood (one virus particle can cause disease), intravenous drug users who share needles and syringes are at extremely high risk. The other common mode of transmission is from hepatitis B infected mothers to the fetus prior to birth.
- Effects & Symptoms: Hepatitis B is one of the major diseases of mankind and is a serious global public health problem. Of the 2 billion people who have been infected with the hepatitis B virus (HBV), more than 350 million have chronic (lifelong) infections. The risk of death from HBV-related liver cancer or cirrhosis is approximately 25% for persons who become chronically infected during childhood. Hepatitis B has a long incubation period, occasionally taking up to 6

months to manifest itself. Early symptoms may be a variety of skin rashes and achy joints. Systemic symptoms include fever, malaise, and abdominal pain or discomfort. Ultimately the yellow color of jaundice appears, first in the whites of the eyes and then the skin.

- Treatment & Prevention: There is no specific treatment for acute hepatitis. Rest is recommended during the acute phase of the disease when the symptoms are most severe. In industrialized countries, surgery and chemotherapy can prolong life up to a few years. Chronic hepatitis B in some patients is treated with drugs called *interferon* or *lamivudine*, which can help some patients. However, *interferon* or *lamivudine* therapy costs thousands of dollars and will never be available to most patients in developing countries. It is preventable with safe and effective vaccines that have been available since 1982.

Public housing

From Wikipedia, the free encyclopedia

Public housing may be a form of housing tenure in which the property is owned by a government authority, which may be central or local. **Social housing** is an umbrella term referring to rental housing which may be owned and managed by the state, by non-profit organizations, or by a combination of the two, usually with the aim of providing affordable housing. Social housing can also be seen as a potential remedy to housing inequality. Some social housing organizations construct for purchase, particularly in Spain and to an extent elsewhere.

Although the common goal of public housing is to provide affordable housing, the details, terminology, definitions of poverty and other criteria for allocation vary within different contexts.

A typical public housing complex in Tseung Kwan O, Hong Kong. The Kin Ming Estate consists of 10 housing blocks, providing affordable housing for approximately 22,000 people. Nearly half of Hong Kong's 7.8 million population lives in public housing.[1]

A local authority 20-storey tower block in Cwmbran, South Wales

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History

The origins of municipal housing lie in the dramatic urban population increase caused by the Industrial Revolution of the 19th century. In the large cities of the period, many social commentators, such as Octavia Hill and Charles Booth reported on the squalor, sickness and immorality that arose. Henry Mayhew, visiting Bethnal Green, wrote in the *The Morning Chronicle*:

> ... roads were unmade, often mere alleys, houses small and without foundations, subdivided and often around unpaved courts. An almost total lack of drainage and sewerage was made worse by the ponds formed by the excavation of brickearth. Pigs and cows in back yards, noxious trades like boiling tripe, melting tallow, or preparing cat's meat, and slaughter houses, dustheaps, and "lakes of putrefying night soil" added to the filth.[2]

Some philanthropists began to provide housing in tenement blocks, and some factory owners built entire villages for their workers, such as Saltaire in 1853 and Port Sunlight in 1888. It was in 1885, after the report from a Royal Commission in England, that the state first took an interest. This led to the Housing of the Working Classes Act of 1885, which empowered Local Government Boards to shut down unhealthy properties and encouraged them to improve the housing in their areas.

Boundary Street 1890, three years later, the London County Council began slum clearance

The City of London Corporation built tenements in the Farringdon Road in 1865,[3] and the world's first large-scale housing project[4] was also built in London, to replace one of the capital's most notorious slums – the Old Nichol.[5] Nearly 6,000 individuals were crammed into the packed streets, where one child in four died before his or her first birthday. Arthur Morrison wrote the influential *A Child of the Jago*, an account of the life of a child in the slum, which sparked a public outcry. Construction of the Boundary Estate was begun in 1890 by the Metropolitan Board of Works and completed by the recently formed London County Council in 1900.[6]

The success of this project spurred many local councils to embark on similar construction schemes in the early 20th century. The Arts and Crafts movement and Ebenezer Howard's Garden city ideas led to the leafy London County Council cottage estates such as firstly Totterdown Fields and later Wormholt and Old Oak. The First World War indirectly provided a new impetus, when the poor physical health and condition of many urban recruits to the army was noted with alarm. In 1916, 41% of conscripts were unfit to serve. This led to a campaign known as *Homes fit for heroes* and in 1919 the Government first compelled councils to provide housing, helping them to do so through the provision of subsidies, under the Housing Act 1919.[7] Public housing projects were tried out in some European countries and the United States in the 1930s, but only became widespread globally after the Second World War.

Americas

Brazil

Construction of social housing in Campo Grande, Brazil using aluminum concrete formwork

Minha Casa Minha Vida (My House, My Life), the Brazilian government's social housing program, was launched in March 2009 with a budget of R$36 billion (US$18 billion) to build one million homes.[8] The second stage of the program, included within the government Growth Acceleration Program (PAC – Programa de Aceleração do Crescimento) was announced in March 2010.[9] This stage foresees the construction of a further two million homes.

Of the total 3 million homes, 1.6 million are for families earning between 0 and 3 times the monthly minimum wage (R$545); 1 million homes are allocated to families with salaries between 3 and 6 times the monthly minimum wage; and the remaining 400,000 homes are for families earning between 6 and 10 times the monthly minimum wage. All funds for Minha Casa Minha Vida properties are provided by the Brazilian public bank, Caixa Econômica Federal.[10] The bank finances development and provides mortgages for qualifying families.

In April 2011, the Minister for Planning, Miriam Belchior announced that one million homes were contracted for the Minha Casa Minha Vida in 2010 and that 500,000 homes would be delivered in 2011. The government budget for the programme was R$39 billion in 2010 and R$40.1 billion in 2011.[11]

Canada

In Canada, public housing is usually a block of purpose-built subsidized housing operated by a government agency, often simply referred to as **community housing**, with easier-to-manage town houses. Canada, especially Toronto, still maintains large high-rise clustered developments in working-class neighborhoods, a system that has fallen into disfavour in both the UK and US. However,

Toronto Community Housing, the second largest public housing agency in North America, has a variety of buildings and communities ranging from individual houses to townhouse communities and mid-rise and high-rise apartments in both working-class and middle-class neighborhoods. They house low-income Canadians.

Moss Park in Downtown Toronto

Following the decentralisation of public housing to local municipalities, Social Housing Services Corporation (SHSC) was created in the Province of Ontario in 2002 to provide group services for social housing providers (public housing, non-profit housing and co-operative housing). It is a non-profit corporation which provides Ontario housing providers and service managers with bulk purchasing, insurance, investment and information services that add significant value to their operations.

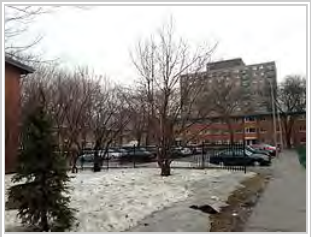
Habitations Jeanne-Mance in Downtown Montreal

Recently, there has been a move toward the integration of public housing with market housing and other uses. Revitalization plans for properties such as in the notorious Downtown Eastside of Vancouver, and Regent Park, Lawrence Heights, and Alexandra Park in Toronto, aim to provide better accommodations for low-income residents, and connect them to the greater community. In Toronto, for instance, the aims of the reconstruction plans of Regent Park are to better integrate it into the traditional grid of streets, improve leisure and cultural amenities, and construct mixed-income buildings. However, the residents of these communities have had little effective input in the plans and have had mixed reactions to the construction.

In 2014, the City of Vancouver, long considered one of the least affordable cities in the world,[12] changed the definition of social housing to mean rental housing in which only 30 percent of dwelling units need to be occupied by households that don't have the income to be able to pay market rents.[13]

Mexico

Multifamiliar Miguel Aleman

At the end of the Second World War, enriched by US investments and an oil boom, Mexico had its first demographic boom, in which the primary destination for rural immigrants was Mexico City. Mario Pani Darqui, a famous architect at time, was charged to build its first big scale projects. Built for the Dirección de Pensiones Civiles y Retiro (the National Pensions office, today ISSSTE), the Centro Urbano (or Multifamiliar) Miguel Alemán (1947–50) and the Centro Urbano (or Multifamiliar) Benito Juárez (1951–52), both in the Colonia Roma, introduced formal ideas from Le Corbusier's Ville Radieuse into the urban fabric.

His later project, the Conjunto Urbano Tlatelolco Nonoalco built in 1960–65, was meant to develop one of the poorest parts of the city, Santiago Tlatelolco, which was becoming a slum. Unfortunately, after a while, instead of giving the residences to the previous residents of Tlatelolco, corruption took place and most of the dwellings were handed to state employees.

During the earthquake of 1985 both the Benito Juárez and Nonoalco-Tlaltelolco complexes suffered major damage, with some buildings collapsing. Today most of the Multifamiliar Benito Juárez has been demolished.

But after all, Mexico has had experience of housing projects since Porfirio Díaz's regime, one of those, still remains and is the Barrio of Loreto in San Ángel, Álvaro Obregón, D.F., that was a project for a paper factory workers.

Puerto Rico

United States

In the nineteenth and early twentieth centuries, government involvement in housing for the poor was chiefly in the introduction of buildings standards. New York City's First Houses, dedicated in 1935, were the nation's first public housing project.[14] Most housing communities were developed from the 1930s onward and initial public housing was largely slum clearance, with the requirement insisted upon by private builders that for every unit of public housing constructed, a unit of private housing would be demolished.

This also eased concerns of the establishment by eliminating or altering neighborhoods commonly considered a source of disease, and reflected progressive-era sanitation initiatives. Moreover, public housing along with the Federal Highway Program demolished the older, sub-standard housing of communities of color across the United States.

However, the advent of makeshift tent communities during the Great Depression caused concern in the Administration. Public housing in its earliest decades was usually much more working-class and middle-class and white than it was by the 1970s. Many Americans associate large, multi-story towers with public housing, but early projects were actually low-rise, though Le Corbusier superblocks caught on before World War II.

The 20-story John F. Hylan Houses in the Bushwick section of Brooklyn, New York City

A unique US public housing initiative was the development of subsidized middle-class housing during the late New Deal (1940–42) under the auspices of the Mutual Ownership Defense Housing Division of the Federal Works Agency under the direction of Colonel Lawrence Westbrook. These eight projects were purchased by the residents after the Second World War and as of 2009 seven of the projects continue to operate as mutual housing corporations owned by their residents. These projects are among the very few definitive success stories in the history of the US public housing effort.

There are also many New York City Housing Authority (NYCHA) efforts that have provided in-demand and inexpensive public housing for decades, see "Public Housing That Worked: New York in the Twentieth Century" by Nicholas Dagen Bloom for a rigorous examination of the U.S. public housing management agency with the country's most extensive holdings. Bloom's "Public Housing" dispels common U.S. public housing myths while detailing advances made by NYCHA, see also NYCHA's own website "Fact Sheet" [3] (http://www.nyc.gov/html/nycha/html/about/factsheet.shtml) for elucidation of the magnitude and scope of their work since 1934.

Public housing was only built with the blessing of the local government, and projects were almost never built on suburban greenfields, but through regeneration of older neighborhoods. The destruction of tenements and eviction of their low-income residents consistently created problems in nearby neighborhoods with "soft" real estate markets. Houses, apartments or other residential units are usually subsidized on a rent-geared-to-income (RGI) basis. Some communities have now embraced a mixed income, with both assisted and market rents, when allocating homes as they become available.

The federal Housing and Urban Development (HUD) department's 1993 HOPE VI program addressed concerns of distressed properties and blighted superblocks with revitalization and funding projects for the renewal of public housing to decrease its density and allow for tenants with mixed income levels.[15][16] Projects continue to have a reputation for violence, drug use, and prostitution, especially in New Orleans, New York City, Philadelphia, Los Angeles, Chicago, and Washington, D.C. as well as others leading to the passage of a 1996 federal "one strike you're out" law, enabling the eviction of tenants convicted of crimes, especially drug-related, or merely as a result of being tried for some crimes.[17]

Other attempts to solve these problems include the 1974[18] Section 8 Housing Program, which encourages the private sector to construct affordable homes, and subsidizes public housing. This assistance can be "project-based", subsidizing properties, or "tenant-based", which provides tenants with a voucher, accepted by some landlords.

Asia

China

In mainland China, the government provides public housing through various sources, such as new housing, abandoned properties, and old flats which are rented at a low price and called 'Lian Zu Fang' (literally 'low-rent house' or 'low-rent housing', Chinese: 廉租房). Additional housing is built by providing free land and exemption from fees to estate developers: the resulting houses are called 'Jing Ji Shi Yong Fang' (literally 'the economically applicable housing', Chinese: 经济适用房).

The concept of the low-cost rental housing can be traced to a 1998 policy statement, but did not truly take off until 2006 due to limited funding and administrative problems. The provision of more affordable housing is one of the key components of China's Twelfth Five-year Plan, which targets the construction of 36 million homes by 2015. That program's costs will be split between the private and public sector and are estimated at five trillion yuan by Chinese investment bank CICC.[19]

Hong Kong

In Hong Kong, public housing is one of the major housing policies of the government. Nearly half of Hong Kong's 7.8 million population lives in public housing.[1]

Japan

Singapore

Clague Garden Estate, a public housing estate in Tsuen Wan

In Singapore, the public housing program, particularly the planning and development of new public housing and the allocation of rental units and resale of existing ownership units, is managed by the Housing and Development Board. Day-to-day management of public housing communities has largely been delegated to Town Councils headed by the local members of parliament.

Most of the residential housing developments in Singapore are publicly governed and developed. Most of the residents in public housing are tenants under a 99-year lease agreement.

Europe

Austria

Karl Marx-Hof, classical public housing in Vienna

Public housing was an important issue right from the foundation of the Republic of German-Austria in 1918. The population was faced with a great deal of uncertainty particularly as regards food and fuel. This led to a significant number of less affluent people to move to the perifery of towns, often building makeshift homes to be closer to where they could grow food. They were called *Siedler* (settlers). As the political situation became stabilised with foundation of the First Austrian Republic in September 1919, the Siedler movement started creating formal organizations like the Austrian Association for Settlements and Small Gardens.[20] The electoral victory of the Social Democratic Party of Austria in the elections for the Viennese *Gemeinderat* (city parliament) gave rise to Red Vienna. Part of their programme was the provision of decent homes for the Viennese working class who made up the core of their supporters. Hence the German word *Gemeindebau* (plural: *Gemeindebauten*) for "municipality building". In Austria, it refers to residential buildings erected by a municipality, usually to provide low-cost public housing. These have been an important part of the architecture and culture of Vienna since the 1920s.

Denmark

In Denmark, public housing is called *Almennyttigt Boligbyggeri* and is owned and administered by app. 700 self-governing, democratic and non-profit organizations by and for the tenants themselves. Many of the public housing organizations in Denmark are rooted in the early history of the labor unions and currently forms about 20% of the total housing stock with c. 7.500 departments countrywide. A membership of a housing organization is usually required to obtain a rental and they are granted with regard to length of membership.[21][22]

Although the buildings are owned and administered by self-governing and economically independent organizations, the State of Denmark is strongly regulating public housing in the country. By law, the municipalities have access to 25% of the rentals, usually reserving them for the poor, the unemployed, the disabled or mentally ill or any other group dependent on social benefits from the municipality. Over the years, these regulations has created many 'especially vulnerable residential areas' – socalled "ghettos" – within the country. The Danish Public Housing has never had any income restrictions, but in recent years new state regulations has made it mandatory for several of them to favor fully employed renters and disfavor unemployed or part-time employed people. This is a relatively new effort by the state to counter the ghettofication, which is now an officially recognized problem countrywide.[21][22]

As in Sweden, state and municipal policies carried out throughout the first decade of the 21st century, has led to an increased privatization of public housing. In many areas, residents have been offered to buy their own flats, thereby effectively changing the status of the property. The privatization of public housing was initiated as part of an ideological program by the right wing governments of the early 21st century and was launched a few years after the closure of the former Ministry of Housing Affairs in 2001.[23] The former ministry was re-opened as Ministry of Housing, Urban and Rural Affairs in October 2011, when a new coallition government led by social-democrats was formed.[24][25]

Finland

The earliest public housing project in Finland was in Helsinki. In 1909, four wooden houses designed by the architect A. Nyberg were built on Kirstinkuja (formerly Kristiinankatu) for the city's workers. The residents were mainly working-class families with several children. The apartments had an average of five people per room, sometimes up to eight. The tiny apartments were equipped with running water, a pantry and an attic cupboard. Every apartment had its own toilet in the cellar. Electric lighting was installed in 1918.

The homes and lives of worker families in Helsinki from 1909 to 1985 are presented in a museum near the Linnanmäki amusement park.

France

Public housing of the rue Jean Fautrier in the 13th arrondissement of Paris, France

After World War II, the population increased at a rate previously unknown, the rural exodus increased, while war damage had reduced the number of houses in many cities. Rental prices dramatically rose, and the government made a law in 1948 to block them, effectively ending the economic benefits of housing investment. Rents were gradually deregulated until debate in the 1980s led to the current rental law of 1989 theoretically balancing landlord and tenant relations. However, there was a major homelessness crisis in the winter of 1953–3 and the necessary laws were gradually mobilized producing high levels of construction almost continuously from the 1960s. Social landlords were a major source of expertise as well as construction actors with links to national and local bodies.[26] The construction industry was at the time inadequate so political support was needed

It is incorrect to refer to French social housing as public housing. The origins of French social housing lie in the private sector, with the first State aid provided to limited-profit companies by the loi Siegfried in 1793. The originally socialist idea was promoted by some French employers in the 2nd half of the 19th century. Public housing companies followed before the Great War.[26] There are still different social housing movements, public, private and some cooperative. Social landlord organizations all have similar regulation and similar access to government loans but there are significant differences<Much is found in the Code de la Construction et de l'Habitation (the Building and Housing Code), Book IV (with social housing allocation and funding elsewhere in the Code). The original objective of these organizations was to provide homes for purchase by installments and about one third of their construction is still for purchase. There are a great many statistics and information about current access and funding on the Ministry of Housing Website: http://www.territoires.gouv.fr/logement-et-hebergement for access. There are now also a number of joint venture public-private companies.

The government launched a series of major construction plans, including the creation of new towns ("villes nouvelles") and new suburbs with HLM (*Habitation à Loyer Modéré*, "low-rent housing"). The state had the funds and the legal means to acquire the land and could provide some advantages to the companies that then built its huge housing complexes of hundreds of apartments. Quality was also effectively regulated, resulting in decent or even top quality housing for the standard of the 1950s and 1960s. The construction of HLMs were subject to much political debate. Much smaller developments are now the norm. This housing is now generally referred to as 'l'habitat social' a slightly wider sphere than just housing.

France still retains this system, a recent law making it an obligation for every town to have at least 20% HLM. Nowadays HLM represents roughly half of the rental market (46% in 2006).[27] Social housing is not all for disadvantaged people who are just one of the target groups. Part of the funding can be provided by employer-employee groups to provide housing for local employees. The 20% target can include intermediate housing for better off groups, although its object is to produce social mix.[28] Gentrification and the very basis of social housing allocation are divisive issues as well as the extent of local control of housing.[29] This housing has always been a multi-actor activity and recent local government reorganization continues to change the political landscape.

While they succeeded in giving lower-income families a place to live in the drive to provide popular housing, this system also led to the creation of suburban ghettos, with a problem of disrepair. There has been a long-term problem of gradual impoverishment of social tenants[30] There, deprived strata of the population, mostly of immigrant origin and suffering massive under-employment, might in the past have been left to simmer away from the more affluent urban centres, sometimes becoming rife with social tensions and violence. This affects a minority of social housing but has a high profile and still produces serous tension.

Tackling this problem at its roots is all but simple, and social mix policies can break up populations seen as difficult by redevelopment. This has not had the hoped for results. It has also been sought to resolve the problem of access to the system by disadvantaged people by a new system where certain groups can apply to court to be housed if refused, the 'right to housing'. This

tends to intensify the controversy over social housing allocation, who should be housed.[31] The French tradition of 'universal' social housing allocation – housing for everyone is called into question by EU competition rules restricting subsidy except for the disadvantaged. In any event, the system is certainly effective in producing construction, although not with the excesses seen in the recent credit crunch elsewhere.

Germany

Between 1925 and 1930 Germany was the site of innovative and extensive municipal public housing projects, mostly in Berlin, Hamburg, Cologne and Frankfurt am Main. These *Siedlungen* (settlements), were made necessary by the dreadful living conditions of pre-war urban tenements. The right to a healthy dwelling was written into the 1919 Weimar Constitution, but few dwellings were built until economic stability in 1925.

These settlements were low-rise, no more than 5 stories, and in suburban settings. Residents were provided access to light, air, and sun. The size, shape, orientation and architectural style of Germany's public housing were informed by the recent experience of the Vienese and the Dutch, the anti-urban Garden City Movement in Britain, by new industrialized mass-production and pre-fabrication building techniques, by the novel use of steel and glass, and by the progressive-liberal policies of the Social Democrats.

Architect Martin Wagner (with Bruno Taut) was responsible for the thousands of dwellings built in and around Berlin, including the Horseshoe Siedlung (named for its shape), and Uncle Tom's Cabin Siedlung (named for a local restaurant). But Wagner was second to the city planner Ernst May in Frankfurt. May was responsible for the construction of 23 separate settlements, 15,000 total units, in five years. He ran his own sizable research facility to investigate, for instance, air-flow in various floorplan configurations, construction techniques, etc. The Austrian architect Margarete Schütte-Lihotzky applied the principles of Taylorism to the kitchen workspace and developed the Frankfurt kitchen while working for Ernst May.

Bruno Taut, Uncle Tom's Cabin Estate, Wilskistrasse, Berlin.

Beyond technical research May also published two magazines and embarked on a significant public-relations project, with films and classes and public exhibitions, to make *Neues Bauen* acceptable to the public. In the late 1920s the principles of equal access to "Licht, Luft und Sonne" (light, air and sun) and the social effects of a guaranteed "Existenzminimum" became a matter of lively popular debate all over Germany. One indirect result of this publicity was the American housing movement: a young Catherine Bauer attended one of May's conferences in 1930, and wrote her seminal "Modern Housing" based on research done in Frankfurt and with Dutch architect JJP Oud.

Berlin-Marzahn, the largest East German *Neubaugebiet* (*"New development area"*), 1987

Increasing pressure from the rising Nazis brought this era to an end in 1933. A majority of the German public housing experts had Social Democrat or Communist sympathies and were forced out of the country.

In East Germany, Communist administration saw the rise of the Plattenbau ("panel building"). Virtually all new residential buildings since the 1960s were built in this style, as it was a quick and relatively cheap way to solve the country's severe housing shortage, which had been caused by wartime bombing raids and the large influx of German refugees from further east.

There were several common plattenbau designs. The most common series was the P2, followed by the WBS 70. the WHH GT 18, and Q3A. The designs were flexible and could be built as towers or rows of apartments of various heights.

Hungary

Panelház (short form: *panel*) is the name of a type of block of flats (panel buildings) in Hungary. It was the main housing type built in the Socialist era. From 1959 to 1990 788,000 panel flats were built in Hungary. About 2 million people, about one fifth of the country's total population, live in these flats. The Hungarian and local municipalities began a renovation program during the 2000s. In the program they have insulated these buildings, replaced the old doors and windows with multi-layer thermo glass, renewed the heating system and colored the buildings in a more pleasant way.[32]

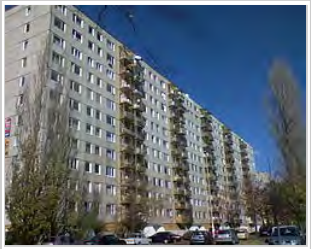
Panelház in Budapest-Kispest.

Ireland

In Ireland, public housing and halting sites (sites used by semi-nomadic Traveller communities) have been built by local authorities and are known as Local Authority Accommodation. Dublin Corporation and the former Dublin County Council provided the lion's share of Irish local authority housing, with County Longford having the largest ratio of local authority to private housing in the state. The government has promoted tenant purchase on favourable terms, and many former social housing areas are now completely or almost completely privately owned. Housing associations now play a significant role in social housing provision. As the Irish state's ability to borrow is diminished government policy favours an increased role for private financing of housing associations instead of capital grants for local authorities.

Netherlands

In the Netherlands, the rent for the cheaper rental homes is kept low through governmental oversight and regulation. These types of homes are known as *sociale huurwoningen*.

In practice this is accomplished by non-profit private housing foundations or associations (*toegelaten instellingen*). Due to frequent mergers the number of these organizations dropped to around 430 (2009). They manage 2.4 million dwellings. The majority of the low-rent apartments in the Netherlands are owned by such organisations. Since the policy changed in 1995 the social housing organizations have become financially independent focusing on their role as social entrepreneurs. In most Dutch municipalities there came to exist a certain minimum capacity of social housing throughout the last decades. In many cities such as Amsterdam, The Hague, Rotterdam and Utrecht the percentage of social housing approaches or even passes 50 percent. The public (financial) supervision is done by the central fund for housing (Centraal Fonds Volkshuisvesting).

The Dutch housing policy is based on a concept of universal access to affordable housing for all and the prevention of segregation.

Romania

The skyline of many Romanian cities became dominated by standardized apartment blocks under the former communist government's policy of tower bloc construction. Beginning in 1974, systematization consisted largely of the demolition and reconstruction of existing villages, towns, and cities, in whole or in part, with the stated goal of turning Romania into a "multilaterally developed socialist society". In 2012, 2.7 million flats date from the communist period, accounting for 37% of total housing in Romania and for about 70% in cities and towns. Subsequent to post-communist privatization, the homeownership rate in this form of housing reached of 99.9%.[33] The new Home Owner Associations (HOAs) were challenged internally by the cumulative effect of defaulting contributions, lack of affordability and the established practice of casual resident service in HOAs, which often triggered mismanagement. On the other hand, HOAs were challenged from outside by non-effective mechanisms to address their internal problems, such as non-existent fast court procedures against defaulting, poor financial assistance to socially disadvantaged households and a private sector unprepared to take on condominium management.[34]

Government built housing in Bucharest, Romania

Former Soviet Union

In the Soviet Union, most of the houses built after World War II were usually 3–5 stories high, with small apartments. In these boroughs, the goal was saving space and creating as many apartments as possible. Construction starting in the 1970s favored 9- and 16-story concrete panel municipal housing in major cities, 7–12 stories in smaller urban areas.

Spain

Spaniards' reluctance to home rental, and government spending cuts in the 1980s, reduced rented public housing in Spain to a minimum. Rented public houses were relatively common in the Franco era (1939–75). With the advent of democracy and the 1978 Constitution, the management of social housing depended mostly on the autonomous regions. This resulted in a wide variety of laws, which make the issue highly dependent on the region.

In spite of this, a scheme for *viviendas de protección oficial* (VPO) has been widely used, consisting of local councils allowing for building contractors and developers to build in public sites or with public loans on condition that a certain percentage of apartments remain subsidized and under control of the local authorities. This is known as *VPO de promoción privada* (*privately developed*), as opposed to the *VPO de promoción pública* (*publicly developed*), in which the whole property is owned and managed by a government authority.

Public housing, winner of an environmental design award, in El Astillero (Cantabria), Spain.

A new plan ("*Plan estatal español de vivienda y rehabilitación para el período 2009–2012*") was put forward by the Rodríguez Zapatero government, aiming to make near a million homes available for public housing, relying both on new construction and refurbishment of unused houses.

Sweden

The Swedish public housing is called 'Allmännyttigt bostadsföretag', which is mostly made out of flats owned by the local council. In difference towards its counterparts in for instance Great Britain, the Swedish Public Housing has never had any income restrictions. Instead, for large parts of the period between 1920–1990 (for instance, during the era of Million Programme), the public housing companies such as Svenska Bostäder were the major operators in housing projects as well as in projects aiming to acquire old and worn down buildings. Although not carrying out housing nor acquisitional projects in recent times, the policies lead to a ubiquitous presence of publicly owned buildings throughout the cities of Sweden, including attractive urban areas, with a rather wide range of income among the tenants.

Rebuilt Million Programme homes in Rinkeby (2009).

Policies carried out in the Swedish cities throughout the first decade of the 21st century have led to the tenants of public housing having bought the publicly owned buildings in which they live, which in turn has led to a significant decrease of publicly owned buildings in attractive urban areas, subsequently leading to an increased development of processes related to gentrification.

United Kingdom

In the United Kingdom public housing is often referred to by the British public as "council housing" and "council estates", based on the historical role of district and borough councils in running public housing. Mass council house building began in about 1920 in order to replace older and dilapidated properties.[7]

A variety of social housing in Salford, England

Housing was a major policy area under Wilson's Labour government, 1964 to 1970, with an accelerated pace of new building, as there was still a great deal of unfit housing needing replacement. Tower blocks, first built in the 1950s, featured prominently in this era. The proportion of council housing rose from 42% to 50% of the nation's housing total,[35] while the number of council homes built increased steadily, from 119,000 in 1964 to 133,000 in 1965 and to 142,000 in 1966.

Allowing for demolitions, 1.3 million new homes were built between 1965 and 1970.[36] To encourage home ownership, the government introduced the Option Mortgage Scheme (1968), which made low-income house buyers eligible for subsidies (equivalent to tax relief on mortgage interest payments).[37] This scheme had the effect of reducing housing costs for buyers on low incomes.[38]

Since the 1970s, non-profit housing associations have been operating an increasing share of social housing properties in the United Kingdom. From 1996 they have also been known as Registered Social Landlords (RSLs), and public housing has been referred to as "social housing" to encompass both councils and RSLs. Despite being non-profit based, RSLs generally charge higher rents than councils. However, the Government introduced a "rent re-structuring" policy in 2002, which aimed to bring council and RSL rents into line in England by 2012.[39] Local planning departments may require private-sector developers to offer "affordable housing" as a condition of planning permission (section 106 agreement). This accounts for another £700m of Government funding each year for tenants in part of the United Kingdom. As of 2012, Housing Associations are now also referred to as "Private Registered Providers of Social Housing" (PRPs).[40]

Local authorities have been discouraged from building council housing since 1979 following the election of Conservative leader Margaret Thatcher as prime minister. The Parker Morris standard was abolished for those that were built, resulting in smaller room sizes and fewer facilities. And the Right to Buy was introduced, resulting in the move of some of the best stock from public tenanted to private owner occupation.

Since the year 2000, "choice-based lettings" (CBL)[41] have been introduced to help ensure social housing was occupied speedily as tenants moved. This can still favour the local over the non-local prospective tenant. In a number of local authority areas, due to the shortage of council housing, three out of four properties may be designated for priority cases (those living in poor overcrowded conditions, with medical or welfare needs, or needing family support) or homeless applicants in order to meet the councils' legal

obligations to rehouse people in need. The percentage of properties set aside for vulnerable groups will vary dependent on the demand for council housing in the area. All local authorities have a Housing Strategy[42] to ensure that council houses are let fairly and fulfil the council's legal obligations; deal with people in need; and contribute to sustainability of housing estates, neighbourhood regeneration, and social inclusion.

1970s council housing in Haringey, North London.

The 1997–2010 Labour Government wished to move council housing away from local authority management. At first, this was through Large Scale Voluntary Transfers (LSVT) of stock from councils to Housing Associations (HAs). Not all council property could be transferred, as in some local authorities, their housing stock was in poor condition and had a capital value less than the remaining debts from construction costs—in effect, the council stock was in negative equity.[43] In some local authority areas, the tenants rejected the transfer option.[44]

The Labour Government introduced a "third way": the Arms Length Management Organisation (ALMO), where the housing stock stays with the Local Authority but is managed by a not-for-profit organisation at arm's length from the Local Authority. It also introduced the Decent Homes programme, a capital fund to bring social housing up to a modern physical standard. To use this fund, the manager, whether ALMO or HA, had to achieve a 2 or 3 star rating from its inspection by the Audit Commission.[45] This was intended to drive up management standards. Council landlords cannot access this funding, another incentive to transfer management of council housing to an ALMO or HA.

Governments since the early 1990s have also encouraged "mixed tenure" in regeneration areas and on "new-build" housing estates, offering a range of ownership and rental options, with a view to engineering social harmony through including "social housing" and "affordable housing" options. A recent research report[46] has argued that the evidence base for tenure mixing remains thin. Social housing occupants may be stigmatised and forced to use a poor door that is separate and less convenient than the door the unsubsidised occupants use and social housing may be less desirably situated.[47]

Most UK social housing tenants have the right to swap homes with another tenant even if their landlords are different. This is called a "mutual exchange".

Oceania

Australia

Public housing high-rise in Collingwood, one of 40–45 such buildings in Melbourne

Public housing in Australia is provided by departments of state governments, with funding provided by both the state and federal government. There are over 300,000 public housing dwellings in Australia, consisting of low-density housing on master-planned estates located in suburban areas, and also inner-city high-rise apartments in Melbourne and Sydney.

In recent decades, rooming and relief housing for the homeless has been privatised, and in recent years this housing has been sold off to avoid maintenance costs and capitalise on sales in a booming property market. In Melbourne, public housing stocks have been in decline for some time, sparking the recent Bendigo street housing campaign in which homeless people are being housed by the community campaign in homes left empty by the state government.

New Zealand

Private companies (such as the New Zealand Company) which fostered early organised European settlement in New Zealand constructed immigration barracks to serve as temporary accommodation for their new arrivals.[48]

The Workers' Dwellings Act of 1905 resulted in the Government of New Zealand commissioning the building of 646 houses.[49]

In 1937 the First Labour Government launched a major public-housing system - it became known as "state housing" - for citizens unable to afford private rents. Most state housing built between 1937 and the mid-1950s consisted of detached 2-to-3-bedroom cottage-style houses; only 1.5% of state houses in 1949 formed part of apartment blocks, all of them in Auckland or in greater Wellington. After World War II ended in 1945, most local authorities also started providing social housing, mainly for elderly people with low incomes.

See also

- Fuggerei (The world's oldest social housing complex still in use.)
- Welfare state

Unlike many other countries, much New Zealand state housing of the 20th century was in the form of detached single-family houses similar to private housing. This is a 1947 development in Oranga, Auckland.

Wikimedia Commons has media related to ***Public housing***.

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Categories: Public housing | House types | Social programs | Urban renewal

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November 1979

The Hague, The Netherlands

Public Standpost Water Supplies

13

Technical Paper Series

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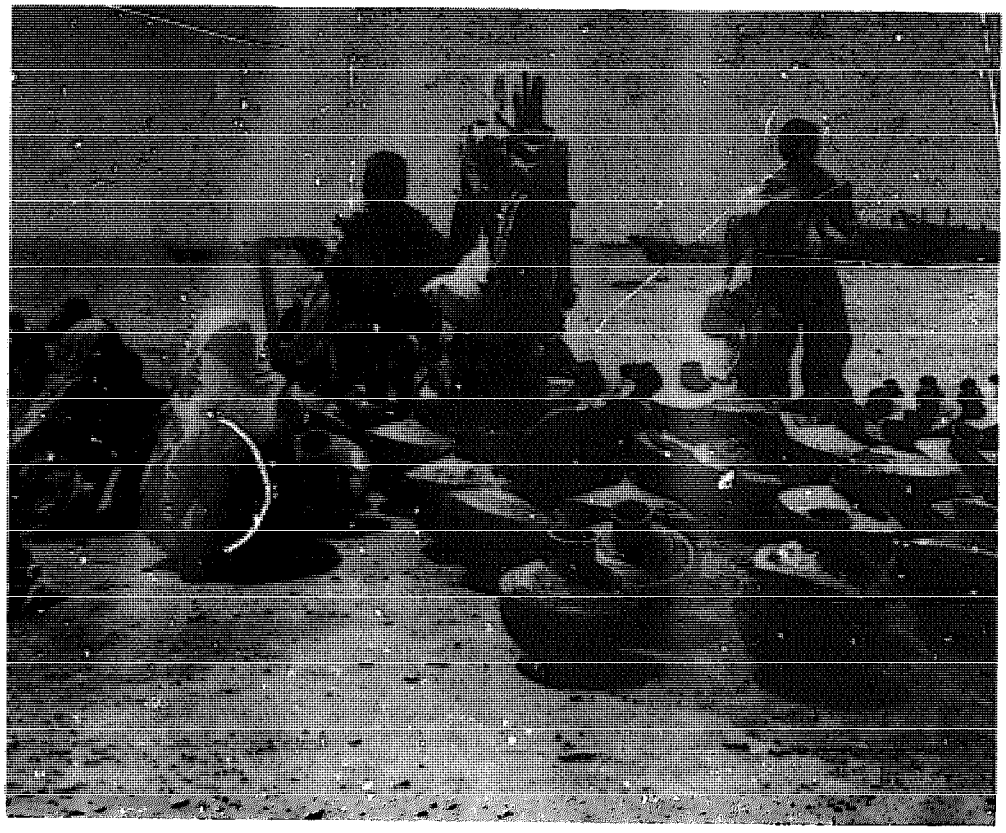

WATER COLLECTION

PREFACE

Recognizing the fundamental importance of water supply and sanitation in the promotion and socio-economic development, member countries of the United Nations Organizations have declared the period 1981 - 1990 as the International Drinking Water and Sanitation Decade. The goal is to provide all people with an adequate supply of safe water and sanitary disposal of human excreta by the end of the Decade. If this goal is to be achieved, some two billion (2 000 000 000) people should be provided with water by the end of the Decade at an estimated cost of about 60 billion dollars, based on existing per capita costs. With this estimate it can be anticipated that cost is likely to be one of the major constraints in the achievement of the Decade targets. It is therefore imperative that the visions of the best but costly options of water supply are not allowed to distract communities from the attainable. Undoubtedly, each community would have liked to be provided with pipe-borne water supply with full house connection. Yet for most communities in the developing countries this would be unaffordable. For many a community the affordable and realistic solution which would be at the same time technically sound would be the public standpost water supply system. As a guide for the proper planning of such systems the present publication would be invaluable.

It used to be assumed that the provision of a community with an adequate and safe water supply would, by itself, be followed by certain health and socio-economic benefits. But the evaluation of some water supply projects has shown that such expected benefits do not necessarily follow becuse due to socio-cultural and managerial problems, the installed water supplies may not be used as anticipated. The present publication seeks to provide the reader with the necessary guidance for overcoming such problems.

It provides insights not only into the economic and financial aspects of the planning of public standpost systems, but also into its social, organizational and managerial aspects. It also deals with community participation in technology selection, operation and maintenance. This is, in effect, a publication on the software of public standposts. The hardware is treated more extensively in the companion volume entitled "Design Manual" (IRC Technical Paper No. 14).

The present publication will be of particular interest to decision makers, planners, administrators, public health workers and engineers responsible for the planning and implementation of public standpost water supplies.

ALBERT WRIGHT

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Enric L.P. Hessing
Programme Officer

PUBLIC STANDPOST WATER SUPPLY

SUMMARY

Public standposts are often installed as a first step in the development of a full house-connected water supply. For many people in developing countries, however, a public standpost could well be the only feasible water supply for a long time to come; particularly in rural areas, where scattered housing makes individual connections extremely expensive, and in low-income urban fringe areas, where little revenue can be expected in return for public services.

In the planning of public standpost water supplies, many technological, economic, organizational and socio-cultural aspects have to be taken into account, in conjunction with each other. The interrelationships between the organizational structure, the choice of technology, the financing and revenue collection, the operation and maintenance, community participation and local organization, requires an integrated approach towards the planning of public standpost water supplies.

The decision to install public standposts is largely determined by economic and financial considerations. However, many other factors influence the decision as well, and a systematic analysis of all relevant factors is needed to determine what level of service is economically and socially appropriate.

The circumstances in which public standposts are commonly used may be summarized as follows:

- where funds for investment in water supplies are severely limited;
- in rural areas where house connections would require lengthy and expensive runs of pipe;
- in urban slums where improvements in housing are needed before individual house-connections are feasible.

Public standposts are economically appropriate mainly where investment funds are severly limited. The capital investment necessary to set up a public standpost water supply is considerably less than that required for a full house-connected supply, particularly when the size of the community served is smaller than 5000.
However, the cost per unit volume of water from public standposts is relatively high, due to the lower consumption rate per head. The total cost of a public standpost water supply varies greatly, depending on sources works, treatment and length of piping required. The cost of the standpost itself is a relatively small amount, but also varies greatly for different countries and situations. It ranges from US$ 20-50 for a very simple standpost used in rural villages, to US$ 200-500 for public standposts in urban settings.

To secure the necessary government or private investment cooperation, it is useful to reinforce health benefit and cost effectiveness arguments with a demonstration of the consumers' willingness to pay for the water and to contribute towards the cost of construction, operation and maintenance. Therefore, it is essential to establish a clear charging policy and to develop an appropriate method of revenue collection.
In many cases, a suitable arrangement could be to meet the costs partly from house connection charges and partly from a general water tax paid by all. Gradually extending the number of house connections, and thus the level of service to the community, will often have a positive influence on the financial viability of the system.

A water supply system has to fit into the community's social pattern, and therefore various socio-cultural factors, which often have a profound influence on the use of water have to be taken into account in the planning and design.

It is important that planners attempt to understand the users' point of view, their water needs, practices and preferences, and the community's social and organizational structure. These factors influence both the technical and organizational side of the design of a public standpost system.

Organization and management are essential elements of a water supply. The responsibility is often divided: planning and construction fall under a government department, while a local authority is responsible for operation and maintenance. The alternative is to have both planning and management governed by a unitary water authority, that also has a high degree of autonomy regarding finance. This agency should be responsible to the government and has to coordinate its activities with local and municipal authorities. A legal framework is always required to define the rights and responsibilities of the water authorities, the local committees and other agencies involved in the organization and management of the water supply system.

Operational management includes operation, maintenance, supervision, revenue collection, and liaison with the users.
It is important that maintenance organization includes regular inspection and preventive maintenance as well as repairs after breakdowns. Supervision is necessary where water is scarce, where there is a risk of vandalism and where water has to be paid for on the spot. Revenue collection, whether periodical, or per volume should be acceptable to the community. Open communication between the water agency and the community is of great importance in the planning, implementation and operation stage.

In general, there is a lack of trained technical and managerial personnel. The importance of the latter category is stressed. Training schemes should be set up for the whole range of skilled personnel required.

Organization and management should incorporate a strong element of community participation. Coordination of activities at local level and a continued dialogue with the population are essential. Depending on the extent of community participation and the local organizational pattern, strengthening of the formal community organization may be required.

The standpost itself is the interface between technology and human activities; it is the place where the hand of the user touches the hardware of the system. Therefore, in designing a public standpost, due attention has to be given to the habits and preferences of the users regarding fetching and use of water

Reasonable access to a standpost could be defined as a walking distance of less than 200 metres; in rural situations distances up to 500 metres may sometimes be acceptable. The number of persons served by any one standpost should preferably not exceed 250 and the number of users per tap should be in the range of 25 - 125.

The volume of water drawn daily from a public standpost is in the range of 20-60 litres per capita. The actual consumption depends not only on local habits concerning domestic water us, but also on the availability of other sources.

In many situations, a design period of 15-20 years would be suitable. The initial design should preferably make allowance for future upgrading of the system through the installation of more and more house connections.

Efficient drainage is essential. The simplest form is a soak-away drain under the tap, or next to the platform. Another possibility is a drainage channel to the platform leading to a discharge pipe. A further consideration might be to use the drainage water for cattle watering, irrigation or fish farming.

Wastage of water is often reported as one of the major problems of public standposts. However, measuring of wastage is difficult and when high figures are reported it may be assumed that these also include the leakage in the pipe network.
Some spillage is normal when buckets and cans are filled. The tap is often left open between fillings of two buckets. In some cases wastage is caused by carelessness on the part of the user, or by vandalism. The solution to the problem may lie in the improvement of public information and community organization, rather than in the installation of a sophisticated anti-waste tap.

Experiments and calculations have shown that the cost of a distribution system is affected much more by pipe lengths than by pipe diameters or the number of standposts. Therefore, the pipe network should be as short as possible. Frequently, this will result in branched networks. Provision for some extra capacity through the choice of wider pipes and the installation of extra standposts is usually a good investment.

I INTRODUCTION

A public standpost is a suitably supported water pipe, connected with a water distribution system and terminating in a tap or faucet, which is located at a public site, and from which water may be drawn for domestic and other uses. In other publications these installations are also referred to as: public standpipes, public hydrants, public fountains, public taps, public spigots or communal water points.

Many water supply agencies in urban areas regard public standposts as only an intermediate step in the development of a fully house-connected water supply. This policy arises partly from an awareness that the impact of water on health is much improved if people have at least one tap in their own homes; the water will then be used more freely and its quality better safeguarded. Another consideration is that payments for water are much easier to collect from people with household connections than from standpost users, consequently the former usually brings in more revenue.

However, for many people in many countries a public standpost could well be the only feasible method of water supply for a very long time to come. This is especially true in rural areas where scattered housing makes individual connections particularly expensive because of the long runs of pipe required. It is also likely to be the case in low-income urban fringe areas which yield little revenue in return for public services.

The *difficulties experienced in operating standposts* often arise from the way water supplies are managed, from inadequate technical design and from a shortage of resources. There are also problems relating to the institutional and organizational structure, particularly where several organizations are involved in water supply, and the boundaries defining their separate areas of responsibility are not clear. When this happens, some tasks may be duplicated and others entirely neglected. Public standposts also suffer from some of the same disadvantages as other public or communal services.

Most of the difficulties are caused by a combination of factors. Therefore, in solving the problems it is necessary to consider the situation as a whole. This may be illustrated by referring to the wastage of water at standposts. If taps are left open, it may simply be because users are careless, but it may also happen because the taps are difficult to turn, due to poor design or poor maintenance, or because the water supply is intermittent and when no water emerges from the tap, the users forget that it is open. Thus a solution to the problem of water wastage may depend on improvements in the technical design, or in management (e.g. improved maintenance), or in user education and local organization. In all probability, several of these improvements will need to be made simultaneously.

The key point to note here is that a public standpost, like any other water supply installation, is not simply an isolated piece of technical equipment, but is part of a system in which there is also a large component of organization and management. It is only by taking an integral view of the whole of this system that we can understand how to operate it successfuly.

Therefore, integral planning of all relevant factors is of crucial importance. From the technical point of view, installing a standpost presents no major difficulties. The problem is how to ensure for continued and proper use and maintenance, and for regular payments of water charges. The best chance of achieving these ends lies in *a careful consideration of all relevant aspects and their inter-relationships during the planning stage* (annex 1).

Against this background, various institutional, organizational, economic, financial, administrative, socio-cultural and technological aspects are discussed in the following chapters.
The institutional aspects include the relationships between central government departments, local and municipal authorities and community organizations. The organizational part comprises the function of the local waterworks staff and the work they do in operating and maintaining the standposts, as well as community participation in this work.
Users interact, formally as well as informally, with the institutional structure and the operational management through community water committees, standpost caretakers, revenue collection, maintenance arrangements, and the day-to-day use of the standpost.

Technological aspects interact with organizational and social aspects in many ways and good technical design of the standposts is of no avail, if the result is not compatible with the organizational and social structure. Therefore, special attention has to be given to the *various inter-relationships* which exist between the technological, organizational, economic and social aspects.

The technical "hardware" part of a public standpost water supply system comprises "upstream components", such as, the catchment, reservoir, treatment works and distribution pipes; and "downstream components", concerned with drainage and the disposal of water after use. The system is likely to serve some individual houses as well as standposts.

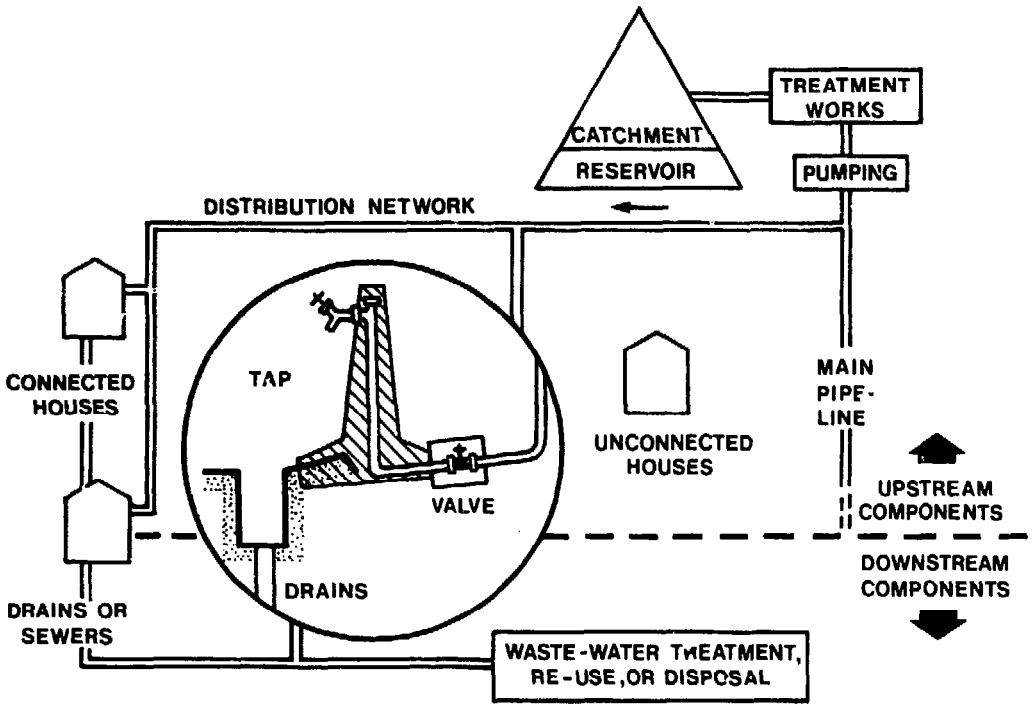

FIGURE 1: COMPONENTS OF STANDPOST WATER SUPPLY SYSTEM

Much of the engineering is likely to be based on standard practice for any type of piped water supply. These standard details are not discussed here, since the scope of this publication is limited to items directly related to public standposts

This publication is mainly directed to features peculiar to public standposts, such as:

(a) the service pipe with its valve, connecting the standposts to the main pipeline;

(b) the tap (faucet) or other water flow control mechanism;

(c) the structure supporting the tap, and the base unit;

(d) drainage of waste water from the standpost area.

In most respects, the service pipe, and indeed the network of supply pipes to which it is connected, need be no different from the pipes used in the system with house-connections. However, the choice of pipe diameters, and therefore supply capacity, greatly influences the economics of a standpost system.

It is evident that in particular the taps and the standpost-platform are of great importance to the whole system, because they represent the principal meeting place or *interface between technology and human activities*. This is the point where users make contact with the hardware, and where operational management must focus much of its efforts on maintenance and public information.

A water supply system is not an end in itself. It usually forms part of a broader programme of rural development, of slum upgrading, or of primary health care. This means that, in addition to the various aspects of the water supply programme itself, the activities in other sectors have to be taken into account as well. Coordination of the water programme with community development, health eduction, or irrigation and fish-farming projects, to name a few examples, will greatly enhance the benefits of all development activities.

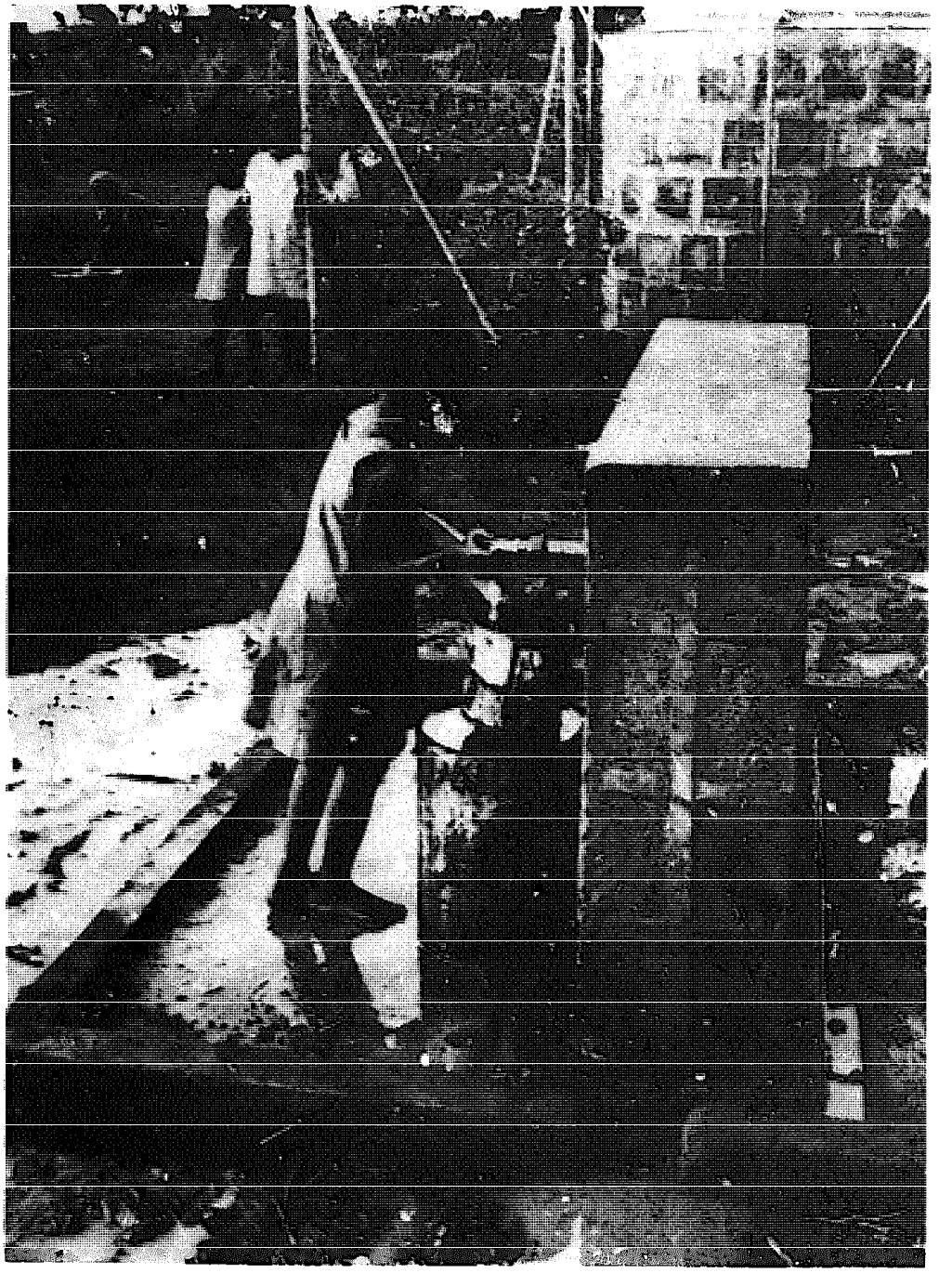

PUBLIC STANDPOST AND TAP AS INTERFACE BETWEEN USER AND TECHNICAL SYSTEM

II ECONOMICS AND FINANCE

GENERAL CONSIDERATIONS

Economic analysis can make an important contribution to the planning of public standpost water supplies in at least three ways. Firstly, before detailed design begins, study of the likely costs in relation to the number of people benefiting can help planners decide on the appropriate level of service. Then, once the service level has been fixed, further examination of capital and recurrent costs can assist in arriving at an optimal design. Finally, economic considerations must be brought to bear when tariff structures and rates are set.

The major benefits from standpost supplies, as compared to drawing water from a stream or open well, are better health, greater convenience and a saving of time. Intuitively, one expects that as the number of distribution points increases, so will the benefits. However, piped water from standposts can become contaminated at the standpost, or when being carried to the dwelling, or inside the dwelling (where it is not likely to be consumed immediately). The longer water is left outside the distribution system, the higher is the risk of contamination. For these reasons, it is not probable that public standpost systems will provide a high level of health benefits. To achieve the full health impact, public standposts will need to be replaced when financially feasible by a system with house connections. While funds remain limited however, standposts may represent the optimal solution.

Since many water-related diseases do not spread only through water but also through infected food and unsanitary living conditions, it is exceedingly difficult to isolate and quantify

the beneficial impact upon health of improved water supply only. Numerous studies bear witness to these difficulties. Even if it were possible to identify exactly what improvement in a community's state of health is due to a better water supply, the next step of putting a monetary value to this improved state of health faces insurmountable difficulties. Therefore, cost/benefit analysis of this type need not and should not be attempted.

Several studies have also demonstrated the crucial role of health education. Health benefits are best achieved when the population is instructed how to draw the water, how to transport it, and how to store it, and when they appreciate the value of more frequent washing. Therefore, public standpost water supplies should never be provided without a substantial educational effort. However, education does not come free, and there is an economic trade-off between the physical distribution facilities and the education campaign.

The planner's view of the economics of a standpost water supply will be strongly influenced by the quality and extent of the service he can provide within the available budget. Decisions about the most appropriate mix between house connections and standposts may be based upon cost-effectiveness considerations, as may decisions about the most appropriate level of water treatment. However, there are considerable problems in doing this, The total costs of the system must first be estimated - they comprise the sum of the capital and the recurrent costs over the system's economic life. Totalling the costs in this way involves assumptions about interest rates, and adjustments to take into account market imperfections, using a process known as "shadow pricing".

Rapid progress in the provision of water supply depends very much on the consumer's willingness and ability to pay for the water. Therefore, if justification for projects cannot be provided on cost/benefit grounds, the alternative may be to give future users the opportunity to show how they value an improved water supply

by paying for the service. Even in relatively poor rural areas "people may prefer to have, and to pay for, a water supply, than to have none at all". (Saunders and Warford, 1976).

COST OF STANDPOST SYSTEMS

A distinction is needed between the *capital investment costs* associated with design and construction, and the *recurrent costs* which cover operation, maintenance, interest payments, redemption, depreciation, and so on.

The capital investment necessary to set up a standpost water supply varies with the size and complexity of the scheme, and with local circumstances. As an indication, total capital costs for standpost systems are in the range US$ 10 - 30 per person served. These costs may include expenditure on source-works, treatment plant (or connection to an existing plant), pipelines, a storage tank, the distribution network, and of course, the standposts and house connections. It is difficult to generalise about the breakdown of total costs among these components, but often about half is required to pay for the distribution network and standposts.

This means that in general, the cost of the standposts themselves constitute a relatively small amount of the total capital costs. As an indication, a standpost with a concrete support construction, two to four taps and a platform with a drainage facility is likely to cost US$ 200 - 500. In contrast, a very simple standpost as used in many villages and rural areas costs as little as US$ 20 - 50. Assuming that at least one standpost is available for 100 - 200 persons, the cost of the standposts will ususally be in the range of 10-30% of the total costs. In comparison, about 30-40% of the total capital costs is normally invested in the pipe system. Careful design of the distribution network can save considerable sums.

The cost of pipes in a water distribution network depends on their length and diameter. The most commonly used equation for expressing the relationship between these factors, reads:

$$C = B_o.L.D^{B_1}$$

in which C = costs, L = Length, and B_o and B_1 are positive constants. B_1 usually has a value between 1 and 2 with 1.4 being typical, regardless of pipe materials, country, size of project, etc. The value B_o depends on the units of C, L and D as well as on construction conditions, pipe material, pipe size and so on. With C in US$ in 1978 prices, L in m, D in mm, pipe materials of PVC or asbestos cement (AC), and pipe sizes less than 150 mm, the value of B_o is usually between 0.01 and 0.2 with 0.03 being typical. If for example B_o = 0.03 and B_1 = 1.4, then 100 mm diameter pipe (supplied and installed) would cost about US$ 19 per m; 50 mm and 150 mm pipe would cost about US$ 7 and US$ 33 per m, respectively.

In a recent study commissioned by the World Bank, the length and average diameter of pipe in public standpost networks were examined in relation to several engineering design variables (Lauria, ed). The study revealed that the cost of a distribution network primarily varies with pipe length. Pipe length per person is essentially constant for a given population density and number of persons per standpost. For example, with 100 persons/ha and 50 persons/standpost required pipe length is about 1 m/person. Where population density is higher and/or the number of persons per standpost is greater, the length per person is less. The pipe diameter is quite insensitive to these design parameters; average pipe size of about 50 mm to 75 mm is adequate for most systems.

The main variable, then, that affects cost is length, and this depends upon population density and the average number of persons per standpost. Population density cannot be modified but the number of persons per standpost is a variable under the planner's control.

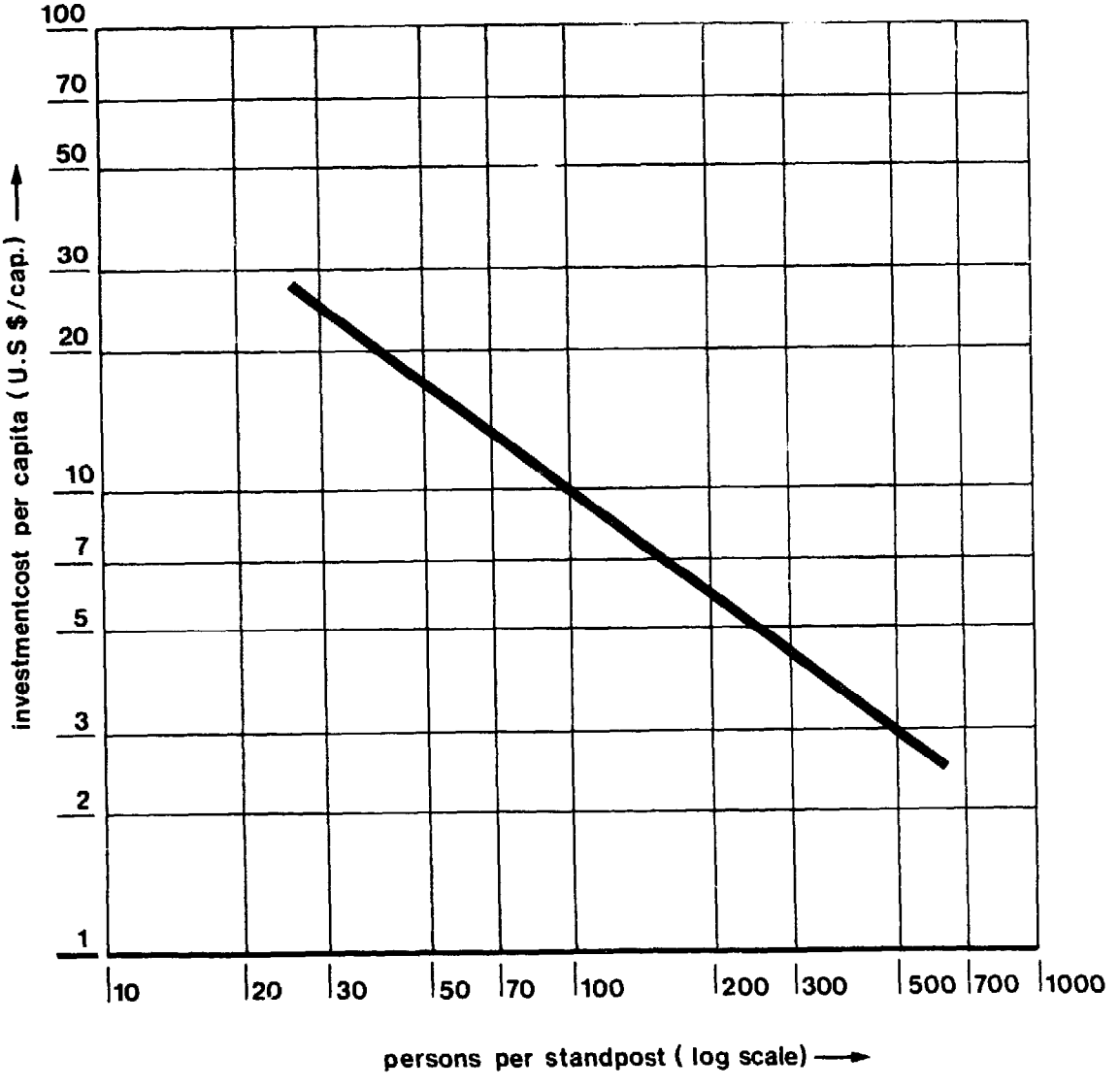

FIGURE 3: INDICATION OF NETWORK PLUS STANDPOST COST PER CAPITA VERSUS PERSONS PER STANDPOST (for given density = 200 persons/ha).

For an assumed density of, 200 persons/ha the variation in per capita cost with a number of persons per standpost (i.e., standpost spacing) is shown in Fig. 3. (This diagram assumes average pipe costs of US$ 10 per metre, and takes the cost of one standpost as US$ 500).

An application of Fig. 3 would be when one knows the number of people to be served and the investment funds available and needs to determine the number of persons per standpost. For instance, with 20 000 persons to be served within a given area with 200/ha density and with US$ 200 000 available, the maximum per capita investment cost is US$ 10. It follows from the graph that the number of persons per standpipe is 100 and the number of standposts should be about 200.

SELECTION OF DESIGN STANDARDS

In any standpost system, the major design variables include the number and spacing of standposts, the volume of water supplies per person, the minimum pressure to be maintained in the pipes, the amount of looping to be provided in the network and the minimum allowable pipe size. The principles used in selecting standards for these variables are essentially the same as those required in any standard-setting process: it is necessary to determine how costs and benefits change as the variable is assigned higher values.

However, because of the formidable difficulties in quantifying benefits, direct application of cost/benefit theory is impracticable. As an alternative, it is possible to determine the marginal costs of assigning increasingly higher values to the design variables, judgement can be used to decide whether they are justified by the increase in benefits.

Consider the design variable "volume of water suppied per person". A small increase in pipe size enables the network to deliver significantly larger flows. It appears then, that designers are entirely justified in choosing pipe sizes to allow for a relatively large consumption of water especially when anticipating future house connections.

The "minimum pressure" in the pipe network is another variable for which marginal costs are relatively small. An increase in this pressure can be arranged either by maintaining greater pressure at the source of supply, or by using larger diameter pipes (which will result in smaller pressure gradients). One or both of these modifications introduced at the design stage will add only slightly to the cost of construction. But since low service pressures can be a serious disadvantage through inconvenience to users and risks of contamination, an increase in minimum pressure can lead to quite large marginal benefits. This implies that designers should not hesitate to specify a 10-metre head of water (or more) as the minimum network pressure.

The spacing or number of standposts is a more difficult variable for which to set a standard. It has already been shown that the number of standposts significantly affects pipe length, which is a major determinant of cost. In addition, the cost of standposts themselves is significant. Thus, the marginal costs of increasing the number of standposts is relatively large. The benefits of closer standpost spacing are chiefly due to increased convenience. Health benefits probably remain small until water is actually piped into the house. It does not seem unreasonable to assume, however, that net benefits increase steadily with closer spacing, in which case the maximum number of standposts should be provided within available financing. A target of about 100 persons per standpost is frequently assumed, which appears to be a good starting point from which to investigate other numbers of users per standpost.

The amount of looping to be provided in the network is another design variable for which selection of a standard is difficult. Standpost networks can almost always be designed as branched systems in which case pipe length and cost is minimized. The advantage of loops is that system reliability is improved particularly in relation to breaks in pipes. The marginal cost of this improved reliability, however, is fairly high. The benefits due to closer standpost spacing probably outweigh those due to increased reliability in most cases, which implies that expenditure might better be used to reduce water-carrying distances than in providing extra looping.

Another variable for which a standard is needed is minimum pipe size. As suggested earlier in this Chapter, 50 mm diameter pipe has been found suitable for most standpost networks. Studies by the World Bank have shown that by specifying 50 mm as a minimum size, the increase in network construction cost for an optimally designed system will be in the order of about 15%.

FINANCING

The financing of public standpost water supplies must be assured before construction begins. Most obviously, sufficient and reliable funding must be available to cover capital expenditure. However, it is equally important that there should also be reliable funding for recurrent expenditure on operation and maintenance. The result is that systems break down and remain out-of-order for lack of money to purchase spare parts. This disastrous outcome usually negates such benefits as the standposts initially provided.

When it comes to financing the construction of public standpost supplies, four potential sources of funds may be considered.

a. contributions from the community to be served; prior to and during construction;

b. financing generated by existing water supplies (revolving funds);

c. domestic or external borrowings that will have to be repaid at specified interest rates;

d. domestic or external grant financing.

It is mainly in rural water supply programmes with community motivation that contributions from the future beneficiaries to the construction cost are likely. Such contributions may be in the form of cash or in kind. They may be levied before and during construction. But the community should also prepare itself for subsequent charges to cover at least operation and maintenance expenditures. In urban slums, community participation is more difficult to achieve. However, it would be well to attempt some participation among the urban poor living in shanty-towns. Necessarily, community contributions will have to be provided by simple socio-economic studies that determine income levels and in effect constitute the first promotional step. Before any construction is initiated, a contract should be drawn up between the community and the executing water authority stipulating the responsibilities of each parts. It is at this stage that the community can be asked to contribute.

Where loans have been raised to finance standposts, tariffs need to be set at a sufficient level to repay them. Alternatively, the loans can be serviced out of general tax revenue, which effectively means subsidizing the water supply. Whichever way the debt is served, lenders have to be informed about the viability of the project. A clear charging policy becomes necessary, including a sound tariff structure and an appropriate method for revenue collection. A socio-economic study will often be required to demonstrate the consumers' ability and willingness to repay the investment cost, and to pay for the ensuing operation and maintenance costs.

Grant financing is still the most common way of paying for water programmes, which may account for the shortages of funds for water supplies experienced in many countries. It is important that grants be reserved for those truly in need. All too often, grants become an excuse for not charging for water at all. The inevitable result is a deteriorating service. What is more, the largest benefits of subsidized supplies go to those who use the most water, and they are not usually the poorest people.

In practice, a combination of grants and loans is frequently used to fund water programmes. In Brazil, for instance, the overall financial objective of the state water companies is that half their capital investments should be self-financed through bank loans which are ultimately repaid. The other half of their investment funds is contributed by the state governments and amount to roughly 5% of tax revenues. In order to repay the loans, the water companies must make as realistic a charge for water as possible, within the ability of the public to pay.

Water supply cannot be considered a free service. Where water is supplied to a community free of charge, this means only that the direct burden of its cost has been shifted away from the consumer. From the point of view of efficiency, there is no doubt that a system of water charges to the user is desirable. It is possible, however, that the pursuit of certain social and other objectives may have higher priority than efficiency criteria.

In many countries, the idea that water supplies should be self-financing conflicts with the view that a water supply is a social service which should be made available to everybody, regardless of the ability to pay. A possible compromise is that the principle of users paying for water is clearly established, but that certain types of supply are subsidized as a service to low-income groups. This means that users of subsidized supplies still pay for the water, but at a rate within their means. Alternatively, one can also reconcile the various objectives by providing a certain quantity of water free of charge or at a reduced price and everything above that quantity at the full price.

The cost of water per unit of volume is determined by the capital costs and the operation costs of the system. The recurrent annual capital costs include interest, redemption and depreciation charges and may easily amount to 15-20% of the total original investment costs. In addition to this to this, there will be operation and maintenance charges, which may easily amount to 5% of the investment costs, per year

For example, a system supplying water to 1000 people through standposts and costing US$ 15 000, would incur annual costs of about US$ 3000. Assuming an average use of 30 litres per capita per day (lcd), the unit cost of water is: 3000 x 1000/(30 000 x 365) = US$ 0.27 per cubic metre (1000 litres).

When similar calculations are carried out for a house connected water supply, with average consumption amounting to 80 lcd, the unit cost of water is often much less. The extra water drawn from a house connected supply more than compensates for the extra capital costs, so that the water is relatively cheaper.

Public water supply systems often comprise house connections for commercial clients and wealthier users and standposts for the rest of the population. It is then possible to introduce tariff structures that charge more than the cost of supply to higher volume consumers and use the surplus to subsidize lower income consumers relying on public standposts. Such "cross-subsidies" can make systems financially self-sufficient, provided that industrial, commercial and wealthier domestic clients can compensate for the large numbers of the poor. As a matter of fact, whenever charges to users are allowed to fall below the costs of supply, the difference has to be covered either from outside through concessionary financing or through cross-subsidies.
In order to determine the extent to which cross-subsidies may be used, it is necessary to consider the alternative supplies available to wealthier consumers. If discriminatory tariffs are allowed

to deviate too much from the costs of supply, industrial, or other large consumers may opt to construct their own supplies and the opportunities for cross-subsidies are lost. A socio-economic study will help indicate a realistic tariff structure.

In general, user charges constitute a reliable way of defraying operations and maintenance expenditures; even the poorest communities should be able to cover these current costs. In rural areas, communities can manage their own payment systems with proper support from the central water authority. In urban systems, efforts should be made to simplify collections to avoid a situation where the cost of charging for services exceeds the revenue collected. Charges should preferably be flat rate, monthly, quarterly or the like. They can be based on the number of dwellings within the standpost area, or upon the number of persons or households living within a certain distance from the standpost. They may also be included in the house rent. Charging something for the supply is also likely to educate the population concerning the value of water and its cost, which will pave the way for house connections.

A primary condition for appropriate methods of revenue collection is that people recognize the charges as legitimate. Therefore, they should be made fully aware of the expenses involved in operation and maintenance so that they understand that a charge is necessary to cover these costs. This requires adequate public information and education.

Metering public standposts may be useful where water is provided to a well defined group of people who can be charged according to the meter reading per fixed period of time. This applies for instance to a school or a health centre or a cluster of families that are willing to accept a collective responsiblity. However, metering and billing each consumer individually is neither feasible nor desirable. In practice, this system would require the presence of a guard whenever the standpost is open to the community, which raises the cost of supply considerably and adds to the adminstrative

burden. On top of that, wherever there is a "middleman" involved in the distribution of water, whether he be a vendor, guard, or concessionaire who operates the standpost, users are likely to find themselves paying exorbitant prices per unit volume of water.

The reduction of wastage and spillage, sometimes quoted as one of the advantages of metering a supply, can in general be better achieved by education of the users and/or social control in the case of a collective responsibility. Thus the case against metering public standpost water supplies is very strong and only in exceptional cases is it justified. Metering for the purpose of studying the consumption pattern is such an exception.

How the revenue from consumers' payments is used depends upon the institutional structure. Where there are unitary water authorities, revenue can be applied directly to the costs of water supply. Problems arise, however, when responsiblity for water supplies is divided between local municipal councils and a government department. If the water charges are levied by a local council, they may be regarded as just another form of local taxation, and there may be no real effort to use the water charges for financing the operation or the development of the water supply. Thus, the water system may be deprived of the revenue it generates and may, as a result, be badly maintained or inefficiently operated, while its revenues are diverted to other local services such as roads or housing. In these circumstances, unitary water authorities have a definite advantage as discussed at greater length in Chapter IV. on Organization and Management.

Socio-economic studies that determine cash income levels may also help indicate how much finance will become necessary to transform the standpost system into one with more connections. Typically, low-income families do not have savings to pay in cash for connection fees that can amount to several months' salaries. To encourage the spread of house connections, credit should be extended

over a long period. It may be better to levy only a nominal connection fee and thereafter recuperate the cost of the connection as part of the water consumption charge over, say, five years. Such a system will require metered house connections with progressive water rates, increasing rapidly with the amount consumed.

In order to facilitate further the spread of house connections, those connected should be encouraged to sell water to their unconnected neighbours with the only conditions that the selling price of water should be clearly posted. This will have the same effect as a denser provision of standposts. There is no need to license sales from individual house connections as is sometimes practised. The desire should only be to dispense as large quantities of water as possible, provided that the water is paid for and provided that the water authority has an opportunity to monitor and compare prices charged at these communal water points.

WATER VENDOR

III SOCIAL ASPECTS

SOCIAL APPROPRIATENESS

An obvious point, frequently stressed nowadays, is that technology should be "appropriate" to the conditions in which it is used. It is desirable that public standposts should be so well adapted to local conditions that they can be regarded as an "appropriate technology" in this sense. The economic issues discussed in the previous chapter show that standposts are economically appropriate in certain places but not in others - they are *economically appropriate* mainly where investment funds are severely restricted and in rural areas where house-connected piped water is excessively costly.

Next to this, it is important to ensure that a water supply system is *socially appropriate*. To achieve this, planners need to know a good deal about the community which the standposts will serve. They will need to know, for example, whether standposts will be acceptable to the local people, and whether the servicing and maintenance requirements are compatible with local skills and organization.

A standpost water supply is only likely to be socially appropriate, consonant with its surroundings and adapted to the users' needs if those who plan and build it have a clear view of its purpose. So when a new water supply is to be constructed, the first step in the design process should be to define the planning objectives, and to decide what kinds of benefit the supply is intended to confer.

PLANNING AND SOCIAL ACCEPTABILITY

The immediate objective of a standpost water supply is usually *to give as many people as possible the benefit of a "safe" water source at a cost which the community can afford.* Further goals may include the upgrading of the water supply at a later date; they will also certainly include long-term objectives concerning improved health and standards of living - goals which may not be defined with much precision in the planner's brief, but which are the ultimate reason for investing in water supply.

In evaluating water supply's appropriateness for the community it is intended to serve, there are key questions to be asked about the planning objectives. They are: first, is the water supply relevant to the felt needs and expressed wishes of the people who use it? Second, are there any conflicts between the objectives of the system's planners and the goal of its users?

It has to be recognized that planning objectives, however benevolently framed, may seriously conflict with what the local people want and need. It is therefore important that planner attempt to understand the users' point of view, perhaps by holding public meetings or discussions with the community leaders, and possibly by social surveys of water use practices and preferences. In this phase of the work planners and community workers need to work closely together.

Consultation of the local population should be carried through with conviction, so that the people take part actively in the planning process. This is a practical necessity if in the end the water supply is to meet their demands satisfactorily.

Besides listening to what people say, planners should take note of local habits regarding laundry, personal hygiene, bathing babies, washing pots and watering gardens. If people are in the habit of doing their laundry at the water sources, then standposts which do not provide for this may be misused. In part of India the bathing of children under standpost taps is common. Such activities may lead to taps becoming contaminated and to water being wasted. However, if local custom is that laundry and personal hygiene are tasks carried out at the water source, the community may feel that a standpost which does not cater for such activities is seriously inadequate. Thus planners should consider what other facilities are available for laundry and washing, and should perhaps ask whether a shower or washroom and a laundry slab might be provided near by the standpost. The point here is that the public standpost must offer a definite advantage in the facilities provided if it is to be fully appreciated and properly used by the community.

Where conflicts arise between the views of planners and those of the local community, this is most often because basic questions about cost and convenience to users have been overlooked by the planners. For local people, the "cost" of water is likely to have three components - the money to pay for use of the standpost; the time they spend carrying water to their homes; and the effort they devote to local organization, construction and maintenance work.

The distance water has to be carried from the standpost may be the most crucial factor. If people have to pay in cash to use the standpost, the advantages in terms of reduced carrying distance must be sufficient for the cost to seem worthwhile. For most users, the health benefits gained by using safer water will seem intangible and remote compared with the benefits of a more convenient supply.

It is important to bear in mind that communities are rarely homogeneous: different interests exist within them. In any community there is a range of incomes among individual households. The amount which people are willing or able to pay for water varies, whereas charges for the use of standposts cannot usually be so flexible. Unless standpost supplies are provided free through a subsidy from sources outside the community, there is a potential conflict of interest between better-off and poorer sections of the community.

The precise nature of the need for water in a particular community depends on the way in which people use the water. In some communities, for example, large volumes of water will be needed to meet the basic requirements for effective food hygiene, because *local customs* in preparing and serving meals entail the use of much water in cooking and the washing of many pots. In another community, however, where meals are more simply prepared the water needed for effective food hygiene may be much less. The same applies for personal hygiene. Thus, the quantity of water required for washing, bathing and cleaning vary considerably, depending on climate, personal habits, religion and status.

The way in which *the carrying of water* is organized directly affects the design of standposts. In most parts of the world, it is the women who fetch the water needed in the household, but in some places the children take over part of their task. Where this custom prevails, it may be necessary to construct public standposts with taps at two different heights. If women carry water on their heads, they usually prefer a standpost with small platforms or stands about 1,0 m above the ground, where the buckets can be placed for filling. The tap may then need to be 1,6 m above the ground. This would be out of the reach of many children, for whom taps at a height of about 1,1 m should be provided.

This is an instance where people's *needs* regarding facilities at the standpost are determined by the way in which they *organize* the carrying of water. If both ox-carrying and head-carrying of water are to continue after the installation of standposts, the standpost design should allow for the different sizes of container in use (annex 2).

SOME PUBLIC HYDRANTS SERVE TOO MANY PEOPLE

A WATER CARRIER WITH YOKE

The layout may have to provide for the bathing of young children at the standpost, or for the washing of laundry. It may be a good idea to observe existing practice at traditional water sources in order to make sure that the standpost offers at least the same facilities as the old supply.
Some needs might not be immediately apparent. The need for women to bath in privacy may be met at the existing water source simply by virtue if its relative seclusion. In the more frequented location of the standpost it may be necessary to provide an enclosed bathroom. Some other solution may be preferred by the users and in this case, of course, it would be essential to consult the women. Women may also value the opportunity for social contacts while fetching the water.

It may seem inconvenient to have to provide for some of these secondary needs. The bathing of children at the standpost may use - some would say "waste" - a considerable amount of water. But it may be less costly in the long run to anticipate and cater for such needs than to take measures to counter "misuse" of a system more narrowly designed. The expensive alternatives may be the employment of guards or the risk of damage resulting either from attempts to adapt the system to the use desired or from vandalism.

If a planner is influenced by prejudices or if he adopts a patronising attitude to people in poorer groups, this can be far more damaging to the success of his projects than any of the cultural beliefs held by the users. Where sanitary facilities are misused, the task of the planner is not to judge the people, but to try and overcome any practical problems the users may have with the system and to provide additional information on the advantages of proper use of the facilities.

Among the cultural factors which may influence users' attitudes towards a water supply, the most important arise in some religions - from associations of water with moral purity and cleanliness. Concepts of ritual cleanliness may influence people's washing routines and affect their views on the choice of a site for the standpost, and on whether it should be exposed to public view or placed inside some sort of enclosure.

However, one should not over-emphasize the negative influence of local culture. For most persons, *the practical convenience of the standpost* is far more important and in many cases, cultural habits play a constructive part in support of local water supply programmes.

THE STANDPOST AS A MEETING PLACE

SOCIAL ORGANIZATION

Communities have both *formal* and *informal* kinds of social organization associated with the use of water. The question of how water carrying is organized is an informal family matter, but access to water sources may be organized in a more formal way.

Many of the details of water use are likely to be covered by informal modes of organization. Questions of where laundry is done and where and when people wash themselves are likely to be the subject of quite definite but informal patterns of organization and behaviour. Informal organization may also include arrangements between families to share some tasks, while the inception of a new standpost scheme may impose new tasks which have to be shared, like cleaning the standpost, or stopping children from playing with the taps.

The informal sector is also important for the social acceptability of new water supplies. If the introduction of a standpost tends to disrupt social contacts which women enjoy while fetching water, or if it makes it impossible to bathe or wash clothes at the water source in the traditional way, the standpost may be less acceptable on those counts.

Another aspect of informal organization associated with water use is that there may be people who are paid to do various tasks: for instance the water vendors. Such people, who are paid to fetch water for others might be opposed to a standpost scheme, as might people with private wells who sell their water. It has happened that a water supply improvement was sabotaged by a man who made leather buckets and ropes for drawing water from wells, and who felt that his livelihood was threatened.

For a public standpost system to be a "socially appropriate technology" in the sense described at the beginning of this chapter, it is not sufficient merely for it to be socially acceptable in terms of convenience, cost and culture. A standpost may be fully accepted in all these ways by the local community, but it may still fail if its operation requires a degree of organization which does not exist. The planning of a standpost system, therefore, must also include the development of a more formal organization capable of operating and maintaining the system, and this will involve training people in the necessary managerial and technical skillls.

Criteria for good organization, such as adequate supervision and maintenance, regular cleaning and disciplined use are strongly linked with technological criteria. If criteria for good organization are fulfilled less expense is necessary in meeting the technolgical criteria.
The ability to dispense water without contamination, the effectiveness in reducing wastage and spillage, the ability to withstand vandalism, and the durability of the standpost are all aims which may be effectively achieved by a combination of technological and organizational factors.

For example: the prevention of contamination of water requires an appropriate technological design as well as regular cleaning and disciplined use. Another example is the reduction of wastage. This has sometimes been interpreted as a purely technical problem, and much effort has been devoted to designing spring-loaded taps which close automatically as soon as the user ceases to press down on them. However, experience shows that the more sophisticated systems do not, in general, show a definite advantage over the ordinary tap as far as reducing waste is concerned. It has often been found that the standposts with mechanical devices to reduce

the discharge and/or wastage in practice challenge the user to find ways to "modify" the system, in order to make water more easily available. Taking all aspects into account, an acceptable system could well be a hand-operated screw tap of good durability, in combination with effective maintenance and proper operation by the consumer.

Thus criteria of good organization, such as social discipline and supervision, are more relevant to this problem than technological design.

It has been noted that vandalism sometimes occurs at standposts which are not acceptable to the community and which people find frustrating and difficult to use. But vandalism may also ocurr because of problems within the organizational part of the overall system, such as failure to organize adequate supervision at the standpost. There may be a failure on the part of the parents, or a lack of social discipline throughout the community; or it may be that management does not fulfil its supervisory functions adequately. Where vandalism can be prevented by adequate planning and organization, time and effort should not be devoted to creating a vandal-proof technology.

IV ORGANIZATION AND MANAGEMENT

INSTITUTIONAL STRUCTURE

Good organization and effective management are essential for the success of public standpost water supply systems. When management is poor, the operation of the water supply tends to be irregular and maintenance is neglected - resulting in low water pressure, irregular and unpredictable flow, frequent breakdowns and general malfunctioning.

The poor administration that leads to those problems may be the result of many factors, including inadequate training, staff shortages and political pressure. The institutional arrangements within which management staff have to work may also be the cause of some failures. Figure 4 illustrates two alternative institutional arrangements. In the first, found in many countries, responsibility for public standposts is divided between one or more government departments and the local authorities. This arrangement has many disadvantages and has often been blamed for the ineffective maintenance of public standposts, handpumps and other communal facilities.

The main alternative, often regarded as more efficient, is to set up a *unitary water authority* to handle all activities associated with water supplies. Though unitary authorities of this kind are responsible to government and have to coordinate their activities with local authorities, they can have a high degree of autonomy in planning and finance. This set-up sometimes has the disadvantage that it tends to become insensitive to users' needs.

A. DIVIDED RESPONSIBILITIES

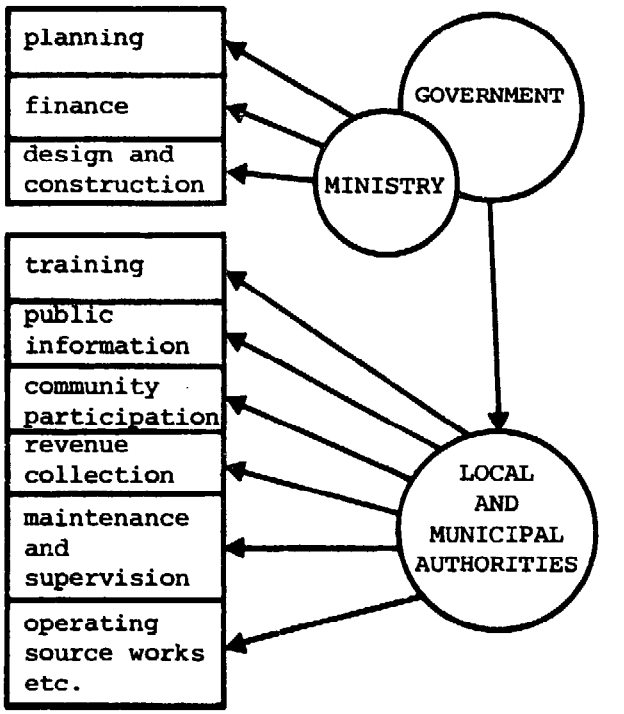

B. UNITARY WATER AUTHORITY

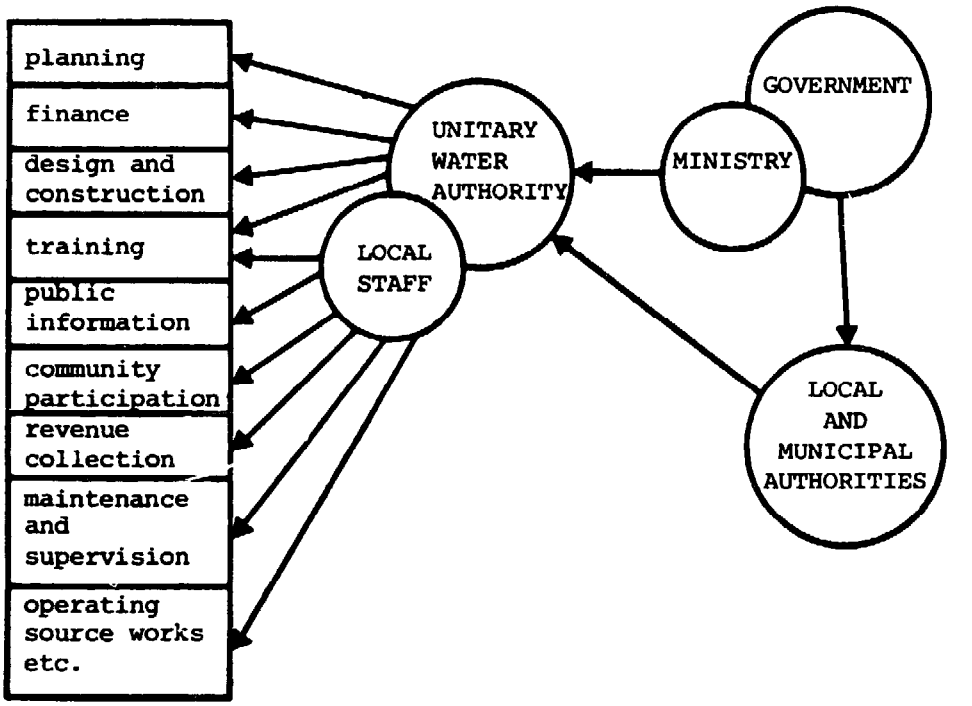

FIGURE 4: TWO ALTERNATIVE INSTITUTIONAL ARRANGEMENTS

Arguments can be raised against either structure, but it is possible to devise modifications of both systems to suit local needs and so avoid potential pitfalls.

In many countries, standposts are constructed by government departments and are then handed over to local or municipal authorities, who are expected to operate and maintain them. These authorities often have very limited resources. They may find it difficult to recruit and retain suitable staff to carry out the necessary maintenance work, as career prospects are limited, service conditions unattractive, and salary scales low. Budget limitations result in poor operation and neglet of maintenance and there is little return on investment. Another disadvantage of this division is that the engineers responsible for construction are not concerned with operation and maintenance. Their design criteria may be drawn up without any reference to the way maintenance will be arranged.

If the responsibility for water supplies is divided among several bodies, steps must be taken to ensure that all essential functions as indicated in figure 4 are properly carried out in coordination with one another. It is noteworthy that where unitary water authorities are set up they almost always deal with waste disposal as well as with water supply, since the two are inextricably linked.

Here is a comprehensive list of the tasks to be undertaken:

(a) *planning*, i.e. defining populations to be served; identifying particular needs in the local community; determining whether public standposts are an appropriate solution; and phasing construction.

(b) *establishing a legal framework* for public standposts, especially regarding ownership, and regarding the rights and responsibilities of all organizations involved.

(c) *design and construction* of standpost water supplies.

(d) *source works:* construction or modification of source-works: treatment works, pipelines, etc., to supply water to the standposts.

(e) *finance:* raising grants or loans to pay for construction; fixing water charges to repay loans or to pay operating costs.

(f) *training* of technicians and management staff, and any members of the local community who undertake responsibilities for maintenance or supervision.

(g) *community involvement and participation*, consulting local people about planned development, giving public information, and health education.

(h) *operational management:* supervision of standposts, maintenance and revenue collection.

In reviewing these functions it will be noted that some entail active operations in the immediate vicinity of the standposts, especially community involvement work (g) and operational management (h). These responsibilities might be undertaken by locally-based staff. Other functions, however, can be centralized at the water agency's headquarters.

Another point to note is the importance of item (b) in the list, the establishment of a *legal framework*. The problem here is that standposts are communal or public facilities and are not privately owned. The ownership of the standpost and the land it occupies may thus need some special legal provision, as may the methods used for raising charges from users. It is obvious that the rights and responsibilities of the water authority need to be legally defined, but it may not be so obvious that any local village water committee that is set up also needs a legal basis, even if a very informal one.

Operation and maintenance of a water supply often entails a considerable amount of administrative work, and this is an issue which planners tend to foget during the early design stages. The importance of *designing the organizational aspects of the water supply in parallel with the technological aspects cannot be over-emphasized.*

The planning of a standpost system, therefore, must include the development of an organization capable of operating and maintaining the system, and this will involve training people in the necessary managerial and technical skills.

STAFF REQUIREMENTS AND TRAINING

Shortage of manpower, particularly for supervision and management, is a major factor in the poor performance of many water supplies. The reason for this is that the need for technical training is usually recognized, but the need for training in management skills is often overlooked. But the need is there, often at a very basic level, for standpost caretakers and supervisors as well as for technical staff, and each employee should be given short additional periods of traning during his employment with the water supply organization. Planners and designers of standpost systems also require training and in-service refresher courses to up-date them on new thinking and new techniques.

Thus training programmes will need to include management as well as technical skills. A water supply programme is not merely an engineering project, but it involves social, health, financial and management aspects as well. Training and recruitment policies need to recognize that a water programme is a multi-disciplinary effort.

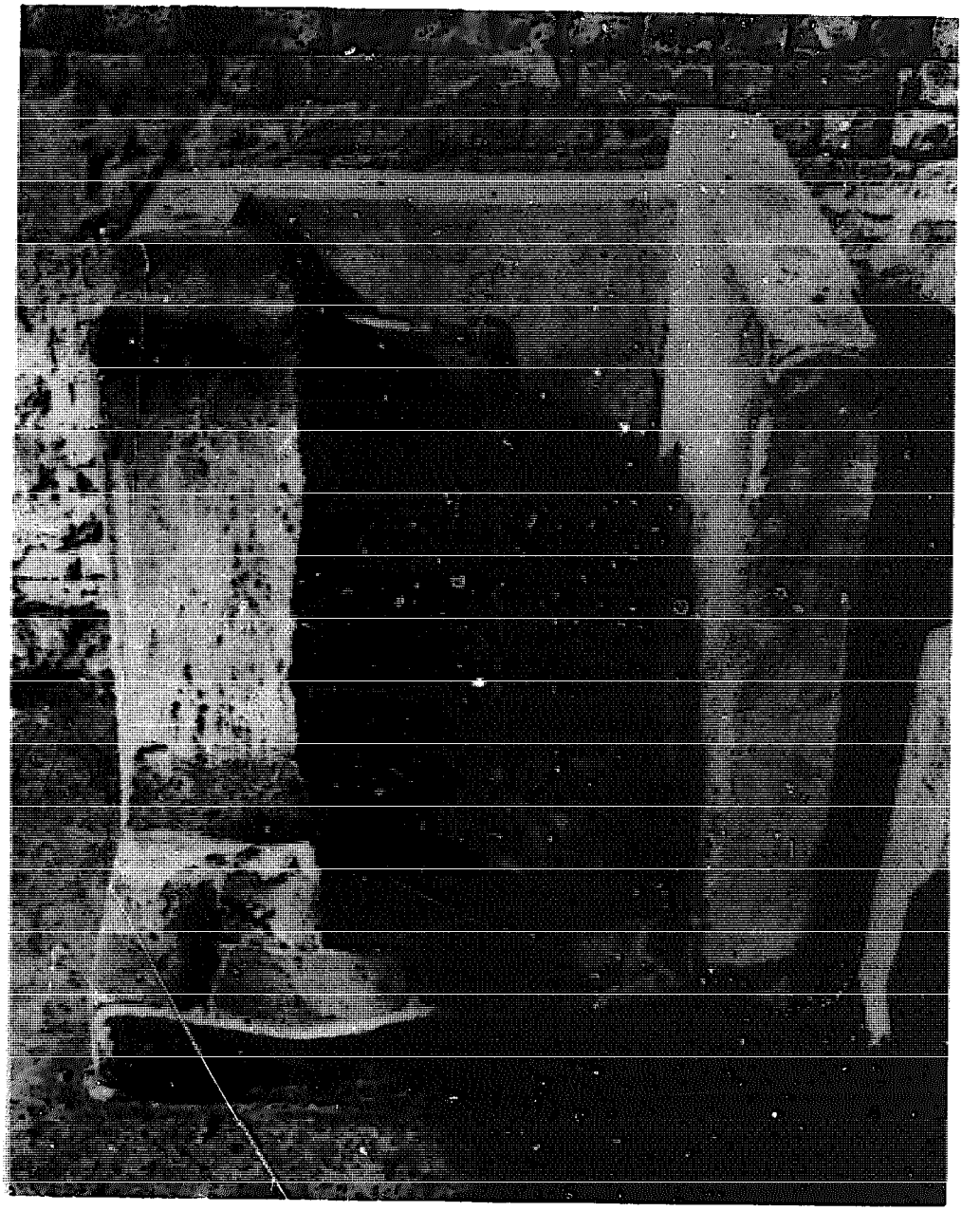

MAINTENANCE: OFTEN A MAJOR PROBLEM

A further point is that, although a water authority may need to initiate a training scheme, its own demands for staff may not be sufficient to support an unassociated training programme. In such cases it may be preferable to set up a scheme to serve all water suppliers in the country, including, for example, the training of plumbers for work in the private sector, The training requirement will have to be considered for the whole range of skilled personnel, such as mechanics for pumps and meters, pipe fitters, bricklayers and administrators. Training for relatively unskilled local caretakers and supervisors may require special provision, e.g. on-the-job training.

OPERATION MANAGEMENT

It is not uncommon that the management of the day-to-day operation and routine maintenance of water supplies is pitifully inadequate. Sometimes through poor maintenance, water supplies are actually failing at a more rapid rate than they are being constructed. To focus attention on this problem and to describe the range of skills and disciplines that are so often lacking, it seems fitting to introduce the term "operation management". This refers to routine management activities, including the organization of maintenance and revenue collection, and is distinct from the level of management which determines general policy and plans the financing of projects.

The immediate objective of a standpost is to supply water. Maintenance and supervision, regular and competent enough to keep the standpost producing water efficiently, must therefore be the first priority for operation management. Another priority must be liaison with users of the standpost on a very basic level,

with means of communication adequate for them to feel that the management staff are responsive to complaints and will carry out repairs when the need for these is reported.
Since it has been stressed that many standpost water supplies today have to be at least partly self-financing, revenue collection is also an important task for operation management.

Where good maintenance and effective lines of communication with users are established, people will feel that they are getting a good service, and may then be reasonably cooperative with management in the matter of revenue-collecting. If, however, the standposts are badly maintained and do not provide a reliable water supply, if the operational staff are arrogant and unresponsive, then there is no point in even trying to collect revenues.

MAINTENANCE

Maintenance is a term which is often used loosely to mean the repair of broken equipment, but here the concept *preventive maintenance* must be introduced to stress the importance of measures aimed at avoiding breakdown. These will normally be very basic activities such as cleaning, tightening bolts, and regularly replacing tap washers. Repair, in contrast, means bringing the standpost back into operation after a breakdown. A maintenance organization should carry out *preventive maintenance* as well as doing repairs. In practice, however, preventive maintenance is often neglected and "maintenance organizations" become merely repair organizations, sending out repair teams only when standposts are broken or taps leak badly.

The key to good preventive maintenance is *regular inspection* of the standpost and attention to minor symptoms or malfunctioning. A tap that drips slightly when it is closed or which is difficult to operate may become a source of serious trouble if neglected. But if it is repaired promptly, while the symptoms are still barely noticeable, that trouble will be prevented. Taps may need more maintenance than any other part of the standpost, but sometimes it is also necessary to carry out repairs to the platform, the support structure and the attachment of piping to the picket on the wall. If a water meter is present, it should be checked. It is also advisable to clean the platform and the drainage system regularly (annex 3).

To sum up, maintenance programmes need to include the following activities:

(a) keeping the standpost and surrounding area clean, and making any small adjustments, such as bolt tightening;

(b) inspection of the standpost once a week by someone with mechanical knowledge and appropriate tools noting and correcting any minor malfunction; observing whether tap washers or other parts need replacement;

(c) arranging for a person or a team with sufficient equipment to visit every standpost at regular intervals, or as necessary, to carry out major overhauls and repairs;

(d) procuring and holding in stock the necessary spare parts, and ensuring that they reach the areas of need without delay;

(e) arranging for all the above activities to be adequately financed (some capital investment will be needed to establish a stock of spare parts in a suitable store where they can be properly supervised).

Given that these are the activities necessary to ensure that public standposts are properly maintained, the question remains how such activities might be organized. Maintenance organization can be classified as "decentralized" if some of the work is delegated to the local level, and as "centralized" if all the activities are carried out by a unitary water authority.

With standposts in rural areas, the decentralized pattern of organization will often be the only realistic option. Alternatives such as cleaning the standpost and periodic inspections to check whether parts need replacing might then be carried out by local persons, who should be given some training as standpost caretakers. Such an arrangement may relieve the central organization of part of the maintenance work and its financial burden, but it will still be necessary for salaried technical staff to visit the standpost occasionally to carry out major overhauls and to give guidance and advice to local caretakers.

In urban areas, centralized organization is more likely to be appropriate. Under this system, day-to-day cleaning and inspection of the standposts is the responsibility of paid supervisors or guards, who may in turn employ labourers for the cleaning work. The guard is a paid employee of the water authority and will liaise directly with the maintenance staff of his organization. This arrangement makes every maintenance activity a direct responsibility of the water authority. Maintenance of urban standposts may, however, be decentralized if licenses or kiosk-holders have an independent status and organize the more basic maintenance activities themselves.

Experience suggests that each public standpost should be inspected about once a week. A trained inspector should be able to check from 25 to 50 standposts every week (in rural and urban areas respectively), and to carry out the routine maintenance. For larger repairs a team consisting of one pipe fitter, one mason and two labourers should be available. Experience will indicate the number of standposts to be covered by this team, though as a rough guide a maintenance supervisor may be responsible for up to 500 standposts, and he could have up to three teams working under him.

Naturally, the amount of maintenance involved, and the resulting costs, depend on the quality and type of construction of the standpost and base unit; the number of people served per standpost; and the quality of the water, especially its corrosive properties. Costs will also depend on the distances to be covered by staff between standposts, and the area served.

One extra task to be added to the duties of the maintenance and inspection staff could be the regular monitoring of water quality. Frequent monitoring, however, is not practicable in many situations, and, in any case, had better be rendered superfluous by maintenance carried out with the specific aim of preventing contamination of the water. This means checking the condition of distribution pipes as well as maintaining the standpost themselves. In badly maintained systems with numerous leaks in the pipelines pressure is often so low that contaminated water from outside the system drains into the pipes and creates serious health risks for consumers.

One feature of maintenance organization which needs more emphasis is that of spare parts. Wherever there may be delays in delivery, the maintenance organization will need to build up a stock of

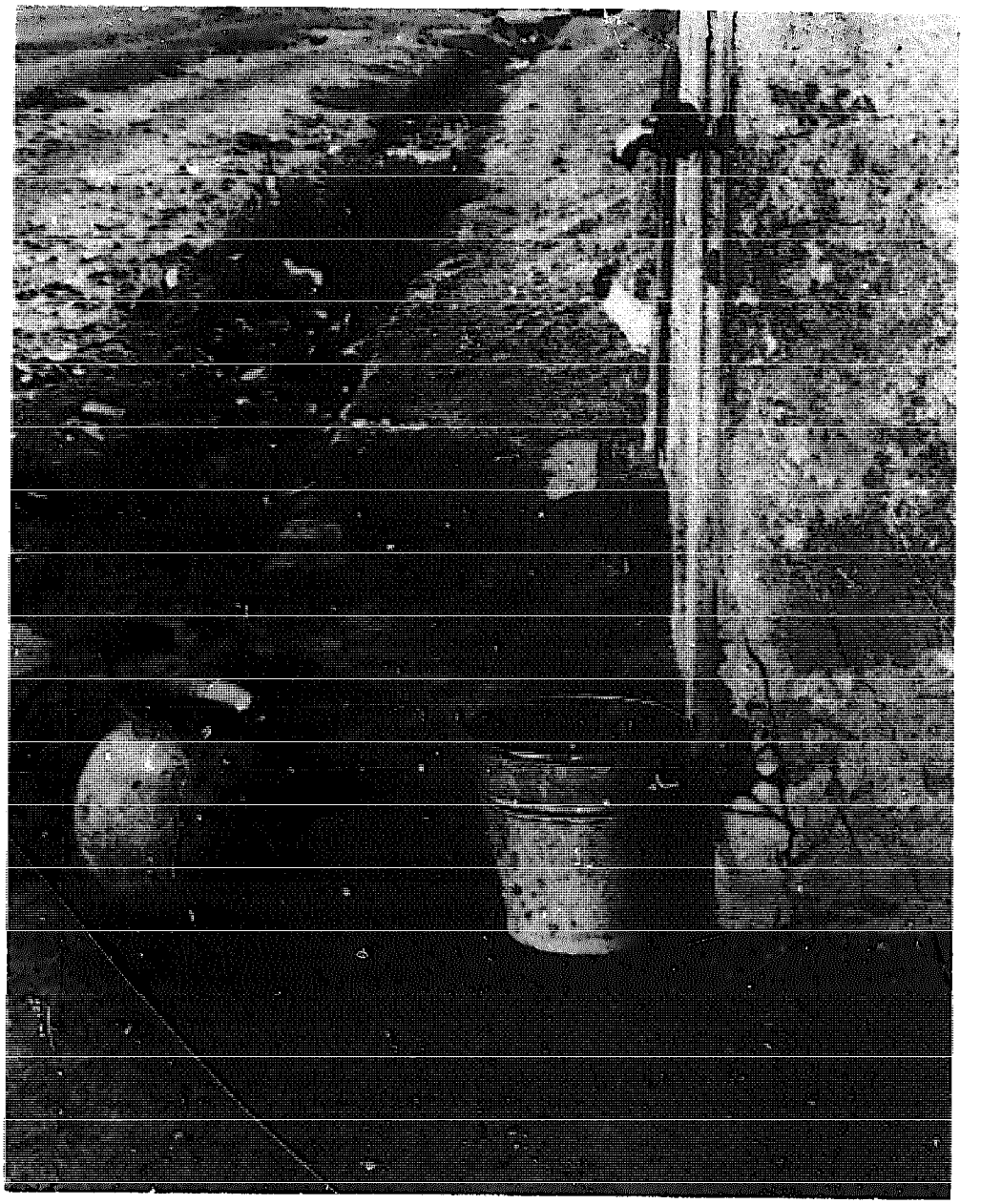

WATER WASTAGE: DISADVANTAGE OF A TAP NOT UNDER CONSTANT SURVEILLANCE

parts, and operate stock control systems which anticipate in future demand for parts, so that they can be ordered in advance. It is preferable, where possible, to use equipment which is manufactured locally.

The key to good stock control, and to other aspects of maintenance, is record keeping. If all visits of maintenance staff to standposts, and the materials used by them, are recorded, it is possible to see at what rate different components are being used. The same records make it possible to check that each standpost is serviced regularly, and can help to identify trouble spots where repairs are being called for more often than average.

SUPERVISION

Supervision of the use of public standposts at all times is advisable in the following situations:

(a) where water is paid for directly according to volume, to collect revenues;

(b) where there are severe water shortages and it is strictly necessary to avoid wastage and spillage;

(c) where pressures are low and the supply irregular, to prevent users damaging the structure in attempts to increase water flow;

(d) in crowded urban areas or where there are large numbers of users, to maintain order and prevent misuse.

Supervision is usually arranged by stationing a guard at each standpost. But if he is there only during daytime, the solution to problems of theft or damage is only partial. It may be necessary to provide a 24-hour guard service. Another approach is to place the public taps inside an enclosure or kiosk in which the guard sits and operates the taps.

The kiosk is then locked at night. This seems to be the most effective method so far devised for collecting revenues and preventing damage. However, guards must be adequately paid and made to feel that their job is important. Where pay is rock bottom and morale is low, guards may be unwilling to exercise their authority and risk unpopularity with the local community, or even fail to fulfil their duties altogether.

REVENUE COLLECTION

Collecting revenues from users is a problem that is frequently mentioned. In many countries there is *widespread antipathy* against paying for water which has to be carried home.

Poor administration, irregular collection of payment, and a poor standard of service all decrease people's willingness to pay. Besides, the financial circumstances of the users are important: those with a regular income are more likely to be able to pay a monthly sum than those who have not; the latter group often prefers to pay on the spot according to quantity used.

It is important to devise *an appropriate method of collecting payments* which is both fair and effective. Several methods are available:

(a) charging through a monthly payment;

(b) charging according to quantity of water used, per bucket or per debbie, with coins or tokens;

(c) charging by head tax, land tax, or levies on cattle;

(d) adding charges to house rents and collecting both together;

(e) in poor areas where the municipal council wishes to provide water free to users, the supply may be metered, and the municipality may then pay the water authority's bill.

In official urban low-cost housing areas, where people sometimes share a water tap with a number of other households, it may be particularly appropriate to include a fixed water rate in the monthly house or plot rent. Authorities face fewer problems when water charges are collected this way.

Some problems are frequently encountered where guards or concessionnaires operate the standposts. They may abuse their position by demanding an inflated price for water, or by opening the tap only at hours convenient to themselves. They may lack the authority to maintain order or to insist on payment, or they may fail to fulfil their duties through being afraid of losing popularity. It is not uncommon for them to neglect the installation, so that its state of maintenance deteriorates. Selection of the right person for the job is therefore essential.

Another problem may arise when the smallest coin in use is worth, say one dollarcent. Payment of one coin for every bucketful (c.10 l) would imply a price of approximately US$ 1,00 per cubic metre. In such circumstances, it may be desirable to have users pay for water by means of tokens which they can purchase in quantity. Then the "one cent coin" might buy tokens, entitling the user to, for instance, two to five buckets of water.

In areas where several systems of revenue collection co-exist, special problems may arise. For example, in some squatter settlements, people refused to pay the flat rate for water from the public standpost because they believed that neighbours in an adjacent area, whose water charges were included in their house rent, were not paying at all. In this instance, there should have been a clear statement of the amount of water charges added to the rent.

It depends on the local customs and the political situation in a country which arrangement for revenue collection will give the most satisfactory results.

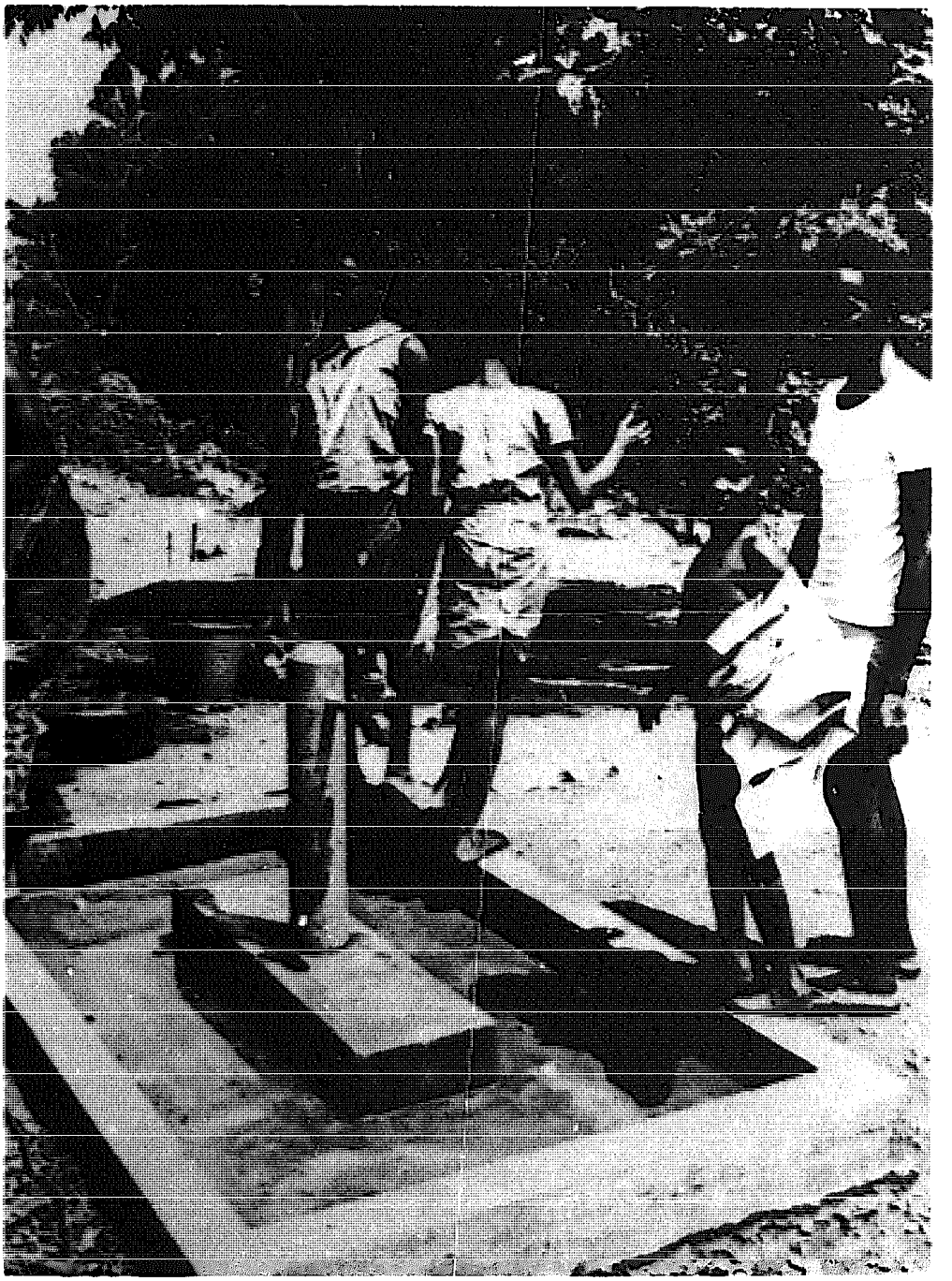

DRAINAGE

V COMMUNITY PARTICIPATION

It is generally considered important to involve the users in the planning and implementation of public standpost water supplies, to the greatest possible extent. Active community participation can be beneficial both for the success of the water supply project and for the development of a spirit of self-reliance in the community.

PARTICIPATION IN THE PLANNING

It will be evident that during the planning of a public standpost system there must be extensive contacts between the planners and the local people in the area to be served. The persons responsible for making these contacts may at the same time be acting as community workers, preparing the local community for the new development. Ideally, this community work will be carried out in such a way as to encourage an active participation of the local people in the planning, implementation and operation of the new water supply scheme, and have them state positively what facilities they want.

The participation of the community in planning requires that consultation takes place before any decisions are taken on the installation of a water supply system with public standposts, or before standposts are rejected in favour of household-connections. For participation to be meaningful, the full range of options should be presented to the community, with a clear

indication of the costs which will have to be borne by the users. Therefore, before the community is consulted, an approximate costing of the options will have to be made, and a decision taken on the amount of subsidy which can be provided from sources outside the community.

Some kind of committee or working group is nearly always of value as a focal point at which external inputs and local knowledge can be brought together. Public meetings may be more effective in ensuring that decisions represent a wide concensus, but even at public meetings it may well be that poorer people feel unable to speak out when any objection of theirs may be overriden. In order to establish the true views of all sections of the community, it may be necessary specifically *to approach the poorer section separately*, outside the context of a public meeting or the presence of better-off members of the community. This might require a small survey or might be done more informally by making enquiries in the various geographical sections of the community. The main requirement is that the person charged with carrying out the survey or the enquiries is fully conscious of the issues involved, and is sensitive to them.

In conclusion, is should be clear that planning a public standpost system requires first the definition of planning objectives, and then communication with the potential users of the system to ascertain their needs and aspirations, and to check that the planning objectives and users' goals are mutually compatible. This process of communication, should ascertain particularly what factors will make for a socially acceptable standpost, and what are the organizational strengths and weaknesses of the local community.

IMPLEMENTATION

Where community participation in construction is the aim, care must be taken that plans make maximum use of the resources which communities can provide, so that the limited resources of the agency can be used effectively in order to benefit the largest possible number of communities.

If a village has taken the initiative in asking for standposts and in collecting funds, the chances of cooperation during the actual construction of the supply are clearly good. The one exception is where a part of the community is less enthusiastic, whether for reasons of factional dispute or for socio-economic or cultural reasons.

In meetings held with the community prior to the construction of a water supply, the agency should make its position on contributions expected from the community clear from the start, both in terms of cash and in terms of labour. The community as a whole, or individual householders, may be offered the alternative of a cash or labour contribution, or households contributing labour may be offered a specified reduction in the subsequent charge for water.

Where the water agency seeks active community participation mainly in the construction phase (and not subsequently in operation), and where the local community has well-established patterns of communal labour or organizing construction of communal facilities, there may be no need for special organizations to be created. Attention need only be paid to good liaison with existing community bodies - ensuring that the work done by communal labour is well coordinated with agency requirements, the arrival of materials etc. Otherwise, however, it will be desirable to establish a water committee, or public health committee, perhaps as a sub-committee of any more general council or improvement committee that exists.

PARTICIPATION IN OPERATION AND MAINTENANCE

Effective community participation in operation and maintenance may be more difficult to organize than participation in construction. Enthusiasm can be generated for a short-term effort with a conspicuous physical result, an effort in which everyone has his part to play. It is hard to generate enthusiasm for unglamorous and inconspicuous work which must be carried out indefinitely and which must in the main be done by one or two individuals rather than the community was a whole. Such work cannot be shared fairly by all beneficiaries, except on a rota basis which is unlikely to be workable. It must therefore be done by volunteers or by paid workers. There are difficulties in maintaining the motivation of volunteers who do a great deal of rather thankless work in their spare time.

In many instances it will be necessary to arrange for a community member to be appointed caretaker. He will be responsible for routine maintenance and supervision, and receive a small stipend. Many communities have difficulties in regularly collecting funds for such salaries. The water agency is often better structured administratively than the community, and thus better suited for making small regular payments. The problem in this case might be that there is not provision for payments for the part-time work which will generally be involved. Yet a legitimate objective of the agency will be to minimize the administrative burden arising from the water supply and to minmize the cost of running it. This will often be achieved by appointing part-time community caretakers instead of full-time workers at much higher cost.

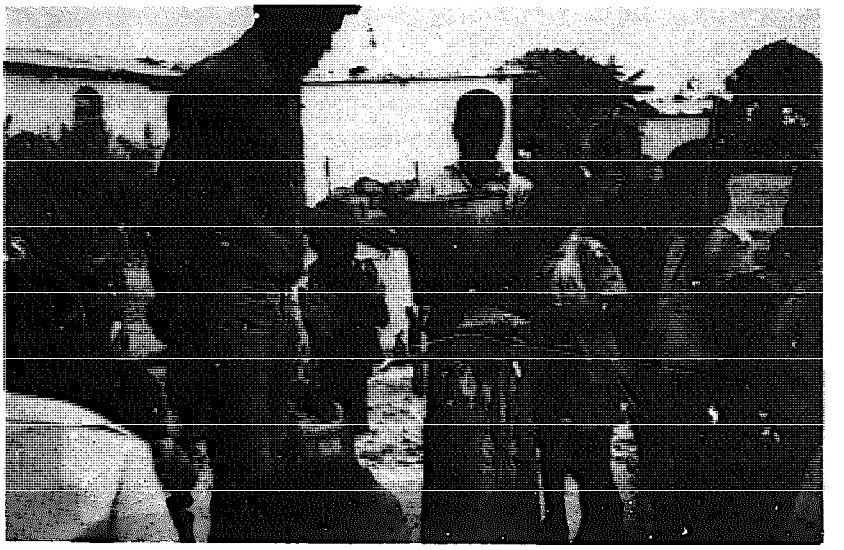

INSTRUCTION AT THE PRIMARY LEVEL

The major tasks of a caretaker are cleaning, preventive maintenance, repair, ensuring correct use and avoiding damage, and, depending on the local arrangement, the collection of payments. He should be supported as much as possible by the water committee and/or local authority. Whether it is best to appoint a separate caretaker for each standpost location will depend on local circumstances: it may be advisable, in particular, if the locations are in socially distinguishable wards, or streets identified with particular subcommunities. If there are water vendors or others whose livelihood is affected by the installation of the new water supply, it may well be possible to employ them as caretakers.

Local circumstances will also determine whether repairs can be made the responsibility of the community. At the very least, the community should not be *prevented* from undertaking repairs unless the water authority has a maintenance organization which

can and will carry out repairs promptly and efficiently. The training requirements for caretakers and for committee members will need to be considered in the light of the extent of their responsibilities, both in technical and organizational aspects.

If the local community assumes responsibility for any repairs, it must be clearly established who is to pay for which expenses - particularly for spare parts. Since a particular repair only benefits the users of one particular standpost, disagreement or a general reluctance to pay may be expected unless the question has been clearly established in advance. Where people have little money, they are often understandably reluctant to shoulder what they see as another man's burden. Where costs and benefits can be clearly seen to be distributed fairly, cooperation can be achieved.

USE OF WATER AND IMPROVEMENT OF HEALTH

Community participation is of vital importance in the area of health education. The health benefits of an improved water supply are most unlikely to be attained to any significant degree unless there are also changes in health-related behaviour, starting with the way the water is handled after leaving the tap, but extending to all aspects of personal hygiene. These changes are most unlikely to occur on any significant scale unless there is general community involvement in the process of health education.

There is, first, a need to build up knowledge of the ways in which water-related diseases might be spread in the local conditions with existing behaviour patterns. This can be done by dialogue between community worker with "expert" knowledge of

the ways in which diseases are transmitted, and local people with their knowledge of local circumstances and behaviour. The community worker may be a health worker; or a special role of community worker may be established within the water agency, and its personnel given training in health aspects. Alternatively, a local person from the community may be selected and given training. In this case, it would be appropriate to extend the training to other basic health tasks; the persons would then act as a community health worker, just one of whose tasks would be health education in relation to water and hygiene. A number of countries are establishing community health worker programmes and there is much scope for cooperation between the water agency and the agency charged with such programmes.

Secondly, there is the need to spread throughout the community the understanding of the ways in which local habits might be changed to reduce the transmission of disease. To be effective this will need the active collaboration of a committee of local people; it could be another task for the water committee. The spread of information is insufficient by itself; there must be positive motivation to make substantial changes in behaviour. The necessary motivation may come from a thorough understanding of the processes involved in the transmission of disease; from the acceptance of authoritative assurances that adopting a given change in habits will have an effect on health; from observing others adopting the change; from the desire to be thought well of by other members of the community; or because actual sanctions are threatened against those who do not adopt the change. Which kinds of motivation can be used in particular cases will depend on local circumstances, but a local committee will be in a better position to use most of them than a community worker from outside. The community worker must, however, endeavour to ensure that the committee itself has sufficient motivation.

COMMUNITY ORGANIZATION

The effectiveness of community participation depends to a large extent on the development of an appropriate community organization. Many communities, particularly in rural areas, will possess a well-established formal organization, and the committees and local caretakers necessary for the operation of a public standpost water supply will need to fit in with this organization. That might mean that the proper place for discussion of water supplies or for the selection of people to act as caretakers is a ward meeting or an existing village committee.
Very often, though, no existing organization is appropriate, and it may be necessary to form a special "water committee", or a broader "public health committee", representing the local community.

In communities where local committees seem feasible, the exact participation structure will depend on the water authority's policies. If the authority seeks active community participation in the construction phase, only, a fairly minimal development of community organization will be necessary. Thus in some places it may be possible to depend on an existing framework of meetings and consultations, and on existing leaders to organize working parties to secure cash contributions. If, however, the community is being asked to play a continuing role in operation and maintenance and in securing the full potential health benefits of the standpost, much bigger demands are made. This approach requires continuity over a long period with regard to standpost operation and second, an effort to involve the whole community, including underprivileged groups, in any health campaign. Both of these objectives can sometimes be met by the formation of a special "water committee" or "public health committee", and it will

therefore be one of the first tasks of the community worker representing the water authority to assist in the formation of such a group.

On a committee set up specifically to deal with water and health, it may be possible to include women or other people normally excluded from committees or meetings, on the grounds that they are more closely involved in water use and hygiene practice. If women and other underprivileged groups are not adequately represented on committees or at meetings, it becomes much more difficult to effect the health benefits which an improved water supply should bring.

The precise role of *water committees* will vary from place to place, but it is possible to draw up a basic list of committee's functions. In general terms, a water committee might have responsibility to do the following things:

(a) to aid communication between the water authority and water users;

(b) to organize self-help, voluntary labour for construction;

(c) to draw up the rules to be observed by users of the supply, to enforce these rules, and prevent misuse;

(d) to select local people for training as standpost caretakers, community health workers, etc;

(e) to collect financial contributions from users;

(f) to reimburse caretakers for any expenses (e.g. purchase of spare parts), and perhaps to pay other costs.

(g) to make suggestions and assist with health education.

This formidable list of responsibilities represents the burden which falls on local people when a water authority devolves considerable responsibility onto the local people. Only communities with a strong tradition of formal organization and with members with a degree of managerial skill are likely to be able to undertake all these tasks successfully.

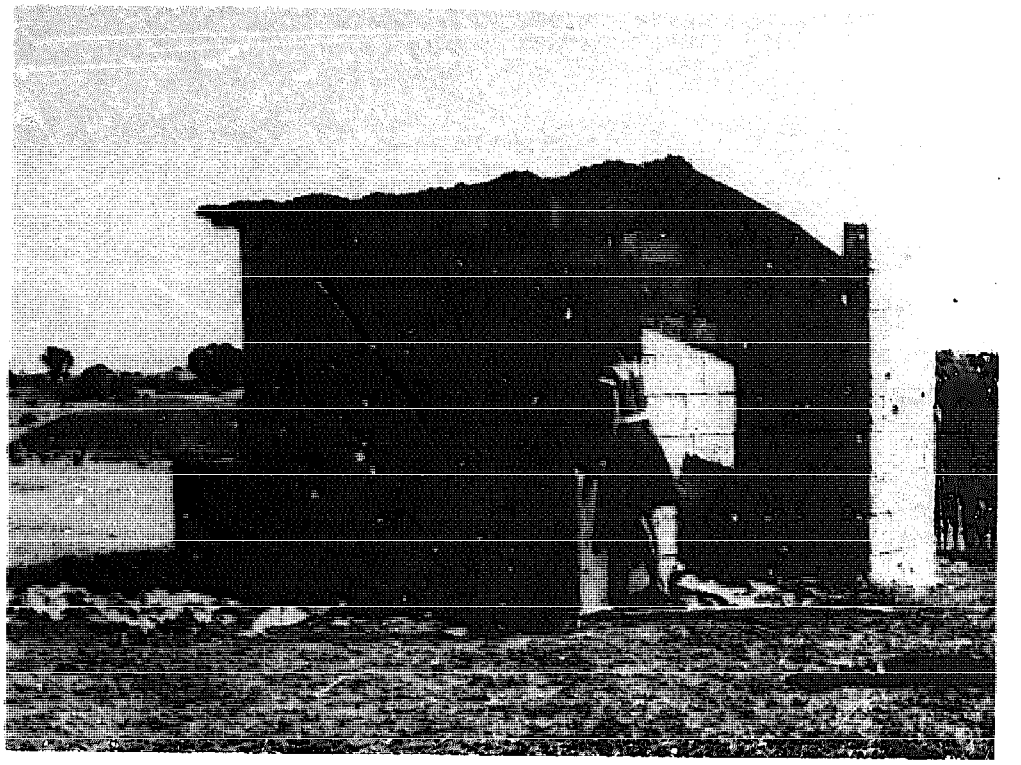

COMFORT STATION

VI TECHNICAL ASPECTS

For more detailed information on the technical aspects reference is made to the Manual on Design and Construction of Public Standposts, published as IRC Technical Paper 14, and which is considered as a companion document to this publication.

CHOICE OF TECHNOLOGY

The term "choice of technology" is often used to denote the problem of making optimum use of capital, labour and natural resources in any programme involving new technology. The designer of water supplies, is, of course, faced with the same problem, and in choosing to install a standpost system he has already made a fundamental "choice of technology".

The decision to provide standposts can be seen as the first of a series of simple steps in a logical design procedure (annex 4). The next step is to collect data relevant to the design of the standpost system, including details on where people do their laundry and what kind of platform they need to support their buckets or other containers.

Then follows an assessment of whether the community is able and willing to *organize the maintenance* of its own standposts and to *collect the necessary payments* from its own members.
It may be possible to encourage the formation of a local committee and leave the management of the standposts mainly to it.

This implies a "decentralized" pattern of maintenance which requires simple, easily maintained equipment. At the other extreme, if the community is very loosely organized a "centralized" pattern of maintenance may be more appropriate.

Such considerations should lead the designer to conclusions about the specification on which to base the *detailed engineering design*. For the purpose of discussion this subject is subdivided as follows: (a) water consumption; (b) hydraulics and capacity; (c) standpost structure and layout, and (d) selection of equipment.

WATER CONSUMPTION

The volume of water drawn from public standposts is typically between 20 and 60 litres per capita per day (lcd). The actual water consumption from a public standpost depends not only on local habits concerning domestic water use, but also on the availability of other water sources. The amount of water drawn for non-domestic uses such as watering gardens can be significant too. In designing a water supply, potential future increases in demand must be catered for. In a public standpost system, it is usually advisable to provide excess capacity for about 10 years, allowing for population growth and increase in per capita consumption during that period. Where a water distribution system with public standposts is planned to provide house connection later, the design of the treatment facility and the distribution system is often based on a use of 100 lcd. Should this prove to be too costly, a design standard of 75 lcd may be acceptable.

Another criterion is the *peak demand* for water. At public standposts in rural areas the peak demand often occurs in the early evening, when the amount of water drawn in an hour may be as much as 5 times the average hourly rate, or even more. Such high peak factors are characteristic of water supplies used solely for domestic purposes, where there is no industrial or agricultural base load. In most cases a peak factor of 3 to 5 will be adequate for the design of standpost water distribution networks.

The designer can control the peak factor to a certain extent by limiting the number of taps at each standpost, or by using flow restricting orifices. Since orifices can be inexpensively made in different sizes and can be easily inserted and removed, they are a preferred method of control.

Such a controlled peak flow, however, should not fall below an acceptable level, in order to avoid users being inconvenienced by long queues. In India, for instance, the criterion is that the discharge rate from taps at urban standposts should be 10 litres per minute, while in rural areas 5 litres per minute is considered adequate.

HYDRAULICS AND CAPACITIES

A water supply system with public standposts consists of a central source, with or without treatment facility, from which the water is piped to the public standposts for distribution. Normally, the pipe system will be branched, terminating in dead ends at the standposts. Branched systems are less expensive, and are much easier to design than systems with loops. A break in the distribution main of a branched system, however, will interupt service to many users.

Where a number of public standposts are connected to a distribution main, it is often acceptable to assume that the water pressure in the distribution main is not much affected by water discharge from the standposts. The taps or other water-dispensing devices of the public standposts may then be considered separate from the distribution system.

It is important to choose an appropriate kind of tap, and also to ensure that the size and number of taps installed will discharge sufficient water to serve the needs of users.
If the standpost is inadequate in this respect, excessively long queues will form at peak periods, and people will be discouraged from using the standpost. As a rule of thumb, there should be one tap at a standpost for every 50 persons to be served.
To get a more precise view of how many taps are needed, it is necessary to examine the situation during peak hours. At most standposts this is either early in the morning or later in the afternoon. During the peak hours, taps may be kept wide open without interruption and the discharge of water from the taps is likely to be between 3 and 5 times the average flow. This latter ratio is referred to as the "peak factor" or "P".

Next to this a certain amount of water is spilled, or is used for rinsing out buckets, so a factor "w" is to be introduced to represent the fraction of the water that is wasted.

If the average demand per capita per day is denoted by "Cd" and the number of people served by the standpost is indicated by "$\frac{N}{S}$", the maximum flow at the standpost can be written as follows:

$$Q_{max} = N \times \frac{1}{S} \times \frac{Cd}{24} \times p \times \frac{1}{1-w} \times \frac{1}{f}$$

The manufacturers of taps can usually supply a graph showing the water discharge rate of a particular tap, at different feed pressures.

The minimum allowable pressure in a system may be as low as 5 metres (0,5 kgf/cm^3), but design pressures between 8 and 20 m are common. Many engineers favour values on the low side (around 10 m) to minimize leakage from the network.

The *number of taps required at a public standpost* obviously depends on the ratio of the required flow (Q_{max}) to the discharge capacity of one tap (q_d), and part of the designer's task is to choose taps of such dimensions that this ratio gives a convenient number of taps. To reduce the discharge capacity of a tap, an orifice can be fitted in the service pipe.

A separate calculation is necessary to determine *the diameter of the service pipe*. Knowledge of the water pressure in the mains, the desired pressure at the tap, and the length of pipe allows the hydraulic loss in the pipe to be calculated. Manufacturers of pipes provide charts showing what diameter pipe will be required to discharge the required peak flow.

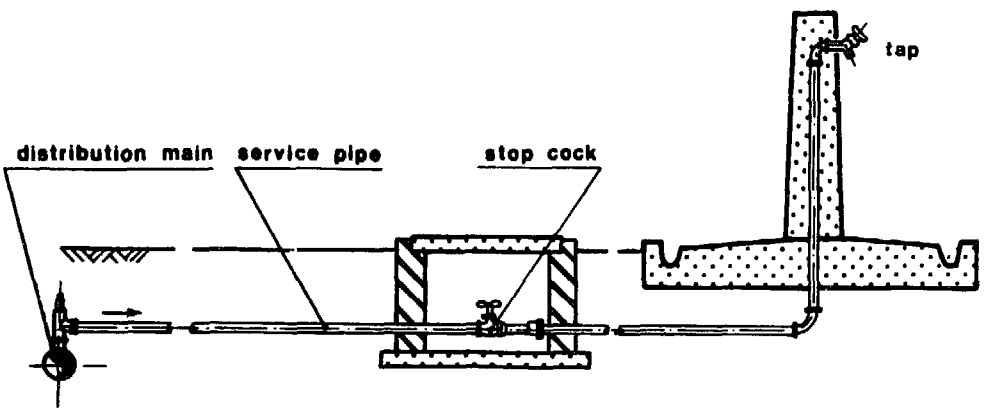

FIGURE 5: TECHNICAL ELEMENTS OF PUBLIC STANDPOSTS

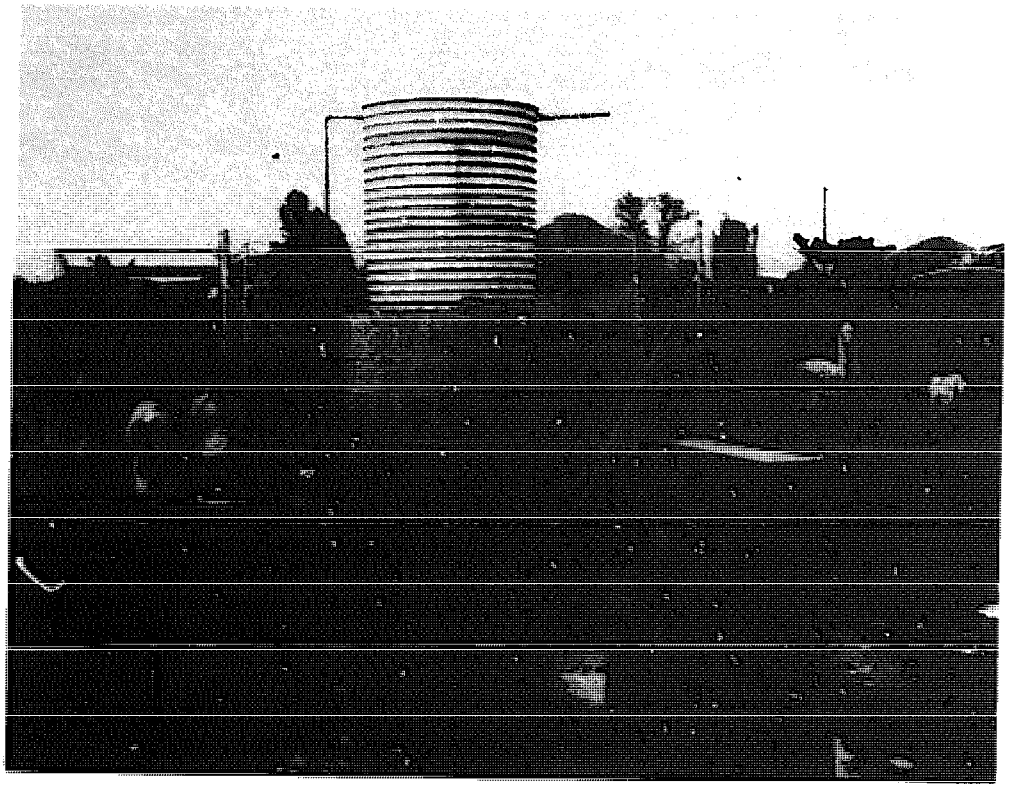

WATER MAY BECOME CONTAMINATED AT ANY POINT

STANDPOST STRUCTURE AND LAYOUT

A standpost structure consists of the wall or post which support the taps and the platform. The floor-surface should be hard and impermeable, and should slope towards some type of drain where waste water can run off. To ensure good drainage, the floor-surface should be raised about 0,10 m above the surrounding ground.

Two basic types can be distinguished. In the simplest and most widely applicable design the floor slopes away from the tap to trenches or soak-away drains at its outer edges (outward slope). Another type has the floor sloping towards the taps (inward slope), with a drainage channel let into the floor below the taps and discharging into a pipe at one end (annex 6).

The latter type of standpost drainage is likely to be relatively costly to construct, and will be justified mainly in urban areas where soak-away drains cannot be used. This type also presents a slightly greater contamination risk than does the outward sloping platform. If the drainage pipe become blocked, the standpost will be surrounded by a pool of stagnant water. It should therefore be used only where maintenance is adequate and drains are kept clear.

In rural areas, where relatively few persons use any one standpost, it may be desirable to economize by dispensing with a hard floor-surface altogether, in which case a soak-away drain is made directly under the tap. This soak-away should consist of a pit of, say, 0,50 m square and 0,80 m deep, filled with rubble or gravel through which spilled water can drain into the soil. The rubble infill should be built up to a suitable level to provide the necessary stand for buckets. Such an arrangement

can work well where soil is permeable and drainage is effective, but should be avoided in places where the ground easily become water-logged.

Wherever it is possible to carry away the waste water in drainage pipe, the water ought preferably to be put to some further use, such as: drinking water for cattle; the irrigation of gardens; or a fish pond.

When use of the waste water is impossible, direct discharge to any existing storm drain or canal is recommended, or the water may be infiltrated into the ground by means of soakage trenches or the number of seepage pits should be decided according to the permeability of the soil - clay soils will require relatively long trenches and sandy soils short ones.

The standpost floor or platform can be made from concrete or any suitable locally available material (brick, stone). The taps need to be well supported by a structure with a strong foundation. Too often the construction is inadequate, with sometimes just an unsupported pipe sticking out of the ground. Broken connecting pipes frequently result from this. Sometimes the rising pipe is strengthened; for example, by using 25 mm steel piping. It is, however, better to encase the pipe in masonry, or to attach the pipe and tap to a pillar or a wall.

There may be a need for small platforms or stands directly beneath the taps, on which users can place their buckets or other containers for filling. Where people carry containers on their heads, the height of these platforms about the ground should be 0,9 - 1,0 m for adults and 0,4 - 0,5 m for children. The height of the taps above these stands range between 0,4 to 1,0 m, depending on the manner of operation and the size of the containers used. In many countries, simple stands of brick or concrete are made underneath each tap, though where investment funds are less limited, metal gratings on which to stand the buckets may be used.

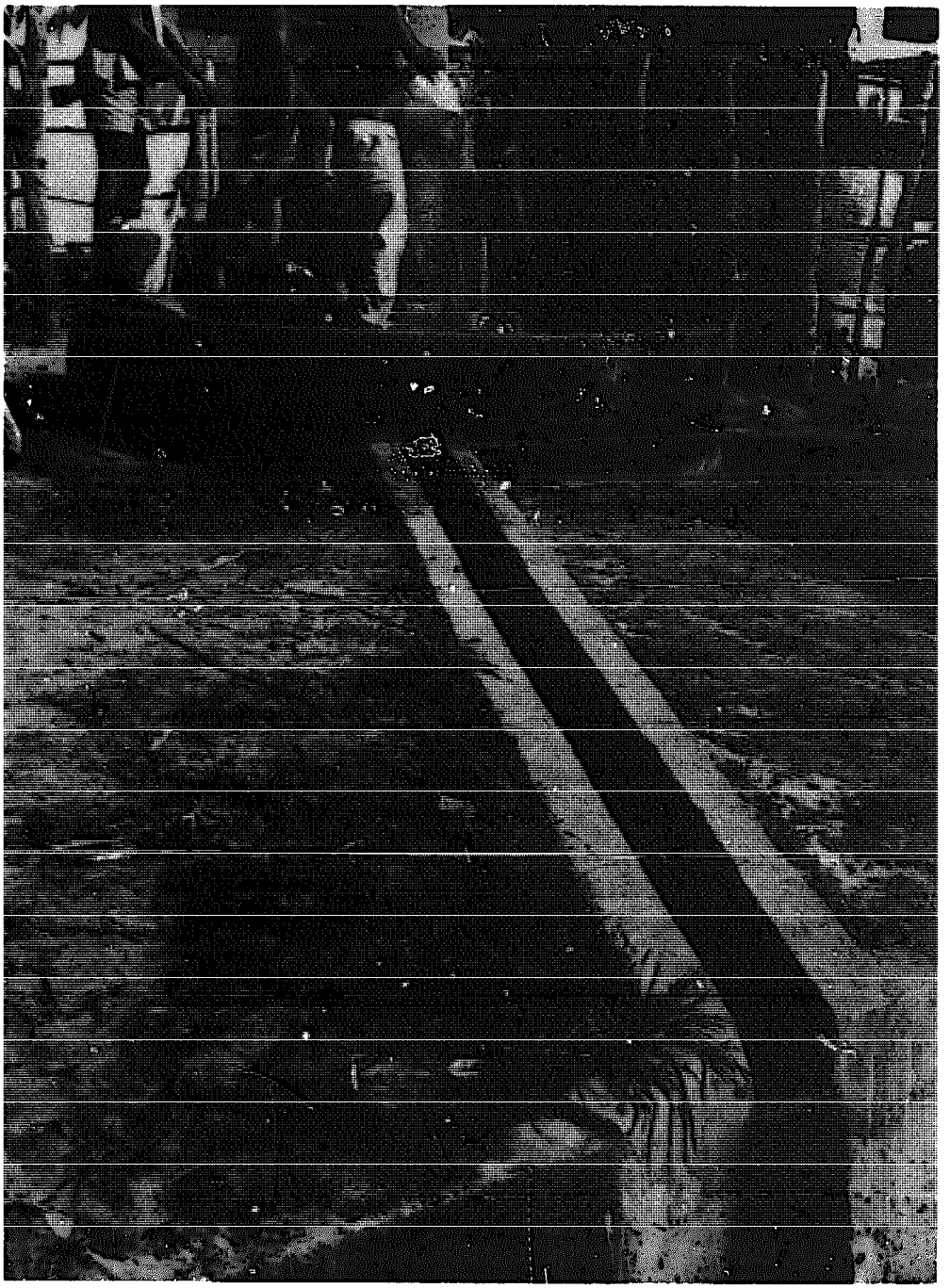

STANDPOST WASTE WATER DRAINAGE CHANNEL

Apart from the basic components of standposts so far described, the layout of the standpost platform may include other features, depending on the preference of users or on the provision to be made for supervision and revenue collection. Some kind of enclosing wall around the standpost may be demanded by the users, or may reduce supervision problems if the wall has a gate which can be locked. If no such arrangement is called for, a protective curb at the edge of the standpost platform may be advisable to keep away traffic from adjoining roads or to prevent cattle from getting onto the platform. This curb may take the form of a raised border, 0,20 m high where traffic is the problem, or may consist of a low wall, 0,80 m high where damage from cattle is expected. If the latter risk is great, it would be wise to have a cattle grid at the entrance. Separate troughs should be provided if livestock are to be watered and these should be situated outside the public standpost enclosure.

If there is a need for laundry and washing facilities, they should be provided near to, but separate from the standpost. Laundry may require only simple arrangements - slabs, sinks and shelter. Alternatively, a *"comfort station"* may be required, incorporating public toilets, showers and washing rooms. To construct a public standpost as part of a comfort station offers a number of technical advantages: the same service piping can supply water for all facilities, and the waste water can be discharged to the sewage system of the comfort station. The public taps should be located outside the outer wall of the comfort station.

ANNEXES

CHECKLIST FOR INTEGRATED PROGRAMME DEVELOPMENT

COMPONENTS	ELEMENTS
PLANNING	integration in national programme feasibility studies budget and financing
INSTITUTIONAL and ORGANIZATIONAL INFRASTRUCTURE	institutional framework legislation organization administration
RESEARCH and DEVELOPMENT	field investigations testing pilot studies
TECHNICAL ENGINEERING	design construction operation maintenance standardization
MANAGEMENT and ORGANIZATION	administration charges policy revenue collection system operation and maintenance indigenous manufacture
ECONOMICS and FINANCE	economic viability investment cost/recurrent costs cost effectiveness analysis financing arrangements revolving funds price structure
MANPOWER DEVELOPMENT	recruitment training courses, manuals, facilities
COMMUNITY DEVELOPMENT	surveys public information community participation sanitation

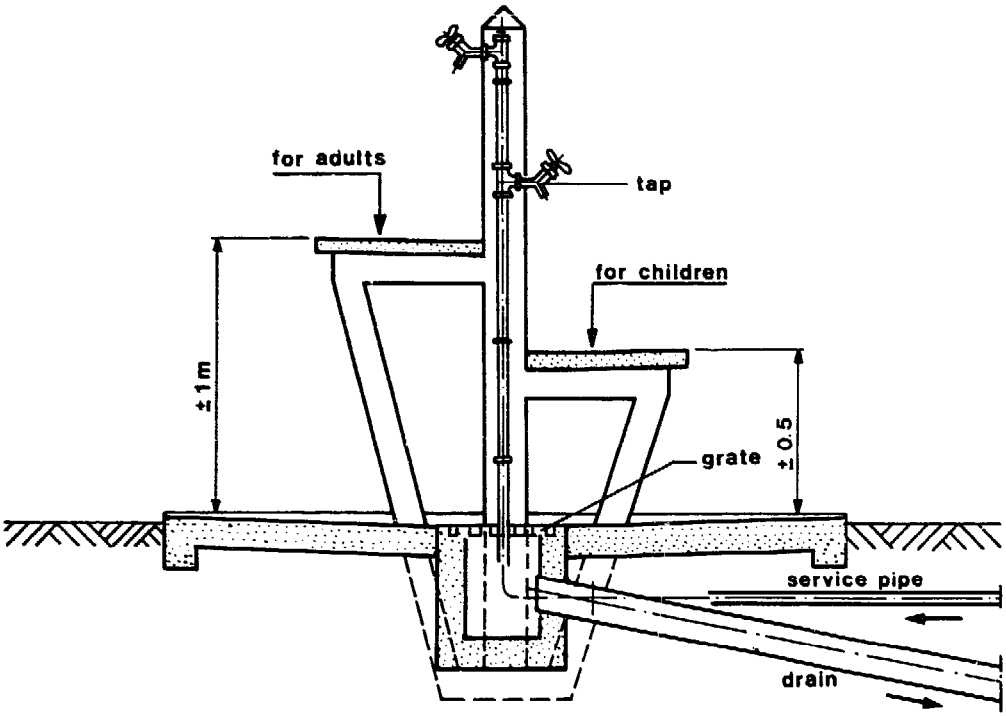

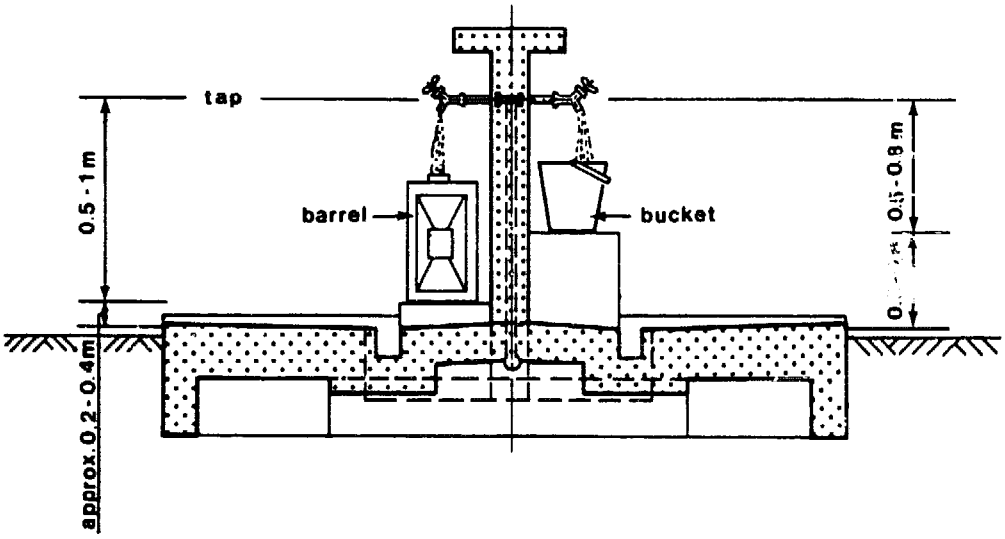

STANDPOSTS WITH RAISED PLATFORM

(a) to accommodate different categories of users

(b) to allow containers of different sizes to be used.

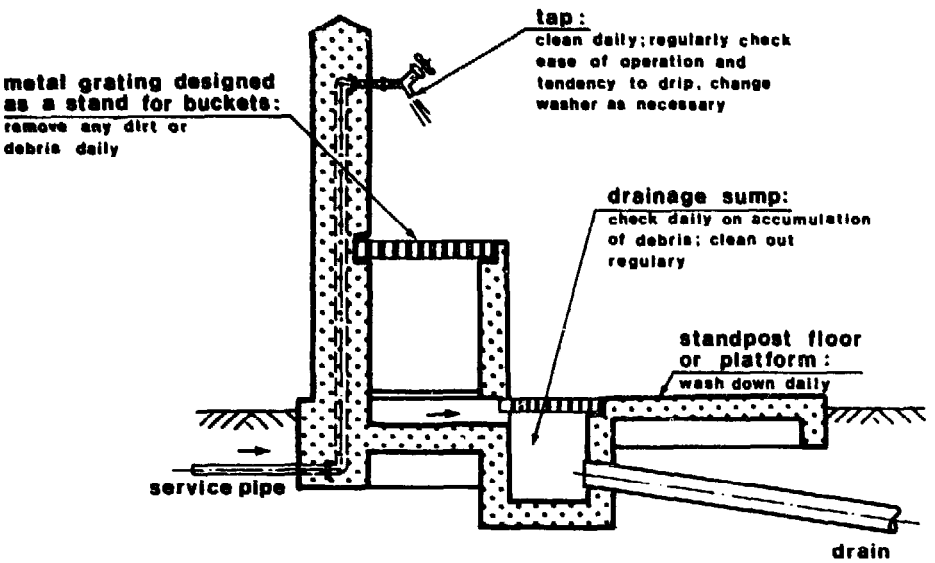

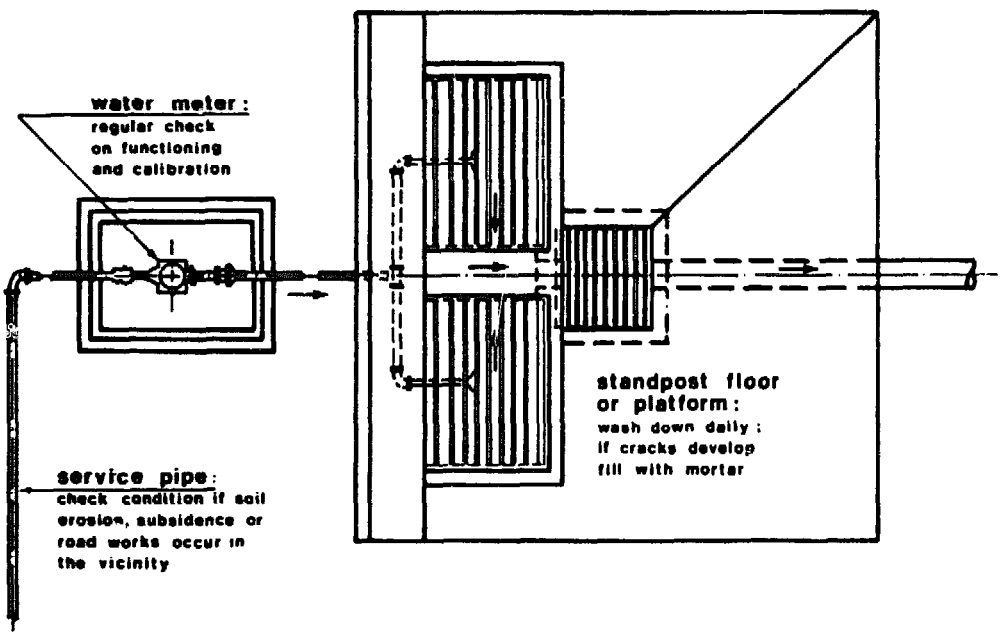

MAINTENANCE POINTS OF A STANDPOST

PROCEDURE FOR STANDPOST DESIGN

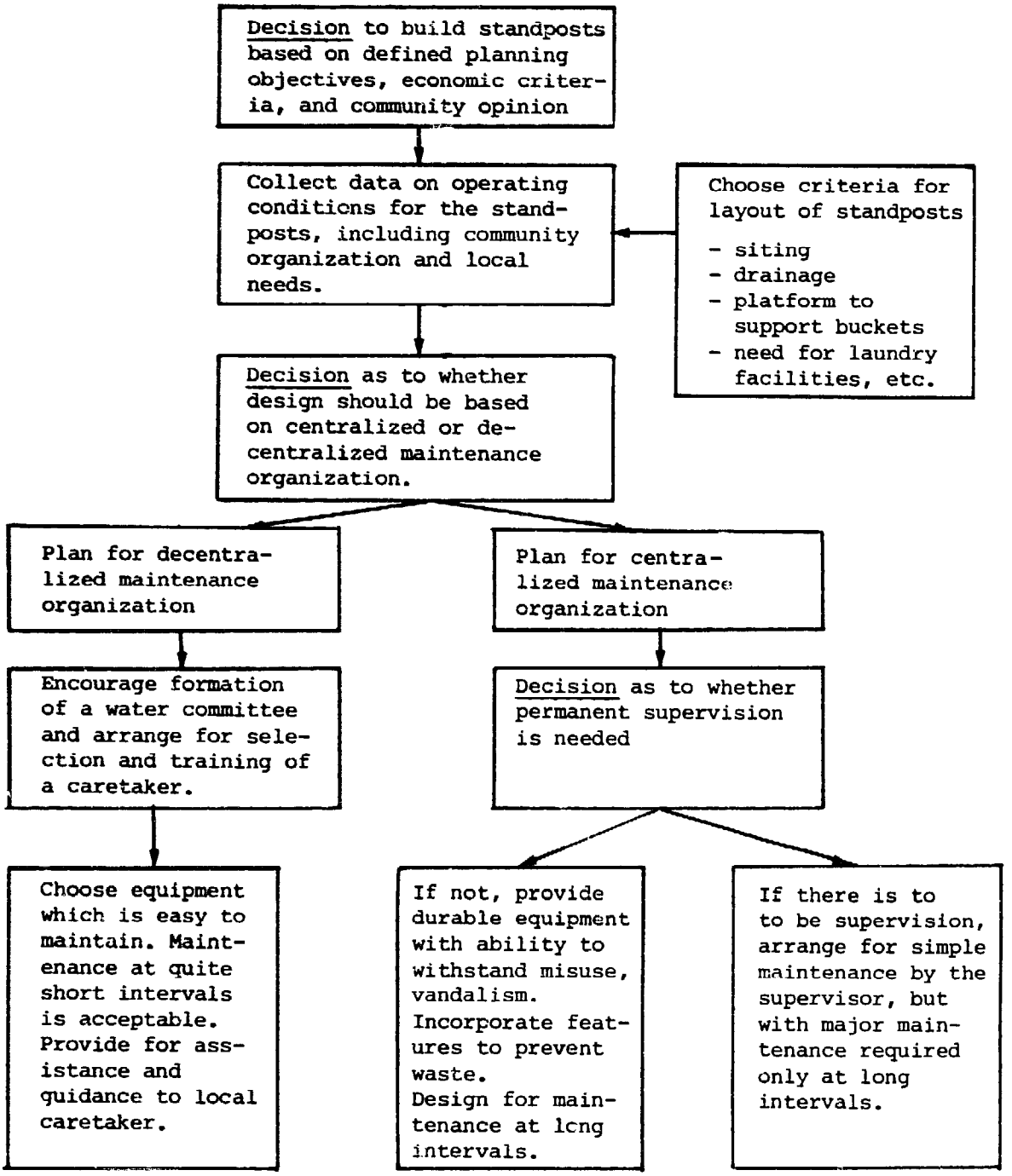

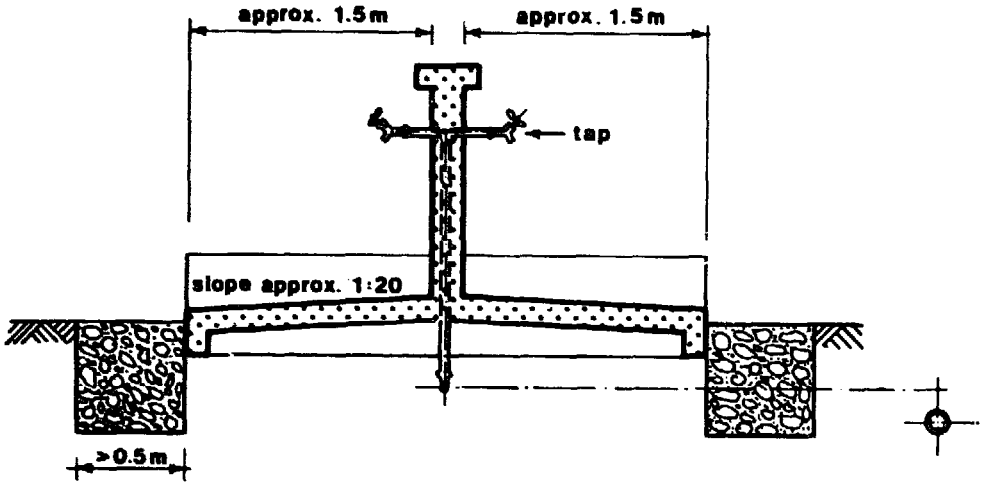

FIGURE A: CROSS-SECTION OF STANDPOST WITH TWO SCREW TAPS AND A CONCRETE PLATFORM

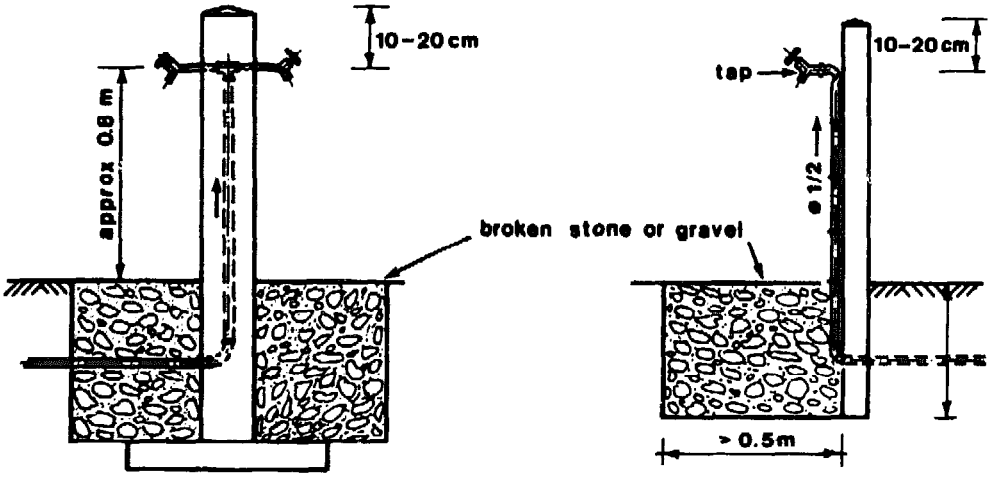

FIGURE B: CROSS-SECTIONS OF SIMPLE STANDPOSTS TYPICAL OF RURAL WATER SUPPLIES

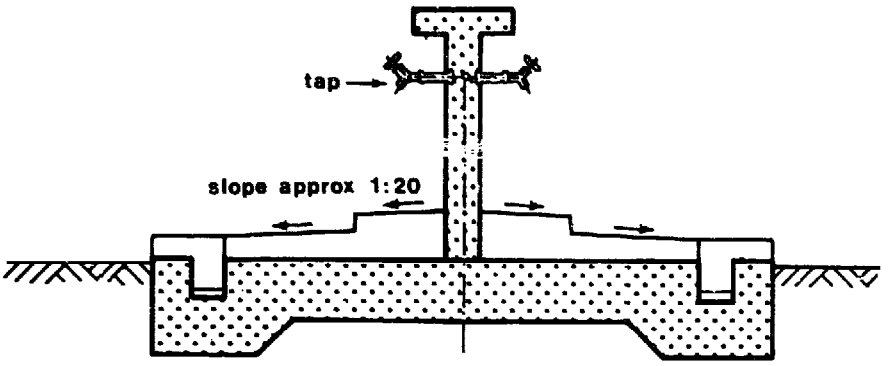

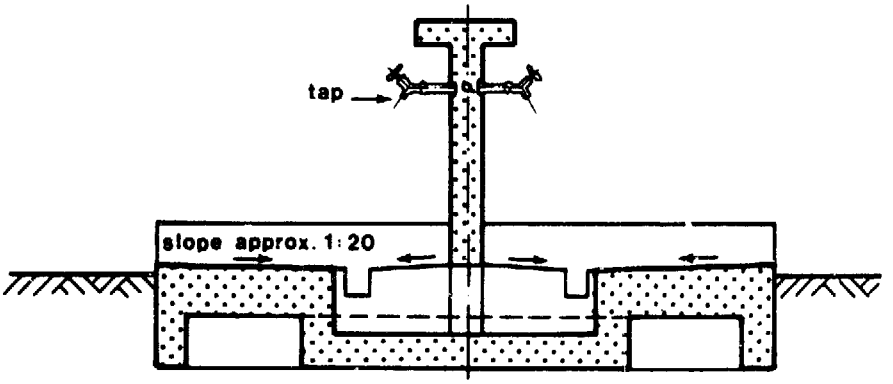

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Public Standpost Water Supplies

A Design Manual

14 Technical Paper Series

The International Reference Centre for Community Water Supply (IRC) is based on an agreement between the World Health Organization and the Netherlands' Government. The general objective of the IRC is to underpin information and technology support programmes in developing countries in the field of community water supply and sanitation and to promote international cooperation therein. Acting as a catalyst, the IRC operates through a worldwide network of regional and national institutions, as well as with international agencies, bilateral donors, non-governmental organizations and individuals.

Requests for information on the IRC, or enquiries on specific problems may be directed to the International Reference Centre for Community Water Supply, Information Section, P.O. Box 140, 2260 AC Leidschendam, the Netherlands.

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COMMUNITY WATER SUPPLY

PUBLIC STANDPOST WATER SUPPLIES

A DESIGN MANUAL

TECHNICAL PAPER 14
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PREFACE

Public standposts will continue to play an important role in improving and accelerating the provision of water supply and sanitation in rural and urban fringe areas, for a long time to come. In the framework of the International Drinking Water Supply and Sanitation Decade (1981-1990), large investments will be made in this sector in that period. This underscores the need for the development of appropriate methods for the planning, design and construction of public standpost water supply systems.

Throughout the world engineers have designed and installed public standposts, incorporating their own ideas. Often they have had to work from scratch and a great deal of valuable professional time has been spent in working out details. The step-by-step method that forms the basis of this Paper enables an engineer or technician to make the necessary calculations in an efficient way. The drawings and bills of quantities, which form the largest section of the Paper, can easily be adapted to suit local conditions. Therefore by using this Paper any technological skills available can be used in the most effective way in selection and modification to devise the most appropriate project. The Paper may also be utilized effectively as a guideline manual for instruction and training purposes.

JOHN PICKFORD

ACKNOWLEGEMENT

This Manual and the companion paper "Public Standpost Water Supplies" (IRC/Technical Paper No. 13) result from a study commissioned by The World Bank. The continuous support of the Bank to that study is gratefully acknowledged.

Further acknowledgement is due to the International Water Supply Consultants (IWACO, Rotterdam) for the preparation of this Manual. Also the contributions of Dr. J. Pickford, Group Leader Water and Waste Engineering for Developing Countries (WEDC), University of Technology, Loughborough, United Kingdom, and Mr. D.J. Elliot, Lecturer, University of Newcastle Upon Tyne, United Kingdom, in reviewing this publication are much appreciated. A special word of thanks is addressed to Marylynn Bianco for her organizational assistance, and to Dick Mos for his technical assistance in the finalization of this Paper.

It is intended to further develop and improve this Manual. Therefore, we fully depend on the willingness of its users to inform us about their experiences with this Manual and to communicate their suggestions for improvement. Any such suggestions on this would be highly appreciated.

Enric L.P. Hessing
Programme Officer

1. INTRODUCTION

A public standpost is a suitably supported water pipe, connected with a water distribution system and terminating in a tap or faucet, which is located at a public site, and from which water may be drawn for domestic and other uses. In other publications these installations are also referred to as: public standpipes, public hydrants, public fountains, public taps, public spigots or communal water points.

Public standposts are often installed as an intermediate step in the development of a fully house-connected water supply system. However, for many people, public standposts could well be the only feasible method of water supply for a long time to come. This is especially true in rural areas where a scattered housing pattern makes individual connections very expensive and in urban areas where improvements in housing are needed before house connections can become a feasible proposition; and in general, where funds for investment in water supply are severely limited.

In planning a public standpost water supply system, many organizational, economic, socio-cultural and technological factors have to be taken into account. These factors and their inter-relationships are discussed in the IRC Technical Paper 13, entitled "Public Standpost Water Supplies" which is regarded as a companion document to this Manual.

The present Manual deals with the technical and engineering aspects of the design and construction of public standposts. It offers a step-by-step design method, including the presentation of design criteria, an example design calculation, construction drawings and technical descriptions.

The design and construction of distribution networks are *not* discussed in this Manual. Information on this subject may be obtained from numerous other sources (see Annex 11).

In designing public standposts a number of alternatives have often to be compared, which requires iterative calculations. The reader is advised to study this Manual a number of times as a whole, before using it as a guideline in the actual design of a public standpost water supply.

The symbols and units used in this publication, are listed in Annexes 1 and 2.

2. DESIGN OF A STANDPOST

The layout of the scheme and the siting of the standposts is one of the most important aspects in the design of a public standpost water supply system. In general, standposts should be located as near to as many houses as possible, easily accessible to all users, but protected from vehicular traffic. The walking distance to the farthest dwelling should preferably not exceed 200 metres (m).

A standpost consists of a platform with a drainage facility, a supporting structure for the pipe and taps, a stand for buckets, the service pipe with valve and meter (optional), and the taps.

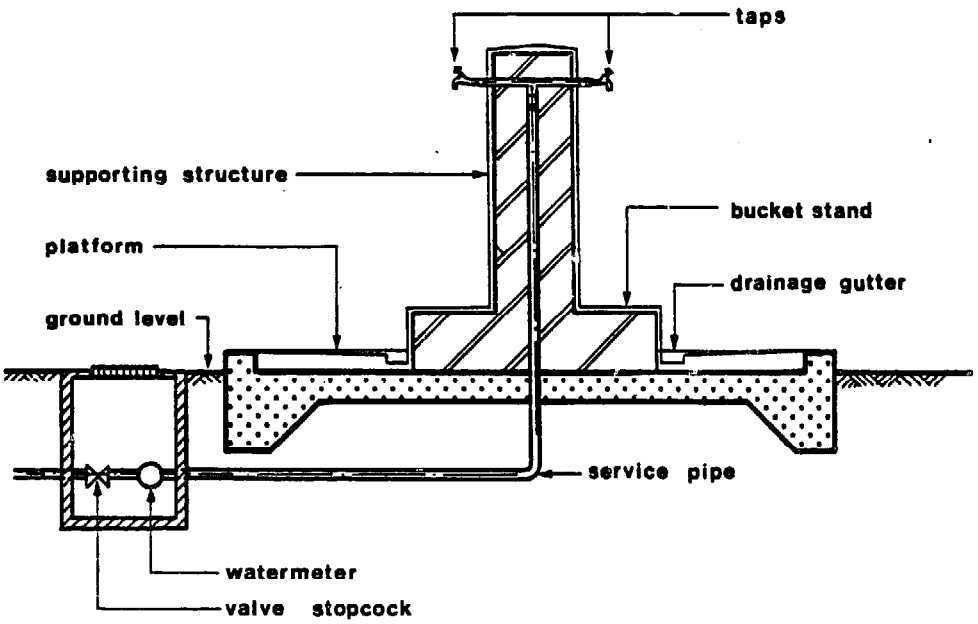

FIGURE 1

CROSS SECTION OF A PUBLIC STANDPOST

The *platform* should extend for at least 1.0 m around the tap(s) and be constructed of hard an impermeable material, preferably concrete or masonary. It should be raised at least 0.10 m above the ground to ensure good drainage and slope away from the taps towards a drainage channel. Alternatively the platform may slope inwards; the waste water is then collected in a gutter underneath the taps and is discharged into a drain.

The slope of both platform and drainage channels should be in the range of 1:50 (2%) and 1:20 (5%). The minimum dimension of the gutter is 0.20 m wide and 0.05 m deep at the beginning of the drain.

If possible, the waste water should be put to some use, for instance: irrigation, cattle watering or fish farming. It may also be led through an open channel to a watercourse, an existing storm-water drain, a soak-away pit or trench.

A soak-away pit consists of a hole of approximately 0.5 m^2 and 0.80 m deep filled with rubble or gravel through which waste water can filter into the soil.
The required length of soak-away trenches depends on the permeability of the soil; in clay soils relatively long trenches are necessary; in sandy soils short ones will suffice.

The *supporting structure* and the attachment of the taps should be solidly constructed. The best way to protect the pipe is to encase it in a brick or concrete column of at least 0.30 m square. To protect the taps, the supporting structure should extend 0.10 m above them.

Underneath the taps a *raised stand* can be constructed to support buckets and containers whilst being filled. The height of the stand, and of the taps themselves, is determined by the size of the containers used, the manner of carrying them, and the question of whether children as well as adults will fetch water.
For example, if people carry containers on their heads, the stand should be 0.9 to 1.0 m high, with the height of the tap above it dependent on the containers size. Children would need a stand 0.5 m high in this case.
The distance between the tap and the top of the container should be less than 0.5 m in order to reduce the spillage of water.

The *service pipe* or supply pipe may be of galvanized steel or PVC, but PVC pipes should only be used where they are covered and cannot be damaged either by misuse or accident. The necessary pipe diameter is dependent on the required discharge capacity, on the type and number of taps at the standpost and on the water pressure. Normally, the diameter of the service pipe is in the range of 12 mm (½-inch) to 36 mm (1½-inch).

The *main valve* or stopcock should be installed in a space which can be locked. *Water meters* may provide important information for studies on consumption and wastage, for calculations of future consumption and on decisions regarding the need for additional public standposts; and may serve as means for establishing the payment due for water used. Meters should only be used when they serve a definite purpose and when regular maintenance in a workshop by properly qualified and equipped staff is available. Every meter should be housed in a box which can be locked and should be inconspicuously located.

The *flow control mechanism* most frequently used is the ordinary screw tap with washers. Possible alternatives are: a ball or plug valve tap; spring-loaded or gravity operated taps; volumetric or delayed-closing valves. Reference is made to Annex 10.

Other features can be included in the design, depending on the users' needs and on provisions made for supervision and revenue collection. The standpost may be surrounded by a wall or fence with a locking gate for protection during unsupervised hours. A curb 0.2 m high can prevent damage by traffic, while a wall 0.8 m high around the standpost area and a cattle grid at the entrance, rules out pollution by animals.

3. THE REQUIRED DISCHARGE CAPACITY PER STANDPOST

An important factor in the design of a public standpost water supply system, is the required maximum discharge capacity (Q_{max}) *per standpost*.
This parameter is the basis for the hydraulic calculation and the determination of the dimensions of the service pipe and of the type and number of taps.

This Q_{max} is determined by the design population (N), the average demand per capita (C_d), the peak factor (P), the number of standposts (S), the waste factor (w) and an efficiency factor (f).
The relationship between the factors is presented by the formula:

$$Q_{max} = N * \frac{1}{S} * \frac{C_d}{24} * P * \frac{1}{1-w} * \frac{1}{f}$$

Each of the six factors that constitute this formula have to be determined separately before the maximum discharge capacity can be calculated.

3.1. Design Population (N)

This factor depends on the initial magnitude of the population to be served, the growth rate of the population, and the design period.

The *initial number of users* (N_o) in the area to be served by the prospective standposts should be counted or estimated.

An indication of the expected *annual growth rate* (r) of the population can be obtained from historical statistical data on the area concerned. If these are not available, one may substitute figures related to a similar area or to the country as a whole.

The standpost must have sufficient capacity to meet the users' water demands during a period of several years. The *design period* (T) is determined by various technical and economic factors; a period of ten years is usually sufficient, but there may be local reasons that make a shorter or longer period desirable.

The *Design Population* (N) can now be calculated according to:

$$N = N_o * \{1+r\}^T$$

One may prefer to work with a growth factor: $m = \{1+r\}^T$. In that case use can be made of a table giving the growth factor as a function of a fixed annual growth rate and the design period. In general the growth factor will be in the range of 1.0-1.6 (see Annex 3).

3.2. Demand per Capita (C_d)

The average volume of water drawn from public standposts is typically between 20 and 60 litres per capita per day (lcd). Local habits related to domestic water use will have to be studied in order to establish an accurate figure, particularly in cases where there has been no previous experience with standposts or where other sources are available. Normally, a provision is also made for livestock watering.

Future increases in demand should be provided for. It is advisable to provide excess capacity for a design period of at least 10 years and that allows for an increased consumption per person.

In the design of the distribution network, allowance may also be made for uses other than domestic, such as small industries, etc.

3.3. Peak Factor (P)

During some hours the standpost will be used more intensively than during the rest of the day. The water supply system should be capable of dealing with this peak demand. Therefore, a peak factor representing the ratio between peak and average demand, is introduced in the calculation Q_{max}. Normally, this peak factor is in the range of 2 to 4, a typical average being 3.

The peak factor can be approximated by $P = 24/t$, in which t is the number of peak hours (normally in the range of 4 to 12 per day). The result of this method tends, however, to be on the high side, as the method presupposes that no water at all is drawn outside the peak hours.

The peak factor should be determined with great care, as it has a considerable influence on the Q_{max}. It is recommended that the local water collection pattern should always be studied thoroughly.

3.4. The Number of Standposts (S)

The required number of standposts is based on two other design criteria, the maximum walking distance to the standpost and the maximum number of users per tap. These two criteria are directly related to the intended "level of service", which results from the consultations between the users and the planners of the public standpost scheme.

The Maximum Walking Distance

In general it is advisable to limit the walking distance to 200 m and in densely populated areas it is often possible to limit the distance to 100 m. In very sparsely populated areas a walking distance of up to 500 m may sometimes be acceptable.

In densely populated areas, however, the application of this criterion may result in too many users per standpost and per tap. Therefore, a second criterion that relates to the population density in a particular area, is required.

The Maximum Number of Users per Standpost

It is advisable to limit the number of users per standpost to 100-250; in no case should this number exceed 500. The number of users per tap should preferably be in the range of 25-125. This criterion is directly related to the maximum discharge capacity of the taps and to the water collection pattern during peak hours.

Proceeding from more or less evenly spaced standposts in a given area (A) and a set maximum walking distance (R), the number of standposts can be assessed using the formula:

$$S = A/\pi R^2$$

A = total area of the scheme in m^2

S = the number of standposts

R = the service radius in m

$\pi = 3.14$

It should be noted that the service radius does not exactly equal the maximum walking distance (see Annex 4).

In case the afore-mentioned approximation of the number of standposts (S) leads to a too high average number of users per standpost, one may increase the number of taps per standpost, in order to meet the criterion set for the maximum number of users per tap. However, the number of taps per standpost should be limited to avoid the crowding of too many people near one standpost; it is advisable not to install more than four taps per standpost.
If by providing more than one tap the criterion of the maximum number of users per tap can still not be met, the number of standposts in the area under consideration is to be increased.

In practice, the actual local geographical and demographical circumstances will determine the siting and the exact number of standposts and taps, as well as the actual number of users for each standpost. However, in most cases, as a first assessment, the above method gives satisfactory results.

3.5. Waste Factor (w)

Part of the water is inevitably spilt by users when filling their containers or drawing water for immediate use at the standpost. To express this numerically, the waste factor (w) is introduced. This factor can be determined by calculating the ratio of the amount of water actually taken away by the users and the total amount of water discharged through the taps.
Spillage and wastage depend on the way in which containers are filled, the type and condition of the taps, the height of the taps above the bucket-stand, the water pressure, and on whether or not the standpost is supervised.

The waste factor can best be estimated from data obtained in other schemes. It should only include the spillage and wastage related to the collection and use of water at the tap and not the leakage of water in the main and branch pipes of the distribution network, as this leakage water is not discharged through the taps.

The waste factor is in the range of 0.1 to 0.4 which means that 10 - 40% of the total discharge at the tap is spilt or wasted. As the waste factor has a considerable influence on the Q_{max} careful assessment of the factor is required.
It is important to decide whether water used for purposes, such as washing of utensils and personal cleaning at the tap should be considered as part of the per capita demand or is to be regarded in terms of spillage or wastage.

3.6. The Efficiency Factor (f)

The efficiency factor is introduced to take into account that the suppliers rating of the capacity of a tap is usually based on continuous discharge at 10 mhw with the tap fully open. In practice the pressure will never be exactly 10 mhw and discharge is usually not continuous. The closing and opening of the tap will make the actual discharge smaller than the theoretical maximum.

Depending on the type of tap, the efficiency factor (f) can range from almost 1.0 for a ball valve (rapid closing tap), to 0.9 and 0.8 for an ordinary screw tap, and 0.7 for spring-loaded taps.

3.7. Calculation Example

The calculation of the required maximum discharge capacity of standposts can best be illustrated by an example; assume the following situation:

N_o = initial number of users = 12 000
r = population growth rate = 2% per year
T = design period = 10 years
A = area of scheme = 100 ha = $1.10^6 m^2$
S = number of standposts
C_d = average demand per capita = 40 lcd
t = number of peak hours = 4.5 h
w = wastage factor = 0.2
f = efficiency factor = 0.9

The design population can be calculated as:

$$N = N_o * \{1+r\}^T = 12000 * 1.02^{10} = 12000 * 1.22 = 14640 \text{ persons.}$$

If the service radius is set as R=200 m and the number of users per standpost is limited to 250, the *number of standposts* can be determined as follows:

a. $S > A/\pi R^2 = 10^6/3.14 * \{200\}^2 = 7.96$ and
b. $S > N/250 = 14640/250 = 58.56$

Consequently, the maximum number of users per standpost is the decisive factor in this case (b). If the number of standposts is now set at 60, the average number of users per standpost is: 14640/60 = 244 persons, and the service radius about 73 m.

The *required discharge capacity per standpost* can be calculated as:

$$Q_{max} = \frac{N}{S} * \frac{C_d}{24} * P * \frac{1}{1-w} * \frac{1}{f} =$$

$$\frac{14640}{60} * \frac{40}{24} * \frac{24}{4,5} * \frac{1}{\{1-0,2\}} * \frac{1}{0,9} = 3012 \text{ l/h}$$

If the area had been 1000 ha instead of 100 ha, the result of the equation $S \geqslant A/\pi R^2$, for R = 200, would have been 80 standposts and the criterion of the maximum walking distance would have been decisive (a). The average number of users per standpost would then have been: 14640/80 = 183 and the Q_{max} equal to 2260 l/h per standpost; assuming that population and standposts are evenly distributed.

However, in practice, and particularly in larger areas, the *population will almost never be evenly distributed.* Therefore, the number of standposts and their location will always have to be determined on the basis of the local geographical cicumstances, including the variation in population density in the area concerned. This may lead to a variation in the number of users per standpost and subsequently to a difference in the required discharge capacity of the various standposts.

The above serves to show that, generally speaking, the maximum number of users per standpost will be the criterion in densely populated areas, whilst in sparsely populated areas the maximum walking distance will be the decisive factor.

Finally, it should be pointed out that Q_{max}, as calculated in this Chapter, only relates to water that is actually discharged via standposts. The total amount of water that is pumped into the distribution network is often reported to be 10-50% higher than the total discharge via standposts and house connections. This is due to *leakage in the pipe system.* This factor is *NOT* included in the calculations in this publication, as this publication only deals with the discharge from standposts.

All the afore-mentioned values have been assumed. The designer should substitute his own data depending on the characteristics of the system he is working on.

4. DESIGN CALCULATIONS

Following the calculation of the maximum required discharge capacity (Q_{max}), the diameter of the service pipe and the required number of taps can be determined. Use is made of a number of graphs, which give the headloss for each component of the system. Before this method is explained in detail (see paragraph 4.2.) a short introduction is given on the various components and parameters that play a role in the graphical calculation.

4.1 COMPONENTS AND PARAMETERS

The sequence of presentation of the components is the same as the sequence followed in the graphical calculation.

4.1.1. *Watermeter*

Usually a watermeter has its nominal discharge at a pressure head of 10 mhw. This means that a "3-m^3" watermeter at 10 mhw discharges 3 m^3/h. Higher flows will result in wear of the meter, and impaired accuracy. The calculated discharge capacity of the standpost should be between 50% and 80% of the maximum capacity of the meter (e.g. where Q_{max} = 3012 l/h, a "5-m^3" watermeter is a good choice).

The headloss curve of a meter should preferably be obtained from its supplier or manufacturer. However, if this is not available, one can select a sufficiently accurate curve for a meter with a similar nominal discharge from the graphs presented in this Manual.

Meters should only be used when they serve a definite purpose, for instance, to obtain information for studies on consumption and wastage or for determining what payments are due for water use. Very often, however, there is no need for a watermeter and if no watermeter is installed, this component should be disregarded in the graphical calculation.

4.1.2. *Material and Diameter of the Service Pipe*

The material and diameter have a direct influence on the hydraulic characteristics of the service pipe, and of course, the same is applicable to the main. This relationship forms the basis for the formula for the *hydraulic gradient* (see Annex 6).

This hydraulic gradient indicates the headloss per meter of pipe. For a given flow, headloss will decrease as pipes with greater diameter are chosen. It is financially attractive to use the smallest possible diameter pipe that delivers the desired flow at the available pressure. On the other hand, a little extra capacity in the form of a larger pipe may prove a good investment in case of unexpectedly high demands, or a falling off of pressure in the main.

For the calculation of the diameter of the service pipe, two different graphs are available: one for galvanized steel and one for polyvinylchloride (pages 31 and 32).

In the graph of the *galvanized steel (GS) pipes* the specific curves of ½, ¾, 1, 1¼ and 1½-inch have been drawn. The internal diameters used comply with galvanized steel pipes, medium class, as specified in ISO-Recommendation R 65, DIN 2240 and BS 1387.
Normalization of steel pipes is nearly worldwide, which is not the case with PVC-pipes.

In the graph of the *PVC-pipes* a bundle of curves with selected internal diameters are presented. However, the actual internal diameters of pipes having the same nominal sizes vary considerably all over the world. Therefore, the most appropriate curve is to be selected from the graph or alternatively a new curve has to be drawn.

To facilitate the choice, some parts of the curves are heavily lined. These parts should be applied with preference so as to ensure that the flow velocity in the pipe is in the range of 0.5-2.0 m/s.

4.1.3. *Length of Service Pipe*

The service pipe should follow the most direct route possible. The length of service pipe should be measured from the connection point at the main pipe to the tap at the standpost. The length, therefore, is greater than the direct horizontal distance between main and standpost (see Annex 5).

In the "length of service pipe" diagram a series of curves has been drawn. The appropriate curve should be selected or a new curve has to be drawn by means of interpolation.

4.1.4. *"Available Head"*

The "available head" is defined as the pressure head that is available to overcome the *hydraulic losses which occur when the water flows* through the pipe, meter and tap. Therefore, the *actual water pressure in the main* has to be adjusted for any *difference in level between the main and the outlet of the taps* (see annexes 3 and 4).

The water pressure in the main or distribution pipe at the point where the service pipe is connected can be measured with a pressure gauge on the pipe, or computed using technical data for the distribution network. Normally, a "design pressure" is chosen of between 5 and 20 mhw; to minimise leakage in the network the pressure is often limited to 10 mhw.

4.1.5. *Type of Tap*

The type of tap to be applied depends upon the required discharge capacity and the availability of the taps.
Generally, the discharge of a tap will be given by the supplier at a pressure head of 10 mhw. A ½-inch ordinary tap commonly delivers 800 l/h and a ¾-inch tap 1500 l/h at a head of 10 mhw.
In the graph a set of curves is presented for specified discharges at a pressure head of 10 mhw. The most appropriate curve should be selected or a new curve has to be drawn, giving the closes: match to the data supplied by the manufacturer of the particular tap.
The preferred range of pressure on the tap (4-10 mhw) is indicated in the graph.

4.1.6. *Number of Taps*

The last section in the graph concerns the determination of the number of taps. Preferably the number of taps on a public standpost should not exceed four, but in the graph the possibility to select up to six taps is offered. A final decision regarding the type and numberof taps is often made on the basis of a comparison of existing alternatives. (see calculation examples 4.2.1. and 4.2.2.)

4.2 HOW TO USE THE GRAPHS

The way to find the diameter of the service pipe and the number of taps by using the graphs (on page 33 and 34) can best be explained by means of an example.

The calculation example for the required discharge capacity, as given in item 3.7, is chosen as the starting point: Q_{max} = 3012 l/h.

In addition to this the following assumptions are made:
- length of service pipe = 80 m;
- pressure in the main at the point of connection of the service pipe = 16,5 mhw;
- the taps are located 1,5 m higher than the main.

Before the actual hydraulic calculations can start, we have to determine the *available head*, the actual pressure in the main has to be adjusted for the differences in elevation between the main and the tap(s). Reference is made to Annex 5. In this case the available head can be calculated as H_a = 16,5 - 1,5 = 15 mhw.

4.2.1. *Example Showing How to Use the Graph for Galvanized Pipes (p.31)*

Start from the vertical Q_{max} - axis horizontally to the watermeter diagram. The watermeter to be used for Q_{max} = 3012 l/h is a "5 m^3" meter.
The intersection with the "5 m^3" watermeter curve is point 1.
The headloss of the watermeter can be read on the horizontal axis (3,7mhw). If no meter is installed, pass horizontally through the watermeter diagram and go directly to the service pipe diagram.

From point 1 travel horizontally to find the diameter of the service pipe, continue to the heavy lined parts of the headloss curves of the service pipes. Find point 2 on the 1½-inch, point 3 on the 1¼-inch and point 4 on the 1-inch curve of the service pipe. There are now three alternatives, and, in principle, all of them have to be considered.

Alternative I (GS; 1-inch Pipe)

Go vertically from point 4, the length of the service pipe diagram and find point 5 at the intersection with the interpolated 80 m curve. The headloss of the service pipe (on the vertical axis) is 20 mhw. The found headloss is more than the "available head" and hence this calculation is stopped.

Alternative II (GS; 1¼-inch Pipe)

Go vertically from point 3 to the intersection with the 80 m curve, find point 6, go across to meet the vertical axis of the length of service pipe diagram and read the headloss of the 80 m service pipe which amount to 4,8 mhw.

To graphically make the addition of the headloss of the water-meter and the service pipe, use can be made of the addition diagram. Start at point 7 and travel along the 45 degree incline to find the intersection with the vertical line from the water-meter diagram; this is point 8 and the addition has been made: total headloss 8,5 mhw.

Travel further horizontally to the "available head" diagram; the lines with an incline of 45 degrees represent steps of 5 metres. The intersection with the related line of 15 mhw gives point 9.

From point 9 go vertically down to the type of tap diagram to point 10, read on the horizontal axis the available head on the tap (approximately 7,5 mhw); this is within the recommended pressure range for taps (4-10 mhw). In this case a ¾-inch ordinary tap was chosen, with a discharge of 1500 l/h at a pressure head of 10 mhw.

To find the number of taps go horizontally from point 10 to the 'number of taps'-diagram for one ordinate; the other ordinate is the required Q_{max} (on the horizontal axis). This gives point 12, that lies within the "3 taps area".
The outcome of this alternative is 3 taps of ¾-inch and a 1½-inch service pipe. But we still have to look at the third alternative as well.

Alternative III (GS 1½-inch Pipe)

In a similar manner as before travel from point 2 to point 13 in the 'length of the service pipe'-diagram; note that the headloss in the 1½-inch pipe is less than in the 1¼-inch pipe.
Then to point 14 in the addition diagram, add the headloss in the pipe (2 mhw) to the headloss of the watermeter (3,5 mhw), find point 15, travel horizontally to point 16 in the "available head"-diagram and down to the selected tap curve and point 17, continue horizontally to point 18 to find the result: exactly 2 taps of the chosen type. This would mean that the required maximum discharge capacity of the standpost can never be exceeded because both taps are then operating at their maximum discharge capacity.

If the planner should stipulate that for 244 users at least 4 taps are required, and if several types of taps are available, one can aim at the '4 taps area' and let the type of tap follow from that. The result could then be 4 taps of ½-inch (nominal 800 l/h) on a 1½-inch service pipe, or 4 taps of nominal 1000 l/h on a 1¼-inch service pipe.

Before a final decision is made always consider the various alternatives and carry out some iterative calculations regarding the number and type of taps in relation to the diameter of the service pipe.

4.2.2. *Example Showing the Use of the Graph for PVC Pipes (P.32)*

Start from the vertical Q_{max} - axis, travel horizontally to the watermeter figure. The intersection with the relevant curve of the "5 m^3" watermeter is called point 1. The headloss of the watermeter at a discharge of approximately 3000 l/h is 3,5 mhw.

Travel horizontally to find the service pipe diameters. If the diameters of the available pipes are not among the given curves, new curves will have to be interpolated. This is done as an example and the point 2, 3 and 4 are the subsequent intersections. The three alternatives can be worked out as follows:

Alternative I

Travel form point 4 vertically to meet the interpolated 80 m curve, find point 5 and travel horizontally to meet the vertical axis; the headloss in the service pipe is 9,5 mhw. The addition of the headloss of the watermeter is done by travelling from point 6 along the 45 degree incline to meet the vertical coming from point 1. The found intersection is called point 7 and the total headloss amounts to approximately 13 mhw. If no watermeter is used, disregard this addition and go straight to the available head diagram.

Travel from point 7 horizontally to the "available head"-diagram, meet the relevant head line and find point 8. Note the available head at the tap is only 2 mhw. This is outside the recommended pressure range, hence this calculation is stopped here.

Alternative II

Travel vertically from point 3 to meet the 80 m curve in the 'length of the service pipe'-diagram (point 9). From here go across to meet the vertical axis; the headloss in the service pipe is 3,5 mhw.

From point 10 travel along the 45 degree line to meet the vertical line coming from point 1, and find point 11; the addition of the headloss in the pipe and the watermeter results in 7 mhw. Travel horizontally to the 'available head'-diagram, make the intersection with the relevant line of 15 mhw (point 12), go down the horizontal axis and note the available head on the tap is 8 mhw. This is within the recommended range. Continue to the 'type of tap'-diagram; the intersection with the chosen type of tap is point 13.

To find the number of taps go horizontally from point 13 to the 'number of taps'-diagram for one ordinate. The other ordinate is the Q_{max} = 3012 l'h on the horizontal axis. The intersection is point 14 and lies within 'the 3 taps area'; this means that this alternative results in 3 types of the chosen type, in this case an ¾-inch ordinary tap with a discharge of 1500 l/h at a headloss of 10 mhw, and a PVC service pipe with an internal diameter of 34 mm.

Alternative III

Start at point 2, being the intersection of the 42 mm internal diameter curve and the horizontal line coming from the watermeter diagram, and follow the example in the graph to point 19.
This is just within the border of the recommended pressure range, but the intersection point 20 lies exactly on the boundry of the 'two taps area'. This gives a profit of 1 tap with regard to the second alternative.

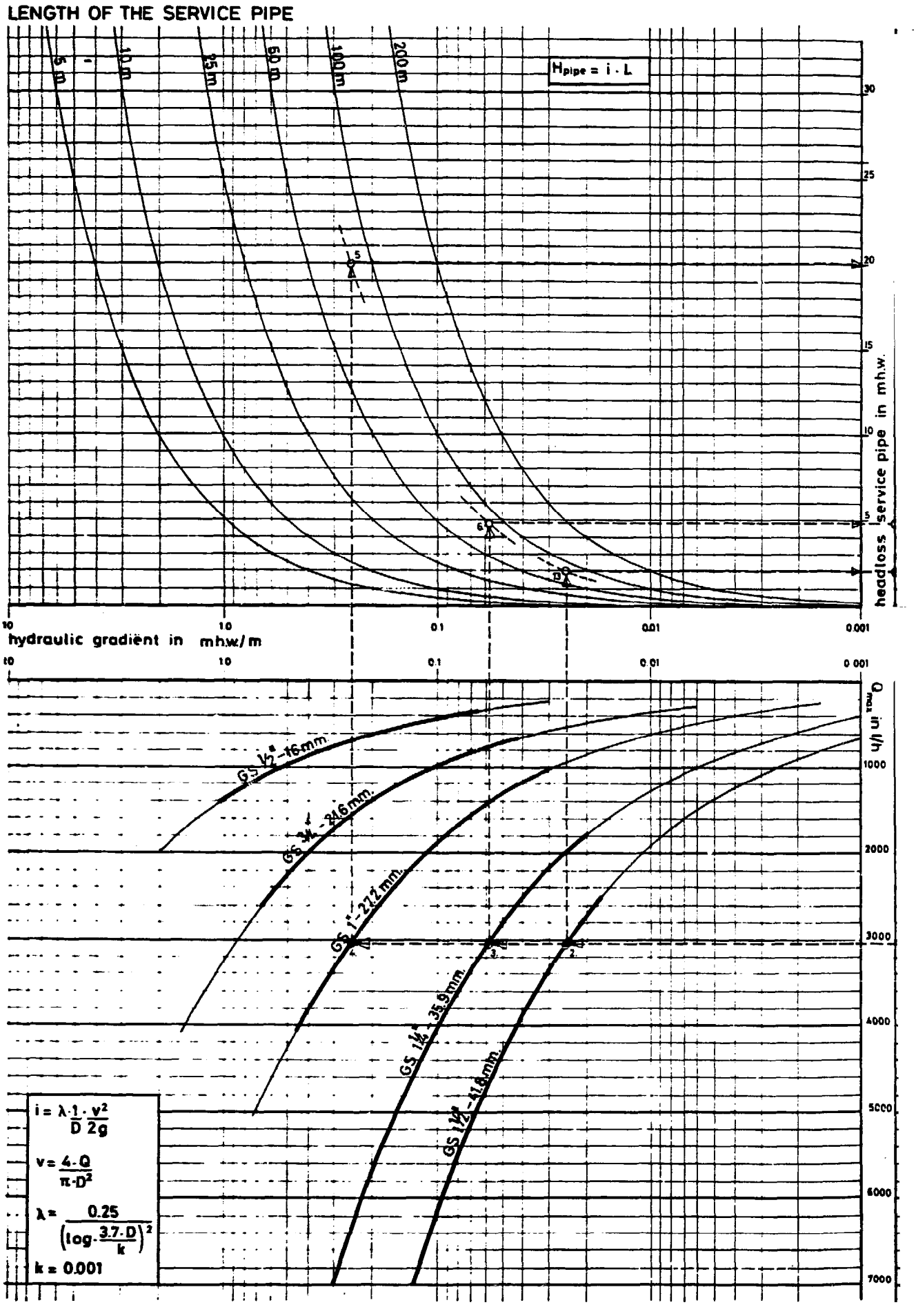

DIAMETER SERVICE PIPE (GALVANISED STEEL).

ADDITION FIGURE

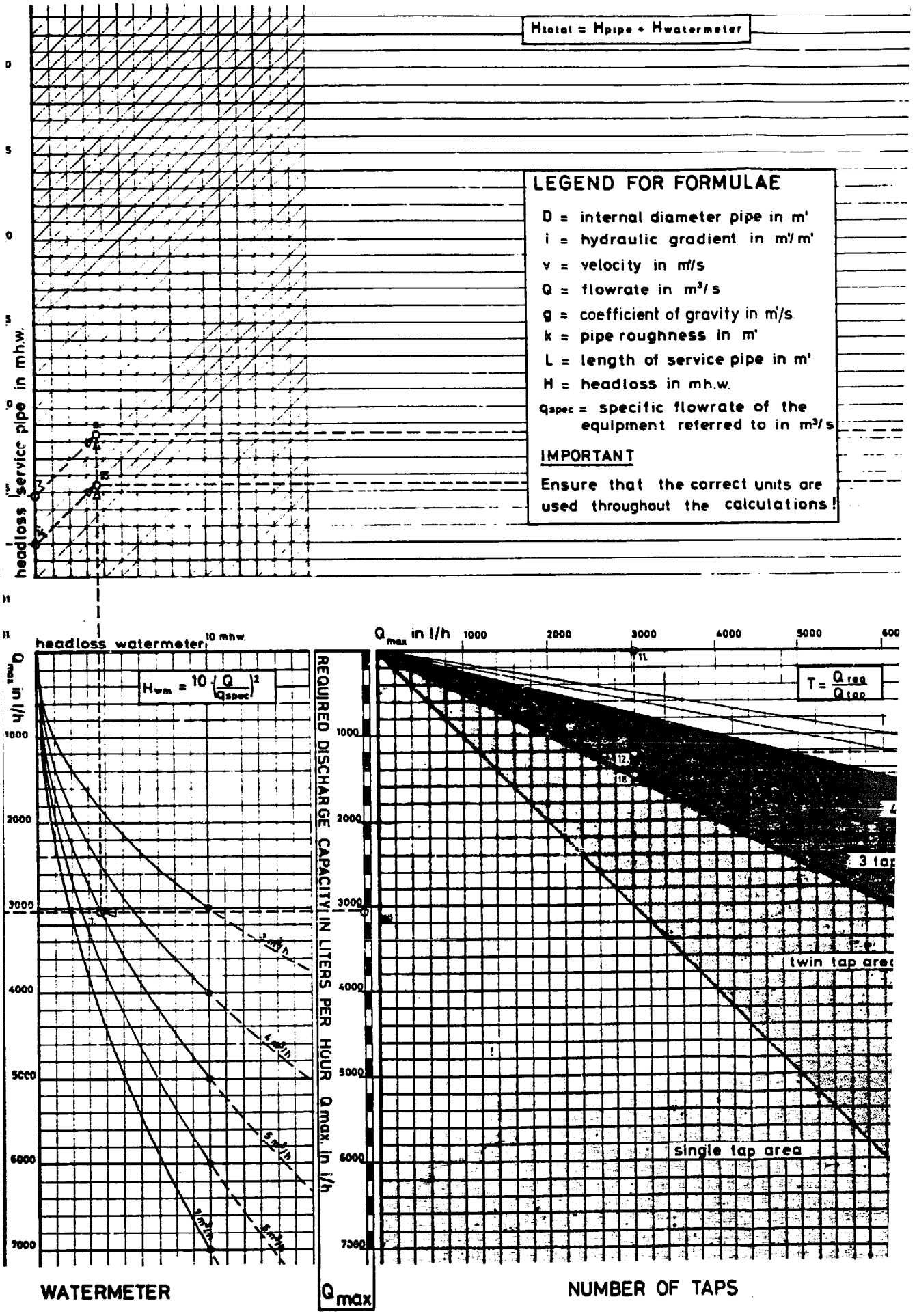

$H_{total} = H_{pipe} + H_{watermeter}$

LEGEND FOR FORMULAE

- D = internal diameter pipe in m'
- i = hydraulic gradient in m'/m'
- v = velocity in m'/s
- Q = flowrate in m^3/s
- g = coefficient of gravity in m'/s
- k = pipe roughness in m'
- L = length of service pipe in m'
- H = headloss in mh.w
- q_{spec} = specific flowrate of the equipment referred to in m^3/s

IMPORTANT

Ensure that the correct units are used throughout the calculations!

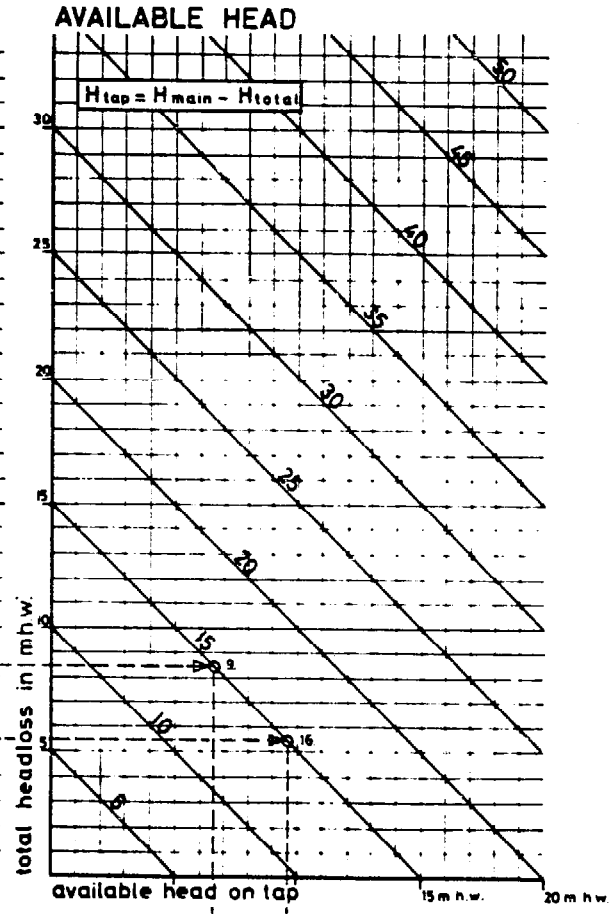

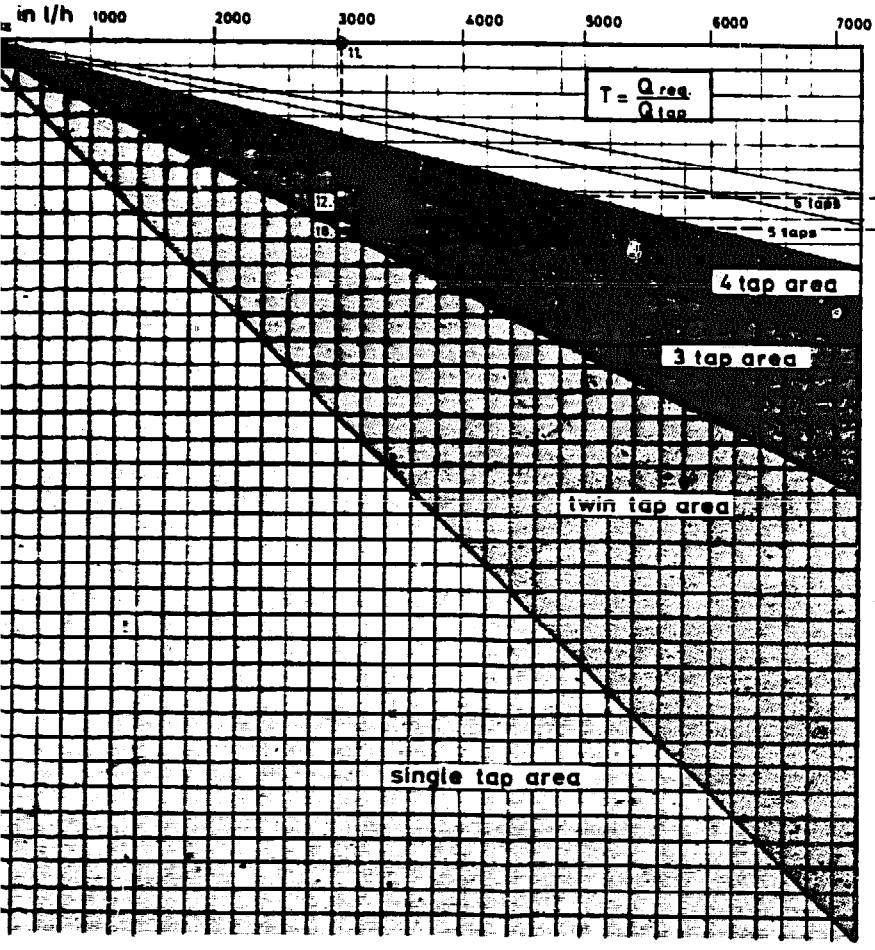

NUMBER OF TAPS

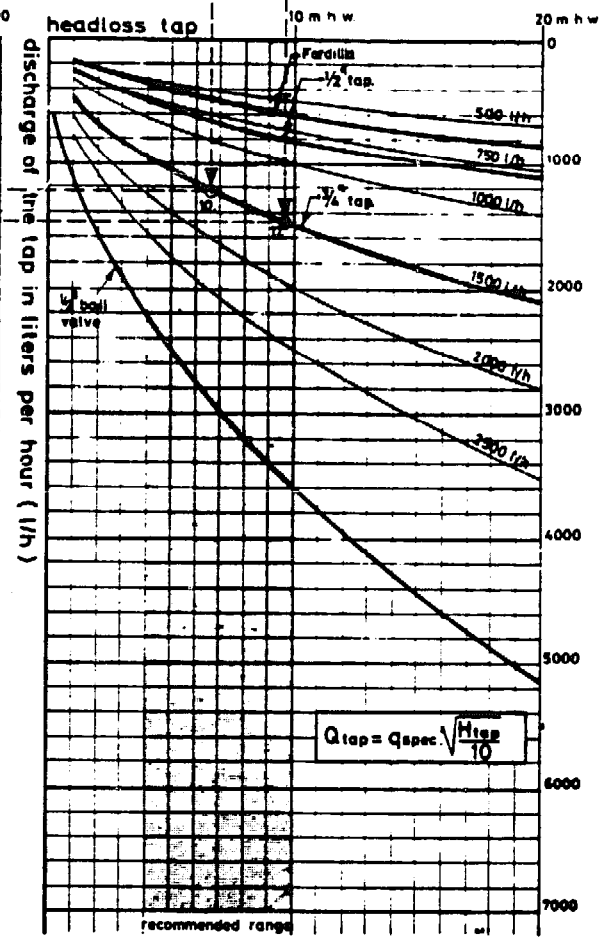

TYPE OF TAP

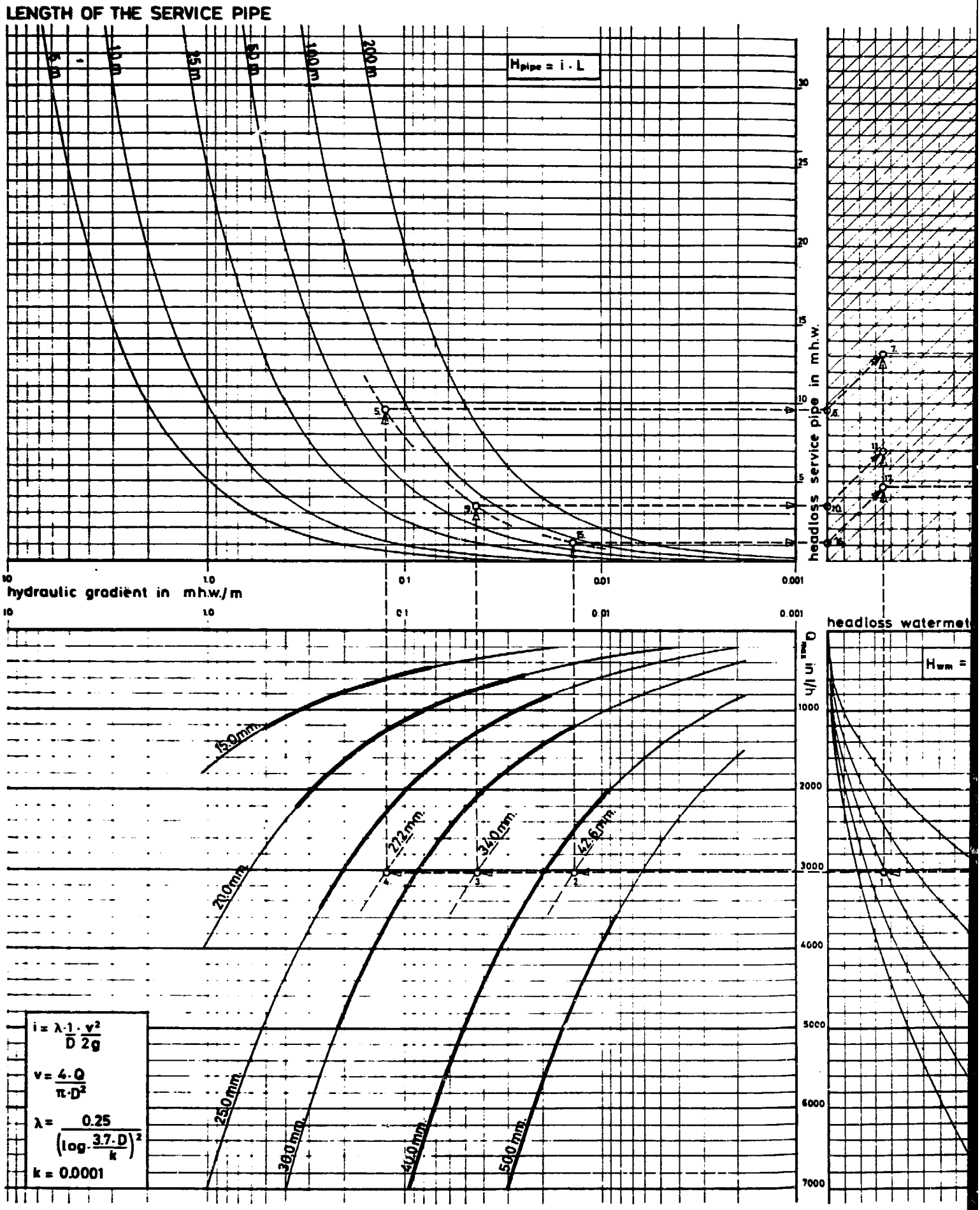

DIAMETER SERVICE PIPE (POLYVINYLCHLORIDE)

WATERMETER

ADDITION FIGURE

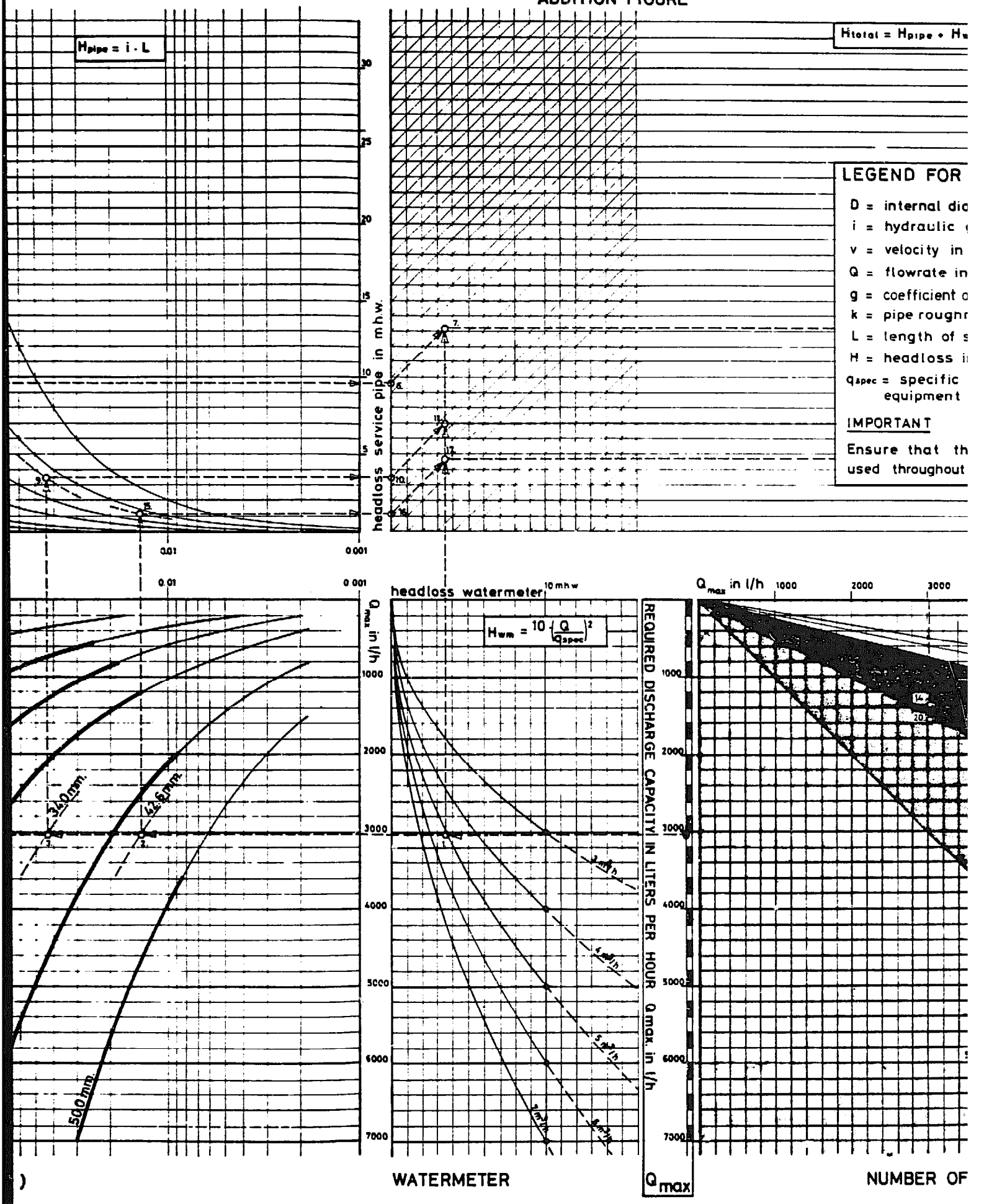

$H_{total} = H_{pipe} + H_{watermeter}$

LEGEND FOR FORMULAE

- D = internal diameter pipe in m'
- i = hydraulic gradient in m'/m'
- v = velocity in m'/s
- Q = flowrate in m^3/s
- g = coefficient of gravity in m'/s
- k = pipe roughness in m'
- L = length of service pipe in m'
- H = headloss in m.h.w.
- q_{spec} = specific flowrate of the equipment referred to in m^3/s

IMPORTANT

Ensure that the correct units are used throughout the calculations!

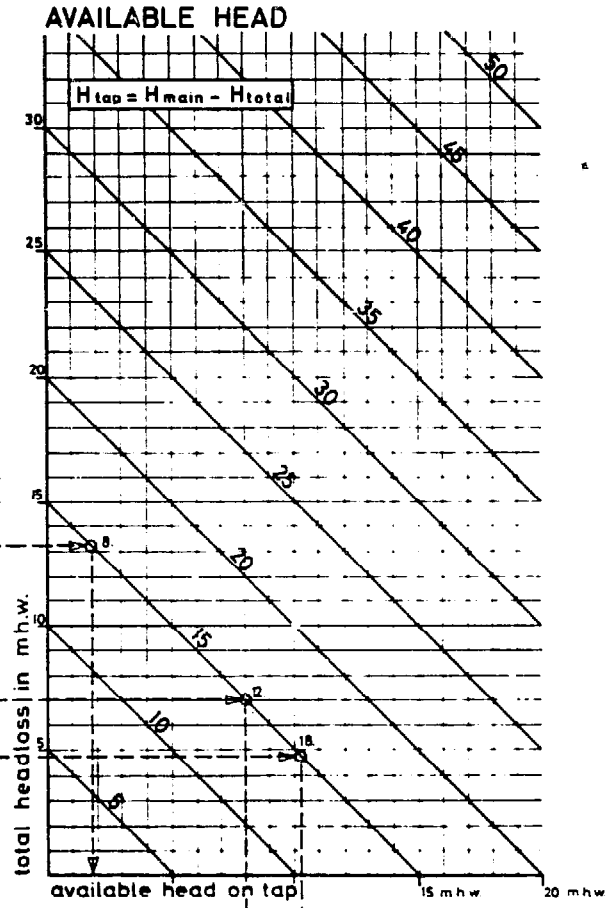

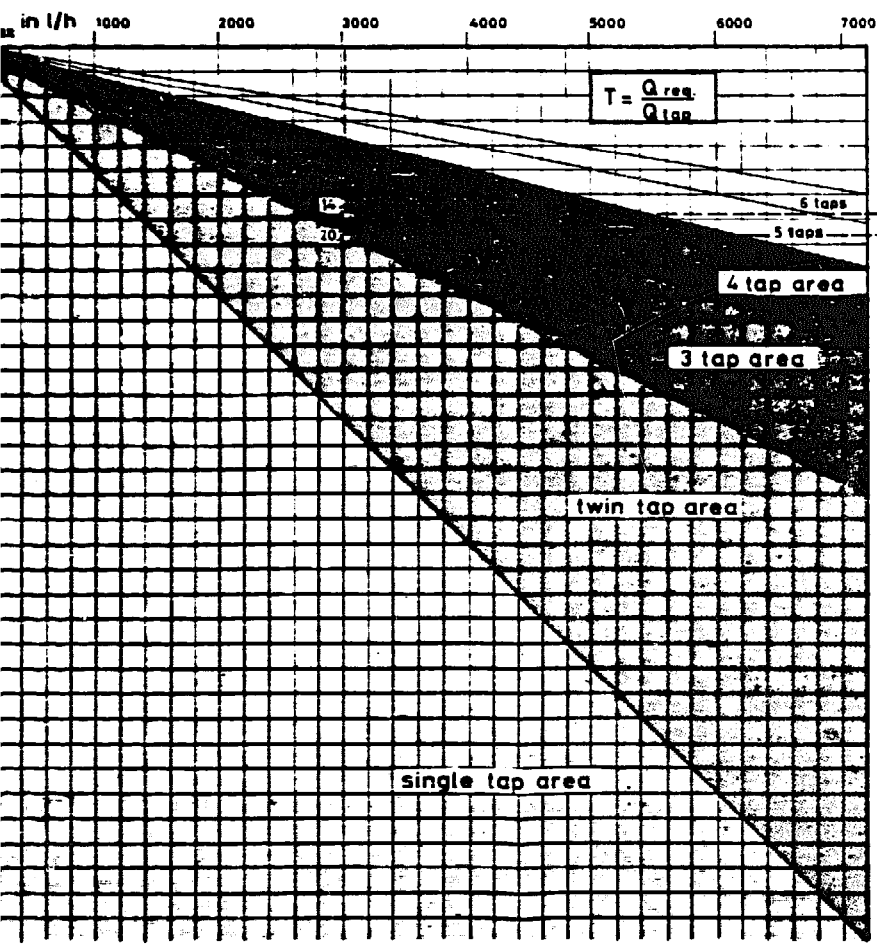

NUMBER OF TAPS

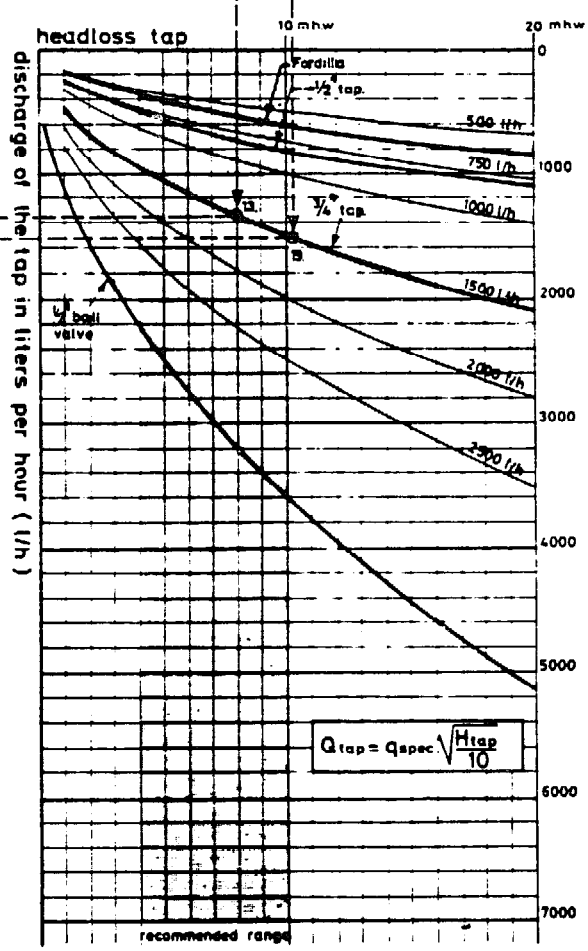

TYPE OF TAP

5. DESIGN DRAWINGS

In addition to the design drawings the following notes are made.

The *service pipe* is the pipe line from the distribution main to the taps. The connection of the service pipe with the main usually consists of a saddle, a T-piece or a ferrule. This is often a weak point in the pipe system and responsible for a great deal of leakage. Thus, it requires much attention during construction.

The choice between *galvanized steel (GS)* and *polyvinylchloride (PVC)* pipes for the service pipe depends on various factors: The advantages of galvanized steel are: the strength, the ease of installation and the availability in almost every country. The disadvantages are: the high weight, the sensitivity to corrosion (internal as well as external) and the relatively high wall roughness in relation to the flowing of water through the pipe.
The advantages of PVC are: the absence of corrosion, the ease of handling due to the low weight and the relatively low wall roughness. The disadvantages are: the limited strength against impact and the lack of standardization in the quality of the material as well as in the pipe dimensions.

It is advisable to always install a *stopcock* in the service pipe, for the purpose of shutting off the waterflow, e.g. for repair or replacing tap washers, etc. The stopcock should be protected and, therefore, installed in a covered pit, preferably within 5 m from the standpost structure. Where a watermeter is used, this should preferably be installed in the same pit.

It is recommended to use galvanized steel pipe for *the part of the service pipe from the stopcock to the taps;* given the higher strength of this material against impact and the ease of installing it and connecting it with the taps. In case the soil has aggressive properties an adequate coating (bitumen or fabric) is required for the part of the pipe that is installed in the ground.

For the purpose of drainage *the slope of the platform* is recommended between 1:50 and 1:20. For a smooth plaster surface a slope of 1:50 is adequate, but for a trowel finished concrete floor, a slope of up to 1:20 is recommended.

To prevent misuse of the taps for hanging buckets, the distance of the taps to the wall should be as small as possible.

In finishing the construction due attention has to be given to the prevention of water-ingress, in particular on the top of the post, on the bucket stand, and at the point where the pipe comes out of the construction.

In general, the design of a standpost should always be adjusted to local habits and circumstances such as the availability of materials and equipment.

TYPICAL DESIGNS DRAWINGS OF PUBLIC STANDPOSTS

5.1. Single tap concrete and brickwork standpost
bill of quantities

5.2. Twin tap concrete and brickwork standpost
bill of quantities

5.3. Three tap concrete and brickwork standpost
bill of quantities

5.4. Four tap concrete and brickwork standpost
bill of quantities

5.5. Twin tap tubular standpost
bill of quantities

5.6. Three tap concrete block masonry standpost
bill of quantities

5.7. Four tap concrete standpost
bill of quantities

5.8. Four tap concrete standpost
bill of quantities

5.9. Four tap rock masonry standpost
bill of quantities

5.10. Twin tap reinforced concrete standpost
bill of quantities

5.11. Three tap concrete/brickwork cattle protected
standpost bill of quantities

5.12. Waterkiosk with 4 taps
bill of quantities

NOTE: The figures in the bills of quanities are to be regarded as indications. The quantities of materials and equipment actually required, are to be calculated specifically for each standpost, according to the actual design.

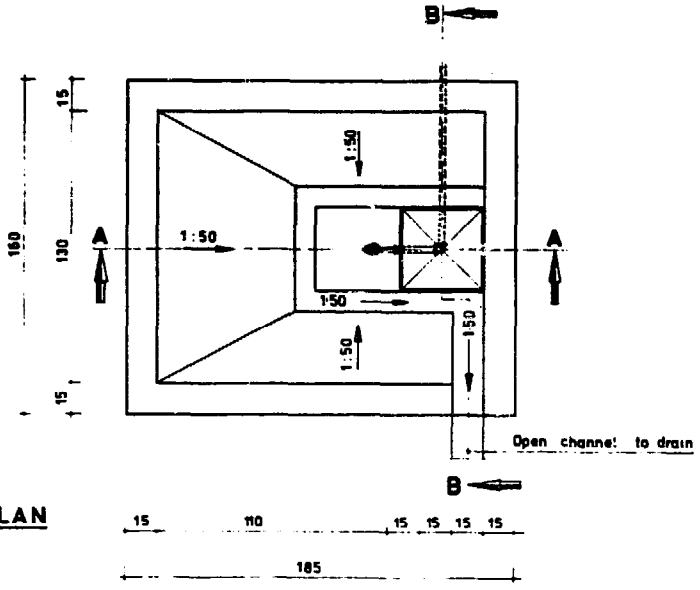

PLAN

REMARKS

- Dimensions are in centimeters, unless otherwise stated.
- Variable sizes should be adjusted to suit local customs and practices.
- All edges to be rounded off.
- All brickwork to be cement plastered 15-25 cm.
- In the absence of a natural drain around the public standpost drainage should be constructed.

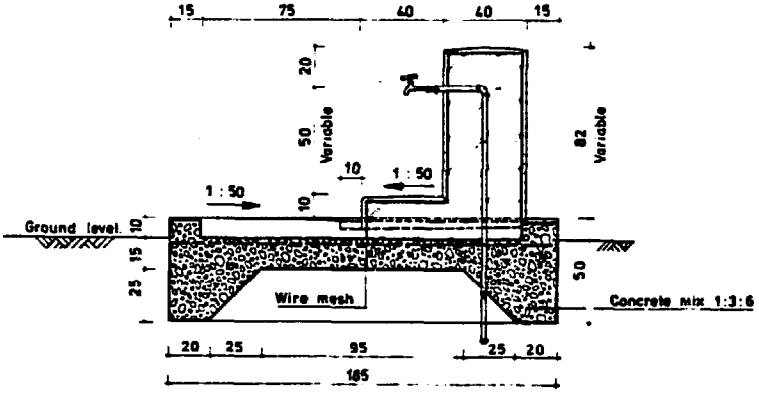

SECTION A-A

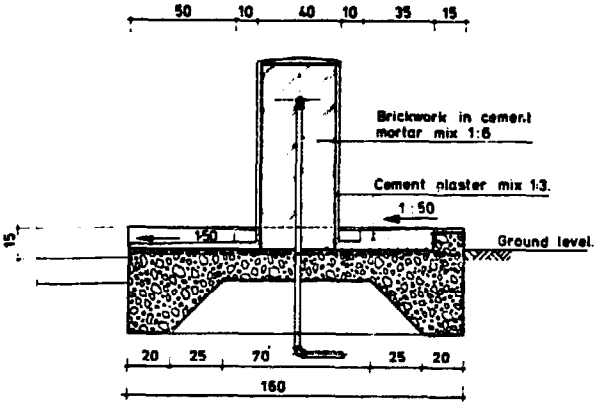

SECTION B-B

SINGLE TAP CONCRETE AND BRICKWORK STANDPOST

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUANTITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	1.6		
2	FORMWORK PLATFORM	m^2	4.0		
3	WIREMESH NETTING DIMENSIONS... x ...	m^2	3.0		
4	CONCRETE PLATFORM MIX 1:3:6	m^3	1.0		
5	BRICKWORK IN CEMENT MORTAR MIX 1:6	m^3	0.2		
6	PLASTERING MIX 1:3, INCLUDING GUTTER	m^2	4.3		
7	REFILLING	m^3	0.5		
	SINGLE TAP CONCRETE AND BRICKWORK STANDPOST				

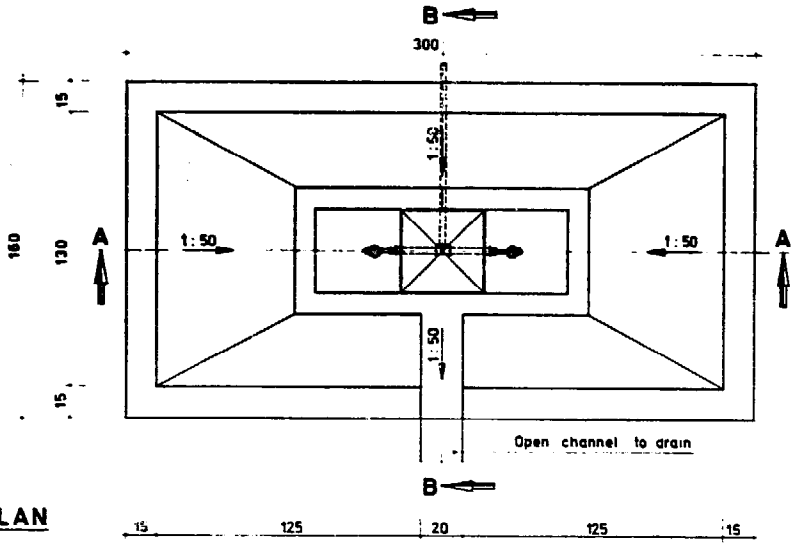

PLAN

REMARKS

- Dimensions are in centimeters, unless otherwise stated.
- Variable sizes should be adjusted to suit local customs and practices.
- All edges to be rounded off.
- All brickwork cement plastered 1.5 - 2.5 cm.
- In the absence of a natural drain around the public standpost drainage should be constructed.

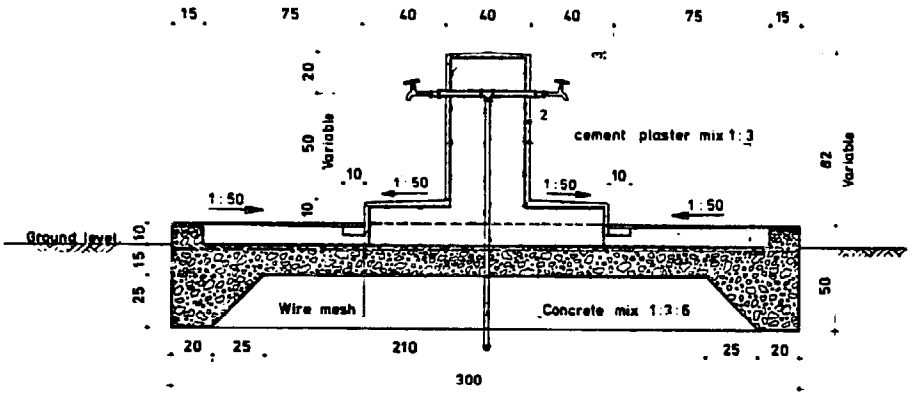

SECTION A-A

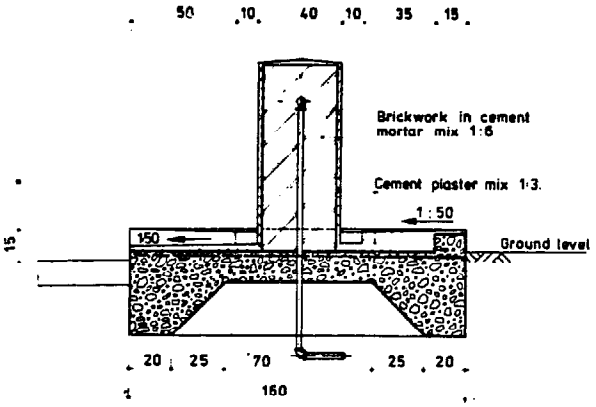

SECTION B-B

TWIN TAP CONCRETE AND BRICKWORK STANDPOST

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUAN-TITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	2.5		
2	FORMWORK PLATFORM	m^2	5.4		
3	WIREMESH NETTING DIMENSIONS... x ...	m^2	4.8		
4	CONCRETE PLATFORM MIX 1:3:6	m^3	1.5		
5	BRICKWORK IN CEMENT MORTAR MIX 1:6	m^3	0.2		
6	PLASTERING MIX 1:3 INCLUDING GUTTER	m^2	5.0		
7	REFILLING	m^3	0.6		
TWIN TAP CONCRETE AND BRICKWORK STANDPOST					-

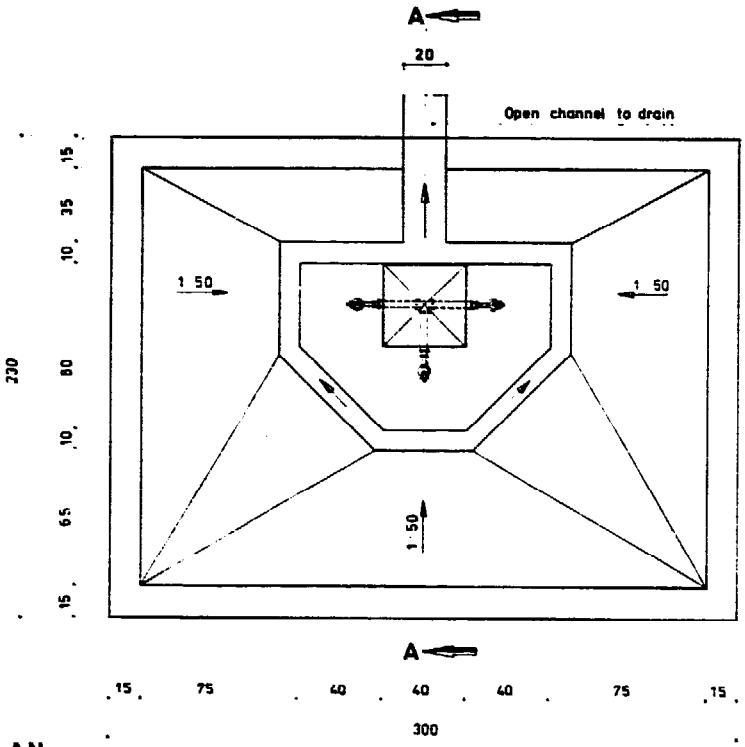

PLAN

REMARKS

- Dimensions are in centimeters, unless otherwise stated.
- Variable sizes should be adjusted to suit local customs and practices.
- All edges to be rounded off.
- All brickwork cement plastered 1.5 – 2.5 cm.
- In the absence of a natural drain around the public standpost drainage should be constructed.

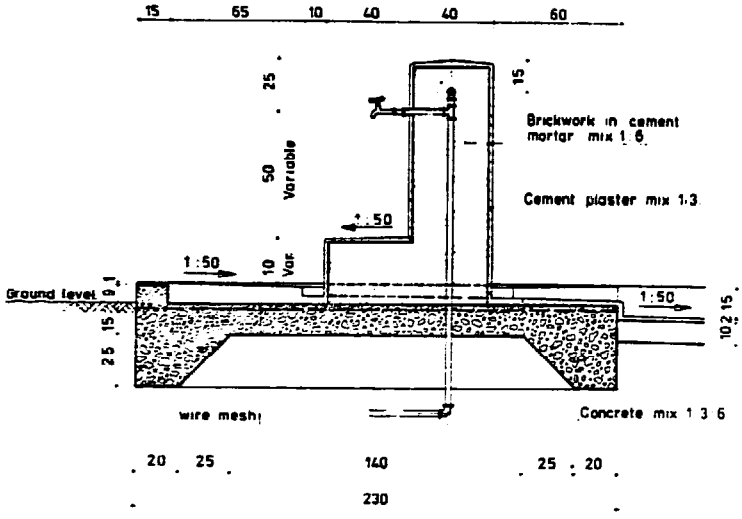

SECTION A-A

THREE TAP CONCRETE AND BRICKWORK STANDPOST

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUANTITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	3.5		
2	FORMWORK PLATFORM	m^2	6.4		
3	WIREMESH NETTING DIMENSIONS... x ...	m^2	6.9		
4	CONCRETE PLATFORM MIX 1:3:6	m^3	2.0		
5	BRICKWORK IN CEMENT MORTAR MIX 1:6	m^3	0.3		
6	PLASTERING MIX 1:3 INCLUDING GUTTER	m^2	8.4		
7	REFILLING	m^3	0.8		
	THREE TAP CONCRETE AND BRICKWORK STANDPOST				

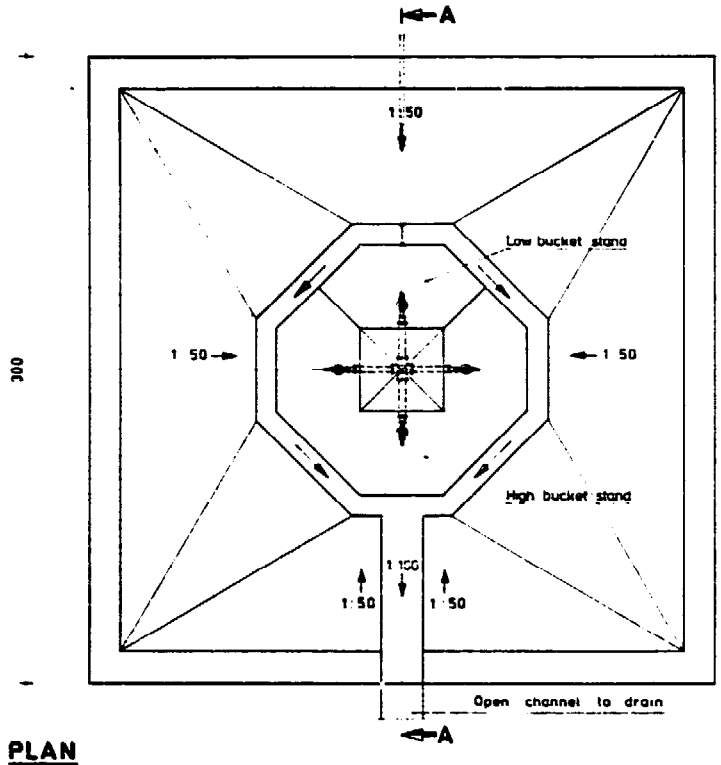

PLAN

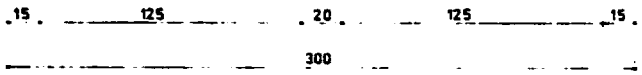

REMARKS

- Dimensions are in centimeters, unless stated.
- Variable sizes should be adjusted to suit local customs and practices.
- All edges to be rounded off
- All brickwork to be cement plastered 1.5 - 2.5 cm
- In the absence of a natural drain around the public standpost drainage should be constructed.

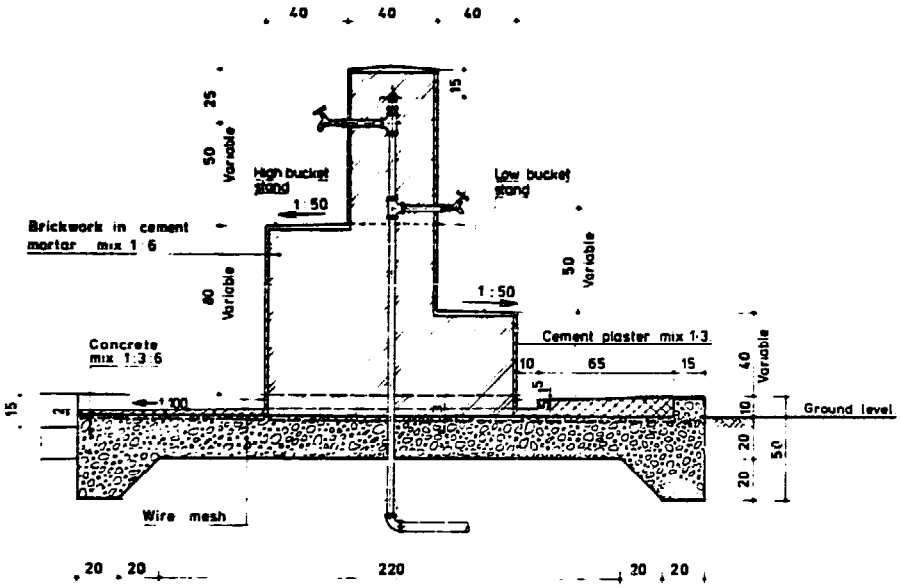

SECTION A-A

FOUR TAP CONCRETE - BRICKWORK STANDPOST

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUANTITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	4.4		
2	FORMWORK PLATFORM	m^2	7.1		
3	WIREMESH NETTING DIMENSIONS... x ...	m^2	9.0		
4	CONCRETE PLATFORM MIX 1:3:6	m^3	2.6		
5	BRICKWORK IN CEMENT MORTAR MIX 1:6	m^3	0.8		
6	PLASTERING MIX 1:3 INCLUDING GUTTER	m^2	12.5		
7	REFILLING	m^3	0.8		
	FOUR TAP CONCRETE AND BRICKWORK STANDPOST				

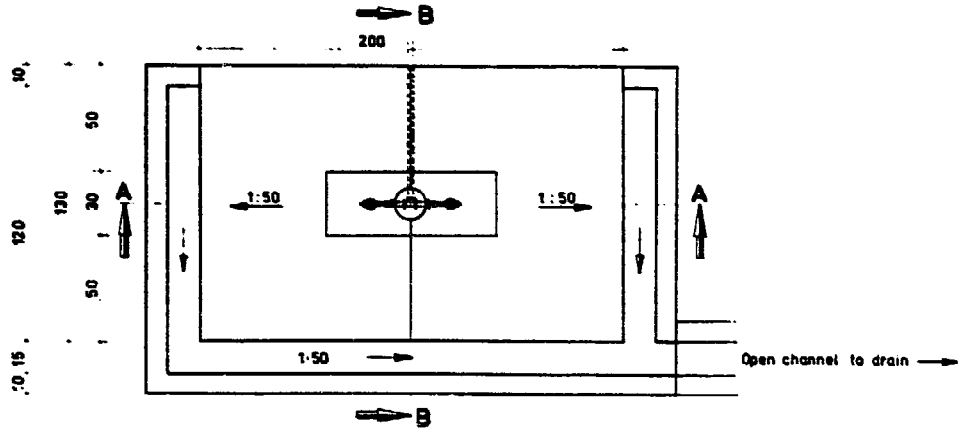

PLAN

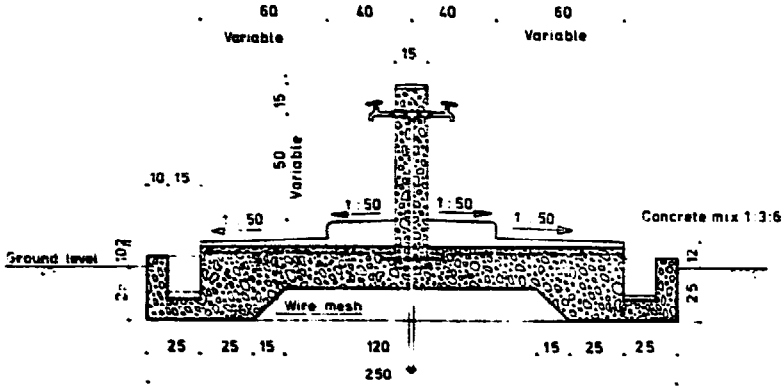

SECTION A-A

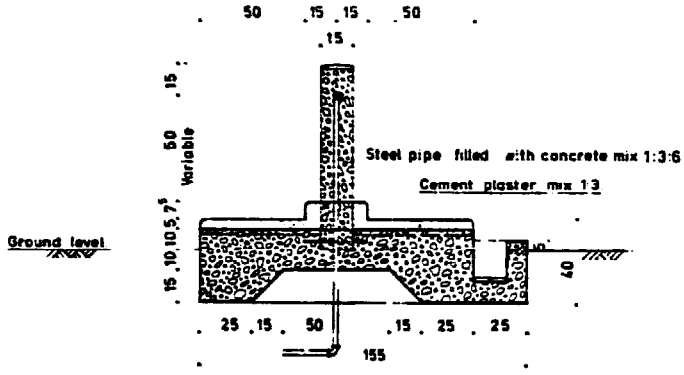

SECTION B-B

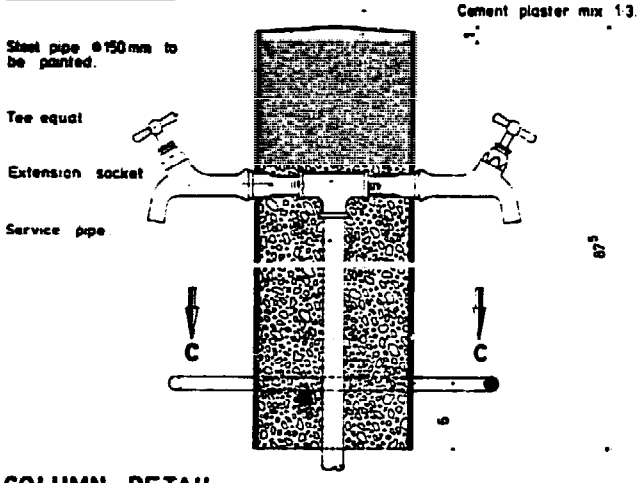

COLUMN DETAIL

0 50 100 150cm

REMARKS

- Dimensions are in centimeters, unless otherwise stated
- All edges to be rounded off
- Variable sizes should be adjusted to suit local customs and practices
- Where a variety of materials are used for column construction, sizes and types of fittings should be altered accordingly
- In the absence of a natural drain around the public standpost drainage should be constructed
- Reinforcing bars (ø 12) to be bent after fitting in steel pipe

0 5 10 15 20 25cm

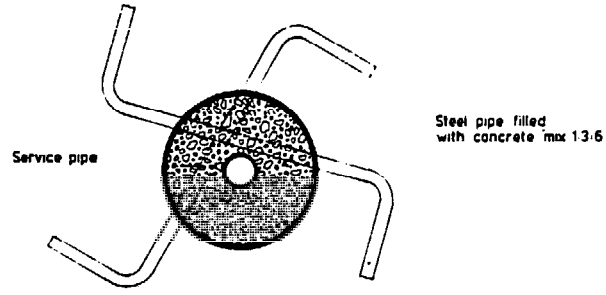

SECTION C-C

ø12 each 50 cm long.

TWIN TAP TUBULAR STANDPOST

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUANTITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	1.3		
2	FORMWORK PLATFORM	m^2	4.1		
3	WIREMESH NETTING DIMENSIONS... x ...	m^2	2.6		
4	CONCRETE PLATFORM MIX 1:3:6	m^3	0.9		
5	STEEL PIPE COLUMN POURED WITH CONCRETE MIX 1:3:6	ea	1		
6	PLASTER ON PLATFORM AND BUCKET STAND MIX 1:3	m^2	2.8		
7	REFILLING	m^3	0.3		
	TWIN TAP TUBULAR STANDPOST				

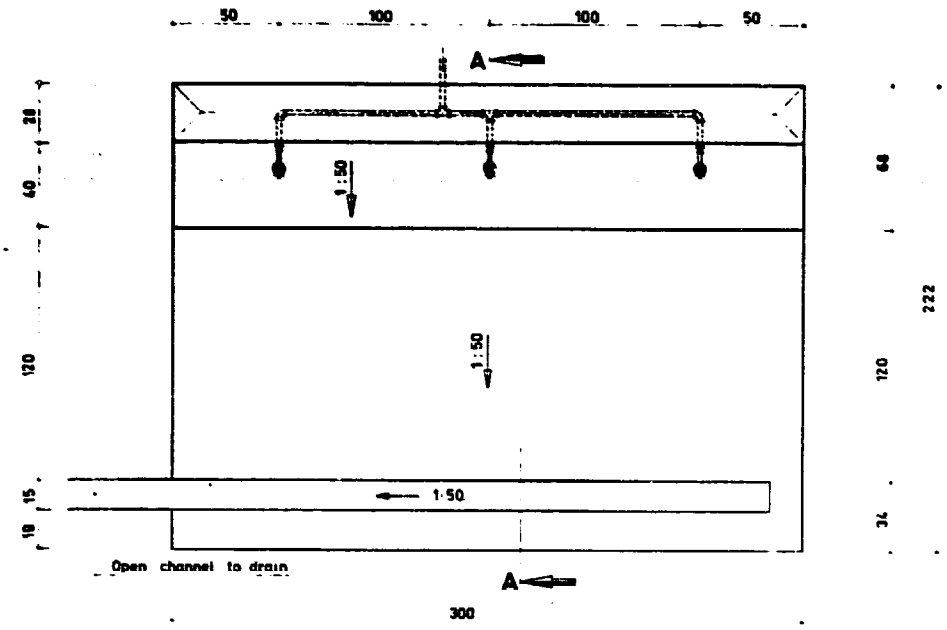

PLAN

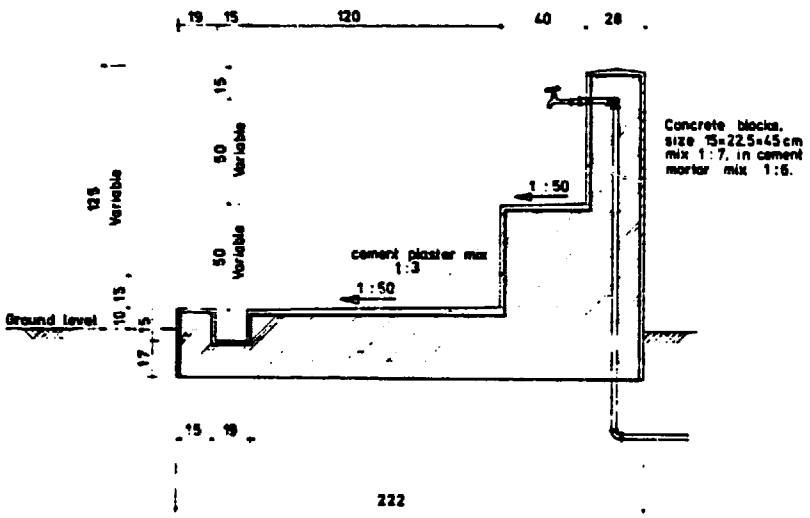

SECTION A-A

REMARKS

- Dimensions are in centimeters, unless otherwise stated.
- All edges to be rounded off.
- Variable sizes should be adjusted to suit local customs and practices.
- Blockwork to be cement plastered 15-2.5 cm.
- In the absence of a natural drain around the public standpost drainage should be constructed.

THREE TAP CONCRETE BLOCK MASONRY STANDPOST

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUANTITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	1.7		
2	BRICKWORK OF CONCRETE BLOCKS IN CEMENT MORTAR MIX 1:6	m^3	3.5		
3	PLASTER, MIX 1:3, ON COLUMN, PLATFORM AND GUTTER	m^2	14.2		
4	REFILLING	m^3	0.4		
	THREE TAP CONCRETE BLOCK MASONRY STANDPOST				

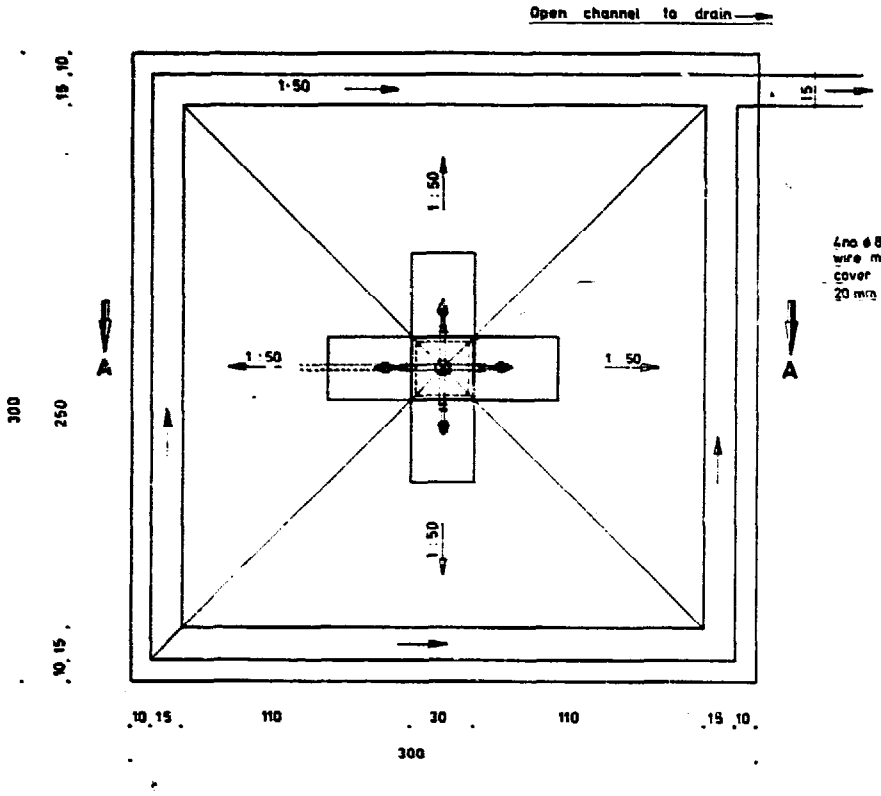

PLAN

REMARKS

- Dimensions are in centimeters, unless otherwise stated.
- Variable sizes should be adjusted to suit local customs and practices.
- All edges to be rounded off or chamfered
- In the absence of a natural drain around the public standpost drainage should be constructed.
- Exposed surfaces of concrete to be rubbed over with a mixture of cement and water after removal of shuttering.

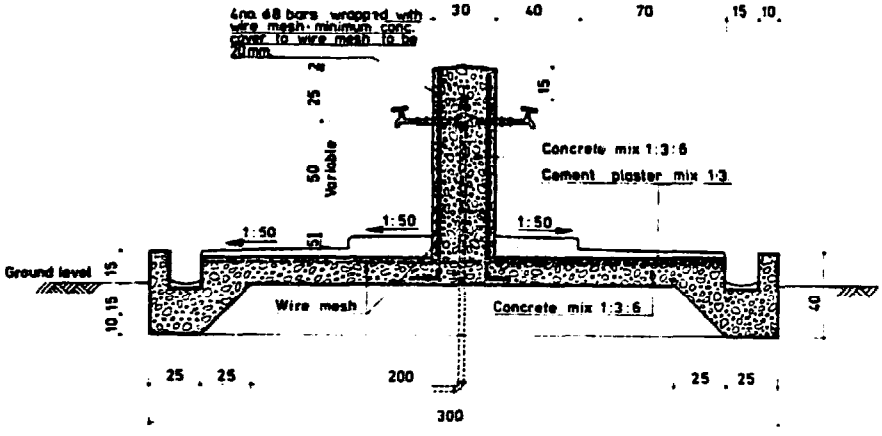

SECTION A-A

FOUR TAP CONCRETE STANDPOST

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUANTITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	2.7		
2	FORMWORK PLATFORM	m^2	8.0		
3	WIREMESH NETTING FOR PLATFORM AND COLUMN DIMENSIONS ...x...	m^2	6.2		
4	CONCRETE PLATFORM MIX 1:3:6	m^3	2.1		
5	FORMWORK COLUMN	m^2	1.0		
6	CONCRETE COLUMN MIX 1:2:6	m^3	0.1		
7	PLASTER ON PLATFORM MIX 1:3	m^2	7.9		
8	REFILLING	m^3	0.5		
	FOUR TAP CONCRETE STANDPOST				

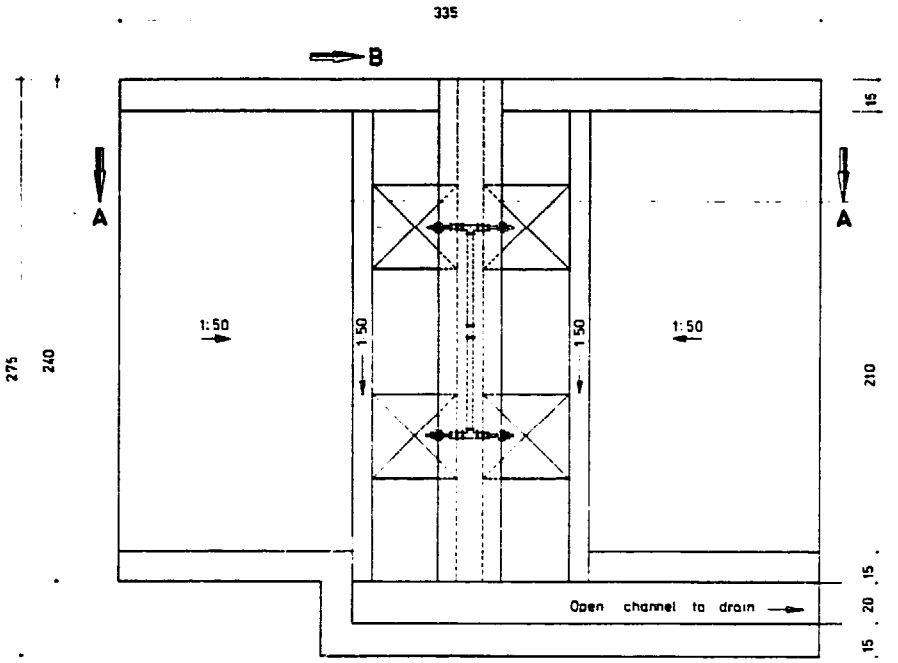

PLAN

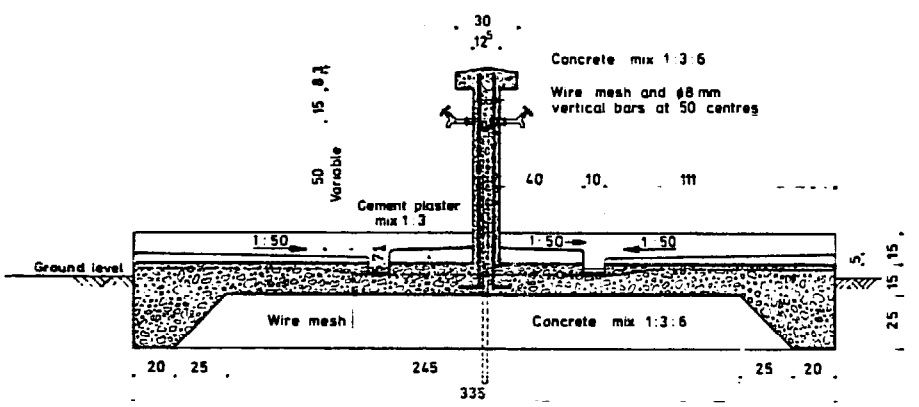

SECTION A-A

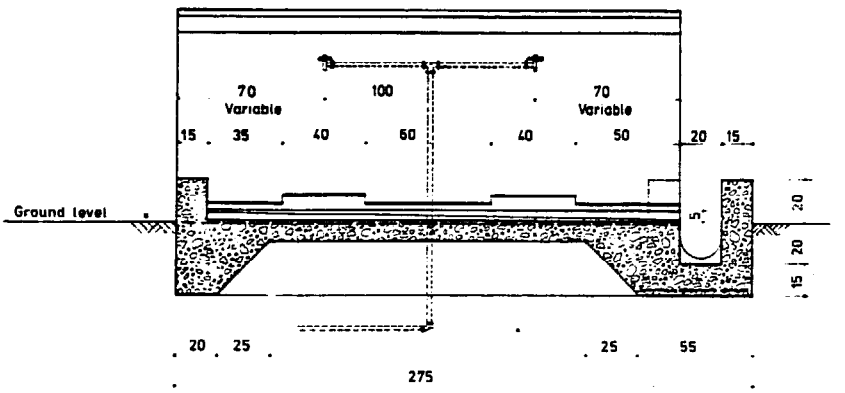

SECTION B-B

REMARKS

- Dimensions are in centimeters, unless otherwise stated
- Variable sizes should be adjusted to suit local customs and practices

Cement plaster to be minimum 2 cm thick

- In the absence of a natural drain around the public standpost drainage should be constructed
- Exposed surfaces of concrete to be rubbed over with a mixture of cement and water after removal of shuttering

All edges to be rounded off or chamfered

FOUR TAP CONCRETE STANDPOST

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUAN-TITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	3.9		
2	FORMWORK PLATFORM, INCLUDING CUTTERS	m^2	8.5		
3	WIREMESH NETTING DIMENSIONS... x ...	m^2	32.8		
4	REINFORCING BARS Ø 8 mm LENGTH TO SUIT	ea	12		
5	CONCRETE PLATFORM MIX 1:3:6	m^3	2.1		
6	FORMWORK WALL	m^2	4.3		
7	CONCRETE WALL MIX 1:2:6 INCL. TROWELLING	m^3	0.3		
8	PLASTERING ON PLAT-FORM, BUCKET STAND AND DRAINGUTTER	m^2	5.7		
9	REFILLING	m^3	1.0		
	FOUR TAP CONCRETE STANDPOST				

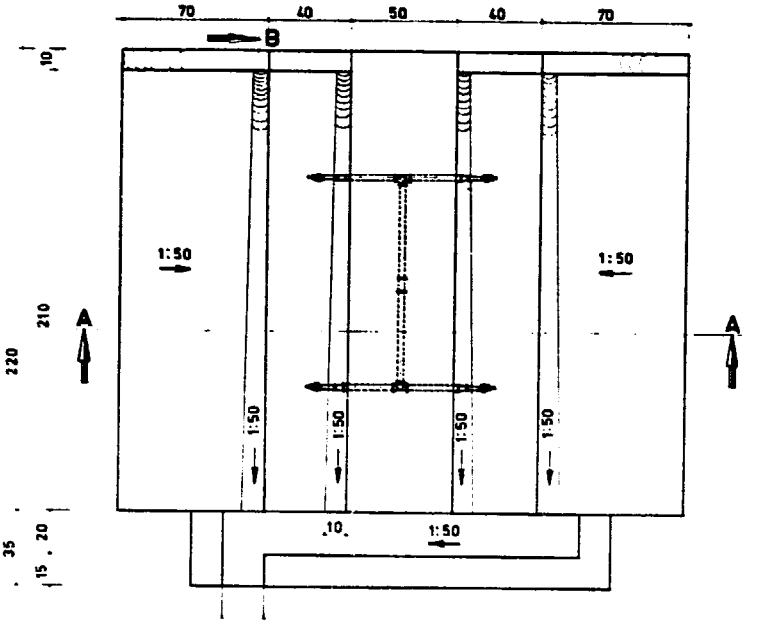

PLAN

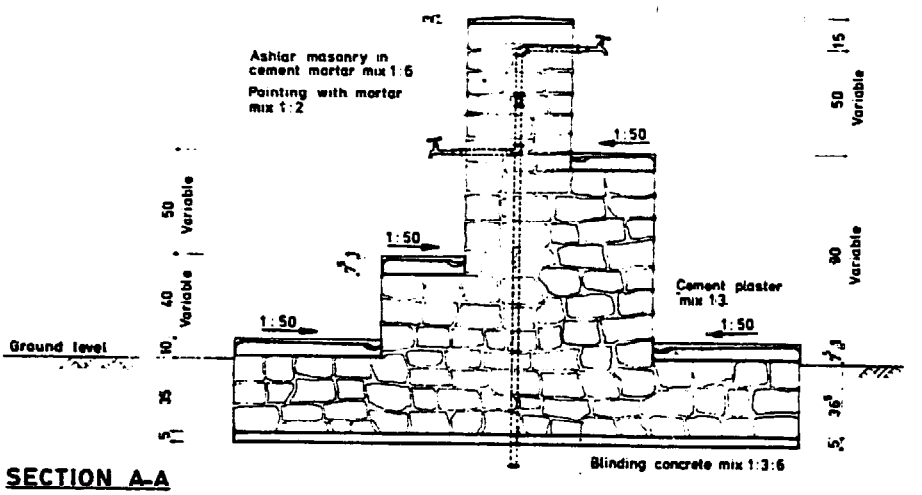

SECTION A-A

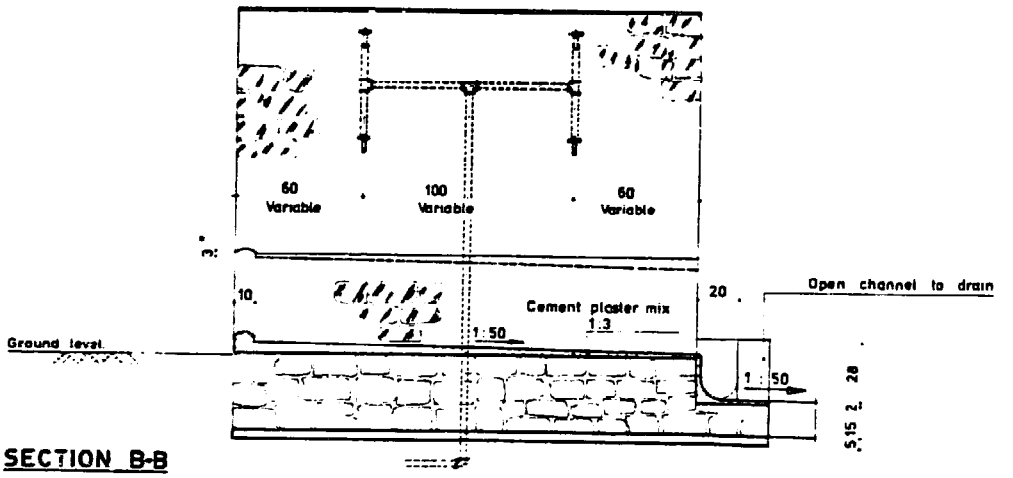

SECTION B-B

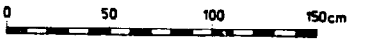

REMARKS

- Dimensions are in centimeters, unless otherwise stated.
- All edges to be rounded off.
- Variable sizes should be adjusted to suit local customs and practices.
- Stones should be tooled on exposed faces.
- In the absence of a natural drain around the public standpost, drainage should be constructed.
- Sizes of stones shown on the drawing are only indicative and may be adjusted depending on local availability.

FOUR TAP ROCK MASONRY STANDPOST

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUANTITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	3.4		
2	BLINDING CONCRETE MIX 1:3:6	m^3	0.3		
3	ROCKMASONRY IN PLASTER MIX 1:3	m^3	4.5		
4	PLASTER ON COLUMN, BUCKET STANDS AND PLATFORM, INCLUDING GUTTERS MIX 1:3	m^2	6.0		
5	POINTING THE MASONRY WITH MORTAR MIX 1:2	m^2	10.0		
6	REFILLING	m^3	1.0		
7	FORMWORK DRAINGUTTER	m^2	1.4		
8	CONCRETE DRAINGUTTER MIX 1:3:6	m^3	0.1		
9	CEMENT MORTAR DRAIN-GUTTER MIX 1:3	m^2	0.4		
	FOUR TAP ROCK MASONRY STANDPOST				

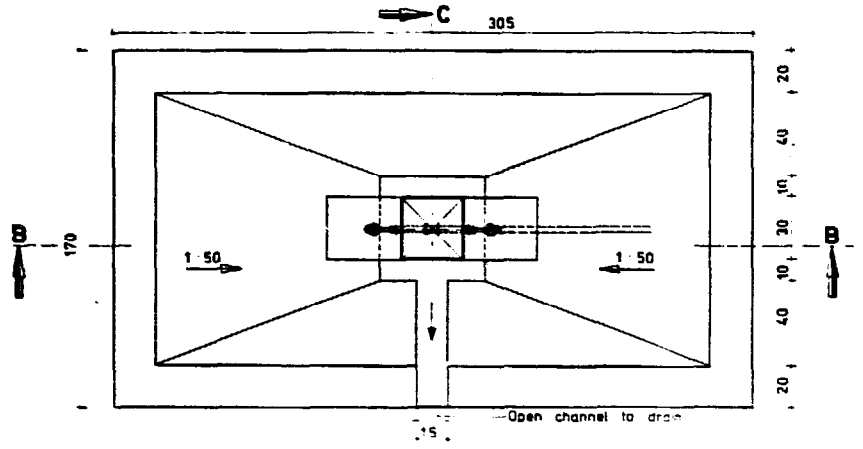

PLAN

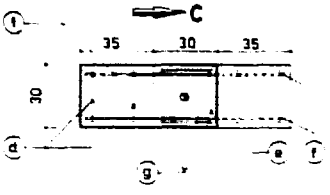

SECTION A-A

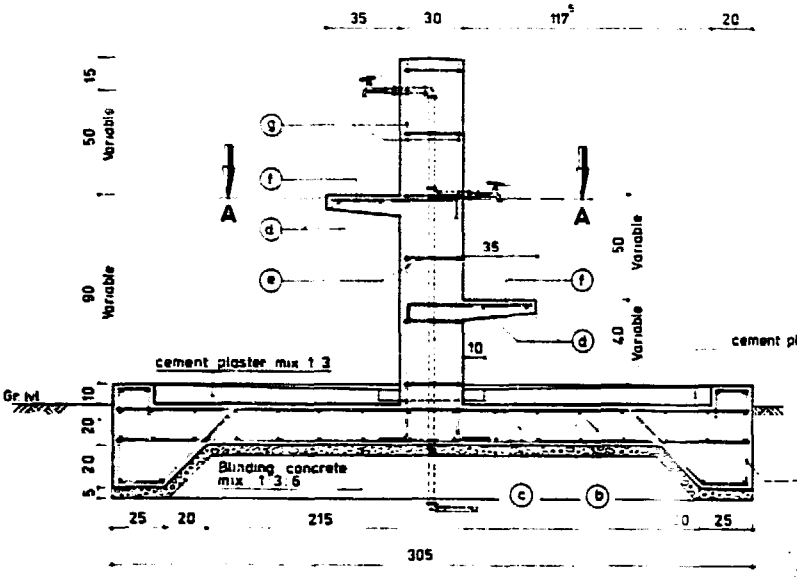

SECTION B-B

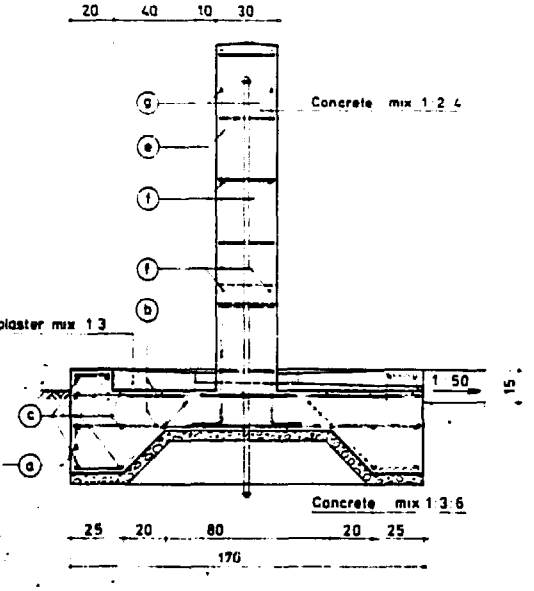

SECTION C-C

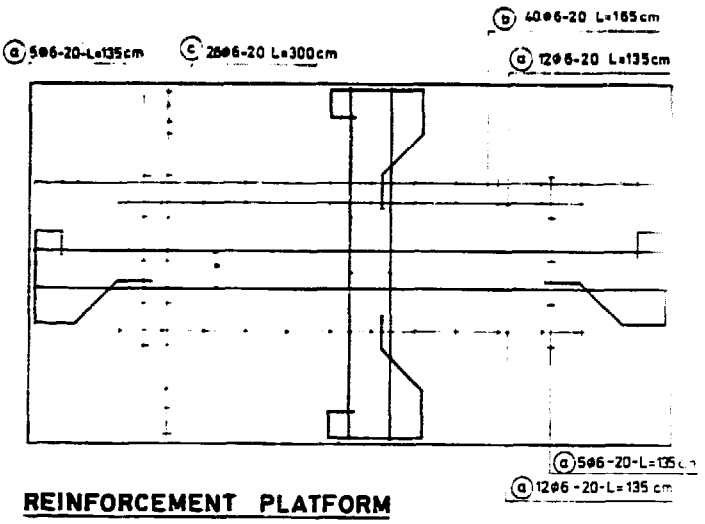

REINFORCEMENT PLATFORM

REMARKS

- Dimensions are in centimeters, unless otherwise stated.
- Variable sizes should be adjusted to suit local customs and practices
- All edges to be rounded off or chamfered
- In the absence of a natural drain around the public standpost drainage should be constructed
- Exposed concrete surfaces to be rubbed over with a mixture of cement and water after ramoval of shuttering
- Cover to reinforcement to be minimum 20 mm

BENDING SCHEDULE

	bar mark	shape of bars outside dimensions	dia. (in mm)	number	length in cm	total length	weight in kg
platform	a		Ø6	34	135	4590	
	b	straight	Ø6	40	165	6600	
	c	straight	Ø6	26	300	7800	
	d	straight	Ø6	4	25	100	
column	e		Ø6	6	110	660	43,8 kg.
	f		Ø10	4	65	260	
	g		Ø10	4	205	820	6,7 kg.

TWIN TAP REINFORCED CONCRETE STANDPOST

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUANTITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	3.0		
2	BUILDING, CONCRETE, 5 cm, MIX 1:3:6	m^2	5.2		
3	FORMWORK PLATFORM	m^2	5.6		
4	REINFORCEMENT COMPLETE	kg	50.5		
5	CONCRETE PLATFORM MIX 1:2:4	m^3	1.8		
6	FORMWORK COLUMN AND BUCKET STANDS	m^2	2.3		
7	CONCRETE COLUMN AND BUCKET STANDS MIX 1:2:4	m^3	0.2		
8	PLASTERING ON PLATFORM MIX 1:3 INCL. GUTTERS	m^2	3.5		
9	REFILLING	m^3	0.7		
	TWIN TAP REINFORCED CONCRETE STANDPOST				

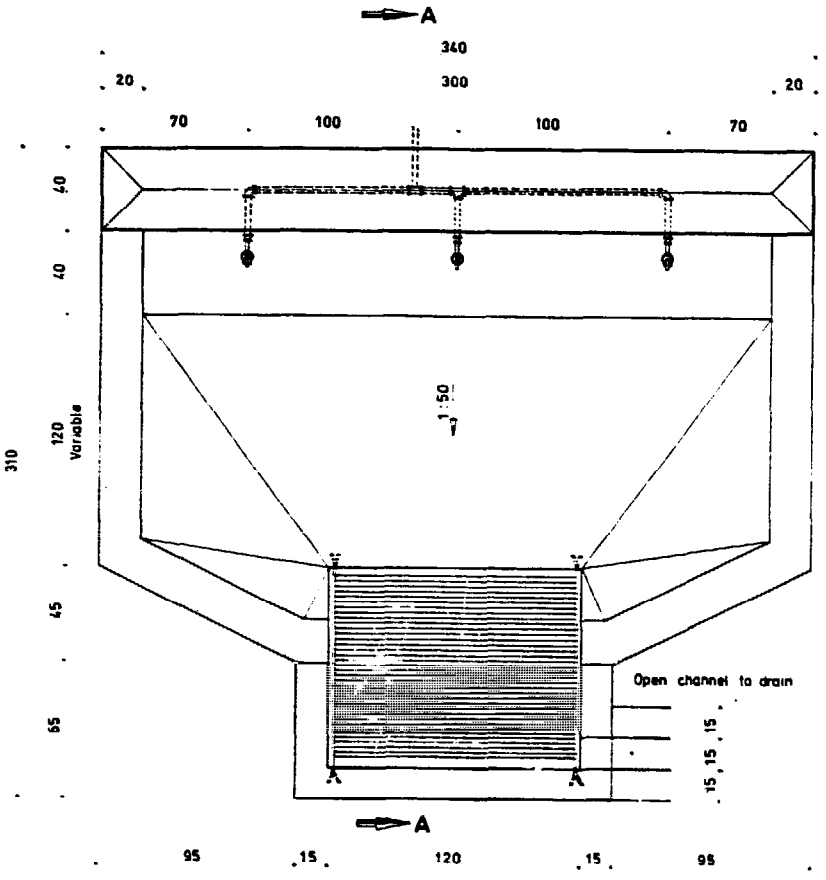

REMARKS

- Dimensions are in centimeters, unless otherwise stated.
- Variable sizes should be adjusted to suit local customs and practices.
- All edges to be rounded off.
- All brickwork to be cement plastered 1.5-2.5 cm.
- In the absence of a natural drain around the public standpost drainage should be constructed.
- Cattle grid should be painted with red oxide paint and lead paint.

PLAN

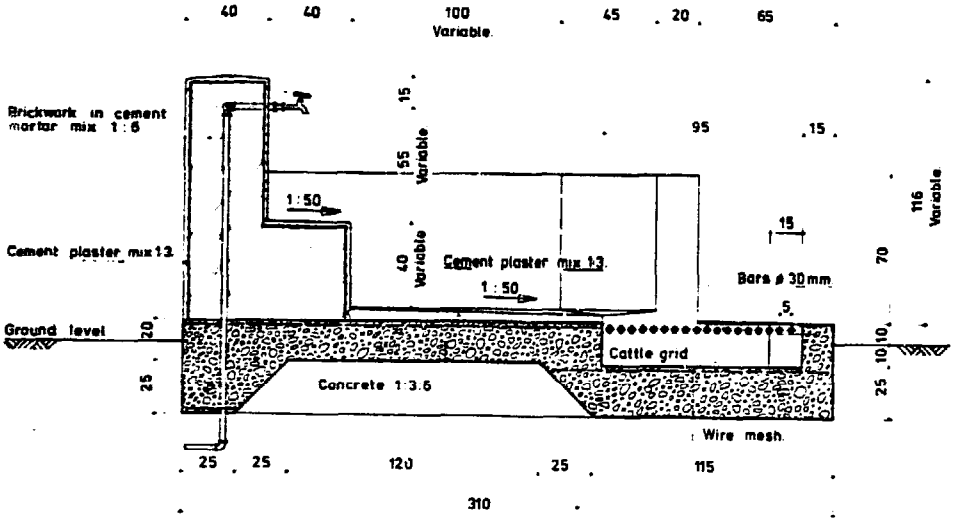

SECTION A-A

THREE TAP CONCRETE / BRICKWORK CATTLE PROTECTED STANDPOST

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUAN-TITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	3.7		
2	FORMWORK PLATFORM INCLUDING PIT	m^2	7.2		
3	WIREMESH NETTING DIMENSIONS... x ...	m^2	10.0		
4	CONCRETE PLATFORM MIX 1:3:6	m^3	2.8		
5	BRICKWORK IN CEMENT MORTAR MIX 1:6 FOR WALLS AND BUCKET STAND	m^3	3.0		
6	PLASTERING ON WALLS, PLATFORM AND BUCKET STAND MIX 1:3	m^2	22.0		
7	CATTLE GRATE, INCL. MOUNTING	ea	1		
8	REFILLING	m^3	0.6		
	THREE TAPS CATTLE PROTECTED STANDPOST				

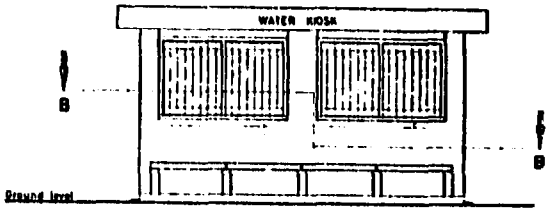

FRONT ELEVATION

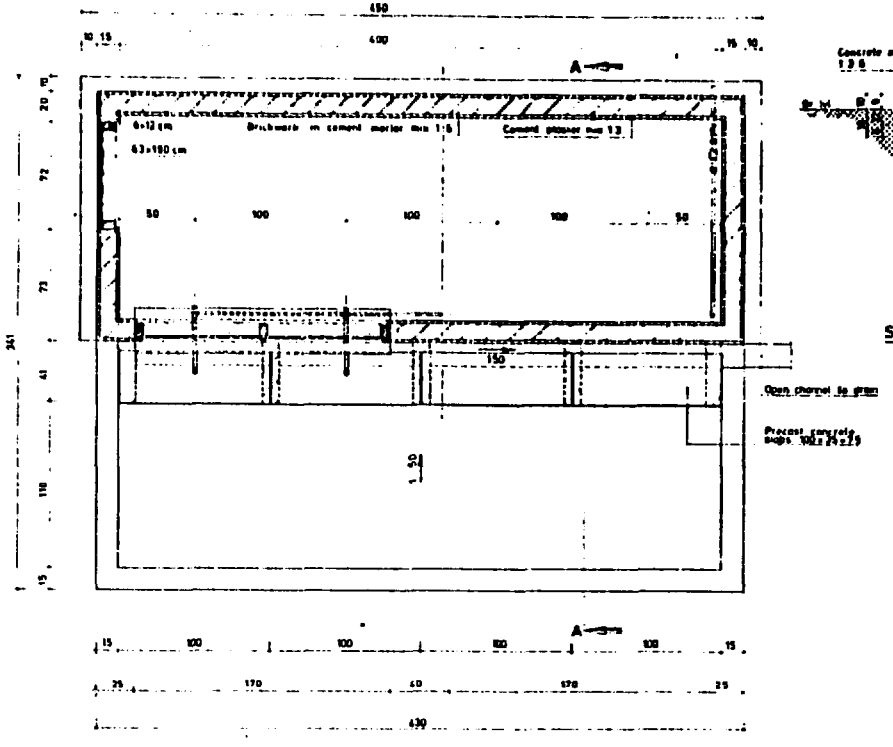

SECTIONAL PLAN B-B

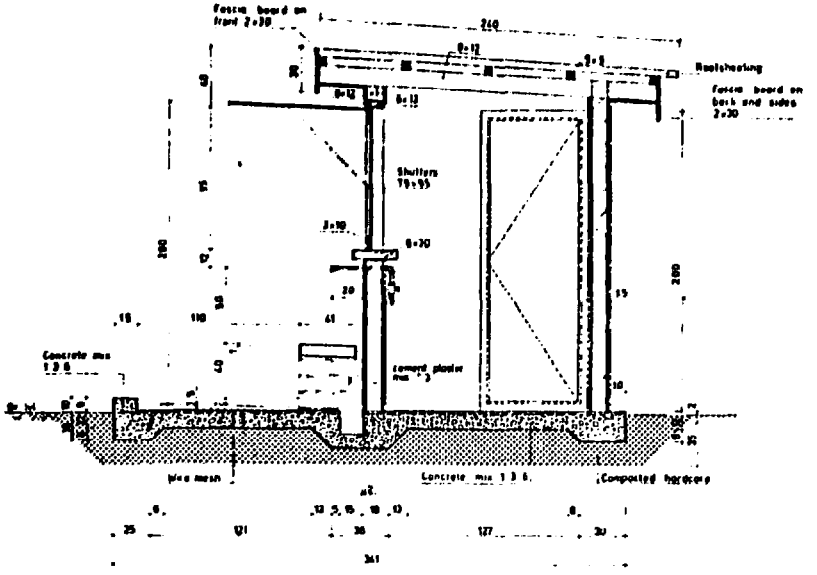

SECTION A-A

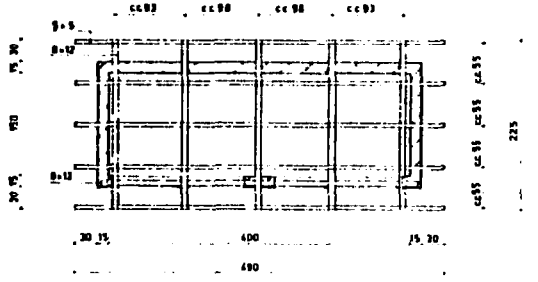

ROOF DETAIL

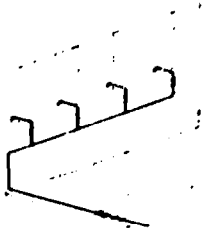

SCHEMATIC LAYOUT OF PIPEWORK

0 50 100 150cm

REMARKS

- Dimensions are in centimeters, unless otherwise stated
- Where a variety of construction materials are used, dimensions of structure should be changed accordingly
- All edges to be rounded off
- In the absence of a natural drain around the kiosk drainage should be constructed
- Depth of foundation to be decided on site

0 50 100 150 200 250 300cm

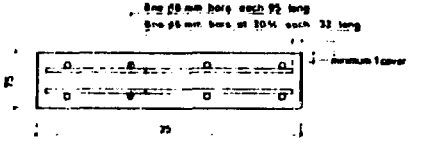

PRECAST CONCRETE SLAB DETAIL

WATER KIOSK WITH FOUR TAPS

BILL OF QUANTITIES OF CIVIL WORKS

ITEM	DESCRIPTION	UNIT	QUANTITY	UNITPRICE	AMOUNT
1	EXCAVATION	m^3	7.0		
2	WIREMESH NETTING FOUNDATION SLABS DIMENSIONS .. x .. mm	m^2	15.0		
3	COMPACT HARDCORE 20 cm	m^2	22.0		
4	EVT. REFILLING WITH CLEAN SAND	m^3	--		
5	FORMWORK FLOORSLAB INCLUDING GUTTERS	m^2	6.2		
6	REINFORCEMENT FLOOR WIRE MESHNETTING DIMENSIONS .. x .. mm	m^2	14.6		
7	CONCRETE FLOOR MIX 1:3:6	m^3	3.5		
8	BRICKWORK WALLS WATER-KIOSK, INCL. BUCKET-STAND IN CEMENT MOR-TAR MIX 1:6, 15 cm THICK	m^2	20.0		
9	FRAMEWORK SHUTTERS AND DOOR, INCL. SHUTTERS, DOOR, IRON-MONGERIES ETC.	--	--		
10	ROOFCONSTRUCTION WITH ALL NECESSARY BEAMS AND ROOFSHEETING INCL. FASTENINGS	--	--		
11	PLASTERING ON WALLS, PLATFORM AND BUCKET STAND WITH CEMENT MORTAR MIX 1:3	m^2	46		
12	PAINTING OF KIOSK	--	--		
13	REFILLING	m^3	2.5		
14	PRECAST CONCRETE SLABS 100 x 75 x 35 mm INCL. REINFORCEMENT	ea	4		
	WATER KIOSK WITH 4 TAPS				

ANNEXES

LIST OF ANNEXES

1. Symbols and abbreviations

2. Units and conversion

3. Growth factor

4. Service radius

5. Pressure head losses

6. Hydraulic equations

7. Stopcock and watermeter

8. Materials

9. Standpost drainage

10. Flow control mechanism

11. List of references

SYMBOLS AND ABBREVIATIONS

SYMBOLS

A	=	area (m^2) or (ha)
a	=	maximum walking distance
Cd	=	average demand per capita (l/d)
D	=	internal diameter of pipe (m) or (mm)
f	=	efficiency factor of a tap
g	=	gravity factor (m/s^2)
H	=	head, pressure head, headloss (mhw)
Ha	=	available head
i	=	hydraulic gradient
k	=	roughness factor (m)
L	=	length (m)
m	=	growth factor
N	=	design population
No	=	initial population
n	=	number of users per standpost
P	=	peak factor
p	=	pressure (mhw)
Q	=	flow rate (m^3/s) or (l/h)
Qmax	=	required maximum discharge capacity (l/h)
qspec	=	specific flow rate (m^3/s)
R	=	service radius (m)
r	=	annual growth rate of population (%)
S	=	number of standposts
T	=	design period
t	=	number of peak hours
v	=	velocity (m/s)
w	=	wastage factor
λ	=	coefficient in hydraulic gradient i
ρ	=	specific density (kg/m^3)
π	=	3,14
$\geq$	=	equal to or larger than
$\leq$	=	smaller than or equal to
*	=	multiplied by

ABBREVIATIONS

GS	=	galvanized steel
PVC	=	polyvinylchloride
lcd	=	litres per capita per day
mhw	=	meter head of water

UNITS AND CONVERSION

In principle Standard International (SI) units are used in this publication. In addition to that, however, and as a compromise towards the daily practice in the drinking water world, some well known units (such as cm, mhw, l/h and inches) are used as well, where this does not harm the accuracy of calculations. In this relation reference is made to the advice of the International Water Supply Association (IWSA) regarding the application of SI units in the field of water supply and sanitation.

UNITS

Length	meter	m
Area	square meter	m^2
Volume	cubic meter	m^3
Time	second,hour	s, h
Mass	kilogram	kg
Force	Newton	N
Pressure	kilogram force	kgf/cm^3
Work, Energy	Joules	J
Power	Watt	W
Velocity	meter per second	m/s
Flow	cubic meter per second	m^3/s

ADDITIONAL UNITS

cm = centimeter = 0,1 m = 10 mm

mhw = meter head of water
1 mhw = 10^3 mm H_2O= $9.807.10^3$ = 0,1 kgf/cm^2
Pa = N/m^2 is a relatively small unit and had the disadvantage of requiring large numbers in calculation; besides the mhw is visually attractive.

l/h = liter per hour, a relevant unit regarding domestic use of water.

inch = imperial equivalent for 25,4 mm; with regard to standardization equipment often used for procurement.

CONVERSION OF IMPERIAL EQUIVALENTS TO SI UNITS

1 inch	=	25,4 mm	1 cu. inch	=	16387 mm^3
1 foot	=	0,305 m	1 cu. foot	=	0,028 m^3
1 yard	=	0,914 m	1 cu. yard	=	0,765 m^3
1 acre	=	4047 m^2	1 gallon	=	0,005 m^3

GROWTH FACTOR AS A FUNCTION OF A DESIGN PERIOD AND THE ANNUAL POPULATION GROWTH RATE IN PERCENTAGE

Design Period in years	Annual population growth rate in %					
	0	2	3	4	5	10
0	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	1.00	1.16	.122	1.27	1.61
10	1.00	1.22	1.34	1.48	1.63	2.59
15	1.00	1.35	1.56	1.80	2.08	4.18
20	1.00	1.45	1.81	2.19	2.65	6.83

The growth factor (m) depends on the annual growth rate (r) and the design period (T): $m = \{1+r\}^T$.

In general the growth factor will be in the range of 1.0 to 1.6.

THE SERVICE RADIUS AND THE MAXIMUM WALKING DISTANCE

Assume that the total area A is divided into a number of circular "standpost service-areas" of equal magnitude and arranged in such a way that the sum of the surface area of all service areas equals the total surface of area A. Say, there are S standposts and R is the radius of the service area. The above is then expressed by the following equation:

$$A = S * \pi R^2$$

This hypothetical situation can be imagined as follows:

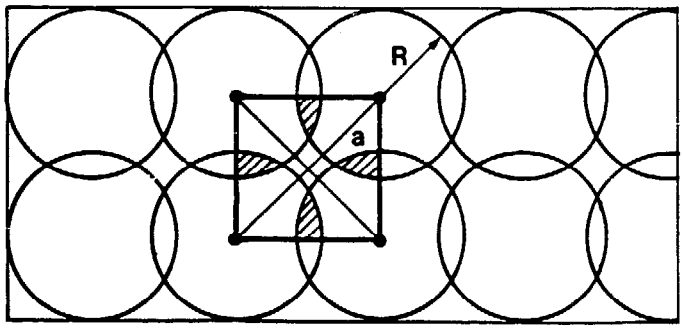

The above equation is only valid if the sum of the surfaces of the "overlapping circular areas" just equals the sum of the surfaces of the areas that are not covered by one of the circular service-areas. In this case the surface of the square just equals the surface of a circular area.

The maximum walking distance (a) be calculated as follows:

$2a^2 = \pi R^2 \rightarrow a = \sqrt{\pi}/2.R = 1,253\ R.$

The equation $A = S * \pi R^2$ is often used to assess the number of standposts S required for a particular area A, assuming a service radius R. As shown above R is not exactly equal to the maximum walking distance, but is a good representation of the maximum walking distance of the majority of the population in a particular area.

PRESSURE HEAD LOSSES DUE TO THE FLOWING OF THE WATER

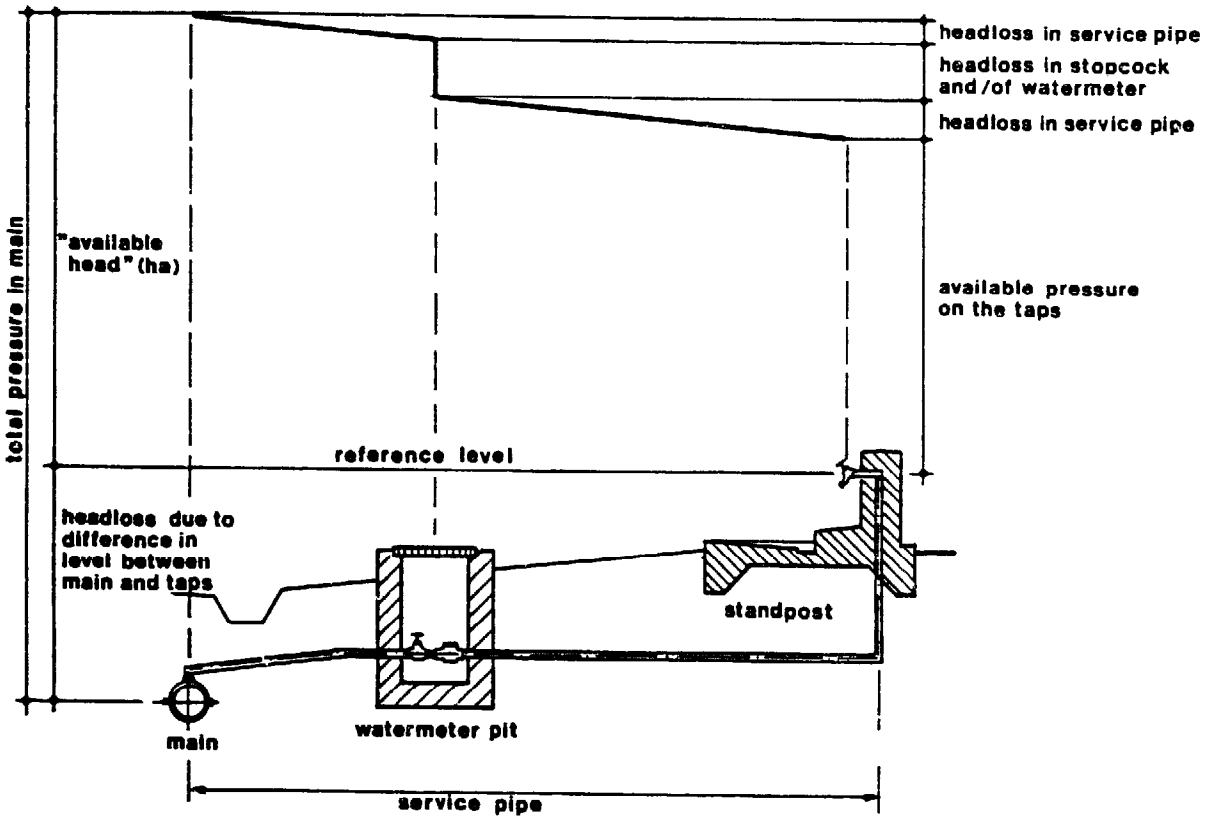

This diagram illustrates:

a) the difference in level between the main and the taps

b) the total length of service pipe being greater than the direct horizontal distance (the possible deviation in the horizontal plan has also to be taken into account).

HYDRAULIC EQUATIONS

1. *Equation of Bernoulli:*

$$H = \frac{V^2}{2g} + \frac{P}{\rho g} + Z$$

H	=	Total energy level ("total head")
$\frac{V^2}{2g}$	=	head related to the velocity of the water
$\frac{P}{\rho g}$	=	pressure head, being the pressure in the water
Z	=	level in relation to a reference level

When the water in a pipe is in rest (V=o) the total head is only determined by the pressure head and the level.

2. *Hydraulic Gradient*

$$i = \lambda \frac{1}{D} \cdot \frac{V^2}{2g} \quad \text{in which} \quad V = 4Q/\lambda D^2$$

$$\lambda = 0.25/\{\log \frac{3.7D}{k}\}^2 \text{ and}$$

k = roughness coefficient

The coefficient k is directly related to the kind of material. For galvanised steel (GS): k = 0.001 and for polyvinylchloride (PVC): k = 0.0001.

3. *Definitions:*

Hydraulic: "of water *flowing through pipes* and channels".

Hydrostatic: "of the equilibrium of liquids and the pressure exerted by liquids *at rest*".

STOPCOCK (VALVE) AND WATERMETER

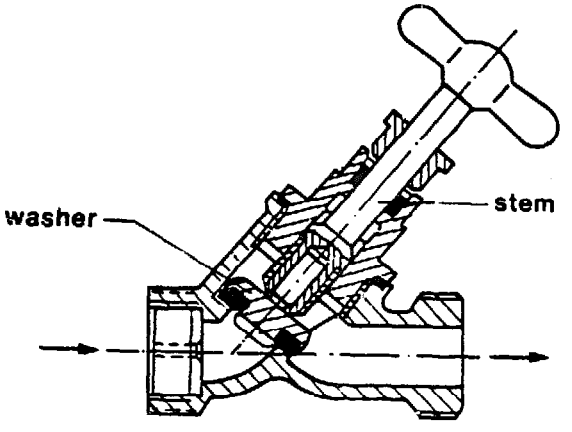

STOPCOCK

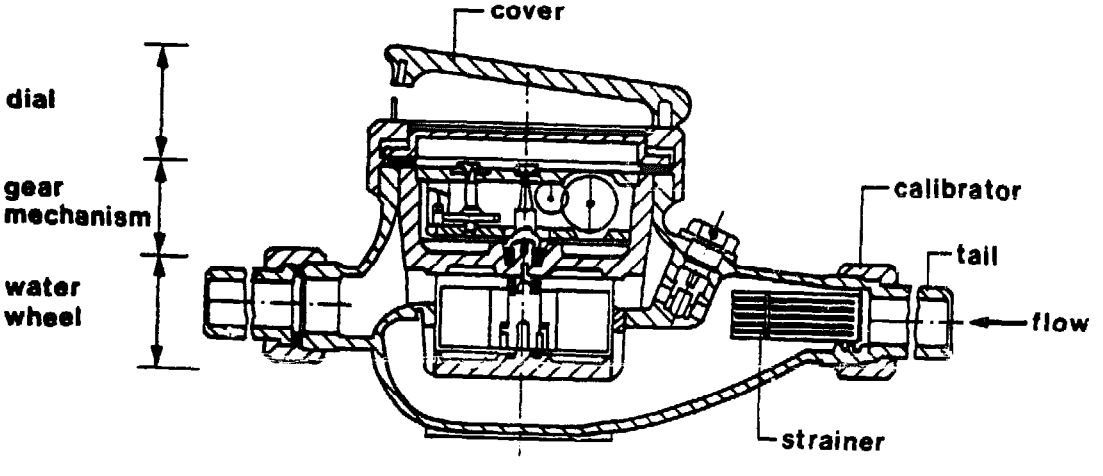

WATERMETER (dry dial)

MATERIALS AND EQUIPMENT COMMONLY APPLIED IN WATER SUPPLY SYSTEMS

MATERIALS AND EQUIPMENT COMMONLY APPLIED IN WATER SUPPLY SYSTEMS

parts of system / Materials	distri-bution pipes	connection of distribution pipe to service pipe		service pipe	stop-cock	water-meter	taps or valves	pipejoint	remarks
		saddle	ferrule						
Steel	*	*	-	-	-	-	-	welded or couplings	
Galvanised steel (gs)	***	*	-	***	-	-	-	screwed sockets	
cast or ductile iron	***	**	*	-	**	-	**	bell and spigot	
polyvinylchloride (pvc)	**	***	-	***	**	-	*	sockets	
polyethylene (pe)	*	-	-	*	-	-	-	welded or brass/cast iron	
asbestos cement (ac)	**	-	-	-	-	-	-	coupling sockets	
brass	-	-	***	-	**	***	***	-	
nylon	-	-	-	-	-	-	*	-	

*** = often applied
** = regularly applied
* = rarely applied

STANDPOST DRAINAGE

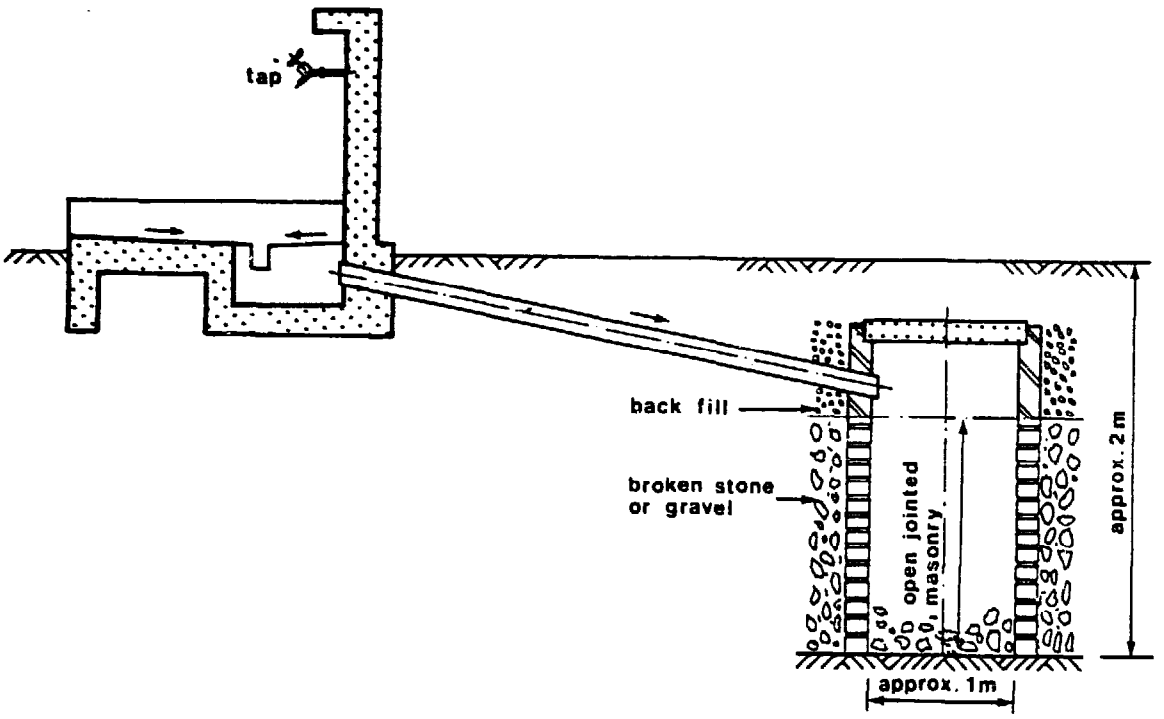

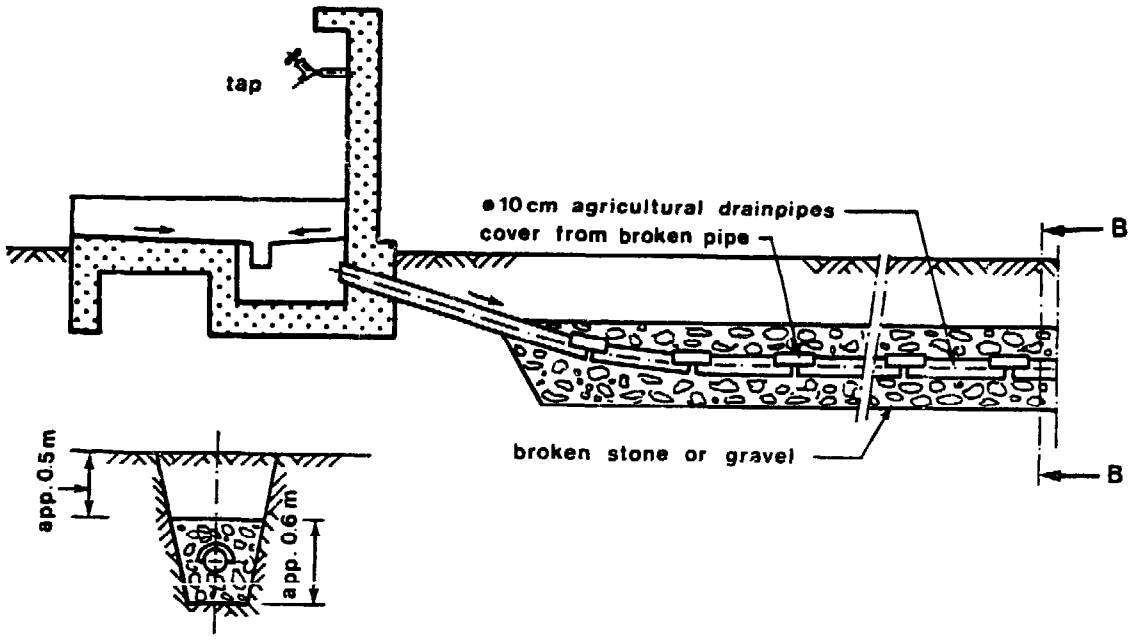

Agricultural drainage-tiles laid in a 'soak-away' trench (unless a more accurate figure is known, the rate of infiltration per m² of sidewall area may be estimated as 10 l/d).

FLOW CONTROL MECHANISMS

A. *SCREW TAPS*, such as the ordinary household type, have many advantages including simplicity of maintenance, and will probably be the most widely chosen. The valve washer in metal taps must be replaced regularly to prevent leakage, but this task is well within the capability of a local caretaker. The amount of wear on the washer and on other parts depends on how the tap is used, and whether it is sometimes closed too tightly. However, once people have become used to the device, and if necessary have been given instruction in its use, there should be no major problems.

Screw taps may be of brass, iron or plastic. Brass taps are often stolen because of the value of the material and can be easily screwed off the end of the pipe unless welded to it. Experience with nylon taps which have nylon valve-seats has been quite good, and less wear has occurred than in metal taps.

There are, of course, many types and brands of screw taps on the market. Small details like the quality of washers and finish of seats can be very important for the amount of maintenance the tap will require.

B. *TAPS WITH A BALL VALVE* appear to offer some advantages, because the closing pressure is not dependent on the force excerted by the user. Thus wear should vary less, and there are no small washers which require frequent changing. Some authorities suggest that such taps are more prone to leaking than well-maintained screw taps. Generally, they give rise to a lower head loss and so provide an adequate rate of flow even when water pressure is relatively low.

A. SCREW TAPS

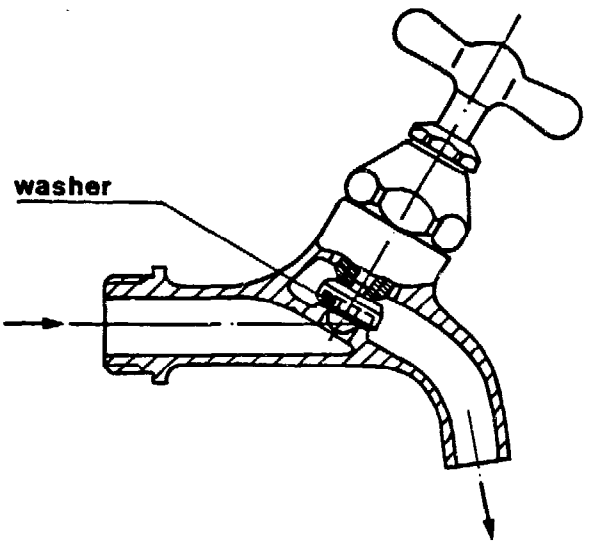

A1: ORDINARY SCREW TAP
IN CLOSED POSITION

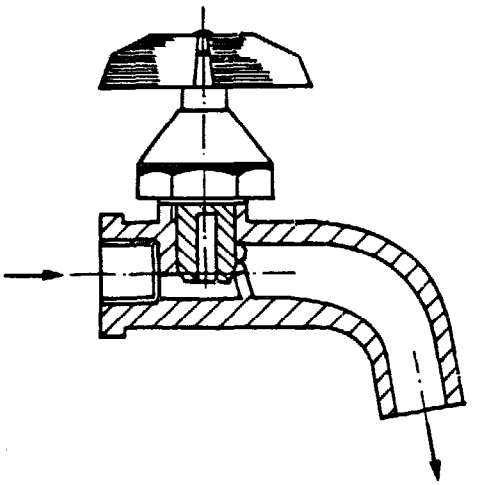

A2: NYLON TAP IN
CLOSED POSITION

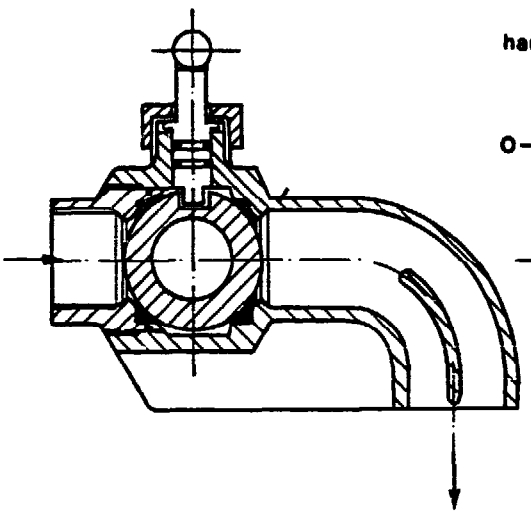

B1: IN CLOSED POSITION

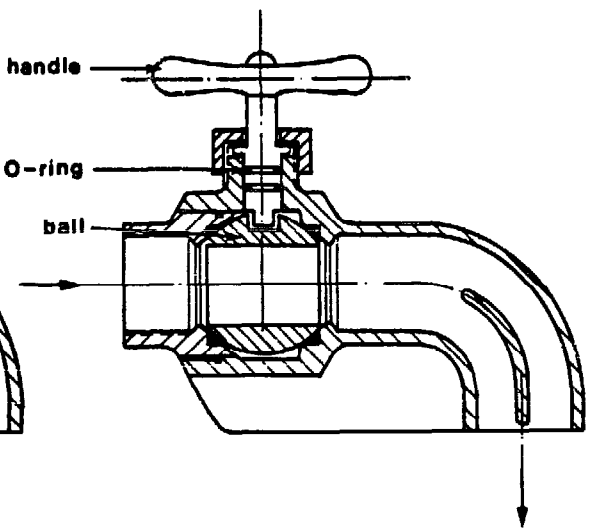

B2: IN OPEN POSITION

C. *SPRING-LOADED OR GRAVITY-OPERATED TAPS* are devices with which the user has to apply some force with the hand in order to keep the water flowing. They appear to be an attractive option for unsupervised standposts where it is of special importance that water waste be avoided. The tap is closed by spring action or by gravity immediately the user's hand is removed.

These taps are relatively cheap, simple to operate and present no complex maintenance problems. However, their value in reducing waste is not always as great as might appear, because they are sometimes kept open by means of a rope, wire or stone attached to the handle.

The gravity-operated taps is widely used in India. It has a heavy mouthpiece which must be pushed up to open the tap. It falls back as soon as the user ceases to hold it.

D. *VOLUMETRIC OR DELAYED-CLOSING TAPS* are similar to spring-loaded taps, but have a more complex mechanism which keeps the tap open for a fixed period of time after the handle has been operated. The tap cannot be held open by weights because it closes after the fixed time interval even when pressure is continually applied. To re-open the tap, the handle or knob has to be operated again.

Such taps may be the most effective at reducing wastage at unsupervised standposts, but they are complicated devices requiring regular maintenance by skilled staff. But it should also be noted that delayed-closing or spring-loaded taps are not always very acceptable to users. Some require considerable force to operate, and it is not excluded that they cause minor injuries when not operated properly.

C. SPRING-LOADED OR GRAVITY-OPERATED TAPS

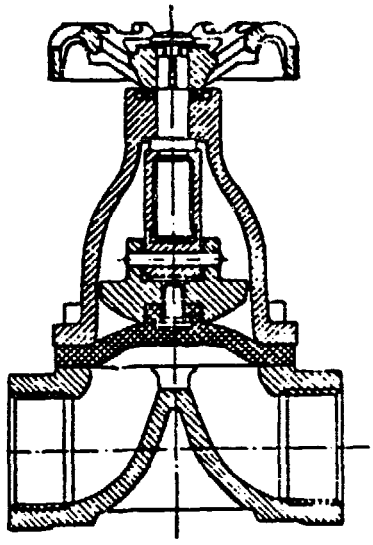

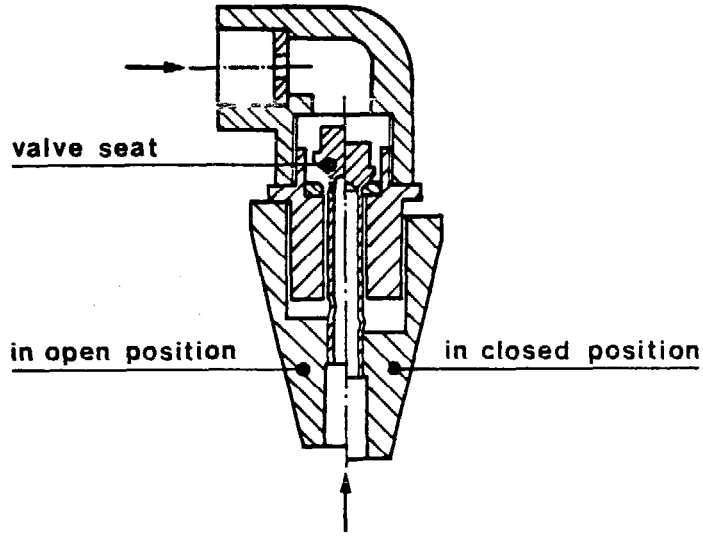

GRAVITY OPERATED TAPS

(Jayson (Pat) Water Taps)

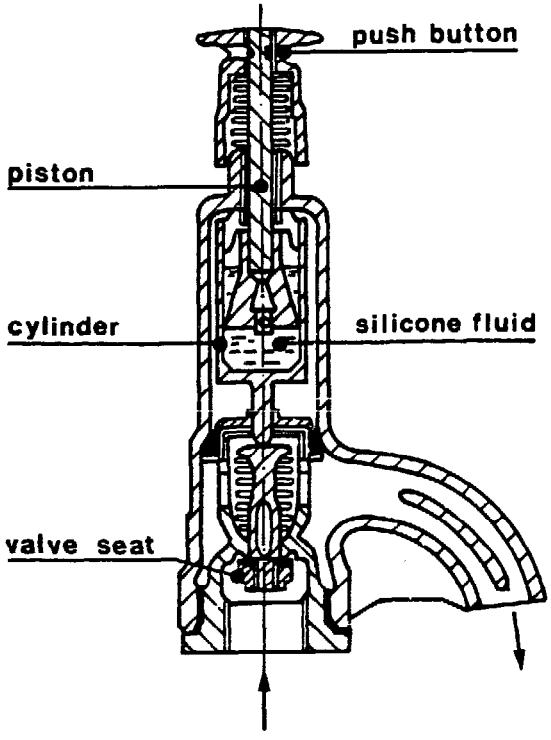

D1: SELF CLOSING TAP
(Fordilla)

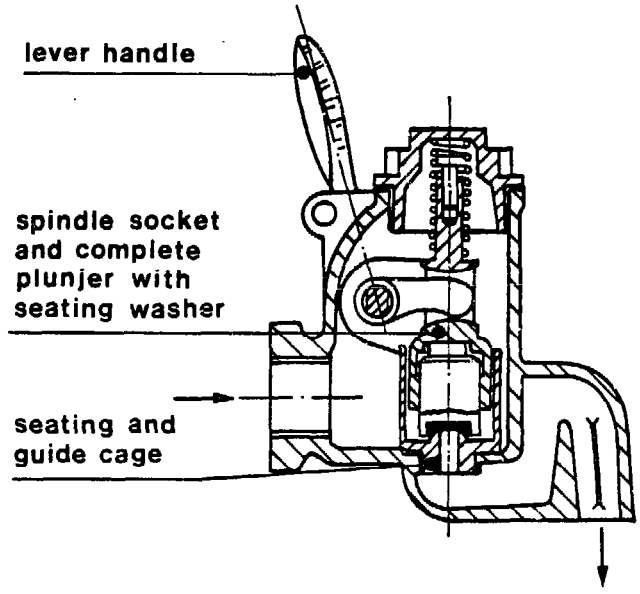

D2: SELF CLOSING TAP
(Tylor wastenot)

The definition of *a tap* is that of a closing device *at the end* of a pipe, whereas *a valve* is fitted *in a pipeline.*

E. *A DIAPHRAGM VALVE* has a body made of either cast iron or polyvinylchloride and a diaphragm usually constructed of neoprene or teflon. The advantages of the diaphragm valve are low pressure losses in comparison with taps; the separation of the operation mechanism from the water by the diaphragm; the glandless construction of the operating mechanism and the low maintenance requirements during its working life.

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Pulsometer pump

From Wikipedia, the free encyclopedia

The **Pulsometer steam pump** is a pistonless pump which was patented in 1872[1] by American Charles Henry Hall. In 1875 a British engineer bought the patent rights of the Pulsometer[2] and it was introduced to the market soon thereafter. The invention was inspired by the Savery steam pump invented by Thomas Savery. Around the turn of the century, it was a popular and effective pump for quarry pumping.

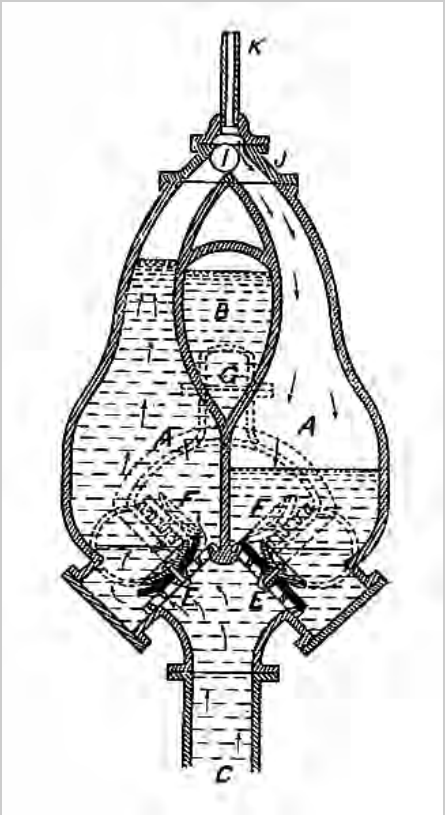

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- 1 Construction and operation
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Construction and operation

This extremely simple pump was made of cast iron, and had no pistons, rods, cylinders, cranks, or flywheels. It operated by the direct action of steam on water. The mechanism consisted of two chambers. As the steam condensed in one chamber, it acted as a suction pump, while in the other chamber, steam was introduced under pressure and so it acted as a force pump. At the end of every stroke, a ball valve consisting of a small brass ball moved slightly, causing the two chambers to swap functions from suction-pump to force-pump and vice versa. The result was that the water was first suction pumped and then force pumped.[3]

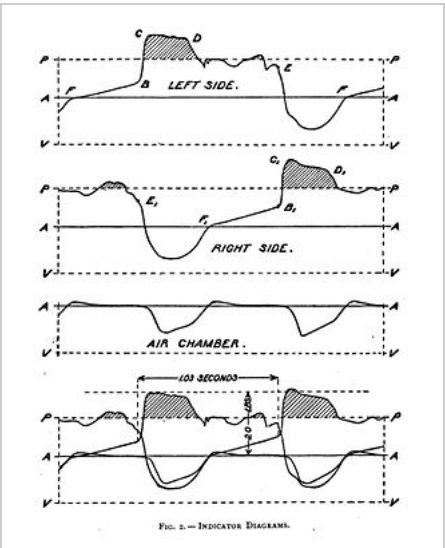

Chart showing pressure inside pulsometer pump

A good explanation can be found in the 1901 article referenced below:

> The operation of the pulsometer is as follows: The ball being at the entrance of the left-hand chamber, and the right-hand being full of water, steam enters, pressing on the surface of the water, and forcing it out through the discharge passage. A rapid condensation of steam occurs from contact with the water and with the walls of the chamber, previously cooled by the water. When the water level has reached the horizontal edge of the discharge passage, a large volume of steam suddenly escapes and is at once condensed by the relatively cold water between the chamber and the discharge valve. The pressure in the chamber quickly decreases; it cannot be sustained by steam

from the boiler, for, in accordance with the inventor's first specifications, the steam pipe is small. If now the pressure in the left chamber is equal, or nearly equal, to that in the right, friction caused by the rapid flow of steam past the ball will draw the ball over and close the right-hand chamber. Cut off from further supply, the steam, in contact with water, begins to condense; a jet of cold water from the discharge pipe spurts up through the injection tube, and by breaking into spray against the side of the steam space, completes the condensation. The partial vacuum produced brings water through the suction valve to fill the chamber; but at the same time the air valve admits a little air, which passes up ahead of the water and forms an elastic cushion to prevent the water from striking violently against the steam ball. The air chamber is for the purpose of preventing water-hammer in the suction pipe.

Pulsometer pump at the London Museum of Water & Steam

Advantages

The pump ran automatically without attendance. It was praised for its "extreme simplicity of construction, operation, compact form, high efficiency, economy, durability, and adaptability". Later designs were improved upon to enhance efficiency and to make the machine more accessible for inspection and repairs, thus reducing maintenance costs.[4]

Detailed analysis

In the January 1901 issue of *Technology Quarterly and Proceedings of the Society of Arts*, an article appeared by Joseph C. Riley[5] describing key operational details and technical evaluation of the pulsometer pump's performance. Riley noted that although somewhat inefficient, the pulsometer's simplicity and robust construction made it well suited to pumping "thick liquids or semi-fluids, such as heavy syrups, or even liquid mud".[6]

Pulsometer Engineering Company Limited

Pulsometer Engineering Company Limited was founded in Britain in 1875 after a British engineer bought the patent rights of the pulsometer pump from Thomas Hall. In 1901 the company moved from London to Reading, Berkshire. In 1961 Pulsometer merged with Sigmund Pumps of Gateshead to form Sigmund Pulsometer Pumps (SPP). SPP Ltd is now part of Kirloskar Brothers Ltd.

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Categories: Pumps | Steam power

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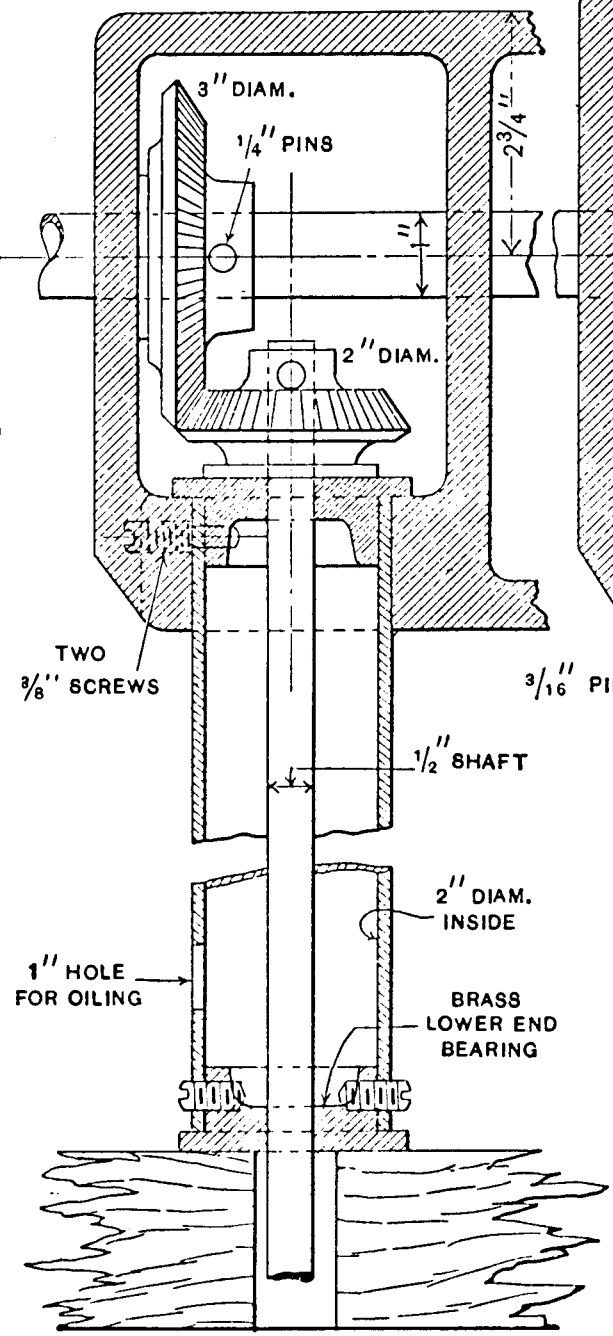

Fig. 34. Arrangement of Gearing and Bearings for Vertical Shaft.

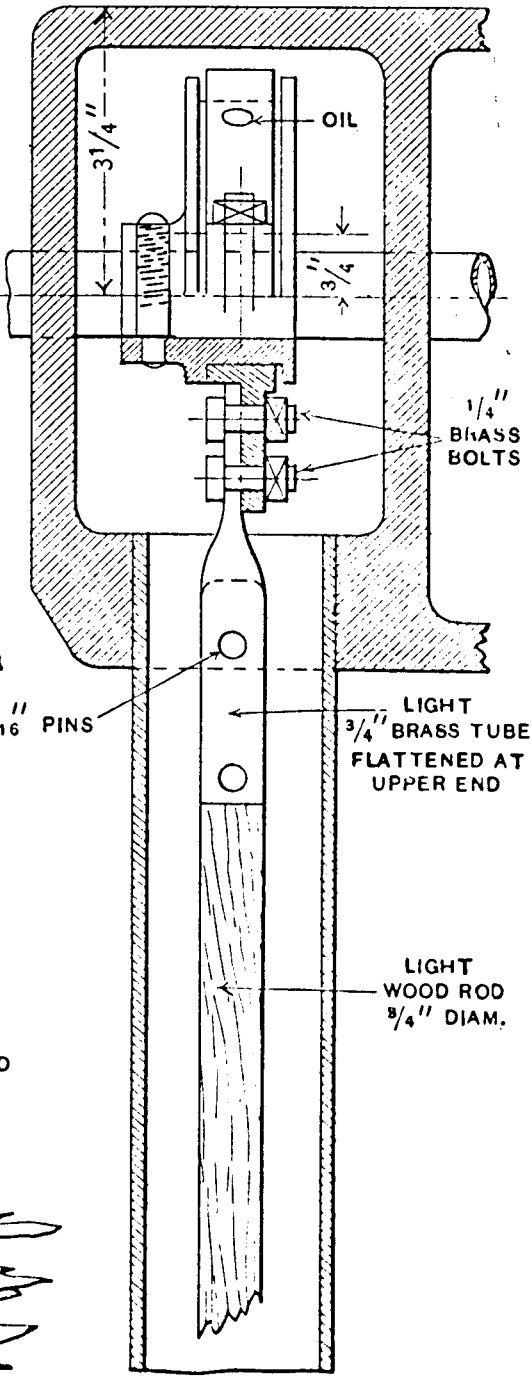

Fig. 35. Eccentric and Rod for Pumping Gear.

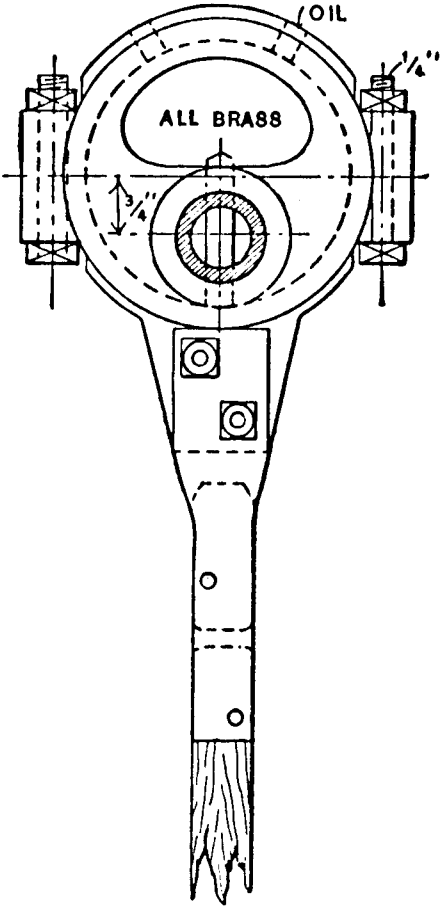

Side View of Eccentric for Pumping Gear.

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Pump Selection: a Field Guide for Developing Countries
WASH Technical Report No. 61

By: Richard McGowan and Jonathan Hodgkin

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Telephone: (703) 243-8200
Fax (703) 525-9137
Telex WUI 64552
Cable Address WASHAID

PUMP SELECTION: A FIELD GUIDE FOR DEVELOPING COUNTRIES

WASH TECHNICAL REPORT NO. 61

JANUARY 1989

Prepared for
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WASH Activity No. 316

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January 1989

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ABBREVIATIONS AND ACRONYMS

AC	alternating current
ADP	animal-drawn pump
AID	U.S. Agency for International Development
ALCC	annualized life-cycle cost
ARD	Associates in Rural Development, Inc.
CIF	cost/insurance/freight (delivered price)
DC	direct current
FLFC	full-load fuel consumption
FOB	freight on board (ex-factory price)
g/kWh	grams of fuel consumed per rated kilowatt-hour
Hp	horsepower
I/V	current/voltage
J	joule
Jm^2-sec	joules per sequare meter per second
kW	kilowatt
kWh	kilowatt-hour
kWh/m^2d	kilowatt-hours per square meter per day (irradiation)
LPD	liters per person per day
l/s	liters per second
mg/l	milligrams per liter
MJ	megajoules
MJ/m^2d	megajoules per square meter per day
m^3/d	cubic meters per day
m^3/h	cubic meters per hour
mph	miles per hour
MPPT	maximum power point tracker
m/s	meters per second
MW	megawatt
NGO	nongovernmental organization
O&M	operation and maintenance
PCU	power-conditioning unit
PCV	Peace Corps volunteer
psi	pounds per square inch
PV	photovoltaic
PVO	private voluntary organization
rpm	revolutions per minute
TDS	total dissolved solids
VLOM	village-level operation and management of maintenance
W	watts
w/m^2-sec	watts per square meter per second
WASH	Water and Sanitation for Health Project
WHO	World Health Organization
Wp	peak watts

PREFACE

This manual was written to help professionals and technicians in developing countries select water pumping equipment that closely matches their requirements in terms of performance, cost, and long-term system support. Funding for the manual was provided by the Water and Sanitation for Health (WASH) II Project under the auspices of the U.S. Agency for International Development's (AID) Bureau for Science and Technology, Office of Health. It was prepared by the engineering staff of Associates in Rural Development, Inc. (ARD).

Much of the information in this manual is based on the authors' experiences with pump testing and evaluation in a variety of developing countries, including Botswana, Malaysia, Sudan, Yemen, Somalia, and Djibouti. We would like to thank the many people who helped us on these projects, including host-country and expatriate engineers, economists, and technicians as well as a number of people from private voluntary organizations (PVOs) and the Peace Corps. We would also like to thank the persons who have reviewed drafts of this report for their useful comments: Peter Bujis of CARE, Joseph Christmas of UNICEF, Mike Godfrey of CARE/Rwanda, Peter Lehman of Humboldt State University, Rita Kirkpatrick of ARD, Ron White--consultant with ARD, and Alan Wyatt of Research Triangle Institute. We would also like to thank John Ashworth (formerly with ARD) for his help in conceptualizing the early phases of this work. In the final stages of preparation, the manual was edited by Diane Bendahmane whose careful reading and detailed comments are greatly appreciated. Finally, we would particularly like to thank Phil Roark (WASH) for his active support throughout the development of this field guide. He has not only kept the writing, shaping, and review of this guide moving forward, he has also made many useful suggestions during the development of the technical approach and presentation of the material.

The cost and performance data given herein represent the best available estimates as of the date of this report for the types of equipment discussed. These values can and do vary considerably, depending on the country where the equipment is used, the expertise of the operator, and the extent to which proper system sizing, operation, and maintenance procedures are followed.

WASH hopes this manual provides a helpful method for pump selection that will be useful to a wide variety of readers. Comments on the method and any additional local data on experiences with equipment, costs, performance, and availability would be welcomed by the authors for inclusion in subsequent revisions.

Chapter 1

INTRODUCTION

1.1 Why This Manual?

The improvement of rural water supplies has been a major focal point of rural development efforts in developing countries. These efforts have not always met with success, often because inadequate attention has been given to proper equipment selection and use. The importance of strengthening local institutions that are capable of handling necessary equipment-support functions, including system design, installation, operation, maintenance, and repair, has frequently not been recognized. Even well designed pumping systems often fail prematurely due to a lack of planning and insufficient funding for the long-term recurrent costs of maintenance and repair.

Over the past few years, system designers have begun to consider recurrent costs in the pump selection process, primarily in response to the rising cost and increasing scarcity of conventional energy supplies in developing countries. Attention is also shifting to alternative energy sources for pumping, particularly in rural areas where users often do not have access to the national power grid. In such areas, users have typically had only two options--diesel systems or handpumps. Dramatic increases in petroleum fuel prices over the last two decades have heightened interest in other types of low- to medium-capacity pumps, such as those powered by wind and solar radiation.

This manual was written to aid a wide variety of people who are involved in making decisions about water pumping equipment and its use:

- managers of water resources development projects;
- development professionals (with some degree of experience with pumps);
- host-country and expatriate engineers and technicians working in both public and private sectors, including nongovernmental organizations (NGOs);
- Peace Corps (PCVs) or other volunteers with a technical background; and
- technically inclined pump users.

It is intended to enable readers to understand better and evaluate more carefully the advantages and disadvantages of different types of pumping systems and their components (e.g., pumps, engines, and controls), associated costs, and long-term operation and maintenance (O&M) requirements. With this information, readers can make knowledgeable, cost-effective choices of water pumping

equipment, which will result in water development projects that are more effective and that offer increased water availability and decreased costs to users.

Many handbooks have been written on the subject of rural water supply, irrigation, and pump selection (see the annotated bibliography in Appendix A). Until recently, most of these focused primarily on the technical aspects of choosing a pump. Issues such as recurrent O&M costs, availability of technical skills and spare parts, system reliability, ease of installation and/or operation, and related considerations that are or may be of paramount importance to users were discussed only briefly.

Pump users in developing countries face a wide range of constraints in ensuring the reliability of water supplies, including

- lack of trained, experienced mechanics and engineers to handle system design, installation, operation, maintenance, and repair;
- lack of fuel and spare parts;
- very limited selection of locally available system types and sizes to meet specific water needs;
- a sometimes wide variety of locally unsupported pumping equipment, chosen not because it meets local needs but rather because the donor prefers it; and
- inadequate information on how properly to match available equipment to water pumping needs.

Pump selection must take all of these constraints into account. The alternative—selecting a system without being adequately informed—will undoubtedly increase water costs and maintenance and repair requirements. Inappropriate equipment selection can have major adverse implications for a project, including

- inadequate or grossly over-sized system capacity;
- over- or under-used water sources;
- increased capital equipment costs;
- higher recurrent costs;
- overly frequent maintenance and repair; and
- unnecessary system downtime due to fuel shortages, inadequate renewable energy resource base, or lack of on-demand water pumping capability.

This manual provides information on the operating characteristics, design procedures, O&M requirements, and advantages and disadvantages of various equipment alternatives to help readers make a better pump selection for both groundwater and surface-water use.

1.2 Goal and Purposes

This manual is designed to enable field technicians and managers who do not necessarily have extensive experience in water engineering to make appropriate choices of water pumping systems and components. It presents the decision-making process as a logical progression, first discussing what information is needed before examining pumping system alternatives, and then showing readers how to gather and analyze the needed information so it can be used in applying a set of selection criteria. The criteria are given in flowchart fashion, so users can apply the data they have acquired to make useful, accurate decisions about pumping equipment alternatives.

To achieve this purpose, the manual attempts to

- describe the process of properly selecting pumping equipment for small-scale potable water supplies, based on site and resource characteristics, as well as the engineering, economic, and institutional characteristics of each type of system;

- assist with the initial screening of water pumping technologies by describing what information is necessary to determine equipment needs and how to gather it;

- provide detailed guidelines for analyzing the data required for a technical comparison of diesel, wind, hand, and solar pumping systems (other types of systems may be included in later revisions of this manual);

- inform readers on recent and past operating experience with diesel, solar photovoltaic (PV), wind, and handpump systems, including problems and attempted solutions as well as new approaches to making different designs more appropriate for operating conditions in developing countries; and

- give estimates of typical capital and recurrent O&M costs for the systems considered here, along with guidelines for adapting these costs to reflect specific conditions in the user's country or region.

This manual is written for a wide audience--it is not intended to be a comprehensive reference manual on the engineering and economic design and analysis of all small-scale water pumping equipment. Where appropriate, readers are referred to other references (see Appendix A) that contain in-depth treatments of particular topics, so those who are interested in the intricacies of a certain subject can examine other resources for additional information. Here, detail has been sacrificed to provide broad coverage of all relevant areas.

1.3 Overview of the Pump Selection Process

This manual uses a straightforward pump selection method that takes into account technical, social and institutional, and cost factors in choosing the most appropriate pumping system(s) for a given level of water demand and specific set of site constraints. It shows readers how to collect and analyze the basic engineering and cost data needed to select any of the four system types considered here--diesel, solar PV, wind, and handpump systems. There are a variety of other types of pumping systems used in developing countries, including hydraulic rams, biogas-powered pumps, and animal traction pumps. These are not covered in this manual, but information on these systems is given in the bibliography (especially Fraenkel 1986).

The selection process involves several stages of information gathering and analyses:

- determining water demand at the site, based on the number of water users (e.g., human, animal, and agricultural);
- measuring and calculating the energy requirement to meet that water demand, based on the physical characteristics of the water source and system design;
- reviewing what equipment is locally available or can be imported to define the range of available pumping options;
- estimating the output of the four types of pumping systems covered in this manual--diesel, solar, wind, and hand;
- determining site-specific cost factors for an economic analysis that compares the life-cycle costs of competing systems; and
- reviewing other supporting issues (e.g., social and institutional) that are important to the successful long-term operation and maintenance of pumping systems.

Flowcharts and illustrations are used to describe the pump selection process. After estimating water demand and applying the technical selection criteria, several viable alternatives often remain. A brief survey of locally available

equipment and an informal evaluation of an area's support infrastructure (e.g., equipment dealers, mechanics, sources of credit, pump user groups, and local O&M costs) emphasizes the importance of pump selection criteria that focus on more than just technical issues. Capital and recurrent cost data that reflect typical system costs in developing countries are used further to reduce the number of acceptable options. Finally, social and institutional criteria are applied to make the final selection.

While the technical constraints associated with various types of pumping systems are fairly obvious and well known, pumping costs (especially for O&M) are not. This manual stresses the typical performance of pumping equipment in developing countries (based on field-test measurements) and the importance of local infrastructural support for long-term reliability. Until recently, very little recurrent cost and performance data have been available that accurately reflect the unique constraints faced by users in developing countries. The cost estimates used in this manual are based on information gathered in a variety of developing countries; they can be adjusted to permit the inclusion of local site-specific data. The cost data presented here draw heavily on a four-year study of diesel, solar, wind, and handpump costs in Botswana conducted by Associates in Rural Development, Inc. (ARD).

The flowchart for the overall technology selection process is presented in Figure 1. While it may appear somewhat complex at first glance, it codifies a complex decision-making process that includes consideration of a large amount of information. The following narrative description of the pump selection process refers to particular steps shown in the flowchart.

1.3.1 Determining Water Requirements and Energy Resources

The first step in the process is to <u>determine site water demands and available energy resources</u>, including constraints on the water source in terms of head, yield, and quality as well as locally available energy resources--diesel fuel supplies, solar irradiation levels, average wind speeds, and availability of human labor for pumping. This step should include a careful review of existing water collection techniques used at your site, if any. After deciding whether or not a pump is appropriate, and determining exactly what you have to work with at the site, you should begin to <u>survey locally available pumping equipment and infrastructure that can support it</u>. Check local suppliers to determine the types of pumping systems that are available, brand names of manufacturers, ranges of output for engine power and pumped water from a variety of heads, and capital equipment costs.

1.3.2 Assessing Locally Available Systems

Next, <u>assess the advantages and disadvantages of system options</u> that are already locally available. Determine <u>which locally available options are acceptable</u> for your application by answering the following questions about each option.

Figure 1. The Pump Selection Process

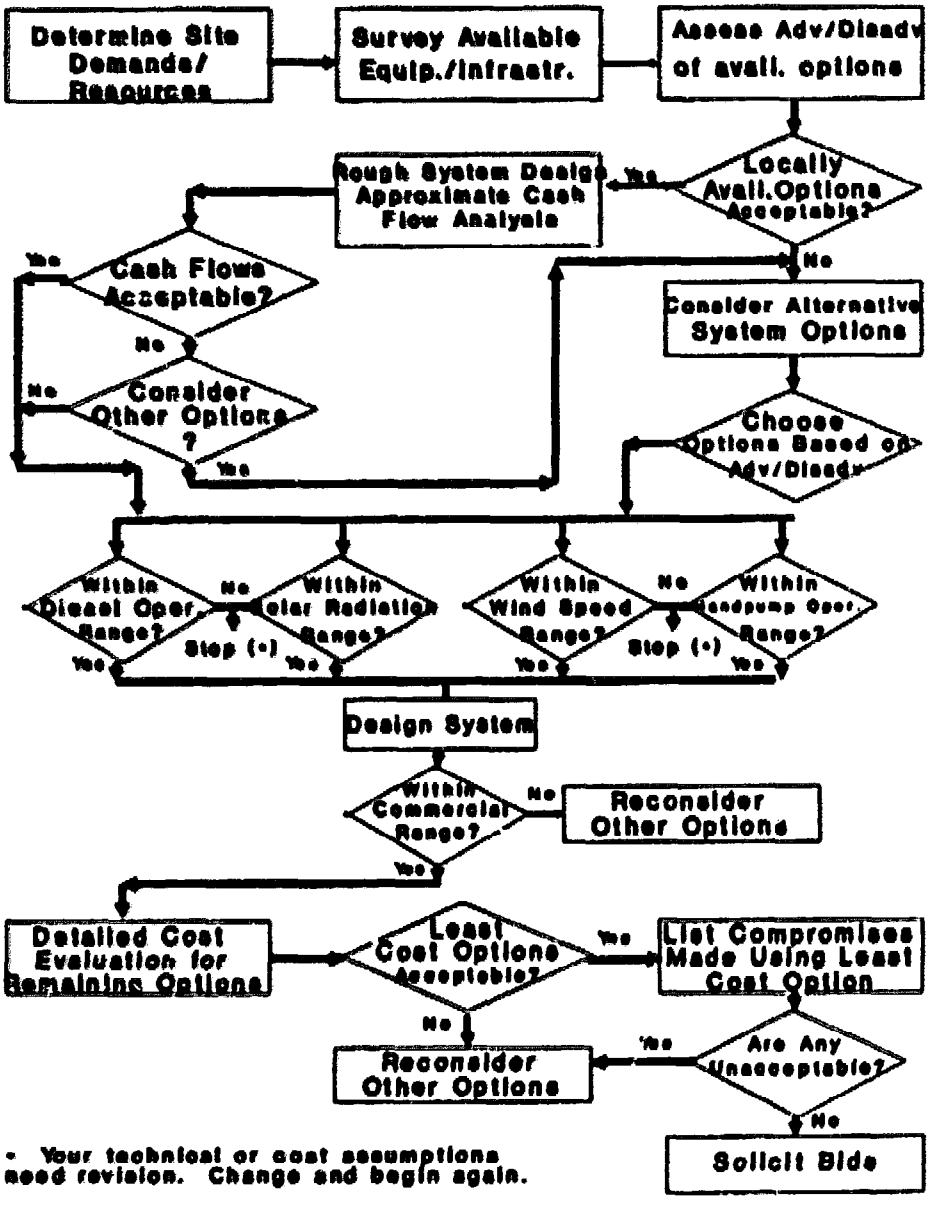

- Do the power ranges fit the site requirements for flow rate and head?

- Is system design assistance available?

- Is skilled labor available for equipment installation, operation, maintenance, and repair?

- Are inventories of spare parts adequate so that the system can be repaired without undue delays?

If the equipment is already being used locally, the answer to all these questions should be yes. If the answer to any of the above is no, you should begin to consider other system options.

1.3.3 Rough System Design and Cash-Flow Analysis

Assuming the answer to all the questions is yes, do a rough system design and cash-flow analysis. Chapters 5 through 8 provide information on system design analysis and Chapter 9 provides sample inputs for cash-flow analysis for the type of system(s) that are locally available. Use information from local dealers on your approximate system needs to complement the design procedures described in this manual.

Next, determine whether the cash flows are acceptable by answering the following questions.

- Can pump users or purchasers raise sufficient capital to buy the system outright? If not, do they have access to credit?

- Will pump users, or whoever is ultimately responsible for the system, realistically be able to cover expected recurrent costs? (Funds may have to be collected from user fees, returns on crops grown, or fees collected from those watering animals. Provisions for meeting recurrent O&M costs should be specified before the system is purchased.)

- Can pump users (or other groups responsible for maintenance and repair) cover the costs of unexpected, but inevitable, breakdowns?

If the answer to any of these questions is no, for whatever reason, you should consider other system options, which may result in a different cash-flow analysis that is more acceptable given the particular circumstances.

1.3.4 Additional Considerations

If the cash flow is acceptable, decide whether there are other reasons (besides financial considerations) why you might want to consider other options. These might include, but would certainly not be limited to,

- user participation and perceptions (Have users been closely involved in the decision-making process, and do they have any objections regarding the current choice of equipment?);
- system reliability (Are there other systems that may increase the probable availability of water supplies?);
- automatic operation (Would individuals or groups involved prefer that a pump operator or attendant [pumper] be hired to oversee the operation of the system or should the system operate unattended?);
- employment generation (Is increasing employment locally a concern, perhaps at additional cost in terms of money and convenience?); and
- training (If the technical support skills available locally are only marginal, is anyone willing to provide support [financial and/or administrative] for setting up training programs to change this situation?).

If you are satisfied that the system you have designed (using equipment that is already locally available) fits your needs and it is not necessary to consider other options, go ahead and <u>solicit bids</u> for procurement. If you are not satisfied, <u>consider alternative system options</u>.

1.3.5 Assessing Systems Not Available Locally

Begin by first listing probable system options, based on the information about available equipment for various system types given in Chapter 4. Which seem to fit your situation best? Review the lists of advantages and disadvantages for different types of systems, based on the comparative information given in that chapter. Decide which advantages and disadvantages are most important in your particular set of circumstances. Discuss them with prospective system users and those who may have to provide various support services--system design, repair of breakdowns, and provision of spare parts.

Depending on the system options chosen for further consideration, the easiest way to decide which of the four types of systems are most appropriate for your requirements is to determine those that can meet the basic operating and site constraints. For example, for wind pumps, is the wind speed at the site during the "design month" (i.e., the worst-case condition when available wind energy is lowest in relation to water demand) above the minimum recommended level in meters per second (3.5 to 4 m/s), and the total head less than about 60 meters?

If not, wind pumps should probably not be considered any further for this application. Similarly, for a solar pump, is the average solar radiation in the design month greater than 5 kilowatt-hours per square meter per day (kWh/m^2d)? (See Chapter 3 for an explanation of solar radiation measurements.) If not, focus your attention on other system alternatives. Similar minimum selection criteria can be used for each type of system and are discussed in subsequent chapters on system design.

1.3.6 Preparing Tentative System Designs

At this point presumably at least one system alternative will have passed the minimum selection criteria. The next step is to design the system for the selected options. Preparing a tentative system design will

- allow you to become more familiar with exactly what parameters must be considered when designing and, more important, when using each type of system and
- force you to rethink your assumptions about which system will be best for your situation, in terms of technical inputs (e.g., fuel, mechanics, and spare parts) and output (required quantities of water to be delivered according to a schedule you specify).

During system design, you should examine manufacturers' literature obtained from pumping equipment distributors in the area. In doing so, you will find out whether or not the system you are designing uses components (e.g. engines, pumps, and controllers) whose capacity is actually within acceptable ranges for commercially available equipment. For example, you may determine that given the relatively favorable wind speeds at your site and the water demand profile, a wind pump with a rotor 10 meters in diameter would be appropriate. However, the largest wind pumps have rotors that are typically only 7.6 meters across, which would not deliver as much water as you require. In that case, you should consider using two or more smaller windmills or reconsider other options.

1.3.7 Comparing the Costs of the Selected Options

If any of the options examined can meet the physical constraints of your application, the next step is to do a detailed cost evaluation of these options. This is basically a refinement of the approximate cash-flow analysis conducted earlier. The point is to get as exact an estimate as possible (given the available data) of the progression of cash flows that will occur during the system's expected lifetime. This will allow you to make reasonable decisions about whether or not those cash flows are acceptable for your system and which of the remaining alternatives is the least-cost option.

1.3.8 Making Necessary Compromises

The next step is to decide whether the cash flows associated with the least-cost option are acceptable. If not, go back and reconsider the other system options more carefully. If so, list the compromises you will have to make if you decide to use the least-cost system, rather than another technically acceptable, but more costly, system. For instance, less expensive equipment may have lower reliability, there may be less chance of getting repairs completed quickly, or users may be less familiar with the system. Then, decide whether any of the compromises are unacceptable to you or system users. If so, reconsider other options. If all the compromises are acceptable, go ahead and solicit bids for the system from dealers you contacted previously.

This process is intentionally somewhat repetitive, so decisions will not be made lightly or solely on the basis of first impressions or unstated motives. Systems that are already available locally are favored over those which will have to be imported. Experience has shown that systems which are newly introduced without adequate attention to developing an associated support infrastructure have typically fallen into disrepair. This is not to say that new types of systems should be avoided. Rather, it is intended to emphasize that there are additional obstacles associated with introducing new technologies which can be insurmountable unless attention is given to developing the required support infrastructure.

The flowchart shows the overall approach to making a selection among several different technologies. The process of determining the actual design of individual systems and exactly what site-specific operating constraints are in effect is covered in later sections of this manual. In the design chapters, process flowcharts are presented that lead readers through the design process for the four types of systems considered in this manual. Preformatted sheets are also provided to help simplify data collection and analysis, the results of which are used in analyzing technical performance and costs for each system type.

1.4 Structure of This Manual

This manual is divided into 10 sections. To compare any pumping technology options, you must first determine water demand at the site. Chapter 2 shows how to calculate this. It discusses water-resource characteristics that are important for system design, such as well yield (if the source is groundwater), pumping head, and water quality. After discussing demand profiles (i.e., how much water is needed and when), this chapter concludes with a subsection on important factors affecting water availability.

Chapter 3 describes how to calculate the energy requirements for meeting the demand profile determined in Chapter 2. It discusses the characteristics of the four types of energy considered in this manual--diesel fuel, wind and solar energy, and human power for handpumping--and recommends sources for gathering needed information on energy resources in your area.

The types of pumping equipment and their operating characteristics are covered in Chapter 4. In the pump selection process, after water demand and head requirements are determined, the next step is choosing a particular pump to match those parameters. Then, an energy source (e.g., windmill or diesel engine) is selected to provide the input energy required by the pump chosen. This chapter includes summaries of the important advantages, disadvantages, and typical applications of different types of pumps and energy sources.

The next four chapters (5 through 8) focus on technical system design for the four types of energy sources considered in this manual—diesel, solar, wind, and human power. Each chapter begins with an initial description of typical equipment, followed by a discussion of system characteristics; operation, maintenance and repair requirements; and typical capital equipment costs. Except for the section on handpumps, which is a much simpler technology, each concludes with a detailed example of the design of a pumping system using that technology. These examples indicate where each type of energy source can and cannot be used, based solely on technical criteria.

The final two chapters on economics and other nontechnical considerations are the final stages in the screening of remaining equipment options. Up to this point, only representative costs are given. Recurrent costs have not been analyzed, and no economic analysis has been undertaken. Chapter 9 briefly discusses analytical methods and then shows how to apply them by taking the reader through two detailed examples that compare two pumping options. These examples are extensions of the technical system design cases presented in Chapters 5 through 8.

It is not necessary to read the entire manual to get help with decisions about pumping systems. Skip around to locate information of specific interest to you. However, all chapters should be read before equipment is finally selected to assure that all pertinent selection criteria are carefully considered.

Chapter 2

WATER DEMAND AND RESOURCES

2.1 Demand

To select an appropriate pumping system, you must first know the water requirement at the site. The water requirement is usually measured in cubic meters per day (m^3/day) and depends mainly on the size of human and animal populations, although it may also include small-scale irrigation or other demands. The amount of water used per capita depends heavily on convenience—when water is more readily available, per capita consumption will increase. Remember this when estimating future increases in demand.

The World Health Organization (WHO) has established the minimum water requirement for human consumption at 30 liters per person per day (LPD). In practice, while 30 LPD is often used as a design value, this is often more than the actual consumption typical of many rural areas. Local water demand varies with location, customs and cultures, climate, distance to and capacity of the water source, and amount of effort or cost associated with meeting the demand. This section describes how to estimate current water requirements and evaluate environmental conditions that limit the quantity and quality of water which can be obtained from a given source. These data are used in the pump selection process primarily to determine pumping rate and, hence, the system's power requirements. Information on local water demand for people, animals, and crops is often available in already existing development reports for your area. You should check these reports and integrate that information into the demand estimation procedures given below.

2.1.1 Site-Specific Conditions

Water demand is dependent on site-specific conditions. Although general guidelines have been established by many development agencies specifying the minimum daily consumption for people, animals, and crops, actual consumption can (and does) vary considerably. This manual is intended to deal only with drinking water for people but, in fact, many village water supplies will be also used to water small livestock. Typical usage figures are given below for the most common consumers.

	People	Cattle	Goats/Sheep	Poultry	Hogs
Demand in liters/day	20-40	20-40	5-15	0.2	10-15

The water requirement for people assumes that people get their water from centrally located standposts. If house taps are used, expected consumption will be considerably greater. The total water requirement for a pump is obtained by multiplying the number of people and animals to be served by the per capita consumption, and they by adding other demands (watering gardens, selling water to nearby consumers, etc.) in the area the pump will serve (the service area). When calculating the total water requirement for a service area, consider that people may keep more animals when water is more readily available. Also, people from surrounding villages outside the service area may want to use the system if their water sources fail or if it is easier for them to get water from the new system.

2.1.2 Variations in Consumption

Water consumption varies over the course of a day, both seasonally and annually. Since pumping systems are normally sized to provide enough water to meet the largest (or peak) daily demand, it is important to determine what peak demand will be. Peak demand can be a function of social (everyone coming home for the holidays), agricultural (garden cropping patterns and watering schedules), or livestock considerations (animals returning from grazing lands during the dry season, or visits from nomadic tribes with their herds). For pumps driven by renewable energy sources (such as wind or solar power), you must also determine what daily demand is for the worst-case situation, called the "design month." The design month is the calendar month when average daily water demand is greatest in relation to the availability of the renewable energy resource. (The sections on wind and solar pump design give more information on determining the design month.) For diesel systems, which often have a very high on-demand pumping rate and so do not require as much storage, you may also have to consider hourly peak demand.

2.1.2 Growth in Demand

Estimates of system capacity require assuming a design period or horizon, which is typically 8 to 10 years. This can be different from the amortization period for economic comparison of different systems (see Chapter 10), as long as there is the potential for expanding the system's capacity at the end of the design period. All system design decisions should take into account the fact that the demand for water will probably increase over time. Demand is affected not only by population growth (people and animals) but also often by ease of access. Per capita consumption (measured in LPD) usually only increases significantly if service increases--that is, if many more water points are installed nearer to users, particularly yard taps. While it is difficult to generalize without information on local population growth, rates of 2 to 4 percent per year are typical for rural villages in developing countries. This may sound small, but a 4 percent annual growth rate means that the demand for water will increase by over 40 percent in 10 years (not assuming any increase in per capita

consumption). Increased demand due to growth in population and per capita consumption can be calculated using this formula:

$$D_F = D_P \times (1 + F_{PG})^{(N-1)} \times (1 + F_{CG})^{(N-1)}$$

where D_F = future demand
D_P = present demand
F_{PG} = population growth factor
N = design period in years
F_{CG} = consumption growth factor

Steadily increasing water requirements place different demands on the various types of systems. These demands are handled in different ways. For diesel or gasoline (petrol) pumps, increased demand can be met simply by increasing the flow rate (engine speed) or operating the system for more hours each day. The latter is also true for handpumps. Solar PV and wind pumps are usually slightly oversized relative to current demand in order to account for future increases in demand. However, this can be a costly approach, particularly for PV systems. PV pump output can be increased by adding modules to the system, up to the power limit of the motor. Once installed, wind pumps have little flexibility in meeting increased demand, so it is important to estimate growth in demand as closely as possible before sizing a wind system. An example of how to estimate demand follows.

Example 1: Determining Demand

A village has 300 residents, but during the summer, 50 students return from a nearby boarding school, increasing the population to 350. The animal population is 50 chickens and 75 goats. The population growth of people and animals is estimated to be 4 percent per year. The design period is 10 years. It is assumed that per capita consumption will not increase, so the third term in the formula above equals 1. How is demand determined?

The greatest demand will occur in summer, when the population is 350. Per capita consumption is assumed to be 20 LPD for people, 5 for goats, and 0.2 for chickens. Thus, present demand is

$$(350 \times 20) + (75 \times 5) + (50 \times 0.2) = 7{,}385 \text{ LPD}$$

From the formula, the demand in 10 years will be:

$$7{,}385 \times (1 + .04)^{(10-1)} = 10{,}511 \text{ LPD (or 42 percent more than } D_p)$$

2.2 Resource Characteristics

While the number of water users and their individual consumption needs are used to calculate demand, actual demand can be constrained by the available water supply. In most cases, if you are choosing a pumping system for a given site, the water source is already known. The source may be surface water (e.g., rivers, lakes, and man-made or natural reservoirs) or groundwater (boreholes, dug wells, and springs). To determine what type of pump(s) can be used and the maximum demand that can be met, you must know certain specific characteristics of the water source:

- the yield of the source in cubic meters per hour or day (m^3/h or m^3/d),
- the static water level in meters,
- the drawdown in meters (the drop in water level during pumping), and
- the quality of the water.

For pump selection, the most important characteristics are yield, static water level, and drawdown. The energy needed to pump water is directly proportional to the total pumping head (explained below) and flow rate. The pumping head depends partly upon the static water level and drawdown. The pumping rate can be no greater than the maximum sustainable yield of the water source, which is the maximum amount of water that can be pumped without significantly depleting the source (see especially Driscoll et al. 1986 for more information). Finally, the choice of equipment may also depend on whether or not the source has significant water quality problems. For wells, information about yield, level, and drawdown should be available from well-completion certificates or test-pumping logs. Yield can limit the flow rate for pumping water and, in turn, the number of hours of pumping that are required to meet demand. This may affect equipment selection since some types of equipment are better matched to higher (diesel) or lower (solar) pumping rates.

2.2.1 Flow Rate

Daily water demand can be met in different ways. For example, if the daily water requirement is 100 m^3/day, the entire amount can be pumped in one hour or it can be pumped over the course of 10 hours at the rate of 10 m^3/hour. Pumping the water as quickly as possible saves time, but it is not always possible or advisable. Pumping at too high a rate from a source with limited yield may cause excessive drawdown. This would increase the total pumping head and would require more energy; it could even cause the pump to run dry. If the water source is a year-around river, it is unlikely there would be any problem meeting small to moderate water requirements, except in the case of a drought. However, most wells and springs are incapable of delivering 100 m^3/hour. Thus, a careful assessment of well yield and pumping rates is necessary before specifying the equipment.

For drilled and dug wells, it is important to know the maximum sustainable well yield or maximum rate at which water can be continually pumped. This provides an upper limit for the pumping rate selected during the design process. The well's maximum sustainable yield and drawdown under these conditions are usually determined as part of the test-pumping procedure. Drawdown and, hence, total pumping head will be less when the pumping rate is less, and the likely drawdown for lower pumping rates can be estimated.

For a given water demand and constant flow rate (such as a diesel pump would deliver), the design pumping rate is determined by taking the daily water requirement in m^3/day and dividing by the number of hours of pump operation per day to get m^3/hour. Your choice of technology is dependent in part upon the required pumping rate. This pumping rate must meet the demand for water, but it must not exceed the source's sustainable pumping rate. If it does, you must either increase the number of hours per day of pump operation, decrease water demand, or develop a new water source.

In addition to the maximum sustainable yield for a single well, you should also consider the sustainable yield of the aquifer catchment area in which your

system(s) is to be located. For example, in some developing countries (Bangladesh and Yemen are good examples), the exceedingly large number of tubewells drilled in some areas has resulted in a drastic lowering of the regional groundwater table. This happens when the total extraction of water from all of the tubewells is greater than the maximum sustainable yield of the aquifer. If historical data on groundwater replenishment rates are available, estimate what effect the pumping rate you propose (and the number of pumps you are planning to install) will have on your water table.

2.2.2 Total Pumping Head

"Head" is a term used for several related quantities that together comprise the effective pressure against which a pump lifts water. Head, usually given in meters or feet of water, is a combination of the following components:

- elevation (static water level plus static discharge head plus drawdown),
- pipe friction,
- velocity, and
- pressure head.

These components are illustrated in Figure 2 and explained in greater detail below. Values for each component must be measured or calculated to determine total pumping head.

Elevation head is usually divided into three parts:

- <u>static water level</u>--the vertical distance from the water level to the surface of the ground;
- <u>drawdown</u>--the distance from the static water level to the lowered level when the pump is operating; and
- <u>static discharge head</u>--the vertical distance from the pump outlet to the highest point in the system, usually the storage tank if there is one.

<u>Elevation</u>

Static water level can easily be measured during site visits or obtained from accurate well-completion records.

Figure 2. Components of Total Pumping Head

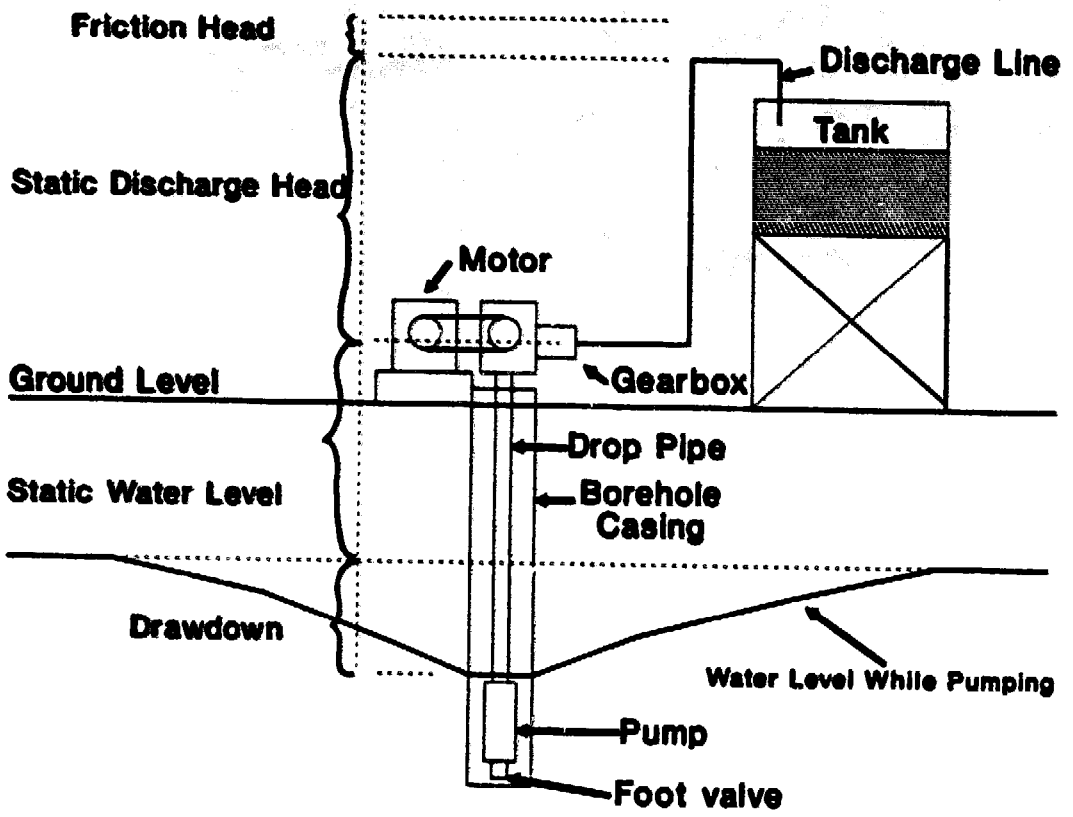

For the size of pumps commonly used for village water supplies, the drawdown is essentially zero for most rivers and streams. With boreholes (wells), the drawdown depends on aquifer performance, well design and development, and the pumping rate. Drawdown information is available from proper test-pumping records and is often given in terms of the specific capacity of the well (measured in m^3/d/meter of drawdown). Drawdown usually increases as the pumping rate increases.

Unfortunately, well drawdown figures are often not readily available. In such cases, test-pumping should be done on the water source before designing the system. If possible, do this during or shortly after the driest part of the year, when yield will likely be at its lowest. This will minimize the possibility of overestimating the yield of your water source. If this is not possible, the drawdown will have to be estimated, preferably with assistance from hydro-geologists familiar with your area. The subsequent selection of pumping equipment should reflect these uncertain conditions (see Chapter 4 on available equipment).

Static discharge head is a function of the system design and local topography. This component of elevation head can be measured during site visits or computed from site surveys and plans.

Pipe Friction

Pipe friction loss depends on the flow rate and the length, diameter, and condition of the pipe used. Friction losses can be calculated using formulas, but they can be determined more easily using graphs or tables. To use such a graph, you must know the type of pipe being used (galvanized iron, smooth plastic, etc.), since friction losses vary with type of pipe. For example, the graphs in Figure 3 can be used to estimate the head loss for galvanized iron or plastic pipes, according to the following example. Additional friction loss tables and figures for a wider range of pipe types, diameters, and minor losses for pipe bends and fittings are given in Appendix B.

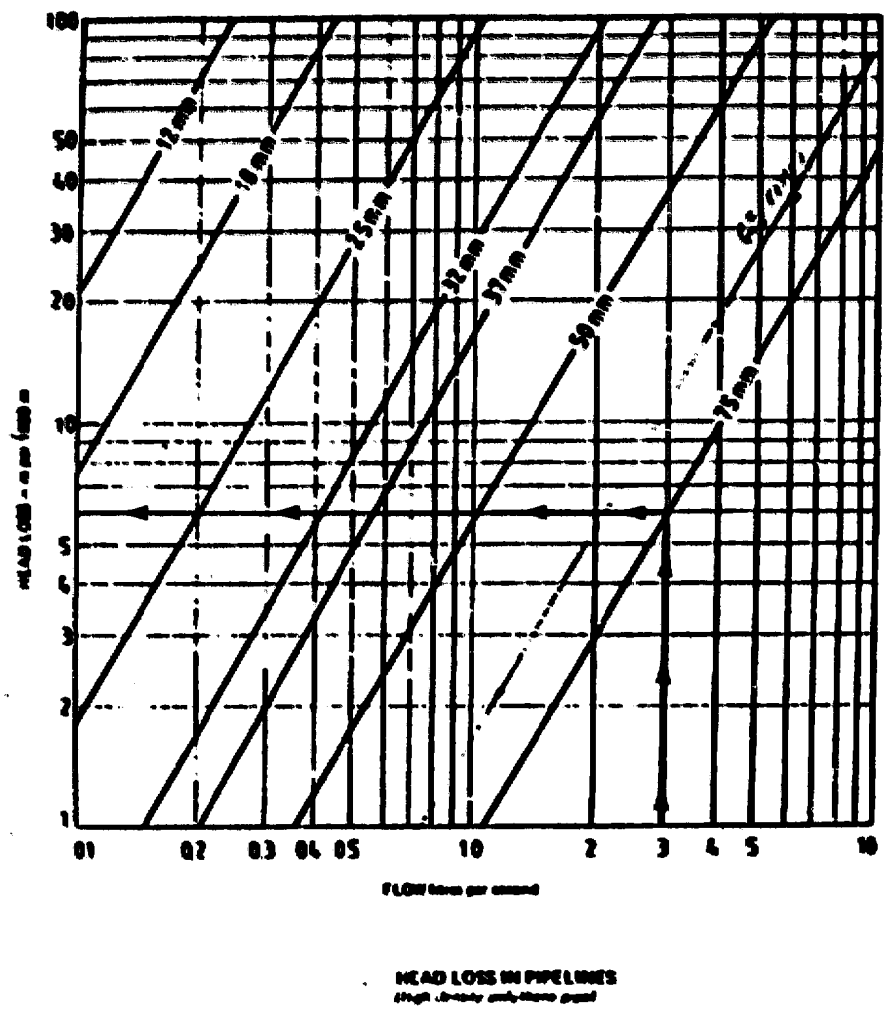

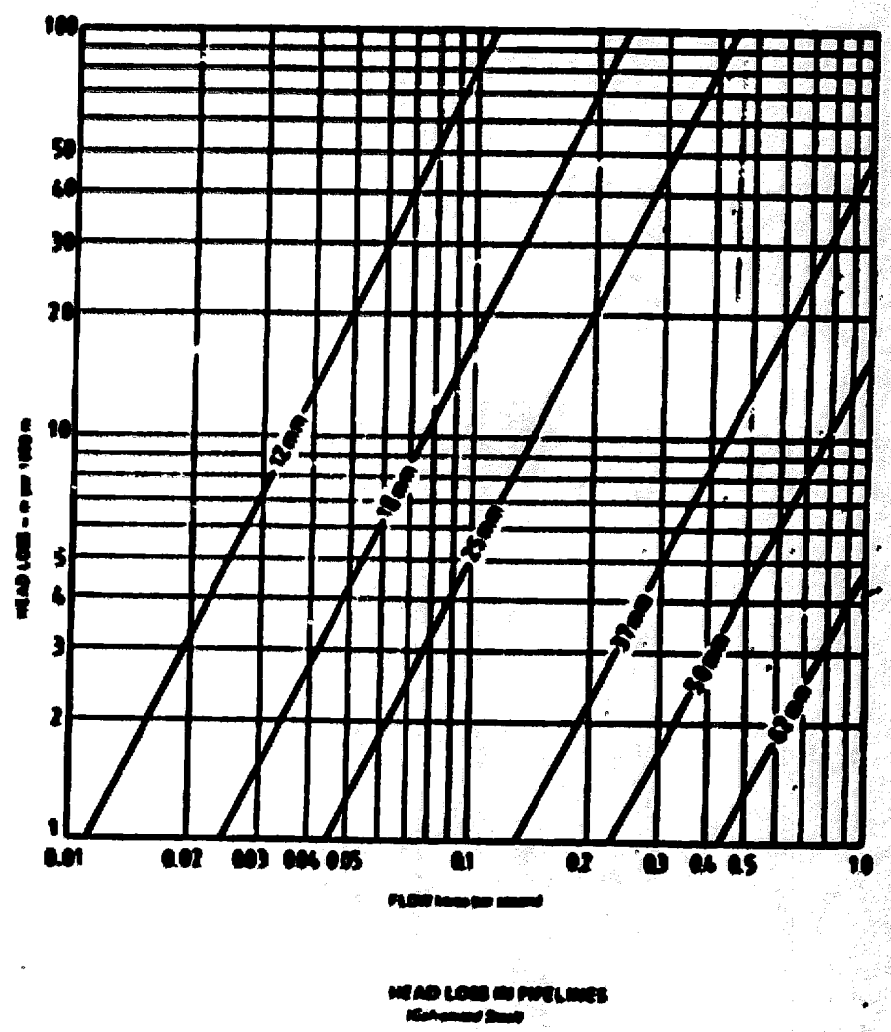

Figure 3. Pipe Friction Loss Charts

Example 2: Pipe Friction Loss

Find the friction loss in meters of head for a smooth plastic pipe that is 250 meters long and 75 millimeters in diameter. Water is being pumped at a rate of 3 liters per second. The pipe has two bends of 90 degrees and two open gate valves.

The left side of Figure 3 for plastic pipe shows about 6 meters of head loss due to friction per 1,000 meters of pipe length (following the arrows on the graph). Since the pipe is 250 meters long, this value must be divided by 4, giving a friction head loss of 1.5 meters. The equivalent length of the bends is 2.3 x 2 = 4.6 meters and that for the gate valves is 1.2 x 2 = 2.4 meters. Since this total additional length (7 meters) is only a small fraction of the total 250 meter pipe length, the bends and valves produce negligible head loss. So, the total friction loss is still 1.5 meters.

As a second example using the same procedure, friction losses for the same pipe length and flow rate, but 50 millimeters in diameter, would be 37 divided by 4 or 9.25 meters. Again, the bends and valves add a negligible amount of head loss. Friction losses for this pipe are six times as great as for the larger diameter pipe.

The preceding example shows the importance of using pipe that is the right size to save on energy costs by minimizing head losses. One common rule of thumb is that pipes should be sized so that friction losses are less than 10 percent of the total head. Another common rule of thumb is that pipes should be sized so that water velocity in the pipes never exceeds 1 m/s. For the example above, for the 75-millimeter pipe, the water velocity (calculated by dividing the flow rate by the cross-sectional area) is 0.97 m/s, which fits the criterion. For the 50-millimeter pipe, it is 2.3 m/s, which does not fit the criterion.

Velocity

Velocity head is a measure of the energy lost when a moving liquid slows down, such as when it flows from a pipe into a storage tank. For purposes of system design, it is measured as pressure loss in meters of water, calculated using the formula:

$$\text{velocity head (in meters)} = \frac{v^2\ (m/s)}{2 \times 9.81\ (m/s^2)}$$

where v is the average velocity of water in the pipe and 9.81 is a constant. For most small-scale pumping applications, the velocity head is small and can be safely ignored.

Example 3: Velocity Head

Determine the velocity head if water is being pumped at a rate of 10 m^3/h through a 100-millimeter pipe at sea level under normal atmospheric conditions.

First, find the velocity v. The cross-sectional area of a 100-millimeter pipe is .031 m^2. This figure can be obtained from standard pipe size tables, such as those given in Driscoll et al. 1986, or by calculating the area from the formula:

$$A = \text{pi} \times (\text{diameter})^2 / 4 = 3.14 \times (90.1 \times 10^{-3}\text{m})^2 / 4 = .0064\ m^2$$

The velocity equals the flow rate divided by the cross-sectional area, so the velocity in the pipe is 10/.0064, which equals 1568 m/h or about 0.44 m/s. Using this result in the formula above gives:

$$\text{velocity head (in meters)} = \frac{(0.44\ m/s)^2}{2 \times 9.81\ (m/s^2)} = 0.01\ m$$

a velocity head which is negligible in most circumstances.

Pressure Head

Pressure head is the additional pressure required to pump water into a pressurized tank. This pressure can be given as additional meters or feet of head using the following conversion:

1 psi = 6.89 kPA = 2.306 feet of water = .703 meters of water.

(psi = pounds per square inch)

It will not often be a factor in water supply systems in developing countries, since pressurized systems are seldom used in rural areas.

Using the approach described here, total pumping head (needed later to determine pumping energy requirements) can be calculated by adding together the values for each of its components.

2.3 Water Quality

Water quality may be an important parameter in pump selection and determining whether the source is suitable for human or animal consumption. Physical parameters included in water-quality testing that are important for equipment selection are

- hardness,
- electrical conductance (or specific conductivity),
- hydrogen-ion concentration or pH, and
- salinity or total dissolved solids (TDS).

Hardness is a measure of the mineral content of water, primarily magnesium and calcium. Hardness in the range of 100 milligrams per liter (mg/l) is considered acceptable, although up to 500 mg/l may be acceptable depending on the availability of better sources. As hardness increases, encrustation and scaling on pipes and pump components is more likely. Over time, this increases pipe friction and decreases the diameter of the pipe, thus affecting the pumping rate and increasing the power requirements. Scale deposition can also decrease well efficiency and may even lead to the loss of a well in extreme cases.

High conductance (above 750 micromhos), low pH (acidic water below 6.5), and/or high TDS levels (above 500 mg/l) indicate aggressively corrosive water. Acidic water, even with low conductance or low TDS, is also corrosive. Otherwise acceptable water with high TDS levels can degrade equipment simply by an excessive wear, as particles moving over the pump's moving parts wear them down.

Corrosion can be chemical or electrochemical. The former occurs when a contaminant exists in sufficient concentration to cause corrosion over a broad area (e.g., a pump casing). The use of bronze and/or stainless-steel components will likely reduce chemical corrosion. Electrochemical or galvanic corrosion is caused by an electrical current flowing between two different metals in contact. To reduce the risk of galvanic corrosion, dissimilar metals should not be directly joined together. Instead, a nonconductive gasket should be used.

2.4 Demand and Supply Profiles

A demand profile refers to water demand over time, usually a year, although the concept can be applied over the course of a day. Water demand varies depending on need as well as supply. Humans and animals tend to drink more water in hot dry seasons. If water is available, consumption will increase at such times. (If surface water is available, the demand for pumped water for animals will decrease.) Sometimes during dry seasons, local water supplies simply dry up, so consumption decreases at some water points and greatly increases at those where water is still available. During dry seasons, borehole yields typically drop in regions where aquifers have low recharge rates. Nomadic people can also

have significant effects on water demand, creating large "spikes" or short periods of very high demand in the profile. Water demand is not necessarily constant from year to year, due to population growth, human and animal migration, changes in size of livestock herds, droughts, and a variety of other factors.

The supply profile depends on the type of pump. For example, a diesel pump normally operates at a constant rate and can deliver water at a moment's notice. The same is true of handpumps, although on a much smaller scale. Solar or wind pumps can deliver water only when the energy resource is available--when the sun is shining or wind is blowing above the windmill's start-up wind speed. This has obvious impacts on system design. For instance, suppose you want to install a solar pump, but system users want water early in the morning. To meet that portion of the daily demand profile, a storage tank is needed to reserve part of the previous day's output.

As a general rule of thumb, wind and solar pumps should be designed with three to four days of storage to account for the fact that they cannot deliver water on demand. While variations in demand can be managed by designing storage into a pumping system, usually this helps meet only short-term water needs (several days at most), not seasonal variations in demand. Storage tanks or basins typically hold an amount equal to a normal village's daily water demand, say 20 cubic meters. It is not usually economical to store enough water for five days given the cost of storage, particularly when using elevated storage tanks. However, if a site is so remote that it takes five or more days to fix breakdowns, the cost of additional storage must be compared to the cost of trucking in water, higher cost preventive maintenance to increase system reliability, backup systems, or other measures to insure water availability during system outages.

Energy resources, which are discussed in detail in Chapter 3, can also vary seasonally. For example, diesel fuel is often unavailable in remote areas during rainy seasons, when roads become impassable. Renewable energy pumping systems, such as wind and solar pumps, can deliver water only when adequate energy resources are available, not during calm or cloudy periods. Other seasonally dependent factors can affect system performance--for instance, upstream flooding could raise sediment levels in a river high enough that pumps become clogged. The possibility of annual and seasonal variations in water demand and supply should be taken into account when designing pumps. With adequate safety measures, demand can usually be met. Remember that for sites where demand variability is high, no reasonably designed system can <u>always</u> be expected to meet demand.

2.5 Water Availability

Water availability is the percentage of time water is available to users during a specified period. This figure is never 100 percent, since every system eventually breaks down. Availability can almost always be increased, but it can be increasingly expensive to do so above a certain level. Pumped water supplies may be unavailable for three reasons--the mechanical system fails (e.g., the motor stops), the source becomes inaccessible (the water table drops below the

pump intake), or the energy resource fails (the wind stops, the diesel fuel runs out, or the sun is covered with clouds). A good design practice for water pumping systems is to focus on ensuring water availability, which depends on

- equipment reliability,
- variations in water and energy resources, and
- the availability of backup equipment and water sources in the event of a system or source failure.

The reliability of different kinds of pumping equipment and system designs can vary considerably, but reliability usually depends on cost and maintenance. Often, better equipment costs more, and there are trade-offs between buying a system that has a high capital cost and low O&M requirements versus low-cost equipment that needs a high level of O&M. Users may have to make compromises if they lack adequate funds for high-quality equipment. However, the most important strategy for preventing problems and minimizing costs is to know the limitations of the water source before you choose a system.

2.5.1 Equipment Reliability

Reliability is usually measured as the mean time between system failures, given in hours of operation. This means that on the average, a component (e.g., pump, engine, or belt), <u>if properly maintained</u>, can be expected to fail after the mean time between failures has elapsed. Better (and often more expensive) components or systems have longer mean times between failures. Usually, it is very difficult to find this information for different component options, so system designers must rely on recommendations when choosing different types or brands of equipment. However, system failure does not depend simply on the quality of the parts used. Reliability is also very dependent upon other factors such as the ready availability of spare parts and people with technical skills to maintain and repair equipment.

System designers usually try to pick components with the highest efficiency that they can afford (see Section 4.1 for an explanation of efficiency). Sometimes new equipment with purportedly high efficiency is used in a system. Only later do users discover that the new part functions well for a short time but does not have the expected reliability and fails prematurely. In general, use proven components that you and local technicians are familiar with or that have proven themselves through long and steady use elsewhere, rather than buying the latest innovation. Let someone else experiment with new or unfamiliar units. In the long run, proven reliability is much more important in reducing the cost of water delivery than a small percentage difference in operating efficiency.

2.5.2 Designing for Reliability

Careful design can greatly increase water availability. For example, the level and the quality of the water in rivers, springs, and wells fluctuate seasonally and annually. System design should take expected and unexpected changes in the water source into consideration. Strategies for dealing with such changes include

- mounting borehole pumps well below the lowest expected water level and river pumps on anchored floats with flexible discharge hoses and using screens to prevent clogging and subsequent damage to pumps and motors;
- using safety devices—circuit breakers on motors to prevent overloading, overheating cutoffs to prevent seizing in pumps or motors when water levels drop below the intake, and pressure-relief valves in discharge lines; and
- designing adequate storage to meet demand during short-term system outages, expected or unexpected—remember, eventually every system breaks down.

There are other types of approaches which can increase water availability. In most common design procedures, components such as engines and pumps are typically oversized to a certain extent. Since pumps require more power to start them turning than to keep them going, motors have to supply higher starting than running torque (see Chapter 5 on diesel engines). For electric motors, this means more amps must be delivered to the motor. Thus, motors and power supplies (e.g., PV arrays or wind-pump rotors) must be sized large enough so they can provide as much as four times the normal running torque to start the system.

Components must also be oversized to account for gradual degradation of performance and growth in demand over the system's expected lifetime. For example, pipes get clogged due to scaling over time, thereby reducing the diameter through which water can flow. This increases the total pumping head and, for a given power input, reduces the flow rate through the pipe. Similarly, as electrical components wear, voltage losses occur that reduce the output of electric motors. As diesel engines become carbonized with use, they produce less shaft power to drive pump transmissions. These and other types of system performance losses mean you must begin with a slightly larger power source if you expect a certain amount of water delivery five years after the system is installed. Guidelines for component sizing that address these problems are given in Chapters 5 through 8.

The need for preventive maintenance cannot be overemphasized. Pumps run better—i.e., more efficiently and at a lower cost per unit of water—when they are regularly maintained. Yet, some user groups may not have adequate incentives to take care of their equipment. While it may seem reasonable to assume that

users will take care of pumping equipment, regular maintenance will not necessarily be carried out. These issues are discussed further in Chapter 9.

2.5.3 Backup Systems

Every pumping system will eventually fail. System designers must consider how users will deal with such failures. You must determine how long an outage will be acceptable to users, remembering that no system gives water 100 percent of the time. Unless the situation is very unusual, the right spare parts or people with appropriate technical skills will not be on hand at the site to fix a system immediately after a breakdown occurs. Thus, an outage is likely to last several days at least.

System design should take into account ways of dealing with maintenance problems. First, you need to have some idea of what problems will be caused even by brief outages. Do people typically store the drinking water needed for several days at their houses, or do they draw water several times a day because they have no off-site storage? If there is little or no off-site storage, a community storage tank should be big enough to store water for at least one day.

Second, backup systems can be used whenever the primary system fails or is shut down for maintenance. While this almost guarantees that you will always have water (so long as your energy source is sufficient), it also means that the system will be more expensive. Further, people often do not place a high priority on maintaining backup systems, and a backup system will not do much good if it does not work when you need it to. Some pumping systems can easily be designed to incorporate backup engines or energy sources. For example, suppose a PV system with a vertical-turbine pump is driven by a pulley on top of the pump shaft. Normally, the pulley is driven by a belt connected to the electric motor. A backup diesel engine could be installed by mounting it so that if the solar system fails, due to equipment failure or simply to a lack of sun, the diesel engine could be used to meet demand until the PV system is working again. Similarly, handpumps could serve as backups for diesel, wind, or solar pumping systems, and diesels could back up wind pumps.

A third solution is to have more than one water supply system (pump and water source). If one system fails or needs to be taken out of service for any reason, the second will still be able to supply some minimum level of service. Of course, this requires the additional expense of digging a second borehole and installing and maintaining a second pumping system.

Any suggested solution for handling system failure must be weighed against the cost of an unexpected outage--if water is unavailable for a certain amount of time, what are the consequences:

- Can enough water be lifted by hand to supply at least drinking water until the pump is fixed?

- Can enough water be trucked in or transported by other means (e.g., donkey carts)? Are the roads passable, what would this cost, and who would pay for it?

- Would people have to travel to or temporarily move nearer another water source until the system is repaired?

- When water is being used for agricultural purposes, what happens if the crop fails?

The costs of the options discussed above or similar emergency-relief measures must be weighed against the cost of a backup system, additional storage, or developing other water sources.

Chapter 3

ENERGY DEMAND AND RESOURCES

An important aspect of choosing pumping equipment is determining the energy required to pump water and assessing what energy sources could be utilized. This chapter offers a method for calculating energy demand and discusses the characteristics and limitations of a variety of energy resources.

3.1 Hydraulic Energy Demand

Energy is the capacity to perform work. In the case of moving or lifting water, hydraulic energy is the capacity to move a specified amount of water a certain distance. Energy is expressed in joules, watt-hours, or horsepower-hours. Power is the rate at which work is performed, measured in horsepower (Hp) or watts (W). Both terms are important in determining the appropriate size for pumping equipment.

The hydraulic energy required to lift a certain volume of water is given by the following equation:

$$E_h = (\rho_w \times g \times Q \times H)/(3.6 \times 10^6)$$

where E_h = hydraulic energy in kilowatt-hours (kWh)

ρ_w = density of water (1,000 kg/m^3)

g = gravitational constant (9.81 m/s^2)

Q = volume of water pumped in m^3/day

H = total pumping head in meters

Substituting the given constants (9.81, 1,000, and 3.6), the equation simplifies to

$$E_h = .00273 \times Q \times H$$

E_h is directly proportional to the head and the daily water demand. Thus, strictly in terms of hydraulic energy requirements, pumping 20 m^3/day from a head of 50 meters is the same as pumping 50 m^3/day through 20 meters of head. Taken together, the head and daily water requirement determine the energy demand. However, this convenient simplification does not take into account differences in friction losses when water is pumped through various lengths of pipe.

The hydraulic energy requirement calculated using the above formula is significantly less than the actual energy needed to move water because of inefficiencies in delivery systems (pumps and engines). For example, the energy efficiency of converting

- diesel fuel to pumped water ranges from 5 to 20 percent,
- solar radiation to pumped water is 2 to 4 percent,
- wind energy to pumped water is on the order of 4 to 8 percent, and
- foodstuffs to water pumped by humans is anywhere from 5 to 10 percent.

When comparing different types of pumping systems, these efficiencies alone do not determine the best choice. Other system characteristics--such as cost, ease of maintenance, and capacity--are also important. However, for a specific type of system (e.g., wind pumps), efficiency is an important consideration in choosing between competing wind systems. The <u>most</u> important energy consideration is whether the available resource is sufficient to meet the pumping requirement.

Each component of a mechanical system (e.g., motor, pump, transmission, etc.) has its own efficiency, which is the ratio of the power out to the power in. Electric motor efficiencies are usually about 65-90 percent (higher for larger sizes), and pump efficiencies range between 40-75 percent, depending on how well the pump is matched to its load (i.e., the head and flow). For convenience, we will refer to the combined pump, motor, and transmission (the entire subsystem) efficiency as the "pump efficiency" or "subsystem efficiency". If pumps are normally purchased in an integral unit with the motor (such as a submersible pump), people commonly refer to the combined pump and motor efficiency as the pump or subsystem efficiency. For example, if the motor efficiency is 80 percent, the pump efficiency 70 percent, and the transmission efficiency 75 percent, the subsystem efficiency is

$$0.80 \times 0.70 \times 0.75 = 42 \text{ percent}$$

Example 4: Hydraulic Energy Requirement

A. What is the hydraulic energy required to pump 20 m^3/d through 75 meters of head? From the formula given above

$$E_h \text{ (in kWh)} = .00273 \times 20\ m^3/\text{day} \times 75\ m$$

$$E_h = 4.1\ \text{kWh}$$

B. If the pump (only) efficiency is 60 percent, how much energy must be provided by an engine?

$$E = 4.1\ \text{kWh}/.60 = 6.8\ \text{kWh}$$

C. If water is pumped over a six-hour period, what is the required mechanical power output from the engine?

$$\text{power} = \text{energy/time}$$

$$6.8\ \text{kWh}/6\ \text{hours} = 1.1\ \text{kW}$$

Note that the choice of flow rate (20 m^3 in a six-hour period or 3.3 m^3/hour) does not change the energy requirement, but does determine the power output requirement for the pumping device. Diesel engines and PV modules, in particular, are denominated in power units, the rate at which a device is capable of performing work. This fact is important in later sections on engine selection.

3.2 Energy Resources

Traditional energy resources for delivering water include gravity, hand lifting, and wind energy, in some cases. More recently, petrochemical fuels and electricity have been utilized and, finally, the use of solar energy has become possible. One basic aspect of the pump selection process is evaluating the availability and potential for using different energy resources. Clearly, if water can be delivered by gravity, it is likely to be the most reliable and cost-effective system. However, if the capital cost of a long pipe or channels is high, or water quality is not suitable for the intended use, other systems should be considered. The following sections provide guidelines for determining the resource information needed to make a preliminary evaluation of pumping equipment options.

3.2.1 Hand Lifting and Carrying

Other than gravity flow, lifting and carrying water by hand is the oldest method of moving it from a source to a destination. Many hand-operated delivery systems have been used around the world (see particularly Fraenkel 1986). The major limitations of hand lifting are the sustainable energy output of humans and the relatively small water delivery rate. Hand lifting can include every option from a rope and bucket to modern, high efficiency handpumps. Remember that under certain circumstances, the bucket and rope method of drawing water may be perfectly appropriate for some sites. Do not dismiss the no-pump option before considering it thoroughly.

A human's maximum continuous power output for short periods is about 100 watts (0.1 kW). This cannot be sustained over the course of a day. For an average adult male, the energy output over a day is about 0.2 to 0.25 kWh. Assuming a pump that is 70 percent efficient, this would amount to pumping only 3.2 m^3/day for a head of 20 meters. With multiple pumpers, which would usually be the case, 0.75 to 1.0 kWh could be produced over a day.

These limits severely constrain the amount of water that can be delivered using hand-operated pumps. However, if the energy requirement is small because the water requirement and/or head are very low, and a willing labor force is available, human-powered systems should seriously be considered as a low-cost, low-maintenance option. The main question would be whether or not daily water demand could be met with handpumps.

3.2.2 Petrochemical Fuel and Electrical Energy

Petrochemical energy sources--diesel fuel, gasoline, and kerosene--are widely available in nearly every country in the world (there are, of course, periodic shortages and fuel delivery problems). Nevertheless, it is important to consider their impact on system operating costs, as well as whether or not they are and will continue to be reliably available in the quantities needed to meet daily energy requirements. Since gasoline and kerosene engines are not nearly so common as diesel motors for pumping water and are generally more expensive for most small-scale water pumping needs, they will not be discussed further here.

Fuel availability and costs depend on many factors, including

- supply at the national level;
- reliability of national and regional distribution systems--public and private, formal and nonformal;
- the existence of priority allocation schemes; and
- local variations in demand--an unexpectedly high periodic demand sometimes depletes fuel supplies.

The suitability of electrically operated pumps depends on their proximity to the electricity grid and the reliability of service. Since grid power is uncommon in most rural areas of developing countries, grid-electric pumps will not be considered further here. However, in most cases where reliable grid power is available at a site, electric pumps are the preferred system for technical and cost reasons.

The appropriateness of a diesel, electrical, or any other pumping system must be at least partially determined on the basis of past energy availability, its likely availability in the future, and the degree of system reliability that is required. When considering diesel or electric pumping systems, you should determine whether past problems with availability and fluctuations in fuel costs are great enough to warrant considering other types of systems.

Diesel engines are available in any rated power output range between 2.0 kW and 20 megawatts (MW), so finding equipment with the right capacity is generally not a problem, except for very small outputs--less than 2.0 kW. A full discussion of factors affecting diesel fuel consumption rates and methods for calculating consumption and power output are given in Chapter 5.

3.2.3 Solar Radiation

The performance of a solar pumping system will be proportional to the solar energy falling on the PV array (the set of solar modules that produce electricity). Solar energy or irradiation is measured with a pyranometer, which gives readings in power per unit of horizontal area, watts or joules per square meter per second (W/m^2 or J/m2-sec). These power measurements are integrated over time (usually a day) to give energy in kilowatt-hours or megajoules per square meter per day (kWh/m^2d or MJ/m^2d).

As an example, a good solar radiation day in a semi-arid climate at less than 25 degrees latitude produces about 6 kWh/m^2d or 21.6 MJ/m^2d, since 1 kWh/m^2d equals 3.6 MJ/m^2d. One peak sunlight hour is defined as 1 kWh/m^2h. The literature of some PV pump manufacturers refers to the number of peak sunlight hours as a way of quickly estimating local solar radiation levels. Remember that irradiation can vary considerably over a day, month, or year, depending on local weather conditions and latitude. In addition, annual averages can vary significantly from one year to the next.

Solar and wind pump sizing is based on the concept of design month, which was mentioned in Chapter 2. During that month, the ratio of available energy (monthly average solar irradiation or wind speed) to the hydraulic energy requirement is at its lowest (see example in Section 7.3.2). In general, solar pumping systems should not be considered unless irradiation during the design month is greater than about 5 kWh/m^2d. Again, this guideline is somewhat flexible, depending on site-specific costs and operating constraints. World-wide maps of solar radiation data do exist (see Kenna and Gillett 1985), but the data are not precise enough to be used as the basis for a site-specific system design.

To assess PV pump suitability and performance the following information is needed, at a minimum:

- the average daily solar energy available at the site during each month of the year and
- the average daily temperature for each month (because PV array output decreases as the operating temperature increases).

As is true of wind speed data, solar irradiation data are somewhat dependent on the terrain and microclimate. However, solar irradiation is generally not so variable as wind speeds, nor is the amount of available solar energy so sensitive to the amount of irradiation as wind energy is to wind speed. Hence the effects of differences at the site from recorded data are not as pronounced for solar as for wind-energy systems. Thus, solar irradiation data from pyranometer sites that are as far away as several hundred kilometers may be acceptable. This is fortunate as the worldwide network of stations measuring solar irradiation is much more limited than that for wind measurements. Variations in the amount of irradiation depend on how different the microclimate at the proposed pumping location is from the recording site.

The electrical energy produced by a PV array depends not only on the operating temperature and incident solar irradiation, but also on the size of the array and the angle at which it is tilted up from the ground. The more nearly perpendicular the array is relative to the sun's rays, the more electrical energy will be produced. Details on solar pump sizing, based on the energy-resource information discussed here, are provided in Chapter 6.

3.2.4 Wind Regimes

The power available in wind is given by the following formula:

$$P_w = 0.5 \times \rho_A \times A \times v_A^3$$

where P_w = power available in the wind in watts

ρ_A = air density in kg/m^3

A = cross-sectional area of wind being intercepted (i.e., area covered by windmill rotor in m^2)

v_A = air velocity in meters per second (m/s)

Note that the power in the wind is proportional to the <u>cube</u> of the wind speed. This means that <u>doubling</u> the wind speed increases the power available by a factor of <u>eight</u>. It also means that small errors in estimating windspeed can result in large errors in estimating available power in the wind. To evaluate the potential use of wind as an energy source, measurements or estimates must

be made of local wind speeds over the course of a year. The energy output of a wind pump is directly proportional to power available in the wind over time. The water output for a particular windmill is proportional to the energy available, which depends on wind speed and rotor diameter, and inversely proportional to the total head.

The wind pattern or regime can be approximately characterized by an average speed (measured in m/s or miles per hour [mph] at a given height) over a given period, usually a month. Generally, windmills should not be considered if a site's average wind speed during the month with lowest speeds is less than 2.5 m/s or the total pumping head is over 60 meters. However, a combination of many site and economic factors finally determines the lowest average wind speed at which windmills are a practical alternative.

Since most people will not want to measure the wind at the proposed site for a year before deciding whether to purchase a system, windspeed data are occasionally available for nearby sites as hourly averages, but more often as daily or monthly averages. To assess the location's suitability for windmills and to estimate performance, monthly average wind speeds near the site are required for a period of at least a year. If available, recorded data for longer periods are very useful in assessing whether that year of data is an accurate representation of wind speeds at the site. The more detailed the windspeed data used in system design, the more accurately you can predict the performance of particular windmills.

At a minimum the following information is needed about the wind regime to assess windmill performance:

- monthly average wind speeds over the course of one year (used to determine the months with low wind speeds);
- the location and height of the recording instruments used, since wind speed varies with height; and
- a description of the terrain where the wind speeds were recorded, and the topography between that location and the proposed pump site (trees, hills, and other features can dramatically affect wind speeds).

In addition to wind data, other important information that must be collected about the proposed pump site includes

- the site's elevation above sea level (this affects air density and, hence, the amount of power in the wind) and
- a description of the terrain around the pump site.

Depending on the reliability of the data sources, the completeness and accuracy of the windspeed information, and the conditions under which it is collected, corrections may need to be applied properly to estimate the wind at the proposed site. These include

- a height correction if the windmill will be located at a different height than where the data were recorded;
- a correction if the data-collection period is short; and
- a correction for local terrain conditions.

Taken together, such corrections can affect local windspeed estimates by as much as 30 to 40 percent. A discussion of corrections and the calculations required to choose a windmill and predict its performance is provided in Chapter 7.

3.3 Information on Energy Resources

It is important that information on energy resources be as complete as possible. In most cases, this means gathering data locally. Site visits are highly recommended for recording important resource parameters and assessing exposure and terrain conditions relevant to possible wind or solar energy use. In addition to data collection at the site, other sources of information on energy resources include

- the national department of meteorological services;
- airports and departments of civil aviation;
- university or polytechnic science departments;
- the country's department of agriculture; and
- agencies responsible for energy, mines, and/or dams.

Additional sources of information concerning the energy resources discussed in this section are briefly described in the annotated bibliography (Appendix A). Local estimates of variability in wind or solar resources may also be helpful, especially if little or no other data are available. Talk with local people about their perceptions of area weather conditions. Their perceptions may be particularly useful in assessing daily variations in resource levels, such as periods of calm or cloud cover. While such information may not always be accurate, remember that most villagers have been living in the same place for a long time and, thus, may be able to verify data from distant weather stations.

Chapter 4

AVAILABLE EQUIPMENT—PUMPS AND DRIVERS

The pump is only one piece of equipment to be chosen as part of a complete pumping system. Pumps are selected based on the required flow rate and head. The engine is then chosen to match the pump's power requirements. This chapter discusses the basic operating characteristics of pumps (i.e., pump curves), the different kinds of water pumps available, and selecting the pump with suitable operating characteristics to meet a particular need. As you might expect, certain types of pumps are appropriate for certain applications—specific head, flow rate, and water quality conditions. The advantages and disadvantages of various kinds of pumps and their suitability for use with different types of engines (referred to more generally as drivers or prime movers) are also covered in this chapter. The final section of this chapter describes the advantages, disadvantages, and most appropriate applications for the four types of pump drivers covered in this manual—diesel, solar, wind, and human power.

4.1 Pump Characteristics

The most important technical characteristic for predicting pump performance is the pump curve. Pump curves (two examples of which are shown in Figure 4) depict a pump's operating range in terms of total head, flow rate, and efficiency. While each pump model has a unique pump curve, different types of pumps have characteristic curves. Figure 4a shows typical pump curves for a vertical turbine pump and Figure 4b for a positive displacement pump operating at a variety of different speeds (note that the axes are reversed in the two figures). These pump performance curves also include power consumption and efficiency curves. Efficiency curves can be used to refine system design by indicating the pump that operates most efficiently for your system's total head. If efficiency curves are not available, you can calculate them given the pumping head, flow rate, and power requirement, using the energy requirement calculation presented in the previous section.

The efficiency of the pumping system and its components can have a considerable effect on recurrent costs. A system with lower efficiency consumes more energy pumping a given amount of water than a similar system with higher efficiency. However, there are often trade-offs between higher efficiency and lower capital costs. Efficiency is a function of each system component (e.g., pump, engine, and transmission) and how well the system was designed to match the physical constraints of the water source. This manual (particularly Chapters 5 through 8) includes detailed discussions of the concept of efficiency, its role in system design, and how to reduce costs by carefully integrating all components of a pumping system.

Figure 4. Pump Performance Curves

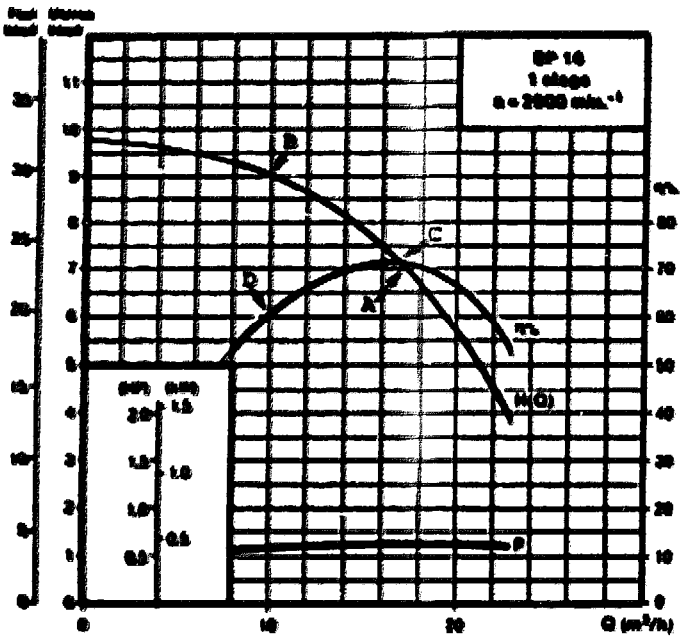

η% = hydraulic efficiency
H(Q) = flowrate
P = power

4a Centrifugal (Grundfos) Vertical Turbine Pump

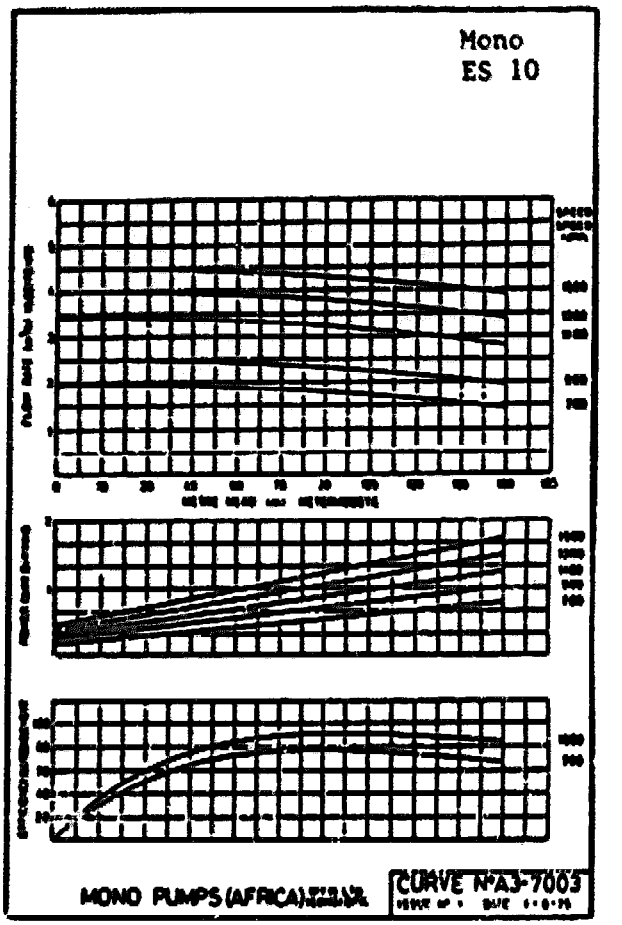

4b Positive Displacement Rotary (Mono Pumps)

To determine the required flow rate and head, you must know the characteristics of your water source, as discussed in Chapter 2. Generally, it is recommended that the average flow rate, in cubic meters per hour (m^3/h) or liters per second (l/s), should be no more than about 70 percent of the maximum sustainable yield of the well or other water source. This will help minimize the possibility of over-pumping the source and will reduce excessive drawdown, thus decreasing the head and energy requirement. Below 70 percent of the well's yield, the flow rate is determined by the water requirement in cubic meters per day (m^3/d) and number of hours you want to operate the system.

The flow rate for diesel pumps is essentially constant because of the engine's constant operating speed. In most cases, you would simply choose the flow rate

(below the 70 percent limit) needed to meet your water requirement if the pump is run six to eight hours per day. Flow rates for handpumps generally do not approach the limit on yield of the water source, but are dependent on the speed at which the pump is manually operated. Because of the cubic relationship between flow rate and wind speed, pumping rates for windmills can be very high during gusts. As a general rule, do not design the output of a wind system to be more than one-third of the source's maximum daily sustainable yield. For example, if the source yield is 3 m^3/h (or 24 x 3 = 72 m^3/d), a windmill should be sized to pump no more than 1/3 of the daily 72 m^3 yield, or 24 m^3/d.

For solar pumping systems without batteries, output varies over the day, with the maximum generally occurring around noon when the sun is highest in the sky. The average daily flow rate (average daily output divided by number of hours of operation) should be no more than about 70 percent of the water source's maximum sustainable yield. For both the solar and wind cases, using these design limits will help prevent over-pumping of the water source (and consequently large drawdown) during periods when the energy resource is strong.

Example 5: Pump Performance at a Given Head

What is the flow rate of the pump in Figure 4a when the total system head is 7 meters? What would it be if the head were increased to 9 meters? What are its efficiency and power requirements?

A. A pump's operating or design point is the value of the point on the pump curve for total system head when the pump is running. From Figure 4a, the operating point (Point A on the graph) of the BP-16 pump is 17 m^3/h at a head of 7 meters.

B. When pumping head is increased (by pumping to a tank, for example), the volume of water output decreases, since it takes more energy to pump to the additional height of the storage tank. Again from Figure 4a, if a ground tank added 2 meters to total system head (making it 9 meters), the pump output would be reduced to about 10 m^3/h (Point B on the graph).

C. As stated above, at 7 meters head the pump delivers 17 m^3/h. Read the value of the efficiency curve at that flow rate to get about 71 percent (reading off the right side scale of the graph to Point C). At 9 meters head and 10 m^3/h, it is only 60 percent efficient (Point D). In both cases, power consumption (shown in the bottom curve) is just below 0.5 kW.

For electric-submersible pump sets, where the pump and its motor are integrated into one unit, pump performance graphs often show multiple head and flow curves and efficiencies for different motor voltages (see the solar pump curves in Figure 5), or for different motors with regular alternating current (AC) submersibles. For PV pumps, an additional parameter that specifies system performance is the level of solar radiation in the plane of the array. For a radiation level, a point on the curve indicates how much water the pump will deliver for a given head. An example of these curves is given in Figure 6.

Various types of pumps have performance curves with very different shapes. Figure 7 shows typical curves for centrifugal and reciprocating pumps. Understanding how these curves apply to a particular situation will help you to choose an appropriate type of pump. For example, if a well has a water level that is seasonally variable (i.e., it depends on rainwater for recharge), there are advantages to choosing a reciprocating over a centrifugal pump. If the centrifugal pump operates at the middle (most efficient) point of its performance curve during the wet season, when the water level drops off in dry months, the total pumping head will increase, thus reducing efficiency and output. However, output for a reciprocating pump is nearly independent of the head. If the water level drops, the system will continue to pump nearly the same amount (as long as the water does not drop below the level of the pump), but at a higher power consumption than if the water level were constant.

4.2 Advantages and Disadvantages of Different Pumps

Many types of pumps are available, but seven are commonly used in diesel, solar, wind, and hand-pumping systems. They are listed below, along with a brief description of their typical use, advantages, and disadvantages. Illustrations of common designs for these pump types are shown in Figure 8. The comments here concern commonly used, commercially available, small-scale pumps (i.e., less than 10 kW). The first three are all centrifugal pumps--they all have a low starting torque and their output and efficiency are very dependent on the operating head.

- **Self-Priming Centrifugal**

  Use: surface-mounted motor and pump for high-volume, low-head applications.

  Advantages: ease of installation, access, and repair, and a low starting torque.

  Disadvantages: limited 5-meter suction head, relatively inefficient compared to centrifugals that have flooded inlets, such as submersible and shaft-driven units.

- **Submersible Centrifugal**

  Use: down-hole, high-volume, high-head, integrated motor/pump unit.

Figure 5. Pump Performance Curves: Submersible Centrifugal Pump at Variable Voltage

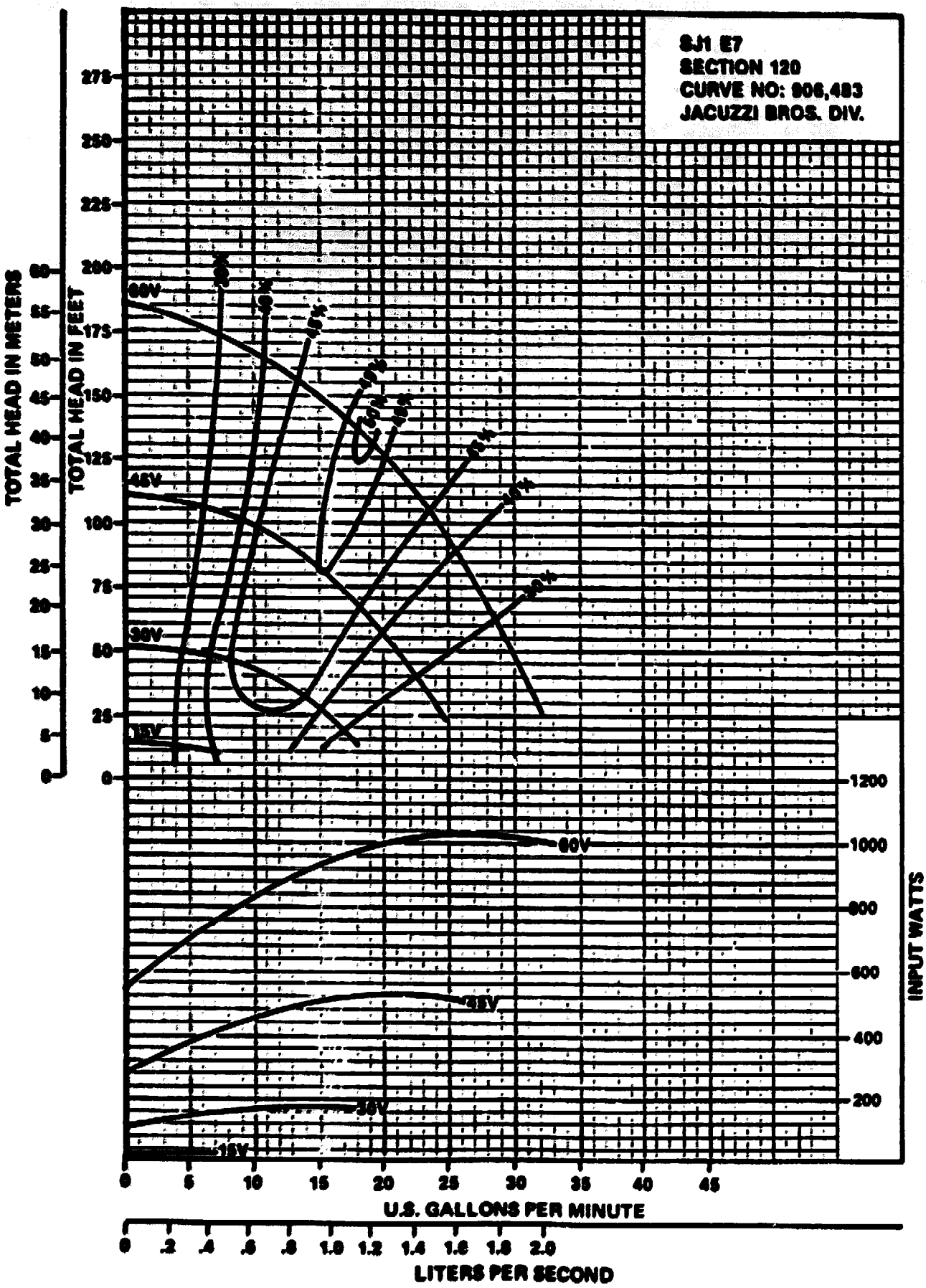

(Jacuzzi Manufacturing Literature)

Figure 6. Solar Pump Performance at Variable Irradiation Levels

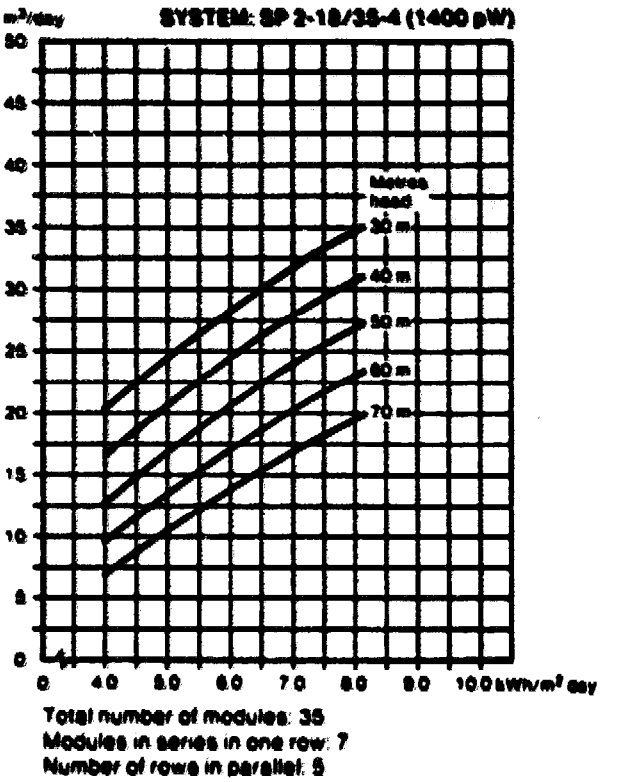

(Grundfos)

Figure 7. Centrifugal vs. Reciprocating Pump Pressure and Capacity Characteristics

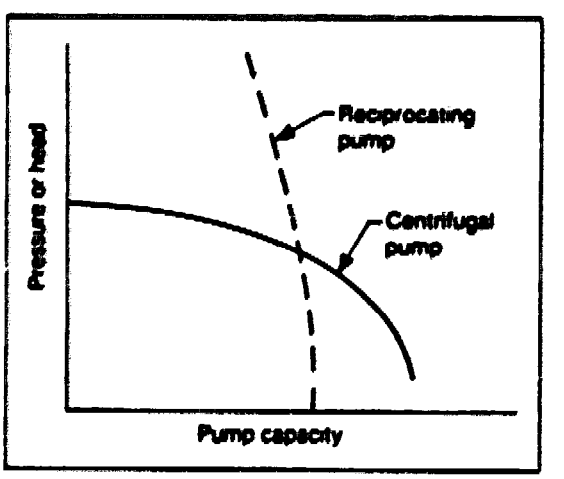

(Driscoll 1986)

Figure 8. Types of Commonly Used Pumps

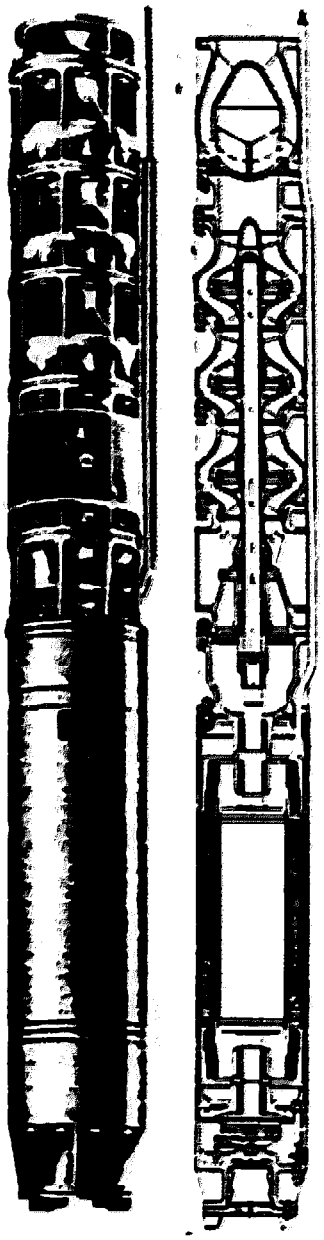

Submersible Centrifugal
(Stewart 1982)

Shaft-Driven Centrifugal
(Grundfos)

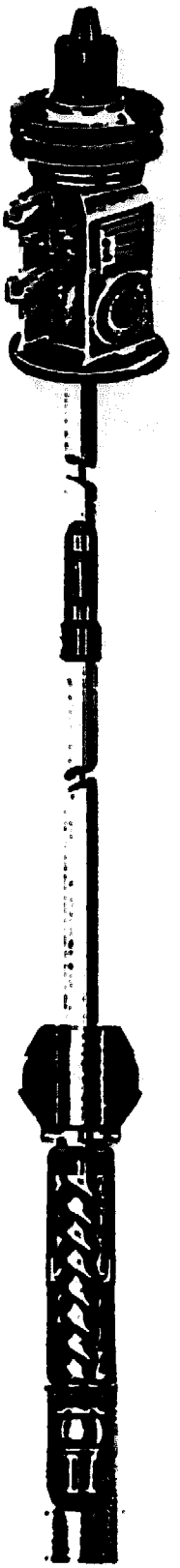

Positive
Displacement Rotary
(Mono Pump)

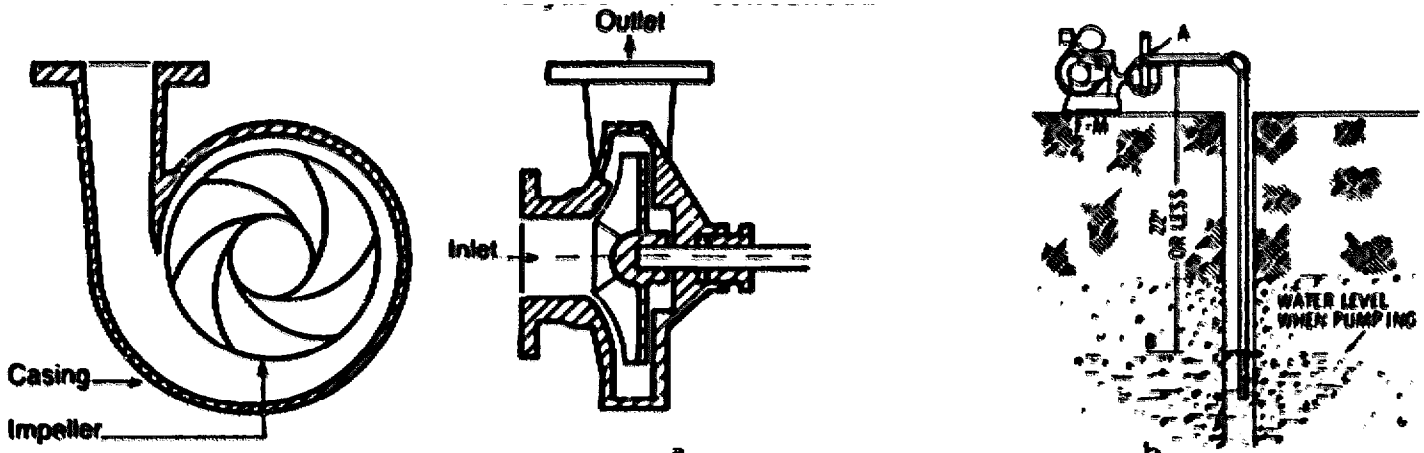

Self-Priming Centrifugal[a] and Typical Installation[b]

[a] (Hofkes and Visscher 1986)
[b] (Stewart 1982)

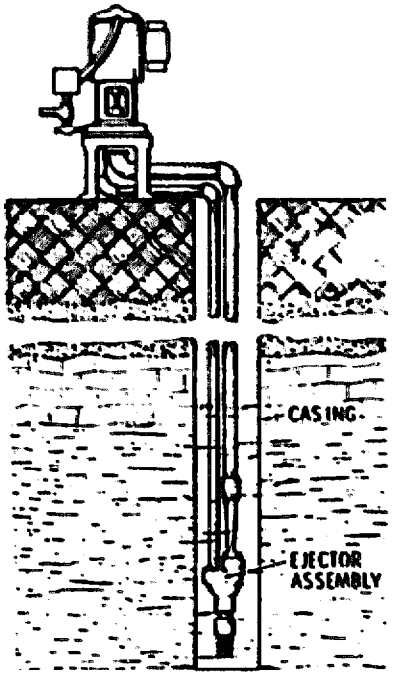

Jet
(Stewart 1982)

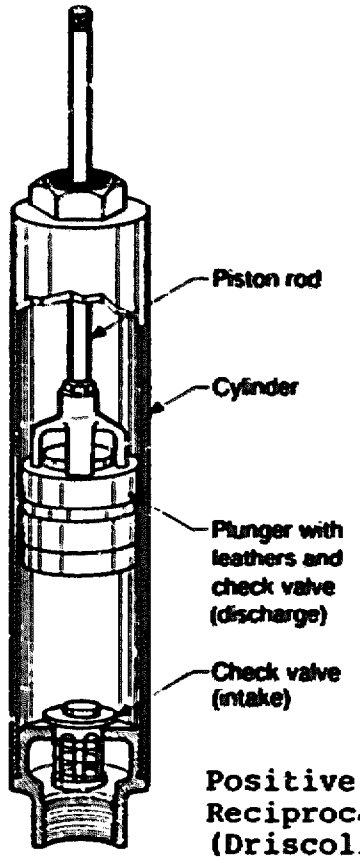

Positive Displacement
Reciprocating Piston
(Driscoll 1986)

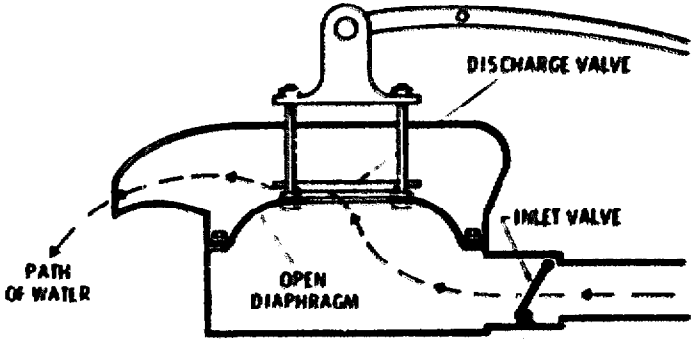

Diaphragm
(Stewart 1982)

Advantages: multi-stage to accommodate a wide range of heads, not restricted.

Disadvantages: sandy or highly saline water causes rapid degradation, water quality affects replacement interval for pump and motor as these are submersed, high capital cost, expensive to repair (pump set requires removing unit from well), requires electricity (i.e., cannot use other drivers), brushless direct-current (DC) submersible motors still in development stage so present DC and AC submersibles must be pulled for periodic brush replacement, inverter losses for AC submersibles when used with PV, limited capacity since currently available units are all nominally one kW.

- Shaft-Driven Centrifugal (Vertical Turbine)

Use: down-hole, medium-volume, medium-head pump driven by rotary shaft.

Advantages: surface-mounted motor offers ease of maintenance, not limited in terms of suction so there are no priming problems, high capacities are available.

Disadvantages: Shaft losses reduce efficiency compared to submersibles, shaft and borehole alignment are critical to proper operation, installation is difficult.

- Jet

Use: medium-head, medium-flow, down-hole pump and surface-mounted motor.

Advantages: can be used beyond suction limit, very reliable, easy access to motor for maintenance, low starting torque—least expensive intermediate-head pump.

Disadvantages: relatively inefficient.

- Positive-Displacement Reciprocating-Piston (Jack)

Use: high-head, low-flow, down-hole piston and cylinder, driven by sucker rod from surface.

Advantages: can pump low flows against very high heads, output is independent of head, simple design.

Disadvantages: maintenance requires periodic replacement of leathers and cylinder, more expensive than centrifugals of same size, relatively inefficient as leathers degrade, most commonly used with windmills, pulsing flow, in PV systems (see Chapter 6) requires batteries or power-conditioning units (PCUs) for high starting current.

- **Positive-Displacement Rotary**

  Use: medium- to high-head, medium-flow, Mono or Moyno pumps.

  Advantages: generally very robust, output fairly independent of head, not confined to suction limit, no priming problems, good efficiency over wide range of heads except for under 20 meters, and no back-flow valve required.

  Disadvantages: sand or very hard water can cause premature degradation of rubber stators, requires gearing, can overload motors if downstream valves are inadvertently closed, installation is difficult. Although newly developed nitrile stators have lower starting torque, standard units require battery or PCU to supply high starting torque.

- **Diaphragm**

  Use: flow produced by flexing diaphragm that is generally used for low-head, low-flow applications.

  Advantages: few moving parts, low internal friction, tolerant of sand or other particulates.

  Disadvantages: constant flexing causes diaphragm wear, fairly uncommon type of pump.

4.3 Pump Selection Considerations

A number of factors to take into consideration when selecting pumps cannot easily be quantified but should be carefully considered in choosing any pump. These include:

- equipment reliability (often a direct function of the complexity of the design);
- frequency and complexity of maintenance requirements and technical skill levels or additional training needed to perform maintenance tasks;
- degree of use in your area--if a pump is commonly used, local mechanics are probably familiar with its operation, and spare parts are likely to be readily available; and
- potential for standardization of equipment, with the goal of minimizing spare parts inventories and technical training requirements.

To some extent, pumps are application-specific. For example, handpumps obviously have a very limited application for irrigation. However, various types of hand-operated pumps--for instance, rower pumps, standard reciprocating-piston handpumps (e.g., Dempster or India Mark II), and rotary pumps (Mono)--have been used in several countries for micro-irrigation. Generally, river-pumping applications for water supply or small-scale irrigation systems, which normally require high flows at low heads, use centrifugal pumps because of their high capacity, reliability, and ease of maintenance. For applications requiring a high capacity system, surface-mounted centrifugals are employed for low heads, and vertical turbine centrifugals for deeper wells--both are relatively inexpensive and their motors are easily serviced. To provide drinking water from wells, submersibles or positive displacement pumps are a more likely choice. They are usually more efficient, but their capacity is lower.

These are just some examples of pump applications. Table 1 shows practical head and output limits with various power sources for these and several other pumps. This information is shown graphically in Figure 9. To a large extent, the choice of a pump will be dictated by constraints associated with the water source--requirements for the head and flow rate, and the variability of the source. In many cases, any one of several different pump types will perform adequately. The important point is to choose a system that will operate efficiently and reliably under the design conditions at your site.

In practical terms, the way to select a particular pump is to first choose the type that is appropriate for your particular application, based on the advantages, disadvantages, and ranges for the flow rate and head given in this section. Then, based on an informal survey of the local availability of makes and models of that type, select four or five models with pump performance curves where your site's operating point is roughly in the middle of the curves (the x-axis represents the flow rate and the y-axis, the head). The final choice is determined by which models require the least energy to pump the amount of water you require from a given head. This can be decided by noting which pumps have the highest operating efficiency for the system's total pumping head. Make sure you are using the correct pump curve in order to reflect the pump's operating speed (e.g., for positive-displacement pumps) or variable voltage conditions (for electric-submersible pumps), if these apply.

4.4 Advantages and Disadvantages of the Drivers Covered in This Manual

As shown in Table 1, certain drivers are suitable for certain types of pumps. This section discusses the qualitative differences between drivers and, where appropriate, the pumps they are best suited for.

Table 1

Pump Ranges and Power Sources

Type of Pump	Practical Depth Range (m)	Capacity Range m3/hr	Common Power Source
Centrifugal			
single stage	15-20	variable	motor solar
multi-stage submersible	50-500	variable	electric motor solar
multi-stage shaft-driven	15-80	variable	motor wind
Jet			
shallow well	up to 7	1-6	motor
deep-well	20-60	1-3	motor
Recip.ocating-Piston Pumps			
shallow well (auction)	up to 7	2-3	human wind
deep well	15-100	2-6	human motor wind
Rotary Positive Displacement	30-150	1-100	motor human solar
Diaphragm	5-30	1-3	human motor

(adapted from Hofkes and Visscher 1986, 61)

Figure 9. Pump Application Range

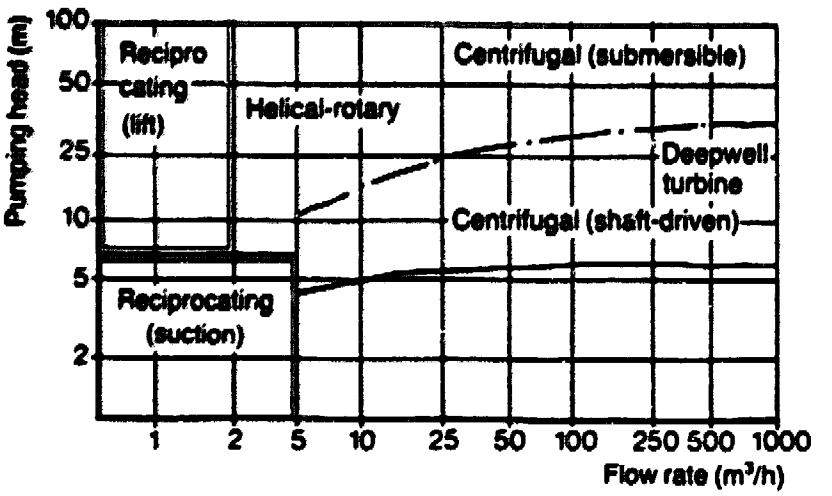

(Hofkes and Visscher 1986, 60)

4.4.1 Diesel Systems

Diesel engines are the standard prime mover in most of the developing world (see Chapter 5). They can be used to drive nearly any type of pump, either directly or through a generator. Diesel engines are normally characterized by

- low capital costs, but relatively high recurrent costs for O&M;
- local familiarity with O&M due to existing infrastructural support networks of widely varying quality that include trained mechanics and spare parts supplies (although this can vary widely from country to country, and even by specific area within a country);
- fuel availability that is highly variable and affected by seasonally dependent transportation networks;
- fuel costs that often vary seasonally but are generally increasing in rural areas despite current decreases in world oil prices;
- on-demand pumping capability, as opposed to wind or solar pumps, which are dependent on the availability of variable renewable energy resources;
- equipment that is commonly available for essentially unlimited capacity in terms of head and flow rate, except for small loads (less than 2 to 3 kW);
- relative portability of smaller units, which are generally high-speed; and
- the need for an attendant during operation.

4.4.2 Solar PV Systems

Solar pumping systems typically consist of a PV array (i.e., the power source), power-conditioning equipment, an electric motor, and a pump (see Chapter 6). They are usually characterized by

- relatively high capital equipment costs and low recurrent costs for operation (since there is no fuel requirement), maintenance, and repairs;
- limited capacity for commercially available equipment--up to 2.2 kW peak power input, which can provide about 40 m^3/day from 25 meters of head (although this can vary widely from country to country and even from one area to another within a

country), given solar radiation levels in many developing countries (Note: although it is very unusual, it is possible to install several stacked PV submersibles in one well. However, this is usually not economically viable);

- no on-demand pumping capability, though water storage tanks or batteries can be used to minimize this limitation;

- low portability for most installations because of the PV array--some smaller units of less than about 500 watts peak can be mounted on trailers for portability;

- electromechanical controls, which allow for unattended operation;

- susceptibility to vandalism--stones can easily break the glazing on PV modules; and

- very high reliability for the power supply (i.e., the array), but not always for the energy supply (the sun).

4.4.3 Wind Systems

Mechanical wind pumps typically consist of a horizontally or vertically mounted windmill (i.e., rotor) and transmission (gearbox or other types) mounted on a tower. Most often, rods connected to the transmission drive a down-hole piston pump. Wind pumps are typically characterized by

- high capital equipment costs and relatively low recurrent costs for operation (because there is no fuel requirement), maintenance, and repair;

- limited capacity given the rotor diameter on commercially available machines (up to 7.6 meters) and wind regimes that are commonly encountered (less than 5 m/s under fairly favorable conditions);

- no on-demand pumping capability, which necessitates providing a large amount of storage capacity to increase water availability;

- the possibility of local manufacture;

- no portability; and

- mechanical controls, which permit unattended operation.

4.4.4 Hand-Operated Systems

Hand-operated pumps are commonly simple lever arms that move piston, diaphragm, or rotary down-hole pumps. They are characterized by

- very low capital and recurrent costs;
- ease of installation, operation, and maintenance;
- very limited capacity for single units—less than about 5 m^3/d for up to 40-50 meter heads, but more at lower heads; and
- the possibility of local manufacture for some simpler models.

4.5 Other Types of Drivers

This manual does not deal specifically with other system types besides the four described above. The approximate head and flow limits for the pump drivers discussed here are given in Figure 10. Six other kinds of pump drivers and one other configuration (hybrid systems) might be of potential use to some readers. Thus, the following are briefly described here (see Fraenkel 1986 for coverage of an exceptionally wide variety of pumps):

- electric generators and grid-connected pump sets,
- wind-electric turbines,
- animal-traction pumps,
- biogas or dual-fuel pumps,
- river current turbines
- hydraulic rams, and
- hybrid systems.

4.5.1 Electrically-Driven Pump Sets

Where electric power is available, grid-connected pump sets are often the most cost-effective system option for rural water supply. Compared to diesel-driven pumps, electric sets are generally easier to install, require less maintenance, and use cheaper fuel (electricity as opposed to diesel or gasoline). However, for sites without any grid electric power, the high cost of extending an existing grid to more remote areas usually makes other pumping alternatives more cost-effective.

Figure 10. Approximate Head and Flow Limits for Pump Systems Available in 1988

(economically competitive applications)

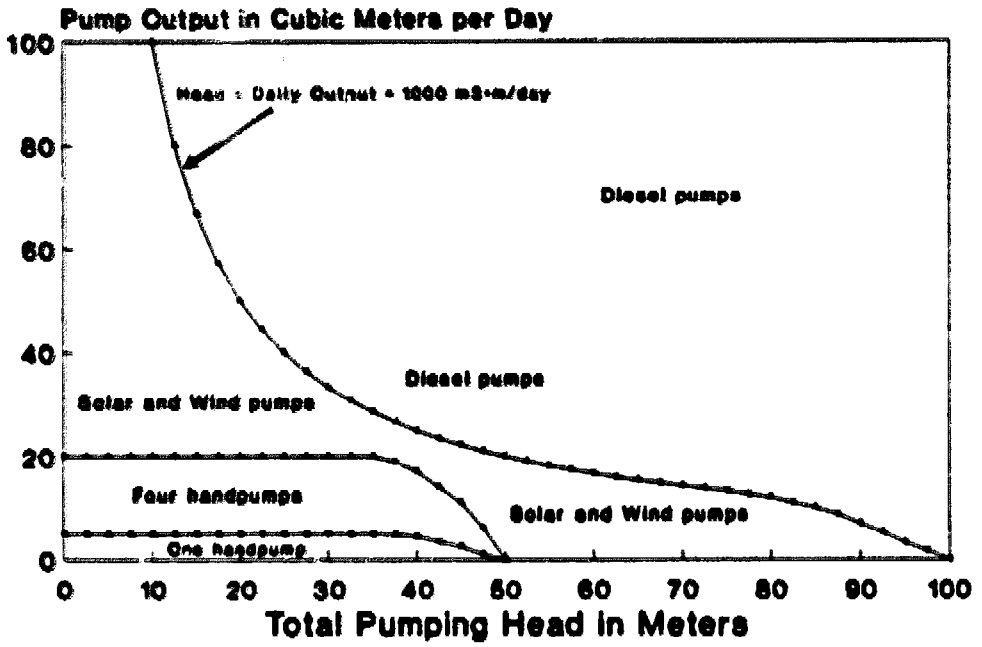

Notes
1. Solar and wind pump outputs depend on radiation and wind speed level.
2. At low head and low flow, all equipment options are possible
3. Lines indicate technical limits of capacity for existing equipment under normal use conditions

4. Based on 3.5 m/s wind speed, and 6 kWh/m^{2}d solar radiation.

In some countries, diesel-driven generators are used to power electric pumps. For sites with other noncompetitive end-uses for the electricity (e.g., village lighting or grinding grain at night), diesel-powered electric generators for water pumping may be cost-effective. In general, such systems offer the flexibility of using electric pump motors, but are inefficient from an energy perspective in that the energy is converted from chemical to mechanical to electrical form and then back to mechanical. Extensive cost data that would permit comparisons with alternatives are unavailable. These systems also require components that are more complex and difficult to repair (e.g., electric generators). They also demand additional skill to maintain and repair and, hence, entail associated training needs. This is a fairly uncommon application in many developing countries, so it will not be discussed further in this manual.

Finally, local "mini-grids" have been suggested as a way of powering electric pumps in rural areas distant from a national grid. Mini-grids—relatively small units in terms of power generation (about 500 kW)—could power a variety of loads in a local area, such as motors and lighting for cottage industry, village lighting and communications, and pumping for the rural water supply. Again, this approach has some merit, but it is fairly rare at present and will not be considered here.

4.5.2 Wind-Electric Turbines

Wind-electric turbines received a considerable boost in popularity in the United States and Europe during the late 1970s and early 1980s when over 15,000 were installed in California. These machines were sited in areas with average wind speeds of more than 7 m/s, a speed that is rare on a regular basis in most areas. Wind-electric turbines are usually designed to operate most efficiently at higher wind speeds than are mechanical wind pumps.

Where high wind speeds prevail (i.e., greater than 6 to 7 m/s), wind-electric turbines can be the most cost-effective choice for power generation at remote sites. However, such high average wind speeds are not usually found in most developing countries. Direct water-pumping applications for wind-electric turbines are still in the development stage, and there is little long-term data on recurrent O&M costs. For these reasons, they will not be discussed further here. However, where windspeeds are sufficient, the potential of this new and interesting application of wind power deserves to be monitored as developments occur.

4.5.3 Animal-Traction Pumps

Animal-drawn pumps (ADPs) have been used to supply water for drinking and small-scale irrigation for thousands of years in countries such as Egypt and Iran. Recent research on ADPs (Kennedy and Rogers 1985) has focused on increasing their efficiency and reliability, lowering their capital costs, and developing units that can be manufactured in developing countries. Work has been undertaken in countries like Botswana (see Hodgkin, McGowan, and White 1988, vol. V) to develop an animal-drawn transmission that can be used in conjunction with a

standard pump, such as the Mono. While many low-flow, relatively low-efficiency animal-traction pumps are being used around the world, very little cost data is available on improved versions that might be relevant to the applications covered in this manual.

4.5.4 Biogas and Dual-Fuel Pumps

Biogas pumps are slightly modified internal combustion engines (usually diesels) which burn biogas, a product of the decomposition of a biomass. The main combustible component of biogas is methane, but it also contains other gases such as carbon monoxide. Biogas pumps have been used experimentally in many countries (e.g., India and Botswana) but have not yet achieved widespread commercial acceptance. Dual-fuel engines are also used to drive water pumps. The two fuels are usually diesel fuel (to get the engine started) and biogas or producer gas from a biomass gasifier (to run the engine after it gets warmed up). Gasifier pumps have been used in the Philippines and Thailand for irrigation pumping but, again, have achieved no significant share of the pumping market (nor, it must be said, have wind or solar pumps). The primary advantage of these engines is that they use renewable energy resources and, depending on the country where they are used, show some potential for taking the place of imported fossil fuels. Their primary disadvantage is that they have all the attendant O&M limitations of diesel pump operation, requiring frequent and often extensive maintenance and frequent repair, due to the typical impurity of their fuel.

4.5.5 River Current Turbines

River current turbines are basically modified paddle wheels which are installed in rivers or streams. The water current drives the pump blades in a circular motion, which is usually mechanically converted into a reciprocating motion to drive a piston pump. The pumps are typically used in low-head, low-flow applications. These pumps have been used experimentally in (among other countries) Mali and Southern Sudan but have achieved no significant commercial success. While they have the distinct advantage of being locally manufacturable in many countries, they have not gained a reputation for being robust enough to attract many potential customers. Research on river current pumps is continuing in several developing countries.

4.5.6 Hydraulic Rams

In certain situations, hydraulic ram pumps are an extremely useful technology for pumping water. Relatively simple in design and construction, locally manufacturable in many countries, and very durable, they can effectively lift water up to 150 meters, using no external power. They use the potential energy of water falling a certain distance to lift a smaller amount of water up a greater distance. The major constraint is that their application is severely limited to sites that have the necessary altitude difference between the water source and the pump to drive the ram. This situation occurs often enough in

some countries, particularly in South and Central America, that rams are an important, if limited, pumping technology.

4.5.7 Hybrid Systems

One disadvantage of nearly every type of pumping device is that it occasionally runs out of the energy resource used to drive it—diesel fuel is sometimes unavailable, the wind stops, or there are several cloudy days in a row. To address this problem, hybrid systems that use more than one power supply (e.g., diesel/wind, wind/PV, or diesel/handpumping systems) have been employed where the demand for water is critical and outages cannot be tolerated. Hybrid systems are almost always more expensive than traditional systems with a single driver.

An example of a hybrid system is PV/diesel, where PV powers an electric submersible pump whenever solar radiation is sufficient. If the array, which is the main driver, produces insufficient power because of several cloudy days in a row, the diesel engine is automatically engaged by the electronic controller and pumps water until the PV unit can again produce sufficient power. Such systems normally use a single pump with two drivers. Since the diesel unit consumes fuel only when it is running, there is no penalty (aside from the engine's initial capital cost) for having it always available in reserve.

While backup systems are similar to hybrids, they usually use completely redundant components. An example is a village water supply system that has several different water sources. A small diesel engine is installed to pump from the best source as the primary pumping unit. When water becomes unavailable for whatever reason (e.g., breakdown of the diesel engine, need to perform maintenance, or depletion of the water source), handpumps installed at another site(s) are used as backups. However, in most situations, handpumps cannot supply the same amount of water as the diesel engine, so a reduced supply must suffice until the primary diesel system is again operational.

An alternative to purchasing and installing hybrid or backup pumps is using larger storage tanks. If sufficient water can be pumped during normal operation so that enough water for several days is available in a storage tank, users will have an adequate supply in the event of system failure.

The next four chapters discuss detailed procedures for designing diesel, solar, wind, and handpumping systems. All are based on the fundamental pump characteristics discussed in this section.

Chapter 5

DIESEL PUMPS

As the most common type of prime mover in much of the developing world, diesel engines are used to drive a wide variety of pumps. In many countries, there is a broad national network (formal or informal) of equipment distributors, local dealers, mechanics, and transportation facilities that supports diesel engines used for pumping and other purposes. In most cases, diesel pump sets are the standard against which all other types of pumping systems must be compared. The two major factors in choosing an appropriate diesel engine are manufacturer and model. A manufacturer with a good reputation for quality products should be chosen. Also, it is important to consider the local availability of equipment and experienced technicians, engine configurations, and local dealer support in terms of spare parts inventories. The choice of model depends on the site-specific pumping task.

5.1 Engine Description

Through drive shafts or pulleys and belts, diesel engines can be used to drive almost any type of pump. They can also drive electric generators to run electric pump sets, which is a configuration that has advantages in cases where submersible pumps are favored and grid electricity is unavailable. However, this manual addresses only the direct mechanical application of diesel engines to water pumping.

The range of diesel engine output is essentially unlimited, with units available from 2 kW to 20 kW. This manual focuses primarily on the 2 to 10 kW range for small-scale water pumping. Diesel pump sets are usually characterized by moderate capital costs and comparatively high recurrent costs for fuel, maintenance, and repair. They are relatively portable, since engines up to 10 kW normally weigh less than 200 kg. Two typical small engines (under 10 kW) and one larger engine (40 kW) are shown in Photographs 1-3.

Diesel engines are internal-combustion engines that use diesel fuel (also called gas oil) as an energy source. They normally have combustion-ignition systems, meaning that the fuel is ignited by high temperatures in the combustion chamber, which are produced during the engine's compression stroke. Spark plugs are not normally used in diesel engines, except in rare instances that will not be considered here. Diesel engines are generally categorized in the following ways:

- high- or low-speed—operating at greater or less than about 2,000 revolutions per minute (rpm);
- single- or multi-cylinder—bigger, more powerful engines have a greater number of larger cylinders;

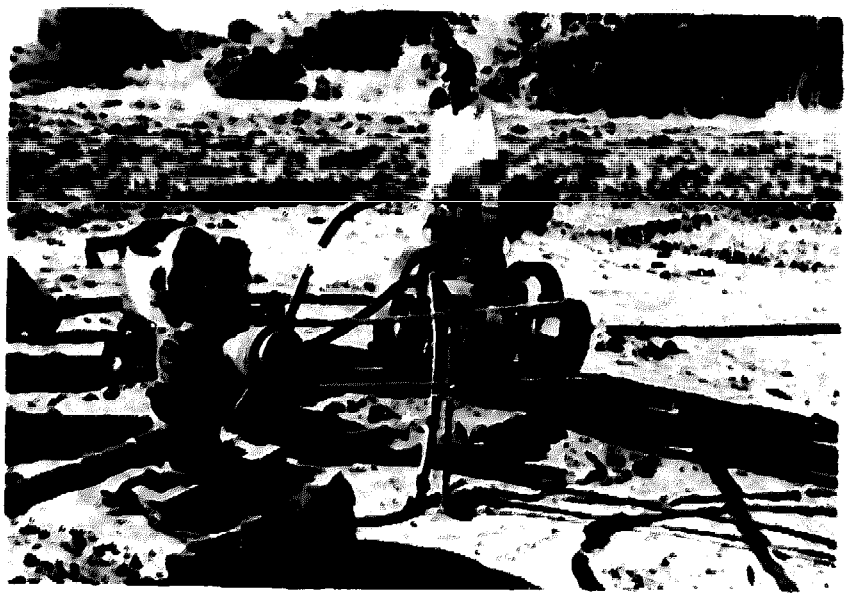

1.

Lister diesel engine with shaft turbine pump for irrigation in Sudan.

2.

Lister diesel engine with Mono pump for village water supply in Botswana.

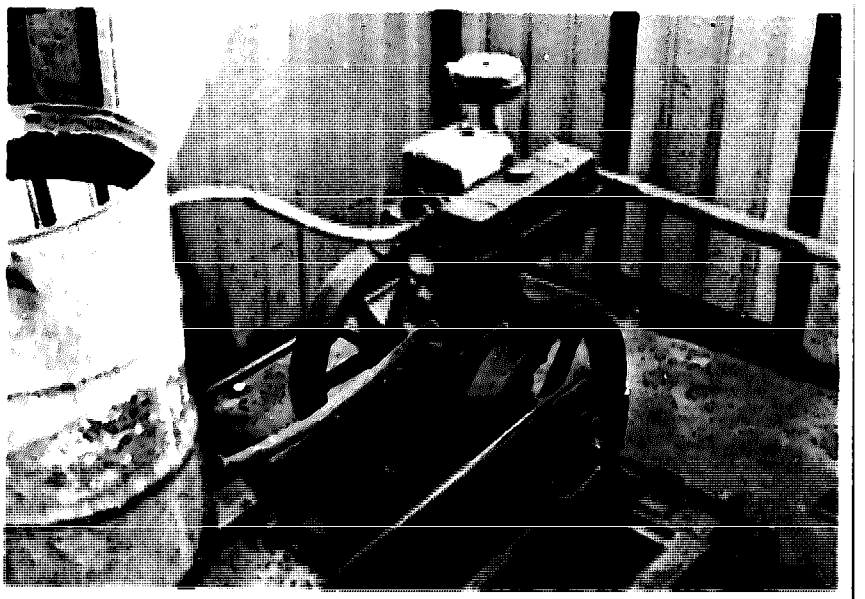

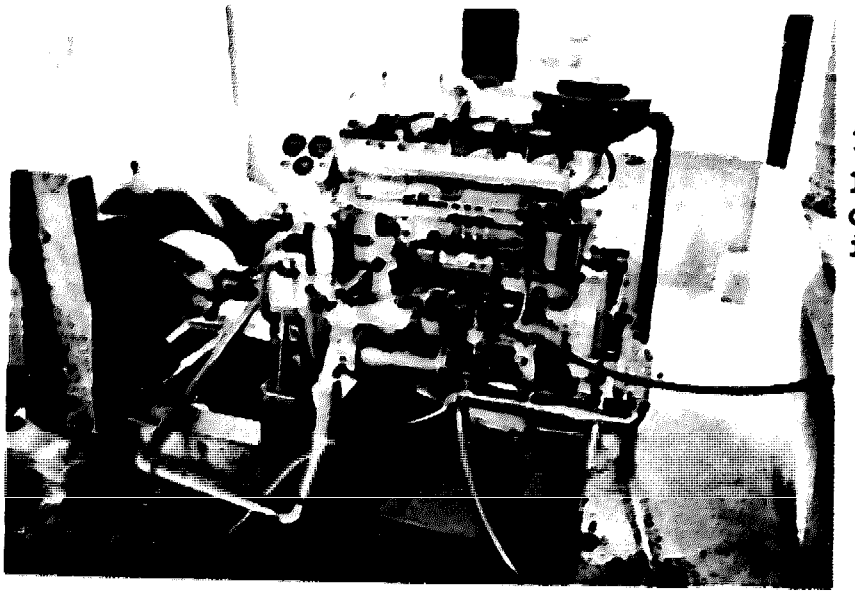

3.

Italian diesel engine with centrifugal pump for irrigation in Somalia.

- air- or water-cooled; and
- two- or four-stroke.

Traditionally, diesel engines for water pumping have been slow-speed, relatively long-lasting engines. Those that are clearly built for long service are generally heavy; they often run at lower speeds (less than 2,000 rpm) and tend to be more expensive in terms of the initial cost. However, they are often more durable and easier to work on when maintenance or repairs are required because of their simple design. The higher speed, lighter engines that are now becoming available tend to be less expensive initially but also to have a shorter service life. Some lighter, high-speed Japanese diesels fall into this category. From the standpoint of life-cycle costs, it is not always clear which is the best choice. Deciding between low- and high-speed engines will depend on other factors, such as funds available for the equipment purchase, availability of spare parts, and quality of service.

Single-cylinder engines typically have rated power outputs between 1 and 10 kW. Multi-cylinder engines are available in a variety of sizes starting at about 8 kW. They tend to run more smoothly than single-cylinder engines but are normally more expensive. Whether you use a single or multi-cylinder engine depends primarily on power requirements.

Water-cooled engines tend to be larger and somewhat quieter when running; they do not require a cooling fan and/or fins as air-cooled units do but involve the additional maintenance of keeping the coolant at a certain level. Larger air-cooled engines need a cooling fan (very small ones sometimes rely only on fins), the operation of which entails an associated power loss. Most engines under 10 kW are air-cooled.

Both two- and four-stroke diesel engines are available. The former have fewer moving parts, tend to operate at higher speeds and wear out faster, are less efficient, and have a higher power-to-weight ratio (i.e., they produce more power per kilogram of engine weight). Oil must be added to diesel fuel for the proper operation of two-stroke engines. Otherwise, damage to the engine may result. For most water pumping applications, four-stroke engines are preferred.

Diesel engines also differ in the way that power is transferred to the pump. Some are connected to the pump shaft through a gear box and others through belts and pulleys. Such transmissions involve associated power losses that have to be accounted for in engine sizing (see Section 5.3 below).

5.2 Selecting a Manufacturer

Diesel pumping systems are widely used in most developing countries, and many types of engines are usually available. The most important question to ask when choosing a manufacturer is whether you have ready access to adequate spare parts and trained local mechanics who can repair the engine. Careful consideration should be given to the make of the equipment, the product support provided by

the manufacturer and its local representatives, and operating and repair capabilities in that particular country.

Extreme caution is suggested when considering "offshore" purchases of mechanical equipment through other than local suppliers, or when buying any equipment that is not already supported locally. Even if some spare parts are included with the original offshore purchase, more will eventually be needed. In addition, any specialized repair tools that may be required and are not available locally will have to be purchased directly from the manufacturer, and local mechanics will not be familiar with the equipment and its particular idiosyncrasies. For all kinds of systems, long-term, trouble-free operation depends largely on local capabilities to service and repair the equipment when necessary. The quality of equipment and service infrastructure vary considerably between countries as well as within a country or region.

It is a good idea to carry out an informal survey of locally available equipment before deciding what to purchase. Discussions with dealers and local engine overhaul shops can help determine spare parts availability and can identify particular makes and models with good reputations as well as those prone to problems. At this stage, you can learn about specific installation and operational features that may affect your choice. Consult several sources to confirm information and opinions, since individuals usually have their own preferences, justified or otherwise. While the initial cost plays an obvious role in selecting a particular manufacturer's equipment, consider that a lower initial cost may mean lower quality equipment that will be expensive to maintain and that will frequently require replacement parts.

5.3 Choosing an Engine Model

After selecting the appropriate flow rate and determining the total head, the power requirement can be calculated as described in Chapters 2 and 4. A particular model of diesel engine is then chosen on the basis of this power requirement. The performance of any diesel engine is usually specified by manufacturers in terms of three variables:

- torque,
- power, and
- fuel consumption.

All vary with engine speed, so they are quoted for specific speeds or given for a range of speeds in graph form. Examples of typical diesel-engine performance curves for torque, power, and fuel consumption are shown in Figure 11. While fuel consumption (grams of fuel consumed per hour of operation) increases with engine speed, specific fuel consumption (in grams of fuel consumed per kilowatt power output) varies with operating speed. In Figure 11, the Kubota ER 1200 is designed to operate most efficiently (i.e., lowest specific fuel consumption) around 1900 rpm, while the Lister STI operates most efficiently at 1500 rpm.

Figure 11. Diesel Engine Performance Curves

Performance curve

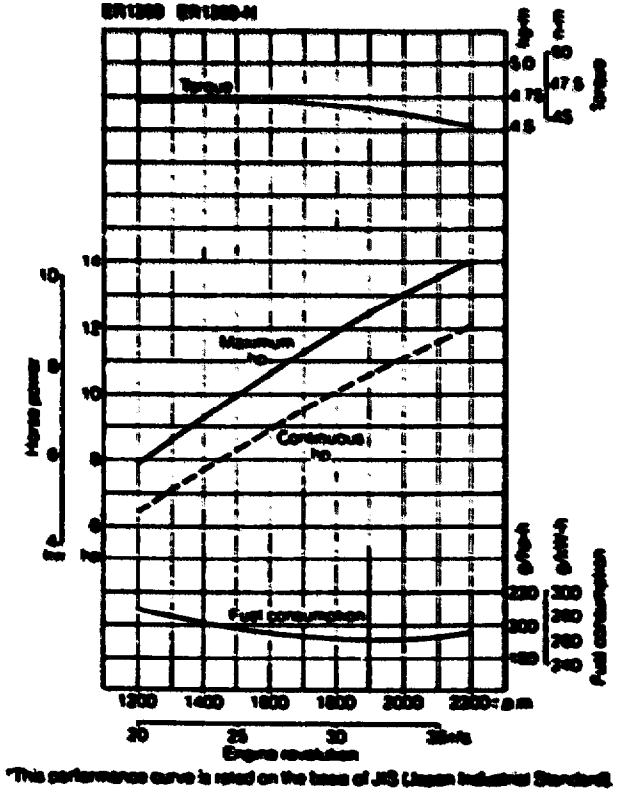

5.1a Kubota ER1200

ST1

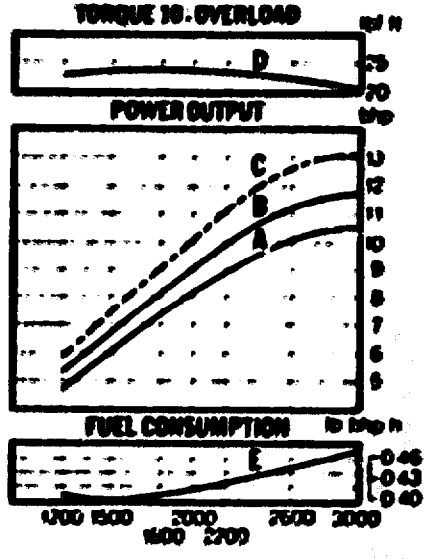

5.1b Lister ST1

Power Output--Lister ST-1		
Engine Speed	Continuous Power kW (Hp)	Maximum Power kW (Hp)
3000	7.8 (10.5)	8.7 (11.7)
2600	7.5 (10.0)	8.4 (11.2)
2000	6.0 (8.1)	6.7 (9.0)
1800	5.4 (7.3)	6.0 (8.1)
1500	4.5 (6.0)	5.0 (6.7)
1200	3.5 (4.7)	3.9 (5.2)

In the Kubota diagram, there are two power output curves. The upper one is for maximum rated power output and the lower for continuous output. Systems should be sized so engines run continuously at or below the lower output curve. This means the continuous power rating of the engine selected should be the same as or greater than the power requirement of a specific pumping task.

Engine performance is always given for specific conditions of temperature, air pressure, and relative humidity, since these variables also affect performance. Fuel consumption is quoted for a given power output at full engine loading. Engine loading is the ratio of power required by the pump to the maximum power available from the engine. Actual (partial-load) fuel consumption is dependent on the engine's condition and loading. As discussed in the following sections, loading has an impact on fuel consumption and maintenance requirements.

The "nameplate" power rating of a diesel engine, which is stamped on the manufacturer's nameplate, is the power available under continuous full-load conditions (i.e., when the load or pump is drawing the full rated power from the engine) at the engine speed indicated and under specified conditions of temperature, air pressure, and humidity. The power available from an operating engine will normally be less than the manufacturer states because operating conditions are unlikely to match those of the nameplate rating. Diesel engine output is "de-rated" or reduced by a certain percentage to account for such differences in conditions. An engine's power output can be calculated using manufacturer's specifications and then de-rating the engine for the specific site and operating conditions. De-rating recommendations vary by manufacturer and engine, but Lister gives these typical de-rating factors for the following conditions:

- for high engine-air inlet temperature, de-rate the power output by 2 percent for every 5.5° above 30° Centigrade;
- for lower barometric pressure (i.e., higher site elevation), de-rate by 3.5 percent for every 300 meters of elevation beyond 150 meters above sea level;
- for high humidity, which is also dependent on temperature, de-rate up to 6 percent (the precise value has to be chosen from a table supplied by the manufacturer); and
- for power-absorbing equipment, common de-rating factors are up to 10 percent for motor-driven radiator fans, 5 percent for belt drives, and 3 to 5 percent for transmissions.

These de-rating factors are calculated individually and then added. The total de-rating percentage is subtracted from 100 percent and then multiplied by the rated power for a full load to determine the de-rated output for the rpm specified.

Example 6: De-Rated Power Output

A Lister ST-1 has a nameplate rating for continuous output of 6 kW at 2,000 rpm. It will be operated at 1,500 rpm at a site 750 meters above sea level where the temperature can be expected to reach 38° Centigrade in the summer and where the humidity is negligible. A pulley-and-belt system will be used to drive the pump. What is the actual power output that can be expected under these conditions?

At 1,500 rpm, the Lister ST-1 develops 4.5 kW under standard conditions, according to the manufacturer's literature (see Figure 11). The de-rating factor for altitude is:

$$((750m - 150m)/300) \times 3.5 \text{ percent} = 7 \text{ percent}$$

The de-rating factor for temperature is:

$$((38 - 30)/5.5) \times 2 \text{ percent} = 3 \text{ percent}$$

Belt losses call for de-rating by 5 percent. Adding these factors together, the total de-rating factor is 15 percent. Thus, the power that can be delivered by an ST-1 operating under these conditions will be:

$$4.5 \text{ kW} \times (1 - .15) = 3.83 \text{ kW}$$

Each manufacturer's literature should include information on standard conditions and de-rating calculations. The total de-rating factor can easily be 20 to 25 percent. In practice, this means the power that can be expected from an engine may be only 75 to 80 percent of the rated power indicated in the specifications for a chosen speed. Selecting an engine based on nameplate output alone can mean purchasing a unit that will not be able to meet a task's power requirements.

Once the de-rated output for an engine has been calculated and matched to the pump's power requirement, an engine model can be chosen. In doing so, engine loading should also be taken into account. Remember that loading is a measure of the power required of an engine relative to the maximum de-rated power it is capable of delivering. Loading does not depend on the total volume of water pumped, but rather on flow rates and head--it is dependent on power, not energy.

For diesel pumping systems, loading is not a function of time, but it can have a significant effect on time-dependent variables associated with engine operation, such as fuel consumption and maintenance requirements and costs. Under most conditions, an engine should be overpowered by 20 to 30 percent (i.e., run at a loading of 70 to 80 percent). Normally, diesel engines are most fuel-efficient at these levels, and a margin of power is available to meet unusually heavy operating conditions, such as at start-up. Engines operated at lower loading levels run cooler. This decreases fuel efficiency and increases carbon buildup in the cylinder(s) and exhaust manifold, which increases service requirements.

Under-loaded engines--running at less than 50 percent of full-load conditions--are common in many situations in developing countries. The reasons include improper determination of head as well as poor engine and/or pump sizing and matching. Another explanation is that for the very low power demands encountered with some small-scale applications, it may not be possible to select an engine which is small enough and has a slow enough speed to permit proper loading (70 to 80 percent) due to the limited availability of small diesel engines and/or limited yield of the water source. The lower limit of diesel engines that are commonly available is about 2 kW. There are some engines as small as 1 kW, but they are uncommon. In such cases, alternatives to diesel engines should be considered.

5.4 Cost Considerations

Cost considerations include initial equipment and installation costs as well as recurrent costs for operation and preventive and corrective maintenance. The initial installed cost of a diesel pump set is significantly higher than the capital cost of the engine and pump. It also includes labor for the installation, transportation, and the cost of other equipment and materials including cement, fencing, a pump house, water meters, non-return and gate valves, and piping, among other items. Diesel engine costs vary considerably depending on the size and procurement source. In 1988 typical cost ranges were as follows:

- US$300 to US$600 per kW for units between 2 and 10 kW, with smaller engines being more expensive per kW and
- US$200 to US$500 per kW for units between 10 and 25 kW, with smaller engines again being more expensive per kW.

These figures do not include ancillary equipment, such as transmissions, gearboxes, and fuel storage tanks.

Recurrent operating costs include labor for a pump operator (if that individual is paid), fuel, lubricants, and consumables. The cost for a pumper typically falls at the lower end of rates for local skilled labor. In some cases, a pumper's duties can be combined with other related activities (e.g., serving as a caretaker or guard), thereby reducing the cost of employing a pumper. Careful

consideration of the magnitude of pumper costs is recommended, as it can be one of the most important recurrent system costs (see Chapter 9).

The fuel and lubricant consumption of a diesel engine accounts for a significant portion of its operating costs. Lubricant use (including oil changes) should be in the range of 3 to 5 percent of fuel consumption by volume. As shown in Figure 11, fuel consumption is dependent on the engine's full rated power (specified by the manufacturer) and loading conditions. Full-load fuel consumption (FLFC) is often given by manufacturers in grams of fuel consumed per rated kWh (g/kWh) or some similar measure such as pounds of fuel consumed per brake horsepower-hour, as in the Lister curve in Figure 11. For small-scale applications, you would normally be interested in the fuel consumption of a specific engine in terms of liters per hour (l/hr). To convert to these units, the calculation is:

$$FLFC = g/kWh \times (.001/SG) \times kW$$

where FLFC = full-load fuel consumption in l/hr
g/kWh = fuel consumption in grams per kWh
SG = specific gravity of diesel fuel (usually 0.87)
kW = engine's rated full-load power output for a specific rpm (not de-rated)

For rough figures, actual fuel consumption can be estimated as the engine's FLFC in l/hr multiplied by the loading, which will be reasonably accurate down to a loading of 20 percent. Below 20 percent, fuel consumption does not decrease much. Note that engine de-rating does not affect this calculation.

Example 7: Engine Loading and Fuel Consumption

The diesel engine in Example 6 is coupled with a pump that is 60 percent efficient and delivers 36 m^3/day from 75 meters of head, running at a constant rpm over a 6-hour period. What is the engine loading and anticipated fuel consumption?

First, determine the power requirement for the load. From the formula for hydraulic energy (E_h) demand given in Section 3.1:

$$E_h = .00273 \times 36\ m^3/day \times 75\ m$$

$$E_h = 7.4\ kWh/day$$

The power (P) input to the pump is then:

$$P = 7.4\ kWh/6\ hours/60\ percent = 2.0\ kW$$

Since the de-rated power output of this engine (from Example 6) is 3.83 kW, the loading will be as follows:

$$loading = 2\ kW/3.83\ kW = 52\ percent$$

This is somewhat lower than desirable. Operating the engine at a lower speed would improve the loading.

From manufacturers' literature, the FLFC for a Lister STI is 240 g/kWh at 1,500 rpm or 1.24 l/hr, using the conversion formula given above. At a loading of 52 percent, actual fuel consumption can be expected to be 1.24 x 0.52 or about 0.64 l/hr. This figure will depend to some extent on the engine's condition, but it is a good approximation.

For a given engine, pump, and site conditions, fuel consumption per cubic meter of water pumped will depend on the loading. At a lower loading, the engine will consume more fuel per unit of water pumped. Using the same procedure given in Example 7, you could calculate the difference that loading makes in fuel consumption per unit of water pumped (using a more precise but complex relationship between fuel consumption and loading than that given above). For example, if you have a Lister ST-1 that is used to pump 30 m^3/day from 90 meters of head, you can vary the flow rate and, hence, the loading by changing the engine speed. Assuming that the head remains essentially constant, annual fuel consumption for the two different loadings would be 1,830 liters at a loading of 34 percent and 1,430 at 73 percent. This represents a savings in fuel and lubricant costs alone (per unit of water pumped) of over 22 percent, not to mention the reduction in maintenance costs associated with running the engine

warmer and thereby reducing carbon buildup. An alternative approach is using a smaller engine at a higher loading. In that case, you would also save money on capital equipment costs, in addition to lower operating, maintenance, and (eventually) engine replacement costs. This example shows the importance of proper loading in the design of diesel pumping systems.

5.5 Service Requirements

Service requirements can be categorized as preventive, corrective, or curative. Preventive maintenance includes servicing that should be done on a routine basis to ensure efficient operation of the system. Corrective maintenance is required for occasional problems that may lead to engine or pump failure, but are not part of normal servicing. Curative maintenance is a response to a breakdown. Corrective and curative maintenance constitute unscheduled service.

Preventive maintenance implies that service is carried out on a routine basis, according to the number of hours of engine use or a timed schedule. In practice, servicing is often not performed regularly, so curative maintenance is required after the engine has broken down. This has obvious consequences for the reliability of the system and the lifetime of the equipment. Breakdowns occur for a wide variety of reasons, including poor installation, a lack of operator attention, and failure to provide regular service or poor-quality servicing. The underlying causes of breakdown frequency may be more complicated and can include a poor understanding of the system, lack of incentives for pumpers to perform well, and funding problems.

As a stand-alone mechanical system, a diesel engine requires an operator, regular servicing, and periodic repair. The pumper's skill and the quality and amount of servicing and repairs that are required are completely interdependent. An operator is responsible for day-to-day operation of the pumping system, including starting and stopping the engine, and replenishing the fuel. The pumper is also responsible for preventive maintenance, such as checking the oil and possibly changing it (as required), tightening loose nuts and bolts, and other minor tasks. Corrective maintenance is usually performed by a mechanic, whose tasks include decarbonizing the engine, cleaning injector nozzles, replacing worn belts, adjusting valve clearances, and changing the oil, air, and fuel filters. Checking the fuel-injection system and cooling system and replacing other worn components as necessary are also part of periodic service requirements.

The manufacturer's literature provided with the engine should indicate proper intervals for servicing (see Appendix C). To give a sense of the range of normal service requirements, oil changes are typically required after every 250 hours of engine operation and decarbonization after every 1,500 hours. The actual requirements for a particular system may vary with the operating environment, application, and mechanic's skill and training. For example, if the engine is operating at a low loading, the decarbonization interval should be shorter. Very often, because engines do not receive proper maintenance, the risk of breakdowns is increased, the overhaul interval is reduced (which increases costs), and the lifetime of the engine is shortened. Almost without exception, the routine maintenance aspect of the service infrastructure for diesel engines is the weakest.

Corrective maintenance, which is required when unanticipated problems occur, includes such activities as replacing worn belts or fuel-tank straps and decarbonization or engine overhauls, if these are not performed as part of scheduled preventive maintenance. Proper corrective servicing will eliminate the need for much curative maintenance.

The rate of breakdowns and unscheduled service is heavily dependent on the operator's attentiveness and the normal servicing the engine receives. Routine preventive maintenance, such as changing the engine oil and replacing filters, is one of the most important factors in minimizing repair costs. However, having at least one breakdown per year (and possibly more) that requires curative maintenance is fairly typical, depending on the engine's age and condition and the quality of service it has received.

The cost of unscheduled servicing is highly variable. Estimates of service and maintenance costs, not including fuel and labor, are likely to be in the range of US$0.15 to US$0.25 per cubic meter of water delivered. This figure may be higher or lower depending on labor costs, the operator's skill, and the quality of the equipment, among other factors. Another way of looking at this is that typical annual O&M costs, not including expenses for fuel and operator labor, range between 25 and 75 percent of the engine's initial cost or 5 to 15 percent of the system's installed capital cost (which includes not only the engine, but also the pump, the concrete pad, the transmission, and other items).

5.6 Equipment Life

The service life of any device depends on the conditions under which it is used, which includes installation and maintenance. Under optimum conditions, an engine should be replaced when the cost of maintaining it exceeds the cost of purchasing a new one. However, users' perceptions of engine life also play a role. If users anticipate getting five years of service, a new engine may be purchased at five years even though the old one is still functional. Light, high-speed engines are likely to have shorter lifetimes than heavy, slow-speed models. The best way to estimate values for equipment lifetimes in your situation is to ask other engine users, local equipment dealers, and operators of repair shops about the makes and models you are interested in.

Usually, the lifetime of an engine is given informally in years. The normal range is two to three years for lower quality, heavily used, and/or poorly maintained engines to 20 years or more for higher quality systems that are reasonably well maintained and overhauled at regular intervals. Lifetime hours of operation vary from under 5,000 to over 50,000 hours. About 20,000 hours is a reasonable approximation for planning and costing purposes. A complete list of diesel maintenance needs and a recommended schedule for meeting those needs are given in Appendix C.

Chapter 6

SOLAR PHOTOVOLTAIC PUMPS

r PV cells are used to convert sunlight directly into electricity. While power can be used for a variety of end-use applications (e.g., communications, lighting, and refrigeration at health clinics), it is ming increasingly popular for water pumping in remote areas As of mid-1988, s estimated that between 5,000 and 10,000 solar pumps have been installed nd the world. Successes in PV research and development have significantly ced costs and increased the reliability of this power source, which has orically been very expensive. Multiple cells (30 to 50) are mounted on a le unit (about 0.3 by 1.2 meters) called a module. The individual modules wired together in groups to form arrays. While the PV arrays themselves are ptionally reliable power sources, the primary limitation on the use of solar s has been and continues to be the high initial capital cost of a system. , since water output is directly proportional to the level of solar diation falling on the modules, relatively high and uniform solar irradiation occur at your site for solar pumps to be a cost-effective pumping option.

r pumps have been used in field applications for about 10 years. Some early ls were plagued by design and manufacturing problems. Considerable gains ncreasing system efficiency and reliability and reducing production costs lowered the cost per unit of water delivered. Still, solar pumps remain ly expensive compared to other pumps, although they do have the potential eing cost-effective pumping alternatives under certain circumstances. This ion describes typical system components as well as the design, operation, tenance, and repair requirements of solar pumps.

System Description

V pumps become more popular, an increasing variety of designs is becoming lable that differ in cost, application, capacity, and reliability. This ion describes the most common kinds of solar pumping systems and several of optional components. The focus is on systems that have been field- d in evaluation programs in countries such as Botswana, Mali, Malaysia, and .

most basic PV pumping system consists of an electrical power source (i.e., array), a motor, and a pump. The electrical output from the array is ered to the motor, which drives the pump. Many variations of this simplest of system use different optional components. More complex designs are rily intended to increase the efficiency or reliability of the water supply, re water can be pumped with a PV array of the same size. Schematic drawings everal typical solar pumping systems (submersibles, vertical turbines, ing suction, and centrifugal suction pumps) are shown in Figure 12.

Figure 12. Typical Solar Pump Designs

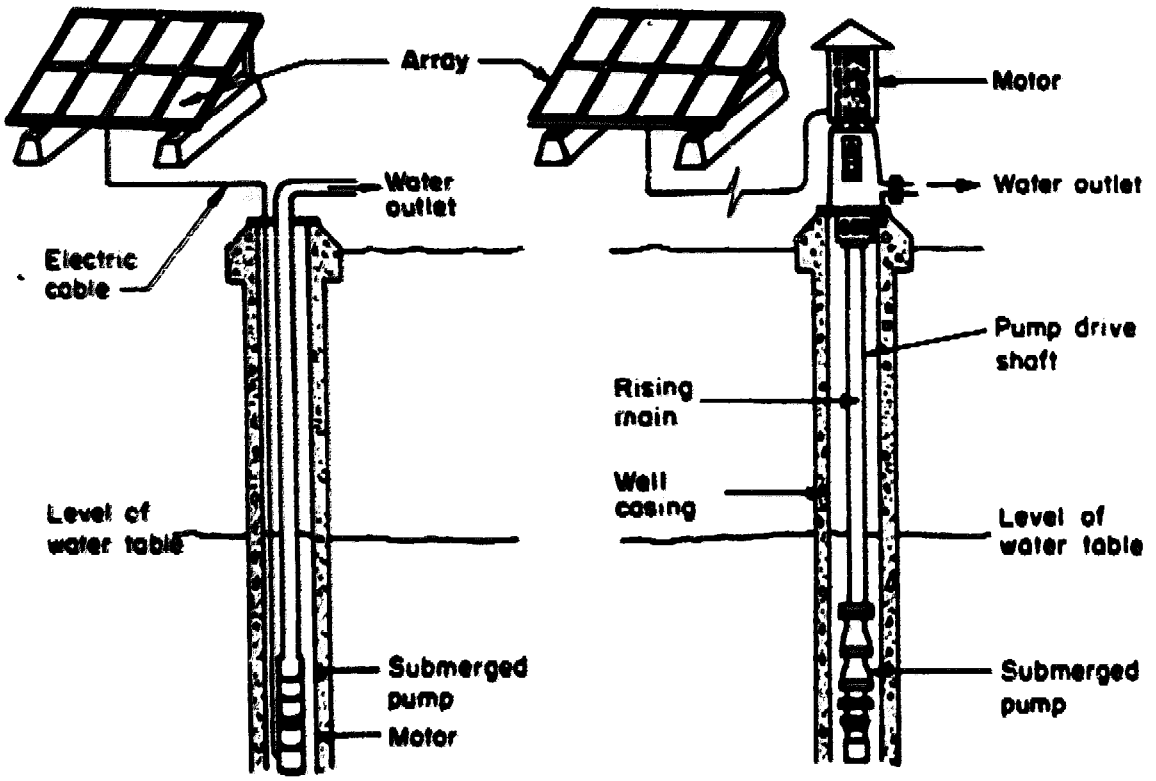

Submersible Unit

Vertical Turbine
(shaft-driven centrifugal)

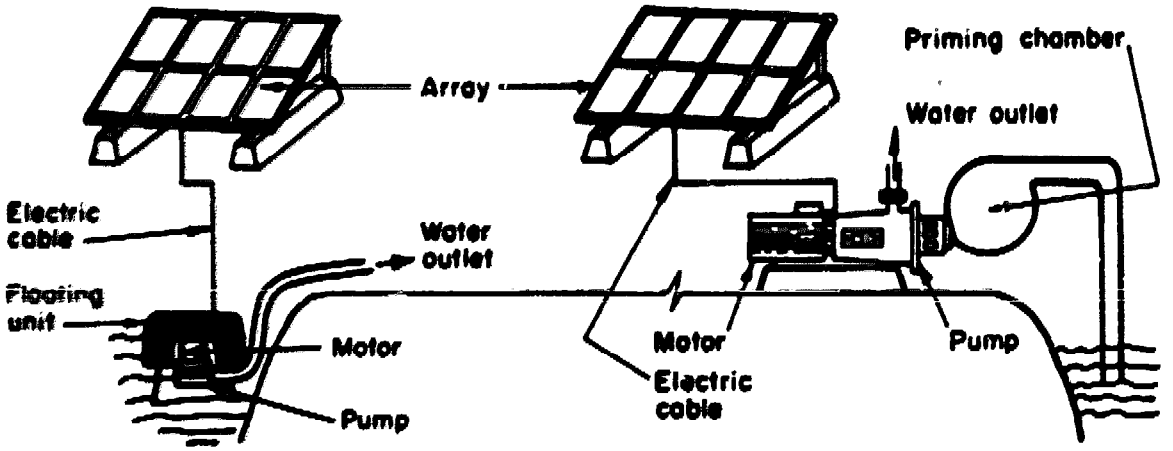

Floating Suction Unit

Centrifugal Suction Unit

(Kenna and Gillett 1985)

6.1.1 The Power Source

PV modules produce a certain current and voltage under specified sunlight conditions. While several types of PV cells are commonly used (e.g., single crystal, semicrystalline, and amorphous), nearly any power module can be employed in a pumping system. Motors used in solar pumping systems have specific electrical operating characteristics chosen to match those of the array. This increases the overall system efficiency, so more water is delivered per dollar invested in the system. The matching of motors and arrays no longer presents significant problems with equipment standardization among different manufacturers' equipment, since most currently available PV modules have similar electrical output.

Arrays can be wired to produce a wide range of electrical output. Modules are connected in series (i.e., with the terminals minus to plus and plus to minus) to increase voltage and, hence, motor speed at a constant current. Wiring modules in parallel (with terminals minus to minus and plus to plus) increases the current output and motor torque at a constant voltage. Motors are designed to operate most efficiently at a certain current and voltage, so care must be taken to select a motor with electrical input requirements that match array output in order to get the best performance from the system. Similarly, the motor output must match the operating characteristics of the pump in order to use power efficiently. Equipment buyers usually need not match these components themselves, as this is normally already taken care of by PV module and pump manufacturers and system designers. However, because of the importance to proper system operation of correctly matching these components, the procedures necessary to do this have been included in this manual. This will allow you to confirm the specifications given by equipment suppliers.

Equipment distributors will specify the array size and configuration (i.e., wiring arrangement for a specific current and voltage combination) needed to pump a certain quantity of water from a given head, based on manufacturer's recommendations. Array sizes are given in term of peak watts (W_p). This is an indicator of the array's expected power output under peak operating conditions, which are defined as 1 kW/m^2 solar irradiation on the array and an operating temperature of 25° Centigrade. Typical power modules are rated at 40 to 60 W_p. The output of PV modules varies depending on the operating temperature and level of solar irradiance—i.e., the solar energy per unit of area in watts per square meter (W/m^2). The higher the solar irradiance level on a PV cell, the higher the power output is; the higher the operating temperature, which depends on the ambient air temperature, the lower the output.

PV pumping system designs can be varied by adding one or more of the following components:

- Controllers. Their functions include regulating current and/or voltage from the array and to the motor, shutting down the motor for various safety reasons, and controlling the system by means of a float switch that turns the motor off when the storage tank is filled/

- **Inverters.** They change the array's electrical output from DC to AC.

- **Power-point trackers.** These convert sunlight into electricity more efficiently.

- **Batteries.** They provide a constant voltage to the motor and store energy, so the system can pump water even when the array is unable to deliver enough power directly.

- **Sun-tracking devices.** These move the array so it is directly perpendicular to the sun, thereby intercepting more radiation and increasing the power output.

Several types of controllers are used with PV pumps, including inverters, power-point trackers, and battery-charge controllers. The PV array produces DC electricity. Some solar pump motors operate directly on DC, others require AC. An inverter is used to convert DC power from an array into AC power for the pump motor. An inverter can also act as a controller to shut down the motor before overloading or overheating occurs and can help the motor and array operate efficiently in other ways.

Solar cell operating characteristics depicted as current-voltage (I/V) curves are shown in Figure 13. They show a certain current and voltage output for the module under various irradiance (i.e., solar irradiation) levels. There is a particular point on an array's operating curve at which it produces maximum power—the maximum power point. A type of controlling device called a maximum power-point tracker (MPPT) forces the array and motor to operate at or near this point. For example, at an irradiance of 1,000 W/m^2, the module shown has a maximum power point at 16 volts and 3 amps. An MPPT does not make a PV array physically track the sun, but some use devices that tilt the array so it is perpendicular to the sun's rays, thus producing more power. Using an MPPT makes a system more complex and adds to the cost, but under certain circumstances, it can be a cost-effective means for producing additional power from an array. Batteries are sometimes used with PV systems as storage devices and/or controllers. Solar irradiation is intermittent due to variable cloudy conditions and the sun's movement across the sky during the day. Batteries store electrical energy from the array, which can then be used by the motor to drive the pump when irradiation is inadequate to drive the system directly. In addition, batteries can serve as controllers to provide constant voltage to the motor, so it operates at a more constant and higher average efficiency. Batteries have disadvantages that should be considered in the system design process. These include additional capital costs, higher maintenance requirements, and periodic replacement costs.

Several kinds of sun trackers can be used to move an array so that it is perpendicular to the sun's rays. These vary considerably in terms of complexity, reliability, and cost. Under certain conditions, array trackers have been shown to produce increases in array output of up to 40 percent over the course of a day. This net gain must be weighed against the increased complexity and cost of these devices.

Figure 13. PV Module Operating Characteristics

Power Specifications*

Model	M75
Power (typical ± 10%)	47.9 Watts
Current (typical at load)	2.94 Amps
Voltage (typical at load)	16.0 Volts
Short Circuit Current (typical)	3.27 Amps
Open Circuit Voltage (typical)	19.9 Volts

Physical Characteristics

Length	48 in/1219 mm
Width	13 in/330 mm
Depth	1.4 in/36 mm
Weight	11.6 lb/5.2 kg

*Power specifications are at standard test conditions of: 1000 W/M², 25°C cell temperature and spectrum of 1.5 air mass.

Performance Characteristics

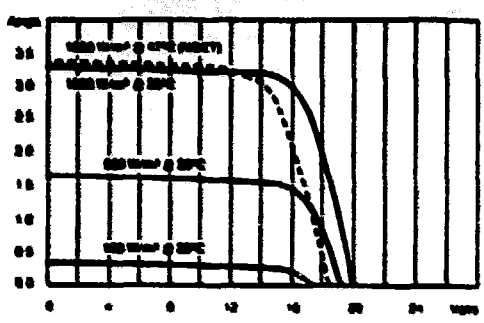

The IV curve (current vs. voltage) above demonstrates typical power response to varying light levels at 25°C cell temperature, and at the NOCT (Normal Cell Operating Temperature), 47°C.

(ARCO Solar, Inc., manufacturer's literature)

Particularly in areas where well yields are low and drawdowns high or where water tables vary considerably due to drought or unusually heavy use, safety devices such as low-water cut-out switches and motor overheating/overloading protection should be included in a pumping system. Some commercial PV pumps are already equipped with these safety devices, but you should request that they be included in any quotation on the price of a system. PV systems should also be properly grounded to protect them from lightning—this inexpensive safety measure should never be overlooked.

All of the controlling and storage mechanisms briefly described here have advantages and disadvantages in terms of their complexity of operation and repair, their effects on system efficiency, and their costs. The emphasis in pump design and component selection should be on trying to achieve long-term reliability, rather than the highest possible system efficiency. Reliability has often been shown to be a strong function of a system's design simplicity.

6.1.2 The Motors

Several types of motors are used in solar pumping systems, including DC motors with or without replaceable brushes and AC motors with inverters. DC motors normally use brushes to carry current. These have to be replaced occasionally when they are worn down. This poses no problem for surface-mounted motors that are easily accessible for maintenance (assuming that the replacement brushes are locally available), but for submersible pumps, where the motor and pump are mounted underwater as an integral unit, changing the brushes requires that the whole pump and drop pipe be pulled from the borehole or other water source--a major operation. Recently, some manufacturers (e.g., A.Y. MacDonald in the United States) have developed brushless DC motors for use with submersible pumps. This innovation will reduce recurrent costs for periodic maintenance of submersible pumps, since the brushes will not have to be replaced on these units.

6.1.3 The Pumps

The most typical kind of pumps used in PV systems are listed below. Their operating characteristics, typical applications, advantages, and disadvantages were discussed in Chapter 4. These pumps are listed again here with the names of some well-known suppliers:

- self-priming centrifugal--AEG, A.Y. MacDonald, and SEI;
- submersible centrifugal--Grundfos, A.Y. MacDonald, Warns, AEG, Solar Voltaics, Totale and Franklin; and
- positive-displacement, reciprocating-piston (jack)--Chronar/Tri-Solar, Lamb, Ergo, and Solamotor.

Less common types include:

- positive-displacement, rotary--Mono, and Robbins Meyers/Moyno;
- jet--A.Y. MacDonald; and
- vertical or deep-well turbine--Chronar/Tri-Solar, Guinard.

In general, PV systems that require high flows for low heads (e.g., for micro-irrigation) use surface-mounted, self-priming centrifugal pumps because of their high capacity, reliability, and ease of maintenance. Submersible units (which are by far the most common), positive-displacement pumps (piston and rotary) and vertical turbines are used for deeper wells and boreholes. Piston pumps are typically high-head, low-flow units. Jet pumps are used for moderate head and flow applications, but are not common.

6.2 Operating Characteristics

The amount of water output for a PV pump depends on the intensity of solar irradiation falling on the PV modules, the total pumping head, and the operating temperature of the array. Higher irradiation levels produce greater electrical output and, consequently, more water. As is true for all pumping systems, the greater the pumping head, the lower the water output for a given level of power input. An array's electrical output and a pump's water output drop off as the operating temperature increases--thus, PV pumps are more efficient in cooler climates.

Solar irradiation varies in several ways:

- daily--as the sun rises and sets and as short-term weather patterns cause cloudy or partially cloudy conditions;
- seasonally--as varying long-term weather patterns occur over the year (e.g., monsoons or dry seasons) and as the angle of declination changes (i.e., the angle between the sun's rays and a horizontal surface on the earth), which is reflected in the sun's lower position in the winter sky and higher position in the summer;
- annually--as weather patterns associated with drought conditions, clouds, air pollution, and monsoons vary; and
- geographically--as a function of latitude and microclimatic weather conditions (e.g., local ground fog and dust storms) at the site.

Cloudiness reduces solar irradiation on the array, sometimes to the point where no water can be pumped unless the system has a battery bank for electrical storage. Solar irradiation varies depending on annual variations in weather (such as drought conditions in Sahelian Africa) as well as on seasonal changes such as monsoons (which in some places like India and Malaysia can obscure nearly all usable solar irradiation for up to several months each year).

A typical operating day for a solar pump is depicted graphically in Figure 14, which shows actual measured data for a solar pump on an average sunny day in Botswana. The graph indicates the hydraulic or subsystem efficiency (also sometimes called "wire-to-water" efficiency, but always the ratio of hydraulic energy out of the subsystem divided by electrical energy into the subsystem), the flow rate in l/s, and the solar irradiation intensity in W/m^2. The figure shows how the pump does not turn on immediately in the morning, but only when the cut-in or threshold irradiation level is reached. This is the minimum level of irradiation at which the array produces enough current to overcome the starting torque of the pump and motor starting. It varies with the system and site. A similar system is shown in Photograph 4.

Figure 14

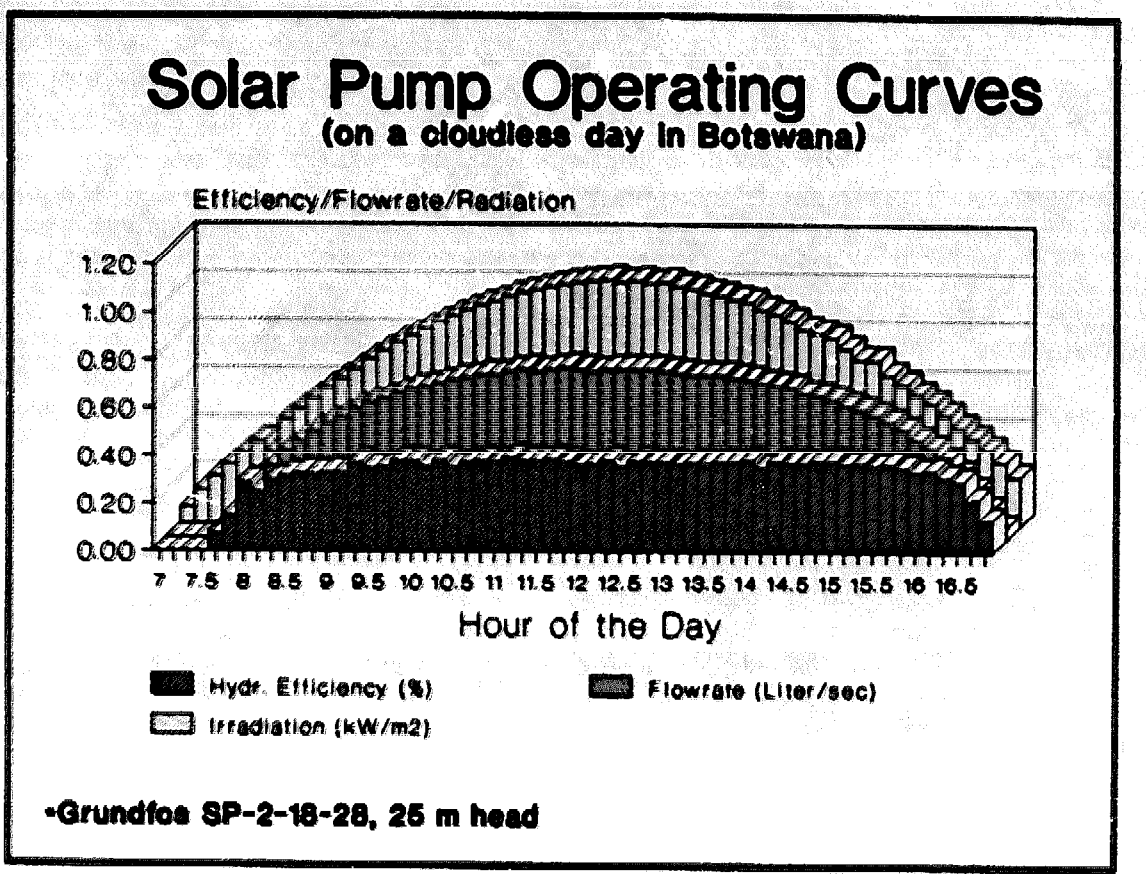

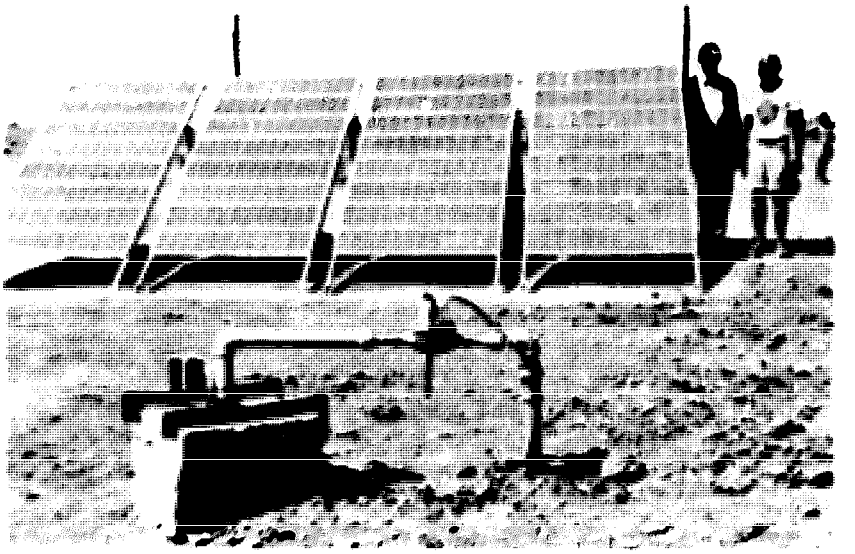

4. Grundfos Submersible Solar Pump for Village Water Supply in Botswana

For poorly designed systems, the cut-in irradiation level may be so high that the pump runs for only a short period during the day or may not turn on at all. By using certain types of controllers (e.g., MPPTs), the system's cut-in irradiation level can be lowered so it operates for a longer period each day. Similarly, for days with low irradiation (for example, a very cloudy day), even a well designed system may never reach its cut-in irradiation level and, hence, will not operate that day.

After the cut-in level is reached, the pump turns on and the flow rate increases until around noon when the sun is at its highest point in the sky. Thereafter, solar irradiation and, consequently, pump output decrease until the cut-out irradiation level is reached in late afternoon and the pump stops. The system's hydraulic efficiency increases early in the day until the unit is in its normal operating range, levels off, and then drops off again in the late afternoon.

Because of the variability in solar irradiation and the consequent variability of pump output over a given period, solar pumps (like wind pumps) require some type of storage system so that water is always available to users. For PV pumps, energy can be stored either electrically (using batteries) or hydraulically (water in a storage tank). Considerable debate has taken place on battery versus water storage, as well as on the amount of each required for any given installation. A general rule of thumb is that systems should be designed with three days of storage. What type of storage depends upon several factors, primarily the respective local cost and availability of storage tanks and batteries, and secondarily the likelihood that the batteries will be properly maintained. Storage tanks require considerably less active maintenance than batteries, and so are less likely to fail over the long run. Batteries in PV pumping systems are not normally serviced properly and thus must be frequently replaced at great expense.

One of the best features of solar pumps is that their normal operating requirements are minimal compared to most other types of systems. A solar pumping system usually operates completely automatically, so pump operators are not strictly required as they are with diesel engines, for example. Nor do solar pumps require fuel.

6.3 Choosing a Solar Pump

Sizing methods for solar pumping systems range from very simple to highly complex. This section covers simpler methods first and then more accurate ones.

6.3.1 A Simple Method of Solar System Sizing

The simplest method of solar sizing calculates the power required, given the estimated head and flow rate requirements. Subsystem efficiency is the ratio of energy out of a system (i.e., water flow for a given head) divided by energy put into the system (electrical energy output from the array). Using a typical estimated subsystem efficiency of 25 to 35 percent, array size can be calculated.

(Note: manufacturers' literature usually quotes this efficiency as measured under ideal conditions, as high as 50 to 60 percent. Our field measurements of subsystem efficiency of many installed solar pumps, including motor, pump and controller, have never been more than 40 percent.)

The actual power required to pump water is defined as

$$P_{req} = (9.81 \times h \times Q)/Eff_{sub}$$

where P_{req} = power required in watts
9.81 = gravitational constant
h = total pumping head in meters
Q = flow rate in liters per second
Eff_{sub} = subsystem efficiency of 0.25 to 0.35

Example 8: Power Requirements

To pump one liter per second (l/s) with 28 meters of head for a system with a subsystem efficiency of 30 percent, what is the electrical output needed from an array?

$$P_{req} = (9.8 \times 28 \times 1)/0.30 = 915 \text{ watts}$$

If a pump set ran for two hours at that rate, energy consumption would be 915 watts multiplied by two hours, which is 1,830 watt-hours or 1.83 kWh. This is the hydraulic energy demand, which was discussed in Chapter 3. The next step is to determine the size of array in W_p that could supply that 915 watts of power under peak solar irradiation conditions.

Example 9: Rough Array Sizing

For the system in Example 8, assume that ARCO Solar M-53 modules are going to be used in the array. Each typically produces about 2.2 amps of current at 15 volts when driving a pump under 1,000 W/m^2 of solar irradiation. The required motor voltage is 105 volts. How should the array be wired, and how many modules should be used?

Since wiring modules in a series increases voltage, the motor voltage of 105 is divided by the module voltage of 15, so seven modules must be wired in series to produce the required voltage. Together, those seven modules have an output of 105 volts multiplied by 2.2 amps, or 231 watts. The required number of series strings of seven modules each is thus the system's overall power requirement (915 watts) divided by the output of each series string (231 watts) or four strings of seven modules, for a total of 28 modules.

This rough calculation assumes a solar irradiation level of 1,000 W/m^2 or 1 kW/m^2. Solar irradiation data are often given in terms of kWh per square meter per day or kWh/m^2d. In the simplest method of system sizing, if your site has a daily solar irradiation level of 6 kWh/m^2d, the pump in Example 9 would produce the same water output over the course of an entire day as if it were running for 6 hours at a constant flow rate equal to the total volume of water pumped during the day divided by the total daily solar irradiation or about

$$6 \text{ hrs/day} \times 1 \text{ l/s} \times 3{,}600 \text{ sec/hour} = 21{,}600 \text{ l/day} = 21.6 \text{ m}^3\text{/day}$$

This rough method of system sizing oversimplifies the real situation in several ways:

- The level of solar irradiation actually varies continually over the course of a day--starting at zero, irradiation increases to its maximum about noon and then drops off to zero again after sunset.

- System efficiency varies with irradiation level and temperature--efficiency improves as irradiation increases (up to a point, again see Figure 14) but drops as the temperature rises in the afternoon.

- It is assumed that all of the 6 kWh/m^2d can be used by the system--in fact, for systems without batteries, irradiation below the cut-in level is wasted because the pump is not running.

6.3.2 A More Accurate Sizing Method

A somewhat more accurate way of estimating the size of the solar array needed to pump a given amount of water is to use the following formula:

$$\text{array size in } W_p = \frac{9.81 \times h \times Q}{H_t \times 3.6 \times F_m \times F_T \times Eff_{sub}}$$

where W_p - peak watts
9.81 - gravitational constant
h - total pumping head in meters
Q - water output in m^3/day
H_t - global solar irradiation in the array plane (kWh/m^2d)
3.6 - conversion factor (kWh to MJ)
Fm - array/load matching factor, 0.9 for centrifugal pumps, 0.8 for others
FT - de-rating factor for operating temperature of array output cells (0.8 for warm climates and 0.9 for cool)
Eff_{sub} - subsystem efficiency

This formula better approximates the actual operation of a solar pump, except that it does not take into account the cut-in and cut-out radiation levels mentioned above, below which the pump will not operate in the early morning and late afternoon. However, these are relatively small errors which tend to overestimate the daily output by 5 percent or so.

Virtually every variable except array size and the gravitational constant changes with the time of day and the season. The array/load matching factor is a measure of the electrical impedance mismatch between a PV array and the subsystem load (i.e., the subsystem controller or pump motor in a direct-coupled system). Simple computer programs are available that can be used to estimate quickly the water output using this formula, including cut-in irradiation levels to reflect the fact that the pump is not operating in the early morning and late afternoon (McGowan and Hodgkin 1985).

Example 10: More Accurate Array Sizing

Use the more accurate formula given above to calculate the size of the array needed to pump 20 m^3/day from 28 meters of head, using the equipment described in Examples 8 and 9.

$$\text{Array Size in } W_p = \frac{9.81 \times 28 \times 20}{6 \times 3.6 \times 0.9 \times 0.8 \times 0.30} = 1.177\ W_p$$

where gravitational constant = 9.81
h (pumping head) = 28 meters
water output = 22 m^3/day
solar irradiation = 6 kWh/m^2d)
conversion factor (kWh to MJ) = 3.6
F_m = 0.9
F_t = 0.8
Eff_{wp} = .30

A 28-module array (one module = 43 W_p) would be adequate here.

In order to give you a better feel for PV system sizing, Table 2 shows the array size needed to pump a given amount of water (10 to 30 m^3/day) at a given head (10 to 60 meters) for three different irradiation levels. The array sizes were computed using the formula above for more accurate array sizing.

Table 2

Sample Solar Pump Sizing Table

Array Size (Watts Peak) to Pump Given Volume at Given Head
(Subsystem efficiency = 30%, and irradiation of 4, 5, and 6 kWh/m²d)

Head (m)	Water Demand (cubic meters per day)								
	10			20			20		
	Solar Irradiation (kWh/m²d)								
	4.0	5.0	6.0	4.0	5.0	6.0	4.0	5.0	6.0
10	315	252	210	631	505	421	946	757	631
20	631	505	421	1,262	1,009	841	1,892	1,514	1,262
30	946	727	631	1,892	1,514	1,262	2,839	2,271	1,892
40	1,262	1,009	841	2,523	2,019	1,682	3,785	3,028	2,523
50	1,577	1,262	1,051	3,154	2,523	2,103	4,731	3,785	3,154
60	1,892	1,514	1,262	3,785	3,028	2,523	5,677	4,542	3,785

For example, to pump 20 cubic meters per day at 30 meters head given a 30 percent subsystem efficiency, if your solar irradiation level is 6.0 kWh/m²d, then you would need a 1,262 watt peak array.

6.3.3 Using Data on Irradiation Conditions

To design a cost-effective system properly, historical data on local solar irradiation conditions should be used, where available. Unfortunately, such information is seldom collected in many areas of most developing countries. Thus, estimates of monthly irradiation levels over the year must be used. Possible sources of local irradiation data (e.g., meteorological data and PV manufacturers' world or area maps) are discussed in Chapter 2. The average daily irradiation level used in array sizing should be based on the design month. The concept of design month for solar pumps is similar to that for windmills--it is the month in which it will be most difficult to meet the water requirement at the site given the available solar energy.

When drawing up bid documents for solar pumps, specify the water requirement as a certain average daily amount from a given head, and supply whatever local irradiation data are available. When reviewing dealers' quotes, use the example given above to check that the systems being proposed are reasonably sized to meet the water demand at the site. Bidders' estimates of water output should be within 15 percent of your calculations from the method described here. Otherwise, the system being proposed will probably be improperly sized to meet your requirements.

The following example illustrates the complete procedure for sizing a solar pump and its components.

Example 11: Detailed Solar Pump System Selection

A solar pump is being considered for use at a village site in rural Sudan, where an elevated tank (5 meters high) stores water pumped from a nearby borehole. The distance from the borehole to the storage tank in the village is 250 meters. The borehole currently has a 4-inch diameter casing. It has been test-pumped for 72 hours by a local drilling contractor, and a yield of 5 m^3/h was measured. The depth from the top of the borehole to the water surface during the test-pumping was 13 meters. Irradiation on a solar array during the design month would be 6 kWh/m^2d (or 21.6 MJ/m^2d). The village currently has 680 people, and the sheikh has determined that the population increases by about 2 percent annually. Currently, people use about 30 liters each per day, but the availability of diesel fuel has been so irregular and its price has been increasing so rapidly that the community has begun to consider buying a solar pump. What type of solar pumping system is appropriate?

<u>First, determine water demand</u>. The current population of 680 is growing at 2 percent per year (F_{PO}). The system should be sized to provide an adequate supply of water over its entire useful life (N), which is expected to be 20 years (some components will have to be replaced as not all of the equipment will last this long). From the formula given in Section 2.1.2, the demand in year 20 will be

$$\begin{aligned} \text{future demand} &= (\text{current demand}) \times (1 + F_{PO})^{(N-1)} \\ &= (680 \text{ people} \times 30 \text{ l/day}) \times (1 + .02)^{(20-1)} \\ &= 30 \text{ m}^3\text{/day} \end{aligned}$$

<u>Second, determine total pumping head</u>. Begin by calculating friction losses. Assume that the maximum pumping rate can be estimated by considering that the 30 m^3/day output requirement will be pumped over 6 "peak sun-hours" (6 kWh/m^2d), so the peak flow rate will be

$$(30 \text{ m}^3\text{/day})/(6 \text{ peak sun-hours/day}) = 5 \text{ m}^3\text{/h} = 1.4 \text{ l/sec}$$

Assume that a 60-millimeter galvanized iron pipe will be used down the borehole and that the pump will be set 5 meters below the dynamic water level. The total length of piping in meters will be

13 (borehole) + 250 (pipe run) + 5 (pump set) + 5 (tank) = 273 meters

Example 11: Detailed Solar Pump System Selection (continued)

From Figure 3 (in Chapter 2) and the tables in Appendix B, the friction loss under these conditions--273 meters of 60-mm galvanized steel pipe with negligible losses due to bends and valves--is 2.2 meters. The total pumping head would then include the dynamic head of 13 meters, the discharge head to the elevated unpressurized tank of 5 meters, and friction losses in the pipes of 2.2 meters for a total of 20.2 meters.

Note that the 2.2-meter friction loss is somewhat greater than 10 percent of the total head. Therefore, you should use slightly larger pipe to reduce the friction loss (thereby reducing the amount of energy required to pump your water). With 100-millimeter pipe, the friction loss is 1 meter. The total head is then 18 + 1 = 19 meters.

Third, determine the array size needed. Following exactly the same procedure as given in Example 10 and using a subsystem efficiency of 32 percent, which is typical of Grundfos submersibles available in Khartoum, and a water demand 30 m^3/d for 19 meters of head, you can compute the array size needed:

$$\text{array size in } W_p = \frac{9.81 \times 19 \times 30}{6 \times 3.6 \times 0.9 \times 0.8 \times 0.32} = 1{,}124\ W_p$$

This figure is the minimum array size in W_p that can meet your water requirement. However, other requirements must be taken into account. The Grundfos submersible you are looking at runs at 105 volts. You are considering using Solarex modules, specifically the MSX-53 version that a dealer in Khartoum has given you a quote on. These 56 W_p modules have a typical operating voltage of 15 volts. This means you will have to wire 105/15 or seven modules in series to get the right voltage.

To find the total number of modules, the last step, divide 1,124 W_p by 56 W_p per module or about 21 modules (rounding up to the nearest multiple of seven). Your array would then be wired as three parallel sets of seven modules each. This system size should match the one described in the dealer's quote. To select the individual pump set, review the pump curves for the types of submersibles the dealer carries, and pick the unit that operates most efficiently at the head for your site (19 meters). Your system sizing is now complete.

6.4 Cost Considerations

Solar pump costs depend primarily on two components—the array size and the pumping unit. Solar module costs usually make up 60 to 85 percent of the total system cost and are usually quoted in terms of dollars per W_p or US\$/W_p. In 1983, module costs were about US\$10/W_p, shipped from the country of manufacture. In 1988, they were being quoted as low as US\$4/W_p to US\$5/W_p. These prices usually do not include freight and insurance charges to ship to developing countries, which can easily add 50 percent or more to the price. For example, in 1988 modules with a U.S. price of \$5/W_p were quoted in Botswana for \$8/W_p. Pump sets (i.e., a pump and motor) designed for use with PV systems range in price from US\$1,000 to US\$3,000 (FOB the manufacturer), with the units rated for lower power output costing less and often used at lower heads (e.g., surface-mounted centrifugal and jet pumps). Units with higher power output for deeper wells run from US\$2,000 to US\$3,000. Submersible AC pumps are generally the most expensive because in addition to the pump and motor, they must have an inverter to convert DC power to AC. Often, the higher cost of these units is more than offset by greater reliability and, consequently, lower recurrent costs.

Other costs associated with solar pumping systems include the array mounting structure, wiring, other types of controllers, water meters, civil works (e.g., a concrete pad for the array and piping), and storage tanks. These costs can vary considerably depending on whether the equipment and/or materials are made locally or imported. Check with local dealers for estimates of these costs.

6.5 Operation, Maintenance, and Repair

Normal operating procedures for PV pumps usually require minimal user interaction, but this does not mean they require no attendance whatsoever. Dust should be washed from the collector array, as required (i.e., when it is obviously coating the modules), and for surface-mounted motors, belt tightness and any overheating of the motor or transmission should be noted. If float switches are used in the system's storage tank, they should be checked periodically for proper operation. Water output should be recorded by reading the flow meter on a daily basis. This will permit a more rapid diagnosis of any problems occurring with the system.

One person should be assigned the responsibility of monitoring pump operation, recording water-use data, and determining the nature and extent of any breakdowns that occur. This individual could be trained to deal with simple repairs, such as loose or broken wires. He or she should also know exactly how to call for a repair crew if repairs are required. Because of the complexity of most of the components in PV pumping systems, it is much more likely that the first response to breakdowns will be to replace a component rather than to make an on-site repair.

In many circumstances, particularly at unattended or remote sites, vandals may break the modules or rip out the wires. Qualified personnel performing periodic maintenance should also check for natural degradation, such as corroded terminals and worn insulation. The equipment should <u>definitely</u> be fenced in to protect it from children and animals and to protect them from electric shock. Animals

can easily shut down an unprotected system by scratching on the array's mounting supports and knocking them over or chewing through the insulation on wiring and short-circuiting the system. Representatives from user groups should be chosen and charged with notifying repair crews promptly so that any necessary repairs can be accomplished quickly to minimize downtime.

PV pumps require little maintenance during most of their useful lives. However, like any other piece of equipment, they do require periodic care. The type of maintenance depends on the type of system. DC motors require periodic brush replacement unless they are brushless. Pump seals fail and must be replaced occasionally. Belt-driven pumps must have the belts tightened and eventually replaced. For piston pumps, the cylinder cup leathers must be replaced about every 12 to 24 months.

Maintenance problems will be worse when systems are installed on low-yield wells, in water sources that have wide fluctuations in water level, or where the water quality is marginal. If low-water or overheating cut-off switches are not used, down-hole equipment, including pumps and motors, can be destroyed when water levels drop below the depth of the pump installation. Under very low-flow conditions where the pump continues to operate, an insufficient flow of water past a submersible pump may not provide sufficient cooling and may result in damage to the pump.

Under typical conditions for properly designed systems, monthly or bimonthly maintenance will consist of visually inspecting electrical connections, tightening nuts and bolts, cleaning the array, checking the array electrically on a quarterly basis to make sure it is working properly, and checking the battery bank, if there is one. This entire process should take no more than one to two hours of a mechanic's time, not including any travel that may be required.

Most problems in PV pumping systems occur with components other than the array. Unless they are vandalized, modules very seldom fail. If they are severely damaged, they may have to be replaced, at great expense (US$250 to US$350 each). It is much more cost-effective to educate users about the importance of teaching children and others not to damage the water supply system.

Most problems occur with the pump, motor, and controller. Generally, the design philosophy behind solar pumps has been to manufacture components that will be replaced rather than repaired, at least for most situations in developing countries. Dealer representatives (who are usually assigned only to developing countries with large numbers of solar pumps) for U.S. or European PV pump manufacturers often carry spare parts for pumps (e.g., impellers and seals) or will replace the unit if it is under warranty.

Motors are more problematic. Depending on the level of technical skills in your area, the rewinding of electric motors can be performed locally. Local mechanics or mechanically inclined users can easily replace the brushes, if the motor is easily accessible. Local mechanics can also replace pump or motor seals, assuming that similar types of equipment are used locally (e.g., grid-electric submersible pump sets). With the exception of brush replacement, most procedures should be carried out in a clean electrical shop in the nearest large town, not in the field.

Of course, appropriate spare parts must be available. If not, considerable time and effort may be required to find the necessary parts locally or to have them shipped from the manufacturer. The importance of a complete spare parts inventory cannot be overemphasized. The biggest problem in system maintenance and repair is the time it takes to address the problem from abroad. When choosing a supplier, remember the importance of local dealers who maintain supplies of spare parts and can fix or are willing to replace failed or defective equipment.

There is little, if any, local manufacture of PV pumping equipment in developing countries. Battery-charge controllers are made in some developing countries, and the number of Spire Corporation's turnkey PV cell and module assembly plants in the developing world is slowly increasing. Given the highly automated and sophisticated manufacturing techniques that are typically used to make PV equipment, all of it will probably be imported. In many countries, there are simply no local dealers. In those with local dealers, their knowledge of the product and proper system design procedures may be minimal, so potential customers must either have access to design guidelines (such as this manual) or look elsewhere for equipment. If this is the case in your area, you might reconsider the possibility of using systems that are already available locally. In other countries, knowledgeable, well-equipped dealerships can provide accurate system design, prompt procurement from existing inventories or as a result of good relations with manufacturers, and trained crews for installation and user training. At present, this type of situation is the exception rather than the rule.

6.6 Equipment Life

Since PV pumps are a relatively new technology (compared to diesel engines, windmills, and handpumps), little is known about the economic lifetime that users can reasonably expect of most systems and components. While field tests have been conducted for certain types of systems, few (if any) PV pumps have been in actual use for more than several years. Module manufacturers now commonly guarantee their products for 10 years against significant loss of power output, and accelerated tests have indicated that modules will retain up to 90 percent of their original power-generating capacity for up to 20 years after the initial installation. The need for module replacement because of damage is very dependent on the site.

Other components are not so robust. The motor will probably have to be replaced every three to seven years, depending on the level of operating power (i.e., the higher the power, the sooner the motor will need replacement), the quality of the water (for submersibles, poor water quality tends to corrode casings and ruin seals more quickly), and the quality of the installation. Electronic components, such as controllers, may also need replacement every three to five years, depending on the quality of the equipment. Array mounts should never need replacement.

Chapter 7

WIND PUMPS

Wind pumping systems or windmills convert the energy in wind into mechanical or electrical energy to drive a pump. This section covers what you need to know to

- gather the necessary information to determine whether a windmill will meet the demand for water at your site and
- select a properly sized windmill and pump if this type of system is appropriate for your site.

Since the vast majority of all wind pumps used in developing countries are mechanical windmills driving piston pumps, that configuration is the primary focus of this chapter. Other types of wind pumps will be mentioned only briefly.

7.1 System Description

Wind energy systems are generally subdivided in two ways--horizontal- or vertical-axis machines (referring to the axis of the rotor) and electrical or mechanical. While it is possible to pump water using the energy produced by any of these four possible configurations, the most common type is the horizontal-axis, mechanical system, which is usually referred to as a steel-bladed, farm-type windmill or, simply, a farm windmill. Dempster, Aeromotor, Fiasa, and Southern Cross windmills are examples of this system design. Figure 15 shows a schematic diagram of this type of wind energy system.

A typical farm windmill has four main parts:

- a horizontal-axis wind wheel, which converts power in the wind into the rotary shaft power of the axis;
- a windmill "head," which changes the rotary motion of the axis to a vertical reciprocating motion and makes any necessary gear reductions;
- a tail attached to the head, which has two purposes--it allows the windmill to track changes in the wind direction and, along with a brake, permits the windmill to be furled (i.e., taken out of the wind and stopped) during high winds or when desired; and

Figure 15. Typical Windmill Installation

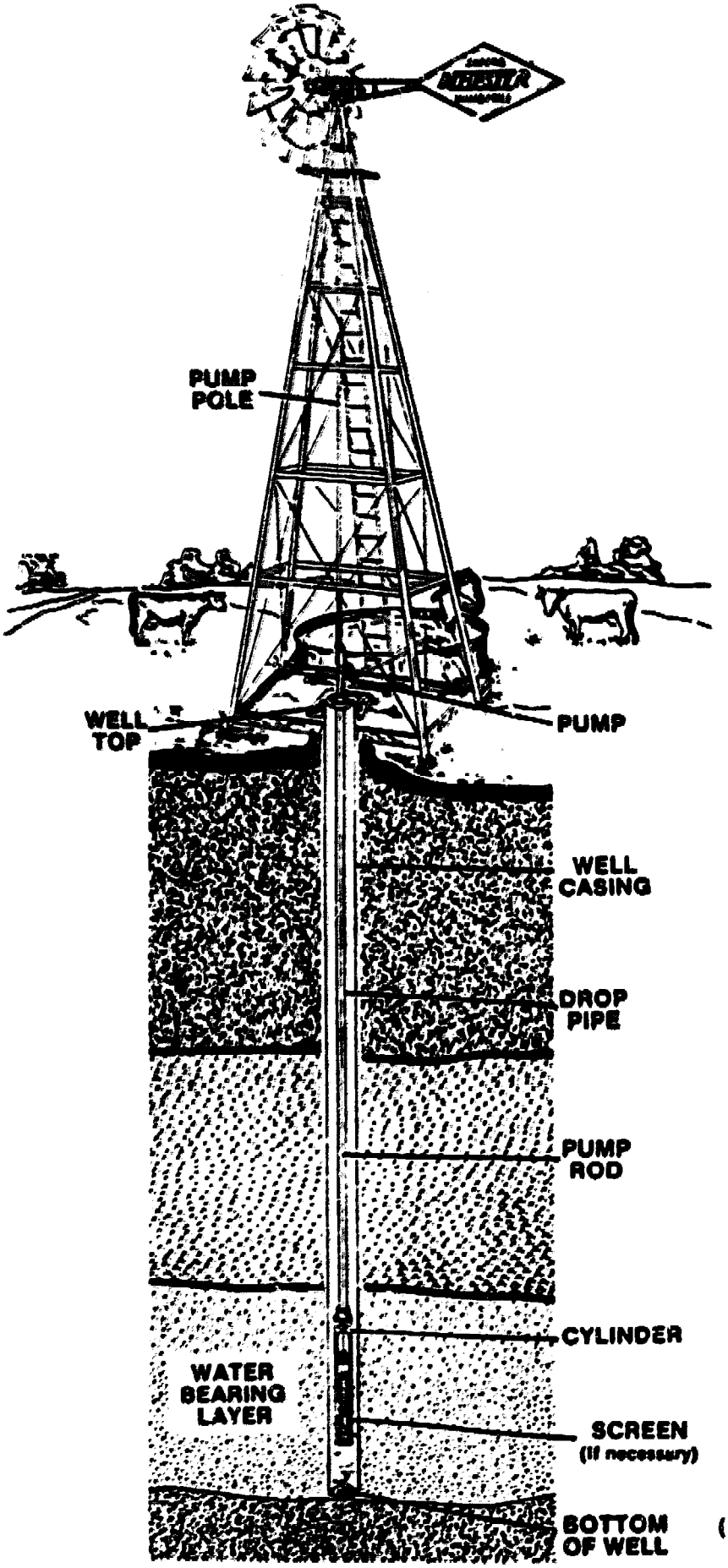

(Dempster Manufacturir
Literature)

- a tower, usually fabricated of steel, on which the windmill head is mounted.

This design is nearly always used with a reciprocating-piston pump. The typical multiblade configuration is designed to provide the required high torque to start the pump at low wind speeds. At higher wind speeds, the efficiency of a system is somewhat reduced due to rotor aerodynamics and load characteristics.

For a fixed wind speed, a windmill's power output is proportional to the diameter of the rotor. Commercial farm windmills vary in diameter from 3.0 to 7.3 meters. Water output depends on the amount of energy delivered to the pump cylinder. Cylinder sizes for reciprocating pumps vary in terms of diameter and length of stroke--the larger the cylinder diameter and the longer the stroke, the more water pumped per stroke. Commonly available cylinders run from 2.25 to 4.0 inches in diameter, although larger sizes can be obtained. The stroke length is generally determined by the design of the windmill head. Towers typically come in heights of 9, 12, and 15 meters.

Recent efforts at improving the design, reducing the weight, and simplifying fabrication procedures for windmills have resulted in a new generation of windmills. These differ from traditional designs in many ways, including the elimination of gears and castings, which permits simplified fabrication techniques, and improved rotor efficiency based on a better understanding of aerodynamic design. Photographs 5 and 6 show two examples of new-generation machines.

Another type of windmill that has been tested and demonstrated on a much smaller scale than the farm windmill is the Savonious vertical-axis design. The rotor consists of several curved metal blades mounted around a central, vertical axis of rotation. Initially, this design showed promise as a simple, inexpensive, easily constructed device for utilizing wind energy. However, for water pumping applications, it has not proven effective. It is inefficient; problems have arisen in controlling its speed to protect it from high winds; towers that are strong and large enough to get the rotor up into the wind-stream are too expensive; and coupling the vertical shaft to a pump that will operate efficiently at the rotor's low rotational speeds has proved difficult.

Other mechanical windmill designs are relatively uncommon, particularly in developing countries. Thus, this section focuses on the steel-bladed, farm-type windmill and recent improvements in this traditional design.

7.2 Operating Characteristics

Water delivery for a wind pumping system depends on a variety of factors, the most significant being

- the wind regime at the site,
- the pumping head,

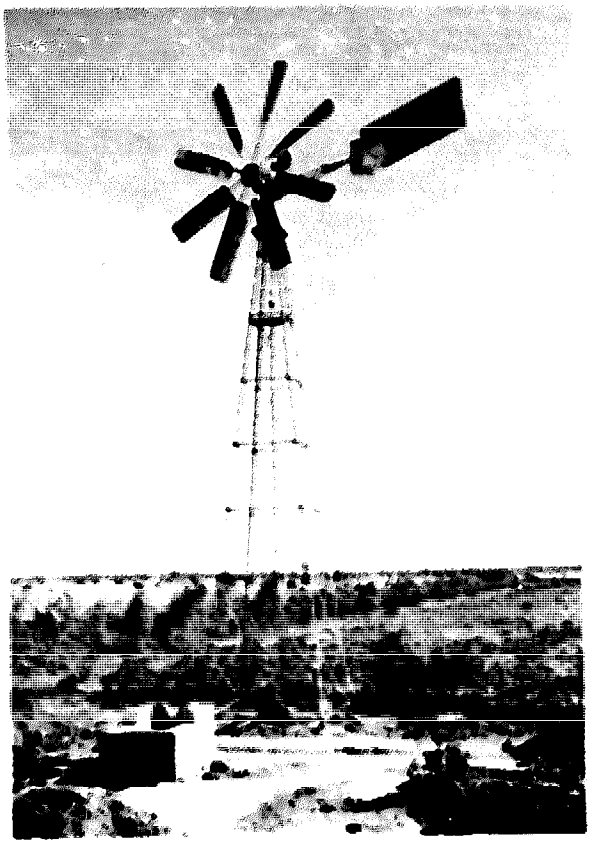

5.

CWD-5000 Windmill for Water and Micro-irrigation near Khartoum, Sudan

6.

Kijito 20-Foot in Botswana

- the diameter of the windmill rotor selected, and
- the pump cylinder.

The single most important factor is the wind speed at the site. The power available in wind varies as the cube of the wind speed--if the wind speed doubles, the power available increases by a factor of eight. Because of variations in wind regimes (e.g., gusts and variable directions), wind speeds can only be measured and predicted in a statistical sense, and water delivery can only be estimated statistically. There is no guarantee that a specific amount of water will be delivered per day, week, or month. This characteristic limits practical windmill use to applications with flexible water requirements or some sort of backup system. It also means that for most applications, a storage tank will be needed, typically holding enough water for three to four days.

Although the other factors listed above are important in the design process, they do not have the same influence on performance as wind speed. The output of a specific windmill/pump combination at a given site is inversely proportional to the pumping head--as the head increases, the output decreases. All other factors being equal, the water output increases as the size of the rotor increases (a larger rotor offers a larger area for wind capture) and the height of the tower increases (winds are faster further from the ground).

Rotor sizing is a fairly simple procedure (see below), but selecting a pump cylinder is more complex. Larger cylinders require greater power to initiate pumping, but once started, they deliver more water per stroke. For each combination of windmill, pumping head, and wind regime, there is an optimum point at which a balance is reached between the longer pumping hours required with smaller cylinders and the higher pumping rates for larger ones. At lower average wind speeds, smaller cylinders are usually selected to maximize total water delivery.

The relationship between wind speed, head, and amount of water pumped for a given size of windmill is shown in Figure 16. (Photograph 7 shows the windmill on which Figure 16 is based.) The two lines show daily water output in cubic meters for a Climax 12-foot diameter machine and 45 meters of head, using 2- and 4-inch cylinders. For example, at an average daily wind speed of 3 m/s, the 4-inch cylinder will pump only about 1.6 m^3/d, but the 2-inch will pump about 2.8 m^3/d because the windmill starts the smaller cylinder moving in lower wind speeds. However, in winds that are 4 m/s and above, the larger cylinder will deliver considerably more water, pumping 8 as opposed to 4.6 m^3/d. This difference increases as the wind speed goes up.

7.3 Choosing a Windmill

In most countries, there is not a wide selection of locally available windmills. It is not so important to have a local dealer for windmills as it is for diesel engines because windmills require less maintenance; nevertheless, a local source

Figure 16

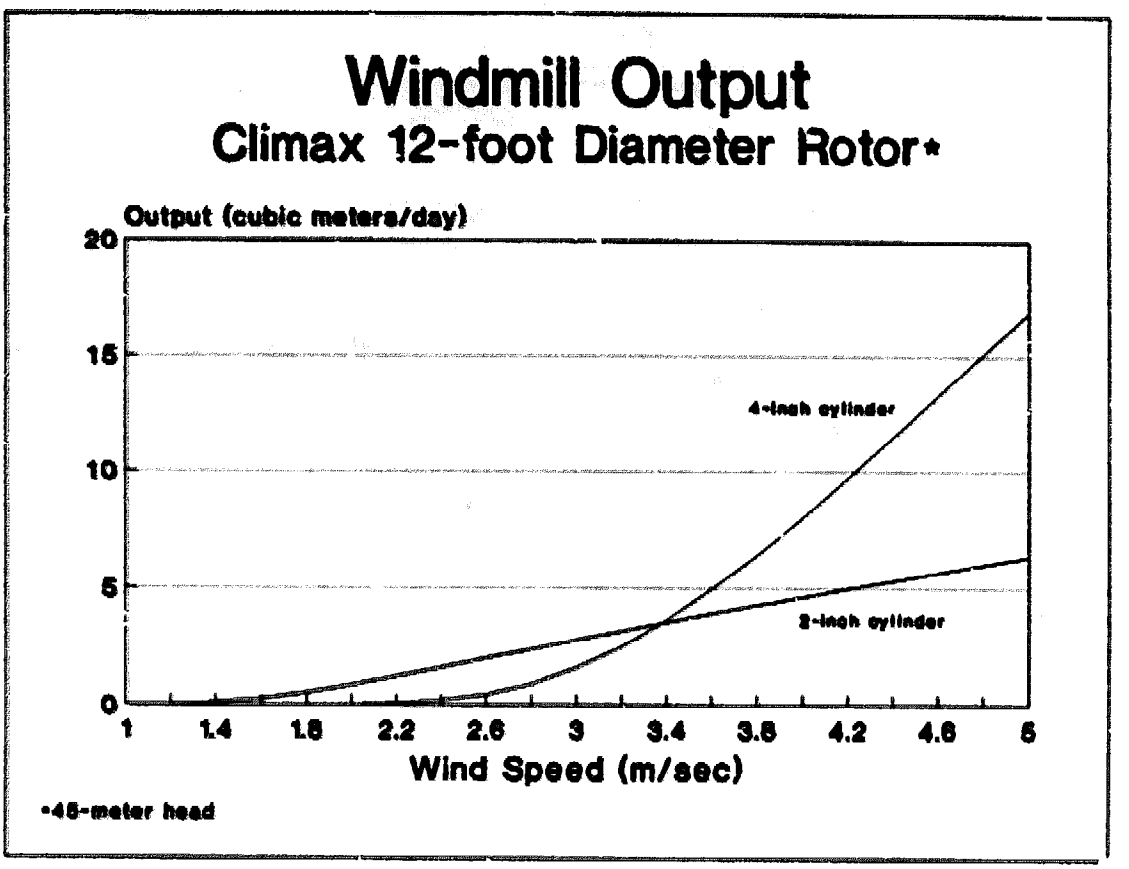

7.

Climax 12-Foot in Botswana used for Village Water Supply and Small Stock Watering

for spare parts is needed. Moreover, if a reputable windmill is manufactured locally in your country or region (e.g., the Kijito in Kenya or the Sanit in Thailand), it is suggested that these makes be considered first. Windmills are usually procured directly from a manufacturer or its agent. The most common approach is to purchase the windmill and tower directly from the manufacturer and the pump cylinder, rod, and pipe from local suppliers. Buying these three components locally is preferable since this ensures that if any parts are omitted or incorrectly specified, they can be replaced locally. It is also a good indicator that spare parts and knowledgeable mechanics will be available if and when they are needed. Finally, purchasing local products for the pump rod and pipe will probably be considerably cheaper.

To follow the design procedures outlined in this section, it is not essential to understand all the aspects of the theory behind wind energy use. Necessary concepts will be introduced as they arise. The general approach in wind system design is to

- determine wind speeds at the site,
- figure the design wind speed,
- calculate the necessary rotor size, and
- choose the proper cylinder.

7.3.1 Site Wind Speeds

There are two ways to estimate average wind speeds at your site. The first assumes that no wind data have been collected at the site but that long-term data is available from a meteorological station relatively nearby. The second method assumes you have recorded several months of wind data at the site, but have no long-term annual data except for information from a nearby meteorological station. In the first case (i.e., no site data), certain correction factors can be applied to estimate wind speeds at your site from meteorological information:

- a height correction, if the windmill will be at a different height than the recording instruments;
- a correction for local terrain conditions; and
- a correction factor if the data has been recorded over a short duration.

These correction factors (described in detail below) should be used with caution. Because the power in the wind is proportional to the cube of the wind speed, small errors in estimating wind speed can lead to large errors in

estimating wind-pump output. Where possible, you should always try to gather at least several months of wind-speed data at your proposed site at the actual planned height of the windmill rotor. These short-term data can then be correlated with longer-term data from the nearest meteorological station. Site-specific data will help you more accurately determine whether a windmill is a good investment or only a marginal one.

Wind data are recorded with an instrument called an anemometer, which is basically an electrical switch that counts the rotations of a multiple cup or propeller rotating at a speed proportional to the surrounding wind speed. The number of rotations are counted, multiplied by a conversion factor, and then divided by the time elapsed to give an average wind speed in meters per second (m/s) or miles per hour (mph).

Anemometers are mounted on poles at a fixed height above the ground, usually 2 or 10 meters. Under normal conditions, wind speeds are greater at higher distances above the ground. This is largely because the effects of surface features and turbulence diminish as the height increases. The variability depends on the distance from the ground and the roughness of the terrain. The wind speed data should indicate the height at which the data were collected (i.e., the height of the anemometer). The most commonly accepted measure of the difference that can be expected in wind speeds between the anemometer's reference height and the proposed height of the windmill is given by the "one-seventh power law":

$$V_2 = V_1 \times (h_2/h_1)^{1/7}$$

where V_2 = unknown wind speed at the windmill's height (h_2)
V_1 = known wind speed at the anemometer's height (h_1)

It is much more difficult to predict average monthly wind speeds if the reference height at which the data were recorded is less than 6 meters. Data collected at heights of less than 6 meters should not be used to select a windmill or predict performance.

In relatively flat areas with no trees or buildings in the immediate vicinity, site selection is not critical. However, in mountainous areas or places where obstacles may block the flow of wind, differences in surface roughness and obstacles between the anemometer and pump site must be taken into account when estimating wind speeds for the site. As a general rule, a windmill tower should be tall enough so that the lowest part of the rotor is at least 9 meters off the ground or 15 feet above any obstruction within a radius of 400 feet.

A correction for local terrain must be used to modify predicted wind speeds if surface conditions at the reference and pumping sites are significantly different. For all practical purposes, terrain characteristics can be divided into three groups:

- smooth—empty cropland and exposed airport locations,
- moderately rough—areas with small bushes or crops, and
- rough—woodland or areas with buildings.

In adjusting estimates between any two of these terrain categories, a 25 percent correction factor should be applied, decreasing the wind speed as surface roughness increases. Figure 17 shows the effects of various obstacles on wind speed, along with the estimated reduction in power at different points behind the obstruction. For example, if a building has a height of H, at a distance of 5H downwind from the building, the turbulence caused by the building reduces power by 43 percent. At a distance 10H downwind, the reduction in power is only 17 percent.

If the length of the recorded data is short, there is a chance that average wind speeds based on the data are not truly representative of long-term averages. If only one year of information is available, average speeds may be in error by 10 percent. Averages for longer periods (three years or more) are likely to be no more than 3 percent in error. If the duration of recorded data is only one year, it is suggested that average wind speeds be discounted by 10 percent as a safety factor to ensure that the windmill will not be undersized.

There is a another simple, but useful, technique for extrapolating from meteorological data to a specific site, if long-term data are available from a nearby meteorological station and you have recorded wind speeds for several months or more at your site (if possible during what you expect will be the design month) (see below). Divide the monthly average wind speeds at the site by the long-term averages for the same months measured at the meteorological site to obtain a correlation factor. Then, use this factor with the meteorological data to estimate the average monthly wind speeds at the site for months with no site-specific data.

Figure 17. Effects of Obstacles on Wind Speed
(See text for explanation.)

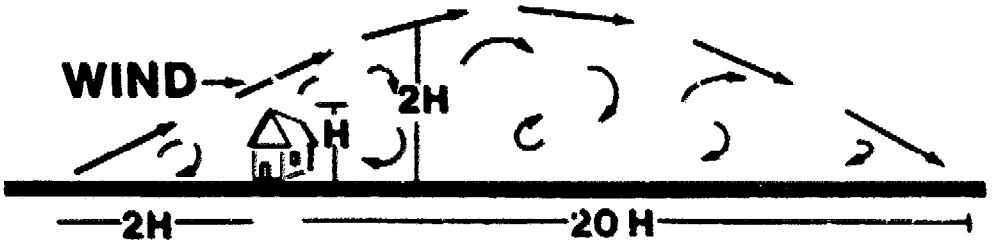

Zone of disturbed flow over small building.

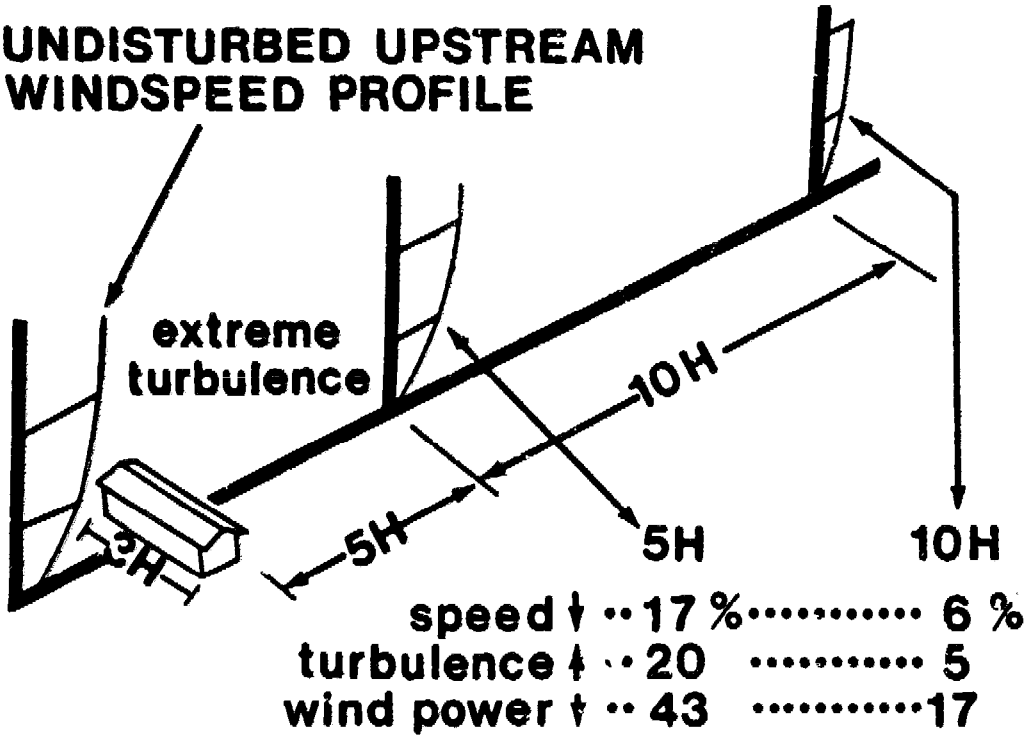

The effects of an undisturbed airflow encountering an obstruction.

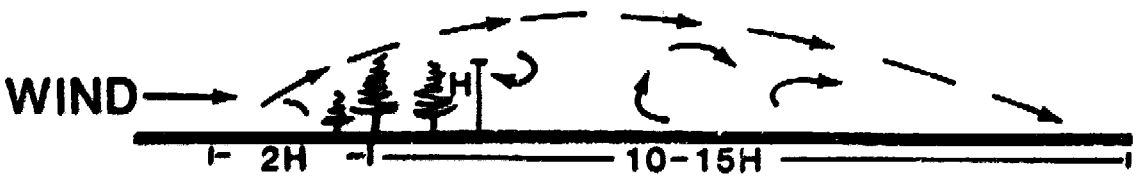

Airflow near shelterbelt.

(Nelson)

Example 12: Windspeed Extrapolation from Another Site's Data

You have installed an anemometer at your site to measure wind speeds for several months. You recorded an average monthly wind speed of 5.0 m/s in April. A nearby meteorological station (with an anemometer at the same height and similar terrain) measured 4.0 m/s for the same month. Estimate the wind speed at your site for a month in which the meteorological station measured 3.5 m/s.

The correlation factor is 5.0/4.0, or 1.25. You can then estimate that the average wind speed at your site was about 3.5 x 1.25, or 4.4 m/s. The accuracy of this sort of extrapolation depends on how closely seasonal variations in wind at the site follow those at the weather station.

7.3.2 Design Month

During the course of a normal year, there are periods of high and low winds. Over a number of years, the pattern of these periods will usually be fairly predictable and should be apparent from an examination of average monthly wind speeds for the region.

In addition to average wind speeds, the water-demand profile at the site must be determined (see Chapter 2), so the design month can be determined. This is the month when it will be most difficult to meet the water requirement utilizing wind energy. If the demand is constant, the design wind speed will be the average for the month with the lowest average speed. If demand fluctuates from month to month, the design wind speed is determined by dividing the average speed cubed by the average daily demand in cubic meters per day (i.e., V^3/m^3/day) for each month and then selecting the month with the lowest value—the design month.

Example 13: Design month

If monthly average wind speeds in m/s for the year starting with January are 2.5, 2.6, 2.7, 2.8, 2.9, 3.2, 3.1, 3.1, 3.0, 2.9, 2.8, and 2.7, and the water requirement is 10 m^3/day from January to June and 12 m^3/day for the remainder of the year, which is the design month?

A quick inspection of the graph shown in Figure 18 below reveals two likely candidates, January and December. Calculations show that the value for V^3/m^3/day is 1.56 in January and 1.64 in December. Thus, the design month is January.

Figure 18. Determining the Design Month

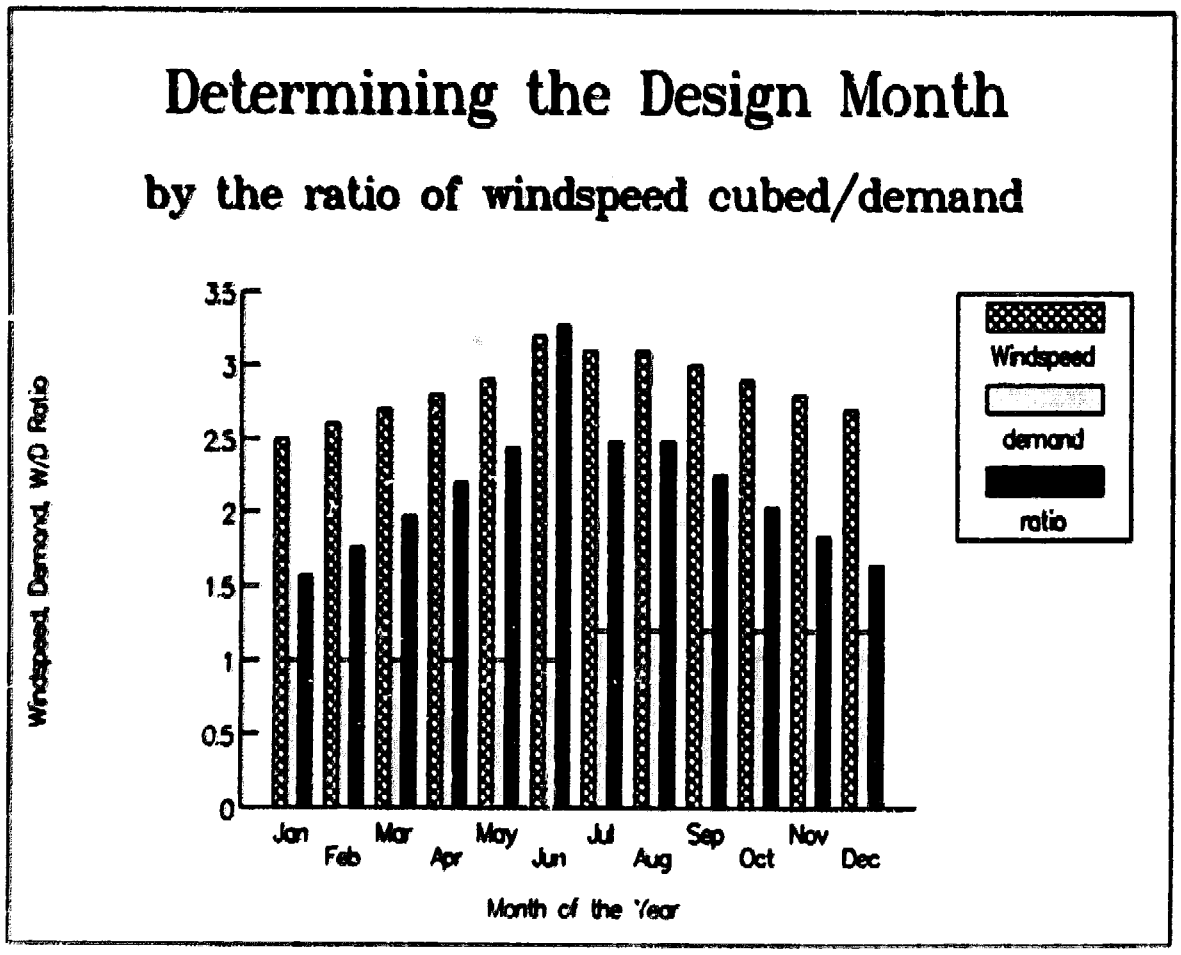

7.3.3 Required Rotor Diameter

The rotor area needed for a specific site depends on the pumping head, design wind speed, water requirement, and overall system efficiency, also called energy efficiency. Windmill output also depends on the pump cylinder chosen. At this stage, it will be assumed that an appropriate cylinder size is available. A method for choosing the proper cylinder size is given in Section 7.3.4. The calculation for selecting an appropriate rotor diameter is

$$D_r^2 = (Q \times H)/(p \times 7.9 \times v_d^3 \times n)$$

where D_r = required windmill rotor diameter in meters
Q = water required in m^3/day
H = total pumping head in meters
p = local air density in kg/m^3
v_d = average wind speed for design month in m/s
n = assumed overall system efficiency as a percentage
7.9 = units conversion factor

For a standard farm-type windmill and average wind speed of 3.5 m/s or greater, use a system efficiency of 6 percent. This figure should be progressively reduced to 4 percent as the average wind speed declines to 2 m/s. For speeds over 4 m/s, a reasonable value for efficiency is 5 to 6 percent. For improved windmills, such as the Kenyan Kijito or Dutch CWD-5000, an efficiency of 8 percent should be used if wind speeds are 3.5 m/s or higher, but this figure should be progressively reduced to 4 percent as the average wind speed declines to 2 m/s. Air density is closely related to air pressure and temperature. In most cases, altitude (i.e., pressure) is the largest factor in air-density calculations. A secondary factor is air temperature. Table 3 below gives correction factors for altitude (K_A) and temperature (K_T). To estimate air density for any altitude and temperature, multiply the density of standard air (1.22 kg/m^3 at sea level and 20° Centigrade) by both factors shown in Table 3. Consult local weather services to get a representative air density for your proposed site.

Table 3

Air Density Correction Factors*

Altitude (m)	=	0	750	1,500		2,250	3,000	
KA	=	1	0.913	0.835		0.760	0.692	
Temperature (oC)	=	-20	-10	0	10	20	30	40
KT	=	1.271	1.125	1.073	1.020	0.989	0.958	0.925

* Adapted from: J. Leki et al., More Other Homes and Garbage (San Francisco: Sierra Club Books, 1981).

Example 14: Estimating Air Density

Estimate the air density at 1,500 meters above sea level at 40° Centigrade. Under these conditions, $K_A = 0.835$ and $K_T = 0.925$. Therefore, air density $= 1.22\ kg/m^3 \times 0.835 \times 0.925 = 0.94\ kg/m^3$. (This means that for a climate like that in Botswana, the power available in the wind is only 77 percent of that at sea level and 10° Centigrade).

Example 15: Rotor Diameter

What is the required rotor diameter for a standard farm windmill if conditions during the design month are $V_d = 3.6$ m/s, H = 25 meters, and $Q = 7m^3$/day, with an air density of 1.0 kg/m^3?

$$D_r^2 = (Q \times H)/(1 \times 7.9 \times V_d^3 \times n)$$
$$D_r^2 = (7 \times 35)/7.9 \times 3.6^3 \times .06)$$
$$D_r^2 = 1.1m^2$$

Thus, D = 3.3 meters or 10.9 feet. So, choose a windmill with a 12-foot diameter, the next largest available size.

7.3.4 Pump Cylinder

To size a pump cylinder properly for a windmill, the concept of system design ratio (X_d) must be introduced. This is the ratio of the system's design wind speed (v_d) to the average wind speed at the site for the design month. The system's design wind speed is the instantaneous operating wind speed at which system efficiency reaches a maximum. For steel-bladed, farm-type windmills, the design wind speed can be approximated as

$$v_d^2 = .15 \times (S \times H \times D_c^2/(D_r^3 \times G))$$

where vd = average wind speed for design month in m/s
S = stroke length in centimeters
H = total head in meters
D_c = diameter of the pump cylinder in inches
D_r = rotor diameter in meters
G = windmill gear ratio

Note that D_r and G are machine parameters that will depend on the windmill selected, and H varies with the site. A pump cylinder can be chosen based on the sizes available. The cylinder diameter (D_c) is given in inches because this is how cylinders are usually measured. All other measurements are in metric units.

A wind pump that is well matched to a site should reach its optimum efficiency around the average wind speed there. This is the case when X_d is 1.0. In many instances, this is indeed true. However, the designer should know that for values of X_d that are slightly below 1.0, the windmill will operate for slightly longer periods because it runs in lighter winds, but it will deliver less water overall, which may have an impact on the size of storage tank required. For values of X_d above 1.0, a windmill may deliver slightly more water on the average, but less during lower wind periods.

The recommended value for X_d is usually between 0.7 and 0.9. Your choice will depend to some extent on the elasticity of demand at the site, but a reasonable compromise is to use a design parameter for X_d of 0.8. The required cylinder size will depend on the value of X_d selected for your site and can be determined using the following formula:

$$D_c^2 = ((X_d \times v_d)^2 \times D_r^2 \times G)/(.15 \times S \times H)$$

where X_d = system design ratio
and all other variables are as defined above.

Example 16: Cylinder Size

A Dempster windmill is to be installed at the site in Example 15. If X_a is 0.8, what is the proper cylinder size? Note that complete machine specifications should be given in the manufacturer's literature on the windmill. For a 12-foot Dempster, they are a stroke length of 18.4 centimeters and gear ratio of 3:1.

$$D_c^2 = ((X_a \times v_d)^2 \times D_r^3 \times G)/(.15 \times S \times H)$$

$$D_c^2 = ((0.8 \times 3.6)^2 \times (3.65)^3 \times 3.0)/(.15 \times 18.4 \times 35)$$

$$D_c^2 = 12.5$$

$$D_c = 3.53 \text{ inches}$$

Therefore, choose a 3.5-inch cylinder.

The sizing method given here is adequate for choosing a windmill and pump cylinder. However, it is possible to make more accurate estimations if more reliable information on the wind resource is available. Computer programs have been developed that permit more accurate and detailed estimates of wind pump output.

7.4 Cost Considerations

This section gives representative costs for several types of windmills and associated equipment, as well as typical recurrent O&M costs and requirements. For models from the same manufacturer, the capital cost of a windmill increases with increasing rotor diameter. As a general estimate, windmills cost between US$200 and US$500 (not including towers) per square meter of rotor area, depending largely on the country of manufacture. Tower costs are proportional to height. For the same-size rotor, traditional designs (e.g., Southern Cross and Fiasa) are sometimes less expensive than "improved" models (Kijito or CWD-5000), but the price is highly dependent on the country of origin. For example, a 16-foot Fiasa on a 40-foot tower costs about US$13,600, shipped from Fiasa Windmills in the United States, and a 12-foot model on the same tower costs US$6,500. In contrast, a Kijito from Kenya costs about US$11,000 for a 24-foot diameter rotor on a 40-foot tower, shipped from Mombasa, while a 12-foot Kijito costs US$5,000.

The price of a pump cylinder depends on the manufacturer, the diameter, and the material. Cylinders manufactured in developing countries are generally less expensive but can be of good quality depending on the source. They are typically available in the 2- to 4-inch range for US$200 to US$800, with larger sizes costing more. The cost of even larger cylinders increases greatly. Most

cylinders are made of brass. Stainless-steel cylinders can be purchased for sites with very corrosive water, but they are often prohibitively expensive.

The prices given here for windmills and cylinders are current as of the summer of 1988, but may vary with new design and manufacturing developments. They also depend on the country of origin—for instance, Kijitos are made in both Kenya and Pakistan but are sold for different prices. The prices quoted here do not include shipping and insurance or local import tariffs and restrictions. If possible, contact a local distributor to get more accurate prices for your area.

7.5 Operating Requirements

As is true of all pumping equipment, the quality of windmill operation and preventive, corrective, and curative maintenance (defined in Section 5.5) will have a definite impact on the reliability of the system, the magnitude of recurrent costs, and the life of the equipment. These aspects of windmill use are closely interrelated, such that following proper procedures in one area will favorably affect other O&M requirements.

Most wind systems do not need a full-time operator, unlike diesel pump sets. When the wind blows, the windmill pumps water. All farm windmills and most of the improved designs have safety mechanisms to turn the rotor out of the wind to protect it during periods of high wind. Despite these self-regulating design features, a part-time operator or caretaker may be advisable for a number of reasons. His or her tasks would include the following:

- periodically checking the windmill and storage tank,
- performing light maintenance,
- manually furling the windmill when the storage tank is full and unfurling it when more water can be added, and
- reporting major repair needs to repair crews.

The issue of paying a part-time operator or caretaker will vary depending on the pump application and community structure. It should be noted that the cost of this item can make a difference in determining the economic and financial feasibility of a wind pump.

7.6 Maintenance and Repair

While normal preventive maintenance requirements for windmills are minimal, they are important. They include routine tightening of all nuts and bolts, changing the lubricating oil, greasing certain parts, and periodically changing the pump-cylinder leathers as they wear out. Ignoring any of these small tasks, can damage the machine and, at best, will decrease its expected service life. If these tasks can be accomplished by a local caretaker instead of an area

mechanic, operating costs will be reduced because labor and transportation costs will be saved. In addition, the system is likely to be more reliable if the responsibility for maintenance rests with someone who benefits directly from its proper operation. This is not possible with some tasks, however, such as changing pump-cylinder leathers, which usually requires tools for pipe lifting.

The frequency of routine maintenance depends on conditions at the site. It is recommended that windmills be checked visually at least once a month and remaining maintenance tasks be carried out annually. The life of cylinder cup leathers depends to some degree on water quality (i.e., grit or sand in the water) and may range from less than a year to over two years. In the absence of other information, an average replacement interval of one year is a reasonable estimate for planning purposes.

Minor problems that do not cause a system to break down require corrective maintenance. The most common problems typically involve the windmill's manual furling mechanism. Broken furling cables do not disable the windmill and, in most cases, the problem can be rectified at the local level. However, if left unrepaired, a broken furling mechanism will prevent the windmill from being manually turned out of high winds, which could cause irreparable damage.

When curative maintenance is required for breakdowns, outside assistance is often needed to restore the windmill to operation. The most common curative maintenance problems are broken or disconnected pump rods. How often this problem arises is highly dependent on the quality of the original installation. Improperly installed rods or crooked borehole casings can cause regular breakage of sucker rods. The problem may arise only every several years or as often as every few months. A typical rate for a reasonably well installed system is once a year.

Field experience has indicated that an average windmill installation will have three to four maintenance problems annually. The reliability and serviceable life of the windmill system will be increased and costs decreased in proportion to the amount of maintenance and repair work that can be handled at the local level as well as the responsiveness of outside help, when it is required.

7.7 Equipment Life

The long-term cost-effectiveness of windmills depends on a system having low recurrent costs and a long useful life. Historically, the popularity of steel-bladed, farm-type windmills in many areas was due to the fact that they possessed these attributes, with typical lifetimes often in excess of 20 years and occasionally as long as 40 to 50. Windmills have not had such a favorable record in developing countries. Often, the first or second breakdown has been the end of a windmill's useful life, because local people were not often trained in proper operation and repair procedures before the system was installed. This situation emphasizes the importance of identifying a capable maintenance and repair organization before installing a wind pump and establishing a satisfactory, cooperative, and responsive relationship between that organization and the users of the system to ensure a long, useful life for the machine.

Chapter 8

HANDPUMPS

Considerable research and development have been undertaken over the last 10 years in an effort to produce more efficient, reliable, low cost handpumps that can be manufaccured locally. As part of the United Nation's International Drinking Water Supply and Sanitation Decade, the World Bank has funded comparative studies of handpumps (Arlosoroff et al. 1987) that have focused on the concept of village-level operation and management of maintenance (VLOM). VLOM pumps can easily be installed, operated, and maintained by village mechanics and technicians without expensive tools.

It is increasingly apparent that handpumps are the least expensive, most reliable technology for many applications, particularly for low-demand sites (about 5 m^3/day). When properly maintained, handpumps can be very reliable, but community involvement in maintenance and repair is usually required to ensure their long-term performance. Such involvement decreases the need for O&M support from outside the local community, which often makes handpumps a more attractive option in the eyes of development planners and, more important, users. Handpumps that can be maintained locally are likely to result in much higher water availability for the community, compared to other systems where maintenance or repair depend on the intervention of centrally based repair crews which are usually overburdened.

This chapter discusses the technical characteristics, costs, and support requirements of handpumps used for domestic water supply. Sizing is a much less complex design issue for handpumps than the other systems discussed in this manual, so the selection criteria presented here focus more on other issues related to maintenance and repair. There is a wide variety of human-powered pumping systems that are used primarily for agricultural purposes, including foot-powered treadles, shadoofs, and chain-and-washer pumps, but these will not be discussed further here. Kennedy and Rogers (1985) and Fraenkel (1986) offer in-depth discussions of these other types of human-powered pumps.

8.1 Types of Handpumps

Over 50 makes and models of handpumps are available worldwide. All depend on human power and, thus, have a limited pumping rate and head range compared to the other mechanical systems considered in this manual. Handpumps can be divided into four categories:

- high lift--positive-displacement pumps capable of pumping from depths of up to about 45 meters,
- intermediate lift--for lifts of up to 25 meters,
- low lift--up to 12 meters, and

- suction pumps--up to 7 meters.

These categories include high-lift reciprocating, diaphragm, progressive-cavity, direct-action, and suction pumps. Illustrations of several common types of pumps are shown in Figure 19. Two typical installations are shown in Photographs 8 and 9.

Deep-well reciprocating-piston pumps are the best-known type of high-lift pumps. They usually have immersed pump cylinders and are operated with lever-arm pump handles. The most common designs are the India Mark II and Afridev. These pumps can lift water from up to about 45 meters, although some other designs are more suitable for lifts of less than 25 meters. Typically, high-lift piston pumps are

- more difficult and expensive to maintain at the village level than low-lift pumps,
- operated at a decreased pumping rate as head increases, and
- generally less suitable for local manufacture in developing countries.

A second design suitable for high-lift pumping is the progressive-cavity pump. Similar to a screw pump in its operation, this design incorporates a rotor turning within a stator that progressively forces water up the drop pipe. The Mono and Moyno brands are examples of this design.

A third type of high-lift pump is the deep-well diaphragm design. It uses a flexible membrane that is repeatedly stretched and relaxed mechanically to provide the pumping action. The French Vergnet is perhaps the best example of this type. These pumps are especially suitable for sandy or silty water. However, compared to reciprocating-piston pumps, they are generally more complex and expensive and often require specialized parts and tools for maintenance and repair.

Direct-action systems, such as Blair and Kangaroo pumps, are suitable only for lifts of up to about 12 meters because the pumper acts directly on the pump, without the advantage of a lever arm. Compared to the designs mentioned above, these pumps tend to be

- low in cost,
- more suitable for village-level maintenance, and
- inappropriate for heavy use--they should probably not be considered for sites where the water demand is above 1.5 to 2 m^3/day.

Figure 19. Different Types of Handpumps

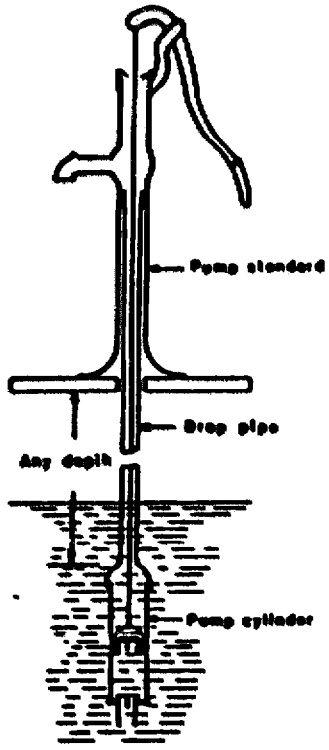

Deep Well Piston Pump*

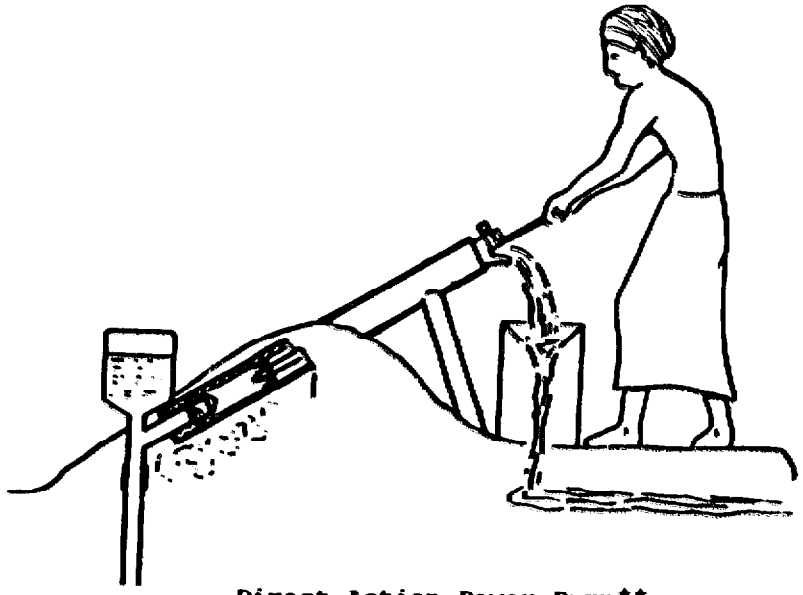

Direct Action Power Pump**

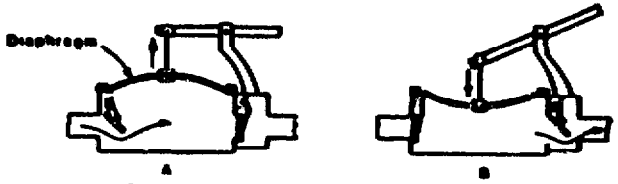

Surface Mounted Diaphragm Pump*

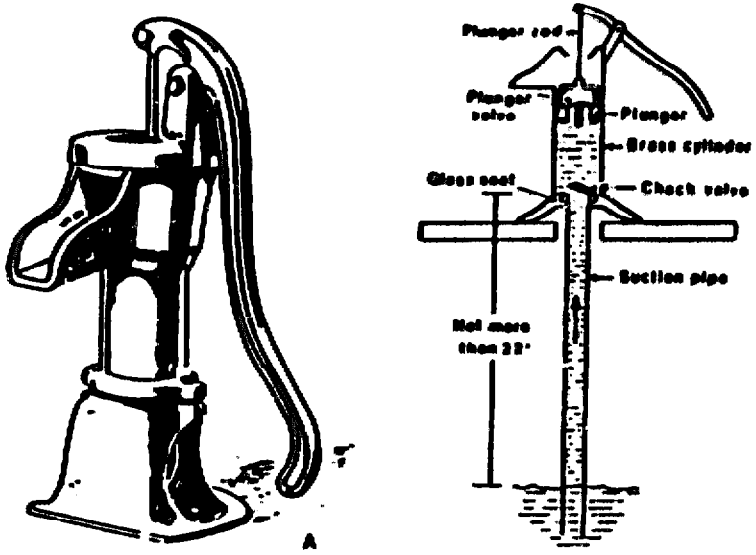

Shallow Well Suction Pump*

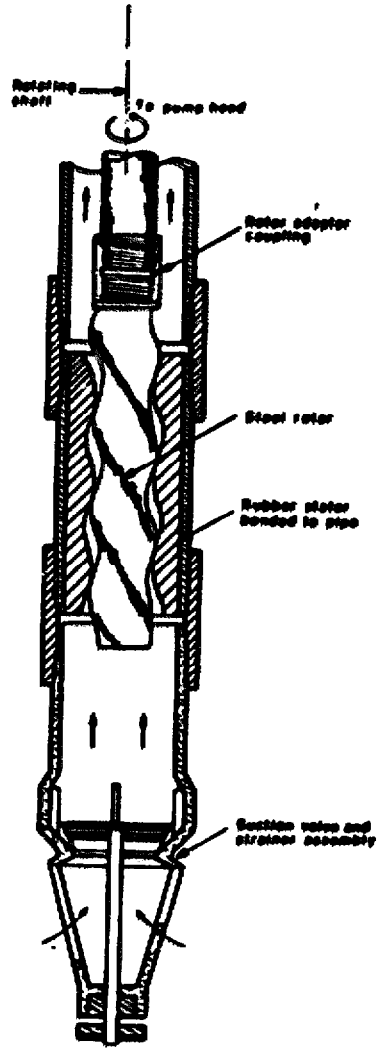

Helical Rotary (Mono) Pump*

*(McJunken 1983)
**(Fraenkel 1986)

8. India Mark II Piston Handpump in Botswana

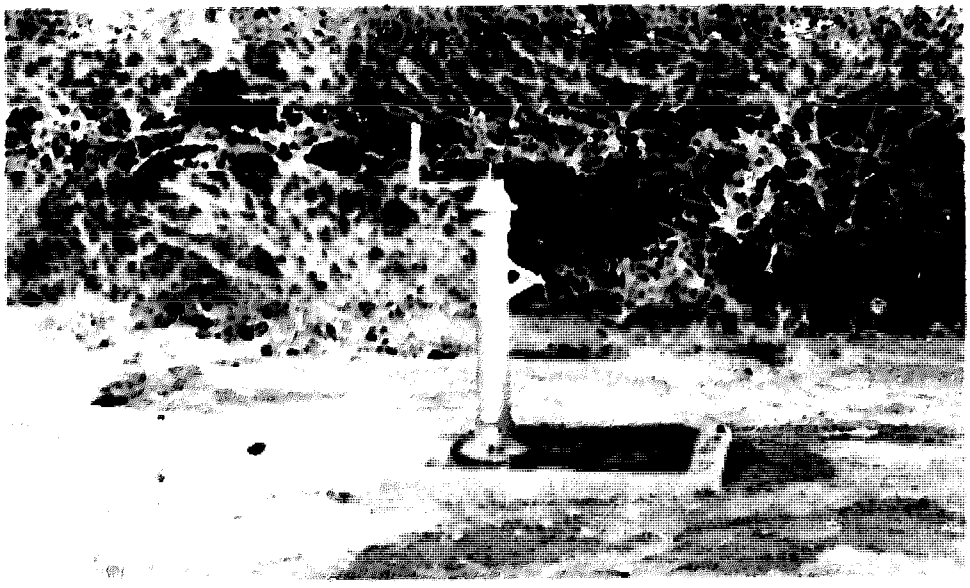

9. Mono Direct Drive Handpump in Botswana

Suction pumps operate by creating a partial vacuum to pull water upward. Thus, they are useful only for lifts of no more than 7 meters, a limit that decreases at higher altitudes. Suction pumps must also be primed before use by pouring water into the space above the plunger. Still, these pumps are very popular in areas where heads are low. This type of pump tends to be

- low in cost,
- easy to service and repair because all moving components are at ground level, and
- primarily suited to meeting fairly limited water needs.

Since low- and intermediate-lift pumps are essentially simplified versions of high-lift pumps, only high-lift and suction pumps will be discussed further in this chapter.

8.2 Operating Characteristics

The operating characteristics and requirements of handpumps are significantly different from those of diesel, solar, and wind systems. These differences between handpumps and the other systems include both advantages and disadvantages. The most important advantages of handpumps are their simplicity of operation, low cost, and potential for local maintenance. The significant disadvantages of handpumps are that their capacity is very limited and they generally cannot be used with piped distribution systems. To some extent, these drawbacks can be overcome by using more than one pump. Of course, this would usually require additional water points, which would entail high costs for drilling or digging more wells at sites where groundwater is pumped.

The capacity of handpumps varies from 5 to 20 liters per minute, or 0.3 to 1.2 m^3 per hour on a continuous basis, depending on the head and pump type. In practice, output is often more dependent on the users than on the capacity of the pump—even if people are organized, lined up, and ready to begin pumping as soon as the preceding person finishes, it still takes time to remove the full container under the discharge pipe and replace it with an empty vessel. Output is also affected by the speed (i.e., effort) with which a pump is used, a factor that varies considerably from user to user. Under typical conditions, a single handpump can deliver 4 to 5 m^3/day, enough for 200 to 250 people. This capacity limits the use of handpumps to villages and settlements with small populations, even if multiple pumps are installed. Depending on particular site constraints, a system of four or five handpumps may provide a reliable water supply that is cost-competitive with other options. This, of course, depends on the costs of digging the wells for each pump.

Usually handpumps deliver water only to the wellhead and cannot easily be adapted to central-standpipe or yard-tap distribution systems. This fact has two implications. First, water sources should be within a convenient walking distance for users. Any economic analysis of the number of water points to be

included in a system should consider the opportunity cost of time required to collect water. Second, compared to distributed water supplies, significant capital savings are realized when a storage and distribution system is not needed.

8.3 Operation, Maintenance, and Repair Requirements

Maintenance programs for pumping systems are usually handled by the community or a centrally based organization. In the former (e.g., VLOM), the community takes direct responsibility for the pumping system and only contacts outside help for repairs if necessary. In centrally based programs, responsibility for a system rests with an outside agency, contacted by the community whenever any servicing is required. Studies over the last several years have repeatedly shown that community involvement is an important factor in successful long-term operation of handpumps. To the greatest extent possible, community participation in pumping projects should be encouraged from the earliest planning stages.

As is true for more complex technologies, the proper design, procurement, and installation of handpumps are necessary, though not sufficient, conditions for successful long-term use. Correct operation, maintenance, and repair procedures are equally important. The VLOM approach to handpump design focuses on reducing users' dependence on external support. This approach can save money and time and can also minimize other problems (e.g., communication, transportation, and improper repairs) often associated with centrally supported maintenance and repair programs. Since handpumps are relatively simple pumping systems, they lend themselves to the VLOM approach.

VLOM programs provide an O&M structure that is more directly responsive to community needs. However, centralized programs with mobile mechanics that serve specific geographic areas can complement the VLOM model by mobilizing trained mechanics, tools, and transportation when more complicated repairs are required. VLOM water supply programs include training components to identify and develop the capability of a village caretaker to perform light maintenance, prevent abuse of the pump through improper operation or vandalism, and quickly summon outside help for maintenance and repairs as required. Caretaker effectiveness is the critical component in successful handpump use.

Regular preventive maintenance for handpumps--for instance, tightening nuts and bolts, and keeping the area clean--should be performed at the local level by the village caretaker. As previously defined, curative maintenance includes actions that are necessary to restore pumping following a breakdown. Most handpumps are not truly VLOM designs, so it is frequently impossible to handle all maintenance and repair at the village level. Often, repairs are required when below-ground components fail due to poor water quality, heavy use, or simple wear. This type of work usually involves the transportation of a repair crew with appropriate tools from a central workshop. In such cases, a prompt response is necessary to ensure a steady supply of water.

Down-hole components that occasionally require maintenance, repair, or replacement are the cylinder, cylinder or cup leathers, drop pipe (through which

water is pumped), and sucker or pump rods, which drive the piston inside the cylinder on piston pumps or turn the rotor on Mono-type pumps. Replacing cup leathers is the most common repair. Depending on the type of cylinder, this may involve pulling the entire cylinder or just the piston. Periodically (with greater frequency at sites with poor water quality), the drop pipe will need to be replaced. Sometimes, pump rods become disconnected and must be replaced if they cannot be fished out of the well.

The most common maintenance problem encountered above ground is the occasional need to replace worn bearings on the pump handle. Other problems invariably arise with the pump head or other components. The frequency of such repairs will depend on the particular pump selected for the site and the care it has received during use. The amount of lost pumping time and repair costs will be a function of the nature of the problem, the availability of necessary spare parts, and the responsiveness of the maintenance structure.

A reasonable range for frequency of repairs is three to four times a year to once every two years. The level that is acceptable will depend on the responsiveness of the repair infrastructure and the total amount of time the pump is out of service. If repairs can be done at the local level, outages will be shorter and a higher breakdown frequency may be acceptable to users. If repairs must be done by a centralized maintenance unit, it may take several days to a week or more before problems are addressed, and a greater frequency of repairs is not as likely to be tolerated.

The expected lifetime for handpumps is difficult to estimate as it depends on the conditions and amount of use as well as care the equipment has received. However, typical ranges are anywhere from 5 to 10 years.

8.4 Choosing a Handpump System and Model

People are often reluctant to consider handpumps because of their obvious limitations, despite the equally obvious potential for cost savings. The following sections offer some basic recommendations regarding constraints on handpump use to assist you in determining whether or not handpumps are the right choice for your site.

8.4.1 Application Limits

Handpumps should not be considered if the total head at your site is more than 45 to 50 meters, due to the physical difficulty of pumping water from greater depths. You should also take into account whether the maximum anticipated head will be further increased by drawdown in low-yield wells or seasonal fluctuations of the water source—both are likely with shallower sources that are more dependent on seasonal recharge.

If the maximum anticipated pumping head is less than 45 meters, the next concern is the water requirement. Given that a typical handpump can serve 200 to 250 people (i.e., provide 4 to 5 m^3/day), the number of handpumps and wells needed for larger sites can easily be calculated. In some circumstances (e.g., very

remote sites where diesel fuel may be expensive or difficult to obtain and where qualified technicians may not be available), four to five handpumps may be a more attractive option than a single diesel pump that has greater pumping capacity and its associated water storage and distribution system. Certainly, the cost of developing additional wells, water storage and distribution systems, and the maintenance associated with these components must be considered in deciding which type of system to use (see Chapter 10 for an economic analysis of pumping systems).

Convenience and health concerns should be considered in system design and siting. Well siting and user convenience are not as important for pumping systems that can distribute water through central standpipes or private connections. However, for handpumps to be a viable option, they should be located no more than a reasonable walking distance from users--400 to 500 meters. At sites where water sources are located well outside village boundaries (perhaps to reduce the risk of pollution), handpumps are probably not suitable because of the distance and time that would be required to collect water. The need to prevent well pollution is also important. Pollution may occur through direct entry, as occurs with open, hand-dug wells, or the migration of contaminants from the surface. Provisions should be made for a well apron and "soak-away" or drain to keep the area around the well as clean and dry as possible.

8.4.2 Selecting a Handpump Model

In terms of equipment, the process of system design for handpumps consists mainly of choosing the pump and, in a few cases, an appropriate cylinder. Pump selection depends on a number of factors, including anticipated maximum lift, water requirements, discharge rate, ease of maintenance and reliability, and resistance to corrosion and abrasion. Additional concerns are the availability of the pump locally and, where appropriate, the potential for local manufacture. When selecting a pump consider these factors in the following order:

- operating conditions--head and output requirements,
- ease of maintenance--dependent on local O&M infrastructure,
- reliability--see the ratings given below,
- resistance to corrosive or abrasive water conditions, and
- potential for local manufacture of the entire pump or some of its components.

In many areas, handpumps can be purchased only through agents from abroad. In others, imported handpumps can be ordered through a local dealer or distributor. Occasionally, local suppliers stock imported pumps or even models manufactured locally. There is increasing interest in promoting the local fabrication of

handpumps in countries where the industrial capacity is sufficient to ensure high-quality products. The advantages of in-country manufacturing include:

- cost savings, as the result of lower labor and shipping costs;
- local technicians' familiarity with the units, thereby ensuring better maintenance and repair capabilities;
- increased availability of spare parts; and
- local income generation.

In addition to a moderately developed industrial capability, an adequate local or regional market must exist before local manufacturing of handpumps should be considered. At the project level, the decision to use handpumps should include an evaluation of the potential for future fabrication of the entire pump or some components. If local manufacturing is seriously being considered, various associated needs must be studied. High-quality manufacturing of pumps and/or spare parts can be an expensive, time-consuming project. The implications and cost of such a program must be carefully considered within the overall context of a country-wide water resources development strategy.

If you determine that handpumps are the most appropriate technology, based on the water demand at the site, the operating constraints, and other factors discussed above, the best single source of information on choosing a particular pump manufacturer and model is Arlosoroff et al. 1987. The section titled "Handpump Compendium" contains summary descriptions of over 100 makes, 86 of which were tested during the World Bank's handpump project. Each description includes an overall assessment and ratings on discharge rate, ease of maintenance, reliability, corrosion resistance, abrasion resistance, and manufacturing needs. After first determining which pumps can be procured locally, use this reference to choose between the available models. The book also contains a set of four pump selection tables organized according to head limits--7, 12, 25, and 45 meters. Within these four categories, pumps are rated on each of the six areas listed above. These summary selection tables are reproduced in Appendix D.

8.5 Cost Considerations

When comparing water costs for handpumps with those for other technologies considered in this manual, special care must be taken to include all relevant costs. Only those items that are common to all systems can be overlooked in such comparisons. For example, if you consider using multiple handpumps to meet a demand for distributed water, you must include the cost of developing multiple water sources. Similarly, if this is to be weighed against the cost of a distributed water supply provided by a diesel pump, remember to include costs for piped distribution, water storage, and associated maintenance and upkeep.

The installed capital cost of a handpump varies depending on the type of system and its location. Prices given here are for 1988. Low-head pumps typically cost US$200, but may be as low as US$50, particularly when they are manufactured locally. Pumps for higher heads, which are usually imported, can cost considerably more, between US$300 and US$1,000 per unit plus shipping. Pump or sucker rods cost about US$2 to US$3 per meter and drop pipe about US$5 to US$7 per meter. The cost for a well cap and concrete drain varies considerably depending on local labor and cement costs, but averages around US$50 to US$100.

8.5.1 Operating Costs

Handpump operation is fairly straightforward. The only "fuel" cost is the pumper's salary, if any. Handpumps do require attended operation, but in most cases, pump operators are the water users themselves and so are not paid. Even so, a proper economic analysis of handpumps should consider the labor cost of pumping water. When considering different system options, be sure to include all the costs of supplying water. For example, some handpump sites may be located outside the village. If you are comparing a handpump system (where water users must carry water from the pump site to their village) to a diesel or other system which pumps water to public, centrally located standpipes, the cost of any additional labor for carrying water from the handpump site to the central location should be included in the analysis (as should the cost of the distribution system for the diesel system).

Handpumps require a time and labor commitment from users, who could use that time in other ways if another pumping option were chosen. This is not usually a factor when considering diesel, solar, or wind pumps. As mentioned above, daily care of a handpump should be entrusted to a caretaker, who has some skills and perhaps enough tools to permit him or her to fix minor problems. This person may or may not be paid by the community or as an employee of some public agency.

8.5.2 Maintenance and Repair Costs

For convenience, maintenance and repair needs have been divided into nine potential problem areas:

- the pump handle;
- the fulcrum or bearings;
- the rod hanger, where the sucker or pump rods attach to the bottom of the fulcrum;
- the pump rods, becoming disconnected from each other or the pump element;
- the rising main or drop pipe;
- the piston seal, often referred to as the leathers;

- the pumping element--for example, the piston in reciprocating pumps and the diaphragm in diaphragm pumps;

- the foot valve, which prevents water from draining out of the drop pipe and causing a loss of priming in suction pumps); and

- other problems.

For piston pumps (including high-lift reciprocating, low-lift suction, and direct-action types), the leathers are typically the most common item needing repair. They will probably require replacement every six months to two years, depending on the quality of the water and the degree of pump use, with heavy use increasing the frequency of replacement. The cylinders will likely last five to seven years, depending on the same factors. A typical maintenance and repair crew can replace the leathers or cylinders in one day (not including transportation to the site), even if the cylinder and drop pipes have to be pulled. If the drop pipes have to be pulled, a special rig or tripod may be needed to lift them from the borehole.

The bearings are the second most common problem area in piston pumps. Depending on the design, the replacement of bearings can be very difficult. New pump designs, such as the Afridev, use plastic bearings that can be easily replaced in order to minimize this problem.

For Mono-type pumps, the bobbins holding the pump rods in place will have to be replaced periodically, in addition to the pump rods and drop pipes. In general, the pump itself is very long-lasting and will probably require replacement only every seven to ten years under normal use. For diaphragm pumps, the part that is most likely to need periodic replacement is the diaphragm, every three to five years. Typical frequencies for the maintenance and repair needs of many pumps are given in the "Handpump Compendium" section in Arlosoroff et al. 1987.

A reasonable estimate for a typical cost range for the maintenance of handpumps is US$25 to US$200 per year, assuming the pump is used regularly for about eight hours per day.

Chapter 9

OPERATION, MAINTENANCE, AND REPAIR

Technical selection of pumping equipment has been explained in detail in the preceding chapters. By now, you should be able to determine which systems meet or fail to meet the pumping requirements at your site. If no systems meet the selection criteria, a reevaluation of the criteria, site, or project is necessary. Assuming that you have narrowed the choice down to one or more system options that are technically acceptable, you must now make certain that these pumping systems can be operated and maintained properly.

Before further selecting systems from among the remaining equipment options you must weigh a number of additional factors involving the complex interrelationship between the physical equipment, pump users, and infrastructural support network that keeps the equipment operating over the long run--system designers, equipment dealers, installation personnel, operators, and maintenance and repair crews. These factors are not nearly so easy to quantify as the head, the flow rate, and the various cost issues discussed in previous sections. As a decision-maker, you must determine what these factors are and weigh their relative importance.

The first important criterion in equipment selection is the technical question of whether the system can deliver the desired amount of water. The next is that proper operation, maintenance, and repair support will be available to ensure that the system will continue to supply water reliably over the long term. This requires an infrastructure that can provide the following important needs:

- spare parts inventories,
- skilled operators and mechanics,
- transportation networks,
- communication, and
- clear lines of authority and responsibility.

In each of the five broad categories of maintenance requirements covered in the following sections, a series of questions are posed that can be used to determine whether or not the local or regional infrastructure will be able to respond to the needs of the specific type, make, and model of equipment you are considering.

9.1 Spare Parts

Probably the most important determinant of whether a pumping system can be maintained over the long run is the availability of spare parts. All parts required for the pump set you select must be available at some location that is relatively near (i.e., can be reached within a reasonable time) or the pump's first failure may mean the end of its service life. Servicing guidelines for diesel engines (often provided by manufacturers) usually divide spare parts into two groups--fast-moving spares and other parts. Fast-moving parts include items needed for preventive procedures and common corrective maintenance, such as gaskets, belts, and injector nozzles. These should be readily available at a nearby location for the engine make and model you choose. Other spare parts that are less commonly needed include cylinder heads, crankshafts, and flywheels. These must also be available, but since the need for them is likely to be less frequent, you may be able to tolerate a longer delay in obtaining them.

For handpumps and windmills, fast-moving spare parts that are often needed are essentially limited to cup or cylinder leathers and wooden sucker rods for windmills. Since these are few in number and relatively inexpensive, these systems are less vulnerable to outages caused by a lack of parts than diesel engines, which require many fast-moving parts. Solar PV pumps do not typically require any fast-moving spare parts, although all hand, wind, and PV pumping systems will occasionally require unexpected repairs (such as replacement brushes for some PV motors). The parts needed to complete these repairs--e.g. a handpump head, windmill blade, or invertor--may only be needed every three, five, or ten years. However, when breakdowns occur, these spare parts should be available in local or nearby regional inventories, since it is highly unlikely that they can be fabricated locally under most circumstances found in developing countries. The more fast-moving the part, the more widely it should be distributed. For example, diesel belts should be available at the local level, but pump cylinders or PV modules need only be available at the district or perhaps national level.

It is possible that parts may only be available at greater distances from the site (i.e., from a central or regional, rather than a local, inventory), so a longer period may elapse before repairs are completed. In that case, the system designer and users must decide how they will meet water requirements until the system can be repaired. In some instances, especially if the part is very expensive and the number of systems being supported is small, it may be too expensive to maintain a regional inventory, so high-cost spare parts will have to be imported on an as-needed basis. If this is the case, it is essential that there be a communication and distribution network in place already, including import agents and distributors, and that planners and water users understand how much time is required to procure imported parts. One solution is to maintain a local inventory of at least one complete set of all spare parts for a system. These can be replaced as they are used.

To get a clear picture of the possible difficulties in obtaining required spare parts for the remaining equipment options, answer the questions below.

1. Are all spare parts available locally at the pump site? List the name of local shop(s) or agent(s) and the types of spare parts they carry.

2. How far is the nearest location outside the village where fast-moving spare parts for your pump set are available? List the name of the village, the distance from the site, and the name of the shop or agent.

3. Where do you have to go to get uncommon spare parts (usually the same location where full service and overhauls are available)? List the names of the agents and the spare parts and service they can provide.

4. How long does it take to get spare parts when they must be ordered or imported?

9.2 Skilled Operators and Mechanics

The second broad category under O&M requirements is skilled personnel. The skills required to operate a pumping system are very different from the technical and diagnostic skills needed to ensure a long service life and proper repairs. Tasks for operators or caretakers typically include

- starting and stopping the pump set, as required;
- performing daily checks of fluid levels (where necessary) and equipment condition;
- handling limited preventive maintenance, as the operator's training and authority and the available parts and tools allow; and
- contacting the proper authority to explain specific problems, when needed.

Operators and caretakers are the most important human component in successful system operation. They form the first line of defense in the ongoing effort to keep a pumping system operational.

Mechanics are necessary when the required maintenance or repair procedure is beyond the operator's authority, capability, or capacity. Typically, mechanics must have

- mobility to travel to the pump site,
- the ability to accurately diagnose problems in the system,
- access to necessary tools to complete minor and major repairs, and
- the skills needed to make complicated repairs in the field.

If individuals in the community possess repair skills, this will help assure that a broken down system is returned to service promptly. Handpumps and windmills are most suitable for local repairs. Since the skills needed are fairly limited, people in the community can be trained to perform most maintenance and repair tasks. The widespread use of diesel engines for pumping water and generating electricity in isolated areas means that there are usually some area mechanics who are at least partly skilled. If the level of local repair capabilities is doubtful, skilled personnel from outside the immediate community may be necessary to ensure that proper maintenance procedures are followed.

Solar pump repairs can require specialized skills that are not normally found in rural areas. Individuals with basic skills in electricity may be available, but the specialized nature of PV technology may mean that suitable technicians will not be available even within the region. Although solar pumps rarely need curative maintenance, it is still important to consider who will perform such repairs. If mechanics are only available regionally, you should also consider how far they may be willing to travel.

To determine the availability of qualified operators or caretakers and trained technicians as well as their potential ability to handle maintenance and repair functions, you should answer the following questions.

<u>Operators</u>

1. Do the people nearby that might serve as potential operators or caretakers have any experience or familiarity with the equipment you are considering?

2. Are there individuals with sufficient education and mechanical aptitude that could be trained to perform these functions well?

3. Are operators likely to have the tools needed to operate the system properly and handle minor repairs?

Mechanics

1. Are skilled mechanics and/or electricians available in the village who have general mechanical, engine-repair, and/or electrical skills?

2. How far must mechanics trained in engine and/or electrical repairs travel to assist with maintenance of the pumping system?

3. Are mechanics from outside the community available year-round, or would transportation problems or other responsibilities make them unavailable sometimes?

4. Can arrangements be made to provide training to mechanics and technicians so that the necessary skills are available when needed?

For all of the above items, you should also consider: How much will this cost? Who will pay for it?

9.3 Authority and Responsibility

The ultimate authority and/or responsibility for a water supply system may rest with a local community leader or organization or a regional or central government agency. When local persons or groups are responsible, they must have sufficient funds and the capacity to mobilize resources to respond to problems, as necessary, if their authority is to be meaningful. If a regional or central organization is responsible, it must be responsive to local needs for maintenance and repair that cannot be handled at the local level.

Regardless of where the formal authority lies, some degree of community responsibility is always important in the successful operation of water supply systems. The choice of technology should take into consideration the capacity of a village to be responsible for a pumping system and the availability of outside sources of periodic assistance. In general, less complex technologies are more suitable for situations where local authorities have responsibility for a system. More complex technologies that require higher levels of O&M support are more appropriate when authority for a system is more centralized.

For example, if care is taken in selecting a handpump, it is likely that most maintenance functions can be carried out locally. At the other extreme, most repairs of solar pumps must be performed by outside agents, who should be clearly identified prior to making a commitment to that technology. This does not mean that solar pumps are necessarily a bad choice, only that there must be responsive mechanisms for maintenance and repairs to ensure the long-term reliability of the system. Diesel systems usually require the largest ongoing commitment of resources because of the complexity of engine O&M relative to other technologies. Sometimes, a community will have a qualified mechanic who is available to perform service functions, assuming that spare parts are

available. Since the quality of local mechanics varies considerably, it is important to check thoroughly the experience of the person designated as a local mechanic. Sometimes, "repairs" can leave the system in worse shape than before. For the most part, windmills can be serviced locally, with the possible exception of changing the pump leathers.

To clarify the lines of authority and responsibility for your system, answer the questions below.

1. What person or organization has ultimate authority over the water supply system? Is this authority local or centralized?

2. Does this person or agency have control of the financial resources necessary for successful O&M? If not, which organization does? Is obtaining funds a major problem for the community or user group when the need arises? Does any other group, in the private or public, formal or informal sectors, have the capacity to respond when problems occur? Are existing cost-recovery schemes (e.g., user fees) adequately enforced at the local level, so as to ensure the availability of O&M funds when they are required?

3. What group or individual in the community or nearby area has responsibility for the water supply system at the local level? Is the group or individual responsible to a local or central authority? Is the responsible party paid or a volunteer? Does it have other functions (e.g., village development or health) that may reinforce or get in the way of its responsibilities for the water system? If an organization is responsible, is it likely to represent a faction of the community or the whole village?

4. Does this responsible party feel it can effectively bring resources to bear on operational problems when needed? If it must call on an outside organization for O&M assistance, will this other organization respond in a timely fashion?

5. If there is a backup system or secondary water source, is it under the same authority as the primary system?

9.4 Transportation

As long as spare parts, skilled labor, and/or fuel must be brought in from outside a village for some or all O&M functions, the quality of the local and regional transportation network must be considered in equipment selection. Factors to be considered include distance, travel time, the quality of roads and whether they are passable year-round or only seasonally, and the availability of vehicles or other means of transportation. For systems that have great needs for outside support, these are very important issues. That is why it is an advantage if skilled personnel and spare part inventories are available locally.

Since the transportation network is critical in moving technicians, parts, and materials to a pump site quickly and efficiently, answering the following questions will give you an understanding of what characteristics of that network affect the long-term operation of a system.

1. What means of transportation are readily available for travel to nearby towns or villages to obtain spare parts or technical assistance--bus, official transportation, private vehicles, other modes?

2. What distances must be traveled to obtain spare parts and to summon mechanics?

3. How long do these trips typically take?

4. Are light- and heavy-duty trucks (four-wheel drive, if necessary) available to transport heavier equipment and spare parts to the site? If not, how can they be made available?

5. How much do these different means of transportation cost per kilometer or trip?

6. Are fuel and parts for vehicles readily available on a year-round basis?

9.5 Communication

Ineffective communication is often a factor in long periods of system downtime, but it is frequently overlooked. There are generally two types of communications problems--response time and inaccurate or incomplete information. If it takes two days to summon assistance, every service requiring such communication requires at least two days plus the time needed for a response. In addition, because messages are often incomplete or inaccurate, maintenance and repair crews might bring the wrong personnel, parts, or tools. A simple message like "there is no water" is not very helpful to a maintenance crew that is trying to decide what spare parts and tools will be required. The crew may have to make an additional trip to complete the repair. The need for rapid, accurate communication of the nature of a problem to the proper person or agency is important in assuring a timely, appropriate response. One suggestion is that all site operators be given written forms (perhaps postcards) with the address and telephone number of the repair crew dispatcher, along with several questions which need to be answered when reporting problems.

The following questions focus on important communication issues.

1. Are the proper steps for summoning maintenance and repair assistance clear to the operator/caretaker and users?

2. Does the operator/caretaker have the training and skills to report most problems accurately to the maintenance/repair crew?

3. When outside assistance is needed for maintenance and repair, how is assistance summoned? Are these channels of communication open year-round? Do they depend on verbal, written, or radio messages?

4. Is assistance requested from different sources, depending on the nature of the problem? If so, list the various types of problems and the corresponding sources of assistance.

5. When assistance is summoned, how long is it likely to take to get a response from each source of help?

9.6 Summary

Evaluating the capability of a maintenance structure is neither simple nor straightforward. It requires an assessment that is based on specific local conditions and the type of equipment being considered. In the process of such an evaluation, there are several important points to keep in mind:

- local capability (e.g., for operation, maintenance, repair, and/or spare parts inventories) is always an advantage;
- complex systems are likely to need more maintenance than simple ones;
- well-known technologies and systems that are easily understood increase the possibilities for local repairs;
- the acceptable length of time for skilled technicians to get to your site with appropriate tools and spare parts depends on water availability requirements and backup sources of supply;
- to the extent possible, maintenance functions should be integrated into the existing infrastructure, either government-operated or private--do not try to set up new organizations to support new types of equipment; and
- be sure to consider the need for and cost of ongoing training in O&M procedures.

While it is impossible to guarantee that an existing maintenance and repair infrastructure will be responsive in the future to needs associated with the equipment you choose, careful consideration of answers to the questions listed in this section should give you a good indication of the likelihood for successful long-term operation of the system.

The final section of this manual addresses the major remaining issue involved in pump selection—costs. An analytical method called present-worth analysis is applied to the two major components of pumping system costs (i.e., capital and recurrent costs) to compare the costs of pumping water with different types of systems.

Chapter 10

FINANCIAL AND ECONOMIC ANALYSIS

The first step in choosing a pump is to select one or more options that will meet the technical requirements at your site. This will probably narrow down the choice. The next step is to find out which of the remaining options can be successfully supported by the O&M infrastructure available in your area. This will probably reduce the number of choices even further. Finally, you need to develop a comparative cost analysis that will allow you to compare the few viable systems left on the basis of life-cycle cost. Life-cycle cost is the basis for an economic comparison called present-worth or present-value analysis. It takes into account all costs incurred over the useful life of your system, including those for the initial equipment (capital costs), installation, operation, maintenance, and repair.

10.1 Present-Worth Analysis Method

While there are many kinds of comparative economic methods, present-worth analysis is a convenient method for assessing the relative costs of different pumping systems. This method analyzes all costs associated with installation and use of a pumping system by reducing them to a single number called the present worth or value. Dividing the present value by the total volume of water pumped over the system's lifetime gives a unit cost for water, referred to here simply as unit cost. Calculating unit costs for two different pumping systems that are designed to deliver the same volume of water from the same head allows you to make direct financial and economic comparisons between the two. This approach can only be used to compare systems that are delivering the same daily output for roughly the same head range. It does not address the question of benefits, so you cannot determine whether the benefits of the pump installation (in terms of increased health benefits or number of gardens irrigated, for example) will be worth the cost.

This chapter describes the method for present-worth analysis by discussing typical cost components (capital costs, recurrent costs for operation, maintenance, and repair), discussing the analytical method, and then taking you through an example showing how it is applied. The distinction between financial and economic costs is discussed, with an example that shows the difference between those two concepts. In general, a system's financial cost is determined from the user's viewpoint, while the economic cost is based on the perspective of the government or society as a whole. Since financial and economic unit costs can vary considerably, it is possible that selection of the most cost-effective system may depend on which perspective you take.

10.2 Types of Costs

Present-worth analysis divides system costs into two basic groups--installed capital and recurrent costs. Installed capital costs are all assumed to occur

at the start of a system's lifetime (i.e., time zero). All later costs (e.g., for operation, maintenance, and spare parts) are recurrent costs.

To determine whether potential owners or users of a pumping system can afford to own and operate it, it is important to estimate all costs as accurately as possible and then examine the cash flows needed to meet future recurrent costs. Some systems (e.g., diesel pump sets) have low capital costs, but high recurrent costs. Others, such as wind and solar systems, have high capital costs, but low recurrent costs. Who will pay these different costs may have a significant impact on the choice of a system. If a system is not going to be wholly dependent on outside funding (e.g., completely subsidized by the government or paid for by a donor organization), it is important to know what cost-recovery mechanism(s) will be used. Will recurrent costs be funded by water-user fees? Are users willing to pay them? Up to how much? Will the government or some other funding source cover a fixed percentage of recurrent costs? Careful consideration of these questions is crucial when selecting a system.

A system's installed capital cost is the total figure for all equipment, materials, labor, and transportation needed for complete installation of a functioning system. Recurrent costs generally include:

- an operator's salary;
- wages for a mechanic to handle regular service and breakdowns;
- spare parts and replacement components;
- transportation, including a driver; and
- overhauls, when necessary.

Recurrent costs can be subdivided into fixed annual, variable annual, and non-annual costs, which are defined in the sections below. Each category can include costs for materials, labor, and transportation. A matrix showing all the different types of system costs is as follows:

	Installed Capital Costs	Recurrent Costs		
		fixed	variable	non-annual
Materials				
Labor				
Transportation				

It is not necessary to consider costs that are common to all of the systems analyzed. For example, assume you are considering using one small diesel engine, one solar pump, or two handpumps to meet demand. For the diesel or solar system, you only need one well or borehole. For the two handpumps, you may need to dig a second well or borehole. If the cost of water source development varies between alternatives, include those costs in your analysis. Depending on the particular application, you may need to consider other additional costs, such as:

- well construction or drilling;
- field surveys;
- design work, including engineering drawings; and
- water storage tanks, which may or may not be needed for different systems and can vary in size.

Where appropriate, these costs should be included in the matrix shown above. Sections 10.2.3 and 10.2.4 give detailed descriptions of how to estimate costs for each part of the matrix.

10.2.1 The Discount Rate

The present worth of recurrent costs is determined by making assumptions about the discount rate and useful life of the system, also called the term of the analysis. The discount rate is used to calculate the present worth of future costs (for instance, replacing a windmill cylinder after five years of operation). It is based on what economists would consider the buyer's best alternative investment. If the best alternative is investing money in a bank at 10 percent interest, the assumed discount rate is 10 percent. This rate may vary for different investors, since deciding on the best alternative depends on personal circumstances and their willingness to take risks.

Discount rates differ according to the user. You have to estimate the return on the best alternative investment given local conditions and users' perceptions. Individuals in the private sector may be reluctant to borrow money because of uncertainty about the future, in which case discount rates may need to be as high as 20 percent. For economic analysis, suitable rates are determined by government economists. The World Bank often uses economic discount rates of 10 to 12 percent. The discount rate can have a large effect on the results of analysis, particularly when competing alternatives differ markedly in their capital and recurrent costs.

10.2.2 The Term of the Analysis

The term of the analysis must be ascertained. Usually, this is the same as the useful life of the major system component that will last the longest. For example, with solar pumps, the longest lasting component is the PV array, which has an estimated life of 20 years. Obviously, not all of the other components will last that long. They will have to be replaced periodically as they fail. The cost of repair or replacement for these components is included in the recurrent costs. Similarly, for a diesel pump, the term of the analysis is the engine's useful lifetime. It can be overhauled several times, but eventually it will have to be replaced. To compare different systems using present-worth analysis, you have to use the same term of analysis for all of them. For example, you want to compare a solar pump and a diesel system. The term of the analysis is assumed to be 20 years, and diesel engines in your area are expected to last only 10 years. You can still use this method by simply assuming that you replace the diesel engine at the end of the tenth year, considering it as a recurrent cost.

10.2.3 Installed Capital Costs

In this section, ranges are given for typical capital and recurrent costs associated with the installation of each type of system. In some cases, these ranges are wide because of the degree of variability in power and differences in where the equipment is purchased and used. When possible, it is best to get more precise cost information from local distributors before doing a present-worth analysis. The installed capital cost for a pumping system includes equipment costs for the power source (driver) and pump, other materials, civil works, and associated labor and transportation costs. The driver could be a diesel engine, a solar array and controller, a windmill head with a tower, or a handpump head. Be sure to include the cost of required accessories. All capital equipment costs also depend on import taxes, duty requirements, and freight charges from the country of origin, but these should be kept separate for the economic analysis.

<u>Diesel Systems</u>

Costs for diesel engines are affected by the rated output, quality of the equipment, and location of the manufacturer. They range from US$500 to US$1,000 per kW. Other major items for diesel systems include:

- the pump and transmission, if any;
- pump houses and fencing, for security and protection of equipment and materials; and
- other components for water storage and distribution, such as tanks, piping, and valves. Under some conditions, the need for a completely reliable system involves considering the purchase of a spare engine and/or pump. In most cases, a good water

meter and pressure gauge should also be purchased for diagnostic purposes.

In addition to these more expensive components, lower cost items needed to install a functioning system can add up to a total that is a significant portion of the overall materials cost. They include engine frames, foundation bolts, non-return valves, unions, gate and pressure-relief valves, spare pulleys, belts or drive shafts, and some tools for operator servicing. Required materials also include cement, sand, gravel, reinforcing mesh, and/or "re-bar" to make a concrete foundation for the engine (or windmill tower, solar array's mounting frame, or handpump base), as well as fencing. These can amount to 10 percent of the equipment's total capital costs. A complete list of parts and materials for each of the four system types is given in Appendix E. Typical costs for diesel pumping systems are given in Table 4.

Table 4

Typical Capital Costs for Diesel Pumping Systems
(in US $)

diesel engine (2 to 10 kW)	1,000 to 4,000
pump (complete)	500 to 3,000
civil works (pad, pump house)	500 to 1,000
other (valves, fuel tanks)	1,000 to 3,000
Total System Cost (CIF*)	3,000 to 11,000

* Cost/insurance/freight (delivered price)

Solar-Powered Systems

For solar pumps, PV modules are the most expensive component. Other system components include the pump, motor, array support structure, wiring, and controller and/or batteries. Array costs are in the range of US$4.0 to US$4.5 per W_p, from the point of manufacture. This cost can easily rise to US$9/$W_p$ or more where distribution and shipping costs are high. In most cases, motors and pumps for a solar system are purchased together because solar pump manufacturers design and match pumps and motors to maximize subsystem efficiency. Controller costs vary considerably depending on the type of control system chosen and the country of manufacture. Some manufacturers may specify controllers that are designed to operate with their systems. Array support structures cost from US$100 to US$200 for racks that hold four to six modules. Wiring costs are usually US$50 to US$200. Unlike diesel pumps, neither PV nor wind systems normally require pump houses, but all three require fencing.

Table 5

Typical Capital Costs for Solar Pumping Systems
(in US $)

PV array (0.6 to 2.2 kW_p)	3,600 to 20,000
pump (no submersible motor)	200 to 700
motor (0.5 to 2 kW)	200 to 800
submersible pump set (motor, pump, and invertor, if needed)	1,500 to 4,000
controllers (where needed)	100 to 1,600
civil works (pad, fencing)	300 to 1,000
other (wiring, racks, rods, meters)	200 to 1,400
Total System Cost (CIF)	4,600 to 28,000

Wind Systems

Windmill and tower costs are highly dependent on shipping charges, as these machines tend to be heavy. In general, units are supplied complete, with no additional or optional parts to be considered. The cost for a windmill head will generally be higher for rotors with larger diameters. The range of costs is US$200 to US$500 per square meter of rotor area. Simpler designs that are fabricated locally or regionally are likely to be less expensive than American or European windmills of similar size. Tower costs are proportional to the size and to the quality of construction; they range from US$1,000 to US$3,000, depending on whether the tower is made locally or purchased and imported with the windmill. Cylinder costs are often dependent on design, with high-quality, ball-valve cylinders being more expensive than those with flap or spool valves. Other items include the drop pipe, pump rod, pipe clamp at the wellhead, cement for the foundation, and fencing.

Table 6

Typical Capital Costs for Wind Pumping Systems
(in US $)

windmill head (cost is a function of size)	600 to 8,000
tower and associated hardware	1,000 to 4,000
pump cylinder with spare leathers	100 to 800
other (foundation, tank, piping)	500 to 2,000
Total System Cost (CIF)	2,200 to 15,000

Handpumps

Handpump costs vary considerably depending on the country of origin. You might assume that locally fabricated units would be the least expensive, but this is not always the case. Handpump costs range from US$300 to US$1,000.

Table 7

Typical Capital Costs for Handpump Systems
(in US $)

handpump head	300 to 1,000
pump cylinder with spare leathers	100 to 400
pump rod (depends on depth)	10 to 150
other (foundation, drain, piping)	100 to 400
Total System Cost (CIF)	510 to 2,000

Besides equipment and materials, capital costs also include the labor and transportation associated with installation. Labor costs are often divided into skilled, semiskilled, and unskilled components. This is partly because the daily or hourly rates are different for these groups and because the unskilled portion is often valued below the wage rate in the economic analysis (see Section 10.4). You should have some idea of labor costs or daily rates for these three groups, including any relevant per-diem or other allowances. Remember to include the preparation associated with collecting tools and equipment in your estimates for installation time.

Time Required for Installation

Assuming that the well is already developed, the minimum amount of time required for installation of a diesel pump is about three to five days and includes pouring a foundation, lowering the pump, installing the engine, and building a prefabricated metal pump house. Solar pumps often take a bit longer but should require no more than seven to eight days, unless the crew is very inexperienced. For the first few installations of any system, the need for on-the-job training will increase installation time somewhat. Windmill installation can easily take up to ten to twelve days in typical developing country situations. Handpumps can typically be installed in two to three days, if all goes well. These figures should be used only as general guidelines for estimating the actual time needed for an installation at your site. Your estimate will depend on the number of people in an installation crew as well as on their training and familiarity with the particular type of system being installed. The size of a typical crew varies from three to ten, of which one to three are usually skilled laborers.

Transportation Costs

Transportation costs are affected not only by the distance to the site, but also by the type of vehicle used and the number of trips. Remember that it may be necessary to make more than one trip to the site to move all the equipment, gear, and personnel needed to complete the installation. Thus, the total transportation distance can easily be two to three times the round-trip distance from the installation center to the site. The type of vehicle(s) affects transportation costs because light, two-wheel drive trucks are less expensive

to operate and maintain than heavier four-wheel drive vehicles and trucks, which may be needed for some installations, such as windmills. To get some idea of transportation costs, talk to vehicle rental agencies or truck users in the private sector. Often it is possible to get a daily rental figure plus a mileage charge, which will probably not include fuel costs. Rental agencies usually have a good estimate of typical fuel use per kilometer.

Once these cost components have been calculated separately, they are added together to determine the installed capital cost. All other costs associated with operation, maintenance, and repair are recurrent costs.

10.2.4 Recurrent Costs

As mentioned above, recurrent costs can be divided into fixed annual, variable annual, and non-annual costs. This section discusses these cost components for all four system types considered in this manual.

Fixed Annual Costs

Fixed annual costs for a pumping system are annual recurrent costs that are not affected by the amount of use a system receives. The major types of fixed costs do not fall neatly into the materials, labor, and transportation categories used above. Rather, they include such items as overhead, finance charges (e.g., interest on a loan used to buy the system), and labor costs for an operator, if any. For example, fuel is not a fixed cost since it depends on how much the engine is run.

Whether or not there are overhead costs and how high they are depends on the way a pumping system is managed and maintained. Overhead can include costs for such things as record-keeping or maintaining a vehicle, office, warehouse, spare parts inventories, or headquarters staff. These costs are often omitted from comparative analysis on the assumption that they will be similar regardless of the system chosen, but this is not necessarily the case. If a system was paid for with cash from business operating funds, personal monies, or a grant, there will be no interest charges.

The labor cost for an operator is usually a fixed cost that depends on the type of pump and daily average use of the system. It rarely changes with hourly usage of the pump each day. For example, diesel pumps are often run by a full-time salaried (i.e., not hourly) operator. In instances where the operator may have additional unrelated responsibilities (e.g., a maintenance person for a school or a driver), the allocation of some time to non-pumping activities can reduce labor costs somewhat. Handpump operation does not require an actual operator. However, it is important to value the time spent pumping water in the economic analysis. Typically, this time is costed at the prevailing wage rate for unskilled labor.

Variable Annual Costs

Items falling in the variable annual cost category include all materials (i.e., fuel, oil, and parts), labor (except for the operator), and transportation required for normal operation, servicing, and repair of the system. These are all the items whose use depends on the amount of time the system is operated during the year. Estimates for these costs can be made by modifying the information provided in Chapters 5 through 8 to meet the specific conditions at your site. These requirements and their associated costs are summarized here.

Annual labor costs are a function of the number and duration of trips made in response to normal service requirements and breakdowns as well as the crew's size and skill levels. Of the four systems considered here, diesel pumps will likely require the most maintenance and repair trips. For planning purposes, count on at least four such trips per year up to as many as one per month, depending on the situation. For solar, wind, and handpump systems, the number of maintenance/repair trips will probably be many fewer, in the range of one to three annually if the installation is properly done. Fewer trips may be needed if the pump operator can perform some minor servicing.

Maintenance and repair crews typically consist of a mix of skilled, semiskilled, and unskilled labor. In estimating annual labor costs for service and repair, consider the specific skill mix required for your system. In the absence of other information, assume a repair crew of three--one skilled and two unskilled--plus a driver for 70 percent of all necessary repairs. Larger crews of as many as eight will be needed for jobs like pulling pipe, replacing engines, or repairing breaks in the pipeline. Labor costs can then be estimated by calculating the total daily wage rate for smaller and larger crews, and then multiplying by the number of days required for each crew. Remember, if all labor arises from salaries included in the overhead figure discussed above, you need not calculate labor costs here.

Annual transportation costs include trips made for service and repair, as described in the preceding paragraphs. In addition, they should include trips to deliver fuel for diesel systems. The cost of such trips will depend on the distance and the type of vehicle used. The distance traveled may or may not be the same as the installation distance--it depends on the relative locations of service facilities and the pump site. You should also consider that it may be possible to combine trips in some cases (e.g., regular servicing and a delivery of diesel fuel).

The type of vehicle used will depend on what is available, plus the requirements of the job and the condition of the roads to the pump site. Of course, lighter vehicles should be used when possible, but this may not always be practical given other constraints. As described above, vehicle charges are often given as a daily rate plus a mileage charge plus fuel. As appropriate, include these figures in calculating transportation costs. Again, if the cost of vehicles is figured into the overhead, the variable annual transportation costs should be reduced or eliminated. Typically transportation costs range from US$0.25 to US$1.00 per kilometer.

Non-Annual Costs

Non-annual costs are those that do not usually recur every year. Costs in this category are treated differently because of their intermittent nature. They include such items as major or minor overhauls for diesel systems, or the replacement or repair of any major system component during the term of the analysis.

For diesel systems, non-annual costs include the overhaul and replacement of the engine, pump, and down-hole components, as necessary. Non-annual costs for solar pumps include the overhaul or replacement of batteries, controllers, electric motors, and down-hole equipment, as well as the replacement of solar modules in case of vandalism or theft. For windmills, non-annual costs will likely be limited to the replacement of the pump and down-hole components--the drop pipe, sucker rods, leathers (if these are not replaced annually), and pump cylinder. The only non-annual costs for handpumps will probably be the replacement of the down-hole components and possibly the pump-head or bearings. For all systems, other non-annual costs may include the repair or replacement of civil works, storage tanks, fences, pump houses, and wells (particularly if hand-dug wells are used).

Summary estimates of recurrent costs for the four types of systems considered in this manual are given in Tables 8 to 11.

Table 8

Recurrent Costs for Diesel Pumps

Fixed Annual	
interest on loan	if applicable
pump operator	varies
Variable Annual	
diesel fuel	
oil and filter changes (monthly)	1 day of labor + US$5 to US$15 each
minor repairs (3-6 times annually)	1 day of labor each + US$10 to US$100
Non-Annual	
engine overhaul	every 2 to 5 years
replace/repair pump and/or pipes	every 5 to 10 years

Note: Fixed costs must be determined based on local practices and specific site conditions. Fuel costs can be calculated using the method given in Chapter 5. The oil and filters (if any) may need to be changed more or less often depending on engine use and operating conditions. For an engine that is used eight to nine hours a day, the oil and filters should probably be changed once a month. Repair costs are highly variable and will be affected by the quality of preventive and curative maintenance. The values given above are typical. Engine overhauls and repair or replacement intervals for the pump and piping are also highly variable. The values shown are indicative of average conditions in developing countries.

Table 9

Recurrent Costs for Wind Pumps

Fixed Annual	
interest on loan	if applicable
pump caretaker, if any	varies
Variable Annual	
replace leathers and oil or grease	1 day of labor + US$5 to US$15
repair 1 to 4 times annually	1 day of labor each + US$0 to US$100
Non-Annual	
replace cylinder and pipes	every 5 to 10 years

Note: Depending on water quality and the extent of pump use, leathers may need to be replaced more often than annually. Other repairs may be required more or less often depending on the quality of the installation and the users' care of the windmill. The replacement interval for the pump cylinder and piping will depend largely on water quality. If the water has highly aggressive or abrasive characteristics, the cylinder and pipes will have to be replaced often, perhaps even more often than indicated in the range.

Table 10

Recurrent Costs for Solar Pumps

Fixed Annual	
interest on loan	if applicable
pump caretaker, if any	varies
clean array, check wiring	1 hr of labor per week
Variable Annual	
replace leathers (for piston pumps)	1 day of labor + US$5 to US$15
minor repair 1-2 times annually	1 day of labor each + US$0 to US$300
Non-Annual	
repair or replace motor/pump	every 3 to 5 years
repair or replace electronic parts	every 3 to 5 years
replace cylinder (if any) and pipes	every 5 to 10 years

Note: Predicting the long-term frequency of repairs and replacement for solar pump components is difficult because few systems have been in operation for more than three to five years. Many early units required the replacement of major components every year or two, particularly for electrical components such as controllers, inverters, and motors. Newer units have surmounted most of those early problems, and much longer component lifetimes are becoming more common. Minor annual repairs consist primarily of replacing poor electrical connections or vandalized modules, if necessary.

Table 11

Recurrent Costs for Handpumps

Fixed Annual	
interest on loan	minor, if applicable
pump caretaker, if any	varies
Variable Annual	
replace leathers	1 day of labor + US$5 to US$15
repair 1 to 4 times annually	1 day of labor each + US$0 to US100
Non-Annual	
repair handle/replace bearings	every 1 to 4 years
replace cylinder, pipes, and rods	every 5 to 10 years
replace pump-head	every 5 to 10 years

Note: Generally, the maintenance and repair requirements for handpumps will be easier to meet, and costs will be lower if the drop pipe does not have to be pulled to replace the leathers or fix the cylinder. Handpumps designed using the VLOM concept will have fewer needs for more expensive repairs by personnel from outside the immediate area.

10.2.5 Filling Out the Cost Matrix

The cost matrix for capital and recurrent costs shown at the beginning of this section should be completed based on the information given above. Two matrices will be necessary if a financial and an economic analysis are carried out. Differences between the two matrices are discussed in Section 10.4.

Note that, for the sake of simplicity, inflation of specific costs over and above the general rate of inflation has not been discussed in this section. While it is true that any or all of the costs discussed here can change (increase or decrease) at a rate different from the general rate of inflation, it is often very difficult to predict the magnitude (or often, even the direction) of those changes. If you have information which convinces you to believe that one or more of the capital or recurrent costs of operating your pumping system will change over the period of the analysis, factor that information into the analysis. Better yet, make several calculations of the unit cost using different assumptions about the change in one or more variables. This "sensitivity analysis" will allow you to see what effect your assumptions have on the unit cost.

10.3 Present-Worth Analysis

This section discusses the analytical method for present-worth analysis. It requires that all future costs be discounted to their present worth, which is most easily accomplished by grouping costs in such a way that simple formulas can be used to calculate the present worth of each group. A list of all relevant formulas used in present-worth analysis is provided in Appendix F.

For the purpose of the analysis, installed capital costs are already present costs. Fixed and variable annual costs for materials, labor, and transportation should be combined to get a total for annual recurrent costs that will be the same for each year of the analysis, if it is assumed that the equipment is operated for the same amount of time every year. Use Equation One to calculate the total present value of these costs.

Equation One:

$$P = A \times \frac{(1 + d)^n - 1}{d \times (1 + d)^n}$$

where P = present worth of a uniform series of future costs
A = annual amount or payment
d = discount rate, as a decimal
n = term of the analysis in years

Note: To simply this calculation, a table of factors which can be used to calculate the present worth of a uniform series of future payments (or costs) are given in Appendix F. To use them, take the annual payment (A) and multiply by the "F1" value given in the tables for a particular interest rate and term of analysis ("N") (see Example 17 below).

Non-annual costs must be treated individually. For each occurrence of a non-annual cost, Equation Two should be used to calculate its present value. It should also be used instead of Equation One to calculate the present worth of individual total annual costs if they vary from year to year over the term of the analysis (i.e., if pump operation varies from year to year). Example 17 demonstrates the method.

Equation Two:

$$P = F \times (1 + d)^{-y}$$

where P = present worth of future cost
F = future amount
d = discount rate, as a decimal
y = year of occurrence for the future cost

Note: To simplify this calculation, tables of the present worth of a single future payment (same as calculated in Equation Two) are given in Appendix F. See Example 17 below for their use.

Example 17: Calculating Present Worth

Assume that the discount rate is 12 percent over the 20-year term of this analysis. The following table shows expected costs over the life of the pumping system you are considering.

	Installed Capital Costs	Recurrent Costs			
		fixed	variable	non-annual	
Materials	3,000		750	1,000	500
Labor	500	1,000	100	100	75
Transportation	300		50	50	50
Total	3,800	1,000	900	1,150	625

Of the non-annual costs shown, the first (totaling $1,150) occurs in year 10. The second ($625) occurs in years 5 and 15. What is the present worth of this system? The present worth of installed capital costs is $3,800. The present worth of fixed and variable (here assumed to be constant) annual costs is given by Equation One:

$$P = A \times \frac{(1 + d)^n - 1}{d \times (1 + d)^n}$$

Substituting values from the table above:

$$P = (\$1,000 + \$900) \times \frac{(1 + .12)^{20} - 1}{.12 \times (1 + .12)^{20}} = \$1,900 \times 7.47 = \$14,192$$

Note: you could simply look up the corresponding value in Appendix F as follows: Look down the term of analysis ("N") column to 20 years, go across to the "F1" column and the appropriate interest rate (12 percent) and read the value 7.4694. Multiply $1,900 (from above) by 7.4694 to get $14,192. The present worth of each of the three non-annual costs must be calculated separately.

Example 17: Calculating Present Worth (contined)

At year 5: $P = \$625 \times (1 + .12)^{-5} = \$355$
At year 10: $P = \$1,150 \times (1 + .12)^{-10} = \$370$
At year 15: $P = \$625 \times (1 + .12)^{-15} = \$114$

Note: You could simply look up the multiplier value for these three calculations in the table in Appendix F as follows: Look down the term of analysis ("N") column to 5 years, go across to the "F2" column and the appropriate interest rate (12 percent) to get the value 0.5674. Multiply the year-5 value of $625 (from above) by 0.5674 to get $355. Similarly, multiply the year-10 value of $1,150 by 0.3220 to get $370, and the year-15 value of $625 by 0.1827 to get $114.

Therefore, the present worth of all costs is:

$$\$3,800 + \$14,192 + \$355 + \$370 + \$114 = \$18,831.$$

Note that this example did not consider the amount of water pumped, nor was a unit cost calculated. This procedure will be shown in the example in the next section.

10.4 Financial Versus Economic Analysis

The basic difference between financial and economic analysis is one of perspective. Financial analysis relates to private costs and benefits, while economic analysis is concerned with social costs and benefits to a community or nation. Usually, the private sector is more concerned with financial analysis. Analysis done to address public-sector needs is often economic. Whether you should perform one or both depends on who provides the money and what the objectives of the pumping system are.

The major difference in calculating financial and economic present worth is making allowances for factors that have social impact, such as,

- foreign-exchange costs and interest rates,
- taxes and subsidies,
- employment generation, and
- training costs.

These allowances are commonly called shadow prices. For example, in most developing countries, the economic cost of labor is less than the actual financial cost. This means that when there is a labor surplus (in most developing countries, this pertains only to unskilled labor), the economic cost to the country or society as a whole is less than the market price or current wage level. Shadow prices are used to reflect the difference between the market price and the true value of goods, services, and other production factors. The shadow price for unskilled labor is a multiplier (usually between 0.4 and 0.7) that decreases the actual cost of unskilled labor in an economic analysis. Its value is usually determined by government economists and planners.

You should note that when the economic cost for labor is less than the financial cost, labor-intensive systems--those with proportionally higher labor requirements--become more attractive than capital-intensive ones from an economic perspective. For instance, this means that the unit cost of a diesel system, which has a higher proportion of labor costs and lower proportion of capital costs than other systems, is lowered by the shadow-pricing of unskilled labor. Similarly, the unit costs of capital-intensive systems such as wind or solar are increased when foreign exchange is shadow-priced at a value greater than one.

In some countries, foreign-exchange costs and real interest rates do not reflect true economic costs. This is evident in the large differences frequently seen in official versus free-market exchange rates. Interest rates used in economic analysis may be dictated by government economists and, thus, may not necessarily reflect the true cost of borrowing capital. In addition, the export earnings of some countries are based on the depletion of resources (e.g., mining). In these cases, funds may be available for import purchases in the short run, but not over longer terms as foreign earnings decline. Circumstances such as these lead to shadow-pricing for foreign-currency requirements that better reflect the real cost of foreign-exchange expenditures. Such shadow-pricing typically increases the cost of imported items by 5 to 15 percent.

From the standpoint of a private user or business person, taxes are part of the cost of doing business, and any government subsidy is considered a benefit. These costs and benefits are likely to influence some activities in the private sector. However, from the government's perspective, they do not represent costs or benefits at all, but merely a transfer of money and control over resources. Economic analysis does not include taxes paid as costs or subsidies as benefits. Actually, taxes and subsidies are often used as mechanisms to help manipulate private-sector activity to bring it more in line with what the government believes is the greater national good. Interest paid on domestic loans and depreciation allowances also fall into this category of transfer payments and, hence, are included in financial but not economic analysis.

Training costs incurred by firms in the private sector are costs from their perspective. Private businesses train individuals with the expectation that they will benefit from their employees' increased skills and ability. However, since employees do not always remain with the firm providing the training, benefits may not always accrue to those firms. This constitutes a disincentive to the private sector to provide training. In most countries, development of a more highly skilled work force is a clearly stated goal. Training costs may not be considered in an economic analysis, if the benefits of a more skilled work force are considered to be equal to or greater than the financial cost. Private-sector training costs may be shadow-priced to reflect potential economic benefits. Example 18 shows the effect of shadow-pricing on economic analysis.

Example 18: Economic Costs

Using the information given in Example 17, calculate the economic cost for that system. The economic price of unskilled labor is one-half of the financial price. Assume that half of the labor cost is unskilled. All equipment and materials are imported, including transportation, since trucks, fuel, tires, and all spare parts must be imported. The shadow price multiplier on foreign exchange is 1.15.

First, determine the economic cost entries for the matrix given in Example 17. Multiplying the financial values of various costs by appropriate shadow price multipliers gives:

	Installed Capital Costs	Recurrent Costs			
		fixed	variable	non-annual	
Materials	3,450		863	1,150	575
Labor	375	750	75	75	56
Transportation	345		58	58	58
Total	4,170	750	996	1,283	689

Again, the first non-annual recurrent cost listed ($1,283) occurs in year 10. The other ($689) occurs in years 5 and 15. The present worth of installed capital costs is $4,170. The present worth of fixed plus variable (here assumed to be constant) annual costs is given by Equation One:

$$P = A \times \frac{(1 + d)^n - 1}{d \times (1 + d)^n}$$

Substituting values from the matrix gives:

$$P = (\$750 + \$996) \times \frac{(1 + .12)^{20} - 1}{.12 \times (1 + .12)^{20}} = \$1,746 \times 7.47 = \$13,042$$

The present worth of each of the three non-annual costs must be calculated separately.

At year 5: $P = \$689 \times (1 + .12)^{-5} = \$391$
At year 10: $P = \$1,283 \times (1 + .12)^{-10} = \$413$
At year 15: $P = \$689 \times (1 + .12)^{-15} = \$126$

Therefore, the present economic worth of all costs (i.e., the system's life-cycle cost) is:

$$\$4,170 + \$13,042 + \$391 + \$413 + \$126 = \$18,142$$

The financial and economic present worth calculated in Examples 17 and 18 do not differ appreciably. The economic cost is slightly less (US$689). In other circumstances, however, these two costs can vary considerably. When comparing different system options, one may be cheaper economically and the other financially. In that case, the choice of a system would depend on the perspective of the potential purchaser.

10.5 Unit Cost of Water

Finally, the unit cost needs to be calculated, which depends on the amount of water pumped. For simplicity, assume that the system delivers a constant 30 m^3/day over its useful life. (Growth in water demand can be included by using a slightly more complex procedure). The economic unit cost is determined by annualizing the system's life-cycle cost and dividing that number by the annual water output, as shown in Example 19.

Example 19: Calculating Unit Cost

Calculate the unit cost of water for the installation described in Examples 17 and 18, assuming that an annual average of 30 m^3/day of water is pumped.

Solve Equation One for "A" to annualize life-cycle costs:

$$P = A \times \frac{(1 + d)^n - 1}{d \times (1 + d)^n} \quad \text{or} \quad A = \frac{P \times d \times (1 + d)^n}{(1 + d)^n - 1}$$

Substituting values from Example 18 gives:

$$A = \frac{\$18,142 \times .12 \times (1 + .12)^{20}}{(1 + .12)^{20} - 1} = \$18,142 \times 0.1339 = \$2,429$$

Dividing this value for annualized life-cycle cost (ALCC) by the annual volume of water pumped gives the economic unit cost:

$$\text{unit cost} = \frac{\text{ALCC}}{365 \times 30\ m^3} = \frac{\$2,429}{10,950\ m^3} = \$0.22/m^3$$

This final value--the economic unit cost of pumping water over the system's lifetime--is the figure you should use to compare this system with other options. Note that this is a somewhat simplified example, since no growth in demand has been assumed.

When evaluating capital costs and the present worth of different technology options, several other points should be considered:

- International donors are more likely to be able to provide funds to cover high capital costs than private individuals or host governments.
- Host governments are often not in a position to cover recurrent costs, even if the capital cost is provided by a donor.

- Governments may or may not be able to justify higher capital costs to benefit from lower life-cycle costs because of short-term monetary constraints.

- In most places, private-sector purchases are very sensitive to initial capital costs, such that low capital costs often influence the choice of technology regardless of the long-term implications.

It is important to make one final point in this section on comparative costs. If you are considering introducing a type of pumping system that is unfamiliar locally because it has the potential for long-term cost savings, remember that simple cost parity is not enough to convince potential buyers to adopt a new or unfamiliar type of system. There would probably have to be a significant price difference to get potential users even to consider the new system.

For example, if you are considering solar or wind pumps in an area that has historically used only handpumps or diesel systems, buyers are not likely to purchase the former simply because they are equal or slightly cheaper in cost than conventional systems. There would probably have to be clearly substantial savings associated with using the new systems to make it worthwhile for users to take the risk of installing unfamiliar equipment. The definition of substantial savings undoubtedly varies depending on the user group, its level of sophistication, education, and willingness to take risks. It may mean that new systems would have to be as much as 10 to 30 percent cheaper in terms of unit costs to be appealing. Even so, to many users the promise of future savings (even in the near future) is not enough to offset the obvious appeal of a system like a diesel pump set that has a low initial cost.

10.6 Summary

This manual has taken you through the essential steps involved in properly selecting a pumping system for a small-scale, rural water supply. Its underlying assumption is that the use of equipment which is already locally available should be the first strategy considered in most cases. It is most likely that the systems commonly found in your area can be serviced locally and thus meet the most critical requirement for ensuring successful long-term operation.

In summary, the approach to pump selection described here is to

- calculate the pumping requirement,

- determine what kind of equipment is available,

- review the local O&M infrastructure to see what types of equipment can be supported,

- determine which kinds of available equipment meet your site requirements and can be supported over the long term.

- calculate how much the remaining viable equipment options will cost to use, and

- select the one with the required cash flows that best fit the needs of the community or agency which will be using it.

While the technical requirements for a pumping system must obviously be met, it should be remembered that skilled labor, the availability of fuel and spare parts, good transportation facilities, and the importance of planning for future cash outlays needed to keep the system operating properly are also very important factors in selecting a pumping system.

It is hoped that this manual has clarified the procedures for determining these requirements and for comparing costs, thus assisting you to make a well-informed choice of a pumping system and components. However, the method given in this manual has been oversimplified in some ways. There are more refined tools available to assist you in selecting a pumping system. Reviewing the annotated bibliography (Appendix A) will give you some insight into areas of further interest. There are also computer programs available that are relatively easy to use and can facilitate certain parts of the method presented here, especially the financial and economic analysis. Finally, remember that additional assistance with pump selection and comparative analysis is available through activities funded by international donors, such as the WASH Project, and a variety of institutions and private firms.

APPENDIX A

Annotated Bibliography

APPENDIX A

Annotated Bibliography

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Most recent comprehensive work published by the World Bank handpump development program. An excellent reference manual for policymakers and professionals on technical, social, and economic aspects of handpump use.

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CIDA, DGIS, GTZ, USAID, and FAO. Handbook for Comparative Evaluation of Technical and Economic Performance of Water Pumping Systems. Amersfoort, Netherlands: Consultancy Services Wind Energy Developing Countries (CWD), March 1987. (Draft.)

Detailed methodology for pump testing as well as technical, institutional, and socioeconomic evaluation of diesel, wind, solar PV, grid-electric, hand, and animal-traction pumps.

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Excellent technical reference on all important aspects of groundwater development, including aquifers; well hydraulics; designing, drilling, and developing wells (boreholes); pump selection and maintenance; and water quality and treatment.

Fraenkel, P. Water-Lifting Devices. FAO Irrigation and Drainage Paper. Rome, Italy: Food and Agriculture Organization of the United Nations, 1986.

Very comprehensive descriptions of the entire range of pumping and water-lifting devices used around the world. Gives operating characteristics and system design criteria for pumps and prime movers. Includes brief discussion of equipment selection.

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Excellent summary of power equipment costs, capacities, and descriptions, including solar, wind, water, biomass and thermal energy, internal and external combustion engines, and electrical generators, as well as instrumentation, monitoring, and control equipment. Somewhat dated on certain topics.

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Good practical reference on domestic water system design and construction, with useful sections on options for hardware and system configurations.

Helvig, O.; Scott, V.; and Scalmanini, J. Improving Well and Pump Efficiency. Denver, Colorado: American Water Works Association, 1984.

Stresses efficiency concepts in water system design. Contains detailed practical strategies for improving the efficiency of wells and water pumping systems.

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Summarizes detailed technical issues and related financial/economic concerns surrounding wind pump use, based on field tests conducted during Botswana Renewable Energy Technology (BRET) Project.

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Good reference on solar pump operation and system sizing. Gives methodology for choosing PV systems based on technical selection criteria.

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Lancashire, S., Kenna, J.; and Fraenkel, P. Windpumping Handbook. London, England: Intermediate Technology Publications, Ltd., 1987.

Good practical reference on wind-pumping technology, including sizing for water supply and irrigation, and information on procurement, installation, and maintenance.

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Very detailed general reference on design and theory of operation for electrical and mechanical wind machines, with an emphasis on water-pumping applications.

McGowan, R., and Hodgkin, J. Water Pump Field Tests in Botswana. Burlington, Vermont: Associates in Rural Development, Inc. (ARD), 1985.

Summarizes results of technical and economic comparisons of diesel, wind, solar, hand, and animal-traction pumps, based on two-year program of field tests conducted during the Botswana Renewable Energy Terminology (BRET) Project.

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Provides checklists for identifying sites and projects and planning and designing community piped water supplies. Useful coverage of system design process, with general focus on most relevant technical issues and good discussion of infrastructural support/planning requirements.

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Good brief summary of all aspects of village drinking-water supply projects. Covers technical aspects, costs (in summary fashion), financial aspects, organization and management, justifying investments, policy issues, and project and program design.

APPENDIX B

Friction Losses

* Theodore Baumeister, Euguene A. Avallone, and Theodore Baumeister, III (eds.), Marks' Standard Handbook for Mechanical Engineers, 8th ed. (New York : McGraw-Hill Book Company), pp. 12-106 and 12-109

Valve Losses in Equivalent Feet and Meters of Pipe for Screwed, Welded, Flanged, and Flared Connections

Nominal pipe or tube size		Globe†		60° Y		45° Y		Angle†		Gate‡		Swing check§		Lift check	
in	mm	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m		
⅜	10	17	5.0	8	2.4	6	1.8	6	1.8	0.6	0.2	5	1.5		
½	12	18	5.5	9	2.7	7	2.1	7	2.1	0.7	0.2	6	1.8		
¾	20	22	6.7	11	3.4	9	2.7	9	2.7	0.9	0.3	8	2.4	Globe and	
1	25	29	8.8	15	4.6	12	3.7	12	3.7	1.0	0.3	10	3.0	vertical	
1¼	32	38	11.6	20	6.1	15	4.6	15	4.6	1.5	0.5	14	4.3	lift	
1½	40	43	13.1	24	7.3	18	5.5	18	5.5	1.8	0.5	16	4.9	same as	
2	50	55	16.8	30	9.1	24	7.3	24	7.3	2.3	0.7	20	6.1	globe	
2½	60	69	21.0	35	10.7	29	8.8	29	8.8	2.8	0.9	25	7.6	valve¶	
3	80	84	25.6	45	13.7	35	10.7	35	10.7	3.2	1.0	30	9.1		
3½	90	100	30.5	50	15.2	41	12.5	41	12.5	4.0	1.2	35	10.7		
4	100	120	36.6	58	17.7	47	14.3	47	14.3	4.5	1.4	40	12.2		
5	130	140	42.7	70	21.6	58	17.7	58	17.7	6	1.8	50	15.2		
6	150	170	51.8	80	24.3	70	21.3	70	21.3	7	2.1	60	18.3		
8	200	220	67.1	115	35.1	85	25.9	85	25.9	9	2.7	80	24.4		
10	250	280	85.3	145	44.2	105	32.0	105	32.0	12	3.7	100	30.5		
12	300	320	97.5	165	50.3	130	39.6	130	39.6	13	4.0	120	36.6	Angle lift	
14	350	360	109.7	185	56.4	155	47.2	155	47.2	15	4.6	135	41.1	same as	
16	400	410	125.0	210	64.0	180	54.9	180	54.9	17	5.0	150	45.7	angle	
18	450	460	140.2	240	73.2	200	61.0	200	61.0	19	5.8	165	50.3	valve	
20	500	520	158.5	275	83.8	235	71.6	235	71.6	22	6.7	200	61.0		
24	600	610	185.9	320	97.5	265	80.8	265	80.8	25	7.6	240	73.2		

*Losses are for all valves in fully open position.
†These losses do not apply to valves with needle-point-type seats.
‡Regular and short pattern plug cock valves, when fully open, have same loss as gate valve. For valve losses of short-pattern plug cocks above 6 in. check manufacturer.
§Losses also apply to the in-line, ball-type check valve.
¶For Y pattern globe lift-check valve with seat approximately equal to the nominal pipe diameter, use values of 60° Y valve for loss.

Smooth-bend tees								Mitre elbows							
Flow-through branch		Straight-through flow						90° ell		60° ell		45° ell		30° ell	
		No reduction		Reduced ½		Reduced ¼									
ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
2.7	0.8	0.9	0.3	1.2	0.4	1.4	0.4	2.7	0.8	1.1	0.3	0.6	0.2	0.3	0.1
3.0	0.9	1.0	0.3	1.4	0.4	1.6	0.5	3.0	0.9	1.3	0.4	0.7	0.2	0.4	0.1
4.0	1.2	1.4	0.4	1.9	0.6	2.0	0.6	4.0	1.2	1.6	0.5	0.9	0.3	0.5	0.2
5.0	1.5	1.7	0.5	2.4	0.7	2.6	0.8	5.0	1.5	2.1	0.6	1.0	0.3	0.7	0.2
7.0	2.1	2.3	0.7	3.1	0.9	3.1	1.0	7.0	2.1	3.0	0.9	1.5	0.5	0.9	0.3
8.0	2.4	2.6	0.8	3.7	1.1	4.0	1.2	8.0	2.4	3.4	1.0	1.8	0.5	1.1	0.3
10	3.0	3.3	1.0	4.7	1.4	5.0	1.5	10	3.0	4.5	1.4	2.3	0.7	1.3	0.4
12	3.7	4.1	1.2	5.6	1.7	6.0	1.8	12	3.7	5.2	1.6	2.8	0.9	1.7	0.5
15	4.6	5.0	1.5	7.0	2.1	7.5	2.3	15	4.6	6.4	2.0	3.2	1.0	2.0	0.6
18	5.5	5.9	1.8	8.0	2.4	9.0	2.7	18	5.5	7.3	2.2	4.0	1.2	2.4	0.7
21	6.4	6.7	2.0	9.0	2.7	10	3.0	21	6.4	8.5	2.6	4.5	1.4	2.7	0.8
25	7.6	8.2	2.5	12	3.7	13	4.0	25	7.6	11	3.4	6.0	1.8	3.2	1.0
30	9.1	10	3.0	14	4.3	16	4.9	30	9.1	13	4.0	7.0	2.1	4.0	1.2
40	12.2	13	4.0	18	5.5	20	6.1	40	12.2	17	5.2	9.0	2.7	5.1	1.6
50	15.2	16	4.9	23	7.0	25	7.6	50	15.2	21	6.4	12	3.7	7.2	2.2
60	18.3	19	5.8	26	7.9	30	9.1	60	18.3	25	7.6	13	4.0	8.0	2.4
68	20.7	23	7.0	30	9.1	34	10.4	68	20.7	29	8.8	15	4.6	9.0	2.7
78	23.8	26	7.9	35	10.7	38	11.6	78	23.8	31	9.4	17	5.2	10	3.0
85	25.9	29	8.8	40	12.2	42	12.8	85	25.9	37	11.3	19	5.8	11	3.4
100	30.5	33	10.1	44	13.4	50	15.2	100	30.5	41	12.5	22	6.7	13	4.0
115	35.1	40	12.2	50	15.2	60	18.3	115	35.1	49	14.9	25	7.6	16	4.9

*(D/d) approximately equal to 1.
†(D/d) approximately equal to 1.5.

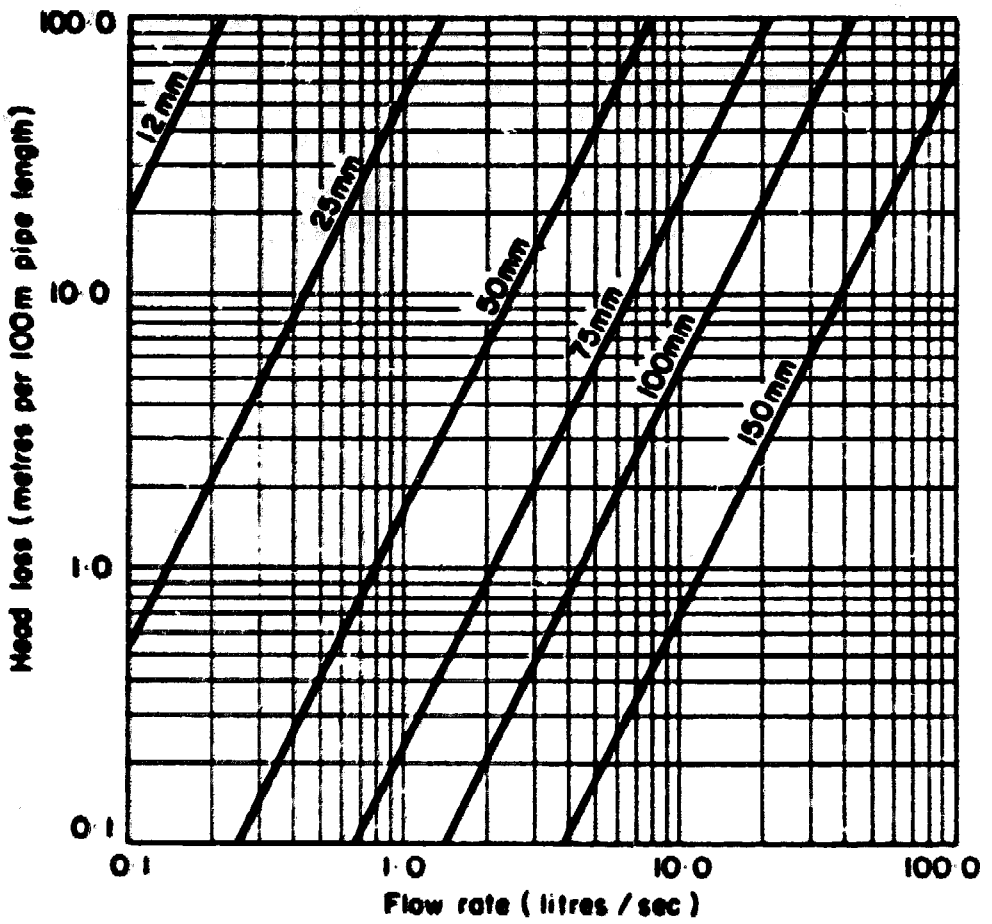

Head loss in smooth pipes of different internal diameter

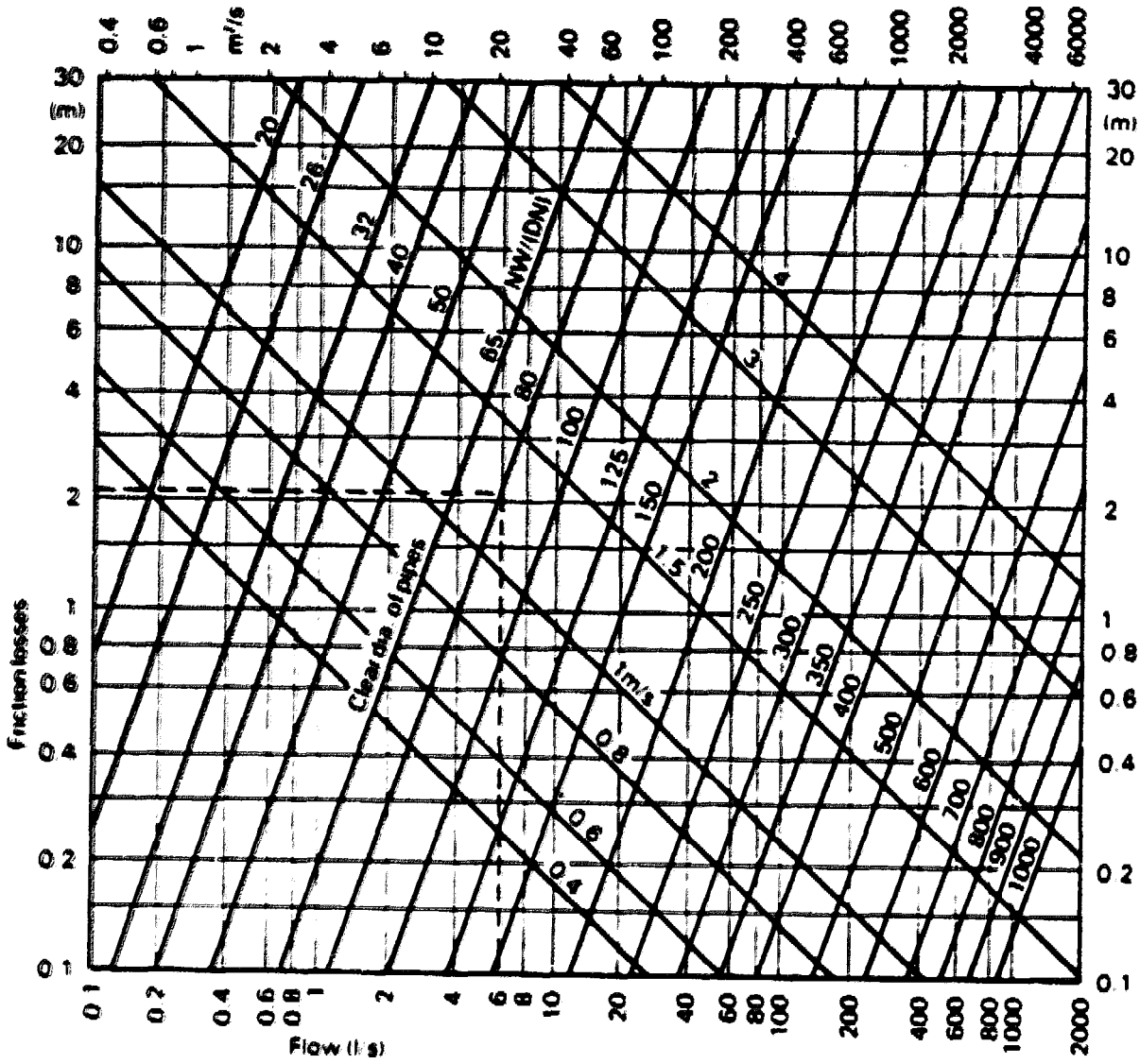

Friction losses in metres per 100m for a new pipeline of cast iron

For other types of pipe multiply the friction loss as indicated by the table by the factors given below:

New Rolled steel	-	0.8
New plastic	-	0.8
Old rusty cast iron	-	1.25
Pipes with encrustations	-	1.7

Determination of head friction losses in straight pipes

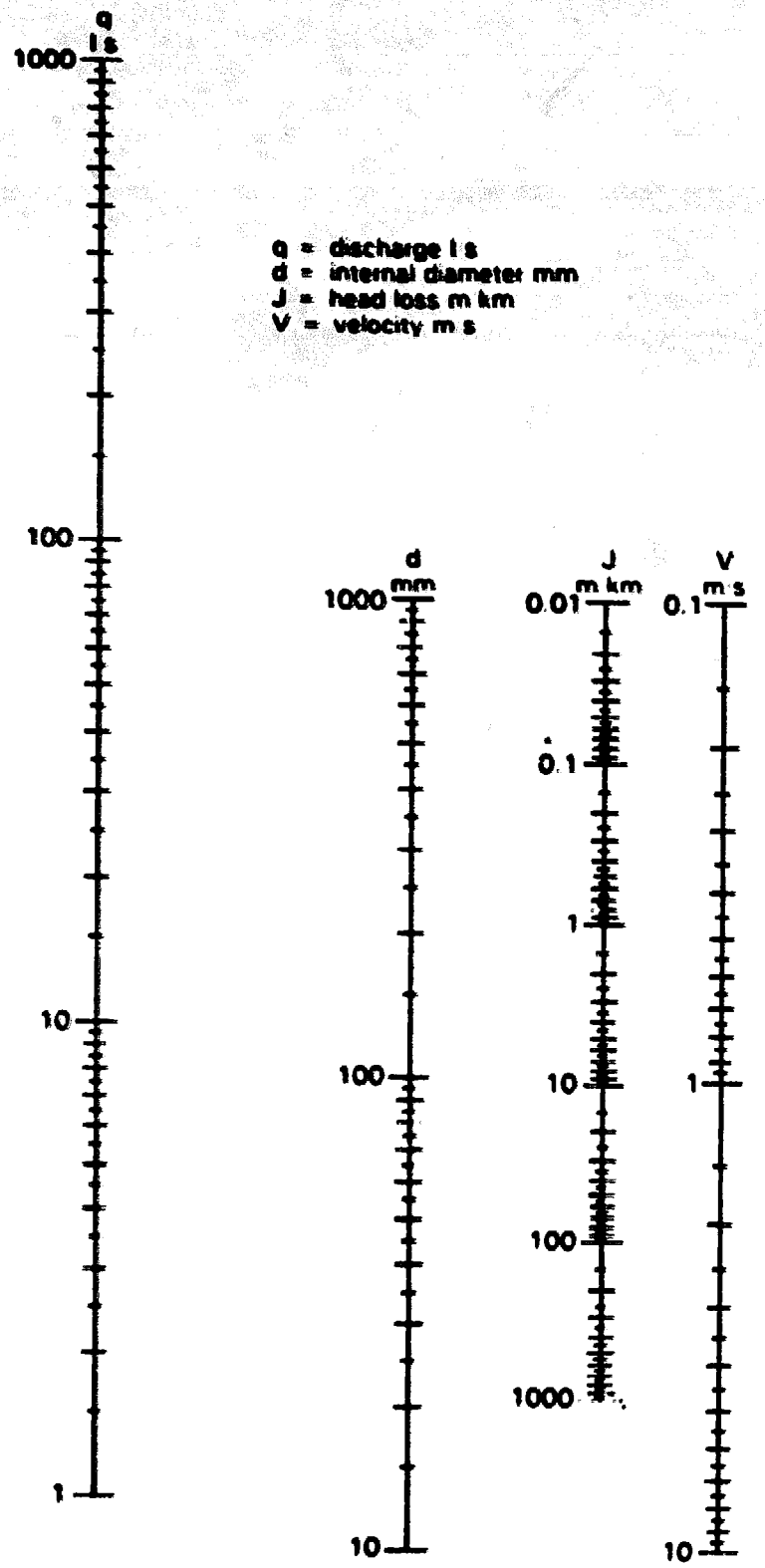

Head loss nomogram calculated for rigid PVC pipes using Blasius formula

APPENDIX C

Typical Recommended Service for Diesel Engines

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The following summarizes the recommended service intervals for Lister engines. The engine model is given in parentheses (e.g., ST, LT, 8/1). Where no model is specified, the procedure applies to all.

Daily	Check supply of diesel fuel and oil level Check air filter (in dusty conditions)
125 hrs	Check air filter (in moderately dusty conditions, renew if necessary) Check for oil and fuel leaks Check and tighten nuts and bolts as necessary Clean engine and mounting
250 hrs	Change engine oil Clean the restrictor banjo union in the lubricating oil feed line Renew oil filter if fitted (ST) Clean injector nozzle if exhaust is dirty Renew fuel filter if necessary Check belt tension
500 hrs	Decarbonize if necessary (LT) Renew fuel filter element (ST) Adjust valve clearances (LT) Change oil in oil bath air filters (8/1 so equipped)
1000 hrs	Decarbonize (8/1) and if necessary (ST) Change filter elements (8/1) Adjust valve clearances (LT)
500 hrs	Decarbonize (LT) Examine and clean fan blades (LT) Check governor linkage and adjustment (LT) Drain and clean fuel tank (LT) Renew fuel filter (LT) Clean and test the injector nozzle (LT) Check fuel pump timing (LT) Check oil pump and its valves (LT) Renew the air filter element (LT)
2000 hrs	Decarbonize (ST) Clean inlet and exhaust system (ST) Examine and clean fan blades (ST) Check governor linkage and adjustment (ST) Drain and clean fuel tank (ST) Renew fuel filter (ST) Clean and test the injector nozzle (ST) Check fuel pump and its valves (ST) Renew the air filter element (ST)

APPENDIX D

Handpump Selection lables*

* Arlosoroff et al. 1987, 80-87

GUIDE TO PUMP SELECTION TABLES

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Column 1 — Pump Name

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Column 3 — Discharge Rate

The discharge rate deemed "adequate" for each pumping lift is noted at the top of the appropriate table. The rate reduces as depth increases, for the reasons explained in Box 5.1. Some deepwell pumps thus achieve lower ratings for low-lift applications, where users will opt for pumps giving greater discharges. A special note is made where a pump is available with a range of cylinder sizes or adjustable stroke length, to suit different depths.

Column 4 — Ease of Maintenance

Ratings indicate the ease with which maintenance can be carried out by:

- A — A village caretaker
- B — An area mechanic
- C — A mobile maintenance team

Column 5 — Reliability

Reliability ratings are an indication of the proportion of the time that the pump is likely to be functioning properly. Separate ratings are given for different daily outputs. The ratings combine judgments of the "mean time before failure" (MTBF) and the probable "downtime" when the pump is waiting to be repaired. They thus take account of the fact that pumps which are suitable for village maintenance and can be repaired quickly may be more "reliable" than those which require more complex maintenance, even if the latter break down less frequently.

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Ratings are based primarily on the materials of the downhole components. Galvanized steel pumprods and rising mains are not corrosion resistant in aggressive water and earn a — rating.

Column 7 — Abrasion Resistance

Ratings indicate the pump's capability to pump sand-laden water. Performance in laboratory and field trials is combined with assessment of the seal and valve types. For non-suction pumps, leather cupseals are rated — , though the extent of abrasion damage will be related to the daily output of the pump. Analysts may therefore accept lower rated pumps for light duty applications.

Column 8 — Manufacturing Needs

Ratings indicate the ease with which a pump could be manufactured in a developing country with the specified level of industrial development.

- 1 — Low industrial base, limited quality control
- 2 — Medium-level industry, no special processes
- 3 — Advanced industry, good quality control

Column 9 — Short List

The Analyst develops a short list by entering a check mark against those pumps meeting his selection criteria.

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Analysts should obtain current prices for short-listed pumps.

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Special features of individual pumps are noted in this column. Amplification of the notes is given below.

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Note 7. The Duba Tropic 7 is a high-discharge pump designed for two-person operation.

Notes 9 and 10. The India Mark II uses a gravity return on the plunger, and requires a minimum cylinder setting of 24 meters (one manufacturer offers a fixed-link system for shallower settings).

Note 14. The Maldev is a pumphead only. All ratings are based on the use of conventional downhole components.

Note 16. Reliability ratings for the Monolift are based on pumps with metal gears. Plastic gears were less reliable.

Note 21. The ●● corrosion rating for the Vergnet is based on current models. Earlier models did suffer from corrosion.

Note 23. The ●● discharge rating for the Volanta takes account of the pump's adjustable stroke length. Present designs require a minimum well diameter of 110mm.

Note 30. Downhole components of the Kangaroo are corrosion resistant. The ● rating relates to the pedal return spring.

Note 40. The Rower is designed as an irrigation pump, and has a high discharge. It is widely used for domestic water supply in Bangladesh.

Maximum pumping lift — 7 meters
"Adequate" discharge rate — 19 liters/minute

1	2	3	4			5			6	7	8			9	10	11
Pump name	Data source	Discharge rate	Ease of maintenance A	B	C	Reliability (m³/d) 1.5	4	8	Corr. res.	Abr. res.	Manufacturing needs 1	2	3	Short list	Price (US$)	Remarks
HIGH LIFT PUMPS (0-45 meters)																
1 Abi ASM	L (F)	—	—	oo	oo	oo	o	—	oo	o	—	o	o			See Note 1
2 Afridev	(F)	o	oo	oo	oo	oo	oo	o	o	o	o	oo	oo			See Note 2
3 AID Deriv. Deepwell	L F	oo	—	oo	oo	oo	o	—	—	—	—	oo	oo			
4 Beatobell	L	o	—	oo	oo	oo	o	—	o	o	o	oo	oo			
5 Climax	L	oo*	—	—	oo	oo	oo	o	—	—	—	—	oo			
6 Dragon 2	L	o	—	oo	oo	oo	o	—	—	—	—	o	oo			
7 Duba Tropic 7	F	oo*	—	o	oo	oo	o	—	—	—	—	—	oo			See Note 7
8 GSW	L (F)	o*	—	oo	oo	oo	oo	o	—	—	—	o	oo			
9 India Mark II (standard)	L F	o	—	oo	oo	oo	oo	oo	—	—	—	o	oo			See Note 9
10 India Mark II (modified)	(F)	o	—	oo	oo	oo	oo	oo	—	o	—	o	oo			See Note 10
11 Jetmatic Deepwell	L	o	—	oo	oo	oo	oo	o	—	—	—	o	oo			
12 Kardia	L (F)	o	—	oo	oo	oo	oo	o	oo	o	—	o	oo			
13 Korat	L F	oo*	—	oo	oo	oo	oo	o	—	—	—	oo	oo			
14 Maldev	L F	oo*	—	oo	oo	oo	oo	o	—	—	o	oo	oo			See Note 14
15 Monarch P3	L F	oo*	—	oo	oo	oo	oo	o	—	—	—	o	oo			
16 Monolift	L (F)	—	—	—	oo	oo	oo	o	—	oo	—	—	oo			See Note 16
17 Moyno	L F	—	—	—	oo	oo	oo	o	—	oo	—	—	o			
18 Nira AF84	L	o	—	oo	oo	oo	oo	o	oo	o	—	o	oo			
19 Philippines Deepset	(F)	o	—	oo	oo	oo	o	—	—	—	o	oo	oo			
20 SWN 80 & 81	F	oo*	—	oo	oo	oo	oo	oo	oo	oo	—	oo	oo			
21 Vergnet	L F	—	o	oo	oo	oo	oo	o	oo	o	—	o	o			See Note 21
22 VEW A18	L	o	—	o	oo	oo	o	—	oo	—	—	—	o			
23 Volanta	L F	oo	o	oo	oo	oo	oo	oo	oo	oo	o	o	oo			See Note 23
INTERMEDIATE LIFT PUMPS (0-25 meters)																
24 Consallen LD6	L F	oo*	—	oo	oo	oo	oo	o	oo	o	—	o	oo			
25 DMR (Dempster deriv.)	F	oo*	—	oo	oo	oo	o	—	—	—	—	oo	oo			
26 Nira AF76	L F	oo*	—	oo	oo	oo	o	—	—	o	—	oo	oo			
LOW LIFT PUMPS (0-12 meters)																
27 Blair	F	o	oo	oo	oo	oo	o	—	oo	o	o	oo	oo			
28 Ethiopia BP50	L	oo	o	oo	oo	oo	o	o	o	—	o	oo	oo			7m max. lift
29 IDRC UM	L	oo	o	oo	oo	oo	o	—	oo	—	o	oo	oo			
30 Kangaroo	L F	oo	—	oo	oo	oo	o	—	o	oo	—	o	oo			See Note 30
31 Malawi Mark V	F	oo	o	oo	oo	o	—	—	oo	o	o	oo	oo			7m max. lift
32 Nira AF85	L F	oo	oo	oo	oo	oo	oo	oo	oo	o	o	oo	oo			
33 Tara	L F	oo	oo	oo	oo	oo	o	—	o	—	o	oo	oo			
SUCTION PUMPS (0-7 meters)																
34 AID Suction	F	oo	o	oo	oo	oo	o	—	—	o	—	oo	oo			
35 Barcura	L	oo	oo	oo	oo	oo	oo	o	o	o	—	oo	oo			
36 Inaisa Suction	F	oo	o	oo	oo	oo	o	—	—	—	—	oo	oo			
37 Jetmatic Suction	(F)	oo	o	oo	oo	oo	o	—	o	o	—	oo	oo			
38 Lucky	F	oo	o	oo	oo	o	—	—	—	o	—	oo	oo			
39 New No. 6	L (F)	oo	oo	oo	oo	oo	o	—	—	oo	—	oo	oo			
40 Power	L (F)	oo	oo	oo	oo	oo	oo	o	o	o	oo	oo	oo			See Note 40
41 SYB 100	F	oo	o	oo	oo	oo	oo	o	o	oo	—	oo	oo			
42 Wasp	F	oo	o	oo	oo	oo	o	—	—	o	—	oo	oo			
ADDITIONAL PUMPS																
A1																
A2																
A3																
A4																

* Indicates that discharge ratings are based on choice of the correct cylinder size from a range offered by the manufacturer.

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Maximum pumping lift — 12 meters
"Adequate" discharge rate — 16 liters/minute

1	2	3	4			5			6	7	8			9	10	11
			Ease of maintenance			Reliability for (m^3/d)					Manufacturing needs					
Pump name	Data source	Discharge rate	A	B	C	1.5	4	8	Corr. res.	Abr. res.	1	2	3	Short list	Price (US$)	Remarks
HIGH LIFT PUMPS (0-45 meters)																
1 Abi ASM	L (F)	o	—	oo	oo	oo	o	—	oo	o	—	o	o			See Note 1
2 Aindev	(F)	oo	oo	oo	oo	oo	oo	o	o	o	o	oo	oo			See Note 2
3 AID Deriv. Deepwell	L F	oo	—	oo	oo	oo	o	—	—	—	—	oo	oo			
4 Beatobelt	L	o	—	oo	oo	oo	o	—	o	o	o	oo	oo			
5 Climax	L	oo*	—	—	oo	oo	oo	o	—	—	—	—	oo			
6 Dragon 2	L	o	—	oo	oo	oo	o	—	—	—	—	o	oo			
7 Duba Tropic 7	F	oo*	—	o	oo	oo	o	—	—	—	—	—	oo			See Note 7
8 GSW	L (F)	o*	—	oo	oo	oo	oo	o	—	—	—	o	oo			
9 India Mark II (standard)	L F	o	—	oo	oo	oo	oo	oo	—	—	—	o	oo			See Note 9
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11 Jetmasc Deepwell	L	o	—	oo	oo	oo	oo	o	—	—	—	o	oo			
12 Kardia	L (F)	o	—	oo	oo	oo	oo	o	oo	o	—	o	oo			
13 Korat	L F	oo*	—	oo	oo	oo	oo	o	—	—	—	oo	oo			
14 Maldev	L F	oo*	—	oo	oo	oo	oo	o	—	—	o	oo	oo			See Note 14
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16 Monolith	L (F)	o	—	—	oo	oo	oo	o	—	oo	—	—	oo			See Note 16
17 Moyno	L F	—	—	—	oo	oo	oo	o	—	oo	—	—	o			
18 Nira AF84	L	o	—	oo	oo	oo	oo	o	oo	o	—	o	oo			
19 Philippines Deepset	(F)	o	—	oo	oo	oo	o	—	—	—	o	oo	oo			
20 SWN 80 & 81	F	oo*	—	oo	oo	oo	oo	oo	oo	oo	—	oo	oo			
21 Vergnet	L F	—	o	oo	oo	oo	oo	o	oo	o	—	o	o			See Note 21
22 VEW A18	L	o	—	o	oo	oo	o	—	oo	—	—	—	o			
23 Volanta	L F	oo	o	oo	oo	oo	oo	oo	oo	oo	o	o	oo			See Note 23
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24 Consallen LD6	L F	oo*	—	oo	oo	oo	o	—	oo	o	—	o	oo			
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26 Nira AF76	L F	oo*	—	oo	oo	oo	o	—	—	o	—	oo	oo			
LOW LIFT PUMPS (0-12 meters)																
27 Blair	F	o	oo	oo	oo	oo	o	—	oo	o	o	oo	oo			
28 Ethiopia BP50	L															7m max. lift
29 IDRC UM	L	oo	o	oo	oo	oo	o	—	oo	—	o	oo	oo			
30 Kangaroo	L F	oo	—	oo	oo	oo	o	—	o	oo	—	o	oo			See Note 30
31 Malawi Mark V	F															7m max. lift
32 Nira AF85	L F	oo	oo	oo	oo	oo	oo	o	oo	o	o	oo	oo			
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Reliability ratings are an indication of the proportion of the time that the pump is likely to be functioning properly. Separate ratings are given for different daily outputs. The ratings combine judgments of the "mean time before failure" (MTBF) and the probable "downtime" when the pump is waiting to be repaired. They thus take account of the fact that pumps which are suitable for village maintenance and can be repaired quickly may be more "reliable" than those which require more complex maintenance, even if the latter break down less frequently.

Column 6 — Corrosion Resistance

Ratings are based primarily on the materials of the downhole components. Galvanized steel pumprods and rising mains are not corrosion resistant in aggressive water and earn a — rating.

Column 7 — Abrasion Resistance

Ratings indicate the pump's capability to pump sand-laden water. Performance in laboratory and field trials is combined with assessment of the seal and valve types. Leather cupseals are rated — , though the extent of abrasion damage will be related to the daily output of the pump. Analysts may therefore accept lower rated pumps for light duty applications.

Column 8 — Manufacturing Needs

Ratings indicate the ease with which a pump could be manufactured in a developing country with the specified level of industrial development.

- 1 — Low industrial base, limited quality control
- 2 — Medium-level industry, no special processes
- 3 — Advanced industry, good quality control

Column 9 — Short List

The Analyst develops a short list by entering a check mark against those pumps meeting his selection criteria.

Column 10 — Capital Cost

Analysts should obtain current prices for short-listed pumps.

Column 11 — Remarks

Special features of individual pumps are noted in this column. Amplification of the notes is given below.

Amplification of the ratings for individual pumps can be found in the Handpump Compendium

NOTES ON TABLES

The notes relate to pumps with the same reference number — i.e. Note 14 refers to Pump 14, the Maldev. In the tables, ratings to which the note refers are highlighted: o

Note 1. The oo corrosion rating for the Abi-ASM is based on current models. Earlier models did suffer from corrosion.

Note 2. The o corrosion rating for the Aindev is based on the use of stainless steel pumprods, offered as an option.

Note 7. The Duba Tropic 7 is a high-discharge pump designed for two-person operation.

Note 14. The Maldev is a pumphead only. All ratings are based on the use of conventional downhole components.

Note 16. Reliability ratings for the Monolift are based on pumps with metal gears. Plastic gears were less reliable.

Note 21. The oo corrosion rating for the Vergnet is based on current models. Earlier models did suffer from corrosion.

Note 23. The oo discharge rating for the Volanta takes account of the pump's adjustable stroke length. Present designs require a minimum well diameter of 110mm.

Maximum pumping lift — 25 meters

"Adequate" discharge rate — 10 liters/minute

1	2	3	4			5		6	7	8			9	10	11
Pump name	Data source	Discharge rate	Ease of maintenance A	B	C	Reliability for (m^3/d) 4	8	Corr. res.	Abr. res.	Manufacturing needs 1	2	3	Short list	Price (US$)	Remarks
HIGH LIFT PUMPS (0-45 meters)															
1 Abi-ASM	L (F)	●	—	○○	○○	●	—	○○	●	—	●	●			See Note 1
2 Afridev	(F)	○○	○○	○○	○○	○○	●	●	●	●	○○	○○			See Note 2
3 AID Demo Deepwell	L F	●	—	●	○○	—	—	—	—	—	○○	○○			
4 Bestobell	L	●	—	●	○○	●	—	●	●	●	○○	○○			
5 Climax	L	○○*	—	—	○○	○○	●	—	—	—	—	○○			
6 Dragon 2	L	●	—	●	○○	—	—	—	—	—	●	○○			
7 Duba Tropic 7	F	○○*	—	●	○○	●	—	—	—	—	—	○○			See Note 7
8 GSW	L (F)	○○*	—	●	○○	●	—	—	—	—	●	○○			
9 India Mark II (standard)	L F	○○	—	●	○○	●	—	—	—	—	●	○○			
10 India Mark II (modified)	(F)	○○	—	○○	○○	○○	●	—	●	—	●	○○			
11 Jermanc Deepwell	L	●	—	●	○○	—	—	—	—	—	●	○○			
12 Kardia	L (F)	○○	—	○○	○○	●	—	○○	●	—	●	○○			
13 Kizan	L F	○○*	—	●	○○	●	—	—	—	—	○○	○○			
14 Maldev	L F	○○*	—	●	○○	●	—	—	—	●	○○	○○			See Note 14
15 Monarch PY*	L F	○○	—	●	○○	●	—	—	—	—	●	○○			
16 Monolift	L (F)	●	—	—	○○	○○	●	—	○○	—	—	○○			See Note 16
17 Moyno	L F	●	—	—	○○	○○	●	—	○○	—	—	●			
18 Nira AF84	L	●	—	●	○○	○○	●	○○	●	—	●	○○			
19 Philippines Deepset	(F)	○○	—	●	○○	●	—	—	—	●	○○	○○			
20 SWN 80 & 81	F	○○*	—	●	○○	●	—	○○	○○	—	○○	○○			
21 Vergnet	L F	●	●	○○	○○	○○	●	○○	●	—	●	●			See Note 21
22 VEW A18	L	●	—	—	○○	●	—	○○	—	—	—	●			
23 Volanta	L F	○○	●	○○	○○	○○	○○	○○	○○	●	●	○○			See Note 23
INTERMEDIATE LIFT PUMPS (0-25 meters)															
24 Consallen LD6	L F	○○*	—	○○	○○	—	—	○○	●	—	●	○○			
25 DMR (Dempster deriv.)	F	○○*	—	●	○○	—	—	—	—	—	○○	○○			
26 Nira AF76	L F	○○*	—	●	○○	—	—	—	●	—	○○	○○			
ADDITIONAL PUMPS															
A1															
A2															
A3															
A4															

* Indicates that discharge ratings are based on choice of the correct cylinder size from a range offered by the manufacturer.

GUIDE TO PUMP SELECTION TABLES

THE RATINGS

Ratings in the Pump Selection Tables are based on evaluation of pump performance in the laboratory and field trials. Three ratings are used:

- ●● = Good
- ● = Adequate
- — = Does not meet minimum requirements.

A more detailed interpretation of the ratings for specific headings can be found in the earlier part of this Chapter.

Column 1 — Pump Name

The pumps are listed alphabetically in four sections, according to the maximum pumping lift recommended by the manufacturer. The reference number which precedes each pump name indicates the order of the pumps in the Handpump Compendium.

Column 2 — Data Source

- L = The pump has been tested in the laboratory
- F = The pump has had a minimum of 2 years' field trials
- (F) = The pump has had limited field trials

Column 3 — Discharge Rate

The discharge rate deemed "adequate" for each pumping lift is noted at the top of the appropriate table. The rate reduces as depth increases, for the reasons explained in Box 5.1. Some deepwell pumps thus achieve lower ratings for low-lift applications, where users will opt for pumps giving greater discharges. A special note is made where a pump is available with a range of cylinder sizes or adjustable stroke length, to suit different depths.

Column 4 — Ease of Maintenance

Ratings indicate the ease with which maintenance can be carried out by:

- A — A village caretaker
- B — An area mechanic
- C — A mobile maintenance team

Column 5 — Reliability

Reliability ratings are an indication of the proportion of the time that the pump is likely to be functioning properly. Separate ratings are given for different daily outputs. The ratings combine judgments of the "mean time before failure" (MTBF) and the probable "downtime" when the pump is waiting to be repaired. They thus take account of the fact that pumps which are suitable for village maintenance and can be repaired quickly may be more "reliable" than those which require more complex maintenance, even if the latter break down less frequently.

Column 6 — Corrosion Resistance

Ratings are based primarily on the materials of the downhole components. Galvanized steel pumprods and rising mains are not corrosion resistant in aggressive water and earn a — rating.

Column 7 — Abrasion Resistance

Ratings indicate the pump's capability to pump sand-laden water. Performance in laboratory and field trials is combined with assessment of the seal and valve types. Leather cupseals are rated — , though the extent of abrasion damage will be related to the daily output of the pump. Analysts may therefore accept lower rated pumps for light duty applications.

Column 8 — Manufacturing Needs

Ratings indicate the ease with which a pump could be manufactured in a developing country with the specified level of industrial development.

- 1 — Low industrial base, limited quality control
- 2 — Medium-level industry, no special processes
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Column 9 — Short List

The Analyst develops a short list by entering a check mark against those pumps meeting his selection criteria.

Column 10 — Capital Cost

Analysts should obtain current prices for short-listed pumps.

Column 11 — Remarks

Special features of individual pumps are noted in this column. Amplification of the notes is given below.

> Amplification of the ratings for individual pumps can be found in the Handpump Compendium.

NOTES ON TABLES

The notes relate to pumps with the same reference number — i.e. Note 14 refers to Pump 14, the Maldev. In the tables, ratings to which the note refers are highlighted ●

Note 1. The ●● corrosion rating for the Abi-ASM is based on current models. Earlier models did suffer from corrosion.

Note 2. The ● corrosion rating for the Afridev is based on the use of stainless steel pumprods, offered as an option.

Note 7. The Duba Tropic 7 is a high-discharge pump designed for two-person operation.

Note 12. The manufacturer recommends a maximum depth of 40 meters for the Kardia.

Note 14. The Maldev is a pumphead only. All ratings are based on the use of conventional downhole components.

Note 16. Reliability ratings for the Monolift are based on pumps with metal gears. Plastic gears were less reliable. A 2:1 gear ratio is supplied for deepwell applications.

Note 21. The ●● corrosion rating for the Vergnet is based on current models. Earlier models did suffer from corrosion.

Note 23. The ●● discharge rating for the Volanta takes account of the pump's adjustable stroke length. Present designs require a minimum well diameter of 110mm.

Maximum pumping lift — 45 meters
"Adequate" discharge rate — 7 liters/minute

1	2	3	4			5	6	7	8			9	10	11
Pump name	Data source	Discharge rate	Ease of maintenance A	B	C	Reliability for (m^3/d) 4	Corr. res.	Abr. res.	Manufacturing needs 1	2	3	Short list	Price (US$)	Remarks
HIGH LIFT PUMPS (0-45 meters)														
1 Abi-ASM	L (F)	o	—	oo	oo	—	oo	o	—	o	o			See Note 1
2 Afridev	(F)	oo	oo	oo	oo	o	o	o	o	oo	oo			See Note 2
3 AID Demv. Deepwell	L F	o	—	o	oo	—	—	—	—	oo	oo			
4 Bestobell	L	o	—	o	oo	—	o	o	o	oo	oo			
5 Climax	L	oo*	—	—	oo	o	—	—	—	—	oo			
6 Dragon 2	L	o	—	o	oo	—	—	—	—	o	oo			
7 Duba Tropic 7	F	oo*	—	o	oo	—	—	—	—	—	oo			See Note 7
8 GSW	L (F)	oo*	—	o	oo	—	—	—	—	o	oo			
9 India Mark II (standard)	L F	oo	—	o	oo	—	—	—	—	o	oo			
10 India Mark II (modified)	(F)	oo	—	oo	oo	o	—	o	—	o	oo			
11 Jetmatic Deepwell	L	oo	—	o	oo	—	—	—	—	o	oo			
12 Kardia	L (F)	oo	—	o	oo	—	oo	o	—	o	oo			See Note 12
13 Korat	L F	oo*	—	o	oo	—	—	—	—	oo	oo			
14 Maldev	L F	oo*	—	o	oo	—	—	—	o	oo	oo			See Note 14
15 Monarch P3	L F	oo*	—	o	oo	—	—	—	—	o	oo			
16 Monolift	L (F)	o	—	—	oo	o	—	oo	—	—	oo			See Note 16
17 Moyno	L F	o	—	—	oo	o	—	oo	—	—	o			
18 Nira AF84	L	o	—	o	oo	o	oo	o	—	o	oo			
19 Philippines Deepset	(F)	oo	—	o	oo	—	—	—	o	oo	oo			
20 SWN 80 & 81	F	oo*	—	o	oo	—	oo	oo	—	oo	oo			
21 Vergnet	L F	o	o	oo	oo	o	oo	o	—	o	o			See Note 21
22 VEW A18	L	o	—	—	oo	—	oo	—	—	—	o			
23 Volanta	L F	oo	o	oo	oo	o	oo	oo	o	o	oo			See Note 23
ADDITIONAL PUMPS														
A1														
A2														
A3														
A4														

* Indicates that discharge ratings are based on choice of the correct cylinder size from a range offered by the manufacturer.

APPENDIX E

Checklist for Materials, Labor, and Transportation

APPENDIX E

Checklist for Materials, Labor, and Transportation

This appendix contains a checklist of materials, labor, and transportation. It can be used to ensure that all items have been considered in the technical and economic analysis.

Diesel

pump
pump head
shafts
pipe engine
clutch
shaft
extension
pulley
belts
pressure relief
water meter
non-return
hose tap
union
gate valve
pipe and fittings (elbows, nipples, couplings, etc.)
cement
sand
gravel
reinforcing
mesh
engine
frame
foundation bolts
lock for pump house
fuel storage tank
labor: skilled supervisory and mechanic semiskilled pipefitters, mechanic helpers unskilled labor
labor per diem allowances
transportation

Delivery pipe network

pipe
elbows, tees, and connections
gate valves
unions
labor: skilled supervisory semiskilled tank installers, pipefitters
unskilled labor
labor per diem allowances
transportation

Distribution pipe network

pipe (more than one size?)
elbows, tees, and connections
distribution boxes and valve chambers
shut-offs and gate valves
standpipes and taps
labor: skilled supervisory semiskilled tank installers, pipefitters
unskilled labor
labor per diem allowances
transportation

Storage tank

storage tank
tank stand
tank liner
water level indicator
inflow and outflow connections
pipe from borehole to tank
labor: skilled supervisory
semiskilled tank installers, pipefitters
unskilled labor
labor per diem allowances
transportation

Solar pumps

modules
array support structures
wiring connections
foundation bolts
array foundation
grounding rod
controller
batteries
battery storage and protection
pump
pump motor
submersible pump cable
safety wire
borehole clamp
sand
gravel
cement
labor: supervisory, skilled electrician
semiskilled pipefitters, electrician helpers
unskilled labor
labor per diem allowances
transportation

Windmills

windmill head
tower
pump cylinder
piping
pumprod
sand
gravel
cement
clamp of forcehead
fence (gate, wire corner posts, regular posts, barbed wire?)
labor: skilled supervisory
semiskilled pipefitters, installers
unskilled labor
labor per diem allowances
transportation

Handpumps

pump head
pump
piping
pumprod
cement
sand
gravel
labor: skilled supervisory
semiskilled or unskilled labor
labor per diem allowances
transportation

Annual costs

financing charges for capital costs
pump operator
fuel and oil
consumables (cleaning materials, etc.)
spares: maintenance (filters, belts, etc.)
spares: repair (pumpset, pipelines, storage)
labor: skilled mechanic/electrician
semiskilled pipefitters
unskilled muscle
labor per diem allowances
transportation (no. of trips)

Non-annual costs

pump replacement
engine replacement
module replacement (damage or theft)
controller replacement
battery replacement
tank replacement
rebuild well/redrill borehole

APPENDIX F

Formulas Used in Present-Worth Analysis

Formulas Used in Present-Worth Analysis*

To Find:	Given:	Factor by Which to Multiply "Given"	Factor Name	Factor Functional Symbol[b]
For single cash flows:				
F	P	$(1 + i)^N$	Single payment compound amount	$(F/P, i\%, N)$
P	F	$\frac{1}{(1 + i)^N}$	Single payment present worth	$(P/F, i\%, N)$
For uniform series (annuities):				
F	A	$\frac{(1 + i)^N - 1}{i}$	Uniform series compound amount	$(F/A, i\%, N)$
P	A	$\frac{(1 + i)^N - 1}{i(1 + i)^N}$	Uniform series present worth	$(P/A, i\%, N)$
A	F	$\frac{i}{(1 + i)^N - 1}$	Sinking fund	$(A/F, i\%, N)$
A	P	$\frac{i(1 + i)^N}{(1 + i)^N - 1}$	Capital recovery	$(A/P, i\%, N)$

[a] i, effective interest rate per interest period; N, number of interest periods; A, uniform series amount (occurs at the end of each interest period); F, future worth; P, present worth.

[b] The functional symbol system is used throughout this book.

*E. Paul DeGarmo, William G. Sullivan, and John R. Canada, Engineering Economy, 7th ed. (New York, New York: Macmillan Publishing Company, 1984), p. 75.

Compound Interest Factors (Based on annual compounding)

Where:

N = Term of Analysis (years)
F1 = Factor for Present Worth of Uniform Series of Future Payments
F2 = Factor for Present Worth of Single Future Payment

Interest Rate (%)

	6		8		10		12	
N	F1	F2	F1	F2	F1	F2	F1	F2
1	0.9434	0.9434	0.9259	0.9259	0.9091	0.9091	0.8929	0.8929
2	1.8334	0.8900	1.7833	0.8573	1.7355	0.8264	1.6901	0.7972
3	2.6730	0.8396	2.5771	0.7938	2.4869	0.7513	2.4018	0.7118
4	3.4651	0.7921	3.3121	0.7350	3.1699	0.6830	3.0373	0.6355
5	4.2124	0.7473	3.9927	0.6806	3.7908	0.6209	3.6048	0.5674
6	4.9173	0.7050	4.6229	0.6302	4.3553	0.5645	4.1114	0.5066
7	5.5824	0.6651	5.2064	0.5835	4.8684	0.5132	4.5638	0.4523
8	6.2098	0.6274	5.7466	0.5403	5.3349	0.4665	4.9676	0.4039
9	6.8017	0.5919	6.2469	0.5002	5.7590	0.4241	5.3282	0.3606
10	7.3601	0.5584	6.7101	0.4632	6.1446	0.3855	5.6502	0.3220
11	7.8869	0.5268	7.1390	0.4289	6.4951	0.3505	5.9377	0.2875
12	8.3838	0.4970	7.5361	0.3971	6.8137	0.3186	6.1944	0.2567
13	8.8527	0.4688	7.9038	0.3677	7.1034	0.2897	6.4235	0.2292
14	9.2950	0.4423	8.2442	0.3405	7.3667	0.2633	6.6282	0.2046
15	9.7122	0.4173	8.5595	0.3152	7.6061	0.2394	6.8109	0.1827
16	10.1059	0.3936	8.8514	0.2919	7.8237	0.2176	6.9740	0.1631
17	10.4773	0.3714	9.1216	0.2703	8.0216	0.1978	7.1196	0.1456
18	10.8276	0.3503	9.3719	0.2502	8.2014	0.1799	7.2497	0.1300
19	11.1581	0.3305	9.6036	0.2317	8.3649	0.1635	7.3658	0.1161
20	11.4699	0.3118	9.8181	0.2145	8.5136	0.1486	7.4694	0.1037

Pump

From Wikipedia, the free encyclopedia

A **pump** is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: *direct lift*, *displacement*, and *gravity* pumps.[1]

A small, electrically powered pump

Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power, come in many sizes, from microscopic for use in medical applications to large industrial pumps.

Mechanical pumps serve in a wide range of applications such as pumping water from wells, aquarium filtering, pond filtering and aeration, in the car industry for water-cooling and fuel injection, in the energy industry for pumping oil and natural gas or for operating cooling towers. In the medical industry, pumps are used for biochemical processes in developing and manufacturing medicine, and as artificial replacements for body parts, in particular the artificial heart and penile prosthesis.

A large, electrically driven pump (electropump) for waterworks near the Hengsteysee, Germany

Single stage pump - When in a casing only one impeller is revolving then it is called single stage pump.

Double/ Multi stage pump - When in a casing two or more than two impellers are revolving then it is called double/ multi stage pump.

In biology, many different types of chemical and bio-mechanical pumps have evolved, and biomimicry is sometimes used in developing new types of mechanical pumps.

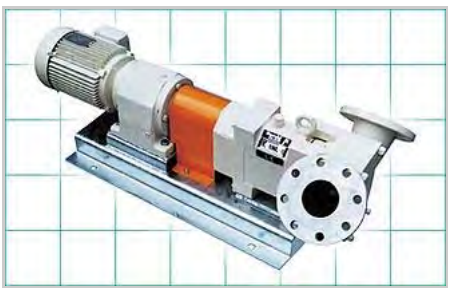

Horizontally mounted lobe pump (right) shown with its electric motor (left) and drive-shaft bearing (middle)

Contents

- 1 Types
  - 1.1 Positive displacement pumps
    - 1.1.1 Positive displacement pump behavior and safety
    - 1.1.2 Positive displacement types
      - 1.1.2.1 Rotary positive displacement pumps
      - 1.1.2.2 Reciprocating positive displacement pumps
      - 1.1.2.3 Various positive displacement pumps
        - 1.1.2.3.1 Gear pump

- 1.1.2.3.2 Screw pump
- 1.1.2.3.3 Progressing cavity pump
- 1.1.2.3.4 Roots-type pumps
- 1.1.2.3.5 Peristaltic pump
- 1.1.2.3.6 Plunger pumps
- 1.1.2.3.7 Triplex-style plunger pumps
- 1.1.2.3.8 Compressed-air-powered double-diaphragm pumps
- 1.1.2.3.9 Rope pumps
- 1.2 Impulse pumps
  - 1.2.1 Hydraulic ram pumps
- 1.3 Velocity pumps
  - 1.3.1 Radial-flow pumps
  - 1.3.2 Axial-flow pumps
  - 1.3.3 Mixed-flow pumps
  - 1.3.4 Eductor-jet pump
- 1.4 Gravity pumps
- 1.5 Steam pumps
- 1.6 Valveless pumps
- 2 Pump repairs
- 3 Applications
  - 3.1 Priming a pump
  - 3.2 Pumps as public water supplies
  - 3.3 Sealing multiphase pumping applications
    - 3.3.1 Types and features of multiphase pumps
      - 3.3.1.1 Helico-axial pumps (centrifugal)
      - 3.3.1.2 Twin-screw (positive-displacement)
      - 3.3.1.3 Progressive cavity (positive-displacement)
      - 3.3.1.4 Electric submersible (centrifugal)
- 4 Specifications
- 5 Pumping power
- 6 Efficiency
- 7 See also
- 8 References
- 9 Further reading
- 10 External links

Types

Mechanical pumps may be **submerged** in the fluid they are pumping or be placed **external** to the fluid.

Pumps can be classified by their method of displacement into positive displacement pumps, impulse pumps, velocity pumps, gravity pumps, steam pumps and valveless pumps. There are two basic types of pumps: positive displacement and centrifugal. Although axial-flow pumps are frequently classified as a separate type, they have essentially the same operating principles as centrifugal pumps.[2]

Positive displacement pumps

A positive displacement pump makes a fluid move by trapping a fixed amount and forcing (displacing) that trapped volume into the discharge pipe.

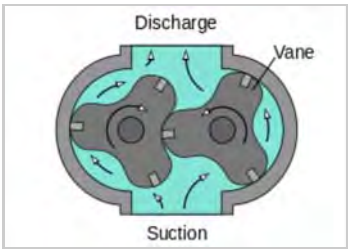

Lobe pump internals

Some positive displacement pumps use an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pump as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The volume is constant through each cycle of operation.

Positive displacement pump behavior and safety

Positive displacement pumps, unlike centrifugal or roto-dynamic pumps, theoretically can produce the same flow at a given speed (RPM) no matter what the discharge pressure. Thus, positive displacement pumps are *constant flow machines*. However, a slight increase in internal leakage as the pressure increases prevents a truly constant flow rate.

A positive displacement pump must not operate against a closed valve on the discharge side of the pump, because it has no shutoff head like centrifugal pumps. A positive displacement pump operating against a closed discharge valve continues to produce flow and the pressure in the discharge line increases until the line bursts, the pump is severely damaged, or both.

A relief or safety valve on the discharge side of the positive displacement pump is therefore necessary. The relief valve can be internal or external. The pump manufacturer normally has the option to supply internal relief or safety valves. The internal valve is usually only used as a safety precaution. An external relief valve in the discharge line, with a return line back to the suction line or supply tank provides increased safety.

Positive displacement types

A positive displacement pump can be further classified according to the mechanism used to move the fluid:

- *Rotary-type* positive displacement: internal gear, screw, shuttle block, flexible vane or sliding vane, circumferential piston, flexible impeller, helical twisted roots (e.g. the Wendelkolben pump) or liquid-ring pumps
- *Reciprocating-type* positive displacement: piston or diaphragm pumps
- *Linear-type* positive displacement: rope pumps and chain pumps

Rotary positive displacement pumps

These pumps move fluid using a rotating mechanism that creates a vacuum that captures and draws in the liquid.

Advantages: Rotary pumps are very efficient because they naturally remove air from the lines, eliminating the need to bleed the air from the lines manually.

Drawbacks: The nature of the pump requires very close clearances between the rotating pump and the outer edge, making it rotate at a slow, steady speed. If rotary pumps are operated at high speeds, the fluids cause erosion, which eventually causes enlarged clearances that liquid can pass through, which reduces efficiency.

Rotary positive displacement pumps fall into three main types:

- Gear pumps - a simple type of rotary pump where the liquid is pushed between two gears
- Screw pumps - the shape of the internals of this pump is usually two screws turning against each other to pump the liquid
- Rotary vane pumps - similar to scroll compressors, these have a cylindrical rotor encased in a similarly shaped housing. As the rotor orbits, the vanes trap fluid between the rotor and the casing, drawing the fluid through the pump.

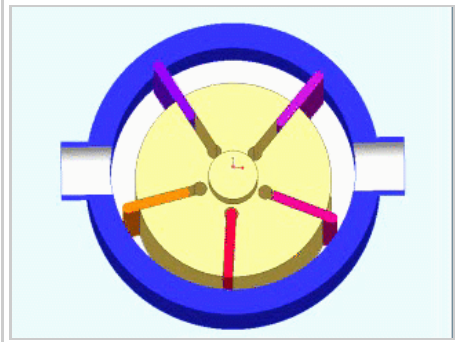

Rotary vane pump

Reciprocating positive displacement pumps

Reciprocating pumps move the fluid using one or more oscillating pistons, plungers, or membranes (diaphragms), while valves restrict fluid motion to the desired direction.

Pumps in this category range from *simplex*, with one cylinder, to in some cases *quad* (four) cylinders, or more. Many reciprocating-type pumps are *duplex* (two) or *triplex* (three) cylinder. They can be either *single-acting* with suction during one direction of piston motion and discharge on the other, or *double-acting* with suction and discharge in both directions. The pumps can be powered manually, by air or steam, or by a belt driven by an engine. This type of pump was used extensively in the 19th century—in the early days of steam propulsion—as boiler feed water pumps. Now reciprocating pumps typically pump highly viscous fluids like concrete and heavy oils, and serve in special applications that demand low flow rates against high resistance. Reciprocating hand pumps were widely used to pump water from wells. Common bicycle pumps and foot pumps for inflation use reciprocating action.

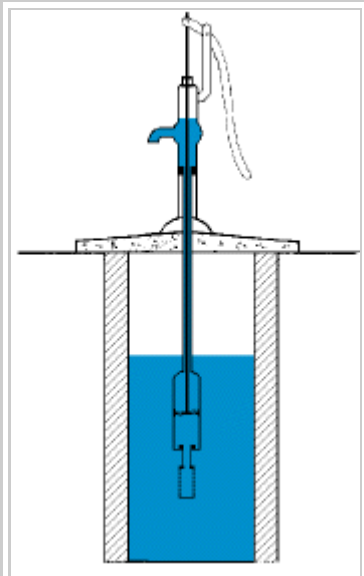

Simple hand pump

These positive displacement pumps have an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pumps as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The volume is constant given each cycle of operation.

Typical reciprocating pumps are:

- *Plunger pumps* - a reciprocating plunger pushes the fluid through one or two open valves, closed by suction on the way back.
- *Diaphragm pumps* - similar to plunger pumps, where the plunger pressurizes hydraulic oil which is used to flex a diaphragm in the pumping cylinder. Diaphragm valves are used to pump hazardous and toxic fluids.
- *Piston pumps* displacement pumps - *usually simple devices for pumping small amounts of liquid or gel manually. The common hand soap dispenser is such a pump.*
- *Radial piston pumps*

Various positive displacement pumps

The positive displacement principle applies in these pumps:

- Rotary lobe pump
- Progressive cavity pump
- Rotary gear pump
- Piston pump
- Diaphragm pump
- Screw pump
- Gear pump
- Hydraulic pump
- Rotary vane pump
- Peristaltic pump
- Rope pump
- Flexible impeller pump

Old hand water pump (c. 1924) at the Colored School in Alapaha, Georgia, US

Gear pump

This is the simplest of rotary positive displacement pumps. It consists of two meshed gears that rotate in a closely fitted casing. The tooth spaces trap fluid and force it around the outer periphery. The fluid does not travel back on the meshed part, because the teeth mesh closely in the center. Gear pumps see wide use in car engine oil pumps and in various hydraulic power packs.

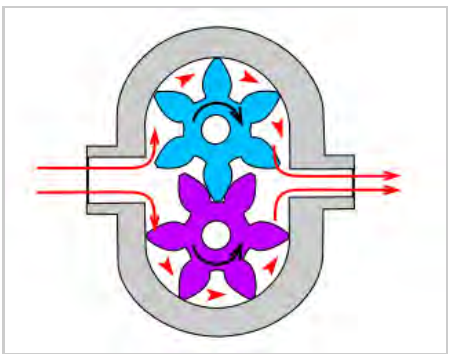

Gear pump

Screw pump

A screw pump is a more complicated type of rotary pump that uses two or three screws with opposing thread — e.g., one screw turns clockwise and the other counterclockwise. The screws are mounted on parallel shafts that have gears that mesh so the shafts turn together and everything stays in place. The screws turn on the shafts and drive fluid through the pump. As with other forms of rotary pumps, the clearance between moving parts and the pump's casing is minimal.

Screw pump

Progressing cavity pump

Widely used for pumping difficult materials, such as sewage sludge contaminated with large particles, this pump consists of a helical rotor, about ten times as long as its width. This can be visualized as a central core of diameter *x* with, typically, a curved spiral wound around of thickness half *x*, though in reality it is manufactured in single casting. This shaft fits inside a heavy duty rubber sleeve, of wall thickness also typically *x*. As the shaft rotates, the rotor gradually forces fluid up the rubber sleeve. Such pumps can develop very high pressure at low volumes.

Roots-type pumps

Named after the Roots brothers who invented it, this lobe pump displaces the liquid trapped between two long helical rotors, each fitted into the other when perpendicular at 90°, rotating inside a triangular shaped sealing line configuration, both at the point of suction and at the point of discharge. This design produces a continuous flow with equal volume and no vortex. It can work at low pulsation rates, and offers gentle performance that some applications require.

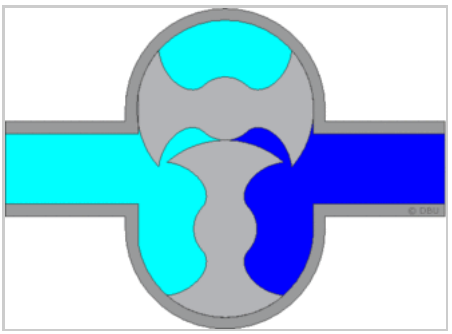

A Roots lobe pump

Applications include:

- High capacity industrial air compressors
- Roots superchargers on internal combustion engines.
- A brand of civil defense siren, the Federal Signal Corporation's Thunderbolt.

Peristaltic pump

A *peristaltic pump* is a type of positive displacement pump. It contains fluid within a flexible tube fitted inside a circular pump casing (though linear peristaltic pumps have been made). A number of *rollers*, *shoes*, or *wipers* attached to a rotor compresses the flexible tube. As the rotor turns, the part of the tube under compression closes (or *occludes*), forcing the fluid through the tube. Additionally, when the tube opens to its natural state after the passing of the cam it draws (*restitution*) fluid into the pump. This process is called peristalsis and is used in many biological systems such as the gastrointestinal tract.

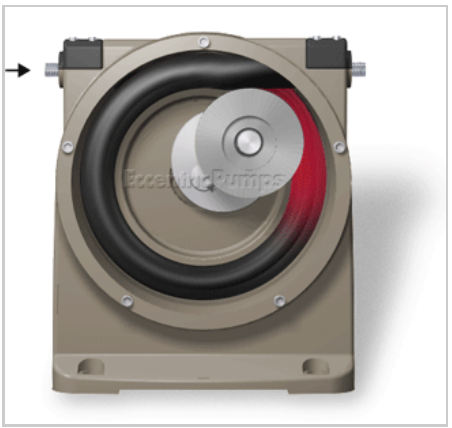

360° Peristaltic Pump

Plunger pumps

Plunger pumps are reciprocating positive displacement pumps.

These consist of a cylinder with a reciprocating plunger. The suction and discharge valves are mounted in the head of the cylinder. In the suction stroke the plunger retracts and the suction valves open causing suction of fluid into the cylinder. In the forward stroke the plunger pushes the liquid out of the discharge valve. Efficiency and common problems: With only one cylinder in plunger pumps, the fluid flow varies between maximum flow when the plunger moves through the middle positions, and zero flow when the plunger is at the end positions. A lot of energy is wasted when the fluid is accelerated in the piping system. Vibration and *water hammer* may be a serious problem. In general the problems are compensated for by using two or more cylinders not working in phase with each other.

Triplex-style plunger pumps

Triplex plunger pumps use three plungers, which reduces the pulsation of single reciprocating plunger pumps. Adding a pulsation dampener on the pump outlet can further smooth the *pump ripple*, or ripple graph of a pump transducer. The dynamic relationship of the high-pressure fluid and plunger generally requires high-quality plunger seals. Plunger pumps with a larger number of plungers have the benefit of increased flow, or smoother flow without a pulsation dampener. The increase in moving parts and crankshaft load is one drawback.

Car washes often use these triplex-style plunger pumps (perhaps without pulsation dampeners). In 1968, William Bruggeman significantly reduced the size of the triplex pump and increased the lifespan so that car washes could use equipment with smaller footprints. Durable high pressure seals, low pressure seals and oil seals, hardened crankshafts, hardened connecting rods, thick ceramic plungers and heavier duty ball and roller bearings improve reliability in triplex pumps. Triplex pumps now are in a myriad of markets across the world.

Triplex pumps with shorter lifetimes are commonplace to the home user. A person who uses a home pressure washer for 10 hours a year may be satisfied with a pump that lasts 100 hours between rebuilds. Industrial-grade or continuous duty triplex pumps on the other end of the quality spectrum may run for as much as 2,080 hours a year.[3]

The oil and gas drilling industry uses massive semi trailer-transported triplex pumps called mud pumps to pump drilling mud, which cools the drill bit and carries the cuttings back to the surface.[4] Drillers use triplex or even quintuplex pumps to inject water and solvents deep into shale in the extraction process called *fracking*.[5]

Compressed-air-powered double-diaphragm pumps

One modern application of positive displacement pumps is compressed-air-powered double-diaphragm pumps. Run on compressed air these pumps are intrinsically safe by design, although all manufacturers offer ATEX certified models to comply with industry regulation. These pumps are relatively inexpensive and can perform a wide variety of duties, from pumping water out of bunds, to pumping hydrochloric acid from secure storage (dependent on how the pump is manufactured – elastomers / body construction). Lift is normally limited to roughly 6m although heads can reach almost 200 psi (1.4 MPa).

Rope pumps

Devised in China as chain pumps over 1000 years ago, these pumps can be made from very simple materials: A rope, a wheel and a PVC pipe are sufficient to make a simple rope pump. Rope pump efficiency has been studied by grass roots organizations and the techniques for making and running them have been continuously improved.[6]

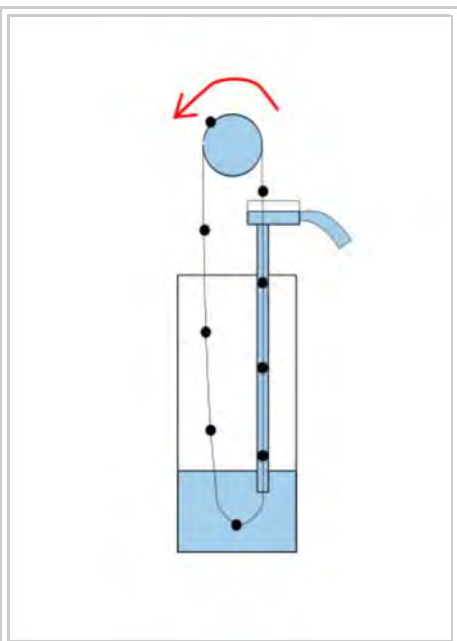

Rope pump schematic

Impulse pumps

Impulse pumps use pressure created by gas (usually air). In some impulse pumps the gas trapped in the liquid (usually water), is released and accumulated somewhere in the pump, creating a pressure that can push part of the liquid upwards.

Conventional impulse pumps include:

- *Hydraulic ram pumps* – kinetic energy of a low-head water supply is stored temporarily in an air-bubble hydraulic accumulator, then used to drive water to a higher head.
- *Pulser pumps* – run with natural resources, by kinetic energy only.
- *Airlift pumps* – run on air inserted into pipe, which pushes the water up when bubbles move upward

Instead of a gas accumulation and releasing cycle, the pressure can be created by burning of hydrocarbons. Such combustion driven pumps directly transmit the impulse form a combustion event through the actuation membrane to the pump fluid. In order to allow this direct transmission, the pump needs to be almost entirely made of an elastomer (e.g. silicone rubber). Hence, the combustion causes the membrane to expand and thereby pumps the fluid out of the adjacent pumping chamber. The first combustion-driven soft pump was developed by ETH Zurich.[7]

Hydraulic ram pumps

A hydraulic ram is a water pump powered by hydropower.

It takes in water at relatively low pressure and high flow-rate and outputs water at a higher hydraulic-head and lower flow-rate. The device uses the water hammer effect to develop pressure that lifts a portion of the input water that powers the pump to a point higher than where the water started.

The hydraulic ram is sometimes used in remote areas, where there is both a source of low-head hydropower, and a need for pumping water to a destination higher in elevation than the source. In this situation, the ram is often useful, since it requires no outside source of power other than the kinetic energy of flowing water.

Velocity pumps

Rotodynamic pumps (or dynamic pumps) are a type of velocity pump in which kinetic energy is added to the fluid by increasing the flow velocity. This increase in energy is converted to a gain in potential energy (pressure) when the velocity is reduced prior to or as the flow exits the pump into the discharge pipe. This conversion of kinetic energy to pressure is explained by the *First law of thermodynamics*, or more specifically by *Bernoulli's principle*.

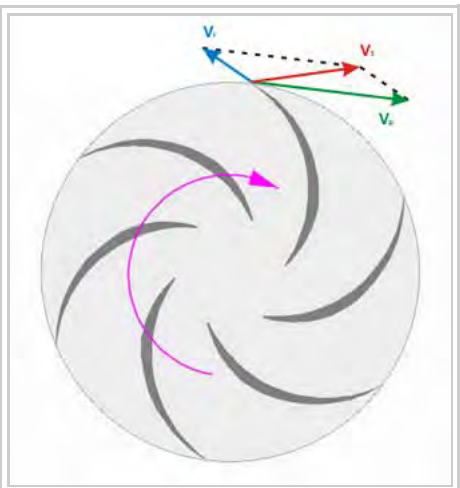

A centrifugal pump uses an impeller with backward-swept arms

Dynamic pumps can be further subdivided according to the means in which the velocity gain is achieved.[8]

These types of pumps have a number of characteristics:

1. Continuous energy
2. Conversion of added energy to increase in kinetic energy (increase in velocity)
3. Conversion of increased velocity (kinetic energy) to an increase in pressure head

A practical difference between dynamic and positive displacement pumps is how they operate under closed valve conditions. Positive displacement pumps physically displace fluid, so closing a valve downstream of a positive displacement pump produces a continual pressure build up that can cause mechanical failure of pipeline or pump. Dynamic pumps differ in that they can be safely operated under closed valve conditions (for short periods of time).

Radial-flow pumps

Such a pump is also referred to as a centrifugal pump. The fluid enters along the axis or center, is accelerated

by the impeller and exits at right angles to the shaft (radially); an example is the centrifugal fan, which is commonly used to implement a vacuum cleaner. Generally, a radial-flow pump operates at higher pressures and lower flow rates than an axial- or a mixed-flow pump.

Axial-flow pumps

These are also referred to as All fluid pumps. The fluid is pushed outward or inward and move fluid axially. They operate at much lower pressures and higher flow rates than radial-flow (centripetal) pumps.

Mixed-flow pumps

Mixed-flow pumps function as a compromise between radial and axial-flow pumps. The fluid experiences both radial acceleration and lift and exits the impeller somewhere between 0 and 90 degrees from the axial direction. As a consequence mixed-flow pumps operate at higher pressures than axial-flow pumps while delivering higher discharges than radial-flow pumps. The exit angle of the flow dictates the pressure head-discharge characteristic in relation to radial and mixed-flow.

Eductor-jet pump

This uses a jet, often of steam, to create a low pressure. This low pressure sucks in fluid and propels it into a higher pressure region.

Gravity pumps

Gravity pumps include the *syphon* and *Heron's fountain*. The *hydraulic ram* is also sometimes called a gravity pump; in a gravity pump the water is lifted by gravitational force.

Steam pumps

Steam pumps have been for a long time mainly of historical interest. They include any type of pump powered by a steam engine and also pistonless pumps such as Thomas Savery's or the Pulsometer steam pump.

Recently there has been a resurgence of interest in low power solar steam pumps for use in smallholder irrigation in developing countries. Previously small steam engines have not been viable because of escalating inefficiencies as vapour engines decrease in size. However the use of modern engineering materials coupled with alternative engine configurations has meant that these types of system are now a cost effective opportunity.

Valveless pumps

Valveless pumping assists in fluid transport in various biomedical and engineering systems. In a valveless pumping system, no valves (or physical occlusions) are present to regulate the flow direction. The fluid pumping efficiency of a valveless system, however, is not necessarily lower than that having valves. In fact, many fluid-dynamical systems in nature and engineering more or less rely upon valveless pumping to transport the working fluids therein. For instance, blood circulation in the cardiovascular system is maintained to some extent even when the heart’s valves fail. Meanwhile, the embryonic vertebrate heart begins pumping blood long before the development of discernible chambers and valves. In microfluidics, valveless impedance pumps have been fabricated, and are expected to be particularly suitable for handling sensitive biofluids. Ink jet

printers operating on the Piezoelectric transducer principle also use valveless pumping. The pump chamber is emptied through the printing jet due to reduced flow impedance in that direction and refilled by capillary action..

Pump repairs

derelict windmill connected to water pump with water storage tank in the foreground

Examining pump repair records and mean time between failures (MTBF) is of great importance to responsible and conscientious pump users. In view of that fact, the preface to the 2006 Pump User's Handbook alludes to "pump failure" statistics. For the sake of convenience, these failure statistics often are translated into MTBF (in this case, installed life before failure).[9]

In early 2005, Gordon Buck, John Crane Inc.'s chief engineer for Field Operations in Baton Rouge, LA, examined the repair records for a number of refinery and chemical plants to obtain meaningful reliability data for centrifugal pumps. A total of 15 operating plants having nearly 15,000 pumps were included in the survey. The smallest of these plants had about 100 pumps; several plants had over 2000. All facilities were located in the United States. In addition, considered as "new", others as "renewed" and still others as "established". Many of these plants—but not all—had an alliance arrangement with John Crane. In some cases, the alliance contract included having a John Crane Inc. technician or engineer on-site to coordinate various aspects of the program.

Not all plants are refineries, however, and different results occur elsewhere. In chemical plants, pumps have traditionally been "throw-away" items as chemical attack limits life. Things have improved in recent years, but the somewhat restricted space available in "old" DIN and ASME-standardized stuffing boxes places limits on the type of seal that fits. Unless the pump user upgrades the seal chamber, the pump only accommodates more compact and simple versions. Without this upgrading, lifetimes in chemical installations are generally around 50 to 60 percent of the refinery values.

Unscheduled maintenance is often one of the most significant costs of ownership, and failures of mechanical seals and bearings are among the major causes. Keep in mind the potential value of selecting pumps that cost more initially, but last much longer between repairs. The MTBF of a better pump may be one to four years longer than that of its non-upgraded counterpart. Consider that published average values of avoided pump failures range from US$2600 to US$12,000. This does not include lost opportunity costs. One pump fire occurs per 1000 failures. Having fewer pump failures means having fewer destructive pump fires.

As has been noted, a typical pump failure based on actual year 2002 reports, costs US$5,000 on average. This includes costs for material, parts, labor and overhead. Extending a pump's MTBF from 12 to 18 months would save US$1,667 per year — which might be greater than the cost to upgrade the centrifugal pump's reliability.[9][10][11]

Applications

Pumps are used throughout society for a variety of purposes. Early applications includes the use of the windmill or watermill to pump water. Today, the pump is used for irrigation, water supply, gasoline supply, air conditioning systems, refrigeration (usually called a compressor), chemical movement, sewage movement, flood control, marine services, etc.

Because of the wide variety of applications, pumps have a plethora of shapes and sizes: from very large to very small, from handling gas to handling liquid, from high pressure to low pressure, and from high volume to low volume.

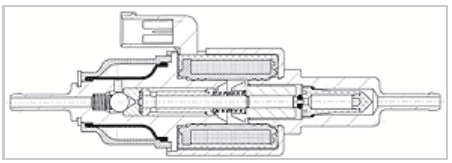

Metering pump for gasoline and additives.

Priming a pump

Typically, a liquid pump can't simply draw air. The feed line of the pump and the internal body surrounding the pumping mechanism must first be filled with the liquid that requires pumping: An operator must introduce liquid into the system to initiate the pumping. This is called *priming* the pump. Loss of prime is usually due to ingestion of air into the pump. The clearances and displacement ratios in pumps for liquids, whether thin or more viscous, usually cannot displace air due to its compressibility. This is the case with most velocity (rotodynamic) pumps — for example, centrifugal pumps.

Positive–displacement pumps, however, tend to have sufficiently tight sealing between the moving parts and the casing or housing of the pump that they can be described as *self-priming*. Such pumps can also serve as *priming pumps*, so called when they are used to fulfill that need for other pumps in lieu of action taken by a human operator.

Pumps as public water supplies

One sort of pump once common worldwide was a hand-powered water pump, or 'pitcher pump'. It was commonly installed over community water wells in the days before piped water supplies.

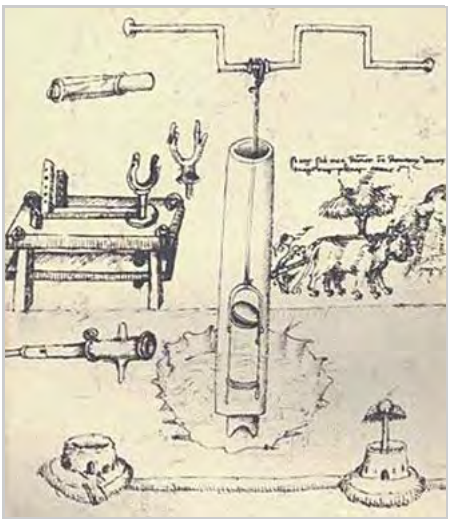

First European depiction of a piston pump, by Taccola, c.1450.[12]

In parts of the British Isles, it was often called *the parish pump*. Though such community pumps are no longer common, people still used the expression *parish pump* to describe a place or forum where matters of local interest are discussed.[13]

Because water from pitcher pumps is drawn directly from the soil, it is more prone to contamination. If such water is not filtered and purified, consumption of it might lead to gastrointestinal or other water-borne diseases. A notorious case is the 1854 Broad Street cholera outbreak. At the time it was not known how cholera was transmitted, but physician John Snow suspected contaminated water and had the handle of the public pump he suspected removed; the outbreak then subsided.

Modern hand-operated community pumps are considered the most sustainable low-cost option for safe water supply in resource-poor settings, often in rural areas in developing countries. A hand pump opens access to deeper groundwater that is often not polluted and also improves the safety of a well by protecting the water source from contaminated buckets. Pumps such as the Afridev pump are designed to be cheap to build and install, and easy to maintain with simple parts. However, scarcity of spare parts for these type of pumps in some regions of Africa has diminished their utility for these areas.

Sealing multiphase pumping applications

Multiphase pumping applications, also referred to as tri-phase, have grown due to increased oil drilling activity. In addition, the economics of multiphase production is attractive to upstream operations as it leads to simpler,

smaller in-field installations, reduced equipment costs and improved production rates. In essence, the multiphase pump can accommodate all fluid stream properties with one piece of equipment, which has a smaller footprint. Often, two smaller multiphase pumps are installed in series rather than having just one massive pump.

Irrigation is underway by pump-enabled extraction directly from the Gumti, seen in the background, in Comilla, Bangladesh.

For midstream and upstream operations, multiphase pumps can be located onshore or offshore and can be connected to single or multiple wellheads. Basically, multiphase pumps are used to transport the untreated flow stream produced from oil wells to downstream processes or gathering facilities. This means that the pump may handle a flow stream (well stream) from 100 percent gas to 100 percent liquid and every imaginable combination in between. The flow stream can also contain abrasives such as sand and dirt. Multiphase pumps are designed to operate under changing or fluctuating process conditions. Multiphase pumping also helps eliminate emissions of greenhouse gases as operators strive to minimize the flaring of gas and the venting of tanks where possible.[14]

Types and features of multiphase pumps

Helico-axial pumps (centrifugal)

A rotodynamic pump with one single shaft that requires two mechanical seals, this pump uses an open-type axial impeller. It's often called a *Poseidon pump*, and can be described as a cross between an axial compressor and a centrifugal pump.

Twin-screw (positive-displacement)

The twin-screw pump is constructed of two inter-meshing screws that move the pumped fluid. Twin screw pumps are often used when pumping conditions contain high gas volume fractions and fluctuating inlet conditions. Four mechanical seals are required to seal the two shafts.

Progressive cavity (positive-displacement)

Progressive cavity pumps are single-screw types typically used in shallow wells or at the surface. This pump is mainly used on surface applications where the pumped fluid may contain a considerable amount of solids such as sand and dirt.

Electric submersible (centrifugal)

These pumps are basically multistage centrifugal pumps and are widely used in oil well applications as a method for artificial lift. These pumps are usually specified when the pumped fluid is mainly liquid.

Buffer tank A buffer tank is often installed upstream of the pump suction nozzle in case of a slug flow. The buffer tank breaks the energy of the liquid slug, smooths any fluctuations in the incoming flow and acts as a sand trap.

As the name indicates, multiphase pumps and their mechanical seals can encounter a large variation in service

conditions such as changing process fluid composition, temperature variations, high and low operating pressures and exposure to abrasive/erosive media. The challenge is selecting the appropriate mechanical seal arrangement and support system to ensure maximized seal life and its overall effectiveness.[14][15][16]

Specifications

Pumps are commonly rated by horsepower, flow rate, outlet pressure in metres (or feet) of head, inlet suction in suction feet (or metres) of head. The head can be simplified as the number of feet or metres the pump can raise or lower a column of water at atmospheric pressure.

From an initial design point of view, engineers often use a quantity termed the specific speed to identify the most suitable pump type for a particular combination of flow rate and head.

Pumping power

The power imparted into a fluid increases the energy of the fluid per unit volume. Thus the power relationship is between the conversion of the mechanical energy of the pump mechanism and the fluid elements within the pump. In general, this is governed by a series of simultaneous differential equations, known as the Navier–Stokes equations. However a more simple equation relating only the different energies in the fluid, known as Bernoulli's equation can be used. Hence the power, P, required by the pump:

$$P = \frac{\Delta p Q}{\eta}$$

where Δp is the change in total pressure between the inlet and outlet (in Pa), and Q, the volume flow-rate of the fluid is given in m^3/s. The total pressure may have gravitational, static pressure and kinetic energy components; i.e. energy is distributed between change in the fluid's gravitational potential energy (going up or down hill), change in velocity, or change in static pressure. η is the pump efficiency, and may be given by the manufacturer's information, such as in the form of a pump curve, and is typically derived from either fluid dynamics simulation (i.e. solutions to the Navier–Stokes for the particular pump geometry), or by testing. The efficiency of the pump depends upon the pump's configuration and operating conditions (such as rotational speed, fluid density and viscosity etc.)

$$\Delta P = \frac{(v_2^2 - v_1^2)}{2} + \Delta z g + \frac{\Delta p_{\text{static}}}{\rho}$$

For a typical "pumping" configuration, the work is imparted on the fluid, and is thus positive. For the fluid imparting the work on the pump (i.e. a turbine), the work is negative. Power required to drive the pump is determined by dividing the output power by the pump efficiency. Furthermore, this definition encompasses pumps with no moving parts, such as a siphon.

Efficiency

Pump efficiency is defined as the ratio of the power imparted on the fluid by the pump in relation to the power supplied to drive the pump. Its value is not fixed for a given pump, efficiency is a function of the discharge and therefore also operating head. For centrifugal pumps, the efficiency tends to increase with flow rate up to a point midway through the operating range (peak efficiency or Best Efficiency Point (BEP)) and then declines as flow rates rise further. Pump performance data such as this is usually supplied by the manufacturer before

pump selection. Pump efficiencies tend to decline over time due to wear (e.g. increasing clearances as impellers reduce in size).

When a system includes a centrifugal pump, an important design issue is matching the *head loss-flow characteristic* with the pump so that it operates at or close to the point of its maximum efficiency.

Pump efficiency is an important aspect and pumps should be regularly tested. Thermodynamic pump testing is one method.

See also

- Affinity laws
- Balancing machine
- Beam pump and walking beam pump
- Bellows - a simple air pumping device
- Biological pump - a phenomenon in nature studied in ecology and meteorology
- Breast pump
- Bush pump
- Chopper pump
- Concrete pump
- Comparison of pumps
- Cyclic pump
- Drum pump
- Fire pump
- Gas compressor
- Gerotor
- Honda pumps
- Inductive pump
- Intelligent pump
- Ion transporter - bio-chemical pump used in living cell membranes to transfer ions
- Jockey pump
- Metering pump
- Peristaltic pump
- Pumping station
- Pumpjack (oil pump)
- Scoop wheel
- Scroll pump, most used in scroll compressors
- Secondary air injection
- Sine pump
- Tesla turbine
- Wind pump
- Slip factor
- Pump organ - musical instrument using bellows

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Pumps and Water Lifters for Rural Development

by A.D. Wood, J.F. Ruff, and E.V. Richardson

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PUMPS AND WATER LIFTERS FOR RURAL DEVELOPMENT

A. R. Wood
J. F. Ruff
E. V. Richardson

Colorado State University
Fort Collins, Colorado

June 1972

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Chapter 1

Introduction

1.1 Objectives

Raising water for irrigation and drainage were among man's first motives for developing water lifting devices. Without such water lifters, many areas of the world would not be fit for agricultural use; too arid to grow food or forage crops, or too wet to allow cultivation. Over some five millenniums, water lifting has grown into a major industry, producing thousands of types and sizes of devices both to lift water and to serve as prime movers.

This state-of-the-art (SOTA) presents a review of how water lifting has developed throughout the world, where it stands today, and provide some insight into its future needs. Recent literature goes into great depth discussing the highly specialized and complex pumps of today. A few other publications briefly mention the operation of several early water lifting devices which are still used in many developing countries today. Through an extensive literature review, this paper inventories the wide range of water lifters which are randomly discussed in these publications and set forth; (a) a unifying classification format, (b) the basic principles of operation and typical applications and installations of each class, and (c) a brief review of applicable prime movers. Though this paper will identify some of the technological gaps which exist in the water lifting science, it is to serve primarily as a reference point for future research which is needed to; (a) improve efficiencies of existing water lifting devices, (b) develop designs suitable for manufacture, operation, and maintenance in developing countries, and (c)

find both new water lifting devices and adaptions of existing devices which can be used with natural prime movers, in light of recent energy shortages.

This report is condensed from the Master Thesis of the senior author. His Master of Science studies and the preparation of this report were sponsored by the U. S. Agency for International Development under contract AID/csd-2460, Institutional Development Grant on Optimum Utilization of Water Resources with Emphasis on Water Driving and Removal Systems.

1.2 Historical Review of Water Lifting

Archaeology gives us some clues as to the early forms of water lifting. Ewbank, 1876, provides interesting accounts of man's earliest vessels, e.g., hollow gourds which were surely the beginning of the bucket. By attaching a vine or rope, the bucket could be lowered to deeper water supplies, or the simple basket could be used to scoop and throw water. This swing basket or mental used in Egypt was probably the first effort made to lift water at a rate sufficient for irrigation. The date of this device's earliest use cannot be ascertained, however, carvings on Egyptian tombs date the counterpoise lift (Figure 3.3) back to about 2000 B.C. (Ewbank, 1876), and it would appear as the next logical step in water lifting methods, i.e., adding a lever to the basket and rope.

Several sources (Flettner, 1926 and Golding, 1962) mention that the Babylonian Emperor Hammurabi reports the use of windmills for an extensive irrigation system in 1700 B.C. This report is frequently questioned and so credit for the first "working" windmill is often given to the Persians, who used a vertical shaft with radially mounted sails. Although these Persian mills were used primarily for grinding, they also introduce the use of crude gears. (For a history of windmills, see Vadot, September 1957 and Reynolds, J., 1970).

Many references describe Joseph's well, which is the first account of the Persian wheel or chain-of-pots (Figure 3.20); however, dates vary anywhere from 1500 to 3000 B.C. (Ewbank, 1876; Eubanks, 1971; Rouse and Ince, 1963). About this same time, the pulley or roller appears to have evolved. In areas such as Mesopotamia where deep wells were dug, the pulley was soon brought into use for mots such as in Figure 3.1 (De Camp, 1963). Writings on clay tablets also relate the use of water raising treadmills in Mesopotamia about 1200 B.C. (De Camp, 1963). Similarly, engravings on ancient medals depict the use of bellows for venting fires some three to four thousand years ago. Although their use for lifting water was not to come for several centuries, this did mark the early use of suction and the simple flap valve (Ewbank, 1876).

By 1000 B.C., the further refinement of gears allowed widespread construction of watermills in Egypt, Mesopotamia, and China. However, it is the Chinese who are credited with combining the watermill and the waterwheel into the noria (Figure 3.21)--a self-powered waterwheel (Roger, 1905). Although wind and waterpower developed during the second millenium B.C., their acceptance in many areas, such as the Roman Empire, was delayed because of the large slave labor force available.

Sometime in the 5th century B.C., Athenagoras, a philosopher, observed the stylish sprinkling pots of the day which had holes in the bottom and proposed that when the top opening was covered, atmospheric pressure could not push down on the water, but only up, i.e., countering gravity and thus retaining the water. However, it was not until about 300 B.C. that Ctesibius combined the discovery of atmospheric pressure and the principle of the bellows into the first suction or lift pump, primarily for use in fighting fires with manual power.

During the 3rd century B.C., Archimedes did much to develop the science of hydraulics. King Hieron II of Syracuse (Sicily) asked him to invent a method for draining the holds of his ships. Archimedes' answer was to push the water up a tube using a simple screw, as in Figure 3.25 (Tokaty, 1971).

In the 2nd century B.C., Hero (or Heron) of Alexandria used several methods to raise water, primarily for entertainment purposes. In one of his novel devices, the "Sun Fountain", he used the sun's heat to vaporize and lift water; the beginnings of solar powered pumping (Ewbank, 1876). Hero also developed the first air lift pump for his "Fountain of Hero" (Ivens, 1920).

Although references do not mention the invention of the paddle or scoopwheel (Figure 3.17), sometime during the last centuries B.C., the Chinese modified this scoop-rotary water lifter into the water ladder (Figure 3.18). As this idea was being carried to Europe aboard trading ships, it was modified again into the chain pump for draining ship holds (Ewbank, 1876). About 31 A.D., the Chinese also have recorded use of a horizontal (vertical shaft) waterwheel to drive bellows (Reynolds, J., 1970).

During the first four centuries A.D., piston pumps, constructed from hollowed logs, gained widespread use throughout Roman-ruled England. They remained in use until cast-iron pumps were commercially manufactured in the 1880's. Throughout the Middle Ages (500-1500 A.C.), various combinations of water lifters, transmissions, and prime movers were experimented with and used by the increasing number of small farmers who did not have slave labor. In the 15th century A.D., Leonardo da Vinci used a watermill to drive a suction pump via an eccentric cam. This allowed

the conversion of rotary motion into reciprocal motion. In addition, he investigated and suggested the use of centrifugal force to lift water, although it was not to be seriously considered for another 200 years (Tokaty, 1971).

In 1511, record is made in Germany of the use of bellows (the same design as fire bellows) to lift water. Another new method of lifting water, the ejector, was invented by Vitrio and Philehert de Lorme in 1570 (Kneass, 1903).

In 1557, Captain Ramelli, an Italian engineer, developed a rotary pump of four spring-loaded vanes in an eccentric cylinder. Some consider this to be the first centrifugal pump, however the action is purely positive displacement.

In the early 17th century, the first gear rotary pump was invented by Grollierde Serviere. Galiler also worked during the 17th century to explain, among other things, the inability of a vacuum to lift more than "18 cubits" of water and extended the concept of atmospheric pressure (Rouse and Ince, 1963).

The 17th century also marked the beginning of rotodynamic pumps. In 1680 Johann Jordan designed a centrifugal pump, primarily out of curiosity although it was not built until 1703. Denys Papin, in 1689, also built a centrifugal to drain some property of a friend. However, these wooden pumps were crude and due to the lack of a uniform, high speed driver, were low in efficiency. The development of centrifugals was also suppressed by the popularity of piston pumps. Even in his 1841 Hydraulics, Ewbank states that "in a hundred years, the present day pump (reciprocating piston) would predominate over all other."

In 1698, Thomas Savery obtained a patent for a pump which displaced water by steam within two chambers. Because of the sometimes violent and rhythmic vibrations which this device produced, it became known as a pulsometer (Figure 1.1). Two similar devices had been built by Santorio in 1626 (Rogers, 1905) and by Edward Somerset in 1628 (Greene, 1913), however Savery's pump was the first to use automatic valves, which made it of practical use for such applications as mine drainage.

In 1705, Newcomen and Cawley utilized the work of Papin and Savery to develop their "Atmospheric Engine" (i.e., steam piston) which they later connected to a piston pump via a rocker arm giving it much the same appearance as a modern oil well pump. Leopold, in 1720, connected the steam piston directly to the water piston and strengthened the design to increase steam pressure and thus, performance.

In 1730, Demour designed and built the vertical pump in Figure 1.2 which was the early basis for axial/mixed flow rotodynamic devices. The inclined tube rotated at 60 rpm, lifting 80 gpm six feet (Greene, 1913).

About this same time in Paris, Gosset and Deuille took the bellows principle, combined it with a leather flap-valve and manually-operated, reciprocating piston, and developed the first diaphragm pump. The 18th century also saw the air lift method of Hero, first used practically in Hungarian mines.

About 1754, Leonhard Euler studied the early centrifugal devices of that century and set forth several theories which would later be used to systematically design rotodynamic pumps. About this same time, John Smeaton is credited with developing the idea of the hydraulic ram (Tokaty, 1971). However, the first ram known to be built was constructed by

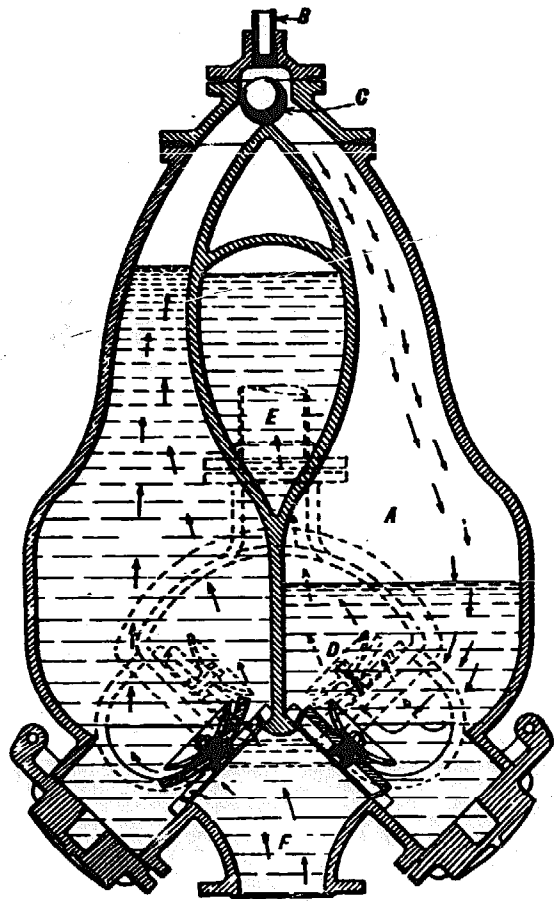

Figure 1.1 Pulsometer

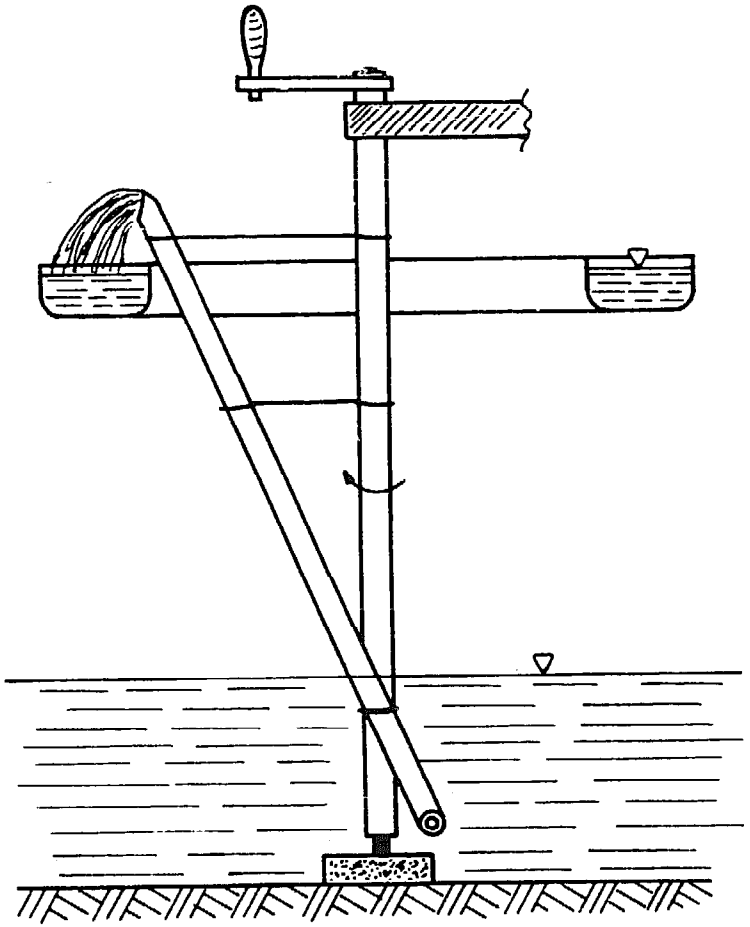

Figure 1.2 Demour's centrifugal pump

the United States was starting settlement of the Great Plains. This settlement demanded the development of all available water resources and two important keys to this development were the piston pump and windmill. (Vadot, (1957), H. M. Wilson (1896), and E. C. Murphy (1901) give interesting accounts of Western windmill history.)

Also during the 19th century, much attention was given to the scoop- and flash-wheels in Holland. Using large steam engines, these wheels were the key to draining the valuable polder land. (The Engineer, 1869 and 1870; Slichter, 1910.)

In his 1841 edition of Hydraulics, Ewbank describes several "novel" devices for lifting water called injectors and ejectors. However, in 1850, Lord James Thomson of England received a patent on his "Thomson pump" which was the beginning of the modern ejector nozzel for steam boilers (i.e., injector) which grew rapidly in popularity with their use in locomotive boilers (Kneass, 1903).

In 1880, J. P. Frizell obtained the first patent on the air lift method, i.e., injecting compressed air into a column of water. The 1890 Engineering News discusses the "development of (this) absolutely new type of pump."

Meanwhile, the use of centrifugal pumps was growing as high-speed drivers such as steam engines, electric motors, turbines, and Pelton wheels became available. After many years of intermittent centrifugal development, the Sulzer brothers began the first systematic and scientific testing program of pumps in 1890. This encouraged many other machinery works to undertake pump manufacturing. By 1905, Roger could write, "... centrifugals have attained a degree of perfection which makes them a serious rival of the plunger pumps."

Several other pumps were developed during this time, but the widespread use of direct-acting pumps and growing popularity of roto-dynamic pumps usually suppressed their development. However, one such unique pump was Humphrey's gas pump which was developed from the principle of John Barber's 1791 explosion pump.

In 1939, Water Supply Engineering discusses advances in pumping over the past decade which include the development of submersible pumps, invention of vertical, helical pumps, development of water lubricated vertical pumps, improvement of centrifugal efficiencies to as high as 93 percent, and increasing use of close-coupled units, as well as noting that "...electric (power) is holding its own...," but diesel engines are becoming more popular.

1.3 Current Trends

The state of water lifters in the world today is highly diversified, both in levels of development and variety of designs. In some areas of the world, designated community members, using only hollow bamboo poles for containers, spend most of every day walking miles to distant water sources and returning with barely enough water for minimal domestic purposes--let along irrigation. Meanwhile--typical of many unevenly distributed technical and natural resources--other areas have thousands of types and sizes of pumps with which to lift and transport ample water for all forms of domestic, industrial, recreational, and agricultural uses.

In industrialized nations, water lifting is a highly technical and competitive industry. The United States has well over 500 pump manufacturers (Thomas Publishing, 1974) with almost countless numbers of accessory suppliers, well contractors, and complementary industries (e.g., pipes,

engines, motors, transmissions, etc.). Likewise, England has some 200 pump manufacturers (Pumping Manual, 1964). Deep well submersible pumps are used to lift water hundreds of feet to supply high-pressure-sprinkler systems which irrigate miles of once "desert" land. Giant axial-flow pumps move hundreds of thousands of gpm through vast pipelines of water supply systems. Equally sophisticated motors, engines, and control devices are used to drive and regulate these pumps.

In these developed countries, the irrigator has usually been concerned with getting the highest discharge possible out of his pump with little worry over maximizing efficiency (Colorado Pump Council, 1975). However, with the rising cost of conventional energy forms (e.g., gas, diesel, electricity), the pump user is looking to improve efficiencies as a means of reducing increased operating costs.

Several users are also looking toward natural energy as a cheaper source of power. Until recently, conversion of natural energy, e.g. solar, to usable power was too expensive to compete with conventional power (i.e., gas, diesel, electricity). However, shortages and the rising cost of these conventional sources of energy are making the harnessing of natural energy more competitive economically, while technology is increasing their feasibility. As will be seen in Chapters 3 and 5, solar pumps and engines are currently in use and being improved. Geothermal heat is being located and harnessed--although not normally feasible for direct agricultural pumping, it can provide cheaper electric power. Many modern irrigators are returning to prime movers of the "past"--the windmill and watermill-- to provide cheaper power.

Meanwhile, in developing countries, water lifting is caught among the inadequacies of ancient methods, the introduction of modern pumps, and

the uncertainty of the world's energy situation. In these countries, it is not uncommon to see a farmer pedaling a wooden water paddle, while alongside his field runs a high speed railway. The cheap and abundant supply of human and/or animal power in most developing areas makes them the prime source of energy for driving water lifters and pumps. When modern pumps and drivers are available in these areas, they are often in poor condition due to lack of maintenance facilities and parts, and/or proper operational instruction to the user.

Chapter 2

Water Lifting Principles

2.1 Classification of Methods

In order to provide a complete and methodical disucssion of the wide variety of water lifting devices and pumps, a classification system is necessary. Throughout the available literature, several criteria are suggested as methods of classification. Table 2.1 lists these criteria and examples of each.

Table 2.1 Criteria for classifying water lifters

Criteria	Examples
1) Basic design	screw, piston, vane, wheel
2) Method of energy transmission	steam, compressed air, mechanical
3) Number of displacements	single, multiple, continuous
4) Arrangement of components	internal gear, outside packing
5) Orientation of axis	vertical, horizontal, incline
6) Number of stages	single, double, multiple
7) Casing type	volute, diffuser, split
8) Material of construction	bronze, steel, wood
9) Application of device	sewage, broiler-feed
10) Working principle	rotary, reciprocating, centrifugal
11) Method of increasing head	positive displacement, kinetic

The Hydraulic Institute, as well as many other references, combine several of these criteria into one classification arrangement--see Hydraulic Institute Standards (any edition) and Hicks and Edwards (1971).

Unfortunately, none of these classification systems include the numerous early devices, many of which are still utilized in developing countries and are included in this paper. Therefore, it was necessary to develop such an all-encompassing system which would be the basis for further discussion. Since all devices can be grouped under one of the two methods of increasing head (11 in Table 2.1)--positive displacement or kinetic--these are the two primary classes for the system shown in Table 2.2 and the basis for the breakdown of all devices and discussion of their operation in Chapters 3 and 4. Within each of these two primary classes, Table 2.2 further suggests an arrangement of sub-classes, utilizing several of the criteria listed in Table 2.1.

It should also be mentioned that the terminology used throughout this paper reflects either the most commonly used nomenclature where several terms exist for the same device or characteristic, or the most physically correct nomenclature where currently popular terms are confusing or misused. This is further explained in the following section and Chapters 3 and 4.

2.2 General Terminology and Theory

Several basic principles are common to all types of water lifting methods. Before selecting a specific method or installation for a given situation, several characteristics, e.g., head, discharge, and power, must be considered--see Section 5.2. These considerations apply equally as well for the manually-operated devices such as the shadouf as for the high-speed centrifugal pump. Therefore, this section discusses the basic water lifting parameters; head, discharge, power and efficiency as they apply to all methods.

Table 2.2a Classification of water lifters and pumps--positive displacement methods

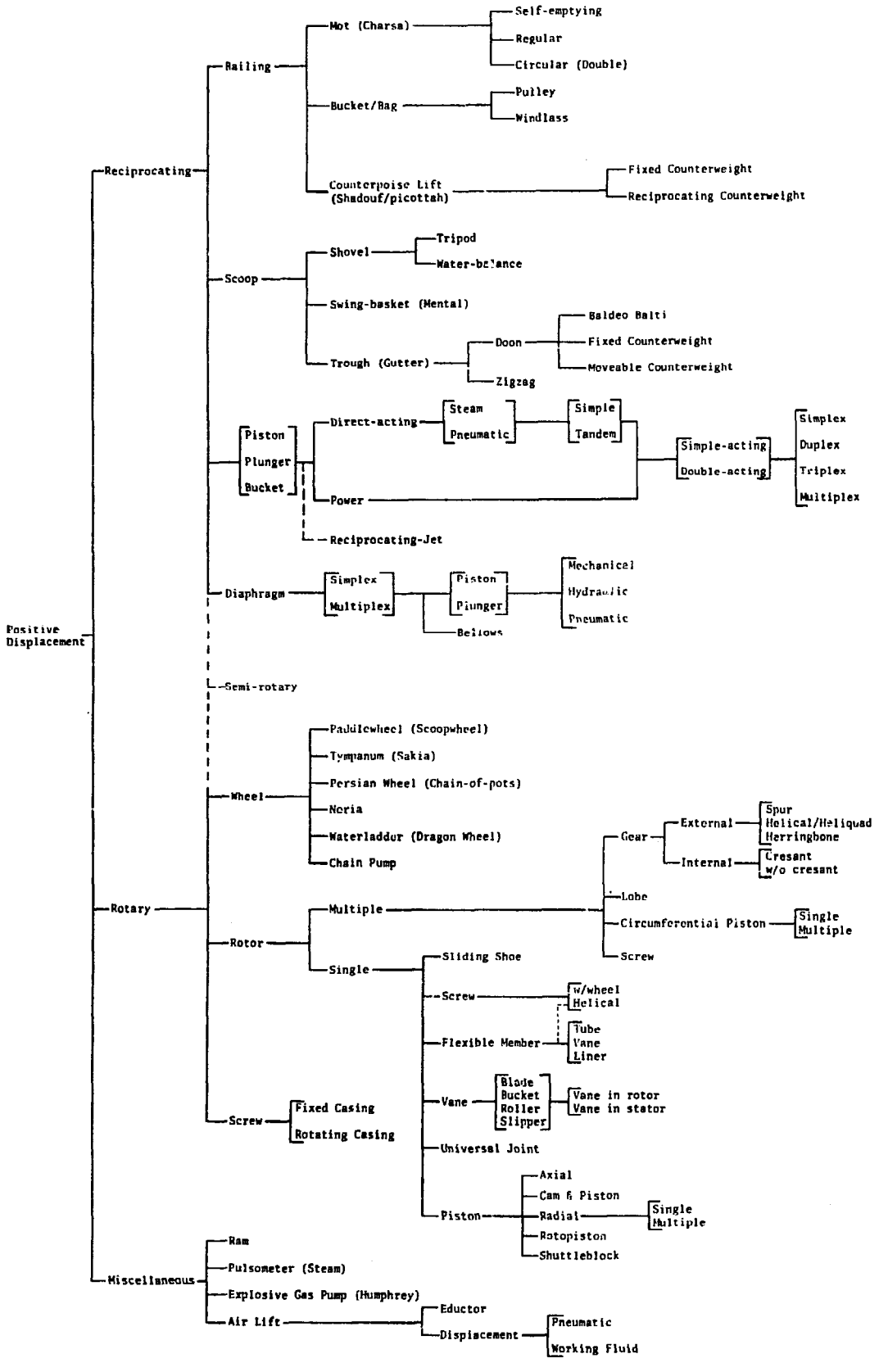

Table 2.2b Classification of water lifters and pumps--kinetic methods

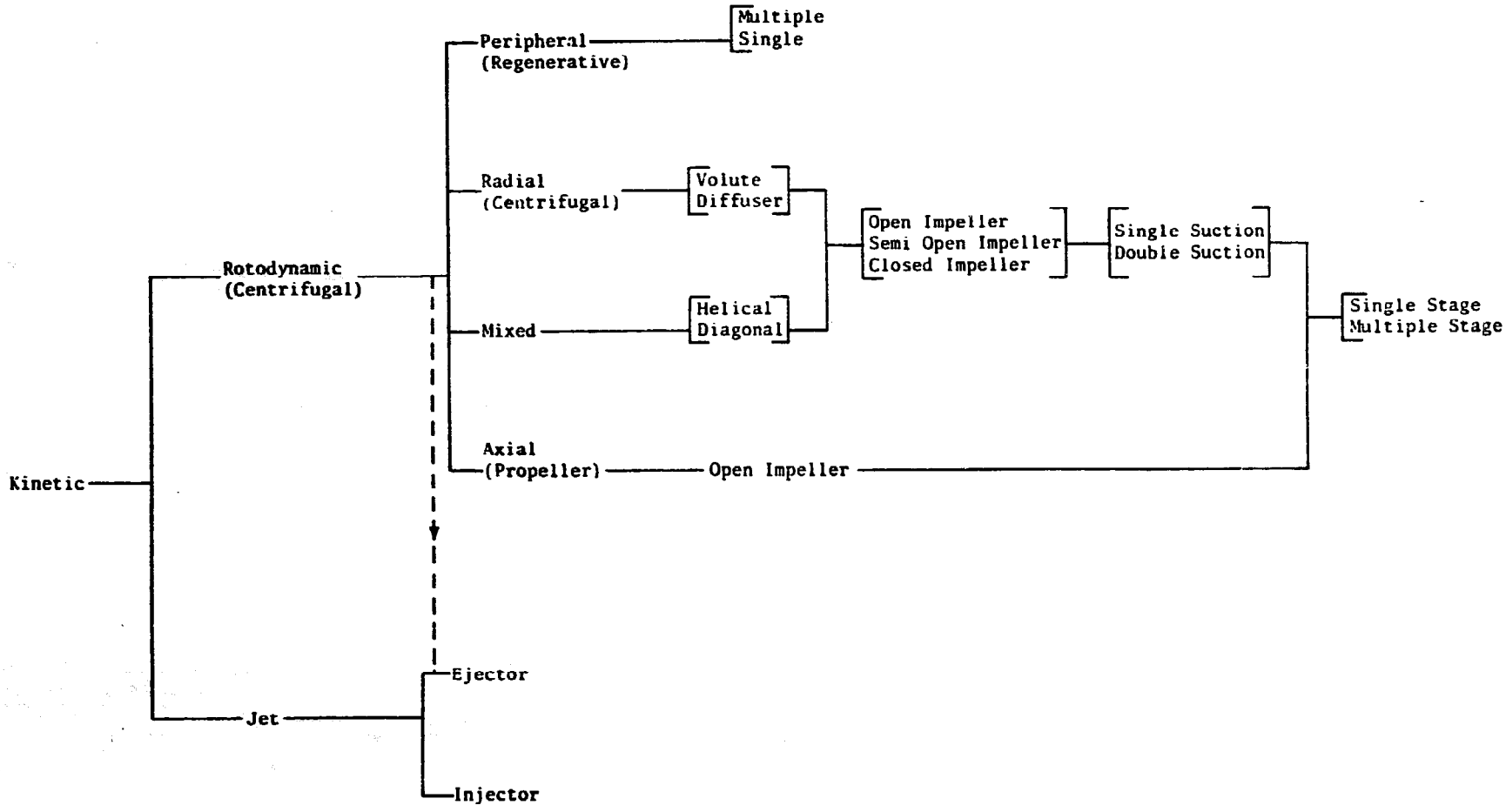

2.2.1 Discharge or Capacity (Q)

Discharge is the quantity of water per unit time (e.g., cubic feet per second, cfs; gallons per minute, gpm) which the lifting device or pump delivers. Since losses may occur with a device or pumping system, discharge is usually taken to be the quantity/time measured at the point where the water leaves the device or pump. Discharge depends on the size of the water lifter and the speed at which it is operated.

2.2.2 Head (H)

The term head, as applied to water lifting, has several components, each one a specific form of energy present in the lifting system. In most irrigation and drainage applications, head terms are usually expressed as the height of a column of water which contains an equal amount of potential energy, e.g., feet of water. The components of head, as they normally apply to irrigation and drainage, are as follows:

(a) Static suction head (H_{SSH}) or submergence is the height of supply-water, if any, which exists above a pump centerline, when the system is at rest. In devices, which have no suction capability, H_{SSH} is the height of water above the device's inlet elevation, i.e., the elevation at which the minimum submergence (ms) necessary to have a discharge greater than zero from the device exists.

(b) Static suction lift (H_{SSL}) is the vertical distance from the static water level to the pump centerline where the water supply exists below the pump.

(c) The static discharge head (H_{SD}) is similarly the vertical distance from the pump centerline or device inlet elevation to the elevation of "free" delivery.

(d) Total static head (H_{TS}) is the vertical distance from the static supply surface to the free delivery elevation, i.e., When a suction left exists,

$$H_{TS} = H_{SSL} + H_{SD} \tag{2.1}$$

or, when a suction head exists,

$$H_{TS} = H_{SD} - H_{SSH} \tag{2.2}$$

(e) Velocity head (H_V) can be expressed as the distance water must free fall to obtain a given velocity, i.e., $H_V = v^2/2g$. This is the amount of kinetic energy which exists as moving water. Except at very high velocities, in low head systems, and for accurate testing, this head term is usually not great enough to be significant.

(f) Friction head (H_F) is the amount of head needed to overcome the resistance created by the system, including pipe skin, bends, intakes, valves, etc.

(g) Pressure head (H_P) need only be considered in systems where the pump discharges into a pressurized system, e.g., sprinkler irrigation. The pressure required by such a system at a given elevation can be converted into an equivalent height of water, e.g., 1.0 psi = 2.31 ft of water.

(h) Drawdown (D) is the vertical distance, if any, which the free surface of a water supply falls while the water lifter or pump is in operation.

(i) Dynamic (or total) suction lift (H_{DSL}) is the sum of the static suction lift, suction friction head, and drawdown (if any), minus the suction velocity head (if considered), i.e.,

$$H_{DSL} = H_{SSL} + H_{FS} - H_{VS} \tag{2.3}$$

(j) Dynamic suction head (H_{DSH}) is the sum of the static suction head and suction velocity head, minus suction friction head and drawdown, i.e.,

$$H_{DSH} = H_{SSH} + H_{VS} - H_{FS}, \tag{2.4}$$

while in Figure 2.4 (not considering H_{VS}),

$$H_{DSH} = H_{SSH} - H_{FS} - D \quad . \tag{2.5}$$

(k) Dynamic discharge head (H_{DD}) is the static discharge head plus the discharge friction and velocity heads, plus any pressure head. When velocity head is considered,

$$H_{DD} = H_{SD} + H_{VD} + H_{FD} \tag{2.6}$$

or where a pressure head exists,

$$H_{DD} = H_{SD} + H_{FD} + H_P \quad . \tag{2.7}$$

(1) Total dynamic head (H_{TD}), also referred to as effective head or just total head, is the entire energy potential of the system against which the water lifter or pump must operate. Where a suction head exists,

$$H_{TD} = H_{DD} - H_{DSH} \quad , \tag{2.8}$$

but where a suction lift is present,

$$H_{TD} = H_{DD} + H_{DSL} \quad . \tag{2.9}$$

As shown in Figure 2.1, the total static head will remain constant for any discharge of the water lifting system. However, because velocity increases with discharge, the velocity and friction heads, being a direct function of velocity, will increase. Similarly, in applications of high capacity pumps in wells, or where a fixed or slow recharging water supply exists, drawdown also increases with discharge. Thus, as the discharge of a pump increases, the total head against which it must operate also increases, as illustrated in the example system head curve of Figure 2.1.

Two additional head terms need to be discussed concerning any water lifting device which operates with a dynamic suction lift. They apply particularly (but not limited) to rotodynamic pumps, which cannot displace air sufficiently enough to reduce intake pressure and thus "suck" water.

Net Positive Suction Head Required (NPSHR) is a function of a specific pump's design and is determined by the pump manufacturer.

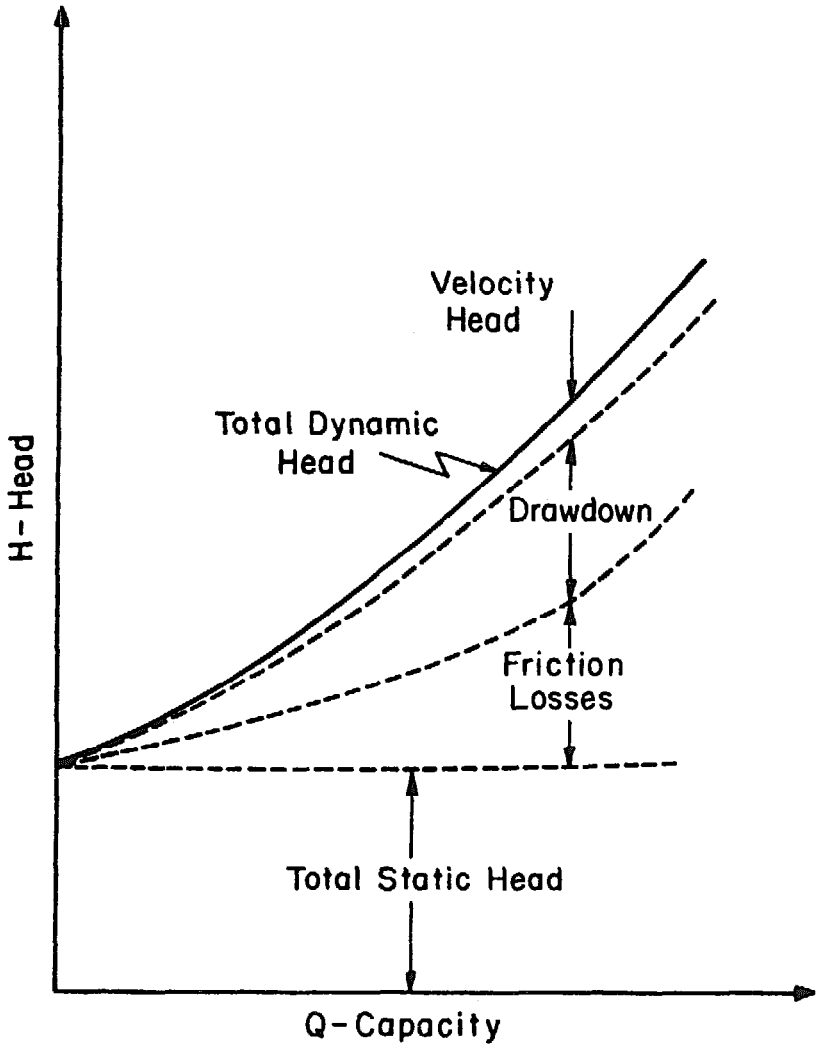

Figure 2.1 Example system head curve showing the change of TDH components with Q

NPSHR is the maximum dynamic suction lift which a pump can handle without allowing the head (or pressure) in the pump to drop below the vapor pressure of the pumped liquid. If the pressure anywhere in the pumping system drops below this vapor pressure, cavitation will likely occur which can sharply decrease the performance of the pump (see Section 4.2.5.) and if severe enough can damage the pump and/or piping (Rouse, 1950). To insure that this phenomenon does not occur, the New Positive Suction Head Available (NPSHA) should be determined for any pumping system planned, and should always exceed the NPSHA. From Figure 2.2

$$NPSHA = P_{atm} - H_{SSL} \text{ (or } + H_{SSH}) - PV - HF \qquad (2.10)$$

where P_{atm} = absolute atmospheric pressure, and

P_V = vapor pressure of pumped liquid.

P_{atm} must be obtained for the local atmospheric conditions and altitude, while P_V is a function of the liquid's volatility at a given temperature.

2.2.3 Power (HP)

Any water lifting device adds energy to the water on which it acts, either by raising it to a higher elevation and/or increasing its pressure, in the case of a sprinkler system. The rate at which the device adds this energy or head to the water is called the water horsepower (WHP) and can be found as

$$WHP = \frac{Q \cdot H_{TD} \cdot \gamma_W}{k} , \qquad (2.11)$$

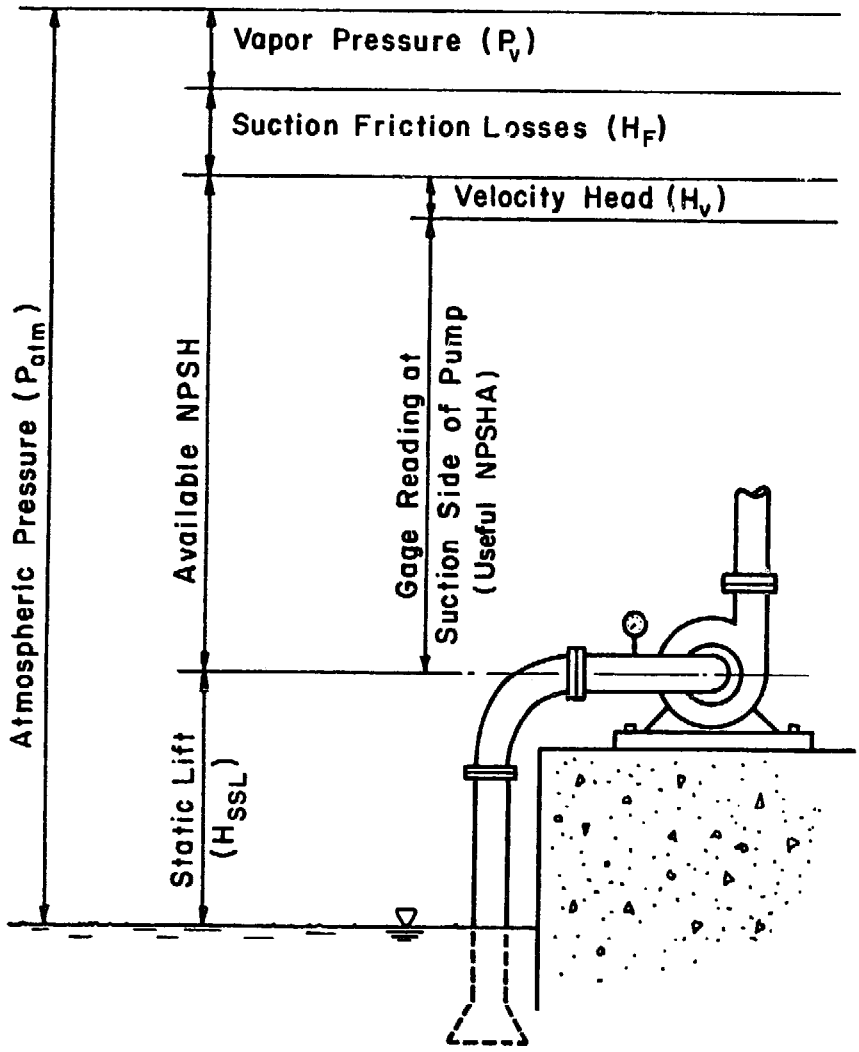

Figure 2.2 Net positive suction head (NPSH)

where

γ_w is the specific weight of water and K is a constant which depends on the units of measurement used for the other terms.

Of course, since water lifting devices like any other machinery have losses (e.g., internal friction, slippage, leakage, etc.), in order to add a given WHP to the water, some higher brake horsepower (BHP) will have to be applied to the pump. This BHP will be the energy which must be delivered to the pump by its prime mover. It should be noted here that this parameter of power is not limited to mechanical prime movers, but that manual and animal BHP can be determined to evaluate the performance of water lifters utilizing such mears of motivation.

2.2.4 Efficiency (Eff)

The efficiency of a water lifter is the ratio of energy added to the water over the energy put into the device to obtain the increase in water energy, or put in terms of power,

$$\text{Eff} = \frac{\text{WHP}}{\text{BHP}} \quad . \tag{2.15}$$

An efficiency can also be calculated for the prime mover which supplies the BHP to the water lifter. Where the method of transmitting this prime mover power (BHP) to the water lifter is not direct, losses may also occur in the transmission. For example, when belts are used between a motor and pump, slippage and heat losses occur which prevent getting all the motor's output power to the pump. Thus, an efficicney for the transmission can also be calculated.

Multiplying all these efficiencies together produces the overall efficiency (OAE) of the water lifting operation, i.e., the percentage of energy put into the prime mover which will actually be added to the water. That is,

$$OAE = Eff_{pump} \times Eff_{mover} \times Eff_{transmission}. \qquad (2.16)$$

In systems using electric power, the OAE is often referred to as wire-to-water efficiency.

2.2.5 Performance Curves

Using various combinations of the parameters defined above, the performance of any water lifting device can be described graphically in performance or characteristic curves. Figure 2.1 showed how an H-Q curve is used to describe a pumping system, i.e., what total head must be produced to deliver a given discharge through that system. Likewise, an H-Q curve can be used to show at what head(s) a water lifter will deliver a specified discharge. Specific curves are given in Chapters 3 and 4 of various types of devices; however, the simple bucket can again serve as a good example. As the height (i.e., head) increases through which a person must lift a bucket of water, it can be expected that he will be able to deliver less buckets per unit time. So, this water lifter's H-Q curve may look something like Figure 2.3. Similarly, the variation of BHP and Eff with Q can be plotted. These performance curves are not limited to modern pumps.

These four characteristic parameters are often plotted together for a specific device using Q as the common absicissa. A fourth curve,

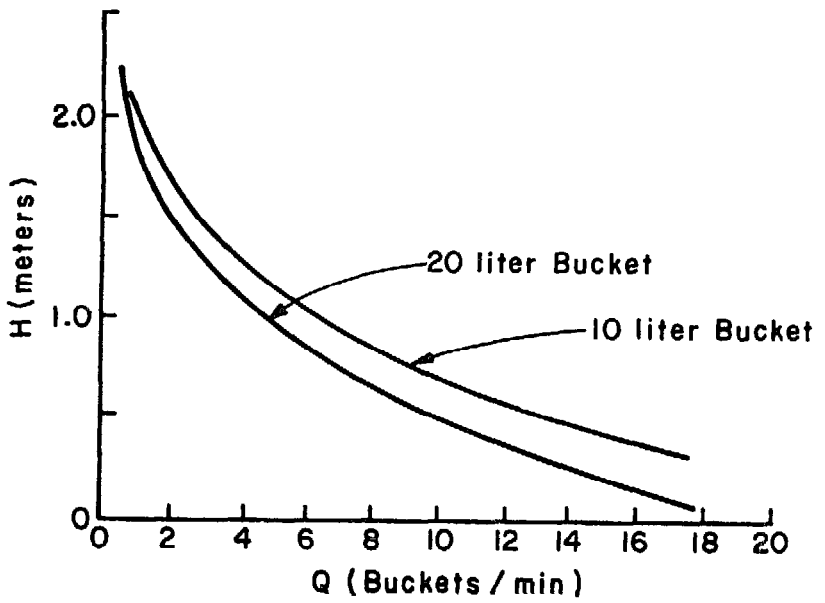

Figure 2.3 Example H-Q curve
(not based on actual data)

NPSHR-Q, is also usually included for any pump which has NPSH limits, e.g., centrifugal pumps. These curves are given for a device operating at a constant speed and size. However, composite performance curves combine the characteristics of various sizes of the same specific pump, operating at a constant speed. Such a composite usually shows the respective H-Q curves for each size and then superimposes constant BHP , Eff , and NPSHR lines over them. Similar composites are also used with H-Q curves for various operating speeds of a constant pump size (Colt Industries, 1974).

With these basic terms and principles, a discussion of water lifting methods can follow with the background necessary for a uniform explanation and comparison of the design and operation of the different devices.

Chapter 3

Positive Displacement Methods

3.1 Introduction

As can be seen from Table 2.2, the positive displacement class of water lifters comprises a wide variety of methods within the two major subclasses, reciprocating and rotary, and additionally, several other devices which do not truly fit into either of these subclasses. Unlike the kinetic class, which due to its relatively recent development (see 1.2) is comprised primarily of modern, commercially manufactured pumps, positive displacement devices range from the early bucket and rope to the waterwheel, to the modern direct-acting piston and peristaltic pumps. However, all these water lifters have one thing in common which is the basis for their classification.

3.2 Reciprocating Methods

Each of these methods provides displacement of water from one head (elevation and/or pressure) to another by a reciprocating motion between the two heads. It is appropriate that this subclass is the first to be reviewed since it comprises the first devices man developed when he wanted to lift more water than he could hold in his two cupped hands.

3.2.1 Bailing

All the methods in this category are simply based on allowing water to fill a container and raising that container to a desired height. The means by which this lifting is accomplished is the criteria for further classification and discussion.

3.2.1.1 Bucket/Bag

Utilizing nothing more than a container such as a bag (e.g., of skin or plastic) or solid bucket, a man can raise water to the head and quantity limits of his reach and strength. As illustrated in Figure 2.3, the performance of this simple water lifting act can be presented as merely the buckets per minute (Q) which can be lifted between two elevations (H) . Or by multiplying Q by the volume of water discharged per bucket, these results can be recorded in more conventional discharge units. One source (Weisback and Herrmann, 1897) reports that using a 0.35 ft^3 (10 liter) bucket, one man can lift about 15 buckets per minute or 300 cfh to a height of 3.3 ft. This performance requires roughly 1100 ft-lbs of work per minute, which is 0.033 WHP.

When the required lift exceeds the reach of a single person, he has three alternatives, or combinations thereof, to increase his lift; (a) taking more time to carry the container up an incline (usually using a yoke to carry a pair of buckets), (b) using two or more people in series along which the bucket(s) can be passes, or (c) utilizing a pole or rope (chain, etc.) attached to the bucket. Alternative (a) is a continuation of Figure 2.3, sacrificing discharge to increase lift, while (b) requires additional work input. Alternative (c) is the beginning of another category of water lifting devices.

3.2.1.2 Bucket and Rope

Utilizing only a rope or pole (often called a cistern pole and having a hook at one end on which to hand a bucket--see Ewbank, 1876, p. 57) to lower a container into a water source, the lift can be significantly increased. However, since the strength of the human lifter still limits the capacity of the container, as more time is consumed lowering and

raising the bucket through greater distances, the discharge again decreases. However, by employing one of several additional devices, the discharge, as well as the lift, of the rope and bucket* can be increased.

3.2.1.3. Bucket, Rope, and Roller

Pulling the rope over a single roller or pulley theoretically requires the lifter to exert the same amount of energy as lifting without the pulley, plus a small amount of overcome friction. However, centering the bucket over the well or water source prevents dragging it up the well wall (with subsequent splashing and friction) and allows the lifter to pull hand over hand without bending or reaching. Also, the lifter can either utilize gravity by pulling the rope down with his weight, or walk away from the pulley with the rope. By using a greater number of pulleys in various arrangements, the amounts of force that must be exerted by the lifter can be significantly decreased, but of course, the distance to pull is increased. This way, the capacity (i.e., weight) of the bucket can be increased.

Of course, with the introduction of such mechanical devices as the pulley, friction losses become a reality and will be reflected as the difference between the measured pull and that predicted by theory. An additional initial cost for pulleys, supports, etc., has also been introduced, as well as a maintenance requirement, e.g., lubricating the pulley. Costs of rope and pulleys will vary greatly, depending on quality, size, and geographical availability. Although commercially manufactured block and tackle units and pulleys can be purchased to decrease wear and friction,

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* This combination will be used throughout further discussion, although other combinations with bags, chains, etc., can often be substituted.

handmade construction can be easily done by the local user--often utilizing "scrap" materials such as wheels, bearings, etc. It is also possible to retain the tripod, pulley, and rope used to construct the well or canal for use in water lifting (see VITA, 1975).

By using a counterweight, the pull needed to lift the full bucket can be reduced, but of course, effort must also be expended to lower the bucket. By using a second bucket as the counterweight, the discharge can be increased. No data appears available for comparison of optimum two bucket or counterweight operation.

As mentioned, rather than pulling the rope hand over hand, the lifter can move away from the roller to draw the container up from the water source. Utilizing animals such as bullocks or camels to do the pulling, this arrangement, called a mot, has been in use in developing countries for centuries. Among the other names found for this device are:

mota	ramiokos (Pakistan)
mote	daly (Arabic)
mohte (India)	delu (Arabic)
charsa (India)	rope and bucket lift

Several variations of this basic device are often used to improve its efficiency and performance. Where possible, the animal(s) walk down a slight incline (usually 5 to 10 degrees), thereby utilizing its weight (i.e., gravity) to aid in the lifting (Figure 3.1). Often two people are needed for this operation--one to drive the animal(s) and one to empty the bucket. Upon reaching the bottom of the incline, the animal is either backed up or turned around and walked forward up the incline. In the latter case, two animals (or two pair) are often used. While one

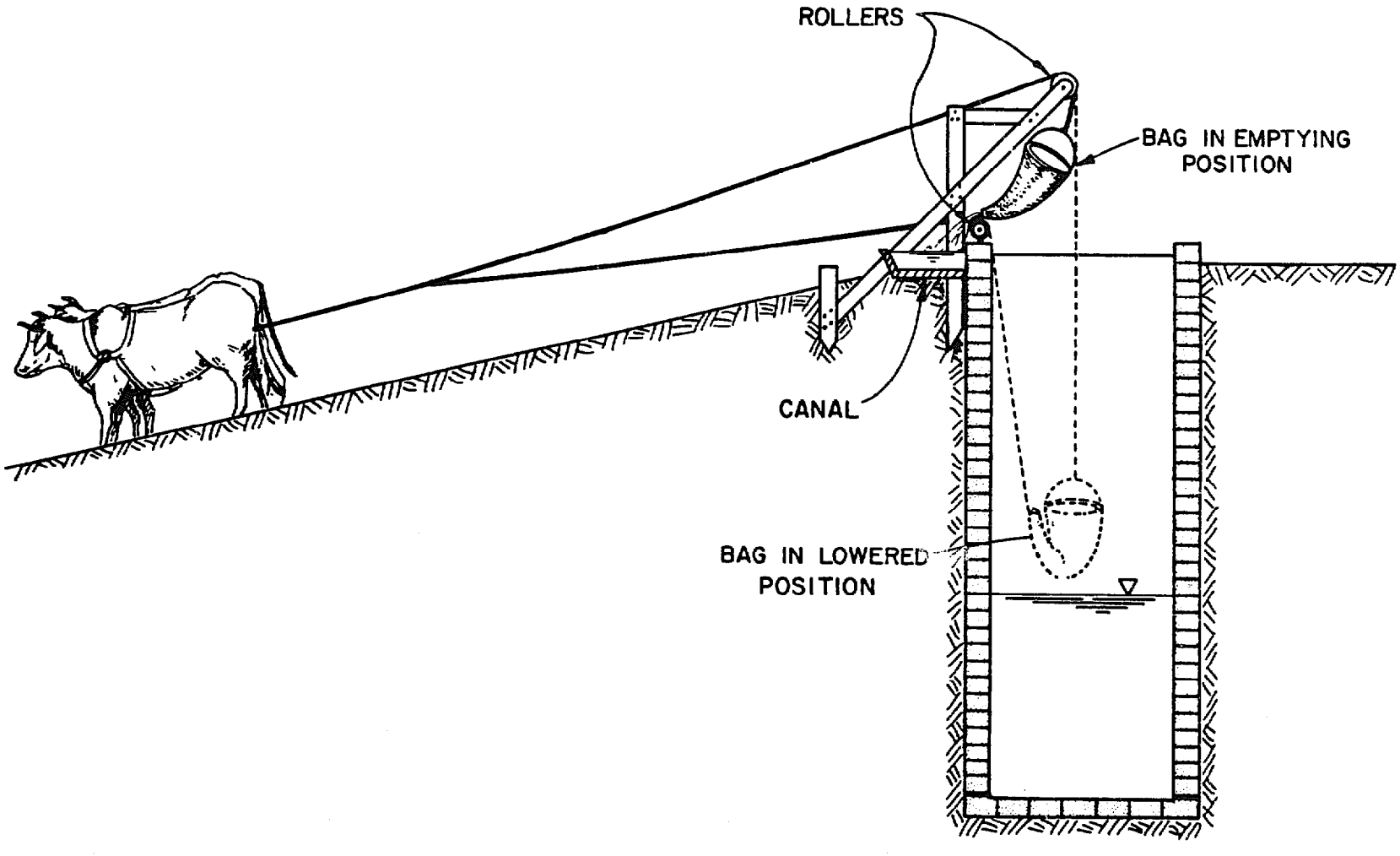

Figure 3.1 Self-emptying mot with inclined tow path

animal is returning to the top, the rope is detached, the bucket lowered to the water source, and the rope hitched to the other animal which has already returned. Although this scheme can increase the buckets per unit time, it also increases the amount of input power, i.e., more animals, a person to drive them, and another to return the rope hitch.

Another modification to the mot eliminates the need for the person emptying the bucket. As illustrated in Figure 3.2, the self-emptying mot or sundio kos utilizes a bag with a large opening at one end (the top when in the water) and a spout at the other. Two ropes are attached, one each to the top and spout. Each rope passes over a separate roller, but both are attached to the pulling animal. While in the water and being lifted, the spout stays above the bag top, but upon reaching its lower roller, the spout is pulled down and allows the bag to drain. These bags are usually hides attached to an iron or wooden ring and may vary in size from about 24 to 42 gallons (Roberts and Singh, 1951). Lifts usually vary from 10 to 50 feet for not use (Wilson, 1896). Discharges of 250 cfh have been reported for a 30 foot lift using one pair of bullocks and 600 cfh with two pair at the same head (Molenaar, 1956).

One other variation of the rope-bucket-pulley is shown in Figure 3.2. It is referred to as a two bucket lift, double mot, or circular mot. This figure also illustrates another design for a solid bucket as it could be used in the conventional mot. This water lifter uses two buckets (with bottom flap valves), attached to two parallel guide rails running up a well or shore wall. A rope (or chain) is attached to each bucket and passed through pulleys on poles diametrically opposite each other, with a circular sweep in between. An animal is usually used to turn this sweep and thus alternately raise and lower the two buckets. As illustrated

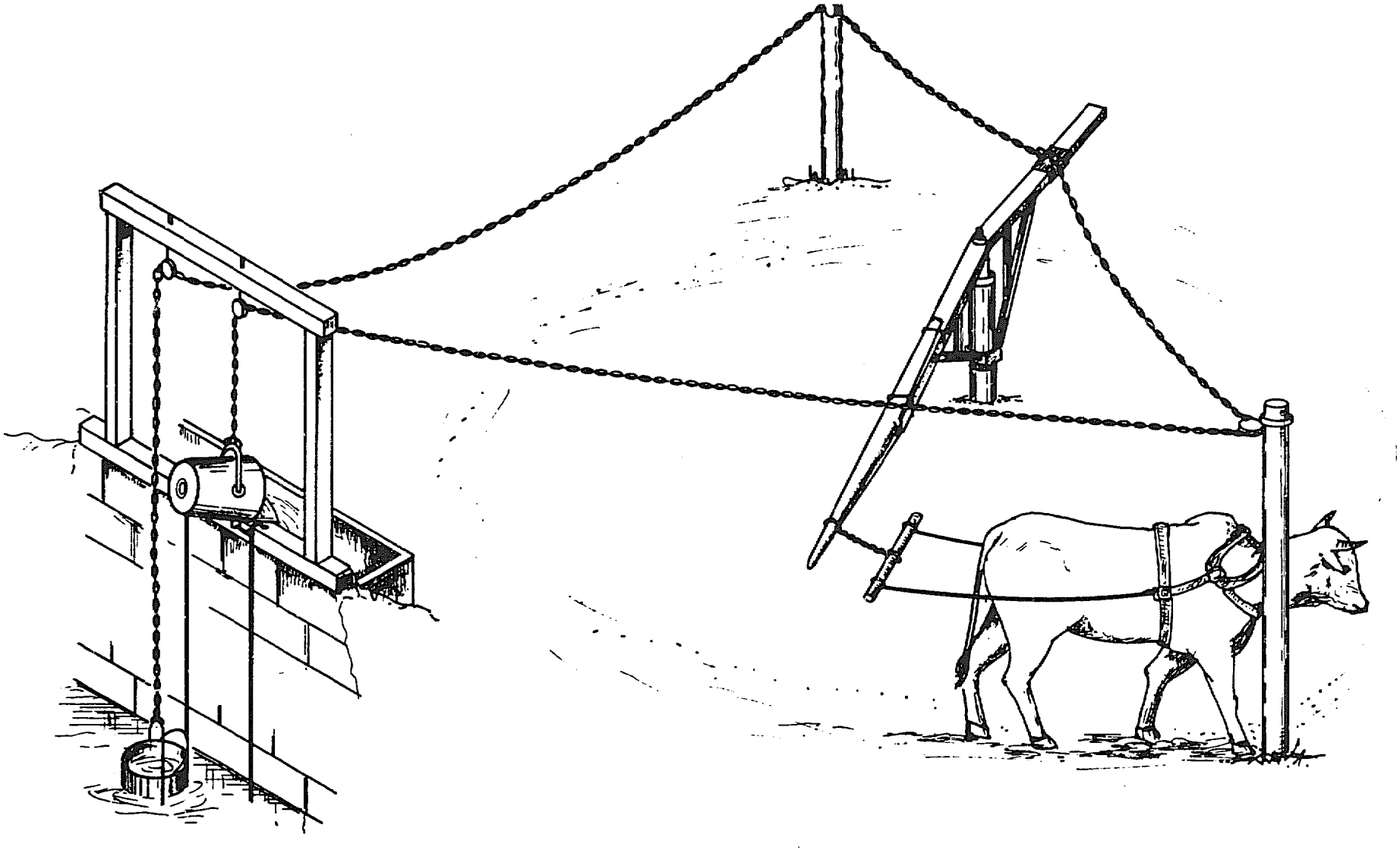

Figure 3.2 Circular mot utilizing two buckets with flap-valves in bottom

here, the circular mot is usually limited to 5-15 foot lifts, with capacities of around 800 cfh. This data is reported by Molenaar using 16 gallon buckets. However, by utilizing additional pulleys and longer ropes, lifts of 30 feet with discharges of 250 cfh have been accomplished using 12 gallon buckets.

Adjusting cost estimates reported by Molenaar in 1956, the initial cost of a mot (including rope, pulleys, trough, supports, bucket, and installation) would be about $50.00, with repair costs of a few dollars a year. Of course, the cost of animals and the land needed to grow feed for the animal (multiplied by the percentage of time for water lifting) must also be included in initial costs. In addition, the cost of feed or loss of production of the land must be considered in the operating cost.

3.2.1.4 Bucket, Rope, and Windlass (Crank)

As with the use of multiple pulleys, the windlass or crank provides mechanical advantage to allow increased capacity (load) of a bucket and rope. Many variations of the windlass are possible, including combinations with pulleys, gears, treadmills, etc. The most commonly used modification is the utilization of two buckets attached to opposite ends of the same rope which is wrapped around the windlass roller. In this way, the buckets counterbalance each other and the BHP must only balance the water weight and friction. The use of these additional devices, such as gears, rollers, and pulleys, can significantly increase the efficiency of the windlass by decreasing the needed BHP . The use of low friction losses. No data appears available on the performance and cost of this simple lifter.

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* Costs throughout this paper have been adjusted to 1975 United States of America Dollars.

3.2.1.5 Counterpoise Lift

The counterpoise lift is another variation of the rope/pole and bucket and was one of the earliest water lifters (see Section 1.2). It has been used throughout the world, with many countries reporting several hundred still in use (Franji and Mahajan, 1969, and Dias, 1953). Many names have been attributed to this device. A list of the most frequently used are:

shaduf (Egypt)	dhenkali
shadoof	dhenkli
shadouf	dhingli
chadouf	picottah (India)
khetara	lat (India)
kerkaz	picotas (Portugal)
kheeraz	sweep
guenina	swape
bascule	

In its most common form today this water lifter consists of a bucket attached to one end of a vertical pole which hangs (freely) from a lever. As can be seen in Figure 3.3, this level pivots about a horizontal cross-bar and is counterbalanced by a weight. This weight is usually sufficient to balance half the weight of the full bucket so that the attendant need only lift half the bucket and water weight. Then, to return the bucket to the water supply, he can use his weight (at least to some degree) to offset the counterweight in order to pull the lever down. However in some cases, the counterweight may be allowed to balance the entire bucket and water weight if the attendant is able to utilize enough of his weight

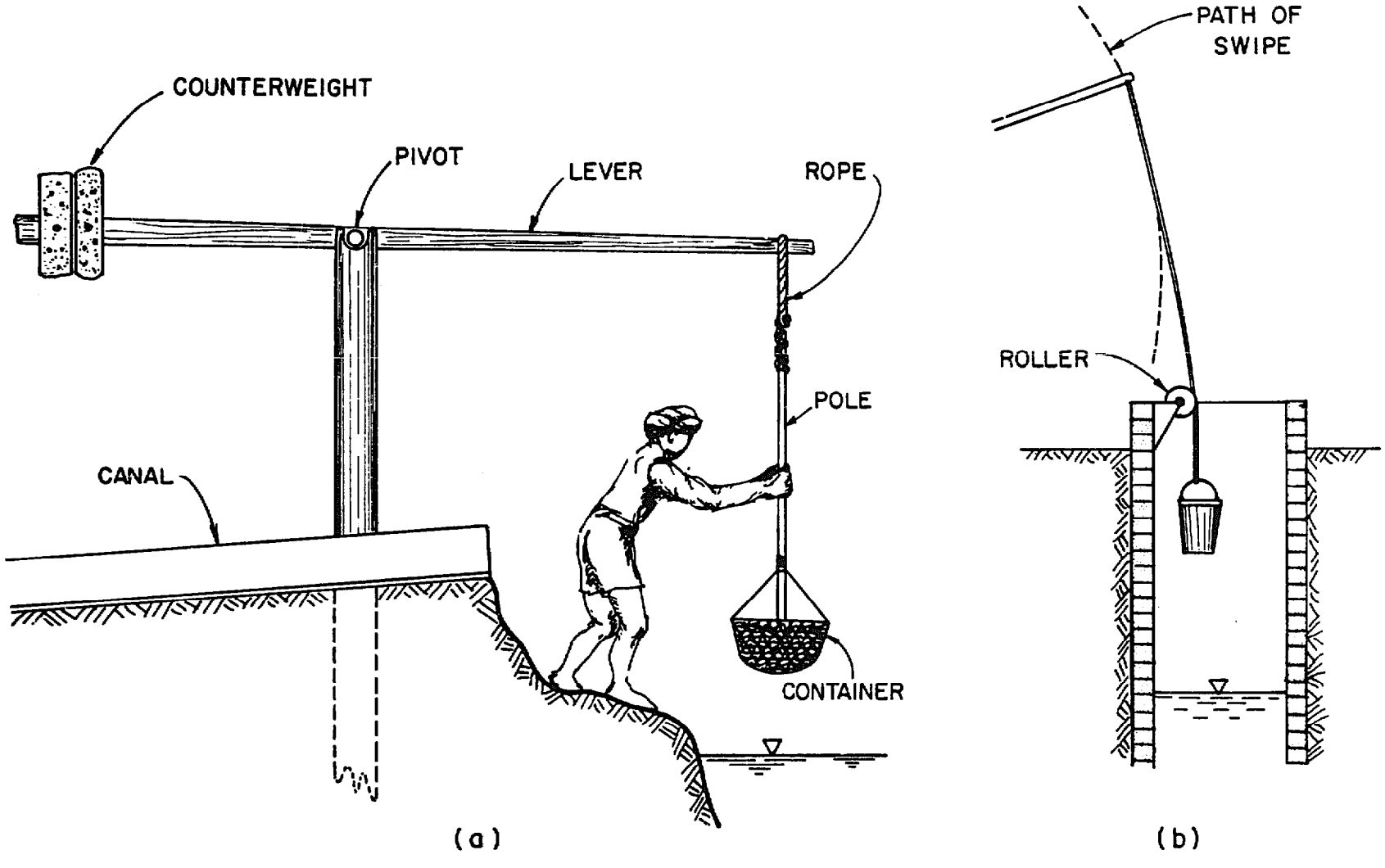

Figure 3.3 (a) Counterpoise lift, and (b) with roller for narrow well

to return the lever. Combinations of weights varying between these two cases are utilized depending on the lift, terrain, and attendant's liking. A pole usually connects the bucket and the lever so that the bucket can be pushed into the water. This is normally done where the lift is 3 to 10 feet. However, if the lift is greater or the water source is in a narrow well (Figure 3.3), a rope or chain may be used instead of a pole. When the lift of single shadouf is exceeded, a series of them are often employed--one discharging into the supply pool of the one above it.

The lever, pivot, and pivot supports are usually of wood, while counterweights vary in composition; rock, dried mud ball, concrete, can be filled with water or sand, etc. The actual water container may be a leather bag fastened to a metal hoop, a used petrol can (Molenaar, 1956), a lined basket, or metal bucket.

Table 3.1 gives the various performance data that have been reported for the shadouf.

Here again, initial costs will vary with lift, capacity, and availability of construction materials; however adjusting Molenaar's information to 1975 U. S. dollars, the bucket, rope and frame can be expected to cost about $12.00.

The term picottah)or paecottah) is often applied to a specific variation of the counterpoise lift which uses one or two persons as movable counterweights in place of, or combined with, the fixed counterweight (Figure 3.4). This device is larger and has a longer lever than a regular shadouf and thus is utilized for higher lifts, usually from 15 to 30 feet. To operate this water lifter, the "counterweight" person(s) walks back and forth along the top of the lever, which has eithera notched or plank walkway, and hand rails. As his weight is shifted, the bucket

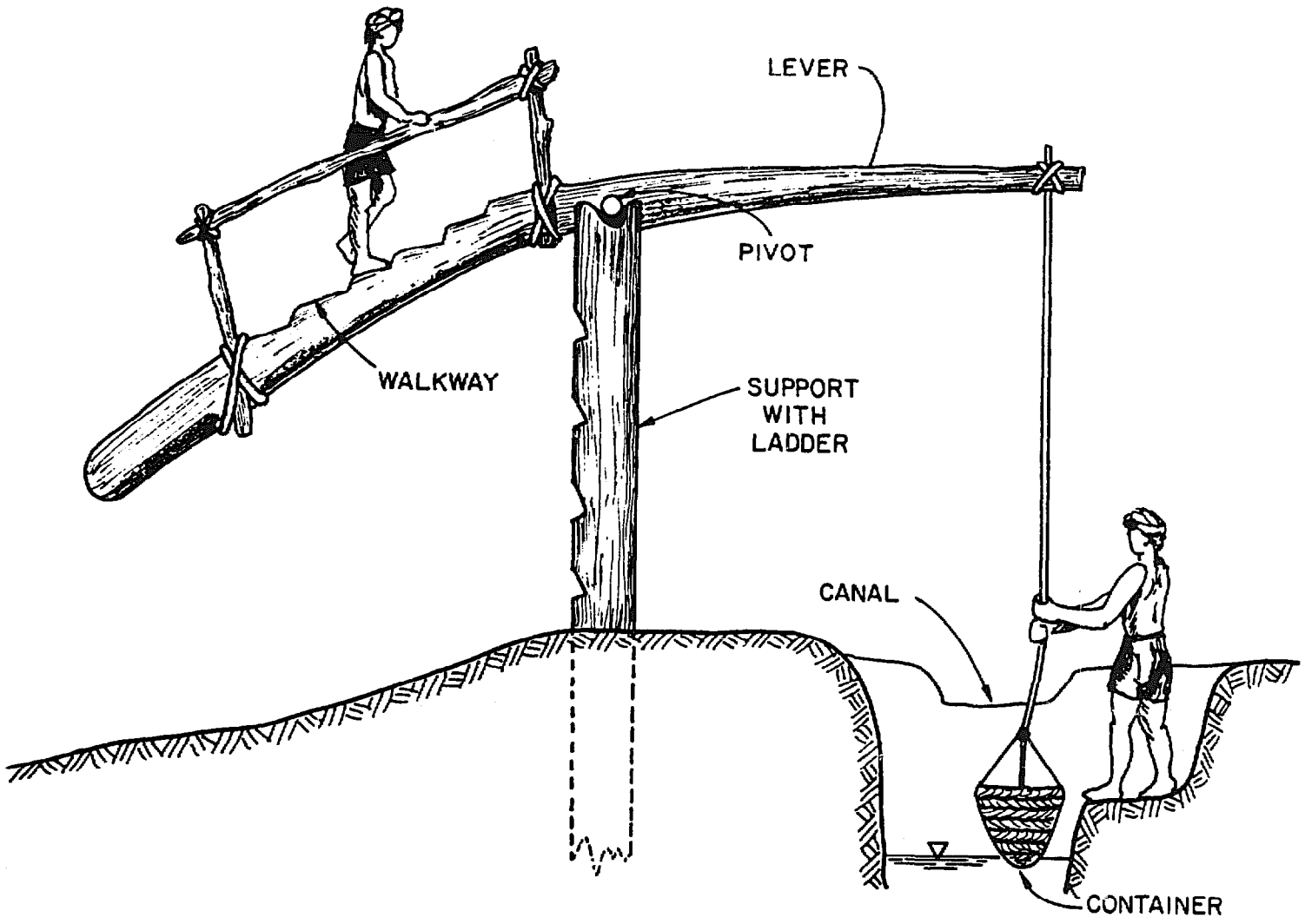

Figure 3.4 Picottah, using man as moveable counterweight

Table 3.1 Shadouf performance

Lift (ft)	Discharge (cfh)	Reference	Remarks
8.2	105	Molenaar, 1956	1 man
8.2	180	Molenaar, 1956	2 men working 2 hr shifts each
6.5	210	Molenaar, 1956	2 men working 2 hr shifts each
3-10	210	Garg, 1971	1 man
6.5	180	Schioler, 1973	1 man
1	3300	Buckley, 1905	1 man
1	5760	Buckley, 1905	2 men
6.5	857-1071 cf/day	Framji and Mahajan, 1969	no hours per day given

will raise and lower. One additional person is needed to empty the bucket. No data is available on the picottah; however it could be expected to have a slightly higher cost than the shadouf, but capable of higher discharges and heads.

3.2.2 Scooping

In low-lying areas, e.g., Nile River Valley, where lifts from water sources to fields are small (i.e., 2 to 5 ft), man found he could scoop and throw water at a greater discharge than he could fill, lift, empty, and return a bucket or bag.

3.2.2.1 Swingbasket

The swingbasket operates just as its name implies. A basket is attached with four ropes, two on each side. Two people, each holding

two ropes, swing the basket back and forth. In the return motion from the higher elevation, the basket is dipped and filled. Then, on the reverse swing, a twisting of the ropes is usually done to throw the water up. This simple device is also referred to as:

latha	katweh	jhatta (Pakistan)
mental	basket scoop (India)	

Reported performance data appears to be rather questionable. Buckley's work in 1905 indicates a discharge of 2000 cfh with a one foot lift, while Molenaar in 1956 reports only 180 cfh with a two foot lift. Based on the performance of a similar device, the shovel (Section 3.2.2.2), the former discharge seems high and the latter low.

Of course, the initial cost of the basket and ropes is very little and repairs can be made almost immediately.

3.2.2.2 Shovel or Scoop

By merely using a semi-enclosed shovel, such as the Dutch scoop in Figure 3.5, a single person can throw water. However, Weishack and Herrmann (1897) report that one person can bail water at about the same discharge he can throw it because of the high spillage losses. Therefore, the shovel is usually attached by rope to a tripod and operated as in Figure 3.5. This method reportedly (Molenaar, 1956) produces a discharge of about 300 cfh up a 3 foot lift. Additional ropes may be attached so that one, or usually two, person(s) can pull the shovel as the first pushes. In this manner, roughly 30 cycles can be made in a minute, throwing about 1500 cfh against a head of 4 feet. This would require each of the three lifters to do about 120,000 ft-lbs of work per hour.

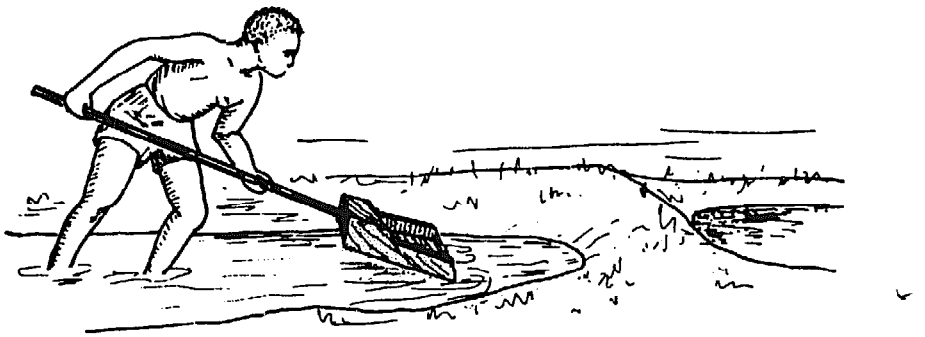

(a)

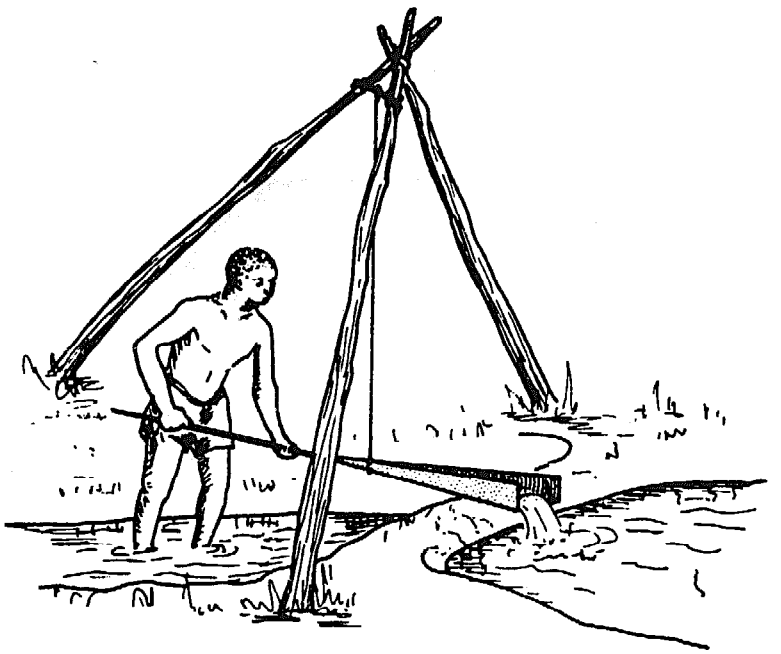

(b)

Figure 3.5 Scoop (a) used as shovel, and (b) with tripod

This device can be quite simple constructed, e.g., using a large can, cut off diagonally on one end and attached with a wooden pole on the other. No cost estimates are available.

This throwing method can be modified by another device to increase performance. The water balance shown in Figure 3.6 makes use of a scoop vertically attached to a balance beam which pivots about a centrally supported axis. By alternately pulling on ropes at opposite ends of the beam, one or more pairs of people can push water up the channel in which the scoop travels. The channel profile is circular within the arc of scoop motion. To facilitate the scoop's entry into the water, flap valves are often used which open on the return stroke. Although the oscillations per unit time will vary with size of balance and number of operators, Weisback and Herrmann (1897) report that about 4700 to 5500 cfh can be raised 4 feet.

3.2.2.3 Gutter

Rather than pushing water through a channel, as with the balance, and encountering high leakage and friction losses, the gutter actually lifts the entire channel. These gutters or troughs were originally hinged at one end to the upper elevation and the other end dipped into the water and lifted, allowing the water to run out. However, the bending and lifting action is very tiring, so gutters are often fitted with handles as in Figure 3.7a (also note flap valve). Where this device is used extensively in Portugal, it is called cegonho (translated as swipe, from Dias, 1953). Another modification is to use the picottah principle and have the operator shift his weight back and forth on a "seesaw" gutter as seen in Figure 3.7b. Dias presents this design with the outboard flap valve to ease filling and the inner flap valve (probably) to prevent the return of any undrained

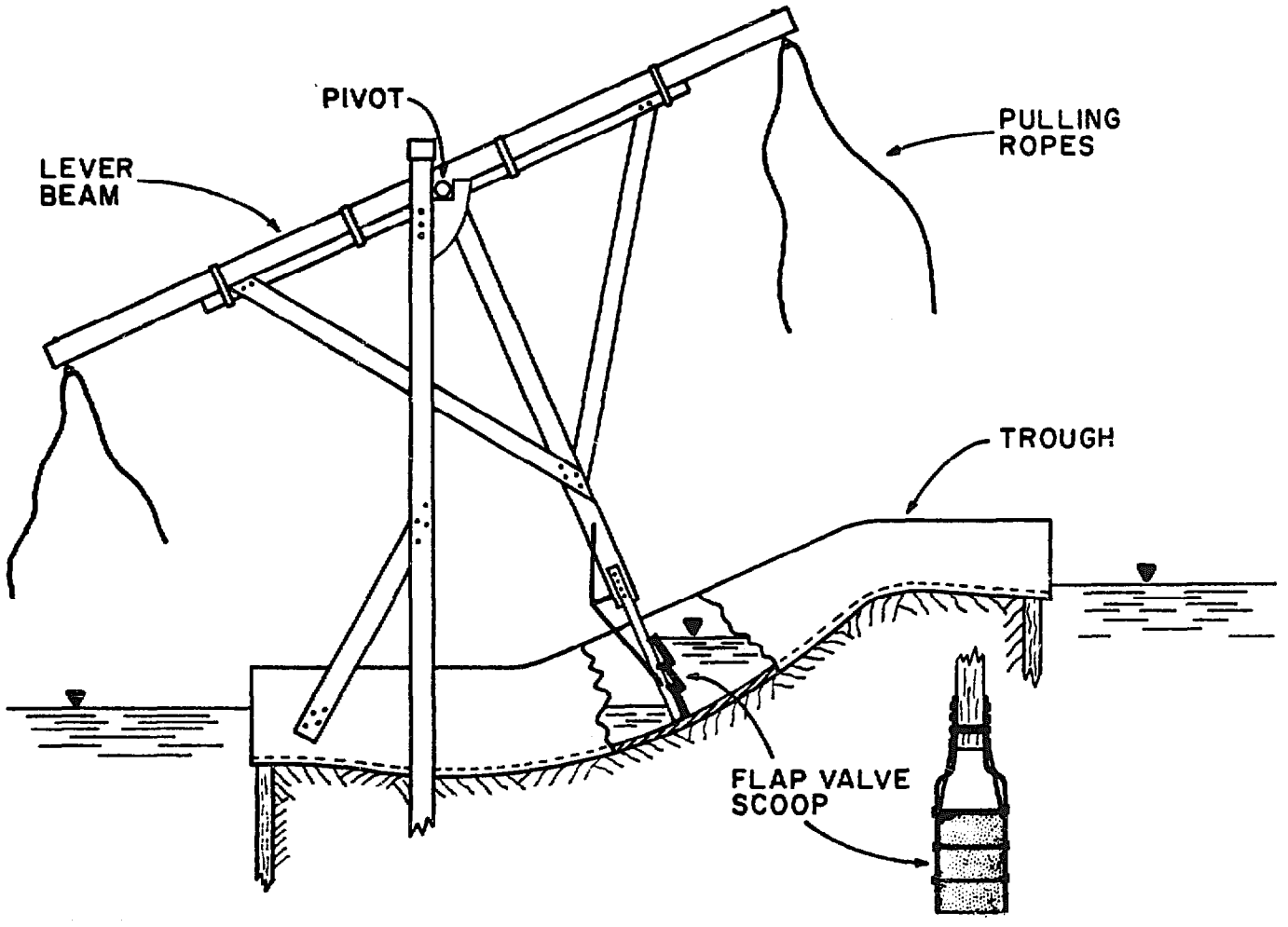

Figure 3.6 Water balance with flap-valve scoop

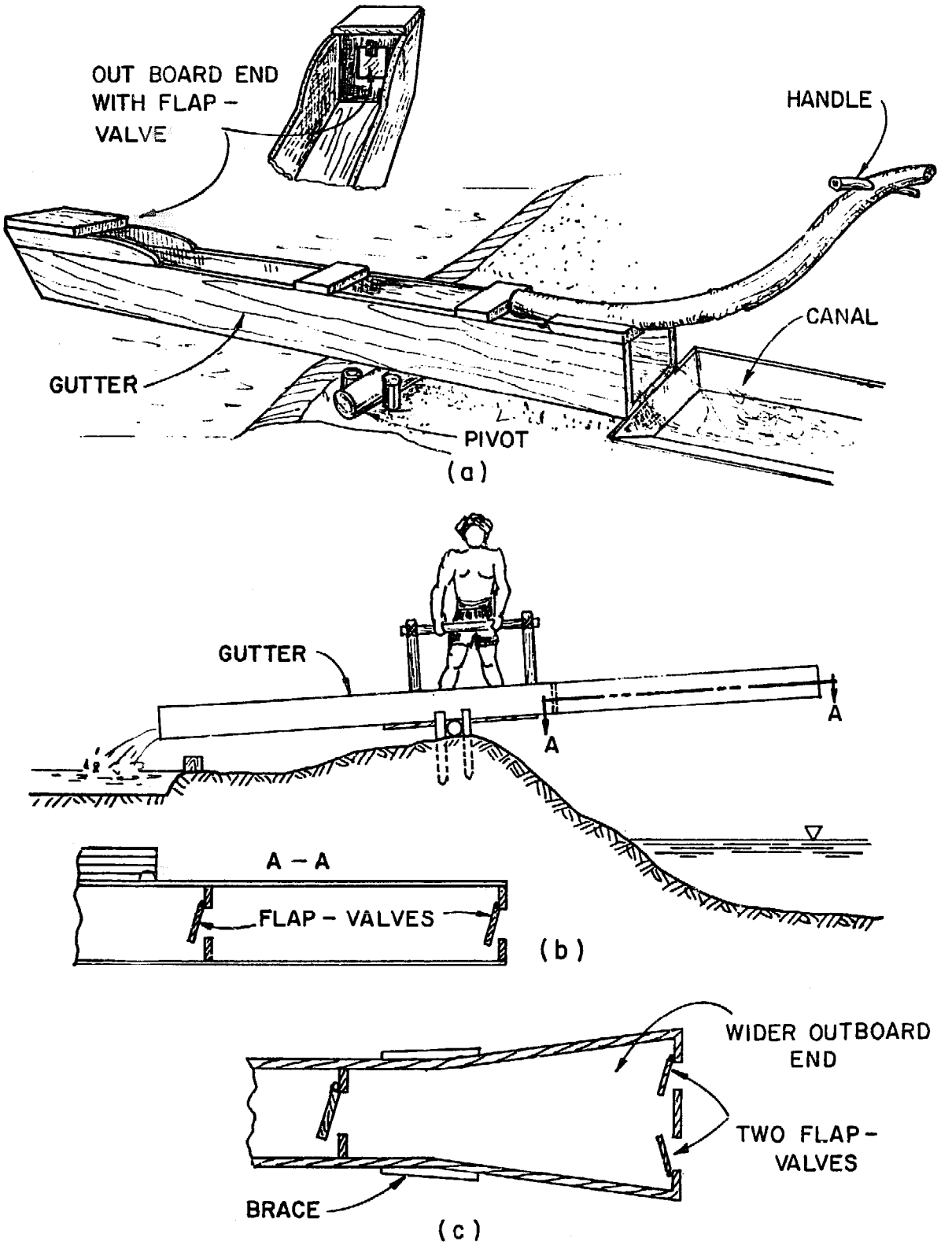

Figure 3.7 (a) Single gutter with handle, (b) "see-saw" gutter, and (c) modifications to increase gutter capacity

water. The capacity of this device could be significantly increased by extending and/or widening the outboard end as in Figure 3.7c.

By using the same circular sweep as in the circular mot, two single gutters can be operated by animal power, as indicated in Figure 3.8. This device, called the baldeo balti in the Punjab (Roberts and Singh, 1951), is primarily for lifts up to five feet, as are most gutter devices. Despite the current use and wide variety of these gutter devices, no data on costs or performance is available for comparisons.

Another modification of the simple gutter is the doon or jantu. As seen in Figure 3.9a, it utilizes the counterweight principle of the shadouf. However, as it is used for small lifts, the counterweight is made sufficient to lift the water and gutter. By stepping up on the end of the gutter, the operator can lower and submerge it. As can be seen, the lever and counterweight must be designed to provide a greater moment (i.e., weight times lever arm) than the full gutter, but less than the empty gutter plus operator.

Schioler (1975) has described what he believes to be a rather new modification of the doon (Figure 3.9b) which again copies the picottah principle, i.e., the operator walks back and forth on the lever to provide a movable counterweight. Because the gutter is attached at both ends to the lever and rises with it, this picottah-style-doon (no specific name has been reported) is capable of lifts greater than the conventional doon.

Two more versions of the gutter have been recently introduced. The first, shown in Figure 3.10a, utilizes a sealed air container, e.g., a petrol can, to lift the gutter by buoyancy instead of by counterweight. The operator merely steps on the outboard end of the gutter to fill it

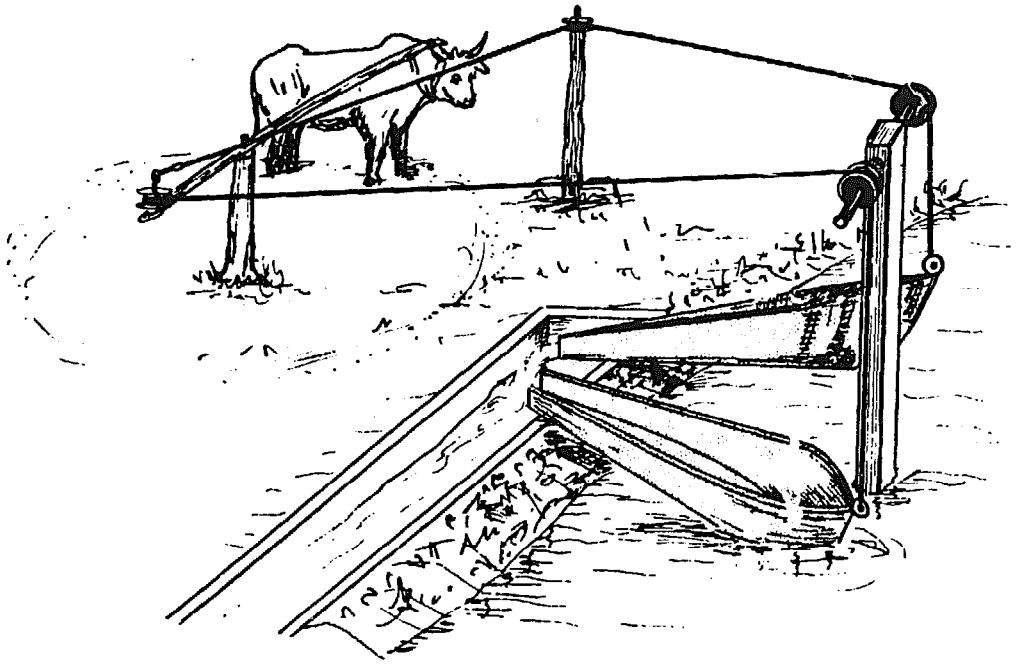

Figure 3.8 Double gutters (a) with lever, and (b) as baldeo balti

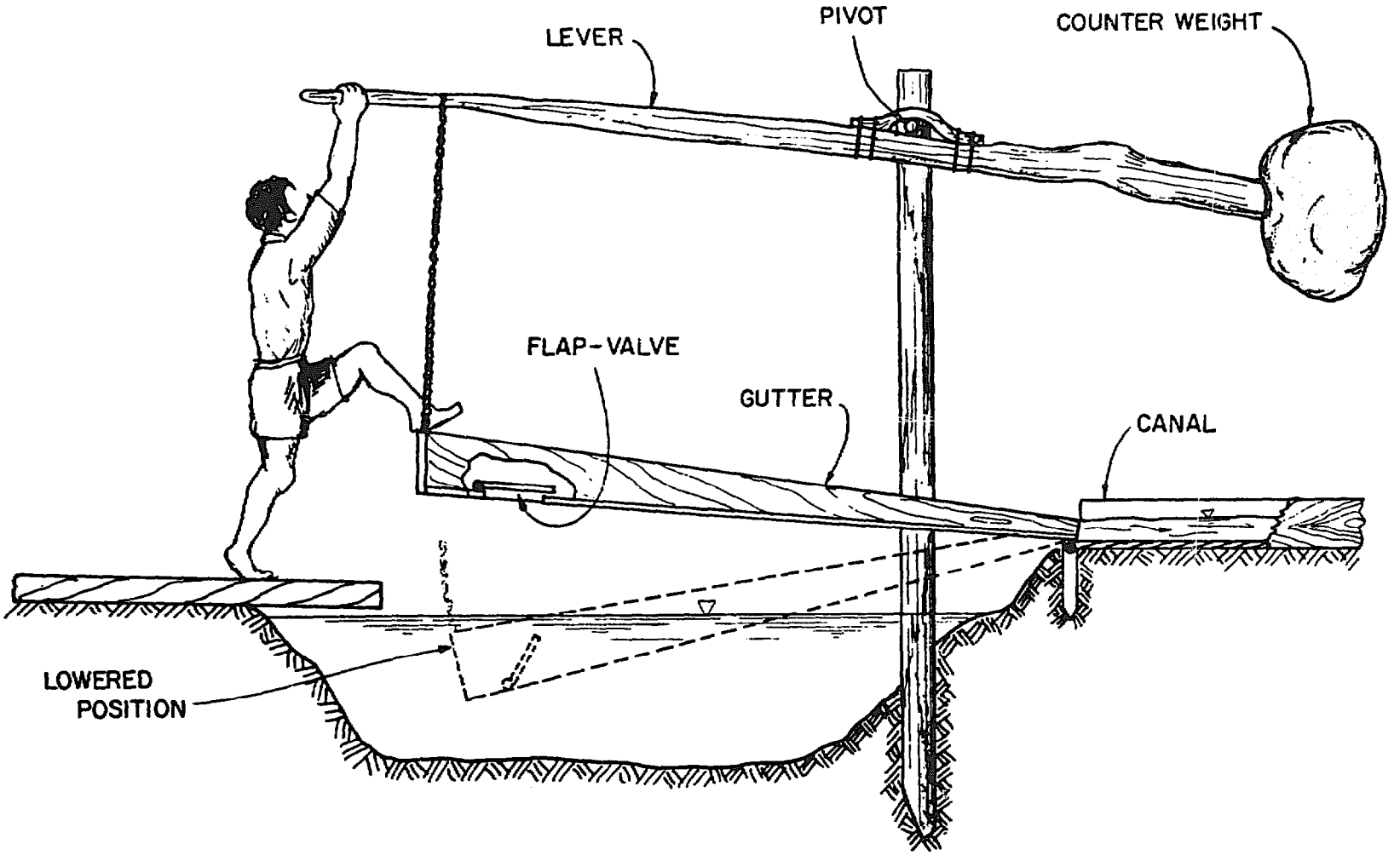

Figure 3.9(a) Doon with flap-valve for aiding submergence

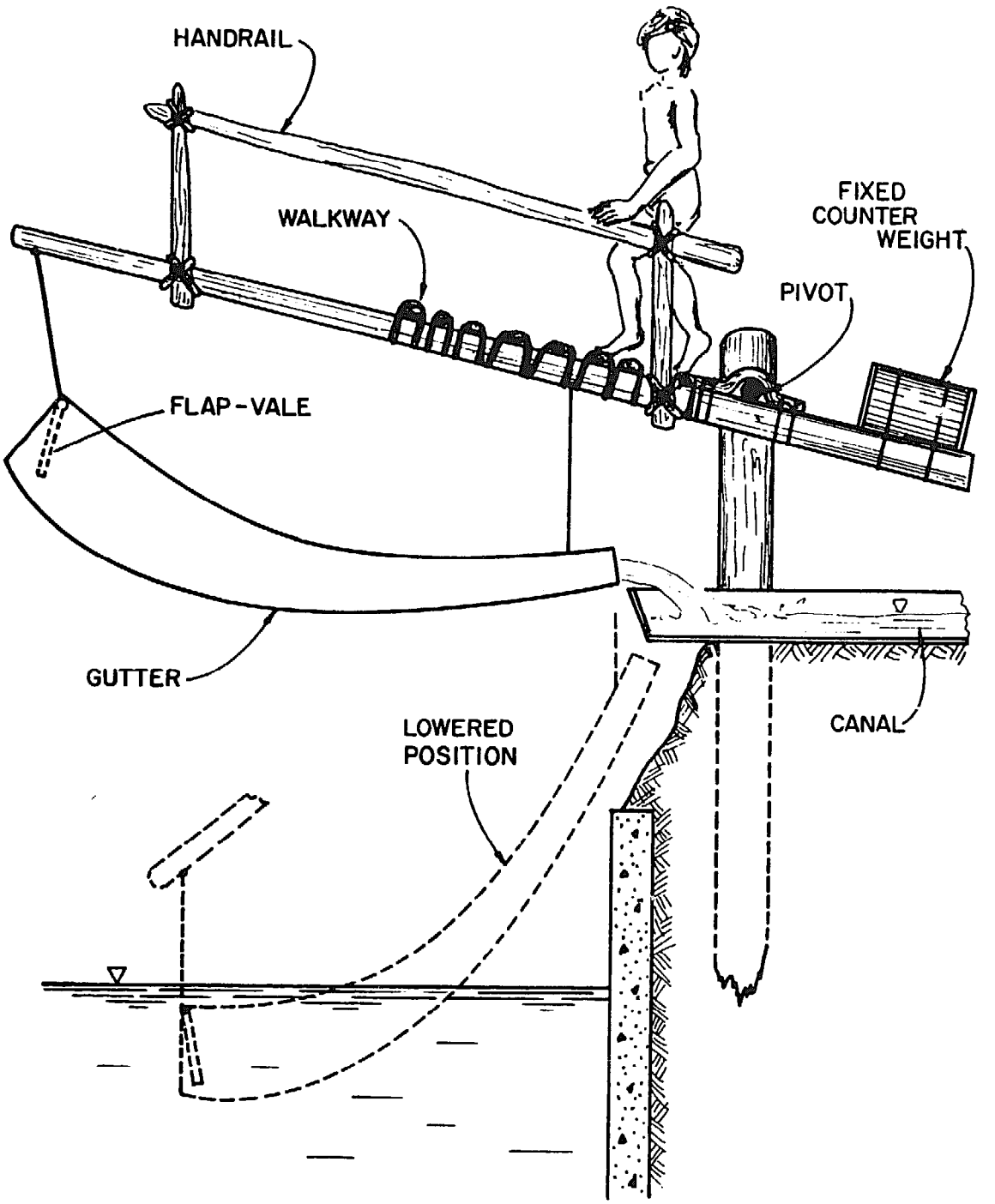

Figure 3.9(b) Picottah-style doon with flap-valve

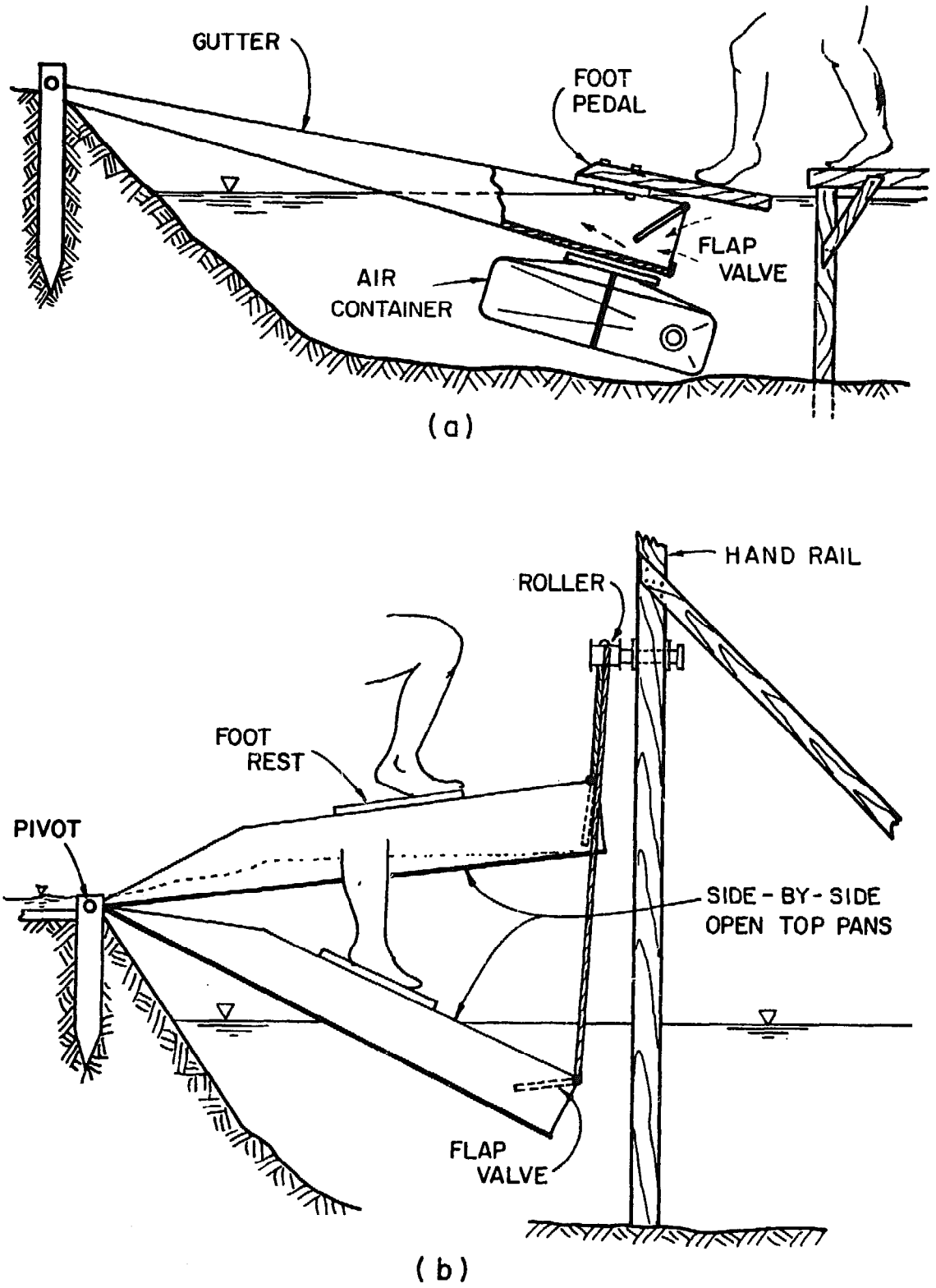

Figure 3.10 Recent modifications of the doon

and steps off to allow buoyancy to lift it. Although no information is available, this device appears cheaper and easier to build and maintain than the conventional doon.

Through recent communication with W. D. Kemper in Pakistan, we have learned of the development of a double-acting, foot-operated gutter. As shown in Figure 3.10b, two pans are connected by a rope which passes over a pulley. The operator stands with one foot on each pan and alternately shifts his weight from one pan to the other. By means of a flapped opening in the outboard end of each pan, it fills and is then raised and drained out the shore-hinged end. Kemper reports that a man in good condition can lift 800 cfh (100 gpm) one foot for several hours. Over short periods, a rate of 130 gpm has been reached. It appears that this device is limited to one or two foot lifts, but is quite efficient and easy to operate. As this device is still under study, no data on costs or efficiency is yet available.

3.2.3 Piston-, Plunger-, and Bucket Pumps

This third subclass of reciprocating methods ranges from the simple, hand "lift pump" (Fig. 3.12 to the sophisticated, direct-acting "steam pump" (Fig. 3.11. Unlike the reciprocating devices previously discussed, these pumps do not need to he submerged (have a static suction head) to lift water, but instead have the ability to "suck" water from a static suction lift (see Section 2.2). All pumps in this class utilize as their primary component one of three similar devices to lift the water;

(a) The plunger-pump uses a soild or semi-solid cylinder (plunger) to displace the water in a surrounding hollow cylinder. When the plunger withdraws (upward) from the cylinder it creates a drop in pressure within the cylinder and thus allows water to

flow in through a check-valve (e.g. flap, ball, etc.). On the reverse stroke (downward), the plunger forces water out through another, but outward opening, check-valve.

(b) The piston-pump operates the same as the plunger pump except that is utilizes a solid piston which fits tightly against the cylinder walls.

(c) The bucket-pump uses a piston having check-valve(s) which open on the downward stroke. On the upward stroke, the piston sucks water in through the bottom inlet and simultaneously pushes water out through the upper outlet. Then, on the downward motion, the piston's check-valves open, allowing the water to flow from beneath the piston to above it--ready to be pushed out on the next upward stroke.

All three of these pump types, but particularly the bucket-pump, are often referred to as lift or force pumps since they can both lift the water to the piston (or plunger) level and force it out of the cylinder. However, as shown in Table 2.2, the next subdivision of these pumps is into direct-acting and power categories, depending on the method used to motivate the piston or plunger.

3.2.3.1 Direct-Acting Pumps

Direct-acting piston or plunger pumps are so named because they utilize a driving piston mounted on a common rod(s) with the water-end piston or plunger. As illustrated in Figure 3.11, steam (or compressed air) alternately enters both sides of the driving piston, causing it to move back and forth, along with the connecting rod which in turn reciprocates the water-end piston or plunger. In most modern designs, the reciprocating connecting rod also automatically moves the inlet and

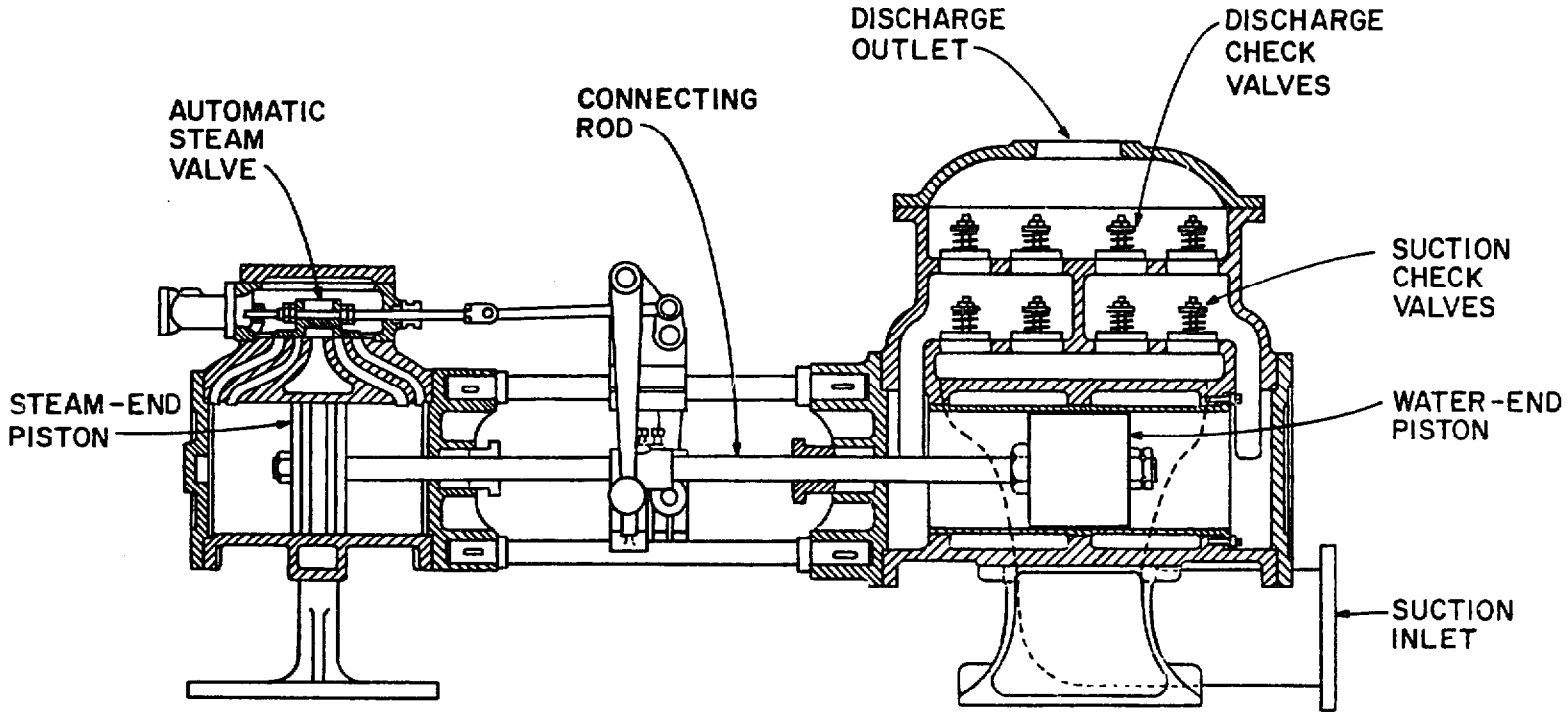

Figure 3.11 Direct-acting, double-acting, piston pump

exhaust valves for the steam (or air) chamber. Although most direct-acting pumps have one steam piston per connecting rod and are referred to as simple, some designs utilize two (or three) tandem pistons. With two piston surfaces to push upon, the same steam pressure can apply twice (theoretically) the power to the water piston.

3.2.3.2 Power Pumps

"Power pump" is the popular nomenclature given to any piston-, plunger-, or bucket-pump which is not direct-acting, although of course, all pumps need power to operate. Also, this term usually denotes mechanically driven (e.g. gas engine, electric motor) pumps, however, since the principle is identical, manual-, animal-, and natural-driven piston pumps are included in this category. In the basic "hand pump", Figure 3.12, the manual power is normally transmitted by means of a reciprocating lever.

3.2.3.3 Characteristics

Several differences exist, other than the method of driving, between direct-acting and power pumps. The speed, i.e., strokes per minute, of a steam pump varies with the discharge head and when this head (on the water piston) equals the pressure on the steam piston(s), the pump will stall. The speed of the power pump does not vary significantly with discharge head and will not stall at excess heads. Instead, it may overheat or stall the prime mover, or if not governed, burst the pump cylinder or valves. Therefore, power pumps are usually specified for high head applications and direct-acting pumps for lower heads. Similarly, since a plunger simply protrudes into the water cylinder and need not slide and seal along the cylinder wall as a piston, plunger pumps are more suitable for high discharge head. However, this sealing at the cylinder wall makes pistons more efficient for high suction lifts.

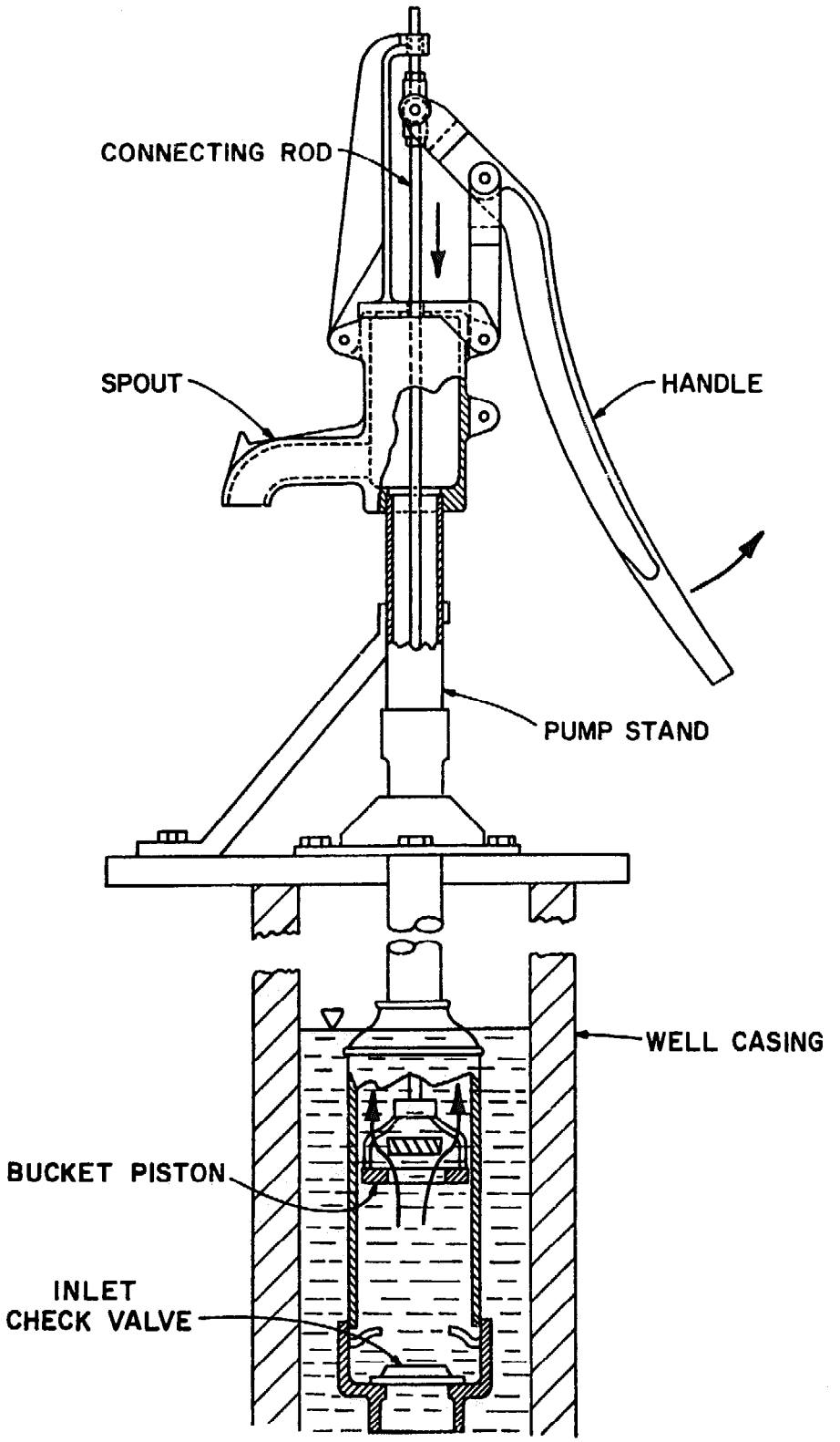

Figure 3.12 "Hand pump" with single-acting, bucket-piston

Another significant difference between direct-acting and power pumps is their discharge per time characteristics. Figure 3.13 illustrates some typical Q-T curves for various reciprocating pumps. Power and direct-acting pumps are similar in that like other positive displacement devices, they have little variation of Q with H .

Another feature of piston-, plunger-, and bucket-pumps is that due to their positive displacement nature, they are self-priming. That is, within the limits of their structural soundness (e.g. cylinder wall strength, air-tightness) and surrounding pressures (i.e. NPSHA), they can displace air in the suction line which causes a pressure drop and thus the suction of water.

3.2.3.4 Applications for Irrigation and Drainage

Since the development of rotodynamic pumps (see Section 1.2), mechanically-driven, power and direct-acting pumps have lost popularity for irrigation and drainage where mechanical prime movers are available. This is due primarily to the fact that rotodynamic pumps produce the high Q , low H performance usually needed for irrigation and drainage situations, whereas positive displacement pumps are better suited for high H and low Q applications. Additionally, rotodynamic pumps contain far less moving parts which require less maintenance and cost.

However, when these direct-acting and mechanical-power pumps are used for irrigation or drainage, they exist in three basic forms. In either a vertical or horizontal position, they can be mounted above the water supply with a suction line extending to the water. In this application, the dynamic suction lift must be considered so as not to exceed the NPSHR. When a conventional direct-acting or power pump cannot be installed near enough to the water surface (e.g., in a well or mine

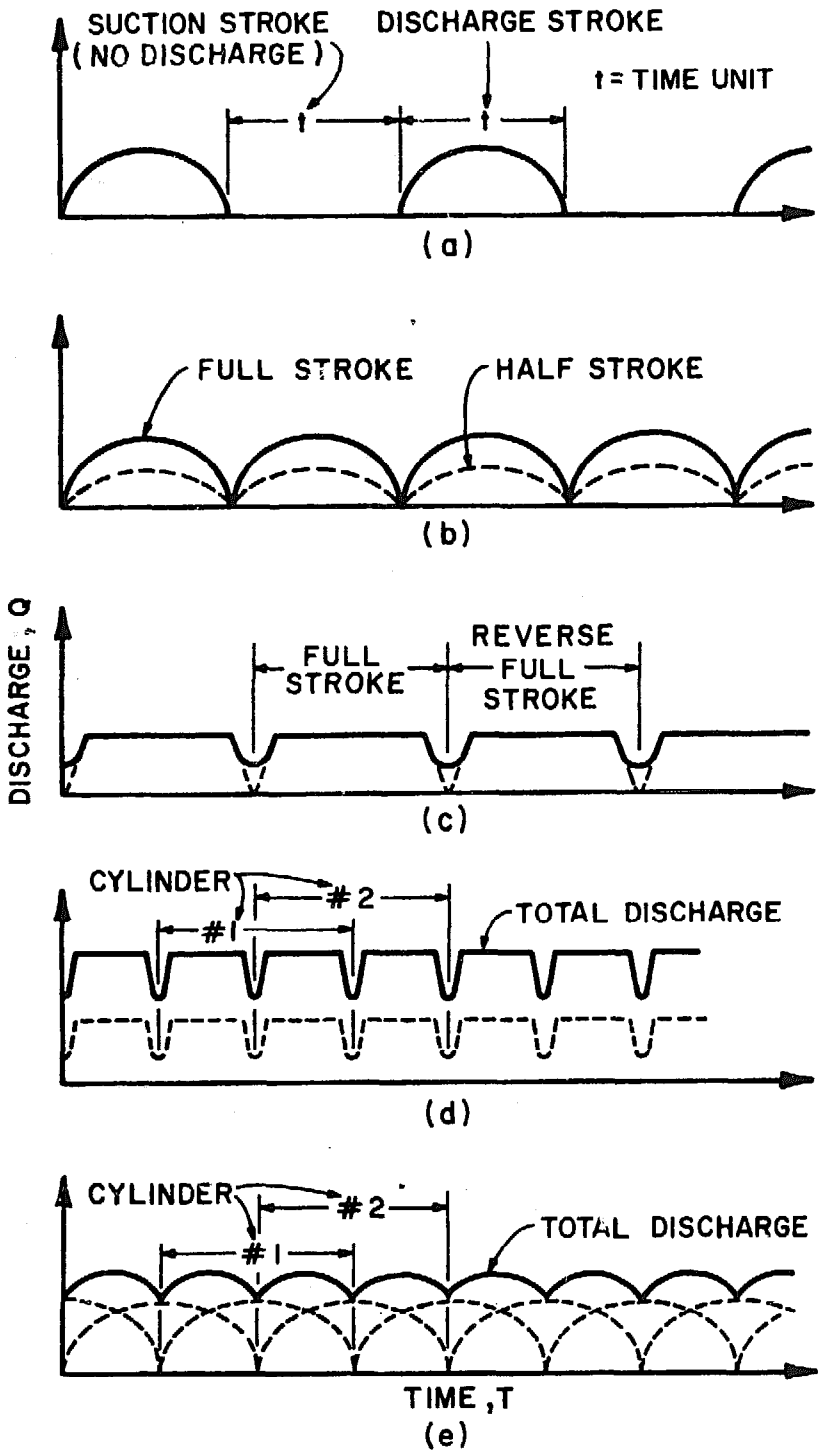

Figure 3.13 Q-T curves for (a) simplex, single-acting power, (b) simplex, double-acting power, (c) simplex, double-acting steam, (d) duplex, double-acting steam, and (e) duplex double-acting power pumps

shaft), two other forms of these pumps can be utilized. The first is commonly called a mine or sinking pump and is simply a compact, direct-acting pump which can be lowered into a narrow shaft along with steam or compressed air hoses for power. The second alternative for deep well pumping is to lower a bucket-piston with connecting rod to within NPSHR limits of the water surface. The rod is connected to a prime mover at the well surface which, due to the long rod length, operates at low speeds (40-65 stokes per minute--spm). These surface prime movers, often referred to as pump heads, are usually gas engines or electric motors, however, throughout the early 1900's, steam pump heads were common (Greene, 1913). These bucket-pumps can be single-acting or can utilize double-acting cylinders as in Figure 3.14.

Initial costs vary greatly on mechanically driven piston and plunger pumps, depending on size, availability, manufacturer, etc. Manufacturer's catalogs must be consulted for exact prices, however, even the smallest lifter-driver units have "new" prices starting at over $200. Several companies manufacture bucket-pump units similar to the one in Figure 3.14, which can be designed to use with several drivers, i.e. the connecting rod can be extended up to a windmill, or it can be attached via a cam gear to a small engine or motor, or a handle can be attached for manual use.

However, in addition to these commercial bucket-pump units, less sophisticated units are easily constructed by local craftsmen in many developing countries. The principles of local manufacture and simple construction have lead several international assistance organizations to develop designs for lift pumps which can readily be utilized in developing countries.

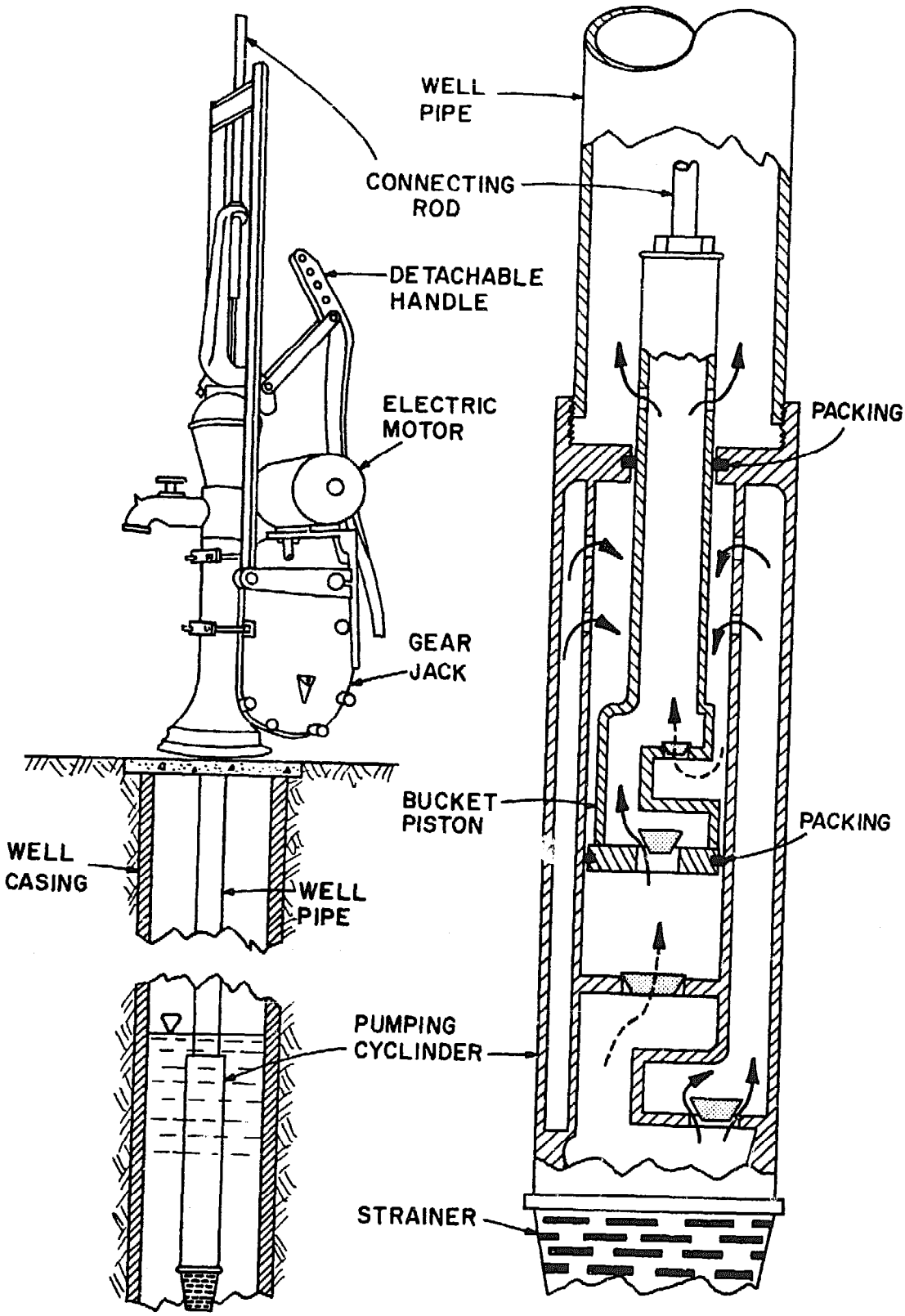

Figure 3.14 Pump head for mechanical or manual power with double-acting, bucket-pump

Among the simplest designs for a bucket-pump is the "inertia hand pump" described in VITA's Village Technology Handbook (1975). It is constructed primarily of scrap materials such as scrap barrel metal and inner tube rubber, and can be made by any craftsmen with the proper tools, e.g. a tinsmith. It is reported to lift 20-30 gpm with a 13 ft head and 60-75 gpm with a 3.3 ft head. Because this design used scrap material, no cost estimate is given.

The Peace Corps, working through such agencies as AID, the Battelle Memorial Institute, UNICEF, and CARE, saw the need for a simple, inexpensive, and dependable hand pump. Specifically, they were looking for a pump design with the following features (Peace Corps, 1975);

(a) low production cost,

(b) long life under severe conditions,

(c) easy maintenance with simple tools and unskilled labor,

(d) suitable for shallow- or deep-well applications,

(e) manufacture in developing countries,

(f) easily operated by small people, including women and children, and

(g) able to discourage pilfering and vandalism.

With these objectives, a pump--shown schematically in Figure 3.12--was developed which had a strong cast-iron cylinder, stand, and handle. In an effort to eliminate poor-wearing leather seals, several synthetic materials were suggested as good substitutes, e.g. nylon, Corfam, Rek-Syn, etc. However, an effort was also made to allow the standard design to be adaptable to locally manufactured parts if imported, commercial materials were unavailable. Pumps of several different component materials were tested with up to the equivalent of 10 years of hard use and the various

materials evaluated for performance and wear--see Fannon and Frink (1970). No costs were available on this "AID pump", however, the above report lists many agencies and businesses which are cooperating in its manufacture.

3.2.4 Diaphragm Pumps

Diaphragm pumps are often considered another form of the piston pump since many designs utilize a piston as an operational component. However, because bellows pumps are also a diaphragm device, this subclass is appropriately considered apart from piston pumps. The major feature of diaphragm pumps is that the reciprocating piston has been replaced by a pulsating, flexible membrane which operates in basically one of three ways.

In bellows devices, the diaphragm comprises a portion of a chamber which can thus expand and contract. The expanding bellows draws water in past an inlet check-valve just as the retracting piston or plunger does. Then, as the bellows in contacted, the water is forced through an outlet check-valve.

This principle, combined with foot-operation (an idea originally used by ancient blacksmiths for venting forges--Rouse and Ince, 1963) has been developed into a low-cost, low-lift pump by the International Rice Research Institute (IRRI) under a contract with AID. As seen in Figure 3.15, the bellows in this "foot pump" are made of canvas with metal reinforcing inserts and a wooden frame. The operator stands on the two foot rests above the bellows and shifts his weight from one foot to the other. This alternately expands and contracts each bellows and thus lifts water.

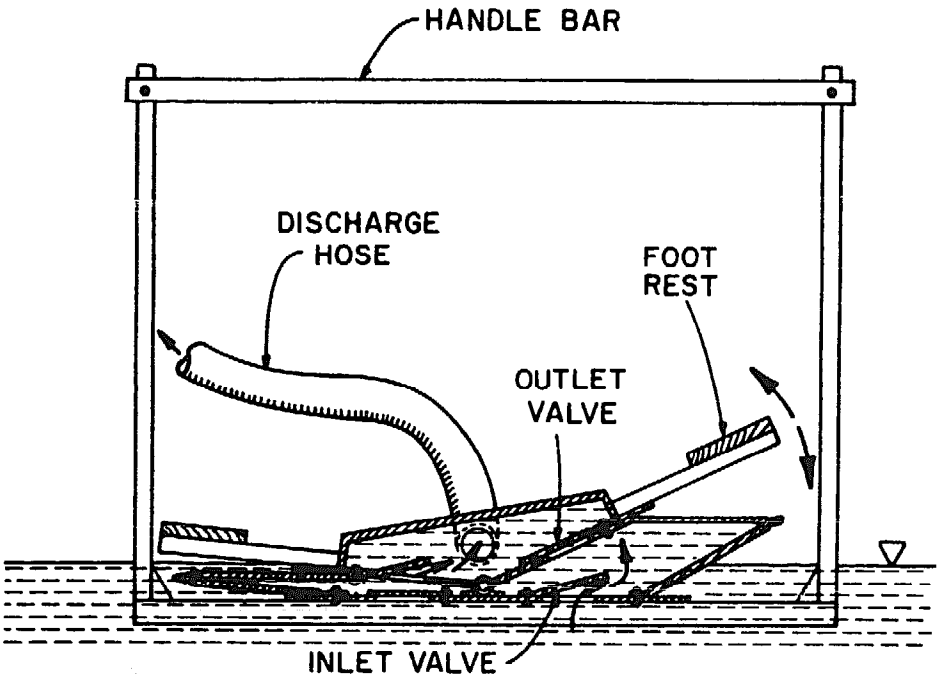

Fig. 3.15 Foot-operated bellows pump
(Courtesy of IRRI)

The IRRI design has a handle bar which serves as both a support while pumping and a handle for carrying the 45 lb pump. It is easy to repair and simple enough for small machine shops to construct. Design drawings are given free of cost to manufacturers who agree to IRRI conditions. Although this design is expected to be rugged for a long service life, additional work is being done to improve its present durability (Kuether, 1975). No cost estimates were available and normal maintenance consists of canvas repair after about 175 hours of use. The performance of this pump is reported (IRRI, 1975) as:

40 gpm at 1.6 ft head

32 gpm at 3.3 ft head

29 gpm at 5.0 ft head

This, of course, will vary depending on the operator.

The second form of diaphragm pumps is similar in operation to the piston pump, however, as shown in Figure 3.16, the diaphragm is attached to both the piston and the cylinder. This has the advantage of removing the sliding friction between piston and cylinder wall. In addition, since the piston only serves to reciprocate the diaphragm, abrasive fluids, e.g. sandy water, can be pumped without wearing the piston and cylinder walls. The common forms of diaphragm-piston pumps are operated in either of two ways. The piston can be reciprocated by a mechanical driver (e.g. gas or diesel engine), or for smaller capacities by hand or foot level mechanisms (Figure 3.30). The other method, is to utilize compressed air or hydraulic pressure on one side of the diaphragm to push it down and then allow a spring loaded piston to pull it up. The pneumatic or hydraulic pressure is automatically regulated to provide the reciprocating motion (e.g. by a solenoid valve and regulator).

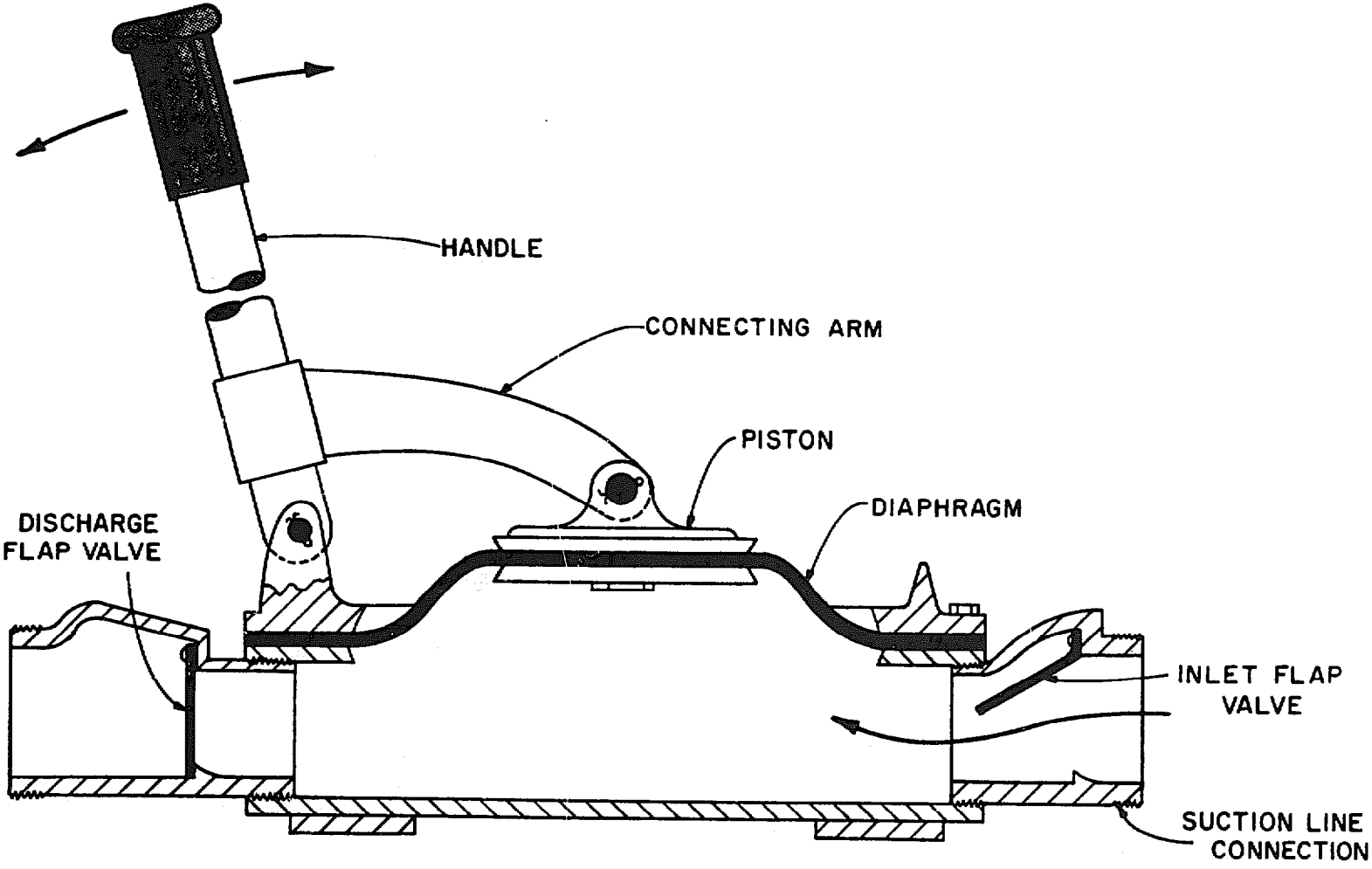

Figure 3.16 Diaphragm pump with handle-lever for manual operation

The third method of diaphragm pump operation is similar to the hydraulic-driven device mentioned above. The only difference is that the piston is not attached to the diaphragm, but instead is utilized as a type of secondary pump above the diaphragm. The piston alternately forces the "working fluid" in and out of the cylinder, pulsating the diaphragm, which in turn pumps another fluid. This method has the advantage of providing even pressures across the diaphragm membrane as opposed to mechanical stroking which produces nonuniform stresses with stretching or fatigue near the piston (Pumping Manual, 1964). This type of diaphragm pump is usually confined to small-discharge, industrial uses, however, it is mentioned to illustrate the use of secondary, working fluids.

As with power pumps, capacity regulation of diaphragm pumps is normally accomplished by varying the driver speed.

3.3 Rotary Methods

The devices in this subclass increase head by displacing (positively) water in a rotary motion. They should not be confused with rotodynamic pumps which also use a rotary motion (see Section 4.2), but utilize primarily high-speed, kinetic energy to increase head. Rotary devices, however, can operate even at very slow speeds and still increase head. As will readily be seen in several of the early devices, (e.g., noria, paddle-wheel), rotary water lifters "trap" the water and push it from one elevation (or head) to a higher one. Although, like reciprocating devices they displace isolated units of water, rotary methods normally discharge a more continuous flow (i.e., at a given speed) because several water pushing components (e.g., blades, buckets, pistons) rotate one behind another.

3.3.1 Wheel

After many of the early reciprocating devices were developed, it was eventually discovered that by mounting several of them on a wheel, a more continuous flow could be obtained, i.e., less time waiting to return the one (or two) lifter(s) back to the water supply. The first device to be discussed is a good example of this development.

3.3.1.1 Paddle-Wheel

This wheel type device utilizes the basic idea of lifting water by scooping it, just as was done with the water balance (Figure 3.11). However, instead on one scoop or paddle moving back and forth, several paddles are attached to the periphery of a wheel and by rotating the wheel, each paddle pushes a unit of water up a channel.

A typical small-capacity, paddle-wheel is shown in Figure 3.17, operating with manual power. In this example, the operator "pedals" the tips of the paddles, however in other versions, the axis of the wheel is attached to a shaft which can then be turned (often via gearing) by some other prime mover, e.g., a windmill, an animal-powered circular sweep, etc. The device shown in Figure 3.17 has widespread use in low lift applications such as rice paddies. In order to minimize losses, a wooden channel is usually provided for the paddle-wheel to rotate inside of. With such a channel, Molenaar (1956) reports the performance of various size paddle-wheels as given in Table 3.2.

Paddle-wheels are also commonly referred to as paddle-pumps, chackrams (India), kharbauwys, flash-wheels, and scoop-wheels, however, the latter two names usually infer large wheels of the size and design used with high-power, mechanical drivers. Such scoop-wheels were used extensively in low-lying areas, such as Holland, around the turn of the 20th century.

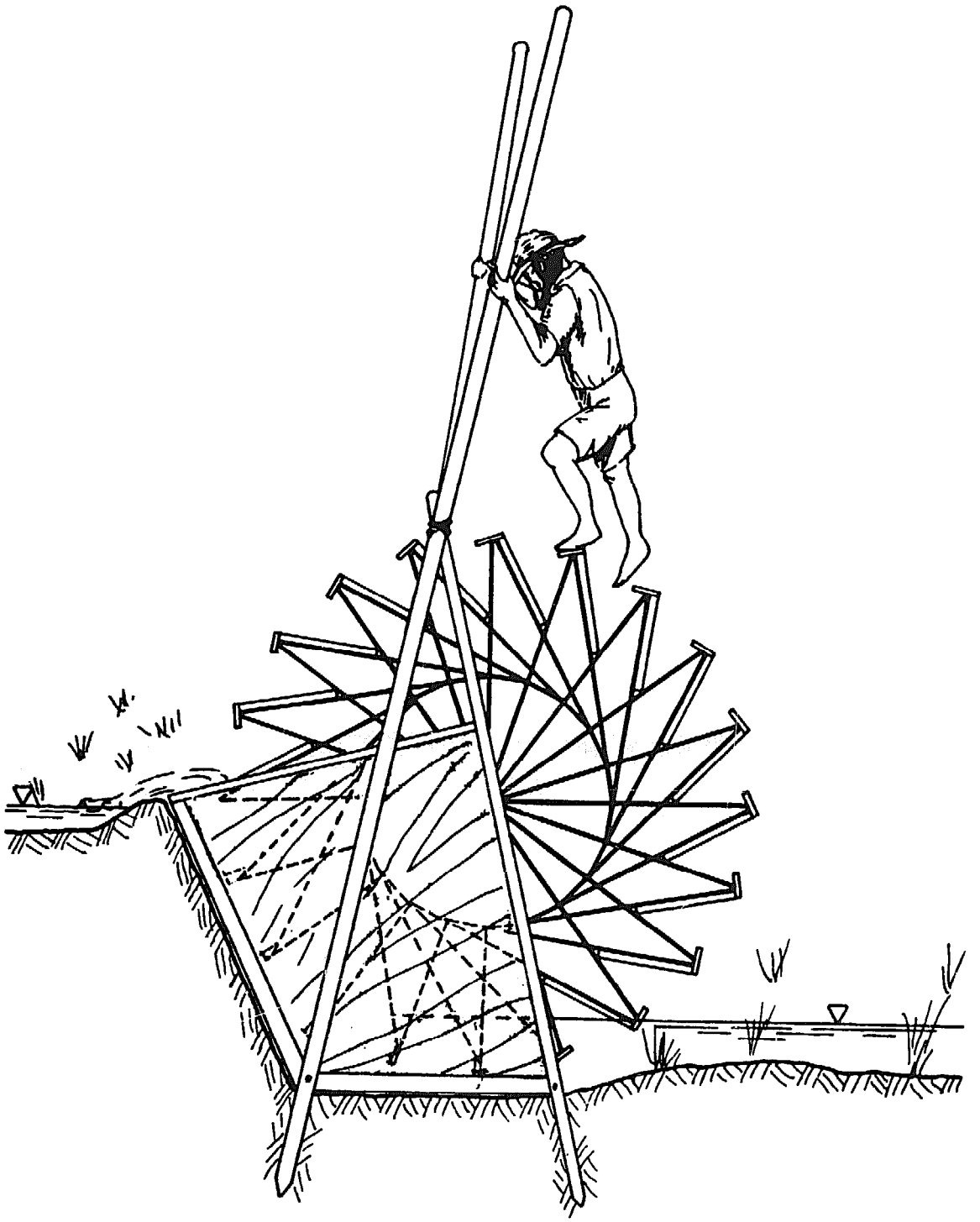

Figure 3.17 Paddle-wheel operated as treadmill

Table 3.2 Manually-operated paddle-wheel performance

Wheel diameter (ft)	Number of paddles	Man Power required for 1-hr. operation	Height lifted (ft)	Discharge (cfs)	Discharge (cfh)
4	8	1-2	0.5-1.5	0.12	443
8	12	6-8	1.0-2.0	0.18	664
10	16	8-12	1.5-2.5	0.31	1106
12	24	12-16	2.0-3.0	0.50	1770

Although windmills originally drove these large scoop-wheels (Starling, 1892), steam engines were later utilized as lifts up to 8 ft and discharges of 250 cfs per wheel (at 2.0 ft heads) increased the power demand (Slichter, 1910).

3.3.1.2 Water Ladder

The water ladder is another rotary scooping device which is also referred to in various forms as:

rahad (Thai)
dragon wheel (China)
chain pump
link-belt box elevator
paddle pump

It consists of an inclined trough and a chain of paddles which is pulled through it by a sprocket at the upper end--see Figure 3.18. The entire device can be made of wood, which allows for construction in developing areas and ease of maintenance. The driving sprocket is attached to a shaft which can be driven by several prime movers. Older designs used the same direct pedaling power as the paddle-wheel (3.3.1.1) or animal-power via a circular-sweep and gearing (Schioler, 1975). Later designs incorporate windmills and small internal combustion engines. Using a small

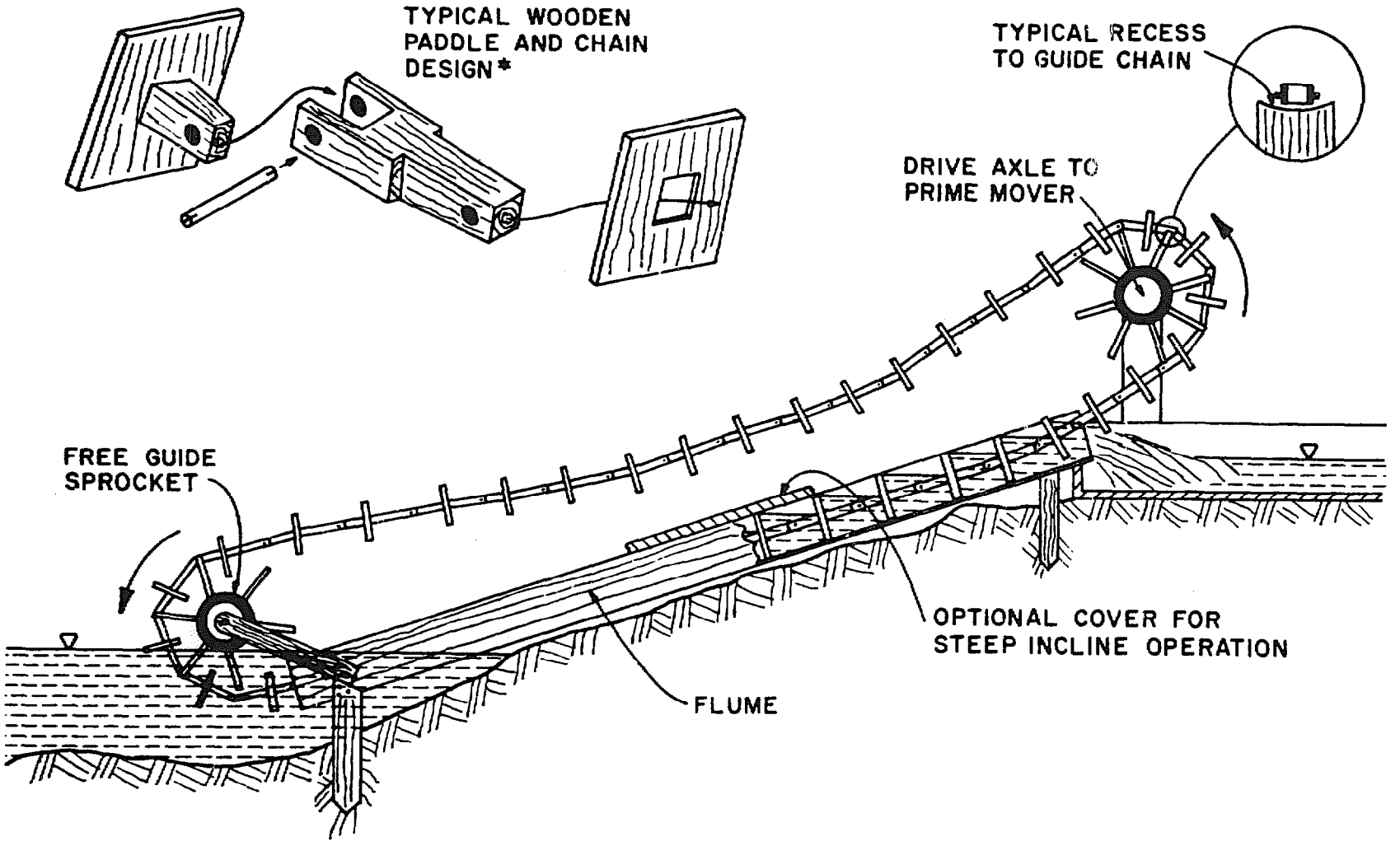

Figure 3.18 Water ladder with open flume (Note: enclosed-flume water ladder is essentially a "chain pump.") (After Schioler, 1975)

engine (2-3 hp) as the prime mover, performance testing was done by Subin Pinkayan at the SEATO Graduate School of Engineering (Bangkok) on a water ladder similar to those used throughout much of Asia. This pump, with a 2-3 hp engine driver, delivered about 0.8 cfs at a 3 ft head. Molenaar (1956) reported that a water ladder powered by 4 men could lift 0.23 cfs 3 ft. The water ladder, as tested by Pinkayan, is normally limited to 3 ft lifts and for operation by two men (i.e., with foot treadle) would cost about $35-$40 (Molenaar, 1956).

3.3.1.3 Chain Pump

The chain pump is very similar in design and operation to the water ladder. In fact, the names are often used interchangeably. Additional names for this device include:

chain-disc pump	Liberation waterwheel (China)
pater-noster pump	chaplet pump

In essence, the chain pump is a water ladder with an enclosed trough which allows its use on steep inclines or vertically, as in Figure 3.19. This enclosed trough eliminates the spacing/depth ratio limit on the capacity of water ladder paddles, i.e., except for leakage losses, the entire space between paddles or discs can be filled with water.

A length of circular pipe commonly serves as the enclosed trough, while the circular discs pulled through it are often fitted with rubber or leather perimeter rings to reduce leakage between discs and the pipe. As in the water ladder, a driving sprocket or notched wheel engages the endless chain at the upper level to pull it around. In vertical installations such as Figure 3.37, the chain is long enough to allow it to hang free below the pipe bottom. This lower pipe end is usually flared to facilitate entry of the discs into the pipe.

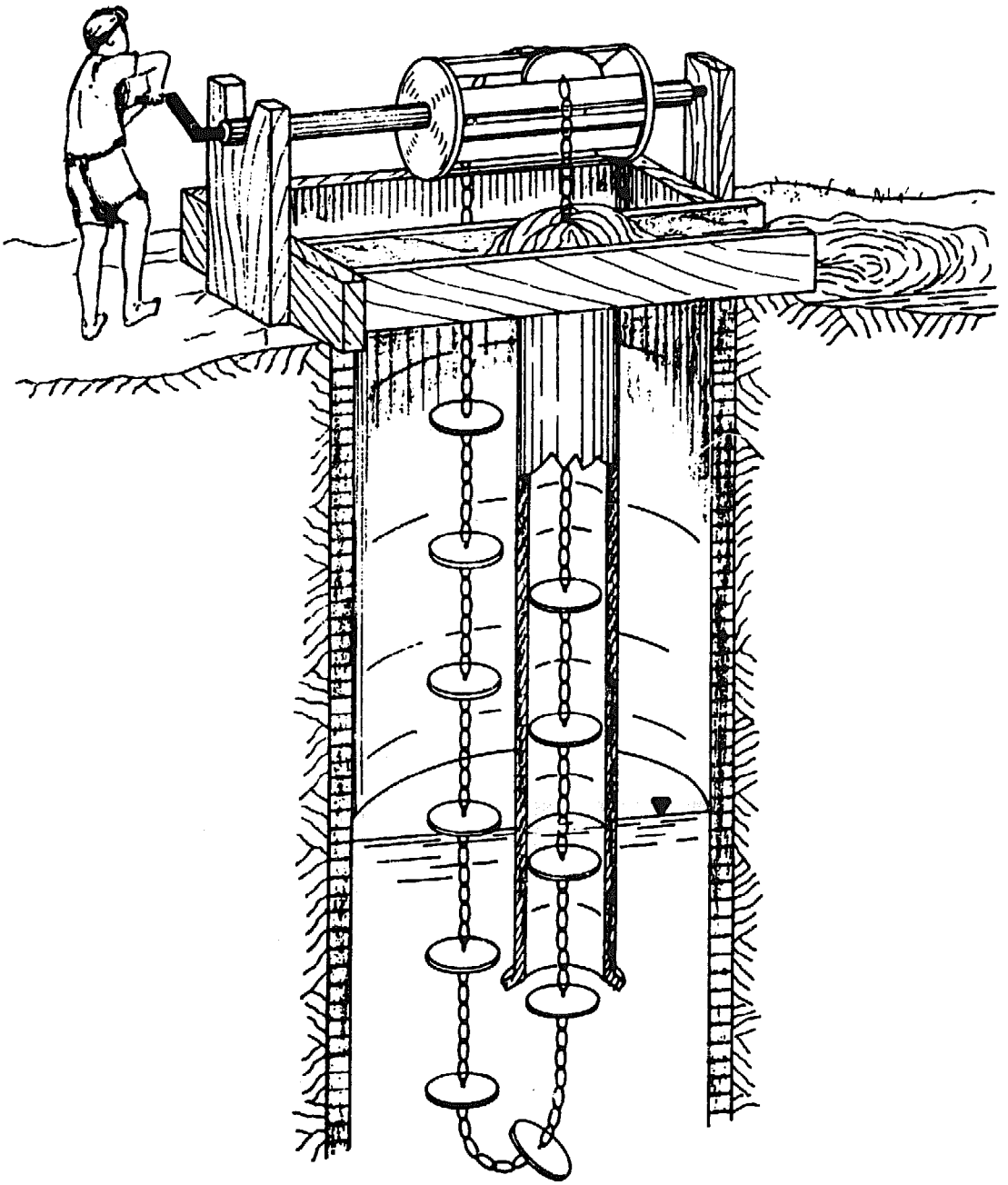

Figure 3.19 Chain pump with manual windlass

Table 3.3 records some of the performance data available on the chain pump.

Table 3.3 Chain pump performance

Lift (ft)	Discharge (cfh)	Reference	Remarks
20	40	Molenaar, 1956	4 men, 4 in. pipe
10	72	Molenaar, 1956	4 men 4 in. pipe
5	110	Molenaar, 1956	4 men 4 in. pipe
20	330	Roberts and Singh, 1951	4 in. pipe, ? hp
240	("low lift")	Framji and Mahajan, 1969	3 in. pipe, ? hp

3.3.1.4 Persian Wheel

Probably one of the most extensively used water lifters, particularly with animal power, is the Persian wheel. In some areas, the term "Persian wheel" refers to any water lifting wheel device which is animal powered. However, as most commonly used, the Perisan wheel is a variation of the chain pump--another name to which it is also referred. It consists of a series of containers (e.g., buckets, pots, bags) attached to two parallel loops of rope or chain which pass over a driving wheel, as in Figure 3.20. As the buckets pass over the open-rim wheel, they empty into a trough below it and then return down to the water supply for refilling. Many combinations of gears and shafts are in use to connect the wheel to the driver.

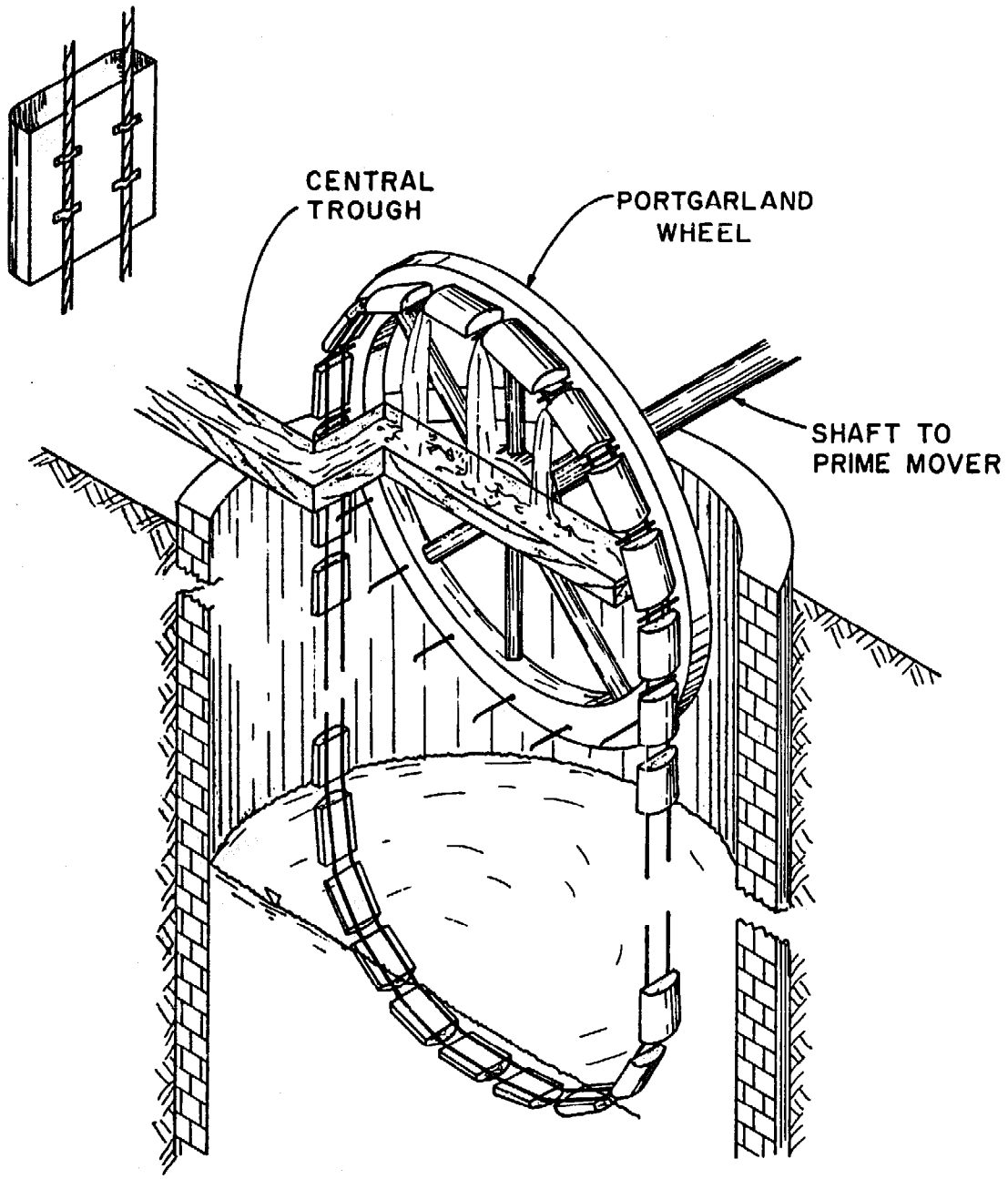

Figure 3.20 Persian wheel with portgarland drive wheel and horizontal drive shaft

Several names which are also applied to the Persian wheel are:

chain-bucket pump	chain-of-pots
bucket wheel	paternoster wheel
Egyptian sakia	rahat (Pakistan)
Egyptian noria	scoop wheel

Other names which refer to specific variations of this device are taboot, when bags are used instead of buckets, and potgarland, when a wheel with horizontal "carrier-pegs" drives the bucket loop (as in Figure 3.20). Until about 70 years ago, the name sakia was also used for the Persian wheel but is now applied to the tympanum (see Section 3.3.1.6).

By lengthening the chain of buckets, this device can lift water from great depths. Two Persian wheels in series (i.e., one below the other) were the lifting mechanism for Joseph's Well (see Section 1.2) which was approximately 300 ft deep. They are usually constructed entirely of wood, except for the containers, however modern versions have begun to use more metal parts. Roberts and Singh (1951) report that Persian wheels with metal gears, bearings, etc. are about 28 percent more efficient than with wooden components. Ball bearings in axles can also improve efficiency and are almost mandatory when engines or electric motors are supplying the power. Schioler (1973) reports the efficiency of a wooden Persian wheel with metal bearing surfaces to be about 60 percent. Table 3.4 lists available performance data on some typical wooden Persian wheels.

The cost of constructing a Persian wheel comprised primarily of wood, with some metal fasteners and wearing surfaces, could be expected to be about $60. (This cost estimate reflects the use of inexpensive labor and materials in developing countries.) Thorkild Schioler's Roman and

Table 3.4 Persian wheel performance

Lift (ft)	Discharge (cfh)	Reference	Remarks
30	325	Molenaar, 1956	? hp some metal parts
20	395	Molenaar, 1956	? hp some metal parts
10	580	Molenaar, 1956	? hp some metal parts
5	760	Molenaar, 1956	? hp some metal parts
25	510	Roberts and Singh, 1951	2 bullocks metal bearings

Islamic Water-Lifting Wheels (1973) gives some excellent details of the construction of Persian wheels and other wheel devices, e.g., gears, bearings, fasteners, etc.

A modified version of the Persian wheel is the zawafa or Egyptian jhallar. Most zawafas today are constructed entirely of metal, although original designs were wooden. Rather than each bucket dumping water into the same central trough within the driving wheel diameter, troughs between the spokes of the driving wheel receive the dumped water and channel it to a common trough alongside the wheel. In this way a stronger, double-rim wheel can be utilized for deep, heavy lifts or where all metal construction is used, and the water need not be lifted much above the desired upper water elevation. Table 3.5 gives some typical performance data of metal zawafas.

Table 3.5 Zawafa performance

Lift (ft)	Discharge (cfh)	Reference	Remarks
6.5	1300	Molenaar, 1956	1 animal
13.0	850	Molenaar, 1956	1 animal
20.0	425	Molenaar, 1956	1 animal
20	2000	Wilson, 1896	4 horses
2.5	5400	Roberts and Singh, 1951	Eff = 76%

The cost of metal zawafas varies greatly with the prices of metals in various geographic areas, however by adjusting the costs given by Roberts and Singh (1951), in a developing country initial costs will probably range from $120-$600.

3.3.1.5 Noria

Another wheel-type water lifter is the noria which has containers (e.g., buckets, pots, etc.) fixed to a driven wheel. Since the containers do not loop below the wheel, as in the Persian wheel, the noria wheel must have a diameter slightly larger than the total static head. There are a large variety of noria designs and installations and it is probably for this reason that almost no performance or cost data is available on this device.

Although norias can be driven by almost any type of prime mover, the name "noria" has often been used when referring specifically to wheels that are driven by water. Such water-driven norias have paddles which are pushed by the swift flow of a water force , e.g., Figure 3.21. Of course, the power supplied to the paddles must be sufficient to lift the water and overcome friction. Therefore, the size (and weight) of the

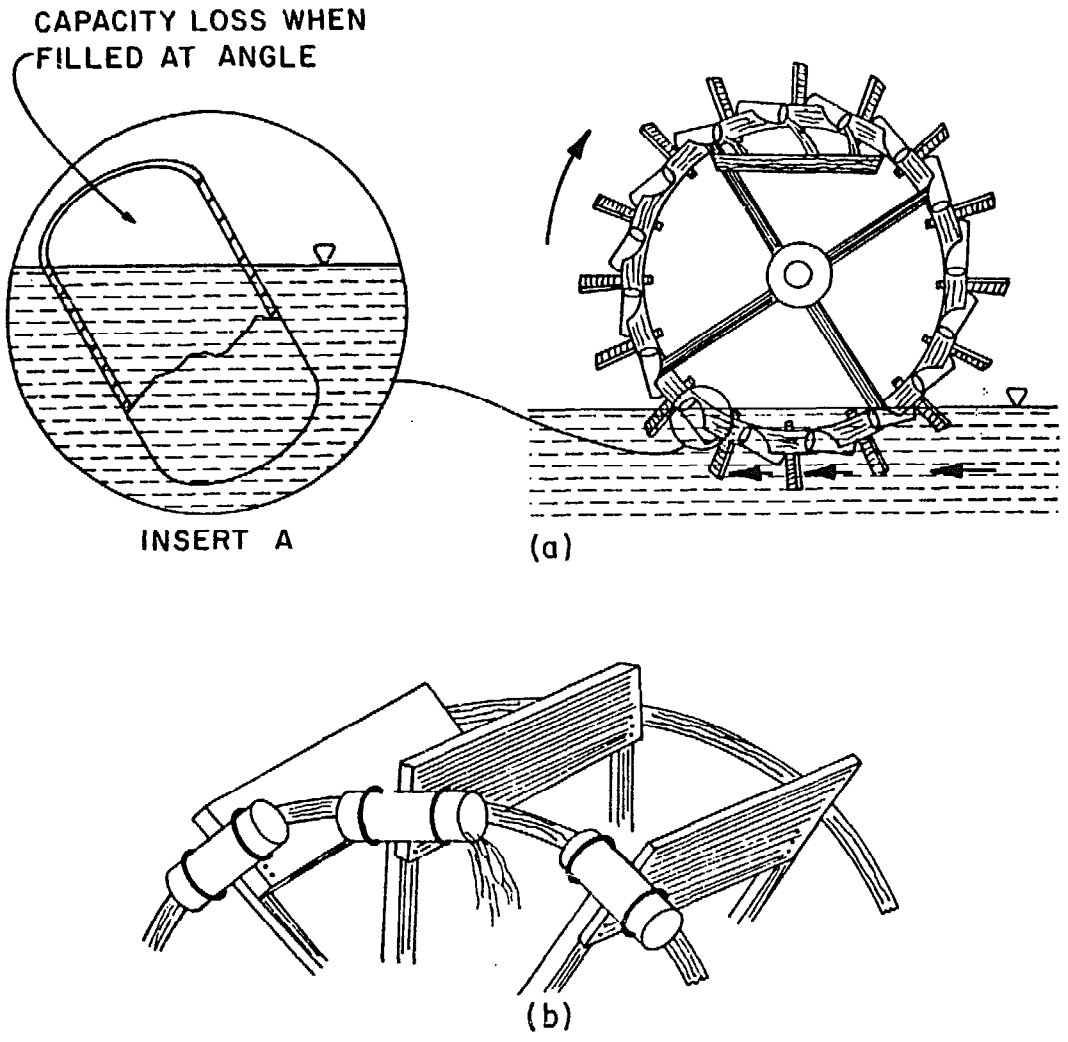

Figure 3.21 Noria; (a) with fixed buckets, driven by current, (b) with larger paddles,

noria and the discharge and head it must supply need to be matched to the available water source is velocity and the paddle surface area. If for instance, the small paddles in Figure 3.21a do not afford enough surface area to receive the necessary momentum of the water flow, then the size of the paddles may have to be increased--possibly utilizing a design more like Figure 3.21b. Two alternatives to increasing paddle size (which increases weight and therefore friction) are; (a) increase the water supply's velocity by decreasing its channels's cross-sectional area as was done with the sluice gate and narrowed channel for the paddle-wheel (see Section 3.3.1.1.), or (b) supply a fall (i.e., head) for the water source so that it can power the noria as an undershot wheel (see Section 5.1). Of course, a separate driving wheel (i.e., water mill) can be placed apart from the noria (e.g., in a swifter width of the river) and connected to it by a horizontal shaft, as would be done for other types of drivers, e.g., Figure 3.22.

A few other common modifications to the noria which are utilized to improve efficiency and/or adapt it to a given installation include:

(a) Use of deep, small diameter containers as in Figure 3.2.a to decrease spillage.

(b) Use of movable buckets, e.g., Figure 3.21c, to allow complete filling (i.e., as opposed to fixed containers which fill at an incline--see Figure 3.21a, Insert A) and prevent emptying until the bucket reaches the upper level trough.

(c) An enclosed noria with compartments built into it and appropriate inlets and outlets utilizes practically the entire wheel circumference and width for increased capacity, e.g., Figure 3.22. The

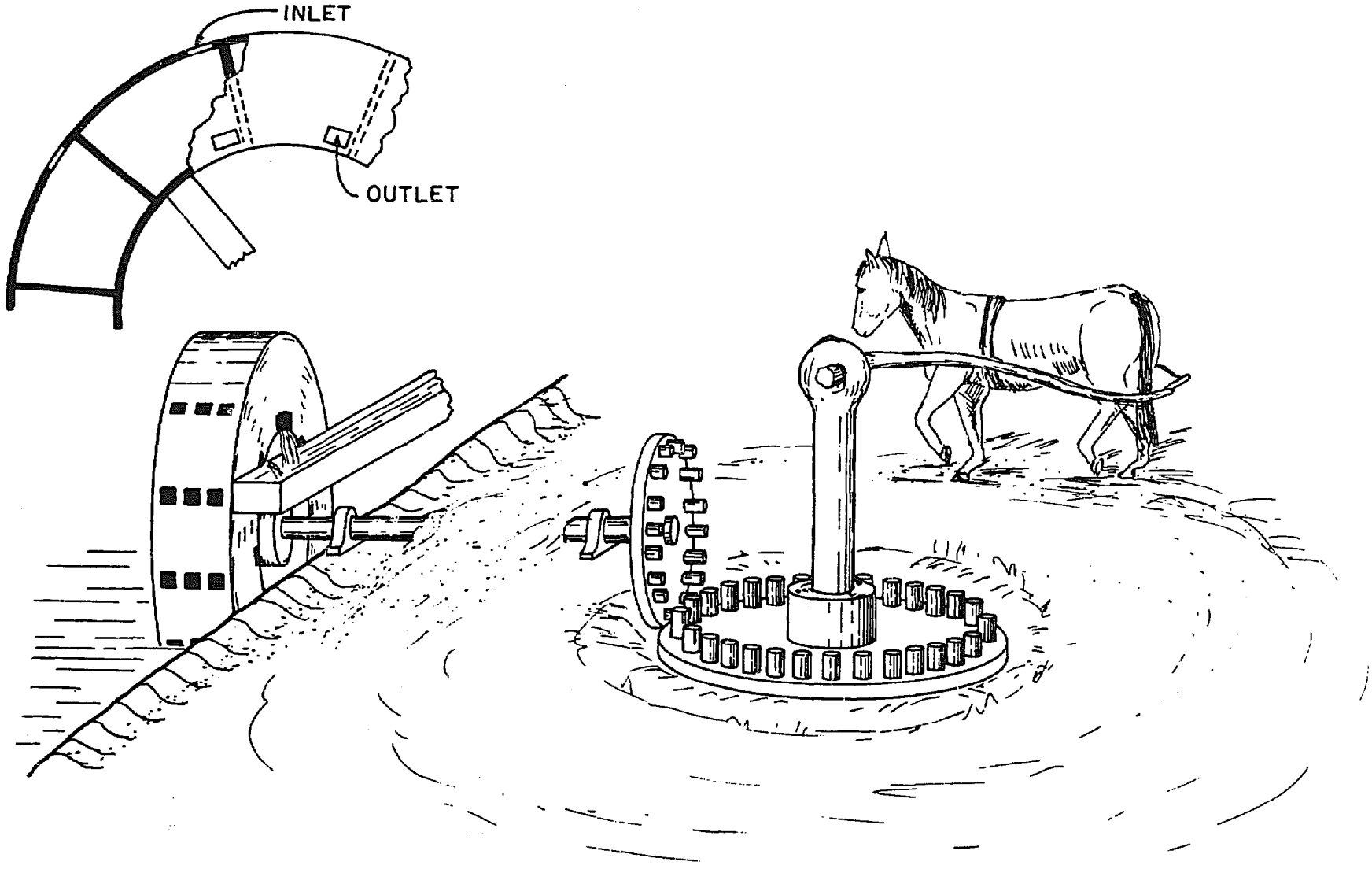

Figure 3.22 Noria with enclosed compartments driven via long shaft and pinion gears by animal

enclosed circumference can also be utilized as a treadmill so that manual power can be directly applied without the use of gears, shafts, etc.

Several other names have been found in use for the noria such as:

scoop-wheel	waterwheel elevator (Algeria)
bucket-wheel	Persian wheel
sakia (Egypt)	tanbusa
dawlab (Persian)	tabliyya
	tulunba

3.3.1.6 Tympanum

The tympanum is a wheel device which consists of several individual, enclosed compartments, similar to the enclosed noria of Figure 3.23. However, in tympanums, each compartment has an inlet on the wheel circumference and an outlet adjacent to the wheel hub. Therefore, it is not necessary to lift the water above the required elevation. Of course, for the same head, a larger diameter tympanum-wheel is needed than noria-wheel, i.e., the tympanum diameter must be slightly more than twice the head. Due to this size requirement, tympanums are usually limited to lifts of less than 10 ft.

Several other names which are applied to this device include:

sakia (Egypt)	taboot
sagia	tanabish (Egypt)
sagiya	drum-wheel
sakiyeh	waterwheel
tablia	spiral wheel
	scoop-wheel

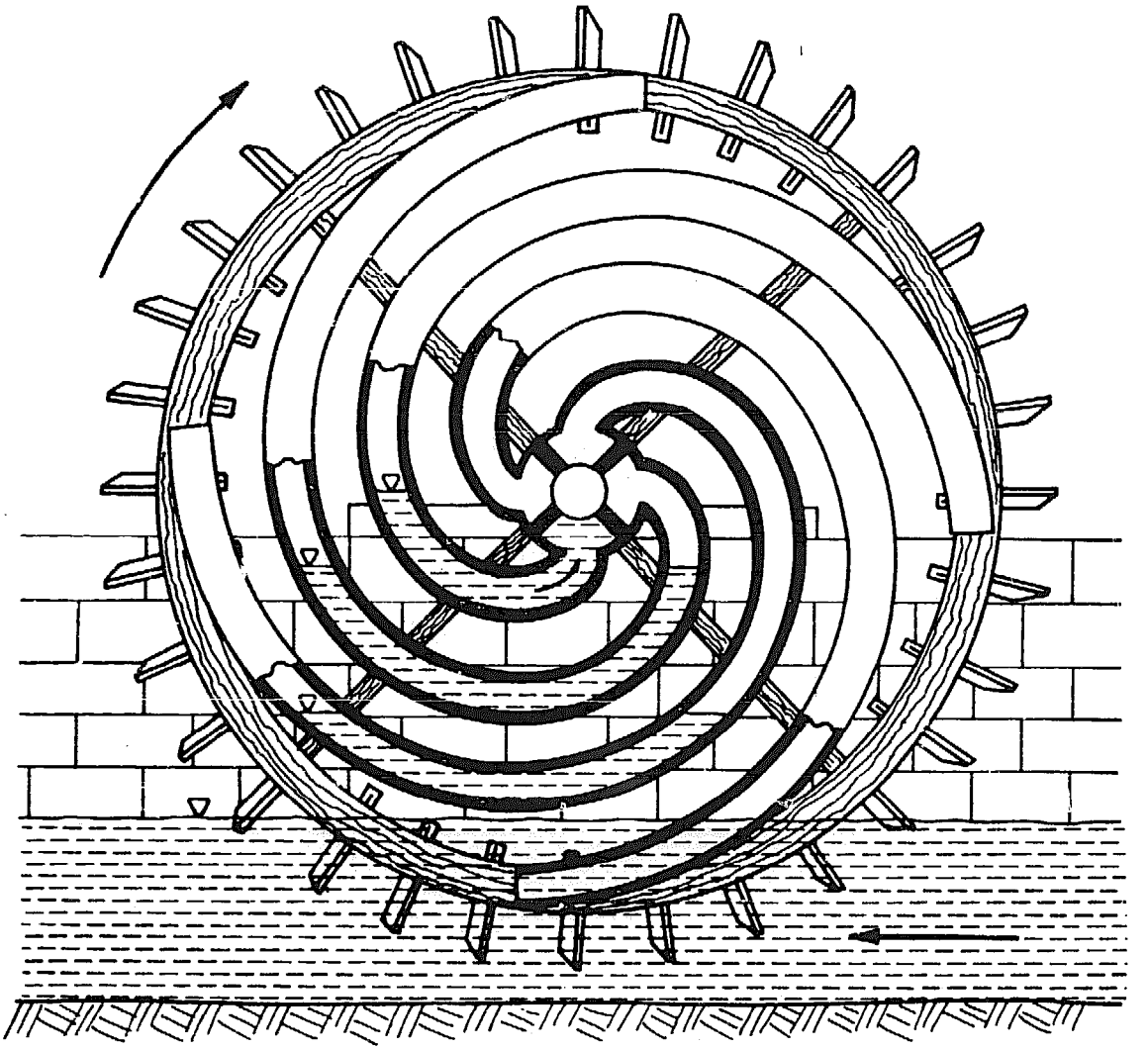

Figure 3.23 Tympanum with spiral troughs equipped with paddles to be current-driven

Most early tympanums were of the easy-to-construct design labeled HRES-D_2 in Figure 3.24. However, early in the 17th century, La Faye noted that this design kept the water at the periphery of the compartment. The water exerted the maximum resisting moment about the axle due to the pull of gravity on the water. This would obviously require more input power to overcome. Therefore, La Faye suggested the spiral-wheel design in Figure 3.33 which kept the water almost vertically in line, beneath the axle and thus created a smaller moment arm (Ewbank, 1876). Several other designs, such as the logarithmic and Archimede's spiral curve (Figure 3.24) are also widely used today.

Recognizing that compartment shape effects the performance of a tympanum, the Hydraulic Research and Experiment Station (HRES) of the United Arab Republic's Ministry of Irrigation conducted a program for testing various designs. Using 6 x 75 cm plastic models of the shapes in Figure 3.24, they determined that the D_2 design was capable of higher discharges at a given head then the others and that its simple, "straight-line" design afforded easy construction by users in developing countries. They also found that utilizing individual outlet compartments, such as are shown in the D_1 , D_2 , and Fathi designs in Figure 3.24, improve the efficiency of a tympanum by preventing discharge from one compartment leaking back into the compartment(s) below it. This separation of discharges can also be accomplished by having the discharge outlets in the sidewalls, as in the enclosed noria. The term tablia is used to specify this type of tympanum.

Tympanums, are commonly constructed of galvanized sheet metal and utilize second-hand roller bearings in the axle. Typical performances of such tympanums are given in Table 3.6. No data is available on construction costs of tympanum devices.

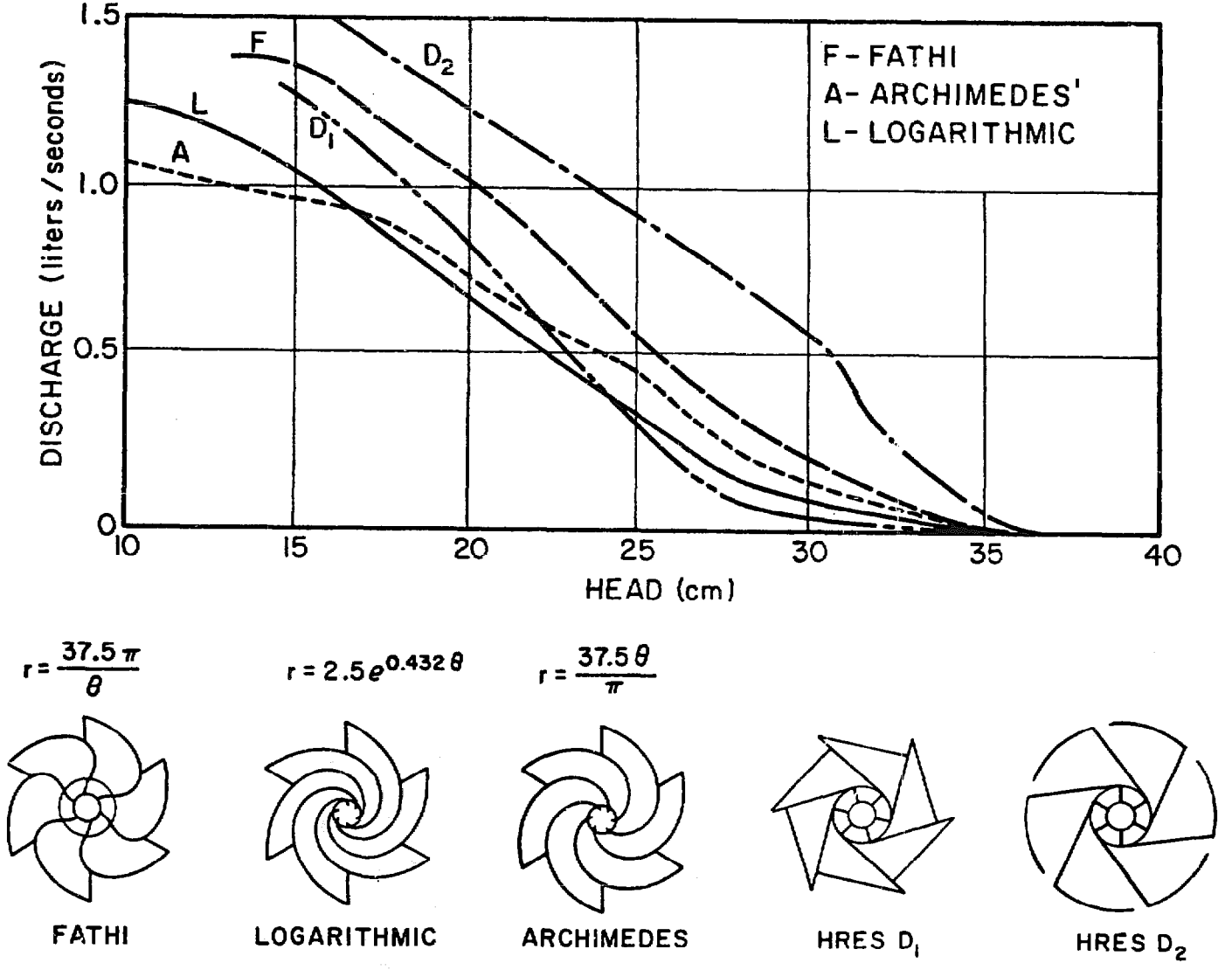

Figure 3.24 Comparison of various tympanum designs (HRES, 1965)

Table 3.6 Tympanum performance

Diameter (ft)	Lift (ft)	Discharge (cfh)	Remarks	Reference
16.4	5.9	1274	1 animal	Molenaar, 1956
13.1	4.3	1805	1 animal	Molenaar, 1956
9.8	3.0	2655	1 animal	Molenaar, 1956
6.6	1.0	4036	1 animal	Molenaar, 1956
9.8	4.9	708	1 animal; tablia	Molenaar, 1956
13.2	8.2	425	1 animal; tablia	Molenaar, 1956

3.3.2 Screw

The basic screw or auger is merely an incline surface rotating around a central axis and when used as a water lift, it in effect pushes the water up the incline-- see Weisback and Herrmann, 1897.

One of the earliest designs for a water-lifting screw utilized a flexible tube wrapped around and secured to an inclined axle, as in Figure 3.25a. This design if often referred to as a water snail, Egyptian screw, or cochleon, however it is rarely used today. Instead, the commonly referred to Archimedean screw, which has been in use for centuries (see Section 1.2), is the more popular screw-device presently in use. Several other names are applied to this water lifter:

screw pump	Roman-screw
water-screw	screw mill
	tambour

As illustrated in Figure 3.25b, this device can be easily constructed primarily of wood with a few basic tools. This type construction is

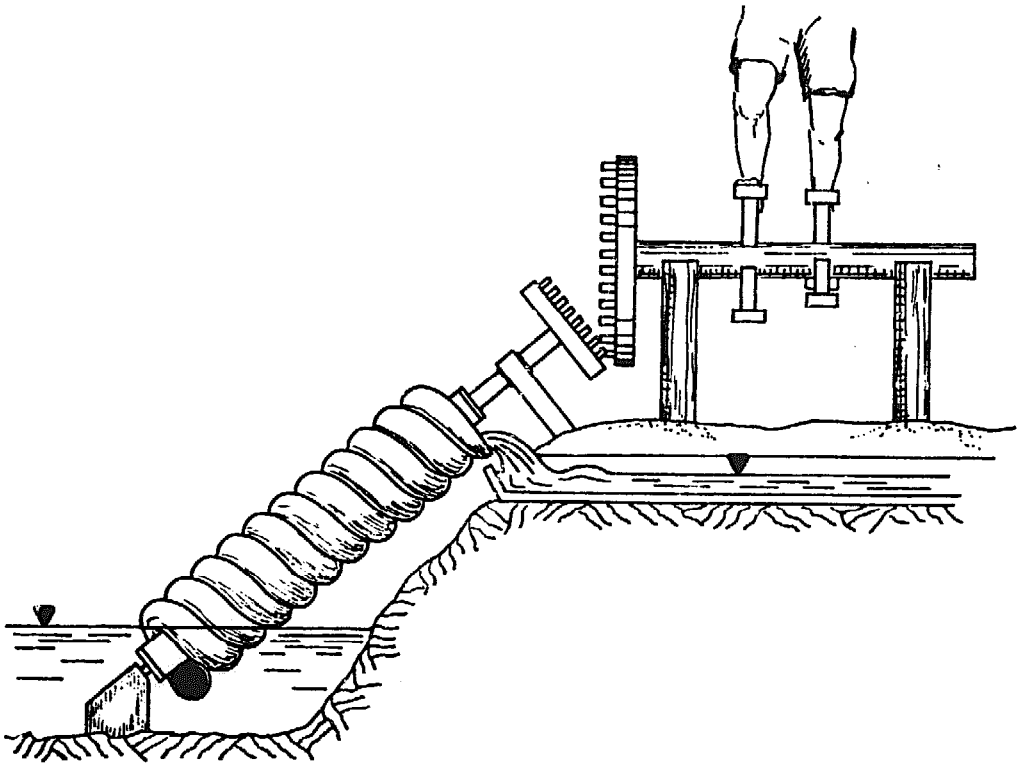

(a)

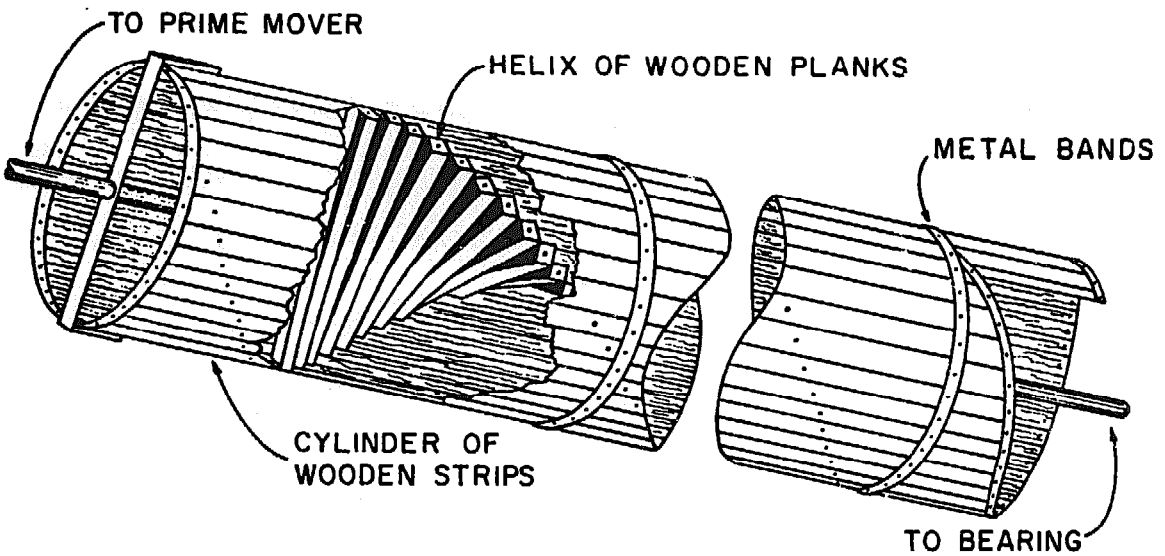

(b)

Figure 3.25 (a) Pedal-power water-snail, and (b) construction of simple, wooden Archimede's screw

sufficiently compact and lightweight so as to allow it to be easily transported, e.g., on the back of an animal such as a donkey-- see Molenaar (1956). A crew of this basic construction, with necessary bearings and handle for manual crank-operation, would cost about $20-$35, depending on available materials (Molenaar, 1956). Typical performances of such devices are listed in Table 3.7, part A.

A variation of this basic wooden design utilizes instead a metal auger which turns inside an outer metal cylinder, as in Figure 2.3. Such

Table 3.7 Screw performance

Lift (ft)	Discharge (gpm)	Power	Remarks	Reference
A.)				
1.6	65	1 man	6 x 1.3 ft	Molenaar, 1956
2.5	65	2 men	8.3 x 1.3 ft	Molenaar, 1956
1.6	100	2 men	6.7 x 1.6 ft	Molenaar, 1956
0.8	130	2 men	5 x 1.8 ft	Molenaar, 1956
B.)				
-	30	engine; 0.75 hp	4 in. diameter; @ 1500 rpm	Rider, 1966
-	65	engine; 1.1 hp	4 in. diameter; @ 1900 rpm	Rider, 1966
10	30	engine	4 in. diameter; @ 2000 rpm; at 90° to horizontal	Rider, 1966
7	75	engine	4 in. diameter; @ 2000 rpm; at 45° to horizontal	Rider, 1966
6	325	engine; 4 hp	6 in. diameter; @ 1350 rpm	Rider, 1966

auger pumps can be produced by light industry in developing countries. In Thailand, such a device, called a "Debbharid," is produced by some 25 factories at the rate of 47,000 per year (Kishida, 1971).

3.3.3 Rotor

Another subclass of rotary water lifters are those which employ a high speed rotor within a fixed casing (or stator) and are commonly called rotary pumps. A wide variety of rotor designs and combinations have been developed. All rotary pumps operate in basically the same manner--the rotor (or rotors) traps water between itself and the stator and then pushes it from the inlet to a higher head outlet. An interesting feature of rotary pumps is that they can pump in either direction, i.e., the suction or discharge line can be attached to either orifice, if, of course, the driver is connected appropriately. Although the discharge is separated into individual massess by the appendages of the rotor(s), the high speed operation of these pumps (normally 40-3600 rpm) presents an almost continuous flow of water. Like reciprocating pumps, rotary pumps maintain an almost constant Q for varying H, and because pressure is usually the major concern in their application, pressure (e.g., psi), rather than Q, is often the common abscissa.

Because rotary pumps must trap the water with relatively no leakage in order to be efficient, only very small clearances (0.001-0.002 in.) must be allowed between rotor and stator. Therefore, with only two exceptions, rotary pumps cannot handle abrasive fluids without excessive wear. They have been found to be used most advantageously in pumping high viscosity fluids at low Q and high H--however, they are not limited to those applications. Rotary pumps have been developed to handle upwards

of 3000 gpm or 5000 psig. Depending on such variables as material, size, and design, rotary pumps--such as some of the more common designs shown in Figure 3.48-- may range in price anywhere from $50 to $14,000 (Holland and Chapman, 1966).

The two rotary pumps which are capable of handling abrasive fluids are the single helical-screw and the flexible impeller designs. As shown in Figure 3.26, the helical rotor pump consists of a helical-shaped rotor which turns inside a molded rubber stator which has a similar inner shape. As the rotor turns, it traps water along the stator walls and "squeezes" it toward the discharge outlet. Helical pumps are commonly used in a horizontal position and close-coupled to an electric motor for pumping from shallow wells, i.e., they have NPSHR limitations just like any other pump. Deep-well helical pumps are capable of heads up to about 1000 ft. Between these two types of helical pumps, they cover a range of discharges from 5-75 gpm. Close-coupled units may vary in price from about $100 to $2000, including motor, while the vertical units will vary with horsepower, at a slightly lower rate than vertical turbine pumps (see Section 4.2.6).

The flexible-impeller or -rotor pump utilizes a flexible, paddle-wheel-like rotor to trap and lift water, as shown in Figure 3.27. Because of the flexible impeller, this pump--unlike most rotary pumps--can operate against a closed discharge without building up damaging pressures. However, since the flexible vanes stay in contact with the casing, high friction losses occur which lower efficiency. Also, at high pressures, these vanes tend to slip, creating leakage losses within the casing. Most flexible impeller pumps are in the $20 to $600 range. They can be made to handle from 0.5 to 100 gpm and with heads up to about 110 ft.

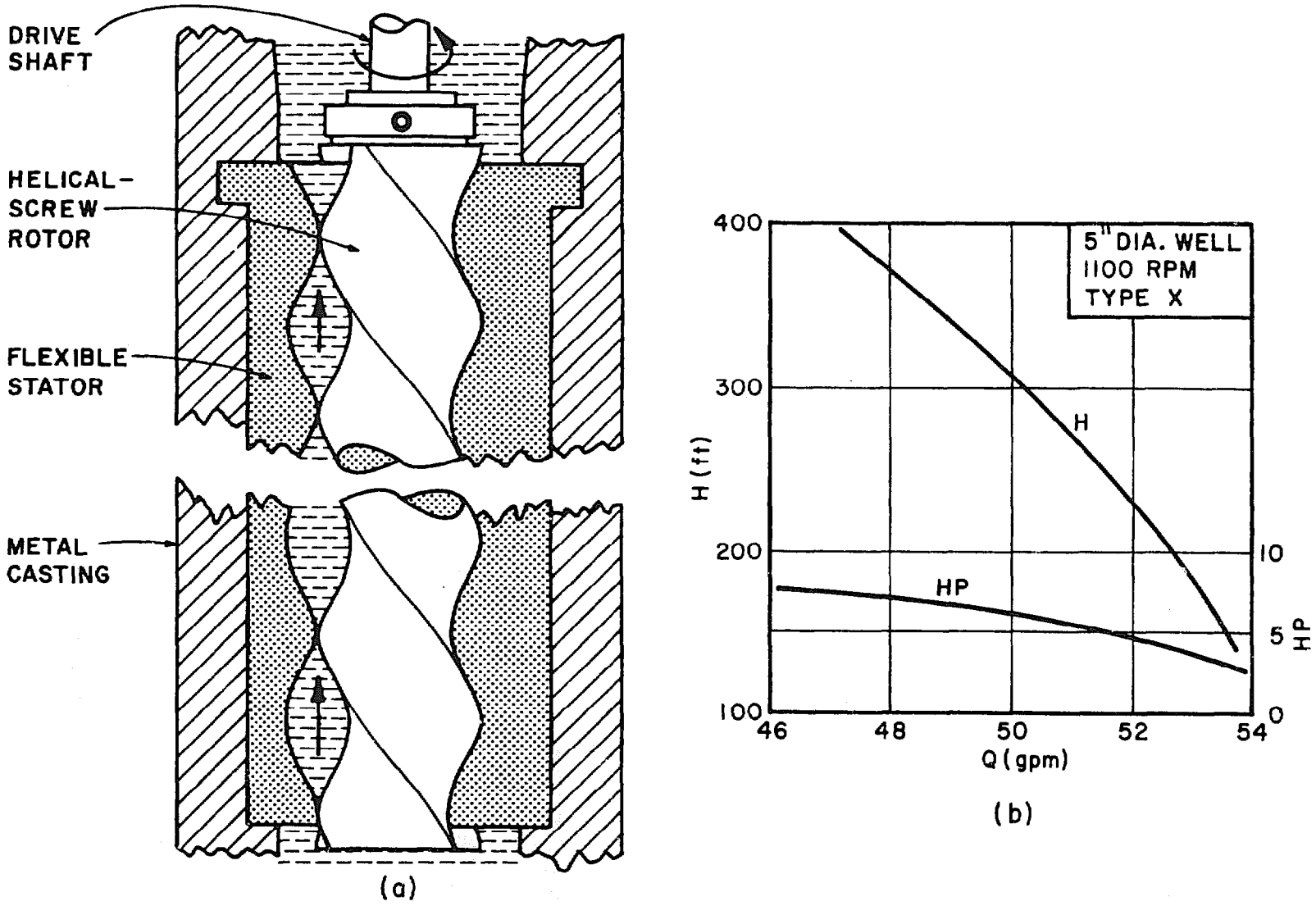

Figure 3.26 (a) Helical-screw rotary, and (b) typical performance curve of "vertical helical" pump

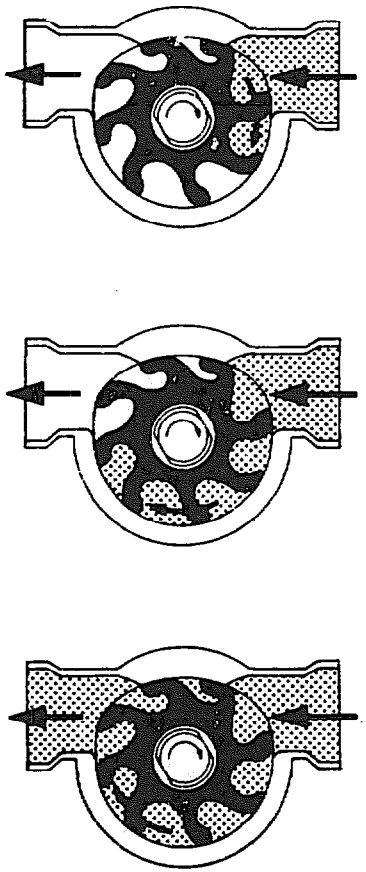

Figure 3.27 Operation of flexible-rotor pump (Courtesy of Jabsco Pumps)

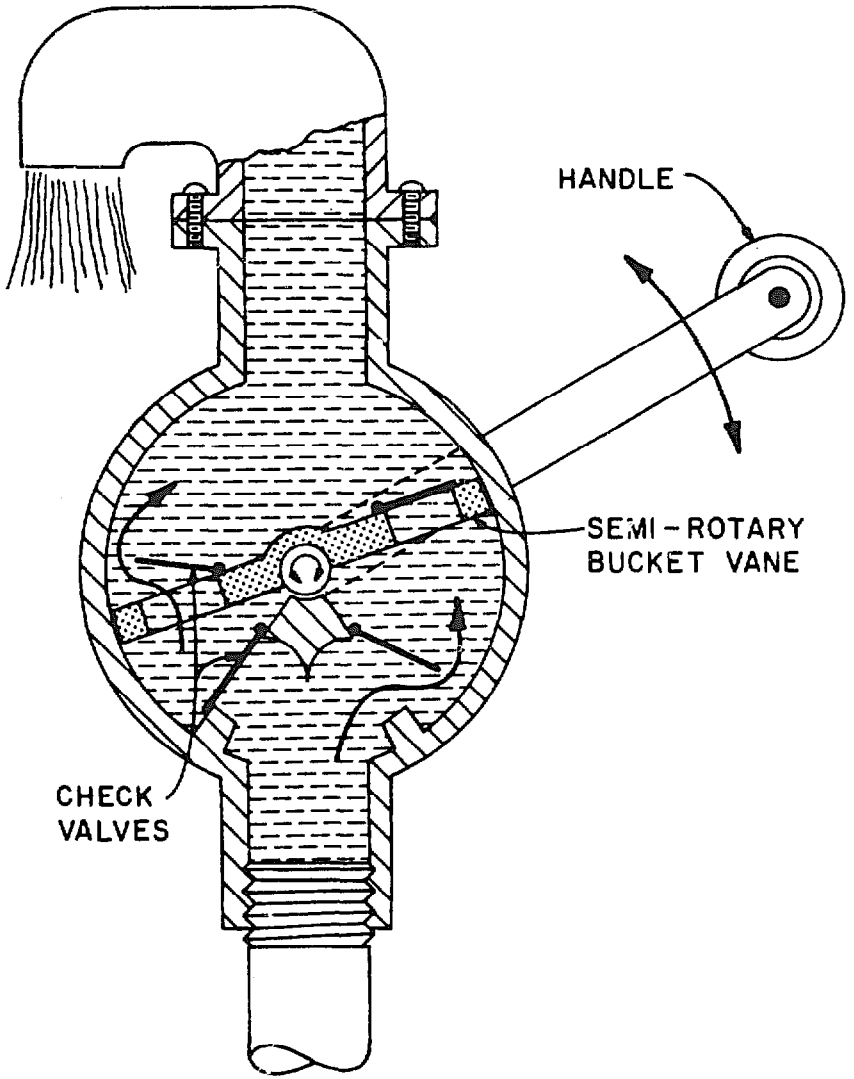

Figure 3.28 Manual, double-acting, semi-rotary pump

The semi-rotary pump, shown in Figure 3.28, is a half-bread device which utilizes both rotary and reciprocating motions. A vane, very similar to the bucket-piston (i.e., with flap valve(s)) is rotated through an arc in a circular casing which also contains a check valve(s) fixed to the casing. As the vane is alternately rotated in opposite directions, each set of fixed- and vane-check valves suctions and discharges a unit of water. To avoid wasting energy, most semi-rotary pumps are double-acting, as in Figure 3.28, and several such pumps may be attached to the same driving shaft. This pump is usually limited to small-capacity, domestic applications and is normally operated by manual power.

3.4 Miscellaneous Methods

As previously mentioned, a few water lifting methods exist which do not fit, either individually or collectively, into any of the established classes. However, since they exhibit primarily positive displacement characteristics, they are appropriately considered in this chapter.

3.4.1 Hydraulic Ram

When a pumping site is available which has an excess water supply with sufficient potential energy (i.e., elevation head), the hydraulic ram can be used to make water power lift water. As illustrated in Figure 3.29, the ram utilizes a flow of water from a source above it to drive a smaller discharge of water to an elevation above the source. In Figure 3.29, water flows down the drive pipe, into the ram and out the waste valve until the water velocity is sufficient to provide enough momentum to close the waste valve. The water is then forced through the check-valve and into the air chamber. This rush of water continues into the chamber

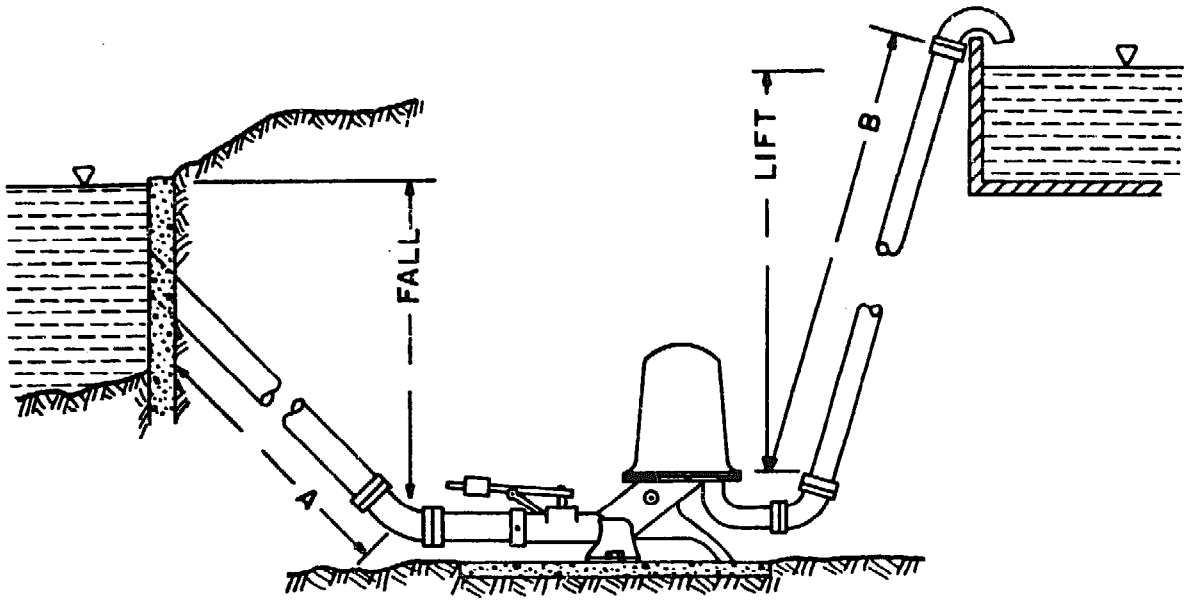

(a)

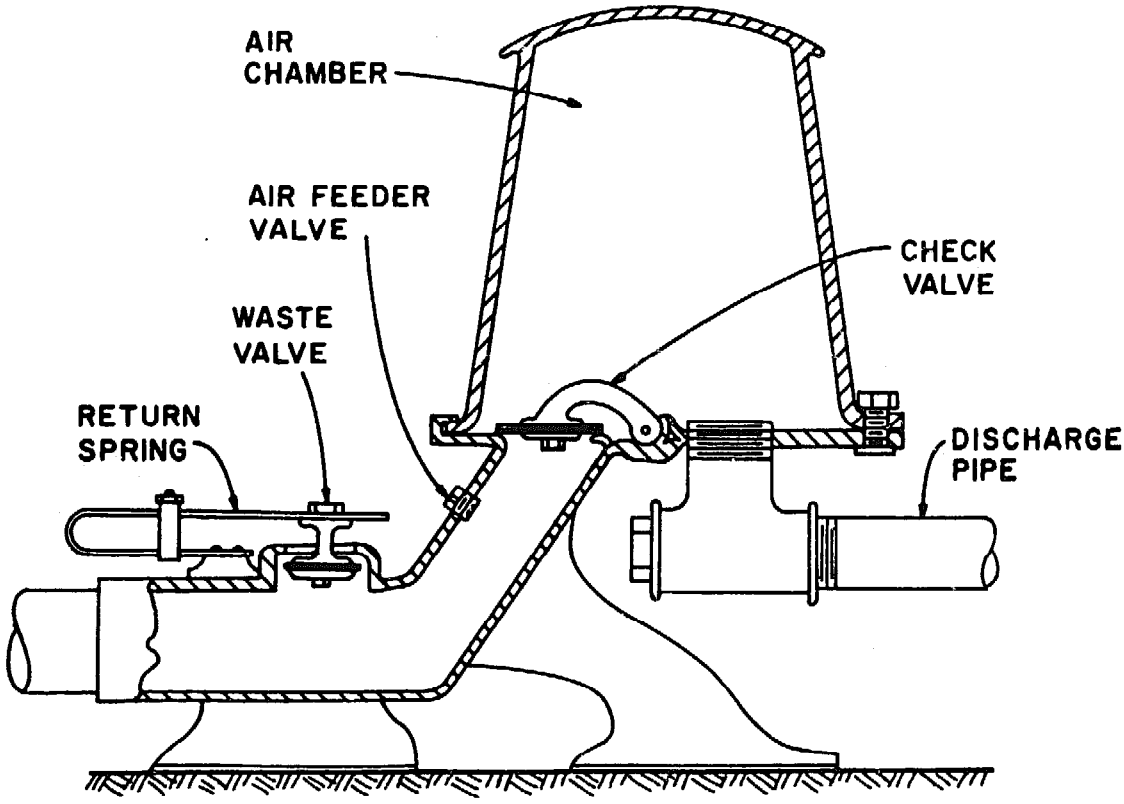

(b)

Figure 3.29 (a) Installation, and (b) typical design of hydraulic ram

until the air pressure within it exceeds the force of the inflowing water. The check valve is then forced shut, causing the water above it to flow up the delivery pipe, while the falling water again flows through the waste valve. This cycle occurs rather rapidly--25 to 100 times per minute. The valves can normally be adjusted to vary the strokes per minute (spm) which in turn regulated the discharge. More water is needed to operate at slower spm's, but a higher percentage of water is also driven up the delivery pipe. This variation in performance is a function of the size and type ram used, as well as the ratio between driving head and delivery head. Table 3.8, part A, lists some ram sizes by pipe diameters, and typical minimum driving (or falling) discharges (Q_f) necessary for them to operate. The efficiency of rams is usually about 60 percent. Some typical combinations of Q_r and H_r are given in Table 3.8, part B. Rams usually need a minimum H_f of 18 inches to operate. With sufficient H_f, some rams are capable of H_d's up to 500 feet. Discharges (Q_d) vary from less than 1 gpm to about 1600 gpm.

Rams vary in cost, depending on size and make, from about $200 to $3000. This usually includes a drive pipe strainer, but does not include pipe or other plumbing accessories. Double-acting rams are $80 to $300 more. Because the ram is a rather simple device (i.e., has few moving parts, no high-speed drive connection, no close tolerances, etc.), several designs have been made available which only need materials that can be obtained in most plumbing or hardware stores; e.g., metal rod, concrete, pipe, bolts, rubber washers, etc. (Kaufman, 1948). A similar, easy-to-construct design has been set forth by VITA for use in developing countries (Kindel, 1975).

Table 3.8 Ram performance

A. Typical capacities for various size rams:

Drive Pipe (in.)	Delivery Pipe (in.)	Minimum Q_f (gpm)
1	½	4
2	1	15
4	2	45
6	3	90
9	4	200
12	5	300
18	8	600
24	10	1000

(after Anderson, 1973)

B. Typical discharge ratios (Q_r) for various head ratios (H_r):

H_r:	2	4	6	12	20
Q_r:	.35	.16	.10	.05	.03

(after Weisbach and Herrman, 1897)

Other names which are often used when referring to hydraulic rams are:

water-ram

impulse pump

hydraulic engines

3.4.2 Air-Lift Methods

Compressed air can be used in two different methods to lift water. The first method, using an eductor pipe, is the one commonly referred to by the general term air-lift pump.

3.4.2.1 Eductor Method

In this air-lift method, compressed air is forced down into a well through a pipe. At a point below the water level, the air is allowed to escape into an eductor pipe which extends from below the water level up to the well surface or a discharge pipe. As shown in Figure 3.30, these pipes can be arranged in one of three ways; (a) the air pipe can be a small pipe inside the eductor, (b) a small air pipe can parallel the eductor on the outside and then connect to it near the bottom, or (c) the air pipe can be larger than the eductor and fit around and below it. However, in all three schemes, the air will mix with the water, creating a lighter fluid in the eductor pipe than the water in the surrounding well. The heavier fluid will thus force the air-water mixture up and out of the eductor pipe. Because the water pressure at the bottom of the eductor must exceed the weight of air-water in it, the air and eductor pipes must be submerged sufficiently to produce this pressure. A foot piece at the end of the air pipe is helpful in improving the efficiency by breaking up the airstream into small bubbles which mix more thoroughly with the water.

Since air-lift pumps have no moving parts they require no other maintenance than is required for the air compressor. They are very applicable to lifting abrasive or dirty water, thus one of their most common usages is in sewage works. The major cost of this type air lift installation (other than the well sinking) is the air compressor (see Chapter 5). The only other initial costs are for piping and the foot piece, all of which can be improvised from second-hand materials.

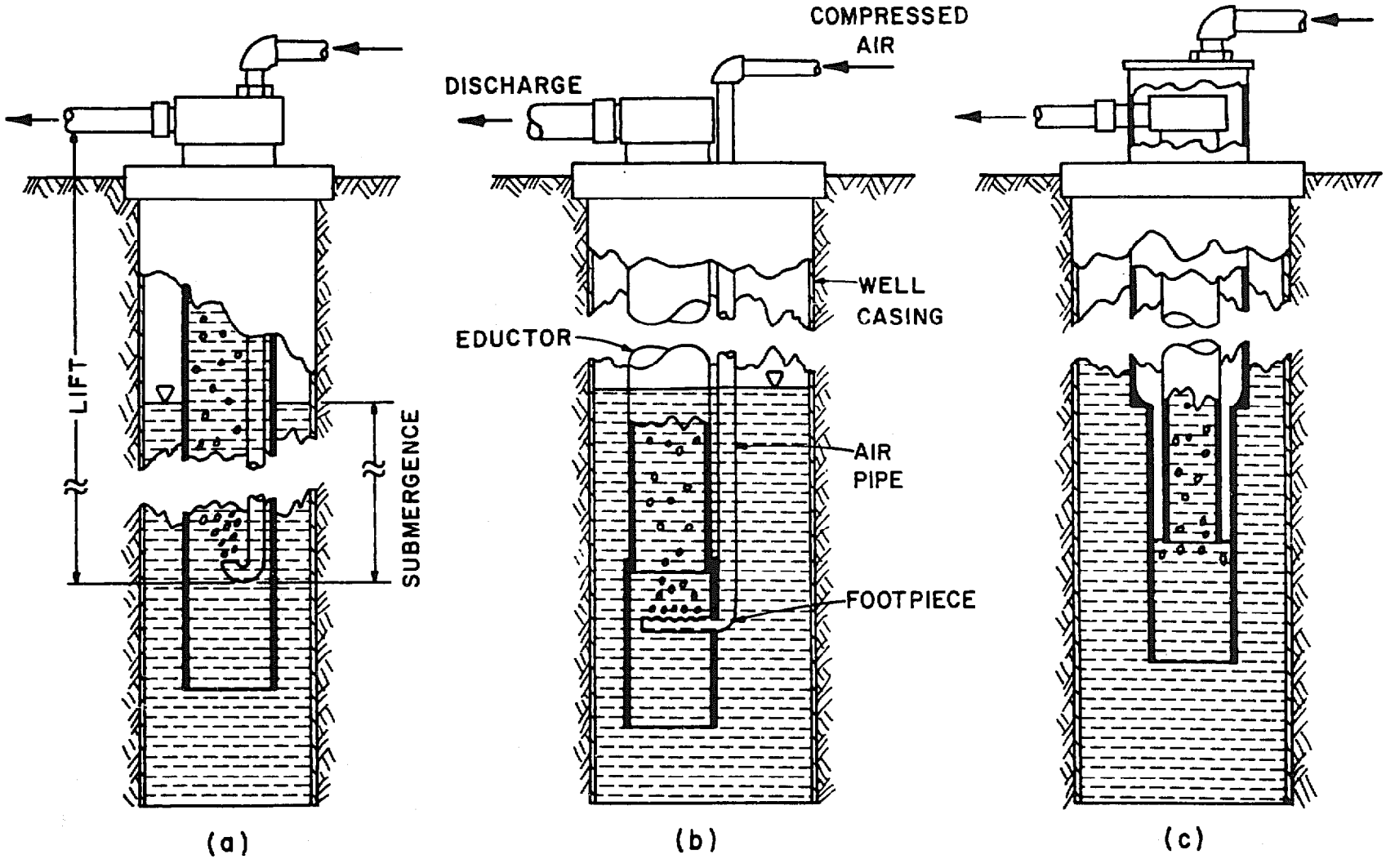

Figure 3.30 Eductor air-lift methods; (a) air pipe in eductor, (b) air pipe outside eductor, and (c) eductor inside air pipe

3.4.2.2 Displacement Method

As mentioned in Chapter 1, the displacement method of lifting water was discovered by Heron. Air is withdrawn from a container which allows water to flow into it. Air is then forced back into the container, displacing the water and forcing it up a discharge pipe.

Since the development of the eductor air-lift methods, displacement-type installations have rarely been used for irrigation and drainage purposes. They require much more plumbing and have several check valves and switches (e.g., the regulator) which must be maintained. However, two recent developments have found new applications for the displacement air-lift principle.

The current "energy shortage" has created an incentive for the development of water lifters which can utilize natural energy. Among them is the solar water pump designed by D. P. Rao and K. S. Rao at the Birla Institute in Pilani, India. They have developed two types of systems--air cooled and water cooled.

In the water cooled arrangment shown in Figure 3.31, the system consists of a solar collector, flash tank, and cooling tank located above ground, and a pair of water tanks located in the water source. Water enters these water tanks by an inlet check valve under atmospheric pressure. A working fluid--pentane or some other petroleum fraction-- flows by gravity from the flash tank into the solar collector where it vaporizes at about 35° -40°C. It then flows through the flash tank and into one of the water tanks. As in the penumatic-operated displacement container, this vapor will create a pressure within the tank sufficient to push the water up a discharge pipe. The water being discharged from the one tank passes through the cooling tank and condenses the vapor in the other water tank.

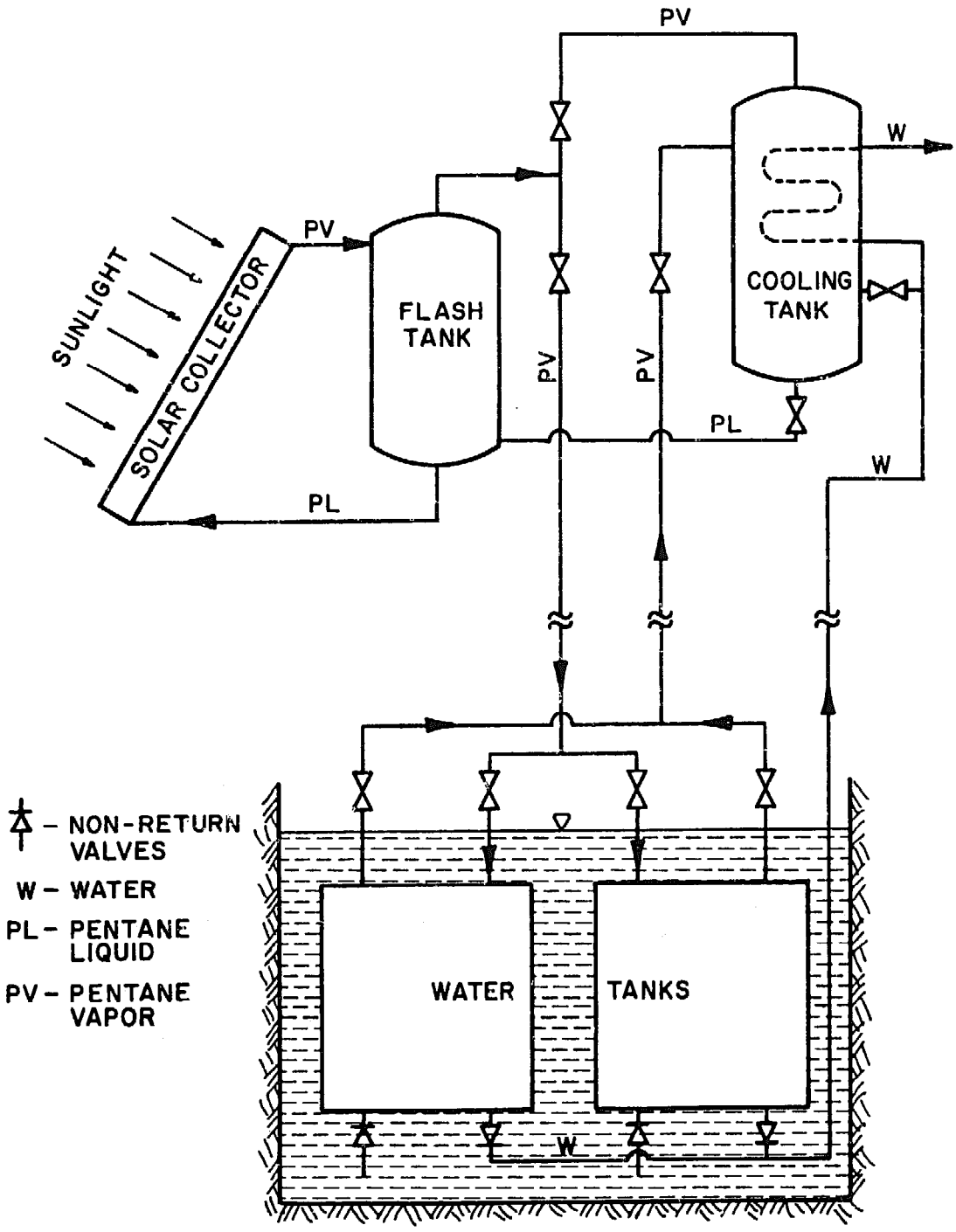

Figure 3.31 Schematic operation of water-cooled solar pump

As that vapor is condensing and returning to the flash tank, water is flowing into the second tank because of the decrease in pressure. Upon completion of these two simultaneous filling and discharging operations, the vapor is switched into the other tank and the cycle repeated.

A similar air-cooled system utilizes only one water tank which is emptied during the daylight heating hours, and filled during the cooling night. This arrangement requires the water tank to be large enough to handle one entire day's pumping requirement.

Early morning sunlight, from about 7-10 A.M., is required to bring the working fluid to vaporization temperature, so that actual pumping can only take place from about 10 A.M. to 4 P.M. With this time limitation in mind, the collector and tanks must be sized to produce the desired daily discharge. Table 3.9 gives some of the results achieved by Rao and Rao (1975) for various size systems. Theoretically, discharge is limited only by the size tanks available and lifts up to 300 ft should be within practical operation capabilities.

Table 3.9 Solar pump performance

	Air-cooled system with 10 x 12 ft water tank		Water-cooled system with two 3 x 5 ft water tanks	
Lift (ft)	Discharge (ft^3/day)	Collector Area (ft^2)	Discharge (ft^3/day)	Collector Area (ft^2)
30	880	250	7,805	1,000
60	880	400	5,406	1,000
90	880	550	3,607	1,000

Because the components are not yet commercially produced as a unit, these pumps are still rather expensive for use in developing countries. The air-cooled system which produced the results in Table 3.9 cost about $1,420 for the tanks, plumbing, and insulation, and $4.50 per ft^2 for the collector. The water-cooled system cost about $2,100, plus the $4.50 per ft^2 of collector, i.e., about $6,400 total. Of course, the operating cost is almost nil--only an occasional recharge of the working fluid. With further development to cut initial costs and improve efficiency, the lack of moving parts (except check valves) and ease of operation by unskilled labor, make this system a feasible solution to reducing pumping costs in a time of rising fuel costs.

The second recent development of the displacement method is the foot operated device in Figure 3.32. It is being manufactured commercially by a French company for use primarily in developing countries. As shown in the figure, a foot pedal reciprocates a small air-piston which is connected to a displacement cylinder in the water supply via a flexible hose. As in the other displacement methods, the change and exhaust of air by the piston causes discharge and filling of the cylinder, respectively. The discharge flow is through another flexible hose which is connected at the surface to appropriate plumbing. In a design for 4 in. diameter wells, this device is reported to deliver 53 cfh at a 66 ft head, and 18 chf at 200 ft (Mengin, 1976).

3.4.3 Pulsometer

Although the pulsometer probably cannot be found in use anywhere today, as mentioned in Chapter 1, it was commonly used for drainage purposes around the turn of this century. It utilizes the principles of both the steam and

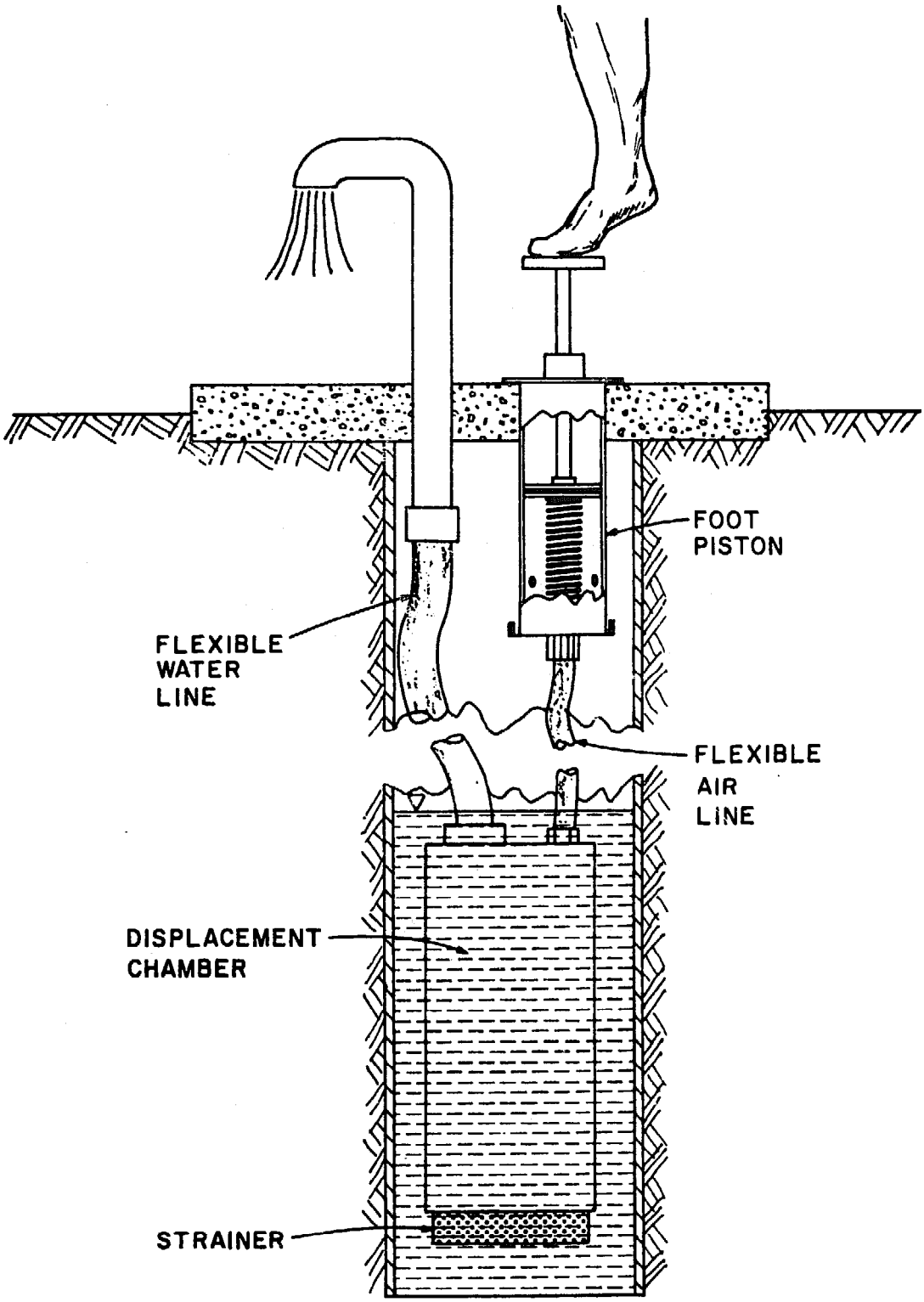

Figure 3.32 Displacement air-lift method operated by foot piston

air-lift pumps. The oscillation of this action between chambers (from about 12 per minute in larger pulsometers to 130 per minute in smaller sizes) causes quite a vibration and was the origin of its common name, pulsometer. (See also Rogers, Vol. 2, 1905, pp. 269-280; Weisback and Herrman, 1897, pp. 286-291).

3.4.4 Explosion Pump

Another unique, but obsolete, water lifter is the explosion pump of Humphrey. Its operation is quite simple and was originally claimed to be more efficient than conventional steam pumps (Greene, 1913, pp. 128-129). A charge of coal gas is exploded in a chamber which drives the water in that chamber up a discharge pipe. The spent gases are exhausted through a valve and a new unit of water is drawn in through inlet ports. The rebound of water in the discharge pipes is the method for exhausting the gases and compressing the new charge of coal gas. Ignition of the explosion is by electric spark (see Unwin, 1909).

Chapter 4

Kinetic Methods

4.1 Introduction

The kinetic class of waterlifters comprises a smaller variety of subclasses than positive displacement devices, but is presently the most widely used class (where available) for irrigation and drainage. This is primarily due to its adaptability to most applications and prime movers. The term centrifugal is commonly used, but erroneously, to denote this entire class--probably because centrifugal pumps were the first devices to develop in this class (Chapter 1). As the term kinetic implies, this class of pumps adds energy to the water by the motion of an impeller or, in the case of jet pumps, the motion of another fluid mass.

"Centrifugal" is also commonly used to classify the group of pumps we have more appropriately labeled rotodynamic (Table 2.2), which includes true centrifugal pumps as well as three other types. Peripheral pumps are often given a distinctive subclass (as in the Hydraulic Institute Standards) since they, like propellers, are not true centrifugal devices. However, the use of this rotodynamic subclass (more commonly used in Europe) can be used to classify all pumps which utilize a high speed rotary (as opposed to positive displacement rotary) motion. The terms velocity, impeller, and rotokinetic are also used occasionally instead of rotodynamic (Lazarkiewicz and Troskolanski, 1965, and Wagner and Lanoix, 1959).

4.2 Rotodynamic Pumps

All rotodynamic devices consist of two primary parts; an impeller which imparts energy by its rotary action, and a casing which guides the fluid to

and from the impeller and confines the energy transfer. Several hundred different designs have been developed by an almost equal number of manufacturers for various applications and mechanical requirements.

4.2.1 Radial Flow

Radial impellers give the fluid a true centrifugal action, i.e., the fluid enters at the eye or axis of the impeller and is thrown radially--at 90° to the shaft axis--outward to the enveloping casing by the impeller vanes. This creates a partial vacuum at the eye which draws in additional water from the suction line)s). As the water is expelled from the vanes, it is guided by the casing in one of two manners. In a volute casing, the water is discharged by the vanes into a widening spiral casing, which converts velocity head into pressure head. In a diffuser casing, a ring of guide vanes, curved backward to the impeller vanes, perform much as multiple volutes--expanding outward to make the pressure conversion. In multiple stage pumps, e.g. submersible well pumps, these diffusers also guide the water into the eye of the next stage. Impellers can additionally be classified as enclosed, semi-open (or semi-enclosed), or open. The enclosed impeller has a shroud on both sides of the vanes, the semi-open has a shroud only on the upstream side, and the open has essentially no shrouds, only the webbing needed to support the vanes.

4.2.2 Axial Flow

Axial Flow impeller pumps, or as they are often called propeller pumps, increase the head on a fluid by the lifting action of the vanes. The fluid flow is parallel to the pump shaft. In most designs, guide vanes are provided immediately after the impeller to convert excess rotational

velocity of the fluid to pressure head. The impeller vanes may be fixed parallel to, or at any angle to, the shaft axis, or they may be adjustable for changes in application conditions.

4.2.3 Mixed Flow

Mixed flow pumps have impellers which impart to the water both axial and radial motion, i.e., the vanes discharge at some angle between 0° and 90° from the axis. Mixed flow impellers are used in two basic pump designs; the helical flow which utilized a volute casing, and the diagonal flow, as used in the bowl construction of vertical well pumps.

4.2.4 Regenerative Flow

Regenerative pumps are also referred to as vortex, peripheral, side channel, and turbine pumps--the latter name often leading to confusion with vertical "turbine" pumps (a misnomer itself). Although the basic principle is the same, a fine distinction exists between peripheral and side channel pumps. A peripheral pump has a volute casing at the impeller tip which decreases in cross sectional area in the direction of flow (i.e., opposite of a volute pump). The side channel pump casing has wider side passages to retard fluid flow. A peripheral impeller receives the water, as its name implies, at its periphery and recirculates the water several times about its short double blade vanes before discharging. This recirculation is produced by the decreasing volute (or side channel) design which causes reverberation of the water back toward the suction inlet. This reverberation or vortex action allows the impeller to impart additional energy to the water. A regenerative pump can develop heads several times greater than a volute pump with the same size impeller and speed, thus

making this type pump useful for high pressure requirements. At the outlet port, the casing narrows to a clearance just sufficient to pass the impeller, thus forcing the water out.

4.2.5 Characteristics

Since the operation principle of radial, mixed, and axial flow pumps is the same, a discussion of their basic characteristics can be made jointly. Because of their unique operation, regenerative pumps are included only where specifically mentioned.

Along with its performance curve, several other parameters can be used to describe a pump's operation. The first such parameter is called (nominal) specific speed, or more properly, kientic specific speed since another term, dynamic specific speed, is also used in design work. It is defined as

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$$

where N is shaft speed in rpm, Q is discharge in gpm, and H is head in feet. Specific speed is used as a "type" number which is constant for similar pumps. It is indicative of impeller shape and varies uniformly with changes in the impeller diameter ratio, D_2/D_1, another characteristic parameter. Figure 4.1 shows this relationship between N_s, D_2/D_1, and impeller type. By utilizing N_s as a selection tool, optimum installation conditions can be designed.

Another parameter, suction specific speed is defined as

$$S = \frac{N\sqrt{Q}}{NPSHR^{3/4}}$$

(Note that for double suction impellers, Q equals half total discharge through the pump.) This number is used primarily for indexing the cavitation performance of a pump.

Also included in Figure 4.1 are typical shapes of pump performance curves as they very from radial to axial flow impellers. By reveiwing these curves, some of the different performance features of various rotodynamic pumps can be observed.

Although the regenerative pump is not in the radial/mixed/axial family of rotodynamic pumps, it also has distinctive curves. The performance curves resemble, in shape only, those of an axial flow pump. This is, power and head are both a maximum at shutoff. However, regenerative pumps usually have a discharge range of 1-200 gpm and single stage heads of up to about 500 feet, while propeller pumps have been built to handle upwards of 100,000 gpm but are limited in head to about 30 feet (Pillai, 1969). Specific speeds of regenerative pumps are the lowest of the rotodynamic class, ranging from 500-1300.

Two additional aspects of rotodynamic pump operation are important to their application; capacity regulation and priming. Unlike positive displacement devices, head may vary significantly with changes in the discharge of a rotodynamic pump. As Smeaton found in the 18th century, discharge, head, and power vary by definite proportions for small charges in pump speed or impeller diameter. Using performance curves with constant

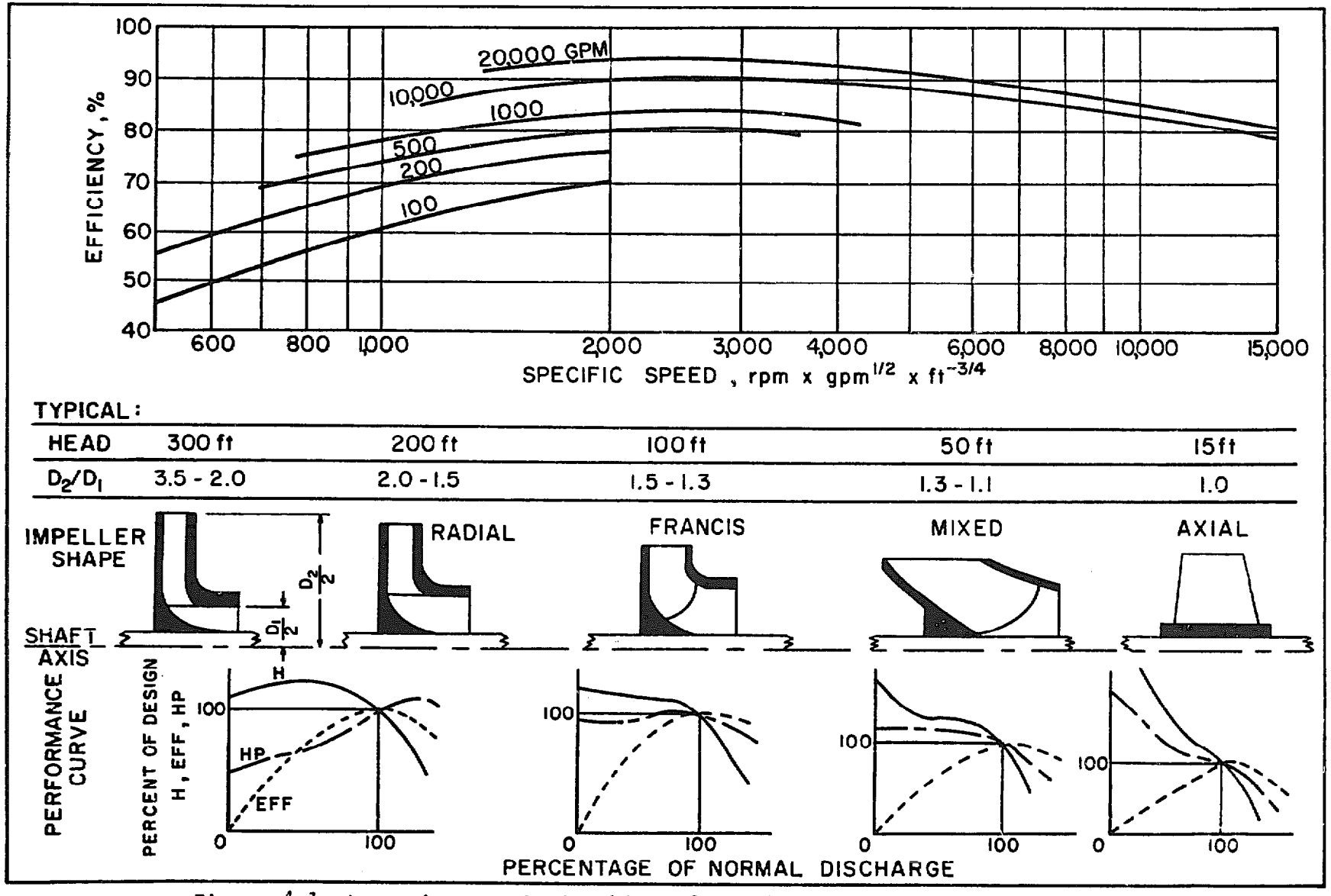

Figure 4.1 Approximate relationships of rotodynamic pump characteristics

speed lines, it can be seen that increasing or decreasing the speed at a constant head will increase or decrease, respectively, the capacity. However, two interdependent changes will also result from such speed changes. Depending on the type pump, the power consumed may increase or decrease, thus providing additonal savings or cost. Also, as in most mechanical devices, higher speeds will increase wear. When pumping abrasive fluids, such as most irrigation and drainage water, this wear can be quite severe. Walker (1972) states that doubling the speed of rotodynamic pumps can result in four times the wear.

As indicated by the affinity laws, a change in impeller size will vary capacity. Except for permanent demand changes, disassembling the pump and exchanging or altering the impeller(s) is not usually practical. However, in propeller pumps, blades with adjustable pitch are available and in centrifugal and mixed flow pumps, adjustable diffusers or guide vanes can be utilized. These adjustable devices have the effect of changing impeller size and capacity by permitting a broader high-efficiency-range (Rouse, 1950).

Capacity regulation can also be accomplished by throttling the discharge. (Throttling the suction line is not recommended since this decreases the NPSHA and thus increases the probability of cavitation.) This will increase the total head against which the pump must operate by increasing friction and therefore lower the discharge.

The second feature of rotodynamic pumps yet to be considered is their need to be primed. Unlike positive displacement pumps, when first started, they cannot displace air to create the pressure differential necessary to "suck" water. Also, since rotodynamic pumps utilize the water they lift

to lubricate all or some of their rotating parts, running dry--even for just a few seconds--can cause excessive wear on waring surfaces which can in turn cause significant efficiency losses.

Various methods are used to prime rotodynamic pumps, depending on pump type and application. They include:

(a) foot-valve and filler method,

(b) providing a dynamic suction head,

(c) removal of air from suction line and pump by air pump,

(d) self priming by recirculation chamber or auxilary positive displacement pump.

Where automatic operation of a pump is required, methods (b) and (d) are used. The use of a foot valve does not sufficiently insure against loss of the prime water and is often considered an unnecessary friction loss.

4.2.6 Applications for Irrigation and Drainage

Due to the wide range of head/capacity situations over which rotodynamic pumps can be used and the flexibility with which they can be combined to various prime movers, this subclass of water lifters has become the most popular for irrigation and drainage when available.

Table 4.1 lists and describes some of the more commonly used irrigation and drainage installations for rotodynamic pumps. The selection of these installations is determined by the water source available and the type of pump and driver required or available. (The selection of pump and driver is discussed in Chapter 5.)

Manufacturers produce a wide range of basic rotodynamic pumps covering many specific head-discharge-application requirements. By modification of

Table 4.1 Typical rotodynamic pump installations

A. RADIAL FLOW AND LOW N_s MIXED FLOW PUMPS

Position of shaft	Installation	Figure	Remarks
Horizontal	1) On shore with pipe suction line	2.2	Usually for permanent installation on foundation; with suction head or lift.
	2) On shore with flexible suction line		Usually for portable use on frame.
	3) On ground surface over shallow well		Depth to water level limited by NPSHR.
	4) In pit over shallow well		Allows increase of NPSHA.
	5) On float or boat in water supply with pipe or flexible suction		Good for greatly fluctuating water level in pond, river, drainage ditch, etc.
	6) In combination with ejector	4.8	For shallow or deep wells.
Incline	7) On trailer, submersed in water supply		Can be run directly from tractor's PTO.
Vertical	8) Over well with pipe or flexible suction line		Same as for horizontal.
	9) In dry pit	4.2	Allows suction head to prime.
	10) Submersed volute on frame		Same as in dry pit, but open to water; long shaft or close-coupled.
	11) Lightweight, portable submersible	4.3	Close-coupled with submersible motor.
	12) Single stage, mixed flow bowl assembly		Uses diagonal impellers; commonly called *vertical turbine pump*.
	13) Multi-stage, mixed flow bowl assembly	4.4	Same as (12); driven from above via shaft or by submersible motor; for deep water sources where well is too narrow for vertical volute (down to 6 in. diameter); water or oil lubricated.
	14) Multi-stage, radial flow assembly	4.5	Used for deepest wells (up to thousands of feet); used with submersible electric or hydraulic motors; sizes down to 4 in. diameter.

B. AXIAL FLOW AND HIGH N_s MIXED FLOW PUMPS

Position of shaft	Installation	Figure	Remarks
Horizontal	1) In siphon arrangement		Used in large pumping stations--not practical for small agricultural uses due to low efficiency and priming difficulties.
	2) At vertical wall of pit		Self priming; for high discharges.
Incline	3) Fixed on shore		Good for installation on levee or canal bank.
	4) On portable frame on shore	4.6c	Allows for use at various heads and locations.
	5) On portable frame on boat	4.6b	Utilizes boat motor and propeller.
Vertical	6) Mounted in well		Only for shallow wells.
	7) Fixed on shore		Can be used with siphon, as shown, to decrease power consumption.
	8) On portable frame		Same as inclined (4) (5).

such variables as impeller size, number of stages, drive speed, etc., these basic designs can be made to fit any intermediate conditions. While the manufacture of the complex vertical turbine and submersible pumps is presently limited to several companies in indistrial nations, volute and propeller pumps are easily manufactured by the basic industries (e.g. foundries) in developing countries (Ahmad, 1969). In fact, a 1961 SEATO thesis by Srisakdi Charmonman explains the design, construction, and performance of an axial-flow pump made quite simply by encasing the propeller of a Thai-style outboard motor (3-1/2-7 hp.) with a cylinder. As illustrated in Figure 4.6, this design permits dual use of the motor for both boat and pump motivation. This pump can be utilized with the anchored boat as a foundation (Figure 4.6b) or dismounted and used on shore (Figure 4.6c). This improvisation provides the simple low head, high discharge pump required for the irrigation and drainage of crops such as rice in lowland areas. Commercial units of this design are reported to be manufactured in Japan for about $300 (Bowers, 1975).

Initial costs of rotodynamic pumps very greatly, depending on the type, size, power, materials of construction, and manufacturer. Many pumps also require numerous accessories and/or sophisticated foundations and installation, manufacturers' catalogs and/or well contractors must be consulted. However, as a rough guide, a buyer can expect to pay (for pump only) up to $500 for sizes under 1 hp, $100-500 per hp up to 10 hp, and $100-400 per hp above 10 hp, with cost per hp decreasing for increasing horsepower (based on 1974-75 U. S. manufacturers' catalogs of new pumps).

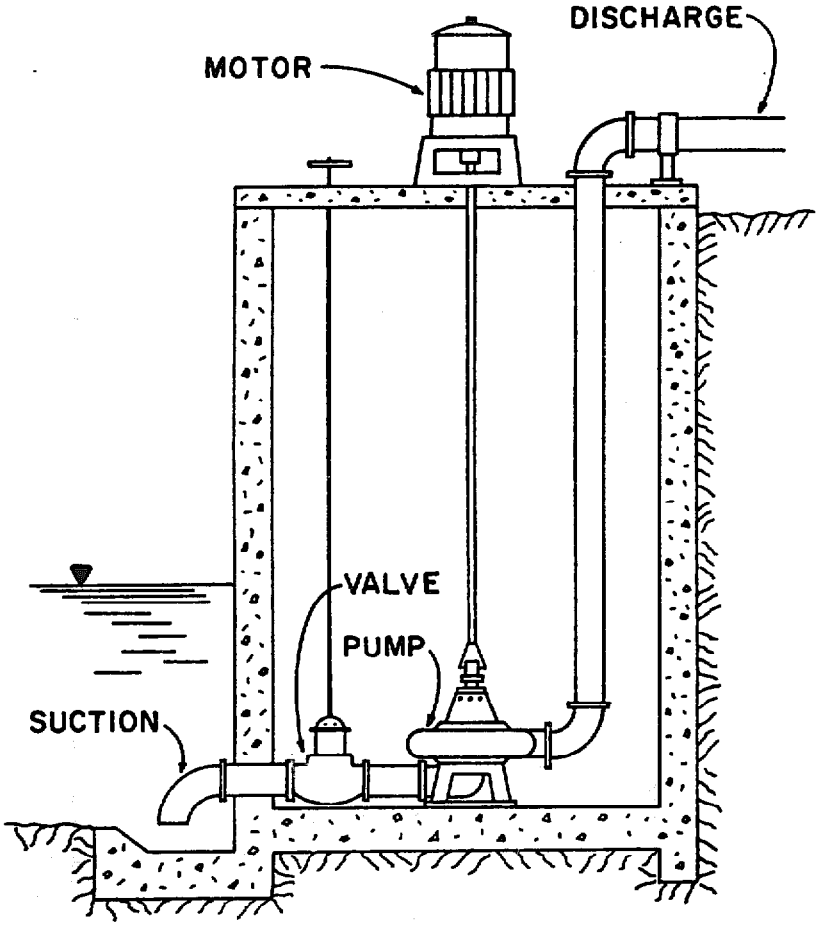

Figure 4.2 Vertical volute in dry pit

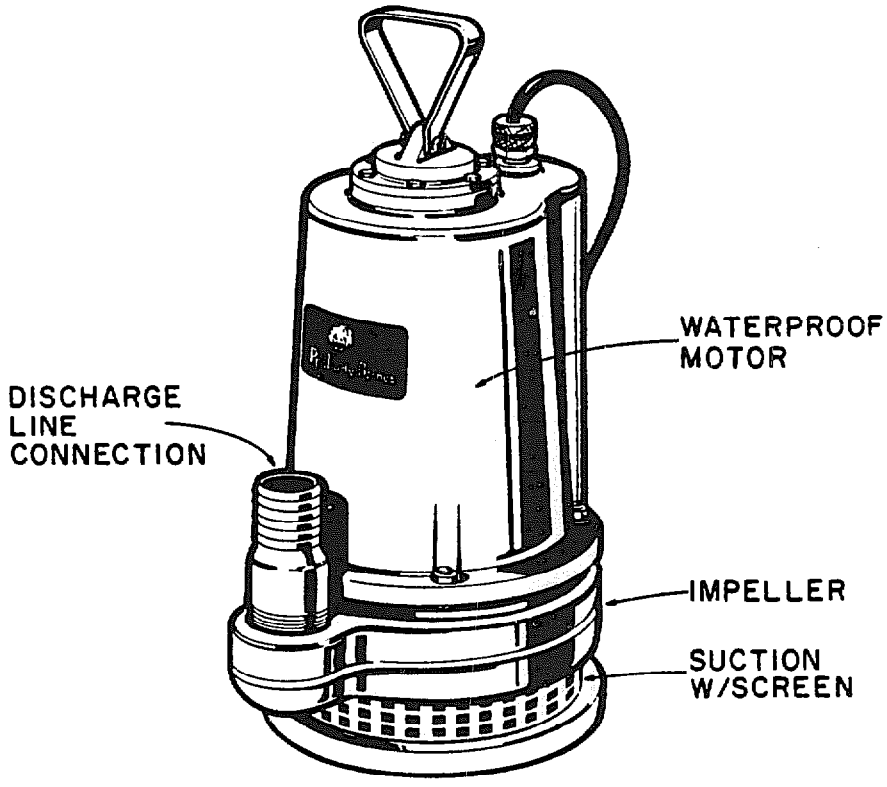

Figure 4.3 Submersible, portable volute pump (courtesy of Peabody Barnes Pump Co.)

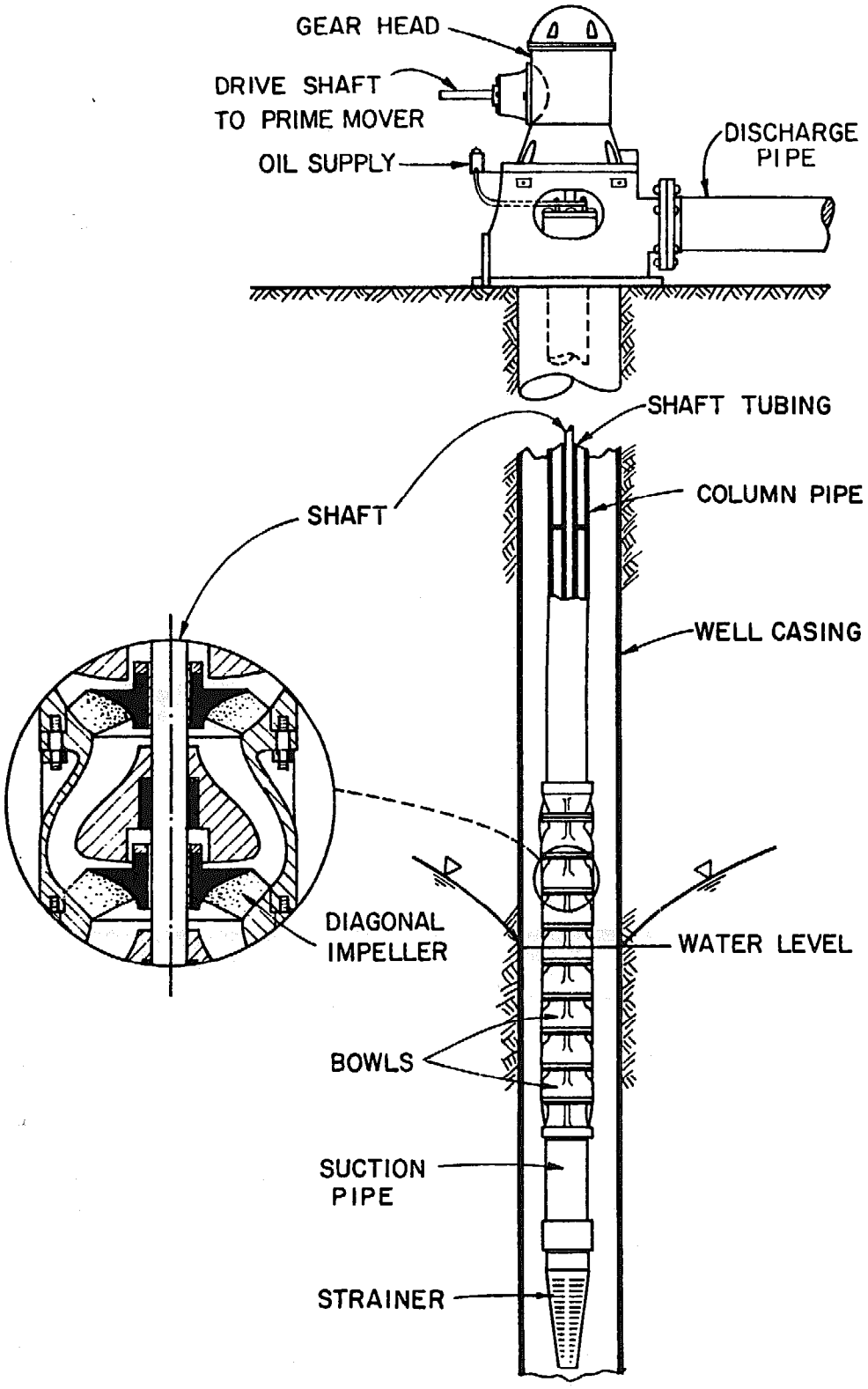

Figure 4.4 Mixed-flow, vertically-mounted, "turbine" pump

pump

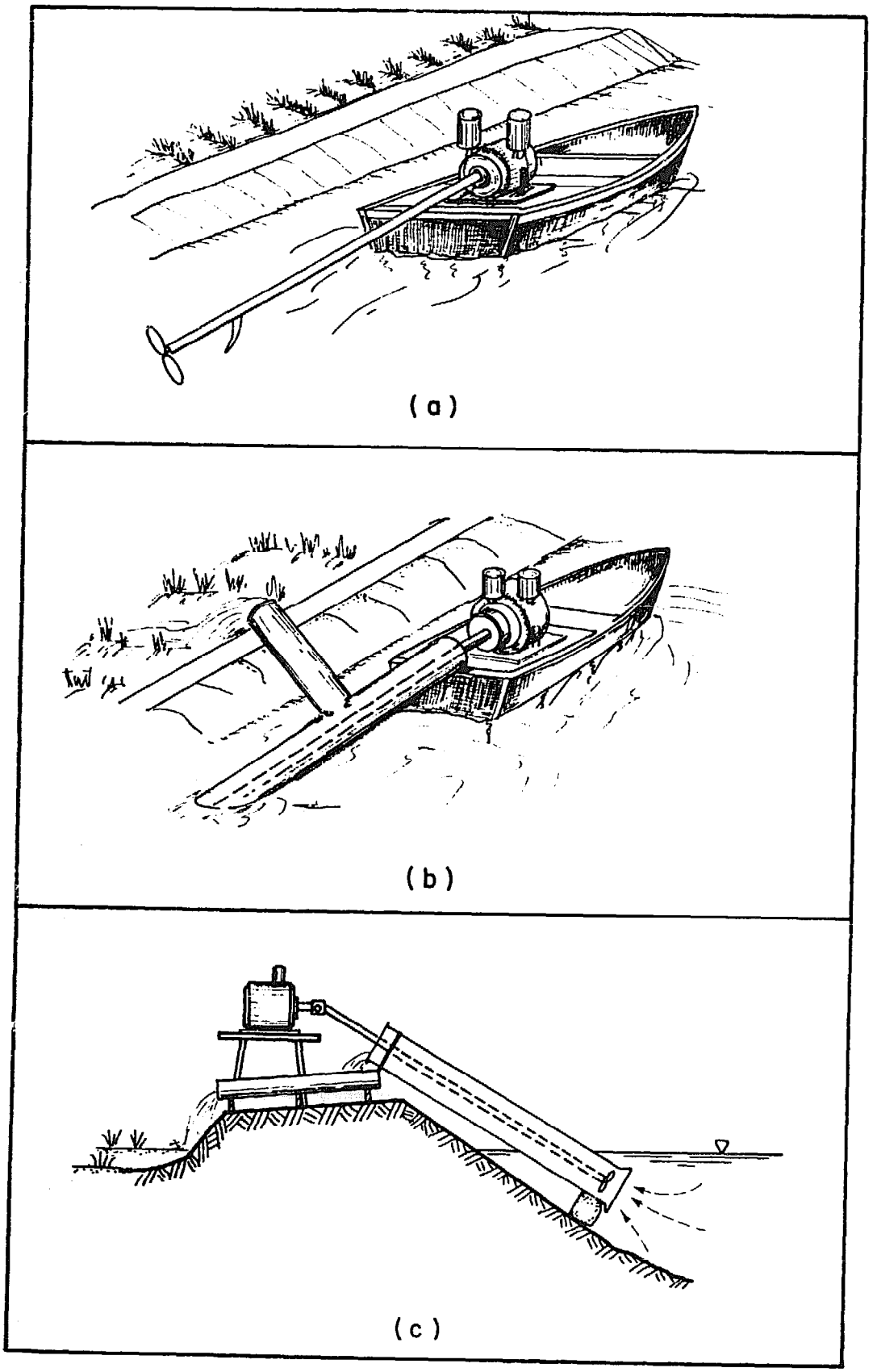

Figure 4.6 (a) Thai-style outboard engine and propeller used (b) for pumping from boat, and (c) from shore

4.3 Jet Pumps

A jet pump is a device which uses the kinetic energy of one fluid (i.e., the driving fluid), rather than an impeller, to pump another fluid. Depending on their application, jet pumps are known by several names; injector, jet heat exchanger, ejector, and eductor. The first two utilize a gas (usually steam) to drive another gas or a liquid, while the latter two devices utilize a liquid (usually water) to drive another liquid or a gas (Engineering, 1968, and Kneass, 1903). The term, eductor, also applies to air-lift pumping (Chapter 3) which is a positive displacement method and should not be confused with the jet principle. Injectors and exchangers are primarily used in conjunction with boilers. Therefore, in irrigation and drainage applications, the use of a "jet pump" usually implies an ejector.

An ejector utilizes a driving pump* to force the driving water at a high pressure into a venturi tube or suction box. There it entrains additional water to deliver a discharge of higher volume and lower pressure. This principle can be used in either of the two methods shown in Figure 4.7. For ease of operation and installation in wells, the sequence of Figure 4.7b is usually utilized in irrigation and drainage systems. However, it is the design in Figure 4.7a that is often used to add fertilizer to irrigation water. The arrangement of Figure 4.7b can increase the capacity of a centrifugal pump, however, at the expense of total head and efficiency. Although ejector efficiencies rarely reach 40 percent, this is also an effective way to increase the suction lift capability of a centrifugal

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* This pump is usually a centrifugal device, however, recent developments are incorporating positive displacement pumps--see Walkden, 1967, p. 318-319.

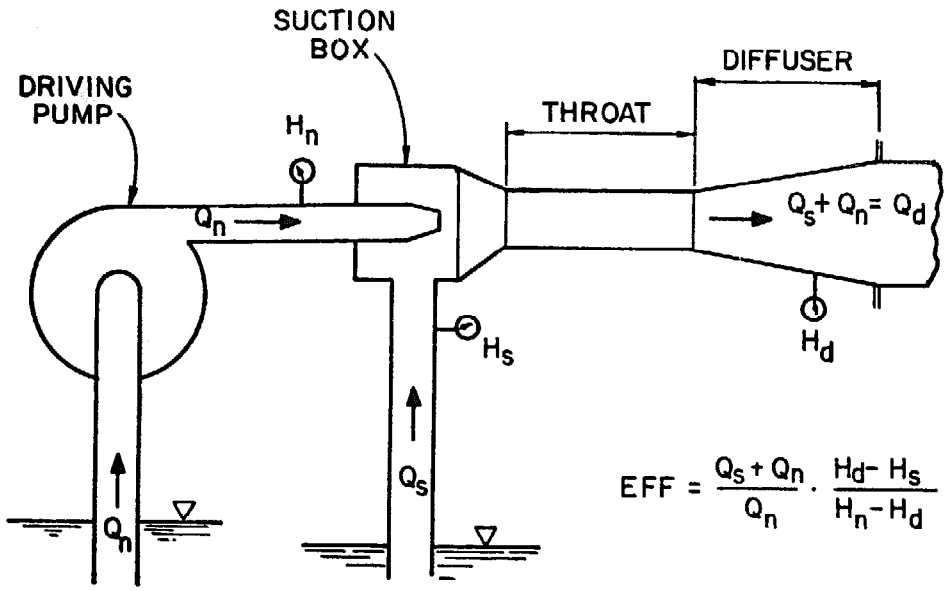

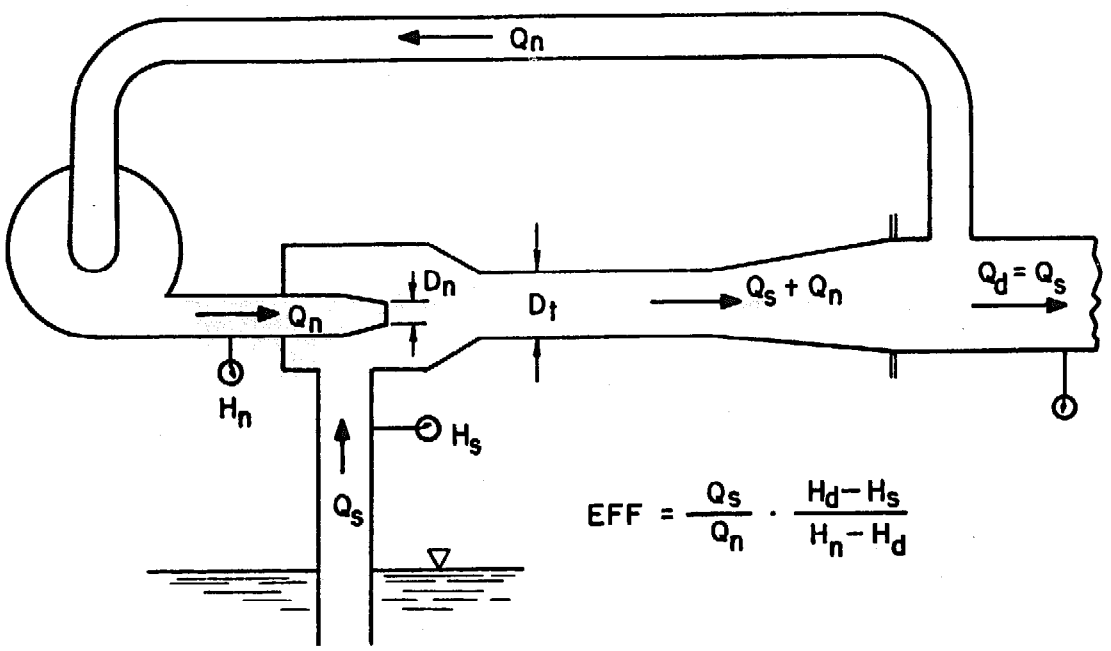

Figure 4.7 Two ejector arrangements:
(a) $Q_d = Q_s + Q_n$, (b) $Q_d = Q_s$,
with Q_n recycled

pump--usually up to a limit of about 120 ft. Units are available in sizes capable of handling up to 10,000 gpm (Eier and Schoenleber, 1942). In the case of a well supply, this also allows all moving parts to remain above ground for easy maintenance. Figure 4.8 illustrates the common arrangement of ejectors for shallow and deep wells.

Because the centrifugal-jet arrangement of Figure 4.7a was not available commercially for irrigation and agricultural drainage applications, work was undertaken at the International Rice Research Institute (IRRI) to develop such a design (Samuel, 1975). This sequence utilizes the entire discharge of the centrifugal pump to lift an additional quantity of water through the ejector. The IRRI design makes this system applicable for low lift agricultural pumping situations, e.g. between canals and paddies.

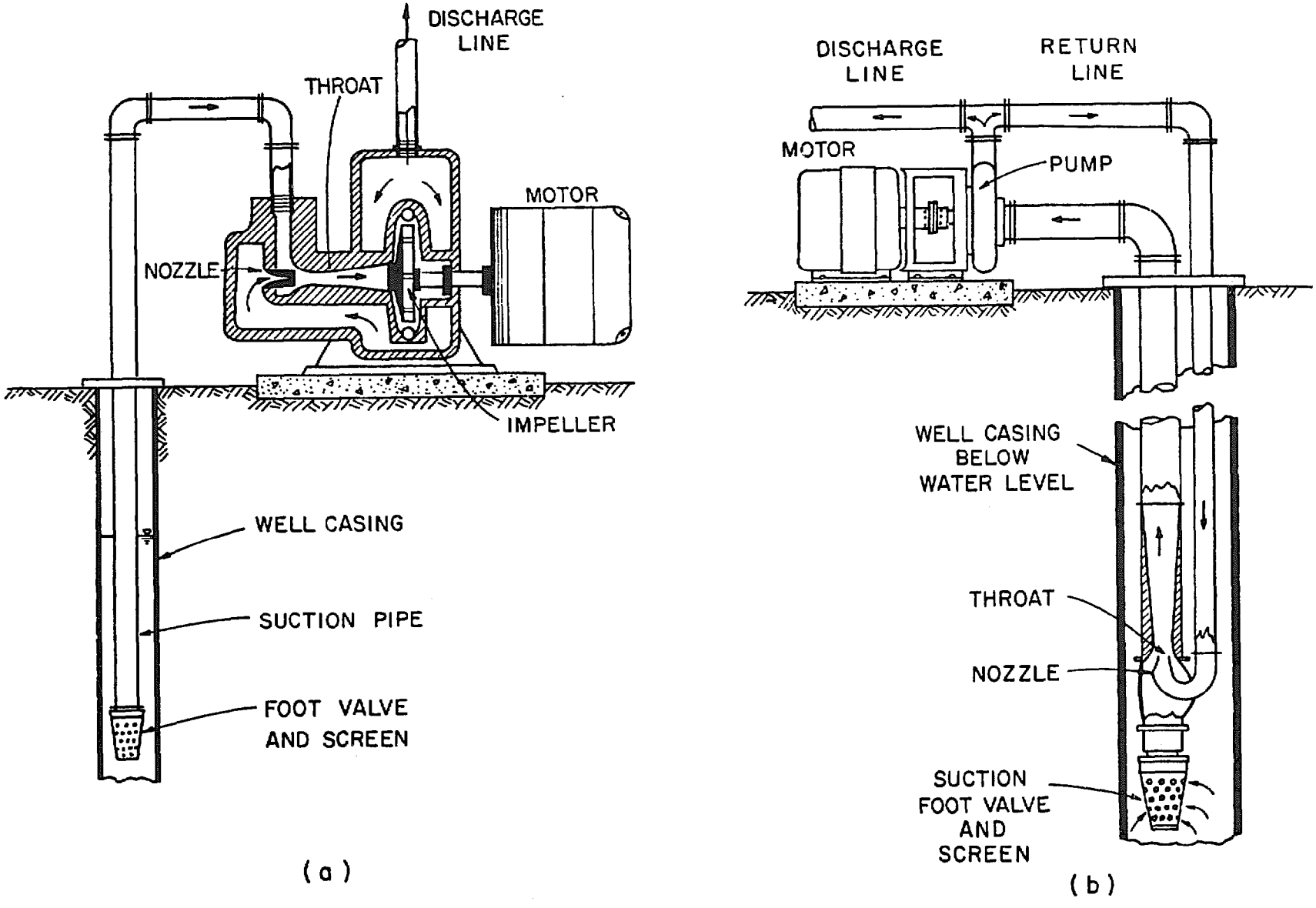

Figure 4.8 Jet pumps for (a) shallow well with ejector/impeller combination unit, (b) deep well with ejector in the well

Chapter 5

Prime Movers

5.1 Introduction

In the preceding chapters, the operations and construction of water lifters and pumps have been discussed with only illustrative mention of the various prime movers that can be used to drive them. The following section will review briefly the operation, construction, and cost of the driving devices which can be used to power water lifters and some of the common methods of transmitting this power (i.e., gears, belts, shaft, etc.).

5.2 Manual

Manual power is an easily transported prime mover which can be used to provide a variety of motions, e.g., circular, reciprocating, twisting, etc. One of the major benefits of utilizing manual power in developing countries is that it helps to alleviate the high unemployment and under-employment rates in these areas. Because human power can be utilized to perform other tasks (e.g., seeding, cultivating, etc.), the cost of maintaining manual power for water lifting can be shared among several duties. When labor must be employed to operate a water lifter, the prime mover cost will be the wages and/or benefits paid to the laborer. These wages vary widely depending on the economic situation in a specific locale. In some developing areas, $.10/hr or $2.40 plus food per month is not uncommon (Molenaar, 1956), but may range up to a few (i.e., 1-2) dollar per hour. When wages include food or family members are utilized, the cost of food must be considered. Allison (1975) reports that in a season requiring 120 man-days of water-lifting labor, 30 kg of rice were eaten by the labor,

which at $.20/kg, cost $6.00. However, available literature relating to water lifting report that a grown man is capable of about 0.06 - 0.08 hp (or 2000-2700 ft-lb/min) of output energy over a sustained period, i.e., about 5 hours, not including rest periods (Allison, 1975 and Staff, 1971).

Human power also varies depending on the type of motion performed. More power can be obtained from leg motion than by the arms. During short time periods (10-15 minutes), the legs can develop about 0.25 hp while the arms can provide only about 0.10 hp (Mengin, 1976).

Several adaptions and additions to basic water lifter designs have been utilized to also reduce energy output per each motion. The doon and counterpoise lift (see Section 3.2) with counterweights to reduce lifted loads are two examples of such designs.

A recent development by Tim Journey (formerly with UNICEF in Bangledesh) has produced another energy conserving device which could be used with several reciprocating water lifters. However, Journey has specifically applied it to the manual piston pump. An overhead, horizontal bar has the pump connecting rod attached to one end and a pendulum to the other end. The pendulum can simply be a vertical pole with a sand bag attached to the bottom. For lifts between 10 and 17 ft, a horizontal push on the pendulum of about 15 to 22 lbs is needed to maintain the pendulum swinging, which utilizes its weight to conserve the manual energy applied to it--see Allison, 1975.

Drs. Sant Garg and Radhey Lal have developed a system by which manual power can be used to drive a centrifugal pump--a water lifter previously restricted to high speed drivers. By means of a 4-bar linkage (called a "crank and rocker mechanism"), the reciprocating motion of two men is converted into a rotary motion. Then, a gear train of six spur gears, with

an overall gear ratio of 1 to 120, increases the first driving gear's 10-20 rpm to a final 1200-2400 rpm which is usable for a centrifugal pump. For a range of lifts from 3.3 ft to 7.5 ft, the small centrifugal used supplied from 330 to 25 cfh, respectively. The use of worm gears and/or fewer gears with higher ratios to reduce friction are among the recommendations made to increase efficiency. (A detailed description of this work is given in a 1967 thesis by Garg.)

Table 5.1 outlines the basic motions which can be provided by manual power and some of the typical water lifter/transmission combinations with which they can be utilized.

5.3 Animal

Like manual power, animals provide a relatively mobile source of driving energy which can be utilized for several duties, e.g., plowing, transportation, water lifting. Thus, if an animal can be used for tasks other than just water lifting, the price and maintenance costs of that animal can be "time-shared" by each task for economic purposes.

Although draft animals constitute a common and vital source of power in many developing countries, their upkeep can be particularly difficult in areas where water is scarce, rainfall is variable, or livestock disease is common (Merrill, 1976). If an operator does not want to, or cannot, provide for the care and feeding of an animal, or he only needs the animal(s) for a short period of time, he can rent or lease the animals. In this case his prime movers cost for water lifting will be the rent (time-shared if used for other duties). However, when an operator owns his own animal(s), he will have an initial purchase cost plus maintenance. Initial costs will vary greatly depending on the type, size, and condition of the animal, and the geographic area.

Table 5.1 Manual power applications

Performed with	Transmission	Water lifter	Remarks
	A. Reciprocating motions		
arms and/or upper torso	rope (may also include pulleys, etc.)	bucket	figure 3.0
	rope	swing basket	may require some leg movement; for 2 persons
	rope	water balance	figure 3.6 can also operate with one person and counterweight
	rope and pole	counterpoise lift	figure 3.3
	rope and pole	shovel	figure 3.5 may require some leg movement
	handle	gutter	figure 3.7a
	handle	diaphragm pump	figures 3.16
	handle and connecting rod	piston pump	figure 3.12 can also incorporate counterweight or spring return devices
	crank and rocker mechanism, gear train	centrifugal pump	see Garg (1967)
legs and lower torso	connecting rod, foot pedal and return device (e.g., spring or counterweight)	piston pump	see Schioler (1975), p. 10
	pedal and spring return	diaphragm pump	adaptation of figure 3.16
	pedal	air diaplacement pump	figure 3.31
	rocking foot rests	bellows pump	figure 3.15
	direct	doons	figures 3.9a and 3.10
	walkway	picottah	figure 3.4
	walkway	gutters	figure 3.7b
	walkway	picottah-style doon	figure 3.9b
	B. Circular motions		
arms and/or upper torso	crank	screw	
	crank	water ladder	figure 3.18 small capacities
	crank and small gear train	rotary	see Eubanks (1971), and Hadeckel (1939)
	lever	semi-rotary	figure 3.28
	crank and windlass	bucket	
	crank and shaft	chain pump	figure 3.19
	crank and cam	piston pump	utilizes eccentric type gearing
legs and lower torso	horizontal axis treadmill or pedals (on lifter or separate with connecting shaft)*	paddle wheel noria Persian wheel tympanum	single unit (i.e., lifter and mill) cut transmission losses; see Schioler (1975) pp. 5-6; for standing support, require arm rest as in figure 3.17 pedaling usually done in sitting position
	horizontal axis treadmill or pedals connected via shaft	screw water ladder chain pump	see figure 3.25a as above
	horizontal axis treadmill and windlass	rope and bucket	needs human ability to turn and reverse rotation
	horizontal axis treadmill (or pedals) and cam	piston pump	with eccentric gear
	horizontal axis pedals and gear train	centrifugal pump	similar to Garg's (1967) device

*Vertical axis mills and pedals can be used, but require pinion gears to convert to vertical rotation.

In some traditional system where various fields are allowed to lay fallow for given time periods, the grass cover of these fields can often supply sufficient feed requirements. However, it may be necessary to supplement this grazing with grain, grain by-products, and/or foods not used for human consumption. In areas where such fallow land is not available (with modern technology and high demands for tillable land, this is often the case), an opportunity cost to allow land for grazing, feed, and shelter must be attributed toward maintenance of animals (Merrill, 1976). Of course, the cost of any manual labor which must be employed or allotted (i.e., family member) to maintain and drive the animal(s) must also be considered when making an economic analysis of using animal power. Non-dependence on imported fuels and spare parts is another factor making animal power more practical for developing farm areas.

Animals, like humans, vary in their ability to convert food energy into usable work depending on size, condition, and species. However, in general, they are about the same, or slightly higher, in this conversion efficiency as humans, i.e., 20-25 percent (Lewis, 1976). Likewise, depending on the individual animal, usable power from animals can be expected to be about 0.6 hp (Merrill, 1976). Starr (1971) reports more specifically that a horse will develop about 0.7 hp, and an ox can provide about 0.3 hp. Tests at the Indian Agricultural Institute in Pusa have shown that the average size bullock is capable of providing 120 lbs of sustained drawbar pull, while a camel is capable of about twice that (Molenaar, 1956). Such power capacities, plus the ability of an animal to work in a given situation (i.e., size, climatic conditions, training necessary), must be considered when matching animal power to a specific

water lifting device. Animals are usually allowed to work in 3 hour shifts since, like humans, they tire and produce less work.

Table 5.2 suggests some of the typical water lifting applications for animal power, including common transmissions. In general, animals are limited in such applications to pulling with a harness or pushing with their feet by means of a treadmill. However, a wide variety of mechanical systems to connect this power to water lifters are utilized.

Schioler makes a suggestion for improving two-animal sweeps. When two animals are harnessed side-by-side and connected to a single sweep arm, the outside animal must walk faster than the inner one, thus they tend to impede each other. If, however, the two animals are harnessed individualy to two separate arms placed diametrically across the sweep, they will not interfere with each other and can walk at the same pace--see Schioler (1957), p. 22.

5.4 Natural

"Natural" prime movers are the forces of nature which, without being converted to a different form, can provide energy to drive a water lifter, i.e., as opposed to mechanical drivers (see Section 5.2.4) which require the consumption and/or conversion of combustible fuels or electricity. Except for possibly having to pay a "users right" for some water and geothermal sources, the natural forces of wind, water, sun, and geothermal heat provide free forms of energy. This can allow applicable water lifters to operate with relatively low running costs.

Table 5.2 Animal power applications

Motion of animal	Transmission	Water lifter	Remarks
A. Reciprocating	rope and roller	mot	figure 3.1 this requires wasting energy on a non-lifting return trip
B. Circular	sweep, rope, pulleys	two-bucket lift	figure 3.2 method to convert circular motion to reciprocating action
	sweep connected to lifter by gears and shaft (i.e., animals walk only around sweep and must go over or under shaft)	paddle wheel tympanum Persian wheel noria water ladder chain pump screw centrifugal pump	figure 3.22 shows this arrangement with a noria; required where sweep tow path cannot surround water lifter, e.g., at shore of lake, canal, etc.; use of high ratio gear train can allow use with centrifugal pump
	sweep directly connected to lifter (i.e., sweep gears mesh directly with lifter and animal walks around sweep and lifter)	paddle wheel tympanum Persian wheel noria chain pump	elimination of shaft and gears, as above, cuts transmission losses
	horizontal axis treadmill connected by shaft and/or gear(s) to lifter	paddle wheel tympanum Persian wheel noria chain pump water ladder screw	see donkey-wheel in Schioler (1975) p. 14; normally limited to smaller animals

5.4.1 Wind

Windmills are currently in the upward stage of another, in a long series, of rise and fall cycles of popularity. As mentioned in Section 1.3, this present increase in usage is due primarily to the existing world energy situation. Although many designs have been developed throughout the ages, only a few basic ones are still in use. However, many major improvements have been developed, primarily to make the output power usable for electricity generation.

One of the simplest and oldest windmills is of the type shown in Figure 5.1. Normally, it is constructed by placing 8-12 poles (often bamboo) radially into a hardwood axle and fastening wire or rope between the outer tips of the poles. Cloth is then attached between the pole spoles to form a wheel of sails, usually about 17 ft in diameter. The sails are usually attached so that they can be furled about the poles when not in use or in high,damaging winds. Most "sail" windmills are permanently fixed to face into the prevailing wind direction as the one in Figure 5.1. However, a rotating mount, similar to those in designs to be discussed later, can be adapted to this type windmill to make it functional in wind from any direction.

Another simple, but higher speed windmill consists of a set of long, narrow blades (e.g., 5ft x 10 in.) fixed to a hub. In developing areas, this design is constructed of 3-4 wooden blades on a wooden or iron hub, and, like the sail type, are usually used to provide a rotational motion via gears or belts for rotary water lifters. One district in Thailand had 21,000 such "propeller engines" in a 1949 survey (Molenaar, 1956).

The large, Dutch-style windmills were the design of a previous age of windmill popularity. However, their spread to the United States (some

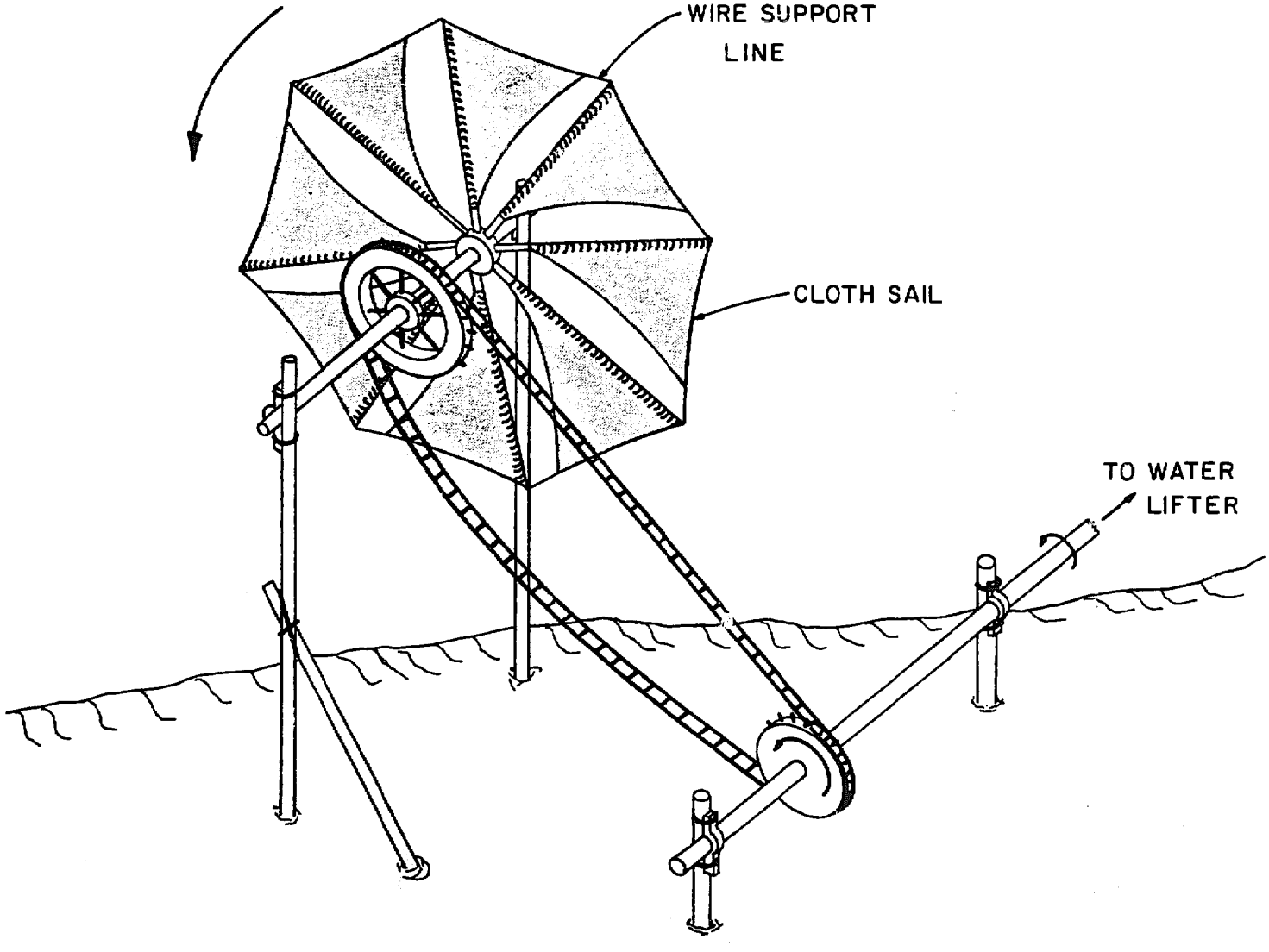

Figure 5.1 Sail type windmill with chain drive

even saw use on the windy plains of Kansas--Murphy, 1901) brought about the development of the American-style windmill which is now used worldwide. Many crude, inefficient designs have been concocted with scrap materials over the past century (see Fetters, 1972), however, wooden and/or metal designs like that in Figure 5.2 have become a standard for water lifting purposes. Several commercial variations of this basic design are also available which utilizes more, but narrower blades than in the previous figure. Although most of these mills utilize a cam mechanism to provide reciprocating motion for a piston pump many are attached to gear mechanisms which retian their rotary form of power.

Commerical windmills of this type range in cost from about $470 for 6 ft diameter mills (including sail wheel, guide vane, brake, turntable, and transmission) to over $4,000 for 16 ft diameter models. Metal towers for these assemblies to be mounted on usually range from about $44 for 3 ft heights to over $3,000 for 47 ft designs.

Another class of windmills has either vertical or horizontal shafts and rotates in the direction of the wind. One type in this class is constructed like a paddle wheel (mounted vertically or horizontally) and the wind is forced to blow on only the paddles on one-half of the wheel by a shield covering the other half--thus causing rotation. Such windmills have been tried throughout the ages (see Section 1.2), but in general have very low efficiencies and are restricted to wind from one direction (Murphy, 1901).

Two more recently popular designs in this class are shown in Figures 5.3 and 5.4. The savonius rotor can be quite simply constructed. A typical design consists of a 50 gallon drum, cut in half longitudinally, and the halves offset by about two-thirds of their diameter. When fixed to

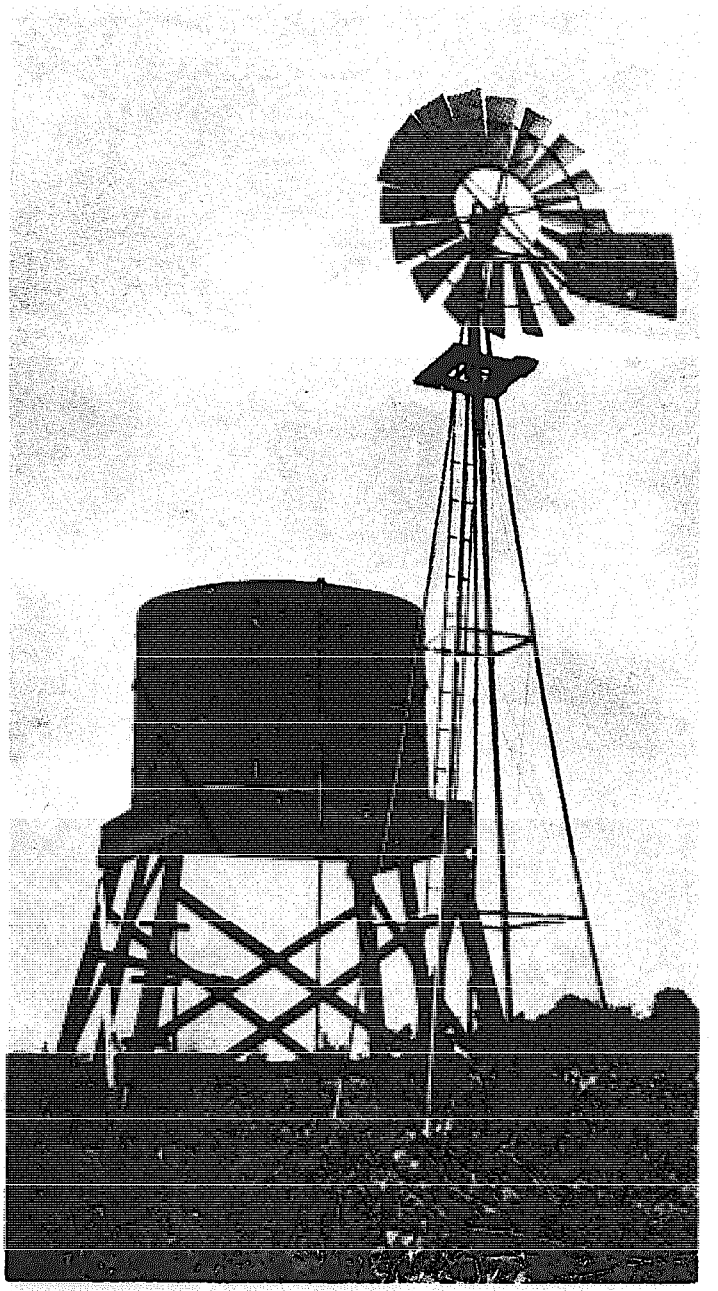

Figure 5.2 American-style windmill with storage tank

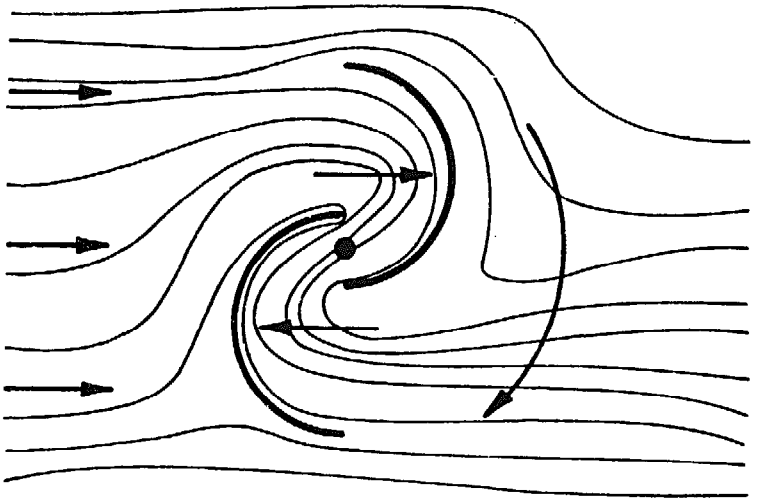

(a)

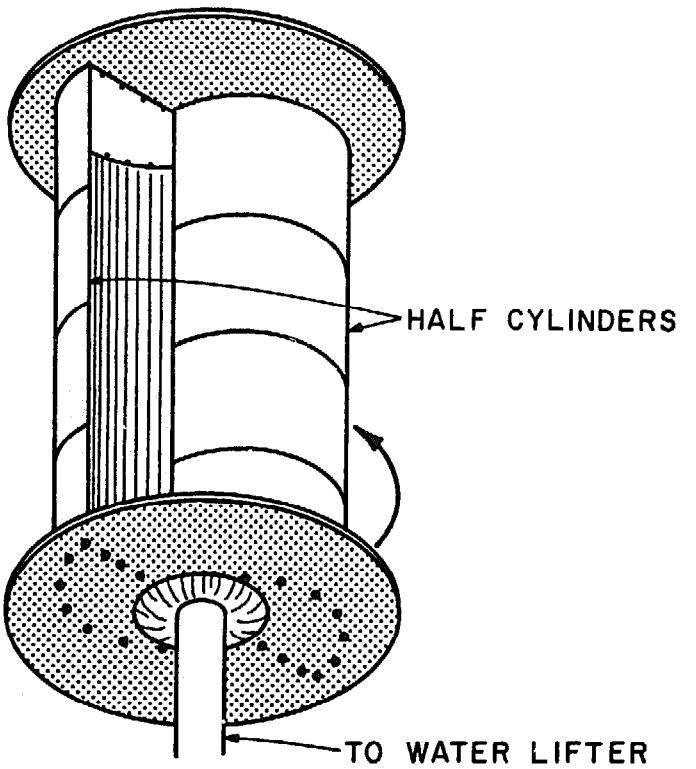

(b)

Figure 5.3 Savonius rotor; (a) air flow and (b) construction

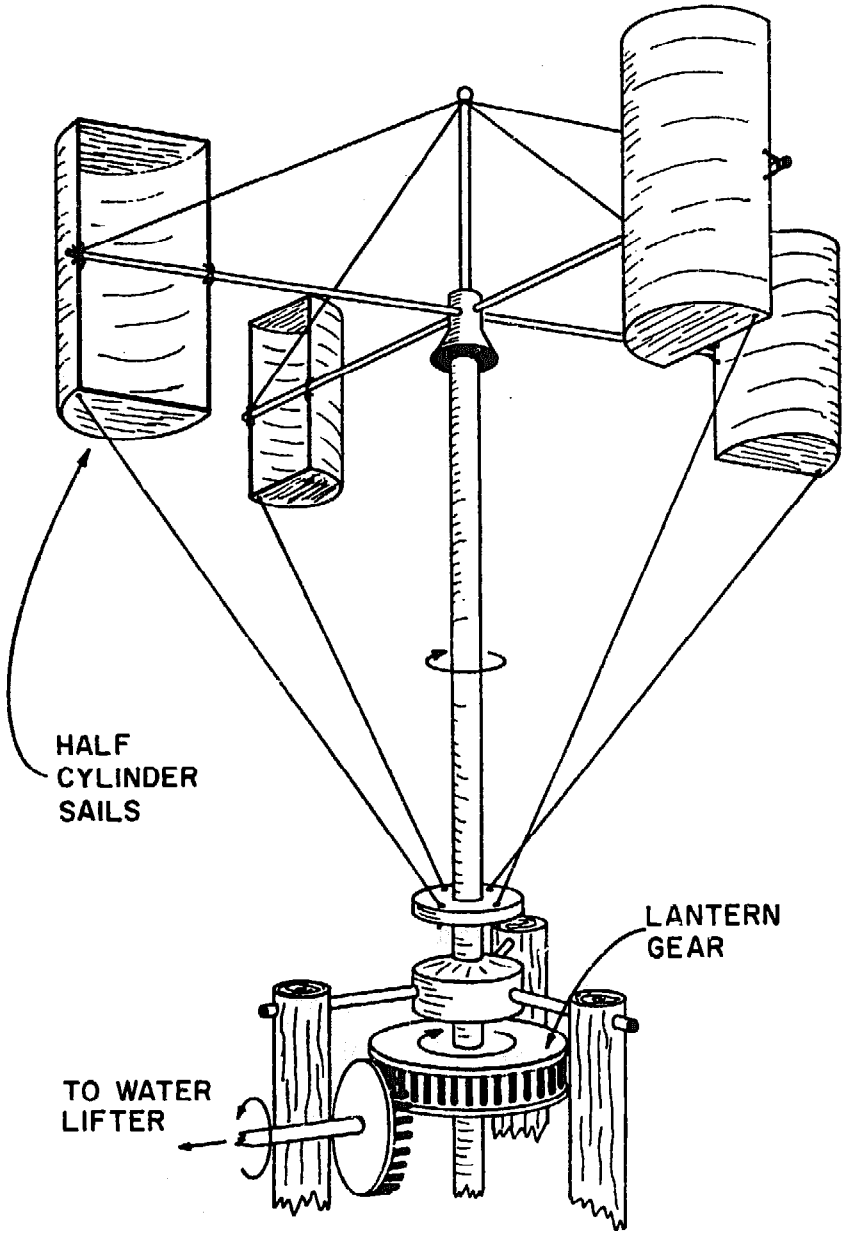

Figure 5.4 Anemometer-type windmill with lantern gear to transmit horizontal rotary motion

a vertical shaft, the wind will flow into one half, creating a rotating moment, and then "spill" into the other half cylinder, causing a similar effect. Savonious rotors rarely attain efficiencies above 31 percent, but due to their easy construction are often found in developing areas. (Performance testing has been done at Brace Institute on a savonius rotor--see Simonds and Bodek, 1964.) The anemometer-type windmill in Figure 5.7 is also easy to construct using cylinder halves and is also functional in wind from any direction.

For the most part, however, the American-style windmill is the most common for water lifting purposes, with some recent applications of the higher-speed propeller designs for use with centrifugal pumps. Much research is underway or being initiated to improve windmill designs, particularly for the generation of electricity (Putnam, 1948 and Hamilton, 1975). However, much of the new knowledge in this general area is being utilized for water lifting and other direct power uses. Work is also being done to evaluate the potential of wind power in various areas of the world to facilitate economic analyses of utilizing windmills (e.g., Latif, 1972).

Windmills such as the American-style are utilized for low-speed/low-power applications such as driving a piston pump, however, with a centrifugal clutch and appropriate gearing,they can be used to drive rotodynamic and rotary pumps (Golding, 1962). High speed/low starting torque designs, are more readily adaptable to driving rotodynamic pumps.

The Brace Institute utilized a three-blade "airscrew" windmill to power a vertical turbine pump which supplied water to a sprinkler irrigation system. This study was conducted in Barbados, West Indies. The pump was run at

2500-3500 rpm to deliver 150-200 gpm at a pressure of 20 psig to the sprinklers. The system was supplemented by a diesel engine for windless periods (Ionson, 1969).

Table 5.3 gives some typical water lifting applications of windmills. In general, since wind is a variable power source, two precautions are usually taken to insure water is available when needed. As in the Brace study, an auxillary power source (e.g., gas engine, electric motor) is kept in reserve for times of low or no wind. The other alternative is to provide a storage facility, e.g., a pond or tank (Figure 5.2), which is capable of holding sufficient water for the longest expected period of windless days. When a rotodynamic pump is powered by a windmill, the installation must provide the pump with a dynamic suction head or an automatically regulated supply of priming water to insure the necessary prime needed for pump operation--see Fateyev (1948), p. 277 (in translation). Except for occasional adjustments and lubrication, windmills have almost no operating costs.

5.4.2 Water

Where a sufficient flow or head of water exists, the energy of this water can be used to rotate a watermill, which can then be used to drive several types of water lifters. (To avoid confusion, it is convenient to refer to wheel devices which receive energy from water as "watermills" (just as windmills receive wind energy), and those which impart energy to water (e.g., noria, tympanum, etc.) as "waterwheels"--see Reynolds, 1070.) Depending on the amount of available flow or head, one or more types of watermills may fit the given installation and intended water lifter(s)

Table 5.3 Typical windmill applications

Type	Transmission	Water Lifter	Remarks
A. Horizontal-shaft windmills			
sail (figure 5.1)	on same incline shaft with	screw	see Reynolds (1970), p. 150
	on tower with chain and sprockets to horizontal shaft	paddle wheel noria tympanum Persian wheel water ladder chain pump	for tower arrangement, see Beaumont (1974);
	as above plus angle gear	screw	figure 3.25
	on tower with eccentric mechanism and connecting rod	bucket pump diaphragm pump	figures 3.14
propeller Figure 5.2	one angle gear and increasing ratio gear train	vertical- or incline-shaft rotary or rotodynamic pump	table 4.1; also see Fateyev (1948), p. 277
	two 90° angle gears and increasing ratio gear train and/or belts and pulleys	horizontal-shaft rotary or roto-dynamic pump	as above
American	angle gear to vertical shaft with increasing ratio gear train	vertical-shaft roto-dynamic or rotary pump	table 4.1
	angle gears or belts to horizontal shaft	paddle wheel chain pump water ladder noria tympanum Persian wheel	see "sail"
	above to incline shaft	screw	
	angle gears or belts, and increasing ratio gear train to horizontal shaft	horizontal-shaft rotodynamic or rotary pump	table 4.1
	eccentric mechanism to connecting rod	bucket pump diaphragm pump	figures 3.14
B. Vertical-shaft windmills			
savonius (figure 5.3 or anemometer (figure 5.4	90° angle gearing to horizontal shaft	paddle wheel tympanum Persian wheel noria water ladder chain pump	see "sail"
	incline angle gearing	screw	figure 3.25
	eccentric mechanism and connecting rod	bucket pump diaphragm pump	see "sail"
	increasing ratio gear train and/or belts and pulleys	vertical-shaft rotodynamic or rotary pump	well suited for axial-flow or helical pumps; table 4.1

(more than one water lifter is often driven off of the same watermill shaft). Table 5.4 summarizes some typical watermill specifications and applications discussed below.

When essentially no head is available, except for that which produces a flow (e.g. stream, river, canal), it is practical only to use an undershot wheel. The simplest to construct is the floating mill version (Bradley, 1912, p. 78), shown schematically in Figure 5.5a. It is installed so that its peripheral paddles (at least two at all times) are immersed in the driving flow. Figures 3.21a and b show such mills combined into a single unit with norias.

Because the efficiency of floating mills is rather low, another version of the undershot wheel, the Poncelet wheel, was developed (about 1800) which, when a suitable site is available, yields better efficiencies. As shown in Figure 5.5b, this mill requires the flow (or at least a portion of it) to be restricted to a channel, the width of the Poncelet wheel, and that a sluice gate be provided just upstream. In this way, a portion of the available flow depth is converted to a velocity head which can increase the power applied to the mill. Poncelet wheels can be expected to have efficiencies between 60 percent to rotate the mill. Figure 5.6a and b illustrate medium and high breast wheels, respectively. A low breast wheel is essentially the same as a Poncelet wheel.

A major loss in efficiency of a breast wheel design is that, unlike under and overshot wheels, the wheel is moving toward the incoming water rather than in the same direction, thus creating energy losses (e.g., for any breast higher than the wheel axle, a moment, counter to the falling-water moment, is produced). This counter moment can be reduced to some degree by the use of a sluice gate, as in Figure 5.6b. Breast wheels

Table 5.4 Typical watermill applications

Type	Eff (%)	H (ft)	D-Diameter (ft)*	Optimum* rpm	Transmission	Water lifter	Remarks
A. Horizontal-shaft watermills							
float mill (figure 5.5a)	30-45	(current flow)	10-50	$\frac{72.8}{\sqrt{D}}$	combined into single unit	paddle wheel noria tympanum	figures 3.21a & b
Poncelet (figure 5.5b)	60-80	3-10	2H-4H (> 14)	$\frac{42.1\sqrt{H}}{D}$	direct shaft, belts, or gears	above plus, Persian wheel water ladder chain pump screw	see table 5.3
Breast (figure 5.6)	40-70	6-15	H-3H	depends on breast height	above plus increasing gear train	rotodynamic or rotary pumps	
Overshot (figure 5.7)	60-85	10-50	0.75H	$\frac{41.8}{\sqrt{D}}$	eccentric mechanism	bucket-piston pump diaphragm pump	figures 3.14 see VITA (1975), p. 117
Pelton wheel	75-90	> 50	1-20	$\frac{76.6\sqrt{H}}{D}$	increasing or equal gear train	rotodynamic or rotary pumps	
Michell turbine	60-85	> 15	1-3	$\frac{72\sqrt{H}}{D}$	above plus eccentric mechanism	high-speed piston, plunger, or diaphragm pumps	
B. Vertical-shaft watermills							
tangent wheel	--	> 15	--	--	Same as Pelton and Michell; angle gears can allow use with horizontal-shaft rotodynamic or rotary pumps.		
turbine	80-90	> 15	1-30	50-220			

*after Merrill, R., 1970

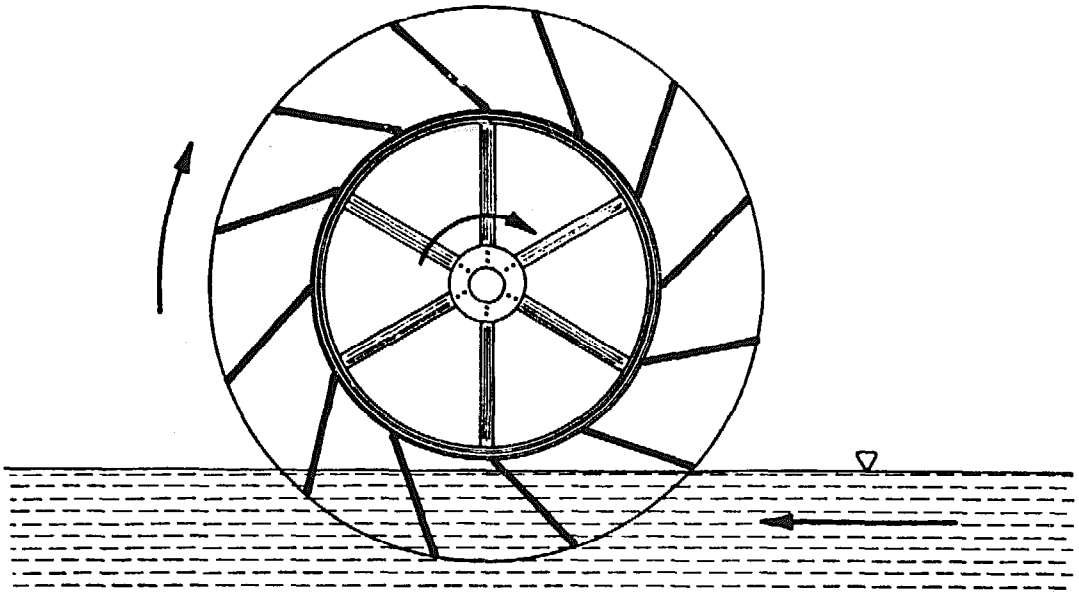

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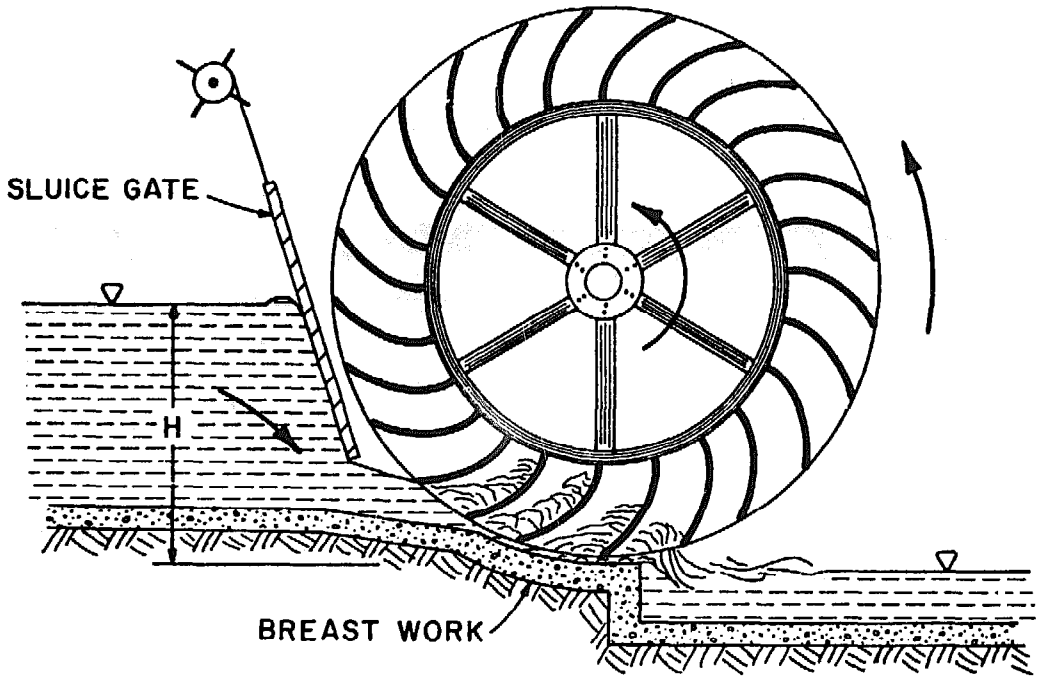

(b)

Figure 5.5 Undershot wheels; (a) floating mill, and (b) Poncelet wheel

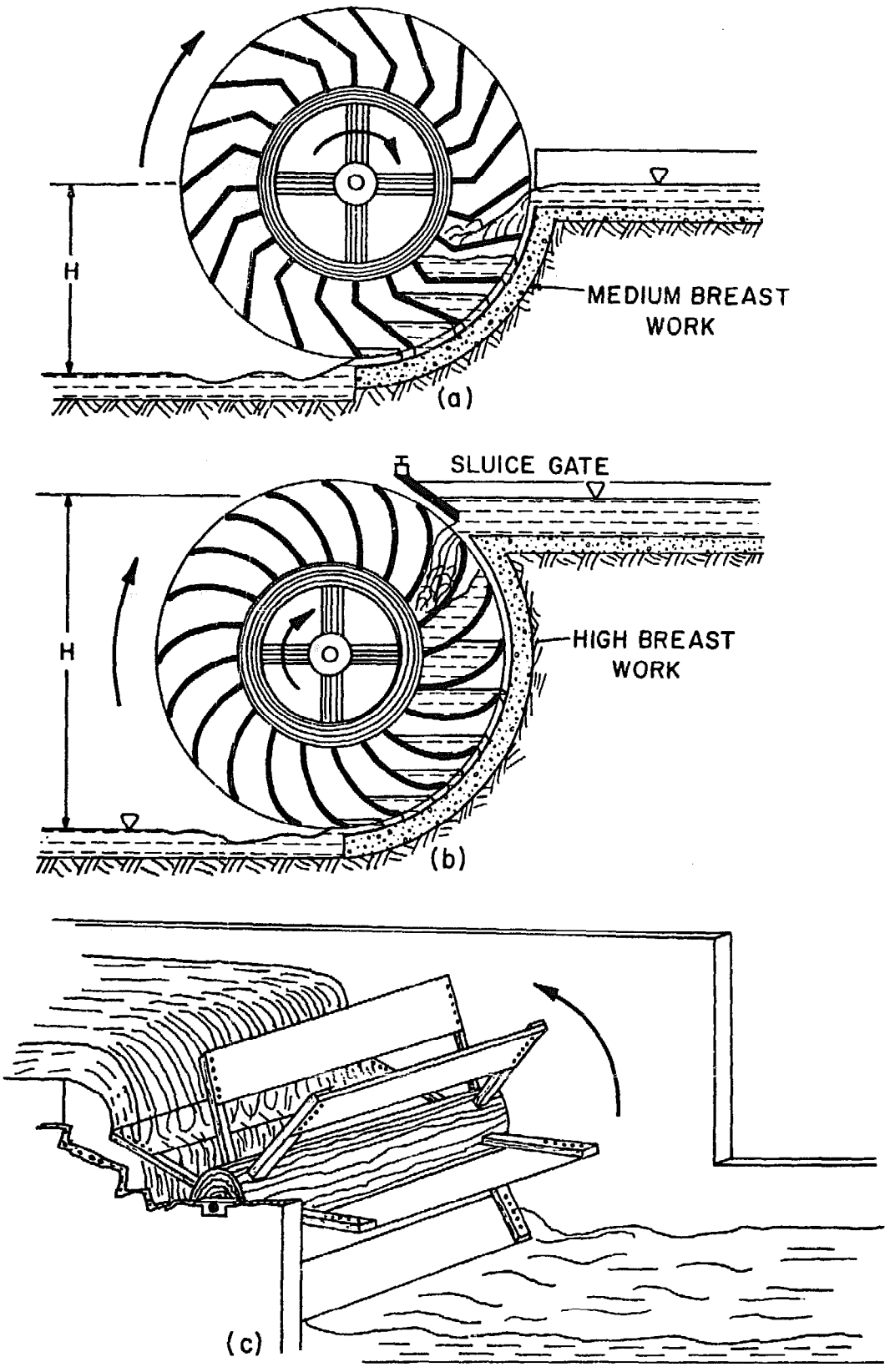

Figure 5.6 (a) Medium-breast wheel, (b) high-breast wheel with sluice gate, and (c) flutter-wheel

efficiencies usually range from 35-40 percent with lower breast works to 60-65 percent for higher breast works.

A rather simple, easy-to-construct version of the breast wheel is the flutter-wheel (Figure 5.6c) which is powered partially as an undershot wheel, i.e., impulse of flowing water, and partially as a breast wheel, i.e., weight of falling water. Although little information is available on this simple mill, it would appear to have much the same performance and applications features as a breast wheel if the paddles extend to the hub--unlike Figure 5.6c (see Rogers, 1905, Vol. 2, p.121). This design could be well suited to many developing areas with very light industry.

Overshot wheels can obtain some of the best efficiencies (60-85%) of the watermills which can be constructed of wood and/or metal with only low to medium technology. They are normally used when heads (H) of 10 to 30 ft are available. When used with a sluice gate, as in Figure 5.7, the power applied to the wheel is a result of both the impulse of the high velocity water from under the gate and the weight of the water falling within the wheel. The driving flow must enter the wheel at or beyond the vertical centerline to avoid the reverse moments encountered with breast wheels.

When heads higher than about 15 ft and some medium industry are available, higher efficiencies (80-90%) can be obtained by utilizing water-mills which are commonly called turbines. Due to the high pressures and velocities involved in a turbine's operation, they are made almost entirely of metal. Turbines are normally utilized to drive electric generators, however, with the proper transmission, turbines can be used to drive rotodynamic and rotary pumps.

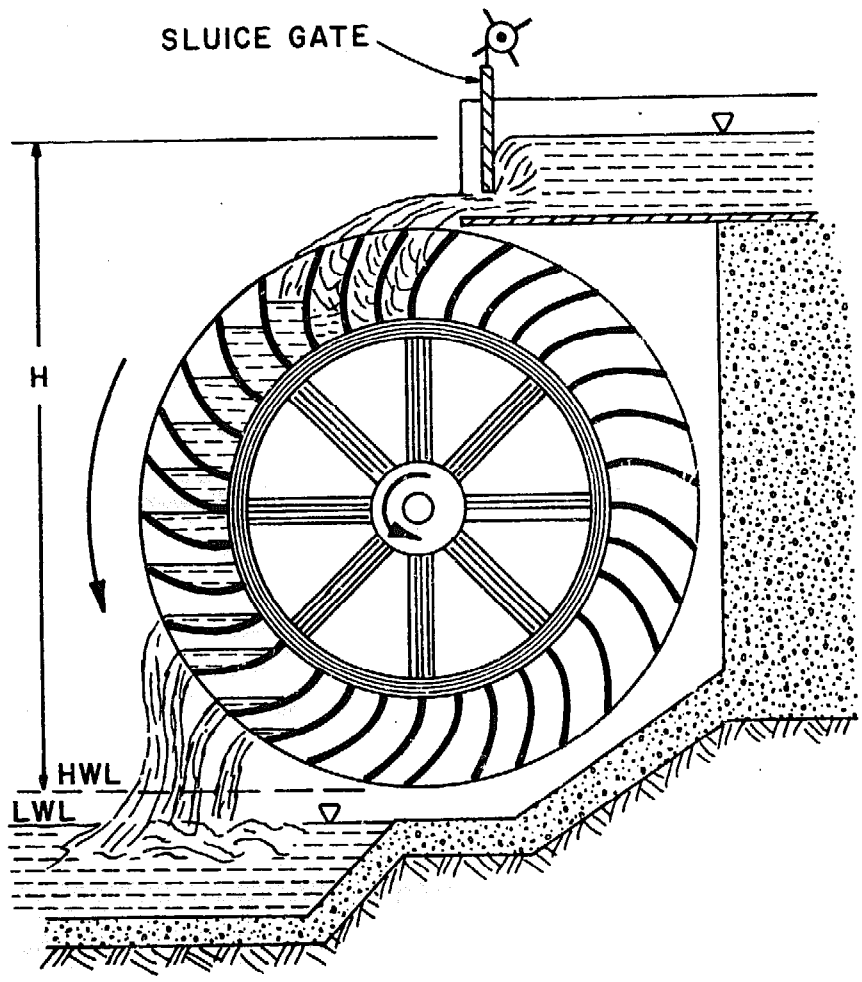

Figure 5.7 Overshot wheel with sluice gate

Although rarely in appropriate sites for irrigation or drainage water lifting, tidal water is another form of natural energy which, if properly harnesses, can provide an inexpensive source of power.

Wave action is a power source which has been adapted through various schemes directly to mechanical energy which can and has been used to pump water. In Monaco, three horizontal,side-by-side rotors drive cam mechanisms, which in turn reciprotate two double-acting piston pumps. The rotors are partially submerged about three feet from a cliff so as to be rotated by both incoming waves from above and out-going undertow from below. Bob Morgan described another device called a "Sea Horse" which he uses to drive a small electric generator, but could also be used to drive small water lifters directly (Eccli, 1974, pp. 102-104). As shown in Figure 5.8, this wavemill consists of two large, buoyant cylinders, set half of an average wavelength apart and each attached to a wire which passes under a pulley directly below the cylinder. As the cylinders bob up and down in the waves, they alternately pull (i.e., one rising while the other falling) on their respective wires. In Morgan's design, these wires drive a ratchet wheel which provides a continuous rotating motion to a flywheel (conserves energy during non-power periods) which in turn drives an electric generator. However, this same scheme could possibly be used to drive reciprocating water lifters, utilizing just the cylinders and wires, or to provide rotary power with the added ratchet wheel and flywheel.

Except for a few schemes, such as those mentioned, tidal power is still an undeveloped source of natural energy.

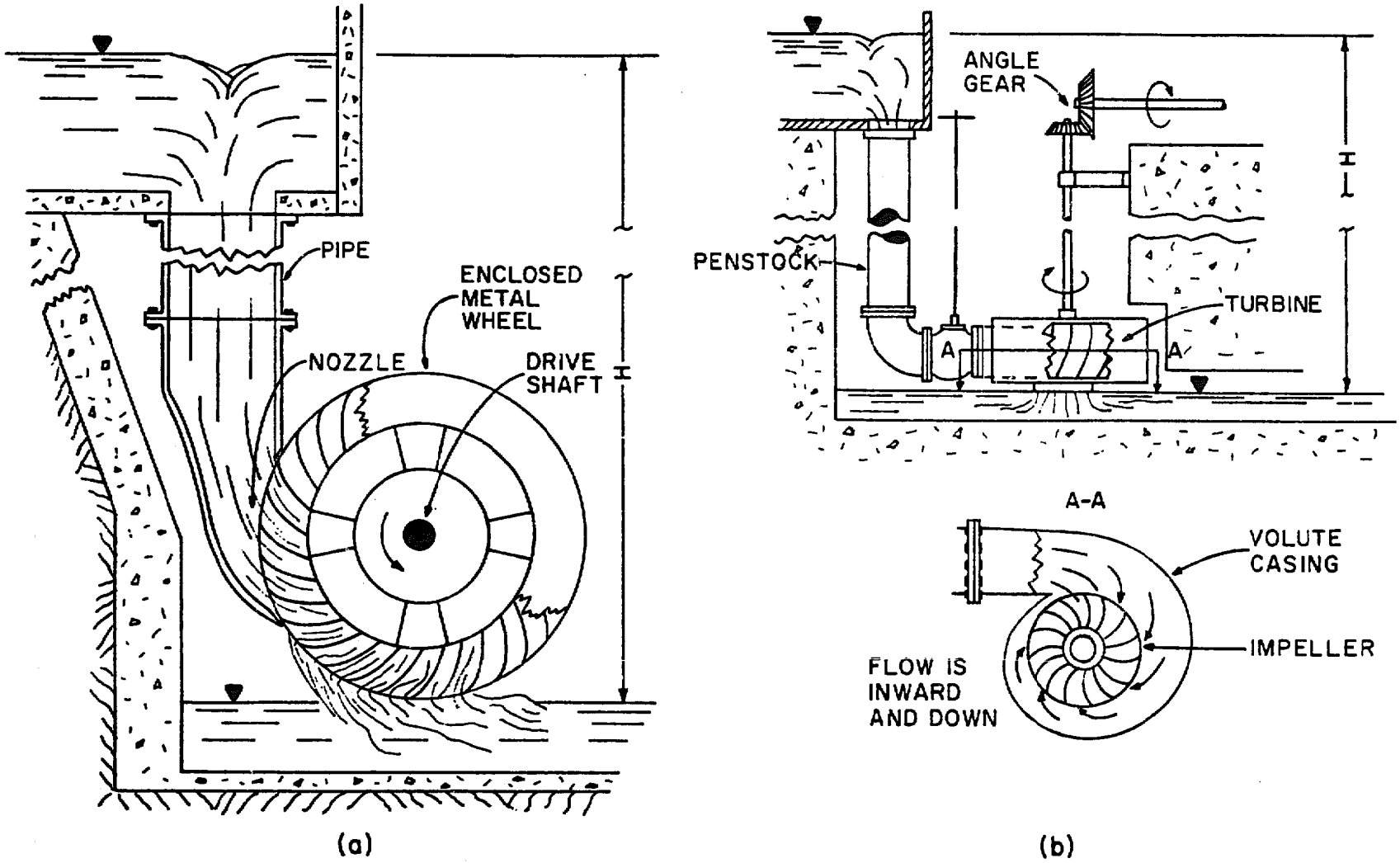

Figure 5.8 (a) Horizontal-shaft tangent wheel (Michell turbine), and (b) impeller turbine (Francis type)

5.4.3 Geothermal

Like tidal energy, geothermal (or terrestrial heat) energy is a "free' natural source of power which is being developed for several uses, but as of yet, not directly for water lifting. In some areas it exists at the ground surface naturally as geysers (e.g., Wairakei, New Zealand; Geysers, California), while in other places it can be reached by borehole. Currently, geothermal heat is used to drive steam turbines for electric generation or for industrial processes (e.g., paper pulp). Its conversion directly to mechanical energy which could be used to drive water pumps is currently unfeasible (i.e., low torque).

5.4.4 Solar

Solar energy is another source of "free" power which has just recently reached a level of technology development which provides for its conversion to mechanical energy. Unlike other natural resources, it exists in all areas of the world, although its degree of intensity varies with latitude, season, weather, and time of day. Although solar energy has long been used for such purposes as heating and drying, the current world energy situations has spurred interest in making its use for these purposes more efficient (i.e., for building heating, cooking, etc.) and in developing new uses. Section 3.4.2.2 included a discussion of the use of solar heating to expand a working fluid which directly pumped water by the displacement method. Many other projects are underway by various research organizations to convert solar energy to mechanical energy which can then be used to do work such as pumping water.

Near Mexico City, four prototype pumping plants are being used which will eventually (according to plans) be developed into a pumping system

with a 330,250 gpd capacity. Batelle Memorial Institute is also working to develop a 50 hp pumping plant. Beale, et at. (1971) report on work done at Ohio University to develop a free piston Stirling engine, which (as they suggest) would be of a size capable of such jobs as lifting water. Beason (1975) reports on a project by Farber, Ingley, and Prescott at the University of Florida to develop another piston-type engine. This engine utilizes a series of pistons, driven by a solar expanded refrigerant, to turn a crankshaft which provides rotary motion.

Many such projects are underway to harness solar energy, but for irrigation and drainage water lifting applications, there is still much to be done.

5.5 Mechanical

Mechanical prime movers are devices which convert electric current or the combustion of a fuel, e.g., wood, oil, gas, into mechanical energy which can then be used to drive a water lifter. A common terminology, which will also be used here, is to call fuel consuming devices engines, and electric prime movers motors. Although the number of engine and motor types constitutes a subject equally or more complex and lengthy than the one of water lifters themselves, this section briefly describes the basic operation and water lifting applications of mechanical prime movers.

Where sufficient electric energy is available, the electric motor can be the ideal prime mover for water lifters, particularly modern pumps. Either alternating current (AC) or direct current (DC) motors can be applied to water lifting requirements, however, due to performance characteristics (e.g., speed-load curve--see Pumping Manual, 1964, pp. 221-228)

and the usually more common availability of alternating current (Anderson, 1973), AC motors are more often utilized. Both types of motors have single or three phase varieties of construction, with single phase units used primarily for power requirements of less than 10 hp. Particularly when used outdoors, waterproof or weatherproff models are also usually specified to protect a motor from natural elements, i.e., dust, rain, ice, insects, etc.

The efficiency of motors (i.e.,in converting electrical to mechanical energy) increases with size. Table 5.5 gives some typical efficiencies of various hp sizes. Although the price of motors varies with factors such as manufacturer, size, construction, (and for used motors, condition), Table 5.5 also lists some typical 1975 prices in the United States. Geographic area will, of course, also vary price, e.g., in Southeast Asia, a locally manufactured 25 hp motor could be expected to cost closer to $700 (Molenaar, 1956).

Table 5.5 Typical electric motor efficiencies and prices

Size (rated hp)	Price (U.S. 1975 $)* New	Price (U.S. 1975 $)* Used	Eff (%)
1/12	30	20	70
1/4	65	40	
1/2	85	50	
1	123	55	
5	200	--	75
10	320	175	86
25	580	--	
50	1,030	290	90
100	2,800	1,300	

*Without accessories (e.g., starter); typical prices @ 1800 rpm, higher prices for higher or lower rpm models.

Where electric power is not economically available, large power requirements are needed, or mobility is desired, engines can be utilized. As with motors, there are a large variety of sizes and designs; e.g., air-cooled, water-cooled, two-stroke, four-cylinder, etc. However, the only major difference to be considered here will be among fuels. Engines using gasoline create a mixture of air and gas, ignite them under compression with an electric spark which causes combustion and thus power to a driving piston. By modification of such components as the manifold, carburetor, timing, and compression ratio, gasoline engines can be adapted to burn butane, propane, or natural gas (methane). Engines for diesel fuel obtain combustion and power by compression along of the fuel and air mixture, which causes ignition. Diesel engines can also be altered to burn a mixture of diesel and methane (called duel-fuel). Kerosene engines are also commonly used (particularly in developing countries--Molenaar, 1956).

The choice of which type engine to use will depend on availability and cost (of both engine and fuel) and power requirements. Table 5.6 list typical/values and the BHP-hr that can be expected from an engine using various fuels. In general, new gasoline engines have efficiencies of about 20 percent, diesel engines slightly higher, and natural gas engines about 15-17 percent. Of course, these efficiencies will vary with engine maintenance and condition.

Fuel cost is usually inversely proportional to the price and life of the engine with which it can be used. For example, while a typical 10 hp gasoline engine might cost about $440 and have a 9 year life, the same size diesel engine should last about 15 years, but cost about $1,000. (Air-cooled gasoline engines are usually allotted only about a 4 year life.)

Table 5.6 Typical energy values and performance of fuels

fuel	energy value BTU/gal	energy value hp-hr/gal	performance* BHP-hr/gal
gasoline	126,000	50	6-10
diesel	145,000	55	6-15
kerosene	118,000	47	5-10
butane	102,000	40	4-8
propane	92,000	36	4-8
natural gas	1,100/ft^3	0.4/ft^3	5-7/100 ft^3
electricity	--	1.34/kw-hr	0.5-1.2/kw-hr
coal			
bituminous	13,000/lb	--	--
lignite	7,000/lb	--	--

*after Pair (1969)

Again, geography will influence cost, e.g., in Asia $1,000 might buy about a 3-5 hp engine. A few other typical U. S. prices for gasoline engines are:

3 hp (1 cyl.) -- $ 100

6 hp (1 cyl.) -- 320

20 hp (2 cyl.) -- 720

30 hp (4 cyl.) -- 950

65 hp (4 cyl.) -- 1700

While, for comparison, a 3 hp diesel sells for about $700, and a 30 hp is about $2,300. Regular maintenance replacement parts (e.g., lube, plugs, filters) are usually about 15 percent of fuel costs. In addition, repairs on an engine can usually be expected to be about 200 percent of original cost, over the engine's life time.

The choice then between which type of engine or motor depends on their prices and availability, the price and availability of fuel (or

electricity), the amount of use (i.e., both lift time and running intervals), user's preference, and power requirement. The following is a common guide to selection by power size:

less than 7-1/2 hp -- gasoline engine or electric motor

7-1/2 - 40 hp -- gasoline or 3-phase electric

40 - 150 hp -- gasoline or diesel (diesel if more than 1000 hr/yr)

more than 150 hp -- diesel

One aspect of user's preference is the ability to obtain skilled attendants to operate and maintain these mechanical drivers. This is a particularly common problem in developing countries (Molenaar, 1956).

Among the basic transmission components are: V-belts, flat-belts, gears (parallel and angle), silent chains, hydraulic-fluid couples, friction clutches, flexible-shafts (e.g., universal joint). A common arrangement for driving a vertical turbine pump is with an engine through a standard, right-angle, pump head transmission. Of course, where the engine or motor, and pump speeds are matched, they can be operated without a transmission, i.e., close-coupled. Another form of transmission, but usable with only a few specialized water lifters (e.g., submersible centrifugal, air-lift, and diaphragm), is compressed air. It, in effect, transmits power from a compressor engine to the lifter. Hydraulic fluid can be similarly used in some applications (see Mexican solar pump in Section 5.2.3.3).

For driving modern pumps, mechanical prime movers have been the primary source of power. However, the changing world energy situation is causing many consumers to improve mechanical operations and/or consider natural energy sources to drive their water lifters, particularly in developing countries.

Chapter 6

Selection

6.1 Introduction

As should be evident from the great number of water lifters and prime movers reviewed in the preceding chapters, selection of the best lifters/mover combination for a specific application must involve quite a narrowing-down procedure. This procedure can be quite complex for modern pumps and engines (or motors), however the selection process in general comprises three basic areas of consideration; (a) availability and adaptability, (b) water requirements, and (c) cost.

6.2 Availability and Adaptability

The availability of goods and services will be the first factor to narrow the field to types of water lifters and drivers which can be utilized for a given application. Of course, with enough capital, any water lifter can be provided or built anywhere in the world, however, normal economic feasibilities will render some pumps unavailable in many areas, particularly in the agricultural regions of developing countries. This availability goes beyond just the initial acquisition of a water lifter and driver. Also included are the availability of spare parts, fuel (or electricity) of the proper quality and in sufficient amounts, and labor, trained to operate and/or maintain the devices.

If a pump and driver are to be bought commercially, the ability to order them in a geographic area and at a given time must be considered. If the water lifter is to be built (e.g., noria, water ladder) the necessary construction materials must be available. In either case, personel capable

of building and installing the devices must also be available. It should also be noted that although the use of natural or mechanical drivers does not directly employ individuals as does a manually-operated water lifter, the employment needs for the light or medium industry to locally produce natural and mechanical drivers can often provide more occupational opporturnities than would the need for individual water lifter operators.

Although assistance programs often provide developing regions with new water lifting equipment, sufficeint training and/or spare parts are sometimes not made, nor kept, available. Thus, in many instances, water lifters fall into disuse and eventually, when left to natural elements, become unrepairable (Fannon and Frink, 1970).

Not only must the availability of a fuel or electricity be considered, but also their quality. Fuels, particularly in developing countries, are often of such low octane or contain too many impurities (e.g., dirt, water, etc.) to make them unusable. If natural prime movers are to be used, their energy potential must be evaluated at the water lifting site--e.g., mean wind or water velocity, daily solar radiation.

In addition to various water lifters and drivers being available for a given installation, they must also be physically adaptable. For example, as mentioned in Chapter 3, some pumps are not well suited for pumping abrasive water. Also, certain prime movers may not be environmentally acceptable to a site (e.g., noise, air pollution).

Likewise, the environment may not be conducive to optimum prime mover operation. As previously mentioned, engines and motor perform poorly when they are too hot, become clogged with dust, rust from exposure, etc. Similar consideration must also be given to manual and animal prime movers. Poor environmental conditions, such as heat, humidity, dust, and insects,

can quickly tire man and animal, causing loss of water lifting performance. In such conditions it may be advantageous to provide supplemental power sources. For example, when dust is a problem, the wind may be strong enough to drive the water lifter via a windmill. As drivers using solar energy become more available, they would seem the ideal power when the heat is too great for man or animal.

6.3 Water Requirements

After the number of water lifters usable for a given application has been reduced by availability and adaptability, possible water lifters must then meet the water requirements for the situation. As discussed in Section 2.2, these are basically the discharge and total head, however the NPSHR and power needs should also be kept in minds if applicable.

Throughout the preceding chapters, the Q and H ranges for various water lifters and pumps have been given. Figure 6.1 presents a guide to the selection of positive displacement and rotodynamic pumps based on typical H-Q ranges. The gray areas serve only as rough boundaries and do not represent absolute limits. Once such an examination of ranges (see also Figure 4.8) has narrowed the field to a few types of pumps, manufacturer's charts, should be consulted to find the optimum size and design. These charts are a performance composite of several pumps. From this selection, the performance curve can be obtained and compared to the H-Q curve of the pumping system (see Figure 2.1). The intersection of the system and pump curves indicates the H and Q at which they will operate. This point should also correspond to as near as possible the maximum efficiency of the pump. If the pump is to operate over a range of discharges or heads, the efficiency curve should be as flat as possible throughout that range.

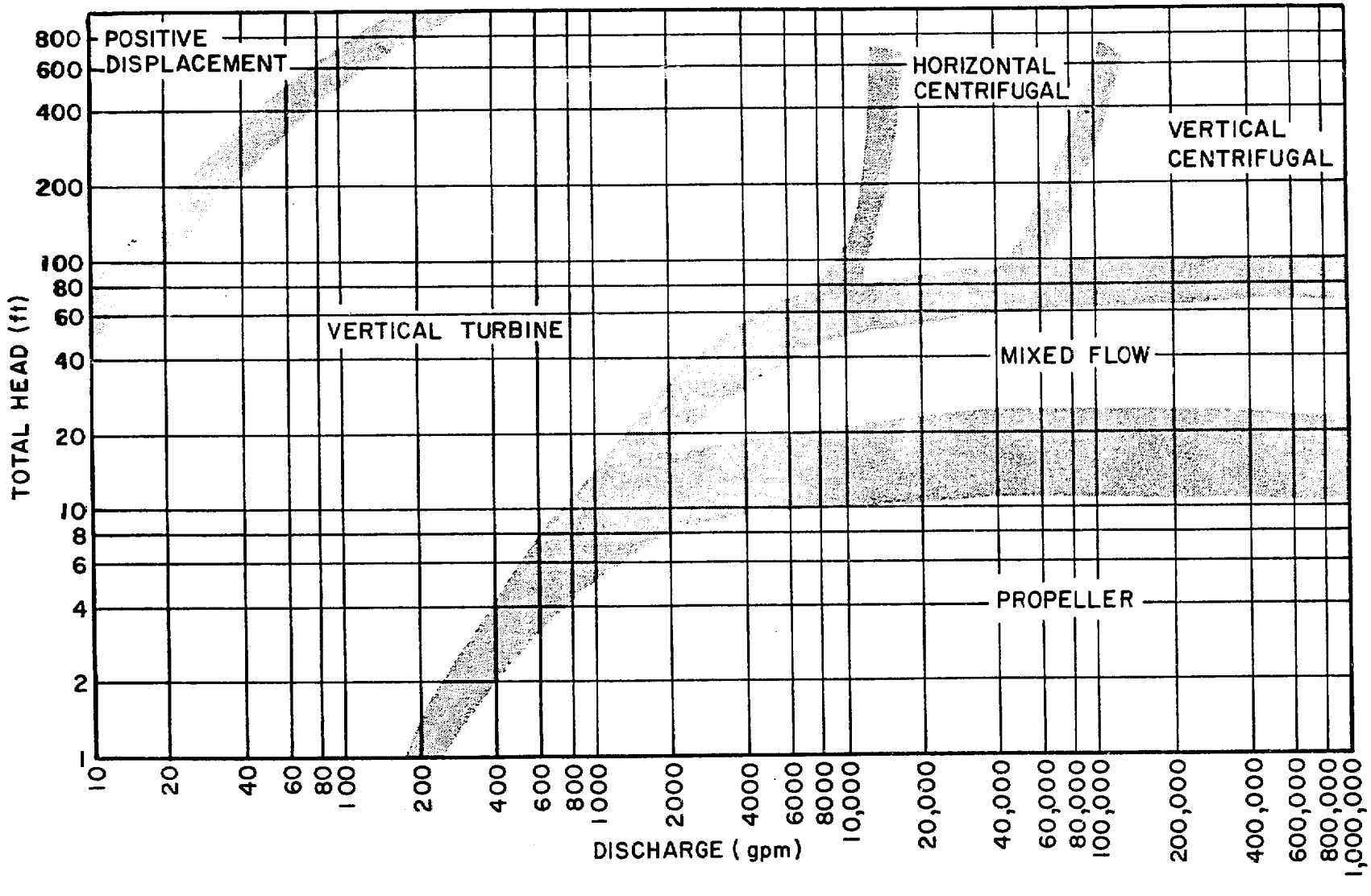

Figure 6.1 Pump selection guide based on H-Q performance (after Finch, 1948, and ECAFE, 1973)

Such systematic selection is not usually possible when dealing with the less sophisticated water lifters, such as shadoofs, mots, norias, etc. Although these devices are often built by trial and error (Schioler, 1975) to fit the given installation, a careful analysis of the head and discharge needs, as well as available power (e.g., animal, slow stream, fast wind, etc.) can allow selection of a good water lifter. Furthermore, as was shown by Figure 2.3, H-Q curves can be developed for any water lifter--even one as simple as the bucket. Such performance curves can be a great asset in improving the application of many of the less sophisticated water lifting devices.

6.4 Cost

After the above factors have been considered in the selection process, those water lifters which appear applicable should then be evaluated for economic feasibility. The initial cost alone of some water lifters and pumps may be too great to be economically competitive with others. However, in some instances, a slightly higher initial cost for higher quality may be offset by lower operating and maintenance costs. Likewise, an economic analysis of the pumping system, i.e., pipe, valves, etc. (if one exists) should be considered in relation to the required pump.

In addition to first costs of the water lifter and system (which may include sinking a well) which should be evaluated as depreciation and interest over the projected life of the equipment, other fixed costs (i.e., taxes and insurance) and operating costs (i.e., power, maintenance, and labor) must be evaluated. The following example illustrates how such an economic analysis may be considered for a mote.

Example 6.1 (after Molenaar, 1956):*

Two pair of bullocks and three men are employed to operate a mote which requires 6 hours of operation to provide 1 acre-inch of water with a 30 ft lift.

1.	Initial investment:	
	a) Well digging and lining	$300.00
	b) Mote and installation	50.00
	c) 4 bullocks (50% of value charged to water lifting)	300.00
	Total investment	$650.00
2.	Overhead charges:	
	a) Interest on investment** (@ 10%)	$ 65.00
	b) Depreciation of equipment**	
	well (40-year life equals 2½%)	7.50
	mote (5-year life equals 20%)	10.00
	bullocks (10-year life equals 10%)	30.00
	Total annual overhead	$112.50
3.	Operating costs per acre-in. (i.e., 6 hours)	
	a) Bullock feed (@ $0.12/hr per pair)	$ 1.44
	b) Labor wages (@ $0.10/hr per man)	1.80
	c) Repairs	.05
	Total operating costs per acre-in.	$ 3.29

* Costs adjusted to U.S. dollars (1975).

** Interest and depreciation calculated on by the straight-line method.

This type analysis can be developed for any water lifter to observe the annual and operating costs. Figure 6.2 presents the results of such economic analyses for several water lifters used in developing countries in such a manner as to compare them for selection purposes. Note that this figure is for a constant head and varying discharge, however other variable combinations can be utilized.

Because not all water lifting operations can easily be evaluated in monetary units, the following example is used to illustrate cost in terms of food consumed. It also analyzes the power and efficiency of the manual operation for a bucket-piston pump.

Example 6.2 (from Allison, 1975):

1. Basic parameters:

   a) One small man under tropical conditions can provide about 2200 ft-lb/min (0.067 hp).

   b) Human efficiency in converting food to mechanical work (beyond basal metabolism) is about 20%.

   c) Work capacity of one man at 2200 ft-lb/min is about 5 hrs/day (excluding rest periods).

   d) A boro crop requires about 33.3 inches of water for a season of 120 days.

   e) Pump efficiency is about 50%.

   f) Crop yields 2,600 lbs of rice per acre.

   g) Area irrigated by single family unit is about 0.5 ac.

2. Calculations:

   a) Energy input = 2200 ft-lb/min = 36.6 ft-lb/sec.

   b) Energy delivered to water (50% eff) = 18.3 ft-lb/sec.

   c) Energy required to lift 1 ft^3 of water 10 ft = 62.4 lb/ft^3 x 10 ft = 624 $ft\text{-}lb/ft^3$.

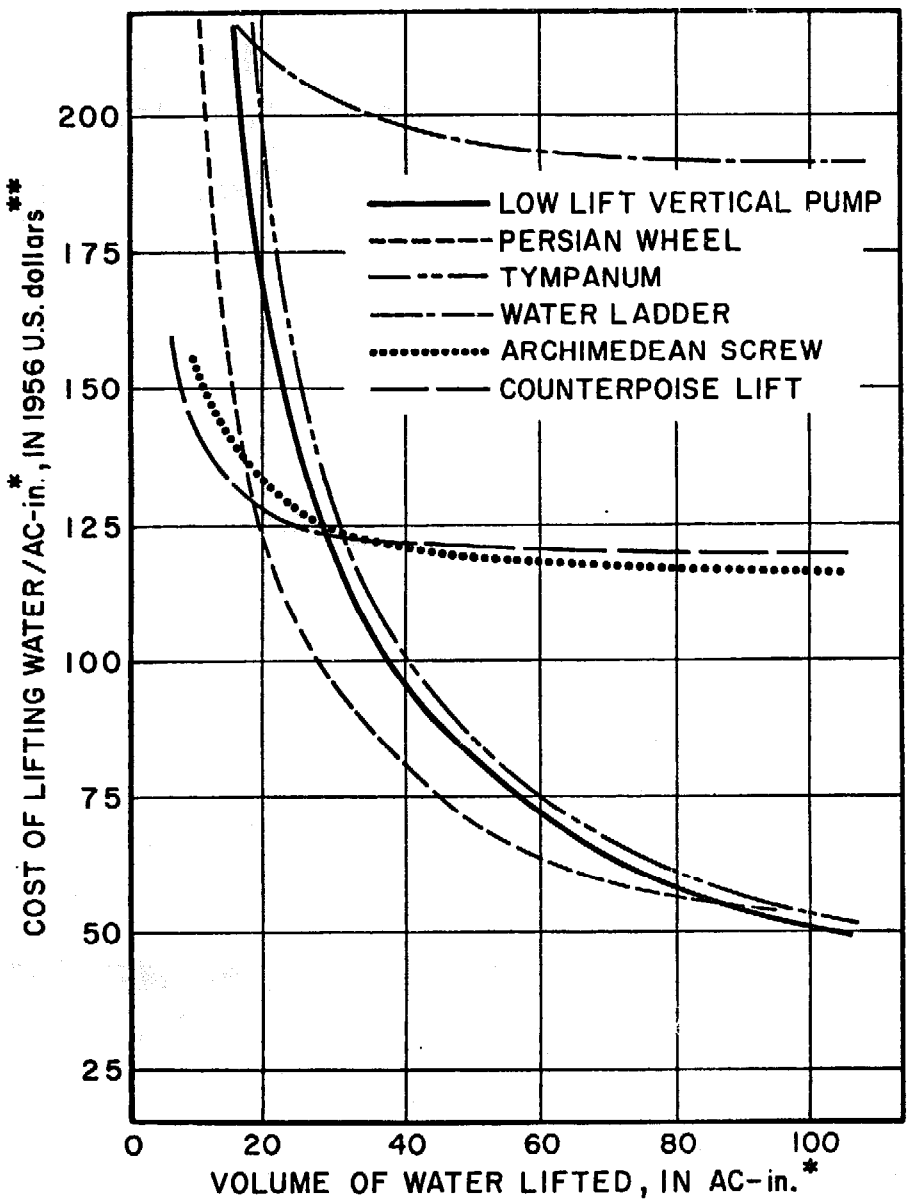

*OR HA-cm (1 HA-cm = 0.97 AC-in.)

**U.S. $1.00 (1956) = U.S. $1.85 (1975)

Figure 6.2 Comparative cost of lifting water to a height of 5.0 ft using various devices (from Molenaar, 1956)

Example 6.2 - Continued

d) Approximate discharge = (18.33 ft-lb/sec) ÷ (624 ft-lb/ft^3) = 0.03 ft^3/sec = 13.5 gpm.

e) Water required = 33.3 in. x 0.5 ac. = 16.7 acre-in. = 450,000 gallons (U.S.).

f) Time required = $\frac{450{,}000 \text{ gal}}{13.5 \text{ gpm}} \times \frac{1 \text{ hr}}{60 \text{ min}} = 556$ hours

i.e., this is less than the 5 hr/day working limit over the 120 day season.

3. Food required to generate energy:

a) To work at 2200 ft-lb/min with a 20% efficiency, requires man to have an energy input =

$$\frac{2200 \times 60}{0.20} = 660{,}000 \text{ ft-lb/hr.}$$

which at 3087 ft-lb/calorie = 214 cal/hr.

b) In 556 hours of pumping, the worker will use

$$556 \times 214 = 118{,}000 \text{ cal.}$$

c) At 1814 calories per lb of rice, this is equivalent to

$$\frac{118{,}000}{1814} = 66 \text{ lbs of rice.}$$

d) This energy input of rice required for the lifting of water is thus about 2.5% of the expected 2,600 lb yield.

These examples of cost analyses have been presented to illustrate their use in the selection of water lifters and prime movers. When coordinated with water requirement, availability, and adaptability considerations, such analyses become part of a systematic approach for efficiently matching water lifter and driver to a given application.

Chapter 7

Improvements and Research Needs

7.1 Introduction

The current state of water lifting methods in the world, as seen through the preceding chapters, varies from ancient to futuristic. With this vast difference in technological levels, emphasis in the past has all too often been of refining recent advances or developing new variations for sophisticated applications. However, the present world energy situation and international assistance organizations have called attention to the need for improving the often grossly inadequate methods used in developing countries. These improvements must be done without making the improved methods dependent on imported parts or fuel for maintenance and operation.

7.2 Modifications to Existing Methods

Additional studies are needed to determine designs and applications of existing methods which maximize efficiency. Too often traditional devices have been passed along for generations without any thought toward efficiency. Even in developed nations using modern pumps, emphasis is on maximum discharge for most irrigation and drainage purposes. However, the need to conserve energy has focused attention on efficiency.

The tympanum study, mentioned in Section 3.3.1.6, which compared the discharge performance of various designs was a step in this direction. However, additional research was suggested there to include power and efficiency analyses. Similarly, the SEATO thesis in Section 3.3.1.2 developed performance characteristics of just one size and design of a water ladder, which was powered by one type of prime mover. The performance

of other water ladder designs, with a variety of prime movers and transmissions needs to be studied also to better evaluate its application and provide criteria for selection.

With such studies as the two above serving as basic examples, similar research into the performance of other water lifters needs to be conducted. As mentioned throughout this paper, data on many devices is either nonexistent or available in only a limited quantity and quality for a scattered or narrow range of capacities, heads, and designs. A survey study is initially needed to determine the present levels of usage and possible benefits of modification for each type of water lifter. In this manner, a priority for detailed performance studies can be made to organize a thorough research program. Through the review of references for this paper, some specific lifters which have a lack of data, but would appear to benefit from such studies include: (a) the mot, particularly the circular mot driven by other than animal power; (b) the counterpoise lift and doon, with emphasis on counterweight placement and weight to minimize manual effort without the present trial-and-error construction techniques; (c) the picottah; (d) the bellows (as partially undertaken by IRRI); and (e) all screw and wheel devices with particular attention to presenting performance as a function of size, power, and speed of operation (i.e., rpm). Among the missing data on most of these devices is cost. Some basic cost parameters such as cost of construction or initial purchase, and of operation, need to be established to provide a practical component for the selection process (Section 5.3).

These studies must include a thorough program encompassing a survey of user's needs, design, testing and evaluation. Such a program was undertaken by Battelle Institute on its AID hand pump and serves as a good

example for further projects (Fannon and Frink, 1970). The feasibility of manufacturing these improved designs with local industry must be kept in mind during these studies. Not only does this minimize foreign dependence, but also increases local employment.

A few specific improvements which might be considered are; (a) the use of flexible tubing in the construction of tympanums and screws (see Figure 3.47a), (b) use of multiple pulley systems to reduce load and therefore animal size or number in mots, and (c) the increased use of flap valves in devices which require submergence of a container (e.g., gutters, shadoof, etc.). An idea, similar to that of the Ag Bank's to build Persian wheels from truck differentials (Svendsen, 1975), is to use automotive rear axles, set vertically on one end, for a circular sweep which can be used with animal power to drive wheel-type water lifters. Specifically, a horizontal arm can be welded (or otherwise attached) to the wheel at the upper end of the axle from which to harness the animal, while the drive-shaft from the water lifter can be attached to the differential--where the automitive drive-shaft was originally connected. Additionally, combinations of prime movers should be studied, e.g., the use of bicycle and manual power in rotary devices, using wind- or watermills with several rotary lifters, and making prime movers more economical by time-sharing among other duties. The improvement of existing prime movers and transmissions is equally as important toward increasing overall water lifting efficiencies. Prime mover studies should not be limited to mechanical methods. Programs to optimize wind- and watermill efficiencies could follow a format of planning, testing, and evaluation similar to that advocated above for water lifters. Coordination of physiological information on manual and animal power with the designing of water lifters is another area which

could substantially improve and encourage the use of often under- or unemployed labor resources. The linkage and gear system developed to allow manual power with a centrifugal pump is a good example of such designing (see Section 5.2.1).

Although such projects can undoubtedly improve water lifting methods, without an equal amount of effort to distribute information of new developments, they are of little use. In addition, education in operating and maintenance techniques must accompany any device into the field to avoid inefficient performance and/or breakdown with later abandoment. The introduction of modern pumps into a developing region should eventually lead to the development of the light or medium industry in that region which can supply and service water lifting operations. This can also create employment for individuals replaced by mechanical drivers (Wade, 1975). A shift in attitudes (by education) is also needed to reduce the emphasis often placed on using larger or more modern devices. The use of animal power should be particularly encouraged in the many developing areas where working livestock is in abundance but often stands idle. In these areas, animal power is usually found to be cheaper to utilize than mechanical power when evaluated on an annual cost basis (Svendsen, 1975).

7.3 Technological Gaps

Although many improvements to water lifters are possible within the limitations of current technology, there are also several advancements which will require the discovery of new technologies and refinement of areas which are just now at the threshold stage. These are primarily in the generation of usable energy, e.g., solar, geothermal, nuclear, tidal.

Reynolds (1970) writes, "...man must pay more attention to the development of natural power, conserving where he can the world's depleted stocks of fuel."

The National Academy of Sciences (1972) specifically advocates research to develop semi-conductor solar generators and working fluid solar engines (see Section 5.2) to lift water. The automotive world has recently reminded us that the internal combustion engine is relatively inefficient, but still capable of major improvements. Nuclear power originally appeared as an answer to natural energy resource shortages, however, environmental and safety problems (or potential problems) are delaying development of this resource.

Inventories of the world's energy potentials are also needed to plan application of various prime movers in different geographic areas. Long, accurate records of such resources as wind and solar energy are usually available in developed countries, but often non-existant in developing areas.

Policies regarding the economics of our resources must also be changed in many areas to both promote conservation and encourage more, but smaller users. The economics of obtaining energy from recycled material (e.g., methane from plant and animal wastes) must be made advantageous so as to both conserve untrapped resources and to utilize to the fullest those resources already in use. As mentioned in previous sections, our technology is too often aimed at the large industries and/or at refining already sophisticated devices. However, as E. F. Schumacher advocates (Wade, 1975), improvements and advancements in technological methods and equipment need to be made "suitable for small scale application." The solar pump, described in Section 3.4.2.2, is an example of such a need to "scale down." At the

present prototype size and cost, this water lifting method is too large and costly for the low-acreage farmer in developing countries--although he could probably benefit the most from such a "free" natural-energy pumping method.

This is not to say that water lifting advancements should be retarded, but only that they should include small-user applications. Just as engineers at the turn of this century thought that no pump could outperform the steam pump (see Section 1.2), the current level of pumping technology must not be considered the last work. Advances such as the KROV pump (Keller, 1975) and the osmotic pump (Levenspiel and de Nevers, 1974) may eventually turn out to be among the commonplace water lifters of the future.

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APPENDIX

Table A.1 Length conversions and abbreviations

For example, read: 1 inch = 2.54 centimeters

unit \ abbr.	in.	cm	ft	m
inch	1.0	2.54	0.0833	0.0254
centimeter	0.394	1.0	0.0328	0.01
foot	12.0	30.5	1.0	0.305
meter	39.4	100	3.28	1.0

1 mile (mi) = 1.61 kilometer (km) = 5280 ft

1 yard (yd) = 3 ft

Table A.2 Area conversions and abbreviations

For example, read: 1 square foot = 0.093 square meters

unit \ abbr.	ft^2	m^2	ac	ha
$foot^2$	1.0	0.093	2.30×10^{-5}	9.3×10^{-6}
$meter^2$	10.76	1.0	24.7×10^{-5}	1×10^{-4}
acr	43,560	4,047	1.0	0.405
hectare	107,630	10,000	2.47	1.0

1 centare (ca) = 1 m^2
1 $in.^2$ = 6.45 cm^2
1 ft^2 = 144 $in.^2$

Table A.3 Volume conversions and abbreviations

For example, read: 1 cubic foot = 0.0283 cubic meters

unit \ abbr.	ft^3	m^3	l	gal	ac-ft
$foot^3$	1.0	0.0283	28.3	7.48	2.30×10^{-5}
$meter^3$	35.3	1.0	1,000	264.2	8.11×10^{-4}
liter	0.0353	0.001	1.0	0.264	8.096×10^{-7}
U.S. gallon	0.134	0.00379	3.79	1.0	3.07×10^{-6}
acre-foot	43,560	1,233.5	1,235,131	325,892	1.0

1 U.S. gallon = 0.833 Imp. gallon = 8.33 pounds water @ 60°F

1 ft^3 = 1728 $in.^3$ = 0.037 yd^3

Table A.4 Pressure conversions and abbreviations

For example, read: 1 foot water = 0.433 pounds/square inch

unit \ abbr.	ft water	psi	in. Hg	mm Hg	kg/cm^2
foot of water	1.0	0.433	0.833	22.43	0.0304
$\frac{\text{pounds}}{\text{inch}^2}$	2.31	1.0	2.04	51.82	0.0703
inch of mercury	1.133	0.491	1.0	25.4	0.0345
millimeters of mercury	0.0446	0.0193	0.0394	1.0	0.0014
$\frac{\text{kilograms}}{\text{centimeter}^2}$	32.8	14.22	28.97	736.03	1.0

Table A.5 Velocity conversions and abbreviations

For example, read: 1 foot/second = 0.305 meters/second

unit \ abbr.	fps	mps	mph	km/h
$\frac{\text{foot}}{\text{second}}$	1.0	0.305	0.682	1.097
$\frac{\text{meter}}{\text{second}}$	3.28	1.0	2.24	3.6
$\frac{\text{mile}}{\text{hour}}$	1.47	0.447	1.0	1.61
$\frac{\text{kilometer}}{\text{hour}}$	0.911	0.278	0.621	1.0

1 knot = 1.151 mph

Table A.6 Discharge conversions and abbreviations

For example, read: 1 cubic foot/second = 488.8 gallons/minute

unit \ abbr.	cfs	gpm	l/sec	mgd
$\frac{\text{foot}^3}{\text{second}}$	1.0	448.8	9.81×10^{-6}	0.646
$\frac{\text{gallon}}{\text{minute}}$	2.23×10^{-3}	1.0	0.063	1.44×10^{-3}
$\frac{\text{liter}}{\text{second}}$	101,937	15.87	1.0	0.0229
$\frac{\text{million gallon}}{\text{day}}$	1.55	694.4	43.7	1.0

1 cubic foot per hour (cfh) = 3600 cfs

Table A.7 Power conversions and abbreviations

For example, read: 1 horsepower = 0.746 kilowatts

unit \ abbr.	hp	kw	$\frac{\text{ft-lb}}{\text{sec}}$	$\frac{\text{kg-cal}}{\text{min}}$
horsepower	1.0	0.746	550	10.55
kilowatt	1.34	1.0	737.6	14.34
$\frac{\text{foot-pound}}{\text{second}}$	1.82×10^{-3}	1.36×10^{-6}	1.0	1.94×10^{-2}
$\frac{\text{kilogram-calorie}}{\text{minute}}$	0.0935	0.0697	51.43	1.0

1 hp = 1.014 metric hp

Table A.8 Specific speed (N_s) conversions

For example, read: N_s = 1 (cfs, ft, rpm) equals N_s = 21.19 (U.S. gpm, ft, rpm)

Units of Quantity and Head*	(1) cfs ft	(2) U.S. gpm ft	(3) Imp. gpm ft	(4) l/sec m	(5) m^3/sec m	(6) m^3/n m
(1)	1.0	21.19	19.34	12.98	0.41	24.63
(2)	0.047	1.0	0.91	0.61	0.019	1.16
(3)	0.052	1.096	1.0	0.67	0.021	1.27
(4)	0.077	1.63	1.49	1.0	0.032	1.90
(5)	2.44	51.64	47.13	31.62	1.0	60.0
(6)	0.041	0.86	0.79	0.53	0.017	1.0

*Rotational speed in revolutions per minute (rpm)

Table A.9 Miscellaneous conversions

Weight

1 ft^3 water = 62.4 lbs
1 liter water = 1 kg
1 gal water = 8.35 lbs
1 lb (avoir) = 1.215 lb (troy) = 0.0005 ton (short)
= 0.000446 ton (long) = 0.454 kg

Temperature

Temp °C = [Temp °F - 32] x 5/9

Work

1 BTU = 777.6 ft-lbs

Table A.10 Symbols

A	- area
BHP	- brake horsepower
D	- diameter
D	- drawdown
E	- energy (expressed as head)
Eff	- efficiency
g	- acceleration due to gravity
H	- head
HP	- horse power
HWL	- high water level
K	- constant used for unit conversion in equations
LWL	- low water level
ms	- minimum submergence
N	- operating speed in evolutions or strokes per unit time
N_s	- specific speed
NPSHA	- net positive suction head available
NPSHR	- net positive suction head required
OAE	- overall efficiency
P	- pressure
Q	- discharge
T	- time
V	- volume
v	- velocity
WHP	- water horsepower
Z	- elevation
γ	- specific weight
ρ	- specific mass

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Chapter 8
Well-Performance Testing Procedures

8-1. Testing Pumps. You will normally use the permanent pump for pump testing. If you use a temporary unit, it must be adequate to draw down the water and hold it at a prescribed flow rate for a period of hours. This test will determine the specific capacity of the well. You can estimate the yield of a small well by bailing water from the well rapidly if no pump is available. You must know the bailer's volume and count the number of times per minute the bailer is brought up full to estimate the GPM of the well. Accurately measuring drawdown is not possible during the test because the water level constantly fluctuates.

a. *Permanent Wells.* You should use two different testing procedures when a pump is available, depending on the intended use of the well and the available testing time. If the well will be a permanent installation and maintained in the future, you should conduct a detailed test. Measure the static water level in the well before testing, and measure the drawdown during the test. Conduct the test as follows:

- Pump at a rate that will lower the water in the well about one-third of the maximum drawdown possible (one-third the distance from the static water level to the top of the well screen) or about one-third of the rated capacity of the pump.
- Monitor and adjust the flow rate early in the test because as the drawdown increases the flow rate decreases.
- Continue pumping at a constant flow rate until the drawdown remains constant (about 1 to 4 hours).
- Record the flow rate, drawdown, and testing time. Initially, take readings rapidly, and then spread out the readings as the test continues. A reading schedule that doubles the time between readings is preferable. The recommended schedule is as follows: 0 (at the start of the test) 30 seconds, 1 minute, 2 minutes, 4 minutes, 8 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 4 hours, and so forth.
- Establish the desired, constant flow rate quickly. You must record the exact time of each reading (not the intended or scheduled time). After the drawdown stabilizes (1 to 4 hours), the pumping rate should increase to a new, constant flow rate, which will produce two-thirds of the capacity of the pump. Do not stop the pump between these test segments.
- Repeat the measurements, noting the exact time that the new flow rate was started. Try to follow the above reading schedule, starting from the time the flow rate was increased. When the drawdown stabilizes, increase the pumping rate to produce the maximum drawdown or about 90 percent of the maximum capacity of the pump. Conduct another reading schedule until the pumping level stabilizes.

You may modify the above procedure depending on well requirements and local site conditions. You should not modify the precision and accuracy of the measurements taken. Test results should become a part of the permanent records. The results are useful for evaluating the efficiency of the well in the future and for determining the need for well rehabilitation. Calculating the GPM

per foot of drawdown gives the capacity of the well. You can use this information to estimate production and to regulate the pump's flow rate to prevent dewatering of the well and possible pump damage.

b. *Temporary Wells.* Conduct a single-stage test rather than the step drawdown test. To establish the flow rate, conduct a 1- to 2-minute test to determine the GPM per foot of drawdown. Let the well return to the original static water level before testing (about 1 hour). Select a flow rate that will produce about two-thirds of the available drawdown but will not reach more than 90 percent of the pump's capacity. Conduct the test as described above, but with only one segment. When the drawdown stabilizes for the selected flow rate, stop the test.

c. *Methods.* See Chapter 4 for a description of pumps used in testing and well production.

(1) Submersible-Pump Method. Use the submersible pump in well-completion kits to pump test the water well. Set the pump deep enough to attain the maximum pumping rate and drawdown. When testing a well with a screen, set the suction of the pump above the top of the screen to prevent lowering the water level below the screen. When testing a well without a screen, try not to dewater the production part of the aquifer. For proper testing, you must have a reliable power source so that testing will not be interrupted. The power must be sufficient to drive the pump at a rated speed so that full capacity can be developed.

(2) Air-Lift Method. This method is sometimes best for military field operations, especially if the well may produce sand that could damage or reduce the life of a submersible pump. An air-lift pump has two major problems. Air turbulence could make drawdown measuring difficult, and entrained air may cause considerable error in measuring the flow rate. After constructing an air-lift pump, check the pump capacity against the expected well yield. To conduct the test, set the pump according to the readings in Table 4-2.

An air compressor that puts out 350 cfm at 200 psi is suitable for performing most air-lift pumping operations. To determine the amount of air needed for pumping water, use the following equation or refer to Figure 8-1.

$$V = \frac{h}{\frac{C\,[\log (H + 34)]}{43}}$$

where--

V = free air (actual) required to raise one gallon of water, in cubic feet.

h = total lift, in feet.

log = logarithmic value.

H = operating submergence, in feet.

C = constant (Table 8-1).

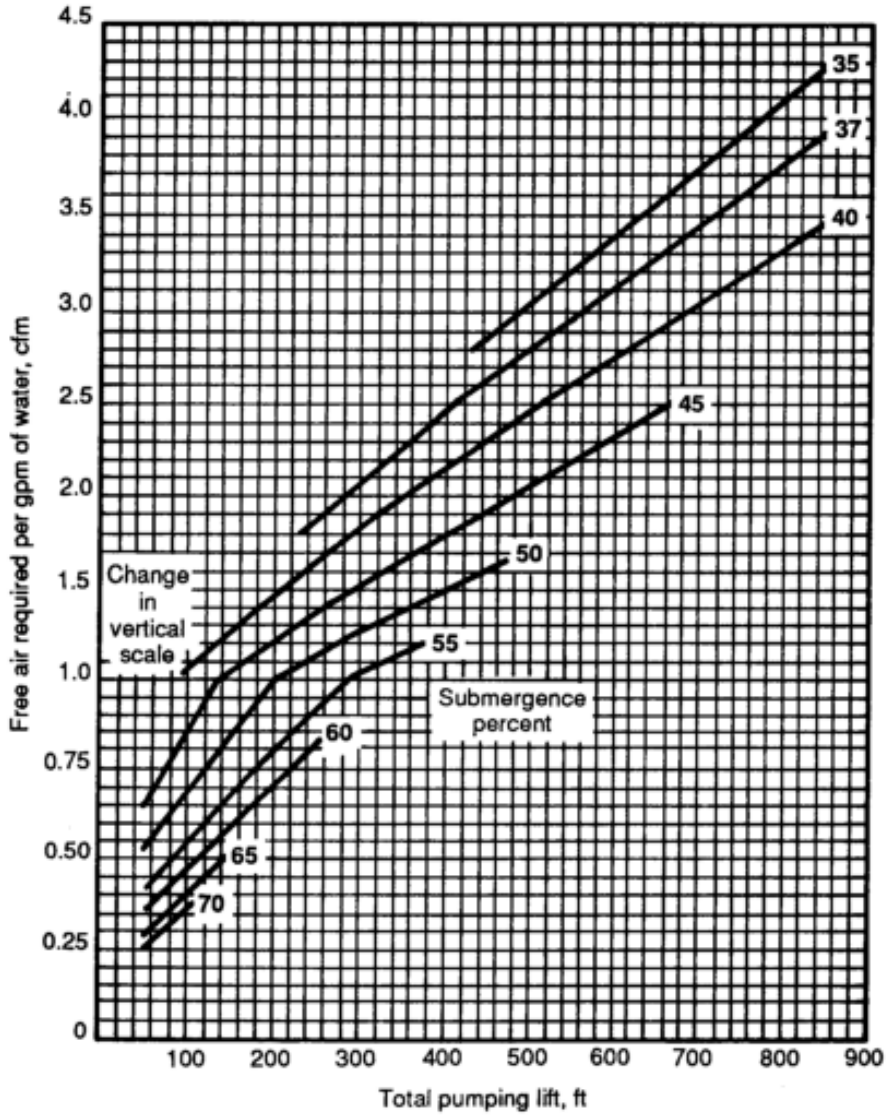

Figure 8-1. Cubic feet of air requirements for various submergences and pumping lifts

Table 8-1. Constants

Constant	Submergence (percent)
366	75
358	70
348	65
335	60
318	55
296	50
272	45
246	40
216	35

The pressure required to start pumping will be equal to the depth of water over the submerged end of the air pipe. After pumping has started, the water in the well will draw down to a working level. The air pressure required will be the total lift, in feet, from the working water level plus the friction loss in the airline. Conduct the test and try to measure flow rate and drawdown quickly. Pumping creates turbulance in the well. Use the air-line method (paragraph 8-2c) to try and measure drawdown. Because of entrained air, use the measured-container method (paragraph 8-3a) to obtain flow-rate measurements.

8-2. Measuring Water Level.

a. *Electric-Line Method.* Water levels can be measured accurately with a two-conductor, battery-powered indicator known as an M-Scope (Figure 8-2). Well-completion kits usually contain an M-Scope. The M-Scope is a battery and a meter connected in series. When the upper wire on the tip of the M-Scope in the well touches the water, the circuit is completed and the meter gives a steady reading. Measure the amount of wire in the well to determine the depth to the water level. The wire is marked at 5-foot intervals for easy measuring.

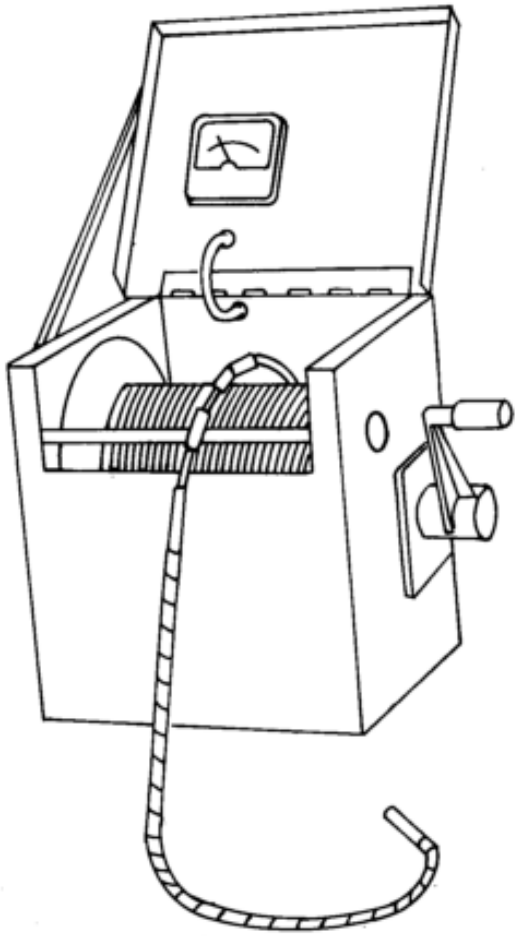

Figure 8-2. M-Scope

b. *Tape Method.* Use this method to measure the depth to the static level in a shallow well. Conduct this test as follows:

- Chalk one end of a weighted steel tape with carpenter's chalk. Lower the tape (Figure 8-3) into the well to a depth of 1 or 2 feet past the chalk. (You can use soluble felt-tip markers as an alternative to chalk.)
- Measure the wetted length of the tape and subtract the amount from the total length lowered below the reference point to obtain the water depth. This test is accurate to within 0.01 foot.

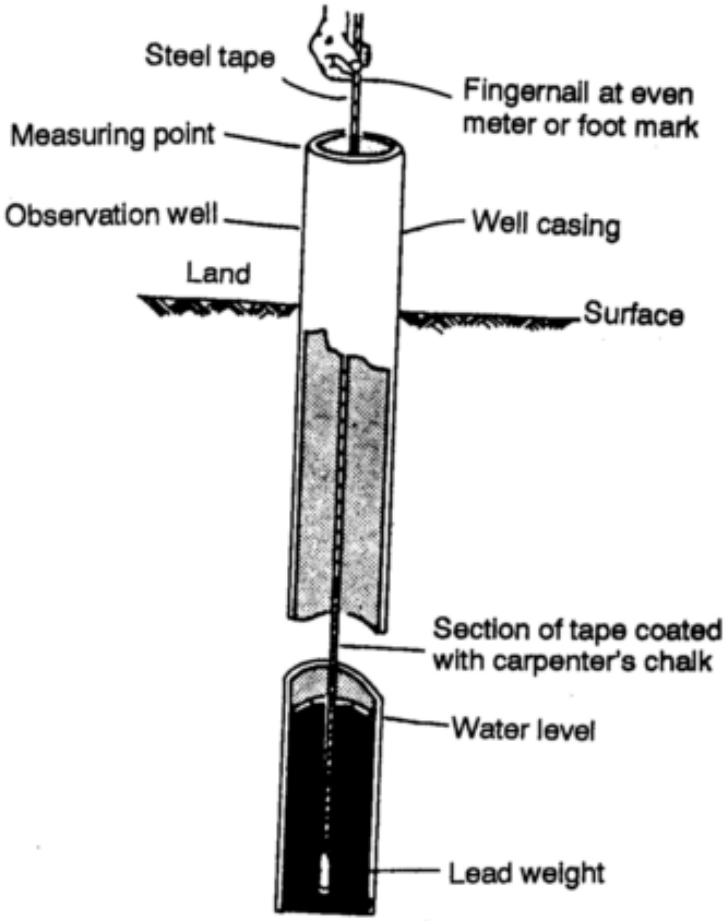

Figure 8-3. Steel-tape measurement method

c. *Air-Line Method.* You can measure the water level with an air line to follow drawdown and confirm a stable head during a test (Figure 8-4). The air line is usually 1/8- or 1/4-inch copper tubing or galvanized pipe that is long enough to extend below the lowest water level you are measuring. Fasten the air line to the pump bowls or cylinder. Install the airline with the pump. The pipe must be airtight; makeup all joints carefully. Measure the vertical length of the airline from the pressure gauge to the bottom of the line at the time of installation.

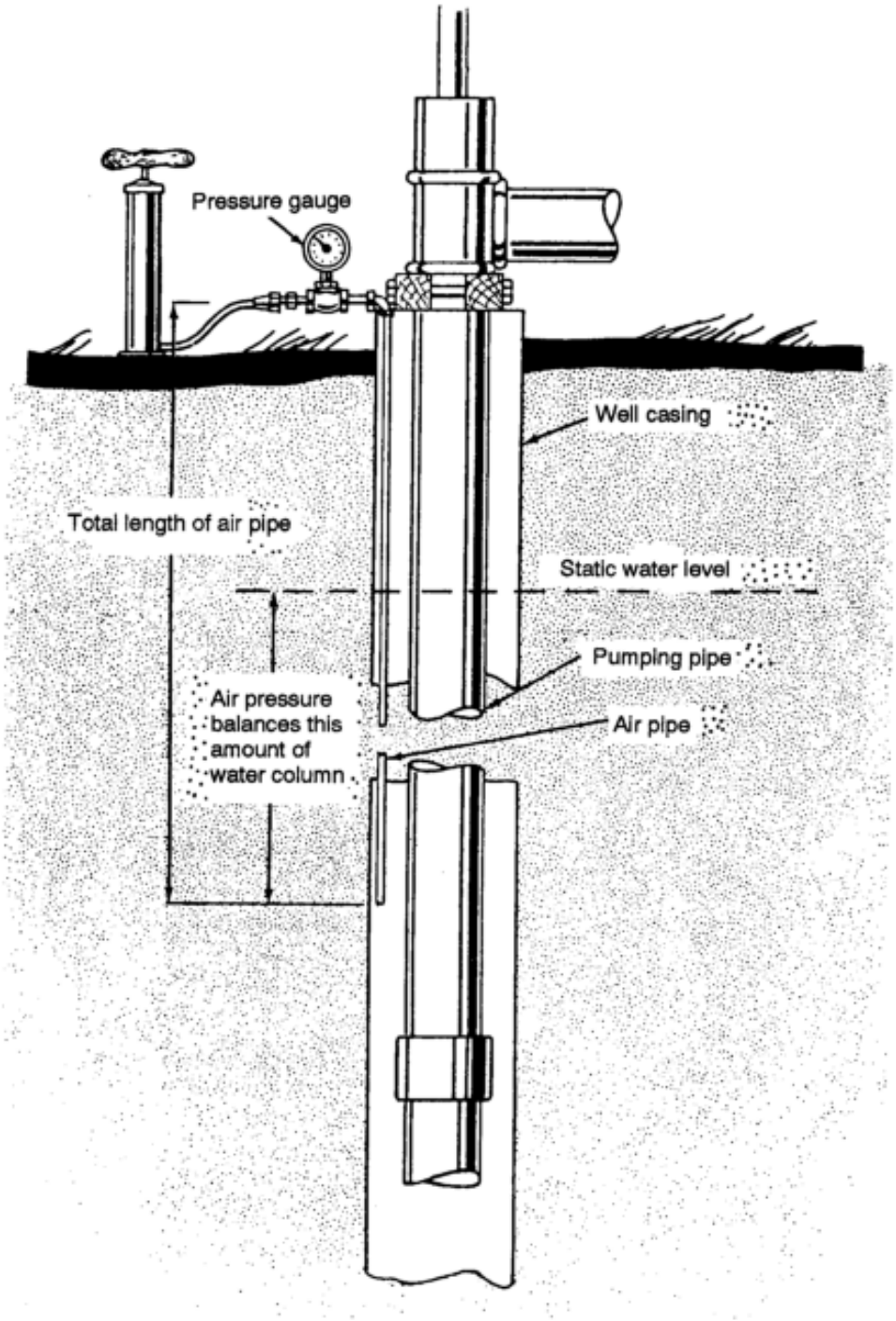

Figure 8-4. Air-line measurement method

Attach a pressure gauge to the airline at the surface with an ordinary tire valve so you can pump air into the line. Pump air into the line until you get a maximum reading. The reading should be equal to the pressure exerted by the column of water standing outside of the airline. Subtract the reading from the total vertical length of air line to get the depth to the water below the center of the gauge. Readings are measured in feet, so you may have to convert your figures.

8-3. Measuring Discharge Rate.

a. *Measured-Container Method.* You can determine the flow rate from a well or pump by measuring the time required to fill a container with a known volume. With this method, use small containers for early measurements and large containers for later measurements. Also, use an instrument, such as a stop watch, for accurate time measurements. Use the following equation:

$$FR = \frac{V(60)}{T}$$

where--

FR = flow rate, in GPM.

v = volume, in gallons.

T = time required to fill container, in seconds.

b. *Flow-Meter Method.* A turbine-type flow meter will give an acceptable flow-rate reading. These meters are used by civilians. You can also use a totalizer-type water meter when the yield is low. Use these meters to measure the total gallons pumped and determine the flow rate. To do this, record the number of gallons that have flowed within a set amount of time and compute the flow rate.

c. *Circular-Orifice Method.* A circular-orifice meter (Figure 8-5) is a device you can make to measure discharge rates. This device gives good results and is compact and easily installed. The meter consists of a sharp-edged circular orifice at the end of a horizontal discharge pipe. The orifice is from one-half to three-fourths the diameter of the pipe. The inside of the pipe must be smooth and free from obstructions for a length of 6 feet from the orifice. The discharge pipe has a small hole on one side with a rubber-tube connection. The pipe is designed so that you can measure the pressure (head) in the discharge pipe at a distance of 2 feet from the orifice.

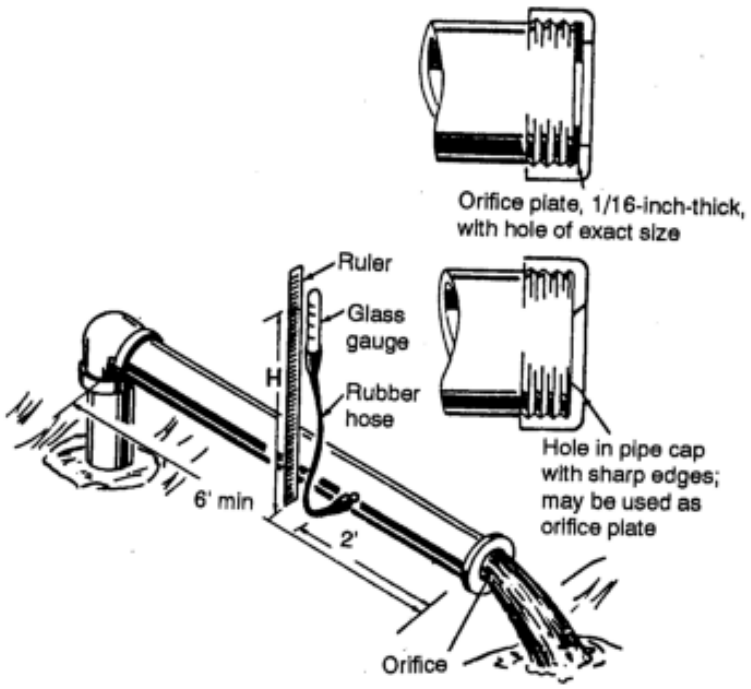

Figure 8-5. Circular-orifice flow meter

The length of hose and ruler depends on the pipe size you use (Table 8-2). The discharge pipe must be horizontal, and the stream must fall free from the orifice. The orifice must be vertical and centered in the discharge pipe. The combination of pipe and orifice diameters for a given test should be such that the head measured will be at least three times the diameter of the orifice.

Table 8-2. Circular-orifice flow measurements

Head of Water in Tube Above Center of Orifice (inches)	4-inch Pipe, 2 1/2-inch Opening (GPM)	4-inch Pipe, 3-inch Opening (GPM)	6-inch Pipe, 3-inch Opening (GPM)	6-inch Pipe, 4-inch Opening (GPM)	6-inch Pipe, 5-inch Opening (GPM)	8-inch Pipe, 4-inch Opening (GPM)	8-inch Pipe, 5-inch Opening (GPM)	8-inch Pipe, 6-inch Opening (GPM)
6	62	102						
7	66	110	88					
8	70	118	94	180	350	170	280	440
9	75	126	100	190	370	180	295	465
10	80	132	106	200	390	190	310	490
12	87	145	115	220	425	210	340	540
14	94	156	125	238	460	225	370	580
16	100	168	132	253	490	240	390	620
18	106	178	140	268	520	255	415	660
20	112	188	150	283	550	270	440	695
22	118	198	158	298	575	280	460	725
25	125	210	168	318	610	300	490	780
30	138	230	182	350	670	330	540	850
35	150	250	198	375	725	360	580	920
40	160	265	210	400	780	380	620	980
45	170	280	223	425	820	400	660	1,040
50	180	300	235	450	870	425	700	1,100
60	195	325	260	490	950	465	760	1,200

d. *Open-Pipe Method.* With this method, the pipe is fully open and you measure the distance the water stream travels parallel to the pipe at a 12-inch vertical drop (Figure 8-6). Use the following procedure:

- Step 1. Measure the inside diameter of the pipe and the distance the stream travels parallel to the pipe at a 12-inch vertical drop. Your results will be in inches.
- Step 2. Estimate the flow from the pipe diameter and the distance the stream travels (Table 8-3). Your results will be in GPM.

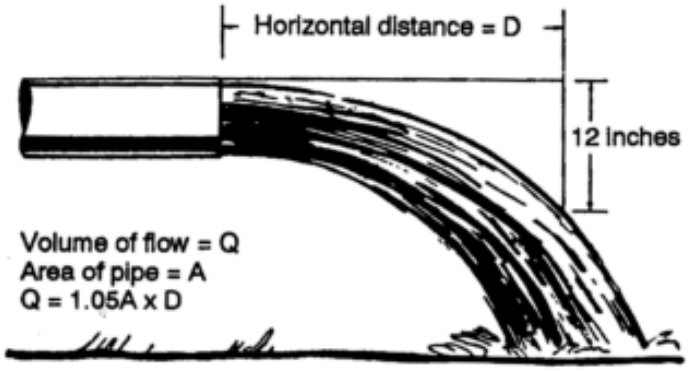

Figure 8-6. Open-pipe-flow measurement method

Table 8-3. Open-pipe-flow measurements

Pipe Diameter (inches)	Horizontal Distance (D) (inches)									
	12	14	16	18	20	22	24	26	28	30
2	41	48	55	61	68	75	82	89	96	102
3	90	105	120	135	150	165	180	195	210	225
4	150	181	207	232	258	284	310	336	361	387
6	352	410	470	528	587	645	705	762	821	880
8	610	712	813	915	1,017	1,119	1,221	1,322	1,425	1,527
10	960	1,120	1,280	1,440	1,600	1,760	1,930	2,080	2,240	2,400
12	1,378	1,607	1,835	2,032	2,286	2,521	2,760	2,980	3,210	3,430

For partially filled pipes, measure either the water depth or the freeboard. Divide the diameter by the water depth to get a

percentage ratio. Measure the stream as above and calculate the discharge. The actual discharge will be, approximately, the value for a full pipe of the same diameter multiplied by the correction factor from Table 8-4.

Table 8-4. Correction factors

Percent	Factor	Percent	Factor
5	0.981	55	0.436
10	0.948	60	0.375
15	0.905	65	0.312
20	0.858	70	0.253
25	0.805	75	0.195
30	0.747	80	0.142
35	0.688	85	0.095
40	0.627	90	0.052
45	0.564	95	0.019
50	0.500	100	0.000

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Chapter 4
Pumps

4-1. Fundamentals.

a. *Pump Types.* Pumps may be classified according to use (for shallow or deep wells), design (variable or positive displacement), or method of operation (rotary, reciprocating, centrifugal, jet, or airlift). This chapter deals with shallow- and deep-well pumps. Shallow-well pumps (suction-lift pumps) are normally installed above ground, on or near the top of the well casing. Deep-well pumps are installed in the well casing with the pump inlets submerged below the pumping level. These inlets are always under a positive head and do not require suction to move or pump the water.

b. *Selection Criteria.* Consider the following items when selecting a pump:

- Size of the well.
- Quantity of water to be pumped.
- Drawdown and pumping levels.
- Type of available power.
- Yield of the well.
- Estimated total pumping head.

Well yield is frequently overlooked when selecting a pump for small wells. Installing a pump that can handle a large discharge capacity can either temporarily drain a small well or exceed the maximum possible suction lift. Therefore, pumping requirements and well characteristics must be matched to determine the optimum pump for each installation. Table 4-1 provides a general guide for use in pump selection. Military well drillers deploying with well-completion kits will normally use the deep-well submersible pumps that are supplied with the kits.

Table 4-1. Guide to pump selection

Type of Pump	Practical Suction Lift	Usual Well-Pumping Depths	Usual Pressure Heads	Advantages	Disadvantages	Remarks
Reciprocating:						
1. Shallow well	22 to 26 feet	22 to 26 feet	100 to 200 feet	1. Positive action 2. Discharge against variable heads	1. Pulsating discharge 2. Subject to vibration and noise 3. Maintenance cost may be high 4. May cause destructive pressure if operated against closed valve	1. Best suited for capacities of 5 to 25 GPM against moderate to high heads 2. Adaptable to hand operation 3. Can be installed in very small diameter wells (2-inch casing) 4. Pump must be set directly over well (deep well only)
2. Deep well	22 to 26 feet	Up to 600 feet	Up to 600 feet above cylinder	3. Pumps water containing sand and silt 4. Especially adapted to low capacity and high lifts		
Centrifugal:						
1. Shallow well	20 feet maximum	10 to 20 feet	100 to 150 feet	1. Smooth, even flow 2. Pumps water containing sand and silt 3. Pressure on system is even and free from shock 4. Low-starting torque 5. Usually reliable and good service life	1. Loses prime easily 2. Efficiency depends on operating under design heads and speed	Very efficient pump for capacities above 50 GPM and heads up to about 150 feet
a. Straight centrifugal (single stage)					Same as straight centrifugal except maintains priming easily	Reduction in pressure with increased capacity not as severe as straight centrifugal
b. Regenerative vane turbine type (single impeller)	28 feet maximum	28 feet	100 to 200 feet			
2. Deep well	Impellers submerged	50 to 300 feet	100 to 800 feet	Same as shallow-well turbine	1. Efficiency depends on operating under design head and speed 2. Requires straight well large enough for turbine bowl and housing 3. Lubrication and alignment of shaft critical 4. Abrasion from sand	
a. Vertical line shaft turbine (multistage)						
b. Submersible turbine (multistage)	Pump and motor submerged	50 to 400 feet	80 to 900 feet	1. Same as shallow-well turbine 2. Easy to frost proof installation 3. Short pump shaft to motor	1. Repair to motor or pump requires pulling from well 2. Sealing of electrical equipment from water vapor critical 3. Abrasion from sand	Difficulty with sealing has caused uncertainty as to service life to date
Jet:						
1. Shallow well	15 to 20 feet below ejector	Up to 15 to 20 feet below ejector	80 to 150 feet	1. High capacity at low heads. 2. Simple in operation 3. Does not have to be installed over the well 4. No moving parts in the well	1. Capacity reduces as lift increases 2. Air in suction or return line will stop pumping	
2. Deep well	15 to 20 feet below ejector	25 to 120 feet, 200 feet maximum	80 to 150 feet	Same as shallow-well jet	Same as shallow-well jet	The amount of water returned to ejector increases with increased lift— 50 percent of total water pumped at 50-foot lift and 75 percent at 100-foot lift
Rotary:						
1. Shallow well (gear type)	22 feet	22 feet	50 to 250 feet	1. Positive action 2. Discharge constant under variable heads 3. Efficient operation	1. Subject to rapid wear if water contains sand or silt 2. Wear of gears reduces efficiency	
2. Deep well (helical-rotary type)	Usually submerged	50 to 500 feet	100 to 500 feet	1. Same as shallow-well rotary 2. Only one moving pump device in well	Same as shallow-well rotary except no gear wear	A cutless rubber stator increases life of pump; flexible drive coupling has been weak point in pump; best adapted for low capacity and high heads

[1]Practical suction lift at sea level. Reduce lift 1 foot for each 1,000 feet above sea level.

4-2. Shallow-Well Pumps. These pumps are limited to the depth from which they can lift water. At sea level, the practical limit is 22 to 25 feet for most pumps. This value decreases about 1 foot for each 1,000-foot increase in elevation above sea level. The operative principle of a shallow-well pump is similar to drinking through a straw. A partial vacuum is created, and the difference between the pressure inside the straw and the liquid outside the straw forces the liquid upward to a new equilibrium.

A pump exhausts air from the intake line, thus lowering the pressure on the intake side below atmospheric pressure. The atmospheric pressure on the water in the well then forces the water up through the suction line into the pump. The atmospheric pressure is the only force available to lift water to the pump. At sea level, the force is about 14.7 pounds per square inch (psi) (about 34 feet of water). The maximum is never reached because pumps are not 100 percent efficient and because other factors (water temperature and friction or resistance to flow in the suction pipe) reduce the suction lift. Since a partial vacuum is required in the suction line, the line must be airtight if the pumps are to function properly. Threaded joints must be carefully sealed with pipe-joint compound and all connections to the pump must be tight.

a. *Pitcher Pump.* This is a surface-mounted, reciprocating or single-acting piston pump (Figure 4-1). The pump has a hand-operated plunger that works in a cylinder designed to be set on top of the well casing. The suction pipe screws into the bottom of the cylinder. The plunger has a simple ball valve that opens on the downstroke and closes on the upstroke. Usually, a check valve at the lower end of the cylinder opens on the upstroke of the pump and closes on the downstroke. Continuous upstroke and

downstroke actions result in a pulsating flow of water out of the discharge pipe. By lifting the pump handle as high as possible, the check valve (lower end of the cylinder) will tilt when the plunger is forced down on top of the valve. Tilting the check valve allows the pump and suction line to drain.

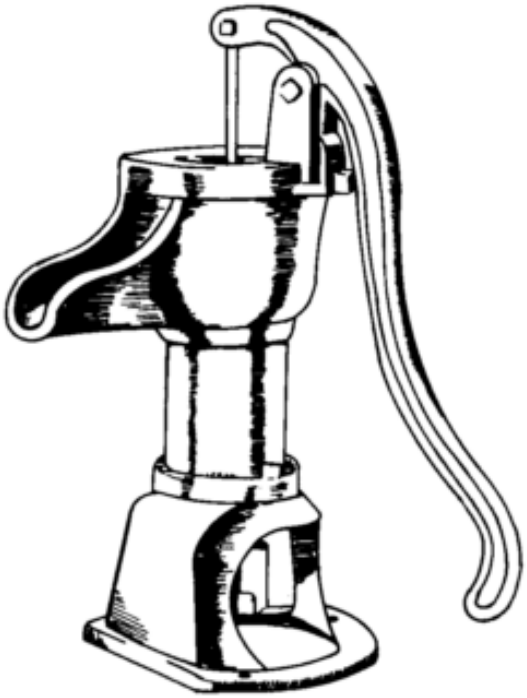

Figure 4-1. Pitcher pump

To reprime the pump after draining, pour water in the cylinder from the top of the pump. To maintain the pitcher pump, renew the plunger, check the valve leathers, and clean the suction pipe. Clean the suction pipe when it becomes clogged with sand, gravel, or other material. The pump will be noisy and the pump handle may fly up when released during the downstroke.

b. *Rotary Pump.* These pumps use a system of rotating gears (Figure 4-2) to create a suction at the inlet and force a water stream out of the discharge. The gears' teeth move away from each other at the inlet port. This action causes a partial vacuum and the water in the suction pipe rises. In the pump, the water is carried between the gear teeth and around both sides of the pump case. At the outlet, the teeth moving together and meshing causes a positive pressure that forces the water into the discharge line.

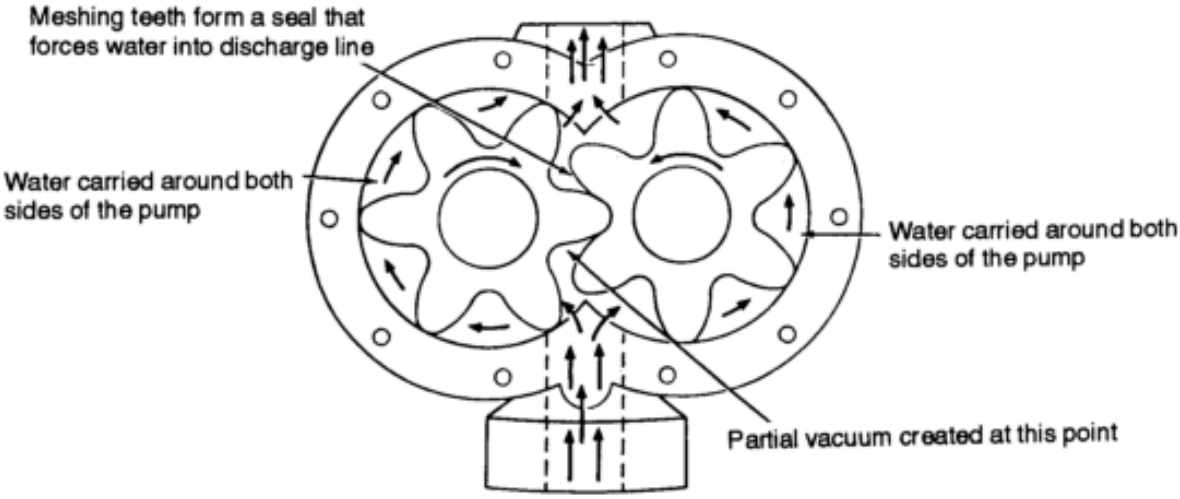

Figure 4-2. Rotary pump

In a rotary gear pump, water flows continuously and steadily with very small pulsations. The pump size and shaft rotation speed determine how much water is pumped per hour. Gear pumps are generally intended for low-speed operation. The flowing water lubricates all internal parts. Therefore, the pumps should be used for pumping water that is free of sand or grit. If sand or grit does

flow through the gears, the close-fitting gear teeth will wear, thus reducing pump efficiency or lifting capacity.

c. *Centrifugal Pump.* These are variable displacement pumps in which water flows by the centrifugal force transmitted to the pump in designed channels of a rotating impeller (Figure 4-3). A closed case, with a discharge opening, surrounds the impeller. The case has a spiral-shaped channel for the water. The channel gradually widens towards the outlet opening. As water flows through the channel, speed decreases and pressure increases. The hydraulic characteristics of the pump depend on the dimensions and shape of the water passages of the impeller and the case.

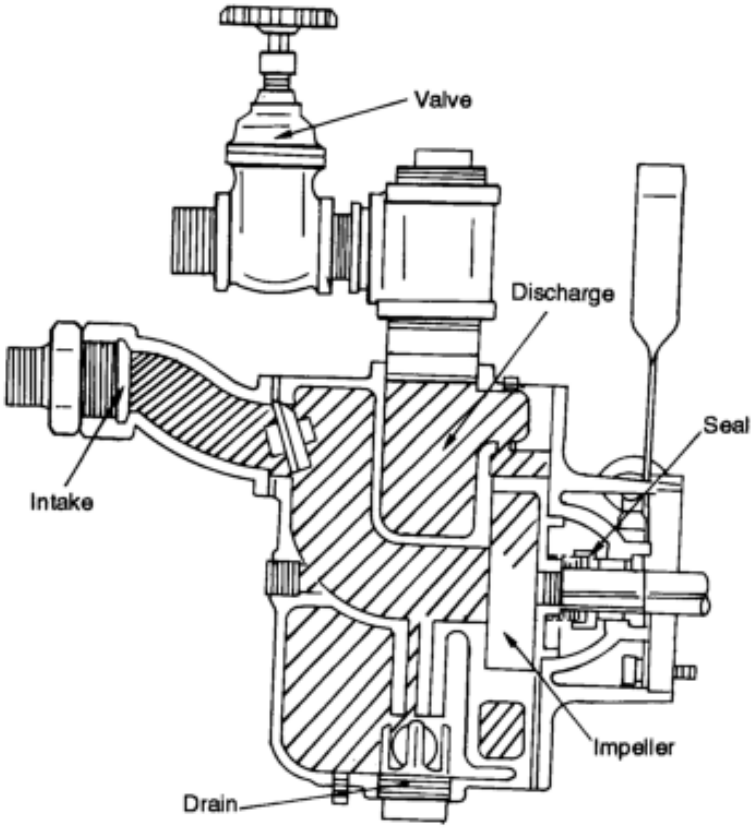

Figure 4-3. Centrifugal pump

The centrifugal pump works as follows:

- Water enters the pump at the center of the impeller and is forced out by centrifugal force. (You may have to fill the pump and suction pipe with water before starting the pump.)
- The expelled water forces the water in the casing out through the discharge pipe, producing a partial vacuum in the center.
- Atmospheric pressure acts on the surface of the water in the well and forces more water up the suction pipe and into the impeller to replace the expelled water.

(1) Head. Head is the pressure against which a pump must work the suction-lift and friction losses and the system pressure that the pump must develop. If the head is increased and the speed is unchanged, the flow rate will decrease. To increase the flow rate, you must increase the speed or decrease the head. If you increase the head beyond the pump's (shutoff head) capacity, water will not be pumped. The impeller only churns the water inside the case; the energy expended heats the water and the pump. If such action continues, enough heat may develop to boil the water and generate steam causing the impeller to rotate in vapor rather than water. With no coolant, the bearings seize, resulting in severe pump and possible motor damage.

(2) Connections. You may have to use several pumps to meet head or flow requirements. You can connect the pumps either in series or in parallel. If you connect two centrifugal pumps in series (the discharge of the first connected to the suction of the second), the discharge capacity stays the same. However, the head capacity is the sum of both pumps head capacities. The increased head capacity is only available as discharge head. You will not gain any appreciable increase in suction lift. You can obtain the same effect by using a multistage pump that contains two or more impellers within one

casing.

If you connect two centrifugal pumps in parallel (both suctions are connected to the intake line and both discharges connected to the discharge line), the discharge head is the same as that of the individual pumps. The discharge capacity is close to the sum of the capacities of both pumps. The increased flow rates result in extra friction losses that prevent the combined flows from being the exact sum of the two pumps.

d. *Self-Priming Pump.* This pump has a priming chamber that makes repriming unnecessary when the pump is stopped for any reason other than an intentional draining. The pump is mounted on a frame with and driven by a two-cylinder, three-horsepower military standard engine (Figure 4-4). The unit is close-coupled. The impeller is secured to an adapter shaft that is fastened and keyed to the engine stub shaft. A self-adjusting mechanical seal prevents water from leaking between the pump and the engine. The pump is designed for optimum performance with a suction lift of 10 feet. You can operate the pump at greater suction lifts, but the capacity and efficiency of the unit are reduced proportionately.

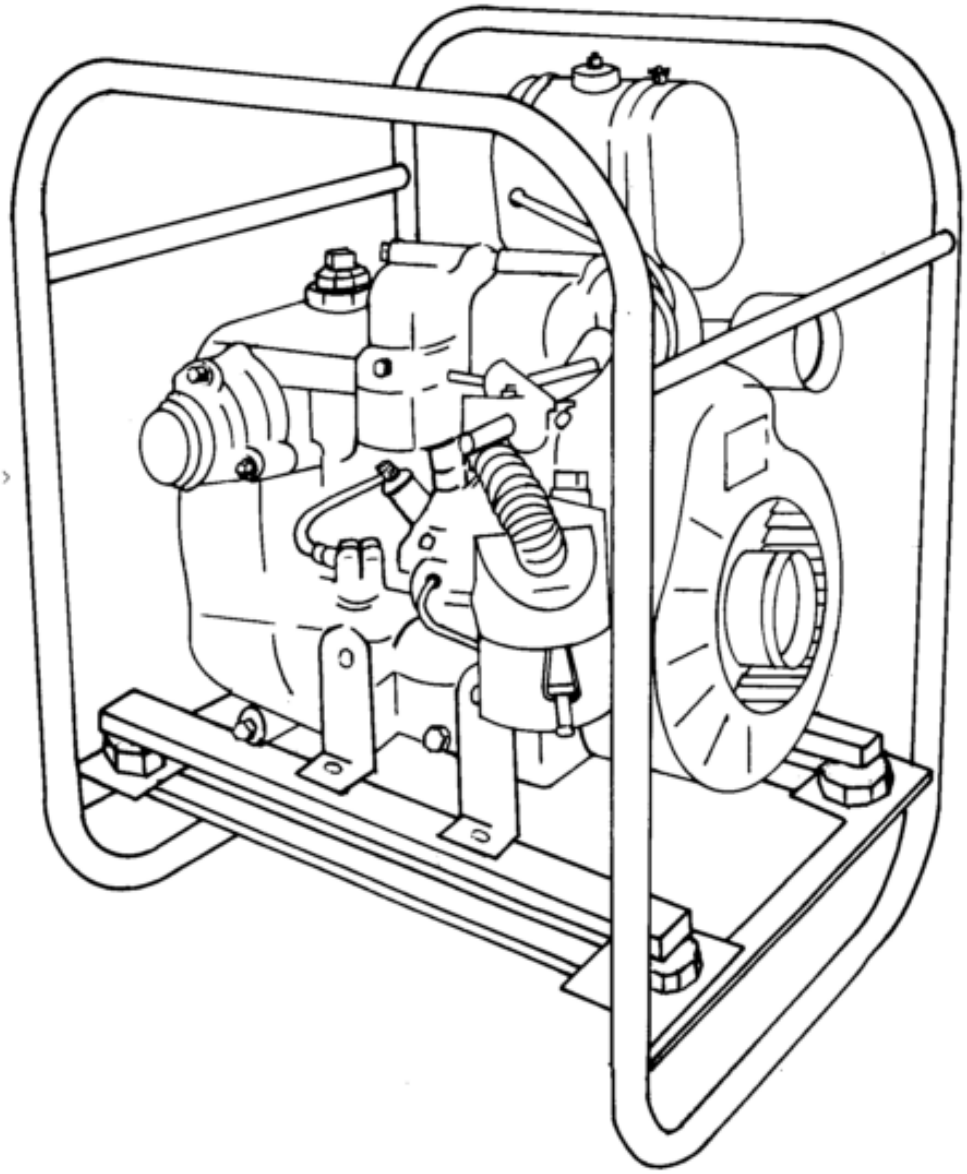

Figure 4-4. Self-priming pump

(1) Installation. Install the pump as close to the source of water supply as possible to minimize the required suction lift. Install full-sized suction piping and keep friction losses as low as possible by using the least possible number of pipe fittings (elbows, bents, unions). To ensure that joints do not leak use pipe cement or teflon tape on all joints. If you use a suction hose, try to ensure that the hose is as airtight as possible. If you have to remove the suction or discharge piping or hose frequently, you should make the connections with unions to reduce wear on the pump housing.

(2) Priming. To prime the pump, remove the priming plug on top of the pumping case, and pour water into the pump case to the discharge-opening level. Failure to fill the priming chamber may prevent priming. If the pump takes longer than 5 minutes to prime, a mechanical problem exists. A self-priming pump is normally primed from a 10-foot suction lift in 2 minutes or less, depending on the length and size of the suction pipe. If you use a valve in the discharge line, you must open it wide during priming.

If the pump fails to prime, look for the following:

- Plugged priming hole.
- Air leak in suction pipe or hose.
- Collapse of lining suction hose.
- Plugged end of suction pipe or suction strainer.
- Lack of water in pump housing.
- Clogged, worn-out, or broken impeller.
- Worn or damaged seal.

4-3. Deep-Well Pumps.

a. *Submersible Pump.* This is a centrifugal pump closely coupled with an electric motor that can operate underwater. The pump is typically multistage containing two or more impellers (depending on head requirements) housed in a bowl assembly. Because the system is designed for underwater operations, it has a waterproof electric motor, watertight seals, electric cables and connections. The motor is located beneath the bowl assembly with the water intake screen between the two units.

Military well-completion kits contain the submersible pump (Figure 4-5). The pump produces 50 GPM at 600 feet and is powered by a 15-horsepower, 460-volt, 3-phase electric motor. The pump comes with 700 feet of electrical conductor cable and 660 feet of 2-inch drop hose that supports the pump and brings the water to the surface distribution system. Currently, the submersible pump is the standard in deep-well, high-production systems.

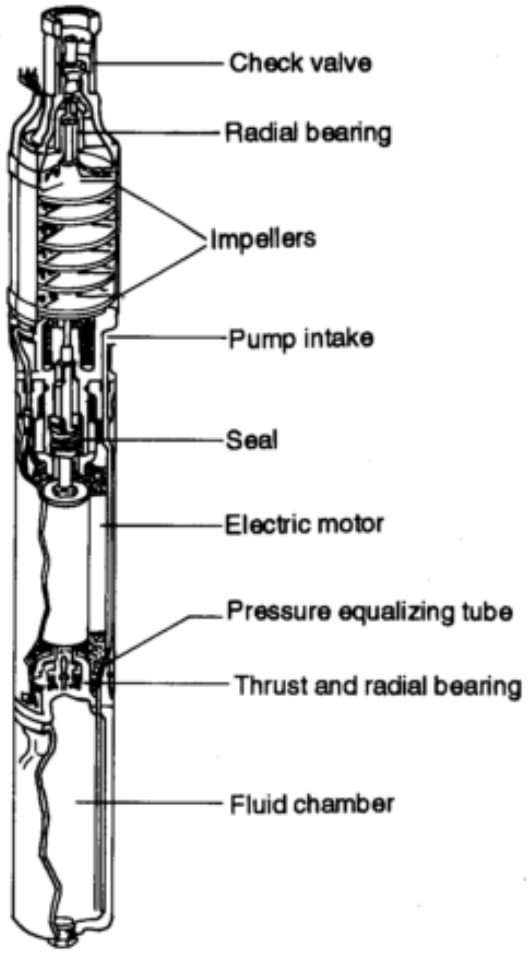

Figure 4-5. Submersible pump

DANGER

Do not handle live electrical wires when wet or while standing in water. Do not step on exposed electrical cables.

The following improvements have made the submersible pump a reliable pump:

- Motors, cables, and seals have very low maintenance requirements.
- Noise levels are reduced because the motor is located in the well.
- Motor operates at a cooler temperature because it is submerged.
- System does not require long drive shafts and bearings, so maintenance problems and deviations in vertical well alignment are not critical factor when using this pump.

The main disadvantage with the pump is that the entire pump and motor assemblies must be removed from the well if repairs or services are required.

b. *Turbine Pump.* The turbine (line shaft) pump is a shaft-driven, centrifugal pump. The pump is hung in a well at the lower end of a string of pipe called the column pipe. The shaft, which drives the pump, runs through the column pipe and extends from the pump to the ground surface where it is connected to a pump-head assembly. Bearings in the column pipe are used to stabilize the shaft.

The turbine pump (Figure 4-6) is a multistage pump containing several impellers or bowl assemblies. The main advantage to the turbine pump is the accessibility to the power source. The power source is either a hollow-shaft electric motor or a reciprocating engine connected by a right-angle drive and is located above ground. The main disadvantages are maintenance requirements for the shaft and bearings and the requirement that the well be vertical with no deviations for installation.

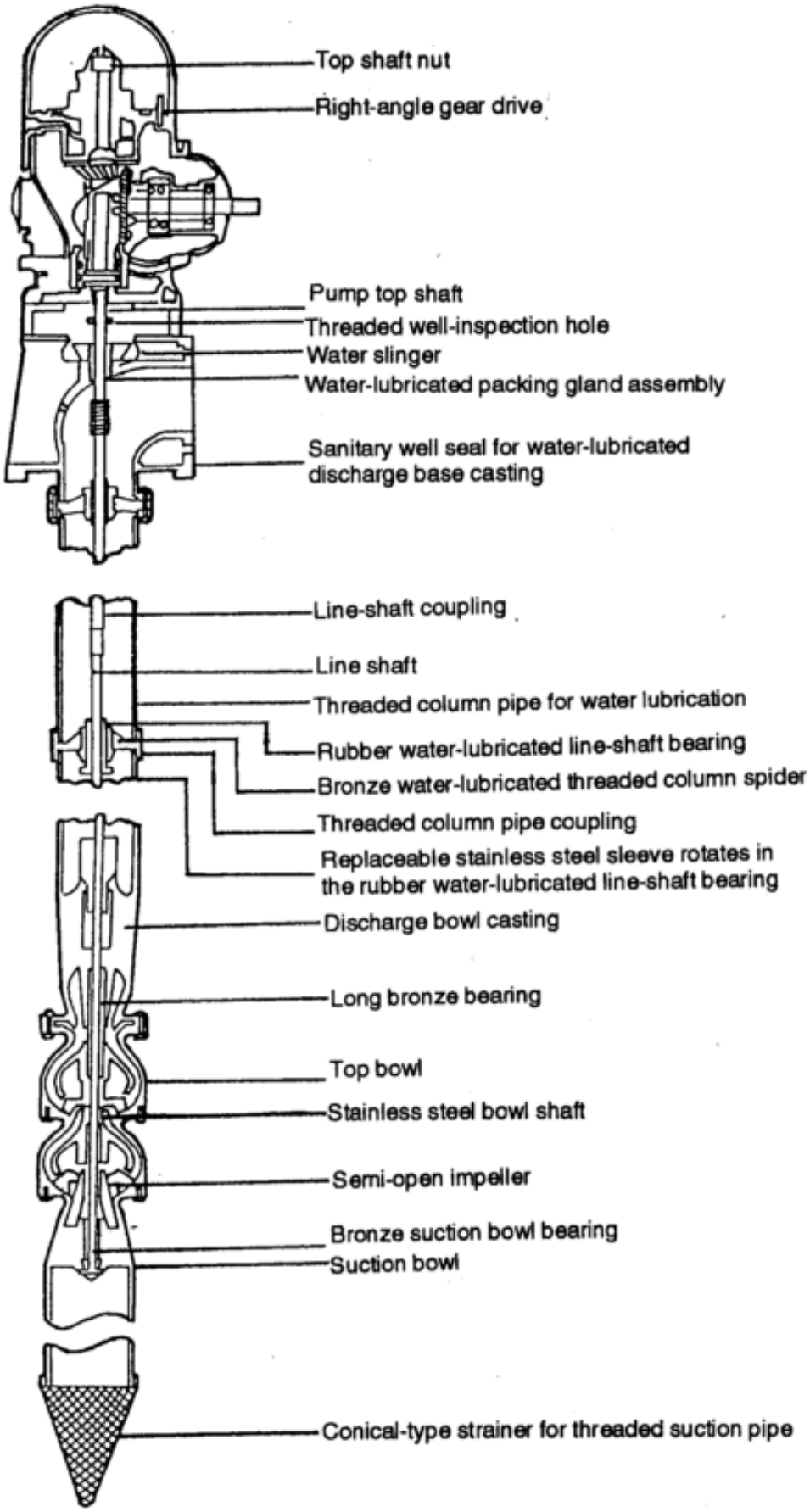

Figure 4-6. Turbine pump

c. *Helical-Rotor Pump.* This pump is a positive-displacement-, rotary-screw-, or progressing-cavity-type pump (Figure 4-7). The pump is designed for relatively low-capacity, high-lift wells that are 4 inches or larger in diameter. The main elements of the pump are a highly polished, stainless-steel helical rotor, a single-thread worm; and an outer rubber stator. The rotor is located in the stator. During the rotation process, the rotor forces a continuous stream of water forward along the cavities in the stator producing a uniform flow. The helical-rotor pump is designed to produce 50 GPM at 1,800 revolutions per minute (RPM) against a 250-foot head.

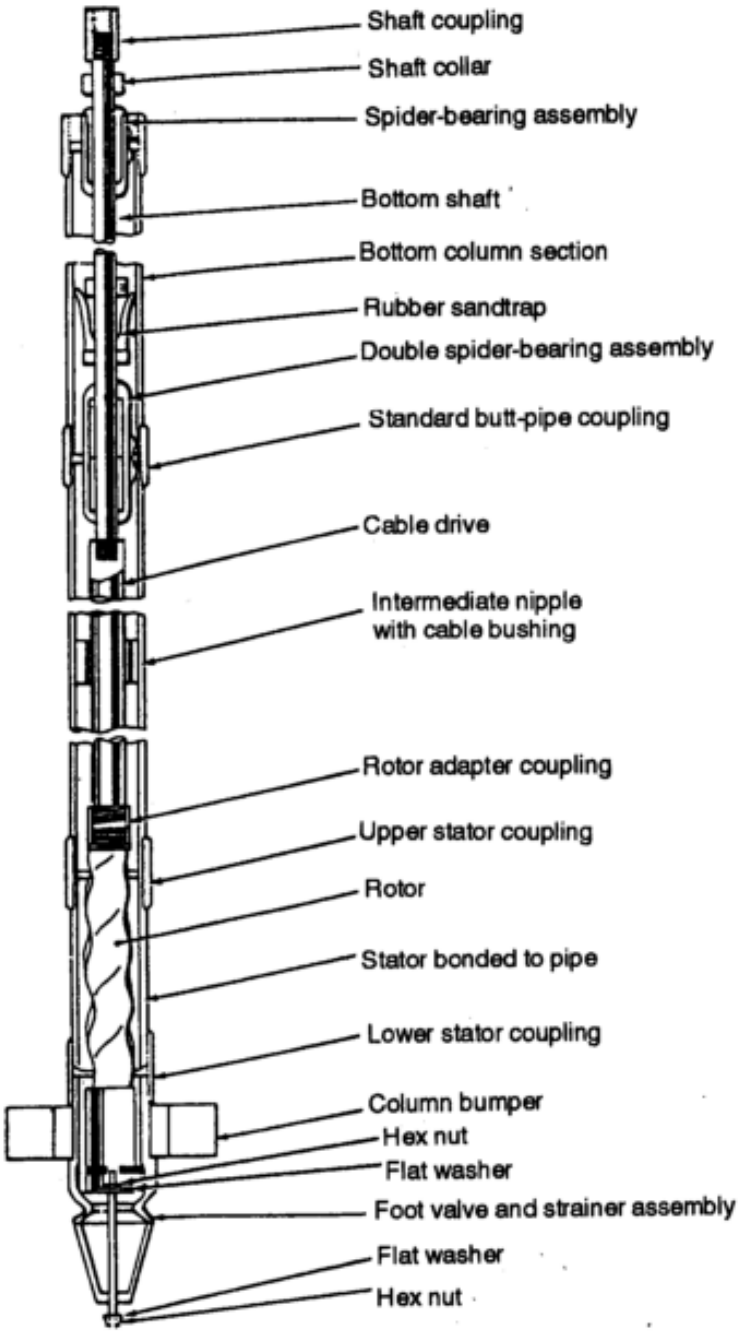

Figure 4-7. Helical-rotor pump

d. *Jet Pump.* This pump is a combination of a surface centrifugal pump, down-hole nozzle, and venturi arrangement (Figure 4-8). It can be used in small diameter wells that require a lift of 100 feet or less. The pump supplies water, under pressure, to the nozzle. The increase in velocity at the nozzle results in a decrease in pressure at that point, which in turn draws water through the foot

valve into the intake pipe. The combined flow then enters the venturi where the velocity is gradually decreased and the pressure head recovered. The excess flow is discharged at the surface through a control valve, which also maintains the required recirculating flow to the nozzle.

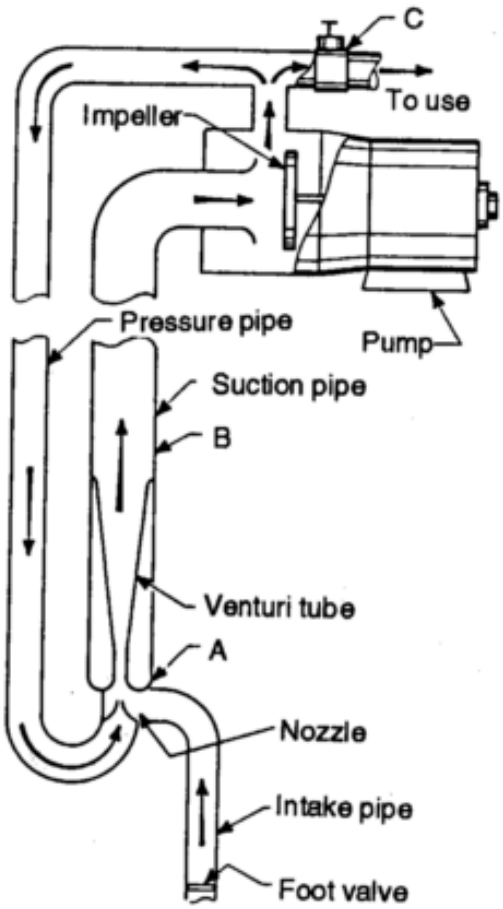

Figure 4-8. Jet pump

A jet pump's efficiency is low compared to an ordinary centrifugal pump. However, other features make the jet pump a desirable pump. They are--

- Adaptability to wells as small as 2 inches in diameter.
- Easy accessibility to all moving parts at the ground surface.
- Simple design resulting in relatively low purchase and maintenance costs.

4-4. Air-Lift Pumps.

a. *Principle.* Water can be readily pumped from a well using an air-lift pump. There are no air-lift pumps in the Army supply system; however, in the field, you can improvise and make a pump using compressed air and the proper piping arrangement. The assembly consists of a vertical discharge (eductor) pipe and a smaller air pipe. Both pipes are submerged in the well below the pumping level for about two-thirds of the pump's length. The compressed air goes through the air pipe to within a few feet of the bottom of the eductor pipe and is then released inside the eductor pipe. A mixture of air bubbles and water forms inside the eductor pipe. This mixture flows up and out the top of the eductor pipe. The pumping action that causes water to rise as long as compressed air is supplied is the difference in hydrostatic pressure inside and outside the pipe resulting from the lowered specific gravity of the mixed column of water and air bubbles. The energy operating the air lift is contained in the compressed air and released in the form of bubbles in the water. Figure 4-9 shows the operating air-lift principle.

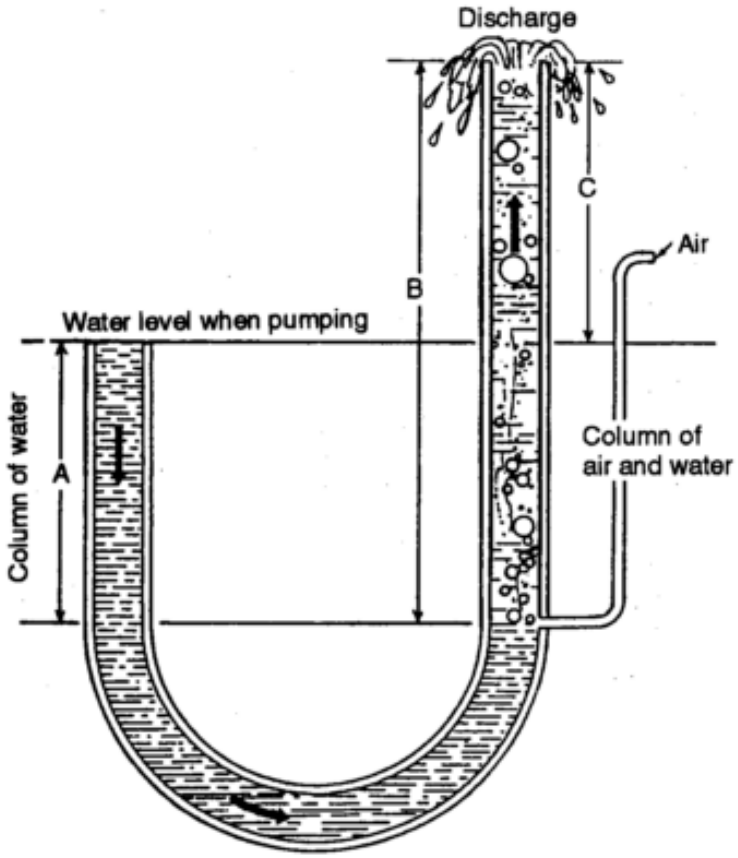

Figure 4-9. Air-lift principle

WARNING

Air and fluids under pressure can cause injury. Make sure all air couplings are tight and that lines and hoses are in good condition.

You should arrange an air lift with the air pipe inside the eductor pipe (Figure 4-10). You can use this arrangement for test pumping wells and for well development. You can use the well casing for the eductor pipe. However, to pump sand and mud from the bottom of a well during well development and completion, use a separate eductor pipe. This type of pump is also useful in wells that, because of faulty design, produce sand with the water. This condition will quickly create excessive wear on most pumps. By setting the educator pipe to the bottom of the screen, sand will be removed before it fills the screen.

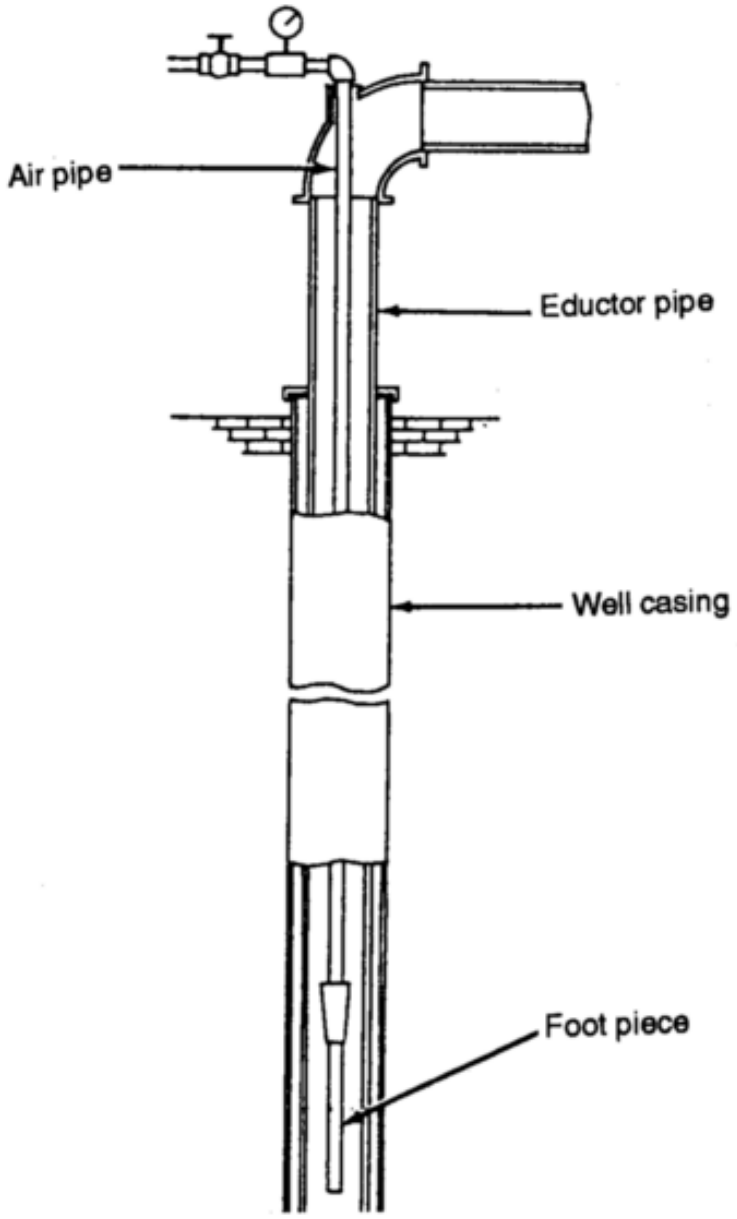

Figure 4-10. Air pipe in an eductor pipe

b. *Installation Design.*

(1) Submergence. Submergence is the proportion (percentage) of the length of the air pipe that is submerged below the pumping level. Use the following formula and Figure 4-11 to determine submergence percentage:

$$\%submergence = \frac{x}{y} \; x \; 100$$

where—

x = *vertical distance from A to C.*
y = *vertical distance from C to D.*

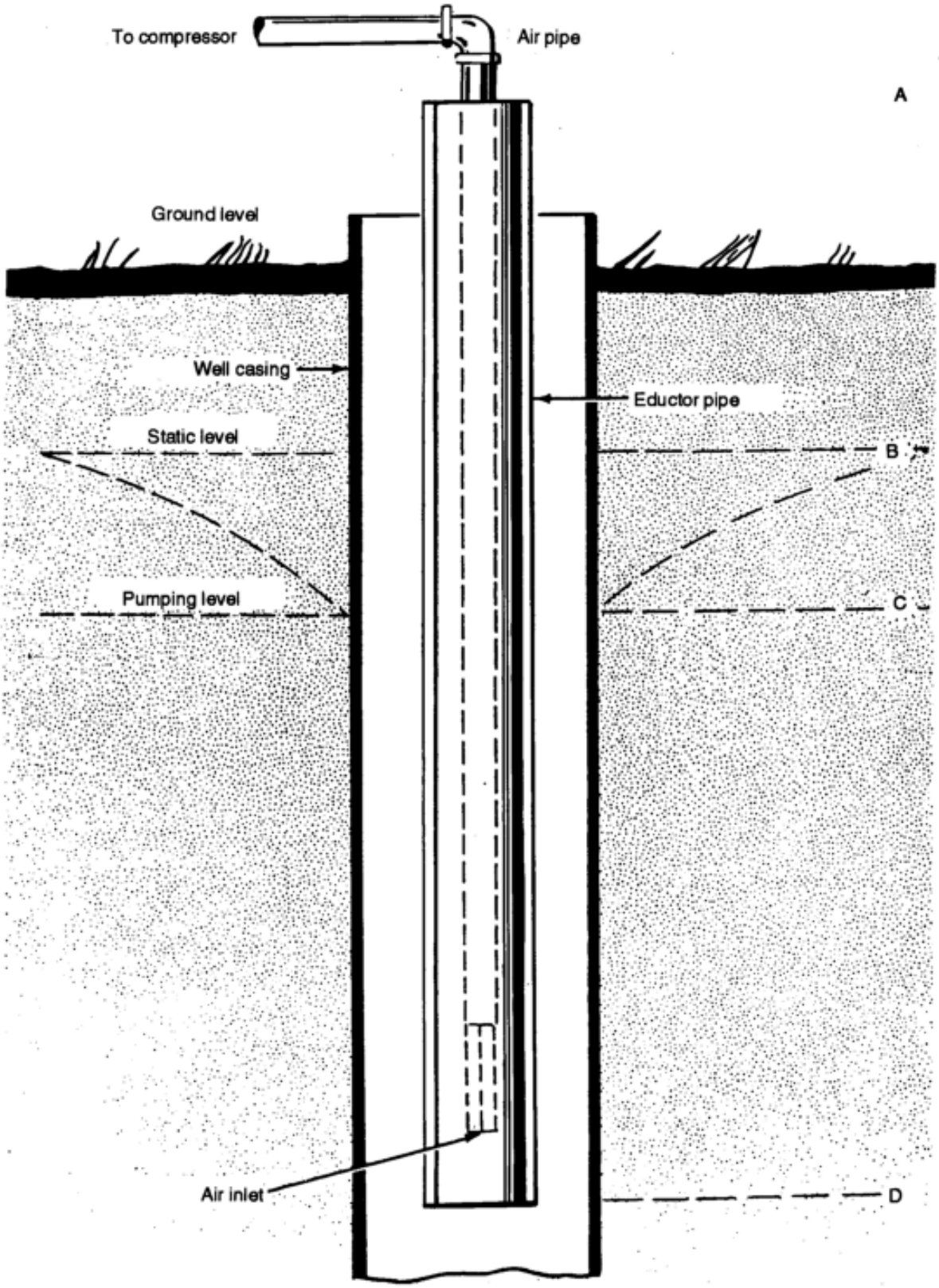

Figure 4-11. Submergence percentage

(2) Air Pressure. To calculate the required air pressure to start the air lift, you must know the length of air pipe submerged below the static level. See Figure 4-11, area from point B to point D, for the starting air pressure. Divide the area from point C to D by 2.31 (constant/conversion factor) to get the required air pressure (psi).

(3) Compressors. The 350 cubic feet per minute (cfm) compressor on military drilling rigs, such as the LP-12, is sufficient for operating an air lift. With a submergence of 60 percent, a lift not exceeding 50 feet and the compressor delivering 350 cfm

of air, a well can be pumped at over 200 GPM. If you need more air, use another compressor in parallel. The maximum pressure that the compressor will produce is 200 psi, which is enough to start an airlift with about 420 feet of air pipe submerged.

CAUTION

Operate compressors upwind of the drilling rig. If you do not, dust could damage the equipment.

(4) Correct Air Amounts. For efficiency, the compressor must deliver the correct amount of air. Too much air causes excessive friction in the pipe lines and waste of air from incomplete expansion in the discharge pipe. Too little air results in a reduced yield and a surging, intermittent discharge. To calculate air-compressor requirements, see Table 4-2.

Table 4-2. Pump readings

Total Depth (feet)	Submergence (percent)
Up to 50	66 to 70
50 to 100	55 to 66
100 to 200	50 to 55
200 to 300	43 to 50
300 to 400	40 to 43
400 to 500	33 to 40

(5) Performance and Efficiency. The performance and efficiency of an air lift vary greatly with the percent of submergence and the amount of lift. Generally, a submergence of 60 percent or more is desirable. If a well has a considerable pumping-level depth, you will have to use a lesser submergence percent. However, if the submergence is too low, the air lift will not operate. See Table 4-3 for performance data for air-lift pumps corresponding to different submergence conditions and lifts. The values are for properly proportioned air and eductor pipes with minimum frictional losses. The efficiencies indicated in terms of gallons of water per cubic foot of air probably cannot be fully attained in military field operations.

Table 4-3. Submergence for air-lift pumping

Lift (feet)	Submergence (percent)	Lift (percent)	Rating	Submergence (feet)	Starting Air Pressure (psi)	Gallons of Water (per cubic foot of air)	Cubic Feet of Air (per gallon of water)	Total Length of Air Line (feet)
25	54	46	Minimum	29	13	4.55	0.22	54
	68	32	Best	53	23	8.34	0.12	78
	76	24	Maximum	79	34	14.30	0.07	104
50	51	49	Minimum	52	23	2.50	0.40	102
	65	35	Best	93	40	4.35	0.23	143
	72	28	Maximum	129	56	6.57	0.15	179
100	47	53	Minimum	89	38	1.43	0.70	189
	60	40	Best	150	65	2.70	0.37	250
	67	33	Maximum	203	88	3.70	0.27	303
150	43	57	Minimum	113	49	1.05	0.95	263
	55	45	Best	183	79	2.04	0.49	333
	62	38	Maximum	245	106	2.70	0.37	395
200	41	59	Minimum	139	60	0.85	1.18	339
	52	48	Best	216	94	1.54	0.65	416
	59	41	Maximum	288	125	1.89	0.53	488
250	39	61	Minimum	160	69	0.71	1.41	410
	49	51	Best	240	104	1.21	0.83	490
	56	44	Maximum	318	138	1.45	0.69	568
300	37	63	Minimum	176	76	0.60	1.67	476
	47	53	Best	266	115	0.96	1.04	566
	53	47	Maximum	339	147	1.18	0.85	639
350	36	64	Minimum	197	85	0.53	1.88	547
	46	55	Best	287	124	0.80	1.25	637
	50	50	Maximum	350	151	0.94	1.06	700
400	35	65	Minimum	215	93	0.48	2.07	615
	43	57	Best	302	130	0.69	1.45	702
	48	52	Maximum	369	160	0.79	1.26	769
450	34	66	Minimum	232	100	0.44	2.27	682
	42	58	Best	326	141	0.61	1.65	776
	47	53	Maximum	399	173	0.68	1.48	849
500	34	66	Minimum	258	112	0.41	2.46	758
	41	59	Best	348	150	0.54	1.85	848
	46	54	Maximum	426	184	0.60	1.66	926
550	34	66	Minimum	283	123	0.38	2.65	833
	40	60	Best	367	159	0.49	2.05	917
	45	55	Maximum	450	195	0.54	1.86	1,000
600	33	67	Minimum	296	128	0.36	2.81	896
	40	60	Best	400	173	0.45	2.25	1,000
	44	56	Maximum	471	204	0.49	2.06	1,071
650	33	67	Minimum	320	139	0.34	2.94	962
	39	61	Best	416	180	0.42	2.40	1,066
	43	57	Maximum	490	212	0.44	2.26	1,140
700	33	67	Minimum	345	149	0.33	3.00	1,045
	39	61	Best	448	194	0.39	2.55	1,148
	43	57	Maximum	528	228	0.42	2.40	1,228

(6) Foot Piece. For best efficiency, the end of the air pipe should have a foot piece (Figure 4-10). This device breaks the air into small streams so that the bubbles formed will be as small as possible. You can make a foot piece by drilling numerous small holes in a short section of pipe.

(7) Discharge Pipe. You can approximate the discharge-pipe length from Table 4-3. Lower submergence than those shown result in a lower pumping efficiency. The planned pumping rate must not cause an excessive drop in the water level, reducing the submergence. The two chief losses in the discharge pipe are air slipping through the water and the water friction in the discharge line. As the velocity of discharge increases, slippage decreases and friction increases. Eductor intake loss occurs at the lower end of the pipe due to friction and to the energy required to accelerate the flow of water into the pipe.

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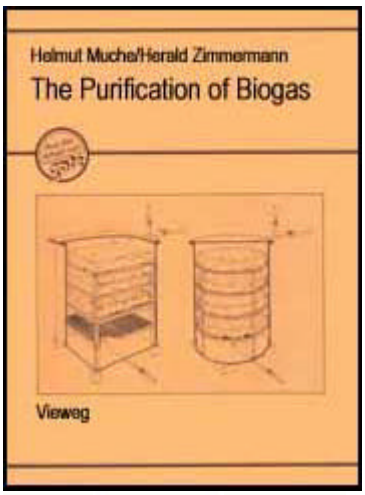

Purification of biogas (1985) (GTZ-Gate)
- *(introductory text)*
- 0. Introduction
- 1. Properties of hydrogen sulphide
- 2. The origins of hydrogen sulphide in biogas plants
- 3. The effect of hydrogen sulphide on the biogas plant and the gas-utilization equipment
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- 10. Summary
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Purification of biogas (1985) (GTZ-Gate)

Helmut Muche/Harald Zimmerman

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The authors:

Helmut Muche, Harald Zimmermann, Ingenieurbüo für Verfahrenstechnik, Lemgo

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0. Introduction

This review attempts to set out the procedures for removing hydrogen sulphide from biogas.

Hydrogen sulphide is particularly harmful when biogas is used in internal combustion engines. Its chemical reactions and those of its combustion product - sulphur dioxide, quickly lead to severe corrosion and wear on engines.

The only practical way of removing the hydrogen sulphide on a small scale is by dry desulphurization using ferrous substances. Locally available, iron-containing soil is suitable for use as the purifying agent in Third World countries. This manual contains a detailed description of criteria for designing the purification chamber. It also presents the basic steps for manufacturing the purifying agent or absorbent.

The paper is mainly directed at staff in the various regional biogas advisory services. In particular the colleagues must give assistance in selecting the soils, and sometimes carry out investigations to identify the composition of the substances. Only an optimally applied purification agent can ensure a long life for the gas user, particularly engines, and avoid unnecessary repairs and maintenance on the plant equipment.

1. Properties of hydrogen sulphide

Physical and chemical properties

Hydrogen sulphide (H_2S) is a colourless, very poisonous gas. It is inflammable and forms explosive mixtures with air (oxygen). H_2S has a characteristic smell of "rotten eggs". This odour is only apparent in a small concentration range (0.05-500 ppm).

H_2S is soluble in water forming a weak acid. A combustion product of H_2S is SO_2 . This makes the exhaust gases very corrosive (sulphuric acid) and contaminates the environment (acid rain).

Toxicity

H_2S is very poisonous (comparable to hydrogen cyanide).

Lower toxic limit 10 ppm H_2S.

Lethal dose

1.2-2.8 mg H2S per lifer of air or 0.1% kills instantly.

0.6 mg H2S per lifer of air or 0.05% kills within 30 minutes to one hour.

Effect

H2S changes the red blood pigment; the blood turns brown to olive in colour. The transport of oxygen is hindered. The person suffocates "internally". The symptoms are irritation of the mucous membranes (including the eyes), nausea, vomiting, difficulty in breathing, cyanosis (discoloration of the skin), delirium and cramps, then respiratory paralysis and cardiac arrest. At higher concentrations immediate respiratory paralysis and cardiac arrest are the only symptoms.

Even if a person survives poisoning, longterm damage to the central nervous system and to the heart remains.

First aid

Fresh air, artificial respiration; warmth, rest, transportation in an inclined position. There is a danger of suffocation if the patient is unconscious!

Medical care

Artificial respiration. Analeptics. Further observation of symptoms, particularly the function of the circulatory and pulmonary systems. Beware of oedema of the larynx. Codeine may be administered for bronchitis as soon as the asphyctic stage is past. Oedema of the lungs during the latent period: treat prophylactically with high doses of prednisolone i.v. In addition, infusions of altogether 0.5 g THAM/kg. Absolute rest, warmth, infection prophylaxis, keep breathing passages free. Only small

quantities of morphine. Combat anhydremia by peroral administration of fluids or rectoclysis.

Chronic effects

Long-term exposure to very small amounts of H2S can lead to chronic poisoning. Symtoms: irritation of the mucous membranes, sensitivity to light, bronchitis, headaches, weariness, circulatory disturbances and loss of weight.

2. The origins of hydrogen sulphide in biogas plants

Formation

Hydrogen sulphide is formed in the biogas plant by the transformation of sulphur-ontaining protein. This can be protein from plants and fodder residues. However, when animal and human faeces are used, bacteria excreted in the intestines is the main source of protein. Inorganic sulphur, particularly sulphates, can also be biochemically converted to H2s in the fermentation chamber.

Amounts

Plant material introduces little H_2S into biogas. On the other hand, poultry droppings introduce, on average, up to 0.5 vol. % H_2S, cattle and pig manure about 0.3 vol. % H_2S.

Protein-rich waste (e.g. swill, molasses etc.) can produce large amounts of hydrogen sulphide (up to 3 vol. %). Inorganic sulphates (from salty, stall rinse water or diluting water) also produce considerable H_2S.

3. The effect of hydrogen sulphide on the biogas plant and the gas-utilization equipment

Fermentation inhibition

Dissolved H_2S is contained in the fermentation slurry. An equilibrium is set up between the dissolved H_2S and the H_2S in the gas phase. The dissolved H_2S in high concentrations can be toxic to the bacteria in the slurry. It can inhibit the production of biogas and cause its composition to alter.

Remedies - put less sulphur-rich material in the plant, dilute with water. In less serious cases stir vigorously (to drive H_2S out of the slurry).

Corrosion by H_2S

The presence of H_2S gas in biogas makes it corrosive to metal parts. Iron is subject to surface attack, although not major corrosion. Galvanized parts are similarly subject to surface corrosion.

The effect on non-ferrous metals in components, such as pressure regulators, gas meters, valves and mountings, is much more serious. They are very quickly corroded. These materials also corrode in gas engines (seals and valves).

Corrosion by SO_2 from H_2S

The combustion product SO_2 combines with water vapour and badly corrodes the exhaust side of burners, gas lamps and engines. Burning biogas in stoves and boilers can also result in damage to the

chimney.

Engines

The acid which is formed corrodes engine parts in the combustion chamber, exhaust system and in various bearings. This is enhanced by frequent starts, short running times and the relatively low temperatures when starting up and after cutting off the engine. The water cooling system also provides the means (water needed to form sulphuric acid) for corrosion.

Service life

Running engines with H_2S -containing gas can reduce the service time to the first general overhaul by about 10-15%.

Engine oil changes

The suphur content of biogas used in gas engines shortens the time between oil changes. SO_2 from combustion and water vapour both dissolve in the lubricating oil. The oil becomes acidic and its properties change. It loses its ability to lubricate and sometimes corrodes metal components. Under continuous operating conditions the interval between oil changes is reduced to 200 - 250 hours.

Cooking stoves

If biogas is burned for cooking and lighting in poorly ventilated rooms' the occupants

4. Determination of the hydrogen sulphide content of biogas

The H_2S content of the purified gas can be measured to check the effectivity of the desulphurization process.

Laboratory method

In the laboratory the H_2S content of gases is usually measured iodometrically using cadmium acetate. However, the necessary techniques are too involved for an application here.

Lead acetate method

A simple way of determining the presence of H_2S in biogas is a test with lead acetate paper. A piece of paper soaked with lead acetate solution is held in the gas stream for a short time. The presence of H_2S colours the strip black. The difficulty with this method is its high sensitivity which means that even a very small amount of H_2S can be detected. A small amount of H_2S, however, is not an indication of greatly reduced efficiency of the desulphurization. Simple desulphurization plants may still posses an adequate purifying performance.

Detection with iodine solution

Another simple method for detecting H_2S is with an alcoholic solution of iodine, such as often available in first aid kits. A small amount of biogas is carefully introduced into the iodine solution. If H_2S is present the reddish brown solution will decolour. The formation of elementary sulphur causes a milky turbidity.

The test-tube method

The test-tube method is a very exact and simple method of determining the H_2S concentration in biogas. Suitable tubes are available for measuring the concentration in both raw and purified gas. The gas detector apparatus (ca. 450,- DM) and the individual test tubes (ca. 5,- DM each) are relatively expensive. Also, the test tubes can only be preserved for a limited time. This method is only expedient in the regional biogas extension service or similar advisory services. This apparatus could then be used to provide empirical field values for individual plants. The intervals for recharging the purifying agent can then be laid down.

As yet there is no simple, cheap, test method available. For this reason a close control of the desulphurization plant is strongly recommended.

5. Methods for removing hydrogen sulphide from biogas

General

Of the many processes traditionally and presently employed, that have been used for large-scale desulphurization of technical gases, only the so-called "dry" process is suitable on a smaller scale for biogas plants. They are acceptable from the point of view of technical complexity and maintenance and the degree of purification is satisfactory.

The desulphurization of biogas is based on a chemical reaction of H_2S with a suitable substance.

The lime process

The oldest process is the desulphurization of gases with quick lime, slaked lime in solid form or with slaked lime in liquid form. The process using quick or slaked lime has not been applied on a large scale for a long time. The large amounts of odourous residue that are produced cannot be satisfactorily disposed of. The handling of large amounts of dissolved or suspended slaked lime requires elaborate equipment.

Large concentrations of CO_2 which are present in biogas make the satisfactory removal of H_2S difficult. The CO_2 also reacts with the quick and slaked lime and uses it up quickly. The $Ca(HCO_3)_2$ formed reacts with $Ca(SH)_2$ which is formed by the reaction of H_2S with $Ca(OH)_2$ thus resulting in the reoccurance of H_2S. However, a large scale biogas plant in Germany with the cogeneration of heat and power has recently been constructed using a lime purifier. The results of long term tests are not yet available.

In as far as enough lump, quick lime is available in the countries concerned, this process could be considered for desulphurization. The apparatus for utilizing quick lime corresponds in construction and function to that used for the desulphurization with iron-containing substances.

Ferrous materials

Ferrous materials in the form of natural soils or certain iron ores are often employed to remove H_2S.

Principle

The ferrous material is placed in a closed, gas tight container (of steel, brickwork or concrete). The gas to be purified flows through the ferrous absorbing agent from the bottom and leaves the container at the top, freed from H_2S.

Chemistry

The absorbing material must contain iron in the form of oxides, hydrated oxides or hydroxides. These react as follows:

$2\ Fe(OH)_3 + 3\ H_2S$ à $Fe_2S_3 + 6\ H_2O$ $Fe(OH)_2 + H_2S$ à $FeS + 2H_2O$

This process terminates, of course, after some time. The greater part of the iron is then present as a sulphide.

Regeneration

However, by treating the sulphidized absorbent with atmospheric oxygen, the iron can be returned to the active oxide form required for the purification of the gas:

$2\ Fe_2S_3 + 3\ O_2 + 6\ H_2O$ à $4\ Fe(OH)_3 + 3\ S_2$

$2\ FeS + O_2 + 2\ H_2O$ à $2\ Fe(OH)_2 + S_2$

The used absorbent can, therefore, be "regenerated". This regeneration cannot be repeated indefinitely. After a certain time the absorbent becomes coated with elementary sulphur and its pores become clogged. Purifying absorbents in gasworks (coke plants) acquire a sulphur content of up to 25% of their original weight, i.e. 40% sulphur by dry weight.

Process techniques

There are three different, dry desulphurizing processes available.

Without regeneration

The purification chamber consists of a box or drum. The absorbent is placed inside it on several, intermediate trays (sieve floors) to ensure that the depth of the absorbent is not more than 20-30 cm. Otherwise the absorbent would easily press together causing an increase in the resistance to the gas flow.

The biogas is fed in at the bottom of the box, flows through the absorbent and leaves the purification chamber at the top, freed from H_2S. When the absorbent becomes loaded with iron sulphides, the gas leaving the chamber contains increasingly more H_2S. The chamber is then opened at the top and the trays with the spent absorbent are removed. Then fresh absorbent is placed on the trays.

After the air in the purification chamber has again been displaced with biogas, the gas connection to the user is re-opened.

The spent absorbent is disposed of as described under the heading "Disposal of spent absorbent".

With regeneration

The spent, sulphide containing absorbent can also be regenerated by exposing it to oxygen. This can either be done by taking the used absorbent out of the chamber and exposing it to the air, or inside the purification chamber by simply sucking ambient air through it.

Since regeneration inside the chamber requires precautions against the formation of unwanted and

dangerous air-gas mixtures and would require powerful fans, regeneration outside the chamber is usually preferred. The absorbent that is to be regenerated, is spread out on the ground in as thin a layer as possible. From time to time it is turned over with a shovel. After a few days it is ready for use again.

This regeneration process can be repeated up to ten times, after which the absorbent is finally spent.

Simultaneous regeneration and loading

Simultaneous regeneration and loading of the absorbent is a special case. Here a certain, small amount of air is added to the biogas. Then sulphide formation and regeneration occur at the same time and place. As such, the absorbent acts effectively as a catalyst.

Expensive gas-measuring and mixing equipment is required for this process, however, so that it is not suitable for small biogas plants.

6. Purifying absorbent

General

The industrial absorbents in Europe are native ores or synthetic materials containing iron hydroxide or hydrated iron oxides. They are employed under such names as "H-Masse", "Lux-Masse", "Wasserwerks-Masse" and "Raseneisenerz".

Iron content

The iron content calculated as the oxide is decisive and should be at least 40-50% by weight. If possible the proportion of "active iron" should be more than 70% of the total iron. "Active iron" is hydrated iron oxide having a particular crystal modification, for instance, alpha-FeOOH and beta-FeOOH. Certain industrial, iron-containing substances such as iron pyrites and slags etc., do not react with H_2S even though they have a similar chemical composition. They are "inactive". Under certain conditions they can be activated by grinding or other mechanical processing. This partially destroys the crystal structure.

Natural materials

Some naturally occurring, ferruginous soils are suitable for use as absorbents. Those ores or soils containing large concentrations of hydrated ferric oxides ($Fe_2O_3H_2O$ or FeO(OH)) are suitable. Such ores are known as brown ironstone. There are various subtypes:

goethite (needle iron ore, pyrrhosiderite): a-FeO(OH),

lepidocrocite (ruby glance): b -FeO(OH),

limonite: (by appearance) amorphous.

They occur mainly as conglomerates and are generally classified as limonites.

The ores in question have various local names:

brown haematite (xanthosiderite),

limonite,

pea ore,

conglomerate ore,

minette (iron ooliths),

sea ore,

bog ore,

stilpnosiderite,

yellow clay ironstone,

yellow ochre.

The ores have various appearances and abundances.

Deposits

Laterite soils occur widely in tropical and subtropical areas. The iron content varies according to location: some of these laterite deposits are large enough to be mined for the production of iron.

Since laterite consists mainly of goethite, it is probably suitable for use as an absorbent. It is, of course, necessary to break or grind the material mechanically to achieve the right particle size. Since areas with laterite soils are usually cultivated for intensive crop production, i.e. the basis exists for a biogas plant, this soil appears likely for the purification agent.

The "terra rosa" found in the Mediterranean region is probably also suitable. It contains 10% of iron, again in the form of goethite.

Activation by regeneration

Some absorbents are less efficient when used for the first time. After they have been regenerated once the purification effect can be improved. The chemical processes involved have activated the material.

7. Requirements on the absorbent

Preparation of the absorbent

The absorbents must fulfil certain requirements in order to show a satisfactory, purifying action.

Alongside the requirements already mentioned concerning the iron content and the chemical composition, the following are important:

Bulk density

The absorbent must not be too "dense", that is it should possess a certain empty or pore volume. If the absorbent is too fine, the gas flow will be hindered. The resistance pressure in the layers and, thus, in the chamber will be too great. In extreme cases the purification chamber can become blocked.

Grinding, stamping

The absorbent material will normally be found in the form of soil or as lumps which should be broken up and ground. Stamping with an appropriate tool is a suitable technique.

Comminution increases the surface area (important for the chemical reaction) and secondly, the crystal structure is improved.

Filler

To obtain the desired porosity, a filler is mixed into the ferrous material. Organic fillers are suitable. They loosen the texture of the absorbent and bind a certain amount of water into it.

Suitable fillers are:

Sawdust or fine woodshavings, milled straw, chaff, fine peat, milled coconut fibre and similar substances.

A mixture with the ferrous material containing 10-15% filler is to be obtained. Water is added while mixing so that the finished mixture has a moisture content of 20-30%.

The finished absorbent

The addition of water and the filler should transform the original powdery, ferrous material into a friable, crumbly mass. It should not smear if rubbed in the hand, but should also not pulverize for lack of water.

Bulk density

The bulk density, which is a measure of the porosity, should be 0.7 - 0.8 kg/litre.

The bulk density can be measured by taking a tin can, for example, with a known volume, filling it loosely with absorbent and weighing it. The absorbent should not be packed down or pressed - but exactly as it is in the purification chamber.

Particle size

The particle size should be from 2 to 5 mm.

pH value

The finished absorbent should have a pH of at least 5. A slight alkalinity is better. If the natural soil is acidic due to humic acid or the filler is acidic (peat especially), then the absorbent can be neutralized by the addition of alkaline material.

The pH value can be adjusted with soda or potash. About 2 to 4% is added to the absorbent. As a substitute alkaline wood or plant ash could also be used.

This treatment, however, is not expected to be as effective as guaranteeing the optimal particle size and porosity.

Preparation of the absorbent

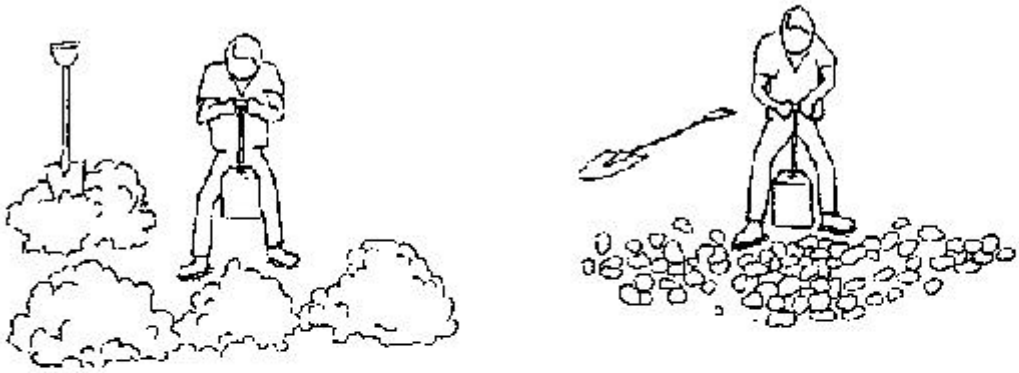

Break up the lumps of soil

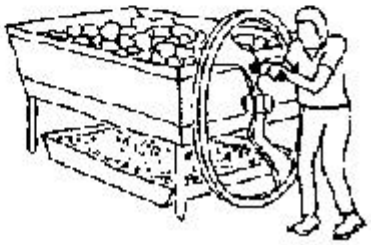

Grind the small pieces

55–70% finely ground soil | 10–15% sawdust, peat, etc. | 20–30% water

Mix the fine soil with the filler and the water

Preparation of the absorbent

8. The desulphurizing apparatus

The absorbent described above must be brought into immediate contact with the gas. This takes place in closed purification chambers. They can be made of steel, gas-tight brickwork or concrete.

Size of the chamber

The area perpendicular to the gas-flow or cross section of the chamber is important. If it is too small, the gas will flow too quickly through the absorbent and the contact time is too short. If the gas flow is too fast channels will open in the absorbent. The gas then flows through these channels and is not properly purified.

The volume (if the cross section is fixed then the height) of the chamber is also important. The chamber must contain enough absorbent for the gas to be in contact with the absorbent over a sufficient distance. Apart from this the purification chamber must be large enough so that it does not constantly need to be refilled.

Dimensioning method

A method for calculating the required size of purification chambers is included at the end of this manual.

Intermediate trays

The purification chamber contains several intermediate trays. A layer of absorbent cat 20-30 cm thick is placed on each tray. This avoids compacting of the absorbent under its own weight.

The intermediate tray floors are permeable to the biogas. They are made from perforated steel sheet or wooden slats. Wickerwork can also be used.

The individual, intermediate trays do not rest upon the absorbent in the tray below, but are supported by small spacers attached to the tray underneath. The layers of absorbent that lie between should not be compacted.

Inserting absorbent

The absorbent should be placed on the trays in such a way that it is not compressed or packed down. It should be piled up higher at the chamber walls to avoid the preferable gas penetration at this position.

The chamber corer

The chamber cover should be designed to give access to the whole chamber cross section. This allows the removal of the intermediate trays from the chamber.

Sealing the cover

The cover must be sealed with the chamber. A rubber seal made from foam rubber' old bicycle inner tubes or a water hose would be suitable.

Fixing

The cover is fixed on to the chamber with clamps or bolts.

Control valves

Control valves are installed in the feed and exit pipes of the purification chamber. These are used to disconnect the chamber from the gas flow while the absorbent is being exchanged.

Scavenging vent

In addition, a scavenging vent is installed. It is used for flushing air out of the chamber with new biogas after exchanging the absorbent and sealing the chamber.

Caution: Danger of fire and explosion

When scavenging. the chamber there is a danger of fire and explosion, due to the gas emerging from the scavenging vent. For this reason the vent exit should be installed high up and away from buildings. Open flames and smoking must be prohibited during all work on the purification chamber.

When scavenging is completed, that is, when two or three times the volume of the chamber has been vented, the valve to the user can be re-opened.

The H_2S content of the gas can also be checked via the scavenging vent even during plant operation (see Section 5).

Desulphurization chamber for biogas

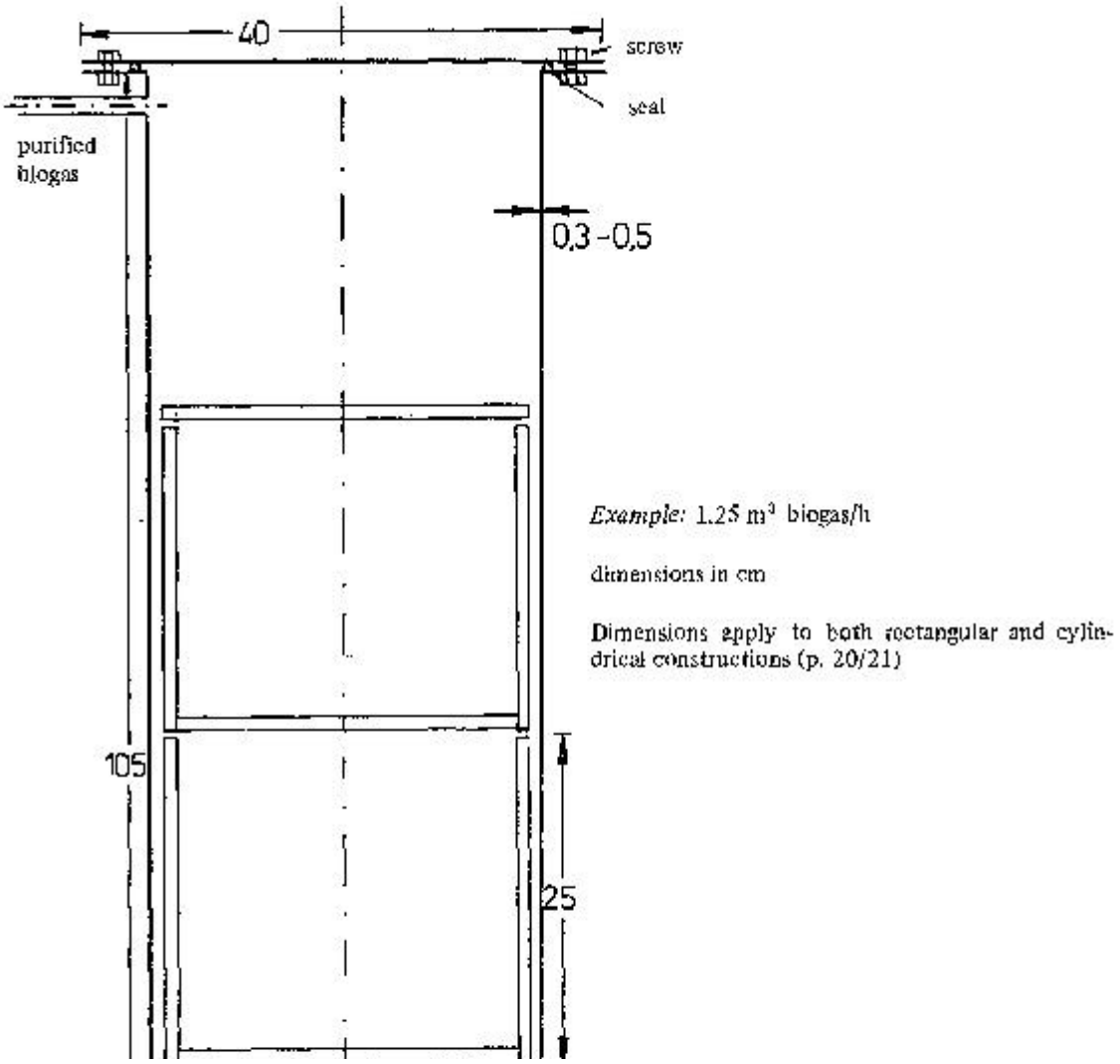

Desulphurization chamber for biogas

Cylindrical purification chamber

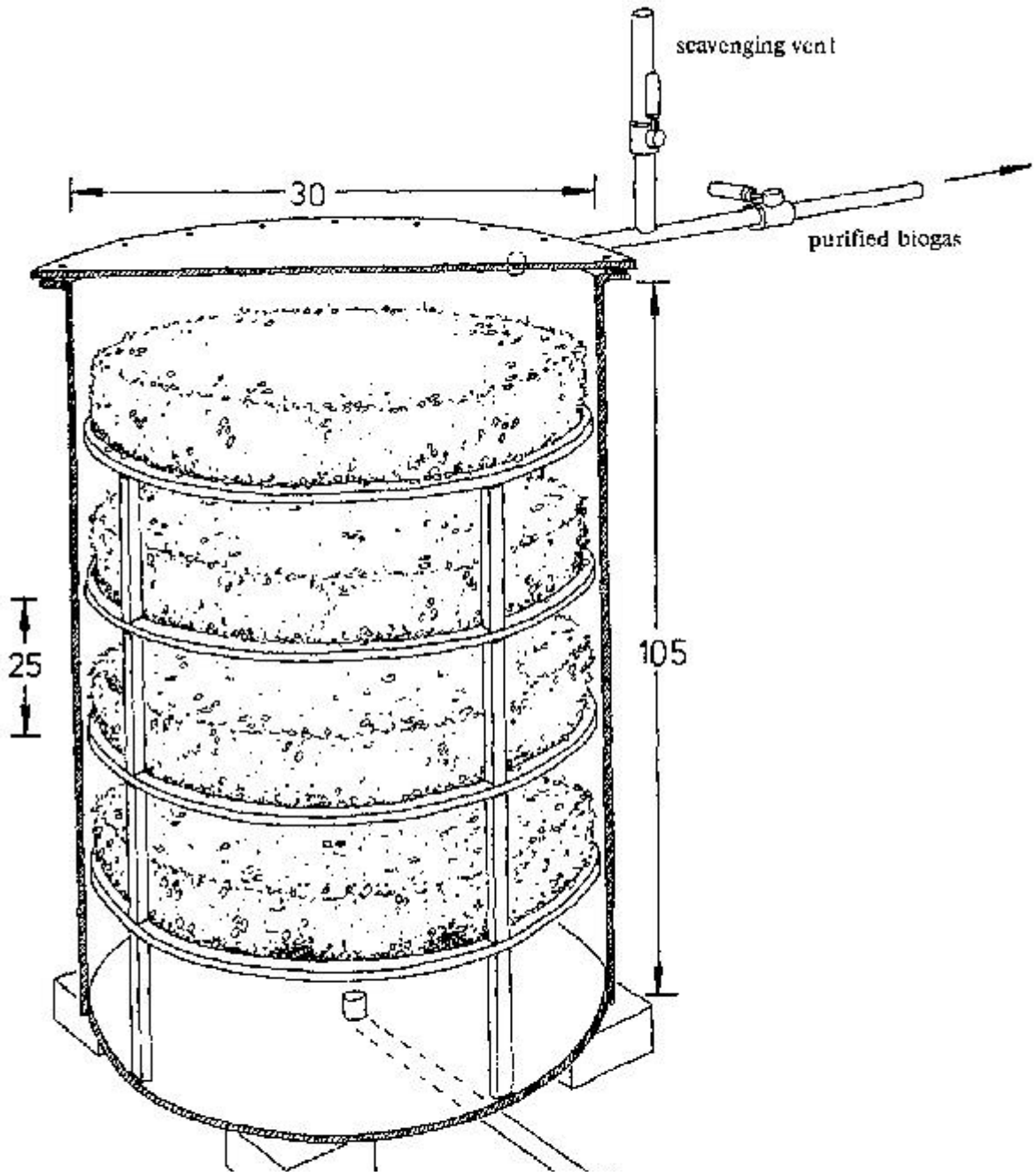

Cylindrical purification chamber

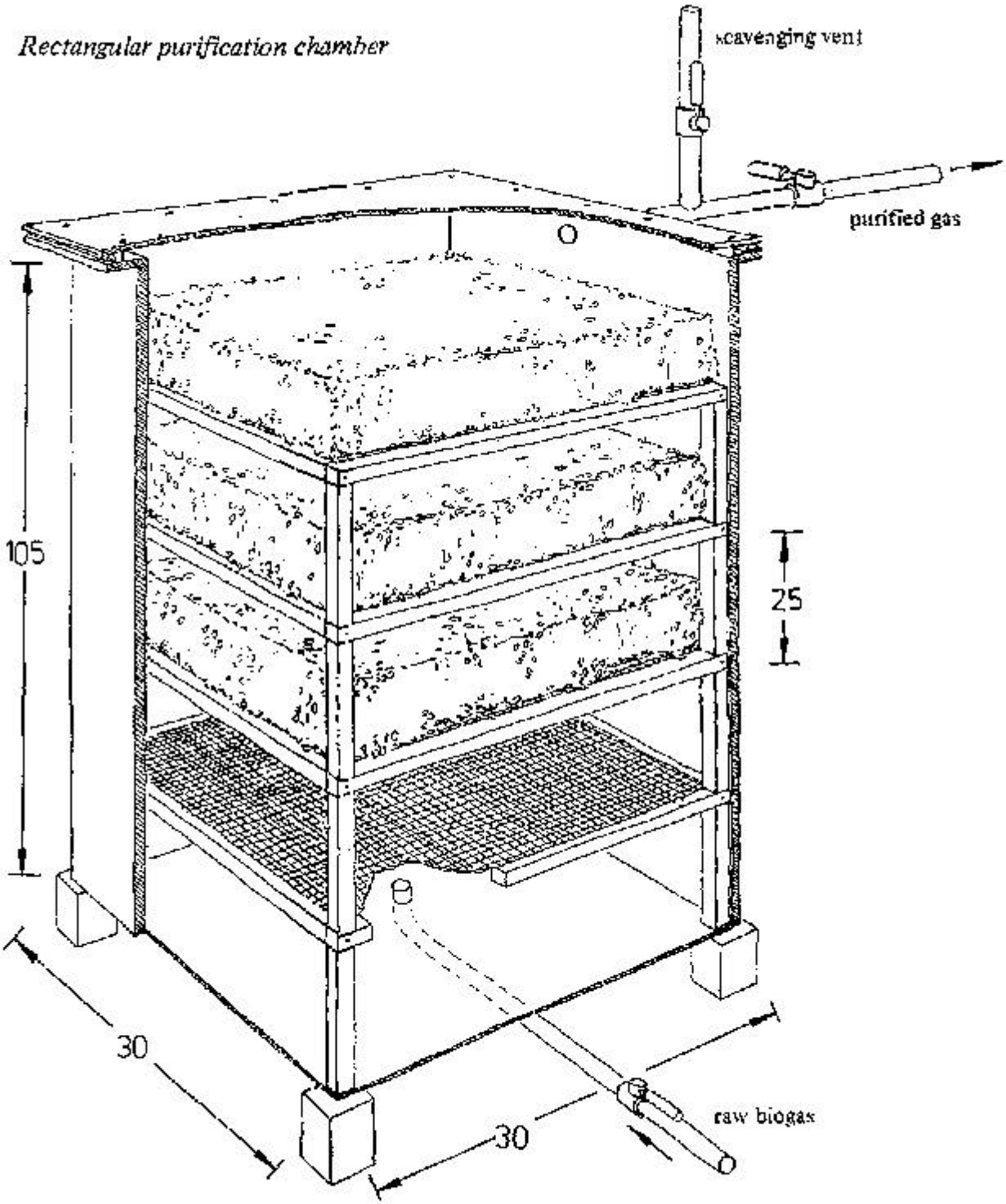

Example: 1.25 m^3/h (see dimensioning calculations)

Rectangular purification chamber

Construction of intermediate trays, cross section

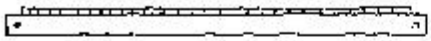

The top tray is only a frame.

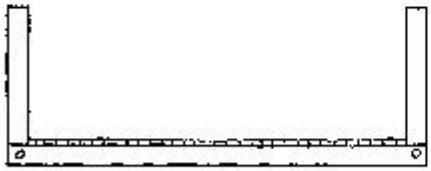

The intermediate trays have spacers extending upwards.

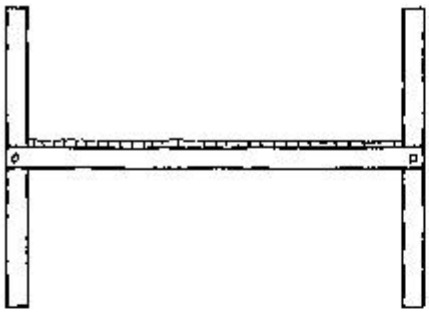

The bottom tray has spacers on the top and bottom.

The intermediate trays can be made from

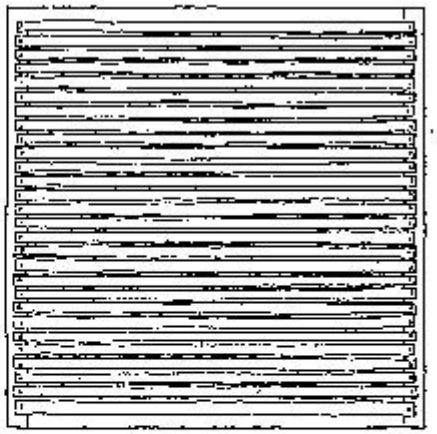

a frame covered with thin slats,

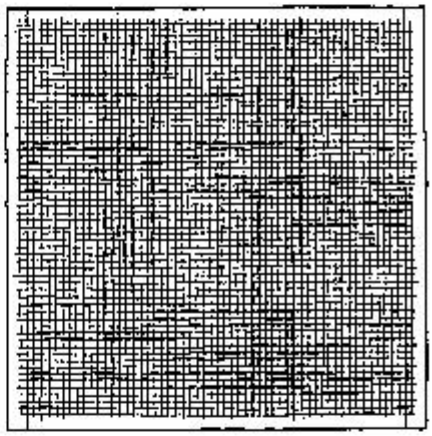

a frame covered with wire-screening,

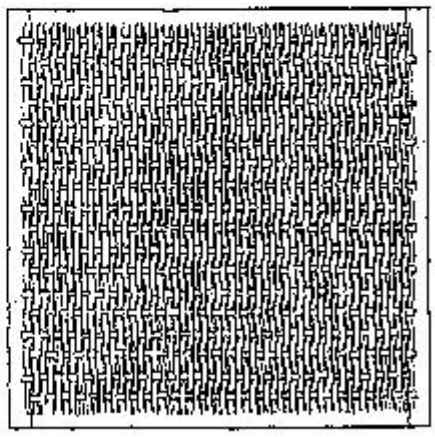

– a frame covered with wickerwork made from rattan or similar material.

Construction of intermediate trays, cross section; The intermediate trays can be made from

9. Operation procedures for gas desulphurization

Filling

Remove the cover of the purification chamber. Put in the bottom tray, which has spacers attached both below and above. Spread a layer of absorbent 20 - 30 cm thick over it. The absorbent at the edge of the tray is `'piled up" against the wall of the chamber.

The material should not be pressed and should be uniformly distributed.

The second, intermediate tray is then placed on the spacers of the bottom one and covered with absorbent. Then the rest of the intermediate trays, which are covered in turn with absorbent, are placed in position.

Sealing

Put the cover on the purification chamber together with the seal and screw it down tight.

Scavenging

Open both the feed valve in front of the chamber and the scavenging vent valve. Leave the control valve to the user closed. Let a volume of gas equivalent to three times the chamber volume escape from the scavenging vent (caution danger of fire and explosion!). Then close the scavenging vent and open the valve to the biogas user.

Emptying the chamber

When the H_2S concentration of the purified biogas begins to rise, the absorbent should be exchanged. See Section 5 for the determination of the H_2S of the gas.

Exchanging the absorbent

Close the control valves (feed and user valves) in front of and behind the purification chamber. Remove the cover of the chamber. Caution - danger of fire and explosion!

Remove the absorbent layer after layer from the chamber. In some cases the individual intermediate trays can be removed together with the entire layer of absorbent. Check the trays for damage and, if necessary, repair or replace them. Then the purification chamber can be refilled with fresh absorbent.

What to do with the spent absorbent?

The sulphur-loaded absorbent can either be regenerated by exposure to the air (oxidation) or be discarded if there is an ample supply. See the next section for details.

Regeneration

The absorbent is regenerated by spreading it on the ground in a thin layer and turning it over periodically. It is oxidized again within a few days and can be re-used.

After it has been utilized and regenerated several times the absorbent finally becomes inactive and must be discarded. Spent material highly concentrated with powdered sulphur reacts under certain

conditions with the oxygen in the air, to form sulphur dioxide - SO_2 - which irritates breathing passages and the eyes, as well as being harmful to the environment.

Self-ignition

It is only seldom that the heat of reaction is sufficient to cause spontaneous combustion. The spent absorbent should however be disposed of in a way to avoid these problems.

Disposal of spent absorbent

Discarded absorbent should thus be placed in pits and immediately covered with earth. When this is done the soil bacteria transform the sulphur and sulphides to relatively harmless sulphates.

It might also be possible to mix the used absorbent with the digested sludge. In this way the sulphur, which had been removed, could be fed back through the soil to the plants, thus completing the natural cycle. A decision can only be made after tests under local conditions.

Degree of desulphurization

Since the desulphurization capacity drops with continued use, the efficiency is not constant during the service life of a charge of absorbent. As it becomes loaded with sulphur, that is as the sulphur concentration increases, the H_2S content of the purified gas also increases. Nearly complete desulphurization can only be achieved when the absorbent is regularly exchanged and then discarded. The absorbent is not completely utilized with this procedure and the time interval between refillings is considerably shortened.

Two chambers in series

Another way of producing a very low H_2S concentration is to use at least two purification chambers in series, that is one after the other.

The first serves as a coarse purification chamber while the second serves as a fine filler chamber. Even when the first chamber allows considerable amounts of H_2S to pass through, the second is capable of reliably binding the remainder. The resulting purified biogas is almost completely free from sulphur.

The absorbent is almost completely utilized. As soon as the first chamber is unable to remove H_2S, its absorbent is exchanged. This chamber is now used as the fine filtering chamber. The second chamber which was the fine chamber is now used as the first, coarse purification chamber. That is, the order of the gas flow has been reversed.

Temperature during desulphurization

The temperature of the gas in the purification chamber should be held as constant as possible to prevent the absorbent from drying out or becoming moist. If necessary the purification chamber should be insulated. The chemical reactions in the purification process operate best at temperatures between 15-25 °C. A higher temperature is better than too low a temperature.

Regeneration of the spent absorbent

Take the intermediate trays with the used absorbent out of the chamber.

Throw the absorbent onto the ground.

Turn the absorbent over several times . . .

. . . and spread it out evenly on the ground.

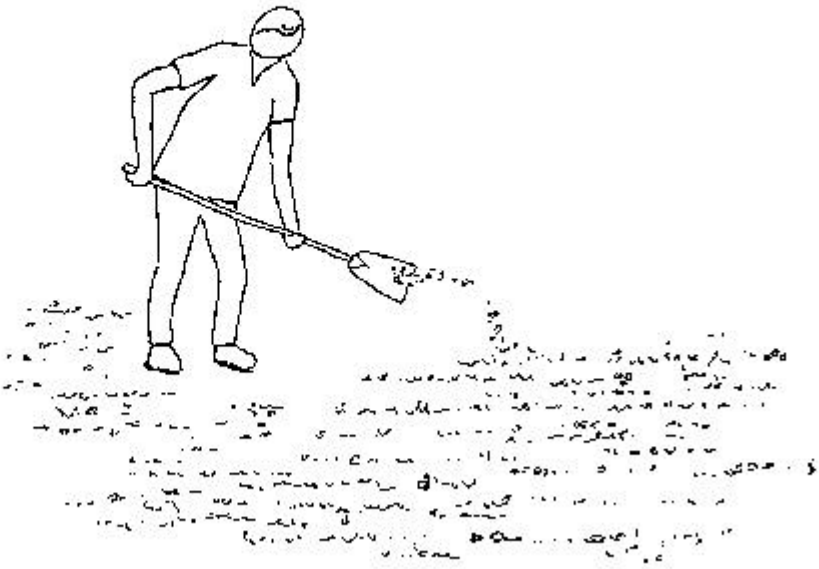

After a time turn the absorbent material over and spread it out again.

Regeneration of the spent absorbent (1)

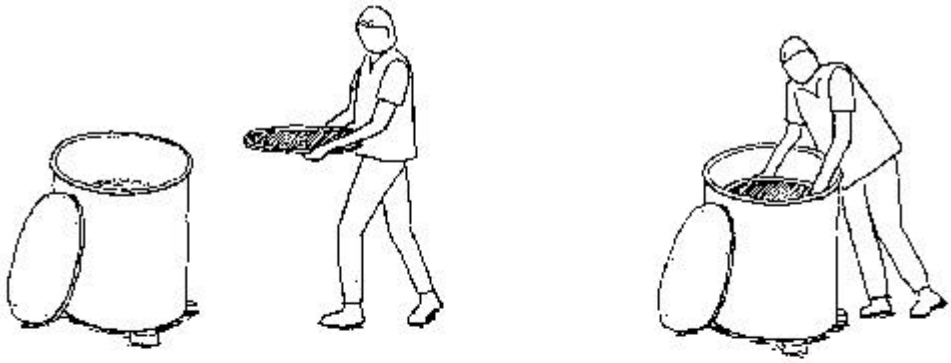

Put the intermediate trays back in the chamber.

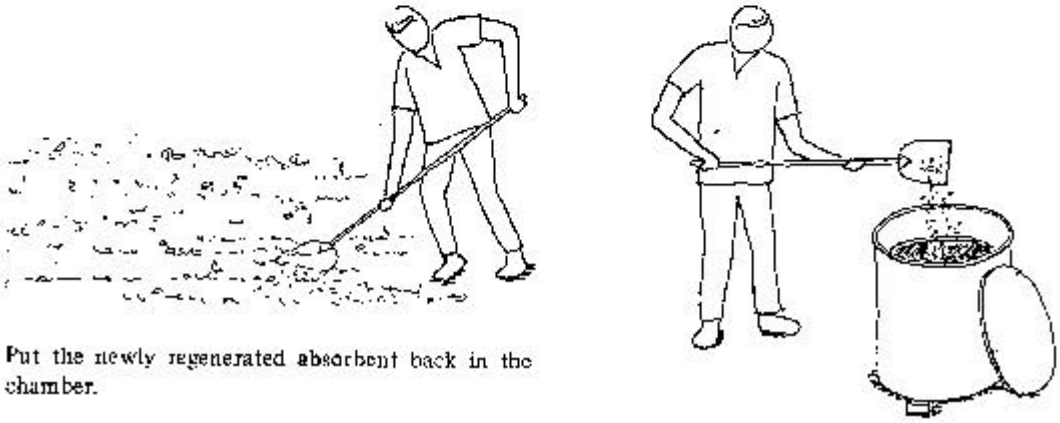

Put the newly regenerated absorbent back in the chamber.

Regeneration of the spent absorbent (2)

Starting up the chamber after refilling with regenerated absorbent

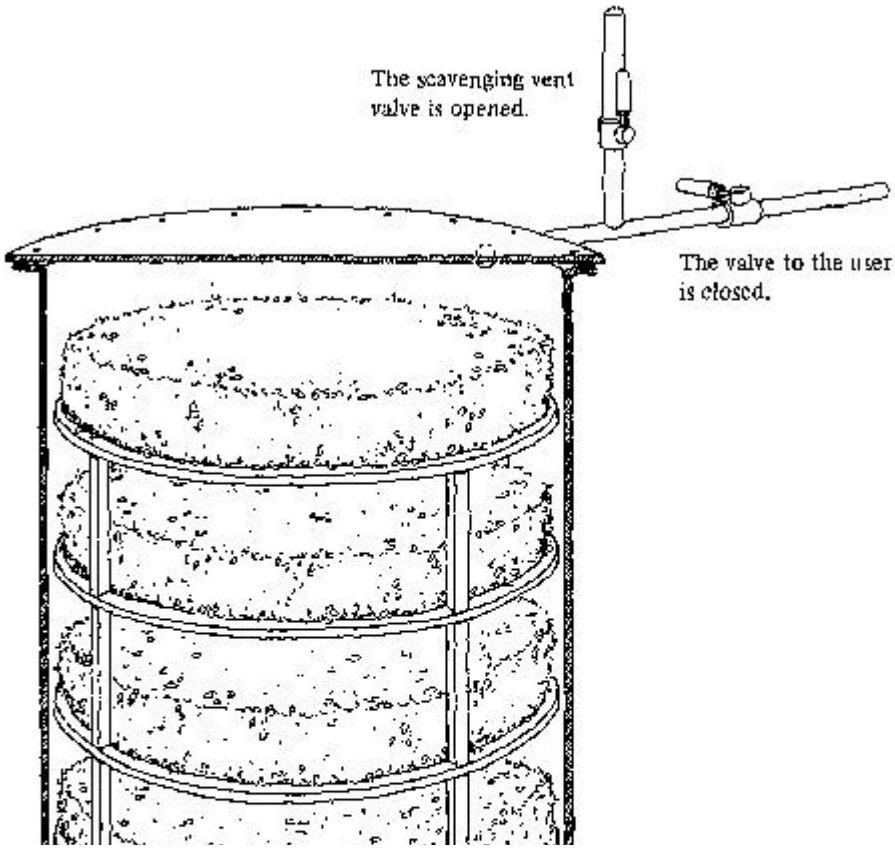

Starting up the chamber after refilling with regenerated absorbent (1)

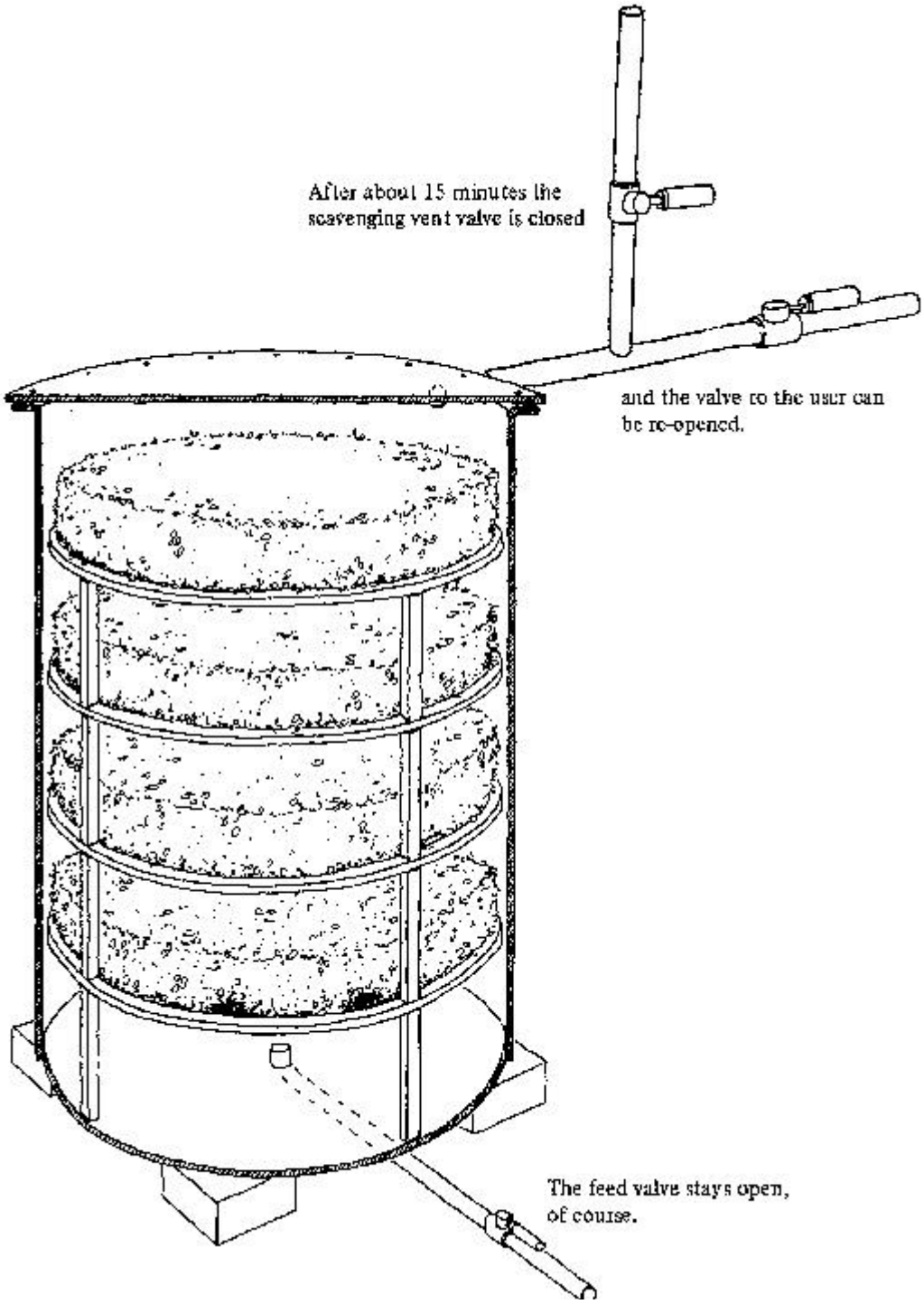

Starting up the chamber after refilling with regenerated absorbent (2)

10. Summary

Hydrogen sulphide is a natural component of biogas. Its concentration depends on the sulphur content of the raw material being digested and lies in the range 1,500 ppm 5,000 ppm or 0,15-0.5 vol. % or 2.1-7 g H_2S/m^3. Hydrogen sulphide is responsible for corrosion of various parts of the plant equipment.

The use of biogas in an internal combustion engine causes uncontrollable corrosion problems. Engine components are very susceptible to corrosion by H_2S and its reaction product SO_2.

The experience of various manufacturers and users, as well as the (older) literature indicate that with the sulphur concentrations mentioned, the service life of the engines can be reduced by up to 15% of their normal value. Not only are the resulting repair and maintenance costs increased but also the costs for service materials such as spark plugs and lubricating oils. Even with special oils the oil change interval drops up to one-fifth of that under normal conditions. The oil becomes acidic from sulphur dioxide and thus loses its lubricating properties.

Acidic exhaust gases corrode the exhaust systems very severely.

Desulphurizing biogas with acceptable investment and operating costs is only possible employing the dry desulphurization method. Iron-containing materials of specified compositions are utilized as absorbing agents for H_2S. Alongside the traditional, commercially available absorbents, certain substitutes can be used. Various tropical and subtropical soils contain sufficient iron in a suitable form. They must be prepared, in order to obtain the proper purifying characteristics. The material must be loose, porous, moist and granular.

The raw soil has to be ground and mixed with a filler and water to obtain a homogeneous texture. The finished absorbent is placed on gas-permeable trays in a purification chamber. The raw biogas is fed in at the bottom and the desulphurized or partially desulphurized gas is extracted from the upper part of the chamber.

Eventually the absorbing agent is saturated with sulphur and can be regenerated either inside the chamber or outside through natural ventilation with air (oxygen). The absorbent material can, therefore, be re-used several times.

Using two or more purification chambers connected in series ensures a continual production of purified gas and allows a good capacity utilization.

The spent absorbent can be disposed of safely by burying it. Various factors must be considered when dimensioning the purification chambers. A certain maximum flowspeed should not be exceeded The gas volume to be purified per unit time determines the cross section of the purification chamber. The chamber volume and, hence, the amount of absorbent determine the operating time for the purification process up to regeneration or exhange of the absorbent.

A calculation procedure simplifies the dimensioning of the desulphurization unit.

Appendix

Calculation method for dimensioning biogas desulphurization units

1. Calculation of the chamber cross section

$$\frac{\text{m}^3 \text{ gas/hour throughput} \times 1000 \times 1000}{3600} = \ldots\ldots\ldots \text{ cm}^3 \text{ gas/s throughput}$$

or

$$\text{m}^3 \text{ gs/hour throughput} \times 278 = \ldots\ldots\ldots \text{ cm}^3 \text{ gas/s throughput}$$

The *maximum flow rate* in the chamber is *0.5 cm/s*

The area of the section is then

$$\frac{\ldots\ldots\ldots \text{ cm}^3 \text{ gas/s throughput}}{0.5 \text{ cm/s flow speed}} = \ldots\ldots\ldots \text{ cm}^2 \text{ cross section of chamber}$$

$$\text{divided by } 10\,000 = \ldots\ldots\ldots \text{ m}^2 \text{ cross section}$$

Length of a chamber side with a square cross section:

$$\sqrt{\text{cross sectional area}} = \ldots\ldots\ldots \text{ cm or m side-length}$$

Radius of chamber for a circular cross section

$$\sqrt{\frac{\text{cross sectional area}}{\pi}} = \sqrt{\frac{\quad}{3.14}} = \ldots\ldots \text{ cm or m radius}$$

2. Calculation of the height of the chamber

The height and the cross sectional area of the chamber determine its volume. The volume deter mines the amount of absorbent that can be put into the unit. The amount in turn determines t operating time of the chamber between absorbent exchanges.

Reference values for the amount of sulphur bound in the absorbent:

without regeneration ca. 15 g sulphur/kg absorbent
with regeneration ca. 150 g sulphur/kg absorbent

The actual values depend on the absorbent used.

Figure

[ ] m^3 biogas per day throughout

[ ] g H_2S/m^3 biogas (measured) or 3 g H_2S/m^3 estimate

[ ] Number of operating days desired between absorbent exchange or regeneration

..... m^3 gas per day throughput × ..... g H_2S/m^3 gas × ..... operating days =

..... g H_2S/operating period

$$\frac{\text{..... g } H_2S\text{/operating period}}{\text{..... g } H_2S\text{/kg absorbent}} = \text{..... kg absorbent/operating period until exchange or external regeneration}$$

Bulk density of the absorbent

..... kg/l (measured) or estimated at 0.8 kg/l

$$\frac{\text{..... kg absorbent/operating period}}{\text{..... kg/l (bulk density)}} = \text{..... liter absorbent/operating period}$$

Addition for dead volume (base, head and intermediate trays): 25%

Chamber volume

..... l absorbent

+ ..... l dead volume addition

..... l chamber volume or divided by 1,000 = ... m^3

Chamber height

$$\frac{\text{chamber volume}}{\text{cross section}} = \frac{\text{..... } m^3}{\text{..... } m^2} = \text{..... m chamber height}$$

3. Number of intermediate trays

$$\frac{\text{height of chamber (m)}}{\text{0.25 m layer depth/tray}} = \frac{\text{..... m}}{\text{0.25 m}} = \text{..... trays}$$

However, there should be at least 3–4 intermediate trays.

When two or more purification chambers are connected in series, they should all have the same cross section.

Figure

Example

Calculation method for dimensioning biogas desulphurization units

1. Calculation of the chamber cross section

$\boxed{1{,}25}$ $\dfrac{\text{m}^3 \text{ gas/hour throughput} \times 1000 \times 1000}{3600}$ = 347,5 cm^3 gas/s throughput

or

$\boxed{1{,}25}$ m^3 gs/hour throughput × 278 = 347,5 cm^3 gas/s throughput

The *maximum flow rate* in the chamber is *0.5 cm/s*

The area of the section is then

$\dfrac{347{,}5 \text{ cm}^3 \text{ gas/s throughput}}{0.5 \text{ cm/s flow speed}}$ = 695 cm^2 cross section of chamber

divided by 10 000 = 0,0695 m^2 cross section

Length of a chamber side with a square cross section:

$\sqrt{\text{cross sectional area}}$ = 26,4 cm or ~~m~~ side-length

Radius of chamber for a circular cross section

$\sqrt{\dfrac{\text{cross sectional area}}{\pi}} = \sqrt{\dfrac{695 \text{ cm}^2}{3.14}}$ = 14,9 cm or ~~m~~ radius

2. Calculation of the height of the chamber

The height and the cross sectional area of the chamber determine its volume. The volume determines the amount of absorbent that can be put into the unit. The amount in turn determines the operating time of the chamber between absorbent exchanges.

Reference values for the amount of sulphur bound in the absorbent:

without regeneration ca. 15 g sulphur/kg absorbent
with regeneration ca. 150 g sulphur/kg absorbent

The actual values depend on the absorbent used.

Figure

30	m^3 biogas per day throughout
3,5	g H_2S/m^3 biogas (measured) or 3 g H_2S/m^3 estimate
60	Number of operating days desired between absorbent exchange or regeneration

...30.. m^3 gas per day throughput × .3,4.. g H_2S/m^3 gas × ..60.. operating days =

6300 g H_2S/operating period

$$\frac{6300 \text{ g } H_2S/\text{operating period}}{150 \text{ g } H_2S/\text{kg absorbent}} = 42 \text{ kg absorbent/operating period until exchange or external regeneration}$$

Bulk density of the absorbent

..0,8.. kg/l (measured) or estimated at 0.8 kg/l

$$\frac{42 \text{ kg absorbent/operating period}}{0{,}8 \text{ kg/l (bulk density)}} = 52{,}5 \text{ liter absorbent/operating period}$$

Addition for dead volume (base, head and intermediate trays): 25%

Chamber volume

52,5 l absorbent
+ 13,1 l dead volume addition

65,6 l chamber volume or divided by 1,000 = 0,066 m^3

Chamber height

$$\frac{\text{chamber volume}}{\text{cross section}} = \frac{0{,}066 m^3}{0{,}0695 m^2} = 0{,}95 \text{ m chamber height}$$

3. Number of intermediate trays

$$\frac{\text{height of chamber (m)}}{0.25 \text{ m layer depth/tray}} = \frac{0{,}95 \text{ m}}{0.25 \text{ m}} = 4 \text{ trays}$$

However, there should be at least 3–4 intermediate trays.

When two or more purification chambers are connected in series, they should all have the same cross section.

Figure

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Technical Paper No. 3

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the purification of water on a small scale

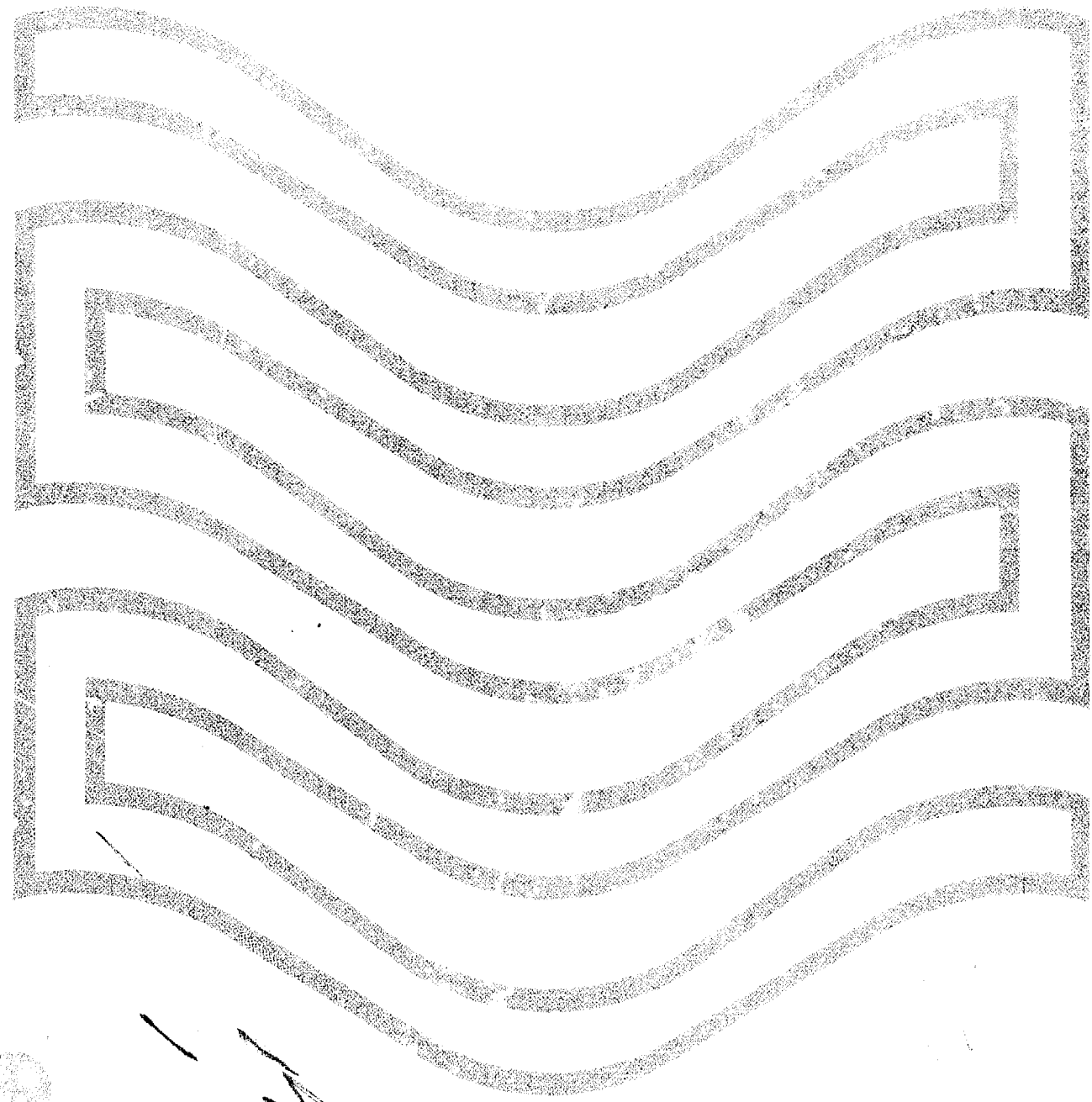

technical paper no. 3

WORLD HEALTH ORGANIZATION

INTERNATIONAL REFERENCE CENTRE FOR COMMUNITY WATER SUPPLY

TECHNICAL PAPER NO. 3

The Purification of Water on a Small Scale

MARCH 1973

THE HAGUE - THE NETHERLANDS

Introduction

In 1956 Mr. R.N. Clark of The Division of Environmental Sanitation of the World Health Organisation in Geneva prepared a note on the Purification of Water on a small scale which was published in the Bull. Wld. Hlth. Org. 1956, 14, 820-826.

There is a great need for these practical instructions, especially for rural areas, where health conditions leave much to be desired and no sanitary drinking water supply exists.

In connection hev with W.H.O. suggested to the I.R.C. for Community Water Supply to repub sh this paper, including new data available.

This I.R.C. technical paper no. 3 resulted from collaborative efforts between I.R.C. and W.H.O. and it is intended to be used by the latter organisation in its briefing of new consultants. It is hoped that the paper will be of use to them and also to many others working in the field of water supply.

I.R.C. will highly appreciate receiving any contribution, which may further improve this paper.

THE PURIFICATION OF WATER ON A SMALL SCALE

There are three general methods for the purification of water on an individual or domestic scale:

1. Boiling
2. Chemical disinfection, and
3. Filtration

These methods can be used singly or in combination.

1. Boiling

Boiling is a satisfactory method for destroying disease organisms in water and it is equally effective whether the water is clear or cloudy, whether it is relatively pure or highly contaminated with organic matter. Boiling destroys all forms of disease organisms usually encountered in water, whether they be bacteria, spores, cercariae, cysts or ova.

The amount of fuel required to boil water varies with the type of fire, stove, and vessel. Under the conditions usually associated with the boiling of drinking water, it requires about 1 kg of wood to boil one litre (approx. 2 lb per quart).

To be safe, water must be brought to a "r[illegible] boil". The appearance of bubbles (simmering) is sometimes confused [illegible] boiling, as is the appearance of mist or steam over the water. None of these signs is sufficient indication that water has reached a boiling temperature. Having reached boiling point the water should continue to boil for at least five minutes. Five minutes will be the minimum suitable to low level locations, say, below 1000 metre elevation and, as a rule, one minute further boiling should be given for locations at intervals of height above sea-level of 1000 metres, the reason being that water will boil at lower temperatures at higher altitudes.

It is also recommended that turbid or cloudy water be boiled somewhat longer than clear water. It is good practice to boil water in the same container in which it is to be cooled and stored and to use this container for no other purpose.

I.R.C.
THE NETHERLANDS
1972

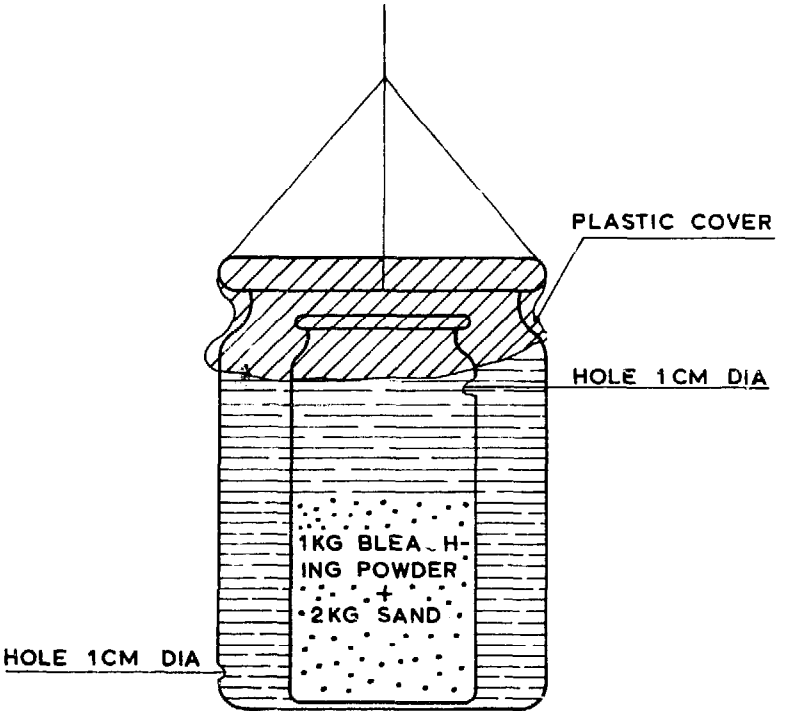

FIG. 1 CHLORINATION POT FOR HOUSEHOLD WELLS
CAP. 400 LITRES PER DAY (100 GPD) OF DRINKING WATER;
CHEMICAL RECHARGE EVERY 3 WEEKS
(SOURCE: CPHERI, NAGPUR, INDIA)

36648

Boiling alters the tase of water because it drives out dissolved gases, particularly carbon dioxide. The practice of aerating water by stirring or by pouring from one container to another is not recommended as this makes for a serious risk of recontamination. Water left for a period of several hours, up to a day, in a partially filled container, where there is a good air surface exposed, even though the mouth of the container is covered, will lose most of the boiled taste in particular if stored in a refrigerator. In any case, it is preferable to be reconciled to the inoffensive taste of boiled water than to run the risk of drinking polluted water

2. Chemical disinfection

Where a house has its own private well as its source of drinking water, the water can be disinfected in the well. Research into simple but efficient methods of disinfection has resulted in several successful designs using chlorine. Fig. 1. illustrates a double jar chlorinator developed at the Central Public Health Engineering Research Institute, Nagpur, India. An alternative method of disinfection by means of iodine is still in development with the W.H.O. International Reference Centre for Community Water Supply.

For water brought into the house from outside sources, simple chemical treatment can be given to ensure its safety. The two chemicals recommended on the grounds of efficiency and easy availability are chlorine and iodine.

Chlorine

Chlorine is a useful disinfectant for drinking water and is effective against the bacteria commonly associated with water-borne diseases. In the usual doses, it is not effective against certain cysts and ova, nor against organisms embedded in solid particles. Chlorine enters almost instantaneously into chemical combination with organic matter in water and in such "combined" form, is only of limited use for disinfection.

Sufficient chlorine must therefore be added to satisfy the "chlorine demand" of water in addition to the amount required for bacterial action.

This combination with other substances may give rise to a chlorine taste, but the presence of such a taste gives some indication that a "free chlorine" residual exists. In general, a cloudy water, or highly polluted water, containing large quantities of organic matter, is not suitable for chlorination. Turbid water can be filtered, and when clear, it can be successfully chlorinated.

Experience indicates that a contact period of about 20-30 minutes is necessary for the chlorine to destroy harmful bacteria.

Chlorine is easiest to apply in the form of a solution. A good stock solution to use in treating water contains about 1% available chlorine. This is about the strength of proprietary disinfectants such as "Milton", "Zonite" or "Javel water".

Other easily available sources of chlorine are the commercial laundry bleaches sold under a variety of trade names (see Annex 1). These will usually contain about 3% to 5% available chlorine and can be easily diluted to a 1% solution by addition of appropriate quantities of pure water.

It is also possible to purchase bleaching powder or chlorinated lime. This is a white powder which contains about 30% available chlorine when freshly made. However, the strength of this powder rapidly diminishes after the container is opened. Storage over a long period, even without opening, can also result in a loss of strength. In using chlorinated lime, it is best to use the whole container at once, immediately after opening, to make up a stock solution. The inert lime will settle in a few hours leaving the active chlorine in the clear solution which can then be poured off and kept in a tightly stoppered bottle for future use. This stock solution is still subject to chemical degradation which complicates the reliability of dosing.

Another type of powder is high-test hypochlorite, which contains about 70% available chlorine. Containers of this powder should be kept as cool as possible, there having been instances of cans bursting when left in the hot sun or in hot storage places. The powder can be used to make a stock solution in the same way as chlorinated lime. High-test hypochlorite is more stable than chlorinated lime, and will keep its strength better after the container is opened, so it is not necessary to use the whole container at once. However, even this material will lose most of its strength in a month or two after the container is opened.

Chlorine solutions are unstable in warm climates. They should be kept in brown or green bottles, well stoppered and stored in dark, cool, places.

To make a litre (one quart) of about 1% stock solution, add the requisite amount of water to any of the following:

either 250 ml (1 cup) of liquid laundry bleach,
or 40 g (2½ tablespoons) of chlorinated lime,
or 15 g (1 tablespoon) of high-test hypochlorite.

Smaller quantities of stock solution can be made by using proportionate amounts.

The proprietary disinfectants, of which examples have been given, generally have a 1% solution strength and can be used without dilution.

To chlorinate water, add three drops of 1% solution to each litre (quart) of water or one fluid ounce to 32 imperial gallons. If the water is clear but highly coloured, like very weak tea, or if it has a noticeable sulphur odour, the dosage should be doubled. It is repeated that a contact period of about 30 minutes should be allowed before use to ensure complete disinfection.

Chlorine is also available in tablet form, of which the following are examples of commercial brands which may be available: "Halazone" and "Chlor-dechlor"; other brand names are given in Annex 1. Directions for use as given on the package should be followed carefully. For example, Chlor-dechlor has a double action. This tablet first disinfects the water with a special chlorine compound. Then, after the outer portion of the tablet dissolves, the inner core neutralizes the remaining chlorine to reduce the taste. If more than one tablet is to be used, the whole amount must be put in at the same time. Tablets added after the dechlorinating core of even one of these tablets is dissolved are completely ineffective.

The foregoing practices are all related to water within the house. Fig. 1. illustrates a practice suitable for well chlorination.

Iodine

Iodine is an excellent disinfecting agent and, as tincture of iodine, is normally available from any chemist. In addition, water disinfectants based on iodine are commercially available, an example of which is "Globaline". Each tablet contains sufficient iodine to disinfect one litre (one quart) of clear water by liberating 8 mg of iodine; for turbid or

highly polluted water, two tablets are recommended. Contact period prior to use should be not less than 20 minutes and in very cold climates this should be increased to 25 minutes. Other makes are shown in Annex 1.

If tincture of iodine is used to disinfect water, normally two drops of 2% strength will suffice for one litre of water. However, water which is cloudy or muddy, or water having noticeable colour, even when clear, is not well suited for disinfection with iodine solution. Turbid water can be filtered and the clear filtrate can then be treated. If the water is known or suspected to be heavily polluted, the dose should be doubled. There is no harm in using the higher dosage, but it will produce a medicinal taste.

The commercially produced tablets are normally iodine compounds, such as tetraglycine potassium tri-iodine, and are effective against amoebic cysts, cercariae, leptospira, and some viruses as well.

When iodine is the disinfectant a similar contact period to that recommended for chlorine should be followed, i.e. 20-30 minutes. When using proprietary tablets the manufacturer's instructions should be carefully read and followed.

Potassium Permanganate

Potassium permanganate has frequently been used for the disinfection of water. It is a powerful oxidizing agent, on which account its action is rapidly spent in waters containing organic material. The commonly used dosage is one part in 2000 or 0.5 g/l. Potassium permanganate may possibly be effective against the cholera vibrio, but it is of little use against other disease organisms. Water treated with potassium permanganate in time produces a dark brown precipitate, which is difficult to remove without scouring. The opinion is expressed that potassium permanganate is not a satisfactory disinfectant and its use is not recommended.

3. Filtration

There are two types of filters commonly used for the treatment of household water supplies: the sand filter, which is relatively coarse; and the ceramic filter, which is of a finer texture. There is also the carbon filter (Fig. 2.) the prime purpose of which is removal of excess chlorine.

Sand filter

The household sand filter, unless skillfully operated, is relatively ineffective against bacteria. It will, however, remove cysts, ova, cercariae, and similarly large organisms, and will strain out most of the coarse and visible matter in suspension, although it may pass some fine turbidity or cloudiness. Sand filtration may be made more effective by first carefully treating the water with alum, as a result of which a clear water can be obtained. Some household filters contain charcoal. This has almost no purifying effect, its function being to absorb certain taste-producing compounds, but even this effect is lost unless the charcoal is frequently renewed. Charcoal filters have the property to absorb organic matter, which can serve as nutrients causing an undesirable bacterial growth in the filter. There are instances of filtered water having a higher bacterial count than the unfiltered water. To a lesser extent this can also happen with sandfilters. From a hygienic point of view these filters should not be used as a single step of treatment. Subsequent to filtration the water should be boiled or disinfected.

With this reservation in mind, the household sand filter finds a definite place in water treatment. It can easily be made for household use wherever fine sand is found. The essential points in making a filter are, firstly, that the depth of sand through which water passes should be at least 60 cm (2 ft) - an additional 15 cm (6 inch) is, in fact, desirable - and, secondly, that the rate of flow through the filter should not be greater than 200 $l/m^2/hr$ (4 Imp. gall./ft^2/hr or 4.8 US gall./ft^2/hr).

A simple filter can be constructed from a steel drum 60 cm (24 inch) in diameter and 75 cm (30 inch) high, with the head cut off. Place the drum on a stand, with a container underneath, and drill a hole 2 mm (3/32 inch) in diameter at the bottom of the drum to serve as the filter outlet.

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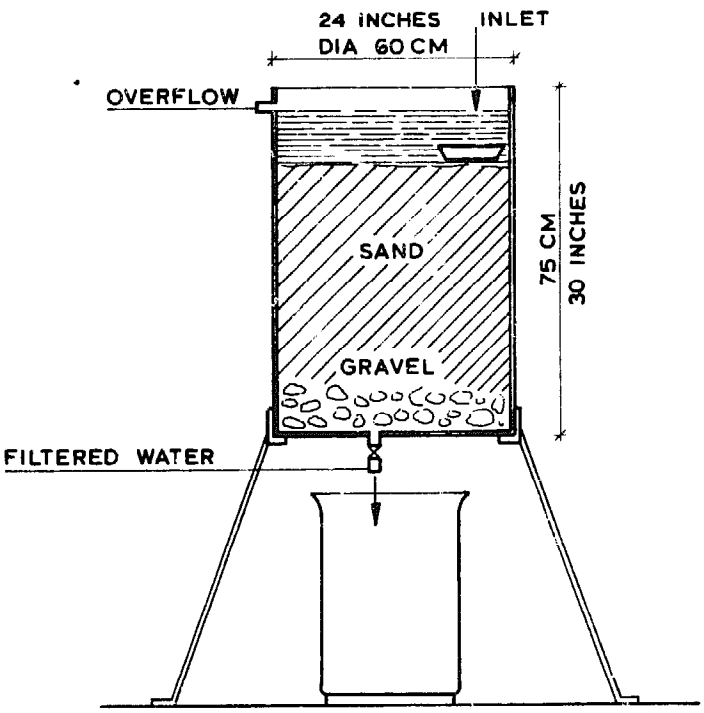

FIG. 3 SAND FILTER
CAPACITY 1 LITRE / MIN (12 GPH)

Place a few centimetres of small stones, about pea-size, in the bottom of the drum and fill to within 10 cm (4 inch) of the top with rather fine sand. Make a hole in the side of the drum just below the top rim for an overflow and insert a short length of pipe for an overflow line. A general layout of such a filter is illustrated in Fig. 3. Drums initially used for oil or chemicals should not normally be used as they may be heavily contaminated. The drum used should be thoroughly cleaned out and disinfected prior to use.

The sand and stones are also likely to be contaminated and have to be carefully cleaned before the filter is assembled. The filter should then be filled with highly chlorinated water and allowed to stand for 2 hours before draining to waste.

To operate the filter keep a continuous flow of water running into the top, just sufficient to keep the filter filled, with a slight overflow. It may be necessary to place a small disc on the surface of the sand under the inlet to prevent a hollow forming in the sand. A filter of these dimensions should deliver one litre per minute (12 gallons per hour) of clear water, which should nevertheless be chlorinated prior to drinking.

In operating such a filter, it is desirable to keep a continuous flow through the filter at all times. The rate of filtration is likely to fall off in time, but the filter should be cleaned only at long intervals possibly of several weeks or even months, since its efficiency depends highly on the biological growth on the surface of the sand. A slow sand filter as described, is a reliable barrier to disease organisms, (even when the after chlorination is failing because of chemical degredation of the chlorine solution).
Passage of organisms, however, will occur in the first week after the start of a newly constructed filter and after cleaning of the filter as described below. Trouble with green growths (algae) can be eliminated by covering the filter to keep it perfectly dark, since this green algae depends on light for growth. When it becomes necessary to clean the filter, a very thin layer, about ½ cm (1/4 inch) can be carefully scraped off and discarded, following which the sand surface should be lightly raked or scratched to leave it loose. After several such cleanings, the sand should be restored to its initial level with clean sand after scraping the filter surface down to a clean level.

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1972

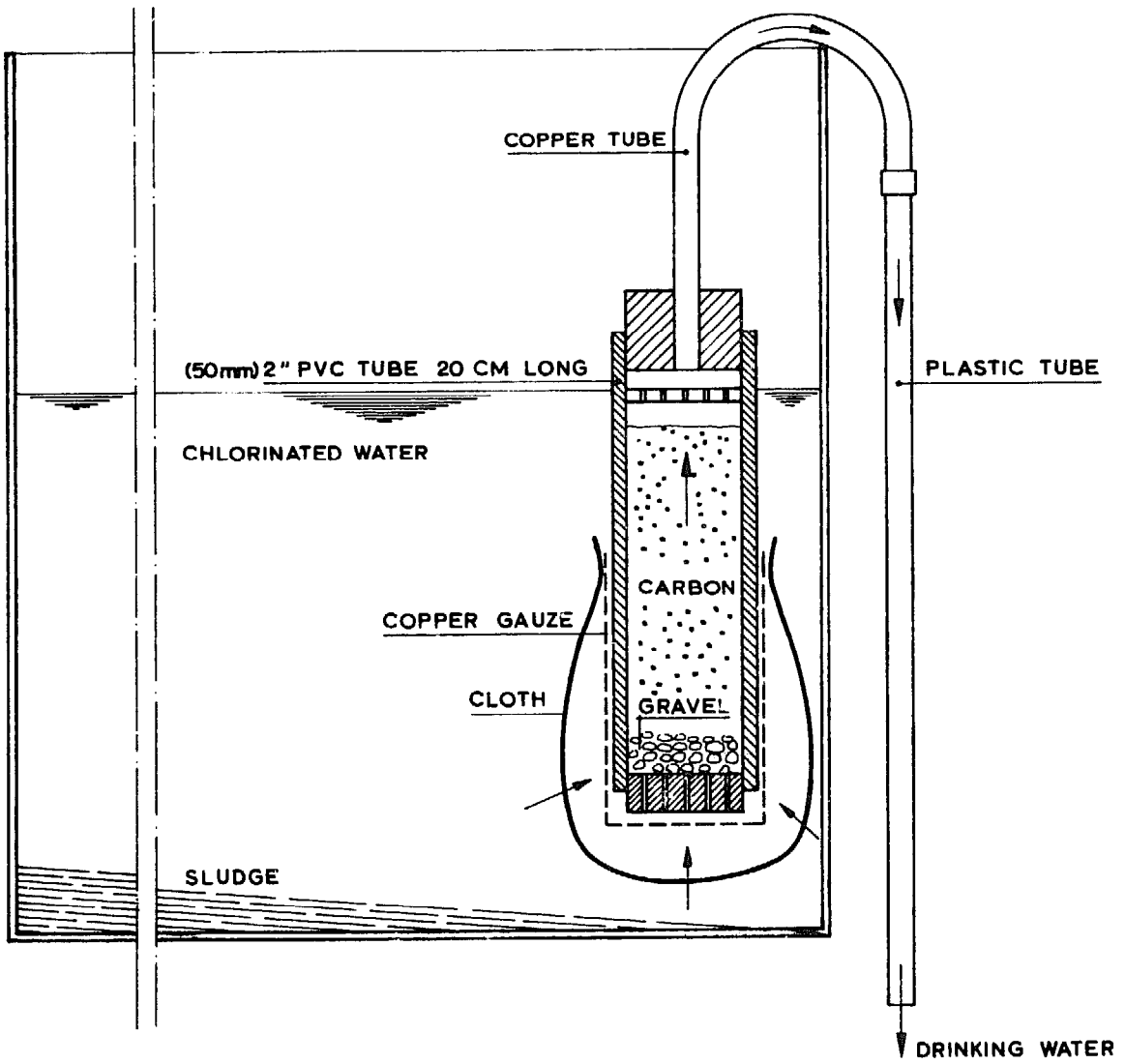

FIG. 2 CARBON FILTER
FOR REMOVING EXCESS CHLORINE
(SOURCE: MIN. OF HEALTH, INDONESIA)

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For more turbid waters, settling or coagulating and settling prior to filtration may be necessary. The latter may be carried out in a separate steel drum by stirring a solution of one tablespoon (10 g) of alum into 100 litres of the water to be treated for about three minutes until a floc starts to form, followed by adding 10 g (one tablespoon) of calcium carbonate under continuous stirring. A period of about half an hour should be allowed for the floc to settle; the settled water is then ready for filtering.

Ceramic filters

There are several types of ceramic filters, such as pressure filters, non-pressure filters, and filter pumps, and there is a wide range of ceramic media having different pore sizes. The heart of any of these is the filter candle, and the method of getting water through the candle is only a matter of convenience. Only clean water should be used with ceramic filters, otherwise, with cloudy or turbid water, the candles clog very quickly.

Coarse-grained filter candles are useful in removing suspended matter, helminth ova, cercariae, and cysts. They may only partially be effective in removing the smaller disease organisms, and consequently water should always be chlorinated or otherwise disinfected after passage through a coarse-grained or industrial-type filter.

Porcelain filters are made with pore sizes from a radius of 50 μ or larger down to 0.30 μ. To be satisfactory for water purification, the maximum pore radius should be about 1.5 μ. Examples of such filters are the Chamberland L_2 and the Selas 015. These and similar fine-grained porcelain filters will remove all disease organisms usually found in drinking water during a limited period of time, and it is quite safe to use water after passage through such a filter without further treatment. After a prolonged use, however, the bacterial growth will penetrate and pass the filter. This breakthrough can generally be prevented by cleaning and boiling the filter at least once a week, even if the filter does not clog. If a filter gets coated or clogged, it should be scrubbed under running water with a stiff brush free from soap, grease, or oil, and then boiled for 15 or 20 minutes.

Another type of filter candle is known as the Kieselguhr, or infusorial or diatomaceous earth filter. Like the porcelain, this also is made with various pore sizes. The finer-grained types are efficient in removing all types of bacteria commonly found in water. Among the well-known Kieselguhr filters are the Berkefeld and Mandler filters. Their porosity is graded as V ("viel", or course), N (normal, or intermediate), and W ("wenig", or fine). The V filters are suitable only for the removal of suspended material, and following filtration with this type of candle, the water should be further treated to destroy bacteria. The N filters remove the smallest bacteria, and it is safe to use water filtered through this grade without further treatment. The same care should be taken of Kieselguhr candles as of porcelain candles, except that they should be cleaned more frequently, at intervals of not longer than four or five days at the most.

There is a special type of filter candle, known as the "Katadyn" filter, in which the surface of the filter wall is impregnated with a silver catalyst in such a way that the porosity is not impaired, but the bacteria coming in contact with the surface are killed by oligodynamic action. Such a filter needs cleaning only when it becomes clogged.

Above filters and their attachments should be carefully examined at frequent intervals to guard against cracks or leaks which might possibly permit unfiltered water to get by. For this reason and from a hygienic point of view, the filtered water should also be disinfected with chlorine.

Filter candles can be mounted in a gravity-type filter, which consists of two reservoirs with the candle or candles attached to the upper one. Water is simply poured in at the top, trickles through the ceramic candles, and is stored for use in the lower compartment. Another mounting is made where piped water is available under pressure. The candle is mounted in a pressure case which is attached directly to the water system, filtered water being drawn from the filter as needed. A third type is fitted with a hand pump. The suction tube is put into a vessel of water, and the pump is operated like a bicycle pump, the filter candle being inside. The filtered water is discharged through another tube. Any of these systems is satisfactory if suitable filter candles are selected.

Water storage

No matter how much care is taken in producing safe water, this will be nullified if the water is contaminated after treatment. If boiled or filtered water is "unprotected" it may be subjected to immediate recontamination. Water treated with chlorine or iodine has "residual protection" which will successfully deal with light recontamination for a considerable period of time. However, this residual effect eventually disappears unless additions of chemicals are made. It is very important to keep the treated water free from the hazards of recontamination.

The principles are simple. Use clean vessels to store water; do not dip anything into the water; and keep the vessels covered to prevent the entry of insects, dust, or other foreign substances.

Cleanliness of the storage vessels involves periodic emptying, washing, and rinsing with heavily chlorinated water, to prevent the accumulation of slime growths.

Wherever practicable, small-mouthed vessels should be used with a neck narrow enough to prevent the entry of a dipper, cup or hand. When large vessels are used, arrangements should be made for easy pouring, either by tipping or by rolling the vessel. The best scheme with large vessels is to use, if possible, a spigot.

To prevent the entry of dirt, dust and other foreign matter, some form of cover is necessary, preferably of impervious washable material. The form and type of cover depends primarily on the vessel. It should be tight enough to keep out flies, wasps, roaches, and other insects, and substantial enough not to be easily lost or broken.

Another precaution relates to the use of commercially produced bottled water and carbonated beverages. The fact that such products are put into bottles and capped does not ensure their purity. When water is bottled, its bacterial content decreases with time, but cysts and ova may survive long periods of storage. The amount of sugar in sweetened drinks determines their bactericidal properties, but complete safety depends on initial purity and long storage.

In the case of carbonated beverages, the carbon dioxide does inhibit bacteria, but its action is selective, since some organisms are more resistant than others. Carbonation alone cannot be counted on to make a beverage safe. Thebest policy would seem to be to use only beverages

bottled in establishments reliably known to use pure ingredients and which maintain a suitably high standard of plant hygiene and standards of operation.

It is also relevant to mention that ice, too, can harbour contamination. Ice cubes should be made from properly treated water; that means, from chlorinated drinking water or piped water from a public water supply. Unless the ice is reliably known to be pure, it should never be put directly into the beverage itself, but only packed round the beverage containers to effect cooling.

Conclusion

In conclusion, when dealing with drinking water it is safest not to take anything for granted. It is frequently, and often wrongly, assumed that all large cities have safe water supplies. Unless the validity of this assumption is established, it would be safer to leave nothing to chance. The transient traveller in particular, would be well advised to do his own unobtrusive job of water purification.

Summary of treatment

Type of water.	Recommended processes for rendering water suitable for drinking.
1. All types	boiling
2. Clear water	chlorination (disinfection)
3. Slightly turbid	filtration and disinfection
4. Turbid	settling, coagulation, filtration and disinfection
5. Special types, e.g. excessive hardness, corrosive, high content of minerals such as iron or manganese	seek professional advice for special treatment

ANNEX 1.

PROPRIETARY NAMES OF SOLUTIONS OR TABLETS SUITABLE FOR WATER PURIFICATION FOR INDIVIDUAL USAGE.

The following proprietary names are given for information only. The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by WHO or the WHO International Reference Centre, in preference to others of a similar nature which are not mentioned.

1. Sources of chlorine

a. Solid form

"Halazone" - tablets	(Use as directed)
"Chlor-dechlor" - tablets	(" " ")
"Hydro-chlorazone" - tablets	(" " ")
"Halamid" - tablets	(" " ")
"Chloramin-T Heyden" - tablets	(" " ")

b. Liquid form

"Zonite" - liquid	(approx. 1% chlorine solution - can be used as supplied)
"Milton antiseptic" - liquid	(" " " ")
"Javel water" - liquid	(" " " ")
"Dankin's solution" - liquid	(approx. 0.5% chlorine solution)
and other commercial laundry bleaches, e.g. "Clorox", "Dazzle" and "Regina"	(usually 3-5% chlorine solution - dilute to 1%)

2. Sources of iodine

a. Solid form

"Individual Water Purification Tablets" - tablets	(use as directed)
"Portable Aqua" - tablets	(" " ")
"Globaline" - tablets	(" " ")

B. Liquid form

"Lugol's solution" - liquid	(approx. 5% iodine solution)
"Tincture of iodine" - liquid	(approx. 2% iodine solution)

Purifying Drinking Water

You've just filled your canteen with "pure" mountain water. Don't drink it yet. Just around the bend upstream there could be a decomposing skunk or raccoon. You always dig your camp latrine at least 200 feet from a water source to prevent contamination. Does everybody else? Without the support of modern medicine, wilderness survival depends on maintaining good health. It only takes one drop of contaminated water to make you ill.

Risks of Untreated Water. Of the many waterborne problems you may develop, the most common is diarrhea. In a survival situation, diarrhea may prove fatal. It causes dehydration and makes hygiene very difficult, increasing the risk of further unpleasant infections, and destroys the will to live. Experts estimate that at least 90% of the surface water in the United States, even in the most remote areas, is contaminated with the illness-causing protozoa Cryptosporidium and Giardia lamblia. Bacteria such as Campylobacter, E. coli and Salmonella are also common. The risk of infection from waterborne viruses, such as Poliovirus and Rotovirus, while lower than that of protozoa or bacteria, increases dramatically during a natural disaster such as a flood or earthquake, when municipal sewage systems can contaminate drinking water supplies. Lakes and streams in high traffic wilderness recreation areas where people swim, bathe or defecate in or near a water source can contain harmful viruses. You should also be concerned about viruses if you're in a third world country with poor sanitation and the water you're eyeing suspiciously may be contaminated with sewage from the people living upstream. A Marine Corps veteran of the Vietnam War relates the story of filling the lister bag for his unit's canteens from a stream, only to later discover that the source of the stream was a rice paddy fertilized with human feces. One of the most common waterborne pathogens, Giardia lamblia, is transmitted from an infected animal (some thirty species of animals, including humans, have been identified as carriers) who excretes the parasite in the form of cysts, which can survive for months in water as cold as 32 degrees. When infected body waste is deposited in or seeps into a water supply that is then consumed by another animal or person, giardiasis may result, and can cause explosive diarrhea, bloating, cramps, nausea, and vomiting. Treatment is with drugs that produce their own unpleasant side effects; fortunately many people seem to recover spontaneously without medical intervention. Many physicians haven't had enough experience with giardiasis to diagnose it correctly. If untreated, the disease may go on for years. Incubation time is 1 to 2 weeks, though some people have gone as long as two months before getting sick. Less than half of the people who drink water heavily contaminated with Giardia cysts actually become infected, and less than a quarter of those develop symptoms, although they may be carriers. Some people cite these statistics to downplay the threat, but why take a chance, when avoiding the risk is so easy? Always assume that water found in the wilderness is contaminated and use one of the three basic methods (boiling, chemical treatment or filtration) to purify it. However, these methods will not desalinate salt water or remove most chemical pollutants. Water can be polluted with chemicals by nature as well as by man. Water that has sat too long in a depression in a tree or brown icicles hanging from tree branches may have absorbed too much tannin from the bark to be drinkable (however, tannin-stained water can be boiled down to make a very effective antiseptic which, unlike synthetic astringents, actually promotes

healing).

Boiling. Boiling is the most reliable method of treating drinking water and will kill Giardia and every other waterborne pathogen that might be lurking in the murk. Most organisms are killed instantly when water reaches the boiling point. Another 5 minutes ensures the purity of your drinking water even at high altitudes. However, the water will still be dirty unless it has been filtered. An improvised pre-filter can be fashioned from a cloth sack suspended from a tripod of tree branches. Charcoal from from your campfire can help filtration, but don't use ashes since this will produce poisonous lye. This type of filtering will make the water more clear but will not kill microorganisms; it still must be boiled. Make sure you have plenty of extra fuel and allow extra time for drinking water to cool. The flat taste that boiled water has can be reduced by pouring it back and forth between two containers. Improvised containers for boiling water can be found in nature or fashioned from natural materials. Kettles for use over flames can be made from bark. Although flammable, it will not burn unless the flames reach above the water line. Bark can be made more pliable either by soaking or gently warming by the fire. The inside of the bark is the most durable side, and forms the outside of the container which is simply made by folding. Rock boiling is done by placing rocks heated in a fire into a container of water. Don't heat rocks found in a stream bed or other damp place since they may have water trapped inside and could explode when heated. Glass-like rocks like flint or obsidian should also be avoided. Handle the hot rocks with tongs fashioned from a springy green branch. Tap off any ash before dropping the rocks into the water. Continue adding rocks until the water boils. "Used" rocks can be returned to the fire. This method can also be used for cooking soups and stews. Cauldrons used for rock boiling can be natural depressions in rocks or trees that will hold water. You can also dig a pit if the ground is non-porous or clay-like enough to hold a puddle. Line the pit with cloth or non-poisonous leaves to reduce sediment and skim the boiled water off the top. You can make a bowl for rock boiling by burning and carving a large piece of wood. Hold a small hot coal in place with a twig and blow on it (through a reed if available) until it flares and burns the larger piece. Then scrape away the charred parts with your knife or a sharp stone. Repeat until it looks like a bowl. If you have some extra time and a lot of patience, you can start with a log and make a canoe instead of a bowl with this technique. Suspended animal skins can also be used for rock boiling; leave the legs and feet on for convenient anchor points.

Chemical treatment. Purifying water with household bleach is recommended in the emergency checklist of the phone book (10 drops per gallon or a teaspoon per 5 gallon container, mix and let stand for 30 minutes). While this is better than nothing, chlorine bleach is not totally effective. Much better are emergency drinking water germicidal tablets containing tetraglycine hydroperiodide, which releases iodine when dissolved in water. Iodine tablets don't weigh very much or take up much space and using them is simple. Add 1 tablet to 1 quart or liter of water and cap loosely to allow a small amount of leakage. Wait 3 minutes. Shake container to allow screw threads on the closure to be moistened, then tighten cap. Wait 10 minutes before drinking. For Giardia control, or if of poor quality (very cloudy) or very cold (which most mountain water is), use 2 tablets per 1 quart or liter of water and wait 20 minutes before drinking. Iodine tablets give water a distinct taste, which you can mitigate by leaving the container open to breathe for an hour. Filtration through an activated carbon filter can also reduce the iodine taste. The manufacturer of "Potable Aqua" iodine tablets also makes an iodine neutralizer to eliminate the taste. You can mask the taste by adding a little Nutrasweet Kool-Aid which, unlike Kool-Aid sweetened with

sugar, weighs next to nothing. The lemonade flavor is quite palatable and not overpoweringly sweet when mixed at half-strength. Aside from the unpleasant taste there are other disadvantages you should consider. While iodine tablets kill all viruses and bacteria, they are less effective against Giardia and virtually powerless against Cryptosporidium. Iodine tablets are probably the most expensive method of treating water (other than boiling with a butane camp stove), especially if you add a chemical neutralizer or Kool-Aid. Be aware that some people are allergic to iodine and persons with thyroid trouble or pregnant women are advised to consult their doctor before use. Iodine should not harm you so long as its use is confined to a few times per year and should not be used for more than a few days at a time. Iodine tablets also lose their strength over time and must be replaced periodically. The manufacturer of "Potable Aqua" iodine tablets recommends that you do not keep an opened bottle more than one year and states that unopened bottles should remain effective up to four years. Finally, disgusting muddy water treated with iodine tablets stays disgusting and muddy.

Filtration. Don't like the notion of gunking up that "pure" wilderness water with Kool-Aid and can't stand the taste of iodine? Filtering water can be done almost as fast as chemical treatment and it does not introduce a bad taste. Make sure the filtering apparatus you buy either can be easily cleaned or has a replaceable filter cartridge or element. Filter pores must be 0.4 microns or less in size to be effective against Giardia. The $20 filter from the camping section of the local discount store with a 1 micron filter may not seem like such a bargain when you are squatting in the bushes with diarrhea. Some filters like the AccuFilter canteen insert (which fits either 1 or 2 quart G.I. canteens), the SweetWater Guardian and the Pur Explorer contain an activated carbon component which removes many organic compounds such as pesticides. Microporous filters do not strain out viruses, which are much smaller than bacteria. Manufacturers of filters that work solely on a microporous principle, without the chemical disinfection necessary to kill viruses, assert that viruses simply aren't an issue in wilderness areas in North America. They're probably right, at least most of the time. However, the AccuFilter canteen insert and the Pur Explorer are hybrid filters that contain both a microporous filter and a mass of iodinated resin beads. As the water flows past the beads, enough iodine is released to kill viruses so long as the concentration of viruses is moderate. There is an optional ViralGuard cartridge sold for the SweetWater Guardian which also contains iodinated resin. The filtered water has a slight iodine taste, but it's not as noticeable as when using iodine tablets. The capacity of filter elements before they must be replaced varies widely, but filtering very dirty water with lots of debris and particles reduces their longevity. Straining water through a fine weave cloth while filling a spare canteen is a good idea to extend the life of the filter used to pump the treated water into a second canteen you will drink from. SweetWater sells a 4 micron pre-filter called the Silt Stopper for their Guardian system, but it should be useful for the intake line of any filter. In terms of cost, generally the more you pay for a filter the longer it should last, which lowers the cost per canteen full. The AccuFilter canteen insert costs $16, but is only good for 20 gallons. The Pur Pioneer (0.5 microns) costs $30 and comes with two filter elements (that cost $5 per pair separately) each good for about 12 gallons. Although the Pur Pioneer comes with an outlet hose that clips to any container, it can also screw directly onto the 1 quart Nalgene wide-mouth drinking bottle favored by many hikers. The SweetWater Guardian (0.3 microns) costs $50 and comes with a replaceable element ($20-$25 each) good for 200 gallons. The optional SweetWater ViralGuard cartridge costs $25 and is good for 90 gallons. The Pur Scout costs $45 and is good for 250 gallons ($30 replacement element). The Katadyn Mini Filter costs $150 and is good for 2000 gallons (replacement element $65). The capacity of the

above mentioned filters is with clean water and with regular cleaning of the units (usually about every 20 gallons). The Pur Explorer is a hybrid filter with iodinated resin to kill viruses, activated carbon to remove both iodine taste and organic compounds, and a microporous filter effective against bacteria and protozoa like Giardia and Cryptosporidium. It is also very easy to clean, having a built-in brush and a self cleaning back-flush mode to remove silt and debris from the pump unit. The Pur Explorer is probably the most effective, lowest cost to use filter available at a cost of $120, good for 500 gallons (replacement element $45). A good water filter will not only remove whatever critters may be present, but also the inevitable sand and silt.

Always purifying your drinking water will help insure your health and keep you in the field to continue your Militia mission, whatever it might be.

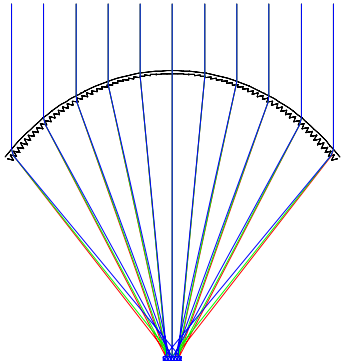

PV Technology For Global Village Power

Village Power '98
Off-Grid PV Systems Workshop
World Bank, Washington, D.C.
October 5, 1998

ENTECH, Inc.

1077 Chisolm Trail

Keller, TX 76248 USA

Contact: Dr. Robert R. Walters

Tel: 817-379-0100 Fax: 817-379-0300

E-Mail: walters@entechsolar.com

Internet: http://www.entechsolar.com

ENTECH, INC.

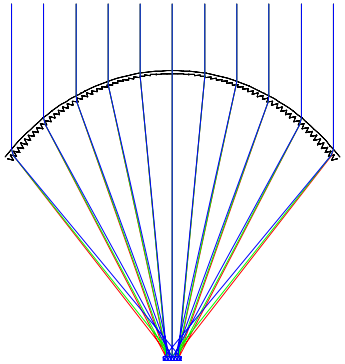

ENTECH'S Terrestrial Photovoltaic Products For Global Village Power

- ***SunLine***
  - **Solar PV System That Produces 800 Watts Of Power For Small And/Or Remote Applications (DC or AC)**
- ***SolarRow***
  - **Solar Photovoltaic System That Uses Sunlight To Produce Power For Multi-kW To Multi- MW Users (DC or AC), For Villages to Utilities**
- **Licenses**
  - **ENTECH Is Developing Local Industry and Jobs by Licensing Companies In-Country to Manufacture and Sell These Products To Provide Local Village Power, As Well As for Other Independent and Sustainable Power Applications**

ENTECH, INC.

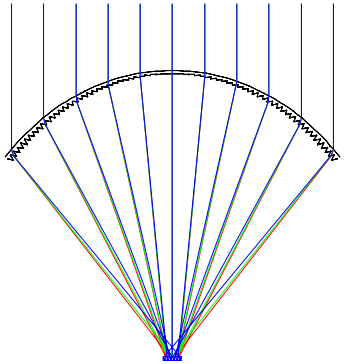

SunLine PV Product

- Power Output: 800 Watts (DC)
- Two 4th-Generation Concentrator PV Modules
- Solar-Charged 12 VDC Battery Powers the Micro-processor Controller and the Sun-Tracking Drives for Both Tilt and Roll Axes
- All-Galvanized Structure Can Be Fabricated In-Country And Fully Assembled in Local Factory for Easy Field Installation

ENTECH, INC.

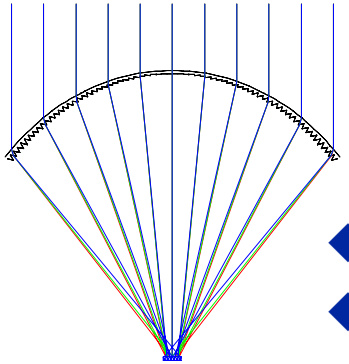

SolarRow PV System Product

- Four *SolarRows* at CSW* Solar Park, Fort Davis, Texas
- Power Output: 25 kW Per *SolarRow,* 100 kW For 4 Rows

* CSW - Central and South West Company - Major Electrical Utility In USA

ENTECH, INC.

ENTECH's Technology Licensing Program Outside U.S.

- **License Agreement Gives In-Country Company (Licensee) Right To Manufacture & Sell *SunLine* & *SolarRow* Products For Village Power And Other Sustainable Power Markets**
- **License Program:**
  - **ENTECH**
    - **Receives Up Front Fee To Cover Technology Transfer & Training**
    - **Ships Fresnel Lenses, Solar Cell Assemblies & Other Specialty Components To Licensee For Life Of Agreement**
    - **Makes Available To Licensee On-Going Tech. Support & Consultation**
  - **Licensee**
    - **Builds Aluminum & Steel Components In-Country**
    - **Assembles Modules, Structures, Controls, Drives & Inverters In-Country**
    - **Sells, Installs, Maintains, And Operates Systems As Desired**

ENTECH, INC.

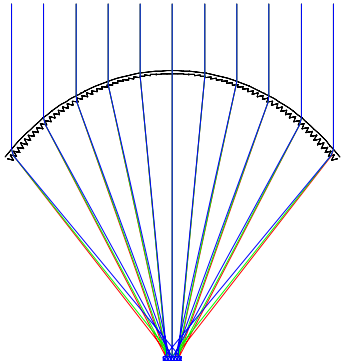

ENTECH PV Product Advantages

- Can Achieve Lower Product Cost Than Competition With
  - Moderate Production Volume
  - Minimal Technical Risks
- Ideal For International Licensing
  - Creates In-Country Jobs & Local Economic Development Through Manufacturing, Assembly, Installation, Operation & Maintenance
  - Creates U.S. Jobs - Manufacture Specialty Components In USA
  - Allows For Rapid Market Expansion
- Provides Predictable Energy Costs For 30 Years Or More

ENTECH, INC.

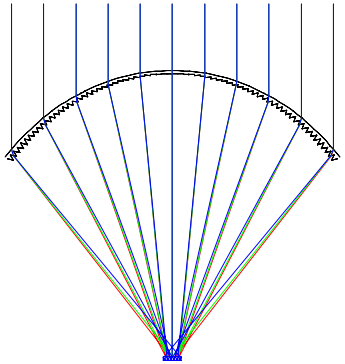

ENTECH PV Product Advantages (Continued)

- Long Term Performance & Reliability Verified By Numerous Third-Parties
- Technology Protected Internationally Through Key Patents
- ENTECH's Solar Power Systems Can Provide:
  - Electricity, Hot Water And/Or Distilled Water For Villages, Homes, Hospitals, Schools, Apartments, And Businesses
  - Electricity For Remote Water Pumping
  - Electricity And/Or Process Heat For Local Industries
  - Electricity For On-Grid or Off-Grid, DC or AC Applications
- Can Rapidly Expand Production To 100's of Megawatts Per Year

ENTECH, INC.

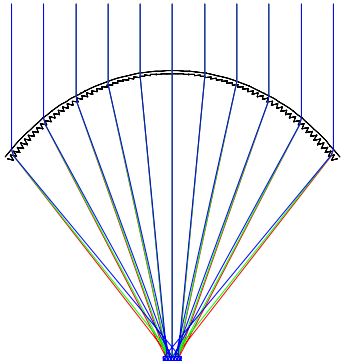

Experience

High-Performance & Reliability

ENTECH, INC.

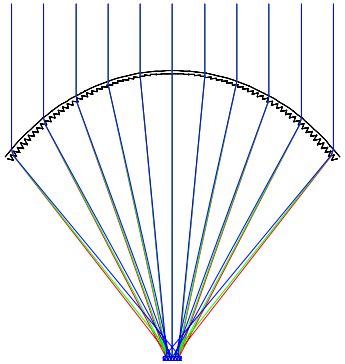

ENTECH Experience

- Technical and Management Team Together Since 1977
- Four Generations of Terrestrial Concentrator PV Technology
- More than $30 Million of R&D Investment to Date
- Prior Successful Contracts:
  - Government - U.S. Dept. of Energy, Sandia National Laboratories, National Renewable Energy Laboratory, Jet Propulsion Laboratory, NASA
  - Utilities - Bechtel/Pacific Gas & Electric Company, Texas Utilities Company, Central and South West Company, Northern States Power, City of Austin Municipal Electric Department, Tennessee Valley Authority
  - Companies - 3M and Overseas Customers
- ENTECH Has Received Over 11 Patents On This Solar Technology
- Recognized as the Leader in Concentrating Photovoltaic Technology for Terrestrial and Space Applications

ENTECH, INC.

High Performance & Reliability

ENTECH Is the Long-Term Leader In Independent PV Tests Of U.S. Manufacturers' Photovoltaic Systems At PVUSA*

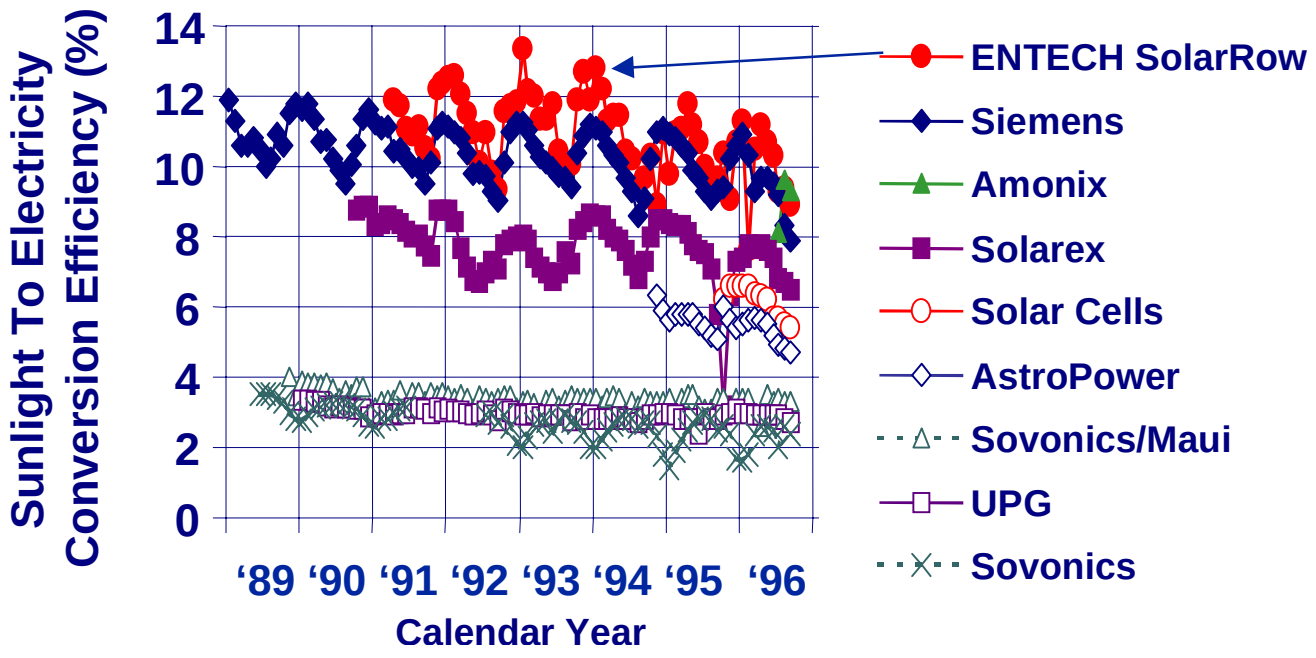

* PVUSA - PhotoVoltaic for Utility-Scale Applications Program (Davis, CA USA)

ENTECH, INC.

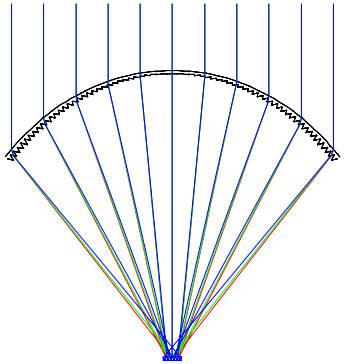

High Performance & Reliability
Predictable PV System Power

Curves Are Predicted Based on Sandia Module Test Data Correlations with 95% Wiring/Mismatch Loss and 94% Inverter Efficiency

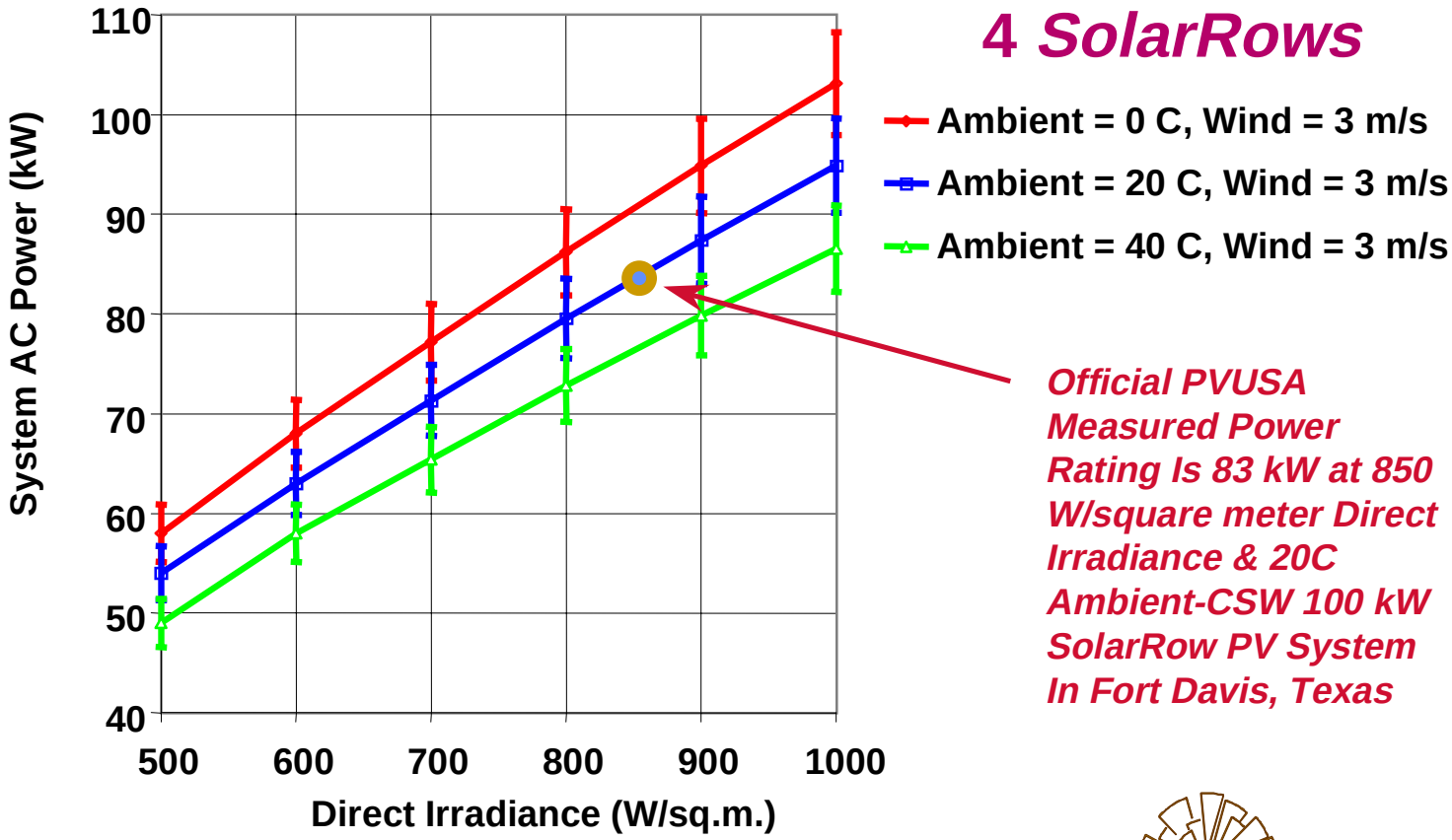

ENTECH, INC.

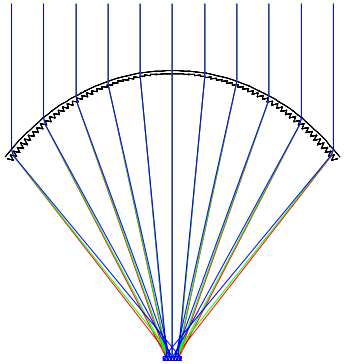

High-Performance & Reliability
SunLine PV System In Minnesota

- Customer: Northern States Power Company
- Location: 3M Center, St. Paul, MN
- Operational Since July 1995
- Survived 3 Minnesota Winters
  - Ice Storms
  - Snowstorms
  - Minus 35C Ambient
  - Many Meters of Total Snowfall
- Survived Severe Wind Storm
  - >30 meters/second Speed
  - Over 250 Mature Trees Blown Down at 3M Center
- Lenses Never Cleaned
- Negligible Degradation
- Automatic, Unattended Operation

ENTECH, INC.

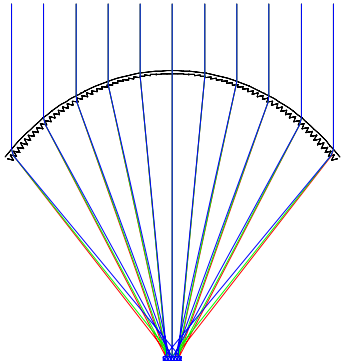

PV Technology Designed For In-Country Jobs & Industry

ENTECH, INC.

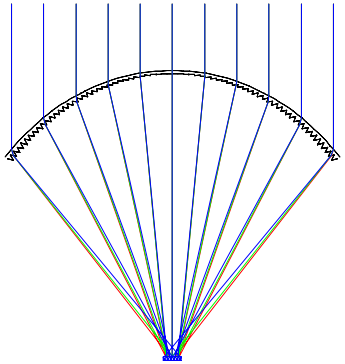

4th-Generation Concentrator PV Module

One-Foot Cross Section

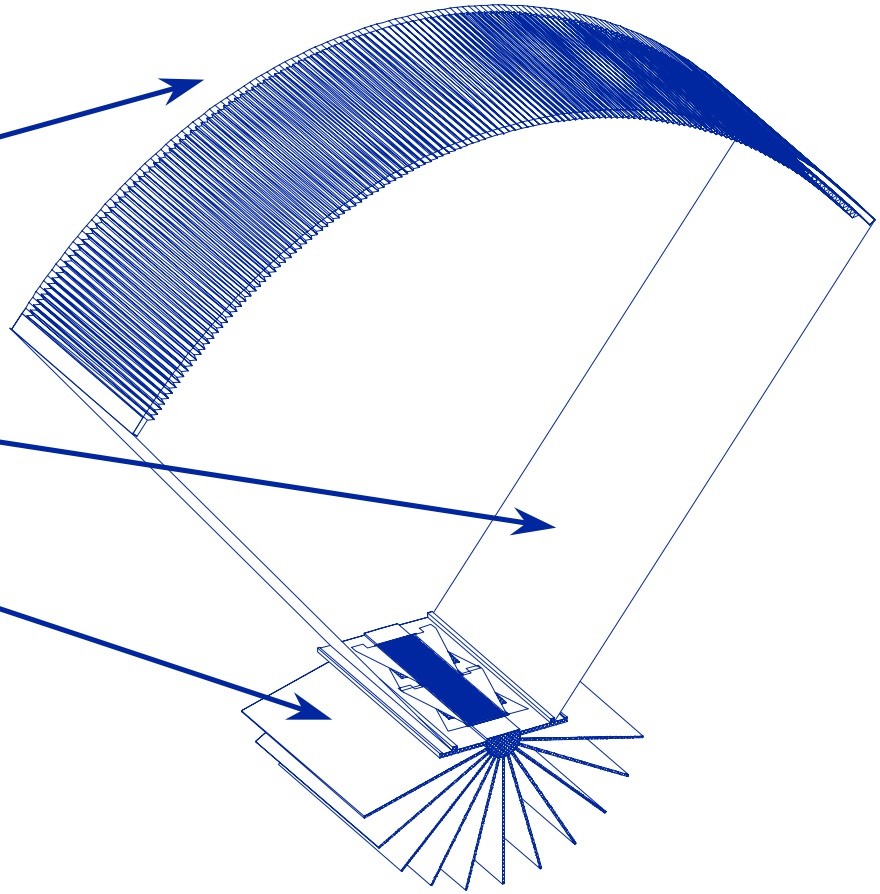

- **Fresnel Lens:**
  - **ENTECH Supplied/3M-Produced Acrylic Lens**
- **Marine Aluminum Housing**
  - **Licensee Supplied**
- **Photovoltaic Receiver:**
  - **ENTECH - PV Cell Assemblies (U.S. Patent 4,711,972)**
  - **Licensee - Receiver Assembly (US Patent 5,498,297)**
  - **Licensee - Extruded Aluminum Heat Sink**

ENTECH, INC.

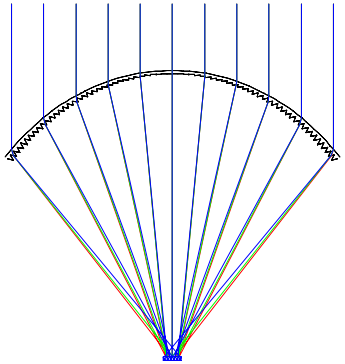

Photovoltaic Receiver Assembly

Assembled In-Country Under License Agreement

U.S. Patent 5,498,297 for New, Streamlined, Dry Tape & Film Receiver Assembly Approach

- **37 Cell Assemblies**
- **1 Extruded Heat Sink**
- **Dielectric Tapes/Films**
- **430-480 W Output**

Heat Sink Fin Area Is 4X Larger Than Lens Aperture Area

<u>Result</u>: Cells Operate As Cool As Cells In Flat Plate PV Modules

ENTECH, INC.

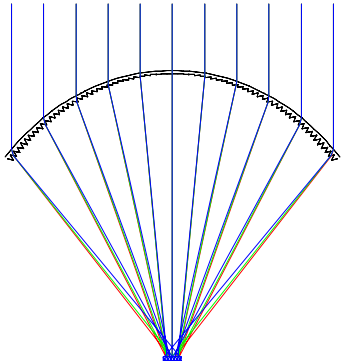

SolarRow Hardware

Aluminum & Steel For SunLine & SolarRow Fabricated & Assembled, Along With Other Components, In-Country Under License Agreement

*** CSW Solar Park, Fort Davis, Texas USA**

- ***SolarRow* Comprises:**
  - **14 Concrete Piers**
  - **13 Galvanized Posts**
  - **One Galvanized Bolt-Together Frame**
  - **72 ENTECH PV Modules**
  - **12 VDC Roll/Tilt Drives, Controls, & Batteries**
  - **DC Combiner Box with Fused Disconnect, MOV's, and Blocking Diodes**
  - **Two Wires Carry 63 Amps at 400 VDC to the DC/AC Inverter**

ENTECH, INC.

AT MICROFICHE REFERENCE LIBRARY
A project of Volunteers in Asia

Set of Construction Drawings for 12PU350 and 12PU500 Windmills

Published by:

Stichting TOOL
Entrepotdok 68A/69A
1018 AD Amsterdam
The NETHERLANDS

Available from:

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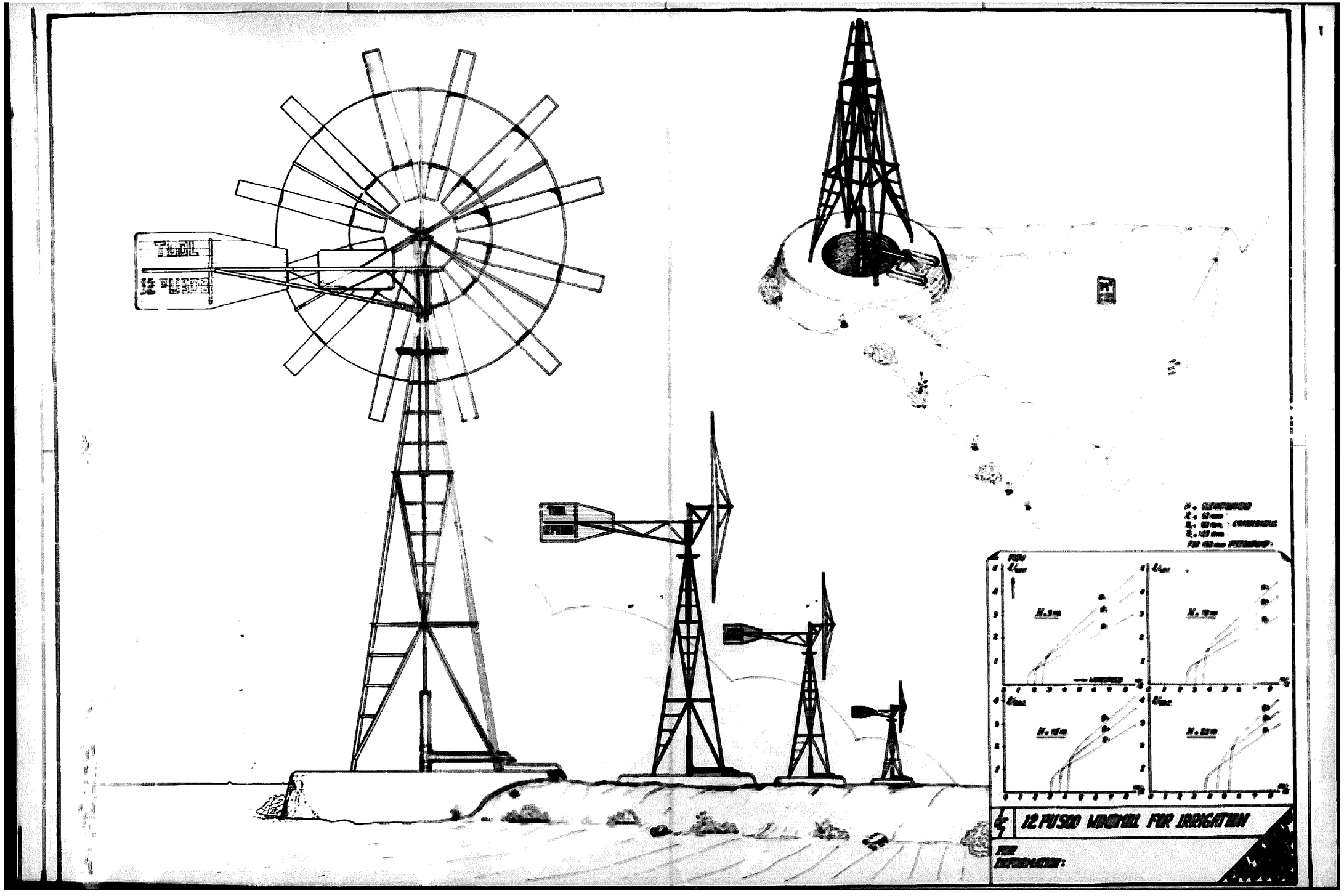
12 PUSOO WINDMILL FOR IRRIGATION
FOR INFORMATION:

WALLTHICKNESS TOWERPIPE NOT LESS THAN 3.5 MM.

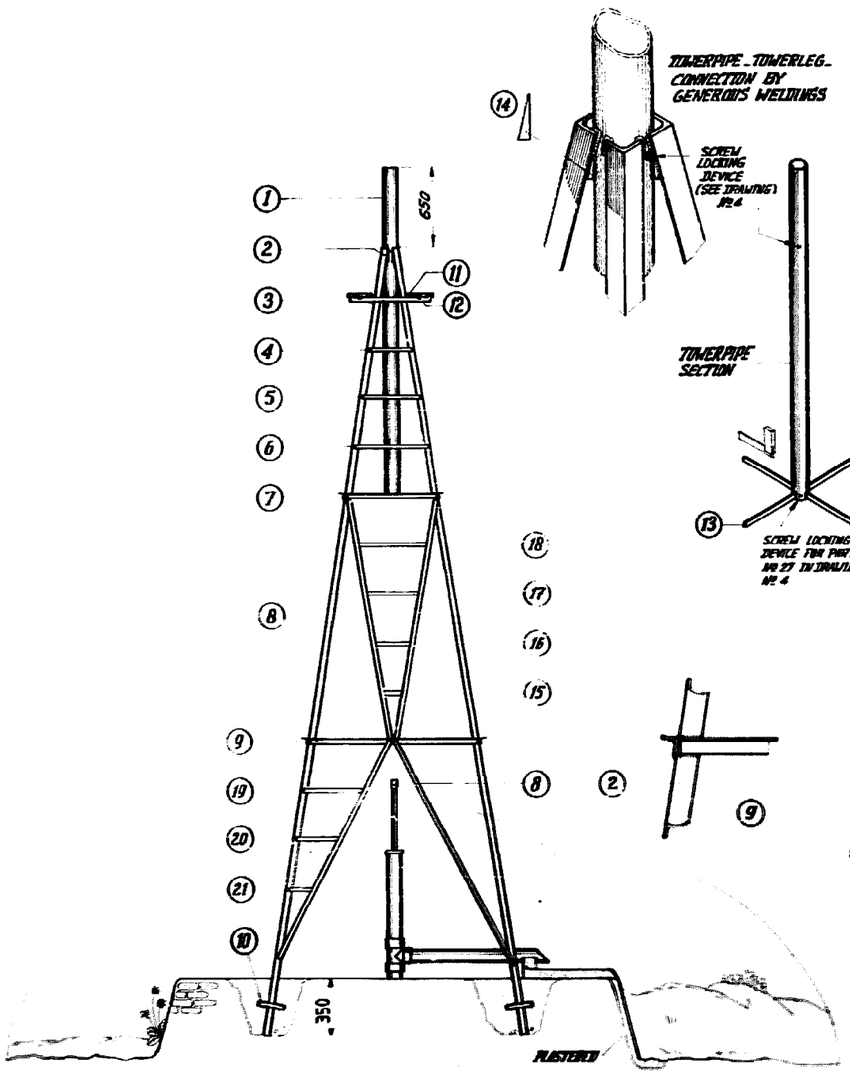

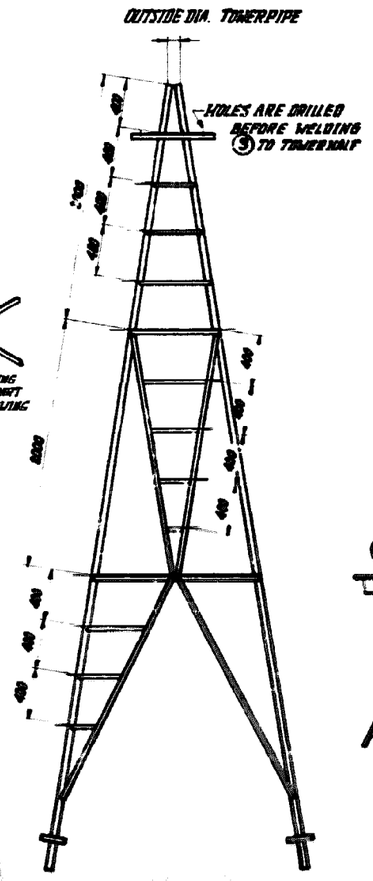

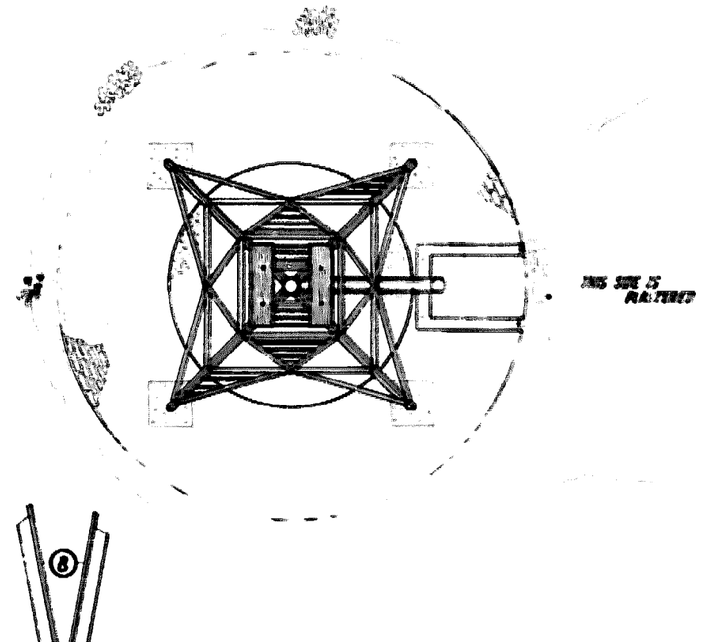

IF DESIRED THE LATTICE MEMBERS CAN BE POSITIONED AND WELDED <u>INSIDE</u> THE TOWER LEGS RESULTING IN A MORE ATTRACTIVE APPEARANCE OF THE TOWER. HOWEVER THE FLANGES AT THE ENDS OF THE ANGLE-IRON MEMBERS NR 7 AND NR 9 SHOULD BE CUT AT ANGLES OF 45 DEGREES.

FIRST TWO OF THESE TOWERHALVES ARE PREFABRICATED BOTH HALVES ARE COMPRESSED AND THE TOWERPIPE-SECTION IS SHIFTED IN AND A COMPLETE TOWER RESULTS

21	2	FLAT. IRON	30 x 6 (1¼" x ¼")	x	932
20	2	"		x	340
19	2			x	930
18	2			x	970
17	2			x	440
16	2			x	340
15	2			x	130
14	8			x	SCRAP
13	4			x	450
12	4	BOLT, NUT, WASHERS	M8 (¼" BSW)		
11	2	PLATE	300 x 300 x 10		
10	4	ANGLE IRON	100 x 100 x 10 (4" x 4" x ¼")		SCRAP
9	4	"		x	[illegible]
8	16			x	[illegible]
7	4			x	700
6	2	FLAT. IRON	30 x 6 (1¼" x ¼")	x	570
5	2	"		x	440
4	2			x	340
3	2	ANGLE IRON	50 x 50 x 6 (2" x 2" x ¼")	x	440
2	4	"	40 x 40 x 4 (1½" x 1½" x ⅛")	x	650
1	1	TOWERPIPE	4" GALVPIPE	x	8000
NR	NUMBER	MATERIAL / SHAPE / REMARKS / MEASUREMENTS			

12 PU500 - TOWERCONSTRUCTION

FOR INFORMATION:

2

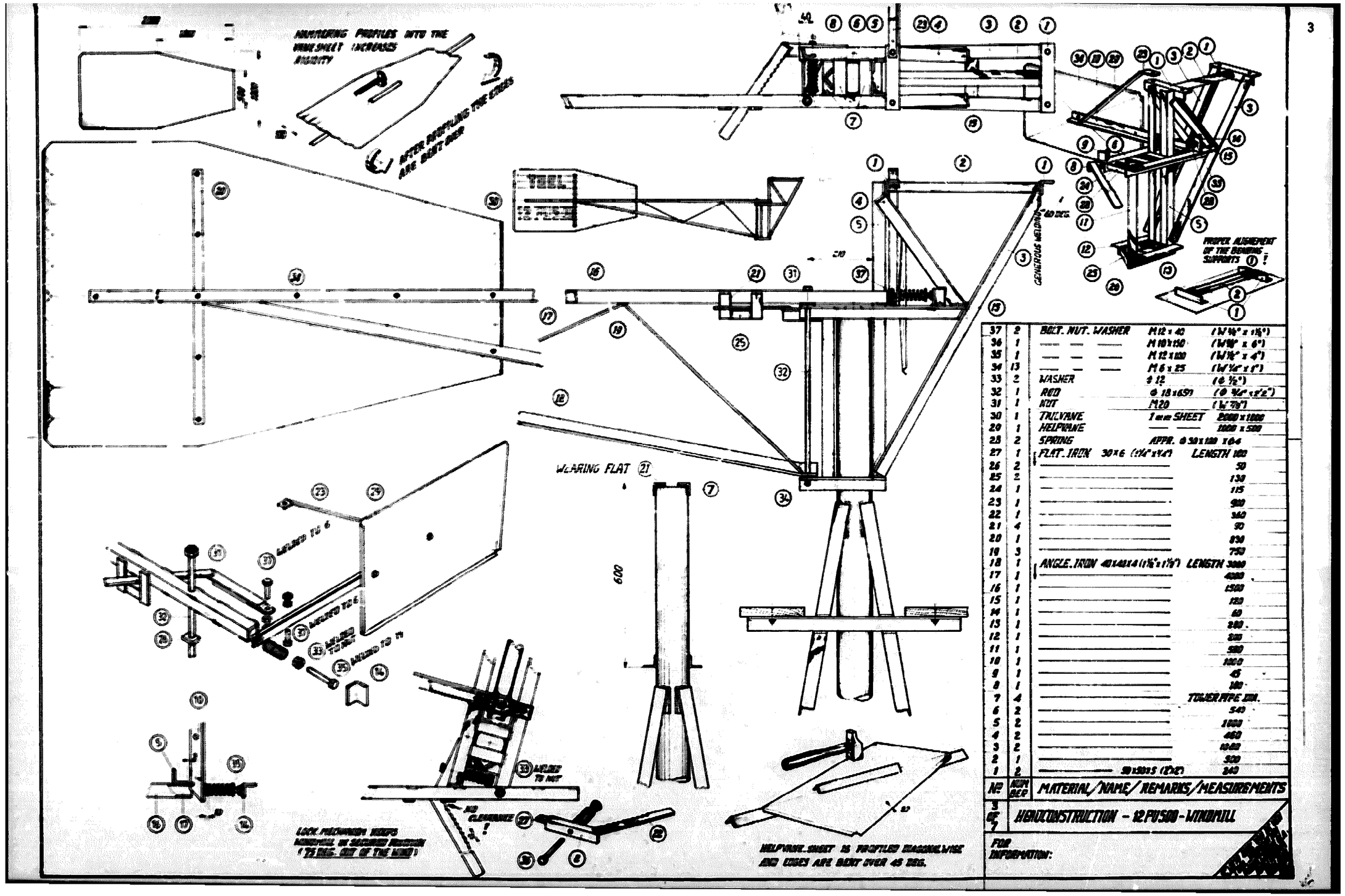

37	2	BOLT. NUT. WASHER	M12 x 40	(W ½" x 1½")
36	1	— — —	M 10 x 150	(W ⅜" x 6")
35	1	— — —	M 12 x 100	(W ½" x 4")
34	13	— — —	M 6 x 25	(W ¼" x 1")
33	2	WASHER	ϕ 12	(ϕ ½")
32	1	ROD	ϕ 18 x 659	(ϕ ¾" x 2'2")
31	1	NUT	M20	(W ⅞")
30	1	TAILVANE	1 mm SHEET	2000 x 1000
29	1	HELPVANE	— —	1000 x 500
28	2	SPRING	APPR. ϕ 50 x 100 x ϕ 4	
27	1	FLAT. IRON	30 x 6 (1¼" x ¼")	LENGTH 100
26	2	—		50
25	2	—		130
24	1	—		115
23	1	—		900
22	1	—		340
21	4	—		50
20	1	—		830
19	3	—		750
18	1	ANGLE. IRON	40 x 40 x 4 (1⅝" x 1⅝")	LENGTH 3000
17	1	—		4000
16	1	—		1500
15	1	—		120
14	1	—		60
13	1	—		280
12	1	—		500
11	1	—		500
10	1	—		1000
9	1	—		45
8	1	—		100
7	4	—		TOWER PIPE DIM.
6	2	—		540
5	2	—		1000
4	2	—		460
3	2	—		1000
2	1	—		500
1	2	—	50 x 50 x 5 (2" x 2")	840

Nº	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS
3	OF 7	HENDCONSTRUCTION – 12PU500-WINDMILL

FOR INFORMATION:

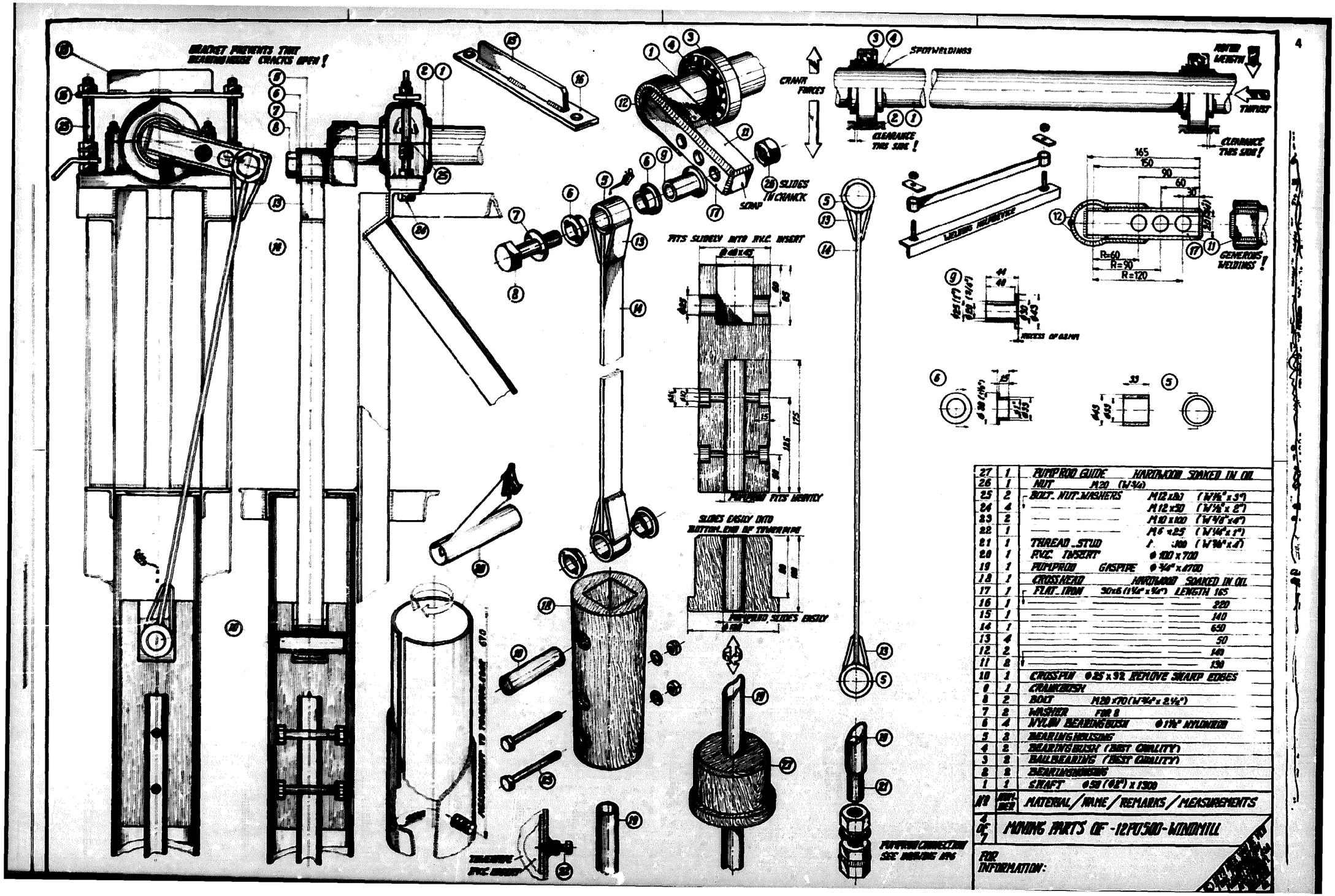

27	1	PUMPROD GUIDE	HARDWOOD SOAKED IN OIL
26	1	NUT	M20 (W¾")
25	2	BOLT. NUT. WASHERS	M12 x 80 (W½" x 3")
24	4		M12 x 50 (W½" x 2")
23	2		M10 x 100 (W⅜" x 4")
22	1		M6 x 25 (W¼" x 1")
21	1	THREAD STUD	M 300 (W⅛" x 12")
20	1	PVC. INSERT	ø 100 x 700
19	1	PUMPROD	GASPIPE ø ¾" x 4700
18	1	CROSSHEAD	HARDWOOD SOAKED IN OIL
17	1	FLAT IRON	50x6 (1⅞" x ¼") LENGTH 165
16	1		220
15	1		140
14	1		650
13	4		50
12	2		140
11	2		130
10	1	CROSSPIN	ø 25 x 92 REMOVE SHARP EDGES
9	1	CRANKBUSH	
8	2	BOLT	M20 x 70 (W¾" x 2¾")
7	2	WASHER	FOR 8
6	4	NYLON BEARINGBUSH	ø 1⅜" NYLONROD
5	2	BEARINGHOUSING	
4	2	BEARINGBUSH (BEST QUALITY)	
3	2	BALLBEARING (BEST QUALITY)	
2	2	BEARINGWASHERS	
1	1	SHAFT	ø 50 (Ø2") x 1300
Nº	NUMBER	MATERIAL / NAME / REMARKS / MEASUREMENTS	

4 OF 7

MOVING PARTS OF -12PO500- WINDMILL

FOR INFORMATION:

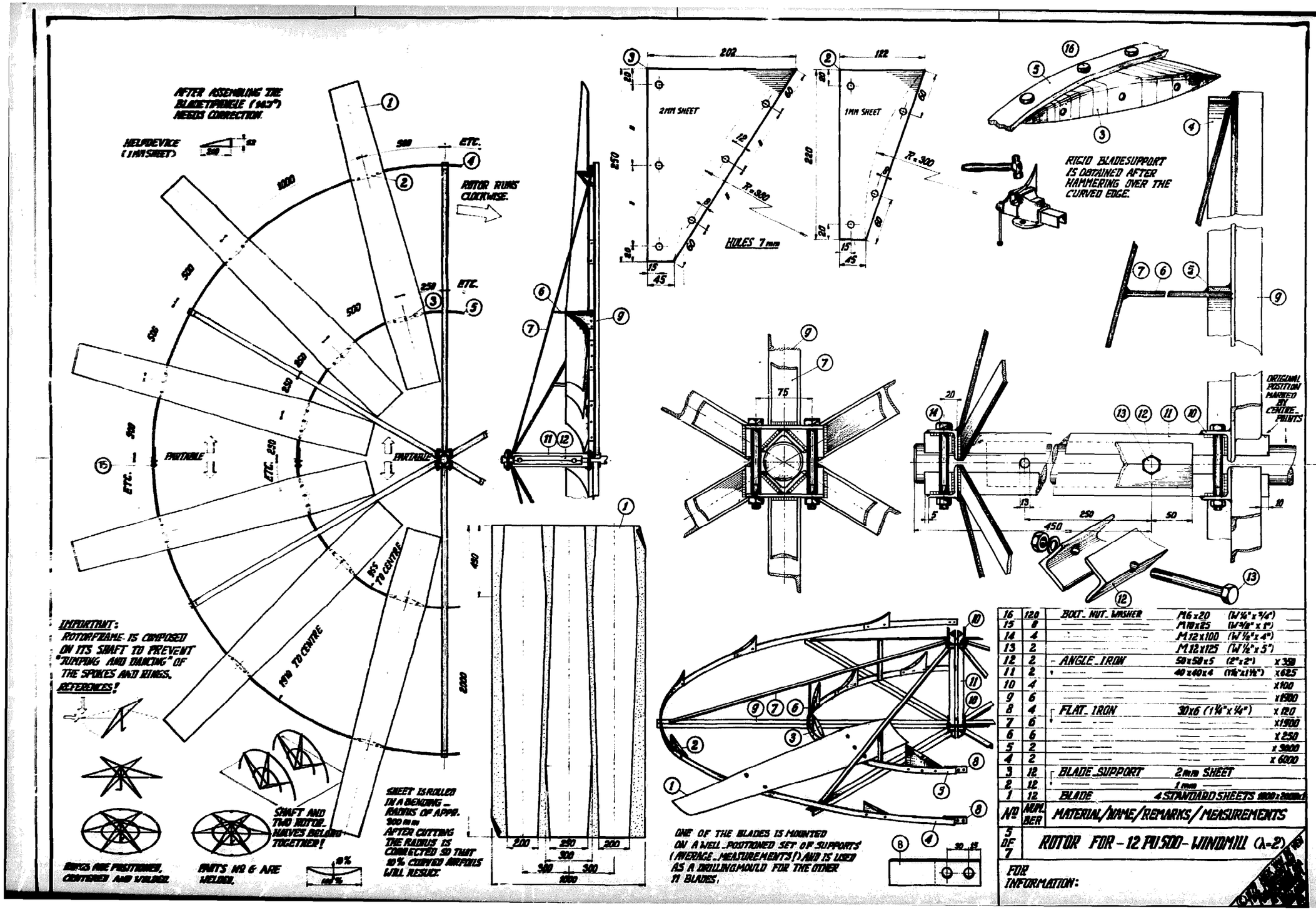

NO	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS		
16	120	BOLT-NUT-WASHER	M6 x 20 (W¼" x ¾")	
15	8		M10 x 25 (W⅜" x 1")	
14	4		M12 x 100 (W½" x 4")	
13	2		M12 x 125 (W½" x 5")	
12	2	ANGLE-IRON	50 x 50 x 5 (2" x 2")	x 350
11	2		40 x 40 x 4 (1⅝" x 1⅝")	x 625
10	4			x 100
9	6			x 1900
8	4	FLAT-IRON	30 x 6 (1¼" x ¼")	x 120
7	6			x 1900
6	6			x 250
5	2			x 3900
4	2			x 6000
3	12	BLADE-SUPPORT	2mm SHEET	
2	12		1mm	
1	12	BLADE	4 STANDARD SHEETS 1000 x 2000 mm	

5 OF 7

ROTOR FOR - 12 PU 300 - WINDMILL (λ=2)

FOR INFORMATION:

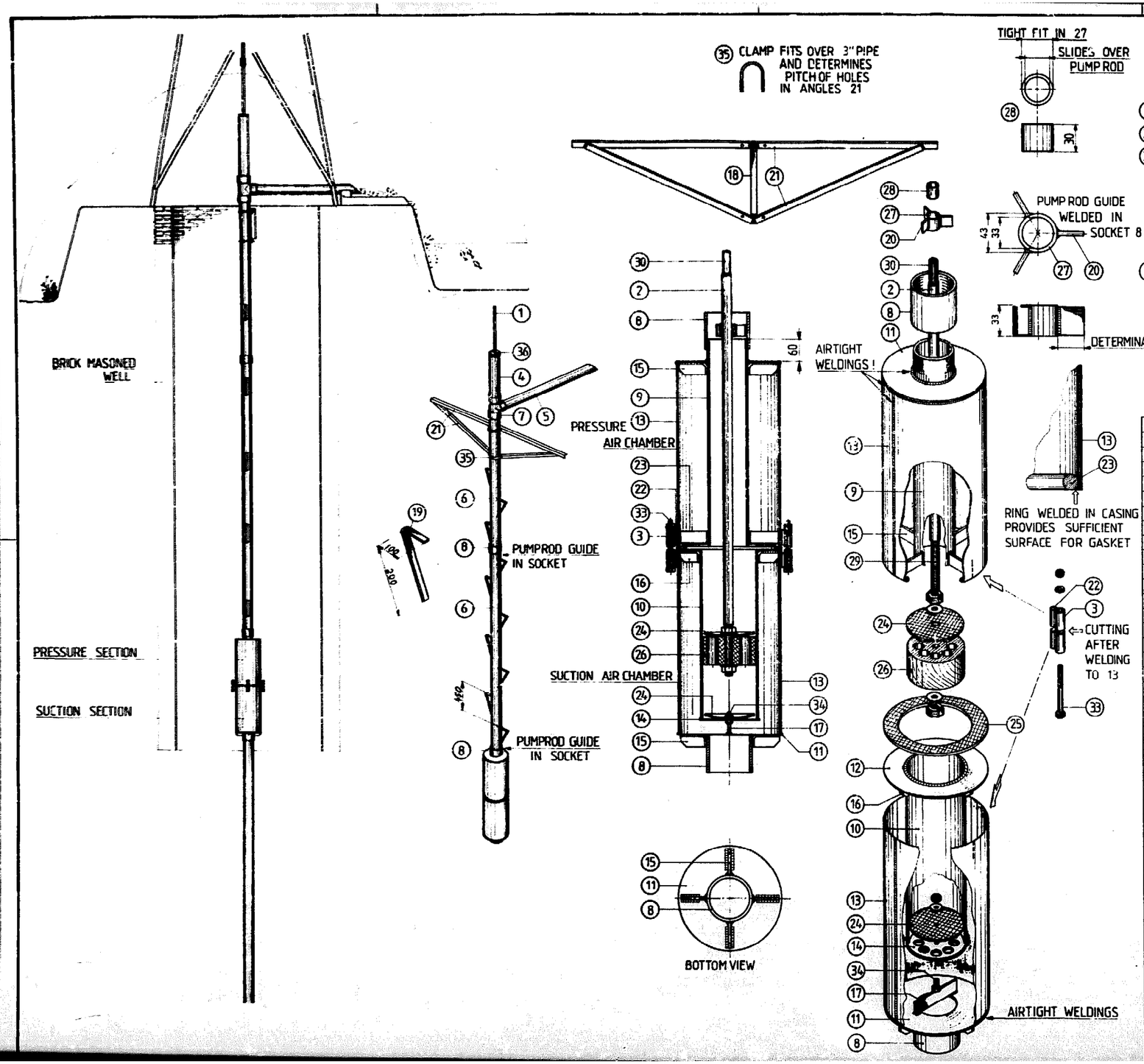

* AMOUNT OR SIZE DEPEND ON CIRCUMSTANCES

36	1	WOODEN PUMP ROD GUIDE : 27 IN DRAWING № 4	
35	2	CLAMP ROD Φ 12 (½")	× 300
34	1	BOLT - NUT - WASHER	M 12 × 20 (W ½" × ¾")
33	4	BOLT NUT WASHER	M 12 × 125 (W ½" × 5")
32	*	SPRING WASHERS	M 24 (W ⅞")
31	*	NUTS	M 24 (W ⅞")
30	*	THREAD STUD	M 24 × 100 (W ⅞" × 4")
29	1	THREAD STUD	M 24 × 150 (W ⅞" × 6")
28	*	GUN METAL BUSH	Φ 33 × 30
27	*	STEEL BUSH	Φ 43 × 33
26	1	PISTON	TEAKWOOD
25	1	GASKET	SOLE LEATHER Φ 250 × 6
24	2	VALVE	Φ 125 × 6
23	1	RING ROD Φ 8 (⅜")	× 745
22	8	FILLING PIECE	× 40
21	2	ANGLE IRON	40×40×4 (1½×1½) × *
20	3	FLAT IRON	30 × 6 (1⅛ × ¼") × *
19	*		× 300
18	1		× 450
17	1		× 155
16	4		× 50
15	12		× 75
14	1	FOOTVALVE	2 mm SHEET Φ 145
13	2	CASING	500 × 775
12	1	CASING FLANGE	Φ 250
11	2	CASING FLANGE	Φ 250
10	1	CYLINDER SEAMLESS	5" GASPIPE × 460
9	1	DELIVERY PIPE	3" × 560
8	*	SOCKET FOR	3"
7	1	T - SOCKET	3"
6	*	DELIVERY PIPE (EXTENSION)	3" × *
5	1	EXHAUST PIPE	3" × *
4	1	TOPPIPE	3" × 750
3	4	PIPE	½" × 100
2	1	PUMPROD	¾" × 950
1	*	PUMPROD EXTENSION	¾" × *
№	NUMBER	MATERIAL / NAME / REMARKS / MEASUREMENTS	

6 OF 7 — **5" PISTON PUMP** FOR 12 PU 500

FOR INFORMATION :

© RGD WILLEM PLANTE TOOL FOUNDATION AMSTELTAAN 6 AMSTERDAM

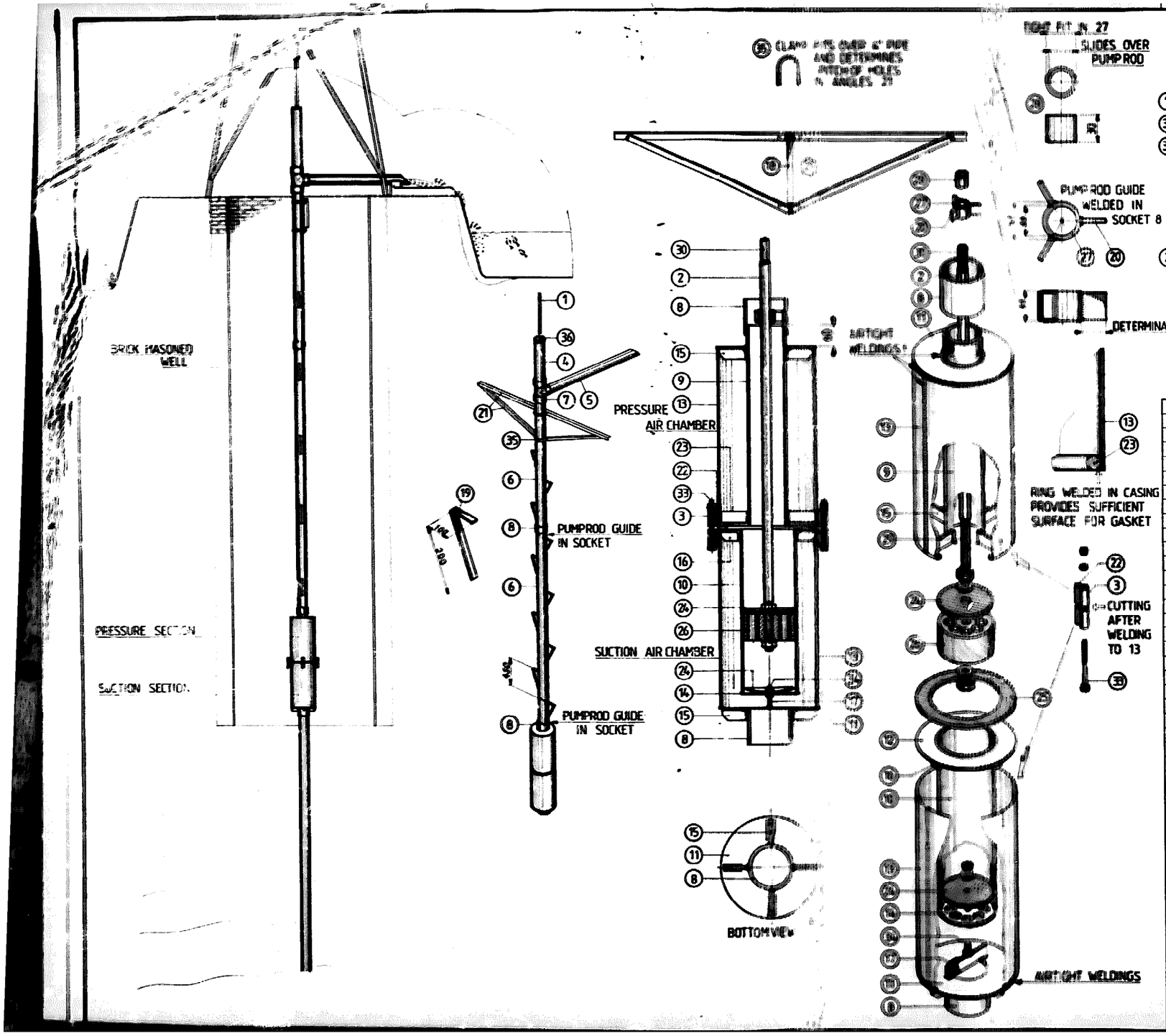

Nº	NUMBER	MATERIAL / NAME / REMARKS / MEASUREMENTS
36	1	WOODEN PUMPROD GUIDE 27 IN
35	2	CLAMP ROD
34	1	BOLT - NUT - WASHER
33	4	BOLT NUT WASHER
32	*	SPRING WASHERS
31	*	NUTS
30	*	THREAD STUD
29	1	THREAD STUD
28	*	GUN METAL BUSH
27	*	STEEL BUSH
26	1	PISTON TEAK WOOD
25	1	GASKET SOLE LEATHER
24	2	VALVE
23	1	RING ROD
22	8	FILLING PIECE
21	2	ANGLE IRON
20	3	FLAT IRON 30
19	*	
18	1	
17	1	
16	4	
15	12	
14	1	FOOT VALVE 2 mm SHEET
13	2	CASING
12	1	CASING FLANGE
11	2	CASING FLANGE
10	1	CYLINDER SEAMLESS 6" GASPIPE
9	1	DELIVERY PIPE 4"
8	*	SOCKET FOR 4"
7	1	T - SOCKET 4"
6	*	DELIVERY PIPE (EXTENSION) 4"
5	1	EXHAUST PIPE 4"
4	1	TOPPIPE 4"
3	4	PIPE 4"
2	1	PUMPROD
1	*	PUMPROD EXTENSION

* AMOUNT OR SIZE DEPEND ON CIRCUMSTANCES

6 OF 7

PISTONPUMP FOR 12 PERSONS WINDMILL

FOR INFORMATION : Workgroup on Development Technology T.H. Twente - Vakgroep 152 P.O. Box 217 Enschede The Netherlands

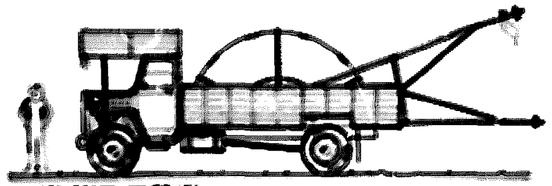

TRANSPORT BY TRUCK

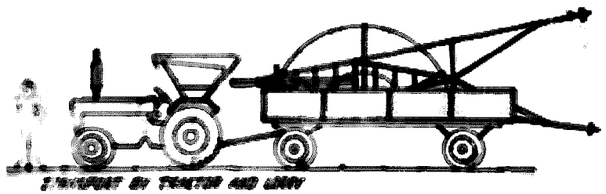

TRANSPORT BY TRACTOR AND LORRY

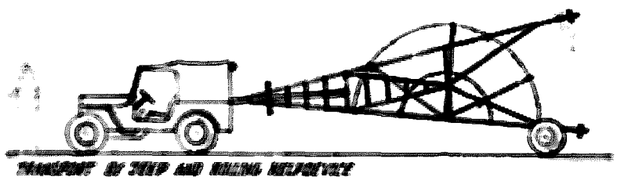

TRANSPORT BY JEEP AND HOISING MECHANICS

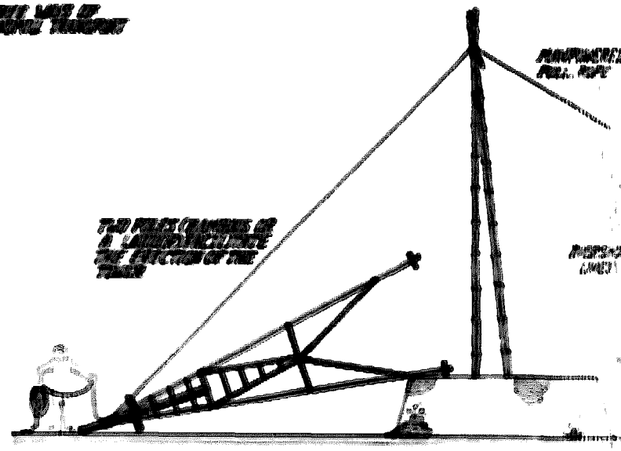

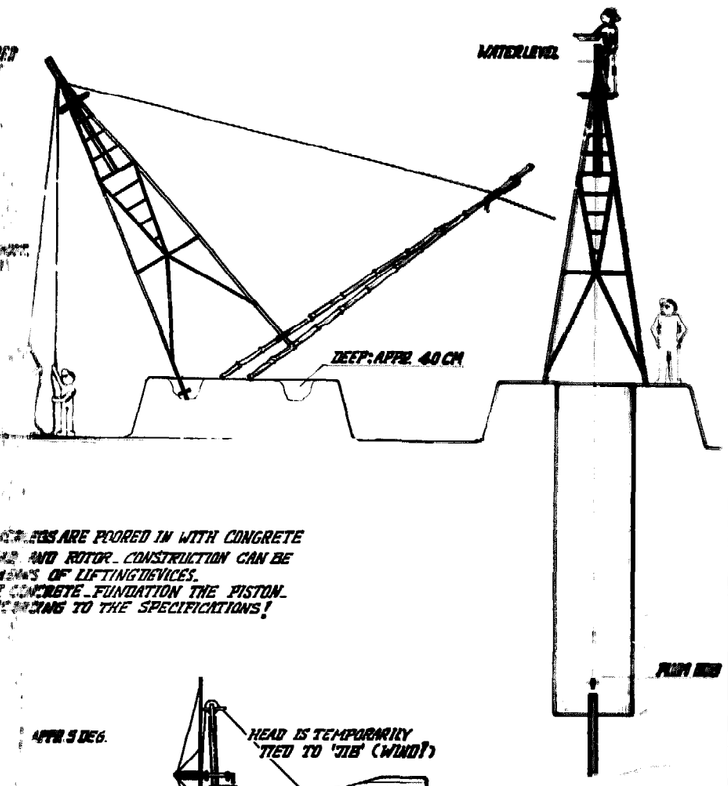

DISADVANTAGE: AFTER PLACING THE TOWER THE TOWER LEGS ARE POORED IN WITH CONCRETE AND AFTER APPR. 5 DAYS THE HEAD AND ROTOR-CONSTRUCTION CAN BE INSERTED SAFE AND QUICK BY MEANS OF LIFTING DEVICES. DURING THE DRYING PERIOD OF THE CONCRETE-FUNDATION THE PISTON-PUMP IS FIXED INTO THE WELL ACCORDING TO THE SPECIFICATIONS!

"JIB" - LIFTING MECHANICS

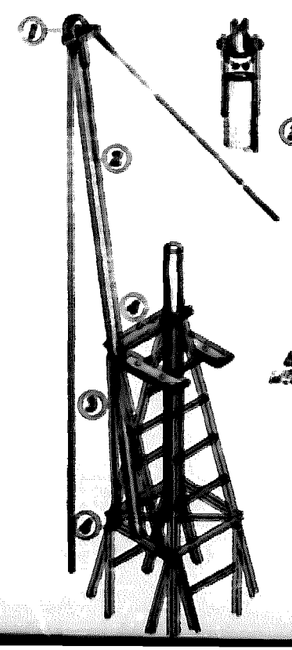

LIFTING HOOK FOR HEAD-CONSTRUCTION

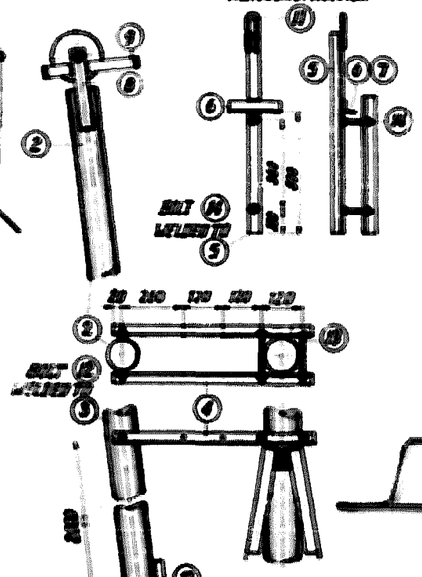

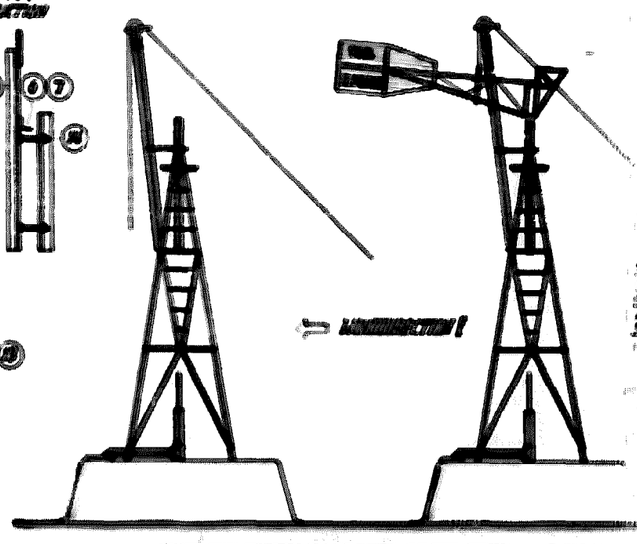

APPR. 5 DAYS.

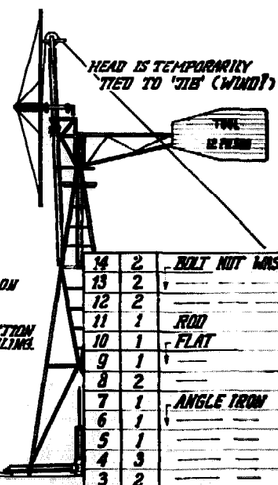

THE PERSONS STANDING ON THE PLATFORM ARE DRAWING THE HEAD-AND ROTOR-CONSTRUCTION INTO THEIR ASSEMBLING.

SINCE THE CENTRE OF GRAVITY OF THE HEAD-CONSTRUCTION IS SITUATED ABOVE THE UPPER TRUSS ANGLE A SPECIAL LIFTING-HOOK IS APPLIED. A SMOOTH SLIDING OVER THE TRANSOM IS ASSURED IF THE FRONT IS OUT OF BALANCE APPR. 5 DEGR.

ROTOR IS LIFTED WITH THE SHAFT COMPLETE WITH BEARINGS FIXED IN THE ROTORHUB IN ITS ORIGINAL POSITION (CENTRE POINTS!) AND FIXED TO THE HEAD CONSTRUCTION. NOW THE JIB CAN BE REMOVED AND THE GUARDS, SAFETY DEVICE AND MOVING PARTS ARE ASSEMBLED.

Nº	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS
14	2	BOLT NUT WASHER M 12 x 75 (W 1/2", 3")
13	2	M 12 x 150 (W 1/2", 6")
12	2	M 12 x 50 (W 1/2", 2")
11	1	ROD Ø 8 (Ø 5/16") x 200
10	1	FLAT 30 x 6 (1 1/4" x 1/4") x 100
9	1	x 600
8	2	x 800
7	1	ANGLE IRON 40 x 40 x 4 (1 1/2" x 1 1/2" x 5/32")
6	1	x 200
5	1	x 600
4	3	x 400
3	2	x 800
2	1	GASPIPE Ø 3" x 400
1	1	PULLEY, SHAFT AND ROPE OR STEELCABLE (20 M)

7 OF 7

INSTALLING THE WINDMILL — 12 PU 500 —

FOR INFORMATION:

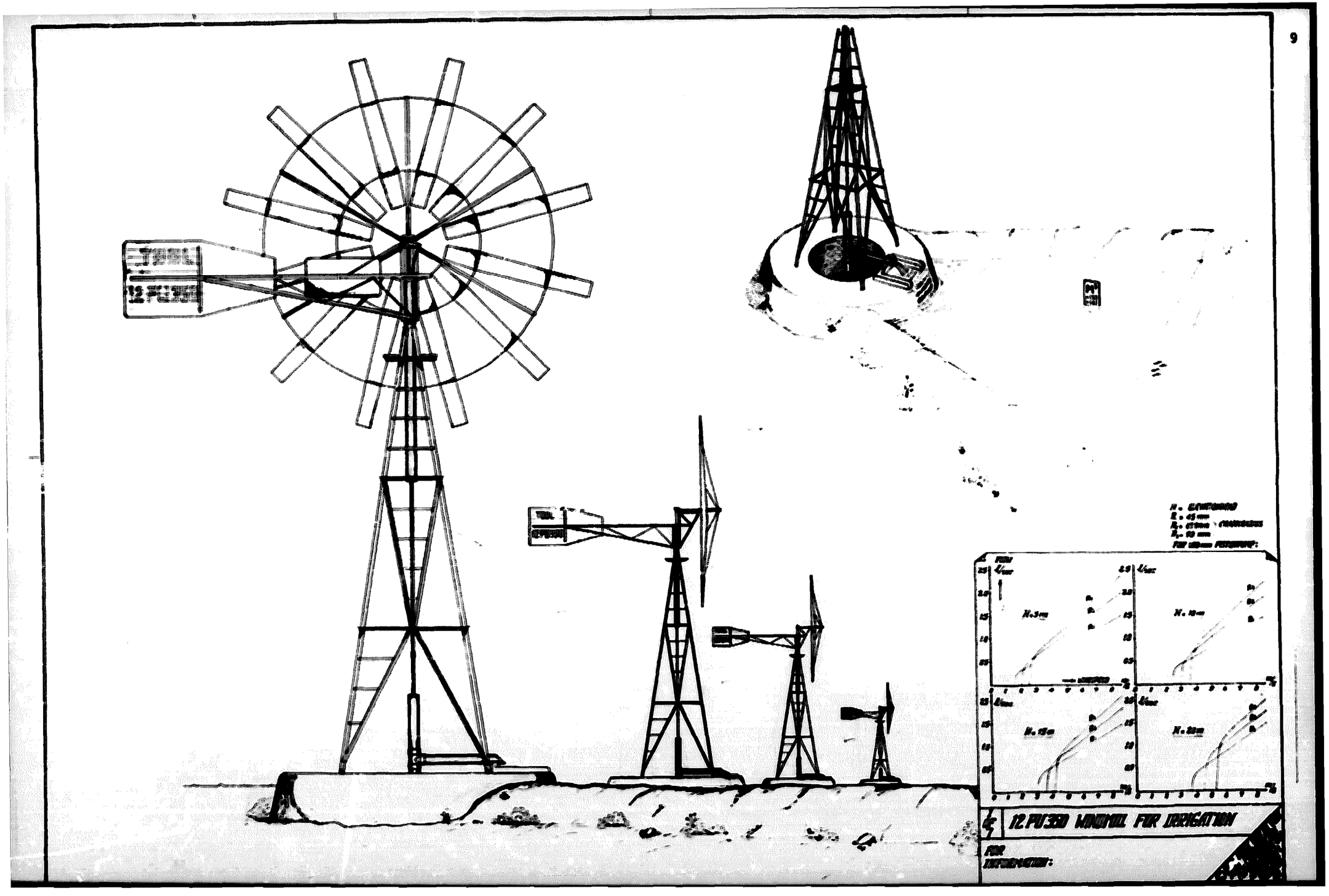
12 PU 350 WINDMILL FOR IRRIGATION
FOR INFORMATION:

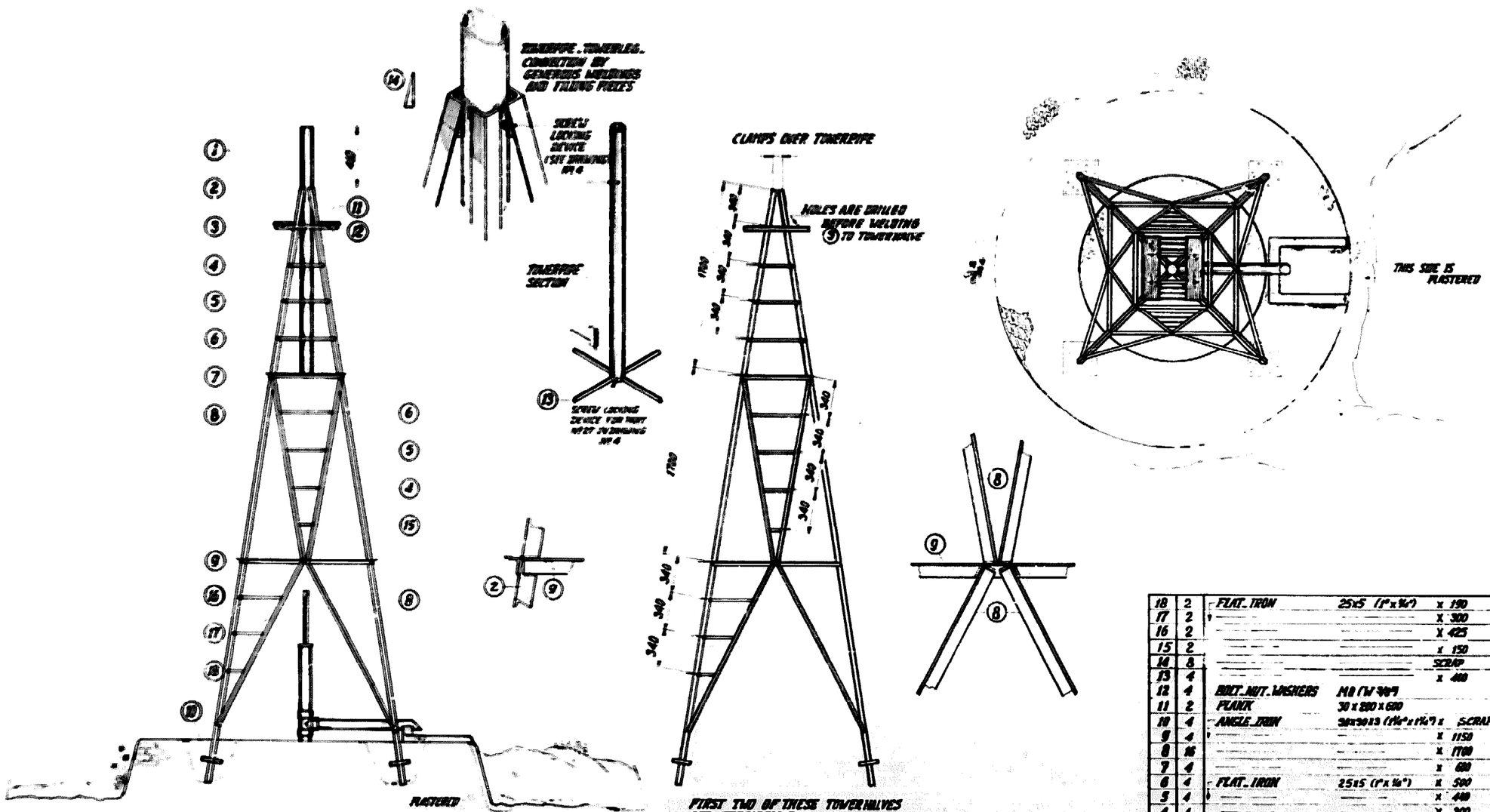

Nº	NUMBER	MATERIAL / NAME / REMARKS / MEASUREMENTS		
18	2	FLAT-IRON	25x5 (1"x 3/16")	x 190
17	2			x 300
16	2			x 425
15	2			x 150
14	8			SCRAP
13	4			x 400
12	4	BOLT-NUT-WASHERS	M8 (1/3")	
11	2	PLANK	30 x 200 x 600	
10	4	ANGLE-IRON	90x90x13 (1 1/16" x 1 1/16")	x SCRAP
9	4			x 1150
8	16			x 1700
7	4			x 600
6	4	FLAT-IRON	25x5 (1" x 3/16")	x 500
5	4			x 440
4	4			x 300.
3	2	ANGLE-IRON	90x90x13 (1 1/16" x 1 1/16")	x 550
2	4			5500
1	1	TOWERPIPE	3" GASPIPE	8150

3 OF 7 -12 PU 350 - TOWERCONSTRUCTION

FOR INFORMATION:

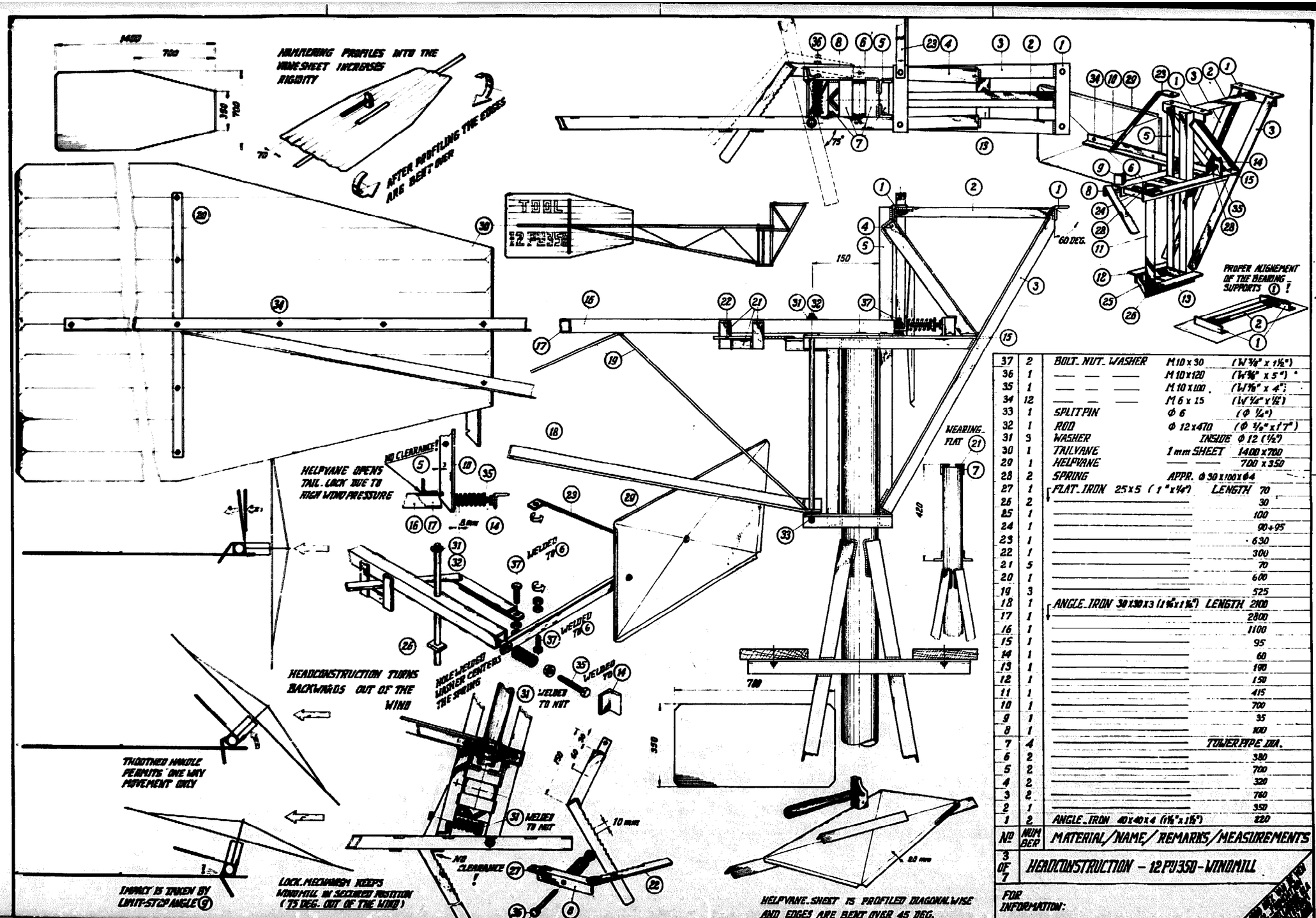

Nº	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS		
37	2	BOLT. NUT. WASHER	M 10 x 30	(W 3/8" x 1½")
36	1	— — —	M 10 x 120	(W 3/8" x 5")
35	1	— — —	M 10 x 100	(W 3/8" x 4")
34	12	— — —	M 6 x 15	(W 1/4" x 1/2")
33	1	SPLIT PIN	Φ 6	(Φ ¼")
32	1	ROD	Φ 12 x 470	(Φ ½" x 1'7")
31	3	WASHER	INSIDE	Φ 12 (½")
30	1	TAILVANE	1 mm SHEET	1400 x 700
29	1	HELPVANE	— —	700 x 350
28	2	SPRING	APPR.	Φ 30 x 100 x Φ 4
27	1	FLAT. IRON 25 x 5 (1" x ¼")	LENGTH	70
26	2	—		30
25	1	—		100
24	1	—		90+95
23	1	—		630
22	1	—		300
21	5	—		70
20	1	—		600
19	3	—		525
18	1	ANGLE. IRON 30 x 30 x 3 (1⅛" x 1⅛")	LENGTH	2100
17	1	—		2800
16	1	—		1100
15	1	—		95
14	1	—		60
13	1	—		190
12	1	—		150
11	1	—		415
10	1	—		700
9	1	—		35
8	1	—		100
7	4	—	TOWER PIPE DIA.	
6	2	—		380
5	2	—		700
4	2	—		320
3	2	—		760
2	1	—		350
1	2	ANGLE. IRON 40 x 40 x 4 (1⅝" x 1⅝")		220

3 OF 7

HEADCONSTRUCTION – 12PU350-WINDMILL

FOR INFORMATION:

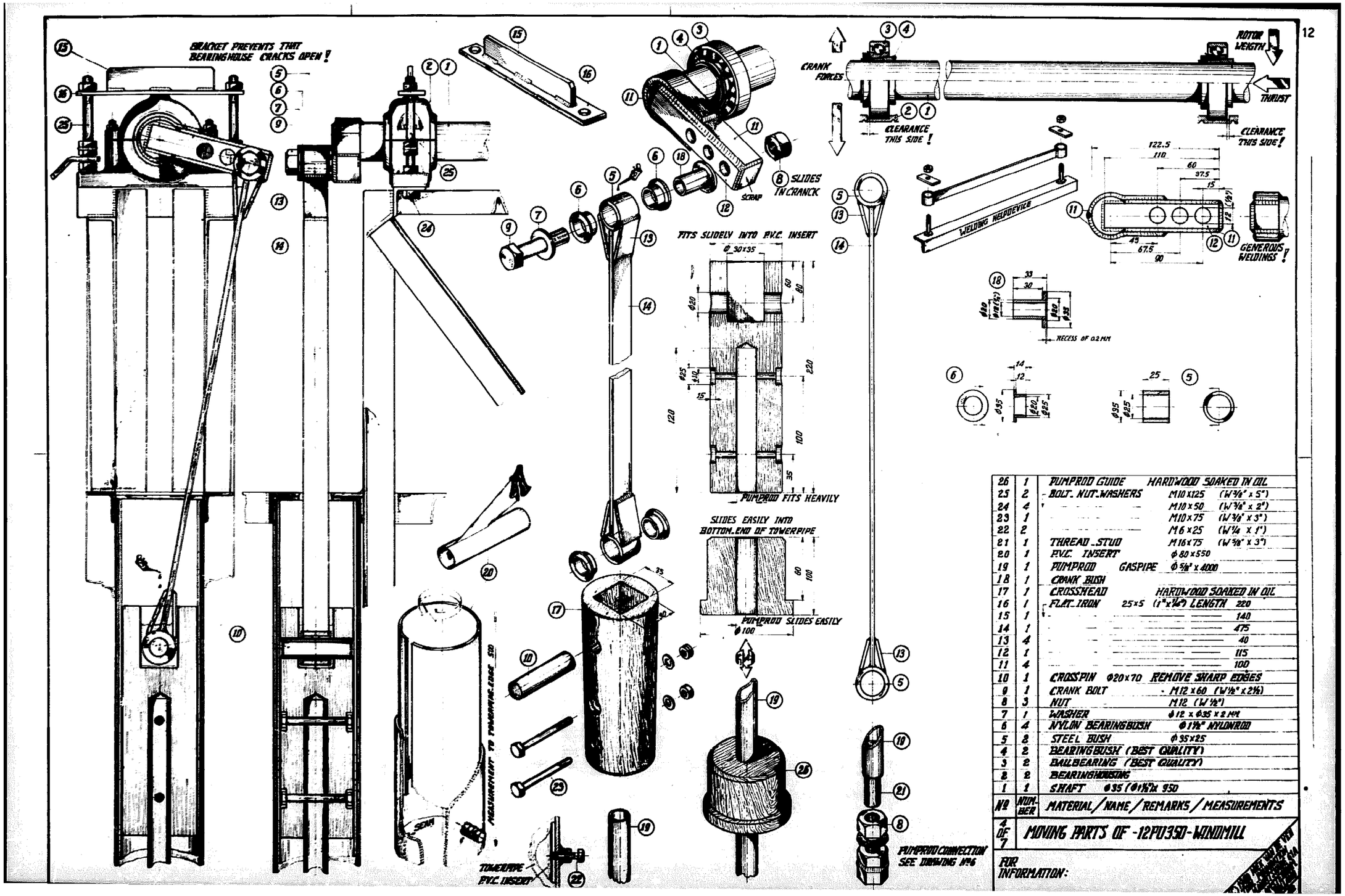

Nº	NUMBER	MATERIAL / NAME / REMARKS / MEASUREMENTS
26	1	PUMPROD GUIDE HARDWOOD SOAKED IN OIL
25	2	BOLT. NUT. WASHERS M10 x 125 (W 3/8" x 5")
24	4	— — — — M10 x 50 (W 3/8" x 2")
23	1	— — — — M10 x 75 (W 3/8" x 3")
22	2	— — — — M6 x 25 (W 1/4" x 1")
21	1	THREAD. STUD M16 x 75 (W 5/8" x 3")
20	1	P.V.C. INSERT Ø 80 x 550
19	1	PUMPROD GASPIPE Ø 5/8" x 4000
18	1	CRANK BUSH
17	1	CROSSHEAD HARDWOOD SOAKED IN OIL
16	1	FLAT IRON 25 x 5 (1" x 1/4") LENGTH 220
15	1	— — — — 140
14	1	— — — — 475
13	4	— — — — 40
12	1	— — — — 115
11	4	— — — — 100
10	1	CROSSPIN Ø 20 x 70 REMOVE SHARP EDGES
9	1	CRANK BOLT M12 x 60 (W 1/2" x 2 1/2")
8	3	NUT M12 (W 1/2")
7	1	WASHER Ø 12 x Ø 35 x 2 MM
6	4	NYLON BEARINGBUSH Ø 1 1/2" NYLONROD
5	8	STEEL BUSH Ø 35 x 25
4	2	BEARINGBUSH (BEST QUALITY)
3	2	BALLBEARING (BEST QUALITY)
2	2	BEARINGHOUSING
1	1	SHAFT Ø 35 (Ø 1 1/2") x 950

4 OF 7

MOVING PARTS OF -12PU350-WINDMILL

FOR INFORMATION:

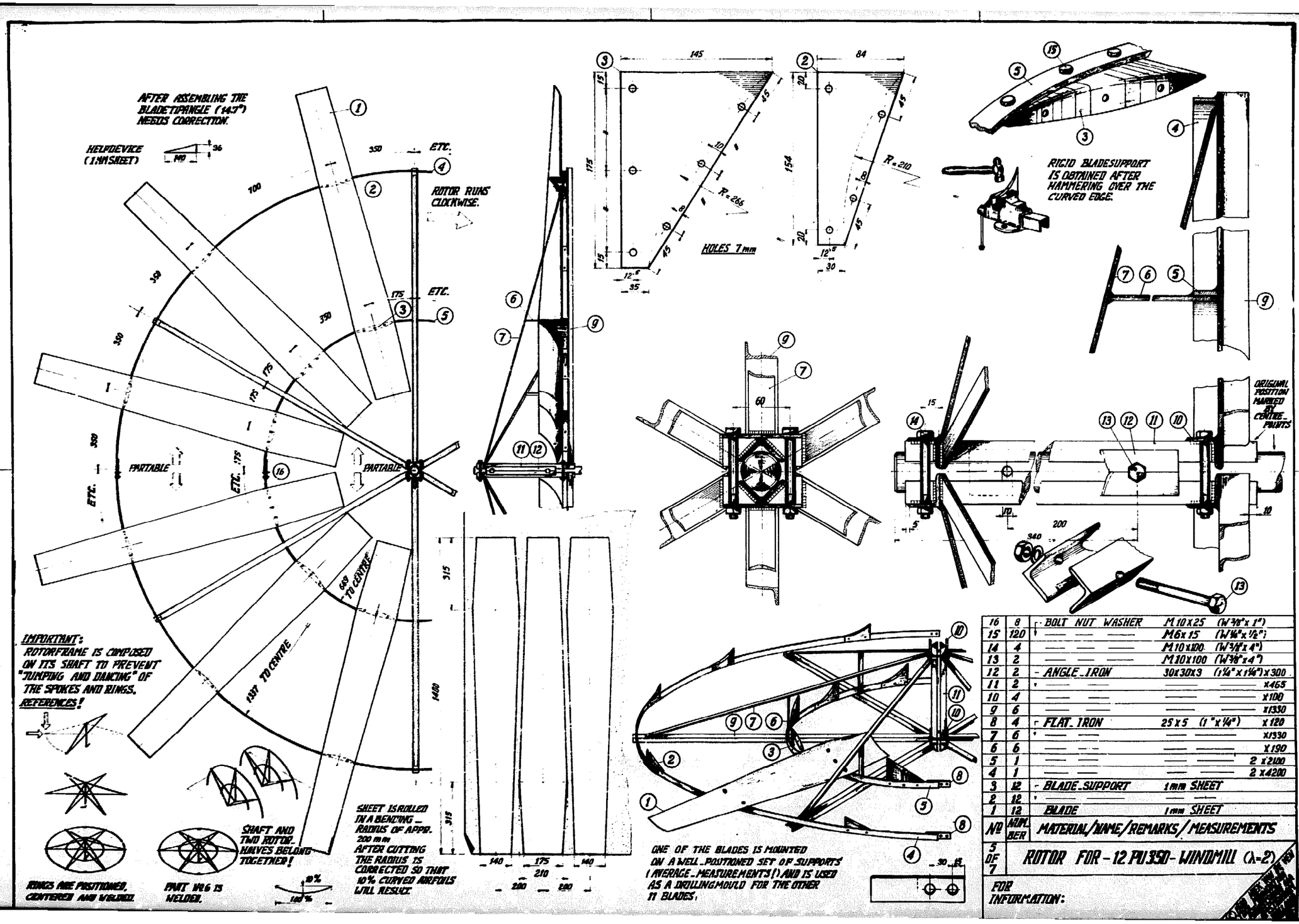

Nº	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS		
16	8	BOLT NUT WASHER	M10x25	(W 3/8" x 1")
15	120	—— —— ——	M6x15	(W 1/4" x 1/2")
14	4	—— —— ——	M10x100	(W 3/8" x 4")
13	2	—— —— ——	M10x100	(W 3/8" x 4")
12	2	ANGLE-IRON	30x30x3	(1 1/4" x 1 1/4") x 300
11	2	—— ——	——	x465
10	4	—— ——	——	x100
9	6	—— ——	——	x1330
8	4	FLAT-IRON	25x5	(1" x 1/4") x 120
7	6	—— ——	——	x1330
6	6	—— ——	——	x190
5	1	—— ——	——	2 x 2100
4	1	—— ——	——	2 x 4200
3	12	BLADE-SUPPORT	1mm SHEET	
2	12	—— ——	——	
1	12	BLADE	1mm SHEET	

5 OF 7

ROTOR FOR-12 PU 350-WINDMILL (λ=2)

FOR INFORMATION:

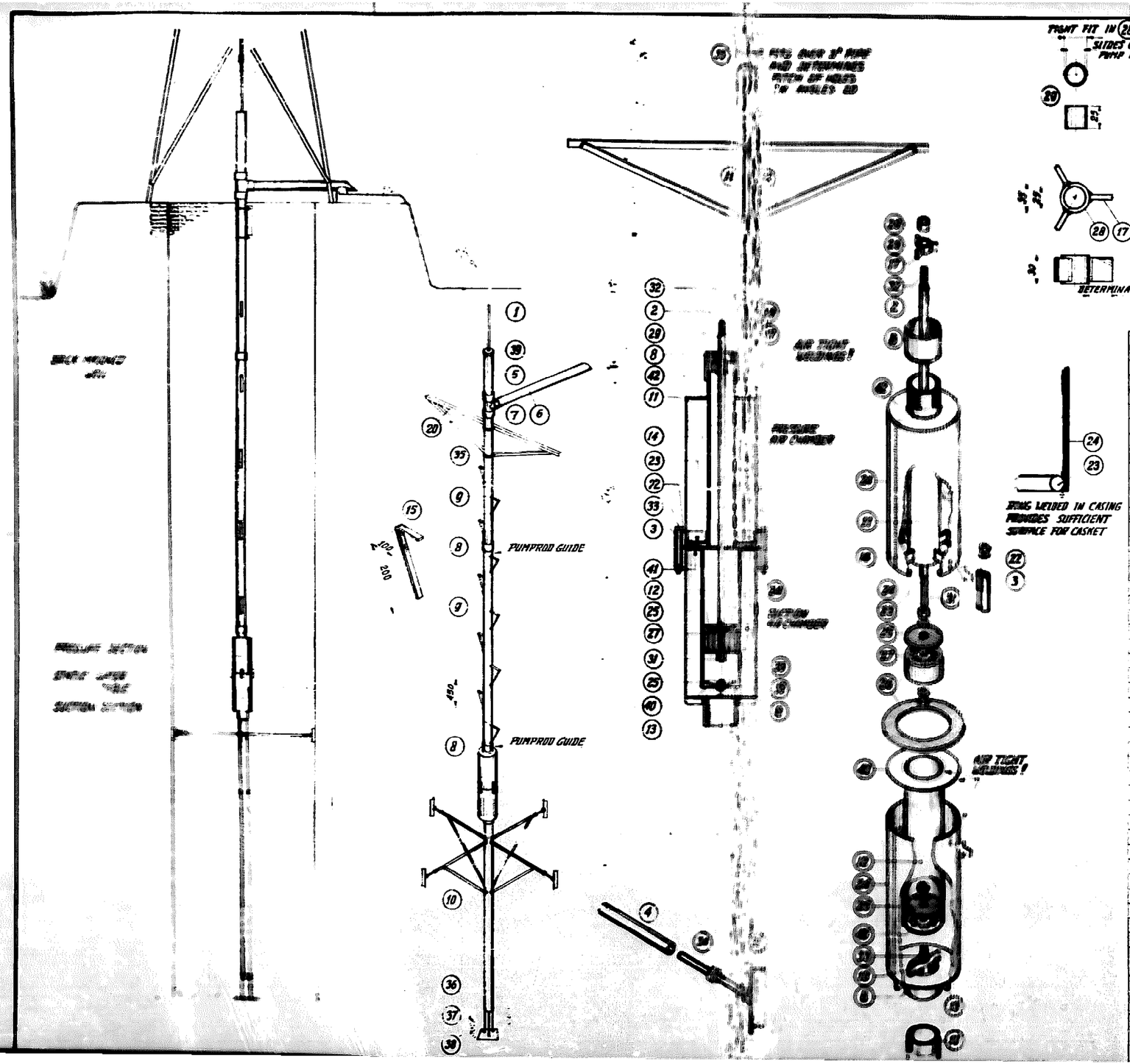

Nº	NUMBER	MATERIAL / NAME / REMARKS / MEASUREMENTS
42	2	CASING _ FLANGE 2mm SHEET
41	1	
40	1	FOOT VALVE (SCRAP FROM Nº 42)
39	1	WOODEN PUMPROD GUIDE : SEE IN DRAWING Nº 6
38	1	BOTTOM SHEET 2mm SHEET
37	1	MESH
36	3	FOOT BAR ROD
35	2	CLAMP ROD
34	4	BOLT _ NUT
33	5	BOLT _ NUT _ WASHER
32	*	THREAD STUD
31	1	
30	*	NUTS M16
29	1	BRONZE BUSH
28	1	STEEL BUSH
27	2	PISTON / FOOTVALVE TEAKWOOD
26	1	GASKET SOLE LEATHER
25	2	VALVE
24	2	CASING 2mm SHEET
23	1	RING ROD
22	4	FILLING PIECE ROD
21	4	ANGLE IRON
20	2	
19	4	
18	1	FLAT IRON
17	3	
16	1	
15	*	
14	4	
13	4	
12	1	CYLINDER SEAMLESS 4" GASPIPE
11	1	DELIVERY PIPE " 3"
10	1	SUCTION PIPE 3"
9	1	DELIVERY PIPE (EXTENSION) 3"
8	*	SOCKET FOR 3"
7	1	T-SOCKET 3"
6	1	EXHAUST PIPE 3"
5	1	TOP PIPE 3"
4	4	PISTONRODS PIPE 1"
3	4	PIPE 1/2"
2	1	PUMPROD 1/2"
1	*	PUMPROD EXTENSION 1/2"

6 OF 7

4" PISTONPUMP FOR 12 FUSSD WINDMILL

FOR INFORMATION:

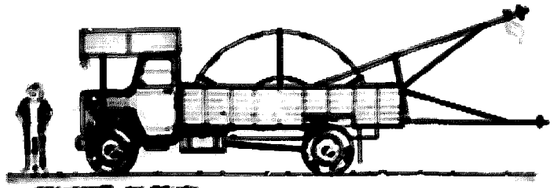

TRANSPORT BY TRUCK

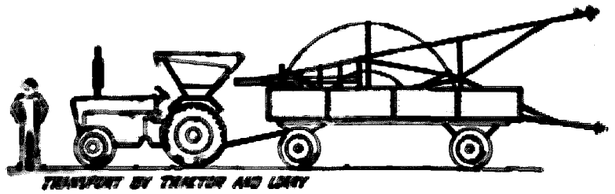

TRANSPORT BY TRACTOR AND LORRY

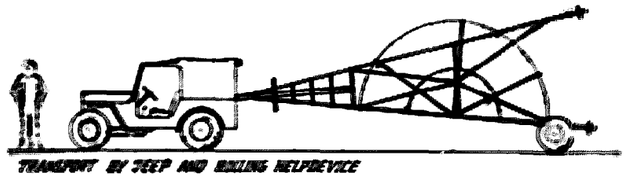

TRANSPORT BY JEEP AND ROLLING HELPDEVICE

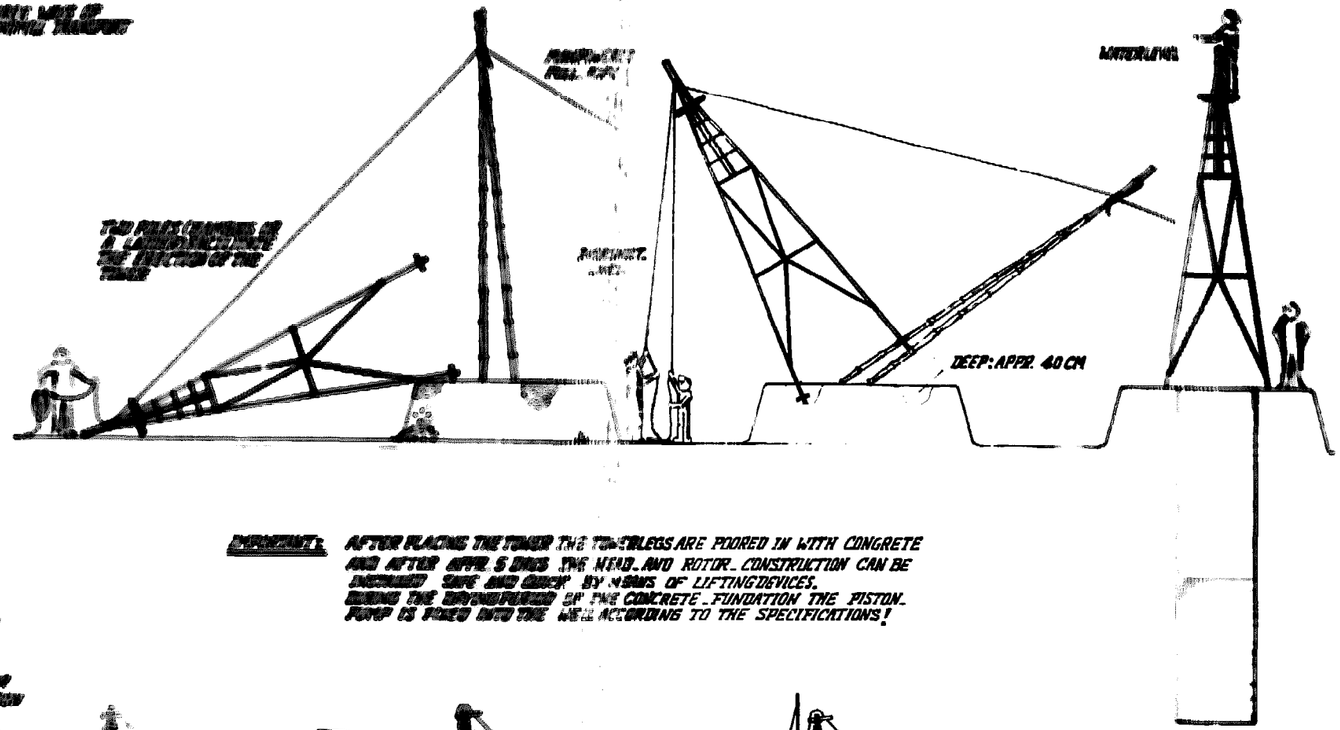

IMPORTANT: AFTER PLACING THE TOWER THE TOWERLEGS ARE POORED IN WITH CONCRETE AND AFTER APPR. 5 DAYS THE HEAD- AND ROTOR- CONSTRUCTION CAN BE INSTALLED SAFE AND QUICK BY MEANS OF LIFTINGDEVICES. DURING THE DRYINGPERIOD OF THE CONCRETE-FUNDATION THE PISTON-PUMP IS FIXED INTO THE WELL ACCORDING TO THE SPECIFICATIONS!

"TIB". LIFTING HELPDEVICE

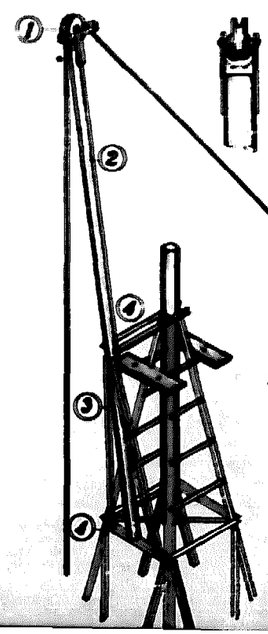

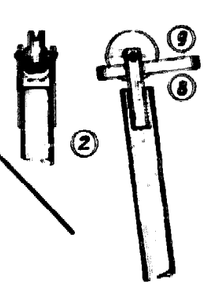

LIFTING HOOK FOR HEADCONSTRUCTION

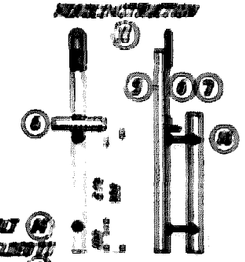

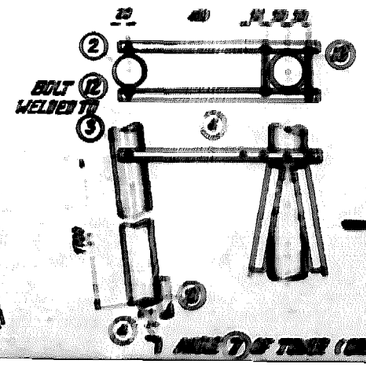

ANGLE OF TOWER (CHANGE IN 8)

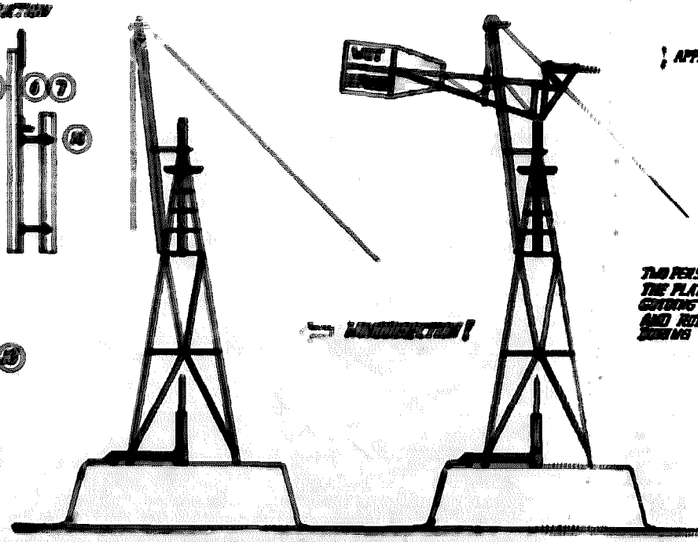

SINCE THE CENTRE OF GRAVITY OF THE HEAD-CONSTRUCTION IS SITUATED ABOVE THE UPPER TOW. ANGLE A SPECIAL LIFTINGHOOK IS APPLIED. A SMOOTH SLIDING OVER THE TOWERPIPE IS ACHIEVED IF THE HEAD IS OUT OF BALANCE APPR. 5 DEG.

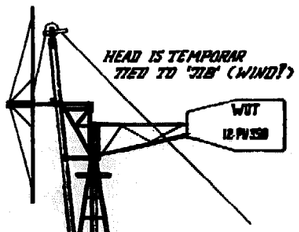

TWO PERSONS STANDING ON THE PLATFORM ARE GUIDING THE HEAD- AND ROTOR- CONSTRUCTION DURING THEIR LIFT.

NOW THE HEAD IS LIFTED AND POSITIONED AT THE TOP OF ITS SHAFT AND SHIFTED IN ITS ORIGINAL POSITION (CENTREPOINTS!) AND FIXED. NOW THE "TIB" CAN BE REMOVED AND THE BLADES, SAFETYDEVICE AND MOVING PARTS ARE ASSEMBLED.

Nº	NUMBER	MATERIAL/NAME/REMARKS/MEASUREMENTS
14	2	BOLT NUT WASHER
13	1	
12	2	
11	1	ROD
10	1	FLAT
9	1	
8	2	
7	1	ANGLE IRON
6	1	
5	1	
4	3	
3	2	
2	1	GASPIPE
1	1	PULLEY-SHAFT AND PIPE (IN STYLCABLE (IN M)
7 BY 7		INSTALLING THE WINDMILL — 12 PU 350 —

FOR INFORMATION:

20 Foot Portable PVC Tower

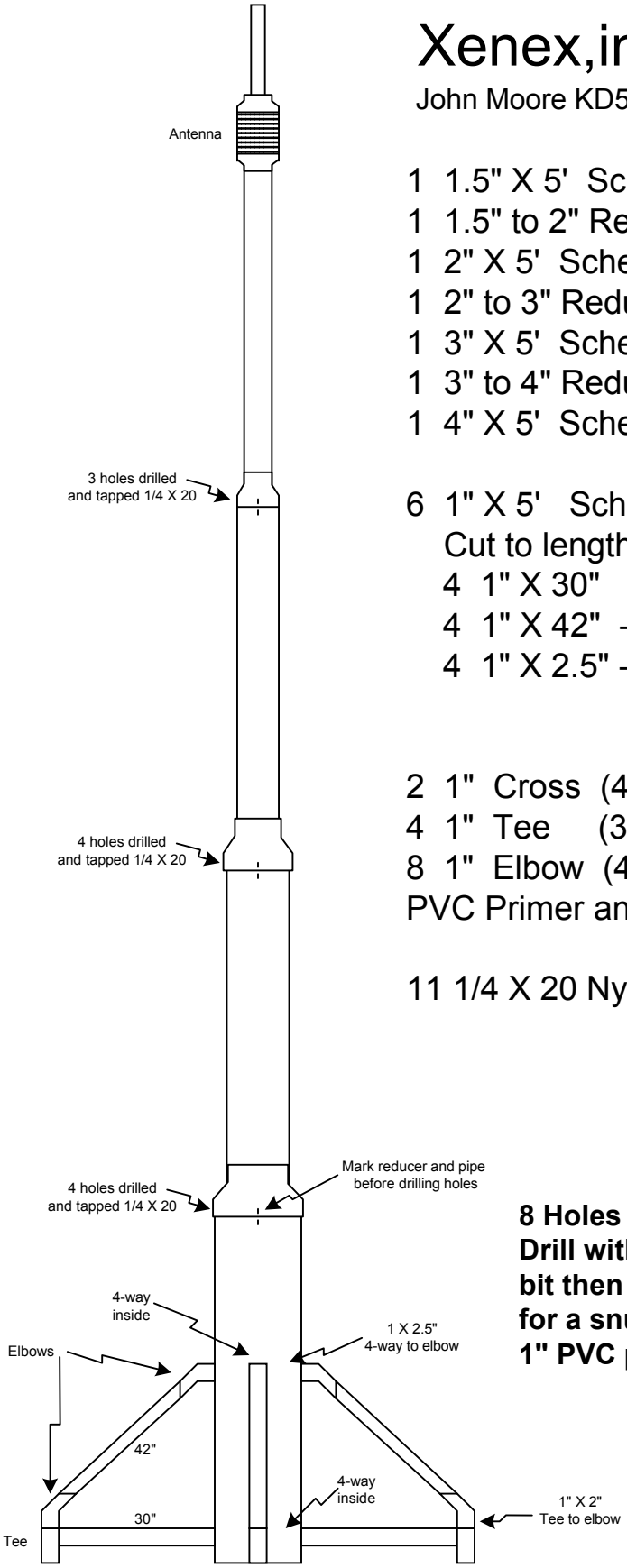

Xenex,inc.

John Moore KD5RVX

Height: 20 Ft.
Weight: 25 lbs.
Cost of materials: 50 $

1 1.5" X 5' Schedule 40 PVC
1 1.5" to 2" Reducer -- glue to 1.5" pipe
1 2" X 5' Schedule 40 PVC
1 2" to 3" Reducer -- glue to 2" pipe
1 3" X 5' Schedule 40 PVC
1 3" to 4" Reducer -- glue to 3" pipe
1 4" X 5' Schedule 40 PVC

6 1" X 5' Schedule 40 PVC (or 3 10' sections)
Cut to lengths:
4 1" X 30" -- lower 4-way to tee
4 1" X 42" -- lower elbow to upper elbow
4 1" X 2.5" -- upper 4-way to upper elbow
Tee

2 1" Cross (4 Way Coupler)
4 1" Tee (3 Way Coupler)
8 1" Elbow (45 degree)
PVC Primer and cement

11 1/4 X 20 Nylon screws 1/2" long

8 Holes -- 1-5/16"
Drill with 1-1/4" wood bit then file to 1-5/16" for a snug fit of the 1" PVC pipe.

4" PVC Pipe

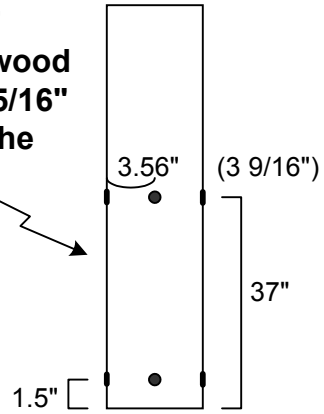

KD5RVX MicroVert Antenna

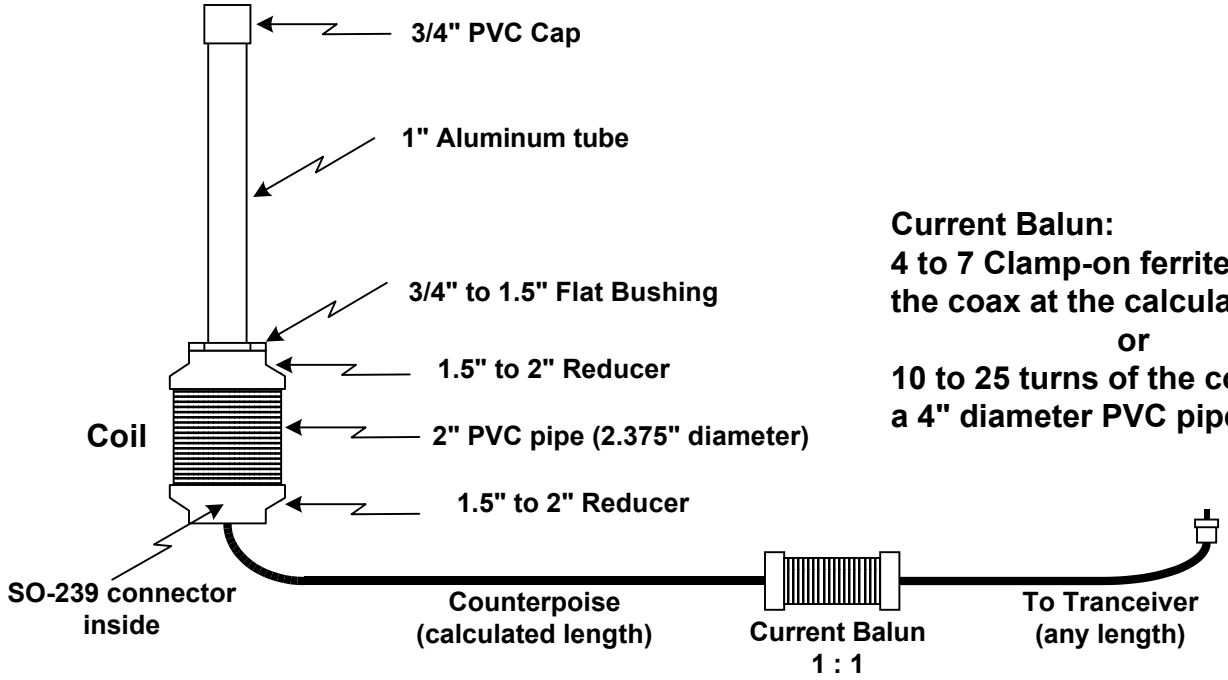

Current Balun:
4 to 7 Clamp-on ferrite beads on the coax at the calculated length
or
10 to 25 turns of the coax around a 4" diameter PVC pipe.

Formulas

$Ls = 185 / F$
Where:
Ls = radiator length in inches
F = freq in megaHertz

$Cs = 0.485\ Ls\ (1 / \log(0.575\ (Ls/d)))$
Where:
Cs = radiator capacitance in pF
Ls = radiator length in inches
d = radiator outside diameter in inches

$L = (159 / F)^2 / Cs$
Where:
L = inductance in microHeneries (uH)
F = Freq in megaHertz
Cs = radiator capacitance in pF

Coil Winding

$$L = \frac{d^2\ t^2}{18d + 40b}$$

Where:
L = inductance in uH
d = coil diameter in inches
t = number of turns
b = coil length in inches

Coax Counterpoise Length

$Lx = 190 / F$
Where:
Lx = counterpoise length in feet
F = freq in megaHertz

Juergen Schaefer , DL7PE, is the author and designer of the "DL7PE Microvert "antenna.
This information is restricted to the private and personal use of radio amateurs.
Commercial use is not permitted.

References:
[1] Jurgen Schaefer
DL7PE-Microvert
AntenneX.com , 2001

Perfectly Versatile Campsite

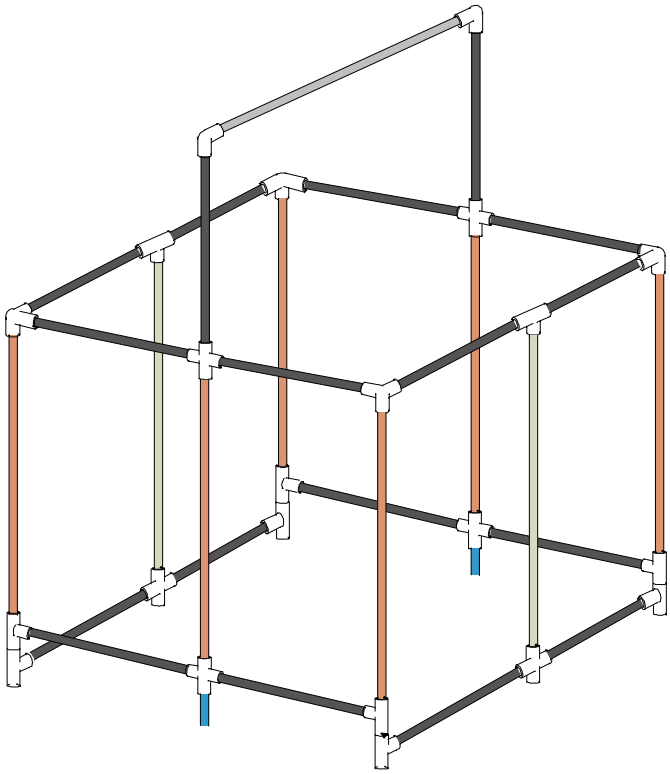

Food Preparation Table

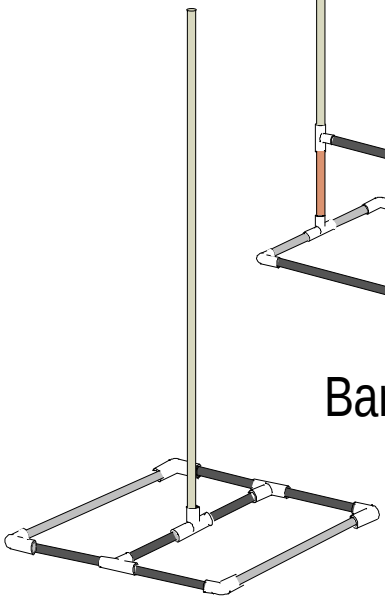

Flag Pole

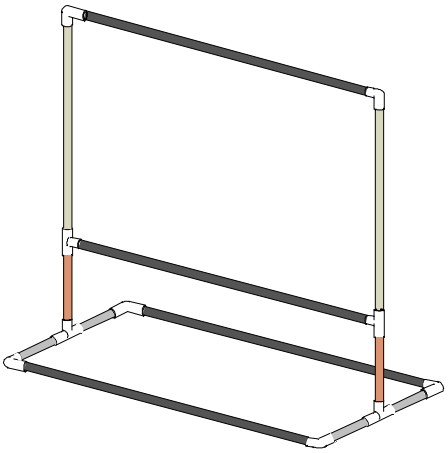

Banner Frame

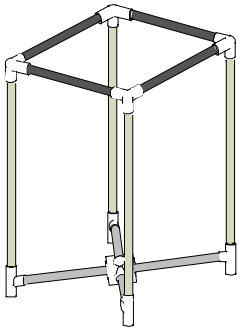

Trash Stand

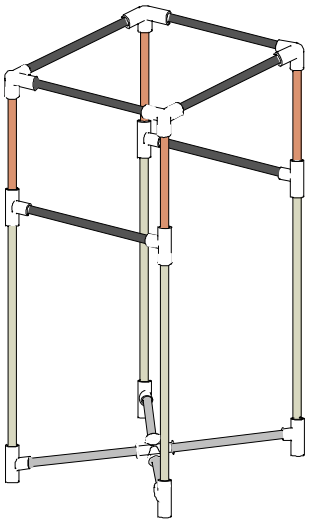

Wash Stand

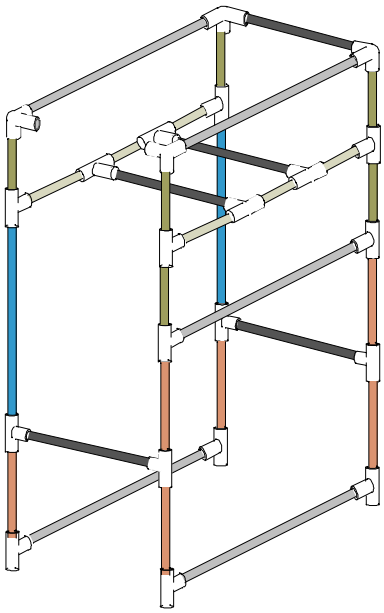

Hand Wash Stand

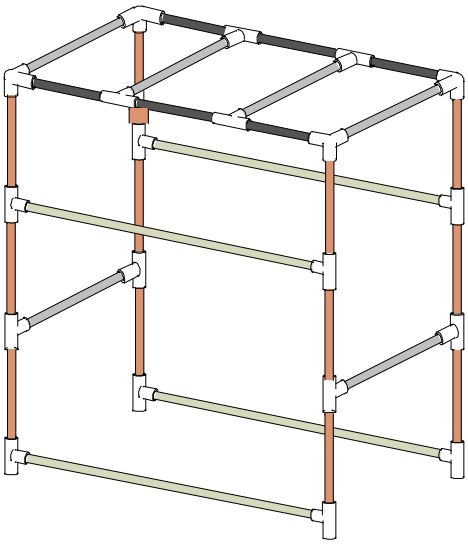

Dishwashing Stand

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Last Update 09/01/2002

Food Preparation Table

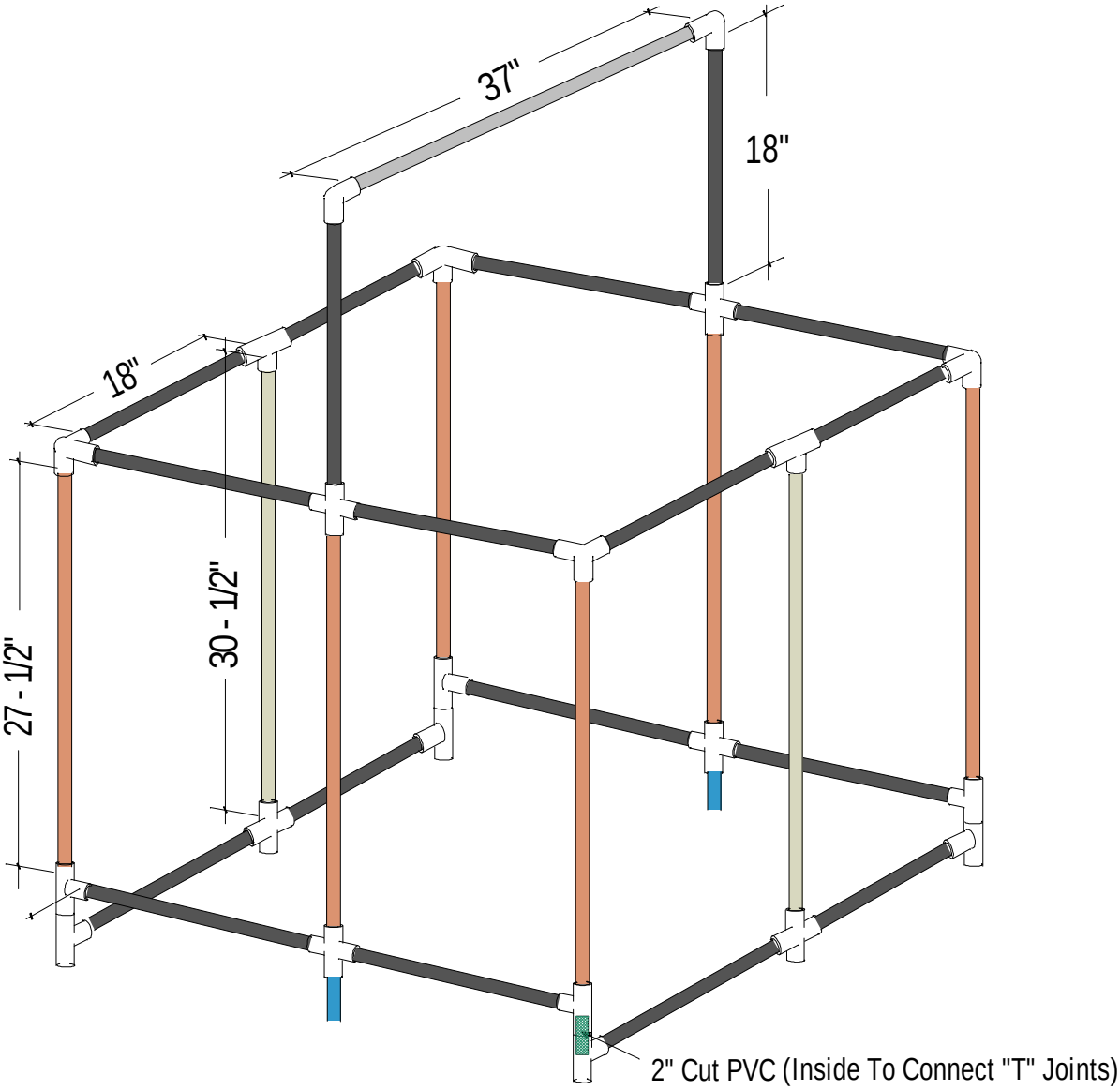

Materials List

*** See pages 10 and 11 for Design Notes**

- (1) 37" Cut PVC
- (18) 18" Cut PVC
- (6) 27 - 1/2" Cut PVC
- (2) 30 - 1/2" Cut PVC
- (2) 4" Cut PVC

All PVC is 3/4" Schedule 40

- (4) 2" Cut PVC (To Connect "T" Joints)
- (4) 90 Slip Side Outlet 90 Degree El
- (10) 90 Degree T - Socket
- (6) Cross Socket
- (2) 90 Degree El - Socket

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Dishwashing Stand

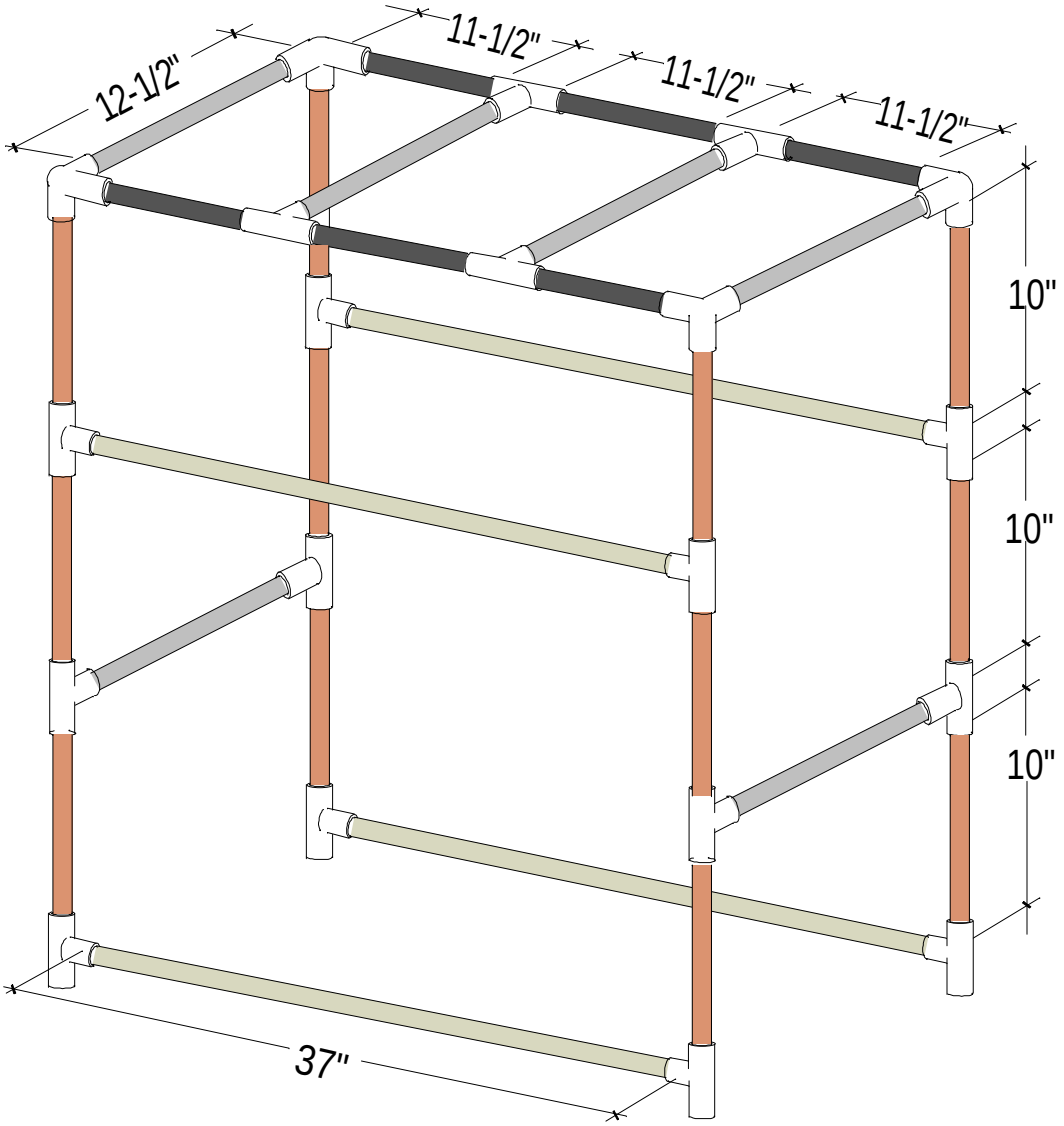

Materials List *See pages 10 and 11 for Design Notes*

- (6) 12 - 1/2" Cut PVC
- (6) 11 - 1/2" Cut PVC
- (12) 10" Cut PVC
- (4) 37" Cut PVC

- (4) Slip Side Outlet 90 Degree El
- (16) 90 Degree T - Socket

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Hand Wash Stand

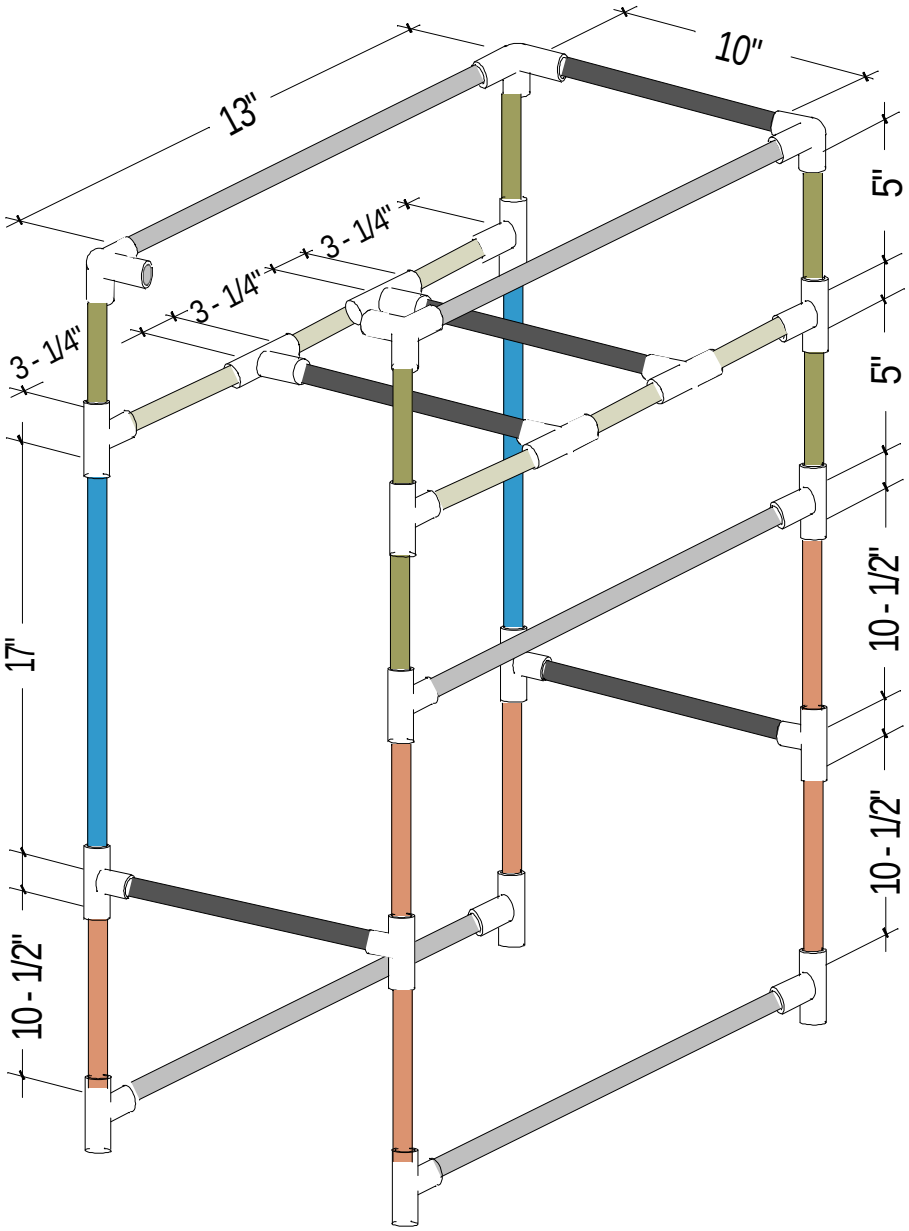

Materials List

* See pages 10 and 11 for Design Notes

- (5) 13" Cut PVC
- (5) 10" Cut PVC
- (6) 10 - 1/2" Cut PVC
- (6) 3 - 1/4" Cut PVC
- (6) 5" Cut PVC
- (2) 17" Cut PVC
- (4) Slip Side Outlet 90 Degree El
- (18) 90 Degree T - Socket

All PVC is 3/4" Schedule 40

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Banner Frame

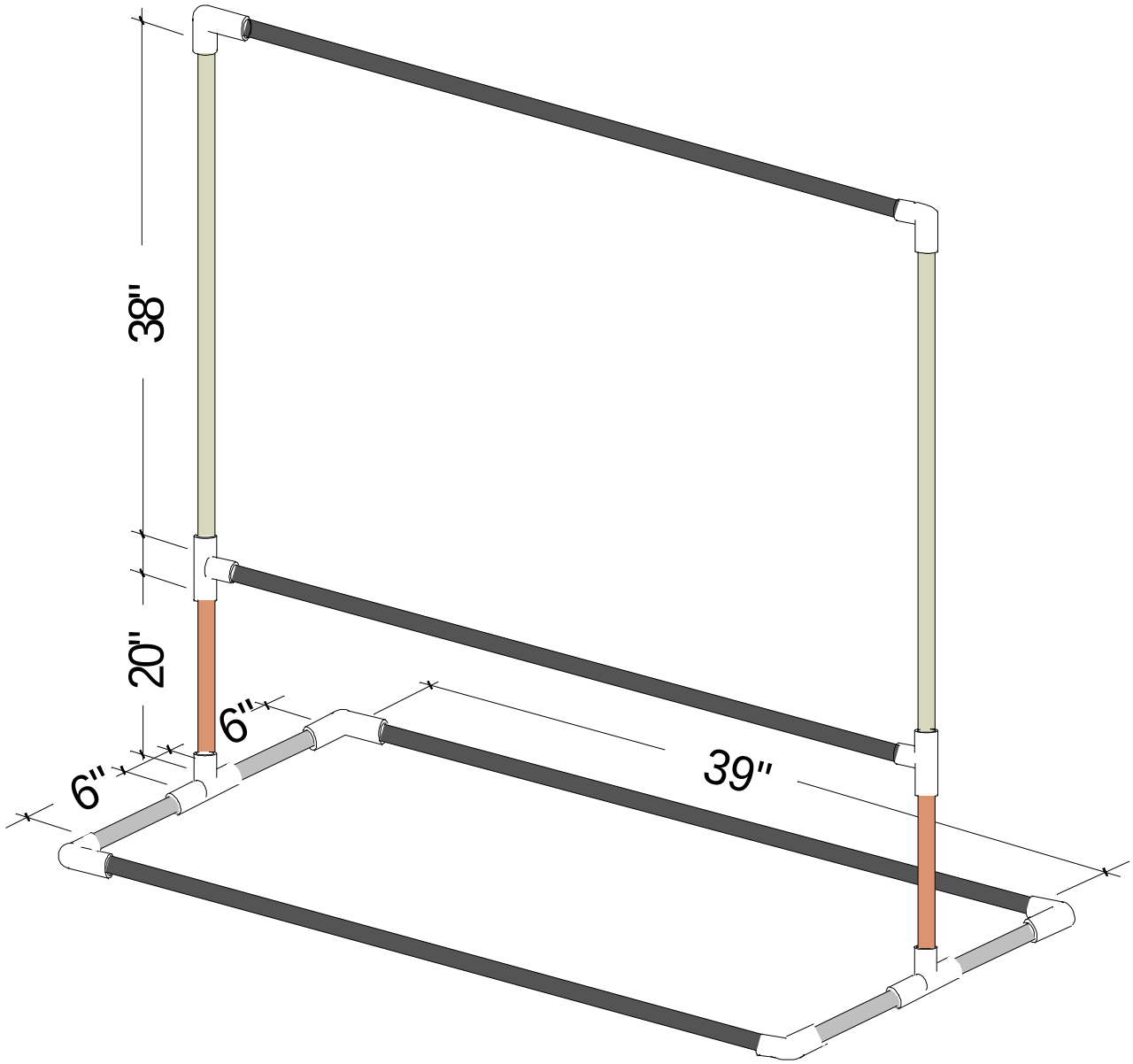

Materials List *** See pages 10 and 11 for Design Notes**

- (4) 6" Cut PVC
- (4) 39" Cut PVC
- (2) 20" Cut PVC
- (2) 38" Cut PVC
- (6) 90 Degree El - Socket
- (4) 90 Degree T - Socket

All PVC is 3/4" Schedule 40

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Wash Stand

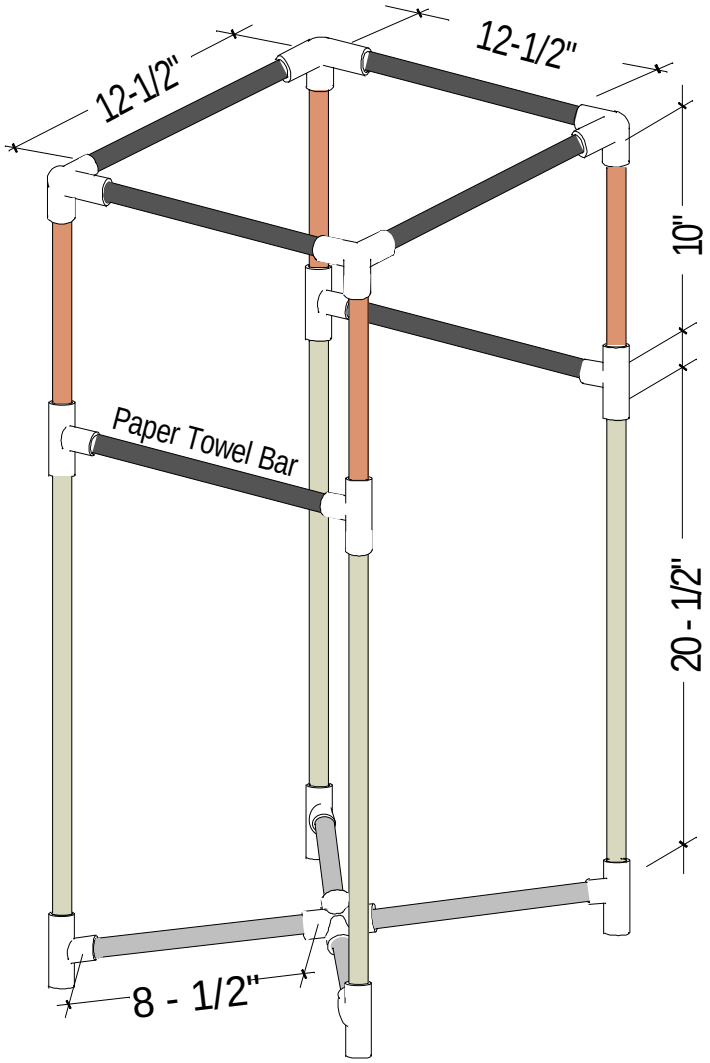

Materials List

*** See pages 10 and 11 for Design Notes**

- (4) 8 - 1/2" Cut PVC
- (6) 12 - 1/2" Cut PVC
- (4) 10" Cut PVC
- (4) 20 - 1/2" Cut PVC
- (4) Slip Side Outlet 90 Degree El
- (8) 90 Degree T - Socket
- (1) Cross Socket

All PVC is 3/4" Schedule 40

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Flag Pole

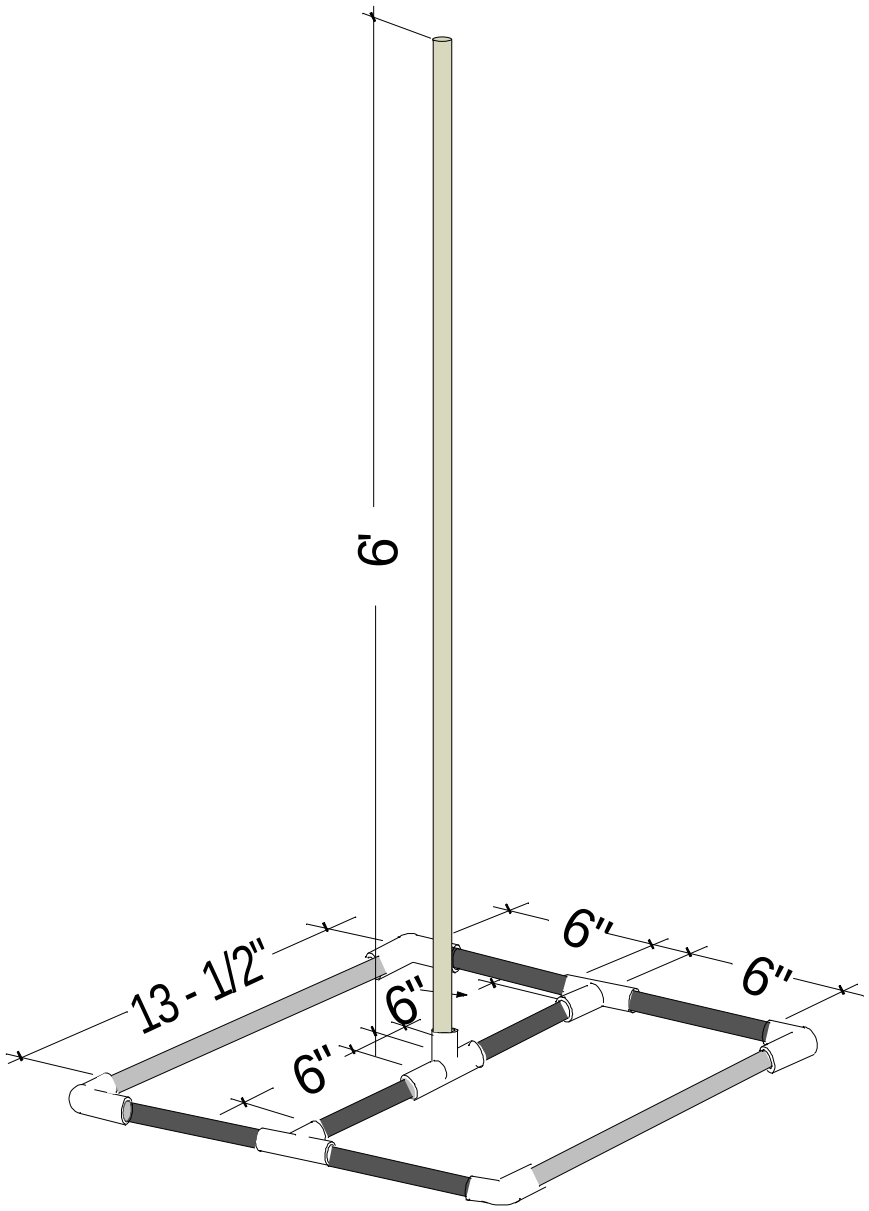

Materials List *See pages 10 and 11 for Design Notes*

- (2) 13 - 1/2" Cut PVC
- (6) 6" Cut PVC
- (1) 6' Cut PVC
- (4) 90 Degree El - Socket
- (3) 90 Degree T - Socket

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Trash Stand

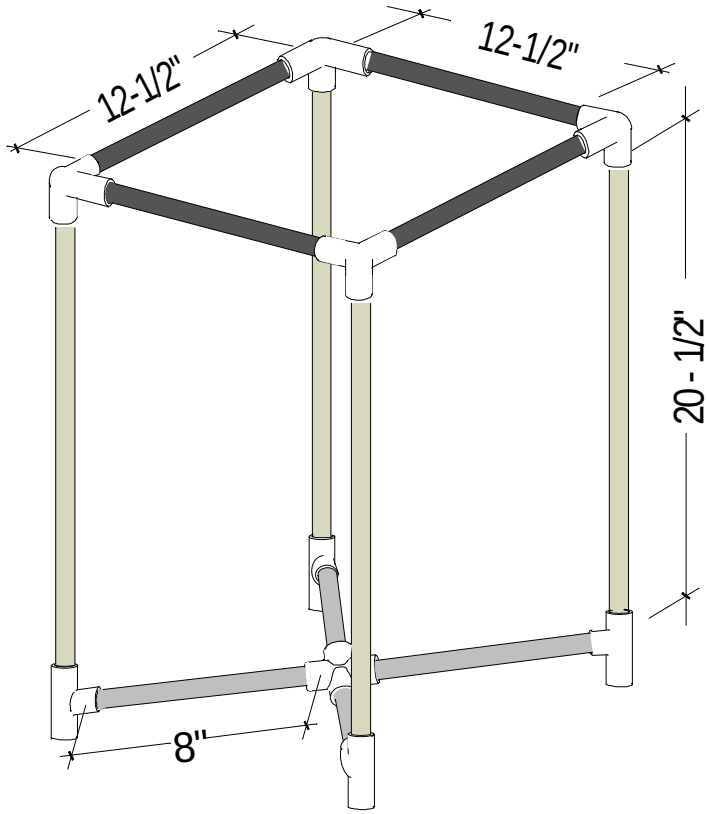

Materials List

*** See pages 10 and 11 for Design Notes***

- (4) 8" Cut PVC
- (4) 12 - 1/2" Cut PVC
- (4) 20 - 1/2" Cut PVC
- (4) Slip Side Outlet 90 Degree El
- (4) 90 Degree T - Socket
- (1) Cross Socket

All PVC is 3/4" Schedule 40

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Table Top

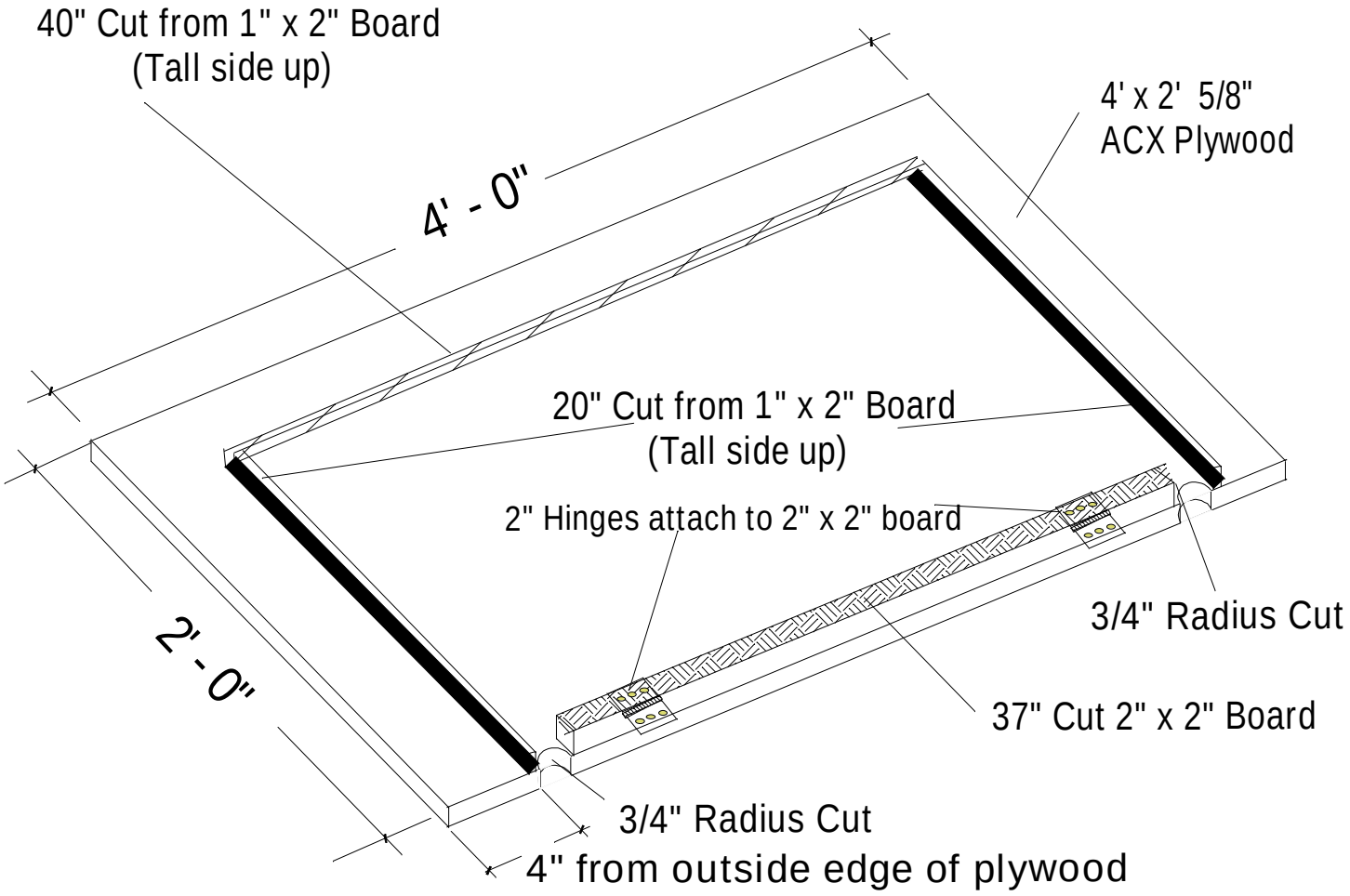

Note: Above figure is the bottom view of 1 of 2 sides of table top.
The 2 sides are attached with (2) 2" hinges when top is folded.
All edges of ACX Plywood should be beveled and sanded.

When folded, two sides will make a box which can store table pieces.
A hook & eye can be used to secure two side closed.

Materials List

*** See pages 10 and 11 for Design Notes***

- (2) 4' x 2' 5/8" ACX Plywood
- (4) 20" Cut 1" x 2" Board
- (2) 40" Cut 1" x 2" Board
- (2) 37" Cut 2" x 2" Board
- (24) 1-1/2" Wood Screws

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What happens when PX returns after 8 years?

(12/25/2016)

Zeta Clues:

http://www.zetatalk.com/science/s29.htm

On the 12th Planet's return voyage, during this passage, the Earth will be protected by the Sun from a full impact, but mild earthquakes and heavy tides will recur at that time. Having passed by the Sun, the 12th Planet now slows. The rate of slowing is dependent on two factors, essentially - its speed and the fact that both its gravitational masters are now behind it. As fast as the 12th Planet picked up speed approaching your Sun, it slows even faster, the nearness of your Sun behind it no small factor in this. Nevertheless, for a traveling planet the size of the 12th Planet, putting on the brakes and turning about is no small matter. It must first come to a stop, which it does in approximately 2 years 3 months after passing your Sun. The 12th Planet's orbit takes it well away from the Sun after passage, so that it moves out a distance equal to 1/4 of the distance between the Sun and its other foci before it slows to a stop. After passing through the Solar System, the 12th Planet moves out on the opposite side some 3.560 times the distance from your Sun to its farthest planet, Pluto, then stops. It then hovers, not moving, essentially, for 3 years 6 months, and then slowly begins a return trip which telescopes or mirrors the voyage out.

http://www.zetatalk.com/science/s124.htm

Strong effects of Planet X are felt for some decades prior to the passage, reaching an extreme point at passage, and remain troubling during the turnaround and return, and then diminish. The Jewish Exodus described a 7 year period of weather and crop problems, and this is now. *Then the passage. Then there is a 7 year turnaround and return. Then another 7 years as the planet is outbound. In all of this, humans have a rough estimate of the attraction force of gravity, but don't deal with speed.*

http://www.zetatalk.com/theword/tword26x.htm

The 12th planet fans out and away from the Sun, then turns clockwise. Forward momentum away from the Sun slowly comes to a halt, as gravity from the Sun alters momentum and shifts the direction of the 12th planet to lateral movement across space. ----. Yielding an orbital path that takes on the shape similar to a slightly flattened ice cream cone. As the 12th planet finishes its orbital path around the backside of the Sun, it arrives once again in the inner solar system. Occurring some 8 years later, after the 12th planet has had its previous close encounter with the earth. Though the effects earth experiences in comparison to the earlier passage are minimal, conditions the Earth faces are different this time, due to several reasons. The turmoil and magnetic interference in the core of the Earth caused by the 12th planet are always present, as the wanderer moves around the backside of the Sun.

---------- Analysis ----------

2 year 3 months to stop
3 year 6 months stopped

2.25	Out
3.5	Stopped
2.25	Back
8	Total

This result is constant with the 8 years Zeta statements in red. We don't use the 7 years as recorded by the ancients.

The side view at the time of the return:

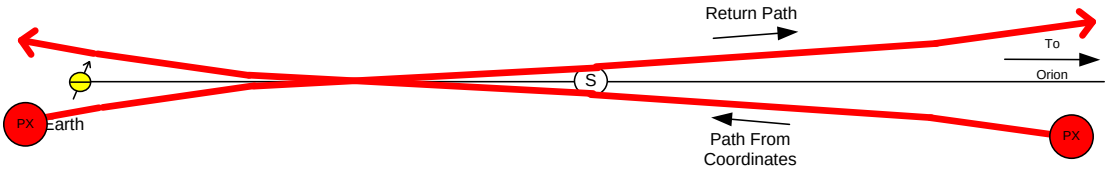

Figure 1: Side View parallel to Planet X path

The top view at the time of the return:

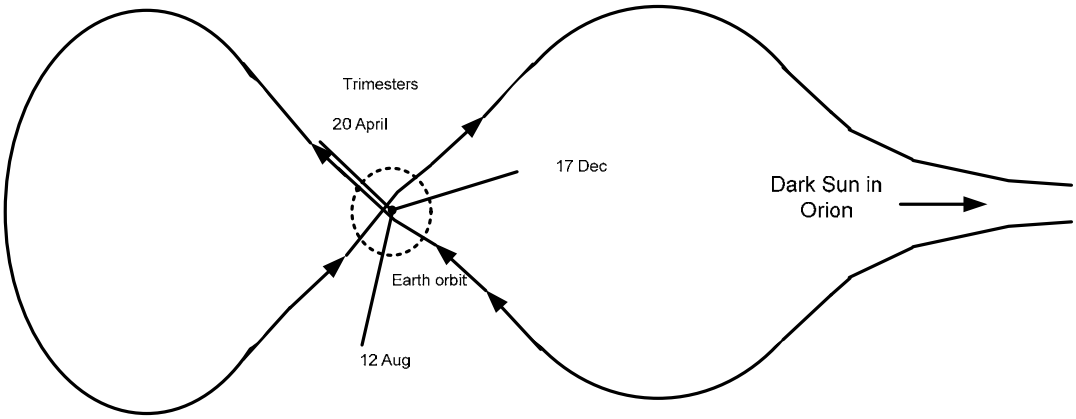

Figure 2: Top View of Planet X path looking South

The left side of figure 2 shows the Zeta's statement about the orbit looking like a squished ice cream cone.

Zeta's PX path:

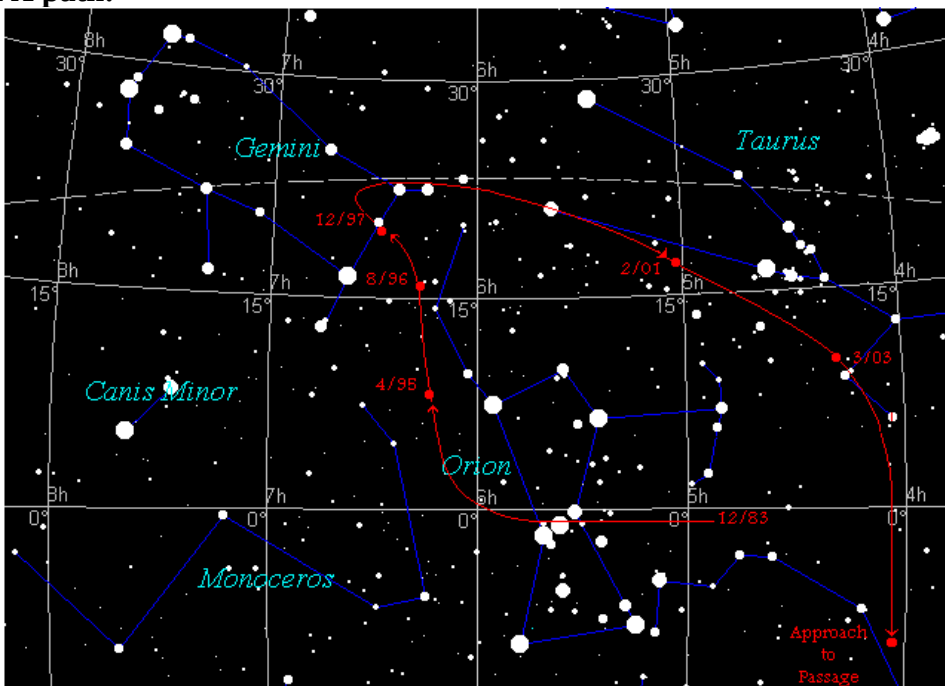

Note the approach to passage is approximately 4.1 hr angle.

Based on the Zeta clues the diagram of the return path is a mirror of the 2017 Pole Shift path. This is mirrored around the approach angle of 4.1 hr angle. The following is the diagram of this.

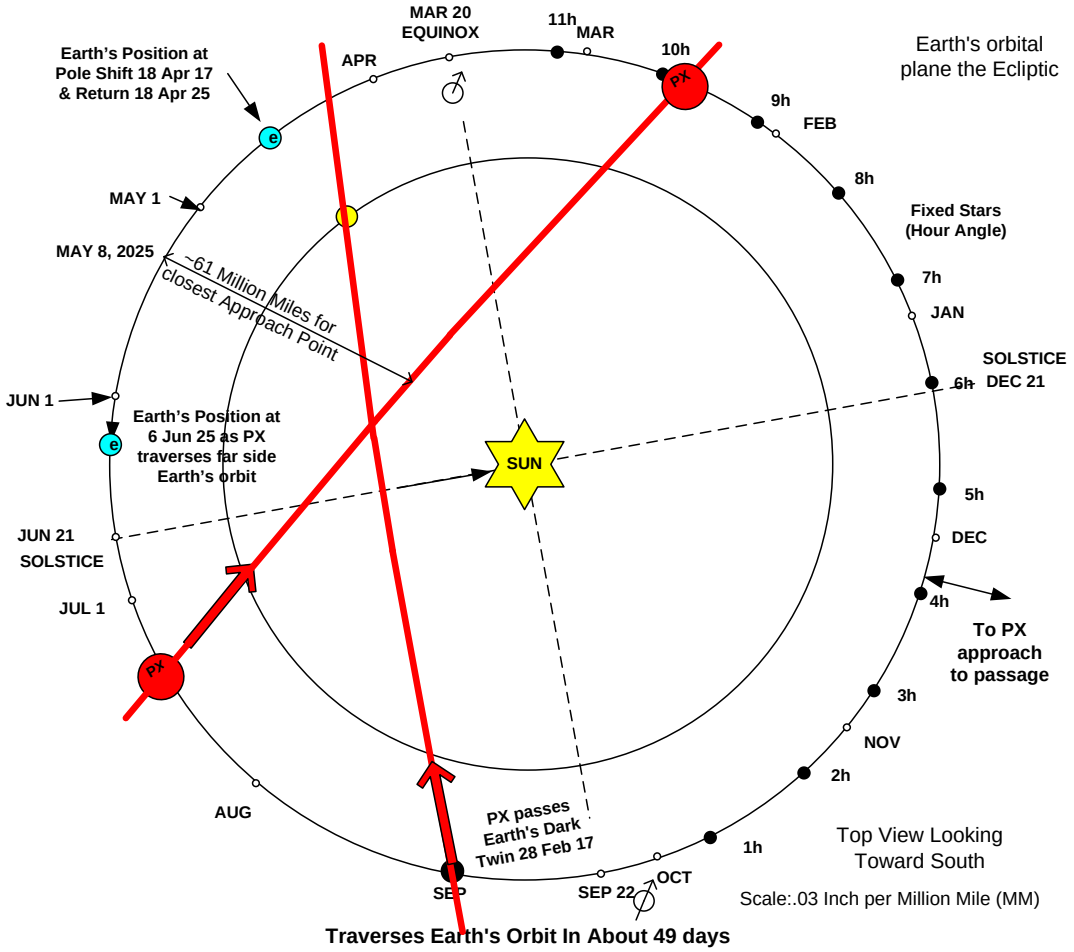

Figure 4: PX Return Path In 2025

The closest approach to of PX to Earth for the return path is about 61 million miles. This is 4.3 times more distant than the original Pole Shift distance of 14 million miles. Since strength of magnetic and gravitational effects decrease with the square of distance then the effects of gravity and magnetic influence for closest approach of 8 May 2025 plus or minus a week or so should be approximately 19 times less than during the pole shift time of 18 April 2017. This assumes it returns 8 years to the day from when it left.

Pyrethrin

From Wikipedia, the free encyclopedia

The **pyrethrins** are a class of organic compounds normally derived from *Chrysanthemum cinerariifolium* that have potent insecticidal activity by targeting the nervous systems of insects. Pyrethrin is synthetically made by industrial methods, but it also naturally occurs in chrysanthemum flowers, thus is often considered an organic insecticide, or at least when is not combined with piperonyl butoxide or other synthetic adjuvants.[1] Their insecticidal and insect-repellent properties have been known and used for thousands of years.

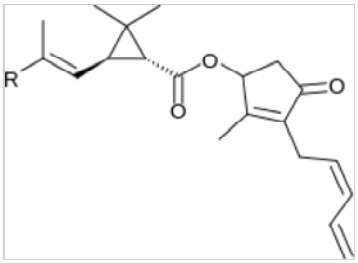

Chemical Structure of Pyrethrin, Pyrethrin I R = CH_3, Pyrethrin II R = CO_2CH_3

Pyrethrins are gradually replacing organophosphates and organochlorides as the pesticides of choice, since these other compounds have been shown to have significant and persistent toxic effects to humans. Because they are biodegradable compounds, pyrethrins are now widely regarded as being preferable to pyrethroids, which is the name of a group of synthetic analogues of pyrethrin that accumulate in the environment. Pyrethrins are considered to be low-toxicity pesticides from a human health standpoint.

Contents

- 1 Chemistry
- 2 History
- 3 Biosynthesis
- 4 Production
- 5 Use as an insecticide
- 6 Toxicity
  - 6.1 Chronic pyrethrin toxicity in humans
  - 6.2 Pyrethrum toxicity
- 7 Environmental effects
  - 7.1 Aquatic habitats
  - 7.2 Bees
- 8 References
- 9 External links

Chemistry

Table 1. Physical and Chemical Properties of Pyrethrin.[2][3][4][5][6][7]

Group	Pyrethrin I			Pyrethrin II		
Chemical Compound	Pyrethrin I	Cinerin I	Jasmolin I	Pyrethrin II	Cinerin II	Jasmolin II
Chemical structure	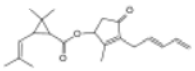	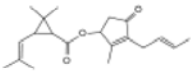	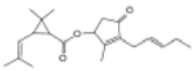	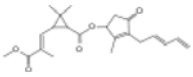	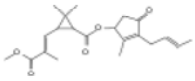	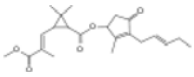
Chemical formula	$C_{21}H_{28}O_3$	$C_{20}H_{28}O_3$	$C_{21}H_{30}O_3$	$C_{22}H_{28}O_5$	$C_{21}H_{28}O_5$	$C_{22}H_{30}O_5$
Molecular mass (g/mol)	328.4	316.4	330.4	372.4	360.4	374.4
Boiling point (°C)	170	136-138	-	200	182-184	-
Vapor pressure (mm Hg)	2.02×10^{-5}	1.1×10^{-6}	4.8×10^{-7}	3.9×10^{-7}	4.6×10^{-7}	1.9×10^{-7}
Solubility in water (mg/L)	0.35	3.62	0.60	125.6	1038	214.8

History

The pyrethrins occur in the seed cases of the perennial plant pyrethrum (*Chrysanthemum cinerariaefolium*), which has long been grown commercially to supply the insecticide. Pyrethrins have been used as an insecticide for thousands of years. It is believed that the Chinese crushed chrysanthemum plants and used the powder as an insecticide as early as 1000 BC. It was widely known that the Chou Dynasty in China widely used pyrethrin for its insecticide properties.[8] Pyrethrins were identified as the potent chemical in the Chrysanthemum plants responsible for the insecticidal properties in the crushed flowers around 1800 in Asia. In the Napoleonic Wars, French soldiers used the flowers to keep away fleas and body lice.[8]

Biosynthesis

Cyclopropanation reaction producing chrysanthemic acid

Well after their use as insecticides began, their chemical structures were determined by Hermann Staudinger and Lavoslav Ružička in 1924.[9] Pyrethrin I ($C_nH_{28}O_3$) and pyrethrin II ($C_nH_{28}O_5$) are structurally related esters with a cyclopropane core. Pyrethrin I is a derivative of (+)-*trans*-chrysanthemic acid.[10][11] Pyrethrin II is closely related, but one methyl group is oxidized to a carboxymethyl group, the resulting core being called pyrethric acid. Knowledge of their structures opened the way for the production of synthetic analogues, which are called pyrethroids. Pyrethrins are classified as terpenoids. The key step in the biosynthesis of the naturally occurring pyrethrins involves two molecules of dimethylallyl pyrophosphate, which join to form a cyclopropane rings by the action of the enzyme chrysanthemyl diphosphate synthase.[12]

Production

Commercial pyrethrin production mainly takes place in mountainous equatorial zones. The commercial cultivation of the Dalmatian chrysanthemum takes place at an altitude of 3000 to 6000 meters above sea level.[13] This is done because pyrethrin concentration has been shown to increase as elevation increases to this level. Growing these plants does not require much water because semiarid

conditions and a cool winter deliver optimal pyrethrin production. Another variety of *Chrysanthemum* used for the production of pyrethrins is the pyrethrum chrysanthemum. These flowers prefer to be grown in dry soils at a lower altitude than the Dalmatian chrysanthemum to optimize pyrethrin production.[14]

Tanacetum cinerariifolium

Most of the world's supply of pyrethrin and *C. cinerariaefolium* comes from Kenya, which produces the most potent flowers. Other countries include Croatia (in Dalmatia) and Japan. The flower was first introduced into Kenya and the highlands of Eastern Africa during the late 1920s. Since the 2000s, Kenya has produced about 70% of the world's supply of pyrethrum.[15] A substantial amount of the flowers is cultivated by small-scale farmers who depend on it as a source of income. It is a major source of export income for Kenya and source of over 3,500 additional jobs. About 23,000 tons were harvested in 1975. The active ingredients are extracted with organic solvents to give a concentrate containing the six types of pyrethrins: pyrethrin I, pyrethrin II, cinerin I, cinerin II, jasmolin I, and jasmolin II.[16]

Processing the flowers to cultivate the pyrethrin is often a lengthy process, and one that varies from area to area. For instance, in Japan, the flowers are hung upside down to dry which increases pyrethrin concentration slightly.[14] To process pyrethrin, the flowers must be crushed. The degree to which the flower is crushed has an effect on both the longevity of the pyrethrin usage and the quality. The finer powder produced is better suited for use as an insecticide than the more coarsely crushed flowers. However, the more coarsely crushed flowers have a longer shelf life and deteriorate less.[14]

Use as an insecticide

Pyrethrin is most commonly used as an insecticide and has been used for this purpose since the 1900s.[16] In the 1800s, it was known as "Persian powder", "Persian pellitory", and "zacherlin". Pyrethrins delay the closure of voltage-gated sodium ion channels in the nerve cells of insects, resulting in repeated and extended nerve firings. This hyperexcitation causes the death of the insect due to loss of motor coordination and paralysis.[17] Resistance to pyrethrin has been bypassed by pairing the insecticide with synthetic synergists such as piperonyl butoxide. Together, these two compounds prevent detoxification in the insect, ensuring insect death.[18] Synergists make pyrethrin more effective, allowing lower doses to be effective. Pyrethrins are effective insecticides because they selectively target insects rather than mammals due to higher insect nerve sensitivity, smaller insect body size, lower mammalian skin absorption, and more efficient mammalian hepatic metabolism.[19]

Although pyrethrin is a potent insecticide, it also functions as an insect repellent at lower concentrations. Observations in food establishments demonstrate that flies are not immediately killed, but are found more often on windowsills or near doorways. This suggests, due to the low dosage applied, that insects are driven to leave the area before dying.[20] Because of their insecticide and insect repellent effect, pyrethrins have been very successful in reducing insect pest populations that affect humans, crops, livestock, and pets, such as ants, spiders, and lice, as well as potentially disease-carrying mosquitoes, fleas, and ticks.

As pyrethrins and pyrethroids are increasingly being used as insecticides, the number of illnesses and injuries associated with exposure to these chemicals is also increasing.[21] However, few cases leading to serious health effects or mortality in humans have occurred, which is why pyrethroids are labeled “low-toxicity” chemicals and are ubiquitous in home-care products.[19] Pyrethrins are widely regarded as better for the environment, and can be harmless if used only in the field with localized sprays, as UV exposure breaks them down into harmless compounds. Additionally, they have little lasting effect on plants, degrading naturally or being degraded by the cooking process.[22]

Specific pest species that have been successfully controlled by pyrethrum include: potato, beet, grape, and six-spotted leafhopper, cabbage looper, celery leaf tier, Say’s stink bug, twelve-spotted cucumber beetle, lygus bugs on peaches, grape and flower thrips, and cranberry fruitworm.[23]

Toxicity

Pyrethrins are among the safest insecticides in the market due to their rapid degradation in the environment.

Similarities between the chemistry of pyrethrins and synthetic pyrethroids is that have a similar mode of action and almost identical toxicity to insects (i.e. both pyrethrins and pyrethroids induce a toxic effect within the insect by acting on sodium channels)

Some differences in the chemistry between pyrethrins and synthetic pyrethroids have the result that synthetic pyrethroids have relatively longer environmental persistence than do pyrethrins. Pyrethrins have shorter environmental persistence than synthetic pyrethroids because their chemical structure is more susceptible to the presence of UV light and changes in pH.

It should be noted that they pose a toxic hazard normally not found in commercial pyrethroid to mammals and humans. While pyrethrum extract is composed of 6 esters which are insecticidal, the semi-synthetic pyrethroid is a composed of only one chemically active compound. As a result, the liver has to break down these additional chains first, which allows the toxicity levels to rise within the bloodstream. which can lead to hospitalization and even death.

Therefore the use of pyrethrin in products such as natural insecticides and shampoos increases the likelihood of toxicity in mammals that are exposed. Medical cases have emerged showing fatalities from the use of pyrithrin, prompting many organic farmers to cease use. One medical case of an 11-year-old girl who used shampoo containing only a small amount (0.2% pyrethrin) to wash her dog. Prolonged exposure aggravated her respiratory tract cause by the compound in the shampoo, causing the girl to suffer from an acute asthma attack, from which she died two-and-a-half hours after first exposure to the shampoo.[24]

Recent reports show that accidental poisoning rates have steadily been increasing since the use of natural pyrethrins, prompting some countries to ban their use altogether. In the USA, the use of pyrethrum in home bug sprays (ie. RAID) was banned in 2012 shortly after cases of fatalities in children emerged, prompting an investigation by the FDA. [25]

Chronic pyrethrin toxicity in humans

Chronic toxicity in humans occurs most quickly through respiration into the lungs, or more slowly through absorption through the skin.[26] Allergic reactions may occur after exposure, leading to itching and irritated skin as well as burning sensations.[27] These types of reactions are rare because the allergenic component of pyrethrin in semi-synthetic phritoids has been removed. [28] The metabolite compounds of pyrethrin are less toxic to mammals than their originators, and compounds are either broken down in the liver or gastrointestinal tract, or excreted through feces; no evidence of storage in tissues has been found.

Pyrethrum toxicity

Exposure to pyrethrum, the crude form of pyrethrin,[28] causes harmful health effects for mammals. Pyrethrum also has an allergenic effect that commercial pyrethroids don't have.[28] In mammals, toxic exposure to pyrethrum can lead to tongue and lip numbness, drooling, lethargy, muscle tremors, respiratory failure, vomiting, diarrhea, seizures, paralysis, and death.[26] Unlike dogs, cats lack a liver enzyme that allows for glucuronidation that allows for metabolism of pyrethrin compounds. Exposure to even low doses may lead to toxicity in some cats.[29] Exposure to pyrethrum in high levels in humans may cause symptoms such as asthmatic breathing, sneezing, nasal stuffiness, headache, nausea, loss of coordination, tremors, convulsions, facial flushing, and swelling.[30] A possibility of damage to the immune system exists that leads to a worsening of allergies following toxicity.[26] Infants are unable to resourcefully break down pyrethrum due to the ease of skin penetration, causing similar symptoms as adults, but with an increased risk of death.[31]

Environmental effects

Aquatic habitats

In aquatic settings, toxicity of pyrethrin fluctuates, increasing with rising temperatures, water, and acidity. Run-off after application has become a concern for sediment-dwelling aquatic organisms because pyrethroids can accumulate in these areas.[32] Aquatic life is extremely susceptible to pyrethrin toxicity, and has been documented in species such as the lake trout. Although pyrethrins are quickly metabolized by birds and most mammals, fish and aquatic invertebrates lack the ability to metabolize these compounds, leading to a toxic accumulation of byproducts.[26] To combat the accumulation of pyrethroids in bodies of water, the Environmental Protection Agency (EPA) has introduced two labeling initiatives. The Environmental Hazard and General Labeling for Pyrethroid and Synergized Pyrethrins Non-Agricultural Outdoor Products was revised in 2013 to reduce runoff into bodies of water after use in residential, commercial, institutional, and industrial areas.[33] The Pyrethroid Spray Drift Initiative updated language for labeling all pyrethroid products to be used on agricultural crops.[33] Because of its high toxicity to fish and aquatic invertebrates even at low doses, the EPA recommends alternatives such as pesticide-free methods or alternative chemicals that are less harmful to the surrounding aquatic environment.[34]

Bees

Pyrethrins are applied broadly as nonspecific insecticides. Bees have been shown to be particularly sensitive to pyrethrin, with fatal doses as small as 0.02 micrograms.[1] Due to this sensitivity and pollinator decline, pyrethrins are recommended to be applied at night to avoid typical pollinating hours, and in liquid rather than dust form.[35]

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External links

- International Center for Pyrethrum research (https://web.archive.org/web/20100526030749/http://pyrethrum.org/index.php?p=1_5_Pyrethrum)
- Pyrethrins and Pyrethroids Fact Sheet - National Pesticide Information Center (http://npic.orst.edu/factsheets/pyrethrins.pdf)
- Pyrethrins and pyrethroids on the EXTOXNET (http://extoxnet.orst.edu/pips/pyrethri.htm)
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Categories: Pyrethroids | Plant toxin insecticides | Biological pest control | Pest control | Insecticides

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Pyroclastic rock

From Wikipedia, the free encyclopedia

Pyroclastic rocks or **pyroclastics** (derived from the Greek: πῦρ, meaning fire; and *κλαστός*, meaning broken) are clastic rocks composed solely or primarily of volcanic materials. Where the volcanic material has been transported and reworked through mechanical action, such as by wind or water, these rocks are termed ***volcaniclastic***. Commonly associated with unsieved volcanic activity—such as Plinian or krakatoan eruption styles, or phreatomagmatic eruptions—pyroclastic deposits are commonly formed from airborne ash, lapilli and bombs or blocks ejected from the volcano itself, mixed in with shattered country rock.

USGS scientist examines pumice blocks at the edge of a pyroclastic flow from Mount St. Helens

Pyroclastic rocks may be a range of clast sizes, from the largest agglomerates, to very fine ashes and tuffs. Pyroclasts of different sizes are classified as volcanic bombs, lapilli, and volcanic ash. Ash is considered to be pyroclastic because it is a fine dust made up of volcanic rock. One of the most spectacular forms of pyroclastic deposit are the ignimbrites, deposits formed by the high-temperature gas-and-ash mix of a pyroclastic flow event.

Rocks from the Bishop Tuff, uncompressed with pumice on left; compressed with fiamme on right.

Classification

Clast size	Pyroclast	Mainly unconsolidated: Tephra	Mainly consolidated: Pyroclastic rock
> 64 mm	Block, bomb	Agglomerate	Agglomerate, pyroclastic breccia
< 64 mm	Lapillus	Layer, lapilli tephra	Lapilli tuff, lapillistone
< 2 mm	Coarse ash	Coarse ash	Coarse (ash) tuff
< 0.063 mm	Fine ash	Fine ash	Fine (ash) tuff

[1]

Three modes of transport can be distinguished: pyroclastic flow, pyroclastic surge, and pyroclastic fall. During Plinian eruptions, pumice and ash are formed when silicic magma is fragmented in the volcanic conduit,

because of decompression and the growth of bubbles. Pyroclasts are then entrained in a buoyant eruption plume which can rise several kilometers into the air and cause aviation hazards. Particles falling from the eruption clouds form layers on the ground (this is pyroclastic fall or tephra). Pyroclastic density currents, which are referred to as "flows" or "surges" depending on particle concentration and the level turbulence, are sometimes called *glowing avalanches*. The deposits of pumice-rich pyroclastic flows can be called ignimbrites.

A pyroclastic eruption entails spitting or "fountaining" lava, where the lava will be thrown into the air along with ash, pyroclastic materials, and other volcanic byproducts. Hawaiian eruptions such as those at Kīlauea can eject clots of magma suspended into gas; this is called a "fire fountain". The magma clots, if hot enough may coalesce upon landing to form a lava flow.

Pyroclastic deposits consist of pyroclasts which are not cemented together. Pyroclastic rocks (tuff) are pyroclastic deposits which have been lithified.

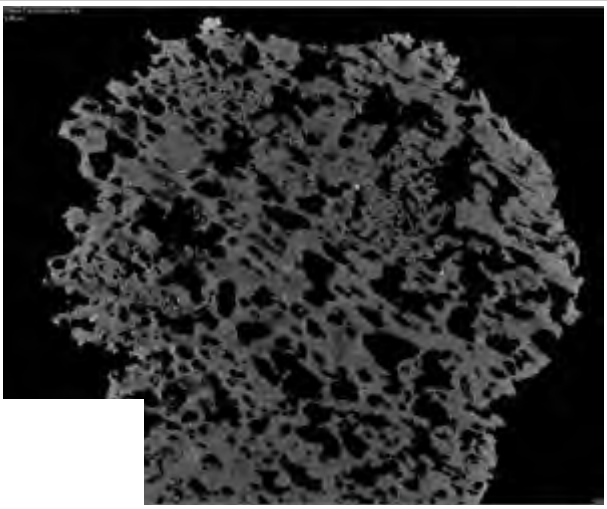

Flight through a µCT-image stack of a Lapilli of the volcano Katla in Iceland. Find spot: Beach near Vik at the end of road 215. Acquisition done using "CT Alpha" by "Procon X-Ray GmbH", Garbsen, Germany. Resolution 11,2µm/Voxel, width approx. 24 mm.

3D-Rendering of the above image stack, in parts transparent. Heavy particles in red.

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Pyrolysis

From Wikipedia, the free encyclopedia

Pyrolysis is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen (or any halogen). It involves the simultaneous change of chemical composition and physical phase, and is irreversible. The word is coined from the Greek-derived elements *pyro* "fire" and *lysis* "separating".

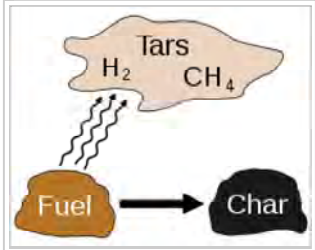

Simplified depiction of pyrolysis chemistry.

Pyrolysis is a type of thermolysis, and is most commonly observed in organic materials exposed to high temperatures. It is one of the processes involved in charring wood, starting at 200–300 °C (390–570 °F).[1] It also occurs in fires where solid fuels are burning or when vegetation comes into contact with lava in volcanic eruptions. In general, pyrolysis of organic substances produces gas and liquid products and leaves a solid residue richer in carbon content, char. Extreme pyrolysis, which leaves mostly carbon as the residue, is called carbonization.

The process is used heavily in the chemical industry, for example, to produce charcoal, activated carbon, methanol, and other chemicals from wood, to convert ethylene dichloride into vinyl chloride to make PVC, to produce coke from coal, to convert biomass into syngas and biochar, to turn waste plastics back into usable oil,[2] or waste into safely disposable substances, and for transforming medium-weight hydrocarbons from oil into lighter ones like gasoline. These specialized uses of pyrolysis may be called various names, such as dry distillation, destructive distillation, or cracking. Pyrolysis is also used in the creation of nanoparticles,[3] zirconia[4] and oxides[5] utilizing an ultrasonic nozzle in a process called ultrasonic spray pyrolysis (USP).

Pyrolysis also plays an important role in several cooking procedures, such as baking, frying, grilling, and caramelizing. It is a tool of chemical analysis, for example, in mass spectrometry and in carbon-14 dating. Indeed, many important chemical substances, such as phosphorus and sulfuric acid, were first obtained by this process. Pyrolysis has been assumed to take place during catagenesis, the conversion of buried organic matter to fossil fuels. It is also the basis of pyrography. In their embalming process, the ancient Egyptians used a mixture of substances, including methanol, which they obtained from the pyrolysis of wood.

Pyrolysis differs from other processes like combustion and hydrolysis in that it usually does not involve reactions with oxygen, water, or any other reagents.[6] In practice, it is not possible to achieve a completely oxygen-free atmosphere. Because some oxygen is present in any pyrolysis system, a small amount of oxidation occurs.

The term has also been applied to the decomposition of organic material in the presence of superheated water or steam (hydrous pyrolysis), for example, in the steam cracking of oil.

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Occurrence and uses

Fire

Pyrolysis is usually the first chemical reaction that occurs in the burning of many solid organic fuels, like wood, cloth, and paper, and also of some kinds of plastic. In a wood fire, the visible flames are not due to combustion of the wood itself, but rather of the gases released by its pyrolysis, whereas the flame-less burning of a solid, called smouldering, is the combustion of the solid residue (char or charcoal) left behind by pyrolysis. Thus, the pyrolysis of common materials like wood, plastic, and clothing is extremely important for fire safety and firefighting. In pyrolysis there is a gas phase present. It should not be confused with hydrothermal reactions such as hydrothermal gasification, hydrothermal liquidation, and hydrothermal carbonization, which occur in aqueous environments because the temperatures and reaction pathways differ, with ionic reactions favored in aqueous reactions and radical reactions favored in the absence of water.

Cooking

Pyrolysis occurs whenever food is exposed to high enough temperatures in a dry environment, such as roasting, baking, toasting, or grilling. It is the chemical process responsible for the formation of the golden-brown crust in foods prepared by those methods.

In normal cooking, the main food components that undergo pyrolysis are carbohydrates (including sugars, starch, and fibre) and proteins. (See: Maillard reaction.) Pyrolysis of fats requires a much higher temperature, and, since it produces toxic and flammable products (such as acrolein), it is, in general, avoided in normal cooking. It may occur, however, when grilling fatty meats over hot coals.

Even though cooking is normally carried out in air, the temperatures and environmental conditions are such that there is little or no combustion of the original substances or their decomposition products. In particular, the pyrolysis of proteins and carbohydrates begins at temperatures much lower than the ignition temperature of the solid residue, and the volatile subproducts are too diluted in air to ignite. (In flambé dishes, the flame is due mostly to combustion of the alcohol, while the crust is formed by pyrolysis as in baking.)

Pyrolysis of carbohydrates and proteins requires temperatures substantially higher than 100 °C (212 °F), so pyrolysis does not occur as long as free water is present, e.g., in boiling food — not even in a pressure cooker. When heated in the presence of water, carbohydrates and proteins suffer gradual hydrolysis rather than pyrolysis. Indeed, for most foods, pyrolysis is usually confined to the outer layers of food, and begins only after those layers have dried out.

Food pyrolysis temperatures are, however, lower than the boiling point of lipids, so pyrolysis occurs when frying in vegetable oil or suet, or basting meat in its own fat.

Pyrolysis also plays an essential role in the production of barley tea, coffee, and roasted nuts such as peanuts and almonds. As these consist mostly of dry materials, the process of pyrolysis is not limited to the outermost layers but extends throughout the materials. In all these cases, pyrolysis creates or releases many of the substances that contribute to the flavor, color, and biological properties of the final product. It may also destroy some substances that are toxic, unpleasant in taste, or those that may contribute to spoilage.

Controlled pyrolysis of sugars starting at 170 °C (338 °F) produces caramel, a beige to brown water-soluble product widely used in confectionery and (in the form of caramel coloring) as a coloring agent for soft drinks and other industrialized food products.

Solid residue from the pyrolysis of spilled and splattered food creates the brown-black encrustation often seen on cooking vessels, stove tops, and the interior surfaces of ovens.

Charcoal

People have used pyrolysis for turning wood into charcoal on an industrial scale since ancient times. Besides wood, the process can also use sawdust and other wood-waste products.

Charcoal is obtained by heating wood until its complete pyrolysis (carbonization) occurs, leaving only carbon and inorganic ash. In many parts of the world charcoal is still produced semi-industrially by burning a pile of wood that has been mostly covered with mud or with bricks. The heat generated by burning part of the wood and the volatile byproducts pyrolyzes the rest of the pile. The limited supply of oxygen prevents the charcoal from burning. A more modern alternative is to heat the wood in an airtight metal vessel, which is much less polluting and allows the volatile products to be condensed.

The original vascular structure of the wood and the pores created by escaping gases combine to produce a light and porous material. By starting with a dense wood-like material, such as nutshells or peach stones, one obtains a form of charcoal with particularly fine pores (and hence a much larger pore surface area), called activated carbon, which is used as an adsorbent for a wide range of chemical substances.

Biochar

Residues of incomplete organic pyrolysis, e.g., from cooking fires, are thought to be the key component of the terra preta soils associated with ancient indigenous communities of the Amazon basin.[7] Terra preta is much sought by local farmers for its superior fertility compared to the natural red soil of the region. Efforts are underway to recreate these soils through biochar, the solid residue of pyrolysis of various materials, mostly organic waste.

Biochar improves the soil texture and ecology, increasing its ability to retain fertilizers and release them slowly. It naturally contains many of the micronutrients needed by plants, such as selenium. It is also safer than other "natural" fertilizers such as animal manure, since it has been disinfected at high temperature. And, since it releases its nutrients at a slow rate, it greatly reduces the risk of water table contamination.[8]

Biochar is also being considered for carbon sequestration, with the aim of mitigation of global warming.[9][10][11] The solid, carbon-containing char produced can be sequestered in the ground, where it will remain for several hundred to a few thousand years.[12]

Coke

Pyrolysis is used on a massive scale to turn coal into coke for metallurgy, especially steelmaking. Coke can also be produced from the solid residue left from petroleum refining.

Those starting materials typically contain hydrogen, nitrogen, or oxygen atoms combined with carbon into molecules of medium to high molecular weight. The coke-making or "coking" process consists of heating the material in closed vessels to very high temperatures (up to 2,000 °C or 3,600 °F) so that those molecules are broken down into lighter volatile substances, which leave the vessel, and a porous but hard residue that is mostly carbon and inorganic ash. The amount of volatiles varies with the source material, but is typically 25–30% of it by weight.

Carbon fiber

Carbon fibers are filaments of carbon that can be used to make very strong yarns and textiles. Carbon fiber items are often produced by spinning and weaving the desired item from fibers of a suitable polymer, and then pyrolyzing the material at a high temperature (from 1,500–3,000 °C or 2,730–5,430 °F).

The first carbon fibers were made from rayon, but polyacrylonitrile has become the most common starting material.

For their first workable electric lamps, Joseph Wilson Swan and Thomas Edison used carbon filaments made by pyrolysis of cotton yarns and bamboo splinters, respectively.

Pyrolytic carbon

Pyrolysis is the reaction used to coat a preformed substrate with a layer of pyrolytic carbon. This is typically done in a fluidized bed reactor heated to 1,000–2,000 °C or 1,830–3,630 °F. Pyrolytic carbon coatings are used in many applications, including artificial heart valves.[13]

Biofuel

Pyrolysis is the basis of several methods that are being developed for producing fuel from biomass, which may include either crops grown for the purpose or biological waste products from other industries.[14] Crops studied as biomass feedstock for pyrolysis include native North American prairie grasses such as *switchgrass* and bred versions of other grasses such as *Miscantheus giganteus*. Crops and plant material wastes provide biomass feedstock on the basis of their lignocellulose portions.

Although synthetic diesel fuel cannot yet be produced directly by pyrolysis of organic materials, there is a way to produce similar liquid (bio-oil) that can be used as a fuel, after the removal of valuable bio-chemicals that can be used as food additives or pharmaceuticals.[15] Higher efficiency is achieved by **flash pyrolysis**, in which finely divided feedstock is quickly heated to between 350 and 500 °C (660 and 930 °F) for less than 2 seconds.

Fuel bio-oil can also be produced by hydrous pyrolysis from many kinds of feedstock, including waste from pig and turkey farming, by a process called thermal depolymerization (which may, however, include other reactions besides pyrolysis).

Adhesives

Neanderthals used pyrolysis of birch bark to produce a pitch with which they secured flaked stones to spear shafts.[16] Recently, researchers have developed a process to pyrolyze birch bark to produce an oil that can replace phenol in phenol formaldehyde resin (these resins are mostly used to manufacture plywood).[17]

Pesticides

Pyrolysis can also be used to produce pesticides from biomass.[18]

Plastic waste disposal

Anhydrous pyrolysis can also be used to produce liquid fuel similar to diesel from plastic waste, with a higher cetane value and lower sulphur content than traditional diesel.[19] Using pyrolysis to extract fuel from end-of-life plastic is a second-best option after recycling, is environmentally preferable to landfill, and can help reduce dependency on foreign fossil fuels and geo-extraction.[20]

Waste tire disposal

In the United States alone, over 290 million car tires are discarded annually. Pyrolysis of scrap or waste tires (WT) is an attractive alternative to disposal in landfills, allowing the high energy content of the tire to be recovered as fuel. Using tires as fuel produce equal energy as burning oil and 25% more energy than burning coal.[21]

An average car tire is made up of 50–60% hydrocarbons, resulting in a yield of 38–56% oil, 10–30% gas and 14–56% char. The oil produced is largely composed of benzene, diesel, kerosene, fuel oil and heavy fuel oil, while the produced gas has a similar composition to natural gas. The proportion and the purity of the products are governed by two major factors:[22]

1. Environment (e.g. pressure, temperature, time, reactor type)

2. Material (e.g. age, composition, size, type)

As car tires age, they increase in hardness, making it more difficult for pyrolysis to break the molecules into shorter chains. This shifts the yield composition towards diesel oil which is composed of larger molecules. Conversely, an increase in temperature increases the likelihood of breaking the molecule chain and shifts the yield composition towards benzene oil which is composed of smaller molecules.[22] Other products from car tire pyrolysis include steel wires, carbon black and bitumen.[23]

Although the pyrolysis of WT has been widely developed throughout the world, there are legislative, economic, and marketing obstacles to widespread adoption.[24] Oil derived from tire rubber pyrolysis contains high sulfur content, which gives it high potential as a pollutant and should be desulfurized.[25] A number of prototype and full-scale pyrolysis plants specialized in carbon black production have successfully established across the world, including the United States, France, Germany and Japan. Because carbon black is used for pigment, rubber strengthening and UV protection, it is a relatively large and growing market. Pyrolysis plants specialized in fuel oil production is not an implausible concept. However, as profits of such ventures come from the added value between the production and distillation of oil, there is little profit without vertical integration in the oil industry. The inconsistency of the feedstock makes it very difficult to control the uniformity of the products and makes oil companies hesitant to purchase oil produced via pyrolysis. Finally, the cost of producing oil through conventional means is generally less expensive than this alternative. To date, there is no known commercially profitable standalone pyrolysis plant that specializes in oil production.[22] However, with funding to upgrade pyrolysis oil to light fuel grade, this may be possible. Nevertheless, pyrolysis is a valuable method for disposing of waste tires.[26]

Chemical analysis

Pyrolysis can be used for the molecular characterisation of molecules when used in conjunction with gas chromatography-mass spectrometry (Py-GC-MS). This technique has been used to analyse the method and products of fungal decay of wood.[27][28]

Thermal cleaning

Pyrolysis is also used for *thermal cleaning*, an industrial application to remove organic substances such as polymers, plastics and coatings from parts, products or production components like extruder screws, spinnerets[29] and static mixers. During the thermal cleaning process, at temperatures between 600 °F to 1000 °F (310 C° to 540 C°),[30] organic material is converted by pyrolysis and oxidation into volatile organic compounds, hydrocarbons and carbonized gas.[31] Inorganic elements remain.[32]

Several types of thermal cleaning systems use pyrolysis:

- *Molten Salt Baths* belong to the oldest thermal cleaning systems; cleaning with a molten salt bath is very fast but implies the risk of dangerous splatters, or other potential hazards connected with the use of salt baths, like explosions or highly toxic hydrogen cyanide gas.[30]
- *Fluidized Bed Systems*[33] use sand or aluminium oxide as heating medium;[34] these systems also clean very fast but the medium does not melt or boil, nor emit any vapors or odors;[30] the cleaning process takes one to two hours.[31]
- *Vacuum Ovens* use pyrolysis in a vacuum[35] avoiding uncontrolled combustion inside the cleaning chamber;[30] the cleaning process takes 8[31] to 30 hours.[36]
- *Burn-Off Ovens*, also known as *Heat-Cleaning Ovens*, are gas-fired and used in the painting, coatings, electric motors and plastics industries for removing organics from heavy and large metal parts.[37]

Processes

In many industrial applications, the process is done under pressure and at operating temperatures above 430 °C (806 °F). For agricultural waste, for example, typical temperatures are 450 to 550 °C (840 to 1,000 °F).

Processes

Since pyrolysis is endothermic,[38] various methods to provide heat to the reacting biomass particles have been proposed:

- Partial combustion of the biomass products through air injection. This results in poor-quality products.
- Direct heat transfer with a hot gas, the ideal one being product gas that is reheated and recycled. The problem is to provide enough heat with reasonable gas flow-rates.
- Indirect heat transfer with exchange surfaces (wall, tubes): it is difficult to achieve good heat transfer on both sides of the heat exchange surface.
- Direct heat transfer with circulating solids: solids transfer heat between a burner and a pyrolysis reactor. This is an effective but complex technology.

For flash pyrolysis, the biomass must be ground into fine particles and the insulating char layer that forms at the surface of the reacting particles must be continuously removed. The following technologies have been proposed for biomass pyrolysis:[39]

- Fixed beds used for the traditional production of charcoal: poor, slow heat transfer result in very low liquid yields.
- Augers: this technology is adapted from a Lurgi process for coal gasification. Hot sand and biomass particles are fed at one end of a screw. The screw mixes the sand and biomass and conveys them along. It provides a good control of the biomass residence time. It does not dilute the pyrolysis products with a carrier or fluidizing gas. However, sand must be reheated in a separate vessel, and mechanical reliability is a concern. There is no large-scale commercial implementation.

- Electrically heated augers: one process uses an electrical current passed through an auger to heat the material giving excellent heat transfer by contact and radiation to the waste material.
- Ablative processes: biomass particles are moved at high speed against a hot metal surface. Ablation of any char forming at a particle's surface maintains a high rate of heat transfer. This can be achieved by using a metal surface spinning at high speed within a bed of biomass particles, which may present mechanical reliability problems but prevents any dilution of the products. As an alternative, the particles may be suspended in a carrier gas and introduced at high speed through a cyclone whose wall is heated; the products are diluted with the carrier gas.[40] A problem shared with all ablative processes is that scale-up is made difficult, since the ratio of the wall surface to the reactor volume decreases as the reactor size is increased.[41] There is no large-scale commercial implementation.
- Rotating cone: pre-heated hot sand and biomass particles are introduced into a rotating cone. Due to the rotation of the cone, the mixture of sand and biomass is transported across the cone surface by centrifugal force. The process is offered by BTG-BTL, a subsidiary from BTG Biomass Technology Group B.V. in The Netherlands. Like other shallow transported-bed reactors relatively fine particles (several mm) are required to obtain a liquid yield of around 70 wt.%. Larger-scale commercial implementation (up to 5 t/h input) is underway.[42]
- Fluidized beds: biomass particles are introduced into a bed of hot sand fluidized by a gas, which is usually a recirculated product gas. High heat transfer rates from fluidized sand result in rapid heating of biomass particles. There is some ablation by attrition with the sand particles, but it is not as effective as in the ablative processes. Heat is usually provided by heat exchanger tubes through which hot combustion gas flows. There is some dilution of the products, which makes it more difficult to condense and then remove the bio-oil mist from the gas exiting the condensers. This process has been scaled up by companies such as Dynamotive and Agri-Therm. The main challenges are in improving the quality and consistency of the bio-oil.
- Circulating fluidized beds: biomass particles are introduced into a circulating fluidized bed of hot sand. Gas, sand, and biomass particles move together, with the transport gas usually being a recirculated product gas, although it may also be a combustion gas. High heat transfer rates from sand ensure rapid heating of biomass particles and ablation stronger than with regular fluidized beds. A fast separator separates the product gases and vapors from the sand and char particles. The sand particles are reheated in a fluidized burner vessel and recycled to the reactor. Although this process can be easily scaled up, it is rather complex and the products are much diluted, which greatly complicates the recovery of the liquid products.
- Mechanical Fluidized Reactor (MFR). A mechanical stirrer agitates a hot bed of pure char particles into which biomass particles are injected. The stirrer also enhances heat transfer from the reactor wall to the agitated bed. No fluidization gas is required: evolving vapors aerate the bed and greatly reduce the power consumption of the mechanical stirrer.[43] This compact reactor has been used for a mobile pyrolysis plant.[44]
- Chain grate: dry biomass is fed onto a hot (500 °C) heavy cast metal grate or apron which forms a continuous loop. A small amount of air aids in heat transfer and in primary reactions for drying and carbonization. Volatile products are combusted for process and boiler heating.

Use of vacuum

In **vacuum pyrolysis**, organic material is heated in a vacuum to decrease its boiling point and avoid adverse chemical reactions. Called flash vacuum pyrolysis, this approach is used in organic synthesis.

Industrial sources

Many sources of organic matter can be used as feedstock for pyrolysis. Suitable plant material includes greenwaste, sawdust, waste wood, woody weeds; and agricultural sources including nut shells, straw, cotton trash, rice hulls, switch grass; and animal waste including poultry litter, dairy manure, and potentially other manures. Pyrolysis is used as a form of thermal treatment to reduce waste volumes of domestic refuse. Some industrial byproducts are also suitable feedstock including paper sludge and distillers grain.[45]

There is also the possibility of integrating with other processes such as mechanical biological treatment and anaerobic digestion.[46]

Industrial products

- syngas (flammable mixture of carbon monoxide and hydrogen): can be produced in sufficient quantities to provide both the energy needed for pyrolysis and some excess production[9][47]
- solid char that can either be burned for energy or be recycled as a fertilizer (biochar).

Fire protection

Destructive fires in buildings will often burn with limited oxygen supply, resulting in pyrolysis reactions. Thus, pyrolysis reaction mechanisms and the pyrolysis properties of materials are important in fire protection engineering for passive fire protection. Pyrolytic carbon is also important to fire investigators as a tool for discovering origin and cause of fires.

Chemistry

Current research examines the multiple reaction pathways of pyrolysis to understand how to manipulate the formation of pyrolysis' multiple products (oil, gas, char, and miscellaneous chemicals) to enhance the economic value of pyrolysis; identifying catalysts to manipulate pyrolysis reactions is also a goal of some pyrolysis research. Published research suggests that pyrolysis reactions have some dependence upon the structural composition of feedstocks (e.g. lignocellulosic biomass), with contributions from some minerals present in the feedstocks; some minerals present in feedstock are thought to increase the cost of operation of pyrolysis or decrease the value of oil produced from pyrolysis, through corrosive reactions.[48] The low quality of oils produced through pyrolysis can be improved by subjecting the oils to one or many physical and chemical processes,[49] which might drive production costs, but may make sense economically as circumstances change.

See also

- Karrick process
- Gasification
- Torrefaction
- Thermal decomposition
- Dextrin
- Wood gas
- Pyrolytic coating

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External links

- The dictionary definition of pyrolysis at Wiktionary
- In Situ Catalytic Fast Pyrolysis Technology Pathway (http://purl.fdlp.gov/GPO/gpo39628) National Renewable Energy Laboratory

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Categories: Pyrolysis | Organic reactions | Chemical processes | Industrial processes | Oil shale technology | Biodegradable waste management | Waste treatment technology | Fire protection

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Q code

From Wikipedia, the free encyclopedia

The **Q code** is a standardized collection of three-letter codes all of which start with the letter "Q". It is a brevity code initially developed for commercial radiotelegraph communication and later adopted by other radio services, especially amateur radio.

Although Q codes were created when radio used Morse code exclusively, they continued to be employed after the introduction of voice transmissions. To avoid confusion, transmitter call signs are restricted; no country is ever issued an ITU prefix starting with "Q".

Codes in the range QAA–QNZ are reserved for aeronautical use; QOA–QQZ for maritime use and QRA–QUZ for all services.

"Q" has no official meaning, but it is sometimes assigned with a word with mnemonic value, such as "Queen's" (e.g. QFE = Queen's Field Elevation), "Query", "Question", or "reQuest".[1]

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Early developments

The original Q codes were created, *circa* 1909, by the British government as a "list of abbreviations... prepared for the use of British ships and coast stations licensed by the Postmaster General". The Q codes facilitated communication between maritime radio operators speaking different languages, so they were soon adopted internationally. A total of forty-five Q codes appeared in the "List of Abbreviations to be used in Radio Communications", which was included in the Service Regulations affixed to the Third International Radiotelegraph Convention in London (The Convention was signed on July 5, 1912, and became effective July 1, 1913.)

The following table reviews a sample of the all-services Q codes adopted by the 1912 Convention:

First Twelve Q Codes Listed in the 1912 International Radiotelegraph Convention Regulations

Code	Question	Answer or Notice
QRA	What ship or coast station is that?	This is ____.
QRB	What is your distance?	My distance is ____.
QRC	What is your true bearing?	My true bearing is ____ degrees.
QRD	Where are you bound for?	I am bound for ____.
QRF	Where are you bound from?	I am bound from ____.
QRG	What line do you belong to?	I belong to the ____ Line.
QRH	What is your wavelength in meters?	My wavelength is ____ meters.
QRJ	How many words have you to send?	I have ____ words to send.
QRK	How do you receive me?	I am receiving (1–5). *1 is unreadable and 5 is perfect.*
QRL	Are you busy?	I am busy.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are the atmospherics strong?	Atmospherics (noise) are very strong.

Later usage

Over the years the original Q codes were modified to reflect changes in radio practice. For example, QSW/QSX originally stood for, "Shall I increase/decrease my spark frequency?", but in the 1920s, spark-gap transmitters were banned in the United States, rendering that meaning obsolete. By the 1970s, the *Post Office Handbook for Radio Operators* listed over a hundred Q codes, covering a wide range of subjects including radio procedures, meteorology, radio direction finding, and search and rescue.

Some Q codes are also used in aviation, in particular QNE, QNH and QFE, referring to certain altimeter settings. These codes are used in radiotelephone conversations with air traffic control as unambiguous shorthand, where safety and efficiency are of vital importance. A subset of Q codes is used by the Miami-

Dade County, Florida local government for law enforcement and fire rescue communications, one of the few instances where Q codes are used in ground voice communication.[2]

The QAA–QNZ code range includes phrases applicable primarily to the aeronautical service,[3] as defined by the International Civil Aviation Organisation.[4] The QOA–QQZ code range is reserved for the maritime service. The QRA–QUZ code range includes phrases applicable to all services and is allocated to the International Telecommunications Union.[5] QVA–QZZ are not allocated.[6] Many codes have no immediate applicability outside one individual service, such as maritime operation (many QO or QU series codes) or radioteletype operation (the QJ series).[7]

Many military and other organizations that use Morse code have adopted additional codes, including the Z code used by most European and NATO countries. The Z code adds commands and questions adapted for military radio transmissions, for example, "ZBW 2", which means "change to backup frequency number 2", and "ZNB abc", which means "my checksum is abc, what is yours?"[8]

Used in their formal "question/answer" sense, the meaning of a Q code varies depending on whether or not the individual Q code is sent as a question or an answer. For example, the message "QRP?" means "Shall I decrease transmitter power?", and a reply of "QRP" means "Yes, decrease your transmitter power", whereas an unprompted statement "QRP" means "Please decrease your transmitter power". This structured use of Q codes is fairly rare and now mainly limited to amateur radio and military Morse code (CW) traffic networks.

Breakdown by service

- QAA to QNZ – Assigned by the International Civil Aviation Organization (ICAO).
- QOA to QQZ – For the Maritime Mobile Service.
- QRA to QUZ – Assigned by the International Telecommunications Union Radiocommunication Sector (ITU-R).

- QN- - The ARRL has also developed its own codes for message handling located in this range. Even though they overlap with other signals, they determined that their exclusive use in NTS nets limits confusion.

Aeronautical Code signals (QAA–QNZ; ICAO)

First defined in ICAO publication "Doc 6100-COM/504/1" and in "ICAO Procedures for Air Navigation Services, Abbreviations and Codes (PANS-ABC)" [Doc8400-4] (4th edition 1989), the majority of the Q codes have slipped out of common use; for example today reports such as QAU ("I am about to jettison fuel") and QAZ ("I am flying in a storm") would be voice or computerized transmissions. But several remain part of the standard ICAO radiotelephony phraseology in aviation. These are also part of ACP131, which lists all ITU-R Q Codes, without grouping them by aeronautical/marine/general use.

	Question ?	Answer or Advice
QAB	May I have clearance (for ...) from ... (*place*) to ... (*place*) at flight level/altitude ... ?	You are cleared (*or* ... is cleared) by ... from ... (*place*) to ... (*place*) at flight level/altitude ...
QAF	Will you advise me when you are (were) at (over) ... (*place*)?	I am (was) at (over) ... (*place*) (at ... hours) at flight level/altitude ...
QAG		Arrange your flight in order to arrive over ... (*place*) at ... hours. *or* I am arranging my flight in order to arrive over ... (*place*) at ... hours.
QAH	What is your height above ... (*datum*)?	I am at .... flight level/altitude ... *or* Arrange your flight so as to reach flight level/altitude ... at ... (*hours or place*).
QAI	What is the essential traffic respecting my aircraft?	The essential traffic respecting your aircraft is ...
QAK	Is there any risk of collision?	There is risk of collision.
QAL	Are you going to land at ... (*place*)? *or* Has aircraft ... landed at ... (*place*)?	I am going to land at ... (*place*). *or* (You may) land at ... (*place*). *or* Aircraft ... landed at ... (*place*).
QAM	What is the latest available meteorological observation for ... (*place*)?	Meteorological observation made at ... (*place*) at ... hours was as follows ... *Note.- The information may be given in Q Code form or the METAR form.*

QAN	What is the surface wind direction and speed at ... (*place*)?	The surface wind direction and speed at ... (*place*) at ... hours is ... (*direction*) ... (*speed*).
QAO	What is the wind direction in degrees TRUE and speed at ... (*position or zone/s*) at each of the ... (*figures*) ... (*units*) levels above ... (*datum*)?	The wind direction and speed at (*position or zone/s*) at flight level/altitude ... is: ... (vertical distance) ... degrees TRUE ... (*speed*).
QAP	Shall I listen for you (*or* for ...) on ... kHz (... MHz)?	Listen for me (*or* for ...) on ... kHz (... MHz).
QAQ	Am I near a prohibited, restricted or danger area? *or* Am I near area ... (*identification of area*)?	You are ... 1) near 2) flying within area ... (*identification of area*).
QAR	May I stop listening on the watch frequency for ... minutes?	You may stop listening on the watch frequency for ... minutes.
QAU	Where may I jettison fuel?	I am about to jettison fuel. *or* Jettison fuel in ... (*area*).
QAW		I am about to carry out overshoot procedure.
QAY	Will you advise me when you pass (passed) ... (*place*) bearing 090 (270) degrees relative to your heading?	I passed ... (*place*) bearing ... degrees relative to my heading at ... hours.
QAZ	Are you experiencing communication difficulties through flying in a storm?	I am experiencing communication difficulties through flying in a storm.
QBA	What is the horizontal visibility at ... (*place*)?	

		The horizontal visibility at ... (*place*) at ... hours is ... (*distance figures and units*).
QBB	What is the amount, type and height above official aerodrome elevation of the base of the cloud [at ... (*place*)]?	The amount, type and height above official aerodrome elevation of the base of the cloud at ... (*place*) at ... hours is: ... eights (... type) at ... (*figures and units*) height above official aerodrome elevation.
QBC	Report meteorological conditions as observed from your aircraft [at ... (*position or zone*)] [(at ... hours)].	The meteorological conditions as observed from my aircraft at ... (*position or zone*) at ... hours at ... (*figures and units*) height above ... (*datum*) are ... *Note.-The answer is required in the format of an AIREP message.*
QBD	How much fuel have you remaining (*expressed as hours and/or minutes of consumption*)?	My fuel endurance is ... (*hours and/or minutes*).
QBE		I am about to wind in my aerial.
QBF	Are you flying in cloud?	I am flying in cloud at ... flight level/altitude ... [and I am ascending (descending) to flight level/altitude ...].
QBG	Are you flying above cloud?	I am flying above cloud and at flight level/altitude ... *or* Maintain a vertical distance of ... (*figures and units*) above clouds, smoke, haze or fog levels.
QBH	Are you flying below cloud?	I am flying below cloud and at flight level/altitude ...

		or Maintain a vertical distance of ... (*figures and units*) below cloud.
QBI	Is flight under IFR compulsory at ... (*place*) [*or* from ... to ... (*place*)]?	Flight under IFR is compulsory at ... (*place*) [*or* from ... to ... (*place*)].
QBJ	What is the amount, type and height above ... (*datum*) of the top of the cloud [at ... (*position or zone*)]?	At ... hours at ... (*position or zone*) the top of the cloud is: amount ... eights (... type) at ... (*figures and units*) height above ... (*datum*).
QBK	Are you flying with no cloud in your vicinity?	I am flying with no cloud in my vicinity and at flight level/altitude ...
QBM	Has ... sent any messages for me?	Here is the message sent by ... at ... hours.
QBN	Are you flying between two layers of cloud?	I am flying between two layers of cloud and at flight level/altitude ...
QBO	What is the nearest aerodrome at which flight under VFR is permissible and which would be suitable for my landing?	Flying under VFR is permissible at ... (*place*) which would be suitable for your landing.
QBP	Are you flying in and out of cloud?	I am flying in and out of cloud and at flight level/altitude ...
QBS		Ascend (*or* descend) to ... (*figures and units*) height above ... (*datum*) before encountering instrument meteorological conditions or if visibility falls below ... (*distance figures and units*) and advise.
QBT	What is the runway visual range at ... (*place*)?	The runway visual range at ... (*place*) at ... hours is ... (*distance figures and units*).
QBV		

	Have you reached flight level/altitude ... [*or* ... (*area or place*)]?	I have reached ... flight level/altitude ... [*or* ... (*area or place*)]. *or* Report reaching flight level/altitude ... [*or* ... (*area or place*)].
QBX	Have you left ... flight level/altitude ... [*or* ... (*area or place*)]?	I have left ... flight level/altitude ... [*or* ... (*area or place*)]. *or* Report leaving flight level/altitude ... [*or* ... (*area or place*)].
QBZ	Report your flying conditions in relation to clouds.	*The reply to* QBZ ? *is given by the appropriate answer form of signals* QBF, QBG, QBH, QBK, QBN *and* QBP.
QCA	May I change my flight level/altitude from ... to ... ?	You may change your flight level/altitude from ... to ... *or* I am changing my flight level/altitude from ... to ...
QCB		Delay is being caused by ... 1) your transmitting out of turn. 2) your slowness in answering. 3) lack of your reply to my ...
QCE	When may I expect approach clearance?	Expect approach clearance at ... hours. *or* No delay expected.
QCF		

		Delay indefinite. Expect approach clearance not later than ... hours.
QCH	May I taxi to ... (*place*)?	Cleared to taxi to ... (*place*).
QCI		Make a 360-degree turn immediately (turning to the ...). *or* I am making a 360-degree turn immediately (turning to the ...).
QCS		My reception on ... frequency has broken down.
QCX	What is your full call sign?	My full call sign is ... *or* Use your full call sign until further notice.
QCY		I am working on a trailing aerial. *or* Work on a trailing aerial.
QDB	Have you sent message ... to ... ?	I have sent message ... to ...
QDF	What is your D-Value at ... (*position*)? *or* What is the D-Value at ... (*place or position*) (at ... hours) for the ... millibar level?	My D-Value at ... (*position*) at ... (*figures and units*) height above the 1013.2 millibars datum is ... (*D-Value figures and units*) ... (*specify plus or minus*). *or* The D-Value at ... (*place or position*) at ... hours for the ... millibar level is (*D-Value figures and units*) ... (*specify plus or minus*). *Note.- When the true altitude (radio*

		*altitude) is greater than the pressure altitude **PS** (Plus) is used and when it is less **MS** (Minus) is used.*
QDL	Do you intend to ask me for a series of bearings?	I intend to ask you for a series of bearings.
QDM	Will you indicate the MAGNETIC heading for me to steer towards you (*or* ...) with no wind?	The MAGNETIC heading for you to steer to reach me (*or* ...) with no wind was ... degrees (at ... hours).
QDP	Will you accept control (*or* responsibility) of (for) ... now (*or* at ... hours)?	I will accept control (*or* responsibility) of (for) ... now (*or* at ... hours).
QDR	What is my MAGNETIC bearing from you (*or* from ...)?	Your MAGNETIC bearing from me (*or* from ...) was ... degrees (at ... hours).
QDT	Are you flying in visual meteorological condition?	I am flying in visual meteorological condition. *or* You are cleared subject to maintaining own separation and visual meteorological conditions.
QDU		Cancelling my IFR flight. *or* IFR flight cancelled at ... (*time*).
QDV	Are you flying in a flight visibility of less than ... (*figures and units*)?	I am flying in a flight visibility of less than ... (*figures and units*) at flight level/altitude ...
QEA	May I cross the runway ahead of me?	You may cross the runway ahead of you.
QEB	May I turn at the intersection?	

		Taxi as follows at the intersection ... (straight ahead DRT turn left LEFT turn right RITE).
QEC	May I make a 180-degree turn and return down the runway?	You may make a 180-degree turn and return down the runway.
QED	Shall I follow the pilot vehicle?	Follow the pilot vehicle.
QEF	Have I reached my parking area? *or* Have you reached your parking area?	You have reached your parking area. *or* I have reached my parking area.
QEG	May I leave the parking area? *or* Have you left the parking area?	You may leave the parking area. *or* I have left the parking area.
QEH	May I move to the holding position for runway number ... ? *or* Have you moved to the holding position for runway number ... ?	Cleared to the holding position for runway number ... *or* I have moved to the holding position for runway number ...
QEJ	May I assume position for take-off? *or* Have you assumed position for take-off?	Cleared to hold at take-off position for runway number ... *or* I am assuming take-off position for runway number ... and am holding.
QEK	Are you ready for immediate take-off?	I am ready for immediate take-off.
QEL		

	May I take-off (and make a ... hand turn after take-off)?	You are cleared to take-off (turn as follows after take-off ...).
QEM	What is the condition of the landing surface at ... (*place*)?	The condition of the landing surface at ... (*place*) is ... *Note.- The information is given by sending appropriate NOTAM Code groups.*
QEN	Shall I hold my position?	Hold your position
QEO	Shall I clear the runway (*or* landing area)? *or* Have you cleared the runway (*or* landing area)?	Clear the runway (*or* landing area). *or* I have cleared the runway (*or* landing area).
QES	Is a right-hand circuit in force at ... (*place*)?	A right-hand circuit is in force at ... (*place*).
QFA	What is the meteorological forecast for ... (*flight, route, section of route or zone*) for the period ... hours until ... hours?	The meteorological forecast for ... (*flight, route, section of route or zone*) for the period ... hours until ... hours is ...
QFB		The ... 1) approach 2) runway 3) approach and runway lights are out of order.
QFC	What is the amount, the type and the height above ... (*datum*) of the base of the cloud at ... (*place, position or zone*)?	At ... (*place, position or zone*) the base of the cloud is ... eighths ... type at ... (*figures and units*) height above ... (*datum*).
QFD	1) Is the ... visual beacon [at ... (*place*)] in operation? 2) Will you switch on the ...	1) The ... visual beacon [at ... (*place*)] is in operation 2) I will extinguish the aerodrome

	visual beacon [at ... (*place*)]? 3) Will you extinguish the aerodrome visual beacon [at ... (*place*)] until I have landed?	visual beacon [at ... (*place*)] until your landing is completed.
QFE	What should I set on the subscale of my altimeter so that the instrument would indicate its height above the reference elevation being used?	If you set the subscale of your altimeter to read ... millibars, the instrument would indicate its height above aerodrome elevation (above threshold, runway number ...).
QFF	[At ... (*place*)] what is the present atmospheric pressure converted to mean sea level in accordance with meteorological practice?	At ... (*place*) the atmospheric pressure converted to mean sea level in accordance with meteorological practice is (*or* was determined at ... hours to be) ... millibars.
QFG	Am I overhead?	You are overhead.
QFH	May I descend below the clouds?	You may descend below the clouds.
QFI	Are the aerodrome lights lit?	The aerodrome lights are lit. *or* Please light the aerodrome lights.
QFL	Will you send up pyrotechnical lights?	I will send up pyrotechnical lights.
QFM	What flight level/altitude ... 1) should I maintain? 2) are you maintaining? 3) do you intend cruising at?	... 1) Maintain (*or* fly at) flight level/altitude ... 2) I am maintaining flight level/altitude ... 3) I intend cruising at flight level/altitude ...
QFO	May I land immediately?	You may land immediately.
QFP		

	Will you give me the latest information concerning ... facility [at ... (*place*)]?	The latest information concerning ... facility [at ... (*place*)] is as follows ... *Note.- The information is given by sending appropriate NOTAM Code groups.*
QFQ	Are the approach and runway lights lit?	The approach and runway lights are lit. *or* Please light the approach and runway lights.
QFR	Does my landing gear appear damaged?	Your landing gear appears damaged.
QFS	Is the radio facility at ... (*place*) in operation?	The radio facility at ... (*place*) is in operation (*or* will be in operation in ... hours). *or* Please have the ... radio facility at ... (*place*) put in operation.
QFT	Between what heights above ... (*datum*) has ice formation been observed [at ... (*position or zone*)]?	Ice formation has been observed at ... (*position or zone*) in the type of ... and with an accretion rate of ... between ... (*figures and units*) and ... (*figures and units*) heights above ... (*datum*).
QFU	What is the magnetic direction (*or* number) of the runway to be used?	The magnetic direction (*or* number) of the runway to be used is ... *Note.- The runway number is indicated by a two-figure group and the magnetic direction by a three-figure group.*

QFV	Are the floodlights switched on?	The floodlights are switched on. *or* Please switch on the floodlights.
QFW	What is the length of the runway in use in ... (*units*)?	The length of runway ... now in use is ... (*figures and units*).
QFX		I am working (*or* am going to work) on a fixed aerial. *or* Work on a fixed aerial.
QFY	Please report the present meteorological landing conditions [at ... (*place*)].	The present meteorological landing conditions at ... (*place*) are ... *Note.- When given in Q Code the information is sent in the following sequence: QAN, QBA, QNY, QBB, QNH and/or QFE and, if necessary, QMU, QNT, QBJ.*
QFZ	What is the aerodrome meteorological forecast for ... (*place*) for the period ... hours until ... hours?	The aerodrome meteorological forecast for ... (*place*) for the period ... hours until ... hours is ... *Note.- When given in Q Code the following sequence of Q signal answer (or advice) forms is to be used: QAN, QBA, QNY, QBB and, if necessary, QMU, QNT and QBJ.*
QGC		There are obstructions to the ... of ... runway ...
QGD	Are there on my track any obstructions whose elevation equals or exceeds my altitude?	There are obstructions on your track ... (*figures and units*) height above ... (*datum*).
QGE	What is my distance to your station (*or* to ...)?	Your distance to my station (*or* to ...) is ... (*distance figures and units*).

QGH	May I land using ... (*procedure or facility*)?	You may land using ... (*procedure or facility*).
QGK	What track should I make good? *or* What track are you making good?	Make good a track from ... (*place*) on ... degrees ... (*true or magnetic*). *or* I am making good a track from ... (*place*) on ... degrees ... (*true or magnetic*).
QGL	May I enter the ... (*control area or zone*) at ... (*place*)?	You may enter the ... (*control area or zone*) at ... (*place*).
QGM		Leave the ... (*control area or zone*).
QGN	May I be cleared to land [at ... (*place*)]?	You are cleared to land [at ... (*place*)].
QGO		Landing is prohibited at ... (*place*).
QGP	What is my number for landing?	You are number ... to land.
QGQ	May I hold at ... (*place*)?	Hold at ... (*place*) at flight level/altitude ... (*datum*) and await further clearance.
QGT		Fly for ... minutes on a heading what will enable you to maintain a track reciprocal to your present one.
QGU		Fly for ... minutes on a magnetic heading of ... degrees.
QGV	Do you see me? *or* Can you see the aerodrome? *or* Can you see ... (*aircraft*)?	I see you at ... (*cardinal or quadrantal point of direction*). *or* I can see the aerodrome. *or* I can see ... (aircraft).
QGW		

	Does my landing gear appear to be down and in place?	Your landing gear appears to be down and in place.
QGZ		Hold on ... direction of ... facility.
QHE	Will you inform me when you are on ... leg of approach?	I am on ... 1) cross-wind leg 2) down-wind leg 3) base leg 4) final leg ... of approach.
QHG	May I enter traffic circuit at flight level/altitude ...?	Cleared to enter traffic circuit at flight level/altitude ...
QHH	Are you making an emergency landing?	I am making an emergency landing. *or* Emergency landing being made at ... (*place*). All aircraft below flight level/altitude ... and within a distance of ... (*figures and units*) leave ... (*place or headings*).
QHI	Are you (*or* is ...) ... 1) waterborne? 2) on land?	I am (*or* ... is) ... 1) waterborne 2) on land at ... hours.
QHQ	May I make a ... approach [at ... (*place*)]? *or* Are you making a ... approach?	You may make a ... approach [at ... (*place*)]. *or* I am making a ... approach.
QHZ	Shall I circle the aerodrome (*or* go around)?	Circle the aerodrome (*or* go around).
QIC		

	May I establish communication with ... radio station on ... kHz (*or* ... MHz.) now (*or* at ... hours)?	Establish communication with ... radio station on ... kHz. (*or* MHz.) now (*or* at ...hours). *or* I will establish communication with ... radio station on ... kHz (*or* ... MHz) now (*or* at ... hours).
QIF	What frequency is ... using?	... is using ... kHz (*or* ... MHz.).
QJA	Is my ... 1) tape 2) mark and space reversed?	Your ... 1) tape 2) mark and space is reversed.
QJB	Will you use ... 1) radio? 2) cable? 3) telegraph? 4) teletypewriter? 5) telephone? 6) receiver? 7) transmitter? 8) reperforator?	I will use ... 1) radio. 2) cable. 3) telegraph. 4) teletypewriter. 5) telephone. 6) receiver. 7) transmitter. 8) reperforator.
QJC	Will you check your ... 1) transmitter distributor? 2) auto-head? 3) perforator? 4) reperforator? 5) printer? 6) printer motor? 7) keyboard? 8) antenna system?	I will check my ... 1) transmitter distributor. 2) auto-head. 3) perforator. 4) reperforator. 5) printer. 6) printer motor. 7) keyboard. 8) antenna system.
QJD	Am I transmitting ... 1) in letters? 2) in figures?	You are transmitting ... 1) in letters 2) in figures.
QJE		

	Is my frequency shift ... 1) too wide? 2) too narrow? 3) correct?	Your frequency shift is ... 1) too wide. 2) too narrow (by ... cycles). 3) correct.
QJF		My signal as checked by monitor ... is satisfactory ... 1) locally. 2) as radiated.
QJG	Shall I revert to automatic relay?	Revert to automatic relay.
QJH	Shall I run ... 1) my test tape? 2) a test sentence?	Run ... 1) your test tape. 2) a test sentence.
QJI	Will you transmit a continuous ... 1) mark? 2) space?	I am transmitting a continuous... 1) mark. 2) space.
QJK	Are you receiving ... 1) a continuous mark? 2) a continuous space? 3) a mark bias? 4) a space bias?	I am receiving ... 1) a continuous mark. 2) a continuous space. 3) a mark bias. 4) a space bias.
QKC		The sea conditions (at ... position) ... 1) permit alighting but not take-off. 2) render alighting extremely hazardous.
QKF	May I be relieved (at ... hours)?	You may expect to be relieved at ... hours [by ... 1) aircraft ... (*identification*) (type ...) 2) vessel whose call sign is ... (*call sign*) {*and/or* whose name is ... (*name*)}].
QKG	Will relief take place when ... (*identification*) establishes ... 1) visual,	Relief will take place when ... (*identification*) establishes ... 1) visual,

	2) communications, contact with survivors?	2) communications, contact with survivors.
QKH	Report details of the parallel sweep (track) search being (*or* to be) conducted? *or* In the parallel sweep (track) search being (*or* to be) conducted, what is (are) ... 1) the direction of sweeps, 2) the separation between sweeps, 3) the flight level/altitude ... employed in the search pattern?	The parallel sweep (track) search is being (*or* to be) conducted ... 1) with direction of sweeps ... degrees ... (*true or magnetic*). 2) with ... (*distance figures and units*) separation between sweeps. 3) at flight level/altitude ...
QKN		Aircraft plotted (believed to be you) in position ... on track ... degrees at ... hours.
QKO	What other units are (*or* will be) taking part in the operation [... (*identification of operation*)]?	In the operation [... (*identification*)], the following units are (*or* will be) taking part ... (*name of units*). *or* ... (*name*) unit is taking part in operation [... (*identification*] (with effect from ... hours).
QKP	Which pattern of search is being followed?	The search pattern is ... 1) parallel sweep. 2) square search. 3) creeping line ahead. 4) track crawl. 5) contour search. 6) combined search by aircraft and ship. 7) ... (*specify*).

QLB	Will you monitor ... station and report regarding range, quality, etc.?	I have monitored ... station and report (*briefly*) as follows ...
QLH	Will you use simultaneous keying on ... frequency and ... frequency?	I will now key simultaneously on ... frequency and ... frequency.
QLV	Is the ... radio facility still required?	The ... radio facility is still required.
QMH		Shift to transmit and receive on ... kHz (*or* ... MHz.); if communication is not established within 5 minutes, revert to present frequency.
QMI	Report the vertical distribution of cloud [at ... (*position or zone*)] as observed from your aircraft.	The vertical distribution of cloud as observed from my aircraft at ... hours at ... (*position or zone*) is : lowest layer observed* ... eights (... type) with base of ... (*figures and units*) and tops of ... (*figures and units*) [**and similarly in sequence for each of the layers observed.*] height above ... (*datum*).
QMU	What is the surface temperature at ... (*place*) and what is the dew point temperature at that place?	The surface temperature at ... (*place*) at ... hours is ... degrees and the dew point temperature at that time and place is ... degrees.
QMW	At ... (*position or zone*) what is (are) the flight level(s)/altitude (s) ... of the zero Celsius isotherm(s)?	At ... (*position or zone*) the zero Celsius isotherm(s) is (are) at flight level(s)/altitude(s) ...
QMX	What is the air temperature [at ... (*position or zone*)] (at ... hours) at flight level/altitude ...?	At ... (*position or zone*) at ... hours the air temperature is ... (*degrees and units*) at flight level/altitude ...

		Note.- Aircraft reporting QMX information will transmit the temperature figures as corrected for airspeed.
QMZ	Have you any amendments to the flight forecast in respect of section of route yet to be traversed?	The following amendment(s) should be made to the flight forecast ... [*If no amendments, signal QMZ NIL*]
QNE	What indication will my altimeter give on landing at ... (*place*) at ... hours, my sub-scale being set to 1013.2 millibars (29.92 inches)?	On landing at ... (*place*) at ... hours, with your sub-scale being set to 1013.2 millibars (29.92 inches), your altimeter will indicate ... (*figures and units*).
QNH	What should I set on the subscale of my altimeter so that the instrument would indicate its elevation if my aircraft were on the ground at your station?	If you set the subscale of your altimeter to read ... millibars, the instrument would indicate its elevation if your aircraft were on the ground at my station at ... hours. *Note.- When the setting is given in hundredths of inch the abbreviation INS is used to identify the units.*
QNI	Between what heights above ... (*datum*) has turbulence been observed at ... (*position or zone*)?	Turblence has been observed at ... (*position or zone*) with an intensity of ... between ... (*figures and units*) and ... (*figures and units*) heights above ... (*datum*).
QNO		I am not equipped to give the information (*or* provide the facility) requested.
QNR		I am approaching my point of no return.
QNT		

	What is the maximum speed of the surface wind at ... (*place*)?	The maximum speed of the surface wind at ... (*place*) at ... hours is ... (*speed figures and units*).
QNY	What is the present weather and the intensity thereof at ... (*place, position or zone*)?	The present weather and intensity thereof at ... (*place, position or zone*) at ... hours is ... *Notes:* a) When present weather information is transmitted by a ground station, the abbreviations shall be selected from those specified in Annex 3, paragraph 4.8.2. b) When present weather information is transmitted by an aircraft, the information shall be selected from items 10 to 12 of the AIREP form.

[9]

Maritime Mobile Service (QOA–QQZ)

Main article Maritime Mobile Service Q Codes

This assignment is specified in RECOMMENDATION ITU-R M.1172.[10]

Q signals are not substantially used in the maritime service. Morse code is now very rarely used for maritime communications, but in isolated maritime regions like Antarctica and the South Pacific the use of Q Codes continues. Q Codes still work when HF voice circuits are not possible due to atmospherics and the nearest vessel is one ionospheric hop away.

	Question ?	Answer or Advice
QOA	Can you communicate by radiotelegraphy (500 kHz)?	I can communicate by radiotelegraphy (500 kHz).
QOB	Can you communicate by radiotelephony (2182 kHz)?	I can communicate by radiotelephony (2182 kHz).
QOC	Can you communicate by radiotelephony (channel 16 - frequency 156.80 MHz)?	I can communicate by radiotelephony (channel 16 - frequency 156.80 MHz).
QOD	Can you communicate with me in ... 0. Dutch 5. Italian 1. English 6. Japanese 2. French 7. Norwegian 3. German 8. Russian 4. Greek 9. Spanish?	I can communicate with you in ... 0. Dutch 5. Italian 1. English 6. Japanese 2. French 7. Norwegian 3. German 8. Russian 4. Greek 9. Spanish.
QOE	Have you received the safety signal sent by ... (*name and/or call sign*)?	I have received the safety signal sent by ... (*name and/or call sign*).
QOF	What is the commercial quality of my signals?	The quality of your signals is ... 1. not commercial 2. marginally commercial 3. commercial.
QOG	How many tapes have you to send?	I have ... tapes to send.
QOH	Shall I send a phasing signal for ... seconds?	Send a phasing signal for ... seconds.
QOI	Shall I send my tape?	Send your tape.
QOJ	Will you listen on ... kHz (*or* MHz) for signals of emergency position-indicating radiobeacons?	I am listening on ... kHz (*or* MHz) for signals of emergency position-indicating radiobeacons.
QOK	Have you received the signals of an emergency position-indicating radiobeacon on ... kHz (*or* MHz)?	I have received the signals of an emergency position-indicating radiobeacon on ... kHz (*or* MHz).

QOL	Is your vessel fitted for reception of selective calls? If so, what is your selective call number or signal?	My vessel is fitted for the reception of selective calls. My selective call number or signal is ...
QOM	On what frequencies can your vessel be reached by a selective call?	My vessel can be reached by a selective call on the following frequency/ies ... (periods of time to be added if necessary).
QOO	Can you send on any working frequency?	I can send on any working frequency.
QOT	Do you hear my call; what is the approximate delay in minutes before we may exchange traffic?	I hear your call; the approximate delay is ... minutes.

All Services (QRA–QUZ)

First defined by the Washington 1927 ITU Radio Regulations. Later defined by ITU-R in Appendix 9 to the Radio Regulations Annex to the International Telecommunications Convention (Atlantic City) 1947. The current callsign table is found in ITU-R Appendix 42. Current interpretation of the Q-code can be found in ITU-R Appendices 14 and 15.

ITU Radio Regulations 1990, Appendix 13: Miscellaneous Abbreviations and Signals to Be Used in Radiotelegraphy Communications Except in the Maritime Mobile Service

	Question ?	Answer or Advice
QRA	What is the name of your vessel (*or* station)?	The name of my vessel (*or* station) is ...
QRB	How far approximately are you from my station?	The approximate distance between our stations is ... nautical miles (*or* km).
QRC	By what private enterprise (*or* state administration) are the accounts for charges for your station settled?	The accounts for charges of my station are settled by the private enterprise ... (*or* state administration).
QRD	Where are you bound for and where are you from?	I am bound for ... from ...
QRE	What is your estimated time of arrival at ... (*or* over ...) (*place*)?	My estimated time of arrival at ... (*or* over ...) (*place*) is ... hours.
QRF	Are you returning to ... (*place*)?	I am returning to ... (*place*). *or* Return to ... (*place*).
QRG	Will you tell me my exact frequency (*or* that of ...)?	Your exact frequency (*or* that of ...) is ... kHz (*or* MHz).
QRH	Does my frequency vary?	Your frequency varies.
QRI	How is the tone of my transmission?	The tone of your transmission is ... 1. good 2. variable 3. bad.
QRJ	How many radiotelephone calls have you to book?	I have ... radiotelephone calls to book.
QRK	What is the intelligibility of my signals (*or* those of ...)?	The intelligibility of your signals (*or* those of ...) is ... 1. bad 2. poor

		3. fair 4. good 5. excellent.
QRL	Are you busy?	I am busy (*or* I am busy with ...). Please do not interfere.
QRM	Are you being interfered with? [AP13] *or* Is my transmission being interfered with? [AP14]	I am being interfered with [AP13] *or* Your transmission is being interfered with ... [AP14] (1. nil 2. slightly 3. moderately 4. severely 5. extremely).
QRN	Are you troubled by static?	I am troubled by static (1. nil 2. slightly 3. moderately 4. severely 5. extremely).
QRO	Shall I increase transmitter power?	Increase transmitter power.
QRP	Shall I decrease transmitter power?	Decrease transmitter power.
QRQ	Shall I send faster?	Send faster (... words per minute).
QRR	Are you ready for automatic operation?	I am ready for automatic operation. Send at ... words per minute.
QRS	Shall I send more slowly?	Send more slowly (... words per minute).
QRT	Shall I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.

QRV	Are you ready?	I am ready.
QRW	Shall I inform ... that you are calling him on ... kHz (*or* MHz)?	Please inform ... that I am calling him on ... kHz (*or* MHz).
QRX	When will you call me again?	I will call you again at ... hours (on ... kHz (*or* MHz)).
QRY	What is my turn? (*Relates to communication*).	Your turn is Number ... (*or according to any other indication*). (*Relates to communication*).
QRZ	Who is calling me?	You are being called by ... (on ... kHz (*or* MHz)).
QSA	What is the strength of my signals (*or* those of ...)?	The strength of your signals (*or* those of ...) is 1. scarcely perceptible 2. weak 3. fairly good 4. good 5. very good.
QSB	Are my signals fading?	Your signals are fading.
QSC	Are you a cargo vessel? [AP13] *or* Are you a low traffic ship? [AP14]	I am a cargo vessel. [AP13] *or* I am a low traffic ship. [AP14]
QSD	Is my keying defective? [AP13] *or* Are my signals mutilated? [AP14]	Your keying is defective. [AP13] *or* Your signals are mutilated. [AP14]
QSE*	What is the estimated drift of the survival craft?	The estimated drift of the survival craft is ... (*figures and units*).

QSF*	Have you effected rescue?	I have effected rescue and am proceeding to ... base (with ... persons injured requiring ambulance).
QSG	Shall I send ... telegrams at a time?	Send ... telegrams at a time.
QSH	Are you able to home on your direction-finding equipment?	I am able to home on my D/F equipment (on station ...).
QSI		I have been unable to break in on your transmission. *or* Will you inform ... (*call sign*) that I have been unable to break in on his transmission (on ... kHz (*or* MHz)).
QSJ	What is the charge to be collected to ... including your internal charge?	The charge to be collected to ... including my internal charge is ... francs.
QSK	Can you hear me between your signals and if so can I break in on your transmission?	I can hear you between my signals; break in on my transmission.
QSL	Can you acknowledge receipt?	I am acknowledging receipt.
QSM	Shall I repeat the last telegram which I sent you (*or* some previous telegram)?	Repeat the last telegram which you sent me (*or* telegram(s) number(s) ...).
QSN	Did you hear me (*or* ... (*call sign*)) on ... kHz (*or* MHz)?	I did hear you (*or* ... (*call sign*)) on ... kHz (*or* MHz).
QSO	Can you communicate with ... direct (*or* by relay)?	I can communicate with ... direct (*or* by relay through ...).
QSP	Will you relay to ... free of charge?	I will relay to ... free of charge.
QSQ	Have you a doctor on board (*or* is ... (*name of person*) on board)?	I have a doctor on board (*or* ... (*name of person*) is on board).

QSR	Shall I repeat the call on the calling frequency?	Repeat your call on the calling frequency; did not hear you (*or* have interference).
QSS	What working frequency will you use?	I will use the working frequency ... kHz (*or* MHz) (*in the HF bands normally only the last three figures of the frequency need be given*).
QSU	Shall I send or reply on this frequency (*or* on ... kHz (*or* MHz)) (with emissions of class ...)?	Send or reply on this frequency (*or* on ... kHz (*or* MHz)) (with emissions of class ...).
QSV	Shall I send a series of Vs on this frequency (*or* on ... kHz (*or* MHz))?	Send a series of Vs on this frequency (*or* on ... kHz (*or* MHz)).
QSW	Will you send on this frequency (*or* on ... kHz (*or* MHz)) (with emissions of class ...)?	I am going to send on this frequency (*or* on ... kHz (*or* MHz)) (with emissions of class ...).
QSX	Will you listen to ... (*call sign(s)*) on ... kHz (*or* MHz)? [AP13] *or* Will you listen to ... (*call sign(s)*) on ... kHz (*or* MHz), or in the bands ... / channels ... ? [AP14]	I am listening to ... (*call sign (s)*) on ... kHz (*or* MHz). [AP13] *or* I am listening to ... (*call sign (s)*) on ... kHz (*or* MHz), or in the bands ... / channels ... [AP14]
QSY	Shall I change to transmission on another frequency?	Change to transmission on another frequency (*or* on ... kHz (*or* MHz)).
QSZ	Shall I send each word or group more than once?	Send each word or group twice (*or* ... times).
QTA	Shall I cancel telegram (*or* message) number ... ?	Cancel telegram (*or* message) number ...

QTB	Do you agree with my counting of words?	I do not agree with your counting of words; I will repeat the first letter or digit of each word or group.
QTC	How many telegrams have you to send?	I have ... telegrams for you (*or* for ...).
QTD*	What has the rescue vessel or rescue aircraft recovered?	... (*identification*) has recovered ... 1. ... (*number*) survivors 2. wreckage 3. ... (*number*) bodies.
QTE	What is my TRUE bearing from you? *or* What is my TRUE bearing from ... (*call sign*)? *or* What is the TRUE bearing of ... (*call sign*) from ... (*call sign*)?	Your TRUE bearing from me is ... degrees at ... hours. *or* Your TRUE bearing from ... (*call sign*) was ... degrees at ... hours. *or* The TRUE bearing of ... (*call sign*) from ... (*call sign*) was ... degrees at ... hours.
QTF	Will you give me the position of my station according to the bearings taken by the direction-finding stations which you control?	The position of your station according to the bearings taken by the D/F stations which I control was ... latitude, ... longitude (*or other indication of position*), class ... at ... hours.
QTG	Will you send two dashes of ten seconds each followed by your call sign (repeated ... times) (on ... kHz (*or* MHz))?	I am going to send two dashes of ten seconds each followed by my call sign (repeated ... times) (on ... kHz (*or* MHz)).

	or Will you request ... to send two dashes of ten seconds followed by his call sign (repeated ... times) on ... kHz (*or* MHz)?	*or* I have requested ... to send two dashes of ten seconds followed by his call sign (repeated ... times) on ... kHz (*or* MHz).
QTH	What is your position in latitude and longitude (*or according to any other indication*)?	My position is ... latitude, ... longitude (*or according to any other indication*).
QTI	What is your TRUE track? [AP13]	My TRUE track is ... degrees. [AP13]
QTI*	What is your TRUE course? [AP14]	My TRUE course is ... degrees. [AP14]
QTJ*	What is your speed? (*Requests the speed of a ship or aircraft through the water or air respectively*).	My speed is ... knots (*or* ... kilometres per hour or ... statute miles per hour). (*Indicates the speed of a ship or aircraft through the water or air respectively*).
QTK*	What is the speed of your aircraft in relation to the surface of the Earth?	The speed of my aircraft in relation to the surface of the Earth is ... knots (*or* ... kilometres per hour or ... statute miles per hour).
QTL*	What is your TRUE heading?	My TRUE heading is ... degrees.
QTM*	What is your MAGNETIC heading?	My MAGNETIC heading is ... degrees.
QTN	At what time did you depart from ... (*place*)?	I departed from ... (*place*) at ... hours.
QTO	Have you left dock (*or* port)? *or*	I have left dock (*or* port). *or*

	Are you airborne?	I am airborne.
QTP	Are you going to enter dock (*or* port)? *or* Are you going to alight (*or* land)?	I am going to enter dock (*or* port). *or* I am going to alight (*or* land).
QTQ	Can you communicate with my station by means of the International Code of Signals (INTERCO)?	I am going to communicate with your station by means of the International Code of Signals (INTERCO).
QTR	What is the correct time?	The correct time is ... hours.
QTS	Will you send your call sign for tuning purposes or so that your frequency can be measured now (*or* at ... hours) on ... kHz (*or* MHz)? [AP13] *or* Will you send your call sign (*and/or* name) for ... seconds? [AP14]	I will send my call sign for tuning purposes or so that my frequency may be measured now (*or* at ... hours) on ... kHz (*or* MHz). [AP13] *or* I will send my call sign (*and/or* name) for ... seconds. [AP14]
QTT		The identification signal which follows is superimposed on another transmission.
QTU	What are the hours during which your station is open?	My station is open from ... to ... hours.
QTV	Shall I stand guard for you on the frequency of ... kHz (*or* MHz) (from ... to ... hours)?	Stand guard for me on the frequency of ... kHz (*or* MHz) (from ... to ... hours).
QTW*	What is the condition of survivors?	Survivors are in ... condition and urgently need ...
QTX		I will keep my station open for further communication with

	Will you keep your station open for further communication with me until further notice (*or* until ... hours)?	you until further notice (*or* until ... hours).
QTY*	Are you proceeding to the position of incident and if so when do you expect to arrive?	I am proceeding to the position of incident and expect to arrive at ... hours (on ... (*date*)).
QTZ*	Are you continuing the search?	I am continuing the search for ... (aircraft, ship, survival craft, survivors or wreckage).
QUA	Have you news of ... (*call sign*)?	Here is news of ... (*call sign*).
QUB*	Can you give me in the following order information concerning: the direction in degrees TRUE and speed of the surface wind; visibility; present weather; and amount, type and height of base of cloud above surface elevation at ... (*place of observation*)?	Here is the information requested: ... (*The units used for speed and distances should be indicated.*)
QUC	What is the number (*or other indication*) of the last message you received from me (*or* from ... (*call sign*))?	The number (*or other indication*) of the last message I received from you (*or* from ... (*call sign*)) is ...
QUD	Have you received the urgency signal sent by ... (*call sign of mobile station*)?	I have received the urgency signal sent by ... (*call sign of mobile station*) at ... hours.
QUE	Can you use telephony in ... (*language*), with interpreter if necessary; if so, on what frequencies? [AP13] *or* Can you speak in ... (*language*), - with interpreter if necessary; if so, on what frequencies? [AP14]	I can use telephony in ... (*language*) on ... kHz (*or* MHz). [AP13] *or* I can speak in ... (*language*) on ... kHz (*or* MHz). [AP14]
QUF		

	Have you received the distress signal sent by ... (*call sign of mobile station*)?	I have received the distress signal sent by ... (*call sign of mobile station*) at ... hours.
QUG	Will you be forced to alight (*or* land)? [AP13]	I am forced to alight (*or* land) immediately. *or* I shall be forced to alight (*or* land) at ... (position or place) at ... hours. [AP13]
QUH*	Will you give me the present barometric pressure at sea level?	The present barometric pressure at sea level is ... (*units*).
QUI	Are your navigation lights working? [AP13]	My navigation lights are working. [AP13]
QUJ	Will you indicate the TRUE track to reach you (*or* ...)? [AP13]	The TRUE track to reach me (*or* ...) is ... degrees at ... hours. [AP13]
QUK	Can you tell me the condition of the sea observed at ... (place or coordinates)? [AP13]	The sea at ... (place or coordinates) is ... [AP13]
QUL	Can you tell me the swell observed at ... (place or coordinates)? [AP13]	The swell at ... (place or coordinates) is ... [AP13]
QUM	May I resume normal working?	Normal working may be resumed.
QUN	*1. When directed to all stations:* [AP13,14] Will vessels in my immediate vicinity ... *or* (in the vicinity of ... latitude, ... longitude) *or* (in the vicinity of ...) please indicate	My position, TRUE course and speed are ...

	their position, TRUE course and speed? *or* *2. When directed to a single station:* [AP14] please indicate their position, TRUE course and speed?	
QUO*	Shall I search for ... 1. aircraft 2. ship 3. survival craft in the vicinity of ... latitude, ... longitude (*or according to any other indication*)?	Please search for ... 1. aircraft 2. ship 3. survival craft in the vicinity of ... latitude, ... longitude (*or according to any other indication*).
QUP	Will you indicate your position by 1. searchlight 2. black smoke trail 3. pyrotechnic lights?	My position is indicated by 1. searchlight 2. black smoke trail 3. pyrotechnic lights.
QUQ	Shall I train my searchlight nearly vertical on a cloud, occulting if possible and, if your aircraft is seen, deflect the beam up wind and on the water (*or* land) to facilitate your landing?	Please train your searchlight on a cloud, occulting if possible and, if my aircraft is seen or heard, deflect the beam up wind and on the water (*or* land) to facilitate my landing. [AP13]
QUR*	Have survivors ... 1. received survival equipment 2. been picked up by rescue vessel 3. been reached by ground rescue party?	Survivors ... 1. are in possession of survival equipment dropped by ... 2. have been picked up by rescue vessel 3. have been reached by ground rescue party.
QUS*	Have you sighted survivors or wreckage? If so, in what position?	Have sighted ... 1. survivors in water 2. survivors on rafts 3. wreckage

		in position ... latitude, ... longitude (*or according to any other indication*).
QUT*	Is position of incident marked?	Position of incident is marked by ... 1. flame or smoke float 2. sea marker 3. sea marker dye 4. ... (*specify other marking*).
QUU*	Shall I home ship or aircraft to my position?	Home ship or aircraft ... (*call sign*) ... 1. to your position by transmitting your call sign and long dashes on ... kHz (*or* MHz) 2. by transmitting on ... kHz (*or* MHz) TRUE track to reach you.
QUW*	Are you in the search area designated as ... (*designator or latitude and longitude*)?	I am in the ... (*designation*) search area.
QUX	Do you have any navigational warnings or gale warnings in force? [AP14]	I have the following navigational warning(s) or gale warning(s) in force: ... [AP14]
QUY*	Is position of survival craft marked?	Position of survival craft was marked at ... hours by ... 1. flame or smoke float 2. sea marker 3. sea marker dye 4. ... (*specify other marking*).
QUZ	May I resume restricted working? [AP14]	Distress phase still in force; restricted working may be resumed. [AP14]

Amateur radio

Amateur radio actually has adapted two different sets of Q codes for use in amateur communications. The first set come from the ITU civil series QRA through QUZ. Most of the meanings are identical to the ITU definitions, however, they must be looked at in the context of amateur communications. For example, QSJ? asks what the charges are for sending the telegraph. Since amateur communications are without charge, this Q code would not make sense.

The second set is the set of QN Signals, used only in ARRL NTS nets. These operating signals generally have no equivalent in the ACP 131 publication or ITU publications, and are specifically defined only for use in ARRL NTS nets. They are not used in casual amateur radio communications.[11][12]

Selected Q codes were soon adopted by amateur radio operators. In December 1915, the American Radio Relay League began publication of a magazine titled *QST*, named after the Q code for "General call to all stations". In amateur radio, the Q codes were originally used in Morse code transmissions to shorten lengthy phrases and were followed by a Morse code question mark (··— —··) if the phrase was a question.

Q codes are commonly used in voice communications as shorthand nouns, verbs, and adjectives making up phrases. For example, an amateur radio operator will complain about QRM (man-made interference), or tell another operator that there is "QSB on the signal" (fading); "to QSY" is to change your operating frequency, or to break in on a conversation QSK is often used even on VHF and UHF frequencies. (See also Informal usage, below.)

Q codes as adapted for use in amateur radio

Code	Question	Answer or Statement
QLE	What is your expected signal?	The expected signal is low...
QNI	May I join the net?	You may check in...
QRA	What is the name (or call sign) of your station?	The name (or call sign) of my station is ...
QRG	Will you tell me my exact frequency (or that of ...)?	Your exact frequency (or that of ...) is ... kHz (or MHz).
QRH	Does my frequency vary?	Your frequency varies.
QRI	How is the tone of my transmission?	The tone of your transmission is (1. Good; 2. Variable; 3. Bad)
QRJ	How many voice contacts do you want to make?	I want to make ... voice contacts.
QRK	What is the readability of my signals (or those of ...)?	The readability of your signals (or those of ...) is ... (1 to 5).
QRL	Are you busy?	I am busy. (or I am busy with ...) Please do not interfere.
QRM	Do you have interference? [from other stations]	I have interference.
QRN	Are you troubled by static?	I am troubled by static.
QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRQ	Shall I send faster?	Send faster (... wpm)
QRS	Shall I send more slowly?	Send more slowly (... wpm)
QRT	Shall I cease or suspend operation?/ shutoff the radio	I am suspending operation. /shutting off the radio
QRU	Have you anything for me?	I have nothing for you.
QRV	Are you ready?	I am ready.
QRW	Shall I inform ... that you are calling him on ... kHz (or MHz)?	Please inform ... that I am calling him on ... kHz (or MHz).
QRX		

	Shall I standby / When will you call me again?	Please standby / I will call you again at ... (hours) on ... kHz (or MHz)
QRZ	Who is calling me?	You are being called by ... on ... kHz (or MHz)
QSA	What is the strength of my signals (or those of ...)?	The strength of your signals (or those of ...) is ... (1 to 5).
QSB	Are my signals fading?	Your signals are fading.
QSD	Is my keying defective?	Your keying is defective.
QSG	Shall I send ... telegrams (messages) at a time?	Send ... telegrams (messages) at a time.
QSK	Can you hear me between your signals?	I can hear you between my signals.
QSL	Can you acknowledge receipt?	I am acknowledging receipt.
QSM	Shall I repeat the last telegram (message) which I sent you, or some previous telegram (message)?	Repeat the last telegram (message) which you sent me (or telegram(s) (message(s)) numbers(s) ...).
QSN	Did you hear me (or ... (call sign)) on .. kHz (or MHz)?	I did hear you (or ... (call sign)) on ... kHz (or MHz).
QSO	Can you communicate with ... direct or by relay?	I can communicate with ... direct (or by relay through ...).
QSP	Will you relay a message to ...?	I will relay a message to ... .
QSR	Do you want me to repeat my call?	Please repeat your call; I did not hear you.
QSS	What working frequency will you use?	I will use the working frequency ... kHz (or MHz).
QST	–	Here is a broadcast message to all amateurs.
QSU	Shall I send or reply on this frequency (or on ... kHz (or MHz))?	Send or reply on this frequency (or on ... kHz (or MHz)).
QSW		

	Will you send on this frequency (or on ... kHz (or MHz))?	I am going to send on this frequency (or on ... kHz (or MHz)).
QSX	Will you listen to ... (call sign(s) on ... kHz (or MHz))?	I am listening to ... (call sign(s) on ... kHz (or MHz))
QSY	Shall I change to transmission on another frequency?	Change to transmission on another frequency (or on ... kHz (or MHz)).
QSZ	Shall I send each word or group more than once?	Send each word or group twice (or ... times).
QTA	Shall I cancel telegram (message) No. ... as if it had not been sent?	Cancel telegram (message) No. ... as if it had not been sent.
QTC	How many telegrams (messages) have you to send?	I have ... telegrams (messages) for you (or for ...).
QTH	What is your position in latitude and longitude (or according to any other indication)?	My position is ... latitude...longitude
QTR	What is the correct time?	The correct time is ... hours
QTU	At what times are you operating?	I am operating from ... to ... hours.
QTX	Will you keep your station open for further communication with me until further notice (or until ... hours)?	I will keep my station open for further communication with you until further notice (or until ... hours).
QUA	Have you news of ... (call sign)?	Here is news of ... (call sign).
QUC	What is the number (or other indication) of the last message you received from me (or from ... (call sign))?	The number (or other indication) of the last message I received from you (or from ... (call sign)) is ...
QUD	Have you received the urgency signal sent by ... (call sign of mobile station)?	I have received the urgency signal sent by ... (call sign of mobile station) at ... hours.
QUE	Can you speak in ... (language), – with interpreter if necessary; if so, on what frequencies?	I can speak in ... (language) on ... kHz (or MHz).
QUF		

	Have you received the distress signal sent by ... (call sign of mobile station)?	I have received the distress signal sent by ... (call sign of mobile station) at ... hours.

Notes for response to radiotelegraph Q-codes: Responses to a radiotelegraph Q-code query or a Q-code assertion may vary depending upon the code. For Q-code assertions or queries which only need to be acknowledged as received, the usual practice is to respond with the letter "R" for "Roger" which means "Received correctly". Sending an "R" merely means the code has been correctly received and does not necessarily mean that the receiving operator has taken any other action. For Q-code queries that need to be answered in the affirmative, the usual practice is to respond with the letter "C" (Sounds like the Spanish word "Si"). For Q-code queries that need to be answered in the negative, the usual practice it to respond with the letter "N" for "no". For those Q-code assertions that merely need to be acknowledged as understood, the usual practice is to respond with the prosign <SN> or <VE> which means "understood". On telegraph cable networks "KK" was often used at the end of a reply to a Q Code to mean "OK" or "Acknowledged". This practice predates amateur radio as telegraph operators in the late 19th Century are known to have used it.

Informal usage

QLF – "Are you sending with your left foot? Try sending with your left foot!" A humorously derogative comment about the quality of a persons sending. [14][15]

QSK – "I can hear you during my transmission" – refers to a particular mode of Morse code operating often called QSK operation (full break-in) in which the receiver is quickly enabled during the spaces between the dits and dahs, which allows another operator to interrupt transmissions. Many modern transceivers incorporate this function, sometimes referred to as *full break-in* as against *semi-break-in* in which there is a short delay before the transceiver goes to receive.[16]

QSY – "Change to transmission on another frequency"; colloquially, "move [=change address]". E.g., "When did GKB (http://www.qsl.net/gm3zdh/coast/uk/gka/closedown/final-msg.htm) QSY from Northolt to Portishead....?"[17]

QTH – "My location is…"; colloquially in voice or writing, "location". E.g., "The OCF *[antenna]* is an interesting build but at my QTH a disappointing performer."[18]

QTHR – "At the registered location…"; Chiefly British in voice or writing, "Historically - the location in the printed Callbook. Modernly - as given in online government records for my callsign". E.g., "You can contact me QTHR"[19]

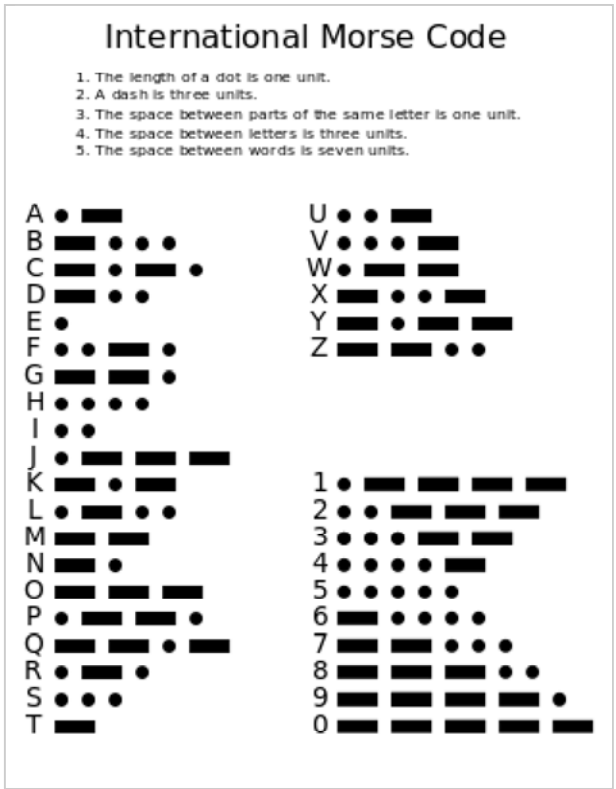

Chart of the Morse code letters and numerals.[13]

German use during World War II

During World War II, according to Bletchley Park's *General Report on Tunny,* [20] German radio teleprinter networks used Q-codes to establish and maintain circuit connections.

In particular: **QKP** was to indicate the Lorenz cipher machine setting for each message and, **QZZ** to indicate that the daily key change was about to take place at the sender's station.

See also

- ACP-131
- Amateur radio
- Brevity code
- International Code of Signals
- International maritime signal flags
- Morse code
- Prosigns for Morse code

- QSK operation (full break-in)
- Ten-code
- Z code

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External links

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- Handbook for Wireless Telegraph Operators (http://www.telegraph-office.com/pages/q-signals-1909.html), October, 1909.
- Radio Laws and Regulations of the United States: Edition July 27, 1914 (http://www.earlyradiohistory.us/1914reg.htm). (Includes the 1912 London Radiotelegraphic Convention)
- List of Q codes (http://www.kloth.net/radio/qcodes.php)
- A resource for Morse Code operation in the amateur radio hobby (http://cw.hfradio.org/)
- Amateur Radio Q Codes (http://www.yourprepconnection.com/attachments/history-q-coes.pdf)
- "Q-Signals" (http://www.zerobeat.net/qrp/qsignals.html)
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Categories: Amateur radio | Encodings | Morse code | Telegraphy | Brevity codes | 1909 introductions

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Qigong

From Wikipedia, the free encyclopedia

Qigong, **qi gong**, **chi kung**, or **chi gung** (simplified Chinese: 气功; traditional Chinese: 氣功; pinyin: *qìgōng*; Wade–Giles: *chi gong*; literally: "Life Energy Cultivation") is a holistic system of coordinated body posture and movement, breathing, and meditation used for health, spirituality, and martial arts training. With roots in Chinese medicine, philosophy, and martial arts, qigong is traditionally viewed as a practice to cultivate and balance qi (chi), translated as "life energy".[1]

According to Taoist, Buddhist, and Confucian philosophy, qigong allows access to higher realms of awareness, awakens one's "true nature", and helps develop human potential.[2]

Qigong practice typically involves moving meditation, coordinating slow flowing movement, deep rhythmic breathing, and calm meditative state of mind. Qigong is now practiced throughout China and worldwide for recreation, exercise and relaxation, preventive medicine and self-healing, alternative medicine, meditation and self-cultivation, and training for martial arts.

Over the centuries, a diverse spectrum of qigong forms developed in different segments of Chinese society. Traditionally, qigong training has been esoteric and secretive, with knowledge passed from adept master to student in lineages that maintain their own unique interpretations and methods. Qigong practices were brought to the public beginning in the 1950s, when the Communist Party institutionalized and began research into traditional Chinese medicine. Although the practice of qigong was prohibited during the Cultural Revolution of the 1960s; it was once again allowed after 1976. On account of the political climate at the time, the emphasis of qigong practices shifted away from traditional philosophy and cultivation, and increasingly focused health benefits, medicine and martial arts applications, and a scientific perspective. Since a 1999 crackdown,

Qigong

Qigong practitioners at World Tai Chi and Qigong Day event in Manhattan.

Chinese name	
Traditional Chinese	氣功
Simplified Chinese	气功
Transcriptions	
Standard Mandarin	
Hanyu Pinyin	qìgōng
Wade–Giles	chi-kung
Tongyong Pinyin	cìgōng
Yale Romanization	chìgūng
IPA	[tɕʰîkʊ́ŋ]
Wu	
Romanization	chi去 khon平
Yue: Cantonese	
Yale Romanization	hei gūng
IPA	[hēi.kʊ́ŋ]
Jyutping	hei3 gung1
Southern Min	
Hokkien POJ	khì-kong
Korean name	
Hangul	기공
Hanja	氣功
Transcriptions	

practice of qigong in China has been restricted. Over the same period, interest in qigong has spread, with millions of practitioners worldwide.

Research concerning qigong has been conducted for a wide range of medical conditions, including hypertension, pain, and cancer treatment. Most systematic reviews of clinical trials have not been conclusive, and all have been based on poor quality clinical studies, such that no firm conclusions about the health effects of qigong can be drawn at this stage.[3]

Revised Romanization	gigong
McCune–Reischauer	kikong
Japanese name	
Hiragana	きこう
Kyūjitai	氣功
Shinjitai	気功
Transcriptions	
Romanization	kikō

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Etymology

Qigong (Pinyin), ch'i kung (Wade-Giles), and chi gung (Yale) are English words for two Chinese characters: ***qì*** (氣) and ***gōng*** (功).

Qi (or *chi*) is often translated as life energy,[1] referring to energy circulating through the body; though a more general definition is universal energy, including heat, light, and electromagnetic energy;[4] and definitions often involve breath, air, gas, or relationship between matter, energy, and spirit.[5] Qi is the central underlying principle in traditional Chinese medicine and martial arts. *Gong* (or *kung*) is often translated as cultivation or work, and definitions include practice, skill, mastery, merit, achievement, service, result, or accomplishment, and is often used to mean gongfu (kung fu) in the traditional sense of achievement through great effort.[6] The two words are combined to describe systems to cultivate and balance life energy, especially for health.[1]

Although the term qigong (氣功) has been traced back to Daoist literature of the early Tang Dynasty (618-907 AD), the term *qigong* as currently used was promoted in the late 1940s through the 1950s to refer to a broad range of Chinese self-cultivation exercises, and to emphasize health and scientific approaches, while de-emphasizing spiritual practices, mysticism, and elite lineages.[7][8][9]

History and origins

With roots in ancient Chinese culture dating back more than 4,000 years, a wide variety of qigong forms have developed within different segments of Chinese society:[10] in traditional Chinese medicine for preventive and curative functions,[11] in Confucianism to promote longevity and improve moral character,[1] in Daoism and Buddhism as part of meditative practice,[2] and in Chinese martial arts to enhance fighting abilities.[8][12] Contemporary qigong blends diverse and sometimes disparate traditions, in particular the Daoist meditative practice of "internal alchemy" (Neidan 内丹术), the ancient meditative practices of "circulating qi" (Xing qi 行氣) and "standing meditation" (Zhan zhuang 站桩), and the slow gymnastic breathing exercise of "guiding and pulling" (Dao yin 導引). Traditionally, knowledge about qigong was passed from adept master to student in elite unbroken lineages, typically with

The physical exercise chart; a painting on silk depicting the practice of Qigong Taiji; unearthed in 1973 in Hunan Province, China, from the 2nd-century BC Western Han burial site of Mawangdui Han tombs site, Tomb Number 3.

secretive and esoteric traditions of training and oral transmission,[13] and with an emphasis on meditative practice by scholars and gymnastic or dynamic practice by the working masses.[14]

Starting in the late 1940s and the 1950s, the mainland Chinese government tried to integrate disparate qigong approaches into one coherent system, with the intention of establishing a firm scientific basis for qigong practice. In 1949, Liu Guizhen established the name "Qigong" to refer to the system of life preserving practices that he and his associates developed based on Dao yin and other philosophical traditions.[15] This attempt is considered by some sinologists as the start of the modern or scientific interpretation of qigong.[16][17][18] During the Great Leap Forward (1958–1963) and the Cultural Revolution (1966–1976), qigong, along with other traditional Chinese medicine, was under tight control with limited access among the general public, but was encouraged in state-run rehabilitation centers and spread to universities and hospitals. After the Cultural Revolution, qigong, along with t'ai chi, was popularized as daily morning exercise practiced en masse throughout China.

Popularity of qigong grew rapidly during the Deng and Jiang eras after Mao Zedong's death in 1976 through the 1990s, with estimates of between 60 and 200 million practitioners throughout China. Along with popularity and state sanction came controversy and problems: claims of extraordinary abilities bordering on the supernatural, pseudoscience explanations to build credibility,[19] a mental condition labeled qigong deviation,[18] formation of cults, and exaggeration of claims by masters for personal benefit.[7][20] In 1985, the state-run "National Qigong Science and Research Organization" was established to regulate the nation's qigong denominations.[21] In 1999, in response to widespread revival of old traditions of spirituality, morality, and mysticism, and perceived challenges to State control, the Chinese government took measures to enforce control of public qigong practice, including shutting down qigong clinics and hospitals, and banning groups such as Zhong Gong and Falun Gong.[9]:161–174[22] Since the 1999 crackdown, qigong research and practice have only been officially supported in the context of health and traditional Chinese medicine. The Chinese Health Qigong Association, established in 2000, strictly regulates public qigong practice, with limitation of public gatherings, requirement of state approved training and certification of instructors, and restriction of practice to state-approved forms.[23][24]

Through the forces of migration of the Chinese diaspora, tourism in China, and globalization, the practice of qigong spread from the Chinese community to the world. Today, millions of people around the world practice qigong and believe in the benefits of qigong to varying degrees. Similar to its historical origin, those interested in qigong come from diverse backgrounds and practice it for different reasons, including for recreation, exercise, relaxation, preventive medicine, self-healing, alternative medicine, self-cultivation, meditation, spirituality, and martial arts training.

Overview

Practices

Qigong comprises a diverse set of practices that coordinate body (調身), breath (調息), and mind (調心) based on Chinese philosophy.[25][26] Practices include moving and still meditation, massage, chanting, sound meditation, and non-contact treatments, performed in a broad array of body postures. Qigong is

commonly classified into two foundational categories: 1) dynamic or active qigong (dong gong), with slow flowing movement; and 2) meditative or passive qigong (jing gong), with still positions and inner movement of the breath.[27]:21770–21772 From a therapeutic perspective, qigong can be classified into two systems: 1) internal qigong, which focuses on self-care and self-cultivation, and; 2) external qigong, which involves treatment by a therapist who directs or transmits qi.[27]:21777–21781

As moving meditation, qigong practice typically coordinates slow stylized movement, deep diaphragmatic breathing, and calm mental focus, with visualization of guiding qi through the body. While implementation details vary, generally qigong forms can be characterized as a mix of four types of practice: dynamic, static, meditative, and activities requiring external aids.

- Dynamic practice

  involves fluid movement, usually carefully choreographed, coordinated with breath and awareness. Examples include the slow stylized movements of T'ai chi ch'uan, Baguazhang, and Xing yi.[28] Other examples include graceful movement that mimics the motion of animals in Five Animals (Wu Qin Xi qigong),[29] White Crane,[30] and Wild Goose (Dayan) Qigong.[31][32] As a form of gentle exercise, qigong is composed of movements that are typically repeated, strengthening and stretching the body, increasing fluid movement (blood, synovial, and lymph), enhancing balance and proprioception, and improving the awareness of how the body moves through space.[33]

- Static practice

  involves holding postures for sustained periods of time.[34] In some cases this bears resemblance to the practice of Yoga and its continuation in the Buddhist tradition.[35] For example Yiquan, a Chinese martial art derived from xingyiquan, emphasizes static stance training.[36] In another example, the healing form Eight Pieces of Brocade (Baduanjin qigong) is based on a series of static postures.[37]

- Meditative practice

  utilizes breath awareness, visualization, mantra, chanting, sound, and focus on philosophical concepts such as qi circulation, aesthetics, or moral values.[38] In traditional Chinese medicine and Daoist practice, the meditative focus is commonly on cultivating qi in dantian energy centers and balancing qi flow in meridian and other pathways. In various Buddhist traditions, the aim is to still the mind, either through outward focus, for example on a place, or through inward focus on the breath, a mantra, a koan, emptiness, or the idea of the eternal. In the Confucius scholar tradition, meditation is focused on humanity and virtue, with the aim of self-enlightenment.[10]

- Use of external agents

  Many systems of qigong practice include the use of external agents such as ingestion of herbs, massage, physical manipulation, or interaction with other living organisms.[2] For example, specialized food and drinks are used in some medical and Daoist forms, whereas massage and body manipulation are sometimes used in martial arts forms. In some medical systems a qigong master uses non-contact treatment, purportedly guiding qi through his or her own body into the body of another person.[39]

Forms

There are numerous qigong forms. 75 ancient forms that can be found in ancient literature and also 56 common or contemporary forms have been described in a qigong compendium.[40]:203–433 The list is by no means exhaustive. Many contemporary forms were developed by people who had recovered from their illness after qigong practice.

In 2003, the Chinese Health Qigong Association officially recognized four health qigong forms:[41]

- Muscle-Tendon Change Classic (Yì Jīn Jīng 易筋经).[42][43]
- Five Animals (Wu Qin Xi 五禽戲).[44]
- Six Healing Sounds (Liu Zi Jue 六字訣).[45]
- Eight Pieces of Brocade (Ba Duan Jin 八段錦).[46]

In 2010, the Chinese Health Qigong Association officially recognized five additional health qigong forms:[47]

- Tai Chi Yang Sheng Zhang (太极养生杖): a tai chi form from the stick tradition.
- Shi Er Duan Jin (十二段锦): seated exercises to strengthen the neck, shoulders, waist, and legs.
- Daoyin Yang Sheng Gong Shi Er Fa (导引养生功十二法): 12 routines from Daoyin tradition of guiding and pulling qi.
- Mawangdui Daoyin (马王堆导引术): guiding qi along the meridians with synchronous movement and awareness.
- Da Wu (大舞): choreographed exercises to lubricate joints and guide qi.

Other commonly practiced qigong styles and forms include:

- Soaring Crane Qigong[48]
- Wisdom Healing Qigong[49]
- Pan Gu Mystical Qigong[50]
- Wild Goose (Dayan) Qigong[51]
- Dragon and Tiger Qigong[52]
- Primordial Qigong (Wujigong)[53][54]

Techniques

Whether viewed from the perspective of exercise, health, philosophy, or martial arts training, several main principles emerge concerning the practice of qigong:[1][33][55][56]

- **Intentional movement**: careful, flowing balanced style
- **Rhythmic breathing**: slow, deep, coordinated with fluid movement
- **Awareness**: calm, focused meditative state
- **Visualization**: of qi flow, philosophical tenets, aesthetics
- **Chanting/Sound**: use of sound as a focal point

Additional principles:

- **Softness**: soft gaze, expressionless face
- **Solid Stance**: firm footing, erect spine
- **Relaxation**: relaxed muscles, slightly bent joints
- **Balance and Counterbalance**: motion over the center of gravity

Advanced goals:

- **Equanimity**: more fluid, more relaxed
- **Tranquility**: empty mind, high awareness
- **Stillness**: smaller and smaller movements, eventually to complete stillness

The most advanced practice is generally considered to be with little or no motion.

Traditional and classical theory

Over time, five distinct traditions or schools of qigong developed in China, each with its own theories and characteristics: Chinese Medical Qigong, Daoist Qigong, Buddhist Qigong, Confucian Qigong, and martial arts qigong.[57]:30–80 All of these qigong traditions include practices intended to cultivate and balance qi.[10][58][59][60]

Qigong practitioners in Brazil

Traditional Chinese medicine

The theories of ancient Chinese Medical Qigong include the Yin-Yang and Five Phases Theory, Essence-Qi-Spirit Theory, Zang-Xiang Theory, and Meridians and Qi-Blood Theory, which have been synthesized as part of Traditional Chinese Medicine (TCM).[57]:45–57 TCM focuses on tracing and correcting underlying disharmony, in terms of deficiency and excess, using the complementary and opposing forces of yin and yang (陰陽), to create a balanced flow of qi. Qi is believed to be cultivated and stored in three main dantian energy centers and to travel through the body along twelve main meridians (Jīng Luò 經絡), with numerous smaller branches and tributaries. The main meridians correspond to twelve main organs (Zàng fǔ 臟腑)). Qi is balanced in terms of yin and yang in the context of the traditional system of Five Phases (Wu xing 五行).[10][11] A person is believed to become ill or die when qi becomes diminished or unbalanced. Health is believed to be returned by rebuilding qi, eliminating qi blockages, and correcting qi imbalances. These TCM concepts do not translate readily to modern science and medicine.

Daoism

In Daoism various practices now known as Daoist Qigong are claimed to provide a way to achieve longevity and spiritual enlightenment,[61] as well as a closer connection with the natural world.[62]

Buddhism

In Buddhism meditative practices now known as Buddhist Qigong are part of a spiritual path that leads

to spiritual enlightenment or Buddhahood.[63]

Confucianism

In Confucianism practices now known as Confucian Qigong provide a means to become a Junzi (君子) through awareness of morality.[64][65]

Contemporary Qigong

In contemporary China, the emphasis of qigong practice has shifted away from traditional philosophy, spiritual attainment, and folklore, and increasingly to health benefits, traditional medicine and martial arts applications, and a scientific perspective.[7][9] Qigong is now practiced by millions worldwide, primarily for its health benefits, though many practitioners have also adopted traditional philosophical, medical, or martial arts perspectives, and even use the long history of qigong as evidence of its effectiveness.[10][55]

Contemporary Chinese medical qigong

Qigong has been recognized as a "standard medical technique" in China since 1989, and is sometimes included in the medical curriculum of major universities in China.[66]:34 The 2013 English translation of the official Chinese Medical Qigong textbook used in China[57]:iv,385 defines CMQ as "the skill of body-mind exercise that integrates body, breath, and mind adjustments into one" and emphasizes that qigong is based on "adjustment" (tiao 調, also translated as “regulation”, “tuning”, or “alignment.”) of body, breath, and mind.[57]:16–18 As such, qigong is viewed by practitioners as being more than common physical exercise, because qigong combines postural, breathing, and mental training in one to produce a particular psychophysiological state of being.[57]:15 While CMQ is still based on traditional and classical theory, modern practitioners also emphasize the importance of a strong scientific basis.[57]:81–89 According to the 2013 CMQ textbook, physiological effects of qigong are numerous, and include improvement of respiratory and cardiovascular function, as well as possible beneficial effects on neurophysiology.[57]:89–102

Conventional medicine

Conventional or mainstream medicine includes specific practices and techniques based on the best available evidence demonstrating effectiveness and safety.[67] Qigong is not generally considered to be part of mainstream medicine because clinical research concerning effectiveness of qigong for specific medical conditions is inconclusive at this stage,[3] and because at present there is no medical consensus concerning effectiveness of qigong.

Integrative, complementary, and alternative medicine

Integrative medicine (IM) refers to "the blending of conventional and complementary medicines and therapies with the aim of using the most appropriate of either or both modalities to care for the patient as a whole",[68]:455–456 whereas complementary generally refers to "using a non-mainstream approach together with conventional medicine", and alternative refers to "using a non-mainstream approach in place of conventional medicine".[69] Qigong is used by integrative medicine practitioners to complement conventional medical treatment, based on complementary and alternative medicine (CAM) interpretations of the effectiveness and safety of qigong.[27]:22278–22306

Scientific basis

Scientists interested in qigong have sought to describe or verify the effects of qigong, to explore mechanisms of effects, to form scientific theory with respect to Qigong, and to identify appropriate research methodology for further study.[57]:81–89 In terms of traditional theory, the existence of qi has not been independently verified in an experimental setting,[70] and the scientific basis for much of TCM and CAM has not been demonstrated.[71][72]

Health applications

Recreation and popular use

People practice qigong for many different reasons, including for recreation, exercise and relaxation, preventive medicine and self-healing, meditation and self-cultivation, and training for martial arts. In recent years a large number of books and videos have been published that focus primarily on qigong as exercise and associated health benefits. Practitioners range from athletes to the physically challenged. Because it is low impact and can be done lying, sitting, or standing, qigong is accessible for disabled persons, seniors, and people recovering from injuries.[1]

Therapeutic use

Therapeutic use of qigong is directed by TCM, CAM, integrative medicine, and other health practitioners. In China, where it is considered a "standard medical technique",[66]:34 qigong is commonly prescribed to treat a wide variety of conditions, and clinical applications include hypertension, coronary artery disease, peptic ulcers, chronic liver diseases, diabetes mellitus, obesity, menopause syndrome, chronic fatigue syndrome, insomnia, tumors and cancer, lower back and leg pain, cervical spondylosis, and myopia.[57]:261–391 Outside China qigong is used in integrative medicine to complement or supplement accepted medical treatments, including for relaxation, fitness, rehabilitation, and treatment of specific conditions.[68][73]

Effectiveness

Based on systematic reviews of clinical research, it is not advisable to draw conclusions concerning effectiveness of qigong for specific medical conditions at this stage.[3]

Safety and cost

Qigong is generally viewed as safe.[74] No adverse effects have been observed in clinical trials, such that qigong is considered safe for use across diverse populations. Cost for self-care is minimal, and cost efficiencies are high for group delivered care.[75] Typically the cautions associated with qigong are the same as those associated with any physical activity, including risk of muscle strains or sprains, advisability of stretching to prevent injury, general safety for use alongside conventional medical treatments, and consulting with a physician when combining with conventional treatment.[76]

Research

Overview of clinical research

Although clinical research examining health effects of qigong is increasing, there is little financial or medical incentive to support research, and still only a limited number of studies meet accepted medical and scientific standards of randomized controlled trials (RCTs).[75] Clinical research concerning qigong has been conducted for a wide range of medical conditions, including bone density, cardiopulmonary effects, physical function, falls and related risk factors, quality of life, immune function, inflammation,[75] hypertension,[77] pain,[78][79] and cancer treatment.[80] A 2011 overview of systematic reviews of clinical trials concluded that "the effectiveness of qigong is based mostly on poor quality research" and "therefore, it would be unwise to draw firm conclusions at this stage".[3] Although a 2010 comprehensive literature review found 77 peer-reviewed RCTs;[75] systematic reviews for particular health conditions show that most clinical research is of poor quality, typically because of small sample size and lack of proper control groups, with lack of blinding associated with high risk of bias.[3]

Systematic reviews of clinical research

A systematic review of the effect of qigong exercises on hypertension found that the available studies were encouraging for the exercises to lower systolic blood pressure. However, an analysis of the studies that found these results showed that they were of relatively poor quality, with the lack of blinding raising the possibility of bias in the results, so no definitive conclusions could be reached.[77] Another systematic review found that qigong exercises improved blood pressure compared to doing nothing, but was not superior to standard treatment such as medications or conventional exercise.[81]

A 2007 systematic review of the effect of qigong exercises on diabetes mellitus management concluded that there may be beneficial effects, but that no firm conclusions could be drawn due to the methodological problems with the underlying clinical trials studies, especially the lack of a control group.[82] A more recent 2009 systematic review found that due to the underlying methodological problems, "the evidence is insufficient to suggest that qigong is an effective treatment for type 2 diabetes".[83]

A systematic review on the effect of qigong exercises on reducing pain concluded that "the existing trial evidence is not convincing enough to suggest that internal qigong is an effective modality for pain management."[78] Another systematic review, which focused on external qigong and its effect on pain, concluded "that evidence for the effectiveness of external qigong is encouraging, though further studies are warranted" due to the small number of studies and participants involved which precluded any firm conclusions about the specific effects of qigong on pain.[79]

A systematic review of the effect of qigong exercises on cancer treatment concluded "the effectiveness of qigong in cancer care is not yet supported by the evidence from rigorous clinical trials."[80] A separate systematic review that looked at the effects of qigong exercises on various physiological or psychological outcomes found that the available studies were poorly designed, with a high of bias in the results. Therefore, the authors concluded, "Due to limited number of RCTs in the field and methodological problems and high risk of bias in the included studies, it is still too early to reach a conclusion about the efficacy and the effectiveness of qigong exercise as a form of health practice adopted by the cancer patients during their curative, palliative, and rehabilitative phases of the cancer journey."[84]

A systematic review of the effect of qigong exercises on movement disorders found that the evidence was insufficient to recommend its use for this purpose.[85]

Mental health research

Many claims have been made that qigong can benefit or ameliorate mental health conditions,[75] including improved mood, decreased stress reaction, and decreased anxiety and depression. Most medical studies have only examined psychological factors as secondary goals, although various studies have shown significant benefits such as decrease in cortisol levels, a chemical hormone produced by the body in response to stress.[75]

Research in China

Basic and clinical research in China during the 1980s was mostly descriptive, and few results were reported in peer-reviewed English-language journals.[27]:,22060–22063 A 1996 review of selected Chinese research concluded that there are many potential medical applications of qigong.[86] Qigong became known outside China in the 1990s, and clinical randomized controlled trials (RCTs) investigating the effectiveness of qigong on health and mental conditions began to be published worldwide, along with systematic reviews.[27]:21792–21798

Challenges for research

The White House Commission on Complementary and Alternative Medicine (CAM) Policy recognized challenges and complexities to rigorous research concerning effectiveness and safety of CAM therapies such as qigong; emphasized that research must adhere to the same standards as conventional research, including statistically significant sample sizes, adequate controls, definition of response specificity, and reproducibility of results; and recommended substantial increases in funding to for rigorous research.[87]

Most existing clinical trials have small sample sizes and many have inadequate controls. Of particular concern is the impracticality of double blinding using appropriate sham treatments, and the difficulty of placebo control, such that benefits often cannot be distinguished from the placebo effect.[27]:22278–22306[88]:22 Also of concern is the choice of which qigong form to use and how to standardize the treatment or dose with respect to the skill of the practitioner leading or administering treatment, the tradition of individualization of treatments, and the treatment length, intensity, and frequency.[27]:6869–6920,22361–22370[88]:130–133

Meditation and self-cultivation applications

Qigong is practiced for meditation and self-cultivation as part of various philosophical and spiritual traditions. As meditation, qigong is a means to still the mind and enter a state of consciousness that brings serenity, clarity, and bliss.[2] Many practitioners find qigong, with its gentle focused movement, to be more accessible than seated meditation.[55]

Qigong for self-cultivation can be classified in terms of traditional Chinese philosophy: Daoist, Buddhist, and Confucian.

Martial arts applications

The practice of qigong is an important component in both internal and external style Chinese martial arts.[2] Focus on qi is considered to be a source of power as well as the foundation of the internal style of martial arts (Neijia). T'ai chi ch'uan, Xing yi, and Baguazhang are representative of the types of Chinese martial arts that rely on the concept of qi as the foundation.[89] Extraordinary feats of martial arts prowess, such as the ability to withstand heavy strikes (Iron Shirt, 鐵衫)[90] and the ability to break hard objects (Iron Palm, 铁掌)[91][92] are abilities attributed to qigong training.

T'ai chi ch'uan and qigong

T'ai chi ch'uan (Taijiquan) is a widely practiced Chinese internal martial style based on the theory of taiji ("grand ultimate"), closely associated with qigong, and typically involving more complex choreographed movement coordinated with breath, done slowly for health and training, or quickly for self-defense. Many scholars consider t'ai chi ch'uan to be a type of qigong, traced back to an origin in the seventeenth century. In modern practice, qigong typically focuses more on health and meditation rather than martial applications, and plays an important role in training for t'ai chi ch'uan, in particular used to build strength, develop breath control, and increase vitality ("life energy").[28][93]

See also

- Asahi Health
- Cybersectarianism
- Falun Gong
- Hua Tuo
- Jing (TCM)
- Physiotherapy
- List of ineffective cancer treatments
- Mind-body problem

- Mindfulness (Buddhism)
- Neidan
- Neigong
- Prana
- Silk reeling
- Sima Nan
- Tao Yin
- Taoist sexual practices
- World Tai Chi and Qigong Day
- Zhong Gong

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External links

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Categories: Chinese martial arts | Chinese words and phrases | Meditation | Qigong | Taoist philosophy | Biofield therapies

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Quad / Riding Mower Cover

Material List:

All Parts 3/4inch PVC Plastic

Item	Qty	Description
A	2	90deg Elbow
B	10	45deg Elbow
C	4	Tee
D	4	Slip Tee
E	2	Crosses
F	4	3-way Corners
G	3	4-way Corners
H	2	60inch Pipe
I	2	10inch Pipe
J	22	42inch Pipe
K	10	1-1/2inch Pipe
L	26	3/4x4 Snap Clamps
M	1	12ft x 16ft Tarp

Assembly Steps:

1. Assemble Base and Sides as shown in Fig. 1
2. Assemble Roof Struts as shown in Fig. 2
   Slide items D onto Roof Struts before attaching 45deg elbows.
3. Assemble Roof Braces as shown in Fig.2
4. Attach Roof Struts to Sides using items K to connect 45deg elbows to side connectors as shown in Fig.2
5. Attach Tarp to structure using items L as shown in Fig.3
6. Attach a Tarp to front opening to make a complete enclosure if desired.

7. For Windy Conditions:
   Secure structure to the ground or to the side of a building and install a self tapping screw through the center of clamps to firmly secure them to the structure.

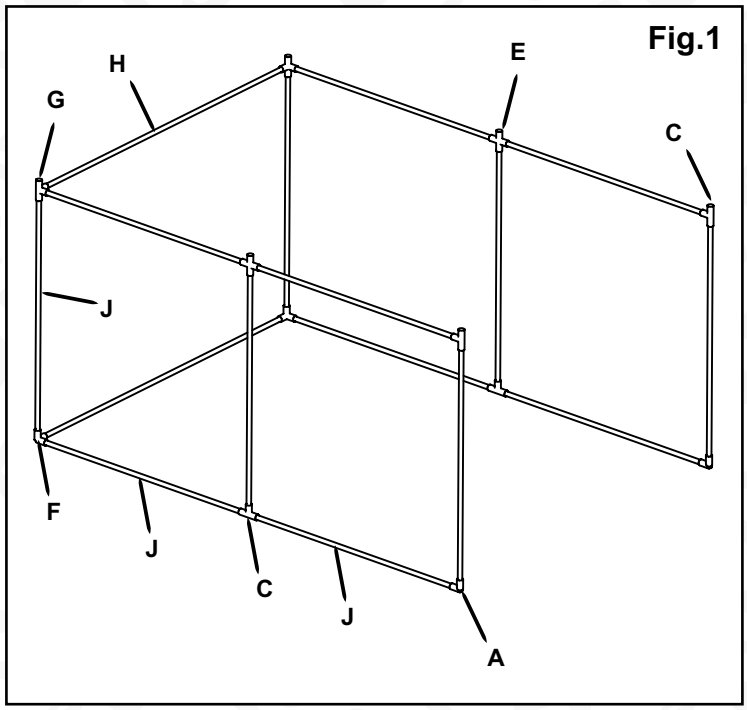

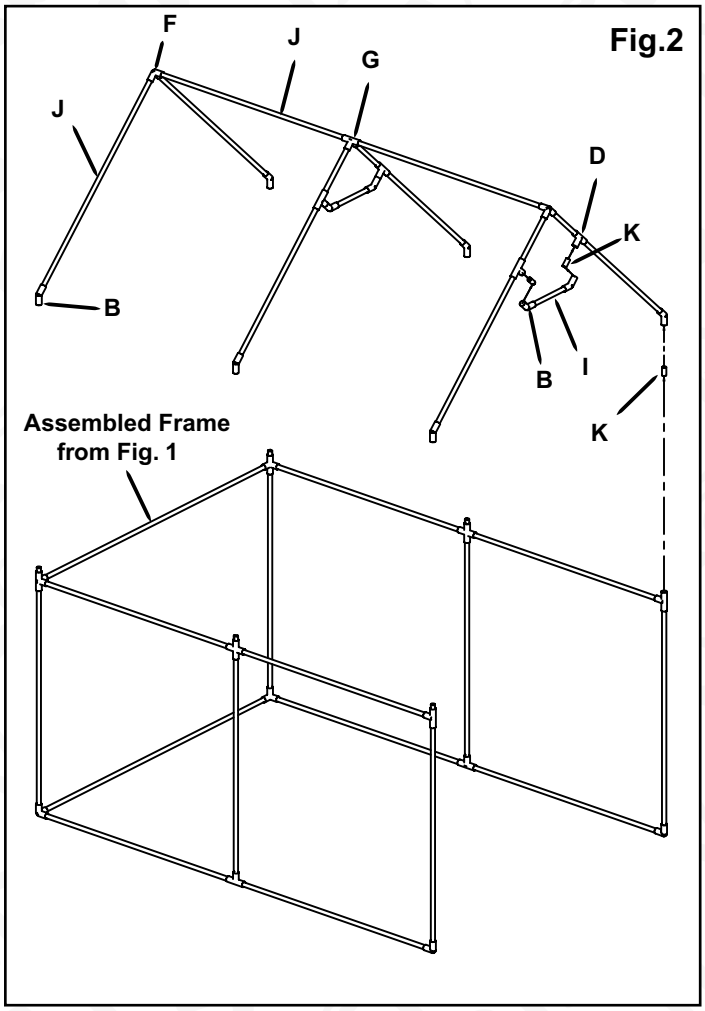

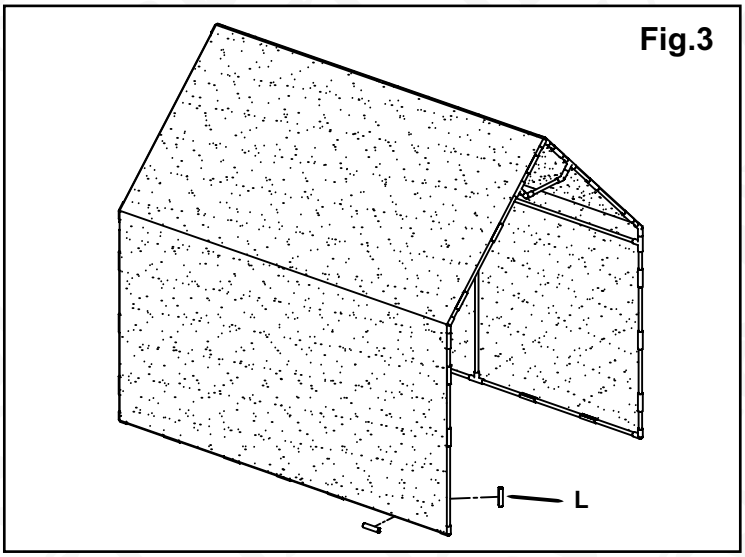

Assembly instructions prepared by:
Dean Hunt / JCDesign
hunt4.jcenews.com
Jan. 2002

Quadracycle

From Wikipedia, the free encyclopedia

A **quadracycle** is a four-wheeled human-powered land vehicle. It is also referred to as a **quadricycle**, **quadcycle**, **pedal car**, **four-wheeled bicycle** or **quike** amongst other terms.

A Rhoades Car 4W2P '4-wheel bike' parked on a Canadian urban street amongst the cars.

Human-powered quadracyles have been in use since 1853 and have grown into several families of vehicles for a variety of purposes, including tourist rentals, pedal taxis, private touring, mountain and industrial use.

Contents

- 1 Nomenclature
- 2 History
- 3 Modern quadracycles
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  - 3.2 Pedal taxi
  - 3.3 Touring
  - 3.4 Mountain quadracycles
  - 3.5 Industrial use
  - 3.6 Racing
  - 3.7 Performance art
- 4 Security
- 5 See also
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- 7 External links

Nomenclature

There is no consensus amongst manufacturers of four-wheeled, human-powered vehicles as to what this class of vehicles should be called, although *quadracycle* is the most commonly used term. Manufacturers who do refer to their products by class of vehicle call them:

- Quadracycle - 11 manufacturers[2][3][4][5][6][7][8][9]
- Four-wheel bicycle - 7 manufacturers[10][11][12][13][14][15][16]
- Quadricycle - 5 manufacturers[1][8][16][17][18]
- Quadcycle - 3 manufacturers[19][20][21]
- Pedal car - 2 manufacturers[22][23]
- Quad - 2 manufacturers[24][25]

As well there are single manufacturers who call them Go-kart,[26] Car,[27] Car-Bike,[28] Ecological car,[29]

Human Powered Vehicle,[30] Pedal Kart,[31] Quadribent,[32] Quattrocycle,[33] Surrey[34] and Twin bike[35]

A tourist rental quadricycle, a Quadricycle International Q-Cycle-6[1]

History

The earliest recorded pedal-powered quadracycle was exhibited in 1853 at the Exhibition of the Industry of All Nations World's Fair held in New York City.[36] This was about the same time that two-wheeled bicycles started to become popular. Quadracycles were one solution to the problem of low-speed stability in early cycles and were typically multi-seat models.[8] Both tandem (in line) and sociable (side-by-side) seating configurations were used.

1885 Coventry Rotary Quadracycle in Washington DC[8]

One early design, predating 1869 was the *Andrews Quadracycle*, built by Andrews of Dublin, Ireland. It was made from one inch-square iron and was propelled with foot levers that moved in a long horizontal ellipse. The *Sawyer Quadricycle* was introduced in 1855 and featured lighter construction, wooden wheels, iron tires and front-wheel steering via a tiller. Like the Andrews Quadracycle it was moved by foot levers driving the rear axle. Starley's *Coventry Rotary Quadracycle* was introduced in 1885 and used conventional bicycle-style rotary pedals instead of foot levers for drive. It was developed from Starley's *Coventry Rotary Tricycle* design and featured tandem seating for two. The *Rudge Quadracycle* of 1888 is described as the first modern practical four-wheeler. It had much lighter construction than earlier models, seated three riders in tandem and was steered by levers from the front seat.[8]

Coventry Rotary Quadracycle (1885) in the Dutch national cycling museum, Velorama, Nijmegen, Netherlands[8]

Early in the twentieth century Massey-Harris in Canada developed the *Canadian Royal Mail Quadracycle*. This was used for mail delivery in Toronto as early as 1901.[8] The Gendron Wheel Company created children's toy replica pedal cars up until World War II.[37][38]

Modern quadracycles

Quadracycle use diminished in the late 19th century as a result of improvements in bicycle technology that made their four-wheel cousins largely obsolete, although small numbers were manufactured through the 1950s for rental use in tourist areas.

A resurgence of 20th century quadracycle use occurred in France where Charles Mochet introduced his Velocar pedal powered two-seat quadracycle in 1924. The various models of the Velocar featured wooden aerodynamic bodies and usually a three speed transmission. Production of final pedal-powered Mochet Velocar Model H ended in 1938, but Mochet went on to become a manufacturer of automobiles. The Velocar proved quite popular, especially during World War II when the French population was under German occupation and gasoline was virtually unavailable for civil use. Restored Mochet Velocars are still found in France.[36][39]

During the 1970s and 1980s, there was a resurgence of interest in quadracycles as personal transportation,

driven by the 1973 oil crisis, environmental concerns about air pollution from automobiles and the search for emission-free alternatives.[36]

Modern quadracycles can be generally placed in six categories:

Boy on Pedal Car

Tourist destination rental

Quadracycles can often be found at tourist attractions where they are available to rent by the hour or day. Modern tourist quadracycles usually feature open seating for two or more riders in a sociable configuration. They are often designed to look like early 20th century automobiles with a bench seat, rack-and-pinion steering, and a canopy top. They are commonly called "surreys", due to their resemblance to horse-drawn wagons of similar appearance and the same name.

A 1945 model Mochet Velocar

Examples of this type include:

- International Surrey Company Surrey[40]
- Quadricycle International Quad-3[41]
- Rhoades Car 4W4P[42]
- Sirenetta[43]

Pedal taxi

Similar to the surrey are pedal taxis or pedicabs. These tend to be four or even six seaters and are used as taxis, pedaled by professional drivers. Like the rental surreys, they are often found at tourist attractions and in the downtown areas of tourist destination cities.

A common rental surrey - a 2008 model International Surrey Company DX Series Surrey designed for 3 adults and 2 small children, equipped with 7 speeds.[34]

Also like the rental surreys, pedal taxis are often constructed to resemble early 20th century cars and often feature awning coverings for protection from the sun.

Examples of this type include:

- International Surrey Limousine[40]
- Momentum Quadracycles MQ4 Cabbie[44]
- Quadracycle Inc QuadraCab[45]
- Delphino (Limo)[18]

Touring

Touring quadracycles are constructed specifically for the personal ownership market and are built to be lighter and faster than rental surreys. Typically, they seat one person or two people in side-by-side seating and feature independent pedaling and gear selection. They can have up to 192 gears, giving them remarkable hill-climbing capabilities.[46] They are used for long distance

travel as well as local use; some are used for cycle-commuting to work.[47]

A tourist rental quadricycle, a Quadricycle International Quad-3[1]

Compared to touring or hybrid bicycles, touring quadracycles are more comfortable to ride, can navigate steeper hills more easily, deal with crosswinds better, and can carry a much heavier load than a bicycle. They have disadvantages compared to bicycles including that they are heavier, require more storage space, typically have slower cruise speeds, are more complex to maintain, and have a larger turning circle.[48] Unlike bicycles (but like tricycles) they are vulnerable to being rolled over on fast corners, and a very low centre of gravity and/or weight transfer by the riders to the inside of the curve is needed to avoid this.

Quadricycle International tourist rental quadricycles, Old Montreal, Quebec, Canada[1]

Examples of this type of vehicle include:

- Lightfoot MicroCar[46]
- Momentum Quadracycles MQ2 Leisure[4]
- Pacific Cycle 2Rider[49]
- Quadracycle International Little Deuce Coupe[50]
- Quadracycle Inc QuadraSport two-seater[51]
- Rhoades Car 4W2PCP two-seater coupe[52]
- RJK Ecological Car[29]
- Steppe by Steppe Quike[53]
- Ultimate Quadracycle CC-Sportster[54]
- Utah Trikes Quad[55]

A modern touring 4-wheel bike - a 2007 model Rhoades Car 4W2PCP Coupe two seater[13]

There are also plans available as well as some amateur-designed touring quadracycles made by combining two bicycles. They have had varying degrees of success.[56]

Examples of plans built quadracycles are:

- Skeldon Bike Co. Granny Bike[57]
- Atomic Zombie StreetFighter[58]

Mountain quadracycles

Some quadracycles are designed to be the four-wheel counterparts of mountain bicycles and are optimized for strength and the ability to deal with steep and rough terrain; these are all single seat designs.

An example of this type is:

- Crank-It Mountain Quad[25]

Industrial use

There are quadracycles designed for local delivery of goods, such as spare parts in a factory environment or laundry at spread-out hotel complexes. They may have two seats and a pickup box or flat bed to allow loads to be transported. Industrial use quadracycles are also capable of pulling small trailers.

A modern touring 4-wheel bike - a 2011 model Quattrocycle four seater with canopy[33]

Some quadracycles in this category have also been designed for military applications, such as light logistics transport.

Examples of this type of quadracycle include:

- Momentum Quadracycles MQ1 Industrial[4]
- Rhoades Car 4W2PLF[59]
- Rhoades Car Go Boy[60]

Racing

Pedal Car Racing can be found in many parts of the world. The UK, France and Italy all have championships and the UK and Hong Kong have a 24-hour race every year. Racing pedal cars are lightweight machines built for the sole purpose of racing and are therefore unsuitable for road use. [61]

Performance art

The El Arbol quadracycle was built as a portable stage and sound system to make a point about the use of fossil fuels for transportation.[62]

Security

Lacking the mass and door locks of automobiles, quadracycles are often secured in the same manner as bicycles with "U" or "D" locks, chains or cables to convenient stout objects such as fence posts, signs or bike racks.[63]

A 4-wheel bike secured with a 15mm X 2.5 m cable and bike "U" lock to a steel signpost[13]

See also

- Human-powered transport
- Outline of cycling
- Surrey
- Wheeled kicksled

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- List of quadracycle manufacturers (http://helmets.org/fourwhel.htm)
- Four-Wheeled Velomobiles (http://www.liggecykelforeningen.dk/Designseminar/4WheelVelomobiles)

Wikimedia Commons has media related to ***Quadricycles***.

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Quadrupole magnet

From Wikipedia, the free encyclopedia

Quadrupole magnets, abbreviated as **Q-magnets**, consist of groups of four magnets laid out so that in the planar multipole expansion of the field, the dipole terms cancel and where the lowest significant terms in the field equations are quadrupole. Quadrupole magnets are useful as they create a magnetic field whose magnitude grows rapidly with the radial distance from its longitudinal axis. This is used in particle beam focusing.

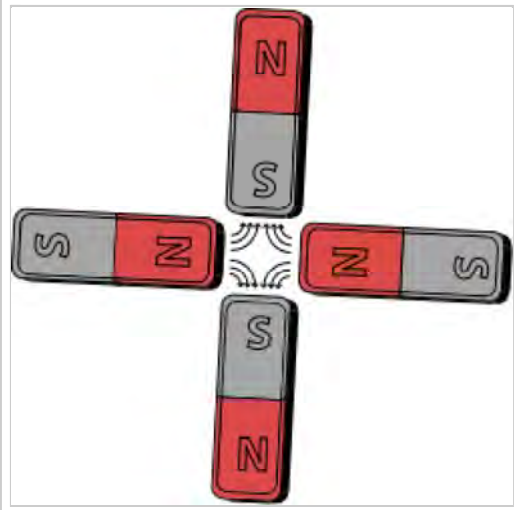

Four bar magnets configured to produce a quadrupole

The simplest magnetic quadrupole is two identical bar magnets parallel to each other such that the north pole of one is next to the south of the other and vice versa. Such a configuration will have no dipole moment, and its field will decrease at large distances faster than that of a dipole. A stronger version with very little external field involves using a k=3 Halbach cylinder.

In some designs of quadrupoles using electromagnets, there are four steel pole tips: two opposing magnetic north poles and two opposing magnetic south poles. The steel is magnetized by a large electric current in the coils of tubing wrapped around the poles. Another design is a Helmholtz coil layout but with the current in one of the coils reversed.[1]

Contents

- 1 Quadrupoles in particle accelerators
- 2 Mathematical description of the ideal field
- 3 See also

- 4 References

Quadrupoles in particle accelerators

Examples of quadrupole magnets

A quadrupole electromagnet as used in the storage ring of the Australian Synchrotron

Quadrupole electromagnets (in blue), surrounding the linac of the Australian Synchrotron, are used to focus the electron beam

At the speeds reached in high energy particle accelerators, magnetic deflection is more powerful than electrostatic, and use of the magnetic term of the Lorentz force:

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B}),$$

is enabled with various magnets that make up 'the lattice' required to bend, steer and focus a charged particle beam.

The quadrupoles in the lattice are of two types: 'F quadrupoles' (which are horizontally focusing but vertically defocusing) and 'D quadrupoles' (which are vertically focusing but horizontally defocusing). This situation is due to the laws of electromagnetism (the Maxwell equations) which show that it is impossible for a quadrupole to focus in both planes at the same time. The

image on the right shows an example of a quadrupole focusing in the vertical direction for a positively charged particle going into the image plane (forces above and below the center point towards the center) while defocusing in the horizontal direction (forces left and right of the center point away from the center).

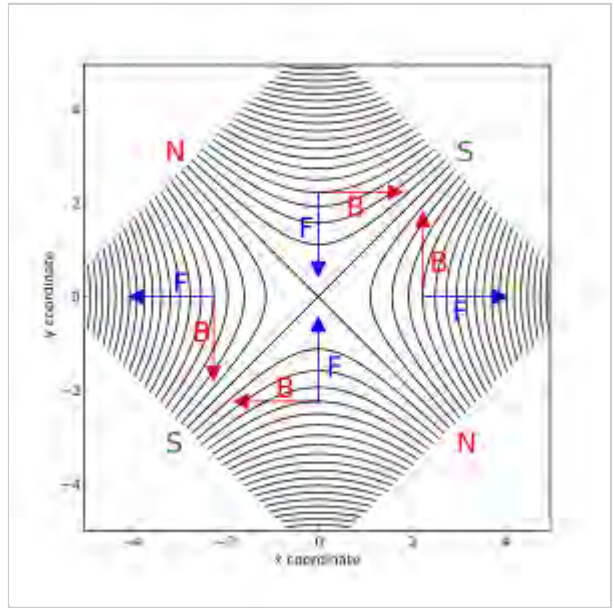

Magnetic field lines of an idealized quadrupole field in the plane transverse to the nominal beam direction. The red arrows show the direction of the magnetic field while the blue arrows indicate the direction of the Lorentz force on a positive particle going into the image plane (away from the reader)

If an F quadrupole and a D quadrupole are placed immediately next to each other, their fields completely cancel out (in accordance with Earnshaw's theorem). But if there is a space between them (and the length of this has been correctly chosen), the overall effect is focusing in both horizontal and vertical planes. A lattice can then be built up enabling the transport of the beam over long distances—for example round an entire ring. A common lattice is a FODO lattice consisting of a basis of a focusing quadrupole, 'nothing' (often a bending magnet), a defocusing quadrupole and another length of 'nothing'.

Mathematical description of the ideal field

The components of the ideal magnetic field in the plane transverse to the beam is given by (see also multipole magnet):

$$B_y = K \cdot x \qquad B_x = K \cdot y$$

if the magnetic poles are arranged with an angle of 45 degrees to the horizontal and vertical planes. K is the field gradient of the vertical component in the horizontal direction (or equivalently, the field gradient of the horizontal component in the vertical direction). Its SI unit is $\mathrm{T/m}$. The sign of K determines whether (for a fixed particle charge and direction) the quadrupole focuses or defocuses particles in the horizontal plane.

See also

- Charged particle beam
- Dipole magnet
- Electron optics
- Halbach cylinder
- Sextupole magnet
- Multipole magnet

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Quantum chemistry

From Wikipedia, the free encyclopedia

Quantum chemistry is a branch of chemistry whose primary focus is the application of quantum mechanics in physical models and experiments of chemical systems. It is also called molecular quantum mechanics.

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- 2 History
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  - 3.1 Wave model
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Overview

It involves heavy interplay of experimental and theoretical methods:

- Experimental quantum chemists rely heavily on spectroscopy, through which information regarding the quantization of energy on a molecular scale can be obtained. Common methods are infra-red (IR) spectroscopy and nuclear magnetic resonance (NMR) spectroscopy.
- Theoretical quantum chemistry, the workings of which also tend to fall under the category of computational chemistry, seeks to calculate the predictions of quantum theory as atoms and molecules can only have discrete energies; as this task, when applied to polyatomic species, invokes the many-body problem, these calculations are performed using computers rather than by analytical "back of the envelope" methods, pen recorder or computerized data station with a VDU.

In these ways, quantum chemists investigate chemical phenomena.

- In reactions, quantum chemistry studies the ground state of individual atoms and molecules, the excited states, and the transition states that occur during chemical reactions.
- On the calculations: quantum chemical studies use also semi-empirical and other methods based on quantum mechanical principles, and deal with time dependent problems. Many quantum

chemical studies assume the nuclei are at rest (Born–Oppenheimer approximation). Many calculations involve iterative methods that include self-consistent field methods. Major goals of quantum chemistry include increasing the accuracy of the results for small molecular systems, and increasing the size of large molecules that can be processed, which is limited by scaling considerations—the computation time increases as a power of the number of atoms.

History

Some view the birth of quantum chemistry in the discovery of the Schrödinger equation and its application to the hydrogen atom in 1926. However, the 1927 article of Walter Heitler and Fritz London is often recognised as the first milestone in the history of quantum chemistry. This is the first application of quantum mechanics to the diatomic hydrogen molecule, and thus to the phenomenon of the chemical bond. In the following years much progress was accomplished by Edward Teller, Robert S. Mulliken, Max Born, J. Robert Oppenheimer, Linus Pauling, Erich Hückel, Douglas Hartree, Vladimir Aleksandrovich Fock, to cite a few. The history of quantum chemistry also goes through the 1838 discovery of cathode rays by Michael Faraday, the 1859 statement of the black body radiation problem by Gustav Kirchhoff, the 1877 suggestion by Ludwig Boltzmann that the energy states of a physical system could be discrete, and the 1900 quantum hypothesis by Max Planck that any energy radiating atomic system can theoretically be divided into a number of discrete energy elements ε such that each of these energy elements is proportional to the frequency ν with which they each individually radiate energy and a numerical value called Planck's Constant. Then, in 1905, to explain the photoelectric effect (1839), i.e., that shining light on certain materials can function to eject electrons from the material, Albert Einstein postulated, based on Planck's quantum hypothesis, that light itself consists of individual quantum particles, which later came to be called photons (1926). In the years to follow, this theoretical basis slowly began to be applied to chemical structure, reactivity, and bonding. Probably the greatest contribution to the field was made by Linus Pauling.

Electronic structure

The first step in solving a quantum chemical problem is usually solving the Schrödinger equation (or Dirac equation in relativistic quantum chemistry) with the electronic molecular Hamiltonian. This is called determining the **electronic structure** of the molecule. It can be said that the electronic structure of a molecule or crystal implies essentially its chemical properties. An exact solution for the Schrödinger equation can only be obtained for the hydrogen atom (though exact solutions for the bound state energies of the hydrogen molecular ion have been identified in terms of the generalized Lambert W function). Since all other atomic, or molecular systems, involve the motions of three or more "particles", their Schrödinger equations cannot be solved exactly and so approximate solutions must be sought.

Wave model

The foundation of quantum mechanics and quantum chemistry is the **wave model**, in which the atom is a small, dense, positively charged nucleus surrounded by electrons. The wave model is derived from the wavefunction, a set of possible equations derived from the time evolution of the Schrödinger equation which is applied to the wavelike probability distribution of subatomic particles. Unlike the earlier Bohr model of the atom, however, the wave model describes electrons as "clouds" moving in orbitals, and their positions are represented by probability distributions rather than discrete points. The strength of

this model lies in its predictive power. Specifically, it predicts the pattern of chemically similar elements found in the periodic table. The wave model is so named because electrons exhibit properties (such as interference) traditionally associated with waves. See wave-particle duality. In this model, when we solve the Schrödinger Equation for an Hidrogenoid Atom, we obtain a solution that depends on some numbers, called quantum numbers, that describes the orbital, the most probable space where an electron can be. These are n, the principal quantum number, for the energy, l, or secondary quantum number, which correlates to the angular momentum, ml, for the orientation, and ms the spin. This model can explain the new lines that appeared in the spectroscopy of atoms. For multielectron atoms we must introduce some rules as that the electrons fill orbitals in a way to minimize the energy of the atom, in order of increasing energy, the Pauli Exclusion Principle, the Hund's Rule, and the Aufbau Principle.

Valence bond

Although the mathematical basis of quantum chemistry had been laid by Schrödinger in 1926, it is generally accepted that the first true calculation in quantum chemistry was that of the German physicists Walter Heitler and Fritz London on the hydrogen (H_2) molecule in 1927. Heitler and London's method was extended by the American theoretical physicist John C. Slater and the American theoretical chemist Linus Pauling to become the **Valence-Bond (VB)** [or **Heitler–London–Slater–Pauling (HLSP)**] method. In this method, attention is primarily devoted to the pairwise interactions between atoms, and this method therefore correlates closely with classical chemists' drawings of bonds. It focuses on how the atomic orbitals of an atom combine to give individual chemical bonds when a molecule is formed. The concept of chemical bond disorts when the aromatic compounds are considered, then you need to apply resonance ideas and hybridization that doesn´t correspond to chemical view of fixed shared pair of electrons between molecules (see Aromaticity).

Molecular orbital

An alternative approach was developed in 1929 by Friedrich Hund and Robert S. Mulliken, in which electrons are described by mathematical functions delocalized over an entire molecule. The **Hund –Mulliken** approach or **molecular orbital (MO) method** is less intuitive to chemists, but has turned out capable of predicting spectroscopic properties better than the VB method. This approach is the conceptional basis of the **Hartree–Fock method** and further post Hartree–Fock methods.

Density functional theory

The **Thomas–Fermi model** was developed independently by Thomas and Fermi in 1927. This was the first attempt to describe many-electron systems on the basis of electronic density instead of wave functions, although it was not very successful in the treatment of entire molecules. The method did provide the basis for what is now known as **density functional theory**. Modern day DFT uses the **Kohn-Sham method**, where the density functional is split into four terms; the Kohn-Sham kinetic energy, an external potential, exchange and correlation energies. A large part of the focus on developing DFT is on improving the exchange and correlation terms. Though this method is less developed than post Hartree–Fock methods, its significantly lower computational requirements (scaling typically no worse than n^3 with respect to n basis functions, for the pure functionals) allow it to tackle larger

polyatomic molecules and even macromolecules. This computational affordability and often comparable accuracy to MP2 and CCSD(T) (post-Hartree–Fock methods) has made it one of the most popular methods in computational chemistry at present.

Chemical dynamics

A further step can consist of solving the Schrödinger equation with the total molecular Hamiltonian in order to study the motion of molecules. Direct solution of the Schrödinger equation is called *quantum molecular dynamics*, within the semiclassical approximation *semiclassical molecular dynamics*, and within the classical mechanics framework *molecular dynamics (MD)*. Statistical approaches, using for example Monte Carlo methods, are also possible.

Adiabatic chemical dynamics

In **adiabatic dynamics**, interatomic interactions are represented by single scalar potentials called potential energy surfaces. This is the Born–Oppenheimer approximation introduced by Born and Oppenheimer in 1927. Pioneering applications of this in chemistry were performed by Rice and Ramsperger in 1927 and Kassel in 1928, and generalized into the RRKM theory in 1952 by Marcus who took the transition state theory developed by Eyring in 1935 into account. These methods enable simple estimates of unimolecular reaction rates from a few characteristics of the potential surface.

Non-adiabatic chemical dynamics

Non-adiabatic dynamics consists of taking the interaction between several coupled potential energy surface (corresponding to different electronic quantum states of the molecule). The coupling terms are called **vibronic couplings**. The pioneering work in this field was done by Stueckelberg, Landau, and Zener in the 1930s, in their work on what is now known as the Landau–Zener transition. Their formula allows the transition probability between two diabatic potential curves in the neighborhood of an avoided crossing to be calculated.

See also

- Atomic physics
- Computational chemistry
- Condensed matter physics
- Electron localization function
- International Academy of Quantum Molecular Science
- Molecular modelling
- Physical chemistry
- List of quantum chemistry and solid-state physics software
- QMC@Home
- *Quantum Aspects of Life*
- Quantum chemistry computer programs
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- The Sherrill Group – Notes (http://vergil.chemistry.gatech.edu/notes/index.html)
- ChemViz Curriculum Support Resources (http://www.shodor.org/chemviz/)
- Early ideas in the history of quantum chemistry (http://www.quantum-chemistry-history.com/)
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Nobel lectures by quantum chemists

- Walter Kohn's Nobel lecture (http://nobelprize.org/chemistry/laureates/1998/kohn-lecture.html)
- Rudolph Marcus' Nobel lecture (http://nobelprize.org/chemistry/laureates/1992/marcus-lecture.html)
- Robert Mulliken's Nobel lecture (http://nobelprize.org/chemistry/laureates/1966/mulliken-lecture.html)
- Linus Pauling's Nobel lecture (http://nobelprize.org/chemistry/laureates/1954/pauling-lecture.html)
- John Pople's Nobel lecture (http://nobelprize.org/chemistry/laureates/1998/pople-lecture.html)

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Quantum mechanics

From Wikipedia, the free encyclopedia

Quantum mechanics (**QM**; also known as **quantum physics** or **quantum theory**), including quantum field theory, is a fundamental branch of physics concerned with processes involving, for example, atoms and photons. Systems such as these which obey quantum mechanics can be in a quantum superposition of different states, unlike in classical physics.

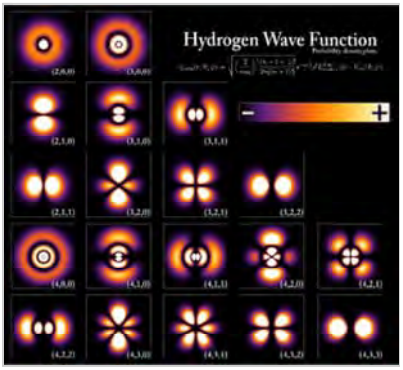

Solution to Schrödinger's equation for the hydrogen atom at different energy levels. The brighter areas represent a higher probability of finding an electron.

Quantum mechanics gradually arose from Max Planck's solution in 1900 to the black-body radiation problem (reported 1859) and Albert Einstein's 1905 paper which offered a quantum-based theory to explain the photoelectric effect (reported 1887). Early quantum theory was profoundly reconceived in the mid-1920s.

The reconceived theory is formulated in various specially developed mathematical formalisms. In one of them, a mathematical function, the wave function, provides information about the probability amplitude of position, momentum, and other physical properties of a particle.

Important applications of quantum theory[1] include superconducting magnets, light-emitting diodes, and the laser, the transistor and semiconductors such as the microprocessor, medical and research imaging such as magnetic resonance imaging and electron microscopy, and explanations for many biological and physical phenomena.

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History

Scientific inquiry into the wave nature of light began in the 17th and 18th centuries, when scientists such as Robert Hooke, Christiaan Huygens and Leonhard Euler proposed a wave theory of light based on experimental observations.[2] In 1803, Thomas Young, an English polymath, performed the famous double-slit experiment that he later described in a paper titled *On the nature of light and colours*. This experiment played a major role in the general acceptance of the wave theory of light.

In 1838, Michael Faraday discovered cathode rays. These studies were followed by the 1859 statement of the black-body radiation problem by Gustav Kirchhoff, the 1877 suggestion by Ludwig Boltzmann that the energy states of a physical system can be discrete, and the 1900 quantum hypothesis of Max Planck.[3] Planck's hypothesis that energy is radiated and absorbed in discrete "quanta" (or energy packets) precisely matched the observed patterns of black-body radiation.

In 1896, Wilhelm Wien empirically determined a distribution law of black-body radiation,[4] known as Wien's law in his honor. Ludwig Boltzmann independently arrived at this result by considerations of Maxwell's equations. However, it was valid only at high frequencies and underestimated the radiance at low frequencies. Later, Planck corrected this model using Boltzmann's statistical interpretation of thermodynamics and proposed what is now called Planck's law, which led to the development of quantum mechanics.

Following Max Planck's solution in 1900 to the black-body radiation problem (reported 1859), Albert Einstein offered a quantum-based theory to explain the photoelectric effect (1905, reported 1887). Around 1900-1910, the atomic theory and the corpuscular theory of light[5] first came to be widely accepted as scientific fact; these latter theories can be viewed as quantum theories of matter and electromagnetic radiation, respectively.

Among the first to study quantum phenomena in nature were Arthur Compton, C. V. Raman, and Pieter Zeeman, each of whom has a quantum effect named after him. Robert Andrews Millikan studied the photoelectric effect experimentally, and Albert Einstein developed a theory for it. At the same time, Ernest Rutherford experimentally discovered the nuclear model of the atom, for which Niels Bohr developed his theory of the atomic structure, which was later confirmed by the experiments of Henry Moseley. In 1913, Peter Debye extended Niels Bohr's theory of atomic structure, introducing elliptical orbits, a concept also introduced by Arnold Sommerfeld.[6] This phase is known as old quantum theory.

According to Planck, each energy element (E) is proportional to its frequency (ν):

$$E = h\nu$$

where h is Planck's constant.

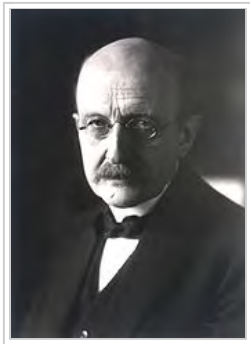
Max Planck is considered the father of the quantum theory.

Planck cautiously insisted that this was simply an aspect of the *processes* of absorption and emission of radiation and had nothing to do with the *physical reality* of the radiation itself.[7] In fact, he considered his quantum hypothesis a mathematical trick to get the right answer rather than a sizable discovery.[8] However, in 1905 Albert Einstein interpreted Planck's quantum hypothesis realistically and used it to explain the photoelectric effect, in which shining light on certain materials can eject electrons from the material. He won the 1921 Nobel Prize in Physics for this work.

Einstein further developed this idea to show that an electromagnetic wave such as light could also be described as a particle (later called the photon), with a discrete quantum of energy that was dependent on its frequency.[9]

The 1927 Solvay Conference in Brussels.

The foundations of quantum mechanics were established during the first half of the 20th century by Max Planck, Niels Bohr, Werner Heisenberg, Louis de Broglie, Arthur Compton, Albert Einstein, Erwin Schrödinger, Max Born, John von Neumann, Paul Dirac, Enrico Fermi, Wolfgang Pauli, Max von Laue, Freeman Dyson, David Hilbert, Wilhelm Wien, Satyendra Nath Bose, Arnold Sommerfeld, and others. The Copenhagen interpretation of Niels Bohr became widely accepted.

In the mid-1920s, developments in quantum mechanics led to its becoming the standard formulation for atomic physics. In the summer of 1925, Bohr and Heisenberg published results that closed the old quantum theory. Out of deference to their particle-like behavior in certain processes and measurements, light quanta came to be called photons (1926). From Einstein's simple postulation was born a flurry of debating, theorizing, and testing. Thus, the entire field of quantum physics emerged, leading to its wider acceptance at the Fifth Solvay Conference in 1927.

It was found that subatomic particles and electromagnetic waves are neither simply particle nor wave but have certain properties of each. This originated the concept of wave–particle duality.

By 1930, quantum mechanics had been further unified and formalized by the work of David Hilbert, Paul Dirac and John von Neumann[10] with greater emphasis on measurement, the statistical nature of our knowledge of reality, and philosophical speculation about the 'observer'. It has since permeated many disciplines including quantum chemistry, quantum electronics, quantum optics, and quantum information science. Its speculative modern developments include string theory and quantum gravity theories. It also provides a useful framework for many features of the modern periodic table of elements, and describes the behaviors of atoms during chemical bonding and the flow of electrons in computer semiconductors, and therefore plays a crucial role in many modern technologies.

While quantum mechanics was constructed to describe the world of the very small, it is also needed to explain some macroscopic phenomena such as superconductors,[11] and superfluids.[12]

The word *quantum* derives from the Latin, meaning "how great" or "how much".[13] In quantum mechanics, it refers to a discrete unit assigned to certain physical quantities such as the energy of an atom at rest (see Figure 1). The discovery that particles are discrete packets of energy with wave-like properties led to the branch of physics dealing with atomic and subatomic systems which is today called quantum mechanics. It underlies the

mathematical framework of many fields of physics and chemistry, including condensed matter physics, solid-state physics, atomic physics, molecular physics, computational physics, computational chemistry, quantum chemistry, particle physics, nuclear chemistry, and nuclear physics.[14] Some fundamental aspects of the theory are still actively studied.[15]

Quantum mechanics is essential to understanding the behavior of systems at atomic length scales and smaller. If the physical nature of an atom were solely described by classical mechanics, electrons would not *orbit* the nucleus, since orbiting electrons emit radiation (due to circular motion) and would eventually collide with the nucleus due to this loss of energy. This framework was unable to explain the stability of atoms. Instead, electrons remain in an uncertain, non-deterministic, *smeared*, probabilistic wave–particle orbital about the nucleus, defying the traditional assumptions of classical mechanics and electromagnetism.[16]

Quantum mechanics was initially developed to provide a better explanation and description of the atom, especially the differences in the spectra of light emitted by different isotopes of the same chemical element, as well as subatomic particles. In short, the quantum-mechanical atomic model has succeeded spectacularly in the realm where classical mechanics and electromagnetism falter.

Broadly speaking, quantum mechanics incorporates four classes of phenomena for which classical physics cannot account:

- quantization of certain physical properties
- quantum entanglement
- principle of uncertainty
- wave–particle duality

Mathematical formulations

In the mathematically rigorous formulation of quantum mechanics developed by Paul Dirac,[17] David Hilbert,[18] John von Neumann,[19] and Hermann Weyl,[20] the possible states of a quantum mechanical system are symbolized[21] as unit vectors (called *state vectors*). Formally, these reside in a complex separable Hilbert space—variously called the *state space* or the *associated Hilbert space* of the system—that is well defined up to a complex number of norm 1 (the phase factor). In other words, the possible states are points in the projective space of a Hilbert space, usually called the complex projective space. The exact nature of this Hilbert space is dependent on the system—for example, the state space for position and momentum states is the space of square-integrable functions, while the state space for the spin of a single proton is just the product of two complex planes. Each observable is represented by a maximally Hermitian (precisely: by a self-adjoint) linear operator acting on the state space. Each eigenstate of an observable corresponds to an eigenvector of the operator, and the associated eigenvalue corresponds to the value of the observable in that eigenstate. If the operator's spectrum is discrete, the observable can attain only those discrete eigenvalues.

In the formalism of quantum mechanics, the state of a system at a given time is described by a complex wave function, also referred to as state vector in a complex vector space.[22] This abstract mathematical object allows for the calculation of probabilities of outcomes of concrete experiments. For example, it allows one to compute the probability of finding an electron in a particular region around the nucleus at a particular time. Contrary to classical mechanics, one can never make simultaneous predictions of conjugate variables, such as position and momentum, to arbitrary precision. For instance, electrons may be considered (to a certain probability) to be located somewhere within a given region of space, but with their exact positions unknown. Contours of constant probability, often referred to as "clouds", may be drawn around the nucleus of an atom to conceptualize where the electron might be located with the most probability. Heisenberg's uncertainty principle quantifies the inability to precisely locate the particle given its conjugate momentum.[23]

According to one interpretation, as the result of a measurement the wave function containing the probability information for a system collapses from a given initial state to a particular eigenstate. The possible results of a measurement are the eigenvalues of the operator representing the observable—which explains the choice of *Hermitian* operators, for which all the eigenvalues are real. The probability distribution of an observable in a given state can be found by computing the spectral decomposition of the corresponding operator. Heisenberg's uncertainty principle is represented by the statement that the operators corresponding to certain observables do not commute.

The probabilistic nature of quantum mechanics thus stems from the act of measurement. This is one of the most difficult aspects of quantum systems to understand. It was the central topic in the famous Bohr–Einstein debates, in which the two scientists attempted to clarify these fundamental principles by way of thought experiments. In the decades after the formulation of quantum mechanics, the question of what constitutes a "measurement" has been extensively studied. Newer interpretations of quantum mechanics have been formulated that do away with the concept of "wave function collapse" (see, for example, the relative state interpretation). The basic idea is that when a quantum system interacts with a measuring apparatus, their respective wave functions become entangled, so that the original quantum system ceases to exist as an independent entity. For details, see the article on measurement in quantum mechanics.[24]

Generally, quantum mechanics does not assign definite values. Instead, it makes a prediction using a probability distribution; that is, it describes the probability of obtaining the possible outcomes from measuring an observable. Often these results are skewed by many causes, such as dense probability clouds. Probability clouds are approximate (but better than the Bohr model) whereby electron location is given by a probability function, the wave function eigenvalue, such that the probability is the squared modulus of the complex amplitude, or quantum state nuclear attraction.[25][26] Naturally, these probabilities will depend on the quantum state at the "instant" of the measurement. Hence, uncertainty is involved in the value. There are, however, certain states that are associated with a definite value of a particular observable. These are known as eigenstates of the observable ("eigen" can be translated from German as meaning "inherent" or "characteristic").[27]

In the everyday world, it is natural and intuitive to think of everything (every observable) as being in an eigenstate. Everything appears to have a definite position, a definite momentum, a definite energy, and a definite time of occurrence. However, quantum mechanics does not pinpoint the exact values of a particle's position and momentum (since they are conjugate pairs) or its energy and time (since they too are conjugate pairs); rather, it provides only a range of probabilities in which that particle might be given its momentum and momentum probability. Therefore, it is helpful to use different words to describe states having *uncertain* values and states having *definite* values (eigenstates). Usually, a system will not be in an eigenstate of the observable (particle) we are interested in. However, if one measures the observable, the wave function will instantaneously be an eigenstate (or "generalized" eigenstate) of that observable. This process is known as wave function collapse, a controversial and much-debated process[28] that involves expanding the system under study to include the measurement device. If one knows the corresponding wave function at the instant before the measurement, one will be able to compute the probability of the wave function collapsing into each of the possible eigenstates. For example, the free particle in the previous example will usually have a wave function that is a wave packet centered around some mean position x_0 (neither an eigenstate of position nor of momentum). When one measures the position of the particle, it is impossible to predict with certainty the result.[24] It is probable, but not certain, that it will be near x_0, where the amplitude of the wave function is large. After the measurement is performed, having obtained some result x, the wave function collapses into a position eigenstate centered at x.[29]

The time evolution of a quantum state is described by the Schrödinger equation, in which the Hamiltonian (the operator corresponding to the total energy of the system) generates the time evolution. The time evolution of wave functions is deterministic in the sense that - given a wave function at an *initial* time - it makes a definite prediction of what the wave function will be at any *later* time.[30]

During a measurement, on the other hand, the change of the initial wave function into another, later wave function is not deterministic, it is unpredictable (i.e., random). A time-evolution simulation can be seen here.[31][32]

Wave functions change as time progresses. The Schrödinger equation describes how wave functions change in time, playing a role similar to Newton's second law in classical mechanics. The Schrödinger equation, applied to the aforementioned example of the free particle, predicts that the center of a wave packet will move through space at a constant velocity (like a classical particle with no forces acting on it). However, the wave packet will also spread out as time progresses, which means that the position becomes more uncertain with time. This also has the effect of turning a position eigenstate (which can be thought of as an infinitely sharp wave packet) into a broadened wave packet that no longer represents a (definite, certain) position eigenstate.[33]

Some wave functions produce probability distributions that are constant, or independent of time—such as when in a stationary state of constant energy, time vanishes in the absolute square of the wave function. Many systems that are treated dynamically in classical mechanics are described by such "static" wave functions. For example, a single electron in an unexcited atom is pictured classically as a particle moving in a circular trajectory around the atomic nucleus, whereas in quantum mechanics it is described by a static, spherically symmetric wave function surrounding the nucleus (Fig. 1) (note, however, that only the lowest angular momentum states, labeled *s*, are spherically symmetric).[34]

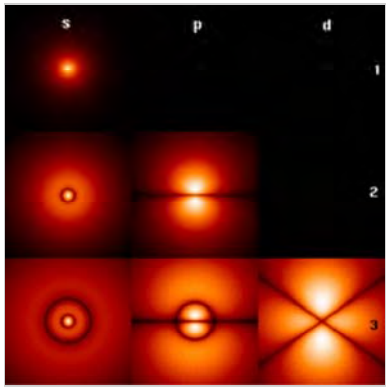

Fig. 1: Probability densities corresponding to the wave functions of an electron in a hydrogen atom possessing definite energy levels (increasing from the top of the image to the bottom: $n = 1, 2, 3, ...$) and angular momenta (increasing across from left to right: *s*, *p*, *d*, ...). Brighter areas correspond to higher probability density in a position measurement. Such wave functions are directly comparable to Chladni's figures of acoustic modes of vibration in classical physics, and are modes of oscillation as well, possessing a sharp energy and, thus, a definite frequency. The angular momentum and energy are quantized, and take **only** discrete values like those shown (as is the case for resonant frequencies in acoustics)

The Schrödinger equation acts on the *entire* probability amplitude, not merely its absolute value. Whereas the absolute value of the probability amplitude encodes information about probabilities, its phase encodes information about the interference between quantum states. This gives rise to the "wave-like" behavior of quantum states. As it turns out, analytic solutions of the Schrödinger equation are available for only a very small number of relatively simple model Hamiltonians, of which the quantum harmonic oscillator, the particle in a box, the dihydrogen cation, and the hydrogen atom are the most important representatives. Even the helium atom—which contains just one more electron than does the hydrogen atom—has defied all attempts at a fully analytic treatment.

There exist several techniques for generating approximate solutions, however. In the important method known as perturbation theory, one uses the analytic result for a simple quantum mechanical model to generate a result for a more complicated model that is related to the simpler model by (for one example) the addition of a weak potential energy. Another method is the "semi-classical equation of motion" approach, which applies to systems for which quantum mechanics produces only weak (small) deviations from classical behavior. These deviations can then be computed based on the classical motion. This approach is particularly important in the field of quantum chaos.

Mathematically equivalent formulations of quantum mechanics

There are numerous mathematically equivalent formulations of quantum mechanics. One of the oldest and most commonly used formulations is the "transformation theory" proposed by Paul Dirac, which unifies and generalizes the two earliest formulations of quantum mechanics - matrix mechanics (invented by Werner Heisenberg) and wave mechanics (invented by Erwin Schrödinger).[35]

Especially since Werner Heisenberg was awarded the Nobel Prize in Physics in 1932 for the creation of quantum mechanics, the role of Max Born in the development of QM was overlooked until the 1954 Nobel award. The role is noted in a 2005 biography of Born, which recounts his role in the matrix formulation of quantum mechanics, and the use of probability amplitudes. Heisenberg himself acknowledges having learned matrices from Born, as published in a 1940 *festschrift* honoring Max Planck.[36] In the matrix formulation, the instantaneous state of a quantum system encodes the probabilities of its measurable properties, or "observables". Examples of observables include energy, position, momentum, and angular momentum. Observables can be either continuous (e.g., the position of a particle) or discrete (e.g., the energy

of an electron bound to a hydrogen atom).[37] An alternative formulation of quantum mechanics is Feynman's path integral formulation, in which a quantum-mechanical amplitude is considered as a sum over all possible classical and non-classical paths between the initial and final states. This is the quantum-mechanical counterpart of the action principle in classical mechanics.

Interactions with other scientific theories

The rules of quantum mechanics are fundamental. They assert that the state space of a system is a Hilbert space and that observables of that system are Hermitian operators acting on that space—although they do not tell us which Hilbert space or which operators. These can be chosen appropriately in order to obtain a quantitative description of a quantum system. An important guide for making these choices is the correspondence principle, which states that the predictions of quantum mechanics reduce to those of classical mechanics when a system moves to higher energies or, equivalently, larger quantum numbers, i.e. whereas a single particle exhibits a degree of randomness, in systems incorporating millions of particles averaging takes over and, at the high energy limit, the statistical probability of random behaviour approaches zero. In other words, classical mechanics is simply a quantum mechanics of large systems. This "high energy" limit is known as the *classical* or *correspondence limit*. One can even start from an established classical model of a particular system, then attempt to guess the underlying quantum model that would give rise to the classical model in the correspondence limit.

When quantum mechanics was originally formulated, it was applied to models whose correspondence limit was non-relativistic classical mechanics. For instance, the well-known model of the quantum harmonic oscillator uses an explicitly non-relativistic expression for the kinetic energy of the oscillator, and is thus a quantum version of the classical harmonic oscillator.

> **Unsolved problem in physics**:
> *In the correspondence limit of **quantum mechanics**: Is there a preferred interpretation of quantum mechanics? How does the quantum description of reality, which includes elements such as the "superposition of states" and "wave function collapse", give rise to the reality we perceive?*
> (more unsolved problems in physics)

Early attempts to merge quantum mechanics with special relativity involved the replacement of the Schrödinger equation with a covariant equation such as the Klein–Gordon equation or the Dirac equation. While these theories were successful in explaining many experimental results, they had certain unsatisfactory qualities stemming from their neglect of the relativistic creation and annihilation of particles. A fully relativistic quantum theory required the development of quantum field theory, which applies quantization to a field (rather than a fixed set of particles). The first complete quantum field theory, quantum electrodynamics, provides a fully quantum description of the electromagnetic interaction. The full apparatus of quantum field theory is often unnecessary for describing electrodynamic systems. A simpler approach, one that has been employed since the inception of quantum mechanics, is to treat charged particles as quantum mechanical objects being acted on by a classical electromagnetic field. For example, the elementary quantum model of the hydrogen atom describes the electric field of the hydrogen atom using a classical $-e^2/(4\pi\,\epsilon_0\,r)$ Coulomb potential. This "semi-classical" approach fails if quantum fluctuations in the electromagnetic field play an important role, such as in the emission of photons by charged particles.

Quantum field theories for the strong nuclear force and the weak nuclear force have also been developed. The quantum field theory of the strong nuclear force is called quantum chromodynamics, and describes the interactions of subnuclear particles such as quarks and gluons. The weak nuclear force and the electromagnetic force were unified, in their quantized forms, into a single quantum field theory (known as electroweak theory), by the physicists Abdus Salam, Sheldon Glashow and Steven Weinberg. These three men shared the Nobel Prize in Physics in 1979 for this work.[38]

It has proven difficult to construct quantum models of gravity, the remaining fundamental force. Semi-classical approximations are workable, and have led to predictions such as Hawking radiation. However, the formulation of a complete theory of quantum gravity is hindered by apparent incompatibilities between general relativity (the most accurate theory of gravity currently known) and some of the fundamental assumptions of quantum theory. The resolution of these incompatibilities is an area of active research, and theories such as string theory are among the possible candidates for a future theory of quantum gravity.

Classical mechanics has also been extended into the complex domain, with complex classical mechanics exhibiting behaviors similar to quantum mechanics.[39]

Quantum mechanics and classical physics

Predictions of quantum mechanics have been verified experimentally to an extremely high degree of accuracy.[40] According to the correspondence principle between classical and quantum mechanics, all objects obey the laws of quantum mechanics, and classical mechanics is just an approximation for large systems of objects (or a statistical quantum mechanics of a large collection of particles).[41] The laws of classical mechanics thus follow from the laws of quantum mechanics as a statistical average at the limit of large systems or large quantum numbers.[42] However, chaotic systems do not have good quantum numbers, and quantum chaos studies the relationship between classical and quantum descriptions in these systems.

Quantum coherence is an essential difference between classical and quantum theories as illustrated by the Einstein–Podolsky–Rosen (EPR) paradox — an attack on a certain philosophical interpretation of quantum mechanics by an appeal to local realism.[43] Quantum interference involves adding together *probability amplitudes*, whereas classical "waves" infer that there is an adding together of *intensities*. For microscopic bodies, the extension of the system is much smaller than the coherence length, which gives rise to long-range entanglement and other nonlocal phenomena characteristic of quantum systems.[44] Quantum coherence is not typically evident at macroscopic scales, though an exception to this rule may occur at extremely low temperatures (i.e. approaching absolute zero) at which quantum behavior may manifest itself macroscopically.[45] This is in accordance with the following observations:

- Many macroscopic properties of a classical system are a direct consequence of the quantum behavior of its parts. For example, the stability of bulk matter (consisting of atoms and molecules which would quickly collapse under electric forces alone), the rigidity of solids, and the

mechanical, thermal, chemical, optical and magnetic properties of matter are all results of the interaction of electric charges under the rules of quantum mechanics.[46]

- While the seemingly "exotic" behavior of matter posited by quantum mechanics and relativity theory become more apparent when dealing with particles of extremely small size or velocities approaching the speed of light, the laws of classical, often considered "Newtonian", physics remain accurate in predicting the behavior of the vast majority of "large" objects (on the order of the size of large molecules or bigger) at velocities much smaller than the velocity of light.[47]

Copenhagen interpretation of quantum versus classical kinematics

A big difference between classical and quantum mechanics is that they use very different kinematic descriptions.[48]

In Niels Bohr's mature view, quantum mechanical phenomena are required to be experiments, with complete descriptions of all the devices for the system, preparative, intermediary, and finally measuring. The descriptions are in macroscopic terms, expressed in ordinary language, supplemented with the concepts of classical mechanics.[49][50][51][52] The initial condition and the final condition of the system are respectively described by values in a configuration space, for example a position space, or some equivalent space such as a momentum space. Quantum mechanics does not admit a completely precise description, in terms of both position and momentum, of an initial condition or "state" (in the classical sense of the word) that would support a precisely deterministic and causal prediction of a final condition.[53][54] In this sense, advocated by Bohr in his mature writings, a quantum phenomenon is a process, a passage from initial to final condition, not an instantaneous "state" in the classical sense of that word.[55][56] Thus there are two kinds of processes in quantum mechanics: stationary and transitional. For a stationary process, the initial and final condition are the same. For a transition, they are different. Obviously by definition, if only the initial condition is given, the process is not determined.[53] Given its initial condition, prediction of its final condition is possible, causally but only probabilistically, because the Schrödinger equation is deterministic for wave function evolution, but the wave function describes the system only probabilistically.[57][58]

For many experiments, it is possible to think of the initial and final conditions of the system as being a particle. In some cases it appears that there are potentially several spatially distinct pathways or trajectories by which a particle might pass from initial to final condition. It is an important feature of the quantum kinematic description that it does not permit a unique definite statement of which of those pathways is actually followed. Only the initial and final conditions are definite, and, as stated in the foregoing paragraph, they are defined only as precisely as allowed by the configuration space description or its equivalent. In every case for which a quantum kinematic description is needed, there is always a compelling reason for this restriction of kinematic precision. An example of such a reason is that for a particle to be experimentally found in a definite position, it must be held motionless; for it to be experimentally found to have a definite momentum, it must have free motion; these two are logically incompatible.[59][60]

Classical kinematics does not primarily demand experimental description of its phenomena. It allows completely precise description of an instantaneous state by a value in phase space, the Cartesian product of configuration and momentum spaces. This description simply assumes or imagines a state as a physically existing entity without concern about its experimental measurability. Such a description of an initial condition, together with Newton's laws of motion, allows a precise deterministic and causal prediction of a final condition, with a definite trajectory of passage. Hamiltonian dynamics can be used for this. Classical kinematics also allows the description of a process analogous to the initial and final condition description used by quantum mechanics. Lagrangian mechanics applies to this.[61] For processes that need account to be taken of actions of a small number of Planck constants, classical kinematics is not adequate; quantum mechanics is needed.

General relativity and quantum mechanics

Even with the defining postulates of both Einstein's theory of general relativity and quantum theory being indisputably supported by rigorous and repeated empirical evidence, and while they do not directly contradict each other theoretically (at least with regard to their primary claims), they have proven extremely difficult to incorporate into one consistent, cohesive model.[62]

Gravity is negligible in many areas of particle physics, so that unification between general relativity and quantum mechanics is not an urgent issue in those particular applications. However, the lack of a correct theory of quantum gravity is an important issue in physical cosmology and the search by physicists for an elegant "Theory of Everything" (TOE). Consequently, resolving the inconsistencies between both theories has been a major goal of 20th and 21st century physics. Many prominent physicists, including Stephen Hawking, have labored for many years in the attempt to discover a theory underlying *everything*. This TOE would combine not only the different models of subatomic physics, but also derive the four fundamental forces of nature - the strong force, electromagnetism, the weak force, and gravity - from a single force or phenomenon. While Stephen Hawking was initially a believer in the Theory of Everything, after considering Gödel's Incompleteness Theorem, he has concluded that one is not obtainable, and has stated so publicly in his lecture "Gödel and the End of Physics" (2002).[63]

Attempts at a unified field theory

The quest to unify the fundamental forces through quantum mechanics is still ongoing. Quantum electrodynamics (or "quantum electromagnetism"), which is currently (in the perturbative regime at least) the most accurately tested physical theory in competition with general relativity,[64][65] has been successfully merged with the weak nuclear force into the electroweak force and work is currently being done to merge the electroweak and strong force into the electrostrong force. Current predictions state that at around 10^{14} GeV the three aforementioned forces are fused into a single unified field.[66] Beyond this "grand unification", it is speculated that it may be possible to merge gravity with the other three gauge symmetries, expected to occur at roughly 10^{19} GeV. However — and while special relativity is parsimoniously incorporated into quantum electrodynamics — the expanded general relativity, currently the best theory describing the gravitation force, has not been fully incorporated into quantum theory. One of those searching for a coherent TOE is Edward Witten, a theoretical physicist who formulated the M-theory, which is an attempt at describing the supersymmetrical based

string theory. M-theory posits that our apparent 4-dimensional spacetime is, in reality, actually an 11-dimensional spacetime containing 10 spatial dimensions and 1 time dimension, although 7 of the spatial dimensions are - at lower energies - completely "compactified" (or infinitely curved) and not readily amenable to measurement or probing.

Another popular theory is Loop quantum gravity (LQG), a theory first proposed by Carlo Rovelli that describes the quantum properties of gravity. It is also a theory of quantum space and quantum time, because in general relativity the geometry of spacetime is a manifestation of gravity. LQG is an attempt to merge and adapt standard quantum mechanics and standard general relativity. The main output of the theory is a physical picture of space where space is granular. The granularity is a direct consequence of the quantization. It has the same nature of the granularity of the photons in the quantum theory of electromagnetism or the discrete levels of the energy of the atoms. But here it is space itself which is discrete. More precisely, space can be viewed as an extremely fine fabric or network "woven" of finite loops. These networks of loops are called spin networks. The evolution of a spin network over time is called a spin foam. The predicted size of this structure is the Planck length, which is approximately 1.616×10^{-35} m. According to theory, there is no meaning to length shorter than this (cf. Planck scale energy). Therefore, LQG predicts that not just matter, but also space itself, has an atomic structure.

Philosophical implications

Since its inception, the many counter-intuitive aspects and results of quantum mechanics have provoked strong philosophical debates and many interpretations. Even fundamental issues, such as Max Born's basic rules concerning probability amplitudes and probability distributions, took decades to be appreciated by society and many leading scientists. Richard Feynman once said, "I think I can safely say that nobody understands quantum mechanics."[67] According to Steven Weinberg, "There is now in my opinion no entirely satisfactory interpretation of quantum mechanics."[68]

The Copenhagen interpretation — due largely to Niels Bohr and Werner Heisenberg — remains most widely accepted amongst physicists, some 75 years after its enunciation. According to this interpretation, the probabilistic nature of quantum mechanics is not a *temporary* feature which will eventually be replaced by a deterministic theory, but instead must be considered a *final* renunciation of the classical idea of "causality." It is also believed therein that any well-defined application of the quantum mechanical formalism must always make reference to the experimental arrangement, due to the conjugate nature of evidence obtained under different experimental situations.

Albert Einstein, himself one of the founders of quantum theory, did not accept some of the more philosophical or metaphysical interpretations of quantum mechanics, such as rejection of determinism and of causality. He is famously quoted as saying, in response to this aspect, "God does not play with dice".[69] He rejected the concept that the state of a physical system depends on the experimental arrangement for its measurement. He held that a state of nature occurs in its own right, regardless of whether or how it might be observed. In that view, he is supported by the currently accepted definition of a quantum state, which remains invariant under arbitrary choice of configuration space for its representation, that is to say, manner of observation. He also held that underlying quantum mechanics there should be a theory that thoroughly and directly expresses the rule against action at a distance; in other words, he insisted on the principle of locality. He considered, but rejected on theoretical grounds, a particular proposal for hidden variables to obviate the indeterminism or acausality of quantum mechanical measurement. He considered that quantum mechanics was a currently valid but not a permanently definitive theory for quantum phenomena. He thought its future replacement would require profound conceptual advances, and would not come quickly or easily. The Bohr-Einstein debates provide a vibrant critique of the Copenhagen Interpretation from an epistemological point of view. In arguing for his views, he produced a series of objections, the most famous of which has become known as the Einstein–Podolsky–Rosen paradox.

John Bell showed that this "EPR" paradox led to experimentally testable differences between quantum mechanics and theories that rely on added hidden variables. Experiments have been performed confirming the accuracy of quantum mechanics, thereby demonstrating that quantum mechanics cannot be improved upon by addition of hidden variables.[70] Alain Aspect's initial experiments in 1982, and many subsequent experiments since, have definitively verified quantum entanglement.

Entanglement, as demonstrated in Bell-type experiments, does not, however, violate causality, since no transfer of information happens. Quantum entanglement forms the basis of quantum cryptography, which is proposed for use in high-security commercial applications in banking and government.

The Everett many-worlds interpretation, formulated in 1956, holds that *all* the possibilities described by quantum theory *simultaneously* occur in a multiverse composed of mostly independent parallel universes.[71] This is not accomplished by introducing some "new axiom" to quantum mechanics, but on the contrary, by *removing* the axiom of the collapse of the wave packet. *All* of the possible consistent states of the measured system and the measuring apparatus (including the observer) are present in a *real* physical - not just formally mathematical, as in other interpretations - quantum superposition. Such a superposition of consistent state combinations of different systems is called an entangled state. While the multiverse is deterministic, we perceive non-deterministic behavior governed by probabilities, because we can only observe the universe (i.e., the consistent state contribution to the aforementioned superposition) that we, as observers, inhabit. Everett's interpretation is perfectly consistent with John Bell's experiments and makes them intuitively understandable. However, according to the theory of quantum decoherence, these "parallel universes" will never be accessible to us. The inaccessibility can be understood as follows: once a measurement is done, the measured system becomes entangled with *both* the physicist who measured it *and* a huge number of other particles, some of which are photons flying away at the speed of light towards the other end of the universe. In order to prove that the wave function did not collapse, one would have to bring *all* these particles back and measure them again, together with the system that was originally measured. Not only is this completely impractical, but even if one *could* theoretically do this, it would have to destroy any evidence that the original measurement took place (including the physicist's memory). In light of these Bell tests, Cramer (1986) formulated his transactional interpretation.[72] Relational quantum mechanics appeared in the late 1990s as the modern derivative of the Copenhagen Interpretation.

Applications

Quantum mechanics has had enormous[73] success in explaining many of the features of our universe. Quantum mechanics is often the only tool available that can reveal the individual behaviors of the subatomic particles that make up all forms of matter (electrons, protons, neutrons, photons, and others). Quantum mechanics has strongly influenced string theories, candidates for a Theory of Everything (see reductionism).

Quantum mechanics is also critically important for understanding how individual atoms combine covalently to form molecules. The application of quantum mechanics to chemistry is known as quantum chemistry. Relativistic quantum mechanics can, in principle, mathematically describe most of chemistry. Quantum mechanics can also provide quantitative insight into ionic and covalent bonding processes by explicitly showing which molecules are energetically favorable to which others and the magnitudes of the energies involved.[74] Furthermore, most of the calculations performed in modern computational chemistry rely on quantum mechanics.

In many aspects modern technology operates at a scale where quantum effects are significant.

Electronics

Many modern electronic devices are designed using quantum mechanics. Examples include the laser, the transistor (and thus the microchip), the electron microscope, and magnetic resonance imaging (MRI). The study of semiconductors led to the invention of the diode and the transistor, which are indispensable parts of modern electronics systems, computer and telecommunication devices. Another application is the light emitting diode which is a high-efficiency source of light.

Many electronic devices operate under effect of Quantum tunneling. It even exists in the simple light switch. The switch would not work if electrons could not quantum tunnel through the layer of oxidation on the metal contact surfaces. Flash memory chips found in USB drives use quantum tunneling to erase their memory cells. Some negative differential resistance devices also utilizes quantum tunneling effect, such as resonant tunneling diode. Unlike classical diodes, its current is carried by resonant tunneling through two potential barriers (see right figure). Its negative resistance behavior can only be understood with quantum mechanics: As the confined state moves close to Fermi level, tunnel current increases. As it moves away, current decreases. Quantum mechanics is vital to understanding and designing such electronic devices.

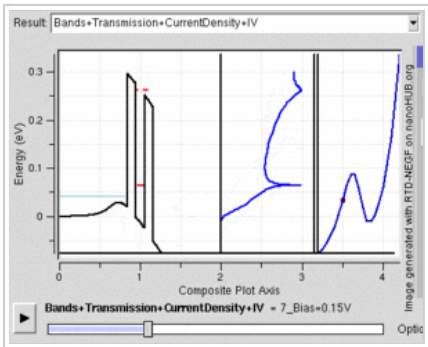

A working mechanism of a resonant tunneling diode device, based on the phenomenon of quantum tunneling through potential barriers. (Left: band diagram; Center: transmission coefficient; Right: current-voltage characteristics) As shown in the band diagram(left), although there are two barriers, electrons still tunnel through via the confined states between two barriers(center), conducting current.

Cryptography

Researchers are currently seeking robust methods of directly manipulating quantum states. Efforts are being made to more fully develop quantum cryptography, which will theoretically allow guaranteed secure transmission of information.

Quantum computing

A more distant goal is the development of quantum computers, which are expected to perform certain computational tasks exponentially faster than classical computers. Instead of using classical bits, quantum computers use qubits, which can be in superpositions of states. Another active research topic is quantum teleportation, which deals with techniques to transmit quantum information over arbitrary distances.

Macroscale quantum effects

While quantum mechanics primarily applies to the smaller atomic regimes of matter and energy, some systems exhibit quantum mechanical effects on a large scale. Superfluidity, the frictionless flow of a liquid at temperatures near absolute zero, is one well-known example. So is the closely related phenomenon of superconductivity, the frictionless flow of an electron gas in a conducting material (an electric current) at sufficiently low temperatures. The fractional quantum hall effect is a topological ordered state which corresponds to patterns of long-range quantum entanglement.[75] States with different topological orders (or different patterns of long range entanglements) cannot change into each other without a phase transition.

Quantum theory

Quantum theory also provides accurate descriptions for many previously unexplained phenomena, such as black-body radiation and the stability of the orbitals of electrons in atoms. It has also given insight into the workings of many different biological systems, including smell receptors and protein structures.[76] Recent work on photosynthesis has provided evidence that quantum correlations play an essential role in this fundamental process of plants and many other organisms.[77] Even so, classical physics can often provide good approximations to results otherwise obtained by quantum physics, typically in circumstances with large numbers of particles or large quantum numbers. Since classical formulas are much simpler and easier to compute than quantum formulas, classical approximations are used and preferred when the system is large enough to render the effects of quantum mechanics insignificant.

Examples

Free particle

For example, consider a free particle. In quantum mechanics, there is wave–particle duality, so the properties of the particle can be described as the properties of a wave. Therefore, its quantum state can be represented as a wave of arbitrary shape and extending over space as a wave function. The position and momentum of the particle are observables. The Uncertainty Principle states that both the position and the momentum cannot simultaneously be measured with complete precision. However, one *can* measure the position (alone) of a moving free particle, creating an eigenstate of position with a wave function that is very large (a Dirac delta) at a particular position *x*, and zero everywhere else. If one performs a position measurement on such a wave function, the resultant *x* will be obtained with 100% probability (i.e., with full certainty, or complete precision). This is called an eigenstate of position—or, stated in mathematical terms, a *generalized position eigenstate (eigendistribution)*. If the particle is in an eigenstate of position, then its momentum is completely unknown. On the other hand, if the particle is in an eigenstate of momentum, then its position is completely unknown.[78] In an eigenstate of momentum having a plane wave form, it can be shown that the wavelength is equal to *h/p*, where *h* is Planck's constant and *p* is the momentum of the eigenstate.[79]

Step potential

The potential in this case is given by:

$$V(x) = \begin{cases} 0, & x < 0, \\ V_0, & x \geq 0. \end{cases}$$

The solutions are superpositions of left- and right-moving waves:

$$\psi_1(x) = \frac{1}{\sqrt{k_1}} \left(A_{\rightarrow} e^{ik_1 x} + A_{\leftarrow} e^{-ik_1 x} \right) \quad x < 0$$
$$\psi_2(x) = \frac{1}{\sqrt{k_2}} \left(B_{\rightarrow} e^{ik_2 x} + B_{\leftarrow} e^{-ik_2 x} \right) \quad x > 0$$

where the wave vectors are related to the energy via

$$k_1 = \sqrt{2mE/\hbar^2}, \text{ and}$$
$$k_2 = \sqrt{2m(E - V_0)/\hbar^2}$$

with coefficients A and B determined from the boundary conditions and by imposing a continuous derivative on the solution.

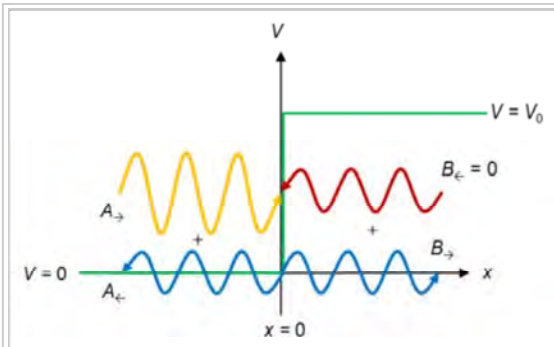

Scattering at a finite potential step of height V_0, shown in green. The amplitudes and direction of left- and right-moving waves are indicated. Yellow is the incident wave, blue are reflected and transmitted waves, red does not occur. $E > V_0$ for this figure.

Each term of the solution can be interpreted as an incident, reflected, or transmitted component of the wave, allowing the calculation of transmission and reflection coefficients. Notably, in contrast to classical mechanics, incident particles with energies greater than the potential step are partially reflected.

Rectangular potential barrier

This is a model for the quantum tunneling effect which plays an important role in the performance of modern technologies such as flash memory and scanning tunneling microscopy. Quantum tunneling is central to physical phenomena involved in superlattices.

Particle in a box

The particle in a one-dimensional potential energy box is the most mathematically simple example where restraints lead to the quantization of energy levels. The box is defined as having zero potential energy everywhere *inside* a certain region, and infinite potential energy everywhere *outside* that region. For the one-dimensional case in the x direction, the time-independent Schrödinger equation may be written[80]

$$-\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} = E\psi.$$

With the differential operator defined by

$$\hat{p}_x = -i\hbar\frac{d}{dx}$$

the previous equation is evocative of the classic kinetic energy analogue,

$$\frac{1}{2m}\hat{p}_x^2 = E,$$

with state ψ in this case having energy E coincident with the kinetic energy of the particle.

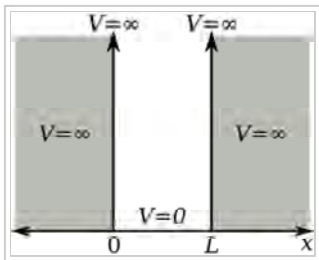

1-dimensional potential energy box (or infinite potential well)

The general solutions of the Schrödinger equation for the particle in a box are

$$\psi(x) = Ae^{ikx} + Be^{-ikx} \qquad E = \frac{\hbar^2 k^2}{2m}$$

or, from Euler's formula,

$$\psi(x) = C\sin kx + D\cos kx.$$

The infinite potential walls of the box determine the values of C, D, and k at $x = 0$ and $x = L$ where ψ must be zero. Thus, at $x = 0$,

$$\psi(0) = 0 = C\sin 0 + D\cos 0 = D$$

and $D = 0$. At $x = L$,

$$\psi(L) = 0 = C\sin kL.$$

in which C cannot be zero as this would conflict with the Born interpretation. Therefore, since $\sin(kL) = 0$, kL must be an integer multiple of π,

$$k = \frac{n\pi}{L} \qquad n = 1, 2, 3, \ldots.$$

The quantization of energy levels follows from this constraint on k, since

$$E = \frac{\hbar^2 \pi^2 n^2}{2mL^2} = \frac{n^2 h^2}{8mL^2}.$$

Finite potential well

A finite potential well is the generalization of the infinite potential well problem to potential wells having finite depth.

The finite potential well problem is mathematically more complicated than the infinite particle-in-a-box problem as the wave function is not pinned to zero at the walls of the well. Instead, the wave function must satisfy more complicated mathematical boundary conditions as it is nonzero in regions outside the well.

Harmonic oscillator

As in the classical case, the potential for the quantum harmonic oscillator is given by

$$V(x) = \frac{1}{2}m\omega^2 x^2.$$

This problem can either be treated by directly solving the Schrödinger equation, which is not trivial, or by using the more elegant "ladder method" first proposed by Paul Dirac. The eigenstates are given by

$$\psi_n(x) = \sqrt{\frac{1}{2^n\, n!}} \cdot \left(\frac{m\omega}{\pi\hbar}\right)^{1/4} \cdot e^{-\frac{m\omega x^2}{2\hbar}} \cdot H_n\left(\sqrt{\frac{m\omega}{\hbar}}x\right),$$

$$n = 0, 1, 2, \ldots.$$

where H_n are the Hermite polynomials

$$H_n(x) = (-1)^n e^{x^2} \frac{d^n}{dx^n}\left(e^{-x^2}\right),$$

and the corresponding energy levels are

$$E_n = \hbar\omega\left(n + \frac{1}{2}\right).$$

This is another example illustrating the quantification of energy for bound states.

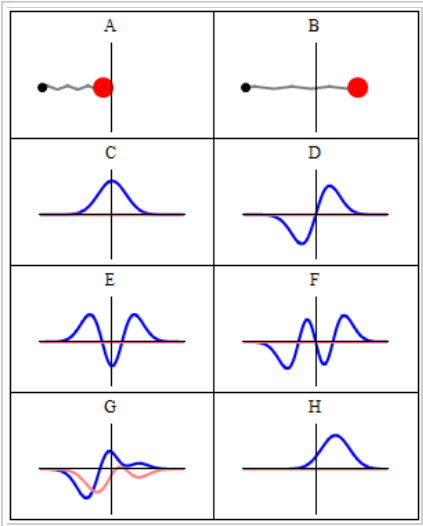

Some trajectories of a harmonic oscillator (i.e. a ball attached to a spring) in classical mechanics (A-B) and quantum mechanics (C-H). In quantum mechanics, the position of the ball is represented by a wave (called the wave function), with the real part shown in blue and the imaginary part shown in red. Some of the trajectories (such as C,D,E,and F) are standing waves (or "stationary states"). Each standing-wave frequency is proportional to a possible energy level of the oscillator. This "energy quantization" does not occur in classical physics, where the oscillator can have *any* energy.

See also

- Angular momentum diagrams (quantum mechanics)
- EPR paradox
- Fractional quantum mechanics
- List of quantum-mechanical systems with analytical solutions
- Macroscopic quantum phenomena
- Phase space formulation
- Regularization (physics)
- Spherical basis

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- Quantum Cook Book (http://oyc.yale.edu/sites/default/files/notes_quantum_cookbook.pdf) by R. Shankar, Open Yale PHYS 201 material (4pp)
- The Modern Revolution in Physics (http://www.lightandmatter.com/lm/) - an online textbook.
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- Introduction to Quantum Theory at Quantiki. (https://web.archive.org/web/20080913201312/http://www.quantiki.org/wiki/index.php/Introduction_to_Quantum_Theory)
- Quantum Physics Made Relatively Simple (http://bethe.cornell.edu/): three video lectures by Hans Bethe
- H is for h-bar. (https://web.archive.org/web/20071002191047/http://www.nonlocal.com/hbar/)
- Quantum Mechanics Books Collection (http://www.freebookcentre.net/Physics/Quantum-Mechanics-Books.html): Collection of free books

Course material

- Quantum Physics Database - Fundamentals and Historical Background of Quantum Theory. (http://qpdb.eu/)
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- Experiments to the foundations of quantum physics with single photons. (http://www.didaktik.physik.uni-erlangen.de/quantumlab/english/index.html)
- AQME (http://www.nanohub.org/topics/AQME) : Advancing Quantum Mechanics for Engineers — by T.Barzso, D.Vasileska and G.Klimeck online learning resource with simulation tools on nanohub
- Quantum Mechanics (https://web.archive.org/web/20091229101144/http://www.lsr.ph.ic.ac.uk/~plenio/lecture.pdf) by Martin Plenio
- Quantum Mechanics (https://web.archive.org/web/20110124130101/http://farside.ph.utexas.edu/teaching/qm/389.pdf) by Richard Fitzpatrick
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Categories: Concepts in physics | Quantum mechanics

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Quartz

From Wikipedia, the free encyclopedia

Quartz is the second most abundant mineral in Earth's continental crust, after feldspar. Its crystal structure is a continuous framework of SiO_4 silicon–oxygen tetrahedra, with each oxygen being shared between two tetrahedra, giving an overall chemical formula of SiO_2.

There are many different varieties of quartz, several of which are semi-precious gemstones. Since antiquity, varieties of quartz have been the most commonly used minerals in the making of jewelry and hardstone carvings, especially in Eurasia.

Quartz

Quartz crystal cluster from Tibet

General	
Category	oxide mineral[1][2]
Formula (repeating unit)	SiO_2
Strunz classification	4.DA.05 (Oxides)
Dana classification	75.01.03.01 (tectosilicates)
Crystal system	α-quartz: trigonal β-quartz: hexagonal
Crystal class	α-quartz: trapezohedral (class 3 2); β-quartz: trapezohedral (class 6 2 2)[3]
Unit cell	a = 4.9133 Å, c = 5.4053 Å; Z=3
Identification	
Color	Colorless through various colors to black
Crystal habit	6-sided prism ending in 6-sided pyramid (typical), drusy, fine-grained to microcrystalline, massive
Twinning	Common Dauphine law, Brazil law and Japan law
Cleavage	{0110} Indistinct
Fracture	Conchoidal
Tenacity	Brittle
Mohs scale hardness	7 – lower in impure varieties (defining mineral)

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Etymology

The word "quartz" is derived from the German word "Quarz" and its Middle High German ancestor "twarc", which probably originated in Slavic, cf. Czech *tvrdý* ("hard"), Polish *twardy* ("hard"), Serbian and Croatian *tvrd* ("hard").[7]

The Ancient Greeks referred to quartz as κρύσταλλος (*krustallos*) derived from the Ancient Greek *κρύος* (*kruos*) meaning "icy cold", because some philosophers (including Theophrastus) apparently believed the mineral to be a form of supercooled ice.[8] Today, the term *rock crystal* is sometimes used as an alternative name for the purest form of quartz.

Crystal habit and structure

Quartz belongs to the trigonal crystal system. The ideal crystal shape is a six-sided prism terminating with six-sided pyramids at each end. In nature quartz crystals are often twinned, distorted, or so intergrown with adjacent crystals of quartz or other minerals as to only show part of this shape, or to lack obvious crystal faces altogether and appear massive. Well-formed crystals typically form in a 'bed' that has unconstrained growth into a void; usually the crystals are attached at the other end to a matrix and only one termination pyramid is present. However, doubly terminated crystals do occur where they develop freely without attachment, for instance within gypsum. A quartz geode is such a situation where the void is approximately spherical in shape, lined with a bed of crystals pointing inward.

α-quartz crystallizes in the trigonal crystal system, space group $P3_121$ and $P3_221$ respectively. β-quartz belongs to the hexagonal system, space group $P6_222$ and $P6_422$, respectively.[9] These space groups are truly chiral (they each belong to the 11 enantiomorphous pairs). Both α-quartz and β-quartz are examples of chiral crystal structures composed of achiral building blocks (SiO_4 tetrahedra in the present case). The transformation between α- and β-quartz only involves a comparatively minor rotation of the tetrahedra with respect to one another, without change in the way they are linked.

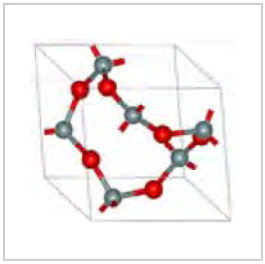

Crystal structure of α-quartz (red balls are oxygen, grey are silicon)

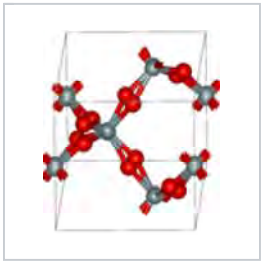

β-quartz

Luster	Vitreous – waxy to dull when massive
Streak	White
Diaphaneity	Transparent to nearly opaque
Specific gravity	2.65; variable 2.59–2.63 in impure varieties
Optical properties	Uniaxial (+)
Refractive index	n_ω = 1.543–1.545 n_ε = 1.552–1.554
Birefringence	+0.009 (B-G interval)
Pleochroism	None
Melting point	1670 °C (β tridymite) 1713 °C (β cristobalite)[3]
Solubility	Insoluble at STP; 1 ppm_{mass} at 400 °C and 500 lb/in^2 to 2600 ppm_{mass} at 500 °C and 1500 lb/in^2[3]
Other characteristics	Piezoelectric, may be triboluminescent, chiral (hence optically active if not racemic)
References	[1][4][5][6]

Varieties (according to microstructure)

Although many of the varietal names historically arose from the color of the mineral, current scientific naming schemes refer primarily to the microstructure of the mineral. Color is a secondary identifier for the cryptocrystalline minerals, although it is a primary identifier for the macrocrystalline varieties.

Major varieties of quartz		
Type	**Color & Description**	**Transparent**
Rock crystal	Colorless	Clear
Amethyst	Purple	Transparent
Rose quartz	Pink, may display diasterism	Transparent
Chalcedony	Cryptocrystalline quartz and moganite mixture. The term is generally only used for white or lightly colored material. Otherwise more specific names are used.	
Carnelian	Reddish orange chalcedony	translucent
Aventurine	Chalcedony with small inclusions (usually mica) that shimmer	Translucent
Agate	Multi-colored, banded chalcedony	Semi-translucent to translucent
Onyx	Agate where the bands are straight, parallel and consistent in size.	
Jasper	Cryptocrystalline quartz, typically red to brown	Opaque
Milky quartz	White, may display diasterism	Translucent to opaque
Smoky quartz	Brown to gray	Opaque
Tiger's eye	Fibrous gold to red-brown colored quartz, exhibiting chatoyancy.	
Citrine	Yellow to reddish orange to brown, greenish yellow	Transparent
Vermarine	Mint green	Transparent
Rutilated quartz	Contains acicular (needle-like) inclusions of rutile	
Dumortierite quartz	Contains large amounts of dumortierite crystals	

Varieties (according to color)

Clear rock crystals on a white base

Pure quartz, traditionally called rock crystal or clear quartz, is colorless and transparent or translucent, and has often been used for hardstone carvings, such as the Lothair Crystal. Common colored varieties include citrine, rose quartz, amethyst, smoky quartz, milky quartz, and others.

The most important distinction between types of quartz is that of *macrocrystalline* (individual crystals visible to the unaided eye) and the microcrystalline or cryptocrystalline varieties (aggregates of crystals visible only under high magnification). The cryptocrystalline varieties are either translucent or mostly opaque, while the transparent varieties tend to be macrocrystalline. Chalcedony is a cryptocrystalline form of silica consisting of fine intergrowths of both quartz, and its monoclinic polymorph moganite.[10] Other opaque gemstone varieties of quartz, or mixed rocks including quartz, often including contrasting bands or patterns of color, are agate, carnelian or sard, onyx, heliotrope, and jasper.

Amethyst

Amethyst is a popular form of quartz that ranges from a bright to dark or dull purple color. The world's largest deposits of amethysts can be found in Brazil, Mexico, Uruguay, Russia, France, Namibia and Morocco. Sometimes amethyst and citrine are found growing in the same crystal. It is then referred to as ametrine. An amethyst is formed when there is iron in the area where it was formed.

Citrine

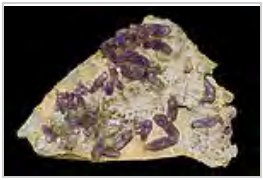
Amethyst crystals on matrix

Citrine is a variety of quartz whose color ranges from a pale yellow to brown due to ferric impurities. Natural citrines are rare; most commercial citrines are heat-treated amethysts or smoky quartzes. However, a heat-treated amethyst will have small lines in the crystal, as opposed to a natural citrine's cloudy or smokey appearance. It is nearly impossible to differentiate between cut citrine and yellow topaz visually, but they differ in hardness. Brazil is the leading producer of citrine, with much of its production coming from the state of Rio Grande do Sul. The name is derived from the Latin word *citrina* which means "yellow" and is also the origin of the word "citron". Sometimes citrine and amethyst can be found together in the same crystal, which is then referred to as ametrine.[11] Citrine has been referred to as the "merchant's stone" or "money stone", due to a superstition that it would bring prosperity.[12]

Citrine from Brazil

Milky quartz

Milky quartz sample

Milk quartz or milky quartz is the most common variety of crystalline quartz. The white color is caused by minute fluid inclusions of gas, liquid, or both, trapped during crystal formation, making it of little value for optical and quality gemstone applications.[13]

Rose quartz

Rose quartz cluster (Size: 3.4 x 3.1 x 1.9 cm)

Rose quartz is a type of quartz which exhibits a pale pink to rose red hue. The color is usually considered as due to trace amounts of titanium, iron, or manganese, in the massive material. Some rose quartz contains microscopic rutile needles which produces an asterism in transmitted light. Recent X-ray diffraction studies suggest that the color is due to thin microscopic fibers of possibly dumortierite within the massive quartz.[14]

Additionally, there is a rare type of pink quartz (also frequently called crystalline rose quartz) with color that is thought to be caused by trace amounts of phosphate or aluminium. The color in crystals is apparently photosensitive and subject to fading. The first crystals were found in a pegmatite found near Rumford, Maine, USA and in Minas Gerais, Brazil.[15]

Smoky quartz

Smoky quartz is a gray, translucent version of quartz. It ranges in clarity from almost complete transparency to a brownish-gray crystal that is almost opaque. Some can also be black.

Vermarine

Vermarine, also known as *prasiolite*, is a variety of quartz that is green in color. Since 1950, almost all natural vermarine has come from a small Brazilian mine, but it is also seen in Lower Silesia in Poland. Naturally occurring vermarine is also found in the Thunder Bay area of Canada. It is a rare stone in nature, most green quartz is heat-treated amethyst.[16]

Smoky quartz from the Alps

Raw natural vermarine

Synthetic and artificial treatments

Not all varieties of quartz are naturally occurring. Some clear quartz crystals can be treated using heat or gamma-irradiation to induce color where it would not otherwise have occurred naturally. Susceptibility to such treatments depends on the location from which the quartz was mined.[17] Prasiolite, an olive colored material, is produced by heat treatment; natural prasiolite has also been observed in Lower Silesia in Poland. Although citrine occurs naturally, the majority is the result of heat-treated amethyst. Carnelian is widely heat-treated to deepen its color.

Because natural quartz is often twinned, synthetic quartz is produced for use in industry. Large, flawless, single crystals are synthesized in an autoclave via the hydrothermal process; emeralds are also synthesized in this fashion.

Like other crystals, quartz may be coated with metal vapors to give it an attractive sheen.

A synthetic quartz crystal grown by the hydrothermal method, about 19 cm long and weighing about 127 grams

Occurrence

Quartz is a defining constituent of granite and other felsic igneous rocks. It is very common in sedimentary rocks such as sandstone and shale and is also present in variable amounts as an accessory mineral in most carbonate rocks. It is a common constituent of schist, gneiss, quartzite and other metamorphic rocks. Quartz has the lowest potential for weathering in the Goldich dissolution series and consequently it is very common as a residual mineral in stream sediments and residual soils.

While the majority of quartz crystallizes from molten magma, much quartz also chemically precipitates from hot hydrothermal veins as gangue, sometimes with ore minerals like gold, silver and copper. Large crystals of quartz are found in magmatic pegmatites. Well-formed crystals may reach several meters in length and weigh hundreds of kilograms.

Naturally occurring quartz crystals of extremely high purity, necessary for the crucibles and other equipment used for growing silicon wafers in the semiconductor industry, are expensive and rare. A major mining location for high purity quartz is the Spruce Pine Gem Mine in Spruce Pine, North Carolina, United States.[18]

The largest documented single crystal of quartz was found near Itapore, Goiaz, Brazil; it measured approximately 6.1×1.5×1.5 m and weighed more than 44 tonnes.[19]

Related silica minerals

Tridymite and cristobalite are high-temperature polymorphs of SiO_2 that occur in high-silica volcanic rocks. Coesite is a denser polymorph of SiO_2 found in some meteorite impact sites and in metamorphic rocks formed at pressures greater than those typical of the Earth's crust. Stishovite is a yet denser and higher-pressure polymorph of SiO_2 found in some meteorite impact sites. Lechatelierite is an amorphous silica glass SiO_2 which is formed by lightning strikes in quartz sand.

History

Austrian rock crystal (pure quartz) cornucopia by Karl Rössler. Circa 1890

The word "quartz" comes from the German *Quarz* ,[20] which is of Slavic origin (Czech miners called it *křemen*). Other sources attribute the word's origin to the Saxon word *Querkluftertz*, meaning *cross-vein ore*.[21]

Quartz is the most common material identified as the mystical substance maban in Australian Aboriginal mythology. It is found regularly in passage tomb cemeteries in Europe in a burial context, such as Newgrange or Carrowmore in Ireland. The Irish word for quartz is *grianchloch*, which means 'sunstone'. Quartz was also used in Prehistoric Ireland, as well as many other countries, for stone tools; both vein quartz and rock crystal were knapped as part of the lithic technology of the prehistoric peoples.[22]

Fatimid ewer in carved rock crystal (clear quartz) with gold lid, c. 1000

While jade has been since earliest times the most prized semi-precious stone for carving in East Asia and Pre-Columbian America, in Europe and the Middle East the different varieties of quartz were the most commonly used for the various types of jewelry and hardstone carving, including engraved gems and cameo gems, rock crystal vases, and extravagant vessels. The tradition continued to produce objects that were very highly valued until the mid-19th century, when it largely fell from fashion except in jewelry. Cameo technique exploits the bands of color in onyx and other varieties.

Quartz crystal demonstrating transparency

Roman naturalist Pliny the Elder believed quartz to be water ice, permanently frozen after great lengths of time.[23] (The word "crystal" comes from the Greek word *κρύσταλλος*, "ice".) He supported this idea by saying that quartz is found near glaciers in the Alps, but not on volcanic mountains, and that large quartz crystals were fashioned into spheres to cool the hands. This idea persisted until at least the 17th century. He also knew of the ability of quartz to split light into a spectrum.

In the 17th century, Nicolas Steno's study of quartz paved the way for modern crystallography. He discovered that

regardless of a quartz crystal's size or shape, its long prism faces always joined at a perfect 60° angle.[24]

Quartz's piezoelectric properties were discovered by Jacques and Pierre Curie in 1880.[25][26] The quartz oscillator or resonator was first developed by Walter Guyton Cady in 1921.[27][28] George Washington Pierce designed and patented quartz crystal oscillators in 1923.[29][30][31] Warren Marrison created the first quartz oscillator clock based on the work of Cady and Pierce in 1927.[32]

Efforts to synthesize quartz began in the mid nineteenth century as scientists attempted to create minerals under laboratory conditions that mimicked the conditions in which the minerals formed in nature: German geologist Karl Emil von Schafhäutl (1803–1890)[33] was the first person to synthesize quartz when in 1845 he created microscopic quartz crystals in a pressure cooker.[34] However, the quality and size of the crystals that were produced by these early efforts were poor.[35] By the 1930s, the electronics industry had become dependent on quartz crystals. The only source of suitable crystals was Brazil; however, World War II disrupted the supplies from Brazil, so nations attempted to synthesize quartz on a commercial scale. German mineralogist Richard Nacken (1884–1971) achieved some success during the 1930s and 1940s.[36] After the war, many laboratories attempted to grow large quartz crystals. In the United States, the U.S. Army Signal Corps contracted with Bell Laboratories and with the Brush Development Company of Cleveland, Ohio to synthesize crystals following Nacken's lead.[37][38] (Prior to World War II, Brush Development produced piezoelectric crystals for record players.) By 1948, Brush Development had grown crystals that were 1.5 inches (3.8 cm) in diameter, the largest to date.[39][40] By the 1950s, hydrothermal synthesis techniques were producing synthetic quartz crystals on an industrial scale, and today virtually all the quartz crystal used in the modern electronics industry is synthetic.

Piezoelectricity

Quartz crystals have piezoelectric properties; they develop an electric potential upon the application of mechanical stress. An early use of this property of quartz crystals was in phonograph pickups. One of the most common piezoelectric uses of quartz today is as a crystal oscillator. The quartz clock is a familiar device using the mineral. The resonant frequency of a quartz crystal oscillator is changed by mechanically loading it, and this principle is used for very accurate measurements of very small mass changes in the quartz crystal microbalance and in thin-film thickness monitors.

See also

- Dallasite
- Fused quartz
- List of minerals
- Quartz reef mining
- Quartzolite
- Shocked quartz

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Categories: Quartz varieties | Dielectrics | Piezoelectric materials | Symbols of Georgia (U.S. state) | Trigonal minerals | Luminescent minerals | Quartz gemstones

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Working Paper No. 40

Quasi-Static Compression Forming of Stabilised Soil-Cement Buildig Blocks

1993

D.E.M.Gooding

Development Technology Unit
Department of Engineering, University of Warwick
Coventry CV4 7AL UK
Tel: +44 (0) 1203 523122 Fax: (0) 1203 418922
email: dtu@eng.warwick.ac.uk

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Quasi-static Compression Forming of Stabilised Soil-cement Building Blocks

by Dr.D.E.Gooding

ABSTRACT

This paper examines the quasi-static compression (slowly applied pressure) method of compacting stabilised soil-cement building blocks. It describes a self-contained piece of research which was conducted to enable the comparison of quasi-static compression with the alternative dynamic methods of soil compaction. It gives an initial over view of the process of soil stabilisation and outlines the roles which soil structure and block curing play in stabilisation. The alternative methods of block compaction are briefly described, followed by a discussion of the material factors which affect the compaction of stabilised soil. A number of simple theoretical models to describe the internal compaction mechanisms of quasi-static compaction are then given.

The results of an experimental investigation to asses the effect of double-sided compaction, mould wall roughness, mould wall taper and pressure cycling relative to the datum process of single-sided, single-cycle compaction are then discussed. This is followed by an experimental investigation to determine the relation between compaction pressure, cement content and seven day wet compressive strength. A formula relating cement content and compaction pressure to wet compressive strength is put forward as the best fit to the experimental data gathered. This formula is then used as the basis for a simple economic analysis of high and low pressure compaction machines.

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INTRODUCTION

The following paper has been produced as the result of an on-going research program to investigate the compaction process used in the production of soil-cement building blocks. It is concerned with the standard quasi-static compaction process. This is the form of compaction normally used in the field by machines such as the Cinva Ram and the Brepack.

The paper is organised into six main sections followed by four appendices containing a bibliography and experimental details. The first section gives an initial overview of the stabilised block technology and briefly describes the roles which various factors play in the final strength of the block. Section two briefly describes the alternative compaction mechanisms and puts this research in context as a reference base for future work to investigate impact and vibration compaction. The third section deals with the material factors which affect the compaction process. The fourth section gives a number of simple theoretical models to describe the compaction process. Section five examines moulding factors which affect the quasi-static compaction of soil-cement blocks. Mould taper, mould roughness, compaction pressure cycling and double sided compaction are examined relative to standard single-sided compaction (the datum process) by recording the pressure transmitted from the compacting soil to the mould walls with an LVDT-based pressure transducer. Section six examines the relationship between compaction pressure, cement content and seven day wet compressive strength. This relationship is then used in a simple economic analysis to asses the cost effectiveness of high and low pressure compaction machines.

1. STABILISED SOIL

Some form of soil covers virtually the whole land surface of the Earth. This soil is usually readily processed with simple hand tools into an easily mouldable material which possesses good compressive strength when dry. Given soil's widespread availability, it is not surprising that it was traditionally widely used as a building material.

The major drawback to building with soil in its natural condition is its susceptibility to water. A soil wall may be considered as a load bearing skeleton of silt and sand glued together by clay. This glue-like behaviour when dry is caused by micro-droplets of water which exist at clay particle interfaces. Clay particles are usually electrostatically charged as a result of surface ion substitution. The charge tightly bonds a thin adsorbed layer of water to the particle's surface. The bonding is sufficiently strong for some adsorbed water to remain even at oven drying temperatures (105-110°C). At the point of contact between two adjacent particles, a micro-droplet of water can exist where the two adsorbed water layers come into contact. These micro-droplets generate both surface and

capillary tension forces which hold the clay particles together. However, when any significant quantity of water is absorbed into empty soil pores, the droplets increase in size and the capillary and surface tension forces reduce, causing the soil to quickly soften and subsequently swell. On repeated wetting and drying the outer surfaces of a soil wall expand and contract more quickly than the main body. In a comparatively short time this leads to cracking and spalling of the outer surfaces and low durability for the wall. Moreover, if the wall becomes saturated with water the compressive strength may fall sufficiently to allow complete collapse.

When a soil has been treated to reduce the effect of strength loss on water saturation to a low level, then it may be considered a permanent, durable building material and may be called stabilised soil.

1.1 THE PRINCIPLES AND PRACTICE OF SOIL STABILISATION

If a soil is to be used in any but the driest of climates, it should be stabilised against the weakening effect of water ingression if it is to be durable. There are three primary methods of stabilising a soil: by adding a chemical waterproofer to reduce the tendency of the soil to adsorb water, by adding a chemical binder to give a strength mechanism which persists even when the block is saturated, or by compressing the soil to increase its density, hence increasing its load bearing capacity and at the same time reducing its water permeability.

Under normal conditions the soil's density is increased by compaction to reduce the soil-pore void volume and hence its permeability. By reducing the permeability of the soil, the length of time for which a soil wall may be exposed to water without adverse effect will be extended. However, increased density will not stop the ultimate failure of a soil wall if it is allowed to become completely saturated. To maintain strength when completely saturated, the soil must have an additional strength mechanism.

The advantages of increased density complement those derived from the addition of chemical waterproofers and binders, such that it is normal practise to compact the soil block whenever an additional stabilising agent is to be employed. The reduced permeability reduces the speed of water ingress, while the reduction in soil-pore void volume results in a lower chemical requirement. Whether binder or waterproofer, the chemical additive extends throughout the soil-pore void structure. If the volume of the void structure is reduced, then the amount of stabiliser required to fill or bridge the voids is reduced and hence an increase in soil density will usually allow a reduction in stabiliser content for the same final block strength (see section six for more information on the pressure-cement trade off).

When adequately stabilised, a soil block should not collapse when saturated with water, even after several cycles of complete wetting and drying. A waterproofing agent such as bitumen cutback has two effects. It reduces the ability of water to wet individual soil grains and hence reduces the ingression of water. It also provides a secondary method of particle adhesion by weakly sticking particles together. A dry soil block which has been waterproofed with bitumen may be weaker than an unstabilised block as the adhesion power of bitumen is frequently less than that provided by the silt and clay fraction which it is supplementing. However, when subjected to water the unstabilised soil block will rapidly loose almost all of its strength while the waterproofed block will largely retain its lower strength.

A binding agent such as cement will also reduce the effect of water saturation. Again any compaction of the soil during production will reduce the permeability of the soil and reduce the soil pore-void volume. The addition of a chemical binding agent does not stop the ingression of water much beyond that provided by the increase in density. Instead the binder provides a secondary method of bonding the soil particles together which is independent of the soil's water content. In the case of cementitious binders, the stabiliser forms hard insoluble fibres throughout the soil pore-voids. These fibres then effectively form a rigid skeleton which continues to hold the soil particles together even when wet. The addition of cementitious binders to an appropriate soil will improve both the wet and dry strength of the final cured block. The following paper is centred on binder-type stabilisation and in particular the production of stabilised soil-cement blocks where the stabilising agent is ordinary portland cement. Other binders, such as lime, have been used to make successfully stabilised blocks; however cement is the most commonly used stabiliser and as such has been the subject of this research.

Regardless of the type of stabiliser used, the production process for stabilised-soil blocks is similar. Firstly the local area is surveyed to establish the location of a suitable soil type.[1] Having found a suitable soil or modified a less than suitable one, the soil is dug, sieved to remove any large particles (greater than 6mm) and break up any large lumps. It is then laid out to dry. A suitable quantity of stabiliser is mixed with the dry soil and a uniform mixture is produced. A suitable quantity of water is then mixed with the soil such that the resulting mix is at the optimum moisture content (see section 3.1) for compaction. This mixture is transferred to the block mould for compaction. After compaction the "green" block is ejected from the mould and transferred to a curing area, which should be flat, level and protected from rain. The block is left to cure before incorporation in a wall. The curing regime differs according to the type of stabilisation being used. The

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1. The process of soil selection and the discussion of soil suitability is covered in an earlier paper, DTU WORKING PAPER No. 38 "Soil Testing for Soil-Cement Block Preparation."

curing requirements for cement stabilised blocks will be covered in section 1.3.

1.2 SOIL STRUCTURE

The soil structure plays a very important role in the stabilisation process. In general use the high cost of soil will dictate the stabilisation of natural local soil. Natural soil exists in layers of differing composition. The top most layer of soil is generally organic and hence unsuitable for stabilisation. The subsequent lower layers will normally be inorganic and contain differing fractions of gravel, sand, silt and clay, and may or may not be suitable for direct stabilisation. If the first inorganic layer is predominantly clayey it will be poor for stabilisation. However, if the second layer is more sandy, a soil more suitable for stabilisation may be produced by blending the two.

Any soil may be described by a particle grading curve and its plasticity or Atterburg limits. The particle grading curve details the proportions of gravel, sand, silt and clay present in the soil while the plasticity limits give information on the properties of the fine (silt and clay-size) components. The different size fractions play different roles within the stabilised block.

Particles of sand size and larger act as the main inert body of the block. These sand and gravel fractions should be present in correct proportions to allow the most dense packing arrangement. The theoretical optimum distribution of particle sizes is that given by the Fuller curve (Fig 1.2a).

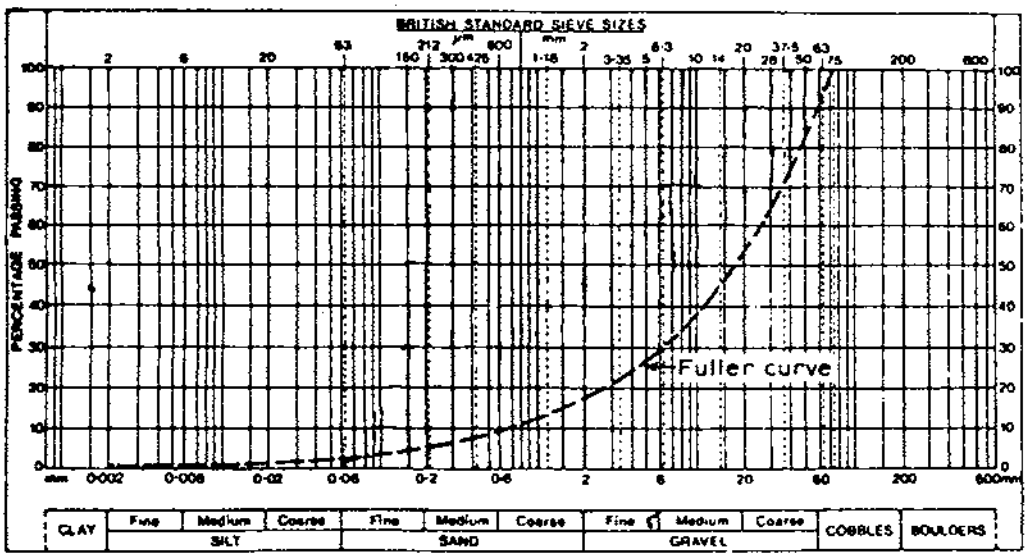

Figure 1.2a The Fuller Curve

The Fuller curve is based upon the assumption that all of the particles are spherical and that the largest particles just touch each other, while there are enough intermediate particles to fill the voids between the largest, but without holding them apart. The intermediate size particles are also similarly arranged with progressively finer particles filling the voids between larger ones. The Fuller distribution is an ideal model and never occurs naturally. However, a natural soil which has an even distribution of particle sizes, termed well-graded, is a good approximation and will ensure adequate packing.

The fine fraction of the soil may be considered as the active fraction. The coarse material is essentially inert, it does not change volume on wetting and does not play a significant role in particle bonding. The fine fraction is responsible for the dry cohesion of a soil. If this fraction is wetted it will expand. Clay consists of a large number of very small usually plate-like shaped particles. In a dry condition these particles pack closely together, held tightly in place by micro-droplets of water. On exposure to more water, capillary suction tends to draw water into the inter-particle fissures and separate the particles. This particle separation occurs simultaneously in three directions such that the clay expands.

The expansion of dry clay on wetting is the source of dimensional variations which can lead to cracking and spalling of a soil-cement block. For block durability, the extent to which the block expands and contracts on exposure to water should be minimised. A stabilised soil-cement block exhibits less dimensional variation than an equivalent unstabilised block. The force exerted by the expanding clay fraction must be resisted if the block is to remain intact over any significant length of time. In the case of soil-cement blocks this expansive force is largely resisted by the confining action of the insoluble cementitious matrix. Hence a large clay content soil will require a large quantity of cement to stabilise it. In order to minimise this expansion for a given water exposure level, and hence the amount of cement required, it is necessary to reduce the clay content of the block to a minimum.

However, the cohesive strength of damp clay is largely responsible for the green strength of the freshly formed block. Indeed a pure sand will exhibit negligible cohesion when dry and only slightly more when damp. It is most important to the economics of soil-cement block production that the fresh block can be ejected from the mould immediately after compaction rather than the cure-in-mould approach seen in conventional concrete work. To enable immediate ejection after compaction, the fresh block must have enough strength to allow at least careful handling without damage.

Hence it can be seen that the clay fraction is both a help and a hindrance to block production and a compromise must be reached. The extent of the compromise and the "optimum" clay content will be different for each particle grading and type of clay, montmorillonites for example exhibiting a much higher

expansion on wetting than other types of clay. Moreover, the compaction pressure used to form the block also plays a role. At high compaction pressures the soil particles are forced into more intimate contact which increases the green strength of the block for a given clay content.

The sensitivity of the soil's Optimum Water Content (discussed in more detail below) also depends on the soil's structure. The enormous range in particle size from gravel (6mm) to clay (less than 0.002mm) results in a large difference in the specific surface area (SSA) of soils containing different proportions of different sized particles. When a soil is made up of predominantly fine material then the SSA of that soil is very large, when the soil contains larger fractions of more coarse material then the SSA is reduced. For a high SSA soil, a given change in water content will have a reduced effect on the compaction process as the area over which the water acts will be relatively large and result in only minor physical change. Conversely for a low SSA soil, the area over which the water acts is reduced and hence the physical effect on the soil is greater.

This effect is illustrated in figure 1.2b (Fig 1.2b). Dry density after compaction is plotted against moisture content at the time of compaction. Curve A shows the pattern for a well graded soil containing a range of particles from gravel to clay size, Curve B shows the pattern for a more narrowly graded soil containing particles from only fine sand to clay size. It can be easily seen that curve A has a more pronounced peak than curve B. It may also be noted that the density peak for curve B is shifted towards higher moisture contents and that the peak dry density is reduced. The increased optimum water content would be expected from the above discussion of SSA while the reduction in dry density would be expected from the discussion on particle grading.

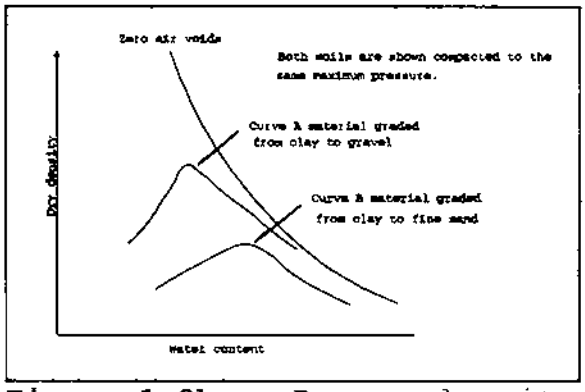

Figure 1.2b Dry density plotted against water content.

The factors affected by the structure of the soil may be summarised as follows:

GRADING The soil grading should be as close to the optimum Fuller curve as practical to enable the most dense packing of the soil particles. The more dense the packing of the soil particles then the lower the permeability of the soil and the higher its compressive strength. The larger the greatest size of particle the more care must be taken in controlling the moisture content.

PLASTICITY The soil should contain sufficient clay to allow adequate green strength on ejection from the mould. Too little

clay and the breakage rate on ejection of the compacted block will be unacceptably high. Too much clay and the long term durability of the block will be adversely affected.

1.3 THE CURING PROCESS

The curing process described below refers to that required for blocks which have been stabilised with ordinary portland cement. The curing regime will be broadly similar for lime stabilised blocks but the length of time for curing should be doubled. For bitumen stabilised blocks, "curing" is the process of evaporation of the bitumen solvent and of the moisture content required for compaction. The bitumen curing process is primarily a drying operation while that for cement and lime is a period of time for the bulk of a chemical hydration reaction to occur.

In the case of bitumen stabilisation drying out of the block is desirable, provided that the drying is not sufficiently rapid to lead to warping of the block. For cement and lime stabilisation, drying out of the block will stop the cementitious hydration reaction and hence not allow the blocks to gain their full strength.

After ejection from the compaction mould the block should be carefully transported. The green blocks are weak until the chemical hydration reaction has occurred and any significant breakage rate will have an adverse effect on the economics of the project. The safest way to transport green blocks is to place them on individual boards and subsequently carrying the board to the curing site. The blocks may be placed onto and removed from the board by placing the palms of the hands flat against the largest sides of the block and squeezing the hands together just enough to grip the block to lift it.

The blocks should be taken to a flat level area which should be protected from direct sunlight and rain. Direct sunlight would cause the blocks to dry out too quickly, while rain would easily erode the fresh blocks at least until the cement has had time to hydrate. During the first four days the block should be kept damp to allow the chemical cement hydration reaction to occur. It is this hydration reaction which gives the soil-cement block its superior wet strength.

The exact mechanism by which a small content of cement may stabilise a large mass of soil is not fully understood. Ordinary Portland Cement is made up of 45% tricalcium silicate (C_3S)[2] and 27% dicalcium silicate (C_2S). In the presence of damp soil these

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[2]. C and S represent Calcium and Silicon respectively, not carbon and sulphur. This is in keeping with most of the published concrete literature and is acceptable, allowing these simple equations to be given as illustrations instead of the more complicated fully balanced chemical equations.

components hydrate to form mono and di-calcium silicate hydrate gels (CSH and C_2SH, see equation below). These gels then slowly crystallise into an insoluble interlocking matrix throughout the soil voids binding the soil particles together. As the matrix is insoluble it gives a strength mechanism which works to restrain the softening and swelling of the unaffected soil, thereby dramatically reducing the weakening effect of water. The interlocking calcium silicate fibres may be seen when a cured soil cement sample is examined under an electron microscope. The hydration of the calcium silicate also results in the release of free lime (CH) according to the reaction:

$$C_3S + 2H = C_2SH + CH$$
$$C_2S + 2H = CSH + CH$$

The free lime then reacts further with the clay fraction (pozzolanic reaction) by the removal of silica from the clay minerals and subsequently forms more calcium silicate gel which also gradually crystallises.

2. BLOCK COMPACTION PROCESSES, THE ALTERNATIVES.

This paper examines the effects of various process and material factors on the production of soil-cement blocks by quasi-static pressure application. This work has been conducted as a self-contained piece of research but will be used as a reference datum for the future examination of alternative compaction mechanisms, the alternatives being dynamic force application by impact and vibration.

QUASI-STATIC COMPRESSION: Quasi-static or slowly applied compaction is the process used by the majority of soil-block making machines. The loose soil is compressed by slowly applying a large force. The magnitude of the pressure which is applied varies from machine to machine but is generally within the range of 1-8 MPa. The Cinva Ram is a well known low-pressure machine which uses force applied manually through a lever mechanism to produce a compaction pressure of about 2 MPa. The Brepack is an example of a high-pressure machine which applies between 8 and 10 MPa compaction. The Brepack uses a lever mechanism for the initial compaction and finishes with a manually operated hydraulic ram.

If a standard block's dimensions are assumed to be 290x140x100 mm then compaction pressures of 2 and 10 MPa equate to static loads of 8.3 and 41.4 metric tonnes. This is an appreciable loading for the structure of any machine to withstand.

DYNAMIC COMPACTION: Dynamic compaction is compaction by a mass which has a non-trivial velocity on impact, much like a hammer blow driving a nail into a piece of wood. Dynamic compaction requires far less massive machinery to generate large forces than quasi-static compaction does (to *push* a nail into a piece of wood requires a much greater static mass than that of the hammer). Dynamic compaction may also require less effort from the manual-machine operator.

A preliminary investigation into the efficiency of road compacting machines by the Transport and Road Research Laboratory (Williams and Maclean, 1950, Ref No.21) showed that slowly applied static loading may not be the most effective method of compaction for soil. It appears that dynamic compaction is more effective in terms of the depth of soil compacted.

Single impact and vibration are an extension of the same theme. Vibration may be thought of as a repeated light blow which, although requiring more complicated machinery to implement, does not involve the dropping of large and potentially dangerous weights.

3. MATERIAL FACTORS AFFECTING THE COMPACTION OF STABILISED-SOIL BLOCKS

3.1 MOISTURE CONTENT

Any soil placed in the mould for compaction should contain a known quantity of water. Earlier literature on the subject has suggested that there exists an optimum water content (OMC) at which the maximum density of the soil may be reached for a given compaction pressure. This is correct. By definition the resulting cured dry density will be highest for a block which has been compacted at its OMC. It should be forcefully noted that the OMC is not a parameter solely dependant on the soil, it varies considerably with the compaction pressure used to form the block. In general, as the compaction pressure increases so the OMC decreases. The content may be conveniently thought of as a lubricant which has adverse effects in excessive quantities. At higher compaction pressure the applied force is greater, the soil particles will move more readily and hence less lubricant (water) will be required.

The sensitivity of any particular soil to moisture depends on the soil's particular composition and has been discussed above with reference to specific surface area. Well-graded soils including a substantial fraction of large-size particles will be more sensitive to moisture content variation than soils with smaller fractions of large size material. The degree of

sensitivity to change in moisture content is an important parameter to consider when producing blocks. If the soil material being used does contain a significant quantity of large size material then the control of the moisture content is more critical.

At the outset of this work a number of tests were conducted to establish the optimum moisture content for the soil used in the subsequent work (artificial *soil-A*). To this end a number of small cylinders were produced at varying water contents and at both 2 and 10 MPa. The soil used for the testing was well graded and the largest size fraction was coarse sand. This type of soil was found to have a low sensitivity to water (it contained a negligible proportion of gravel-size material), resulting in a flat moisture/density curve. However as a result of the low aspect ratio of the cylindrical mould used, the soil-strength required for successful demoulding was quite high. This emphasised the importance of green strength from an early stage in the experimental proceedings. The OMC at 10 MPa was found to be 8% and the cylinders became too weak to allow demoulding without the most careful and elaborate system at 10%! At lower moisture contents the green samples became progressively stronger. This follows readily from the strength mechanism described above for unstabilised soil.

Although the ultimate compressive strength of the block is important, so too is the green strength of the block. By lowering the moisture content at compaction, the green block produced will be stronger although the final cured strength will be lower. The extent to which the reduction in moisture content will reduce the final strength of the block depends on the nature of the soil. In general a more sensitive soil will show a larger drop in final strength as a result of the larger drop in compacted density. It is usually the case that compaction above[3] the optimum water content will result in a weak green compact. If this green compact is not sufficiently strong to allow handling on ejection then it is likely that the breakage rate both on ejection and subsequent transportation will be high.

Low green strength is one of the major problems for many block production systems. Indeed Dr. Lawson (1992, Ref No.22) found breakage rates to be as high as 50% for blocks produced on a Cinva Ram type machine in Nigeria. If an excessive green breakage rate is found then the water content should be reduced to increase the green strength. It should be remembered that any block which has been broken on ejection or during handling operations is lost. It may not be broken up and recompacted, as the cement hydration reaction will have progressed to such an extent that the amount of remaining unreacted cement would be too low for adequate stabilisation.

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[3] With low clay content soils even compaction at the OMC may produce blocks with inadequate green strength.

The moisture content at the time of compaction also has an effect on the durability in terms of the blocks' permeability. It has been reported by CRAterre that compaction at moisture contents less than the optimum will result in a more permeable structure than compaction above optimum. A verification of this work will be carried out at The University of Warwick shortly. CRAterre use the concept of flocculated and dispersed microstructure to explain this phenomenon (Doat et al, 1979, Ref No.8). At low water contents the plate-shaped clay particles mutually attract each other. The outer edge of one plate electrostatically attracts the centre section of the neighbouring plates, leading to a flocculated clay structure (fig 3.1a). At high water contents, the surface charge of the clay plates is largely neutralised by the surrounding water dipoles and creates a pattern of mutually repelling particles or a dispersed structure (fig 3.1b). However at present the magnitude of this permeability change is not clear. In wet climates where water penetration is likely to be of importance then compaction slightly wet of the OMC may be appropriate to increase the blocks' resistance to water.

In summary, compaction at the OMC will produce the most dense blocks (by definition). Compaction wet of the OMC will produce blocks with a lower green strength on demoulding but possibly a lower permeability when cured. Compaction dry of the OMC will produce blocks with a higher green strength on demould and possibly a higher permeability.

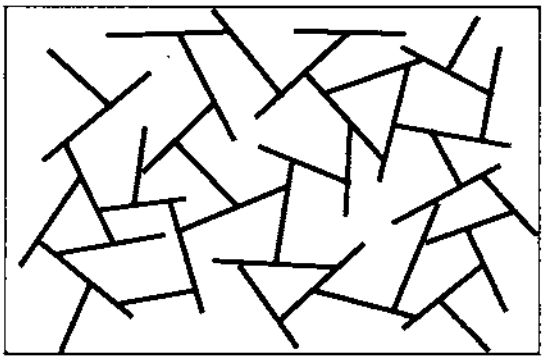

Figure 3.1a Flocculated

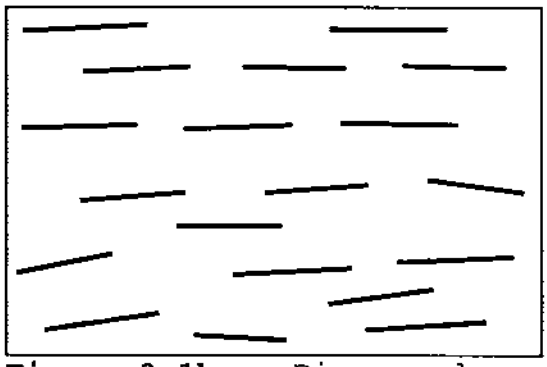

Figure 3.1b Dispersed

Compaction at the OMC is the best compromise. In dry climates and where low green strength has been seen to be a problem, the moisture content may be reduced. In wet climates were low green strength has not appeared as a problem then compaction at slightly increased moisture content may be considered. It should be remembered that the final cured strength of the block may be increased and the permeability reduced by increasing the cement content (although this may be costly) whereas the green strength may only be increased by improving the structure of the soil, compacting to higher pressure or reducing the compaction moisture content.

3.2 COMPACTION DELAY

The strength of the final cured block depends heavily on the adequate hydration of the cement. Cement is the most expensive ingredient in the production of stabilised soil blocks. Ordinary Portland Cement starts to react immediately on coming into contact with water. The reaction progresses quickly to begin with and progressively slows down over several weeks.

The hydration of the cement produces the insoluble calcium silicate hydrate skeleton which extends throughout the soil voids. This skeleton provides the restraining mechanism which gives soil cement its superior wet strength. The precipitation of these fibres begins as soon as the cement comes into contact with water. The fibres' effect is significantly reduced if they are deposited as discrete entities rather than as a continuous skeleton. Most of the fibres which form prior to the compaction of the soil cement mix will be broken during the pressing process and are then not as effective. The most effective precipitation occurs after the compaction process when the soil particles will remain undisturbed. As a result, the final strength of the stabilised block depends to a degree on the length of time for which the cement is exposed to water prior to compaction. Ingles and Metcalf (Ingles & Metcalf, 1972, Ref No.10) have reproduced a graph from G.West which indicates that over 50% of the final strength of cement stabilised soil may be lost by a delay of 2 hours (Fig 3.2a). Even after half an hour West indicates that between 30 and 40% of the strength is lost. A set of trials conducted at The University of Warwick on cylindrical test compacts has failed to convincingly reproduce such dramatic results. This may be because the short curing period used (seven days) was insufficient, not allowing the samples to cure for long enough to develop sufficient strength for adequate testing in the compression-test equipment available. However, a general trend was observed confirming some loss in (seven day) strength with increased delay between water addition and compaction. A 2 hour delay in compaction produced a strength loss of about 20%.

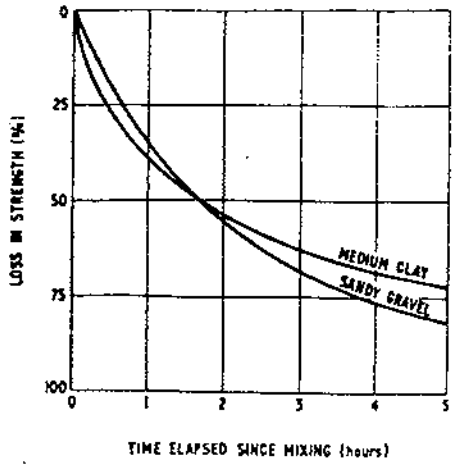

Figure 3.2a Cured strength loss due to compaction delay

4. MODELS TO DESCRIBE THE INTERNAL COMPACTION MECHANISM FOR COMPRESSED BLOCKS PRODUCED BY QUASI-STATIC COMPRESSION.

A number of simple models were initially postulated to describe the internal compaction mechanism; a simple hydrostatic fluid model, a pipe flow model, a solid model (based on Poisson's Ratio) and an elasto-plastic band compaction model.

4.1 Simple Hydrostatic Fluid Model.

The simplest model which might be used to describe the compaction process is the hydrostatic fluid model. This model assumes that the soil behaves like a contained fluid, namely that the pressure within the soil is the same in all lateral directions and increases in a downward vertical direction only as a result of the overburden pressure (weight of soil above the layer in question). This overburden pressure is insignificant compared to the external pressures applied to a block during moulding.

This model predicts that if a compaction pressure of 10MPa is applied to the top surface of the mould, both the mould walls and the base of the mould should also experience a transmitted pressure of 10 MPa. It further predicts that there will be no shear force between the soil and the mould walls.

4.2 Pipe Flow Model.

This model assumes that the soil is behaving like a viscous fluid flowing through a pipe. A viscous fluid may support a shear force while it is flowing. The more viscous the fluid, the longer it will take to flow and the larger the shear force it can maintain. This model predicts that if a pressure of 10 MPa is applied to the top surface of the mould the soil will "flow" downwards towards the bottom of the mould away from the source of high pressure. As some of the applied force is resisted by the mould wall shear force, the force on the bottom of the mould is reduced. As the distance from the compacting piston increases so the area for shear with the mould wall increases. As a result, progressively more force is transferred to the mould walls as a shear force or friction. This effectively reduces the driving force or pressure. The reduced driving pressure then results in a lower lateral pressure than that predicted by the simple hydrostatic model.

The above model is based on fluid pipe flow; flow through an open ended pipe. In the case of soil compaction one end of the mould is fixed and soil is forced towards it by the movement of the opposite end. According to fluid theory, when the velocity of flow reduces to zero, hydrostatic conditions should again prevail as a stationary fluid cannot support a shear force. As the flow of soil may be expected to stop when the compacting

piston ceases to move this zero soil flow should result in equalised hydrostatic conditions, the mould wall pressure should equalise to the simple hydrostatic state mentioned above. If the mould wall pressure does not equalise then either the soil has become so viscous that its rate of flow is too slow to show this equalisation in the time available (typically 30 sec for block production) or that the soil may not be described as a fluid by the end of compaction. If the mould wall pressure does not equalise then the soil must be resisting internal shear forces, behaving as a solid.

4.3 Solid Model (Poisson's Ratio)

By applying a pressure to the top surface of a solid object, vertical strain is induced in the medium this results in a lateral stress which in turn causes lateral strain. The ratio of vertical compressive strain to lateral tensile strain is defined as the Poisson's Ratio of the medium and is constant within the elastic deformation regime. Typically, for most metals, Poisson's Ratio is around 0.3 (for a fluid it would be 0.5).

Poisson's Ratio is normally used to describe the deformation of unconfined solids when subjected to compressive or tensile stress. A simple unconfined example would be the compression of a steel cube. In such a simple case the Poisson's Ratio is relatively simple to define, the three axial strains being simple to measure and uncomplicated by constraint interference. In the case of soil block compaction this is not the case. Lateral strain is less than it would be when unconfined, as the movement is restrained by the mould walls. The applied stress results in a vertical strain, this producing a lateral stress resulting in a lateral strain. This lateral strain acts on the mould walls, as a result the mould walls deflect. The resistance of the mould walls to the soil deflection decreases the amount of lateral soil strain which can take place.

The mould walls restraining influence further complicates the model as the wall is not completely rigid. The wall elastically deflects as a result of the stress within the soil. The amount of deflection depends both on the stiffness of the wall and the soil stress acting on it. As the wall deflects it provides more resistance to movement as its effective rigidity increases, also as the soil expands so the soil stress is reduced. There should then exist a balanced condition where the restraining force exerted by the wall is equal to the residual soil stress. What effect this residual soil stress will have is unclear. The walls' restraining force may be considered as producing a lateral compressive force which in turn would produce a vertical stress opposing the initial compaction force.

The compaction may be described by this solid model provided that the soil's Poisson Ratio is assumed to change as the compaction cycle progresses. During the initial compaction stage (say up to 10% of the final compaction pressure) a large block

height reduction takes place, typically 80-90% of the total height reduction, with almost no measurable lateral strain. This indicates largely plastic flow; on the removal of the compacting force only limited recovery takes place (typically 1-3 mm, 1/80th of the total deflection). As the block height reduces further the amount of relaxation expansion increases.

4.4 Elasto-plastic Band Compaction Model.

This model assumes that the compaction proceeds over a set of surfaces arranged roughly parallel with the moving compaction piston. As the compaction force is applied, so the top layer of soil plastically and, to a lesser extent, elastically compresses. As the soil plastically compresses it becomes stiffer and passes more of the applied force on to lower layers which are thus compressing at a slower rate. On decompression the plastic deformation is not recovered but the elastic compression reverses resulting in a degree of material expansion.

5. MOULDING FACTORS AFFECTING THE COMPACTION OF SOIL-CEMENT BLOCKS

Blocks are commonly moulded in a single cycle by moving a piston down into a parallel sided mould containing soil. The mould walls start with some roughness due to machining during manufacture, and this may increase due to soil abrasion during use. This process has been taken as a datum ("standard compaction"). Research was undertaken to better understand the standard compaction process and to investigate a number of variants to it. The pressure transmitted through the soil to the bottom of the mould was taken as a key variable that should correlate strongly with block density and subsequent cured block strength.

The following section examines the effect of the following moulding parameters:

Double Sided Compaction (instead of single sided)
Mould Wall Friction (high verses low)
Mould Wall Taper (instead of parallel-sided mould)
Pressure Cycling (instead of simple compression)

The effects of the changes in moulding parameters were observed by measuring the pressure transmitted to the mould wall through the compacting soil. The transmitted pressure was recorded by placing an LVDT-based pressure transducer (designed in-house) in seven separate locations in the mould wall and mould piston. The compacting pressure was applied in discrete increments up 2MPa or 10MPa. At each increase in load the block

height, mould wall deflection and transmitted pressure were recorded. Details of the experimental method and the experimental instrumentation are included in appendices C and D.

The initial testing was conducted on blocks made without the use of cement such that the material could be reused and the testing procedure would be less time dependant. Moreover, without the addition of cement the soil mix has a higher internal friction[4] and therefore amplifies the effect of the changes in pressing parameters. It has been assumed that although the magnitude of the variation in the observed parameters will be different for cement mixes, the pattern of change will be similar. Any variation apparent in a non-cement mix is likely to be present in a mix containing cement, but to a lesser degree. Following the initial set of tests two further set of blocks were produced with the addition of cement, one set by the datum process and one by double-sided compaction. These soil-cement blocks were allowed to cure for seven days and then tested for wet compressive strength to asses the actual improvement in strength resulting from double-sided compaction.

All of the blocks produced were made from an artificial soil (*Soil-A*). This soil has been carefully tested both to BS1377 and by the methods given in the Development Technology Unit Working Paper (DTU) No.38 "Soil Testing for Soil-Cement Block Preparation". The soil is composed of Kaolin grade E powder and a poor quality building sand (high fines content). It has a low plasticity index and is well graded with particles from clay to coarse sand size. This soil has been used to allow repeatable experimentation for the duration of this work and if required the soil may be reconstructed at a later date. By using an artificial soil the large variation in properties of natural soil can be minimised. The details of this soil are included in appendix B.

5.1 SINGLE-SIDED COMPACTION - THE DATUM PROCESS

The first case which was examined was that for single-sided compaction. This is used as the datum against which to compare the other cases and as such it is examined in detail. Figure 5.1a shows the pressure variation as recorded by the LVDT transducers[5]. The pressure applied to the top face of the block, via the piston, was increased in small equal steps so as to achieve a uniform increase over time. It was then reduced at the same rate back to zero. After each step pressure and displacement readings were made, the applied pressure being held constant for long enough for these readings to stabilise (quasi-

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[4] The fine cement particles appear to act like a dry lubricant during compaction. Without cement the soil mix displays higher internal friction.

[5] The detailed description of the performance, calibration and location of the LVDT transducers is given in appendix D

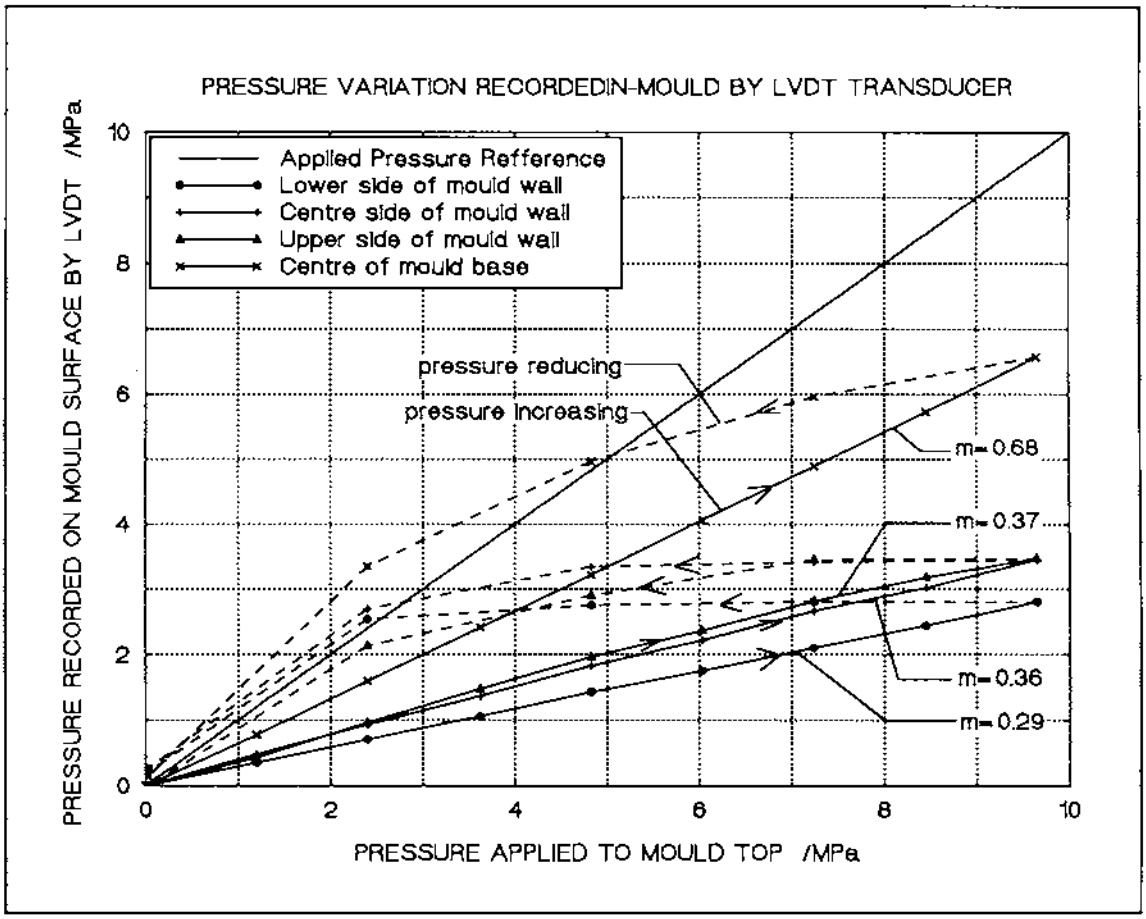

Figure 5.1a Compaction pressure plotted against transmitted pressure

static process). Pressure recorded on the block wall is plotted against pressure on the mould top (applied pressure calculated from the applied force and the known area of the mould surface). Only one transducer was initially used and hence the traces in figure 5.1a are actually the amalgamation of six separate block pressings, each trace being the average of two presses.

The maximum pressure readings agreed surprisingly well between pairs of blocks, averaging an agreement within ± 0.25 MPa (± 4% for base pressure). The applied pressure plot has been included in the figures for ease of comparison and plots as a straight line with a maximum of 9.66MPa (40 tonnes applied to the largest block face). In general the internal pressure throughout the mould increases linearly with the applied pressure but with differing rates of gain around the block (Table 5.1).

The transducer on the mould base recorded the highest pressure gain of 68%, rising to a maximum of 6.7 MPa compared to the applied 9.7 MPa, a loss of 3 MPa.

The transducers located at the upper and central regions of the mould-side wall both gave recorded maximum pressures of 3.5MPa (3.5 for the upper region and 3.48MPa for the central region i.e gain = 37% and 36% respectively). The pressure

distribution along the length of the block at mid-height was also recorded. The pressure recorded at one third the length along the mould side wall was also 3.5 MPa (gain = 37%), while the pressure recorded at the end of the mould wall was 3.9 MPa (gain = 40%), slightly higher than at the centre.

The lower centre side wall transducer recorded a maximum pressure of 2.8MPa.

Table 5.1 Average Transmitted Pressure Recorded by LVDTs

Location of LVDT	Average Max Pressure /MPa	95% Confidence bounds	Pressure Gain %
Base	6.67	6.40..6.94	68
Upper Side	3.50	N/A	37
Centre Side	3.48	3.14..3.83	36
Lower Side	2.80	2.75..2.86	29

If the increase in pressure in the upper region of the mould wall (Fig 5.1a) is examined, it can be seen that this rise decreases slightly with increasing applied pressure and may be tending towards a maximum. This trend is not apparent for the remaining traces.

This pattern does not fit any obvious simple model and the only firm conclusion which may be drawn is that the soil condition is far from a simple hydrostatic fluid model.

The pattern of quasi-static pressure reduction was also recorded. The mould base pressure begins to drop off as soon as the applied pressure is reduced and continues to reduce at an increasing rate. At approximately 5MPa the base pressure is the same as the applied pressure. Below 5MPa the base pressure continues to decrease but remains higher than the reducing applied pressure.

The mould wall pressures also fall back as log curves. There is a lag period between when the applied pressure is reduced and when the mould wall pressures begin to drop significantly. This lag is least for the upper regions of the mould and increases for the central and lower regions respectively.

The material inside the mould under full (9.7MPa) compression will have undergone both plastic and elastic deformation. Large plastic deformation is evident from the significant volume reduction, typically 1.5:1. Elastic deformation is also apparent, although less pronounced, by the

increase in block height as the applied load is removed (see Fig 5.1b, block height during compaction).

The pattern of mould pressure fall may indicate a pattern of vertical and horizontal stress reduction. As the applied pressure is reduced so those regions of the block nearest to the moving piston begin to decompress. In the upper regions of the block this decompression takes place initially in the vertical direction, the direction of movement. The resulting elastic expansion of the material is largely vertical as the mould maintains a lateral constraint. The vertical expansion reduces the lateral stress which is being applied to the mould-side walls, according to a poisson-type relation. As the upper lateral stress reduces so does the frictional shear stress with the mould wall. The reduction in mould wall shear stress effectively reduces the vertical constraining force, allowing the lower regions of the block to decompress. As the applied pressure is reduced further so the region of elastic expansion moves downward.

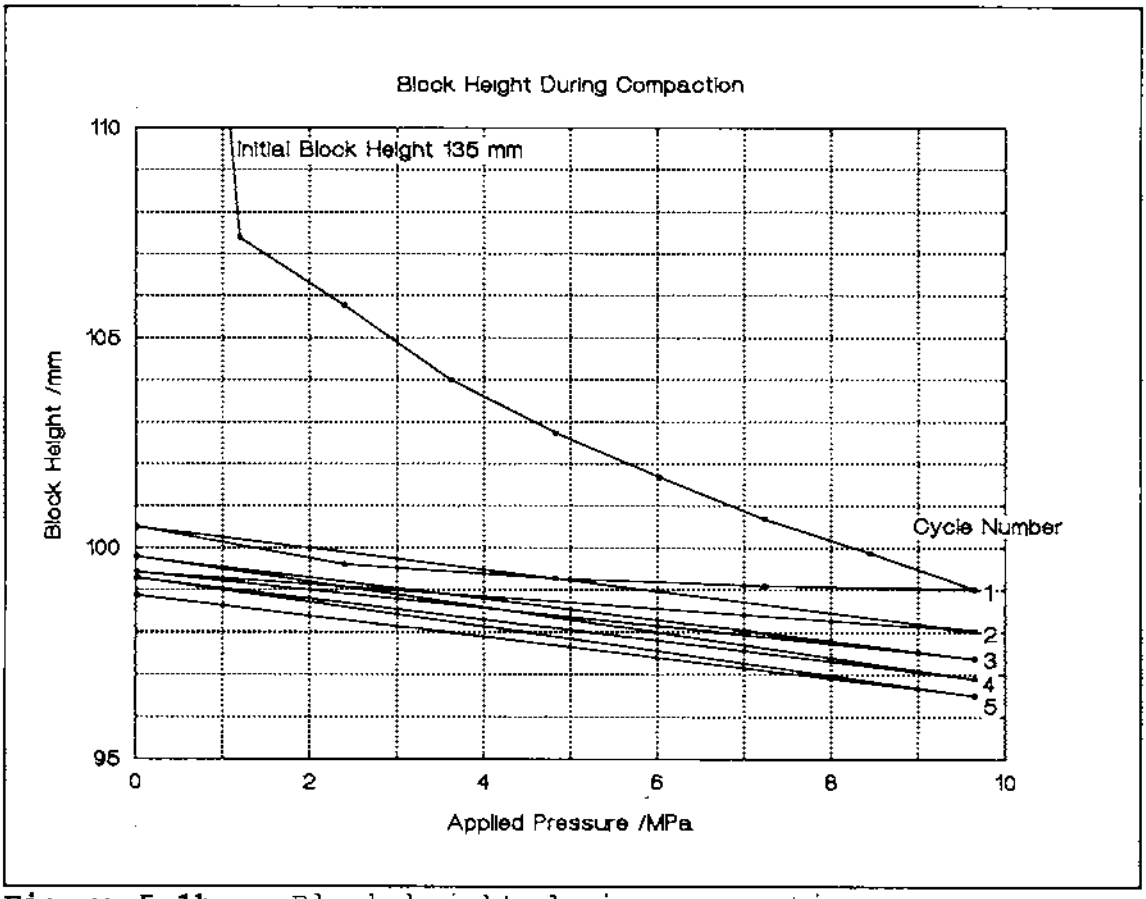

Figure 5.1b Block height during compaction.

The upper region of the block, being the nearest to the moving piston during compaction, would be expected to be in the most stressed/compacted state (closest to a hydrostatic condition). Therefore it could be assumed that this region would exhibit the largest elastic recovery and consequently the most

rapid rate of reduction in side wall pressure. The central region of the block would be in a similar condition but could not begin to significantly decompress until the upper layer's vertical restraining influence had diminished sufficiently. This would then result in an effective lag in lateral decompression which would increase with distance from the moving piston i.e. towards the lower regions. Fig 5.1a (above) illustrates this progressive decompression. If the lateral and base pressures are examined at an applied pressure of 2.4MPa, it can be seen that the base pressure is the largest, greater than that applied but reducing the most rapidly. The upper region transducer shows that the lateral pressure in this band is the lowest and reducing quickly but not as fast as the base pressure. The central region has just begun to decompress significantly but remains higher than either the lower or upper regions and the lowest region is yet to begin dropping significantly.

In summary, as the applied pressure is raised to a maximum of 9.7MPa, the base pressure as recorded by the LVDT rises to 68% of this value and the mould side pressures to only 37%, 36% and 29% (upper, central and lower regions of the block respectively). On compression the bottom and side pressures rise linearly with applied (top) pressure. On decompression however, they fall back more slowly than the applied pressure, showing a strong hysteresis pattern.

5.2 DOUBLE-SIDED COMPACTION

There are various ways of applying "double-sided" pressure. The one used here was to fix the base plate, move the top plate (piston) and to let the sidewalls of the mould "float". An exact equality of top and bottom pressures was not achieved, as it might have been with mechanically linked top and bottom pistons. Perfect double-sided compression might have raised the sidewall pressure a little higher, probably to about 50% of the applied piston pressure.

The plot of applied pressure against recorded pressure is shown as Fig 5.2. The arrangement of the double sided compaction rig was such that only the central side wall and base pressures were recorded. Both of the recorded pressures were seen to be significantly higher than for single sided, 7.9MPa and 4.4.Mpa for the base and centre-side respectively. This represents a 12% increase in mould base pressure and a 9% increase in mould sidewall pressure (to 81% and 45% respectively).

This would appear to clearly indicate that double sided compaction was more effective in compressing the block. However, although significant in terms of pressure transmission for a high internal friction mix (no cement) when 5% cement was added to the mix, the pressure difference between single sided and double sided reduced to 10% and 5% for base and centre respectively.

Furthermore, when these blocks were tested for wet compressive strength after seven days of damp curing, the single

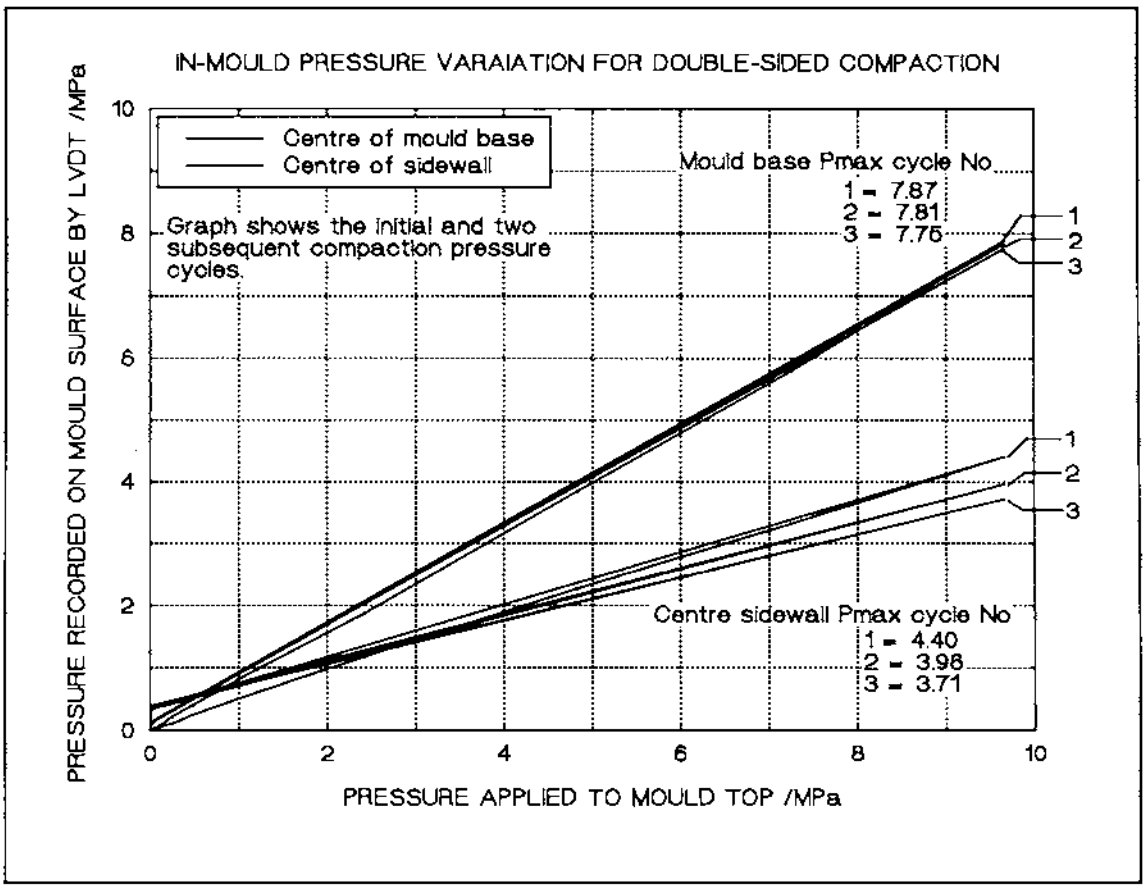

Figure 5.2a Pressure transmission for double-sided compaction

sided ones gave an average of 2.84 MPa (std 0.076) while the double sided ones gave an average of 3.03 MPa (std 0.087). This represents only a 7% increase in wet compressive strength, although this difference is likely to increase marginally with additional curing time.

Having initially stated that by using a soil mix without cement the internal friction would be higher, the difference between the above cases with and without cement should be expected. The apparently large increase in transmitted pressure for the no-cement blocks translates into only a small increase for the cement blocks.

If it is assumed that density is proportional to strength as has been suggested by other authors (Ingles & Metcalf, 1972, Ref No.10 & Webb, 1991, Ref No.20) then it might be expected that double sided compaction would produce a more uniform internal density distribution. If the compacted sintered bearing is taken as an example; single sided compaction produces a compact which is demonstrably more dense in the region nearest to the compacting piston. When compaction is double-sided the compact density is improved throughout but with a reduced improvement in the central region. If this is related to stabilised block strength then this would suggest that double-sided compaction should produce blocks which have more uniform internal density

distribution and hence a more uniform strength distribution through their height.

Double sided compaction is more effective than single sided compaction which is clearly shown by the increase in both base and mould wall pressures. However, this increase only results in a 7% increase in seven day wet strength. As such the additional mechanical complexity and associated cost required to produce a commercial double sided block press would appear unwarranted.

5.3 REDUCTION IN MOULD WALL FRICTION

The effect of reducing mould wall friction was examined by lining the mould with a twin thickness of plastic sheeting, separated by a lubricating oil film. Figure 5.3 shows the plot of applied pressure against the recorded pressures. Lining the mould with plastic was used as an experimental technique to assess the effect of mould wall friction and would not be recommended for field use. During compaction the inner layer of plastic was dragged down with the compacting soil and forced to ruck into the body of the block thus producing flawed blocks. However, this should not invalidate the pressure transmission data gathered.

Both the base pressure and all of the recorded mould wall pressure were seen to rise significantly compared with the much rougher datum model. The base pressure rose to 7.6MPa whilst the upper and lower mould wall regions rose to 4.1 and 3.6 MPa respectively. This represents a 13% increase in base pressure and a 17% and 29% increase in upper and lower pressures. Again it would be expected that this would translate into a reduced effect in the final wet strength of the blocks but it does show that mould wall friction plays an important role in determining the effectiveness of the applied pressure in block compaction. It would be recommended that the mould should be as smooth as possible and that any machining marks etc should be orientated in the direction of the soil material movement during compaction i.e. perpendicular to the compaction piston.

5.4 MOULD WALL TAPER

Mould wall taper was investigated by angling the mould side walls to 1° and 5° from the vertical. This was done by separating the mould walls and bolting them in place with tapering sets of shim steel to produce the desired angles. The mould was arranged such that compaction was from the larger side of the taper. Figure 5.4 shows the plot of applied pressure against recorded pressure. The base pressure was seen to rise slightly to 6.9MPa but this was believed to be a function of the experimental method. The same dry mass of soil was used to produce each block throughout the set of tests and as a result

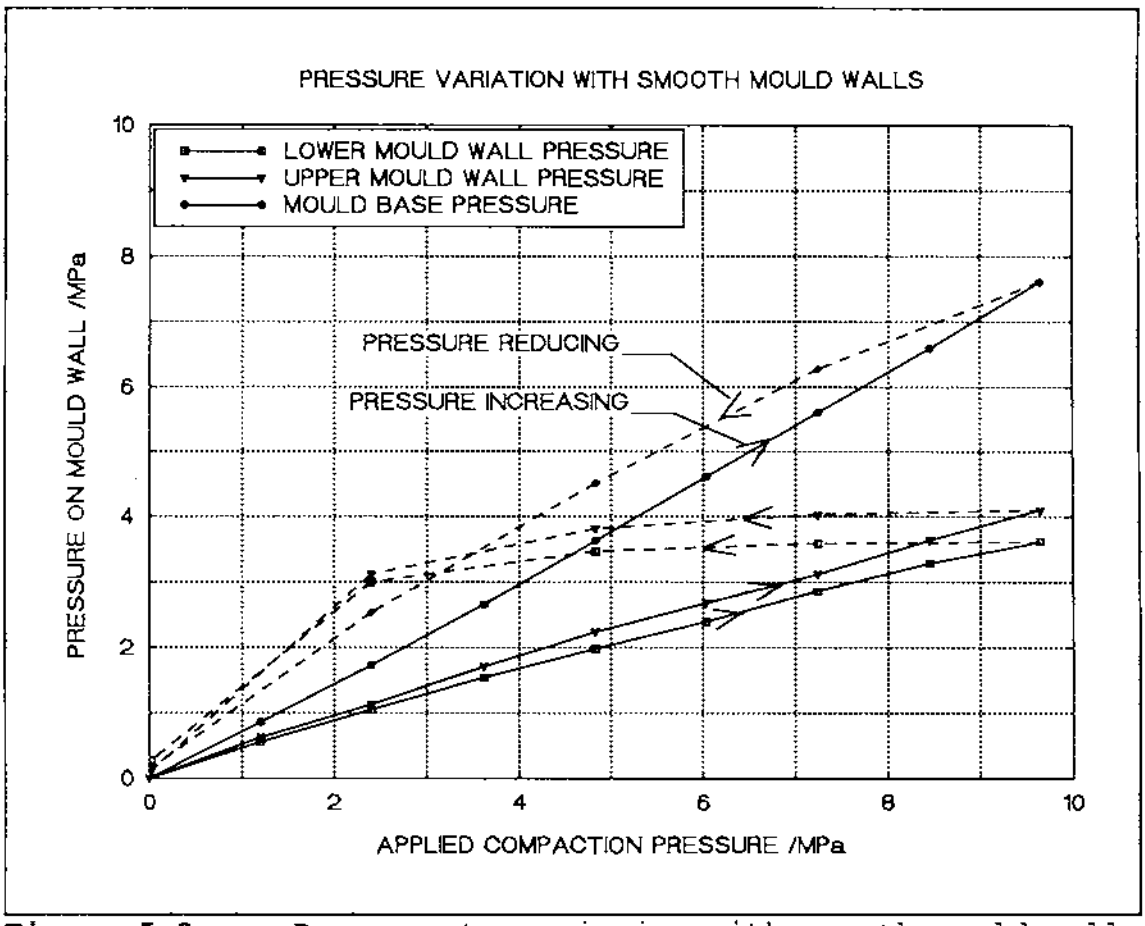

Figure 5.3 Pressure transmission with smooth mould walls

of the manner in which the mould was tapered, the final block height was reduced. Therefore some increase in base pressure would be expected as the height through which the applied pressure was acting was reduced. The mould side wall pressures were also recorded. The upper region pressure was significantly lower than that for the standard mould configuration but this was again a result of the manner in which the mould was tapered, the reduced block height and increased separation between the compacting piston and the mould wall effectively placed the upper transducer above the top of the block. The central and lower region pressure were slightly increased at 4.2 and 2.9MPa but not above what might be expected as a result of the increase in projected area seen by the compacting material. The 5° taper mould produced similar results; the base pressure increased to 7.5MPa while the central pressure increased to 4.4MPa.

In conclusion, mould taper does not have any apparent beneficial effect on pressure transmission. The block ejection cycle however required much lower forces which had to be sustained for a much shorter period of time. Taper may be used to ease ejection but the somewhat awkward shape of the blocks does not seem to justify the improved ease of ejection. Taper would not be recommended for incorporation into block production machines.

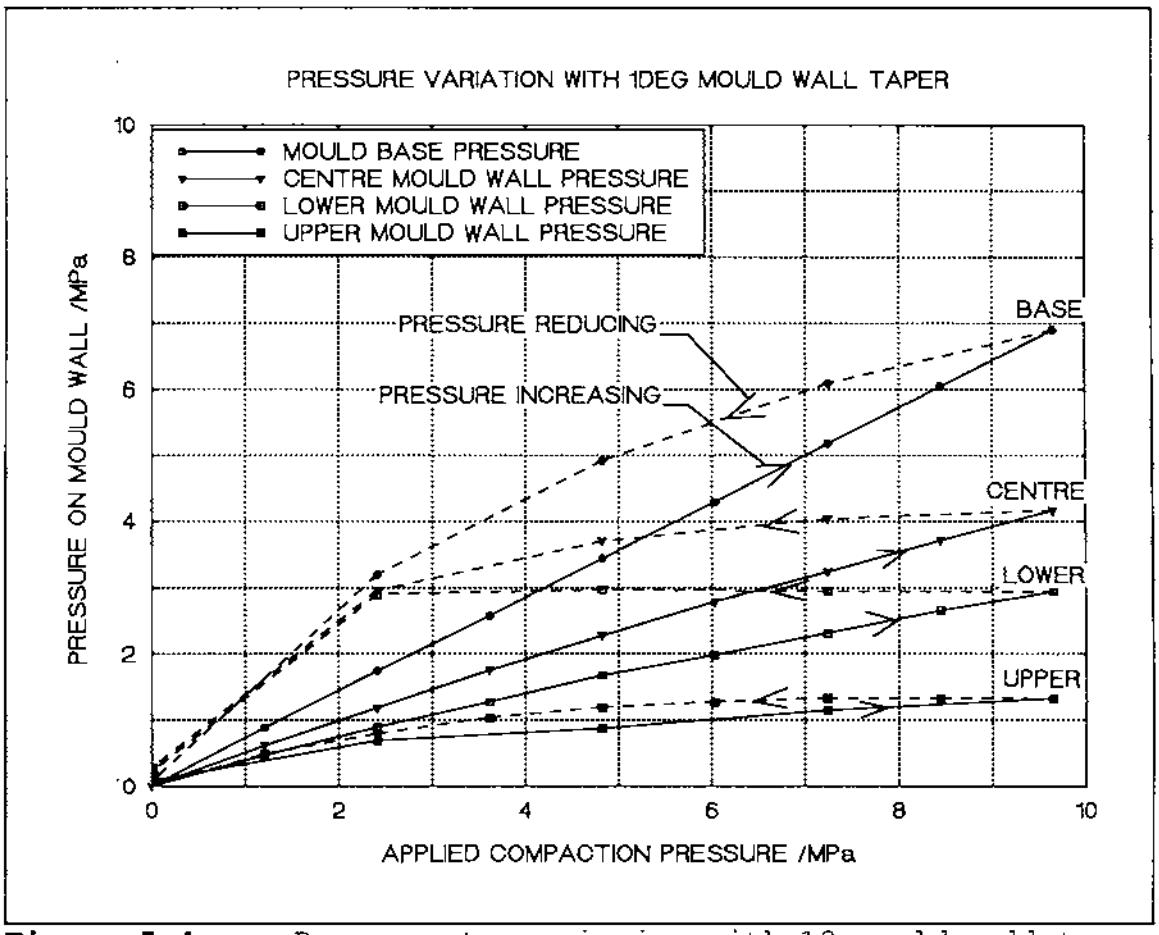

Figure 5.4 Pressure transmission with 1° mould wall taper

5.5 PRESSURE CYCLING

Here the term pressure cycling is used to imply the decompression of a fully compacted block to various levels of pressure and the subsequent recompression back to the original fully compacted applied pressure.

The manner in which a soil block would respond to applied pressure cycling was unclear. Three possible effects were expected prior to experimentation. The cycling would have no effect on the transmitted pressure, the transducers recording the same value of pressure as that recorded for the initial cycle. The cycling would progressively increase the transmitted pressure to a limiting maximum, independent of the magnitude of the cycle. The cycling would increase the transmitted pressure to a limiting maximum value depending on the magnitude of the cycle.

Table 5.5a Pressure transmission on full-pressure cycling

Cycle No	Maximum applied pressure /MPa	Maximum mould base pressure /MPa	Maximum upper mould wall pressure /MPa	Maximum centre mould wall pressure /MPa	Maximum lower mould wall pressure /MPa
1	9.65	6.72	3.48	3.55	2.84
2	9.65	6.85	2.55	3.38	2.26
3	9.65	6.93	2.14	3.20	2.04
4	9.65	6.92	1.87	3.18	1.89
5	9.65	6.92	1.69	3.13	1.81

Table 5.5a shows the pattern of pressure change in the mould side wall for cycling from 9.7 to 0.1 MPa for standard single sided compaction. It can be seen that the base pressure remains almost constant, in general rising slightly with successive cycles but not significantly (the LVDT hysteresis will account for an increase of 0.1MPa per cycle when cycling from 0 to 7 MPa). The mould side wall pressure appears to drop significantly with each cycle, dropping less with successive cycles.

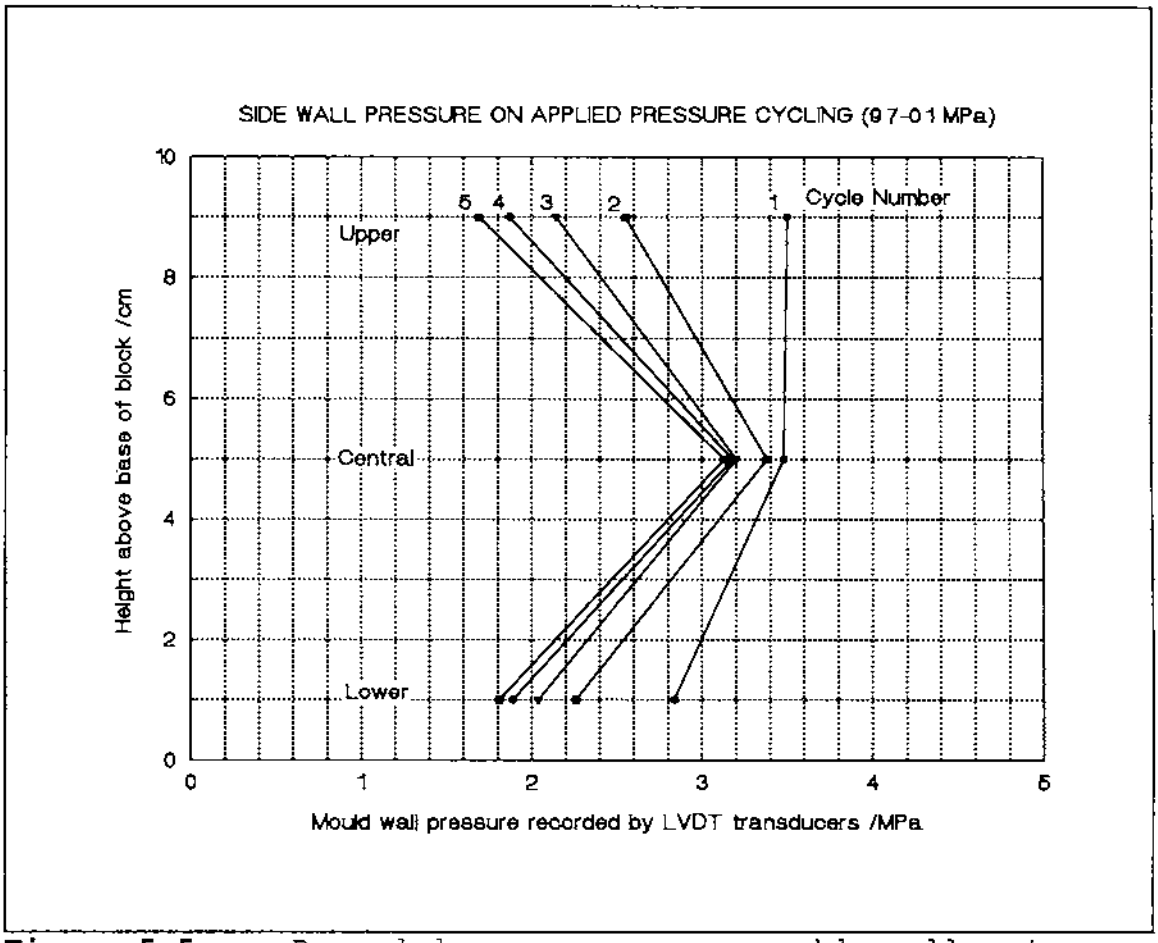

Figure 5.5a Recorded pressure on mould walls (upper, central and lower regions) with successive pressure cycles

Figure 5.5a shows the pattern of pressure reduction with successive cycles plotted with height of the transducer from the base of the block. This appears to indicate that the cycling action reduces the upper and lower side wall pressure at a greater rate than that for the central region. It might be argued that the reduction in upper side wall pressure is a result of the reduction in block height (see below). However, the reduction in the central and lower regions could not be accounted for on this basis.

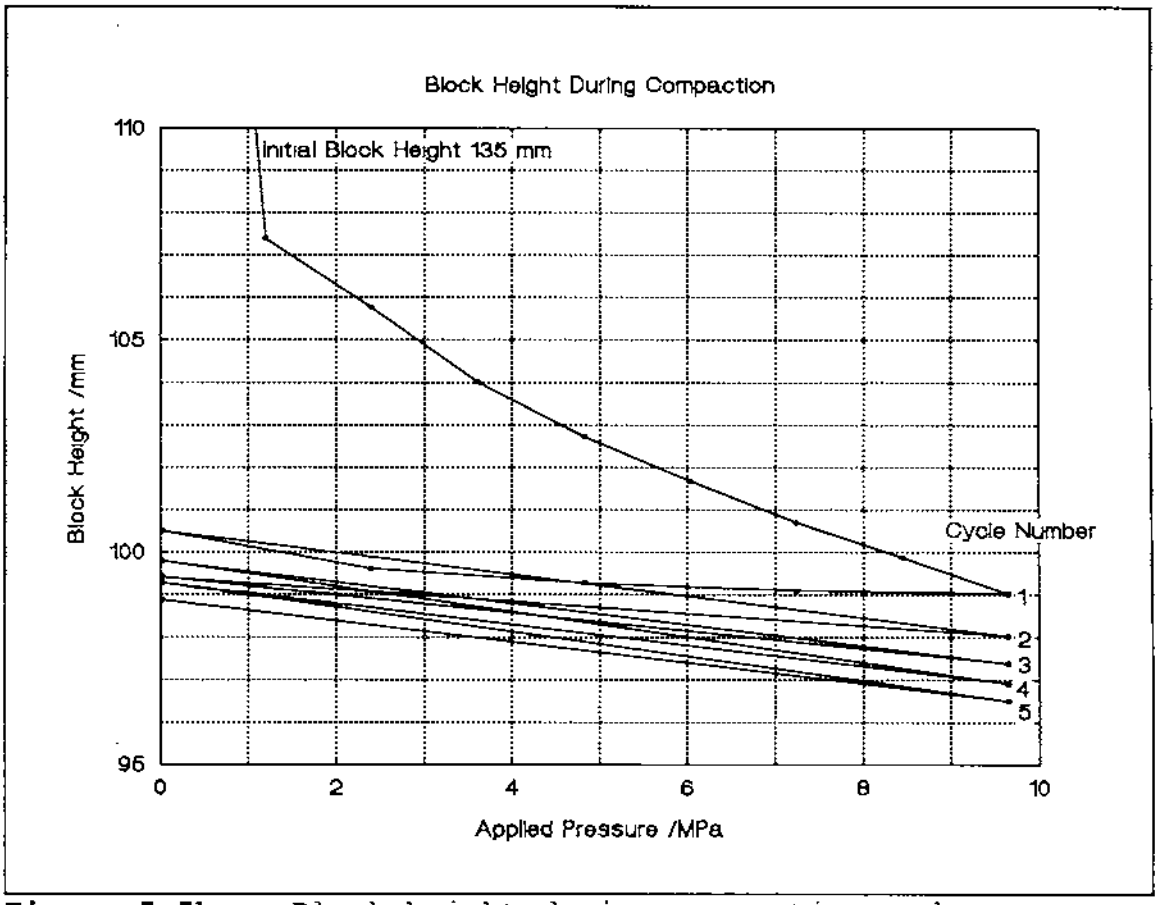

Figure 5.5b Block height during compaction and decompression.

If Figure 5.5b is examined then it can be seen that the block height reduces to 96.5 mm under full pressure after 5 cycles. The upper transducer's centre line is 90 mm above the base of the block and the active face is 5mm in radius. The transducer is therefore recording the upper side wall pressure from 3.9-13.9 mm below the upper surface for the first cycle and from 1.5-11.5 mm below the surface for the fifth cycle. The pressure reduction might then be accounted for if it is assumed that the edge region of the compaction piston is at atmospheric pressure (0 MPa on the LVDT scale) and that a region of transition from 0 to 3.5 MPa (max side wall pressure on the first cycle) exists. As the upper face of the block moves downward approaching the upper LVDT then it might be expected that the recorded pressure would drop. However without including a pore pressure type concept, it appears more difficult to explain the fall in the lower side wall pressure. No satisfactory explanation has yet been formulated.

Partial pressure cycling (cycling from full compaction pressure to a lesser pressure greater than zero) is shown as Figure 5.5c. Table 5.5b shows the numerical values for the maximum and minimum cycled pressure values for each cycle. This plot of applied pressure against recorded pressure is from one of the blocks which were used to determine the effect

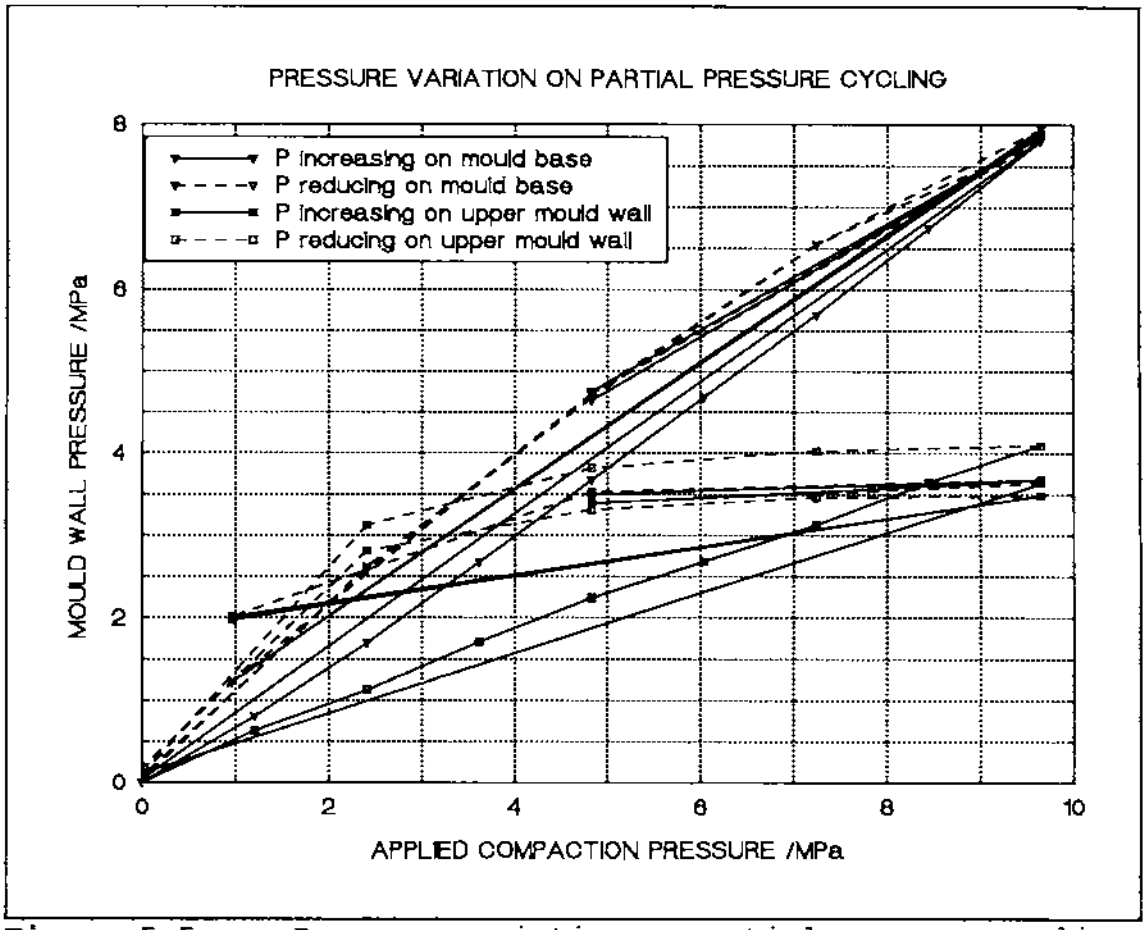

Figure 5.5c Pressure variation on partial pressure cycling

Table 5.5b Pressure values relating to figure 5.5c

Cycle No	Applied pressure /MPa	Mould base pressure /MPa	upper mould wall pressure /MPa
1	0.00 → 9.66	0.00 → 7.80	0.00 → 4.10
2	0.20 → 9.66	0.05 → 7.82	0.12 → 3.63
3	4.83 → 9.66	4.64 → 7.86	3.39 → 3.67
4	4.83 → 9.66	4.75 → 7.87	3.49 → 3.68
5	0.97 → 9.66	1.22 → 7.91	2.01 → 3.48
6	0.97 → 9.66	1.22 → 7.95	1.97 → 3.48
End	0.02	0.10	0.19

of reduced friction but this trace shows the effect of residual wall shear forces well. The block was initially compacted to 10 MPa and then cycled down to 0.1MPa. On repressurising the mould wall side pressure dropped significantly. The block was then cycled from full pressure to half pressure twice and showed no

This appears to suggest that pressure cycling has little or no effect on a region unless the pressure is dropped back to significantly less than the lag period pressure mentioned above (section 5.1).

5.6 Summary

From the work outlined above it may be concluded that the internal compaction state of the soil material within the mould is not hydrostatic. It would appear unlikely that the side mould walls, under datum conditions, will ever exceed 50% of the applied pressure and normally be less than 40%. This being the case, significant material savings in mould wall thickness would appear possible. A significant reduction in the pressure applied to the compacting piston is apparent in the base plate which may be assumed to be indicative of internal shear and inter-particle, particle-mould-wall friction. The mould wall shear is significant and may be reduced by smoothing/lubricating the mould walls. Taper has little or no beneficial effect on the compaction proses but does reduce the ejection load and the time for which the load must be applied. Double sided compaction does have a significant beneficial effect on compaction but this benefit would be small compared to the cost of the extra mechanical complexity entailed.

6. THE PRESSURE-CEMENT-COMPRESSIVE STRENGTH RELATION

6.1 INTRODUCTION

The compaction pressure and the cement content used in the manufacture of stabilised soil blocks are, for a given soil, the prime determinants of the block's final cured strength. Compaction pressure and cement content may be traded against each other for a given final cured strength. The compaction pressure used in field production will depend on the type of compaction machinery selected at the project outset and so may be considered a capital cost for the process while the cement content used may be considered a running cost. As high pressure compaction machines are more expensive to purchase than low pressure machines it is useful to examine the relative effect of both compaction pressure and cement content on cured strength.

M.G.Lunt of the UK Building Research Establishment (Building Research Establishment, 1980, Ref No.4) conducted a series of tests on two Ghanaian soils (both with high fines content, 49.0 and 56.0%) to assess the effect of increased compaction pressure on the blocks' performance when stabilised with 6% lime by dry weight. He concluded that "Improved performance can be achieved by increasing the compaction pressure although the degree of improvement diminishes as this pressure is increased. It is suggested that presses operating in the range 8 to 16 MPa could give satisfactory and economical results." This work thus suggests that there may be some economic advantage in using a high pressure compaction machine. However, increasing the compaction pressure is only one way to improve the final compressive strength of a block. Although it is generally accepted that the performance of a block will be improved both by raising the compaction pressure and by increasing the stabiliser content, the relative effect of these two changes appears to be uncharted. For example, does a doubling of compaction pressure give the same improvement in strength as a doubling of cement content? The following section examines the effect of both compaction pressure and stabiliser (cement) content on the final (seven day) wet compressive strength of the *soil-A* used for the above tests.

6.2 EXPERIMENTAL INVESTIGATION

A number of soil-cement cylinders were produced for a range of compaction pressures from 1 to 10 MPa and a range of cement contents from 3% to 11%. For each combination of pressure and cement three cylinders were produced, the average value of the wet compressive (seven day) strength was used in subsequent comparisons. The *soil-A* used is described in appendix B. This soil was selected as one which should be suitable for stabilisation based on previous authors' reports (United Nations, 1964, Ref No.17). Although the numerical values given below are

unlikely to be correct for other soil types, it is expected that the trends exhibited will be, provided that the other soils fall within the range of suitable soils as defined in DTU Working Paper No.38.

The mould used was that specified in BS1924 (British Standards Institution, 1975, Ref No.3). A constant water content of 8% was used throughout the set of experiments[1]. The mould was filled with a constant mass (± 0.2%) of stabilised mixture regardless of the cement content. The cylinders produced were between 110mm and 125mm high, depending on the compaction pressure used, each having a nominal diameter of 50mm. The compacted green cylinders were sealed inside plastic bags in a damp atmosphere in batches of three and left to cure for seven days before complete immersion in water prior to wet compressive strength testing.

The results of the testing showed that both an increase in cement and an increase in compaction pressure increases the seven day wet strength, however the relative influence of each is different. Figure 6.3a and 6.4a respectively show the rate of gain in strength when either cement or compaction pressure is held constant. On each graph the data points connected by dashed lines are the average of three experimental results. The error bars associated with the data points represent a statistical confidence level of 90%, the length of the bars giving an indication of the scatter in results.

In order to relate cement percentage and compaction pressure, the raw experimental data (compaction pressure, cement percent and cured strength) was used as the input for a PC-based modelling package SPSS. A number of models were tried of which a natural log against natural log type plot was found to be the best. The solid lines on the figures given below represent the best fit to the data generated by SPSS;

$$\ln(str) = (0.315 \times \ln(pr)) + (1.216 \times \ln(cem)) - 2.178)$$

Where; str = compressive strength in MPa
pr = compaction pressure in MPa
cem = cement content percentage.

This model gave an adjusted R square measure of fit of 98.2% (Multiple R 99.1%)

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[1] The optimum water content at the time of compaction should strictly have been found for each compaction pressure and cement content. However the *soil-A* used has a low sensitivity to moisture content and as such the effect on the experimental data should be minimal.

6.3 THE EFFECT OF COMPACTION PRESSURE AND ENERGY ON SEVEN DAY WET STRENGTH

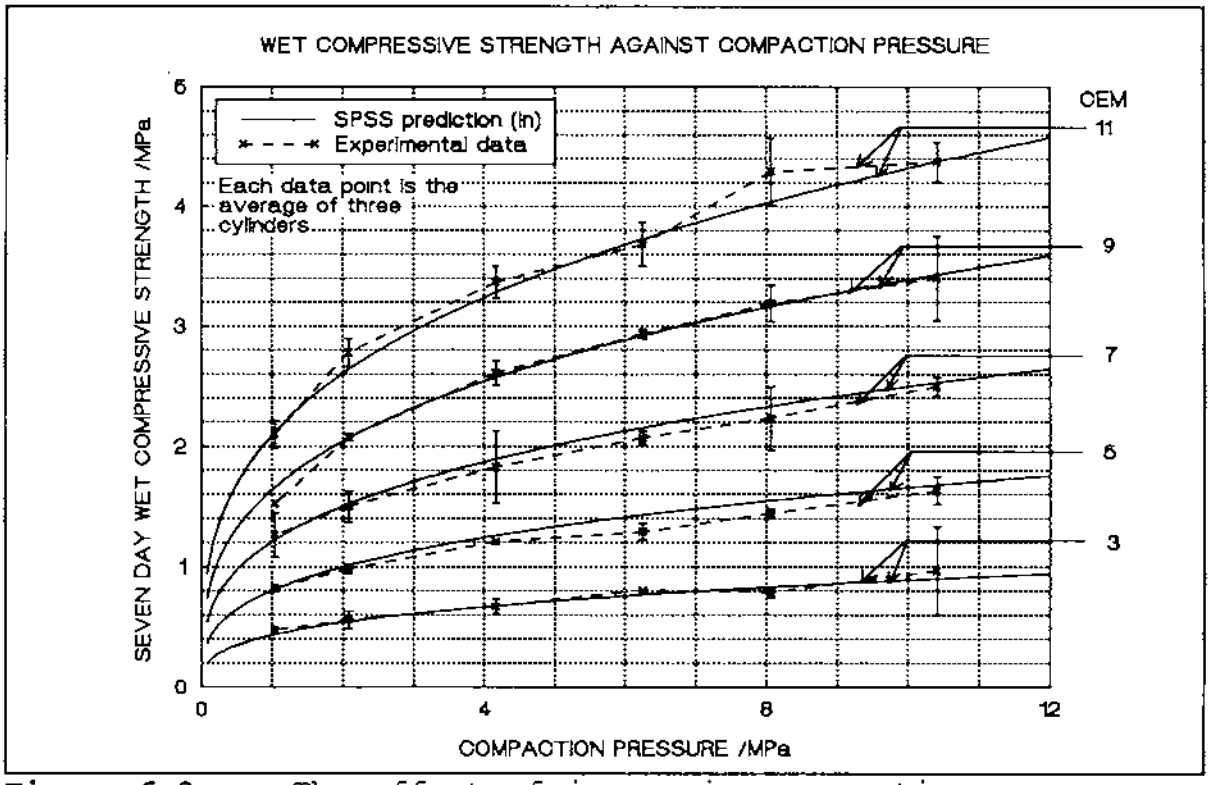

Figure 6.3a The effect of increasing compaction pressure on seven day wet compressive strength

For a given cement content (Fig 6.3a) strength increases with increased compaction pressure. Below 2 MPa this increase is rapid while above this the rate of increase reduces, tending towards a maximum strength as previously reported by Lunt (in Building Research Establishment, 1980, Ref No.4). Table 6.5 (below) shows the effect of doubling compaction pressure on the wet compressive strength. The figure given is the fractional increase in absolute strength resulting from doubling the respective variable. It can be seen that although the absolute rate of gain in strength is higher for high cement contents, the fractional increase in strength is fairly constant. A doubling of compaction pressure results in roughly 23% increase in wet compressive strength throughout the range.

Figure 6.3a shows that a given change in the compaction pressure of low pressure machines will have a large effect on the cured strength. A poorly operated or poorly maintained Cinva Ram may only operate at 1MPa, instead of the 2MPa usually quoted. This would result in a cured block strength 25% lower than that for a well operated/maintained machine.

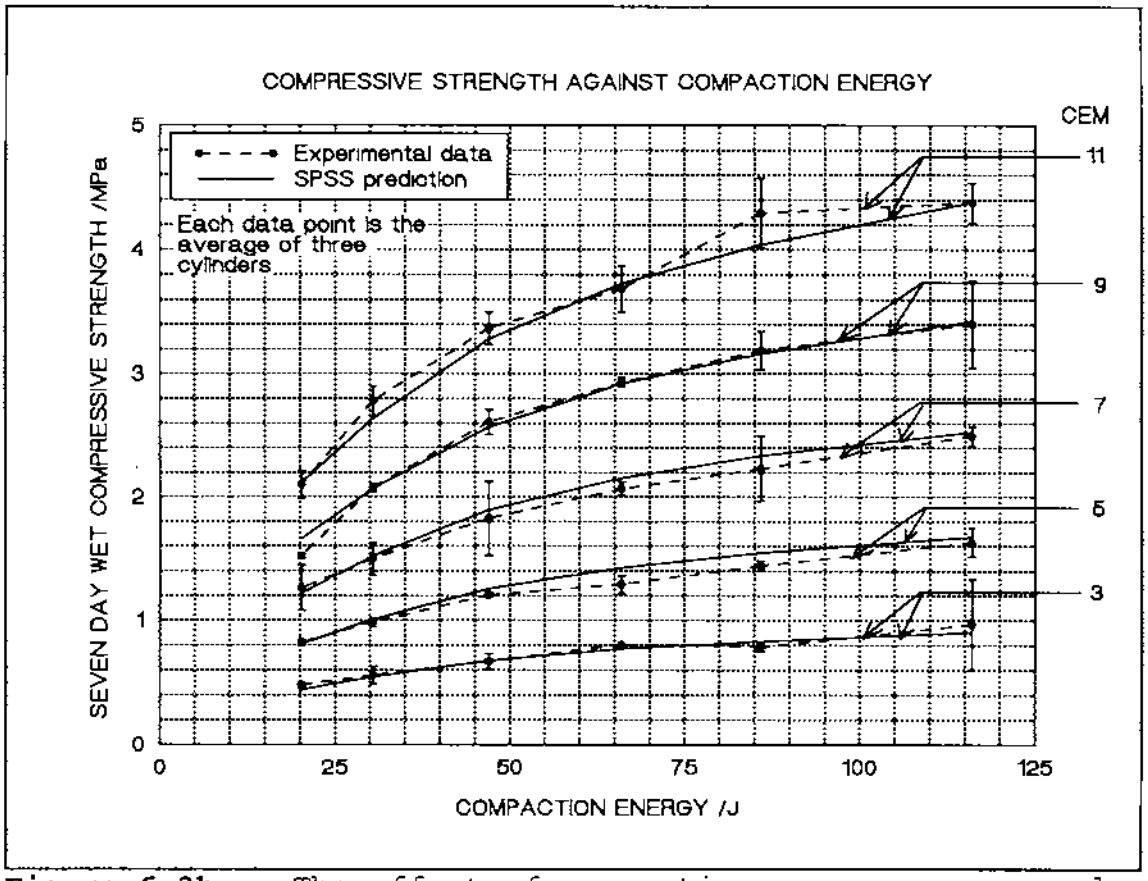

Figure 6.3b The effect of compaction energy on seven day wet compressive strength

Figure 6.3b is a plot of compressive strength against compaction energy. This graph is similar to 6.3a but shows the compaction process in terms of the energy expended in compacting the samples[2]. If the 3% cement trace is examined then it can be seen that by doubling the compaction energy from 25 to 50J the compressive strength increases by 37%, but doubling the energy from 50J to 100J only increased it by 22.9%. This is in keeping with the results shown in figure 6.3a as the energy required to increase the compaction pressure one unit is greater at higher pressures than at lower ones and hence the diminishing return.

[2]. The energy values are based on those found when quasi-statically compacting full-size blocks and were not directly recorded for the cylinders.

6.4 THE EFFECT OF CEMENT CONTENT ON SEVEN DAY WET STRENGTH

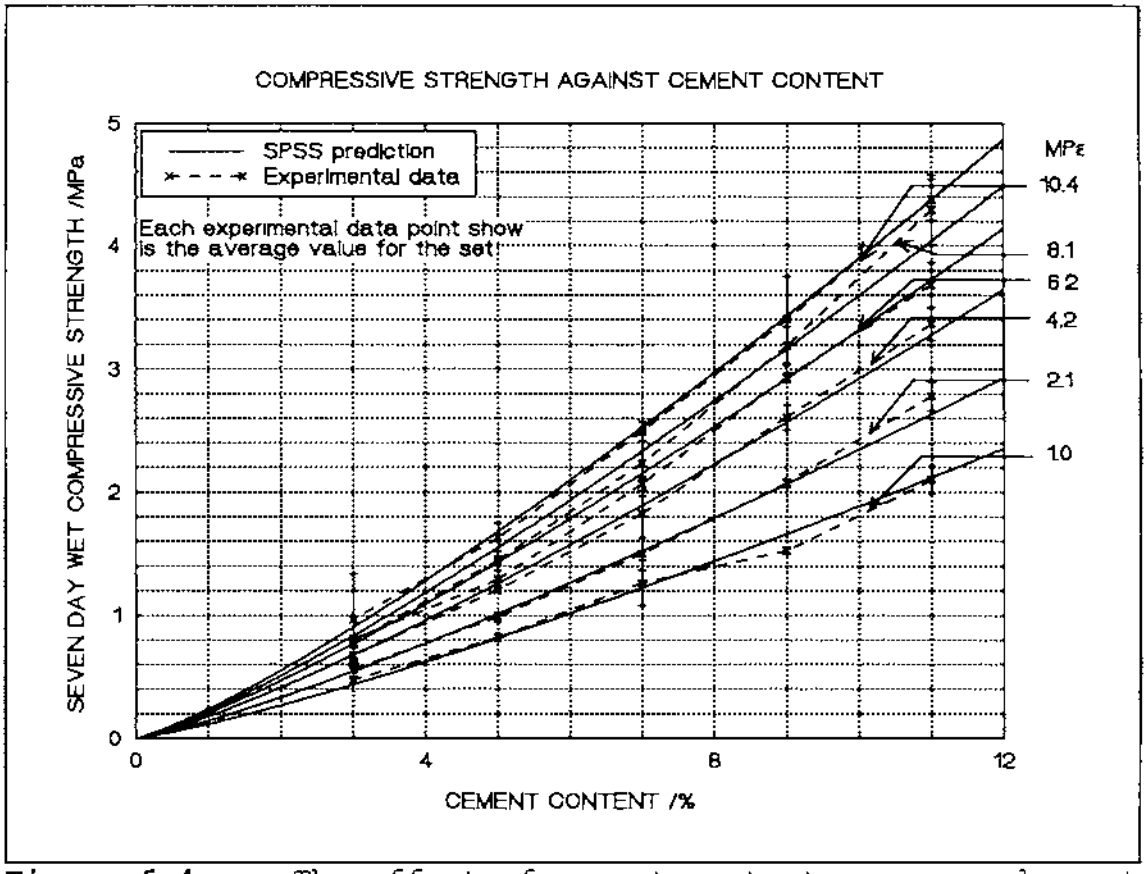

Figure 6.4a The effect of cement content on seven day wet compressive strength

If figure 6.4a is examined it can be seen that for a given pressure the rate of increase in absolute strength increases with increasing cement content. However, if table 6.5 (below) is examined it can be seen that the fractional increase in strength remains approximately the same, reducing slightly at higher cement contents. A doubling of cement content from 3 to 6% at a compaction pressure of 1.0 MPa produces a strength increase of 140% while a doubling of cement from 6 to 12[3]% produces an increase of 133%.

[3] The values for 12% cement used here are based on the SPSS model and represent an extrapolation above the maximum experimental value of 11%.

6.5 THE PRESSURE-CEMENT-STRENGTH RELATIONSHIP

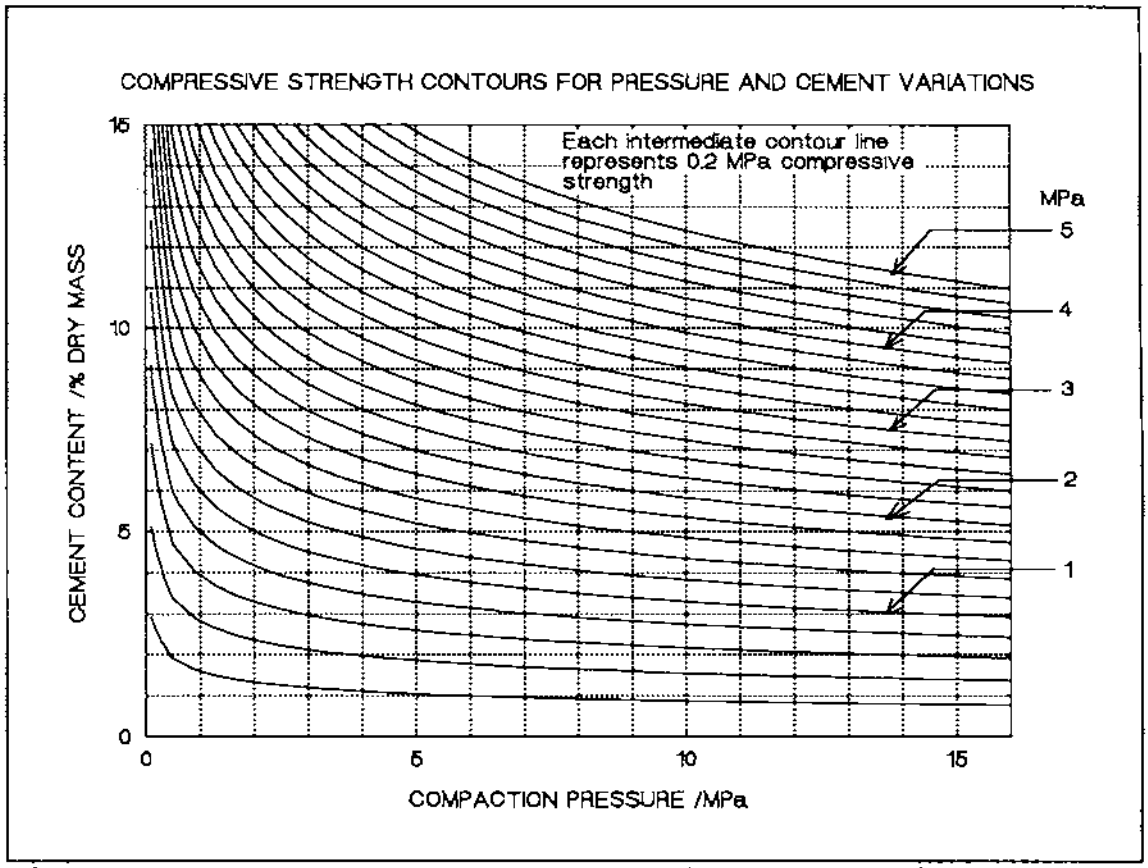

Figure 6.5a A contour plot relating compressive strength to cement content and compaction pressure

Figure 6.5a and 6.5b show the combined picture. Figure 6.5a is a contour plot showing lines of constant wet strength in relation to cement content and compaction pressure. Figure 6.5b is a three dimensional representation of the strength equation produced by SPSS from the experimental data. It can be seen from these figures that increasing the cement content of a stabilised block will in general provide a more effective method of increasing strength than increasing compaction pressure. Two standard wet strength values are normally quoted, either 1.4 MPa (Fitzmaurice 1958) or 2.8MPa (Webb 1988)[4]. The relative effect of cement and compaction pressure may be examined by regarding the reduction in cement content required when changing production from a 2MPa compaction machine to a 10 MPa machine at each of these two strength standards. Figure 6.5a shows that for a wet strength of 1.4 MPa and a compaction pressure of 2 MPa a cement

[4] Strength standards for soil-cement blocks are now becoming more widespread and vary from country to country to reflect the differing climates.

content of 6.6% would be required, while for a compaction pressure of 10MPa a cement content of 4.3% would be needed. In effect, for this soil, increasing the compaction pressure five times produces only a 35% reduction in cement demand. If the 2.8 MPa strength standard is considered, the same five fold increase in compaction pressure again results in a cement saving of only 35%.

Table 6.5 The relative effects of pressure and cement

Doubled Parameter	Strength Increase Compaction 2 → 4 MPa Energy 25 → 50 J Cement 3 → 6 %	Strength Increase Compaction 4 → 8 MPa Energy 50 → 100 J Cement 6 → 12 %
Compaction Pressure Doubled (11%cem)	2.59 → 3.23 MPa + 24.7%	3.23 → 4.03 MPa + 24.7%
(3%cem)	0.54 → 0.67 MPa + 24.1%	0.67 → 0.82 MPa + 22.4%
Compaction Energy Doubled (11%cem)	2.38 → 3.35 MPa + 40.7%	3.35 → 4.20 MPa + 25.0%
(3%cem)	0.49 → 0.70 MPa + 37.0%	0.70 → 0.86 MPa + 22.9%
Cement Content Doubled (10.4MPa)	0.90 → 2.10 MPa + 133.3%	2.10 → 4.89 MPa + 132.9%
(1.0MPa)	0.42 → 1.01 MPa + 140.5%	1.01 → 2.35 MPa + 132.7%

The trend which emerges from this study is that the final wet strength achieved by the block is much more sensitive to changes in the cement content than in the compaction pressure. By increasing the compaction pressure 400% the cement saving resulting is 35%. In order to interpret these figures, a simple economic model was constructed to compare the cost effectiveness of a 2MPa Cinva Ram and a 10MPa Brepack when producing blocks of 1.4 and 2.8 MPa wet compressive strength. This model is presented in the following section, 6.6.

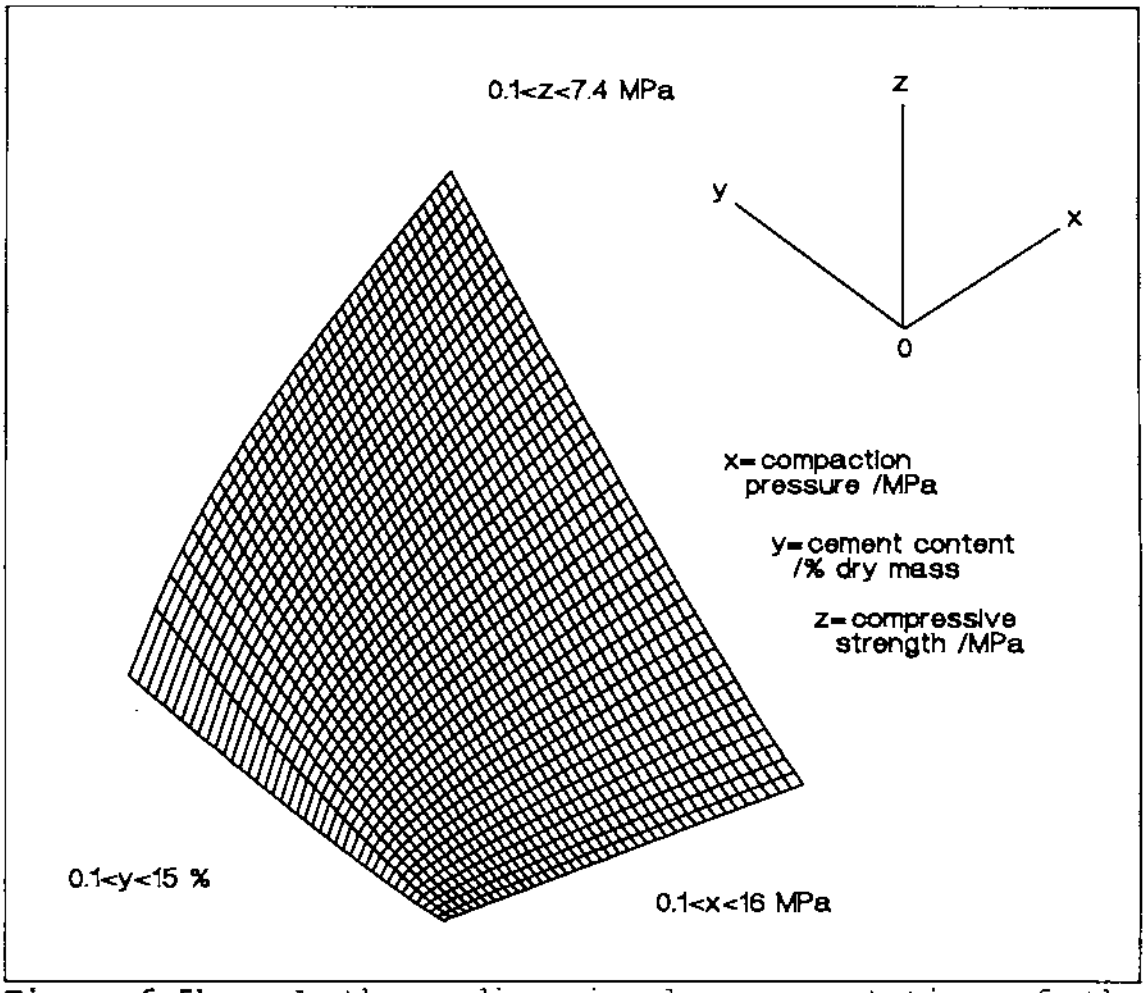

Figure 6.5b A three dimensional representation of the relationship between compaction pressure, cement content and compressive strength

6.6 SIMPLE ECONOMIC COMPARISON BETWEEN MACHINES GIVING RESPECTIVELY 2 AND 10MPa COMPACTION

The following model uses the 2MPa compaction pressure Cinva Ram and 10MPa Brepack machines for comparison. Two comparisons are made, one for blocks of 1.4 MPa wet compressive strength and one for blocks having 2.8MPa wet compressive strength.

It is assumed that both machines are operating in the same country with the same cost for cement and labour; £3.00 per 50 kg bag and £3.50 per man day (the costs quoted are those for Sri Lanka in 1993). Both machines use the same *soil-A*, as used in the above experimentation, compacted at 8% water content, both produce blocks of 290x140x100mm.

Both of the machines are manually operated toggle lever mechanisms. The Brepack generates higher pressure by the incorporation of a hydraulic ram which is operated after initial

compaction by toggle lever has occurred. As large variations in the actual and quoted production outputs of each of these machines is common (production output depends heavily on the experience and dedication of the operators), it has been assumed that the maximum Cinva Ram output, quoted by the machine manufacturers, of 300 blocks per 8 hour day will be achieved and will be taken as the datum from which to extrapolate a comparable production figure for the Brepack. The maximum Cinva Ram production rate equates to the production of one block every 96 seconds. It will be assumed that the additional time taken to operate the Brepack hydraulic system is 20 seconds giving the Brepack a production rate of one block every 116 seconds or 248 blocks per 8 hour day.

The labour requirement for the Brepack may also be based on that for the Cinva Ram. The machines produce different numbers of blocks of different density; 300 blocks per day (see above) of 1980 kg/m^3 for the Cinva and 248 blocks per day of 2130 kg/m^3 for the Brepack. Hence the labour required, per day or per block, for soil winning and block compaction is different. If the labour distribution shown below is assumed for the Cinva Ram when producing blocks of 1.4 MPa wet compressive strength (requiring 2,084.4 kg of soil per 300 blocks) then soil winning/processing labour costs may be calculated per kg of soil required. Similarly the labour cost of compaction and stacking may be calculated per block, 16 man hours are required to compact 300 Cinva Ram blocks (a labour cost of £0.023 per block) while 16 man hours are required to produce 248 Brepack blocks (£0.028 per block).

It is assumed that the soil used is free and the only cost is then the cost of winning which is included in the labour cost.

It is assumed that the working life of a Cinva Ram is 3 years at full production resulting in 270,000 blocks when working for 6 days per week and 50 weeks per year. The life of the Brepack is also assumed to be 270,000 blocks.

It is assumed that the initial capital will be recouped with 30% interest within the working life of the machine assuming a 60% utilisation i.e. in five years for the Cinva Ram and six years for the Brepack. This results in a discount factor of 2.436 for the Cinva Ram and 2.643 for the Brepack.

LABOUR COSTS

Labour per day for a Cinva Ram producing 300 blocks (1.4 MPa wet compressive strength) per 8 hour day

soil winning	2 men to dig the soil, spread it out for drying and crush/sieve the dried material.
soil winning	1 man to mix the material and prepare batches for compaction.

block pressing	2 men to operate the machine and stack the green blocks for curing.

Assuming the above labour distribution for a Cinva Ram production unit then the cost of labour per kg of soil used may be found.

Soil required per block (see data)	6.948 kg
No of blocks produced per day	300
Total mass of soil required	2,084.4 kg
Labour cost per man per day	£3.50
Labour required to win/process soil	3 man days
Total soil winning labour cost	£10.50
Soil winning labour cost per kg	£0.0050

Labour cost for block pressing (Cinva Ram)	£0.0233 per block
Labour cost for block pressing (Brepack)	£0.0282 per block

CEMENT COST

Cement cost per 50kg bag	£3.000
Cement cost per kg	£0.060

CINVA RAM DATA (prices in Pounds Sterling 1993)

Purchase cost of machine £382.88 (1988 cost reported by Webb (1988) inflated by 5% pa)
Total freshly demoulded weight of one block 8.0kg (demould density 1980kg/m^3, volume 290x140x100mm)

1.4MPa wet compressive strength

Cement percentage required for 1.4MPa wet strength 6.6% (based on figure 6.5a)

Mass of soil per block	6.948 kg
Mass of cement per block	0.459 kg
Mass of water per block	0.593 kg

2.8MPa wet compressive strength

Cement percentage required for 2.8MPa wet strength 11.7% (based on figure 6.5a)

Mass of soil per block	6.631 kg
Mass of cement per block	0.776 kg
Mass of water per block	0.593 kg

CINVA RAM ANALYSIS FOR 1.4MPa WET COMPRESSIVE STRENGTH

Cost of cement per block 0.459 kg cement per block @ £0.060 per kg	£0.0275
Cost of soil winning labour per block 6.948 kg soil per block @ £0.0050 per kg	£0.0347
Cost of soil pressing labour per block (for Cinva Ram)	£0.0233
Cost of machine depreciation per block £382.88 ÷ 2.436 x 5 ÷ 270,000	£0.0029
Total cost per block	£0.0884

CINVA RAM ANALYSIS FOR 2.8MPa WET COMPRESSIVE STRENGTH

Cost of cement per block 0.776 kg cement per block @ £0.060 per kg	£0.0466
Cost of soil winning labour per block 6.631 kg soil per block @ £0.0050 per kg	£0.0332
Cost of soil pressing labour per block (for Cinva Ram)	£0.0233
Cost of machine depreciation per block £382.88 ÷ 2.436 x 5 ÷ 270,000	£0.0029
Total cost per block	£0.1060

BREPACK DATA (prices in Pounds Sterling 1993)

Purchase cost of machine £3828.80 (1988 cost reported by Webb (1988) inflated by 5% pa)
Total freshly demoulded weight of one block 8.65kg (demould density 2130 kg/m^3, volume 290x140x100mm)

1.4MPa wet compressive strength

Cement percentage required for 1.4MPa wet strength 4.3%

Mass of soil	7.679 kg
Mass of cement	0.330 kg
Mass of water	0.640 kg

2.8MPa wet compressive strength

Cement percentage required for 2.8MPa wet strength 7.6%

Mass of soil	7.444 kg
Mass of cement	0.566 kg
Mass of water	0.640 kg

BREPACK ANALYSIS FOR 1.4MPa WET COMPRESSIVE STRENGTH

Cost of cement per block 0.330 kg cement per block @ £0.060 per kg	£0.0198
Cost of soil winning labour per block 7.679 kg soil per block @ £0.0050 per kg	£0.0384
Cost of soil pressing labour per block (for Brepack)	£0.0282
Cost of machine depreciation per block £3828.80 ÷ 2.643 x 6 ÷ 270,000	£0.0322
Total cost per block	£0.1180

BREPACK ANALYSIS FOR 2.8MPa WET COMPRESSIVE STRENGTH

Cost of cement per block 0.566 kg cement per block @ £0.060 per kg	£0.0340
Cost of soil winning labour per block 7.444 kg soil per block @ £0.0050 per kg	£0.0372
Cost of soil pressing labour per block (for Brepack)	£0.0282
Cost of machine depreciation per block £3828.80 ÷ 2.643 x 6 ÷ 270,000	£0.0322
Total cost per block	£0.1316

The data given above is summarised in table 6.6 below. It can be seen from this simple analysis that for a final wet strength of 1.4 MPa and 2.8 MPa, high pressure compaction is 33.5% and 24.1% more expensive respectively.

The above model assumes a 30% interest rate and hence penalises the Brepack as a result of its higher capital cost. However this high capital cost is not the only penalty.

The Brepack compaction process must take longer than the Cinva Ram as an additional hydraulic circuit must be pressurised and hence the compaction cost in terms of operator labour is higher as the productivity is reduced.

Table 6.6a Block production cost comparison (Sri Lanka)

Cost per Block	wet strength 1.4 MPa	wet strength 2.8 MPa
Cinva Ram 2 MPa compaction	£0.088	£0.106
Brepack 10 MPa compaction	£0.118 +33.5% over 2 MPa	£0.132 +24.1% over 2 MPa

Compaction at higher pressure produces denser blocks which use less cement but more soil. Hence the costs associated with the soil are increased. In the above model it was assumed that the soil would be available free of charge except for the labour cost involved in winning it. If a secondary cost must be paid for the soil, land rental or a purchase price, then the high pressure compaction route is further disadvantaged.

Table 6.6b Percentage breakdown of block costs (Sri Lanka).

Cost Parameter	Cinva Ram 1.4 MPa strength	Brepack 1.4 MPa strength	Cinva Ram 2.8 MPa strength	Brepack 2.8 MPa strength
cement	31.1%	16.6%	44.0%	25.8%
soil winning labour	39.2%	32.4%	31.3%	28.3%
pressing labour	26.4%	23.8%	22.0%	21.4%
machine depreciation	3.3%	27.2%	2.7%	24.5%
total	100%	100%	100%	100%

Table 6.6b shows the percentage cost breakdown for the four blocks produced. It can be seen that although the high pressure compaction machine does reduce the cement demand, both the machine depreciation and the labour costs counteract this benefit.

For these machines using this soil type, increasing the cement content appears to be more economic than increasing the compaction pressure. Even if the life of the high pressure machine is doubled high pressure compaction remains the more costly. However what is not clear from this analysis is the quality of the final blocks. Although both machines should produce blocks with the same wet compressive strength, their densities will be different. Ultimate bearing strength when wet is not the only valid measure of performance but the most expedient to test and numerically quantify. The blocks' durability may be different as a result of their differing

density. Work is currently under way at The University of Warwick to investigate this.

The above analysis is only valid for the cement and labour rates quoted for Sri Lanka. In other areas the relative cost of cement and labour may be completely different. For example in rural Zimbabwe the cost of cement is increased to £3.50 per 50kg bag while the wage rate is reduced to £0.80 per man per day. The effect of this shown in tables 6.6c and 6.6d

Table 6.6c Block production cost comparison (rural Zimbabwe)

Cost per Block	wet strength 1.4 MPa	wet strength 2.8 MPa
Cinva Ram 2 MPa compaction	£0.0479	£0.0698
Brepack 10 MPa compaction	£0.0701 +46.3% over 2 MPa	£0.0864 +23.8% over 2 MPa

It can be seen that even for a rural environment, where the daily wage rate is much lower than the cost of a bag of cement, high pressure compaction remains the more expensive option. For this case it is primarily the machine depreciation cost which dominates the analysis as the labour costs are greatly reduced.

Table 6.6d percentage breakdown of block costs (Zimbabwe)

Cost Parameter	Cinva Ram 1.4 MPa strength	Brepack 1.4 MPa strength	Cinva Ram 2.8 MPa strength	Brepack 2.8 MPa strength
cement	67.0%	32.9%	77.8%	45.9%
soil winning labour	15.8%	12.1%	10.4%	9.5%
pressing labour	11.1%	9.1%	7.6%	7.3%
machine depreciation	6.1%	45.9%	4.2%	37.3%
total	100%	100%	100%	100%

If the cement cost were increased to £6.00 per 50kg bag while the labour cost remained at the Sri Lankan value of £3.50 per man per day then the high pressure compaction route still remains the more expensive although the margin of difference is reduced (table 6.6e) to 18.8% and 8.5% for 1.4 MPa and 2.8MPa strength standards respectively.

Table 6.6e Block production cost comparison (if £6.00 per 50 kg of cement in Sri Lanka)

Cost per Block	wet strength 1.4 MPa	wet strength 2.8 MPa
Cinva Ram 2 MPa compaction	£0.1160	£0.1525
Brepack 10 MPa compaction	£0.1378 +18.8% over 2 MPa	£0.1655 + 8.5% over 2 MPa

The above analysis is not able to cover differences in the production efficiency and adaptability. Compaction to high pressure produces blocks which have a higher freshly demoulded (green) strength as a result of their higher density. This reduces the risk of block breakage during ejection and transportation to the curing area which has been reported by Lawson (Lawson, 1992, Ref No.22) to be as high as 50% in some extreme cases.

Moreover, because of the increased green block density the range of soil which can be used for production is larger for the high pressure machines. Green strength depends on the soil particle grading and the block density. If the green block density is reduced then for the same green strength or handleability the soil's clay content must be increased. i.e. high pressure compaction allows the use of soils with lower clay contents than those acceptable for low pressure compaction.

In conclusion, in most situations low pressure compaction will be more economic than high pressure compaction, provided that the block breakage rate is acceptably low, i.e. a moderate to high[5] clay content soil is used. If the cost of high pressure machines can be significantly reduced, while keeping the production rate similar to that of the low pressure machines, then high pressure compaction may prove to be more economic. Moreover if high pressure compaction is found to increase block durability then a small cost premium may be acceptable.

[5] Moderate and high clay contents within the acceptable clay content bounds of 10 - 30%.

APPENDICES

APPENDIX A: BIBLIOGRAPHY

APPENDIX B: *SOIL-A* PROFILE

APPENDIX C: EXPERIMENTAL METHOD

APPENDIX D: EXPERIMENTAL INSTRUMENTATION

APPENDIX A BIBLIOGRAPHY

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APPENDIX B SOIL-A DETAILS

Soil-A is an artificial soil produced at the University of Warwick by blending building sand with grade E kaoline powder. This soil was used for all experimentation to aid repeatability and allow a consistent soil composition throughout the course of the current research work. The soil was blended such that it fell within the ideal specification for soil-cement given by United Nations (1964, Ref No.17). This states that the optimum soil composition is; 75% sand, 25% silt and clay, of which more than 10% is clay.

Building Sand:

Grading:	Sand	84.2%
	Silt	8.8%
	Clay	7.0%

Grading curve:

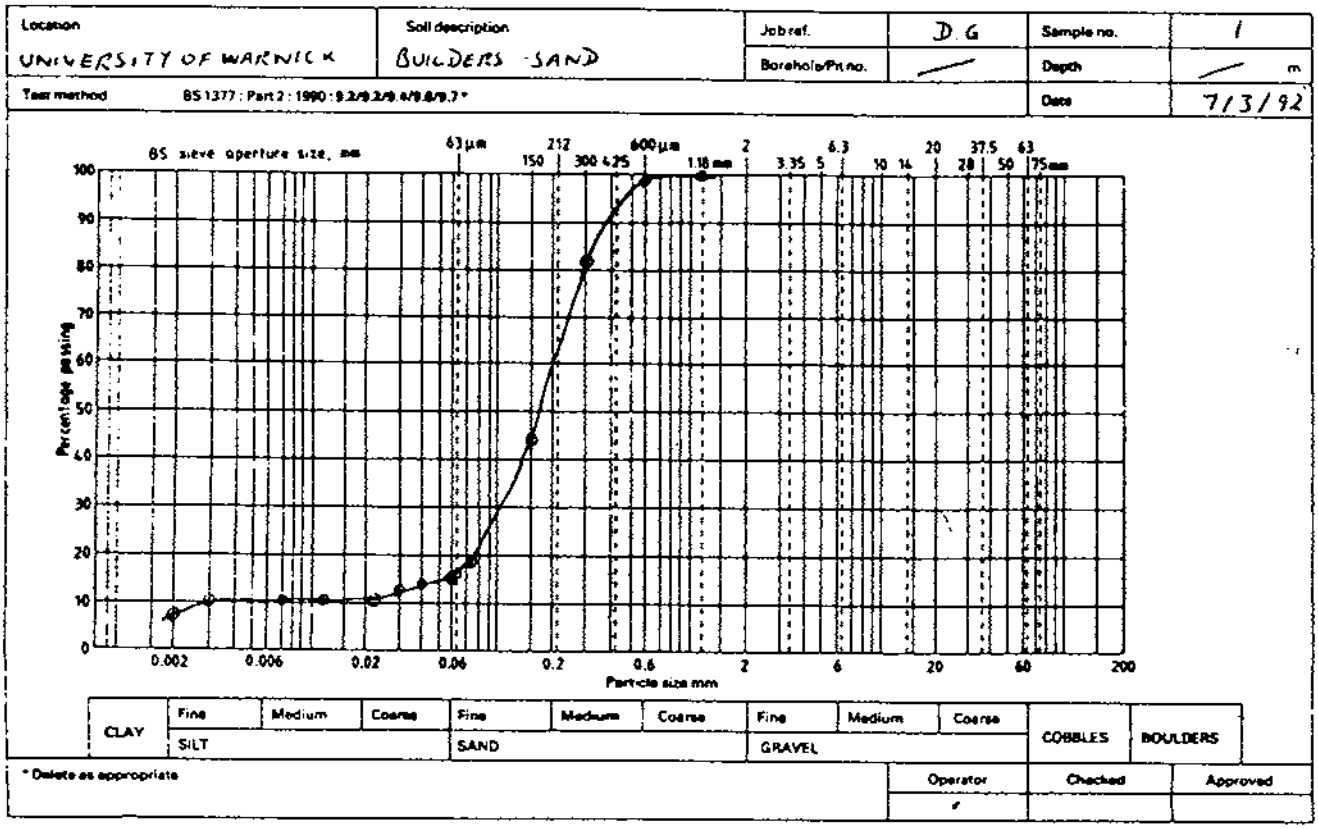

Kaoline Grade E powder:

Specific gravity	2.6
Specific Surface Area	8.0 M^2/g
Water soluble salts	0.15 %
SiO_2	50 %
Al_2O_3	35 %
Ph	5 ± 0.5

Soil-A mix proportions:	Building Sand	9 parts	(7.2 kg)
	Kaoline	1 parts	(0.8 kg)

Soil-A grading	76.5%	Sand
	8.0%	Silt
	15.5%	Clay

Soil-A grading curve:

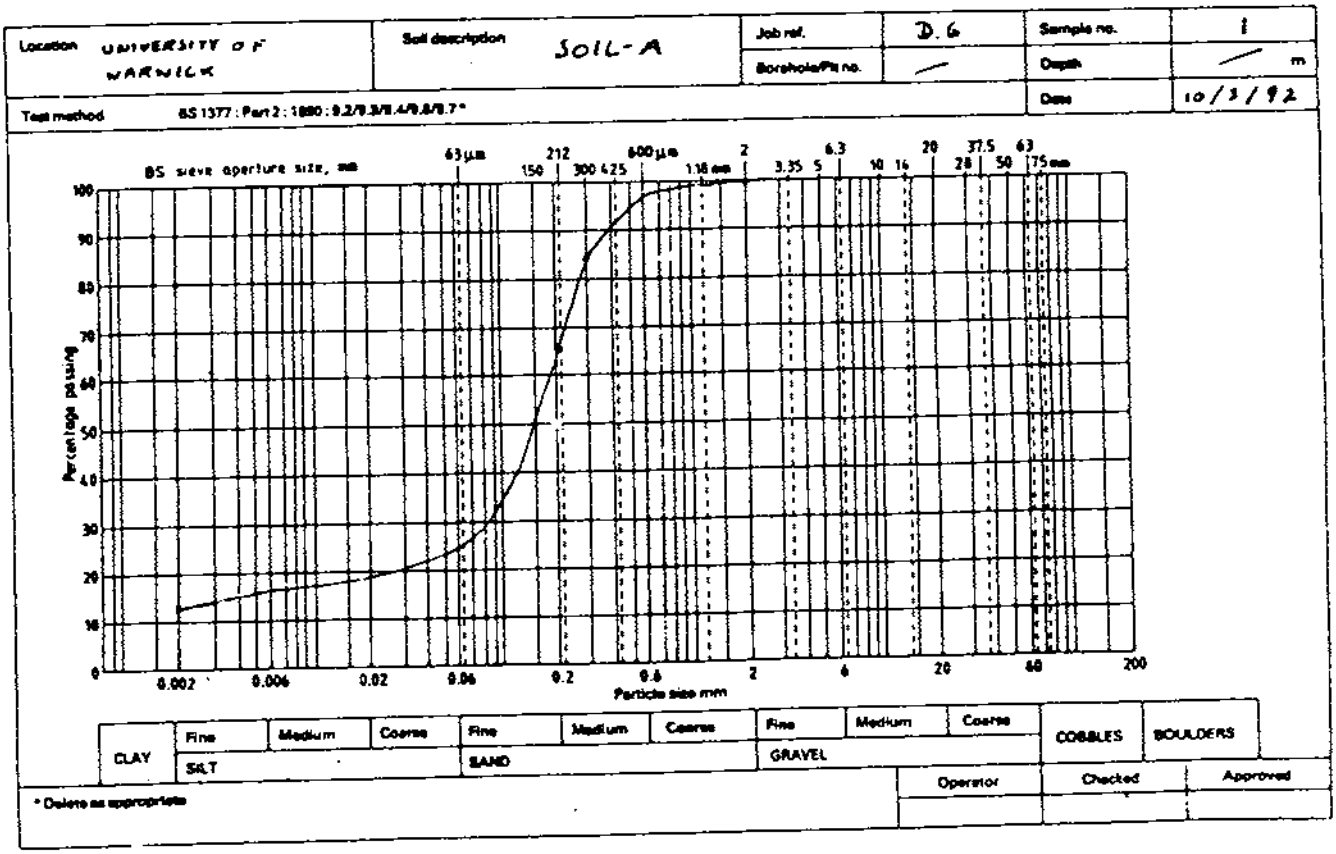

APPENDIX C : EXPERIMENTAL METHOD

UNSTABILISED BLOCK PRODUCTION (290X140X100mm)

For each block a batch of *Soil-A* was manufactured and mixed for 5 minutes with distilled water to give a moisture content of 4% (for batch proportions see below). This batch was then left overnight to homogenise before remixing to 8% moisture content. All batch proportions were weighed to ±0.05g. All mixing was mechanical, using a large Hobart soil mixer.

The material to fill the mould was weighed out as three equal quantities into three plastic bags and sealed.

After oiling the mould with a release agent (engine oil), the soil was placed in the mould. The contents of each bag was lightly tamped before adding the next. The mould top was then placed on the soil and its height above the compression machine bed measured and recorded. A dial gauge was then positioned such that the block height during compaction could be measured.

The block was then compressed in 5 tonne force increments up to 40 tonnes. After each force increment the applied force was held constant long enough for the block height and both LVDT readings to stabilise and be recorded (typically 1 minute). The block was then decompressed in a similar manner.

The compressed block was ejected from the mould by pressing the mould walls down over the lower piston. The green block was then transferred to a wooden base plate and its final dimensions recorded.

UNSTABILISED MIX PROPORTIONS

7.200kg builders sand (0.5% moisture content)
0.800kg kaoline grade E powder (0.7% moisture content)
0.277kg distilled water (for 4% homogenisation)
0.318kg distilled water (8% moisture content for compaction)

Mass of 8% moisture content *soil-A* for block compaction 8.532kg

STABILISED BLOCK PRODUCTION (290X140X100mm)

For stabilised block production the above method was used but after homogenisation at 4% moisture content, 0.398kg of cement and 0.350kg of distilled water were added.

On ejection from the mould the green blocks were transferred

to a plastic bag containing a damp tissue and sealed. The blocks were then left to cure for six days before immersion in water for the final 24 hours. Curing temperature was 22-24°C. After seven days the blocks were tested for wet compressive strength. Both the upper and lower block faces were capped with fibre board before compressive strength testing in a Denison concrete testing machine.

STABILISED SOIL-CEMENT CYLINDERS (ϕ 50mm, height 100mm)

The method given below is a copy of that used during manufacture. Six days after compaction each sample was soaked for 24 hours. On the seventh day after compaction the samples were capped with fibre board and tested for compressive strength in a Denison concrete testing machine. Although the Denison machine was operating below its range of grade 1 calibration (± 1 %) it had been recently recalibrated by an authorised testing house who indicated that the largest error given by the machine would be ± 3 % of the recorded value.

1. Measure out all ingredients for required batch. The water should be weighed into a pre-wetted container to allow for the quantity which remains in the container.

2. Place the 4% homogenised soil in the mixer. Sprinkle the cement onto the soil and note the time. Mix for 2 to 3 minutes or until the mixture looks uniform in colour, place a large plastic bag around the top of the mixer's bowl to reduce the evaporation of the water. Sprinkle in the weighed water, try not to pour the water onto the sides or the mixing paddle. Mix for a further 3 to 4 minutes or at least until the mixture looks uniform.

3. Weigh out 453.6g of the mixture, leaving the mixing bowl covered with a large plastic bag to reduce the moisture loss.

4. Oil the mould with the release oil and assemble for filling. Place approx one third of the mixture into the mould using the paper funnel. Take care not to spill any soil. Tamp the soil down with the steel bar. Repeat this for the next two thirds of the mix. Place the mould piston on top and try to centralise the main body between the end pistons.

5. Place the mould, red ring down, in the centre of the compression machine plated and compress to the required force twice (forces listed below).

6. Lift off the compression machine. Remove top and bottom pistons. Place the ejection ram in the base and the collars on top of the mould. Lower the compression machine to eject the sample. If you try and rotate the mould while compressing, it will be apparent when the sample has been ejected far enough for final removal by hand. Note the time that the sample was ejected.

7. Write the identification number on the top face and place it into a plastic bag. Repeat the above for the next two cylinders and then weigh and measure the length of each. Finally place them inside a plastic bag with one moist tissue and seal the bag.

Compaction forces:

1 MPa	= 1.960 kN	use 2.0 kN	(1.018 MPa)
2 MPa	= 3.93 kN	use 4.0 kN	(2.037 MPa)
4 MPa	= 7.85 kN	use 8.0 kN	(4.074 MPa)
6 MPa	= 11.78 kN	use 12.0 kN	(6.112 MPa)
8 MPa	= 15.71 kN	use 16.0 kN	(8.149 MPa)
10 MPa	= 19.63 kN	use 20.0 kN	(10.186 MPa)

ORDER:

Start with 10 MPa compression and 11% cement. Follow with 10 MPa 9% etc. This should minimise confusion with the compression machine!

BATCH PROPORTIONS:

All cylinders are to be compacted at eight percent water content and a dry mass of soil + cement of 420g, giving a fill mass per cylinder of 453.6g .

The figures below relate to batch mass measures. Each batch should contain enough material to make 3 cylinders with some material left over, approx 225g.

It is important to remember to note the time when the cement is added to the 4% moisture content soil.

BATCH TO MIX UP AND STAND OVERNIGHT:

(measure all mass to ± 0.05g)

9kg	lab-dry soil
1kg	kaolin from bag
0.347kg	distilled water

3% CEMENT BATCH:

1484.4g	4% homogenised soil
42.7g	cement
60.6g	distilled water

5% CEMENT BATCH:

1456.0g	4% homogenised soil
70g	cement
61.7g	distilled water

7% CEMENT BATCH:

1428.7g	4% homogenised soil
96.3g	cement
62.7g	distilled water

9% CEMENT BATCH:

1402.5g	4%homogenised soil
121.5g	cement
63.8g	distilled water

11% CEMENT BATCH:

1377.3g	4% homogenised soil
145.6g	cement
64.8g	distilled water

APPENDIX D : EXPERIMENTAL INSTRUMENTATION

THE LVDT TRANSDUCER

The LVDT transducer (see figures D1, D2 and D3) was designed to flush-mount in the mould walls. The main body of the transducer is machined from EN24T steel to form a circular spring. The thickness and shape of the spring are such that it will remain well inside the elastic region of the steel such that deflection is proportional to the applied load. The spring is deflected by a cylindrical piston mounted in a tubular guide. Both the outer faces of the tubular guide and of the cylindrical piston are flush with the spring body face and mould wall under conditions of no load.

The LVDT plunger is screwed into the rear spring boss. The LVDT body is clamped inside the transducer by the olive ring. Any deflection of the spring is sensed by the LVDT and converted into a voltage signal. The voltage output from the LVDT is fed into a conditioner and finally displayed on a digital voltmeter. The LVDT transducers and conditioners are both made by Schlumberger Industries and were supplied by RS Components Ltd, catalogue No 646-527 and No. 646-599 respectively. The Schlumberger Part numbers are LVDT SM1 and type OD3 911040 transducer conditioner.

Initially quite large hysteresis was observed on unloading. This was found to be caused by an air lock between the piston and the spring body. The design was subsequently modified by including a 1.5mm diameter vent hole. Two such transducers were manufactured and used during the experimentation.

Figures D4 and D5 show the calibration plots for transducer No.1 and No.2 respectively. Minor machining differences led to each unit having a different spring constant and hence a different gain. The gain of each unit was found to be constant over time and constant within normal laboratory temperatures. The zero offset was found to vary with time, typically 1mV per 30 minutes. The zero load voltage was recorded immediately before each experiment so that the zero offset could be determined, this offset was assumed to remain constant for the duration of each test (20 minutes). The transducers' hysteresis lead to a 0.1MPa over reading after four full cycles.

The pressure transmitted to the mould wall was found by entering the recorded voltage into the transducer equation:

$$y = mx + c$$

where y = transmitted pressure /MPa
m = transducer gain (found from calibration curves) /MPa/mV
x = recorded voltage /mV
c = zero offset correction (found by $c = -mx$ at zero load)

Figure D6 shows the possible locations for the transducers in the mould side wall.

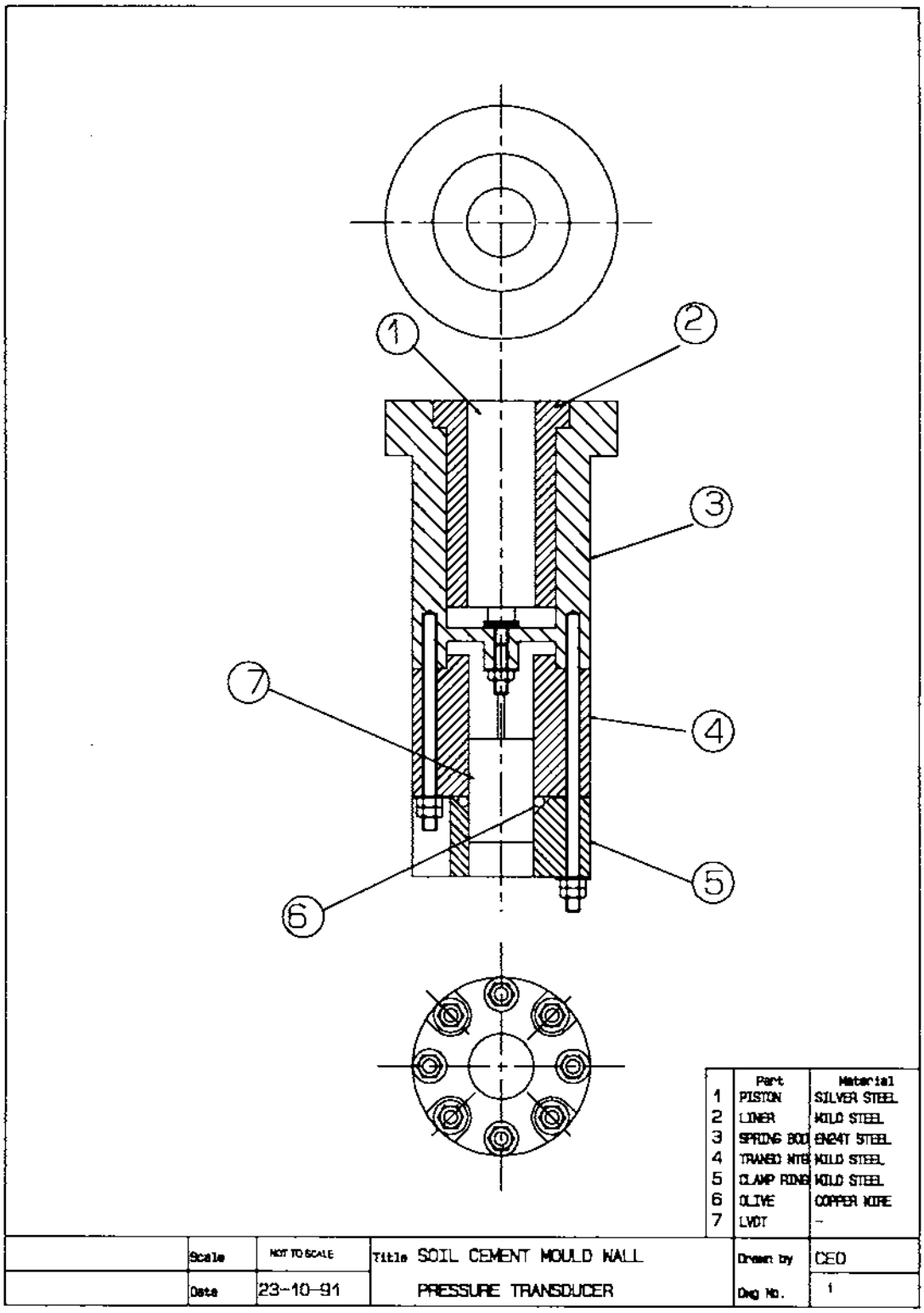

Figure D1 LVDT Transducer Assembly Drawing

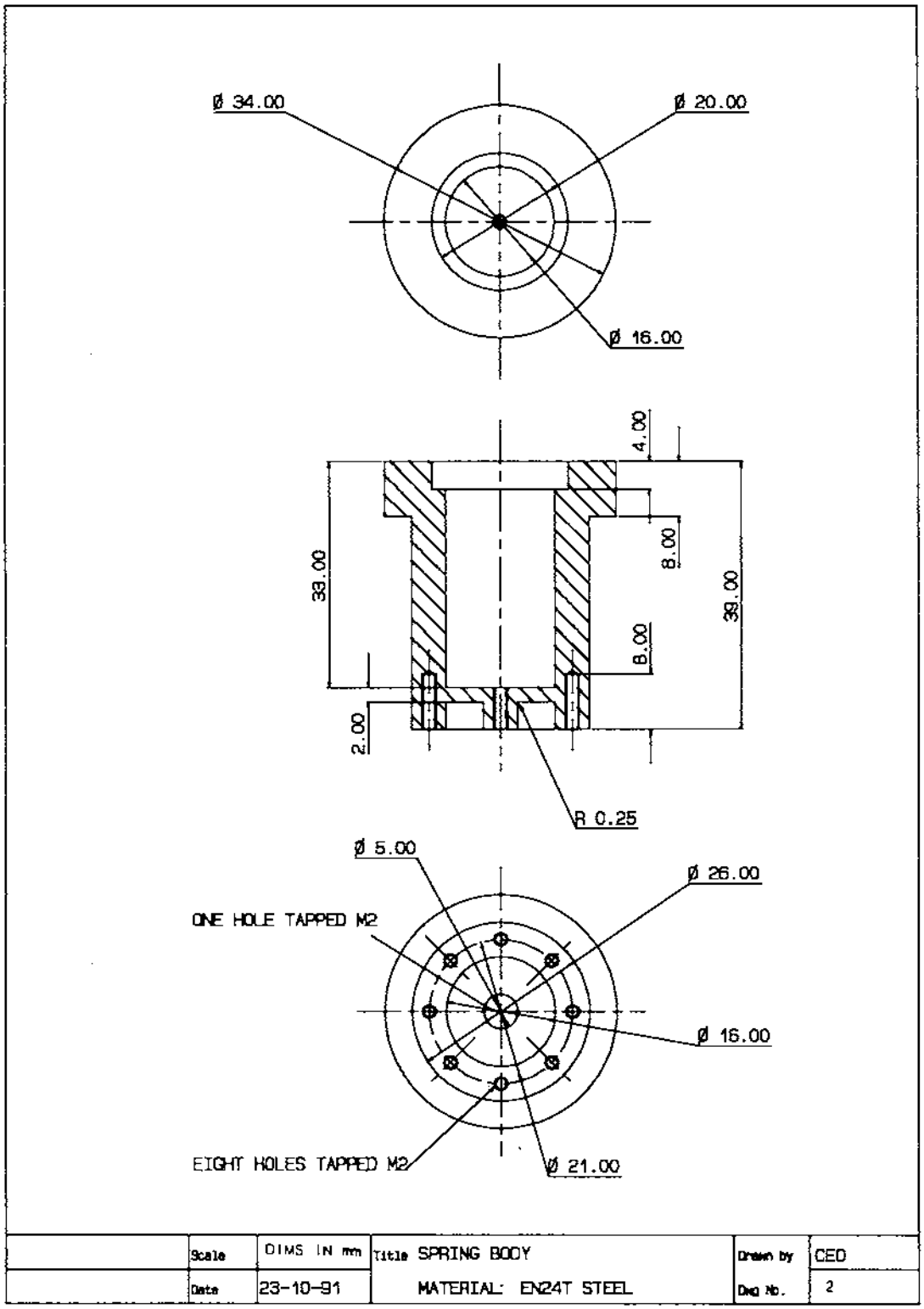

Figure D2 LVDT Transducer Spring Body

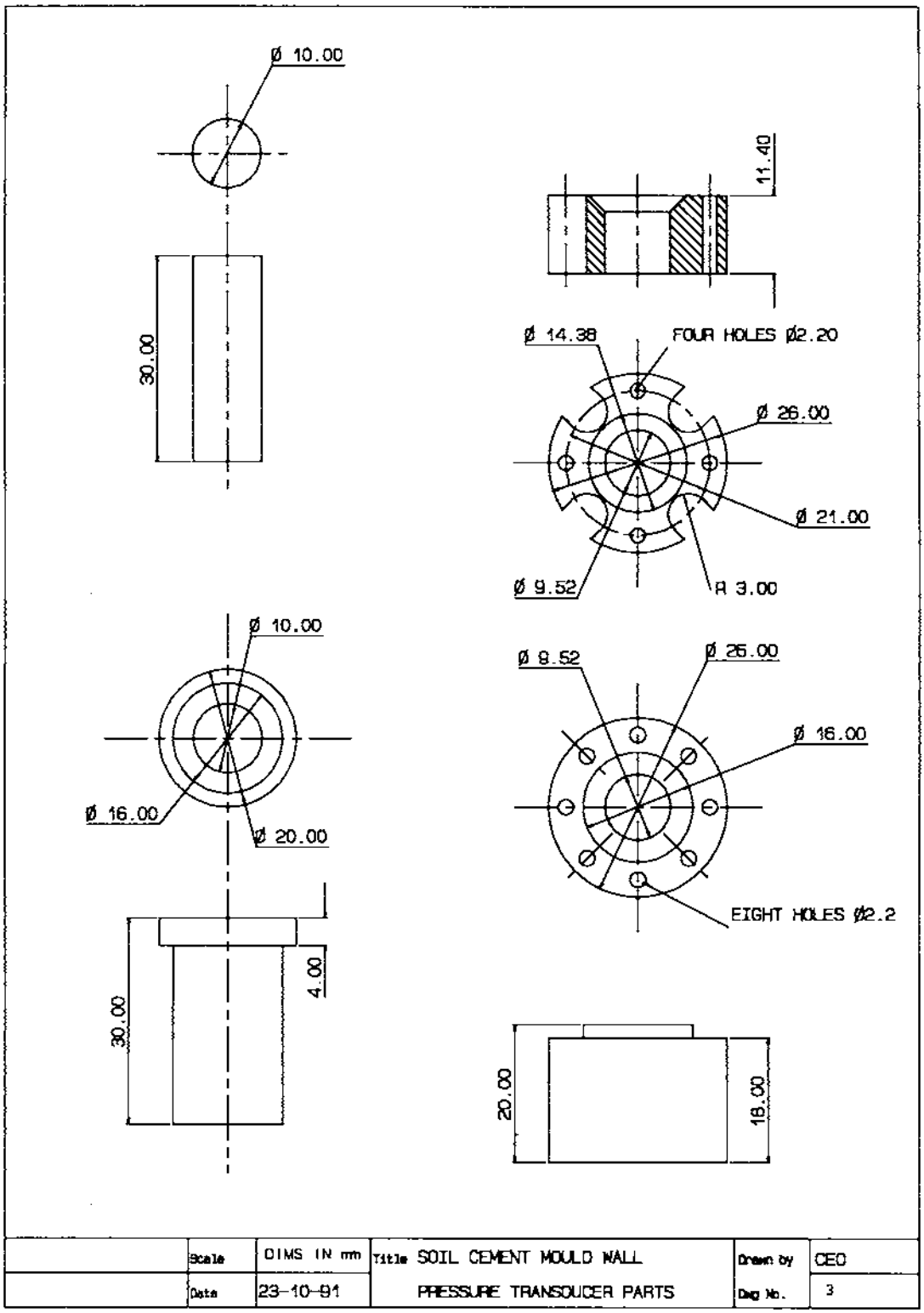

Figure D3 LVDT Transducer Parts

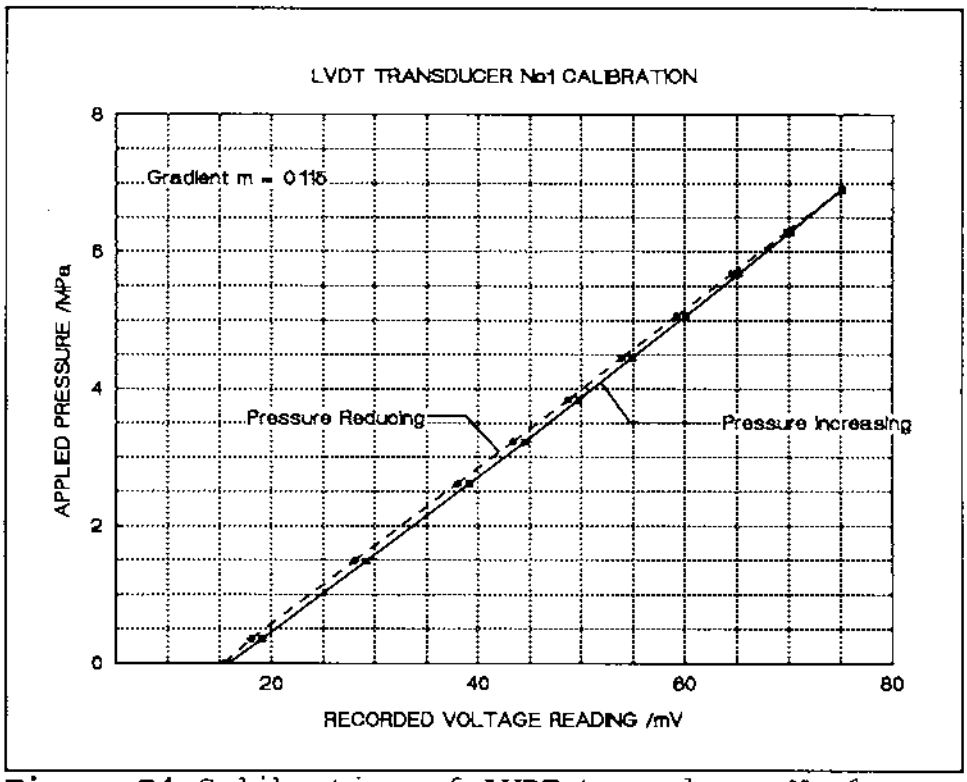

Figure D4 Calibration of LVDT transducer No.1

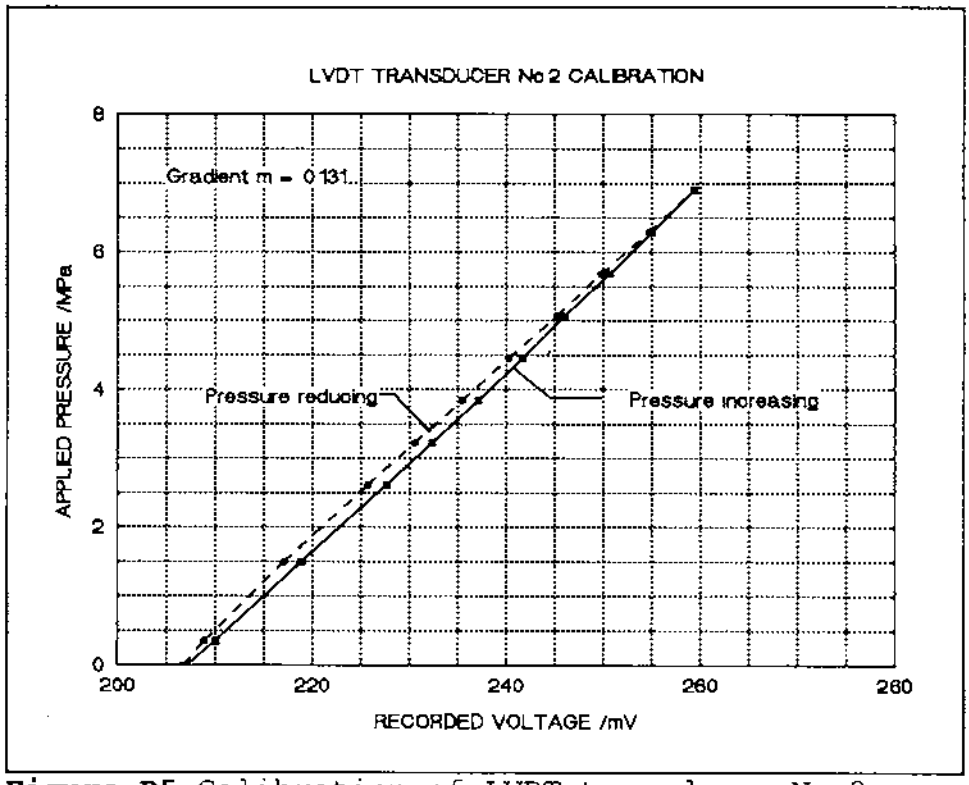

Figure D5 Calibration of LVDT transducer No.2

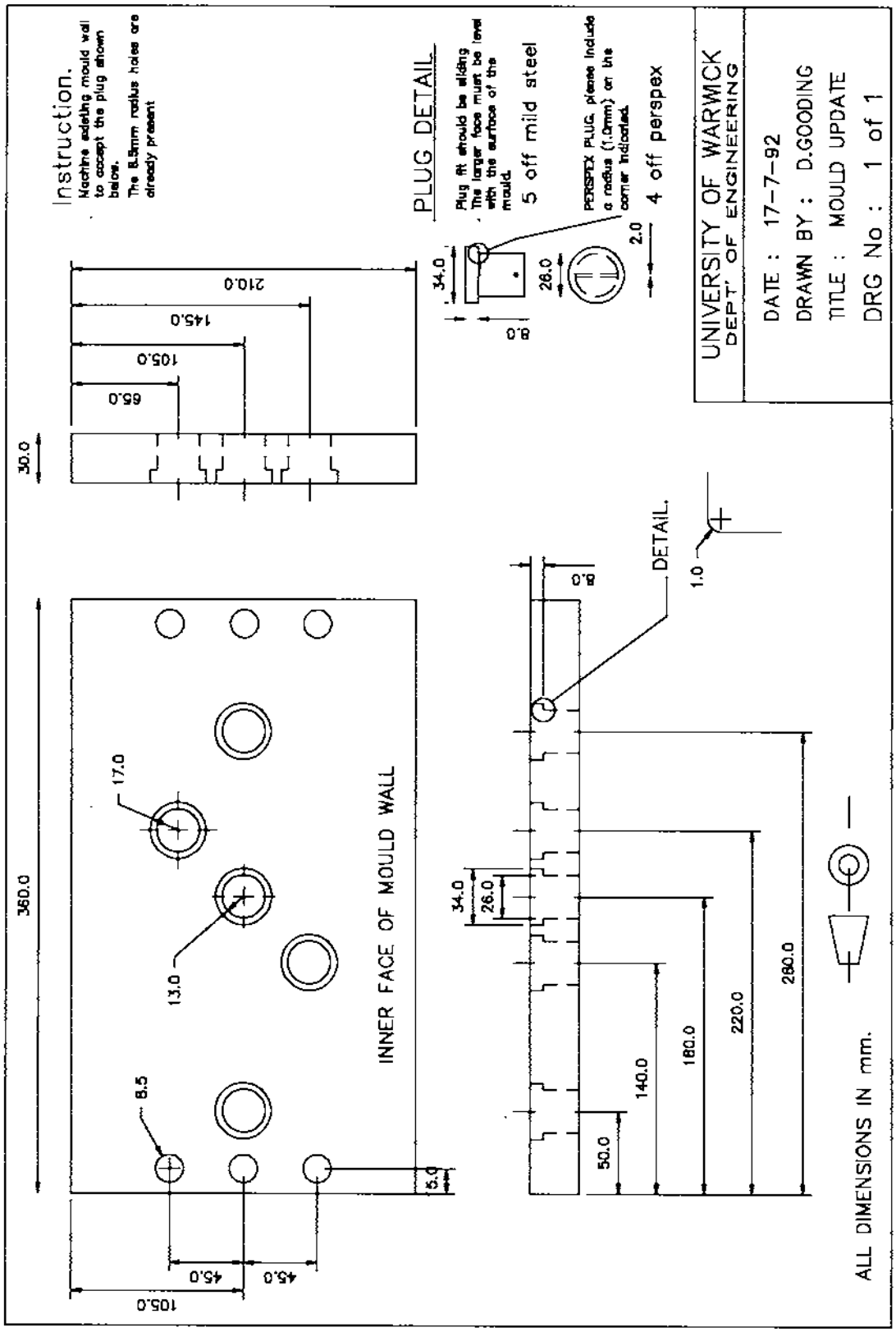

Figure D6 Transducer location sites in mould side wall

Testing Machine Details:

All wet compressive strength tests were made on a Denison Concrete test machine 7229/T91081, max load 100kN. Certified to grade 1 calibration at time of testing.

All soil-cement cylinders were compacted on a Monsanto Tensometer Type E (No. N120-79) with a 25kN load cell (No. 263). Certified to grade 1 calibration at time of testing.

All soil-cement blocks were compacted on an Amsler compression machine (No. ES1120), max load 40 tonnes. Certified to grade 1 calibration at time of testing.

Queen bee

From Wikipedia, the free encyclopedia

The term "**queen bee**" is typically used to refer to an adult, mated female that lives in a honey bee colony or hive; she is usually the mother of most, if not all, of the bees in the beehive.[1] The *queens* are developed from larvae selected by worker bees and specially fed in order to become sexually mature. There is normally only one adult, mated queen in a hive, in which case the bees will usually follow and fiercely protect her.

Carniolan queen bee with attendants on a honeycomb.

The term "queen bee" can be more generally applied to any dominant reproductive female in a colony of a eusocial bee species other than honey bees. However, as in the Brazilian stingless bee *Schwarziana quadripunctata*, a single nest may have multiple queens or even dwarf queens, ready to replace a dominant queen in a case of sudden death.[2]

Contents

- 1 Development
- 2 Virgin queen bee
  - 2.1 Piping
- 3 Reproduction cycle
  - 3.1 Supersedure
- 4 Daily life
- 5 Identification
- 6 Queen rearing
- 7 References
- 8 External links

Development

A queen cup

Queen larvae floating on royal jelly in opened queen cups laid on top of wax comb.

When conditions are favorable for swarming, the queen will start laying eggs in queen cups. A virgin queen will develop from a fertilized egg. The young queen larva develops differently because it is more heavily fed royal jelly, a protein-rich secretion from glands on the heads of young workers. If not for being heavily fed royal jelly, the queen larva would have developed into a regular worker bee. All bee larvae are fed some royal jelly for the first few days after hatching but only queen larvae are fed on it exclusively. As a result of the difference in diet, the queen will develop into a sexually mature female, unlike the worker bees.

Older queen larvae in queen cell lying on top of wax comb

Queens are raised in specially constructed queen cells. The fully constructed queen cells have a peanut-like shape and texture. Queen cells start out as queen cups. Queen cups are larger than the cells of normal brood comb and are oriented vertically instead of horizontally. Worker bees will only further build up the queen cup once the queen has laid an egg in a queen cup. In general, the old queen starts laying eggs into queen cups when conditions are right for swarming or supersedure. Swarm cells hang from the bottom of a frame while supersedure queens or emergency queens are generally raised in cells built out from the face of a frame.

As the young queen larva pupates with her head down, the workers cap the queen cell with beeswax. When ready to emerge, the virgin queen will chew a circular cut around the cap of her cell. Often the cap swings open when most of the cut is made, so as to appear like a hinged lid.

During swarming season, the old queen will likely leave with the prime swarm before the first virgin queen emerges from a queen cell.

Virgin queen bee

A virgin queen is a queen bee that has not mated with a drone. Virgins are intermediate in size between workers and mated, laying queens, and are much more active than the latter. They are hard to spot while inspecting a frame, because they run across the comb, climbing over worker bees if necessary, and may even take flight if sufficiently disturbed. Virgin queens can often be found clinging to the walls or corners of a hive during inspections.

Metamorphosis of the queen bee	
Egg	hatches on Day 3
Larva (several moltings)	Day 3 to Day 8½
Queen cell capped	~ Day 7½
Pupa	~ Day 8 until emergence
Emergence	~Day 15½ - Day 17
Nuptial Flight(s)	~Day 20 - 24
Egg Laying	~Day 23 and up

Virgin queens appear to have little queen pheromone and often do not appear to be recognized as queens by the workers. A virgin queen in her first few hours after emergence can be placed into the entrance of any queenless hive or nuc and acceptance is usually very good, whereas a mated queen is usually recognized as a stranger and runs a high risk of being killed by the older workers.

When a young virgin queen emerges from a queen cell, she will generally seek out virgin queen rivals and attempt to kill them. Virgin queens will quickly find and kill (by stinging) any other emerged virgin queen (or be dispatched themselves), as well as any unemerged queens. Queen cells that are opened on the side indicate that a virgin queen was likely killed by a rival virgin queen. When a colony remains in swarm mode after the prime swarm has left, the workers may prevent virgins from fighting and one or several virgins may go with after-swarms. Other virgins may stay behind with the remnant of the hive. Some virgins have been seen to escape the hive to avoid being killed and seek out another without a queen, such as in the eusocial bee *Melipona scutellaris*.[3] As many as 21 virgin queens have been counted in a single large swarm. When the after-swarm settles into a new home, the virgins will then resume normal behavior and fight to the death until only one remains. If the prime swarm has a virgin queen and the old queen, the old queen will usually be allowed to live. The old queen continues laying. Within a couple of weeks she will die a natural death and the former virgin, now mated, will take her place.

Unlike the worker bees, the queen's stinger is not barbed and she is able to sting repeatedly without dying.

Piping

Capped queen cell opened to show queen pupa (with darkening eyes).

Piping describes a noise made by virgin and mated queen bees during certain times of the virgin queens' development. Fully developed virgin queens communicate through vibratory signals: "quacking" from virgin queens in their queen cells and "tooting" from queens free in the colony, collectively known as piping. A virgin queen may frequently pipe before she emerges from her cell and for a brief time afterwards. Mated queens may briefly pipe after being released in a hive.

Piping is most common when there is more than one queen in a hive. It is postulated that the piping is a form of battle cry announcing to competing queens and the workers their willingness to fight. It may also be a signal to the worker bees which queen is the most worthwhile to support.

The piping sound is a G♯ (aka A♭). The adult queen pipes for a two-second pulse followed by a series of quarter-second toots.[4] The queens of Africanized bees produce more vigorous and frequent bouts of piping.

Reproduction cycle

The surviving virgin queen will fly out on a sunny, warm day to a "drone congregation area" where she will mate with 12-15 drones. If the weather holds, she may return to the drone congregation area for several days until she is fully mated. Mating occurs in flight. The young queen stores up to 6 million sperm from multiple drones in her spermatheca. She will selectively release sperm for the remaining 2–7 years of her life.[5]

The young virgin queen has a limited time to mate. If she is unable to fly for several days because of bad weather and remains unmated, she will become a "drone layer." Drone-laying queens usually signal the death of the colony, because the workers have no fertilized (female) larvae from which to raise worker bees or a replacement queen. (Pearcy et al. 2004)

Though timing can vary, matings usually take place between the sixth and tenth day after the queen emerges. Egg laying usually begins 2 to 3 days after the queen returns to the beehive, but can start earlier than this.[6]

A special, rare case of reproduction is thelytoky: the reproduction of female workers or queens by laying worker bees. Thelytoky occurs in the Cape bee, *Apis mellifera capensis*, and has been found in other strains at very low frequency.

Supersedure

As the queen ages her pheromone output diminishes. A queen bee that becomes old, or is diseased or failing, is replaced by the workers in a procedure known as "supersedure".

Capped supersedure queen cells

Supersedure may be forced by a beekeeper, for example by clipping off one of the queen's middle or posterior legs. This makes her unable to properly place her eggs at the bottom of the brood cell; the workers detect this and then rear replacement queens. When a new queen becomes available, the workers kill the reigning queen by "balling" her, clustering tightly around her. Death through balling is accomplished by surrounding the queen bee and raising her body temperature, causing her to overheat and die. Balling is often a problem for beekeepers attempting to introduce a replacement queen.

If a queen suddenly dies, the workers will flood with royal jelly several cells where a larva has just emerged. The young larva floats on the royal jelly; the worker bees then build a larger queen cell from the normal-sized worker cell, which protrudes vertically from the face of the brood comb. Emergency queens are usually smaller and less prolific.

Daily life

Unmarked queen with attendants.

Although the name might imply it, a queen bee does not directly control the hive. Her sole function is to serve as the reproducer. A well-mated and well-fed queen of quality stock can lay about 1,500 eggs per day during the spring build-up—more than her own body weight in eggs every day. She is continuously surrounded by worker bees who meet her every need, giving her food and disposing of her waste. The attendant workers also collect and then distribute queen mandibular pheromone, a pheromone that inhibits the workers from starting queen cells.[7]

The queen bee is able to control the sex of the eggs she lays. The queen lays a fertilized (female) or unfertilized (male) egg according to the width of the cell. Drones are raised in cells that are significantly larger than the cells used for workers. The queen fertilizes the egg by selectively releasing sperm from her spermatheca as the egg passes through her oviduct.

Identification

The queen bee's abdomen is noticeably longer than the worker bees surrounding her and is longer than a male bee's. Even so, in a hive of 60,000 to 80,000 honey bees, it is often difficult for beekeepers to find the queen with any speed; for this reason, many queens in non-feral colonies are marked with a light daub of paint on their thorax. The paint used does no harm to the queen and makes her much easier to find when necessary.

Marked queen

Although the color is sometimes randomly chosen, professional queen breeders use a color that identifies the year a queen hatched, which helps them to decide whether their queens are too old to maintain a strong hive and need to be replaced. The mnemonic taught to assist beekeepers in remembering the colour order is Will You Raise Good Bees (white, yellow, red, green, blue). Sometimes tiny convex disks marked with identification numbers (*Opalithplättchen*) are used when a beekeeper has many queens born in the same year.

Color		Year ends in
white		1 or 6
yellow		2 or 7
red		3 or 8
green		4 or 9
blue		5 or 0

Queen rearing

Beekeepers use several different methods to raise more queens and mate them. Examples are the Jenter kit, walk-away split, grafting, Cloake board, artificial insemination, and a mating yard.

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Categories: Beekeeping | Insect reproduction | Bees

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Worksheet Topics ›

Ohm's Law

Basic Electricity

Question 1

For a given amount of water pressure, which will flow a greater rate of water: a small (restrictive) nozzle or a large (unrestrictive) nozzle? Explain how this relates to the study of voltage, current, and resistance in a simple electric circuit.

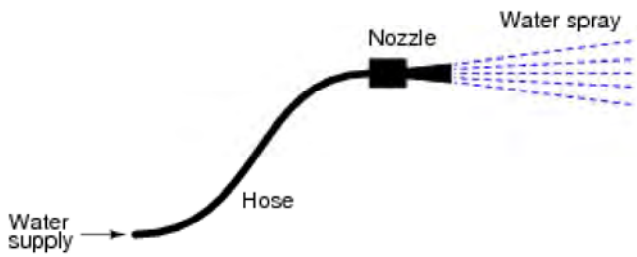

Reveal answer

Question 2

Suppose you were to build this circuit and take measurements of current through the resistor and voltage across the resistor:

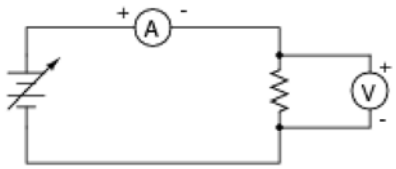

Recording these numerical values in a table, the results look something like this:

XXXXXXX	XXXXXXX
Current	Voltage
0.22 A	0.66 V
0.47 A	1.42 V
0.85 A	2.54 V
1.05 A	3.16 V
1.50 A	4.51 V
1.80 A	5.41 V
2.00 A	5.99 V
2.51 A	7.49 V

Plot these figures on the following graph:

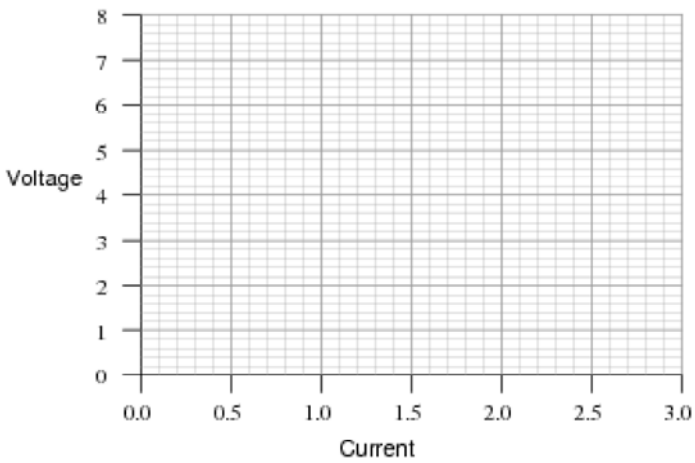

What mathematical relationship do you see between voltage and current in this simple circuit?

Reveal answer

Question 3

Explain, step by step, how to calculate the amount of current (I) that will go through the resistor in this circuit:

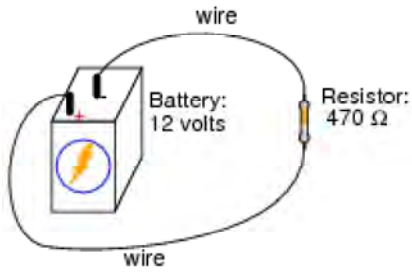

Reveal answer

Question 4

_____

∫f(x) dx *Calculus alert!*

_____

Plot the relationships between voltage and current for resistors of three different values (1 Ω, 2 Ω, and 3 Ω), all on the same graph:

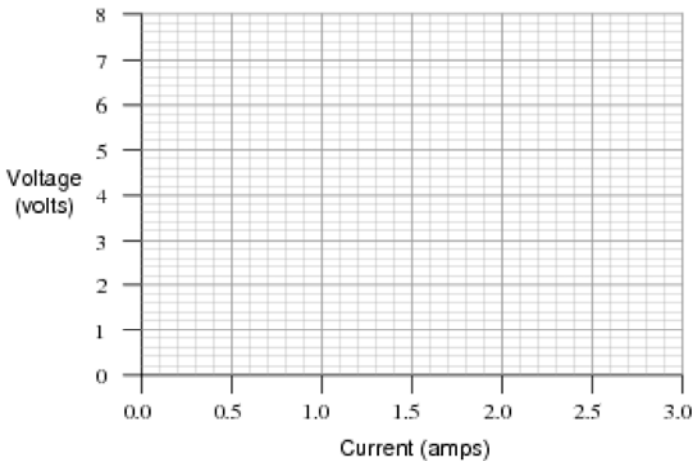

What pattern do you see represented by your three plots? What relationship is there between the amount of resistance and the nature of the voltage/current function as it appears on the graph?

Advanced question: in calculus, the instantaneous rate-of-change of an (x,y) function is expressed through the use of the *derivative* notation: [dy/dx]. How would the derivative for each of these three plots be properly expressed using calculus notation? Explain how the derivatives of these functions relate to real electrical quantities.

Reveal answer

Question 5

What is the value of this resistor, in *ohms* (Ω)?

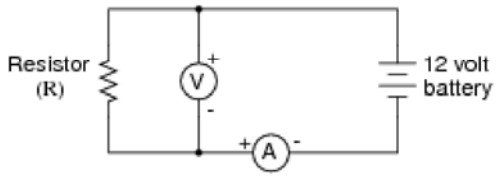

Voltmeter indication = 12.3 volts
Ammeter indication = 4.556 milliamps

Reveal answer

Question 6

A common saying about electricity is that ït always takes the path of least resistance." Explain how this proverb relates to the following circuit, where electric current from the battery encounters two alternate paths, one being less resistive than the other:

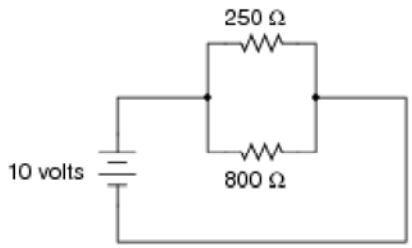

Reveal answer

Question 7

One style of light bulb, very different from the ïncandescent" design which works on the principle of a super-heated wire filament emitting light, is called a *gas discharge tube*. In this design of light bulb, light is produced by the direct ëxcitation" of gas molecules as electric current passes between two electrodes:

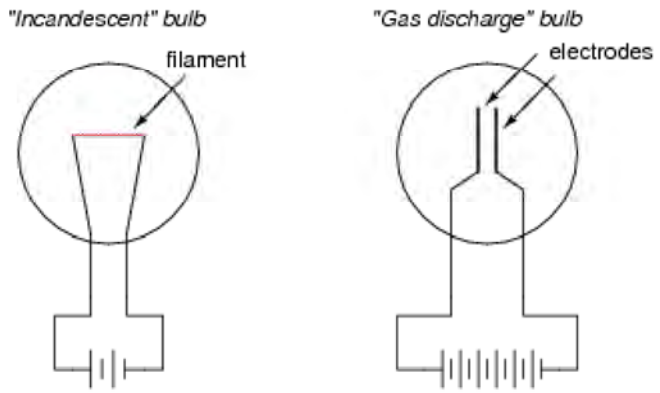

Both types of light bulbs have interesting voltage/current plots, neither one being identical to the voltage/current plot of a resistor. First, the voltage/current plot for an incandescent light bulb:

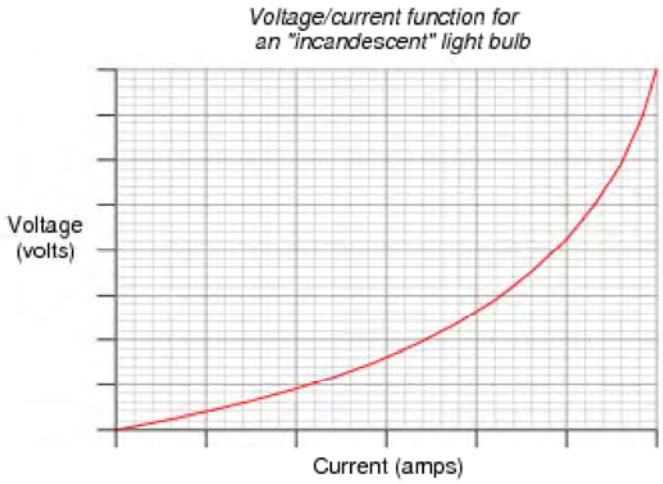

Next, the voltage/current plot for a gas-discharge light bulb:

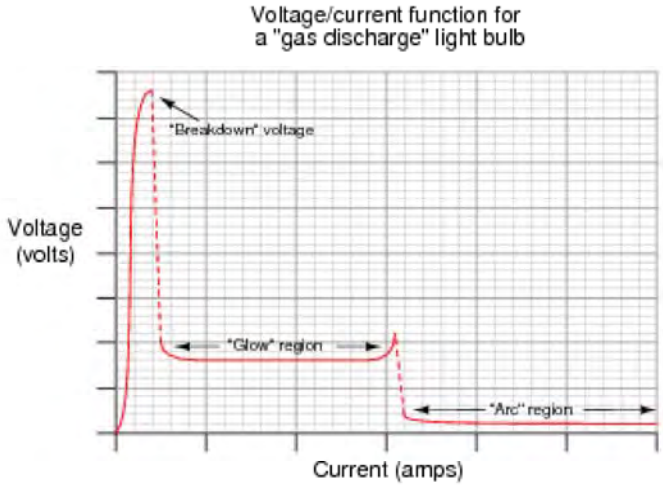

Based on these two graphs, what can you say about the electrical resistance of each bulb type over its operating range?

Reveal answer

Question 8

Draw the schematic diagram for an experimental circuit to gather data necessary to plot the voltage/current graph of a gas discharge lamp.

Reveal answer

Question 9

What is *negative resistance*?

Reveal answer

Question 10

What would happen if a wire having no resistance at all (0 Ω) were connected directly across the terminals of a 6-volt battery? How much current would result, according to Ohm's Law?

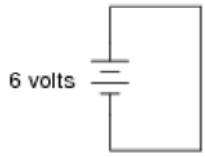

Suppose we were to short-circuit a 6-volt battery in the manner just described and measure 8 amps of current. Why don't the calculated figures from the previous paragraph agree with the actual measurement?

Reveal answer

Question 11

Shunt resistors are often used as current-measuring devices, in that they are designed to drop very precise amounts of voltage as large electric currents pass through them. By measuring the amount of voltage dropped by a shunt resistor, you will be able to determine the amount of current going through it:

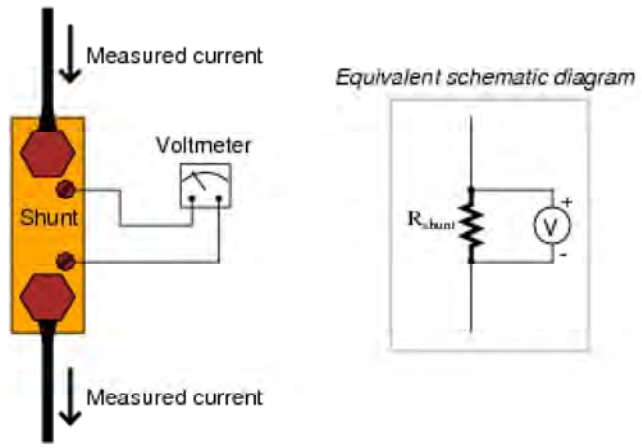

Suppose that a shunt resistance is labeled with the following rating: **150 A , 50 mV**. What is the resistance of this shunt, in ohms? Express your answer in metric notation, scientific notation, and plain decimal notation.

Reveal answer

Question 12

Don't just sit there! Build something!!

Learning to mathematically analyze circuits requires much study and practice. Typically, students practice by working through lots of sample problems and checking their answers against those provided by the textbook or the instructor. While this is good, there is a much better way.

You will learn much more by actually *building and analyzing real circuits*, letting your test equipment provide the "answers" instead of a book or another person. For successful circuit-building exercises, follow these steps:

1. Carefully measure and record all component values prior to circuit construction.
2. Draw the schematic diagram for the circuit to be analyzed.
3. Carefully build this circuit on a breadboard or other convenient medium.

4. Check the accuracy of the circuit's construction, following each wire to each connection point, and verifying these elements one-by-one on the diagram.
5. Mathematically analyze the circuit, solving for all values of voltage, current, etc.
6. Carefully measure those quantities, to verify the accuracy of your analysis.
7. If there are any substantial errors (greater than a few percent), carefully check your circuit's construction against the diagram, then carefully re-calculate the values and re-measure.

Avoid very high and very low resistor values, to avoid measurement errors caused by meter "loading". I recommend resistors between 1 kΩ and 100 kΩ, unless, of course, the purpose of the circuit is to illustrate the effects of meter loading!

One way you can save time and reduce the possibility of error is to begin with a very simple circuit and incrementally add components to increase its complexity after each analysis, rather than building a whole new circuit for each practice problem. Another time-saving technique is to re-use the same components in a variety of different circuit configurations. This way, you won't have to measure any component's value more than once.

Reveal answer

Question 13

One of the fundamental equations used in electricity and electronics is *Ohm's Law*: the relationship between voltage (E or V, measured in units of *volts*), current (I, measured in units of *amperes*), and resistance (R, measured in units of *ohms*):

$$E = IR \quad I = \frac{E}{R} \quad R = \frac{E}{I}$$

Where,

E = Voltage in units of volts (V)

I = Current in units of amps (A)

R = Resistance in units of ohms (Ω)

Solve for the unknown quantity (E, I, or R) given the other two, and express your answer in both scientific and metric notations:

I = 20 mA, R = 5 kΩ; E =

I = 150 μA, R = 47 kΩ; E =

E = 24 V, R = 3.3 MΩ; I =

E = 7.2 kV, R = 900 Ω; I =

E = 1.02 mV, I = 40 μA; R =

E = 3.5 GV, I = 0.76 kA; R =

I = 0.00035 A, R = 5350 Ω; E =

I = 1,710,000 A, R = 0.002 Ω; E =

E = 477 V, R = 0.00500 Ω; I =

E = 0.02 V, R = 992,000 Ω; I =

E = 150,000 V, I = 233 A; R =

E = 0.0000084 V, I = 0.011 A; R =

Reveal answer

Question 14

A quantity often useful in electric circuit analysis is *conductance*, defined as the reciprocal of resistance:

$$G = \frac{1}{R}$$

The unit of conductance is the *siemens*, symbolized by the capital letter "S". Convert the following resistance values into conductance values, expressing your answers in both scientific and metric notations:

R = 5 k Ω ; G =

R = 47 Ω ; G =

R = 500 M Ω ; G =

R = 18.2 μΩ ; G =

Now, algebraically manipulate the given equation to solve for R in terms of G, then use this new equation to work "backwards" through above calculations to see if you arrive at the original values of R starting with your previously calculated values of G.

Reveal answer

Question 15

Suppose an electric current of 1.5 microamps (1.5 μA) were to go through a resistance of 2.3 mega-ohms (2.3 MΩ). How much voltage would be "dropped" across this resistance? Show your work in calculating the answer.

Reveal answer

Question 16

One of the fundamental equations used in electricity and electronics is *Ohm's Law*: the relationship between voltage (E or V, measured in units of *volts*), current (I, measured in units of *amperes*), and resistance (R, measured in units of *ohms*):

$$E = IR \quad I = \frac{E}{R} \quad R = \frac{E}{I}$$

Where,

E = Voltage in units of volts (V)

I = Current in units of amps (A)

R = Resistance in units of ohms (Ω)

Solve for the unknown quantity (E, I, or R) given the other two, and express your answer in both scientific and metric notations:

I = 45 mA, R = 3.0 kΩ; E =

I = 10 kA, R = 0.5 mΩ; E =

E = 45 V, R = 4.7 kΩ; I =

E = 13.8 kV, R = 8.1 kΩ; I =

E = 500 μV, I = 36 nA; R =

E = 14 V, I = 110 A; R =

I = 0.001 A, R = 922 Ω; E =

I = 825 A, R = 15.0 mΩ; E =

E = 1.2 kV, R = 30 MΩ; I =

E = 750 mV, R = 86 Ω; I =

E = 30.0 V, I = 0.0025 A; R =

E = 0.00071 V, I = 3389 A; R =

Reveal answer

← **Previous Worksheet** (/worksheets/magnetism/)

Next Worksheet → (/worksheets/electric-shock/)

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Quick hard cider recipe

Do you ever have the problem of running out of wine or other alcoholic beverages at large religious festivals? Are you tired of the constant buying of wine at high prices? There is one fool-proof hard cider recipe that anyone can make in one month. One time I bought a hard cider brewing kit, made it and it tasted ok but was too dry for me. I went to a meeting at a brewing club and was told that the simplest way to make hard cider was to take a 5 gallon carboy (large glass bottle the kind that used to be used for water years ago) fill it with apple cider, pitch, or put in two packets of wine yeast (do not use bread yeast otherwise it will taste very bad) and let it sit for a month.

To make this hard cider a few things must be in order to ensure the batch does not turn out bad. First, sterlyize the bottle either with iodine or with one cap bleach mixed with water, then rinse very well. Pour in the apple cider, freash squeezed not from store. (You can get this from any apple orchard and have them pour it in for you). With the cider in the jug put in the two packets of wine yeast. Shaking is not necessary. You'll need a blowoff tube. The blowoff tube is simply a clear plastic tube about the diameter of a cigar. Take the blowoff tube and stick it into a cork with a hole in it just large enough to squeeze the tube into. Put the cork in the hole of the bottle and the other end of the tube in a bucket of clean water. The reason for this is to allow the air created from the yeast to escape without letting air into the carboy, which would spoil the batch making it very sour. The carboy should be kept in a cool dark place but not the refrigerator. I doubt it would even fit there anyways. A closet is a good place. You should check on it every day or so as sometimes the cork pops off from the pressure. Let's say for instance that you put on the cork on but had no hole in it with the blow off tube sticking out of it, the cork would pop off and you'd have hard cider all over the walls, ceiling and floor and possible you from the cork blowing off. After the month is over siphone the nectar of the Gods into a clean carboy, large punchbowl or whatever you're going to use to hold it for the ritual. If you know something about bottling you can bottle it but that is a differant set of procedures. When siphoning the mixture out be sure not to disturb the carboy too much otherwise you'll stir the yeast (thick white layer on inside bottom of carboy) up which will cloud the cider and make it taste bad. One good way to siphon the mixture is to use a racking tube which is a hard clear plastic tube long enough to go to the bottom of the carboy but you want to get wta's above the thick white layer on the bottom.

1. Put cider in carboy
2. pitch yeast
3. put on cork & blow off tube
4. stick blowoff tube end in water
5. forget about it mostly for a month
6. after a month siphon it into another clean carboy
7. Do ritual and party hardy

This is a simple error-proof method of making hard cider. You can do the same thing with any fresh squeezed fruit juice. This mixture will be "alive" from the yeast as opposed to the dead wine you buy at the local liquor store. We are a people who revere life, shouldn't we be putting life into us?

Even cane or thin bamboo lengths can be bound together to construct a simple, yet effective bow.

Alternatively many twigs strapped together can provide an adequate assembly.

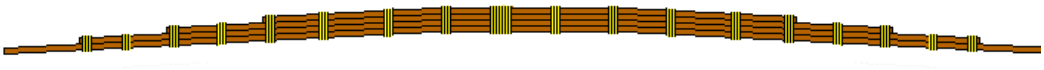

Quickie Bows

Quickie bows can be constructed in less than five minutes from a variety of materials. And can have the added advantage of being a takedown. (taken apart again for easy transport)

Just two branches whose cut dimensions are about 40" long, 1/2" in diameter at one end, and 1/8" or so at the other. Taper the wider ends and lash the limbs together overlaping the tapered faces to thicken the handle. Straight knot-less branches yield safer more efficient limbs. Tilling the final product will give a more efficient and acurate bow.

Steeply tapered branches will permit 59" to 70" bows, an effective length range. Less tapered branches must be longer in order to tiller properly. Short low tapered limbs are too round in the handle, and too nock heavy, so efficiency suffers.

Simple composite bow arm

Even a simple compound design can be used from metal pipe and will serve the same purpose as any complex design.

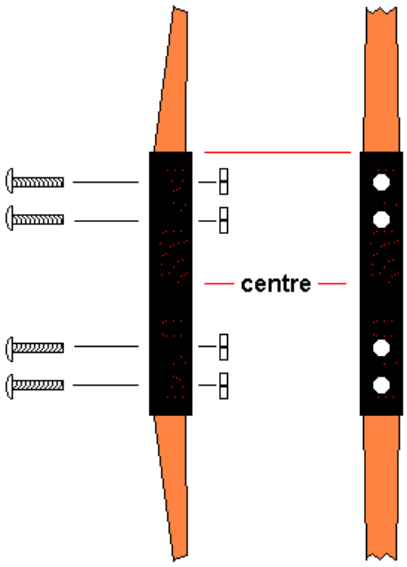

Simple composite bow arm

Side view

Front view

Steel bar bent drilled and screwed together for added strength. The middle section can be twisted sideways to provide a better handle and a near to true bowstring center.

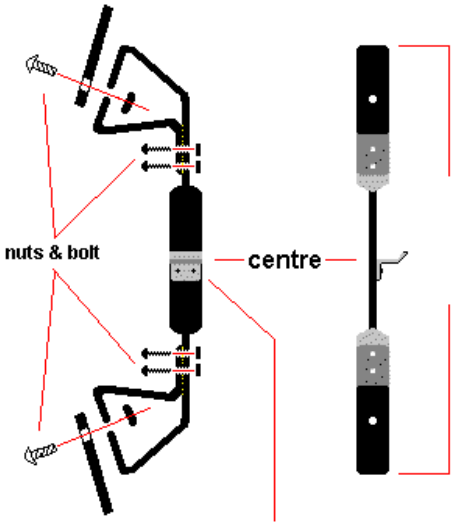

Arrow rest bent and bolted onto center frame

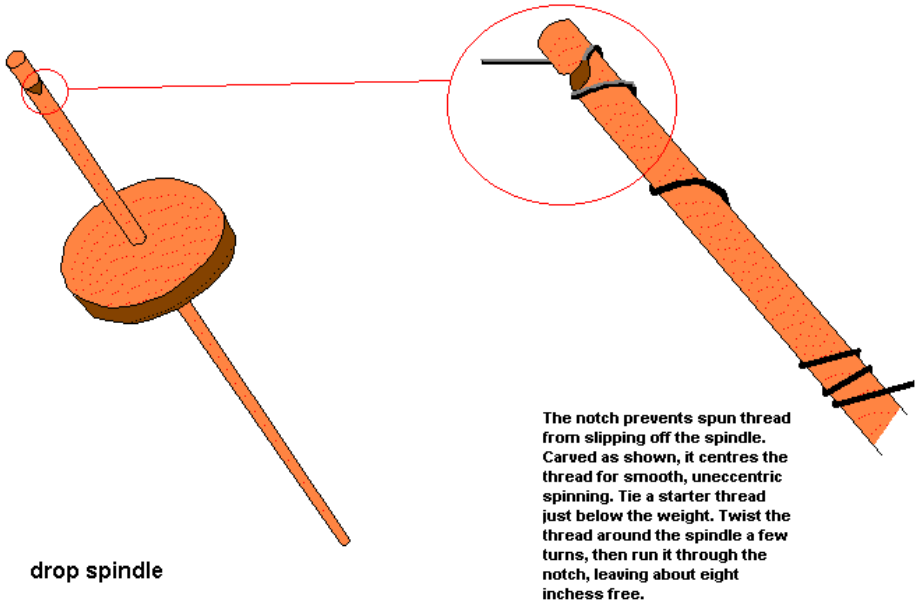

Another alternative is simple garden cane, or bamboo. With bundles of these you can raise the draw weight by increasing the number and also simulate tillering by using more cane mid bow, fewer canes towards the tip.

Unlike a normal bow, each cane is strained independently. Strain on a single cane is the same whether bent alone or incorporated in a multi-cane bundle. Draw weight can be raised simply by adding canes.

A good effective bow was constructed from four 1/2" diameter, bamboo, garden supply bean poles. Lengths were 23", 36", 54.5" and 70". Thick ends staggered. Wrapped every five inches. At 28" this bow drew a staggering 58 lb and cost practically nothing to make.

(Information provided from The Traditional Bowyers Bible)

September/October 1998 Backwoods Home Magazine

Quiet your noisy generator with an automobile muffler

By Jon B. Bushey

Having a cabin in a remote area of Utah, I depend upon a generator to provide electricity. I have a solar electric system, but for the high power tools I run the generator. I don't mind filling it with gas, restarting it, or even the maintenance. But the noise drives me crazy.

I have read articles in *BHM* about generator sheds to reduce noise, but I didn't want to go to that much work. Plus my generator needs to be portable as we work about the "ranch."

For a few years, I had tried to find a replacement muffler that would reduce the noise. It seemed to me the stock muffler was intended to reduce sparks—not lessen the noise. I found out later how true that was. I searched the hardware catalogs for mufflers and even ordered a few that looked promising. After trying them, I found that they too did little to quiet the engine. I visited various small engine shops and asked about "quiet mufflers." I was told again and again that the mufflers were all the same—"Just live with it."

Now, it's important to realize that this had become a quest. The more I heard that there's nothing that can be done, the more I thought that there has to be something. I searched more catalogs, called engine dealers, and rummaged part stores. Every time we had to start the generator the noise would grind on me. Not only the pulsing sound waves crushing my eardrums, but the emotional grinding of being helpless.

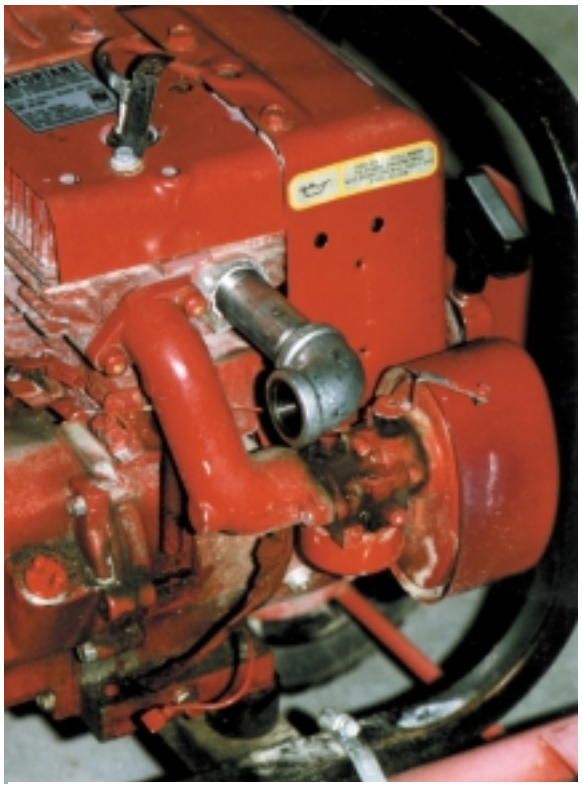

In this picture, you can see where I threaded an extra nipple into the engine. I used Teflon plumbing tape to seal the threads. The 90-degree elbow is where I will attach the nipple/connector/exhaust-pipe assembly. The muffler then slips over the assembly.

Determined to try anything, I sought a new fresh approach. I thought, "Okay, if the small engine dealers can't (or won't) come up with a solution, I'll try someplace else." I reasoned that the small mufflers just don't have the capacity (volume, size) to do anything about the noise. What about taking an automotive muffler and somehow hooking it up? As an engineer, I knew there could be dozens of technical challenges, not only in "hooking" the parts together, but getting them to work together effectively. And what about the metal work—I didn't have a machine shop or welder. I had nothing more than hand tools. Was I getting in over my head?

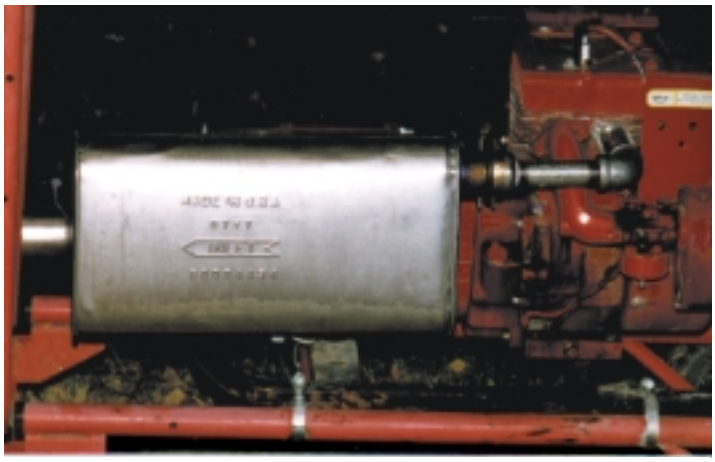

The finished unit

At this point, if someone had told me, like I'm telling you, how simple this is, I never would have believed them. After years of research, design, trials, and errors, the job ended up taking about half an hour. And most of the half hour was running around—maybe 10 minutes of actual work.

There are two secrets that make this a dream-come-true. First, a lot of small engines, like my eight-horse Tecumseh, use NPT to thread the muffler on. Briggs & Stratton uses NPT also, but in ½, ¾, or 1-inch diameter. Mine has ¾-inch threads. Check your engine, as you will need to know the size. The second secret is that the NPT connectors used to join pipes have a little smaller outside diameter than the inside diameter of an automotive

exhaust pipe. This means that an off-the-shelf piece of pipe, threaded at one end for your engine, will slip inside a car muffler.

Now, to get the pipe and connector to mate your small engine to a car muffler, go to the hardware store and walk down the plumbing aisle. Yes, we are getting engine parts; it's just that normal people use them for plumbing. Find a "nipple" that has the diameter of your engine's muffler. As a rule of thumb, it's a ½-inch for 5-horse, 3/4 for 8-horse, and a 1-inch for 10-horse. You will need to get a length that will suit your engine's mounting. I got a 2 ½-inch. I also got a 90-degree elbow because I wanted the muffler to parallel the generator. It was easier for me to support the muffler that way. You may need additional fittings to get the muffler in a position for mounting.

The final thing we need is a connector/adapter. Use either one. The result

The before and after connector/adapters

we are looking for is to have one end of the pipe to be a little less than 1 3/4-inches outside diameter.

The smaller of the two shown in the photo above is the result of putting together the nipple and the connector. The other is the result of taking the two parts to a muffler shop. At the muffler shop, I had them weld a small piece of exhaust pipe onto the outside of the connector. The connector is not visible in the larger set because it is hidden inside the exhaust pipe. While at the muffler shop get a muffler and a muffler clamp. I paid $30 for the welding, muffler, and clamp. I also got a tail pipe and another clamp because it made it easier for me to mount the muffler.

Make sure to securely mount the muffler. Between the weight and the vibration, the threads cannot support the muffler. And, of course, the muffler will get very hot.

I did some measurements of the sound levels before and after. I just used a simple cassette recorder with a sound meter, so the results are not accurate. However, it wasn't really needed anyway—the difference in sound level is very apparent to the ear.

It turns out there is not much difference between no muffler and having one of the many small engine mufflers attached. The small engine mufflers just don't make any noticeable difference in the sound level. After hooking up the car muffler (and all the plumbing), I went to pull the rope starter and I could hardly believe the difference. It was hard to tell the engine was turning over. After a second or two, the engine powered up to speed and the noise did increase. Keep in mind that a generator runs at ½ to ¾ throttle so there's going to be some noise. While the sound is still noticeable, it's much more peaceful than before. If you're curious about what your generator would sound like, you can use your vehicle as a test. Start your engine and let it idle out of gear. Next, press the accelerator until you reach about 2700 RPM. The sound your engine makes will be about the same as the generator with these modifications. If you don't have a tachometer, accelerate to about four times the hot idle, the same as going down the highway doing 55 mph. Δ

A country moment

Tony Pennucci holds his 16¾ pound catfish caught at Copco Lake in northern California as Jason Lemke, age 10, looks on.

Rabbit haemorrhagic disease

From Wikipedia, the free encyclopedia

Rabbit haemorrhagic disease (**RHD**), also known as **rabbit calicivirus disease** (**RCD**) or **viral haemorrhagic disease** (**VHD**), is a highly infectious and often fatal disease that affects wild and domestic rabbits of the species *Oryctolagus cuniculus*. The infectious agent responsible for the disease is **rabbit haemorrhagic disease virus** (**RHDV**), or **rabbit calicivirus** (**RCV**), genus *Lagovirus* of the family Caliciviridae. The virus infects only rabbits, and has been used in some countries to control rabbit populations.

Rabbit hemorrhagic disease virus

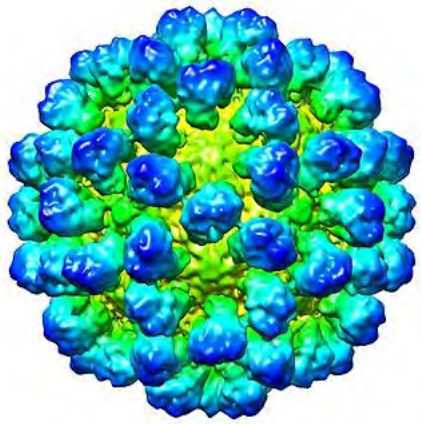

CryoEM reconstruction of Rabbit Hemorrhagic Disease Virus (RHDV) capsid. EMDB entry EMD-1933 (http://www.pdbe.org/EMD-1933)[1]

Virus classification

Group:	Group IV ((+)ssRNA)
Order:	Unassigned
Family:	*Caliciviridae*
Genus:	*Lagovirus*
Species:	***Rabbit hemorrhagic disease virus***

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History

RHD first appeared in the Winter of 1983 in Jiangsu Province of the People's Republic of China. It was first isolated and characterized by S.J. Liu *et al*. in 1984.[2] The Chinese outbreak was spread by the angora rabbit, which had originated in Europe. Fourteen million domesticated rabbits died within nine months in the outbreak.[3]

In 1984 the virus that caused the disease was identified. The virus spread westward and reached Europe in 1988. The virus has since appeared in Mexico, Cuba, Australia, New Zealand and the United States.[2] In 1992, the United Kingdom reported its first case of RHD in domestic show rabbits. By the late 1990s, RHD stretched to forty countries and had become endemic in wild and feral rabbit populations in Europe, Australia, New Zealand and Cuba.[3] In Europe, there was a rapid increase in research into RHD, due to the importance of the

commercial breeding of rabbits for meat and fur production.

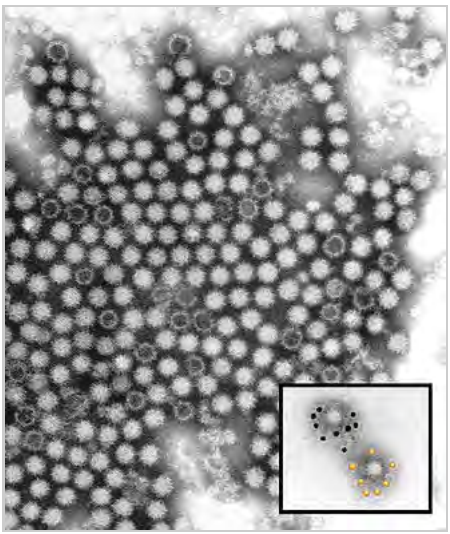

Rabbit Calicivirus CSIRO

The first reported case in the United States was in Iowa on March 9, 2000. The affected breeds included Palominos and California Whites. By April 6, 25 of the 27 affected rabbits had died of the infection. In order to contain the disease, the remaining two rabbits were euthanized. No new introductions of rabbits were placed on the farm for two years after the discovery of RHD and August 1999 was the last time rabbits left and/or returned to the farm. The United States experienced other outbreaks of RHD in 2001 (Utah, Illinois, New York) and 2005 (Indiana).[3]

In 2010, a new virus variant called rabbit hemorrhagic disease virus 2 (RHDV2) emerged in France.[4]

World geographic distribution

Asia

Within a few months of RHD being reported in China in 1984, the disease was widely seen in many commercial rabbitries and had reached the Republic of Korea. RHD has also been reported in India and the Middle East.

Americas (North and South)

Since 1993, RHD has been endemic in Cuba; it is also believed to be thriving in Bolivia. From 1988 to 1992 Mexico dealt with an RHD endemic in domestic rabbits.[3]

After outbreaks of RHD in 2000, 2001, and 2005 in domesticated rabbits, the United States has eradicated RHD from its rabbit populations. The native species, cottontails *(Sylvilagus floridanus)*, black-tailed jackrabbits *(Lepus californicus)* and volcano rabbits *(Romerolagus diazzi)* seem not to be susceptible to the virus.[3]

Australia

In 1991 a strain of the virus, Czech CAPM 351RHDV, was imported to Australia[5] under strict quarantine conditions to research the safety and usefulness of the virus if it was used as a biological control agent against Australia and New Zealand's rabbit pest problem. Testing of the virus was undertaken on Wardang Island in Spencer Gulf off the coast of the Yorke Peninsula, South Australia. In 1995 the virus escaped quarantine and subsequently killed 10 million rabbits within 8 weeks of its release.[6]

New Zealand

In July 1997, after considering over 800 public submissions, the New Zealand Ministry of Health decided not to allow RHDV to be imported into New Zealand to control rabbit populations. This was backed up in an early August review of the decision by the Director-General of Agriculture. However, in late August it was confirmed that RHDV had been deliberately and illegally introduced to the Cromwell area of the South Island.

An unsuccessful attempt was made by New Zealand officials to control the spread of the disease. It was, however, being intentionally spread, and several farmers (notably in the Mackenzie Basin area) admitted to processing rabbits that had died from the disease in kitchen blenders for further spreading.

Had the disease been introduced at a better time, there would have been a more effective control of the population. Unfortunately, it was released after breeding had commenced for the season, and rabbits under 2 weeks old at the time of the introduction were resistant to the disease. These young rabbits were therefore able to survive and breed rabbit numbers back up. Ten years on, rabbit populations (in the Mackenzie Basin in particular) are beginning to reach near pre-plague proportions once again though they have not yet returned to pre RCD levels.[7][8]

Resistance to RHD in New Zealand rabbits has led to the widespread use of Compound 1080 (Sodium fluoroacetate). Farmers and land managers are having to increase their use of 1080 to protect pastoral land from rabbits and preserve the gains made in recent years through the use of RHD.[9]

Europe

RHD is endemic throughout most of Europe. Italy's first case of RHD was recorded in 1986 and Spain's in 1988. France, Belgium (June) and Scandinavia followed in 1990. Within a few years of RHD's first appearance in Europe it had caused the largest mortality in domestic and wild rabbits in Germany, Austria, Spain and Italy. Spain was the worst affected by RHD, which in turn also affected the rabbit-specialized Iberian lynx.[10][11]

When the United Kingdom's first case of RHD in 1992 was discovered, the disease was transmitted into the wild by domesticated pet rabbits. Sources vary in the number of confirmed cases of RHD; there were 9 known outbreaks in 1994, 32 cases but some sources believe there were as many as 512 cases of RHD in 1995, and around 30 RHD cases in 1996 throughout Scotland, England and Wales.

In April 2016, a highly lethal disease started affecting one of the northernmost feral rabbit populations in the world in Helsinki, Finland. The outbreak has since been identified to be caused by the new RHDV2 strain of the virus, being the first appearance of RHD in the country. Cases of viral transmission to domesticated pet rabbits have been confirmed and vaccinating rabbits has been recommended.[12]

Transmission

Transmission of RHD occurs by direct contact with an infected animal and fomites. Rabbits acquire RHD through oral, nasal or conjunctival pathways. Urine, faeces and respiratory secretions may also shed the virus. The virus may also be carried by the wind. Carriers of the virus may remain infectious for up to a month depending on climate conditions; however, the virus has been known to persist for as little as 2 days and as long as 215 days. An infected carcass or hairs from an infected animal may also transmit RHD. Fomites such as clothing, contaminated food, cages, bedding, feeders and water will also harbour the virus. Even though the virus cannot reproduce in other mammals, predators and scavengers such as foxes, ferrets and some birds can excrete the virus through their faeces after ingesting an infected rabbit carcass. Flies, rabbit fleas, and mosquitoes can also spread the virus between rabbits.[3]

Climate appears to play a crucial role in the transmission of RHD. In normal conditions, most outbreaks of RHD occur in winter or spring. High temperatures in late spring and summer will considerably reduce the spread of the virus. RHD will also be more prevalent in dry and semi-dry areas than in areas that are relatively cool and humid.[6]

Signs

RHD primarily infects only adult rabbits. In fact, research has shown that rabbits younger than 8 weeks of age are resistant to the virus. The incubation period for the RHD virus is between 1 and 3 days, with death following 1 to 2 days after the infection. There is a wide range of RHD symptoms. Most rabbits will show no signs of external symptoms of RHD.

Symptomatic cases of RHD will display fever, squeals, and often coma leading to death within 12 to 36 hours. In less severe cases, rabbits may display uneasiness, excitement, anorexia, swollen eyelids, paralysis, ocular haemorrhages, and "paddling" or loss of skin. Convulsions may be seen as well. A fatal bloody discharge from the nose has been exhibited along with blood-stained cage floors, though these symptoms may have occurred after death. Rabbits who have recovered from the less severe symptoms usually develop severe jaundice with weight loss and lethargy. Diarrhoea, constipation and abdominal cramping are then exhibited right before death a few weeks later.

RHD causes rapid development of blood clot formation in major organs such as the heart, lungs and kidneys. The clots block blood vessels causing heart and respiratory failure. An infected rabbit that has died from RHD will often have its legs straight out and head over its neck.[6]

Diagnosis

RHD may be indicated when several animals in the herd die after experiencing a fever and lethargy. Differential diagnosis includes pasteurellosis, myxomatosis, poisoning, heat exhaustion, and *E. coli* or *Clostridium perfringens* type E enterotoxemia.

Rabbits that die from RHD are usually in good outward state. However, the most frequent post-mortem lesions are necrosis of the liver, and splenomegaly. The liver of RHD rabbits may have a fine reticular pattern of necrosis outline each lobule and maybe yellow, gray or pale in colour. The liver is also usually friable and swollen. The spleen will be black in colour and also swollen with rounded edges, while the kidneys are dark brown in colour. Haemorrhages will also be seen many other organs and tissues. The trachea may present a foamy, bloody mucous. Enteritis of the small intestine and swollen meninges may also occur.

Laboratory tests such as reverse transcription polymerase chain reaction (RT-PCR), Western blotting, negative-staining immunoelectron microscopy, and ELISAs may be performed on samples from the liver, blood, spleen or other organs.

Morbidity, mortality, and immunity

RHD is extremely hard to locate in the wild since about 75% of rabbits with RHD will die in their burrows underground. Due to this difficulty, the morbidity and mortality estimates for RHD have a broad range. The morbidity rate ranges from 30% to 100% and the mortality rate from 40% to 100%; however, the typical mortality rate is usually around 90%.[3]

In the wild, outbreaks in rabbits vary depending on the season, breeding cycles and geographical location. Some areas will see a high morbidity and mortality among its rabbit populations followed by calmer periods.

Maternal antibodies such as immunoglobulin G (IgG), which are readily transmitted to the young across the placenta, may explain why very young rabbits are resistant to RHD. Some scientists also believe that the

immature immune system of a young rabbit cannot produce the number of chemicals needed to initiate clotting in order to kill. Rabbits may develop immunity against other strains of the RHD virus, while others may endure persistent infections. The immunity does not survive through the next generation, leaving open the possibility of further outbreaks in the population.[13]

Control

Countries that are uninfected by RHD may place restrictions on importation from endemic countries. According to the Merck/Merial Manual For Pet Health, Home Edition, 2007, RHD is a reportable disease in the United States. If a diagnosis is made by a veterinarian, a notification to the "appropriate government authorities" must be made.[3]

Because of the highly infectious nature of the disease, strict quarantine is necessary when outbreaks occur. Depopulation, disinfection, surveillance and quarantines are the only way to properly and effectively eradicate the disease. Good disinfectants include 10% sodium hydroxide, 1-2% formalin, 2% One-Stroke Environ, and 10% household bleach. The RHD virus is resistant to ethers and chloroform. Deceased rabbits must be removed immediately and discarded in a safe manner. Surviving rabbits are quarantined or humanely euthanized. Test rabbits may be used to monitor the virus on vaccinated farms.[3]

There are several vaccines available against VHD in the UK: Cylap, made by Fort Dodge Animal Health; Lapinject made by CEVA Animal Health; and Anivac, made by Animalcare Ltd. All last for 12 months and contain inactivated strains of VHD. A live combination vaccine, Nobivac Myxo-RHD, made by MSD Animal Health, has recently become available. Its active ingredient is a live myxoma-vectored RHD virus strain 009 and it offers a duration of immunity of 1 year against both RHD and myxomatosis.[14]

Use as biological control agent

The European rabbit is the second most serious pest in New Zealand. Rabbits compete with livestock for grazing pasture, kill trees, shrubs, and have contributed to the extinction of some native plants. Consequently, rabbits contribute to soil erosion by eliminating the protective vegetation and disturb the soil by burrowing. The estimated combined cost of control and production losses in New Zealand as a result of rabbits is about $23 million annually.[15] This figure is only a small portion of the damage caused by rabbits. Parts of Australia have long experienced similar problems.

The use of RHD as a control agent is a recent tactic in a long string of efforts to reduce populations of European rabbits in areas where they are not native. With eventual, proper vaccination plans, the safety of domesticated (livestock and pet) rabbits might not be a concern regarding intentional use of RHD for this purpose.

See also

- Rabbits in Australia

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- NOAH Compendium of Animal Medicines - Cylap (http://www.noahcompendium.co.uk

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External links

- Disease card (http://www.oie.int/fileadmin/Home/eng/Animal_Health_in_the_World/docs/pdf/Disease_cards/RHD.pdf)

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Categories: Animal viral diseases | Rabbit diseases | Hemorrhagic fevers | Animal virology

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Rabbiting

From Wikipedia, the free encyclopedia

Rabbiting (also **rabbit hunting** and **cottontail hunting**) is the sport of hunting rabbits, often using ferrets or dogs to track the prey and various trapping and shooting methods to catch them.[1][2]

Hunting of rabbits involving dogs (usually beagle or basset hounds) is called beagling.

Huckleberry Finn, illustration by E. W. Kemble from the original 1884 edition of the book by Mark Twain

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Hunting

Hunters without hounds have the following options. A hunter, alone or with a partner, walks through the possible locations of rabbit hiding places, kicking or stomping possible covers to chase the rabbit out. In winter an advantage is visible rabbit tracks after fresh snow. Unravelling tracks allows the hunter to locate the hiding place: if no tracks leave out of a suspected location, then the quarry is located. After this, hunters with short range arms (archers or the ones with small calibre) may scrutinize the location to find the rabbit and shoot it immobile. Alternatively, one may just as well scare the animal out and shoot it on the run.[3]

Trapping methods

Typically, long nets are placed around burrows so that a bolting rabbit (that is, one leaving its burrow while being chased by a ferret or other animal) will become ensnared, allowing the hunter to dispatch it. Another method is to use a purse net, which is a net with a draw string at the opening. This net is placed over the burrow, so that when the rabbit bolts, it will run into the net and cause the draw string to pull the net shut.

Rabbits are occasionally killed by a priest, but may also be killed with a sharp blow of the hand to the base of the neck, or by holding the neck between the thumb and first finger and using a whipping motion.

Ferreting

Ferrets tend to be the primary animal used in rabbiting, due to their ease in moving about burrows. A jill (female ferret) is more typically used in a hunt than a hob (male ferret), as the hob is more likely to "lay up" (killing and eating a rabbit in the burrow, resulting in the hob falling asleep) due to it being stronger than the jill. In modern rabbiting, ferrets may wear a locator collar, and the hunter will use a device that emits a faster clicking noise the closer it is to the ferret's collar. When the ferret lays up, the hunter uses the device to locate the ferret, digging down to remove it and the trapped rabbit.

An old rabbit trap

Some hunters now rely on firearms to take the prey, rather than laying down nets. Three or four hunters with shotguns will attempt to shoot the rabbit as it bolts from the burrow while being chased by the ferret. A method used to determine when the rabbit is preparing to bolt is to listen for thudding sounds coming from the burrow.

A silverback ferret being used to hunt

Spotlighting

Spotlighting can refer to any form of rabbit hunting performed at night with the aid of powerful hand-held, rifle mounted or vehicle mounted search lights. The light is often used in conjunction with a dog such as a sighthound, (or lurcher) alongside an air rifle, or some other firearm such as a .22LR.17 HMR The rabbit is illuminated by the light and then shot, or in the case of the dog chased and captured. (See coursing.) Spotlighting is also known as lamping [4]

Using a vehicle is a very popular method of spotlighting (also referred to as Lamping in the United Kingdom) Pick ups and 4x4 are preferred modes of transport. ATVS are also popular vehicles for rabbiting. They provide rapid acceleration making it easy to chase down rabbits.[5]

Long netting

A long net is used (similar to the purse nets used when ferreting) to catch rabbits that have been scared across a field.[6] long netting was the primary method of catching farmed rabbits in England before they become a major pest. This method is still used today when ferret or shooting isn't an effective method due to hedgerows or large warrens.

A rabbit taken from a longnet

Historic rabbiting

In medieval times, a hawk or falcon would have been used to catch the rabbit as it exited the warren burrow. For this type of hunt, an albino ferret would typically be used, allowing the bird-of-prey to more easily recognize it. While this hunting style is still occasionally used, especially in the UK where it remains popular, (see Falconry) the above methods have almost entirely replaced it.

United Kingdom

In the UK the hunting of rabbits rarely involves dogs. The rabbit population is endemic in the UK.

The use of ferrets (domesticated polecats) in rabbit hunting is common.

Women hunting rabbits with a ferret in the Queen Mary Psalter

First the hunter finds the rabbit warren. Once located the hunter lays down catch-nets over all the rabbit holes. The next step is to place one or two ferrets down the rabbit holes without disturbing the catch-net. Now the hunter waits for a rabbit to run out of the warren into a catch-net.

Polecat at the British Wildlife Centre, Newchapel, Surrey

Other methods include shooting with air-rifles, .22 rimfire rifles, or shotguns, the latter two requiring a licence.

United States

In the U.S., many states have hunting seasons for rabbits. In Virginia, the season lasts throughout November, December, and January.[3]

See also

- Hare coursing

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Categories: Hunting by game

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Rabbit

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Rabbits are small mammals in the family Leporidae of the order Lagomorpha, found in several parts of the world. There are eight different genera in the family classified as rabbits, including the European rabbit (*Oryctolagus cuniculus*), cottontail rabbits (genus *Sylvilagus*; 13 species), and the Amami rabbit (*Pentalagus furnessi*, an endangered species on Amami Ōshima, Japan). There are many other species of rabbit, and these, along with pikas and hares, make up the order Lagomorpha. The male is called a *buck* and the female is a *doe*; a young rabbit is a *kitten* or *kit*.

Rabbit

Temporal range: Late Eocene-Holocene, 53–0 Ma

PreЄ Є O S D C P T J K Pg N

Young rabbit in Montana, United States

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Subphylum:	Vertebrata
Class:	Mammalia
Order:	Lagomorpha
Family:	Leporidae in part

Genera

Pentalagus	*Brachylagus*
Bunolagus	*Sylvilagus*
Nesolagus	*Oryctolagus*
Romerolagus	*Poelagus*

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Habitat and range

Rabbit habitats include meadows, woods, forests, grasslands, deserts and wetlands.[1] Rabbits live in groups, and the best known species, the European rabbit, lives in underground burrows, or rabbit holes. A group of

burrows is called a warren.[1]

Outdoor entrance to a rabbit burrow

More than half the world's rabbit population resides in North America.[1] They are also native to southwestern Europe, Southeast Asia, Sumatra, some islands of Japan, and in parts of Africa and South America. They are not naturally found in most of Eurasia, where a number of species of hares are present. Rabbits first entered South America relatively recently, as part of the Great American Interchange. Much of the continent has just one species of rabbit, the tapeti, while most of South America's southern cone is without rabbits.

The European rabbit has been introduced to many places around the world.[2]

Terminology

Male rabbits are called *bucks*; females are called *does*. An older term for an adult rabbit is *coney*, while *rabbit* once referred only to the young animals.[3] Another term for a young rabbit is *bunny*, though this term is often applied informally (especially by children) to rabbits generally, especially domestic ones. More recently, the term *kit* or *kitten* has been used to refer to a young rabbit. A young hare is called a *leveret*; this term is sometimes informally applied to a young rabbit as well.

A group of rabbits is known as a *colony*, or *nest* (and occasionally a *warren*, though this more commonly refers to where the rabbits live).[4] A group of young rabbits with the same parentage is referred to as a *litter*, and a group of domestic rabbits is sometimes called a *herd*.[5]

Biology

Evolution

A skin-skeletal preparation showing its incisors

Because the rabbit's epiglottis is engaged over the soft palate except when swallowing, the rabbit is an obligate nasal breather. Rabbits have two sets of incisor teeth, one behind the other. This way they can be distinguished from rodents, with which they are often confused.[6] Carl Linnaeus originally grouped rabbits and rodents under the class Glires; later, they were separated as the scientific consensus is that many of their similarities were a result of convergent evolution. However, recent DNA analysis and the discovery of a common ancestor has supported the view that they share a common lineage, and thus rabbits and rodents are now often referred to together as members of the superorder Glires.[7]

Morphology

The rabbit's long ears, which can be more than 10 cm (4 in) long, are probably an adaptation for detecting predators. They have large, powerful hind legs. The two front paws have 5 toes, the extra called the dewclaw. The hind feet have 4 toes.[8] They are plantigrade animals while at rest; however, they move around on their

toes while running, assuming a more digitigrade form. Unlike some other paw structures of quadruped mammals, especially those of domesticated pets, rabbit paws lack pads. Their nails are strong and are used for digging; along with their teeth, they are also used for defense.

Video of a European rabbit, showing ears twitching and a jump

Wild rabbits do not differ much in their body proportions or stance, with full, egg-shaped bodies. Their size can range anywhere from 20 cm (8 in) in length and 0.4 kg in weight to 50 cm (20 in) and more than 2 kg. The fur is most commonly long and soft, with colors such as shades of brown, gray, and buff. The tail is a little plume of brownish fur (white on top for cottontails).[2] Rabbits can see nearly 360 degrees, with a small blind spot at the bridge of the nose.[9]

Ecology

Set of wax models showing development of the rabbit heart

Rabbits are hindgut digesters. This means that most of their digestion takes place in their large intestine and cecum. In rabbits, the cecum is about 10 times bigger than the stomach and it along with the large intestine makes up roughly 40% of the rabbit's digestive tract.[10] The unique musculature of the cecum allows the intestinal tract of the rabbit to separate fibrous material from more digestible material; the fibrous material is passed as feces, while the more nutritious material is encased in a mucous lining as a cecotrope. Cecotropes, sometimes called "night feces", are high in minerals, vitamins and proteins that are necessary to the rabbit's health. Rabbits eat these to meet their nutritional requirements; the mucous coating allows the nutrients to pass through the acidic stomach for digestion in the intestines. This process allows rabbits to extract the necessary nutrients from their food.[11]

A litter of rabbit kits (baby rabbits)

A nest containing baby rabbits

Rabbits are prey animals and are therefore constantly aware of their surroundings. For instance, in Mediterranean Europe, rabbits are the main prey of red foxes, badgers, and Iberian lynxes.[12] If confronted by a potential threat, a rabbit may freeze and observe then warn others in the warren with powerful thumps on the ground. Rabbits have a remarkably wide field of vision, and a good deal of it is devoted to overhead scanning.[13] They survive predation by burrowing, hopping away in a zig-zag motion, and, if captured, delivering powerful kicks with their hind legs. Their strong teeth allow them to eat and to bite in order to escape a struggle.[14] The longest-lived rabbit on record, a domesticated European rabbit living in Tasmania, died at age 18.[15] The lifespan of wild rabbits is much shorter; the average longevity of an eastern cottontail, for instance, is less than one year.[16]

Sleep

Rabbits are crepuscular, most active at dawn and dusk. The average sleep time of a rabbit in captivity is said to be 8.4 hours.[17] As with other prey animals, rabbits often sleep with their eyes open so sudden movements will wake the rabbit and alert it to dangers.[18]

Diet and eating habits

A young rabbit looking through the grass.

Rabbits are herbivores that feed by grazing on grass, forbs, and leafy weeds. In consequence, their diet contains large amounts of cellulose, which is hard to digest. Rabbits solve this problem via a form of hindgut fermentation. They pass two distinct types of feces: hard droppings and soft black viscous pellets, the latter of which are known as caecotrophs and are immediately eaten (a behaviour known as *coprophagy*). Rabbits reingest their own droppings (rather than chewing the cud as do cows and numerous other herbivores) to digest their food further and extract sufficient nutrients.[19]

Rabbits graze heavily and rapidly for roughly the first half-hour of a grazing period (usually in the late afternoon), followed by about half an hour of more selective feeding. In this time, the rabbit will also excrete many hard fecal pellets, being waste pellets that will not be reingested. If the environment is relatively non-threatening, the rabbit will remain outdoors for many hours, grazing at intervals. While out of the burrow, the rabbit will occasionally reingest its soft, partially digested pellets; this is rarely observed, since the pellets are reingested as they are produced. Reingestion is most common within the burrow between 8 o'clock in the morning and 5 o'clock in the evening, being carried out intermittently within that period.

Hard pellets are made up of hay-like fragments of plant cuticle and stalk, being the final waste product after redigestion of soft pellets. These are only released outside the burrow and are not reingested. Soft pellets are usually produced several hours after grazing, after the hard pellets have all been excreted. They are made up of micro-organisms and undigested plant cell walls.

The chewed plant material collects in the large cecum, a secondary chamber between the large and small intestine containing large quantities of symbiotic bacteria that help with the digestion of cellulose and also produce certain B vitamins. The pellets are about 56% bacteria by dry weight, largely accounting for the pellets being 24.4% protein on average. The soft feces form here and contain up to five times the vitamins of hard feces. After being excreted, they are eaten whole by the rabbit and redigested in a special part of the stomach. The pellets remain intact for up to six hours in the stomach; the bacteria within continue to digest the plant carbohydrates. This double-digestion process enables rabbits to use nutrients that they may have missed during the first passage through the gut, as well as the nutrients formed by the microbial activity and thus ensures that maximum nutrition is derived from the food they eat.[2] This process serves the same purpose within the rabbit as rumination does in cattle and sheep.[20]

Rabbits are incapable of vomiting.[21]

Rabbit diseases

Rabbits can be affected by a number of diseases. These include pathogens that also affect other animals and/or humans, such as *Bordetella bronchiseptica* and *Escherichia coli*, as well as diseases unique to rabbits such as rabbit haemorrhagic disease: a form of calicivirus,[22] and myxomatosis.

Rabbits and hares are almost never found to be infected with rabies and have not been known to transmit rabies to humans.[23]

Among the parasites that infect rabbits are tapeworms such as *Taenia serialis*, external parasites like fleas and mites, coccidia species, and *Toxoplasma gondii*.[24][25]

Differences from hares

The most obvious difference between rabbits and hares is how their kits are born. Rabbits are altricial, having young that are born blind and hairless. In contrast, hares are precocial, born with hair and good vision. All rabbits except cottontail rabbits live underground in burrows or warrens, while hares live in simple nests above the ground (as do cottontail rabbits), and usually do not live in groups. Hares are generally larger than rabbits, with longer ears, larger and longer hind legs and have black markings on their fur. Hares have not been domesticated, while European rabbits are both raised for meat and kept as pets.

Domesticated rabbits

The only rabbit to be widely domesticated is the European rabbit, which has been extensively bred for food and later as a pet. It was first widely kept in ancient Rome and has been refined into a wide variety of breeds during and since the Middle Ages.

Vase with rabbit below, made 1777 in Sweden.

Domesticated rabbits have mostly been bred to be much larger than wild rabbits, though selective breeding has produced a range of sizes from dwarf to giant, which are kept as pets and food animals across the world. They have as much colour variation among themselves as other livestock and pet animals. Their fur is prized for its softness; today, Angora rabbits are raised for their long, soft fur, which is often spun into yarn. Other breeds are raised for the fur industry, particularly the Rex, which has a smooth, velvet-like coat and comes in a wide variety of colors and sizes.

As food and clothing

Leporids such as European rabbits and hares are a food meat in Europe, China, South America, North America, some parts of the Middle East. By some estimates, world's annual rabbit meat production stands at around 200 million tons.[26]

Rabbit is sold in UK butchers and markets, and some supermarkets sell frozen rabbit meat. Additionally, some have begun selling fresh rabbit meat alongside other types of game. At farmers markets and the famous Borough Market in London, rabbits will be displayed dead and hanging unbutchered in the traditional style next to braces of pheasant and other small game. The countries where rabbit meat consumption is highest are Malta (8.89 kg per inhabitant), Italy (5.71 kg per inhabitant), Cyprus (4.37 kg per inhabitant), France (2.76 kg per inhabitant), Belgium (2.73 kg per inhabitant), Spain (2.61 kg per inhabitant) and Portugal (1.94 kg per inhabitant).[27]

Rabbit meat was once commonly sold in Sydney, Australia, the sellers of which giving the name to the rugby league team the South Sydney Rabbitohs, but it quickly became unpopular after the disease myxomatosis was introduced in an attempt to wipe out the country's large feral rabbit population. Rabbit meat is also commonly used in Moroccan cuisine, where it is cooked in a tajine with "raisins and grilled almonds added a few minutes

before serving".[28]

Rabbits - Kitchen, Hôtel Dieu, Beaune

In China, rabbit meat is particularly popular in Sichuan cuisine. Among popular dishes are stewed rabbit, spicy diced rabbit, BBQ-style rabbit, and even spicy rabbit heads, which have been compared to the duck neck.[26] Rabbit meat is comparably unpopular elsewhere in the Asia-Pacific.

When used for food, rabbits are both hunted and bred for meat. Snares or guns are usually employed when catching wild rabbits for food. In many regions, rabbits are also bred for meat, a practice called cuniculture. Rabbits can then be killed by hitting the back of their heads, a practice from which the term *rabbit punch* is derived. Rabbit meat is a source of high quality protein.[29] It can be used in most ways chicken meat is used. In fact, well-known chef Mark Bittman says that domesticated rabbit tastes like chicken because both are blank palettes upon which any desired flavors can be layered.[30] Rabbit meat is leaner than beef, pork, and chicken meat. Rabbit products are generally labeled in three ways, the first being Fryer. This is a young rabbit between 2.0 and 2.3 kilograms (4.5 and 5 lb) and up to 9 weeks in age.[31] This type of meat is tender and fine grained. The next product is a Roaster; they are usually over 2.3 kilograms (5 lb) and up to 8 months in age. The flesh is firm and coarse grained and less tender than a fryer. Then there are giblets which include the liver and heart. One of the most common types of rabbit to be bred for meat is New Zealand white rabbit. The largest rabbit meat producing countries (100,000 tons or more per year) are China, Russia, Italy, France and Spain.[27]

Tanned rabbit pelt; rabbit pelt is prized for its softness.

In efficient production systems, rabbits can turn 20 percent of the proteins they eat into edible meat, compared to 22 to 23 percent for broiler chickens, 16 to 18 percent for pigs and 8 to 12 percent for beef; rabbit meat is more economical in terms of feed energy than beef.[27]

An Australian 'Rabbiter' circa 1900

Compared with the meat of other species (especially pork and beef), rabbit meat is richer in proteins and certain vitamins and minerals, while it has less fat; rabbit fat contains less stearic and oleic acids than other species and higher proportions of the essential polyunsaturated linolenic and linoleic fatty acids.[27] The main health issues associated with the use of rabbits for meat are tularemia or rabbit fever which is an infection that may be contracted from close contact with rabbits[32] and the so-called rabbit starvation. Rabbit starvation is most likely due to the deficiency of fat in rabbit meat. In comparison, pemmican is a meat-based food that is nutritionally complete but is composed of dry meat fibers and fat in a 1:1 ratio by weight. Rabbit starvation is similar to other metabolic issues that arise in times of extreme starvation. An analogous condition (though with different symptoms) occurs when carbohydrates are ingested in the absence of fat and protein.[33] These conditions are not well-documented by Western medicine because such total absence of fat and protein are relatively rare and not likely to occur where medical attention is available. However, a slim variety of historical writings refer to rabbit starvation, for example, Vilhjamur Stefansson in the late 19th century, and in the

journals of Charles Darwin.

Rabbit pelts are sometimes used for clothing and accessories, such as scarves or hats. Angora rabbits are bred for their long, fine hair, which can be sheared and harvested like sheep wool. Rabbits are very good producers of manure; additionally, their urine, being high in nitrogen, makes lemon trees very productive. Their milk may also be of great medicinal or nutritional benefit due to its high protein content.[34]

An old wooden cart, piled with rabbit skins, in New South Wales, Australia

Environmental problems

Rabbits have been a source of environmental problems when introduced into the wild by humans. As a result of their appetites, and the rate at which they breed, feral rabbit depredation can be problematic for agriculture. Gassing, barriers (fences), shooting, snaring, and ferreting have been used to control rabbit populations, but the most effective measures are diseases such as myxomatosis (myxo or mixi, colloquially) and calicivirus. In Europe, where rabbits are farmed on a large scale, they are protected against myxomatosis and calicivirus with a genetically modified virus. The virus was developed in Spain, and is beneficial to rabbit farmers. If it were to make its way into wild populations in areas such as Australia, it could create a population boom, as those diseases are the most serious threats to rabbit survival. Rabbits in Australia and New Zealand are considered to be such a pest that land owners are legally obliged to control them.[35][36]

In culture and literature

Rabbits are often used as a symbol of fertility or rebirth, and have long been associated with spring and Easter as the Easter Bunny. The species' role as a prey animal also lends itself as a symbol of innocence, another Easter connotation. They appear in folklore and modern children's stories, often but not invariably as sympathetic characters.

Additionally, rabbits are often used as symbols of playful sexuality, which also relates to the human perception of innocence, as well as its reputation as a prolific breeder.

Domestic rabbits can overpopulate rapidly, becoming a nuisance, as on this university campus.

Folklore and mythology

The rabbit often appears in folklore as the trickster archetype, as he uses his cunning to outwit his enemies.

- In Aztec mythology, a pantheon of four hundred rabbit gods known as Centzon Totochtin, led by Ometotchtli or Two Rabbit, represented fertility, parties, and drunkenness.
- In Central Africa, the common hare (*Kalulu*), is "inevitably described" as a trickster figure.[37]
- In Chinese folklore, rabbits accompany Chang'e on the Moon. Also associated with the Chinese New Year (or Lunar New Year), rabbits are also one of the twelve celestial animals in the Chinese Zodiac for the Chinese calendar. It is interesting to note that the Vietnamese lunar new year replaced the rabbit with a cat in their

European rabbit in Shropshire, England, infected with myxomatosis, a disease caused by the Myxoma virus

calendar, as rabbits did not inhabit Vietnam.
- A rabbit's foot is carried as an amulet believed to bring good luck. This is found in many parts of the world, and with the earliest use being in Europe around 600 B.C.[38]
- In Japanese tradition, rabbits live on the Moon where they make mochi, the popular snack of mashed sticky rice. This comes from interpreting the pattern of dark patches on the moon as a rabbit standing on tiptoes on the left pounding on an usu, a Japanese mortar (See also: Moon rabbit).
- In Jewish folklore, rabbits (shfanim שפנים) are associated with cowardice, a usage still current in contemporary Israeli spoken Hebrew (similar to English colloquial use of "chicken" to denote cowardice).

- In Korean mythology, as in Japanese, rabbits live on the moon making rice cakes (Tteok in Korean).
- In Anishinaabe traditional beliefs, held by the Ojibwe and some other Native American peoples, Nanabozho, or Great Rabbit, is an important deity related to the creation of the world.
- Among English speakers, the rabbit may be invoked at the start of the month out of apotropaic or talismanic superstition.
- A Vietnamese mythological story portrays the rabbit of innocence and youthfulness. The Gods of the myth are shown to be hunting and killing rabbits to show off their power.

Tile with two rabbits, two snakes and a tortoise. Illustration for Zakariya al-Qazwini's book. Iran, 19th century.

On the Isle of Portland in Dorset, UK, the rabbit is said to be unlucky and speaking its name can cause upset with older residents. This is thought to date back to early times in the quarrying industry, where piles of extracted stone (not fit for sale) were built into tall rough walls (to save space) directly behind the working quarry face; the rabbit's natural tendency to burrow would weaken these "walls" and cause collapse, often resulting in injuries or even death. The name rabbit is often substituted with words such as “long ears” or “underground mutton”, so as not to have to say the actual word and bring bad luck to oneself. It is said that a public house (on the island) can be cleared of people by calling out the word rabbit and while this was very true in the past, it has gradually become more fable than fact over the past 50 years. See also Three hares.

Other fictional rabbits

The rabbit as trickster appears in American popular culture; for example the Br'er Rabbit character from African-American folktales and Disney animation; and the Warner Bros. cartoon character Bugs Bunny.

Anthropomorphized rabbits have appeared in a host of works of film, literature, and technology, notably the White Rabbit and the March Hare in Lewis Carroll's *Alice's Adventures in Wonderland*; in the popular novels *Watership Down*, by Richard Adams, along with its film and television adaptations, *Rabbit Hill* by Robert Lawson, as well as in Beatrix Potter's Peter Rabbit stories, and Oswald the Lucky Rabbit, a 1920s cartoon character.

Urban legends

It was commonly believed that pregnancy tests were based on the idea that a rabbit would die if injected with a pregnant woman's urine. This is not true. However, in the 1920s it was discovered that if the urine contained the hCG, a hormone found in the bodies of pregnant women, the rabbit would display ovarian changes. The

rabbit would then be killed to have its ovaries inspected, but the death of the rabbit was not the indicator of the results. Later revisions of the test allowed technicians to inspect the ovaries without killing the animal. A similar test involved injecting Xenopus frogs to make them lay eggs, but animal tests for pregnancy have been made obsolete by faster, cheaper, and simpler modern methods.

Classifications

A black rabbit

Eastern cottontail (*Sylvilagus floridanus*)

Wikimedia Commons has media related to ***Rabbit breeds***.

Rabbits and hares were formerly classified in the order Rodentia (rodent) until 1912, when they were moved into a new order Lagomorpha. This order also includes pikas.

Order **Lagomorpha**

- Family **Leporidae**
  - Genus *Pentalagus*
    - Amami rabbit/Ryūkyū rabbit, *Pentalagus furnessi*
  - Genus *Bunolagus*
    - Bushman rabbit, *Bunolagus monticularis*
  - Genus *Nesolagus*
    - Sumatran striped rabbit, *Nesolagus netscheri*
    - Annamite striped rabbit, *Nesolagus timminsi*
  - Genus *Romerolagus*
    - Volcano rabbit, *Romerolagus diazi*
  - Genus *Brachylagus*
    - Pygmy rabbit, *Brachylagus idahoensis*
  - Genus *Sylvilagus*
    - Forest rabbit, *Sylvilagus brasiliensis*
    - Dice's cottontail, *Sylvilagus dicei*
    - Brush rabbit, *Sylvilagus bachmani*
    - San Jose brush rabbit, *Sylvilagus mansuetus*
    - Swamp rabbit, *Sylvilagus aquaticus*
    - Marsh rabbit, *Sylvilagus palustris*
    - Eastern cottontail, *Sylvilagus floridanus*
    - New England cottontail, *Sylvilagus transitionalis*
    - Mountain cottontail, *Sylvilagus nuttallii*
    - Desert cottontail, *Sylvilagus audubonii*
    - Omilteme cottontail, *Sylvilagus insonus*
    - Mexican cottontail, *Sylvilagus cunicularis*
    - Tres Marias rabbit, *Sylvilagus graysoni*
  - Genus *Oryctolagus*
    - European rabbit, *Oryctolagus cuniculus*
  - Genus *Poelagus*
    - Central African Rabbit, *Poelagus marjorita*
  - Three other genera in family, regarded as hares, not rabbits

See also

- Animal track
- Dwarf rabbit
- Hare games
- Jackalope
- List of animal names
- Rabbits in the arts
- Rabbit show jumping

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- Windling, Terri. *The Symbolism of Rabbits and Hares* (http://www.endicott-studio.com/rdrm/rrRabbits.html)

External links

- American Rabbit Breeders Association (http://www.arba.net/) organization which promotes all phases of rabbit keeping
- House Rabbit Society (http://www.rabbit.org/) an activist organization which promotes keeping rabbits indoors.
- RabbitShows.com (http://www.rabbitshows.com/) an informational site on the hobby of showing rabbits.
- The (mostly) silent language of rabbits (http://www.muridae.com/rabbits/rabbittalk.html)
- World Rabbit Science Association (http://world-rabbit-science.com/) an international rabbit-health science-based organization
- The Year of the Rabbit (http://www.life.com/image/first/in-gallery/55521/the-year-of-the-rabbit#index/0) – slideshow by *Life magazine*
- House Rabbit Society- FAQ: Aggression (http://www.rabbit.org/faq/sections/aggression.html#basics)

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Categories: Rabbits and hares | Herbivorous animals | Mythological rabbits and hares | Extant Ypresian first appearances

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Rabbit with vegetables

1,2 kg rabbit, cut in pieces

flour, salt, pepper

1/3 cup cooking oil

2 cups hot water

1 teaspoon salt

1/4 cup flour or maizena

4 cups raw vegetables such as peas, carrots, onion, cabbage, celery, cauliflower, mealies

Method

1. Mix flour, salt and pepper and roll rabbit pieces in it.
2. Heat oil in large pan or pot and brown rabbit pieces on all sides, turning often.
3. Add water and put the lid on.
4. Cook slowly on low heat for about 1 hour, or until meat is almost soft. Add more water if necessary.
5. Add vegetables and salt and cook for 25 minutes or until vegetables are done.
5. Mix the 1/4 cup flour or maizena with a little cold water.
6. Add slowly to the meat and cook until thick.

Serve with rice or potatoes.

Curried rabbit

(Four servings of 1 cup each)

2 cups cooked rabbit meat, cut in pieces

2 cups meat extract (or vegetable extract)

1 tablespoon curry powder

1/4 cup finely chopped onion

1/3 cup flour

1/4 cup milk

salt and pepper

Method

1. Bring extract to boil, add curry and onion and cook until soft.
2. Stir flour into milk, add a few tablespoons of hot liquid and mix.
3. Stir the flour mixture into the rest of the hot liquid and cook over low heat until thick and smooth.
4. Add rabbit meat, salt and pepper and heat well.

Serve with rice.

Rabbit-skin glue

From Wikipedia, the free encyclopedia

Rabbit-skin glue is a sizing that also acts as an adhesive. It is essentially refined rabbit collagen, and was originally used as an ingredient in traditional gesso.

Rabbit-skin glue, pellets (left) and partially dissolved in water (right)

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- 2 Production
- 3 Uses
  - 3.1 Adhesive
  - 3.2 Sizing
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History

In traditional oil painting as practiced by the Renaissance painter, skin glue was used to coat the canvas. This is necessary because the linseed oil that forms the base of most oil paint contains linolenic acid that will destroy the canvas fibers over time. Though this did help to seal the canvas, they still had to cover it with another layer of a substance similar to paint in order to protect it. The primary purpose of Rabbit-skin glue is to stretch the canvas.

Production

Rabbit skin glue is an animal glue created by prolonged boiling of animal connective tissue. Rabbit skin glue can be bought in powder form or in larger chunks. Preparation involves using the correct proportion of water to glue to achieve the correct consistency and strength. It should be heated to just short of the boiling point. Too much heat results in a product with reduced adhesive qualities. Manufacturers of rabbit, and cow & horse hide glue recommend dissolving at 60–63 °C (140–145 °F).

Uses

Adhesive

As an adhesive, Rabbit-skin glue is used in the production of the bellows of concertinas, and in other smaller, light instruments—prominently in violins. Its supreme advantages are very fast bonding; and easy debonding with hot water if an instrument must be disassembled for internal repairs. It also has very low creep, which is the tendency of some glues to plastically yield under even low but consistent stresses over time. For example, guitar bridges are subject to high lateral stresses that with the wrong glue can lead it to creep forward.

The proteins of the glue soak into the wood and interlace with its pores. Setting of the glue occurs with cooling and drying, so the working time is very short, on the order of minutes, to stick the parts together and get full strength, unlike PVA glue which might provide 20–30 minutes. Furthermore, since the glue only works by microscopically stitching the wood fibers together, any gaps in the joint are not going to be successfully filled, and so the mating surface must be very smooth.

Sizing

When used in painting as a sizing, it is spread thoroughly over a canvas that has been placed on the stretcher. When the glue dries, it tightens the canvas. After this has been allowed to dry, an oil-based primer is then applied. A canvas sized with rabbit-skin glue can be made tighter than with other alternatives—such as an acrylic-based gesso—because of the shrinkage. This type of canvas is also valuable because it can be sanded to a flatter texture, which allows the painter to achieve a finer level of detail than can be achieved with a typical acrylic gesso ground.

This rabbit-skin glue ground is only appropriate for use under oil paint. Acrylic-based media will flake off a canvas prepared with rabbit-skin glue and are therefore not appropriate.[1]

Rabbit skin glue is considered to be a major cause of cracking in oil paintings by most modern conservators. Because the glue is hygroscopic, it continually absorbs moisture from the atmosphere, causing the glue to swell and shrink as ambient humidity levels change. Over many humidity cycles, this repeated flexing causes the brittle oil paint to crack. Modern substitutes for rabbit skin glue are available, such as Gamblin's PVA size [2] and Golden Acrylics' GAC100. These substitutes do not have the hygroscopic properties of rabbit skin glue, while still being very slightly hygroscopic, and should not cause the damage to oil paints that rabbit skin glue does. However, these modern replacements do not stiffen and tighten the canvas as well as rabbit skin glue does, so some artists still prefer to use rabbit skin glue.

See also

- Sizing

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Categories: Painting materials | Adhesives | Gilding

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RABIES

GUIDE FOR THE MEDICAL, VETERINARY AND ALLIED PROFESSIONS

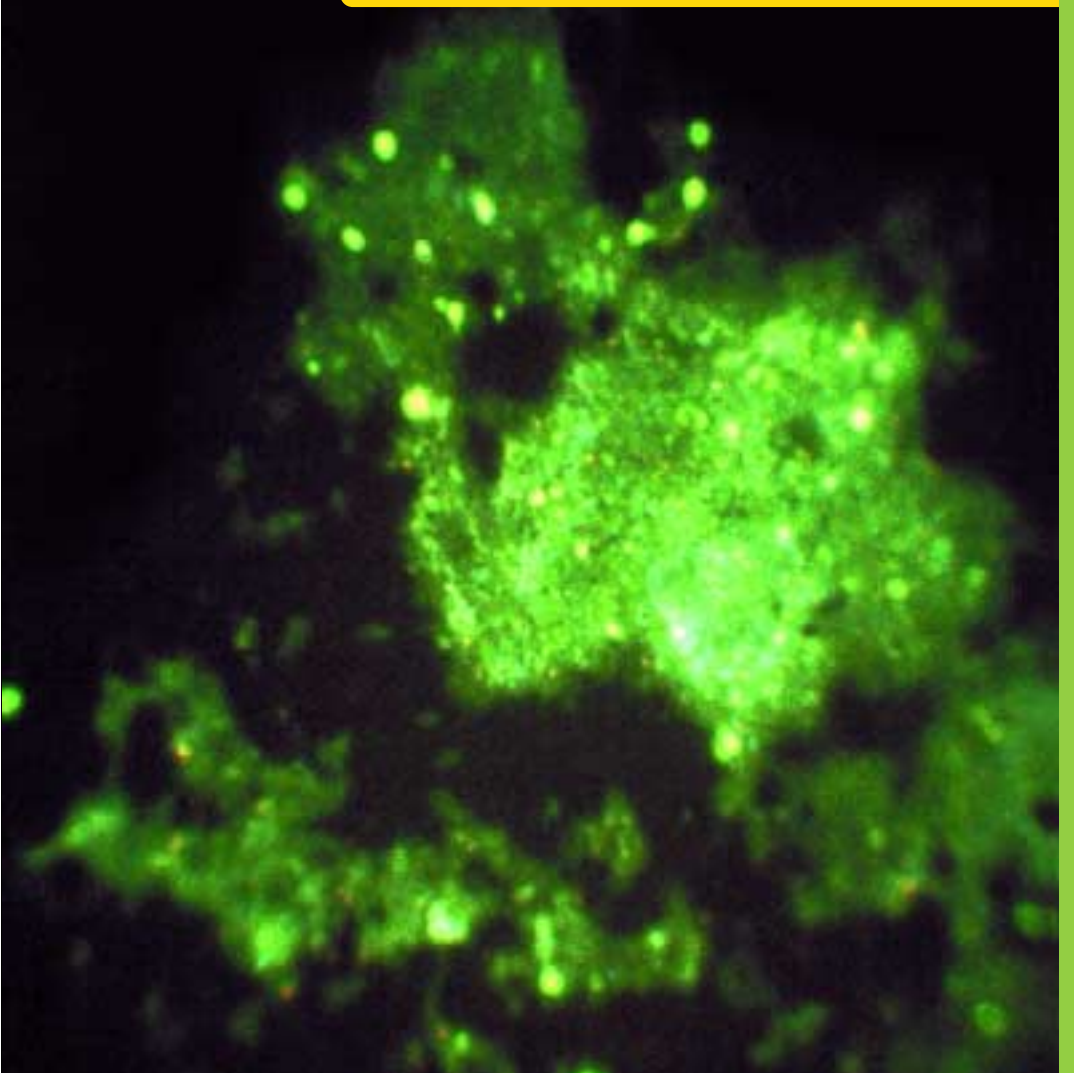

G.C. Bishop
D.N. Durrheim
P.E. Kloeck
J.D. Godlonton
J. Bingham
R. Speare
Rabies Advisory Group

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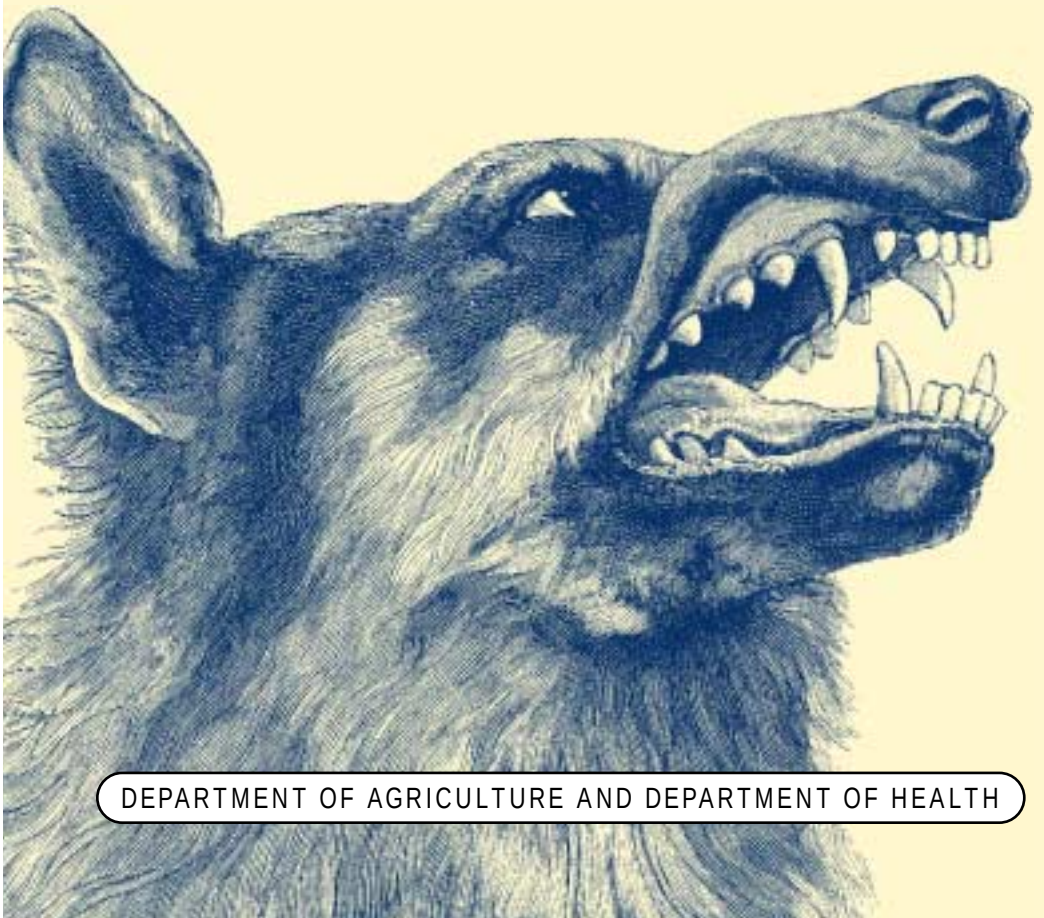

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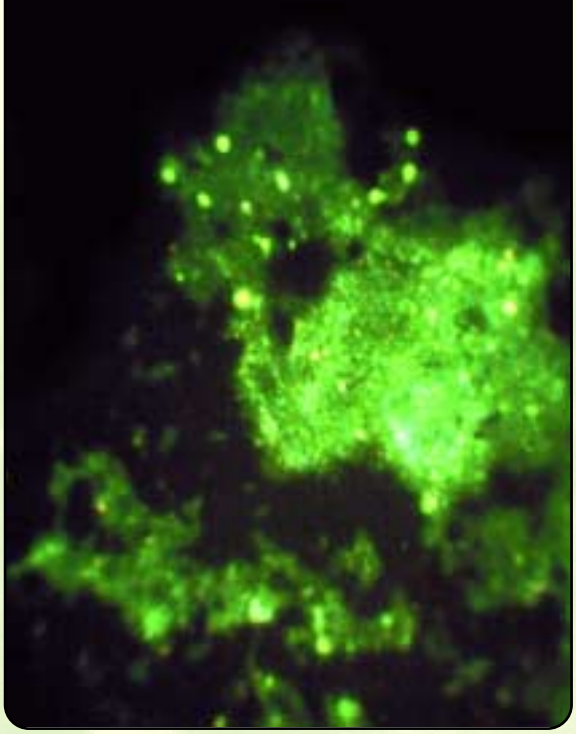

Cover photo: Brain material, stained with antirabies fluorescein conjugate, containing large numbers of oval-shaped, apple-green Negri bodies

RABIES

GUIDE FOR THE MEDICAL, VETERINARY AND ALLIED PROFESSIONS

Compiled by:
G.C. Bishop, D.N. Durrheim, P.E. Kloeck,
J.D. Godlonton, J. Bingham, R. Speare
and the Rabies Advisory Group

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TRIBUTE TO GEORGE BISHOP

This publication is dedicated to the memory of our gifted and unique fellow-author, colleague and friend

He passed away tragically and unexpectedly on 25 August 2001, on the eve of this project's completion. His fellow-authors unanimously agreed to add the finishing touches to this living tribute to George's selfless dedication to rabies control and his burning passion to prevent human suffering in marginalised communities that bear the brunt of this terrible disease.

This was a poignant exercise. Careful review of structure, sentences and even individual words provided vivid recollections of George's expansive sense of humour, attention to detail and tenacious pursuit of accuracy. Although this endeavour was shrouded by the painful realisation that despite our most valiant efforts, we could never hope to emulate George's writing and editing skills, we were, however, encouraged in this venture by an acute knowledge that he would have wished it completed even if only a single rabies death could thereby be averted.

The veterinary and public health fraternities have lost a highly respected and a beloved friend. He was the unlauded hero of rabies control in Africa and certainly did not receive the due credit during his lifetime.

All who knew George are profoundly grateful for having had this privilege. His family's deep sense of loss is shared by all his colleagues and friends, in particular the Rabies Advisory Group.

FOREWORD

Rabies is a disease of animals but too often the outcome is gauged in terms of human suffering and death. Despite this, in areas of the world where rabies is endemic there is often a lack of communication between veterinary and medical professionals, to the extent that the disease continues to thrive and potential victims are not treated. The problem is partly exacerbated by a lack of awareness and experience of the disease and of what to do when confronted by suspect cases. In these technologically advanced days, although it is possible to learn "all there is to know" about almost any subject, it is sometimes difficult to distil the essence.

In most parts of the world, rabies is endemic in either dogs (canine rabies) or in wildlife species (sylvatic rabies). South Africa is one of only a few countries where both forms of the disease occur. Indeed, not only does South Africa have to contend with canine and therefore human rabies, but the sylvatic form of the disease is present in canids, such as jackals and bat-eared foxes, and in viverrids, such as mongooses and in bats.

For many years the South African Rabies Advisory Group (RAG) has worked assiduously to raise awareness of rabies to government agencies, local medical and veterinary professionals as well as to the public. Much has been published, videos have been prepared, surveillance and diagnostic systems have been put in place, treatment centres established and vaccine made available.

This publication on rabies has been prepared for distribution to the medical, veterinary and allied professions. It is written, not only from the vast volume of rabies literature available, but drawn from the experience of those who have been involved in the fight against rabies in South Africa over many years. The scientific information has been thoroughly researched and critical points are emphasised on each page.

In the chapter 'Rabies in animals', attention is drawn to the importance of accurate identification of suspect species, because the species involved in a rabies incident may have a bearing on decisions concerning the treatment of potential victims and/or control policies. The publication contains clear pictures of the terrestrial mammal species which have been found rabies positive in South Africa. Also in this part are sections on diagnosis, prevention and the procedures to be followed when rabies is suspected.

Human rabies is dealt with in depth. Again, prevention and procedures to be followed are highlighted and there is an especially relevant section on management of humans exposed to rabies, a terrain that is not always covered in textbooks on rabies. Of special relevance to South Africa are the sections on rabies legislation and control strategies.

Above all else, this is an instructive manual, with a welcome absence of any attempt to 'blind with science'. No one should be put off by the word 'Professions' in the title, it is eminently readable by the interested layman. It is relevant to and deserves a wider audience than South Africa alone, because the information is applicable to many southern and eastern African countries. It successfully bridges the gap between the mysticism and ignorance that surrounds rabies and the hard fact that it is one of the most deadly diseases known to man.

Arthur King – Formerly Rabies Research Leader
Weybridge, United Kingdom

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REVIEWERS AND CONTRIBUTORS

Dr Arthur King
Dr Charles Rupprecht
Prof. Bob Swanepoel
Prof. John Skinner
Dr Hans van de Pypekamp
Prof. Werner Coetzer
Dr Courtney Meredith
Dr Raj Maharaj
Dr Neil Cameron
Dr Gideon Brückner
Dr Brian Weaver

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Ms Vigie Govender
Mrs Tokkie Tischendorf
Mrs Saras Naidoo
Mr Ron Bennett

Acknowledgement is especially due to the parents who granted permission for publication of the photographs of their children appearing in this publication. Their contribution towards the fight against rabies is sincerely appreciated.

RABIES ADVISORY GROUP

Dr G. Akol
Dr J. Bingham
Mr G.C. Bishop
Prof. D.N. Durrheim
Dr J.D. Godlonton
Dr P.E. Kloeck (Chairperson)
Dr A. Liebenberg
Dr M. Swart
Dr E. van Vollenhoven

PHOTOGRAPHS AND ILLUSTRATIONS

Dr G. Mills, plates 1, 2
Prof. J. Skinner, plates 5, 6
Aventis Pasteur, plate 7
Dr M. Swart, plates 8, 17, 24, 25
Dr P.E. Kloeck, plates 10–12, 36–39
Dr G. Brückner, plates 13,15
Dr H. van de Pypekamp, plate 14
Dr A. Liebenberg, plates 18–20, 22–23, 26–28
Mr G. Bishop, plates 29, 33
Mr J. de Lange, plates 30–32
Dr J. Bingham, plate 35
Dr R. Carter, plate 40

Any omission in acknowledgement is regretted. This manual is made available for the express purpose of medical, veterinary and nursing training and education.

INTRODUCTION

Rabies, a fatal disease of humans and all other mammals, is caused by a virus which has been associated with animal bites for more than 3 000 years and it is the oldest infectious disease known to medical science.[1] Dogs have long been recognised as the main transmitters of the disease to people.[2,3] When compared with other formidable human diseases such as bubonic plague and smallpox, and animal diseases such as rinderpest and anthrax, rabies has probably never caused comparably high numbers of deaths in humans and animals. However, the horrendous manner in which rabies manifests itself in its victims continues to attract the attention of scientists, health and veterinary workers. The true scale of rabies in South Africa remains clouded by the many thousands of people protected by post-exposure treatment each year after rabies exposure and the undiagnosed human and animal rabies cases not reflected in official statistics.

Animal rabies is endemic throughout South Africa and the disease is currently responsible for the laboratory confirmed deaths of between 10 and 30 people each year. Tragically, with very few exceptions, those who succumbed to the disease over the past decade did not receive the correct post-exposure treatment and died following bites by rabid dogs.

There have been several new and exciting developments in our knowledge of the disease and in measures used to control rabies in South African animals. The use of monoclonal antibody typing, together with gene sequencing technology, have revealed several different strains of the rabies virus, some of which appear to show clear host preferences. The entire country was declared rabies-endemic during 1999 and it is now compulsory for all dogs and cats to be vaccinated at least once every three years.

Since 1994, the national Rabies Advisory Group (RAG) has reviewed advances in rabies management and control, and made recommendations on control policy. The RAG's suggestions were ratified by the Interprovincial Veterinary Working Group (national and provincial veterinary directors) and the Department of Health. This publication represents the RAG's effort to enhance awareness of rabies, and improve pre and post-exposure measures in the human and animal populations of the country.

Tragically, most people who died of rabies in South Africa over the past few decades, did not receive the correct post-exposure rabies treatment following bites by rabid dogs

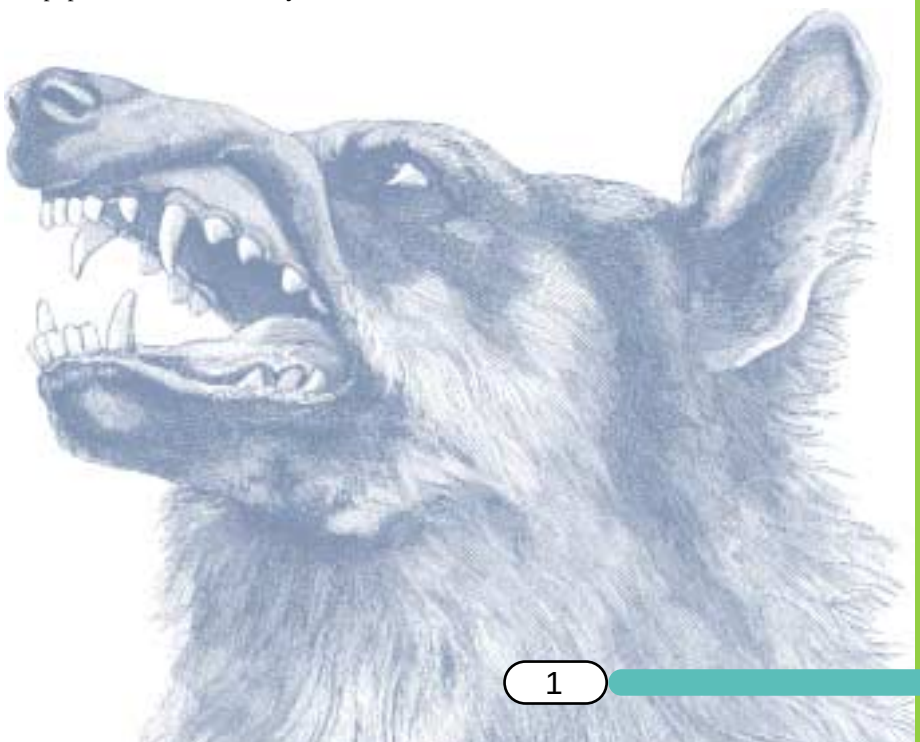

RABIES IN SOUTH AFRICA

HISTORICAL ASPECTS

Rabies may have existed as a disease entity in South Africa for more than a century. There is anecdotal evidence of human disease, as a result of wild animal exposure, in the mid-19th and early 20th centuries.[4] The disease was first confirmed in dogs, by rabbit inoculation, in 1893 but this relatively small outbreak was thought to have followed the importation of an infected owned dog from England during the previous year. The outbreak was rapidly controlled by muzzling dogs, introducing movement control and destroying strays. The disease did not apparently spill over into wild animals. Endemic rabies was first confirmed in 1928 following the deaths of two children who had been bitten by a yellow mongoose in the Wolmaransstad district of the North West Province.[5] The existence of four serotypes, or genotypes, of rabies virus in Africa is considered by some to be strong circumstantial evidence that the continent was the cradle of Lyssavirus evolution.[6,7]

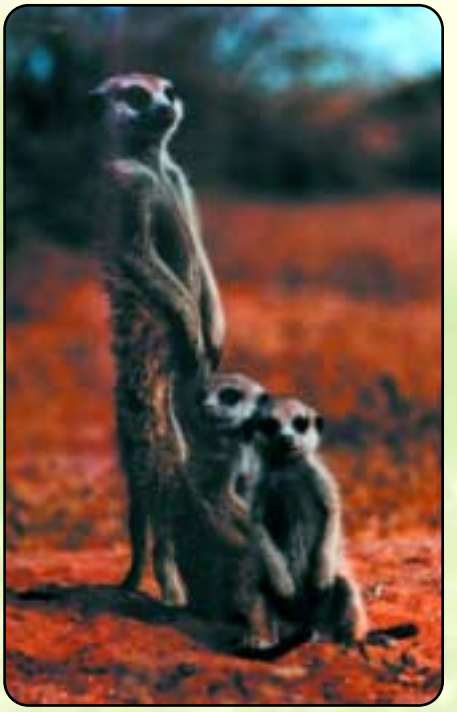

Plate 1: Suricates (above) often live in close proximity to yellow mongoose colonies and are frequently diagnosed rabid

The occurrence of endemic "herpestid" (often referred to as "viverrid") mongoose rabies is closely associated with the distribution of the yellow mongoose. This species occurs widely on the central plateau of the country. Attempts at depopulation of yellow mongooses proved prohibitively expensive and largely ineffectual, and were halted by the end of the 1970s. This small mongoose often lives in close proximity to ground squirrels and suricates (Plate 1). The number of ground squirrels and suricates found to be rabid is probably lower than might be expected, but in the field there is often confusion with species identification. Erroneous nomenclature has often arisen from language translations and colloquial misnomers.

There is no firm evidence that canid (canine) rabies was important in South Africa prior to the late 1940s. The occasional rabid dog is thought to have been infected through contact with the endemic mongoose form of the disease. Veterinary authorities were, however, aware of a more invasive form of rabies that existed in Namibia and Botswana prior to 1950. Dog rabies was confirmed in 1950 in the Limpopo Province and reached Zimbabwe later that year. Establishment of infection in the black-backed jackal population has resulted in the disease remaining endemic in the northern parts of South Africa ever since (Plate 2). Records indicate that the prevalence of bovine and jackal rabies is closely associated in these areas. After spreading through Mozambique from 1952, the first cases of dog rabies in KwaZulu-Natal, which had previously been free of the disease, were diagnosed in 1961. Vigorous control measures, including vaccination and destruction of stray dogs, were enforced by the local veterinary authorities who successfully eliminated the disease by the end of 1968. The reappearance of rabies in KwaZulu-Natal in 1976 and its subsequent endemicity was associated with the migration of refugees from Mozambique. Subsequently rabies incidence has been exacerbated during periods of sociopolitical instability and drought. The situation deteriorated with the division of veterinary authority, inability to control dog movement and often inadequate vaccine coverage in the more densely populated areas. There is no evidence of feral dog populations in KwaZulu-Natal and nearly all dogs appear to be dependent to a greater or lesser extent on humans. The movement of rabies northwards from KwaZulu-Natal into south-eastern Mpumalanga and southwards into the Transkei and Ciskei areas of the Eastern Cape Province could be expected following the large-scale migration of families and their pets.

Plate 2: Black-backed jackal are common in the northern regions of South Africa where they are important rabies vectors

The bat-eared fox appears to be the dominant maintenance host in the western areas of South Africa. Rabies is also diagnosed frequently in black-backed jackal in the northern parts of the country. The outbreak in Namibian kudu antelope, with an estimated loss of some 30 000 to 50 000 animals, remains a unique example of large-scale interherbivorial spread.

RABIES AND RABIES-RELATED VIRUSES

The causative agent of rabies is a member of the Lyssavirus genus of the Rhabdoviridae family of bullet-shaped viruses, which have a single-stranded RNA genome. The genus includes the classical rabies virus (genotype 1) and six so-called rabies-related viruses, Lagos bat virus (genotype 2), Mokola virus (genotype 3), Duvenhage virus (genotype 4), European bat lyssaviruses 1 and 2 (genotypes 5 and 6), and the recently discovered Australian bat genotype 7.[3,8]

Three of the six rabies-related viruses, namely Mokola, Lagos bat and Duvenhage viruses have been isolated in South Africa to date (Table 1). Mokola was also isolated in neighbouring Zimbabwe from six cats and a dog, and Lagos bat virus was found in a cat in the same country. Lagos bat virus has not been associated with human disease whereas Mokola was isolated from the brain of a girl who died from paralytic disease in Ibadan, Nigeria during 1971 but the source of infection was not established.[3,9,10] The two cats from which isolations of Lagos bat virus were made in South Africa and Zimbabwe, had both been vaccinated against rabies. The Zimbabwean cat manifested lethargy and paresis without any aggression. In contrast, all five cats (four of which had been vaccinated against rabies) from which Mokola virus has been isolated since 1996 in South Africa, displayed aggression when handled. Mokola virus has yet to be isolated from a bat and there is still no evidence that rabies-related viruses have adapted to spread in carnivores. To date, infection of bats with classical rabies virus (Lyssavirus 1) has only been confirmed to occur in the Americas.[11]

Three of six rabies-related viruses, namely Mokola, Lagos bat and Duvenhage viruses have been isolated in South Africa to date

TABLE 1: Isolations of rabies-related viruses in South Africa

Location	Year	Host	Virus
Pinetown, KZN[12]	1980	Three fruit bats	Lagos bat
Stanger, KZN[13]	1982	Cat	Lagos bat
Durban, KZN[14]	1990	Fruit bat	Lagos bat
Warmbaths, Limpopo[15]	1970	Human	Duvenhage
Louis Trichardt, Limpopo[12]	1981	Insectivorous bat	Duvenhage
Umhlanga, KZN[12]	1970	Cat	Mokola
East London, Eastern Cape[16]	1995	Cat	Mokola
Mdantsane, Eastern Cape[17]	1996	Cat	Mokola
East London, Eastern Cape[17]	1996	Cat	Mokola
Pinetown, KZN[17]	1997	Cat	Mokola
Pinetown, KZN[17]	1997	Cat	Mokola
Pietermaritzburg, KZN[17]	1998	Cat	Mokola

*KZN = KwaZulu-Natal

In February 1970, an adult male patient from Warmbaths, approximately 100 km north of Pretoria, died after a five-day illness, which was diagnosed clinically as rabies. Infection was thought to have taken place following a bite on the lip from a bat, thought to be an insectivorous species.[15] This index virus was subsequently typed as Duvenhage virus and a further isolation has subsequently been made from a bat in South Africa during 1981.[12]

Rabies virus is antigenically most closely related to the Australian bat Lyssavirus and most distant from Mokola virus.[8,18] An illustration of the distant relationship between rabies virus and Mokola is the fact that standard post-rabies vaccination gives relatively poor protection against Mokola. In the absence of specific vaccines and immunoglobulins it is reasonable that standard rabies vaccine and immunoglobulin be used in all instances of potential exposure to rabies-related viruses.

Over the past 20 years an important development has been the recognition, through monoclonal antibody and gene sequencing studies, that strains of Lyssavirus 1 which cycle in particular host species and often within distinct geographic regions, tend to undergo genetic adaptation resulting in the development of biotypes.[14,19,20] These biotypes, which have subtle unique differences in antigenicity and pathogenicity, may become adapted to a particular host species. This species may then become the maintenance host, permitting the spread of infection to other species. A diagrammatic representation of this cycle in dogs is provided in Fig. 1. A hypothetical diagram of mongoose cycles is depicted in Fig. 2.

The major host species recognised in South Africa today are the dog, yellow mongoose, black-backed jackal and bat-eared fox (Fig. 3). The canine strain is less variable than the mongoose strains and has been most frequently isolated from dogs, bat-eared foxes and black-backed jackal.[21] There are several mongoose virus strains and they are associated with the yellow mongoose, slender mongoose, suricate and ground squirrel. Mongoose virus does not have the same propensity for epidemic spread in dogs as the canid biotype.[18]

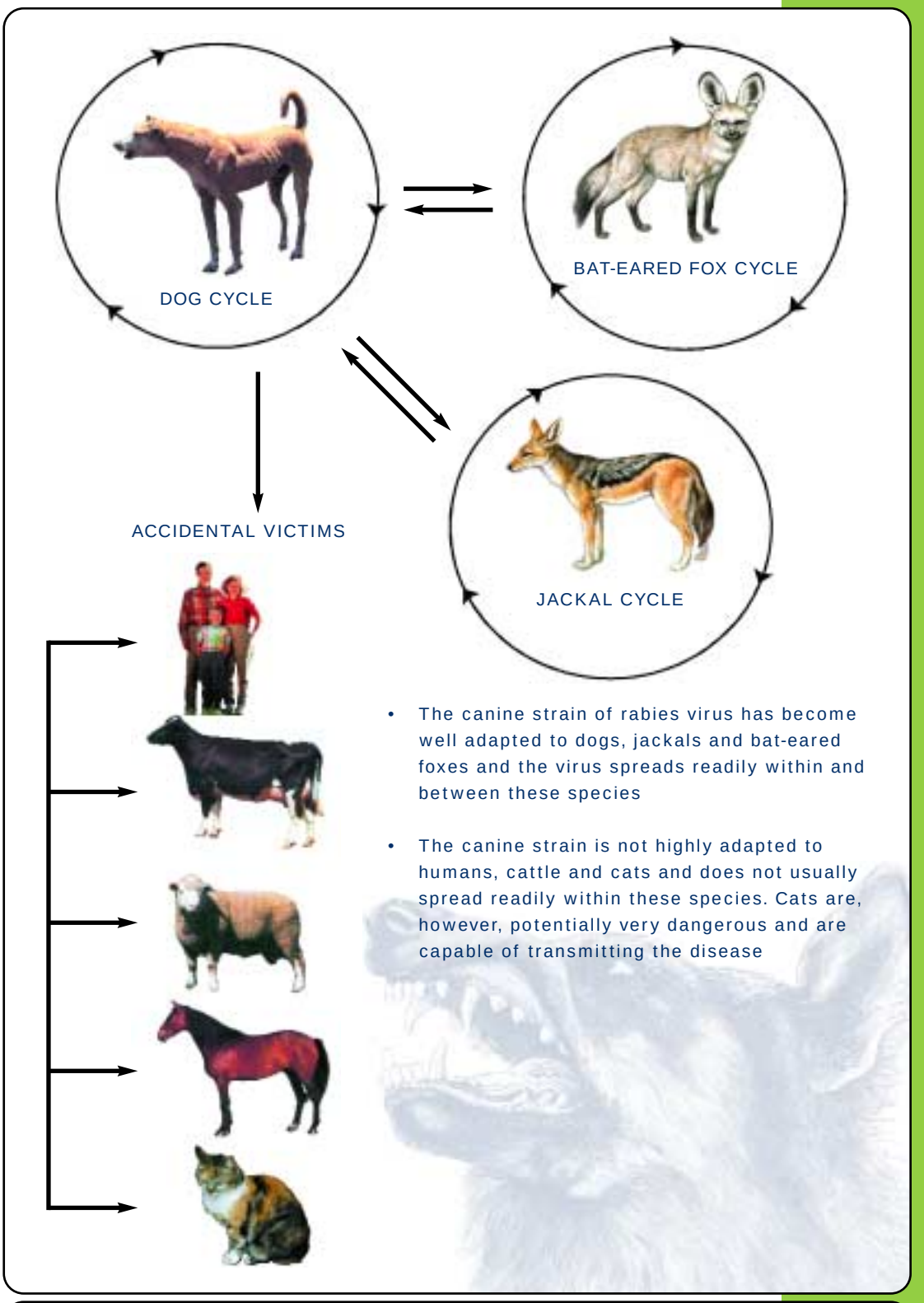

Fig.1: An illustration of canid rabies virus strain cycles in various species

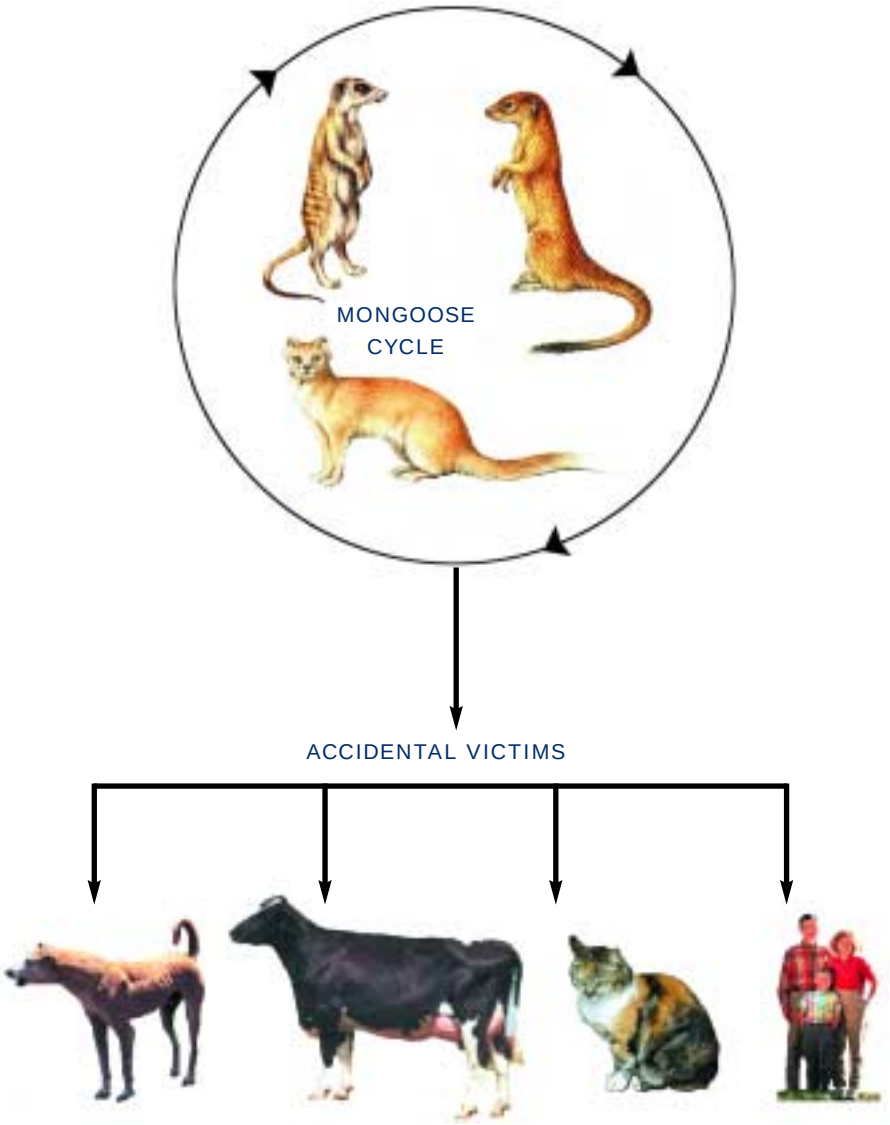

- Some mongoose strains of rabies virus may be well adapted to other mongoose species, especially the yellow and slender mongoose, and suricate. This virus type spreads readily within and between these species

- The mongoose strain is not highly adapted to dog, bat-eared fox and black-backed jackal species and does not usually spread readily between these animals

Fig. 2: An illustration of possible mongoose rabies virus strain cycles in various species

PATHOGENESIS AND IMMUNITY IN HUMANS AND ANIMALS

Pathogenesis

Rabies virus gains entry into a new host by introduction of virus-containing saliva into a bite wound. Entry may also be gained by saliva contamination of the mucous membranes of the mouth, eyes and nasal passages. The virus does not penetrate intact skin.[22] At the site of entry, there may be local viral proliferation in non-neural tissue followed by viral attachment to nerve cell receptors and entry into peripheral nerve endings.[23] The virus is transported along afferent axons, eventually reaching the central nervous system where proliferation is followed by widespread distribution of the virus throughout the brain and spinal cord. Following centrifugal transport along efferent cranial nerves, the salivary glands become infected and virus particles are shed in the saliva. Infection of the brain commonly leads to behavioural changes that induce the host to bite other animals, thereby transmitting the virus. The clinical picture can be highly variable between different species, individuals of the same species, and even within the course of the disease in a particular individual. The widespread central nervous system infection almost inevitably leads to death, usually through respiratory paralysis, but also through secondary circulatory, metabolic or infectious processes.

Plate 3: Severe facial lacerations in a child caused by dog bites. Children are frequently victims of dog bites. Facial bites usually result in much shorter rabies incubation periods

Shedding of virus in saliva usually occurs simultaneously with, or soon after, the appearance of clinical signs.

However, the virus may be shed before the appearance of clinical signs. During most of this incubation period, the virus is in transport along axons.[24] However, in exceptionally long incubation periods, lasting more than four months, it is thought that the virus may remain latent, probably at the site of introduction before entry into the peripheral nervous system.[25] The length of the incubation period is affected by several factors. Bite sites in close proximity to the brain, such as those on the head, tend to have shorter incubation periods. Likewise, deep or very severe bites, where a higher dose of virus is introduced, have a greater probability of disease development and shorter incubation periods.[22] Once the virus is affecting the central nervous system and its function, the clinical course is acute

Shedding of virus in saliva usually occurs simultaneously with, or soon after, the appearance of clinical signs

and progressive with death usually within 10 days in animals and five days or less of the onset of rabies symptoms in humans (J.D. Godlonton, personal communication).

Following central nervous system infection, the virus is transported centrifugally along cranial nerves and along motor and sensory pathways as well as the spinal cord. This results in the presence of viral particles in peripheral nerve tracts in many tissues, particularly those of the head. Therefore, a diagnosis of rabies may sometimes be possible by examination of skin sections, where antigen can be detected within nerve tracts, or corneal smears.[26,27] Rabies virus has been detected in small quantities in several non-neural tissues, including corneal epithelium and hair follicles at the base of the neck, although the replication of rabies virus is not usually pronounced in non-neural tissue other than the salivary glands.

In all mammalian species the host is not infectious for most of the incubation period. Rabies infection is fatal in all species and no species is known to have a carrier state where virus is shed in the absence of clinical signs or imminent clinical signs. Although rare exceptions may occur, human survivors of clinical disease have usually had severe residual neurological sequelae.

Immunity

The immune mechanism by which rabies virus is cleared from the host is not well understood. Protective immunity against rabies involves both B-cell (humoral) and various pathways of the T-cell response.[28] The effective humoral response is directed only against the glycoprotein envelope of the virus. Other proteins do not play any role in generating neutralising antibodies. Cytotoxic T-cell responses are directed against the glycoprotein, nucleoprotein and phosphoprotein components of the virus. Where the host has been successfully vaccinated, virions within a wound will be cleared mainly by the humoral immune system through neutralisation before they gain entry into the nervous system. Once inside the neurons, virions are inaccessible to this immune pathway. This is the main reason for urgent initiation of post-exposure vaccination and passive immunoglobulin treatment. Additional cytolytic immune mechanisms may operate against intracellular virus. This may be the cause of the characteristic paralytic signs seen when rabid animals are improperly vaccinated. Inoculation of rabies virus-containing saliva into a wound does not normally induce a detectable immune response.

Animal and human rabies vaccines consist of inactivated whole-virus antigens grown on a cell culture or neural tissue substrate and, in the case of more modern cell-culture vaccines, partially purified to remove unnecessary proteins. Generally, veterinary vaccines are used for pre-exposure treatment, while human vaccines, which are considerably more expensive to produce, are used post-exposure. Pre-exposure prophylaxis may be recommended in people at high risk. There are no records of human rabies cases that have occurred in people fully vaccinated according to World Health Organisation (WHO) recommendations with pre-exposure regimens by the intramuscular route.

Post-exposure treatment of humans, using vaccine and immunoglobulin according to WHO recommendations (page 39, table 10 and Fig.7 page 41), provides rapid and effective protection if administered soon after exposure. The most frequent causes of failure of post-exposure treatment are delays in administering the first vaccine dose or immunoglobulin, failure to complete the vaccine course and failure of correct wound management. Infiltration of the wound with immunoglobulin does not interfere with stimulation of the immune system by vaccine, which is administered at a site distant from the wound.

Rabies vaccine strains in current use protect against many Lyssavirus serotypes. Animal models predict that the vaccines will protect against all true rabies strains, the European bat lyssaviruses and Duvenhage virus.[29] Further evidence for the lack of protection against Mokola virus is the discovery of Mokola virus infection in several vaccinated cats.[17]

RABIES IN ANIMALS

SPECIES INVOLVED

A diagrammatic representation of the areas of rabies transmission by the four principal rabies vectors in South Africa is provided in Fig. 3. The map is an approximation and there will be areas where considerable overlap occurs. Mongoose isolates of rabies virus have far outnumbered canid isolates on the central plateau of South Africa, which is inhabited by the yellow mongoose. Areas indicated as dog, black-backed jackal and bat-eared fox endemic have yielded mainly the canid strain. Endemicity changes constantly and the domestic dog, which is dependent on humans for its existence, may be transported very rapidly over long distances.[21,30] Future outbreaks of canine rabies in heavily populated, canine rabies-free areas of South Africa, are inevitable unless high levels of dog vaccination are achieved and maintained.

A list of species confirmed rabid by various South African laboratories over the period 1928 to 2000, is provided in Table 2. The list is not exhaustive and additional species will undoubtedly be included in future. To date, about 37 % of all animal rabies cases have been dogs (67 % from KwaZulu-Natal). Yellow mongooses have contributed 17 % of the total but most of the 1 310 unspecified mongooses were certainly also *Cynictis penicillata*. The mongoose grouping (including suricates) contributed more than 27 % of the total rabies cases. Dogs and mongooses therefore represent 64 % of total cases. Species usually regarded as dead-end hosts (cattle, sheep, goats, horses and pigs) contributed 22 % of the total.

Plate 4: The bat-eared fox is an important vector in the arid regions of South Africa

Apart from the large-scale kudu outbreak in Namibia rabies has rarely been diagnosed in the large game reserves of southern Africa. Except for very rare intrusions of rabid domestic dogs from Mozambique into the Kruger Park, the Kruger and KwaZulu-Natal game reserves have remained rabies-free [Onderstepoort Veterinary Institute (OVI) and Allerton Veterinary Laboratory unpublished laboratory records]. Small outbreaks have occurred in other game reserves.[31]

The geographical location of all animal rabies cases diagnosed over the five year period, 1995 to 1999, is displayed in Fig. 4. Illustrations of some of the wild animal species most frequently diagnosed rabid since 1990 are found in Plates 5 and 6.

Rabies infection is fatal in all species and no species has a carrier state where virus is shed in the absence of clinical signs or imminent clinical signs

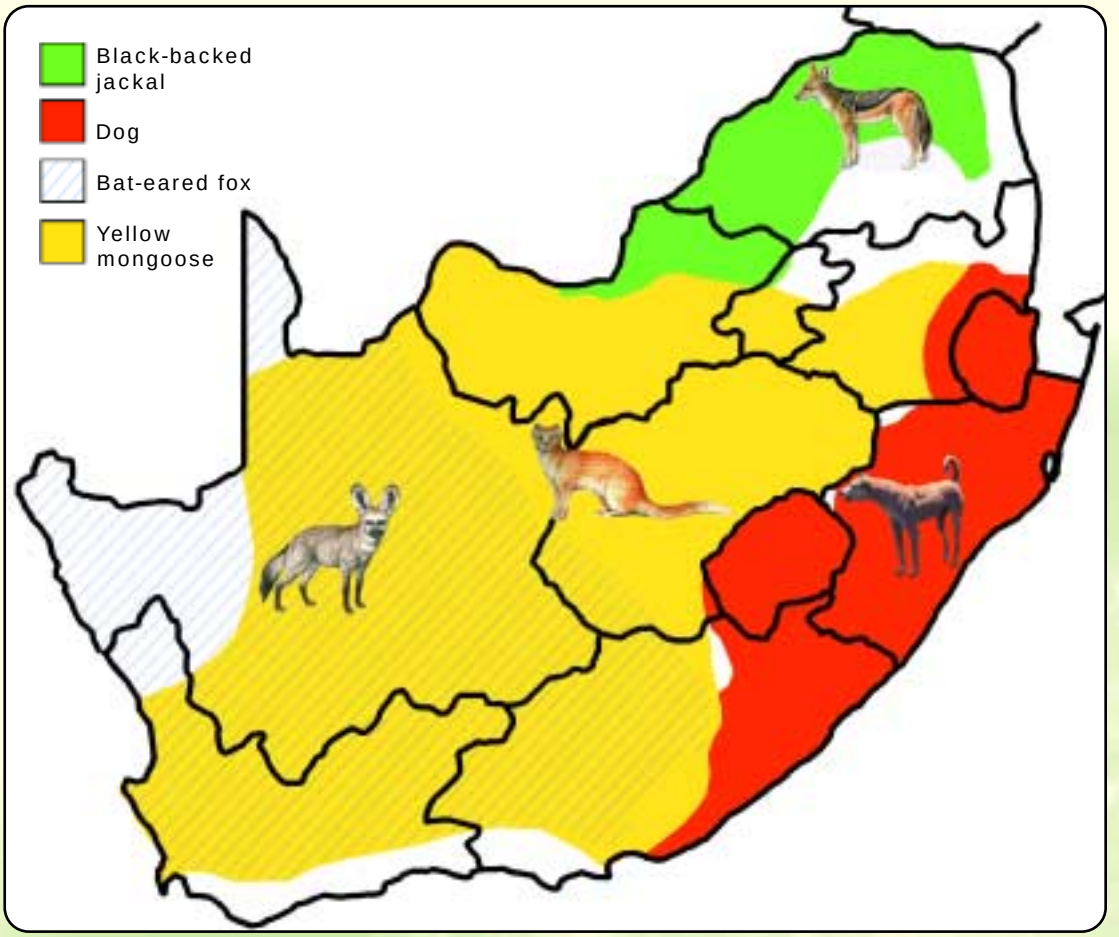

Fig. 3: The distribution of rabies endemicity by major vectors in South Africa

TABLE 2: Rabies cases diagnosed in South Africa, 1928 to 2000

Animal		1928–91	1992–2000	Total
Domestic				
Dogs	*Canis familiaris*	3 322	2 433	5 755
Cats	*Felis domesticus*	437	146	583
Cattle	*Bos* species	2 211	818	3 029
Sheep	*Aries ovis*	119	39	158
Goats	*Capra hirsutus*	60	74	134
Horses and donkeys	*Equus calabus, Eq. asinus*	53	28	81
Pigs	*Suis scrofula*	25	11	36
Guinea pigs	*Cavia porcellus*	1	0	1
Total domestic		**6 228**	**3 549**	**9 777**
Wild				
Yellow mongoose	*Cynictis penicillata*	2 034	553	2 587
Slender mongoose	*Galerella sanguinea*	16	46	62
Small grey mongoose	*Galerella pulverulenta*	38	13	51
Large grey mongoose	*Herpestes ichneumon*	0	1	1
Banded mongoose	*Mungos mungo*	3	2	5

Wild animals (continued)		1928–91	1992–2000	Total
Water mongoose	*Atilax paludinosus*	11	17	28
Selous mongoose	*Paracynictis selousi*	1	0	1
Dwarf mongoose	*Helogale parvula*	1	0	1
White-tailed mongoose	*Ichneumia albicauda*	2	0	2
Suricate	*Suricata suricatta*	112	86	198
Mongoose species		1 272	42	1 314
Civet	*Civettictis civetta*	3	3	6
Small-spotted genet	*Genetta genetta*	167	25	192
Lion	*Panthera leo*	0	1	1
African wildcat	*Felis lybica*	13	24	37
Caracal	*Felis caracal*	14	3	17
Serval	*Felis serval*	0	3	3
Small-spotted cat	*Felis nigripes*	3	2	5
Felid species		168	17	185
Honey badger	*Mellivora capensis*	18	9	27
Striped polecat	*Ictonyx striatus*	66	5	71
Striped weasel	*Poecilogale albinucha*	1	1	2
Black-backed jackal	*Canis mesomelas*	206	185	391
Bat-eared fox	*Otocyon megalotis*	263	160	423
Wild dog	*Lycaon pictus*	0	7	7
Cape fox	*Vulpes chama*	7	11	18
Aardwolf	*Proteles cristatus*	22	31	53
Brown hyaena	*Hyaena brunnea*	1	0	1
Spotted hyaena	*Crocuta crocuta*	1	0	1
Ground squirrel	*Xerus inauris*	32	11	43
Tree squirrel	*Paraxerus cepapi*	1	1	2
Greater cane rat	*Thryonomys swinderianus*	2	0	2
Cape hyrax	*Procavia capensis*	8	3	11
Chacma baboon	*Papio ursinus*	1	0	1
Warthog	*Phacochoerus aethiopicus*	1	0	1
Impala	*Aepyceros melampus*	0	1	1
Duiker	*Sylvicapra grimmia*	17	3	20
Steenbok	*Raphicerus campestris*	4	0	4
Kudu	*Tragelaphus strepsiceros*	3	4	7
Eland	*Taurotragus oryx*	0	3	3
Blesbok	*Damaliscus dorcas phillipsi*	1	0	1
Bushbok	*Tragelaphus scriptus*	0	1	1
Reedbuck	*Redunca arundinum*	1	0	1
Springbuck	*Antidorcus marsupialis*	3	0	3
Burchell's zebra	*Equus burchelli*	1	1	2
Herbivore species		6	0	6
Scrub hare	*Lepus saxatilis*	1	0	1
Unknown species		34	2	36
Total wild		**4 559**	**1 277**	**5 836**
Total animals		**10 787**	**4 826**	**15 613**

Note:

- A total of 17 bats, believed to have been infected with rabies-related viruses, have been omitted from this table
- A number of the cats listed are known to have been infected with Mokola virus (rabies-related virus)
- Most of the "Mongoose species" are believed to have been yellow mongoose

The present areas of canine rabies endemicity will expand rapidly, unless high levels of dog vaccination are achieved and maintained

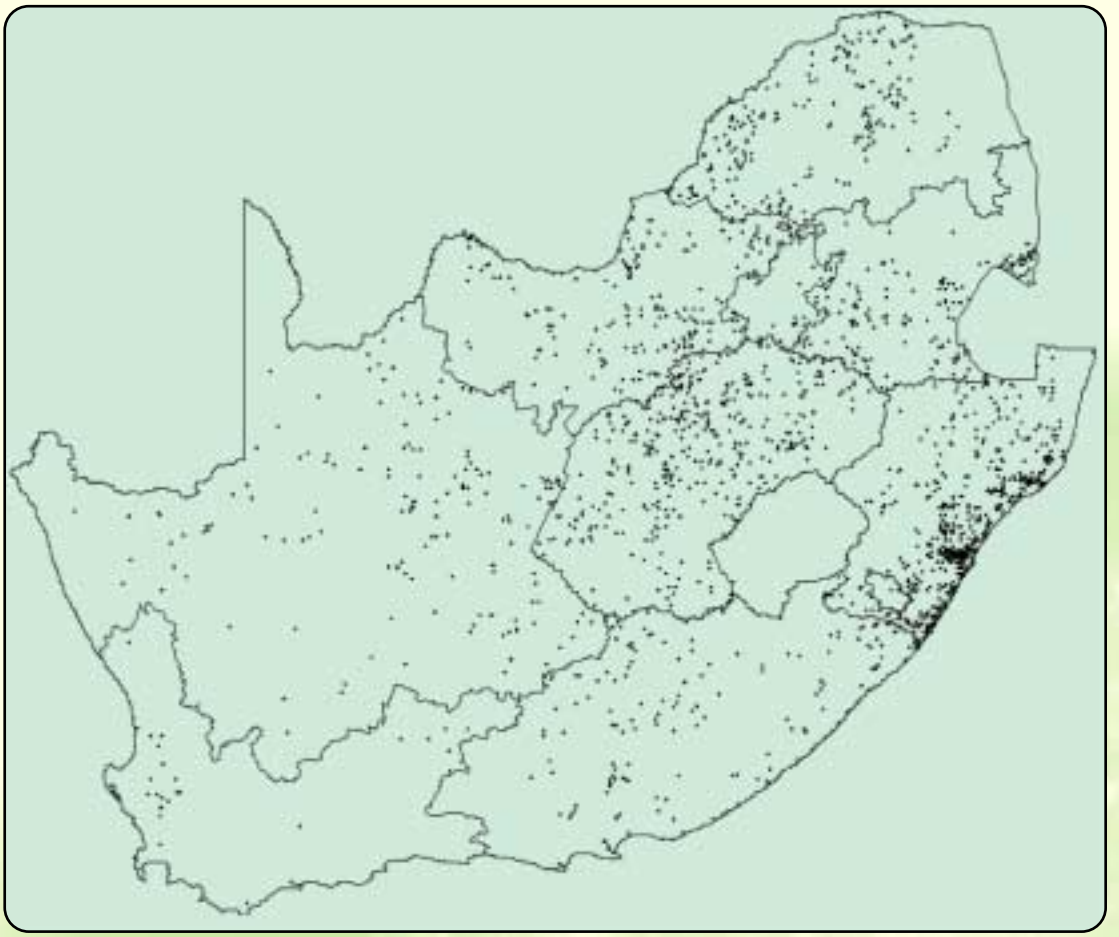

Fig. 4: Geographical locations of animal rabies cases diagnosed over the five year period, 1995 to 1999

Plate 5: Wild mammal species associated with rabies in South Africa

Plate 6: Wild mammal species associated with rabies in South Africa (continued)

TRANSMISSION AND EPIDEMIOLOGY

An understanding of the importance of the virus-host-environment relationship is crucial to understanding the complex epidemiology of animal rabies.[20] With recent developments in monoclonal antibody technology and gene sequencing, it is possible to demonstrate that distinct variants of rabies viruses (Lyssavirus type 1) have become adapted to specific hosts. The South African canid strain appears to be homogeneous whereas there are at least four or five mongoose strains. Within the mongoose strains, an association has been shown with different yellow mongoose populations occurring in geographically distinct areas.[18,32] The underlying causes of rabies-virus-host preference and the factors that determine the propensity of a rabies virus strain to spread, or become compartmentalised, have not been elucidated. Rabies does not appear to have an extended asymptomatic carrier phase and a symptomless carrier animal, which sheds rabies virus but does not succumb to the disease, has not been demonstrated in South Africa. Animals infected with rabies virus succumb to the disease.

More than 300 animal rabies (Lyssavirus type 1) isolates from KwaZulu-Natal have been typed using monoclonal antibodies and these have all proved to be canid strain.[21] This finding clearly implicates the domestic dog as the reservoir species in that province and is justification for the veterinary authorities' policy of intensive dog vaccination. A good knowledge of local dog ecology (dog numbers, turnover rates, reasons for ownership, other diseases, housing) is crucial when planning control measures. Feral dogs do not appear to be an important factor in KwaZulu-Natal and therefore owners' management of their dogs should not be overlooked.

Dog rabies is almost exclusively endemic in developing countries where control measures are difficult to apply and education of the public is complicated by competing priorities. Dog rabies has often erroneously been referred to as "urban" rabies but the disease is clearly a rural problem in many parts of the Eastern Cape, Mpumalanga and KwaZulu-Natal. The term "urban" may have originated with the belief that urban domestic dogs maintained a rabies cycle that originated from sylvatic mongoose rabies spreading to dogs in South Africa.[20] The identification of different rabies variants by means of monoclonal antibody typing and gene sequencing has put this postulate to rest.

Canine rabies is currently endemic in the north-eastern regions of the Eastern Cape, the entire KwaZulu-Natal, and the eastern and south-eastern areas of Mpumalanga adjoining Swaziland.[21,30] Within these regions, prevalence appears to be highest in areas with the highest human densities. Human migration has increased considerably during the past decade and it may only be a matter of time before canine rabies makes its presence felt in other densely populated areas of the country.

During the past 30 years, the canid strain of rabies virus has accounted for most black-backed jackal rabies cases in the Limpopo Province and bat-eared fox rabies cases in the Northern Cape, Free State and Eastern Cape. A rabid black-backed jackal, some 20 km from Soweto, yielded the canid strain in 1995. Why large-scale spreading to the local dog populations did not occur, remains a mystery.

Humans, cattle and other domestic animals are the main victims of canid rabies in dog rabies-endemic regions.[21,30] In the Limpopo and North West Provinces, cattle are most frequently affected by outbreaks in black-backed jackal. Epidemics appear to occur in cycles of eight to 10 years, and two specific epidemics from 1974 to 1980 and 1988 to 1996 had significant economic implications. During the former more than 1 000 cattle succumbed to clinical rabies on 93 farms (H. van de Pypekamp, personal communication). Rabies in jackal was controlled by poison baits until the 1980s. This method proved unsuccessful and often led to the death of nontarget species. It has since been replaced by mass vaccination of livestock in endemic areas with far better results. Unlike dog rabies, sylvatic rabies may be influenced to a far greater extent by seasonal availability of water and food. Competition between species during the mating season and dispersal of progeny seeking new territories, appear to be important explanatory factors.[18] The increased prevalence of the disease in black-backed jackal in areas of the Limpopo Province from July to November over a number of years coincided with mating and whelping in these animals.[33,34]

Rabies appears to spread fairly well within bat-eared fox populations, yet transmission of infections to other species is relatively rare. The underlying reasons for this are still to be elucidated. Population dynamics (including population turnover) and the distribution of susceptible animals are extremely important factors determining the prevalence of rabies in other species, and the bat-eared fox is no exception.

The most important maintenance host of mongoose rabies is the yellow mongoose, *Cynictis penicillata*, a diurnal animal that lives in colonies of 10 or more individuals. The disease has been endemic in yellow mongoose populations for decades and possibly centuries. Attempts by veterinary authorities to control the disease by depopulation, for example by gassing burrows and trapping, have only had a transient effect. These measures may ultimately have accelerated the spread of the disease by increasing the territories of yellow mongoose colonies with concomitant increased movement. Spreading infection to suricates, which are migratory herpestids living in groups of up to 30 individuals, and ground-squirrel populations are fairly common, because these species often share warrens or live in close proximity to yellow mongoose colonies.

Humans and domestic animals such as sheep, cattle and dogs have been infected and succumbed to mongoose rabies virus but are regarded as dead-end hosts because spread within these species is rare.

CLINICAL SIGNS

Apart from behavioural changes, there are no definitive, species-specific clinical signs of rabies.[24,35] Although certain clinical signs are more frequent than others, even the most experienced diagnostician may make an incorrect diagnosis when presented with an unusual case. Rabies can mimic many other diseases but it always has a neurological component.

Plate 7: Aggressive behaviour in unusual circumstances is well documented in domestic and wild animals infected with rabies virus

Histories, submitted to diagnostic laboratories have often included the words: "typical rabies" or "typical dumb rabies" or "typical furious rabies" without any further elaboration of what the sender regarded as "typical".[21,30] Some early workers in the rabies field appeared to agree on a typical presentation of a rabid dog and Baer cites Philumenus, Ibn Sina and Galen (130 AD) as all agreeing that: "If you hear that the dog is wasted in the body, dry, red in the eyes, tail hanging limp, its tongue hanging out and discoloured, bumping into people it meets, irrationally running and stopping, biting with furious rage people it has never met before, then you may be sure the dog is rabid".[36]

Humans, cattle and other domestic animals are the main victims of canine rabies in dog rabies-endemic regions

The most important maintenance host of mongoose rabies is the yellow mongoose

Because rabies affects the central nervous system, it is nearly always associated with behavioural changes that may manifest in many different ways. Classically, rabies has been described as having a prodromal phase followed by either an excitive furious form, or a paralytic dumb form.[37] The veterinarian is, however, rarely afforded the opportunity to observe an animal throughout the clinical course of disease and diagnosis is often made after minimal observation, especially in endemic areas where rabies awareness is heightened. For this reason, a list of clinical signs in rabid animals (in no particular order) during various stages in the course of the disease is provided here.[18,24,37] Some of the signs, such as a change in disposition, may only be noticed after close observation by owners or people closely associated with the particular animal.

Plate 8: Paralytic rabies in a dog that is salivating profusely

Dogs: Change in temperament, attacking and biting anything (often injuring mouth and breaking teeth), exaggerated responses to sound and light, restlessness, nervousness, snapping at imaginary flying insects, disorientation, wandering aimlessly, a fixed stare, drooling saliva, hoarse howling, choking sounds, "bone in throat" syndrome, a febrile reaction, uncoordinated actions and progressive paralysis, dilated pupils, irritability, photophobia, infliction of self-injury, convulsions, and muscle spasms.

Cats: Generally aggressive, uncoordinated, frothing, muscular tremors, dilated pupils, staring, a threatening posture, abnormal vocalisation, lack of response to owners, unprovoked attacks, biting (sometimes without releasing grip), convulsions, paralysis, coma, hiding away, some cats appear unusually affectionate and purr, or extend and retract their claws.

Cattle: Several animals may have clinical signs at the same time, a typical hoarse bellow, aggressive particularly on provocation, vicious attacks on inanimate objects, butting other cattle, attacking humans, wind-sucking, "bone in throat" syndrome, separate themselves from rest of herd, anorexia, knuckling of fetlocks especially hind limbs, swaying gait, tail and posterior limb paralysis, jaw and tongue paralysis, profuse salivation, dragging hooves, pseudo-oestrous, hypersexual behaviour, decreased milk production, dilated pupils, fixed stare, grinding teeth, pica, tenesmus with diarrhoea, frequent urination, loss of condition, and emphysema.

Sheep/goats: Symptoms resemble those of cattle but hypersexual behaviour, sexual excitement, incessant bleating, aggression, aimless running, pawing and paddling, and grinding of teeth are prominent.

Horses: Febrile reactions, altered behaviour, biting of wound site, aggression, thrashing, paralysis, and inability to swallow.

Pigs: Hiding in corners of pen, hypersexual behaviour, aggression, biting, and may kill offspring.

Wild animals: Often lose fear of humans.
Yellow mongooses generally demonstrate tame behaviour, but some are very aggressive.
Jackal are usually aggressive, and lose fear of humans.
Wild cats display similar behaviour to domestic cats.
Badgers are usually vicious and fierce.
Kudu salivate profusely, may be paralysed, docile, tame, even entering houses.
Duiker are sometimes very aggressive.

Plate 9: Behavioural changes are common in wild animals, which may appear to become "tame". This rabid kudu has entered the kitchen of a Namibian farmhouse

Plate 10: Knuckling fetlocks and hind-quarter paralysis in a bovine

Plate 11: Hind-quarter paralysis in a calf

Rabies can mimic many other diseases but it always has a neurological component, with behavioural changes

Plate 12: Inquisitive cattle are often bitten by animals which exhibit unusual behaviour. Many cattle may be bitten at the same time in these circumstances

Plate 13: Rabid cattle may become very thirsty and attempt to drink but are unable to swallow. Sick animals often loiter at watering points

Plate 14: Continuous bellowing is well documented in cattle

Plate 15: Salivation, which is particularly acute in terminal disease, persistent bellowing and wind-sucking in a bovine

An analysis of the unsolicited histories submitted on 2 743 rabies specimen submission forms (2 465 confirmed dogs, 169 cattle, 59 cats, 37 goats and 13 horses) to Allerton Provincial Veterinary Laboratory in KwaZulu-Natal over approximately 12 years, is provided in Tables 3 to 7.

TABLE 3: Clinical signs reported in histories submitted for 2 465 confirmed rabies cases in dogs from September 1987 to December 1999

Clinical sign	No.	%
Aggression	1 095	44
Bit human, other animal	628	26
Behavioural changes	559	23
Salivation	541	22
Slack or dropped jaw, jaw paralysis	418	17
Incoordination, ataxia	392	16
Biting foreign objects	353	14
Abnormal sounds, howling	333	14
Not eating	236	10
Paralysis, paresis	183	7
"Nervy", agitated, sensitive to noise/ light	153	6
Dumb, dull, lethargic	146	6
Exhausted, collapsed, emaciated	117	5
Central nervous system disorder, confused, "crazy"	110	5
Vacant expression, fixed stare	108	4
Running in circles, running aimlessly	95	4
Muscle twinges, spasms	91	4
Convulsions, seizures	87	4
Tongue hanging out	60	2
Pyrexia	49	2
Difficulty in swallowing	46	2
Depression	39	2
"Fly snapping"	38	1
"Bone in the throat"	35	1
Disappeared for a few days	31	1
Vomiting	27	1
Hydrophobia	20	1
"Chewing gum fit"	18	1
Blind, appeared to be blind	18	1
Self-mutilation, biting itself	16	1
Hiding away	13	1
Diarrhoea	12	1

Animals displaying signs of neurological disease, as well as all stray and wild animals suspected of exposing humans to rabies infection, should be euthanised for laboratory confirmation

TABLE 4: Clinical signs reported in histories submitted for 169 confirmed rabies cases in cattle from September 1987 to December 1999

Clinical sign	No.	%
Abnormal sounds, bellowing	120	71
Salivation	94	56
Aggression	75	44
Behavioural changes	43	25
Chasing chickens, cattle and other animals	26	15
Incoordination, ataxia	23	14
Not eating	22	13
Paralysis, paresis	10	6
Exhausted, collapsed, emaciated	9	5
Vacant expression, fixed stare	9	5
"Nervy", agitated, sensitive to noise/light	7	4
Hypersexual behaviour	6	4
Convulsions, seizures	6	4
Bit human, other animal	6	4
Central nervous system disorder, confused, "crazy"	5	3
Biting foreign objects	5	3
Running in circles, running aimlessly	5	3
Walking in circles	4	2
Muscle twinges, spasms	4	2
Disappeared for a few days	3	2
Knuckling of fetlocks	3	2
Dumb, dull, lethargic	3	2
Restless	3	2
Difficulty in swallowing	3	2
Pyrexia	2	1
Hydrophobia	2	1
Slack or dropped jaw, jaw paralysis	2	1
Tongue hanging out	2	1
"Bone in the throat"	1	1
Depression	1	1
Unusually tame	1	1
Blind, appeared to be blind	1	1
Vomiting	1	1

TABLE 5: Clinical signs reported in histories submitted for 59 confirmed rabies cases in cats from September 1987 to December 1999

Clinical sign	No.	%
Bit human, other animal	28	48
Aggression	25	42
Behavioural changes	16	27
Incoordination, ataxia	7	12
Biting foreign objects	5	9
Salivation	4	7
Slack or dropped jaw, jaw paralysis	4	7
"Nervy", agitated, sensitive to noise/light	3	5
Disappeared for a few days	3	5
Abnormal vocalisation	3	5
Not eating	3	5
Convulsions, seizures	3	5
Exhausted, collapsed, emaciated	2	3
Self-mutilation, biting itself	1	2
Paralysis, paresis	1	2
Pyrexia	1	2
Restless	1	2
Dumb, dull, lethargic	1	2
Depression	1	2
Unusually tame	1	2
Walking in circles	1	2
Difficulty in swallowing	1	2

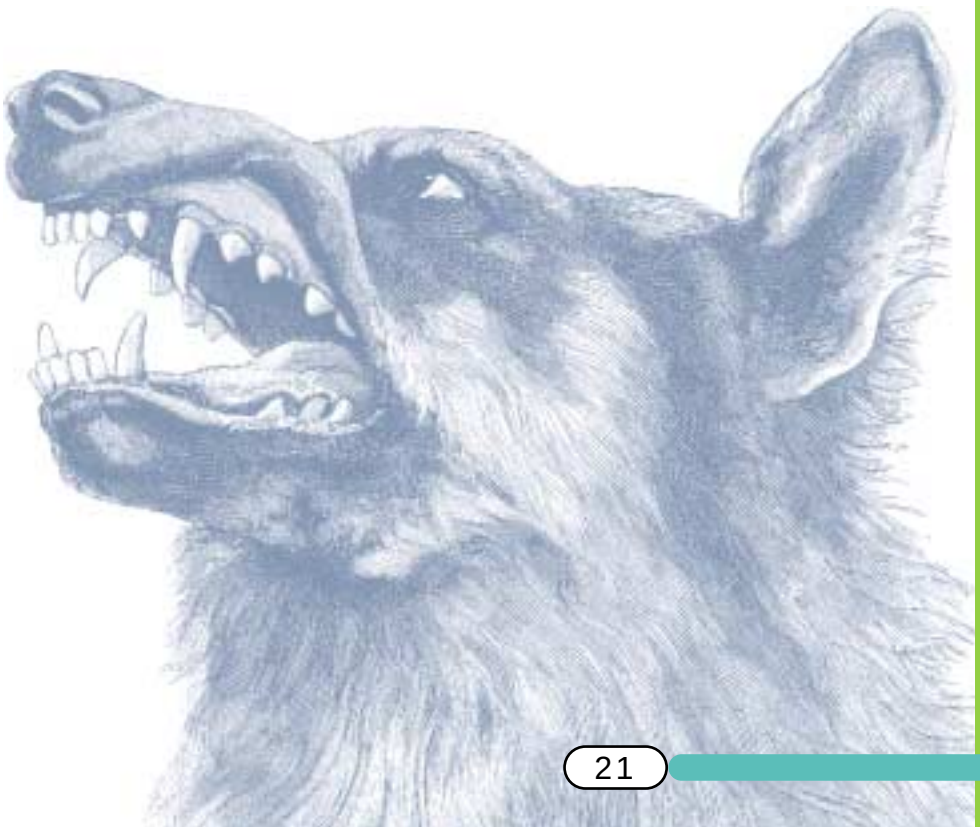

TABLE 6: Clinical signs reported in histories submitted for 37 confirmed rabies cases in goats from September 1987 to December 1999

Clinical sign	No.	%
Aggression	20	54
Behavioural changes	13	35
Difficulty in swallowing	11	30
Biting foreign objects	11	30
Abnormal vocalisation	11	30
Chasing chickens, cattle, other animals	10	27
Salivation	6	16
Bit human, other animal	5	14
Paralysis, paresis	4	11
Central nervous system disorder, confused, "crazy"	3	8
Not eating	3	8
"Nervy", agitated, sensitive to noise/light	2	5
Self-mutilation, biting itself	2	5
Knuckling of fetlocks	2	5
Muscle twinges, spasms	1	3
Hiding away	1	3
"Chewing gum fit"	1	3
Hypersexual behaviour	1	3
Incoordination, ataxia	1	3

TABLE 7: Clinical signs reported in histories submitted for 13 confirmed rabies cases in horses from September 1987 to December 1999

Clinical sign	No.	%
Aggression	8	62
Behavioural changes	6	46
Self-mutilation, biting itself	5	38
Biting foreign objects	4	31
Incoordination, ataxia	3	23
Bit human, other animal	3	23
Central nervous system disorder, confused, "crazy"	2	15
Chasing other animals	2	15
Muscle twinges, spasms	1	7
Pyrexia	1	7
Running in circles, running aimlessly	1	7
Slack or dropped jaw, jaw paralysis	1	7
Hypersexual behaviour	1	7

DIAGNOSIS

Confirmation of a rabies diagnosis cannot be made by gross pathology or histology. Specific tests must demonstrate the presence of rabies antigen. Animals displaying signs of neurological disease, and all stray and wild animals suspected of exposing humans to rabies infection, should be euthanised for examination. The Directorate Veterinary Services may hold suspected cats and dogs in quarantine for observation by a veterinarian for a period of at least 10 days.[38] Animals displaying signs of illness during the period of observation are euthanased for laboratory examination. A vaccination history may be of some assistance during the assessment but greater reliance should be placed on the animal's clinical picture. Although the inactivated veterinary vaccines used in South Africa are known to be extremely effective for periods exceeding three years following vaccination, there are compelling reasons for avoiding undue reliance on vaccination history alone.[18]

These include:

- the incorrect vaccine may have been administered
- the incorrect dosage and route may have been used
- the vaccine might have passed its expiry date
- the vaccine may have been incorrectly handled or stored
- the animal may have been misidentified
- vaccination may have been performed after infection had already occurred
- the animal may have been immuno-suppressed
- the animal may have been diseased or in poor condition when vaccinated
- the animal may have been very young at vaccination and not boosted at three months.

In addition, rabies has rarely been recorded in immunised animals.

Laboratory diagnosis

Rabies tests on domestic and wild animal specimens are performed at approved laboratories. Presently the Rabies Unit at the Onderstepoort Veterinary Institute (OVI) near Pretoria, and the Allerton Provincial Veterinary Laboratory (APVL), Pietermaritzburg are the approved laboratories in South Africa.

It is essential that a complete history of the animal involved and the circumstances surrounding the collection of the specimen be supplied to the laboratory. Specimen forms may be obtained from the OVI or APVL. The specimen form appearing as Fig. 6, page 31, may be reproduced and used for submission to either laboratory. State veterinarians must also receive a copy of the completed specimen form when the animal's brain is sent to the laboratory. The state veterinarian

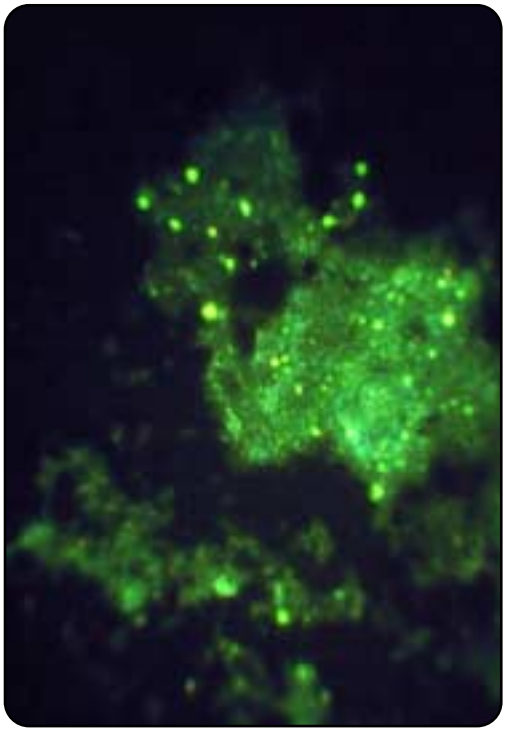

Plate 16: The fluorescent antibody test is used routinely to diagnose rabies in the brain tissue of animals and humans. Note the oval apple-green Negri bodies which are diagnostic of the disease

It is essential that a complete history of the animal involved and the circumstances surrounding the collection of the specimen be supplied to the laboratory

must send a copy of this form to the provincial Department of Health for the attention of the section responsible for communicable disease control if they suspect that the animal had rabies or a positive test result is received.

The fluorescent antibody test (FAT) is the standard diagnostic test currently used in South Africa. The presence of rabies virus antigen is demonstrated in brain smears by means of immunofluorescence using antirabies fluorescein conjugate. The FAT is more than 99 % reliable in experienced hands. The conjugate currently produced by the Rabies Unit at the OVI is also capable of detecting rabies-related virus antigen.

Supplementary tests used include cell culture, mouse inoculation, the polymerase chain reaction and immunohistological tests. Histopathology, which makes use of formalin-impregnated brain sections, is unreliable but may help to exclude conditions in the differential diagnosis of rabies.[39]

The FAT can be completed within 2 hours of receiving suitable brain material and delays in obtaining laboratory results are usually due to transportation problems.[21,30] Because post-exposure treatment of humans should be instituted without delay, decisions on the correct course of action are usually taken before the results of veterinary diagnostic tests become available. However, the results of laboratory tests are used, in conjunction with the clinical history, to decide whether antirabies prophylaxis should be continued or discontinued.

Differential diagnosis

Rabies must be considered in the differential diagnosis of any suspected mammalian encephalitis. Various conditions that have been confused with rabies are listed in Table 8.[18,40]

TABLE 8: Several conditions that may be clinically confused with animal rabies

Dogs	Cattle	Horses	Sheep	Cats
Diseases				
Distemper	Cerebral theileriosis	Equine encephalosis	Heartwater	Toxoplasmosis
Infectious canine hepatitis	Thrombotic meningoencephalitis *(Haemophilus somnus)*	Encephalomyelitis (equine herpesvirus 1)	Botulism	Meningitis/ encephalitis
Meningitis/encephalitis	Cerebral babesiosis	Tetanus	Meningitis/ encephalitis	
Cerebral babesiosis	Heartwater			
Cerebral cysticercosis *(Taenia solium)*	Sporadic bovine encephalomyelitis (*Chlamydia psittaci*)			
Toxoplasmosis	Botulism			
Tetanus	Meningitis/encephalitis			
Ehrlichiosis				
Other conditions				
Oesophageal obstruction	Oesophageal obstruction		Coenurus cerebralis *(Taenia rnulticeps)*	Traumatic accidents
Foreign objects lodged in mouth/throat	Cerebrocortical necrosis (thiamine deficiency)		Cerebrocortical necrosis (thiamine deficiency)	Maternal aggression
Brain tumours	Foreign objects lodged in mouth/throat		Brain abscesses	Inter-cat aggression
Maternal aggression	Brain abscesses			Brain tumours
Traumatic accidents	Epidural abscesses			
Oestrous behavioural changes	Brain tumours			
Mineral/ pesticide poisoning				
Diminazene	Lead	Pesticide poisoning	Urea	Organophosphate
Chlorinated hydrocarbon	Urea		Organophosphate	Chlorinated hydrocarbon
Strychnine	Organophosphate		Chlorinated hydrocarbon	Strychnine
Organophosphate	Chlorinated hydrocarbon			
Methaldehyde				
Plant poisoning				
	Homeria and *Moraea* spp. (tulp)	Seneciosis	*Homeria* and *Moraea* spp. (tulp)	
	Pennisetum clandestinum (kikuyu grass)	*Fusarium moniliforme* (leukoencephalo-malacia)	*Cynanchum* spp. (monkey rope)	
	Dipcadi glaucum (wild onion)		*Diplodia maydis* (diplodiosis)	
	Diplodia maydis (diplodiosis)			
	Albizia spp.			
	Cestrum spp. (ink berry)			
	Cynanchum spp. (monkey rope)			
	Matricaria nigellifolia (stagger weed)			
	Aspergillus clavatus (mycotoxicosis)			

Plate 17: Terminal rabies can be confused with many other animal diseases, such as corridor disease, cerebral redwater and heartwater

PREVENTION OF RABIES

Pre-exposure vaccination

A number of recently developed, highly-effective, thermostable, inactivated vaccines are available in South Africa for veterinary use. The duration of immunity conferred varies from one to three years. Most veterinary vaccines are only registered for use in specific species, for example dogs. Although there are no safety limitations to their use, their efficiency in other species, for example mongoose, is not guaranteed. All rabies vaccines registered for human and animal use must conform to established potency standards. A minimum antigenic potency of 2,5 IU per dose is mandatory.[41]

The vaccines may be used in young pups, but they must be boosted at three months of age and again within the following year. Revaccination must be carried out every three years thereafter. Cattle and sheep may be vaccinated annually or every two to three years, depending on the vaccine manufacturer's instructions. Some farmers inoculate their herds every year in jackal and dog rabies endemic areas with these inexpensive vaccines as they consider this practice to be economically sound. Following an outbreak in domestic livestock, vaccination of animals without visible bite wounds is strongly recommended. In cases where bite wounds are visible, or there is direct evidence that an animal was bitten, the animal should immediately be isolated and destroyed.

Post-exposure treatment

Post-exposure treatment (PET) of bite-contact unvaccinated carnivores, including dogs and cats, is not recommended in South Africa. Preliminary reports indicate that antibodies in the form of antirabies immunoglobulin (RIG) in combination with vaccine yielded poor results.[42] The use of PET in animals is not without risk and is not recommended for use in animals in South Africa.

PROCEDURES TO BE FOLLOWED WHEN RABIES IS SUSPECTED IN ANIMALS

Collection and dispatch of specimens

People responsible for collecting specimens must be vaccinated against rabies.

Animals should be euthanised without causing extensive damage to the brain. Protective clothing, which should include gloves, an overall, a plastic apron, gumboots and a visor, must be worn while removing the brain. Collection of specimens should occur in a dedicated post-mortem room or in the field. It is advisable that a bucket and disinfectant be available for on-site cleaning. The minimum equipment required is a coarse-bladed saw, a knife, a scalpel, forceps, scissors and a spatula (Plate 18).

The skin should be divided in the mid-line and the skull split along the mid-line into two halves using a coarse-bladed saw (Plates 23–27). This divides the brain as well. The brain should then be carefully removed with the aid of the scissors and forceps. In large animals sawing across just in front of the base of the horns is useful for opening the skull (Plates 19–20).

All bovines with neurological symptoms that test negative for rabies are tested for bovine spongiform encephalopathy (BSE). Although BSE has never been diagnosed in South Africa, ongoing surveillance is essential to prove that the country remains disease free.

It is preferable to submit the entire brain. If this is not possible, submit one half of the brain and brainstem or alternatively, cut off most of the cerebrum and submit only the brainstem, cerebellum, medulla oblongata and one cubic centimetre section from each of the cranial, lateral and caudal cerebrum. Brain samples should be submitted in 50 % glycerol-saline in a leak-proof bottle. If preservative is not available, brains may be stored in empty bottles and submitted without delay on ice by courier service, or hand-delivered to the laboratory.

Brain samples should be submitted in 50 % glycerol-saline

Rabies can be diagnosed from any part of the brain, the spinal cord, peripheral nerves and salivary glands. However, the test is most reliable using the thalamus, pons medulla oblongata, hippocampus and cerebellum (Plates 21–22) (Bingham & Van der Merwe in press).

The specimen bottles should each be enclosed separately in a plastic packet and then tied off together in another plastic packet. The parcel containing the bottles should contain copious quantities of shredded paper, or other absorbent material, to absorb any fluid that may leak from the bottles (Plate 28). Accurate documentation on the correct submission form and a complete case history are extremely important for guiding laboratory interpretation, follow-up actions and control measures. All specimens submitted to a laboratory should be boldly marked as "Suspected rabies".

The head and carcass should be burnt or buried in a plastic bag. After removal of a brain all equipment and work surfaces must be thoroughly disinfected and cleaned before removing the brain of another animal. All disposable clothing should be incinerated while reusable protective wear must be disinfected or autoclaved before washing.

Plate18: Basic equipment needed for removing a brain

Plate 19: In large animals saw across just in front of the base of the horns

Plate 20: This incision exposes the brain

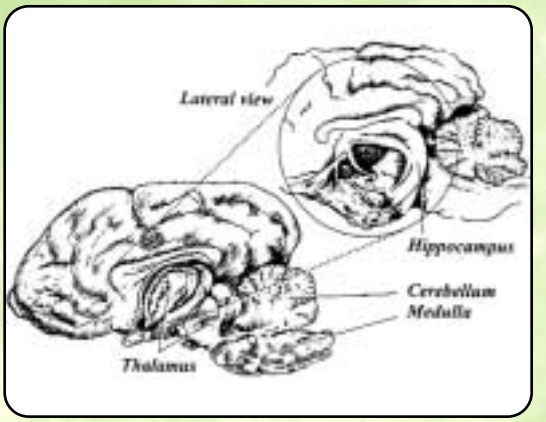

Plate 21: Schematic presentation of the anatomy of the brain

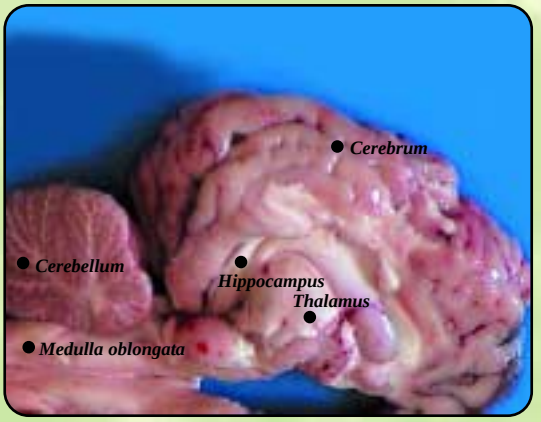

Plate 22: Lateral view of the anatomy of the brain

Plate 23: Alternative approach by longitudinal section

Plate 24: The skin is cut down the mid-line to expose the skull. Note the protective gloves being worn by the person removing the dog's brain

Plate 25: The skull is being sawn along the mid-line. Note the protective gloves, visors and overalls being worn by both operators

Plate 26: The skull is opened and the brain is carefully removed using a scissors and forceceps

Plate 27: An animal brain which has been split longitudinally in half

Plate 28: Brain specimens secured in screw cap plastic jar, sealed in two plastic bags, surrounded by sufficient absorbent material and packed in a firm cardboard box

Plate 29: Brain removal during human autopsy. Note the protective equipment being worn by the operators

Reporting procedure and documentation

The results of laboratory tests for rabies must be disseminated as indicated in the diagram below (Fig. 5). All results should preferably be faxed but where this is not possible, results must be communicated by phone and an official letter posted. State veterinarians and the provincial veterinary director will appoint a responsible clerk to maintain a register.

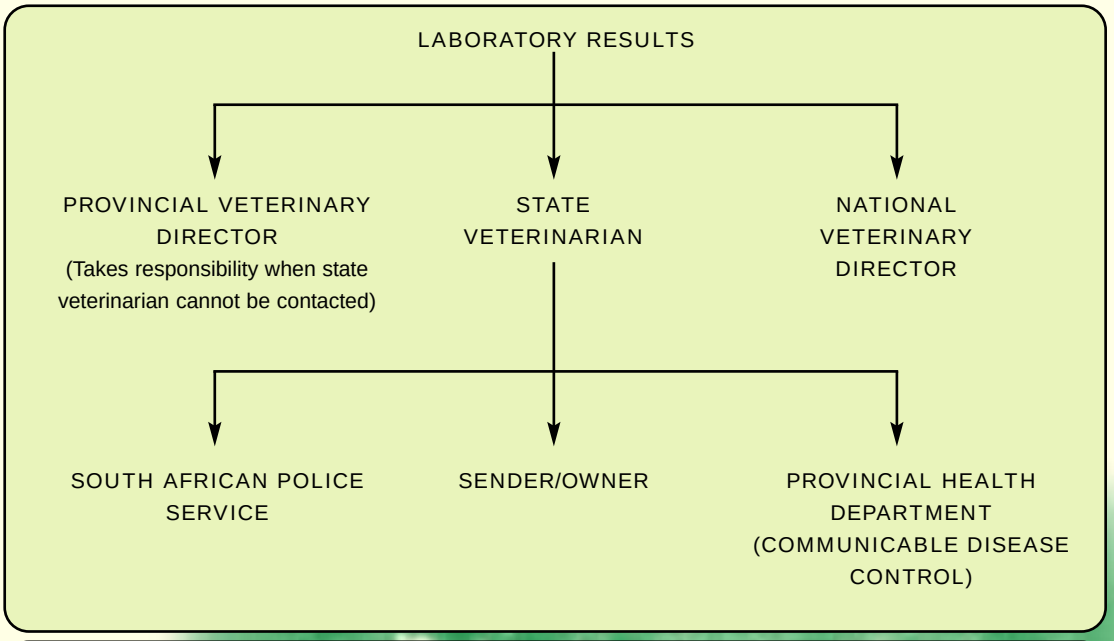

Fig. 5: Distribution of laboratory results

DIRECTORATE VETERINARY SERVICES
RABIES SPECIMEN SUBMISSION FORM

Please send a copy of this form to your local state veterinarian
Complete all sections thoroughly and carefully. If insufficient space, write on reverse
Specimens must be submitted on ice, or in glycerol-saline, in clearly labelled, leak-proof containers and not in formalin

SENDER: NAME | SENDER'S REFERENCE

ADDRESS

PHONE CODE & NUMBER | FAX

OWNER: NAME | PHONE NUMBER

ADDRESS

SPECIMEN ORIGIN: FARM NAME AND ADDRESS

FARM NUMBER | GRID REFERENCE

STATE VET. AREA | MAGISTERIAL DISTRICT

SPECIES: COMMON NAME | AGE (IF DOG)

SCIENTIFIC NAME:

CLINICAL SIGNS AND HISTORY: DATE OF DEATH | DURATION OF SIGNS

CLINICAL SIGNS AND HISTORY

VACCINATION HISTORY: (If known) DATES OF VACCINATIONS

Mark with "X" if: NOT VACCINATED | VACCINATION UNCERTAIN | VACCINATED BUT DATE UNCERTAIN

HUMAN CONTACTS:

NONE | DON'T KNOW

NUMBER OF CONTACTS			
BITE	SALIVA	HANDLING	OTHER (SPECIFY)

NAME OF CONTACT	ADDRESS	PHONE CODE AND NUMBER

RESPONSIBLE PERSON: (PRINT) | RANK/OCCUPATION

DATE: | SIGNATURE:

OFFICIAL | RABIES # | LAB # | DATED REC'D | TIME REC'D

DATE OF TEST | TIME OF TEST | DATE FAXED | TIME FAXED

COMMENT:

FAT RESULT

Fig. 6: Rabies specimen submission form

RABIES IN HUMANS

EPIDEMIOLOGY OF HUMAN RABIES

Rabies is an ongoing scourge exacting an unnecessarily large toll on human life. It is estimated to cause 30 000 deaths each year in India alone, while the World Health Organization estimates that between 35 000 and 50 000 rabies deaths occur worldwide annually.[43,44,45] Rabies virus is transmitted *via* the saliva of infected animals and has the highest case fatality rate of any known human infection if the disease has manifested. Once the virus has entered the central nervous system of the host, the resulting encephalomyelitis is fatal. Fortunately the availability of efficacious and safe vaccines and immunoglobulin has prevented many fatalities and almost 10 million people receive post-exposure treatment annually after potential rabies exposure, mostly following dog bites.

Rabies and the developing world

Rabies remains endemic throughout the world except for certain Western European countries and a number of islands, but more than 99 % of all human rabies deaths occur in the poorest developing countries.[46,47] Recorded deaths in developing countries probably provide a gross underestimate of the true situation as these areas generally have notoriously poor notification systems. Reasons underlying the preponderance of rabies cases in poor countries are complex but include opposing needs and limited resources for veterinary control, the prohibitive cost of post-exposure vaccine and immunoglobulin, poorly informed communities, inadequately trained health and veterinary staff, and inaccessibility of health-care facilities.[48,49,50] The use of nonsterile needles and syringes for rabies vaccination also poses a risk for transmission of blood-borne pathogens, such as HIV, hepatitis B and hepatitis C in many of these countries.

Of considerable concern is the re-emerging status of rabies in Africa.[51] This trend has been attributed to rapid population growth with parallel dog population growth directed by security concerns, for example a growth of 4,7 % in the dog population in Zimbabwe between 1954 to 1986, mobility of human populations, particularly political refugees, high rates of urbanisation and a disintegration of veterinary rabies control.[52,53,54] The latter is of particular importance as dog rabies vaccination is a more cost-effective measure for preventing human rabies than reliance on post-exposure prophylaxis for dog-bite victims.[55]

Distribution in South Africa

During the first half of the 20th century most human rabies cases in South Africa resulted from herpestid, particularly yellow mongoose, bites in the central plateau areas. However, following the introduction of canid virus into Limpopo Province in the late 1940s, and later into KwaZulu-Natal in 1961, dogs became the most important source of human infection. In recent years (Table 9) the vast majority of South African human rabies cases have followed bites from infected dogs in KwaZulu-Natal.[56,57] Most victims have been children under the age of 10 years. Children are particularly vulnerable because of their height, inquisitive nature, interest in animals and inability to protect themselves.

Surveillance of human rabies is poor in many parts of South Africa and it is likely that the situation may be worse than that reflected by official notifications. A careful history taken from a victim's family has demonstrated a high sensitivity for diagnosing rabies in other African settings and may prove a useful approach in areas suspected of having rabies cases that have not been notified.[58]

Canine vaccine delivery targeted to highest risk populations and broad intersectoral collaboration are believed to have contributed to the marked reduction in human rabies in KwaZulu-Natal during the latter part of the 1990s.[59,60]

Transmission to humans

Practically all human rabies cases result from viral introduction through broken skin into flesh by the bite of a rabies infected mammal. Virus is usually present in the saliva of the affected animal during clinical disease but

TABLE 9: Laboratory-confirmed human rabies cases in South Africa, 1984 to 2000

Year	Kwa-Zulu-Natal	Eastern Cape	Mpuma-langa	Northern Cape	Free State	North West	Limpopo Province	Western Cape	Gau-teng	Total
1984	10	0	0	0	4	0	0	0	0	14
1985	6	0	1	0	0	0	0	0	0	7
1986	7	0	1	0	0	1	0	0	0	9
1987	16	1	0	1	0	0	0	0	0	18
1988	25	1	0	0	2	0	0	0	0	28
1989	10	0	0	0	0	0	0	0	0	10
1990	11	0	0	1	0	0	0	0	0	12
1991	20	0	0	0	0	0	0	0	0	20
1992	22	2	0	0	0	0	0	0	1	25
1993	21	2	0	0	1	0	0	0	0	24
1994	18	1	0	0	0	0	0	0	0	19
1995	29	0	0	0	0	0	0	0	0	29
1996	12	2	0	0	0	0	0	0	0	14
1997	3	2	0	0	0	1	0	0	0	6
1998	5	1	0	0	0	0	0	0	0	6
1999	4	2	0	1	0	0	0	0	0	7
2000	7	1	0	0	0	1	0	0	0	9
Total	**226**	**15**	**2**	**3**	**7**	**3**	**0**	**0**	**1**	**257**

excretion may be intermittent. Experimental demonstration of virus in salivary glands or saliva several days before the onset of the disease in dogs and in cats, is cause for concern.[61,62,63] Success of transmission depends on a number of factors, particularly the number of bites, viral load, depth of bites, their location and presence or absence of clothing. Record review of untreated human cases suggests that the infection rates vary from virtually 100 % with a short incubation period following severe, multiple bites to the head and neck, to 0,5 % for bleeding, superficial bites through clothing.[64]

A number of disconcerting additional transmission routes have been described.[46,65,66] Aerosol transmission has been documented in laboratory staff working with rabies virus and this route has also been suggested for individual cases where rabies was acquired in caves heavily infested with bats. Because rabies is not a viraemic disease, it is not spread through occupational exposure to blood in health-care settings through surgical instrument or needle pricks, or blood transfusion.

An additional transmission route has emerged in recent years with the transplantation of corneas from infected cadavers.[67] The possibility of transmission from an infected patient to family members has also been postulated in one Ethiopian study.[68]

Chaos frequently follows slaughtering and consumption of cattle that are subsequently diagnosed as rabid. This practice must be actively discouraged, for despite inactivation of the virus by cooking, the butchering process itself could prove hazardous. It is reassuring that despite many such reports there is no record of human infection as a result of this practice.[68]

The World Health Organization estimates the worldwide, annual number of deaths due to rabies to be between 35 000 and 50 000

As all mammals are susceptible to rabies, any infected mammal could potentially transmit rabies to people. However mice, rats, shrews and monkeys have yet to be incriminated as vectors of rabies in South Africa. Rats and mice, particularly those kept as pets, frequently inflict retaliatory bites on children when cornered and caught. Rabies infection has never been confirmed in birds. Although bats have not been shown to transmit classical rabies in South Africa yet, they may be vectors of other dangerous forms of Lyssaviruses and they do transmit rabies in the Americas.

PREVENTING HUMAN RABIES

Rabies is one of the top 10 global infectious causes of mortality and one of the most amenable to available preventive measures.[69] Primary care providers can play a crucial role in preventing rabies, by providing accurate prevention messages including the avoidance of suspicious animals, immunising people at high risk of rabies exposure, ensuring optimal wound management, and correctly administering immunoglobulin and rabies vaccine after suspected exposure to rabies virus.

Pre-exposure prophylaxis

A recent review found that at current rabies vaccine prices, routine use of pre-exposure vaccination is generally not cost-effective.[70] There are, however, particular high-risk situations where pre-exposure vaccination is cost-effective and it would be negligent not to recommend it. In South Africa the cost of pre-exposure prophylaxis is borne by vaccine recipients or their employers.

Pre-exposure vaccination involves administration of rabies vaccine on days 0, 7 and 28 (or day 21). Variation of a few days in the timing of second and third doses does not, however, affect the immune response. Human diploid cell vaccine (HDCV) and purified Vero cell vaccine (PVCV) in three doses have been shown to be effective.[71] HDCV is preferable for the elicitation of a good immunogenic response. Rabies vaccine induces an active immune response that includes the production of neutralising antibodies. The antibody response requires approximately seven to 10 days to develop and usually persists for at least two years. Single booster doses can either be routinely administered every one to three years depending on the perceived risk of rabies exposure or given on the basis of demonstrated waning of serum virus-neutralising antibody levels to below 0,5 IU/ml . Intramuscular HDCV provides high levels of neutralising serum antibody at two years post-vaccination.[72]

The intramuscular route should always be used whenever the vaccine recipient is taking chloroquine or is immunocompromised. As it has repeatedly been found that people with intact immune systems experience a satisfactory response to approved vaccines, it is only necessary to demonstrate an adequate serological response in immunocompromised individuals or those working with live virus and those who are blood donors for rabies vaccines products.[73,74] Rabies-neutralising antibodies are analysed by a neutralisation test. A booster vaccination should be administered three days later to all vaccinated individuals bitten by rabid animals irrespective of their antibody titres and they should not receive immunoglobulin.[41]

Although a two-dose schedule (days 0 and 28) has also been investigated, results have confirmed the superior long-term immunogenicity of the three-dose approach.[75]

High-risk occupational groups

People with increased occupational risk of exposure to infection, such as veterinary staff, wildlife handlers, laboratory personnel working with rabies virus or animal welfare staff, should receive pre-exposure prophylaxis. This should preferably be by administration of three doses of vaccine into the deltoid muscle on days 0, 7 and 28.[71]

Because the virus may be present in the saliva of patients with rabies, there is a risk of health worker exposure.[76] Therefore pre-exposure vaccination should be offered to all members of medical teams treating patients suffering from rabies.[77] Surveillance staff responsible for bleeding dogs as a plague indicator species in rabies endemic areas are another occupational group that clearly merit pre-exposure vaccination.

Children in rabies-endemic areas

Routine vaccination could be beneficial for children in countries where rabies is enzootic. As children are particularly vulnerable and experience a higher frequency of bites to the head and neck as a result of their inclination to approach animals, there are advocates for inclusion of rabies vaccine in the Childhood Expanded Programme on Immunisation in rabies-endemic areas.[78] A controlled trial in Vietnamese children showed that combining purified rabies Vero cell vaccine with diphtheria, tetanus, whole-cell pertussis and inactivated poliomyelitis vaccine and administering these vaccines at two, three and four months, or alternatively at two and four months, resulted in all infants developing protective antibody concentrations against all five diseases with no serious adverse events.[79] A larger trial, also in Vietnamese infants, comparing intramuscular and intradermal vaccine administration demonstrated that both routes provided acceptable protective antibody titres (³ 0,5 IU/ml).[80]

Unfortunately current vaccine costs prohibit routine childhood vaccination against rabies. There is, however, a clear mandate for children to be formally educated on rabies transmission, the disease and prevention, particularly as educational interventions have proven effective in reducing the number of dog bites in children.[81,82]

Rabies and travellers

Rabies is an important disease for the burgeoning travelling community. In the United States, for example, 37 % of people dying from rabies are infected in foreign countries.[22] Canine and feline rabies are endemic in the developing countries of Asia, Africa and South America. This poses a risk to travellers, particularly in the backpacking or adventure category. Unfortunately discussion on reducing rabies risk is one of the topics often neglected by travel medicine advisors during pre-travel consultations.[83,84] Travellers to these areas must be educated concerning their risk of rabies exposure and informed regarding local reservoir species so that they can avoid contact with potentially rabid animals. They should also receive instruction on correct wound cleaning, the importance of correct post-exposure treatment with vaccine and immunoglobulin, and their availability at the traveller's destination.

Travellers with potential occupational exposure should certainly receive appropriate three-dose pre-exposure vaccination and this should also be considered for all long-term expatriate residents in high-risk areas, particularly those living in close proximity to the local population and their dogs.[85]

Debate continues over the merit of administering routine pre-exposure vaccination for other categories of international travellers to rabies-endemic countries.[71,86,87] The rate of animal bite exposure in international travellers has been estimated to be two to four people per thousand and in the majority of these cases there is some concern about rabies infection. However, where correct post-exposure therapy is available, this is effective in preventing rabies and pre-exposure prophylaxis is of less importance. Although local reactions, such as pain, swelling and itching, occur in most vaccine recipients and mild systemic reactions, such as headache, nausea, muscle aches, abdominal pain and dizziness are reported by 5 to 40 % of people vaccinated, serious adverse events are rare. The major constraint against routine administration remains the cost of pre-exposure vaccination. The cost, for example, of preventing rabies in United States tourists to Thailand by routine pre-exposure vaccination was estimated at between US$ 40 to 50 million per rabies death prevented.[88]

On the other hand, areas where stray dogs are a problem are often the specific areas where canine rabies is endemic, and efficacious vaccines and immunoglobulin are not available.

Practically all human rabies cases result from introduction of virus through broken skin by the bite of a rabies infected mammal

The death of a human from rabies should be viewed as a health system failure

Fraudulent vaccines, nerve-tissue derived vaccines and equine immunoglobulin commonly associated with severe adverse reactions may be used in these countries.[89] In certain areas tourists are frequently exposed to dogs, for example a survey of European travellers in Thailand found that in less than a three week period 1,3 % of tourists experienced dog bites and 8,9 % dog licks.[90] Advantages of pre-exposure rabies vaccination include requiring only two boosters, on days 0 and 3, if there is an exposure, no need for immunoglobulin, and diminished concern about inadequate therapy and vaccine failure.

Advice and vaccination should be adapted to the individual needs and exposure risks of travellers, taking into account the area visited, local rabies epidemiology, mode of travel, and underlying medical conditions and medication. Travellers who are immunocompromised by disease or medication are a group deserving particular attention. They should ideally postpone pre-exposure vaccination and consider avoiding activities for which rabies pre-exposure prophylaxis is indicated. When this is not possible, immunocompromised individuals who are at risk of rabies exposure should be vaccinated and their antibody titres checked post-vaccination.[91]

MANAGEMENT OF HUMANS EXPOSED TO RABIES

The death of a person from rabies should be viewed as a health system failure. This contention is supported by a review of failed post-exposure treatment in Thailand, which found that delays, failure to provide post-exposure treatment or deviations from the recommended regimen contributed directly to the deaths of young children.[92] Findings from studies in South Africa and Thailand have highlighted deficiencies in health workers' knowledge on managing suspected rabies exposures.[49, 93]

It is therefore recommended that a confidential enquiry routinely be conducted to establish avoidable factors which may have contributed to the death.

Although no controlled human trial of rabies post-exposure prophylaxis utilising wound treatment, immunoglobulin and vaccination has been conducted and such a study would be unethical, extensive global experience provides convincing support for this approach.[94,95,96]

There is a critical need for veterinary and health workers to be adequately trained on assessing rabies risk and appropriate response. It is also imperative that health and veterinary workers involved in managing human cases with potential exposure to rabies virus remain in close communication so that patient management can be modified by data about the source animal. The health worker is obliged to make contact with the responsible state veterinarian. Laboratory-confirmed human rabies and exposure to proven rabid animals is notifiable in South Africa.

Assessing risk after exposure

Important factors that assist decisions on treatment, include details of the nature of the contact and the implicated animal's behaviour.[97] It is imperative that prophylaxis be instituted as soon as possible after exposure to rabies virus, even before there is laboratory confirmation of rabies in the animal.[98] Ideally post-exposure prophylaxis would be administered to all bite victims but in many countries, including South Africa, post-exposure prophylaxis is performed at the Department of Health’s expense and current vaccine prices preclude this approach. The approach adopted in South Africa focuses on providing prophylaxis to those individuals at high risk of rabies infection but patients who remain concerned for their own safety should be encouraged to receive vaccination at their own expense.

Judgement on whether to initiate post-exposure treatment is assisted by an estimation of risk based on the following criteria, with a high risk of exposure necessitating vaccination:[41]

- type of contact (Fig. 7, page 41)
- incidence of rabies in the animal's district of origin
- animal's behaviour (any abnormal behaviour could indicate rabies)
- species of animal involved (Table 2, page 10)

- vaccination status of animal (if not vaccinated, then higher risk)
- results of rabies laboratory testing (a negative result from an approved rabies veterinary laboratory indicates a lower risk)
- when the biting animal cannot be traced, caught or identified, or the brain is not available for laboratory examination, it should be assumed that the animal was rabid.

The most important criteria are the non-availability for assessment of the biting animal in an endemic area, abnormal behaviour in the animal and type of contact. A diagrammatic representation of the recommended approach is given in Fig. 7 (page 41). If in doubt, it is preferable to vaccinate.

Management of the wound

To reduce the risk of rabies, it is important that thorough cleaning of the bite wound is initiated as soon as possible. The bite wound should be copiously flushed immediately for 5 to 10 minutes with water, while irrigation of deep puncture wounds, for example following a feline bite, should be performed using a syringe. If antiseptic is available, for example a 1 in 20 dilution of 5 % chlorhexidine in water, then this may be added to the water. Bleeding should be encouraged and wound suturing should preferably be avoided or delayed.[99] Applying an iodine-based disinfectant or 70 % alcohol to the wound after flushing is also indicated, as these chemicals inactivate rabies virus.[69]

To reduce the risk of rabies, it is important that thorough cleaning of the bite wound is initiated as soon as possible

To lessen the risk of bacterial infection, antibiotic therapy should be considered. As most infections following mammalian bites comprise multiple pathogens, with mixed aerobic and anaerobic species, it is essential that therapy should be selected appropriately.[100,101,102] In addition to the usual aerobic and anaerobic bacteria, important potential pathogens include *Pasteurella multocida*, which is isolated in 20 to 30 % of dog-bite wounds and can cause serious infection with severe complications, and *Capnocytophaga canimorsus*, which can induce sepsis following apparently minor bites to previously healthy individuals.[103,104]

The value of antibiotic prophylaxis is hotly debated, with certain clinicians advocating routine prophylactic antibiotic use while others restrict use to high-risk wounds. High-risk wounds include full-thickness skin wounds, wounds requiring surgical debridement and wounds in patients more than 50 years of age. An informative review spanning nearly 30 years found that general use of prophylactic oral antibiotics reduced dog-bite bacterial infection rates by 50 % and infection rates of bites to the hand by 75 %.[105] Unfortunately, as many as 25 dog-bite victims would need to be treated with prophylactic antibiotic therapy in a developed country setting, to prevent a single bacterial infection and therefore prophylactic use is uneconomical.[106] The potential for wound infection in a developing country, such as South Africa, where immediate access to health care is not always guaranteed, environmental contamination is common and immunocompromise is prevalent, is much greater. In most cases therefore appropriate antibiotics to cover aerobic and anaerobic infections should accompany thorough wound cleaning.[107,108]

The administration of antirabies immunoglobulin complements rabies vaccination in situations where viral transmission may have occurred

Antibiotic therapy is modified in line with laboratory culture and susceptibility results when a patient requires hospitalisation as a result of severe local or systemic sepsis. Additional indications for hospitalisation include penetrating injuries of tendons, joints or the central nervous system, severe bites to hands or head and neck, patients requiring reconstructive plastic surgery and patients with certain high-risk medical conditions, for example diabetes, asplenia and peripheral vascular disease.

To prevent tetanus, a booster dose of tetanus toxoid (TT) adsorbed vaccine (0,5 ml intramuscular) should be given at the time of wound treatment in individuals who have completed a primary course of tetanus vaccination. Most adult tetanus cases occur in people who do not have a vaccination history.[109] However, the benefits of regular tetanus boosting throughout adult life are insufficient to justify the costs of an administration programme and potential sensitivity reactions.[110]

Human antirabies immunoglobulin

The administration of antirabies immunoglobulin (RIG) complements rabies vaccination in situations where viral transmission may have occurred, as production of neutralising antibodies takes seven to 10 days after vaccination. RIG is safe and provides rapid passive immunity that persists with a half-life of approximately three weeks.[111,112]

The human RIG currently used in South Africa is produced by fractionation of pooled serum from immunised people. The introduction of human RIG proved a valuable replacement to the previously used antirabies serum prepared in horses. Although the latter was effective and is still used in many developing countries, it may induce serum sickness. To ensure potency, it is essential that RIG be maintained between 2 and 8 °C during handling and storage. All patients who have received RIG should be observed for an hour thereafter. An emergency pack for treating anaphylaxis should be available.

The dosage of human RIG currently available in South Africa is 20 International Units (IU) per kg body-mass.[73] RIG is supplied in 2 ml ampoules with a virus-neutralising antibody content of 300 IU. Preferably the complete dose of RIG should be infiltrated into the depth of the wound or tissue immediately adjacent to the wound. Where this is not anatomically possible, the remaining RIG may be injected intramuscularly. Although this RIG has traditionally been administered into the buttock, recent disturbing evidence of low-circulating rabies-neutralising antibodies following RIG injection into gluteal fat suggests that any remaining RIG should rather be administered into the deltoid muscle.[113] With multiple wounds, where the dose of RIG based on body mass is insufficient to infiltrate all wounds, the dose may be diluted up to 50 % in saline to allow infiltration of all wounds. Failure to infiltrate all wounds is believed to have contributed to the deaths of a number of children.[114]

RIG is administered on the day of initial patient presentation, traditionally referred to as day 0, with the first dose of vaccine but at separate injection sites. This is irrespective of the time elapsed since exposure, which represents a departure from the previous recommendation that RIG should only be given to patients presenting within a week of exposure.[97] If RIG is not available when vaccination is initiated, it may be administered up to day 7 after vaccination. RIG administration is not recommended prior to vaccination, nor is it currently recommended for individuals who have received pre-exposure vaccination as it is believed that RIG may interfere with the rapid anamnestic response to vaccine.

Rabies vaccines

Rabies vaccine, when given post-exposure, induces immunity within seven to 10 days. The cell-culture vaccines currently registered for use in South Africa, human diploid cell vaccine (HDCV) and purified Vero-cell rabies vaccine (PVCV), are highly purified and inactivated and meet the WHO potency standard of greater than or equal to 2,5 IU per dose.

All persons judged to be at high risk for rabies exposure should be vaccinated, with treatment being initiated as soon as possible even if there has been a delay in presentation to the health service. The treatment schedules presented here are based on the most recent WHO recommendations, and are valid for the cell-culture vaccines registered in South Africa. However, it must be emphasised that the Essen intramuscular regimen is the preferred schedule and administration route, and expert advice should be sought before using an alternative regimen. The vaccination schedule may be discontinued if the suspected source animal remains healthy for 10 days after the exposure or if an approved veterinary laboratory reports the brain specimen from an euthanised animal as negative.[41]

TABLE 10: WHO-approved post-exposure rabies vaccination regimens

Regimen	Summary	Day (number of sites)						
		0	3	7	14	21	28	90
Essen (IM 1 x 5)	One dose into deltoid on each of five visits	(1)	(1)	(1)	(1)		(1)	
Zagreb (IM 2-1-1)	Double dose IM (1 dose at 2 sites) on day 0, followed by single doses on days 7 and 21	(2)		(1)		(1)		
Thai Red Cross (ID 2-2-2-0-1-1)	Double 0,1ml dose ID (1 dose at 2 sites) on days 0, 3, 7 followed by single doses on days 28 and 90	(2)	(2)	(2)			(1)	(1)
Oxford (ID 8-0-4-0-1-1)	Eight 0,1ml doses in separate sites on day 0, then four 0,1ml doses on day 7 (separate sites), then single doses at 28 and 90 days	(8)		(4)			(1)	(1)

The *standard*, or *Essen schedule* (Table 10) of vaccination, is the recommended schedule and may be used in all types of exposure to infection requiring immunisation. A single dose of vaccine is administered intramuscularly into the deltoid of adults or into the anterolateral thigh of infants or children less than one year of age on days 0, 3, 7, 14 and 28 of treatment. Vaccine should not be injected into the buttock as fat depots may interfere with vaccine uptake. Some authorities advocate giving a single dose in both deltoids on day 0, i.e. doubling the first dose of vaccine, in a number of circumstances. These include situations where there has been a delay of 48 hours or more in starting treatment, RIG was administered before the first dose of vaccine, underlying chronic medical conditions such as cirrhosis or immunosuppression exist, or victims are taking chloroquine.[64]

On day 14, people who have received any of the recommended cell culture vaccines on days 0, 3 and 7 should have protective levels of virus-neutralising antibodies.[115,116,117] Although exclusion of the fifth dose of vaccine has been suggested, this approach has been criticised because persistency of antibody response has not been investigated, nor has this regimen been compared against the standard schedule.[118,119]

Persons who have received pre-exposure vaccination should be given only two booster doses of vaccine on days 0 and 3 (with no RIG) if bitten by a suspect rabid animal.

A second intramuscular regimen approved by WHO is the 2-1-1 *Zagreb* intramuscular regimen (Table 10). This abbreviated schedule is usually advocated for use only in risk category 2 (not category 3) exposure victims. This approach aims to induce a rapid endogenous immune response. The use of RIG simultaneously with this schedule is controversial although there is no

Preferably the complete dose of RIG should be infiltrated into the depth of the wound or tissue immediately adjacent to the wound

evidence that immunoglobulin given in this way suppresses the immunogenicity of rabies vaccine.[97,120] Two doses of vaccine are given intramuscularly on day 0, into both deltoids in adults or anterolateral thighs in infants and children less than one year, and this is followed by single intramuscular doses on days 7 and 21.

More recently multisite intradermal regimens with cell-culture vaccines have demonstrated great effectiveness in specific situations while being more affordable.[97,121] Both the *Thai Red Cross* and *Warrell's Oxford multiple site* intradermal schedules are highly immunogenic without notable suppression from RIG administration on day 0 (Table 10).[114] The Thai Red Cross two-site intradermal method consists of one intradermal dose at two sites on days 0, 3, 7, and a single dose on days 30 and 90. The 8-site intradermal method consists of 1 ml HDCV or purified chick embryo vaccine divided between 8 intradermal sites on day 0, i.e. deltoids, anterior thighs, suprascapular and lower quadrant of abdomen bilaterally, and then 0,1 ml intradermally administered at four sites on day 7, i.e. bilaterally into deltoids and thighs, and then single 0,1 ml intradermal doses on day 30 and day 90.

Although the intradermal schedule has proven effective it should not be used in immunocompromised individuals, or people using chloroquine antimalarials.[122] As South Africa has not had a tradition of administering any vaccines by the intradermal route there are few health workers trained in this procedure. With the switch to intradermal BCG this situation will change, making these latter two routes of administration more acceptable.

The two cell-culture vaccines available in South Africa (HDCV and PVCV) can be used interchangeably.[123]

Unlike earlier central nervous system derived vaccines, for example Semple and suckling mouse-brain products, HDCV and PVCV, have an excellent safety profile. The former vaccines are still widely used in developing countries because of their affordability. However, their uncertain immunogenicity and accompanying risk of severe neurological adverse reactions, with a frequency of between 1 in 120 to 1 in 1 200 vaccine recipients, make them a poor option.[124,125,126]

Adverse events to HDCV, PVCV, purified chick embryo and purified duck embryo vaccines are uncommon and severe reactions are exceedingly rare with these vaccines.[127,128,129] Single cases of peripheral polyneuropathy, and other local and systemic reactions such as itchiness, fever, urticaria and arthralgia are experienced in a very small proportion of patients.[130,131,132,133] Rabies vaccine has been extensively used in pregnancy without any adverse sequelae.[134] Any adverse events should be notified to the relevant provincial and national officials for full investigation.

It is essential that the cold chain be maintained with rabies vaccine kept between 2 and 8 °C during all handling and storage. Vaccine must be used on the day opened. Unused vaccine must be discarded. All patients should be observed for an hour after receiving vaccine and an emergency pack for treating anaphylaxis should be available.

The flow diagram in Fig. 7 provides a useful approach to the person with a suspected rabies exposure. This should be reproduced and made available in all clinics and hospital casualty units in rabies endemic areas.

1. Assess the exposure category (see B below)
2. Record full details and history of the incident
3. Proceed as indicated in the flow chart

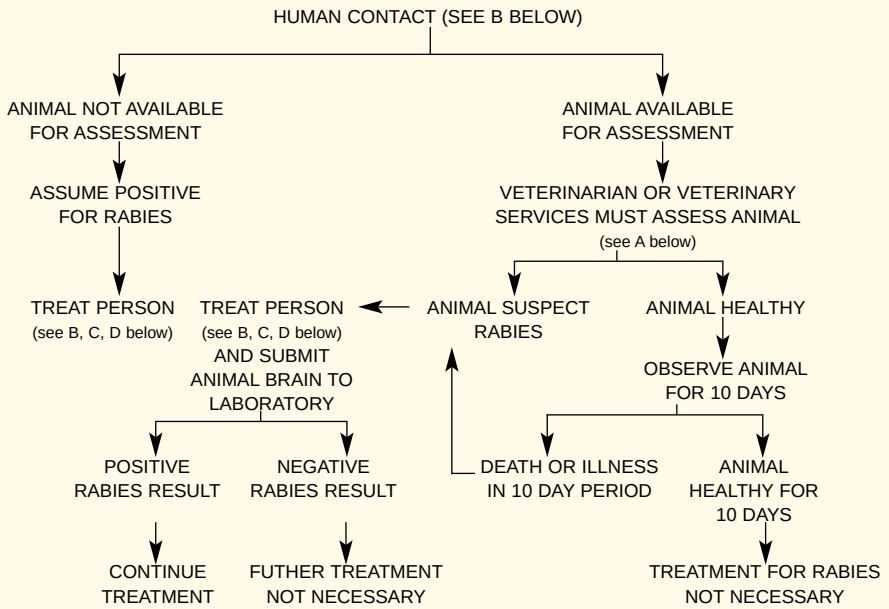

A. ANIMAL ASSESSMENT

The following aspects must be considered:

1. **Vaccination:** tangible proof of current rabies vaccination status (dog or cat) must be obtained. See constraints on pages 51 and 52
2. **Behavioural changes:** all aspects must be considered
3. **Possible exposure:** any known incident during the previous few months
4. **Rabies endemicity:** entire RSA is rabies endemic but current incidence and prevalence are important
5. **Provocation:** was the animal's reaction due to provocation?
6. **Stray (unsupervised animals):** this history may be unreliable

B. CATEGORIES OF RABIES EXPOSURE

Risk Cat.	Type of exposure	Action to be taken
1	Touching/feeding animal Licking of intact skin	None if case history is reliable If history is not reliable, treat as for category 2
2	Nibbling of uncovered skin Superficial scratch without bleeding Licking of broken skin	Apply wound treatment Administer vaccine Do not administer antirabies immunoglobulin Stop vaccination if animal is rabies negative on laboratory test, or remains healthy after 10 days observation
3	Bites/scratches which penetrate the skin and draw blood Licking of mucous membranes	Apply wound treatment Administer vaccine Administer antirabies immunoglobulin Administer anti-tetanus and antibiotic treatment Stop vaccination if animal is rabies negative on laboratory test, or remains healthy after 10 days observation

C. WOUND TREATMENT

1. Wash wound thoroughly under running water with soap, or saline or chlorhexidine, or cetrimide, for 5 minutes
2. Apply disinfectant, e.g. Betadine or aqueous iodine (Zepharin)
3. Do not suture or apply compressive bandages
4. Administer anti-tetanus treatment and antibiotics if necessary

D. ANTIRABIES TREATMENT (CATEGORY 3)

1. Unimmunised patient: infiltrate immunoglobulin (20 IU/kg) on day 0 into and around wound, with remainder into gluteus. Inject single dose vaccine into deltoid muscle on days 0, 3, 7, 14 and 28
2 Previously immunised patient: inject single dose vaccine into deltoid muscle on days 0 and 3
3. Late presentation (more than 48 hours after exposure): inject double dose vaccination (one dose into each deltoid) on day 0, single dose on day 3, 7,14, 28

Fig. 7: Actions following human exposure to an animal bite

Diagnosing human rabies

The clinical features of rabies, particularly in the terminal stages of the disease, reflect the neural nature of the pathology. Conditions that cause an acute or subacute encephalopathic picture may be confused with rabies, therefore a definitive diagnosis is important to identify conditions amenable to therapy.

Clinical picture

The highly variable incubation period of human rabies is a phenomenon that is not understood completely.[69,135] Deep or multiple bites, particularly to the head and neck, may result in an incubation period of less than two weeks. However, incubation periods exceeding two years are also well documented.[136] Generally incubation periods seldom exceed 90 days and usually range between two and eight weeks, with 90 % being less than six months.

Nonspecific prodromal features last for one to four days and include fever, headache, malaise and nonspecific gastrointestinal symptoms. Neuropsychiatric symptoms, including irritability, depression, anxiety and insomnia, may be present. Sensory symptoms at the bite site, which has usually healed, are commonly experienced and may include intense pruritis, paraesthesia or pain.

Following the nonspecific prodromal symptoms is a period lasting one to six days during which neurological signs and behavioural symptoms dominate. These include agitation and restlessness, incoherent or illogical speech and psychomotor hyperactivity, including episodic terror, hallucinations and manic behaviour, or generalised convulsions that may be triggered by various sensory stimuli. A remarkable and tragic feature distinguishing rabies from other acute encephalopathic neurological conditions are the lucid periods during which patients are well orientated.

As the disease continues there is progressive loss of neurological function. This is characterised by an inability to swallow (dysphagia), speech involvement (dysarthria), hypersalivation and spasms of the involuntary musculature with resultant classical hydrophobia, or fear of water.[136] Aerophobia, following exposure to air movement, is another typical symptom. Focal neurological abnormalities are surprisingly rare, while tachycardia and hyperpyrexia are more frequent. Convulsions and muscular spasms become prominent as the patient's mental state deteriorates with progressive disorientation, hallucinations, confusion and coma. Other clinical presentations include priapism, excessive libido and spontaneous pneumomediastinum.[137,138,139] Patients usually die within five days of disease onset as a result of progressive cardio-respiratory failure, often preceded by obvious central nervous system respiratory irregularity. Progression to a nonreactive electroencephalograph (EEG) or sudden demise during a generalised seizure are common terminal events.

Occasionally the agitated phase is absent and progressive paralysis as a result of spinal cord affectation is the prominent feature.[140] This may be asymmetrical, particularly affecting the limb that was bitten, or may mimic acute flaccid paralysis with symmetrical ascending paralysis and sphincter involvement but with accompanying sensory disturbance. Death from respiratory and bulbar paralysis in this form of rabies usually follows a longer period of clinical illness than seen with furious rabies.

Common complications include respiratory arrest, pneumonitis, hypoxia because of ventilation-perfusion abnormalities, cardiac arrhythmia, interstitial myocarditis, posterior pituitary disorders, internal hydrocephalus and gastrointestinal bleeding.

Although there have been reports of human survival despite clinical disease, less than half a dozen are accepted as authentic, and intensive supportive hospital care appears to have been an essential element in each of these cases.[141,142,143] In South Africa and similar developing countries where medical attention is usually sought late and sophisticated intensive care facilities are not available, most patients succumb within one to three days of hospital admission.[136]

TABLE 11: Differential diagnosis of rabies in humans (adapted from Warrell[140])

- Hysterical pseudo-hydrophobia
- Tetanus
- Encephalitides, including other viral infections
- Delirium tremens
- Various chemical intoxications
- Postvaccinal encephalomyelitis
- Behavioural disorders, including acute psychiatric presentations
- Typhoid fever
- Poliomyelitis
- Acute flaccid paralysis

Confirming rabies in humans

The clinical picture is almost definitive in rabies endemic areas. A history of contact with an animal proven to be rabid makes the diagnosis more reliable. There are two reasons for establishing a definite diagnosis of rabies prior to demise. Firstly, the prognosis is so devastatingly poor that relatives may demand, and deserve, a definite diagnosis. Secondly, it would be negligent to withhold therapy for another treatable condition if rabies was not the cause of the illness.

No laboratory test currently exists to diagnose rabies during the incubation period. Even after the onset of clinical signs, laboratory diagnosis is not simple and negative results do not preclude rabies. It is therefore often necessary to perform complementary tests on different specimens or even to repeat tests.[144]

Spread of virus from the brain in nerve fibres to the eye and nerve networks around hair follicles, may allow detection of antigen by fluorescent antibody testing in corneal impression smears or nuchal skin biopsies.[26] For preparation, impression smears require only air drying before being wrapped in tissue paper, while skin biopsies should be refrigerated without preservatives before being dispatched to the National Institute for Communicable Diseases.[64]

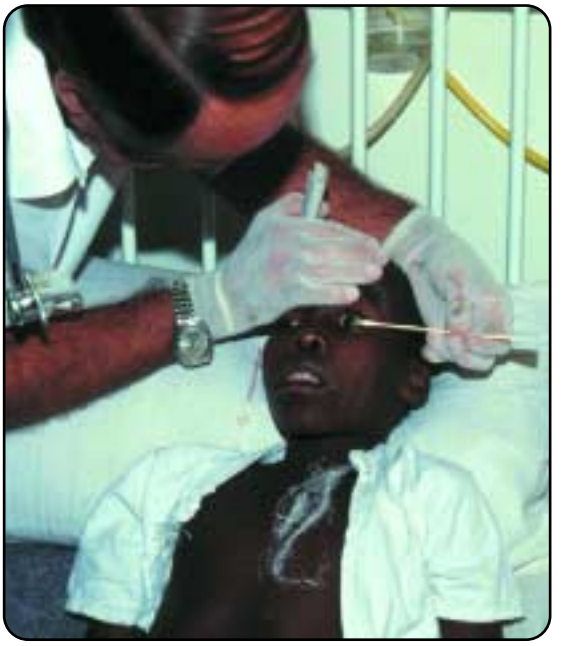

Plate 30: The collection of a corneal scraping to assist in the antemortem diagnosis of rabies

Saliva and cerebrospinal fluid (CSF) specimens may also be submitted, although these frequently generate false negative results. CSF serology is particularly problematic, as it only becomes positive a number of days after symptom onset. Detection of antibody in the CSF does, however,

A remarkable and tragic feature distinguishing rabies from other acute encephalopathic neurological conditions is lucid periods during which the patients are well orientated

confirm rabies infection because vaccine-induced antibody does not penetrate the blood-brain barrier. Rabies virus can also occasionally be isolated from CSF.

Serum antibody can only be detected after onset of clinical disease, or seven to 10 days after vaccine administration. An antemortem brain biopsy may rarely be justified to eliminate rabies as a differential diagnosis, for example where herpes encephalitis is suspected.[64] Histopathological examination of brain sections for the presence of viral intracyptoplasmic inclusions in neurons, the Negri bodies, is a painstaking procedure and often unreliable. Fluorescent antibody and immunoperoxidase tests using rabies virus specific antibodies are reliable techniques. Polymerase chain reaction (PCR) to detect rabies virus DNA in CSF has proven valuable in confirming diagnosis. All human specimens for rabies diagnosis in South Africa should be submitted to the National Institute for Communicable Diseases, where there is considerable expertise in rabies diagnosis.

If diagnosis is not confirmed prior to death, then postmortem diagnosis should be made. Medical practitioners who will be responsible for performing autopsies should receive standard pre-exposure vaccination against rabies and take careful infection control precautions when obtaining specimens. These include wearing an impervious gown and apron, gloves and a visor.[145] The ideal postmortem brain specimen is the entire brain, with the two halves preserved separately in 50 % glycero-saline and 10 % buffered neutral formalin in sealed screwtop jars for virological and histological examination, respectively but matched small cubes (1–2 cm) of cerebrum, cerebellum, hippocampus, medulla, thalamus and brainstem stored in a similar way may also be submitted. Necropsy diagnosis can also be done by taking a brain biopsy specimen with a trucut needle inserted through the superior orbital fissure into the cranial cavity.[146] This latter technique has the advantage of avoiding a full necropsy where the deceased's relatives are opposed to it and reduces the number of health personnel exposed.

Careful labelling and packaging in secure rigid secondary, and where possible tertiary, containers full of absorbent material (paper or sawdust) and direct communication with the National Institute of Communicable Diseases are essential before the specimen is dispatched by courier (Plate 29, page 29).

Managing clinical rabies

The almost universally futile nature of clinical rabies management makes it imperative that relatives of the victim be honestly counselled as to the extremely poor prognosis. Every effort must be made to ensure a patient's comfort with adequate sedation, while high-quality supportive care is provided. It should be emphasised that although life-support measures may prolong the clinical course of disease, they are unlikely to result in survival, except on extremely rare occasions.[22,147]

Concerted efforts must be made to ensure that the patient is as comfortable as possible and symptoms alleviated. This includes adequate sedation and pain relief with opioids and anxiolytic treatment, maintenance of nutrition and correction of fluid-electrolyte and acid-base balances, and mechanical respiration.[99] As multiple systems bear the brunt of terminal disease, careful monitoring is necessary. Antiviral drugs, particularly interferon and interferon-inducers, have been employed with little success.[148] Corticosteroid use has not proven effective and antirabies vaccine has no proven benefit in treatment. Intensive nursing care may limit complications, such as bedsores and pneumonia.

Infection control precautions are important for health workers responsible for managing these patients and should include both standard precautions (hand washing, gloves, mask, eye protection or a face shield, gown and plastic apron) and respiratory precautions (isolation in a private room preferably with an extraction fan, wearing respiratory protection and limiting the movement of the patient).[145,149] If a staff member is exposed to potentially contaminated secretions, e.g. patient saliva contamination of a mucous membrane, then they should immediately receive post-exposure treatment, by flushing with copious clean water and vaccination according to their vaccination status.

The rabies virus is not particularly resistant and is inactivated by heat, sunlight and desiccation. Objects soiled by infective secretions must be disinfected by boiling or autoclaving.[74] Disposable items used in treating patients should be incinerated. Surgical instruments should be autoclaved, while other items in the patient's environment should be cleaned with an appropriate disinfectant, containing chlorine (10 000 ppm available chlorine) or glutaraldehyde. The corpse of a rabies victim is thought to pose little risk but it is prudent to avoid embalming the body.[74]

In the arguably best-documented case report of survival, that of a six-year old boy bitten by a rabid bat in the United States of America, it appears that careful monitoring and rapid supportive therapy to prevent hypoxia, intracranial hypertension, cardiac arrythmias, seizures and nosocomial infection, may have contributed to his recovery.[142]

Serum antibody can only be detected after onset of clinical disease, or seven to 10 days after vaccine administration

Plate 31: This child appeared to be thirsty but pushed the glass away when water was offered. Such behaviour is referred to as hydrophobia

Plate 32: A child with rabies showing marked anxiety

Plate 33: Death is inevitable when rabies clinical signs become apparent and consoling the family members must be given priority

Plate 34: Generalised seizures are seen in preterminal rabies. Seizures may be elicited by sensory stimuli such as air movement, sound and attempts to drink

RABIES LEGISLATION

HUMAN RABIES AND THE LAW

There are a number of important legal considerations relating to the diagnosis, management and reporting of rabies in humans in South Africa.

Negligence

When deciding whether a doctor has been negligent the court assesses whether the doctor concerned acted as a "reasonable medical practitioner would have done under the same circumstances".[150] Four questions are usually considered; if the first two are satisfied then the accused person is said to have owed the injured person a "duty of care". Whether this has been breached is determined by answering the next questions.

The questions are:

- Would a reasonable medical practitioner in the same position have foreseen harm?
- Would a reasonable medical practitioner have taken steps to guard against occurrence of harm?
- What steps would a reasonable medical practitioner have taken to prevent the harm?
- Did the accused take these steps?

The more serious the potential results and the greater the likelihood that harm will occur, the greater the possibility that the courts will impose a duty of care.

Therefore, with the existence of national guidelines on the management of persons potentially exposed to rabies in South Africa, breach of these guidelines, for example failure to adequately treat the wound, failure to notify a state veterinarian or police officer about the existence of a potentially rabid animal, failure to complete the correct regimen of post-exposure prophylaxis, would most likely be considered unreasonable care and therefore negligence.[151]

The Health Act (Act No. 63 of 1977)

In terms of section 45 of the Health Act (Act No. 63 of 1977) rabies is a notifiable disease. It is therefore required that the responsible local or provincial authority and state veterinarian be informed of any human rabies case, death or contact on the prescribed form, GW17/5. Rabies is unique as it is the ONLY notifiable disease where contact by a person with an infected animal is also notifiable.

Postmortem

A suspected rabies death should be considered as due to an unnatural cause. A definitive diagnosis is of particular importance where an animal owner may be liable for not ensuring that his/her dog or cat was vaccinated according to legal requirements. A postmortem should be requested and although relatives should be counselled, consent to conduct the postmortem is not necessary.

ANIMAL RABIES AND THE LAW

The Animal Diseases Act (Act No. 35 of 1984) provides for the control of specific animal diseases and for measures to promote animal health.[38] The Minister of Agriculture may make regulations for accomplishing the purposes of the Act and has determined that rabies control measures should be applied throughout the country. The decision was based on the geographical distribution of animal rabies cases diagnosed over a five year period from 1995 to 1999 (Fig. 4).

The Animal Disease Regulations identify rabies as a controlled animal disease. Table 12 describes the general rabies control measures applicable in South Africa.

TABLE 12: Rabies control regulations

Animal disease	Nature, causal organism and symptoms	Susceptible animals	Controlled veterinary Act to be performed in respect of:		
			Susceptible animals	Contact animals*	Infected animals
1	2	3	4	5	6
Rabies	Fatal, viral disease to which man is also susceptible, mainly transmitted by the bite of an infected animal and characterised by behavioural deviation, salivation, aggressiveness, progressive paralysis and abnormal vocalisation	All warm-blooded animals...	All dogs and cats in the Republic shall be immunised with an efficient remedy by an officer, veterinarian or authorised person at the age of three months followed by a second vaccination within 12 months, at least 30 days after the first vaccination and thereafter every three years Dogs and cats younger than three months may be vaccinated provided that they are again vaccinated at the age of three months, followed by a third vaccination within 12 months and thereafter every three years	Contact animals shall be isolated and immunised with an efficient remedy by or under the supervision of a veterinarian, an officer or authorised person, unless the state veterinarian decides to destroy the animals	Infected animals shall be isolated and destroyed by the responsible person or an officer, veterinarian or authorised person: provided that a responsible person who destroys such animal shall retain the carcass for the attention of an officer, authorised person or veterinarian

* Contact animals are animals that have been, or are suspected to have been, bitten or scratched by a rabid animal, or received saliva, brain or other infectious material from a rabid animal into a wound, the mouth or eyes

All suspected outbreaks of rabies must be reported to the responsible state veterinarian or animal health technician for investigation. This may include euthanasia of the suspected animal after which brain samples are submitted to confirm the diagnosis. If symptoms are not suspicious, the animal may be kept in quarantine under observation for a period determined by the state veterinarian.

Vaccination

Vaccination is a cost-effective method of protecting companion animals against rabies. Safe and efficacious vaccines that induce a protective immunological response within two weeks of vaccination are readily available. Vaccination adverse events are extremely rare and if they occur, generally mild. All dogs and cats in South Africa must be vaccinated strictly according to the regulations, which read as follows:

"All dogs and cats in the Republic shall be immunised with an efficient remedy by an officer,

All dogs and cats regardless of their age, weight or pregnancy status may safely be vaccinated

veterinarian or authorised person at the age of three months followed by a second vaccination within 12 months, at least 30 days after the first vaccination and thereafter every three years. Dogs and cats younger than three months may be vaccinated provided that they are again vaccinated at the age of three months, followed by a third vaccination within 12 months and thereafter every three years." The administration of vaccine before three months of age is justified by the incidence of rabies in puppies in South Africa. The Southern and Eastern African Rabies Group agreed at their conference in Nairobi in 1997, that there was no age below which vaccination of a dog against rabies would not be effective. There are definite benefits in vaccinating very young puppies, especially in areas of high prevalence where the chances that the dog will not present again for vaccination are high. As vaccine coverage is low in many dog populations, it can be assumed that few puppies will have significant passive protective neutralising antibodies to reduce the efficacy of vaccination.

During a mass vaccination campaign in Tunisia puppies less than three months of age responded to vaccination with no significant interference by passive maternal immunity.[152] Dogs of all ages, even those less than three months of age, should be included in rabies mass vaccination campaigns.

All dogs and cats regardless of their age, weight or pregnancy may safely be vaccinated. Rabies vaccines may be safely administered on their own or together with canine distemper, adenovirus type 2, parainfluenza, leptospirosis and parvovirus vaccines.

It is usually not economically feasible to vaccinate all livestock against rabies. However, consideration should be given to vaccinating livestock that are particularly valuable, kept in areas of high-risk or during focal epidemics caused by black-backed jackal. Wild mammals kept as pets should probably be vaccinated annually, although trials have not been performed in these species to determine vaccine efficacy or the ideal vaccination schedule.

All parenteral rabies vaccines registered in South Africa must be inactivated and induce at least three years protection following primary vaccination.

Interprovincial movement restrictions

As South Africa in its entirety is considered a rabies endemic area, all interprovincial movements of dogs and cats must be accompanied by a valid rabies vaccination certificate.

Puppies and kittens less than three months of age may be vaccinated at weaning and can then be moved immediately to any destination in the country provided that they are revaccinated at three months of age. The rabies vaccination certificate of an appropriately vaccinated dog or cat is valid for three years in South Africa.

All carnivorous wild animal species, including jackal, mongoose, bat-eared fox, wild dog, lion, leopard, cheetah and hyena must be vaccinated against rabies with an inactivated vaccine before being moved anywhere in South Africa and all movements must be accompanied by a valid rabies vaccination certificate.

Export from South Africa

The Department of Agriculture's veterinary health certificate must be completed for international movements (Fig. 8). All vaccinations performed for international movements may only be carried out by an authorised person using a registered vaccine. When this certificate is completed by a registered private practitioner, it must be endorsed by a state veterinarian.

Conditions for importation and validity of rabies vaccinations are determined by the importing country. The onus is on the owner to determine the requirements of an importing country. South Africa presently has agreements with Botswana, Lesotho, Malawi, Namibia, Swaziland and Zimbabwe, and these countries accept dogs and cats from South Africa accompanied by a valid vaccination certificate, where the certificate is signed by a state veterinarian, registered private veterinarian or authorised government veterinary official.

Immunity is only considered valid 30 days after the date of vaccination and remains valid for 12 months. Puppies and kittens under three months of age can be exported provided that their mother was vaccinated against rabies at least one month but not more than 12 months prior to the birth of the litter. This information must be recorded on the veterinary health certificate as required by the importing country.

Where booster inoculations are administered before the expiry date of previous vaccinations, the certificate is valid with immediate effect.

Import into South Africa

The present import permit required for importation or reimportation of dogs or cats into South Africa requires a health declaration certifying:

- the residential status of the animal in the exporting country
- that the area of origin is not under veterinary restriction for any disease to which carnivores are susceptible
- that they have not been in contact with animals infected or suspected of being infected with rabies
- that they have a valid rabies vaccination certificate.

A rabies vaccination certificate is only valid if the strain of vaccine used conforms to the potency standard recognised by the WHO (2,5 international units of antigen per dose) and the animal was vaccinated at least 30 days, but not longer than 12 months prior to export to South Africa.

Alternatively, puppies under the age of three months may be vaccinated at any age after birth, but must thereafter be revaccinated at three months, and boosted according to the schedule.

In addition, animals under three months of age are considered to have valid vaccination provided their dam was vaccinated at least 30 days, but not more than 12 months prior to giving birth. It is important to note that such animals must be vaccinated against rabies at three months of age in the Republic and the owner is obliged to then inform the South African veterinary authorities. In addition, dogs should be free of *Brucella canis*, *Trypanosoma evansi*, *Babesia gibsoni*, *Dirofilaria immitis* and *Leishmaniasis*.

The legislation governing import and export of domestic animals and wildlife is extensive and subject to continuous revision and amendment. Persons requiring further information on permits are advised to contact their nearest state veterinarian or to write directly to the Director: Veterinary Services, Private Bag X138, Pretoria 0001.

Conditions for importation and validity of rabies vaccinations are determined by the importing country. The onus is on the animal's owner to determine these requirements

REPUBLIC OF SOUTH AFRICA
DIRECTORATE OF VETERINARY SERVICES
IDENTITY, RABIES VACCINATION AND MOVEMENT CERTIFICATE FOR DOGS AND CATS MOVING BETWEEN PROVINCES IN THE REPUBLIC OF SOUTH AFRICA

NB: KEEP THIS CERTIFICATE AS PROOF OF VACCINATION. TAKE IT WITH YOU FOR REVACCINATIONS AND WHEN YOUR DOG OR CAT MOVES BETWEEN PROVINCES.

A1 Identification and description of animal:

Dog ☐ Cat ☐ Male ☐ Female ☐

Date of birth:..... /...../..... Colour:.....

Name of animal:..... Breed:.....

Distinguishing marks:.....

Microchip number: .....

A2 Owner's name:.....

Owners address: .....

.....

A3 This serves as an official vaccination certificate for interprovincial and international movements on condition that:

1. it accompanies the animal;
2. the property of origin is free from quarantine restrictions imposed for rabies control purposes;
3. the certificate is signed and stamped in the space below.

A4

Vaccinations	**Date**	**Name of vaccine**	**Batch No**	**Signature and address of veterinarian/authorised official**
Primary				
Revaccinations				

A5 General information on Rabies Vaccination of Dogs and Cats in South Africa

- All dogs and cats three months and older shall be immunised twice within a 12 month period, administered at least 30 days apart and thereafter every 3 years. Vaccination shall be carried out by an authorised person using a registered vaccine.
- Puppies and kittens under the age of three months can be vaccinated, provided they are revaccinated at three months and then according to the above schedule.
- Pregnant dogs and cats can be safely vaccinated.
- For international movement, some countries require a registered veterinarian to have vaccinated the animal and some stipulate annual rabies vaccinations. It is the owner's responsibility to ascertain the requirements of the importing country.

Fig. 8: Identity, rabies vaccination and movement certificate for dogs and cats moving between provinces in the Republic of South Africa

Rabies contact animals

Contact animals are animals that have been, or are suspected to have been, bitten or scratched by a rabid animal, or received saliva, brain or other infectious material from a rabid animal into a wound, the mouth or eyes. This includes the unweaned offspring of infected animals.

The management of contact domestic animals exposed to rabies can be complicated by the lack of an immediate perceived threat to human life. As human exposure is likely should a domestic animal develop rabies, the recommendation is normally to cull the exposed animal. Management of these cases is difficult because of emotional attachment to the animal, the value of the animal, difficulties in determining vaccination status and the democratic rights of individuals.

It is imperative that contact animals be traced, identified, safely confined and reported to the state veterinarian without delay. Failure to report such cases may subsequently result in the spread of the disease to humans or other animals. The state veterinarian will determine which contact animals pose a risk and what control measures are necessary to prevent any further spread of the disease.

Where rabies is confirmed in wild carnivores, mongooses, dogs and cats, all dogs and cats that were in close contact with the infected animal, for example those of the same household, must be euthanised under the supervision of a veterinary officer or authorised person, if they do not have a valid vaccination certificate.

Livestock known to have been bitten should be slaughtered immediately.[153] Equines must be isolated and/or destroyed by an authorised person subject to conditions determined by the state veterinarian. Unvaccinated contact livestock including cattle, sheep, goats and horses may, in exceptional cases and subject to written permission and conditions determined by the state veterinarian, be immunised and held in isolation and close observation for six months.

Tissue and milk from a rabid animal should not be used for human or animal consumption. Meat that has been cooked and milk that has been pasteurised or refrigerated should not pose a danger. People drinking raw milk and butchering a carcass should, however, be ragarded as a category 2 contact and should be vaccinated.

After taking samples from an animal with rabies or suspected of having rabies, carcasses must be burnt or buried.

A test to determine rabies antibodies is available for cats and dogs that have been exposed to rabies. The state veterinarian must be consulted should such tests be required, so that the necessary arrangements can be made with the OVI.

Vaccinated dogs and cats with neutralising antibody titres exceeding of 0,5 IU/ml can be considered to have responded to vaccination, although the presence of neutralising antibodies does not guarantee protection against challenge. It is essential that a full history is obtained and that blood samples are taken before booster vaccination (within 1–2 days post exposure). Furthermore, the date(s) and type of contact, for example bite, scratch, and information on blood sampling and rabies vaccination(s) must be submitted with the serum samples.

It is imperative that contact animals be traced, identified, confined safely and reported to the state veterinarian without delay

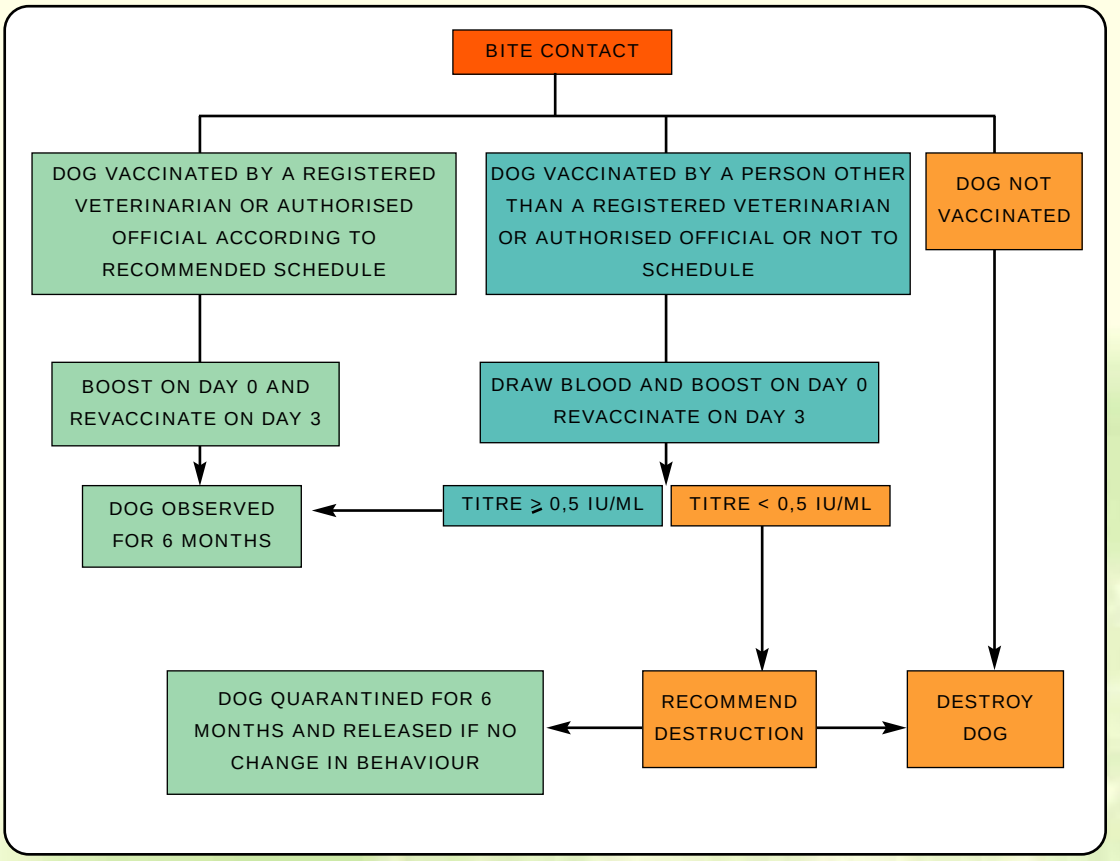

Fig. 9: Actions to be taken following bite contact with a dog

Vaccinated dogs, with antibody titres equal to or greater than 0,5 IU/ml, must be revaccinated (booster) as soon as possible after exposure (preferably within 1–2 days) and boosted three days later. The owner must be informed that there is an element of risk and if the animal shows any signs of abnormal behaviour or illness, this must immediately be reported to the state veterinarian. The animal must be confined to an adequately secure facility for six months and kept under close observation. A permit must be obtained from the state veterinarian to move the animal from the property.

Vaccinated dogs with antibody titres of less than 0,5 IU/ml, must be isolated and destroyed under the supervision of a veterinary officer or authorised person. Should the owner request that the dog not be euthanised, and the state veterinarian is of the opinion that the dog can be effectively isolated (quarantined), he/she can authorise such isolation at a specific place in officially approved facilities under specified conditions stipulated by him/her. This course of action should only be considered under the most exceptional circumstances and the owner must be warned in writing that there is a considerable degree of risk involved and that they will be legally liable for any resultant exposure.

The animal must be effectively isolated for a six-month quarantine period. An official quarantine notice must be served by the state veterinarian on the responsible person and the conditions of quarantine conveyed in writing on an official quarantine notice. Lifting of quarantine must also be carried out in writing. During this period the animal must be under daily observation by the owner. The animal may not be released without the written approval of the state veterinarian (Fig. 10, page 54).

Quarantine facilities

This should be a well-designed and constructed, dog and cat-proof kennel/cage from which the animal cannot escape during the quarantine period. It should be of sufficient size to house the animal comfortably and hygienically. The facility should also be designed so that the animal can be properly attended and the cage cleaned with running water. This facility must be approved by a state veterinarian.

Direct contact with the animal by humans and other animals must be avoided at all costs and gloves must be worn when feeding/providing water to the animal. Officials of the veterinary department should inspect the facilities at least once a week. If the animal shows any signs of abnormal behaviour or illness, the state veterinarian must be notified immediately. All costs resulting from quarantine are incurred at the owner's expense. Before entering quarantine, any animal with a vaccination history must be revaccinated and then boosted three days later. The vaccine must be administered within one to two days after exposure.

Animals which have had contact with rabid animals, regardless of their vaccination and immune status or type of contact, pose a risk of transmitting rabies to people and animals, should they become rabid. The conditions of quarantine and element of risk associated with this course of action, must be conveyed to the owner in writing (Fig. 10). It is recommended that all household members be vaccinated against rabies.

Unfortunately adherence to the quarantine requirements does not guarantee that the animal will not subsequently develop rabies.

The presence of neutralising antibodies does not guarantee protection against rabies infection

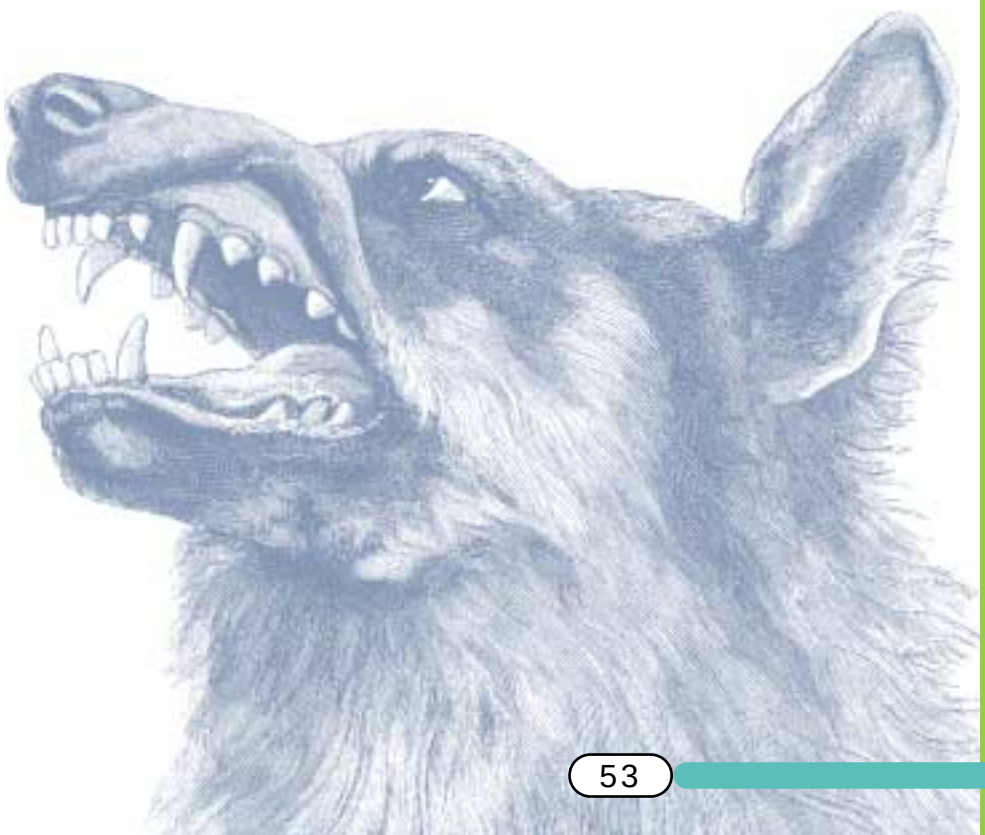

Director: Veterinary Services

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RABIES RISK NOTIFICATION FORM AND QUARANTINE REQUIREMENTS

The risks associated with post-exposure control measures in confirmed rabies contact cases in vaccinated dogs and cats:

1. Animals which have had contact with rabid animals, and have been tested and found to have antibody levels of less than 0,5 IU/ml pose a risk of transmitting rabies to people and other animals, should they become rabid. The owner may be liable for any resultant consequences.

   The reasons for insufficient immunity include the following:

   - Vaccine
     - The use of expired vaccine
     - The incorrect handling, storage and transport of vaccine
   - Vaccine administration
     - Incorrect dosage and route
   - Animal aspects
     - Failure to develop adequate immunity (immunosuppression)
     - Poor condition or diseased when vaccinated or soon afterwards (e.g. distemper, parvo virus infection, biliary fever, internal parasites, etc)
     - Absence of antibodies (no seroconversion)
   - Incompatibility of vaccine and the rabies strain
   - Unreliability of vaccination history
     - Mistaken or falsified identification of animal
     - Incorrect vaccine used
   - Neutralisation of vaccine by maternal antibodies

Fig. 10: Rabies risk notification form and quarantine requirements

2. Quarantine requirements

- The quarantine period for the animal shall be not less than six months
- The facility should be a well designed and constructed dog and cat-proof kennel or cage from which the animal cannot escape during the quarantine period. It should be of sufficient size to house the animal comfortably and hygienically
- The facility should be constructed in such a manner that the animal can be properly attended to and the cage cleaned with running water. This facility must be approved by a state veterinarian
- Direct contact with the animal by humans and other animals must be avoided at all costs
- Gloves must be worn when feeding/providing water to the animal
- Veterinary officials shall inspect the facilities as often as required but not less frequently than once a week
- If the animal shows any signs of abnormal behaviour or illness, the state veterinarian must be notified immediately
- All costs of the quarantine will be incurred by the owner
- All members of the family should be vaccinated against rabies according to the recommended schedule

I, the undersigned, hereby certify that I fully understand the contents and implications of this rabies risk notification form and could be held liable for any consequences arising from negligence or non-adherence to the conditions mentioned

Signed on the _____ day of _____ at _____

_____

Signature:

_____

Name:

_____

Witness 1: Witness 2:

Fig. 10: Rabies risk notification form and quarantine requirements (continued)

RABIES CONTROL STRATEGIES

It is beyond the scope of this publication to provide details of appropriate rabies control principles and strategies for all circumstances and geographic areas in South Africa. The following general principles should, however, always be considered and adapted when controlling a specific outbreak. Control strategies include quarantine, confirmation of diagnosis, determining the origin and spread of an outbreak, and specific measures to terminate transmission. The property on which the disease has presumably occurred, should immediately be placed under quarantine. This may be done by serving a quarantine notice on an individual person or, if a large area is involved, by means of a notice in the *Government Gazette* or printed media.

It is absolutely essential to confirm the diagnosis of rabies. Good-quality specimens must be collected. The investigating officer must submit full details of all contact animals, the date of contact and animals' vaccination status. In the case of dogs and cats, full particulars of rabies vaccination, including the vaccination dates, type of vaccine, batch number and name of the vaccinating officer must be determined. Human contacts must be reported and referred to the relevant local health authority.

It is important to determine the possible origin of the rabies outbreak by checking whether any wild carnivores, mongooses or stray cats and dogs have recently been noticed in the area. In addition the investigating officer should establish whether animals were attacked and obtain a full history of any bite wounds inflicted. An investigation to determine whether any other animals in the area or on neighbouring farms were bitten or had contact with the suspicious vector should be performed.

All neighbours of infected farms must be notified about the disease so that they can prevent it spreading to their livestock. It is always a good idea to notify the local farmers' association or even the district agricultural union of outbreaks. In this way, inhabitants of the entire area are alerted to the outbreak. This can also promote the state veterinary services' surveillance efforts. In urban areas the community is generally notified through newspapers, radio and television.

When an outbreak has been confirmed, the responsible state veterinarian decides on the area requiring vaccination. The general rule for urban outbreaks caused by the mongoose strain, is to vaccinate all dogs and cats in the affected street and neighbouring blocks. With farm outbreaks, animals on the infected property should be vaccinated. With outbreaks on small holdings it is important to vaccinate animals on surrounding properties.

If the outbreak is confirmed as the result of a canid strain of rabies virus, the objective must be to vaccinate all dogs and cats within the immediate surrounding area up to a radius of approximately 25 km, at the discretion of the state veterinarian.

LARGE-SCALE VACCINATION

This approach is the initial response to rabies outbreaks in endemic high-risk areas. The aim should be to vaccinate at least 70 % of the animal population at risk in a single campaign within as short a period as possible. Where this cannot be achieved, two or more campaigns should be conducted within a year.

CORDON VACCINATION

The aim of cordon vaccination is to create a barrier of animal immunity. This approach has become increasingly important during the second phase of canine rabies elimination, particularly in the vicinity of international borders and national as well as provincial game reserves. This is necessary to prevent reinfection of areas currently free from rabies and to protect rabies-free wildlife areas. A cordon of 20 to 30 km is usually sufficient for this purpose.

RING VACCINATION

The long-distance transport of animals, particularly dogs that may be incubating the disease, is of increasing con-

cern to veterinary authorities attempting to curtail the spread of rabies. This factor may result in outbreaks of canine rabies anywhere in the country at any time. It is therefore essential that immediate vaccination of the susceptible dog and cat populations be performed during the primary outbreak to prevent further exponential spread of the disease. In areas where an isolated case has been diagnosed, ring vaccination with a radius of 20 to 30 km, where at least 70 % of dogs are vaccinated, has proven successful in controlling or eliminating rabies.

DOOR-TO-DOOR VACCINATION

Vaccination on a home-to-home basis is generally more expensive, resource intensive and time consuming, but coverage is invariably better. An example of the success of this approach is illustrated by a campaign in Eerstehoek, a rural district in Mpumalanga. In 1998, 20 officials vaccinated 6 498 dogs in 30 villages extending over 594 km^2 on a home-to-home basis. All vaccinated dogs were identified with neckbands. Almost all dogs (95,4 %) were vaccinated within seven days and the direct cost per dog vaccinated was calculated at R4,52.[154]

CENTRAL-POINT VACCINATION

These campaigns are usually conducted at least annually in areas where rabies is endemic and the prevalence of outbreaks is high. The public are requested to bring their pets to identified venues. Accurate epidemiological information, good advertising and adequate planning are of paramount importance to ensure high coverage. Results vary from 20 to 80 % and depend on the degree of attention to detail. Coverage is generally better if the campaign follows shortly after a well-publicised rabies outbreak.

Vaccination of dogs and cats on farms can be very cost-effective if combined with other activities, such as tuberculosis or brucellosis testing, or anthrax vaccination. Farmers and their workers must be informed of the vaccination activities in advance. It is important that dogs and cats belonging to workers are also vaccinated during these campaigns.

Vaccination of dogs against rabies during routine cattle-dipping activities in rural areas is relatively inexpensive but, unfortunately, does not reach a high proportion of the dog population.

Vaccination clinics are usually held in lower-risk areas, such as formal urban areas where properties are securely fenced. These clinics operate at pre-arranged times and places. Although vaccination clinics may supplement campaigns, they cannot replace them. They primarily target animals missed during a campaign or newly-acquired puppies requiring vaccination, therefore boosting overall vaccination cover.

Plate 35: A communal dog eating an oral rabies bait

ORAL VACCINATION

Sylvatic rabies has been successfully eradicated in Switzerland and other European countries

The aim of large-scale vaccination is to inoculate at least 70 % of the animal population at risk in a single campaign within as short a period as possible

using bait vaccine. A bait containing a live, avirulent rabies virus mutant, SAG2, has been formulated specifically for dogs and the first field trials were conducted in South Africa (G.C. Bishop 1999, unpublished data). The baits were offered to 755 dogs and more than 75 % of these dogs accepted them readily. The vaccine is effective against challenge and safe for use in both target and nontarget species. Although oral rabies vaccines are not yet registered for use in South Africa, the benefits of this strategy are obvious because the handling of dogs is practically eliminated and the approach is less labour-intensive than central-point vaccination. Education of communities before embarking on this course of action is imperative.

KEY FACTORS WHICH INFLUENCE SUCCESS

Key factors that influence the success of control campaigns include: accurate epidemiological information, aggressive marketing, careful planning, thorough logistical preparation, intersectoral cooperation and enthusiasm.[155]

Ideally human and dog census figures should be obtained. This may require a separate local survey. Historical information of human and animal rabies cases together with previous vaccination records for the outbreak areas are integral to the success of the entire venture. Appropriate maps indicating roads, population distribution, schools, clinics, community centres and other key community meeting points allow efficient planning of the campaign.[156] Cultural perceptions of local communities, level of education, attitude towards previous campaigns and awareness of rabies should be borne in mind. Cost analyses of previous campaigns and control strategies can be used to advocate for funding.

Aggressive marketing is probably the most important prerequisite for ensuring adequate coverage. This should aim at maximum mobilisation of communities by utilising all appropriate media within available resources. Television, radio, newspapers, water and electricity accounts, schools, tribal and district authorities, health authorities and clinics, churches, dip-tanks, pamphlets, posters, loudspeakers, and word of mouth are all avenues that have been successfully utilised in South Africa. Innovative measures such as advertisements placed on taxis and inserts on audio tapes distributed *via* the minibus association have also improved coverage. Small incentives and inexpensive gifts, such as peak hats and stickers with rabies prevention messages, have heightened awareness and promoted enthusiastic participation in vaccination campaigns.

It is important to remember that communication and marketing channels differ between communities, and it is therefore essential to identify and utilise the most locally appropriate means. The horrific nature of rabies results in extensive coverage being provided by various media organisations and local and district authorities, usually free of charge.

Community needs and circumstances should always influence decisions on the timing and location of vaccination campaigns. A tailored strategy for each community must be well planned in advance of a campaign. Vaccination campaigns should be conducted at a time when people are available to bring their dogs. This is generally before or after normal working hours in affluent societies, in the afternoon in areas where schoolchildren are expected to bring dogs, and during weekends, particularly Saturday mornings, or school holidays in both urban and rural areas.

The choice of venue should be carefully considered. In urban areas a large open space that is well lit and preferably near shops, schools, community centres or a post office in an area of high population density, generally yields the best results.

Distances between vaccination points should not exceed 3 to 4 km. Surveys indicate that in communities lacking transport, the majority of the community will seldom walk, drag or carry their dogs beyond 2 km to be vaccinated. Where annual campaigns are held, rainfall pattern, temperature and weather conditions should be considered if high vaccination coverage is to be obtained.

Ensure that adequate supplies of vaccine, certificates, and clean sterile syringes and needles are available. Sufficient tables, chairs and assistants are vital for a smooth-running and efficient campaign. Ensure that all admin-

istrative material and equipment are available before initiating the campaign. These include the items on the campaign equipment checklist (Table 13).

TABLE 13: Campaign equipment checklist

Veterinary	Stationery	General	Marketing
Vaccine Syringes Needles Stericaps Veterinary medicines Medical aid kit Protective clothing Restraining equipment Forceps	Certificate books Pens Official stamps Clipboards	Cooler box Ice packs Trunks Soap Water Towels Umbrella Mobile telephone Tables and chairs Gas stove Pots for sterilising equipment	Banners Posters Direction boards Loudspeaker

The type of operation chosen will determine the scale of interdepartmental liaison and intersectoral collaboration between the Departments of Health, Justice, Education and the South African Police Service required. It is important that tribal authorities, organised agriculture, local government, private veterinarians and welfare organisations must be involved to ensure success.

The success of any disease control programme is directly related to the enthusiasm and commitment of team leaders and members. The decision on appointing campaign leaders should therefore be carefully considered.

Excellent results are usually obtained where "operational headquarters" are established and team members fully briefed on campaign objectives and background rabies epidemiology. Team members should be well orientated to local circumstances and cultural practices, and be supplied with all the necessary equipment prior to the initiation of the campaign. Full briefing and regular reporting must continue throughout the campaign. During rabies vaccination campaigns, issuing of vaccination certificates is optional and at an owner's request.

Rabies vaccine is generally available at all private veterinary practices and state veterinary offices throughout South Africa. Owners of dogs and cats can also purchase rabies vaccine through pharmaceutical companies and pharmacists.

Post-vaccination surveillance for outbreaks is a fundamental requirement of any rabies control programme. The efficiency of vaccination campaigns is generally evaluated by the impact on rabies incidence in target and nontarget species. Ongoing surveillance is required to detect residual foci or reinfection of areas where rabies has been eliminated. Campaigns should be carefully analysed for coverage, efficiency, cost effectiveness and lessons learnt.

It is important to remember that communication and marketing channels differ between communities and it is therefore essential to identify and utilise the most locally appropriate means

ADDITIONAL MEASURES ENHANCING RABIES CONTROL PROGRAMMES

Enforcement of registration or licensing of all dogs and cats may enhance rabies control programmes, as vaccination is an essential prerequisite to licensing. A fee is frequently charged for a licence and revenues collected may be used to maintain rabies control programmes.

"Spot fines", admission of guilt citations and prosecution of owners for violating control regulations, including the failure to vaccinate or licence their animals and failure to obtain or present a "proof of vaccination" certificate during interprovincial movements, may be used in extreme cases to ensure rabies control.

All communities should be encouraged to control stray animals and sterilisation programmes should be promoted.

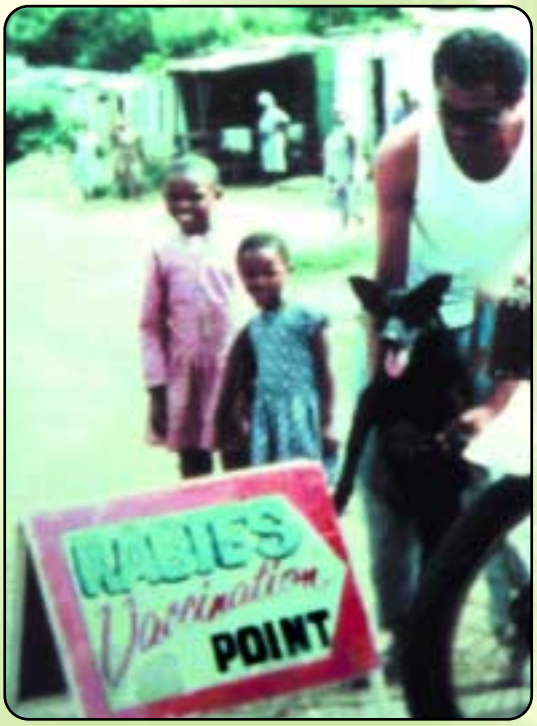

Plate 36: Maintaining high visibility and befriending communities are two very important aspects in rabies control and prevention

Plate 37: Central vaccination points must be carefully selected and easily accessible. Promotional T-shirts and caps are being worn by this group

Plate 38: Dogs may be vaccinated intra-muscularly or subcutaneously with rabies vaccine

Plate 39: Cats must also be vaccinated against rabies in South Africa

Plate 40: The target species in canine rabies endemic areas. The objective should be to vaccinate a high proportion of the dog population in order to create a large group of rabies-immune, mature and healthy dogs

A good knowledge of local dog ecology (dog numbers, turnover rates, reasons for ownership, other diseases, housing) is crucial when planning control measures

Rabies vaccines may be used in young puppies, which must be boosted at three months of age and again within the following year. Revaccination must be performed every three years thereafter

FREQUENTLY ASKED QUESTIONS

- How often must I vaccinate my dog? See page 47, 48
- My child was bitten by a mouse (shrew, rat, or monkey). Must he or she receive antirabies treatment? Page 34, 36
- Must I have my cat vaccinated against rabies? See page 47, 48
- I have been bitten by a dog. The dog is very aggressive and frequently bites people. What must I do? Page 36, 37, 41
- I was bitten by a rabid dog two weeks ago and I was given rabies vaccine within a day of the incident but no RIG was administered. What must I do now? Page 38—40
- I was bitten by a rabid dog four days ago and I was given rabies vaccine within a day of the incident but no RIG was administered. What must I do now? Page 38
- My farm staff dug up the carcass of a rabies positive cow that had been buried a day ago. The staff then consumed the meat of this carcass. What must be done now? Page 33.
- We have been drinking the milk of a rabid cow up to the day she was destroyed. What should be done? Page 51
- What is the earliest age that I may vaccinate my puppy or kitten for rabies? Page 47, 48
- Is it safe to give rabies vaccine at the same time as other dog vaccines, e.g. distemper, parvo and hepatitis? Page 48
- What side-effects will rabies vaccination have on my animal? Page 47, 48
- One of my dogs is positive for rabies. What should I do about my other animals? Page 51—55
- How soon after vaccination are my dogs protected against rabies? Page 47
- Should wild animals which are kept as pets be vaccinated against rabies? Page 48

- My cow was positive for rabies. What must I do about this cow's calf and the other cattle that were in contact with this cow? Page 51

- My dog and cat were vaccinated during a rabies campaign. However, I do not have any documentary proof that vaccination was done. Should there be contact with rabid animals, what is their vaccination status? Page 51, 52

- Can rabies be transmitted between people? Page 33

- I was bitten by a mongoose two weeks ago. What should I do? Page 36, 41

- Can birds contract rabies? Page 34

- What part do bats play in rabies transmission in South Africa? Page 3, 11

- Can clinical rabies in humans be treated? Page 44

EXPERT ADVICE ON RABIES IS AVAILABLE FROM:

Allerton Provincial Veterinary Laboratory
Tel: (033) 347 6200

Onderstepoort Veterinary Institute, Rabies Unit
Tel: (012) 529 9440

Rabies Advisory Group
Animals: (013) 741 3218
Humans: (033) 386 3859 and 082 352 6879

National Institute of Communicable Diseases
Tel: (011) 321 4200

Department of Agriculture, Directorate Veterinary Services
Tel: (012) 319 7679

RABIES EDUCATIONAL VIDEOS

for health workers, schools and the community
are available from:
2 Iona Place, Boughton, Pietermaritzburg, 3201, South Africa
Tel: (033) 344 2029
e-mail: Bishop@futurenet.co.za

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Persons who have received pre-exposure vaccination should receive only two booster doses of vaccine on days 0 and 3

In recent years the vast majority of South African human rabies cases have followed bites from infected dogs in KwaZulu-Natal

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FOR FURTHER INFORMATION CONTACT:

Allerton Provincial Veterinary Laboratory
Tel: (033) 347 6200

Onderstepoort Veterinary Institute,
Rabies Unit
Tel: (012) 529 9440

Rabies Advisory Group
Animals: (013) 741 3218
Humans: (033) 386 3859 and 082 352 6879

National Institute of Communicable Diseases
Tel: (011) 321 4200

Department of Agriculture,
Directorate Veterinary Services
Tel: (012) 319 7679

Raceway (aquaculture)

From Wikipedia, the free encyclopedia

A **raceway**, also known as a **flow-through system**, is an artificial channel used in aquaculture to culture aquatic organisms. Raceway systems are among the earliest methods used for inland aquaculture. A raceway usually consists of rectangular basins or canals constructed of concrete and equipped with an inlet and outlet. A continuous water flow-through is maintained to provide the required level of water quality, which allows animals to be cultured at higher densities within the raceway.[1][2][3][4][5]

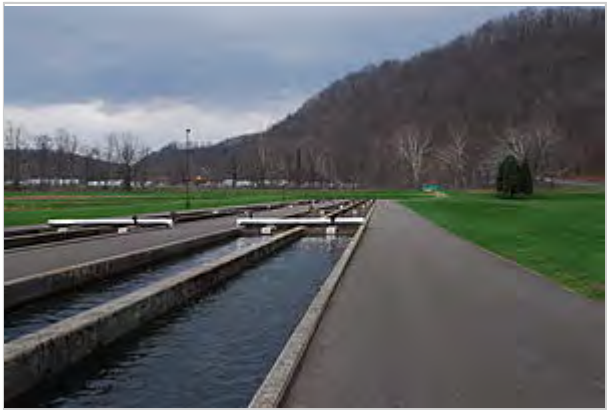

Raceways at a West Virginia fish hatchery

Freshwater species such as trout, catfish and tilapia are commonly cultured in raceways.[6][7][8][9][10] Raceways are also used for some marine species which need a constant water flow, such as juvenile salmon,[9][11][12] brackish water sea bass and sea bream[13][14] and marine invertebrates such as abalone.[15]

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- 2 Construction
- 3 Size
- 4 Water flow
- 5 Maximum load
- 6 Feed
- 7 Waste water
- 8 In shrimp farming
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Site selection

The most important factor to consider when selecting a site for a raceway farm is the water supply. Water sources for raceway aquaculture operations are usually streams, springs, reservoirs or deep wells. Trout do best in spring water because it keeps a constant temperature, while catfish need a strong flow, about 80 litres per second for every 0.4 hectares of raceway. A backup water supply should be positioned so, if the water supply or pump fails, it can flow by gravity into the start of the raceway.[16]

Construction

Most raceways are made of reinforced concrete, though some earthen raceways are also built. Earthen raceways with plastic liners cost little and are easy to build, but cleaning and disinfecting them is difficult and plastic linings are fragile. Reinforced concrete is more expensive, but is durable and can be shaped in complex ways. Raceway tanks can also be built from polyester resin. These tanks have smooth walls, and are mobile and easy to service. However, their cost limits them to small sizes, under 5 cubic metres.[16][17]

Size

A raceway is most often a rectangular canal with a water current flowing from a supply end to an exit end. The length to width ratio is important in raceways. To prevent the fish stock from swimming in circular movements, which would cause debris to build up in the centre, a length to width ratio of at least six to one is recommended. If the width is too large this could result in a feeble current speed which is not desirable (see below). The length of a raceway unit is usually constrained by the water quality or by how much stock a unit can hold for ease of management.[3][4] The average depth of a raceway for fin fish, such as rainbow trout, is about one metre.[17] This means each section in a raceway should be about 30 m long and 2.5–3 m wide. The landscape should sloped to one or two percent, so the flow through the system can be maintained by gravity. The raceway should not be curved, so the flow will be uniform.[16]

A raceway farm for freshwater fin fish usually has a dozen or more parallel raceway strips build alongside each other, with each strip consisting of 15 to 20 or more serial sections.[16] The risk of unhygienic conditions increases towards the lower level sections, and can be kept in check by ensuring there are not too many sections and the water flow is adequate. In order to isolate any diseased section and avoid transmitting the disease back to the upper raceways, each section should have its own drainage channel.[16] Controls, such as weirs, are also needed to ensure individual raceways can't accidentally overflow or empty.[16]

Water flow

The water flow rate in a raceway system needs to be sufficiently high to meet the respiratory (dissolved oxygen) requirements for the species concerned and to flush out metabolic wastes, especially ammonia.[18] In a well designed system, the existing water in the raceway is largely replaced by new water when the same volume of new water enters the raceway. Self-cleaning can sometimes be achieved if the fish stocks density is sufficiently high and the water level is sufficiently low. For example, if trout are stocked at 20 kilograms per cubic metre, they can keep the raceway unit clean by their swimming movements, preventing waste solids from settling to the raceway floor.[3][4]

However, in most cases it is necessary to frequently clean raceways. The simplest way is to lower the water level in the raceway units, which increases the speed of the water current, and then herd the fish together till they flush the waste from the raceway.[17] Solid wastes which accumulate at the raceway

bottom can be removed by pumps.[19] Oxygen levels in the water can be kept high if the raceway units are placed one after the other with intermediate drops over weirs, or by the use of aeration systems such as pumps, blowers and agitators.[17][19]

Generally the water should be replaced about every hour.[3][4] This means a typical raceway section requires a flow rate around 30 liters per second.[16] However, the optimum flow through rate depends on the species, because there are differences in the rates at which oxygen is consumed and metabolic wastes are produced. For example, trout and juvenile salmon are less tolerant of degraded water quality and require a more rapid water turnover than catfish or tilapia.[18] The flow rate necessary to maintain water quality can also change through the year, as the temperature changes and the cultured species grow larger. For reason such as these, continuous monitoring of water quality is important, including measurements of water flow rates, pH levels and temperature, as well as the levels of dissolved oxygen, and suspended and solid waste material.[17][19]

Maximum load

The maximum load of organisms that can be cultured in a raceway system depends on the species, and particularly on the size of the species. For trout, stocking rates of 30 to 50 kg/m^3 are normal at the end of a rearing cycle, while for marine species, such as sea bass and sea bream, the achievable load is lower, between 15 and 20 kg/m^3. The total volume required for a raceway is calculated by dividing the total amount of fish in kg by the desired stocking rate in kg per m^3.[17]

Feed

In most raceway aquaculture food needs to be supplied. The composition of the food, and the amount and time of feeding needs to be adjusted to the specific species.[20] This can be optimised to reduce costs and minimize the amount of waste.

Waste water

The treatment of waste water issuing from raceway farms is a major concern. Fish fecal matter and uneaten feed are typically the major elements of solid waste produced in raceway aquaculture farms. These can adversely impact the environment in the receiving water body.[19][21] Of particular environmental concern is the waste product phosphorus. Excessive discharge of phosphorus to receiving waters can result in eutrophication. For example, in Korea poor waste treatments in trout farms resulted in reservoirs and rivers developing red tides, which caused wider social problems.[19]

Because raceway aquaculture operations discharge large volumes of water, the concentration of discharged solids is low. This means it is not easy to treat and implement practical, cost effective treatments. Technologies for the removal of solids include microscreens, dual-drain tanks, swirl separators, plate separators, baffles, media filters, air flotation, foam fractionation, chemical flocculation, and constructed wetlands. But because of the impracticality and / or high costs of these

methods, most of them are not applicable for commercial aquaculture. As a consequence, sedimentation (settling) is still the most widely applied and cost effective technology.[10] Since 1999, regulations in South Korea require that all raceway farms provide waste water treatment facilities covering at least 20% of the farmed area to prevent pollution of the freshwater environment.[19] Open race way ponds were used for removal of heavy metal ions like lead using live *Spirulina (Arthospira) sp*.[22]

In shrimp farming

Recently Dr. Addison Lawrence received a patent for his System and Method for Super-Intensive Shrimp Production (http://www.google.com/patents/US20100294202). This system employs artificial raceways to produce large quantities of shrimp. In an interview with Undercurrent News Lawrence said, “We have several very interested commercial groups interested in using the technology to develop shrimp farms in the United States, and we have several groups interested in developing farms outside of the US,"[23] Super-Intensive Shrimp Production offers the capability to have no outflow, saving on water costs, reducing the impact on local water resources and reducing the environmental impact of shrimp farming.

See also

- Fish hatchery
- Fish ladder
- Raceway pond

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Antenna (radio)

From Wikipedia, the free encyclopedia

In radio and electronics, an **antenna** (plural **antennae** or **antennas**), or **aerial**, is an electrical device which converts electric power into radio waves, and vice versa.[1] It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an electric current oscillating at radio frequency (i.e. a high frequency alternating current (AC)) to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals, that is applied to a receiver to be amplified.

Antennas are essential components of all equipment that uses radio. They are used in systems such as radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, and satellite communications, as well as other devices such as garage door openers, wireless microphones, Bluetooth-enabled devices, wireless computer networks, baby monitors, and RFID tags on merchandise.

Typically an antenna consists of an arrangement of metallic conductors (elements), electrically connected (often through a transmission line) to the receiver or transmitter. An oscillating current of electrons forced through the antenna by a transmitter will create an oscillating magnetic field around the antenna elements, while the charge of the electrons also creates an oscillating electric field along the elements. These time-varying fields radiate away from the antenna into space as a moving transverse electromagnetic field wave. Conversely, during reception, the oscillating electric and magnetic fields of an incoming radio wave exert force on the electrons in the antenna elements, causing them to move back and forth, creating oscillating currents in the antenna.

Antennas can be designed to transmit and receive radio waves in all horizontal directions equally (omnidirectional antennas), or preferentially in a particular direction (directional or high gain antennas). In the latter case, an antenna may also include additional elements or surfaces with no electrical connection to the transmitter or receiver, such as parasitic elements, parabolic reflectors or horns, which serve to direct the radio waves into a beam or other desired radiation pattern.

The first antennas were built in 1888 by German physicist Heinrich Hertz in his pioneering experiments to prove the existence of electromagnetic waves predicted by the theory of James Clerk Maxwell. Hertz placed dipole antennas at the focal point of parabolic reflectors for both transmitting and receiving. He published his work in *Annalen der Physik und Chemie* (vol. 36, 1889).

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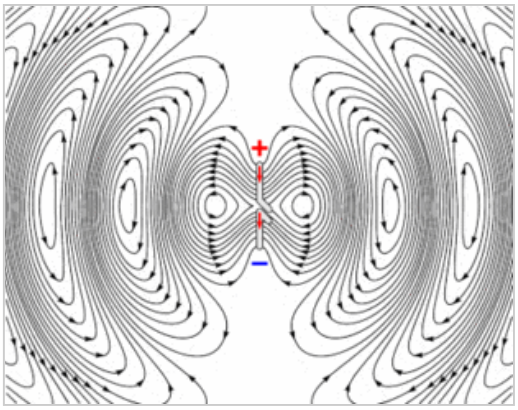

Animation of a half-wave dipole antenna transmitting radio waves, showing the electric field lines. The antenna in the center is two vertical metal rods, with an alternating current applied at its center from a radio transmitter *(not shown)*. The voltage charges the two sides of the antenna alternately positive *(+)* and negative *(−)*. Loops of electric field *(black lines)* leave the antenna and travel away at the speed of light; these are the radio waves.

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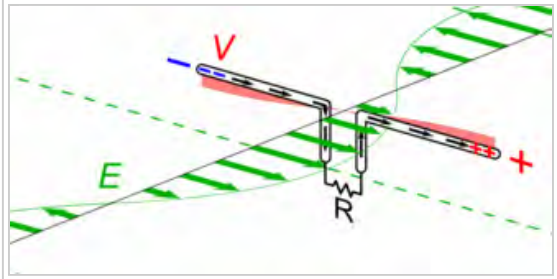

Animated diagram of a half-wave dipole antenna receiving energy from a radio wave. The antenna consists of two metal rods connected to a receiver *R*. The electric field *(E, green arrows)* of the incoming wave pushes the electrons in the rods back and forth, charging the ends alternately positive *(+)* and negative *(−)*. Since the length of the antenna is one half the wavelength of the wave, the oscillating field induces standing waves of voltage *(V, represented by red band)* and current in the rods. The oscillating currents *(black arrows)* flow down the transmission line and through the receiver (represented by the resistance *R*).

Terminology

The words *antenna* (plural: *antennas*[2] in US English, although both "antennas" and "antennae" are used in International English[3]) and *aerial* are used interchangeably. Occasionally the term "aerial" is used to mean a wire antenna. However, note the important international technical journal, the *IEEE Transactions on Antennas and Propagation*.[4] In the United Kingdom and other areas where British English is used, the term aerial is sometimes used although 'antenna' has been universal in professional use for many years.

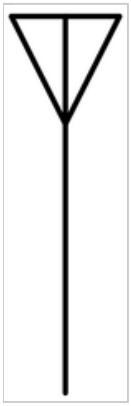

Electronic symbol for an antenna

The origin of the word *antenna* relative to wireless apparatus is attributed to Italian radio pioneer Guglielmo Marconi. In the summer of 1895, Marconi began testing his wireless system outdoors on his father's estate near Bologna and soon began to experiment with long wire "aerials". Marconi discovered that by raising the "aerial" wire above the ground and connecting the other side of his transmitter to ground, the transmission range was increased.[5] Soon he was able to transmit signals over a hill, a distance of approximately 2.4 kilometres (1.5 mi).[6] In Italian a tent pole is known as *l'antenna centrale,* and the pole with the wire was simply called *l'antenna.* Until then wireless radiating transmitting and receiving elements were known simply as aerials or terminals.

Because of his prominence, Marconi's use of the word *antenna* (Italian for *pole*) spread among wireless researchers, and later to the general public.[7][8][9]

In common usage, the word *antenna* may refer broadly to an entire assembly including support structure, enclosure (if any), etc. in addition to the actual functional components. Especially at microwave frequencies, a receiving antenna may include not only the actual electrical antenna but an integrated preamplifier or mixer.

An antenna, in converting radio waves to electrical signals or vice versa, is a form of transducer.[10]

Overview

Antennas are required by any radio receiver or transmitter to couple its electrical connection to the electromagnetic field. Radio waves are electromagnetic waves which carry signals through the air (or through space) at the speed of light with almost no transmission loss. Radio transmitters and receivers are used to convey signals (information) in systems including broadcast (audio) radio, television, mobile telephones, Wi-Fi (WLAN) data networks, trunk lines and point-to-point communications links (telephone, data networks), satellite links, many remote controlled devices such as garage door openers, and wireless

remote sensors, among many others. Radio waves are also used directly for measurements in technologies including radar, GPS, and radio astronomy. In each and every case, the transmitters and receivers involved require antennas, although these are sometimes hidden (such as the antenna inside an AM radio or inside a laptop computer equipped with Wi-Fi).

Antennas of the Atacama Large Millimeter submillimeter Array.[11]

Whip antenna on car, common example of an omnidirectional antenna

According to their applications and technology available, antennas generally fall in one of two categories:

Omnidirectional or only weakly directional antennas which receive or radiate more or less in all directions. These are employed when the relative position of the other station is unknown or arbitrary. They are also used at lower frequencies where a directional antenna would be too large, or simply to cut costs in applications where a directional antenna isn't required.
Directional or *beam* antennas which are intended to preferentially radiate or receive in a particular direction or directional pattern.

In common usage "omnidirectional" usually refers to all horizontal directions, typically with reduced performance in the direction of the sky or the ground (a truly isotropic radiator is not even possible). A "directional" antenna usually is intended to maximize its coupling to the electromagnetic field in the direction of the other station, or sometimes to cover a particular sector such as a 120° horizontal fan pattern in the case of a panel antenna at a cell site.

One example of omnidirectional antennas is the very common *vertical antenna* or whip antenna consisting of a metal rod (often, but not always, a quarter of a wavelength long). A dipole antenna is similar but consists of two such conductors extending in opposite directions, with a total length that is often, but not always, a half of a wavelength long. Dipoles are typically oriented horizontally in which case they are weakly directional: signals are reasonably well radiated toward or received from all directions with the exception of the direction along the conductor itself; this region is called the antenna blind cone or null.

Half-wave dipole antenna

Both the vertical and dipole antennas are simple in construction and relatively inexpensive. The dipole antenna, which is the basis for most antenna designs, is a balanced component, with equal but opposite voltages and currents applied at its two terminals through a balanced transmission line (or to a coaxial transmission line through a so-called balun). The vertical antenna, on the other hand, is a *monopole* antenna. It is typically connected to the inner conductor of a coaxial transmission line (or a matching network); the shield of the transmission line is connected to ground. In this way, the ground (or any large conductive surface) plays the role of the second conductor of a dipole, thereby forming a complete circuit. Since monopole antennas rely on a conductive ground, a so-called grounding structure may be employed to provide a better ground contact to the earth or which itself acts as a ground plane to perform that function regardless of (or in absence of) an actual contact with the earth.

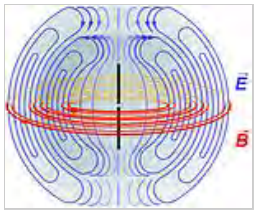

Diagram of the electric fields *(blue)* and magnetic fields *(red)* radiated by a dipole antenna *(black rods)* during transmission.

Antennas more complex than the dipole or vertical designs are usually intended to increase the directivity and consequently the gain of the antenna. This can be accomplished in many different ways leading to a plethora of antenna designs. The vast majority of designs are fed with a balanced line (unlike a monopole antenna) and are based on the dipole antenna with additional components (or *elements*) which increase its directionality. Antenna "gain" in this instance describes the concentration of radiated power into a particular solid angle of space, as opposed to the spherically uniform radiation of the ideal radiator. The increased power in the desired direction is at the expense of that in the undesired directions. Power is conserved, and there is no net power increase over that delivered from the power source (the transmitter.)

For instance, a phased array consists of two or more simple antennas which are connected together through an electrical network. This often involves a number of parallel dipole antennas with a certain spacing. Depending on the relative phase introduced by the network, the same combination of dipole antennas can operate as a "broadside array" (directional normal to a line connecting the

elements) or as an "end-fire array" (directional along the line connecting the elements). Antenna arrays may employ any basic (omnidirectional or weakly directional) antenna type, such as dipole, loop or slot antennas. These elements are often identical.

However a log-periodic dipole array consists of a number of dipole elements of *different* lengths in order to obtain a somewhat directional antenna having an extremely wide bandwidth: these are frequently used for television reception in fringe areas. The dipole antennas composing it are all considered "active elements" since they are all electrically connected together (and to the transmission line). On the other hand, a superficially similar dipole array, the Yagi-Uda Antenna (or simply "Yagi"), has only one dipole element with an electrical connection; the other so-called parasitic elements interact with the electromagnetic field in order to realize a fairly directional antenna but one which is limited to a rather narrow bandwidth. The Yagi antenna has similar looking parasitic dipole elements but which act differently due to their somewhat different lengths. There may be a number of so-called "directors" in front of the active element in the direction of propagation, and usually a single (but possibly more) "reflector" on the opposite side of the active element.

Greater directionality can be obtained using beam-forming techniques such as a parabolic reflector or a horn. Since high directivity in an antenna depends on it being large compared to the wavelength, narrow beams of this type are more easily achieved at UHF and microwave frequencies.

At low frequencies (such as AM broadcast), arrays of vertical towers are used to achieve directionality [12] and they will occupy large areas of land. For reception, a long Beverage antenna can have significant directivity. For non directional portable use, a short vertical antenna or small loop antenna works well, with the main design challenge being that of impedance matching. With a vertical antenna a *loading coil* at the base of the antenna may be employed to cancel the reactive component of impedance; small loop antennas are tuned with parallel capacitors for this purpose.

An antenna lead-in is the transmission line (or *feed line*) which connects the antenna to a transmitter or receiver. The *antenna feed* may refer to all components connecting the antenna to the transmitter or receiver, such as an impedance matching network in addition to the transmission line. In a so-called aperture antenna, such as a horn or parabolic dish, the "feed" may also refer to a basic antenna inside the entire system (normally at the focus of the parabolic dish or at the throat of a horn) which could be considered the one active element in that antenna system. A microwave antenna may also be fed directly from a waveguide in place of a (conductive) transmission line.

Cell phone base station antennas

An antenna counterpoise or ground plane is a structure of conductive material which improves or substitutes for the ground. It may be connected to or insulated from the natural ground. In a monopole antenna, this aids in the function of the natural ground, particularly where variations (or limitations) of the characteristics of the natural ground interfere with its proper function. Such a structure is normally connected to the return connection of an unbalanced transmission line such as the shield of a coaxial cable.

An electromagnetic wave *refractor* in some aperture antennas is a component which due to its shape and position functions to selectively delay or advance portions of the electromagnetic wavefront passing through it. The refractor alters the spatial characteristics of the wave on one side relative to the other side. It can, for instance, bring the wave to a focus or alter the wave front in other ways, generally in order to maximize the directivity of the antenna system. This is the radio equivalent of an optical lens.

An antenna coupling network is a passive network (generally a combination of inductive and capacitive circuit elements) used for impedance matching in between the antenna and the transmitter or receiver. This may be used to improve the standing wave ratio in order to minimize losses in the transmission line and to present the transmitter or receiver with a standard resistive impedance that it expects to see for optimum operation.

Reciprocity

It is a fundamental property of antennas that the electrical characteristics of an antenna described in the next section, such as gain, radiation pattern, impedance, bandwidth, resonant frequency and polarization, are the same whether the antenna is transmitting or receiving.[13][14] For example, the "*receiving pattern*" (sensitivity as a function of direction) of an antenna when used for reception is identical to the radiation pattern of the antenna when it is *driven* and functions as a radiator. This is a

consequence of the reciprocity theorem of electromagnetics.[14] Therefore, in discussions of antenna properties no distinction is usually made between receiving and transmitting terminology, and the antenna can be viewed as either transmitting or receiving, whichever is more convenient.

A necessary condition for the aforementioned reciprocity property is that the materials in the antenna and transmission medium are linear and reciprocal. *Reciprocal* (or *bilateral*) means that the material has the same response to an electric current or magnetic field in one direction, as it has to the field or current in the opposite direction. Most materials used in antennas meet these conditions, but some microwave antennas use high-tech components such as isolators and circulators, made of nonreciprocal materials such as ferrite.[13][14] These can be used to give the antenna a different behavior on receiving than it has on transmitting,[13] which can be useful in applications like radar.

Characteristics

Antennas are characterized by a number of performance measures which a user would be concerned with in selecting or designing an antenna for a particular application. Chief among these relate to the directional characteristics (as depicted in the antenna's *radiation pattern*) and the resulting *gain*. Even in omnidirectional (or weakly directional) antennas, the gain can often be increased by concentrating more of its power in the horizontal directions, sacrificing power radiated toward the sky and ground. The antenna's power gain (or simply "gain") also takes into account the antenna's efficiency, and is often the primary figure of merit.

Resonant antennas are expected to be used around a particular *resonant frequency*; an antenna must therefore be built or ordered to match the frequency range of the intended application. A particular antenna design will present a particular feedpoint impedance. While this may affect the choice of an antenna, an antenna's impedance can also be adapted to the desired impedance level of a system using a matching network while maintaining the other characteristics (except for a possible loss of efficiency).

Although these parameters can be measured in principle, such measurements are difficult and require very specialized equipment. Beyond tuning a transmitting antenna using an SWR meter, the typical user will depend on theoretical predictions based on the antenna design or on claims of a vendor.

An antenna transmits and receives radio waves with a particular polarization which can be reoriented by tilting the axis of the antenna in many (but not all) cases. The physical size of an antenna is often a practical issue, particularly at lower frequencies (longer wavelengths). Highly directional antennas need to be significantly larger than the wavelength. Resonant antennas usually use a linear conductor (or *element*), or pair of such elements, each of which is about a quarter of the wavelength in length (an odd multiple of quarter wavelengths will also be resonant). Antennas that are required to be small compared to the wavelength sacrifice efficiency and cannot be very directional. Fortunately at higher frequencies (UHF, microwaves) trading off performance to obtain a smaller physical size is usually not required.

Resonant antennas

The majority of antenna designs are based on the *resonance* principle. This relies on the behaviour of moving electrons, which reflect off surfaces where the dielectric constant changes, in a fashion similar to the way light reflects when optical properties change. In these designs, the reflective surface is created by the end of a conductor, normally a thin metal wire or rod, which in the simplest case has a *feed point* at one end where it is connected to a transmission line. The conductor, or *element*, is aligned with the electrical field of the desired signal, normally meaning it is perpendicular to the line from the antenna to the source (or receiver in the case of a broadcast antenna).[15]

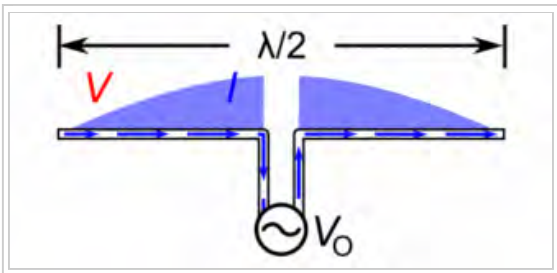

Standing waves on a half wave dipole driven at its resonant frequency. The waves are shown graphically by bars of color (red for voltage, *V* and blue for current, *I*) whose width is proportional to the amplitude of the quantity at that point on the antenna.

The radio signal's electrical component induces a voltage in the conductor. This causes an electrical current to begin flowing in the direction of the signal's instantaneous field. When the resulting current reaches the end of the conductor, it reflects, which is equivalent to a 180 degree change in phase. If the conductor is ¼ of a wavelength

long, current from the feed point will undergo 90 degree phase change by the time it reaches the end of the conductor, reflect through 180 degrees, and then another 90 degrees as it travels back. That means it has undergone a total 360 degree phase change, returning it to the original signal. The current in the element thus adds to the current being created from the source at that instant. This process creates a standing wave in the conductor, with the maximum current at the feed.[16]

The ordinary half-wave dipole is probably the most widely used antenna design. This consists of two ¼-wavelength elements arranged end-to-end, and lying along essentially the same axis (or *collinear*), each feeding one side of a two-conductor transmission wire. The physical arrangement of the two elements places them 180 degrees out of phase, which means that at any given instant one of the elements is driving current into the transmission line while the other is pulling it out. The monopole antenna is essentially one half of the half-wave dipole, a single ¼-wavelength element with the other side connected to ground or an equivalent ground plane (or *counterpoise*). Monopoles, which are one-half the size of a dipole, are common for long-wavelength radio signals where a dipole would be impractically large. Another common design is the folded dipole, which is essentially two dipoles placed side-by-side and connected at their ends to make a single one-wavelength antenna.

The standing wave forms with this desired pattern at the design frequency, f_0, and antennas are normally designed to be this size. However, feeding that element with $3f_0$ (whose wavelength is ⅓ that of f_0) will also lead to a standing wave pattern. Thus, an antenna element is *also* resonant when its length is ¾ of a wavelength. This is true for all odd multiples of ¼ wavelength. This allows some flexibility of design in terms of antenna lengths and feed points. Antennas used in such a fashion are known to be *harmonically operated*.[17]

Current and voltage distribution

The quarter-wave elements imitate a series-resonant electrical element due to the standing wave present along the conductor. At the resonant frequency, the standing wave has a current peak and voltage node (minimum) at the feed. In electrical terms, this means the element has minimum reactance, generating the maximum current for minimum voltage. This is the ideal situation, because it produces the maximum output for the minimum input, producing the highest possible efficiency. Contrary to an ideal (lossless) series-resonant circuit, a finite resistance remains (corresponding to the relatively small voltage at the feed-point) due to the antenna's radiation resistance as well as any actual electrical losses.

Recall that a current will reflect when there are changes in the electrical properties of the material. In order to efficiently send the signal into the transmission line, it is important that the transmission line has the same impedance as the elements, otherwise some of the signal will be reflected back into the antenna. This leads to the concept of impedance matching, the design of the overall system of antenna and transmission line so the impedance is as close as possible, thereby reducing these losses. Impedance matching between antennas and transmission lines is commonly handled through the use of a balun, although other solutions are also used in certain roles. An important measure of this basic concept is the standing wave ratio, which measures the magnitude of the reflected signal.

Consider a half-wave dipole designed to work with signals 1 m wavelength, meaning the antenna would be approximately 50 cm across. If the element has a length-to-diameter ratio of 1000, it will have an inherent resistance of about 63 ohms. Using the appropriate transmission wire or balun, we match that resistance to ensure minimum signal loss. Feeding that antenna with a current of 1 ampere will require 63 volts of RF, and the antenna will radiate 63 watts (ignoring losses) of radio frequency power. Now consider the case when the antenna is fed a signal with a wavelength of 1.25 m; in this case the reflected current would arrive at the feed out-of-phase with the signal, causing the net current to drop while the voltage remains the same. Electrically this appears to be a very high impedance. The antenna and transmission line no longer have the same impedance, and the signal will be reflected back into the antenna, reducing output. This could be addressed by changing the matching system between the antenna and transmission line, but that solution only works well at the new design frequency.

The end result is that the resonant antenna will efficiently feed a signal into the transmission line only when the source signal's frequency is close to that of the design frequency of the antenna, or one of the resonant multiples. This makes resonant antenna designs inherently narrowband, and they are most commonly used with a single target signal. They are particularly common on radar systems, where the same antenna is used for both broadcast and reception, or for radio and television *broadcasts*, where the antenna is working with a single frequency. They are less commonly used for reception where multiple channels are present, in which case additional modifications are used to increase the bandwidth, or entirely different antenna designs are used.

Electrically short antennas

It is possible to use simple impedance matching concepts to allow the use of monopole or dipole antennas substantially shorter than the ¼ or ½ wavelength, respectively, at which they are resonant. As these antennas are made shorter (for a given frequency) their impedance becomes dominated by a series capacitive (negative) reactance; by adding a series inductance with the opposite (positive) reactance – a so-called loading coil – the antenna's reactance may be cancelled leaving only a pure resistance. Sometimes the resulting (lower) electrical resonant frequency of such a system (antenna plus matching network) is described using the concept of *electrical length*, so an antenna used at a lower frequency than its resonant frequency is called an *electrically short antenna*.

For example, at 30 MHz (10 m wavelength) a true resonant ¼ wavelength monopole would be almost 2.5 meters long, and using an antenna only 1.5 meters tall would require the addition of a loading coil. Then it may be said that the coil has lengthened the antenna to achieve an electrical length of 2.5 meters. However, the resulting resistive impedance achieved will be quite a bit lower than that of a true ¼ wave (resonant) monopole, often requiring further impedance matching (a transformer) to the desired transmission line. For ever shorter antennas (requiring greater "electrical lengthening") the radiation resistance plummets (approximately according to the square of the antenna length), so that the mismatch due to a net reactance away from the electrical resonance worsens. Or one could as well say that the equivalent resonant circuit of the antenna system has a higher Q factor and thus a reduced bandwidth, which can even become inadequate for the transmitted signal's spectrum. Resistive losses due to the loading coil, relative to the decreased radiation resistance, entail a reduced electrical efficiency, which can be of great concern for a transmitting antenna, but bandwidth is the major factor that sets the size of antennas at 1 MHz and lower frequencies.

Arrays and reflectors

The amount of signal received from a distant transmission source is essentially geometric in nature due to the inverse-square law, and this leads to the concept of *effective area*. This measures the performance of an antenna by comparing the amount of power it generates to the amount of power in the original signal, measured in terms of the signal's power density in Watts per square metre. A half-wave dipole has an effective area of 0.13 λ^2. If more performance is needed, one cannot simply make the antenna larger. Although this would intercept more energy from the signal, due to the considerations above, it would decrease the output significantly due to it moving away from the resonant length. In roles where higher performance is needed, designers often use multiple elements combined together.

Rooftop television Yagi-Uda antennas like these are widely used at VHF and UHF frequencies.

Returning to the basic concept of current flows in a conductor, consider what happens if a half-wave dipole is not connected to a feed point, but instead shorted out. Electrically this forms a single ½-wavelength element. But the overall current pattern is the same; the current will be zero at the two ends, and reach a maximum in the center. Thus signals near the design frequency will continue to create a standing wave pattern. Any varying electrical current, like the standing wave in the element, will radiate a signal. In this case, aside from resistive losses in the element, the rebroadcast signal will be significantly similar to the original signal in both magnitude and shape. If this element is placed so its signal reaches the main dipole in-phase, it will reinforce the original signal, and increase the current in the dipole. Elements used in this way are known as *passive elements*.

A Yagi-Uda array uses passive elements to greatly increase gain. It is built along a support boom that is pointed toward the signal, and thus sees no induced signal and does not contribute to the antenna's operation. The end closer to the source is referred to as the front. Near the rear is a single active element, typically a half-wave dipole or folded dipole. Passive elements are arranged in front (*directors*) and behind (*reflectors*) the active element along the boom. The Yagi has the inherent quality that it becomes increasingly directional, and thus has higher gain, as the number of elements increases. However, this also makes it increasingly sensitive to changes in frequency; if the signal frequency changes, not only does the active element receive less energy directly, but all of the passive elements adding to that signal also decrease their output as well and their signals no longer reach the active element in-phase.

It is also possible to use multiple active elements and combine them together with transmission lines to produce a similar system where the phases add up to reinforce the output. The antenna array and very similar reflective array antenna consist of multiple elements, often half-wave dipoles, spaced out on a plane and wired together with transmission lines with specific phase lengths to produce a single in-phase signal at the output. The log-periodic antenna is a more complex design that uses multiple in-line elements similar in appearance to the Yagi-Uda but using transmission lines between the elements to produce the output.

Reflection of the original signal also occurs when it hits an extended conductive surface, in a fashion similar to a mirror. This effect can also be used to increase signal through the use of a *reflector*, normally placed behind the active element and spaced so the reflected signal reaches the element in-phase. Generally the reflector will remain highly reflective even if it is not solid; gaps less than $1/10$ generally have little effect on the outcome. For this reason, reflectors often take the form of wire meshes or rows of passive elements, which makes them lighter and less subject to wind. The parabolic reflector is perhaps the best known example of a reflector-based antenna, which has an effective area far greater than the active element alone.

Bandwidth

Although a resonant antenna has a purely resistive feed-point impedance at a particular frequency, many (if not most) applications require using an antenna over a range of frequencies. The frequency range or *bandwidth* over which an antenna functions well can be very wide (as in a log-periodic antenna) or narrow (in a resonant antenna); outside this range the antenna impedance becomes a poor match to the transmission line and transmitter (or receiver). Also in the case of the Yagi-Uda and other end-fire arrays, use of the antenna well away from its design frequency affects its radiation pattern, reducing its directive gain; the usable bandwidth is then limited regardless of impedance matching.

Except for the latter concern, the resonant frequency of an antenna system can always be altered by adjusting a suitable matching network. This is most efficiently accomplished using a matching network at the site of the antenna, since simply adjusting a matching network at the transmitter (or receiver) would leave the transmission line with a poor standing wave ratio.

Instead, it is often desired to have an antenna whose impedance does not vary so greatly over a certain bandwidth. It turns out that the amount of reactance seen at the terminals of a resonant antenna when the frequency is shifted, say, by 5%, depends very much on the diameter of the conductor used. A long thin wire used as a half-wave dipole (or quarter wave monopole) will have a reactance significantly greater than the resistive impedance it has at resonance, leading to a poor match and generally unacceptable performance. Making the element using a tube of a diameter perhaps 1/50 of its length, however, results in a reactance at this altered frequency which is not so great, and a much less serious mismatch and effect on the antenna's net performance. Thus rather thick tubes are often used for the elements; these also have reduced parasitic resistance (loss).

Rather than just using a thick tube, there are similar techniques used to the same effect such as replacing thin wire elements with *cages* to simulate a thicker element. This widens the bandwidth of the resonance. On the other hand, it is desired for amateur radio antennas to operate at several bands which are widely separated from each other (but not in between). This can often be accomplished simply by connecting elements resonant at those different frequencies in parallel. Most of the transmitter's power will flow into the resonant element while the others present a high (reactive) impedance, thus drawing little current from the same voltage. Another popular solution uses so-called *traps* consisting of parallel resonant circuits which are strategically placed in breaks along each antenna element. When used at one particular frequency band the trap presents a very high impedance (parallel resonance) effectively truncating the element at that length, making it a proper resonant antenna. At a lower frequency the trap allows the full length of the element to be employed, albeit with a shifted resonant frequency due to the inclusion of the trap's net reactance at that lower frequency.

The bandwidth characteristics of a resonant antenna element can be characterized according to its Q, just as one uses to characterize the sharpness of an L-C resonant circuit. A common mistake is to assume that there is an advantage in an antenna having a high Q (the so-called "quality factor"). In the context of electronic circuitry a low Q generally signifies greater loss (due to unwanted resistance) in a resonant L-C circuit, and poorer receiver selectivity. However this understanding does not apply to resonant antennas where the resistance involved is the radiation resistance, a desired quantity which removes energy from the resonant element in order to radiate it (the purpose of an antenna, after all!). The Q of an L-C-R circuit is defined as the ratio of the inductor's (or capacitor's) reactance to the resistance, so for a certain radiation resistance (the radiation resistance at resonance does not vary greatly with diameter) the greater reactance off-resonance causes the poorer bandwidth of an antenna employing a very thin conductor. The Q of such a narrowband antenna can be as high as 15. On the other hand, the reactance at the same off-resonant frequency of one using thick elements is much less, consequently resulting in a Q as low as 5. These two antennas may perform equivalently at the resonant frequency, but the second antenna will perform over a bandwidth 3 times as wide as the antenna consisting of a thin conductor.

Antennas for use over much broader frequency ranges are achieved using further techniques. Adjustment of a matching network can, in principle, allow for any antenna to be matched at any frequency. Thus the loop antenna built into most AM broadcast (medium wave) receivers has a very narrow bandwidth, but is tuned using a parallel capacitance which is adjusted according to the receiver tuning. On the other hand, log-periodic antennas are *not* resonant at any frequency but can be built to attain similar characteristics (including feedpoint impedance) over any frequency range. These are therefore commonly used (in the form of directional log-periodic dipole arrays) as television antennas.

Gain

Gain is a parameter which measures the degree of directivity of the antenna's radiation pattern. A high-gain antenna will radiate most of its power in a particular direction, while a low-gain antenna will radiate over a wider angle. The *antenna gain*, or *power gain* of an antenna is defined as the ratio of the intensity (power per unit surface area) I radiated by the antenna in the direction of its maximum output, at an arbitrary distance, divided by the intensity I_{iso} radiated at the same distance by a hypothetical isotropic antenna which radiates equal power in all directions. This dimensionless ratio is usually expressed logarithmically in decibels, these units are called "decibels-isotropic" (dBi)

$$G_{\text{dBi}} = 10 \log \frac{I}{I_{\text{iso}}}$$

A second unit used to measure gain is the ratio of the power radiated by the antenna to the power radiated by a half-wave dipole antenna I_{dipole}; these units are called "decibels-dipole" (dBd)

$$G_{\text{dBd}} = 10 \log \frac{I}{I_{\text{dipole}}}$$

Since the gain of a half-wave dipole is 2.15 dBi and the logarithm of a product is additive, the gain in dBi is just 2.15 decibels greater than the gain in dBd

$$G_{\text{dBi}} = G_{\text{dBd}} + 2.15$$

High-gain antennas have the advantage of longer range and better signal quality, but must be aimed carefully at the other antenna. An example of a high-gain antenna is a parabolic dish such as a satellite television antenna. Low-gain antennas have shorter range, but the orientation of the antenna is relatively unimportant. An example of a low-gain antenna is the whip antenna found on portable radios and cordless phones. Antenna gain should not be confused with amplifier gain, a separate parameter measuring the increase in signal power due to an amplifying device.

Effective area or aperture

The *effective area* or effective aperture of a receiving antenna expresses the portion of the power of a passing electromagnetic wave which it delivers to its terminals, expressed in terms of an equivalent area. For instance, if a radio wave passing a given location has a flux of 1 pW / m^2 (10^{-12} watts per square meter) and an antenna has an effective area of 12 m^2, then the antenna would deliver 12 pW of RF power to the receiver (30 microvolts rms at 75 ohms). Since the receiving antenna is not equally sensitive to signals received from all directions, the effective area is a function of the direction to the source.

Due to reciprocity (discussed above) the gain of an antenna used for transmitting must be proportional to its effective area when used for receiving. Consider an antenna with no loss, that is, one whose electrical efficiency is 100%. It can be shown that its effective area averaged over all directions must be equal to $\lambda^2/4\pi$, the wavelength squared divided by 4π. Gain is defined such that the average gain over all directions for an antenna with 100% electrical efficiency is equal to 1. Therefore, the effective area A_{eff} in terms of the gain G in a given direction is given by:

$$A_{\text{eff}} = \frac{\lambda^2}{4\pi} G$$

For an antenna with an efficiency of less than 100%, both the effective area and gain are reduced by that same amount. Therefore, the above relationship between gain and effective area still holds. These are thus two different ways of expressing the same quantity. A_{eff} is especially convenient when computing the power that would be received by an antenna of a specified gain, as illustrated by the above example.

Radiation pattern

The radiation pattern of an antenna is a plot of the relative field strength of the radio waves emitted by the antenna at different angles. It is typically represented by a three-dimensional graph, or polar plots of the horizontal and vertical cross sections. The pattern of an ideal isotropic antenna, which radiates equally in all directions, would look like a sphere. Many nondirectional antennas, such as monopoles and dipoles, emit equal power in all horizontal directions, with the power dropping off at higher and lower angles; this is called an omnidirectional pattern and when plotted looks like a torus or donut.

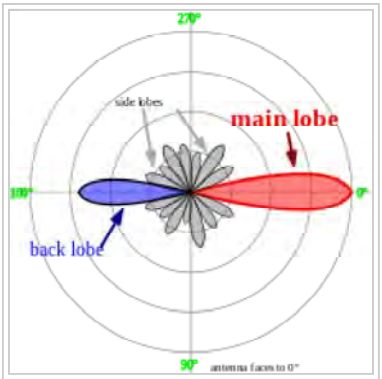

Polar plots of the horizontal cross sections of a (virtual) Yagi-Uda-antenna. Outline connects points with 3db field power compared to an ISO emitter.

The radiation of many antennas shows a pattern of maxima or "*lobes*" at various angles, separated by "*nulls*", angles where the radiation falls to zero. This is because the radio waves emitted by different parts of the antenna typically interfere, causing maxima at angles where the radio waves arrive at distant points in phase, and zero radiation at other angles where the radio waves arrive out of phase. In a directional antenna designed to project radio waves in a particular direction, the lobe in that direction is designed larger than the others and is called the "*main lobe*". The other lobes usually represent unwanted radiation and are called "*sidelobes*". The axis through the main lobe is called the "*principal axis*" or "*boresight axis*".

Field regions

The space surrounding an antenna can be divided into three concentric regions: the reactive near-field, the radiating near-field (Fresnel region) and the far-field (Fraunhofer) regions. These regions are useful to identify the field structure in each, although there are no precise boundaries.

In the far-field region, we are far enough from the antenna to neglect its size and shape. We can assume that the electromagnetic wave is purely a radiating plane wave (electric and magnetic fields are in phase and perpendicular to each other and to the direction of propagation). This simplifies the mathematical analysis of the radiated field.

Impedance

As an electro-magnetic wave travels through the different parts of the antenna system (radio, feed line, antenna, free space) it may encounter differences in impedance (E/H, V/I, etc.). At each interface, depending on the impedance match, some fraction of the wave's energy will reflect back to the source,[18] forming a standing wave in the feed line. The ratio of maximum power to minimum power in the wave can be measured and is called the standing wave ratio (SWR). A SWR of 1:1 is ideal. A SWR of 1.5:1 is considered to be marginally acceptable in low power applications where power loss is more critical, although an SWR as high as 6:1 may still be usable with the right equipment. Minimizing impedance differences at each interface (impedance matching) will reduce SWR and maximize power transfer through each part of the antenna system.

Complex impedance of an antenna is related to the electrical length of the antenna at the wavelength in use. The impedance of an antenna can be matched to the feed line and radio by adjusting the impedance of the feed line, using the feed line as an impedance transformer. More commonly, the impedance is adjusted at the load (see below) with an antenna tuner, a balun, a matching transformer, matching networks composed of inductors and capacitors, or matching sections such as the gamma match.

Efficiency

Efficiency of a transmitting antenna is the ratio of power actually radiated (in all directions) to the power absorbed by the antenna terminals. The power supplied to the antenna terminals which is not radiated is converted into heat. This is usually through loss resistance in the antenna's conductors, but can also be due to dielectric or magnetic core losses in antennas (or antenna systems) using such components. Such loss effectively robs power from the transmitter, requiring a stronger transmitter in order to transmit a signal of a given strength.

For instance, if a transmitter delivers 100 W into an antenna having an efficiency of 80%, then the antenna will radiate 80 W as radio waves and produce 20 W of heat. In order to radiate 100 W of power, one would need to use a transmitter capable of supplying 125 W to the antenna. Note that antenna efficiency is a separate issue from impedance matching, which may also

reduce the amount of power radiated using a given transmitter. If an SWR meter reads 150 W of incident power and 50 W of reflected power, that means that 100 W have actually been absorbed by the antenna (ignoring transmission line losses). How much of that power has actually been radiated cannot be directly determined through electrical measurements at (or before) the antenna terminals, but would require (for instance) careful measurement of field strength. Fortunately the loss resistance of antenna conductors such as aluminum rods can be calculated and the efficiency of an antenna using such materials predicted.

However loss resistance will generally affect the feedpoint impedance, adding to its resistive (real) component. That resistance will consist of the sum of the radiation resistance R_r and the loss resistance R_{loss}. If an rms current I is delivered to the terminals of an antenna, then a power of I^2R_r will be radiated and a power of I^2R_{loss} will be lost as heat. Therefore, the efficiency of an antenna is equal to $R_r / (R_r + R_{loss})$. Of course only the total resistance $R_r + R_{loss}$ can be directly measured.

According to reciprocity, the efficiency of an antenna used as a receiving antenna is identical to the efficiency as defined above. The power that an antenna will deliver to a receiver (with a proper impedance match) is reduced by the same amount. In some receiving applications, the very inefficient antennas may have little impact on performance. At low frequencies, for example, atmospheric or man-made noise can mask antenna inefficiency. For example, CCIR Rep. 258-3 indicates man-made noise in a residential setting at 40 MHz is about 28 dB above the thermal noise floor. Consequently, an antenna with a 20 dB loss (due to inefficiency) would have little impact on system noise performance. The loss within the antenna will affect the intended signal and the noise/interference identically, leading to no reduction in signal to noise ratio (SNR).

This is fortunate, since antennas at lower frequencies which are not rather large (a good fraction of a wavelength in size) are inevitably inefficient (due to the small radiation resistance R_r of small antennas). Most AM broadcast radios (except for car radios) take advantage of this principle by including a small loop antenna for reception which has an extremely poor efficiency. Using such an inefficient antenna at this low frequency (530–1650 kHz) thus has little effect on the receiver's net performance, but simply requires greater amplification by the receiver's electronics. Contrast this tiny component to the massive and very tall towers used at AM broadcast stations for transmitting at the very same frequency, where every percentage point of reduced antenna efficiency entails a substantial cost.

The definition of antenna gain or *power gain* already includes the effect of the antenna's efficiency. Therefore, if one is trying to radiate a signal toward a receiver using a transmitter of a given power, one need only compare the gain of various antennas rather than considering the efficiency as well. This is likewise true for a receiving antenna at very high (especially microwave) frequencies, where the point is to receive a signal which is strong compared to the receiver's noise temperature. However, in the case of a directional antenna used for receiving signals with the intention of *rejecting* interference from different directions, one is no longer concerned with the antenna efficiency, as discussed above. In this case, rather than quoting the antenna gain, one would be more concerned with the *directive gain* which does *not* include the effect of antenna (in)efficiency. The directive gain of an antenna can be computed from the published gain divided by the antenna's efficiency.

Polarization

The *polarization* of an antenna refers to the orientation of the electric field (E-plane) of the radio wave with respect to the Earth's surface and is determined by the physical structure of the antenna and by its orientation; note that this designation is totally distinct from the antenna's directionality. Thus, a simple straight wire antenna will have one polarization when mounted vertically, and a different polarization when mounted horizontally. As a transverse wave, the magnetic field of a radio wave is at right angles to that of the electric field, but by convention, talk of an antenna's "polarization" is understood to refer to the direction of the electric field.

Reflections generally affect polarization. For radio waves, one important reflector is the ionosphere which can change the wave's polarization. Thus for signals received following reflection by the ionosphere (a skywave), a consistent polarization cannot be expected. For line-of-sight communications or ground wave propagation, horizontally or vertically polarized transmissions generally remain in about the same polarization state at the receiving location. Matching the receiving antenna's polarization to that of the transmitter can make a very substantial difference in received signal strength.

Polarization is predictable from an antenna's geometry, although in some cases it is not at all obvious (such as for the quad antenna). An antenna's linear polarization is generally along the direction (as viewed from the receiving location) of the antenna's currents when such a direction can be defined. For instance, a vertical whip antenna or Wi-Fi antenna vertically oriented will transmit and receive in the vertical polarization. Antennas with horizontal elements, such as most rooftop TV

antennas in the United States, are horizontally polarized (broadcast TV in the U.S. usually uses horizontal polarization). Even when the antenna system has a vertical orientation, such as an array of horizontal dipole antennas, the polarization is in the horizontal direction corresponding to the current flow. The polarization of a commercial antenna is an essential specification.

Polarization is the sum of the E-plane orientations over time projected onto an imaginary plane perpendicular to the direction of motion of the radio wave. In the most general case, polarization is elliptical, meaning that the polarization of the radio waves varies over time. Two special cases are linear polarization (the ellipse collapses into a line) as we have discussed above, and circular polarization (in which the two axes of the ellipse are equal). In linear polarization the electric field of the radio wave oscillates back and forth along one direction; this can be affected by the mounting of the antenna but usually the desired direction is either horizontal or vertical polarization. In circular polarization, the electric field (and magnetic field) of the radio wave rotates at the radio frequency circularly around the axis of propagation. Circular or elliptically polarized radio waves are designated as right-handed or left-handed using the "thumb in the direction of the propagation" rule. Note that for circular polarization, optical researchers use the opposite right hand rule from the one used by radio engineers.

It is best for the receiving antenna to match the polarization of the transmitted wave for optimum reception. Intermediate matchings will lose some signal strength, but not as much as a complete mismatch. A circularly polarized antenna can be used to equally well match vertical or horizontal linear polarizations. Transmission from a circularly polarized antenna received by a linearly polarized antenna (or vice versa) entails a 3 dB reduction in signal-to-noise ratio as the received power has thereby been cut in half.

Impedance matching

Maximum power transfer requires matching the impedance of an antenna system (as seen looking into the transmission line) to the complex conjugate of the impedance of the receiver or transmitter. In the case of a transmitter, however, the desired matching impedance might not correspond to the dynamic output impedance of the transmitter as analyzed as a source impedance but rather the design value (typically 50 ohms) required for efficient and safe operation of the transmitting circuitry. The intended impedance is normally resistive but a transmitter (and some receivers) may have additional adjustments to cancel a certain amount of reactance in order to "tweak" the match. When a transmission line is used in between the antenna and the transmitter (or receiver) one generally would like an antenna system whose impedance is resistive and near the characteristic impedance of that transmission line in order to minimize the standing wave ratio (SWR) and the increase in transmission line losses it entails, in addition to supplying a good match at the transmitter or receiver itself.

Antenna tuning generally refers to cancellation of any reactance seen at the antenna terminals, leaving only a resistive impedance which might or might not be exactly the desired impedance (that of the transmission line). Although an antenna may be designed to have a purely resistive feedpoint impedance (such as a dipole 97% of a half wavelength long) this might not be exactly true at the frequency that it is eventually used at. In some cases the physical length of the antenna can be "trimmed" to obtain a pure resistance. On the other hand, the addition of a series inductance or parallel capacitance can be used to cancel a residual capacitative or inductive reactance, respectively.

In some cases this is done in a more extreme manner, not simply to cancel a small amount of residual reactance, but to resonate an antenna whose resonance frequency is quite different from the intended frequency of operation. For instance, a "whip antenna" can be made significantly shorter than 1/4 wavelength long, for practical reasons, and then resonated using a so-called loading coil. This physically large inductor at the base of the antenna has an inductive reactance which is the opposite of the capacitative reactance that such a vertical antenna has at the desired operating frequency. The result is a pure resistance seen at feedpoint of the loading coil; unfortunately that resistance is somewhat lower than would be desired to match commercial coax.

So an additional problem beyond canceling the unwanted reactance is of matching the remaining resistive impedance to the characteristic impedance of the transmission line. In principle this can always be done with a transformer, however the turns ratio of a transformer is not adjustable. A general matching network with at least two adjustments can be made to correct both components of impedance. Matching networks using discrete inductors and capacitors will have losses associated with those components, and will have power restrictions when used for transmitting. Avoiding these difficulties, commercial antennas are generally designed with fixed matching elements or feeding strategies to get an approximate match to standard coax, such as 50 or 75 Ohms. Antennas based on the dipole (rather than vertical antennas) should include a balun in between the transmission line and antenna element, which may be integrated into any such matching network.

Another extreme case of impedance matching occurs when using a small loop antenna (usually, but not always, for receiving) at a relatively low frequency where it appears almost as a pure inductor. Resonating such an inductor with a capacitor at the frequency of operation not only cancels the reactance but greatly magnifies the very small radiation resistance of such a loop. This is implemented in most AM broadcast receivers, with a small ferrite loop antenna resonated by a capacitor which is varied along with the receiver tuning in order to maintain resonance over the AM broadcast band

Antenna types

Antennas can be classified in various ways. The list below groups together antennas under common operating principles, following the way antennas are classified in many engineering textbooks.[19][20][21]

Isotropic: An isotropic antenna (isotropic radiator) is a *hypothetical* antenna that radiates equal signal power in all directions. It is a mathematical model that is used as the base of comparison to calculate the gain of real antennas. No real antenna can have an isotropic radiation pattern. However *approximately* isotropic antennas, constructed with multiple elements, are used in antenna testing.

The first four groups below are usually resonant antennas; when driven at their resonant frequency their elements act as resonators. Waves of current and voltage bounce back and forth between the ends, creating standing waves along the elements.

Dipole

"Rabbit ears" dipole variant for VHF television reception

Yagi-Uda television antenna for analog channels 2-4, 47-68 MHz

Log-periodic dipole array covering 140-470 MHz

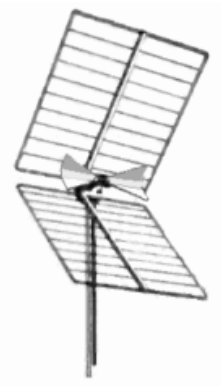

Corner reflector UHF TV antenna with "bowtie" dipole driven element

Two-element turnstile antenna for reception of weather satellite data, 137 MHz. Has circular polarization.

The dipole is the prototypical antenna on which a large class of antennas are based. A basic dipole antenna consists of two conductors (usually metal rods or wires) arranged symmetrically, with one side of the balanced feedline from the transmitter or receiver attached to each.[20][22] The most common type, the half-wave dipole, consists of two resonant elements just under a quarter wavelength long. This antenna radiates maximally in directions perpendicular to the antenna's axis, giving it a small directive gain of 2.15 dBi (practically the lowest directive gain of any antenna). Although half-wave dipoles are used alone as omnidirectional antennas, they are also a building block of many other more complicated directional antennas.

- *Yagi-Uda* - One of the most common directional antennas at HF, VHF, and UHF frequencies. Consists of multiple half wave dipole elements in a line, with a single driven element and multiple parasitic elements which serve to create a uni-directional or beam antenna. These typically have gains between 10 and 20 dBi depending on the number of elements used, and are very narrowband (with a usable bandwidth of only a few percent) though there are derivative designs which relax this limitation. Used for rooftop television antennas, point-to-point communication links, and long distance shortwave communication using skywave ("skip") reflection from the ionosphere.
- *Log-periodic dipole array* - Often confused with the Yagi-Uda, this consists of many dipole elements along a boom with gradually increasing lengths, all connected to the transmission line with alternating polarity. It is a directional antenna with a wide bandwidth. This makes it ideal for use as a rooftop television antenna, although its gain is much less than a Yagi of comparable size.
- *Turnstile* - Two dipole antennas mounted at right angles, fed with a phase difference of 90°. This antenna is unusual in that it radiates in *all* directions (no nodes in the radiation pattern), with horizontal polarization in directions coplaner with the elements, circular polarization normal to that plane, and elliptical polarization in other directions. Used for receiving signals from satellites, as circular polarization is transmitted by many satellites.
- *Corner reflector* - A directive antenna with moderate gain of about 8 dBi often used at UHF frequencies. Consists of a dipole mounted in front of two reflective metal screens joined at an angle, usually 90°. Used as a rooftop UHF television antenna and for point-to-point data links.
- *Patch (microstrip)* - A type of antenna with elements consisting of metal sheets mounted over a ground plane. Similar to dipole with gain of 6 - 9 dBi. Integrated into surfaces such as aircraft bodies. Their easy fabrication using PCB techniques have made them popular in modern wireless devices. Often used in arrays.

Monopole

Quarter-wave whip antenna on an FM radio for 88-108 MHz

Rubber Ducky antenna on UHF 446 MHz walkie talkie with rubber cover removed.

VHF ground plane antenna

Mast radiator antenna of medium wave AM radio station, Germany

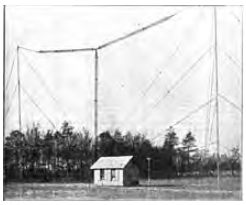

T antenna of amateur radio station, 80 ft high, used at 1.5 MHz.

Monopole antennas consist of a single conductor such as a metal rod, mounted over the ground or an artificial conducting surface (a so-called *ground plane*).[20][23] One side of the feedline from the receiver or transmitter is connected to the conductor, and the other side to ground and/or the artificial ground plane. The monopole is best understood as a dipole antenna in which one conductor is omitted; the radiation is generated as if the second arm of the dipole were present due to the effective image current seen as a reflection of the monopole from the ground. Since all of the equivalent dipole's radiation is concentrated in a half-space, the antenna has twice (3 dB increase of) the gain of a similar dipole, not considering losses in the ground plane.

The most common form is the quarter-wave monopole which is one-quarter of a wavelength long and has a gain of 5.12 dBi when mounted over a ground plane. Monopoles have an omnidirectional radiation pattern, so they are used for broad coverage of an area, and have vertical polarization. The ground waves used for broadcasting at low frequencies must be vertically polarized, so large vertical monopole antennas are used for broadcasting in the MF, LF, and VLF bands. Small monopoles are used as nondirectional antennas on portable radios in the HF, VHF, and UHF bands.

- *Whip* - Type of antenna used on mobile and portable radios in the VHF and UHF bands such as boom boxes, consists of a flexible rod, often made of telescoping segments.
  - *Rubber Ducky* - Most common antenna used on portable two way radios and cordless phones due to its compactness, consists of an electrically short wire helix. The helix adds inductance to cancel the capacitive reactance of the short radiator, making it resonant. Very low gain.
  - *Ground plane* - a whip antenna with several rods extending horizontally from base of whip attached to the ground side of the feedline. Since whips are mounted above ground, the horizontal rods form an artificial ground plane under the antenna to increase its gain. Used as base station antennas for land mobile radio systems such as police, ambulance and taxi dispatchers.
- *Mast radiator* - A radio tower in which the tower structure itself serves as the antenna. Common form of transmitting antenna for AM radio stations and other MF and LF transmitters. At its base the tower is usually, but not necessarily, mounted on a ceramic insulator to isolate it from the ground.
- *T and inverted L* - Consist of a long horizontal wire suspended between two towers with insulators, with a vertical wire hanging down from it, attached to a feedline to the receiver or transmitter. Used on LF and VLF bands. The vertical wire serves as the radiator. Since at these frequencies the vertical wire is electrically short, much shorter than a quarter wavelength, the horizontal wire(s) serve as a capacitive "hat" to increase the current in the vertical radiator, increasing the gain. Very narrow bandwidth, requires loading coil to tune out the capacitive reactance and make it resonant. Requires low resistance ground (electricity)
- *Inverted F* - Combines the advantages of the inverted-L antenna and the F-type antenna of, respectively, compactness and good matching. The antenna is grounded at the base and fed at some intermediate point. The position of the feed point determines the antenna impedance. Thus, matching can be achieved without the need for an extraneous matching network.
- *Umbrella* - Very large wire transmitting antennas used on VLF bands. Consists of a central mast radiator tower attached at the top to multiple wires extending out radially from the mast to ground, like a tent or umbrella, insulated at the ends. Extremely narrow bandwidth, requires large loading coil and low resistance counterpoise ground. Used for long range military communications.

Array

VHF collinear array of folded dipoles

Sector antennas *(white bars)* on cell phone tower. Collinear arrays of dipoles, these radiate a flat, fan-shaped beam.

108 MHz reflective array antenna of AN-270 radar used during WW2.

Reflective array UHF TV antenna, with bowtie dipoles to cover the UHF 470-890 MHz band

US Air Force PAVE PAWS phased array radar antenna for ballistic missile detection, Alaska. The two circular arrays are composed of thousands of crossed dipole antennas.

Batwing VHF television broadcasting antenna

Crossed-dipole FM radio broadcast antenna

Curtain array shortwave transmitting antenna, Austria. Wire dipoles suspended between towers

Turnstile antenna array used for satellite communication

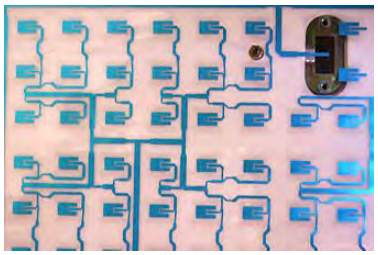

Flat microstrip array antenna for satellite TV reception.

Array antennas consist of multiple antennas working as a single antenna. Typically they consist of arrays of identical driven elements, usually dipoles fed in phase, giving increased gain over that of a single dipole.[20][24][25]

- *Collinear* - Consist of a number of dipoles in a vertical line. It is a high gain omnidirectional antenna, meaning more of the power is radiated in horizontal directions and less into the sky or ground and wasted. Gain of 8 to 10 dBi. Used as base station antennas for land mobile radio systems such as police, fire, ambulance, and taxi dispatchers, and sector antennas for cellular base stations.
- *Reflective array* - multiple dipoles in a two-dimensional array mounted in front of a flat reflecting screen. Used for radar and UHF television transmitting and receiving antennas.
- *Phased array* - A high gain antenna used at UHF and microwave frequencies which is electronically steerable. It consists of multiple dipoles in a two-dimensional array, each fed through an electronic phase shifter, with the phase shifters controlled by a computer control system. The beam can be instantly pointed in any direction over a wide angle in front of the antenna. Used for military radar and jamming systems.
- *Curtain array* - Large directional wire transmitting antenna used at HF by shortwave broadcasting stations. It consists of a vertical rectangular array of wire dipoles suspended in front of a flat reflector screen consisting of a vertical "curtain" of parallel wires, all supported between two metal towers. It radiates a horizontal beam of radio waves into the sky above the horizon, which is reflected by the ionosphere to Earth beyond the horizon
- *Batwing* or *superturnstile* - A specialized antenna used in television broadcasting consisting of perpendicular pairs of dipoles with radiators resembling bat wings. Multiple batwing antennas are stacked vertically on a mast to make VHF television broadcast antennas. Omnidirectional radiation pattern with high gain in horizontal directions. The batwing shape gives them wide bandwidth.
- *microstrip* - an array of patch antennas on a substrate fed by microstrip feedlines. Microwave antenna that can achieve large gains in compact space. Ease of fabrication by PCB techniques have made them popular in modern wireless devices. Beamwidth and polarization can be actively reconfigurable.

Loop

Loopstick antenna from an AM broadcast radio, about 4 in (10 cm) long. The antenna is inductive and, in conjunction with a variable capacitor, forms the tuned circuit at the input stage of the receiver.

Loop antenna for transmitting at high frequencies, 2m diameter

Separate loop antenna for AM radio

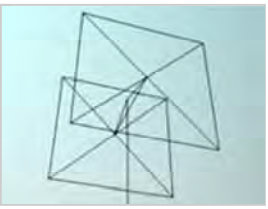

A two-element quad antenna used by an amateur radio station

Loop antennas consist of a loop (or coil) of wire.[20][26][27] Loops with circumference of a wavelength (or integer multiple of the wavelength) are resonant and act somewhat similarly to the half-wave dipole. However a loop small in comparison to the wavelength, also called a magnetic loop, performs quite differently. This antenna interacts directly with the magnetic field of

the radio wave, making it relatively insensitive to nearby electrical noise. However it has a very small radiation resistance, typically much smaller than the loss resistance, making it inefficient and thus undesirable for transmitting. They are used as receiving antennas at low frequencies, and also as direction finding antennas.

- *Ferrite (loopstick)* - These are used as the receiving antenna in most consumer AM radios operating in the medium wave broadcast band (and lower frequencies), a notable exception being car radios. Wire is coiled around a ferrite core which greatly increases the coil's inductance. Radiation pattern is maximum at directions normal to the ferrite stick.
- *Quad* - consists of multiple wire loops in a line with one functioning as the driven element, and the others as parasitic elements. Used as a directional antenna on the HF bands for shortwave communication.

Aperture

NASA Cassegrain parabolic spacecraft communication antenna, Australia. Uses X band, 8 – 12 GHz. Extremely high gain ~70 dBi.

Microwave horn antenna bandwidth 0.8–18 GHz

X band marine radar slot antenna on ship, 8 – 12 GHz.

Dielectric lens antenna used in millimeter wave radio telescope

Aperture antennas are the main type of directional antennas used at microwave frequencies and above.[20][28] They consist of a small dipole or loop feed antenna inside a three-dimensional guiding structure large compared to a wavelength, with an aperture to emit the radio waves. Since the antenna structure itself is nonresonant they can be used over a wide frequency range by replacing or tuning the feed antenna.

- *Parabolic* - The most widely used high gain antenna at microwave frequencies and above. Consists of a dish-shaped metal parabolic reflector with a feed antenna at the focus. It can have some of the highest gains of any antenna type, up to 60 dBi, but the dish must be large compared to a wavelength. Used for radar antennas, point-to-point data links, satellite communication, and radio telescopes
- *Horn* - Simple antenna with moderate gains of 15 to 25 dBi consists of a flaring metal horn attached to a waveguide. Used for applications such as radar guns, radiometers and as feed antennas for parabolic dishes.
- *Slot* - Consist of a waveguide with one or more slots cut in it to emit the microwaves. Linear slot antennas emit narrow fan-shaped beams. Used as UHF broadcast antennas and marine radar antennas.
- *Dielectric resonator* - consists of small ball or puck-shaped piece of dielectric material excited by aperture in waveguide Used at millimeter wave frequencies

Traveling wave

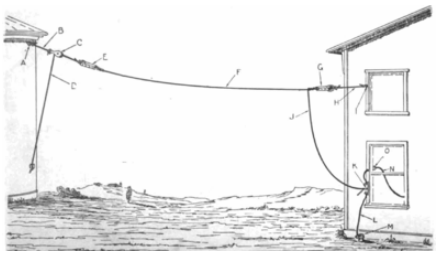

A typical random wire antenna for shortwave reception, strung between two buildings.

Quadrant antenna, similar to rhombic, at an Austrian shortwave broadcast station. Radiates horizontal beam at 5-9 MHz, 100 kW

Array of four axial-mode helical antennas used for satellite tracking, France

Unlike the above antennas, traveling wave antennas are nonresonant so they have inherently broad bandwidth.[20][29] They are typically wire antennas multiple wavelengths long, through which the voltage and current waves travel in one direction, instead of bouncing back and forth to form standing waves as in resonant antennas. They have linear polarization (except for the helical antenna). Unidirectional traveling wave antennas are terminated by a resistor at one end equal to the antenna's characteristic resistance, to absorb the waves from one direction. This makes them inefficient as transmitting antennas.

- *Random wire* - This describes the typical antenna used to receive shortwave radio, consisting of a random length of wire either strung outdoors between supports or indoors in a zigzag pattern along walls, connected to the receiver at one end. Can have complex radiation patterns with several lobes at angles to the wire.
- *Beverage* - Simplest unidirectional traveling wave antenna. Consists of a straight wire one to several wavelengths long, suspended near the ground, connected to the receiver at one end and terminated by a resistor equal to its characteristic impedance, 400 to 800Ω at the other end. Its radiation pattern has a main lobe at a shallow angle in the sky off the terminated end. It is used for reception of skywaves reflected off the ionosphere in long distance "skip" shortwave communication.
- *Rhombic* - Consists of four equal wire sections shaped like a rhombus. It is fed by a balanced feedline at one of the acute corners, and the two sides are connected to a resistor equal to the characteristic resistance of the antenna at the other. It has a main lobe in a horizontal direction off the terminated end of the rhombus. Used for skywave communication on shortwave bands.
- *Helical (axial mode)* - Consists of a wire in the shape of a helix mounted above a reflecting screen. It radiates circularly polarized waves in a beam off the end, with a typical gain of 15 dBi. It is used at VHF and UHF frequencies for communication with satellites and animal tracking transmitters, which use circular polarization because it is insensitive to the relative orientation of the antennas.
- *Leaky wave* - Microwave antennas consisting of a waveguide or coaxial cable with a slot or apertures cut in it so it radiates continuously along its length.

Effect of ground

Ground reflections is one of the common types of multipath.[30][31][32]

The radiation pattern and even the driving point impedance of an antenna can be influenced by the dielectric constant and especially conductivity of nearby objects. For a terrestrial antenna, the ground is usually one such object of importance. The antenna's height above the ground, as well as the electrical properties (permittivity and conductivity) of the ground, can then be important. Also, in the particular case of a monopole antenna, the ground (or an artificial ground plane) serves as the return connection for the antenna current thus having an additional effect, particularly on the impedance seen by the feed line.

When an electromagnetic wave strikes a plane surface such as the ground, part of the wave is transmitted into the ground and part of it is reflected, according to the Fresnel coefficients. If the ground is a very good conductor then almost all of the wave is reflected (180° out of phase), whereas a ground modeled as a (lossy) dielectric can absorb a large amount of the wave's power. The power remaining in the reflected wave, and the phase shift upon reflection, strongly depend on the wave's angle of incidence and polarization. The dielectric constant and conductivity (or simply the complex dielectric constant) is dependent on the soil type and is a function of frequency.

For very low frequencies to high frequencies (<30 MHz), the ground behaves as a lossy dielectric,[33] Thus the ground is characterized both by a conductivity [34] and permittivity (dielectric constant) which can be measured for a given soil (but is influenced by fluctuating moisture levels) or can be estimated from certain maps. At lower frequencies the ground acts mainly as a good conductor, which AM middle wave broadcast (.5 - 1.6 MHz) antennas depend on.

At frequencies between 3 and 30 MHz, a large portion of the energy from a horizontally polarized antenna reflects off the ground, with almost total reflection at the grazing angles important for ground wave propagation. That reflected wave, with its phase reversed, can either cancel or reinforce the direct wave, depending on the antenna height in wavelengths and elevation angle (for a sky wave).

On the other hand, vertically polarized radiation is not well reflected by the ground except at grazing incidence or over very highly conducting surfaces such as sea water.[35] However the grazing angle reflection important for ground wave propagation, using vertical polarization, is *in phase* with the direct wave, providing a boost of up to 6 db, as is detailed below.

At VHF and above (>30 MHz) the ground becomes a poorer reflector. However it remains a good reflector especially for horizontal polarization and grazing angles of incidence. That is important as these higher frequencies usually depend on horizontal line-of-sight propagation (except for satellite communications), the ground then behaving almost as a mirror.

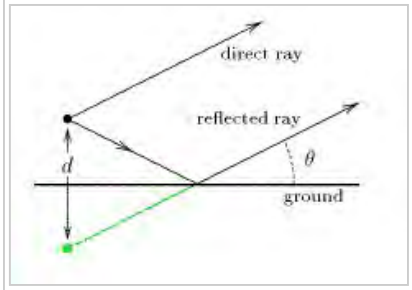

The wave reflected by earth can be considered as emitted by the image antenna.

The net quality of a ground reflection depends on the topography of the surface. When the irregularities of the surface are much smaller than the wavelength, we are in the regime of specular reflection, and the receiver sees both the real antenna and an image of the antenna under the ground due to reflection. But if the ground has irregularities not small compared to the wavelength, reflections will not be coherent but shifted by random phases. With shorter wavelengths (higher frequencies), this is generally the case.

Whenever both the receiving or transmitting antenna are placed at significant heights above the ground (relative to the wavelength), waves specularly reflected by the ground will travel a longer distance than direct waves, inducing a phase shift which can sometimes be significant. When a sky wave is launched by such an antenna, that phase shift is always significant unless the antenna is very close to the ground (compared to the wavelength).

The phase of reflection of electromagnetic waves depends on the polarization of the incident wave. Given the larger refractive index of the ground (typically n=2) compared to air (n=1), the phase of horizontally polarized radiation is reversed upon reflection (a phase shift of π radians or 180°). On the other hand, the vertical component of the wave's electric field is reflected at grazing angles of incidence approximately *in phase*. These phase shifts apply as well to a ground modelled as a good electrical conductor.

This means that a receiving antenna "sees" an image of the antenna but with reversed currents. That current is in the same absolute direction as the actual antenna if the antenna is vertically oriented (and thus vertically polarized) but opposite the actual antenna if the antenna current is horizontal.

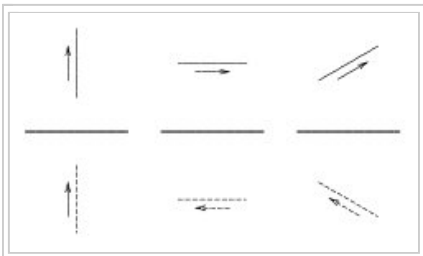
The currents in an antenna appear as an image in *opposite* phase when reflected at grazing angles. This causes a phase reversal for waves emitted by a horizontally polarized antenna (left) but not a vertically polarized antenna (center).

The actual antenna which is *transmitting* the original wave then also may *receive* a strong signal from its own image from the ground. This will induce an additional current in the antenna element, changing the current at the feedpoint for a given feedpoint voltage. Thus the antenna's impedance, given by the ratio of feedpoint voltage to current, is altered due to the antenna's proximity to the ground. This can be quite a significant effect when the antenna is within a wavelength or two of the ground. But as the antenna height is increased, the reduced power of the reflected wave (due to the inverse square law) allows the antenna to approach its asymptotic feedpoint impedance given by theory. At lower heights, the effect on the antenna's impedance is *very* sensitive to the exact distance from the ground, as this affects the phase of the reflected wave relative to the currents in the antenna. Changing the antenna's height by a quarter wavelength, then changes the phase of the reflection by 180°, with a completely different effect on the antenna's impedance.

The ground reflection has an important effect on the net far field radiation pattern in the vertical plane, that is, as a function of elevation angle, which is thus different between a vertically and horizontally polarized antenna. Consider an antenna at a height *h* above the ground, transmitting a wave considered at the elevation angle θ. For a vertically polarized transmission the magnitude of the electric field of the electromagnetic wave produced by the direct ray plus the reflected ray is:

$$|E_V| = 2\,|E_0|\,\left|\cos\left(\frac{2\pi h}{\lambda}\sin\theta\right)\right|$$

Thus the *power* received can be as high as 4 times that due to the direct wave alone (such as when θ=0), following the *square* of the cosine. The sign inversion for the reflection of horizontally polarized emission instead results in:

$$|E_H| = 2\,|E_0|\,\left|\sin\left(\frac{2\pi h}{\lambda}\sin\theta\right)\right|$$

where:

- E_0 is the electrical field that would be received by the direct wave if there were no ground.
- θ is the elevation angle of the wave being considered.
- λ is the wavelength.
- h is the height of the antenna (half the distance between the antenna and its image).

For horizontal propagation between transmitting and receiving antennas situated near the ground reasonably far from each other, the distances traveled by tne direct and reflected rays are nearly the same. There is almost no relative phase shift. If the emission is polarized vertically, the two fields (direct and reflected) add and there is maximum of received signal. If the signal is polarized horizontally, the two signals subtract and the received signal is largely cancelled. The vertical plane radiation patterns are shown in the image at right. With vertical polarization there is always a maximum for θ=0, horizontal propagation (left pattern). For horizontal polarization, there is cancellation at that angle.

Radiation patterns of antennas and their images reflected by the ground. At left the polarization is vertical and there is always a maximum for θ=0. If the polarization is horizontal as at right, there is always a zero for θ=0.

Note that the above formulae and these plots assume the ground as a perfect conductor. These plots of the radiation pattern correspond to a distance between the antenna and its image of 2.5λ. As the antenna height is increased, the number of lobes increases as well.

The difference in the above factors for the case of θ=0 is the reason that most broadcasting (transmissions intended for the public) uses vertical polarization. For receivers near the ground, horizontally polarized transmissions suffer cancellation. For best reception the receiving antennas for these signals are likewise vertically polarized. In some applications where the receiving antenna must work in any position, as in mobile phones, the base station antennas use mixed polarization, such as linear polarization at an angle (with both vertical and horizontal components) or circular polarization.

On the other hand, classical (analog) television transmissions are usually horizontally polarized, because in urban areas buildings can reflect the electromagnetic waves and create ghost images due to multipath propagation. Using horizontal polarization, ghosting is reduced because the amount of reflection of electromagnetic waves in the *p* polarization (horizontal polarization off the side of a building) is generally less than *s* (vertical, in this case) polarization. Vertically polarized analog television has nevertheless been used in some rural areas. In digital terrestrial television such reflections are less problematic, due to robustness of binary transmissions and error correction.

Mutual impedance and interaction between antennas

Current circulating in one antenna generally induces a voltage across the feedpoint of nearby antennas or antenna elements. The mathematics presented below are useful in analyzing the electrical behaviour of antenna arrays, where the properties of the individual array elements (such as half wave dipoles) are already known. If those elements were widely separated and driven in a certain amplitude and phase, then each would act independently as that element is known to. However, because of the mutual interaction between their electric and magnetic fields due to proximity, the currents in each element are *not* simply a function of the applied voltage (according to its driving point impedance), but depend on the currents in the other nearby elements. Note

that this now is a near field phenomenon which could not be properly accounted for using the Friis transmission equation for instance. This near field effect creates a different set of currents at the antenna terminals resulting in distortions in the far field radiation patterns; however, the distortions may be removed using a simple set of network equations.[36]

The elements' feedpoint currents and voltages can be related to each other using the concept of **mutual impedance** Z_{ji} between every pair of antennas just as the mutual impedance $j\omega M$ describes the voltage induced in one inductor by a current through a nearby coil coupled to it through a mutual inductance M. The mutual impedance Z_{21} between two antennas is defined[37] as:

$$Z_{ji} = \frac{v_j}{i_i}$$

where i_i is the current flowing in antenna i and v_j is the voltage induced at the open-circuited feedpoint of antenna j due to i_1 when all other currents i_k are zero. The mutual impendances can be viewed as the elements of a symmetric square impedance matrix **Z**. Note that the diagonal elements, $Z_{ii} = \frac{v_i}{i_i}$, are simply the driving point impedances of each element.

Using this definition, the voltages present at the feedpoints of a set of coupled antennas can be expressed as the multiplication of the impedance matrix times the vector of currents. Written out as discrete equations, that means:

$$\begin{array}{ccccccccc} v_1 & = & i_1 Z_{11} & + & i_2 Z_{12} & + & \cdots & + & i_n Z_{1n} \\ v_2 & = & i_1 Z_{21} & + & i_2 Z_{22} & + & \cdots & + & i_n Z_{2n} \\ \vdots & & \vdots & & \vdots & & & & \vdots \\ v_n & = & i_1 Z_{n1} & + & i_2 Z_{n2} & + & \cdots & + & i_n Z_{nn} \end{array}$$

where:

- v_i is the voltage at the terminals of antenna i
- i_i is the current flowing between the terminals of antenna i
- Z_{ii} is the driving point impedance of antenna i
- Z_{ij} is the mutual impedance between antennas i and j.

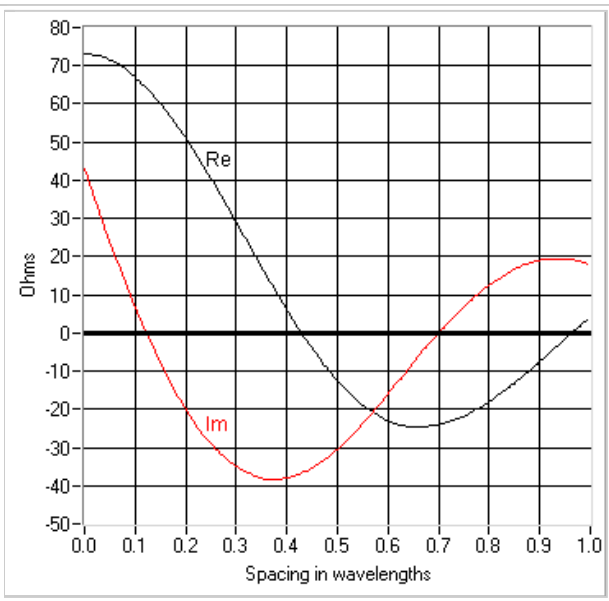

Mutual impedance between parallel $\frac{\lambda}{2}$ dipoles not staggered. Curves **Re** and **Im** are the resistive and reactive parts of the impedance.

As is the case for mutual inductances,

$$Z_{ij} = Z_{ji}.$$

This is a consequence of Lorentz reciprocity. For an antenna element i not connected to anything (open circuited) one can write $i_i = 0$. But for an element i which is short circuited, a current is generated across that short but no voltage is allowed, so the corresponding $v_i = 0$. This is the case, for instance, with the so-called parasitic elements of a Yagi-Uda antenna where the solid rod can be viewed as a dipole antenna shorted across its feedpoint. Parasitic elements are unpowered elements that absorb and reradiate RF energy according to the induced current calculated using such a system of equations.

With a particular geometry, it is possible for the mutual impedance between nearby antennas to be zero. This is the case, for instance, between the crossed dipoles used in the turnstile antenna.

Gallery

Antennas and supporting structures

A building rooftop supporting numerous dish and sectored mobile telecommunications antennas (Doncaster, Victoria, Australia).

A water tower in Palmerston, Northern Territory with radio broadcasting and communications antennas.

A three-sector telephone site in Mexico City.

Telephone site concealed as a palm tree.

Diagrams as part of a system

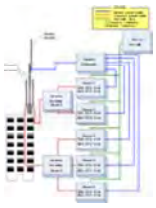

Antennas may be connected through a multiplexing arrangement in some applications like this trunked two-way radio example.

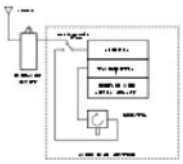

Antenna network for an emergency medical services base station.

See also

- Category:Radio frequency antenna types
- Category:Radio frequency propagation

Wikimedia Commons has media related to ***Antennas***.

- Cellular repeater
- DXing
- Electromagnetism
- Mobile broadband modem
- Numerical Electromagnetics Code
- Radial (radio)
- Radio masts and towers
- RF connector
- Smart antenna
- TETRA

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Categories: Antennas (radio) | Radio electronics

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Radio frequency

From Wikipedia, the free encyclopedia

Radio frequency (**RF**) is any of the electromagnetic wave frequencies that lie in the range extending from around 3 kHz to 300 GHz, which include those frequencies used for communications or radar signals.[1] RF usually refers to electrical rather than mechanical oscillations. However, mechanical RF systems do exist (see mechanical filter and RF MEMS).

Although radio *frequency* is a rate of oscillation, the term "radio frequency" or its abbreviation "RF" are used as a synonym for radio – i.e., to describe the use of wireless communication, as opposed to communication via electric wires. Examples include:

- Radio-frequency identification
- ISO/IEC 14443-2 *Radio frequency power and signal interface*[2]

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- 2 Radio communication
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- 5 Effects on the human body
  - 5.1 Extremely low frequency RF
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Special properties of RF current

Electric currents that oscillate at radio frequencies have special properties not shared by direct current or alternating current of lower frequencies.

- The energy in an RF current can radiate off a conductor into space as electromagnetic waves (radio waves); this is the basis of radio technology.
- RF current does not penetrate deeply into electrical conductors but tends to flow along their surfaces; this is known as the skin effect. For this reason, when the human body comes in contact with high power RF currents it can cause superficial but serious burns called *RF burns (Note that RF burns result from electrical energy, while Radiation burns result from electromagnetic energy)*.
- RF currents applied to the body often do not cause the painful sensation of electric shock as do lower frequency currents.[3][4] This is because the current changes direction too quickly to trigger depolarization of nerve membranes.

- RF current can easily ionize air, creating a conductive path through it. This property is exploited by "high frequency" units used in electric arc welding, which use currents at higher frequencies than power distribution uses.
- Another property is the ability to appear to flow through paths that contain insulating material, like the dielectric insulator of a capacitor. This is because capacitive reactance in a circuit decreases with frequency.
- In contrast, RF current can be blocked by a coil of wire, or even a single turn or bend in a wire. This is because the inductive reactance of a circuit increases with frequency.
- When conducted by an ordinary electric cable, RF current has a tendency to reflect from discontinuities in the cable such as connectors and travel back down the cable toward the source, causing a condition called standing waves. Therefore, RF current must be carried by specialized types of cable called transmission line.

Radio communication

To receive radio signals an antenna must be used. However, since the antenna will pick up thousands of radio signals at a time, a radio tuner is necessary to *tune into* a particular frequency (or frequency range).[5] This is typically done via a resonator – in its simplest form, a circuit with a capacitor and an inductor form a tuned circuit. The resonator amplifies oscillations within a particular frequency band, while reducing oscillations at other frequencies outside the band. Another method to isolate a particular radio frequency is by oversampling (which gets a wide range of frequencies) and picking out the frequencies of interest, as done in software defined radio.

The distance over which radio communications is useful depends significantly on things other than wavelength, such as transmitter power, receiver quality, type, size, and height of antenna, mode of transmission, noise, and interfering signals. Ground waves, tropospheric scatter and skywaves can all achieve greater ranges than line-of-sight propagation. The study of radio propagation allows estimates of useful range to be made.

Frequency bands

Frequency	Wavelength	Designation	Abbreviation[6]
3–30 Hz	10^5–10^4 km	Extremely low frequency	ELF
30–300 Hz	10^4–10^3 km	Super low frequency	SLF
300–3000 Hz	10^3–100 km	Ultra low frequency	ULF
3–30 kHz	100–10 km	Very low frequency	VLF
30–300 kHz	10–1 km	Low frequency	LF
300 kHz – 3 MHz	1 km – 100 m	Medium frequency	MF
3–30 MHz	100–10 m	High frequency	HF
30–300 MHz	10–1 m	Very high frequency	VHF
300 MHz – 3 GHz	1 m – 10 cm	Ultra high frequency	UHF
3–30 GHz	10–1 cm	Super high frequency	SHF
30–300 GHz	1 cm – 1 mm	Extremely high frequency	EHF
300 GHz – 3 THz	1 mm – 0.1 mm	Tremendously high frequency	THF

In medicine

Radio frequency (RF) energy, in the form of radiating waves or electrical currents, has been used in medical treatments for over 75 years,[7] generally for minimally invasive surgeries using radiofrequency ablation including the treatment of sleep apnea.[8] Magnetic resonance imaging (MRI) uses radio frequency waves to generate images of the human body.

Radio frequencies at non-ablation energy levels are sometimes used as a form of cosmetic treatment that can tighten skin, reduce fat (lipolysis), or promote healing.[9]

RF diathermy is a medical treatment that uses RF induced heat as a form of physical or occupational therapy and in surgical procedures. It is commonly used for muscle relaxation. It is also a method of heating tissue electromagnetically for therapeutic purposes in medicine. Diathermy is used in physical therapy and occupational therapy to deliver moderate heat directly to pathologic lesions in the deeper tissues of the body. Surgically, the extreme heat that can be produced by diathermy may be used to destroy neoplasms, warts, and infected tissues, and to cauterize blood vessels to prevent excessive bleeding. The technique is particularly valuable in neurosurgery and surgery of the eye. Diathermy equipment typically operates in the short-wave radio frequency (range 1–100 MHz) or microwave energy (range 434–915 MHz).

Pulsed electromagnetic field therapy (PEMF) is a medical treatment that purportedly helps to heal bone tissue reported in a recent NASA study. This method usually employs electromagnetic radiation of different frequencies - ranging from static magnetic fields, through extremely low frequencies (ELF) to higher radio frequencies (RF) administered in pulses.

Effects on the human body

Extremely low frequency RF

High-power extremely low frequency RF with electric field levels in the low kV/m range are known to induce perceivable currents within the human body that create an annoying tingling sensation. These currents will typically flow to ground through a body contact surface such as the feet, or arc to ground where the body is well insulated.[10][11]

Microwaves

Microwave exposure at low-power levels below the Specific absorption rate set by government regulatory bodies are considered harmless non-ionizing radiation and have no effect on the human body. However, levels above the Specific absorption rate set by the U.S. Federal Communications Commission are considered potentially harmful (see Mobile phone radiation and health).

Long-term human exposure to high-levels of microwaves is recognized to cause cataracts according to experimental animal studies and epidemiological studies. The mechanism is unclear but may include changes in heat sensitive enzymes that normally protect cell proteins in the lens. Another mechanism that has been advanced is direct damage to the lens from pressure waves induced in the aqueous humor.

High-power exposure to microwave RF is known to create a range of effects from lower to higher power levels, ranging from unpleasant burning sensation on the skin and microwave auditory effect, to extreme pain at the mid-range, to physical burning and blistering of skin and internals at high power levels (see microwave burn).

General RF exposure

The 1999 revision of Canadian Safety Code 6 recommended electric field limits of 100 kV/m for pulsed EMF to prevent air breakdown and spark discharges, mentioning rationale related to auditory effect and energy-induced unconsciousness in rats.[12] The pulsed EMF limit was removed in later revisions, however.[13]

For health effects see electromagnetic radiation and health.

For high-power RF (electromagnetic, not electrical) exposure see radiation burn.

For low-power RF exposure see radiation-induced cancer.

As a weapon

A heat ray is an RF harassment device that makes use of microwave radio frequencies to create an unpleasant heating effect in the upper layer of the skin. A publicly known heat ray weapon called the Active Denial System was developed by the US military as an experimental weapon to deny the enemy access to an area. A death ray is a weapon that delivers heat ray electromagnetic energy at levels that injure human tissue. The inventor of the death ray, Harry Grindell Matthews, claims to have lost sight in his left eye while developing his death ray weapon based on a primitive microwave magnetron from the 1920s (note that a typical microwave oven induces a tissue damaging cooking effect inside the oven at about 2 kV/m.)

Measurement

Since radio frequency radiation has both an electric and a magnetic component, it is often convenient to express intensity of radiation field in terms of units specific to each component. The unit *volts per meter* (V/m) is used for the electric component, and the unit *amperes per meter* (A/m) is used for the magnetic component. One can speak of an electromagnetic field, and these units are used to provide information about the levels of electric and magnetic field strength at a measurement location.

Another commonly used unit for characterizing an RF electromagnetic field is *power density*. Power density is most accurately used when the point of measurement is far enough away from the RF emitter to be located in what is referred to as the far field zone of the radiation pattern. In closer proximity to the transmitter, i.e., in the "near field" zone, the physical relationships between the electric and magnetic components of the field can be complex, and it is best to use the field strength units discussed above. Power density is measured in terms of power per unit area, for example, milliwatts per square centimeter (mW/cm²). When speaking of frequencies in the microwave range and higher, power density is usually used to express intensity since exposures that might occur would likely be in the far field zone.

See also

- Amplitude modulation
- Electromagnetic Interference
- Electromagnetic radiation
- Electromagnetic spectrum
- EMF measurement
- Frequency allocation
- Frequency bandwidth
- Frequency modulation
- Plastic welding
- Pulsed electromagnetic field therapy
- Spectrum management

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13. http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radio_guide-lignes_direct/index-eng.php Safety Code 6: Health Canada's Radiofrequency Exposure Guidelines - Environmental and Workplace Health - Health Canada

External links

- Definition of frequency bands (VLF, ELF … etc.) IK1QFK Home Page (vlf.it) (http://www.vlf.it/frequency/bands.html)
- Radio, light, and sound waves, conversion between wavelength and frequency (http://www.sengpielaudio.com/calculator-wavelength.htm)
- RF Terms Glossary (http://www.sunmantechnology.com/resources_gls_rfts.html)

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Categories: Radio spectrum | Radio technology | Waves | Electromagnetic spectrum | Television terminology

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Radio propagation

From Wikipedia, the free encyclopedia

Radio propagation is the behavior of radio waves as they travel, or are propagated, from one point to another, or into various parts of the atmosphere.[1] As a form of electromagnetic radiation, like light waves, radio waves are affected by the phenomena of reflection, refraction, diffraction, absorption, polarization, and scattering.[2]

Radio propagation is affected by the daily changes of water vapor in the troposphere and ionization in the upper atmosphere influenced by the Sun. Understanding the effects of varying conditions on radio propagation has many practical applications, from choosing frequencies for international shortwave broadcasters, to designing reliable mobile telephone systems, to radio navigation, to operation of radar systems.

Several different types of propagation are used in practical radio transmission systems. Line-of-sight propagation means radio waves which travel in a straight line from the transmitting antenna to the receiving antenna. It does not necessarily require a cleared sight path; at lower frequencies radio waves can pass through building walls and foliage. Line of sight transmission is used in short to medium range radio transmission such as garage door openers, cell phones, cordless phones, walkie-talkies, wireless networks, FM radio and television broadcasting and radar, and satellite communication, such as satellite television. Line-of-sight transmission on the surface of the Earth is limited to the distance to the visual horizon, about 40 miles. It is the only propagation method possible at microwave frequencies and above. At microwave frequencies moisture in the atmosphere (rain fade) can degrade transmission.

At lower frequencies in the MF, LF, and VLF bands, due to diffraction radio waves can bend over obstacles like hills, and travel beyond the horizon as surface waves which follow the contour of the Earth. These are called ground waves. AM broadcasting stations use ground waves to cover their listening areas. As the frequency gets lower the attenuation with distance decreases, so very low frequency (VLF) and extremely low frequency (ELF) ground waves can be used to communicate worldwide. VLF and ELF waves can penetrate significant distances through water and earth, and these frequencies are used for mine communication and military communication with submerged submarines.

At medium wave and shortwave frequencies (MF and HF bands) radio waves can reflect or refract from a layer of charged particles (ions) high in the atmosphere, called the ionosphere. So radio waves transmitted at an angle into the sky can be reflected back to Earth beyond the horizon, at great distances, even transcontinental distances. This is called skywave or "skip" propagation. It is used by amateur radio operators to talk to other countries, for diplomatic communications, and shortwave broadcasting stations that broadcast internationally. Skywave communication is variable, dependent on conditions in the upper atmosphere, and can be disrupted by events like solar flares, it is most reliable at night and in the winter. Due to its unreliability, since the advent of communication satellites in the 1960s many long range communication needs that previously used skywaves now use satellites.

In addition there are several less common radio propagation mechanisms, such as tropospheric scattering (troposcatter) and near vertical incidence skywave (NVIS) which are used in specialized communication systems.

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Free space propagation

In free space, all electromagnetic waves (radio, light, X-rays, etc.) obey the inverse-square law which states that the power density of an electromagnetic wave is proportional to the inverse of the square of the distance from a point source[3] or:

$$\rho_P \propto \frac{1}{r^2}.$$

Doubling the distance from a transmitter means that the power density of the radiated wave at that new location is reduced to one-quarter of its previous value.

The power density per surface unit is proportional to the product of the electric and magnetic field strengths. Thus, doubling the propagation path distance from the transmitter reduces each of their received field strengths over a free-space path by one-half.

Modes

Radio frequencies and their primary mode of propagation

Band		Frequency	Wavelength	Propagation via
ELF	Extremely Low Frequency	3–30 Hz	10,000-100,000 km	
SLF	Super Low Frequency	30–300 Hz	10,000-1,000 km	
ULF	Ultra Low Frequency	0.3–3 kHz (300–3,000 Hz)	1,000–100 km	
VLF	Very Low Frequency	3–30 kHz (3,000 –30,000 Hz)	100–10 km	Guided between the earth and the ionosphere.
LF	Low Frequency	30–300 kHz (30,000 –300,000 Hz)	10–1 km	Guided between the earth and the D layer of the ionosphere. Surface waves.
MF	Medium Frequency	300–3000 kHz (300,000–3,000,000 Hz)	1000–100 m	Surface waves. E, F layer ionospheric refraction at night, when D layer absorption weakens.
HF	High Frequency (Short Wave)	3–30 MHz (3,000,000 –30,000,000 Hz)	100–10 m	E layer ionospheric refraction. F1, F2 layer ionospheric refraction.
VHF	Very High Frequency	30–300 MHz (30,000,000 –300,000,000 Hz)	10–1 m	Infrequent E ionospheric (E_s) refraction. Uncommonly F2 layer ionospheric refraction during high sunspot activity up to 50 MHz and rarely to 80 MHz. Generally direct wave. Sometimes tropospheric ducting or meteor scatter
UHF	Ultra High Frequency	300–3000 MHz (300,000,000 –3,000,000,000 Hz)	100–10 cm	Direct wave. Sometimes tropospheric ducting.
SHF	Super High Frequency	3–30 GHz (3,000,000,000 –30,000,000,000 Hz)	10–1 cm	Direct wave. Sometimes rain scatter.
EHF	Extremely High Frequency	30–300 GHz (30,000,000,000 –300,000,000,000 Hz)	10–1 mm	Direct wave limited by absorption.
THF	Tremendously High frequency	0.3–3 THz (300,000,000,000 –3,000,000,000,000 Hz)	1–0.1 mm	

Surface modes (groundwave)

Lower frequencies (between 30 and 3,000 kHz) have the property of following the curvature of the earth via -[groundwave] propagation in the majority of occurrences.

In this mode the radio wave propagates by interacting with the semi-conductive surface of the earth. The wave "clings" to the surface and thus follows the curvature of the earth. Vertical polarization is used to alleviate short circuiting the electric field through the conductivity of the ground. Since the ground is not a perfect electrical conductor, ground waves are attenuated rapidly as they follow the earth's surface. Attenuation is proportional to the frequency making this mode mainly useful for LF and VLF frequencies (see also Earth-ionosphere waveguide).

Today LF and VLF are mostly used for time signals, and for military communications, especially one-way transmissions to ships and submarines, although radio amateurs have an allocation at 137 kHz in some parts of the world. Radio broadcasting using surface wave propagation uses the higher portion of the LF range in Europe, Africa and the Middle East.

Early commercial and professional radio services relied exclusively on long wave, low frequencies and ground-wave propagation. To prevent interference with these services, amateur and experimental transmitters were restricted to the higher (HF) frequencies, felt to be useless since their ground-wave range was limited. Upon discovery of the other propagation modes possible at medium wave and short wave frequencies, the advantages of HF for commercial and military purposes became apparent. Amateur experimentation was then confined only to authorized frequency segments in that range.[4]

Direct modes (line-of-sight)

Line-of-sight is the direct propagation of radio waves between antennas that are visible to each other. This is probably the most common of the radio propagation modes at VHF and higher frequencies. Because radio signals can travel through many non-metallic objects, radio can be picked up through walls. This is still line-of-sight propagation. Examples would include propagation between a satellite and a ground antenna or reception of television signals from a local TV transmitter.

Ground plane reflection effects are an important factor in VHF line of sight propagation. The interference between the direct beam line-of-sight and the ground reflected beam often leads to an effective inverse-fourth-power ($1/\text{distance}^4$) law for ground-plane limited radiation. [Need reference to inverse-fourth-power law + ground plane. Drawings may clarify]

Ionospheric modes (skywave)

Skywave propagation, also referred to as skip, is any of the modes that rely on refraction of radio waves in the ionosphere, which is made up of one or more ionized layers in the upper atmosphere. F2-layer is the most important ionospheric layer for long-distance, multiple-hop HF propagation, though F1, E, and D-layers also play significant roles. The D-layer, when present during sunlight periods, causes significant amount of signal loss, as does the E-layer whose maximum usable frequency can rise to 4 MHz and above and thus block higher frequency signals from reaching the F2-layer. The layers, or more appropriately "regions", are directly affected by the sun on a daily diurnal cycle, a seasonal cycle and the 11-year sunspot cycle and determine the utility of these modes. During solar maxima, or sunspot

highs and peaks, the whole HF range up to 30 MHz can be used usually around the clock and F2 propagation up to 50 MHz is observed frequently depending upon daily solar flux 10.7cm radiation values. During solar minima, or minimum sunspot counts down to zero, propagation of frequencies above 15 MHz is generally unavailable.

Although the claim is commonly made that two-way HF propagation along a given path is reciprocal, that is, if the signal from location A reaches location B at a good strength, the signal from location B will be similar at station A because the same path is traversed in both directions. However, the ionosphere is far too complex and constantly changing to support the reciprocity theorem. The path is never exactly the same in both directions.[5] In brief, conditions at the two terminii of a path generally cause dissimilar polarization shifts, dissimilar splits into ordinary rays and extraordinary or *Pedersen rays* which are erratic and impossibly identical or similar due to variations in ionization density, shifting zenith angles, effects of the earth's magnetic DIPOLE contours, antenna radiation patterns, ground conditions and other variables.

Forecasting of skywave modes is of considerable interest to amateur radio operators and commercial marine and aircraft communications, and also to shortwave broadcasters. Real-time propagation can be assessed by listening for transmissions from specific beacon transmitters.

Meteor scattering

Meteor scattering relies on reflecting radio waves off the intensely ionized columns of air generated by meteors. While this mode is very short duration, often only from a fraction of second to couple of seconds per event, digital Meteor burst communications allows remote stations to communicate to a station that may be hundreds of miles up to over 1,000 miles (1,600 km) away, without the expense required for a satellite link. This mode is most generally useful on VHF frequencies between 30 and 250 MHz.

Auroral backscatter

Intense columns of Auroral ionization at 100 km altitudes within the auroral oval backscatter radio waves, perhaps most notably on HF and VHF. Backscatter is angle-sensitive—incident ray vs. magnetic field line of the column must be very close to right-angle. Random motions of electrons spiraling around the field lines create a Doppler-spread that broadens the spectra of the emission to more or less noise-like—depending on how high radio frequency is used. The radio-auroras are observed mostly at high latitudes and rarely extend down to middle latitudes. The occurrence of radio-auroras depends on solar activity (flares, coronal holes, CMEs) and annually the events are more numerous during solar cycle maxima. Radio aurora includes the so-called afternoon radio aurora which produces stronger but more distorted signals and after the Harang-minima, the late-night radio aurora (sub-storming phase) returns with variable signal strength and lesser doppler spread. The propagation range for this predominantly back-scatter mode extends up to about 2000 km in east-west plane, but strongest signals are observed most frequently from the north at nearby sites on same latitudes.

Rarely, a strong radio-aurora is followed by Auroral-E, which resembles both propagation types in some ways.

Sporadic-E propagation

Sporadic E (Es) propagation can be observed on HF and VHF bands.[6] It must not be confused with ordinary HF E-layer propagation. Sporadic-E at mid-latitudes occurs mostly during summer season, from May to August in the northern hemisphere and from November to February in the southern hemisphere. There is no single cause for this mysterious propagation mode. The reflection takes place in a thin sheet of ionisation around 90 km height. The ionisation patches drift westwards at speeds of few hundred km per hour. There is a weak periodicity noted during the season and typically Es is observed on 1 to 3 successive days and remains absent for a few days to reoccur again. Es do not occur during small hours; the events usually begin at dawn, and there is a peak in the afternoon and a second peak in the evening.[7] Es propagation is usually gone by local midnight.

Observation of radio propagation beacons operating around 28.2 MHz, 50 MHz and 70 MHz, indicates that maximum observed frequency (MOF) for Es is found to be lurking around 30 MHz on most days during the summer season, but sometimes MOF may shoot up to 100 MHz or even more in ten minutes to decline slowly during the next few hours. The peak-phase includes oscillation of MOF with periodicity of approximately 5...10 minutes. The propagation range for Es single-hop is typically 1000 to 2000 km, but with multi-hop, double range is observed. The signals are very strong but also with slow deep fading.

Tropospheric modes

Tropospheric scattering

At VHF and higher frequencies, small variations (turbulence) in the density of the atmosphere at a height of around 6 miles (10 km) can scatter some of the normally line-of-sight beam of radio frequency energy back toward the ground, allowing over-the-horizon communication between stations as far as 500 miles (800 km) apart. The military developed the White Alice Communications System covering all of Alaska, using this tropospheric scattering principle.

Tropospheric ducting

Sudden changes in the atmosphere's vertical moisture content and temperature profiles can on random occasions make microwave and UHF & VHF signals propagate hundreds of kilometers up to about 2,000 kilometers (1,300 mi)—and for ducting mode even farther—beyond the normal radio-horizon. The inversion layer is mostly observed over high pressure regions, but there are several tropospheric weather conditions which create these randomly occurring propagation modes. Inversion layer's altitude for non-ducting is typically found between 100 meters (300 ft) to about 1 kilometer (3,000 ft) and for ducting about 500 meters to 3 kilometers (1,600 to 10,000 ft), and the duration of the events are typically from several hours up to several days. Higher frequencies experience the most dramatic increase of signal strengths, while on low-VHF and HF the effect is negligible. Propagation path attenuation may be below free-space loss. Some of the lesser inversion types related to warm ground and cooler air moisture content occur regularly at certain times of the year and time of day. A typical example could be the late summer, early morning tropospheric enhancements that bring in signals from distances up to few hundred kilometers for a couple of hours, until undone by the Sun's warming effect.

Tropospheric delay

This is a source of error in radio ranging techniques, such as the Global Positioning System (GPS).[8] See also the page of GPS meteorology.

Rain scattering

Rain scattering is purely a microwave propagation mode and is best observed around 10 GHz, but extends down to a few gigahertz—the limit being the size of the scattering particle size vs. wavelength. This mode scatters signals mostly forwards and backwards when using horizontal polarization and side-scattering with vertical polarization. Forward-scattering typically yields propagation ranges of 800 km. Scattering from snowflakes and ice pellets also occurs, but scattering from ice without watery surface is less effective. The most common application for this phenomenon is microwave rain radar, but rain scatter propagation can be a nuisance causing unwanted signals to intermittently propagate where they are not anticipated or desired. Similar reflections may also occur from insects though at lower altitudes and shorter range. Rain also causes attenuation of point-to-point and satellite microwave links. Attenuation values up to 30 dB have been observed on 30 GHz during heavy tropical rain.

Airplane scattering

Airplane scattering (or most often reflection) is observed on VHF through microwaves and, besides back-scattering, yields momentary propagation up to 500 km even in mountainous terrain. The most common back-scatter applications are air-traffic radar, bistatic forward-scatter guided-missile and airplane-detecting trip-wire radar, and the US space radar.

Lightning scattering

Lightning scattering has sometimes been observed on VHF and UHF over distances of about 500 km. The hot lightning channel scatters radio-waves for a fraction of a second. The RF noise burst from the lightning makes the initial part of the open channel unusable and the ionization disappears quickly because of recombination at low altitude and high atmospheric pressure. Although the hot lightning channel is briefly observable with microwave radar, no practical use for this mode has been found in communications.

Other effects

Diffraction

Knife-edge diffraction is the propagation mode where radio waves are bent around sharp edges. For example, this mode is used to send radio signals over a mountain range when a line-of-sight path is not available. However, the angle cannot be too sharp or the signal will not diffract. The diffraction mode requires increased signal strength, so higher power or better antennas will be needed than for an equivalent line-of-sight path.

Diffraction depends on the relationship between the wavelength and the size of the obstacle. In other words, the size of the obstacle in wavelengths. Lower frequencies diffract around large smooth obstacles such as hills more easily. For example, in many cases where VHF (or higher frequency) communication is not possible due to shadowing by a hill, it is still possible to communicate using the upper part of the HF band where the surface wave is of little use.

Diffraction phenomena by small obstacles are also important at high frequencies. Signals for urban cellular telephony tend to be dominated by ground-plane effects as they travel over the rooftops of the urban environment. They then diffract over roof edges into the street, where multipath propagation, absorption and diffraction phenomena dominate.

Absorption

Low-frequency radio waves travel easily through brick and stone and VLF even penetrates sea-water. As the frequency rises, absorption effects become more important. At microwave or higher frequencies, absorption by molecular resonances in the atmosphere (mostly from water, H_2O and oxygen, O_2) is a major factor in radio propagation. For example, in the 58–60 GHz band, there is a major absorption peak which makes this band useless for long-distance use. This phenomenon was first discovered during radar research in World War II. Above about 400 GHz, the Earth's atmosphere blocks most of the spectrum while still passing some - up to UV light, which is blocked by ozone - but visible light and some of the near-infrared is transmitted. Heavy rain and falling snow also affect microwave absorption.

Measuring HF propagation

HF propagation conditions can be simulated using radio propagation models, such as the Voice of America Coverage Analysis Program, and realtime measurements can be done using chirp transmitters. For radio amateurs the WSPR mode provides maps with real time propagation conditions between a network of transmitters and receivers.[9] Even without special beacons the realtime propagation conditions can be measured: a worldwide network of receivers decodes morse code signals on amateur radio frequencies in realtime and provides sophisticated search functions and propagation maps for every station received.[10]

Practical effects

The average person can notice the effects of changes in radio propagation in several ways.

In AM broadcasting, the dramatic ionospheric changes that occur overnight in the mediumwave band drive a unique broadcast license scheme, with entirely different transmitter power output levels and directional antenna patterns to cope with skywave propagation at night. Very few stations are allowed to run without modifications during dark hours, typically only those on clear channels in North America. Many stations have no authorization to run at all outside of daylight hours. Otherwise, there would be nothing but interference on the entire broadcast band from dusk until dawn without these modifications.

For FM broadcasting (and the few remaining low-band TV stations), weather is the primary cause for changes in VHF propagation, along with some diurnal changes when the sky is mostly without cloud cover. These changes are most obvious during temperature inversions, such as in the late-night and

early-morning hours when it is clear, allowing the ground and the air near it to cool more rapidly. This not only causes dew, frost, or fog, but also causes a slight "drag" on the bottom of the radio waves, bending the signals down such that they can follow the Earth's curvature over the normal radio horizon. The result is typically several stations being heard from another media market — usually a neighboring one, but sometimes ones from a few hundred kilometers away. Ice storms are also the result of inversions, but these normally cause more scattered omnidirection propagation, resulting mainly in interference, often among weather radio stations. In late spring and early summer, a combination of other atmospheric factors can occasionally cause skips that duct high-power signals to places well over 1000km away.

Non-broadcast signals are also affected. Mobile phone signals are in the UHF band, ranging from 700 to over 2600 Megahertz, a range which makes them even more prone to weather-induced propagation changes. In urban (and to some extent suburban) areas with a high population density, this is partly offset by the use of smaller cells, which use lower effective radiated power and beam tilt to reduce interference, and therefore increase frequency reuse and user capacity. However, since this would not be very cost-effective in more rural areas, these cells are larger and so more likely to cause interference over longer distances when propagation conditions allow.

While this is generally transparent to the user thanks to the way that cellular networks handle cell-to-cell handoffs, when cross-border signals are involved, unexepected charges for international roaming may occur despite not having left the country at all. This often occurs between southern San Diego and northern Tijuana at the western end of the U.S./Mexico border, and between eastern Detroit and western Windsor along the U.S./Canada border. Since signals can travel unobstructed over a body of water far larger than the Detroit River, and cool water temperatures also cause inversions in surface air, this "fringe roaming" sometimes occurs across the Great Lakes, and between islands in the Caribbean. Signals can skip from the Dominican Republic to a mountainside in Puerto Rico and vice versa, or between the U.S. and British Virgin Islands, among others. While unintended cross-border roaming is often automatically removed by mobile phone company billing systems, inter-island roaming is typically not.

See also

- Diversity scheme
- Earth bulge
- Earth-ionosphere waveguide
- Electromagnetic radiation
- Fading
- Fresnel zone
- Free space
- Inversion (meteorology)
- Kennelly–Heaviside layer
- Near and far field
- Radio atmospherics
- Radio frequency
- Radio horizon
- Radio propagation model

- Rayleigh fading
- Ray tracing (physics)
- Schumann resonance
- Skip (radio)
- Skip zone
- Skywave
- Tropospheric propagation
- TV and FM DX
- Upfade
- VOACAP - Free professional HF propagation prediction software
- Critical frequency

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External links

Wikimedia Commons has media related to ***Radio propagation***.

- Solar widget (http://rigreference.com/solar) Propagation widget based on NOAA data. Also available as WordPress plugin.
- ARRL Propagation Page (http://www.arrl.org/propagation-of-rf-signals) The American Radio Relay League page on radio propagation.
- HF Radio and Ionospheric Prediction Service - Australia (http://www.ips.gov.au/HF_Systems/)
- NASA Space Weather Action Center (http://sunearthday.nasa.gov/swac/data.php)
- HF Propagation Tutorial by the late NM7M (http://www.astrosurf.com/luxorion/qsl-hf-tutorial-nm7m.htm)
- Space Weather and Radio Propagation Resource Center (http://sunspotwatch.com) Live data and images of space weather and radio propagation.
- Solar Terrestrial Dispatch (http://www.spacew.com/)
- Online Propagation Tools, HF Solar Data, and HF Propagation Tutorials (http://www.hamqsl.com/solar.html)
- DXing.info - Propagation links (http://www.dxing.info/propagation)
- HF Radio Propagation Software for Firefox - Propfire (http://www.n0hr.com/Propfire.htm) Firefox plug-in for monitoring propagation, website utility to display HF propagation status, and article on understanding HF radio propagation forecasting
- The Basics of Radio Wave Propagation (http://ecjones.org/propag.html) A resource by Edwin C. Jones (AE4TM), MD, PhD, Department of Physics and Astronomy, University of Tennessee.
- Dynamic Radio Propagation Data (http://dx.qsl.net/propagation/propagation.html) Constantly updated radio propagation data pulled from various sources.
- Solar Cycle 24 prediction and MF/HF/6M radiowave propagation forecast webpage (www.solarcycle24.org) (http://www.solarcycle24.org/)
- 160 Meter (Medium Frequency) Radiowave Propagation Theory Notes webpage (www.wcflunatall.com/nz4o5.htm) (http://www.wcflunatall.com/nz4o5.htm/)
- Unusual HF Propagation Phenomena. 13 Apr 2009 (http://www.qslnet.de/member/la3za/prop/) Includes useful recordings each type. Retrieved 9 Oct 2009.
- Overview of radio propagation modes (http://www.radio-electronics.com/info/propagation/radio-propagation/radio-propagation-overview-tutorial.php)
- Propagation: Es & Thunderstorms (http://lists.contesting.com/archives//html/Propagation/2005-04/msg00075.html) by Thomas F. Giella, NZ4O, ex KN4LF.
- Radio propagation tutorial (https://www.electronics-notes.com/articles/antennas-propagation/propagation-overview/basics.php)

The following external references provide practical examples of radio propagation concepts as demonstrated using software built on the VOACAP model.

- Online MOF/LOF HF Propagation Prediction Tool (http://www.hamqsl.com/solar1.html#moflof)
- High Frequency radio propagation de-mystified. (http://hfradio.org/ace-hf/ace-hf-demystified.html)
- Is High Frequency radio propagation reciprocal? (http://hfradio.org/ace-hf/ace-hf-reciprocal.html)
- How does noise affect radio signals? (http://hfradio.org/ace-hf/ace-hf-noise.html)

The following external link is designed for use by cell phones and mobile devices that can display content using Wireless Markup Language and the Wireless Application Protocol:

- WAP/WML Space Weather and Radio Propagation Resources (http://wap.hfradio.org/) Space weather and radio propagation resources.

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Categories: Radio frequency propagation

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Radio receiver

From Wikipedia, the free encyclopedia

In radio communications, a **radio receiver** (commonly also called a **radio**) is an electronic device that receives radio waves and converts the information carried by them to a usable form. It is used with an antenna. The antenna intercepts radio waves (electromagnetic waves) and converts them to tiny alternating currents which are applied to the receiver, and the receiver extracts the desired information. The receiver uses electronic filters to separate the desired radio frequency signal from all the other signals picked up by the antenna, an electronic amplifier to increase the power of the signal for further processing, and finally recovers the desired information through demodulation.

Early broadcast radio receiver. Truetone model from about 1940

The information produced by the receiver may be in the form of sound (an audio signal), images (a video signal) or digital data.[1] A radio receiver may be a separate piece of electronic equipment, or an electronic circuit within another device. Devices that contain radio receivers include television sets, radar equipment, two-way radios, cell phones, wireless computer networks, GPS navigation devices, satellite dishes, radio telescopes, bluetooth enabled devices, garage door openers, and baby monitors.

In consumer electronics, the terms *radio* and *radio receiver* are often used specifically for receivers designed to reproduce the audio (sound) signals transmitted by radio broadcasting stations, historically the first mass-market commercial radio application.

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Types of radio receivers

Various types of radio receivers may include:

- Consumer audio and high fidelity audio receivers and AV receivers used by home stereo listeners and audio and home theatre system enthusiasts as well as audiophiles.
- Communications receivers, used as a component of a radio communication link, characterized by high stability and reliability of performance.
- Simple crystal radio receivers, also known as a crystal set, which operate using the power received from radio waves.
- Satellite television receivers, used to receive television programming from communication satellites in geosynchronous orbit.
- Specialized-use receivers such as telemetry receivers that allow the remote measurement and reporting of information.
- Measuring receivers or measurement receivers are calibrated laboratory-grade devices that are used to measure the signal strength of broadcasting stations, the electromagnetic interference radiation emitted by electrical products, as well as to calibrate RF attenuators and signal generators.
- Scanners are specialized receivers that can automatically scan two or more discrete frequencies, stopping when they find a signal on one of them and then continuing to scan other frequencies when the initial transmission ceases. They are mainly used for monitoring VHF and UHF radio systems.
- Internet radio devices

ALMA's Band 5 receivers detect electromagnetic radiation with wavelengths between about 1.4 and 1.8 mm (211 and 163 GHz).[2] The picture shows only peripheric components of the receiver such as the Local Oscillator multiplier chain. The main receiver components of the ALMA band 5 receiver, such as horn antennae, superconductive SIS mixers, and cryogenic low-noise amplifiers, reside on a cartridge that is inserted into a cryostat and cooled to 4K, 12K, and 90K, respectively

Consumer audio receivers

In the context of home audio systems, the term "receiver" often refers to a combination of a tuner, a preamplifier, and a power amplifier all on the same chassis. Audiophiles will refer to such a device as an **integrated receiver**, while a single chassis that implements only one of the three component functions is called a **discrete component**. Some audio purists still prefer three discrete units - tuner, preamplifier and power amplifier - but the integrated receiver has, for some years, been the mainstream choice for music listening. The first integrated stereo receiver was made by the Harman Kardon company, and came onto the market in 1958. It had undistinguished performance, but it represented a breakthrough to the "all in one" concept of a receiver, and rapidly improving designs gradually made the receiver the mainstay of the marketplace. Many radio receivers also include a loudspeaker.

Hi-Fi / Home theater

Today AV receivers are a common component in a high-fidelity or home-theatre system. The receiver is generally the nerve centre of a sophisticated home-theatre system providing selectable inputs for a number of different audio components like record players, CD players, tape decks and video components like VCRs, DVD players, video game consoles and television sets.

With the decline of gramophone record vinyl discs, modern receivers tend to omit inputs for phonograph turntables, which have separate requirements of their own. All other common audio/visual components can use any of the identical line-level inputs on the receiver for playback, regardless of how they are marked (the "name" on each input is mostly for the convenience of the user). For instance, a second CD player can be plugged into an "AUX" input, and will work the same as it will in the "CD" input jacks.

Some receivers can also provide digital signal processors (DSP) to give a more realistic auditory illusion of listening in a concert hall. Digital audio S/PDIF and USB connections are also common today. The home theater receiver, in the vocabulary of consumer electronics, comprises both the 'radio receiver' and other functions, such as control, sound processing, and power amplification. The standalone radio receiver is usually known in consumer electronics as a tuner.

Some modern integrated receivers can send audio out to seven loudspeakers and an additional channel for a subwoofer and often include connections for headphones. Receivers vary greatly in price, and support stereophonic or surround sound. A high-quality receiver for dedicated audio-only listening (two channel stereo) can be relatively inexpensive. Excellent ones can be purchased for $300 or less. Because modern receivers are purely electronic devices with no moving parts unlike electromechanical devices like turntables and cassette decks, they tend to offer many years of trouble-free service. In recent years, the home theater in a box has become common, which often integrates a surround-capable receiver with a DVD player. The user simply connects it to a television, perhaps other components, and a set of loudspeakers.

Portable radios

Portable radios include simple transistor radios that are typically monoaural and receive the AM, FM, or short wave broadcast bands. FM, and often AM, radios are sometimes included as a feature of portable DVD/CD, MP3 CD, and USB key players, as well as cassette player/recorders.

Early portable radio receiver

AM/FM stereo car radios can be a separate dashboard mounted component or a feature of in car entertainment systems.

A boombox or boom-box, sometimes known as a ghetto blaster or a jambox, in parts of Europe as a "radio-cassette", is a name given to larger portable stereo systems capable of playing radio stations and recorded music, often at a high level of volume.

Self-powered portable radios, such as clockwork radios are used in developing nations or as part of an emergency preparedness kit.[3]

History

Radio waves were first identified in German physicist Heinrich Hertz's 1887 series of experiments to prove James Clerk Maxwell's electromagnetic theory. Hertz used spark-excited dipole antennas to generate the waves and micrometer spark gaps attached to dipole and loop antennas to detect them.[4][5][6] These primitive devices are more accurately described as radio wave sensors, not "receivers", as they could only detect radio waves within about 100 feet of the transmitter, and were not used to attempt communication but were instead used as part of an experiment to verify a theoretical proof.

Spark era

The earliest radio communication systems, used during the first three decades of radio, 1887-1917, called the *wireless telegraphy* or "spark" era, used spark gap transmitters which generated radio waves by discharging a capacitance through an electric spark.[8][9][10] Each spark produced a transient pulse of radio waves consisting of a sinusoidal wave which decreased rapidly exponentially to zero.[4][6] Spark transmitters produced strings of these damped waves, and could not generate the sinusoidal continuous waves which are modulated to carry sound in modern AM and FM transmission. Thus spark transmitters could not transmit audio (sound), and instead transmitted information by radiotelegraphy; the transmitter was switched on and off rapidly by the operator using a telegraph key, creating different length pulses of these damped radio waves ("dots" and "dashes") to spell out text messages in Morse code.[6][9]

Guglielmo Marconi who built the first radio receivers, with his early spark transmitter *(right)* and coherer receiver *(left)* from the 1890s. The receiver records the Morse code on paper tape

Therefore, the first radio receivers did not have to demodulate the radio signal - extract an audio signal from it as modern receivers do - just detect the presence or absence of the radio signal, and produce a sound in the earphone during the "dots" and "dashes" of the Morse code.[6] The device which did this was called a "*detector*". Since there were no amplifying devices during this era, the sensitivity of the receiver mostly depended on the detector, and many different detector devices were tried. Radio receivers during the spark era *(see diagram)* consisted of these parts:

- An *antenna*, to intercept the radio waves and convert them to tiny radio frequency electric currents.
- A *resonant circuit* (tuned circuit), consisting of a capacitor connected to a coil of wire (an inductor), which acted as a bandpass filter to select the desired signal out of all the signals picked up by the antenna. Either the capacitor or inductor was adjustable to tune the receiver to the frequency of different transmitters. The earliest receivers, before 1897, did not have tuned circuits, they responded to all radio signals picked up by their antennas, so they had little frequency-discriminating ability and received any transmitter in their vicinity.[11] Most receivers used a pair of tuned circuits with their coils magnetically coupled, called a resonant transformer (oscillation transformer) or "loose coupler".
- A *detector*, which produced a pulse of DC current for each damped wave received.
- An indicating device such as an *earphone*, which converted the pulses of current into sound waves. The first receivers used an electric bell instead. Later receivers in commercial wireless systems used a Morse siphon recorder,[4] which consisted of an ink pen mounted on a needle swung by an electromagnet (a galvanometer) which drew a line on a moving paper tape. Each string of damped waves constituting a Morse "dot" or "dash" caused the needle to swing over, creating a displacement of the line, which could be read off the tape. With such an automated receiver a radio operator didn't have to continuously monitor the receiver.

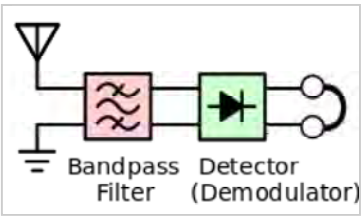

Generic block diagram of an unamplified radio receiver from the wireless telegraphy era[7]

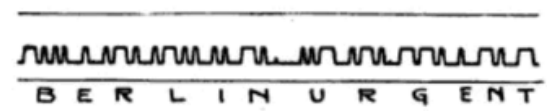

Example of transatlantic radiotelegraph message recorded on paper tape by a siphon recorder at RCA's New York receiving center in 1920. The translation of the Morse code is given below the tape.

The signal from the spark gap transmitter consisted of damped waves repeated at an audio frequency rate, from 120 to perhaps 4000 per second, so in the earphone the signal sounded like a musical tone or buzz, and the Morse code "dots" and "dashes" sounded like beeps.

The first person to use radio waves for *communication* was Guglielmo Marconi.[9][12] Marconi invented little himself, but he was first to believe that radio could be a practical communication medium, and singlehandedly developed the first wireless telegraphy systems, transmitters and receivers, beginning in 1895,[12] mainly by improving technology invented by others.[9][13][14][15] [16][17] Oliver Lodge and Alexander Popov were also experimenting with similar radio wave receiving apparatus at the same time in 1895,[14][18] but they are not known to have transmitted Morse code during this period,[9][12] just strings of random pulses. Therefore, Marconi is usually given credit for building the first radio receivers.

Coherer receiver

The first radio receivers invented by Marconi, Oliver Lodge and Alexander Popov in 1894-5 used a primitive radio wave detector called a coherer, invented in 1890 by Edouard Branly and improved by Lodge and Marconi.[4][9][11][14][18][19][20] The coherer was a glass tube with metal electrodes at each end, with loose metal powder between the electrodes.[4][9][21] It initially had a high resistance. When a radio frequency voltage was applied to the electrodes, its resistance dropped and it conducted electricity. In the receiver the coherer was connected directly between the antenna and ground. In addition to the antenna, the coherer was connected in a DC circuit with a battery and relay. When the incoming radio wave reduced the resistance of the coherer, the current from the battery flowed through it, turning on the relay to ring a bell or make a mark on a paper tape in a siphon recorder. In order to restore the coherer to its previous nonconducting state to receive the next pulse of radio waves, it had to be tapped mechanically to disturb the metal particles.[4][9][18][22] This was done by a "decoherer", a clapper which struck the tube, operated by an electromagnet powered by the relay.

Coherer from 1904 as developed by Marconi.

The coherer is an obscure antique device, and even today there is some uncertainty about the exact physical mechanism by which the various types worked.[4][13][23] However it can be seen that it was essentially a bistable device, a radio-wave-operated switch, and so it did not have the ability to rectify the radio wave to demodulate the later amplitude modulated (AM) radio transmissions that carried sound.[4][13]

In a long series of experiments Marconi found that by using an elevated wire monopole antenna instead of Hertz's dipole antennas he could transmit longer distances, beyond the curve of the Earth, demonstrating that radio was not just a laboratory curiosity but a commercially viable communication method. This culminated in his historic transatlantic wireless transmission on December 12, 1901 from Poldhu, Cornwall to St. John's, Newfoundland, a distance of 3500 km (2200 miles), which was received by a coherer.[13][17] However the usual range of coherer receivers even with the powerful transmitters of this era was limited to a few hundred miles.

One of Marconi's first coherer receivers, used in his "black box" demonstration at Toynbee Hall, London, 1896. The coherer is at right, with the "tapper" just behind it, The relay is at left, batteries are in background

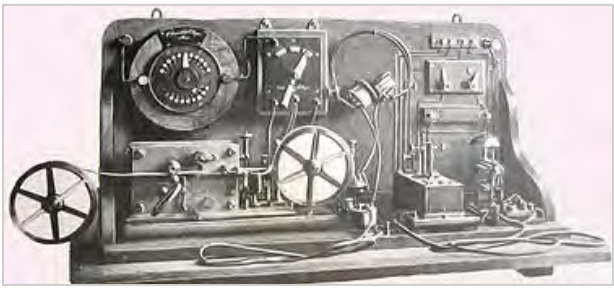

A typical commercial radiotelegraphy receiver from the first decade of the 20th century. The coherer *(right)* detects the pulses of radio waves, and the "dots" and "dashes" of Morse code were recorded in ink on paper tape by a siphon recorder *(left)* and transcribed later.

The coherer remained the dominant detector used in early radio receivers for about 10 years,[21] until replaced by the crystal detector and electrolytic detector around 1907. In spite of much development work, it was a very crude unsatisfactory device.[4][9] It was not very sensitive, and also responded to impulsive radio noise (RFI), such as nearby lights being switched on or off, as well as to the intended signal.[9][21] Due to the cumbersome mechanical "tapping back" mechanism it was limited to a data rate of about 12-15 words per minute of Morse code, while a spark-gap transmitter could transmit Morse at up to 100 WPM with a paper tape machine.[24][25]

Other early detectors

The coherer's poor performance motivated a great deal of research to find better radio wave detectors, and many were invented. Some strange devices were tried; researchers experimented with using frog legs and even a human brain from a cadaver as detectors.[4][26]

By the first years of the 20th century, experiments in using amplitude modulation (AM) to transmit sound by radio (radiotelephony) were being made. So a second goal of detector research was to find detectors that could demodulate an AM signal, extracting the audio (sound) signal from the radio carrier wave. It was found by trial and error that this could be done by a detector that exhibited "asymmetrical conduction"; a device that conducted current in one direction but not in the other.[27] This rectified the alternating current radio signal, removing one side of the carrier cycles, leaving a pulsing DC current whose amplitude varied with the audio modulation signal. When applied to an earphone this would reproduce the transmitted sound.

Below are the detectors that saw wide use before vacuum tubes took over around 1920.[28][29] All except the magnetic detector could rectify and therefore receive AM signals:

- **Magnetic detector** - Developed by Guglielmo Marconi in 1902 from a method invented by Ernest Rutherford and used by the Marconi Co. until it adopted the Audion vacuum tube around 1912, this was a mechanical device consisting of an endless band of iron wires which passed between two pulleys turned by a windup mechanism.[30][31][32][33] The iron wires passed through a coil of fine wire attached to the antenna, in a magnetic field created by two magnets. The hysteresis of the iron induced a pulse of current in a sensor coil each time a radio signal passed through the exciting coil. The magnetic detector was used on shipboard receivers due to its insensitivity to vibration. One was part of the wireless station of the RMS *Titanic* which was used to summon help during its famous 15 April 1912 sinking.[34]

Magnetic detector

- **Electrolytic detector** ("**liquid barretter**") - Invented in 1903 by Reginald Fessenden, this consisted of a thin silver-plated platinum wire enclosed in a glass rod, with the tip making contact with the surface of a cup of nitric acid.[4][31][35][36][37] The

electrolytic action caused current to be conducted in only one direction. The detector was used until about 1910.[31] Electrolytic detectors that Fessenden had installed on US Navy ships received the first AM radio broadcast on Christmas Eve, 1906, an evening of Christmas music transmitted by Fessenden using his new alternator transmitter.[4]

Electrolytic detector

- **Thermionic diode (Fleming valve)** - The first vacuum tube, invented in 1904 by John Ambrose Fleming, consisted of an evacuated glass bulb containing two electrodes: a cathode consisting of a hot wire filament similar to that in an incandescent light bulb, and a metal plate anode.[11][38][39][40] Fleming, a consultant to Marconi, invented the valve as a more sensitive detector for transatlantic wireless reception. The filament was heated by a separate current through it and emitted electrons into the tube by thermionic emission, an effect which had been discovered by Thomas Edison. The radio signal was applied between the cathode and anode. When the anode was positive, a current of electrons flowed from the cathode to the anode, but when the anode was negative the electrons were repelled and no current flowed. The Fleming valve was used to a limited extent but was not popular because it was expensive, had limited filament life, and was not as sensitive as electrolytic or crystal detectors.[38]

Early Fleming valve.

Marconi valve receiver for use on ships had two Fleming valves *(top)* in case one burned out. It was used on the RMS *Titanic*.

- **Crystal detector (cat's whisker detector)** - invented around 1904-1906 by Henry H. C. Dunwoody and Greenleaf Whittier Pickard, based on Karl Ferdinand Braun's 1874 discovery of "asymmetrical conduction" in crystals, these were the most successful and widely used detectors before the vacuum tube era[27][28] and gave their name to the *crystal radio* receiver *(below)*.[31][41][42] One of the first semiconductor electronic devices, a crystal detector consisted of a pea-sized pebble of a crystalline semiconductor mineral such as galena (lead sulfide) whose surface was touched by a fine springy metal wire mounted on an adjustable arm.[11] This functioned as a primitive diode which conducted electric current in only one direction. In addition to their use in crystal radios, carborundum crystal detectors were also used in some early vacuum tube radios because they were more sensitive than the vacuum tube grid-leak detector.

A galena cat's whisker detector from a 1920s crystal radio

During the vacuum tube era, the term "detector" changed from meaning a radio wave detector to mean a demodulator, a device that could extract the audio modulation signal from a radio signal. That is its meaning today.

Tuning

The word "tuning" means adjusting the frequency of the receiver (its *passband*) to the frequency of the desired radio transmitter, to receive the desired radio transmission. Although in many modern radio receivers (such as television sets) this is done automatically by pressing a "channel up" or "channel down" button, some older radios still use the traditional method of turning a "tuning" knob until the station is heard in the speaker. However the very first receivers in the spark era could not be tuned at all.

The first receivers had no tuned circuit, the detector was connected directly between the antenna and ground. Due to the lack of any frequency selective components besides the antenna, the bandwidth of the receiver was equal to the broad bandwidth of the antenna.[10][11][19][43] This was acceptable and even necessary because the first Hertzian spark transmitters also lacked a tuned

circuit. Due to the impulsive nature of the spark, they radiated a very "noisy" signal, the energy of the radio waves was spread over a very wide band of frequencies, a wide bandwidth.[44][45] To receive enough energy from this wideband signal the receiver had to have a wide bandwidth also.

It was found that when more than one spark transmitter was radiating in a given area, their frequencies overlapped, so their signals interfered with each other, resulting in garbled reception.[10][43][46] It became clear that, if multiple transmitters were to operate simultaneously, some method of *selective signaling* was needed, to allow the receiver to select which transmitter's signal to receive.[46][47] As radio transmission and detection systems were being developed it was also theorized that the multiple wavelengths produced by a poorly tuned transmitter were overlapping each other causing the signal to "dampen", or die down, greatly reducing the power and range of transmission.[48] In 1892, William Crookes gave a lecture[49] on radio in which he suggested using resonance to reduce the bandwidth of transmitters and receivers. Different transmitters could then be "tuned" to transmit on different frequencies so they didn't interfere.[17][44][50] The receiver would also have a resonant circuit (tuned circuit), and could receive a particular transmission by "tuning" its resonant circuit to the same frequency as the transmitter, analogously to tuning a musical instrument to resonance with another. This is the system used in all modern radio.

Tuning was used in Hertz's original experiments[51] and practical application of tuning showed up in the early to mid 1890s in wireless systems not specifically designed for radio communication. Nikola Tesla's March 1893 lecture demonstrating the wireless transmission of power for lighting (mainly by what he thought was ground conduction[52]) included elements of tuning. The wireless lighting system consisted of a spark-excited grounded resonant transformer with a wire antenna which transmitted power across the room to another resonant transformer tuned to the frequency of the transmitter, which lighted a Geissler tube.[14][50] Use of tuning in free space "Hertzian waves" (radio) was explained and demonstrated in Oliver Lodge's 1894 lectures on Hertz's work.[53] At the time Lodge was demonstrating the physics and optical qualities of radio waves instead of attempting to build a communication system but he would go on to develop methods (patented in 1897) of tuning radio (what he called "syntony"), including using variable inductance to tune antennas.[54][55][56]

By 1897 the advantages of tuned systems had become clear, and Marconi and the other wireless researchers had incorporated tuned circuits, consisting of capacitors and inductors connected together, into their transmitters and receivers.[10][14][17][19][43][55] The tuned circuit acted like an electrical analog of a tuning fork. It had a high impedance at its resonant frequency, but a low impedance at all other frequencies. Connected between the antenna and the detector it served as a bandpass filter, passing the signal of the desired station to the detector, but routing all other signals to ground.[11] The frequency of the station received ***f*** was determined by the capacitance ***C*** and inductance ***L*** in the tuned circuit:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Inductive coupling

In order to reject radio noise and interference from other transmitters near in frequency to the desired station, the bandpass filter (tuned circuit) in the receiver has to have a narrow bandwidth, allowing only a narrow band of frequencies through.[10][11] The form of bandpass filter that was used in the first receivers, which has continued to be used in receivers until recently, was the double-tuned inductively-coupled circuit, or resonant transformer (oscillation transformer or RF transformer).[10][14][17][19][55][57] The antenna and ground were connected to a coil of wire, which was magnetically coupled to a second coil with a capacitor across it, which was connected to the detector.[11] The RF alternating current from the antenna through the primary coil created a magnetic field which induced a current in the secondary coil which fed the detector. Both primary and secondary were tuned circuits;[43] the primary coil resonated with the capacitance of the antenna, while the secondary coil resonated with the capacitor across it. Both were adjusted to the same resonant frequency.

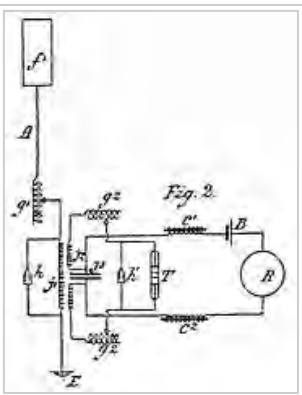

Marconi's inductively coupled coherer receiver from his controversial April 1900 "four circuit" patent no. 7,777.

This circuit had two advantages.[11] One was that by using the correct turns ratio, the impedance of the antenna could be matched to the impedance of the receiver, to transfer maximum RF power to the receiver. Impedance matching was important to achieve maximum receiving range

in the unamplified receivers of this era.[7][11] The coils usually had taps which could be selected by a multiposition switch. The second advantage was that due to "loose coupling" it had a much narrower bandwidth than a simple tuned circuit, and the bandwidth could be adjusted.[10][57] Unlike in an ordinary transformer, the two coils were "loosely coupled"; separated physically so not all the magnetic field from the primary passed through the secondary, reducing the mutual inductance. This gave the coupled tuned circuits much "sharper" tuning, a narrower bandwidth than a single tuned circuit. In the "Navy type" loose coupler *(see picture)*, widely used with crystal receivers, the smaller secondary coil was mounted on a rack which could be slid in or out of the primary coil, to vary the mutual inductance between the coils.[10][58] When the operator encountered an interfering signal at a nearby frequency, the secondary could be slid further out of the primary, reducing the coupling, which narrowed the bandwidth, rejecting the interfering signal. A disadvantage was that all three adjustments in the loose coupler - primary tuning, secondary tuning, and coupling - were interactive; changing one changed the others. So tuning in a new station was a process of successive adjustments.

Braun receiving transformer from 1904

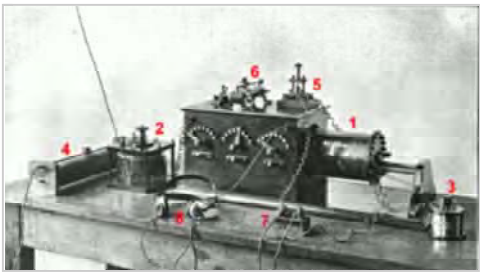

Crystal receiver from 1914 with "loose coupler" tuning transformer. The secondary coil *(1)* can be slid in or out of the primary *(in box)* to adjust the coupling. Other components: *(2)* primary tuning capacitor, *(3)* secondary tuning capacitor, *(4)* loading coil, *(5)* crystal detector, *(8)* headphones

Selectivity became more important as spark transmitters were replaced by continuous wave transmitters which transmitted on a narrow band of frequencies, and broadcasting led to a proliferation of closely spaced radio stations crowding the radio spectrum.[11] Resonant transformers continued to be used as the bandpass filter in vacuum tube radios, and new forms such as the *variometer* were invented.[58][59] Another advantage of the double-tuned transformer for AM reception was that when properly adjusted it had a "flat top" frequency response curve as opposed to the "peaked" response of a single tuned circuit.[60] This allowed it to pass the sidebands of AM modulation on either side of the carrier with little distortion, unlike a single tuned circuit which attenuated the higher audio frequencies. Until recently the bandpass filters in the superheterodyne circuit used in all modern receivers were made with resonant transformers, called IF transformers.

Patent disputes

Marconi's initial radio system had relatively poor tuning limiting its range and adding to interference.[61] To overcome this drawback he developed a four circuit system with tuned coils in "*symphony*" at both the transmitters and receivers.[61] His 1900 British #7,777 (four sevens) patent for tuning filed in April 1900 and granted a year later opened the door to patents disputes since it infringed on the Syntonic patents of Oliver Lodge, first filed in May 1897, as well as patents filed by Ferdinand Braun.[61] Marconi was able to obtain patents in the UK and France but the US version of his tuned four circuit patent, filed in November 1900, was initially rejected based on it being anticipated by Lodge's tuning system, and refiled versions were rejected because of the prior patents by Braun, and Lodge.[62] A further clarification and re-submission was rejected because it infringed on parts of two prior patents Tesla had obtained for his wireless power transmission system.[63] Marconi's lawyers managed to get a resubmitted patent reconsidered by another examiner who initially rejected it due to a pre-existing John Stone Stone tuning patent, but it was finally approved it in June 1904 based on it having a unique system of variable inductance tuning that was different from Stone[64][65] who tuned by varying the length of the antenna.[62] When Lodge's Syntonic patent was extended in 1911 for another 7 years the Marconi Company agreed to settle that patent dispute, purchasing Lodge's radio company with its patent in 1912, giving them the priority patent they needed.[66][67] Other patent disputes would crop up over the years including a 1943 US Supreme Court ruling on the Marconi Companies ability to sue the US government over patent infringement during World War I. The Court rejected the Marconi Companies suit saying they could not sue for patent infringement when their own patents did not seem to have priority over the patents of Lodge, Stone, and Tesla.[14][50]

Crystal radio receiver

Although it was invented in 1904 in the wireless telegraphy era, the crystal radio receiver could also rectify AM transmissions and served as a bridge to the broadcast era. In addition to being the main type used in commercial stations during the wireless telegraphy era, it was the first receiver to be used widely by the public.[68] During the first two decades of the 20th century, as

radio stations began to transmit in AM voice (radiotelephony) instead of radiotelegraphy, radio listening became a popular hobby, and the crystal was the simplest, cheapest detector. The millions of people who purchased or homemade these inexpensive reliable receivers created the mass listening audience for the first radio broadcasts, which began around 1920.[69] In the 1920s the crystal receiver was superseded by vacuum tube receivers and became obsolete. However it continued to be used by youth and the poor until World War 2.[68] Today crystal radios, the simplest type of radio receivers, are constructed by students as educational science projects.

Prior to 1920 the crystal receiver was the main type used in wireless telegraphy stations, and sophisticated models were made, like this Marconi Type 106 from 1915.

Family listening to the first broadcasts around 1920 with a crystal receiver. The mother and father have to share an earphone

After vacuum tube receivers appeared around 1920, the crystal set became a simple cheap alternative radio used by youth and the poor.

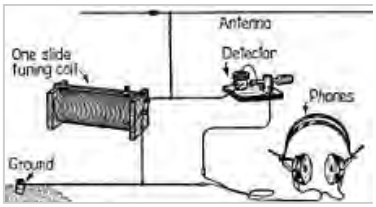

Simple crystal radio. The capacitance of the wire antenna connected to the coil serves as the capacitor in the tuned circuit.

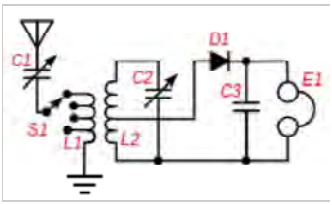

Typical "loose coupler" crystal radio circuit

The crystal radio used a crystal detector called a cat's whisker detector, invented by Harrison H. C. Dunwoody and Greenleaf Whittier Pickard in 1904, to rectify the radio signal to extract the audio from the radio frequency carrier.[11][31][70] It consisted of a mineral crystal, usually galena (PbS, lead sulfide) which was lightly touched by a fine springy wire (the "cat whisker") on an adjustable arm.[31][71] The resulting crude semiconductor junction functioned as a Schottky barrier diode, it only conducted current in one direction. Only particular sites on the crystal surface functioned as rectifying junctions, and the junction could be disrupted by the slightest vibration. So a usable site was found by trial and error before each use; the operator would drag the cat's whisker across the crystal until the radio began functioning. Frederick Seitz, a later semiconductor researcher, wrote:

> Such variability, bordering on what seemed the mystical, plagued the early history of crystal detectors and caused many of the vacuum tube experts of a later generation to regard the art of crystal rectification as being close to disreputable.[72]

Like other receivers of this era the crystal radio was unamplified and ran off the power of the radio waves received from the radio station, so it had to be listened to with earphones; it could not drive a loudspeaker.[11][71] It required a long wire antenna, and its sensitivity depended on how large the antenna was. During the wireless era it was used in commercial and military longwave stations with huge antennas to receive long distance radiotelegraphy traffic, even including transatlantic traffic.[73][74] However, when used to receive broadcast stations a typical home crystal set had a more limited range of about 25 miles.[75] In sophisticated crystal radios the "loose coupler" inductively-coupled tuned circuit was used to increase the Q. However it still had poor selectivity compared to modern receivers.[71]

Heterodyne receiver and BFO

Beginning around 1905 continuous wave (CW) transmitters began to replace spark transmitters for radiotelegraphy because they had much greater range. The first continuous wave transmitters were the Poulsen arc invented in 1904 and the Alexanderson alternator developed 1906-1910, which were replaced by vacuum tube transmitters beginning around 1920.[6]

The continuous wave radiotelegraphy signals produced by these transmitters required a different method of reception.[76][77] The radiotelegraphy signals produced by spark gap transmitters consisted of strings of damped waves repeating at an audio rate, so the "dots" and "dashes" of Morse code were audible as a tone or buzz in the receivers' earphones. However the new continuous wave radiotelegraph signals simply consisted of pulses of unmodulated carrier (sine waves). These were inaudible in the receiver headphones. To receive this new modulation type, the receiver had to produce some kind of tone during the pulses of carrier.

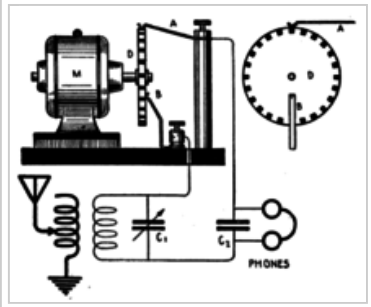

Radio receiver with Poulsen "tikker" consisting of a commutator disk turned by a motor to interrupt the carrier.

The first crude device that did this was the "ticker" or "tikker", invented in 1908 by Valdemar Poulsen.[28][76] [78] This was a vibrating interrupter with a capacitor at the tuner output which served as a rudimentary modulator, interrupting the carrier at an audio rate, thus producing a buzz in the earphone when the carrier was present.[79] A similar device was the "tone wheel" invented by Rudolph Goldschmidt, a wheel spun by a motor with contacts spaced around its circumference, which made contact with a stationary brush.

In 1901 Reginald Fessenden had invented a better means of accomplishing this.[76][78][80][81] In his *heterodyne receiver* an unmodulated sine wave radio signal at a frequency f_O offset from the incoming radio wave carrier f_C was applied to a rectifying detector such as a crystal detector or electrolytic detector, along with the radio signal from the antenna. In the detector the two signals mixed, creating two new *heterodyne* (beat) frequencies at the sum $f_C + f_O$ and the difference $f_C - f_O$ between these frequencies. By choosing f_O correctly the lower heterodyne $f_C - f_O$ was in the audio frequency range, so it was audible as a tone in the earphone whenever the carrier was present. Thus the "dots" and "dashes" of Morse code were audible as musical "beeps". A major attraction of this method during this pre-amplification period was that the heterodyne receiver actually amplified the signal somewhat, the detector had "mixer gain".[78]

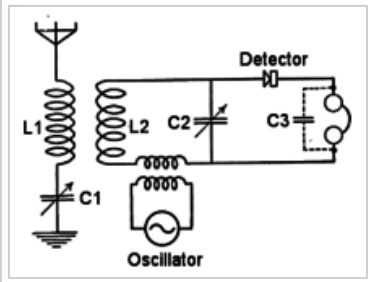

Fessenden's heterodyne radio receiver circuit

The receiver was ahead of its time, because when it was invented there was no oscillator capable of producing the radio frequency sine wave f_O with the required stability.[82] Fessenden first used his large radio frequency alternator,[79] but this wasn't practical for ordinary receivers. The heterodyne receiver remained a laboratory curiosity until a cheap compact source of continuous waves appeared, the vacuum tube electronic oscillator[78] invented by Edwin Armstrong and Alexander Meissner in 1913.[28][83] After this it became the standard method of receiving CW radiotelegraphy. The heterodyne oscillator is the ancestor of the *beat frequency oscillator* (BFO) which is used to receive radiotelegraphy in communications receivers today. The heterodyne oscillator had to be retuned each time the receiver was tuned to a new station, but in modern superheterodyne receivers the BFO signal beats with the fixed intermediate frequency, so the beat frequency oscillator can be a fixed frequency.

Armstrong later used Fessenden's heterodyne principle in his superheterodyne receiver *(below)*.[78][79]

Vacuum tube era

The Audion (triode) vacuum tube invented by Lee De Forest in 1906 was the first practical amplifying device and revolutionized radio.[38] Vacuum tube transmitters replaced spark transmitters and made possible four new types of modulation: continuous wave (CW) radiotelegraphy, amplitude modulation (AM) around 1915 which could carry audio (sound), frequency modulation (FM) around 1938 which had much improved audio quality, and single sideband (SSB).

The amplifying vacuum tube used energy from a battery or electrical outlet to increase the power of the radio signal, so vacuum tube receivers could be more sensitive and have a greater reception range than the previous unamplified receivers. The increased audio output power also allowed them to drive loudspeakers instead of earphones, permitting more than one person to listen. The first loudspeakers were produced around 1915. These changes caused radio listening to evolve explosively from a solitary hobby to a popular social and family pastime. The development of amplitude modulation (AM) and vacuum tube transmitters during World War I, and the availability of cheap receiving tubes after the war, set the stage for the start of AM broadcasting, which sprang up spontaneously around 1920.

The advent of radio broadcasting increased the market for radio receivers greatly, and transformed them into a consumer product.[84][85][86] At the beginning of the 1920s the radio receiver was a forbidding high-tech device, with many cryptic knobs and controls requiring technical skill to operate, housed in an unattractive black metal box, with a tinny-sounding horn loudspeaker.[85] By the 1930s, the broadcast receiver had become a piece of furniture, housed in an attractive wooden case, with standardized controls anyone could use, which occupied a respected place in the home living room. In the early radios the multiple tuned circuits required multiple knobs to be adjusted to tune in a new station. One of the most important ease-of-use innovations was "single knob tuning", achieved by linking the tuning capacitors together mechanically.[85][86] The dynamic cone loudspeaker invented in 1924 greatly improved audio frequency response over the previous horn speakers, allowing music to be reproduced with good fidelity.[85][87] Convenience features like large lighted dials, tone controls, pushbutton tuning, tuning indicators and automatic gain control (AGC) were added.[84][86] The receiver market was divided into the above *broadcast receivers* and *communications receivers*, which were used for two-way radio communications such as shortwave radio.[88]

Unlike today, when almost all radios use a variation of the superheterodyne design, during the 1920s vacuum tube radios used a variety of competing circuits.

A vacuum tube receiver required several power supplies at different voltages, which in early radios were supplied by separate batteries. These were the standard batteries used in early radios:[89][90][91]

- "A" battery - This supplied current to heat the filaments of the tubes, which consumed the bulk of the power in early radios. The first tubes used 6V at several amperes, so lead-acid automobile batteries were often used, as they could be recharged. Later tubes used 3V or 1.5V from dry cell batteries.
- "B" battery - this supplied the plate (anode) voltage for the tubes, including the audio output power to the earphone or loudspeaker. These were rectangular multicell carbon-zinc batteries. They were made in multiples of 22.5 volts: 22.5, 45, 67.5, and 90 volts, and often had taps to give different voltages.
- "C" battery - a few radios required a third voltage of about 4V to bias the grid of the tubes negative.

By 1930 adequate rectifier tubes were developed, and the expensive batteries were replaced by a transformer power supply that worked off the house current.[84][85]

Vacuum tubes were bulky, expensive, had a limited lifetime, consumed a large amount of power and produced a lot of waste heat, so the number of tubes a receiver could economically have was a limiting factor. Therefore, a goal of tube receiver design was to get the most performance out of a limited number of tubes. The major radio receiver designs, listed below, were invented during the vacuum tube era.

A defect in many early vacuum tube receivers was that the amplifying stages could oscillate, act as an oscillator, producing unwanted radio frequency alternating currents.[11][92][93] These parasitic oscillations mixed with the carrier of the radio signal in the detector tube, producing audible beat notes (heterodynes); annoying whistles, moans, and howls in the speaker. This was due to feedback in the amplifiers; one major feedback path was the capacitance between the plate and grid in early triodes.[92][93] This was solved by the Neutrodyne circuit, and later the development of the tetrode and pentode around 1930.

During the "Golden Age of Radio" (1920 to 1950), families gathered to listen to the home radio in the evening, such as this Zenith console model 12-S-568 from 1938, a 12 tube superheterodyne with

Edwin Armstrong is one of the most important figures in radio receiver history, and during this period invented technology which continues to dominate radio communication.[79] He was the first to give a correct explanation of how De Forest's triode tube worked. He invented the feedback oscillator, regenerative receiver, the superregenerative receiver, the superheterodyne receiver, and modern frequency modulation (FM).

pushbutton tuning and 12 inch cone speaker.

The first vacuum tube receivers

The first amplifying vacuum tube, the Audion, a crude triode, was invented in 1906 by Lee De Forest as a more sensitive detector for radio receivers, by adding a third electrode to the thermionic diode detector, the Fleming valve.[38][59][94][95] It was not widely used until its amplifying ability was recognized around 1912.[38] The first tube receivers, invented by De Forest and built by hobbyists until the mid 1920s, used a single Audion which functioned as a grid-leak detector which both rectified and amplified the radio signal.[59][92][96] The grid-leak detector circuit was also used in regenerative, TRF, and early superheterodyne receivers *(below)* until the 1930s.

De Forest's first commercial Audion receiver, the RJ6 which came out in 1914. The Audion tube was always mounted upside down, with its delicate filament loop hanging down, so it did not sag and touch the other electrodes in the tube.

To give enough output power to drive a loudspeaker, 2 or 3 additional Audion stages were needed for audio amplification.[59] Many early hobbyists could only afford a single tube receiver, and listened to the radio with earphones, so early tube amplifiers and speakers were sold as add-ons.

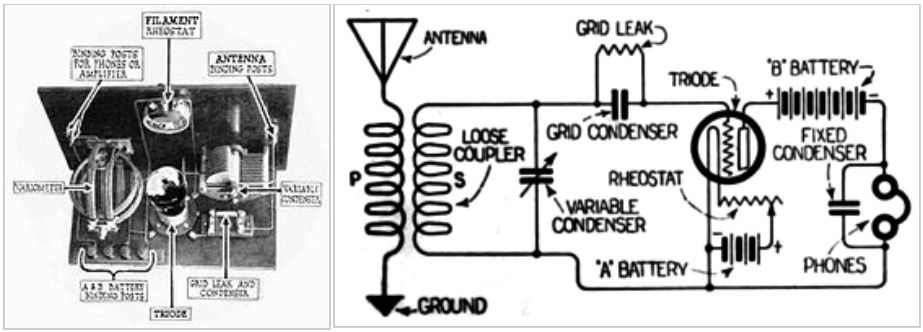

Example of single tube triode grid-leak receiver from 1920, the first type of amplifying radio receiver. In the grid leak circuit, electrons attracted to the grid during the positive half cycles of the radio signal charge the grid capacitor with a negative voltage of a few volts, biasing the grid near its cutoff voltage, so the tube conducts only during the positive half-cycles, rectifying the radio carrier.

In addition to very low gain of about 5 and a short lifetime of about 100 hours, the primitive Audion had erratic characteristics because it was incompletely evacuated, some residual air was left in the tube by De Forest, who believed that ionization was key to its operation.[97][98] This made it a more sensitive detector[97] but also caused its electrical characteristics to vary during use.[59][94] As the tube heated up, gas released from the metal elements would change the pressure in the tube, changing the plate current and other characteristics, so it required periodic bias adjustments to keep it at the correct operating point. Each Audion stage usually had a rheostat to adjust the filament current, and often a potentiometer or multiposition switch to control the plate voltage. The filament rheostat was also used as a volume control. The many controls made multitube Audion receivers nightmarishly complicated to operate.

By 1914, Harold Arnold at Western Electric and Irving Langmuir at GE had realized that the residual gas in the tube that caused these problems was not necessary; the Audion could operate on electron conduction alone.[94][97][98] They were able to evacuate tubes to a lower pressure of 10^{-9} atm, producing the first "hard vacuum" triodes. These more stable tubes did not require bias adjustments and allowed radios to have fewer controls and be more user-friendly.[94] During World War I civilian radio use was prohibited, but by 1920 these tubes came on the market and large scale production of vacuum tube radios began. The "soft" incompletely-evacuated tubes were used as detectors through the 1920s then became obsolete.

Regenerative (autodyne) receiver

The regenerative receiver, invented by Edwin Armstrong[99] in 1913 when he was a 23-year-old college student,[100] was used very widely until the late 1920s particularly by hobbyists who could only afford a single-tube radio. Today transistor versions of the circuit are still used in a few inexpensive applications like walkie-talkies. In the regenerative receiver the gain (amplification) of a vacuum tube or transistor is increased by using *regeneration* (positive feedback); some of the energy from the tube's output

circuit is fed back into the input circuit with a feedback loop.[11][92][101][102][103] The early vacuum tubes had very low gain (around 5). Regeneration could not only increase the gain of the tube enormously, by a factor of 15,000 or more, it also increased the Q factor of the tuned circuit, decreasing (sharpening) the bandwidth of the receiver by the same factor, improving selectivity greatly.[92][101][102] The receiver had a control to adjust the feedback. The tube also acted as a grid-leak detector to rectify the AM signal.[92]

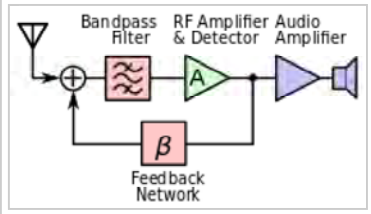

Block diagram of regenerative receiver

Another advantage of the circuit was that the tube could be made to oscillate, and thus a single tube could serve as both a beat frequency oscillator and a detector, functioning as a heterodyne receiver to make CW radiotelegraphy transmissions audible.[92][101][102] This mode was called an autodyne receiver. To receive radiotelegraphy, the feedback was increased until the tube oscillated, then the oscillation frequency was tuned to one side of the transmitted signal. The incoming radio carrier signal and local oscillation signal mixed in the tube and produced an audible heterodyne (beat) tone at the difference between the frequencies.

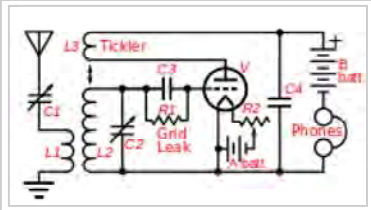

Circuit of single tube Armstrong regenerative receiver

A widely used design was the Armstrong circuit, in which a "tickler" coil in the plate circuit was coupled to the tuning coil in the grid circuit, to provide the feedback.[11][92][103] The feedback was controlled by a variable resistor, or alternately by moving the two

nemade Armstrong
nerative receiver,
2. The "tickler" coil
is visible on the
t panel, coupled to
input tuning coils.

Commercial regenerative receiver from the early 1920s, the Paragon RA-10 *(center)* with separate 10R single tube RF amplifier *(left)* and three tube DA-2 detector and 2-stage audio amplifier unit *(right)*. The 4 cylindrical dry cell "A" batteries *(right rear)* powered the tube filaments, while the 2 rectangular "B" batteries provided plate voltage.

Homemade one-tube Armstrong regenerative receiver from the 1940s. The tickler coil is a variometer winding mounted on a shaft inside the tuning coil *(upper right)* which can be rotated by a knob on the front panel.

windings physically closer together to increase loop gain, or apart to reduce it.[101] This was done by an adjustable air core transformer called a variometer (variocoupler). Regenerative detectors were sometimes also used in TRF and superheterodyne receivers.

One problem with the regenerative circuit was that when used with large amounts of regeneration the selectivity (Q) of the tuned circuit could be *too* sharp, attenuating the AM sidebands, thus distorting the audio modulation.[104] This was usually the limiting factor on the amount of feedback that could be employed.

A more serious drawback was that it could act as an inadvertent radio transmitter, producing interference (RFI) in nearby receivers.[11][92][101][102][103][105] In AM reception, to get the most sensitivity the tube was operated very close to instability and could easily break into oscillation (and in CW reception *did* oscillate), and the resulting radio signal was radiated by its wire antenna. In nearby receivers, the regenerative's signal would beat with the signal of the station being received in the detector, creating annoying heterodynes, (beats), howls and whistles.[11] Early regeneratives which oscillated easily were called "bloopers", and were made illegal in Europe. One preventative measure was to use a stage of RF amplification before the regenerative detector, to isolate it from the antenna.[92][101] But by the mid 1920s "regens" were no longer sold by the major radio manufacturers.[11]

Superregenerative receiver

This was a receiver invented by Edwin Armstrong in 1922 which used regeneration in a more sophisticated way, to give greater gain.[93][106][107][108][109] It was used in a few shortwave receivers in the 1930s, and is used today in a few cheap high frequency applications such as walkie-talkies and garage door openers.

In the regenerative receiver the loop gain of the feedback loop was less than one, so the tube (or other amplifying device) did not oscillate but was close to oscillation, giving large gain.[106] In the superregenerative receiver, the loop gain was made equal to one, so the amplifying device actually began to oscillate, but the oscillations were interrupted periodically.[93][110] This allowed a single tube to produce gains of over 10^6.

Tuned radio frequency (TRF) receiver

The tuned radio frequency (TRF) receiver, invented in 1916 by Ernst Alexanderson, improved both sensitivity and selectivity by using several stages of amplification before the detector, each with a tuned circuit, all tuned to the frequency of the station.[11][93][110][111][112] It was very popular in quality radios during the 1920s until the superheterodyne replaced it in the 1930s. The TRF receiver consisted of these parts:

- One or more tuned radio frequency amplifier stages, each consisting of an amplifying tube or transistor and a tuned circuit. In vacuum tube radios these consisted of a tube amplifier followed by an air core interstage coupling transformer with a capacitor across one winding.
- A detector stage, in tube radios usually a triode grid-leak detector.
- One or more audio amplifier stages

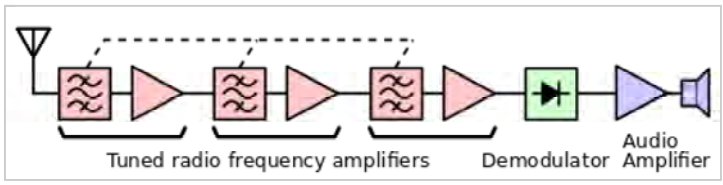

Block diagram of a tuned radio frequency receiver. The dotted line indicates that the bandpass filters must be tuned together.

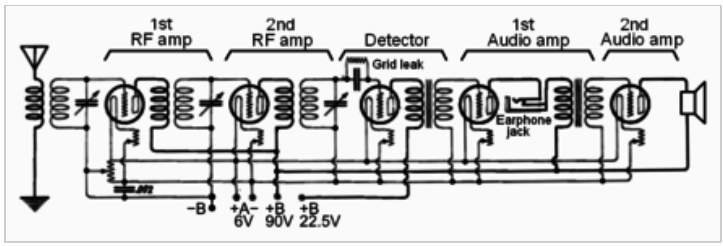

Typical 5 tube TRF circuit from 1924 has 2 stages of RF amplification, a grid-leak detector stage, and 2 stages of transformer-coupled audio amplification

A major problem of early TRF receivers was that they were complicated to tune, because each resonant circuit had to be adjusted to the frequency of the station before the radio would work.[11][93] In later TRF receivers the tuning capacitors were linked together mechanically ("ganged") on a common shaft so they could be adjusted with one knob, but in early receivers the frequencies of the tuned circuits could not be made to "track" well enough to allow this, and each tuned circuit had its own tuning knob.[110][113] Therefore, the knobs had to be turned simultaneously. For this reason most TRF sets had no more than three tuned RF stages.[92][104]

Early 6 tube TRF receiver from around 1920. The 3 large knobs adjust the 3 tuned circuits to tune in stations

Atwater-Kent TRF receiver from the 1920s with 2 RF stages *(left)*, detector and two audio amplifier tubes *(right)*. The loudspeaker consists of an earphone coupled to an acoustic horn which amplifies the sound.

Tuning a Neutrodyne TRF receiver with 3 tuned circuits *(large knobs)*

A second problem was that the multiple radio frequency stages, all tuned to the same frequency, were prone to oscillate,[113][114] and the parasitic oscillations mixed with the radio station's carrier in the detector, producing audible heterodynes (beat notes), whistles and moans, in the speaker.[11][92][93][112] This was solved by the invention of the Neutrodyne circuit *(below)* and the development of the tetrode later around 1930, and better shielding between stages.[112]

Today the TRF design is used in a few integrated (IC) receiver chips. From the standpoint of modern receivers the disadvantage of the TRF is that the gain and bandwidth of the tuned RF stages are not constant but vary as the receiver is tuned to different frequencies.[114] Since the bandwidth of a filter with a given Q is proportional to the frequency, as the receiver is tuned to higher frequencies its bandwidth increases.[115][116]

Neutrodyne receiver

The Neutrodyne receiver, invented in 1922 by Louis Hazeltine,[117][118] was a TRF receiver with a "neutralizing" circuit added to each radio amplification stage to cancel the feedback to prevent the oscillations which caused the annoying whistles in the TRF.[11][93][112][113][119] In the neutralizing circuit a capacitor fed a feedback current from the plate circuit to the grid circuit which was 180° out of phase with the feedback which caused the oscillation, canceling it.[92] The Neutrodyne was popular until the advent of cheap tetrode tubes around 1930.

Reflex receiver

The reflex receiver, invented in 1914 by Wilhelm Schloemilch and Otto von Bronk,[120] and rediscovered and extended to multiple tubes in 1917 by Marius Latour[120][121] and William H. Priess, was a design used in some inexpensive radios of the 1920s[122] which enjoyed a resurgence in small portable tube radios of the 1930s[123] and again in a few of the first transistor radios in the 1950s.[93][124] It is another example of an ingenious circuit invented to get the most out of a limited number of active devices. In the reflex receiver the RF signal from the tuned circuit is passed through one or more amplifying tubes or transistors, demodulated in a detector, then the resulting audio signal is passed *again* though the same amplifier stages for audio amplification.[93] The separate radio and audio signals present simultaneously in the amplifier do not interfere with each other since they are at different frequencies, allowing the amplifying tubes to do "double duty". In addition to single tube reflex receivers, some TRF and superheterodyne receivers had several stages "reflexed".[124] Reflex radios were prone to a defect called "play-through" which meant that the volume of audio did not go to zero when the volume control was turned down.[124]

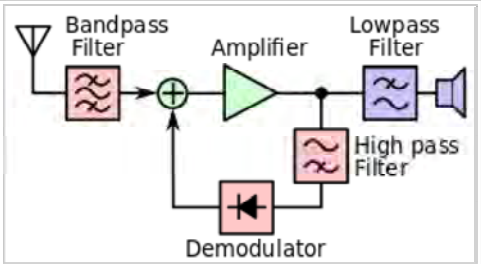

Block diagram of simple single tube reflex receiver

Superheterodyne receiver

The superheterodyne, invented in 1918 during World War I by Edwin Armstrong[125] when he was in the Signal Corps, is the design used in almost all modern receivers, except a few specialized applications.[79][110][126] It is a more complicated design than the other receivers above, and when it was invented required 6 - 9 vacuum tubes, putting it beyond the budget of most consumers, so it was initially used mainly in commercial and military communication stations.[127] However, by the 1930s the "superhet" had replaced all the other receiver types above.

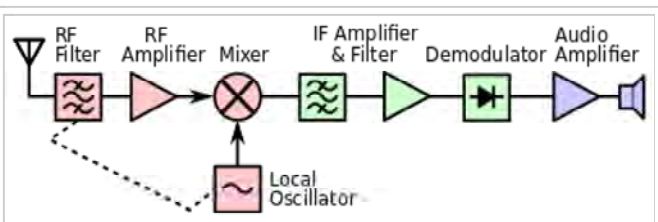

Block diagram of a superheterodyne receiver. The dotted line indicates that the RF filter and local oscillator must be tuned in tandem.

In the superheterodyne, the "heterodyne" technique invented by Reginald Fessenden is used to shift the frequency of the radio signal down to a lower "intermediate frequency" (IF), before it is processed.[115][127][128][129] An unmodulated sinusoidal signal f_{LO} generated by a *local oscillator* (LO) is mixed with the

incoming radio signal f_{RF} from the antenna in a nonlinear vacuum tube or transistor called the "*mixer*". The result at the output of the mixer is a heterodyne or beat frequency at the difference between these two frequencies: $f_{IF} = |f_{RF} - f_{LO}|$ This lower frequency is called the *intermediate frequency* (IF). The IF also contains the modulation (sidebands) that was present in the original RF signal. This signal is amplified and bandpass filtered as in the TRF receiver,[110] then is demodulated in a detector, producing an audio signal.

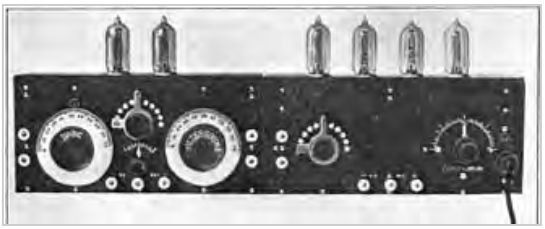

The first superheterodyne receiver built at Armstrong's Signal Corps laboratory in Paris during World War I. It is constructed in two sections, the mixer and local oscillator *(left)* and three IF amplification stages and a detector stage *(right)*. The intermediate frequency was 75 kHz.

The superheterodyne design is superior to other receivers for these reasons:[115][116]

- At the high frequencies used for radio transmission, signal processing circuitry often performs poorly. Amplifying devices have little gain, and are prone to instability and parasitic oscillation, as was seen in the TRF receiver.[115] By shifting the signal down to a lower intermediate frequency, the amplification, filtering and detection can be done at a more convenient frequency where the electronics works better. Armstrong invented the superheterodyne to receive high frequencies around 5 MHz, which were above the 1 MHz frequency range of most vacuum tubes of the time.[126] Today active devices still perform poorly at the microwave frequencies which modern telecommunication links use.
- The different frequencies of different stations are all converted to the same frequency, the IF, for filtering, so the bandwidth and gain of the receiver is constant over its frequency range. To tune the receiver to a different frequency, only the frequency of the local oscillator f_{LO} needs to be changed. The rest of the receiver after the mixer operates at a fixed frequency, the IF. All the other receivers above require that the bandpass filter (tuned circuit) be adjustable to different frequencies. Since the bandwidth of the filter is proportional to the frequency, the bandwidth of the receiver increases as it is tuned to higher frequencies.[110] It is also easier to build tunable oscillators than tunable electronic filters. In an analog television set, for example, if the superheterodyne design was not used, all the complicated filters that separate out the luminance carrier, chroma carrier and the audio subcarrier from the television signal would have to be made adjustable, and retuned each time the channel was changed.
- The total amplification of the receiver is divided between three amplifiers at different frequencies; the RF, IF, and audio amplifier. This reduces problems with feedback and parasitic oscillations that are encountered in receivers where most of the amplifier stages operate at the same frequency, as in the TRF receiver.[115]
- The most important advantage is that better selectivity can be achieved by doing the filtering at the lower intermediate frequency.[110][115] One of the most important parameters of a receiver is its bandwidth, the band of frequencies it accepts. In order to reject nearby interfering stations or noise, a narrow bandwidth is required. In all known filtering techniques, the bandwidth of the filter increases in proportion with the frequency, so by performing the filtering at the lower IF, rather than the frequency of the original radio signal f_{RF}, a narrower bandwidth can be achieved. Modern FM and television broadcasting, cellphones and other communications services, with their narrow channel widths, would be impossible without the superheterodyne.[110]

During the 1940s the vacuum tube superheterodyne receiver was refined into a cheap-to-manufacture form called the "All American Five" because it only required 5 tubes, which was used in almost all broadcast radios until the end of the tube era in the 1970s.

Modern transistor superheterodyne clock radio

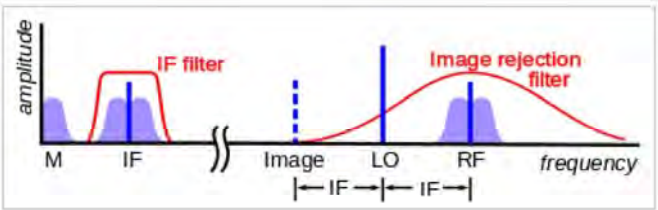

How a superheterodyne works. The incoming radio signal (**RF**) from the antenna consists of a carrier frequency *(dark blue)* with sidebands *(light blue)* on either side containing the modulation. Mixing this with the local oscillator signal (**LO**), creates a heterodyne intermediate frequency (**IF**) at the difference between these frequencies. This is bandpass filtered in the IF amplifier, and the demodulator extracts the modulation (**M**). Because the **Image** frequency when mixed with the **LO** also creates a signal at the **IF**, the

RF image rejection filter on the input of the receiver filters out any radio signal at the image frequency.

The RF filter on the front end of the receiver is needed to prevent interference from any radio signals at the image frequency. When the incoming radio signal f_{RF} is mixed with the local oscillator signal f_{LO}, *two* new frequencies (heterodynes) are created,[129] one at the sum $f_{RF} + f_{LO}$, and one at the difference $f_{RF} - f_{LO}$ of the frequencies. Because of this, without an input filter the receiver can receive incoming RF signals at two different frequencies,[116][126][129][130] one above the LO frequency: $f_{RF1} = f_{LO} + f_{IF}$, and one below the LO frequency: $f_{RF2} = f_{LO} - f_{IF}$. The receiver can be designed to receive on either of these two frequencies; the former is called *low-side injection* because the LO signal frequency is below the received frequency, while the latter is *high-side injection*.[129] Whichever is chosen, the other frequency is called the *image frequency*. If the receiver is receiving a signal on one of these frequencies, for example f_{RF1}, any other radio station or radio noise on the other frequency f_{RF2} will be received also, interfering with the desired signal. Therefore, the superheterodyne requires a bandpass filter on the input to reject this image frequency.[126] This image rejection filter does not need great selectivity, but as the receiver is tuned to different frequencies it must "track" in tandem with the LO.

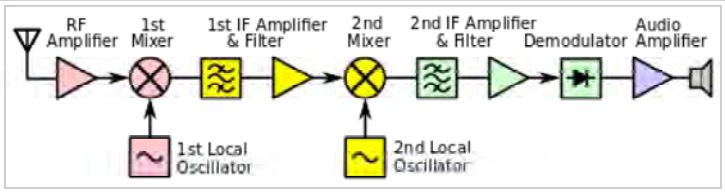

Double conversion superheterodyne block diagram

Double-conversion superheterodyne: In choosing the intermediate frequency (IF) used in a superhet, there is a tradeoff between image rejection and selectivity.[126][129] Since the separation between the desired frequency and the image is $2f_{IF}$, the higher the IF, the farther apart these two frequencies are, and the better the image rejection. However, the lower the IF, the narrower the bandwidth the IF filter can achieve, and the better the selectivity. In order to achieve both good image rejection and selectivity, many modern superhet receivers use *two* intermediate frequencies; this is called a *dual-conversion* or *double-conversion* superheterodyne. The incoming RF signal is first mixed with one local oscillator signal in the first mixer to convert it to a high IF frequency, to allow efficient filtering out of the image frequency, then this first IF is mixed with a second local oscillator signal in a second mixer to convert it to a low IF frequency for good bandpass filtering. Some receivers even use triple-conversion.

Terminology used with superheterodyne receivers:

- *RF front end* - refers to all the components of the receiver up to and including the mixer; all the parts that process the signal at the original incoming radio frequency.
- *Converter* - in many superhet circuits the same tube or transistor functions as both the local oscillator and the mixer. This is called a converter.
- *IF strip* - The IF filter and amplifier usually consists of several tuned amplifier stages as in the TRF receiver. This is called the IF strip.
- *First detector, second detector* - the mixer tube or transistor is sometimes called the "first detector", while the demodulator that extracts the modulation from the IF signal is called the "second detector". In a dual-conversion superhet there are two mixers, so the demodulator is called the "third detector".

To receive radiotelegraph (CW) or single-sideband modulation (SSB), a beat frequency oscillator (BFO) is used.

Semiconductor era

The invention of the transistor in 1947 revolutionized radio technology, making truly portable receivers possible, beginning with transistor radios in the late 1950s. Although portable vacuum tube radios were made, tubes were bulky and inefficient, consuming large amounts of power and requiring several large batteries to produce the filament and plate voltage. Transistors did not require a heated filament, reducing power consumption, and were smaller and much less fragile than vacuum tubes.

The development of integrated circuits (ICs) in the 1970s created another revolution, allowing an entire radio receiver to be put on a chip. ICs reversed the economics of vacuum tube radios; since the marginal cost of adding additional amplifying devices (transistors) to the chip was essentially zero, the size and cost of the receiver was dependent not on the active components as with vacuum tubes, but on the passive components; inductors and capacitors, which could not be integrated easily on the chip.[4] As a result, the current trend in receivers is to use digital circuitry on the chip to do functions that were formerly done by analog circuits which require passive components. In a digital receiver the IF signal is sampled and digitized, and the bandpass filtering

and detection functions are performed by digital signal processing (DSP) on the chip. Another benefit of DSP is that the properties of the receiver; channel frequency, bandwidth, gain, etc. can be dynamically changed by software to react to changes in the environment; these systems are known as software-defined radios or cognitive radio.

In modern wireless technology, radio transmitters and receivers are embedded in portable digital devices such as laptops, cell phones, GPS receivers, Bluetooth headsets, wireless routers and work automatically, in the background, to keep the device in touch with other devices, without wires. They transmit binary digital data by modulation methods such as frequency shift keying (FSK) allowing portable digital devices to communicate via wireless networks.

A modern smartphone has several digital radio transmitters and receivers to connect to different devices; a cellular receiver, a wireless modem, a bluetooth modem, and a GPS receiver

Digital technologies

Many of the functions performed by analogue electronics can be performed by software instead. The benefit is that software is not affected by temperature, physical variables, electronic noise and manufacturing defects.[131] For really high-performance receivers, such as satellite communications receivers and military/naval receivers, two-stage ("double conversion") and even three-stage ("triple conversion") superheterodyne processing is frequently used. Single-conversion receivers are rather simple-minded in their nature.

DSP technology

DSP technology, short for digital signal processing, is the use of digital means to process signals and is coming into wide use in modern shortwave receivers. It is the basis of many areas of modern technology including cell phones, CD players, video recorders and computers. A digital signal is essentially a stream or sequence of numbers that relay a message through some sort of medium such as a wire. The primary benefit of DSP hardware in shortwave receivers is the ability to tailor the bandwidth of the receiver to current reception conditions and to the type of signal being listened to. A typical analog only receiver may have a limited number of fixed bandwidths, or only one, but a DSP receiver may have 40 or more individually selectable filters.

PC controlled radio receivers

"PC radios", or radios that are designed to be controlled by a standard PC are controlled by specialized PC software using a serial port connected to the radio. A "PC radio" may not have a front-panel at all, and may be designed exclusively for computer control, which reduces cost.

Some PC radios have the great advantage of being field upgradable by the owner. New versions of the DSP firmware can be downloaded from the manufacturer's web site and uploaded into the flash memory of the radio. The manufacturer can then in effect add new features to the radio over time, such as adding new filters, DSP noise reduction, or simply to correct bugs.

A full-featured radio control program allows for scanning and a host of other functions and, in particular, integration of databases in real-time, like a "TV-Guide" type capability. This is particularly helpful in locating all transmissions on all frequencies of a particular broadcaster, at any given time. Some control software designers have even integrated Google Earth to the shortwave databases, so it is possible to "fly" to a given transmitter site location with a click of a mouse. In many cases the user is able to see the transmitting antennas where the signal is originating from.

Radio control software

The field of software control of PC radios has grown rapidly in the last several years, with developers making a number of advances. Since the Graphical User Interface or GUI interface PC to the radio has unlimited flexibility, any number of new features can be added by the software designer. Features that can be found in advanced control software programs today include a band table, GUI controls corresponding to traditional radio controls, local time clock and a UTC clock, signal strength meter, an ILG database for shortwave listening with lookup capability, scanning capability, text-to-speech interface, and integrated Conference Server.

Software-defined radios

The next level in radio / software integration are so-called pure "software defined radios". The distinction here is that all filtering, modulation and signal manipulation is done in software, usually by a PC soundcard or by a dedicated piece of DSP hardware. There may be a minimal RF front-end or traditional radio that supplies an IF to the SDR. SDR's can go far beyond the usual demodulation capability of typical, and even high-end DSP shortwave radios. They can for example, record large swaths of the radio spectrum to a hard drive for "playback" at a later date. The same SDR that one minute is demodulating a simple AM broadcast may also be able to decode an HDTV broadcast in the next. A well known open-source project called GNU Radio is dedicated to evolving a high-performance SDR. All the source code for this SDR is freely downloadable and modifiable by anyone.

See also

- Car audio
- Crystal radio receiver
- Demodulation
- Dielectric wireless receiver
- Digital Audio Broadcast (DAB)
- Direct conversion receiver
- Minimum detectable signal
- Neutrodyne
- Radar
- Radar warning receiver
- Radiogram (furniture)
- Receiver (information theory)
- Regenerative radio receiver
- Selectivity (electronic)
- Sensitivity (electronics)
- Noise (electronics)
- Distortion
- Satnav
- Superheterodyne receiver
- Table radio
- Telecommunication
- Television receive-only
- Transistor radio
- Tuned radio frequency receiver
- Tuner (radio)

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Radio spectrum

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The **radio spectrum** is the part of the electromagnetic spectrum from 3 Hz to 3000 GHz (3 THz). Electromagnetic waves in this frequency range, called radio waves, are extremely widely used in modern technology, particularly in telecommunication. To prevent interference between different users, the generation and transmission of radio waves is strictly regulated by national laws, coordinated by an international body, the International Telecommunication Union (ITU).[1]

Different parts of the radio spectrum are appointed by the ITU for different radio transmission technologies and applications; some 40 radiocommunication services are defined in the ITU's Radio Regulations (RR).[2] In some cases, parts of the radio spectrum are sold or licensed to operators of private radio transmission services (for example, cellular telephone operators or broadcast television stations). Ranges of allocated frequencies are often referred to by their provisioned use (for example, cellular spectrum or television spectrum).[3]

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By frequency

A **band** is a small section of the spectrum of radio communication frequencies, in which channels are usually used or set aside for the same purpose.

Above 300 GHz, the absorption of electromagnetic radiation by Earth's atmosphere is so great that the atmosphere is effectively opaque, until it becomes transparent again in the near-infrared and optical window frequency ranges.

To prevent interference and allow for efficient use of the radio spectrum, similar services are allocated in bands. For example, broadcasting, mobile radio, or navigation devices, will be allocated in non-overlapping ranges of frequencies.

Each of these bands has a basic bandplan which dictates how it is to be used and shared, to avoid interference and to set protocol for the compatibility of transmitters and receivers. See detail of bands:http://www.ntia.doc.gov/files/ntia/Spectrum_Use_Summary_Master-06212010.pdf

As a matter of convention, the ITU divides the radio spectrum into 12 bands, each beginning at a wavelength which is a power of ten (10^n) metres, with corresponding frequency of $3\times10^{8-n}$ hertz, and each covering a decade of frequency or wavelength. Each of these bands has a traditional name. For example, the term *high frequency* (HF) designates the wavelength range from 100 to 10 metres, corresponding to a frequency range of 3 MHz to 30 MHz. This is just a naming convention and is not related to allocation; the ITU further divides each band into subbands allocated to different uses.

Band name	Abbreviation	ITU band	Frequency and wavelength in air	Example uses
Extremely low frequency	ELF	1	3–30 Hz 100,000 km – 10,000 km	Communication with submarines
Super low frequency	SLF	2	30–300 Hz 10,000 km – 1000 km	Communication with submarines
Ultra low frequency	ULF	3	300–3000 Hz 1000 km – 100 km	Submarine communication, communication within mines
Very low frequency	VLF	4	3–30 kHz 100 km – 10 km	Navigation, time signals, submarine communication, wireless heart rate monitors, geophysics
Low frequency	LF	5	30–300 kHz 10 km – 1 km	Navigation, clock time signals, AM longwave broadcasting (Europe and parts of Asia), RFID, amateur radio
Medium frequency	MF	6	300–3000 kHz 1 km – 100 m	AM (medium-wave) broadcasts, amateur radio, avalanche beacons
High frequency	HF	7	3–30 MHz 100 m – 10 m	Shortwave broadcasts, citizens' band radio, amateur radio and over-the-horizon aviation communications, RFID, over-the-horizon radar, automatic link establishment (ALE) / near-vertical incidence skywave (NVIS) radio communications, marine and mobile radio telephony
Very high frequency	VHF	8	30–300 MHz 10 m – 1 m	FM, television broadcasts and line-of-sight ground-to-aircraft and aircraft-to-aircraft communications, land mobile and maritime mobile communications, amateur radio, weather radio
Ultra high frequency	UHF	9	300–3000 MHz 1 m – 100 mm	Television broadcasts, microwave oven, microwave devices/communications, radio astronomy, mobile phones, wireless LAN, Bluetooth, ZigBee, GPS and two-way radios such as land mobile, FRS and GMRS radios, amateur radio, satellite radio
Super high frequency	SHF	10	3–30 GHz 100 mm – 10 mm	Radio astronomy, microwave devices/communications, wireless LAN, most modern radars, communications satellites, cable and satellite television broadcasting, DBS, amateur radio, satellite radio

Extremely high frequency	EHF	11	30–300 GHz 10 mm – 1 mm	Radio astronomy, high-frequency microwave radio relay, microwave remote sensing, amateur radio, directed-energy weapon, millimeter wave scanner
Terahertz or Tremendously high frequency	THz or THF	12	300–3000 GHz 1 mm – 100 µm	Experimental medical imaging to replace X-rays, ultrafast molecular dynamics, condensed-matter physics, terahertz time-domain spectroscopy, terahertz computing/communications, remote sensing, amateur radio

ITU

The **ITU radio bands** are designations defined in the ITU Radio Regulations. Article 2, provision No. 2.1 states that "the radio spectrum shall be subdivided into nine frequency bands, which shall be designated by progressive whole numbers in accordance with the following table[4]".

The table originated with a recommendation of the IVth CCIR meeting, held in Bucharest in 1937, and was approved by the International Radio Conference held at Atlantic City in 1947. The idea to give each band a number, in which the number is the logarithm of the approximate geometric mean of the upper and lower band limits in Hz, originated with B.C. Fleming-Williams, who suggested it in a letter to the editor of *Wireless Engineer* in 1942. (For example, the approximate geometric mean of Band 7 is 10 MHz, or 10^7 Hz.)[5]

Table of ITU Radio Bands

Band Number	Symbols	Frequency Range	Wavelength Range†
4	VLF	3 to 30 kHz	10 to 100 km
5	LF	30 to 300 kHz	1 to 10 km
6	MF	300 to 3000 kHz	100 to 1000 m
7	HF	3 to 30 MHz	10 to 100 m
8	VHF	30 to 300 MHz	1 to 10 m
9	UHF	300 to 3000 MHz	10 to 100 cm
10	SHF	3 to 30 GHz	1 to 10 cm
11	EHF	30 to 300 GHz	1 to 10 mm
12	THF	300 to 3000 GHz	0.1 to 1 mm

† This column does not form part of the table in Provision No. 2.1 of the Radio Regulations

IEEE

Radar-frequency bands according to IEEE standard[6]

Band designation	Frequency range	
HF	0.003 to 0.03 GHz	High Frequency[7]
VHF	0.03 to 0.3 GHz	Very High Frequency[7]
UHF	0.3 to 1 GHz	Ultra High Frequency[7]
L	1 to 2 GHz	Long wave
S	2 to 4 GHz	Short wave
C	4 to 8 GHz	Compromise between S and X
X	8 to 12 GHz	Used in WW II for fire control, X for cross (as in crosshair). Exotic.[8]
K_u	12 to 18 GHz	Kurz-under
K	18 to 27 GHz	German Kurz (short)
K_a	27 to 40 GHz	Kurz-above
V	40 to 75 GHz	
W	75 to 110 GHz	W follows V in the alphabet
mm or G	110 to 300 GHz [note 1]	Millimeter[6]

1. The designation mm is also used to refer to the range from 30 to 300 GHz.[6]

EU, NATO, US ECM frequency designations

NATO LETTER BAND DESIGNATION[9][8][10]				BROADCASTING BAND DESIGNATION
NEW NOMENCLATURE		OLD NOMENCLATURE		
BAND	FREQUENCY (MHz)	BAND	FREQUENY (MHz)	
A	0 – 250	**I**	100 – 150	Band I 47 – 68 MHz (TV) Band II 87.5 – 108 MHz (FM)
		G	150 – 225	Band III 174 – 230 MHz (TV)
B	250 – 500	**P**	225 – 390	
C	500 – 1 000	**L**	390 – 1 550	Band IV 470 – 582 MHz (TV) Band V 582 – 862 MHz (TV)
D	1 000 – 2 000	**S**	1 550 – 3 900	
E	2 000 – 3 000			
F	3 000 – 4 000			
G	4 000 – 6 000	**C**	3 900 – 6 200	
H	6 000 – 8 000	**X**	6 200 – 10 900	
I	8 000 – 10 000			
J	10 000 – 20 000	**Ku**	10 900 – 20 000	
K	20 000 – 40 000	**Ka**	20 000 – 36 000	
L	40 000 – 60 000	**Q**	36 000 – 46 000	
		V	46 000 – 56 000	
M	60 000 – 100 000	**W**	56 000 – 100 000	
US- MILITARY / SACLANT				
N	100 000 – 200 000			
O	100 000 – 200 000			

Waveguide frequency bands

Band	Frequency range [11]
R band	1.70 to 2.60 GHz
D band	2.20 to 3.30 GHz
S band	2.60 to 3.95 GHz
E band	3.30 to 4.90 GHz
G band	3.95 to 5.85 GHz
F band	4.90 to 7.05 GHz
C band	5.85 to 8.20 GHz
H band	7.05 to 10.10 GHz
X band	8.2 to 12.4 GHz
K_u band	12.4 to 18.0 GHz
K band	15.0 to 26.5 GHz
K_a band	26.5 to 40.0 GHz
Q band	33 to 50 GHz
U band	40 to 60 GHz
V band	40 to 75 GHz
E band	60 to 90 GHz
W band	75 to 110 GHz
F band	90 to 140 GHz
D band	110 to 170 GHz
Y band	325 to 500 GHz

Comparison of radio band designation standards

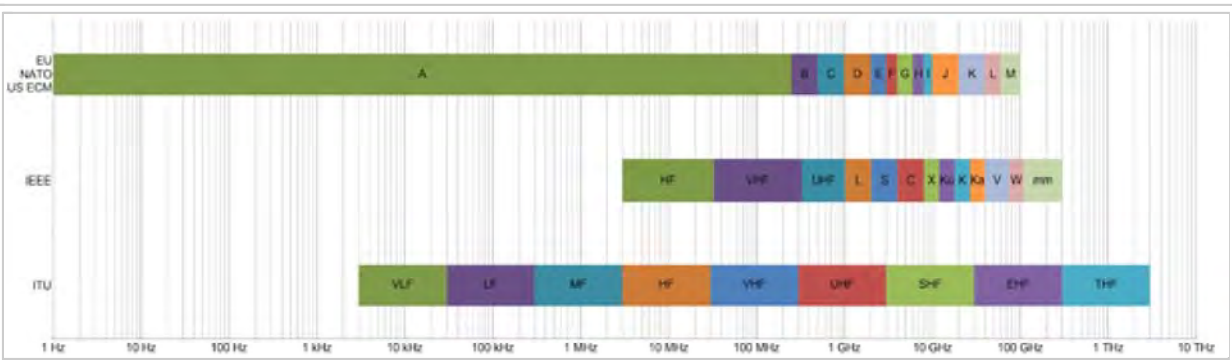

Comparison of frequency band designations

Frequency	IEEE[6]	EU, NATO, US ECM	ITU	
			no.	abbr.
3 Hz		A		
30 Hz			1	ELF
300 Hz			2	SLF
3 kHz			3	ULF
30 kHz			4	VLF
300 kHz			5	LF
3 MHz			6	MF
30 MHz	HF		7	HF
250 MHz	VHF		8	VHF
300 MHz		B		
500 MHz	UHF		9	UHF
1 GHz		C		
2 GHz	L	D		
3 GHz	S	E		
4 GHz		F	10	SHF
6 GHz	C	G		
8 GHz		H		
10 GHz	X	I		
12 GHz		J		
18 GHz	K_u			
20 GHz	K			
27 GHz		K		
30 GHz	K_a			
40 GHz		L	11	EHF
60 GHz	V			
75 GHz		M		
100 GHz	W			
110 GHz				
300 GHz	mm			
3 THz			12	THF

By application

Broadcasting

Broadcast frequencies:

- Longwave AM Radio = 148.5 kHz – 283.5 kHz (LF)
- Mediumwave AM Radio = 530 kHz – 1710 kHz (MF)
- Shortwave AM Radio = 3 MHz – 30 MHz (HF)

Designations for television and FM radio broadcast frequencies vary between countries, see Television channel frequencies and FM broadcast band. Since VHF and UHF frequencies are desirable for many uses in urban areas, in North America some parts of the former television broadcasting band have been reassigned to cellular phone and various land mobile communications systems. Even within the allocation still dedicated to television, TV-band devices use channels without local broadcasters.

The Apex band in the United States was a pre-WWII allocation for VHF audio broadcasting; it was made obsolete after the introduction of FM broadcasting.

Air band

Airband refers to VHF frequencies 118 to 137 MHz, used for navigation and voice communication with aircraft. Trans-oceanic aircraft also carry HF radio and satellite transceivers.

Marine band

The greatest incentive for development of radio was the need to communicate with ships out of visual range of shore. From the very early days of radio, large oceangoing vessels carried powerful long-wave and medium-wave transmitters. High-frequency allocations are still designated for ships, although satellite systems have taken over some of the safety applications previously served by 500 kHz and other frequencies. 2182 kHz is a medium-wave frequency still used for marine emergency communication.

Marine VHF radio is used in coastal waters and relatively short-range communication between vessels and to shore stations. Radios are channelized, with different channels used for different purposes; marine Channel 16 is used for calling and emergencies.

Amateur radio frequencies

Amateur radio frequency allocations vary around the world. Several bands are common for amateurs worldwide, usually in the HF part of the spectrum. Other bands are national or regional allocations only due to differing allocations for other services, especially in the VHF and UHF parts of the radio spectrum.

Citizens' band and personal radio services

Citizens' band radio is allocated in many countries, using channelized radios in the upper HF part of the spectrum (around 27 MHz). It is used for personal, small business and hobby purposes. Other frequency allocations are used for similar services in different jurisdictions, for example UHF CB is allocated in Australia. A wide range of personal radio services exist around the world, usually emphasizing short-range communication between individuals or for small businesses, simplified or no license requirements, and usually FM transceivers using around 1 watt or less.

Industrial, scientific, medical

The ISM bands were initially reserved for non-communications uses of RF energy, such as microwave ovens, radio-frequency heating, and similar purposes. However, in recent years the largest use of these bands has been by short-range low-power communications systems, since users do not have to hold a radio operator's license. Cordless telephones, wireless computer networks, Bluetooth devices, and garage door openers all use the ISM bands. ISM devices do not have regulatory protection against interference from other users of the band.

Land mobile bands

Bands of frequencies, especially in the VHF and UHF parts of the spectrum, are allocated for communication between fixed base stations and land mobile vehicle-mounted or portable transceivers. In the United States these services are informally known as business band radio. See also Professional mobile radio.

Police radio and other public safety services such as fire departments and ambulances are generally found in the VHF and UHF parts of the spectrum. Trunking systems are often used to make most efficient use of the limited number of frequencies available.

The demand for mobile telephone service has led to large blocks of radio spectrum allocated to cellular frequencies.

Radio control

Reliable radio control uses bands dedicated to the purpose. Radio-controlled toys may use portions of unlicensed spectrum in the 27 MHz or 49 MHz bands, but more costly aircraft, boat, or land vehicle models use dedicated radio control frequencies near 72 MHz to avoid interference by unlicensed uses. The 21st century has seen a move to 2.4 gigahertz spread spectrum RC control systems.

Licensed amateur radio operators use portions of the 6-meter band in North America. Industrial remote control of cranes or railway locomotives use assigned frequencies that vary by area.

Radar

Radar applications use relatively high power pulse transmitters and sensitive receivers, so radar is operated on bands not used for other purposes. Most radar bands are in the microwave part of the spectrum, although certain important applications for meteorology make use of powerful transmitters in the UHF band. Radio waves are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light. Radio waves have frequencies as high as 300 GHz

to as low as 3 kHz, though some definitions describe waves above 1 or 3 GHz as microwaves, or include waves of any lower frequency. At 300 GHz, the corresponding wavelength is 1 mm (0.039 in), and at 3 kHz is 100 km (62 mi). Like all other electromagnetic waves, they travel at the speed of light. Naturally occurring radio waves are generated by lightning, or by astronomical objects.

Artificially generated radio waves are used for fixed and mobile radio communication, broadcasting, radar and other navigation systems, communications satellites, computer networks and innumerable other applications. Radio waves are generated by radio transmitters and received by radio receivers. Different frequencies of radio waves have different propagation characteristics in the Earth's atmosphere; long waves can diffract around obstacles like mountains and follow the contour of the earth (ground waves), shorter waves can reflect off the ionosphere and return to earth beyond the horizon (skywaves), while much shorter wavelengths bend or diffract very little and travel on a line of sight, so their propagation distances are limited to the visual horizon.

To prevent interference between different users, the artificial generation and use of radio waves is strictly regulated by law, coordinated by an international body called the International Telecommunications Union (ITU), which defines radio waves as "electromagnetic waves of frequencies arbitrarily lower than 3 000 GHz, propagated in space without artificial guide".[1] The radio spectrum is divided into a number of radio bands on the basis of frequency, allocated to different uses

See also

- Bandplan
- Bandstacked
- Cellular frequencies
- DXing
- Frequency allocation
- Geneva Frequency Plan of 1975
- North American Regional Broadcasting Agreement
- Open spectrum
- Radio astronomy
- Radio § Communication system
- Scanner (radio)
- Two-way radio
- U-NII
- Ultra-wideband
- WARC bands

Notes

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- AFR 55-44/AR 105-86/OPNAVINST 3430.9A/MCO 3430.1, 27 October 1964 superseded by AFR 55-44/AR 105-86/OPNAVINST 3430.1A/MCO 3430.1A, 6 December 1978: Performing Electronic Countermeasures in the United States and Canada, Attachment 1,ECM Frequency Authorizations.

External links

- UnwantedEmissions.com (http://www.unwantedemissions.com) A reference to radio spectrum allocations.
- "Radio spectrum: a vital resource in a wireless world" (http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/index_en.htm) European Commission policy.

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Radio wave

From Wikipedia, the free encyclopedia

Radio waves are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light. Radio waves have frequencies as high as 300 GHz to as low as 3 kHz, though some definitions describe waves above 1 or 3 GHz as microwaves, or include waves of any lower frequency. At 300 GHz, the corresponding wavelength is 1 mm (0.039 in), and at 3 kHz is 100 km (62 mi). Like all other electromagnetic waves, they travel at the speed of light. Naturally occurring radio waves are generated by lightning, or by astronomical objects.

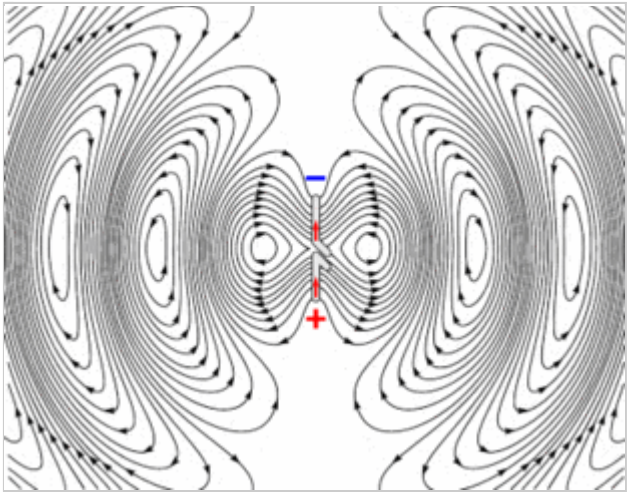

Animation of a half-wave dipole antenna radiating radio waves, showing the electric field lines. The antenna in the center is two vertical metal rods, with an alternating current applied at its center from a radio transmitter *(not shown)*. The voltage charges the two sides of the antenna alternately positive *(+)* and negative *(−)*. Loops of electric field *(black lines)* leave the antenna and travel away at the speed of light; these are the radio waves. The action is drastically slowed down in this animation.

Artificially generated radio waves are used for fixed and mobile radio communication, broadcasting, radar and other navigation systems, communications satellites, computer networks and innumerable other applications. Radio waves are generated by radio transmitters and received by radio receivers. Different frequencies of radio waves have different propagation characteristics in the Earth's atmosphere; long waves can diffract around obstacles like mountains and follow the contour of the earth (ground waves), shorter waves can reflect off the ionosphere and return to earth beyond the horizon (skywaves), while much shorter wavelengths bend or diffract very little and travel on a line of sight, so their propagation distances are limited to the visual horizon.

To prevent interference between different users, the artificial generation and use of radio waves is strictly regulated by law, coordinated by an international body called the International Telecommunications Union (ITU), which defines radio waves as "electromagnetic waves of frequencies arbitrarily lower than 3 000 GHz, propagated in space without artificial guide".[1] The radio spectrum is divided into a number of radio bands on the basis of frequency, allocated to different uses.

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- 1 Discovery and exploitation
- 2 Propagation
- 3 Speed, wavelength, and frequency
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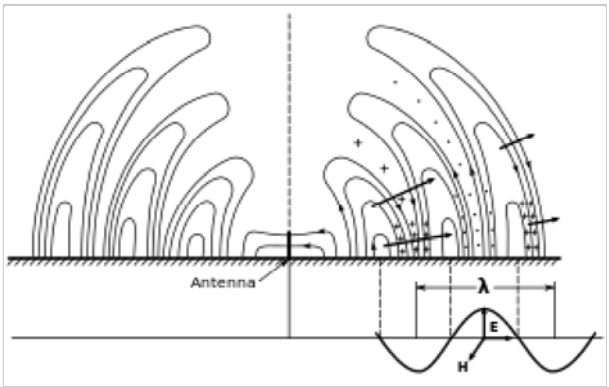

Diagram of the electric fields (E) and magnetic fields (H) of radio waves emitted by a monopole radio transmitting antenna (small dark vertical line in the center). The E and H fields are perpendicular as implied by the phase diagram in the lower right.

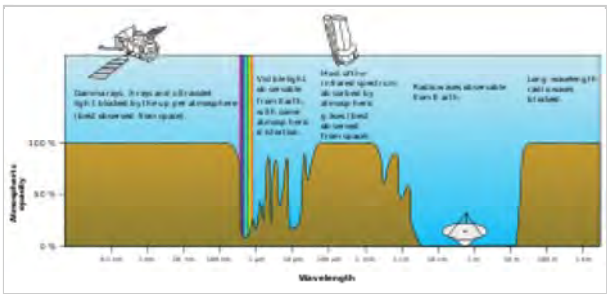

Rough plot of Earth's atmospheric transmittance (or opacity) to various wavelengths of electromagnetic radiation, including radio waves.

Discovery and exploitation

Radio waves were first predicted by mathematical work done in 1867 by Scottish mathematical physicist James Clerk Maxwell.[2] Maxwell noticed wavelike properties of light and similarities in electrical and magnetic observations. His mathematical theory, now called Maxwell's equations, described light waves and radio waves as waves of electromagnetism that travel in space, radiated by a charged particle as it undergoes acceleration. In 1887, Heinrich Hertz demonstrated the reality of Maxwell's electromagnetic waves by experimentally generating radio waves in his laboratory,[3] showing that they exhibited the same wave properties as light: standing waves, refraction, diffraction, and polarization. Radio waves were first used for communication in the mid 1890s by Guglielmo Marconi, who developed the first practical radio transmitters and receivers.

Propagation

The study of electromagnetic phenomena such as reflection, refraction, polarization, diffraction, and absorption is of critical importance in the study of how radio waves move in free space and over the surface of the Earth. Different frequencies experience different combinations of these phenomena in the Earth's atmosphere, making certain radio bands more useful for specific purposes than others. Practical radio systems use three different techniques of radio propagation to communicate:

- *Line of sight:* This refers to radio waves that travel in a straight line from the transmitting antenna to the receiving antenna. It does not necessarily require a cleared sight path; at lower frequencies radio waves can pass through buildings, foliage and other obstructions. This is the only method of propagation possible at microwave frequencies and above. On the surface of the Earth, line of sight propagation is limited by the visual horizon to about 40 miles. It is the method used in short range radio communication systems such as cell phones, walkie-talkies, wireless networks, FM and television broadcasting and radar. By using dish antennas to transmit beams of microwaves, point-to-point radio relay links transmit telephone and television signals over long distances up to the visual horizon, and ground stations can communicate with satellites and spacecraft billions of miles from Earth.
- *Ground waves:* At lower frequencies, in the medium wave and longwave bands, due to diffraction vertically polarized radio waves can bend over hills and mountains, and propagate beyond the

horizon, traveling as surface waves which follow the contour of the Earth. This allows mediumwave and longwave broadcasting stations to have coverage areas beyond the horizon, out to hundreds of miles. As the frequency drops, the losses decrease and the achievable range increases. Military very low frequency (VLF) and extremely low frequency (ELF) communication systems can communicate over most of the Earth, and with submarines hundreds of feet underwater.

- *Skywaves:* At medium wave and shortwave wavelengths, radio waves reflect off a conductive ionized layer in the atmosphere called the ionosphere. So radio waves directed at an angle into the sky can return to Earth beyond the horizon; this is called "skip" or "skywave" propagation. By using multiple skips communication at intercontinental distances can be achieved. This technique is used by military over-the-horizon (OTH) radar systems, by radio amateurs, and by shortwave broadcasting stations to broadcast to other countries. Skywave propagation is variable and dependent on atmospheric conditions; it is most reliable at night and in the winter.

Speed, wavelength, and frequency

Radio waves travel at the speed of light.[4][5] When passing through an object, they are slowed according to that object's permeability and permittivity.

The wavelength is the distance from one peak of the wave's electric field (wave's peak/crest) to the next, and is inversely proportional to the frequency of the wave. The distance a radio wave travels in one second, in a vacuum, is 299,792,458 meters (983,571,056 ft) which is the wavelength of a 1 hertz radio signal. A 1 megahertz radio signal has a wavelength of 299.8 meters (984 ft).

Radio communication

In order to receive radio signals, for instance from AM/FM radio stations, a radio antenna must be used. However, since the antenna will pick up thousands of radio signals at a time, a radio tuner is necessary to *tune in* a particular signal.[6] This is typically done via a resonator (in its simplest form, a circuit with a capacitor, inductor, or crystal oscillator, but many modern radios use Phase Locked Loop systems). The resonator is configured to resonate at a particular frequency, allowing the tuner to amplify sine waves at that radio frequency and ignore other sine waves. Usually, either the inductor or the capacitor of the resonator is adjustable, allowing the user to change the frequency at which it resonates.[7]

See also

- Radio astronomy
- Television transmitter

Look up ***radio wave*** in Wiktionary, the free dictionary.

Notes

1. ITU Radio Regulations, Chapter I, Section I, General terms – Article 1.5, definition: *radio waves or hertzian waves*
2. Harman, Peter Michael (1998). *The natural philosophy of James Clerk Maxwell*. Cambridge, England: Cambridge University Press. p. 6. ISBN 0-521-00585-X.

3. "Heinrich Hertz: The Discovery of Radio Waves". Juliantrubin.com. Retrieved 2011-11-08.
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- Heinrich Hertz: "Electric waves; being researches on the propagation of electric action with finite velocity through space" (http://historical.library.cornell.edu/cgi-bin/cul.cdl/docviewer?did=cdl334&view=50&frames=0&seq=5) (1893). Cornell University Library Historical Monographs Collection. Reprinted by (http://www.amazon.com/dp/1429740361/) Cornell University Library Digital Collections.
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Categories: Radio technology | Waves | Electromagnetic spectrum

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Radio

From Wikipedia, the free encyclopedia

Radio is the technology of using radio waves to carry information, such as sound, by systematically modulating properties of electromagnetic energy waves transmitted through space, such as their amplitude, frequency, phase, or pulse width.[n 1] When radio waves strike an electrical conductor, the oscillating fields induce an alternating current in the conductor. The information in the waves can be extracted and transformed back into its original form.

The Alexandra Palace, here: mast of the broadcasting station

Radio systems need a transmitter to modulate (change) some property of the energy produced to impress a signal on it, for example using amplitude modulation or angle modulation (which can be frequency modulation or phase modulation). Radio systems also need an antenna to convert electric currents into radio waves, and vice versa. An antenna can be used for both transmitting and receiving. The electrical resonance of tuned circuits in radios allow individual stations to be selected. The electromagnetic wave is intercepted by a tuned receiving antenna. A radio receiver receives its input from an antenna and converts it into a form that is usable for the consumer, such as sound, pictures, digital data, measurement values, navigational positions, etc.[2] Radio frequencies occupy the range from a 3 kHz to 300 GHz, although commercially important uses of radio use only a small part of this spectrum.[3]

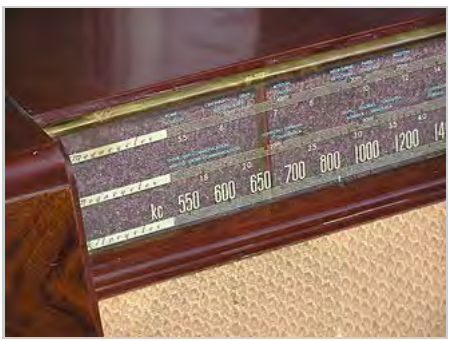

Classic radio receiver dial

A radio communication system sends signals by radio.[4] The radio equipment involved in communication systems includes a transmitter and a receiver, each having an antenna and appropriate terminal equipment such as a microphone at the transmitter and a loudspeaker at the receiver in the case of a voice-communication system.[5]

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Etymology

The term "radio" is derived from the Latin word "radius", meaning "spoke of a wheel, beam of light, ray". It was first applied to communications in 1881 when, at the suggestion of French scientist Ernest Mercadier, Alexander Graham Bell adopted "radiophone" (meaning "radiated sound") as an alternate name for his photophone optical transmission system.[6] However, this invention would not be widely adopted.

Following Heinrich Hertz's establishment of the existence of electromagnetic radiation in the late 1880s, a variety of terms were initially used for the phenomenon, with early descriptions of the radiation itself including "Hertzian waves", "electric waves", and "ether waves", while phrases describing its use in communications included "spark telegraphy", "space telegraphy", "aerography" and, eventually and most commonly, "wireless telegraphy". However, "wireless" included a broad variety of related electronic technologies, including electrostatic induction, electromagnetic induction and aquatic and earth conduction, so there was a need for a more precise term referring exclusively to electromagnetic radiation.

The first use of *radio-* in conjunction with electromagnetic radiation appears to have been by French physicist Édouard Branly, who in 1890 developed a version of a coherer receiver he called a *radio-conducteur*.[7] The radio- prefix was later used to form additional descriptive compound and hyphenated words, especially in Europe, for example, in early 1898 the British publication *The Practical Engineer* included a reference to "the radiotelegraph" and "radiotelegraphy",[8] while the French text of both the 1903 and 1906 Berlin Radiotelegraphic Conventions includes the phrases *radiotélégraphique* and *radiotélégrammes*.

The use of "radio" as a standalone word dates back to at least December 30, 1904, when instructions issued by the British Post Office for transmitting telegrams specified that "The word 'Radio'... is sent in the Service Instructions".[9] This practice was universally adopted, and the word "radio" introduced internationally, by the 1906 Berlin Radiotelegraphic Convention, which included a Service Regulation specifying that "Radiotelegrams shall show in the preamble that the service is 'Radio'".

The switch to "radio" in place of "wireless" took place slowly and unevenly in the English-speaking world. Lee de Forest helped popularize the new word in the United States—in early 1907 he founded the DeForest Radio

Telephone Company, and his letter in the June 22, 1907 *Electrical World* about the need for legal restrictions warned that "Radio chaos will certainly be the result until such stringent regulation is enforced".[10] The United States Navy would also play a role. Although its translation of the 1906 Berlin Convention used the terms "wireless telegraph" and "wireless telegram", by 1912 it began to promote the use of "radio" instead. The term started to become preferred by the general public in the 1920s with the introduction of broadcasting. ("Broadcasting" is based upon an agricultural term meaning roughly "scattering seeds widely".) British Commonwealth countries continued to commonly use the term "wireless" until the mid-20th century, though the magazine of the British Broadcasting Corporation in the UK has been called Radio Times since its founding in the early 1920s.

In recent years the more general term "wireless" has gained renewed popularity, even for devices using electromagnetic radiation, through the rapid growth of short-range computer networking, e.g., Wireless Local Area Network (WLAN), Wi-Fi, and Bluetooth, as well as mobile telephony, e.g., GSM and UMTS cell phones. Today, the term "radio" specifies the transceiver device or chip, whereas "wireless" refers to the lack of physical connections; thus equipment employs embedded *radio* transceivers, but operates as *wireless* devices over *wireless* sensor networks.

Processes

Radio systems used for communication have the following elements. With more than 100 years of development, each process is implemented by a wide range of methods, specialised for different communications purposes.

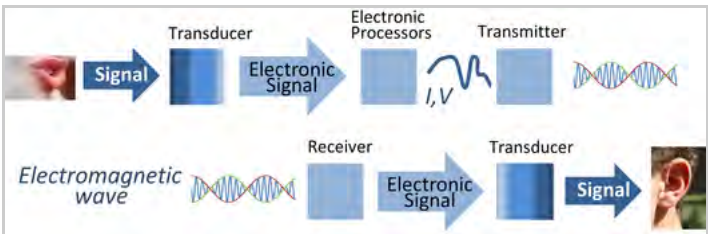

Radio communication. Information such as sound is converted by a transducer such as a microphone to an electrical signal, which modulates a radio wave sent from a transmitter. A receiver intercepts the radio wave and extracts the information-bearing electronic signal, which is converted back using another transducer such as a speaker.

Transmitter and modulation

Each system contains a transmitter, This consists of a source of electrical energy, producing alternating current of a desired frequency of oscillation. The transmitter contains a system to modulate (change) some property of the energy produced to impress a signal on it. This modulation might be as simple as turning the energy on and off, or altering more subtle properties such as amplitude, frequency, phase, or combinations of these properties. The transmitter sends the modulated electrical energy to a tuned resonant antenna; this structure converts the rapidly changing alternating current into an electromagnetic wave that can move through free space (sometimes with a particular polarization).

Amplitude modulation of a carrier wave works by varying the strength of the transmitted signal in proportion to the information being sent. For example, changes in the signal strength can be used to reflect the sounds to be reproduced by a speaker, or to specify the light intensity of television pixels. It was the method used for the first audio radio transmissions, and remains in use today. "AM" is often used to refer to the medium wave broadcast band (see AM radio), but it is used in various radiotelephone services such as the Citizen Band, amateur radio and especially in aviation, due to its ability to be received under very weak signal conditions and its immunity to capture effect, allowing more than one signal to be heard simultaneously.

Frequency modulation varies the frequency of the carrier. The instantaneous frequency of the carrier is directly proportional to the instantaneous value of the input signal. FM has the "capture effect" whereby a receiver only receives the strongest signal, even when others are present. Digital data can be sent by shifting the carrier's

frequency among a set of discrete values, a technique known as frequency-shift keying. FM is commonly used at Very high frequency (VHF) radio frequencies for high-fidelity broadcasts of music and speech (see FM broadcasting). Analog TV sound is also broadcast using FM.

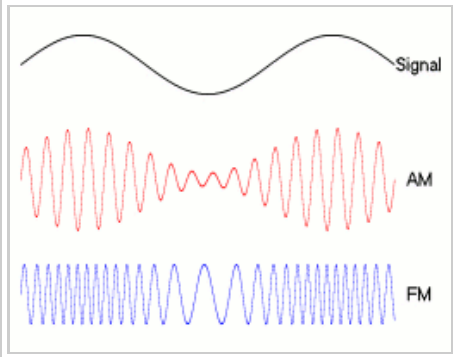

An audio signal (top) may be carried by an AM or FM radio wave.

Angle modulation alters the instantaneous phase of the carrier wave to transmit a signal. It may be either FM or phase modulation (PM).

Antenna

An *antenna* (or *aerial*) is an electrical device which converts electric currents into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an electric current oscillating at radio frequency (i.e. high frequency AC) to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals, that is applied to a receiver to be amplified. Some antennas can be used for both transmitting and receiving, even simultaneously, depending on the connected equipment.

Rooftop television antennas. Yagi-Uda antennas like these six are widely used at VHF and UHF frequencies.

Propagation

Once generated, electromagnetic waves travel through space either directly, or have their path altered by reflection, refraction or diffraction. The intensity of the waves diminishes due to geometric dispersion (the inverse-square law); some energy may also be absorbed by the intervening medium in some cases. Noise will generally alter the desired signal; this electromagnetic interference comes from natural sources, as well as from artificial sources such as other transmitters and accidental radiators. Noise is also produced at every step due to the inherent properties of the devices used. If the magnitude of the noise is large enough, the desired signal will no longer be discernible; the signal-to-noise ratio is the fundamental limit to the range of radio communications.

Resonance

Electrical resonance of tuned circuits in radios allow individual stations to be selected. A resonant circuit will respond strongly to a particular frequency, and much less so to differing frequencies. This allows the radio receiver to discriminate between multiple signals differing in frequency.

Receiver and demodulation

The electromagnetic wave is intercepted by a tuned receiving antenna; this structure captures some of the energy of the wave and returns it to the form of oscillating electrical currents. At the receiver, these currents are demodulated, which is conversion to a usable signal form by a detector sub-system. The receiver is "tuned" to respond preferentially to the desired signals, and reject undesired signals.

Early radio systems relied entirely on the energy collected by an antenna to produce signals for the operator.

Radio became more useful after the invention of electronic devices such as the vacuum tube and later the transistor, which made it possible to amplify weak signals. Today radio systems are used for applications from walkie-talkie children's toys to the control of space vehicles, as well as for broadcasting, and many other applications.

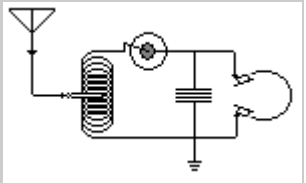

A crystal receiver, consisting of an antenna, adjustable electromagnetic coil, crystal rectifier, capacitor, headphones and ground connection.

A *radio receiver* receives its input from an antenna, uses electronic filters to separate a wanted radio signal from all other signals picked up by this antenna, amplifies it to a level suitable for further processing, and finally converts through demodulation and decoding the signal into a form usable for the consumer, such as sound, pictures, digital data, measurement values, navigational positions, etc.[11]

Radio band

Light comparison		
Name	**Frequency (Hz) (Wavelength)**	**Photon energy (eV)**
Gamma ray	> 30 EHz (0.01 nm)	124 keV - 300+ GeV
X-Ray	30 EHz - 30 PHz (0.01 nm - 10 nm)	124 eV to 120 keV
Ultraviolet	30 PHz - 750 THz (10 nm - 400 nm)	3.1 eV to 124 eV
Visible	750 THz - 428.5 THz (400 nm - 700 nm)	1.7 eV - 3.1 eV
Infrared	428.5 THz - 300 GHz (700 nm - 1 mm)	1.24 meV - 1.7 eV
Microwave	300 GHz - 300 MHz (1 mm - 1 m)	1.24 µeV - 1.24 meV
Radio	300 MHz - 3 kHz (1 m - 100 km)	12.4 feV - 1.24 meV

Radio frequencies occupy the range from a 3 kHz to 300 GHz, although commercially important uses of radio use only a small part of this spectrum.[12] Other types of electromagnetic radiation, with frequencies above the RF range, are infrared, visible light, ultraviolet, X-rays and gamma rays. Since the energy of an individual photon of radio frequency is too low to remove an electron from an atom, radio waves are classified as non-ionizing radiation.

Communication systems

A *radio communication system* sends signals by radio.[13] Types of radio communication systems deployed depend on technology, standards, regulations, radio spectrum allocation, user requirements, service positioning, and investment.[14]

The radio equipment involved in communication systems includes a transmitter and a receiver, each having an antenna and appropriate terminal equipment such as a microphone at the transmitter and a loudspeaker at the receiver in the case of a voice-communication system.[15]

The power consumed in a transmitting station varies depending on the distance of communication and the transmission conditions. The power received at the receiving station is usually only a tiny fraction of the

transmitter's output, since communication depends on receiving the information, not the energy, that was transmitted.

Classical radio communications systems use frequency-division multiplexing (FDM) as a strategy to split up and share the available radio-frequency bandwidth for use by different parties communications concurrently. Modern radio communication systems include those that divide up a radio-frequency band by time-division multiplexing (TDM) and code-division multiplexing (CDM) as alternatives to the classical FDM strategy. These systems offer different tradeoffs in supporting multiple users, beyond the FDM strategy that was ideal for broadcast radio but less so for applications such as mobile telephony.

A radio communication system may send information only one way. For example, in broadcasting a single transmitter sends signals to many receivers. Two stations may take turns sending and receiving, using a single radio frequency; this is called "simplex." By using two radio frequencies, two stations may continuously and concurrently send and receive signals - this is called "duplex" operation.

History

In 1864 James Clerk Maxwell showed mathematically that electromagnetic waves could propagate through free space.[16] The effects of electromagnetic waves (then-unexplained "action at a distance" sparking behavior) were actually observed before and after Maxwell's work by many inventors and experimenters including Luigi Galvani (1791), Peter Samuel Munk (1835), Joseph Henry (1842), Samuel Alfred Varley (1852), Edwin Houston, Elihu Thomson, Thomas Edison (1875) and David Edward Hughes (1878).[17][18][19] Edison gave the effect the name "etheric force"[20] and Hughes detected a spark impulse up to 500 yards (460 m) with a portable receiver, but none could identify what caused the phenomenon and it was usually written off as electromagnetic induction.[21] In 1886 Heinrich Rudolf Hertz noticed the same sparking phenomenon and, in published experiments (1887-1888), was able to demonstrate the existence of electromagnetic waves in an experiment confirming Maxwell's theory of electromagnetism. The discovery of these "Hertzian waves" (radio waves) prompted many experiments by physicists. An August 1894 lecture by the British physicist Oliver Lodge, where he transmitted and received "Hertzian waves" at distances up to 50 meters, was followed up a year later with experiments by Indian physicist Jagadish Bose in radio microwave optics and construction of a radio based lightning detector by Russian physicist Alexander Stepanovich Popov. Starting in late 1894, Guglielmo Marconi began pursuing the idea of building a wireless telegraphy system based on Hertzian waves (radio). Marconi gained a patent on the system in 1896 and developed it into a commercial communication system over the next few years.[22]

Early 20th century radio systems transmitted messages by continuous wave code only. Early attempts at developing a system of amplitude modulation for voice and music were demonstrated in 1900 and 1906, but had little success. World War I accelerated the development of radio for military communications, and in this era the first vacuum tubes were applied to radio transmitters and receivers. Electronic amplification was a key development in changing radio from an experimental practice by experts into a home appliance. After the war, commercial radio broadcasting began in the 1920s and became an important mass medium for entertainment and news.

World War II again accelerated development of radio for the wartime purposes of aircraft and land communication, radio navigation and radar. After the war, the experiments in television that had been interrupted were resumed, and it also became an important home entertainment medium.

Uses of radio

Early uses were maritime, for sending telegraphic messages using Morse code between ships and land. The earliest users included the Japanese Navy scouting the Russian fleet during the Battle of Tsushima in 1905. One of the most memorable uses of marine telegraphy was during the sinking of the RMS *Titanic* in 1912, including communications between operators on the sinking ship and nearby vessels, and communications to shore stations listing the survivors.

Radio was used to pass on orders and communications between armies and navies on both sides in World War I; Germany used radio communications for diplomatic messages once it discovered that its submarine cables had been tapped by the British. The United States passed on President Woodrow Wilson's Fourteen Points to Germany via radio during the war. Broadcasting began from San Jose, California in 1909,[23] and became feasible in the 1920s, with the widespread introduction of radio receivers, particularly in Europe and the United States. Besides broadcasting, point-to-point broadcasting, including telephone messages and relays of radio programs, became widespread in the 1920s and 1930s. Another use of radio in the pre-war years was the development of detection and locating of aircraft and ships by the use of radar (*RA*dio *D*etection *A*nd *R*anging).

Today, radio takes many forms, including wireless networks and mobile communications of all types, as well as radio broadcasting. Before the advent of television, commercial radio broadcasts included not only news and music, but dramas, comedies, variety shows, and many other forms of entertainment (the era from the late 1920s to the mid-1950s is commonly called radio's "Golden Age"). Radio was unique among methods of dramatic presentation in that it used only sound. For more, see radio programming.

Audio

One-way

AM radio uses amplitude modulation, in which the amplitude of the transmitted signal is made proportional to the sound amplitude captured (transduced) by the microphone, while the transmitted frequency remains unchanged. Transmissions are affected by static and interference because lightning and other sources of radio emissions on the same frequency add their amplitudes to the original transmitted amplitude.

Bakelite radio at the Bakelite Museum, Orchard Mill, Williton, Somerset, UK.

In the early part of the 20th century, American AM radio stations broadcast with powers as high as 500 kW, and some could be heard worldwide; these stations' transmitters were commandeered for military use by the US Government during World War II. Currently, the maximum broadcast power for a civilian AM radio station in the United States and Canada is 50 kW, and the majority of stations that emit signals this powerful were grandfathered in (see List of 50 kW AM radio stations in the United States). In 1986 KTNN received the last granted 50,000-watt class A license. These 50 kW stations are generally called "clear channel" stations (not to be confused with Clear Channel Communications), because within North America each of these stations has exclusive use of its broadcast frequency throughout part or all of the broadcast day.

FM broadcast radio sends music and voice with less noise than AM radio. It is often mistakenly thought that FM is higher fidelity than AM, but that is not true. AM is capable of the same audio bandwidth that FM

employs. AM receivers typically use narrower filters in the receiver to recover the signal with less noise. AM stereo receivers can reproduce the same audio bandwidth that FM does due to the wider filter used in an AM stereo receiver, but today, AM radios limit the audio bandpass to 3–5 kHz. In frequency modulation, amplitude variation at the microphone causes the transmitter frequency to fluctuate. Because the audio signal modulates the frequency and not the amplitude, an FM signal is not subject to static and interference in the same way as AM signals. Due to its need for a wider bandwidth, FM is transmitted in the Very High Frequency (VHF, 30 MHz to 300 MHz) radio spectrum.

A Fisher 500 AM/FM hi-fi receiver from 1959.

VHF radio waves act more like light, traveling in straight lines; hence the reception range is generally limited to about 50–200 miles (80–322 km). During unusual upper atmospheric conditions, FM signals are occasionally reflected back towards the Earth by the ionosphere, resulting in long distance FM reception. FM receivers are subject to the capture effect, which causes the radio to only receive the strongest signal when multiple signals appear on the same frequency. FM receivers are relatively immune to lightning and spark interference.

Bush House, old home of the BBC World Service.

High power is useful in penetrating buildings, diffracting around hills, and refracting in the dense atmosphere near the horizon for some distance beyond the horizon. Consequently, 100,000-watt FM stations can regularly be heard up to 100 miles (160 km) away, and farther, 150 miles (240 km), if there are no competing signals.

A few old, "grandfathered" stations do not conform to these power rules. WBCT-FM (93.7) in Grand Rapids, Michigan, US, runs 320,000 watts ERP, and can increase to 500,000 watts ERP by the terms of its original license. Such a huge power level does not usually help to increase range as much as one might expect, because VHF frequencies travel in nearly straight lines over the horizon and off into space. Nevertheless, when there were fewer FM stations competing, this station could be heard near Bloomington, Illinois, US, almost 300 miles (480 km) away.

FM subcarrier services are secondary signals transmitted in a "piggyback" fashion along with the main program. Special receivers are required to utilize these services. Analog channels may contain alternative programming, such as reading services for the blind, background music or stereo sound signals. In some extremely crowded metropolitan areas, the sub-channel program might be an alternate foreign-language radio program for various ethnic groups. Sub-carriers can also transmit digital data, such as station identification, the current song's name, web addresses, or stock quotes. In some countries, FM radios automatically re-tune themselves to the same channel in a different district by using sub-bands.

Two-way

Aviation voice radios use Aircraft band VHF AM. AM is used so that multiple stations on the same channel can be received. (Use of FM would result in stronger stations blocking out reception of weaker stations due to FM's capture effect). Aircraft fly high enough that their transmitters can be received hundreds of miles away, even though they are using VHF.

Marine voice radios can use single sideband voice (SSB) in the shortwave High Frequency (HF—3 MHz to 30 MHz) radio spectrum for very long ranges or Marine VHF radio / *narrowband FM* in the VHF spectrum for

much shorter ranges. Narrowband FM sacrifices fidelity to make more channels available within the radio spectrum, by using a smaller range of radio frequencies, usually with five kHz of deviation, versus the 75 kHz used by commercial FM broadcasts, and 25 kHz used for TV sound.

Degen DE1103, an advanced world mini-receiver with single sideband modulation and dual conversion

Government, police, fire and commercial voice services also use narrowband FM on special frequencies. Early police radios used AM receivers to receive one-way dispatches.

Civil and military HF (high frequency) voice services use shortwave radio to contact ships at sea, aircraft and isolated settlements. Most use single sideband voice (SSB), which uses less bandwidth than AM.[24] On an AM radio SSB sounds like ducks quacking, or the adults in a Charlie Brown cartoon. Viewed as a graph of frequency versus power, an AM signal shows power where the frequencies of the voice add and subtract with the main radio frequency. SSB cuts the bandwidth in half by suppressing the carrier and one of the sidebands. This also makes the transmitter about three times more powerful, because it doesn't need to transmit the unused carrier and sideband.

TETRA, Terrestrial Trunked Radio is a digital cell phone system for military, police and ambulances. Commercial services such as XM, WorldSpace and Sirius offer encrypted digital satellite radio.

Telephony

Mobile phones transmit to a local cell site (transmitter/receiver) that ultimately connects to the public switched telephone network (PSTN) through an optic fiber or microwave radio and other network elements. When the mobile phone nears the edge of the cell site's radio coverage area, the central computer switches the phone to a new cell. Cell phones originally used FM, but now most use various digital modulation schemes. Recent developments in Sweden (such as DROPme) allow for the instant downloading of digital material from a radio broadcast (such as a song) to a mobile phone.

Satellite phones use satellites rather than cell towers to communicate.

Video

Analog television sends the picture as AM and the sound as AM or FM, with the sound carrier a fixed frequency (4.5 MHz in the NTSC system) away from the video carrier. Analog television also uses a vestigial sideband on the video carrier to reduce the bandwidth required.

Digital television uses 8VSB modulation in North America (under the ATSC digital television standard), and COFDM modulation elsewhere in the world (using the DVB-T standard). A Reed–Solomon error correction code adds redundant correction codes and allows reliable reception during moderate data loss. Although many current and future codecs can be sent in the MPEG transport stream container format, as of 2006 most systems use a standard-definition format almost identical to DVD: MPEG-2 video in Anamorphic widescreen and MPEG layer 2 (*MP2*) audio. High-definition television is possible simply by using a higher-resolution picture, but H.264/AVC is being considered as a replacement video codec in some regions for its improved compression. With the compression and improved modulation involved, a single "channel" can contain a high-definition program and several standard-definition programs.

Navigation

All satellite navigation systems use satellites with precision clocks. The satellite transmits its position, and the time of the transmission. The receiver listens to four satellites, and can figure its position as being on a line that is tangent to a spherical shell around each satellite, determined by the time-of-flight of the radio signals from the satellite. A computer in the receiver does the math.

Radio direction-finding is the oldest form of radio navigation. Before 1960 navigators used movable loop antennas to locate commercial AM stations near cities. In some cases they used marine radiolocation beacons, which share a range of frequencies just above AM radio with amateur radio operators. LORAN systems also used time-of-flight radio signals, but from radio stations on the ground.

Very High Frequency Omnidirectional Range (VOR), systems (used by aircraft), have an antenna array that transmits two signals simultaneously. A directional signal rotates like a lighthouse at a fixed rate. When the directional signal is facing north, an omnidirectional signal pulses. By measuring the difference in phase of these two signals, an aircraft can determine its bearing or radial from the station, thus establishing a line of position. An aircraft can get readings from two VORs and locate its position at the intersection of the two radials, known as a "fix."

When the VOR station is collocated with DME (Distance Measuring Equipment), the aircraft can determine its bearing and range from the station, thus providing a fix from only one ground station. Such stations are called VOR/DMEs. The military operates a similar system of navaids, called TACANs, which are often built into VOR stations. Such stations are called VORTACs. Because TACANs include distance measuring equipment, VOR/DME and VORTAC stations are identical in navigation potential to civil aircraft.

Radar

Radar (Radio Detection And Ranging) detects objects at a distance by bouncing radio waves off them. The delay caused by the echo measures the distance. The direction of the beam determines the direction of the reflection. The polarization and frequency of the return can sense the type of surface. Navigational radars scan a wide area two to four times per minute. They use very short waves that reflect from earth and stone. They are common on commercial ships and long-distance commercial aircraft.

General purpose radars generally use navigational radar frequencies, but modulate and polarize the pulse so the receiver can determine the type of surface of the reflector. The best general-purpose radars distinguish the rain of heavy storms, as well as land and vehicles. Some can superimpose sonar data and map data from GPS position.

Search radars scan a wide area with pulses of short radio waves. They usually scan the area two to four times a minute. Sometimes search radars use the Doppler effect to separate moving vehicles from clutter. Targeting radars use the same principle as search radar but scan a much smaller area far more often, usually several times a second or more. Weather radars resemble search radars, but use radio waves with circular polarization and a wavelength to reflect from water droplets. Some weather radar use the Doppler effect to measure wind speeds.

Data (digital radio)

Most new radio systems are digital, including Digital TV, satellite radio, and Digital Audio Broadcasting. The oldest form of digital broadcast was spark gap telegraphy, used by pioneers such as Marconi. By pressing the key, the operator could send messages in Morse code by energizing a rotating commutating spark gap. The rotating commutator produced a tone in the receiver, where a simple spark gap would produce a hiss, indistinguishable from static. Spark-gap transmitters are now illegal, because their transmissions span several hundred megahertz. This is very wasteful of both radio frequencies and power.

The next advance was continuous wave telegraphy, or CW (Continuous Wave), in which a pure radio frequency, produced by a vacuum tube electronic oscillator was switched on and off by a key. A receiver with a local oscillator would "heterodyne" with the pure radio frequency, creating a whistle-like audio tone. CW uses less than 100 Hz of bandwidth. CW is still used, these days primarily by amateur radio operators (hams). Strictly, on-off keying of a carrier should be known as "Interrupted Continuous Wave" or ICW or on-off keying (OOK).

2008 Pure One Classic digital radio

Radioteletype equipment usually operates on short-wave (HF) and is much loved by the military because they create written information without a skilled operator. They send a bit as one of two tones using frequency-shift keying. Groups of five or seven bits become a character printed by a teleprinter. From about 1925 to 1975, radioteletype was how most commercial messages were sent to less developed countries. These are still used by the military and weather services.

Aircraft use a 1200 Baud radioteletype service over VHF to send their ID, altitude and position, and get gate and connecting-flight data. Microwave dishes on satellites, telephone exchanges and TV stations usually use quadrature amplitude modulation (QAM). QAM sends data by changing both the phase and the amplitude of the radio signal. Engineers like QAM because it packs the most bits into a radio signal when given an exclusive (non-shared) fixed narrowband frequency range. Usually the bits are sent in "frames" that repeat. A special bit pattern is used to locate the beginning of a frame.

Communication systems that limit themselves to a fixed narrowband frequency range are vulnerable to jamming. A variety of jamming-resistant spread spectrum techniques were initially developed for military use, most famously for Global Positioning System satellite transmissions. Commercial use of spread spectrum began in the 1980s. Bluetooth, most cell phones, and the 802.11b version of Wi-Fi each use various forms of spread spectrum.

Modern GPS receivers.

Systems that need reliability, or that share their frequency with other services, may use "coded orthogonal frequency-division multiplexing" or COFDM. COFDM breaks a digital signal into as many as several hundred slower subchannels. The digital signal is often sent as QAM on the subchannels. Modern COFDM systems use a small computer to make and decode the signal with digital signal processing, which is more flexible and far less expensive than older systems that implemented separate electronic channels.

COFDM resists fading and ghosting because the narrow-channel QAM signals can be sent slowly. An adaptive system, or one that sends error-correction codes can also resist interference, because most interference can affect only a few of the QAM channels. COFDM is used for Wi-Fi, some cell phones, Digital Radio Mondiale, Eureka 147, and many other local area network, digital TV and radio standards.

Heating

Radio-frequency energy generated for heating of objects is generally not intended to radiate outside of the generating equipment, to prevent interference with other radio signals. Microwave ovens use intense radio waves to heat food. Diathermy equipment is used in surgery for sealing of blood vessels. Induction furnaces are used for melting metal for casting, and induction hobs for cooking.

Amateur radio service

Amateur radio, also known as "ham radio", is a hobby in which enthusiasts are licensed to communicate on a number of bands in the radio frequency spectrum non-commercially and for their own experiments. They may also provide emergency and service assistance in exceptional circumstances. This contribution has been very beneficial in saving lives in many instances.[25]

Amateur radio station with multiple receivers and transceivers

Radio amateurs use a variety of modes, including efficient ones like Morse code and experimental ones like Low-Frequency Experimental Radio. Several forms of radio were pioneered by radio amateurs and later became commercially important, including FM, single-sideband (SSB), AM, digital packet radio and satellite repeaters. Some amateur frequencies may be disrupted illegally by power-line internet service.

Unlicensed radio services

Unlicensed, government-authorized personal radio services such as Citizens' band radio in Australia, most of the Americas, and Europe, and Family Radio Service and Multi-Use Radio Service in North America exist to provide simple, usually short range communication for individuals and small groups, without the overhead of licensing. Similar services exist in other parts of the world. These radio services involve the use of handheld units.

Wi-Fi also operates in unlicensed radio bands and is very widely used to network computers.

Free radio stations, sometimes called pirate radio or "clandestine" stations, are unauthorized, unlicensed, illegal broadcasting stations. These are often low power transmitters operated on sporadic schedules by hobbyists, community activists, or political and cultural dissidents. Some pirate stations operating offshore in parts of Europe and the United Kingdom more closely resembled legal stations, maintaining regular schedules, using high power, and selling commercial advertising time.[26][27]

Radio control (RC)

Radio remote controls use radio waves to transmit control data to a remote object as in some early forms of guided missile, some early TV remotes and a range of model boats, cars and airplanes. Large industrial remote-controlled equipment such as cranes and switching locomotives now usually use digital radio techniques to ensure safety and reliability.

In Madison Square Garden, at the Electrical Exhibition of 1898, Nikola Tesla successfully demonstrated a radio-controlled boat.[28] He was awarded U.S. patent No. 613,809 for a "Method of and Apparatus for Controlling Mechanism of Moving Vessels or Vehicles."[29]

See also

- Outline of radio

Notes

1. While the term 'radio-' is actually the combining form of radiant (e.g., radioactive, radiotherapy), the process that was originally called radiotelegraphy has become so common that it is nearly always called just 'radio' and the associated electromagnetic waves are called *radio waves*. In practice, radio frequencies are significantly below that of visible light from about 3 kHz to 300 GHz.[1]

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FAO FOOD AND NUTRITION PAPER 14/16

manual of food quality control
16. radionuclides in food

Edmond J. Baratta
International Expert, Radioactivity
Food and Drug Administration
Winchester, Massachusetts, USA

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREFACE

The world's attitude toward radionuclide contamination of foods suddenly changed on April 26, 1986. On that date the accident and fire at the nuclear reactor at the Chernobyl power station released a considerable amount of radioactive substances into the atmosphere. Radioactive particles were transported over Europe and Asia by air currents and eventually settled to earth to begin a new life as environmental contaminants. Widespread monitoring of radionuclide contamination of foods had been commonplace in the 1950's and 60's. However, since the cessation of above-ground testing of nuclear weapons in the 1960's there had been little public concern and consequently reduced monitoring of radionuclides in foods.

As a result of the widespread fallout of radionuclides from Chernobyl, nations began intensive sampling and analysis efforts to determine the level and extent of the contamination. Food sampling and regular monitoring of radioactivity levels were activated by all the countries affected by the fallout and by countries importing food from affected areas.

In December 1986 FAO convened an Expert Consultation in Rome to discuss and recommend limits for radionuclide contamination of foods. As the result of this consultation and further elaboration within the Codex Alimentarius Commission, Guideline Levels for Radionuclides in Foods Following Accidental Nuclear Contamination for Use in International Trade were established. These Guidelines are published in Codex Alimentarius, Volume 1, FAO and WHO, 1992, ISBN 92-5-103120-7.

Although years have passed since the Chernobyl accident, nations continue to carry out monitoring activities for radionuclides. In an effort to provide assistance and standardization to public and private radionuclide monitoring systems, the Food and Agriculture Organization of the United Nations has prepared this comprehensive manual which contains background information along with sampling and analysis methodology for determining radionuclides in foods.

FAO wishes to acknowledge the efforts of Edmond J. Baratta, Winchester Engineering and Analytical Center, Food and Drug Administration (FDA), Winchester, MA, USA, who prepared the text for this manual. The contribution of other FDA staff including the dedicated assistance of Ms. Donna **A.** Cuneo, who typed the many early and final drafts of this manual. The generous support of James W. Fitzgerald, Director of the Winchester Engineering and Analytical Center, is gratefully acknowledged.

This publication is available to persons and organizations. Comments and suggestions for possible further editions of this publication should be send to:

The Chief
Food Quality and Standards Service
Food and Nutrition Division
Food and Agriculture Organization of the United Nations
00100 Rome, Italy

SPECIAL NOTE

The Laboratory procedures described in this Manual are designed to be carried out by properly trained personnel in a suitably equipped laboratory. In common with many such procedures, they may involve hazardous materials.

For the correct and safe execution of these procedures, it is essential that laboratory personnel follow standard safety precautions.

While the greatest care has been exercised in the preparation of this information, FAO expressly disclaims any liability to users of these procedures for consequential damages of any kind arising out of or connected with their use.

The analytical procedures detailed herein are also not to be regarded as official because of their inclusion in this Manual. They are simply procedures which have been found to be accurate and reproducible in a variety of laboratories.

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RADIONUCLIDES IN FOOD

I. INTRODUCTION TO RADIOACTIVITY & RADIATION

ELEMENTARY NUCLEAR PHYSICS

1. INTRODUCTION

The modern epoch in physics may be said to have begun with the discovery of X-rays by Roentgen in 1895. This was followed by the discovery of radioactivity by Becquerel in 1896. These two discoveries led to other development in the understanding of nuclear structure, reactions, and the various types of particles involved. All these investigations finally culminated in the discovery of "Fission" which resulted in the development of atomic energy, both in peace and war. We shall review here briefly our knowledge of nuclear radiation and atomic structure.

2. ATOMIC STRUCTURE

All matter is made up of elements. The smallest part of an element is the atom. The size of a hydrogen atom, which is the smallest, has a weight of about 1.67×10^{-24} grams. In comparison, a uranium atom would weigh about 4.0×10^{-22} grams. The atom itself consists of a central nucleus surrounded by a cloud of electrons ranging in number, from one for hydrogen to ninety-two for uranium. These electrons are said to move in orbits around the central nucleus. The size of the nucleus is considerably smaller than that of the atom, the size of the hydrogen nucleus being 1.4×10^{-13} cm. The nucleus itself consists of protons which carry a unit positive charge 'e' (e= 1.6×10^{-17} coulombs) and neutrons which carry no charge. The mass of the neutron is only slightly greater than that of the proton. The electron carries a unit negative charge and has a mass approximately 1/1840 of that of a proton or a neutron. Hence most of the mass of the atom is carried in the nucleus. *It* is also known that most of the energy of the atom is also stored in the nucleus.

3. ELEMENTS AND ISOTOPES

All the elements of the periodic table are made up of protons and neutrons in the nucleus and electrons orbiting around it. The total charge carried by the nucleus is equal to the number of protons in it. This number is called the 'atomic number' and is characteristic of each element. Since the atom as a whole is electrically neutral, there will be as many electrons around the nucleus as there are protons in it. The number of protons plus neutrons gives the 'mass number' of the atom. Thus the mass number of carbon, ${}_6C^{12}$, is 12 and the atomic number is 6. If two nuclei have the same number of protons in the nucleus, but different number of neutrons, they are called isotopes. For example, ${}_4Be^7$ and ${}_4Be^{10}$ are isotopes of beryllium having the same number of protons and the number of neutrons being **3** and 6 respectively. Isotopes have the same chemical properties which depend on the number of electrons in the orbits around the nucleus, but different physical properties which depend on the central nucleus.

4. RADIOACTIVITY

As mentioned before, it was noted early in this century that certain substances are radioactive, that is, they spontaneously emit different types of radiations and transform into other elements depending on the emitted radiations. This process, which was first noted in the heavy elements like uranium, radium etc., was found to obey exponential decay law, that is, the amount of radiation emitted decreases with time in such a manner that the period for reduction to half the initial value is constant. This period is called the "half life" and is characteristic of the concerned isotope. The various types of radiations emitted in radioactive decay are described in subsequent sections.

5. ALPHA RADIATION

Alpha radiation is emitted generally by the heavy elements like uranium, thorium, radium etc. They are identical with the nucleus of the helium atom, carrying two protons and two neutrons. Hence their mass is about four times that of the nucleus of the hydrogen atom (one proton only) and the charge is $+2e$, that is, twice that of the hydrogen nucleus. The alpha radiation is usually highly energetic, having energies in the range of 4 to 9 Million electron volts. (1 MeV = 1.602×10^{-6} ergs). In view of its heavy mass and charge, alpha particles are highly ionizing and are easily absorbed. Hence they can travel only a few centimeters or so in air.

They cannot penetrate beyond the skin and are harmful only when they enter the body organs either by inhalation or by ingestion of contaminated food.

All the alpha radiations emitted from a nucleus will have the same energy and in some cases, two or three discrete energy values. The alpha radiations have a fixed penetration range in the various materials which is characteristic of the material and alpha energy.

Beyond this range, the alpha radiation cannot penetrate. On alpha emission, the element will transform into another element of atomic number *two* less and the mass number four less than those of the original element.

6. BETA RADIATION

Beta particles are particles identical to electrons. They are emitted in radioactive decay with various energies ranging from nearly zero to a maximum energy characteristic of the decaying radioactive isotope. Hence their energy spectrum differs from that of alpha rays which have discrete energies. The beta rays can travel a few feet in air but cannot penetrate much beyond the depth of the skin of a person. Hence, like the alpha rays, they are harmful only when they are inside the body. From outside they can cause only skin bums. Beta rays are absorbed in an approximately exponential manner, that is, they have a characteristic thickness in the particular material which will reduce the radiation intensity to half the initial value. This value depends on the atomic number of the material, its density and the maximum energy of the beta particles.

Although theoretically the intensity of the beta radiation cannot be reduced to zero due to the exponential absorption, it can be reduced to negligibly small values by using several "half value thicknesses" of the shielding material.

In emitting beta rays, the radioactive material transforms into another element of atomic number one higher than the original element as the nucleus loses one negative charge (or gains one positive charge). The mass number, however, remains the same as the number of nucleons in the nucleus remains the same. Some nuclei emit a positively charged beta particle, "positron". In such cases, the element transforms into an element with atomic number one lower than the original one.

7. GAMMA RADIATION

Gamma radiation is electromagnetic radiation similar to light but of much higher energy. The wavelength of gamma rays is much shorter than that of visible light. The energy of the electromagnetic radiation or photon is given as $W = hy$, where h is the Planck's constant, y (nu) is the frequency, equal to $c\lambda^{-1}$, c being the velocity of light and λ (lambda) the wave length of the radiation. Gamma rays are emitted in radioactive decay along with alpha or beta radiations. Like alpha rays, gamma rays have discrete energies. They are absorbed exponentially in materials, but in view of their great penetrating power, only thick blocks of concrete, lead or other high density materials can reduce their intensity to small value. The gamma rays can deliver a whole body dose either from outside or inside the body due to their high penetrating power.

The element does not change due to gamma radiation, but will change depending on the accompanying alpha or beta radiation.

8. NUCLEAR REACTIONS

In addition to radioactivity, the nucleus of the atom can undergo changes and emit radiations as a result of various types of "nuclear reactions". In these reactions, the nucleus is bombarded by particles like alpha rays, protons, neutrons etc., which are generated (and accelerated) in accelerators, reactors etc. The nucleus on bombardment, emits other particles like protons, neutrons, deuterons and changes accordingly. The emitted particles like protons, deuterons etc., carrying charge have fixed ranges in materials. Neutrons like the gamma rays, are exponentially absorbed and are hazardous in view of their high penetrating power. In many of the nuclear reactions, the energy put in for the reaction is more than the energy got out. That is, they are 'endoergic' and not 'exoergic'.

9. NUCLEAR FISSION

One nuclear reaction of great interest is the nuclear fission which takes place in heavy nuclei like uranium, plutonium etc. When a neutron enters the nucleus of an atom of one of the above elements, the atom splits into two nearly equal parts releasing two or more neutrons and about 200 MeV of energy. These neutrons can strike other nuclei and cause further fissions and thus a chain reaction can be built up under certain conditions.

Although many isotopes of heavy elements can fission, only a few like U-235, Pu-239, **U-233** can sustain a fission chain reaction from which energy can be usefully tapped. (This **is** because of the possibility of fission in these isotopes from the neutrons released from their own fission. Other isotopes would require neutrons of higher energies than that of the neutrons produced in their own fission.)

If the fission reaction is controlled to maintain a steady level of fissions, we have the nuclear reactors from which energy can be usefully tapped. In nuclear weapons, however, the chain reaction is allowed to build up at a very rapid rate to create an explosion.

In the fission reaction, the uranium atom splits into two or more parts and the products formed are elements of much smaller atomic number. These fission products are highly radioactive, emitting beta and gamma rays and are very hazardous. They have half lives ranging to several years, and, depending on their chemical properties, they can enter the human body. Thus these fission products can give internal as well as external dose.

10. NUCLEAR FUSION

In nuclear fusion, light nuclei like those of the isotopes of hydrogen, fuse together to form bigger nuclei. These reactions, like fission, are exoergic and release enormous amounts of energy. **A** fusion process can be realized by bombarding light element by cyclotrons or other high energy accelerators, In these cases, only an extremely small fraction of the bombarding particles is utilized for fusion and hence the energy obtained is extremely small compared to the energy required for accelerating the bombarding particles. However, at extremely high temperatures, it is possible to get significant amounts of energy. The best illustration of the thermonuclear process is the formation of helium from hydrogen in the stars. Another example is the hydrogen bomb, in which using the high temperatures of the nuclear fission reaction as the trigger, a fusion chain reaction is built up to release enormous amounts of energy. However, controlled release of energy by fusion', as in fission reactors, has not yet been achieved.

A. NATURAL RADIOACTIVITY

INTRODUCTION

Man has always been exposed to low-level ionizing radiation which is present in his environment. This radiation, referred'to as "natural background", is not directly caused or produced by man, but due rather to natural causes or sources.

Because the exposure which man has received from background radiation causes a few discernible effects, a knowledge of the sources of this radiation and the dose which man receives from it would be helpful in establishing, for man, levels of exposure which are not expected to have significantly harmful effects.

The sources of natural background can be separated into the two following categories:

a) Those which are found in their original or natural environment.

b) Those which are found not in their natural environment but rather have been rearranged or moved by man to an artificial environment.

a) NATURAL SOURCES OF EXPOSURE

Sources in their Natural Environment

1. Cosmic radiation

Primary cosmic rays consist of high energy protons, helium nuclei, and heavy ions, which originate outside of the earth's atmosphere, and are present throughout the universe. A small fraction of them strikes the earth's atmosphere and produces secondary radiations which give a continuous radiation dose to the earth's inhabitants. These "secondaries" consist of photons, electrons, mesons and neutrons.

The radiation intensity vanes with latitude. It is about 10% lower at the geomagnetic equator than at higher latitudes of 45" or greater. Of more importance, however, it the variation of intensity with altitude. The dose at 40,000 ft. is about 100 times as great as it is at sea level. Cosmic radiation constitutes approximately 25% of the total background dosage to the population.

2. Terrestrial radiation

Several of the elements in the earth's crust are radioactive. Those which contribute most to natural background are C^{14}, K^{40}, and members of the U^{238} and Th^{232} series. On the average, one square mile of soil one foot deep contains about one ton of K^{40}, three tons of U^{238}, and six tons of Th^{232}. Surface rock contains about twice as much uranium and thorium as does the soil. Uranium is found in chemical combination in deposits of rocks and minerals in Colorado, New Mexico, Utah and other Western states; also to some extent in Tennessee and Florida. Thorium is found in large mineral bearing deposits in the Rocky Mountain States and the Carolinas. Potassium40 is found primarily in granite and alum shales with lesser amounts in soil and sandstone.

Water and air also contain C^{14}, K"", Th^{232} and U^{238} and their daughter products, though to a much lesser extent. The levels of radioactivity in the air vary considerably with location, weather, and atmospheric conditions.

b) SOURCES IN AN ARTIFICIAL ENVIRONMENT

Man disturbs some natural sources of radioactivity by removing them from their natural environment and transporting them to an artificial one. By so doing, he tends to concentrate them in some places and to diffuse them in other places.

1. Uranium mining and milling operations

Because radioactive wastes are discharged into the air and water from mining operations, these operations are considered to add to the background exposure of the population. Here, as in terrestrial radiation, the food, water, and air which man consumes contain radiocontaminants. Though there is an external exposure hazard to the mining and milling workers, the dose which the general population receives is primarily an internal one.

2. Building materials

Many of the materials which man uses for his buildings contain U^{238} and Th^{232} from the earth's crust. The uranium and thorium constitute external sources of exposure while their daughter products, beginning with the gases radon and thoron respectively, provide internal sources of exposure through the air.

The intensity of radiation which man receives from building materials depends upon the type of structure in which he dwells. The dose rates from wood, brick, and concrete are in ratios of about 1:2:3.

c) OVERALL DOSES FROM NATURAL BACKGROUND

Assuming that a person spends two-thirds of his time indoors and that the distribution of buildings in which he spends his time is divided equally, the gonadal dose rate which he would receive from external exposure ranges from about 0.55-1.05 mGy/year. This figure includes the dose rate from cosmic and terrestrial radiation as well as that from building materials. The total internal gonadal dose rate from mining and milling, terrestrial, and building material sources is about 0.23 mGy/year.

A breakdown of the doses received from the various natural background sources is as follows:

SOURCE OF RADIATION DOSE TO GONADS (mGy/year)	
External	
Cosmic Rays at Sea Level	0.30-0.70
Terrestrial plus Buildings	0.25-0.75
Radon and Thoron in Air	0.02
Internal	
Potassium - K^{40}	0.20
Carbon - C^{14}	0.01
Radon, Thoron and Daughter Products	0.02
Total Background Dose	0.80-1.70 mGy/year

It should be remembered that the dose rates as listed above are only average figures giving typical dose rates under "normal" circumstances. The background dose to any person or section of the country can vary from these figures by a factor of 2 or 3.

B. ARTIFICIAL RADIOACTIVITY

NUCLEAR DETONATIONS AND FALLOUT

INTRODUCTION

The testing of various nuclear and thermonuclear devices, whether dropped from an airplane, in towers, barges, or slightly below the earth's surface, thrusts radioactive fission products and earth and water mixtures into the stratosphere (the latter occurs principally as a result of larger explosions). These particulate mixtures also include unfissioned and unfused device materials, casing and structural test materials (which may be activated by neutrons from the detonation), and remains of plant and animal life (which also may undergo neutron activation).

Depending upon the altitude and physical-chemical nature of these particles, they fall back to earth, under the influence of gravity and meteorological conditions, during a span of seconds to decades. When they make contact with the terrestrial and aquatic environment, these materials are more properly call fallout. The terms rainout and snowout may also be used as sub-categories of "fallout".

Adsorptive and absorptive transfers of fall-out into the biosphere are possible causes for concern by mankind. The ultimate deposition of fallout radionuclides in various human "critical organs" may tend to increase the incidence of various neoplasms, shorten lifespan, and accelerate normal aging processes.

a) NUCLEAR AND THERMONUCLEAR DEVICES WHICH CAN CAUSE FALLOUT

Three basic types of devices have been tested for warfare applications as bombs, rocket warheads, and artillery shells. Some of these may be modified for usage in clearing waterway channels, producing heat and radionuclides in underground mines, and other possible peace time applications.

1. Fission Device (also called atomic, or nuclear weapon)

This device utilizes only fissionable material such as uranium-235 or plutonium-239. The first one was detonated on a tower at Trinity Site, New Mexico on July 16, 1945. A blast equivalence of about 20 kilotons (KT) of trinitrotoluene (TNT) is common for such a weapon. Both gun-barrel and spherical assemblies have proven successful. The devices may be made small enough to fit into an artillery or bazooka shell.

2. Fission-Fusion Device (also called hydrogen or thermonuclear weapon)

This weapon is basically a fission device which is surrounded by the heavy isotopes of hydrogen: deuterium and tritium. The fission core releases tremendous quantities of heat and neutrons which initiate fusion reactions in the hydrogenous shell. Fusion events in turn release enormous quantities of energy and very high speed neutrons. The first hydrogen bomb was detonated by the United States in the spring of 1952.

3. Fission-Fusion-Fission Device (also called superweapon)

This device consists of a hydrogen bomb surrounded by a casing of relatively inexpensive natural uranium. Fast neutrons from the fusion are capable of fissioning the uranium, and a nominal weapon of this design may release the equivalent of 20-40 megatons(MT) of TNT. The first super bomb was detonated by the U.S. on March 1, 1954, in the Pacific Proving Grounds. Difficulties of delivery constitute essentially the only limitation upon the possible size of these weapons.

b) RADIOACTIVITY PRODUCED AND DISPERSED BY NUCLEAR DETONATIONS

Three types of radioactive material are produced and dispersed by nuclear detonations. These are: unfissioned weapon materials, mixed fission products, and materials with induced activity.

1. Unfissioned Materials

For the earlier designs, detonation efficiencies were less than 1%. This means that quantities of unfissioned uranium and plutonium may be detected near the site of detonation. The extremely toxic radio-and chemical properties of these materials indicates that their ingestion and inhalation should be avoided. In general, however, unfissioned materials will not appear in significant amounts beyond the distance at which blast and radiation effects are severe.

2. Mixed Fission Products

Millions of curies of mixed fission products are produced for each kiloton of TNT blast equivalence of a nuclear device. The primary fission fragments consist of about 60 various radionuclides and these eventually decay to form several hundred secondary fission products. This mixture of fission products, as produced by a 20 kiloton weapon, decays at a progressively slower rate with time as indicated in Table I.

Table I[27] - Total Gamma Activity of Fission Products From a 20-Kiloton Device

Time After Detonations	Activity (Megacuries)
1 minute	820.000
1 hour	6,000
1 day	133
1 week	13
1 month	2.6
1 year	0.11
10 years	0.008
100 years	0.0006

One fission product of biological importance is strontium-90. It has been estimated that all detonations by the United States, the United Kingdom, and U.S.S.R. until the latter part of 1958 produced approximately 7,000,000 curies of this radionuclide.[28]

3) Induced Radioactivity

The species and quantities of radionuclides formed by neutron bombardment depend largely upon the environment of the detonation site. Both short-and long-lived materials are formed, primarily by (n, γ) and (n, p) reactions, and their decay pattern is similar to that for fission products. Typical radionuclides **formed** in this manner during nuclear detonations are carbon-14, sodium-24, silicon-31, aluminum-28, chlorine-38, and cobalt-60, zinc-65, manganese-54, and scandium-46.

It has been estimated that, **for** air bursts, 20,000 curies of carbon-14 are produced per megaton of weapon yield. Surface detonations give only about one-half this amount of carbon-14 since not as much atmospheric nitrogen is available for the reaction. The production reaction is as follows:[(2)]

$$_{7}N^{14} + {}_{0}n^{1} \rightarrow {}_{6}C^{14} + {}_{1}H^{1}$$

Excluding the 1960 nuclear bomb tests of France, detonations to date have produced about 3,000,000 curies of carbon-14 which are now distributed in the stratosphere, troposphere, ocean, and terrestrial biosphere.

It has been estimated that there are 170 megacuries of cosmic ray-produced carbon-14 in the above mentioned reservoirs before bomb testing began. Total C^{14} global activity is probably slightly in excess of 174 megacuries.

During the 1958 U.S. Pacific bomb tests, tungsten was intentionally incorporated into detonation devices so that radioactive tungsten-I85 would be produced by an (n, γ) reaction. This radionuclide has provided valuable information on the rate of fallout and has been a tool for studying weather phenomena.")

c) DETONATION FIREBALL AND THE PHYSICAL NATURE OF FALLOUT

After a delay of a few millionths of a second from the time of initial weapon detonation, a luminous gaseous sphere, called a fireball, is formed in the extremely hot atmosphere. Depending upon weapon design and size, the maximum size of the fireball may vary from 900 feet to over three miles in diameter. Luminosity of the fireball usually does not vary greatly with the energy equivalence of the bomb.

Vaporized bomb materials, water droplets, and debris condense to form the "atomic cloud" as the fireball increases in size and cools. This cloud is red or reddish brown when first formed because of the heat catalyzed production of nitrogen dioxide, nitrous acid, and other nitrogen compounds from atmospheric gases and water vapor. Eventually the cloud changes to white due to the water droplets present in it. In surface or near surface, strong updraft called "afterwinds", sucks dirt and debris up from the ground into the radioactive cloud. As the upward thrust of debris slowly subsides, gravity begins to retrieve particulates to the earth's surface. This causes a lengthening and widening of the columnar cloud, and eventually the debris disperses widely due to the jet stream, meteorological conditions, and the continued influence of gravity.

1. Types of Fallout Particles

Fallout particles may be grouped as follows:

a) Plated-type fallout

Vaporized bomb products and induced activities which condense out as a thin shell coating on elevated particles of earth and debris form this type of fallout. Much fallout is of this nature especially if the detonation takes place at a site relatively devoid of silicate sand.

b) Fused-type fallout

Bomb materials may undergo a thermal fusion with silicate to form minute melted, glassy "beads" which contain air bubbles and mineral grains. These may be transparent to opaque and pale green or yellow to brown or black in color. Radioactivity is distributed irregularly throughout these spherical or irregular forms.

c) Droplet-type fallout

If a device is detonated near a body of water, large quantities of water may be vaporized in the fireball. As the vapor condenses out of the cooling atomic cloud, fission products and earth debris may be suspended in water droplets and then fall back to earth as precipitation.

2. Categories of Fallout

Fallout from near surface bursts may also be categorized according to the elapsed time between the time of detonation and complete descent to earth.

a) First fallout - also called Local fallout

About 80% of the radioactive particulates produced by a surface detonation is deposited within a few hours at a distance no further than a few hundred miles from the burst point. Particles which have a diameter of 340 microns, 250 microns, and 150 microns may fall from 80,000 feet in about 45 minutes, 90 minutes and 4 hours respectively.[4] It is the first fallout which constitutes the acute radiological hazard. Detonation of a

single superweapon may contaminate an area of 5,000 square miles or greater to lethal levels for external beta and gamma exposures.

b) Second fallout - also called Tropospheric fallout

Fallout particles of smaller sizes and masses are deposited in the lower atmospheric layers, and are gradually brought down in a matter of one to two months by ordinary weather phenomena.

These tropospheric particulates may travel completely around the world in a shell-like fashion but they usually stay in a rather narrow radioactive band which has the general latitude of the detonation site.

c) Delayed fallout - also called Stratospheric fallout

This type of fallout is created by surface detonations of weapons **of** megaton size or greater which propel radioactive particulates of sub-micron diameters to heights of 16 miles or more. The estimated **mean** residence time of stratospheric fallout is now estimated to be 1 to **3** years. 1958 Russian bomb tests in the Arctic resulted in a stratospheric residence time of about one year.

d) DISTRIBUTION OF STRATOSPHERIC FALLOUT

Theories as to the mechanism of stratospheric fallout have been established by Dr. Willard Libby and Dr. Lester Machta. The Libby theory proposed that there is a rapid stratospheric mixing with uniform leakage back into the troposphere where fallout is deposited according to meteorological patterns. Meanwhile, Machta's fallout model has produced slow stratospheric mixing with unequal leakage back from the stratosphere as a result of tropospheric-stratospheric air mixing in the vicinity of the jet streams. Available data on surface deposition levels indicate that the Machta preferential stratospheric fallout theory is the more satisfactory explanation.

C. RADIOACTIVITY IN THE ENVIRONMENT

a) Metabolism of radiation in Man and Animals

INTRODUCTION

Many radionuclides are produced by man's use of nuclear energy. Of these, only a limited number are important as sources of internal radiation to the human body. These specific radiocontaminants can reach man by way of the terrestrial food chain. This discussion has a two-fold purpose; namely 1) to describe the characteristics that determine the environmental significance of a radionuclide and 2) to present a detailed description of the food chain behavior of several of these radionuclides of environmental significance.

CHARACTERISTICS OF RADIONUCLIDES OF ENVIRONMENTAL IMPORTANCE

In order for a radionuclide to be a significant environmental contaminant it must possess certain characteristics. These characteristics must be such that they allow the nuclide to move from its point of origin, through the food chain, and still remain a possible health hazard to man. In general the radionuclides of environmental significance are those which are readily taken up by plants and animals that are used by man. They are either isotopes of elements important in metabolism or closely similar to them. For example, the alkali metal, cesium 137 is metabolically similar to potassium. It is readily absorbed and circulates freely throughout the body irradiating all tissues. The fission product iodine 131, an isotope of the essential element iodine, concentrates in the thyroid gland. Strontium 90 and radium 226 are alkaline earths like calcium and follow it to the bone. Carbon 14 and hydrogen 3, isotopes of two very essential elements, are distributed throughout all living tissues. Because the metabolic processes of all plants and animals are similar, radionuclides which concentrate in animal tissues are usually those which pass most readily through the food chain.

A. Specific Characteristics

The relative importance of individual radionuclides depends on many factors. Among the most important factors, the following can be cited:

1. Fission yield and half-life

Radionuclides with relatively high fission-yields and moderate to long half-lives will be the most important in food chain transference. Since reduction or biological discrimination generally occurs at each step in the food chain, the radionuclides produced in the greatest abundances will have the best opportunity to reach the human population in the greatest quantity. Of necessity, these radionuclides will have to have a sufficiently long half-life to survive through the food chain in significant amounts.

2. Rate of entry and survival through the food chain

Only those radionuclides which enter the food chain at a significant rate and quantity will be of importance to man. These radionuclides must also possess characteristics that allow for their continued movement through the chain. For example, significant quantities of cesium 137 are rendered unavailable to plants in many soils due to entrapment in the lattice structure of some clays.

3. Uptake-gastrointestinal absorption by man and animals

Radionuclides which undergo significant gastrointestinal absorption by man and animals are those of greatest concern in food chain transference. These radiocontaminants are also readily transferred to animal products such as milk and meat which are used as food by man.

4. Amount deposited and retained in the critical organ

The most hazardous irradiation situation results from radionuclides that are concentrated by essential organs of the body in relatively large quantities and are retained in these organs for long periods of time. The

deposition of strontium 90, a bone-seeker of long biological half-live, is an example of such a situation.

5. Type and energy of radiation emitted

The magnitude of the hazard from radionuclide deposition in the body is dependent on the type and energy of radiation. For the deposition of the same activity of a radionuclide in a given organ the hazard from the type of radiation would be alpha > beta > gamma. The hazard from the given emitter would also increase with increasing energy of emission.

B. Characteristics Based on Physical, Chemical, and Biological Properties

An arbitrary separation of the above listed characteristics into physical and biochemical categories can be made for discussion purposes.

1. Physical Properties

The fission process gives rise to a mixture of radionuclides with a wide range of half-lives. Each of these nuclides are produced in a certain proportion (abundance) which is dependent on the fissioning material and the energy of the fissioning neutrons. The abundances of the various nuclides produced have been found to be approximately the same for the different fissionable materials. Table 1 presents the most important fission products, based on fission abundance and half-life, which are of immediate concern in environmental contamination.

Table 1.[1,2] FISSION PRODUCTS IMPORTANT DUE TO FISSION ABUNDANCE AND HALF-LIFE'

(Atom Yield > 0.03 per cent; half-life > 10 hrs)

Chemical character	Isotope	Fission abundance (%)	Half-life
Halogens	^{131}I, ^{133}I, ^{135}I	3.1, 6.3, 6.0	8.1d, 22h, 6.7h
Oxygenated anions	^{132}Te-^{132}I	4.0	78h, 2.4h
Alkali metals	^{132}Cs-^{137}Ba	6.2	37y, 2.6m
Alkaline earths	^{89}Sr, ^{90}Sr-^{90}Y ^{140}Ba-^{140}La	4.6, 5.1	51d, 26y, 61h 12.8d, 40h
Rare earths	^{91}Y, ^{95}Zr-^{95}Nb ^{141}Ce, ^{144}Ce-^{144}Pr ^{143}Pr, ^{147}Nd, ^{147}Pm	-**, 6.3 6.0, 5.0 -**, 2.9, 2.7	57d, 65d, 35d 33d, 290d, 17.5m 13.7d, 11.6d, 3.7y
Noble metals	^{103}Rh, ^{106}Ru-^{106}Rh	3.4, 0.5	40d, 1.0y, 30s

'Fission abundance values are approximately the same for U^{233}, U^{235} and Pu^{239}
**Data lacking on abundance

These nuclides are characterized by a high fission abundance and a moderate too long half-life when considering parent-daughter relations. Many of these radioisotopes can subsequently be eliminated from food chain consideration because 1) they do not possess the necessary bio-chemical characteristics for efficient transfer through the food chain and 2) the half-lives are not significantly long enough to present a long-term health hazard. The more important nuclides will be those which are formed in high abundances, with a moderate to long half-lives and which are isotopes of, or chemically similar to essential elements.

2. Biochemical properties

The chemical and biological properties of the various radionuclides greatly affect their ability to move through the food chain. Table 2 presents the fission-products of biological importance **grouped** according to similar chemical characteristics, and shows the relative uptake by the total body and critical organ from the gastrointestinal tract.

From Table 2 it is seen that the important fission products are **those** which comprise the rare earths, the zirconium-niobium isotopes, the noble metals particularly ruthenium and rhodium, the isotopes of iodine, the alkali metal cesium and the alkaline earths, especially strontium and barium. Some indication of their relative importance biologically can be seen by examining the fractional uptake from the gut of these various groups of isotopes. It will be seen that although the rare earths constitute an important group of fission products, they are of little concern in the food chain due to their limited gastrointestinal absorption and concentration in the critical organ by man and animals. A similar situation exists for the isotopes of zirconium, niobium and the noble metals. This leaves the alkaline earths, strontium and barium, the alkali metal cesium and the iodine isotopes **as** nuclides of primary importance. Depending on the particular situation, these nuclides will assume a greater or lesser degree of importance in the food chain. Additional biological factors which aid in accessing the potential health hazard from the particular nuclide include 1) the quantity deposited and the residence time **of** the nuclide in the critical organ, and 2) the essentialness or indispensability of the critical organ to the .organism.

Table 2.[1,2] FISSION-PRODUCTS OF BIOLOGICAL, IMPORTANCE*

Chemical character	**Isotopes important on account of abundance & half-life body**	**Gastrointestinal uptake From GI tract to: Total**	**Critical organ**	
Halogens	^{131}I, ^{133}I, ^{135}I	1.0	**0.3**	Thyroid
Oxygenated anions	^{132}Te-^{132}I	0.25		
Alkali metals	^{132}Cs-^{137}Ba	1.0	0.4	Muscle
Alkaline earths	^{89}Sr, ^{90}Sr-^{90}Y	0.3	0.2	Bone
	^{140}Ba-^{140}La	0.05	0.04	Bone
Rare earths	^{91}Y, ^{95}Zr-^{95}Nb ^{141}Ce, ^{144}Ce-^{144}Pr ^{143}Pr, ^{147}Nd, ^{147}Pm	10^{-4}	$3x10^{-5}$	Bone, liver
Noble metals	^{103}Rh, ^{106}Ru-^{106}Rh	0.03	$4x10^{-3}$	Bone, liver

*Isotope pairs are classed according to the chemical and biological characteristics of the parent

SPECIFIC RADIONUCLIDES

The fission products which enter the environment from fallout or from various nuclear facilities include more than 30 radioactive nuclides. From the above discussion it is evident that all **of** these radionuclides are not equally harmful to the human population. Intensive study of fission product behavior in the food chain has revealed that strontium 89, strontium 90, barium 140, iodine 131 and cesium 137 are the radionuclides of major concern. Strontium 90 and cesium 137 are radionuclides of long physical half-life and are considered long term hazards. Strontium 89, barium 140 and iodine 131 due to their shorter physical half-lives are only short term hazards. This discussion will deal primarily with the environmental behavior of strontium 90, iodine 131 and cesium 137. Other radionuclides of concern (e.g., barium 140, strontium 89, radium 226, carbon **14,** etc.) will only receive brief consideration.

A. Fission-Product Alkaline Earth Metals

The radionuclides of major importance in the alkaline earth series are strontium 89, strontium 90 and barium **140.** Their half-life characteristics are tabulated in Table 3. Like calcium, these alkaline earth radionuclides are deposited in large amounts in the skeleton. All three radionuclides are produced in relatively large abundance during nuclear fission (see Table **1)** and assume a greater or lesser degree of importance in food chain contamination depending on the time period considered after the contaminating event. Strontium 89 and strontium 90 behave the same chemically so that the food chain behavior of one applies to the other as well.

The main terrestrial pathways for radio-strontium (i.e., strontium 89 and strontium 90) are shown in Figure 1.

The relative importance of one pathway over that of another with respect to population body burdens does not only depend on the particular isotope of radiostrontium but also on dietary characteristics of the particular population such as the type and quantity of food ingested, geographical location, degree of food processing and economic status.

As an example of the behavior of a particular radionuclide in the food chain, strontium 90's movement in the pathway atmosphere to soil to plant to animal to milk to man can be cited. **As** a given quantity of strontium 90 moves through this pathway, the various environmental components, including man, tend to discriminate or reduce the quantity which is finally available for bone deposition in man. The strontium 90 is deposited on the soil and effectively diluted with soil constituents before being assimilated by the plant. The grazing animal received the contaminant through ingestion of various vegetative forms and reduces the quantity of strontium 90 excreted into the milk by inherent discriminatory processes. The remaining strontium 90 is then available for deposition in man.

The main terrestrial pathway for barium **140** is presented in Figure 2. Because of barium **140's** short physical half-life **(12.8** days) it is generally of lesser importance as an environmental contaminant. Its occurrence in environmental media indicates the presence of relatively fresh fission products.

Table 3. Characteristics of Alkaline Earth Radionuclides[3,4]

Radionuclide	**Half-lives**		
	Physical	Biological	Effective
Strontium 89	**51** days	50 years	50 days
Strontium 90	28 years	50 years	18 years
Barium **140**	**13** days	65 days	11 days

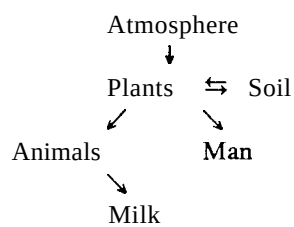

Figure 1. Main Terrestrial Pathways in the Food Chain for Radiostrontium[5]

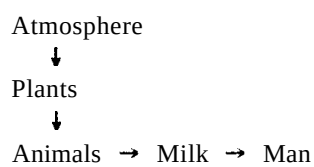

Figure 2. Main Terrestrial Pathway in the Food Chain for Barium 140[5]

Before discussing alkaline earth radionuclide behavior in the various food chain steps, a discussion of how their movement is quantitatively measured is needed in order to understand overall food chain transference. Their movement in biological systems can be considered in terms of particular radionuclide itself or in terms of comparative movement with stable calcium. The choice of measurement and mode of data expression is governed by the objective of the particular investigation. By far, the most widespread method of measuring alkaline earth radionuclide behavior is to relate it to the behavior of stable calcium. This is particularly true for radiostrontium. The method involves measuring strontium-calcium rations in the various samples (e.g., soil, milk, diet, bone, etc.) and observing the resulting changes in these ratios at various steps in the food chain. Comar, et al.[6] have defined the term "Observed Ratio" (OR) to describe the comparative behavior of strontium-calcium ratios that exist at equilibrium between the precursor and the sample (Equation 1).

$$\text{sample/precursor} = \frac{(Sr/Ca)\text{sample}}{(Sr/Ca)\text{precusor}} \qquad (1)$$

The observed ratio has been used to describe the overall discrimination that occurs between two environmental media or a number of physiological processes (e.g., the discrimination that occurs when the element pair passes from soil(precusor) to the plant(sample) or when the element pair passes from man's diet(precursor) to his bone(sample). It is actually a measure of the relative affinity of a environmental media or physiological process for strontium or calcium. For example, if the strontium-calcium ratio in one individual bone is 2 picocuries of strontium 90 per gram of calcium and the strontium-calcium ratio in the diet is 8 picocuries of strontium 90 per gram of calcium the observed ratio is 0.25 (i.e., 2 pCi per gram/8 pCi per gram). This result suggests that a discrimination exists against strontium in favor of calcium in a ratio of 1:4 in gram from diet to the bone. For many food chain transfer processes the OR has been found to be less than 1, implying that in these processes discrimination in favor of the passage of calcium occurs. Rearrangement of the observed ratio expression for the case of diet to bone yields the expression

$$= \frac{\%\ \text{Strontium 90 recention(body-diet)}}{\%\ \text{Calcium retention (body-diet)}} \qquad (2)$$

In this form the OR is a measurement of the percent strontium 90 retention divided by the percent calcium retention in going from the diet to body.

In contrast to the OR which indicates overall discrimination by one or more processes, the Discrimination Factor (DF) describes the discrimination produced by one physiological process. For example, $DF_{absorptive}$ designates the contribution of overall discrimination in the body that results from differential handling of the two elements by the absorptive process. Formulae have been developed to determine the DF's for the most important physiological discriminatory processes (gastrointestinal absorption, renal excretion, placental transfer and mammary secretion) in a fashion similar to those for observed ratios.

The relationship between the OR and DF is

$$OR = (DF,)\,(DF_2)\,(DF,)\ldots(DF_n) \qquad (3)$$

Thus the OR is the product of the total number of discrimination factors operative. When a single physiological process is involved the OR and DF are identical.

The validity and use of observed ratios in describing radiostrontium behavior in the food chain depends on many factors. Several of these deserve brief mention at this time for an initial understanding of the problem. At the domestic animal and human level of the food chain, it is well documented that calcium metabolism is under homeostatic control.[6,7] This means that variations in dietary calcium within normal physiological limits does not alter the constance of the calcium levels in blood, milk and the total body. In contrast to calcium behavior, strontium metabolism is not under homeostatic control (not regulated by the normal amounts of stable strontium) but rather appears to be regulated by the calcium level or perhaps the total alkaline earth level. Thus under normal dietary conditions the calcium level of the various body fluids and the total body content are relatively constant whereas the stable strontium level appears to be regulated by one or more of the dietary' levels of strontium, calcium or total alkaline earth. Whether just one of these factors or all three are responsible is not known. *An* important generalization from the above is that within normal dietary ranges the stable strontium to calcium ratio and the strontium 90 to calcium ratio in the body tissues or fluids will be directly related to the ratios that exists in the diet. This had led to the development of quantitative expressions such as the OR and DF for these ratios.

The practical application of OR values depend upon their constancy. It has been shown that the

discrimination occurring between food chain components can change as an interrelated function of age, diet, and time.[8,9,10,11,12] However, the OR values appear to be reasonably constant under normal dietary conditions and are consistent enough to be used for prediction purposes. This is especially helpful in the case of predicting strontium 90 bone deposition in the population since widespread dietary and skeletal burden information is limited. This is probably the greatest advantage of the OR concept - the ability to predict radiostrontium movement and concentration in food chain media that are difficult and/or economically infeasible to quantitatively assay. The use of OR is also facilitated by the fact that many aspects of calcium metabolism are well known. Of course the assumptions and limitations inherent in the use of the OR concept for prediction purposes should always be kept in mind. A few examples will illustrate the prediction value of this concept.

The OR concept may be used to integrate samples for an estimate of total Sr^{90}/Ca ratio intake. The Sr^{90}/Ca ratio intake of the dairy cow can be estimated by calculation from milk values. By dividing the Sr^{90}/Ca ratio in milk by 0.1 (a typical value for OR milk, diet for the dairy cow) would give an estimate of the Sr^{90}/Ca ratio of the cow's diet ($Sr/Ca_{(diet)} = Sr/Ca_{(milk)}/OR$). This estimation of dietary intake is surely simpler and in many cases would be more accurate than measuring total intake directly or summing up the strontium 90 and calcium contributions from feed and water. The use of the OR concept in this case assumes a constant OR value for a diet which is considered typical. These assumptions appear quite well founded.[6] On the other hand, the prediction assumes that the cow's calcium intake is uniformly labeled with strontium 90, that the animal is in equilibrium with his diet and that the strontium 90 and calcium in the milk comes primarily from that of the diet. These conditions may or may not be operative depending on the particular circumstances.[1,13,14]

A second use of the OR concept is the prediction of human bone burdens of strontium 90. The most direct approach to the problem would be to establish retention curves. Theoretically, net retention of strontium 90 in bone is expected to have a high initial value governed by the absorptive mechanism and then fall to zero as the individual approaches equilibrium conditions with the intake. Studies such as indicated in Figure 3 have shown that the net retention of stable strontium in man is zero at steady state.

It is difficult to estimate body burdens since the retention of strontium 90 is primarily a function of time of dietary intake. It is also a function of dietary history, nutrition, age, and history of past intake of strontium 90. To use this approach retention curves for varying condition of age, dietary history and nutritionwould have to be determined, and if such curves were available it would then be necessary to determine integrated life-time values of retention. Thus a specific value for strontium 90 has little meaning unless it can be related to the above factors and some unit of bone. Returning now to the OR for bone burden predictions, the strontium 90 to calcium ratio in the bone can be estimated by using the $OR_{(bone/diet)}$ for the human and an estimate of the dietary strontium 90 to calcium ratio. The $OR_{(bone/diet)}$ for the human has been estimated from animal stable strontium-calcium ratios and tracer studies. Dietary surveys have been used in estimating the strontium 90 and calcium intake. Once an estimate of the strontium 90 per gram of calcium has been established for the bone, the strontium 90 content of the skeleton can be determined from the total calcium, a value which is relatively well known. Of course a prediction of this type has a number of limitations which should be borne in mind. Especially in the case where the estimated bone burdens are going to be used in subsequent dose calculations. The OR calculation here assumes a skeleton formed entirely from a diet of a given strontium 90 to calcium ratio which is in equilibrium with the bone. With reference to the adult human population and the length of time strontium 90 has been in the environment, this is not the case since strontium 90 has not been present long enough to uniformly label the adult skeleton or attain equilibrium conditions. The use of the OR calculation for the adult population then will most probably represent the maximum local concentration in areas of newly forming or exchangeable bone at equilibrium conditions. On the other hand, children who have been exposed to a relatively constant dietary strontium 90 to calcium ratio will have skeletons that are more uniformly labeled than those of adults. They would also be expected to closer to true equilibrium conditions. However, as a result of other problems such as determining children's intake, a lesser degree of discrimination in the very young, strontium 90 contribution from the mother during the fetal period, etc., predictions of children's bone burdens will perhaps only be of a little greater accuracy than those for adults.

Another isotope pair has been considered in describing strontium 90 movement in the food chain - the specific activity of strontium 90 (i.e., the ratio of strontium 90 to stable strontium). It has been shown that the strontium 90 to stable strontium ratio of the diet will be identical to the strontium 90 to stable strontium ratio of the tissue (bone) that has been formed from that diet (for man).[6] Thus the OR concept could be used for these ratios in a manner similar to that for strontium 90 and calcium. However, a strontium 90 to stable strontium value for bone is not easily related to the total amount of strontium 90 in the total skeleton because the stable strontium content of bone is variable. The stable strontium content of bone depends on the stable strontium and calcium intake - a result of the lack of strontium homeostasis. Thus, even if the strontium 90 to stable strontium ratio of the diet is known, a value of strontium 90 or stable strontium per unit of bone or calcium is required to obtain the amount retained in bone. Because data on stable strontium intake and bone

content is limited, and both of these parameters can be quite variable, the strontium 90 to stable strontium ratio provides little information that is useful for prediction purposes on the amount of strontium 90 retained in bone.

There are several general conclusions that can be drawn from the foregoing discussion on measurement of radiostrontium in the food chain. The OR concept appears to be the most satisfactory method at present to predict overall radiostrontium movement in the food chain, especially on a long term behavioral basis related to bone deposition in the human population. Other methods such as strontium 90 to stable strontium ratios and absolute concentration values (e.g., pCi/l, etc.), suffer from the disadvantages of limited baseline data or the fact that they give information only on one point in time. Comparison of human body burdens predicted from the OR concept to those measured from limited dietary and associated bone analysis compare reasonable well."'' In general the measured bone levels are somewhat lower than those predicted from the OR concept. It appears that radiostrontium behavior in the food chain should be reported both in terms of strontium-calcium ratios and in absolute values so that maximum use of the data can be obtained.

1. Behavior in soils and plants

Strontium 90 may enter the food chain through absorption by plant roots or direct contamination by aerial deposition on above ground plant structures. The contaminated plants may he consumed by man directly or indirectly through his use of animal products (Figure 1). Strontium 89 and barium 140 are'only transferred up the food chain in significant quantities by initial aerial deposition on above ground plant parts (short half-lives restrict soil absorption). With respect to strontium 90, it is important to distinguish between root uptake and aerial deposition since the amount absorbed from the soil depends on the cumulative deposit, while the extent of direct contamination depends on the quantity of recent deposition. This section will deal primarily with strontium 90 behavior since this radionuclide represents the most hazardous food chain situation.

a) Strontium 90 absorption from the soil.

Field experiments indicate that, depending on the soil type, the strontium 90 to calcium ratio is likely to be in the range of 1-10 pCi of strontium 90 per gram of calcium if 1 millicurie of strontium 90 per square kilometer is present in the soil.[15] The amount taken up by crops each year ranges from 0.2 to 3 per cent of that in the soil; the exact quantity being dependent on a number of soil characteristics."''

The most important factor determining the extent of strontium 90 uptake by plants is the quantity of labile' calcium present in the soil. The plant uptake of strontium 90 is greatest in soils of low calcium content. Addition of lime to these soils will generally reduce the strontium 90 uptake, but usually not by more than a factor of 3. When soils contain quantities of calcium that result in optimal plant growth addition of more lime has little or no effect. Soil characteristics other than calcium content usually have comparable effects on strontium and calcium absorption; thus little difference in their ratio is realized in the plant. The addition of organic matter and fertilizers in large quantities has varying and complex effects. However, when these materials are applied in the usual agricultural quantities little effect is obtained. Although various plant species show a wide variation in their ability to absorb strontium 90, it is well documented that this characteristic is correlated with the ability to absorb calcium.

Additional factors which affect the absorption of strontium and calcium from the soil are the clay and humus content, the pH, the concentration of electrolytes other than calcium and the moisture content. In general, it is possible to predict how certain characteristics of the soil influence the uptake of strontium 90. However, it is not possible to give all the details on strontium 90 uptake from a particular soil or field without extensive knowledge of all factors which influence its behavior. For example, light sandy soils will allow strontium 90 to penetrate to a deeper extent than in heavier clay soils. However, a relatively greater part of the roots will be in contact with strontium 90 in the sandy soils due to its deeper penetration. On the other hand, the strontium will also be diluted with more calcium because of the greater depth of penetration. In this case, these two mechanisms are working in opposition. In general, light soils (sandy soils in the temperate and latosol type of soil in the tropics) are poor in calcium. The strontium-calcium ratio in these soils will thus be higher than that of heavy soils (clay soils in the temperate regions and margalites in the tropics).

Another area of strontium 90 behavior that has received considerable investigation is that of movement in the soil. Downward movement in undisturbed soils is slow and even after several years 50 per cent or more of the added strontium 90 may be in the upper 5 centimeters of the soil.[17] The rate of downward movement depends on the soil type, clay and humus content, electrolyte concentration and degree of water penetration. The exact nature of the movement is unknown but it is believed that movement with water and self diffusion

*Labile calcium = calcium present in soil solution + echangeable calcium present to replenish the soil solution

may be involved. In agricultural practices, cultivation of the soil causes the strontium 90 to become more uniformly distributed in the ploughed layer. Depth of cultivation combined with the rooting characteristics of the crop (deep versus shallow) is of primary importance in determining the degree of strontium 90 intake. For example, ploughing to a depth of 20 to 30 centimeters has resulted in a reduction of strontium 90 uptake by a factor of 3 when compared to surface application for shallow rooted crops such as rye, grass or kale.'"' For more deeply rooted crops the effect is smaller.

Considerable investigation has been given to the possibility that with the passage of time strontium 90 may become fixed in the soil in a less soluble form and be less available for plant uptake. Some investigators have found no evidence of fixation while others report a small quantity of fixed strontium 90 over a period of three or more years.[15, 17] It is possible that this effect varies considerably from one soil to the next. However, present evidence indicates that fixation of strontium 90 by soils is unlikely to reduce its availability to plants to any significant extent over a period of several years.

Results from water culture studies indicate that the Observed Ratio (plant shoot/solution) is close to 1 (Table 4).[15]

This value is generally applicable to plants growing in soil when the strontium is uniformly distributed or when differences in root depths are compensated for. Different strontium to calcium ratios have been observed in different tissues of the plant and this indicates a differential movement of the two ions. When the two elements enter the plant through the roots, the resulting ratio in the aerial organs most distant from the root is in general lower than the average in the plant. The ratio of strontium 90 to calcium in the vegetative tissues is often about half of that in the roots and twice that in grain and seeds. Stems may have considerable higher ratios than other plant structure. The most detailed study of the differential movement of the two ions between tissues has been that of whole grain. The ratio in wheat flour *(seed* portion of grain) has been reported to be 0.7 of that in the whole grain.'"' These plant discriminatory processes have little effect on the strontium 90 to calcium ratio in man's diet. Most human dietary calcium in the Western Hemisphere comes directly or indirectly from milk via leaf tissue which has a strontium 90 to calcium ratio similar to that of the rooting medium.

Different values have been reported for the OR (plant shoot/soil), but this variation can be attributed to the difficulties in estimating the availability of strontium 90 and calcium to the plant from the different soils. Because of the non-uniform distribution and the difficulties of determining the availability of the two ions in soil that are actually available for plant absorption, the strontium 90 to calcium ratio in the plant prediction from the OR concept is probably not a true reflection of what is available from the soil. **Also,** the lack of steady state conditions in the soil will normally limit the use of the $OR_{(plant/soil)}$ for prediction purposes on a wide basis.

b) Direct Contamination of plants by strontium 90

In contrast to soil absorption where only strontium 90 is of significance, all three important alkaline earth radionuclides, strontium 89, strontium 90 and barium 140, may be transferred to the human population through direct deposition on vegetative forms. Direct contamination can be divided into two categories: **1)** superficial contamination in which the radioactive material adheres to the crop surface, and 2) direct inside contamination which results from absorption through the leaves, flowers and stems with subsequent movement to other plant parts. Superficial contamination is of major importance where food and animal feed are consumed fresh. In the case of human consumption a relatively large portion of this contamination can be washed off, however, domestic animals will be presented with the total deposit for food chain transference. Direct inside contamination is dependent on the transport characteristics of the alkaline earth elements. For several of the elements, little is known about these characteristics. For calcium it is known that the transpiration' stream is the prime mover. Strontium 89 and strontium 90 are expected to behave in a similar manner. This theory has been confirmed by field and laboratory experiments in that the strontium 90 that enters through the roots is distributed to the aerial plant parts by the transpiration stream, but that which is deposited on the aerial structures **is** only slightly distributed to other tissues. In direct contamination the calcium content of the plant is another major factor in affecting the resultant Sr/Ca ratio since the entering aerial strontium 90 does not have the benefit of dilution with soil constituents. The plant calcium content, is somewhat dependent on the plant species. In general, the calcium content of the monocotyledons (plants containing one seed leaf in embryonic stage) is lower than that of dicotyledons (plants containing two seed leaves in embryonic stage). Most of our vegetables are dicotyledons of relatively high calcium content. Clover and weeds (animal feed) are dicotyledons while the real grasses are monocotyledons.

*One of the primary mechanisms causing the rise of water in plants (loss of water from plants)

Table 4. Strontium-Calcium Observed Ratios in Absorption **by Plants**[15]

Species	Method	$OR_{(plant\ shoot/solution)}$
Barley	^{89}Sr, ^{45}Ca	– 1
Ten Species	^{89}Sr, ^{45}Ca	0.7-1.3
Tomato	Stable Sr, Ca	– 1
Five Species	^{89}Sr, Stable Ca	1.1
Wheat	^{90}Sr, Stable Ca	1.0
Pea	In sand culture	*0.9*

Direct contamination has also been subdivided according to the organs of the plant contaminated. Thus, there is floral, foliar and plant-base contamination by radiostrontium. Floral deposition is of major importance with crops such **as** wheat and grain which are able to entrap considerable quantities of radiostrontium (also cesium 137) in their inflorescences. This entrapment results in a higher contamination of the grain than other plant structures. Other crops such as corn and beans do not exhibit this characteristic because their flowering parts are covered with sheaths which prevent floral contamination.

Foliar deposition is most significant for vegetables and grasses. The amount of radiostrontium retained on vegetation by this mechanism depends on the extent and duration of rainfall, and the extend and structure of the aerial plant parts. Experimental studies indicate that about one-quarter of the deposit that comes down in rain may initially lodge on the vegetation of permanent pastures consumed by cattle.'"' Leaf absorption is slow and the material is readily lost in rain. Plant-base contamination is significant in the case of perennial pastures which are able to absorb radiostrontium essentially all year long. Radiostrontium on stems and leaves can be washed down to the base of plants where it will be taken up by stems and surface roots without benefit of soil dilution. Radiostrontium uptake in this manner results in transport to all plant parts via the transpiration stream.

2. Metabolism in domestic farm animals

Since animal products are quite important in the human diet, the role of domestic animals in the food chain must be studied in detail. Again the alkaline earth fission-products metabolism is similar to that of calcium, a mineral element of major importance in animal metabolism. Environmental surveys have indicated that this group is transferred most rapidly to man through the pathways atmosphere-plants-animals-milk-man and atmosphere-plants-man. One pathway may assume a greater or lesser degree of importance depending on the kind and quantity of food comprising the diet and the fission-product and calcium content of the foods of the diet. Numerous studies have shown that the alkaline earth radionuclides are secreted into the milk of domestic farm animals in significant quantities. Since this food item is the major component of the diet of young children (considered to be the most sensitive population group), and is consumed relatively soon after contamination, it has been the food most often analyzed for an indication of any environmental contamination. Thus, many studies have centered on the mechanisms and quantities of alkaline earth radionuclides secreted into the milk of animals that are used by the human population. Other major areas of study include the tissue distribution of this group of elements in farm animals subjected to acute and chronic ingestion, determination of metabolic discriminatory processes using the OR and DF concept, and determining the effect of various dietary modifications on alkaline earth behavior in the animal and its products.

a) Tissue distribution of the alkaline earth radionuclides

Two intake modes are of major importance for the alkaline earth radionuclides. First, a single or "one shot" intake of the radionuclides. This has application to the environmental Contamination situation in which the animals are allowed to graze on a contaminated pasture for a few hours and then placed on uncontaminated feed. **A** typical distribution of an oral dose of several alkaline earth radionuclides is shown in Table 5.[16]

The distributions are contrasted to calcium 45 as a reference. The values of Table 5 should be considered as relative orders of magnitude involved and are somewhat dependent on both the experimental method employed and the time of experimentation. In general, the same results are obtained when the radionuclides are ingested as mixed fission-products, separate radioisotopes or incorporated into plant and grain materials with physical mixing. The data of Table 5 indicate that more radiostrontium than barium is secreted into the milk of the cow. This results from greater discrimination by the cow against barium 140 in contrast *to* radiostrontium. Fecal excretion is seen *to* be the major route of elimination for both barium 140 and radiostrontium. After a single administration of radiostrontium, the levels in milk will steadily rise until a peak

occurs at about 30 hours. For the next 5 days the levels decrease with an effective half-life of 30 to 40 hours. Barium 140 behavior is similar with an effective half-life of about 45 hours.

Table 5. Distribution of ^{140}Ba, $^{89,90}Sr$ and ^{45}Ca in the Cow and Goat[16]

Material	cow			Goat	
	^{140}Ba	$^{89,90}Sr$	^{45}Ca	$^{89,90}Sr$	^{45}Ca
Urine'	1.0	1.5	1.5	2.4	2.1
Feces'	98	95	78	93	77
Milk*	0.08-0.6	0.9	9.0	0.6	5.3
Milk"	0.01	0.1	0.9	1.6	9.9

'Values expressed as percent of dose summed over a 7 day period
–Values expressed as percent daily dose/liter after equilibrium

The second intake mode of interest is that of a constant intake over an extended period of time. When cows are subjected to chronic ingestion of radiostrontium the equilibrium distribution of the daily intake of the element is approximately the same as for the value for a single dose summed over a seven day period (the values of Table 5). Therefore the values in Table 5 can be considered as daily excretions after equilibrium has been reached. Milk values reach a plateau in about six days indicating that the animal is in near equilibrium with the diet. If contaminated feeding is continued with **no** further addition of radiostrontium and barium 140 to the feed, the radiostrontium and barium 140 levels will decrease with effective half-lives corresponding to the physical half-lives of the isotopes. The total amount of radiostrontium secreted into the milk ranges from 0.5 to *2* percent of the daily intake.[16] This is a reflection of variation in milk yields since the quantity of radiostrontium secreted per liter is relatively constant at about 0.1 percent of the daily intake.

The distribution of the radiostrontium in the goat is also shown in Table 5. The distribution is similar to the cow except that a much greater amount of calcium and radiostrontium are secreted in the milk of the goat. This is a result of the fact that the goat secretes a much larger quantity of the dietary calcium and radiostrontium into each liter of milk.

b) Determination of OR and DF Factors

Observed Ratios and Discrimination factors have been established for a number of metabolic processes in domestic animals. Experimental studies in this area have determined the major metabolic processes which are active in discrimination against alkaline earth radionuclides. Extrapolation of these data along with limited studies on the human population have yielded valuable information on the behavior of these radionuclides in man. Table 6 presents selected observed ratios and discriminatory factors that have been determined for animals and man.

The OR's and DF's of Table *6* have been calculated from the use of radioisotopes of barium, strontium, and calcium; strontium 90 and stable calcium. Discrimination factors have yielded important information on the physiological mechanisms that are important in the differential movement of the alkaline earth radionuclides. The more significant physiological processes that aid **in** the body's discriminating against strontium in favor of calcium are: 1) absorption from gastrointestinal tract, 2) urinary excretion, **3)** transfer across the plancenta and **4)** secretion into milk (Table *6)*. The processes that involve physiological handling and active transport across biological membranes are thought to be the most important.

Table 6. Selected OR and DF Values[6, 18, 19]

Material	cow		Goat	Rat	Man
	Ba/Ca	Sr/Ca	Sr/Ca	Sr/Ca	Sr/Ca
OR(bone/diet)	--	0.20	0.20	0.28	0.25
OR(milk/diet)	0.05	0.11	0.12	--	0.10
OR(fetus/mother's diet)	--	--	--	0.17	0.13
OR(fetus/mother)	--	--	--	0.65	0.6
OR(plasma/diet)	--	0.18	0.29	--	--
OR(urine/diet)	2.8	1.6	1.5	3.0	0.6
OR(feces/diet)	1.4	1.3	1.2	--	--
DF(absorptive)	0.12	0.24	0.24	0.5	0.70
DF(urinary)	0.70	0.80	0.60	0.80	0.70
DF(Fecal)	0.76	0.98	--	--	--
DF(lactional milk)	0.70	0.64	0.61	--	--

The observed ratios of major practical importance for prediction purposes are those for (bone/diet), (milk/diet) and (fetus/mother's diet). Laboratory studies and dietary surveys of strontium 90 to calcium ratios in diets and bones have indicated that the OR (bone/diet) is close to 0.25 (ranges 0.17 - 0.54) for adult mammals (including humans) which are on normal diets.“” This is the value used most often for prediction of bone levels and implies that there is a four-fold reduction in the strontium 90 to calcium ratio in going from diet to bone. For adults this strontium 90 to calcium ratio represents the maximum concentration at the sites of active bone formation or exchange at steady-state conditions. Calculation of OR (bone/diet) values for adults from fallout data is not possible because of the short time strontium 90 has been in the environment with respect to the period during which the bones of adults have been formed.

c) Chronic exposure over long periods

There are two practical chronic exposure situations with respect to intake of dietary radiostrontium (especially for long-lived strontium 90). The first situation applies to adults who have had a relatively short exposure time to environmentally deposited strontium 90 relative to the length of time that their bones have been formed. The second situation applies to children who have had a life-time exposure to environmentally deposited strontium 90.

For an adult exposed to dietary strontium 90, approximately 20 percent of the ingested radionuclide may initially be deposited in the skeleton. As ingestion continues the net retention decreases to zero as the skeleton becomes labeled under constant intake. Those initially exposed as adults, most probably, do not reach this steady-state condition during their lifetime. The amount of strontium 90 retained depends on the past history of the individual in relation to this dietary intake.

To explain strontium 90 behavior in children requires consideration of the growth and turnover of the skeleton with respect to calcium and strontium. These concepts are briefly summarized in the following paragraphs.“”. [21, 22]

1. The infant child is born with approximately 30 grams of calcium in the body and a strontium concentration of about 200 micrograms per gram of calcium. At this time the infant has an urgent need for phosphate for its soft tissues and if the dietary phosphate is not adequate, as in the case of breast feeding, calcium and strontium phosphates are utilized from the skelton. A constant bodily calcium level is maintained but a negative strontium balance (excretion > intake) may result.

2. The newborn's kidneys are able to discriminate between strontium and calcium; however, the intestinal mucosa's discriminatory ability may not be as great as that of the adult. Therefore, at this age the infant's discriminatory processes favoring retention of calcium and discharge of strontium are less than in later life. However, this lesser ability to discriminate between the two ions at this age is partially offset by the lower initial strontium 90 to calcium ratio of the fetus due to the discrimination of the mother's plancenta, and if the child is breast fed the strontium 90 to calcium ratio of his intake is appreciably less than that of older age groups.

3. During the growth in infancy there is a fast accretion of mineral into the skeleton, a threefold

increase in the first year of life. There is probably a complete remodeling of the bones. The exact amount of mineral reused and replaced with dietary sources is not known. Values from 30 to 100 percent have been predicted for the first and second years of life. This high turnover rate results in an equilibration of bone mineral with dietary sources and leads to a relatively uniform distribution of strontium 90 in the skeleton. The concentration of strontium and strontium 90 in terms of calcium will be approximately one half of that of the diet (at age 1).

4. As the infant grows the rate of accretion and turnover of existing bone decreases. At the same time the discrimination against strontium in favor of calcium approaches that of the adult. By age 7 the skeletal mass has increased by less than threefold since age 1. The strontium concentration in terms of calcium is about the same as in infancy and the strontium 90 concentration is less than in infancy.

5. From age 7 onward acquisition of new bone rises again but turnover appears to be minimal. Thus, at around puberty growth appears to be a matter of adding on new mineral to existing bone. At about this time the stable strontium intake of the child approaches the adult value. Also, at this time the relative distribution of absorbed calcium and strontium between bone and excreta alters markedly with these absorbed minerals being shunted more to excreta and less to bone. Up to this time, strontium 90 in bone has been related to the proportion of the total life span which has been spent in the contaminated surroundings. There has been a continued decrease of strontium 90 concentration in bone with age.

6. On attaining adult life acquisition of bone mineral ceases but a certain amount of maintenance or replacement continues. The adult healthy individual is in equilibrium with his mineral intake; that is absorption of calcium and strontium just balances excretion. In old age, and in cases of demineralizing diseases, there may be a net loss of minerals. The above concepts have been derived from planned experiments in the laboratory or from survey data acquired from monitoring strontium 90. These experiments and surveys have aided much in the understanding of the dynamics of mineral metabolism; however, the full picture is far from complete.

B. Radioiodine

In nuclear fission a number of radioisotopes of iodine are formed. Among the most prominent are iodine 131, half-life 8.1 days; iodine 132, half-life 2.2 hours; and iodine 133, half-life 21 hours. In fresh fission-products, the shorter-lived radioiodine isotopes will initially make the major exposure contribution because of their greater abundance. However, in older fission-products (on the order of a few days), the shorter-lived iodine isotopes will have decayed, and iodine 131 will be the radionuclide of major concern. Thus, the study of the environmental behavior of radioiodine has been concentrated on iodine 131 which has a relatively long half-life compared with the other iodine isotopes.

The major pathways of iodine 131 in the food chain are illustrated in Figure 3.

Atmosphere → Plants → Animals → Milk → Man

Figure 3. Main Terrestrial Pathways in the Food Chain for Iodine 131[5]

Because of the relatively short half-life of iodine 131, the soil pathway is not important. Since iodine 131 is only of major concern for relatively short periods of time following the deposition of fresh fission-products, it is only necessary to consider dietary foods which reach man shortly after contamination. Milk is the primary example of such a food. Experimental studies and dietary surveys have indicated that milk is the only food product that contributes a significant amount of iodine 131 to the human diet. Thus the most important pathway for iodine 131 is atmosphere-plants-animals-milk-man. It is possible that the pathway atmosphere-plants-man could result in ingestion of significant amounts of iodine 131 from unwashed fruits and vegetables that have been exposed to surface contamination. However, exposure by this route would most probably be only significant on a local or individual basis.

The quantity of iodine 131 reaching the population is dependent on the extent of deposition on the plants that lactating animals consume. This deposition may vary greatly due to the difference in the plants and the extent to which deposited iodine 131 is removed from the plants by weathering, Discriminatory processes of the grazing animal tend to reduce the final quantity of iodine 131 that reaches the population. The amount of discrimination by the animal may be quite variable and is a function of many factors (feeding practice, season of the year, type of intake, ctc.)

1. Behavior in soils and plants

As mentioned previously, absorption of iodine 131 from the soil is for all practical purposes unimportant since it will disappear through radioactive decay before it can be taken up by plant roots and transmitted to man. Iodine 131 reaches the soil as an anion. Since anions are practically non-adsorbed by soils rapid loss of iodine 131 from soils would be predicted. However, a rather high retention (60 to 80 percent) of iodine 131 in soils has been reported by some researchers.[16] This discrepancy may be due to the difficulty of extrapolating the results obtained with high concentrations to circumstances where low concentrations occur.[16] More study is needed in this area. From the viewpoint of food chain pathways, it will usually only be necessary to consider foliar absorption on plants. The pathway of floral absorption will be of little importance because of the usual delay between the harvesting of the crop and its consumption. Since man's intake of iodine 131 is primarily from milk, the most important question from a practical standpoint is the extent to which iodine 131 is retained on vegetation consumed by cattle.

Due to many factors, among which are the manner of pasture management, physical and chemical state of iodine 131 and the different nature of the grazing animals, it is difficult to make many generalizations which are broadly applicable to this question. However, laboratory and field studies on the deposition characteristics of iodine 131 on vegetation indicate that 1) the rate of deposition of iodine 131 is quite variable as a result of differences in the physical state of the radionuclide, 2) deposited iodine 131 exhibits a chemical state that is not well understood; however, it is known that it is difficult to wash off a major fraction of the radioiodine, 3) once deposited iodine 131 will be readily transported to other plant structures, and 4) during precipitation iodine 131 will be deposited at a much faster rate than in dry weather, but rain also washes the plant and most probably removes some unknown amount of the radionuclide (there have been no systematic studies in this area).[23] Care should be exercised in applying information gained in investigations at one atomic installation of that of another. For example, it is not known how applicable findings at the Hanford Atomic Works, a semi-arid region, would be to a grassland area of the Midwest or Northeast.

2. Metabolism in domestic farm animals

Since milk is the major source of iodine 131 to the population, the secretion of this radionuclide into the milk of lactating animals has received major study. Other areas that have received considerable attention are the distribution of iodine 131 in animal tissues and secretion, and the factors that modify iodine 131 metabolism.

a) Secretion of iodine 131 into milk

Two experimental approaches have commonly been used to study the secretion of radioiodine into milk. A single oral administration of radioiodine has been used to simulate the environmental situation of short exposure to the grazing animal such as might occur after a brief escape of radioiodine from a reactor. The second approach consists of orally administrating radioiodine over long periods of time to simulate the situation where the feed is contaminated, and it is impossible or impractical to provide uncontaminated feed. The laboratory approach is believed not to differ significantly from that where radioiodine is contained in fallout.

b) Distribution of iodine 131 in animal tissues and excretions

Table 8 presents typical data on the levels of iodine 131 found in the milk, urine, feces and thyroid gland of the cow and goat following single dose and chronic administration.

The values are rough averages and the ranges are given in parenthesis. The variability is observed to be high and may be the result of biological differences between the individual animals and the sensitivity of iodine metabolism to the many variables operating. The most important values for food chain transference purposes are the milk concentrations. Typical values for the cow are 8 percent of a single dose in the total milk after seven days and approximately 1 percent of the daily dose per liter. The milk concentration variability, especially for the goat, is in part a result of the different levels of milk production. This is especially true for the goat. In estimating iodine 131 intake from milk, allowance must be made for the lesser absolute intake of iodine 131 by the goat. That is, produced on the same pasture, the concentration of iodine 131 in goat's milk would be 5 to 10 times that in cow's milk; however, the cow would most likely have a higher absolute quantity of iodine 131 in milk due to greater intake and milk production. Greater than 90 percent of the iodine 131 occurring in goat and cow's milk has been shown to be in the iodide form.

Another metabolic area of interest is the tissue distribution of iodine 131 as a function of time and type

of intake. Typical data are presented in Table 9.

The important observation of Table 9 is the large difference between thyroid and other tissues. The difference is the result of the method of iodine 131 administration rather than the species. Tissue levels such as those of Table 9 could possibly be used to predict the tissue iodine 131 content of meat-producing animals under transient or long-term contamination conditions.

c) Factors modifying iodine 131 metabolism

Several investigators have reported a seasonal difference in the ability of the cow to secrete iodine 131 into milk.[16, 24] The magnitude of the difference and the mechanism operating are not known. It is probably an important physiological mechanism, and more work in this area is needed to determine the controlling mechanism(s). For public health purposes, this information is very important since it has an influence on how much iodine 131 is secreted into the milk. Along the same line of investigation, there is little evidence to illustrate a relationship between milk production and efficiency of secretion of ingested iodine 131 into milk. However, the total amount of iodine 131 secreted into milk appears to be a function of the amount produced with the quantity secreted per liter being relatively insensitive to changes in milk production.

Another area of radioiodine metabolism that has received considerable attention is that of adding various chemical compounds to the animal's diet in order to reduce the secretion of iodine 13I into milk. At the same time, the resulting reduction in thyroid burden of the animal has also been observed in hope of obtaining some indication of iodine behavior in the human population. Table 10 illustrates the effect of various chemicals on the amount of iodine 131 secreted into milk.

It is noted that the cows receiving no chemicals have an ability to concentrate iodines from blood plasma into milk. Little is known about the mechanism on how this is accomplished. With respect to this concentrating mechanism, the cow shows little ability when compared to the human being, dog, cat or guinea pig. Milk-plasma ratios in the cow range from about 1-4 while the other species mentioned have ratios of 20-30. The addition of chemicals is observed to reduce the milk-plasma ratio and the percent of the daily dose secreted per liter of milk for all cases (Table 10). However the reduction of the percent of iodine 131 secreted into the milk is not as much as would be predicted from the milk-plasma ratios. This is because the chemicals increase the plasma level of iodine 131 as well as reduce the milk concentration.

Table 8.[24] Secretions of Iodine 131 into the Milk, Urine, Feces and Thyroid of the Cow and Goat

Percent of single dose of ^{131}I*	**cow**	**Goat**
In Milk'	8(4-20)	40(6-54)
In Urine'	50(30-75)	33(8-52)
In Feces'	20(13-50)	15(2-20)
In Thyroid	10(5-30)	30(2-50)
Percent of daily ingested ^{131}I	**cow**	**Goat**
Per liter of milk	l(0.5-2.7)	65(22-150)
In Daily Urine	(35-50)	(10-50)
In Daily Feces	(20-40)	(10-30)
In Thyroid	(30-270)	(90-500)

'Dose refers *to* total intake activity
**All excretion values are cumulative totals over a 7 day period.

Table 9.[16] Tissue Distribution of Iodine 131 in the Cow and Sheep

Tissue	cow Single dose of ^{131}I[a] as percentage of dose/kg	Sheep Continuous dose of ^{131}I[b] as percentage of daily dose/kg
Thyroid	450	30,000
Muscle	0.02	
Heart		2
Liver	0.03	8
Kidney	0.05	6
Lung	0.05	4
Pancreas	0.04	3
Blood	0.07	3

[a]Sacrificed after 7 days [b]Sacrificed after steady-state conditions

Table 10.[16] Effect of Various Chemicals on the Concentration of Iodine 131 in Cow's Milk

Chemical	Amount g/day	^{131}I in milk as percentage of daily dose/l	^{131}I milk/plasma ratio
	0	2.3	1.40
NaI	10	0.7	0.27
	0	0.5	2.09
NaSCN	10	0.2	0.66
	0	1.5	2.6
$KClO_4$	10	0.4	0.32

Table 11.[24] Relation of Daily Intake of Stable Iodine to Stable Iodine Milk Concentration

Daily intake of iodine by cow (mg)	Iodine level in milk (mg/l)
1.6	0.028
20	0.27
2,000	19
4,000	25

Table 12.[24] Relative Biological Availability of ^{131}I to Individuals

Age	Thyroid wt., g	%uptake in thyroid	%uptake/g of thyroid	Fresh milk consumption	(%^{131}I/g thyroid) X(liters milk/day)
FETUS					
12 wk		0	0		0
12-15			0.1-1	1	0.1-1
15-32			1-5	1	1-5
PERSON					
0-6 mo.	2	30	15	0-0.5	0-7.5
6-12 mo.	2	30	15	0.5	7.5
1-2 yr.	2-5	30	12	0.5	6
2-5 yr.	3-5	30	10-6	0.5	5-3
5-10 yr.	5-10	30	6-3	0.7	4-2
10-15 yr.	10-15	30	3-2	0.7	2-1
15-20 yr.	15-20	30	2-1.5	0.6	1
20-30 yr.	20	30	1.5	0.3	0.4
Above 30	20	30	1.5	0.2	0.3

Another interesting sidelight of feeding chemicals to the cow is that the chemicals may be secreted into the iodine metabolism of the consumer. The data of Table 11 illustrate the daily intakes and milk concentrations of stable iodine for the dairy cow.

Assuming that man consumes about 0.2 mg of iodine a day, it is apparent that supplementing the cow's diet could significantly raise the iodine intake of individuals consuming milk. This metabolic behavior could have significant meaning (other factors being considered) in terms of public health action with respect to thyroidal deposition of iodine 131.

3. Metabolism in man

a) General behavior

Like radioactive strontium, radioiodine is a potential hazard to man since it is concentrated in significant quantities by the thyroid gland. The thyroid is a small, essential endocrine gland located in the neck and has a particular need for iodine. The gland synthesis iodine containing hormones which regulate the overall metabolism of the body. It ranges in weight from less than a gram at birth to about 25 grams in a 25 year old adult, remaining constant thereafter. As with all metabolic processes, very specific conditions must be defined in order to describe thyroid behavior since so many parameters take part in the process.

Iodine (inorganic iodide) is essentially 100 percent absorbed from the gastrointestinal tract. The thyroid gland traps from 10-50 percent of the absorbed amount, and oxidizes inorganic iodide to elemental iodine. The iodine may then be incorporated into the thyroid protein thyroglobulin. Enzymatic breakdown of thyroglobulin with subsequent reactions produce thyroxine and iodothyroxines, the active thyroid hormones. The hormones are secreted from the thyroid, circulated in the blood stream and are finally broken down. The free iodine may be retrapped or excreted. Excretion is mainly through the urinary route.

b) Biological availability

From a practical viewpoint, a relative factor expressing the biological significance of iodine 131 to the general population from food chain contamination can be expressed as (%^{131}I uptake per gram of thyroid) X (fresh milk consumed)[4]. Table 12 presents several pertinent parameters from predicting the biological availability of iodine 131 in relation to thyroid burden.

It should be pointed out that the data of Table 12 are quite variable and single values are only used for illustrative purposes. Very little data are available for the uptake and thyroid weights of the fetus and young age groups. Limited studies on adults have shown that the uptake value may be somewhat less than that presently recommended (30 percent). The important point of Table 12 is that due to the combined effects of thyroid weight and milk intake the 0 to 2 year age group would be expected to have the highest iodine 131 exposure. The other groups would progressively lower exposures by factors of 10 - 20 at the ends of the age

range.

c) Dietary supplementation

From the standpoint of possible practical application there is considerable interest in the effects of stable iodine and thyroid extracts on iodine 131 uptake. It is believed that the quantity of iodine retained by the thyroid from day to day is almost the same and is a function of the percentage of the total iodine intake which goes to the gland.[26] Sudden changes in stable iodine intake have little effect on changing the percent iodine uptake by the thyroid; however, chronic changes in intake causes the thyroid to adapt by large changes in the percent of absorbed iodine going to the thyroid. Studies have shown reduction of 75 percent or more of the iodine 131 accumulation in the thyroid with increased levels of stable dietary iodine.[26] Administration of thyroid extract has also been shown to have a similar effect.

C. Radiocesium

The major terrestrial pathways of cesium 137 are shown in Figure 4.

Atmosphere
↓
Plants
↓
Animals → Milk → Man
↓
Animal Products → Man

Figure 4. Major Terrestrial Pathways in the Food Chain for Radiocesium[5]

In contrast to strontium 90, cesium 137 does not readily follow the soil step. This nuclide is fixed in forms largely unavailable to plants as a result of entrapment in the lattice structure of certain clays. Plant contamination, therefore, occurs primarily by direct deposition. Since cesium 137 is capable of concentrating in soft tissues (e.g., muscle), the step from animal to animal products (other than dairy products) assumes importance for this radionuclide. A long-term genetic dose is thus possible from ingestion of foods contaminated with cesium 137. Since a significant quantity of cesium 137 is excreted into animal milk, the pathway atmosphere-plants-animals-milk-man is most important for diets containing average amounts of milk. In general, the biological significance of cesium 137 is somewhat less than that of strontium 90 because of its shorter effective half-life in the body.

Cesium 137 behavior in the food chain and concentration in various media is frequently expressed in terms of cesium-potassium ratios in a fashion analogous to that used for strontium and calcium. However, while strontium and calcium are closely interrelated in their food chain movement and can be used with relatively good degree of accuracy for prediction purposes, this is apparently not true for the cesium-potassium pair. Studies investigating the OR relationship at various levels in the food chain indicate that the various OR values change markedly under different conditions.[15] It appears that all of the weaknesses of the strontium-calcium ratio are magnified in the cesium-potassium pair. However, due to usage, the cesium 137 contents of diets and animals including man are often expressed as picocuries of cesium 137 per gram of potassium. This expression of concentration has some merit over that of other methods (e.g., picocuries per kilograms of body weight) since it correlates better with lean body mass, and hence organ dose, than does more conventional units. The concentration ratio may be approximately converted to other useful units since the potassium content of the body and many foodstuffs are relatively constant and well known. The ratio concentration also tends to minimize differences due to age and sex when these population characteristics are not known from the measured group. Use of picocuries of cesium 137 per grain of potassium in this fashion implies no consideration of the similarity of the metabolism of cesium 137 and potassium.

1. Behavior in soils and plants

The behavior of cesium 137 in soils and plants has not been studied to the extent of that of strontium 90. It is interesting to contrast the behavior of strontium 90 and cesium 137 since they are the major radionuclides of concern in evaluating long term environmental contamination. Where possible, this is the approach used in the following discussion.

a) Plant ahsorption and soil movement **of** cesium **137**

The uptake of cesium 137 from soil has been studied in laboratory experiments and to a lesser degree in field experiments. These may be used for the basis of predicting field behavior. Cesium 137 has been shown to be less absorbed by plants than strontium 90. The relative amounts absorbed being dependent on the soil type. Short-term experiments indicate that cesium 137 from soils of the temperate regions usually enter plants to about one-tenth the extent of strontium 90.[15] With the passage of time, on the order of several years,the value may decrease to one-twenty-fifth of that of strontium 90. However, differences have been observed with other soil types. For example, tropical soils containing little clay minerals have shown greater plant uptake of cesium 137. The marked differences in the plant uptake of strontium 90 and cesium 137 from temperate soils is a result of fixation of cesium 137 by the soil in forms inaccessible to plants. The fixation appears to involve the entrapment of cesium 137 in the lattice structures of clay minerals. Once fixed, cesium is replaced from soil only to a small extent by divalent ions, however, addition of stable cesium, ammonium, or potassium reduces the amount of fixation. Addition of stable carrier cesium can increase plant uptake of cesium 137. Addition of stable potassium may decrease plant absorption of cesium 137 when the soil is low in available potassium. When available potassium is high no affect may be observed.

A typical study illustrating the comparative downward movement of cesium 137 and strontium 90 in several undisturbed soils is shown in Table 13.

It should be noted that the data of Table 13 are only valid in undisturbed soils since agricultural land which has been plowed and harrowed will have a top layer with a more homogeneous distribution of the radionuclides. As a result of strong binding (fixation) the downward movement of cesium 137 is considerably less than strontium 90 for the clay and sandy soils.

b) Direct **contamination of** plants by cesium **137**

Cesium, like potassium, is readily absorbed and distributed throughout plant tissue. Studies performed to determine the metabolic interaction of cesium and potassium in plants are hampered by the appearance of toxic effects at relatively high ratios of cesium to potassium. However, studies investigating the OR (plant/solution) relationship have shown that the OR may be increased by a factor of 2-10 as the soil solution potassium concentration is increased.[15] This behavior points out the difficulty in trying to use the cesium-potassium ratio to describe the differential behavior of the two ions.

Cesium 137 may enter plants directly by foliar, floral or plant-base absorption. It is retained on plant foliage in a manner similar to that of strontium and is readily removed by rain. Like strontium 90, the relative rate of entry of cesium 137 into the plant tissues is not known. Once deposited on foliage, the cesium 137 is distributed throughout the plant. This is in contrast to radiostrontium which undergoes little distribution within the plant. For example, approximately 30 percent of the deposited cesium 137 on the foliage of potatoes may reach the tubers as compared with less than 1 percent of strontium 89.[17]

The extent to which cesium 137 enters plans from direct contamination as opposed to absorption from the soil has received considerable attention. Since large quantities of cesium 137 are fixed in various soils, plant levels would be expected to be closely related to the rate of deposition. In general, this idea is borne out (dietary surveys); however, in some regions the cesium 137 has not decreased in the expected manner with decreasing rates of deposition. Two possible explanations have been proposed for this observation.[17] First, cesium 137 undergoing plant-base absorption may be held available at the base of the plant for absorption for longer periods than currently anticipated. This may be particularly true for the root-mats of permanent pastures. Secondly, the slow rate **of** fixation may render additional quantities of the total soil reservoir of cesium 137 available for root absorption. More study in this area is needed before the relationships between the level of cesium 137 in plants, the cumulative soil deposit and the rate of deposition are fully understood.

2. Metabolism in domestic **farm** animals

Like radiostrontium, barium 140, and iodine 131, milk is the major pathway by which cesium 137 enters the human population. Although cesium 137 may be found in most tissues of the body, the soft tissue is generally considered the critical organ. The major area of study in cesium 137 animal metabolism has been the transfer of the radionuclide to **milk.** However, for cesium 137 this area has received less attention than for radiostrontium. Other metabolic characteristics which have received consideration are the qualitative and quantitative tissue distribution after single and chronic exposures, and the effect of dietary modifications on cesium 137 uptake.

Table 13.[16] Comparative Downward Movement of Cesium 137" and Strontium 90 in Several Undisturbed Soils.

	Clay Soil		Sandy Soil		Calcareous soil"	
Depth(cm)	pH 4.6		pH 6.6		pH 7.6	
	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs
0-2.5	50	98	63	98	37	43
2.5-5.0	20	2	22	2	24	21
5.0-7.5	15	0	13	0	19	15
7.5-10.0	12	0	2	0	16	16
10.0-12.5	3	0	0	0	3	4
12.5-15.0	0	0	0	0	1	1

*Percentage in each zone after 20 months experimental study
**Calcium carbonate containing

a) Secretion into milk of cesium 137

Studies have shown that about 10 percent of a single oral dose of cesium 137 will be secreted in the milk of the dairy cow in a 7 day collection period.[16] Daily administration of cesium 137 for long periods (30 days) results in about 10 percent of the daily dose being secreted into the milk. However, the animals of the particular study had not quite reached equilibrium with their intake. The amount of cesium 137 secreted per liter averages about 1.4 percent of the daily administration. These data from a typical study are presented in Table 14.

Table 14.[16] Distribution of Radiocesium after Oral Administration to Dairy Cows and Goats

Material	cow	Goat
Milk (% daily dose)	13	7.0
Milk (% daily dose/l)	1.4	9.4
Urine (% daily dose)	30	40
Feces (% daily dose)	55	40

The relative order of distribution of the dose is the important concept of Table 14. It is noted that fecal excretion is more in the cow than in the goat. Also, a greater amount of cesium is recovered per liter of goat's milk. This is similar to the situation for radiostrontium and radioiodine. Radiocesium is excreted into the cow's milk by a factor of 10 greater than for radiostrontium. This is probably due to the greater gastrointestinal absorption of cesium than strontium. Body burdens of about 4 to 5 times the daily intake for the cow and goats, respectively, have been observed from chronic administration. Biological half-lives for the cow and goat have been estimated to be 20, and 2 to 3 days, respectively. Addition of stable cesium to the cow's diet has been reported as having little effect on the distribution of cesium 137 in the milk, urine, or feces.

b) Tissue distribution of cesium 137

The tissue distribution of a single dose of radiocesium to sheep and beef cattle has been observed to be similar.

Table 15 presents a typical 7 day tissue distribution of cesium 137 on several domestic animals after a single oral dose.

The concentrations of cesium 137 in the various tissues is seen to be of the same order of magnitude,

kidney, showing the highest concentration. Since cesium **137** is a long half-life radionuclide, its tissue distribution after chronic ingestion is more applicable to long term environmental contamination. The data of Table **16** show the tissue distribution of cesium **137** in the goat as a result of chronic feeding.

The various tissues show a reasonably similar quantity of radioactivity. The kidney appears somewhat high while the brain is rather low. Comparison with Table 15 indicates that other species (cow, sheep, etc.) would be expected to have tissue distribution on the order of magnitude of that of the goat when exposed to chronic intake.

Table **16** also presents several calculated observed ratios for the cesium-potassium pair in the tissues of the goat. **In** this particular study a OR value of **1.3** indicates that the goat preferentially secretes radiocesium into the milk. **A** similar value **(1.6)** has been reported for the dairy cow. For the organs and tissues of Table **16** with **an** observed ratio greater than one (liver, lung, kidney, and mammary gland), a concentration of cesium **137** with respect to the diet is implied. This suggests that cesium does not follow potassium metabolisms in the manner and closeness that strontium follows calcium metabolism. Further investigation of cesium-potassium metabolism is needed before any definite conclusions can be stated. For example, limited studies in rats indicate that a ninefold increase in dietary potassium causes a twofold reduction in cesium **137** muscle retention. (Table **17).**

The OR(muscle/diet) is observed to vary as a function of potassium content of the diet; a ninefold increase in diet carrying a fivefold increase in the OR(muscle/diet). This is in direct contrast to the predicted behavior of the OR(bone/diet) for strontium.

Table 15.[16] Radiocesium in the Tissues of Farm Animals after an Oral Dose' (percentages)

Tissue	cow	Sheep	Pig
Blood	2.8	4.7	6.0
Plasma	1.3	2.6	1.0
Muscle	30	41	23
Liver	26	24	21
Kidney	45	74	26
Femur Chaft	0.5	7.6	5.2

"Data are expressed as percentage of dose x 10^5/g, corrected to 500 pounds body weight

Table 16.[16] Equilibrium Distribution of Radiocesium in the Tissues of the Goat'

Tissue	Cs^{137} as percentage of daily dose/kg	Cs/K Observed Ratio (tissue/diet)
Muscle	4.6	0.6
Brain	0.5	0.3
Liver	8.4	1.4
Lung	7.3	1.1
Kidney	17.0	3.7
Mammary Gland	7.1	1.4
Blood	0.5	0.6
Milk	5.6	1.3

*25 days of feeding

3. Metabolism in man

Cesium **137** is absorbed from the gastrointestinal tract of man virtually completely and primarily distributed to the soft tissues of the body. There has been some evidence that significant quantities of cesium **137** are concentrated in bone; however, results at present are quite variable and further investigation is needed

before any definite conclusions can be drawn. Cesium 137 like potassium has a relatively short biological half-life in man and equilibrium with the intake is established rather rapidly, regardless of age.

At least two exponential processes (2 compartment model) can be recognized in the elimination of cesium **137** from man following the administration of a single dose.[15] **A** small fraction (10 to 15 percent) is excreted with a biological half-life of 1 to 1.5 days. The remainder is eliminated at a much slower rate with considerable variation between individuals and biological half-lives. Values **as** low as 50 to 60 days and as high as 150 to 160 days have been reported for the biological half-life. Measurements on apparently normal individuals with whole body counting techniques have yielded an average value **of** 100 days. Potassium, on the other hand, has a much more rapid body turnover which apparently depends largely on the dietary intake.

Table 17.[19] Effect of Dietary Potassium on Cesium 137 Retention in Muscle of Rat'

Level of Dietary K%	**%Daily Dose of muscle Cs^{137}**		**Dietary Cs/K %Daily Dose/mg**	**$\frac{Cs/K}{Cs/K^{muscle}}$**
	per gram	per mg K		(diet)
0.2	14	3.9	3.9	I.0
0.6	10	2.9	1.3	2.2
1.8	7.5	2.1	0.4	5.3

The biological half-life of cesium 137 in different species appears to be related to body size - being rapid in small animals like the mouse and rat, and longer in large individuals such as man. Ruminants (e.g., cattle) form an exception to the rule. They have a rather rapid biological half-life when compared to similar sized animals. The level of dietary potassium appears to have little effect on the removal of cesium 137 from the human body. ***An*** increase of dietary potassium causes only a transitory increase in the urinary excretion of cesium 137, and it shortly returns to its former rate.

D. Other Radionuclides

Several additional radionuclides which are either man-made or natural constituents of the terrestrial environmental deserve brief consideration.

1. Fission and activation products

Radionuclides produced in the fission process, other than those of the alkali and alkaline earth groups, will generally be of minor importance because they are short-lived and pass through terrestrial food chains to only a small extent. None of these radionuclides are absorbed by man in any appreciable amount.

In addition to the fission products, a wide variety of induced activities may result from the activation of material surrounding the fission reaction or through the release of effluent from reactors. Radionuclides originating from these situations include isotopes of iron, sodium, manganese, magnesium, phosphorus, cobalt and zinc. None of these radioisotopes enter the terrestrial food chain to any extent approaching that of the contaminants already described. However, several of these radionuclides (e.g., phosphorus 32 and zinc 65) concentrate in aquatic forms and may reach man through the aquatic food chain.

Carbon 14 (half-life 5560 years), both natural and man-made, is produced from atmospheric nitrogen. Its natural production is the result of cosmic ray interaction; man-made carbon 14 is produced from interaction of neutrons, with nitrogen. Past atmospheric weapons testing (up until 1959) has increased the natural occurring carbon 14 level in the troposphere of the Norther Hemisphere by about 30 percent.[17] Carbon 14 readily enters the biological carbon cycle and contributes to the whole body population dose. Tritium (hydrogen 3, half-life 12.5 years) like carbon 14 is both naturally occurring and man-made. Natural production is again by cosmic ray interaction; man-made production occurs by activation of atmospheric nitrogen by neutrons coming primarily from weapons testing. Tritium can also be reactor-produced by neutron activation of deuterium (heavy water) moderator and lithium hydroxide, a coolant additive. Natural tritium levels have been modified by atmospheric nuclear weapons tests, especially by high yield fusion devices. As expected both carbon 14 and hydrogen 3 are readily incorporated into all media of the food chain.

2. Natural radioactivity

There are a number of naturally occurring radionuclides in the biosphere. They enter and are transferred through the food chain to varying extents. A major portion of the work with natural occurring radionuclides has been undertaken in order to establish base-line levels in the environment. Such levels have been used for comparison in assessing the degree of contamination of the environment with artificial radioactivity.

The most important naturally occurring radionuclides belong to the uranium, thorium and actinium series. The actinium series is the least abundant of the three. These natural series are composed of a number of the heavier elements of varying half-lives which exhibit extremely complex decay schemes. Studies of the transfer of these radionuclides to man via the food chain involves measuring the activity levels in plants which are consumed directly by man, and plants such as grasses which form the principal food of animals which in turn become the principal food of man. Dietary surveys indicate that there is a wide range of natural activities in vegetation and there appears to be no simple correlation with the activities found in the soil which have a much smaller range. Also, there is not much information available concerning the discrimination factors for soil-food and man-food processes. It appears that the majority of these radionuclides are absorbed by plants and animals only to a very small extent when compared to the most pertinent artificial radioisotopes. Little quantitative data are available on absorption phenomena. The greatest attention has been paid to radium since this element appears to be the principal one absorbed by plants. However, dietary surveys have indicated that the Occurrence of this element in the majority of foods is well below that of man-made strontium 90.

The following naturally occurring radionuclides are present in a singular form in the environment: rubidium, lanthanium, samarium and ruthenium. Little information is available on plant and animal absorption of these natural radionuclides. They are known to be present in the environment at considerable lower concentrations than the most abundant naturally occurring radioisotope, potassium 40. Consideration of several of their characteristics such as their chemical nature, the behavior of their man-made counterparts and their essentialness to plants would tend to indicate that these radionuclides are little absorbed by plants.

SUMMARY

In order to determine the environmental significance to man of a particular artificial radionuclide many

characteristics of the environment and man must be considered. Such characteristics include the fission-yield and half-life of the radionuclide, the rate of entry and survival of the contaminant through the terrestrial food chain, the rate and quantity of uptake of the radioisotope by terrestrial media (plants, animals, man, etc.), the amount of the contaminant deposited and retained in the critical organ of man, and the type and energy of the radiation emitted by the radioisotope. Additional physical and bio-chemical characteristics of the radionuclide must be considered and related to the contaminant's behavior in individual terrestrial food chain media. From the above considerations, strontium 90 and cesium 137 are the most hazardous long-term contaminants that can readily reach man through the terrestrial food chain. Strontium 89, barium 140 and iodine 131 are also potential internal hazards to man; however, as a result of their shorter physical half-lives they are most significant as relatively short-term contaminants.

Much work has shown that the most important terrestrial pathway in the food chain for these radionuclides is atmosphere-plant-animal-milk-man. In most cases this is the pathway by which these radionuclides reach man the quickest and in greatest quantity. Other pathways in the food chain may assume significant importance as contributors, depending on the particular situation.

The remaining fission products, activation products and naturally occurring radionuclides that are found in the terrestrial environment are of lesser hazard to man as a result of their limited movement in the food chain. However, depending on special circumstances some of these radionuclides may assume a greater importance than normally expected..

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b) Radionuclides in the Food Chain

INTRODUCTION

The use of nuclear energy by man involves the production of artificial radionuclides which present a potential public health problem with regard to the contamination of the terrestrial food chain. The release of these radionuclides has not introduced to our environment a new pollutant but rather has increased an old pollutant in terms or radiation exposure. The problem then is a matter of evaluating the extent of man-made radioactivity in the environment and its subsequent health significance.

At present fallout from past nuclear weapons tests is the most widespread source of artificial radionuclide contamination to the terrestrial environment. With limited nuclear testing other sources such as, nuclear reactor operations, nuclear fuel reprocessing, waste disposal and medical and industrial uses of radioisotopes will be receiving more emphasis as significant sources of environmental contamination.

This discussion is primarily concerned with the qualitative behavior and transfer of atmospheric releases of man-made radionuclides through the food chain and their deposition in the human population. Where applicable reference is made to the behavior of the more important naturally occurring radionuclides of the uranium, thorium and actinium series along with the singularly occurring radionuclides.

THE FOOD CHAIN

The pathways which radionuclides follow in moving from their origin to man constitute the food chain.

Radioactive materials are removed from the atmosphere by meteorological processes, primarily precipitation. In general, the most serious food chain contamination problem arises from direct deposition of radioactive materials on animal feed crops or on food crops directly consumed by man. Following this initial deposition, the radioactive materials may be removed by various processes such as, being washed off by rain or blown off by wind. The extent of this removal is a function of many physical and biological parameters. Man's intake of radioactive material may occur from contaminated food crops, from contaminated meat and meat products and from contaminated milk or milk products. The inhalation route (atmosphere directly to man) may be important under special circumstances. The relative importance of the various pathways of intake will depend on many factors among which are the physical half-lives of the radionuclides, the rate and route by which they pass through the food chain and the dietary habits of the population. The immediate and generally most significant pathway is pasture-cow-milk-man for the more significant radionuclides up to approximately one hundred days following deposition (one time event). Plant losses are such that after this time period adsorption from the soil by plants is the most significant pathway for the longer-lived radionuclides. The final step in the food chain (uptake by man) primarily depends on the chemical characteristics of the radionuclide and the metabolism of the concentrating organ.[2]

As an example of radionuclide behavior in the terrestrial food chain, the pathway of the fission product strontium-90 may be cited. It has been shown that this nuclide is readily transferred to man from atmospheric nuclear testing by deposition on the earth's surface with subsequent plant uptake and transference to milk by the grazing animal population.

In considering the relationships between the food chain and any particular radionuclide it becomes necessary to first consider the source of the contaminant. The source should be considered at it relates to the physical and chemical state of the radionuclide since these properties relate to the degree of movement in the food chain. Fission-products from an atmospheric burst would not be expected to exist in the same physical and chemical state as those from a reactor incident, fuel reprocessing plant or waste treatment facility. Even among the latter operations a wide variety of physical and chemical states of the fission-products would be expected.

As an example of the foregoing the various forms of the fission products of ruthenium and iodine with respect to their source of production can be cited.

Studies of the movement and effects of radionuclides in the food chain are of value because they 1) make possible the prediction of the relationships between the kinds of radioactivity in the various steps within the food chain and the resulting levels in the human population, 2) provide a means for evaluating ways by which the levels in the human population may be minimized, 3) provide background information for setting up environmental sampling programs and for interpreting the data obtained, 4) make available animal data which

may be useful for estimating behavior of radionuclides in humans, and 5) make possible predictions of the possible effects of environmental contamination, especially in the grazing animal population.

RADIONUCLZDE BEHAVIOR IN TERRESTRIAL MEDIA

Radioactive materials from atmospheric releases are deposited on the earth's surface by precipitation or direct deposition. Although the discussion of possible fallout patterns is beyond the scope of this presentation, it should be stated that fallout distribution depends on many parameters. For nuclear weapons testing, these include meteorological conditions, fission yield, type of explosion (i.e., ground, water or air), and geographical location. In the case of a nuclear incident, such as an air release from a nuclear reactor, the factors of major concern would be the existing fission product inventory, the micrometeorological conditions and the nature **of** the surrounding terrain.

The incorporation of radionuclides from fallout into the food chain depends on the physical properties of the fallout material and the chemical behavior of the nuclides. The observed wide range of chemical composition and particle sizes in various nuclear events leads to the conclusion that the biological availability of the radioisotopes cannot be predicted from the event without some knowledge of the characteristics cited above. With respect to weapons testing, surface bursts in the kiloton range over continental soils result in predominantly siliceous radioactive particles while tower bursts of the same.energy range yield particles which exhibit incorporation of tower materials. Megaton explosions over coral islands have yielded primarily calcareous (calcite or calcium carbonate containing) particles.[3]

Very little quantitative information is available on the exact physical and chemical form of the metallic radionuclides that constitute the bulk of the radioactivity from world-wide fallout. The information that is available has been obtained from the various methods of sampling fallout as it impinges on the earth's surface. Comparisons have been made using gummed films, pots, ion exchange columns connected to funnels, and collectors employing artificial grass. It has been observed that gummed surfaces collect on the average about 60-70 percent more gross radioactivity per unit of horizontal area than a high walled pot. The alkali metals (e.g., cesium-137) and alkaline earths (e.g., strontium-89 and strontium-90) are collected at a much lower efficiency on gummed surfaces than the less reactive metals and their less soluble oxides (e.g., zirconium-95, cerium-144 and yttrium-91). The lower collection efficiency for the presumed soluble fallout (alkali and alkaline earth metals) has been attributed to washing off by rain. When rain water is collected in a pot and filtered, nearly all the strontium, barium and cesium isotopes pass through the filter and are presumed to be in solution at the time they are deposited in rain (this may not always be true for cesium). Conversely, the less reactive material composing the bulk of the gross radioactivity is generally associated with the particulate material.[4]

A. Soil-Plant Considerations

For discussion purposes, the movement of radionuclides through the food chain can be conveniently considered by examining the system's major components. These are the soil, plant and animal. However, in order to evaluate the overall hazard from deposition and movement in the food chain all the components must be considered on an interrelated behavioral basis.

A major part of the biological experimentation concerned with radionuclide movement in the food chain, especially with fallout constituents, has been done with soluble forms of the respective radioisotopes. Consequently, the observed effects are assumed to exceed those which would be expected from the less soluble fallout. Use **of** soluble sources is presumed to provide maximal effects.

1. Soil considerations[5]

Radionuclides presently in soils are of two kinds - natural and artificial. The natural radionuclides are either extremely long-lived such as potassium-40, thorium-232 and uranium-238, or they are daughters of long-lived radionuclides such **as** radium-226, polonium-210, bismuth-212, etc. The artificial radionuclides are man-made fission products which have become widely distributed in soils by atmospheric circulation and deposition. The most important radionuclides of this group being those of relatively long half-life such as, strontium-90 and cesium-137.

Although the natural radioactivity contents of soils is much higher than that of the fission products, the movement of natural radionuclides in the food chain has not caused much concern for human health. Possible reasons are that these radionuclides have always been with us and natural variations in their abundance have not caused any apparent differences in human well being. Except for the element potassium and radium, there

have been few studies on the availability of natural radionuclides in soils for food chain transference. For potassium the majority of studies carried out have been more concerned with the natural elements' nutritional value rather than its radioactive significance. On the other hand, there has been much concern for fission products in soils of agricultural importance and in materials from these soils that are used for food. This concern is due primarily to 1) the artificial nature of these fission products, 2) their potential as significant contaminants of the food chain, **3)** the health implications to the human population, and **4)** a nerd to be able to predict the behavior of much higher concentrations of them in soils. Much work is presently being undertaken to find ways to minimize plant uptake of these fission products from soils. This area of study can be termed the effects of "soil amendments".

a) Soil characteristics[6]

Soils consist of mineral and organic matter, water, and air **arranged in a** physicochemical system that provides for plant rooting and nutritional supplement. **A** vertical profile through various soils reveals horizontal layers which differ in their physical characteristics and their ability to support different kinds and quantities of vegetation. In **a** typical situation three layers may be recognized. The uppermost, which may range from 1 to almost 2 feet in thickness, is the surface soil which supports the majority of the life processes taking place. The second layer consists of the subsoil, extending to about three feet below the surface. Further below the surface yet, to a depth of about 5 feet, is a layer of loose and partly decomposed rock which is the parent material of the soil.

The inorganic portion of the surface soil may be categorized into a number of textural classes, depending on the percentage of sand, silt and clay. Sand consists predominantly of primary minerals such **as** quartz and has a particle size ranging from *50* microns to about 2 millimeters; silt consists of particles in the range of 2 to 50 microns; while, the clay particles are smaller than 2 microns in diameter. The clay fraction of soils is largely responsible for controlling the processes which provide nourishment for plants. The platelike particles of aluminum silicates comprising the clay contain an abundance of negative surface charges which attract positively charged ions. This is one of the most important properties of soils. Most of the positively charged nutrient ions in soils are not in the water phase, but are absorbed on the surfaces of soil particles. In this way a greater reservoir of nutrients can be held in solution by the soil water. If soil clays did not have this ability to bind cations many dissolved nutrients would not remain in soils but would be leached from them by normal water movement. In contrast to cation nutrients in soils, anion nutrients generally exist in combination with organic matter or as anions while in the inorganic form. These anion nutrients must generally undergo decomposition to inorganic anion forms before being utilized by plants. There is no anion exchange mechanism in the soil similar to the cation exchange mechanism.

Cations entering soils in water solution are exchanged with cations adsorbed on the surface of clays. With time soils become acidic as a result of the replacement of adsorbed cations by the hydrogen ions of water. Because of this hydrogen ion buildup soils must be limed (addition of calcium hydroxide) from time to time to assure optimum plant growth. The liming procedure replaces the hydrogen ions with calcium and magnesium ions.

b) Soil reactions[3, 6, 7, 8, 9, 10, 11]

Soil contamination is the first step in the process of plant root uptake. Radionuclides are made available for uptake by 1) soil penetration by rain water or natural erosion processes, and 2) mixing into the soil by cultivation practices. In the first case, the resulting concentration gradient of radionuclides coupled with the rooting pattern and depth of plant structures are important considerations in plant uptake. In the second case, cultivation methods such as plowing, harrowing and discing mixes the fallout to depth of cultivation and increases the uptake by plants grown in soil. In general rapid soil penetration is dependent on the structure of the soil, adsorptive properties of the radionuclide, electrolyte concentration of the soil and the rate of water movement down through the soil. Rapid penetration is enhanced by low humus and low clay content, low valence, high electrolyte concentration of the soil and rapid movement of water.

Since the adsorption of nutrients or inorganic ions by the roots of plants usually involves soluble exchangeable ions in the soil, the radioactive ions compete with and replace other ions on exchange sites in the soil. In some of the reactions with the soil, the new ions of fallout origin become nonexchangeable and some quantity of the radionuclides become unavailable for plant uptake. Thus, the availability of a radionuclide for plant uptake from the soil depends on the types of interactions that occur between the soluble radionuclide and the soil constituents. Several of these soil radionuclide interactions are listed below.

Adsorption[6]. The exchange capacity is the term commonly used to designate the ability of a soil to adsorb

cations. It is usually expressed as the number of milliequivalents of cation(s) required to neutralize the negative charge of 100 grams of soil at a given pH (usually 7). In general, the adsorption of an ion will depend on its ion exchange properties-valence, ionic size and chemical form in solution. Radionuclides exhibiting favorable ion exchange properties will be removed from the soil solution in a sequential manner dependent on their relative affinities for the adsorption media. For example, a trivalent ion would be more readily adsorbed than a divalent ion which in turn would be more readily adsorbed than a monovalent ion. However, other factors may override the above. Thus, cesium-137 (monovalent) is more strongly adsorbed than strontium-90 (divalent) in many soils as a result of its entrapment in the lattice structure of some clays.

Desorption[3]. Desorption can be considered in its broadest sense as the reverse of the adsorption process. Those radionuclides which are most strongly adsorbed will be the most difficult to desorb or leach from the soil. In the strontium-cesium example cited above, water desorption of cesium is less than that of strontium. The amount of desorption of the above two ions can be altered by the characteristics of the leaching solution (salt concentration, acidity and presence of complexing agents) and by the characteristics of the soil (base saturation and buffer capacity). Addition of amendments such as lime and organic matter also change desorption phenomena. Since adsorption is the primary and initial retention mechanisms in the soil and desorption is the primary mechanism affecting availability to the plant root, both adsorption and desorption phenomena are important in considering subsequent plant uptake. These parameters are especially important with respect to the rate and total quantity of radionuclide movement in the soil.

Presence of other ions[3]. The presence of other ions exert a strong effect on the adsorption of a particular cation. When used in large amounts all cations will reduce the adsorption of strontium and cesium. The usual replacement of cations on soil materials is lithium < sodium < potassium < ammonium < rubidium < cesium < hydrogen < magnesium < calcium < strontium < barium < iron < aluminum < lanthanium. The presence of anions have also been shown to have a marked effect on cation adsorption. The order of decreasing strontium adsorption in the presence of anions is sulfate > chloride > nitrate while increased adsorption occurs with oxalates and phosphates.

Effect of pH[3]. Most studies of pH effects on soil reactions have varied the pH of the leaching solution. These studies have attempted to duplicate the actual condition which is variation of soil pH instead of pH variation of the contaminating solution. Such investigations have yielded data of the type illustrated in Table 1.

Table 1.[3] Maximum Adsorption as a Function of pH

Radionuclide	pH
Strontium	7-9
Cesium	>6
Yttrium	>6
Cerium	>6
Plutonium	2.5-9

At highly acidic and alkaline conditions, soil minerals decompose and yield decomposition products which compete with the fission products for adsorptive sites. Under these conditions it is expected that there would be less radionuclide adsorption.

Fixation[3,9]. Fixation of radionuclides in the soil is a process that renders these constituents unavailable to plants. Neutral salt solutions are usually used to extract the exchangeable cations from soil. These extracted cations are considered to be the cations that are available for plant nutrition. The amount of fixation in a particular soil is the difference between the amount of cation applied and the available or extractable amount. The degree of fixation is an arbitrary term which depends on the experimental methods used. Current investigation in this area has indicated, especially with respect to strontium and cesium, that fixation is a property of the soil type since both fixed and non-fixed quantities of these elements have been found in soils. Several mechanisms that have been proposed for the fixation process include precipitation as slightly soluble materials, physical trapping between clay platelets and in other insoluble precipitates, and diffusion into existing crystals.

Effect of organic matter[10,11]. Additions of large quantities of organic matter (tons per acre) affects soil reactions and subsequent plant uptake. The major factors involved here appear to be an increased microbial activity which competes with the soil and plant for the mineral elements; and an increased tie-up of ions from the soil solution by the adsorptive capacity of the added organic matter. The net effect observed with respect

to radionuclide behavior is a reduction in plant uptake. The amount of reduction is primarily a function of soil type and radionuclide.

2. Plant characteristics

Plants are a major vector in the transfer of radionuclides from the environment to man. Contamination occurs by two processes: soil uptake and aerial uptake.

a) Soil uptake[3, 6, 12, 13]

Although almost every element can be found in soil to some degree, sixteen elements are considered necessary for the growth and reproduction of plants. These are carbon, hydrogen, oxygen, nitrogen, phosphorus, sulfur, potassium, calcium, magnesium, iron, manganese, zinc, copper, molybdenum, boron and chlorine. Carbon, hydrogen and oxygen are primarily supplied by the atmosphere while all others are supplied from the soil. Radionuclides of the above elements will pass into the plant root in the same manner as the stable forms. In some cases the radionuclide element may not be required for normal metabolism (e.g., iodine, cobalt, uranium and radium); however, they are known to be present in plants although no metabolic function is known. In general it can be assumed that if the ion is in the soil it will probably occur to some greater or lesser extent in the tissue of the plant grown in the soil.

The more important factors that affect the uptake of radionuclides by plants through their root systems are 1) the chemical and physical form of the ion of the radionuclide, 2) the plant species and its metabolic requirements, 3) the soil type and chemical characteristics and 4) the soil management practices. Numerous theories have been proposed for the mechanism of uptake of ions by plant roots. Most hypothesis agree that the uptake of the element occurs in an ionic form, and the concentrating of the element within the plant root is a metabolic function. Most of the mechanisms also provide for a biological compound that serves as a carrier for the element. Disagreement in the various hypothesis occurs in the areas of the exact mechanism of uptake and the transporting mechanism(s) of ions between soil and plant root.

The relative uptake of various elements from soils have been shown to be strontium > iodine > barium > cesium, ruthenium > cerium > yttrium, promethium, zirconium, niobium > plutonium.[12] Where commas appear between the isotopes, difficulty has been encountered in determining the relative order of magnitude of uptake. In a particular soil at comparable activity levels the relative order or uptake by plants does not vary much but the total quantity taken varies considerably with different soils. Variations that are encountered in the order and absolute magnitude of uptake result from the differences in radionuclide concentrations in the soil and in the reactions of the various radionuclides with the different soils. With respect to radionuclides from nuclear detonations, about two percent of the radioactivity in a contaminated soil may be absorbed by a single crop of plants.[3] However, soils usually adsorb less than a tenth of a percent of the total deposited. Strontium-89 and strontium-90 absorption may account for as much as seventy percent of this total from one year old mixed fission products. It is generally accepted that about one percent of the applied strontium will be taken up by single crops of plants. Less than one tenth of a percent of the deposited amount of other elements is taken up by single crops of plants. Higher amounts of uptake of some of the radionuclides may be obtained in pot experiments.

The translocation of radionuclides is believed to be primarily governed by the uptake process and less by plant metabolism. The main route appears to be the central zone of the vascular tissue of the plant. Upward movement of the elements strontium and calcium relative to that of phosphorous, sulfur, iodine and rubidium is limited. Cesium, rubidium and potassium exhibit a greater redistribution within the plant than does strontium, calcium, yttrium and other multivalent cations.[3,12] Radionuclides of higher valence such as strontium-90, ruthenium-106, cerium-141, yttrium-91 and zirconium + niobium-95 tend to accumulate in the leaves to the highest extent relative to fruits and stems. Radionuclides of lower valence such as cesium-137, rubidium-86 and potassium-40 are distributed more uniformly throughout the plant and exhibit less preference for a particular plant structure. Plant content of these radionuclides will vary with the stage of plant development. With respect to species differences, the order of fission product uptake by the different plant families has been reported as Leguminasae (pea family - clover, alfalfa, beans, etc.) > Solanaceae (potato family - tomatoes, potatoes, tobacco, etc.) > Compositae (composite family - dandelions, lettuce, sagebrush, etc.) > Gramineae (grass family - crab grass, wheat, rice, etc.) for the tops and Leguminasae > Compositae > Solanaceae for the roots. However, other investigators report no consistent differences between the lower and higher plant families."'

b) Aerial contamination and uptake[3,6,8,13,14,15,16]

In addition to indirect plant contamination (i.e., absorption from the soil) three methods of direct plant

contamination have been established:

Foliar deposition. This term refers to the deposition of radioactive materials on the leaves of the plant. The deposited radioactive material may a) adhere to the leaf surface, b) be absorbed into the leaf or c) washed from the plant onto the soil. The magnitude of plant contamination from this process will depend on the radionuclide(s) deposited, plant species and existing weather conditions.

Floral absomtion. This term refers to the absorption of the deposited materials by the inflorescences (flowering parts) of plants. For example, the inflorescences of wheat plants have a shape that tends to maximize entrapment of fallout particles. Thus, contamination of this plant shortly before maturity results in greater radionuclide absorption in the peripheral part of the plant.[8]

Plant base absomtion. This term describes the absorption of material that has been washed down to the basal parts of the plant. Material absorbed in this fashion may or may not be diluted by other elements of the soil.

Plant contamination may thus be caused directly by foliar and floral contamination or indirectly by absorption from the soil. **A** combination of direct and indirect contamination is possible by plant-base absorption.

The relative importance of these alternative routes of entry will depend on the growth form of the plants and the role of the various parts of the plant in relation to the dietary habits of man. Foliar absorption occurs readily in all species whereas floral absorption is of practical significance with grain crops only. Plant-base absorption is particularly important in perennial pastures but not necessarily confined to them. In many cases it is difficult to distinguish between foliar absorption and either floral or plant-base entry. During rain the contamination may wash downward over the surfaces of the plant and foliar and floral absorption merge into plant-base entry. **As** materials are further leached into the soil surrounding the plant-base, plant-base entry becomes indirect absorption through the roots.

Direct contamination is' also a function of the size and solubility of the contaminant. Large particles characteristic of near-in fallout from nuclear detonations usually rebound from leaf surfaces. In general particles larger than 40 microns in diameter are only slightly retained.[16] Particles larger than this diameter are associated with local fallout but are not characteristic of fallout at considerable distances from the detonation. Insoluble materials which are more characteristic of near-in fallout result only in superficial plant contamination. The greatest plant contamination occurs from finely divided soluble deposits - world-wide fallout is in this form. It is important to note that findings based on one situation are not applicable to the other (i.e., plant contamination due to local versus world-wide fallout).

Little data are available showing the extent of fission product uptake by above-ground plant parts from world-wide fallout. However, evidence is increasing that the major portion of plant contamination from fallout has resulted from deposition on foliage.[8,16] The exact quantity contributed may primarily depend on the plant's growing habits and on the existing weather conditions during the absorption period. Tracer studies indicate that entry can occur through the leaves, stem, fruit and bark. The extent of entrance of materials in solution into plants appears to be directly proportional to the amount applied and to the time period of absorption. Other significant information such as the rate of absorption, extent of internal transport and pattern of distribution within plants is dependent on the specific radionuclide, plant and other internal and external factors. With respect to the extent of internal transport, several studies have indicated both acropetal (transport to the tip or extremities of the petal) and basipetal (transport to base of petal), transport occurs following application of phosphorous-32, potassium-42, rubidium-86 and cesium-137 to above-ground plant parts. In contrast to this calcium-45, strontium-89 and 90, yttrium-90, ruthenium-103 and barium-140 do not move freely from the absorbing organ and basipetal transport is negligible.'")

3. Soil-plant relations[3,13]

The soil and plant components of the soil-plant system are individually complex. The system is dynamic in that there is a steady input of ions by the soil and a steady uptake of ions by the soil and a steady uptake of ions by the plant. When the input equals the uptake for **a** specific element steady state conditions prevail. From a nutritional standpoint, steady-state conditions are probably common for many vegetative forms in the environment. However, for world-wide fallout this is most probably not the case because of the limited residence time of most radionuclides in the soil. The degree of attainment of steady-state conditions may often be regulated by one or more of the soil-plant factors mentioned in the preceding sections.

a) Effects of soil amendments

Various soil amendments have been investigated in order to reduce plant uptake of radionuclides from the soil. Among these are lime, gypsum, fertilizers and various types of organic matter. Most work in this area has been concerned with the fission-product strontium-90 since it is the most hazardous radionuclide that undergoes absorption from the soil. Limited work has been reported for cesium-137, ruthenium-103 and cerium-144.[3]

When amendments are added to the soil two processes occumng within the soil are altered: 1) the exchange reactions governing the distribution of ions between the clay and the soil solution and 2) the competitive effects during the course of absorption by plants. Since various cations will compete **for** the same adsorption site, increasing the concentration of one decreases the uptake of others in the same group. This hypothesis has been proved to be correct within certain ranges by numerous greenhouse and field experiments. For example, the addition of calcium to acid soils low in calcium content results in a reduction of strontium-90 uptake. Similar observations have been observed on the uptake of cesium-137 from soils low in potassium when stable potassium is added. In some investigations fertilizer has increased the uptake of fission-products, but in others no increase occurred. The effects of organic matter have been cited previously.

In general, the soil that will provide minimum uptake of fission-products appears to be one that is ideal for maximum crop growth. These prerequisites include a soil of high exchangeable calcium, high exchangeable potassium, high organic matter content and a slightly alkaline reaction.

b) Concentration factors and observed ratios[3]

Since the uptake of a radioelement depends on its concentration in the external medium, the term concentration factor is often used to express the relative uptake of different elements. It is defined **as** the ratio of plant tissue concentration to the external medium concentration. Results from solution culture studies are usually expressed in the fresh tissue weight while oven dry weight is used for soil culture studies. The formula for calculating concentration factors is presented in Equation 1.

$$\text{C.F.} = \frac{\mu\text{Ci/g plant tissue}}{\mu\text{Ci/g external medium}} \qquad (1)$$

There is relative agreement in the order of concentration factors for different radioisotopes using various laboratory and field procedures. Some reported concentration factors for fallout radionuclides in soil culture experiments are 0.05 for the alkaline earth group and 0.009 for the rare earths. Using soluble forms in nutrient solution concentration factors from 0.05 to 1.0 have been observed for strontium, cesium, iodine and barium. For ruthenium, yttrium and cerium the range is 0.0001 to 0.001. Thus, the concentration factor is an arbitrary term which depends on the experimental conditions.

Another term used quite often to describe the quantitative soil-plant relations is the Observed Ratio. The OR is **used** to report the uptake of fission-products relative to a chemically similar element. For example, the OR for strontium is the ratio of strontium to calcium in the plant(sample) divided by the ratio of strontium to calcium in the nutrient medium (precursor). For calculation purposes the Observed Ratio is determined as indicated in Equation 2.

$$\text{OR(sample/precursor)} = \frac{\text{Sr/Ca(sample)}}{\text{Sr/Ca(precursor)}} \qquad (2)$$

The OR (plant/nutrient solution) for strontium relative to calcium when only plant discrimination is measured is close to 1.0. This indicates no discrimination against strontium and is generally true for all plant parts except the roots, where OR values larger than 1 have been observed. Other OR values reported for the rubidium/potassium and cesium/potassium systems in various plants are 0.85 and 0.20 respectively: These systems indicate discrimination against rubidium and cesium in favor of potassium.

c) Soil versus aerial contamination[2,17]

In evaluating the effect of deposition to man an additional consideration of some importance in soil relations is the significance of soil versus aerial contamination with respect to subsequent transfer of radioactive materials up the food chain. More recent deposition is believed to contribute predominantly to foliar and floral contamination (direct), whereas the older deposit regulates the absorption from the soil. **If** contamination of man's diet comes primarily from the direct mechanism, the radioactivity levels in the diet would be expected

to be related to the quantity of current deposition. Under these conditions a decrease in the rate of deposition would result in a rather rapid decrease in dietary contamination. Alternatively, the primary mode of dietary contamination may be the indirect method. In this case the levels appearing in the diet would be dependent on the cumulative deposit in the soil and the extent of equilibrium conditions within the soil system. Since the cumulative deposit and attainment of equilibrium conditions are time dependent, dietary contributions from soil absorption would be of greater significance on a longer term basis. If deposition ceased completely, dietary levels resulting from soil absorption would fall slowly due to the decreasing availability of fission products to plant forms. This decreased availability would be due to 1) the slow radioactive decay of the cumulative deposit and 2) the loss of existing soil deposited radionuclides through physical processes (e.g., leaching).

B. Plant-Animal Considerations

From the preceding sections, root uptake and aerial contamination have been identified as the methods by which radioactive materials contaminate crops that are eaten by man or that serve as food for stock animals. Much remains to be learned about how each radionuclide moves from the root into the edible portion of the plant, through the body of an nals and into the **milk,** meat and other foods of man. More yet remains to be learned about the behavior and distribution of radionuclides in the bodies of animals and man. **A** quantitative understanding of these relationships is needed before the dose received by man from the deposition of a radionuclide in the environment or the concentration in a food can be evaluated.

1. Contamination of animals and animal products[0]"

Certain radionuclides are readily transferred to the human population via domestic grazing animals which are effective collectors of contamination from various vegetative forms. There are many factors which effect the degree to which animals are contaminated. The most important include 1) pasture type used for grazing, 2) extent of barn feeding (purchased and stored), **3)** miscellaneous feeding practices - age of food and supplemental feeding use of purchased feed, etc., **4)** water source and *5)* animal housing - degree of sheltering animals from surface contaminants. Because of the many variables involved the degree of animal and animal product contamination may be quite variable, even from apparently similar sources.

Of particular interest in this pathway of the food chain are the relationships that exist between the quantities of radionuclides ingested by the animal and the subsequent quantities which are deposited in the tissues and secretions that serve as human food. To study these relationships requires a knowledge of the metabolic characteristics of the animal and the particular radionuclide. The following section on radionuclide metabolism presents a general discussion of various aspects of the subject.

2. Radionuclide metabolism[18,19]

Classically, metabolism refers to the biological processes whereby complex cellular elements are synthesized (catabolism) or conversely complex substances are degraded (anabolism) to supply energy for biochemical reactions. Kinetics usually refers to the phases of metabolism involving rates of transfer and compartment volumes, i.e., various tissue spaces into which a substance is distributed. In general, from the point of view of radiological hazards, interest focuses mainly on the kinetic aspects of metabolism.

Radionuclide metabolism is arbitrarily considered as organic or inorganic though such a distinction cannot, in fact, be made. Organic metabolism is somewhat synonymous with the more commonly referred to processes of intermediary metabolism. Illustrative of this would be the passage of carbon-I4 through a biological system. Minerals, e.g., potassium, sodium, calcium, strontium, etc., may be viewed as being an inorganic phase. This arbitrary separation only simplifies the study of radionuclide metabolism.

a) Experimental methodology in metabolic studies

Metabolic studies of radionuclides and oftentimes their stable counterparts are applications of tracer experimentation. Tracer concepts can generally be **used** for the study of radionuclides in biological systems though one must realize the assumptions inherent in the theory. Illustrative of the latter are situations in which a tracer is not homogeneously distributed in **a** compartment such as the skeleton.

Only fundamental approaches will be cited. Upon introduction of isotopes into the animal body, concentrations in various body fluids, excretory products and biopsies containing assimilated material can be analyzed. Sacrifice of the animal and proper dissection lead to more precise distribution and concentration assays. Techniques of autoradiography lead to knowledge of differential distribution as well as quantitative data. Yet, methods employing sacrifice give data only applicable to some increment in time.

A method of nondestructive study would be ideal but such is not yet available. In recent years, techniques of total body counting have been developed and, applicable in localizing as well as quantifying radioisotope within the body. At present, this system is only useful in studying gamma emitting nuclides within the animal.

Most metabolic data have resulted from single dose experiments. In some instances, single administration data **may** not provide complete information and multiple doses of the same nuclide may be required. Study of skeletal metabolism is probably the best example **of** the latter since a non-homogeneous distribution results from a single dose. More exacting procedures utilizing multiple radioactive forms **of** the same nuclide *can* greatly enhance the information in a study of metabolism. Thus chronic administration, especially simulating fallout conditions, needs to be carried out to give an adequate picture of the metabolism of certain nuclides.

b) Methods of data interpretation

In the study of radionuclide metabolism most data have been represented by an exponential function with regard to accumulation, transfer and elimination:

$$R = Ae^{-\lambda t} \tag{3}$$

where:

R = quantity in biological compartment at time t
A,X = constants characteristic of the compartment
e = exponential function

The latter is appealing and would be expected if the biological system functioned as a simple diffusion process. Also, the concept is similar to the exponential decrease seen with radioactive disintegration. Hence the concept of biological half-life analogous to radiological half-live evolves and one may speak of a biological half-life for loss of the radionuclide through biological processes. With more detailed metabolic models, a multiple exponential form has been **used.** This model assumes that the radionuclide is distributed among several biological compartments and is lost from each with a characteristic half-life. The equation takes the form:

$$R = Ae^{\lambda_1 t} + Be^{\lambda_2 t} + Ce^{\lambda_3 t} + \ldots \tag{4}$$

where:

R is the amount retained at time t and A, B, C and λ_1, λ_2 and λ_3 are constants characteristic of the various compartments.

Another expression that has been used quite often relates retention of some radionuclides, especially bone seekers, to a power function of time:

$$R = At^{-b} \tag{5}$$

where:

R is the amount retained at time t and **A** and b are constants.

With a sufficient number of terms, the multiple exponential expression can give **as** good a fit to experimental data **as** the power function. However, when both methods are extrapolated beyond the data on which they are based the two forms lead to widely varying results. It is probable that a number of mathematical functions will ultimately be required to adequately interpret the multiple biological functions inherent in metabolic phenomena.

c) General considerations involved in radionuclide metabolism

1. Routes of assimilation

For practical purposes only the gastrointestinal mode of entry of nuclides into the compartments of a biological system are important. In special situations, the pulmonary and **skin** routes may be important in permitting assimilation. The intravenous route of entry is artificial and only important as an experimental tool. However, it must be noted that it simulates the situation once a nuclide is absorbed into the blood stream. This method to some extent bypasses the uncertainties involved in study with natural routes of assimilation.

The gastrointestinal system is probably the most important route of entry for soluble forms of nuclides. Insoluble forms will, dependent on the degree of solubility, remain in the gut with this organ receiving the bulk of the radiation exposure. Alpha emitters will dissipate about one percent of their energy in the tissues of the gastrointestinal tract. A much greater percentage of the energy from beta emitters will be absorbed and dissipated within the gastrointestinal tract. Insoluble gamma emitters will effectively radiate the intestine, however, the rest of the body will also be exposed.

Pertinent examples of the more important fission products are tabulated in Table 2.

Table 2.[8,20,21] Characteristics of the More Important Fission-Products of Food Chain Significance

Radioisotope	Yield U^{235}(a) (%)	Yield U^{238}(b) (%)	Type of radiation	Physical half-life	GI absorption[c]
Sr^{90}/y^{90}	5.1	3.2	β	28 years	30
Cs^{137}	6.2	6.2	β, γ	29 years	100
Pm^{147}	2.9		β	2.6 years	0.01
Ce^{144}	5.0	4.5	β, γ	285 days	0.01
Ru^{106}/Rh^{106}	0.5	2.7	β, γ	1.0 years	0.03
Zr^{95}	6.3	5.7	β, γ	65 days	0.01
Sr^{89}	4.6	2.0	β	51 days	30
Ru^{103}	3.4		β, γ	39.7 days	0.03
Nb^{95}	6.3		β, γ	35 days	0.01
Ce^{141}	6.0		β, γ	33 days	0.01
Ba^{140}/La^{140}	6.1	5.7	β, γ	12.8 days	5
I^{131}	3.1		β, γ	8.05 days	100

(a) Thermal neutron fissioning, (b) Fast neutron fissioning, (c) Assume radionuclide occurs in soluble form

Gastrointestinal absorption for the nuclides range from 100 percent for iodine-131 and cesium-137 to less than one percent for seven of the other potential environmental contaminants listed. Table 2 assumes that the radionuclides occur in a soluble form on ingestion. Most are both gamma and beta emitters. Active versus passive absorptive mechanisms plus the physicochemical nature of the nuclide are responsible for selective absorption. Yet, nuclides such as iodine-131 are 100 percent absorbed, no matter what form in which they are administered. Absorption of strontium can vary markedly, dependent upon chemical forms whereas almost all forms of zirconium are insoluble.

2. Solubility versus insolubility

The physicochemical nature of the radionuclide bears great influence on its passage through a biological system. Such factors as the particular compound in which the nuclide is incorporated, the valance state and ionic form, particle size, complex formation, and whether bound to a protein make great differences in the biological activity of radionuclides. These parameters are usually simplified by categorizing the physicochemical form of the nuclide as soluble or insoluble. Also, it is important to recognize that some nuclides especially those high in atomic number are insoluble of themselves, regardless of any other physical or chemical characteristic. Thus, often a barrier to the incorporation of certain nuclides into biological systems exists due

to their very nature.

3. Influence of other nuclides on assimilation

The presence of other elements and compounds of other elements will often greatly influence the assimilation of nuclides. Numerous interrelationships exist between metabolic phenomena, e.g., influence of calcium on strontium retention.

4. Absolute versus relative uptake

In certain instances, especially due to the nature of the biological mechanism involved, there may exist relative and absolute degrees of nuclide assimilation. Certain biological systems may have specific quantitative requirements per unit time. For instance, would calcium continue to be absorbed from the diet if its concentration in the diet was constantly increased? More likely an absolute amount may be absorbed per unit time with rejection of the excess dietary calcium. If assimilation were to be expressed in terms of percent absorption in this instance, one would be misled. Thus, the concept of relating assimilation to fractional uptake could be inaccurate in describing the biological phenomena.

5. Specific activities and biological availability

The expression of nuclides in terms of specific activity (SA = radioactive/stable) often times more adequately describes the biological processes. However, it must be stipulated that the radioactive and stable forms of the nuclide be homogeneously mixed before specific activities of various compartments may be intercompared. In the diet, presence of the radioactive and stable elements as different compounds with different solubilities may make an expression of specific activity invalid, for the physicochemical form must be the same in order that both be metabolized in the same way. Hence, a specific activity may be present in the biological system, even after equilibrium, because of differences in physicochemical availability.

6. Deposition of nuclides within the biological system

Little generalization can be made about nuclides in this all important phase of metabolism. Nuclides do fall into somewhat gross categories such as "bone seekers", "marrow seekers", etc. Although a nuclide may have an inclination for certain organs it is important to realize that metabolism in that organ may be considerably different for different nuclides seeking the same organ. Thus, calcium and radium can be incorporated into bone in entirely different ways.

7. Routes of elimination

Urinary and fecal excretion are by far the most important exits of nuclides from the body, varying in importance with particular nuclides. Sweat, sloughing of various skin structures, exhalation and secretions of minor organs may contribute to excretion. Perspiration losses of calcium, sodium, and potassium may be significant and should be recognized in balance studies.

d) Metabolic classification of radionuclides

No completely satisfactory classification of nuclides is possible. One approach is to group the nuclides according to position in the periodic table. It would be expected that nuclides of the same group would behave similarly because of their like chemical properties. However, caution must be taken in accepting the latter assumption. As examples, elements of Group VII, fluorine, chlorine, bromine, iodine, and astatine have strikingly different modes of metabolism. Fluorine is deposited in bone, chlorine and bromine are fairly equally extensive with the extracellular fluid space, and iodine is concentrated in the thyroid gland. Astatine is also localized in the thyroid gland.

1. Hydrogen (tritium)

Tritium is of major importance as tritiated water. Tritium equilibrates rapidly with total body water and its loss from the body is determined by the turnover rate of the body water which can vary widely depending upon fluid intake. An average biological half-life of twelve days is assumed. Tritium oxide is one of the few radionuclides absorbed through the intact skin.

2. The noble **gases**

Of neon, argon, krypton, xenon and radon, only the latter has received considerable attention. The metabolic characteristics of this group is characterized by differential solubility in body fats and the absence of chemical reactions with body components. Radium is transferred through the food chain and deposited in bone with subsequent radon liberation. Recent developments in this area are concerned with the retention of the liberated radon. Recent investigation indicates that in long-standing cases of radium poisoning an average of seventy percent of the radon produced is exhaled.

3. The alkali metals - **Group I**

Though, sodium, potassium, rubidium and cesium are members of Group I, their metabolic fates are considerably different. Again, pointing out the fact that like chemical properties, does not always indicate like metabolism. Indeed, their biological half-lives are 11, 35, 80, and 110 days respectively - a marked range.

Potassium-40, the most abundant natural isotope in biological systems is not a fission product. Its exceedingly long physical half-life of years has resulted in an abundance of the radionuclide remaining since the time of creation. Its distribution is more principally intracellular in mammals with much lower concentrations present in extracellular fluids (lean body mass). It is one of the most easily measured gamma emitting radionuclides present in animals. Roughly, there are 2.2 grams of potassium per kilogram of lead body mass and it is one-hundred percent absorbed with most of it being excreted in urine.

Sodium is of interest mainly as an indicator of dose after neutron exposures with production of sodium-24 in the body. Studies with sodium-22 have elucidated the metabolism of this element. It is distributed mainly in the extracellular fluids with much lower intracellular concentrations. Significant concentrations of sodium are retained in the mineral portion of bone with a very slow turnover rate.

Cesium-137 and cesium-134 are fission products found as human contaminants. Cesium seems to be principally concentrated in muscle, but has a similar whole body distribution to that of potassium. The metabolic fate of rubidium more closely resemble cesium than the other alkali metals.

4. The transition elements **of Group I**

Copper, silver and gold have no immediate environmental importance as contaminants of the food chain. The common radioisotopes of these elements have relatively short half-lives, limited gastrointestinal absorption and are used primarily in medical applications.

5. The alkaline **earths - Group II**

As environmental contaminants, elements of this group are undoubtedly among the most important. Barium, lanthanium, radium, calcium, strontium and yttrium are probably the most intensively studied group of nuclides since they are readily transferred through the food chain to man. Strontium, barium and radium are metabolized in a manner similar to calcium. In the animal body they are rapidly and almost exclusively deposited in the skeleton. Some of the radionuclides of longer half-life deposited in the skeleton will remain there throughout life. A single exposure or **a** number of short term exposures result in a heterogeneous pattern of bone deposition. Chronic exposure results in a more uniform pattern of deposition. This dependence of distribution on duration of exposure further complicates dose evaluation.

Barium-140, a fairly short-lived fission product, is of lesser metabolic interest due to its short half-life (12.8 days) and limited gastrointestinal absorption. The metabolic behavior appears very similar to that of strontium.

Research into the metabolism of radium dates at least to the 1920's, stemming from industrial and medical contamination of many people with the radionuclide. Gastrointestinal absorption is approximately 30 percent of ingested dose. In general, radium is deposited in bone and is retained there for long periods of time. Irregular deposition in osteons with "hot spot" formation has **been** stressed resulting in tumor formation, etc., if the concentration is great enough. Normal total body concentration has been estimated at 1×10^{14} gram. The degree of deposition in other tissues of the body is unsettled and there is some confusion on this point with recent reports of high concentrations found in soft tissue. Recent **results** of long term studies suggest a m ıch different retention for radium as compared to other bone seekers when interpreted by a power function. This point is extremely important, in that, regulatory standards of deposition of other radionuclides in bone have been based on radium metabolic data.

Radionuclides of the lighter alkaline earths, beryllium, magnesium and calcium have been used extensively in studies of their metabolic behavior but there is no particular environmental hazard from any of these isotopes.

6. The transition elements of Group II

Only zinc-65 is of interest as an environmental contaminant being transmitted in the food chain through aquatic biota exposed to reactor wastes. Neutron activation during fission results in its presence in close-in fallout. This radionuclide is said to be concentrated in the prostate and to a lesser degree in bone and skin, though it still has a wide spread distribution throughout the body.

7. Group 111

The radioisotopes of boron, aluminum and scandium have attracted little interest as internal emitters. Gallium, indium, and thallium have been studied with respect to medical applications. Yttrium and lanthanium are very similar to the rare earths and are considered later with these elements.

8. Group IV

Carbon-14, a natural environmental contaminant due to cosmic ray activation of nitrogen-14, has been increased by about 10 percent through neutron activation of the atmospheric nitrogen-14 consequent to nuclear detonation. The metabolism of carbon is very complex and is almost synonymous with intermediary metabolism. Levels of carbon-14 in man and in the atmosphere (assuming no further nuclear testing) should drop off faster than anticipated from the carbon-14 half-life because of the continuing equilibration of new carbon-14 with the total biospheric carbon. Other elements of this group have been studied for their biological and therapeutic effects but little interest is attached to then as internal hazards from food chain transference.

9. Group V

Only phosphorous-32 is of major importance as an environmental contaminant. It is an activation product formed in reactor cooling water and can be concentrated to significant levels by aquatic food chain forms. Niobium as a daughter product of zirconium-95 is present in fallout materials but is of no more importance than its parent because of limited gastrointestinal absorption. Other radioisotopes of this group are of primary interest from a toxicological and biochemical aspect.

10. Group VI

There are no prominent fission product radionuclides in this group with respect to significant food chain contamination. Molybdenium-99, a fission product and chromium-51, an activation product, are introduced into the environment in limited quantities but are of little significance as a result of their relatively short half-lives and limited gastrointestinal absorption. Sulfur and polonium have been the most extensively studied isotopes of this group. Radioisotopes of the transition elements of this group, chromium, molybdenium and tungsten have all been used in biological studies.

11. Group VII

The isotopes of radioiodine are the only fission product in this group of significant environmental importance. They are characterized by their ability to concentrate in the thyroid gland and their short physical half-lives.

12. Group VIII

Although the activation products iron-59 and cobalt-60 may be released to the environment from reactor operations and associated processes, they are not environmentally significant contaminants because of their limited absorption in terrestrial organisms (mainly limited gastrointestinal absorption). However, they are used extensively as biological tracers in medical and related areas. Of the other elements of this group, only ruthenium has received considerable attention. Ruthenium-103 and 106 are prominent short-lived fission products resulting from nuclear testing. Though virtually non-absorbed by various food chain forms, the small amount gaining entry into animals is deposited initially in the kidney and liver with longer retention in the skeleton.

13. The rare earths and actinide elements

The rare earths (lanthanides) and the actinides in addition to yttrium behave metabolically similarly. The rare earths are produced in high yield from fission reactions of the elements of the actinide series. These radionuclides behave similarly in the majority of their chemical and biochemical reactions. Once absorbed most are deposited in bone with degrees of localization in the liver and reticuloendothelial system (that which engulfs foreign particles in the animal body). There is a noted progression with increasing atomic number in the chemical behavior within these groups (more noted in the lanthanides) which is reflected in changes in their biological behavior. With increasing atomic number, there is a greater tendency for bone deposition and less for deposition in the liver. The lighter elements tend more to fecal and heavier ones more toward urinary excretion. Bone retention is much longer than in other organs. Their distribution appears to be particularly sensitive to the quantity of material involved. Carrier free radioisotopes are concentrated to a greater or lesser extent in bone while, with the addition of stable element along with the radio-element, there is a tendency for deposition in the liver and reticuloendothelial system. The exact mechanism of bone deposition for these groups is believed to be different than that for the alkaline earths.

Although radionuclides of these elements are widely distributed over the earth, they have not been identified in appreciable quantity in plants, animals and man. This is a consequence of their extremely low solubility in biological materials and corresponding low absorption from the gastrointestinal tract. In most experimental animals, less than one-hundredth of a percent of an ingested dose is absorbed.

COMMENTARY

The contamination of the terrestrial food chain from the various uses of nuclear energy constitutes a potential health problem to man. To cope with this problem requires a consideration of the physical, chemical and biological characteristics of the radiocontaminants and the terrestrial food chain. The methods of fission product deposition along with the mechanisms of soil, plant and animal contamination need to be fully understood. With the above considerations in mind, the particular radionuclides of health importance to man in the terrestrial environmental can be identified and their metabolic relationships studied. By sampling the appropriate media a comparison of the quantities of these artificially produced fission products with the naturally occurring radionuclides can be made and then an assessment of the degree of environmental contamination can be obtained.

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II. METHODOLOGY

A. PREPARATION OF SAMPLES

Preparation of food samples for analysis of radionuclides involves three major operations. Each is essential to obtain results which are valid, accurate, and precise.

The first is to insure that the food sample represents the edible portion or the portion actually consumed. Inedible material such as bone, apple cores, nut shells, and egg shells should not ordinarily be included as part of the sample. To be valid as a dietary sample of a meal, the food for the entire meai should be prepared and "served" in reasonable portions or multiples thereof. Any convenient amount of a single food item can be sampled and the radionuclide content reported on a weight or volume basis.

The second operation in food sample preparation is to make the sample homogeneous so that aliquots will be identical in composition. This is best accomplished by blending or homogenizing using commercial blenders or specially constructed homogenizers, depending on the sample load and typical sample size.

The third operation is to put the homogeneous sample into solution. It is accomplished by ashing in a muffle furnace, digesting in acid, by fusing, or by a combination of these. The volatilization temperatures of the radioactive elements to be analyzed influences the choice of procedure. Volatile gamma emitters such as radioiodine and cesium isotopes can be measured in the undissolved homogenate by gamma spectrometry. If a radioelement, volatile at dry ashing temperatures, cannot be determined by gamma spectrometry, it can be analyzed chemically after the sample has been dissolved by acid digestion.

Fresh samples should be analyzed immediately upon receipt or refrigerated for a short time only or frozen. Food samples should be packaged in waterproof containers, and if frozen during storage, thawed prior to analysis. This treatment obviates the need for adding a preservative to the samples. Convenient sample and aliquot size for individual food items or composites of known constituents can be determined from the Table A.

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1. Blending

Several methods of sample blending may be used to homogenize liquid, semi-liquid, and solid samples of food, excluding inedible, hard and resistant parts such as bones and skin. One of the procedures described here can be applied to large or small number of samples or to samples of large or small volume. Because they differ primarily in the type of apparatus employed, choice of procedure will be dictated by the sample load, sample size, availability of funds arid equipment, and personal preference of the analyst.

Principle of Method

The food sample is weighed and thoroughly blended in a homogenizing apparatus until the sample becomes a homogeneous slurry. Portions of the slurry are measured into appropriate containers for analysis by gamma spectrometry and/or for ashing prior to radiochemical analysis.

PROCEDURE

Reagents

none

Apparatus

evaporating dish
laboratory balance

stainless steel electric food blender, 1-gallon capacity

Procedure

1. Weigh the total sample, and homogenize it in a 1-gallon capacity blender. After the sample appears to be a slurry, blend it for 3 minutes longer.

2. Measure 3.5-liters of the homogenized sample into a tared Marinelli type beaker and determine the aliquot weight. This portion is counted for gamma activity in a gamma scintillation spectrometer. After the blended sample is counted for gamma activity it may be transferred to a pre-weighed evaporating dish to be ashed in preparation for further analysis.

2. Ashing

Two similar procedures for ashing food samples are given here. They can be used in connection with the method of blending described above or be applied to a blended dietary sample or a raw, cooked, or unhomogenized food item, although special care must be taken in ashing intact fatty substances. If not homogenized, most samples should be cut into small pieces before being ashed. In each procedure, ambient temperature is progressively increased to reduce the consistency of the sample to that of a coarse gravel.

Muffle furnaces are the only major laboratory equipment needed, and the number of samples that can be ashed per day depends primarily on the number and capacity of furnaces available. The minimum time required to ash a single sample is a little over three days; however, the sample needs to be watched or handled only occasionally.

Principle of Method

The blended sample is dried and then ashed in a muffle furnace by progressively increasing the furnace temperature to 500°-600°C. The ash is then cooled, weighed, pulverized or mixed by a similar method, and divided into portions needed for analysis.

PROCEDURE A

Reagents

none

Apparatus

Corning Ware dish
electric drying oven
evaporating dish
gas oven
muffle furnace
plastic container

Procedure

1. Transfer a suitable portion (see Table A) of a blended sample to a tared Coming Ware dish and obtain the aliquot weight. Dry the sample in an electric drying oven at 115" C for 48 hours.

2. Transfer the sample to a gas oven and char for 4 hours at 250° C. Then raise the temperature to 315" C for an additional 4 hours. Then raise the temperature to 480" C and char for 8 hours more. Remove the sample, and cool it.

3. Transfer the cooled, charred ash to an evaporating dish and place it in a vented muffle furnace. Raise the temperature to 550°-600°C and ash for 16 hours.

4. Cool, weigh, and then grind the ash to a fine powder using a mortar and pestle.

5. Transfer the powdered ash to a plastic container from which portions can be removed for chemical analysis.

PROCEDURE B

Reagents

none

Apparatus

Coming Ware dish
drying oven
muffle furnace
plastic container

Procedure

1. Transfer a suitable portion (see Table A) of a blended sample to a tared Corning Ware dish and obtain the aliquot weight.

2. Dry the sample in an oven at 100" to 120" C for 48 hours.

3. Transfer the sample to a vented muffle furnace, and raise the temperature slowly from 200" C to 550°C. Keep the temperature of the furnace at 550°C and ash the sample for 48 hours.

4. Cool, weigh, and then grind the ash to a tine powder using a mortar and pestle.

5. Transfer the powdered ash to a plastic container from which portions can be removed for chemical analysis.

3. Fusion

If a food sample contains a high concentration of silica, it may be necessary to perform a sodium carbonate fusion on the ash in order to dissolve it.

SODIUM CARBONATE FUSION

Principle of Method

Barium and strontium carriers are added to an aliquot of food ash and the mixture is fused with sodium hydroxide and sodium carbonate. The melt is taken up in distilled water, washed, and treated with sodium carbonate to yield a precipitate of alkaline earth carbonates. The carbonate precipitate can then be analyzed for strontium 89, strontium 90 and barium 140.

Reagents

Carrier solutions:
Ba^{+2} as barium nitrate, $Ba(NO_3)_2$: 20 mg Ba^{+2} per ml
Sr^{+2} as strontium nitrate, $Sr(NO^3)_2$: 20 mg Sr^{+2} per ml
sodium carbonate, Na_2CO_3: anhydrous granules or powder, 3N, 0.1N
sodium hydroxide, NaOH: pellets

Apparatus

long-handled tongs, nickel-tipped
nickel crucible, 250-ml capacity
nickel spatula

Procedure

1. Weigh a 10-gram or smaller portion of food ash into a 250-ml nickel crucible. Record the weight. (Note: Sample size depends on the silica content of the ash.]

2. Pipet 1.0 ml of strontium carrier solution and 1.0 ml of harium carrier solution (or an amount of carrier suitable to the analysis to be made) into the crucible. Mix thoroughly with a nickel spatula.

3. To this mixture add 50 grams of sodium hydroxide pellets, or 5 grams for each gram of ash, and mix thoroughly.

4. Fuse over a blast burner for 20-30 minutes. Then slowly stir in 5 grams of anhydrous sodium carbonate, or 0.5 gram for each gram of ash. Continue to heat the clear red melt for 20-30 minutes.

5. Using long-handled, nickel-tipped tongs, remove the crucible from the flame and very cautiously cooi it in a cold-water bath. Take up the cooled melt in about 200 ml of hot distilled water and disintegrate it by gentle boiling.

6. Using distilled water, transfer the mixture to a 250-ml centrifuge bottle. Centrifuge, and discard the supernatant liquid.

7. To the residue add 40 ml 3N Na_2CO_3 as a wash. Heat for 10 minutes on a hot plate. Centrifuge, and discard the supernate.

8. Repeat Step 7 to put the precipitate in a form suitable for further analysis

Table A. Required mount and approximate ash content of various sample media

Medium		Required amount (kg)*	Approximate ash content (%)
Apples		13.0	0.3
Bananas		4.0	0.9
Beans	(green, snap)	5.5	0.6
	(kidney, dry)	2.5	1.6
	(large lima, dry)	2.5	1.6
	(pinto, dry)	2.5	1.8
Beef	(meat)	5.0	18.0
Bread		1.7	2.0
Cabbage		7.0	0.5
Celery		4.5	0.8
Cereals	(All Bran)	0.5	8.2
	(Cheerios)	1.0.	4.5
	(Corn Flakes)	1.5	3.1
	(Grape-Nuts)	1.5	2.6
	(Rice Krispies)	1.5	3.1
	(Shredded Wheat)	2.5	1.4
	(Special "K")	1.5	3.0
	(Wheaties)	1.0	4.8
Coffee	(instant)	0.4	12.0
Crab	(whole)	0.5	14.5
DietFood	(composite)	3.5	1.0
Eggplant		5.0	0.8
Eggs		5.0	0.7
Fish	(whole)	0.5	6.5
	(edible, red snapper)	2.0	1.8
Grass	(dry)	1.0	5.5
	(green)	2.0	2.0
Lettuce		7.0	0.5
Milk	(evaporated)	2.5	1.6
	(fresh)	5.0	0.7
Margarine		1.6	2.3
Oranges		9.0	0.4
Oysters	(meat)	0.5	6.0
Pork	(meat)	5.0	0.8
Potatoes	(fresh)	4.0	1.0
Pumpkins		8.5	0.4
Rice	(white)	7.0	0.5
Rutabagas		6.0	0.6
Shrimp	(whole)	1.0	4.5
Squash		5.0	0.7
Tomatoes		4.5	0.8
Watermelon		13.0	0.3

*In order to have sufficient ash for the chemical procedures listed in this manual.

B. INSTRUMENTATION

1. Laboratory Facilities

The physical location of the room and the arrangement of the equipment are important factors to be considered when establishing a counting facility.

The site should be chosen so as to take maximum advantage of any natural existing shielding. By locating the room in the basement of a building it is generally possible to utilize natural shielding as well as to obtain maximum separation from busy areas. Temperature, humidity, and dust control are all important and equipment should be provided to optimize and stabilize these environmental parameters.

Cleanliness and general good housekeeping procedures are of the utmost importance in the operation of a low level counting room. Such practices tend to assure minimum background levels by reducing or eliminating contamination and this leads to more accurate results. Traffic in and out of the counting room should be kept at an absolute minimum. This may be accomplished by the use of in-wall sliding glass door pass boxes for the submission of samples for processing. It is often an excellent idea to provide shoe coverings for personnel entering the mom.

2. Instruments for Measuring Radioactivity

Instruments for measuring radioactivity make use of the ionizing properties of nuclear radiation. Basically they provide a medium with which the radiation can interact and a means of detecting and identifying this interaction. All instruments can be classified by their interaction medium under three general categories: gas ionization detectors, scintillation detectors or phosphors, and solid state detectors.

When a charged particle such as an alpha or beta particle moves through a gas at high velocity it may act on a gas molecule or atom to remove an electron and produce an ion pair. Gas ionization detectors contain an enclosed volume of gas in which two collecting electrodes are placed. When a direct voltage is applied across these electrodes in the presence of ionizing radiation, five types of response will be observed as the voltage is increased. These five distinct regions of response are:

a In the ion recombination region many of the ion pairs recombine with each other before reaching the collecting electrode. Gas ionization instruments are not operated in this region of response.

b In the ionization chamber region the applied voltage is sufficient to prevent significant recombination of ion pairs and the ions are collected in a one-to-one ratio with those formed. Ionization chamber instruments operate in this region of response.

c At voltages in the proportional region the ions are accelerated to achieve enough energy to produce secondary ionization in the gas medium, thus amplifying the primary ion current. Although the ion current or pulse size is amplified, to an extent described by the "gas amplification factor", it is still proportional to the energy of the incident particle or radiation. Thus gas ionization detectors operating in the proportional region can detect alpha particles selectively in the presence of beta (or gamma) radiation. Alpha and beta proportional counters with or without windows to separate samples from the gas ionization medium operate at voltages in the proportional region of response.

d Geiger counters, or GM counters, operate in the Geiger-Mueller region where the gas amplification factor is so large that an avalanche of electrons spreads along the entire length of the anode. Here the pulse size is independent of the number of primary ions or energy of the incident radiation. This accounts for the high sensitivity of GM detectors and their inability to distinguish between the various types of radiation.

e In the continuous discharge region the gas amplification factor is so large that the gas begins to arc generating a series of self-perpetuating discharges. Operation of any gas ionization instrument at voltages in this region even for a few seconds will seriously damage the electrodes.

Scintillation detectors make use of the long-known ability of ionizing radiations to produce short-lived flashes of light (scintillations) in phosphors. The light flashes can produce photoelectrons from a photosensitive cathode in a photomultiplier tube and these photoelectrons are further amplified into a pulse which can be counted. When the scintillator is large enough to absorb all the energy of the radiation in the excitation and ionization interaction, the output pulse will be proportional to the energy of the incident radiation. This proportional response is necessary for gamma scintillation spectrometry. Scintillators are of many materials

including organic crystals such as anthracene, liquid solutions of an organic scintillator such as p-terphenyl in an organic solvent, solid solutions of an organic scintillator in a plastic solvent (plastic scintillation detectors), inorganic crystals such as sodium iodide or zinc sulfide, and noble gases.

Solid state detectors make use of the property of some insulators such as diamond or silver chloride crystals, or semiconductors such as germanium or silicon, to show an instantaneous conductivity when high-energy particles or radiation interact with the material of which they are composed.

C. DETECTORS

a. Alpha Activity

Alpha particles are helium nuclei and carry a positive charge equal to twice the electron (beta) charge. Alpha particles, like gamma rays, are monoenergetic emissions. The most commonly counted alpha emitters, such as radon and thoron daughters, have energies of 5 to 7 million electron volts (MeV) and a mean range in air of about 5 centimeters. Samples to be counted for these particles should be very thin to minimize loss of energy in the sample through self-absorption, and should little or no distance between the sample and the detector to minimize loss of energy in air. Because of the low penetrating power of alpha particles, end-window counters are generally unsatisfactory for alpha counting unless the window thickness is 0.1 milligram per square centimeter or less.

For each instrument described, there is an operating high voltage which will yield consistent counting results. To determine the operating voltage, counts are made with a known alpha source at 50-volt increments. The initial counts will appear at the threshold voltage of the instrument, the lowest at which pulses are detected. As the voltage is increased, more counts are observed, until a leveling-off of the count rate occurs. This level area, or plateau, continues until there is a sharp increase in the counts. The operating voltage is selected midway along the plateau. The manual provided with each commercially available instrument usually discusses in some detail the selection of the probable operating voltage.

After the operating voltage has been selected, calibration must be performed to obtain quantitative data. Calibration involves selecting a suitable standard, preparing it in a form to simulate the samples, and counting the calibration standard at the selected operating voltage.

For calibrating alpha counters, sample thickness must be considered because of self-absorption in the sample can be severe. Performance standards are a very necessary part of routine counting. Their use insures that the counter is functioning the same when the sample is counted as it was when calibration was performed.

Background count rate should be determined at least twice daily to detect possible fluctuations caused by contamination, radio-frequency or line-current pulses, or by a change in the natural background radiation from radon-thoron daughters in the air or from cosmic radiation. A change in background due to contamination of the counter is most apt to occur if the samples are placed within the detector for counting.

1. INTERNAL PROPORTIONAL ALPHA COUNTER

Application

Internal proportional alpha counters are gas-flow counters useful for measuring levels of alpha activity commonly found in environmental samples. The counters are termed "internal" because the sample is placed into the sensitive part of the detector, and counting gas is purged throughout both counting chamber and sample. Because of this procedure, the counter can be contaminated by the sample. At the same time, this essentially eliminates all losses but those from self-absorption. For samples deposited on a planchet, this counter is as sensitive as any alpha counting system, and can be used to count activities ranging from the lowest to the very highest.

To be detected, the alpha particles have only to penetrate the sample itself and produce several ion pairs in the gas. The detector is almost equally sensitive over the inside diameter, although a slight decrease in response is noted at the edge of the counting dish. Any metallic planchet is suitable for counting in an internal proportional counter, but care should be taken to have the solids uniformly distributed in the dish. This is especially true for counting alpha activity if there is much solid material in the sample, as absorption losses from unevenly distributed solids will be inconsistent. Stainless steel dishes are used for most samples, but cannot be used with chlorides. In this case, aluminum must be used.

Operation

The counters are termed "proportional" because they operate at voltages where the size of the pulse is proportional to the number of ion pairs produced. A counting gas mixture of 90 percent argon and 10 percent methane (P-10 gas) is commonly used. The electrons from ion pairs produced in this gas are collected by the central electrode to generate a pulse which is recorded by a scaler. Since alpha particles dissipate more energy in the chamber than beta particles, they produce more ion pairs and consequently large pulses. The smaller beta-gamma pulses, if present, are discriminated against by operating at the relatively low voltage of approximately 1000 V which produces a small amplification. Ability to count only alpha emissions at one voltage and alpha plus beta-gamma emissions at another makes the proportional counter a versatile detector.

If the instrument used for counting samples of high activity is also used for counting those of low activity, background measurements should be more frequent than twice daily to check for contamination. For an unshielded 2 1/4-inch diameter hemisphere and piston, the alpha background is about 0.2 counts per minute.

The alpha counting efficiency for weightless samples is slightly higher than 50 percent. The efficiency for anything but weightless samples is substantially lower due to severe self-absorption losses.

2. ALPHA SCINTILLATION COUNTER - Zinc Sulfide Screen

Application

The alpha scintillation counter is used for counting flaky or dusty samples such as air samples, that could easily contaminate an internal proportional counter. Uneven self-absorption losses from these samples can result in poor reproducibility, even with the scintillation counter. This instrument lends itself quite readily to mobile laboratory or field use because no gas supply is needed.

Since the sample is external to the detector, the counting dish or planchet need not be conducting. It should be shallow enough to enable the sample to be placed close to the zinc sulfide screen to minimize air absorption losses. In this configuration, the alpha scintillation counter is almost as sensitive as the internal proportional counter. Samples deposited on membrane filters provide a nearly ideal geometry because they are flat and usually evenly distributed. Self-absorption, however, can be severe for air samples having a high solids content.

Operation

The counter is composed of a zinc sulfide screen (zinc sulfide deposited on lucite or some other transparent substance), and a photomultiplier tube housed in a light-tight box coupled through a cathode follower into a scaler. The voltage that must be used depends on the photomultiplier tube characteristics. The tube should have a uniform photo-cathode which yields a satisfactory plateau. No additional amplification of the pulses is required, and operating voltages are usually less than 2000 V, enabling use of the simplest scalers.

A 2-inch diameter weightless sample close to a 3 1/2-inch screen has a counting efficiency greater than 40 percent. For the same weightless sample, the efficiency will be about 50 percent in an internal proportional alpha counter. The efficiency obtained is much better than for an end window alpha counter, since the zinc sulfide screen has no window.

The background is about 0.2 cpm for a 3 1/2-inch slope per 100 volts.

3. ALPHA SCINTILLATION COUNTER - Liquid Scintillation

Application

The liquid scintillation counter was designed primarily for counting weak beta emitters such as tritium (^3H) and carbon 14. It can also be used successfully for alpha counting. Its chief advantage is that there can he no self-absorption losses in the sample to cause non-reproducible counting. Sample preparation may require some training in radiochemistry.

The samples are mixed with the scintillator and the mixture is placed in low potassium-content glass or polyethylene vials. The alpha counting efficiency approaches 100 percent, and the minimum sensitivity for radium 226 is about 0.2 picocurie per sample for a 100-minute count.

An alternate method is to place the sample in a small vial coated with zinc sulfide powder. With this procedure, the background is about 0.02 counts per minute, and the minimum sensitivity for radium 226 is approximately 0.02 picocurie per sample for 100-minute counting periods.

The liquid scintillation for alpha counting has not been used extensively by the laboratories; but is described here as an alternate to the more specialized radon emanation technique which'follows.

Operation

A typical liquid scintillation counter uses two photomultiplier tubes in coincidence. Noise pulses or originating in the tubes can be discriminated against as they are much smaller than alpha pulses. With the coincidence circuit, pulses must occur simultaneously in each tube to be recorded as a count.

4. RADON COUNTER - Gas Phase Counting

Application

The radon counter is used for the determination of radium 226 by measuring radon 222 and its daughters. The daughters of importance to the determination are the short-lived alpha emitters polonium 218, bismuth 214, and polonium 214. Lead 214 which follows polonium 218 in the decay chain is a beta emitter.

Gas phase scintillation counting yields the maximum sensitivity for radium 226. With appropriate sample preparation, it can be used for almost any sample for activities down to 0.01 picocurie per sample if 1,000-minute background and sample counts are made.

Operation

The radium 226 is stored in a sealed tube until the system has reached secular equilibrium (about 28 days) or at least until an amount of radon 222 sufficient for counting has grown into the radium 226 solution. Then the radon gas is purged into the evacuated scintillation cell by using radon-free gas, such as aged air or nitrogen at a low purge rate.

The cell containing the radon must be stored in a light-tight container for approximately 5 hours to enable the radon daughters to reach equilibrium. At equilibrium, for every radon 222 disintegration three alpha particles will be available for counting. This storage time can vary as long as the degree of equilibrium attained is considered in the calculation of radium 226 activity. The storage time should be long enough to allow any actinon (^{219}Rn) or thoron (^{222}Rn) daughters of radium 223 or radium 224, if present, to decay out. It is usually convenient to store the cell in the same light-tight container which houses the photomultiplier tube. From its photomultiplier tube, which detects the light flashes in the cell, to its scaler, this counter is very similar to the zinc sulfide screen already described. The scintillation cell substitutes for the screen as the detector.

The counter is plateaued and calibrated by preparing a standard solution of radium 226 and processing the standard in the same manner as the samples are processed. This determines the efficiency of the purge and the counting.

Counting efficiency for the radon and daughters is approximately 80 percent in a properly coated cell. The background is usually 0.1 count per minute. Each cell must be checked independently on the phototube used for sample counting. It is important to keep the cell and the tube as a matched unit, as each can affect background and counting efficiency.

b. Beta Activity

Beta particles (Beta Activity) are negatively charged electrons ejected from the nucleus when a neutron decays to a proton and an electron. They are not monoenergetic, but have a continuous distribution of energies from zero up to E_{max}, the maximum value reported for the particular radioisotope. Each radionuclide has a different decay scheme which can be used to help identify the constituents of a sample containing beta emitters. Some beta emitters have many E_{max} values due to the way the atom reached a stable state. The average energy of the beta particles from a given emitter is generally taken to be about one third of the maximum. The energy released by decay partially determines the type of instrument needed.

For each instrument described, there is an operating high voltage plateau which will yield consistent counting results. To determine this voltage range, counts are made with a beta emitter which has approximately

the same beta energy as the beta emitter in the samples. Counts are made at 50-volt increments. When the counts from one SO-volt increment to the next are within 1 percent of each other, the plateau has been reached and the operating voltage lies in this plateau. Each instrument vanes as to the length of the plateau and the best operating voltage. The operating voltage is influenced by the construction of the counter and for a gas ionization detector, the type of gas used. Additional information will be found in the operating manual supplied with the particular instrument and in several references listed at the end of this Section.

1. GEIGER-MUELLER COUNTER

Application

The Geiger-Mueller (GM) counter is a gas ionization detector operated in the Geiger-Mueller region of response. In this application, the gas ionization chamber is called a GM tube. The cathode of this tube is usually a part of its wall, and the anode is a central wire mounted within the cathode. GM tubes contain the counting gas, which is usually a noble gas mixed with a small percentage of some halogen or organic gas to provide quenching. Typical gas mixtures are argon and ethanol, helium and isobutane, and n w n and an organic halide.

The GM counter is relatively inexpensive, can be used with every simple rate meters and scalers, has a very low threshold of sensitivity, and is relatively trouble-free. Its high background, low counting efficiency, and inability to differentiate between two or more types of incident radiation can be disadvantageous in some applications.

The GM detectors are used to count samples containing near-tracer levels of activity. Although all pulses produced in the GM tube are the same size whether they originate from a low or high energy beta particle, qualitative identification of beta emitters in samples of high enough activity can be obtained by placing various thicknesses of aluminum absorbers between the sample and the GM tube. In this manner, the endpoint energy, or E, of the beta emissions from the source can be determined.

Almost any planchet is suitable for the GM detector, and reproducible results will be obtained as long as the planchet diameter is smaller than the diameter of the GM tube itself. In a 11/2-inch thick lead shield, a 11/2-inch diameter tube will have a background of about 30 counts per minute. If the radioactive material is near the edge of a 2-inch diameter planchet, the counting efficiency is less than if the same activity is deposited near the center. Since the sealing window must have a density thickness of about 2 milligrams per square centimeter, and there is an air path between the sample and window, there is a substantial absorption loss for beta energies less than 400 keV (E_{max}).

Operation

The counting efficiency of this instrument is the lowest of those described here, especially for low-energy beta particles, because of the relatively thick window and poor geometry. Significant dead-time losses can occur if the count rate is high (above 10,000 counts per minute) and will usually be a problem only when the instrument is being calibrated at high levels of activity. If sample count rates are excessive, the sample must be counted at a greater distance from the tube. Normal losses due to dead-time are 0.5 percent per 1,000 counts per minute.

A plateau should be obtained at regular intervals to ensure that the GM detector is functioning properly. The plateau should not have a slope of more than 2 percent per 100 volts, and for a new tube should be about 250 volts long. As the tube ages, the plateau will shorten. The operating voltage should be chosen at the lower third of the plateau to prolong the life of the tube. Each tube has its own voltage requirement, but most operate at voltages of less than 2,000.

Once this operating voltage has been determined, the tube should be checked against a performance standard at least three times each day - in the morning, around noon, and at the close of the working day. Background measurements should be made at least twice a day.

Each Geiger-Mueller counter will be accompanied by an operating manual when purchased. It should be consulted for more specific information on calibration and operation of the counter.

2. INTERNAL PROPORTIONAL BETA COUNTER

Application

The internal proportional counter, previously discussed under, a. Alpha Activity - 1. Internal Proportional Alpha Counter, is also useful for measuring gross beta activity, where count rates are apt to be higher than in samples chemically separated to contain a single betaemitting nuclide. It can be a satisfactory instrument for measuring levels of beta activity as low as 5 picocuries per sample if long counting times are used. Even weak beta emitters can be counted, because the sample is within the counter itself. The detector has a 2-pi geometry, and counting efficiency can be as high as 75 percent because of backscatter from the planchet. The increased backscatter is a function of beta energy and of the atomic number of the planchet material.

When beta activity of a sample containing both alpha and beta emitters is to be measured, care must be taken to subtract the count contributed by the alpha emitters from the total count obtained at the beta plateau. The gamma counting efficiency is very low, ranging from approximately 1 percent for 1.0 MeV gammas to approximately 5 percent for 0.1 MeV gammas, and any contributions from gamma emissions can usually be neglected.

Operation

When the internal proportional counter is operated at approximately 1,800 volts, it becomes a beta counter, although alpha and gamma radiations are also counted. There are therefore two plateaus, one for alpha and one for alpha plus beta-gamma emissions. The efficiency for counting alpha activity at voltages in the beta-gamma plateau is some what higher than that obtained at voltages in the alpha plateau. This ratio must be determined if the alpha count is to be subtracted from the beta-plus-alpha count to obtain the corrected beta activity.

The plateau is determined by counting an extended source (2-inch diameter) having approximately the same beta energy as the samples. The operating voltage should be chosen about midway on the beta-gamma plateau. The plateau should be checked at one-month intervals or whenever a new tank of gas is installed.

The background at the beta plateau of an unshielded chamber of 2 1/4-inch internal diameter is approximately 55 counts per minute and is about 30 counts per minute for one shielded with 2 inches of lead.

The counting efficiency is a function of energy, sample thickness, and backing material of the sample. Distribution of activity in the planchet is relatively unimportant, although the efficiency is somewhat lower at the edges of the dish. Table B shows typical efficiencies for counting radionuclides of various average beta energies in the internal proportional counter.

It is extremely important that the samples be conducting to ground to eliminate a static charge buildup which will produce sporadic and inconsistent counts. This static buildup can be compared to formation of a cloud over the sample. During cloud formation, the counts would be suppressed, and when the cloud is removed (discharged) a burst of counts would be observed. Therefore, a non-metal planchet such as polyethylene or glass cannot be used.

The manufacturer's operating manual should be consulted for additional information on operating characteristics and trouble shooting.

Table B. Typical counting efficiencies of the internal proportional beta counters for weightless samples

Radionuclide	Average β Energy (MeV)	Total Efficiency (%)
^{95}Nb	0.046	52
^{147}Pm	0.062	58
^{131}I	0.180	65
^{36}Cl	0.252	70
^{137}Cs-^{137m}Ba	0.268	70
^{90}Sr-^{90}Y	0.566	73
^{89}Sr	0.589	73
^{91}Y	0.615	73
^{32}P	0.693	73
^{90}Y	0.931	73

Counting chamber diameter: 2 1/4 inches;
Planchet dimensions: 2-inch diameter by 1/4 inch high,
0.018-inch thick stainless steel

3. END-WINDOW PROPORTIONAL COUNTER

Application

End-window proportional counters have application for counting moderate to high activity level and for samples that cannot be fixed well in the planchet or sample holder. Large counters of this type can be used to count high-volume air samples such as those collected on 8-inch by 10-inch glass fiber filters.

The end-window instrument is less sensitive than the internal proportional counter because of poorer sample geometry and because of absorption losses in the air path and window. Although a very thin window can be utilized for alpha counting, it is not particularly recommended because of the end-window detector's poor efficiency for alpha detection. It can be used as a screening instrument for alpha and low-energy beta emitters, but is unsuitable for quantitative measurement of these emitters.

Almost any type of planchet can be used with the end-window counter, but for reproducible results its diameter must be somewhat shorter than that of the window. There is no problem of static charge build-up because the sample is external to the counter.

Operation

The end-window proportional counter operates on essentially the same principle as the internal proportional counter. The detector ordinarily uses P-10 gas (argon-methane mixture).

Counting efficiency of the end-window proportional counter is little more than half that of the internal proportional counter. Again, this is due to absorption of some beta particles in the air path and in the window material. The lower energy betas (E_{max} less than 300 KeV) and the backscattered events are especially attenuated.

Background is lower than that of the internal proportional counter because there is less detector area. Contamination is not as apt to occur because the sample is external to the counter. Background counts need be taken only once or twice daily unless a sample contacts the window or contaminates the inside of the shield

or sample holder.

Plateaus should be taken at the same intervals and for the same reasons as for the internal proportional counter. Additional information on operation or trouble shooting will be found in the manufacturer's operating manual.

(4) LOW-BACKGROUND BETA COUNTER

Application

The low-background beta counter is designed for measuring low levels of activity. Its primary application is for the determination of strontium fission products in the environment, and use of the counter should be restricted to samples of low to moderate activity. It has the highest sensitivity of any common laboratory beta counter for samples mounted in counting dishes. The instrument is sensitive to about 0.5 picocurie per sample for energetic beta-emitters counted 100 minutes or more. It is possible to determine activity levels of less than one picocurie per sample for the energetic strontium beta emitters. For betas having E^{max} less than 0.3 MeV, other counters should be considered.

The counting dish can be of almost any material depending on the chemical procedure required for sample preparation. The diameter of the dish should be smaller than the diameter of the counter to obtain reproducible results. The two most commonly used planchets are the stainless steel dishes and the nylon ring and dish types. For some applications, the nylon ring and disk offers the advantages of producing a more uniform sample and is easier to prepare. A thin Mylar cover is placed over the sample to eliminate loss of sample and to prevent contamination of the counting chamber. The absence of a wall on the planchet and the protective cover over the sample allows the samples to be placed closer to the window of the counter, thereby yielding higher counting efficiencies.

Operation

A low-background beta counter is shielded by two inches of lead or equivalent to stop external gamma rays, and by coincidence circuitry to reduce the contribution from cosmic interactions in the shielding material. The circuitry consists of one or more guard detectors placed over the central detector(s) so that any radiation interacting in both the guard and central detector(s) is not recorded as a count.

The detectors are commonly GM end-window tubes with thin windows (less than 0.1 milligram per square centimeter) and a positive gas pressure maintained by a low purge rate. Sometimes P-10 gas (argon-methane mixture) is used, and the counter is then operated as a proportional counter. However, the detector is usually operated in the Geiger-Mueller region, using helium-isobutane as the gas, where the pulses produced are very large and no additional amplification is required. The system is usually packaged as a complete unit of central detector, guard tubes, shielding, and scaler. The scaler will have the required high voltage and separate registers for the central detector(s) and guard tube(s).

The counting efficiency for yttrium 90 distributed uniformly on a 2-inch stainless steel planchet placed close to a 2 1/4-inch detector, is about 42 percent, and is about 50 percent for the nylon ring and disk mount.

For samples having activity levels of less than 5 picocuries per sample, adequate counting times in these instruments are usually 100 minutes or overnight. Background measurements must be made at least once daily for 100 minutes or more. In the Geiger-Mueller mode of operation the background count rate should be about 1 count per minute for a 2-inch diameter tube. When the detector is operated in the proportional mode, the background count rate can be further reduced by use of discriminators.

5. LIQUID SCINTILLATION COUNTER

Application

This instrument is particularly well suited to counting low-energy beta emitters such as tritium or carbon 14. By mixing the sample with the liquid scintillation medium, self-absorption losses are eliminated. Counting efficiency can approach 100 percent for high-energy beta emissions, but for those of carbon 14 and tritium the efficiency is much less. Use of the liquid scintillation counter is not limited to counting low-energy beta emitters, but it or a method equivalent to it, such as gas phase counting, is essential for counting weak beta emitters with reliability.

Early models required placing the phototubes in a freezer to reduce the dark current noise to an acceptable level. Recent improvements, however, make this unnecessary for all but the lowest levels of activity (less than about 30 picocuries per sample for ^{14}C).

Operation

In a liquid scintillation counter, the samples and scintillator form a homogeneous mixture in solvents such as toluene, xylene, and 1,4-dioxane. Light flashes produced in the mixture are detected and amplified by the photomultiplier tube.

The samples are placed into a transparent or translucent bottle to enable the light to be transmitted to the phototubes. As in any other counter, the calibration standard must contain the same radionuclide prepared in the same medium. The background count rate is determined by counting the activity of a bottle containing both solvent and scintillator, since this mixture is the sensor and a slight amount of activity may be present in the material itself. Background counts should be taken at least once each day.

Most of the liquid scintillation counting systems designed for low level counting place two phototubes in coincidence. Only one is considered the detector, and it is connected to the analyzer. When both tubes receive a pulse simultaneously, a count is registered equivalent to the energy of the radiation absorbed. When only one tube sees the pulse, no count is recorded. In this way the dark current, or photomultiplier background, is practically eliminated. A discriminator is used to eliminate additional low energy pulses, but the weaker pulses from soft betas are also eliminated, thereby reducing the counting efficiency for these emissions.

The beta energy of the nuclide to be counted determines the discriminator setting and window width. Window width is also dependent on whether or not there is more than one beta emitter present.

Most liquid scintillation counters are coupled to an analyzer with at least two channels. This enables more than one beta emitter to be analyzed at the same time as long as their E_{max} values differ by at least a factor of three.

More detailed information on operation of the liquid scintillation counter will be found in the manufacturer's instruction manual.

c. Gamma Activity

Gamma rays are electromagnetic radiations emitted by the nucleus as photons of discrete energies. The photons have no mass and have high penetrating power. Therefore, sample preparation is generally much less of a problem for counting gamma emitters than for counting either alpha or beta emitters.

The method for measuring gamma activity is basically to capture part or all of the energy released through decay, and to convert it into a current flow or pulse which can be recorded. The gross count can be taken by totaling the pulses recorded on scalers. For spectral analysis, the pulses are sorted out by energy, and the number of pulses counted in each energy band is stored separately. A pulse height analyzer is used for this spectral analysis.

1. SEMICONDUCTOR DETECTORS

A semiconductor is a material that can act as an insulator or as a conductor. In electronics the term solid state is often used interchangeably with semiconductor, but in the detector field the term can obviously be applied to solid scintillators. Therefore, semiconductor is the preferred term for those detectors which are fabricated from either elemental or compound single crystal materials having a band gap in the range of approximately 1 to 5 eV. The group IV elements Silicon and Germanium are by far the most widely-used semiconductors, although some compound semiconductor materials are finding use in special applications as development work on them continues.

Table C shows some of the key characteristics of various semiconductors as detector materials:

Table C. Element vs. Band Gap

Material	Z	Band Gap	Energy/e-h pair (eV)
Si	14	1.12	3.61
Ge	32	0.74	2.98
CdTe	48-52	1.47	4.43
HgI_2	80-53	2.13	6.5
GaAs	31-33	1.43	5.2

Semiconductor detectors have a P-I-N diode structure in which the intrinsic (I) region is created by depletion of charge camers when a reverse bias is applied across the diode. When photons interact within the depletion region, charge carriers (holes and electrons) are freed and are swept to their respective collecting electrode by the electric field. The resultant charge is integrated by a charge sensitive preamplifier and converted to a voltage pulse with an amplitude proportional to the original photon energy.

Since the depletion depth is inversely proportional to net electrical impurity concentration, and since counting efficiency is also dependent on the purity of the material, large volumes of very pure material are needed to ensure high counting efficiency for high energy photons.

Prior to the mid-1970's the required purity levels of Si and Ge could be achieved only by counter-doping P-type crystals with the N-type impurity, lithium, in a process known as lithium-ion drifting. Although this process is still widely used in the production of Si(Li) X-ray detectors, it is no longer required for germanium detectors since sufficiently pure crystals have been available since 1976.

The band gap figures in Table C signify the temperature sensitivity of the materials and the practical ways in which these materials can be used as detectors. Just as Ge transistors have much lower maximum operating temperatures than Si devices, so do Ge detectors. As a practical matter both Ge and Si photon detectors must be cooled in order to reduce the thermal charge carrier generation (noise) to an acceptable level. This requirement is quite aside from the lithium precipitation problem which made the old Ge(Li), and to some degree Si(Li) detectors, perishable at room temperature.

The most common medium for detector cooling is liquid nitrogen, however, recent advances in electrical cooling systems have made electrically refrigerated cryostats a viable alternative for many detector applications.

In liquid nitrogen (LN_2) cooled detectors, the detector element (and in some cases preamplifier components), are housed in a clean vacuum chamber which is attached to or inserted in a LN_2 Dewar. The detector is in thermal contact with the liquid nitrogen which cools it to around 77°K or -200°C. At these temperatures, reverse leakage currents are in the range of 10^{-9} to 10^{-12} amperes.

In electrically refrigerated detectors, both closed-cycle Freon and helium refrigeration systems have been developed to eliminate the need for liquid nitrogen. Besides the obvious advantage of being able to operate where liquid nitrogen is unavailable or supply is uncertain, refrigerated detectors are ideal for applications requiring long-term unattended operation, or applications such as undersea operation, where it is impractical to vent LN, gas from a conventional cryostat to its surrounding.

Detector structure

The first semiconductor photon detectors had a simple planar structure similar to their predecessor, the Silicon Surface Barrier (SSB) detector (see section on particle detection). Soon the grooved planar Si(Li) detector evolved from attempts to reduce leakage currents and thus improve resolution.

The coaxial Ge(Li) detector was developed in order to increase overall detector volume, and thus detection efficiency, while keeping depletion (drift) depths reasonable and minimizing capacitance. Other variations on these structures have come, and some have gone away, but there are several currently in use.

Performance

Resolution: Semiconductor detectors provide greatly improved energy resolution over other type.. of radiation detectors for many reasons. Fundamentally, the resolution advantage can be attributed to the **small** amount of energy required to produce a charge carrier and the consequent large "output signal" relative to other detector types for the same incident photon energy. At 3 eV/e-h pair (see Table 1) the number of charge carriers produced in Ge is about one and two orders of magnitude higher than in gas and scintillation detectors respectively. The charge multiplication that takes place in proportional counters and in the electron multipliers associated with scintillation detectors, resulting in large output signals, does nothing to improve the fundamental statistics of charge production.

The resultant energy reduction keV (FWHM) vs. energy for various detector types is illustrated in Table D.

Table D. Energy Resolution vs. Detector Type

Energy (keV)	**5.9**	**1.22**	**1.332**
Proportional Counter	1.2		
X-ray NaI(Tl)	3.0	12.0	
3x3 NaI(Tl)		12.0	60
Si(Li)	0.16		
Planar Ge	0.18	0.5	
Coaxial Ge		0.8	1.8

Efficiency: The efficiency of detector materials is closely related to their atomic number. Table C gives the atomic number of common semiconductor detector materials and it is easy to see why silicon is relegated to use in the relatively low energy X-ray range. Although the compound semiconductors have high atomic numbers, charge trapping and other practical considerations have denied us large volume devices which are necessary for high energy gamma-ray spectroscopy. The discussions of efficiency center mainly on the Ge detector.

At low energies, detector efficiency is a function of cross-sectional area and window thickness while at high energies total active detector volume more or less determines counting efficiency. Detectors having thin contacts, e.g. Si(Li), Low-Energy Ge and Reverse Electrode Ge detectors, are usually equipped with a Be cryostat window to take full advantage of their intrinsic energy response.

Coaxial Ge detectors are specified in terms of their relative full-energy peak efficiency compared to that of a **3x3** in. NaI(Tl) Scintillation detector at a detector to source distance of 25 cm. Detectors of greater than 100% relative efficiency have been fabricated from germanium crystals ranging up to about 75 mm **in** diameter. About *2* kg of germanium is required for such a detector.

2. GROSS GAMMA COUNTER

Application

A gross gamma counter is frequently used **as** a screening device to provide a rapid means of selecting from a group of environmental samples those which have a relatively high activity. It is also used in tracer experiments where a known radionuclide is to be counted, **as** in determining chemical yield for an analytical procedure by use of a tracer. Depending on the type of sample to be counted, a solid or a well crystal detector can he **used** for these applications.

Operation

A relatively small crystal scintillator, such as a 2-inch by 2-inch right cylinder, is frequently **used** for gross gamma counting because total absorption of the gamma rays is not necessary. Any partial interaction with the crystal which produces a pulse above the threshold will register as a count. Shielding is desirable, but it **need** not **he** massive. About 1 inch to 1-1/2 inches of lead, or equivalent, is adequate for most applications. With this amount of shielding, a 2-inch by 2-inch crystal will have a background of approximately 300 counts per minute.

A photomultiplier tube detects the light flashes produced in the crystal scintillator. The output from this tube is coupled to a scaler having an amplifier, or an amplifier is inserted as a separate component. Although a simple scaler may be adequate, low-energy sources, in particular, may require a relatively stable high voltage supply.

The gross gamma counter is the simplest and cheapest of the gamma counters routinely used in the laboratory. Its principal limitations are that it has no energy discrimination and that its relatively high background ***makes*** it useful only for samples of fairly high activity.

.**As** for all gamma counting, gross gamma counting requires minimal sample preparation because self-absorption losses are not a major problem. For the same reason, almost any sample configuration can be used. It is important, however, to maintain a constant geometrical configuration for a given sample type and to calibrate with a standard having the same configuration as the sample. Even where only relative counts are needed, as for checking chemical procedures, the geometry must be kept constant for all count rates being compared, or it must be calibrated for a variety of sample sizes and configurations.

For most gamma measurements, a discriminator should be used to eliminate much of the low-energy component of background. **An** optimum setting can be obtained by taking counts at various discriminator settings, both from background and from a source. The best discriminator setting for a given gamma energy is the setting at which the highest value of the ratio S^2/B is obtained, where S is the sample count rate and B is the background count rate.

Gross gamma counting efficiencies vary with energy, but they are quite high because only a partial interaction is needed. For spectrometry, however, total interaction of the gamma photon is needed if the pulse is to be recorded under the photopeak.

Background should be measured twice daily or more often if high activity sources are being moved about nearby. A change in position of these sources will affect the background.

3. GAMMA SPECTROMETER

Application

Gamma spectrometry is **used** extensively to identify radionuclides. The spectrometer becomes a quantitative tool with suitable calibration and background data accompanied by measurement of spectral interferences. Self-absorption losses are negligible, so large-volume samples can be scanned with little or no prior preparation.

The spectrometers are pulse height analyzers of the single-channel or multichannel type. They are now coupled to computer systems giving them great flexibility and many "automated" software packages to perform calculations at high speeds. **A** pulse height analyzer sorts pulses according to energy expended in the detector. The multichannel analyzer simultaneously sorts and records pulses falling in many different energy bands or increments in a given time interval. For a given analyzer, the total energy range scanned is divided into equal increments called channels. The single channel analyzer detects and records pulses in only one energy band at a time. The single-channel analyzer is adequate for counting tracer levels of activity, but for low activity samples, the multichannel analyzer is essential becduse of the excessive counting time required to cover a spectrum channel by channel with a single-channel analyzer.

Either a 3-inch by 3-inch or 4-inch by 4-inch right cylindrical thallium-activated sodium iodide [NaI(Tl)] crystal provides optimum sensitivity for gamma energies **up** to 2 MeV. These sizes are therefore used for environmental samples containing fallout debris and natural radioactivity. For low-activity gamma spectrometry. the phototube base should be removed and a mu-metal cover should shield the tube to prevent magnetic fields from distorting the spectra.

Low-energy gamma spectrometry (Ey < 150 keV) requires a very thin crystal less than 0.5 inches thick enclosed by a thin protective can. This thin crystal can also be used to detect the X rays emitted by some radionuclides to help identify the components of a sample spectrum. Very high-energy gamma photons (Ey > 2 MeV) are not seen efficiently by the thin detector. Since the predominant gamma energies of gamma emitters in most environmental samples are less than 2 MeV, large crystals will not be discussed.

The Crystal Detector

A detector for the gamma spectrometer system in addition to the solid state detectors as in section 1. is a sodium iodide crystal optically coupled to a photomultiplier tube. The tube is connected into the analyzer through a pre-amplifier and linear amplifier. The analyzer records each pulse in its proper channel or energy increment. Each channel represents a certain amount of energy absorbed in the crystal. The spectrum shows a characteristic photopeak at the full energy of the gamma ray, and at lower energy regions shows counts which arise from partial interactions of the gamma rays with the crystal. By knowing the decay schemes of radionuclides, it is possible to identify specific isotopes by their gamma energies.

Crystal size is very important in gamma spectrometry. If too large a crystal for the application is chosen, the background will be unnecessarily high. If a crystal is too small for the energies being scanned, the photopeak counting efficiency will be low because few of the gamma photons will expend their full energy in the crystal. The detector is energy dependent, the efficiency being lower for higher energies. This is especially noticeable in pulse height analysis, because the entire photon energy must be spent in the crystal to be recorded under the photopeak. This type of interaction is called photoelectric, and it is the most important interaction in gamma spectrometry.

All higher energy photons contribute to a lower region of the energy spectrum because of Compton interaction. In the Compton interaction, only a portion of the total energy is absorbed in the crystal and the remainder is scattered out of the crystal. The energy absorbed is recorded as a pulse in a channel below that of the photopeak. The amount of energy lost by this process is somewhat energy dependent, but it can be from almost full energy to only a small percentage of the total energy of the gamma photon. Frequently there are multiple Compton interactions, and if they occur in the crystal, the total energy absorbed will be additive. In some instances, the sum may equal the full gamma energy of the photon, and the pulse will then be recorded under the photopeak.

Another form of gamma interaction important to gamma spectrometry is pair production. This process occurs only at gamma energies above 1.02 MeV. One electron of the pair is negatively charged, and the other positively. The positively charged electron, positron, is slowed down until it interacts with a negatively charged electron and both are annihilated. Their rest mass energy of 1.02 MeV is converted to two photons, each having an energy of 0.51 MeV, which are emitted in opposite directions.

This conversion results in a peak in the gamma spectrum at 0.51 MeV. If the counting geometry is such that both of the photons can interact with the detector simultaneously (as in a well-type detector), a sum peak at 1.02 MeV will be observed. If, however, one or both entirely escape the detector, there will be peaks observed at energies of 0.51 or 1.02 MeV less than the full energy of the photon.

Counting Efficiency

The term "total efficiency" denotes the ratio of the net gamma counts observed in a peak spectral region to the total number of disintegrations of the radionuclide of interest in the same period of time, and is determined by the following equation.

$$\text{Total efficiency (\%)} = \frac{\text{Observed counts in peak region - background in peak region}}{\text{Total disintegrations}} \times 100$$

If the activity of a standard is given in terms of total disintegration rate, the gamma abundance is not needed to determine the photopeak efficiency of a particular radionuclide. A radioactive standard of ruthenium 106-rhodium 106 (^{106}Ru-^{106}Rh) will serve as an example. Let the following information be given:

^{106}Ru activity in the sample = 100,000 dpm
^{106}Rh (daughter of ^{106}Ru) gamma energy = 0.51 MeV
Abundance of the 0.51 MeV gamma of ^{106}Rh = 20%
Net gamma count rate between 0.44 and 0.56 MeV = 2000 cpm

The equation can then be written in one of three ways:

1) ^{106}Ru or ^{106}Rh Eff. (W) = $\frac{\text{Net cpm in peak region}}{\text{dpm in sample of } ^{106}\text{Ru or } ^{106}\text{Rh}} \times 100$

$= \frac{2{,}000}{100{,}000} \times 100$

$= 2\ \%$

2) ^{106}Ru-^{106}Rh Eff. (%) = $\frac{\text{Net cpm in peak region}}{\text{dprn in sample of } ^{106}\text{Ru-}^{106}\text{Rh}} \times 100$

$= \frac{2{,}000}{200{,}000} \times 100$

$= 1\ \%$

3) 0.51 MeV Eff. (%) = $\frac{\text{Net cpm in peak region}}{\text{dpm in sample} \times \text{gamma abundance}} \times 100$

$= \frac{2.000}{100{,}000 \times 0.20} \times 100$

$= 10\%$

In the third case, the efficiency for the 0.51 MeV gamma photons would actually be less than 10% because the 2,000 counts in the photopeak region include Compton interactions from higher energy gamma emissions from ^{106}Rh.

Graphs of gamma efficiency plotted against gamma energy can be very useful if the gamma abundance values are accurately known and if the standard is precisely rated. If a range of gamma energies is obtained and the gamma abundances are known, it is possible to predict the gamma efficiency for an unknown radionuclide.

Resolution

Resolution is a measure of the sharpness of a photopeak and it determines the ability of a detector to separate or distinguish between the peaks of gamma rays having similar energies. Without good resolution, photopeaks of similar energies are difficult to quantify.

Resolution is calculated by the following formula:

The units of energy can be either channel number of MeV, keV, etc. for purposes of calculation.

Resolution (%) = $\frac{\text{peak width in energy at half maximum count rate}}{\text{peak energy}} \times 100$

Resolution is a function of energy, and in general it decreases with increasing energy. Cesium 137 has been generally accepted as the standard for comparison of resolution. It is therefore important to specify the energy in reporting resolution when it has been determined at photopeaks other than 0.662 MeV peak of cesium 137. A typical resolution for a 4-inch by 4-inch NaI(Tl) crystal with a 3-inch phototube is about 8.5 percent of cesium 137.

Linearity

Before any calibration or sample counting can be attempted, the analyzer must be linear. To determine this, a combination of accurately known gamma energies covering a substantial portion of the spectral region of interest must be measured. Gamma energy is then plotted against the channel number at which its photopeak occurs. Zero energy should be at the origin, and a nearly straight line with a siope approximately equal to one should be obtained. If the analyzer is linear, channel number 25 should represent one-fourth the energy represented by channel number 100.

Non-linearity can be corrected by analyzer adjustments described in the manufacturer's instruction manual. Daily checks should be made to ensure that the system remains linear.

Procedures for Interpreting Gamma Spectra

The advent of multichannel pulse height analysis gamma spectrometry initiated an entirely new method of collecting data. At first, all results were qualitative, but invariably the question arose of how much of each was present. The questions was first asked in reference to iodine 131 in milk samples because of the significance of this radionuclide as a potential health hazard.

The first approach to quantitating individual components in a mixture of gamma emitters was to smooth off the bottom of each peak at the Compton continuum, and relate area under that peak, in counts per minute, to the disintegration rate of the nuclide represented. As a refinement of this, spectrum stripping was developed. In this procedure, individual components were graphically separated. Next came the simultaneous equation approach for unscrambling the spectrum, and recently the least squares method and modifications of it have been used.

Before any spectral analysis can be performed, a library of spectra must be obtained for all the radionuclides of interest in all the various sample sizes and shapes. This channel-by-channel spectral information is necessary not only for calibration purposes but also for quantifying the data obtained from radionuclide mixtures.

Compton Continuum Subtraction

The easiest way to obtain an estimate of the activity for each radionuclide in a spectrum is to smooth off each photopeak and determine the contribution to that photopeak from the gamma photon occumng at that energy.

The difference between the count rate on the dotted line and the count rate at the peak represents the contribution from the gamma photon producing the peak. As an example, channel 18 has 5000 counts and the dotted line passes through the 1000-count portion of the graph. The contribution of this photopeak to channel 18 is 4000 counts. The 1000 counts represents the Cornpton contribution from gamma photons of higher energy. If the counting efficiency for this radionuclide was determined over five channels, then two channels on each side of the peak must be used to obtain a corrected count rate. The net counts per minute are then divided by the efficiency to obtain the disintegration rate.

This method is satisfactory when the peak is fairly well defined and when no other photopeaks are immediately adjacent and overlapping the peak being quantified. The method only corrects for Compton interference, gamma photons interacting with less than their full energy. At best, the corrected result is an approximation which is quite satisfactory if the photopeak is relatively high compared to the interference. It is not satisfactory, however, if the peak is only slightly above the Compton continuum. The placement of the dotted line involves some subjective judgment, but this is not a serious problem when the same analyst interprets spectra from both standard and sample.

D. METHODS OF ANALYSIS

(1) Gamma-emitting Radionuclides

(a) Iodine-131, Barium-140, and Cesium-137 in Milk and Other Foods

Gamma-Ray Spectroscopic Method

A. Principle

Applicable to ^{131}I, ^{140}Ba, and ^{137}Cs in fluid milk preserved with HCHO and I and Cs in foods. Because of the nature of gamma-emitting radionuclides, attenuation of gamma-rays in food slurries or mixture would be similar to that of milk or H_2O. Unlike in **milk** samples, other radionuclides might be present in foods. Therefore, before performing calculation, gamma-ray energy spectrum should be inspected for any radionuclides besides ^{40}K, ^{131}I, ^{137}Cs, and ^{140}Ba. Since cessation of above-ground weapons testing in the 1960s, no other gamma-ray emitters have been regularly observed **or** detected in food. (Should any be detected, matrix technique should be expanded using standard source for suspected radionuclide to deternune matrix coefficient.)

Known volume is placed in counting vessel positioned over and around right cylinder scintillation crystal detector, NaI(Tl), of multichannel gamma spectrometer. Gamma radiation is counted for given time. Accumulated pulses from selected photon energy range are separated from other gamma-emitting radionuclides and background radiation by simultaneous equations. ^{40}K is always present as natural contaminant in food and will contribute counts in 1 or more of photopeak ranges. Mutual interferences among these **4** photopeaks are eliminated by applying matrix technique to separate activities of the **4** nuclides. Measurement of one standard source of each nuclide provides the matrix coefficients.

In special cases, newly formed fission products may be present, e.g., ^{133}I and ^{135}I, which may interfere either through direct overlapping of photopeaks or by contributing Compton-continuumcounts. Such interference may be minimized by waiting for decay of short-lived radionuclides, by additional counting following decay, or by chemical separation.

B. Apparatus

(a) *Alignment sources.*—Gamma ray energies, at least I near ^{137}Cs spectrum, with well known energies and abundance of gamma rays in photopeaks, for alignment. Solid sources, ca 0.1 μCi, are preferred over liquid sources. ^{207}Bi is satisfactory single source with several photopeaks; ^{137}Cs and ^{60}Co are good pair.

(b) *Counter.*—Low level gamma spectrometer consisting of shielded TI-activated NaI scintillation detector, **4** × 4 in., coupled to multichannel pulse-height analyzer and readout system.

(c) *Counting* vessel (*Marinelli* beaker).—Use 3.5 L beaker, for 4 × **4** in. detector. Beaker and lid available from plastic laboratory-ware suppliers such as Bel-Art Products, Industrial Rd, Pequannock, NJ 07440-1992, No. H26852 for beaker and No. H26587 for lid.

C. *Reagents*

(a) *Carrier solutions.*—10 mg/mL. Prepare solutions of CsCl (1.267 g/100 mL), NaI (1.181 g/100 mL), and $BaCl_2 \cdot 2H_2O$ (1.779 g/100 mL). Store in polyethylene or glass bottles.

(b) ***Stock*** *standard solutions.*—10 000 pCi/mL. Dilute calibrated solutions of ^{131}I, ^{140}Ba, and ^{137}Cs to approximate indicated strength.

(c) Potassium-40 stock standard solution.—1.89 dpm (disintegrationslmin) ^{40}K/mg K. Dissolve 240 g KCI (equivalent to 126 g K) in **3** L H_2O in Marinelli beaker and dilute to 3.5 L.

(d) *Calibrating solutions.*—For ^{137}Cs and ^{140}Ba, add 3–5 mL carrier solution, **(a),** to 3 L H_2O in Marinelli beaker, **mix**, add convenient amount of stock standard solution **(h),** sufficient to reduce counting error to ca 1% when counted within 10–100 min, mix, adjust pH to 3.5–4.5, and dilute to 3.5 L. Prepare ^{131}I solution similarly, but adjust pH to 8.5.

D. Preparation of Sample

No special preparation is needed for milk samples. For other foods, do not include inedible material such as bone, apple cores, nut shells, and egg shells as part of sample. Homogenize sample in blender or mechanical homogenizer. Dietary samples prepared for consumption do not require blending, hut must be sufficiently mixed to ensure representative sample.

E. Determination

Using alignment sources centered on detector, adjust spectrometer to cover range at least between 0 and 2 MeV, in intervals (channels) of 10 or 20 keV. Adjust voltage or gain control so that the 2 gamma photopeaks of standard fall in their appropriate channels. Check and adjust alignment daily.

Place Marinelli beaker containing 3.5 L calibrating solution (d), over detector, and count standard for time (10–100 min) sufficient to reduce counting error to ca 1%. Repeat with each calibrating solution and with H_2O. Recalibrate spectrometer yearly or more frequently if gamma ray resolution changes.

Transfer 3.5 L well mixed milk sample at room temperature into Marinelli beaker, place over detector, and count 100 min or time sufficient to give desired counting statistics.

F. Calculations

(a) ***Counter efficiency.***—Total individual counts observed in channels of photopeak range for each calibrating solution. Subtract total background count for same photopeak range. Divide net count by counting time in min and amount of radionuclide in pCi, and record cpm/pCi for each.

(b) ***Interference coefficients.***—When counting standard solution of each radionuclide, ^{131}I, ^{137}Cs, ^{140}Ba, ^{40}K, ratio of net counting rate in energy range of each of the other radionuclides to net counting rate in its own photon energy range gives its fractional interfering coefficient for each of the other energy ranges, e.g., ^{131}I ratio of net counting rate in ^{137}Cs energy range to net counting rate in ^{131}I photon energy range gives its fractional interfering coefficient for ^{137}Cs energy range.

Designate counting rate for ^{131}I, ^{140}Ba, ^{137}Cs, and ^{40}K with symbols I, B, C, and K, respectively. Designate net counting rates (observed—background) in their respective photon energy ranges as N_i, N_b, N_c, and N_k, respectively. Then, f, fractional coefficients or contributions of nuclide in particular range, is designated by 2 lower case subscripts; first one indicates nuclide contributing counts to energy range (column) and second, nuclide photon energy range (row). The following 4 equations:

$$N_i = I + f_{bi} B + f_{ci} C + f_{ki} K \quad (1)$$
$$N_b = f_{ib} I + B + f_{cb} C + f_{kb} K \quad (2)$$
$$N_c = f_{ic} I + f_{bc} B + C + f_{kc} K \quad (3)$$
$$N_k = f_{ik} I + f_{bk} B + f_{ck} C + K \quad (4)$$

can be solved simultaneously by matrix algebra, using inversions to provide numerical constants W, X, Y, and Z in equations 5, 6, 7, and 8. These constants are used to solve for concentration of each of these 4 nuclides in sample. Net counting rate for each nuclide is:

$$^{131}I = I = W_1N_i + W_2N_b + W_3N_c + W_4N_k \quad (5)$$
$$^{140}Ba = B = X_1N_i + X_2N_b + X_3N_c + X_4N_k \quad (6)$$
$$^{137}Cs = C = Y_1N_i + Y_2N_b + Y_3N_c + Y_4N_k \quad (7)$$
$$^{40}K = K = Z_1N_i + Z_2N_b + Z_3N_c + Z_4N_k \quad (8)$$

Calibration to derive values for constants in equations 5, 6, 7, and 8 is applicable as long as instrument alignment and mode of operation remain constant and gamma-emitting nuclides are limited to the 4 elements in matrix. Long-hand inversion of 4 × 4 matrix is tedious and subject to mistakes. Use of computer is recommended to provide numerical constants for equations 5–8. Thereafter, desk calculations can determine concentrations of ^{131}I, ^{140}Ba, ^{137}Cs, and ^{40}K in samples in absence of computer by summing counts in each photopeak, subtracting background, and applying equations 5–8.

(c) ***Iodine-131, barium-140, cesium-137, potnssium-40 activities.***—From spectral gamma counts of sample, substitute net value from equations 5 through 8 and convert net counts/min for each nuclide to pCi/L milk at time of counting:

$$^{131}I(pCi/L) = (\text{net cpm})_i/(E_i \times V)$$
$$^{140}Ba(pCi/L) = (\text{net cpm})_b/(E_b \times V)$$
$$^{137}Cs(pCi/L) = (\text{net cpm})_c/(E_c \times V)$$
$$^{40}K(pCi/L) = (\text{net cpm})_k/(E_k \times V),$$

where E_i, E_b, E_c, E_k = counting efficiency/pCi from standard solutions for ^{131}I, ^{140}Ba, ^{137}Cs, ^{40}K, respectively, and V = sample volume, L.

(b) Iodine-131, Ruthenium-106, and Cesium-137 in Foods

Gamma-Ray Spectroscopic Method

A. Principle

Applicable to ^{131}I, ^{106}Ru, and ^{137}Cs in foods. Because of the nature of gamma-emitting radionuclides, attenuation of gamma-rays in food slurries or mixture would be similar to that of milk or H_2O. Unlike in milk samples, other radionuclides might be present in foods. Therefore, before performing calculation, gamma-ray energy spectrum should be inspected for any radionuclides besides ^{40}K, ^{131}I, ^{137}Cs, and ^{106}Ru. Since cessation of above-ground weapons testing in the **1960s,** no other gamma-ray emitters have been regularly observed or detected in food except ^{134}Cs. (Should any ^{134}Cs be detected, matrix technique should be expanded using standard source for suspected radionuclide to determine matrix coefficient.)

Known volume is placed in counting vessel positioned over and around right cylinder scintillation crystal detector, NaI(Tl), of multichannel gamma spectrometer. Gamma radiation is counted for given time. Accumulated pulses from selected photon energy range are separated from other gamma-emitting radionuclides and background radiation by simultaneous equations. ^{40}K is always present as natural contaminant and may contribute counts in one or more of photopeak ranges. Mutual interferences among these **4** photopeaks are eliminated by applying matrix technique to separate activities of the **4** nuclides. Measurement of one standard source of each nuclide provides the matrix coefficients.

In special cases, newly formed fission products may be present, e.g., ^{133}I and ^{135}I, which may interfere either through direct overlapping of photopeaks or by contributing Compton-continuumcounts. Such interference may be minimized by waiting for decay of short-lived radionuclides, by additional counting following decay, or by chemical separation.

B. Apparatus

(a) *Alignment sources.*—Gamma ray energies, at least 1 near ^{137}Cs spectrum, with well known energies and abundance of gamma rays in photopeaks, for alignment. Solid sources, ca 0.1 μCi, are preferred over liquid sources. ^{207}Bi is satisfactory single source with several photopeaks; ^{137}Cs and ^{60}Co are good pair.

(h) *Counter.—Low* level gamma spectrometer consisting of shielded TI-activated NaI scintillation detector, **4** × **4** in., coupled to multichannel pulse-height analyzer and readout system.

(c) *Counting vessel* (*Marinelli beaker*).—Use **3.5** *L* beaker, for **4** × **4** in. detector. Beaker and lid available from plastic laboratory-ware suppliers such as Bel-Art Products, Industrial Rd, Pequannock, NJ **07440-***1992,* **No.** H26852 for beaker and No. H26587 for lid.

C. Reagents

(a) *Carrier solutions.*—10 mg/mL. Prepare solutions of CsCl (1.267 g/100 mL), NaI *(1.181* g/100 mL), and $RuCl_3$ **(2.06 g/100** mL). Store in polyethylene or glass bottles.

(b) *Stock standard solutions.*—10 *000* pCi/mL. Dilute calibrated solutions of ^{131}I, ^{140}Ba, and ^{137}Cs to approxiinate indicated strength.

(c) *Potassium-40 stock standard solution.* —*1.89* dpm (disintegrations/min) ^{40}K/mg K. Dissolve **240** g KCl (equivalent to **126** g K) in **3** L H_2O in Marinelli beaker and dilute to *3.5* L.

(d) *Calibrating solutions.*—For ^{137}Cs and ^{106}Ru, add **3–5** mL carrier solution, **(a),** to 3 L H_2O **in** Marinelli beaker or other standardized volume, mix, add convenient amount of stock standard solution, **(b),** sufficient to reduce counting error to ca 1% when counted within *10–100* min, mix, adjust pH to **3.5–4.5,** and dilute to **3.5** L or other standard volume. Prepare ^{131}I solution similarly, but adjust pH to 8.5.

D. Preparation of Sample

Food samples do not include inedible material such as bane, apple cores, nut shells, and egg shells as part of sample. Homogenize sample in blender or mechanical homogenizer. Dietary samples prepared for consumption do not require blending, but must be sufficiently mixed to ensure representative sample.

E. Determination

Using alignment sources centered on detector, adjust spectrometer to cover range at least between 0 and **2** MeV, in intervals (channels) of 10 or ***20*** KeV. Adjust voltage or gain control so that the 2 gamma photopeaks of standard fall in their appropriate channels. Check and adjust alignment daily.

Place Marinelli beaker containing 3.5 L calibrating solution or other standardized container, ie 400 mL plastic container (cottage cheese type)(d), over detector, and count standard for time (10–100 min) sufficient to reduce counting error to ca **1**%. Repeat with each calibrating solution and with H_2O. Recalibrate spectrometer yearly or more frequently if gamma ray resolution changes.

Transfer 3.5 L well mixed sample at room temperature into Marinelli beaker or other standard volume, place over detector, and count 100 min or time sufficient to give desired counting statistics.

F. Calculations

(a) *Counter efficiency.*—Total individual counts observed in channels of photopeak range for each calibrating solution. Subtract total hackground count for same photopeak range. Divide net count by counting time in min and amount of radionuclide in pCi, and record cpm/pCi for each.

(b) *Interference coefficients.*—When counting standard solution of each radionuclide, ^{131}I, ^{137}Cs, ^{106}Ru, ^{40}K, ratio of net counting rate in energy range of each of the other radionuclides to net counting rate in its own photon energy range gives **its** fractional interfering coefficient for each of the other energy ranges, e.g., ^{131}I ratio of net counting rate in ^{137}Cs energy range to net counting rate in ^{131}I photon energy range gives its fractional interfering coefficient for ^{137}Cs energy range.

Designate counting rate for ^{131}I, ^{106}Ru, ^{137}Cs, and ^{40}K with symbols I, R, C, and K, respectively. Designate net counting rates (observed—background) in their respective photon energy ranges as N_i, N_r, N_c, and N_k, respectively. Then, f, fractional coefficients or contributionsof nuclide in particular range, is designated by 2 lower case subscripts; first one indicates nuclide contributing counts to energy range (column) and second, nuclide photon energy range (row). The following **4** equations:

$$N_i = I + f_{bi} R + f_{ci} C + f_{ki} K \quad (1)$$
$$N_r = f_{ir} I + R + f_{cr} C + f_{kr} K \quad (2)$$
$$N_c = f_{ic} I + f_{bc} R + C + f_{kc} K \quad (3)$$
$$N_k = f_{ik} I + f_{rk} R + f_{ck} C + K \quad (4)$$

can be solved simultaneously by matrix algebra, using inversions to provide numerical constants W, **X,** Y, and Z in equations 5, 6, 7, and 8. These constants are used to solve for concentration of each of these **4** nuclides in sample. Net counting rate for each nuclide is:

$$^{131}I = I = W_1N_i + W_2N_r + W_3N_c + W_4N_k \quad (5)$$
$$^{106}Ru = R = X_1N_i + X_2N_r + X_3N_c + X_4N_k \quad (6)$$
$$^{137}Cs = C = Y_1N_i + Y_2N_r + Y_3N_c + Y_4N_k \quad (7)$$
$$^{40}K = K = Z_1N_i + Z_2N_r + Z_3N_c + Z_4N_k \quad (8)$$

Calibration to derive values for constants in equations **5,** 6, 7, and 8 is applicable as long as instrument alignment and mode of operation remain constant and gamma-emitting nuclides are limited to the **4** elements in matrix. Long-hand inversion of **4** × **4** matrix is tedious and subject to mistakes. Use of computer is recommended to provide numerical constants for equations 5–8. Thereafter, desk calculations can determine concentrations of ^{131}I, ^{106}Ru, ^{137}Cs, and ^{40}K in samples in absence of computer by summing counts in each photopeak, subtracting background, and applying equations 5–8.

(c) *Iodine-131, ruthenium-106, cesium-137, potassium-40 activities.*—From spectral gamma counts of sample, substitute net value from equations 5 through 8 and convert net counts/min for each nuclide to pCi/L at time of counting:

$^{131}I(pCi/L) = (net\ cpm)_i/(E_i \times V)$
$^{106}Ru(pCi/L) = (net\ cpm)_b/(E_b \times V)$
$^{137}Cs(pCi/L) = (net\ cpm)_c/(E_c \times V)$
$^{40}K(pCi/L) = (net\ cpm)_k/(E_k \times V)$,

where E_i, E_b, E_c, E_k = counting efficiency/pCi from standard solutions for ^{131}I, ^{106}Ru, ^{137}Cs, ^{40}K, respectively, and **V** = sample volume, L.

(c) Cesium-134/137 in Foods

Gamma-Ray Spectroscopic Method

A. *Principle*

See (b) "Iodine-131, Ruthenium-106 and Cesium-137 in Foods"

B. Apparatus

See as in "A. Principle"

C. Reagents

(a) ***Carrier solutions.***—10 mg/mL. Prepare solutions of CsCl(1.267 g/100 mL). Store in polyethylene or glass bottles.

(b) ***Stock standard solutions.***—10 000 pCi/mL. Dilute calibrated solutions of ^{134}Cs and ^{137}Cs to approximate indicated strength.

(c) ***Potassium-40 stock standard solution.*** —1.89 dpm (disintegrations/min) ^{40}K/mg K. Dissolve 240 g KCl (equivalent to 126 g K) in 3 L H_2O in Marinelli beaker and dilute to 3.5 L, or other standard volume.

(d) ***Calibrating*** solutions.—For ^{137}Cs and ^{134}Cs, add 3-5 mL carrier solution, **(a),** to 3 L H_2O in Marinelli beaker or other standard container, mix, add convenient amount of stock standard solution, **(b),** sufficient to reduce counting error to ca 1% when counted within 10–100 min, mix, ad-just pH to 3.5–4.5, and dilute to 3.5 L or other standardized volume.

D. Preparation of Sample

Food samples do not include inedible material such as bone, apple cores, nut shells, and egg shells as part of sample. Homogenize sample in blender or mechanical homogenizer. Dietary samples prepared for consumption do not require blending, but must be sufficiently mixed to ensure representative sample.

E. Determination

Using alignment sources centered on detector, adjust spectrometer to cover range at least between 0 and 2 meV, in intervals (channels) of 10 or 20 keV. Adjust voltage or gain control so that the 2 gamma photopeaks of standard fall in their appropriate channels. Check and adjust alignment daily.

Place calibrating solution(d), over detector, and count standard for time (10–100 min) sufficient to reduce counting error to ca 1%. Repeat with each calibrating solution and with H_2O. Recalibrate spectrometer yearly or more frequently if gamma ray resolution changes.

Transfer well mixed sample at room temperature into standardized container, place over detector, and count 100 min or time sufficient to give desired counting statistics.

F. Calculations

(a) ***Counter efficiency.***—Total individual counts observed in channels of photopeak range for each calibrating solution. Subtract total background count for same photopeak range. Divide net count by counting time in min and amount of radionuclide in pCi, and record cpm/pCi for each.

(b) *Interference coefficients.*—When counting standard solution of each radionuclide, ^{134}Cs, ^{137}Cs, ^{40}K, ratio of net counting rate in energy range of each of the other radionuclides to net counting rate in its own photon energy range gives its fractional interfering coefficient for each of the other energy ranges, e.g., ^{134}Cs ratio of net counting rate in ^{137}Cs energy range to net counting rate in ^{134}Cs photon energy range gives its fractional interfering coefficient for ^{137}Cs energy range.

Designate counting rate for ^{134}Cs, ^{137}Cs, and ^{40}K with symbols B, C, and K, respectively. Designate net counting rates (observed—background) in their respective photon energy ranges as N,, N,, and N_k, respectively. Then, f, fractional coefficients or contributions of nuclide in particular range, is designated by 2 lower case subscripts; first one indicates nuclide contributing counts to energy range (column) and second, nuclide photon energy range (row). The following 3 equations:

(1) $N_b = B + f_{cb} C + f_{kb} K$
(2) $N_c = f_{bc} B + C + f_{kc} K$
(3) $N_k = f_{bk} B + f_{ck} C + K$

can be solved simultaneously by matrix algebra, using inversions to provide numerical constants X, **Y,** and Z in equations **4,** 5, and **6.** These constants are used to solve for concentration of each of these 3 nuclides in sample. Net counting rate for each nuclide is:

(4) $^{134}Cs = B = X_2N_b + X_3N_c + X_4N_k$
(5) $^{137}Cs = C = Y_2N_b + Y_3N_c + Y_4N_k$
(6) $^{40}K = K = Z_2N_b + Z_3N_c + Z_4N_k$

Calibration to derive values for constants in equations **4, 5,** and 6 is applicable as long as instrument alignment and mode of operation remain constant and gamma-emitting nuclides are limited to the 3 elements in matrix. Long-hand inversion of 3 × 3 matrix is tedious and subject to mistakes. Use of computer is recommended to provide numerical constants for equations **4-6.** Thereafter, desk calculations can determine concentrations of ^{134}Cs, ^{137}Cs, and ^{40}K in samples in absence of computer by summing counts in each photopeak, subtracting background, and applying equations 4-6.

(c) Cesium-I*34*, *cesium-1*37, *potassium-40* activities.—From spectral gamma counts of sample, substitute net value from equations **4** through **6** and convert net counts/min for each nuclide to pCi/L food at time **of** counting:

$^{134}Cs(pCi/L) = (\text{net cpm})_b/(E_b \times V)$
$^{137}Cs(pCi/L) = (\text{net cpm})_c/(E_c \times V)$
$^{40}K(pCi/L) = (\text{net cpm})_k/(E_k \times V)$,

where E_b, E_c, E_k = counting efficiency/pCi from standard solution for ^{134}Cs, ^{137}Cs, ^{40}K, respectively, and V = sample volume, L.

References: JAOAC ***56,*** 204(1973); ***65,*** 1039(1982); **69,** 270, 301(1986); **72,** 667(1989).
OFFICIAL METHODS of ANALYSIS, AOAC, 15th EDITION, ARLINGTON 1990, Method 973.67

(2) Beta-emitting Radionuclides

(a) Tritium in Water

Scintillation Spectrometric Method

A. Principle

Sample is distilled to remove quenching materials and non-volatile radioactive materials. Distillation is to dryness to ensure complete transfer of 'H and background samples are prepared and counted alternately to nullify errors produced by aging of scintillation medium or instrument drift.

B. Apparatus

(a) *Liquid scintillation* spectrometer.—Coincidence-type. Available from Packard Instrument Co., 2200 Warrenville Rd, Downers Grove, IL 60515; and others.

(b) Liquid *scintillation vial.*—20 Ml; low-K glass, polyethylene, nylon, or equivalent bottles, available from manufacturers under **(a).**

C. Reagents

(a) *Scintillation solution.*—Thoroughly mix 4 g PPO (2,5-diphenyloxazole), 0.05 g POPOP (1,4-bis(5-phenyloxazol-2-yl) benzene), and 120 g solid naphthalene in 1 L spectral grade 1,4-dioxane. (Available from Aldrich Chemical Co., Inc.). Store in dark bottles. Solution is stable 2 months.

(b) *Tritium standard* solution.—Pipet 4 MI H_2O of known ^3H activity and 16 MI scintillation solution into scintillation vial, tightly cover vial with screw cap, and mix thoroughly by shaking.

(c) *Background* solution.—Mix 4 mL distilled H_2O (free of ^3H activity to be measured in samples) with 16 mL scintillation solution as in **(b).**

D. Preparation of Sample

Distill 20–30 mL sample to dryness. Mix 4 mL sample distillate with 16 mL scintillation solution as in C(b).

E. Determination

Prior to counting, dark-adapt and cool sample, background, and standard solutions ca 3 h in instrument freezer at $>2''$ (to prevent solidification of solution with time), or at ambient temperature if ambient temperature liquid scintillation spectrometer is used. Count solutions for total of 200,000 counts or 100 min, whichever is sooner.

F. Calculation

$$\text{Counting efficiency, } E = (S - B)/D$$

$$\text{'H, pCi (picoCuries)/mL} = (C - B)/(E \times 4 \times 2.22)$$

where S = gross cpm (counts/min) of standard, B = cpm background, D = dpm (disintegrations/min) of ^3H activity in standard, and C = gross cpm for sample.

References: JAOAC **52,** 90(1969).
OFFICIAL METHODS of ANALYSIS, AOAC, 15th EDITION, ARLINGTON 1990, Method 969.48

(b) Dehydration of Food Samples for Assay of Tritium in Free Water

INTRODUCTION

This procedure is for a low-temperature, distillation apparatus for Dehydration of Food Samples for Assay of Tritium in Free Water.

REAGENTS

Dry ice or dry ice-alcohol slurry

Ultima Gold Rx (Packard Instruments) or Equivalent

EQUIPMENT

Liquid scintillation spectrometer (Packard Instruments Company, Model 3385) or Equivalent

Polyethylene vials, stored in darkness.

NESLAB RTE 220 Cooling Bath Unit or equivalent

The distillation unit consists of two identical glass tubes joined to a one-piece adapter by means of 35/25 O-ring joints to form a closed distillation system. One tube holds the sample and the second serves as the water trap.

The water trap is cooled in dry ice or in a slurry of dry ice-alcohol contained in a 16 in. x 12 in. x **16** in. high Styrofoam box with two-inch-thick walls and bottom. The two-inch thick walls (four in all) and bottom of the box are made by gluing one-inc sheets of Styrofoam with "Sticky Styroglue" from Styroformics Division, PolymerTempera, Inc., Medford, Massachusetts, 02155.

Each assembled distillation unit is placed so the adaptor spans the top edge of the Styrofoam **box.** The water trap rest in the cold bath while the sample tube rests in a cylindrical, ceramic heater outside the box. Three distillation units tit on each of two opposite sides. The heaters are supported on small jacks. A one-inch thick sheet of Styrofoam is supported over the refrigerant and helps to contain the cold space. The water traps pass through holes in this sheet.

A stopcock serves to direct the distilled water from the sample tube to the water trap and also permits evacuation of the unit via the water trap at the start of distillation. The evacuation is accomplished by connection of the unit to the mechanical vacuum pump through the 18/9 O-ring joint.

Operation of the Distillation Unit

The 3-way stopcock serves to direct the distilled water from the sample tube to the water trap and also permits evacuation of the unit via the water trap at the start of distillation. The evacuation is accomplished by connection of the unit to the mechanical vacuum pump through the 1819 O-ring joint.

At the start the stopcock is oriented so as to connect the trap to the vacuum pump and the trap is evacuated. The stopcock is then turned to connect the sample tube to the water trap and allow air in the sample tube to pass to the evacuated trap. After a few seconds the stopcock is turned again to connect the water to the vacuum pump and the trap is again pumped out. This succession of operations is repeated until the pressure in the glass unit reads zero on a Dubrovin gauge, 0 - 20 mm range. The stopcock is finally set to allow moisture to distill from the sample tube to the water trap. The distillation should be done with only very gently heating in order that the distillate will be a clear liquid suitable without further treatment for liquid scintillation counting of its tritium content.

DISTILLATION PROCEDURE

1. Orient the 3-way stopcock so the trap is connected to the vacuum pump.

2. Evacuate the trap.

3. Turn the stopcock to connect the sample tube to the water trap and allow air in the sample tube to pass to the evacuated trap.

4. After a few seconds turn the stopcock to connect the water to the vacuum pump and evacuate the trap again.

5. Repeat until the pressure in the glass unit reads zero on a Dubrovin gauge, 0 - 20 mm range.

6. Set the stopcock to allow moisture to distill from the sample tube to the water trap.

7. Distillate with very gently heating.

8. When distillation is complete, remove the sample tube and water trap and seal with their respective closures.

9. Cool the sample tube and trap to room temperature.

10. Wipe off the lubricating grease on the glass joint of the water trap.

11. Wipe off any moisture condensed on the outside of the water trap.

12. Place the trap and sample tube in light-weight, polyurethane containers.

13. Weigh the sample tube and water trap.

14. Record the weight of the dried residue and distillate. Verify proper agreement with the original sample weight and products.

15. Clean the equipment between samples by soaking in boiling detergent solution. This should dislodge or soften the dried residue in the sample tube and remove grease (Apiezon M) from the lubricated joints. If highly radioactive samples are processed, steam the apparatus to remove adsorbed tritium.

COUNTING PROCEDURE

1. Prepare the counting mixture under amber or red light:

   a. Transfer 10 mL of the distillate to a screw-cap, polyethylene liquid scintillation vial.

   b. Add 15 mL of phosphorus solution (scintillation cocktail).

   c. Cap the vial and shake for at least 30 seconds.

   d. Age in a liquid scintillation spectrometer, as specified by manufacturer of LS counter.

4. Count the samples in a liquid scintillation spectrometer. Sum the results of two, 50-minute counts and treat as a single, 100-minute count.

5. Determine the background with a counting mixture containing 10ml of distilled, deep-well water.

6. Determine the counting efficiency with an NBS tritiated water standard.

7. Correct the sample count for background and efficiency.

8. The spectrometer readout provides the results as counts per minute (cpm) per 10 mL. Convert to nanocuries per kilogram (nCi/kg) of food using Equation 1.

$$nCi/kg = \frac{C - bg \times R}{W \times E \times V \times 2.22} \qquad (1)$$

where:

C = count rate in cpm

V = volume of distillate counted = 10 mL
bg = background count rate
R = volume of distillate recovered
W = wgt. of food which produced R

2.22 = conversion factor for dpm to nCi
E = counting efficiency

9. Calculate the counting error using Equation 2.

$$2-\sigma_{ce} = \frac{\pm 2R \times \sqrt{\left(\frac{G}{t}\right) + s^2(B)}}{E \times V \times W \times 2.2} \qquad (2)$$

where:

G = gross count (sample + background)
$s^2(B)$ = variance of background values
t = time (minutes)
ce = counting error

REFERENCES

1. Stewart, M. L., et al. A Tritiated Water Recovery System. Int. J. of Applied Rad and Iotopes, Volume 23, 1972, Pages 387-8

2. Liebermann and Moghissi in International Journal of Applied Radiation and Isotopes, 21, 319-327 (1970)

5. Drobinski, J. C., Jr., et al. Analysis of Environmental Samples for Carbon^{14} and Tritium. Health Physics, Volume 11, 1965, Pages 385-95.

(c) Strotitiurn-90 in Water

Beta Particle Counting Method

A. Principle

Applicable to H_2O, and to sewage and industrial waste if organic matter is destroyed and interfering ions are eliminated. Added carrier Sr along with radionuclides are separated from other radioactive elements and inactive sample solids by precipitation as $Sr(NO_3)_2$ from fuming HNO,. Sr is finally precipitated as $SrCO_3$, which is dried, weighed, and set aside ca 2 weeks for ingrowth of ^{90}Y. Precipitate is then dissolved and ^{90}Y is prepared for counting by *(a)* extraction by tributyl phosphate and evaporating on planchet, or (*b*) addition of Y carrier and precipitating as oxalate.

Radioactive Ba and Ra which interfere are removed by addition of Ba carrier, Ca interferes with Sr precipitation, but is removed by HNO, precipitation and acetone treatment.

B. Apparatus

(a) *Counting* paris.—Stainless steel, ca 50 mm diameter and 7 mm deep.

(b) Filtration *assembly.*—For mounting precipitates tor counting. Consists of (1) 2-piece filtering apparatus for 2.4 cm filter such as stainless steel filter holder (Interex Corp., 3 Strathmore Rd, Natick, MA 01760, No. 12-103; ICN Pharmaceuticals, Inc., Life Sciences Group, No. 83012), Teflon filter holder, or equivalent. (2) Nylon (Zytel 101) disk with ring for mounting precipitate.

(c) *Filn, Mylar.*—To cover precipitates during counting and storage, ca 0.025 cm thick. Available in rolls 1.5" (3.8 cm) wide as manufacturer's No. 92A, E. I. du Pont de Nemours, Electronics Dept, Barley Mill Plaza, Kirk Mill: Mylar Product Information, Wilmington, DE 19805.

(d) *Glass fiber filter paper.*—No. 934-AH, 2.4 cm diameter, available from Whatman, Inc.

(e) *Centrifuge tubes.*—40 mL, heavy duty with short cone bottom and pour-out lip.

(f) Beta particle *counter.*—Low background, shielded, anticoincidence counter. Determine counter efficiency for ^{90}Y as oxalate and ^{89}Sr as carbonate for specific counter and geometry.

C. Reagents

(a) Dilute *acetic acid.*—6*N.* Add 345 mL CH_3COOH to H_2O and dilute to 1 L.

(b) *Ammonium* acetate *buffer.*—pH 5.5. Dissolve 154 g NH_4CH_3COO in 700 mL H_2O, add 57 mL CH_3COOH, adjust pH to 5.5 with dropwise addition of either CH_3COOH or 6N NH_4OH, as necessary, and dilute to 1 L.

(c) *Dilute ammonium hydroxide.*—6*N.* Dilute 400 mL NH_4OH to 1 L with H_2O.

(d) *Barium carrier solution.*—10 mg Ba/mL. Dissolve 19.0 g $Ba(NO_3)_2$ in H_2O and dilute to 1 L.

(e) Dilure hydrochloric *acid.*—6*N.* Add 500 mL HCI to H_2O and dilute to 1 L.

(f) *Fuming nitric acid.*—21*N.* Specific gravity 1.48, 90% HNO,.

(g) *Dilute nitric acid.*—(*1*) 14N.—Add 875 mL HNO, to H_2O and dilute to 1 L. **(2)** 6N.—Add 384 mL HNO, to H_2O and dilute to 1 L. ***(3)*** *0.1N.*—Add 6.25 mL HNO_3 to H_2O and dilute to 1 L.

(h) ***Oxalic acid*** *solution.*—Saturated. Approximately *11* g $H_2C_2O_4.2H_2O$ in 100 mL H_2O.

(i) *Mixed* rare earth carrier solution.—Dissolve 12.8 g $Ce(NO_3)_3.6H_2O$, 14 g $ZrOCl_2.8H_2O$, and 25 g $FeCl_3.6H_2O$ in 600 mL H_2O containing 10 mL HCI, and dilute to 1 L. (*Caution:* $Ce(NO_3)_3$ is toxic. Wear resistant rubber or plastic gloves.)

(j) *Sodium* ***carbonate*** *solution.*—2*N.* Dissolve 142 g $Na_2CO_3.H_2O$ in H_2O and dilute to 1 L.

(k) *Sodium* chromate ***solution.***—0.5*M.* Dissolve 117 g $Na_2CrO_4.4H_2O$ in H_2O and dilute to 1 L.

(l) *Sodium hydroxide solution.*—6*N.* Dissolve 240 g NaOH in H_2O and dilute to I L.

(m) *Strontium carrier solution.*—10 mg Sr/mL. Dissolve 24.16 g $Sr(NO_3)_2$ in H_2O and dilute to 1 L. Standardize by pipetting (in triplicate) 10 mL solution into 40 mL centrifuge tubes and adding 15 mL 2N Na_2CO_3. Stir and heat in boiling H_2O bath 15 min. Filter through weighed, fine porosity, fritted glass, 15 mL crucible. Wash with three 5 mL portions H_2O and three 5 mL portions absolute alcohol or acetone, wipe crucible with absorbent tissue, and dry to constant weight at 110" (ca 20 min). Cool in desiccator and weigh.

$$\text{mg Sr/mL} = \text{mg } SrCO_3 \times 0.5935110$$

(n) *Tributyl phosphate (TBP), equilibrated.*— Shake TBP with equal volume **14N** HNO_3. Separate and discard lower acid phase.

(o) *Yttrium carrier solution.*—10 mg Y/mL. Dissolve 12.7 g Y_2O_3 in 30 mL HNO, by stirring and heating. Add additional 20 mL HNO, and dilute to 1 L with H_2O. 1 mL = 34 mg $Y_2(C_2O_4)_3.9H_2O$. Determine

exact equivalence as in step (f) or (g) of D. Determination.

D. Determination

(a) *Precipitation as carbonate.*—To 1 L drinking H_2O (or less, but containing ≥25 pCi "Sr) or filtered raw H_2O sample in beaker, add **2.0** mL HNO, and **mix.** Add 2.0 mL each of Ba and Sr carrier solutions and mix well. (Precipitate of $BaSO_4$ will not cause difficulty.) Heat to bp, and add 20 mL *6N* NaOH and *20* mL *2N* Na_2CO_3. Stir, and let simmer ca 1 h at 90–95°. Let cool until precipitate has settled (1–3 h). Decant and discard supernate. Transfer precipitate to 40 mL centrifuge tube, centrifuge, and discard supernate.

(b) *Purification as nitrate.*—Cautiously add **4** mL HNO, dropwise to precipitate. Heat to bp, stir, and cool under running H_2O. Add 20 mL fuming HNO,, cool 5–10 min in ice bath, stir, and centrifuge. Discard supernate. Add **4** mL H_2O to residue, stir, and heat to bp to dissolve $Sr(NO_3)_2$. Centrifuge while hot and decant supernate into clean centrifuge tube. Add *2* mL *6N* HNO, to residue, heat to bp, centrifuge while hot, and combine supernate with aqueous supernate. Discard insoluble residue of $BaSO_4$, SiO_2, etc.

Cool combined supernates, add *20* mL fuming HNO_3, cool 5–10 min in ice bath, stir, centrifuge, and discard supernate. Add **4** mL H_2O to precipitate and dissolve by heating, cool, add 20 mL fuming HNO,, cool 5–10 min in ice bath, stir, centrifuge, and discard supernate. If >200 mg Ca is present in sample, repeat H_2O solution and fuming HNO, precipitation.

(c) *Removal of rare earths.*—After last HNO, precipitation, invert tube in beaker ca 10 min to drain off most of excess HNO,. Add 20 mL acetone to precipitate. Stir thoroughly, cool, centrifuge, and discard supernate. Dissolve precipitate of strontium and barium nitrates in 10 mL H_2O and boil 30 sec to remove any remaining acetone.

Add *0.25* mL mixed rare earth carrier solution and precipitate rare earth hydroxides by making solution basic with *6N* NH_4OH. Digest in boiling H_2O bath 10 min. Cool in ice bath, centrifuge, decant supernate to clean tube, and discard precipitate. Repeat addition of rare earth carrier solution, precipitation, and decantation. Note time as beginning of ^{90}Y ingrowth period.

(d) *Removal of barium.*—Add 2 drops methyl red indicator and then *6N* CH_3COOH, dropwise with stirring, until solution is red. Add *5* mL acetate buffer solution, heat to bp, and add 2 mL Na_2CrO_4 solution dropwise with stirring. Digest in boiling H_2O bath *5* min. Cool in ice bath, centrifuge, decant supernate into clean tube, and discard residue.

(e) *Precipitation as strontium carbonate.*—Add 2 mL *6N* NaOH to supernate; then add *5* mL *2N* Na_2CO_3 and heat to bp. If pH is <9, add additional NaOH solution. Cool in ice bath ca *5* min, centrifuge, and discard supernate. Add 15 mL H_2O to precipitate, stir, centrifuge, and discard wash H_2O. Repeat washing and weigh SrCO, as in *(1)* or **(2):**

(1) Slurry precipitate with small volume H_2O, and transfer to weighed stainless steel pan. Dry under IR lamp, cool, and weigh. ***(2)*** Transfer precipitate to weighed paper or glass filter mounted in 2 piece funnel. Let settle by gravity for uniform deposition; then apply suction. Wash precipitate with three 5 mL portions H_2O, three 5 mL portions alcohol, and three 5 mL portions ether or acetone. Dry 15–30 min in 110–125° oven, cool, and weigh.

Store precipitate ≥2 weeks to permit ingrowth of ^{90}Y. Separate and count ^{90}Y by (f) or (g).

(f) *Separation by TBP extraction.*—If SrCO, is weighed in pan, place **pan** in small funnel in mouth of *60* mL separator and carefully add 1 mL *6N* HNO, dropwise. Tilt pan to empty, and rinse with two 2 mL portions *6N* HNO,.

If SrCO, is weighed on filter, dislodge bulk of precipitate into small funnel in mouth of *60* mL separator. Cautiously add 1 mL *6N* HNO_3 dropwise to dissolve remaining precipitate. Rinse filter and funnel with two *2* mL portions of *6N* HNO,.

Remove pan or filter and add 10 mL fuming HNO, to separator through funnel. Remove funnel and add 1 mL Y carrier solution to separator. Add 5.0 mL TBP, shake thoroughly 3–5 min, let separate, and transfer aqueous layer to second 60 mL separator. Add 5.0 mL TBP to second separator, shake 5 min, let separate, and transfer aqueous layer to third *60* mL separator. Combine TBP extracts and wash with two *5* mL portions *14N* HNO,. Record time *as* beginning of ^{90}Y decay. (Combine acid washings with aqueous phase in third separator if second ingrowth of ^{90}Y is desired.)

Back-extract ^{90}Y from combined organic phase with 10 mL 0.1*N* HNO, 5 min. Either *(1)* repeat TBP extraction as above, beginning "Add 5.0 mL TBP, . . ." and finally back-extracting ^{90}Y into 10 mL 0.1*N* HNO, and continue as in (g), beginning "Gradually . . ."; or *(2)* transfer aqueous phase to 50 mL beaker and evaporate on hot plate to 5–10 mL. Transfer residual solution to weighed stainless steel counting pan and evaporate. Rinse with two 2 mL portions 0.1*N* HNO,, add rinsings to counting pan, evaporate to dryness, and weigh. Count in internal proportional or end window counter and calculate ^{90}Sr as in **E.**

(g) *Separation by yttrium oxalate precipitation.*— Dissolve SrCO, by cautiously adding 2 mL *6N* HNO, dropwise, and transfer to *40* mL centrifuge tube, rinsing with 0.1*N* HNO,. Add 1 mL *Y* carrier solution, 2 drops methyl red, and NH_4OH dropwise to methyl red end point. Add additional *5* mL NH_4OH and record time

as end of ^{90}Y ingrowth and beginning of decay. Centrifuge and decant supernate into beaker. (Save supernate and washings for second ingrowth, if desired.) Wash precipitate with two 20 mL portions hot H_2O. Add 5–10 drops *6N* HNO,, stir to dissolve precipitate, add 25 mL H_2O, and heat in H_2O bath at 90". Gradually add 15–20 drops saturated oxalic acid solution with stirring, and adjust pH to 1.5–2.0 (pH meter or indicator paper) with dropwise addition of NH_4OH. Digest precipitate *5* min; then cool in ice bath with occasional stirring.

Transfer precipitate to weighed glass fiber filter in 2-piece funnel. Let precipitate settle by gravity for uniform deposition and then apply suction. Wash precipitate with 10–15 mL H_2O, three 5 mL portions alcohol, and then three 5 mL portions ether. Air dry precipitate 2 min with suction, weigh, mount on nylon disk and ring with Mylar cover, count, and calculate ''Sr as in **E.**

E. Calculations

(a) Strontium-90 *calculation.*—

$$^{90}Sr,\ pCi/L = \text{net cpm}/(abcdfg \times 2.22)$$

where a = counting efficiency for ''Y; b = chemical yield (fraction) of extracted or precipitated ''Y; c = mg final Y oxalate precipitate/mg Y oxalate in 1 mL carrier; d = chemical yield (fraction) of Sr determined as in D(e) (20 mg Sr equivalent to 33.6 mg $SrCO_3$) or by flame photometry; f = volume, L, original sample; g = ^{90}Y decay factor = $e^{-\lambda t}$; e = base of natural logarithms; $\lambda = 0.693/T_{1/2}$; T,, = 64.2 h for ''Y; **and** t = time, h, between separation and counting.

(b) Counting *efficiency.*—Prepare curve from various weights yttrium oxalate precipitate spiked with $^{90}Sr/^{90}Y$, precipitated as in D(g).

(c) *Correction for* carrier recovery.—If sample contains more than trace stable Sr, it will act as carrier and will result in > 100% yield. In such *case* determine Sr by flame photometry.

References: JAOAC ***56,*** 208(1973).
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(d) Strontium-89 and Strontium-90 in Milk
Ion Exchange Method

A. Principle

Fresh milk samples are preserved with HCHO and stored to obtain ^{90}Y ingrowth. After storage, Y, Sr, and Ba carriers and citrate solution are added. Citrate forms Y complex which is adsorbed on anion exchange resin. Y is desorbed and separated from radionuclides by tributyl phosphate extraction. Y is re-extracted into dilute HNO, and precipitated as oxalate, which is weighed and counted for ^{90}Y activity to calculate ^{90}Sr.

Radio-Sr is desorbed along with Ca and radio-Ba; Ca, radio-Ba, and rare earth radionuclides are separated by repetitive precipitations; Sr is precipitated as $SrCO_3$ and counted. Total radio-Sr minus ^{90}Sr by ^{90}Y measurement yields value for ^{89}Sr.

B. Operating Notes

Radio-Ba and La radionuclides will interfere without purification. Purification from Ca is important for recovery tests but need not be as thorough if Sr recovery is determined by ^{85}Sr tracer or flame photometry. Thoroughly desorb columns before re-use and test periodically to assure complete desorption.

C. Apparatus

See **(A) Strontium-90 in Water B. Apparatus (b)–(f)**, plus following:

Ion exchange system.—Consists of 1 L graduated separator, 250 mL separator with fritted glass disk as cation exchange column, and 30 mL separator with fritted glass disk **as** anion exchange column (Kontes Glass Co., No. K-427530).

D. Reagents

***See* Strontium-90 in Water C. Reagents (c), (e)–(g)**, plus following:

(a) *Ammonium acetate buffer.*—pH 5.0. Dissolve 153 g NH_4CH_3COO in 900 mL H_2O. Adjust pH to 5.0 with CH_3COOH, using pH meter, and dilute to 1 L.

(b) *Anion exchange resin.*—Dowex 1-X8(Cl form), analytical grade, 50–100 mesh size, available from Bio-Rad Laboratories.

(c) *Barium carrier solution.*—20 mg Ba/mL. Dissolve 38.1 g $Ba(NO_3)_2$ in H_2O, add 1 mL HNO,, and dilute to 1 L.

(d) *Cation exchange resin.*—Dowex 50W-X8 (Na form), analytical grade, 50–100 mesh size, available from Bio-Rad Laboratories. Convert commercially available H form into Na form by passing 1.5 L 4N NaCl through 170 mL resin placed in column and rinsing with ca 500 mL H_2O until wash H_2O is Cl-free when tested with 1% $AgNO_3$.

(e) Citrate *solution.—2M.* Dissolve 384 g anhydrous citric acid (420 g monohydrate) in H_2O, adjust to pH 6.5 with dilute NaOH solution, and dilute to 1 L.

(f) *Oxalic acid solution.—2N.* Dissolve 126 g $H_2C_2O_4.H_2O$ in warm H_2O, cool, and dilute to 1 L.

(g) Silver *nitrate solution.—1%.* Dissolve 1 g $AgNO_3$ in H_2O and dilute to 100 mL. Store in brown bottle.

(h) Sodium chloride *solution.—4N.* Dissolve 236 g NaCl in H_2O and dilute to 1 L.

(i) *Sodium carbonate solution.—3N.* Dissolve 159 g Na_2CO_3 in H_2O and dilute to 1 L.

(j) *Sodium chromate solution.—1N.* Dissolve 81 g Na_2CrO_4 in H_2O and dilute to 1 L.

(k) Strontium currier *solution.*—20 mg Sr/mL. Dissolve 48.3 **g** $Sr(NO_3)_2$ in H_2O, add 1 mL HNO,, and dilute to 1 L. Standardize by pipetting 1 mL portions into six separate 40 mL centrifuge tubes containing 15 mL H_2O. Adjust pH (indicator paper or meter) to 8.5–9.0 with 6N NH_4OH. Add, with stirring, 3–5 mL 3N Na_2CO_3 and digest 5 min in near boiling H_2O bath. Cool to room temperature and process precipitate as in G(d) or **(e).**

(l) Trihutyl *phosphate (TBP), pre-equilibrated.*— Add 150 mL H_2O and 30 mL 3N Na_2CO_3 to 300 mL TBP in 1 L separator. Shake 2–3 min and let separate. Discard lower aqueous phase. Add 150 mL H_2O to separator, shake 2–3 min, and let separate. Discard lower aqueous phase. Add 150 mL 14N HNO, and shake 5 min. Let separate and discard lower aqueous phase. Repeat 14N HNO, treatment twice.

(m) *Yttrium* carrier *solution.*—10 mg Y/mL. Dissolve 12.7 g Y_2O_3 in 50 mL HNO, by heating (avoid boiling). Dilute to 900 mL with H_2O, adjust pH to 2.0 with NH_4OH, and dilute to 1 L with H_2O. Standardize by pipetting 1 mL portions into each of six 40 mL centrifuge tubes containing 15 mL H_2O. Add 5 mL 2N oxalic acid and adjust pH to 1.5 with 6N NH_4OH, using pH meter. Digest in hot H_2O bath 10 min, and cool to below room temperature. Centrifuge and discard supernate. Process precipitate as in G(d) or (e).

Use Y_2O_3 of 99.999% purity (Morton-Thiokol Inc., 152 Andover St, Danvers, MA 01923). Material of lower purity may require purification because of radioactive contaminants.

E. Preparation *of* Sample

Preserve freshly drawn sample with ca 3 mL HCHO solution for each L milk and refrigerate for known period of time up to 2 weeks to allow ^{90}Y ingrowth. Thoroughly mix preserved, stored sample. If homogeneous, transfer 1 L to separator, C. If nonhomogeneous, before transfer, filter through loose bed of Pyrex glass wool to prevent clogging of resin columns.

F. Removal of Radioelements by Ion Exchange

Combine 1.00 mL each of Y, Sr, and Ba carriers with 10 mL citrate solution **(e),** in small beaker or vial. Using distilled H_2O, transfer quantitatively to 1 L sample in separator, and mix well.

Add 170 mL Dowex 50W-X8 **(d),** to 250 mL separator filled with H_2O. Add 15 mL Dowex 1-X8 **(b),** to 30 mL separator filled with H_2O. Connect all separators together in order sample (top), anion column, cation column (bottom), and place beaker to collect effluent. Open stopcocks of sample, anion, and cation separators, in that order, and note time. Control effluent rate at 10 mL/min with anion column stopcock. Check and adjust effluent flow periodically.

Stop flow when milk level reaches top of each resin bed and note time. Record as mean time the average period of effluent flow. This time is taken as beginning of ^{90}Y decay. Do not permit unnecessary delay during elution. Discard eluate.

Connect separator containing 300 mL warm H_2O, continue elution at 10 mL/min as above, and discard. Separate columns.

G. Yttrium-90 Separation, *Purification,*

Connect separator containing 100 mL 2*N* HCI to top of anion separator. Open upper stopcock and then lower stopcock, and control effluent flow at 2 mL/min. Collect 15 mL eluate. Close both stopcocks and remove top separator. Stir resin thoroughly with glass stirring rod, and rinse into resin column with small volume 2N HCI. Reconnect separator, and continue 2N HCl elution, collecting total of 70 mL Y eluate. Retain eluate.

Adjust flow rate to 10 mL/min for remaining 30 mL acid to recharge separator. Discard this eluate. Wash resin with ≥ 100 mL H_2O until CI-free by $AgNO_3$ test. Separator is ready for next determination.

Add 5 mL 2N oxalic acid to retained eluate and adjust pH to 1.5 with 6N NH_4OH, using pH meter. Stir, heat to near bp in H_2O bath, cool in ice bath, centrifuge, decant, and discard supemate. Proceed as in **(a)** or **(b),** depending on whether ^{140}Ba-^{140}La is absent or present from gamma analysis of sample.

(a) *If fresh fission products* arc absent.—Dissolve precipitate in 1 mL *6N* HCI, add 15 mL H_2O, and filter through Whatman No. 541 paper into 40 mL centrifuge tube. Wash paper, collecting washings in tube, discard paper, and continue as in *(c).*

(b) *If fresh fission* products are presetit.—Dissolve precipitate in 10 mL HNO_3; transfer solution to 60 mL separator, washing centrifuge **tube** with additional 10 mL HNO,. Add 10 mL equilibrated TBP, (I), shake 2–3 min, let separate, and drain and discard lower acid phase. Add 15 mL 14N HNO, to separator, shake 2–3 min, let separate, and drain and discard lower acid phase. Repeat 14N HNO, treatment to remove light lanthanide elements, particularly ^{140}La. Add 15 mL H_2O to separator and shake 2–3 min. Let separate, and drain aqueous phase containing most of Y into 40 mL centrifuge tube. Repeat wash, using 15 mL 0.1*N* HNO_3, adding it to centrifuge tube.

(c) *Preparation* d yttrium oxdate.—Add 5 mL 2N oxalic acid to purified Y solution from **(a)** or **(b),** and adjust to pH 1.5 with NH_4OH, using pH meter. Digest solution in hot H_2O bath 10 min with occasional mixing. Cool in ice bath, centrifuge, and discard supemate. Separate and count ^{90}Y oxalate as in **(d)** or (e), standardize carrier by the same technique used for sample, and calculate ^{90}Sr activity from ^{90}Y count as in I(a).

(d) *Filtration method.*—Place **2.8** cm glass fiber filter on stainless steel planchet and weigh together. Transfer tared filter to filter holder, as in Strontium-90 in Water B(b)(*1*), and assemble.

With H_2O spray, quantitatively transfer yttrium oxalate precipitate to filter funnel, using minimum of suction so that precipitate is distributed uniformly over filter area. Increase suction **as** necessary after most of precipitate is on filter. Wash precipitate with three 10 mL portions warm H_2O, three 5 mL portions alcohol, arid three 5 mL portions ether. Continue suction ca ***2-3*** min. Carefully remove filter, place on original planchet, and let stand at room temperature 10–15 min. Weigh and calculate yield yttrium oxalate (likely $Y_2(C_2O_4)_3 \cdot 9H_2O$) hy dividing this weight by weight obtained on standardization of carrier, D(m).

Remove filter from planchet, place on top of nylon disk, cover with piece of Mylar film, place nylon ring over Mylar film, and press ring onto nylon disk. Cut off excess film. Count ^{90}Y activity, without undue delay, in low background anticoincidence beta counter. Repeat counting after 3 days to confirm purity of ^{90}Y

by its rate of decay. Record dates and time of counting.

***(e) Direct** dispersion method.*—Wash precipitate twice with 20 mL portions warm H_2O, cool to below room temperature, centrifuge, and discard supemate. Quantitatively transfer precipitate to tared stainless steel dish. Uniformly disperse precipitate over dish bottom and dry under IR lamp to constant weight. Count in β particle counter.

H. Strontium-89 Separation, Purification,

Connect 1 L separator containing 1 L 4N NaCl to cation separator. Open upper stopcock and then lower stopcock, and control effluent flow at 10 mL/min. Collect ca 1 L eluate in 2 L beaker, but leave resin covered with **2–3** mL solution. Retain eluate.

Wash cation separator with 500 mL H_2O from top separator at rate of 10 mL/min. Discard wash H_2O. **If** resin becomes clogged with milk solids, back-wash separator or transfer resin to beaker, agitate with H_2O, and decant.

Dilute retained eluate to 1.5 L with H_2O, heat to 85–90" on hot plate, and add 100 mL 3N Na_2CO_3 with gentle stirring. Remove from heat and cool to room temperature. Decant bulk of clear supernate. Quantitatively transfer precipitate to 250 mL centrifuge bottle with H_2O and centrifuge; discard supernate. Add 50 mL H_2O and disperse precipitate. Centrifuge, discard supemate, and repeat. Dry precipitate 4 h in oven at 110°.

.Dissolve precipitate with vigorous stirring by adding ca 4 mL 6N HNO_3 in small amounts (magnetic stirrer is helpful). Filter through Whatman No. 541 paper into 40 mL graduated centrifuge tube. Rinse bottle with 4 mL 6N HNO, and pour washing through paper. Discard paper. Add 20 mL 21N HNO, to filtrate. Stir and cool in ice bath; centrifuge and discard supemate. ($Sr(NO_3)_2$ precipitation is critical in obtaining good recovery of **Sr** adequately separated from Ca.) Recoveries from single precipitation are as follows:

HNO,	Sr Rec., %	Ca Rec., %
14N	81 ± 4	2.6 ± 0.9
16N	98 ± 1.4	11 ± 2
18*N*	100 ± 1.7	51 ± 3

Dissolve precipitate in **5** mL H_2O and adjust to pH 5.0 with NH_4OH, using pH meter. Add 5 mL NH_4CH_3COO buffer. Heat in H_2O bath, add 1 mL 1*N* Na_2CrO_4, and **mix** well. Digest in bath 5 min. Centrifuge and decant supernate into small beaker. Evaporate to ca 2 mL, add 2 mL 6N HNO,, and transfer to 40 mL centrifuge tube, using one 3 mL H_2O rinse. Add 20 mL 21*N* HNO,, stir, cool in ice bath, centrifuge, and discard supernate. Add **3** mL H_2O and 5 mL 6N HNO, to dissolve precipitate. Add 20 mL 21*N* HNO_3, stir, cool in ice bath, centrifuge, and discard supemate. Record time as beginning of ^{90}Y ingrowth.

Dissolve precipitate in few mL H_2O and adjust pH to 8.5–9.0 with 6N NH_4OH. Add **3–5** mL 3N Na_2CO_3 to precipitate $SrCO_3$. Centrifuge, and discard supernate. Disperse precipitate in 10 mL H_2O, centrifuge, and discard supernate. Separate and count $SrCO_3$ as in **(a)** or **(b):**

(a) *Filtration method.*—Proceed as in G(d), but wash precipitate with three 5–10 mL portions H_2O, transfer to original planchet, and dry 30 min in oven at 110". Cool in desiccator and weigh. Count as in G(d), record time of counting, and calculate ^{89}Sr as in I(b).

(b) ***Direcr** dispersion* method.—Wash precipitate twice with ca 10 mL portions H_2O, dispersing precipitate, centrifuge, and decant and discard supernate. Quantitatively transfer precipitate to tared stainless steel dish. Uniformly disperse precipitate over dish bottom, dry 30 min in 110° oven. Cool in desiccator and weigh. Count in β particle counter. Record time of counting and calculate ^{89}Sr as in I(b)

I. Calculations

***(a) For** strontium-90* activity. —

$$^{90}Sr \text{ activity, pCi/L} = (\text{cpm} \pm \sigma)/R_S R_Y E_Y D_Y I_Y V$$

where cpm = net beta count rate of ^{90}Y

$$\sigma = \sqrt{\frac{N_s}{t_s} + \frac{N_b}{t_b}}$$

N_S = **sample** count rate

N_b = background count rate
t_s = sample counting time
t, = background counting time
R, = fraction Sr carrier recovered
R_Y = fraction Y carrier recovered
E_Y = counter efficiency for ''Y as Y oxalate, cpm/pCi
D, = decay correction factor (= $e^{-\lambda t}$, defined in **973.66E(a)**) for ^{90}Y, where t is time of sepg ''Y from ''Sr to time of counting, **974.37G(d)** or ***(e)***
I, = ingrowth correction factor (= $1-e^{-\lambda t}$) for degree of equilibrium attained during ''Y ingrowth period, where t is time from start of ingrowth period to time of sepg ''Y from ^{90}Sr
V = sample volume, L

(b) *For strontium-89 activity.-*

^{89}Sr activity,

$$pCi/L = \frac{1}{E_s D_s}\left(\frac{N_s+\sigma}{R_s V} - C_s(a_s E'_s + E_Y I_Y)\right)$$

where E, = counter efficiency for ^{89}Sr as SrCO,, cpm/pCi
D, = decay correction factor (= $e^{-\lambda t}$) for ^{89}Sr, where t is time from sample collection to time of counting

$$\sigma = \sqrt{\frac{N_s}{t_s} + \frac{N_b}{t_b}}$$

R, = fraction Sr carrier recovered
N_s = net counts/min of observed radio-Sr
V = sample volume, L
C_s = ^{90}Sr activity, pCi/L
a, = absorption factor for ''Sr as SrCO, obtained from self-absorption calibration curve. (Self-absorption curves for ^{89}Sr and ^{90}Sr derived by pptg series of carrier SrCO, concentrations over expected recovery range in presence of constant amount of ^{89}Sr and ^{90}Y-free ^{90}Sr, respectively. Ordinate is ratio of count rate for each thickness to count rate at 0 sample thickness and abscissa is sample weight for given type of sample mount.)
E'_s = counter efficiency for ''Sr as SrCO,, cpm/pCi
E, = counter efficiency for ''Y as Y oxalate, cpm/pCi
I, = correction factor (= $1-e^{-\lambda t}$) for degree of equilibrium attained during ''Y ingrowth period, where t is time ''Y was separated from SrCO, to time of counting, **974.37H**(a) or **(b)**

References: JAOAC **56,** 213(1973); **57,** 37(1974).
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(e) Strontium-89 and 90 in food and ashed milk

Application

This method is applicable to the analysis of ash from food samples, including dairy products, and biological materials.

Principle of Method

Strontium carrier is added to an aliquot of dissolved ash and the alkaline earth carbonates are precipitated. The precipitate is dissolved in nitric acid and silica is removed by dehydration. Strontium is then precipitated as the nitrate and purified by washing with nitric acid. Any remaining phosphate is removed by conversion of alkaline earth phosphates to carbonates. Barium and radium are removed by chromate precipitation and final purification is made by hydroxide scavenging. Strontium carbonate is precipitated, dissolved in nitric acid; yttrium carrier added and the solution stored for yttrium-90 ingrowth. The yttrium is then separated from the strontium by extraction into TTA from pH **5** solution, back extracted with dilute nitric acid, precipitated **as** the oxalate, weighed to determine yield and counted for yttrium-90 beta activity. The strontium is precipitated **as** the carbonate, weighed and counted for total radio-strontium beta activity.

Reagents

Ammonium Acetate Buffer, pH 5
Ammonium Hydroxide, NH_4OH, Concentrated, (15N), 613
Barium Camer, Ba^{++} - 20 mg/ml
Ethyl Alcohol, C_2H_5OH - Absolute (100%)
Hydrochloric Acid, HCI - 6N
Methyl Orange Indicator, 0.1% (w/v)
Nitric Acid, HNO, - Concentrated, 1.0N, 0.1N
Oxalic Acid, $H_2C_2O_4$ - 2N
Phenolphthalein Indicator, 1% (w/v)
Scavenging Carrier, Fe^{+++}, Ce^{+++}, Zr^{++++}, 10 mg/ml
Sodium Dichromate, $Na_2Cr_2O_7$ - 0.5N
Sodium Carbonate, Na_2CO_3 - 3N
Strontium Carrier, Sr^{++} - 90 mg/ml
2-Thenoyltrifluoroacetone, TTA - 10% in Benzene
Yttrium Carrier, Y^{+++} - **20** mg/ml

Special **Apparatus**

Low Background Beta Counter

Procedure

1. Add 1.0 ml of strontium carrier to a **250** ml aliquot of dissolved ash in a 600 ml beaker.

2. Add concentrated NH_4OH to the first appearance of a precipitate, heat to near boiling, and add 3N Na_2CO_3 slowly until the effervescence ceases, then add an additional 150 ml. Allow the precipitate to settle, preferable overnight, decant or suction off the supernatant and discard.

3. Transfer the precipitate to a 250 ml centrifuge bottle using H_2O, centrifuge and discard the supernatant.

4. Dissolve the precipitate in a few ml of concentrated HNO, and transfer using a minimum of H_2O to a 250 ml beaker and take to dryness on a hot plate.

5. Bake for **20-30** minutes, cool, and dampen the salts with a few ml of concentrated NHO,. Add 50 ml of hot H_2O and boil for several minutes **(3-5** min.).

6. Filter the hot solution through Watman #541 filter paper into a 250 nil beaker, wash the filter paper with warm water and 1N HNO,. Take the solution to near dryness on a hot plate. (Add 10 ml of concentrated HNO_3 and again take the solution to near dryness.).

7. Slurry the salts with 30 nil 75% HNO, and transfer to a 90 ml centrifuge tube using 75 ml 75% HNO_3. Heat in a water bath, cool in an ice bath, centrifuge, and discard the supematant.

8. Fill the centrifuge tube to the 75 ml mark with 75% HNO,, mix well, heat in a water bath, cool in an ice bath, centrifuge and discard the supernatant.

9. Dissolve the precipitate in 15 ml of H_2O, adjust the pH with 6N NH_4OH to a phenophtalein endpoint (pH 9), heat in a water bath, cool, centrifuge, and transfer the supernatant to a 40 ml centrifuge tube.

10. Add 10 ml of H_2O and 10 ml of 3N Na_2CO_3 to the precipitate. Heat with occasional stirring in a water bath for **30** minutes, centrifuge and discard the supernatant. Dissolve the precipitate in *2* ml of concentrated HCI and combine with the supernatant from step 9. Any residue is discarded. After passing this point in the analysis, the procedure must be continued past step 15 in the same day.

11. Adjust the pH of the solution with 6N NH_4OH to a methyl orange endpoint about (pH 4.5) and add 10 ml of pH 5.0 ammonium acetate buffer. Warm the solution in a water bath, add 1 ml of 0.5N $Na_2Cr_2O_7$ and digest for several minutes. Add 1 ml of barium carrier and digest for several minutes. Centrifuge and transfer the supernatant to **a** 40 ml centrifuge tube.

12. Wash the precipitate with 5 ml of H_2O, centrifuge and combine the supernatant with that from step 11. Discard the precipitate.

13. Neutralize the solution to a pH 7 with 6N NH_4OH and add sufficient Na_2CO_3 to precipitate $SrCO_3$ *(– 5* - 10 ml). Warm, cool, centrifuge, and discard the supernatant.

14. Dissolve the precipitate in 3 ml of concentrated HCI, and add 20 ml of water and heat in a water bath. Add **3** drops each of scavenging Zr, Ce, and Fe carriers, and make the solution alkaline with 6N NH_4OH. Digest for several minutes, centrifuge, and transfer the supernatant to a 40 ml centrifuge tube. Discard the precipitate. This is the beginning of the ingrowth of yttrium-90.

15. Add 5 ml of 3N Na_2CO_3 to the solution, centrifuge, and discard the supernatant. Record the date.

16. Dissolve precipitate in HNO,, bring up to 25 ml volume with 1N HNO, and H_2O. Stir with 1 ml pipette, blow pipette into solution. Pipette 1 ml into 25 ml volume tlask. Blow remaining solution from pipette back to test tube. Fill flask to line with HNO,. Run diluted solution on flame photometer for pre-extraction strontium yield. Add 1 ml yttrium carrier to remaining **24** ml in test tube and store for at least 12 days ingrowth.

17. Transfer the solution to 60 ml separatory funnel, using a minimum of H_2O; neutralize with 6N NH_4OH to methyl orange endpoint, add 10 ml of ammonium acetate buffer and 10 ml of 10%TTA in benzene. Shake for 5 minutes. Record the time, this is the beginning of the decay of yttrium-90.

18. Transfer the aqueous layer to a clean 60 ml separatory funnel and add 10 ml of 10%TTA in benzene. Shake for 5 minutes. Transfer the aqueous phase to a 90 ml centrifuge tube.

19. The organic layers from steps 17 and 18 are combined in one of the separatory funnels. Wash the empty funnel with 10 ml of ammonium acetate buffer and add it to the funnel containing the organic. Shake for 2 minutes and combine the aqueous phase with that from step 18.

20. Add 5 ml of 0.1N HNO, to the separatory funnel and shake for 5 minutes. Transfer the aqueous phase to a 40 ml centrifuge tube.

21. Repeat step 20 twice.

22. Heat the solution from steps 20-21 in a water bath, add 10 ml of 2N $H_2C_2O_4$, adjust pH to 1.0 - 1.5 with concentrated NH_4OH, digest for several minutes, centrifuge and discard the supernatant.

23. Add warm H_2O to the precipitate to the 40 ml mark, mix, centrifuge and discard the supernatant.

24. Place a 2.4 cm glass fiber filter paper on a stainless steel planchet and weigh together. Place the filter paper into a filtration apparatus.

25. Take the precipitate up in 10 ml of warm H_2O and transfer using warm H_2O to the filter paper. Wash the precipitate with three 10 ml portions of ethyl alcohol.

26. Carefully place the filter paper back onto the stainless steel planchet and dry in an oven at 125°C for 20 minutes. Cool in a desiccator and re-weigh the planchet and paper. Calculate the chemical yield of yttrium by dividing the weight of the precipitate by the weight of yttrium oxalate obtained from I ml of carrier.

27. Transfer the filter paper plus the precipitate to **a** plastic holder and cover with mylar. Count for the beta activity of yttrium-90 in a low background beta counter. Record the time of counting, to determine the decay factor of yttrium-90 from the time of separation to the counting time.

28. Heat the combined aqueous phases from steps 18 and 19 in a water bath and add 25 ml of 3N Na_2CO_3. Centrifuge and discard the supernatant.

29. Add 40-50 ml of H_2C to the precipitate, mix well, centrifuge, and discard the supernatant.

30. Place **a 2.4** cm glass fiber filter paper on a stainless steel planchet and weigh together. Place the filter paper into a filtration apparatus.

31. Transfer the precipitate to the filter paper using H_2O and wash the precipitate with three 10 ml portions of H_2O.

32. Carefully place the filter paper back onto the stainless steel planchet. Place under a heat lamp for 5-10 minutes, cool in a desiccator and re-weight the planchet and paper.

33. Transfer the filter paper plus the precipitate to a plastic holder and cover with mylar. Count for total radio-strontium beta activity in a low-background beta counter. Record the time of counting, to determine the ingrowth factor of yttrium-90 from the time of separation to the time of counting.

34. Re-dissolve the $SrCO_3$ from the filter paper using 1N HNO, and make to volume in a 100 ml volumetric flask using 1N HNO,. Measure the strontium concentration flame photometrically and compute the yield. If step 16a was done, this step is optional.

Calculations

^{90}Sr pCi/kg =

$$\frac{A \times B \times C}{2.2 \times D \times E \times F \times G \times H \times I \times J \times K}$$

A = Net counts per minute yttrium-90.
B = Sample volume in liters.
C = Weight of total ash in grams.
D = Yttrium-90 efficiency factor as determined.
E = Yttrium chemical yield.
F = Yttrium-90 decay factor.
G = Yttrium-90 ingrowth factor.
H = Strontium chemical yield.
I = Weight of ash dissolved in grams.
J = Aliquot taken in liters.
K = Weight of sample in kilograms.

^{89}Sr pCi/kg =

$$\frac{1}{D \times E} \times \frac{A \times B \times C}{2.2 \times F \times G \times H \times I} - J(K + L \times M)$$

A = Net counts per minute total radiostrontium.
B = Sample volume in liters.
C = Weight of total ash in grams.
D = Strontium-89 efficiency factor as determined.
E = Strontium-89 decay factor.
F = Strontium chemical yield.
G = Weight of ash dissolved in grams.
H = Aliquot taken in liters.
I = Weight of sample in kilograms.
J = pCi/kg of strontium-90.
K = Strontium-90 efficiency factor as determined.
L = Yttrium-90 efficiency factor.
M = Yttrium-90 ingrowth factor.

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(f) Radium-228 in Foods arid Water

Introduction

This procedure is for the rapid determination of radium-228 in foods and water. The method can be used to determine radium-228 levels as required in the EPA Drinking Water Standards. (Ref 1)

Radium-228, a Beta Emitter, is found in soils and ores containing naturally occurring thorium nuclides. The detection of radium-228 is difficult because the beta energies emitted are weak having E-Max's of 0.04 and 0.014 MeV. Its detection is complicated also by the presence of other radium isotopes, such as radium-226, 223, and 224, which emit energetic alpha particles, and also emit beta radiation from their short lived daughter products. Radium-228 is determined by measuring the ingrowth of its daughter actinium-228 which has a 6.1 hour half-life. This procedure involves the isolation and measurement of the actinium-228 which has an energetic beta of 2.3 MeV maximum.

The method is dependent on the separation of actinium-228 from contaminating radium nuclides as well as lead, polonium and bismuth daughter products. The interference from actinium-227, a daughter of uranium-235, is insignificant as this nuclide has a weak beta of only 0.047 MeV. making it very difficult to detect. The analytical method presented is a rapid determination of the naturally occurring beta emitter actinium-228 and is based on a combination technique of solvent extraction and ion exchange. The procedure is designed for analysis of natural waters and various foods such as fruits, spices, and tea. It is of radiobiologic interest because actinium-228 is also a measure of radium-228, which if found in foodstuffs and ingested, is hazardous due to the high energetic beta of its immediate daughter product actinium-23-8 and subsequent alpha emitting daughter products. (Ref 2) The method is sensitive to the level of the EPA Drinking Water Standard, 5 picocuries/liter (pCi/l).

Method

The solvent extraction-ion exchange procedure for the separation of actinium is outlined below. The method is suitable for various foods and natural waters. With modifications, it can be applied to other types of materials.

Initial precipitation of actinium with lanthanum fluoride separates actinium from the bulk of the cations except thorium and uranium. To remove most of the uranium the precipitate is treated with dichromate to keep the uranium soluble in the hexavalent state. The solution is passed through an anion exchange column to complete the removal of lead, bismuth, polonium and any remaining uranium. To remove the thorium, which has been carried quantitatively to this point, the solution is extracted with 2-thenoyltritluoroacetone (TTA)-benzene solution in the presence of aluminum nitrate. As a final decontamination step, the solution is passed through a cation exchange column from which the actinium is selectively eluted by use of citric acid leaving any radium or thorium on the resin.

Reagents

The two resin columns employed were about 20 centimeters in length. The anion exchange column was made from Dowex 1X8 (100 to 200 mesh). The length of the resin bed was approximately 7 centimeters. The anion exchange resin column was washed in 1.8M HCl and the column prepared by washing with several column volumes of 1.8M HCI. The cation column was made by using Dowex 50X8 (100 to 200 mesh). The column was about 7 centimeters in length and it was made up in 0.2M HNO, and prepared by washing with several column volumes of 0.2M HNO,.

Reagents used were:

(a) 2-thenoyltritluoroacetone in benzene 0.5M;
(b) sodium hydroxide 19M;
(c) lanthanum nitrate carrier - 12 milligrams lanthanum per milliliter;
(d) hydrochloric acid 1.8M;
(e) nitric acid approximately 0.2M;
(f) ammonium hydroxide 1M;
(g) oxalic acid 7%;
(h) citric acid 5% adjusted to pH 5.0;
(i) hydrotluoric acid 1.0M plus nitric acid 1.0M;
(j) aluminum nitrate 2.0M;

(k) saturated potassium dichromate;
(l) concentrated HF;
(m) HCI and
(n) NH_4OH.

Equipment

(a) Resin Columns 20 cm x 1 cm id.
(b) Filtration Apparatus, Stainless Steel
(c) 1" nylon ring and disk mounts, mylar cover
(d) Low-background beta counter
(e) centrifuge tubes, conical, plastic, 50 ml
(f) glass fiber filter paper

Procedure

1. To a sample in solution (Note 1) add one ml lanthanum carrier. Then, enough concentrated hydrofluoric acid (5 milliliters approximately) is added to precipitate the lanthanum as a fluoride. Stir for 10 minutes. Centrifuge, wash and make final collection in 40 ml centrifuge tube. Make all required washings (after each centrifugation) with 1M HF + 1M HNO, in this step.

2. To the collected precipitate, add several drops of saturated $K_2Cr_2O_7$ solution and 1 ml concentrated HF. Dilute to approximately 20 ml, and allow to digest for 5 minutes.

3. Centrifuge, discard aqueous fraction, wash with 20-30 ml HNO_3-HF solution. Repeat washings until precipitate is white discarding supemates. Add 20 ml of NaOH reagent and digest for 5 minutes. Centrifuge, discard aqueous phase. (Wash with NaOH if necessary to remove excess of contaminating precipitate.) Add several drops of 1M NaOH to the $Ac(OH)_3$ precipitate and wash with approximately 20 ml of water. Centrifuge and discard supernate.

4. Dissolve the precipitate in approximately 10 ml of 1.8M HCI. Pass the solution through the previously prepared anion exchange column. Collect the HCl solution which passes through the ion exchange column in centrifuge tube. Wash the column with one column volume ($\approx$ 20 ml) of 1.8M HCI and combine with the solution.

5. To the solution from step 4 add concentrated NH_4OH to reprecipitate the actinium-lanthanum as hydroxides. Centrifuge, discard supernate and wash precipitate with water using several drops of 1M NH_4OH; centrifuge and again discard supernate.

6. To the precipitate add no more than 1 drop concentrated nitric acid; add 5 to 10 ml dilute nitric acid, add 1 ml 2.0M aluminum nitrate. Adjust pH to 1.0 with NaOH, if necessary. Transfer to a 125 ml separatory funnel with dilute nitric acid washings. Add 10 ml of TTA-benzene (0.5M) solution. Shake for 5 minutes. Allow layers to separate and discard benzene layer. In cases of gross thorium contamination, repeat extraction step.

7. Add the entire aqueous phase to a previously prepared cation exchange column, making sure funnel stem has been washed with 0.2M HNO,. Allow the solution to pass through the column and wash column with 1 column volume of 0.2M nitric acid. Discard solution and washings. Elute with 5% citric acid (pH 5.0) discarding the first column volume and collecting the next 30 ml.

8. To the 30 ml eluent from step 7 add 10 to 12 ml of 7% oxalic acid to reprecipitate the lanthanum-actinium as oxalate. Centrifuge, wash with water (adding several drops of 7% oxalic acid). Centrifuge, transfer the precipitate with washings *to* glass fiber filter paper, wash, dry, weigh and mount the precipitate on a 1" nylon ring and disk. Count on a low background Beta counter. The actinium-228 decay must be followed for several hours with counting, if necessary, the following day.

NOTE 1

To a sample known to contain large amounts of interfering ions the following clean-up steps must be performed first:

A. Add one ml Barium carrier (20 mg/ml) to sample

B. Precipitate barium with 10 ml of ammonium sulfate (50% w/v)

C. After allowing the barium sulfate to settle well, discard the supernatant and place the precipitate in a test tube

D. Add 2M sodium carbonate to the precipitate, heat in water bath, and occasionally stir to help convert barium sulfate to barium carbonate

E. Dissolve barium carbonate in 1M HCI then put to one side for 36 hours for ingrowth (98.3% equilibrium between ^{228}Ra and ^{228}Ac)

Now proceed to Step 1.

References

1. EPA (1976) National Interim Primary Drinking Water Regulations, EPA-570/9-76-003, US EPA, Washington, DC

2. FDA (1979) ".Quality Standards for foods with no identity standards- bottled water", Fed. Reg. 44 (45), 12169

3. Baratta, E.J. and M.H. Feldman, "Determination of Actinium in Uranium Mill Effluents", USAEC Topical Report WIN-123 (1961)

4. NBS Technical Note-I 137 "Evaluation of Methods for Assay of Radium-228 in Water" National Bureau of Standards U.S. Dept. of Commerce (1981)

5. Baratta, E.J. and Ella M. Lumsden "Determination of Radium-228 in Foods and Water" JOAC 65 No.6 (1982)

(3) Alpha-emitting Radionuclides

(a) Uranium

A. Occurrence

Uranium, the heaviest naturally occurring element, is a mixture of three radioactive isotopes: uranium 238(99.275 %), uranium 235(0.72 %), and uranium 234(0.005 %). Most drinking water sources, especially ground waters, contain soluble carbonates and bicarbonates that complex and keep uranium in solution.

B. Method

This is a radiochemical procedure which determines total uranium alpha activity without making an isotopic uranium analysis.

Radiochemical Method

A. General Discussion

a. Principle: The sample is acidified with hydrochloric or nitric acid and boiled to eliminate carbonate and bicarbonate ions. Uranium is co-precipitated with ferric hydroxide and subsequently separated. The ferric hydroxide is dissolved, passed through an anion-exchange column, and washed with acid, and the uranium is eluted with dilute hydrochloric acid. The acid eluate is evaporated to near dryness, the residual salt is converted to nitrate, and the alpha activity is counted.

b. Interference: The only alpha-emitting radionuclide that may be carried through this procedure is protactinium 231. However, this isotope, which is a decay product of uranium 235, causes very little interference. Check reagents for uranium contamination by analyzing a complete reagent blank.

c. Sampling: Preserve sample by adjusting its pH to <2 with HCI or HNO_3, at time of collection.

B. Apparatus

a. Counting instrument, gas-flow proportional or alpha scintillation counting system.

b. ***Ion-Exchange column***, approximately 13 mm ID x 150 mm long with 100-mL reservoir.

c. Membrane filter apparatus, **47-mm** diam.

C. Reagents

a. Ammonium hydroxide, NH_4OH, *5N*, 1%
b. ***Anion-exchange resin.****
c. Ferric chloride carrier: Dissolve 9.6 g $FeCl_3 \cdot 6H_2O$ in 100 mL 0.5*N* HCI; 1 mL = 20 mg Fe^{3+}.
d. Hydriodic acid (hydrogen iodide), HI, 41%
e. Hydrochloric acid, HCI, conc, *8N*, *6N*, *0.1N*.
f. ***Iodic acid,*** 1mg/mL: Dissolve 100 mg HIO, in 100 mL *4N* HNO,.
g. ***Nitric acid,*** HNO,, conc, *4N*
h. Sodium hydrogen sulfite, 1%:Dissolve 1 g $NaHSO_3$ in 100 mL *6N* HCI.
i. Uranium standard solution: Dissolve 177.3 mg natural undepleted uranyl acetate†, $UO_2(C_2H_3O_2)_2 \cdot 2H_2O$, in 1000 mL 0.2*N* HNO,; 1 mL = 100 μg U = 150 dpm U = 67.6 pCi U.
NOTE: Commonly available uranyl salts may be formed from depleted uranium; verify isotopic composition before use.

*Dowex 1X4, 100-200 mesh, chloride form, or equivalent.

†Standard radioactive solutions with uranium isotopes in equilibrium are available from the U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, NRA/STD, P.O. Box 93478, Las Vegas, Nev. 89193.

D. Calibration

Determine counting efficiency, E, for a known amount of uranium standard solution (about 750 dpm) evaporated from 6 to 8 mL of 1 mg/mL HIO_3 solution in a 50-mm-diam stainless steel planchet. After flaming planchet, count for at least 50 min. Run a reagent blank with the standard portions and count.

$$E = \frac{C - B}{D}$$

where:

C = gross alpha count rate of standard, cpm,
B = alpha background count rate, cpm, and
D = disintegration rate of uranium standard, dpm.

Determine uranium recovery factor by adding a measured amount of uranium standard to the same volume of sample and taking it through the entire procedure. Alpha count the separated, evaporated, and flamed uranium planchet. Determine the recovery factor on at least 10% of all drinking water samples. For non-drinking water samples, it may be necessary to determine the recovery factor in every sample.

$$\text{Recovery factor}, R = \frac{C' \; B'}{DE}$$

where:

C' = gross count rate of sample with added uranium, cpm,
B' = count of reagent blank, cpm,
D = disintegration rate of uranium standard, dpm, and
E = counting efficiency.

E. Procedure

1. If the sample has not been acidified, add 5 mL conc HCI or HNO, to 1 L sample in a 1500-mL beaker. Add 1 mL $FeCl_3$ carrier. In each batch of samples include a distilled-water blank. Cover with watch glass and heat to boiling for 20 min. If pH is greater than 1, add conc HCI or HNO, dropwise to bring pH to 1. While sample is boiling, gently add 5N NH_4OH until turbidity persists while boiling continues; then add 10 mL more. Continue boiling for 10 min more, then set aside for 30 min to cool and settle. After sufficient settling, decant and filter supernate through a 47-mm, 0.45-μm membrane filter using a large filtering apparatus. Slurry the remaining precipitate, transfer to the filtering apparatus, and filter with suction. Complete transfer using 1% solution of NH_4OH delivered from a polyethylene squeeze bottle. Place filtering apparatus over a clean 250-mL filtering tlask, add 25 mL 8N HCI.

2. Prepare an ion-exchange column by slurrying the anion-exchange resin with 8N HCI and pouring it into a 13-mm-ID column to give a resin bed height of about 80 mm. Transfer solution to the 100-mL reservoir of the ion-exchange column. Rinse side-arm filtering flask twice with 25-mL portions of 8N HCl. Combine in the ion-exchange reservoir. Pass sample solution through the anion-exchange column at a flow rate of not more than 5 mL/min. After sample has passed through column, elute the iron (and plutonium if present) with six column volumes of freshly prepared 8N HCl containing 1 mL 47% HI /9 mL 8N HCl. Wash column with two additional column volumes of 8N HCI. Discard all washes. Elute uranium into a 100-mL beaker with six column volumes of 0.1N HCl. Evaporate acid elute to near dryness and convert residue to the nitrate form by three successive treatments with 5-mL portions of conc HNO,, evaporating to near dryness each time. ***Do not bake.*** Dissolve residue (of which there may be very little visible) in 2 mL 4N HNO,. Using a transfer pipet, transfer to a marked planchet. Complete transfer by rinsing beaker three times with 2-mL portions of 4N HNO,. Evaporate planchet contents to dryness under a heat lamp, flame to remove traces of HIO,, cool, and count for alpha activity.

3. To regenerate anion-exchange resin column, pass three column volumes of 1% $NaHSO_3$ in 6N HCI through the column, follow with six column volumes of 6N HCI, and then three column volumes of distilled water. Do not let resin become dry. When ready for the next set of samples, equilibrate by passing six column volumes of 8N HCI through the column.

F. Calculations

$$\text{Uranium } \alpha \text{ activity, pCi/L} = \frac{C'' - B'}{2.22 \times ERV}$$

where:

C'' = gross count rate of sample, cpm,
V = volume of sample, L, and other factors are as defined above.

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STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTE WATER, ***APHA 18th Edition*** (1992)

(h) Radium-226

Precipitation Method

A. General **Discussion**

a. Application: This method is suitable for determination of the alpha-emitting isotopes of radium.

b. Principle: Because of the difference in half-lives of the nuclides in the series including the alpha-emitting Ra isotopes, these isotopes can be identified by the rate of ingrowth and decay of their daughters in a barium sulfate precipitate.[1-3] The ingrowth of alpha activity from radium 226 increases at a rate governed primarily by the 3.S-d half-life radon 222. The ingrowth of alpha activity in radium 223 is complete by the time a radium-barium precipitate can be prepared for counting. The ingrowth of the first two alpha-emitting daughters of radium 224 is complete within a few minutes **and** the third alpha daughter activity increases at a rate governed by the 10.6-h half-life of lead 212. The activity of the radium 224 itself, with **a** 3.6-d half-life, also is decreasing, leading to a rather complicated ingrowth and decay curve.

Lead and barium carriers are added to the sample containing alkaline citrate, then sulfuric acid (H_2SO_4) is added to precipitate radium, barium, and lead as sulfates. The precipitate is purified by washing with nitric acid (HNO,), dissolving in alkaline EDTA, and re-precipitating as radium-barium sulfate after pH adjustment to 4.5. This slightly acidic EDTA keeps other naturally occurring alpha emitters and the lead carrier in solution.

B. Apparatus

a. Counting instruments: One of the following is required:
1) *Internal proportional counter*, gas-flow, with scaler and register.
2) *Alpha scintillation counter*, silver-activated zinc sulfide phosphor deposited on thin polyester plastic, with photomultiplier tube, scaler, timer, and register; or
3) *Proportional counter,* thin end-window, gas-flow, with scaler and register.
b. Membrane filter holler, or stainless steel or TFE filter funnels, with vacuum source (Fisher Filtraton or equiv.).
c. *Membrane filters* (Millipore Type HAWP or equiv.), or *glass fiber filters* (No. 934-AH, diam. 2.4 cm, H. Reeve Angel or equiv.).

C. Reagents

a. Citric acid, 1M: Dissolve 210 g $H_3C_6H_5O_7.H_2O$ in distilled water and dilute to 1 L.
b. Ammonium hydroxide, conc and *5N:* Verify strength of old 5N NH_4OH solution before use.
c. *Lead nitrate carrier:* Dissolve 160 g $Pb(NO_3)_2$ in distilled water and dilute to 1 L; I mL = 100 mg Pb.
d. Stock barium chloride solutioti: Dissolve 17.79 y $BaCl_2.2H_2O$ in distilled water and dilute to 1 L in a volumetric flask; 1 mL = 10 mg Ba.
e. Barium chloride carrier: To a 100-mL volumetric flask, add 20.00 mL stock $BaCl_2$ solution using a transfer pipet, dilute to 100 mL with distilled water, and mix; 1 mL = 2.00 my Ba.
f. Methyl orange indicator solution.
g. Phenolphthalein indicator solution
h. Bromcresol green indicator solution: Dissolve 0.1 g bromcresol green sodium salt in 100 mL distilled water.
i. Sulfuric acid, H_2SO_4, *18N.*
j. Nitric acid, HNO,, conc.
k. EDTA reagent, 0.25M: Add 93 g disodium ethylenediaminetetraacetate dihydrate to distilled water, dilute to 1 L, and mix.
1. *Acetic acid,* conc.
m. Ethyl alcohol, 95%.
ti. Acetone.
o. Clear acrylic solution: § Dissolve *50* mg clear acrylic in 100 mL acetone.

§Lucite or equivalent.

p. Stock radium 226 solution: Take every precaution to avoid unnecessary contamination of working area, equipment, and glassware, preferably by preparing ^{226}Ra standards in a separate area or room reserved for this purpose. Obtain a National Institute of Standards and Technology (NIST, formely National Bureau of Standards, NBS or other equivalent source ie; National Physics Laboratory U.K.; Institute for Reference Materials and Measurements, E.U.) gamma ray standard containing 0.1 μg ^{226}Ra as of date of standardization. Using a heavy glass rod, cautiously break neck of ampule, which is submerged in 300 mL acid $BaCl_2$ solution in a 600-mL beaker. Chip ampule unit until it is thoroughly broken or until hole is large enough to give complete mixing. Transfer solution to a 1-L volumetric flask, rinse beaker with acid $BaCl_2$ solution, dilute to mark with same solution, and mix; 1 mL = approximately 100 pg ^{226}Ra. Determine the time in years, t, since the NIST or other standardization of the original ^{226}Ra solution. Calculate pCi ^{226}Ra/mL as:

pCi ^{226}Ra = $[1-(4.3x10^{-4})(t)][100][0.990]$

q. Intermediate radium 226 solution: Dilute 100 mL stock radium solution to 1000 mL with acid $BaCl_2$ solution: 1 mL = approximately 10 pCi ^{226}Ra.

r. Standard radium 226 solution: Add 30.0 mL intermediate radium solution to a 100-mL volumetric flask and dilute to mark with acid $BaCl_2$ solution: 1 mL = approximately 3 pCi ^{226}Ra and contains about 2 mg of Ba. See ¶*p et seq.* above for corrections.

D. Procedure for Radium in Drinking Water and for Dissolved Radium

1. To 1 L sample in a 1500-mL beaker, add 5 mL 1*M* citric acid, 2.5 mL conc NH_4OH, 2 mL $Pb(NO_3)_2$ carrier, and 3.00 mL $BaCl_2$ carrier. In each batch of samples include a distilled water blank.
2. Heat to boiling and add 10 drops methyl orange indicator.
3. While stirring, slowly add 18*N* H_2SO_4 to obtain a permanent pink color; then add 0.25 mL acid in excess.
4. Boil gently 5 to 10 min.
5. Set beaker aside and let stand until precipitate has settled (3 to 5 h or more). ‖

‖If original concentrations of isotopes of radium other than ^{226}Ra are of interest, note date and time of this original precipitation as the separation of the isotopes from their parents: use a minimal settling time and complete procedure through ¶*j* without delay. Assuming the presence of and separation of parents, decay of ^{223}Ra and ^{224}Ra begins at the time of the first precipitation(¶*i*). The time of the first precipitation is not needed if the objective is to check the final precipitate for its ^{226}Ra content only.

6. Decant and discard clear supernate. Transfer precipitate to a 40-mL or larger centrifuge tube, centrifuge, decant, and discard supernate.
7. Rinse wall of centrifuge tube with a 10-mL portion of conc HNO_3, stir precipitate with a glass rod, centrifuge, and discard supernate. Repeat rinsing and washing two more times.
8. To precipitate, add 10 mL distilled water and 1 to 2 drops phenolphthalein indicator solution. Stir and loosen precipitate from bottom of tube (using a glass rod if necessary) and add 5*N* NH_4OH, dropwise, until solution is definitely alkaline (red). Add 10 mL EDTA reagent and 3 mL 5*N* NH_4OH. Stir occasionally for 2 min. Most of the precipitate should dissolve, but a slight turbidity may remain.
9. Warm in a steam bath to clear solution (about 10 min.), but do not heat for an unnecessarily long period.# Add conc acetic acid dropwise until red color disappears; add 2 or 3 drops bromcresol green indicator solution and continue to add conc acetic acid dropwise, while stirring with a glass rod, until indicator turns green (aqua).## $BaSO_4$ will precipitate. Note date and time of precipitation as zero time for ingrowth of alpha activity. Digest in a steam bath for 5 to 10 min, cool, and centrifuge. Discard supernate. The final pH should be about 4.5, which is sufficiently low to destroy the Ba-EDTA complex, but not Pb-EDTA. A pH much below 4.5 will precipitate $PbSO_4$.

#If solution does not clear in 10 min. cool, add another mL 5*N* NH_4OH, let stand 2 min. and heat for another 10-min period.

##The end point is most easily determined by comparison with a solution of similar composition that has been adjusted to pH 4.5 using a pH meter.

10. Wash Ba-Ra sulfate precipitate with distilled water and mount in a manner suitable for counting as given in ¶'s *11, 12 or 13* following.
11. Transfer Ba-Ra sulfate precipitate to a tared stainless steel planchet with a minimum of 95% ethyl alcohol and evaporate under an infrared lamp. Add 2 mL acetone and 2 drops clear acrylic solution, disperse recipitate evenly, and evaporate under an infrared lamp. Dry in oven at 110°C, weigh, and

determine alpha activity, preferably with an internal proportional counter. Calculate net counts per minute and weight of precipitate.

12. Weigh a membrane filter, a counting dish, and a weight (glass ring) as a unit. Transfer precipitate to tared membrane filter in dish, add glass ring, and dry at 110°C. Weigh and count in one of the counters mentioned under ¶ B*a* above. Calculate net counts per minute and weight of precipitate.
13. Add 20 mL distilled water to the Ba-Ra sulfate precipitate, let settle in a steam bath, cool, and filter through a special funnel with a tared glass fiber filter. Dry precipitate at 110°C to constant weight, cool, and weigh. Mount precipitate on a nylon disk and ring with an alpha phosphor on polyester plastic film[4], and count in an alpha scintillation counter. Calculate net counts per minute and weight of precipitate.
14. If the isotopic composition of the precipitate is to be estimated, perform additional counting as mentioned in the calculation below.
15. *Determination of combined efficiency and self-absorption factor:* Prepare standards from 1 L distilled water and the standard radium 226 solution (¶ C*p* preceding). Include at least one blank. The barium content will impose an upper limit of 3.0 mL on the volume of the standard radium 226 solution that can be used. If *x* is volume of standard radium 226 added, then add (3.00-*x*)mL $BaCl_2$ carrier(¶3*e* above). Analyze standards as samples, beginning with ¶D*1*, but omit 3.00-mL $BaCl_2$ carrier.

From the observed net count rate, calculate the combined factor, *bc*, from the formula:

$$bc = \frac{net\ cpm}{ad \times 2.22 \times pCi\ radium\ 226}\dagger\dagger$$

where:

ad = ingrowth factor (see below) multiplied by chemical yield.

††See calculation that follows

If all chemical yields on samples and standards are not essentially equal, the factor *bc* will not be a constant. In this event, construct a curve relating the factor *bc* to varying weights of recovered $BaSO_4$.

5. Calculation

$$Radium,\ pCi/L = \frac{net\ cpm}{a\ b\ c\ d\ e \times 2.22}$$

where:

a = ingrowth factor (as shown in the following tabulation):

Ingrowth *h*	Alpha Activity from ^{226}Ra
0	1.000
1	1.016
2	1.036
3	1.058
4	1.080
5	1.102
6	1.124
24	1.489
48	1.905
72	2.253

b = efficiency factor for alpha counting
c = self-absorption factor
d = chemical yield
e = sample volume

The calculations are based on the assumption that the radium is radium 226. If the observed concentration approaches 3 pCi/L, it may be desirable to follow the rate of ingrowth and estimate the isotopic content[2,3] or, preferably, to determine radium 226 by radon 222.

The optimum ingrowth periods can be selected only if the ratios and identities of the radium isotopes are known. The number of observed count rates at different ages must be equal to or greater than the number of radium isotopes present in a mixture. In the general case, suitable ages for counting are 3 to 18 h for the first count; for isotopic analysis, additional counting at 7, 14, or 28 d is suggested, depending on the number of isotopes in mixture. The amounts of the various radium isotopes can be determined by solving a set of simultaneous equations.[3] This approach is most satisfactory when radium 226 is the predominant isotope; in other situations, the approach suffers from statistical counting errors.

References

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5. STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTE WATER, *APHA 18TH Edition(1992)*

(c) Isotopic Analysis of Pu in Food Ash

The method was set up for soil and has been changed slightly to use on food ash. The method includes a procedure for (A) 10 gram ash samples and (B) a rapid procedure for 1 gram ash sample.

I. Procedure A

Summary

The principle of the analytical procedure follows: A known quantity of plutonium-236 tracer is added to the ashed sample which is decomposed by sequential nitric acid-hydrofluoric acid and nitric acid-hydrofluoric acid-hydrochloric acid digestions. Boric acid is added to complex the fluoride ion and to aid in the extraction of plutonium from any remaining insoluble residue. Sequential iron hydroxide precipitations are performed with sodium hydroxide and ammonium hydroxide to respectively remove amphoteric elements and calcium and to eliminate soluble fluorides. The hydroxide precipitate is dissolved in nitric acid saturated with boric acid and plutonium is isolated and purified by ion exchange separation. The plutonium is then electroplated on a stainless steel disk. The plutonium isotope and concentrations are determined by alpha spectrometry.

Tracer

Plutonium-236 solution - stock standard solution of 2.5 x 10^4 dpm of plutonium-236 in 2 M nitric acid in minimal solution (available from Amersham Corp). Solution made for tracer should contain approximately 10 dpm/ml.

Acids

All solutions are made with distilled water. All acids are reagent grade and meet American Chemical Society (ACS) specifications.

(a) Boric Acid - crystalline
(b) Hydrochloric Acid - concentrated (12 M), 4 M and 2 M
(c) Hydrofluoric Acid - concentrated (48% solution)
(d) Nitric Acid - concentrated (16 M), 8 M saturated with boric acid, 8 M

Reagents

All solutions are made with distilled water. All reagents are reagent grade and meet ACS specifications unless otherwise defined.

(a) Ammonium Hydroxide - concentrated (15 M)
(b) Ammonium Iodide-Hydrochloric Acid Solution - 1 part of 1 M ammonium iodide to 20 parts 12 M hydrochloric acid (freshly made)
(c) Anion Exchange Resin - Dowex 1X4 (100-200 mesh, nitrate or chloride form)
(d) Iron Carrier - 10 mg Fe (III)/ml in 2 M hydrochloric acid
(e) Sodium Bisulfite - anhydrous
(f) Sodium Nitrite - crystalline
(g) Sodium Hydroxide - 50% solution

Instrumentation

1. A windowless 2 pi gas flow proportional counter.

2. An alpha spectrometer system capable of 40 to 50 KeV resolution of actual samples electrode deposited on flat, minor finished stainless steel planchets with a counting efficiency of > 17% and a background of <0.010 cpm over the designated energy region. Resolution is defined as the full width half maximum (FWHM) in KeV, the distance those points on either side of the alpha peak where the counter is equal to one-half the maximum count (Heath, 1964)

Anion Exchange Resin Columns -- Dowex 1X4 (100-200 mesh nitrate form)

Remove the fines from an appropriate amount of resin by repeated suspension in distilled water and

decantation. Decant the water and add a volume of concentrated (16 M) nitric acid approximately equal to 50% of the volume of the resin slurry. Using 8 M nitric acid from a wash bottle, transfer sufficient resin to a 1.3 cm ID ion exchange column to give a 10-cm bed of settled resin. Convert the resin to the nitrate form by passing 100 ml of 8 M nitric acid through the column at maximum flow rate.

Sample Decomposition

1. Weigh a representative 10.0 ± 0.1 gram of the food ash sample* and transfer to a 250 ml PTFE (Teflon) beaker.

   * Sample weight is approximately 200 g before drying and ashing.

2. Add 16 M nitric acid, a few drops at a time, as fast as the frothing and vigor of the reaction will permit until the entire sample is covered.

3. Add an appropriate quantity of plutonium-236 tracer.

   Note: If the activity is expected to be less than 1 dpm/g, or is unknown, add 10 dpm of the tracer. For higher levels add as much plutonium-236 tracer as the estimated activity of plutonium-239 or plutonium-238 in the sample.

4. Add an additional 60 ml of 16 M nitric acid and 30 ml of 48% hydrofluoric acid and digest on a hotplate with frequent stirring (Teflon stirring rod) for about 1 hour.

   Caution: Hydrofluoric acid is an extremely hazardous liquid. Use gloves to avoid contact with skin and work in a fume hood to avoid breathing vapors.

5. Remove from the hotplate and cool somewhat before adding 30 ml each of 16 M nitric acid and 48% hydrofluoric acid. Digest on the hotplate with intermittent stirring for an additional hour.

6. Remove from the hotplate and cool completely. Carefully add 20 ml of 12 M HCl and stir. Heat on a hotplate for 45 minutes with occasional stirring after initial reaction has subsided.

7. Add 5 g of powdered boric acid and digest for an additional 15 minutes with occasional stirring.

8. Add approximately 200 mg of sodium bisulfite crystals and continue heating until the solution has evaporated to a liquid volume of approximately 10 ml.

9. Add 50 ml of distilled water and digest on a hotplate with stirring for 10 minutes to dissolve the soluble salts. (Some insoluble salts may remain.)

Sodium Hydroxide Precipitation

10. Cool and transfer approximately equal parts of the total sample (including insolubles if present) into two 250 ml centrifuge bottles with a minimum of distilled water from a wash bottle.

11. Add 1 ml of iron carrier solution (10 mg Fe^{3+}/ml) to each centrifuge bottle and stir.

12. Add 50% sodium hydroxide with stirring to each bottle to a pH of approximately 9. Add 5-10 ml excess of the sodium hydroxide and stir for 1 minute.

13. Centrifuge for approximately 5 minutes, decant and discard the supernate(s).

14. Dissolve each precipitate with about 30 ml (60 ml total) of 8 M nitric acid saturated with boric acid. Digest on a hot water bath for 10 minutes.

15. Cool and centrifuge for 5 minutes. Decant the supernates into the original 250 ml PTFE beaker and save.

16. Wash each residue with approximately 10-20 ml (20-40 ml total) of 8 M nitric acid saturated with boric acid. Centrifuge for 5 minutes and combine the supernates with those in Step 15. (Discard remaining residue).

17. Heat the supernates on a hotplate and evaporate to near dryness.

Ammonium Hydroxide Precipitation

18. Add approximately 30 ml of water and heat to dissolve the salts. Cool, and transfer equal portions into centrifuge bottles.

19. Add 15 M ammonium hydroxide dropwise with stirring to a pH of approximately 9. Centrifuge and discard the supernate.

Ion Exchange Separations

20. Dissolve the precipitate(s) with a volume of 16 M nitric acid approximately equal to the volume of the precipitate(s) and transfer using 8 M nitric acid into a 250 ml beaker. Add 8 M nitric acid to a total volume of approximately 75 ml.

Note: If the volume of the hydroxide precipitate is considerably greater than should be expected from the 10 mg of Fe added, the final volume should be brought up to approximately 100 ml with 8 M nitric acid or, alternatively, the dissolved hydroxides should be evaporated to salts before addition of the 8 M nitric acid solution. The final molarity of the HNO_3 is not extremely critical, but should be in the range of 7-9.

21. Add approximately 200 mg of sodium nitrite ($NaNO_2$) crystals and stir with a stirring rod. Bring to a quick gentle boil on a hot plate, and cool. Avoid prolonged heating.

22. Pass the sample (at maximum flow rate) through an anion-exchange resin column (nitrate form) prepared as described previously.

23. When the solution just drains to the top of the resin bed, add 8 M nitric acid to the column reservoir and wash the resin column at maximum flow rate. Discard the effluents from the sample and washes.

24. Repeat step 23 until the resin column has been washed with a total of six column volumes of 8 M nitric acid.

25. Wash the resin column with six column volumes of 12 M hydrochloric acid using the same technique. Discard the hydrochloric acid washes.

26. Elute the plutonium with four column volumes of freshly prepared ammonium iodide-hydrochloric acid solution (1 part 1 M NH_4I to 20 parts of 12 M HCl) and collect in a 150 ml beaker.

27. Evaporate the solution to approximately 5 ml on a hot plate. Add 2 ml of 16 M nitric acid after reaction stops. Add 1 ml $HClO_3$. When fumes start add 2 ml conc H_2SO_4 and evaporate down to a 1 ml of H_2SO_4.

Preparation and Plating of Sample

28. To the beaker containing the sample, add 0.5 ml H_2O. Swirl beaker and transfer the activity to the cell using a medicine dropper.

29. Add 7 drops of 0.7 M H_2SO_4 and approximately 0.5 ml H_2O to the beaker. Swirl and transfer with a dropper to the cell.

30. Wash the beaker with approximately 0.5 ml H_2O once or twice and transfer to the cell with a dropper.

31. Add indicator methyl orange or methyl red to the cell.

32. Add to the cell one dropperful of NH_4OH. Using automatic stirrer, titrate to the color change with NH_4OH. Back titrate with 0.7 M H_2SO_4 to the color change. Add 2 drops in excess. The volume should not be much above the stirrer, approximately 7 ml.

33. Plate for 2 hours at approximately 450 milliamps, between 5 and 6 volts. Then add one dropperful NH_4OH and plate for 1 minute. Pour supernate into a beaker and save until plating has been known

to be successful.

34. Disassemble the cell. Rinse plate in a beaker of H_2O containing some NH_4OH and then ignite in a flame.

Calculations

$$pCi/g = \frac{A}{2.2xBxCxD}$$

B = Instrument counting efficiency (Alpha spectrometer/Silicone diode detector)

$$B = \frac{R_S \times E_{2\pi}}{R_{2\pi}^*} \quad (^*2\pi = 2 \text{ pi})$$

C = Recovery factor

$$C = \frac{R_6}{T \times B}$$

D = Weight in grams of sample

R_S = the net counting rate of the known electroplated source over the entire energy region on the alpha spectrometer (cpm)

$E_{2\pi}$ = the counting efficiency of the 2π counter

$R_{2\pi}$ = the net counting rate of the same source (R_S) on the 2 pi counter in cpm

R_6 = net count rate in ^{236}Pu energy region

T = time

B = efficiency

II. Procedure B

The principle of the analytical procedure for 1 g sample follows (analysis of effluent and environmental samples from uranium mills and of biological samples - U. S. Public Health Service, D. R. Rushing, J. Garcia and D. A. Clark).

A known amount of Pu-236 tracer is added to the sample which is decomposed by a flux which in turn is dissolved in 3 M H_2SO_4. The activity is then precipitated, as LaF_3 which in turn is dissolved in 2 M aluminum nitrate and 2 M HNO_3. Hydroxylamine hydrochloride is added and then sodium nitrite to have the Pu all in the same state. The solution is purified by TTA. Four samples tried - 2 tea and 2 pepper. Average mean recovery was 77.0 $\pm$ 5.0

Tracer

Plutonium-236 solution - 2.5 x 10^4 dpm of plutonium-236 in a 2 M nitric acid in minimal solution (available from Amersham Corp). Solution made up for tracer should contain approximately 10 dpm/ml.

Acids

All solutions are made with distilled water. All acids are reagent grade and meet the American Chemical Society (ACS) specifications.

(a) Sulfuric Acid, concentrated
(b) Hydrofluoric Acid, concentrated and 1 M
(c) Nitric Acid 10 M, 2 M and 1 M
(d) Perchloric Acid, concentrated

Reagents

All solutions are made in distilled water unless noted. All reagents are reagent grade and meet ACS specifications unless defined otherwise.

(a) TTA in benzene, 0.45 M.
(b) Aluminum Nitrate, 2 M
(c) Hydrogen Peroxide, 30%
(d) Hydroxylamine Hydrochloride, 1 M
(e) Sodium Nitrate, crystalline
(f) Sodium Carbonate, anhydrous
(g) Sodium Tetraborate, powdered
(h) Lanthanium Nitrate, 20 mg/ml

Instrumentation

1. A windowless 2 pi gas flow proportional counter.

2. An alpha spectrometer system capable of 40 to 50 KeV resolution of actual samples electrode deposited on flat, minor finished stainless steel planchets with a counting efficiency of >17% and a background of <0.010 cpm over the designated energy region. Resolution is defined as the full width half maximum (FWHM) in KeV, the distance those points on either side of the alpha peak where the counter is equal to one-half the maximum count (Heath, 1964).

Procedure for a 1 g Ash Sample for Plutonium in Food

1. Use Nicholson's original flux - sodium carbonate and sodium tetrabonate in a ratio 3:1 - mix well and then place it in a platinum dish. Heat and fuse the contents of the dish and mix thoroughly by swirling. Let the flux cool and grind it with a porcelain mortar and pestles so that it passes a 10 mesh screen or finer.

2. Weigh a g of sample and then weigh 8 g of the ground flux, mix both well in a suitable platinum crucible.

3. Add known amount of ^{236}Pu for recovery.

4. Heat the mixture until dissolved (fused), then cool.

5. Place crucible in a plastic beaker containing 120 ml H_2O, 20 ml conc. H_2SO_4, 1 ml La carrier (20 mg/ml) and 1 ml H_2O_2 -when the fused mixture is released from crucible remove the crucible and rinse well with H_2O.

6. When reaction has stopped, stir with a teflon stirrer and add 10 ml conc. HF and let stand at least 1/2 hour.

7. Centrifuge the precipitate (LaF_3) in plastic tube.

8. Wash the precipitate with a solution of approximately 10 ml of 1 M HNO_3 and 1 M HF

9. Dissolve precipitate with a 1.2 ml of 2 M aluminum nitrate and 4 ml 2 M HNO_3, stir and heat lightly (in H_2O bath), allow approximately 5 minutes, then cool.

10. Add 1 ml 1 M hydroxylamine hydrochloride to solution and heat for 5 minutes, then cool.

11. Transfer the solution (which is 6.2 ml) into a small separatory funnel, preferably a 60 ml one.

12. Weigh out 0.276 g of $NaNO_2$ and dissolve it in 2 ml H_2O.

13. Add the above $NaNO_2$ solution to separatory funnel and mix well.

14. When reaction is complete add 8.2 ml 0.45 M TTA and then shake (extract) for 5 minutes.

15. Discard the aqueous phase.

16. Wash organic phase 2 times with 1 M HNO_3, shaking each time for 1-2 minutes.

17. Back extract Pu with equal volumes of 10 M HNO_2 twice, shaking for 1-2 minutes each time. Combine aqueous layers in a 100 ml beaker.

18. Evaporate to approximately 5 ml, then all 1 ml of conc. $HClO_3$ and 1 ml conc. H_2SO_4. Heat until fumes of $HClO_3$ have stopped. Sample is ready for plating.

19. Proceed to Step 28, Preparation and Plating of Sample of Procedure A.

(d) Determination of Thorium by Alpha Spectrometry

Application

This method is applicable to the analysis of various types of solubilized environmental samples.

Principle of Method

Lanthanum carrier is used to co-precipitate thorium as the fluoride with HF. Solution of the precipitate is accomplished by warming with HCl and H_3BO_3. The precipitation of lanthanum (Th) hydroxide removes the alkaline earths contamination. Solution of the hydroxide precipitate in concentrated HCl and the subsequent passage through an anion column removes several contaminating nuclides, since thorium is not sorbed on the anion column at any HCl concentration.

The effluent from the ion exchange column, which contains the Th, is evaporated to dryness. The residue is dissolved in 0.2M HNO_3 and the Th extracted with TTA to separate the Th from the La carrier.

The thorium is then plated on a 1" stainless steel disk. The total thorium activity is determined by measuring the alpha activity in an internal proportion counter. The isotopes of thorium present may be determined by alpha spectrometry.

Reagents

Lanthanum carrier - 12 mg La^{+++}/ml
Hydrofluoric acid, HF - 48%
Boric acid, H_3BO_3 - saturated solution
Hydrochloric acid, HCl - concentrated, 4M, 0.7M
Ammonium hydroxide, NH_4OH - concentrated
Anion exchange resin - Dowex AG 1X10, (200-400) mesh, chloride form, see Appendix at end of Method for preparation
Nitric acid, HNO_3 - concentrated, 0.2M, 4M
Perchloric acid, $HClO_4$ - 70%
2-Thenoyltrifluoroacetone, TTA - 10% w/v in benzene
Sulfuric acid, H_2SO_4 - concentrated, 0.7M
Methyl red or methyl orange

Special Apparatus

Electroplating apparatus
Electroplating cell
Stainless steel plating disks, 1 inch diameter
Internal proportion counter
Alpha scintillation spectrometer
Ion exchange columns

Procedure

1. To a suitable aliquot of a solubilized sample in a Teflon beaker add concentrated HCl until strongly acid. Add 1 ml of La^{+++} carrier.

2. Add 2 ml of hydrofluoric acid and mix thoroughly. Allow to stand for one hour for the precipitate to form completely. Decant. Discard the supernatant liquid. Transfer the precipitate to a 40 ml polycarbonate centrifuge tube. Centrifuge. Discard the supernatant liquid.

3. Dissolve the precipitate with 2 ml of a saturated solution of H_3BO_3 and 1 ml of concentrated HCl. Dilute to 30 ml with water.

4. Make the solution alkaline with concentrated NH_4OH. Centrifuge. Discard the supernatant liquid.

5. Dissolve the precipitate with concentrated HCl and sorb onto the Dowex anion column (see Appendix at end of Method column preparation).

6. Wash the column with 35 ml of concentrated HCl. Collect the effluent, which contains the thorium, in a 150 ml beaker.

7. Evaporate the effluent to dryness on a hot plate. Add 1 ml of concentrated HNO_3 and 1 ml of 70% $HClO_4$ and again take to dryness.

8. Dissolve the residue in approximately 10 ml of 0.2M HNO_3. Pour the solution into a 60 ml separatory funnel. Rinse the beaker with 1 ml of 0.2M HNO_3 and combine with the solution in the funnel.

9. Add 10 ml of 10% TTA solution to the separatory funnel and shake for 5 minutes. Draw off the aqueous layer into a clean 60 ml funnel.

10. Add 10 ml of 10% TTA solution to the funnel containing the aqueous layer and shake again for 5 minutes. Draw off and discard the aqueous layer.

11. Combine the organic phases into one of the funnels. Rinse the empty separatory funnel with 10 ml of 4M HNO_3 and add this to the funnel containing the TTA.

12. Shake the TTA-HNO_3 mixture for 5 minutes. Draw off the aqueous layer into a 150 ml beaker.

13. Add 10 ml of 4M HNO_3 to the organic phase in the separatory funnel. Shake again for 5 minutes. Draw off the aqueous layer and combine with the solution in the 150 ml beaker.

14. Add 1 ml of concentrated HNO_3 and 1 ml of 70% $HClO_4$ to the combined aqueous layers and take to dryness on a hot plate.

15. Add 1 ml of water to the electroplating cell.

16. To the beaker containing the sample add 7 drops of concentrated H_2SO_4 and 0.5 ml H_2O. Swirl beaker and transfer the thorium to the cell using a medicine dropper.

17. Wash beaker with 7 drops concentrated H_2SO_4 and 0.5 ml H_2O and transfer to the cell with a medicine dropper.

18. Wash beaker twice with approximately 0.5 ml H_2O and transfer to the cell with a dropper.

19. Add a drop of methyl orange or methyl red to the cell. Add fresh concentrated ammonia (or ammonia that has been stored under oil to keep free of CO_2) dropwise until there is a color change.

20. Back-titrate with 0.7M H_2SO_4 to the color change. Add two drops in excess. The volume should not be much above the stirrer. ($\sim$7ml)

21. Plate for one hour at approximately 450 milliamps, between 5 and 6 volts. Then add one dropperful of carbonate-free NH_4OH and plate for one minute. Pour solution into a beaker and save until plating is known to have been successful.

22. Disassemble the cell. Rinse plate in a beaker of H_2O containing some carbonate-free NH_4OH and ignite in a flame. If a stainless steel plate has been used, flame until the plated area just turns blue.

23. Count the plated sample in an internal proportion counter to obtain gross alpha counts. Then count in an alpha spectrometer.

Calculations

$$\text{total dpm} = \frac{\text{net cpm (IPC)}}{\text{efficiency}}$$

$$\text{pCi of Th isotope/aliquot taken} = \frac{\text{Counts in peak channels}}{(2.22)\ \text{total counts in all channels}} \times \text{total dpm}$$

References

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Appendix:

Preparation of anion column:

Dowex AG 1X10, Cl^- form, 200-400 mesh. A glass tube 16 mm in diameter and 17 cm-24 cm long is drawn out to a tip at one end. A glass wool plug is placed at this end. Add to the tube a water slurry of resin until it settles to a column height of 6.5 cm. Place a glass wool plug on top of the column. Wash the resin successively with 20 ml 12M HCl, 20 ml 4M HCl, 20 ml 0.7M HCl, and 20 ml of 12M HCl.

E. DATA HANDLING

INTRODUCTION

The quality of the data reported depends not only upon the care with which sampling and analysis are performed, but also upon the care with which calculations of the resulting data are performed, and upon the manner in which the data are presented in reports.[1] A key aspect of a quality assurance program is maintaining records that document every step of the process that leads to the data that ultimately are reported.

LABORATORY RECORDS

A measurement is useful if it is representative of the environmental material or parameter that is under study. Laboratory notes made during the analysis of a sample serve as a basis for judging the quality of the analysis, indicating whether any problems arose during the analytical procedures that might have adversely affected their outcome. For this reason, every effort should be made during sample preparation and analysis to record all aspects of the procedure that might reasonably be expected to affect the outcome of the analysis. As a general rule, every possibly relevant variable that is amenable to quantification should be recorded, even if only by a check mark on a form. These records may be needed not only by the person who is writing them, and only for the time period during which they are being written, but in many instances they may be needed by other persons and at some future time. It is important, therefore, that the notes be both legible and clear in meaning, so that others who read them will be able to reconstruct the events that are referred to.

It is often convenient to preserve electronically the data records from those instruments which provide digital electronic output signals. When this is done, great care must be taken to ensure that blocks of data are thoroughly annotated to identify the time and location and all other important circumstances concerning the measurements. Often the best way to do this is to organize blocks of data into files with distinctive file names, and to keep a logbook with the supporting information for each file. Alternatively, if electronic editing capabilities are available, comments can be entered into the data file itself.

DATA REDUCTION AND STORAGE

There are types of data, such as those related to possible legal actions involving the Government, that should be stored indefinitely. When data are stored electronically, backup files must be prepared to eliminate the possibility that the data may inadvertently be lost. When it begins to become evident that a medium on which data are stored, such as a particular type of magnetic disk or tape, is in danger of becoming obsolete, and there is thus a danger that the data will become irretrievable, the data should be copied to a better medium.

Whenever data are to be transferred or stored, an appropriate control procedure should be established to minimize the danger that human error will compromise the quality of the data. Data reduction is normally accomplished electronically using computer programs, both to avoid the drudgery of repeated "hand" calculations and to avoid calculation errors. For small numbers of unusual measurements or samples, however, hand calculations may be more efficient than writing a computer program of limited applicability. When unfamiliar calculations are performed, whether by hand or by using computer programs, care must be taken to be sure that the logic built into the calculation is correct. Calculations are often checked by performing them on data that lead to a known result.

DATA REPORTING

When data are reported, an estimate of their uncertainty must be given. Contained below are the guidelines and definitions of the terms that are useful for reporting the errors and uncertainties of data. The meaning of reported uncertainties must be indicated either by stating exactly what they represent or by describing how they were calculated, because a simple $X \pm Y$ statement may be interpreted in any one of a number of ways. The statement of uncertainty should include estimates of all significant sources of error involved, whether these result from the field measurement or sampling phase, the analysis phase or the data reduction phase, if they will affect the final result within the number of significant figures reported.

When data are reported, the reporting format must be commensurate with their expected use. Tables of data allow the full presentation of values and of their estimated uncertainties. Graphical presentation typically allows better visualization of the data. With both tabular and graphical presentations, it is important to assume that nothing will be immediately obvious to the reader, and the column headings or legends must include all information that is necessary in order to understand the data that are presented.

When data are presented, it is important to report only the appropriate number of significant figures. Usually the data should be carried to additional figures during preliminary calculations and then the final result should be rounded off to the proper number of significant figures. When the tables are printed by a computer, the format that is used may result in too many decimal places being reported for some samples. If this happens, the table should be edited to limit all data to the appropriate number of figures. One approach to determining the number of significant figures to be reported (Sanderson et al., 1980)[2] first determines the number of significant figures in the uncertainty, and rounds the reported value to the same decimal place as the uncertainty. In this approach, it is assumed that the rounded-off standard deviation reported should not differ from the calculated value of the standard deviation by more than 20%. For example, if the calculated standard deviation is 0.1635, it should be reported as 0.16, which differs from the original by over 22%. The value of the measurement is then rounded such that its last significant figure will be in the same decimal place as that of the error.

When data are presented in memoranda or reports, it is usually both possible and desirable to include a complete discussion of the quality assurance data that are pertinent to the measurements. The information to be presented may include, in addition to the uncertainties, various statistical tests and indications of analytical sensitivity, such as the lower limit of detection (LLD), the instrumental detection limit (IDL), the method detection limit (MDL), the limit of detection (LOD) Currie, 1988),[3]
the specificity (identification), and purity (absence of contaminant). The specificity and purity may be estimated from the resolution of a signal or from the goodness of fit to known quantities, such as energy, wavelength or rate of radioactive decay. Reporting the results for quality control samples, replicates and blank samples also provides important information about the quality of data. If a discussion of quality assurance cannot be included in a journal or symposium publication, normally a separate, supporting quality assurance report should be prepared.

Terms such as "below detection limits" should not be reported in place of the actual analytical results obtained. Reporting results as "less than" some minimum detectable level also results in some loss of statistical information, and may lead to erroneous interpretations. When low activities or concentrations are measured, the actual results obtained, including any negative values, normally should be reported along with the associated overall uncertainties and the measures of analytical sensitivity that are mentioned above. An interpretation of negative values can be included in the text. Waite et al. (1980)[4] and Gilbert Kinnison (1981)[5] have discussed techniques that may be followed in averaging data sets that contain "less than" values.

A number of terms have been used by the scientific community to describe data quality, but these terms are often given different meanings by different individuals. The definitions that follow are the preferred usage for the purposes of this document and have been taken from Croarkin (1985)[6], Taylor (1985, 1987)[7,8] and Taylor and Opperman (1986),[9].

Error - The difference between the true value and the measured value of a quantity or parameter.

Uncertainty - The range of values within which the true value is estimated to lie. It is a best estimate of possible inaccuracy due to both random and systematic errors.

Random Errors - Errors that vary in a nonreproducible way around the limiting mean. These errors can be treated statistically by use of the laws of probability.

Systematic Errors - Errors that are reproducible and tend to bias a result in one direction. Their causes can be assigned, at least in principle, and they can have both constant and variable components. Generally, these errors cannot be treated statistically.

A statement of uncertainty assigns credible limits to the reported value, stating to what extent that value may differ from its true value. The uncertainty of a measured value can be defined by a statistically determined confidence interval for the random error and by an estimate of the bounds for systematic error; they should be stated separately. When appropriate, they may also be combined into a single range to describe the overall uncertainty. Since there are a variety of methods suggested in the literature for combining random and systematic errors, the particular method used must be explicitly stated. One accepted practice (Croarkin, 1985)[6] is to combine in quadrature, systematic errors that are known to be independent, to add linearly systematic errors that may not be independent, and to combine systematic and random errors linearly. The confidence level chosen must be stated whenever a confidence interval is reported.

Systematic errors which can be determined by calculation or by experiment should be eliminated by an appropriate correction. Estimating the magnitude of some systematic errors may require scientific judgement

on the part of the experimenter. All significant sources of error should be identified and reported.

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III RADIATION PROTECTION GUIDELINES

1. PHILOSOPHY OF RADIATION PROTECTION

The setting and execution of guidelines for radiation protection are based upon an underlying philosophy in which two factors are of prime importance. First is the assumption that radiation effects follow a linear, or non-threshold dose-response relationship. There is convincing evidence, particularly insofar as the genetic effects of radiation are concerned, that there exists a non-threshold phenomenon; and although positive proof is thus far lacking, it has been deemed prudent to adopt this more conservative hypothesis in setting protection standards for large numbers of people. According to the non-threshold concept, there is no radiation dose so small that it does not involve some degree of risk. The non-threshold relationship, therefore, implies that there is no radiation protection guideline, no matter how low, which can insure absolute safety to every individual in a large population receiving the guideline dosage. However, since the magnitude of the risk is proportional to the dose received, untoward effects would become manifest at very low dose levels only if extreme large numbers of exposed individuals were observed.

The second major factor to consider is that radiation, like many other developments of modern life (such as the automobile) confers great benefit upon both society and the individual along with its risk to health. Consideration of the extend of these benefits makes a certain degree of risk acceptable. Thus, a balance must be struck in each contemplated radiation usage, in which the benefit to be gained is weighed against the anticipated risk. If the benefit outweighs the risk, the radiation is utilized so that its maximum benefit will be realized while human exposure will be maintained at the minimum consistent with deriving these benefits. The overall public health philosophy, then, is to attain maximum advantage from the use of ionizing radiation while minimizing concomitant exposure, that is, eliminating wherever possible all unnecessary exposure to radiation.

The Radiation Protection Guide (RPG) may be defined as the radiation dose which should not be exceeded without careful consideration of the reasons for so doing. In light of the non-threshold phenomenon, every effort should be made to encourage the maintenance of radiation exposures as far below the guide as practicable. Methods of estimating guides are primarily based on past experience in which individuals have been exposed to radiation for various reasons and upon animal experiments which have contributed greatly to the study of the effects of radiation. From this combined knowledge and from an understanding of the relative biological damage produced by various types of radiation, protection guides for whole-body exposure and for various organs have been recommended. These guides, of course, represent doses far below those at which any effects have thus far been observed.

2. BASIS FOR RADIATION PROTECTION GUIDES

Establishment of "safe" levels of long-term radiation dose requires knowledge of the cause-effect relationship between radiation dose and biological damage. Such damage may appear many years after initial exposure and is usually indistinguishable from the normal diseases and impairments of man. Information accumulated on this subject is, therefore, difficult to evaluate and is often controversial. Nevertheless, observations involving man and animal life have resulted in the accumulation of significant data. These include:

A. Genetic Effects

1. Studies involving fruit flies and mice
2. Hiroshima and Nagasaki populations (inconclusive)

B. Incidence of Neoplasms

1. Bone tumors in radium dial painters
2. Leukemia in radiologists
3. Thyroid carcinoma in children irradiated in infancy
4. Various neoplastic diseases, including leukemia, in patients receiving therapeutic radiation for a variety of reasons
5. Leukemia in offspring of mothers irradiated during pregnancy.
6. Leukemia in survivors of Hiroshima and Nagasaki bombings

C. Life-Span Shortening

1. Studies with various animal species.
2. Radiologists vs. other physicians

Evaluations of these observations in terms of allowable radiation dose to man is an exceedingly complex task. The National Council on Radiation Protection and Measurements (NCRP) has accepted the task and over the past 30 years has established recommendations regarding maximum permissible doses. Because of the fragmentary evidence currently available, the NCRP points out that these levels are not necessarily completely safe limits but rather levels which should carry an acceptable risk.

In 1959, the Federal Radiation Council was formed to provide a Federal policy on human radiation exposure. This organization published its first report in May, 1960. Its recommendations were essentially the same as those of the NCRP and the International Commission of Radiological Protection (ICRP). The Council suggested, however, that the terms "Radiation Protection Guides" replace the former "Maximum Permissible Doses." The newer terminology recommended by the Federal Radiation Council is used throughout this section.

3. CURRENT RECOMMENDED DOSE LIMITS

Radiation Protection Guides vary depending on whether the whole body or only a portion thereof is exposed and whether radiation workers or the general public is involved.

A. Radiation Workers

1. ACCUMULATED DOSE (EXTERNAL SOURCES)

a. For external exposure to the whole body, the maximum average dose rate should not exceed 5 rems per year (0.05 Sv per year). The same dose rate applies to the head and trunk, active blood forming organs, the gonads, and the lenses of the eyes.

No occupational dose is allowed persons under 18 years of age. The accumulated dose at any subsequent age, therefore, should not exceed 5(N-18) rems (0.05(N-18) Sv), where N is the age of the worker in years.

b. Generally, however, where only a single portion of the body is exposed, Radiation Protection Guide average dose rates are higher. For example, it is recommended that the average dose rate to the hands and forearms and to the feet and ankles should not exceed 75 rems per year (0.75 Sv per year).

2. ACCUMULATED DOSE (INTERNAL SOURCES)

a. Certain elements, upon ingestion, inhalation, etc., deposit uniformly throughout the body. Radioisotopes of these elements deliver a dose to the whole body. The Radiation Protection Guide dose rate for whole body exposure from such radionuclides has the same limit as from external sources (i.e., 5 rems per year or 0.05 Sv per year). No occupational exposure is allowed persons under 18 years of age.

b. Other radionuclides tend to localize in one or more selected body organs. Based on the essentiality of the organ to proper body function, epidemiological experience with radium, and genetic considerations, other Radiation Protection Guides have been specified for selected critical body organs.

(1) For most individual organs, it is recommended that the maximum average dose rate not exceed 15 rems per year (0.15 Sv per year).

(2) For the thyroid and skin, the maximum average dose rate should not exceed 30 rems per year (0.30 Sv per year); for the gonads, the average dose rate should not exceed 5 rems per year (0.05 Sv per year).

(3) For compact bone, the <u>maximum</u> permissible dose rate is limited to the <u>average</u> dose rate which would result from a body burden of 0.1 microcurie (3.7×10^4 Bq) of radium. (This amount of radium would yield a dose rate of approximately 28 rems per year (0.28 Sv per year)).

B. General Population Groups

Recommended Radiation Protection Guides for the general population are considerably below those for radiation workers. One of the reasons for this stricter limitation on allowable dose is related to the possibility of genetic effects from radiation exposure. Because the general population contains all of the germ plasm controlling the genetic viability of the race, any mutational effects on this population would have a far greater total impact than exposure of that small segment of the population working with radiation.

Currently it is recommended that the yearly radiation exposure of individuals in general population (exclusive of natural background and the deliberate exposure of patients by dentists and doctors) should be held to one-tenth of the permissible occupational levels. Thus, for whole-body exposure of individuals in the general population, the radiation dose should not exceed 0.5 rem per year.

Exposure of the total population (this includes radiation workers and special groups, as well as the general population) presents a different problem. Here it is necessary to make assumptions concerning the relationship between the recommended Radiation Protection Guide of 0.5 rem per year (0.005 Sv per year) for individuals in the general population, and the average dose received by average total population groups. The Federal Radiation Council suggests the use of the arbitrary assumption that the majority of individuals do not vary from the average by a factor greater than three. Thus, they recommend the use of 0.17 rem (0.0017 Sv) as a Radiation Protection Guide for yearly whole-body exposure of average total population groups. This is in keeping with their recommendation that the average genetically significant dose to the total population not exceed 5 rems (0.05 Sv) up to age 30 (exclusive of natural background and purposeful exposure of patients by practioners of the healing arts).

Assessment of the amount of radiation dose received by a given individual or population group requires totalling the doses received from external and internal sources. External exposures may be measured with a sufficient degree of accuracy by direct roentgen-rate monitoring procedures. Internal doses are assessed in terms of the concentration of specific radionuclides in air, water, milk, and food which may be inhaled or ingested. To enable comparison of the radioactivity concentrations measured in these various environmental phases with Radiation Protection Guides , concentration values[1] which are related to the established RPG have been derived for many radionuclides.

[1]Concentration values are expressed in terms of Radioactivity Concentration Guides (RCG) or Maximum Permissible Concentrations (MPC).

C. Factors Influencing Radioactivity Concentration Guides

The Radioactivity Concentration Guide is the concentration of radioactivity in the environment which is determined to result in whole-body or organ doses equal to the RPG. In calculating RCG values for a given radionuclide, the following factors must be taken into consideration:

1. INITIAL BODY UPTAKE

Large fractions of some elements are absorbed when taken into the body. In the case of certain other elements, only small fractions are absorbed in passage through the gastrointestinal tract.

Therefore, the greater retention would increase the hazard from the first group as compared with the second, other factors being equal.

When radionuclides are inhaled, unless information specific to the radionuclide is available, it is assumed, in the case of soluble compounds, that 25 percent is retained in the lower respiratory tract. From here, the nuclides move into the blood stream and a portion of each is deposited in its critical tissue within a few days. Approximately 50 percent is held in the upper respiratory tract and is swallowed. In the case of insoluble compounds, it is assumed that 12 percent is retained in the lower respiratory tract, which is usually taken as a critical organ. The remainder is eliminated by exhalation and swallowing.

2. FRACTION RETAINED IN THE BODY

The rate of elimination from the blood and tissues of the body varies considerably for different elements or compounds. The time required for one-half of the original quantity of radioactive material to be removed from the body by biological processes is called the biological half-life.

Some materials in the blood stream are eliminated rapidly from the body whereas large fractions of others remain in the body organs. For example, radium, plutonium, and strontium are deposited in the bone where the rate of turnover is very slow; i.e.; the biological half-life is many years. Radioisotopes of these elements are much more hazardous than those of carbon, sodium, and sulfur which have biological half-lives of a few days or weeks. The principal biological methods of elimination of radionuclides from the body are the urine, feces, exhalation, and perspiration. Usually elimination is much more rapid before the radionuclide is translocated from the body to a more permanent area, such as the bone. This time is usually from a few days to a few weeks. After the initial period, the elimination rate becomes more nearly exponential, and the application of the term "biological half-life" has more meaning.

3. ORGAN OR TISSUE IN WHICH RETAINED[2]

a. Radiosensitivity - Certain body organs or tissues are more radiosensitive than others. For example, the lymphatic tissue and bone marrow are much more radiosensitive than muscle or nerve tissue. Therefore, in equal concentrations, an element like plutonium is more hazardous than uranium because the plutonium concentrates in the most sensitive part of the bone, whereas the uranium goes to other portions of the bone, to the kidneys, and to other relatively insensitive organs.

b. Size - For a given number of microcuries of a radionuclide in a critical organ, the smaller the organ the greater the concentration and the greater the dose delivered to the critical tissue. Iodine presents a much greater problem than sodium, since the iodine is very selectively absorbed in a much smaller organ, the thyroid gland, whereas sodium is rather uniformly distributed throughout the whole body. In many cases the radionuclide is deposited in a large organ but localized in a small portion of that organ, so that, in effect, the mass of the critical tissue may become very small.

c. Essentiality - Some organs are either not essential to the body function, or, when they are damaged or removed, special steps can be taken to supplement or compensate for their reduced function. For these reasons damage in some cases to the bone-marrow, kidneys, eyes, etc., may represent a greater hazard than equal tissue damage to the thyroid gland.

4. PHYSICAL PROPERTIES OF THE RADIONUCLIDE

a. Type and Energy of Radiation - The hazard is proportional to the relative biological effectiveness or quality factor of the radiation; e.g., alpha radiation is more damaging than beta radiation for a given energy of radiation. As the energy of the radiation is increased, the damage also increases.

b. Half-Life - The shorter the physical or radioactive half-life of a radionuclide, the less is the biological hazard. The radioactive half-life and the biological half-life may be combined into a single "effective" half-life by means of the formula:

$$T_{eff} = \frac{(T_r) \times (T_b)}{T_r + T_b}$$

D. Calculations of Radioactivity Concentration Guides

As an example of the approach used in determining RCG values, the case of cesium-137 is illustrated.

1. The element cesium is distributed rather uniformly throughout the body. Therefore, an RPG for the radiation worker of five rems per year is selected for any radioisotope of this element.

2. Experimental and theoretical studies have shown that the presence in the body of 30 microcuries (1.11×10^6 Bq) of ^{137}Cs will yield a whole body dose rate of five rems per year. This quantity, 30 microcuries, is referred to as the "maximum permissible body burden" for ^{137}Cs.

[2]In certain instances, an organ of the body, such as the GI tract or lung, may receive a significant dose due to the mere presence of the radionuclide in material inhaled or ingested. Under these circumstances, the organ so exposed (even though not absorbing the radionuclide) may become the "critical organ."

3. If, however, 30 microcuries (1.11×10^6 Bq) of ^{137}Cs were deposited within the body, they would not remain there long because of biological elimination and radioactive decay. Therefore, a certain amount could be ingested continually without exceeding the maximum permissible body burden.

4. A "standard man" consumes approximately 2200 milliliters of water per day. Approximately one-half of this is ingested during the working hours. If the daily intake of ^{137}Cs via drinking water is to be limited such that the "maximum permissible body burden" will not be exceeded (0-0.5 Sv) (and the average yearly radiation worker whole-body dose rate not exceed five rems), then the concentration of this nuclide in drinking water must not exceed 4×10^{-4} mCi/ml (14.8 Bq/ml), is the Radioactivity Concentration Guide (RCG) for ^{137}Cs in drinking water for consumption by radiation workers, based on an eight-hour per day, 40-hour work week for a radiation worker. .

In a similar manner, it can be shown that an average concentration of 6×10^{-8} Ci/ml soluble ^{137}Cs in air in the working environment would result in a worker receiving a whole-body dose rate of five rems per year.

E. Standardization of Calculations

When efforts were first made to establish permissible body burdens and Radioactivity Concentration Guide values for the various radionuclides, it became evident that it would be difficult, if not impossible, to compare suggested values from the different laboratories unless all used the same basic assumptions relative to the average man. Most of the calculations were based on the same fundamental physical assumptions relative to the energy schemes and radioactive half-life values, but each person making these calculations used his own preferred values for the mass and effective radius of the body organs, the rates of ingestion and inhalation, elimination rates, etc. This difficulty was recognized at several major conferences. As a consequence certain characteristics of the so-called "standard man" were agreed upon.

F. Graded System of Actions

It was felt by the Federal Radiation Council that a commitment to the single values represented by the Radioactivity Concentration Guides might prove arbitrary and inflexible, and not provide adequate guidance for taking assessment and control actions appropriate to the risk involved. Therefore, the Council's Report No. 2 introduced the concept of graded scales of RANGES of action in which average daily intake of a radionuclide by samples of exposed population groups are listed in three ranges. These ranges apply to certain selected radionuclides of health significance, namely, radium-226, strontium-89, strontium-90, and iodine-131. In general, the single radioactivity concentration guide equivalent corresponds to the upper limit of RANGE II. For intakes in RANGE I, the Council guideline recommends periodic, confirmatory surveillance as necessary; for RANGE II, quantitative surveillance and routine control is indicated; and for RANGE III, the Council advises evaluation and application of control measures as necessary.

G. Protective Action Guides

All of the foregoing guidelines are predicated upon the more or less constant release of low-level radioactivity into the environment from the routine uses of radiation, and assume continuous radionuclide intake by the population. Control, then, is based primarily at the source. There are cases, however, in which the contamination of the environment might be accidental or unforeseen, producing contamination which is transient and not likely to recur; these might include reactor incidents which result in relatively high but temporary local radioactivity levels, for example. In cases of this kind, the "contaminating event" would not occur on a regular basis, and control, or protective action, might be based upon limiting or changing the uptake of certain contaminated foods by the population. However, the impact of such measures upon the community which they are designed to benefit requires careful consideration by responsible authorities to insure that the benefit of the action taken is not outweighed by its other effects. To deal with this kind of situation, the Council, in its Reports No. 5 and No. 7, introduced the Protective Action Guide (PAG) concept. The PAG is defined as the projected absorbed dose to individuals in the general population which would warrant protective action following a contaminating event. It is assumed that the corresponding projected dose to a suitable sample of the exposed population would be one-third of the PAG. These guidelines have, thus far, been established for iodine-131, strontium-90, and cesium-137. It should be noted that a decision to take action to limit a community's intake of an important basic food item containing radionuclides involves a balancing of the health benefits to be attained against undesirable features of the protective action, such as disruption of dietary habits and nutritional needs. It follows, then, that control actions could be employed at dose levels above or below the PAG, depending upon the degree of total impact which the action has upon the community.

IV SUMMARY

Based on current information, Radiation Protection Guides for radiation dose have been recommended. These levels are subject to modification as more knowledge is gained. In view of their status and the possibility that any radiation dose may be damaging, it is well to recall the definition of the Radiation Protection Guide as that radiation dose which should not be exceeded without careful consideration of the reasons for doing so. Every effort should be made to encourage the maintenance of radiation doses as far below the Guide as practical. Table I summarizes the current recommendations of the ICRP and Federal Radiation Council. Table II are examples of the post-Chernobyl "action levels" as applied by various countries. Table III are examples of the Interim International Radionuclide Action Levels for Foods.

Table I summarizes the current recommendations of the ICRP and the Federal Radiation Council.

Table I. Radiation Protection Guides

Type of Exposure	**Condition**	**Dose[1](rem)[2]**
Radiation worker:	Accumulated dose	Five Times number of years beyond age 18
(a) Whole body, head, and trunk, Active blood-forming organs, gonads, or lens of eye	13 weeks	3
(b) Skin of whole body and thyroid	Year	30
	13 weeks	10
(c) Hands and forearms, feet and ankles	Year	75
	13 weeks	25
(d) Bone	Body burden	0.1μCi of ^{226}Ra or its biological equivalent
(e) Other organs	Year	15
	13 weeks	5
Population:		
(a) Individual	Year	0.5 (whole body)
(b) Average	30 years	5 (gonads)

[1]Minor variations from other recommendations are not considered significant in light of present uncertainties

[2]Dose in Sieverts (Sv) is obtained by multiplyings by 10^{-2}

Table II. Examples of post-Chernobyl "action levels" applied by different countries as of December 1986 for radionuclides in imported foods

Country	Radionuclide	Food	Action Level[1] (Bq/kg or Bq/L
Brazil	$^{134}Cs + ^{137}Cs$	Milk powder	3700
		Other foods	600
Canada	^{131}I	Milk	10
		Dairy Products	40
		Other foods	70
	^{137}Cs	Milk	50
		Dairy Products	100
		Other foods	300
		Spices	3000
European Community Countries[2]	$^{134}Cs + ^{137}Cs$	Milk and infant foods	370
		Other foods	600
	^{131}I	Milk	500[3]
		Vegetables	350
People's Republic of China	^{131}I	Milk	1300
		Fruits and vegetables	270
		Cereals	340
		Beverages	130
	^{137}Cs	Milk	4600
		Fruits and vegetables	1000
		Cereals	1200
		Beverages	460
Poland	"Total Beta Activity"	Milk powder for infants and children to 6 years	1320
Sweden	^{131}I	All foods	2000
	^{137}Cs	All foods	300
USA	^{131}I	Infant foods	56
		Other foods	300
	$^{134}Cs + ^{137}Cs$	All foods	370

1 Different terms used in different countries e.g. "Levels of concern" (USA), "Screening limits" (Canada), "Maximum permitted levels for import from third countries" (EC countries).

2 Belgium, Denmark, France, Federal Republic of Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, United Kingdom.

3 Recommended values by EC in May 1986.

Table III. Examples of Interim International Radionuclide Action Levels for Food (IRALF)

Radionuclide	Target Organ	Dose Level (mSv)	Dose Conversion Factor (Sv/Bq)	Radionuclide Intake (Bq corresponding) to the dose	Food Intake (kg)	IRALF (Bq/kg)
Sr-90						
-1st year	bone surface (infant)	50	1.9×10^{-6}	26,000	375	70
-following years		10	1.9×10^{-6}	5,200	375	20
I-131						
-1st year	thyroid (infant)	50	2.9×10^{-6}	17,000	40	400
Cs-134						
-1st year	whole body (adult)	5	2.0×10^{-8}	250,000	750	350
-following years		1	2.0×10^{-8}	50,000	750	50
Cs-137						
-1st year	whole body (adult)	5	1.4×10^{-8}	360,000	750	500
-following years		1	1.4×10^{-8}	71,000	750	100
Pu-239						
-1st year	bone surface (infant)	50	1.7×10^{-5}	3,000	375	10
-following years		10	1.7×10^{-5}	590	375	2

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IV GLOSSARY OF TERMS

INTRODUCTION

This Glossary of Terms has been included to assist the reader in understanding the abbreviations, symbols, and terms common to the radioassay procedures which appear in this manual. Many of the terms will be understood by anyone who has read the chapter on laboratory procedure included in most elementary quantitative analysis textbooks. Some will be familiar to those having basic knowledge of radiation physics. Others will be recognized as terms for which a traditional meaning has been extended to have a special meaning in certain contexts. A few, however, fall into the category of laboratory colloquialisms. Although these should be avoided in formal writing, they have been allowed to a limited extent, particularly in the step-by-step procedures.

All definitions have been restricted to the context in which the terms are used in this manual. The Glossary of Terms is neither a dictionary nor a complete glossary of terms. The rapid growth and development of scientific and technological knowledge precludes publication of any single complete glossary of current technical terms.

(1) ABBREVIATIONS AND SYMBOLS

A	activity, unless otherwise specified
AC	alternating current
α	alpha; alpha particles, energy of alpha particles, etc.
~, ≈	approximately
BP	boiling point
β	beta; as beta particles beta radiation, etc.
C	centigrade
Ci	curie(s)
cm	centimeter(s); 10^{-2} m
cm^2	square centimeter(s)
cph	count(s) per hour
cpm	count)s) per minute
d	day(s), in reference to half-life
dpm	disintegration(s) per minute
°	degree(s)
E	energy, unless otherwise stated
E_{max}	maximum energy
e.g.	*exempli gratia;* for example
et al.	*et alli;* and others
etc.	*et cetera;* and so forth
F	Fahrenheit
ft	foot (feet)
ft^3	cubic foot (feet)
g	gram(s)
GM	Geiger-Müller
γ	gamma; as gamma rays, gamma energy, etc.
h	hour(s), in reference to half-life
i.e	*id est;* that is
in	inch(es)
in^2	square inch(es), sq in
in^3	cubic inch(es), cu in
keV	kiloelectron volt(s); 10^3 electron volts
kg	kilogram(s); 10^3 grams
L or l	litre(s), liter(s)
λ	lambda; 1. decay constant 2. microliter; 10^{-3} milliliter
M	molar, as applied to concentration of a substance in a solution
mA	milliampere(s); 10^{-3} ampere
max	maximum
meq	milliequivalent(s)
MeV	million electron volts

mg	milligram(s); 10^{-3} gram
min	minute(s)
ml	millilter(s); 10^{-3} liter
mm	millimeter(s); 10^{-3} m
μCi	microcurie(s); 10^{-6} curie
μg	microgram(s); 10^{-6} gram
-	minus
N	normal, as applied to concentration of a substance in a solution
nCi	nanocurie(s); 10^{-9} curie
pCi	picocurie(s); 10^{-12} curie
ppm	part(s) per million
/	per, devided by
%	percent, per hundred
+	plus
±	plus or minus, expressing a range
rpm	revolution(s) per minute
s, sec	second(s)
sp gr	specific gravity
σ	sigma; standard deviation
t	time, in hours days, etc.
$T_{1/2}$	half-life, equal to 0.693 devided by the decay constant
V	volt(s)
v/v	volume to volume; by volume
wt	weight
w/v	weight to volume; by weight
y	year(s), in reference to half-life

(2) DEFINITION OF TERMS AND LABORATORY PRACTICE

aliquot — *adj.:* 1. *Chem.* - fractional, as an aliquot portion of a chemical solution, implying a measure part.
2. *Math.* - contained an exact number of times in something else (*e.g.*, 5 is an aliquot part of 15)
n.: an aliquot part; a measured portion of the whole

analytical balance — *n.*: a balance capable of weighing to 0.1 milligram

aspirate — *v.t.*: 1. to draw off or move fluids by suction; to draw off fluids with an aspirator. 2. to draw air through

background — *n.*: the sum of phenomena always present to affect physical apparatus or instrument response in the absence of a sample, above which a phenomenon must show itself in order to be measured. The term is applicable to radioactivity measurements (*e.g.*, counts or currents from cosmic rays), photometric measurements, etc., and is sometimes used in the sense of "blank determination".

blend — *v.t.*: to break down or mix to form a homogenous mass so that any portion of the mass is identical in composition, form, etc. to any other portion
n.: a homogenous mass or mixture

carrier — *n.*: a substance in ponderable amount which will carry a trace substance with it through a chemical or physical process. If carriers are of the same element as the trace substance (*e.g.* Sr for ^{90}Sr), they are called *isotopic* carriers; if of a chemical similar element (*e.g.*, Ba for Ra), they are called *non-isotopic* carriers.

carrier recovery — *n.*: that fraction or portion of a carrier substance initially added which is finally recovered in the final product; esp., that which is finally recovered in a sample to be counted. Carrier recovery may be determined by weight, by flame spectrophotometry, or by other chemical or physical means.

centrifuge — *n.*: an apparatus for the separation of substances by centrifugal force
v.: to separate by centrifugal force substances of different densities

chemical yield — *n.*: the quantity of a chemical product, such as a precipitate, obtained as a result of a chemical process expressed as a fraction or percentage of the amount theoretically obtainable [see yield]

count — *n.*: 1. the external indication of a device designed to enumerate ionizing events. Count may refer to a single detected event or to the total number of events registered in a given period of time; loosely, a disintegration, an ionizing event, or a voltage pulse. 2. (*Collog.*) a counting rate; the number of counts observed per unit time
v.t.: to measure the radioactivity or a substance by enumerating the ionizing events it produces in a detector during a known time interval

count rate — *n.*: the number of ionizing events detected per unit time. *Background* count rate is the number of ionizing events registered by the detector system in unit time when no sample is present. *Net* count rate is the number of ionizing events registered by the detector per unit time in the presence of the sample excluding the background count rate.

daughter — *n.*: any radioactive or stable nuclide produced by the radioactive disintegration of a radionuclide, either directly or as the result of a series of transformations in a radioactive decay chain (^{90}Sr; ^{218}Po is a daughter of ^{222}Ra)
adj.: designating a relationship in a radioactive decay series, as daughter product

decant — *v.t.*: to pour off gently; usually, to pour off the clear liquid above a settled or centrifuged residue

dry — *v.t.*: to remove the moisture from; to make devoid of moisture. Rigorously, *drying* means treatment in an oven at a temperature between 100° C and 110° C, but the term is extended to include the use of a hot plate or an infra-red lamp. *Drying* implies a more gentle treatment than igniting or baking.
adj.: free of moisture; not wet or damp

dryness — *n.* the state or quality of being dry. *Take to* dryness implies the removal of liquid, but not prolonged baking.

equilibrate — [see radioactive equilibrium]

extract — *v.t.*: to obtain or withdraw from a composite substance by any chemical or mechanical process, as by distillation, dissolution, etc.
n.: that which has been extracted, usually in a concentrated form

extraction — *n.*: the process of extracting or separating a certain substance from a mixture usually by means of solvents; exp., a process of separating or isolating a substance in solution by virtue of its varying degree of solubility in different solvents

gamma scan — *n.*: (*Colloq.*) a spectrum of gamma energies, usually in printed or plotted form, as that obtained from gamma pulse height analysis
v.: (Colloq.) the process of obtaining a gamma spectrum; the process of examining a sample for gamma emitters by pulse height analysis or spectrometry

homogenate or homogenizing — *n.:* that which has been homogenized; the homogeneous mass resulting from blending

homogenized — *adj.:* uniformly blended; made homogenous; [see blend] - *Special:* with milk, to indicate treatment by a technical process using high temperature and pressure to break up and uniformly disperse fat globules.

ingrowth — *n.: (Colloq.)* the formation of a daughter product from its radioactive parent (*e.g.*, ^{90}Y from ^{90}Sr), usually applied to accumulation of the daughter product in a solution in which the radioactive parent has been isolated.

ion exchange — *n.*: a chemical process involving the reversible interchange of ions at a phase boundary, usually between a solution and a particular solid material, such as an ion-exchange resin *adj.*: ion-exchange

The special terminology used in reference to this process is defined in the context of the following statement. < A solution is poured through an *ion-exchange column* which is a tube containing an *ion-exchange resin*. The solution that comes through is the *effluent* (general term). The material retained on the column (on the resin) is the *adsorbate*. The adsorbate is *eluted* from the resin by passage of a reagent solution, the *eluant*, through the column. The effluent from the process of *elution* is the *eluate*. The column (resin) is *washed* by pouring a reagent wash solution through it, usually to restore the resin to its original ionic state. >

isotope — *n.*: one of two or more species of atoms of the same element that have the same atomic number, occupy the same position in the periodic table, and are nearly identical in chemical behavior but differ in atomic mass or mass number and so behave differently in radioactive transformations. radioisotope: a radioactive isotope

nuclide — *n.*: one of two or more species of atoms of the same element that have the same atomic number, occupy the same position in the periodic table, and are nearly identical in chemical behavior but differ in atomic mass or mass number and so behave differently in radioactive transformations. radioisotope: a radioactive isotope

parent — *n.*: a radionuclide that disintegrates directly or through a series of transformations to yield a specified nuclide, the daughter; (*e.g.*, ^{238}U is the parent of all members of the uranium series including the stable end product ^{206}Pb) *syn.*: radioactive precursor

purity — *n.*: the state of being free from mixture or contact with contaminants, pollutants, or other substances which will interfere with a chemical process or end product

qualitative — *adj.*: 1. showing the nature or identity of any or all elements or materials in a compound or mixture without reference to the quantities present, not quantitative. 2. (*Colloq.*) improperly used to describe an analysis or analytical result in the sense of *approximate* or *rough*

quantitative — *adj.*: 1. determining or showing the quantity or amount of any or all elements in a given compound or solution or the components of a mixture. 2. complete, as quantitative transfer.

radioactive equilibrium — *n.*: the state attained among the members of a radioactive decay series or part of a series in which each parent has a longer half-life than its daughter, when the ratios between the activities of successive members remain constant, *i.e.*, the ratio of parent activity to daughter activity is independent of time.
Secular equilibrium is approached, but never completely attained, when the half-life of the parent is so long that there is no appreciable change in the amount of parent during the time required for later products to attain equilibrium, so that equal numbers of atoms of all members of the series disintegrate in unit time, *i.e.*, all members of the series exhibit the same activity (*e.g.*, ^{226}Ra and its series through ^{214}Bi).
Transient equilibrium will be reached if the half-life of the parent is so short that the quantity of parent decreases appreciably during the given time interval, so that all members of the series decrease in amount or activity exponentially with the half-life of the parent (*e.g.*, ^{222}Rn and its series through ^{214}Bi; ^{140}Ba to ^{140}La).

reagent grade — *adj.* or *n.*: conforming to American Chemical Society specifications for reagent chemicals as published in *Reagent Chemicals: American Chemical Society Specifications, 1960*, by the American Chemical Society Committee on Analytical Reagents

recovery — *n.*: the quantity of a product obtained as a result of a reaction or process or series of these, expressed as a fraction or percentage of that theoretically obtainable from the quantity of one of the chemicals or radioactive components initially present or added [see carrier recovery]

rinse — *v.*: to treat a container with water or other suitable liquid to facilitate a quantitative transfer, usually a mechanical action
n.: the liquid agent used to facilitate a quantitative transfer

scavenger — *n.*: a substance added to remove impurities or to overcome the undesirable effects of one or more of the substances contained in a mixture (*e.g.*, Fe, Cd, and Zr are often used as scavengers to remove rare earths by precipitation.)

spectrometry — *n.*: the art or process of using a spectrometer, of measuring spectra, or of determining wavelengths or energies of the various radiation; implying measurement, as a spectrometer is a spectroscope fitted for measurements of the spectra observed with it; also, pulse height analysis

standard — *n.*: an established measure of volume, quantity, quality, or value; esp., a material of known composition which closely resembles in chemical and physical characteristics the sample to be analyzed and which is used for calibration
adj.: having the accuracy or authority of a standard, serving as a gauge or model, as a standard weight

standard, radioactive — *n.*: a sample of radioactive material in which the number and type of radioactive atoms at a given reference time is known; a standard against which radiation measurement equipment can be calibrated

supernate — *n.*: a supernatant liquid or substance; esp., a liquid from which a precipitate has been thrown down; also, supernatant

surveillance — *n.*: a continuous scrutiny or inspection of an area, environment, population, etc.: - esp., a continuous program of detecting, measuring, recording, and evaluating the condition of an area, environment, or population with respect to its content of radioactive material or its exposure to radiation.
adj.: pertaining to surveillance

transfer — *v.*: to convey from one place to another; esp., to remove a measured or known quantity of a sample from one container to another, as with a pipette
n.: the act of making a transfer [see quantitative]

wash — *v.*: to cleanse, purify by immersing in or applying water or other liquid, often accompanied by agitation; - esp., to remove mother liquor from a precipitate by thorough mixing with water or other suitable liquid followed by separation by centrifugation or filtration. Treatment with several small portions of the liquid is much more effective than with one or two larger portions. Solution and reprecipitation is sometimes more effective in purifying than is washing.
n.: the liquid used to cleanse or purify

water, deionized — *n.*: reagent water prepared by passage through mixed-bed ion-exchange resins in the H^+ and OH^- forms

water, demineralized — *n.*: deionized water

water, distilled — *n.*: reagent water prepared by distillation

water, reagent — *n.*: water suitable for use in the analytical laboratory, prepared from tap water by distillation or deionization to contain not more than 5.0 parts per million of dissolved solids and to have an electrical conductivity of not more than 8 micro-mhos per centimeter at 25°C. Reagent water as defined above is suitable for the procedures of this manual; however, high purity reagent water should meet the more stringent American Chemical Society specifications for distilled water.

weightless — *adj.*: having such a small mass that it may be neglected, as for self-absorption corrections. A sample weighing less than 0.1 milligram per square centimeter may be considered weightless in determining its beta activity.

yield — *n.*: the quantity of a product obtained as a result of a reaction or process or series of these expressed as a fraction or percentage of that theoretically obtainable from the quantity of one of the chemical or radioactive components initially present or added [see carrier recovery]

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Raft

From Wikipedia, the free encyclopedia

A **raft** is any flat structure for support or transportation over water.[1] It is the most basic of boat design, characterized by the absence of a hull. Although there are cross-over boat types that blur this definition, rafts are usually kept afloat by using any combination of buoyant materials such as wood, sealed barrels, or inflated air chambers (such as pontoons), and are typically not propelled by an engine.

Traditional raft, from 1884 edition of *Adventures of Huckleberry Finn*.

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Human-made rafts

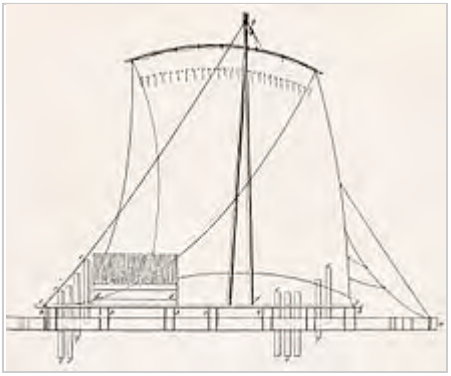

Sketch by F.E. Paris (1841) showing construction of a native Peruvian balsa raft

Traditional or primitive rafts are constructed of wood or reeds. Modern rafts may also use pontoons, drums, or extruded polystyrene blocks . Inflatable rafts use durable, multi-layered rubberized fabrics. Depending on its use and size, it may have a superstructure, masts, or rudders. Timber rafting is used by the logging industry for the transportation of logs, by tying them together into rafts and drifting or pulling them down a river . This method was very common up until the middle of the 20th century but is now used only rarely.

Large rafts made of balsa logs and using sails for navigation were important in maritime trade on the Pacific Ocean coast of South America from pre-Colombian times until the 19th century. Voyages were made to locations as far away as Mexico, and many trans-Pacific voyages using replicas of ancient rafts have been undertaken to demonstrate possible contacts between South America and Polynesia.[2]

The type of raft used for recreational rafting is almost exclusively an inflatable boat, manufactured of flexible materials for use on whitewater.

Natural rafts

Lumber rafts on the Peter I Canal. Early 20th century picture by S. Prokudin-Gorsky

In biology, particularly in island biogeography, non-manmade rafts are an important concept. Such rafts consist of matted clumps of vegetation that has been swept off the dry land by a storm, tsunami, tide, earthquake or similar event; in modern times they sometimes also incorporate other kinds of flotsam and jetsam, e.g. plastic containers. They stay afloat by its natural buoyancy and can travel for hundreds, even thousands of miles and ultimately are destroyed by wave action and decomposition, or make landfall .

Rafting events are important means of oceanic dispersal for non-flying animals. For small mammals, amphibians and reptiles in particular, but for many invertebrates as well, such rafts of vegetation are often the only means by which they could reach and – if they are lucky – colonize oceanic islands before human-built vehicles provided another mode of transport .

Image gallery

Three Arks for a log drive on Pine Creek, in Lycoming or Tioga County, Pennsylvania, USA. The left ark was for cooking and dining, the middle ark was the sleeping quarters and the right ark was for the horses. The arks were built for just one log drive and then sold for their lumber. The line of the Jersey Shore, Pine Creek and Buffalo Railway can be seen on the eastern shore: the mountainside behind it is nearly bare of trees from clearcutting.

Children successfully test their raft, in Brixham Harbour, South Devon, England. The raft is made from wooden poles, rope and blue barrels.

Raft carrying visitors to Tom Sawyer Island at Disneyland, about 1960.

Rafting on the Dunajec River at Pieniny, about 2005-2010.

A modern steamboat and primitive rafts in the Chilean port of Huasco in the 1850s.

See also

- Great Raft
- Kon-Tiki
- L'Égaré II
- La Balsa and Las Balsas
- Lifeboat
- Pre-Columbian rafts
- Pumice raft
- *The Raft of the Medusa*
- Supertramp
- Thor Heyerdahl
- Poon Lim

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1. G. & C. Merriam Co., *Websters New Collegiate Dictionary*, 1976, ISBN 0-87779-339-5
2. Smith, Cameron M. and Haslett, John F. (1999), "Construction and Sailing Characteristics of a Pre-Columbian Raft Replica," *Bulletin of Primitive Technology*, pp. 13-18

External links

- World of Boats (EISCA) Collection ~ Australian Reed Raft (http://www.worldofboats.org/boats/view/98/19/raft)
- World of Boats (EISCA) Collection ~ Brazilian Jangada (http://www.worldofboats.org/boats/view/92/9/raft)
- Homemade Raft Plans and Photos of Rafts (http://www.captainfletch.com/projects/boats/barellraft/barrelraft.asp)
- Neutrino Raft - vessels made from scrap (http://www.floatingneutrinos.com/)

Look up ***raft*** in Wiktionary, the free dictionary.

Wikimedia Commons has media related to ***Rafts***.

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Categories: Boat types | Rafts | Timber rafting

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Rafting

From Wikipedia, the free encyclopedia

Rafting and **white water rafting** are recreational outdoor activities which use an inflatable raft to navigate a river or other body of water. This is often done on whitewater or different degrees of rough water, and generally represents a new and challenging environment for participants. Dealing with risk and the need for teamwork is often a part of the experience.[1] The development of this activity as a leisure sport has become popular since the mid-1970s, evolving from individuals paddling 10 feet (3.0 m) rafts with double-bladed paddles to multi-person rafts propelled by single-bladed paddles and steered by a tour guide at the stern. It is considered an extreme sport, and can be fatal. The International Rafting Federation, often referred to as the IRF, is the worldwide body which oversees all aspects of the sport.[2]

Rafting in Himachal Pradesh, India

Whitewater Rafting along the Cagayan de Oro River, Philippines.

Rafting on the Arkansas River, Colorado, USA

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Classes of white water

Otherwise known as the International Scale of River Difficulty, below are the six grades of difficulty in white water rafting. They range from simple to very dangerous and potential death or serious injuries.

Class 1: Very small rough areas, might require slight maneuvering. (Skill level: Very basic)
Class 2: Some rough water, maybe some rocks, might require some maneuvering. (Skill level: Basic paddling skill)
Class 3: Small waves, maybe a small drop, but no considerable danger. May require significant

maneuvering. (Skill level: Some experience in rafting)
Class 4: Whitewater, medium waves, maybe rocks, maybe a considerable drop, sharp maneuvers may be needed.(Skill level: Exceptional rafting experience)
Class 5: Whitewater, large waves, large volume, possibility of large rocks and hazards, possibility of a large drop, requires precise maneuvering. (Skill level: Full mastery of rafting)
Class 6: Class 6 rapids are considered to be so dangerous that they are effectively unnavigable on a reliably safe basis. Rafters can expect to encounter substantial whitewater, huge waves, huge rocks and hazards, and/or substantial drops that will impart severe impacts beyond the structural capacities and impact ratings of almost all rafting equipment. Traversing a Class 6 rapid has a dramatically increased likelihood of ending in serious injury or death compared to lesser classes. (Skill level: Full mastery of rafting, and even then it may not be safe)

Rafting in Ladakh, India

Rafting on the Pacuare River, Costa Rica.

Techniques

Rafts in white water are very different vehicles than canoes or kayaks and have their own specific techniques to maneuver through whitewater obstacles. Examples of these techniques include.

- **Punching** – Rafts carry great momentum, and on rivers hydraulics that are dodged by canoes and kayaks are often punched by rafts. This involves the rafting crew paddling the raft to give it enough speed to push through the hydraulic without getting stopped.
- **High siding** – If a raft is caught in a hydraulic it will often quickly go sideways. In order to stop the raft flipping on its inside edge, the rafters can climb to the side of the raft furthest downstream, which will also be the side of the raft highest in the air leading to its name. In this position the rafters may be able to use the draw stroke to pull the raft out of the head.
- **Low siding-** more of a professional maneuver sometimes used at LOW water to slide through a channel less than the size of your craft.

Capsizing

- **Dump truck** – Rafts are inherently stable craft because of their size and low center of mass, and often they will shed gear and passengers before they actually capsize. In the industry, if a raft dumps some or all of its passengers but remains upright, it is said to have dump-trucked.
- **Left over right** or **right over left** – Rafts almost always flip side over side. If the left tube rises over the right tube, the raft is said to have flipped left over right and vice versa.
- **Taco** – If a raft is soft, or under-inflated, it may taco, or reverse taco. Rafts are said to have tacoed if the middle of the raft buckles and the front of the raft touches or nearly touches the back of the raft. This is often a result of surfing in a hydraulic. A reverse taco is when the nose or stern of the raft is pulled down under water and buckles to touch the middle, back or nose of the raft.
- **End over end** – Occasionally rafts will flip end over end. This is usually after the raft has dump-trucked to lighten the load, allowing the water to overcome the weight of the boat, flipping it

vertically before it lands upside down. Rafts will more often taco and turn sideways, making an end-over-end flip very rare in most rafts.

- **Downstream flip** – A raft capsizes after encountering an obstacle, such as a rock, a feature like a hydraulic, or even another raft. These objects are usually stationary or possibly surfing in a hydraulic. In this event, the raft becomes unstable and usually flips over downstream or in the direction of travel. A downstream flip may be exacerbated by a heavier load or more people in the raft. People may physically assist in the inertia of the flip by pulling the boat over on top of themselves.
- **Back roller** – A broad reversal such as that formed below a dam or ledge. Rafts can be particularly vulnerable to back rollers, because they can quickly fill a raft and then push it down at the back. If there are snags at the bottom of the river, dumped rafters can be caught and drowned in the aerated and therefore less buoyant water.
- **Dark-siding** - A rafter climbing over a side tube as the raft flips. In swim beer rules, anyone who witnesses one of these owes beer to the "successful dark-sider". He or she may be responsible for any beer owed for the ensuing clean-up, depending on the region.

Re-righting

- **Flip line** – The flip line technique is the most used in commercial rafting where flips are common. The guide will take a loop of webbing that has a biner on it and attach it to the perimeter line on the raft. Standing on top of the upside down raft they will hold the line and lean to the opposite side from where the flip line is attached, re-righting the raft.
- **Knee flipping** – Capsized rafts that are small enough with little or no gear attached can be knee flipped. This involves the rafter holding the webbing on the underside of the raft, and pushing their knees into the outer tube, and then lifting their body out of the water, leaning back to overturn the raft.
- **T rescue** – Somewhat like the kayak technique, some rafts are large enough that they need to be overturned with the assistance of another raft or land. Positioning the upturned raft or land at the side of the raft, the rafters can then re-right the raft by lifting up on the perimeter line.
- **T-grip re-flip** - The T-grip on a rafting paddle may be used to re-flip light rafts by inserting the Tee into the self bailing holes around the floor perimeter and re-righting the boat in the same manner as the flip line technique.

Tricks

- **Pillow ride-** Water will "pillow" as current hits a vertical surface. The craft can be pointed into this type of hydraulic,and with varying degrees of success can be driven smoothly up the vertical surface, smoothly off the side and either into an eddy or into the current. This can be a dangerous maneuver as it can easily flip or dump a raft. This should never be done intentionally on strainers, undercuts, or above sieves. ALWAYS exercise caution, but have fun.
- **Surfing** – Craft often use waves/ hydraulics on rivers to surf. Normally this is done by "eddying out" below a hydraulic and paddling back into the trough of the wave, sometimes boil line or "chunder pile" the opposite is being surfed in which you lose control (any you did really have) and you are along for the ride. These can often be retentive hydraulics, if a swimmer finds one they can be held indefinitely depending on water level or particular hydraulic characteristics.
- **Drop surfing-** instead of paddling back in as above, you take forward momentum into the hydraulic and instead of "T- ing" up to it you hit the hole with an angle and spin upstream to stay

in the hydraulic and start surfing, or begin being surfed. Advanced Maneuver! Always be aware of what is up and downstream before attempting any surfing intentionally.
- **Nose dunks** – Large self-bailing rafts can enter hydraulics called holes from downstream and submerge their nose, or reverse taco. This can be a safe way to get rafters wet in a hydraulic. (see surfing)
- **Pirouette** – A move executed by either a sweep or draw stroke, sending the raft spinning with the current. Often useful for avoiding obstacles.
- **Back Pivot** - Turning the raft from a ferry angle to a bow-downstream position. Used in tight places to recover from an extreme ferry angle, this maneuver narrows the passing space of the boat and allows it to slide closely past obstructions.

Safety

White water rafting can be a dangerous sport, especially if basic safety precautions are not observed. That said, fatalities are rare in both commercial and private rafting.[3] Meta-analyses have calculated fatalities fell between 0.55[4] - 0.86%[5] per 100,000 user days. Studies have shown that injury rates in rafting are relatively low,[6] however may be skewed due to a large number of unreported incidents.[7] Typical rafting injuries include trauma from striking an object, traumatic stress from the interaction of the paddler's positioning and equipment and the force of the water, overuse injuries, and submersion/environmental injuries, non environmental, undisclosed medical conditions (such as heart problems).[3]

Depending on the area, safety regulations covering raft operators may exist in legislation. These range from certification of outfitters, rafts, and raft leaders, to more stringent regulations about equipment and procedures. It is generally advisable to discuss safety measures with a rafting operator before signing on for a trip. The equipment used and the qualifications of the company and raft guides are essential information to be considered.

Like most outdoor sports, rafting in general has become safer over the years. Expertise in the sport has increased, and equipment has become more specialized and improved in quality. As a result, the difficulty rating of most river runs has changed. A classic example would be the Colorado River in the Grand Canyon, which has swallowed whole expeditions in the past, leaving only fragments of boats. In contrast, it is now run safely by commercial outfitters hundreds of times each year with relatively untrained passengers.[8]

Risks in white water rafting stem from both environmental dangers and from improper behavior. Certain features on rivers are inherently unsafe and have remained consistently so despite the passage of time. These would include 'keeper hydraulics', 'strainers' (e.g. fallen trees), dams (especially low-head dams, which tend to produce river-wide keeper hydraulics), undercut rocks, and of course dangerously high waterfalls. Rafting with experienced guides is the safest way to avoid such features. Even in safe areas, however, moving water can always present risks—such as when a swimmer attempts to stand up on a rocky riverbed in strong current, risking foot entrapment. Irresponsible behavior related to rafting while intoxicated has also contributed to many accidents.

To combat the illusion that rafting is akin to an amusement park ride, and to underscore the personal responsibility each rafter faces on a trip, rafting outfitters generally require customers to sign waiver forms indicating understanding and acceptance of potential serious risks. Rafting trips often begin with safety presentations to educate customers about problems that may arise.

White water rafting is often played for the adrenaline rush and this can become a problem for participants' safety. White water rafting accidents have occurred but are not common.

Due to this the overall risk level on a rafting trip with experienced guides using proper precautions is low.[9] Thousands of people safely enjoy raft trips every year.

Environmental issues

Rafting in Montenegro

Like all outdoor activities, rafting must balance its use of nature with the conservation of rivers as a natural resource and habitat. Because of these issues, some rivers now have regulations restricting the annual and daily operating times or numbers of rafters.

Conflicts have arisen when rafting operators, often in co-operation with municipalities and tourism associations, alter the riverbed by dredging and/or blasting in order to eliminate safety hazards or create more interesting whitewater features in the river. Environmentalists argue that this may have negative impacts to riparian and aquatic ecosystems, while proponents claim these measures are usually only temporary, since a riverbed is naturally subject to permanent changes during large floods and other events.

Rafting contributes to the economy of many regions which in turn may contribute to the protection of rivers from hydroelectric power generation, diversion for irrigation, and other development. Additionally, white water rafting trips can promote environmentalism. Commercial rafting companies that employ professional raft guides to lead multi-day trips through the National Wild and Scenic Rivers System have the potential to develop the environmental stewardship and general environmental behaviors of visitors. Studies suggest that environmental efficacy increases when there is an increase in the length of the trip, daily immersion, and the amount of resource interpretation by the guide. Educating visitors has the potential to counteract negative affects of that visitation.[10] By experiencing firsthand the beauty of a river, individuals who would otherwise be indifferent to environmental issues may gain a strong desire to protect and preserve that area because of their positive outdoor experience.

See also

- Packraft
- Liloing
- Paddling
- Raft Guide
- Swiftwater rescue

- Tubing
- Whitewater canoeing
- Whitewater

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External links

- International Rafting Federation (http://www.intraftfed.com/)
- United States Rafting Association (http://www.usaraftassociation.com/)

Wikimedia Commons has media related to ***Rafting***.

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Categories: Rafting | Whitewater sports

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Kon-Tiki (Scouting)

From Wikipedia, the free encyclopedia

Kon-Tiki refers to one of the three annual raft-building competitions, held in South Africa (Cape Town and Gauteng by Scouts South Africa) and Australia (by Scouts Australia).

Rafts on Sandvlei during the Kon-Tiki Adventure for Scouts and Guides at Lakeside, Cape Town in 2006

Named after Thor Heyerdahl's Kon-Tiki expedition of 1947, teams compete to build and live on a raft for a weekend. Support crew or "Land-Crew" teams compete in other, ground-based competitions. The first KonTiki was held in 1985 at Murray Park in Springs

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Cape Town event

The Cape Town competition is held at the Sea Scout Base on the banks of Zandvlei. The weekend starts on the Friday afternoon with teams arriving and starting construction of the raft. The building criteria are very strict and judging takes place continuously until the raft launch on the Saturday at 2 pm. Much of the judging is related to the aspect of safety to ensure that the Scouts and Guides (ages 11 to 17) have a safe adventure.

Gauteng event

The Gauteng competition is held at Arrowe Park in Benoni, Gauteng (previous events held at Murray Park, Springs). The competition is run in a very similar fashion to the Cape Town one, with the exception that the rafts launch at 11h00 on the Saturday morning. There are also numerous other activities and competitions for the support crew to partake in, such as the *Beaver Challenge*, *Spare Time Activities*, *Dress-up competition* and others. The 2015 theme was "Here be Dragons".

Australian event

In 2012, Scouts Australia (SA Branch) ran the first Kon-tiki Raft Challenge outside South Africa. The competition is based on that of the South Africans.

See also

- Scouts South Africa
- Girl Guides Association of South Africa
- Scouts Australia

External links

- Cape Western Area Kon-Tiki site (http://www.kontiki.za.org/)
- Gauteng Area Kon-Tiki site (http://www.kontiki.scouting.org.za/)

Retrieved from "https://en.wikipedia.org/w/index.php?title=Kon-Tiki_(Scouting)&oldid=740653228"

Categories: Scouting events | Scouting stubs

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Rain garden

From Wikipedia, the free encyclopedia

A **rain garden** is a planted depression or a hole that allows rainwater runoff from impervious urban areas, like roofs, driveways, walkways, parking lots, and compacted lawn areas, the opportunity to be absorbed. This reduces rain runoff by allowing stormwater to soak into the ground (as opposed to flowing into storm drains and surface waters which causes erosion, water pollution, flooding, and diminished groundwater).[1] They should be designed for specific soils and climates.[2] The purpose of a rain garden is to improve water quality in nearby bodies of water and to ensure that rainwater becomes available for plants as groundwater rather than being sent through stormwater drains straight out to sea. Rain gardens can cut down on the amount of pollution reaching creeks and streams by up to 30%.[3]

Business parking lot that drains to a rain garden. The curb retains the asphalt pavement, yet lets water flow off the edges.

Native and adapted plants are recommended for rain gardens because they are more tolerant of one's local climate, soil, and water conditions; have deep and variable root systems for enhanced water infiltration and drought tolerance; habitat value and diversity for local ecological communities; and overall sustainability once established. There can be trade-offs associated with using native plants, including lack of availability for some species, late spring emergence, short blooming season, and relatively slow establishment. The plants — a selection of wetland edge vegetation, such as wildflowers, sedges, rushes, ferns, shrubs and small trees — take up excess water flowing into the rain garden. Water filters through soil layers before entering the groundwater system. Root systems enhance infiltration, maintain or even augment soil permeability, provide moisture redistribution, and sustain diverse microbial populations involved in biofiltration.[4] Also, through the process of transpiration, rain garden plants return water vapor to the atmosphere.[5] A more wide-ranging definition covers all the possible elements that can be used to capture, channel, divert, and make the most of the natural rain and snow that falls on a property. The whole garden can become a rain garden, and each component of the whole can become a small-scale rain garden in itself.

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Restoring the water cycle and mitigating urbanization

In developed areas, natural depressions where storm water would pool, are filled in. The surface of the ground is often leveled or paved. Storm water is directed into storm drains which often may cause overflows of combined sewer systems or poisoning, erosion or flooding of waterways receiving the storm water runoff.[6][7][8] Redirected storm water is often warmer than the groundwater normally feeding a stream, and has been linked to upset in some aquatic ecosystems primarily through the reduction of dissolved oxygen (DO). Storm water runoff is also a source of a wide variety of pollutants washed off hard or compacted surfaces during rain events. These pollutants include volatile organic compounds, pesticides, herbicides, hydrocarbons and trace metals[9] Rain gardens are designed to capture the initial flow of storm water and reduce the accumulation of toxins flowing directly into natural waterways through ground filtration. They also reduce energy consumption. For example, “the cumulative storage capacity of these rain gardens exceeds a conventional stormwater’s system’s by 10 times.”[10] The National Science Foundation, the United States Environmental Protection Agency, and a number of research institutions are presently studying the impact of augmenting rain gardens with materials capable of capture or chemical reduction of the pollutants to benign compounds.

Rain garden, SUNY College of Environmental Science and Forestry, Syracuse, New York

Rain gardens are often located near a building’s roof drainpipe (with or without rainwater tanks). Most rain gardens are designed to be an endpoint of drainage with a capacity to percolate all incoming water through a series of soil or gravel layers beneath the surface plantings. A French drain may be used to direct a portion of the rainwater to an overflow location for heavier rain events. By reducing peak stormwater discharge, rain gardens extend hydraulic lag time and somewhat mimic the natural water cycle displaced by urban development and allow for groundwater recharge. While rain gardens always allow for restored groundwater recharge, and reduced stormwater volumes, they may also increase pollution unless remediation materials are included in the design of the filtration layers .[11]

The primary challenge of rain garden design centers on calculating the types of pollutants and the acceptable loads of pollutants the rain garden's filtration system can handle during storm-water events. This challenge is specifically acute when a rain event occurs after a longer dry period. The initial storm water is often highly contaminated with the accumulated pollutants from dry periods. Rain garden designers have previously focused on finding robust native plants and encouraging adequate biofiltration, but recently have begun augmenting filtration layers with media specifically suited to chemically reduce redox of incoming pollutant streams.

Rain gardens are beneficial for many reasons: improve water quality by filtering runoff, provide localized flood control, are aesthetically pleasing, and provide interesting planting opportunities. They also encourage wildlife and biodiversity, tie together buildings and their surrounding environments in attractive and environmentally advantageous ways, and provide significant partial solutions to important environmental problems that affect us all.

A rain garden provides a way to use and optimize any rain that falls, reducing or avoiding the need for irrigation. They allow a household or building to deal with excessive rainwater runoff without burdening the public storm water systems. Rain gardens differ from retention basins, in that the water will infiltrate the ground within a day or two. This creates the advantage that the rain garden does not allow mosquitoes to breed. Compost, rather than soil, has better effects on filtering groundwater and rainwater. Compact lawn soil /cannot harbor groundwater nearly as well, because the water simply flows off.

History

The first rain gardens were created to mimic the natural water retention areas that occurred naturally before development of an area. The rain gardens for residential use were developed in 1990 in Prince George's County, Maryland, when Dick Brinker, a developer building a new housing subdivision had the idea to replace the traditional best management practices (BMP) pond with a bioretention area. He approached Larry Coffman, the county's Associate Director for Programs and Planning in the Department of Environmental Resources, with the idea.[12] The result was the extensive use of rain gardens in Somerset, a residential subdivision which has a 300–400 sq ft (28–37 m^2) rain garden on each house's property.[13] This system proved to be highly cost-effective. Instead of a system of curbs, sidewalks, and gutters, which would have cost nearly $400,000, the planted drainage swales cost $100,000 to install.[12] This was also much more cost effective than building BMP ponds that could handle 2-, 10-, and 100-year storm events.[12] Flow monitoring done in later years showed that the rain gardens have resulted in a 75–80% reduction in stormwater runoff during a regular rainfall event.[13]

This is also referred to as Water Sensitive Urban Design (WSUD) in Australia, Sustainable Urban Drainage Systems or SUDS in the United Kingdom, and low impact development (LID) in the United States, and is cited by the U.S. Environmental Protection Agency (EPA).[14]

Some *de facto* rain gardens predate their recognition by professionals as a significant LID tool. Any shallow garden depression implemented to capture and retain rain water within the garden so as to drain adjacent land without running off a property is at conception a rain garden — particularly if vegetation is maintained with recognition of its role in this function. Vegetated roadside swales, now promoted as "bioswales", remain the conventional drainage system in many parts of the world from long before extensive networks of concrete sewers became the conventional engineering practice in the industrialized world.

What is new about such technology is the emerging rigor of increasingly quantitative understanding of how such tools may make sustainable development possible. This is as true for wealthy developed communities retrofitting bioretention into built stormwater management systems, as for developing communities seeking a faster and more sustainable development path.

Characteristics

A rain garden requires an area where water can collect and infiltrate, and plants to maintain infiltration rates, diverse microbe communities, and water holding capacity. Transpiration by growing plants accelerates soil drying between storms. This includes any plant extending roots to the garden area.

Simply adjusting the landscape so that downspouts and paved surfaces drain into existing gardens may be all that is needed because the soil has been well loosened and plants are well established. However, many plants do not tolerate saturated roots for long and often more water runs off one's roof than people realize. Often the required location and storage capacity of the garden area must be determined first. Rain garden plants are then

selected to match the situation, not the other way around.

A home rain garden recently planted

Soil and drainage

When an area's soils are not permeable enough to allow water to drain and filter properly, the soil should be replaced and an underdrain installed. This bioretention mixture should typically contain 60% sand, 20% compost, and 20% topsoil, and there is a current trend to replace compost with biochar. Existing soil must be removed and replaced. Do not combine the sandy soil (bioretention) mixture with a surrounding soil that does not have high sand content. Otherwise, the clay particles will settle in between the sand particles and form a concrete-like substance, as demonstrated in a 1983 study.[15] Deep plant roots also create additional channels for storm water to filter into the ground. Microbial populations feed off plant root secretions and break down carbon (such as in mulch or desiccated plant roots) to aggregate soil particles which increases infiltration rates. A five-year study by the U.S. Geological Survey indicates that rain gardens in urban clay soils can be effective without the use of underdrains or replacement of native soils with the bioretention mix. Pre-installation infiltration rates should be at least .25 in/hour, however. Type D soils will require an underdrain paired with the sandy soil mix in order to drain properly.[16]

Sometimes a drywell with a series of gravel layers near the lowest spot in the rain garden will help facilitate percolation. However, a drywell placed at the lowest spot can become clogged with silt prematurely turning the garden into an infiltration basin defeating its purpose. Depression-focused recharge of polluted water into wells poses a serious threat and should be avoided. Similarly plans to install a rain garden near a septic system should be reviewed by a qualified engineer. The more polluted the water, the longer it must be retained in the soil for purification. This is often achieved by installing several smaller rain garden basins with soil deeper than the seasonal high water table. In some cases lined bioretention cells with subsurface drainage are used to retain smaller amounts of water and filter larger amounts without letting water percolate as quickly.

Rain gardens are at times confused with bioswales. Swales slope to a destination, while rain gardens do not; however, a bioswale may end with a rain garden. Drainage ditches may be handled like bioswales and even include rain gardens in series, saving time and money on maintenance. Part of a garden that nearly always has standing water is a water garden, wetland, or pond, and not a rain garden. Using the proper terminology ensures that the proper methods are used to achieve the desired results.

Plant selection

Plants selected for use in a rain garden should tolerate both saturated and dry soil. Using native plants is generally encouraged. This way the rain garden may contribute to urban habitats for native butterflies, birds, and beneficial insects.

Well planned plantings require minimal maintenance to survive, and are compatible with adjacent land use. Trees under power lines, or that up-heave sidewalks when soils become moist, or whose roots seek out and clog drainage tiles can cause expensive damage.

Trees generally contribute most when located close enough to tap moisture in the rain garden depression, yet do not excessively shade the garden. That said, shading open surface waters can reduce excessive heating of habitat. Plants tolerate inundation by warm water for less time because heat drives out dissolved oxygen, thus a plant tolerant of early spring flooding may not survive summer inundation.

Another plant that works particularly well is bamboo. It has been tested, and it can clean water 27.6% better than domestic plants like grass or clovers. Rice, although it is hard to grow and maintain, works even better.

Rain garden projects

Australia

- Healthy Waterways Raingardens Program promotes a simple and effective form of stormwater treatment, and aims to raise peoples' awareness about how good stormwater management contributes to healthy waterways. The program encourages people to build rain gardens at home, and has achieved its target is to see 10,000 rain gardens built across Melbourne by 2013.[17]
- Melbourne Water's database of Water Sensitive Urban Design projects, including 57 case studies relating to rain gardens/bioretention systems. Melbourne Water is the Victorian State Government agency responsible for managing Melbourne's water supply catchments.[18]
- Water By Design is a capacity building program that supports the uptake of Water Sensitive Urban Design, including rain gardens, in South East Queensland. It was established by the South East Queensland Healthy Waterways Partnership in 2005, as an integral component of the SEQ Healthy Waterways Strategy.[19]

United Kingdom

- The Wildfowl and Wetlands Trust's London Wetland Centre includes a rain garden designed by Nigel Dunnett.[20]
- Islington London Borough Council commissioned sustainable drainage consultants Robert Bray Associates to design a pilot rain garden in the Ashby Grove development which was completed in 2011. This raingarden is fed from a typical modest domestic roof catchment area of 30m² and is designed to demonstrate how simple and cost effective domestic rain gardens are to install. Monitoring apparatus was built into the design to allow Middlesex University to monitor water volumes, water quality and soil moisture content. The rain garden basin is 300mm deep and has a storage capacity of 2.17m³ which is just over the volume required to store runoff from the roof catchment in a 1 in 100 storm plus 30% allowance for climate change.[21][22]
- The Day Brook Rain Garden Project has introduced a number of rain gardens into an existing residential street in Sherwood, Nottingham[23]

United States of America

- The 12,000 rain garden campaign for Puget Sound is coordinating efforts to build 12,000 rain gardens in the Puget Sound Basin of Western Washington by 2016. The 12,000 rain gardens website provides information and resources for the general public, landscape professionals, municipal staff, and decision makers. By providing access to the best current guidance, easy-to-use materials, and a network of trained "Rain Garden Mentor" Master Gardeners, this campaign seeks to capture and cleanse over 200 Million gallons of polluted runoff each year, and thereby significantly improve Puget Sound's water quality.[24]
- Maplewood, Minnesota has implemented a policy of encouraging residents to install rain gardens. Many neighborhoods had swales added to each property, but installation of a garden at the swale was voluntary. The project was a partnership between the City of Maplewood, University of Minnesota Department of Landscape Architecture, and the Ramsey Washington Metro Watershed District. A focus group was held

with residents and published so that other communities could use it as a resource when planning their own rain garden projects.

- In Seattle, a prototype project, used to develop a plan for the entire city, was constructed in 2003. Called *SEA Street*, for Street Edge Alternatives, it was a drastic facelift of a residential street. The street was changed from a typical linear path to a gentle curve, narrowed, with large rain gardens placed along most of the length of the street. The street has 11% less impervious surface than a regular street. There are 100 evergreen trees and 1100 shrubs along this 3-block stretch of road, and a 2-year study found that the amount of stormwater which leaves the street has been reduced by 99%.[25]
- 10,000 Rain Gardens is a public initiative in the Kansas City, Missouri metro area. Property owners are encouraged to create rain gardens, with an eventual goal of 10,000 individual gardens.
- The West Michigan Environmental Action Council has established Rain Gardens of West Michigan as an outreach water quality program.[26] Also in Michigan, the Southeastern Oakland County Water Authority has published a pamphlet to encourage residents to add a rain garden to their landscapes in order to improve the water quality in the Rouge River watershed.[27] In Washtenaw County, homeowners can volunteer for the Water Resources Commissioner's Rain Garden program, in which volunteers are annually selected for free professional landscape design. The homeowners build the gardens themselves as well as pay for landscaping material. Photos of the gardens as well as design documents and drainage calculations are available online.[28] The Washtenaw County Water Resource Commisioner's office also offers yearly in person and online Master Rain Gardener classes to help guide those interested in the rain garden design, building, and upkeep process.[29]
- The city of Portland, Oregon, has established a Clean River Rewards program, to encourage residents to disconnect downspouts from the city's combined sewer system and create rain gardens. Workshops, discounts on storm water bills, and web resources are offered.[30]
- In Delaware, several rain gardens have been created through the work of the University of Delaware Water Resources Agency, and environmental organizations, such as the Appoquinimink River Association.[31]
- In New Jersey, the Rutgers Cooperative Extension Water Resources Program has already installed over 125 demonstration rain gardens in suburban and urban areas. The Water Resources Program has begun to focus on using rain gardens as green infrastructure in urban areas, such as Camden and Newark to help prevent localized flooding, combined sewer overflows, and to improve water quality. The Water Resources Program has also revised and produced a rain garden manual in collaboration with The Native Plant Society of New Jersey.[32]

See also

- Climate-friendly gardening
- Constructed wetland
- Ecohydrology
- Green roof
- Microclimate
- Runoff footprint
- Urban runoff
- Water-energy nexus

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- UK Rain Garden Guide (http://raingardens.info/)

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Rain gutter

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A **rain gutter** or **surface water collection channel** is a component of water discharge system for a building. [1] An *eaves gutter* is also known as an *eavestrough* (especially in Canada), *eaves channel*, *dripster*, *guttering* or simply as a *gutter*.[2] The word *gutter* derives from from Latin *gutta*(noun), meaning "a drop, spot or mark".[3]

Lead guttering: slate and pitched valley gutter flow into parapet gutter, with downpipe and overflow

Eaves gutter and downpipe

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Description

Gutters prevent water ingress into the fabric of the building by channelling the rainwater away from the exterior of the walls and their foundations. Water running down the walls causes dampness in the affected rooms and provides a favourable environment for growth of mould, and wet rot in timber. [4]

A rain gutter may be a:

- Roof integral trough along the lower edge of the roof slope which is fashioned from the roof covering and flashing materials.
- Discrete trough of metal, or other material that is suspended beyond the roof edge and below the projected slope of the roof.
- Wall integral structure beneath the roof edge, traditionally constructed of masonry, fashioned as the crowning element of a wall.[5]

A roof must be designed with a suitable fall to allow the rainwater to discharge. The water drains into a gutter that is fed into a downpipe. A flat roof will have a watertight surface with a fall of 1 in 60, or 1 in the case of lead. They can drain internally or to a eaves gutter, which has a minimum 1 in 360 fall towards the downpipe. [6] The pitch of a pitched roof is determined by the construction material of the covering. For slate this will be at 25%, for machine made tiles it will be 35%. Water falls towards a *parapet gutter*, a *valley gutter* or an *eaves gutter*. [7] When two pitched roofs meet at an angle, they also form a *pitched valley gutter*: the join is sealed

with valley flashing. Parapet gutters and valley gutters discharge into internal rainwater pipes or directly into external down pipes at the end of the run. [7]

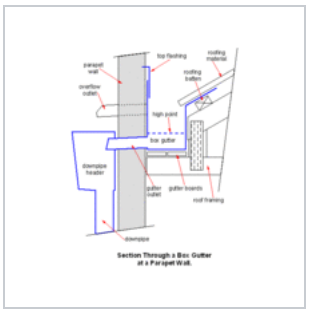

A parapet gutter at the base of a sloping roof and a parapet wall, outflowing to a downpipe

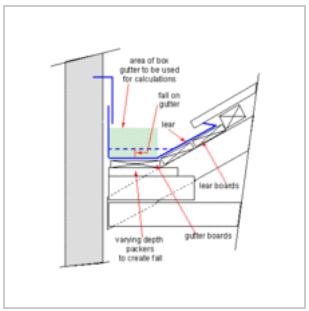

A simpler parapet gutter.

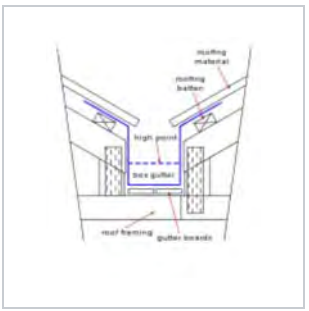

A valley gutter between two parallel roof surfaces.

Eaves gutters can be made from a variety of materials such as cast iron, lead, zinc, galvanised steel, painted steel, copper, painted aluminium, PVC (and other plastics) and occasionally from concrete, stone, and wood.[8]

Water collected by a rain gutter is fed, usually via a downpipe (also called a leader or conductor),[9] from the roof edge to the base of the building where it is either discharged or collected.[10] The down pipe can terminate in a shoe and discharge directly onto the surface, but using modern construction techniques would be connected through an inspection chamber to a drain that led to a surface water drain or soakaway. Altenatively it would connect via a gulley (u-bend) with 50mm water seal to a combined drain.[11] Water from rain gutters may be harvested in a rain barrel or a cistern.[12]

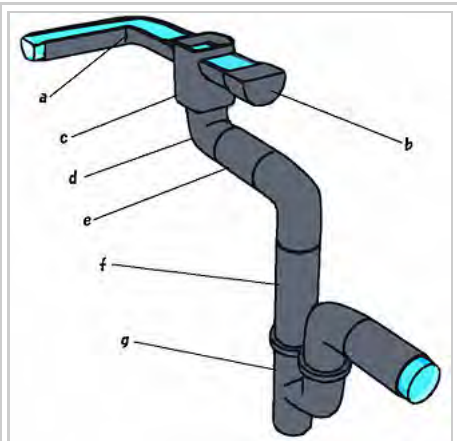

a: Rainwater gutter
b: Endcap
c: Hopper
d: 112° bend
f: Downpipe
g: Manifold

Rain gutters can be equipped with gutter screens, micro mesh screens, louvers or solid hoods to allow water from the roof to flow through, while reducing passage of roof debris into the gutter.[13]

Clogged gutters can also cause water ingress into the building as the water backs up. Clogged gutters can also lead to stagnant water build up which in some climates allows mosquitoes to breed. [14]

History

The Romans brought rainwater systems to Britain, the technology was subsequenty lost, but was re-introduced by the Normans. The White Tower, at the Tower of London had external gutters.[15] In March 1240 the Keeper of the Works at the Tower of London was ordered by King Henry "to have the Great Tower whitened both inside and out". This was according to the fashion at the time. Later that year the king wrote to the Keeper, commanding that the White Tower's lead guttering should be extended with the effect that "the wall of the tower ... newly whitened, may be in no danger of perishing or falling outwards through the trickling of the

rain".[16]

In Saxon times, the thanes erected buildings with large overhanging roofs to throw the water clear of the walls in the same way that occurs in thatched cottages. The cathedral builder used lead parapet gutters, with elaborate gargoyles for the same purpose. With the dissolution of the monasteries- those buildings were recycled and there was plenty of lead that could be used for secular building. The yeoman would use wooden gutters or lead lined wooden gutters. [15]

When The Crystal Palace was designed in 1851 by Joseph Paxton with its innovative ridge-and-furrow roof, the rafters than spanned the space between the roof girders of the glass roof also served as the gutters. The wooden Paxton gutters had a deep semi-circular channel to remove the rainwater and grooves at the side to handle the condensation. They were under trussed with an iron plate and had preformed notches for the glazing bars: they drained into a wooden box gutter that drained into and through structural cast iron columns.[17]

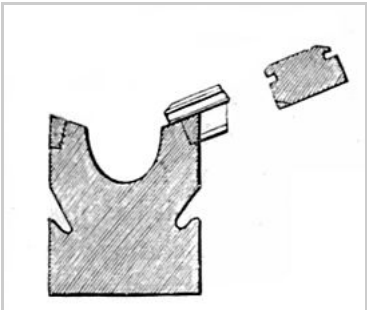

Cross section of a Paxton gutter with glazing bar

The industrial revolution introduced new methods of casting-iron and the railways brought a method of distributing the heavy cast-iron item to building sites. The relocation into the cities created a demand for housing that needed to be compact. Dryer houses controlled asthma, bronchitis, emphysema as well as pneumonia. In 1849 Joseph Bazalgette proposed a sewerage system for London, that prevented run-off being channelled into the Thames. By the 1870s all houses were constructed with cast iron gutters and down pipes.[15] The Victorian gutter was an ogee, 115mm in width, that was fitted directly to the fascia boards eliminating the need for brackets.[18]

Types

Cast iron

Cast iron gutters were introduced in the late 18th century as an alternative to lead. Cast iron enabled eaves gutters to be mass produced: they were rigid and non-porous while lead could only be used as a liner within timber gutters. Installation was a single process and didn't require heat. [19] They could be attached directly to the fascia board. Cast iron gutters are still specified for restoration work in conservation areas, but are usually replaced with extruded aluminium made to the same profile.[18]

UPVC

In UK domestic architecture, guttering is made from UPVC sections. The first PVC pipes were introduced in the 1930’s for use in sanitary drainage systems. Polyethylene was developed in 1933. The first pressurised plastic drinking water pipes were installed in the Netherlands in the 1950s During the 1960’s rain water pipes, guttering and down pipes using plastic materials were introduced followed by PVC soil systems which became viable with the introduction of ring seals. A British Standard was launched for soil systems, local authorities started to specify PVC systems. By 1970 plastic rainwater systems accounted for over 60% of new installations.[20] A European Standard EN607 has existed since 2004.[21]

A collector with 112mm gutter, draining into 68mm downpipe

Available gutter fittings

Available pipe and gutter fittings

Fitting a gutter to a 45° connector

Zinc

In UK commercial and European commercial and domestic architecture, guttering is made from zinc. Metal gutters with bead stiffened fronts is governed in the UK by BS EN612:2005.[22]

Vernacular buildings

Guttering can be made from any locally available material such as stone or wood. Porous materials may be lined with pitch or bitumen.

Wooden gutter at an open air museum

Wood used on a stone building

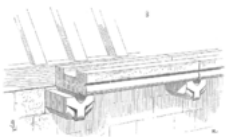

Stone gutter in Burgundy

Stone gutters in Slovenia

Finlock gutters

Finlock gutters, also known as concrete gutters, can be employed on a large range of building.[23] There were used on domestic properties in the 1950s and 1960s, as a replacement for cast iron gutters when there was a shortage of steel and surplus of concrete. They were fitted with a aluminium and bitumastic liner.Finlock concrete gutter units are made up of two troughs – one is the visible gutter and the other sits across the cavity wall.The blocks which can range from 8 to 12 inches (200 to 300 mm) can be joined using reinforcing rods and concrete, to form lintels for doors and windows.[24]

See also

- Chantlate
- Copper in architecture
- Cornice
- Gargoyle
- Rain chain

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External links

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- An Illustrated glossary of roofs and roofing terms. (https://web.archive.org/web/20121017003751/http:

Wikimedia Commons has media related to ***Rain***

//www.builderbill-diy-help.com/roof-glossary.html)

gutters.

- Tutorial on installing plastic guttering (https://www.youtube.com/watch?v=L_jLdNJxxoM)
- Tutorial on installing metal sheet guttering (https://www.youtube.com/watch?v=Oo_GXULZl8I)

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Categories: Roofs | Architectural elements | Stormwater management | Rain

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Rain

From Wikipedia, the free encyclopedia

Rain is liquid water in the form of droplets that have condensed from atmospheric water vapor and then precipitated—that is, become heavy enough to fall under gravity. Rain is a major component of the water cycle and is responsible for depositing most of the fresh water on the Earth. It provides suitable conditions for many types of ecosystems, as well as water for hydroelectric power plants and crop irrigation.

Falling rain

Rain

0:00 MENU

typical sound of rain with thunder

Problems playing this file? See media help.

The major cause of rain production is moisture moving along three-dimensional zones of temperature and moisture contrasts known as weather fronts. If enough moisture and upward motion is present, precipitation falls from convective clouds (those with strong upward vertical motion) such as cumulonimbus (thunder clouds) which can organize into narrow rainbands. In mountainous areas, heavy precipitation is possible where upslope flow is maximized within windward sides of the terrain at elevation which forces moist air to condense and fall out as rainfall along the sides of mountains. On the leeward side of mountains, desert climates can exist due to the dry air caused by downslope flow which causes heating and drying of the air mass. The movement of the monsoon trough, or intertropical convergence zone, brings rainy seasons to savannah climes.

The urban heat island effect leads to increased rainfall, both in amounts and intensity, downwind of cities. Global warming is also causing changes in the precipitation pattern globally, including wetter conditions across eastern North America and drier conditions in the tropics. Antarctica is the driest continent. The globally averaged annual precipitation over land is 715 mm (28.1 in), but over the whole Earth it is much higher at 990 mm (39 in).[1] Climate classification systems such as the Köppen climate classification system use average annual rainfall to help differentiate between differing climate regimes. Rainfall is measured using rain gauges. Rainfall amounts can be estimated by weather radar.

Rain is also known or suspected on other planets, where it may be composed of methane, neon, sulfuric acid, or even iron rather than water.

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Formation

Water-saturated air

Air contains water vapor, and the amount of water in a given mass of dry air, known as the *mixing ratio*, is measured in grams of water per kilogram of dry air (g/kg).[2][3] The amount of moisture in air is also commonly reported as relative humidity; which is the percentage of the total water vapor air can hold at a particular air temperature.[4] How much water vapor a parcel of air can contain before it becomes saturated (100% relative humidity) and forms into a cloud (a group of visible and tiny water and ice particles suspended above the Earth's surface)[5] depends on its temperature. Warmer air can contain more water vapor than cooler

air before becoming saturated. Therefore, one way to saturate a parcel of air is to cool it. The dew point is the temperature to which a parcel must be cooled in order to become saturated.[6]

There are four main mechanisms for cooling the air to its dew point: adiabatic cooling, conductive cooling, radiational cooling, and evaporative cooling. Adiabatic cooling occurs when air rises and expands.[7] The air can rise due to convection, large-scale atmospheric motions, or a physical barrier such as a mountain (orographic lift). Conductive cooling occurs when the air comes into contact with a colder surface,[8] usually by being blown from one surface to another, for example from a liquid water surface to colder land. Radiational cooling occurs due to the emission of infrared radiation, either by the air or by the surface underneath.[9] Evaporative cooling occurs when moisture is added to the air through evaporation, which forces the air temperature to cool to its wet-bulb temperature, or until it reaches saturation.[10]

The main ways water vapor is added to the air are: wind convergence into areas of upward motion,[11] precipitation or virga falling from above,[12] daytime heating evaporating water from the surface of oceans, water bodies or wet land,[13] transpiration from plants,[14] cool or dry air moving over warmer water,[15] and lifting air over mountains.[16] Water vapor normally begins to condense on condensation nuclei such as dust, ice, and salt in order to form clouds. Elevated portions of weather fronts (which are three-dimensional in nature)[17] force broad areas of upward motion within the Earth's atmosphere which form clouds decks such as altostratus or cirrostratus.[18] Stratus is a stable cloud deck which tends to form when a cool, stable air mass is trapped underneath a warm air mass. It can also form due to the lifting of advection fog during breezy conditions.[19]

Coalescence and fragmentation

Coalescence occurs when water droplets fuse to create larger water droplets. Air resistance typically causes the water droplets in a cloud to remain stationary. When air turbulence occurs, water droplets collide, producing larger droplets. As these larger water droplets descend, coalescence continues, so that drops become heavy enough to overcome air resistance and fall as rain. Coalescence generally happens most often in clouds above freezing, and is also known as the warm rain process.[20] In clouds below freezing, when ice crystals gain enough mass they begin to fall. This generally requires more mass than coalescence when occurring between the crystal and neighboring water droplets. This process is temperature dependent, as supercooled water droplets only exist in a cloud that is below freezing. In addition, because of the great temperature difference between cloud and ground level, these ice crystals may melt as they fall and become rain.[21]

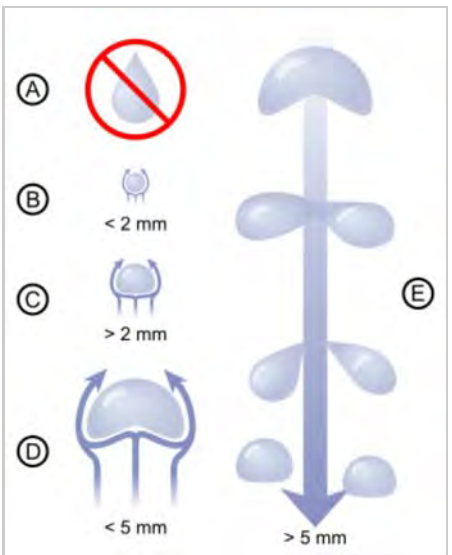

The shape of rain drops depending upon their size

Raindrops have sizes ranging from 0.1 to 9 mm (0.0039 to 0.3543 in) mean diameter, above which they tend to break up. Smaller drops are called cloud droplets, and their shape is spherical. As a raindrop increases in size, its shape becomes more oblate, with its largest cross-section facing the oncoming airflow. Large rain drops become increasingly flattened on the bottom, like hamburger buns; very large ones are shaped like parachutes.[22][23] Contrary to popular belief, their shape does not resemble a teardrop.[24] The biggest raindrops on Earth were recorded over Brazil and the Marshall Islands in 2004 — some of them were as large as 10 mm (0.39 in). The large size is explained by condensation on

large smoke particles or by collisions between drops in small regions with particularly high content of liquid water.[25]

Rain drops associated with melting hail tend to be larger than other rain drops.[26]

Intensity and duration of rainfall are usually inversely related, i.e., high intensity storms are likely to be of short duration and low intensity storms can have a long duration.[27][28]

A raindrop on a leaf

Droplet size distribution

The final droplet size distribution is an exponential distribution. The number of droplets with diameter between d and $D + dD$ per unit volume of space is $n(d) = n_0 e^{-d/\langle d \rangle} dD$. This is commonly referred to as the Marshall–Palmer law after the researchers who first characterized it.[23][29] The parameters are somewhat temperature-dependent,[30] and the slope also scales with the rate of rainfall $\langle d \rangle^{-1} = 41 R^{-0.21}$ (d in centimeters and R in millimetres per hour).[23]

Deviations can occur for small droplets and during different rainfall conditions. The distribution tends to fit averaged rainfall, while instantaneous size spectra often deviate and have been modeled as gamma distributions.[31] The distribution has an upper limit due to droplet fragmentation.[23]

Raindrop impacts

Raindrops impact at their terminal velocity, which is greater for larger drops due to their larger mass to drag ratio. At sea level and without wind, 0.5 mm (0.020 in) drizzle impacts at 2 m/s (6.6 ft/s) or 7.2 km/h (4.5 mph), while large 5 mm (0.20 in) drops impact at around 9 m/s (30 ft/s) or 32 km/h (20 mph).[32]

Rain falling on loosely packed material such as newly fallen ash can produce dimples that can be fossilized.[33] The air density dependence of the maximum raindrop diameter together with fossil raindrop imprints has been used to constrain the density of the air 2.7 billion years ago.[34]

The sound of raindrops hitting water is caused by bubbles of air oscillating underwater.[35][36]

The METAR code for rain is RA, while the coding for rain showers is SHRA.[37]

Virga

In certain conditions precipitation may fall from a cloud but then evaporates or sublimes before reaching the ground. This is termed virga and is more often seen in hot and dry climates.

Causes

Frontal activity

Stratiform (a broad shield of precipitation with a relatively similar intensity) and dynamic precipitation (convective precipitation which is showery in nature with large changes in intensity over short distances) occur as a consequence of slow ascent of air in synoptic systems (on the order of cm/s), such as in the vicinity of cold fronts and near and poleward of surface warm fronts. Similar ascent is seen around tropical cyclones outside of the eyewall, and in comma-head precipitation patterns around mid-latitude cyclones.[38] A wide variety of weather can be found along an occluded front, with thunderstorms possible, but usually their passage is associated with a drying of the air mass. Occluded fronts usually form around mature low-pressure areas.[39] What separates rainfall from other precipitation types, such as ice pellets and snow, is the presence of a thick layer of air aloft which is above the melting point of water, which melts the frozen precipitation well before it reaches the ground. If there is a shallow near surface layer that is below freezing, freezing rain (rain which freezes on contact with surfaces in subfreezing environments) will result.[40] Hail becomes an increasingly infrequent occurrence when the freezing level within the atmosphere exceeds 3,400 m (11,000 ft) above ground level.[41]

Convection

Convective rain, or showery precipitation, occurs from convective clouds (e.g., cumulonimbus or cumulus congestus). It falls as showers with rapidly changing intensity. Convective precipitation falls over a certain area for a relatively short time, as convective clouds have limited horizontal extent. Most precipitation in the tropics appears to be convective; however, it has been suggested that stratiform precipitation also occurs.[38][42] Graupel and hail indicate convection.[43] In mid-latitudes, convective precipitation is intermittent and often associated with baroclinic boundaries such as cold fronts, squall lines, and warm fronts.[44]

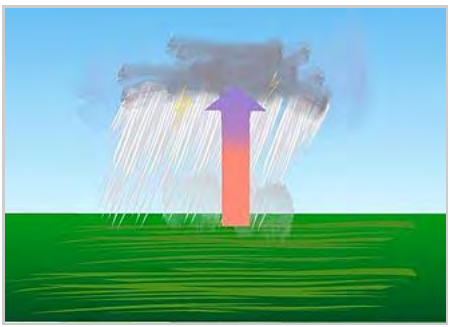

Convective precipitation

Orographic effects

Orographic precipitation occurs on the windward side of mountains and is caused by the rising air motion of a large-scale flow of moist air across the mountain ridge, resulting in adiabatic cooling and condensation. In mountainous parts of the world subjected to relatively consistent winds (for example, the trade winds), a more moist climate usually prevails on the windward side of a mountain than on the leeward or downwind side. Moisture is removed by orographic lift, leaving drier air (see katabatic wind) on the descending and generally warming, leeward side where a rain shadow is observed.[16]

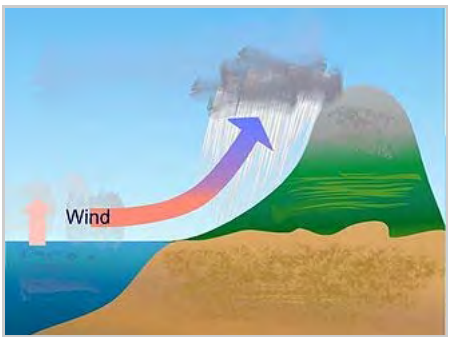

Orographic precipitation

In Hawaii, Mount Waiʻaleʻale, on the island of Kauai, is notable for its extreme rainfall, as it has the second highest average annual rainfall on Earth, with 12,000 mm (460 in).[45] Systems known as Kona storms affect the state with heavy rains between October and April.[46] Local climates vary considerably on each island due to their topography, divisible into windward (*Koʻolau*) and leeward (*Kona*) regions based upon location relative to the higher mountains. Windward sides face the east to northeast trade winds and receive much more rainfall; leeward sides are drier and sunnier, with less rain and less cloud cover.[47]

In South America, the Andes mountain range blocks Pacific moisture that arrives in that continent, resulting in a desertlike climate just downwind across western Argentina.[48] The Sierra Nevada range creates the same

effect in North America forming the Great Basin and Mojave Deserts.[49][50]

Within the tropics

The wet, or rainy, season is the time of year, covering one or more months, when most of the average annual rainfall in a region falls.[51] The term *green season* is also sometimes used as a euphemism by tourist authorities.[52] Areas with wet seasons are dispersed across portions of the tropics and subtropics.[53] Savanna climates and areas with monsoon regimes have wet summers and dry winters. Tropical rainforests technically do not have dry or wet seasons, since their rainfall is equally distributed through the year.[54] Some areas with pronounced rainy seasons will see a break in rainfall mid-season when the intertropical convergence zone or monsoon trough move poleward of their location during the middle of the warm season.[27] When the wet season occurs during the warm season, or summer, rain falls mainly during the late afternoon and early evening hours. The wet season is a time when air quality improves,[55] freshwater quality improves,[56][57] and vegetation grows significantly.

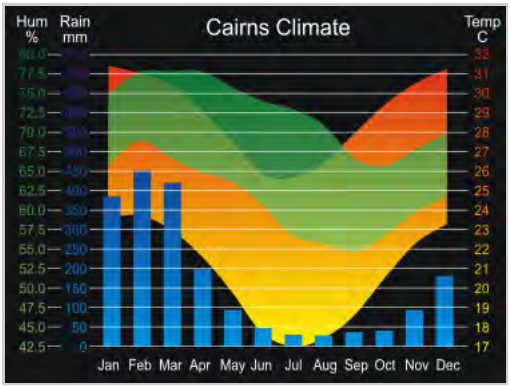

Rainfall distribution by month in Cairns showing the extent of the wet season at that location

Tropical cyclones, a source of very heavy rainfall, consist of large air masses several hundred miles across with low pressure at the centre and with winds blowing inward towards the centre in either a clockwise direction (southern hemisphere) or counter clockwise (northern hemisphere).[58] Although cyclones can take an enormous toll in lives and personal property, they may be important factors in the precipitation regimes of places they impact, as they may bring much-needed precipitation to otherwise dry regions.[59] Areas in their path can receive a year's worth of rainfall from a tropical cyclone passage.[60]

Human influence

The fine particulate matter produced by car exhaust and other human sources of pollution forms cloud condensation nuclei, leads to the production of clouds and increases the likelihood of rain. As commuters and commercial traffic cause pollution to build up over the course of the week, the likelihood of rain increases: it peaks by Saturday, after five days of weekday pollution has been built up. In heavily populated areas that are near the coast, such as the United States' Eastern Seaboard, the effect can be dramatic: there is a 22% higher chance of rain on Saturdays than on Mondays.[61] The urban heat island effect warms cities 0.6 °C (1.1 °F) to 5.6 °C (10.1 °F) above surrounding suburbs and rural areas. This extra heat leads to greater upward motion, which can induce additional shower and thunderstorm activity. Rainfall rates downwind of cities are increased between 48% and 116%. Partly as a result of this warming, monthly rainfall is about 28% greater between 32 to 64 km (20 to 40 mi) downwind of cities, compared with upwind.[62] Some cities induce a total precipitation increase of 51%.[63]

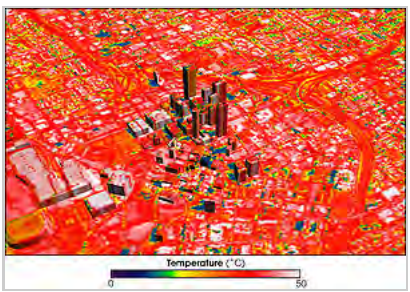

Image of Atlanta, Georgia showing temperature distribution, with blue showing cool temperatures, red warm, and hot areas appear white.

Increasing temperatures tend to increase evaporation which can lead to more precipitation. Precipitation generally increased over land north of 30°N from 1900 through 2005 but has declined over the tropics since the 1970s. Globally there has been no statistically significant overall trend in precipitation over the past century, although trends have varied widely by region and over time. Eastern portions of North and South America, northern Europe, and northern and central Asia have become wetter. The Sahel, the Mediterranean, southern Africa and parts of southern Asia have become drier. There has been an increase in the number of heavy precipitation events over many areas during the past century, as well as an increase since the 1970s in the prevalence of droughts—especially in the tropics and subtropics. Changes in precipitation and evaporation over the oceans are suggested by the decreased salinity of mid- and high-latitude waters (implying more precipitation), along with increased salinity in lower latitudes (implying less precipitation and/or more evaporation). Over the contiguous United States, total annual precipitation increased at an average rate of 6.1 percent since 1900, with the greatest increases within the East North Central climate region (11.6 percent per century) and the South (11.1 percent). Hawaii was the only region to show a decrease (−9.25 percent).[64]

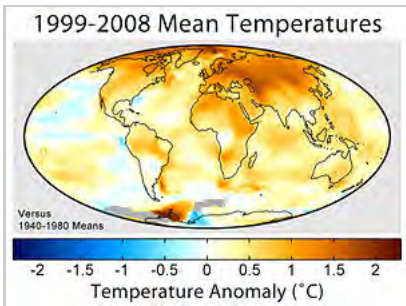

Mean surface temperature anomalies during the period 1999 to 2008 with respect to the average temperatures from 1940 to 1980

Analysis of 65 years of United States of America rainfall records show the lower 48 states have an increase in heavy downpours since 1950. The largest increases are in the Northeast and Midwest, which in the past decade, have seen 31 and 16 percent more heavy downpours compared to the 1950s. Rhode Island is the state with the largest increase 104%. McAllen, Texas is the city with the largest increase, 700%. Heavy downpour in the analysis are the days where total precipitation exceeded the top 1 percent of all rain and snow days during the years 1950-2014[65][66]

The most successful attempts at influencing weather involve cloud seeding, which include techniques used to increase winter precipitation over mountains and suppress hail.[67]

Characteristics

Patterns

Rainbands are cloud and precipitation areas which are significantly elongated. Rainbands can be stratiform or convective,[68] and are generated by differences in temperature. When noted on weather radar imagery, this precipitation elongation is referred to as banded structure.[69] Rainbands in advance of warm occluded fronts and warm fronts are associated with weak upward motion,[70] and tend to be wide and stratiform in nature.[71]

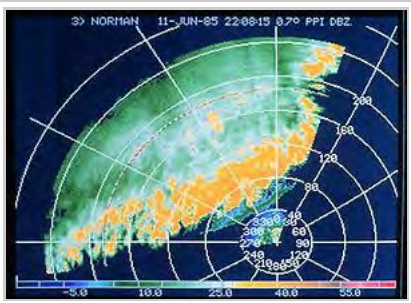

Band of thunderstorms seen on a weather radar display

Rainbands spawned near and ahead of cold fronts can be squall lines which are able to produce tornadoes.[72] Rainbands associated with cold fronts can be warped by mountain barriers perpendicular to the front's orientation due to the formation of a low-level barrier jet.[73] Bands of thunderstorms can form with sea breeze and land breeze boundaries, if enough moisture is present. If sea breeze rainbands become active enough just ahead of a cold front, they can mask the location of the cold front itself.[74]

Once a cyclone occludes, a **tr**ough **o**f **w**arm air **al**oft, or "trowal" for short, will be caused by strong southerly winds on its eastern periphery rotating aloft around its northeast, and ultimately northwestern, periphery (also known as the warm conveyor belt), forcing a surface trough to continue into the cold sector on a similar curve to the occluded front. The trowal creates the portion of an occluded cyclone known as its comma head, due to the comma-like shape of the mid-tropospheric cloudiness that accompanies the feature. It can also be the focus of locally heavy precipitation, with thunderstorms possible if the atmosphere along the trowal is unstable enough for convection.[75] Banding within the comma head precipitation pattern of an extratropical cyclone can yield significant amounts of rain.[76] Behind extratropical cyclones during fall and winter, rainbands can form downwind of relative warm bodies of water such as the Great Lakes. Downwind of islands, bands of showers and thunderstorms can develop due to low level wind convergence downwind of the island edges. Offshore California, this has been noted in the wake of cold fronts.[77]

Rainbands within tropical cyclones are curved in orientation. Tropical cyclone rainbands contain showers and thunderstorms that, together with the eyewall and the eye, constitute a hurricane or tropical storm. The extent of rainbands around a tropical cyclone can help determine the cyclone's intensity.[78]

Acidity

The phrase *acid rain* was first used by Scottish chemist Robert Augus Smith in 1852.[79] The pH of rain varies, especially due to its origin. On America's East Coast, rain that is derived from the Atlantic Ocean typically has a pH of 5.0-5.6; rain that comes across the continental from the west has a pH of 3.8-4.8; and local thunderstorms can have a pH as low as 2.0.[80] Rain becomes acidic primarily due to the presence of two strong acids, sulfuric acid (H_2SO_4) and nitric acid (HNO_3). Sulfuric acid is derived from natural sources such as volcanoes, and wetlands (sulfate reducing bacteria); and anthropogenic sources such as the combustion of fossil fuels, and mining where H_2S is present. Nitric acid is produced by natural sources such as lightning, soil bacteria, and natural fires; while also produced anthropogenically by the combustion of fossil fuels and from power plants. In the past 20 years the concentrations of nitric and sulfuric acid has decreased in presence of rainwater, which may be due to the significant increase in ammonium (most likely as ammonia from livestock production), which acts as a buffer in acid rain and raises the pH.[81]

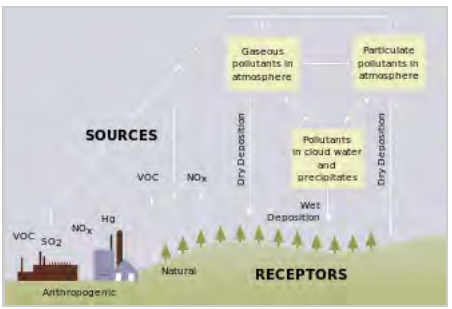

Sources of acid rain

Köppen climate classification

The Köppen classification depends on average monthly values of temperature and precipitation. The most commonly used form of the Köppen classification has five primary types labeled A through E. Specifically, the primary types are A, tropical; B, dry; C, mild mid-latitude; D, cold mid-latitude; and E, polar. The five primary classifications can be further divided into secondary classifications such as rain forest, monsoon, tropical savanna, humid subtropical, humid continental, oceanic climate, Mediterranean climate, steppe, subarctic climate, tundra, polar ice cap, and desert.

Rain forests are characterized by high rainfall, with definitions setting minimum normal annual rainfall between 1,750 and 2,000 mm (69 and 79 in).[83] A tropical savanna is a grassland biome located in semi-arid to semi-humid climate regions of subtropical and tropical latitudes, with rainfall between 750 and 1,270 mm (30 and 50 in) a year. They are widespread on Africa, and are also found in India, the northern parts of South America, Malaysia, and Australia.[84] The humid subtropical climate zone is where winter rainfall is associated

with large storms that the westerlies steer from west to east. Most summer rainfall occurs during thunderstorms and from occasional tropical cyclones.[85] Humid subtropical climates lie on the east side continents, roughly between latitudes 20° and 40° degrees away from the equator.[86]

An oceanic (or maritime) climate is typically found along the west coasts at the middle latitudes of all the world's continents, bordering cool oceans, as well as southeastern Australia, and is accompanied by plentiful precipitation year-round.[87] The Mediterranean climate regime resembles the climate of the lands in the Mediterranean Basin, parts of western North America, parts of Western and South Australia, in southwestern South Africa and in parts of central Chile. The climate is characterized by hot, dry summers and cool, wet winters.[88] A steppe is a dry grassland.[89] Subarctic climates are cold with continuous permafrost and little precipitation.[90]

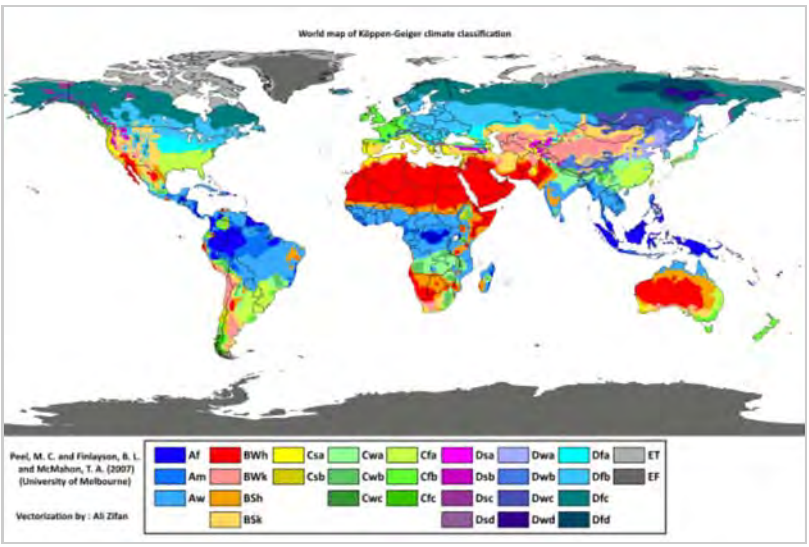

Updated Köppen-Geiger climate map[82]

Af	BWh	Csa	Cwa	Cfa	Dsa	Dwa	Dfa	ET
Am	BWk	Csb	Cwb	Cfb	Dsb	Dwb	Dfb	EF
Aw	BSh			Cfc	Dsc	Dwc	Dfc	
	BSk				Dsd	Dwd	Dfd	

Measurement

Gauges

Standard rain gauge

Rain is measured in units of length per unit time, typically in millimeters per hour,[91] or in countries where imperial units are more common, inches per hour.[92] The "length", or more accurately, "depth" being measured is the depth of rain water that would accumulate on a flat, horizontal and impermeable surface during a given amount of time, typically an hour.[93] One millimeter of rainfall is the equivalent of one liter of water per square meter.[94]

The standard way of measuring rainfall or snowfall is the standard rain gauge, which can be found in 100-mm (4-in) plastic and 200-mm (8-in) metal varieties.[95] The inner cylinder is filled by 25 mm (0.98 in) of rain, with overflow flowing into the outer cylinder. Plastic gauges have markings on the inner cylinder down to 0.25 mm (0.0098 in) resolution, while metal gauges require use of a stick designed with the appropriate 0.25 mm (0.0098 in) markings. After the inner cylinder is filled, the amount inside it is discarded, then filled with the remaining rainfall in the outer cylinder until all the fluid in the outer cylinder is gone, adding to the overall total until the outer cylinder is empty.[96] Other types of gauges include the popular wedge gauge (the cheapest rain gauge and most fragile), the tipping bucket rain gauge, and the

weighing rain gauge.[97] For those looking to measure rainfall the most inexpensively, a can that is cylindrical with straight sides will act as a rain gauge if left out in the open, but its accuracy will depend on what ruler is used to measure the rain with. Any of the above rain gauges can be made at home, with enough know-how.[98]

When a precipitation measurement is made, various networks exist across the United States and elsewhere where rainfall measurements can be submitted through the Internet, such as CoCoRAHS or GLOBE.[99][100] If a network is not available in the area where one lives, the nearest local weather or met office will likely be interested in the measurement.[101]

Remote sensing

One of the main uses of weather radar is to be able to assess the amount of precipitations fallen over large basins for hydrological purposes.[102] For instance, river flood control, sewer management and dam construction are all areas where planners use rainfall accumulation data. Radar-derived rainfall estimates compliment surface station data which can be used for calibration. To produce radar accumulations, rain rates over a point are estimated by using the value of reflectivity data at individual grid points. A radar equation is then used, which is,

$$Z = AR^b,$$

where Z represents the radar reflectivity, R represents the rainfall rate, and A and b are constants.[103] Satellite derived rainfall estimates use passive microwave instruments aboard polar orbiting as well as geostationary weather satellites to indirectly measure rainfall rates.[104] If one wants an accumulated rainfall over a time period, one has to add up all the accumulations from each grid box within the images during that time.

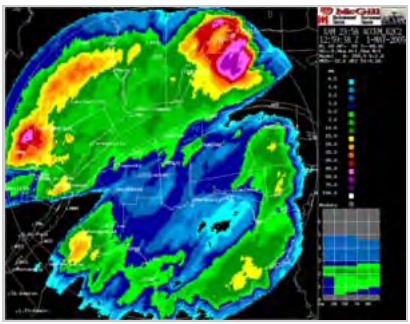

Twenty-four-hour rainfall accumulation on the Val d'Irène radar in Eastern Canada. Zones without data in the east and southwest are caused by beam blocking from mountains. (Source: Environment Canada)

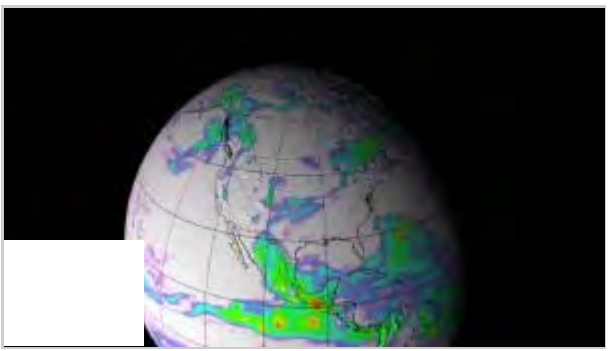

1988 rain in the U.S. The heaviest rain is seen in reds and yellows.

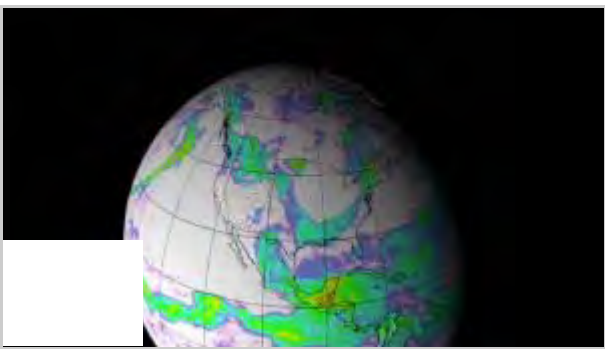

1993 rain in the U.S.

Intensity

Rainfall intensity is classified according to the rate of precipitation:

- Light rain — when the precipitation rate is < 2.5 mm

Heavy rain in Glenshaw, Pennsylvania

0:00 MENU

The sound of a heavy rain fall in

(0.098 in) per hour
- Moderate rain — when the precipitation rate is between 2.5 mm (0.098 in) - 7.6 mm (0.30 in) or 10 mm (0.39 in) per hour[105][106]

suburban neighborhood

Problems playing this file? See media help.

- Heavy rain — when the precipitation rate is > 7.6 mm (0.30 in) per hour,[105] or between 10 mm (0.39 in) and 50 mm (2.0 in) per hour[106]
- Violent rain — when the precipitation rate is > 50 mm (2.0 in) per hour[106]

Euphemisms for a heavy or violent rain include gully washer, trash-mover and toad-strangler.[107] The intensity can also be expressed by rainfall erosivity. R-factor (http://eusoils.jrc.ec.europa.eu/library/themes/erosion/RainfallErosivity/)[108]

Return period

The likelihood or probability of an event with a specified intensity and duration, is called the return period or frequency.[109] The intensity of a storm can be predicted for any return period and storm duration, from charts based on historic data for the location.[110] The term *1 in 10 year storm* describes a rainfall event which is rare and is only likely to occur once every 10 years, so it has a 10 percent likelihood any given year. The rainfall will be greater and the flooding will be worse than the worst storm expected in any single year. The term *1 in 100 year storm* describes a rainfall event which is extremely rare and which will occur with a likelihood of only once in a century, so has a 1 percent likelihood in any given year. The rainfall will be extreme and flooding to be worse than a 1 in 10 year event. As with all probability events, it is possible, though improbable, to have multiple "1 in 100 Year Storms" in a single year.[111]

Forecasting

Example of a five-day rainfall forecast from the Hydrometeorological Prediction Center

The Quantitative Precipitation Forecast (abbreviated QPF) is the expected amount of liquid precipitation accumulated over a specified time period over a specified area.[112] A QPF will be specified when a measurable precipitation type reaching a minimum threshold is forecast for any hour during a QPF valid period. Precipitation forecasts tend to be bound by synoptic hours such as 0000, 0600, 1200 and 1800 GMT. Terrain is considered in QPFs by use of topography or based upon climatological precipitation patterns from observations with fine detail.[113] Starting in the mid to late 1990s, QPFs were used within hydrologic forecast models to simulate impact to rivers throughout the United States.[114] Forecast models show significant sensitivity to humidity levels within the planetary boundary layer, or in the lowest levels of the atmosphere, which decreases with height.[115] QPF can be generated on a quantitative, forecasting amounts, or a qualitative, forecasting the probability of a specific amount, basis.[116] Radar imagery forecasting techniques show higher skill than model forecasts within 6 to 7 hours of the time of the radar image. The forecasts can be verified through use of rain gauge measurements, weather radar estimates, or a combination of both. Various skill scores can be determined to measure the value of the rainfall forecast.[117]

Impact

Effect on agriculture

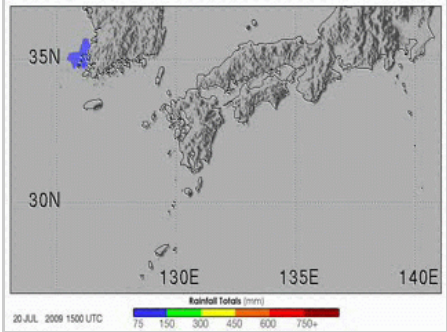

Rainfall estimates for southern Japan and the surrounding region from July 20–27, 2009.

Precipitation, especially rain, has a dramatic effect on agriculture. All plants need at least some water to survive, therefore rain (being the most effective means of watering) is important to agriculture. While a regular rain pattern is usually vital to healthy plants, too much or too little rainfall can be harmful, even devastating to crops. Drought can kill crops and increase erosion,[118] while overly wet weather can cause harmful fungus growth.[119] Plants need varying amounts of rainfall to survive. For example, certain cacti require small amounts of water,[120] while tropical plants may need up to hundreds of inches of rain per year to survive.

In areas with wet and dry seasons, soil nutrients diminish and erosion increases during the wet season.[27] Animals have adaptation and survival strategies for the wetter regime. The previous dry season leads to food shortages into the wet season, as the crops have yet to mature.[121] Developing countries have noted that their populations show seasonal weight fluctuations due to food shortages seen before the first harvest, which occurs late in the wet season.[122] Rain may be harvested through the use of rainwater tanks; treated to potable use or for non-potable use indoors or for irrigation.[123] Excessive rain during short periods of time can cause flash floods.[124]

In culture

Cultural attitudes towards rain differ across the world. In temperate climates, people tend to be more stressed when the weather is unstable or cloudy, with its impact greater on men than women.[125] Rain can also bring joy, as some consider it to be soothing or enjoy the aesthetic appeal of it. In dry places, such as India,[126] or during periods of drought,[127] rain lifts people's moods. In Botswana, the Setswana word for rain, *pula*, is used as the name of the national currency, in recognition of the economic importance of rain in this desert country.[128] Several cultures have developed means of dealing with rain and have developed numerous protection devices such as umbrellas and raincoats, and diversion devices such as gutters and storm drains that lead rains to sewers.[129] Many people find the scent during and immediately after rain pleasant or distinctive. The source of this scent is petrichor, an oil produced by plants, then absorbed by rocks and soil, and later released into the air during rainfall.[130]

Global climatology

Approximately 505,000 km^3 (121,000 cu mi) of water falls as precipitation each year across the globe with 398,000 km^3 (95,000 cu mi) of it over the oceans.[131] Given the Earth's surface area, that means the globally averaged annual precipitation is 990 mm (39 in). Deserts are defined as areas with an average annual precipitation of less than 250 mm (10 in) per year,[132][133] or as areas where more water is lost by evapotranspiration than falls as precipitation.[134]

Deserts

The northern half of Africa is occupied by the world's most extensive hot, dry region, the Sahara Desert. Some

deserts are also occupying much of southern Africa : the Namib and the Kalahari. Across Asia, a large annual rainfall minimum, composed primarily of deserts, stretches from the Gobi Desert in Mongolia west-southwest through western Pakistan (Balochistan) and Iran into the Arabian Desert in Saudi Arabia. Most of Australia is semi-arid or desert,[135] making it the world's driest inhabited continent. In South America, the Andes mountain range blocks Pacific moisture that arrives in that continent, resulting in a desertlike climate just downwind across western Argentina.[48] The drier areas of the United States are regions where the Sonoran Desert overspreads the Desert Southwest, the Great Basin and central Wyoming.[136]

Largest deserts

Isolated towering vertical desert shower

Polar desert

Since rain only falls as liquid, in frozen temperatures, rain cannot fall. As a result, very cold climates see very little rainfall and are often known as polar deserts. A common biome in this area is the tundra which has a short summer thaw and a long frozen winter. Ice caps see no rain at all, making Antarctica the world's driest continent.

Rainforests

Rainforests are areas of the world with very high rainfall. Both tropical and temperate rainforests exist. Tropical rainforests occupy a large band of the planet mostly along the equator. Most temperate rainforests are located on mountainous west coasts between 45 and 55 degrees latitude, but they are often found in other areas.

Around 40-75% of all biotic life is found in rainforests. Rainforests are also responsible for 28% of the world's oxygen turnover.

Monsoons

The equatorial region near the Intertropical Convergence Zone (ITCZ), or monsoon trough, is the wettest portion of the world's continents. Annually, the rain belt within the tropics marches northward by August, then moves back southward into the Southern Hemisphere by February and March.[137] Within Asia, rainfall is favored across its southern portion from India east and northeast across the Philippines and southern China into Japan due to the monsoon advecting moisture primarily from the Indian Ocean into the region.[138] The monsoon trough can reach as far north as the 40th parallel in East Asia during August before moving southward thereafter. Its poleward progression is accelerated by the onset of the summer monsoon which is characterized by the development of lower air pressure (a thermal low) over the warmest part of Asia.[139][140] Similar, but weaker, monsoon circulations are present over North America and Australia.[141][142] During the summer, the Southwest monsoon combined with Gulf of California and Gulf of Mexico moisture moving around the subtropical ridge in the Atlantic Ocean bring the promise of afternoon and evening thunderstorms to the southern tier of the United States as well as the Great Plains.[143] The eastern half of the contiguous United States east of the 98th meridian, the mountains of the Pacific Northwest, and the Sierra Nevada range are the wetter portions of the nation, with average rainfall exceeding 760 mm (30 in) per year.[144] Tropical cyclones enhance precipitation across southern sections of the United States,[145] as well as Puerto Rico, the United

States Virgin Islands,[146] the Northern Mariana Islands,[147] Guam, and American Samoa.

Impact of the Westerlies

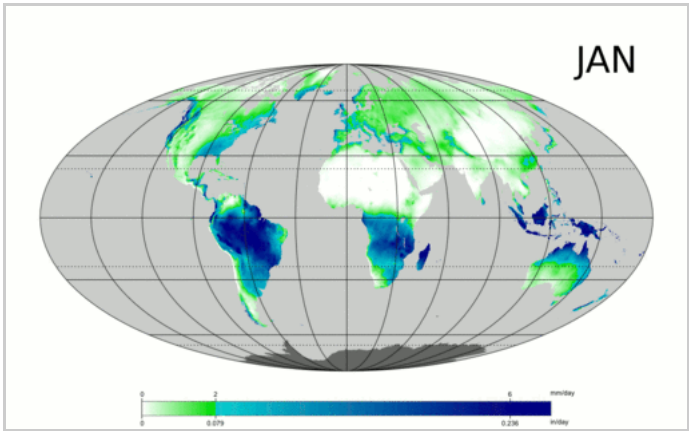

Long-term mean precipitation by month

Westerly flow from the mild north Atlantic leads to wetness across western Europe, in particular Ireland and the United Kingdom, where the western coasts can receive between 1,000 mm (39 in), at sea-level and 2,500 mm (98 in), on the mountains of rain per year. Bergen, Norway is one of the more famous European rain-cities with its yearly precipitation of 2,250 mm (89 in) on average. During the fall, winter, and spring, Pacific storm systems bring most of Hawaii and the western United States much of their precipitation.[143] Over the top of the ridge, the jet stream brings a summer precipitation maximum to the Great Lakes. Large thunderstorm areas known as mesoscale convective complexes move through the Plains, Midwest, and Great Lakes during the warm season, contributing up to 10% of the annual precipitation to the region.[148]

The El Niño-Southern Oscillation affects the precipitation distribution, by altering rainfall patterns across the western United States,[149] Midwest,[150][151] the Southeast,[152] and throughout the tropics. There is also evidence that global warming is leading to increased precipitation to the eastern portions of North America, while droughts are becoming more frequent in the tropics and subtropics.

Wettest known locations

Cherrapunji, situated on the southern slopes of the Eastern Himalaya in Shillong, India is the confirmed wettest place on Earth, with an average annual rainfall of 11,430 mm (450 in). The highest recorded rainfall in a single year was 22,987 mm (905.0 in) in 1861. The 38-year average at nearby Mawsynram, Meghalaya, India is 11,873 mm (467.4 in).[153] The wettest spot in Australia is Mount Bellenden Ker in the north-east of the country which records an average of 8,000 mm (310 in) per year, with over 12,200 mm (480.3 in) of rain recorded during 2000.[154] Mount Wai‘ale‘ale on the island of Kaua‘i in the Hawaiian Islands averages more than 12,000 mm (460 in)[155] of rain per year over the last 32 years, with a record 17,340 mm (683 in) in 1982. Its summit is considered one of the rainiest spots on earth. It has been promoted in tourist literature for many years as the wettest spot in the world.[156] Lloró, a town situated in Chocó, Colombia, is probably the place with the largest rainfall in the world, averaging 13,300 mm (523.6 in) per year.[155] The Department of Chocó is extraordinarily humid. Tutunendaó, a small town situated in the same department, is one of the wettest estimated places on Earth, averaging 11,394 mm (448.6 in) per year; in 1974 the town received 26,303 mm (86 ft 3.6 in), the largest annual rainfall measured in Colombia. Unlike Cherrapunji, which receives most of its rainfall between April and September, Tutunendaó receives rain almost uniformly distributed throughout the year.[157] Quibdó, the capital of Chocó, receives the most rain in the world among cities with over 100,000 inhabitants: 9,000 mm (354 in) per year.[155] Storms in Chocó can drop 500 mm (20 in) of rainfall in a day. This amount is more than what falls in many cities in a year's time.

Continent	Highest average		Place	Elevation		Years of record
	in	mm		ft	m	
South America	523.6	13,299	Lloró, Colombia (estimated)[a][b]	520	158[c]	29
Asia	467.4	11,872	Mawsynram, India[a][d]	4,597	1,401	39
Oceania	460.0	11,684	Mount Wai‘ale‘ale, Kauai, Hawaii (USA)[a]	5,148	1,569	30
Africa	405.0	10,287	Debundscha, Cameroon	30	9.1	32
South America	354.0	8,992	Quibdo, Colombia	120	36.6	16
Australia	340.0	8,636	Mount Bellenden Ker, Queensland	5,102	1,555	9
North America	256.0	6,502	Henderson Lake, British Columbia	12	3.66	14
Europe	183.0	4,648	Crkvice, Montenegro	3,337	1,017	22
Source (without conversions): *Global Measured Extremes of Temperature and Precipitation*, National Climatic Data Center. August 9, 2004.[158]						

	Continent	Place	Highest rainfall	
			in	mm
Highest average annual rainfall[159]	Asia	Mawsynram, India	467.4	11,870
Highest in one year[159]	Asia	Cherrapunji, India	1,042	26,470
Highest in one calendar month[160]	Asia	Cherrapunji, India	366	9,296
Highest in 24 hours[159]	Indian Ocean	Foc Foc, La Reunion Island	71.8	1,820
Highest in 12 hours[159]	Indian Ocean	Foc Foc, La Reunion Island	45.0	1,140
Highest in one minute[159]	North America	Unionville, Maryland, USA	1.23	31.2

Outside of Earth

On Titan, Saturn's largest natural satellite, infrequent methane rain is thought to carve the moon's numerous surface channels.[161] On Venus, sulfuric acid virga evaporates 25 km (16 mi) from the surface.[162] There is likely to be rain of various compositions in the upper atmospheres of the gas giants, as well as precipitation of liquid neon in the deep atmospheres.[163][164] Extrasolar planet OGLE-TR-56b in the constellation Sagittarius is hypothesized to have iron rain.[165]

See also

- Precipitation types
- Rain dust
- Rain sensor
- Rainbow
- Raining animals
- Red rain in Kerala

- Petrichor - the cause of the scent during and after rain
- Sanitary sewer overflow
- Sediment precipitation
- Water resources
- Weather
- Rainmaking
- Johad
- John Rainwater - pseudonymous mathematician

Notes

- **a b c** The value given is continent's highest and possibly the world's depending on measurement practices, procedures and period of record variations.
- ^ The official greatest average annual precipitation for South America is 900 cm (354 in) at Quibdó, Colombia. The 1,330 cm (523.6 in) average at Lloró [23 km (14 mi) SE and at a higher elevation than Quibdó] is an estimated amount.
- ^ Approximate elevation.
- ^ Recognized as "The Wettest place on Earth" by the *Guinness Book of World Records*.[166]

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External links

- What are clouds, and why does it rain? (http://www.geography-site.co.uk/pages/physical/climate/why%20does%20it%20rain.html)
- BBC article on the weekend rain effect (http://news.bbc.co.uk/2/hi/sci/tech/146120.stm)
- BBC article on rain-making (http://news.bbc.co.uk/2/hi/asia-pacific/3893671.stm)
- BBC article on the mathematics of running in the rain (http://news.bbc.co.uk/1/hi/magazine/4562132.stm)

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Rainwater Harvesting for Domestic Water Supply in Developing Countries: A Literature Survey

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RAINWATER HARVESTING FOR DOMESTIC WATER SUPPLY IN DEVELOPING COUNTRIES: A LITERATURE SURVEY

WASH C-252

KENT KELLER

1 JUNE 1982

Drawing from White et al, 1972, by permission

RAINWATER HARVESTING FOR DOMESTIC WATER SUPPLY IN DEVELOPING COUNTRIES: A LITERATURE SURVEY

ABSTRACT

Interest in rainwater harvesting ("RWH") for water supply in developing countries has grown with interest in supporting locally organized and implemented efforts to meet basic human needs. RWH is an attractive way of increasing the quantity of water available for household use in areas with water shortages. Catchments using existing roof structures and surfaces, in combination with self-help built storage containers, represent a particularly promising approach. The literature is reviewed; publications most useful to prospective designers and implementors of RWH projects are identified. Feasibility and costs assessment guidelines for simple RWH systems are given. Construction of selected catchment and storage technologies is described. When a small existing roof is used for catchment, several gallons per day could be provided for at least part of the dry season in central Africa, at a cost (for self-help construction of the storage tank) of under US$ 100. Costs of tanks with effective covers may be reduced by applying or modifying traditional storage techniques or planning storage into construction of new buildings.

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RAINWATER HARVESTING FOR DOMESTIC WATER SUPPLY IN DEVELOPING COUNTRIES: A LITERATURE SURVEY

1. Introduction

Effective rainwater harvesting (RWH") techniques have been known and practiced for thousands of years in many areas of the world. Today there is a rapid increase in interest in the potnetial of RWH for water supply, as development assistance groups devote more and more attention to small-scale, locally-implemented projects for meeting basic human needs.

This high level of interest should not be surprising. As an option for development of water resources, RWH presents a number of advantages. It is a way to increase the quantity of water available to households on an incremental basis; it does not require mobilizing vast quantities of resources, all at once, to import the materials and expertise involved in planning and building large complex systems. In combination with sanitation or other projects, RWH planning and construction can serve as the focus for community organization efforts. RWH relies and builds upon local skills and experiences in construction, water consumption, and rainfall patterns. And when proven techniques are combined imaginatively with local structures and materials, RWH systems can be relatively low in capital cost. For example, in southern Chad, * an existing sheet metal or tile roof with a plan area of 30 m^2, guttering made and hung with local wood and fiber, and three tanks made of traditional baskets and cement mortar, could be built at a cash cost of about US$ 80 (assuming

---

* see section 4.1

self-help labor)**. This system would provide several gallons of water per day for much of the year, substantially improving a family's water supply situation during at least a part of the dry season. Use of locally-available containers to replace or supplement the cement mortar tanks might reduce costs a great deal. And if water storage could be planned and built into a new public facility such as a school or health center, a much larger supply might be developed for a relatively small increment in construction costs.

Finally, RWH may be the only way to increase availability of water where ground and surface supplies cannot be developed further.

Why has the great potential of RWH only recently come to the attention of an international audience of development planners and practitioners? Answers to this question lie in the traditional structure and administration of development assistance. International assistance bodies and national development planning authorities, each striving for broad-scale impact within the short term, have tended to devote their resources to water supply technologies and projects they can design centrally and implement regionally or nationally. While a history of failures indicates that this is not the most effective strategy for meeting water needs, it has nevertheless been the tendency if not the rule. Successful RWH programs, on the other hand, would clearly depend

**assuming a cement price of US$ 5.00 and less than 10% of total expenditures for sand and gravel. See section 4.2.

on local considerations: climate, participation of users, building styles, materials, and skills.

Another reason for the historical lack of interest in RWH is that the systems are simple, requiring neither the imported technology nor experts which international development assistance organizations are set up to provide.

These characteristics of RWH, however, are precisely the features which have aroused the interest of individuals and groups committed to supporting locally-organized efforts with concrete, acheiveable goals. While providing planning assistance and funds for such projects will present challenges for many organizations, the potential benefits--in increased quantity of convenient, clean water for people in many areas--call for a close look at the range of RWH techniques. The rest of this paper is an attempt to survey the field by reviewing literature and identifying published accounts of greatest value for planning and assessing RWH systems. An additional objective is to identify and describe the construction of a few of the most promising and widely applicable of the catchment and storage techniques identified in the literature survey.

2. OVERVIEW

2.1 The Range of Rainwater Catchment Technique

Rainwater harvesting -- like any other kind of water supply -- is a means of taking water out of the hydrologic cycle for some human or productive use. Most water supply strategies interrupt the cycle after the water is on or in the ground, diverting water out of streams or pumping it up from below the surface. In rainwater harvesting, the water is intercepted as it falls.

Rainwater harvesting is an attractive alternative for water supply in many areas where other sources are in short supply, but it would seem to make particular sense in arid regions where most rainfall is lost to any kind of use because it is held only briefly in parched soil and evaporates, returning directly to the atmosphere. (Myers, 1962).

Rain is a diffuse source of water in the same way that sunlight is a diffuse source of energy; but, also like sunlight, it is (usually) relatively clean, and it can be collected and stored until it is available in useful quantities.

The range of water harvesting approaches and applications is tremendous, spaning a broad spectrum of technologies and a considerable reach of human history. Furrows in the soil surface were used in ancient Israel and are used today in Australia (now called "road catchments") to provide water for agriculture. In Roman times, cisterns varying in capacity from 30 to 3,000 m^3 were excavated out of soft limestone and filled with surface water diverted off of hillsides (Davis, 1963). Certain tree trunks, when hollowed out, can hold a considerable volume of water caught from flow down the tree branches.

In general, rainwater harvesting can be defined as "the process of collecting natural precipitation from prepared watersheds for beneficial use" (Currier, 1973). In practice, most RWH schemes can be understood as systems with two basic components: 1) a surface or "catchment" for collecting rain and channeling a flow of water, and 2) some kind of reservoir for receiving the water from the catchment and holding it for use or distribution. There are many possible ways of classifying and organizing RWH systems for purposes of description and analysis. Systems can be classified according to the broad type of catchment surface employed: untreated soil, treated soil, or artificial sheet material. Often RWH systems are called "ground catechments" or "roof catchments" according to the elevation of the catchment surface. Sometimes it is useful to distinguish between systems in which the surface of stored water is below the ground (e.g. in a buried tank) or, alternatively, above the ground (as in a jar). These categories often overlap and intermingle in practice. For example, rooftop catchment surfaces may feed above-ground tanks, buried tanks, open ponds, or all three; and conversely, underground tanks may collect water from treated or untreated soil surfaces or, on the other hand, from some kind of roof.

2.2 Implications of Type of Use for Choice of Techniques

Survey of the literature on techniques and applications suggests that establishing categories of intended use (e.g. domestic use vs. agricultural use) is helpful. The nature and requirements of the use then indicate certain techniques as preferable to other alternatives. For example, agricultural uses--water for stock watering or for irrigation -- call for large quantities of water, with quality less of a concern. Clearly large catchment areas are required and the ground surface is the obvious choice. Since color and clarity are not important, any of a wide variety of physical and chemical soil treatments, easily

applied over large expanses of ground, may be considered. Tanks without covers will often be chosen to reduce costs.

On the other hand, water for domestic use should be cleaner and more convenient than agricultural water. Roofs are an obvious choice for a catchment surface as their elevation protects them from many of the sources of contamination and damage which plague ground surface catchments. Tanks built into or adjacent to homes and public buildings mean that the distribution point is convenient. Public health considerations usually dictate some kind of cover for tanks, which reduces evaporation and means they can be built smaller yet support thesame rate of consumption provided by larger, uncovered tanks.

Thus the nature of domestic use indicates rooftop catchments and tanks in or near buildings, for RWH schemes for domestic water supply. Obviously this will not always be true, and this report will describe domestic supply schemes with ground-surface catchments and open/underground tanks (e.g. Maikano and Nyberg, 1980; Ionides, et al., 1969). In many areas, lack of suitable roofing materials will stand in the way of rooftop catchment, at least until alternativeroofing is available. But where suitable roofs exist -- and few areas are entirely without some impermeable roofing, at least atop public facilities -- the catchment structure and surface are paid for, and available cash and effort can be invested in adequate guttering, foul flush systems, and tanks for storage. Additionally, rooftop catchment systems do not involve the all-out mobilization of labor required by most community ground-surface catchment systems (Farrar and Pacey, 1974; Grover, 1971). Village water supply can improve incrementally with catchment systems, each requiring a small up-front cash outlay, undertaken one at a time.

2.3 Rooftop Catchments for Household and Small Community Water Supply in Developing Countries

This report, then, will focus on rooftop catchment systems which have been used in developing countries. Ground-surface catchment techniques will not be ignored; rather, they will be surveyed and considered for their potential applications for low-cost domestic water supply.

In addition to scarcities of capital and lack of access to many kinds of modern industrial expertise, here are listed conditions, some of which are prevalent in many developing countries, relevant to RWH as a local-level water supply option:

a. tropical and subtropical climates: marked wet and dry seasons; rainfall coming in short, torrential bursts; very high potential evaporation rates, often exceeding 2 m per year (Grove, 1978).

b. soils which dry out and crack during sustained dry periods, reducing the capacity of soil horizons to absorb and retain water and limiting groundwater recharge (Myers, 1962); satisfactory groundwater sources often too deep to develop using available human or animal power, and too expensive to develop using imported engine-driven pumps.

c. dangers of waterborne and other infectious diseases wherever water is ponded or stored in the open.

d. rural proverty with corresponding nutrition deficits; lack of experience in organizing for community public works.

3. LITERATURE REVIEW AND BIBLIOGRAPHY

3.1 Broad Concerns and Basic Constraints in Rainwater Harvesting

3.1.1 Rainfall patterns

Rainfall is random and even sporadic in occurrance. This is especially true in continental climatic regimes; (Grove, 1978) notes that for Africa as a whole, rainfall totals will be within 10% of averagfe in only about 4 of 10 years. In effect, this means that there is some likelihood during any given year of at least moderate drought. Grove (1978) says that observers in East Africa contend that most of the rain in that area falls "in a few spells lasting about a week". Thus, even during the rainy seasons, there may be dry periods of considerable length.

Even in climates moderated by nearby bodies of water, the amount and frequency of rainfall during any given month or year can beexpected to depart from the norm represented by averagfe precipitation statistics.

What does this imply for water supplies from simple rainwater catchment systems? At a minimum, an addition of relatively clean water during rainy periods can be expected. In areas with high rainfall totals and short dry seasons, having rainwater for household use in some kind of simple above-ground container may be a significant advance over using groundwater polluted by interaction of near-surface wastes and high water table.

With investments in storage capacity, water could be provided during periods of rain and some water would be available during parts of dry periods. Larger investments in storage (and possibly catchment area as well) could make water available throughout dry periods, although this would be impracticably expensive in many rural areas (see section 4.1, "Using Rainfall Data to Design a RWH System").

3.12 Needs

The value of achievable improvements in water available through RWH must be measured against local water needs. It could be that during wet months, there is agreement that water is adequate in quantity, quality, and convenience. In such a case there would be little to be gained by channeling water from rooftops into small containers; real gains would only be made if larger storage tanks could provide for more water during the dry months.

Local peoples' perceptions of their needs may also differ with those of outside evaluators. For example, it could be that from a public health point of view, abundant water in puddles and ponds should not be drunk, and that rainwater collected in jars would be preferable. Local people, on the other hand, may be accustomed to water from open sources and see little point in investing in cleaner drinking water.

3.1.3 Costs and comparisons with alternatives

Implicit in the above discussion is the need to calculate the costs of a proposed RWH system, and examine those costs and related benefits in light of the feasibility of other kinds of water supply improvements. Discussion of benefit/cost comparison techniques for water supply is outside the scope of this report, but a few basic observations can be made. White et al (1972) have generalized that construction and financing costs of individual RWH systems are substantially higher, on a per head basis, than simple community improvements such as standpipes and community wells. They estimate a per capita construction cost of US $15 for cisterns, as compared with US $7 per capita for community wells (East Africa, 1972). However, White et al (1972) also point out that greater dispersion of settlement and aridity of climate each tend to work to raise the

per capita costs of any kind of water supply improvement: "The range of costs is (decreasing) from arid dispersed environments to humid nucleated areas" (page 88). Thus in many climatic and settlement regimes the cost advantege of standpipes and wells may disappear; and indeed in some areas there may be no practicable means for providing such community improvements.

Parker (1973), Farrar and Pacey (1974), and Grover (1971) have each made observations as to the conditions which favor simple RWH systems in comparison with alternatives. RWH will be relatively attractive:

a. where the barriers to organzing and providing large amounts of labor (for self-help community systems) are high;

b. where capital for water supply improvements can be made available only in small amounts;

c. where the community organizational infrastructure does not exist to arrange financing, construction, or maintenance of community sytems;

d. where settlement patterns are dispersed;

e. where impervious roofing surfaces are in use.

In a particular situation the cost advantage of simple RWH systems over other alternatives will also depend on availabilities of materials, skills, cash, and/or financial assistance. Actual costs of catchment and storag depend on what existing structures (such as roofs) can be used, the local prices of the building materials which must be purchased to build the remaining parts of the system, and expenditures for labor (although in this report, discussions of costs will assume self-help labor). Specific cost estimates for storage and catchment technologies are

included in the following sections, and rough materials cost estimates for a proposed system can be calculated using the guidelines in section 4. It is worthwhile, though, to make some general observations:

a. most of the materials cost involved in building rooftop catchment systems goes into providing storage (the term "tank" will be used in this report) which does not leak and protects water quality. The most common materials used are combinations of cement, sand, gravel, bricks, stones, steel rod or wire, and steel netting ("chickenwire").

b. the costs of storage in tanks, as measured in materials cost per cubic meter (m^3) of water capacity, vary widely. Among the tanks included in this report, cost/m^3 ranges from under US \$ 1.00/m^3 for a proposed salt-lined open reservoir system in Mali (Cluff, 1975) to US \$30.00/m^3 or more for manufactured "tin" tanks for rooftop catchment in Eastern Africa (White et al, 1972).

c. as tanks increase in volume, their ratio of wall and cover area to capacity decreases. Thus larger tanks will tend to have lower materials costs per m_3 of capacity.

d. however, large tanks built with manufactured or imported materials may cost more per m^3 than smaller tanks built with locally available materials (see chart, page 59).

e. "family-sized" tanks, built with cement mortar and a variety of other materials, can be built for costs of US \$8.00-15.00/m^3 (1982) in developing countries.

3.14 Maintenance and Public Health

The objective of maintenance, of course, is to keep the system working (collecting rainwater) and, at the same time, see that the quality of the water provided is as high as possible. Achieving these goals requires attention to each of the processes which transmit water from the atmosphere to the user: contact with the catchment surface, transport in some kind of channel to the tank, residence in the tank, and delivery.

Rooftop catchment surfaces collect dust, vegetable matter, and bird droppings which can clog transport channels to the tank, cause rapid sediment buildup on the tank bottom, and in some cases) contaminate the water stored in the tank. Gutters and downpipes (used to transport water from the edge of the roof to the tank) must be cleaned frequently so that they will not overflow during heavy rain. A bigger problem is consistently diverting the dirty water which "washes" the roof at the beginning of each storm so that it will not contaminate stored water in the tank, and subsequently allowing clean water to flow into the tank. In Java, where steel-reinforced cement motor tanks are being built by the hundreds (Winarto, 1981; Pompe et al, 1982), the bamboo trough from the gutters to the tank inlet is propped away from the inlet hole until after the first few minutes of rain. When the roof is clean, it is moved into position over the inlet screen by a child. This scheme has no mechanism to break down, and the household is always aware of the precise time of the beginning of the rain because washed clothes hanging out to dry must be brought indoors. A variation on this simple but effective strategy, when smaller tanks are used without downspouts, is to move the tank into position or uncover it after the roof is clean (see the drawing on the cover sheet).

Other arrangements have been devised which require some kind of addition to the trough or downpipe from the gutters to the tank. These include a tipping funnel mounted under the gutter outflow (UNEP, 19079), "butterfly valves" (Dooley, 1978) which are turned manually after the roof is cleaned, and "roofwashers", in the first "foul flush" is collected in a container. These various devices all require cleaning and repair, and moving the flow of water into position when the roof is clean often easier and almost always cheaper. Techniques for fastening downpipes and a variety of "foul flush" devices are described in more detail in section 3.2.3.

Filters of sand, gravel and charcoal are often suggested as a way of keeping sediment and contaminants out of large cisterns (e.g. Office of Water Programs/EPA, 1974; VITA, 1977). The designs usually show a small concrete box atop the cistern cover, which in turn has a removable cover for cleaning. Such filters require frequent inspection and flushing to prevent dangerous bacterial buildup on the filtering grains. Because of this high maintenance requirement, Henderson et al (1973) recommend against use of a filter with cisterns and suggest that an effective "foul flush" system be installed in the downpipe instead. Farrar and Pacey (1974) question the effectiveness of sand as a filter when the flow of water through it is intermittent. Our conclusion is that it is better to invest available resources and effort in keeping the "foul flush" out of the tank than in filters.

The maintenance requirements of the tank itself will depend to a large extent on the effectiveness of roof, gutter, and downpipe cleaning, as well as the practicality of the "foul flush" system. The other important factor in tank maintenance is the quality of the tank cover and screening on any inlet and outlet holes. If sunlight reaches the water its temperature rises and algae grow.

Unprotected openings bring mosquito breeding, particularly dangerous in malarial areas where tanks are located near homes. But regardless of the quality of the cover and screening, all tanks need to have sediment scooped out and walls scrubbed. "Heaven's water..." (1980) suggests vinegar, baking soda, and chlorine bleach solutions as cleaning agents. Any cleaning material can be used to remove scum from tank walls as long as it would not contaminate the new charge of water.

Any tank's access hole or tap area must be kept clean and well drained. Cracks in mortar should be replastered after each cleaning of the inside surface.

A pump, if used to lift water out of a tank, has substantial maintenance requirements of its own.

The maintenance requirements of ground surface catchment systems are broadly similar to those of rooftop catchment systems. "Foul flush" devices are not used; sometimes sedimentation basins near the outflow of the catchment area (e.g. Maikano and Nyberg, 1980) are used instead. Ground surface catchments are vulnerable to contamination and damage caused by human and animal traffic. Ionides et al (1969) and Grover (1971) propose fencing catchment areas to keep all such traffic off the surface, but this would be expensive and ineffective in many areas. Maikano and Nyberg (1980) say that traditional grain threshing floors used a catchment surfaces in Botswana could be fenced inexpensively, possibly using tree branches.

A general point to be made about the maintenance of ground surface catchment systems which serve a group of families is that some degree of community organization is required. By contrast, maintenance of household rooftop catchment systems requires no such commitments.

A summary of key maintenance considerations follows:

1. Any RWH system has catchment, channeling, storage, and delivery components which must be given frequent attention.

2. Community systems require community organization for effective maintenance; household systems require a correspondingly smaller scale of organization.

3. Rooftop catchment surfaces have the advantage of not being vulnerable to human and animal traffic which causes contamination and damage to ground suface catchments.

4. A procedure or device for keeping the "foul flush" out of the tank deserves particular attention.

5. Gutters and downpipes must be inspected and cleaned especially carefully.

6. Any tank needs periodic cleaning. Its design should take this fact into account.

3.1.5 Publications and how to obtain them +++

Commission on International Relations/NAS, 1974, More Water for Arid Lands: Promising Technologies and Research Opportunities, book, 154 pages, mention name of your group or insitutional affiliation when requesting a free copy from BOSTIC (JH215), Office of the Foreigh Secretary, National Academy of SCiences, 2101 Constituion AVenue, Washington, D.C. 20418, USA.

Still useful and provocative after 8 years in print, this overview is divided in two halves, "water supply" and "water conservation". Topics: runoff agriculture, reuse of water, reducing evaporation from water and soil surfaces, trickle irrigation, selecting water-efficient crops, and others. The chapter on rainwater harvesting dislcusses techniques and research in Australia, Zämbabwe, and the western U.S., as well as the ancient gravel mounds and strips used to harvest rainwter from hillsides in the Negev 4000 years ago. Includes good photographs of the "sand-sausage" tanks described in Ionides et al (1969) and Farrar and Pacey (1974), and section 3.3.4 (below).

Frasier, G.W., and Myers, L.E., (?), in preparation, a handbook on rainwater harvesting with parts devoted to domestic water supply. Will be published as a USDA handbook, available from the Superintendedt of Documents, Washington, D.C., in 1983. For further information contact Dr. Frasier (see section 3.2.4).

Hofkes, E.H., ed., 1981, Small Community Water Supplies, Technical Paper no. 18, IRC/WHO, book, 413 pages, request a free copy from IRC, P.O. Box 5500, 2280 HM RIJSWIJK, The Netherlands.

"A handbook/source document on technology of small community water supply systems". This useful overview contains a 12-page section which is probably the best short published summary of rainwater as a source of domestic water supply that we have seen. Includes good drawings of an underground rainwater storage well (as used in China) and a venetian cistern. Bibliography of 12 items.

IRC says that the editor is currently working on a "design manual for RWH systems".

+++here, as in sections 3.2.4 and 3.3.6, much of the access information has been taken from Darrow and Pam (1976) and Darrow et al (1981).

ITDG, in preparation, "a practical manual describing rainwater harvesting techniques as an option for water supply." This book will probably not be available until late 1983, but the consistens quality of ITDG publications leads us to believe that it will be well-researched and useful to a broad range of workers. "The emphasis will be on low-cost systems for small communities and the scope will cover the provision of water for domestic and agricultural purposes. The manual is intended for use by project holders and field workers and consequently is planned to include, wherever possible, practical information derived from experience in the field. In order to achieve this objective ITDG is anxious to make contact with field personnel who would be willing to share something of their experiences--successes and failures." (personal communication, Adrian Cullis, ITDG.) Write to Ms. Cullis at: Applied Research Section, Shinfield Road, Reading, Berkshire RG2 9BE, United Kingdom.

White, G.F., Bradley, D.J., and White, A.U., 1972, Drawers of Water: Domestic Water Supply in East Africa, book, 306 pages, US$16 (clothbound) from University of Chicago Press, 11030 S. Langley, Chicago, Illinois 60628 USA.

An effective, carefully assembled overview of domestic water supply in the developing tropics, of interest to a broad range of workers involved in the formulation of water supply strategies. Of particular interest: analysis of basic types of water improvements and their varying applicability over the range of environments and settlement patterns in East Africa, where the authors studied from 1965-68. A key source for planners, containing lessons and insights relevant to much of the developing world.

3.2 Catchment technologies

3.2.1 Surfaces and materials.

Roofing materials. In many areas where rooftop rainwater catchment might be an attractive option, existing roofs with clearly suitable surfaces are rare. This section outlines some of the most promising of recent developments in low-cost, impervious roofing for developing countries.

The "conventional" materials of choice for impervious roofs in developing countries are usually corrugated galvanized metal sheet (variously called "tin", "galvanized", "iron sheet", "zincpan", etc.) , fired tile, and "asbestos" sheet. Manufactured metal sheet is light in weight, easy to install, and sheds water better than the other alternatives; it is also, however, expensive or altogether unavailable in many isolated areas where rooftop catchment might be most appealing. Tile is fairly impervious but its manufacture requires a source of good clay soil and fuel for firing; it is also substantially heavier than most other materials. Manufactured corrugated asbestos sheet is strong and light in weight, but like metal sheet, expensive and often practically unavailable (Hofkes, see section 3.1.5, suggests that certain asbestos roofing materials may shed asbestos fibers into the runoff).

"Traditional" materials may have some potential as rain-shedding surfaces for roofs which can be guttered. McDowell (1976; see section 3.3.6) reports that thatched roofs have been guttered with polyethylene and that the water from the roof is potable (some sources question the potability of water collected from thatch surfaces). Hall (1981; see section 3.2.4) discusses thatching materials and techniques, emphasizing the cost-effectiveness and broad potnetial of a traditional technology. The durability of thatch has been widely questioned; public-health-minded investigators often express concern over thatch as a breeding place for insects and even rhodents.

The fabrication of rain-shedding shingles from coconut tree trunks is an example of the use of local materials which might fit well in a rooftop catchment system.

Fibre reinforced cement ("FRC") corrugated sheets, and processes for local-level fabrication in developing countries, have received considerable attention (UNIDO, 1978; Parry, 1981; I.T. Building Materials Workshop; see entries in section 3.2.4). UNIDO estimates that at a cement price of US$5 per 50-kg bag, FRC sheets reinforced with sisal fibers could be fabricated for a materials cost of about $0.90/m^2 in many developing countries (1978). Parry (1981), reporting on the pioneering work on small-scale manufacturing technologies for FRC sheet, says that "By comparison with the conventional alternatives, if production labour costs are counted, fibre cement roofing components generally turn out to be: 1) Between one-third and one-quarter the cost of asbestos cement roofing sheets and requiring a similar roof structure. 2) Slightly more expensive than locally-produced traditional clay tiles but requiring a mcuh simpler and cheaper roof structure. 3) About three-quarters the cost of galvanized corrugated iron sheets and requiring similar or slightly more expensive roof structures. 4) About the same cost as medium quality traditional thatch where materilas have to be bought commercially by house builders, but with a similar roof structure. If made and supplied on a self-help basis with labour costs not counted, the FRC roofing products would frequently work out as the cheapest roofing of all."

Parry also emphasizes the importance of proper tools and adequate training in the methods for successful manufacture. FRC sheets (made under carefully controlled conditions) in natural exposure tests show no deterioration after four years.

A variety of natural fibers, which are usually mixed with the cement or placed manually as the sheets are cast, can be used in FRC sheets. Coconut hull fibers ("ijuk") are being tested in Indonesia at the Development Technology Institute, Bandung (Anshori Jausal, personal communication). Crushed bamboo culm is apparently another alternative.

The mechanical forming of waste fiber into boards, which are then soaked in an asphalt bath, is one of many techniqeus being investigated in India.

NAS (1974; see Roofing in Developing Countries , section 3.2.4) provides an overview of new roofing technologies. Development of more effective low-cost roofing is one of the keys to the broad-scale feasibility of rooftop catchment schemes in developing countries.

Ground Surfaces. Grover (1971, page 52) offers a useful list of the range of ground surface catchment tecnologies:

"a. Clearing sloping surfaces of vegetation and loose material,

b. Improving vegetation management by changing ground cover,

c. Mechanical treatments, such as smoothing and compacting the surface,

d. Reducing soil permeability by the application of chemicals,

e. surface-binding treatments to permeate and seal the surface,

f. Covering the catchment with a rigid surface, and

g. Covering the catchment with a flexible surface."

With its emphasis on rooftop catchment, this report will devote relatively little space to ground surface catchments. We hope to indicate the range of possibilities and the kinds of investigations into a very broad and widely-researched topic.

The lowest-cost alternative in ground catchment is, of course, a traditional one--the diversion of runoff from completely unprepared ground surfaces. This is how "hafirs" fill in the Sudan; Ionides et al (1969) describe a strategy for locating "sand-sausage" tanks in Botswana which took advantage of the collecting effect of road tracks. The "efficiency" (ratio of collected runoff to rainfall) of unprepared ground surfaces may be no more than about 5% (Lauritzen, 1961; Cluff, 1974).

A variety of materials and treatments can improve efficiency of ground-

surface catchments. Myers (1974, page 3) provides a list of "desirable characteristics for materials for catchment aprons...:

1. Runoff from the structure must be nontoxic to man and animals.
2. The surface of the structure should be smooth and impermeable to water.
3. The structure should have high resistance to weathering damage and should not deteriorate because of internal chemical or physical processes such as crystallization.
4. The structure need not have great mechanical strength but should be able to resist damage by hail or intense rainfall, wind, occasional animal traffic, moderate flow of water, plant growth, insects, birds, and burrowing animals.
5. The materials used should be inexpensive, on an annual cost basis, and should permit minimum site preparation and construction costs.
6. Maintenance procedures should be simple and inexpensive."

AVailable materials and treatments meet some (and fail to meet others) of these specifications. Steel (Lauritzen, 1967) has the obvious drawback of great expense; butyl (Lauritzen and Thayer, 1966; Bradley, 1967) is also expensive and may impart a noticeable, if harmless, color to water. Paraffin may be "the most promising of all the chemical treatments tested. Paraffin is cheap, easily applied, and its life expectancy is at least five years when applied to a sandy soil" (Eshenaur, 1982). Application of sodium salts, to reduce seepage on catchment surfaces and in reservoir banks (e.g. Cluff, 1975) is low in cost but relatively short-lived and dependent in effectiveness on soil composition. Sprayed asphalt has been widely considered and proposed (Frasier, 1975; see section 3.2.4). Asphalt, after weathering, also tends to impart a dark co loring to water which might be eliminated by spraying with

one of a variety of treatments. Grover (1971) proposed such a sprayed asphalt catchment for a community rainwtaer harvesting scheme in Kenya.

The University of Arizona, U.S.A., has been a center for research into ground surface catchments, although the emphasis of the research has been to develop catchments for agricultural uses. Cluff (1974) describes a range of approaches being investigated there including "compacted earth" , "compacted earth sodium treated", "gravel covered plastic", and a sequence of layers, "asphalt-plastic-asphalt-chipcoat" (see Frasier, 1975 section 3.2.5). As described, the treatments are heavily dependent on large, exensive machinery; however, some of them might be adapted for application using labor-intensive methods.

The organization Christian Care (Farrar and Pacey, 1974, see illustration in section 3.3.4) suggests a concrete apron to collect water for their underground tanks. Maikano and Nyberg (1980) describe a pilot rainwater catchment project in Botswana which makes use of traditional grain threshing floors as catchment surfaces. These floors are plastered with a mixture of clay and cow dung and the project is monitoring the water collected for chemical and pathogen concentrations.

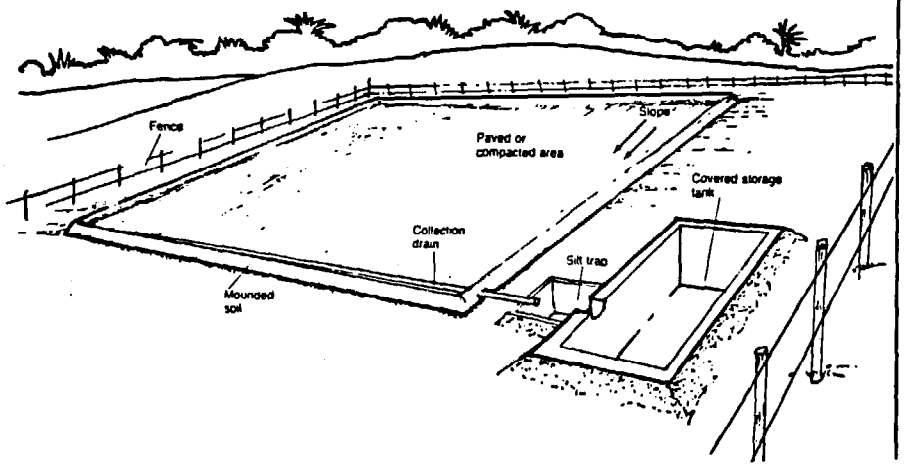

Figure 4. Ground Catchment

Institute for Rural Water, 1982c (draft) by permission

3.2.2 Guttering systems

Clearly, effective guttering is a key to rooftop catchment systems; water can be neither stored nor consumed if it is not channelled efficiently from the roof to the tank. Yet the materials and techniques for construction of effective gutters is a topic that is omitted from almost all accounts. Technically, guttering is far less challenging than construction of cost-effective water storage, and its cost is usually a relatively small part of tltal costs. Possibly guttering has been largely ignored in published accounts for these reasons.

General considerations. How big do gutters need to be? Size needs will obviously vary with the intensity of local storms and the ground area covered by the roof. Ree (1976), investigating runoff yields from sloping metal roofs, used sheet metal gutters 20 cm wide by 10 cm deep, each with a downpipe 15 cm in diameter. Each of these gutters had a capacity of twice the greatest runoff rate recorded from half the 12 x 18 m area of roof over a period of one year in Oklahoma, USA. Thus gutters half as wide or half as deep would have handled the year's heaviest rain from that roof. In general, gutters and downpipes with a cross-sectional area (width x depth) of 100 cm^2 will probably be big enough to handle all but the most torrential rains from most roofs.

A greater problem than gutter size is probably hanging gutters securely so that they do not sag or fall during heavy rainfall, and keeping them positioned so that they catch both gushing flow and dripping flow from the edges of the roof. Ensuring adequate slope for the entire system, so that water does not stand and damage gutters or attract mosquitoes, is equally important.

Manufactured metal gutters. Aluminum or galvanized sheet metal gutter-

ing is the technology of choice in most areas in developed countries. The gutter sections are joined with sepcial brackets and hung with metal straps or long spikes with sleeves which are driven through the upper part of the gutter's width and into wood backing. As of this writing, in the U.S. aluminum guttering and downpipe sections cost about US$1.85 / m (galvanized sheet is slightly less expensive but tends to corrode more quickly unless coated with high-quality rust-resistant paint). Hardware for joining and hanging the system costs another $0.60 per meter. This would make the materials costs of guttering and downpipe for a building 6 m long approximately $30 (1982, US). Higher cost or complete unavailability are likely to eliminate manufactured metal gutters as possibilities in most rural areas of developing countries.

Alternatives using local materials. McDowell (1976, page 33) observes:

"It is noticed that, in many areas, houses will have a short length of roughly fashioned guttering fixed under the eaves just above the door, and that water from this will be collected in an old oil drum or other container. It seems that this type of device is used more for the purpose of preventing water from running in through the doorway of the hut than as a serious approach to water collection. However, the existence of this "technology" could provide the link point for development of simple but effective roof catchment systems."

McDowell also reports on the use of split bamboo culms with joints removed, and "V"-shaped gutters made by nailing two boards together at right angles edge-to-edge. This construction seems likely to leak but the "V" might be

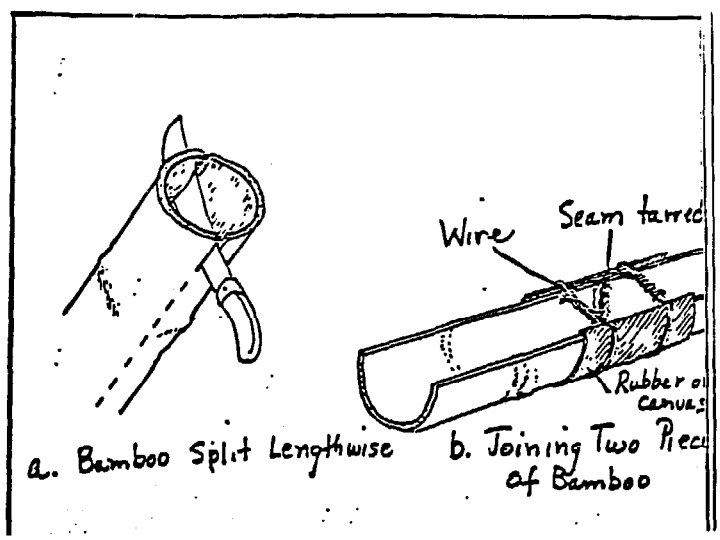

Institute for Rural Water, 1982 (draft), by permission

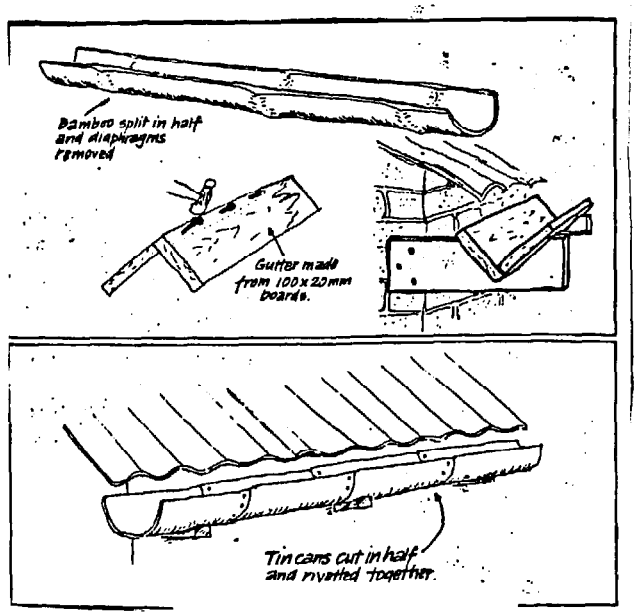

Basics, October 1978, page 4

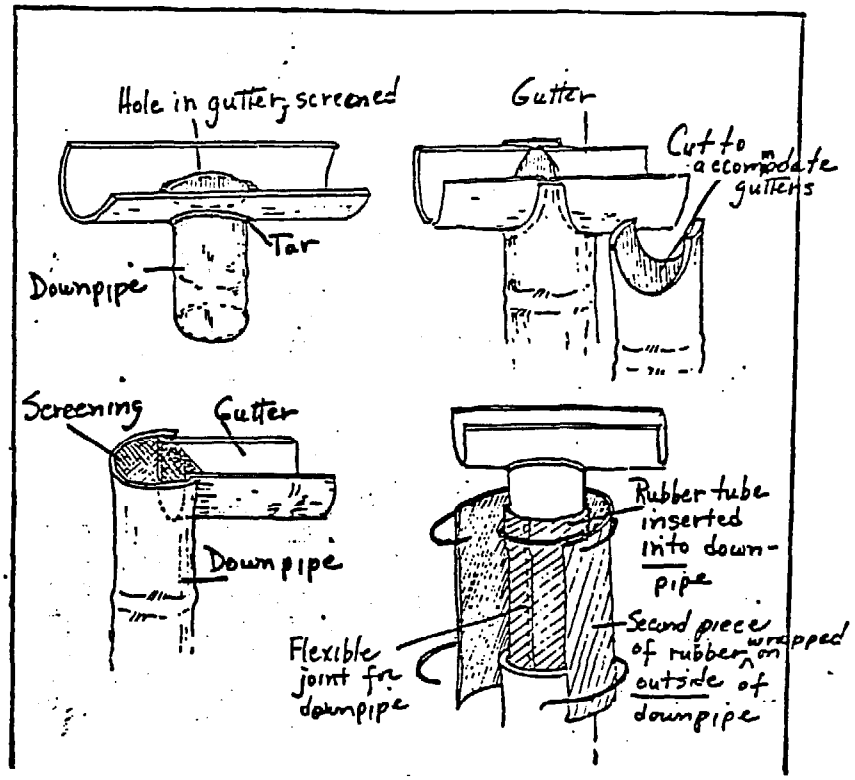

Joining Gutters and Downpipes
(Institute for Rural Water, 1982, by permission)

sealed with tar, pitch, or some local gum. Institute for Rural WAter (1982; see section 3.2.4) provides good ideas for joining sections of bamboo guttering with iwre and some flixible sheet material such as rubber or canvas, and joining gutters and downpipes with similar materials (see figures). Institute for Rural Water also suggests hanging gutters with twisted wire or local fiber, wrapped around the gutter and tied to holes in roof sheeting or to the ends of roof supports (see figure below).

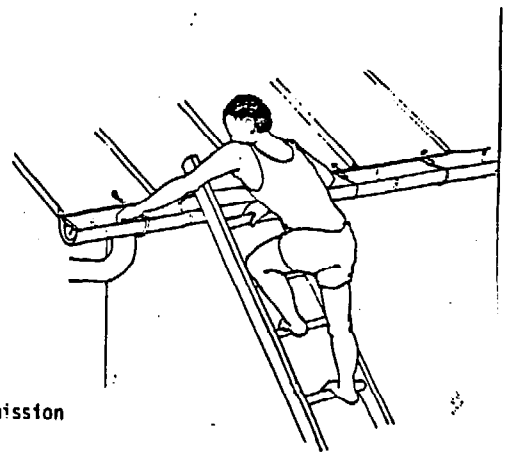

INstitute for Rural Water, 1982b (draft), by permission

3.2.3 Diverting the "foul flush"

The crucial importance of some routine or technique for keeping dirty water, flowing off a roof at the beginning of a storm, out of the stroage tank has been discussed above in section 3.1.4. In general, there is more to be gained by devising an effective "foul flush" method than by investing in filters, which clog and contaminate quickly (e.g. Midwest Plan Service, 1979). There are two kinds of foul-flush devices, those which require the flow of water to be switched manually from waste to the tank after the appropriate interval, and those which are "automatic".

Manual systems. Usually lower in cost and easier to devise, these will be the obvious choice in most poor areas. An attractive and simple approach is to attach the downpipe so that it can be propped in the "waste" position, then propped in the tank inlet after the roof is clean. Open trough downpipes like split bamboo can be suspended beneath the outflow of the gutter with wire or local fiber; closed downpipes with a flexible joint can be moved in the same manner (see figure below).

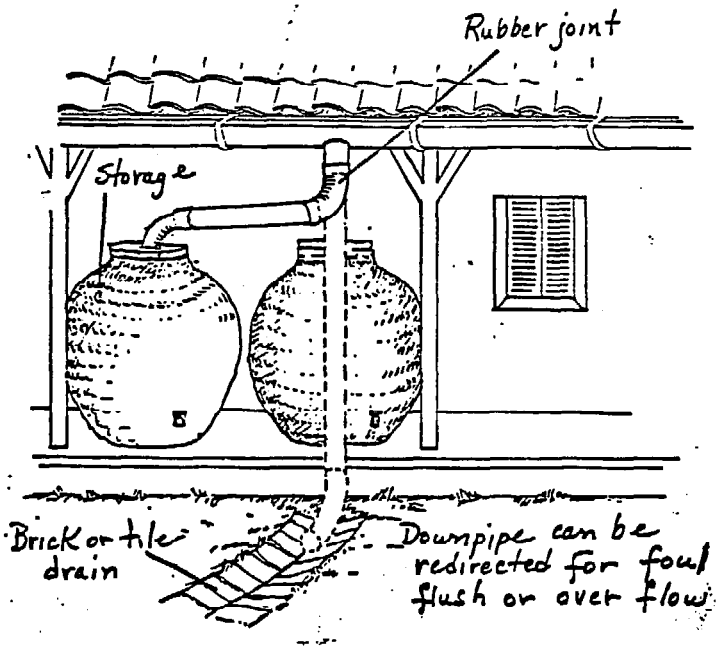

INstitute for Rural Water, 1982 (draft), by permission

The task of moving the downpipe can be performed consistently by a child; people in developing countreis tend to be conscious of the precise moment fo the start of rainfall because drying laundry must be brought under shelter.

Another simple technique for tanks with small covers is to leave the cover on, blocking the flow of water into the tank, until the roof is clean. A similar approach (for very small containers like jars) is to move the container into position under the downpipe only after an appropriate interval. Both these routines may be objectiona ble from a public health point of view: they cause mud and pools of standing water at the tank. Nevertheless, they may be the method of choice where a more complex downpipe and foul flush arrangement is impracticable.

Bypass valves built into metal downpipes may be an option in some areas. Often referred to as "butterfly" valves, they require sheet metal working capability, and thus would be expensive or impossible to fabricate in many situations. It might be possible to devise a similar valve for downpipe arrangements made of other materials, but a movable downpipe will probably be the cheaper, more functional alternative.

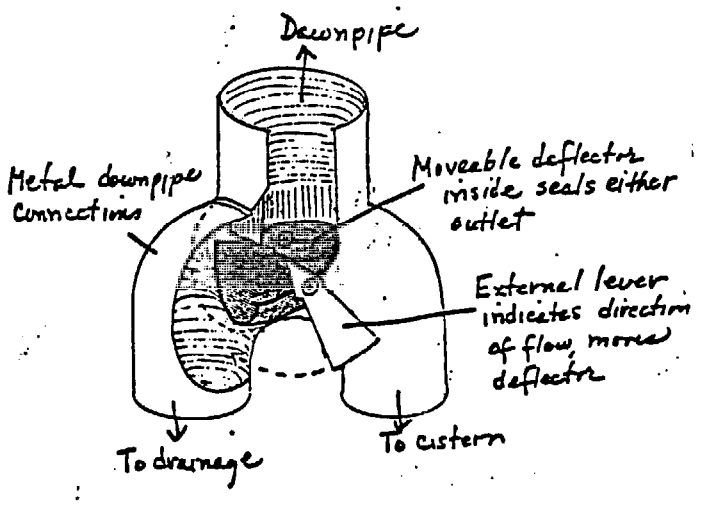

Institute for Rural Water, 1982b (draft), by permisssion

Automatic systems. Automatic roof cleaning devices are available commercially only in a few areas, but they may be fabricated from local materials in some situations. One simple automatic device is a container or receptacle for dirty water called a "roofwasher" (Midwest Plan Service, 1979; see figure below). After the roofwasher receptacle fills up with the foul flush, water begins to overflow into the storage tank. A screen is usually attached between the downpipe and the foul flush container as shown in the figure to keep our leaves and other large pieces of debris that would float on the water

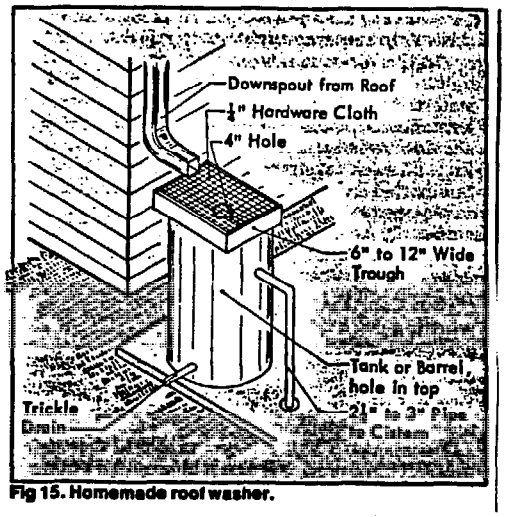

Fig 15. Homemade roof washer.

Midwest Plan Service (1979) by permission

in the receptacle and clog the overflow pipe to the tank. Oil or fuel tins, used for hauling water in many areas, might be converted to roofwashers. Midwest Plan Service (1979) recommends about 10 liters of roofwasher receptacle capacity for every 30 m^2 of building area. Other sources (e.g. Dooley, 1978) say a roofwasher should be big enough to hold the first 20 minutes of runoff.

A problem with such a simple device is that when the beginning of a rainstorm is torrential, water will pour vigorously into the roofwasher from the downpipe, stirring dirt and bird droppings so that they are carried through the overflow pipe into the tank instead of settling at the bottom of the receptacle. Modification: a baffle mounted crossways, inside the roofwasher to inhibit this stirring action, and/or a vertical screen dividing the

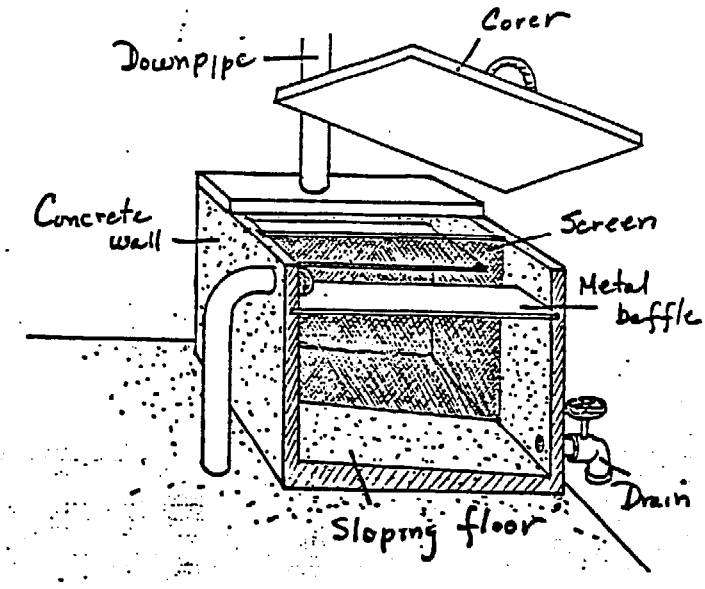

Institute for Rural Water, 1982
(draft) by permission

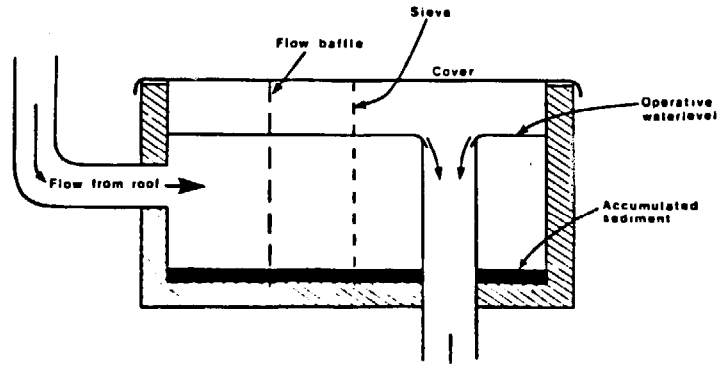

UNEP (1979)
by permission

downpipe side from tank inlet side (see figures above). Roofwashers must have a drain and removable cover so that they can be cleaned after each rain.

More complicated "automatic" foul flush devices tend to require more attention and stronger structures with more hardware for mounting in the downpipe. Reported in use in Australia, "swing funnels" are made of sheet metal, with a large inflow side divided into two compartments, and hinged on a horizontal pin (see figure below).

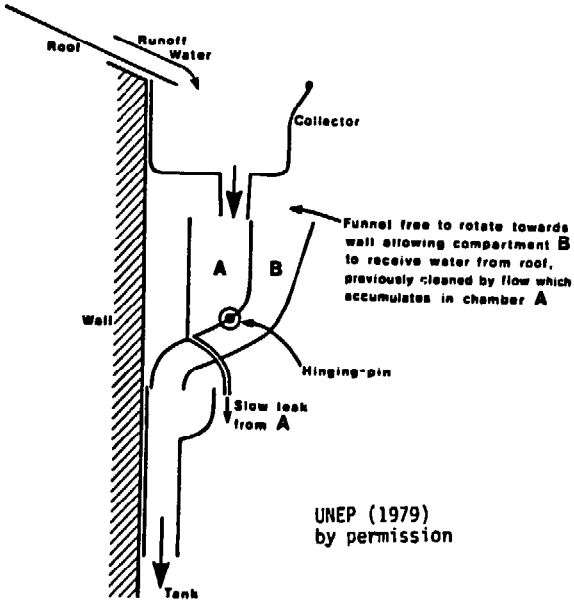

UNEP (1979)
by permission

At the start of a storm, water pours from the gutter into the first compartment. As the weight of the assembly increases, the funnel swings so that water pours from the gutter into the second compartment which leads through the downpipe into the tank. Such a funnel would have to be quite large to hold the recommended volume of foul flush. Mounting and hinge-

pins would also have to be quite strong. This particular device is unlikely to be the most attractive of foul flush options in most places, but it is an interesting idea.

3.2.4 Publications and how to obtain them

Frasier, G.W., ed., 1974, Proceedings of the Water Harvesting Symposium, Phoenix, Arizona, March 26-28, 1974, Agricultural Research Service/USDA report no. ARS-W-22, 323 pages, currently out of print. Request infomration from the editor, Southwest Rangeland Watershed Research Center, 442 East 7th Street, Tucson, Arizona 85705, USA.

A wide-ranging compilation of 40 papers and reports on rainwater harvesting. Much of the material is quite technical and most of it concerns development of systems for agriculture. It is , however, a fine overview of the specturm ov developments in ground surface catchment. Of particular interest: "Engineering aspects of water harvesting research at the University of ARizona" (Cluff, 1974, pages 27-39) and "Storage systems for harvested water" (Dedrick, 1974, pages 175-191).

Hall, N., 1981, "Has Thatch a Future?", Appropriate Technology, London, Vol. 8, no. 3, December 1981, pages 7-9, £ for the issue with Air Speeded Post from Intermediate Technology Publications, Ltd., 9 King Street, London WC2E 8HN, United Kingdom.

"Thatch is currently out of favour almsot everywhere. It is veing replaced by modern sheet materials or expensively manufactured tiles. However, as the essential ingredients of modern building become more and more costly with the rising price of raw materials and the fuel required to process them, it is undoubtedly worth re-appriasing traditional materials." The author, who is studying thatch and has found little information available on the topic, presents a concise summary of thatch grass types and methods of thatch ing roofs, highlighting Balinese "prefabricated" techniques. No mention of guttering thatch roofs for rainwater catchment.

The author's address: Open University, Walton Hall, Milton Keynes, Bucks, United Kingdom.

Institute for Rural Water, 1982, "Constructing, Operating, and Maintaining Roof Catchments". Water for the World technical note no. RWS.1.C.4, USAID, request from the Development Information Center, Agency for International Development, Washington, D.C., 20523 USA.

A good overview of simple rooftop catchment systems, discussion roofing and gutter installation, foul flush disposal, and maintenance. ABout 4 pages of text, the remainder figures, several of which are reproduced with permission above.

Request "Evaluating Rainfall Catchments (RWS.1.P.5), "Designing Roof CAtchments" (RWS.1.D.4), "Designing a Household Cistern" (RWS.5.D.1), and "Constructing a Household Cistern" (RWS.5.C.1_), from the same source.

I.T. Building Materials Workshop, "Production and Installation of Corrugated Roof Sheet made from Fibre REinforced Cement: Basic Operating Manual for Honduras and Guatemala", 19 pages, request from I.T. Building Materials Workshop, Corngreaves Trading Estate, Overend Road, Larley, West Midlands, B64 7DD, United Kingdom.

Describes, in good detail and with excellent line drawings, the tools, sheetmaking table and molds, and techniques for FRC sheets outlined in Parry (1981, below). "This manual describes the basic production and application techniques for the roofing products. Modifications have been incorporated to suit local circumstances in Honduras and Guatemala...The document is intended as a namual for the assistance of groups who are already in possession of the

Ideal Deployment of Sheetmaking and Curing Equipment

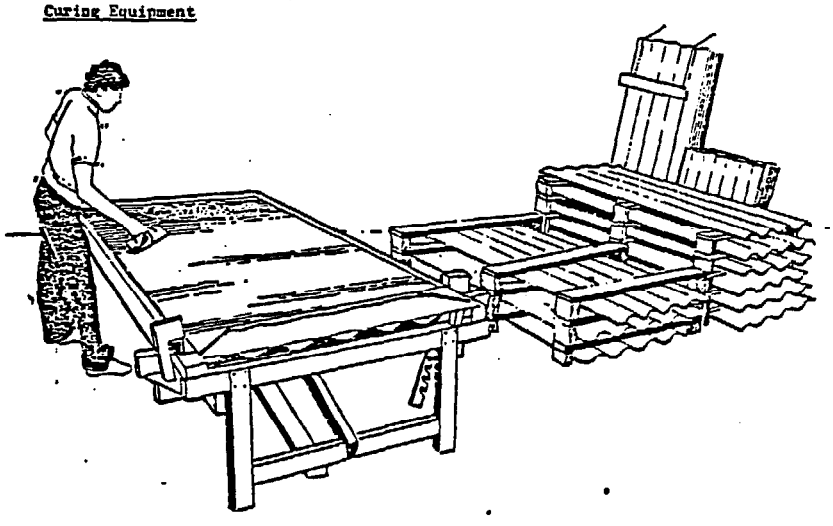

I.T. equipment to make corrugated roof sheets and ridge tiles, and have received first hand training from an experienced operator".

NAS, 1974, Roofing in Developing Countries: Research for New Technologies, book, 57 pages, give name of group or institutional affiliation when requesting a free copy from BOSTIC (JH215), Office of the Foreign Secretary, National Academy of Sciences, 2101 Constitution AVenue, Washington, D.C. 20418, USA.

A useful overview of the range of possible low-cost roofing materials relying on local materials and/or new techniques. Includes appendices on low-cost roofing research in India.

Parry, J.P.M., 1981, "Development and tEsting of Roof Cladding Materials Made from Fibre Reinforced Cement", Appropriate Technology, London, Volume 8, no. 2,September 1981, pages 20-23, £ 1.50 for the issue and Air Speeded Post from Intermediate TEchnology Publications Ltd., 9 King Street, London WC2E 8HN, United Kingdom.

A summary of the I.T. Building Materials Workshop findings on fibre-reinforced cement sheeting for use in the manufacture of roofing components. "The final outcome of the development work was a complete low-cost roofing system involving a new corrugated cladding panel which has the coverage of a one metre sheet but which is fitted like an extremely large but lightweight tile." Manufacturing processes for implementation on a small scale in developing countries (see I.T. Building Materials Workshop, this section) are outlined. The author believes that FRC sheets were being made at the combined rate of about 2,000 a month by several production teams in at least seven countries in April 1981. Cost and roof structure requirements comparisons are made with coventional materials; cost advantages hinge on the lifetime of the new sheets: "only time will tell the eventual lifespan of the FRC products, but the development has now reached the point where it can be considered as a viable alternative to conventional materials and one which is especially appropriate because of its facility to be produced labour-intensively, on a small scale, in virtually any urban or rural situation."

3.3 Storage Technologies or "Tanks"

3.3.1 General considerations

As has been noted in other sections, the water storage facility or "tank" is usually the most expensive part of simple RWH systems, and at the same time the most difficult to construct so that it will perform satisfactorily over a long period. An adequate tank must not leak; it must be structurally strong enough to support thegreat load of the water it will hold; and it must be covered, to keep out sunshine, dirt, insects, and (if the tank is buried) dirty surface water.

As far as users are concerned, the tank is also the focus of the system; it is usually both the storage and distribution point, requiring cleaning and maintenance to ensure both these functions.

In fact, a tank which addresses storage needs and performs well is the key to a rooftop catchment system. It is for this reason that this section on tanks is the bulkiest part of this report.

Tanks can be categorized by their applications into three groups:

1. tanks used with individual household rooftops, mostly above ground
2. tanks used with larger rooftops or several rooftops--community centers, schools, etc; above, partially buried, and below ground.
3. tanks used with surface catchments.

Within each of these three groups there are many different kinds of tanks, each with its own construction methods, materials costs, and labor requirements. Each of these factors, along with the capacity needed (see technical note on using rainfall data to design a RWH system, section 4), enters into decisions about

what kind of tank to build. These key aspects of tank designs are described as fully as space permits in the subsection below; see also section 3.1.3 on costs and the technical note on section 4 on costs of materials. Here, a few general comments about choice of tanks design will be made.

The tank's function--as an individual household source or source for a group of families--is probably the single most important determinant of tank sizing and design. This choice can be made only in close consultation with the people who will build and use the tank; without their participation growing out of genuine support for the idea, a tank-building effort has little prospect of success. In their comments on the slow progress of open tank construction for irrigating school gardens in Botswana, Farrar and Pacey (1974) note:

"In any community where a tank programme is contempleted, it would seem important to enquire into the 'felt needs' of the people. To which category of water use do they give highest priority?

a) drinking water: for home or school use?
b) washing water
c) water for gardens: again, at home or at school?

In most parts of southern Africa, water for school gardens would be given the lowest priority."

Whether to build an above-ground tank or an excavated (underground) tank deserves considerable thought. Watt (1978) notes,

"Storing water in tanks built on the surface has many disadvantages when compared with storage tanks excavated into the ground. Besides avoiding the need for laborious excavation which is almost impossible in some hard dry soils, the tanks can be observed for leaks and easily repaired by trowelling a layer of mortar onto the inside of the empty tank. In addition, although the stored water is likely to become hotter in the sun, the risks of polluted material falling into the tanks are reduced. Water stored above ground can flow out under its own weight whereas it has to be pumped out of a ground tank."

The main advantage of underground tanks, on the other hand, is that the earth supports the tank lining and contents, making it possible to build deeper tanks with thinner walls. This means that building materials can be conserved and used to make leakproof wall surfaces instead of structural wall reinforcement.

Underground tanks do not always require a pump. Figures in Section 3.3.3, (below) shows how a concrete block tank supported with earth embankments can be fitted with a tap.

Larger tanks require fewer materials per unit of water storage capacity than smaller tanks, which tend to give them a cost advantage. Constructing smaller tanks, though, tends to require less expertise and preparation, fewer tools, and less cash "up-front". Large tanks may bring with them structural problems; for example, large areas of flat plastered wall are more vulnerable to cracking than smaller walls (e.g. Maikano and Nyberg, 1980). Thus, in many cases smaller tanks, or groups of smaller tanks, will be chosen in preference to a single larger one.

Different kinds of tanks demand different standards of workmanships in construction. Ferrocement and other tanks made with mortar plaster will crack and leak if mortar is not made with clean components in proper proportions, and applied properly to the reinforcing framework. A prototype made by people who have never made one before may not perform satisfactorily; a failure should be planned on or experience sought.

The walls of underground tanks must be built carefully, especially if they are of brick or masonry. Cairncross and Feachem (1978) say these tanks should only be built by an experienced builder (and indeed, local masons should always

be involved). Individual Water Supply Systems (Office of Water Programs/EPA, 1974) emphasizes the importance of high-quality workmanship and recommends against "unskilled labor". Bricking, plastering, and curing are all part of a tank with a long life which will not leak.

3.3.2 Tanks used with individual household rooftops

Recycled, used containers. A wide variety of locally-available containers can be used to catch water flowing from guttering or sim ply dripping off the edge of roofing. White et al (1973) dscribe the use of steel petrol drums with one end cut out in West Africa (see picture at the front of this report). These drums hold about 0.17 m^3 and cost about US $2.50 (1969); they can be covered with a board and a rock. Watt (1975) notes that Thais collect rainwater from roofs in large pottery jars. He reports a price of about US $5.00 (1975) for a 0.3 m^3 jar.

Cement mortar jars. Apparently first devised in Thailand (Watt, 1975), these jars have been enthusiastically built in other parts of southeast Asia and Africa (McDowell, 1976). Cloth sacking filled with rice hulls or some vegetable waste is used as a jar-shaped mold, onto which cement mortar is plastered. McDowell (1976) says that jars can be constructed with capacities up to 3 m^3 using this method; the author has seen prototypes of even larger models, made with soil-cement, in Java. A great attraction of this method of storing rainwater is its low cost. Watt (1975) reports materials costs of US $0.50 per 0.25 m^3 jar; that entire sum is for cement.

Most jars of this type are apparently made in the size range of 0.15-0.5 m^3, as larger jars lacking reinforcement tend to crack where the wall meets the base. See section 4 for Watt's instructions on making a 0.25 m3 jar.

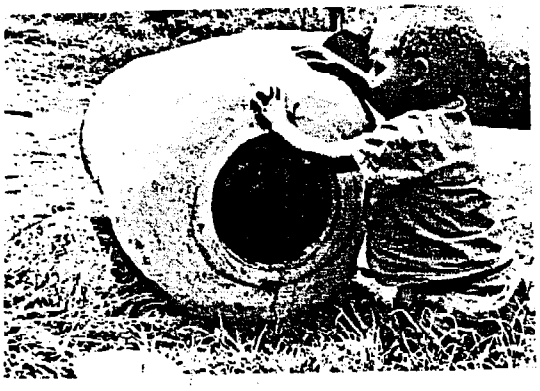

cement jar

McDowell (1976)
both by permission

plastered basket

Jim Bell (personal communication) reports on a variation of this method for making water jars of about the same size widely practiced in Liberia. A hole, the shape of the jar is excavated in the soil: wire netting ("chickenwire") is pegged to the walls of the hole, which are then plastered with cement mortar. After the jar has cured, it is dug out of its earthen "mold".

Traditional baskets plastered with cement mortar. Originating in Thailand, this technique has been used to build hundreds of tanks in Kenya, Burundi, Rwanda, Swaziland, Tanzania, Lesotho, and Zambia. The usual technique is to plaster a granary basket which is set into a cement or concrete foundation.

"In Kenya, the basket frame is made from sticks cut from woody shrub which grows throughout the country. In Rwanda and Burundi, the frame is made from bamboo, presumably provided that the material is strong, the basket could be made from any number of shrubs or sticks which can be woven into basket form. The basket is constructed on the ground by weaving the sticks into round shapes. The actual shape does not seem very important, but it is recommended that the bottom be omitted so that the sides can bond with the base" (UNICEF, Eastern Africa Regional Office, 1982).

Apparently tanks up to 7.5 m^3 in capacity have been constructed by reinforcing the basket frame with bands of straight wire or wire mesh. The more common size, requiring no metal reinforcement, is about 1.5 m high and has a capacity of about 2.3 m^3. Assuming a cement price of $7.14 per 50-kg bag, (rural Zaire, 1981), and allowing about 20% of total materials costs for sand, gravel and outlet pipe, a 2.3 m^3 tank of this type could be built for about US $42.00 (1981). See section 4 for detailed notes on construction as carried out using a "Ghala" basket in Kenya (UNICEF East AFrica Regional Office, 1982).

Cast concrete ring tank. Relying on thin unreinforced concrete rings, poured between concentric steel forms, these tanks have been promoted by the Thai Ministry of Health for use at schools in a country where many buildings in rural areas have galvanized sheet metal or tile roofs (Watt, 1978 b). The rings, which are about 1.5 m in diameter and 0.6 m high, can be stacked to give tank capacities of up to 7 m^3. Watt estimates materials costs of US $40.00 (1977) for a tank of this size, not including the cost of the forms. Watt points out that forms could be used again and again in a tank construction project and suggests central production of the rings under skilled supervision. The cured, high-quality rings could then be transported by truck to the tank location for placement on their concrete foundations.

Brian Grover (personal communication) reports that the Thai Ministry of Health and the Population Development Association of Thailand, in collaboration with the U.S. Peace Corps, are building similar tanks with bamboo staves cast into the rings for reinforcement.

Ferrocement tanks. These tanks are built using a techniques in which cement mortar paste is applied by hand to a reinfocing wire mesh. "True" ferrocement has much more steel reinforcement than called for in the tanks described here. Still the principle is the same: metal reinforcing strands distribute loads evenly through the cement mortar, preventing the cracking that would occur in unreinforced materials of similar thickness (Office of the Foreign Secretary/NAS, 1973). Tank walls 4 cm thick are strong enough to hold 2 m depths of water above ground. Thus walls require much less total material than conventional concrete walls. (Briscoe (1981) notes that ferrocement tank walls do not necesarily require less cement than concrete walls.)

In his handbook for field workers (Watt, 1978, Ferrocement Water Tanks and Their Construction, see section 3.3.6 below), Watt notes:

"The main advantages...of this material over other tank construction materials, such as galvanized corrugated iron, are its cheapness and easy working using the minimum of expensive materials, equipment and skills. It is, in addion, very durable. Some of the tanks described in the manual have been inconstant use for over 25 years with only a few instances of failure--due in the main to poor workmanship in construction."

Watt goes on to say that ferrocement techniques are particularly suited for low-income rural areas because 1) they use commonly available materials (cement, sand, water, and wire); 2) only simple skills ar needed: "...untrained people can make satisfactory tanks after only a few days supervision..."; 3) users of the tanks can help in construction; 4) only simple hand tools are required.

Clearly an important advantage of ferrocement tank construction is that it can be taught and learned readily. Early development of these techniques was done at the Friends Rural Training Center, Hlekweni, near Bulawayo, Zimbabwe. Roy Henson of the Center reports training of a half-dozen craftsmen and construction of 210 9 m^3 tanks in Matabeleland in 1971-72 (Farrar and Pacey, 1974). At the Asian Institute of Technology in Bangkok, trainings are held for field workers fromn developing nations who, in turn, train local craftsmen in the techniques. AIT-trained field workers in Central Java make modified ferrocement tanks and have begun using woven bamboo staves to reinforce smaller tanks. They and their trainees have reportedly built 1,400 tanks up to 10 m^3 in capacity (Winarto, 1981). And in West java, two separate programs are planned to construct a total of 650 tanks made using the Central Java techniques (Pompe et al, 1982).

Ferrocement tanks are typically built one of two methods. In the first layers of wire netting ("chickenwire") are attached to a grid framework of 6 mm (or larger) steel rod. Mortar is trowelled directly onto this framework from the outside (Sharma and Gopalaratnam, 1980) or against a sheet of woven bamboo mat

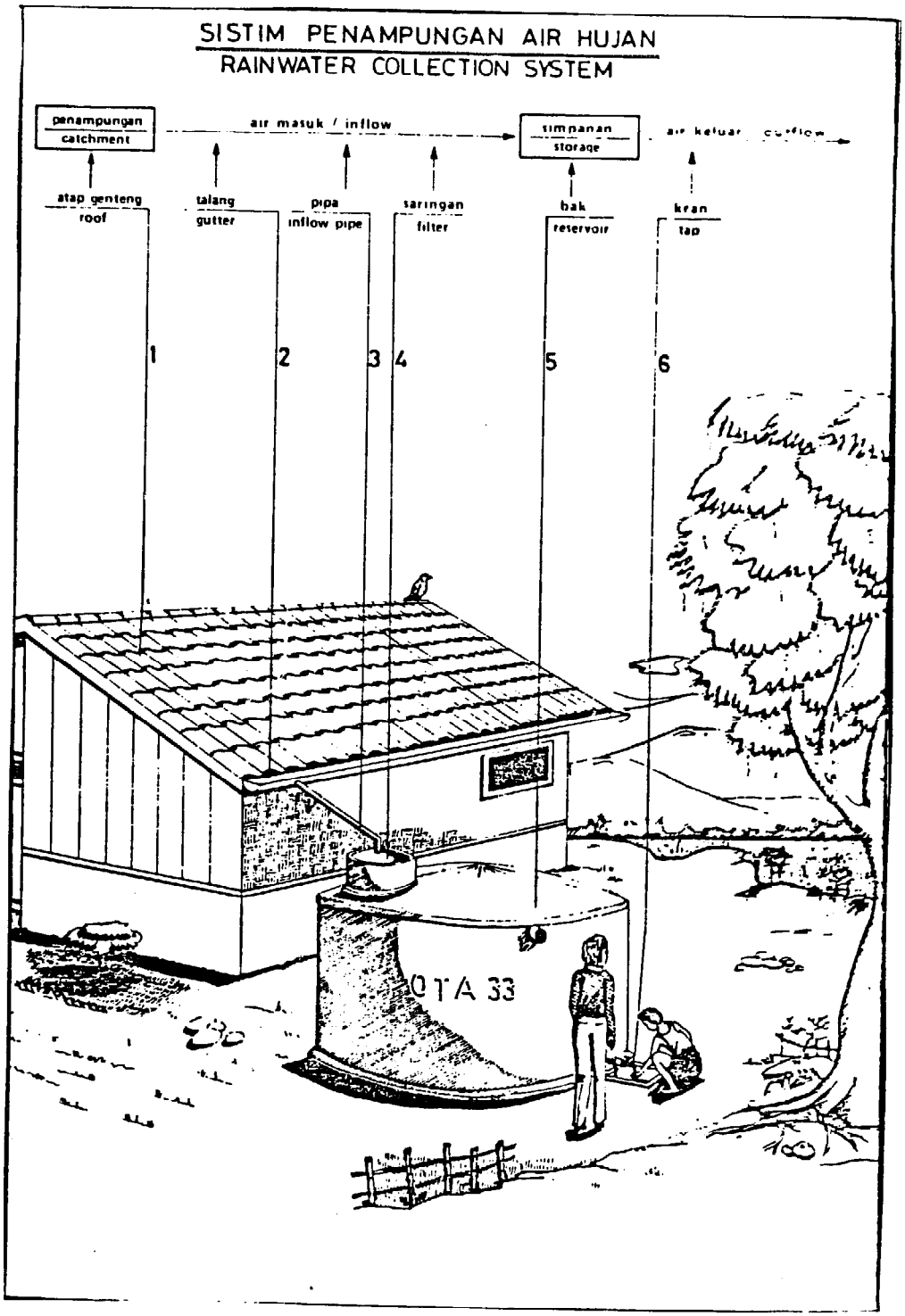

Ferrocement tank installation in Java
Pompe et al, 1982 , by permission

tied temporarily against the inside of the framework wall to act as a "form" (Winarto, 1981; Pompe et al, 1982). When reinforcing the vertical rods are continuous from the floor through the wall and into the cover, cured tanks can be moved on makeshift rollers. The materials costs for a 1.2 m^3 tank of this type with integral floor and cover were estimated at US $33.00 (Thailand; Sharma and Gopalaratnam, 1980).

In the second construction method, no reinforcing framework of steel rods is used. Wire netting and plain straight wire are wrapped around a sturdy inner cylindrical form and plastered with thin coats of cement mortar (Watt, 1978; Watt, 1977; Farrar and Pacey, 1974; see Ferrocement Water Tanks and Their Construction, and "Catchment Tanks in Southern Africa: A Review", section 3.3.6). Like tanks with steel rod reinforcement, these tanks are installed on a concrete foundation; but unlike them, they must be built in place. Materials costs are usually substantially less than for tanks of the first type because a single layer of wire netting and plain wire cost less than the steel rod framework. Assuming a cement price of US $7.14 per 50-kg bag, wire netting price of $1.00 per m^3 tank described by Watt (his construction steps are presented in section 4) could be built for about $150.00. Similar tanks of 9 m^3 capacity built at the Friends Rural Training Center, Hlekweni, cost $62.50 including gutters (1973, Zimbabwe; Farrar and Pacey, 1974).

These costs do not include money spent on materials for the cylindrical inner forms around which the wire and netting are wound. Calvert and Binning (1977) report using mats woven from wood and bamboo, pitpit, or wildcane for forms in the New Hebrides. However, the forms recommended by Roy Henson and Watt, made of sections of corrugated iron sheet roof bolted together make it much easier to plaster to a uniform wall thickness and build consistently good tanks. If

FIGURE 9 A paste of mortar is forced into the layers of mesh by hand . . . (Smith Kampempool, Applied Scientific Research Corporation of Thailand)

FIGURE 10 . . . or trowel. The mortar is dry enough to remain in place when applied; a formwork is not needed. (Noel D. Vietmeyer, National Academy of Sciences)

Office of the Foreign Secretary/NAS, 1973
by permission

corrugated iron sheeting costs US $2.20 per m_3, this kind of form for a 10 m^3 tank would cost $50.00 plus costs of angle iron, hardware, and fabrication. The form will, in some areas, cost as much as the materials for one tank. However, the form is portable and can be used to build many tanks. Where a large number of tanks are to be built in one area, this technique should be considered.

In New Zealand, ferrocement water tanks are manufactured by a number of firms using method similar to those described by Watt. With a welded grid of 10 mm rod in the floor, tanks with capacities of 0.7 m^3 to 18 m^3 are portable (hauled from factory to farms in trucks) and often guaranteed for 25 years (Office of the Foreign Secretary/NAS, 1973).

Manufactured "Tin" or corrugated sheet metal tanks. These tanks have been used for many years in many areas. Farrar and Pacey (1974) report that in parts of southern Africa, most foreigners have "tin" tanks alongside their homes. The costs of these tanks are high and extremely variable, depending on distance from point of manufacture. Farar and Pacey give the cost of a 9 m^3 version as US $112.00 (1973, Zimbabwe); White et al (1973) say that "tin" tanks of 1.4 m^3 capacity cost $39.00 to $84.00 in East Africa (1972). The corrugated metal from which these tanks are fabricated may not last longer than 5 years in a damp climate, even then galvanized. Calvert and Binning (1977) report that in the salt-laden atmosphere of New Hebrides, 16 gage tanks fail after 3 or 4 years.

3.3.3 Tanks used with larger rooftops or several rooftops

Underground ferrocement tanks. Most tanks of this type are basically an earthen pit lined with wire-reinforced mortar. As with other underground tank designs, structural strength is provided by the confining earth walls, meaning that the ferrocement lining can be made only a centimeter thick. A further

advantage of these tanks is that their construction requires neither the steel rod framework nor forms needed to build aboveground ferrocement tanks.

Calvert and Binning (1977; see "Low Cost Water Tanks in the Pacific Islands", section 3.3.6) describe an innovative design complete with reinforced cover, 3.5 in diameter and 2 m deep, volume 15-20 m^3. First a circular concrete foundation or "footing" is poured; soil from the footing trench is used to make a gently sloping earthen dome in the center of the circle. A 5 cm layer of cement plaster reinforced with wire netting and steel rod is laid over the dome, and two 0.6 m holes were left near opposite edges. After this forrocement dome cures, digging begins through the holes and the tank is excavated beneath. 2 layers of wire netting are used to strengthen the plaster applied to the earth walls.

The authors believe that these tanks should not cost more than about US $250 (1976, New Hebrides). They suggest that the design is suitable for "collecting a village's water supply drained from the roof of a large public building." While fabrication of cover which will not crack may require some experimentation, the approach seems promising. Maikano and Nyberg (1980) report trails of similar covers for underground tanks in Botswana.

A ferrocement-lined underground-grain storage bin suitable for storing water has been documented in the Harar Province of Ethiopia (Office of the Foreign Secretary/NAS, 1973; Sharma et al 1979; see Ferrocement; applications in developing countries and "State-of-the-art Review on Ferrocement Grain Storage Bins", section 3.3.6). Traditional grain pits, conical in shape with sides sloping inward to a narrow mouth at the surface, are lined with plaster reinforced with wire netting and given a concrete floor. A small cover is needed, and provision made so that surface water will run away from the mouth of the pit. Ferrocement linings have been installed in pits of this type with depths of up to 3 m and floor diameters of 4 m.

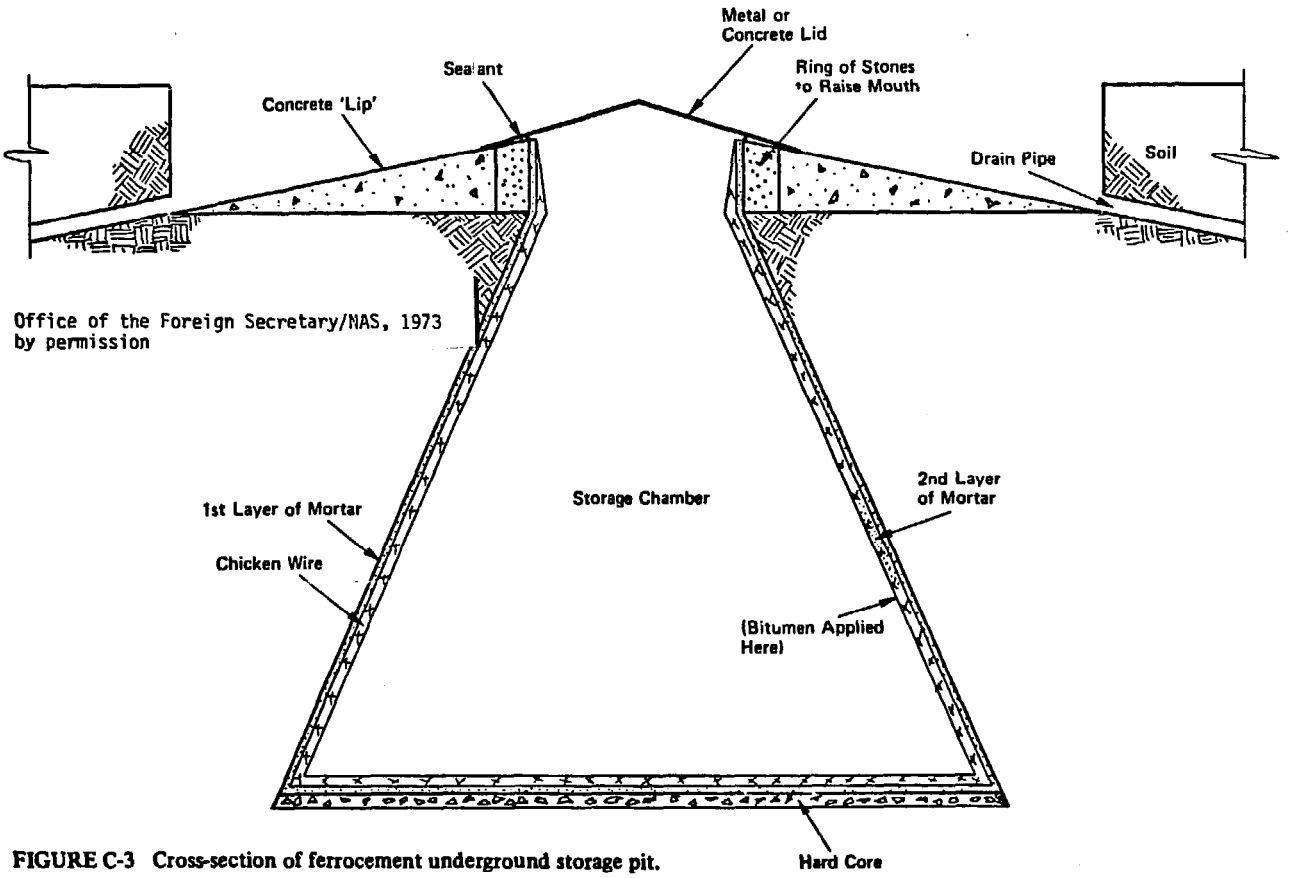

FIGURE C-3 Cross-section of ferrocement underground storage pit.

Soil type will affect smoothness of earthen walls and the ease with which plaster can be applied to the sides of an excavation. Calvert and Binning (1977) say that their tanks should be dug out in "soft" soil. Sharma et al (1979) say that traditional grain pits have been lined successfully in all the major soil types of the Harar province of Ethiopia.

The linings of traditional dogon granaries with ferrocument pioneered by Hans Guggenheim and described by Watt (1978), represents an interesting above-ground version of the Ethiopian scheme. Existing adobe-brick granaries, about 2.4 m high and 2.6 m in diameter, are lined with plaster reinforced with wire netting and covered in the Traditional manner with timbere-reinforced adobe. The flat roofs of the adjacent houses are already equipped with water spouts to drain the torrential (if infrequent) rains. The system seems to be an extremely inexpensive and elegant way to provide a rooftop catchment system with storage capacity of about 13 m^3. Clearly only very sturdy adobe walls would be suitable; Watt noted that trouble can begin when adobe walling begins to erode in the rain.

Buried and partically buried brick and masonry tanks. Stones and bricks have been used all over the world to build structures to hold water. Stones or bricks laid with mortar have great strength under compressive loads, but lask strength to resist loads from the side. This means that the lower parts of walls in deep tanks, where the water pressure is greatest, tend to buckle outward if they are not built strongly enough. This fact, in turn, is the principal motivation for buying (or partically burying) this type of tank: the deeper parts of the walls are supported by earth. Brick and masonry tanks when covered properly also tend to keep water cooler than above-ground tanks, and can be built in to a basement or share a foundation wall.

Buried brick and masonry tanks have their disadvantages, however. Cracks and leaks, which allow stored water to escape and contaminated ground and surface water to enter are harder to detect and in many cases harder to repair. If a pump is used to raise water, the tank must be fitted with a strong (and expensive) cover that will bear human traffic safely. A pump, in itself, may bring with it serious maintenance problems.

A wide variety of shapes and sizes is possible. Rectangular tanks are easy to design and can be readily incorporated into a building. Circular and elliptical tanks require less wall surface (and hence less material) per unit volume of storage capacity. The walls of circular and elliptical tanks are also stronger, and there is a shorter zone of weakness where mortar cracks are most likely to develop along the line where the wall meets the floor (Maikano and Nyberg, 1980; Cairncross and Feachem, 1978; see Small Water Supplies, section 3.3.6). Cairncross and Feachem say, in fact, that stone and masonry tanks more than 2 m acorss should be circular.

We have found few accounts of brick and masonry tanks in use, probably because their construction is nothing new or noteworthy. Wright (1956) shows a drawing of an underground tank "...walled up with stone or bricks and mortar and plastered with cement mortar".

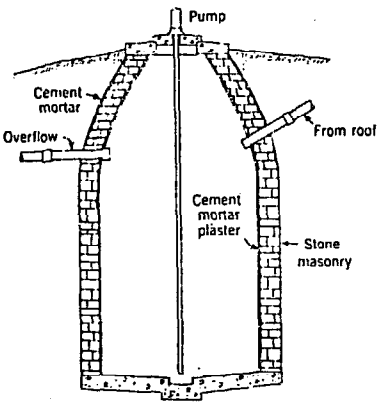

Wright (1956) by permission

In Sou thern Africa, "...the occasional large buildings in rural areas--schools, churches, halls, etc.--can provide a water supply to the community on about the same scale as that from 'beehive' tanks (45-90 m^3, see section 3.3.4 below, ed.)...Four or five 9,000 liter tanks would be needed for many school buildings, though a more usual method of providing this capacity is to build a single large tank of concrete blocks. The difficulty is that tank walls built in this way are ill-suited to resist the sideways pressure of the water, so concrete block tanks are usually built in shallow excavations with piled earth used to buttress the sides. (The figure) illustrates a tank of this kind, showing how the tap may be placed so that water can be drawn off by gravity flow."

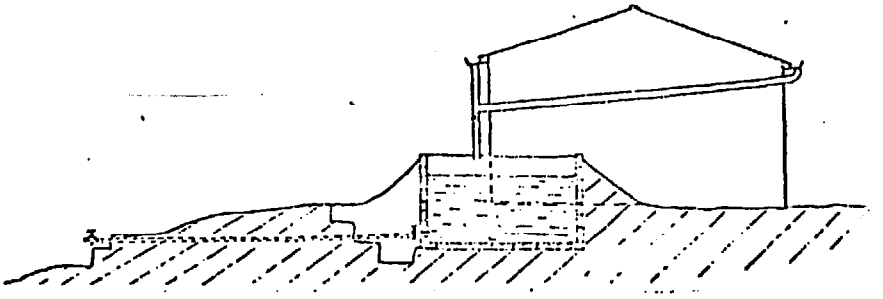

Farrar and Pacey, 1974 by permission

(Farrar and Pacey, 1974, see "Catchment Tanks in Southern Africa: A Review", section 3.3.6). In this same paper, a 71 m^3 tank of this type built in Ghana (parker, 1973) is said to have cost US $260.00 (1973). At $3.63/$m^3$ (1973) of storage capacity, this would be one of the cheaper tanks (in cost/m^3 of storage) we have seen documented.

Many of the cisterns built into the basements of residences in Bermuda, where provision for rooftop catchment and storage is required by building codes, are made of concrete block plastered with cement mortar. Volume of these cisterns varies with the size of the dwelling, but most fall within the range of 50 m^3 to 90 m^3 (John Sands, Solar Engineering Technology, personal communication).

One of the strongest arguments for considering tanks of this type is that they can readily bve designed and built into or alongside new public buildings for a relatively small increment in procurement and labor costs. See the discussion of construction details of stone and masonry tanks in section 4.

Underground concrete tanks. These tanks have been widely used for rainwater storage in the developed countries. In the United States they are usually referred to as "cisterns" and are frequently built into or alongside basements with capacities ranging from 10 m^3 to 50 m^3. Properly reinforced with steel rod, concrete is probably the strongest material for walls for water storage. It is resistant to cracking and leaking, and its cover can be cast with an inspection hole so as to effectively seal out contaminants from the surface. The great disadvantage of underground concrete tanks is their expense: they require large quantities of cement, gravel, sand, and steel; and materials for forms, and expertise in the methods, are often also expensive and scarce in rural areas of developing countries.

This type of tank or "cistern" is widely documented in literature published in U.S. textbooks on rural water supply and sanitation. Salvato (1958) and Wright (1959) describe a cistern with simple sand filters, overlapping manhole covers and hand pumps, and "butterfly" valves in the downpipe for diverting dirty water from the roof at the beginning of a rain. Both sources give simple guidelines for matching cistern size to roof area in light of the water needs of farming households in the U.S. Wagner and Lanoix (1959) give simple sizing guidelines and discuss location: tanks shjould be higher than and at least 3 m from any sewage disposal installation. They also emphasize the need to keep gutters clean and sloping evenly toward the downpipe to prevent setting water. VITA's Using Water Resources (see section 3.3.6) gives tools and materials lists, and quantitites, proportions, and procedures for constructing a cistern and sand-grael filter. (Village Technology Handbook (VITA, 1973; see section 3.3.6. gives detailed information on building with concrete. The sizing guidelines given for matching cistern volume to roof area assume that the cistern should hold a full year's water supply for the family using it. See the note in section 4 on using rainfall data to plan a rooftop catchment system.

The Manual of Individual Water Systems (Office of Water Programs/EPA, 1974), originally published by the US Public Health Service in 1950, presents the text and cross-section drawings of a cistern which are referred to an appear in Salvato (1959), Wagner and Lanoix (1959), and VITA (1973). Henderson and Smith (1973; see Planning for an Individual Water System, section 3.3.6) and Midwest Plan Service (1979) are two more recent books published by government extension programs in the US for rural applications. They give similar information on cisterns, with useful color sketches and cross-sections. Midwest Plan Service recommends against use of filters for the water from the downpipe, noting that they can

quickly become contaminated. They suggest, instead, an adequate "roofwasher" system (see the note on gutters and foul flush devices, section 4).

"Heaven's Water: in Rural Places, Cisterns Gather the Rain" (1980) is a useful presentation of the pros and cons of cistern systems as seen by users in Indiana, U.S., written for a popular audience. The users emphasize the importance of some kind of a "roofwasher" system, discussing several alternatives. This article also relates some of the potential problems with rooftop catchment systems in industrialized countries: "'Rainfall itself carries dust and even chemicals. Near Highways, there is probably a significant lead content in the air. Downwind from industrial plants, there will be a problem with pollution. You need to be site-specific with cisterns.'"

Also mentioned are cleaning solutions for yearly scrubbing of the insides of cistern walls: 3 parts vinegar to one part water; 1 kg baking soda dissolved in 8 lkiters of water. This is the only source we have seen which recommends against the addition of chlorine to water being stored in a tank, saying that it can interact with impurities to form chloroform. A chlorinator which treats the water as it is pumped to the house, or iodine solution or pasteurization, is recommended instead. Other sources recommend periodic chlorination of the water in the tank.

Dooley (1978) discusses cisterns for the rural U.S. in another popular journal. She uses chlorine bleach to disinfect cistern water and describes a chlorine level test using hydrochloric acid. Dooley also recommends scrubbing the inside of the cistern with bleach to disinfect it every two or three years.

Even in the U.S., where the materials are readily available, concrete cisterns are expensive. Dooley (1978) estimates materials costs of a 36 m^3 underground reinforced tank at about US $1,000 (U.S., 1977). Such a tank would be impossible to build in most situations in rural areas of developing countries. The discussion

of underground reinforced concrete tanks is included here because elements of their design may be useful when large rectangular tanks are built into public buildings. Wright (1959) shows a design in which one wall of a cistern is the wall of a building foundation or basement.

Wright (1956)
by permission

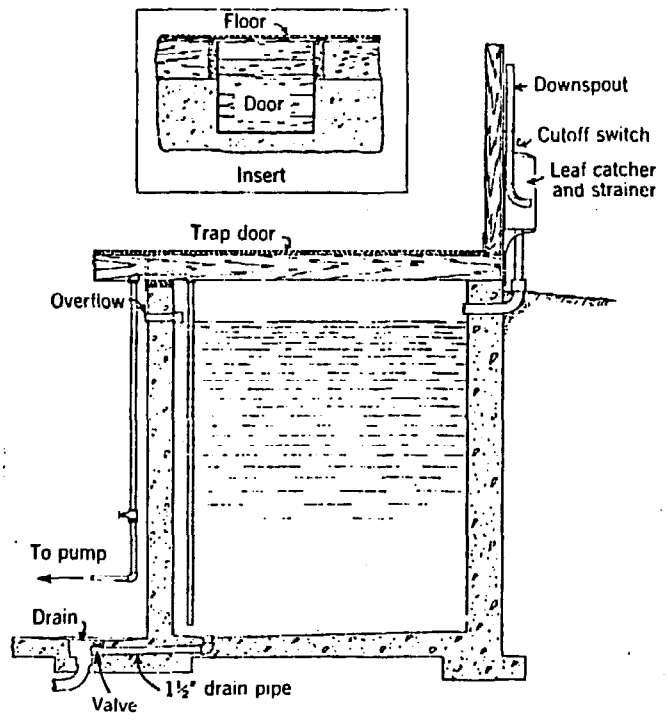

Fig. 3-27. A cistern suitable for a basement. The foundation wall serves as one or more sides of the cistern, the other walls being constructed of concrete. Note that the cistern is entirely enclosed to keep out dust and rodents and that a leaf catcher and strainer is provided on the down spout. Entrance to the cistern for cleaning and repairs may be through a trap door, as shown, or through a special door in the side between two floor sills as shown in the insert.

3.3.4 Tanks Used with surface catchments

As noted in the section on catchment surfaces, ground level catchment systems have been used primarily to harvest rainwater for irrigation, stockwatering, or some other agricultural purpose. In some situation in developing countries, rooftop catchment systems will be more attractive for domestic supply because of the reduced organization and cash reqirements of rooftop systems, not to mention problems related to acquisition of land and protection of ground-level catchment surfaces.

Nevertheless, tanks used with ground surface catchment represent a possible improvement upon the practice, established in many areas, of using water which collects in natural surface depressions. Some designs offer low materials costs per unit of water storage capacity. Additionally, some of the tanks which have been proposed for use with ground catchments might be used with a rooftop catchment instead, or used as overflow storage in combination with another, smaller rooftop catchment tank.

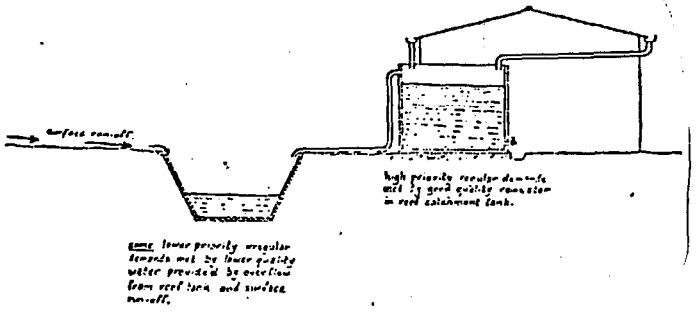

Farrar and Pacey, 1974 by permisssion

One particularly interesting scheme involves tanks used with traditional threshing floors in Botswana (Maikano and Nyberg, 1980; see Rural Water Supply in Developing Countries, section 3.3.6). The tanks are about 2 m deep, 2.5 to 4 m in diameter, and hold 10-25 m^3 of water. The first of these tanks were rectangular, but circular ones have been recommended to the pilot project because their wall area is less for an equal storage capacity, and the finished walls should be less likely to crack. Water is channeled into the tanks through a short length of PVC pipe from a shallow settling basin in one corner of floor, where some sedimentation occurs. A brick curb is built around the perimeter of the tank to keep out surface water and provide a foundation for the cover, made of lengths of tree trunk or precast concrete slabs reinforced with barbed wire. Domed cement covers, plastered over wire mesh on an earthen mold, are also being tried. These covers are allowed to cure and then lifted into place on the curb. The construction of the cover seems to be much like the method of Calvert and Binning (1977). Inside the excavation a "thin layer" of cement mortar plaster is applied on wire nett ing pegged to the sides. Again the approach seems to be much like that of Calvert and Binning (1877), who splashed a liquid cement mixture on the soil walls and plastered cement mortar onto that surface. The materials costs of the tanks appear to be fairly low: for a 25 m^3 tank, the authors estimate about US $135.00 for cement, chicken wire, and PVC pipe (Botswana, 1980). It is not clear if this amount includes the cover.

The tanks are intended to provide water for people and cattle. Maikano and Nyberg (1980) note that "The cistern will require cleaning before the beginning of the next rains. Plastering of the tank and cover may have to be done as cracks are noticed."

Most widely known of recent community rainwater harvesting schemes in Africa is, without doubt, the pilot project for providing water to irrigate school gardens in Botswana (Ionides et al, 1969). Large excavations were lined with alternating layers of polythene, mud, and "sand-sausages" (thin plastic tubing about 15 cm in diameter, filled with a mixture of 14 parts sand to one part of cement and soaked briefly in water before placement in the liner). The hardened "sand-sausage" provided low-cost wall strength and were also used to build "beehives", which were essentially well casings in tanks filled with sand in the manner of an artificial aquifer. A technical problem with the lining chosen for popularization (several configurations were considered) was building the inflow side of the tank strong enough to withstand the erosive force of rushing water during a storm. Another likely problem seemed to be rodents eating through the polythene sheet layers of the lining.

Materials costs for the sand-sausage tanks were very low: Farrar and Pacey estimeted US $75.00 for a 45 m^3 tank (1973), Botswana). The technique for lining the excavations seemed to have promise, as well. Still, the tanks have not been widely adopted. School gardens and vegetables for the children were, like the tank, ideas originating substantially from the outside. A second reason may be the great labor requirement of these tanks combined with poor nutrition, reducing peoples' capacity and enthusiasm for manual labor (Farrar and Pacey, 1974; see "Catchment Tanks in Southern Africa: a Review", section 3.3.6).

The "beehive" design, using the liner describe design, using the liner described and filled with sand to reduce evaporation (water is drawn through beehive-shaped wells), may have promise for community domestic water supply efforts: "The performance of the 'beehive' tanks that have been built has generally been satisfactory, and from a technical point of view, we would regard this type of catchment tank as a highly attractive approach to the water supply problems of semi-arid areas."

Farrar and Pacey (1974) also give a brief description of the "Water Harvester", built by the Christian CARE Organization in Zimbabwe: "The cylindrical holes are dug to about 2 meters depth, lined with brick or stone, then plastered with cement to make them water proof. Concrete lids are made to keep the water clean." The system shown uses three tanks linked underground with pipe, so that only one pump is needed. The rough estimate of the cost of these linked cylinder tanks is US $75.00 for 9 m^3 of storage (1973, Zimbabwe).

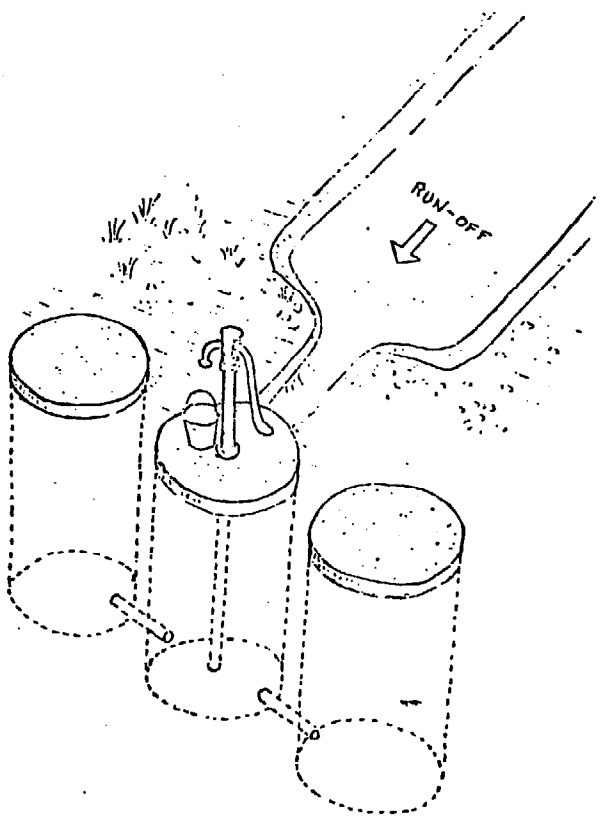

Farrar and Pacey (1974) by permission

Research into the use of synthetic asphalt, plastic, and rubber liners to water proof large excavations or "hafirs" (a traditional name for a depression where water collects during wet months in the Sudan) goes back at least as far as the early 60's. Thorsky (1961) and Ellsperman (1962) present methods for lining hafirs with capacities in the range of 7,500 m^3 with sprayed asphalt and PVC sheet. Their reports describe experimental work, and no indication of implementation for community water supply is given.

Grover (1971) supervised construction of a 270 m^3 tank excavated into coral on an island off the coast of Kenya. The tank was lined with 0.8 mm thick butyl rubber sheet. This prototype effort was sufficiently promising that Grover proposed 3 similar tanks (each with a volume of 2,300 m^3) to meet the storage requirements of a ground catchment system for the farm and domestic needs of 200 families on another coral island. These proposed tanks would have been covered with a floating sheet of the same butyl material, reducing evaporation to a negligible level. The cost of butyl (about 3.7/m^3, 1969, in Kenya) made the cost of each of Grover's proposed tanks about US $18,000 (Kenya, 1970) including pumps. The cement stabilized, asphalt---sprayed catchment surface was expected to cost an additional $15,000.

Cluff (1975) points out that evaporation of 2-3 ma/year in Mali causes existing ponds or "mares" to disappear during the dry season, and proposes constructing embankments to make deeper reservoirs adjacent to the mares. This would reduce the surface/volume ratio of the storage (reducing evaporation) and might provide enough capacity to meet the domestic water needs of groups of several thousand people. In one case Cluff proposed an 80,000 m^3 system, lined with salt to reduce seepage, and estimated that its capital cost (including the cost of earthmoving and an imported engine-driven pump to move water from the mare to the reservoirs) would be less than US $1.00 per m^3 of storage (1975, Mali).

None of these huge open tank systems has been built, but Cluff used precipitation records, local watershed characteristics, demand figures and labor costs in his analysis and proposals for several villages. His report is provocative.

3.3.5 Costs of materials, costs/m^3 of water storage

On the following pages is a tabular summary of most of the materials cost information in section 3.3. The tanks are listed in sequence from smallest in storage capacity to largest. Differences in local materials prices and dates of documentation call for extreme care when making comparisons. The figures do, however, show that:

1. In general, large tanks (e.g. 12, 14, 15 below) can be built at lower cost/m^3 of storage than small tanks.

2. Some small tank options (e.g. 2 below) may be among the cheapest of all tanks.

3. Tanks built with similar methods, but to meet different engineering standards, may vary greatly in cost (compare 4, designed at a university, and 10, developed "in the field").

4. "Household-sized" tanks can be built for materials costs of under US$18/$m^3$ (2,6,7,10 below).

See section 4.2.1 for direct comparisons of materials requirements of tanks 6, 10, and 12.

3.3.5 Costs of materials, costs/m^3 of water storage (continued)

TANK (C: cover, P: pump, G: gutters)	MATERIALS	MATERIALS+ COST (US$)	COST/M^3 ++ (US$)
1. 0.17 m^3 steel drum, East Africa (White et al, 1972)	manufactured	2.50	14.90 (1969)
2. 0.25 m^3 cement mortar jar, Thailand (Watt, 1975)	cement mortar, concrete	0.50	2.00 (1974)
3. 0.3 m^3 pottery jar, Thailand (Watt, 1975)	purchased locally	5.00	16.70 (1973)
4. 1.2 m^3 ferrocement tank (C), Thailand (Sharma and Gopalaratnam, 1980)	cement, sand & gravel, steel mesh & rod	33	28 (1980)
5. 1.4 m^3 "tin" tank, East Africa (White et al, 1972)	manufactured	39-84	28-60 (1969)
6. 2.3 m^3 plastered "Ghala" basket, East Africa (UNICEF, 1982)	cement, sand & gravel	42*(est)	18 (1982)
7. 7.0 m^3 cast concrete ring tank (C), Thailand (Watt, 1978 b)	cement, sand & gravel	40(1)	5.70 (1977)
8. 9 m^3 ferrocement tank (C,G) Zimbabwe (Farrar and Pacey, 1974)	cement, sand & gravel, steel netting and wire	62.50(1)	6.90 (1973)
9. 9.0 m^3 galvanized corrugated iron tank, Zimbabwe (Farrar and Pacey, 1974)	manufactured	112	12.50 (1973)
10. 10 m^3 ferrocement tank (C) (Watt, 1978)	cement, sand & gravel, steel netting and wire	150*(est)	13 (1982)

\+ author's figure unless indicated otherwise
++ my calculations, not those of authors
* assumes US$ 7.14 (Zaire, 1981) per 50 kg bag of cement; other materials estimated. See text
(1) excluding costs of metal forms

3.3.5 (continued)

TANK (C: cover, P: pump, G: gutters)	MATERIALS	MATERIALS+ COST (US$)	COST/M^3 ++ (US$)
11. 15-20 m^3 underground ferrocement (C), New Hebrides (Calvert and Binning, 1977)	cement, sand & gravel, steel netting and rod	250	12.50 (1976)
12. 25 m^3 underground ferrocement tank, Botswana (C?) Maikano and Nyberg, 1980)	cement, steel netting, PVC pipe	135	5.40 (1980)
13. 36 m^3 buried reinforced concrete cistern (C,P?) USA (Dooley, 1978)	cement, sand & gravel, steel rod, materials for forms	1000	27.50 (1978)
14. 45 m^3 "sand-sausage" open tank, Botswana (Farrar and Pacey, 1974)	cement, sand, plastic tubing	75	1.67 (1973)
15. 71 m^3 partially buried concrete block tank (C, G), Ghana (Farrar and Pacey, 1974)	cement, sand, concrete block	260	3.70 (1973)
16. 2,300 m^3 butyl-lined tank (C,P), Kenya (Grover, 1971; proposed only)	0.8 mm butyl sheet, cement, hand pumps	18,000 (2)	7.83 (1970)
17. 80,000 m^3 NaCl-lined earth reservoir system, Mali (Cluff, 1975; proposed only)	NaCl, engine-driven pump	not enumerated	under 1.00 (1974)

(2) not including cost of sprayed asphalt catchment surface, estimated at an additional $15,000

3.3.6 Publications and how to obtain them

-- Cairncross, S., and Feachem, R., 1978, Small Water Supplies, book, 78 pages, £1.50 from the Ross Institute, London School of Hygiene and Tropical Medicine, Keppel Street (Gower Street), London WCIE 7HT, United Kingdom.

This book is a compact presentation of basic information on building small-scale water supply systems. Discussions include sources of water, watrer treatment, water lifting, and storage and distribution. Contains 2-page section on building water tanks of bricks and masonry. No diagrams, but text gives guidelines for wall, footing, and floor thicknesses; plastering and waterproofing; cleaning and maintenance; inlets, outlets, overflows, screening, and covers; and drainage. In some cases the construction specifications given provide for more strength, and use more materials, than necessary.

-- Calvert,R.C., and Binning, R.J. 1977, "Low Cost Water Tanks in the Pacific Islands", article, 3 pages, in Appropriate Technology magazine, Vol 4, no. 3, November 1977,£0.75 for the issue including Air Speeded Post, from Intermediate Technology Publications, Ltd., 9th King Street, London WC2E 8HN, United Kingdom.

Describes fabrication of ferrocement cover on an earthen dome, excavation of tank from beneath the cover, and plastering of ferrocement lining for 15-20 m^3 tanks built in "soft" sdoil in the New Hebrides. The authors believe the tanks can be built for under US $250.00. They also describe a method for building above-ground ferrocement tanks using locally available wood and reed materials for forms.

-- Farrar, D.M., and Pacey, A.J., 1974, "Catchment Tanks in Southern Africa: A Review", Africa Fieldwork and Field Technology Report no. 6, 13 pages, request

Farrar and Pacey 74 (cont)

from Paul Sherlock, OXFAM, 274 Banbury Road, Oxford OX2 7DZ United Kingdom.

An excellent critical description and evalution of open and "beehive" "sand-sausage" ground surface catchment tanks, ferrocement roof catchment tanks, and combinations of these designs in Swaziland, Botswana, and Zimbabwe. The authors give the most complete construction cost information we have seen, and also discuss manual labor requirements as a barrier to completion of some of the technically sound "sand-sausage" tank projects. Step-by-step instructions for making a 7.5 m^3 version of the ferrocement tanks built in the hundreds around the Friends Rural Center, Bulawayo.

Anyone considering a rooftop catchment system or project in Africa should try to read this report.

-- Henderson, G.E., Jones, E.E., and Smith, G.W., 1973, Planning for an Individual Water System, book, 156 pages, $5.00 from American Association for Vocational Instructional Materials, Engineering Center, Athens, Georgia 30602, USA.

A well-written book on conventional water installations for rural and farming families in the U.S. Includes good color drawings of cisterns, roofwashers, and a fil ter. Better pictures, but less construction detail, than in Using Water Resources (below)

-- Maikano, G.J., and Nyberg, L., 1980, "Rainwater Catchment in Botswana", paper, 5 pages, in the book Rural Water Supply in Developing Countries: Proceedings of a Workshop on Training held in Zomba, Malawi, 5-12 ? August 1980. Ask for a free copy of the book from International Development Research Center, Box 8500, Ottawa, Canada K1G 3H9.

Bibliography and access information for section "Storage Techniques"

An account of a pilot program for popularizing underground ferrocement tanks to store water caught on traditional grain threshing floors. Rainwater harvested using these systems is for families and cattle, and should allow farmers to move to their land and begin plowing 17 days earlier in the rainy season than otherwise. Not many construction details are given, but domed ferrocement covers and poured concrete covers reinforced with barbed wire are mentioned. Maintenance of the tank and catchment floor are emphasized. "Today, the pilot project has about 10 underground tanks built and more are under construction. In all it is hoped to have 80 completed by the end of 1980".

-- Office of the Foreign Secretary, 1973, Ferrocement: Applications in Developing Countries, book, 91 pages, mention your institutional affiliation or name of your group when requesting a free copy from: Board on Science and Technology for International Development (JH215), Office of the Foreign Secretary, National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C. 20418, USA.

A basic book on the range of ferrocement techniques and potential applications, sidely referred to throughout the literature on the topic. Chapters cover ferrocement for boatbuilding, food storage facilities, fooe-processing equipment, low-cost roofing, and the basics of construction of shells and walls. Appendixes include diagrams construction steps, and cost breakdowns for food-storage silos in Thailand and Ethiopia which can be used for storing water. (These silos are also described in the article by Sharma, et al, below).

-- Pompe, C., van Kerkvoorden, R., and Siswoyo, H., 1982, "Ferrocement Applications in the West Java Rural Water Supply Project", article, pages 51-61 in Journal of Ferrocement, Vol. 12, no. 1, January 1982. Ask for a reprint or xeroxed copy at ~~cost~~ from International Ferrocement Information Center, Asian Institute of
$.20 per page plus $2.00 per request

Bibliography and access information for section "Storage Techniques"

Technology, P. O. Box 2754, Thailand.

An overview of the project which plans to construct hundreds of 5 m^3 and 10 ,^{3} ferrocement tanks, as well as a reservoir and community water supply system built largely of ferrocement. Presents a chart comparing costs of various rainwater storage tanks in Java, including gutters and labor costs of Rp 1000 (US$1.60) per man-day. Also includes good drawings showing construction details of the 10 m^3 tank and 2.5 m^3 bamboo-cement tank.

-- Sharma, P.C., Pama, R.P., Valls, J., and Gopalaratnam, V.S., 1979, "State-of-the-art Review on Ferrocement Grain Storage Bins", article, pages 135-150 in Journal of Ferrocement, Vol 9, no. 3, July 1979. Reprint or xerox copy at $0.20 per page plus $2.00 from International Ferrocement Information Center, Asian Institute of Technology, P. O. Box 2754, Bangkok, Thailand.

Describes construction techniques and costs for four ferrocement grain storage structures "...developed in different parts of the world that have been extensively field tested satisfactorily." An above-ground conical bin which has been called the "Thailo", holding 4 tons of grain or 9.5 m^3 of water and an undergound pit silo lined with reinforced plaster are two maodels which h.ave been used to store water. The authors give the cost of a 9.5 m^3 underground plastered pit built in India, at US $62.00.

-- UNICEF East Africa Regional office, 1982, "From Kenya--How to Make Plastered basket tanks for storing water", article pages 7-8 in Appropriate Technology magazine, Vol 8, no. 4, March 1982. ± 1.50 from Intermediate Technology Publications, 9 king Street, London WC2E 8HN, United Kingdom. Also available from UNICEF, East African

Bibliography and access information for section "Storage Techniques"

Regional Office, P. O. Box 44145, Nairobi, Kenya.
Describes activities and gives background of the Karen Appropriate Technology Unit outside Nairobi. Cement mortar jars (like those described by Watt, 1975, below) and a PVC bag suspended in a thatch-covered bamboo-lined pit are two tank designs tied at the center. Also mentions other ideas in passing: "It is noticed that, in many areas, houses will have a short length of roughly fashioned guttering fixed under the eaves just above the door, and that water from this will be collected in an old oil drum or container...(this) could provide the link point for development to simple but effective roof catchment systems." And, "Collection of water from grass roofs, even on circular huts, is possible by using a polythene film guttering or by simple guttering made from split bamboo or from two planks joined to give a "V" section." Many other ideas for food production/storage/preparation, and effective institutional involvement in village technology activities.

--VITA, 1977, Using Water Resources, book, 143 pages, $5.95 from Volunteers in Technical Assistance, 1815 North Lynn Street, Suite 200, Arlington, VA 22209 USA.

This is a reprint of a part of VITA's Village Technology Handbook, available for $10.00 (387 pages) from the same address, and including excellent sections on concrete and bamboo construction as well as health and sanitation, agriculture, and food processing and preservation. Using Water Resources contains a good 6-page piece on planning and building a conventional US-type concrete cistern with a capacity of 10 m^3 or more, including drawings of a filter and a "roofwasher".

Bibliography and access information for section "Storage Techniques"

The book as a whole is good basic reading for anyone consideriong construction of a small water supply.

-- Watt, S.B., 1978, Ferrocement Water Tanks and Their Construction, book, 118 pages, £ 2.95 from Intermediate Technology Publications, Ltd., 9 King Street, London WC2E 8HN, United Kingdom.

For those considering a rooftop catchment system, this book may be the single most useful publication listed here. Gives straightforward guidelines for design, descriptions of materials, and tools required, and a detailed, step-by-step summary of methods for building the ferrocement tansk (using metal forms) which have been "used successfully for over 25 years in different parts of the world" (see technical note in section 4). Also describes construction of several variations on the basic method, including small jars of unreinforced mortar (see technical note in section 4), 1-25 m^3 manufactured tanks in New England, a 6 m^3 tank built without formwork in the U.K. 10 m^3 ferrocement-lined traditional adobe grain storage bins in Mali, a 40 m^3 roofed tank built with makeshift formwork in Zimbabwe, and a 150 m^3 open tank built with makeshift formwork in Arizona, USA.

Lists amounts of materials required for each design, and gives a brief discussion of using rainfall data to plan a rooftop catchment system (see technical note, section 4).

-- Watt, S.B., 1978, "Rainwater Storage Tank in Thailand", article, pages 16-17, in Appropriate Technology magazine, Vol 5, no. 2, August 1978, £ 0.75 for the issue including Air Speeded Post, from Intermediate Technology Publications, Ltd., 9 King Street, London, WC2E 8HN, United Kingdom.

Bibliography and access information for section "Storage Techniques"

Describes construction of tanks made out of stacked ureinforced concrete rings, cast in 1.5 m. diameter cylindrical stee forms. The 60-cm-high rings can be stacked up to four high and have low materials costs (US $40.00 for a 7 m^3 tank) but the inner and outer steel forms would be expensive. Watt suggests that high-quality rings could be cast centrally under supervision and trucked to location for assembly.

-- Winarto, 1981, "Rainwater Collection Tanks Constructed on Self-Help Basis", article, pages 247-253 in Journal of Ferrocement, Vol 11, no. 3, July 1981. Ask for a reprint or xeroxed copy at $.20 per page plus $2.00 per request from International Ferrocement Information Center, Asian Institute of Technology, P. O. Box 2754, Bangkok, Thailand.

An account of the adaptation of standard ferrocement tank methods to the materials availabilities of rural Java. Detailed verbal instructions for building a steel rod reinforced 9 m^3 tank with integral floor and cover. Bamboo mats are used as plastering forms. Some pictures; construction could be attempted with basic knowledge of the techniques in Ferrocement Water Tanks and Their Construction (Watt, 1978). Also describes construction of smaller tanks built with bamboo (instead of steel rod) reinforcement cages. The steel rod and bamboo cage designs presented here have been adopted by the West Java Rural Water Supply Project (Pompe et al, above).

4. Technical notes describing planning and construction of promising rooftop catchment and storage technologies

4.1 Using rainfall data to design a rooftop catchment system +++

The principal factors affecting the design of a rainwater catchment system are a. local rainfall patterns; b. area of the rainfall catchment; c. volume of the container the water is stored in; and d. the amount of water to be provided by the system for consumption. The first of these factors is the most important and, at the same time, the one we can do the least about. So the amount of rain that fall, and the periods of time between rains, are the basic natural facts which should shape the combination of the other three factors in a rainwater catchment system.

This section, then, will show how to think about:

a. area of rainfall catchment;

b. volume of storage; and

c. amount of water to be provided for consumption,

given available information on rainfall.

In rich countries the usual aprpriach in water supply is to start with an amount for consumption, and then to design storage and catchment to provide that amount of water even during dry periods. In this approach, maximum emphasis is placed on convenience and reliability. In developing countries, on the other hand, concerns about convenience and reliability must nearly always take second place to concerns about costs. In these situations it often makes sense to start with available resources--existing physical structures, cash, local materials, and labor--, and then to work out a plan for

+++ methods in this section are extracted and modified from Watt (1978, pages 109-112), VITA (1977, page 111), and Hardenbergh and Rodie (1960, pages 103-104).

expending those resources in such a way as to come closest to a target for water consumption. We will take this latter approach in this section.

Rainfall data. The degree of detail of rainfall data varies widely. Obviously we would like to know how much rain falls during storms, and how much time separates the storms. This would allow us to determine of a catchment and storage combination would take all the water from a storm or waste some of it; we could also easily determine whether the storage would hold enough water to last until the next storm would be expected to occur. In practice, rainfall data this detailed are very hard to get. In many areas, the best data available are month-by-month rainfall totals. These figures can be obtained from weather bureaus, airports, and sometimes from agricultural research or extension stations. The data should have been taken over several years.

In many places it may be impossible to find month-by-month rainfall totals. The next best alternative, then, is to find out monthly average totals for your area. The last and least desirable alternative is to find out yearly average totals for your area. Average totals are less useful because it is impossible to tell from them how often, and how extreme, are the deviations. (We noted in section 3.1.1 that there is less than a one-in-two chance of rainfall totalling within 10% of the yearly average, for any particular year, for the continene of Africa. We can expect that monthly deviations from the average would be at least as great.) This means that a system planned using average rainfall totals might provide water as expected only about two thirds of the time. For thie reason, VITA recommends (Using Water Resources, see section 3.3.6) that average rainfall totals be multiplied by 2/3 to give an estimate of the minimum rainfall. We can be much more certian that actual rainfall in

the future will meet or exceed this minimum rainfall estimate.

In any case, whether you use month-by-month rainfall totals or average totals, it is important to try to get information which has been collected over several years. Here is part of a table (van der Leeden, 1975, page 442) showing monthly averages (for data collected over 3 years) for Am Timan, Chad.

TABLE 7-2. TEMPERATURE AND PRECIPITATION DATA FOR REPRESENTATIVE WORLD - WIDE STATIONS (continued)

				TEMPERATURE											AVERAGE PRECIPITATION													
					Average Daily								Extreme															
					JAN.		APR.		JULY		OCT.																	
COUNTRY AND STATION	LATITUDE	LONGITUDE	ELEVATION	Length of record	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Length of record	January	February	March	April	May	June	July	August	September	October	November	December	YEAR
	° ′	° ′	FEET	YEAR	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	YEAR	IN.	IN.	IN.	IN.	IN.	IN.	IN.	IN.	IN.	IN.	IN.	IN.	IN.
Cameroon:																												
Ngaoundere	07 17N	13 19E	3,601	9	87	55	87	64	82	63	82	61	102	46	10	*	*	1.1	5.5	7.0	8.4	10.6	9.6	9.2	5.3	0.5	*	57.2
Yaounde	03 53N	11 32E	2,526	11	85	67	85	66	80	66	81	65	96	57	11	0.9	2.6	5.8	6.7	7.7	6.0	2.9	3.1	8.4	11.6	4.6	0.9	61.2
Central African Republic:																												
Bangui	04 22N	18 34E	1,270	5	90	68	91	71	85	69	87	69	101	67	5	1.0	1.7	5.0	5.3	7.4	4.5	8.9	8.1	5.9	7.9	4.9	0.2	60.8
Nzele	08 24N	20 39E	1,939	3	99	67	98	73	86	69	90	68	109	58	3	0.2	1.3	0.6	1.7	9.4	6.1	9.3	10.1	10.7	7.8	0.6	0.0	55.8
Chad:																												
Am Timan	11 02N	20 17E	1,430	3	98	56	105	68	89	70	96	67	113	43	3	0.0	0.0	0.1	1.2	4.3	5.0	7.3	12.3	5.8	1.2	0.0	0.0	37.2
Fort Lamy	12 07N	15 02E	968	6	93	57	107	74	92	72	97	70	114	47	6	0.0	0.0	0.0	0.1	1.2	2.6	6.7	12.6	4.7	1.4	0.0	0.0	29.3
Largeau (Faya)	18 00N	19 10E	837	5	84	64	104	69	109	76	103	72	121	37	5	0.0	0.0	0.0	0.0	*	0.0	*	0.7	*	0.0	0.0	0.0	0.7

Figuring runoff. The amount of runoff, or water available for storage in a tank, is related to the horizontal area covered by the catchment surface. (As we work this example, we will assume that we plan to use the roof of a building for a catchment surface. This seems to be a sensible use of existing resources in many areas. The procedure used in the example could equally well be used for a variety of catchment surface sizes and types.) For a building, this area is the ground area covered by the roof., as shown in the figure.

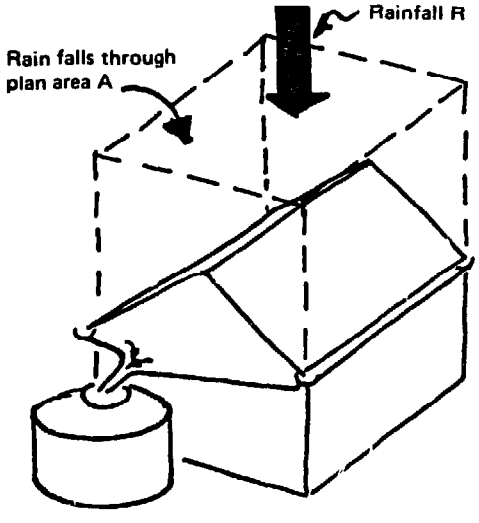

Watt (1978) by permission

Let's assume that the ground area covered by the roof is 30 m^2 (the area of a 5 x 6 meter building). The amount of runoff which could be collected from the roof is:

$$R = \text{area} \times \text{rainfall} \times 0.9^{*}$$
$$= 30\ m^2 \times \text{rainfall} \times 0.9.$$

Runoff or "R" can be figured for any kind of rainfall total. Using monthly average rainfall totals would give monthly average R; using a yearly minimum estimate would give a yearly minimum estimate R.

Using runoff totals to plan storage capacity. The amount of water in storage should come as close as possible to providing for water needs during dry periods. Take, for example, a family of five, each of which needs a minimum of 20 liters of water per day over a dry period of one month. Their water needs during the month would be:

$$\text{needs} = 5\ \text{people} \times 20\ \text{l./day} \times 30\ \text{days}$$
$$= 3{,}000\ \text{liters}.$$

This means that to supply this need for water, a storage tank would have to contain at least 3 m^3 at the beginning of the dry period. A tank containing 2 m^3 (2,000 liters) would provide most, but not all, of the family's minimum needs.

Simple graphical method . If you can compute monthly runoff totals, cimple graphs can help show dry periods and wet periods and indicate the need for storage. We will work out an example using the data for Am Timan (above).

The first step is to calculate runoff totals for each month. The rainfall data available for Am Timan are monthly average totals, so multiplying

* Ree (1976) says that a sheet metal roof with good guttering is about 90% efficient. Other materials may be less efficient.

each of these by the roof area gives monthly average runoff. Then, to get a minimum runoff, the product is multiplied by 2/3. Here is the calculation for October (average rainfall in October, from the table above, is 30.5 mm):

$$R_{(Oct)} = \text{area} \times \text{rainfall}_{(Oct)} \times 2/3 \times 0.9$$

$$= 30\ m^2 \times 0.0305\ m \times 2/3 \times 0.9$$

$$= 0.55\ m^3.$$

This calculation is performed for each month. These minimum runoff totals are shown on the following graph, figure 1, with the peak month of the wet season at the far left (this makes the procedures below more straightforward):

Figure 1.

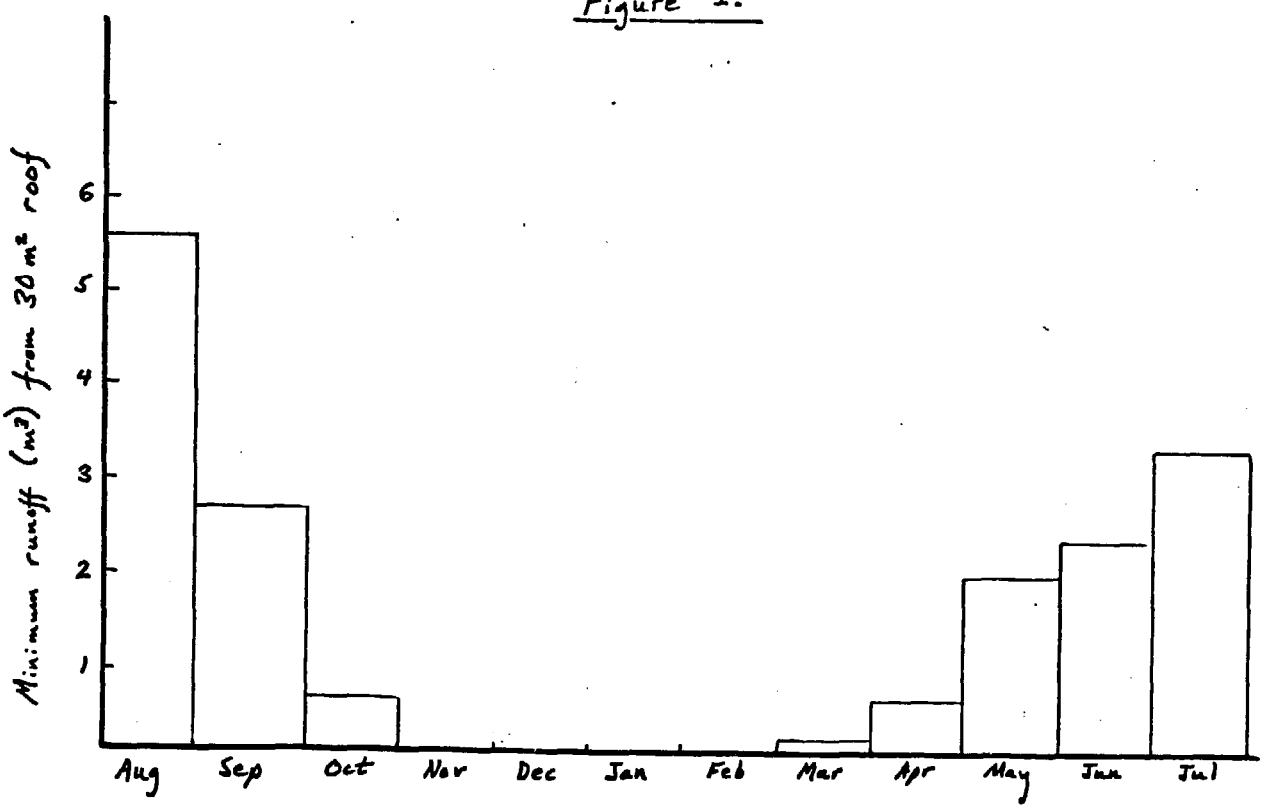

The second step is to show "cumulative" runoff--that is, each monthly total from figure 1 above is added to the total of the previous months. Thus the graph shows the sum of all runoff, which increases or remains the same throughout the year. For October, for example, the graph will show the sum

of the runoff totals for the months of August, September, and October. The solid line of the following graph shows minimum cumulative runoff ("minimum" because we have multiplied each monthly runoff figure by 2/3):

Figure 2.

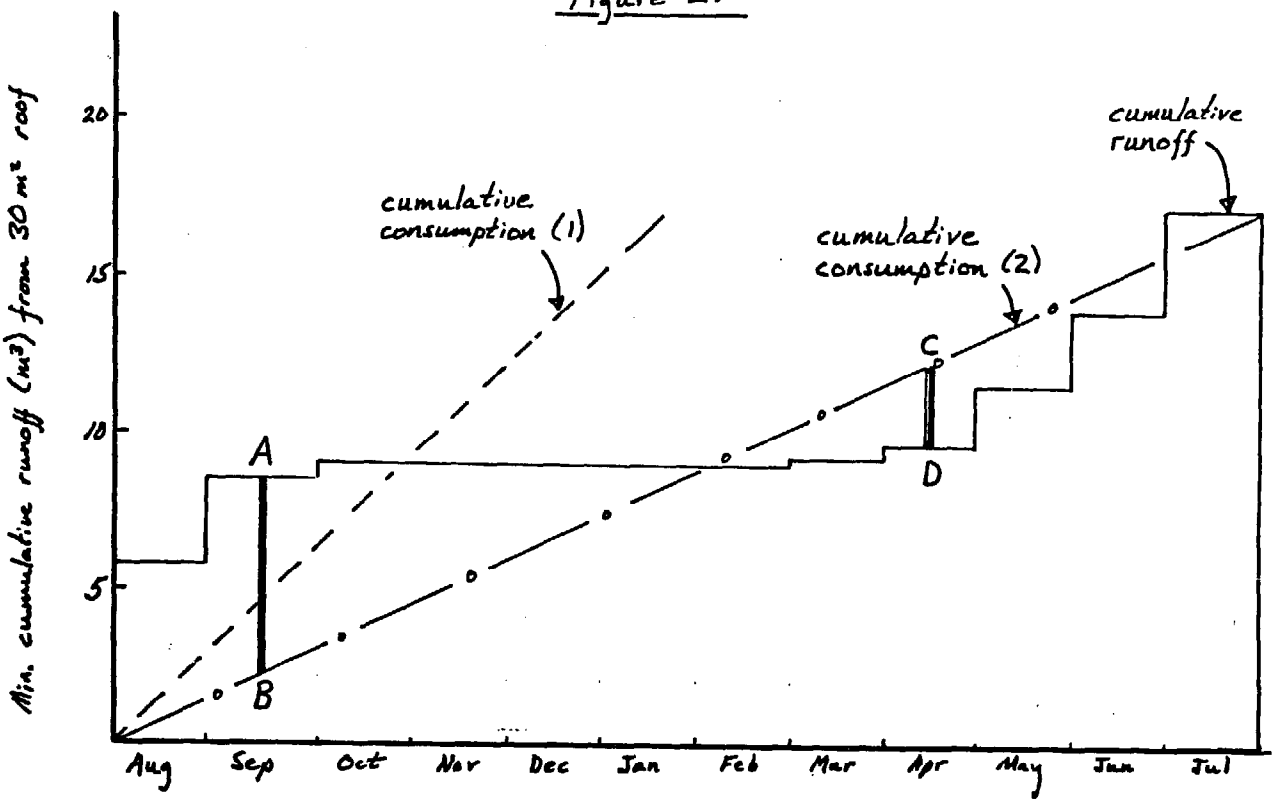

Note that the line is horizontal for the months with rainfall and runoff totals of zero: for these months, there is no increase in the cumulative runoff. At the end of a year the cumulative runoff is 17.2 m^3. This means that a tank with a capacity of 17.2 m^3 could theoretically hold all the water collected over an average year's time from our 30 m^2 roof in Am Timan.

The final step is to show cumulative water consumption on the graph along with cumulative runoff. Take, for example, the family of five, each member consuming 20 l. per day. At the end of one month the family will have used 5 x 20 l. x 30 days = 3,000 l. or 3 m^3; at the end of two months they will have used another 3 m^3 for a total of 6 m^3, and so on. This cumulative consumption is shown as the dashed line on the graph above, figure 2. The dashed line runs below the cumulative runoff line until October, but rises

above it after that. This shows that the 30 m^2 roof cannot provide enough water to support this rate of consumption.

What rate of consumption can the 30 m^2 roof provide? We can determine this by drawing a second consumption line (the dashed line with dots, figure 2) so that is meets the runoff line at the end of the year (on this graph, in the middle of the wet season). Thus cumulative consumption equals cumulative runoff for the year. Runoff increases faster than consumption for August and September, but then the runoff line levels off and consumption increases faster than runoff from October to June. Then in June and July runoff again increases faster than consumption.

The volume of storage required to provide this rate of consumption, and use all the runoff from the roof, can also be dtermined from the graph. This volume is the sum of the greatest vertical distance from the runoff line <u>above</u> the consumption line to the consumption line (distance AB in figure 2, which represents about 6 m^3), and the greatest vertical distance from the runoff line <u>below</u> the consumption line to the consumption line (distance CD in figure 2, representing about 3 m^3). So a tank which could store about 6 + 3 = 9 m^3 could theoretically hold enough runoff from the 30 m^2 roof to provide the steady consumption rate indicated by the dash-dot line (2). This line rises at the rate of about 1.4 m^3 per month; 1.4 m^3 (1,400 liters) divided by 5 people, divided again by 30 days gives a consumption rate of a little more than 9 liters per day for each member of the family.

<u>Water rationing and storage.</u> Most families in areas with water shortages tend to consume more water during wet months and less water during dry months. Thus a line representing cumulative consumption on a graph like the ones above would not be straight (like lines 1 and 2) but instead tend to curve, following the cumulative runoff line. The graph in figure 3 (below) shows

a curving consumption line (3); using the method for calculating storage above, it is easy to show that much less storage volume is needed to provide for this rate of consumption which changes with the seasons.

The technique described in this section is a useful tool for making an educated guess at how much water could be provided by a proposed system. It is best, however, to bear in mind the words of Watt (1978, page 112) in his discussion of system size: "In the real world the climate is unlikely to be uniform enough to allow these steps to give more than a rough indication of tank size".

Figure 3.

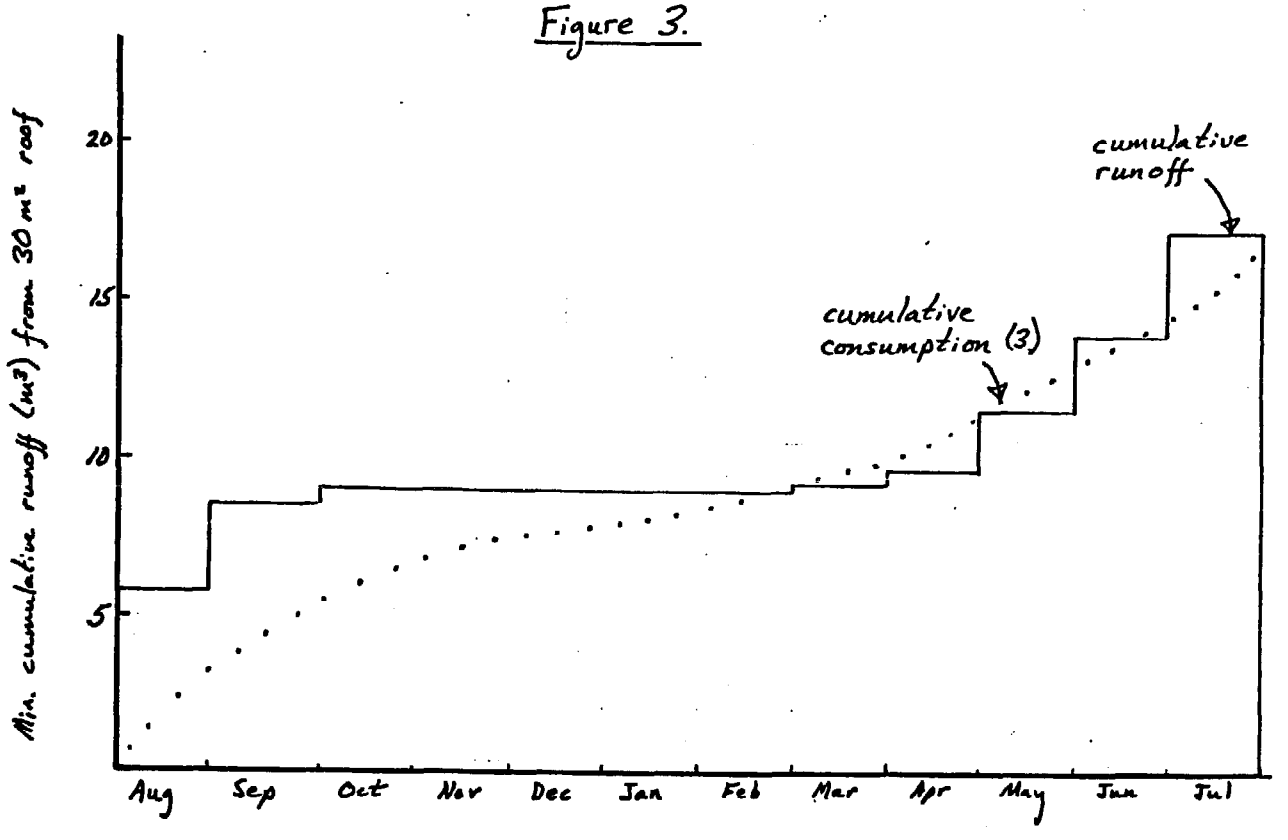

4.2 Costs of construction

4.2.1 Materials quantities for 4 tanks

The following page compares the materials inputs for construction of tanks discussed in section 3.3 and listed in table 3.3.5. Using this kind of information, local prices can be applied to roughly determine costs and make cost-based judgements about the relative attractiveness of different designs.

"Trade-offs" are evident: for example, the cement mortar plastered basket (UNICEF, 1982) requires more cement / m^3 of storage than any of the other three, but meeds no metal reinforcing material and little gravel.

The subsequent section (4.2.2) gives guidelines and examples for roughly calculating amounts of cement needed to build a variety of tanks.

4.2.1 (continued) Materials quantities for 4 tanks

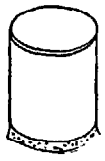

Ferrocement Tank with foundation
(no cover) (after Watt, 1978)
10 m3

materials per m3 storage:

1.2 bags cement
0.1 m3 sand
.05 m3 gravel
16 m2 chickenwire

cement	:12 bags (50 kg. each)
sand	: 1 m3
gravel	: 0.5 m3
chickenwire	: 16 m2

plus: straight wire, use of forms

Cement mortar plastered basket
with foundation (no cover)
(after UNICEF, 1982)
2.3 m3

materials per m3 storage:

2.2 bags cement
.06 m3 sand
.02 m3 gravel

cement	: 5 bags
sand	: .13 m3
gravel	: .04 m3

Reinforced cement mortar
plastered underground tank
(after Maikano and Nyberg, 1980)
20 m3

materials per m3 storage:

0.6 bag cement
.05 m3 sand
1.6 m2 chickenwire

cement	: 12 bags
sand	: 1 m3
chickenwire	: 32 m2

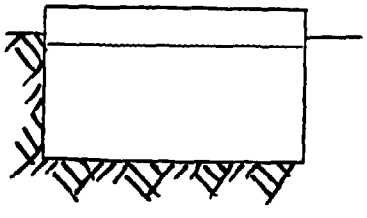

Underground concrete tank
with cover
12 m3

materials per m3 storage:

1.1 bag cement
.0 8 m3 sand
.12 m3 gravel

cement	: 13 bags
sand	: 1 m3
gravel	: 1.4 m3

plus: reinforcing rod, material for forms

4.2.2 Calculating costs of materials

The following discussion on figuring costs shows how to obtain rough amounts for some of the amin materials needed for construction of roof catchment systems. The procedures are simple, and computations like them can be used to get an idea of whether materials for a proposed catchment are affordable, and to compare the costs against the costs of alternatives. They do not take many important questions into account: they ignore the time required for delivery, and any costs of labor, for example.

Here is a summary of the computations of materials costs:

$$\text{cost of cement (for concrete)} = \text{volume of concrete} \times \frac{7 \text{ bags cement}}{\text{m3 concrete}} \times \frac{\text{price}}{\text{bag}}$$

$$\text{cost of cement (for mortar)} = \text{volume of mortar} \times \frac{10 \text{ bags cement}}{\text{m3 mortar}} \times \frac{\text{price}}{\text{bag}}$$

$$\text{cost of roofing material (sheet)} = \text{area of roof} \times \frac{\text{price}}{\text{m2}}$$

The first two examples are worked out for materials that would be needed for construction of the 10 m^2 ferrocement tank described in section 4.3.2 (see also table 3.3.5, no. 10,and section 4.2.1). Other materials, in addition to the ones mentioned here, would be needed--sheet metal for forms, for example. The final example concerns cost of sheet metal for roofing. See section 4.1 for how to think about how much rainwater a given roof can collect.

Cement in concrete floors, footings, and foundations of tanks

1. Figure the volume of concrete needed. For a 2.8 m diameter floor which will be 7.5 cm thick,

$$\text{area} = \pi r^2 = 6.2\ m^2$$

$$\text{volume} = \text{area} \times \text{thickness} = 6.2\ m^2 \times 0.075\ m = 0.47\ m^3.$$

2. Figure the amount of cement needed to make the concrete. Concrete mixed in the proportions 1:2:3, cement:sand:gravel, is plenty strong for self-help floors, footings, and walls when made with clean materials and cured properly.* Concrete mixed 1:2:3 contains about 7 bags (@ 50 kg per bag) per m^3. Using this information, we can figure the number of bags needed:

$$\text{bags of cement} = \text{volume of concrete} \times \frac{7\ \text{bags}}{m3\ \text{concrete}} = 0.47\ m^3 \times \frac{7\ \text{bags}}{m3\ \text{concrete}} = 3.3\ \text{bags}.$$

3. Figure the cost, using the price of a bag of cement in your area. For example,

$$\text{cost} = \#\ \text{of bags} \times \text{price per bag} = 3.3\ \text{bags} \times \$7.14\ (\text{US\$, Zaire, 1981}) = \$23.49.$$

* determined using the "concrete calculator", VITA (1973). You many decide to use a lower porportion of cement. The "concrete calculator" shows how to adjust the volumes of the other materials.

Mortar for plastering floors, walls, and roofs of tanks

1. Figure the volume of mortar needed. For a floor plastered with 5 cm. of mortar, 2.5 m in diameter,

$$\text{area} = \pi r^2 = 4.9\ m^2$$

$$\text{volume} = \text{area} \times \text{thickness} = 4.9\ m^2 \times 0.05\ m = 0.25\ m^3.$$

For a cylindrical tank with walls 2 m high, plastered with a total of 4 cm of mortar,

$$\text{area} = 2\pi r\ (\text{height}) = 15.7\ m^2$$

$$\text{volume} = \text{area} \times \text{thickness} = 15.7\ m^2 \times 0.04\ m = 0.63\ m^3.$$

So the total volume needed, for walls and floor, is $0.25\ m^3 + 0.63\ m^3 = 0.88\ m^3$.

2. Figure the amount of cement needed to make this volume of mortar. Mortar mixed 1:3, cement:sand, is recommended for waterproof walls. This mix contains about 10 bags (@ 50 kg) per m^3 (always check with local masons and collect opinions on mixes, if you are inexperienced). So:

$$\text{bags of cement} = \text{volume of mortar} \times \frac{10 \text{ bags}}{m^3 \text{ mortar}}$$

$$= 0.88\ m^3 \times \frac{10 \text{ bags}}{m^3 \text{ mortar}}$$

$$= 8.8 \text{ bags.}$$

3. Figure the cost of the cement, using the price of a bag of cement in your area. For example, in Zaire,

$$\text{cost} = \#\text{ of bags} \times \text{cost per bag}$$

$$= 8.8 \text{ bags} \times \frac{\$7.14}{\text{bag}}$$

$$= \$62.83.$$

Roofing material (corrugated metal sheet)

1. Figure the area of roof to be covered with the metal sheet. Allow for overhang, and consider where gutters will be hung, when making measurements. A building 8 m long with a pitched roof might have 2 roof surfaces of equal area:

$$\begin{aligned} \text{total area} &= 2\ (\text{length} \times \text{width}) \\ &= 2\ (8\ \text{m} \times 3\ \text{m}) \\ &= 48\ \text{m}^2 \end{aligned}$$

2. Using this area, figure the cost, using the price of metal sheet in your area. For example,

$$\begin{aligned} \text{cost} &= \text{area} \times \text{price per m}^2 \\ &= 48\ \text{m}^2 \times \frac{\$2.20}{\text{m}^2} \quad \text{(Mônrovia, 1981, US\$)} \\ &= \$105.60 \end{aligned}$$

This is only a rough figure, because it ignores the size of the individual sheets and how much they must be cut to fit the roof surface. Also, the sheets must overlap a little to shed water properly. This means that the actual area of sheet needed, and the cost, may be 15-20% more.

If gutters are to be made with the sheet material, this may increase the cost again. Sometimes sections of gutter and hanging straps can be made with pieces cut when the sheets are fit to the roof.

4.3 Building Water Tanks

The construction information in this section is for three of the most widely docemented of the tanks outlined above in section 3.3.2. Here we intend to give the interested reader detailed information on the materials, tools, and skills involved in their construction; some readers with confidence in their manual skills would be able to attempt construction from the information given. We do not mean to imply that these are the three "best" tank designs for household rooftop catchment; in fact, each of these three tanks requires a relatively great amount of cement per m^3 of storage (see, for example, section 4.2.1). They are, however, three of the most "teachable" of the designs documented. See section 3.3 for a more complete discussion of water stroage alternatives.

Each of the tanks described in this section is made with cement mortar, which is a mixture of sand and cement and water. It is always important to make mortar with the cleanest available materials, and to keep soil and other contaminants out of the mortar mixture . Watt (1978) suggests using a mixing board or making a small concrete pad on a layer of gravel. The board is probably a better choice where the tanks or jars will be built far from each other.

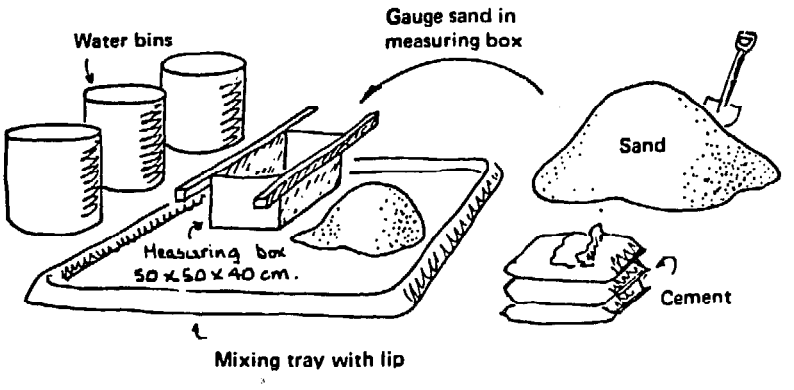

Watt (1978) by permission

The mortar mixtures used for the following tanks and jars contain proportions of cement:sand ranging from 1:2 to 1:3 (measured by volume). Mixtures with more cement are easier to plaster with and may be stronger and more waterproof for the surfaces of smaller jars with littel reinforcement. For larger containers, a 1:3 cement:sand mixture is strong enough and less likely to crack when curing.

Sand for mortar should be clean. A range of sand grain sizes is OK, but sand with lots of fine silt should be avoided because it causes mortar made with it to flake off. Sand and any other materials to be used in construction should be gathered before any work strats. Study the list of materials preceeding each of the tanks, and read through the instructions carefully beginning.

Clean water should be added to the cement and sand after they have been thoroughly mixed together with a trowel or shovel. Make a hole in the pile of cement/sand mix and pour the water in, a little at a time. While a mix that is too "dry" will be difficult to apply, a "wet" mix will not be as strong when cured. Use as little water as possible to obtain a workable mixture. STart with an amount of water that is half the volume of the cement, and add water sparingly.

Do not mix more mortar than can be applied to the tank or jar in about 1/2 hour! After about this amount of time, mortar begins to set and cannot be applied properly (Watt, 1978).

Concrete is used instead of mortar for the foundations of most tanks and jars because it contains gravel or small stones and is less likely to break or weaken under the load of a heavy tank and its contents. The gravel used in concrete ideally contains a range of sizes, and the stones should not be flat. Like sand, gravel m ust be clean, or the concrete will be weak.

Concrete used for foundations can be mixed in proportions ranging from 1:2:3 to 1:3:6. Regardless of the proportions, concrete should be made with as little water as possible and mixed in a clean place. Containers like those shown in the figure above can be used to measure the proportions of materials in mortar and concrete mixes. REsist the temptation to estimate proportions or use the blade of a shovel to measure with; this will result in a weaker mix.

The Village Technology Handbook (VITA, 1973; see section 3.3.6) includes an excellent section on selecting mixes, preparing, and building with concrete.

4.3.1 0.25 m^3 cement plaster jar

Unlike the other water containers in this section, this jar is built entirely of mortar. It contains no strengthening fibers nor wires. The mortar is applied to a " mold" which is usually made of sacking material (like burlap) filled with something heavy enough to plaster against.

Because these jars have no reinforcing material, they are made with a mortar mix which is "rich" in cement. The proportions of materials recommended in the following instructions (copied by permission from Watt, 1978, see section 3.3.6) are 1:2, cement:sand (measured by volume). Watt does not mention the proportion of water to be used. He says instead that the mortar should be mixed as "dry" as possible, for highest strength. Refer back to the discussion of making mortar above.

The following instructions are for construction of a small jar which holds about 0.25 m^3. Watt says that people with no experience have been taught to make the jars in less than two days. Much larger jars, which have screens, lids, and taps, have been constructed using this method. Subsituting soil and

lime for some of the cement and sand in the mortar has also been tried.

MATERIALS: 1/2 bag of cement (less than this should be required)

clean sand

clean water

burlap, "gunny cloth", or other strong sacking material

sand, grain husks, or sawdust to fill the sacking

TOOLS: needle and thread, or other tool for sewing the sacking

mixing board or pad and containers for measuring and mixing mortar materials

trowel and wooden stick

STEPS IN CONSTRUCTION REQUIRING SPECIAL CARE:

Making sure that the material used to fill the sacking (step 2.4) is heavy enough to keep its shape during plastering. It is a good idea to try filling the sack on the ground before beginning contruction.

Making the mortar. Do not make the mortar for applying to the mounl until you are actually ready to begin (step 2.8). This should allow you to work with a "dry" mortar mixture for maximum strength. Mixing the cement and sand well, before adding the water, is especially important.

Curing the new jar (step 2.10).

*Photo 2 Making a small water jar: 250 litres. Thailand***

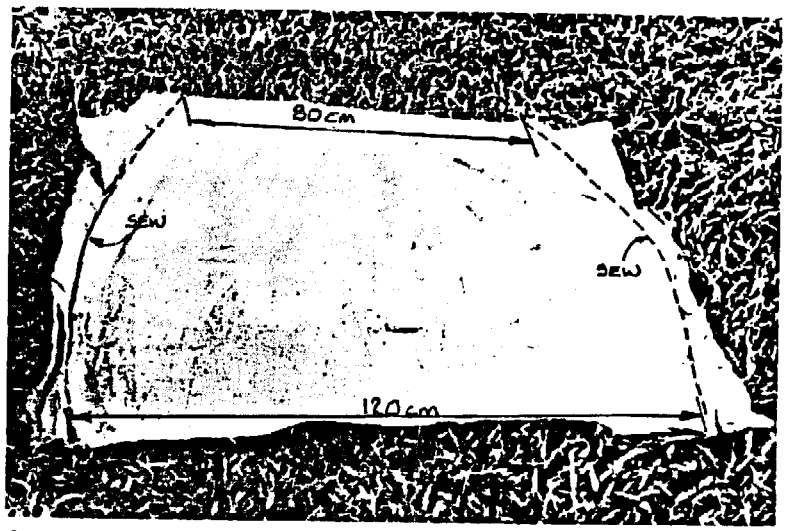

2.1 *Place two pieces of gunny cloth (hessian sacking) 125cm by 110cm together and mark out. Sew the two pieces together along the curved lines leaving the top and bottom open.*

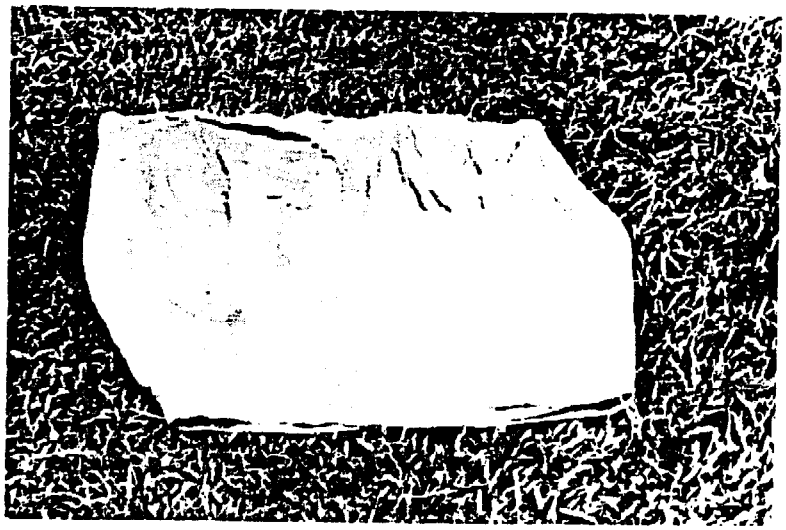

2.2 *After sewing, turn the sack inside out.*

** copied from Watt, 1978, by permission, ITDG

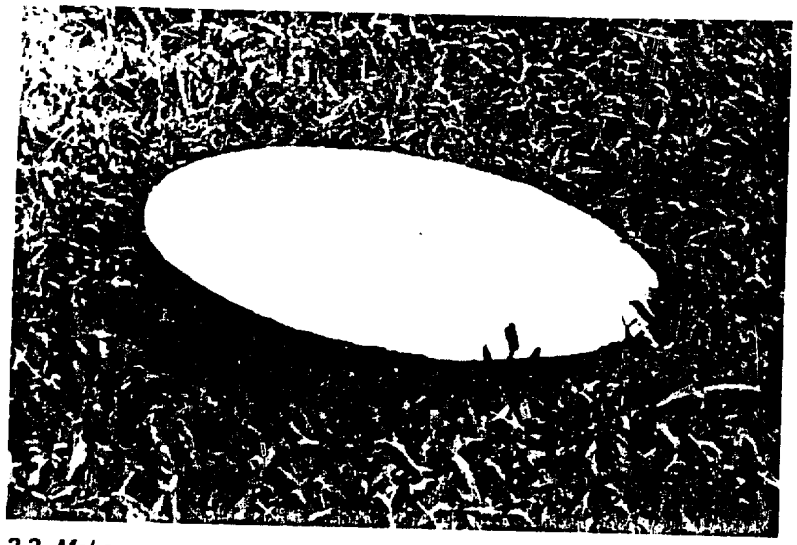

2.3 *Make a precast mortar bottom plate, 60cm in diameter and 1.5cm thick. Make the mortar from a mix of 1:2 cement:sand by volume as dry as possible consistent with easy trowelling.*

2.4 *Place the sack on the bottom plate with the smaller opening downwards and fill the space inside with paddy husk, sawdust or sand. The weight of the fill will hold the lower edge of the sack firmly on the bottom plate. Make sure that the mortar bottom plate sticks out from under the sacking.*

2.5 *When the sack is filled up, fold the top and tie it into the shape of a traditional water jar. Use a piece of wood to tap on the mould to make it round and fair.*

2.6 *Spray some water on the mould before plastering to make it damp.*

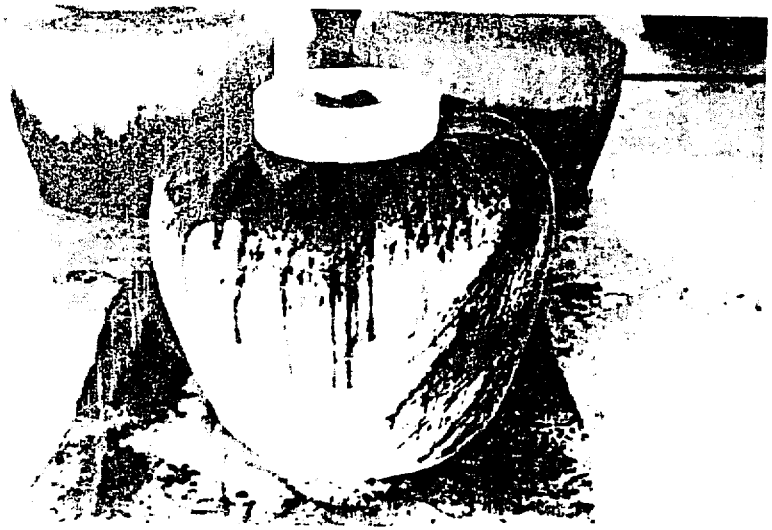

2.7 *Place a circular ring on the top of the sack to make a mould for the opening of the jar. This can be made of wood or precast mortar.*

2.8 *Trowel a first layer of mortar onto the mould to a thickness of about 0.5cm.*

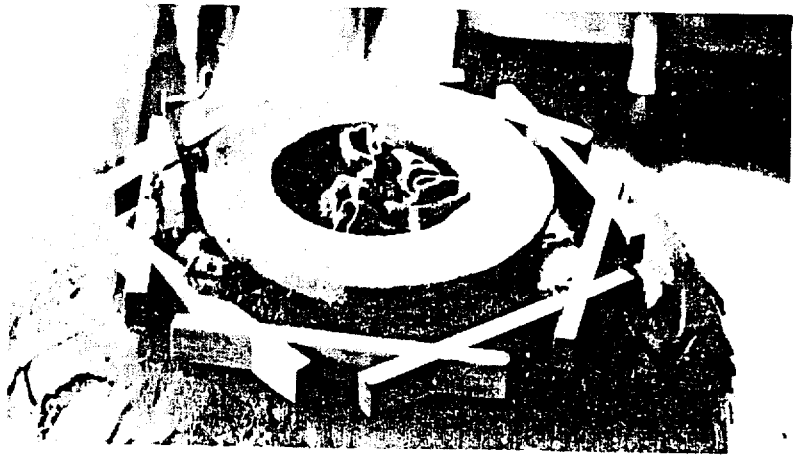

2.9 *Plaster the second layer of 0.5cm in the same manner as the first layer. Check the mortar layer for thickness by pushing in a nail: any weak or thin spots should be built up with an extra layer of mortar. Build up the opening.*

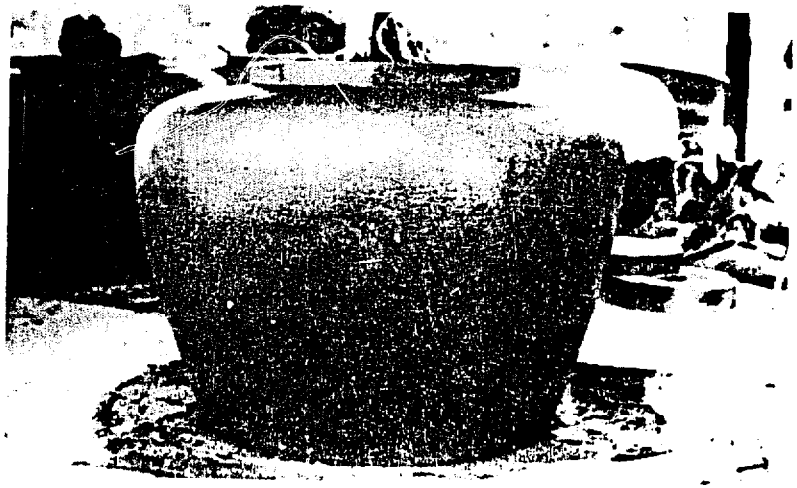

2.10 *Remove the contents of the gunny bag and the bag 24 hours after the jar has been made. Check the jar for any defects and correct these with mortar; the inside of the jar should also be painted with a cement slurry. Cure the jar out of sunlight and drying winds, preferably under damp sacking or plastic sheet for at least 2 weeks.*
This technique has been used with great success in Thailand and pots of up to 4000 litres (approx 1000 galls.) capacity have been made in this way.

4.3.2. Ferrocement tank, 10 m^3

The following description and instructions have been copied from Ferrocement Water Tanks and their Construction (see section 3.3.6). This tank design is based, in part, on years of experience with the construction method in Zimbabwe; other versions are being built in Thailand and Indonesia. See section 3.3.2 for more information on ferrocement tanks.

Chapter Seven **

Small Tanks for Domestic Use: 10m^3 Capacity

These tanks have been used for many years in parts of Africa and have been designed to be as simple as possible to build in self help programmes. The users, who are at first unskilled in this sort of construction, can contribute their time and efforts in collecting sand and water, digging the foundations and preparing the mortar under the general guidance of a trained builder. With experience they quickly learn how to make the tanks without further guidance.

A trained builder with five helpers takes about three days to construct the tank. The users often contribute some money towards the cost of the tank, which helps to cover the builders' wages, the cement, reinforcement and the hire of the formwork.

Design

The tanks have been designed for construction by relatively unskilled workers. They have a diameter of 2.5 metres, a height of 2 metres, giving a capacity of 10 cubic metres. The final wall thickness will be about 4cm. The tanks are built on site and should not be moved.

Formwork

The 2m high formwork is made from 16 sheets of standard galvanised roofing iron, 0.6mm thick with 7.5cm corrugations, rolled into a cylinder with a radius of 1.25m.

Steel angle iron (40 x 40 x 5mm) is bolted vertically on the inside face at the ends of each set of four sheets – this allows the sheets to be bolted together to form a circle. Between the ends of each section is placed a wedge which is pulled out to allow the formwork to be dismantled (see Fig.19).

** copied from Watt, 1978, by permission, ITDG.

Fig.18 Standard formwork to make 10m³ tank

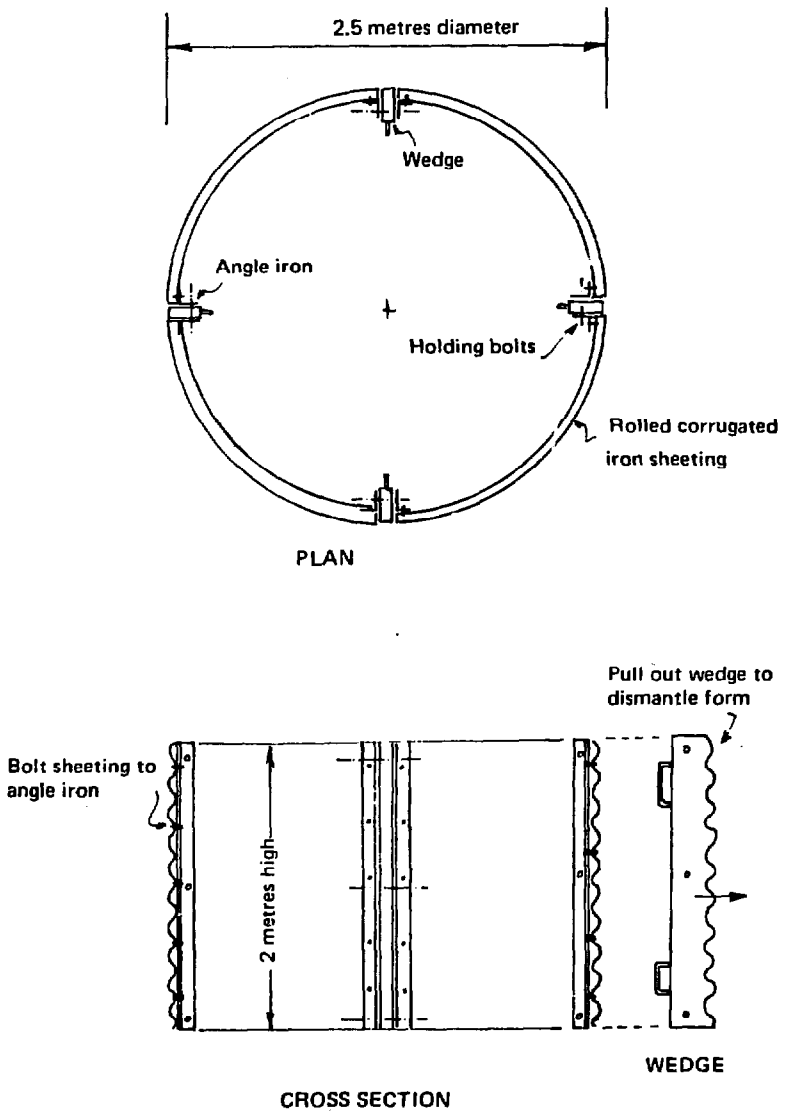

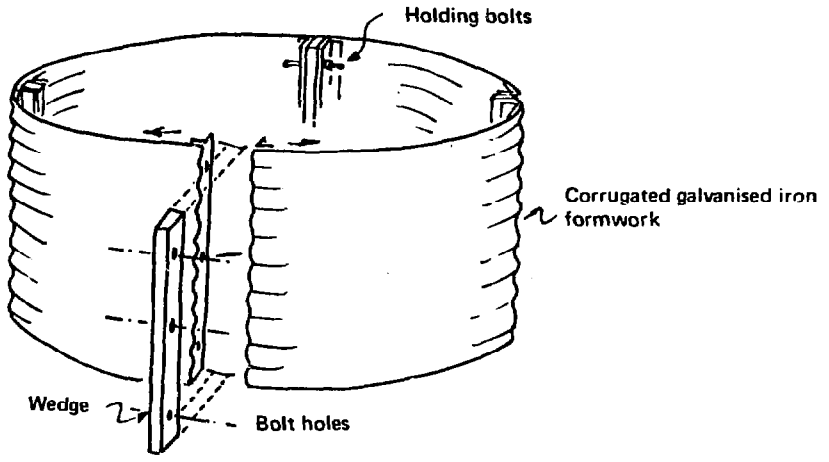

Fig.19 Assembling the formwork

Construction

A circular area 2.8m in diameter is cleared at the required site for the tank and excavated down through the loose topsoil. A 10cm layer of sand and gravel is laid evenly over the excavation and a 7.5cm layer of concrete laid on top of this; the concrete mix of 1:2:4 (cement:sand:gravel by volume) will form the foundation slab under the tank.

Into this concrete foundation is cast a 1m length of 20mm bore steel water pipe with a tap on the outside end. The pipe is curved so that it projects 10cm above the floor of the tank; a piece of wire is threaded through the pipe to act as a pull through after the tank has been built (see Fig.20).

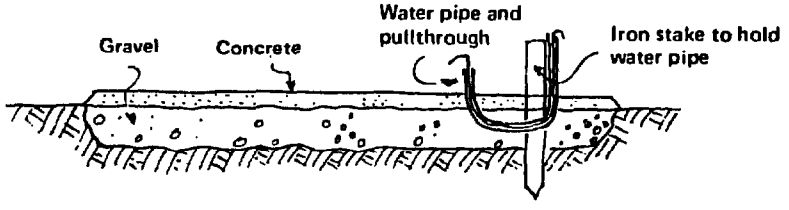

Fig.20 Foundation of tank

When this concrete floor slab has hardened the formwork for the tank is erected. The bolts passing through the angle

iron and wedges are tightened to provide a rigid cylindrical form. This is cleaned free from cement and dirt, oiled and the wire netting wrapped around it to a single thickness and tucked under the forms. The netting has a 50mm mesh, and is made from 1.0mm wire (see Fig.21).

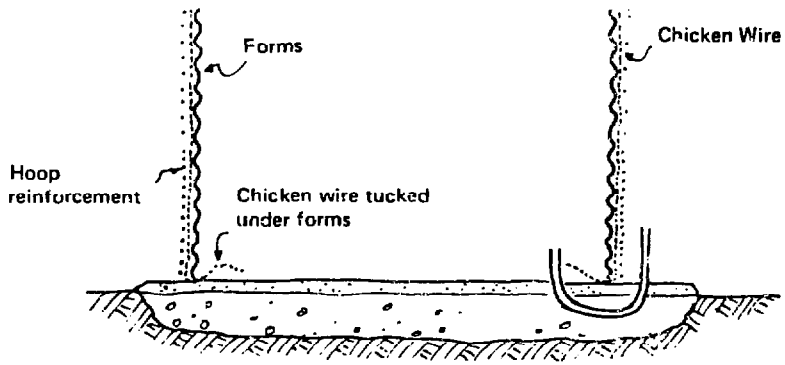

Fig.21 Erect formwork and wind on reinforcing wire

To form the hoop reinforcements, the 'straight' galvanised iron wire, 2.5mm diameter, is wound tightly around the tank from the base at the following spacings:—

2 wires in each corrugation for the first eight
1 wire in each corrugation to the top
2 wires on top corrugation.

About 200m of 2.5mm diameter wire will be needed, weight 8 kg. The netting provides vertical reinforcement to the tank and also holds the hoop wire out of the corrugations.

The outside is then plastered with a layer of mortar made from a mix of 1:3 (cement:sand by volume) and as soon as this has begun to stiffen a second mortar layer is trowelled on to cover the reinforcing wires to a depth of 15mm. The surface is finished smooth with a wooden float.

After a day or so the formwork is dismantled by removing the holding bolts and by pulling out the wedges which will leave the shuttering free to be stripped away from the inside mortar wall. The sections are lifted clear of the tank to be thoroughly cleaned of any mortar or cement.

A 20cm length of 8cm diameter downpipe is built into the wall at the top of the tank to act as an overflow and the

inside of the tank is plastered with mortar to fill up the corrugations. When this has hardened sufficiently a second final coat is trowelled onto the inside and finished with a wooden float.

A 5cm thick layer of mortar is next laid onto the floor of the tank and the junction with the floor and the walls built into a coving.

The floors are unreinforced and these tanks would fracture if they were moved.

Take care that the mortar does not block up the outlet pipe. Before the mortar on the floor has stiffened, form a shallow depression in the middle; this will allow the tank to be cleaned at a later date — the sediment can be brushed into the hole and cupped out (see Fig.22).

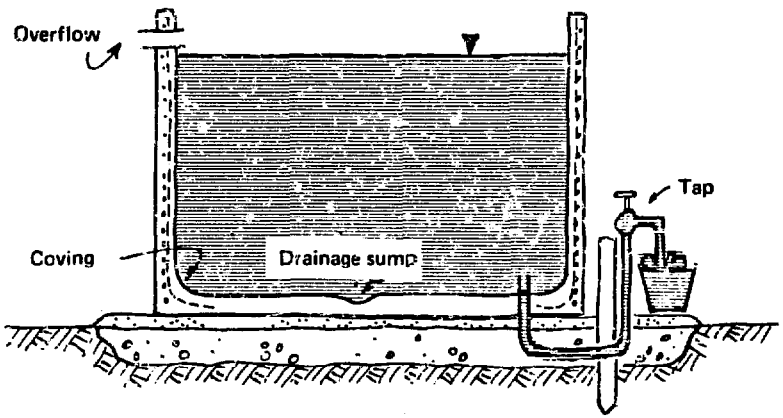

Fig.22 The completed tank

The inside of the tank is painted with a thick cement slurry to seal the tank, a small volume of water is allowed to stand in the bottom of the tank and the tank is covered and cured for seven days.

Roof

The tank is covered with sheets of 0.5mm galvanised sheeting supported on two lengths of angle iron. Alternatively, a reinforced mortar roof may be built in the ways described in Chapter 10. Building a mortar roof is not difficult but it requires extra sets of formwork.

Materials required for 10m³ tank with galvanised iron roof

Cement	600 kg.
Plain wire 2.5mm diameter	200m
Chicken mesh 1m wide	16m
Water pipe 20mm bore	1m
Water tap	1 No.
Overflow pipe	20cm of 8cm dia. iron or concrete pipe
Galvanised iron sheet and angle iron for roof	
Sand	$1.0m^3$
Gravel	$0.5m^3$

4.3.3 THE GHALA TANK

This tank is made by plastering a sturdy basket for holding grain. While this design comes from Kenya, the idea could be used to make similar tanks out of baskets made from a wide variety of indigenous materials. Most of the information and the drawings for these instructions come from an article in the Magazine APPROPRIATE TECHNOLOGY, March 1982 (see Section 3.3.6).** The authors say that ghala-type tanks can be built as large as 7,500 liters and should last ten years. Most of these tanks have been built closer to the size of the tank described here, which has a capacity of about 2,300 liters.

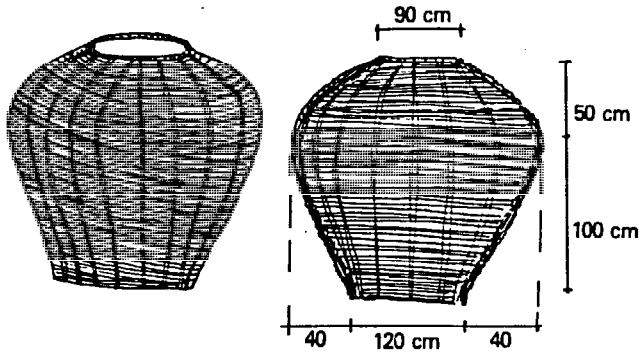

Fig. 1 Ghala basket constructed without a base.

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GHALA TANK (cont.)

MATERIALS:
- 5 bags of cement (50 kg each).
- 12 wheelbarrows of clean sand.
- 4 wheelbarrows of clean gravel. Most pieces of this gravel should be about 1.25 cm in diameter.
- clean water.
- enough small rocks to build the foundations. See step 1 below.
- 2 m of water pipe about 1.25 cm in diameter, with 90° elbow (see fig. 2).
- tap to fit the water pipe.
- one ghala-type basket, woven without a base (fig. 1).

TOOLS:
- mixing board or pad, and containers for measuring proportions of mortar and concrete materials.
- shovel and trowel.
- pipe threader.

STEPS IN CONSTRUCTION REQUIRING SPECIAL CARE:

--- Compacting the foundation until it is solid enough to support the weight of concrete, tank, and water (step 1).

--- Mixing mortar "dry" enough that it will not fall off the overhang of the inside of the basket, yet wet enough that it can be worked into the weave of the basket walls (steps 6 and 7 below). If you can, make a small quantity of mortar and try applying it to the basket before beginning construction.

--- Plastering the inside of the bottom of the basket to give a strong, leak-proof bond to the foundation (step 7).

--- Curing: keeping the walls damp while the newly constructed tank strengthens, before it is used.

GHALA TANK (cont.)

CONSTRUCTION:

--- 1. Lay the rocks for the foundation, in a circle about 2 m diameter and 20 cm deep (fig. 2).

--- 2. Spread a mixture of soil, sand and gravel over the rocks and stamp or pound down to a 1.5 cm thickness (fig. 2).

--- 3. Prepare concrete as described above. Use proportions 1:2:4, cement:sand:gravel (measured by volume). This concrete is to be laid on the foundation; making the mix with about 20 l. of cement should yield enough concrete for a layer about 7.5 cm thick.

--- 4. Spread about 1/3 of the concrete on the foundation. Place the water pipe and tap in the wet concrete as shown in fig. 2.

--- 5. Spread the remaining concrete on the foundation. Immediately place the basket in the center and work its lower part into the concrete. Work some of the concrete up against the basket wall (fig. 2) to make sure the basket is firmly anchored.

--- 6. After the concrete is set, prepare mortar as described above. Use proportions 1:3, cement:sand (measured by volume).

--- 7. Apply the mortar by hand or with a trowel to the inside of the basket walls, starting from the bottom of the basket. This layer of mortar should be about 1.25 cm thick. Use a little extra mortar where the bottom of the basket meets the concrete of the foundation; fill and smooth this area so that the bond will be strong.

--- 8. While the first layer of mortar is stiffening, prepare mortar for the second layer. Use proportions 1:2, cement:sand (measured by volume). Apply to the inside of the basket and smooth into a layer about 1.25 cm thick with a trowel. Then apply any remaining mortar to the outside of the basket. This may help protect the original basket materials and will help strengthen the tank.

GHALA TANK (cont.)

--- 9. As soon as the second layer of mortar sets, cover the tank with wet sacks or cloths. (These covers should be kept wet for about a week. It is much easier to keep the covers damp for proper curing if the tank can be shaded from the sun.) After about 12 hours, fill the tank about 1/4 full with water; this keeps the inside damp.

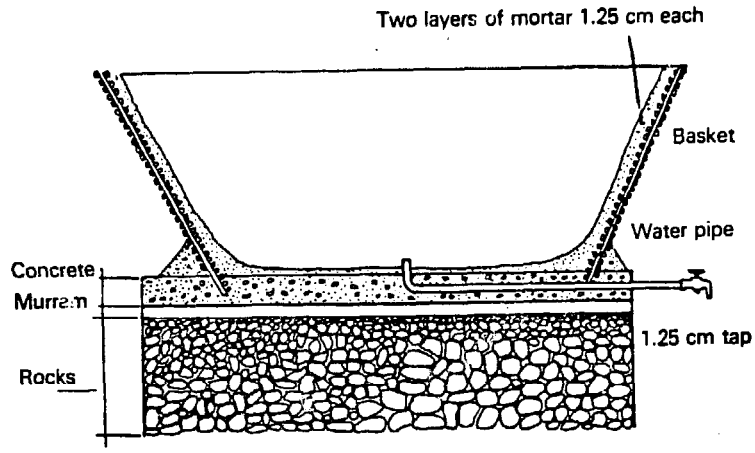

Fig. 2 Construction of the foundation and positioning of the basket.

GHALA TANK (cont.)

--- 10.Make a lid. A concrete lid can be poured into a 3 to 5 cm deep circular hold in the soil, carefully cut to match the diameter of the opening at the top of the tank (fig. 3). Line the hole with sand so that the lid can be pulled out easily; using soil or some other material, carefully make mounds in the hole for air and water holes. A handle can also be placed in the concrete as it stiffens. See the details of figs. 3 and 4.

The authors of the article in APPROPRIATE TECHNOLOGY note that lids can be made out of wood or other materials.

However the lid is made, its holes should be screened to keep out mosquitoes and dirt.

Fig. 3 Construction of the lid.

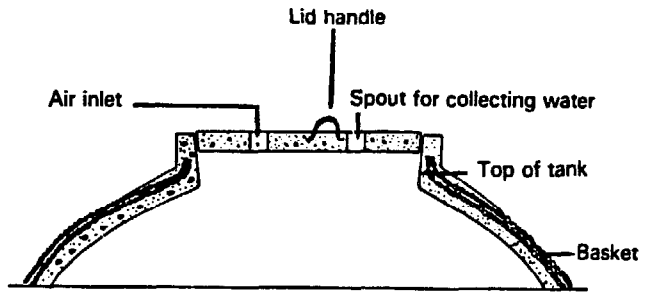

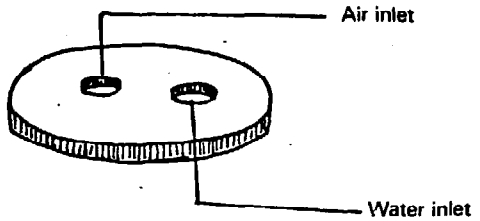

Fig. 4 Detail of the lid.

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*Items marked with an asterisk are reviewed in the section noted

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The collection of rainfall and run-off in rural areas

Arnold Pacey with Adrian Cullis

WITH ILLUSTRATIONS BY PHIL CLARK

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PREFACE

Rainwater collection and storage has been a long-standing interest of ITDG, stemming from the work in the 1960s of one of its earliest advisers, Michael Ionides, on low-cost water storage reservoirs in the Sudan. ITDG subsequently initiated a rainwater harvesting and micro-irrigation demonstration project with the Department of Community Development in Botswana in 1967. Further project work followed in Swaziland, Jamaica and Brazil (with the financial support of the Ministry of Overseas Development and Oxfam) and at the end of the 1970s Peter Stern, founder chairman of ITDG's Water Panel, proposed a research project for a rainwater harvesting publication to continue investigating the subject. Funding for the proposal was secured from the Shell Grants Committee in 1982 (as a contribution towards the U.N. International Drinking Water Supply and Sanitation Decade, 1981–90) and Adrian Cullis undertook a major literature search as well as carrying out practical work in Kenya. Arnold Pacey then used the results of this research in writing this book. The opinions, estimates and definitions expressed in the book are the responsibility of the authors and should not necessarily be taken to represent the views of ITDG.

Rainwater harvesting has attracted considerable attention in recent years in work covering a wide range of techniques — from the collection of rainwater from roofs to the retention of surface and sub-surface flow in rivers. The main interest of the authors has been methods of collecting and conserving rainwater at as early a stage as possible in the hydrological cycle to ensure the best use of rainfall, before it has run away into rivers and groundwater, or has disappeared as evaporation. Additional benefits from such measures of water control will often include a reduction in both soil erosion and in the damage caused by flooding. The authors believe that the systems they describe could hold out the greatest immediate hope for thousands of scattered, small communities that cannot be served by more centralized water supply schemes in the foreseeable future. For the purpose of this book, therefore, rainwater harvesting, or 'collection', has been defined as 'the gathering and storage of water running off surfaces on which rain has directly fallen' and not the 'harvesting' of valley floodwater or stream flow.

At the outset of our research ITDG was planning to produce a handbook which would describe in mainly technical terms the different methods of harvesting rainwater for domestic, livestock and crop production

purposes. During the literature search it became clear that there were already plenty of documents in existence which adequately described the technical details, especially for domestic systems. What was missing, however, was material on designing and implementing schemes which were socially, technically, economically and environmentally appropriate for use in different patterns of livelihood and organization. This book aims to present the subject from these various perspectives in order to emphasize the importance of such interdependent dimensions of rural development.

Equally neglected, we concluded, was the subject of how systems, once established, could be sustained or copied by other groups so that larger numbers of people could benefit from the same ideas. These observations, together with the known limitations of a purely technical text, led us to shift our emphasis towards a more people-oriented treatment of the subject. This does not mean, however, that this book will not interest the technician — on the contrary, the mixture of technical and non-technical matters should help to stimulate the awareness of factors often overlooked by the single-subject specialist. The book is intended for rural development workers, especially those involved with water resources for domestic and agricultural purposes. The authors have tried to avoid a dull 'official' account of the subject and believe that the ideas presented will be stimulating to practical field-workers, project planners or managers, policy makers and academics — indeed to anyone with a commitment to rural development with the poor.

During the research and production of this work ITDG has been helped by numerous individuals and we are particularly grateful to the following: Jack Lawrence for his guidance during the initial stages; John Gould, Brian Latham, Steve Layton, Derek Ray, Angela Sinclair, Jeremy Swift (in connection with Chapter 2) and Peter Wright (Chapter 7) for contributing case study material; and Peter Stern for his invaluable advice throughout. My special thanks are due to Arnold Pacey, who not only edited the material which appears in the book but also provided invaluable assistance at all stages of the project. ITDG is, of course, greatly indebted to the Shell Grants Committee for their financial support.

Readers may be interested to know of other outcomes of this project, which are the assembly of a unique collection of documents on rainwater harvesting (kept at ITDG's Head Office in Rugby and accessible by arrangement) and the fact that ITDG has again become involved in a rainwater harvesting project overseas, in Turkana, north-west Kenya — with the possibility of involvement with other projects in Kenya and India. It is my hope that at least some of the lessons learned through the research and publishing of this book can be applied in practice in order to support the poor in their struggle for survival.

John Collett
Programme Officer, The Intermediate Technology
Development Group (ITDG)
Rugby, UK
August 1985

1. TECHNICAL PERSPECTIVES ON RAINWATER COLLECTION

RAINFALL AND WATER RESOURCES

Modern technologies for obtaining and using water are concerned chiefly with the exploitation of river systems and the development of ground water by means of wells and boreholes. On average, however, river flows together with the annual turnover of groundwater account for less than 40 per cent of the rain and snow which falls on the world's *land* surfaces. The remainder is lost to the land by evaporation from the soil, or from pools, marshes and lakes, and by evapotranspiration from the leaves of growing plants. In some of the world's driest areas, rivers account for as little as 4 per cent of precipitation.

Yet civil engineers have concentrated their efforts on the major rivers, seeing them, perhaps, as 'a sort of challenge', and considering how many dams they could build on them, how great a command area could be created, and so on. 'But for the vastly greater areas of the world's surface that are outside big river systems, they had virtually nothing to offer' (Ionides 1976).

Clearly, if rivers only represent a small proportion of annual precipitation, one method to try outside the big river systems is to collect rainwater immediately it falls, and before large evaporation losses occur. In earlier phases of human civilisation, major rivers were certainly exploited, but there was also a complementary and more extensive pattern of settlement in areas where rivers were few, and where the direct collection of rainfall was one of the few methods available for securing a water supply. Rainfall was collected from house roofs (Fig. 1.1) and was also sometimes directed into cisterns from paved courtyards, from hill and rock surfaces, and even from specially surfaced areas sloping towards cistern inlets (Fig. 1.2).

More surprisingly, among earlier civilizations, productive agriculture extended much further into the semi-desert areas of Arabia, Sinai, North Africa and Mexico than has seemed possible in more recent times. Moreover, this is explicable not by a markedly better climate in the past, but by the use of rainwater collection and conservation techniques. Figure 1.3 illustrates one approach, where a channel dug across a hillside intercepts water running downslope during storms, and directs that water

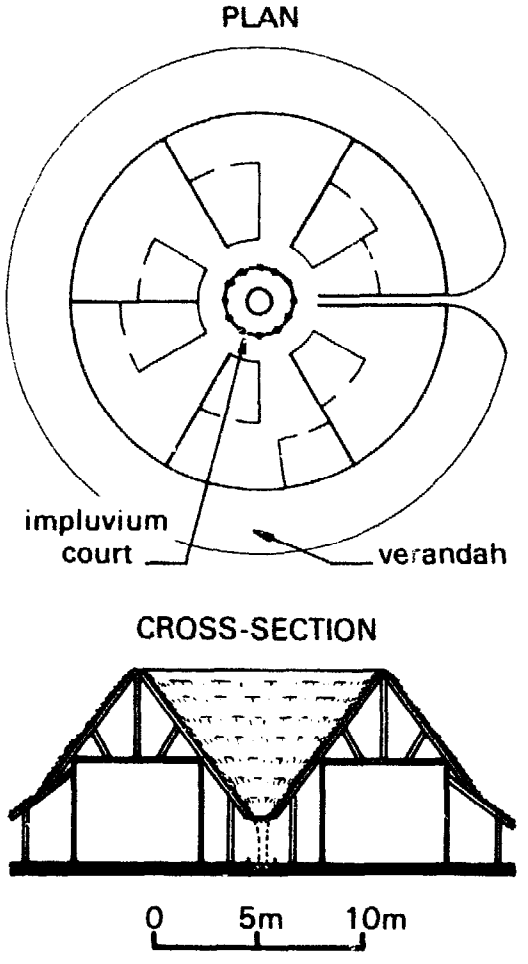

Fig. 1.1 A traditional, though rather rare, example of collecting rainwater from roofs – found in a house in Senegal about 1940. (Denyer, 1978) Water dripping from the eaves falls directly into the circular tank in the courtyard or sometimes into the impluvium court itself, from where it drains to an underground cistern. Square houses using the same principle have been common in the Yoruba and Benin regions of Nigeria. There are also houses with larger courtyards where the paving serves as a catchment surface. Runoff from the roof then enters the cistern only after flowing over the paved area. (UNEP 1983)

onto a field on flatter ground. Many variants of this technique, referred to as 'runoff farming' are known to have existed, and new methods have been developed in recent years.

Agriculture in the Old World originated in a climatically dry region in the Middle East, and may have depended to some degree on irrigation or runoff farming methods from the start (Evenari/Mashash 1975). The techniques involved seem to have been forgotten in subsequent agricultural development located in moister regions of Europe, Asia and America. The most notable evidence about such techniques has emerged from research into runoff farming and rainwater collection systems in the Negev Desert, in southern Israel. It is clear that in this region, rainwater provided a livelihood for a considerable population more than 2,000 years ago, continuing until about 700 A.D. The restoration of ancient farms where the

techniques were used and the application of lessons learned has made new settlements possible in the desert, and has stimulated research elsewhere. However, conditions in the Negev Desert are atypical, and techniques developed there are not easily applicable in other regions, as will be explained in Chapter 6. Runoff farming should not, therefore, be thought of as *generally* applicable in deserts and 'arid' regions. Other areas where it has been successful have moister climates than these terms imply, though not moist enough for reliable crop production without use of runoff.

In North America, some notable research on runoff farming has been stimulated by realization that people living in what is now Mexico and the south-western United States prior to European settlement had methods of directing runoff water onto plots where crops were raised, thereby making a productive agriculture possible in an otherwise unpromising, semi-arid environment. In a few instances, similar systems are still used, and much research has been devoted to elucidating their operation (see Chapter 6) and in devising new but analogous methods of rainwater collection, for example, utilizing chemical soil treatments. There have also been important innovations in Australia, where something like a million people, mostly in remote areas, are today dependent on rainwater as their most important (but rarely their only) source of supply (Perrens 1982). Other work on rainwater collection techniques has been supported by the Intermediate Technology movement in Britain, and it is from this that the present book has stemmed. Again, ancient precedents were important. The initiator of this work, Michael Ionides, traced the origin of his ideas

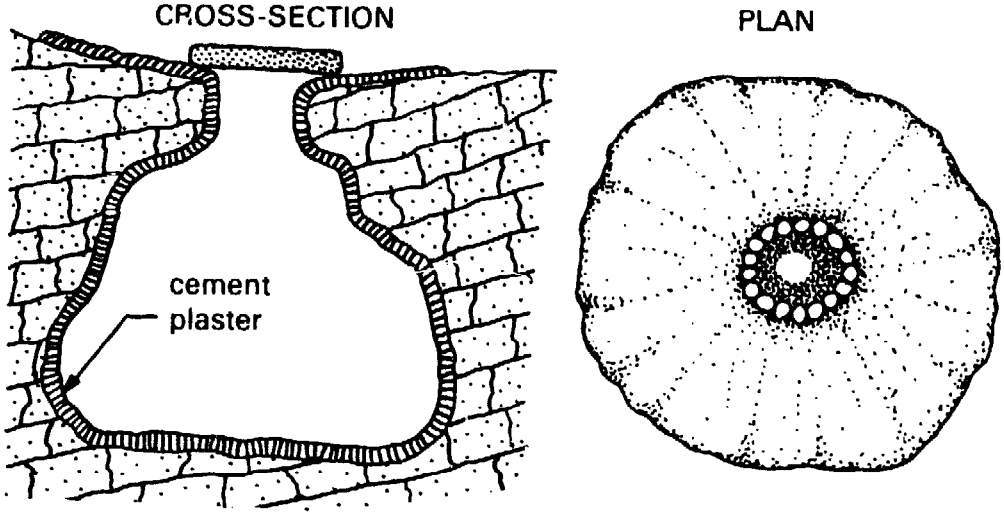

Fig. 1.2 An underground cistern filled by rainwater from an artificial catchment area laid on the ground surface. This is a traditional technique in the Yucatan peninsula of Mexico. The underlying rock is limestone, and in the absence of a prepared catchment, rainwater infiltrates into the ground without significant runoff. Cisterns are excavated in the rock and waterproofed with a thin layer of cement plaster. Many of them are very old, dating back to pre-conquest times. (Gordillo et al. 1982)

Note: *Drawing is not to scale.*

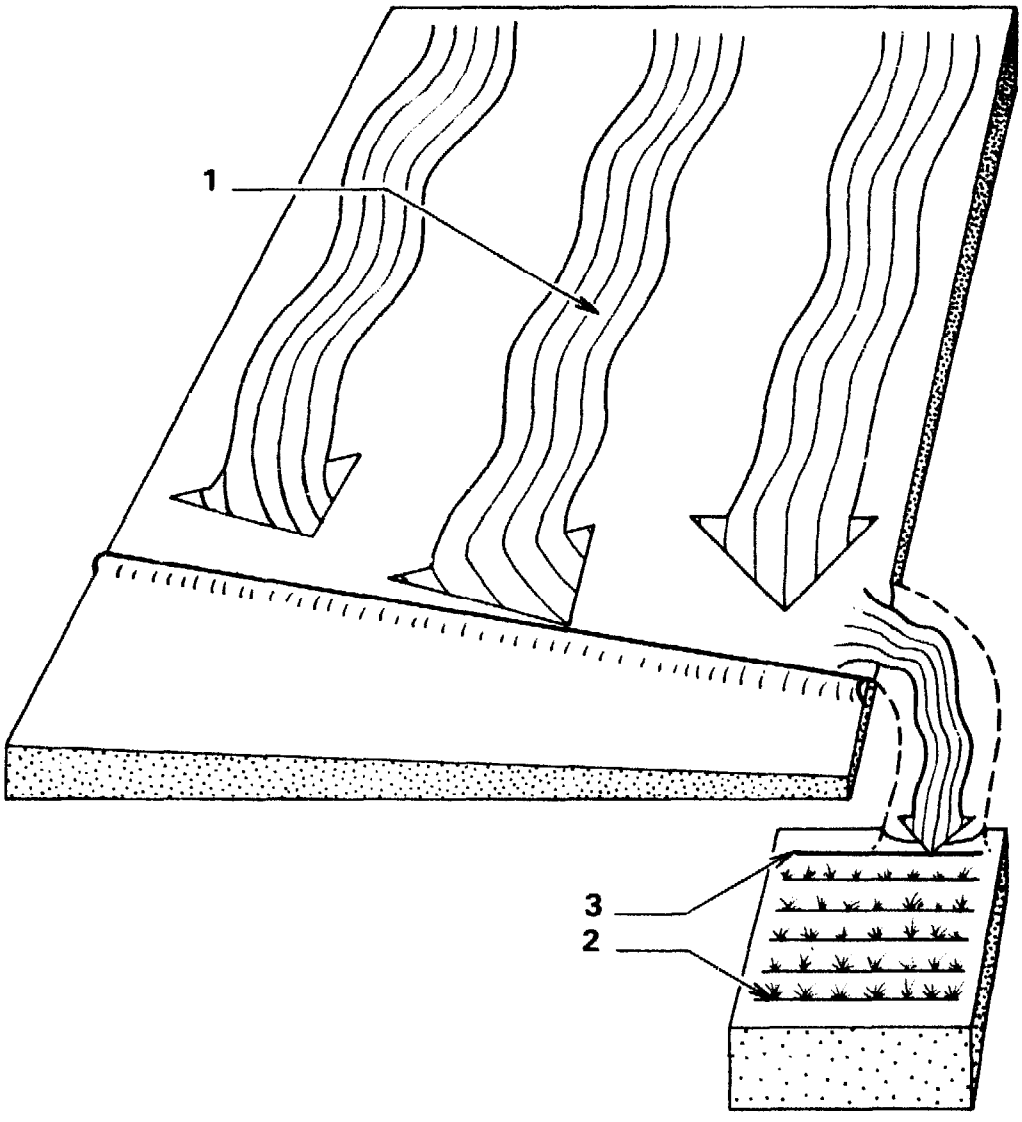

Fig. 1.3 The concept of runoff farming. Rain falling on the catchment area (1) is collected at the foot of the slope and conveyed to the cultivated plot (2) where its flow is checked and spread out by a bank (3). There may be additional banks to control flow over the plot.

Note: *Diagram is schematic and not to scale.*

back to 1926, when he was working in Iraq on 'the reconstruction of an ancient Babylonian irrigation canal' (Ionides 1976), and to his work on old water supply systems in Jordan (Ionides 1939).

He always stressed that the storage of rainwater in enclosed tanks was 'an ancient way' of enabling a water supply to last through a long dry season. He argued that a revival of the technique was inevitable for two reasons. 'The first reason is need. There are great tracts of semi-arid territory where population growth is pressing on the water supplies for drinking. . . . The second reason is opportunity'. Modern materials made possible a new approach to the construction of storage tanks and

catchment surfaces, and could 'open the way for a massive attack on a problem which is becoming more and more acute as the years go by'.

The collection of rainwater from roofs has been a common practice in many moist climatic zones, not just in semi-arid areas. In Kenya, Indonesia and elsewhere, use of water from roofs has sometimes been a particular advantage at busy times in the farming year. There is most rainwater to collect at the very season when people are working hardest on the land, and have least time for carrying water from distant sources; thus even a small rainwater tank may ease a seasonal labour bottleneck. There are also islands and other places with no rivers and no good groundwater sources, and where rainfall is the only feasible means of providing a water supply.

The technique of rainwater collection for domestic supply or runoff farming, is essentially small in scale. It utilizes the roofs of individual houses, or ground catchments, which, because they are small, maximize the efficiency of runoff collection. Thus a scatter of small rainwater catchments, each serving an individual farm, homestead or hamlet, is the characteristic pattern. This implies an *extensive* form of development, in contrast to the *intensive* irrigation and hydropower potential of big dams built on major rivers.

Where large concentrations of population have to be supported, intensive forms of development are inescapable, and must sometimes include large dams and river basin projects. In such areas, rainwater collection will have only a small role to play, perhaps complementing other water sources or giving individual families a private source of supply. By contrast, on small islands and in a few other exceptional places where there are no significant rivers, ingenuity has sometimes been used in devising rainwater catchment schemes to supply substantial towns. Gibraltar has one of the largest rainwater systems in existence, and on both Gibraltar and Bermuda, regulations compel householders to collect water from their own roofs. In the limestone districts of Jamaica, there are many small rainwater supplies, some private and some communal.

Despite these exceptions, when studying the socio-economic conditions under which rainwater can be most effectively used, we are quickly brought back to the semi-arid areas where rivers may be few or only seasonally flowing, and where climatic conditions and environmental resources tend to restrict settlement to a scattered, extensive pattern. In such areas, rainwater collection offers its greatest technical advantage in terms of the conservation of the scarce water resource. The fact that it also fits the settlement pattern so well tends to confirm its appropriateness.

DEFINING RAINWATER COLLECTION

The principle of collecting and using precipitation from a small catchment area is often referred to as 'rainwater harvesting'. This term derives from a

more general name, 'water harvesting', first used in Australia by H. J. Geddes to denote, 'the collection and storage of any farm waters, either runoff or creek flow, for irrigation use'. This nomenclature has since been used very loosely, as if the collection of rainfall and all other water harvesting amounted to the same thing. Yet in the above definition, water harvesting includes stream flow in creeks and gullies, not just rainwater at the point where it falls. Other definitions include water arising from all kinds of precipitation, not just rainfall. This book deals only with water running off surfaces on which rain has directly fallen, not with stream flow, and utilization of this runoff will be referred to as 'rainwater collection' (or concentration). Something needs to be said, however, about other forms of precipitation. For example, in Afghanistan, the winter snow is sometimes 'harvested' by manually collecting and packing it into a deep watertight pit. With the top sealed, the snow melts very slowly during the following summer, and water is withdrawn from the bottom of the pit. However, this book is concerned with countries where snow is a rare occurrence, so this technique is not further considered.

It is also sometimes said that dew and mist can usefully contribute to water supplies. Having himself shaken enough dew off long grass for a scanty morning wash, at least one of the present authors is not inclined to dismiss the idea. In the Negev Desert, where mean rainfall is less than 150mm, dew is equivalent to a further 20-30mm of precipitation. From this general region comes the Biblical story about harvesting dew by spreading a fleece on the ground in the evening. Next morning, enough dew could be wrung from it 'to fill a drinking cup' (Judges 6:38). In a place in Africa where the eaves of buildings are observed to drip in the early mornings after a dew, it was estimated that a roof area of 29m^2 could yield 320 litres of dew water in a year. An Indian publication suggests lining a small depression with a plastic sheet and piling stones on this, so that dew forming on the stones drips onto the plastic (CCSK 1983).

However, the amounts of water which can be collected in these ways will always be very small. Dew may sometimes contribute a little extra water to a system designed for collecting rainfall, but the number of situations where it is worth devising structures specifically to collect dew and mist will be rare indeed. The so-called 'dew ponds' of southern England were filled mainly by rainwater, and ground surface catchments were constructed to drain into them. However, their linings, which were made by compacting clay over a layer of straw, favoured rapid cooling of the sides and bottom of an empty pond at night, and hence some increased condensation of dew may have contributed very slightly to their contents.

Because of the marginal relevance of snow and dew collection, this book deals only with precipitation in the form of rain, and particularly with rain close to the point where it is intercepted by the ground or by a roof. The concern is with collecting rainwater before it has flowed very far over the

ground, in order to avoid as far as possible the losses to which runoff is subject. Stern (1978, 1979) points out that in the semi-arid regions within or close to the tropics, runoff water from a *small* catchment may amount to half the rainfall, even though only around 5 per cent of the rain may ultimately enter a river system. This is because the smaller the catchment area from which runoff water is collected, the less water is lost by evaporation or interception in depressions. Shanan and Tadmor (1979) observe that in the Negev Desert, watersheds of 300 to 500 hectares in extent produce less than 3mm of runoff on average each year. By contrast, a 'micro watershed' of 0.02ha may produce 10-30mm of runoff per year depending on slope, shape of catchment, soil conditions and the intensity of the storms.

Analysing this in more detail Shanan and Tadmor consider three main ways by which rain falling on a watershed is detained and 'lost'. Firstly, it may be intercepted by the leaves of plants growing on the watershed, evaporating without reaching the ground. In a dry area, vegetation is usually sparse, and interception losses are likely to be less than 2 per cent of rainfall. In a moist area with more vegetation, they may be more than 5 per cent.

Secondly, as already noted, runoff accumulates in any depression on the watershed to form puddles. On steep slopes, this may happen to only a small extent. On flatter land, there will usually be many large puddles after a storm, and where these are observed it may well mean that around 2-4mm of rainfall from that storm is accounted for by 'depression storage'.

The third way in which runoff is diminished is by infiltration into the soil. At the beginning of a storm, the dry soil may absorb all the rain that reaches it. However, some soils crust over under the impact of raindrops, in which case, infiltration diminishes almost to nothing, and runoff begins quite quickly. Even with soils which do not form a crust, the infiltration rate diminishes considerably once the surface has been thoroughly wetted.

Much therefore depends on local conditions. Moreover, infiltration occurs at a faster rate in hot weather than in cold; it is affected in complex ways by stones on the watershed, and usually reduced quite considerably if vegetation is removed.

Referring to the comparison made earlier between small (0.02ha) and large watersheds, one may comment that the proportion of rainfall lost due to interception by vegetation is likely to be independent of catchment size, whereas the proportion accounted for by depression storage and infiltration will tend to become greater the further the runoff flows across the ground surface. It may perhaps be added that while a small watershed is a more *efficient* collector of rainfall, in areas where showers are very localized and precipitation is patchy, a large catchment area may sometimes produce runoff on occasions when individual small watersheds do not receive rain at all.

It needs to be made clear that the rainwater collection methods discussed in this book are mainly (but not exclusively) concerned with *small* catchment areas or watersheds. To establish the distinction between techniques relevant with these applications and other forms of water harvesting, it is useful to consider the following example. In Yemen, when rains fall in the mountains, which rise to 2,500m, torrents of water rush down steep valleys, or *wadis*, towards the Red Sea. Much of the water soaks into the sandy soil of the coastal plain and evaporates, but a proportion is diverted onto fields, where enough infiltrates the soil in most years to support a crop. Some of the diversion structures used are again very ancient, and this type of irrigation may have been practised in the area for 3,000 years. However, the water is only utilized in this way after it has flowed some distance as a well-defined stream, and after some has already been lost. It is a method which fits the general definition of water harvesting, and may be appropriately described as 'floodwater harvesting', or 'spate irrigation'. But if the same water were to be collected as *rainwater*, this would be a matter for people living in the mountain areas where the rain falls. They could collect water from house roofs, or from small areas of ground whose slope and surface are suited to a high rate of runoff into an excavated tank, or onto cultivated terraces, and all these techniques are in fact used to an extent. But clearly, the latter are very different techniques from those involved in using floodwater far down the wadis.

Typically, floodwater flows are collected behind dams or by means of diversion weirs. In many semi-arid areas, sand accumulates in the beds of the larger ephemeral streams, and a flow of water persists in the sand long after the floodwaters have subsided. These 'sand rivers' are regularly exploited by the inhabitants of semi-arid areas, often simply by digging a hole in the dry river bed to reach the water. Such supplies may be improved by constructing subsurface dams in stream beds to hold back the flow in the sand, or by constructing silt-trapping dams across gullies. All these techniques, together with more conventional means of using dams and bunds to hold back floodwater, come into the general category of water harvesting. None of them, however, may be described as rainwater collection.

Shanan and Tadmor imply a very specific way of defining the distinction between rainwater collection and the harvesting of floodwater flows. They point out that when rain is falling on a small catchment, water will move downslope in a sheet of roughly even depth, often described as 'overland flow'. Some distance from the top of the slope, however, as the sheet flow becomes deeper and swifter, turbulence and erosion of the soil surface begins, and the water tends increasingly to flow in rills. In one case analysed, the transition from sheet flow to turbulent flow occurred 90m from the top of the slope and more generally we can expect it within 50-150m of the top of a gentle (1 per cent) slope.

In runoff farming, a careful balance has to be struck between the efficiency of a catchment in producing runoff and its susceptibility to erosion. While it is always possible to increase runoff by clearing slopes of vegetation and compacting the surface, the dangers of this leading to erosion are greater with longer slope lengths and steeper gradients. The precise distance downslope at which erosive flow begins not only depends on the gradient, though, but also on the soil, the intensity of the rain and many other environmental conditions. In designing catchment systems, a considerable margin of safety is needed to allow for unusually intense storms, and with 'microcatchments' in their local desert environment, Shanan and Tadmor specified a maximum slope length of 25m on a 1 per cent slope, and 14m with a 3 per cent incline. For the purpose of definition rather than design, however, the 50m-150m slope length can be taken to differentiate rainwater collection from other ways of manipulating runoff or harvesting floodwater.

In the work described by Shanan and Tadmor (though not in the programmes discussed in Chapters 6 and 7 below), the microcatchment is the most characteristic method of using rainwater directly to support growing crops. It must be explained, then, that this term refers to a bare catchment area on a gentle slope demarcated by a low bank or bund. The catchment has a small cultivated plot at its lowest point, watered by runoff from the whole area. The collection of sheet flow or overland flow, 'differentiates the design of microcatchments' from the design of runoff systems in which water is utilized, 'after it has collected in channels'.

To summarize these points, rainwater collection is defined here so that it comprises the harvesting of runoff only on the basis of what might be called 'microcatchment principles', that is runoff from:

- roofs;
- artificial surfaces at ground level:
- land surfaces with slopes less than 50-150m in length.

In practice, however, there is no easy distinction between runoff farming on short and long slopes. A more practical distinction is between runoff from *within-field catchments* and *external catchments*. The first category refers to systems where patches (or strips) of catchment area alternate with cultivated plots inside the field boundary. The most common version is where strips of bare ground are aligned with the contour, and runoff from these areas is used by growing crops on parallel, cultivated strips. On steeper slopes, the cultivated strips become terraces. Figure 1.4 compares this arrangement — in diagram i(a) — with other runoff farming methods. Microcatchments — in diagram i(b) — are also within-field catchments, in contrast to the *external* catchments shown in both parts of Figure 1.4ii. Within-field catchments invariably have short slope lengths and conform with the definition of rainwater collection given above. External catchments, by contrast, often (but not always) have slope lengths greater than

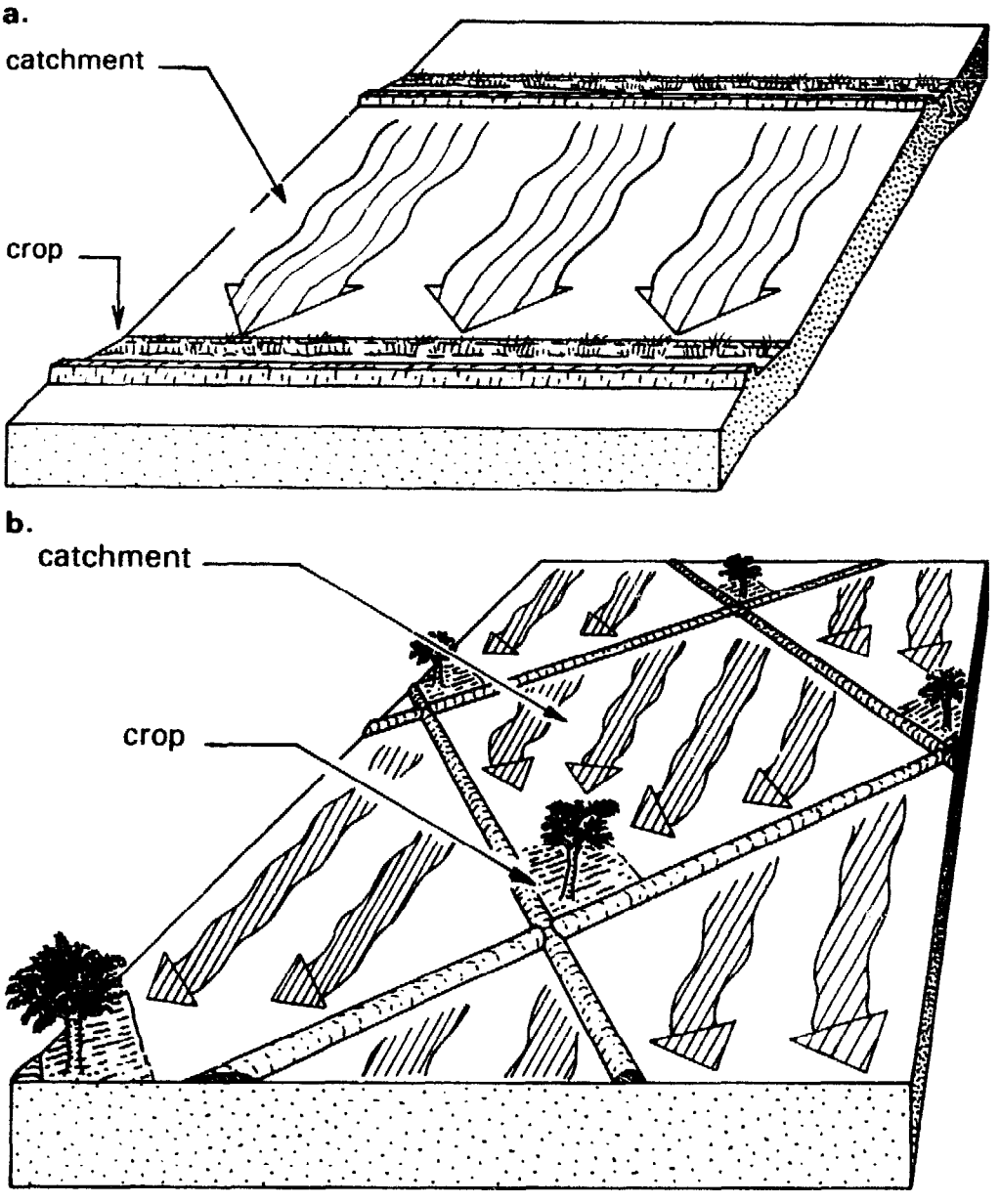

Fig. 1.4 (i) Within-field catchments. Rainwater collection on contour strips (a) and micro-catchments (b). (Adapted from Kutsch 1982)

Note: *Diagrams are schematic and not to scale (slopes are much exaggerated).*

50-150m. On these longer slopes, runoff is a smaller proportion of the total rainfall because of losses from depression storage and infiltration, but as already noted, it may be capable of causing erosion. According to Critchley (1984), this has been a considerable problem in experiments carried out in Kenya, because when inflow to the cultivated plot 'becomes turbulent', there may be serious 'damage to earthen structures'.

In Figure 1.4ii, diagram (b) represents the diversion of flood flows from a natural gully onto cultivated land, and is an example of 'floodwater

CLASSIFYING TECHNIQUES AND USES

With these definitions in mind, we can examine the uses of rainwater in more detail. It is tempting to think of just two contrasting applications. In one, water from a house roof is collected in a tank owned by the household and is used for drinking and cooking. The other is exemplified by the various runoff farming and microcatchment techniques. In these latter systems, the soil of the cultivated areas itself provides the storage medium, and water is abstracted directly by the plants' roots.

We can get a better perspective, however, by thinking briefly about the whole range of water sources which might conceivably be used for domestic or agricultural purposes. If the water sources available are rivers on the one hand or wells on the other, relevant techniques are clearly outside the scope of this book, as Figure 1.5 indicates. When it comes to surface runoff, the preceding paragraphs make a distinction between turbulent, erosive runoff from long catchments (which raise problems of soil conservation) and sheet runoff from short catchments. Figure 1.5 shows this further subdivision and indicates how the scope of this book is chiefly limited to application of sheet runoff, whilst recognizing that with most types of runoff farming (except microcatchments), there is some overlap between short and long catchments.

However, it would be wrong to make too sharp a division between domestic and agricultural applications, or between roof and ground surface catchments. Sometimes water from roofs is used to irrigate crops, if only on a garden scale. An example is a house in Botswana which has two rainwater tanks. One stands on the ground and collects water directly from the roof to provide water for drinking and cooking. The other is an excavated tank filled by overflows from the first tank as well as by runoff water from hard ground near the house. This tank is used to provide small amounts of water for the garden, as well as some water for washing and laundry. The principle is illustrated by Figure 1.6, which shows a slightly improved version of its application.

In other situations, especially where a larger supply is required than a single roof can provide, a ground surface catchment may be fenced to prevent contamination by livestock and may then produce water for domestic purposes. Thus one cannot say that roof catchments are associated solely with the domestic use of rainwater and ground surface catchments with its agricultural use. Nor can one totally separate systems which store water in the soil for use by growing crops from systems employing tanks or cisterns for storage. At one particular farm in the Negev Desert investigators found a conduit carrying water from a hillside catchment which had two branches, one supplying a cistern within the farmhouse, and the other discharging onto the fields.

Another example is reported from the southern United States where

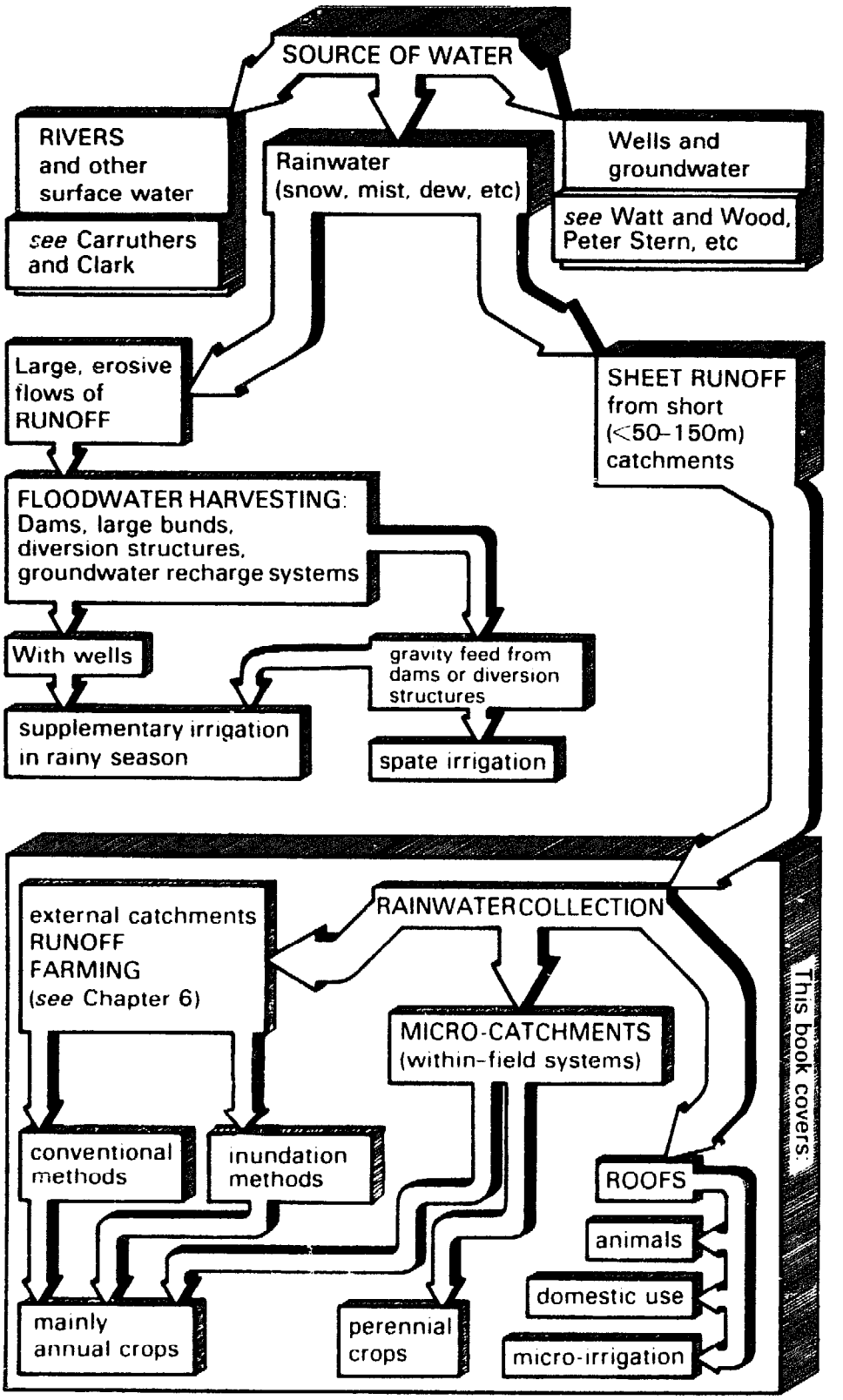

Fig. 1.5 Rainwater collection in relation to other water resource development. (Note that some categories in this diagram overlap, especially the 'inundation method' of crop production which can be used with either runoff from an external catchment or spate irrigation.)

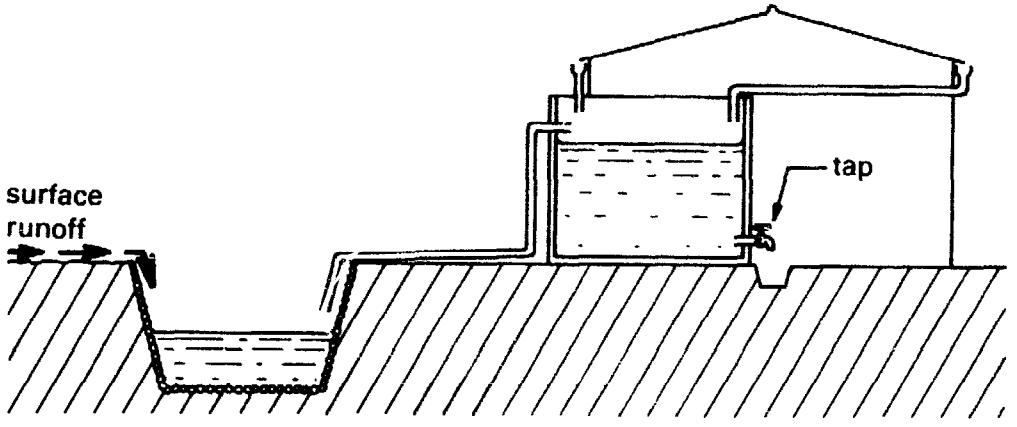

Rainwater catchment from roof and ground surface

Fig. 1.6 Two rainwater tanks used in conjunction. Water for drinking and cooking is drawn from the tank fed directly from the house roof, whilst water for other purposes is taken from the excavated tank. (Farrar 1974)

experience has shown that runoff onto cultivated strips is sometimes too great when the crop is at an early stage in its growth. To deal with this, arrangements have sometimes been made to divert part of the runoff into tanks and hold it in reserve for use in irrigating the crop later (Luebs and Laag 1975). This illustrates the distinction between irrigating crops from water stored in a tank and the runoff farming principle of storing water as soil moisture. When that distinction is collated with the differences noted earlier between the use of large and small catchments, we are confronted with a considerable variety of ways of using rainwater and runoff, as Table 1.1 seeks to indicate.

The possible range of techniques and their combination is increased when options for domestic supply and livestock watering are added to the table. Some of the most striking examples are to be seen where rainwater is collected from large rock surfaces. In parts of Kenya, this is done by building small dams directly on the rock (Nissen Petersen 1985). In one case, a whole village, including its livestock, is supplied throughout the year. In Zimbabwe, there are instances of the collection of rainwater from granite massifs (Richards 1972), and rock catchments are also used on several Caribbean islands. Their efficiency is commonly improved by the application of a coat of cement plaster to badly fissured areas of rock surface.

One especially good example of a large modern rainwater system is to be seen on Gibraltar, where two kinds of catchment surface are in simultaneous use. On the west side, water collected directly from rock surfaces is channelled into underground tanks. On its other main slope, Gibraltar has a sandy subsoil which produces very little runoff, so here an artificial catchment has been formed by laying some 14ha of corrugated iron sheeting on timber battens, with 'gutters' at two levels to collect the water (Fig. 1.7). These catchments produce about 10 per cent of the local

Table 1.1 A classification of rainwater collection systems according to catchment, storage and use. The different uses to which rainwater is put are indicated as follows:

DD — drinking water and all domestic uses
S — water for livestock
G — garden irrigation from cistern, tank or dam
F — field irrigation from tank or dam
R — runoff farming with *external* catchments
M — use of runoff from *within field* catchments (as on contour strips and microcatchments)
W — floodwater distribution to support crops (spate irrigation, water spreading, etc.)

	SMALL CATCHMENTS with sheet runoff (typified by micro catchments)		*LARGE CATCHMENTS with turbulent runoff and/or channel flow*	
	ROOFS of all kinds	*GROUND SURFACES less than 50-150m length, within field catchments*	*SLOPES longer than 50-150m and minor rills and gullies*	*FLOW in WADIS, GULLIES, RIVERS and all natural drainage channels*
WATER STORAGE TECHNIQUES				
TANKS ABOVE GROUND	**DD**	**DD***	n.a.	n.a.
EXCAVATED TANKS, CISTERNS and HAFIRS	**DDSG**	**DDSG**	n.a.	n.a.
SMALL DAMS ('tanks' in INDIA)	n.a.	**DD*SG**	**SFDD**	**(SFDD)**
SOIL MOISTURE[1]	n.a.	**M**	**R**	**(W)**

* *especially on rock catchments*
( ) *floodwater harvesting techniques outside the scope of this book*
n.a. *not usually applicable*
[1] *This area is elaborated in Table 6.2.*

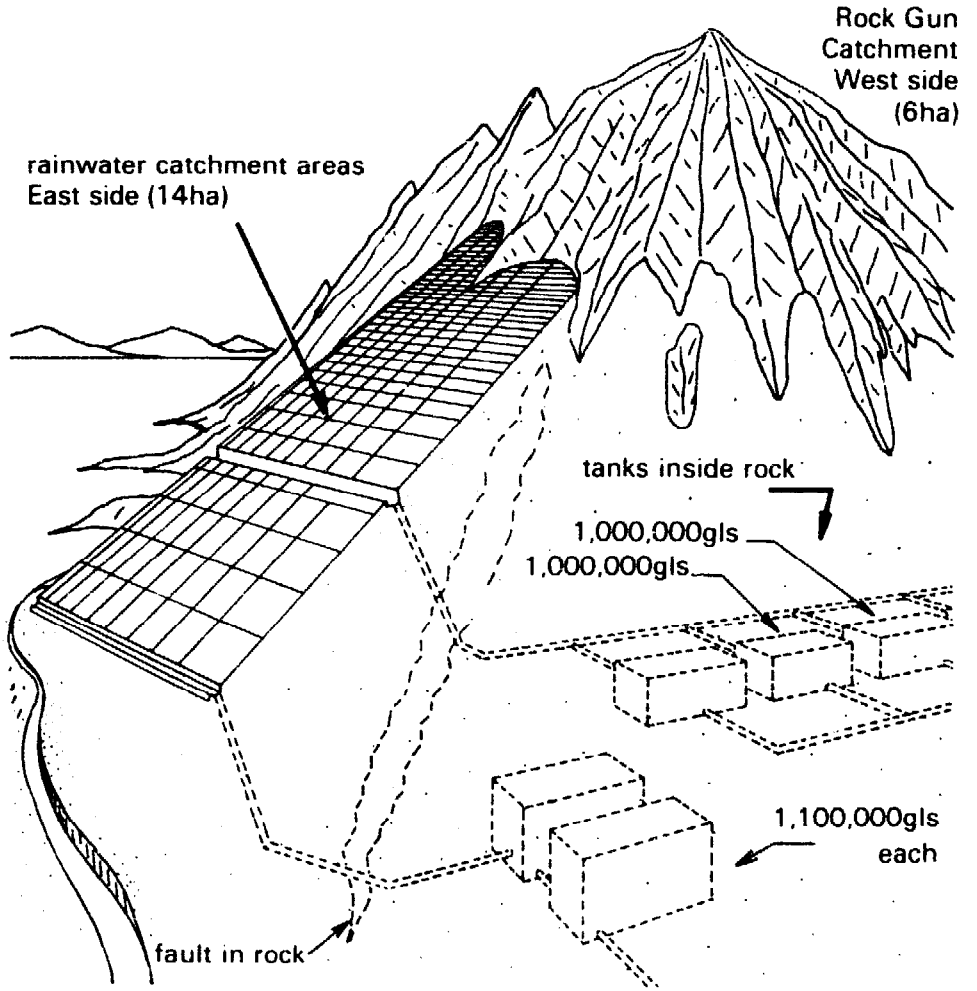

Fig. 1.7 Rainwater collection on Gibraltar. Apart from rainwater collected from house roofs and from rock surfaces on the west of the peninsula, there is a large artificial catchment on the east side consisting of corrugated iron sheeting supported on wooden piles driven into the sandy subsoil. (F.J. Gonzalez 1972)

community's potable water requirement, the rest being obtained from groundwater, desalination and importation (Doody 1980).

Elaborate rainwater catchments such as this are only justified when the need is for a domestic water supply and other sources are very limited. On a smaller scale, the cisterns or tanks which collect water from house roofs are also relatively costly and are justified chiefly when the water is used for high priority domestic purposes. Excavated cisterns, suitably lined with cement plaster or other impermeable material, can be cheaper and may collect large volumes of water from ground surfaces. As with the example in Figure 1.6, such tanks are well suited to purposes with lower priority than drinking water — such as laundry, watering gardens, or providing for livestock.

Small dams are often built for collecting water from the larger types of catchment, where the volume of water is too large for storage in a tank.

Examples include farm dams in Australia and the small dams in India which are generally known as 'tanks'. In both countries, most examples are sited in gullies or 'creeks', and are classed as 'floodwater harvesting' here. As Table 1.1 notes, such dams or tanks are used for watering livestock (in Australia) and for irrigation (in India), although domestic water may be obtained from them also.

CATCHMENT SURFACES

Detailed accounts of the various components of rainwater systems are distributed among subsequent chapters. For example, conveyance and storage for drinking water systems are described in Chapter 5. First, however, it is important to consider catchment surfaces in more detail because, according to the definitions given earlier, it is the nature of the catchment which most clearly distinguishes rainwater collection from other kinds of water harvesting. Specifically, catchments used to collect rainwater (as opposed to floodwater or surface water generally) are frequently artificial surfaces, or else are ground surfaces which have been specially prepared and demarcated.

Rainwater may be collected from any kind of roof. Tiled or metal roofs are easiest to use, and may give the cleanest water, but it is perfectly feasible to use roofs made of palm leaf or grass thatch. The only common type of roof which is definitely unsuitable, especially to collect water for drinking, is a roof with lead flashings, or painted with a lead-based paint. It is suggested that roofs made of asbestos sheeting should not be used if fibres are being detached from damaged areas (IRC 1981).

Caution is advised in many texts regarding thatched roofs, which are said to harbour sources of contamination, but there seems to be no evidence that water from a well thatched roof presents significantly greater hazards to consumers than water from other roofs. Greater precautions may be advisable to ensure that debris from the roof does not enter the tank, and the water should usually be boiled before drinking. The most important consideration, however, is that if a project is to help low-income groups, there may be no choice but to tackle the problems of collecting water from thatch or palm-leaf roofs, either by use of a low level collecting tank (Figure 1.1), or by devising means of attaching gutters (Figure 1.8).

In West Africa, rainwater has long been collected from thatched roofs and there appears to be no strong objection on grounds of taste to its use for drinking (Novieku 1980). In other places, with thatch of other types, water from roofs is often discoloured and although it may be fit to drink, people may dislike it. In a survey of 150 households in three Botswana villages, many families were found to collect rainwater from roofs in some informal way by placing buckets, basins or oil drums under the eaves. However, while this was done at 43 out of 51 households which had metal roofs, only

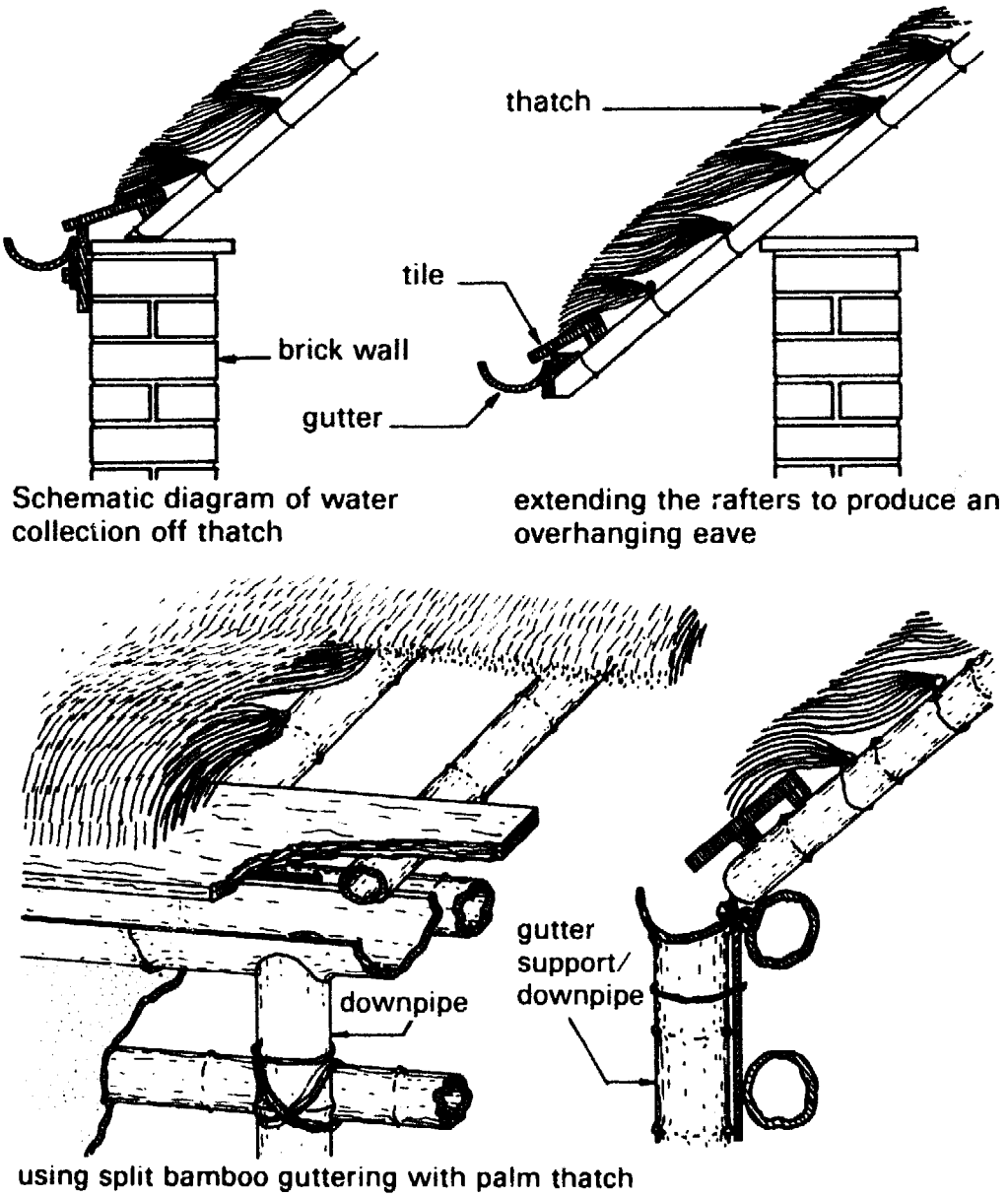

Fig. 1.8 Gutters for rainwater collection from thatch. (Hall 1982)

9 of the 99 households with thatched roofs collected water from them, and only at one did the householder admit drinking the water (Gould 1983).

One advantage for the household in collecting rainwater from its roof is that the roof has already been paid for, and so additional investments are limited to gutters and tanks. Such investments may be more than people can afford, however, and even when storage tanks have been obtained, gutters may only be attached to one side of the building, or sometimes only to short lengths of roof. Indeed, lack of guttering is sometimes said to be one of the primary limiting factors restricting the wider adoption of rainwater collection (Chapter 5).

The collecting of rainwater from ground-level catchments is sometimes possible using a hard surface created for some other purpose. School playgrounds and threshing floors have both been used in Botswana. More usually, though, a catchment area or watershed is developed for rainwater collection by applying some more specific form of treatment to the ground surface. UNEP has proposed a classification of surface treatments which, with one addition, is as follows:

- clearing sloping surfaces of vegetation and loose material;
- improving vegetation management by planting with different species or by cropping;
- mechanical treatment of the soil, including smoothing and compacting the surface, as on contour strips and microcatchments;
- making a hard surface using traditional soil stabilization techniques (as used on Botswana threshing floor catchments);
- reducing soil permeability by application of chemicals (e.g. sodium salts);
- applying chemical binders such as asphalt to seal the surface;
- covering the catchment with conventional paving materials;
- covering the catchment with other rigid materials;
- covering the catchment with flexible/plastic material.

Most of these techniques fall into one or other of two main groups — firstly, those which involve *treatment* of the soil itself, either mechanically or with chemicals, to reduce infiltration by rainwater and achieve greater runoff, and secondly, those which entail *covering* the soil with another material, as with the last three items in the list (compare Table 3.1 in Chapter 3).

As regards treatment of the soil, much research has been carried out in the United States on substances which can be mixed with, spread or sprayed over the soil (Frasier 1975). Experiments have been made with sodium salts (which encourage surface crusting on soils containing clay); with silicones (which are water repellent); and with oil, paraffin wax, bitumin or asphalt (which bind soil particles together). The sodium treatment is cheap but may not last for more than a year and can lead to increased soil erosion. The other methods tend to be expensive, though most are less costly than such alternatives as covering ground surface catchments with plastic sheeting, butyl rubber, or even aluminium foil, all of which have occasionally been tried (Maddocks 1975). Not only is the use of these last materials expensive, but unless supervision and maintenance is meticulous, their durability is not good — weed growth from below or stray animals can easily puncture surfaces.

More significant than research findings with the materials is to notice what is done in practice. Where public water supply is an urgent need and

ample funds are available, ground catchments have been successfully surfaced with smooth concrete, butyl rubber or plastic sheet. These materials are now used in preference to corrugated iron catchments of the Gibraltar type for economic reasons. Butyl rubber, which also makes a good lining for excavated storage tanks, may be the most widely used of the modern materials. On Hawaii, over 300 butyl catchments and reservoirs have been constructed. Plastic sheeting — usually black polythene — has been less successful because of its vulnerability when exposed to wind and sun. One method of countering this has been to cover the plastic catchment surface with a 3cm layer of pea-sized gravel. Less runoff is obtained, but there is a marked gain in durability and encouraging results have been reported, for example, from trials in Jamaica.

Where a ground catchment must fill a farm pond from which livestock drinking water is supplied, or where it supports the cultivation of crops by runoff farming methods, plastic surfaces are rarely used except on a very small scale. In Australia, for example, rainwater harvesting is widely practised on farms, but one commentator emphasizes that the technique is used by 'commercial farmers' and must therefore be 'economically attractive' (Laing 1981). This excludes most exotic materials, and means that improvement of catchment surfaces to obtain greater runoff must depend very largely on earth forming, smoothing and compaction.

One particularly notable Australian technique was developed by analogy with road-building and is referred to as the 'roaded catchment'. The point is that a well-constructed highway must have a camber and surface capable of disposing of rainwater quickly into the roadside drains. If a small catchment is covered with a series of parallel, cambered roadways surfaced with smooth, compacted soil, ditches laid out between them can collect rainwater and discharge it into a suitable storage reservoir. Early results were highly satisfactory, especially on clay or clay-loam soils, and since the 1950s, roaded catchments have been widely adopted in Western Australia. Individual catchments of 2-4ha have been constructed for livestock water supply, and larger ones are also to be seen, some over 40ha.

With mechanical earth-moving equipment needed for construction, roaded catchments may not be immediately applicable for low-income developing communities, where it might make more sense to look at traditional technologies, at least for small catchments. For example, in Botswana, the ground within household compounds is surfaced with a clay/cow-dung mixture which can be smoothed to form a hard, polished, impermeable surface from which some provision for rainwater drainage has to be provided. As already noted, threshing floors made this way have recently been utilized as catchments. In other countries, various mixtures of soil with clay, lime, dung or even cassava flour are used as 'cements' for sealing flat roofs as well as making floors, and these traditional soil stabilization techniques deserve to be better appreciated. Where cow-dung

is used, it is probably inert by the time floor surfaces have dried thoroughly, and is not a source of contamination.

In many places, ground catchments must be made at low cost and with very basic techniques. Sometimes all that can be attempted on a large catchment is the filling of obvious depressions, and construction of banks or bunds to divert runoff into storage, or to retain it on cultivated land. Even so, 20 to 30 per cent of rainfall may often be collected as runoff. In low-rainfall areas where the priority is to maximize runoff, vegetation may be completely removed. Where rainfall is higher, control of erosion is often more important and trees or grass are planted on catchments (as sometimes in India). Where it is possible to obtain sufficient runoff from grassed catchment areas, they may be used by grazing animals, though of course, this would not be considered where the water is for domestic use because animals are invariably a source of contamination, and so are fertilizers if they are used.

Here an important distinction can be made between multi-purpose and single-purpose catchment surfaces. The roof of a house is designed primarily to provide shelter and privacy. Sometimes it is also a status symbol. Flat roofs in some countries are used for sleeping, storage and drying clothes. Thus when a roof is used to collect water, it is very much a multi-purpose structure, and may serve some purposes which conflict with requirements for rainwater collection, especially regarding contamination. Other examples of multi-purpose catchments, apart from those used for grazing, include school playgrounds and public roads. Most catchments of these kinds are appropriate only for agricultural (or industrial) application, not for domestic supply.

These points about how catchments are used, and more generally, about how rainwater is applied, make it clear that rainwater collection is not something that can be analysed in a purely technical manner. Its relevance in any situation depends critically on whether it is compatible with other economic and domestic activities, on whether people have the organization necessary to build and maintain the system, whether they have adequate housing, and above all, whether they regard a water supply of this kind as a high priority. Many of these factors arise from the way in which the people obtain their livelihood, and that must be a central concept in any examination of where and how rainwater collection techniques have most to offer.

2. WATER, LIVELIHOOD AND ORGANIZATION

THE GEOGRAPHICAL RELEVANCE OF RAINWATER

All water resources are limited, but the nature of the limiting factors varies greatly from one part of the world to another. The relatively low proportion of rainfall reaching river systems in climatically dry regions is one factor already mentioned. Groundwater is much favoured for drinking water supplies because of its freedom from contamination, but in the more arid parts of the world, potable groundwater is not always available. Sometimes it can be found, but is too salty for human consumption. There are also 'extensive areas in Africa, the drier parts of South America, the Indian sub-continents and many islands in the sub-tropics where groundwater can be found but the recharge rate of wells is inadequate to meet demands' (Stern 1982). It may also be very deep, and hence costly to exploit, and to pump. Not surprisingly, places where rainwater collection has been most fully applied are frequently in regions where these other water resources are inadequate. However, sceptics are quick to point out that rainwater collection has limitations also, noting the questionable reliability of a system dependent on erratic rainfall, and the diseconomies of scale associated with rainfall storage when each household acquires its own small storage tank. As regards reliability, in almost no circumstances can stored rainwater be regarded as the sole source of supply. At some times, and for some purposes (such as laundry or garden irrigation), other water sources will have to be used. But for the individual household which wants the convenience of its own supply under its own control, and often for whole communities where the area lacks rivers or groundwater, the possibility of developing rainwater collection systems can be very attractive.

Islands may have water supply problems simply because there are no large catchments from which rivers can flow or aquifers can be recharged. Coral islands have highly permeable ground from which there is no runoff. Bermuda is notable as an island on which rainwater collection has been particularly well developed, and so is the quasi-island of Gibraltar. In both places, water is collected from the roofs of all households as well as from large corporately managed catchments (Figure 1.7) But even so, rainwater is not the sole source of supply. Seawater or brackish groundwater is used

for secondary purposes, and desalination plant has been introduced. Furthermore, during periods of drought, water has been imported by ship. There are other islands, including several in the Pacific and Caribbean regions, where rainwater is an important source for drinking water supplies but where technologies for its collection are less advanced (Fujimura 1982, Layton 1984).

Places where geological conditions have so limited other sources of supply that rainwater collection is strongly emphasized include parts of Nova Scotia (Canada), Jamaica, Java (Indonesia) and the Yucatan Peninsula of Southern Mexico. In the three latter areas, the underlying rocks are permeable limestones, whilst in Nova Scotia, and also in West Java, the high mineral content of the groundwater makes it unfit to drink.

Climatically dry areas where rainwater is collected, not only for domestic supplies but for watering livestock, for runoff farming and even sometimes for irrigation, include much of Australia, parts of India, the Middle East, North Africa, parts of East Africa, Mexico and the south-western United States. These areas constitute a large proportion of the earth's surface with a fairly large (if thinly dispersed) population, often dependent on raising livestock, and they will be a considerable preoccupation in this book.

In all such areas, rainwater collection is frequently the 'least cost' form of water supply, largely because of the high cost of alternatives. Even where this cannot be claimed, it may be easier to mobilize household capital for a family rainwater tank than to secure large-scale investments in public supplies. Moreover, in some regions generally well-endowed with low-cost supplies, rainwater collection may fill a gap in existing provision. It may be that the quality of the water is advantageous for washing (where public supplies provide hard water), or for drinking (where borehole water is slightly brackish). Or in moist tropical climates, there is sometimes a particular season when work pressures and water needs are both critical, and the convenience of having a household tank of rainwater is very great. Rainwater collection may also have some insurance value against failure of other sources. Even in England there are some regions where water authorities encourage householders to store rainwater from roofs for use in times of drought, when watering gardens from the public supply may be prohibited (SWW 1984).

DISSEMINATION OF TECHNIQUES

With so many examples of the advantageous use of rainwater, it is puzzling to some commentators that there are still numerous villages in Asia, Africa and Latin America which experience desperate water shortages but where no effort appears to be made to exploit the rainwater resource. Equally, there are many areas where it might seem that agriculture could benefit greatly from runoff farming techniques. One reaction has been to carry out

more research to improve the performance of available techniques or reduce their cost. Efforts have a'so been devoted to making more technical information available, and yet the spread of techniques still seems painfully slow. Three possible reasons for this situation need to be explored.

Firstly, although progress in *organized* projects for disseminating rainwater collection has been disappointing, it sometimes turns out that more people are collecting water from roofs or using runoff farming methods than is generally realized. Often they employ techniques which are informal or inconspicuous, or the spread of a new technique has been promoted by local craftsmen and traders whose activities have not been recorded. The latter is true in parts of Kenya, for example, where quite significant numbers of households have acquired tanks to collect roof runoff on their own initiative. Thus it may simply be the official version of rainwater collection which spreads slowly. Local people may have their own approaches — as later chapters will explain.

Secondly, it needs to be noticed that much of the research done on rainwater collection has been of a purely technical kind. There has been relatively little investigation of the processes by which a successful water tank construction project might be 'replicated' or 'extended', spreading from one village to another over wide areas. Such processes not only involve the spread of information, but also depend on village organization, on the organization of support services and technical assistance, and on manpower, skills, money and material resources. These various aspects of the extension or replication process are well illustrated by programmes in Thailand and Indonesia and in publications influenced by them (Fricke 1982, Keller 1982), and are discussed in Chapter 4 of this book.

Thirdly, however, it is necessary to consider a facet of the culture of western technology which is sometimes hard to recognize and face up to — that our enthusiasm for the ingenuity of a technical device, or its performance under test, can often mislead us into believing that it is more relevant than is really the case. There is a distinct danger that we begin to interpret people's needs or to study environmental circumstances very selectively, examining only those facets of a problem which the favoured technique might remedy, and neglecting other aspects which ought to rule it out.

With regard to runoff farming in the Negev Desert, for example, nobody can fail to be impressed by techniques which allow crops to be grown wihout conventional irrigation, solely by using the low desert rainfall of less than 150mm per year. The old vision of the desert blooming as the rose seems within reach, and in our enthusiasm, we naturally think of the many other desert areas of the world which could be reclaimed for agriculture. Yet the Negev version of runoff farming is unusual both in the environmental niche it exploits (rainfall in a cool, winter growing season) and in its social and cultural origins. Thus, most fieldworkers attempting to

apply the Negev techniques in other areas have had to modify them considerably or even abandon the attempt altogether (see Chapter 6).

Often our commitments to research and to particular innovations leave us open to the criticism that we find solutions first and then search for problems they may fit. Thus the nature of 'world hunger' and malnutrition has sometimes been misrepresented to suit the particular forms of agricultural innovation or 'food aid' that the West had to offer. And there is a similar danger of misrepresenting the special problems of semi-arid regions in Africa and elsewhere, in order to suit the particular techniques and patterns of organization favoured by western agencies. Rainwater technologies have long been used by the inhabitants of these regions and so are undeniably relevant — but there is still need to be wary of imposing alien and inappropriate versions.

For example, in semi-arid areas of Africa where pastoralism is the chief means of livelihood, traditional ways of using rainwater are by means of excavated cisterns, 'hafirs' (from the Arabic *hufra*), small dams and natural water holes. For African pastoralists south of the Sahara, natural water holes are probably most important, although small artificial excavations are also common. But in western Sudan and parts of Ethiopia and Kenya, the much larger hafir is used for collecting rainwater for all purposes.

Typically, hafirs are located on land with very gentle slopes where there are no well-defined drainage channels or sites for small dams. Thus a hafir has to be created by excavation, the spoil being used to build a bund around its perimeter (Figure 2.1). Long bunds extending upslope are also usually necessary to direct sheet runoff into the hafir. In small hafirs, livestock may gain access to the water by wading in at the inflow side, but this leads to erosion and rapid silting, and it is preferable for animals to be watered via a well and suitable drinking troughs, as indicated in the diagram. A further refinement is for inflow of water to be via a silting basin from which a pipe leads into the hafir; in this case, the bund may extend round all four sides of the excavation. The capacity of a hafir may be as little as 1,500m^3, e.g. in the Ogaden region of Ethiopia, or as much as 200,000m^3 in Sudan. In Botswana, where hafirs were introduced around 1970, a typical capacity is 9,000m^3 (Classen 1980).

Sandford (1983) notes that in the areas where traditional hafirs and cisterns were most highly developed, drinking troughs and other arrangements for distributing water to livestock were carefully planned and rules for maintenance and use of these water sources were meticulously enforced. Guards might be posted at hafirs, for example, which would be carefully fenced. He notes that such provision is neglected in many modern installations. In north-east Kenya, one result has been that of 100 hafirs or 'hafir-dams' built after 1969, most had silted up ten years later. At some of them, maintenance was adequately managed by local herdsmen for so long

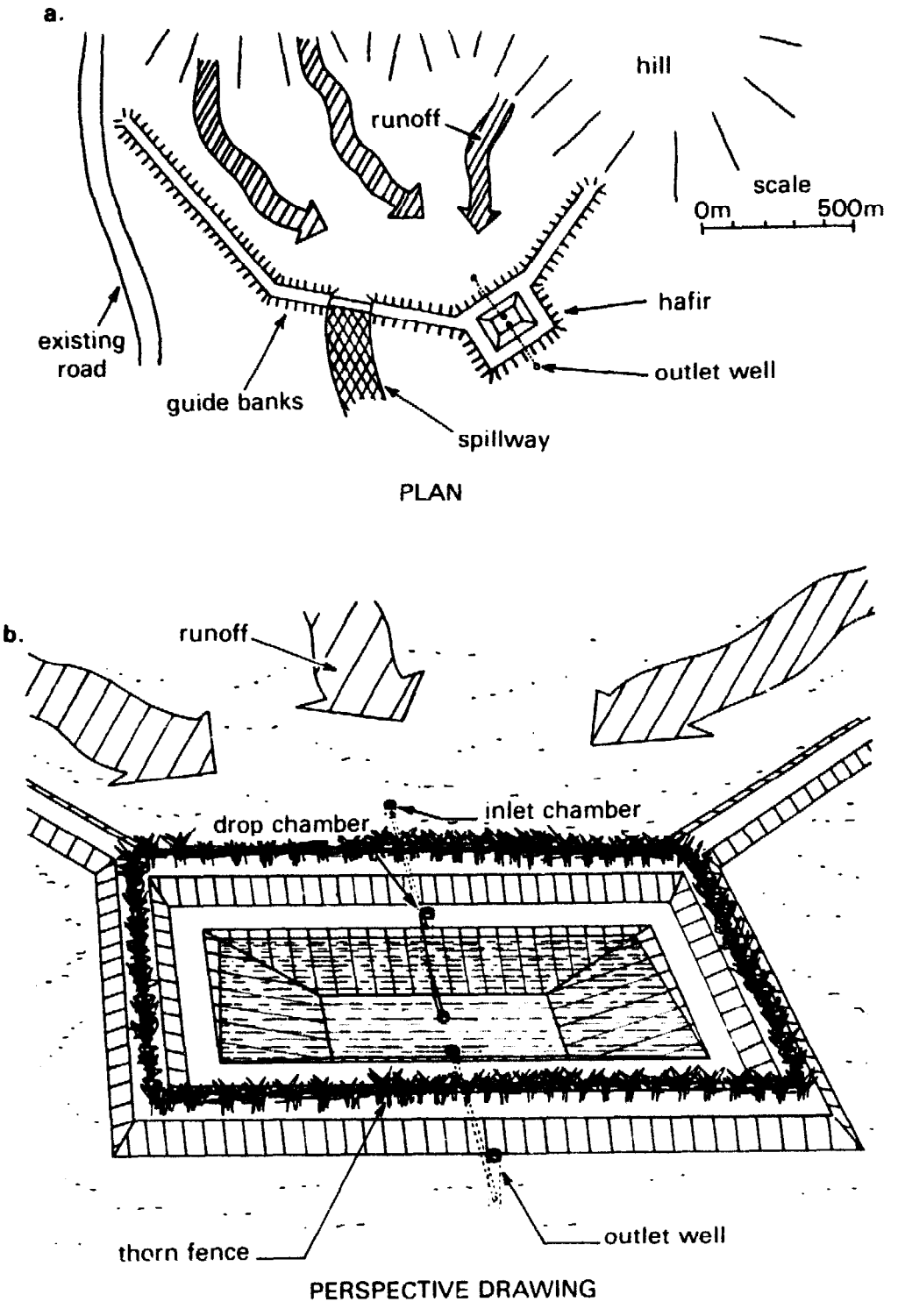

Fig. 2.1 Plan (a) and perspective view (b) of a Somali 'hafir' (or 'balli') with access to the stored water via a well. Hafirs of this sort are strongly fenced to prevent animals getting to the water and treading down the banks. (Based on a drawing provided by Gifford and Partners, Southampton)

as use of the hafirs was limited to their own social groups. However, once the government opened them to all comers, including some ethnically different pastoral groups, nobody would take responsibility for maintenance.

In North Africa and adjacent regions of the Middle East, rock formations with soft strata underlying harder rock lend themselves to the construction of large excavated cisterns, with the harder layers as natural roofing. Such cisterns are filled by runoff from hillsides (Fig. 2.2) and may provide water for large herds of animals. A major rainwater collection

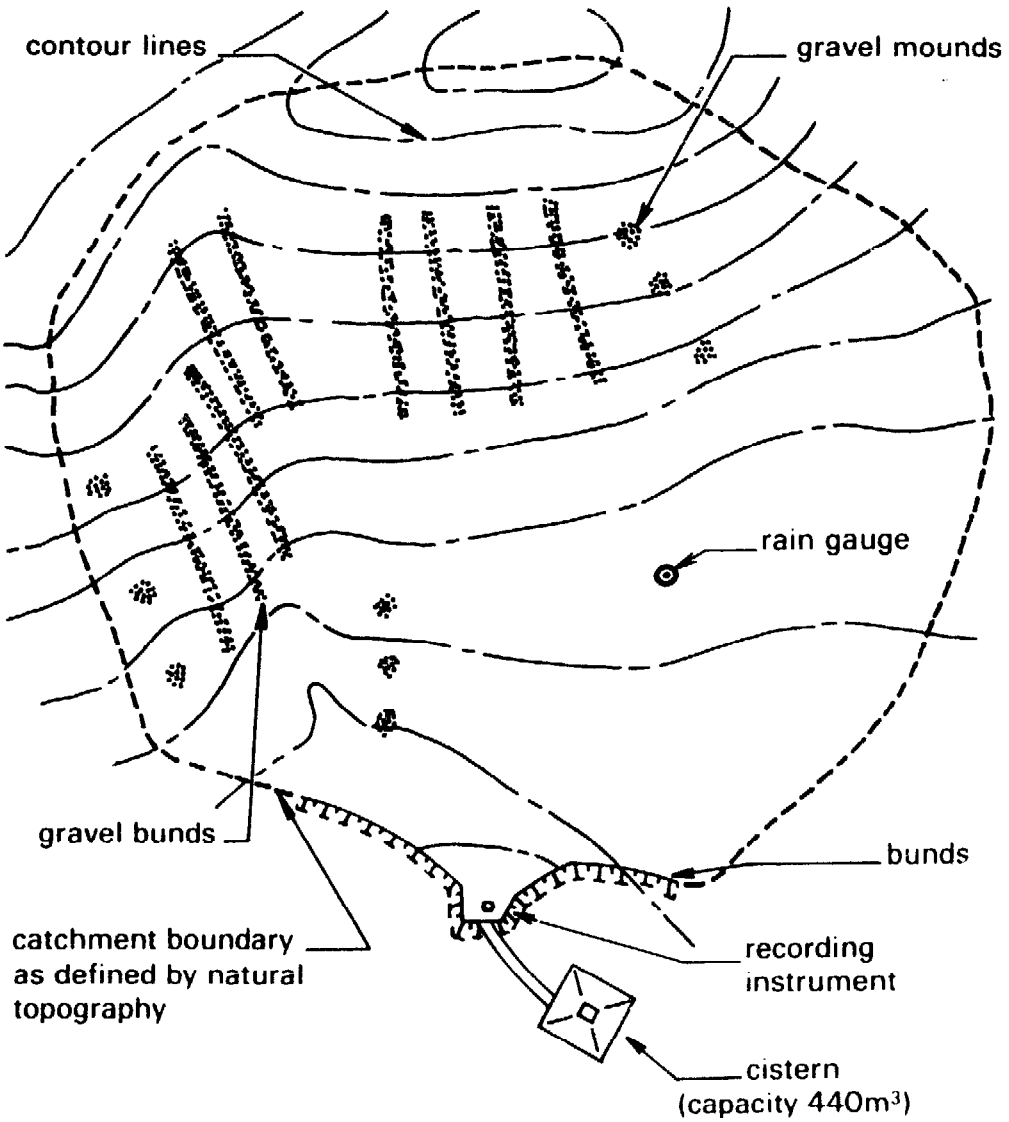

Fig. 2.2 Plan showing the location of an excavated cistern in relation to its catchment area. This example in the Negev Desert was probably once used for watering camels on a caravan route. After restoration about 1960, it has provided water for 300–350 sheep during several months each year. Its capacity is 440m³ and the catchment is 1.2ha in extent. The plan shows how runoff from the catchment has been enhanced by raking gravel off the hillside, most of it being left in mounds or long heaps running down slope. There are two low bands at the foot of the slope directing runoff into the cistern. (Evenari/Mashash 1981)

project completed before recent controversies about semi-arid areas came to a head was carried out in Libya between 1955 and 1962 (Stewart 1960; Ray 1983). One of its aims was to repair existing cisterns, and over 7,000 were either renovated or newly built. It was estimated that $0.75m^3$ of water in a cistern could support one sheep through about half the grazing season, and the cistern could be expected to fill three years in five. In other years, drought would limit the amount of water available and hence the number of animals which could be kept, and this was a very valuable and effective check on overgrazing at times when the growth of grass and forage was also limited by deficient rainfall. With a sharply changed political climate in Libya, no long-term assessment of the results of this scheme is available. Misrepresentation of the problems of pastoral peoples living in areas such as this is evident in many accounts of the 'environmental crisis' which confronts them, which is often labelled 'desertification'. In the countries immediately south of the Sahara Desert, for example, there has been a serious loss of tree cover, much soil erosion, and a general spread of desert-like conditions. Large numbers of people — many of them former pastoralists — became destitute in the long drought of the early 1970s, and with the underlying problems unresolved, widespread and tragic suffering has again resulted from the drought of 1983-5.

Yet simply to describe this as an *environmental* problem rather than a social or institutional one is part of the misrepresentation. Environmental problems are usually regarded as calling for technological solutions, which is principally what the developed countries feel they have to offer. But a more fundamental issue is the way in which the policies of government agencies in almost all these countries have for several decades weakened the traditional institutions through which pastoralists once regulated the grazing of their herds, and by which a balance was struck between the use of different areas by cultivators and pastoralists. In India as well as Africa, there has been a tendency for cultivated areas in semi-arid regions to expand at the expense of grazing lands.

In these circumstances purely technical responses to drought in the form of boreholes and rainwater conservation can achieve nothing. Proclaiming a 'crisis of desertification' as a problem requiring various forms of 'technical fix' is equally misleading. As Sandford (1983) says, there is no real agreement among experts as to how desertification should be defined, let alone how it should be measured, nor is there agreement as to its causes. Those who blame overgrazing by the herds of nomadic pastoralists cannot agree on how large those herds should be, and those who blame the extension of cultivated areas have few convincing remedies. Indeed, most statements about this widespread 'crisis' are one-sided interpretations angled towards favoured technical solutions.

But even with these warnings in mind, it is still possible to see a consensus among several commentators (Sandford 1983, Swift 1977, Ray 1984) about

the relevance of rainwater collection, especially if it is complemented by appropriate institutional innovation. For example, Swift (1984) points to associations of herders formed in Niger during the early 1980s. Comprising about 20 pastoralist households each, these are managing grazing lands on a co-operative basis and appear to be the right units to manage small-scale rainwater collection systems on those lands.

In this part of Africa, natural rain-filled pools are the first source of water used by pastoralists after rain has fallen. There is scope for deepening some of these, for constructing artificial pools to complement them and for better management of their use by pastoral communities. Such rain-filled drinking points for livestock could help sustain pastoral lifestyles, and their advantage over borehole supplies is that the stored rainwater at any one point would be limited in quantity. Its exhaustion would force herds to move to another water point before vegetation in the vicinity is over-grazed — a matter of very considerable importance. Indeed one might say that rainwater collection is the most 'environmentally appropriate' technology for this application, and that boreholes are frequently quite inappropriate.

In India, as Ray points out, environmental problems are very different. There is drought and erosion on farms in central India, waterlogging and salinity in north India, and deforestation everywhere. Rainwater conservation could make a modest contribution to the solution of many of these problems, but faces major political and bureaucratic obstacles.

It is not, of course, the job of water engineers to initiate national programmes for institutional change, nor to campaign for political reform. But they do have a responsibility to ensure that the technological developments they favour are truly appropriate to the problems of local people, particularly disadvantaged groups, and are not being used by politicians and other interest-groups as a means of evading or disguising the need for more fundamental kinds of change.

At the local level, too, engineers or planners have a responsibility to consider whether their goals in promoting a specific technique are compatible with the needs and values of the people they seek to help. There is an increasing awareness of the way in which the objectives of planners, however well-meaning, may be in conflict with the aims of the people for whose welfare they plan. Such conflicts have been examined in the context of small water supplies (Thomas and Lockett 1978), rural sanitation (Pacey 1980) and the wider needs of pastoral communities (Sandford 1983).

Chauhan and Gopalakrishnan (1983) very effectively expose the illusions which arise when the lofty goals of the United Nations Water Decade are translated to village level: 'poor villagers . . . have their own clear perception of basic human needs . . . Earning enough from employment or land to buy more and better food for the family and to build a more durable house, is considered fundamental. Sanitation and even health are not.'

If people are simply asked whether they would like a better water supply and whether they would like a school for their children, they will, of course, say 'Yes'. Such things are certainly desirable. But, as Sandford notes, to ask whether the people want a school does not establish whether the school conflicts with other aims. New schools and water supplies almost invariably demand that people divert time and resources from some other activity, which may be of higher priority for them. Then the school may be badly attended and the water supply unmaintained. To avoid such situations, it is essential to discuss projects fully so that the people can see what obligations would be placed on them by the introduction of a new water supply, and so that planners and water engineers can appreciate the wider needs and goals of local people and identify potential points of conflict.

At this point, it is possible to identify two ways of safeguarding planning for rainwater collection (or any other specialized technique) against the danger of becoming merely a reflection of technological enthusiasms. The first involves the vexed question of participation by ordinary people in planning and implementing projects. Chapters 3 and 4 will argue that even if this does tend to slow down a project, the comments of local people should always be sought, both as a check on the social appropriateness of the project and as a means of obtaining practical information about the local environment, including water sources, building materials and so on.

The other safeguard is to check the economic appropriateness of projects in a more comprehensive way than has hitherto been usual, emphasizing especially their impact on people's livelihoods. This is the subject for the remainder of chapter 2.

PERCEIVING NEEDS AND UNDERSTANDING LIVELIHOODS

Economists make the point that when a new technology is introduced, its success depends on it being both technically effective and economically efficient. It must fit its environment and do what it sets out to do reliably and well. But it must also make sense in terms of the productivity with which resources are used. Over-enthusiasm for favoured techniques can lead to them being promoted solely for their environmental and technical effectiveness, with factors relating to efficient resource-use being forgotten.

However, Ray (1984) makes the further point that efficient resource-use in the context of rainwater collection will be seen differently according to whether the water is essential for survival or whether it is a means of profit. For some pastoralists and many islanders, rainwater collection is a pre-condition of life in their particular environments, and the same may be true of many scattered groups of farmers in dry regions. Such people may spend a much larger fraction of their limited resources on water supply than

would be usual elsewhere, sometimes building cisterns and catchments that would seem extravagant by other standards. As Ray points out, survival is not conducive to economic analysis, 'particularly where the survivors are mainly subsistence-based poor farmers and labourers', or else pastoralists.

By contrast, in most of India, the relevance of rainwater technologies is mostly as a form of resource development for agriculture, with implications for erosion control and forestry. Survival is less often in question, and a hard-headed view of economic benefits is much more in order. But however hard-headed one's approach, there is still a choice to be made between economic analysis which considers mainly profit and cash income, and alternative economic views which focus more closely on the all-pervading problem of poverty. Cullis (1984) argues that existing rainwater projects have had least impact, 'where it really matters, amongst the lives of the rural poor'. There are few examples, he suggests, of modern rainwater technologies being 'actively maintained and widely used' by such people.

Economic analysis relevant to this priority arguably needs to be centred on the concept of *livelihood*, and some general points can be made by classifying different types of livelihood which rainwater collection may help to sustain. In the various environmental conditions already mentioned, these may fairly simply be identified as the following:

- In arid and semi-arid regions, livelihoods are commonly based on pastoralism, with small areas of irrigated crop production and some dryland farming based on drought-resistant crops. There may also be a rather small number of artisans and traders.
- In moister areas where rainwater collection is used mainly to provide a supplementary water source, its relevance seems often to be related to the seasonal pattern of crop production.
- On islands and in other places mentioned where rainwater collection is almost the only possible source of supply, livelihoods are often based on tourism and trade, and the main uses of water will thus be in domestic supply and cooking. There will often be some small-scale, but intensive, agriculture for which water is needed.

This approach gives us a list of economic activities which can be examined in order to check the relevance of rainwater collection to raising production, increasing incomes, or enlarging employment opportunities — and it is vital that all such prospective improvements in production or income should be thoroughly evaluated. As the economists quoted earlier have pointed out, many good ideas in technology are never taken up because the contribution they make to production, or to the more efficient use of resources is too small to justify their cost. Where rainwater collection is used to provide water for crops, it is possible to work out the value of the extra crop production and check this against the costs of the rainwater scheme.

Where water is used mainly in the household, however, it is not so easy to compare benefits and costs. People may benefit through better domestic hygiene, better health, and a reduction in the time they spend carrying water from distant sources. Some of these gains may be reflected in raised levels of production, especially if the time saved is diverted to work in the fields or to some form of small-scale manufacture. But it is a mistake to think that improved domestic supplies must always be justified by their contribution to increasing production.

Where concern is with the improvement of livelihoods, it has to be recognized that a family's livelihood is only *partly* dependent on production and income as these are conventionally understood. Hypothetically, one might imagine a group of herdsmen, farmers or even artisans living in the open, eating raw food, and having no children to care for. Such a group could, theoretically, provide the whole of its livelihood from its own production and trade without devoting any of its labour to domestic tasks. However, in normal communities, livelihoods depend heavily on domestic work which is not always regarded as 'productive'. Such work includes food preparation and cooking, maintenance of the home, domestic hygiene, and child care. Household water supplies contribute significantly to almost all these basic livelihood support activities. Thus if we are going to talk about the economic benefits of water supply, it is essential that we come to economic terms with the real significance of these various domestic tasks.

The activities which more conventionally count as 'production' all have a market value. Crops grown and goods manufactured can be sold (though in practice they may be partly retained for family consumption). Many kinds of service are paid for, and wages represent the market value of labour. By contrast, many activities which relate to the home, to cooking and to children are carried out by housewives working without wages, whose 'output' has no market value.

One way of thinking about this is to use concepts formulated in what is sometimes called the 'new home economics'. These are founded on the idea that two kinds of production are necessary to support people's livelihoods, 'market' production and 'home' production (Evenson 1981). The unpaid work which women do in the home may have no market value, but such 'home production processes' are economic activities in that they 'utilize resources which have real costs, i.e. they could be devoted to alternative income-generating pursuits'. One of the resources is water. Another is the women's own labour power, which is often subjected to conflicting demands from 'market' activities, (tending a crop or earning wages) and from home production duties. A third type of resource used in home production is the household's capital equipment — its cooking pots, stoves, brushes, water-carrying containers, and if it possesses them, pipes, taps, cisterns and so on. Finally, there are resources such as food which are

regularly bought in and subjected to some form of processing in the course of the home production activity.

Arguments of this sort proceed by saying that although home production has no market value, a cash value can be ascribed to it by noting what kind of market opportunities are given up in order to undertake home production. If a woman has the chance to take paid work and might then earn up to six rupees per day, but instead she chooses to stay at home and care for her children, then she is said to be 'producing' a child-care 'service' which she values at more than six rupees.

Evenson (1981) argues that ideas about income and livelihood 'take on a quite different meaning in this approach. The conventional definition of income is oriented to market goods.' However, in the new home economics, the value of goods consumed in a household is not just what is paid for them. It also takes account of the resources applied to them within the household. The value of a meal is not just the market cost of the basic ingredients plus the cost of the fuel and water used in cooking. There is also some 'value added' as a result of the time and effort and capital used in preparing and cooking it. Thus the value of goods and services consumed in a household *exceeds* the value of the market goods involved in their production.

Theoretically, one might attempt to estimate the value of water used in the home by an extension of this approach. When water has to be carried some distance from its source to the household where it is used, water carrying must be regarded as an aspect of 'home production'. The low productivity of this activity will enforce *time* and *resource* constraints on other activities. There are many documented instances of malnutrition in young children occurring at busy times in the farming year because women have so much work to do in the fields that they spend less time preparing food. Mothers are torn between 'market' and 'home' production activities, and if water-carrying time can be reduced, this might allow production to rise in either or both sectors.

At the same time, when domestic water has to be carried some distance it is observed that families rarely use *enough* water for hygiene practice to be adequate. The high incidence of diarrhoeal and skin diseases in many countries may be directly attributed to this resource constraint. If the only water obtainable is contaminated, its poor quality may also be regarded as a resource constraint.

If a greater volume of water is made available to a family, domestic and personal hygiene can improve, there may be new possibilities with regard to cooking, home maintenance might be better, and garden vegetables might be watered. All these benefits could be valued either as home production, or, in the case of the vegetables, as market production and a benefit/cost ratio for the improved water supply could then be calculated.

More simply, we may look back at the different circumstances in which

rainwater collection is commonly applied and ask: 'what is the significance of the techniques for people's livelihoods in relieving either time constraints or resource constraints?' For example, in semi-arid areas and on islands where rainwater harvesting is used, water shortages are likely to be a constraint on all forms of production, and the prime requirement is to make more of the resource available. By contrast, in moist climates, it may less often be necessary to think of rainwater collection as a means of relieving a resource constraint, e.g. supplying more water to crops, but it may be relevant to consider reducing time constraints, especially on 'home' production activities such as child care. Table 2.1 summarizes other livelihood support activities for which rainwater harvesting might have relevance, and for the sake of completeness, points out that many livelihoods depend not only on production but on receipts of welfare, interest or other 'transfers of resources'. Conversely, livelihoods are diminished to the extent that interest or taxes have to be paid out.

These arguments may again seem academic, but in Chapter 3, we will find that they are relevant to establishing *design criteria* for rainwater harvesting systems. For example, it may prove that a larger volume of water storage is required for each household when *resource* constraints are critical than when the problem is one of *time* constraints on production during a fairly short season.

There is not always a sharp distinction between the different categories in Table 2.1. In most respects, growing vegetables and other crops is certainly a 'market production' activity, because even when the food is grown for subsistence rather than for market, and the work is done without pay by women of the household, the crops have a market value and may be occasionally sold if a surplus is produced, or the family has an urgent need for cash. However, Ninez (1984) points out that many household gardens are used as what she calls 'budget gardens', meaning that they form part of a family's strategy for adapting to changing economic circumstances. When families are poor, or if a wage-earner loses his job, the household garden is likely to be intensively used for growing vegetables and even staples. If the family becomes more prosperous, vegetables and herbs may be increasingly oriented towards making meals taste better rather than as substitutes for food purchases, and flowers may also be grown. When such changes occur, there is a shift from use of the garden for 'market production' towards its use as a means of improving the quality of life within the home, which counts as a 'home production' activity.

Many of the other benefits of using rainwater come into the 'home production' category, especially where the water is cleaner or has a better taste than water from elsewhere. If better health results from using cleaner water, this too may have more significance as 'quality of life' than as higher production potential.

The point about household gardens is particularly relevant in that they

Table 2.1 Some basic livelihood support activities, with rough indications of the possible relevance of rainwater collection in relieving either 'time' (T) or 'resource' (R) constraints.

	arid and semi-arid regions	*regions with moist climates*	*islands, isolated 'riverless' communities*
SOURCES OF LIVELIHOOD			
Market production			
Animal husbandry	**R**	-	-
Crop production	**R**	**T***	**R**
Services, trade, tourism	-	-	**R**
Manufactures, artisan trades	**R****	-	**R****
Water vending	(**R**)	(**R**)	(**R**)
Home production			
Carrying the family's water	**T**	**T**	-
Food preparation and cooking	**R**, **T**	**T***, **R**†	**R**
Child care	**R**, **T**	**T***	**R**
Domestic hygiene, personal hygiene	**R**	**R**†	**R**
Home maintenance	**R**	-	**R**
Transfers of resources			
Total receipts less payments from			
- inheritance			
- interest			
- rents			
- taxes			
- welfare handouts	-	-	-
Fixed water rates	**R**	**R**	**R**

* *In moist climates, time constraints which can be relieved by rainwater collection are usually limited to short seasons when labour requirements for other work are at a peak*

** *Manufacture of many types of rainwater tank requires water, e.g. for ferrocement or for puddling clay. Many tanks fail because cement or concrete is not 'cured' by being kept wet for a time after setting.*

† *resource constraints possibly due to contamination of available water*

( ) *Rainwater collection may have a negative effect on livelihoods unless water vendors control tanks*

will often be watered more frequently if the family acquires a tank for collecting rainwater from its own roof. Even if the water in the tank is reserved for drinking, water from other sources may more often be used to sustain a vegetable crop through a rainless period or for transplanting seedlings. Even with crop production on a *field* scale a rainwater tank which is too small for any sort of regular irrigation may allow a crop to be planted with water earlier than otherwise, leading to gains either in yield or in opportunities for a second crop. Ray (1984) considers that in the right circumstances, this use of rainwater for early planting may have a very high economic efficiency as measured in terms of benefits and costs.

Another instance where the sharp distinctions of Table 2.1 need to be qualified concerns payment for water. Where charges for a water supply or for irrigation water are levied at a fixed rate almost as a tax, they can be classed in the table as 'transfer' payments. However, when water is sold by vendors, it becomes a market commodity like food which some households depend on for a livelihood and others purchase. In these circumstances, water carrying should be classed as market production rather than home production.

This example serves as a reminder that in examining connections between rainwater collection and livelihoods, we need to be aware that an ill-designed project might lead to increased inequalities, or may actually worsen livelihoods for the poorest groups in society. There are several ways in which this may occur. Firstly, it is important to recognize that one person's time constraint is sometimes another's employment opportunity. Some people gain their livelihoods as water vendors or as well-diggers and may be thrown out of work when better-off people acquire rainwater tanks, unless the tanks lead to the creation of relevant, new kinds of employment.

Secondly, where tanks collecting rainwater from roofs are proposed, families with thatched roofs may not be catered for, and families without permanent homes, and hence lacking permanent roofs, cannot be served — yet they may be the poorest families who have most need of the water.

Thirdly, even when equipment is subsidized, it may still be too expensive for the very poor, and only better-off families will then benefit from the subsidy. There is thus a need to devise systems which have very low costs, or whose costs take the form of resources which the poor already possess, chiefly their own labour during seasons when employment opportunities are least.

THE SOCIAL RELEVANCE OF RAINWATER

Whilst preceding paragraphs may classify the benefits of rainwater technologies, it is important to enquire whether local people see things in

the same way. *Time* constraints, for example, may easily be misunderstood. Where women normally carry their household water, the time saved when supplies improve is not necessarily used for increased production. In one Indian village, better water supplies led to more water being consumed, so the women spent just as much time carrying it, even though the distance was shorter (Chauhan and Gopalakrishnan 1983). The question might then be whether the increased consumption led to an improvement in livelihoods.

On the other hand, there are undoubtedly situations, especially in sub-Saharan Africa, where labour shortages during peak times in the cultivation cycle are a constraint on agricultural yields and output. The problem is particularly great in those countries such as Botswana, Lesotho and Kenya, where migration of men to cities or industrial areas means that food production is largely left to women and children. There are also some places where it is usual for men to carry water — for example, Java (Latham 1984b); or where water is carted rather than being manually carried, in which case, water carrying will be more likely to compete for time with 'market' rather than 'home' production.

For such reasons, men and women will often see the benefits of rainwater collection differently, and neither may value the particular advantages which planners imagine to be important. There are other viewpoints to consider also. Rainwater projects must produce benefits that are valued by those whose support is needed if they are to be financed from public funds. Therefore, as well as benefits for individual householders or farmers, it may well be necessary to show that a rainwater project has something to offer the wider community. One limitation here is that although rainwater collection may lead to some increase in market production in the semi-arid hinterland area, the overall production increase for the nation is likely to be quite small. The question then is: 'how can policy-makers be persuaded to allocate scarce resources and improve water supplies with such little result?' On the premise that rainwater harvesting schemes in poor dry areas should also provide some tangible benefits to people in the better-off heartlands, Ray (1983) suggests that there can be wider gains in the following respects:

Resource conservation. Many semi-arid zones provide the upper catchments for rivers which flow through the towns and cities of the heartlands. Flood control, erosion control, groundwater recharge, and reduced silting at major dams are possible benefits from rainwater harvesting. Measures to reafforest watersheds and control grazing can be readily related to the direct interests of city-dwellers. Rainwater harvesting schemes which require public expenditure for conservation measures can be justified on these grounds.

Cost-effectiveness. For scattered settlements, rainwater harvesting can often be presented as a cheaper alternative to a much more costly piped water scheme which would be impossible to justify on economic grounds.

Employment and skills. Populations in semi-arid areas may be too dispersed to construct major schemes and works, but perfectly adequate for small-scale rainwater harvesting construction. The making of jars and cisterns helps build up local skills as well.

Self-reliance. A further benefit which may be appreciated by the planners responsible for committing public money to finance rainwater collection in marginal areas is that with improved water supplies, such areas become less likely to require famine relief and health expenditures; they may become more politically stable and more closely identified with the nation as a whole. At the same time, if livelihoods in these areas improve, there may be less migration to shanty towns on the fringes of cities. Even better, past rural migrants to the towns may return home.

Ray (1983) concludes that these potential benefits, 'are not the ones usually cited by donor agencies', but are present as implicit goals in most rainwater collection schemes considered a 'success' by those involved. The goals we mentioned earlier, concerned with alleviating poverty and improving livelihoods, are often more explicitly recognized as the objectives of rainwater and similar projects. However, in practice it is important to demonstrate that rainwater harvesting 'is also a worthwhile investment from the national point of view'.

The idea that rural development might provide counterattractions capable of bringing people back from the towns, or at least, stemming the flow of migrants to the urban areas, has often proved a vain hope. However, one project in the hinterland of Bombay provides a small but successful example. Known as the Gram Gourav Pratisthan, meaning Village Pride Trust, its location is indicated on Fig. 2.3. The basic principle is that households owning very small areas of land — some as little as 0.2ha — can come together to manage a water source and use it for irrigation. This makes it possible to grow two crops each year instead of one, and the results have been sufficiently impressive for recent migrants to Bombay with land rights in the area to join the water management groups and subscribe their share of the cost. In one village, some 25 families out of 100 were living in Bombay or other towns, and the project leader estimated that 15 would shortly return 'for a better life than in the slums'. In another village, 7 out of 35 families in a water management group had returned to the countryside from an urban existence in Sholapur (Chambers 1981; Parulkar 1982).

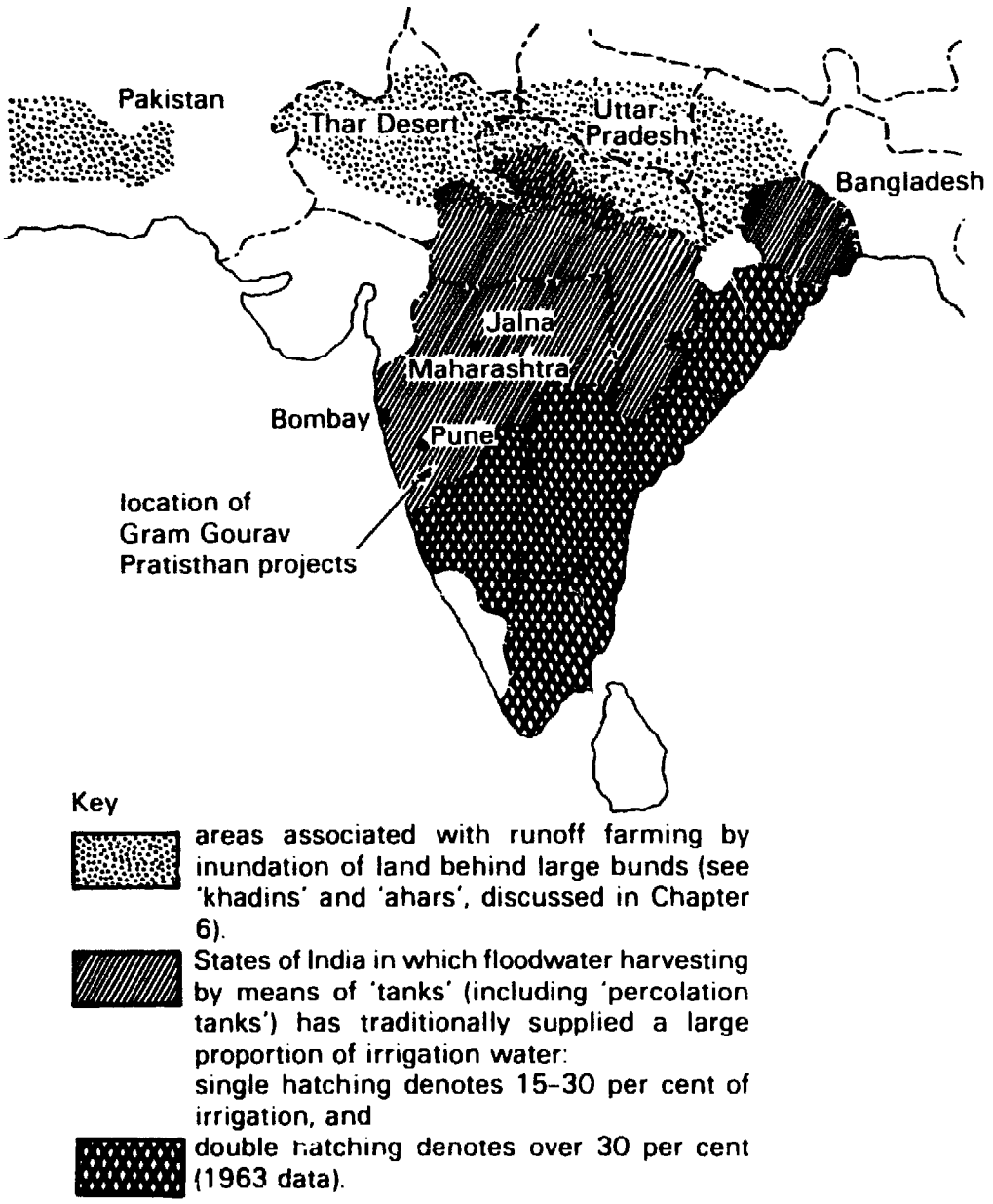

Fig. 2.3 Location of the Gram Gourav Pratisthan (GGP) projects in India, and the background of contrasting water harvesting traditions. The GGP projects make use of water from percolation 'tanks'. (Prasad 1979; UNEP 1983)

This programme is based on floodwater harvesting by check dams and percolation tanks built across small streams. A percolation tank is, in effect, a dam built on permeable ground so that floodwater is held back long enough to percolate into the ground and raise water levels in wells further down the valley (Fig. 2.4). Thus the water is stored underground as much as behind the dam (where evaporation losses are high), but a pump is then required to draw water from the well and irrigate cultivated land. The problem for the owners of the very small plots is that although the percolation tanks and wells exist, the cost of the pump (usually electrically

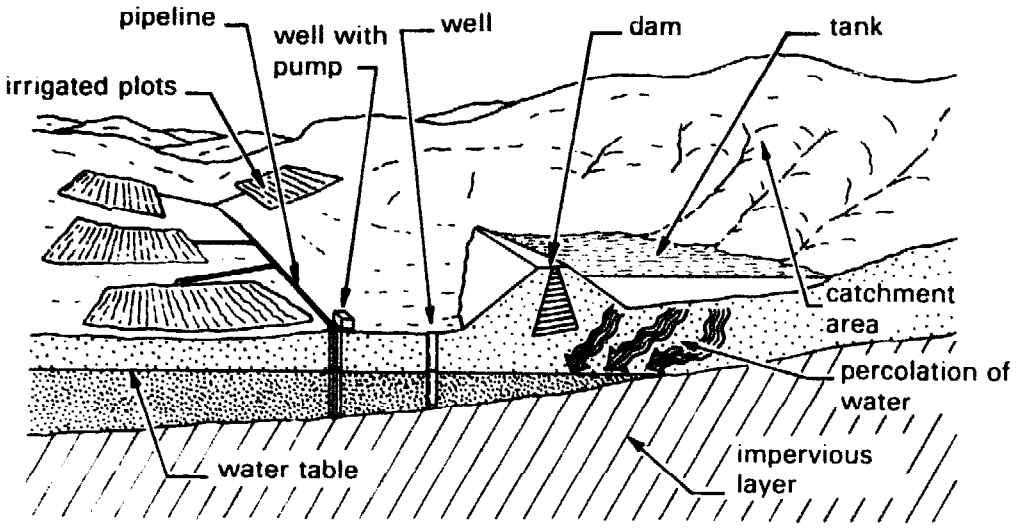

Fig. 2.4 Schematic view of the operation of a percolation tank which retains floodwater and recharges an aquifer so that land may be irrigated by pumping from wells. Percolation tanks are usually formed by building dams or bunds across natural drainage channels. They fall into the general category of 'water harvesting', or 'floodwater harvesting', but depend on channel flow and are usually on a larger scale than 'rainwater collection' in its most specific sense.

powered) and the necessary pipes is more than they can afford and greater than can be justified by their own fraction of a hectare. It is only if 30 or 40 families with adjacent plots share a pump that a scheme becomes viable.

In fact, the programme now consists of 52 water management groups in which there are a total of 1,725 families with 1,333ha of land to irrigate (Ray 1984). The success of the scheme depends on its parent organization (known as the Pani Panchayat) which sponsors the water management groups, offering soft loans, negotiating grants and establishing legal title to water rights at wells. Each group has its own leader and a paid field assistant whose job is to keep a log book of irrigations requested and carried out, and of loan repayments. Fortnightly meetings are held for group leaders and assistants where problems are discussed and information from the official agricultural extension service is circulated.

As with the pastoral groups in Africa mentioned earlier, there is the prospect here that water technologies can raise the level of livelihood for the rural poor provided that the scale is right for a group of families to work together. The organisational factor is crucial. There is a need to avoid the inefficiencies of large co-operatives, but yet to overcome the disadvantages of extreme small scale which the individual low income family will otherwise face.

It is tempting to assume that villages, where they exist, provide the right size of unit. But villages may be divided, sometimes bitterly, by conflicts of interest, and in India by caste. In African countries as well as in India, bland assumptions about community participation in water developments can be entirely invalidated by such problems. In several instances in South

India, for 'historical and economic reasons, the sense of being one village community does not exist' (Chauhan and Gopalakrishnan 1983). However, some sections of a village may be united by common interests, by common problems of poverty or poor housing, as well as by networks of extended family relationships. It is groups based on such bonds that may have the best chance of success in the 'participatory' schemes for management of agricultural or water resources (UNRISD 1974).

In the Gram Gourav Pratisthan most water management groups appear to have been formed on the initiative of their own members, many of whom do have family links or share common problems. One group includes a number of widows farming their own land. Once groups are formed, representative members attend regular meetings of the Pani Panchayat to request recognition of their project. Small groups such as this obviously need some such parent organization to provide technical advice, to co-ordinate purchases of equipment, and so on.

The importance of effective organization is also emphasized by the fate of many traditional rainwater or floodwater harvesting systems under modern conditions. Often the labour to build and maintain dams, tanks and runoff collecting channels was organized under a degree of pressure from authoritarian social structures. Sometimes these were relatively paternalistic and fostered a sense of village solidarity and co-operation; sometimes, as in parts of West Africa (as well as Asia), water resources were developed under systems of caste-work and even slavery. With the decline of such institutions, maintenance of old earthworks has often been neglected and the construction of new ones has ceased.

For example, the decline in the efficiency and use of floodwater harvesting in India by means of tanks and contour bunds (*ahars*) has been attributed to the disappearance of *zamindar* landlords who owned large tracts of land and could require tenants to remove silt from tanks or build new bunds. Ray (1984) confirms that the 'broader context' of rainwater harvesting in India is dominated by 'the decline of traditional authority' and the parallel loss of 'village concensus' and communal effort. The new atmosphere is one in which opportunity for individual gain has been greatly enhanced.

Experience in other countries underlines this point. In North Yemen, the ancient feudal system in which less than 10 per cent of the population controlled 90 per cent of the land was also highly successful in sustaining agricultural production through water conservation. But recently, with tenants gaining more independence by taking up temporary industrial employment outside the country, runoff farms and terraced cultivation have been neglected.

In the very different conditions of Mao's China, major water conservation works — including much floodwater harvesting — were constructed by large labour forces organized by the communes. But with the more

individualistic type of farming recently introduced — the so-called 'responsibility system' — it is suggested that the maintenance and extension of these works will become much more difficult (Hinton 1984).

One cannot envisage the return of autocratic landlords, or even a new development of large communes, and questions may therefore be raised about the continuing relevance or applicability of some forms of water harvesting. The value of the Pani Panchayat programme in India is that it demonstrates a form of organization for water management which does not depend on authoritarian structures but on voluntary co-operation. However, it may also be that the smaller scale of rainwater collection as compared with floodwater harvesting will eventually provide a better fit with the new kinds of organization which are emerging.

3. DATA COLLECTION AND DESIGN CRITERIA

TECHNICAL AND SOCIAL ASSESSMENTS

The essence of appropriate technology is that equipment and techniques should be relevant to local resources and needs, to feasible patterns of organization, and to the local environment. It is easy to talk generally about these things, as in the previous chapter, but the design of rainwater tanks or runoff farming systems for a specific area requires a much more detailed analysis. Information will be needed about rainfall, existing water sources, availability of materials, housing and roof types, and the people's means of livelihood. However, there are likely to be different points of view about local needs and how the project may affect them — as was also seen in the previous chapter. Experts on water supply, local residents and government officials may all have different views about what should be the goals of the project. One essential task, therefore, is to collect information which clarifies these different views and seeks common ground between them.

It may appear that the more technical aspects of a cistern or ground surface catchment will have to be designed by trained personnel without reference to local views. However, design decisions made this way are often compromised by site conditions, or negated by the purposes for which people actually use rainwater. One might make a precise technical calculation about the optimum size of tank only to find that a different size is built in order to make construction easier, or to cut costs. Even if the tank is built to specification, its size may prove to be wrong because its users draw water from it in different quantities or at different intervals from those assumed, or use it in unexpected ways, such as to store water brought from other sources (as in Botswana and Indonesia: Latham 1984b; Gould 1983). In other words, innovations concerning the use of tanks are likely to be made after the design process, as conventionally understood, has been completed.

Thus the development of an appropriate technology for rainwater collection (or for anything else) cannot be achieved by the simple process of collecting information and using it to formulate an optimum design. It is necessary instead to think in terms of an 'innovative dialogue' in which

information, opinion and innovation come from users of the system as well as designers. A more conventional term for this process is 'adaptive research', which usefully denotes the need to modify techniques to suit local conditions but which does not sufficiently acknowledge the input which must come from local informants. If an introduced technology is to take root in a particular locality what is needed, in addition to research as a specialist activity carried out by experts, is a dialogue — such as that described by Payne (1985) as 'interactive research'. He argues that the impact of technical expertise on human welfare is limited by 'how well we make the connection between professionalism and the problems experienced and perceived by the majority of the population'. In the context of rural society, an approach is required in which professionals interact with local people, 'not merely to study them but to listen and learn from them'.

One example concerns experts on crop storage who recommended a range of metal grain bins for use in Andhra Pradesh (in India) on the basis of conventional engineering criteria. They ignored existing grain storage methods in the area, assuming them to be inefficient and wasteful without making any measurements that could provide a check. But their recommended grain bins were found to be costly and inappropriate, and no progress was made until another research team began again, this time with a study of the traditional storage techniques already in use, and devised improvements of them based on discussion with local craftsmen (Greeley 1978). The same contrast is to be seen in technical reports on rainwater collection. All too often such reports discuss hydrology in terms of computer runs on rainfall records, but offer only the barest comment on whether local people already collect rainwater from roofs (perhaps in portable containers) or whether they already cultivate small plots by runoff farming methods. Indeed one has to turn to the work of social anthropologists (e.g. Bradfield 1971, Morgan 1974) to find out about such things.

Yet if water specialists were better prepared to observe traditional water catchment arrangements, they could gather many general clues about the hydrology of the area and the kinds of technique likely to work well, as will be shown in Chapter 6. If they were prepared to 'interact' more directly and talk to local farmers, they could learn about dates when the soil is moist enough for planting, frequency of crop failures, and many other matters. Moreover, awareness of traditional techniques might suggest how modern equipment could be used to build on existing practices rather than displacing them.

One manual on the training of fieldworkers for rainwater tank construction projects which recognizes these points is the *Training Guide* of the American WASH programme. This suggests that the initial compilation of information for planning a rainwater project in a particular village should be subdivided between a 'social assessment' and a 'technical

assessment'. Both are conceived in terms of dialogue — that is, interactive research.

The technical assessment begins by seeking out formal rainfall records from weather stations near the project area. Frequently, the figures obtained will be unreliable, or will come from places that seem unrepresentative of the project site. Fieldworkers must then necessarily turn to the 'oral, qualitative data base', asking people about wet and dry seasons, observing visual impressions of rainfall intensity, and noting folklore about droughts (Kay 1983). Thus the WASH *Training Guide* advises that if amounts of rainfall have to be guessed using records from some rather distant weather station and a map showing isohyets, villagers can provide a check on the adequacy of the estimates so obtained. By contrast, the *social* assessment suggested is concerned with collecting information on:

- existing rainwater catchment practices;
- opinions of local people about the usefulness and quality of water collected from roofs — what type of water use would have highest priority: drinking, cooking, washing, livestock or garden?
- opinions as to whether shared or individually owned rainwater tanks would be best;
- views of people interested in acquiring rainwater cisterns as to how much time and money they would wish to expend.

Information should also be collected on the chief means of livelihood in the village and on time and resource constraints affecting these. Some preliminary views can be formed as to whether, and how, rainwater collection could make a contribution to local livelihoods. It is important that this be done searchingly and frankly because there is always a danger that a project team aiming to build rainwater cisterns will press ahead towards construction without being sure that the cisterns can really meet a need, or that people want them and can afford them.

If technical and social assessments lead to the conclusion that it would be desirable to construct cisterns in a particular locality there would then be need for further data collection, this time to compile what the *Training Guide* calls an 'inventory of local skills, materials and experience.' The importance of this is that if one can devise rainwater collection equipment based on materials which people know how to use, it will be easier and cheaper to build and maintain. Data included in the inventory would cover costs and wages, as well as dealing with available materials and identifying local craftsmen (especially masons, basket-makers, or people capable of making large pots).

In countries such as Thailand and Indonesia, to which the *Training Guide* is closely related, it may seem obvious that local skills of this sort

should be fully used. But in Africa, where local skills may be less clearly compatible with western techniques, project planners have often ignored them completely. Many development programmes fail, and much environmental degradation and soil erosion occur because local construction techniques are ignored or undervalued.

THE SIGNIFICANCE OF HOUSING

In nearly all technical and social assessments, and in most inventories of materials and skills, considerable attention must necessarily be devoted to housing conditions. If collecting of rainwater from roofs is envisaged there is an obvious requirement for information about the materials of which roofs are made. Enquiries should also be made about whether any gutters have been fitted, and whether households already collect rainwater — even if from only small lengths of roof (Fig. 3.1).

If surveys extend to other aspects of housing, and also to ancillary buildings, they can yield useful information about local building materials and methods. It may be especially instructive to examine grain storage bins, since these are often roughly the same size and shape as rainwater cisterns. Thus, in the past, disused rainwater tanks have been re-used as granaries (in Botswana for example) and conversely several innovations in cistern design have originated from traditional types of food store. For example, the *Ghala* tank which is built in Kenya is made by modifying a traditional granary basket or Ghala and plastering it inside and out with a 2:1 sand/cement mixture (see Box 3.1) This technique also owes a good deal to reports of traditional water jars in Thailand. Another example is the large adobe (mud-walled) grain bins used by the Dogon people of Mali, West Africa, which were adapted as water tanks by the addition of wire reinforcement and a plastered cement lining (Watt 1978).

Examination of local buildings and their surroundings may reveal other techniques which are relevant. The Botswana house compounds and threshing floors which are surfaced with a clay/cow dung plaster and can be used very effectively as rainwater catchments were mentioned in Chapter 1, whilst in Asia, the use of bamboo in construction is another local technique from which much has been learned (Kaufman 1983)

However, a housing survey may be valuable as much for its social as for its technological implications. One point to notice is whether houses are being extended or rebuilt, or whether many are in disrepair. Experience in several countries is that where houses are being actively improved, it is relatively easy to arouse people's interest in such things as latrines, rainwater tanks or new types of cooking stove — items which can all be perceived as desirable additions to the home. On the other hand, if housing is seriously overcrowded or poorly constructed and people cannot afford any improvement, they will not be able to afford rainwater tanks either.

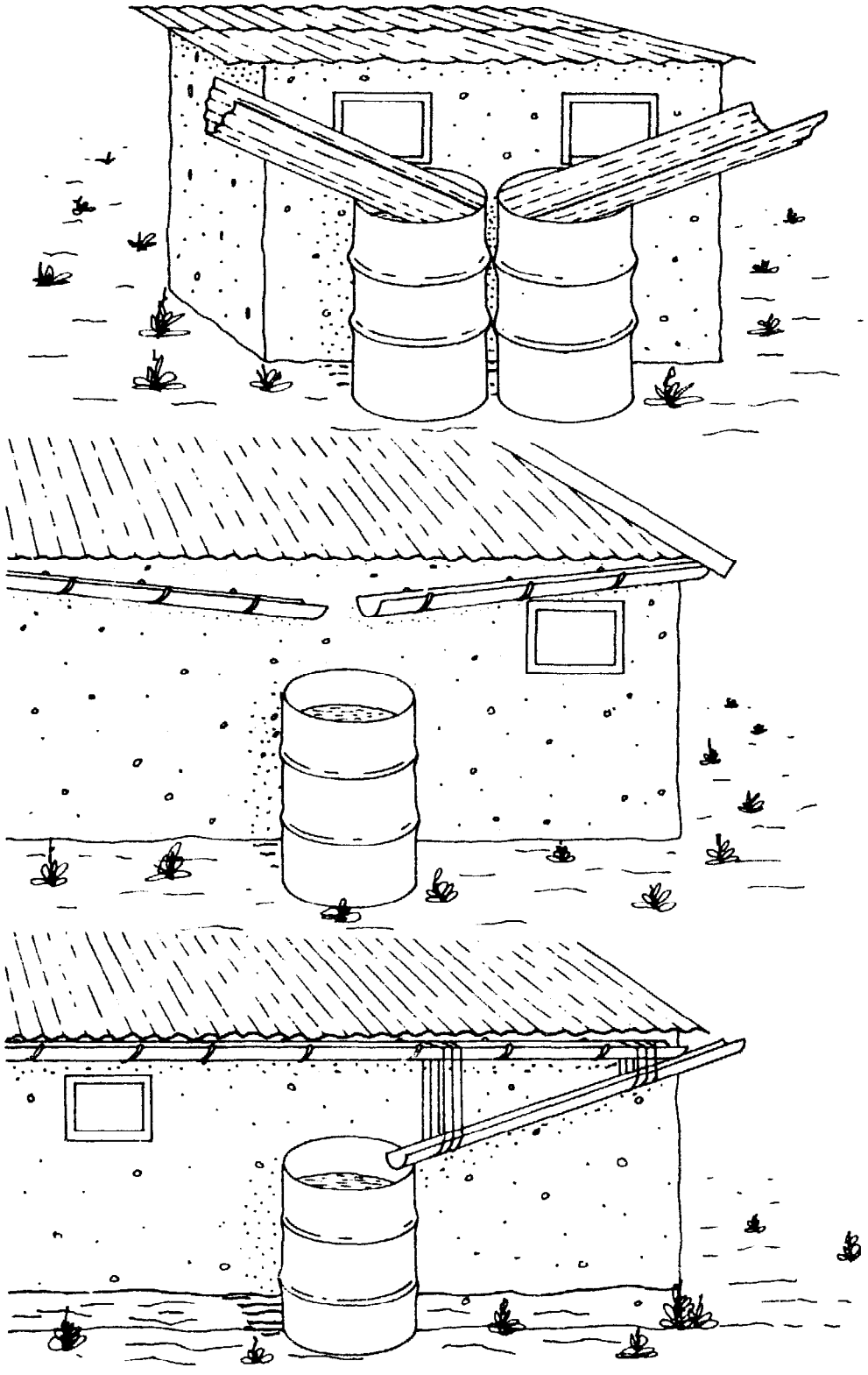

Fig. 3.1 Improvised rainwater collection with 200 litre oil drums used for storage (after Hofkes, 1981 and White et al., 1972). A survey in Kisii, Kenya, revealed that 33 per cent of households collected water in oil drums compared with 17 per cent which had permanent tanks. Most of the remaining families collected some runoff from roofs in pots, pans or buckets placed under eaves during storms. (Omwenga 1984)

Box 3.1 Construction of a plastered basket or 'Ghala' tank of 2.3m³ capacity. (UNICEF, 1982)

Materials See Table 5.3

Construction of basket A 'Ghala' or granary basket is made without a base as in Diagram 1. In Kenya, the basket frame is made from sticks from a woody shrub which grows country-wide. In Rwanda and Burundi, the frame is made from bamboo. Provided that the material is strong, the basket could conceivably be made from any number of shrubs or sticks which can be woven into basket form.

The actual shape does not seem very important, but it is recommended that the bottom be omitted so that the sides can bond with the base.

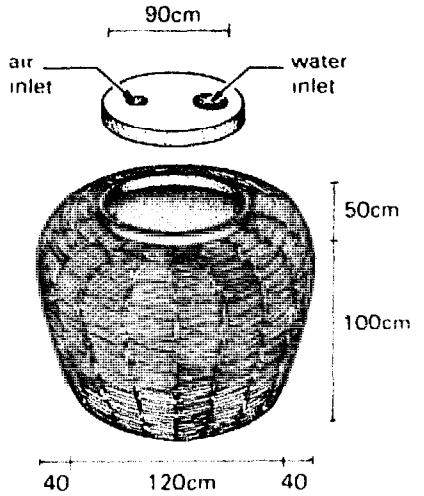

Diagram 1

Method of construction

1a. Construct a foundation of rocks 200cm diameter, 20cm deep.

b. Spread murram on the rocks and stamp down to a 1-5cm thickness. (Murram is a naturally occurring mix of sands, clays and pebbles commonly used in road surfaces.)

c. Lay a 2.5cm layer of concrete 1:2:4 on the foundation.

d. Place the water pipe with socket and tap fitted in position as shown in Diagram 2.

e. Place a 5cm layer of concrete 1:2:4 on the foundation.

f. Immediately place the basket centrally on the foundation and work it into the concrete.

g. Add concrete as necessary around the base of the basket to ensure that it is firm within the foundation (see Diagram 2).

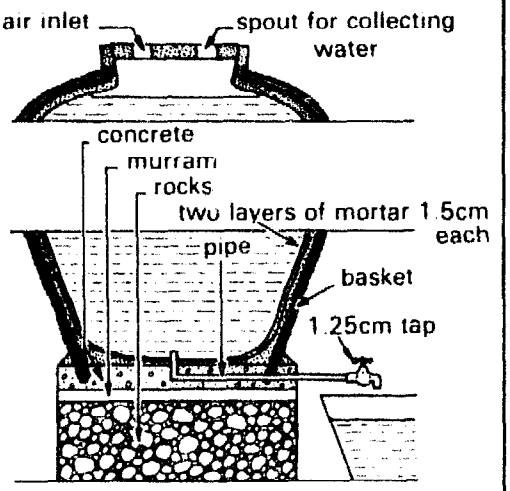

Diagram 2

2a. After the base has set, a mason should begin plastering the inside from the bottom up. Careful attention must be given to bond the sides with the base, adding a little cement to give a smooth curve.

b. Plaster the inside of the basket with two layers of plaster. The first layer should be a 1.5cm thick 1:3 cement and sand mixture and the second 1.5 cm thick 1:2 cement and sand mixture.

c. Apply the plaster with a trowel, first by throwing the cement on to the weave and then smearing it on and smoothing it in. The outside of the tank is plastered in a similar fashion.

d. Cure the plaster by draping the tank with wet sacking as soon as the cement has set. After 12 hours, fill the tank to a quarter capacity—this greatly helps the curing process. Keep the sacking wet for a minimum of seven days.

Note: *poor curing has been the major cause of tanks cracking and the correct use of the procedure should be strongly emphasized. It should also be pointed out that curing cement can contaminate drinking water up to 48 days.*

e. Construct a lid on the ground using reinforced cement (see Diagram 2). A suitable form can easily be cut out in the earth. Lids are usually between 3-5 cm thick, depending on the tank opening.

One way of checking on how realistic a proposed cistern design might be is to enquire about the cost of building a house in the locality concerned. If materials needed for the cistern cost more than 10 or 15 per cent of what is needed to buy materials for a house, the cistern is probably too costly. The Ghala tank in Kenya, and cisterns built in Indonesia and Thailand using bamboo reinforcement instead of metal, have been highly significant in enabling low-cost tanks to be made, though there is still some way to go in ensuring their durability. Another way of keeping costs down — which is used in many projects — is to construct smaller tanks than would otherwise be desirable.

However, the point of a survey of housing conditions goes deeper than seeking clues to what people can afford. It can also be a useful starting point for discussion with local people about their most urgent needs. What people say they want will often be quite different from what the professional thinks they need. And while the professional may validly provide information to encourage people to see their needs in a different light, this should be in the context of a dialogue, not pressurized forms of health education designed to change views at all costs. What professionals ought to recognize is that however great their sense of mission and however justifiable their views about water, local householders will see their inadequate supply as just one of a whole range of problems, others being connected with housing, food, low income, family relationships and so on — all the problems of poverty and of the human condition. A particular improvement in water supply, attractive in isolation, may not fit well with a strategy for coping with other problems, and in any case, the poorest people may see their most urgent needs in terms of food and housing, not water and health (Chauhan and Gopalakrishnan 1983).

What water-supply professionals need to do in such circumstances is to look for common ground where their own goals and those of the people overlap. If they aim only to build a certain type of rainwater cistern, and it is clear that the people have other priorities, there may be no basis for a project. However, it is unlikely that the issue will be posed as starkly as this. More probably, the survey of housing will identify some groups of homes with tiled or metal roofs in good repair and evidence of recent improvements and extensions, and it will be tempting to feel that these would provide the best starting point for a rainwater programme. In other areas, by contrast, houses may be in poor repair, with no recent building work done, and roofs so roughly thatched that collection of rainwater from them is hardly feasible.

It has often been commented that quick visual surveys of housing provide one of the easiest methods of identifying places where the low-income groups are to be found, and for advocates of rainwater harvesting this is likely to expose a particularly critical dilemma. Having found the groups of people likely to be most in need of a better wa.er supply, one may

then find that a rainwater system is almost impossible for them because of its cost and/or their inadequate roofs. One may then learn from the people that they want better housing far more urgently than they want water tanks.

At this point, the rainwater advocates will need seriously to consider where their priorities lie. Is their commitment and that of the funding agency to a specific technology, or to seeking to improve the livelihoods of the poor? To use the jargon of more sophisticated policy debates, is the priority 'technology push' or 'response to need'?

If the primary commitment is to demonstrate rainwater technology, the best chance of a successful project will be in the areas where houses already have good roofs and active home improvements are evident. On the other hand, if there is a commitment to working in the poor areas, various other possibilities ought to be considered. Firstly, there is the option of postponing rainwater collection as an immediate aim and initiating a housing improvement programme instead. This is more likely to accord with the people's own sense of priorities than is a specialist form of development which would leave the worst of their living conditions untouched. Sometimes, work with the very poor will mean accepting the continued use of traditional roofing materials and tackling the problems of collecting rainwater from thatch (Fig. 1.8). More often, perhaps, a housing improvement programme will lead to the installation of new types of roofing. Then, very simple forms of rainwater collection could be introduced almost immediately, perhaps using containers people already possess (Fig. 3.1), with short lengths of modern guttering, or if they can afford it, Ghala tanks (Box 3.1) or a local equivalent.

Better housing materials may be a particularly urgent need in the shanty towns which fringe many urban areas, where materials for thatched roofs may be almost unobtainable and corrugated iron expensive. Locally made tiles may be available or possibly wooden shingles — which can be made from coconut tree trunks that have been split. There are also new materials such as fibre reinforced cement, made into tiles. These have sisal or coconut-coir reinforcement and are potentially very cheap in regions where sisal or coconuts are grown (and where cement is available) (Parry 1981). In India, corrugated fibre sheeting made from waste paper has been successfully used, with impregnated asphalt for waterproofing and durability (Rao 1975).

A second option for advocates of rainwater collection who also feel a commitment to working with the poorest social groups is to try and understand why people in the project area are so poor. This would mean extending the data gathering exercise to seek extra information on local means of livelihood, and to gain insights into whether water resource development might contribute in any way. If the people have access to land, would extra water allow more crops to be grown? Or could it extend the

growing season? If rainwater collection from roofs is not feasible, are there ground catchments that could be used — or even opportunities to collect runoff from road surfaces?

A third strategy, and the one most usually suggested for areas of poor housing, is to promote a communal rainwater system using the roof of some large public building as a catchment, such as a school or a church. Alternatively, where people cannot afford their own cisterns, but their house roofs are suitable for rainwater collection, shared tanks are a possibility. In Indonesia, for example, large tanks ($9m^3$ capacity) are sometimes shared by four families, and smaller tanks ($4.5m^3$) by two. Such arrangements may often be necessary, but there are difficulties in allocating responsibilities for maintenance of shared facilities and in ensuring that individual users do not take disproportionate amounts of water. Although there are generally doubts about the merits of communal as opposed to individual catchment tanks, where discussions have been held with local people, it is usually possible to state quite clearly which approach is preferred. Molvaer (1982) and Sinclair (1983) report 'a preference for individual household tanks in the Kitui District of Kenya', whereas Swift (1984) indicated 'the suitability of communal ground catchment systems' in some pastoral areas of West Africa where 'communal decision-making is a traditional practice'.

Clearly, then, information collection about housing is not simply a matter of observing and mapping roof types and building materials, but has implications which must lead on to discussion with local people about their preferences regarding house improvement, shared facilities, and several other matters.

THE HYDROLOGY OF RAINWATER SYSTEMS

With the data requirements of rainwater projects set in their wider context, it is now important to consider the more technical kinds of information that are essential for planning, especially those concerning rainfall. A first and vital point to notice is that the hydrology of rainwater collection needs to be approached differently according to whether one is dealing with runoff farming or the collection of water from roofs. With the latter, projects can be successfully initiated using very uncertain knowledge of rainfall amounts, but in runoff farming, a detailed appreciation of rainfall intensity and runoff is essential from the start. Many hours of labour may be required to construct bunds, channels and terraces to control the flow of runoff on cultivated land. If these are inadequate for the volume of runoff which actually occurs, and are destroyed or seriously damaged in the first major storm, the demonstration effect of the project will be extremely negative. The cultivators affected by such an experience may never try again.

Therefore, in areas where there is no prior experience of runoff farming,

Shanan and Tadmor, speaking about winter rainfall conditions (1979), advise that *at least* two years should be spent collecting rainfall and runoff data on site before any large-scale construction begins. There may be some traditional runoff farming in the area, study of whose performance can allow cultivation on new sites to begin earlier, and Chapter 7 indicates approaches based on this which differ markedly from what Shanan and Tadmor advise, particularly with reference to summer rainfall. However, it will always be desirable to identify a weather station in the region where records can be used as a guide to long-term minimum and average rainfalls. To check whether its data correlate with weather at the project site, daily records from the weather station should be compared with both quantities and timing of rainfall observed on site during the two year preliminary period.

Information to be sought from a weather station might also include data on temperatures and evaporation rates, especially for the season when the rain is recorded. This is because runoff farming must be carried out in a different way if the growing crop has to cope with the heavy evaporation losses of a hot summer, or alternatively, if it can benefit from the cooler growing conditions of a winter rainfall regime (see Chapter 6).

Information on rainfall intensities is especially important in the context of soil erosion. Storms in which intensities exceed 25mm/hour are very likely to cause erosion on exposed ground surfaces. In most temperate regions, only 5 per cent of rain comes into this category, but in the tropics, it can be up to 40 per cent.

For the design of microcatchments or runoff farming systems, then, we need a considerable amount of hydrological information, as summarized in Box 3.2. For example, during the nine growing seasons which occurred at Lokitaung in north-east Kenya between the years 1975-83, the average rainfall was 218mm. The following simple calculation was made to estimate the catchment: cultivation ratio for a sorghum crop:

Turkana sorghum requires 400mm of rain within the growing season, but the average rainfall is 218mm. Rain falling on the cultivated plot is therefore deficient by an average of 182mm, and an equivalent amount of water is the *minimum* which must be supplied in the form of runoff from the catchment area. However, it will be desirable to supply much more runoff than this since the actual rainfall will frequently be less than average. In this instance, experience suggested that if runoff equivalent to 400mm of rain on the cultivated area could be achieved in an 'average' season, providing the crop with 618mm in total, then the minimum requirement would be achieved in many drier years.

If the area of the cultivated plot in m^2 is represented by B, then runoff equivalent to an extra 400mm of rain amounts to a volume of $400 \times B$ litres of water.

Box 3.2 Summary of measurements needed for design of microcatchments and runoff farming systems.

DATA REQUIRED

1. Daily rainfall measurements over 2-3 years from rain gauges about 2km apart on the project area.

2. Estimates of average and minimum monthly and annual rainfall.

3. Measurements of rainfall intensity and ***runoff*** in individual storms so that earthworks can be designed to cope with maximum water flows. Textbooks on runoff farming (Shanan and Tadmor 1979) and soil conservation (Hudson 1971) give details.

4. Estimates of total runoff in months prior to and during the growing season in order to calculate the catchment area needed to provide sufficient water for the crop. Ratios of *cultivated to catchment areas* vary from 1:2 or 1:5 in Texas and Arizona (Fangmeier, 1975; Jones and Hauser, 1975) to 1:20 or 1:30 in the Negev Desert (Evenari *et al.*, 1982).

5. Measurements of open pan evaporation and of ***soil moisture*** may be useful in refining calculations of necessary catchment areas, optimum planting dates, etc.

To measure RAINFALL INTENSITY, it is best to use a continuously recording rain gauge with a pen trace. It is also possible to time the lengths of individual storms, note rainfall, and calculate average intensity in mm/hour. (Peak intensity may be estimated from the average values by methods given in the aforementioned textbooks.)

To measure RUNOFF, small runoff plots can be laid out on proposed catchment area, (see diagram). Sites should be chosen with surface conditions and slopes that are typical. Allowance must be made for the fact that runoff is a much greater proportion of rainfall on small catchments as compared with large ones (Chapter 1).

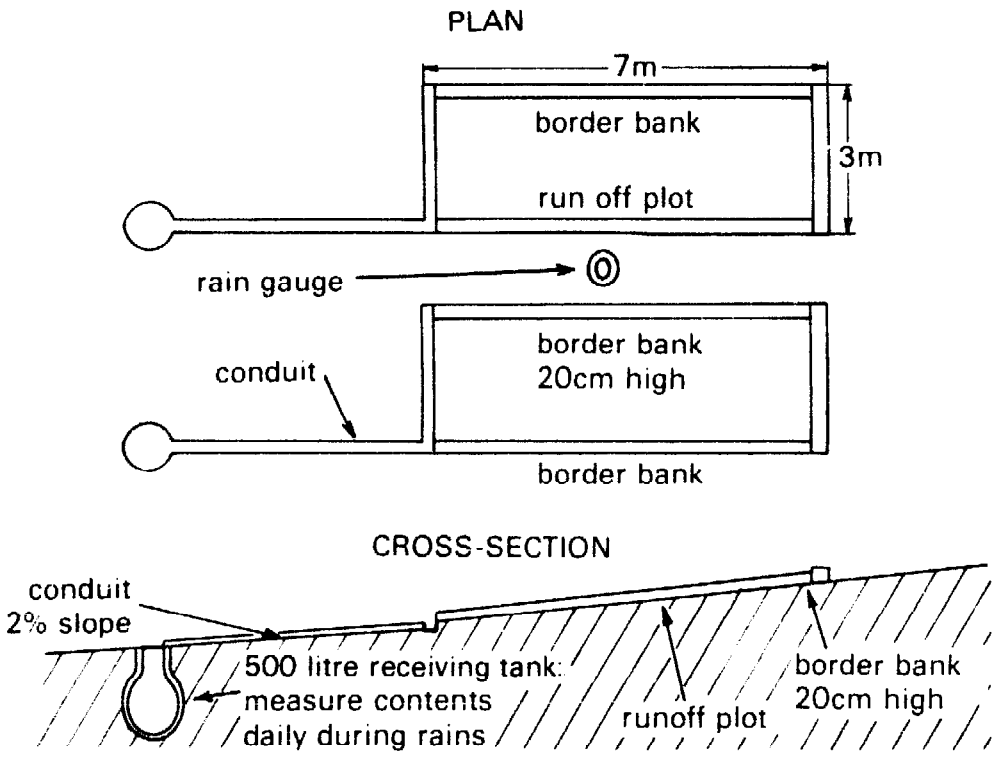

The amount of runoff actually obtained from the catchment was estimated by the method described in Box 3.2, and was found to be 30 per cent of the rainfall, that is:

$$\frac{30}{100} \times 218\text{mm in an average year.}$$

If the area of the catchment is A, the actual volume of water running off it is then:

$$\frac{30}{100} \times 218 \times A \text{ litres,}$$

which must provide the requirement of 400 × B litres previously specified. Equating these two quantities, we can then calculate the necessary ratio of catchment area to cultivated area, A:B.

$$\text{Thus A:B} = \frac{400}{218} \times \frac{100}{30} = 6.1:1$$

Despite the allowances made in this calculation for drier seasons than average, a greater margin of safety is actually sought in this part of Kenya, and the ratio of catchment to cultivated area normally used is about 10:1.

By contrast, when rainwater is to be collected from house roofs, much more approximate data is usually sufficient. The main question hydrologists need to ask is 'how big should the storage tank or cistern be?' This breaks down into three subsidiary problems:

1. matching the capacity of the tank to the area of the roof;
2. matching the capacity of the tank to the quantities of water required by its users;
3. choosing a tank size that is appropriate in terms of costs, resources and construction methods.

Some researchers have devoted considerable attention to calculating answers for the first two questions, using computers to process long runs of rainfall records where these are available (see Fujimura 1982), or even to simulate data where records are missing. This may be appropriate in some richer countries where the usual approach is to start with the second question above, specifying a desirable level of consumption and then designing catchment areas and storage tanks so that this can be provided. By contrast, in poorer countries much greater weight has to be placed on cost, and hence on the third question. It also makes sense to take account of what resources are available — roofs as they already exist, local materials, and labour. One can then work out a plan for expending these resources in a way that comes as close as possible to a target for water

consumption (Keller 1982). In practice, costs and construction methods tend to limit tanks to smaller capacities than would otherwise be justified by roof areas or likely needs of consumers.

For this reason, elaborate calculations aimed at matching tank capacity to roof area and consumption are usually unnecessary. However, a simplified calculation of this form can give a rough idea of the potential for rainwater collection in a particular region. The starting point is data for average monthly rainfall, expressed in millimetres, and measurements of the roof from which rain is to be collected — its length and *horizontal* width. The volume of water (in litres) likely to be collected each month is then found by multiplying the average monthly rainfall by the horizontal area covered by the roof (in square metres), and then multiplying by 0.8.

The latter figure is the runoff coefficient, and allows for the fact that some rainfall will be lost from the roof by evaporation and in other ways. While 0.8 is typical for a hard roof, the number to adopt here would be better chosen in the light of the roofing material actually used, for which some rough figures are given in Table 3.1.

Table 3.1 Runoff coefficients. (Hofkes, 1981; UNEP, 1983; Frasier, 1975 and Gould, 1983)

Type of catchment	Coefficients
Roof catchments	
— tiles	0.8 - 0.9
— corrugated metal sheet	0.7 - 0.9
Ground surface coverings	
— concrete	0.6 - 0.8
— plastic sheeting (gravel covered)	0.7 - 0.8
— butyl rubber	0.8 - 0.9
— brick pavement	0.5 - 0.6
Treated ground catchments	
— compacted and smoothed soil	0.3 - 0.5
— clay/cow-dung threshing floors (Botswana: Gould 1983)	0.5 - 0.6
— silicone-treated soil	0.5 - 0.8
— soil treated with sodium salts	0.4 - 0.7
— soil treated with paraffin wax	0.6 - 0.9
Untreated ground catchments	
— soil on slopes less than 10 per cent	0.0 - 0.3*
— rocky natural catchments	0.2 - 0.5

* *Figures for specific sites should be determined using runoff plots as in Box 3.2.*

When expected monthly volumes of water have been estimated in this way, the figures are plotted on a diagram such as Figure 3.2. In this diagram, each calculated monthly total is added to the total for previous months so as to represent, by an approximate, stepped form of graph, the way in which water levels in a cistern would rise through the year if none were drawn off and used. In Figure 3.2, the dry season is from May to September. Very little water enters the tank then, so the line on the diagram remains almost horizontal.

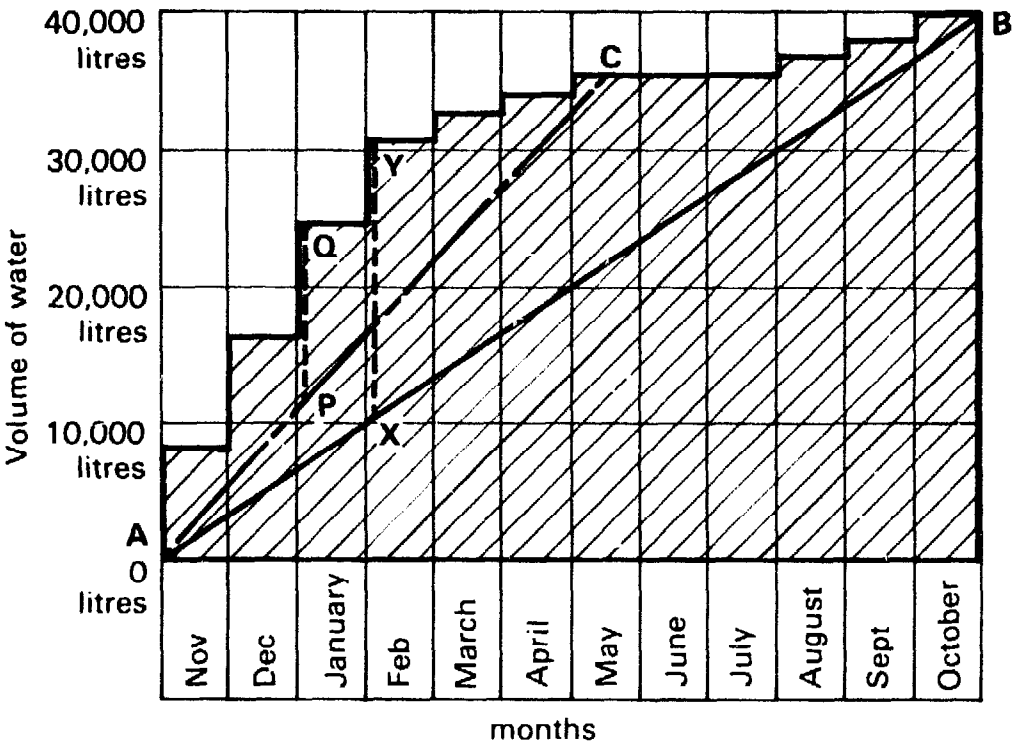

Fig. 3.2 Diagram representing volumes of water collected from a roof (stepped line), and the consumption of water by users of a rainwater tank filled from that roof (sloping lines **AB** *or* **AC***). Each step in the line representing water collected indicates the contribution made by one month's rainfall. The diagram is drawn so that its left hand side corresponds to the month in which the tank is most likely to be empty. The steps thus represent the gradual filling of the tank during the rainy season.*

When plotting graphs of this kind, it is important to start at the left hand side with the beginning of the rainy season, when the tank is assumed to be empty, so that the way in which the water level rises during the rains is clearly illustrated. In Figure 3.2, the graph begins in November, which is the first month of really heavy rainfall.

Usually it is assumed that people will take the same amount of water from the tank each day throughout the year. This is unrealistic because consumption varies greatly with the seasons, and according to whether water from other sources is being used. However, by assuming a constant rate of consumption, we get a rough indication of the system's capabilities.

Again referring to Figure 3.2, the total amount of water running off the roof in a year of average rainfall is recorded as about 40,000 litres. So theoretically, if their cistern is of adequate size, the owners of the roof could ration themselves so as to use all this water in 365 daily withdrawals of 112 litres each. This steady rate of use is represented by the straight upward sloping line **AB**. At point **B**, where this line meets the stepped line representing rain water entering the system, the tank has been emptied, though it should be filled again almost immediately with the onset of the new rainy season. However, at point **X**, where the two lines are farthest apart, the tank is fuller than at any other time. The distance separating the two lines, **XY**, then represents a volume of 20,000 litres, which is thus an estimate of the capacity the tank should have — 20 m^3 — if it is to provide the 112 litre daily ration.

Although it is unlikely that any household would draw exactly the same ration from the tank on every day of the year, it is possible to think of this as one method of using a rainwater tank. It might be called the 'rationing method'. By contrast, Parker (1973) working in Ghana, regarded it as more realistic to think of people using their tanks according to a 'rapid depletion method'. This envisaged that members of the household take all the water they require from the rainwater tank for as long as it contains water, and then turn to an alternative source. They will especially tend to do this if the alternative source is a long way from the house, or if they are working hard in the fields during the season when the tank is full, because the tank is so much more convenient.

In Figure 3.2, the steep line **AC** represents use of the tank by the 'rapid depletion' method, with point **C** indicating the date when the tank is empty. This is in May, and the maximum amount of water stored, represented by line **PQ**, is about 15,000 litres. So a tank of this latter size — 15m^3 — would meet the rate of consumption shown as **AC** for about six months in the year: November to May.

This illustrates the paradoxical choice which often has to be made between a *large* tank capable of meeting a rationed rate of consumption over a whole year, or a *small* tank capable of providing for greater consumption on a rapid depletion basis. For most households, the latter will be the more realistic option.

Hafirs and excavated cisterns on arid grazing lands will have to meet a very different pattern of demand. During the brief rainy season, when animals can drink at natural water holes, there may be no withdrawals of water from a cistern or small hafir, only losses due to evaporation and perhaps leakage (Fig. 3.3, line **AB**). Then, when the water holes have dried up, herds will be moved so that they can graze within each reach of the hafir, and will be watered there regularly — perhaps daily, or perhaps on alternate days. Withdrawals will be very heavy — cattle drink between 20 and 100 litres per day depending on their breed and size, and varying with

ambient temperatures, but camels, goats and sheep require much less (usually less than 5 litres). As water levels in the cistern or hafir get low, the herdsmen will find out which other water points in the region can still provide for their livestock, and will then move on. Figure 3.3 illustrates a location with a short July-August rainy season, and indicates schematically the likely consumption of 200 cattle for a 6 week period in the dry season. Once again, the stepped line shows inflows to the cistern, and the straight lines **ABC** show consumption. The cistern is empty at point **C**, and the maximum storage required is indicated by **PX**.

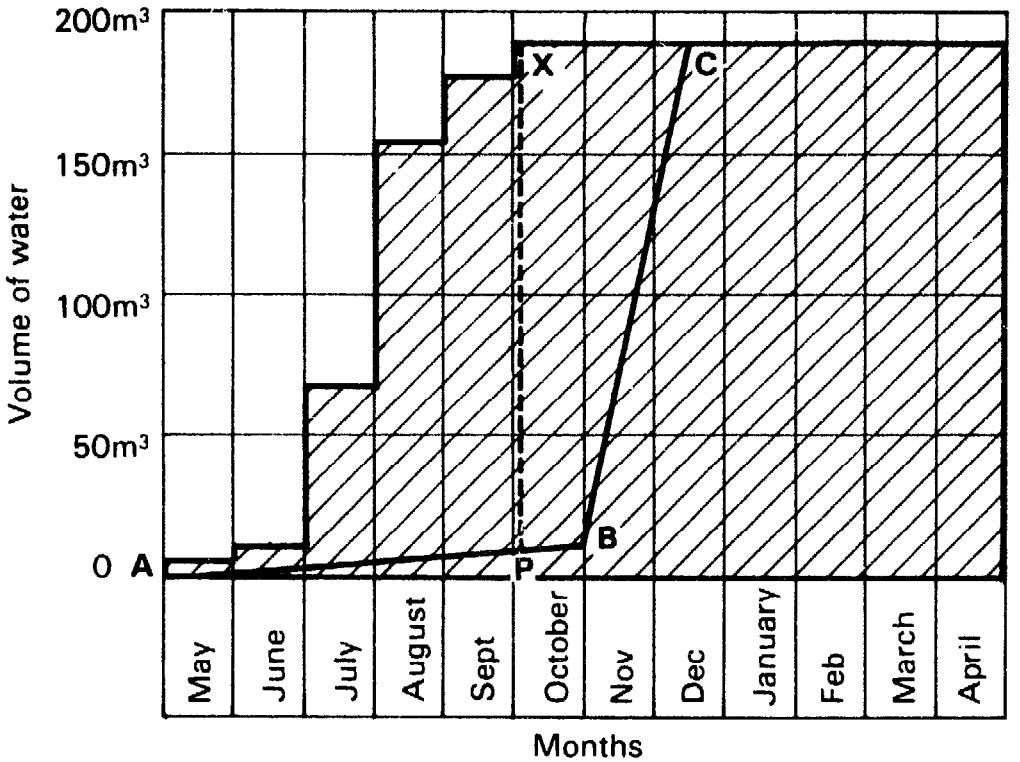

Fig. 3.3 Volumes of water flowing into, and being consumed from a cistern (or very small hafir) in an arid pastoral region. The rains come mainly in July and August. The cistern is used to provide drinking water for livestock which graze in the area during November and early December. The cistern is empty during mid-December until early May.

AB *represents loss of water by evaporation while the cistern is not being used;*
BC *is the consumption of 200 cattle during 6 weeks, at the rate of 20 litres/head/day (approximately);*
PX *is the storage capacity required to meet this demand, which in this case is very slightly more than the volume of water consumed by the animals.*

In designing a cistern or hafir for use in these circumstances, the starting point should probably be an examination of how much grazing local grasslands and forage shrubs can withstand. Cattle will graze within a day's walk of the water point. If it is thought that the area defined by this can only safely feed 200 cattle for six weeks, care should be taken to limit the capacity **PX** to their likely requirements, so that lack of water forces the herd to move on in due time, and allows the vegetation to recover.

TANK CAPACITIES IN PRACTICE

Reverting to the question of how large *household* water tanks should be, we have seen that it is unrealistic to assume that people will ration themselves precisely when using rainwater. However, lessons can still be learned by gathering together some of the varied recommendations for tank sizes which have been based on the idea of rationing. Thus in Table 3.2, the data given by a number of authors have been recalculated to provide information in a standard format relevant to roofs of revatively small houses, $30m^2$ in extent. Where the original authors emphasize figures for much larger roofs, these are also included.

Not all the figures in this table are comparable. Differing methods of calculation (or estimation) have been used, and differing assumptions about runoff coefficients. More fundamentally, divergent views about how reliable rainwater systems should be are incorporated in the figures. Several authors specify conditions under which the system will operate with 95 per cent reliability — that is, with the tank containing water and maintaining the daily ration for 95 per cent of the time, but with supply failures during drought leaving the tank empty for 5 per cent of the time. As the figures for Botswana and Java show, recommendations may be greatly modified if altered requirements regarding reliability are fed into the calculation.

A surprising feature of Table 3.2 is that despite the large variations which might be expected to arise from different assumptions of this sort, recommendations for tank capacities mostly lie in a rather small range between $3m^3$ and $8m^3$. This is particularly remarkable in view of the wide range of climatic conditions represented. However, information from Java indicates that, in high-rainfall regions, authors may be suggesting smaller tanks than are feasible because they assume that households will restrict themselves to a rather limited daily ration. So even if local rainfall could provide a larger ration — say 60 litres per day in Java — tank capacities are specified for half this, presumably because that is consistent with a tank capacity which people can afford. Only for the two most prosperous countries represented, Australia and Bermuda, are significantly larger tanks recommended with a view to maximizing the daily ration.

This may seem to confirm the unreality of sophisticated hydrological calculations. Not only is the idea of a strict daily ration at variance with normal human behaviour, but many calculations are not entirely objective — they incorporate assumptions about how big the daily ration should be based on economic criteria. Observations of how much water people use for drinking and cooking can, of course, provide a rough guide, and a ration of 5 litres per person daily seems to accord with conditions in Indonesia (Kerkvoorden 1982) With typical families of between four and six individuals, it is thus tempting to design for 30 litres per household

Table 3.2 Some recommended rainwater tank capacities based on the assumption that water consumption is rationed to ensure an all-year supply (Water Panel, 1974 and data from the authors cited) (rel. = reliability)

REGION AND DATA SOURCE	*MEAN ANNUAL RAINFALL* (mm)*	*SAMPLE ROOF AREA* (m^2)*	*RECOMMENDED TANK CAPACITY (m^3)*	*THEORETICAL DAILY RATION FOR RELIABLE ALL-YEAR SUPPLY (litres)*
AFRICA				
Ghana, N.E. region (Parker 1973)	800 in two wet seasons;	30	7.5	66 (*a*)
Swaziland, Lowveld (Farrar 1974)	635 with 6 dry months.	30	5.0	37 (*a*)
Botswana, Francistown (Gould 1983)	470 with 7-9 dry months.	30	4.5 4.5 8.0	31 (80% rel.) 22 (95% rel.) 31 (95% rel.)
INDONESIA				
Java, Jakarta area (Irish *et al* 1982)	1800 no really dry months.	30	1.2 5.0 3.6 7.8	30 (80% rel.) 60 (80% rel.) 30 (99% rel.) 60 (99% rel.)
Madura (Irish *et al* 1982)	1500 with 5 dry months.	30	5.1	30 (99% rel.)
Java, Yogyakarta area (Latham 1984)	1800 with 6 dry months.	(*b*)	5.0	30 (*c*)
THAILAND				
Khon Kaen area (Nopmongcol *et al* 1981)	1300 with 4 dry months	60 30	11.5 5.8	90 (95% rel.) 45 (95% rel.)
AUSTRALIA				
Sydney (Perrens 1982)	1210 no dry months.	320 30	126 11.8	800 (*d*) 74 (*d*)
Griffith, New South Wales (Perrens 1982)	390 with no defined wet season.	965 30	336 10.5	800 (*d*) 25 (*d*)
BERMUDA				
(Waller 1982)	1500 no dry months.	30	11.7	— (*e*)

* *Most authors do not state recommendations for 30m^2 roofs but give graphs or tables from which these can be read off; the term 'dry month' is relative and does not imply total lack of rain.*

(*a*) *no statement of reliability (rel.) in these instances*

(*b*) *Latham quotes actual roof areas from which rainwater is collected ranging from 12 to 31m^2 with 62m^2 available in the latter case*

(*c*) *recommendations based on experience, not exact calculation*

(*d*) *average probability of failure once in 5 years*

(*e*) *figures based on local regulations, not exact calculation*

daily. If the recommendations of Table 3.2 are followed, this would suggest tanks of $3.6m^3$ capacity for households in the Jakarta area.

In practice, however, tanks are constructed according to a smaller number of standard sizes: $2.5m^3$ and $10m^3$ in West Java, and $4.5m^3$ and $9m^3$ in the Yogyakarta area. So even if the recommendations concerning the most appropriate capacity could be regarded as precise and realistic, a tank could not be provided to match it. Many programmes standardize tank sizes and cannot tailor capacities to suit the rainfall of a particular area nor the number of consumers in a particular household, so on these grounds also, sophisticated calculation is unnecessary.

Commenting on tank capacities in the Yogyakarta region, Latham (1984b) concludes that they are 'determined by cost and ease of construction' more than by hydrological theory. On the basis of experience he suggests that the minimum storage volume per family which can supply *only drinking water* (5 litres/person/day) is about $5m^3$ for Yogyakarta. 'If any other use is to be satisfied by rainwater, each family should have $10m^3$ of storage.' As it is, $4.5m^3$ tanks are usually shared between pairs of families. They are used on a rapid depletion basis, and often go dry 'in as little as one month'.

Having commented that most of the recommended tank sizes in Table 3.2 are in the range $3\text{-}8m^3$ for a $30m^2$ roof area, we may add that the standard sizes adopted in programmes operating in Africa and Asia represent a somewhat larger range: $2\text{-}12m^3$. One reason, of course, is variation in roof area. Although $30m^2$ is a fairly typical catchment size (e.g. in Kenya and Indonesia), Latham (1984b) points out that many tanks collect water from only half a roof. In Indonesia and Thailand, $60m^2$ or even $100m^2$ could be used, justifying much larger tanks. By contrast, in Africa, many houses will have roofs of less than $30m^2$.

However, tank capacities are in practice usually determined by what people can afford. The choice of a tank may also depend on what contribution it makes to people's livelihoods. If a tank is used by rapid depletion and only provides water for a few months each year, it is worth asking in what season will that water benefit livelihoods most?

Ray (1983) comments on the use of rainwater in gardens to extend the cropping season by a few weeks and allow a supplementary crop to be grown. If this relatively modest, seasonal use of water provides a major increment to livelihoods, either through sales or nutritional value, it may be optimal for a project to install tanks of only $3m^3$ capacity (which local people might say are too small), even though the unit costs of such tanks are greater than for tanks of $10m^3$ capacity. The economies of scale arising from the larger tank will be wasted if the extra water is unproductively used.

More typically, if the supply of drinking water from a tank is most significant in saving time spent carrying water during a busy season, the

best size of tank will be the one which provides all the water needed during that season, but no more. However, where the problem a community faces is one of resource constraints — an absolute shortage of water at some time in the year, or a serious problem of water quality — it is less easy to suggest solutions for which small tanks will be adequate. The time when water is most needed may be the end of the dry season, yet this is when a small tank is almost certain to be empty. Noting this problem in Indonesia, Ray suggests that households might ultimately be advised to acquire two small tanks, one for use on a rapid depletion basis, the other to be held in reserve and not used at all until other sources have dried up. By contrast, in Kenya, Ray notes that when Ghala tanks were first introduced, the size was usually 1.1m^3, but these were felt to be rather small, and 2.2m^3 tanks are now most popular. In this context, village-level research by UNICEF concluded that rainwater collection can form a valuable *wet season* supply for the household, and that small containers suited to this limited function do make an impact on the household (Molvaer 1982).

Thus development workers are slowly accepting the seasonal value of tanks used on a rapid depletion basis, and have moved away from emphasis on rainwater for all-year supply, necessitating large and costly storage systems. Moreover, experience in Kenya is that once tanks of about 2 or 3m^3 are made available, they are in high demand. Agencies concerned to help the rural poor might perhaps do best by concentrating on this relatively small size of tank, in Kenya at any rate, since those who can afford larger tanks buy them on their own initiative. Many houses belonging to better-off farmers may be observed to possess 5-10m^3 tanks, made locally from corrugated galvanized iron, or from fired bricks (with cement lining and wire reinforcement).

In Indonesia, the preferred type of tank is one built of ferrocement with 9 or 10m^3 capacity. However, in order to provide a low-cost alternative for poor families, much work has been done on a tank in which bamboo is used in place of metal to reinforce the plastered cement walls. With this method of construction, the maximum size for a satisfactory tank is felt to be 4.5m^3 and several hundred tanks of this size have been built (O'Reilley 1984). As with Ghala tanks, there are still doubts about how long-lasting they will be. If the bamboo reinforcement is left exposed at any point, it deteriorates rapidly. In Thailand, bamboo is used to reinforce relatively thick-walled tanks built of concrete (rather than cement). There seem to be fewer problems with this method of construction, and tanks of just under 12m^3 capacity are regularly made (Fricke 1982).

It is construction methods such as these, and what can be afforded, which determine most choices of tank capacity, not hydrology. Data such as those of Table 3.2 are marginally useful mainly as a check on the tanks' theoretical capability.

WATER QUALITY AND HEALTH

A major advantage of rainwater collected from house roofs is that it is usually much cleaner than water from other sources (apart from boreholes and springs), and thus may offer a considerable advantage if reserved for drinking and cooking. However, it should not be assumed that water from roofs is totally free from contamination. Birds, small animals and wind-blown dirt may all contribute some pollution. Moreover, the water is usually lacking in mineral salts (including fluorides and calcium salts) whose presence in other water supplies is regarded as beneficial in appropriate proportions.

Wherever water quality tests have been carried out, some bacteriological contamination of water from roofs has been found. Often it is very slight, but one outbreak of diarrhoea on a Caribbean island was traced to bird excreta on a roof. On Belau, a Pacific island, water from 60 per cent of roofs was free of contamination, but samples from 25 per cent showed high total counts of coliform bacteria, and included some faecal coliforms (Romeo 1982). Experience in Bermuda seems to reflect a more consistently high rainwater quality, with no faecal coliforms detected and a maximum of 2 or 3 total coliforms per 100ml (Waller 1982).

Such findings may not always be very significant because conditions in the storage tank or cistern are more critical than conditions on the roof. A cistern formed by excavation below ground level, and any tank without a cover , is very much at risk. On the other hand, if a tank is completely covered, and if organic debris is prevented from entering with the water by means of a suitable strainer or filter, any bacteria or parasites carried by water flowing into the tank will tend to die off. Thus water drawn from tanks several days after the last rainfall will usually be of better bacteriological quality than the fresh rainwater.

When rain falls after a long dry period, water collected from a roof may carry noticeable amounts of debris arising from dust and leaves which have accumulated on the roofs and in gutters. Many authorities therefore recommended that water running off the roof during the first 10-20 minutes of a storm should be discarded, and many devices have been suggested for diverting this initial 'foul flush' away from storage tanks. The simplest method is to have flexible joints in the pipes conveying water from gutters to tanks (Fig. 3.4), or gadgets which automatically hold back or discard a certain volume of water before allowing any to enter the tank have also been designed. The simplest is a 10-litre receptacle through which rainwater passes on its way to the tank (Fig. 3.5).

Few devices for foul flush rejection seem likely to be used or maintained consistently in village conditions, so it is worth noticing that although they are valuable in preventing visible debris from entering a tank, such devices have less effect on bacteriological pollution. Contrary to former belief,

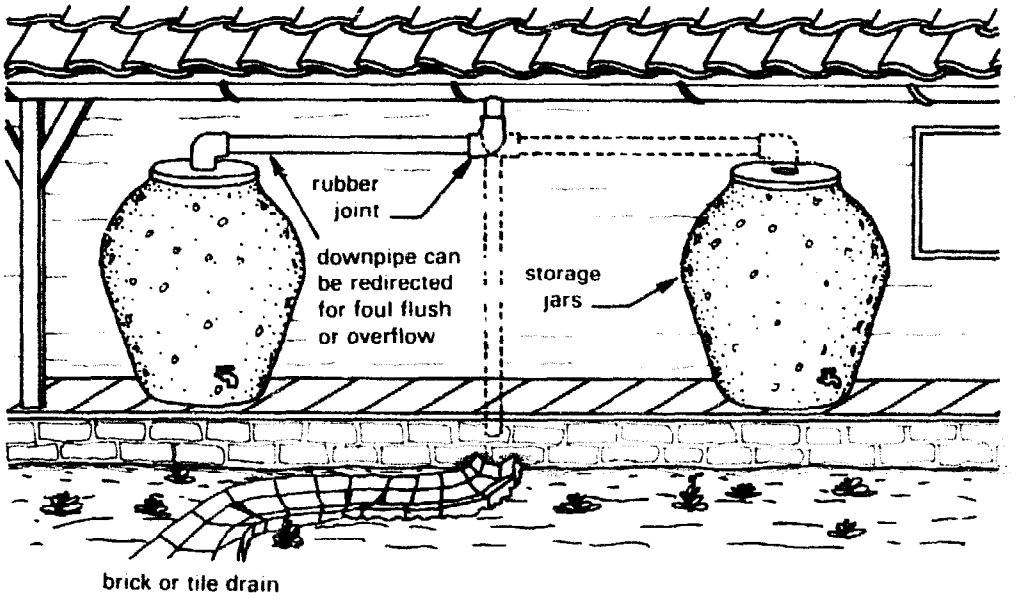

Fig. 3.4 Jointed downpipes enable the first flush of rainwater after a long dry period to be diverted away from storage jars. (Institute for Rural Water 1982)

recent tests suggest that bacteria are likely to be present in runoff from a roof throughout a storm, increasing as rainfall intensity increases (Wheeler and Lloyd 1983). Thus the omission of a foul flush deflector may not be crucial. However, the material which would then be washed into the tank may affect the appearance and taste of the water; it will mean that the tank needs to be cleaned out more often; and more importantly, there is every chance that organic debris in the tank will enable bacteria and other organisms to survive longer, with the result that the usual improvement in water quality during a period of storage does not occur. Thus it is still strongly advised that for any catchment surface, the first 15-20 minutes of rain should be diverted away from drinking water tanks if at all possible, perhaps using jointed downpipes as in Figure 3.4.

However, in view of the difficulties which may make the rejection of first flush water impracticable, it is important to note the more basic precautions for ensuring that rainwater is of good quality. The roof and gutters should be accessible for cleaning, which should be done at the beginning of every rainy season, and their regular maintenance is also very important. On Bermuda, roofs are whitewashed for greater cleanliness. There should also be some form of coarse screening between guttering and the delivery pipe, and a finer screen or filter at the point where water enters the tank. Even with the simplest screens, though, maintenance in village conditions is poor (Latham 1984b). Another maintenance task which should be carried out annually or when the tank becomes empty is to clean it out, removing sediments and if possible disinfecting it. If water quality is still regarded as suspect it may be necessary to advise filtering water through a ceramic filter or boiling it before drinking. The worst fouling of roofs by birds and insects as well as by debris occurs under trees, and roofs in such

situations ought not to be used for rainwater collection if alternatives exist.

Ground surface catchments and excavated tanks are particularly vulnerable to contamination. In Botswana, excavated tanks covered with corrugated metal roofs become a habitat for frogs and other small animals, and the water shows a high level of bacteriological pollution. In Swaziland, excavated tanks were built in the early 1970s whose storage space was totally enclosed, and into which water flowed via a layer of sand. Water from these was of consistently high quality, though a frog gained access to the pump shaft of one (Farrar 1974).

Controversy sometimes arises as to whether rainwater tanks should be advocated for drinking water supply if freedom from contamination cannot be guaranteed. It is suggested that engineers should not advocate use of a water source from which they themselves are not prepared to drink. However, the question that might be better asked is whether the rainwater system leads to an improvement in people's livelihoods, not whether it meets some idealized standard. If the water provided is of a better standard than would otherwise be used, or if it is of the same standard but more readily available, livelihoods may benefit. What one needs to beware of are systems which look good to the engineer but which would actually tend to erode livelihoods, either because the costs involved are too great, or even because health hazards are worsened. The greatest danger of the latter arises where tanks and gutters become mosquito breeding sites. Thus in areas where malaria is endemic, the most important health precautions are not those aimed at preventing contamination, but precautions against mosquitoes. These include ensuring that gutters do not contain depressions in which water is left standing, and fitting a fine gauze on all openings to the tank, such as overflow pipes. Maintenance is again crucial. A report from Indonesia notes that gauze on overflow pipes had been damaged, perhaps by children, and suggested that it should be fitted on the inside of the opening where it would be less vulnerable (Latham 1984b).

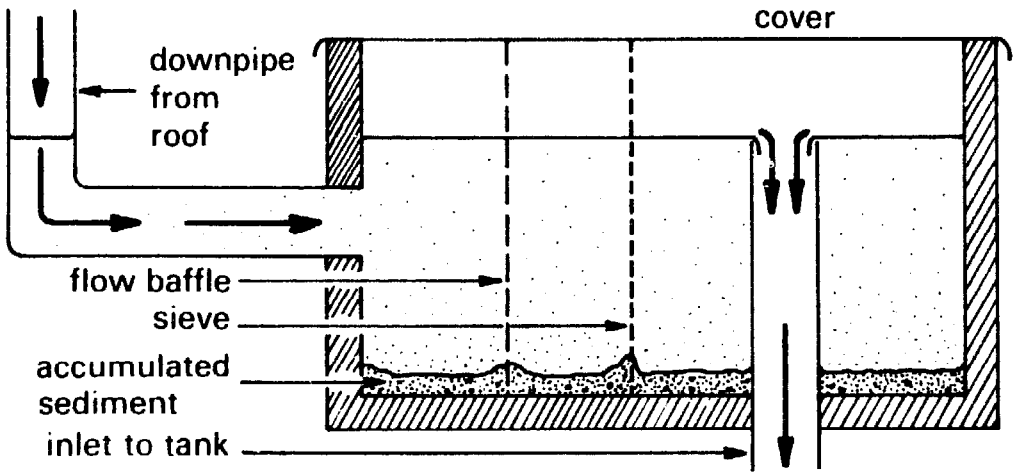

Fig. 3.5 Baffle tank designed to hold back sediments, leaves and other debris before rainwater from a roof enters storage. (UNEP 1983)

It is of course true that ordinary people who are not biochemists judge the purity of water by taste, colour and smell — and women in South India judge it by how long pulses take to cook (Chauhan 1983). One should therefore not be surprised if in some countries, such as Bangladesh (Ahmed 1972) people prefer dirty pond water to tubewell water because of the taste. Similarly, a report from Indonesia mentions that mud is sometimes mixed with rainwater to give it the required local flavour (Soedjarwo 1981).

Following the injunction that engineers drink the water they expect others to imbibe, one of the present authors spent a week in Swaziland drinking water (after boiling) obtained at dams where cattle had stirred up a heavy suspension of colloidal clay. This gave the water a sickly-sweet taste, acceptable to the author in soup and coffee but not in tea, and it was easy to appreciate that people accustomed to this would find pure water excessively bland. Technical and social assessments in a village should therefore include assessment of water quality from existing sources and enquire which sources people prefer. Effective health education may, of course, persuade people to accept a blander taste, but it may also be worth experimenting with recipes in which rainwater confers better flavours. During surveys, enquiry might also be made about traditional methods for improving water quality. In parts of South America, crushed bark from certain trees is added to water. Elsewhere, various seeds are used, or curd from sour milk, and in parts of India, leaves from the neem tree. The use of such substances with rainwater could be helpful in providing a familiar taste.

STRATEGIES FOR DATA COLLECTION

This discussion of two specialist areas, hydrology and health, has shown that the information required for planning a rainwater project does not only consist of data which need specialist expertise for their collection and analysis, but also involves much more general information, for example about existing water sources and how they are used, or local experience of the effects of drought. Such information, often looked down on as 'anecdotal', may be useful for filling gaps in the technical data, and in showing whether rainwater collection can make a contribution to improved livelihoods, and if so, for whom and in what form.

In order to collect this information, people who speak the local language need to visit villages where projects are envisaged and carry out surveys like the social and technical assessments discussed earlier. The individuals who do this may be community workers or health workers already employed in the area; they may be agricultural extension workers, and they may include residents elected by the villages concerned. In a large programme, community workers may need to carry out surveys in a considerable number of villages, and any local residents who take part will

clearly need careful briefing. Thus it is desirable to provide some formal training for the survey teams, and the WASH *Training Guide* quoted earlier envisages an intensive course lasting a week (5½ working days).

During such a course the community workers (as we shall now describe them), need to be told not only why the information is needed, but also how to collect it systematically. To this end, it may be useful to provide them with *checklists* of points which can be learned by *observation* (for example, concerning building materials, roof types, and roofs overhung by trees) at the same time, giving them *questionnaires* covering points about which local people should be asked. Such checklists and questionnaires might be compiled in a preliminary way by picking out the main points made in each of the previous sections of this chapter, though they will also need to be refined in the light of local experience. The important point to remember is that the technical assessment should principally be seeking answers to the question 'is a rainwater project technically feasible in this village?' Meanwhile, the social assessment seeks to know whether there would be active support for such a project from the people. The relationship of these questions to the later survey of skills, materials and resources, is illustrated by a 'decision tree' in Figure 3.6.

One important point about decision trees is that they pose questions which must be answered 'yes' or 'no', and so therefore the decision about whether a rainwater project should go ahead can be answered in the negative. It is important that surveys are carried out in a way which leaves this option open. Where advocates of rainwater collection are over-keen on their favoured technology, there is a danger that they will compile questionnaires on the assumption that the project will go ahead and only its details can be modified. As Chauhan (1983) puts it, surveys of this kind tend to be 'treated like market research for a new consumer product. If the community is indifferent to the product, it is assumed that the answer is to advertise the benefits more widely and educate the 'target population' that this is what they *should* want. The designers of programmes and technology will rarely admit that the "products" themselves may be inappropriate.'

To guard against this danger, it first needs to be recognized that although the use of checklists and questionnaires is almost inevitable if information is to be systematically obtained, over-use of them can have the effect of excluding real dialogue with the local people and preventing them from 'participating' in anything but a formal sense. A questionnaire may allow us to find out what we want to know, but nothing more — it will tend to exclude ideas and information volunteered by local people.

It is therefore strongly advised that questionnaires used when interviewing householders should be brief and confined to essentials. The interview should be open-ended, and the community workers should be prepared to listen for perspectives on local problems which the project organizers may not have considered. Often such insights are best generated if people are

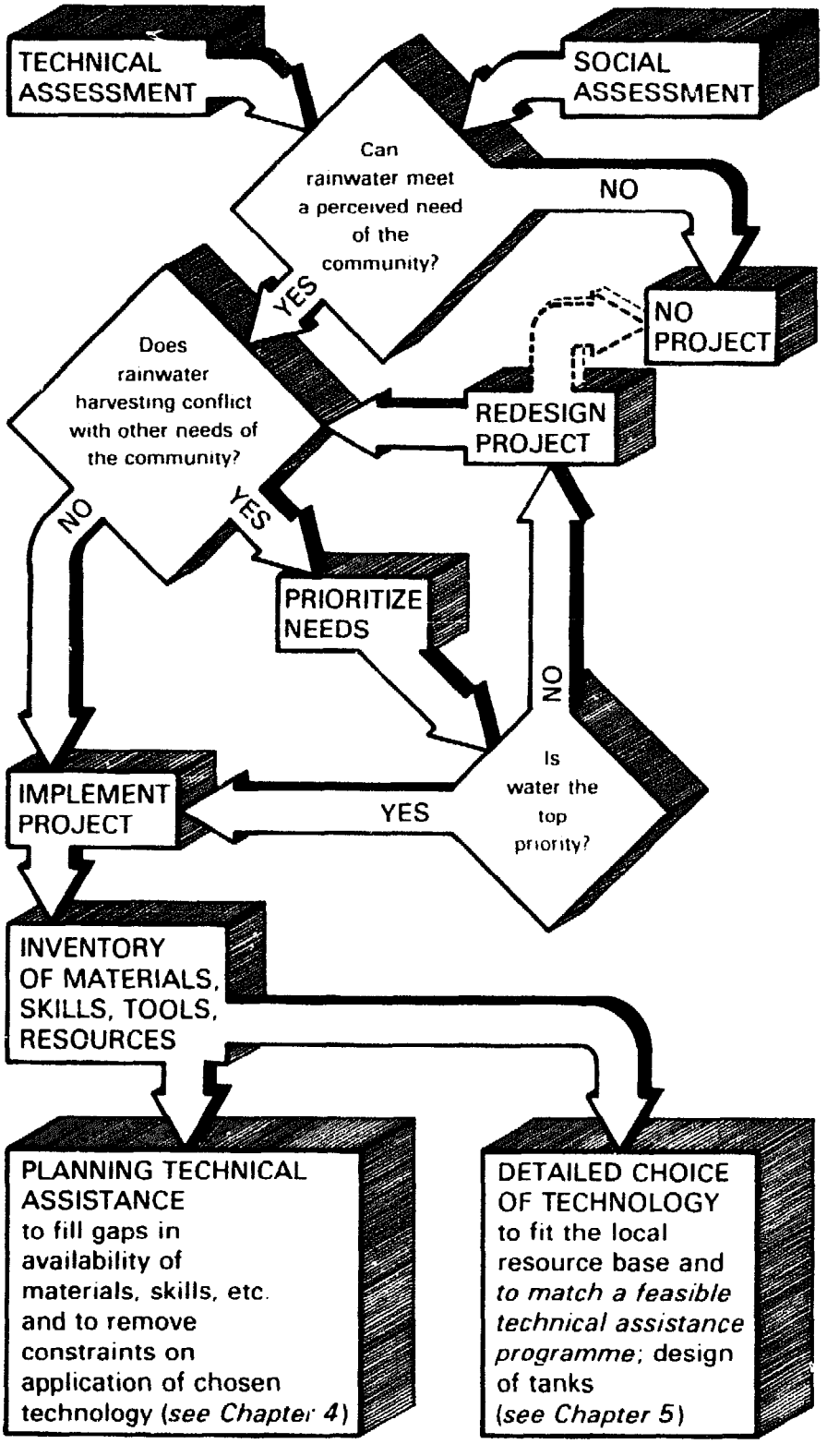

Fig. 3.6 'Decision tree' representing successive phases in the planning of a village rainwater collection project.

interviewed in groups rather than individually. For example, a group of older and younger women with a female interviewer may express views which a mixed group would not, and the age difference could stimulate comparisons which would show which recent changes in housing or water supplies are valued as 'improvements'. It is particularly important to obtain women's views, as it is, of course, women who usually have the greater responsibility for domestic water use — and often for home improvements and gardens also. Apart from informal interviews with groups of neighbours, or members of extended families, discussion with people attending village gatherings may be useful, as may formal meetings and committees convened specifically to discuss water supplies.

One of the two Indonesian rainwater programmes mentioned earlier in this chapter (e.g. in Table 3.2) illustrates many of these points very effectively. It is run by a local agency, Yayasan Dian Desa (YDD) in the Yogyakarta area of Java. Villages which seem likely candidates for projects are chosen by YDD from among the poorer communities in a district where conventional water sources are unreliable and inadequate due to the nature of the underlying rocks. Many of the villages are critically short of water at times.

The first step taken in any individual community is to visit it on an evening when people are meeting in the headman's house (maybe to watch a favourite television programme). Several YDD people will go to these sessions, just to meet people, talk about family affairs, and to introduce themselves. Eventually, conversation turns to water, and when tea is made, the YDD people produce their own containers of fresh water. Its taste is quite different from that of water from local ponds, and villagers are invited to try it. Further meetings are arranged where the benefits of good water and the disadvantages of local water are discussed more fully and more information is obtained from the villagers about local needs. Finally the YDD staff mention the possibility of building rainwater tanks. The basic technology is carefully explained and the demands which would be made of villagers during construction are discussed. If people accept the idea, the next step is the choice by the village committee of a local person (known as a 'cadre') to be trained in the construction technique.

Building the tanks presents few problems once the procedure has been discussed in this way. The villagers do the work themselves with the help of the cadre, and are asked to provide the bamboo required. Indeed, one advantage of using bamboo reinforcement in the tanks is that it increases the villagers' input and makes the tanks less of a gift. Where people can afford it, they are asked to pay for the other materials also — many are too poor. All groups, however, make a sufficiently large contribution to feel that the tanks belong to them and, as a result, maintenance is generally good.

TAKING TIME

If building tanks in Indonesia presents few difficulties, effective use of the water they contain seems more problematic. It has been found that for as much as a year after they acquire a tank, some householders are doubtful about the water it provides. They are unaccustomed to its taste, and are unfamiliar with water that looks so clear. Some fear that chemicals in the tank (perhaps detergents) are the cause of its strange appearance. A good deal of reassurance is required about this, and YDD staff make frequent informal visits on their way to other projects in the area. In addition, they organize educational activities aimed at ensuring prudent use of the water, care of the tanks, and confidence that the water is safe. The taste problem takes a long time to overcome, but easy availability of the water helps persuade owners to use it for drinking and cooking.

Latham (1984b) comments that: 'All this is time-consuming but YDD see it as a necessary part of introducing the tanks', and as a major factor making for the sucess of their programme. Provision of water is regarded as a starting point for village development, and YDD link it to additional programmes of animal and crop improvement. Many hundreds of tanks have been built, but more important than numbers is the willingness of YDD personnel to spend time in the villages alongside the people concerned listening to local views and working out solutions to water supply problems.

In other countries, also, and in other aspects of rural development, it is noticeable that the most effective fieldworkers and agencies are usually those which are prepared to spend time with the people they attempt to help. In Kenya, one project which was building excavated rainwater-tanks and latrines grew up through a long period during which a lone fieldworker got to know local families, built up 'an accurate picture of people's problems', and gave encouragement to 'decision-making mechanisms' based on village meetings. Indeed, so much time was spent on these activities that funds from America were in danger of being cut off due to 'lack of results'. Commenting on this, Batchelor (1985) notes that although most agencies realise that a period of assessment and 'familiarization' is required in any project, 'pressure from performance-orientated donors often cuts this short or . . . at least combines it with a prototype project'.

Occasionally, programmes seem to run smoothly without the preliminaries advocated here, but, when that occurs it is usually because people have been prepared for the new technology by other experiences. Subsequent chapters discuss a rainwater tank programme in part of Thailand where some people were already using large jars to collect water from their roofs. Thus the taste of the water and the method of collecting it did not seem so alien as it did in the YDD region. However, one result of there being shorter periods of assessment and discussion is that the Thai

programme is now criticized for being too construction-orientated and for paying too little attention to maintenance and local-level organization (Fricke 1982).

All these issues do not just apply to tanks collecting runoff from roofs, but also to other forms of rainwater collection. Obviously, though, social and technical assessments and subsequent discussion are very different in detail if a runoff farming project or a communal effect to exploit a rock catchment is planned — or if nomadic herdsmen are being approached about renovating cisterns or building new livestock watering points. However, it has not been possible to describe a rock catchment project here, nor any programme concerned with pastoralists, largely because of the lack of documentation. In the latter case this is because the orientation of the book is towards the work of non-government organizations, most of which have left the problems of pastoralists to government.

Therefore, although provision of water for livestock in arid and semi-arid areas is potentially one of the most appropriate of all applications of rainwater collection, little more will be said about it here. Instead, the remainder of the book will discuss firstly, rainwater tanks used to provide domestic water, and then later, attempts to apply the same concepts about the organization of programmes to some recent work on runoff farming.

4. RAINWATER TANKS AND TECHNICAL ASSISTANCE

TECHNICAL ASSISTANCE PACKAGES

Development workers have frequently been perplexed at the slow rate with which applications of rainwater technologies have spread. In one village in Lesotho, 63 per cent of houses have iron roofs, but less than 2 per cent have gutters (Feacham *et al.* 1978). In Ghana, a similar reluctance of house-owners with metal roofs to install gutters has also been noticed (Parker 1973). In both countries, women face long walks to fetch water, and people appreciate the value of rainwater and place containers under their eaves when it rains. So their lack of interest in gutters and permanent storage containers is not due to any ignorance of the value of rainwater.

Even where organized programmes have built significant numbers of roof catchment tanks within limited districts, one can rarely report that the techniques they introduce are being actively replicated in surrounding areas. Nor can one often say that local builders, craftsmen or businessmen have copied the programme's construction methods and are promoting the techniques on their own account.

Some general reasons for this disappointing situation have already been discussed, and others, some of them specific to particular areas, may be identified during social assessments. In both Lesotho and Ghana, one constraint could be that the installation of gutters would be a job for the man of the household, and it is usually the women who carry water and who put out small containers to collect rainwater during storms. If rainwater tanks were promoted as improvements to the appearance and structure of a house rather than simply as a means of saving time spent carrying water, they might appeal more strongly to the men. Thus rainwater technologies may fail to spread because they are not perceived in the same way by all villagers, and water supply experts rarely take enough trouble to find out how different groups do perceive them.

Another constraint, however, is that in the past there has been no real concept of technical assistance at village level. If Lesotho villagers can obtain gutters, downpipes and brackets as cheaply as Feacham *et al* claim, and money is not an obstacle, do the villagers actually have the tools necessary to fix them? If it is the women who would have to do the fixing

while men are absent in urban employment, do they have the skill, and if not, is anyone trying to assist them?

One mistake made in the early days of the Appropriate Technology movement was to think that small-scale technologies could be disseminated around the world merely by publishing relevant information and making it widely available. Clearly, the availability of information is essential, and we should take a comprehensive view of how it may be spread — through advertising, the printed word, the broadcast media, talks and demonstrations, advisory services and extension work. But it is wrong to assume that if a book or even a demonstration project can show that a new technique is of potential benefit to people, that technique will be quickly taken up by them without further promotion. As Whitcombe (1983) puts it, the replication of any 'appropriate' technology is a highly complex process, and few agencies have been able to develop a 'methodology to go beyond prototype development'. If a 'truly appropriate technology' is developed its originators often assume that 'it will sell itself'.

Tanks and large jars for collecting rainwater from roofs do sell themselves in a few places, and there are also one or two agencies which have reasonably effective methodologies for replication. Table 4.1 lists examples of such agencies, and by implication, suggests that their success may be attributable to the comprehensiveness of their technical assistance activities within village communitites. None of them limits itself to demonstration projects, or to providing information via educational or extension work.

Compared with the examples in Table 4.1, the technical assistance methodologies of many agencies tend to be deficient in some of the following ways:

- fully comprehensive packages of help with information, skills, materials and money are rarely developed;
- there is a lack of commercial involvement, e.g. with builders interested in constructing rainwater tanks as a business venture (in contrast, see Layton 1984);
- there is inflexibility and lack of dialogue with potential users of rainwater because of over-commitment to one specific technique;
- there may not be sufficient attention to local organization, especially in relation to maintenance;
- follow-up and monitoring of completed tanks or other works may be neglected.

It was suggested in the previous chapter that village surveys could culminate in the compilation of an inventory of local materials, tools, skills and resources (Fig. 3.6). This inventory can be helpful in identifying technology which matches the resources of the village; it is also a starting point for developing the necessary technical assistance package. However

Table 4.1 Technical assistance in four roof catchment programmes

COUNTRY and area	*ZIMBABWE* Bulawayo area	*KENYA* Karai location, Kiambu	*INDONESIA* Gunung Kidul near Yogyakarta	*THAILAND* Khon Kaen Province
AGENCY and source	Friends' Training Centre (Hlekweni 1975)	UNICEF (Molvaer 1982)	YDD* (Winarto 1981; Latham 1984)	CBATDS† (Fricke 1982; Power 1983)
OPTIONS OFFERED TO VILLAGERS				
rainwater tanks	ferro-cement 9m³ (later brick)	Ghala tanks 1.1, 2.2 and 4.5m³	ferro-cement 9m³; bamboo cement 4.5m³	bamboo concrete, 6–11m³
roofing materials	experimental	NO	NO	NO
guttering	metal type supplied	n.d.‡	metal or bamboo	n.d.
complementary programmes	agricultural	cooking stoves	agricultural	varied: family planning
COMPONENTS OF TECHNICAL ASSISTANCE PACKAGES				
training specialist craftsmen	YES	YES	NO	NO
or community-worker technicians	NO	NO	'cadres'	'village technicians'
bulk purchase & transport of materials	YES	YES	YES	YES
loan of formwork	YES	formwork not needed	formwork of local material	YES
financial help: payment by instalments	NO	n.d.	YES	YES
subsidies	YES	YES	YES	slight
printed leaflets, instructions on construction	YES	n.d.	YES	YES
follow up work on maintenance, health education	slight	YES	strongly developed	YES

* *YDD is the local Indonesian agency Yayasan Dian Desa.*

† *CBATDS is the Community Based Appropriate Technology and Development Service of the Thai agency PDA*

‡ *n.d. denotes no data available*

good the match between the chosen technology and local resources, there will always be some constraints on the use of that technology, such as a lack of certain skills, or the high costs of cement and transport of materials, or the need for a particular tool. The aim of technical assistance is of course to reduce the effect of these constraints by the various means listed in Table 4.1. Training is probably most universally important, but bulk purchases and transport of materials aimed at reducing costs are often necessary, as is the loan of tools, or some sort of financial help for householders acquiring rainwater tanks. Helping people to organize themselves for carrying out the work and perhaps for following it with other changes in village conditions is also important, though it is too big an issue to analyse within the confines of Table 4.1 (however, for a comparison see Table 7.2).

The cost of rainwater systems may seem to demand particular attention from those who plan technical assistance activities. Very small rainwater tanks or jars will often be used because that is all that people can afford, and sometimes shared tanks are proposed in order to reduce the cost falling on each household. However, a good deal can be learned from regions where significant numbers of households are prosperous enough to afford the full cost of individually owned roof catchment-tanks. In the Khon Kaen province of Thailand, for example, many people have well-constructed timber houses built on platforms (Fig. 4.1) with corrugated iron roofs. They already collect rainwater, and even in the poor villages, 30 per cent of households have some guttering. Elsewhere, as many as 60 per cent do. Roof areas are large, often exceeding $100m^2$, though guttering may only be installed on half the area (Nopmongcol *et al.* 1981). Hemispherical ferrocement jars up to $2m^3$ in capacity are available commercially and are purchased by some households.

Such an area is clearly ripe for a programme aiming to build larger tanks, and one need not be too surprised at the success of the agency represented in Table 4.1 which has completed 6,500 tanks in four years (Nation 1984). The tanks range in size up to $11.3m^3$ but are typically $9.4m^3$; they are made of bamboo-reinforced concrete.

With housing standards in this area so high, it may be appropriate to draw comparisons with technical assistance offered in a much more prosperous country. The South Australian government initiated a 'rainwater tank promotion campaign' in the Adelaide area during 1981, based mainly on advertising and the provision of information. According to Hoey and West (1982), this led to many new tanks being purchased by householders. The main features of the scheme were:

- a booklet written for householders giving advice about the installation and maintenance of gutters and tanks;
- an advisory service (by telephone);

Fig. 4.1 Raised wooden platform houses with corrugated iron roofs in Khon Kaen Province, Thailand. Gutters are usually attached to only one slope of the roofs. The houses have bamboo-reinforced concrete rainwater tanks such as those built within the programme described in the text. See also Table 4.1. This illustration is from a booklet distributed in Thailand by UNICEF. (UNICEF and Fricke 1982)

- a major newspaper publicity campaign which stimulated advertising by local manufacturers of tanks; but
- no financial incentives or subsidies.

In poorer communities, financial help is often essential and advisory services need to be more personal and practical. But in countries where better-off families purchase rainwater tanks on their own initiative, such as Thailand and parts of Kenya, and where tanks are available on the market, local versions of this sort of campaign could be very effective. They could lead to existing tanks being better used as well as new ones being installed, and could encourage better maintenance. One should not be squeamish about 'social marketing' of this kind. It can contribute to development by

encouraging the constructive use of private resources and by reducing demand on stretched public water supplies. It can also confer 'status' and improve the 'image' of the technology concerned, which is a more important factor in arousing enthusiasm than most health educators and extension workers care to admit. Moreover, such campaigns aimed at better-off groups may indirectly widen political support for subsidized projects in poorer areas.

In Thailand, although the prior existence of gutters and some small rainwater jars made it easy to arouse interest in the larger tanks, a considerable amount of technical assistance has still been necessary. Householders work together in loosely organized mutual-help groups with 10 or 15 people in each, but they still need help from a 'village technician'. This is a local person recruited to attend special training sessions. Technical assistance also includes the loan of metal formwork and tools, bulk purchases of cement, and a scheme whereby householders can pay for the materials by instalments. The initial payment is equivalent to US$22, and subsequent monthly payments are in the range $6 to $10. The option of payment by instalments has been crucial. The total cost to a householder of a large (11.3m^3) tank was $175 in 1982 when the 1.4m^3 ferrocement jar — which is all most people could otherwise afford — would have a market price of only $25 (Fricke 1982).

Taking a general view of costs and methods of payment, strategies likely to be helpful include use of low-cost, local materials wherever possible; bulk purchasing (e.g. of cement) as a means of negotiating lower prices; credit or saving schemes to make payment easier; and of course, outright subsidies.

Small mutual-help groups may have a part to play in enabling people to cope with costs as well as in practical construction. For example, savings clubs oriented towards bulk purchasing have been successful in parts of Africa. They usually consist of neighbours, or groups of families with similar interests and existing ties of friendship, and they agree a common goal for which all members wish to save over a specified period of time (up to a year). Savings clubs of this type hold weekly meetings for members at which they pay a fixed contribution and have a stamp stuck on their cards. When sufficient money has been accumulated, the materials which club members have agreed to buy are purchased in bulk and shared among them. This system has been successfully used in Zambia for the purchase of corrugated iron roofing sheets for home improvements.

Such schemes work well if there is an agreed objective in which people can sustain a shared interest. The best examples have been in Zimbabwe where farming families have saved to make bulk purchases of fertilizer. With such things as rainwater tanks it is usually better if the desired improvement comes much sooner, and if the saving is done retrospectively when the benefits of the project are apparent. This is what happens in

Thailand when people pay for tanks in instalments. The scheme is made possible by the operation of a 'revolving loan fund'. Under this system, the agency responsible for the rainwater programme sets aside a fixed sum of money from which the cost of each family's tank is paid. This constitutes a loan to the family, and as they pay back the money month by month, the fund is replenished and new tanks can be financed for other households. People should be encouraged to regard loan funds as money belonging to the community as a whole and not to an impersonal body such as a bank. They will then be aware that delaying repayment of their loan will postpone the day when a neighbour can borrow money for his own rainwater system.

TRAINING VILLAGERS AND CRAFTSMEN

When householders acquire rainwater tanks on their own initiative, this is most often by purchasing them ready-made from a factory (as is possible with small cement mortar jars in Thailand). Galvanized corrugated iron tanks are available for purchase ready-made in many countries in a range of sizes up to about $10m^3$.

Few organized programmes which promote rainwater collection use factory-made tanks, often because of a self-help emphasis within the village, but also because of transport difficulties and the high cost of these sorts of tanks — especially the metal ones. However, since tank construction is a skilled task, any self-help effort must involve specially trained individuals, even if most of the more basic tasks are left to the householders themselves. Indeed, the provision of skilled help needs to be linked in a co-ordinated way to the help given with supplies of materials (such as cement), and the help, just discussed, with payment. As we have seen, village-level technical assistance must go far beyond providing information and education if it is to cater for the needs of low-income communities. Assistance with *skills*, *supplies* and *payment* are three of its most important practical ingredients, and there is also the question of organization.

Several approaches to the development of necessary skills have been used in rainwater projects. Training may be offered to village craftsmen (as in Kenya), or to community workers or individuals chosen at village meetings who are given special training as 'village technicians' (in Thailand) or construction 'cadres' (Indonesia).

There is a sharp distinction to be noticed here between the 'community-worker technicians' and the specialist craftsman (Table 4.1). If a village technician is thought of as a community worker, his role will be seen as assisting and supervising householders who build their own tanks. In Thailand, where groups of householders help each other, a group usually finds that after relying heavily on the village technician in building their first one or two tanks, they are able to construct others without further help. Thus skills become widely diffused in the village. By contrast, the

village craftsmen trained in Kenya carry out the whole construction task for householders. They do not assist others to acquire building skills but function as specialists, potentially able to work as commercial tank-building contractors.

The WASH *Training Guide* (see Chapter 3) envisages that the skills of tank-building should be taught to 'masons' at the same time as community social workers are trained to carry out surveys, social assessments and related educational work. This implies a non-commercial view of the mason's role, and aims to provide a basis for co-operation between masons and community workers. If community workers are to explain the rainwater tanks adequately to people, they must know how they are built. At the same time, masons may co-operate in much of the survey work, particularly in technical assessments and in compiling inventories of materials and resources. The WASH *Guide* assumes that masons can be trained in the same one-week course as the community workers, if it is organized with separate sessions for practical work. However, time-tabling tank construction exercises in such a course may be difficult because of the time required for cement or concrete to set. Layton (1984) is probably more realistic when he describes three-week courses for training young men to build ferrocement tanks on a commercial basis in the North Solomons (Papua New Guinea). Business development officers take part in the training in an effort to teach entrepreneurial as well as technical skills.

Much pioneer work on rainwater tanks has taken place in Zimbabwe under the aegis both of Young Farmers' Clubs and of church organizations. One starting point was the high costs and corrosion problems associated with the galvanized iron rainwater tanks which were already widely used in Zimbabwe. Efforts to produce cheaper and more durable tanks mostly involved ferrocement construction.

The Young Farmers' groups put their main efforts into large circular tanks with domed tops. Some were built to collect water from roofs and rock catchments. Others, constructed in exactly the same way, were built in excavations in order to collect water from ground catchments with smooth, cemented surfaces (Fig. 4.2) and with chicken wire reinforcement (e.g. at Rowa).

By contrast, a church group based at Hlekweni, near Bulawayo in the south-west of Zimbabwe, concentrated on a smaller ferrocement tank for collecting water from roofs. Its size was standardized (at $9m^3$) so that many tanks could be built by repeatedly using the formwork. The method of construction is explained by Watt (1978) and more briefly in Box 4.1. Of particular interest here is the technical assistance which enabled householders to acquire the tanks, and the distinctive approach to the transfer of skills which was developed. Whilst individuals were trained as specialist craftsmen, they were encouraged to work *with* householders, and

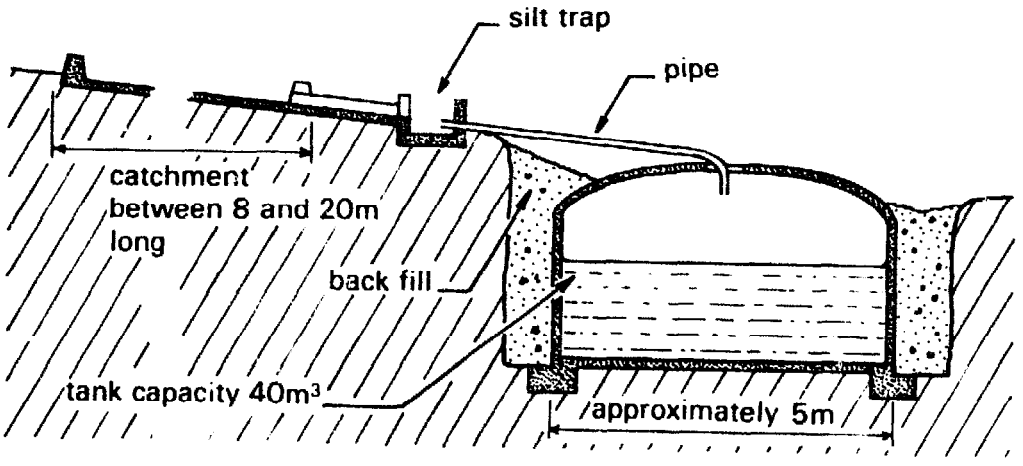

Fig. 4.2 A ferrocement rainwater tank in Zimbabwe built in an excavation so as to collect water from a smooth, cemented catchment. Withdrawal of water from the tank is by means of a hand-pump (not shown). A tank of this size (40m³) would normally require a catchment measuring about 20m × 10m, i.e. larger than the example shown. (Hall 1975; see also Watt 1978)

the latter for their part were asked to provide sand for mixing the cement plaster, and to contribute their labour where unskilled work was required. This helped to hold down costs, but also meant that householders learned more about tank construction on the job, and thus might be better able to maintain their tanks subsequently.

The technical assistance package also involved a subsidy on costs and the supply of metal guttering (which was specially made at Hlekweni) as well as the loan of formwork and tools. At first, some tanks were built without payment from the householder, the cost being born by drought relief funds. However, villagers were sceptical, expecting that money would be demanded at some later stage. From 1970, it was decided to charge a nominal amount (equivalent to US$12) and the tanks were then in such demand that four builders trained at the centre were kept constantly busy. But it was noticed that only the better-off families with good houses were acquiring the tanks, which could not easily be fitted to traditional thatched houses with curving eaves, so it was decided to phase out the subsidy. There were hopes that it would be possible for the builders to continue work on a commercial basis. However, although the tanks were cheaper than the competing galvanized iron ones, they were still too costly for most villagers. Thus the effect of rising cement prices and the withdrawal of subsidy was that fewer tanks were built.*

Reports from the area ten years later suggest that many of these tanks are still in use. However, since 1977, Hlekweni has been building rainwater

*The eventual record was (Hlekweni 1975): 1971: 73 tanks at nominal charge equivalent to US$12; 1972: 59 tanks costing householders $30 each; 1973: 55 tanks at $30; 1974: 12 tanks at full commercial price, i.e. about US$75 (Keller, 1982, quotes material costs as $62.50 in 1973, and via Watt, 1978, quotes $150 for 1982 price levels).

Box 4.1 Procedure for building a 9m³ tank of the type developed at the Friends' Training Centre, Hlekweni, Zimbabwe. (Hlekweni, 1975; Watt, 1978)

*1. **The formwork*** needed to build this tank can be used repeatedly for construction of many tanks. It is made from sheets of corrugated iron curved to a radius of 1.25m and is in four sections, each quarter of a circle in plan, and equal to the full height of the tank. Each section has angle iron riveted to the vertical edges. When the formwork is assembled, the angle iron flanges face up to one another and have holes which allow them to be bolted together through a wooden wedge (Diagram 1).

*2. **A circular foundation*** 2.8m in diameter is dug out on site and a concrete floor 80mm thick is laid. A 20mm bore pipe bent to a U-curve is concreted into the floor in such a position that one end will project upwards in the finished tank 80mm above the floor and the other end will be outside and can be fitted with a tap.

*3. **Erection of the formwork*** follows when the floor slab has hardened. After oiling the formwork, wire netting of 50mm mesh is wrapped round it and tucked under it at the bottom (Diagram 2). Then a length of 2.5mm plain wire is pulled round each corrugation and the ends are twisted together until the wire is taut. (Two wires are used in the four bottom corrugations and in the topmost one.)

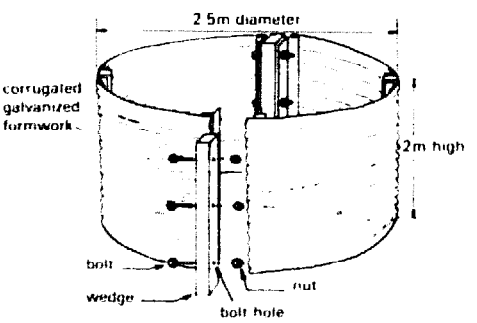

Diagram 1

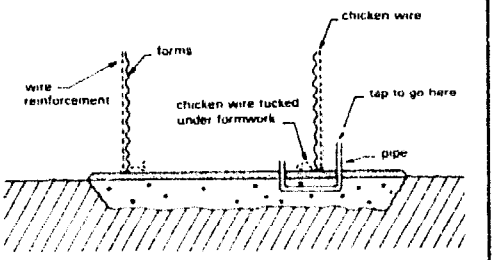

Diagram 2

*4. **Plastering of the outside*** then begins, first with a thin layer of 1:3 cement/sand, then two hours later with a second layer to a depth of 15mm. This should be finished smooth with a float, entirely hiding the corrugations.

*5. **The formwork is unbolted*** some 48 hours after the second plastering. Ladders used for climbing into the tank are leaned against the house, not against the incomplete tank. An overflow pipe with mosquito screen on its inner end is built into the top of the tank wall. Then a 50mm layer of concrete is laid on the floor.

*6. **The inside walls*** are plastered once the floor has set. Two layers of 1:3 cement/sand are applied to fill up the corrugations. The inside walls and floor are finished off with a thick cement slurry to render the tank water-tight.

*7. **Curing***. Water to a depth of 50mm is poured in and the walls are periodically moistened or otherwise kept wet for seven days.

tanks of brick with wire reinforcement and cement linings, because the availability of broken bricks (or bricks made on site) makes these cheaper (Gould 1983).

Experiences of this sort show that the design of a rainwater tank is not merely an abstract problem in engineering, but is crucially related to the type of technical assistance that can be organized, and the sort of materials and other resources which are available in the locality. (This is why technical assistance has been discussed in this book before the chapter on tank design.) Both the planning of technical assistance and the design of hardware depend on establishing what materials, labour, and financial contribution it is reasonable to ask householders to provide. Careful thought will also be necessary about the provision of guttering and downpipes, although this is a striking omission in many reports on rainwater collection programmes. It may be that guttering is considered to be simpler than tank construction and is taken for granted – which presumably means that householders must supply their own. But for some people installation of a gutter may seem a formidable task, and it has sometimes been said that inadequate guttering is a major constraint, discouraging some householders from acquiring tanks at all.

In places where satisfactory rainwater jars or tanks are available on the market, technical assistance should perhaps aim mainly to provide guttering and offer advice as to which type of tank to buy, with possibly some help from a revolving loan fund to pay for it. Some programmes may make their task over-complicated by concentrating too much effort on building tanks independently of the market. Their task might be simpler if they exploited the existence of the commercially available tanks and concentrated on the constraints which prevent low-income groups from acquiring them.

SELF-SUSTAINING PROGRAMMES

It should be the ultimate aim of every programme that its work will become self-sustaining, and independent of external subsidy. This means that tank construction must be incorporated into the normal production system of the country, whatever that might be — individual craftsmen with their own businesses, larger commercial organizations, local collectives or publicly-owned factories. In many countries, the long-term future of household rainwater collection will depend on what the individual family can obtain on the market, and on what craftsmen and commercial outlets have to offer. The public service traditions of many aid agencies make them reluctant either to form a relationship with local commerce or to teach entrepreneurial skills to the craftsmen they train. Yet these things may be necessary if rainwater techniques are to take root and continue to develop in a region. Indeed, it may be desirable to offer training to people who

explicitly wish to exploit the techniques for commercial profit, charging them an appropriate fee for the training. This happens in principle with the three-week courses on ferrocement tank construction in the North Solomons. However, instead of paying cash, 'would-be entrepreneurs' are merely asked to provide food and accommodation for the Training Unit staff (Layton 1984).

The Zimbabwe project referred to earlier was probably right to envisage that the builders it trained should ultimately operate independently with their own tank construction businesses, though the tanks being built proved too large and expensive for this goal to be achieved. A programme in Karai Location, Kenya, organized by UNICEF (Table 4.1) seems to have come nearer to success in this respect. One reason is probably that it started with much smaller tanks of the Ghala type (described in Box 3.1), with correspondingly lower costs.

At first, the people trained in the Ghala technique were young men who had not yet settled down. When some left the area, training was offered to established local craftsmen who already had skills as basket makers or masons. At first they were sceptical and did not think the tanks would become popular, but after a year or so, demand increased rapidly. However, UNICEF had asked that a committee of local people be set up to organize the project. Orders for tanks were channelled through the committee, so the craftsmen could not promote their business independently. Molvaer (1982) implies that this has inhibited technical initiative. Some craftsmen have thought it best to merely do 'what they were told' since that is what they were paid for. However, some owners of tanks have had ideas for improvements, and a couple of ideas did also come from craftsmen. The main change which resulted was that concerning the basket-work frame of the tanks which was not initially plastered on the outside. Tanks made this way were found not to be durable, and so now plaster is always applied both inside and outside.

This programme has developed considerable momentum and one sign that it might become self-sustaining is that craftsmen now recruit and train apprentices on their own initiative. UNICEF therefore no longer has to train each new craftsman, as they did with the first two groups of tank builders. However, 'without orders — and orders are due to acceptance by the committee — the craftsmen would go idle' (Molvaer 1982), and the idea of a craftsman himself seeking orders seems to have been very slow to develop. Householders are showing initiative in acquiring rainwater tanks, including some from outside the area officially covered by the programme, but the committee is still in charge.

Molvaer comments that a change in approach would help craftsmen to acquire 'a bit of the entrepreneurial spirit', but adds that individuals whose enterprise is encouraged ought to be those with roots in the local community. A man who has close ties with the people for whom he works is

more likely to conduct his business in a manner combining a sense of service with the necessary entrepreneurial skills. Besides these attributes, craftsmen also need to be more open to innovation. Molvaer suggests creating a 'climate of change' by disseminating information about rainwater techniques in other areas. In Karai, basket-framed Ghala tanks were adopted after some failures of *unreinforced* cement jars. But in other parts of Kenya, there have been unhappy experiences with Ghala tanks (Sinclair 1983), and despite the 300 or more built at Karai, they are still regarded as unproven. Thus a programme supported by the Diocese of Machakos encouraged a more robust technology, in *concrete ring* tanks, whilst *brick* is used by some private contractors and *metal* tanks are available commercially. In one area, some 150 *ferrocement* jars of $5m^3$ capacity have been built to a UNICEF design (Byrne 1983). It is suggested, then, that a more innovative spirit would develop if there were active exchanges of experience between the craftsmen who build these varied types of tank.

A different model of what constitutes a self-sustaining programme is needed when rainwater techniques are implemented by mutual-help groups of neighbours without the involvement of specialist craftsmen. This applies both to rainwater tank construction, and to the co-operative groups of up to forty families practising small-scale irrigation of the kind discussed in Chapter 2. Neither mutual-help groups nor community workers can usually be 'self-sustaining' in isolation. They need encouragement, advice and technical support on a continuing basis, as well as help in negotiating with commercial suppliers and government departments. Some kind of 'parent' organization for the small groups is therefore necessary, and we may consider three ways in which it may operate.

Firstly, there may be a regional or national federation of local mutual-help groups with administrative officers elected by its members. Secondly, the parent body may be officially organized. Many governments operate services to support farmers' co-operatives, and the same framework — or a more flexible version capable of dealing with smaller groups — could be adapted for this purpose.

Thirdly, however, the 'parent' role may be undertaken by a voluntary agency or non-government organization. All the examples cited so far are of this type. They include the Pani Panchayat organization linking groups of small-scale irrigators in India (Chapter 2) and the roof catchment programmes in Thailand and Indonesia (Table 4.1). For the activities of such bodies to have a permanent effect and to be self-sustaining, it is important that agencies undertaking this role have deep roots within the countries concerned. Few foreign or international agencies have a sufficiently strong commitment to very long-term support of specific projects. However, any agency of this kind could make its programmes increasingly self-sustaining by encouraging an evolution toward a federal

organization in which the mutual-help groups it supports eventually assume control and manage the parent body themselves.

One function of the parent organization will be to sustain technical assistance activities so that the replication of rainwater tanks continues. However, it must also support villages which have already built rainwater tanks but are encountering problems in their operation. An indication of what may be needed in this respect can be seen from the activities of the Indonesian agency Yayasan Dian Desa (YDD). Its routine technical assistance activities are summarized in Table 4.1. They centre on the training of village construction supervisors or 'cadres' to assist in building tanks and to act as contact persons. Some cadres are paid for special tasks but most of their work is voluntary. Materials and transport for tank building are supplied and subsidized by YDD, who also send a staff member to villages where construction is beginning. Even when tanks are completed, staff members visit villages regularly, keeping in contact with cadres, monitoring operation of the tanks, and checking whether rainwater is providing the expected benefits.

An example of the problems discussed by YDD staff during their village visits, is the cost of the ferrocement tanks — which has been a major constraint, as in Zimbabwe. Kaufman (1983) records a discussion about this which took place in a village during 1979. A village headman made the comment that when the reinforcing bars and wires for a ferrocement tank were assembled, they 'resembled his cassava storage bin, except of course this his storage bin was made of woven bamboo'. He wondered whether it would be possible to replace some of the metal reinforcment in the tanks with bamboo. The local cadre then remarked that 'in constructing pit latrines, he often used a cylindrical woven bamboo liner, which he plastered with cement. Such a cylinder could conceivably be built above ground and function as a water tank'.

Kaufman notes that this conversation saw the birth of 'a new hybrid technology: bamboo-cement'. YDD staff who were present were quick to experiment with bamboo in the manner suggested, and made rapid progress with the design of a small ($4.5m^3$) 'single-family' tank which has since been built in large numbers (Fig. 4.3) It costs considerably less than a ferrocement tank of the same size, but its durability has been disappointing because the smallest accident or defect in the cement plaster can lead to rapid decay of the bamboo which is exposed. Initially, however, bamboo-cement seemed a real break-through. Trained cadres were often the chief means by which villagers learned the method of construction and sometimes one cadre would train another (Kaufman 1983). Although this points to a self-sustaining pattern of development, it seems unlikely that volunteer cadres could, or would, function successfully for long without support from YDD.

The continued contact of YDD with villages also led to recognition that

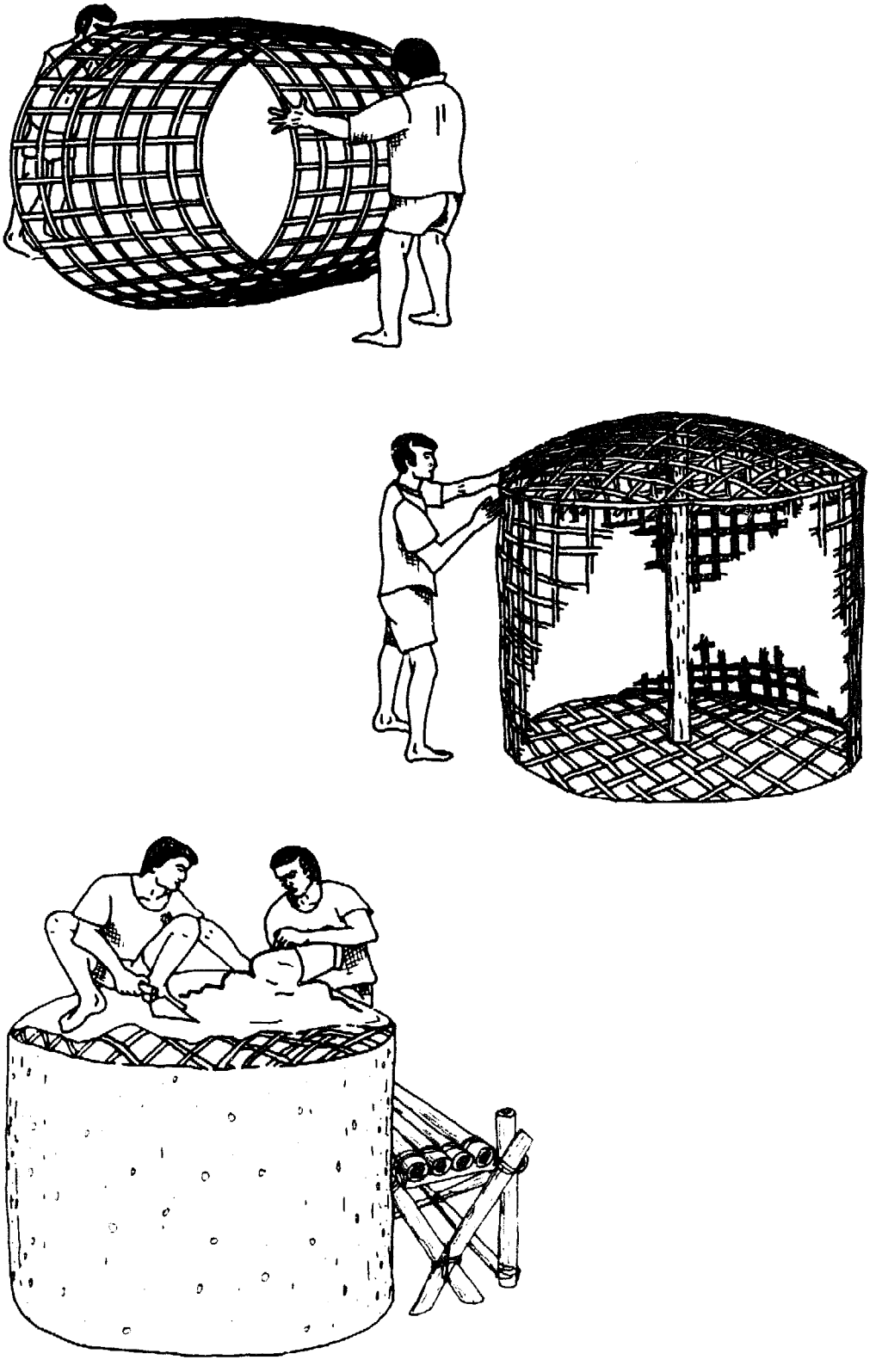

Fig. 4.3 Three stages in the construction of a bamboo-cement rainwater tank in Indonesia. In the final diagram, cement plaster is being applied to the bamboo reinforcement whose assembly is seen in the other two diagrams. (Kaufman 1983)

many tanks were not achieving 'their intended effect on the local water situation'. Instead of being used to provide emergency water in the dry season, it was found that tanks were being most fully used in the rainy season and were often empty long before the 'critical period' of water scarcity toward the end of the dry season. Noting this, YDD staff also observed rainwater being drawn from tanks for 'non-essential' purposes as well as contaminated water from ponds being poured into the tanks on occasion. In other words, the long-term commitment of YDD led them to *monitor* the operation of the completed tanks and so to discover these apparent eccentricities in usage. That in turn led them to suggest an improved and expanded educational effort to help people become 'better managers' of water resources.

MAINTENANCE, MONITORING AND INNOVATIVE DIALOGUE

For a programme to be self-sustaining, it is not enough for rainwater systems to be replicated effectively — they should also be well maintained so that their benefits are permanent. Their operation should be carefully monitored by the parent organization with particular attention to deficiencies in maintenance, and to any defects in tanks which develop over time, so that the long-term technical assistance provided can adapt to problems as they arise.

Where rainwater tanks have been acquired through commercial transactions between householders and craftsmen, if the craftsman is a local person who has close links with his customers, he will quickly be alerted if tanks crack or start to leak, even if this is after a long period of use. His training should cover the repair and maintenance of tanks as well as their construction. Indeed, he might be encouraged to visit customers periodically during the rainy season to inspect tanks when they are full and look for wet spots and cracks. Those whose tanks show evidence of faults could then be revisited in a season when tanks are empty, so that necessary repairs can be carried out.

Many maintenance tasks are simply a matter of keeping gutters, screens and filters clear of debris, as discussed in Chapter 3. These are matters for which householders must be responsible. In some areas, it will be especially important that mosquito net or gauze on overflow pipes and other apertures is always in good condition. Householders should be encouraged to check on this regularly, but it should also be seen as a responsibility of craftsmen doing other repairs that they also check mosquito protection. Project organizers may also find it useful to draw up a schedule, such as that given in Box 4.2 to ensure that all the maintenance tasks listed are covered in the training of craftsmen and in the educational work they undertake within the villages. Good maintenance is often difficult to achieve, and the

Box 4.2 A schedule of operation and maintenance tasks for concrete and ferrocement rainwater tanks and associated roofs and gutters. (IWACO, 1982-considerably modified)

TASKS NEEDING FREQUENT ATTENTION FROM HOUSEHOLDERS

1. Roof surfaces and gutters to be kept free of bird droppings. Gutters and inflow filters must be regularly cleared of leaves and other rubbish.
2. The mosquito net on the overflow pipe should be checked regularly, and renewed if necessary.
3. Unless there is some automatic means of diverting the first flush of water in a storm away from the tank, the inflow pipe should be disconnected from the tank during dry periods. Then 15-20 minutes after rain begins, it can be moved back into position so that water flows into the tank.
4. The water level in the tank may be measured once a week using a graduated stick (which should be kept in a clean place and not used for any other purpose). During dry periods, the drop in water level should correspond approximately with consumption. If this is not the case, the tank is leaking, and wet spots on its walls should be carefully looked for.

ANNUAL OR INFREQUENT TASKS FOR WHICH TECHNICAL ASSISTANCE MAY BE REQUIRED

1. At the end of the dry season, when the tank is empty, any leaks that have been noticed should be repaired. Where there have been wet spots on the walls, a cement/water mixture is applied on the inside and finished off with a layer of plaster. If there has been evidence of leakage but no wet spots have been discovered on the walls, the floor should be treated with a cement/water mixture and then finished off with a layer of plaster.
2. The roof surface, gutters, supporting brackets and inflow pipes need to be checked and repaired if necessary.
3. If a sand filter is incorporated, the filter sand should be washed with clean water or renewed. Other types of strainer, filter or screen must be checked and repaired as necessary
4. The mosquito net on the overflow pipe should be checked and if necessary renewed.
5. Removal of deposits from the bottom of the tank is periodically necessary. Depending on local conditions, this may be desirable annually (IWACO 1982) or only once in 3-5 years.
6. After repairs have been carried out inside a tank, after deposits have been cleaned out, and after a new tank has been completed, the interior should be scrubbed down with a solution of one of the following: *3 parts vinegar to one of water, OR 1 kg baking powder to 9 litres of water, OR ¼ cup (75ml) of 5% chlorine bleach to 45 litres of water.* After scrubbing, the tank should be left for 36 hours and finally washed down with clean water.

subject should appear prominently on the agenda of all monitoring and evaluation activities.

In the Indonesian work, maintenance problems reported include failure to clean and repair inlet filters on tanks and damage to mosquito screens (Latham 1984b). However, maintenance has largely been left in the hands of householders and village 'cadres' and is generally thought to be good. The main problem to emerge has been the deterioration of some bamboo-cement tanks, which illustrates the importance of monitoring for design policy and future choice of technology, as well as for planning technical support.

In discussing these issues, general comment on the desirability of 'participation' has been avoided because of the often misplaced ideological connotations of this over-used word. The case studies have indicated ways in which villagers have participated more or less actively in rainwater projects, although the technical assistance provided from outside their communities has usually been more crucial.

'Dialogue' or 'partnership' (Drucker 1985) are other equally over-used words, but ones which may have a rather more important meaning to convey. In Indonesia, we have seen that an exchange of ideas between villagers and professional staff led to the invention of bamboo-cement construction, and in Kenya, exchanges between craftsmen were seen as offering potential for innovation. When YDD staff in Indonesia observed how villagers were using rainwater and planned an educational programme to improve water management, this was dialogue of another kind. It was a response to what people were doing rather than what they were saying, and it led to innovation in the 'software' element of the programme. To install hardware and then not to monitor its utilization and performance is to ignore a dialogue which could lead either to improvements in hardware, or to recognition of unforeseen maintenance or training needs.

Innovative dialogue and partnership is necessary at every stage in the development of a rainwater programme (or indeed any other kind of water supply). It should begin whenever an outside agency arrives in an area with new ideas, and should continue through construction and monitoring until, perhaps many years later, some of the original ideas in modified form have become part of the local culture and are being implemented in a self-sustaining manner. The beginning of the dialogue might be a social assessment in which it emerges that local people have a view of their most urgent needs and goals which differs significantly from outsiders' expectations. In a survey in Guinea-Bissau, villagers were found to identify their most urgent needs with food supplies. Asked about improved water provision, they spoke of water for rice-growing and for irrigating vegetables (Chauhan 1983).

A project which sets out to build rainwater tanks cannot usually be so responsive to local needs that it can divert its energies to irrigating ricefields. It should not, however, insist that rainwater be used only for drinking if the people feel their greatest need is water for a small vegetable plot. Where people use rainwater tanks in unexpected ways, it is nearly always a mistake to see this as simply 'misuse'. The villagers may well be bad at managing water resources, but an agency which is open to dialogue will also wish to consider that apparent misuse is really a reflection of some unmet, unarticulated need. Rather than misusing tanks, the people may be innovating intelligently to cope with the unrecognized need. The biggest exceptions to this may concern health aspects of water quality and contamination which are not obvious to the layman, and where

'misuse' may well reflect a requirement for information and 'education'.

Very occasionally a new technique will be so well suited to what people want, and so well marketed, that it seems to catch on overnight without adaptation. More usually, however, innovative dialogue is a slow process in which hardware and patterns of maintenance and use are gradually modified. Even in Thailand, where small pottery rainwater jars were already in widespread use and people were receptive to suggestions about larger containers, quite a number of tanks had to be built before the new technique crossed the 'threshold of popularization' (Fricke 1982). In the Kenya programme already quoted, only a few people, mostly from better-off households, took advantage of the water jars being offered when they first appeared, and it was twelve months before the threshold of popularization was crossed. Yet these are programmes in which progress has been unusually good.

Innovative dialogue requires patience and a long-term commitment. It is not something to which experts flown in from overseas can contribute greatly during brief consultancies. Significantly, two of the agencies represented in Table 4.1 are local ones with roots in the areas where they work; in addition the Zimbabwe programme has been experimenting with rainwater collection for around fifteen years. It is not unusual for innovative dialogue to extend over long periods such as this. Another example is in Botswana, where experiments with excavated rainwater catchment tanks have been undertaken at intervals since 1966, but without widespread construction of such tanks until the early 1980s. Slow progress has been attributed to an initial lack of government support (Gibberd 1981), but radical modifications of the technique and the purposes for which it was used also seem significant in securing its recent more widespread adoption.

The chief technical problem in the Botswana work was to line excavations so that the stored rainwater would not seep away. Linings made of butyl rubber and PVC sheeting were tried (Gibberd 1969), but the technique selected for development in the early projects was one previously tested in Sudan (Ionides 1966). The basic components were polythene sheeting, mud, and a specially-made building block referred to as a 'sausage'. The latter was a short length of 'lay-flat' polythene tube tied at the ends and filled with a sand and cement mix. The sausages were laid without mortar before the mix set, with 20cm lengths of gauge 8 wire pushed through to hold them together (Fig. 4.4). Being enclosed by polythene, the mix did not dry out quickly, (a perennial problem with the use of mortar in hot climates) and the cement was able to cure fully, achieving high strength with a very lean mixture of 13 parts of sand to 1 part cement. The sausages were laid after the excavation intended for water storage had been lined with two or more alternate layers of polythene sheeting and mud. The function of the sausages was to support

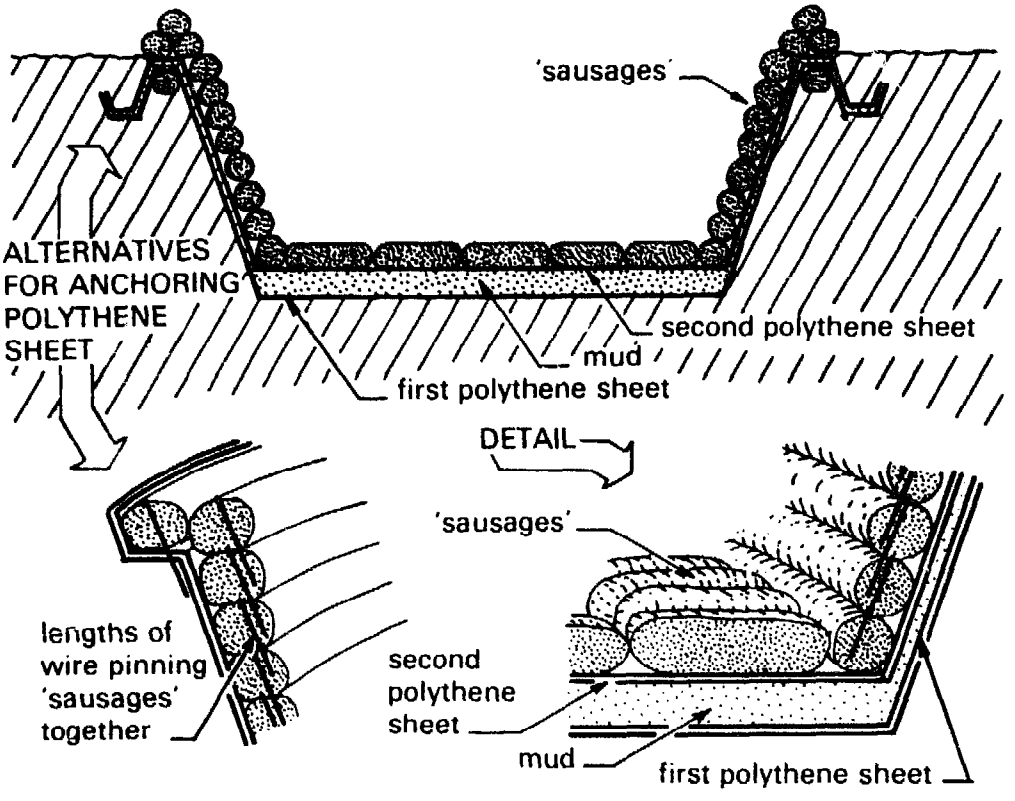

Fig. 4.4 Simplified diagram illustrating the method of lining an excavated water tank with polythene sheeting and 'sausages' containing a weak cement/sand mix. The diagram is based on tanks built in Francophone West Africa where they are known as 'bassins type Botswana'.

Note: *The size of the sausages relative to the dimensions of the tank is somewhat exaggerated.*

the sides and protect the sheeting from exposure and damage, whilst the reason for the alternating mud and polythene layers was to create a self-sealing effect should a puncture occur.

Initial trials with this technique in Botswana were carried out by Vernon Gibberd, who subsequently took several initiatives aimed at replicating it. For example, in 1968 he ran a course which attracted a mixed attendance of men and women, village leaders and local staff of the government Community Development Department. This led to the construction of at least two catchment tanks, one at the home of a course participant. The latter (which was privately paid for) had a fault and leaked at first, but after repairs with cement, it has seen fourteen years of continuous use. It is filled by runoff from hard ground immediately surrounding the owner's house, and is complemented by more conventional tanks which collect rainwater from the house roof.

Another initiative in which Gibberd was involved was a programme for building excavated rainwater tanks at primary schools to enable 'micro-irrigation' to be practised in school gardens. Twelve schools took part in the programme, teachers were trained and tanks were built, but as

compared with the other projects discussed in this chapter, the technical assistance provided was of a very short-term and limited kind. The Intermediate Technology Development Group (ITDG), based in Britain, recruited an assistant to work with Gibberd, and a grant was obtained to cover the cost of materials. However, there was no parent organization in the region to monitor progress after the tanks were completed, or to provide continuing technical support, and the future of the work was left entirely in the hands of teachers at the schools where tanks were built.

Unfortunately, many of the teachers were transferred to other schools quite soon after the catchment systems were completed. Had there been adequate monitoring and follow-up the new teachers replacing them could have been encouraged to maintain and use the catchments. As it was, however, Gibberd had other responsibilities and his ITDG assistant had left the country. Neither was immediately aware of the altered staffing at the schools. Thus the new teachers were given no help in continuing with rainwater collection and in most cases it was entirely abandoned.

There is much parallel experience in other countries where attempts to develop rainwater systems or gardens at schools have been disappointing. Ghala tanks at schools in Kenya have been far less successful than those at private homes (Sinclair 1983), and the same may prove true of excavated catchment tanks at schools in a neighbouring area (Childers 1984). Similarly, ITDG's second project in southern Africa, at schools in Swaziland, did not achieve all that was expected of it. This again entailed the construction of excavated tanks utilizing playgrounds for rainwater catchment, but this time — with the aim of providing water for drinking — domed 'beehive' structures were built inside the tanks to enclose the stored water (as advocated by Ionides 1966). Sand spread on top of the 'beehives' then ensured that water was filtered as it entered the tank, and a small hand-pump was installed for withdrawing water.

A mismatch between these tanks and the schools is suggested by a generally gloomy picture of slow construction, incomplete tanks and broken pumps (Moody 1972), but the occasional successful example emphasizes the role an enthusiastic teacher can play. One such in Swaziland was the headmistress of Secusha School who ensured that her school's tank was properly completed, took trouble over maintenance of the pump, and made good use of water from the tank in cooking school meals.

Teachers in Botswana also included occasional enthusiasts. Tamasane School had a well-run garden even before its catchment system was built (Moody 1969). With the aid of water from the tank, it was providing vegetables for 200 meals per week by July 1968. When visited by one of the present authors in 1972, the garden and tank were in full use, and the whole school seemed impressively well run, with models and pottery made by the

children on display. Ten years later, Gould (1983) reported that the tank was still being used (though it had needed repair by cementing over most of the lining), water being drawn for washing clothes as well as for growing tomatoes. It seems that many of the schools projects that fail do so because they are based on the assumption that all the teachers involved will be as committed as were those in the successful project. The reality is that most teachers, like most community workers, most village technicians, and most mutual-help groups, need continuing support from a locally-based technical assistance organisation.

VILLAGE ROLES IN REPLICATION AND INNOVATION

The conventional view of 'participation' in water programmes tends to envisage considerable responsibility and voluntary effort being undertaken by community workers, teachers, and village people in general. The concept of a practical or innovative dialogue between a technical assistance organization and villagers may be more realistic because it does not presuppose anything final about allocation of responsibilities. Rather, it stresses the monitoring of practical experience and the exchange of views with the aim of detecting problems as they arise, and modifying organization (and hence responsibilities) or hardware accordingly.

Many people are inclined to see the Botswana schools project as a 'total failure' but Gould (1983) takes a more positive view, arguing that there was some replication of the catchment systems elsewhere, and that the Botswana work may have had 'influence . . . on later developments of the technology'. If it had influence, then on some level there must have been dialogue, even if the absence of effective monitoring and the lack of help with immediate problems at the schools indicates that the dialogue was incomplete.

In order to work out what sort of dialogue took place and whether it influenced innovation or replication, some of the oranizations and individuals connected with rainwater development in Botswana have been identified and are indicated by the marked(°) names in Figure 4.5. This diagram summarizes a great deal of research into the contributions of the various groups, and seeks to show not only the slow and sometimes unexpected ways in which innovations arise, but also the occasionally crucial role played by highly motivated individuals. Reviewing water supplies in several African and Asian countries, Chauhan (1983) concludes that the 'key agents of development' are often exceptionally dedicated professionals, sometimes unidentified staff members in a voluntary agency or government ministry, but sometimes playing a more conspicuous part, as Vernon Gibberd did in this instance. Other individuals with more modest but still significant roles were the Morwa school teacher and members of the Zimbabwe programme quoted earlier. The latter kept in

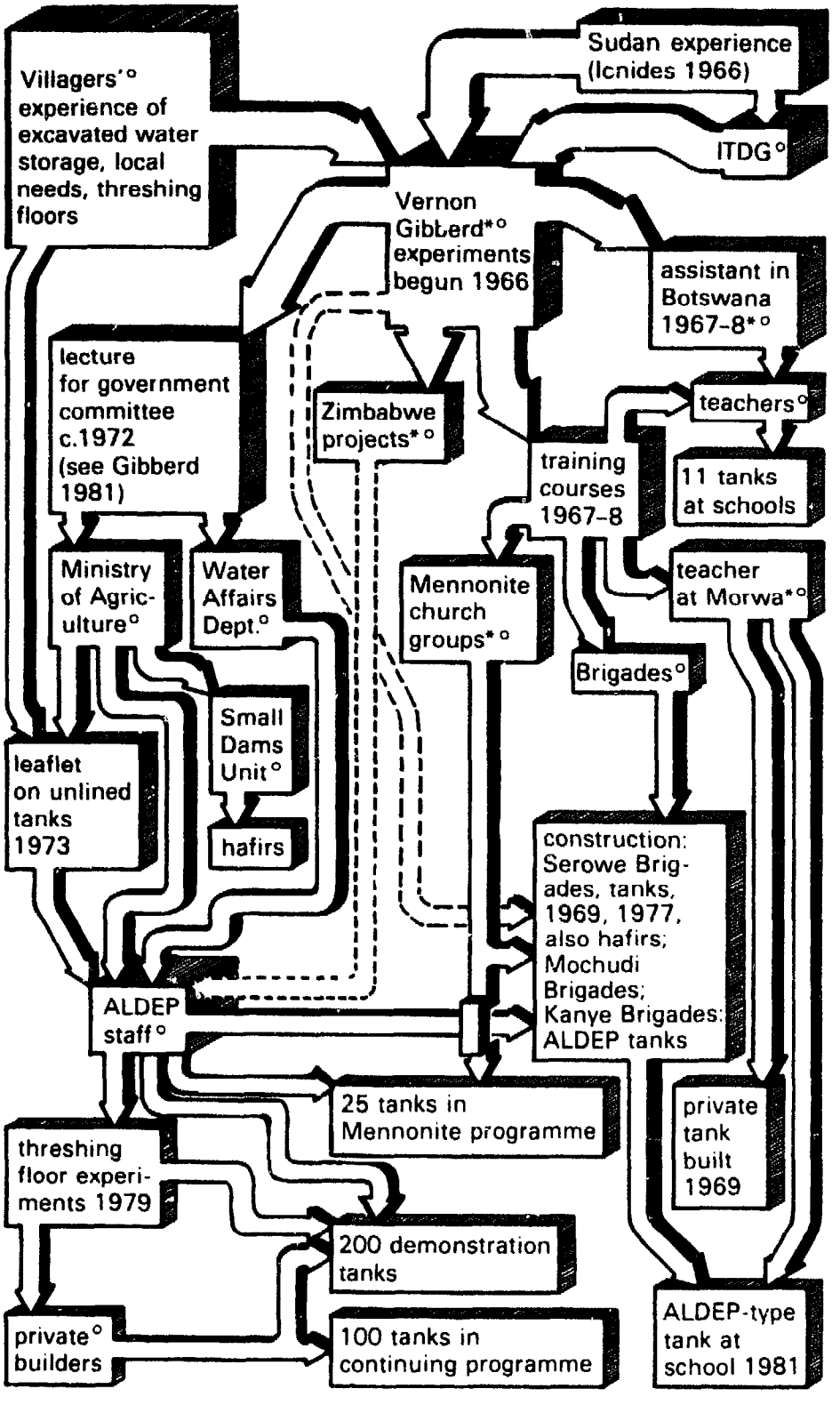

Fig. 4.5 A representation of the development of rainwater collection techniques in Botswana between 1966 and 1981, showing the main flows of ideas and information (arrows), and identifying some key participants in the innovative dialogue (°). (Sources for developments prior to 1972: personal interviews (*) by one of the authors; for later developments, Gould 1983 and Cullis 1984). ALDEP is the Arable Lands Development Programme.

regular contact with the Botswana [illegible] and built their own trial tanks with polythene sausages.

Figure 4.5 also mentions village people, some of whose children attended the schools where tanks were built. Their voluntary labour was called on during construction, but not enough attention was paid to their experience, opinions and priorities. For example, water for school gardens was not a priority for them, but water at arable lands distant from the villages was of greater concern. Moreover, rainwater collection in excavated 'tanks' was not something entirely new in which people needed instruction from an outside agency. Many farmers already made excavations for rainwater collection near to their arable land (Gibberd 1969). These excavations were unlined, and so were only feasible on clay soils, but they retained rainwater during the short period in each year when people were living on their lands. For this particular application, then, the seasonal availability of rainwater was well matched to a specific need.

Government initiatives in rainwater collection were slow to develop (despite Gibberd's urgent advocacy of them (1981)), but appear to have taken more account of villagers' experience than did the ITDG work. For example, in 1973, the Ministry of Agriculture issued a well-illustrated leaflet advising farmers on the construction of unlined 'water catchment tanks' on their arable land. Though reflecting influence from the earlier programme, the leaflet also gave formal recognition to the traditional practice of excavating small rainwater ponds, recommending dimensions and promising help from extension officers in assessing soil conditions. At the same time, the Ministry was using earth-moving machinery to construct 'hafirs' (Classen 1980), which were much larger, unlined excavations designed to provide water for livestock.

Another direction in which the Botswana tradition of excavated drainage storage could develop was indicated by a footnote in the Ministry's 1973 leaflet. This said that if a farmer's unlined excavation did not hold water, it 'could be lined with plastic sheeting or cement — seek advice from your District Agricultural Officer'. The idea of a cement lining was taken further in 1979 when chicken wire was pegged to the sides of experimental excavated tanks and cement was plastered onto it; the resulting ferrocement lining was highly effective, and produced what amounted to a new type of tank in this region. Strikingly similar rainwater tanks have since been built in Kenya (Batchelor 1985; Childers 1984), probably with knowledge of the Botswana experiments derived from Maikano and Nyberg (1980). In a leaflet describing the Kenyan design, UNICEF advocates a hemispherical excavation rather than the shape indicated in Figure 4.6, and refinements in the method of covering the tank and the inlet filter.

The Botswana tanks were developed as part of the Ministry of Agriculture's Arable Lands Development Programme (ALDEP), and are also notable for the way in which threshing floors of traditional

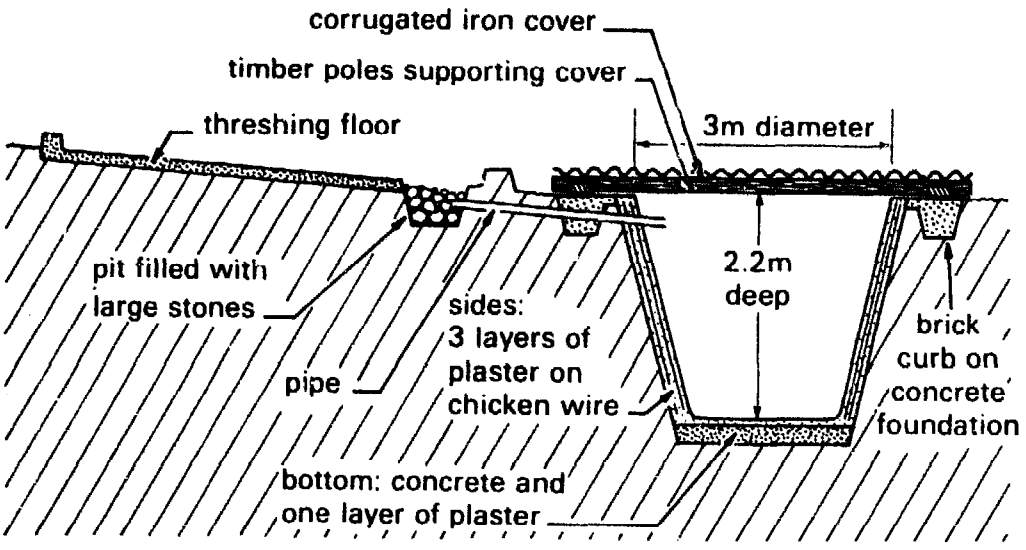

Fig. 4.6 Excavated rainwater tank in Botswana with ferrocement lining. The catchment area is a threshing floor surfaced with a clay/cow dung mixture which is worked to a smooth, hard finish. (Whiteside 1982; Gould 1983)

Note: *Vertical dimensions have been exaggerated.*

construction were adapted as catchment surfaces (Maikano and Nyberg 1980). Here again it seems that government water experts were learning from villagers, and especially from the occasional farmer who diverted drainage water from a threshing floor to fill his excavated storage. Another source of ideas, possibly indirect, was experience in Zimbabwe with cement-surfaced catchments of about the same size and shape as threshing floors (Fig. 4.2). The Zimbabwe installations also included ferrocement tanks, though information about simpler methods of lining excavations with ferrocement seems also to have reached the ALDEP workers from ITDG.

Thus, a very diverse range of exchanges of information involving government staff, farmers, and outside agencies all played a part in the innovative dialogue which led to the development of the ALDEP rainwater collection tank (Fig. 4.5). Following the success of the initial experiments, a nationwide pilot project was launched in which 200 demonstration tanks were built for farmers in a wide scatter of locations. This can be seen as a way of extending the dialogue by seeking to encourage additional farmers to acquire tanks, thereby spreading knowledge of the tanks and at the same time gaining experience of their use under a greater variety of conditions. This extended dialogue has included other people also: a Mennonite church community has begun building tanks for farmers in its area, usually of 10-15m^3 capacity, and young men in the artisan training 'brigades' have been involved in tank construction. The teacher at Morwa whose private tank was mentioned earlier arranged for a large (40m^3) tank on the ALDEP model to be made at the school of which she is headmistress; it was intended

for watering a vegetable garden (Gould 1983). In addition, one local community development trust has produced its own instruction booklet describing how excavated tanks of this sort are made (Whiteside 1982).

Alongside these voluntary contributions to 'dialogue' and replication, the official ALDEP technical assistance programme offers loans and subsidies for farmers wishing to acquire tanks, and has trained local builders to make the ferrocement linings, with the intention that they should undertake the work on a commercial basis. The builders, however, complain that the officially fixed price is too low for them to make a profit.

A conventional perspective on the development of rainwater catchment in Botswana would tend to stress only *formal* arrangements for technical assistance, noting the short-term nature of ITDG's initial commitment and the much more substantial ALDEP programme. The exchange of information which contributed to innovation would also be seen in formal terms, and would include evaluations commissioned by ITDG and consultants' reports to government departments (e.g. Classen 1980). The conventional perspective would thus ignore or under-state informal learning processes — the information picked up from villagers, and the role of individuals whose private use of rainwater tanks and personal initiatives have spread ideas even when official bodies seemed to lack interest.

It is probably true that informal processes of dialogue always play some part in filling gaps in organized technical assistance programmes and help to keep them in touch with local realities. They are an essential accompaniment to more formal research effort and to technical assistance if the replication and improvement of a technology is to proceed at all vigorously. Examples have been cited from Indonesia as well as Botswana in which knowledge of existing village techniques contributed to significant innovations, and parallel experiences have been noted in other technologies (Pacey 1983).

Agencies must operate in an organized way, however, and cannot simply leave informal exchanges of information to proceed at their own pace. Thus organized *assessment, monitoring* and *evaluation* are important elements in the planned component of innovative dialogue. Evaluation usually refers to a longer-term perspective than is dealt with by the monitoring activities described so far. Rather than looking for immediate problems of operation or maintenance, evaluation tends to ask broader questions of a water supply: 'is it being fully used?' 'Is it achieving its intended benefits for health or livelihoods?' The World Health Organization (1983) has developed a 'minimum evaluation procedure' (MEP) which allows such questions to be investigated without excessively time-consuming research. Survey procedures are similar to those used in the social and technical assessments described in Chapter 3, but now they apply to completed rainwater systems or other supplies and adopt specific criteria of function and use. These latter include the quantity of water

supplied, its quality, the reliability of supply, and the alternative sources which are used when the supply fails.

But however thoroughly an agency learns from such evaluations, replication of the technology it promotes will not come about solely as a result of formal knowledge and official schemes of technical assistance. The crossing of 'thresholds of popularization' depends also on the inter-actions between individuals and local organizations which generate enthusiasm and stimulate ideas — inter-actions between householders and builders who construct tanks; between farmers and extension officers; between commercial and public sectors in the economy. The role of villagers in this process should not be misrepresented by exaggerated claims about participation, but neither should it be under-estimated.

5. DESIGN FOR DRINKING WATER SYSTEMS

CONSTRAINTS ON ROOF CATCHMENTS

The design and construction of storage tanks is technically the most interesting and difficult aspect of rainwater collection, and it is perhaps inevitable that a discussion of design should focus on that. However, in Chapter 1 it was suggested that rainwater collection should be thought of as involving a *system* whose components were identified as including catchment surfaces, gutters, and some aspects of the end-use of the water, as well as storage tanks. Moreover, it was observed that most components in these systems have associated means of protection against such hazards as contamination of water, mosquito breeding, and animals falling into tanks.

In subsequent chapters, an even broader view of rainwater systems has been suggested, embracing the livelihoods of people who use rainwater, the organization of groups of users, and constraints limiting the replication of techniques. These are all things which may influence the detailed design of tanks and gutters. In Chapter 3, for example, we observed that the capacity of the storage tank a family requires might vary according to whether the family needs an all-year supply, or whether its livelihood depends on work done during an especially critical season when a convenient source of water has particularly high value in time-saving or for growing a vital crop.

Constraints affecting the replication of rainwater techniques — high costs, inadequate guttering, unsuitability of local roofing materials — clearly require close attention during the design stage of any project. In practice, most rainwater programmes do not tackle major problems of repair and reconstruction of roofs, but install tanks only where roofs are judged adequate as catchment surfaces. However, the point has been made that if a programme gives priority to low-income groups, the bad state of their housing, including roofs, should receive attention. Technical support for roof repair or replacement might then become part of the programme. This might involve introducing and testing new low-cost materials such as sisal-cement roofing tiles; it might include training builders in a new technique or paying them to assist householders who cannot carry out their own repairs; or it might entail setting up a revolving loan fund or savings

scheme so that a householder can pay for corrugated iron sheeting in easy stages (Chapter 4).

Guttering seems to be a difficulty for many householders, yet it is rarely mentioned in reports from technical assistance programmes. Where there are practical obstacles to installing conventional gutters, one option may be to devise ways of collecting water from roofs without them. In Bermuda, this is achieved by means of slanting ridges on the roof surface known as 'glides' (Fig. 5.1). They are formed of lengths of stone cut to a triangular shape, or else are precast in concrete, and are bedded on the limestone roof slates with cement mortar. This method is only practicable where roof surfaces are smooth, and it would not be satisfactory with corrugated iron. Elsewhere, troughing below the eaves but near to ground level has been used to collect rainwater in small containers. Such troughing may be particularly appropriate for thatched roofs (Fig. 5.1) and could be used to fill a larger permanent tank or jar at a low level, perhaps constructed in a shallow excavation.

The cost of conventional guttering is often said to be small compared with the cost of a tank. In the Zimbabwe work discussed in the previous chapter, metal guttering was made by the technical assistance organization in its own workshop. When the total cost of a ferrocement tank installation was quoted as roughly equivalent to US$75, this included $6 for gutters and a further $6 for fixing them. The latter was a labour cost which could be saved by householders able to fix the gutters themselves. But since lack of the necessary skills appears to be a constraint in itself, the cost of guttering in this instance should be reckoned as $12 or 16 per cent of the total.

The conveyance of water from eaves gutters to the inlet of a storage tank can be via an extra length of guttering (Fig. 5.2), or it can involve a complex array of downpipes (Fig. 5.3). In view of the need to keep costs low and avoid maintenance problems, the simpler approach is clearly preferable. However, when a large tank is filled from gutters on both sides of a house, it may not be easy to have extension gutters bridging across from the eaves to the tank. In that case, to avoid the complications illustrated by Fig. 5.3, two small tanks may be better, each filled by one side of the roof. Despite the diseconomies of scale which make two small tanks considerably more expensive than a single large one, the saving on downpipes can lead to a cheaper installation, or at least to no greater expense (see Table 5.1). In many countries, including Thailand, Indonesia and Kenya, many low-income households can only afford small tanks collecting water from one side of the roof, in any case. A second tank on the other side is therefore an option for future improvements rather than an immediate possibility.

In tropical areas, the high intensity of rainfall in some of the heavy downpours that occur means that gutters must be larger than in temperate regions if they are not to overflow. In general, gutters with a cross-sectional area of 200cm^2 will be able to cope with all but the heaviest rain when

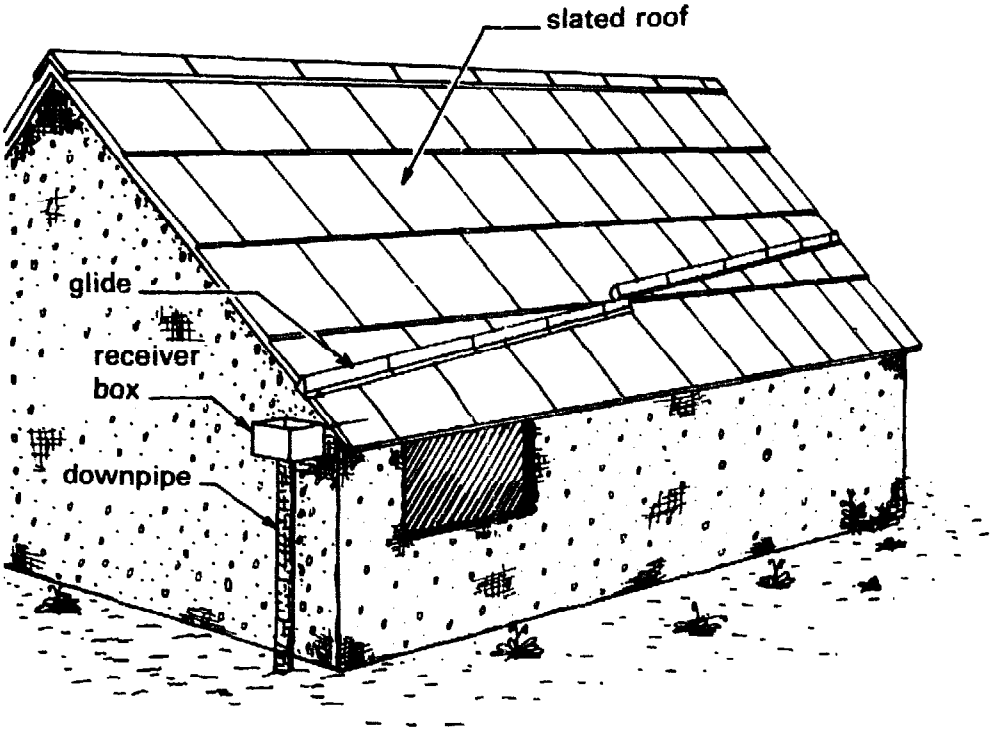

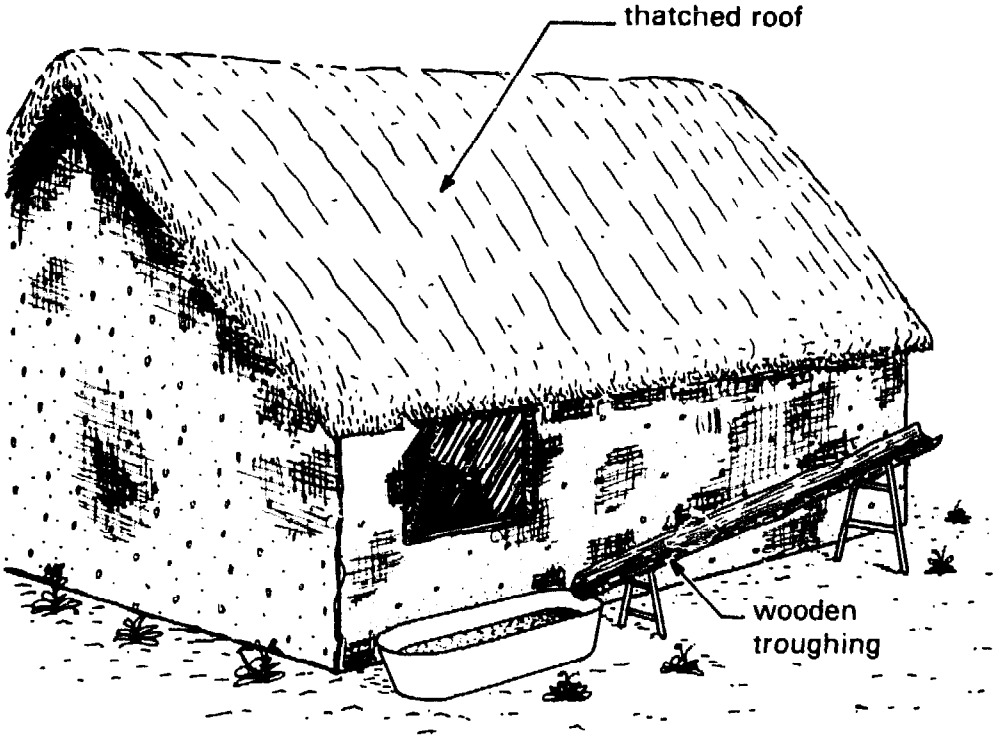

Fig. 5.1 Alternatives to guttering: glides (Bermuda) and low-level troughing (Ghana). (Waller 1982 (Bermuda) and Novieku 1980 (Ghana))

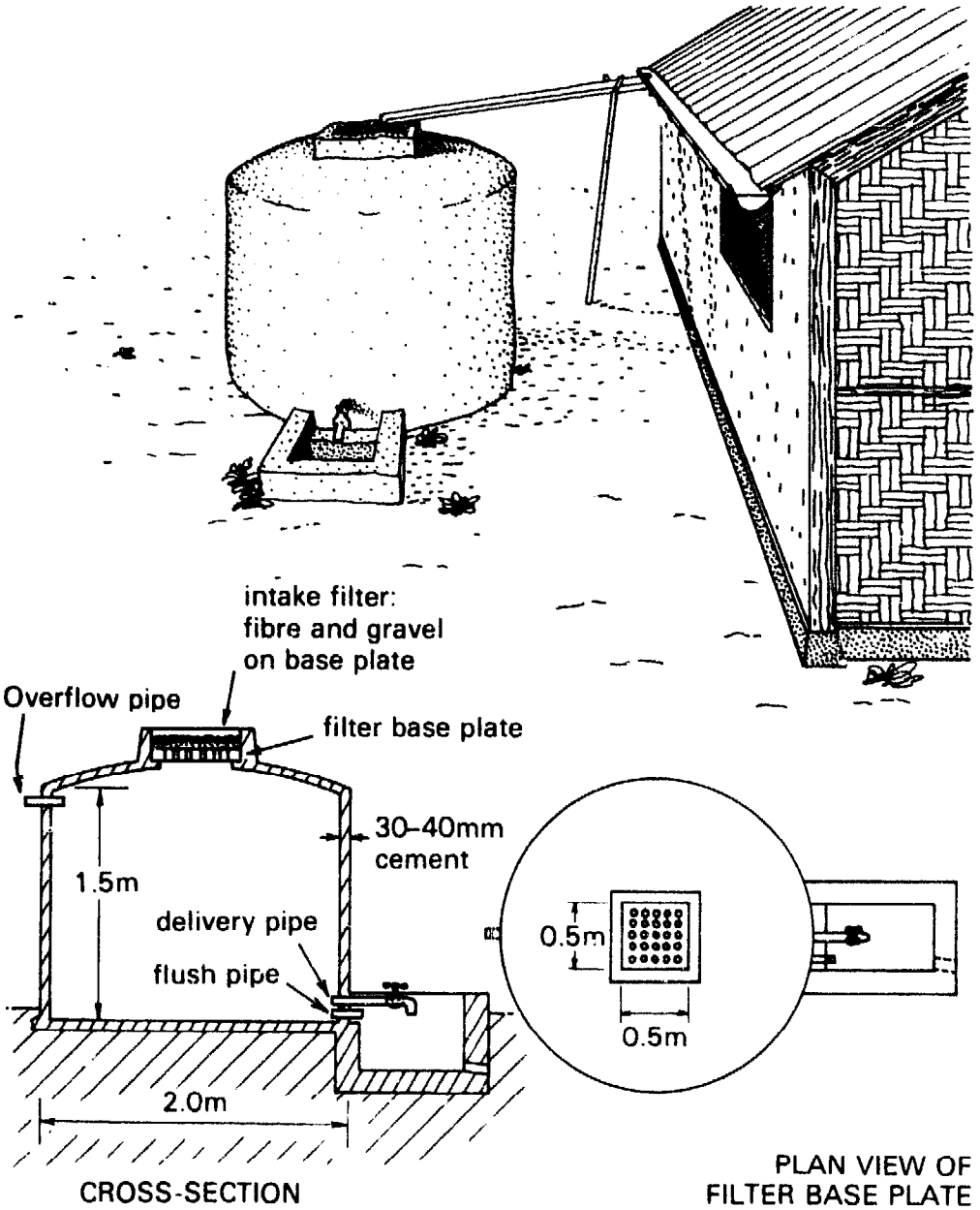

Fig. 5.2 A bamboo-cement rainwater tank in Indonesia with a short length of guttering making the connection between the eaves gutter and the inlet filter on the tank. The guttering can be temporarily moved to divert 'first flush' water away from the tank. The section and plan show details of the inlet filter. (Kaufman 1983)

attached to a small roof, which implies approximately 200mm width for gutters of semicircular section (Figure 5.4). However, where local materials such as bamboo are used, sizes will have to depend mainly on what is available.

Another problem is simply the weight of the gutter when loaded with water. Gutters will need to be well supported so that they cannot sag or be pulled away from their supports. They must be carefully positioned to

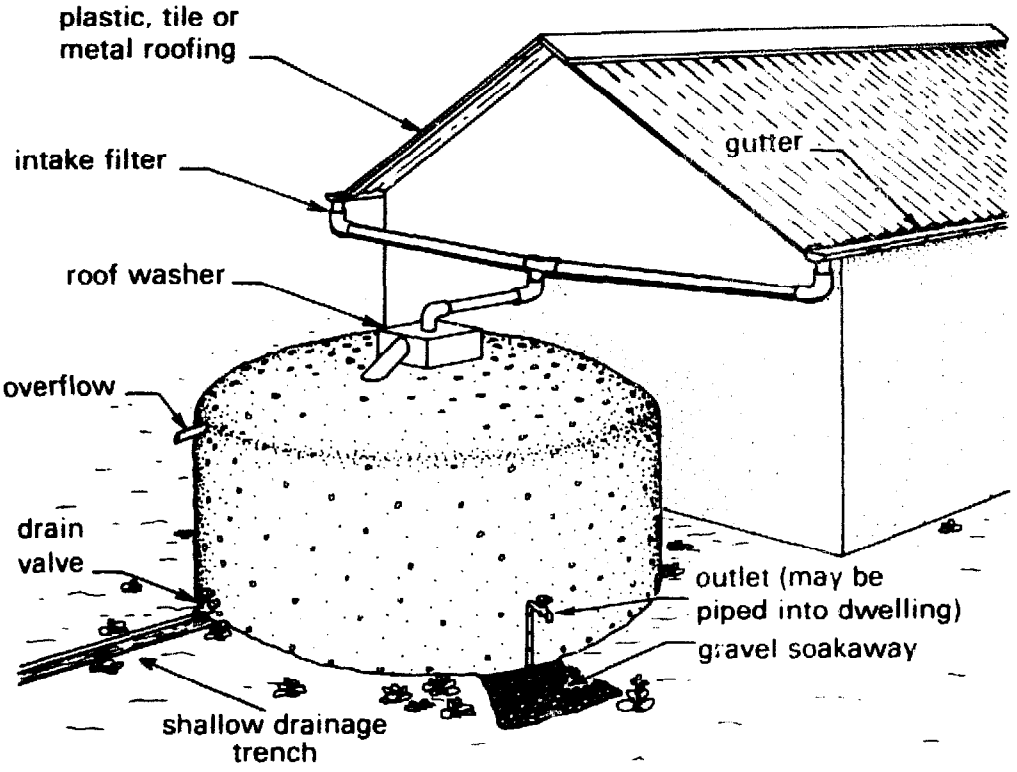

Fig. 5.3 Downpipes for collecting water from both sides of a pitched roof. (Institute for Rural Water 1982)

catch both gushing flow from the roof and also drips. In addition, they need an adequate slope for their entire flow length so that stagnant pools which could provide breeding places for mosquitoes are avoided. For all these reasons, fixing gutters is not a simple task to be left in the hands of inexperienced people, but should be taken seriously in technical assistance programmes.

The way in which gutters are actually supported must depend very much on the construction of the house. Sometimes it is possible to fix iron or timber brackets to walls, but for houses that have wide eaves, some method of attachment to the rafters will be necessary. It may often be easiest to bind gutters to their supports with thick wire, though rope may be used provided that it is replaced regularly, before rotting weakens it. Several techniques for fixing gutters to thatched roofs were illustrated earlier (Fig. 1.8), some of which are applicable for tiled roofs with very little modification, and Figure 5.4 shows other possibilities. It is, of course, impossible to illustrate every feasible method.

As to construction of the gutter itself, one of the simplest methods is to nail cedar or other planks together in a V-shape (Fig. 5.4). The joint is sealed with tar or any suitable, locally available, resinous material (McDowell 1976). Metal gutters can sometimes be made locally, and both metal and plastic (PVC) guttering may be available for purchase. Halved tin cans riveted together have been demonstrated by several appropriate

Table 5.1 Comparative costs of one large tank collecting water from both sides of a roof as compared with two small tanks*.

	Large tank collecting from both sides of a roof	*Two small tanks, each collecting from one side of the roof*
Cost of tanks:		
$10m^3$ size	100	—
$5m^3$ size	—	56
		56
Cost of guttering	17	17
Cost of downpipes	15	3
	132	132

* *Figures are based on experience in Zimbabwe and data on economies of scale indicated by Edwards and Keller, 1984. The notional cost of a large tank is set at $100.00.*

technology centres (e.g. in Nairobi), but no widespread practical applications have been reported. Much the most widely used and important form of guttering produced from local materials is that made from bamboo, for which detail is given in Box 5.1.

Large rainwater tanks may be nearly as high as the eaves of the houses they serve so only short lengths of downpipe are required. Current practice is to connect the downpipe directly to the gutter without a receiver box, and to use a large diameter pipe — 100mm or more — or a length of open gutter. The downpipe should be big enough to carry flows from intensive rainfall and for clogging by leaves to be unlikely. The most important point to consider at this stage is the method that should be adopted to prevent debris from being washed into the tank and to arrange for the dirty 'first flush' rainwater after a dry spell to be discarded. Due to the extra cost of installing any elaborate device and the near impossiblity of maintaining it in rural situations, most programmes do no more than provide a screen or filter at the entry to the tank to prevent the grosser forms of debris from passing. In the Indonesian work quoted earlier, an inlet filter moulded into the tank roof is a prominent feature of the design (Fig. 5.2). No special provision is made for first flush diversion, but the length of guttering which takes the place of the downpipe can be moved during any dry periods and replaced after the first few minutes of rain in a new wet season. Other simple methods of moving downpipe outlets away from tanks during dry

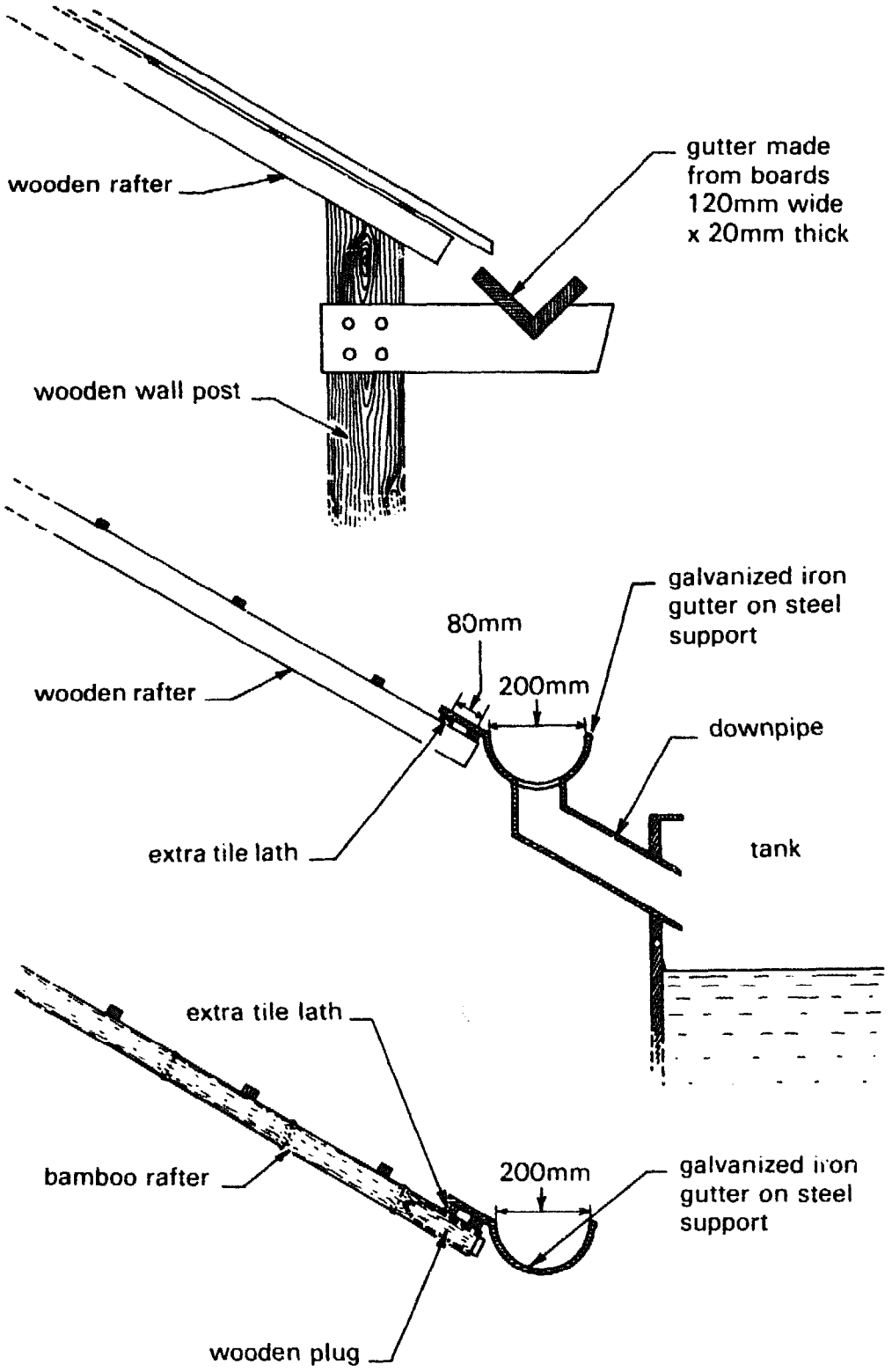

Fig. 5.4 Methods of fixing metal gutters to rafters, and wooden gutters to wall posts. (See Fig. 1.8 for other techniques.) Where rafters are made of bamboo the hollow ends of the rafters need to be plugged with wood before laths are attached to carry the gutter. (For clarity, rafters are shown without the tiles or corrugated iron sheeting they support.)

Box 5.1 Bamboo guttering. (Institute for Rural Water 1982; VITA 1973)

Bamboo gutters are made by splitting bamboo culms (i.e. stems) lengthways down the middle, and removing the partitions inside.

The culms may be split using a sharp knife (Diagram 1) which should have a short handle and a broad blade. Heavy culms can be more easily tackled by mounting an iron wedge on a post (Diagram 2). An axe is then used to make a small breach at the top end of the culm; the wedge is inserted into the breach, and the culm is pushed or pulled toward the wedge until it splits. The edges of the split bamboo are razor-sharp and should be handled with care.

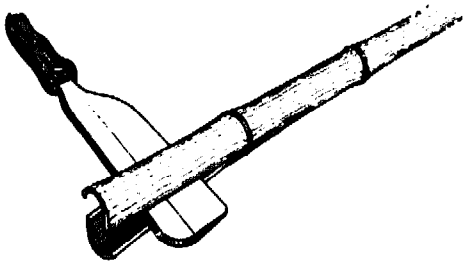

Diagram 1

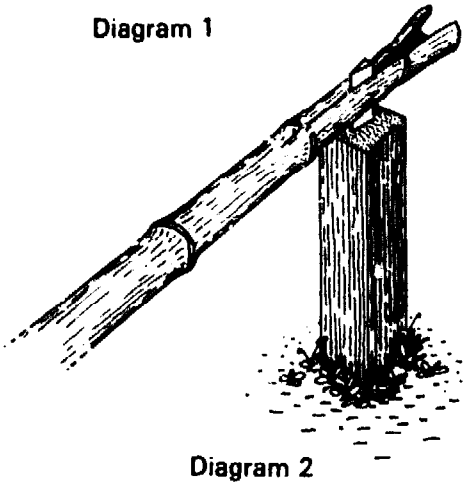

Diagram 2

Bamboo guttering may be tied to the roof structure with wire at 0.5m intervals. One way of joining lengths of gutter is to use a piece of rubber cut from an old inner tube. The rubber fits under the gutters and is secured to them by wire (Diagram 3). Tar or caulking is then used to make a seal. Ensure that the two pieces of bamboo fit together closely before sealing the joint.

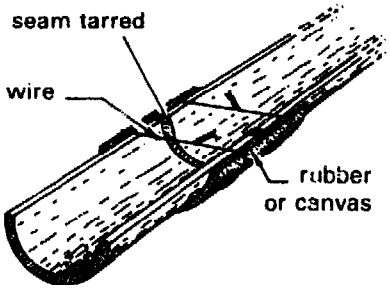

Diagram 3: Joining two pieces of bamboo

Downpipes can also be made from bamboo (Diagram 4). The joints shown have little inherent strength and depend on the gutters and downpipes being securely fixed in position against the walls and roof before the joint is made. Sealing of joints is again done with tar or caulking compound.

Place a small mesh wire screen over the opening of the downpipe so that leaves or other debris which could contaminate the water do not enter the cistern. The mesh should be large enough to catch leaves and debris but allow water to flow through.

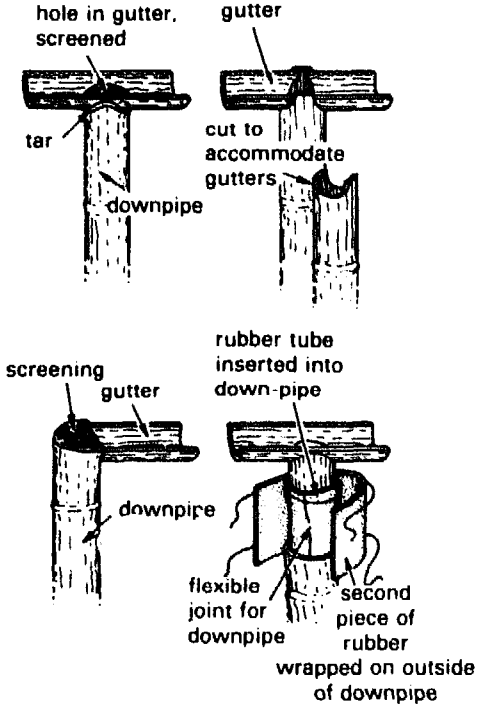

Diagram 4: Joining gutters and downpipes

spells were illustrated in Fig. 3.4. Of all the programmes quoted so far, only the one in Thailand incorporates any device for holding back first flush water. It consists of a length of large diameter pipe suspended alongside the rainwater tank (Fig. 5.5). This is sealed at the bottom with a plug. When rain begins to fall, this length of pipe must fill before any water can enter the tank. It will thus retain any sediments carried by the first flush water. After each storm, the plug is removed and the pipe is drained.

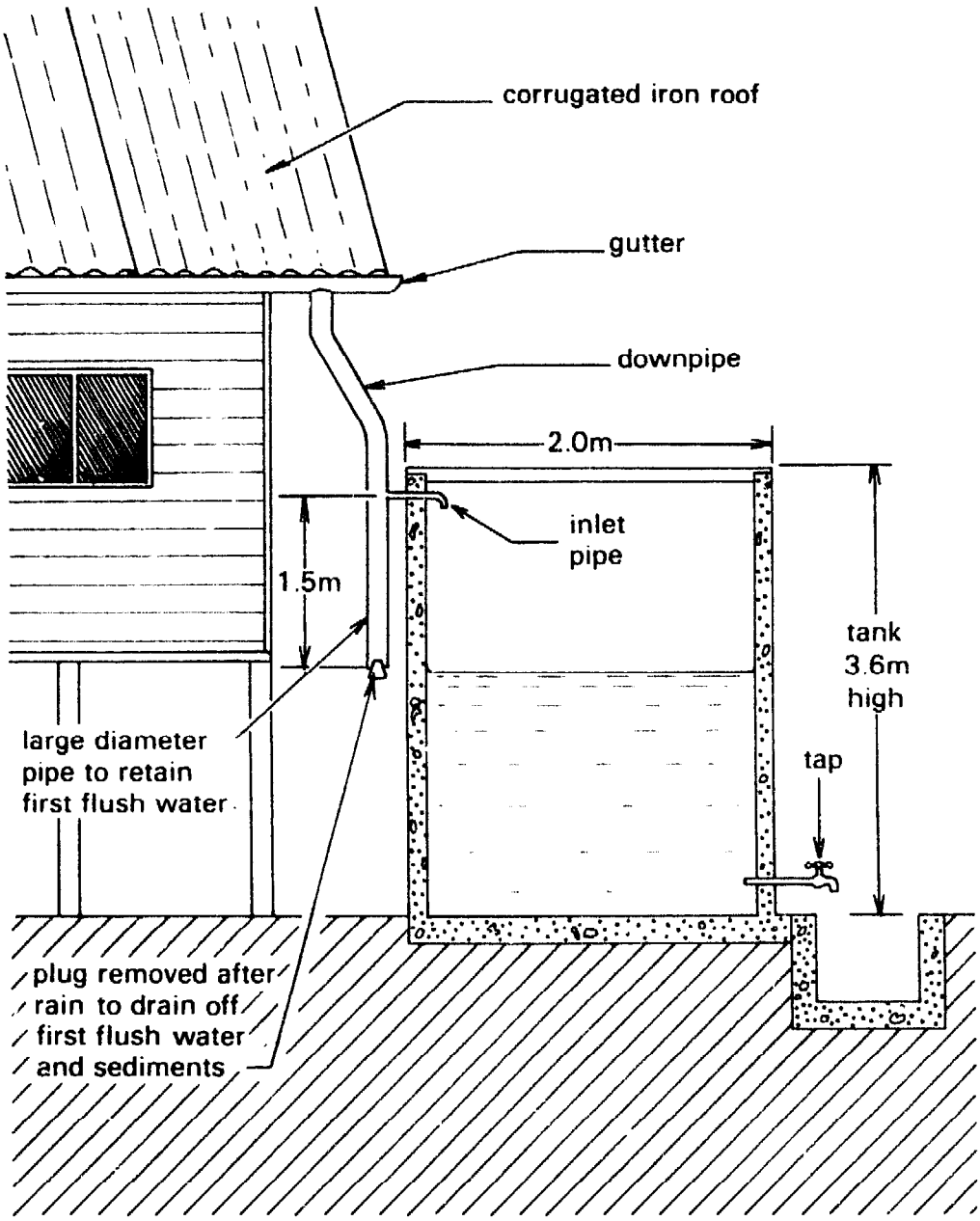

Fig. 5.5 A method of first-flush rejection which is used with bamboo-reinforced concrete tanks in Thailand.

RAINWATER TANK DESIGN

The key decisions that have to be made about tank design relate firstly to materials and methods of construction, and secondly to tank capacity. Both decisions depend critically on costs. Whilst large tanks show economies of scale, so that the cost per cubic metre of water stored may be reduced, with smaller tanks, there is more scope for using local materials and cutting costs that way. Indeed, available choices of materials and methods of construction vary greatly with tank size.

Very small rainwater tanks are often containers made for other purposes which have been pressed into service when the rainy season begins. They include buckets, barrels, bowls, large clay pots, and even tin baths. The ubiquitous oil drum of $0.2m^3$ capacity may be adapted for use as a permanent rainwater tank (Fig. 3.1) and in some countries, large pottery water jars with capacities up to $0.3m^3$ are made for the purpose. However, the development of techniques for manufacturing similar jars from cement mortar is now providing a cheaper alternative to the pottery jar.

Unreinforced cement mortar jars can be made in a range of capacities from $0.3m^3$ upwards. For the smaller sizes, the easiest method of construction is to use sacking stuffed with sand or sawdust as the basic framework onto which cement mortar is plastered (Box 5.2). Like many other techniques for using cement mortar (e.g. for granary bins, NAS 1973), the technique originated in Thailand. However, it has also been used in Kenya notably in the Karai project described in Chapter 4 — but there the sacking/sawdust formwork was found rather cumbersome for large jars, and Ghala tanks were ultimately regarded as more satisfactory. It is of interest, then, that Thai innovators have recently been building cement mortar jars of $1.8m^3$ capacity ('Jumbo jars') using specially made curved bricks or blocks to construct the formwork. These blocks are themselves cast in cement, and are used repeatedly, so that many jars can be made with one set of about 90 of them. Mud is used as a 'temporary mortar' when the formwork is erected. It crumbles away easily when the tank is complete and the blocks are removed (Latham 1984a). This method is used for factory production of Jumbo jars in Thailand. Wire reinforcement is incorporated during construction, so that the jar have sufficient strength to be loaded into lorries for delivery. This makes them comparable to the ferrocement tanks built in many rural programmes.

Many other types of material can be used to make the medium-sized water storage containers suitable for collecting rainwater from the roofs of small houses. However, there has been a striking tendency in the last decade for rural development programmes to opt for cement-based materials. Unreinforced jars (including Ghala tanks) and bamboo-cement tanks have been used for sizes up to about $4.5m^3$, whilst for capacities

Box 5.2 Construction of a cement mortar jar of 1.0m³ capacity. (Institute for Rural Water, 1982)

1. The ***mould*** or ***formwork*** for a 1.0m³ jar is made from two pieces of gunny cloth or hessian sacking cut and stitched together with twine as in Diagram 1. After sewing, the resulting bottomless bag is turned inside out.

2. To make the ***bottom*** of the tank, mark out a circle on the ground 1.0m in diameter and place half bricks or other suitable material around its circumference to act as formwork. Spread paper or plastic sheeting on the ground within the circle to stop the mortar sticking. Mix a 1:2 cement/sand mortar and spread within the circle to a depth of 15mm.

3. When the bottom plate has set, place the sacking bag narrow end down on the plate and begin filling it with sand, sawdust or rice husks. Make sure the mortar base sticks out from under the sack, as in Diagram 2, and tuck the edges of the sacking under the sand or sawdust filling so that the weight of the material holds the sack onto the plate.

4. ***Fill the sack***, fold the top and tie it closed. Then smooth and press the sack into a regular shape. Make a circular ring from wood or cement mortar and place this on top as formwork for the opening in the jar. (Diagram 3).

5. Spray the sacking with water until it is thoroughly wet. Then plaster on a ***first layer of cement mortar*** to a thickness of 5–7mm.

6. ***Plaster on the second 5mm layer*** in the same manner as the first, checking the thickness by pushing a nail in. Build up any thin spots.

7. Remove the sack and its contents 24 hours after plastering is finished. Repair any defects in the jar with mortar, paint the inside with cement slurry. Then ***cure*** the jar for two weeks protecting it from sun and wind under damp sacking.

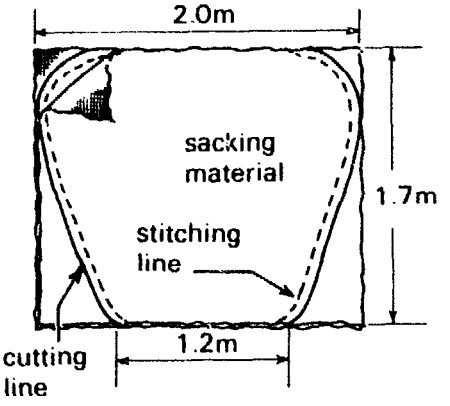

Diagram 1

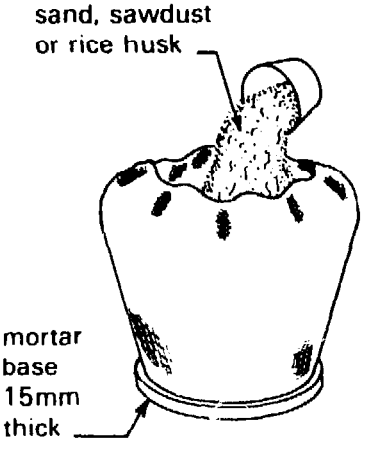

Diagram 2

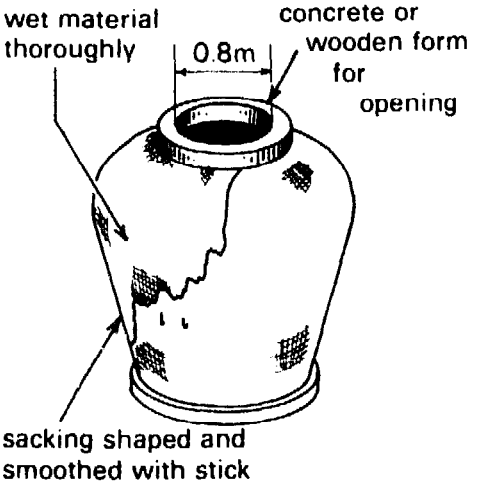

Diagram 3

Box 5.2 Construction of a cement mortar jar of 1.0m³ capacity. (Institute for Rural Water, 1982)

1. The ***mould*** or ***formwork*** for a 1.0m³ jar is made from two pieces of gunny cloth or hessian sacking cut and stitched together with twine as in Diagram 1. After sewing, the resulting bottomless bag is turned inside out.

2. To make the ***bottom*** of the tank, mark out a circle on the ground 1.0m in diameter and place half bricks or other suitable material around its circumference to act as formwork. Spread paper or plastic sheeting on the ground within the circle to stop the mortar sticking. Mix a 1:2 cement/sand mortar and spread within the circle to a depth of 15mm.

3. When the bottom plate has set, place the sacking bag narrow end down on the plate and begin filling it with sand, sawdust or rice husks. Make sure the mortar base sticks out from under the sack, as in Diagram 2, and tuck the edges of the sacking under the sand or sawdust filling so that the weight of the material holds the sack onto the plate.

4. ***Fill the sack***, fold the top and tie it closed. Then smooth and press the sack into a regular shape. Make a circular ring from wood or cement mortar and place this on top as formwork for the opening in the jar. (Diagram 3).

5. **Spray the sacking** with water until it is thoroughly wet. Then plaster on a ***first layer of cement mortar*** to a thickness of 5-7mm.

6. ***Plaster on the second 5mm layer*** in the same manner as the first, checking the thickness by pushing a nail in. Build up any thin spots.

7. Remove the sack and its contents 24 hours after plastering is finished. Repair any defects in the jar with mortar, paint the inside with cement slurry. Then ***cure*** the jar for two weeks protecting it from sun and wind under damp sacking.

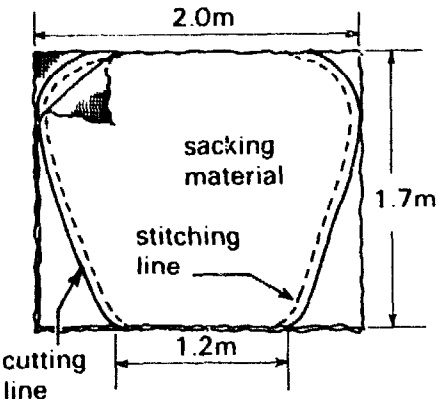

Diagram 1

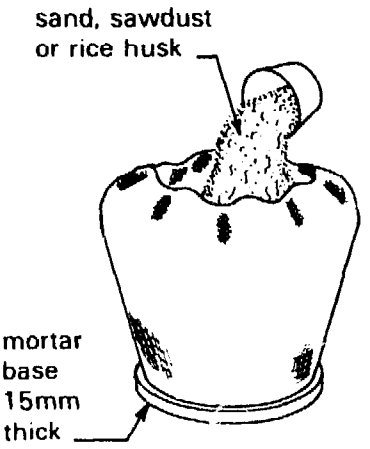

Diagram 2

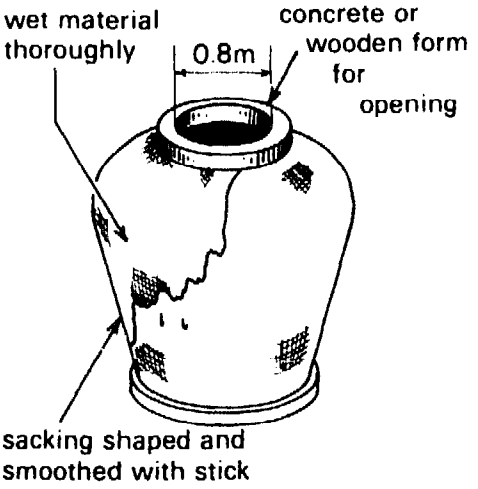

Diagram 3

between 5 and 12m^3, cylindrical tanks are the norm, and are made of ferrocement or concrete.

Outside rural development work, however, it needs to be remembered that galvanized corrugated iron tanks are often available in this range of sizes and are probably more widely used than any other type. Tanks built of brick are widespread in some countries, and there are also more exotic materials (including fibreglass). In addition, there are butyl rubber liners supported by metal frames or other containers. In Jamaica, for example, metal silos for storage of animal feed are available much more cheaply than metal water tanks, and to provide water storage they can be fitted with a butyl or other plastic lining (Maddocks 1973). In Senegal, similar linings have been used to turn large mud-walled grain bins into water tanks (UNESCO 1981).

Reasons why ferrocement or other cement-based materials are so often preferred include favourable experience of their use in village conditions and with self-help construction. However, costs are also lower and the tanks may last longer than other types. The short life of many corrugated metal tanks is frequently commented on (e.g. by Layton 1984), but the problem is usually one of faulty installation — physical damage to the galvanised surface, lack of a firm and well-drained foundation, and the use of electrolytically incompatible metals for pipes or other fittings. In Kenya, metal tanks last for ten years when properly installed on a raised platform.

Galvanized corrugated iron tanks also have merits when looked at in terms of social benefits and livelihoods. In many areas they are the most readily available tanks for those householders able to purchase at full market prices, and in some places — including parts of Kenya and Papua New Guinea — their construction provides jobs for significant numbers of 'tin-smiths'.

It is impossible to quote cost figures that are applicable to all countries. Cement prices, transport costs and inflation rates vary, and policies for employing craftsmen and/or self-help labour on site also differ from one programme to another. Table 5.2 quotes some figures for West Java (Indonesia) together with some interpolated data from Africa and Thailand which seem very roughly comparable. Cement-based tanks are the cheapest option almost everywhere. The figures for unit storage also indicate economies of scale which will show up in any programme. Where people can only afford relatively small tanks, it makes sense to investigate the costs of bamboo-cement and Ghala tanks. Despite evident low costs in comparison with other 2.5m^3 tanks, their unit costs are not especially attractive — big ferrocement tanks may sometimes be cheaper per cubic metre of storage capacity.

The chief exception, where a small tank appears to defeat the scale factor, is the Thai Jumbo jar of 1.8m^3 capacity. It is economical in its use of materials, and costs are also kept down by factory methods of construction.

Table 5.2 Comparative costs for different kinds of rainwater tank (1981–2 prices).
The majority of figures are Doelhomid's estimates for West Java, Indonesia (1982), quoted in U.S. dollars and including labour costs. Figures given by Keller (1982) are set in brackets to emphasize that they are not precisely comparable with the West Java data, and brackets are also used for figures from Thailand (Fricke, 1982; Power, 1983)

TYPE OF TANK	Tank capacity 2.3–3m³		Tank capacity 9–10m³	
	total cost	unit cost per m³	total cost	unit cost per m³
Fibreglass	400	160	1800	180
Sheet metal	-	-	900	90
Galvanized corrugated iron	(150)[a]	(60)[a]	(350)[a]	(35)
Ferrocement - West Java type	94	38	200	20
Ferrocement - Zimbabwe type				
materials only	-	-	(150)[b]	(15)[b]
materials & labour	-	-	(220)[a]	(22)[a]
Bamboo-reinforced concrete (Thailand)				
materials only	-	-	(135)[c]	(14)[c]
materials & labour (contractors' price)	-	-	(306)[c]	(32)[c]
Bamboo-cement (West Java type)	70	28	-	-
Ghala tank (Kenya) materials only	(42)[b]	(18)[b]	-	-

[a] authors' estimates
[b] Keller (1982) basing his estimates for the ferrocement tank on Watt (1978) and for Ghala tanks on 2.3m³ capacity
[c] Fricke (1982) and Power (1983) for a 9.4m³ tank

At 1984 price levels, one of these jars would cost the equivalent of US$23, which implies a unit cost of less than $13 per m³ (Latham 1984a). That is lower than any unit cost in Table 5.2, despite the rise in prices since the data for the table were collected. The large bamboo-reinforced concrete tanks which are also built in Thailand have unit costs around twice those of the Jumbo jar yet show some of the lowest costs in Table 5.2. Probably the figures from other countries are not comparable, but details of the Thai bamboo-reinforced tanks to be given later indicate that their low cost is due partly to a relatively small requirement for cement as well as to the absence

of metal reinforcement. Rather elaborate formwork is used, however, and so average costs are only low when the formwork is re-used and its cost spread over many tanks.

For tanks with capacities larger than $15m^3$, such as might be needed to collect rainwater from the roof of a large public building, ferrocement remains a possibility (Watt 1978), but brick, stone or cement block construction are also widely used. Such tanks or reservoirs are often built in shallow excavations so that the mass of soil against the tank walls helps withstand the water pressure inside. Where excavation is decided on, however, the cheapest option for a large volume of storage may well be simply to line the sides of a hole with ferrocement, as described previously (see Fig. 4.6). Other forms of excavated storage which might be considered are discussed at the end of this chapter.

Brickwork deserves more detailed consideration not only because of its regular use for building tanks in some countries, but because under certain conditions, it lends itself to very low-cost forms of construction both for small and large tanks. Indeed, costs for brickwork have been omitted from Table 5.2 because of their great variability from place to place. In West Java, a $10m^3$ brick tank costs nearly twice as much as a ferrocement one (Doelhomid 1982), but in Zimbabwe, ferrocement tanks are no longer built by the Hlekweni Training Centre (Table 4.1) because brickwork is cheaper. This is due to the availability of locally fired bricks and cheap broken bricks.

However, trial designs for brickwork tanks have been developed in West Java, and Figure 5.6 shows some structural detail. A quite different type of brick construction which has been used in Zimbabwe is also presented in the same diagram. This latter illustrates the use of steel reinforcing wires to strengthen the tank against the internal water pressure. There is a double skin of brickwork which is built in stages, beginning with three or four courses of the inner skin of bricks. When these are in place, reinforcing wires are drawn tightly round the tank at the points shown, and fixed in place. Then the outer skin is raised by three courses and the space in between is grouted with mortar before the inner brickwork is built up any further. This form of reinforcement is suited to a large tank, in this case of $25m^3$ capacity containing a 2m depth of water. The low-cost brick tanks now being built in Zimbabwe are not identical but they also incorporate wire reinforcement. By contrast, the West Java design in Figure 5.6 is for a much smaller tank ($2.2m^3$) with water depths no greater than 1.2m (though Kerkvoorden quotes 1.5m). There is no wire reinforcement but a fairly substantial foundation helps take up the water pressure. Both tanks are made watertight by applying a cement plaster to the inside of the walls, and when this has set, by brushing it over with a thick cement slurry. However, the floor is dealt with differently in the two instances. The Zimbabwe tank (Fig. 5.6b) has a heavy concrete floor slab which is plastered like the walls

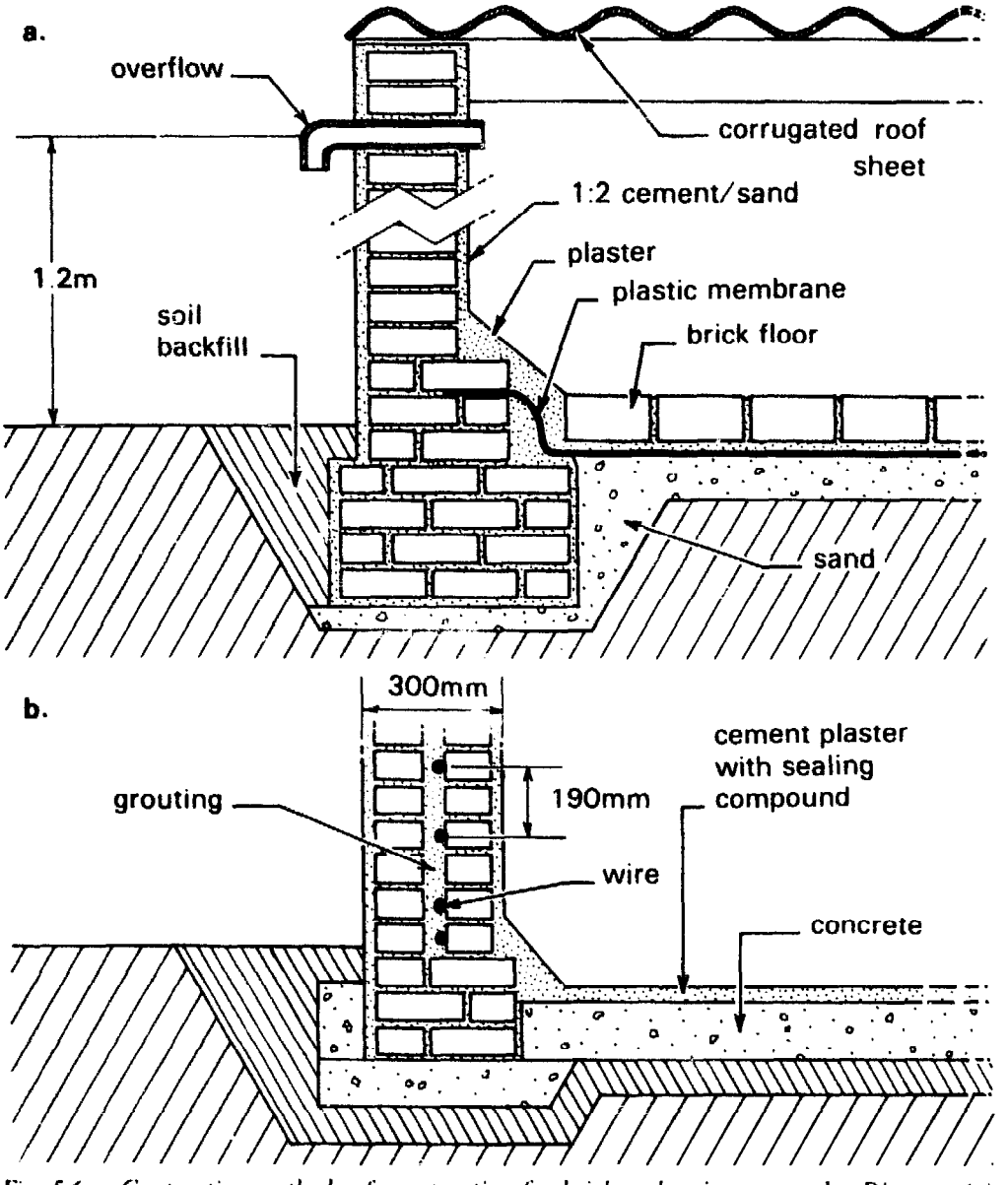

Fig. 5.6 Contrasting methods of construction for brickwork rainwater tanks. Diagram (a) shows a small tank built in West Java, Indonesia without reinforcement. (Kerkvoorden 1982) The other diagram (b) is a detail of a larger tank designed in Zimbabwe with wire reinforcement between two skins of brickwork. (Hall 1975)

Note: *Bricks are not of standard size.*

and then painted with a proprietary sealing compound. The West Java tank has a brick floor with a plastic membrane below it.

Cylindrical tanks constructed in brick are widely used in East Africa (UNEP 1983), and Nissen-Petersen (1982) describes the use of concrete blocks to build similar tanks in Kenya. Again there are reinforcing wires encircling the tank, this time set in the mortar between the courses of blockwork. More typical of Kenya are *matofali* tanks, that is, made of locally burned brick. They are typically of about $10m^3$ capacity and are to

be seen at the homes of wealthy farmers and in larger sizes are used for collecting water from the roofs of public buildings.

Rainwater tanks built with blocks of coral and lined with locally made cement are to be seen on Wasini Island, off the coast of Kenya (Gould 1983), and tanks with limestone walls are widely used in Jamaica. Despite annual rainfall of 1500mm, parts of Jamaica have a highly permeable limestone such that conventional surface and groundwater sources cannot be developed. Many individual houses have tanks collecting water from roofs, and there are also large public tanks or reservoirs filled from ground surface catchments, some with capacities up to $500m^3$.

The household tanks are built partly or wholly below ground level and water is drawn from them using buckets or pumps. Because of the permeability of the stone, a waterproof lining of cement or marl is needed. Tanks tend to be large, and Maddocks (1973) quotes costs of construction for one of $27m^3$ capacity which include a high charge for the labour involved in excavation (US$311 at 1973 prices). After that, construction of the tank itself costs US$989 — which is a large sum even by the standards of the 1981-2 prices in Table 5.2.

DESIGN CRITERIA AND CEMENT-BASED MATERIALS

It is clear from previous paragraphs that a decision about construction methods and materials for any tank-building programme is closely linked to the decision about the capacities required, and that both are closely constrained by cost. It might appear that a choice concerning capacity should be determined by the available catchment area and the rainfall pattern in the area. However, the limitations of hydrological analysis were made clear in Chapter 3. Tanks in low-income communities are nearly always smaller than the hydrological optimum. Therefore, all that is needed from hydrology in most cases is a rough guideline that will prevent money being wasted on an occasional over-large tank that never fills. In Botswana, for example, although Gould (1983) quotes sophisticated hydrological calculations, for many purposes he is content to use a simplified rule to the effect that tank capacity (in m^3) should not be more than about 0.2 times the catchment area (in m^2). Local experience in other regions will suggest similar rules of thumb, perhaps with larger multipliers where rainfall is higher.

Thus, hydrology merely provides an upper limit on the choice of tank capacities and other criteria are basically more important. They include questions about what people can afford, what employment opportunities are created, and what technical assistance can be provided. Where employment is a consideration and it is intended that tank constructors should run their own business, we have noted that $6m^3$ ferrocement tanks have been successful in the North Solomons and $2.3m^3$ Ghala tanks have

potential in Kenya; we have also seen that in many countries, there is a place for galvanized iron tanks as well. However, where technical assistance is directed toward training villagers or community workers to help house-holders build their own tanks, it is more important to consider which types of construction are easiest to teach to inexperienced people. In this context, Keller (1982) picks out three types which he regards as especially 'teachable', as follows:

- unreinforced cement mortar jar, 1.0m^3 capacity (see Box 5.2);
- plastered Ghala basket, 2.3m^3 (Box 3.1);
- ferrocement tank, 9m^3 (Box 4.1).

Choice of tanks for their 'teachability' does not, of course, automatically lead to the lowest possible costs. As already noted, brickwork may be a cheaper form of construction than ferrocement where bricks are locally made, or alternatively, bamboo-cement tanks may seem the best low-cost option.

At this point, however, there are other criteria which ought to influence the choice of tank. Bamboo-cement tanks in Indonesia have not proved very durable, and many have lasted for less than five years. Doubts have also been expressed about Ghala tanks. It is probable that much depends on good workmanship with both these types, and on whether adequate curing of the cement mortar is possible. Curing depends on preventing tanks from drying out during a 7-14 day period after construction by pouring some water into the tank, shading it from the sun, and draping damp sacking or cloth over exposed areas. In districts where water is short and people cannot give frequent attention to keeping sacking damp, curing is often poor and tank failures are frequent. In such circumstances, bamboo-cement or Ghala tanks are perhaps inadvisable. Instead, forms of construction should be chosen in which tanks are over-designed and so would be much stronger than necessary if good workmanship and adequate curing could be guaranteed. Tanks which most conspicuously demonstrate tolerance of bad curing are those built of concrete, including bamboo-reinforced types in Thailand and concrete ring tanks in Kenya. However, concrete construction may not be a low-cost option in places where a suitable aggregate cannot be easily obtained.

A final point concerns the type of technical assistance in which some components are supplied to villages from a central depot. Where specially-made formwork is required, as with most concrete tanks, and also with the ferrocement tank described in Box 4.1, this must nearly always be supplied on loan as part of the technical assistance programme. It may also speed up construction if some materials are prepared centrally. For example, chicken wire for ferrocement tanks might be cut to length, or bamboo reinforcement could be prepared this way with benefits for quality control.

In Indonesia, where hundreds of rainwater tanks are now made each year, methods of this sort are being introduced to speed up production. Where tanks are made from pre-cast concrete rings, it will usually be an advantage to establish a central site in a village where rings can be made for households in the immediate vicinity.

To sum up then, criteria influencing the design of tanks for collecting rainwater from house roofs should include the following:

- cost;
- availability of materials (e.g. aggregate, bamboo, local brick);
- employment opportunities;
- 'teachability' and the organization of technical assistance;
- adequate curing of cement mortar;
- design tolerance for bad workmanship;
- possible supply of components from a central depot;
- hydrology as a check on maximum capacities.

Whilst construction procedures for the three most 'teachable' methods of building rainwater tanks have already been described in the information boxes, it remains to list the materials required, which is done in Table 5.3. When tanks are built by their prospective owners, and where suitable sand and aggregate can be obtained locally, the biggest factor in the total cost of a tank is the amount of cement needed, and the metal components such as pipes, taps and wire reinforcement. Table 5.3 quotes the number of 50kg bags of cement required per cubic metre of water storage in the completed tank. The authors of this book have collected data on cement requirements for a much larger range of tank sizes and types, and it is clear that there are some definite economies of scale involved. Whether made of ferrocement or concrete, tanks larger than $7m^3$ in capacity never require more than 1.4 bags of cement per cubic metre of storage, whereas cement mortar jars and Ghala tanks with less than $3m^3$ capacity all require more than 1.7 bags and often as much as 2.0 bags of cement per cubic metre. Among the smaller tanks, the Thai Jumbo jar is exceptionally economical in cement. However, according to Kaufman (1983), the bamboo-cement tanks built in Indonesia require 1.8 bags/m^3, so whilst they economize by using bamboo instead of metal reinforcement, they do not show savings in cement. Concrete often appears to be a costly form of construction (Kerkvoorden 1982), but bamboo-reinforced concrete tanks in Thailand and Kenya require somewhat less cement than ferrocement tanks of similar capacity. The walls of the Thai tanks are three times thicker than the walls of equivalent ferrocement but the extra bulk is accounted for by the gravel aggregate used in the concrete.

It should also be noted that lists of materials required to build a tank include some allowance for wastage. In Thailand, metal boxes were made

Table 5.3 Materials needed for the construction of some widely used types of rainwater tank. (Watt, 1978, Fricke, 1982, Keller, 1982, and sources quoted in the information boxes referred to)

	Unreinforced cement mortar jar, as in Box 5.2	*Ghala tank, as in Box 3.1*	*Ferrocement tank, as in Box 4.1*	*Bamboo reinforced concrete tank as built in Thailand*
Capacity	1.0m³	2.3m³	9.0m³	11.3m³
Local materials	rice husks, sawdust or sand to stuff sacking formwork	woven stick granary basket - murram or clay		bamboo
Special requirements	hessian sacking 4m x 1.7m		corrugated iron formwork	metal formwork as in Figure 5.9
Cement (50kg bags)	2 bags	5 bags	12 bags	13 bags
Sand	200kg	500kg	1300kg	1300kg
Gravel, 25mm	-	200kg	500kg	2000kg
Quarry chippings	-	300kg	-	800kg
Chicken wire 50mm mesh	-	-	16m²	-
Straight wire, 2.5mm gauge	-	-	200m	-
Water pipe, 15mm	-	1m	2m	1m
Overflow pipe, 50mm	-	-	0.2m	0.2m
Taps	-	1 no.	1 no.	1 no.
Roof or lid	made of wood or cement mortar	cement mortar	6m² sheet metal	concrete
Bags of cement per m³ storage	2.0	2.2	1.3	1.15

for measuring out materiais for bamboo/concrete tanks, to ensure that the required 1:2:3 proportions by volume of cement, sand and gravel were adhered to when the concrete was mixed. Experience shows that this has cut waste so effectively that the cement requirements for an 11.3m^3 tank has been reduced from 14 to 13 bags (Fricke 1982). In other projects also it may help to use gauging boxes because specific volumes of sand and gravel are difficult to judge by shovelling. For example, if a box is made to the size 0.5 × 0.5 × 0.27m one box full of sand mixed with a 50kg bag of cement will give a 1:2 cement/sand mortar mix.

Instructions given earlier for building Ghala tanks (Box 3.1) describe how a cover for the tank is made, but similar information is not given for the ferrocement tank described in Box 4.1. In Zimbabwe, where the tanks originated, they were fitted with sheet metal covers. Corrugated iron can also be used if it is firmly fixed in place, and access by mosquitoes is prevented by cementing the spaces under the corrugations. Another technique is to make the framework for a tank roof using chicken wire supported by wooden joists. This is then covered with hessian and painted with a cement slurry. However, the most elegant way of covering a ferrocement tank is to construct the roof in ferrocement also. This may be done by leaving some of the chicken wire reinforcement protruding at the top when the walls of the tank are plastered. Then, after the walls are finished and the formwork is removed, two layers of wire mesh are placed over the tank. They are knitted into the chicken wire at the sides and tied with wire, and a square hole is cut for an access hatch. Then they are firmly supported by props and boards from below to form a shallow, dome-shaped roof, and cement plaster is applied from above. When this has set, the props are removed and the underside of the roof is plastered (Fig. 5.7).

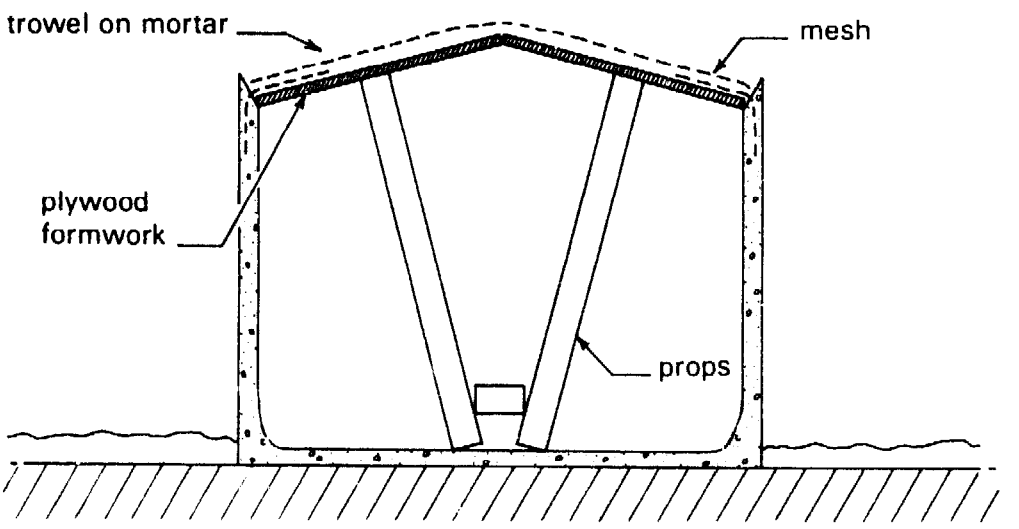

Fig. 5.7 Method of constructing a ferrocement roof for a tank of the same material. The diagram shows plywood formwork supported by props under the mesh of chicken wire reinforcement. (Watt 1978)

It is nearly always an advantage to paint exposed water tanks white to reflect the sun's heat, keep the water cool, and reduce evaporation. With ferrocement, and probably other cement mortar tanks, especially those with cemented roofs of the type just described, thermal expansion and contraction entails some risk of cracks developing. If the tank is painted white and as a result does not get so hot in sunlight, this risk will be reduced.

One other way of using ferrocement is to strengthen an existing structure and render it watertight. In Papua New Guinea, galvanized iron tanks are widely used but suffer such serious corrosion that they must often be replaced within two years. However, an alternative to replacement is to use the corroded tank as a permanent formwork within which a new ferrocement lining can be made. Using rather similar techniques, mud-walled grain bins in Mali and Senegal have been lined with ferrocement to convert them into rainwater tanks (Watt 1978; UNESCO 1981). The mud walling not only serves as formwork during construction but is retained as a permanent part of the tank, contributing to its strength and making it possible to use 50 per cent less cement than would otherwise be required in a tank of similar size.

Adobe or mud walling has also been used as purely temporary formwork. In this instance, wire reinforcement is wrapped around a cylinder of mud walling and cement plaster is applied. When the plaster has set, the mud walling is demolished and the structure is plastered from the other side.

This use of mud walling highlights an important issue surrounding the design of all the cement-based types of tank: to what extent can costs be reduced by using local materials for formwork or to replace metal reinforcement? Apart from mud, local wood or fibre may be used. Ghala tanks in Kenya and bamboo-cement tanks in Indonesia are the outstanding examples, though Kerkvoorden (1982) also mentions sisal cement and experiments with palm fibre reinforcement (Ijuk cement).

As already noted, however, there is doubt about the durability of both bamboo-cement and Ghala tanks. This raises a problem of design concerning the relationship between permanent structural reinforcement and the temporary formwork used during construction. The role of any reinforcement in a completed tank is to take up tensile stresses, but not by itself to provide stiffness. During construction, however, when the mortar is wet, the stiffness of the structure and its ability to retain its shape can depend either on the formwork or on the inherent stiffness of the reinforcement, or on both. Ferrocement tanks are sometimes built with very flimsy formwork such as bamboo matting, which has been used in Nepal and Indonesia (Winarto 1981). It is even possible to build them with no formwork at all (Watt 1978). In all these instances, heavy welded mesh is needed for reinforcement, or vertical rebars or angle irons are set in the floor slab so that the reinforcing system will stand up on its own like a cage

without formwork. By contrast, the method of ferrocement construction recommended earlier (Box 4.1) depends on rigid formwork, whilst the reinforcement system itself is light and could certainly not stand up on its own.

At first sight, the basket frame of a Ghala tank would appear to be reinforcement of the stiffer kind; cement plaster is applied to it without need for any formwork. However, in some instances, the Ghala basket has been plastered entirely from the inside, leaving the basketwork exposed externally. In the course of time, the basketwork has rotted, and while this appears to have led to some tank failures, in other cases the basketwork has been stripped away leaving an unreinforced cement mortar jar still capable of serving its purpose. It seems, then, that the primary role of the basket frame is to function as formwork by supporting the cement mortar during construction. No doubt it also contributes to the strength of the finished tank, but perhaps only marginally.

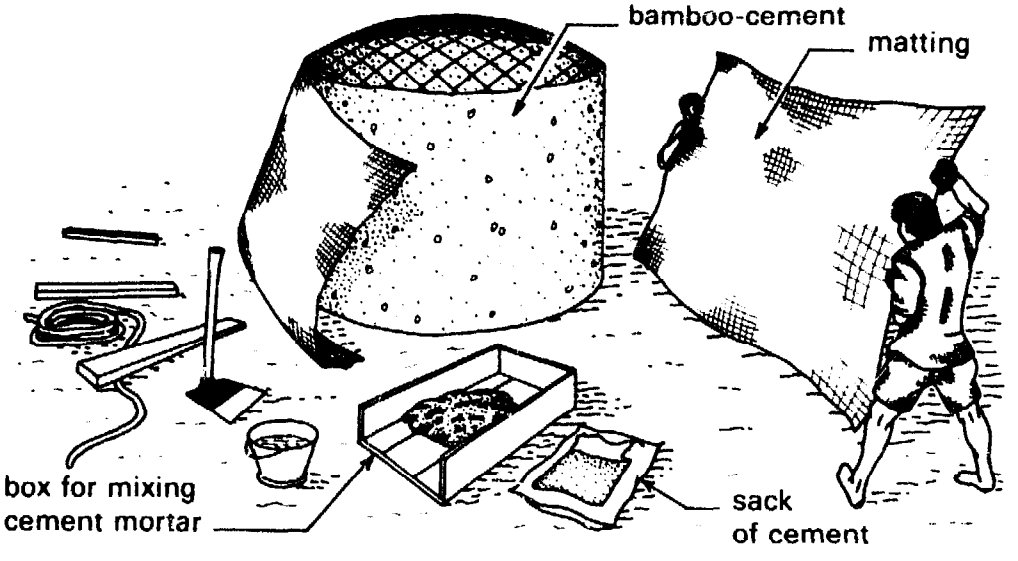

Fig. 5.8 Bamboo matting used as formwork in Indonesia. The tank is initially plastered from inside with the matting wrapped round the outside. The diagram shows the matting being stripped away after the interior plastering has been completed. The next stage is to plaster the exterior of the tank. (Kaufman 1983)

In Indonesia, the mesh of bamboo strips used in bamboo-cement tanks is designed as a true reinforcing system. The tank walls are plastered from both sides so that the bamboo is in the centre of the cement mortar mass. However, it is also clear that the bamboo reinforcement functions as a rigid frame during construction (Fig. 4.3), and the formwork used is a relatively flexible bamboo matting (Fig. 5.8). An inherent disadvantage is that if the bamboo decays, the remaining cement mortar is not a solid mass with considerable strength of its own but has voids at critical points. Because of the need for the reinforcement to stand as a rigid frame during construction the tanks may contain much more reinforcement than necessary. Initially,

Plate 1. The methodical collection of rainwater in the domestic system of a fairly affluent family in Thailand, showing funnel/filter and a flexible pipe filling the galvanized tank. (Alongside can be seen the traditional decorated clay jars, called 'dragons' fitted with lids.) (John Collett)

Plate 2. A very basic domestic system in Thailand — a split (halved) bamboo gutter directing runoff from the roof (wooden tiles) into an old oil drum. (John Collett)

Plate 3. A cement jar for rainwater collection at a house near Musani, Kenya, 1983. (John Gould)

Plate 4. A 'Ghala' basket performing the same function at Mwingi, Kenya 1983. (John Gould)

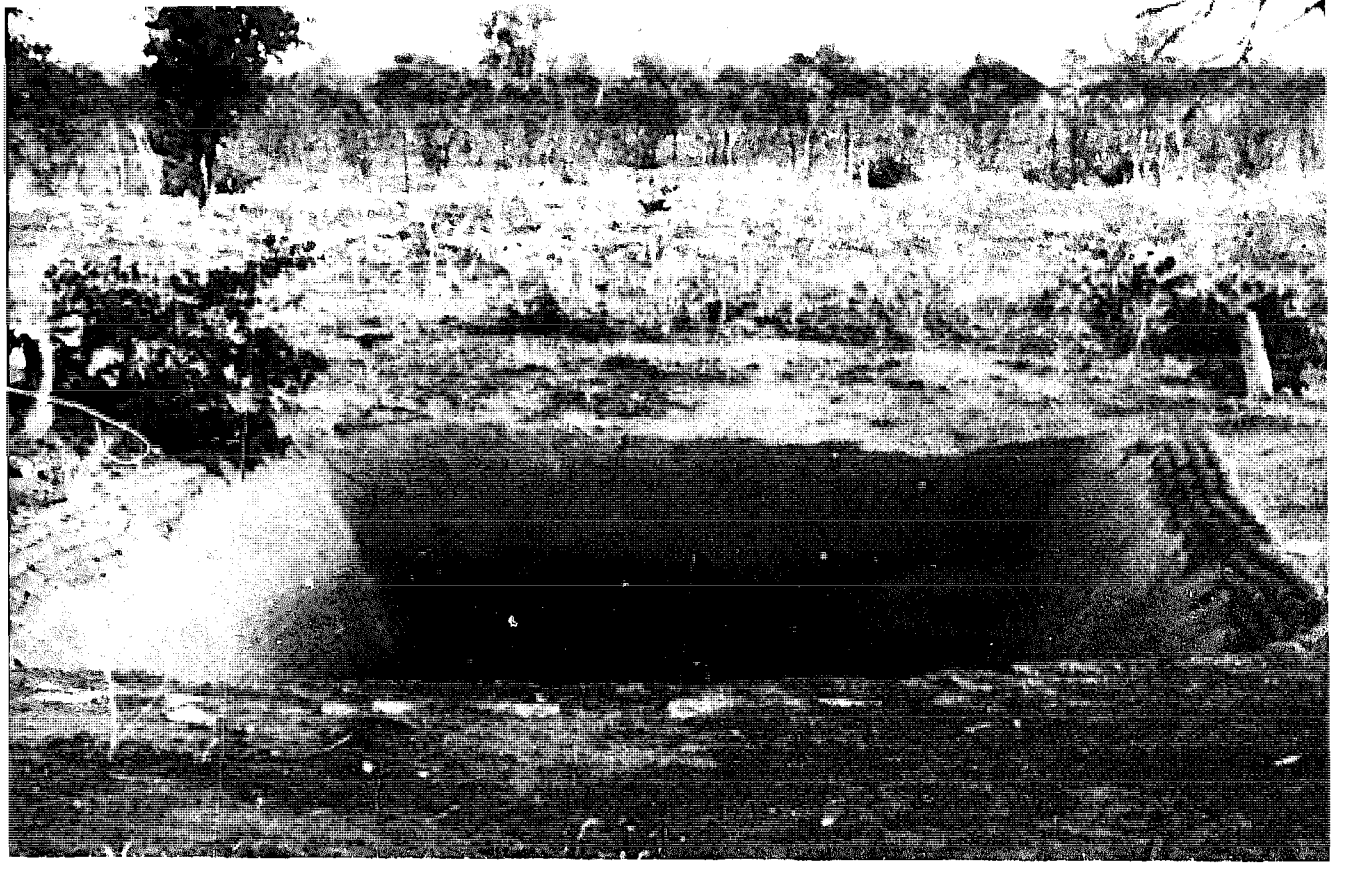

Plate 5. An excavated rainwater tank at Tamasane, Botswana, built in 1968, replastered in early 1970s and still operating in 1983. It is used to irrigate a school garden (see pages 92-3). The absence of a fence or cover can be dangerous — even tragic.

Plate 6. An excavated brick-and-cement ground catchment tank of 50 cubic metres at Morwa, near Gabarone, Botswana. (The tank was financed by money raised by the children through the school fund and the free labour of a local builder.) The tank waters the school garden in the dry season. (John Gould)

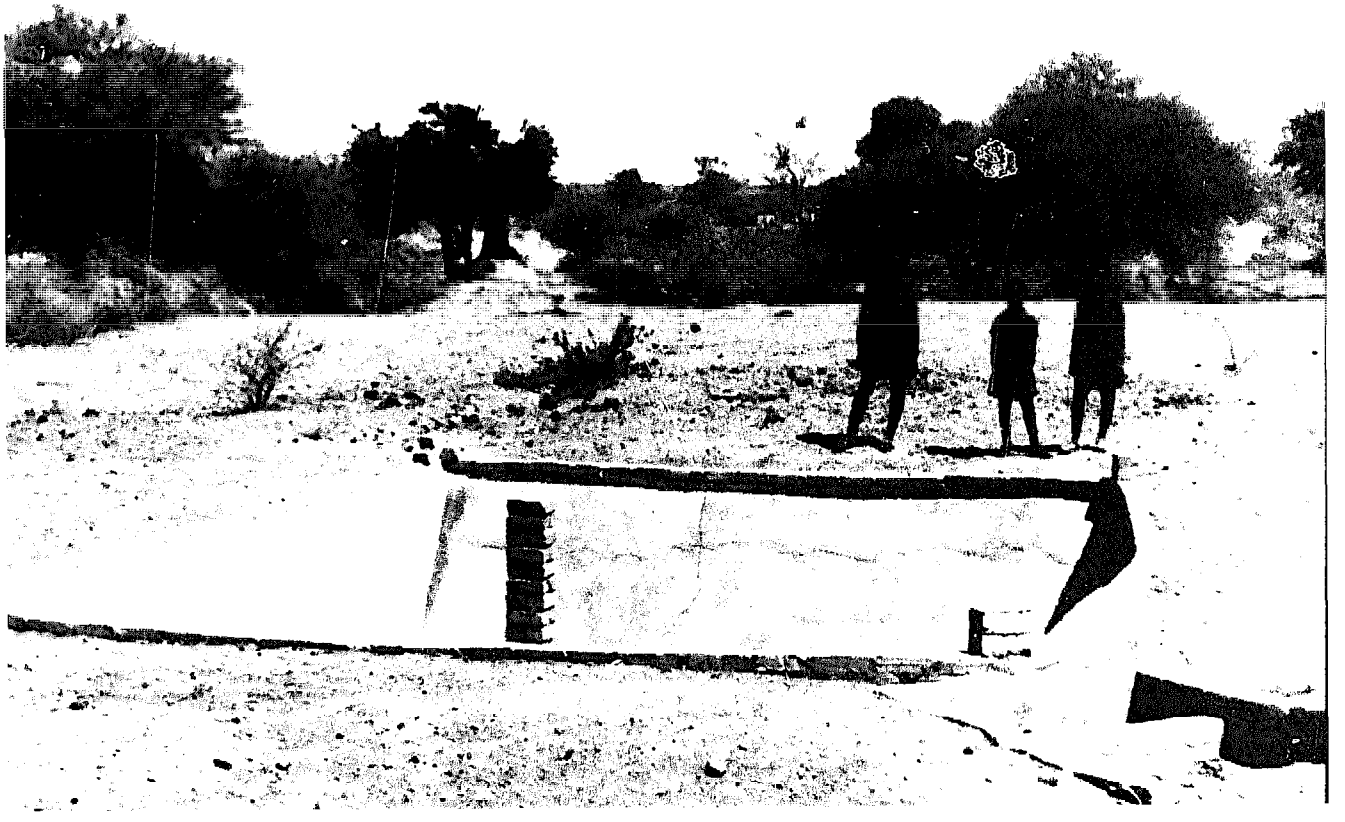

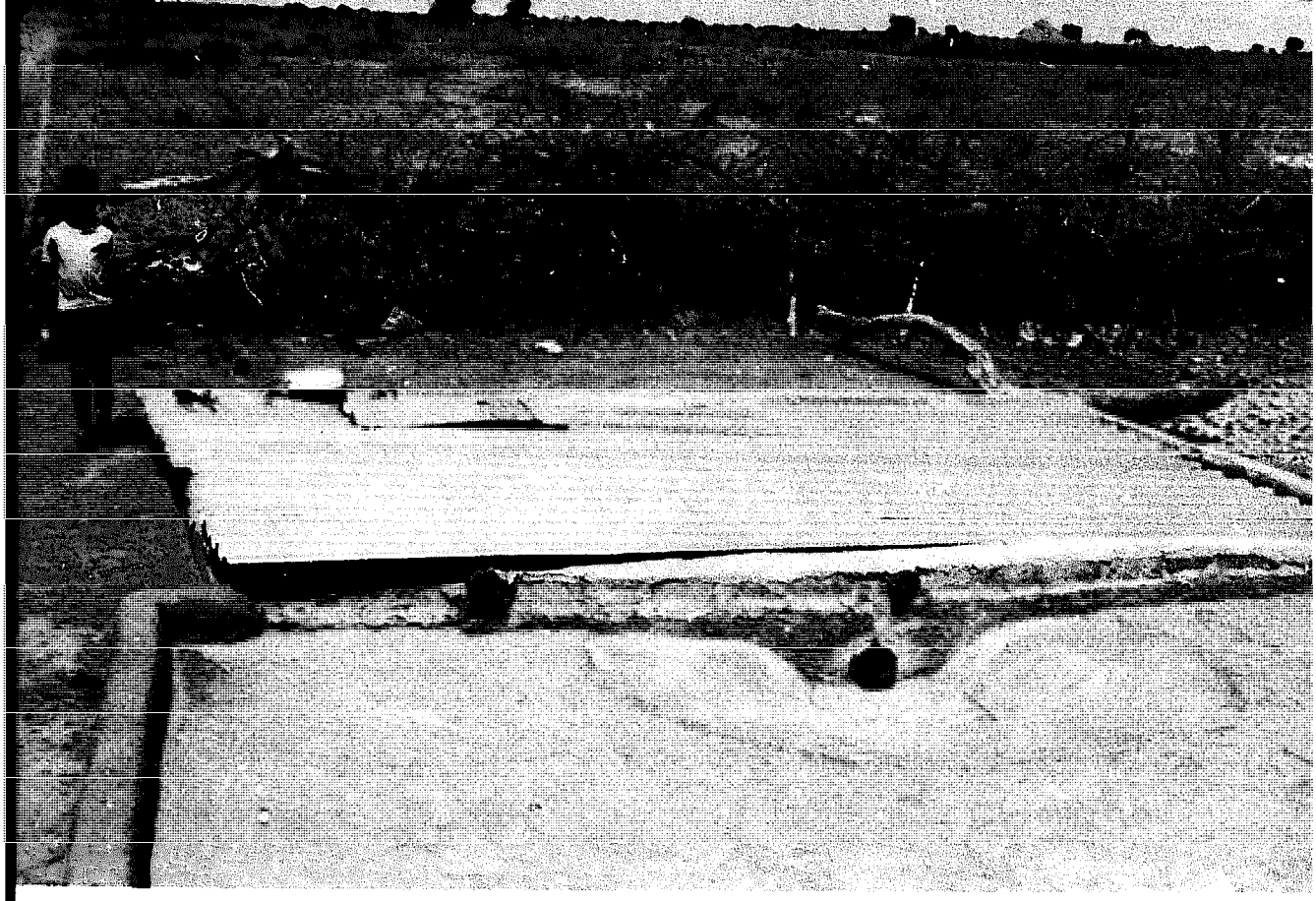

Plate 7. A corrugated iron covered rainwater catchment tank at Pelotshetlha, Botswana. The corner of the threshing floor catchment apron can be seen in the foreground. (John Gould)

Plate 8. A brick and cement rainwater catchment tank at Pelotshetla. In the background a woman can be seen smearing the threshing floor catchment apron with a mixture of dung, water and mud. (John Gould)

Plate 9. A bamboo-cement water tank, Indonesia, being plastered. The walls and floor of the tank are plastered first inside, then outside. (Ben Young)

Plate 10. A model of miniature contour barriers used in a demonstration to teach local farmers in Yatenga, Burkina Faso (see page 171).

Plate 11. Small stone barriers in Burkina Faso roughly comparable to the 'hoops' in Kenya illustrated in Figure 7.3.

Plate 12. Stone barriers for slowing sheet runoff on very gently sloping land in Burkina Faso.

Plate 13. One of a series of water-harvesting bunds built with gabion-reinforced spillways, near Lokitaung, Kenya.

Plate 14. Detail of gabion spillway construction in a bund system — part of the River Naupwala water harvesting scheme, near Lokitaung, Kenya.

then, they are stronger than need be, but if the bamboo decays they are more seriously weakened than might otherwise happen.

Many instances of failure in these tanks are attributed to decay resulting from exposure of the bamboo by accident or poor workmanship. Thus improved durability might result from rethinking the role of the bamboo reinforcement. Use of more rigid formwork during construction might open new possibilities for design. Alternatively, small tanks could perhaps be made which, like the Ghala tank, would survive the decay of the bamboo. The latter approach would mean conceiving the bamboo frame primarily as providing support during construction and applying the plaster so that the frame is no longer central to the tank walls. It might also mean modifying the shape of the tank since jar shapes are inherently stronger than cylinders. In cylindrical tanks, the junction between the vertical walls and horizontal floor is a weak point with special need for reinforcement. The benefits to be obtained by any such changes could, of course, only be assessed after observation of kinds of failure in both bamboo-cement and Ghala tanks. Ghala tanks can be and have been made with bamboo basket frames, and it might be particularly instructive to compare their durability with that of bamboo-cement tanks.

Further light on the use of bamboo is shed by experience of bamboo-reinforced *concrete* in Thailand. The concrete consists of a 1:2:3 mix of cement, sand and gravel, and tanks built of this material are set on a 100mm thick concrete foundation slab. Concrete construction is of course based on pouring the mix rather than plastering, and so to make a cylindrical tank, formwork is needed both inside and outside the tank to contain the wet concrete. The metal formwork used in Thailand is illustrated in Figure 5.9, which also shows vertical bamboo culms serving as reinforcement. Horizontal bamboo reinforcement, curving with the tank walls, is also incorporated. The formwork is 0.6m in height, so the walls of the tank are built in stages up to 2.4, 3.0 or 3.6m above the ground. These dimensions correspond to tank capacities of 7.5, 9.4 and 11.3m^3 and suit the high eaves level of Thai platform houses (Figs. 4.1 and 5.5).

The walls of these tanks are 100mm thick as compared with 30mm for most small ferrocement tanks. The extra thickness allows for greater tolerance of poor workmanship such as badly mixed concrete. Fricke (1982) comments that improper curing is also quite often observed but does not usually affect performance. The thick walls and bamboo reinforcement reduce potential for structural defects or load failure. This high degree of tolerance reduces requirements for constant supervision by skilled personnel. Tanks are nearly always watertight so long as the internal plastering is properly done.

Features of design which make construction easy for inexperienced people are obviously important in self-help programmes. Where gravel for making concrete is unavailable on site and a ferrocement tank is chosen as

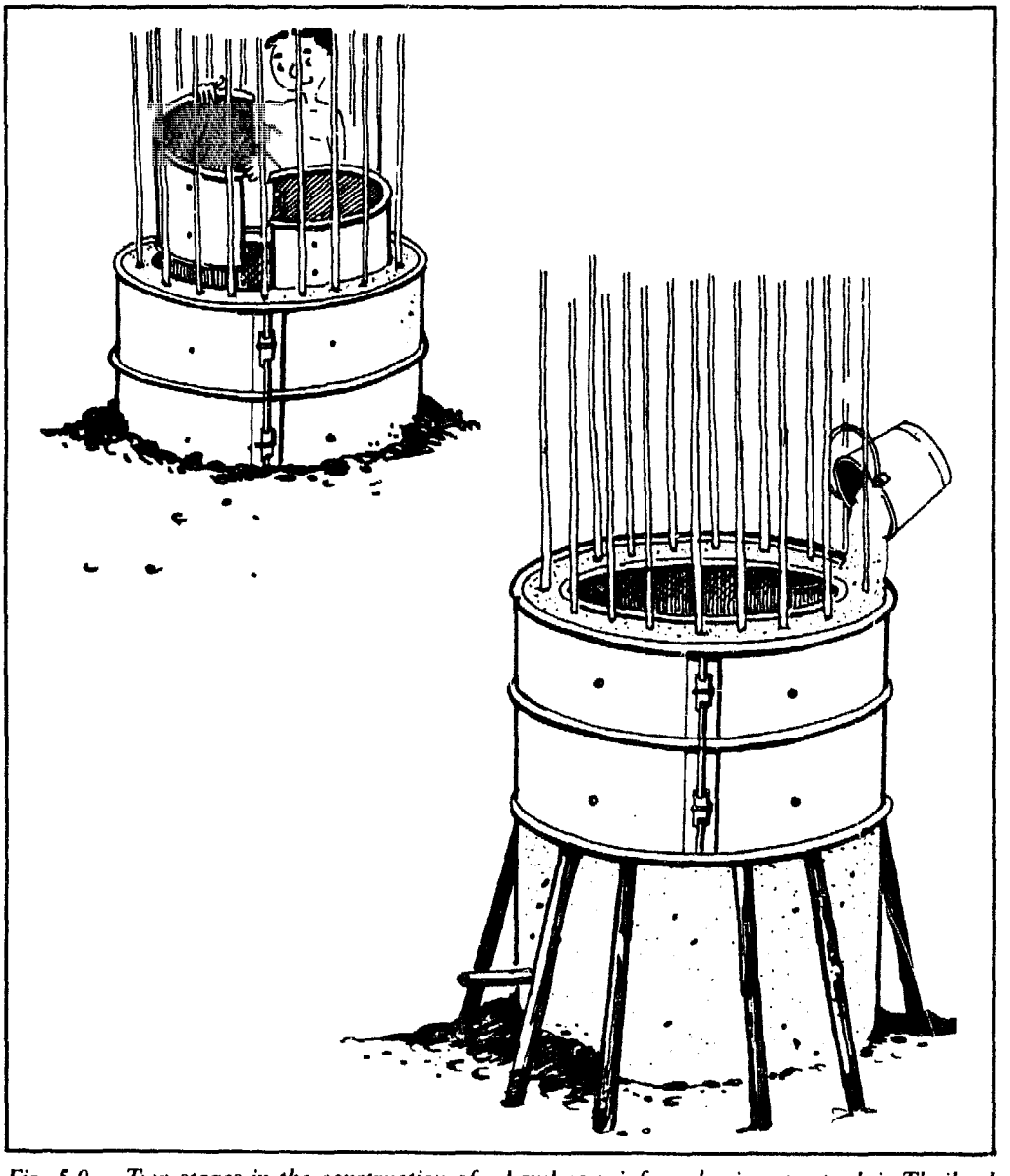

Fig. 5.9 Two stages in the construction of a bamboo-reinforced rainwater tank in Thailand showing how the concrete is poured between two cylinders of formwork, and how the formwork is raised after each 0.6m high section of the tank is completed. This illustration is from a booklet distributed by UNICEF. (UNICEF and Fricke 1982)

an alternative to concrete, the design illustrated in Box 4.1 is recommended above the many other types of ferrocement tank. This is because the corrugated iron formwork makes it easy for unskilled workers to achieve the correct wall thickness. If two layers of plaster are applied on each side to the point where the corrugations are filled up and a smooth finish is obtained, the tank walls will have a sufficient thickness (at least 30mm) at every point. However, where elaborate types of formwork are required, they must be used repeatedly to justify their cost, and so rapid construction is desirable with the formwork passed on quickly to other households where tanks are to be built.

Tests carried out in Thailand on the bamboo reinforcement confirm some aspects of Indonesian experience. For example, it is found that different species of bamboo vary greatly in strength and durability. Also, when bamboo-reinforced concrete beams were tested under load, failure was found to occur when the bond between the bamboo and the cement gave way. Bond strength could be increased significantly if the bamboo was coated with *dammar* which helps to keep the moisture content of the bamboo low (Nopmongcol *et al.* 1981).

Use of local materials to keep costs down also had implications for the types of cement and sand used. Recommendations given here presuppose that Portland cement is available, but it may often be cheaper to use local types of cement. This may entail problems which first need to be investigated. In Thailand, for example, concrete tanks are made with a local silica cement. This is recognized as a disadvantage but the over-design of the tanks means that local cement has proved satisfactory. On Wasini Island (Kenya) cement made locally from coral lime has for long been used in lining excavated cisterns and tanks built of coral blocks, though commercial cement is now more common (Gould 1983).

As regards sand, the main requirement is that it should be free from organic or chemical impurities. These would tend to weaken the mortar, and indeed, a major reason why mortar should always be mixed on a board or slab, not on the ground, is to keep it free of such impurities. If there is any doubt about local sand, it may be advisable to wash it with a large volume of water (if this can be obtained). Watt (1978) suggests that a moderately coarse sand which makes the mortar more difficult to work has the advantage of better resistance to shrinkage cracks than mortar made with a fine sand.

EXCAVATED RAINWATER TANKS

Excavations used for rainwater storage are of three main types: 'hafirs', catchment tanks and underground cisterns. Hafirs are chiefly used to provide water for livestock (Fig. 2.1), and hence are outside the scope of this chapter on domestic rainwater collection.

Excavated cisterns, often cut in soft rock below harder layers capable of forming a roof, are to be found in large numbers in the Middle East and North Africa, and also in parts of central America (Fig. 1.2). However, most are very old and there are few instances of new construction. In the Negev, excavated cisterns were made under the floors of individual dwellings, both in towns and at isolated farmsteads. These household cisterns were usually of 5-10m^3 capacity, that is, of much the same size as many of the domestic rainwater tanks currently built. Much larger cisterns were also excavated for community water supply and for livestock.

Almost the only examples of underground cisterns recently constructed in

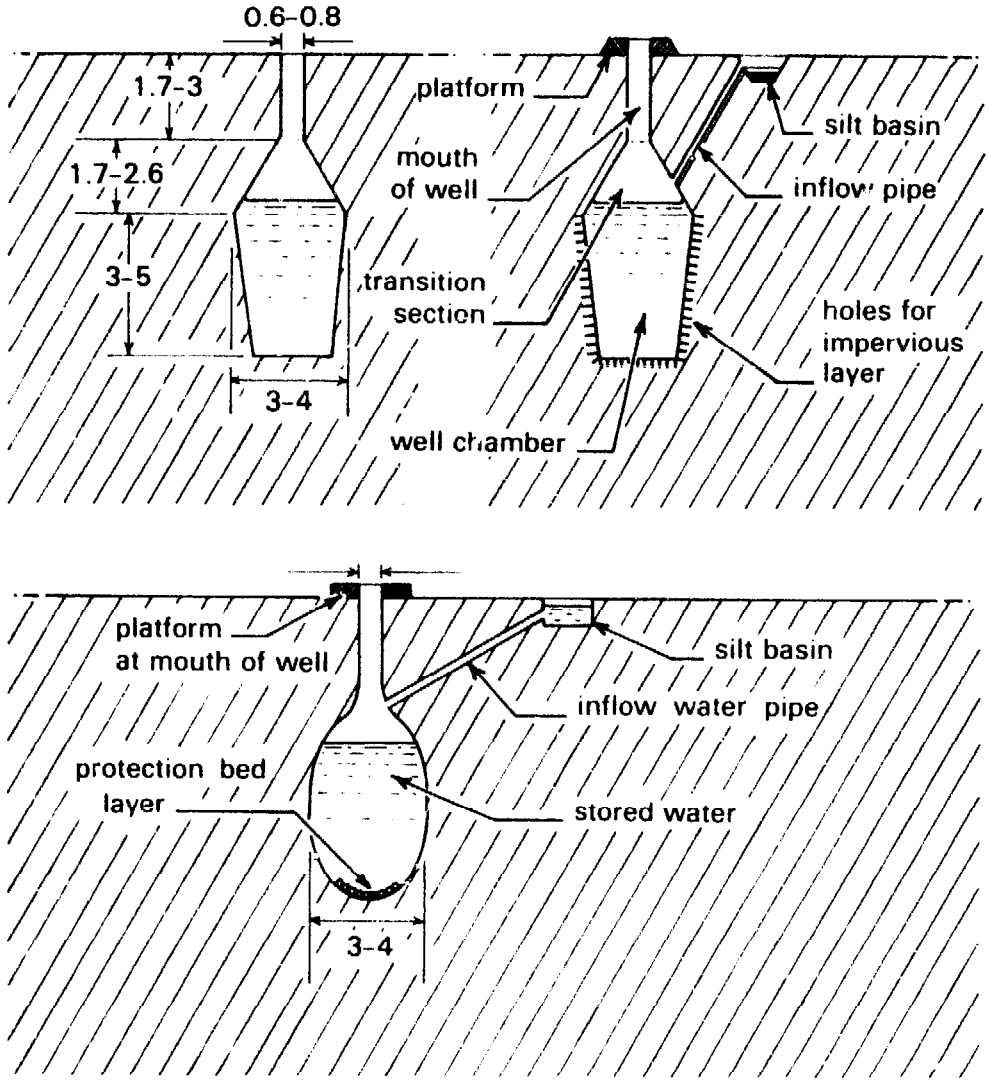

Fig. 5.10 Cross sections of underground rainwater cisterns in the Gansu and Shanxi provinces of China. (Dimensions are in metres.) (UNEP 1983)

large numbers are those reported from China (UNEP 1983) and referred to as 'water storage wells' (Fig. 5.10). These are chiefly confined to loess plateau regions but are very numerous there. In one part of Shanxi Province, 45,000 such cisterns were constructed between 1970 and 1974. In many villages, each household has its own cistern which consists of a jar-shaped or kiln-shaped cavity excavated in the cohesive loess subsoil to a depth of as much as 10m and with a storage capacity around 15m^3. The soil has a low permeability, but even so, cisterns are usually plastered inside with a lime-clay mixture to make them watertight. Sites are chosen so that the cistern can be filled by runoff from yards, roads, barren ground surfaces and house roofs. Water flows into the tanks via small silt-trapping basins.

Although well-digging techniques have occasionally been used to construct rainwater cisterns elsewhere, for example in Zimbabwe (See

figures in Pacey *et al.* 1977), excavated water storage in the rural development context has nearly always been conceived in terms of relatively shallow catchment tanks, or small dams on rock surfaces or steep slopes. Other types include *nadis*, or artificial ponds in the Rajasthan arid zone in India (Sharma and Joshi 1981) and *telegas* in Indonesia. The latter are constructed in karstic limestone by lining natural sink holes with mud or clay, supported by bamboo framing over large cavities. Water is collected from small areas of unimproved hillside catchment — typically 1000m^2 in extent — and is used for domestic and livestock purposes. Traditionally there was also some fish farming in these 'tanks'. More recently, telegas have sometimes been deepened, holes in the bottom have been concreted over, and the whole interior lined with clay.

Modern catchment tanks are typically about 2m deep and are used for domestic water supply chiefly where house roofs are either unsuitable for rainwater collection or provide insufficient storage area. An instance which has been given much publicity (UNEP 1983) concerns a purely hypothetical scheme for Manda Island, off the Kenya coast, but more realistic examples are to be found on Wasini island, further south on the same coastline (Grover 1971). This coral island has already been mentioned because of the large number of household rainwater tanks in use there. In addition, however, there are two large excavated catchment tanks which provide public supplies. One has been in continuous use since the early 1950s: it has a ground surface catchment about 1,000m^2 in extent with a smooth concrete finish. The other excavated tank was completed in 1969 and has a capacity of 300m^3 with a lining of butyl rubber sheeting. The catchment was levelled using spoil from the excavation. Its area of 1,500m^2 was not determined by hydrological calculation but rather by the amount of spoil. The levelled surface was stabilized by mixing cement with topsoil and rolling, and was sealed by spraying asphalt in kerosene (Grover 1971).

The chief technical problems associated with this type of drinking water supply are lining and roofing the tank and protecting the water from contamination. Whilst butyl rubber is frequently used for lining excavated tanks and in some regions may be the cheapest method, the ferrocement lining described in Chapter 4 (Fig. 4.6) is likely to be more durable. The roofing of tanks to reduce evaporation and prevent contamination is a much more intractable problem. On Wasini Island, the tank built in 1969 was provided with a cover of butyl rubber sheet supported by ropes. Holes were made in the cover at intervals so that rainwater would not accumulate on it and weigh it down. However, this did not prove satisfactory. The cover sagged and tore and soon failed completely. Like the older tank on the island, it now has a pitched corrugated iron roof of 18m span (Gould 1983).

The two Wasini tanks differ markedly in the precautions taken to prevent contamination. The catchment area of the older tank is

surrounded by a high wall topped by broken glass, and the catchment surface is regularly swept clean. Water from the tank is sampled every two weeks to check on its quality. By contrast, the newer tank, situated in a large village some distance from the main settlement, has no fencing around its catchment and goats wander about at will. The surface is visibly contaminated by goat droppings and other debris. The water from this tank is sampled regularly also, but the results have not yet led to a demand for fencing of the catchment.

In Botswana, ferrocement-lined rainwater tanks have been given flat roofs of corrugated iron supported by poles (Fig. 4.6). This is a durable and effective means of reducing evaporation losses, but the tanks are still open to contamination. More satisfactory, though limited to small tanks of circular shape, is a ferrocement cover reported from the New Hebrides islands in the Pacific. This cover is of a domed shape and is constructed *before* excavation of the tank is begun. First, a circular earth mound is made for use as formwork in constructing the dome. Chicken wire is spread over it and pegged down, then plastered with cement to a thickness of 50mm. Two man-holes of 0.6m diameter are left in the plaster. When the cement has set and cured, excavation begins with men removing spoil through the holes. The excavation is finally lined with ferrocement in the same way as the Botswana tanks (Calvert and Binney 1977). Similar ferrocement linings for excavated tanks have also been used in Kenya (UNICEF 1984).

Whilst there is still much to do in refining designs for rainwater tanks, particularly in reducing costs and devising satisfactory ways of covering them, it is clear from this chapter that a good range of well-tried technical options now exists. The constraints which limit their use in many countries are therefore not strongly related to limitations in the technology — the problem, as we saw in the previous chapter, is more commonly due to inadequate organization and technical assistance.

6. TRADITIONS IN RUNOFF FARMING

CROPPING WITH SUMMER RAINFALL

The World Bank (1984) has commented that none of its economic statistics 'can convey the human misery spreading in sub-Saharan Africa'. Since 1970, food production has stagnated in many areas or has increased only slowly, and grain output per capita has shown a steady downward trend (FAO 1983, World Bank 1984). In 1984, 'abnormal' shortages were reported in 24 countries, with famine conditions attributed to drought in several of them. It is with a considerable sense of urgency, then, that one notes the relevance of rainwater collection techniques in certain limited but significant areas of Africa, both for food production and for the conservation of eroding soils. Kutsch (1982) has reviewed climatic and soil conditions with a view to identifying areas in which the prospects for rainwater concentration and runoff farming seem good, and when his recommendations for Africa are plotted on a map (Fig. 6.1), it is striking that they coincide quite closely with the areas which have experienced food shortages in 1983-4.

However, there has been no serious investigation of the potential of runoff farming in many of these areas. This reflects another of the World Bank's comments, about 'weaknesses of agricultural research'. Information about existing traditions of runoff farming is inadequate nearly everywhere. Sometimes the only well-documented information has been provided by anthropologists and geographers (e.g. Morgan 1974) and agriculturalists have made no contribution at all. By contrast, much more research has been done in India, where some very large runoff farming systems exist (Kolarkar *et al.* 1983), but this is insufficiently appreciated elsewhere. Similar comments can be made about 'micro-irrigation', the range of techniques which allows restricted volumes of water (such as rainwater tanks can provide) to be used for vegetable production (NAS 1974; Gibberd 1969), or for early planting of rain-fed crops (Ray 1983), though it will not be possible to detail these techniques even here.

The use of rainwater in runoff farming is only one of a number of approaches to land and water management which together might contribute to a slow recovery of pastoralism, crop production and forestry in drought-prone areas. Its potential varies according to local climate and

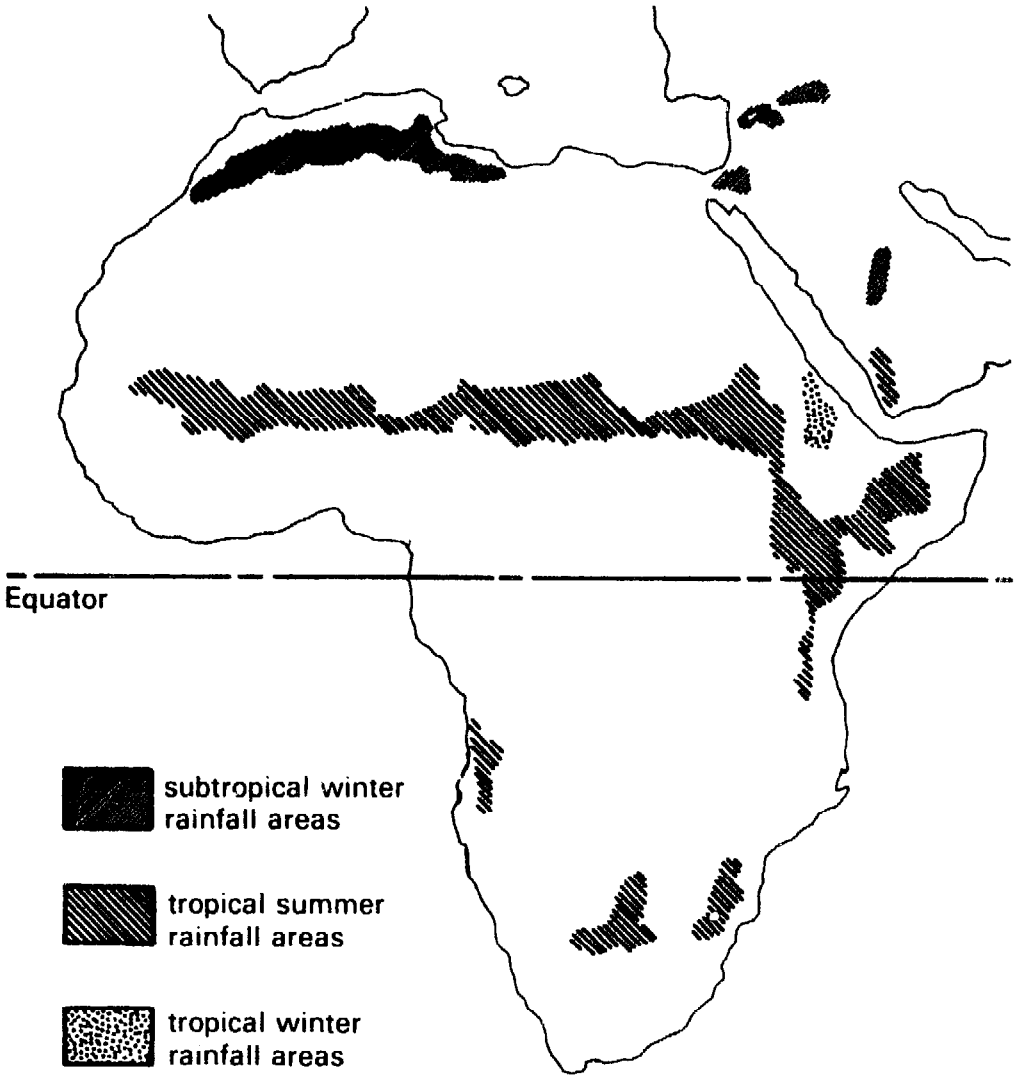

Fig. 6.1 Areas in Africa which Kutsch (1982) identifies as likely to be suitable for runoff farming, together with some adjacent parts of the Middle East. The technique is already used in many of the areas marked which lie north of the equator.

soils (see Table 6.1), and also depends on patterns of social organization. Yet the areas where it might make some contribution contain considerable populations, including many of the 30 million people in the African Sahel.

Potentially, then, rainwater collection in agriculture has a far greater importance — and for more people's livelihoods — than rainwater for domestic supply. But the latter subject has been dealt with first in this book because of better information and clearer evidence of constructive progress. Much of that progress in countries such as Thailand, Indonesia and Kenya is due to local adaptive research or 'innovative dialogue' which has allowed techniques to develop in response to local conditions. Progress is also attributable to the thoroughness with which technical assistance has been planned and provided. Part of the purpose of this section of the book will be to enquire whether any of these lessons about innovation and

technical assistance are applicable to agricultural uses of rainwater. Techniques of runoff farming will first be reviewed with the aim of identifying opportunities for innovation, application and development, especially in sub-Saharan Africa and India. Then in Chapter 7, the replication of successful techniques and the planning of technical assistance for runoff farming will be discussed.

Because of the inadequacy of research into runoff farming in many parts of the world, most discussions of the techniques focus on the few areas from

Table 6.1 Environmental conditions and crop characteristics suitable for runoff farming (i.e. farming which makes use of microcatchments, *or* contour strips/ terraces, *or* external catchments). (NAS 1974, and data quoted in this chapter)

1. Climatic conditions

(a) *Winter rainfall areas*
- minimum average annual rainfall of approximately 100mm can be used (e.g. in the Negev), but 200mm would be more viable.

(b) *Tropical summer rainfall areas*
- for small external catchments and within-field catchments, 500-600mm average annual rainfall should generally be regarded as necessary.
- minimum average rainfall of 150mm can be used when measures are taken to maximize moisture storage (e.g. khadins, Rajasthan).

2. Soil conditions

(a) *within-field catchment systems*
- deep soils, clay content, crust-forming capability.

(b) *external catchments*
- crust-forming soils or relatively impermeable ground (including rock surfaces).

(c) *cultivated areas*
- deep soils (1.5-2.5m), high water-storing capacity;
- low salinity.

(d) - *earthworks* - stable soil types not subject to piping.

3. Crop characteristics

(a) *perennials, trees* (e.g. on microcatchments)
- must be able to withstand long periods of drought.

(b) *annual crops*
- short growing season (e.g. quick-maturing millets)
- deep-rooting habit (e.g. sorghum)
- tolerance of occasional waterlogging as well as drought.

which detailed studies have been reported — the Negev Desert in Israel (Evenari *et al.* 1968, 1982; Shanan and Tadmor 1979) and the south-western part of North America (Frasier 1975; Dutt *et al.* 1981). It has been tempting to assume that the techniques described in these reports offer the best available demonstration of this type of farming. The Negev example has gained a particular authority not only because of the impressive achievements of desert farming there, and because of the thoroughness of the research work done, but also because of its historical origins. It is a system which has a demonstrable long-term viability. What is too easily forgotten is that other countries, notably India, have equally venerable traditions of runoff farming, some of which may be more relevant to hydrological conditions in the tropical areas.

Kutsch (1982) points out that requirements for runoff farming are very different in regions where rainfall comes in winter, as it does in the Negev and North Africa, as compared with tropical regions where rainfall occurs in summer, at times when evaporation rates are very high. Kutsch identifies many areas in Africa where climates, soils and slopes may in principle be suitable for runoff farming, but is also careful to distinguish areas with summer and winter rainfall, and these are plotted separately on the map in Figure 6.1. Having personally studied traditional runoff farming mainly in Morocco, where the rains come in winter, Kutsch is justifiably cautious about making definite recommendations about arid tropical areas with summer rainfall.

Significantly, the regions which Kutsch tentatively picks out as 'suitable' for runoff farming in the tropics are mostly those with annual average rainfall of at least 300mm, and we would add that the most suitable are areas with 500-600mm.* They are almost never regions where rainfall is as low as in the Negev (100mm). However, he also points out that annual rainfall is not the most important criterion. What matters more is the balance of rainfall and evaporation during the growing season, which is rather favourable in the Negev. By contrast, in summer rainfall areas evaporation rates during the rainy season are very high, and crop water needs are correspondingly greater. A runoff farming system designed for a crop with a 100-day growing season will usually need several storms producing significant amounts of runoff spaced at regular intervals within the 100-day period if the crop is to do well. In the Negev, a couple of storms within the cool winter growing season can produce sufficient soil moisture on a runoff farm to support a crop. In tropical areas with summer rainfall and high evaporative demand, there is no question of such sparse rains being sufficient.

One limitation of most of the techniques on which detailed research has

*The latter is a conservative recommendation because of evidence that *average* rainfall levels in much of Africa are declining (though interpretation of this evidence is controversial).

been done is that because crops are grown during the season when rainfall is expected, it is necessary to avoid collecting too much rainwater on cultivated plots because inundation and waterlogging can kill growing plants, especially seedlings. Thus in American experiments, arrangements have sometimes been made for excess runoff to be diverted away from cultivated plots (Luebs and Laag 1975), and in the Negev, most plots are equipped with spillways of such a height that excessive depths of water on the cropped area are avoided.

In regions with more exacting climatic conditions of limited rainfall in a hot summer season, different strategies are needed, based on storing more water in the soil profile, and sometimes also postponing the planting of the crop until after the season of highest evaporative demand is past. One such strategy involves building high bunds or banks along contours so that extended strips of land may be inundated to a depth of as much as a metre. This water slowly infiltrates the soil or evaporates, and a crop is planted as the water subsides. By this time, the season of highest temperatures may be over, so the crop is able to grow under conditions where evaporative demand is relatively modest.

This technique is used in Sudan, on plains to the east of the Nile where there are large areas of clay soil and gentle slopes. Here embankments are made 'to intercept sheet-wash runoff following heavy storms'. Quick-maturing millet is planted immediately the water left by a storm has subsided. 'The crop grows and matures in 80 days, using the moisture that has been induced to infiltrate the soil behind the bunds' (Wickens and White 1978). According to Kutsch (1982), plots cultivated like this are known as *teras*. He describes them as artificial basins used for cropping on slightly sloping land. The technique conforms with the definition of rainwater collection proposed in Chapter 1 in that the water is sheet flow (not channel flow) on the short and gentle slopes of the Sudan plains.

In North and South Yemen, a similar approach to water storage in the soil is used but in connection with floodwater harvesting rather than rainwater. Indeed, the rainfall from which the floods originate occurs mainly in a nearby mountain area, not in the immediate environs of the cultivated land. It flows in torrents down steep wadis, and where these discharge onto flatter land, the water is diverted from its natural channel by dams or barrages, and is led via canals to innundate large areas of land. There the water is ponded to a considerable depth behind large bunds, sometimes 2-3m in height. Within ten or fifteen days the flooding has subsided and crops can be planted (Clouet 1979; Thomas 1982; Podchivalov 1983).

Similar techniques are used in other tropical arid or semi-arid areas where the rains come in summer, including parts of southern Pakistan (where systems of this kind are known as *sailabas* or *kuskabas*), and northern India (which has *khadins* and *ahars*). In some of these places the

source of water is rainfall on a nearby catchment, as in Sudan, but in others, floodwater is used, as in Yemen.

CLASSIFYING RUNOFF FARMING METHODS

The existence of these techniques for using summer rainfall calls for some modification of the classification of rainwater storage methods suggested in Chapter 1. In that discussion, four methods of rainwater storage were compared — tanks above ground, excavated cisterns, small dams and 'soil moisture'. The latter term adequately summarizes how water is stored where runoff farming is practised under winter rainfall conditions, with runoff flowing onto cultivated plots while crops are growing. Although such plots may be temporarily inundated to a depth of 10 or 15cm, this flooding must be very short-lived if the crop is to flourish. Thus the technique presupposes that water will infiltrate quickly and will be stored as soil moisture, leaving ample empty pore space in the soil for aeration of the crop's root zone. The maximum amount of moisture which can be held in soil under these conditions is referred to as the *field capacity* of the soil profile.

The deep inundations practised in summer rainfall areas store more water than this in the soil profile by *saturating* it — that is, by filling up all the pore space so that the soil becomes waterlogged. Because most crops (apart from rice) cannot tolerate this, they are planted after the inundation has subsided but when the water table is still within a few centimetres of the soil surface. Only as the season progresses does the water table fall leaving a steadily larger aerated root zone for the growing crop.

Thus two methods of storing water in the soil need to be distinguished according to whether storage takes place at field capacity (i.e. air in the pore space) or at saturation (i.e. pore space filled with water). In view of this, the comments made in Chapter 1 about moisture storage in soil need the clarification which is provided by Table 6.2. This table, like Table 1.1 in the first chapter, not only classifies techniques according to how water is stored, but also according to the type of catchment from which the runoff comes. Firstly, patches or strips of bare ground *within the fields* being cropped may serve as catchments. Secondly, the water may be sheet flow from *external catchments*, or thirdly, it may be *floodwater* in a stream or channel.

Where moisture storage takes place at field capacity, any of these three catchment types may be used. However, the small-scale option of within-field catchments is not compatible with large bunds and deep inundations, so storage of runoff water in the soil at saturation is usually found only in connection with external catchments or with floodwater utilization. Thus *five* categories of runoff and flood farming are distinguished in Table 6.2, and examples are cited of regions in which they have been used.

Table 6.2 A classification of rainwater and floodwater harvesting systems according to catchment and storage.

Some uses of rainwater also dealt with in Table 1.1 are denoted as follows:

DD - *drinking water and domestic use*
S - *water for livestock*
G - *garden irrigation (and micro-irrigation)*
F - *field irrigation*

	SMALL CATCHMENTS with sheet runoff		*LARGE CATCHMENTS with turbulent runoff and/or gullying and channel flow*	
	ROOFS of all kinds	*GROUND SURFACES less than 50–150m length; WITHIN-FIELD CATCHMENTS*	*SLOPES longer than 50–150m EXTERNAL CATCHMENTS*	*FLOW in WADIS, GULLIES, RIVERS, and all natural channels FLOODWATER*
WATER STORAGE TECHNIQUES				
TANKS ABOVE GROUND	**DD**	**(DD)**	n.a.	n.a.
EXCAVATED TANKS	**DDSG**	**DDSG**	n.a.	n.a.
SMALL DAMS ("tanks" in INDIA)	n.a.	**DDSG**	**SFDD**	**SFDD**
SOIL AT FIELD CAPACITY	n.a.	contour strips, furrows, bunds and terraces (Morocco, India, North America); microcatchments (Tunisia, Negev);	runoff farms in valley bottoms (Negev, Morocco); bordered gardens (North America); hill terraces with external catchments (Morocco); upland runoff plots (Papago areas, Arizona);	diversion systems (Negev), diversions for water spreading (North America); terraced wadis (Tunisia); check dams for silt trapping (China, North America); warping (China); alluvial fan farms (Hopi areas, Arizona);
SOIL AT SATURATION	n.a.	n.a	runoff farming by inundation: *'teras'* (Sudan) *'ahars'* (India) *'khadins'* (India)	diversion systems (Yemen, India); river flood-plain farming (Africa);

Source of examples quoted: India and China - UNEP 1983; Sudan - Wickens and White 1978; Tunisia - El Amani 1977; Morocco - Kutsch 1982; Arizona - Bradfield 1971; North America - UNEP 1983.

The focus of this book is on small-scale uses of rainwater and the localized application of runoff, not on the exploitation of major floodwater flows, so whilst only three of the five categories are discussed in detail here the following examples of floodwater utilization are of considerable interest. Firstly, Figure 6.2a shows one of a number of dams constructed at regular intervals in the bed of a small valley to conserve both soil and water.

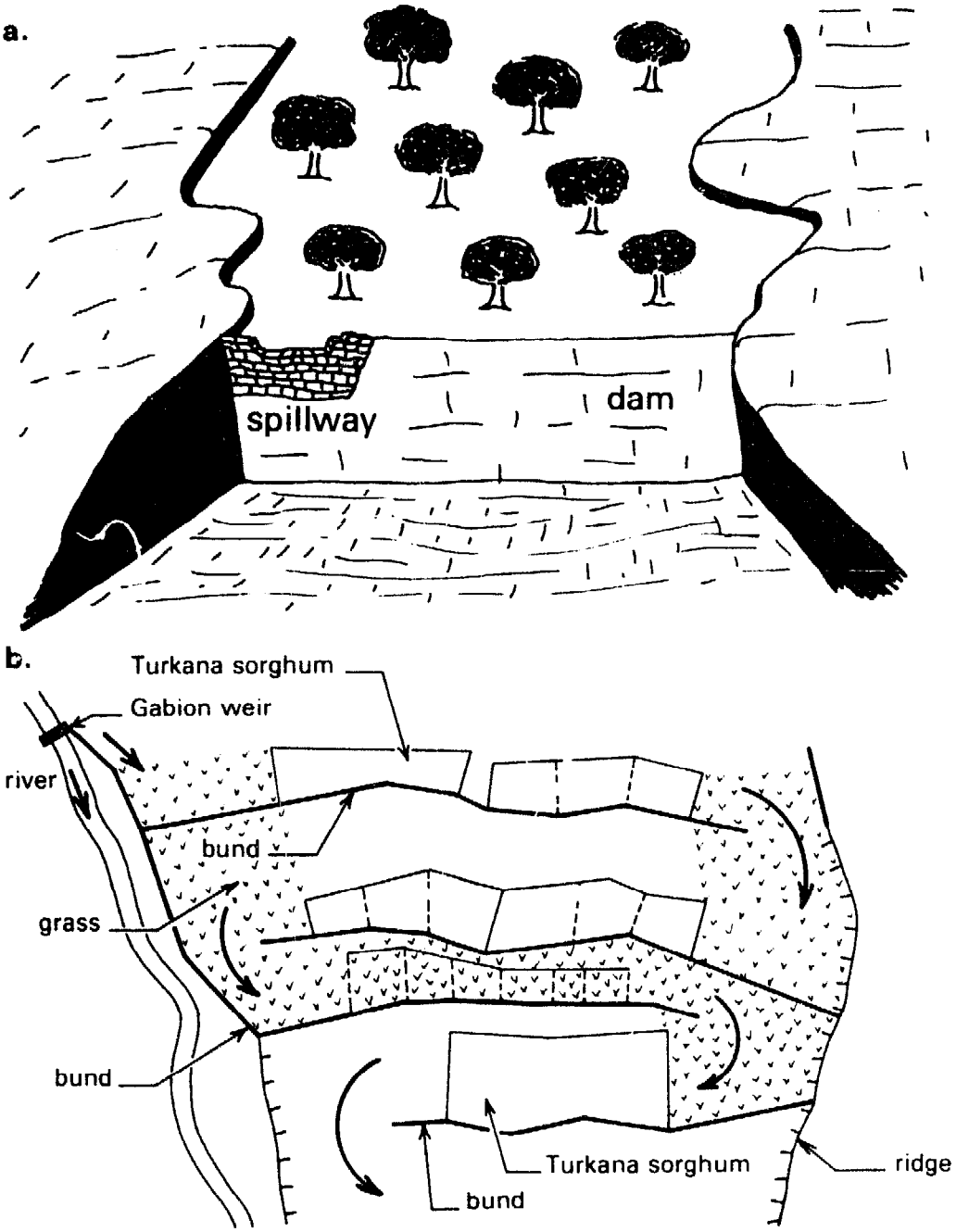

Fig. 6.2 Two forms of floodwater harvesting involving the exploitation of channel flow: (a) making terraces within the floodwater drainage channel, as exemplified by a terraced wadi in Tunisia (El Amami 1977); (b) water-spreading illustrated by a pilot project in Kenya; note the large plots planted with 'Turkana sorghum', a local quick-maturing variety. (Fallon 1963)

These dams function as silt traps, and as soil builds up behind them, fertile plots are formed. Many versions of this technique are to be found — in China, in Mexico (where maize is grown on the accumulated sediments), and in Tunisia. In parts of the latter country, stone dams holding back sediments have the effect of terracing long lengths of wadi, enabling olive, fig and date palm trees to be grown on the terraces, and sometimes cereals also. The natural wadi flow during rains is controlled by spillways and provides water for all these crops in a region where rainfall is only 150-200mm. Terraced wadis in Tunisia have been developed quite considerably in recent years, and state encouragement has led to the systematic design of spillways to standard dimensions (for example, with crests 50cm above the terrace soil level.)

Secondly, a very common way of using flood flows in a wadi or river channel is to construct a dam or barrage to divert water onto cultivated land. Such arrangements have been found on ancient sites in the Negev and are still actively used in South Yemen (Thomas 1982) and many other countries. The diverted water may be used in several ways. The land may be inundated (as in Yemen), or water spreading techniques may be employed. The latter term indicates a flow of diverted floodwater across a prepared 'spreading area' at very low velocities. Thus the water is not ponded on the land, but flows over it. On soils with high infiltration capacities, sufficient is stored as soil moisture to support a crop. Water spreading is particularly appropriate on grassed areas used for forage production, and is practised on the plains of North America and in Australia. However, it has also been used experimentally in West Africa and Kenya. It typically entails constructing a small diversion structure across a seasonal water-course and the use of short lengths of bund to spread the flow without erosion (Fig. 6.2b).

A final way of using river floods where these spread out over a wide river bed or flood plain is simply to wait until floodwaters are subsiding and then plant crops on the areas which have been inundated. This approach is widely used in Africa where major rivers such as the Niger and Senegal pass through semi-arid areas. It is also practised on the margins of Lake Chad and rivers which flow into it.

RUNOFF FARMING BY INUNDATION

With regard to runoff farming as opposed to the exploitation of floodwater, the inundation method used in Sudan, Pakistan and India has been developed to its highest level of sophistication in the latter country. Techniques differ in detail, but the principle is to allow runoff to collect behind a bund and leave the water standing until the planting date for the crop approaches. Then the land is drained and the crop is sown. The area behind the bund is known as a submergence tank, or an *ahar* (in Bihar), or

a *khadin* (in Rajasthan), and may cover many hectares (for locations, see Fig. 2.3).

During the period when runoff is ponded behind the bunds, ahars are treated as reservoirs from which water is taken for a number of different purposes. Firstly, overflow via spillways is allowed for; water discharged in this way is often trapped by a second ahar further downslope. There it may be supplemented by water released from sluices in the first ahar when that is drained prior to sowing. Secondly, supplies may be pumped from an ahar to irrigate other land, or may be released for irrigation by gravity flow via pipes passing through the bund. Box 6.1 gives some technical detail and indicates the location of pipes through which irrigation water is released.

A third way of exploiting the water in an ahar, or more particularly, in the very similar khadins of Rajasthan, is to take advantage of infiltration from the inundated land to the water table beyond the bund. Wells are commonly dug downslope from a khadin, and in the Thar Desert (in Rajasthan) such wells are important sources of water for livestock. The wells also help to avoid the build-up of salinity in the khadin soils by increasing the rate of drainage through them. In this area, catchments include large areas of weathered rock which can produce unusually saline runoff.

Cultivation on ahars and khadins is more systematic than in the similar, but much simpler, basins used for runoff farming by inundation in Sudan and elsewhere because the provision of sluices in the bunds allows ponded water to be released in time for the preferred planting date. Thus in Rajasthan, wheat and pulses are sown in November and the main harvest is in April. This very effectively avoids the season when evaporative demands on crops are highest, for during the rainy monsoon season from July to October, potential evapotranspiration is 697mm, whilst during the first half of the growing season, November to February, it is only 106mm (Kolarkar *et al.* 1983). Evaporation rates are highest of all in the hot months of May and June. Some light rain may fall in December, but the majority of the crop's soil moisture requirements are provided by the runoff ponded on the land before planting.

The sharp contrast between this approach to runoff farming and the methods more usual in the Negev, North Africa and America is emphasized in Table 6.3. Here, the American examples show crops benefiting from soil moisture which is present before they are planted, but depending primarily on the rainfall and runoff which occur while the crops are growing. In the contrasting inundation system, almost the whole of the crop's water requirements are met by water present in the soil prior to planting. The table also shows that in areas of reasonably good rainfall, where catchments are relatively small, runoff may contribute much less water than rain falling directly on the cultivated plot. In these circumstances, runoff farming may show little advantage over conventional agriculture in

Box 6.1 Technical details of ahar construction. (Prasad, 1979)

1. ***An ahar***, made on land with very gentle gradients (so that large areas can be flooded), presupposes clay soils.
2. ***The bund***, unlike a dam, does not contain a clay core or hearting, nor a cut-off trench. The soil is uniform throughout the section. Upstream and downstream faces usually have slopes of 1:2, although the downstream slope must be adjusted to keep the phreatic line (i.e. the boundary of the saturated zone) within the bund. The height of the bund does not exceed 3m (including a 1m freeboard), and the top width is normally 1m. The upstream face may be pitched with stone.
3. ***The length of the bund*** may vary from 150m to 10km or more. The bund follows the contours as far as possible. However, on very gently sloping land (e.g. a fall of 0.1m in 1km) exact alignment is not important. Where it is desired to terminate the bund it is turned transverse to the contour to meet higher ground.
4. ***A long spillway*** is always incorporated, the crown of which is 1m lower than the top of the bund. It is topped with stone and has a gently graded downstream slope which is paved with stone.
5. ***Sluice-gates*** are set in masonry structures so that the ahar may be emptied quickly in time for sowing. The sluice gates are made of steel plate and are about 1m square; they are operated with a screw. Water discharged from them is led to a local stream, or to another ahar downslope.
6. ***Pipes*** made of stoneware, concrete or cast iron, 150–300mm in diameter, are embedded in the bund at intervals of 50–100m to enable water to be released for irrigation. To prevent erosion around the pipe, small blocks of masonry are built up around it at both ends. When the release of water is to be prevented, the upper ends of the pipes are simply plugged with straw and earth.

PLAN (Not to scale)

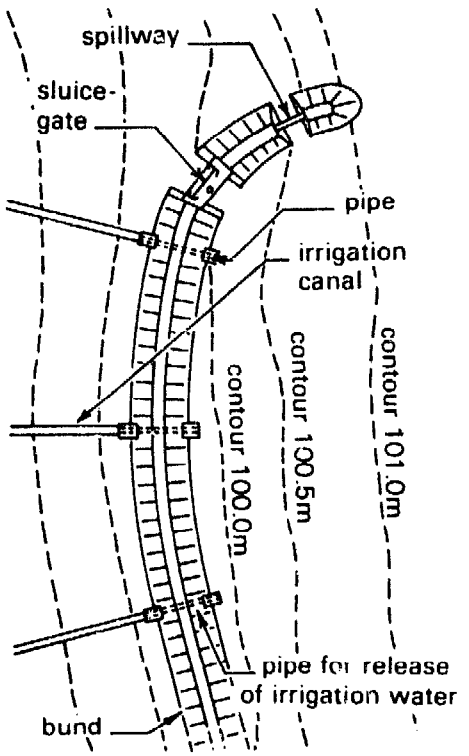

SECTION OF BUND

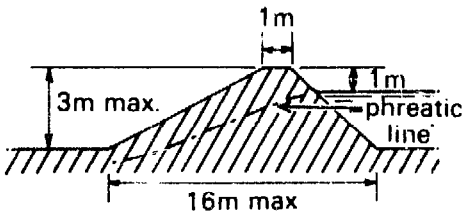

Table 6.3 Sources of soil moisture used by crops under contrasting runoff farming systems.
Data given by the authors cited have been recalculated as percentages of total consumptive use to facilitate comparison. (From Journal of Arid Environments, 'Khadin – a method of harvesting water for agriculture in the Thar desert' by A.S. Kolarkar *et al.*)

	INDIA Runoff farming by inundation (soil initially saturated)	*NORTH AMERICA 'Conventional' runoff farming (soil at field capacity or less)*	
CROP and district	WHEAT Rajasthan	BARLEY California	SORGHUM Texas
SOURCE	Kolarkar *et al.* 1980	Luebs & Laag 1975	Jones & Hauser 1975
MEAN ANNUAL RAINFALL	200mm	300mm	470mm
RATIO, catchment to cultivated areas	11:1	2:1	2:1
SOURCES OF MOISTURE			
Water and moisture in the soil profile prior to planting:			
a) due to runoff from the catchment	82%	10%	14%
b) due to rainfall on cultivated plots	15%	12%	18%
Rainfall and runoff during the growing season:			
a) due to runoff from the catchment	0*	39%	12%
b) due to rainfall on cultivated plots	3%*	39%	56%

* *Only occasional light showers during the growing season; no runoff except at margins of cultivated area.*

seasons of average rain. The benefits consist chiefly of an improved reliability of yield in poor years because then runoff helps the crop to survive periods of drought (Jones and Hauser 1975).

Whilst the contrast between the inundation system and the North American and Negev methods is clear, different versions of the inundation system ought also to be noticed. In Bihar and adjacent areas of India, as in Sudan, ahars are built on very gently sloping land. During the monsoon rainwater running off the ground above the bund submerges very large areas behind the bund because the ground is so nearly flat. The soil in these regions has a high clay content, which again makes them comparable with

Sudan, so its moisture-retaining capacity is good. Sometimes in India a special variety of rice is sown in the bed of the ahar before it actually fills up. This 'floating rice' can grow in deep water, and although the yield is low, the effort is worthwhile when a second crop, winter wheat, is to be planted once the ahar is drained (Prasad 1979).

Though some ahars may only be 1ha in extent with a bund 100m long, others may be as large as 500ha and the largest of all submerge 4,000ha with bunds wandering along the contours for 10km or more. Large numbers of these systems exist in Bihar state providing about 800,000ha of runoff cultivation, and there are others in Uttar Pradesh (See Fig. 2.3 also).

In Rajasthan, khadins are necessarily rather different because rainfall is less than in Bihar and soils are sandy, so there is almost no runoff from gentle slopes. Instead, khadins are generally located near to low eroded hills and ridges of sandstone and limestone which serve as catchments, generating runoff which flows down to relatively flat valley land. Bunds are constructed in the valleys where they can collect and hold back the runoff water and the sediments it carries (Fig. 6.3).

In this desert area, rainfall is higher than in the Negev, but comes in summer rather than winter. In the Jaisalmer District, where the annual average rainfall is 164mm, many of the older khadins are so constructed

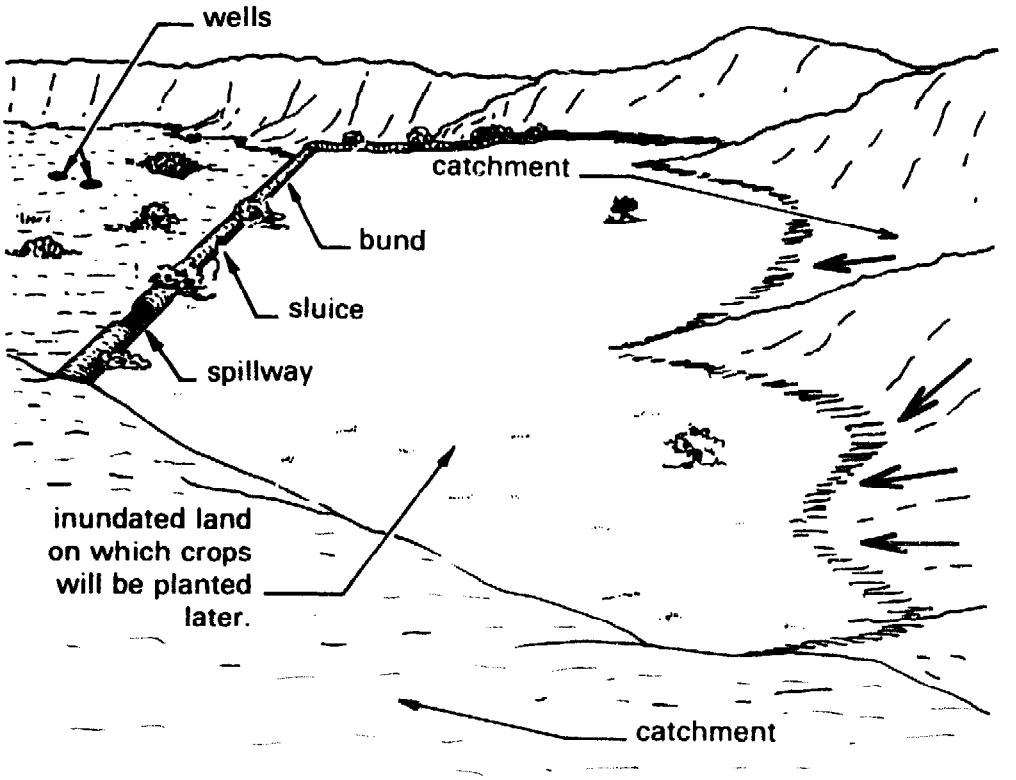

Fig. 6.3 A 'khadin' viewed from the hillside which serves as its catchment, showing an ideal setting for this type of runoff farming - valley land with very gentle slopes adjacent to rocky uplands. (Kolarkar et al. 1983)

that they will fill with a total precipitation of less than 100mm. Water stands in the khadin areas during the whole monsoon period reaching a depth of 0.5 to 1.25m. In November, after the land has been drained via sluices and the crop has been planted, the water table slowly subsides but continues to supply moisture to the growing crop. Typically the depth of the water table at harvest will be about 2m (Kolarkar *et al.* 1983).

Like ahars, individual khadins may be very large. In Jaisalmer District, Kolarkar states that there are over 500 with a total cultivated area of 12,140ha. The first to be made in this area was constructed five centuries ago. Over the years, accumulation of sediments inside a khadin cause a gradual increase in soil level, with fine loam or clay loam soils developing, in contrast to the sandy soils of surrounding areas. The long period for which khadin soils are moist promotes microbial activity and as a result, they contain more humus, are more fertile, and have better moisture-holding characteristics than local desert soils.

It should be noted that while most khadins are true runoff farming systems, filled directly by sheet runoff and from small gullies on immediately adjacent hillsides, there are also some which depend on diverted floodwater. Prasad describes one near Bharatpur which was built in 1895 with a bund 19km long and which is fed by water from a nearby river. It inundates 4,100ha which is later used for winter crops, and water is released from it to allow irrigation of 4,800ha more.

Some western engineers have argued that if techniques of this sort are to be employed in future agricultural development programmes, the land to be inundated ought to be levelled when the bund is constructed. This, they say, would ensure a more even availability of water to crops. But it would add considerably to costs, and the suggestion represents a misunderstanding of the way these systems operate. The build-up of sediments over the years ensures that the land is levelled naturally. Farming methods are slowly modified as soils deepen and the system matures. Artificial land levelling would only offer a temporary advantage in the early stages. Whatever measures are taken, soil and moisture conditions are bound to vary across the width of an ahar due to a varying depth and quality of sediment, and this can be exploited by growing different crops on different parts of the land. Millet may be grown on the margins where there is less moisture while wheat is often the main crop on the deepest soils. Fuelwood trees may also be planted, and date palms can be grown below the bund to make use of seepage water (Ray 1984).

A bigger difficulty confronting any proposals for the extension of this type of runoff farming is the organization involved. With individual ahars or khadins covering several hundred hectares, they are normally divided between many small farmers. Ray quotes a khadin of 150ha cultivated by 25-30 individuals, with some holdings as small as 1ha and the largest around 7ha. In such circumstances, co-ordination of efforts to ensure that

bunds are maintained and sluices are opened at mutually beneficial times requires considerable organization. This significantly affects prospects for the perpetuation and replication of these systems as will be discussed in the next chapter.

Runoff farming by inundation can be used on a smaller scale with less massive earthworks in areas where rainfall is higher, and this may offer better prospects for replication. In Rajasthan, Kolarkar *et al.* (1980) point out that while khadins are used particularly in areas with less than 200mm rainfall per year, a different form of inundation is practised in the Siwana area where rainfall is above 250mm. Here, contour bunds only 0.3m high divide low-lying land into strips. Water is led onto the uppermost strip; it gradually flows to lower strips, and is allowed to stand to 0.2m depth. The inundation subsides by November when the crop is sown.

RUNOFF USE ON GROWING CROPS

Runoff farming by inundation works well on clay soils, but on sandy soils, the water table may recede too quickly after the rains cease to support a crop through the whole of its growing season. On the sandy desert soils of Rajasthan, khadins only acquire adequate moisture storage capability after several years of sedimentation. Ray reports on two new khadins which had not yet received their 'optimum load of silt' and so did not retain water into the post-monsoon dry season. Farmers using them planted their land during the summer monsoon rains so that runoff would flow directly onto the cropped plots. Thus structures ultimately intended to make possible the cultivation of winter crops after an earlier deep inundation were initially used for cropping in the more difficult summer conditions, with runoff applied directly to the cropped land.

When used in this way, a khadin works on the same principle as the runoff farms of the Negev and North Africa which have external catchments with bunds and channels to direct water onto growing crops. There are, however, important differences in construction. The relationship of external catchments to cultivated areas is similar, but the size of the bunds required and the methods of water control are very different. A khadin depends on use of a large bund capable of impounding water at a depth of a metre or more. But where water is applied to a growing crop, runoff is not usually impounded at more than 0.1-0.2m. The actual depth of ponded water which can be tolerated by a crop depends on the infiltration capacity of the soil and on how quickly the water will subside. Control of depth depends on dividing up the cultivated area by small bunds built along contours, each of which has a spillway at intervals along its length — every 20m or so. The latter are commonly built of stone with good foundations and an apron on the downstream side to prevent erosion (see Fig. 6.4). Typical dimensions are suggested in Box 6.2, but if experience

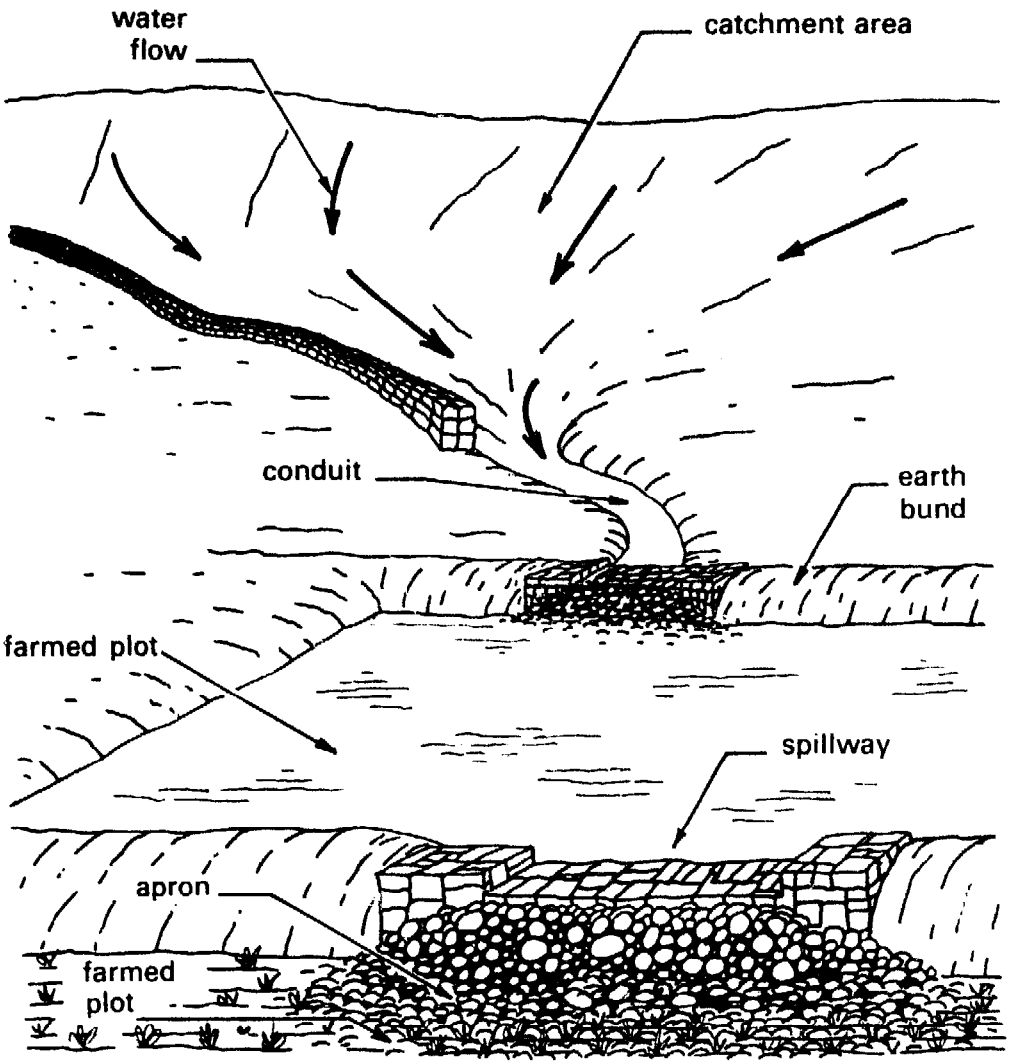

Fig. 6.4 Components of a typical system for runoff farming with an 'external catchment', including a low bund or wall for collecting runoff on the catchment, and the bunds and spillways necessary for water control on the farmed plot. (Cullis 1984)

Note: *Diagram is schematic and not to scale.*

shows that the water depths impounded are too great or too little, spillway heights can be modifed by some simple rebuilding.

Water discharged from the spillways on one plot is usually impounded on other plots lower down the field. In a wet year, the uppermost plots may get rather too much water, whereas in drought years the lowest plots may not get enough. At a site in Kenya where this system is the subject of experiment, it is recommended that sorghum should be grown on the upper plots as often as is consistent with crop rotation, since sorghum is tolerant of waterlogging (Critchley 1984). By contrast, it may be advisable to grow drought-resistant millets in the lowest plot.

Yet another way of adjusting to variations in water availability on different plots is to vary the planting density. In a district near Agadir in

Box 6.2 Bunds and spillways for cropped areas receiving runoff from external catchments in the tropics. (Barrow, 1983; Critchley, 1984)

1. On land receiving runoff from ***external catchments***, bunds aligned with contours, having spillways at 20m intervals along their lengths serve to control applications of water to cultivated plots.

2. ***Dimensions*** must depend on the maximum amount of water to be impounded after any one storm. Much depends on rainfall intensities, runoff coefficients, soils, and the catchment area. The following are typical dimension which should be checked against local conditions.

3. For a plot of 0.1ha on a 1% slope, the ***bund*** might be 0.4m high and 0.5-1.0m wide at the base. One man should be able to construct a 10m length of bund in a day, building it up in 50mm layers of soil, and compacting each layer by trampling before starting the next.

4. Bunds are made at 15-20m intervals down the slope. A farmer may be well advised to build only a couple of bunds in the first year. If these are successful and there are regular overflows from the spillways, he may wish to add further bunds subsequently.

5. ***Spillways*** should preferably be built of stone (see diagram) or if this is not available, of termite-proof timber or concrete. The downstream slope should be as gentle as possible with a level area at its foot covered with stones or gravel. Special care is needed at the ends of the spillway to build up a stone shoulder around the ends of the bund and make sure these cannot be eroded. Grass growth on spillways and bunds should be encouraged to stabilize the soil.

6. ***Typical dimensions of spillways***:

height, 0.1-0.15m;
width at base, 0.8m;
length, 1.0-2.5m;

7. One rule of thumb is that the total length of spillway needed (in metres) should be 0.5 times the catchment area (in ha). So a 50m length of bund receiving water from 8ha of catchment requires a total spillway length of 4m, either as two 2m spillways, or three 1.35m spillways.

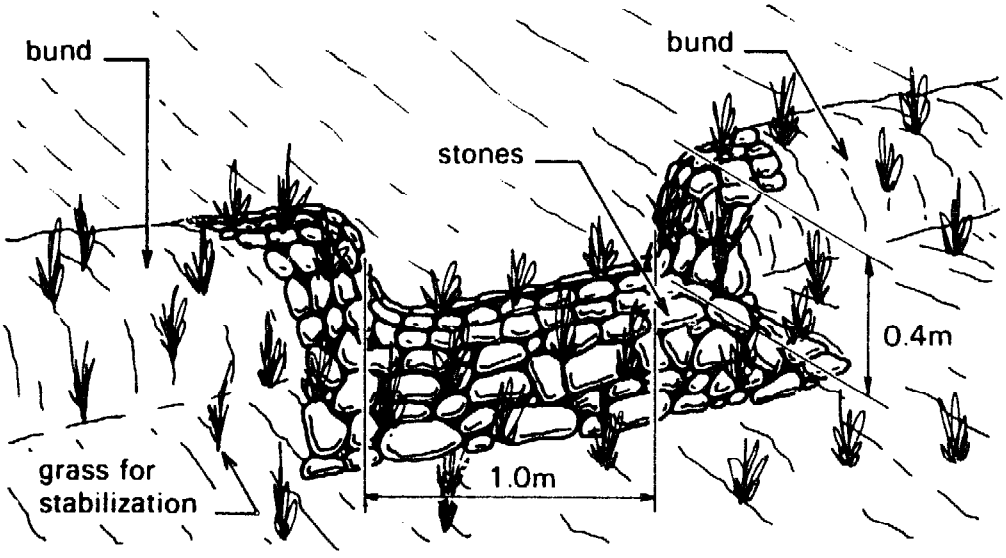

Morocco which receives winter rainfall, Kutsch (1982) has observed that when wheat or barley is grown on plots watered by runoff it is sown to a density of 100 plants per m^2. By contrast, on plots depending solely on direct rainfall without supplementation by runoff, the planting density is 70 plants per m^2. Smallholders adapt the weight of seed they use to the average soil moisture situation they expect. The deliberate reduction of plant density results in some sacrifice of yield in seasons of ample rainfall, but it makes for greater certainty that there will be useful grain production in a drought year.

Water availability depends partly on the ratio between areas of catchments and cultivated plots. In desert regions, this ratio may be in the range 10:1 up to 30:1. However, it needs to be stressed repeatedly that runoff farming in areas with average annual rainfall less than 200 to 300mm is only likely to be viable in special circumstances — either when crops can be grown during the coolest time of the year, or when khadins (or something comparable) can be built. For small-scale runoff farming in the tropics, average precipitations in the range 500-600 are suitable (Table 6.1). Then ratios of catchment to cultivated areas may typically be between 20 and 5:1.

WITHIN-FIELD CATCHMENTS

Apart from noticing area ratios, we should also observe how the overall areas of runoff farms vary. Where runoff is applied directly to growing crops without any deep inundation, bunds and spillways are modest in size and can be constructed by an individual farmer on his own land. Thus systems may be quite small, with perhaps 1-10ha of cultivated land. Although this may all be within the holding of one farmer, the external catchment from which he collects runoff may consist of grazing land used by others. An even smaller scale of operation, with greater control by the individual farmer, is possible when runoff is applied to growing crops from within-field catchments. These are of two main types. The catchments may be narrow strips of land from which rainwater runs onto elongated cultivated areas formed by contour ridges or bunds. Alternatively, within-field catchments may consist of a series of roughly square plots like the microcatchments described in Chapter 1.

The strips of catchment area in contour farming are rarely much more than 10m wide, measured downslope, and microcatchments are usually less than 90m long. These modest dimensions offer two technical advantages over the much larger external catchments. Firstly, the problems caused by turbulent, erosive runoff flows from large catchments are avoided, and secondly, with smaller losses from depression storage and infiltration, the proportion of the rainfall which runs onto the cultivated plot is greater. Areas required for use as catchments are therefore less, as typical ratios of

Table 6.4 Typical ratios of catchment to cultivated areas illustrating the lower ratios characteristic of small 'within-field' catchments

average annual rainfall	*area ratios*		*source*
	within-field catchments	*external catchments*	
300—600mm			
Kenya, Baringo area	1:1, 2:1	5:1, 20:1	Critchley 1984
Kenya, N. Turkana area		10:1, 20:1	Cullis 1984
Texas, USA	2:1	-	Jones & Hauser 1975
Arizona, USA	3:1, 5:1	-	Fangmeier 1975
150—300mm			
*Tunisia**	2:1	10:1	El Amami 1977
Arizona, USA	12:1	33:1	Morin & Matlock 1975
India, Rajasthan	-	11:1, 15:1	Kolarkar *et al.*, 1980, 1983
80—120mm			
*Israel, Negev Desert**			
a) runoff farms, range for 100 examples	-	17:1-30:1	Evenari *et al.*, 1982
b) microcatchments	10:1	-	Shanan & Tadmor 1979
c) contour strips	4:1, 20:1	-	

* *winter rainfall areas*

catchment to cultivated area show (see Table 6.4). Land use can thus be more efficient.

Methods of *contour farming* using runoff from uncultivated strips are very varied, depending on the slope of the land, and on the extent to which farming is mechanized. On flat land, catchment strips can be formed by throwing up low, broad ridges which are sometimes known as 'micro-watersheds'. The troughs intervening between them are then cultivated (Figure 6.5a). On gentle slopes, contour ridges can be used to form strips of cultivation (sometimes referred to as 'desert strips' in American publications: Fig. 6.5b). Finally, on steep slopes, contour bunds may be built to create terraces, often with sloping catchment strips alongside each level terrace (Fig. 6.5c), but sometimes with groups of two or three terraces supplied with runoff from a single catchment.

Although micro-watersheds have been tried experimentally in Botswana and elsewhere (Gibberd 1969), this technique is most easily applied where tractor-drawn equipment allows the watersheds to be evenly graded (Dutt *et al.* 1981). Contour ridges and bunds are more widely applicable and can be formed using hand tools or animal-drawn equipment. Some African programmes in which contour bunds and barriers have been built will be described in Chapter 7, and details of one type of contour ridge are given in Box 6.3.

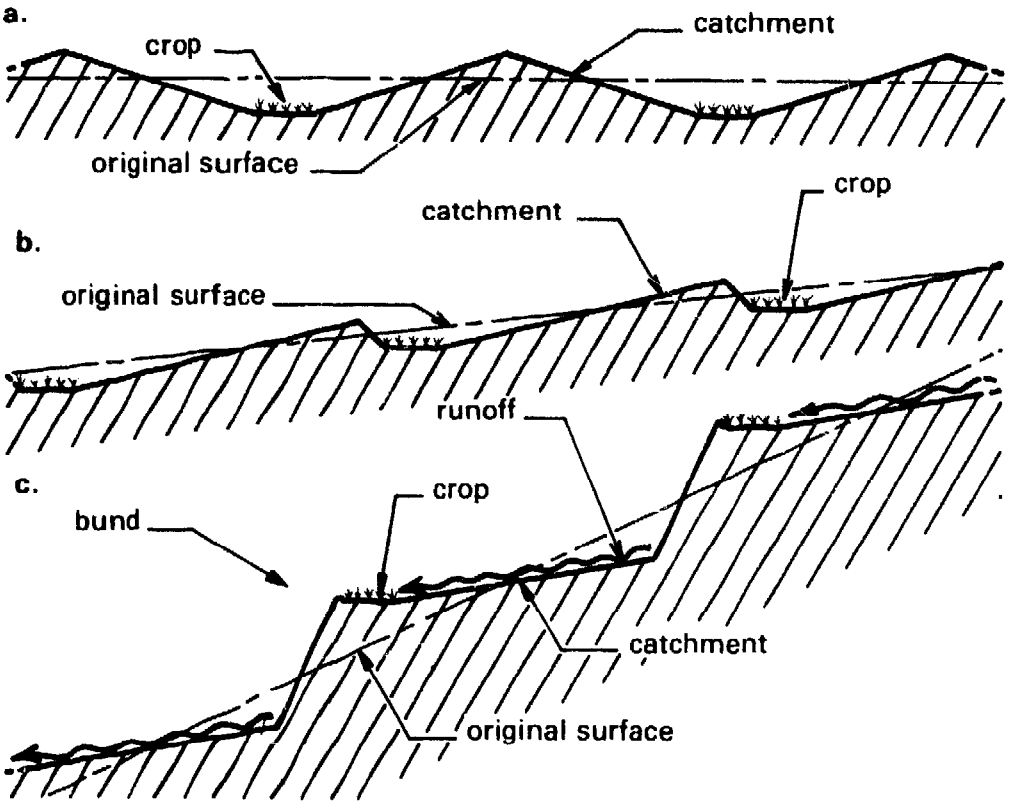

Fig. 6.5 Variations on the theme of contour farming (Dutt et al. 1981; Cullis 1984) (a) micro-watersheds on slopes of less than 1 per cent; (b) contour ridges (desert strips) on slopes of 1–3 per cent; (c) contour bunds forming terraces on slopes steeper than 3 per cent.

Terrace systems for runoff farming on steeper slopes have a long history in many parts of the world, including India, and North Africa. Details vary according to terrain, soils and whether stone is used for building up terrace walls. The width of the cultivated strip depends on local soils and the crops being grown, but in Texas, in a region with 470mm of rain, a catchment to cultivated area ratio of 2:1 has been used for sorghum production. The ridges or bunds defining the outer edge of a terrace are usually about 0.3m above terrace soil level.

In the drought-prone regions of India, contour bunds are fairly widespread as a means of using runoff water to support growing crops (Ray 1984). However, such bunds, which are constructed precisely along the contour in order to *retain* rainwater around the plants, should be distinguished from the graded bunds or furrows, also widespread in India, which are intended to control soil erosion by channelling excess runoff into water-courses and sometimes into 'tanks'. However, Krantz (1981) argues that graded bunds are not always very effective in controlling erosion, and Ray quotes experience of badly constructed bunds which unintentionally depart from the contour. Far from retaining water around plants, the latter become regular streams 'complete with waterfalls'. If catastrophic erosion is to be avoided, then, construction must be adequate

Box 6.3 Forming contour ridges. (Cullis, 1983)

Introduction Closely comparable with the 'desert strips' of Israel and North America, contour ridges have proved an effective means of supporting crop production in semi-arid regions.

Description Runoff is collected behind earth bunds, and therefore concentrated for plant growth. A modification to this system involves the periodic spacing of barriers perpendicular to the flow which prevents the lateral movement of runoff.

Note: A cutoff drain at the top of the site leads all *external* water away from the system.

Design The width of the cropped area in relation to that of the catchment is dependent mainly on hydrological and soil conditions, together with crop water requirements. In a semi-arid part of Kenya with a mean annual rainfall of 600mm, cropped strips of 0.15m width are supplied with adequate runoff from catchments 2 to 3m wide.

Labour Using hand tools, it has been estimated that 0.5ha can be contour-ridged in 16 days, and thereafter maintained with only a few days work per year. The excavation of a cut-off drain, to protect such field systems requires approximately 25–30 person-days to construct. Thus relatively few labour demands are made to reclaim quite large areas.

Note: Hand hoes and shovels may, to some extent, be complemented by draught-animal power to speed up the work or overcome a seasonal labour shortage.

Cropping In the semi-arid sub-tropics of the Sahel, contour ridges have been successfully used for arable cropping of local sorghum and millet varieties. In particularly wet years, the catchment may also be planted with drought resistant legumes such as cowpeas or tepary beans.

In more arid regions, contour ridges can be used to assist the regeneration of forage, grasses and hardy local trees in overgrazed areas. Grass seeds should be spread along the bunds prior to the rains; once established they will spread out onto the catchment area.

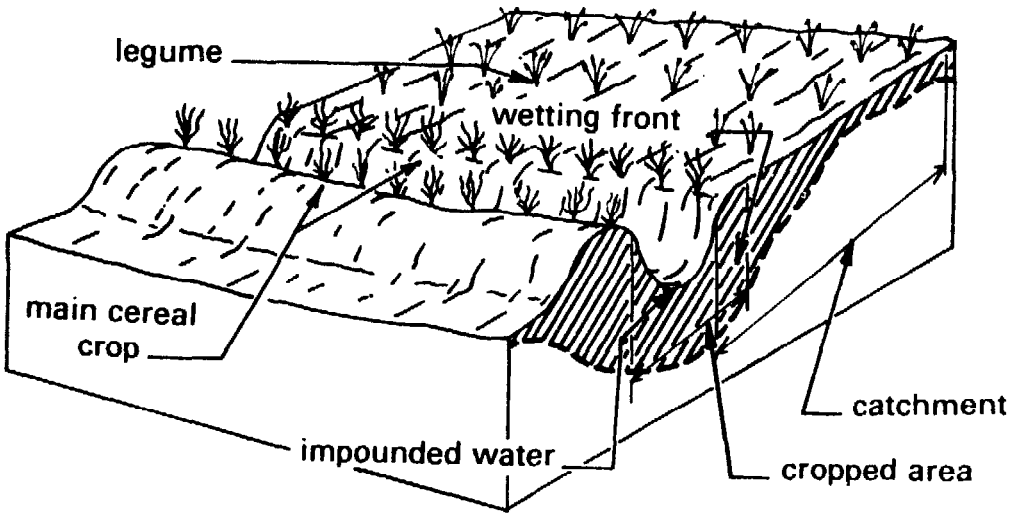

both in accuracy of surveying, and in making bunds big enough to cope with the largest likely volumes of water.

On stony slopes in Morocco it is logical that stone is used to build up the bunds or terrace walls, often on very steep slopes. Here there is sometimes little distinction between within-field and external catchment systems. In Figure 6.6a, water from external catchments higher up a steep hillside is controlled by an impediment wall, built without mortar, which holds back debris and gravel and ensures that the runoff is spread evenly along the length of the terraces. In 6.6b, there are within-field catchments above the main terraces, each crossed by three contour ridges. However, the topmost field is also allowed to receive runoff from an external catchment. On contour bench terraces in Texas, extra runoff of this kind is deliberately

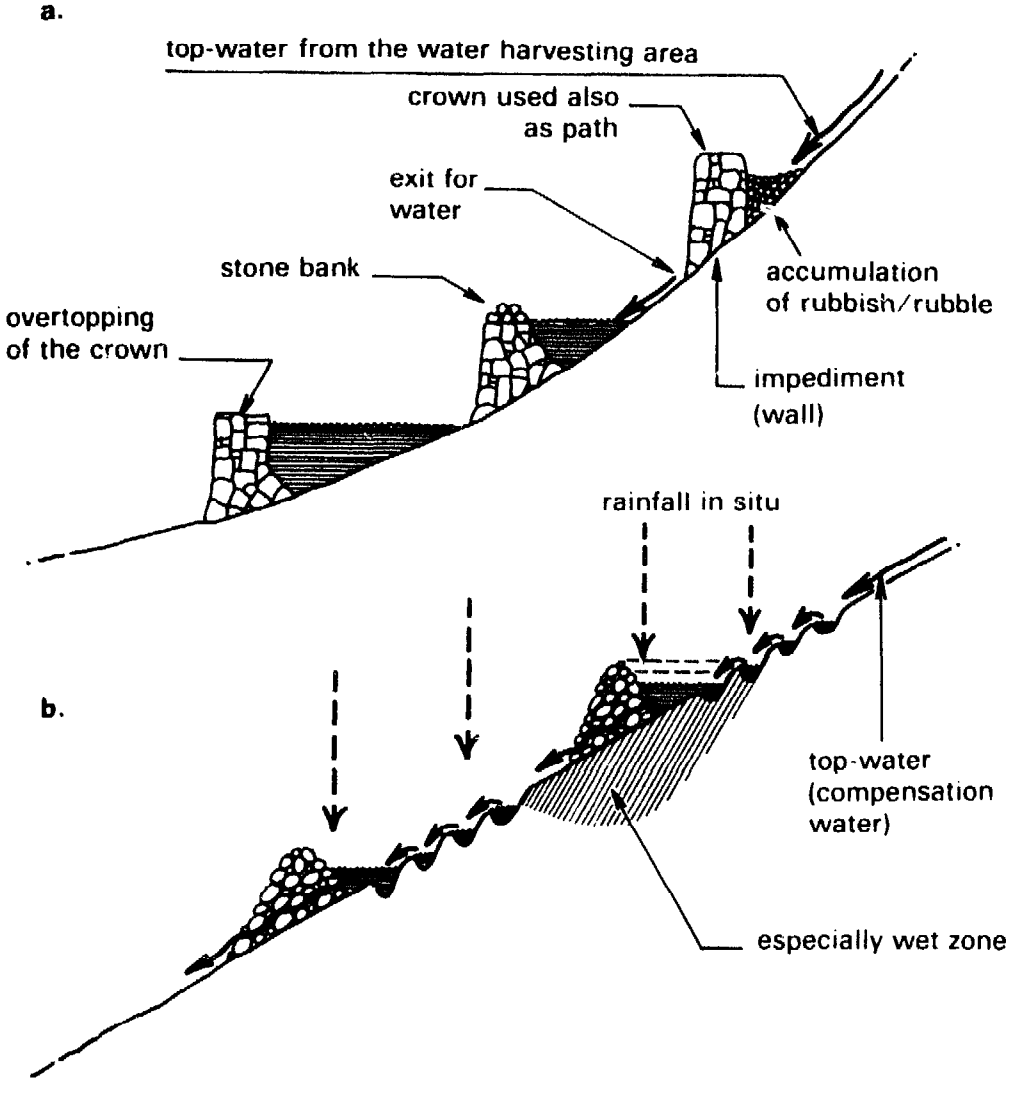

Fig. 6.6 Terraces with stone bunds or walls used on steep slopes in Morocco. (Kutsch 1982) In diagram (a) the terraces receive water from an external catchment; the impediment wall reduces the speed of runoff and spreads it whilst holding back debris; in diagram (b) contour ridges and stone bunds are combined within one system. N.B. The gradients are exaggerated.

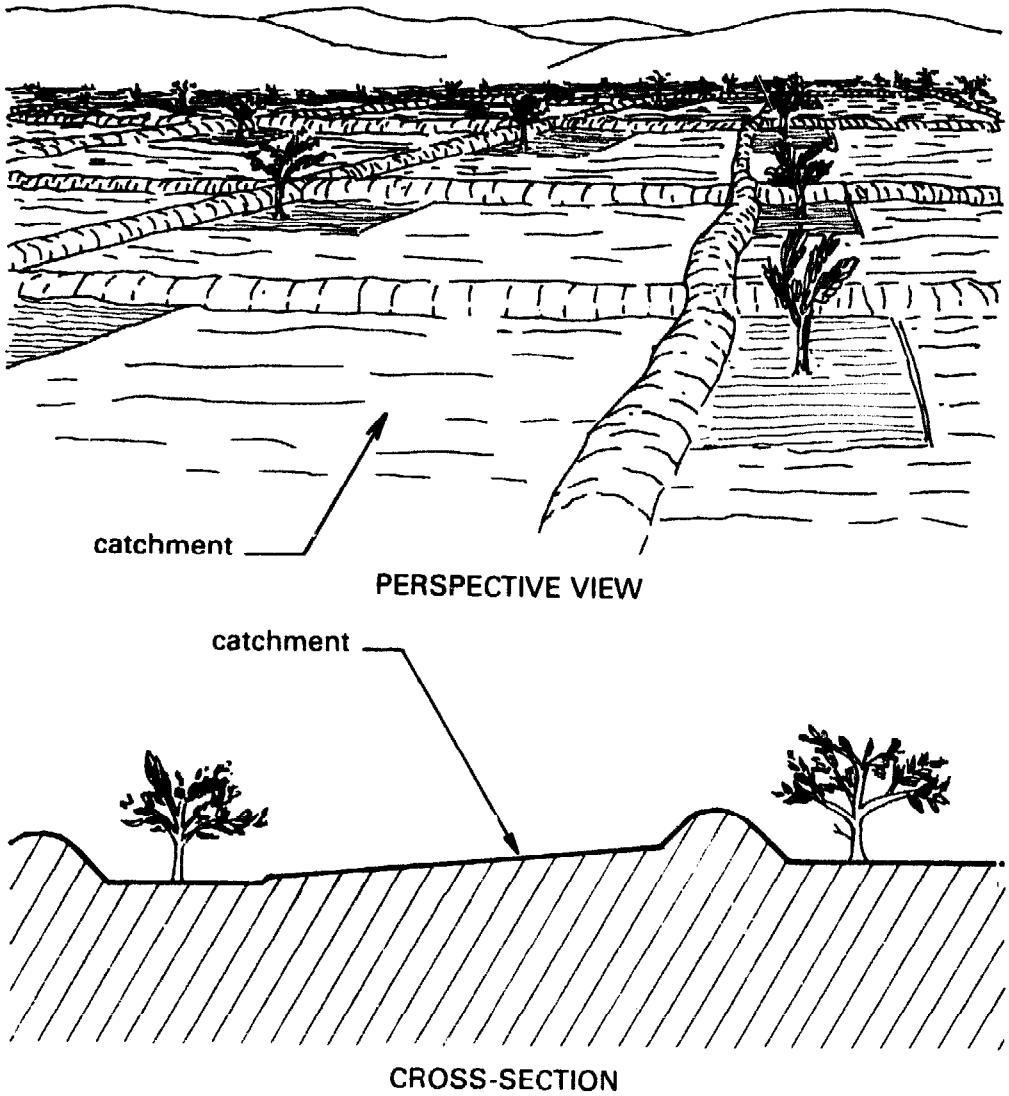

Fig. 6.7 Microcatchments in which almond trees are growing in the Negev Desert. The trees are located in a small patch of cultivated soil at the lowest point in each microcatchment.

avoided by making cut-off drains above the upper catchment strips, the aim being to avoid uncontrolled, erosive runoff which could inundate the crop or damage bunds. In Morocco, by contrast, the stone terrace walls allow excess water to pass rapidly, both by infiltrating between stones and by overtopping the walls.

The other main form of within-field catchment, used chiefly for tree crops, was first formally recorded by French travellers in southern Tunisia during the nineteenth century. There, olive trees were being grown within what are now referred to as microcatchments. As the name implies, these are small, often roughly square patches of bare ground which shed runoff into a basin excavated in the lowest corner. Low earth bunds, 0.2-0.3m high, form boundaries to the microcatchment area and direct runoff into this basin where typically a single tree is planted (Fig. 6.7).

Knowledge of the Tunisian version of this technique eventually influenced research in the Negev and led to trials with a range of microcatchment sizes varying from 16m^2 to 1,000m^2 (Shanan and Tadmor 1979). Finally, a quadrangular shape was adopted with large microcatchments (up to 250m^2) for fruit trees and smaller ones for salt-bushes grown for forage.

Publication of this work has led to further experimentation with microcatchments in North America and Australia, India and Kenya. Dimensions vary with rainfall, soil and the types of trees (or other plants) being grown. In a part of Kenya with rainfall less than 400mm, microcatchment areas measuring 10m × 10m have been successful with planting basins 0.75m deep and 1.25m square. Using hand tools alone, one man might make one or two microcatchments in a day, but ox-ploughs can also be used for making the ridges. The technique is used on very gently sloping land and surveying instruments may be needed to locate the lowest point in each plot.

A hybrid design amalgamating elements of the microcatchment concept with aspects of the contour ridge techniques has been used for establishing grass on bare slopes in Kenya. The system involves constructing ridges in short arcs (see Fig. 7.3). The arcs lie on the contour at their ends, but dip below it at their mid point. These arcs or 'hoops' can be regarded as small microcatchments, open on their upslope side and receiving runoff from outside their immediate area. If grass seed has been broadcast over the area, runoff carries it into the lowest part of each hoop where clumps of grass quickly become established, and from which they spread until the whole slope is covered.

AFRICAN TRADITIONAL SYSTEMS

With these various categories of rainwater and runoff application on cropped land in mind, we can now reconsider traditional African versions of the techniques. A starting point is provided by Kutsch's (1982) account of runoff farming in Morocco, which systematically distinguishes techniques depending on some basic engineering construction (bunds, channels, spillways) from systems which exploit natural runoff flows with little or no construction. Kutsch refers to the latter as 'simple water-concentrating systems', and he calls the former 'improved' systems.

In classifying the many runoff farming methods found in Morocco, Kutsch makes it clear that 'simple' systems are almost always of the external catchment type, and points out that even in the total absence of earthworks to control runoff water, farming methods can be carefully designed to make use of runoff, with tillage and planting density adjusted to exploit the extra water available (Fig. 6.8).

In discussing traditional agriculture south of the Sahara, Kutsch

recognizes that while very few 'improved' techniques are used, 'simple' types of runoff farming have been widespread. He cites cultivation in depressions known as *cuvettes* in West Africa, and mentions the *teras* used in Sudan for runoff farming by inundation. The latter, however, do entail the construction of earthworks and might be classified as 'improved'.

It is difficult to carry this analysis very far, however, because there have been very few scientific studies of traditional runoff farming in Africa. Comparable practices used in North America prior to European settlement linger on in a few areas and have been researched in more detail. The results are relevant in showing what features one should look for in traditional runoff agriculture. Some of the best studies describe land occupied by the Hopi and Papago peoples of Arizona. Bradfield (1971) notes that Hopi fields are predominantly on alluvial soils deposited in 'fans' where runoff water flows down the sides of a valley, and gullies carrying flash floods reach gentler slopes, depositing their sediment loads. Much of the runoff infiltrates the soils on these fans and is held as soil moisture. Hopi farmers can identify sites where moisture, drainage and fertility are suitable for agriculture by noticing variations in the natural vegetation. Fields made on such land require only short lengths of bund to spread the water a little more evenly. The sediments and organic debris deposited by floodwater are important in maintaining soil fertility since the fields are not manured. Indeed, commenting on Papago agriculture in the same general region, Nabhan (1984) argues that techniques of this sort are a form of 'nutrient harvesting' as well as water harvesting.

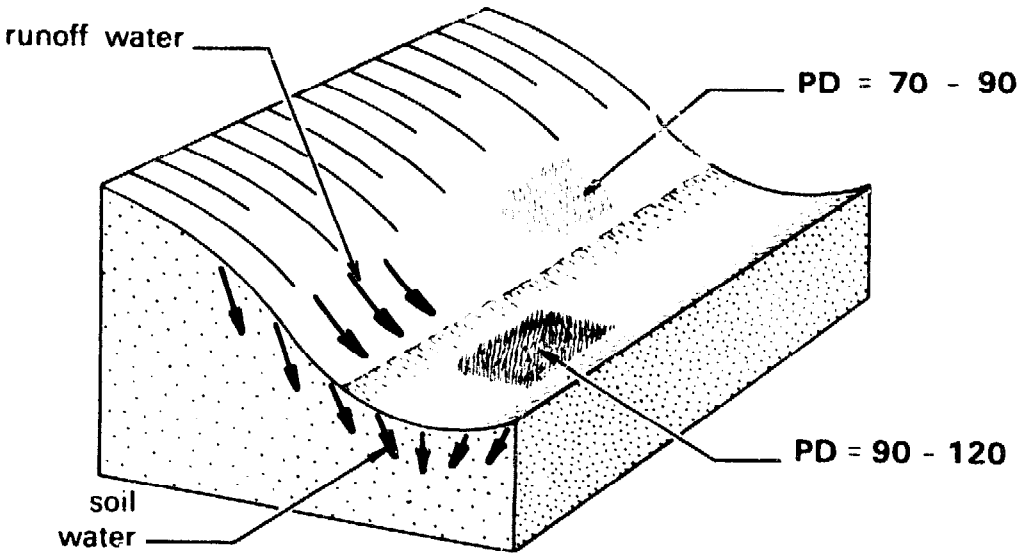

Fig. 6.8 Farmers in Morocco vary the weight of seed sown per unit area of land in order to adapt plant density (PD) to the moisture likely to be available. In this instance, the farmer expects the crop growing in the depression to benefit from runoff and has accordingly aimed for a higher plant density. He has thus planned his cropping as a form of 'simple' runoff farming. (Kutsch 1982)

PD *is expressed in plants/m²*

Earlier, Nabhan (1979) had classified the 'perennially moist microniches' which farmers in arid areas in Arizona have traditionally exploited for growing crops. Some are associated with groundwater and sub-surface moisture, others with floodwater flows, and still others with runoff on upland sites. Many of the techniques employed are 'simple' in Kutsch's terms, but 'improved' systems are also found. Some entail construction of dams or spreader dykes, and some the diversion of water from intermittent or even perennial streams by means of weirs and short lengths of canal. However, the three most basic methods of floodwater and runoff farming which Nabhan observed are:

- upland runoff harvesting before water reaches natural drainage channels;
- exploitation of flash floods by planting on alluvial fans or on the beds of intermittent streams;
- planting on the margins of streams or rivers which flood.

The only study known to us which examines runoff farming in sub-Saharan Africa with comparable detail concerns field systems in the southern part of Turkana District, in northern Kenya (Morgan 1974). Rainfall in this area averages less than 200mm per year, but sorghum is regularly grown by exploiting sites where runoff or floodwater provides sufficient soil moisture. Figure 6.9 maps a small part of the Kerio River valley, and marks the sites of several sorghum 'gardens'. It is noticeable that all three categories of site listed above for Arizona can be identified here also. The use of runoff before water reaches natural drainage channels is demonstrated by the elongated sorghum plot at the foot of the Morulim hill, an outcrop of lava rock. Flash floods water the large fields at Nachor and Kangatet, where dashed lines on the map indicate the route taken by the main flood flows. The third category, planting on streams or river margins, is seen at the bottom of the map at Nagaloki and Lomomuk. As on Hopi and Papago lands, the selection of sites for cultivation is guided by observing the natural vegetation. Waterlogged ground characterized by a particular Acacia species is avoided and plants indicative of better drained soils are looked for. A quick-maturing variety of sorghum is grown which can be harvested within 65 days of planting, and can thus take advantage of very transitory accumulations of moisture.

Cultivation of the crop in south Turkana is undertaken entirely by women. The 5ha field at Nachor was divided into 43 plots in 1967 which were worked by 41 women. Great care was taken of the crop with special platforms erected as vantage points for bird scaring, but the terrain was left in its natural state with no earthworks at all either for water spreading or erosion control. Thus the Nachor field was being eroded by gullying at its downstream end, and land was being lost by deposition of gravel at the upstream end.

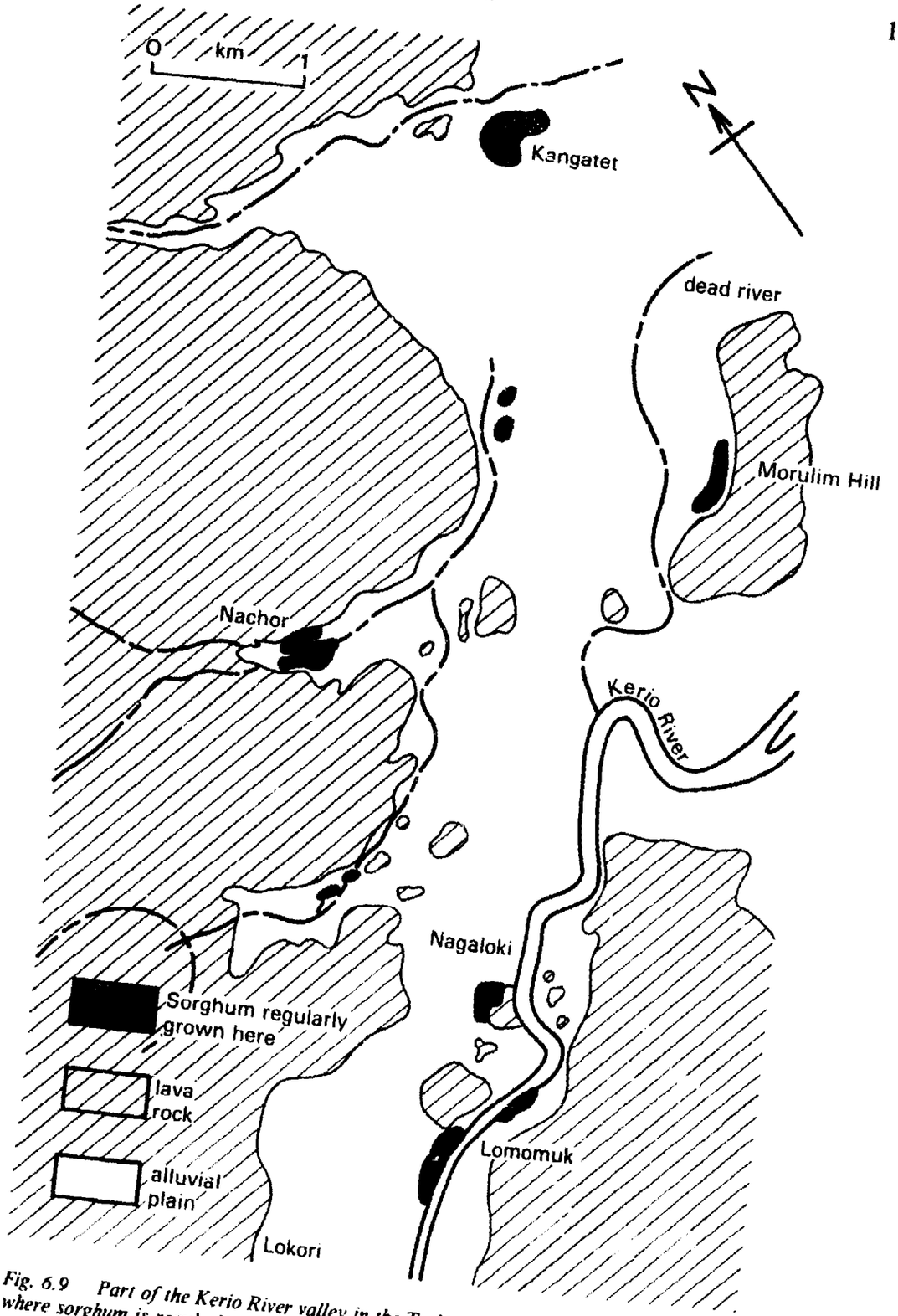

Fig. 6.9 Part of the Kerio River valley in the Turkana area of northern Kenya showing sites where sorghum is regularly grown (dark areas) in relation to natural drainage channels which carry occasional floods (shown by dashed lines). (Morgan 1974)

Despite the fact that runoff and flood farming in Turkana employ only 'simple' techniques, agriculturalists attempting to introduce improved methods in the region have found some aspects of the local tradition highly relevant to their efforts. In one of the earliest of 'improved' schemes, the water-spreading experiment illustrated in Figure 6.2b, the value of the quick-maturing 'Turkana sorghum' was recognized, and seed was brought for planting on the project site from a local woman (Fallon 1963). This project was also influenced by local opinions on planting dates, with the result that there was an October sowing in the first year which the promoters had not planned. Another project in Turkana District, initiated by the Salvation Army, enlisted the support of local people to indentify suitable sites. As in Hopi country and in the Kerio valley, the natural vegetation provided clues. The people were able to point out that the presence of the dwarf shrub *Duosperma* indicated deep loam soils with good potential for runoff farming. One or two of the sites chosen on this basis had previously been used by them for sorghum cultivation (Hillman 1980; Cullis 1984).

'Simple' forms of flood farming and runoff farming exist throughout the semi-arid region immediately south of the Sahara from southern Mauretania and Niger eastwards to Sudan and Somalia. Examples of indigenous 'improved' systems are also to be found, including teras in Sudan and stone barriers across river beds in Somalia. In West Africa, Martin (1979, quoted Cullis 1984) mentions stone bunds used to control runoff in Adar Doutchi (see map, Fig. 7.2). Sorghum is cultivated behind small dams in southern Mauretania, presumably by a version of the inundation method, and natural water spreading sites are exploited in Burkina Faso (ICHS 1972). Wickens and White (1978) comment that: 'these arrested runoff techniques are mostly traditional in origin and aim at increasing the water available to the crop by concentrating local runoff onto particular sites. Simply, the idea is to manipulate the natural accumulation in depressions . . .'

Many of the people in these areas are pastoralists, who may consume relatively small amounts of grain relative to their consumption of animal products, but who yet are often heavily dependent on cereals during certain seasons. Sometimes they obtain this grain by trade, but sometimes they grow it themselves. In that case, the important thing about simple forms of runoff farming is that constant attention to maintenance of terrace walls and bunds is not necessary. Fields can be left for long periods while animals are taken to some more distant area for grazing. Thus Hillman (1980) comments on the difficulty of establishing improved runoff farming among pastoral peoples in the Turkana who are 'unclear' about the aims of such relatively elaborate methods.

Agriculturalists and water conservation engineers working in sub-Saharan Africa often seem unclear in their turn as to how the traditional systems should be regarded. Though some agriculturalists, as we have seen,

have learned from the local technology, others ignore it entirely. Small patches of sorghum grown casually by women can too easily be disregarded when experts are oriented towards more formalized systems of farming.

In a valuable account of runoff farming experiments in another part of Kenya, Critchley (1984) well expresses the ambivalent view which is usually taken of existing 'simple' methods. He states that there is 'no long history of runoff harvesting in Kenya', but simultaneously notes that there is a local tradition of cultivating sites 'where there is some inflow from an external catchment'. Moreover, this traditional practice has influenced the work of the programme Critchley describes. Following efforts to introduce within-field catchments in the form of contour ridges, it was found that farmers were reluctant to adopt this approach when their land was already receiving runoff from an external catchment (Fig. 6.10a). It therefore seemed better to assist farmers to improve the efficiency with which they used this existing source of runoff by helping them build bunds and spillways on their fields (Figure 6.10b). If the runoff available from the external catchment proved insufficient, part of the plot could later be re-organized with contour ridges and within-field catchment strips.

Critchley's report presents an excellent example of 'innovative dialogue'. Rather than insisting on the method which seemed technically preferable, his programme was flexible enough to incorporate farmers' preferences based on local traditions. Critchley's report also records suggestions made by the handful of farmers involved in the experiments, such as the 'alternative channel' indicated in Figure 6.10c. It is perhaps worth adding that nearly all 'simple' systems of runoff farming depend on external catchments. Hence wherever 'simple' forms of runoff farming are practised, there may be the same tendency that Critchley observed for farmers to be resistant to alternative within-field systems.

DESIGN PARAMETERS

One difficulty confronting any effort to introduce runoff farming into a new area is that there are a very large number of technical factors which need adjustment if the basic principles are to be adapted to local conditions. The design of a runoff farming system requires a multi-factorial approach — taking account of crop water requirements, tillage, weeding practices and planting densities as well as water management. The latter by itself involves many factors relating to soils, slopes, rainfall intensities, and whether the rain comes in summer or winter. Tillage and weed control both affect moisture loss from the soil, often critically. Limits to what can be achieved by water management can sometimes be balanced by choices concerning crops. The variation in planting density used in Morocco to adjust for different levels of soil moisture is a case in point. The cultivation of quick-maturing varieties of millet (Sudan) and sorghum (Kenya) is another

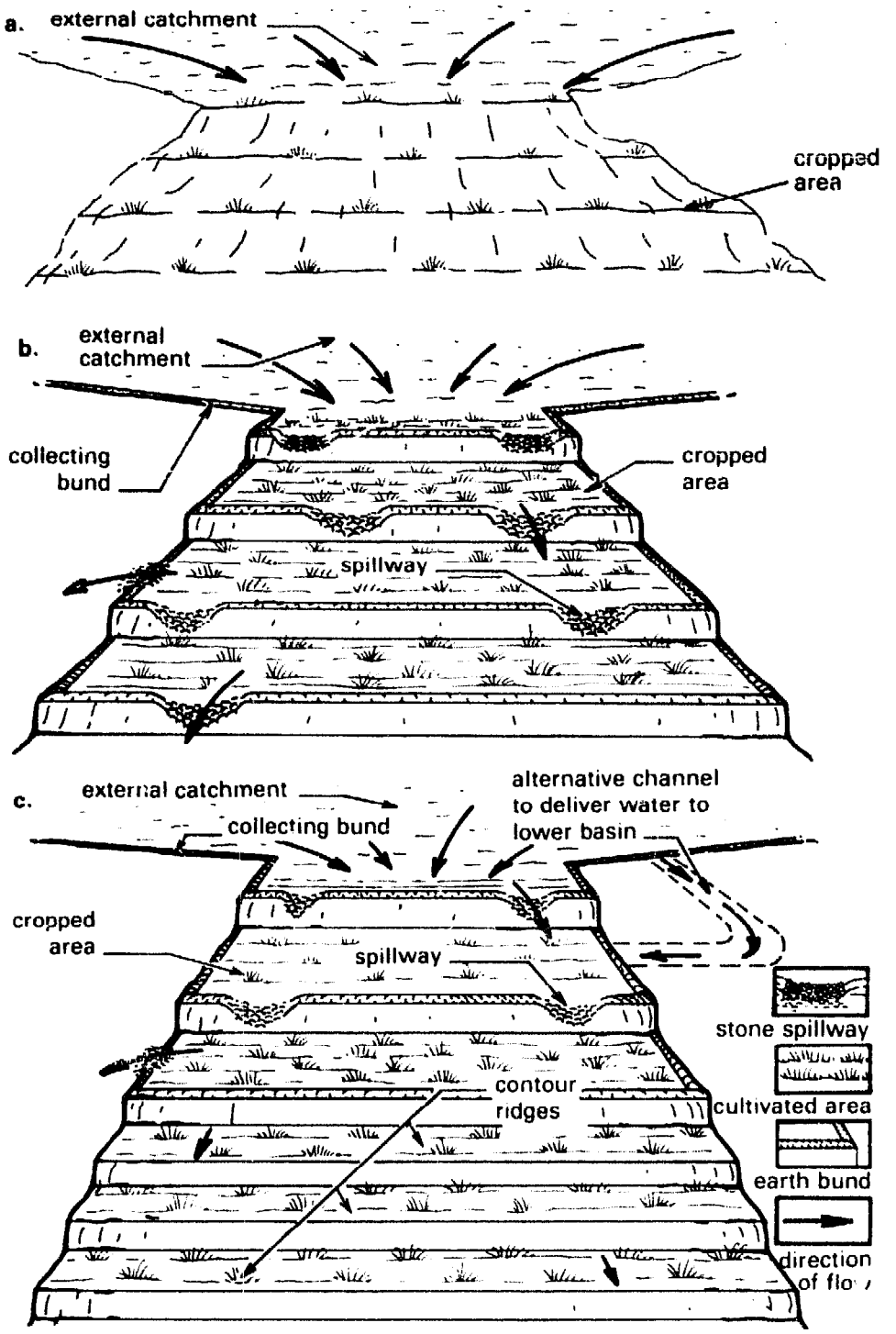

Fig. 6.10 Three stages in the development of a runoff farm with an external catchment in the Baringo Pilot Project area, Kenya. (Critchley, 1984 – with modifications) (a) 'simple' runoff farming as practised before the project began – the plot was chosen for cultivation because runoff naturally concentrates there; (b) 'improved' runoff farming with collecting bunds to increase the water available and with bunds and spillways to control water on the cultivated area; (c) a further modification with contour ridges on the lowest plot because insufficient runoff was available from the external catchment. The alternative channel to the middle basin was suggested by one of the farmers in the project.

example, allowing short-lived moisture reserves to be exploited. Sorghum is much favoured as a deeper-rooting crop than, say, maize. It is able to use the whole of the soil profile and has the ability to withstand temporary waterlogging as well as drought.

With a crisis of food production engulfing so much of Africa, reliance on traditional runoff farming is obviously insufficient. Plots of land that chance to receive runoff due to the shape of the terrain are far too limited; they are often vulnerable to erosion, and the flows of runoff they receive are unevenly distributed. But although these systems may be inefficient in these respects, and although they look casual to an engineer, they are based on local environmental knowledge and have been appropriate to the needs and resources of the people who have used them in the past. Such systems are no longer fully appropriate in the context of larger populations and a fundamentally altered economy, but may have continuing value in at least three respects.

Firstly, these systems demonstrate the relevance of runoff farming in many 'drought-prone' areas which are currently experiencing food shortages. Secondly, existing methods exemplify types of runoff manipulation which are compatible with local lifestyles, social systems and patterns of organization.

Thirdly, though, they represent a fund of experience concerning soils, crops, climate and runoff flows. In designing new systems, it is almost impossible to combine the multitude of factors already involved successfully without long and careful trials. On a purely technical level, the benefit of seeking to learn from traditional systems, however apparently 'simple' and insufficient, is that they are likely to include effective choices regarding some of the critical crop or soil factors. Learning from them may thus allow mistakes to be avoided and the development of improved systems to be speeded up. Traditional techniques may also offer clues as to the suitability of inundation as opposed to more conventional methods, as well as influencing choices between within-field and external catchments. In all these respects, traditional methods can provide starting points for adaptive research and innovative dialogue.

The introduction of 'improved' systems of runoff farming cannot, of course, depend entirely on knowledge of traditional systems. It will also be important to collect all the data possible on rainfall and runoff volumes, using the methods outlined earlier in Box 3.2, or at least, simplified versions of those methods. It will be necessary, in addition, to design bunds and spillways on the basis of conventional agricultural engineering experience, as outlined, for example, in Boxes 6.2 and 6.3. Further ideas about the layout of contour bunds will be presented in the next chapter, together with details of a surveying technique that will ensure their accurate alignment with the contour (Box 7.1), and it will be possible to see in more detail how 'modern' and 'traditional' ideas may interact.

7. REPLICATION OF RUNOFF FARMING

COMPLEMENTARY SURVIVAL STRATEGIES

In the chapters on rainwater collection from house roofs, it was argued that effective promotion of the technique may often depend on offering a very comprehensive technical assistance package, including help with organization, training, bulk purchase of materials, loan of equipment, and financial support. The balance struck between these different forms of help would depend on whether the constraints likely to restrict construction of rainwater tanks are lack of skills, shortages of materials, high costs, or some combination of these.

The promotion of runoff farming calls for a somewhat different approach since it is concerned much more with the management of soil and water resources which farmers already possess, and does not usually require large quantities of additional materials. Thus in analysing the constraints which may discourage the spread of runoff farming practice, one is less likely to identify a need for special purchases of materials or equipment (although seed and farm tools may sometimes be needed). Instead, there are more likely to be constraints relating to organization and seasonal labour shortages — or relating to complementary activities such as livestock or grain trading.

It is also important to be aware of constraints which programme organizers can themselves create by ignoring traditional techniques, by closing options prematurely, or by insisting on over-elaborate design procedures. These points involve questions of what Biggs *et al.* (1984) refer to as 'technology responsibility', meaning the responsibility of an agency to make its own selection of the techniques it promotes. The agency must make its selection with an awareness of where its own prejudices lie, and with a willingness to modify its choices in response to local reactions and local needs. To present a large range of alternative techniques and leave the poor to select those which are most suitable is 'unrealistic and irresponsible'. But to suppose that an external agency is likely to make a good choice on its own, without discussion among local people,is equally mistaken. Biggs *et al.* comment that the best agencies are those which willingly admit to changing their minds in the light of local conditions, and this

chapter will document one instance where an agency abandoned its preference for microcatchment techniques in favour of methods relating to traditional runoff control practices in the area where it was working.

'Technology responsibility' might also involve a willingness to step outside the conventional specialisms to consider needs in a community which have nothing directly to do with rainwater, but which may significantly affect prospects for its utilization. For example, in the context of rainwater collection from roofs, it was suggested that some people might need help with house improvements as well as with water tanks — and there is one programme in Kenya which links the provision of rainwater tanks to the installation of improved cooking stoves.

It is even more likely that technical assistance for runoff farming will need to operate in a context of other, complementary developments. This is because runoff farming may be an important survival strategy in a drought-prone environment and may impinge on many aspects of the livelihoods it helps to sustain. The importance of this is very evident from the African case-studies which occupy much of this chapter.In these instances, runoff farming is one of several methods for the insurance of food production against the effects of erratic rainfall. One example is a programme in a part of West Africa where average rainfall is 680mm. It might be thought that with such ample rains, which come within a single season, runoff farming techniques would be superfluous. Indeed, it might be expected that enough soil moisture to support a crop would be provided by the rain falling directly on the cultivated land, without need of extra water from a separate catchment area.

In the area concerned, which is the Yatenga region of Burkina Faso (formerly Upper Volta), it is certainly true that when rainfall approaches the average level, runoff makes little difference to crop yields. During the 1982 growing season, rainfall in part of the area was 400-500mm, and in fields where runoff farming was practised, yields were only marginally higher than elsewhere. However, in 1983, there was a drought with rainfall down to 350mm, and under those conditions, fields receiving runoff yielded 48 per cent more than control plots. In drought years, then, the extra soil moisture from retained runoff might make all the difference between the production of a reasonable crop and a catastrophically poor harvest. It has been noted that in some years, the biggest advantage is gained at the beginning of the season. Early sowing is more successful on land receiving runoff, and sometimes the crop is established a month earlier than on other land. This extends the length of the growing season, and ensures some minimum production even in years when the rains finish early.

These conclusions are paralleled by the results of runoff farming experiments in North America. In regions where average rainfall is relatively high, the main benefits of runoff techniques are not high production in an average year, but improved reliability of yield in drought

years (Jones and Hauser 1975). In the very worst seasons, needless to say, crop failures are likely even with runoff farming.

Since runoff techniques have this significance as crop insurance strategies, it is not surprising to find that there are traditional forms of runoff farming in the parts of Yatenga from which the foregoing figures are quoted. One consists of the excavation of small soil depresssions, about 0.2m in diameter spaced about 1m apart. Much runoff which would otherwise be lost is captured this way, and is concentrated in the root zone of plants sown in the depressions.

The technique is comparable to 'pitting', a method of retaining runoff used on dry rangelands in Mexico, in other parts of North America, at one time in Kenya, and also tried on arable land in Zimbabwe. In some Mexican work, the pits were made with a modified disc plough, and were effective for range seeding in areas with 200m average rainfall. In the experiments most directly comparable to the Yatenga technique, 'pits' covered about 20 per cent of the land and filled with runoff from the remainder (Fierro 1981). An ox-drawn implement was devised for making pits of this sort in Zimbabwe (Hlekweni 1975).

The Yatenga approach differs in many details from conventional pitting. For example, manure may be placed in the bottom of each soil depression before the planting season. Pits also effectively trap windborne leaves as mulch. Termites come to feed on this and leave tunnels behind them which facilitate root growth and increase water infiltration (Fig. 7.1). The termites have usually gone before the crop is sown and have not been observed to do it any harm.

Rainfall in the Yatenga is erratic in more than one sense. Riesman (1977) quotes the 1969 rainfall figures for two places only 25km apart. Despite this proximity, and despite fairly ample rainfall in total, monthly amounts were very different (Table 7.1). At Djibo, low rainfall in July had a very bad effect on the immature crop, making this a 'near famine year', while Pobé had a reasonably even distribution of rain throughout the growing season and yields were good. Runoff farming at Djibo would perhaps have

Table 7.1 Rainfall (mm) recorded at two stations in Burkina Faso during the 1969 growing season. The two stations are only 25km apart, but monthly rainfall varies considerably. (Riesman, 1977, *Freedom in Fulani Social Life*. University of Chicago Press.)

	May	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*TOTAL*
Djibo	11	137	38	174	39	101	500
Pobé	56	102	102	202	76	45	583

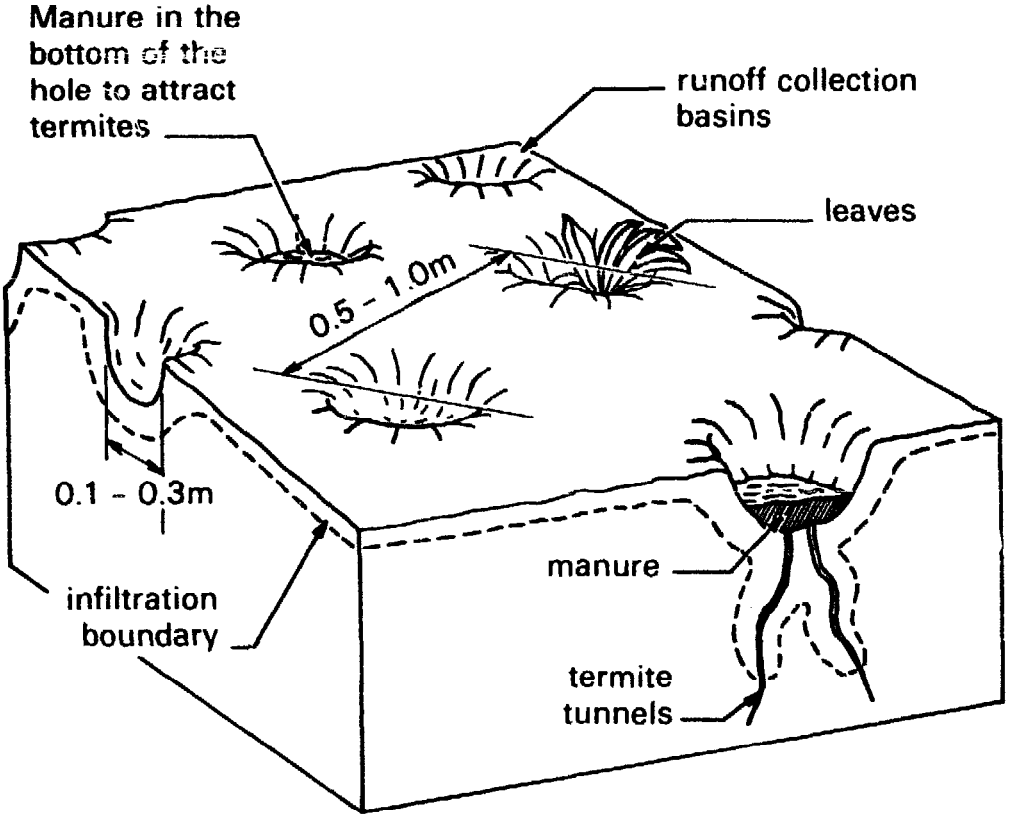

Fig. 7.1 Soil depressions within which seeds of cereal crops are planted – a traditional method of using runoff to support crops in the Yatenga region of Burkina Faso. (Wright 1984)

enabled enough extra water to infiltrate the soil in June to tide the crop over the dry weeks of July.

When average rainfall figures are plotted on a map (Fig. 7.2), it can be seen that isohyet lines are very close together. This indicates that quite small disturbances in the 'normal' geographical distribution of rainfall can make a big difference to the amount of rain received at any one place. The map also shows that average rainfall is consistently higher in the southern regions of Burkina Faso. In 1983, although 'the north had almost no harvest . . . because of drought, in some parts of the south, barns were overflowing with millet after a bumper harvest: farmers were worried about the low price they would receive for their crop on the saturated local market' (Twose 1984).

Across the border in Mali in an area where average rainfall is quoted as 600mm (but where rainfall has been below this nominal 'average' for seventeen years — 1968-85), actual rainfall in most areas during 1984 was typically around 200-250mm. This rain was again patchy and among a hundred and more drought-stricken villages, there were actually *seven* whose fields received ample rain, producing excellent crops (Brittain and Toulmin 1984).

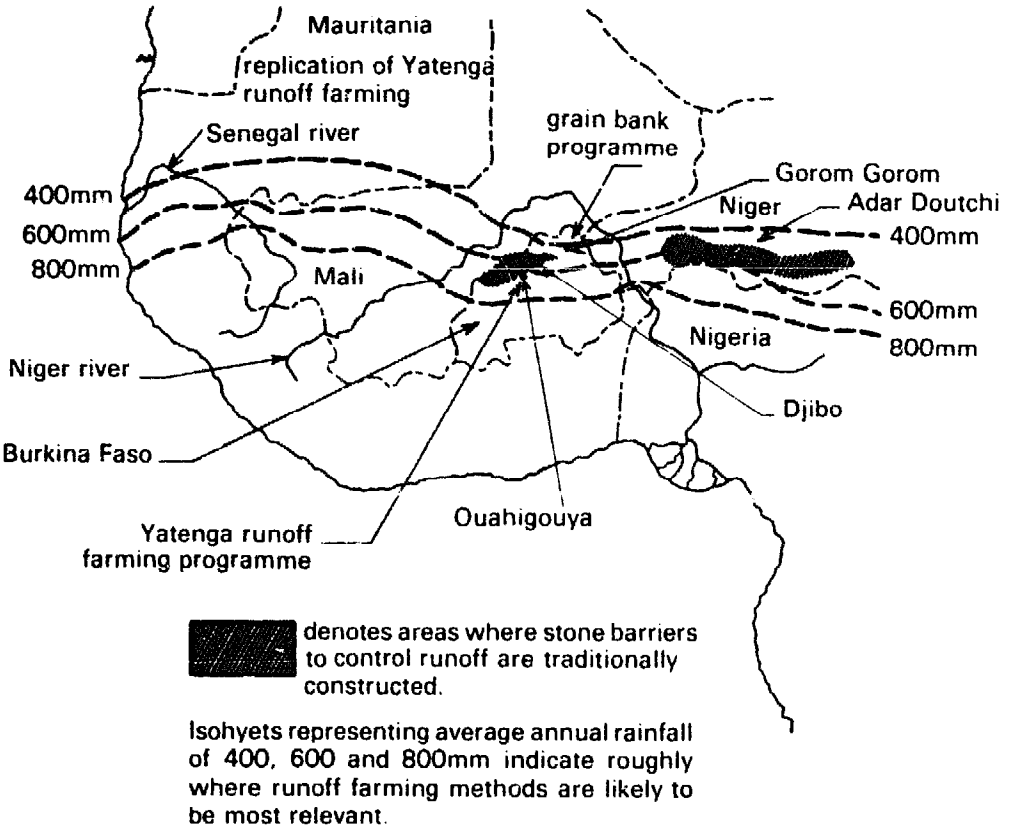

Fig. 7.2 Location of the West African programmes discussed in the text.

Strategies for coping with this extreme patchiness in rainfall, all of which affect the prospects for runoff farming, may involve livestock, migrant labour, choice of crop varieties, grain storage, and food trading. For example, quick-maturing varieties of millet provide some insurance against the rains finishing early and such varieties were increasingly sown during the 1970s. Another strategy is that women customarily travel to villages which have had good crops to help with harvesting and threshing, and to glean on their own account (Brittain and Toulmin 1984). Men travel further afield to seek paid employment, so that they have money to buy food.

Prior to 1920, it was common for cultivators in Burkina Faso to maintain granaries capable of holding three years' requirements of millet, so that after a good harvest, they could survive two successive bad ones (George 1980). The practice declined as a money economy developed and people increasingly needed cash to pay taxes and to buy the necessities they did not produce themselves. Now the tendency is for farmers to sell a large part of their crop soon after harvest and then buy food later in the year. This makes them very vulnerable if food prices rise steeply especially as merchants tend not to release grain until the prospects for a high profit seem good. Locally-run grain banks have made some headway in overcoming this problem.

According to Twose (1984), more than 500 co-operative and village groups in Burkina Faso now buy grain produced by their members immediately after harvest. They store the grain locally, and resell it to members as needs arise, always at the official price (which is generally much lower than the prices at which merchants sell). With financial help from government or agencies, some of these groups now travel to areas with surpluses to buy grain for their village grain banks, so bypassing traders.

RUNOFF FARMING IN PASTORAL AREAS

One of the most important strategies by which people have traditionally safeguarded their livelihoods is through the balance they strike between livestock and grain production. In the situation illustrated by Table 7.1 in which rains are very patchy, the advantage of livestock is that they can be moved from drought areas to graze in districts where rainfall has been good. Nomadic pastoralists track down 'pockets of good pasture' resulting from localized storms. Where groups depend entirely on livestock, they have tended to suffer as cultivated areas have expanded, depriving them of some of their best grazing. In Chapter 3, it was commented that the excavation of hafirs or ponds which fill with rainwater can sometimes compensate for loss of grazing by allowing new rangelands to be used.

Many people, however, have traditionally depended on a combination of livestock activities with cultivation. Riesman (1977) describes how some communities in the north of Burkina Faso are primarily cultivators and how their cattle are effectively treated as extra fields — 'fields on the hoof' — which can be moved to places where rainfall is good, even when drought blights grain crops in conventional, static fields. Although these people think of themselves as herdsmen, their crops provide the greater part of their food in a normal, rainy year, and their livestock are partly a form of insurance. Cultivation is not left to the women, as so often among cattle-raising groups, and active men spend more time with their millet than with their herds.

In the Turkana District of Kenya, the balance between livestock and crops is struck differently. Average rainfall is much lower, and it is therefore logical that crops are less important. Indeed, some years may be so dry that no crop is planted at all. One result is that the people move more, and fields are used intermittently. Thus although the basic principles of runoff farming influence people in their choice of sites for cultivation, building permanent structures to capture runoff has seemed pointless to these farmers, and they have been content with natural concentrations of runoff in dips and hollows. As Hillman (1980) puts it, they regard the rainfall as too erratic to justify construction of bunds and the like.

Yet there is no denying their interest in using runoff. Fallon (1963) has reported on the enthusiasm with which local people participated in a water-

spreading project near Lorengippe, planting their own sorghum plots 'haphazardly' after the first season of formal cropping was over. Despite this encouraging start, however, the land was subsequently used by the government Range Management Division for the production of grass seed. Local herders were given some limited access, but after a number of seasons moved away. Indeed, with all programmes in Turkana, the necessarily unpredictable movements of herds have created problems for those attempting to promote permanent runoff cultivation.

More recently, in a report commissioned by FAO, Finkel has stressed that for success with runoff farming in Turkana, techniques must be consistent with the cultural patterns of the pastoralists, and thus should not require permanent settlement near the site. Fields should be designed to require only seasonal attention, without need for maintenance during periods when no crops are in the ground. With this in mind, Finkel recommends that structures should be overdesigned, and that schemes should be as similar as possible to traditional runoff farming practices. As a practical illustration of what might be appropriate, he suggests a series of small cultivation plots enclosed on their downslope sides by bunds laid out on either a trapezoidal or semicircular plan (Fig. 7.3).

The idea is to minimize damage from any breaching of a bund by dividing up the area into small plots, rather than enclosing large areas within a single large embankment. Finkel speculates that herdsmen might prefer to use the plots to grow forage for animals rather than cereals, and suggests that 75 per cent of runoff farming areas might be developed for fodder production.

Clearly, then, technical assistance for runoff farming cannot be narrowly concerned with the design of bunds or microcatchments, but should also be related to the several other methods by which people insure the continuance of their livelihoods. Thus if we were to try and analyse the components necessary in a technical assistance programme (as was done for rainwater tanks in Chapter 4), activities relating to livestock, or in other circumstances, grain storage, might be noted as needing attention. However, there are few programmes in which these varied elements have been put together. In one place there may be an exemplary runoff farming experiment, and in another, encouraging development of grain banks, but rarely are methods of insurance for food supplies dealt with in an integrated way.

EROSION CONTROL

Runoff farming as an insurance measure for areas of erratic rainfall has so far been described in terms which imply stability in the relationship of people to the land, whereas in practice, degradation and erosion of soils is widespread in many of the areas where runoff farming might be used. In

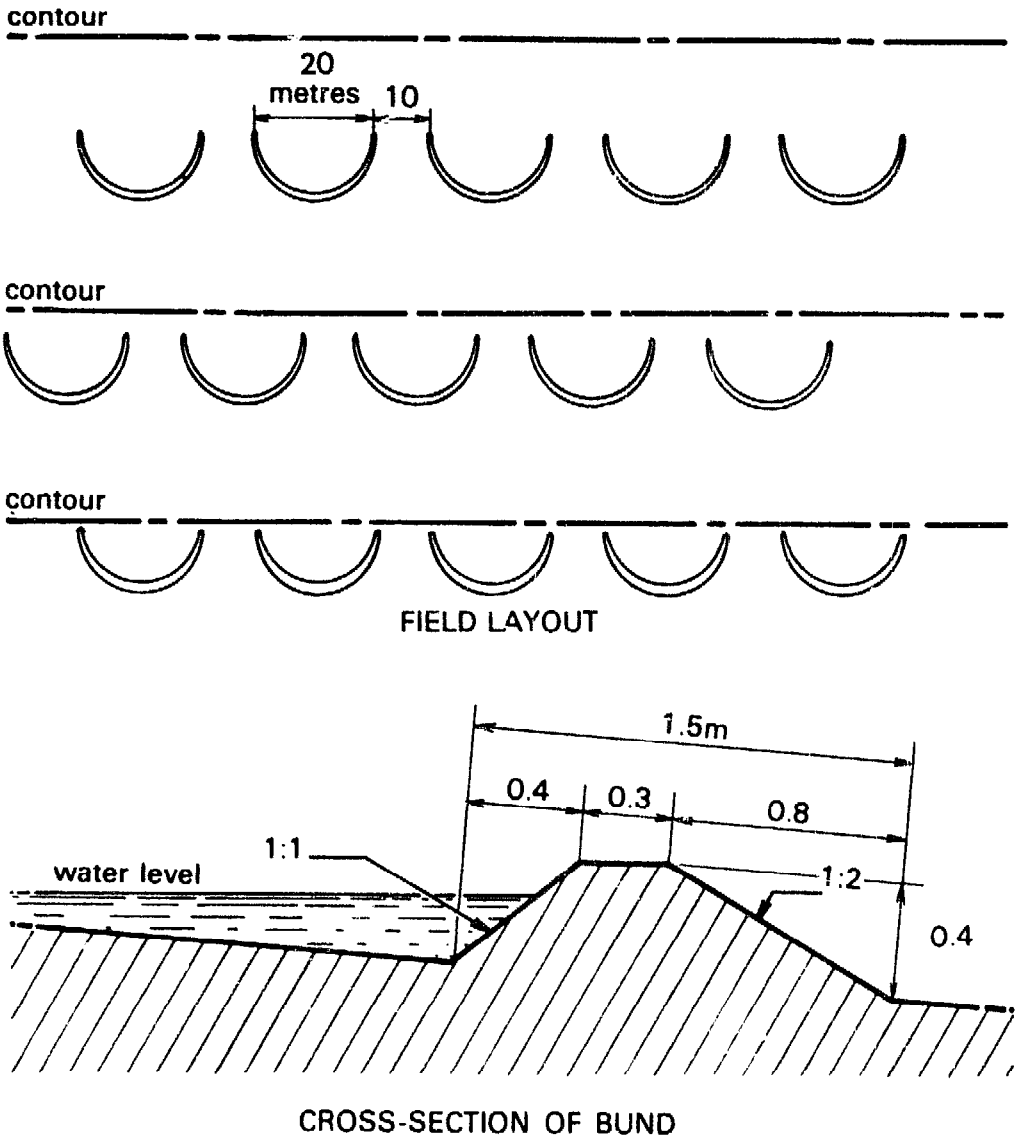

Fig. 7.3 Semi-circular cultivated plots with curved bunds or 'hoops' to hold back runoff. This is one of several ideas suggested for the Turkana District of Kenya. Hoops have been used for some time in Baringo District. (Dimensions are in metres.) (Finkel 1984)

Rajasthan, while khadins allow cultivation to flourish in some areas, desert sands elsewhere are encroaching on formerly productive land where trees and grass cover have been over-exploited (Eckholm and Brown 1977). In Ethiopia, problems of a similar kind prompted one villager to tell how, when he was a boy, 'we grew water-melons here and we had fruit trees and lots of sorghum and plenty of butter. Today the fruit trees have gone, we cannot grow any melons, and milk yield is down' (Twose 1984).

In the northern parts of Burkina Faso, especially in the Yatenga region around Ouahigouya (Fig. 7.2), there is a comparable situation. Land is literally disappearing as soils erode to leave large barren patches without vegetation. These covered 11 per cent of the landscape in 1973, and

continually spread, encroaching on cultivated areas (Marchal 1977). Local farmers and herdsmen are often forced to ask themselves whether the land can support them any longer, and many are leaving. Although efforts were made to halt this creeping disaster during the 1960s and '70s — some as a result of European aid, and others based on farmers' own efforts — little headway was made. However, in 1979, a new initiative was taken by the development agency Oxfam, after one of its staff had visited the Negev to study the operation of runoff farming systems there. On returning to his post in Burkino Faso, he arranged the construction of 200 microcatchments distributed among seven villages near Ouahigouya. Microcatchments like those used for tree crops in the Negev were chosen because it was felt that loss of tree cover was a major factor in the degradation of the environment. Farmers offered their most badly eroded land for the experiments, and catchment plots measuring 10m by 10m were laid out. Trees were planted in basins 2m square and 0.1-0.2m deep located in the lowest portion of each microcatchment. However, as well as planting trees, some farmers deliberately sowed cereals and others accidently introduced sorghum when they manured the basins. The sorghum was very successful, and at harvest, had 'massive heads, comparable to the best in adjacent fields' (Thomson 1980).

This stimulated a change in the aims of the project. The farmers had planted cereals as well as trees because grain crops were a much more immediate priority for them. With its philosophy of encouraging active participation by people involved in its projects, Oxfam was inclined to respond to this priority. At the same time, there was a change in personnel, with a new project leader arguing that the Negev-style microcatchments were inappropriate to the area (Cullis 1984). Whilst they were effective in establishing trees, they also required much labour for construction, particularly in the dry season. Yet at exactly that time of year, many younger men were absent, earning wages as migrant labourers in more prosperous regions to the south.

As the project developed in this new direction, it made greater use of a technique which farmers in Yatenga and adjacent areas indicated by the map in Figure 7.2 had traditionally practised — the construction of stone barriers to hold back run-off. However, whilst such barriers had previously been built in short lengths to intercept concentrated runoff flows, or to divert streams, they were now developed as extended contour bunds. Unlike conventional bunds, though, the stonework of these barriers allowed water to percolate slowly through to the strip of land below. By this means, water was evenly distributed over the fields and excessive inundation of the land above the barrier was avoided.

Some commentators have argued that the diversion of runoff flows onto the land is inappropriate in this area, with its high average rainfall, because the central problem is soil erosion caused by too much runoff. But it is clear

that capturing runoff on the fields has led to greater reliability of yield in times of drought, and this has motivated several hundred farmers to adopt the stone barrier technique. By contrast, programmes which have tackled soil erosion only, with no benefit to crop yields in seasons of low rainfall, have failed to make any impact on the farmers. A programme financed from European funds in the early 1960s which diverted erosive flows into established streams rather than retaining them on the land is a case in point.

What was required was a dual-purpose system, capable of exploiting natural runoff flows to ensure adequate crop production in drought years, but capable also of controlling excess runoff and preventing erosion when rainfall is ample. According to Wright (1984) stone contour barriers forming 'permeable' bunds or terraces achieve this dual purpose on land where large runoff flows concentrate. Where there is less runoff, however, he advocates impermeable earth bunds capable of holding back all the water on a terrace up to a point where there is overflow at the spillways. However, there is little emphasis on the deliberate development of extra catchment areas in this work. The aim is merely to use such runoff as occurs on existing natural catchments.

Wright uses a schematic diagram to indicate various options for the layout of contour barriers and suggests that choices must depend primarily on whether sheet runoff or channel flow has to be dealt with, and in what volume. Systems A and B in Figure 7.4 are for sheet flow, while C and D are designed to pass larger volumes of water in a natural drainage channel. System A has no spillways since this is an array of 'permeable', stone-built barriers. In practice most farmers start with system A, 'and then watch for damage after a heavy rainfall'. If none occurs, and if water distribution is adequate, no further construction is needed. However, if there is damage in a limited number of places, usually where the crest of the barrier is slightly lower than it should be, then those places can be reinforced, or small spillways can be built (like those described in Box 6.2).

As well as making terraces with stone barriers, grassed terrace borders are also encouraged. Crop residues — especially sorghum and millet stalks — bundled together are staked down on the contour where the terrace is to be formed, and perennial grasses are then transplanted or sown along the upslope side of this barrier which retains moisture and gives shelter to the grass. Both the crop stalks and the grass if protected from livestock will hold back sediments carried by runoff and promote a gradual build-up of the terrace.

It was hoped from the outset that farmers would be able to extend stone or grass borders along the contours on their own initiative, since it was recognized that any arrangement which required them to call in an outside specialist would not be utilized. The problem, then, was to find a method of surveying contours they could use independently, and organize some form of training in its operation. Two simple methods of surveying were

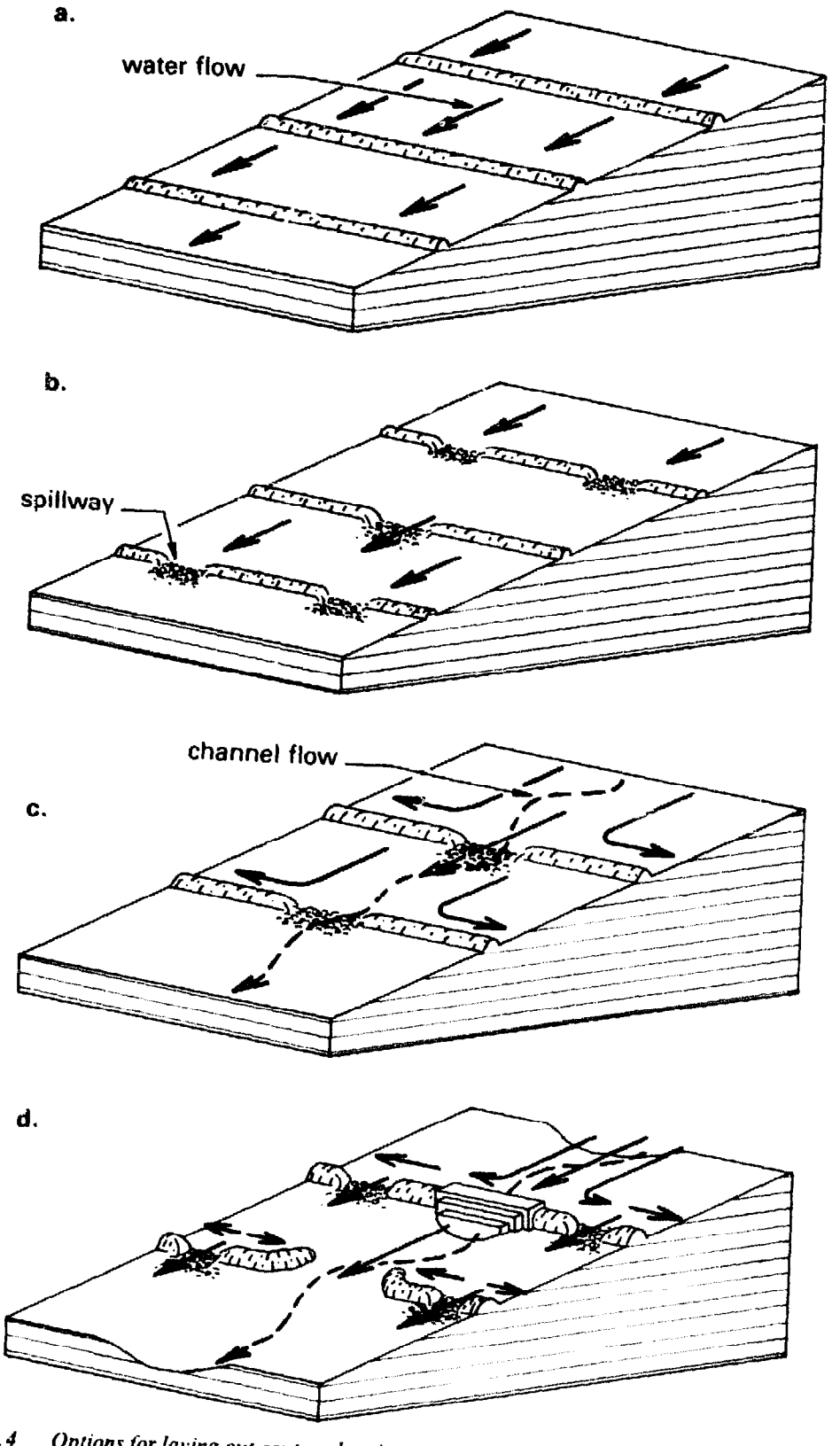

Fig. 7.4 Options for laying out contour barriers. (after Wright 1984) (a) simple stone barriers for sheet runoff; (b) barriers with spillways; (c) barriers with spillways for channel flow; (d) small dams and spillways for large channels.

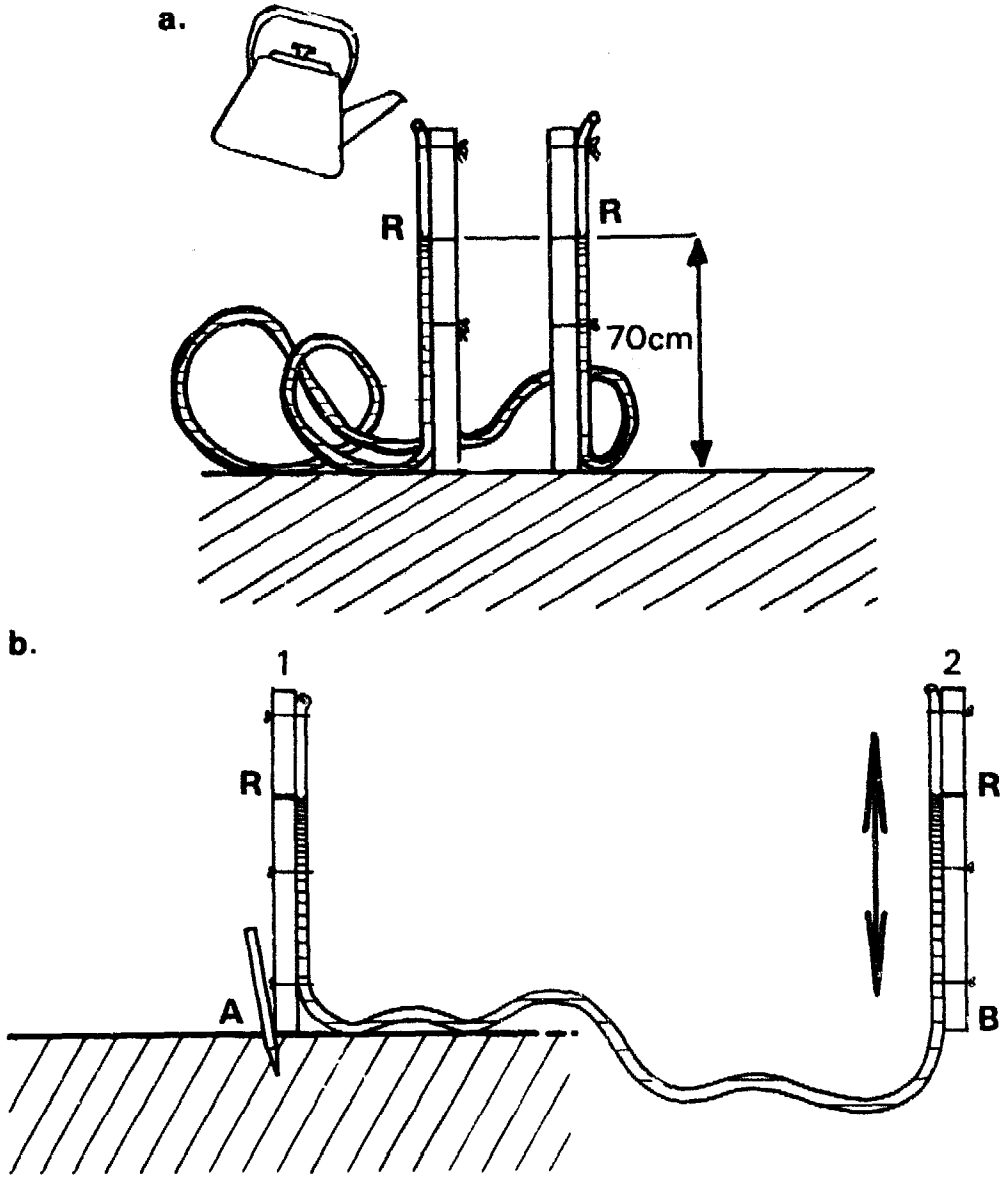

Fig. 7.5 The water tube level for surveying contours. (a) With the poles held vertically side by side, the clear plastic tube is filled with water up to the mark 'R' on each pole. (b) One pole is held vertically at a known point on the contour (marked by a peg) while the other pole is moved up or down slope until the water level arrives at mark 'R'. The foot of the pole is then on the same contour as its fellow. (CIEPAC 1980)

considered, one using an A-frame with plumb-line and the other based on observing water levels in a length of tubing. The water tube method was chosen as the easiest to use on the terrain in this area. The principle is illustrated in Figure 7.5 and further detail is provided in Box 7.1.

FARMER TRAINING

Surveying contours appears to be a critical constraint in many soil conservation and runoff farming programmes, and provision of training

in a technique which any farmer can use on his own land may be the single most important task which a technical assistance programme can undertake. A range of simple surveying levels appropriate to this purpose has been reviewed by Collett and Boyd (1977).

In the Yatenga work basic training, which has enabled farmers to learn the use of a level in two-day courses, also involves discussion of the functions of contour barriers. A typical training course is likely to include the following:

- a demonstration of model contour barriers;
- practice surveys with the water tube level;
- visits to fields where contour barriers have previously been built;
- discussion of fieldwork.

The model used for the demonstration consists of a sloping plot of soil, 2m square, on which miniature contour barriers are made. A watering can is then used to simulate rainfall so that the effect of different types of barrier can be observed (Plate 10).

For practice in surveying in nearby fields, farmers are divided into groups of three or four, each of which is given a water tube level to work with. If there is a water-course on the site, contour lines are traced from there, spaced at intervals which would be appropriate if contour bunds or barriers are going to be built. Finally, in the discussion session, farmers not only talk over — and, if necessary, criticize — the contour bunds seen during the field visit, but are also asked to consider how they will organize the work on their own land. Will they construct barriers individually, or will they help each other?

The effectiveness of farmer training may depend as much on what it excludes as on the extent of the local knowledge it uses. Thus a programme which can teach a single, crucial technique to a large number of farmers may be of more value than one which promotes many ideas simultaneously but reaches only a few individuals. In the Yatenga work, one omission was hydrological calculation of the spacing of contour barriers, the length of spillways and the like. Despite the advice quoted in Chapter 3 about the need for years of hydrological observation and careful calculation before any earthworks are constructed, insistence on this proviso would, in this instance, create a considerable constraint, sufficient perhaps to bring the programme to a complete halt. Many farmers in the area are illiterate and cannot be asked to perform numerical calculations. Yet they have their own insights into the local problem, and their own techniques of stone barrier construction, and it has been essential that these resources of knowledge and intelligence be fully used.

Wright comments that farmers have developed terrace systems on their own land in stages, adjusting for mistakes as these are detected. They may

Box 7.1 Determination of contour lines with a water tube level. (Wright, 1984)

Components of the level

—One length of clear plastic tubing, 6–10mm inside diameter and 10–20m long.
—Two poles about 1.5m long.
—Four rubber straps made from inner tube to attach tubing to poles.
—Two rubber straps to mark the water levels in the tube.
—One to two litres water.

Method of use (see also Fig. 7.5)

1. Uncoil the tubing and lay it on the ground, stretching out any bends.
2. From a container of water held at shoulder height, siphon water into one end of the tube, sucking from the other end—or fill the tube by pouring into a funnel at one end.
3. Remove any air bubbles.
4. Tie each end of the tube to one of the poles. Then place both poles together on a flat, smooth surface and hold them vertical side-by-side. Add or remove water as necessary to ensure that the water levels are about 0.4–0.5m below the tube ends.
5. Attach a rubber strap to each tube so that it marks the position of the water level.
6. Place one of the poles so that it marks the end of the contour whose alignment is to be determined. Take the second pole along the suspected line of the contour, moving it up and down the slope until the water level matches with the position of the rubber marker. The second pole is now standing on the same contour as the first, and a peg should be driven into the ground to mark the spot.
7. The second pole now remains stationary while the first one is carried forward to look for a third point on the contour line.
8. Proceed in the same manner until a suitable length of contour has been marked out.

Hints

1. Work during the coolest time of day, because heat causes the tube to stretch, requiring frequent realignment of the rubber straps which mark the water level. To re-adjust, repeat steps 4 and 5 above.
2. Raising one end of the tube much higher than the other can spill water. If this occurs, repeat steps 4 and 5.
3. When starting on a new site, begin by tracing the highest contour line required. If there are water-courses visible, start each line on the main water-course and work away from it, first on one side and then the other.

begin with a single bund or barrier of the simplest type. The 'empirical experience' gained then enables them to develop more complicated structures within a couple of seasons, 'without the need for calculations and with a minimum of frustration. Runoff from watersheds of up to 10ha have been exploited by "second year" farmers in the Yatenga'.

Textbooks discuss the proper spacing of contour bunds in considerable detail. Much depends on optimizing economic as well as hydrological variables. In the Yatenga, Wright says, 'illiterate farmers make economic choices right along with the rest of us and they should be allowed and

trusted to do so'. For optimum water infiltration, the top of each barrier should be level with the foot of the next bund upslope. Thus spacing will tend to be closer on steeper slopes. This is discussed with farmers during training sessions, and they understand it well. However, they may initially space barriers at wider intervals, often as much as 50m apart. Although this is not ideal, it confers some benefits, especially erosion control, and is often a response to shortage of labour when members of the family are working away from home. As one farmer said of his newly constructed terraces: 'If I see during this season that they are too far apart, I'll add some new ones in between them next year'. Because farmers can assess their economic priorities better than anyone else, 'it has been found preferable to allow them to resolve such questions on their own rather than trying to teach complicated formulas that will cause confusion'.

It took a year of trial and error to work out the details of this training programme and to modify procedures for using the water tube level. The next two years were spent teaching the use of the level, and 500 farmers from over 100 villages in the Yatenga region have learned the technique. Twose adds that the experience gained has been used in replicating the work in Mauritania.

The most active groups of farmers in Yatenga have been those experiencing the most severe soil erosion. This is illustrated by a survey of over 100 fields where contour barriers had been built, many of which had clearly been selected for treatment because of the large volumes of erosive runoff to which they were subject. In some fields, it was clear that heavily degraded land was being successfully reclaimed for agriculture.

Reporting this, Wright attributes the success of the project to the urgency of the problems of drought and erosion faced by farmers who could see the productivity of their land falling year by year. He argues that farmers have built contour barriers because the technique offers an immediate increase in yield and reduction of drought risk; he adds that soil conservation measures and tree-planting schemes — which do not show immediate benefits for crops — are taken up far more slowly. This is a cause for concern, because it is doubtful whether soil fertility can be maintained under continuous cropping with the manure available unless tree planting and other measures are pursued. But farmers are occasionally to be seen gathering dead leaves to mulch their fields, and some farmers have planted trees along their contour barriers. Indeed, Twose (1984) mentions a local tradition of planting acacia trees on cropped land because of their ability (as leguminous plants) to restore soil fertility. There has also been some natural regeneration of trees and bushes where contour bunds have stabilized the soil. Thus there is cause for 'guarded optimism' (Wright 1984).

On this analysis, the effectiveness of the Yatenga programme in replicating runoff control and farming techniques is attributed to its direct relevance to an urgently felt need. That in turn was a result of

farmer involvement in making choices about which of a number of options should be pursued — microcatchments or contour barriers, trees or cereal crops.

COMPONENTS OF TECHNICAL ASSISTANCE

At this point, it seems worth putting together the details of the various technical assistance programmes discussed. Both in connection with runoff farming, and in relation to rainwater tank construction, there have been three major topics to consider: firstly, how *technological options* are presented; then what *practical help* is given; and finally, what *organization* is necessary (Table 7.2).

With regard to technological options, it is always necessary for the responsible agency to make some initial choices, but it is equally necessary for it to be willing to learn from existing techniques used by local people, and to modify its own methods accordingly. In the Yatenga, some options were introduced by Oxfam (and Peace Corps) personnel with their specialist knowledge of Negev microcatchments and of surveying techniques; other options were rooted in the farmers' own experience of attempting to control runoff using stone barriers and soil depressions. The emergence of an effective technique arose from an innovative dialogue between these two kinds of knowledge and was due to the flexibility of the programme in responding to the farmers' own judgements. A third type of option might have been included, concerning complementary means of insuring against food shortage (Table 7.2).

Ray (1984) indicates a good deal about how such options should be considered when he talks about the need for 'dynamically appropriate' technology to overcome the problems of static poverty. By this he means technology which 'can be altered' in response to local needs, and whose management can develop to accommodate new resources and opportunities. Programmes which Ray picks out as 'dynamic' are those which are capable of changing direction, like the work in Yatenga when it shifted its emphasis from microcatchments to contour barriers. Those which he identifies, by contrast, as static include some in India which offer a single technique, such as irrigation from 'tanks', or a standard set of improvements to khadin agriculture. The latter he sees as unlikely to adapt to social change, and looks on as weak in many of the wider aspects of development.

Reviewing other components of effective technical assistance programmes (Table 7.2), we may note that the work in Yatenga also included a highly relevant *practical assistance package*, centred on the two-day training sessions described above. No significant help to farmers was needed in terms of supplies or finance except that the basic components of the water tube level had to be provided — that is, 10-20m lengths of clear plastic tubing. Wright also mentions that provision of picks, shovels and food for

Table 7.2 Components of technical assistance programmes for runoff farming (compare Table 4.1). Examples cited refer to the Yatenga programmes in Burkina Faso (and occasionally to the Gram Gourav Pratisthan or Pani Panchayat programme in Maharashtra, India).

COMPONENTS	*EXAMPLES*
TECHNOLOGICAL OPTIONS	
- options selected by professional fieldworkers and agency staff	e.g. microcatchments
- options based on local techniques and skills	e.g. stone barriers, including their construction and spacing
- options for complementary developments	e.g. livestock projects or grain banks
PRACTICAL ASSISTANCE PACKAGES	
- training, including training for women farmers where they exist	e.g. training farmers to survey contours; (in GGP, India, one group of women farmers, the 'widows')
- materials and equipment	e.g. water tube level supplied
- financial help, credit facilities	(in GGP, India, grants from government and foreign sources negotiated by 'parent body')
- follow-up work	e.g. agricultural extension, continued advocacy of tree-planting
ORGANIZATION AND INSTITUTIONAL DEVELOPMENT	
- village-level institutions and organization	e.g. potential for mutual help, co-ops, development of female versus male roles (in GGP, India, 30-40 family groups of irrigators)
- 'parent organizations'* giving support to village-level groups, making contact with banks, government, etc	e.g. local voluntary agencies (in GGP, Pani Panchayat meetings linking local groups)
- government institutions and development agencies	e.g. agricultural extension services, government irrigation departments

* *Biggs et al., 1984*

working parties can help in encouraging co-operative effort, but suggests that the group work can often be organized so that each member contributes to a stock of tools and materials which are shared during the project.

That raises the question of how replication of runoff farming systems is best *organized* among the farmers themselves, and at a higher level, what *institutional structure* is required to support it. In the Yatenga training sessions, farmers were invited to consider four ways of organizing the work:

(i) they could work separately on their own land;
(ii) an individual farmer might invite a group of others to help him, paying them in cash or food;
(iii) several farmers could work collectively on individually owned fields;
(iv) several farmers could agree to share their land, planning its use and carrying out work collectively.

Despite efforts to encourage mutual-help groups of the latter two types, it appears that the trend is for individual farmers to survey contours and construct barriers on their own, especially in times of famine when migration in search of work fragments the group structure.

The most successful villages, however, are those who work collectively, which allows for the informal training of uninitiated farmers as well. In terms of the wider institutional structure, efforts were initially made to interest the appropriate government body, the Organisation Régional de Développement (ORD). However, this agency did not respond, and thus the training programmes and other work have been promoted mainly through an informal project organization co-ordinated by Oxfam. As the success of the techniques becomes apparent one finds the ORD taking a much more active role in training, and it is now expected that they will eventually take over all aspects of the project if funding is available.

A range of more general institutional issues affect the availability of labour for such tasks as building bunds or cultivating runoff-fed land, and include such basic matters as the division of labour between the sexes. Those who plan technical assistance programmes rarely give enough thought to this, and often have no realistic view about how improved farming methods are to be promoted in communities where runoff agriculture is chiefly the province of women. Few agricultural extension services are oriented toward working with women, and very few women are employed as extension officers. Moreover, it might well be found that the amount of time which women must spend on domestic work seriously limits their opportunities to attend training sessions or to construct earthworks. The informality and lack of engineering structures on women's sorghum fields in Kenya (see Chapter 6) may partly be a reflection of time shortage. Thus, a very different approach to the organization of the work may need to be developed, perhaps after exploration of local attitudes to male and female roles with a view to securing male co-operation in time-consuming construction work.

Availability of labour for construction is in practice an important factor influencing the choice of runoff farming technique for a particular site. A system with an external catchment constructed in the sophisticated manner typical of those in the Negev may require 600-800 man-days per hectare to complete, with a continuing requirement for maintenance after-

wards. Evenari *et al.* (1982) even record a figure of 2,000 man-days per hectare for the reconstruction of a runoff farm in the Negev. By contrast, contour barriers, bunds or terraces having within-field catchments may call for only 40-100 man-days of construction work per hectare, depending on soil conditions.

Where people leave home at certain times of the year in search of paid work or to care for livestock, ambitious works cannot always be attempted because of shortage of labour. By contrast Cullis tells of famine relief schemes in Kenya since 1981 where earthworks for runoff farming have been constructed as a 'food-for-work' exercise, and more labour was available than could be purposefully employed. Inadequate planning, design and supervision has resulted in many of the earthworks being washed away. Structures have been generally poorly maintained and the impounded land under-utilized because food handouts rather than food production has been the motivating factor.

Another aspect of the organization of rainwater harvesting is raised by Ray (1984) when he comments that in India especially, 'the rural poor are reluctant co-operators'. Where survival is at stake, collective action is much more acceptable than otherwise. After analysing a number of Indian projects, he suggests that important factors in the development of co-operation are strong local leadership, official encouragement, and access to outside finance. This emphasizes the point made earlier that local mutual-help groups are unlikely to get very far without some sort of higher-level institutional support to provide advice and encouragement and to assist negotiations with banks and grant-giving bodies. The latter point is important because one reason for encouraging co-operative action is so that groups of poor people can obtain the same advantages as rich farmers in terms of marketing, access to credit and economies of scale. In Burkina Faso, there seemed to be no particular advantage in co-operative work on contour bund construction. Thus although farmers were encouraged by the programme organizers to work in groups, the trend was for them to work individually. While the majority of this work may still be done individually, the trend is now towards collective action taken on individual parcels of land.

By contrast, the quite separate programme for insurance of food supplies by establishing grain banks does involve poor farmers co-operating in group action. This is necessary so that the farmers can achieve sufficient economic strength to compete with merchants who speculate on grain prices, taking advantage to scarcity to make large profits. As previously mentioned, there are some 500 village groups in Burkina Faso buying and storing grain to meet their members' future needs. In the local runoff farming projects, the economic weakness of the farmer is not an immediate problem and so there is less incentive to collective action.

LOCAL ORGANIZATION AND GOVERNMENT ROLES

Whatever measures are proposed — contour barriers or grain banks — some sort of institutional support for farmers' efforts is likely to be needed. In relation to contour barriers, its primary function is to provide training, and with regard to grain banks, to help with finance. In both instances, any widespread extension of the work may well depend on persuading governments to play a role in providing this necessary support. In India, Ray has noted two states which illustrate government encouragement for water harvesting, Rajasthan and Maharashtra, which have programmes for khadins and 'tanks' respectively.

In one part of Rajasthan, Kolarkar and his colleagues estimate that there were 500 khadins in 1980, whereas Ray thought that there were 700 or more three years later. Thus there is evidence of very effective replication of this form of runoff farming, for which the state Department of Irrigation has been responsible. There is also support for the work from the nearby Central Arid Zone Research Institute, which is carrying out extension work on some khadins to demonstrate improved varieties of wheat and green gram, grown with chemical fertilizer.

In this area, though, one sees the disadvantage of runoff farming on such a large scale. The many small farmers who have plots within a single khadin do not appear to be well organized. They leave management of the system to the Department of Irrigation, which decides when water should be drained off at the sluices prior to planting, and which also handles maintenance. The Department's costs are paid for by a tax on the cropped land. The farmers make representations when they see the need for maintenance or other action, but otherwise do not participate in the running of the scheme. At the same time, there is a strict demarcation between the state Department of Irrigation and the Department of Agriculture, the latter employing the extension officers who give advice to farmers about crops and fertilizers. Ray suspects that lack of co-ordination here impedes extension links with farmers.

Despite achievements in constructing new khadins and in providing new spillways and sluices for old ones, there are doubts as to whether khadin development is proceeding fast enough or efficiently enough to meet the needs of a growing population. Some local experts believe that new canals bringing irrigation water from outside the region will ultimately become more important. Moreover, khadins only provide a limited number of plots for farmers, and leave many of the poorest cultivators uncatered for. Many of these limitations of the system arise from its somewhat cumbersome and bureaucratic organization. From a purely technical point of view, it is a highly effective form of runoff farming.

In Maharashtra, scene of the other major example of an official

programme for replication of a water harvesting technique, the main institution concerned was once again the local state government's Department of Irrigation, and later the administrators of India's Employment Guarantee Scheme. Both have been active in constructing percolation tanks, a form of floodwater harvesting in which water held behind a dam percolates into the ground, raising the water table at wells further down the valley. (The principle was illustrated earlier by Figure 2.4.) In Maharashtra, new percolation tanks have been constructed in the last two decades wherever officials of the Department of Irrigation, 'felt that physical conditions were encouraging' (Ray 1984). However, the construction of new 'tanks' is one thing; their effective exploitation is another. It is striking that the case studies of effective use which have received publicity tend to be examples where voluntary agencies rather than government departments have taken initiatives. One instance concerns groups of poor farmers who share irrigation pumps, and who were mentioned earlier (Chapter 2). Their irrigation water is pumped from wells in which the water table is sustained by a perculation tank some little way upstream. The earlier discussion also commented on the two levels of organization which characterize this project — the groups of 30–40 families that manage their own small irrigation systems — and the parent organization that provides technical assistance and negotiates financial support from more remote bodies to which the poorest farmers would not normally gain access. Initially, government grants were obtained, but when these stopped in 1981, finance came instead from foreign aid and from some Indian industrialists (Biggs *et al.* 1984).

Another case study from Maharashtra again involves the abstraction of irrigation water from wells below a percolation 'tank'. This 'tank' in fact consists of a dam 400m long impounding 300,000m^3 of water from a large catchment. Improvements introduced by the project include reafforestation on the catchment, to reduce erosion, and a number of measures to compensate for the poor performance of some wells down-slope from the dam. In places, check dams on streams improved percolation of water into the wells, but a large pump was also needed to raise water directly from the dam for irrigation of some of the land.

Two voluntary organizations jointly run this project which is located near Jalna (Fig. 2.3). One is a local body, whilst the other is Action for Food Production (AFPRO), which is active in many parts of India. Ray (1984) comments that because these are indigenous institutions, they cannot 'walk away from failure', and therefore proceed more cautiously than many foreign aid agencies which seek 'rapid dissemination' of favoured techniques. Both bodies were initially worried by the lack of organization within the local community. People who owned land, about 2–4ha per household, belonged to a co-operative, but there seemed no way of bringing poorer families in. AFPRO and its partner decided to go ahead

when they had established that people were at least willing to co-operate in planting trees on the catchment and fencing the area to keep livestock out. In another village, where there was no such co-operation, a similar project was not commenced.

There are obvious lessons in these case-studies about the organization which is necessary, firstly if a project is to succeed at all, and secondly if it is to help the poorest groups of people. The latter, it often seems, only benefit if they are well organized to help themselves. In the last project discussed, landless families in the end did find a way of working together for their own profit. They observed the considerable growth of grass within the newly fenced forestry area on the catchment, and negotiated the right to cut the grass and sell it as fodder to buffalo owners in a nearby town. In the other programme mentioned, however, the groups of irrigators seem to have achieved more — perhaps because their membership of about 30-40 families in each group is near the optimum size for self-management, and brings together sufficient resources for an effective operation.

In the very different circumstances of Africa's arid and semi-arid regions, pastoralists and farmers also need better organization for land and water management as well as to balance the activities of stronger commercial and government agencies. The case is put for grain bank collectives by Twose, and for pastoral co-operatives by Swift (1977), but has not yet been formulated with any clarity in rainwater harvesting programmes. In Burkina Faso, farmers apparently did not feel the need for organization initially.

Sandford (1983) offers an analysis of options for the organization of pastoralists which can be loosely applied to any rural group likely to be involved in managing water resources. Firstly, there are options concerning the functions of different units of organization: government departments, community groups, individuals and commercial firms. All too often, the problem is the weakness of groups at the community level compared with government and commerce. Then there are options as to whether organizations should be multipurpose or specialist. For example, should co-operative efforts in runoff farming be pursued separately from co-operative efforts in other spheres, or should a single village group be responsible both for the local grain bank and the organization of contour bund construction?

There are also questions to ask about how local groups should relate to one another and to sources of professional expertise. One might hope for a self-governing federation of small local groups capable of functioning as their 'parent organization' — that is, negotiating with banks or with government, and employing any professional staff needed (Biggs *et al.* 1984). The Indian groups of irrigators who send representatives to regular Pani Panchayat meetings enjoy a degree of representation, but the programme is in fact run by a local voluntary agency. In other instances, government departments,

perhaps through their extension services, may attempt to provide technical and financial advice directly to local groups.

In the context of runoff farming, one difficulty may be a lack of competent professionals for either parent bodies or extension services to employ. There is certainly professional training available, in India, Israel and the United States, and it is supported by textbook material of wider interest.* However, not all this training is fully relevant to tropical areas, nor is it all calculated to make professionals aware of the significance of local traditions in runoff farming, and how these may affect the contribution farmers can make to the development and application of improved techniques. As a result one encounters complaints from some areas where runoff farming is being encouraged that each new 'expert' who arrives promotes his own favourite technique, be it microcatchments, desert strips, floodwater diversions or Negev-style runoff farms, and nobody seeks to encourage a consistent pattern of development, building on existing local traditions of runoff farming. Yet that consistency may often be the key to effective technical assistance.

* Prasad 1979; Shanan and Tadmor 1979; Matlock and Dutt 1984 are relevant teaching texts from the three countries respectively.

8. RAINWATER ECONOMICS AND FUTURE PROSPECTS

THE OUTLOOK FOR RUNOFF FARMING

The arid area of Rajasthan is said to be the most densely populated desert in the world, and significantly, it is the location of several forms of rainwater harvesting. Houses are constructed with basement cisterns ('water-retaining cellars') into which runoff from roofs is directed. Patches of soil with underlying clay are variously dug out or bunded up to form excavated rainwater catchment ponds (called *nadis*). Finally, of course, there are the khadin runoff farming systems described in Chapter 6. In other regions of the world also, one may find runoff farming and rainwater collection from roofs in simultaneous use, notably in some arid and semi-arid parts of the Middle East and Africa. Moreover, a selective technical account of rainwater and of runoff utilization could be written to emphasize how closely allied these agricultural and domestic versions of the technique may be.

However, if we look at the social and economic conditions under which rainwater collection is expected to develop in the modern world, we observe the greatest possible contrasts. Tanks for collecting water from house roofs are constructed of modern materials — galvanized steel or ferrocement — and can be represented as very desirable home improvements. Moreover, the tanks can be bought from contractors or built on a do-it-yourself basis, and the marketing of the tanks or materials for building them can be a profitable activity for small private businesses. Indeed, the suggestion has been made here that development agencies should encourage commercial marketing of tanks as the most effective way of extending or replicating their use whilst continuing to assist poorer families who can benefit from them. In some countries, then — including Kenya, Thailand and probably Indonesia — rainwater tanks have many of the attributes of a modern consumer good, and there are excellent prospects for their promotion.

With runoff farming, the outlook is very different. Whilst it is possible to describe many traditional and historical examples of the technique, only a handful of successful modern programmes can be quoted. Much detailed technical information has emerged from experimental projects in Israel

and the United States, but little has been reported about experience of modern runoff farming in regular use. Where traditional runoff techniques in India, the Middle East and North Africa are documented, many reports are pessimistic, describing systems in decline or having been totally abandoned. Rajasthan in India and Tunisia in North Africa were quoted earlier as having official policies of encouraging runoff farming. But in Rajasthan we also noted comments to the effect that irrigation would ultimately produce greater increases in food production, and in Tunisia, planned improvements to terraced wadi systems are made in the context of a deterioration of other floodwater and runoff collection methods. El Amami (1977) speaks of 'inconsistency between inherited practices and new socio-economic needs' in Tunisia. Specific reasons for deterioration in traditional runoff farming he notes are, firstly, over-planting in olive groves so that individual trees receive less runoff, and more seriously, lack of labour to construct and maintain bunds, terrace walls, spillways and so on.

On arid and semi-arid grazing lands, very simple runoff techniques with very low labour requirements are more positively reported. Measures include contour furrowing, pitting, and forming semicircular bunds or 'hoops' (Fig. 7.3) to trap runoff and promote growth of grass, shrub and cactus forage. Tree-planting and re-seeding is also undertaken to hold back runoff, control erosion and establish more nutritious forage species (Sandford 1983). In Australia and the United States, mechanization allows furrowing and pitting to be undertaken with very little manpower. In Kenya, there have been encouraging experiments with 'hoops' (Barrow 1982, Critchley 1984). In Tunisia and other parts of North Africa, treatment has been extended over large areas with planting of forage plants including Acacia trees and the cactus *Atriplex* (Sandford 1983).

Runoff farming for crop production is a very different matter, however, and the amount of labour required for constructing and maintaining bunds and terraces is remarked on everywhere. In several North African and Middle Eastern countries, a movement of labour away from farming to well-paid jobs in tourism and industry has led to a decline in runoff agriculture. Tunisia is one example. Another is North Yemen, where Clouet (1979) ascribes the stagnation of runoff farming to a drift of workers towards high-wage employment in Saudi Arabia. Until 1960, runoff agriculture and floodwater farming enabled Yemen to produce grain surpluses within a feudal system of land tenure. But now, with alternative opportunities not far away, and in the absence of land reform, young and progressive people are leaving the rural areas. As a result, the bunds and terraces of farms are not being maintained, grain production has suffered, and North Yemen has become a net importer of cereals.

Where young Yemenis have retained their interest in farming, and have had remittances from relatives in oil-rich countries to invest, they have

preferred to use 'modern' methods, and have replaced floodwater cultivation and runoff farming with boreholes and diesel-powered irrigation pumps. 'Within the last ten years, the number of boreholes has increased tremendously. The per-metre cost of drilling reached the fabulous sum of £600 in the early days and in remote areas, but is now down to £130. Japanese diesel engines can be found everywhere . . .' (Merabet 1984).

In such circumstances, some people appear to think that rainwater collection and runoff farming are too labour-intensive to compete, and are incapable of producing the large increase in food output needed by expanding populations. In many cases, the traditional techniques originated within institutions which few people would wish to perpetuate. Feudal land ownership in Yemen and the zamindar system in India (Chapter 2) restricted individual choices in a way which is now seen as unacceptable. The attraction of the private boreholes which many Yemeni and Indian farmers opt for is that these bring farming more closely under the individual's control, making it not only less subject to difficult weather conditions, but also independent of the decisions of landowners or bureaucratic Irrigation Departments. Advocates of runoff farming should therefore give special attention to techniques which can be used by individuals on their own land (which may have been one factor in the success of the Yatenga programme in Burkina Faso — Chapter 7). Alternatively, where catchments or bunds are best shared by groups of farmers, acceptable forms of organization need very careful thought.

The problem is not just that experience of modern, high-wage economies encourages farmers to take an individualistic view of investments and profits. More fundamentally, some experts believe that low rates of financial return are inevitable in runoff farming, and regard irrigation as the only viable modern method of agricultural production in arid and semi-arid areas.

However, one should beware of such arguments and their implication that runoff farming is simply out-dated. In most places where runoff farming is in decline, there are other symptoms of a deteriorating agricultural ecology, including soil erosion, desertification, failures in food production, and indeed, poor results from expensive modern irrigation systems. A more reasoned point of view might therefore be that agricultural policies are seriously inadequate in these parts of the world, and that the apparently uncompetitive position of runoff farming is merely one aspect of that. More specifically, there is a growing recognition that many governments, especially in Africa, have given insufficient support to basic food production, and instead have given preference to export crops.

Several countries which, like North Yemen, were once exporters of grain now have to import it, and although this is partly due to the growth of population, it also reflects varying degrees of stagnation in local

agriculture. Traditional runoff farming in Morocco was so well developed that Kutsch (1982) thought that no further improvements in water management were possible, only improvement in agronomy. Yet he also recorded the negative impact of commercial activities, including tourism, noting particulary how the expansion of towns and their demands for drinking water has disturbed the water balance within some catchment basins and has attracted labour away from farming. It is significant, then, that overall food production showed almost no expansion during the 1970s. In 1980, food production in Morocco was up by 16 per cent on the average of a decade earlier, but in the following year, it fell back to 5 per cent less than the earlier average (FAO 1983).

In Africa south of the Sahara, similar trends are even more clearly evident. Governments have been encouraged to favour cash crops in their agricultural policies by the nature of the technical and financial aid they have received from western countries, and by the need for export earnings to repay loans associated with this aid. Urban elites have done well out of these arrangements, and agricultural research, both international and local, has given technical support, concentrating on irrigation and on crops such as cotton, rice and groundnuts. Meanwhile, food crops such as the sorghums and millets have been neglected by researchers and policy-makers alike, and Africa's semi-arid food-producing areas have been 'crucially deprived' of extension services, capital and technology. As Eckholm and Brown (1977) put it, a 'structural transformation' is needed to correct this, but vested interests within the countries concerned, as well as among western aid donors, have so far prevented such a change.

Meanwhile, Twose (1984) notes that although the countries of Africa's Sahel zone have had a consistently poor record in producing food for local consumption over the last twenty years, they have achieved 'steady success' in the cultivation of cash crops such as cotton and groundnuts. Indeed, some have been exporting groundnuts and vegetables whilst simultaneously needing food aid to prevent famine. One problem is that grain yields are dropping because the best land is given over to cash crops, and farming for local food needs has been relegated to marginal areas. In 1920, the average farmer in Niger obtained 500kg of grain per hectare. By 1978, this was down to 350kg, and Niger was only able to maintain some increase in total grain cultivation because a greatly expanded area of land was cultivated — largely at the expense of pastoralists.

Irrigation has often been emphasized in planning for these regions because it has appeared to be the best way of making farmers less dependent on erratic rainfall. However, this policy has had limited success because of a build-up of salt in irrigated soils — a problem which does not usually occur in runoff farming because of the better quality of runoff water from very small catchments. Irrigated agriculture also involves large investments and high recurrent costs and is energy-intensive when water

has to be pumped. In order that these costs may be repaid, the authorities responsible for large irrigation schemes must raise a levy from farmers working the irrigated land, who are then forced to grow the crops which will be most profitable in cash terms so that they can pay the levy. Such crops do not usually include the cereals eaten by the local rural population.

It may well be, then, that the policies which emphasize export crops rather than food are a major reason why runoff farming in many countries seems a relatively poor prospect. Export crops bring in the cash resources which can support investments in irrigation. Food crops can be profitable too, but at a lower level of investment. At this level, runoff farming is often appropriate as a means of improving crop reliability, and if further insurance against the effects of erratic rainfall is required, this can in principle be provided by local grain banks. If food crops do not seem profitable, that may be at least partly because governments do not offer the same kind of support in terms of marketing arrangements as they provide for export crops. Farmers in Burkina Faso who had a good harvest of millet in 1983 found prices falling despite shortages elsewhere in the country. They therefore planned to grow cotton in place of millet in the next year because 'they knew that the cotton would be collected swiftly by the Government services and they would get a good price for their harvest' (Twose 1984).

Another factor in the equation is environmental degradation in low rainfall areas where trees have been cut for firewood,and many former pastoral areas have been taken over for cultivation. The resulting losses of natural vegetation expose soils to erosion and to the processes by which productive land turns into desert. The most active agent in this destructive process is uncontrolled runoff, and if the natural vegetation which once retained or slowed runoff and stabilized soils is lost, artificial means of runoff control are essential. A very wide range of techniques is available, including conventional soil conservation at one end of the spectrum (Hudson 1971) and floodwater harvesting at the other (UNEP 1983). The limited range of runoff farming techniques discussed here differ from soil conservation in that they make productive use of runoff rather than merely seeing it as a problem requiring control. These techniques differ from floodwater harvesting (and irrigation) because they use rainwater close to the point where the rain falls, so limiting evaporation and losses.

In India, soil conservation and water harvesting have developed very differently, partly because of an ample labour supply. Whilst individual farmers have invested in private boreholes for irrigation, efforts to find employment for landless labourers have led to construction of large-scale earthworks under 'food-for-work' and employment guarantee schemes. Indeed, it might be argued that the availability of this labour, together with the Indian tradition of large-scale organization and construction, has led to

an over-emphasis on tanks, dams, ahars and khadins, and that perhaps conventional runoff farming based on within-field catchments and contour bunding would use land and water resources more efficiently.

To some extent, this is a question of floodwater harvesting versus true runoff farming. In some places, dams and reservoirs (i.e. 'tanks') for floodwater harvesting occupy as big an area of land as the cultivated plots which benefit from the water retained. In such circumstances, it may sometimes be that capturing runoff by contour bunds higher up in the catchment area and nearer to where the rain falls would retain more water for cropping, while enabling the lower ground occupied by dams and 'tanks' to be used instead for cultivation.

QUESTIONS OF ECONOMICS

It is one thing to notice general impressions of the high labour requirements of runoff farming, but quite another to find hard data on the subject. Because many traditional systems are neglected by policy-makers, few figures on labour or other costs have been compiled. As to modern systems, so many are experimental that reports tend to focus on their technical rather than their economic performance.

Farmers, planners and extension personnel assessing any new or modified technology will estimate its gross benefits in terms of yields and the likely price they will obtain for the crop. They will then compare the benefits with the cost of labour, seed and fertilizer inputs required to produce the crop. From this they will estimate the 'net benefit' of the new technology as compared with alternatives and if the net benefit is substantial, they will probably adopt the new approach (Carruthers 1983). Especially where small farmers are concerned, such calculations need to include allowance for risks due to drought, pests and so on. This can be done by repeating the cost/benefit calculations for seasons with the worst likely outcomes.

Costs associated with runoff farming include costs of construction, amortization and maintenance, in addition to the cost of seed, fertilizer, tillage and so forth. Maintenance can be substantial on microcatchments, which need inspection after every storm so that any minor breaks in bunds can be promptly repaired (Shanan and Tadmor 1979). On the other hand, ahars are said to require very little maintenance (UNEP 1983). There may also be costs that are not borne by the farmer but which affect others in society. Many of the latter will arise from conflicts of land use — for example, if runoff farming develops by excluding animals from common pastures which serve as catchments, herdsmen suffer and overgrazing is more likely on such pastures as remain open. Water used for agricultural or commercial purposes by dominant groups may increase their income in ways which are not available for the poor; this can lead to changes which

not only worsen the relative but also the absolute position of the poor such as the severance of arrangements to share food in times of disaster (WHO 1981).

Even confining attention to the direct costs borne by farmers, not all the figures from the case studies quoted have been available to the authors. In Burkina Faso, lack of data is one result of an explicit policy that farmers should be left to make their own economic judgements. When they do, it is evident that they find contour barriers economically worthwhile on those parts of their land where erosion has been robbing them of most production. It is also evident that the labour required is an economic cost that is sometimes difficult to meet, with the result that farmers space the barriers further apart than the technical optimum. It is experiences like this, and figures for the number of man-days required to construct bunds and runoff farms (UNEP 1983, Evenari *et al.* 1982) which lead to the conclusion that labour requirements are sometimes a major constraint on the development of runoff farming.

In India, more data are available but are often applicable to floodwater harvesting rather than runoff farming, and especially for collection of floodwater in percolation 'tanks'. Particularly good economic results have been recorded in both the Maharashtra programmes discussed in the previous chapter, with production sometimes increased by as much as 300 per cent (Biggs *et al.* 1984). Such improvements are possible where irrigation aided by a percolation tank has led to double cropping, with millet or sorghum followed in the year by wheat. Farm incomes may be enhanced by factors of two or three. However, it again seems that 'a farming system which includes water harvesting raises the employment requirements per hectare', so the overall increase in farm receipts is to some extent distributed among the extra labour force, and *net* receipts to farmers may rise by less dramatic amounts. Ray (1984) comments that this benefit is important for poor people and as the Pani Panchayat and similar schemes develop, 'the scope for labour-intensive vegetable production should increase'.

Economic data on the cost of *domestic rainwater tanks* are more plentiful, though the benefits remain difficult to assess. One study quoted by Pacey *et al.* (1977) compared different types of drinking-water supply capable of providing a minimal 10 litres per head daily throughout the year. Rainwater tanks were included on the assumption that water from them would be rationed by users to provide an assured daily supply. This somewhat artificial view was taken so that comparison could be made with piped systems which are designed to provide a constant supply. The study was limited to rural conditions and included some very simple arrangements for piping water from springs on hillsides to public standpipes at very low cost. The figures that resulted from this study made rainwater tanks look very expensive. Expressed in U.S. dollars at 1971 prices, the range of capital costs was roughly as follows:

Rainwater tanks	
serving 1-5 people:	$20-65 per person;
Large rainwater tanks	
serving 20-30 people:	$10-$15 per person;
Piped water supplies:	$2-$12 per person;
Hand-dug wells:	$1 - $5 per person.

This is not a realistic way of comparing costs, however. Rainwater tanks and piped water supplies have such different characteristics that for most purposes, there is no point in saying that one is cheaper than the other. Instead, it makes more sense to ask whether the level of investment required for rainwater tanks is within the same range as other investments being made in the local community. Table 8.1 presents some figures for different kinds of investment in water and sanitation. Where piped water is laid into people's homes, rainwater tanks are unlikely to be built at all, but where water is distributed via public standpipes, tanks still offer advantages in terms of convenience and individual control. Thus the only piped supplies included in this table are those with public outlets. In making comparisons, it must also be remembered that rainwater tanks are usually individual investments by families, whereas a standpipe supply is normally a public investment to which families may only contribute a small amount directly.

The figures in Table 8.1 suggest that the smaller sizes of rainwater tank require about the same level of investment as the construction of a pit latrine. It would be unrealistic to compare benefits, but it might be possible to argue that if families can afford one they can afford the other — or that similar levels of financial support will be needed by those who can pay for neither.

Another point of view noted in Chapter 3 is that because rainwater tanks are so closely connected with a family's house, their capital cost should be in some sort of proportion to the resources invested in the house. The same has also been said about latrines, and Nimpuno (1978) has argued that 10 per cent of the cost of a house is an appropriate limit. However, in many rural areas, the average investment in a house is almost impossible to estimate since so many family homes are extended over a long period of time using the family's own labour for construction. However, the figures for latrines quoted in Table 8.1 appear to be within bounds which Nimpuno would accept, and it is difficult to argue that a greater proportionate investment is justified for rainwater tanks. Thus, while many small tanks fall within an appropriate price range, most 9-10m^3 tanks do not. Yet it is clear from what was said in Chapter 3 that many family houses have sufficiently extensive roofs to justify the larger size of tank.

Biggs *et al.* (1984) suggest that the most effective programmes in tackling the problems of poverty are usually those which begin by defining clearly

Table 8.1 Typical levels of investment in water and sanitation in rural communities.
Figures are in U.S. dollars at 1977–8 price levels. (For more detail of rainwater tanks, but at 1981–2 prices, see Table 5.2.) Piped water supply to public standpipes probably receives a higher level of subsidy than most other types of development, but all are partly or largely paid for by beneficiaries.

Nature of investment	*Typical investment per family (assuming 6-person family)*	
Piped water to public standpipes (IRC 1979)	\$60–\$180	materials & labour; typical Asia/Africa per capita cost times 6
Pit latrines:		
Botswana	\$13–\$24	materials only
Zimbabwe	\$30–\$40	
Nigeria	\$40	
(Oluwande 1978)		
Rainwater tanks		
9–10m³ ferrocement tank with cover and gutters, Zimbabwe	\$62–\$90	materials only
7m³ concrete ring tank with cover, Thailand (Keller 1982)	\$40	
1.2m³ ferrocement tank with cover (Keller 1982)	\$33	materials at 1980 prices

the particular low-income groups they wish to help — landless people, smallholders with less than 0.5ha of land, and so on. Thus instead of discussing average levels of investment in housing, latrines or tanks, the argument should perhaps be based on the needs of people with housing conditions below a defined minimum. Under those circumstances, the advocate of rainwater collection may need to devote a good deal of his or her effort to improving the houses themselves, or at least their roofs. Where rainwater tanks can be introduced, small and cheap factory-made ones— like the unusually economical Jumbo Jar in Thailand — may then be most

appropriate. The cost of this at the factory gate was equivalent to only US$23 at 1984 price levels (Latham 1984b), but whether the same economy and efficiency of production can be achieved in other countries remains to be seen.

QUESTIONS OF LIVELIHOOD

Although it is possible to argue that small rainwater tanks confer economic benefits and are cost-effective, these benefits are always difficult to measure. We can point to the time people save through not having to carry water from a distant source. We can also argue that cleaner water brings better health and enables people to work more productively. These points are significant, but perhaps only during brief seasons when planting or harvest make heavy demands on a family's time and labour. If people use water from a tank at other seasons, its benefits may include better child care or more leisure, but nothing that economists would wish to measure. Thus it may be relevant to recall the point made in Chapter 2 that people's livelihoods do not consist entirely of goods and services which have market value; they depend also on 'home production', defined as activities which improve the quality of life for family members without involving market transactions.

In many cases, the greater convenience of the rainwater supply will show benefits for 'home production' activities such as cooking, housework and child care to a greater extent than benefits measurable in market values. Tanks can also be attractive to people because they are under the family's control and do not involve the conflicts with neighbours sometimes associated with shared facilities. They also have some of the attractions of modern consumer goods and in some communities, acquisition of a tank may seem a definite step forward in modernizing the home. Thus the benefits of rainwater tanks perceived by their owners may be of three general kinds:

- market benefits (time saved for remunerative work);
- home production benefits (cooking, child care, etc);
- non-economic and social benefits (individual control, modernization).

Non-economic factors can influence attitudes to agricultural uses of water as well, but seem to pull in a less positive direction as far as rainwater harvesting is concerned. We have noted how options which offer most in terms of individual control, up-to-date equipment and modernization are sometimes perceived to be boreholes and motor-driven pumps. Undoubtedly, irrigation from boreholes offers market benefits also by enabling farmers to increase their production very greatly, growing two or even three crops a year on the same land instead of being limited to a brief rainy season.

In India, arrangements of this kind may be linked to floodwater harvesting via the recharge of wells from percolation 'tanks' (Figure 2.4). Elsewhere, borehole irrigation may be a straight replacement for floodwater harvesting or runoff farming, and its attraction as a form of modernization can be so great that farmers with spare cash (as in North Yemen) invest in boreholes even when the chances of fully recouping the high drilling charges must be small.

In present circumstances, then, and in the absence of official emphasis on food production or environmental priorities in the policies of many countries, runoff farming is likely only to be attractive in regions where irrigation is not feasible, either because groundwater resources are lacking, or because people cannot afford the high investment involved. In the latter case, where it is people's poverty which makes them look to this technique, their economic assessment of its benefits may be oriented more to basic livelihood than to market advantage. Thus the effect of runoff on the *reliability* of crop yields may be more important to many families than any large production increases.

It is against this background that Ray (1983) sees three features of *both* rainwater tanks and runoff farming as particularly significant. Firstly, he notes that economies of scale offer a financial incentive to build large rainwater 'tanks', dams, khadins and the like, but simultaneously points out the difficulties of efficient management in large projects run either by community organizations or by bureaucrats. He argues that the most successful projects are those which offer the advantages of private ownership without the economic penalties of small scale. He cites the rainwater tank programmes of Indonesia and Thailand as examples, and suggests that domestic rainwater supplies should almost always be based on household rather than communal facilities. As to rainwater collection for agriculture, he might well have cited the runoff farming programme in Burkina Faso discussed in Chapter 7 as an example where farmers can exercise individual control.

The second feature of rainwater collection noted by Ray is its unreliability. Tanks are often empty for part of the year. Crop failures due to drought occur on runoff farms even though yields are *more* reliable than if runoff were not used at all. Thus grain banks or something similar are needed to insure a dependable food supply. An example cited is the trend away from rainwater usage in North Yemen, both for agricultural and domestic purposes, which is attributable to a demand for more reliable systems.

The third distinguishing feature of rainwater harvesting is the poverty of many of the areas where it is practised. A good groundwater supply developed for irrigation and also for domestic purposes offers more options for improved living standards than rainwater harvesting. Thus rainwater techniques tend to be observed mainly on the margins of

cultivation, especially the edges of deserts, where they offer modest improvements in the living standards of very poor people. For many advocates of these techniques, that will be a central reason for promoting their development and use. Various technical measures are possible to bring the benefits of rainwater collection within reach of the poorest families. Innovations in low-cost roofing and small, inexpensive tanks have already been mentioned. Similarly, it may be possible to concentrate on low-cost contour bunding which poor farmers can use on their land, rather than more ambitious forms of runoff farming.

However, 'technical fixes' for the problems of poverty are unlikely to be enough. It will often be necessary for poor families to share resources if they are to gain from rainwater collection at all, perhaps sharing a tank, perhaps helping each other meet the labour requirements of construction, or perhaps joining together to bargain for land and water rights. If people feel strong preferences for doing things individually, or if they see one advantage of a household tank that it is under the family's individual control, collective action may not be acceptable. However, few communities are entirely lacking in channels for collective activity. For example, in writing about nomadic pastoralists, Sandford (1983) notes that while they traditionally value the freedom of the individual to manage his herds in his own way, they simultaneously value 'social relations' which limit the damage individuals might do to shared facilities such as livestock watering points; they also have forms of mutual help which improve chances of survival in time of drought. Similarly with other groups, it should be possible to identify areas where individual autonomy is regarded as important, and areas where it is possible for co-operation to secure economies of scale or to bring improvements in water supply within the reach of the very poor.

Thus a United Nations research programme has suggested, with admirable clarity, that 'mutual aid groups' should be considered 'the primary unit of development' for the low-income, 'marginalized' rural sector (UNRISD 1974). Examples cited in this book include 30–40 family groups of irrigators in the Indian Pani Panchayat programme, and groups of pastoralists in Niger with about 20 families in each. The United Nations recommendations are that a group of this sort should be an 'informal, self-selecting set of individuals with confidence in one another, on the basis of kinship, neighbourhood or friendship'. Once established, such groups should be registered and receive official recognition; they should be linked with larger agrarian organizations and peasant movements capable of representing common interests alongside other pressure groups such as those representing big farmers and traders. They should also serve the purpose of advancing grass roots training in technical skills, co-operative organization and self-management. In more practical terms, 'mutual aid groups could act as partnerships for farming . . . as credit societies . . . as

work teams for irrigation maintenance or soil conservation campaigns' — or for rainwater tank construction and runoff farming.

FOOD AND ENVIRONMENT

For some western commentators, the most significant remark in the last few pages will be the point that rainwater harvesting tends to be used, 'on the margins of cultivation, especially the edges of deserts'. There is a school of thought among environmentalists which sees loss of vegetation and degradation of soils on desert margins as a far more serious long-term problem than poverty and famine among the people who live there. Indeed, Sandford (1983) accuses some of these environmentalists of 'astonishing inhumanity' in their recommendations for halting and reversing 'desertification', not least because they hold local populations as being chiefly responsible for the loss of vegetative cover and the spread of soil erosion. They thus ignore the external pressures which favour cash crops over food and so compel the extension of cultivation into areas which would be better reserved for grazing. Having assigned blame this way, the same 'experts' welcome natural disasters as 'squeezing out the inefficient'.

More positive environmentalist views, expressed by Eckholm and Brown, stress that many problems of the desert margins would be soluble if far more emphasis were given to food crops in the areas concerned. If yields from such crops were to improve, pressures for the expansion of the cultivated areas could be contained. A policy based on this principle would undoubtedly involve runoff farming, both as a means of improving crop production and yield reliability, and to control erosive runoff flows.

Even within this context, though, there could still be conflicts between environmental concerns and local people's worries about the security of their livelihoods. This is illustrated by the case-study from Burkina Faso in the previous chapter. Western advisers wished to control soil erosion by planting trees, whilst farmers wanted to reclaim eroded land for growing grain. The solution ultimately arrived at, based on the building of contour bunds, favoured the farmers's goals. However, it was still an effective demonstration of how, when the natural vegetation which originally limited erosion is removed, runoff control by bunds, terraces, check dams and the like can prove a vital alternative means of controlling erosion. Thus, on the desert fringes runoff farming can either be regarded as a crutch to use in re-establishing trees and grass, or as a permanent feature, allowing trees to be partially replaced by crops without the dangers of desertification.

An example of runoff farming as a crutch for re-establishing grass cover was the use of simple 'hoop' microcatchments in Kenya, discussed in Chapter 6 (see also Figure 7.3). Once perennial grasses are flourishing within the hoops and begin to spread beyond them, the grass itself binds the

soil together and retains runoff, and further maintenance of the hoops becomes unnecessary.

However, it is not only in marginal areas of Africa that conflicts of purpose between environmentalists and others influence prospects for rainwater collection. In Chapter 2, several reasons why urban policy-makers might favour rainwater collection in remote catchment areas were noted, including 'conservation' and a wish to reduce flood risks in crowded urban areas. In parts of India with relatively wet climates, trees planted on catchments can slow runoff and retain water during rain. Then, 'water harvesting is done by the trees' (Ray 1984), and the aims of policy-makers and environmentalists are met. However, the small farmers who work the land cannot afford the five years or more that it may take to start realizing a useful income from trees.

Where such conflicts between long-term environmental aims and short-term needs of farmers arise, Ray's views on India coincide with Wright's implied conclusions about Burkina Faso. Both agree that the proper role for development agencies is to accept the 'short-term first' strategy based on food production priorities. Experience seems to show that bunds and 'tanks' that provide immediate benefits in terms of cereal crop yield and reliability can be effective in reducing the most urgent erosion problems, and can lead on to tree planting below bunds or on catchment areas later.

The case-studies of rainwater collection presented in this book have illustrated three major aspects of the subject from three geographical vantage points: South-east Asia, India and Africa. One contrast here was between areas where shortage of water is a *resource constraint* for both agriculture and domestic needs, and areas where poor domestic supplies may exert *time constraints* on people's livelihoods. In Thailand and Indonesia, there were the examples of a very positive development of rainwater tanks in areas where rainfall is ample for agriculture, but where domestic water supplies are difficult to provide. In these areas, the main benefits of rainwater collection are neither environmental nor economic (in the 'market' sense), but are more concerned with people's livelihoods on the level of housing conditions and home production. One or two areas in Africa, notably in Kenya and Zimbabwe, illustrate the same points, though with much smaller programmes, and have provided some of the data presented in Table 8.1.

In India, agricultural usage predominates in all forms of water harvesting, but the context is one in which organization and institutional structure have favoured large-scale schemes, many dealing with floodwater rather than runoff — and hence strictly outside the scope of this book. That is true, for example, of percolation tanks in Maharashtra, although they have been quoted for the light they shed on the organization of cultivators and the potential of successful rural development to attract urban migrants back to the land (Chapter 2). Some khadins in Rajasthan

(though not all) are true runoff farming devices with hillside catchments and valley cultivation in comparable conditions of landform and aridity to those of the Negev, but with strikingly different techniques to exploit summer rather than winter rains.

The third and most disturbingly problematic area for rainwater and runoff application has concerned 'drought-prone' areas in Africa. Arguably, runoff farming and related soil conversion measures are more desperately needed here than anywhere else, but it is precisely here that 'modernization' has appeared to reduce prospects for runoff agriculture, particularly where irrigation has been developed, where cash crops have been favoured, or where well-paid employment has drawn labour away from farming. Development is also complicated by the need to strike a balance between cultivation and pastoral development. However, growing awareness of the factors linking environmental degradation, food shortages and famine in these regions may result in a more positive view of runoff farming for crops and rainwater collection for pastoral use. Whether that translates into practical measures depends on the extent to which there are policy reforms giving more emphasis to food crops — reforms which would conflict with the vested interests of urban elites and western trading and financial blocs. However, it is to be hoped that the spectre of famine and economic collapse in much of Africa will erode some of this opposition. In its report for 1984, the United Nations Economic Commission for Africa warned of 'unparalleled catastrophe' if policy changes were not made, and if western action did not go beyond the limited food aid currently being given.

It is not, of course, the purpose of this book to campaign for policy changes, but rather to ensure that if they occur, and if they lead to a renaissance in the prospects for runoff farming, fieldworkers and agencies are adequately prepared. Thus, on one hand, they need to be prepared with technical expertise for exploiting what runoff farming and rainwater collection have to offer: greater (but not total) reliability in crop yields, an aid to re-establishing trees and grass cover, drinking water at critical if limited periods, and a more efficient use of water resources by collecting rainwater near to where it falls. On the other hand, many agencies need better understanding of local-level technical assistance — that is, how practical constraints which restrict implementation of new techniques can be identified and tackled. They also need better appreciation of how such assistance should build on traditional technology, and tie in with patterns of organization capable of sustaining rainwater techniques, whilst benefiting low-income groups and small farmers.

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** denotes *practical* manuals recommended for details of construction of rainwater tanks, runoff farming methods, and/or related training procedures.

† short booklets or leaflets giving *practical* details of a single technique.

‡ unpublished material. Much of this is stored at ITDG Head Office, Myson House, Railway Terrace, Rugby, CV21 3HT, UK.

NB Volume numbers of journals are italicized whilst part numbers, where relevant, are placed in brackets. Thus 'Volume 3, number 4' abbreviates to *3* (4).

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INDEX *(with GLOSSARY)*

Unusual words, and terms used with special or restricted meanings, are explained in the following two ways:

1. By an explanatory phrase or synonym placed in brackets within the index entry.
2. By page references to fuller definitions where these are given in the text of the book.

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Rainwater harvesting

From Wikipedia, the free encyclopedia

Rainwater harvesting is the accumulation and deposition of rainwater for reuse on-site, rather than allowing it to run off. Rainwater can be collected from rivers or roofs, and in many places the water collected is redirected to a deep pit (well, shaft, or borehole), a reservoir with percolation, or collected from dew or fog with nets or other tools. Its uses include water for gardens, livestock, irrigation, domestic use with proper treatment, and indoor heating for houses etc. The harvested water can also be used as drinking water, longer-term storage and for other purposes such as groundwater recharge.

Rainwater capture and storage system at the Monterrey Institute of Technology and Higher Education, Mexico City.

A cistern for rainwater storage

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Advantages

Rainwater harvesting provides an independent water supply during regional water restrictions and in developed countries is often used to supplement the main supply. It provides water when there is a drought, can help mitigate flooding of low-lying areas, and reduces demand on wells which may enable groundwater levels to be sustained. It also helps in the availability of potable water as rainwater is substantially free of salinity and other

salts. Application of rainwater harvesting in urban water system provides a substantial benefit for both water supply and wastewater subsystems by reducing the need for clean water in water distribution system, less generated stormwater in sewer system,[1] as well as a reduction in stormwater runoff polluting freshwater bodies.

There has been a large body of work focused on the development of Life Cycle Assessment and Life Cycle Costing methodologies to assess the level of environmental impacts and money that can be saved by implementing rainwater harvesting systems.

More development and knowledge is required to understand the benefits rainwater harvesting can provide to agriculture. Many countries especially those with an arid environment use rainwater harvesting as a cheap and reliable source of clean water.[2] To enhance irrigation in arid environments, ridges of soil are constructed in order to trap and prevent rainwater from running down hills and slopes. Even in periods of low rainfall, enough water is collected in order for crops to grow.[3] Water can be collected from roofs, dams, and ponds can be constructed in order to hold large quantities of rainwater so that even on days where there is little to no rainfall, there is enough available to irrigate crops.[3]

Quality

The concentration of contaminants is reduced significantly by diverting the initial flow of run-off water to waste.[4] Improved water quality can also be obtained by using a floating draw-off mechanism (rather than from the base of the tank) and by using a series of tanks, withdraw from the last in series. Pre-filtration is a common practice used in the industry to ensure that the water entering the tank is free of large sediment. Pre-filtration is important to keep the system healthy.

Conceptually, a water supply system should match the quality of water with the end use. However, in most of the developed world high quality potable water is used for all end uses. This approach wastes money and energy and imposes unnecessary impacts to the environment. Supplying rainwater that has gone through preliminary filtration measures for non-potable water uses, such as toilet flushing, irrigation, and laundry, may be a significant part of a sustainable water management strategy.

System setup

Rainwater harvesting systems can range in complexity, from systems that can be installed with minimal skills, to automated systems that require advanced setup and installation. The basic Rainwater harvesting system is more of a plumbing job than a technical job as all the outlets from the building terrace are connected through a pipe to an underground tank that stores water.

Systems are ideally sized to meet the water demand throughout the dry season since it must be big enough to support daily water consumption. Specifically, the rainfall capturing area such as a building roof must be large enough to maintain adequate flow. The water storage tank size should be large enough to contain the captured water.

For low-tech systems, there are many low-tech methods used to capture rainwater: rooftop systems, surface water capture, and pumping the rainwater that has already soaked into the ground or captured in reservoirs and storing it into tanks (cisterns).

Before a rainwater harvesting system is built, it is helpful to use digital tools. For instance, if you want to

detect if a region has a high rainwater harvesting potential, rainwater harvesting GIS maps can be made using an online interactive tool (http://www.rainfoundation.org/tools/map-your-rain.html). Or if you need to estimate how much water is needed to fulfill a community's water needs, the Rain is Gain tool helps with this. Tools like these can save time and money before a commitment to build a system is undertaken, in addition to making the project sustainable and last a long time.

Life Cycle Assessment: Design for Environment

EEAST Model for LCAs of Rainwater Harvesting Systems.

Contemporary system designs require an analysis of not only the economic and technical performance of a system, but also the environmental performance. Life Cycle Assessment is a methodology used to evaluate the environmental impacts of a precut or systems, from cradle-to-grave of its' lifetime. Devkota et al.,[5][6] developed such a methodology for rainwater harvesting, and found that the building design (e.g., dimensions) and function (e.g., educational, residential, etc.) play critical roles in the environmental performance of the system. The Economic and Environmental Analysis of Sanitations Technologies, EEAST (https://defneapul.wikispaces.com /Water+sustainability) model evaluates the greenhouse gas emissions and cost of such systems over the lifetime of a variety of building types.

To address the functional parameters of rainwater harvesting systems, a new metric was developed - the demand to supply ratio (D/S) - identifying the ideal building design (supply) and function (demand) in regard to the environmental performance of rainwater harvesting for toilet flushing. With the idea that supply of rainwater not only saves the potable water but also saves the stormwater entering the combined sewer network (thereby requiring treatment), the savings in environmental emissions were higher if the buildings are connected to a combined sewer network compared to separate one.[6]

Rain water harvesting by freshwater flooded forests

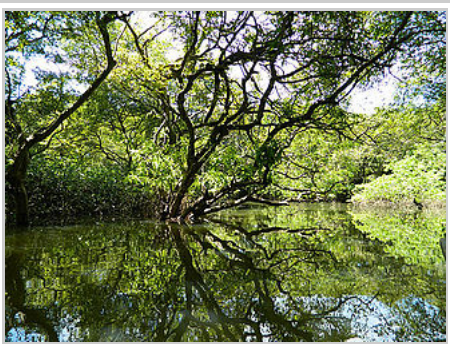
Ratagul Freshwater Flooded Forest, Bangladesh

Rainwater harvesting is possible by growing fresh water flooded forests without losing the income from the used /submerged land.[7] The main purpose of the rainwater harvesting is to utilize the locally available rainwater to meet water requirements throughout the year without the need of huge capital expenditure. This would facilitate the availability of uncontaminated water for domestic, industrial and irrigation needs.

New approaches

Instead of using the roof for catchment, the RainSaucer, which looks like an upside-down umbrella, collects rain straight from the sky. This decreases the potential for contamination and makes potable water for developing countries a potential application.[8] Other applications of this free standing rainwater collection approach are sustainable gardening and small plot farming.[9]

A Dutch invention called the Groasis Waterboxx is also useful for growing trees with harvested and stored dew and rainwater.

Traditionally, storm water management using detention basins served a single purpose. However, Optimized Real-Time Control (OptiRTC) lets this infrastructure double as a source of rainwater harvesting without compromising the existing detention capacity.[10] This has been used in the EPA headquarters to evacuate stored water prior to storm events, thus reducing wet weather flow while ensuring water availability for later reuse. This has the benefit of increasing water quality released and decreasing the volume of water released during combined sewer overflow events.[11][12]

Presentation of RainSaucer system to students at Orphanage in Guatemala.

Generally, check dams are constructed across the streams to enhance the percolation of surface water into the sub soil strata. The water percolation in the water impounded area of the check dams, can be enhanced artificially many folds by loosening the sub soil strata / overburden by using ANFO explosives as used in open cast mining. Thus local aquifers can be recharged quickly by using the available surface water fully for using in the dry season.

History

Around the third century BC, the farming communities in Balochistan (now located in Pakistan, Afghanistan and Iran), and Kutch, India, used rainwater harvesting for agriculture and many uses also.[13] In ancient Tamil Nadu , rainwater harvesting was done by Chola kings.[14] Rainwater from the Brihadeeswarar temple (located in Balaganpathy Nagar, Thanjavur, India) was collected in Shivaganga tank.[15] During the later Chola period, the Vīrānam tank was built (1011 to 1037 CE) in Cuddalore district of Tamil Nadu to store water for drinking and irrigation purposes. Vīrānam is a 16 km (9.9 mi) long tank with a storage capacity of 1,465,000,000 cubic feet (41,500,000 m^3).

Rainwater harvesting was done in the Indian states of Madhya Pradesh, Maharashtra, and Chhattisgarh in the olden days. Ratanpur, in the state of Chhattisgarh, had around 150 ponds. Most of the tanks or ponds were utilized in agriculture works.

It is a little-known fact that for centuries the town of Venice depended on rainwater harvesting. The lagoon which surrounds Venice is made of brackish water which is not suitable for human drinking. The ancient inhabitants of Venice established a system of rainwater collection which was based on man-made insulated collection wells.[16] Water would percolate down the specially designed stone flooring, and be filtered by a layer of sand, then collecting at the bottom of the well. Later, as Venice acquired territories on the mainland, it started to import water by boat from local rivers, but the wells remained in use, and were especially important in time of war when access to the mainland water could be blocked by an assailant.

Current use

- In China and Brazil rooftop rainwater harvesting is being practised for providing drinking water, domestic water, water for livestock, water for small irrigation and a way to replenish groundwater levels. Gansu province in China and semi-arid north east Brazil have the largest rooftop rainwater harvesting projects ongoing.
- In Bermuda, the law requires all new construction to include rainwater harvesting adequate for the

residents.[17]
- The U.S. Virgin Islands have a similar law.
- In Senegal and Guinea-Bissau, the houses of the Diola-people are frequently equipped with homebrew rainwater harvesters made from local, organic materials.
- In the Irrawaddy Delta of Myanmar, the groundwater is saline and communities rely on mud-lined rainwater ponds to meet their drinking water needs throughout the dry season. Some of these ponds are centuries old and are treated with great reverence and respect.
- In the United States: until 2009 in Colorado, water rights laws almost completely restricted rainwater harvesting; a property owner who captured rainwater was deemed to be stealing it from those who have rights to take water from the watershed. Now, residential well owners that meet certain criteria may obtain a permit to install a *rooftop precipitation collection system* (SB 09-080).[18] Up to 10 large scale pilot studies may also be permitted (HB 09-1129).[19] The main factor in persuading the Colorado Legislature to change the law was a 2007 study that found that in an average year, 97% of the precipitation that fell in Douglas County, in the southern suburbs of Denver, never reached a stream—it was used by plants or evaporated on the ground. In Colorado you cannot even drill a water well unless you have at least 35 acres (14 ha). In New Mexico, rainwater catchment is mandatory for new dwellings in Santa Fe.[20] Texas offers a sales tax exemption on the purchase of rainwater harvesting equipment. Both Texas[21] and Ohio allow the practice even for potable purposes. Oklahoma passed the Water for 2060 Act in 2012, to promote pilot projects for rainwater and graywater use among other water saving techniques.[22]
- In Beijing, some housing societies are now adding rainwater in their main water sources after proper treatment.
- In Ireland, Professor Micheal Mcginley established a project to design a rainwater harvesting prototype in the Biosystems design Challenge Module at University College Dublin

Canada

A number of Canadians have started implementing rainwater harvesting systems for use in stormwater reduction, irrigation, laundry, and lavatory plumbing. Substantial reform to Canadian law since the mid-2000s has increased the use of this technology in agricultural, industrial, and residential use; but ambiguity remains amongst legislation in many provinces. Bylaws and local municipal codes often regulate rainwater harvesting.

India

- Pan India Potential:No authenticated potential of rainwater harvesting has been assessed in India. On absolute local basis it has been carried out at some places.
- Tamil Nadu: Tamil Nadu was the first state to make Rainwater Harvesting compulsory for every building to avoid groundwater depletion. The scheme was launched in 2001 and has been implemented in all rural areas of Tamil Nadu. We can see posters all over Tamil Nadu including Rural areas to create awareness about harvesting RainwaterTN Govt site (http://www.tn.gov.in/dtp/rainwater.htm). It gave excellent results within five years, and slowly every state took it as a role model. Since its implementation, Chennai saw a 50 percent rise in water level in five years and the water quality significantly improved.[23]
- Karnataka: In Bangalore it is mandatory for adoption of rainwater harvesting for every owner or the occupier of a building having the sital area measuring 60 ft (18.3 m) X 40 ft (12.2 m) and above and for newly constructed building measuring 30 ft (9.1 m) X 40 ft (12.2 m) and above dimension. In this regard, BWSSB has initiated and constructed “Rain Water Harvesting Theme Park” in the name of Sir.

M. Visvesvaraya in 1.2 acres (4,900 m^2) land situated at Jayanagar, Bangalore. In this park, 26 different type of Rain Water Harvesting models are demonstrated along with the water conservation tips. The Auditorium on the first floor is set up with Green Air conditioning system and the same will be utilized to arrange the meeting and showing the video clip about the rainwater harvesting to students as well as general public.[24]

- Rajasthan: In Rajasthan, rainwater harvesting has traditionally been practised by the people of the Thar Desert. There are many ancient water harvesting systems in Rajasthan, which have now been revived.[25] Water harvesting systems are widely used in other areas of Rajasthan as well, for example the chauka system from the Jaipur district.[26]
- Kerala:
- Maharashtra: At present, in Pune, rainwater harvesting is compulsory for any new housing society to be registered.
- In Mumbai city in Maharashtra rainwater harvesting is being considered as a good solution to solve the water crisis.

The Mumbai city council is planning to make rainwater harvesting mandatory for large societies.[27] An attempt has been made at the Department of Chemical Engineering, IISc, Bangalore to harvest rainwater using upper surface of a solar still, which was used for water distillation[28]

Israel

The Southwest Center for the Study of Hospital and Healthcare Systems in cooperation with Rotary International is sponsoring a rainwater harvesting model program across the country. The first rainwater catchment system was installed at an elementary school in Lod, Israel. The project is looking to expand to Haifa in its third phase. The Southwest Center has also partnered with the Water Resources Action Project (WRAP) of Washington D.C. WRAP currently has rainwater harvesting projects in the West Bank. Rainwater harvesting systems are being installed in local schools for the purpose of educating schoolchildren about water conservation principles and bridging divides between people of different religious and ethnic backgrounds all while addressing the water scarcity issue that the Middle East faces.[29]

New Zealand

Although New Zealand has plentiful rainfall in the West and South, for much of the country, rainwater harvesting is the normal practice for most rural housing and is encouraged by most councils [30]

Sri Lanka

Rainwater harvesting has been a popular method of obtaining water for agriculture and for drinking purposes in rural homes. The legislation to promote rainwater harvesting was enacted through the Urban Development Authority (Amendment) Act, No. 36 of 2007.[31] Lanka rainwater harvesting forum[32] is leading the Sri Lanka's initiative.

South Africa

The South African Water Research Commission has supported research into rainwater harvesting. Reports on

this research are available on their 'Knowledge Hub'.[33] Studies in arid, semi-arid and humid regions have confirmed that techniques such as mulching, pitting, ridging and modified run-on plots are effective for small-scale crop production.[34]

United Kingdom

In the United Kingdom, water butts are often found in domestic gardens and on allotments to collect rainwater, which is then used to water the garden. However, the British government's Code For Sustainable Homes encouraged fitting large underground tanks to new-build homes to collect rainwater for flushing toilets, watering and washing. Ideal designs had the potential to reduce demand on mains water supply by half. The code was revoked in 2015.

United States

- Colorado: Until 2009, water rights laws almost completely restricted rainwater harvesting; a property owner who captured rainwater was deemed to be stealing it from those who have rights to take water from the watershed. Now, residential well owners that meet certain criteria may obtain a permit to install a *rooftop precipitation collection system* (SB 09-080).[35] Up to 10 large scale pilot studies may also be permitted (HB 09-1129).[36] The main factor in persuading the Colorado Legislature to change the law was a 2007 study that found that in an average year, 97% of the precipitation that fell in Douglas County, in the southern suburbs of Denver, never reached a stream—it was used by plants or evaporated on the ground. In Colorado, one is not permitted to drill a water well unless one has at least 35 acres (14 ha) of land.
- New Mexico: In New Mexico, rainwater catchment is mandatory for new dwellings in Santa Fe.[20]
- Texas offers a sales tax exemption on the purchase of rainwater harvesting equipment. Both Texas[37] and Ohio allow the practice even for potable purposes.
- Oklahoma passed the Water for 2060 Act in 2012, to promote pilot projects for rainwater and graywater use among other water saving techniques.[22]

Non-traditional

- In 1992, American artist Michael Jones McKean created an artwork in Omaha, Nebraska at the Bemis Center for Contemporary Art that created a fully sustainable rainbow in the Omaha skyline. The project collected thousands of gallons of rainwater storing the water in six daisy-chained 12,000 gallons tanks.[38] The massive logistical undertaking, during its 5-month span, was one of the largest urban rainwater harvesting sites in the American Mid-West.

See also

- Atmospheric water generator
- Water conservation
- Peak water
- Nelapattu Bird Sanctuary
- Deepwater rice
- Air well (condenser)
- Detention basin

- Retention basin

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- American Rainwater Association (http://www.arcsa.org)
- Canadian Rainwater Association (http://www.canarm.org)

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Categories: Water supply | Water conservation | Irrigation | Appropriate technology | Hydrology and urban planning | DIY culture | Aquifers | Rainwater harvesting | Sustainable gardening

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Rainwater tank

From Wikipedia, the free encyclopedia

A **rainwater tank** (sometimes called a **rain barrel** in North America in reference to smaller tanks, or a **water butt** in the UK) is a water tank used to collect and store rain water runoff, typically from rooftops via rain gutters. A rainwater catchment or collection (also known as "rainwater harvesting") system can yield 2358 litres (623 gal) of water from 2.54 cm (1 in) of rain on a 93 m^2 (1,000 sq ft) roof. Rainwater tanks are devices for collecting and maintaining harvested rain.

Rainwater tanks are installed to make use of rain water for later use, reduce mains water use for economic or environmental reasons, and aid self-sufficiency. Stored water may be used for watering gardens, agriculture, flushing toilets, in washing machines, washing cars, and also for drinking, especially when other water supplies are unavailable, expensive, or of poor quality, and when adequate care is taken that the water is not contaminated and is adequately filtered.

Underground rainwater tanks can also be used for retention of stormwater for release at a later time and offer a variety of benefits described in more detail below. In arid climates, rain barrels are often used to store water during the rainy season for use during dryer periods.

Rainwater tanks may have a high (perceived) initial cost. However, many homes use small scale rain barrels to harvest minute quantities of water for landscaping/gardening applications rather than as a potable water surrogate. These small rain barrels, often recycled from food storage and transport barrels or, in some cases, whiskey and wine aging barrels, are often inexpensive. There are also many low cost designs that use locally available materials and village level technologies for applications in developing countries where there are limited alternatives for potable drinking water.[1] While most are properly engineered to screen out mosquitoes, the lack of proper filtering or closed loop systems may create breeding grounds for larvae. With tanks used for drinking water, the user runs a health risk if maintenance is not carried out.[2]

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- 2 Tanks
- 3 Water supply augmentation
  - 3.1 Colorado law
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- 7 External links

Contamination and maintenance

If rainwater is used for drinking, it is often filtered first. Filtration (such as reverse osmosis, ultraviolet sterilization, or ultrafiltration) may remove pathogens. While rain water is pure it may become contaminated

during collection or by collection of particulate matter in the air as it falls.[3] While rain water does not contain chlorine, contamination from airborne pollutants, which settles onto rooftops, may be a risk in urban or industrial areas. Many water suppliers and health authorities, such as the New South Wales Department of Health, do not advise using rainwater for drinking when there is an alternative mains water supply available. However, reports of illness associated with rainwater tanks are relatively infrequent, and public health studies in South Australia (the Australian state with the highest rainwater usage rate) have not identified a correlation. Rainwater is generally considered fit to drink if it smells, tastes and looks fine;[4] However some pathogens, chemical contamination and sub-micrometre suspended metal may produce neither smell, taste and not be visible.

Australian standards may differ greatly from other places in the world where rainwater is commonly used for drinking water. In the United States, rainwater is being increasingly used throughout the country for various purposes. In the semi-arid western state of New Mexico, for instance, many residents in the Taos and Santa Fe areas in particular use rainwater either for landscaping purposes or even all household uses (including potable indoor water). The "smells, tastes, and looks fine" standard used in the above paragraph is not an absolute indicator of rainwater safety. Most people who are rainwater users for potable purposes in the USA make certain that their water is safe through filtration, ultraviolet sterilization, and testing.

Certain paints and roofing materials may cause contamination. In particular, a Melbourne Water publication advises that lead-based paints never be used. Tar-based coatings are also not recommended, as they affect the taste of the water. Zinc can also be a source of contamination in some paints, as well as galvanized iron[5] or zincalume roofs, particularly when new, should not collect water for potable use. Roofs painted with acrylic paints may have detergents and other chemicals dissolve in the runoff. Runoff from fibrous cement roofs should be discarded for an entire winter, due to leaching of lime. Chemically treated timbers and lead flashing should not be used in roof catchments. Likewise, rainwater should not be collected from parts of the roof incorporating flues from wood burners without a high degree of filtration. Overflows or discharge pipes from roof-mounted appliances such as air-conditioners or hot-water systems should not have their discharge feed into a rainwater tank.

"Copper Poisoning," a 2010 news article, linked copper poisoning to plastic tanks. The article indicated that rainwater was collected and stored in plastic tanks and that the tank did nothing to mitigate the low pH.[6] The water was then brought into homes by copper

piping. The copper was released by the high acid rainwater and caused poisoning in humans. It is important to note that, while the plastic tank is an inert container, the collected acid rain could and should be analysed and pH adjusted before being brought into a domestic water supply system. The solution is to monitor stored rainwater with *swimming pool strips*, cheap and available at swimming pool supply outlets.

Some of the rainwater tanks around CERES Community Environment Park, in Melbourne, Australia.

If the water is too acidic, the state, county or local health officials may be contacted to obtain advice, precise solutions and pH limits, and guidelines as to what should be used to treat rainwater to be used as domestic drinking water.

Maintenance includes checking roofs and rain gutters for vegetation and debris, maintaining screens around the tank, and occasionally desludging (removing sediment by draining and cleaning the tank of algae and other contaminants).

Rainwater tanks which are not properly sealed (secured at the top) may act as breeding grounds for mosquitoes.[7]

Several options for dealing with the mosquito issue are: 1. Flushing ALL water once a week 2. Using a small amount of cooking oil to suffocate the larvae (the water is still ok for landscape use after this) 3. Adding the bacillus Bt to the water. This bacteria will not harm animals. 4. Adding mosquito eating fish

Another way to store rainwater without worry of contamination by mosquitos is to use underground storage tanks. Underground tanks keep the water too cool (@55 degrees F) for mosquito larvae and also are dark, preventing both mosquito, bacterial, and algae growth. A very good article by Richard Hill goes into depth about the benefits of underground rainwater storage.[8]

Tanks

Rainwater tanks may be constructed from materials such as plastic (polyethylene), concrete, galvanized steel, as well as fiberglass and stainless steel which are rust and chemical-resistant. Tanks are usually installed above ground, and are usually opaque to prevent the exposure of stored water to sunlight, to decrease algal bloom.[3]

A plastic water container (IBC)

Tanks may be covered and have screen inlets to exclude insects, debris, animals and bird droppings. Almost all steel tanks currently produced for household rainwater collection come with a plastic inner lining to increase the life of the tank, prevent leaks and protect the water quality.

Apart from rooftops, tanks may also be set up to collect rainwater from concrete patios, driveways and other impervious surfaces.

Initial sizes typically ranged in capacity from around 400 to 100,000 litres (100 to 25,000 US gallons), today modern technology has allowed modular and scalable applications to go into sizes of millions of litres or hundreds of thousands of US gallons.[9]

Large polyethylene rainwater tanks being installed.

Smaller tanks, such as the plastic 208-litre (55-gallon barrel) are also used in some cases. Modern modular systems which are scalable, like the 193 litre (51 gal) Rainwater HOG module[10] and the 500 litre (133 gallon) Stratco Aquabarrel[11] can be used to decentralize the rainwater catchment by storing smaller volumes at each downspout. Larger tanks are commonly used where there is no access to a centralised water supply. Companies such as Solar Survival Architecture recommend a 300-gallon (1135 litre) tank for a house supporting 2 people (if compost toilets are placed) and if your region receives 762 mm of precipitation a year. If it receives less (between 254 mm and 762mm), 2 or 3 of these 300 gallon tanks can be placed (so that more rain can be gathered at times when it does rain). Also affecting tank size is predicted rainfall and rainfall variability; the higher prices for larger tanks; intended use of rainwater and typical consumption for these uses; the area of roof draining into the tank; security of supply desired.

Most rainwater catchment tanks used throughout the world are composed of virgin polyethylene, a substance which in the USA is both FDA and NSF approved for potable water storage. Other types of tanks used for rainwater storage include fiberglass, galvanized metal, stainless steel, and concrete. Each type of tank has positive and negative aspects. Polyethylene tanks, when placed above ground, can be subject to algae growth as well as the possibility of a short life (@20 years) due to normal UV exposure in sunlight. The very strong fiberglass tanks must undergo a specific coating process to be brought up to potable grade. Galvanized tanks must either be lined or coated both for potability as well as to prevent the inevitable rusting at any welded seams. Uncoated galvanized tanks will leach zinc into the stored water and are not recommended in most instances - certainly not for water stored for human consumption. Concrete tanks leach a more benign substance - lime - into stored water and many are used around the world for rainwater storage.

One method of harvesting rain water has been is modular, scalable systems which are installable underground. These came as an evolution of a geosynthetic applications called Infiltration Tanks, which when stacked provide a void space volume which allows for the storing of water. Improved and more cost effective industrial design now allow for theoretically limitless storage of water underground. Examples of these modular structures are Atlantis Matrix Tanks[12] used in the Manly Stormwater Treatment and Re-use project of Manly Council in Australia.[13]

Water supply augmentation

In some cities, installation of rainwater tanks may be mandatory, or may help a new building be approved. For example, in Victoria, Australia new houses which have rainwater tank connected to all flush toilets are given an additional 1-star of the required 5-star House Energy Rating. Some governments subsidise purchases of rainwater tanks or provide rebates in areas where they are considered an important means of water supply augmentation.[14] In the United States, Santa Fe County, New Mexico requires a rainwater collection system on all new construction with greater than 2,500 square feet, mostly for landscaping purposes and to prevent over-reliance on wells but in some instances because ground water is prohibitively expensive to obtain, if even available.

Rainwater to supplement drinking water supplies may be seen as an alternative to other water supply options such as recycling or seawater desalination. Tanks are often perceived to have environmental costs that are comparatively lower than other water supply augmentation options.

Rainwater collection can be made compatible with centralised water supply by tapping it using an electropump.

Widespread use of rain barrels also changes the amount of rainwater reaching the ground in a particular area and draining into streams. Depending on the climate, this either helps prevent erosion, sedimentation, and/or pollution, and can reduce the strain on stormwater drainage systems; or it could cause rivers to dry up and ponds to stagnate if the water is diverted to a different watershed. If collected water is used in the same watershed in which it is collected, rainwater collection actually can stabilize flow in rivers and provide more regular and filtered groundwater transfer into ponds.

Colorado law

In the State of Colorado, United States, the installation of rainwater collection barrels is subject to the Constitution of the State of Colorado, state statutes and case law.[15] This is a consequence of the system of water rights in the state; the movement and holding of rainwater is inextricably linked with ownership of water rights and is enshrined in the constitution of the State of Colorado. The use of water in Colorado and other western states is governed by what is known as the prior appropriation doctrine. This system of water allocation controls who uses how much water, the types of uses allowed, and when those waters can be used. This is often referred to as the priority system or "first in time, first in right." Since all water arriving in Colorado has been allocated to "senior water right holders" since the 1850s, rainwater prevented from running downstream may not be available to its rightful owner. In 2009, legislation in Colorado was enacted that permits capture of rain water for residential use subject to strong limitations and conditions.[16] To be permitted, a residence may not be connected to a domestic water supply system serving more than 3 single-family dwellings. The permit must be purchased from the State Engineer's office and is subject to water usage restrictions.[17]

Internal rainwater tank

Rainwater tanks or drums may be used inside a house to provide thermal mass for a trombe wall (or **water wall**). Rainwater Hog modular tanks invented by Sally Dominguez to fit within building structure were used in the Modabode House of the Future floor and on the foyer wall of the Department of Sustainability building in Anglesea, Victoria, harnessing the higher value of the stored rainwater to add effective thermal mass to the enclosed spaces.[18]

Specially designed rainwater tanks can also be embedded in or under the concrete slab of a building (*stab tank*).

A house in Cape Schanck Victoria, Australia uses an internal rainwater tank to provide cooling to the living room in summer. During winter the tank is drained and wrapped in an insulating jacket. The tank also provides structural support to the roof, and excess water is used for domestic use including drinking.[19][20]

See also

- Aljibe
- Cistern
- Drinking water
- Electropump
- Rain gutter
- Hand pump
- Irrigation tank - ancient India

- Plumbing
- Rainwater harvesting
- Rainwater harvesting in Canada
- Runoff water
- Storage tank
- Sustainable living
- Water Sensitive Urban Design
- Water tank
- Well

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- Standard Methods for the Examination of Water and Wastewater (http://www.standardmethods.org/) (standardmethods.org)
- American Rainwater Catchment Systems Association

External links

- Code of Federal Register - CFR Title 21 Part 129 (http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?CFRPart=129) Helpful information and water tank installation instructions. This is a US Government document, published as part of the Federal Register, these are both government rules and guidelines of water tank installations.
- The Texas Manual on Rainwater Harvesting (http://www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf)
- Guide on saving water around the garden. (http://www.direct.gov.uk/en/Environmentandgreenerliving/Greenergarden/DG_064410)
- Waterwise - Reducing Water in the UK house (http://www.waterwise.org.uk/reducing_water_wastage_in_the_uk/house_and_garden/water_butts.html)
- Rain barrel construction - Great Lakes Green Initiative (http://www.glgi.org/mediawiki/index.php?title=Rain_barrel)
- Building a water barrel system (http://www.emmitsburg.net/gardens/articles/adams/audrey/water_barrel.htm)
- ARCSA (http://www.arcsa.org) American Rainwater Catchment Systems Association
- CANARM (http://www.canarm.org) Canadian Association for Rainwater Management

Wikimedia Commons has media related to ***Rainwater tanks***.

Drinking water/Rain barrel has media related to: Rainwater tank

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Categories: Water conservation tools | Appropriate technology | Liquid containers | Water supply infrastructure | Rainwater harvesting

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Raised-bed gardening

From Wikipedia, the free encyclopedia

Raised-bed gardening is a form of gardening in which the soil is formed in three-to-four-foot-wide (1.0–1.2 m) beds, which can be of any length or shape. The soil is raised above the surrounding soil[1] (approximately six inches to waist-high), is sometimes enclosed by a frame generally made of wood, rock, or concrete blocks, and may be enriched with compost.[2] The vegetable plants are spaced in geometric patterns, much closer together than in conventional row gardening.[2] The spacing is such that when the vegetables are fully grown, their leaves just barely touch each other, creating a microclimate in which weed growth is suppressed[2] and moisture is conserved.[3] Raised beds produce a variety of benefits: they extend the planting season,[2] they can reduce weeds if designed and planted properly,[2] and they reduce the need to use poor native soil. Since the gardener does not walk on the raised beds, the soil is not compacted and the roots have an easier time growing.[4] The close plant spacing and the use of compost generally result in higher yields with raised beds in comparison to conventional row gardening. Waist-high raised beds enable the elderly and physically disabled to grow vegetables without having to bend over to tend them.[4]

Raised garden bed of lettuce, tomatoes, basil, marigolds, zinnias, garlic chives, zucchini.

Raised bed gardening

Picardo Farm, Wedgwood neighborhood, Seattle, Washington: A community allotment garden with raised beds for the physically disabled.

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Overview

Raised beds lend themselves to the development of complex agriculture systems that utilize many of the principles and methods of permaculture. They can be used effectively to

control erosion and recycle and conserve water and nutrients by building them along contour lines on slopes.[3] This also makes more space available for intensive crop production.[2] They can be created over large areas with the use of several commonly available tractor-drawn implements and efficiently maintained, planted and harvested using hand tools.

This form of gardening is compatible with square foot gardening and companion planting.

Circular raised beds with a path to the center (a slice of the circle cut out) are called keyhole gardens.[5] Often the center has a chimney of sorts built with sticks and then lined with feedbags or grasses that allows water placed at the center to flow out into the soil and reach the plants' roots.

Materials and construction

Vegetable garden bed construction materials should be chosen carefully. Some concerns exist regarding the use of pressure-treated timber.[6] Pine that was treated using chromated copper arsenate or CCA, a toxic chemical mix for preserving timber that may leach chemicals into the soil which in turn can be drawn up into the plants, is a concern for vegetable growers, where part or all of the plant is eaten. If using timber to raise the garden bed, ensure that it is an untreated[2] hardwood to prevent the risk of chemicals leaching into the soil. A common approach is to use timber sleepers joined with steel rods to hold them together. Another approach is to use concrete blocks, although less aesthetically pleasing, they are inexpensive to source and easy to use. On the market are also prefab raised garden bed solutions which are made from long lasting polyethylene that is UV stabilized and food grade so it will not leach undesirable chemicals into the soil or deteriorate in the elements. A double skinned wall provides an air pocket of insulation that minimizes the temperature fluctuations and drying out of the soil in the garden bed. Sometimes raised bed gardens are covered with clear plastic to protect the crops from wind and strong rains.[4] Pre-manufactured raised bed gardening boxes also exist.[1] There are variants of wood, metal, stone and plastic. Each material type has advantages and disadvantages.[7]

See also

- Kitchen garden
- Therapeutic garden
- Hügelkultur: another type of raised bed
- Waru Waru – A traditional Quechua, pre-Inca system involving raised beds
- Square foot gardening

Raised garden beds with painted wooden edgings at Wise Words Community Garden in Mid-City, New Orleans

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External links

- The Synergistic Garden (http://video.google.com/videoplay?docid=2865701754864235132)—A video by Emilia Hazelip, which provides practical information on how to garden with raised beds.
- Appeal: Keyhole gardening saves lives in world's most eroded land (http://www.independent.co.uk/news/world/africa/appeal-keyhole-gardening-saves-lives-in-worlds-most-eroded-land-702081.html)

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Categories: Agricultural soil science | Horticulture and gardening | Permaculture | Types of garden

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Raising Earthworms Successfully

Prepared by:

Rhonda Sherman
Extension Solid Waste Specialist
Biological and Agricultural Engineering
North Carolina State University, Raleigh, NC

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Introduction

Over the past several years, many people have begun raising earthworms as a source of income or as a means of managing organic waste. Some are drawn to the business by extravagant claims of vast potential markets for earthworms in large waste disposal systems and agriculture and as a source of food for animals. Despite these claims, the current major commercial use of earthworms is as bait for freshwater sport fishing.

Although several other outlets for sales of worms exist, there is much competition for markets. Research and development on uses for worms are under way throughout the world, but the opening of new markets for worms and castings will be slow and somewhat uncertain. Those interested in getting into the earthworm business should explore potential local markets carefully, particularly if a full-time occupation is the goal.

Earthworm growers can make money by selling earthworms and vermicompost or from tipping fees (charging to have organic materials normally disposed of in landfills "tipped" by a dump truck onto the worm grower's site, to be fed to the earthworms). Vermicomposting is the process of turning organic debris into worm castings (manure). The focus is on processing the waste rather than creating ideal conditions for raising earthworms. Earthworm size and their reproductive rates are frequently lower than those of the same species raised in vermiculture systems. Large vermicomposting facilities typically make money primarily from tipping fees, followed by sales of castings, and then, in a distant third place, by sales of earthworms.

Vermiculture is the raising of earthworms for resale, so the focus is on ideal conditions for worm growth, reproduction, and health. Worm farmers usually purchase and haul feedstock or pay for feedstock to be delivered to them. Others may get the material for free but pay for it to be pre-composted and hauled to their site. Worm growers make money from sales of earthworms and sometimes, but not always, by selling castings. In

addition, some operations sell related products, such as shipping boxes, worm bins, harvesters, soil mixes, books, and videos.

Potential Markets for Earthworms and Vermicompost

Several options are available for the sale of earthworms. Home vermicomposters, composters, and gardeners are interested in buying earthworms. Fish hatcheries, tropical fish stores, pet stores, zoos (with exotic fish and birds), game bird breeders, frog farmers, and poultry growers buy worms as feed for animals. Community educators, such as Extension agents or recycling coordinators, often need a steady supply of earthworms for setting up new worm bins. Private laboratories, universities, and high schools use worms for research and classroom needs.

Growers living near or on the way to fresh or salt water fishing resorts can sell earthworms directly to fishing enthusiasts (check with the local zoning authority to be sure such a business is permitted in the area). Placing advertisements in national magazines directed to fishing enthusiasts and home gardeners or advertising on the Internet may create sales for earthworms.

It may be possible to sell earthworms to locally owned sporting goods or fishing tackle stores, although most of the larger stores of this type rely on established wholesalers for their bait supplies. The bait market may not be the best choice for this enterprise because there is usually more interest in nightcrawlers (larger worms) than smaller compost worms, the market is often saturated, and the competition is stiff.

Other markets for earthworms include:

- Large-scale vermicomposting facilities.
- Worm growers just entering the business.
- Institutions and businesses that do on-site vermicomposting of their food scraps and other organic materials (including prisons, hospitals, schools, colleges and universities, restaurants, grocery stores, and office buildings).

- Farmers desiring to vermicompost animal manure (including livestock and poultry farms, rabbitries, and horse stables).
- Worm growers with orders too large to fill from their own stocks.
- Industries with organic wastes suitable as feedstock for worms, such as papermills, breweries, cardboard manufacturers, land reclamation sites, generators of sludge/biosolids, food processors, canneries, wineries, and cotton mills.

Many worm growers focus on selling vermicompost rather than earthworms. Vermicompost is a blend of castings and decomposed organic matter that has been placed in a worm bin. The nutrient content of vermicompost depends on the types of feedstocks and bedding provided for the worms. Studies have shown that vermicompost enhances plant growth, suppresses disease in plants, and increases microbial activity in soil. Vermicompost also improves water retention, aeration, and porosity in soils.

Due to its high cost, compared to commercial fertilizers, vermicompost is not commonly used as a soil amendment or plant growth enhancer by large commercial plant growers. Nonetheless, vermicompost is increasingly being used by organic gardeners and is sold commercially in some nurseries as a soil amendment or planting medium for ornamental plants. A growing body of research demonstrating the beneficial uses of vermicompost is helping to increase market outlets. Vermicompost may be sold in bulk by the cubic yard or bagged with a variety of compost and soil blends. Markets include home improvement centers, nurseries, landscape contractors, greenhouses, garden supply stores, grocery chains, flower shops, discount houses, and the general public.

A relatively new product coming on the market is vermicompost tea (a liquid). Organic matter, microorganisms, and nutrients are extracted from vermicompost to produce the tea. Unlike vermicompost and compost, this tea may be applied directly to plant foliage, reportedly to enhance disease suppression. Vermicompost tea also may be applied to the soil as a supplement between compost applications to increase biological activity.

Vermicompost tea is NOT leachate that leaks out of the bottom of a worm bin. Leachate is produced when excess liquid passes through organic material in the worm bin,

including undigested, decomposing organics. The liquid extract of undigested material may contain pathogens and chemicals that are toxic to plants and humans.

Before attempting to make vermicompost tea, investigate how to do it and what equipment to use by reading and conducting personal interviews with those who make it. Information on compost tea and vermicompost tea may be obtained through Internet search engines and the Compost Tea Industry Association (www.composttea.org).

Vermicompost tea may be sold in bulk to orchards, nurseries, greenhouses, landscapers, and retailers (who will bottle it for resale).

Earthworm Classification

Earthworms are terrestrial invertebrates with thousands of species grouped into three categories according to their behavior in the natural environment: anecic, endogeic, and epigeic.

Anecic species, represented by the common nightcrawler (*Lumbricus terrestris*), construct permanent vertical burrows as deep as 4 to 6 feet in the soil. They feed on organic debris on the soil surface and convert it into humus. If anecic species are deprived of their permanent homes, they will discontinue breeding and cease to grow.

Endogeic species, such as *Aporrectodea calignosa*, build wide-ranging, mainly horizontal burrows where they remain most of the time, feeding on mineral soil particles and decaying organic matter. They are the only species of earthworms that actually feed on large quantities of soil. As they move through the soil and feed, they mix and aerate the soil and incorporate minerals into the topsoil.

Epigeic species, represented by the common redworm (*Eisenia fetida*), do not build permanent burrows; instead, they are usually found in areas rich in organic matter, such as the upper topsoil layer, in the forest under piles of leaves or decaying logs, or in piles of manure. Since they don't burrow deeply into the soil and prefer to eat rich organic

matter, epigeic worms adapt easily to vermiculture and vermicomposting systems. *Eisenia fetida* and *Eisenia andreii* constitute about 80 to 90 percent of the earthworms raised on a large-scale commercial basis.

Biology of Earthworms

The physical structure of earthworms is similar among the different species. Earthworms belong to the phylum Annelida, which means "ringed." The "rings" around worms are called segments. Redworms have about 95 segments, while nightcrawlers have about 150. Earthworm bodies are streamlined, containing no protruding appendages or sense organs, to enable them to pass easily through soil. Worms have well-developed nervous, circulatory, digestive, excretory, muscular, and reproductive systems.

The head or anterior end of the earthworm has a prostomium, a lobe covering the mouth that can force open cracks in the soil into which the earthworm can crawl. Setae (bristles) on each segment can be extended or retracted to help earthworms move. Lubricating mucous, secreted by skin glands, helps worms move through soil and stabilizes burrows and castings.

The earthworm's digestive tract extends the whole length of its body. Worms swallow soil (including decomposing organic residues in the soil) or residues and plant litter on the soil surface. Swallowed matter is mixed by strong muscles and moved through the digestive tract while enzyme-filled fluids are secreted and blended with the materials. The digestive fluids release amino acids, sugars, bacteria, fungi, protozoa, nematodes, and other microorganisms, in addition to partially decomposed plant and animal materials from the food the worms have swallowed. Simpler molecules are then absorbed through intestinal membranes and are utilized by earthworms for energy and cell production.

Earthworms do not have specialized breathing devices. They breathe through their skin, which needs to remain moist to facilitate respiration. Like their aquatic ancestors, earthworms can live for months completely submerged in water, and they will die if they dry out.

A red pigment in earthworms' skin makes it sensitive to ultraviolet rays. Brief exposure to strong sunlight causes paralysis in some worms, and longer exposure kills them. Earthworms seen lying dead in puddles after a rainstorm likely were killed by exposure to light, not by drowning, since they can live submerged in water. However, worms will emerge from their burrows seeking oxygen when unoxygenated rainwater filters down through the soil and squeezes most of the rest of the oxygen from the soil spaces.

Taste cells are located in and near an earthworm's mouth, and worms show definite food preferences. Experiments have demonstrated that they will pass up cabbage if celery is available and shun celery if carrot leaves are offered.

Earthworms are hermaphroditic, meaning each individual possesses both male and female reproductive organs. The eggs and sperm of each earthworm are located separately to prevent self-fertilization. When worms mate, they face in opposite directions and exchange sperm; the eggs are fertilized at a later time. Mature eggs and sperm are deposited in a cocoon produced by the clitellum, a swollen, saddle-shaped structure near the worm’s head. Within the cocoon, the sperm cells fertilize the eggs, and then the cocoon slips off the worm into the soil. The number of worms inside each cocoon and the length of time it takes them to hatch varies according to worm species and environmental conditions. Approximately four *Eisenia fetida* baby worms will emerge from a cocoon in 30 to 75 days, and another 53 to 76 days must pass for the newly hatched worms to reach sexual maturity.

Earthworm cocoons resemble grape seeds in size and shape, with one end rounded and the other slightly pointed. Cocoons are initially pearly-yellow in color, then deepen to brown as the young inside mature and get ready to hatch.

Earthworms can only reproduce using sperm from members of their own species. Claims of hybrid worms are not valid.

Earthworm Production

Earthworms have certain minimum care requirements that must be met on a regular schedule. The key environmental factors affecting earthworm growth, reproduction, and health are temperature, moisture, aeration, pH (acidity-alkalinity), and food material.

Temperature

Earthworms live and breed at temperatures between 55 and 85 degrees Fahrenheit. For commercial earthworm production, the ideal temperatures for growth and activity range from 60° to 80°. Bed temperatures should be between 60° and 70° to facilitate intensive cocoon production and hatching. If bed temperatures rise too high, they may be lowered by adding water, activating fans in or near the system, and reducing the amount of feedstock applied.

Moisture

Earthworms need adequate moisture to help them breathe through their skin. Beds need to sustain a moisture range of 60 to 85 percent and feel crumbly-moist, not soggy-wet. They should be sheltered from direct sunlight so they do not dry out and overheat. One method of increasing cocoon production after worms are fully established is to stop watering the beds for several days or until the top 1 or 2 inches are scarcely moist. Then dampen the beds enough to restore them to their recommended moisture content.

Aeration

Earthworms can survive in relatively low oxygen and high carbon dioxide environments and even stay alive when submerged in water if it contains dissolved oxygen. If there is no oxygen, however, earthworms can die. Oxygen may be depleted if earthworm beds are kept too wet or if too much feed is introduced. By reducing the amount of moisture, cutting back on feed, and turning the pile with a pitchfork or three-prong garden tool, oxygen will be restored. Turning the materials in the beds every two to three weeks will help keep the beds aerobic.

pH (acidity-alkalinity)

The pH of soil indicates whether it is acidic (1 to 6), neutral (7), or alkaline (8 to 14). Earthworms will grow in a pH range of about 4.2 to 8.0. For commercial production, however, earthworm beds should be kept at a pH range of 6.8 to 7.2. Check levels weekly with a pH kit, available in garden supply centers or feed stores. Take readings at different levels in the bed: the top feed area, 3 inches deep, and 8 inches deep. If an acid condition is detected in an earthworm bed, agricultural lime (calcium carbonate) may be mixed with bedding material to remedy the condition. Sprinkle half a pound of limestone on each 24 square feet of bedding surface, and water the bed. It is far less common for an overalkaline condition to exist. To remedy alkalinity, mix enough dry peat moss into the bedding until pH readings indicate a range of 6.8 to 7.2.

Setting Up an Earthworm-Growing Operation

The first question to ask when considering starting a vermiculture or vermicomposting business is, "How can I market the product(s)?" not "How will I produce the product(s)?" Other questions to consider include:

- What income do I want or expect?
- Will I work at it part-time or full-time?
- What business experience do I have? Have I run a business, developed a business plan, or marketed products?
- Does my region have marketing opportunities for earthworms and castings?
- Who are my competitors, and how can I be different?
- What financial resources are available to me?
- What physical resources do I have (land, buildings, machinery, labor)?
- Will I work solo or in partnership with others?
- In what type of climate do I reside? (This affects how I will need to shelter the earthworms.)

The next step is to learn as much as possible about earthworm farming and the current and projected needs of the industry. Read books, bulletins, pamphlets, and newsletters; watch videos; and consider attending workshops, seminars, and conferences. The

following resources will help (this is not an exhaustive list nor is it an endorsement or criticism of others not listed):

- Periodicals
  - *BioCycle Journal of Composting and Organics Recycling* (www.jgpress.com)
  - *Casting Call* (www.vermico.com)
  - *Worm Digest* (www.wormdigest.org)
  - *In Business* (www.jgpress.com
  - *Entrepreneur* (www.entrepreneur.com)
- Books and manuals (find vendors by typing in titles on an internet search engine)
  - *Commercial Vermiculture: How to Build a Thriving Business in Redworms* by Peter Bogdanov (1996).
  - *Raising Earthworms for Profit* by Earl Shields (1994-revised).
  - *Earthworms for Ecology & Profit,* Vols. 1 & 2 by Ronald Gaddie, Sr., and Donald Douglas (1977).
  - *Profitable Earthworm Farming* by Charlie Morgan (1975, revised). Other titles by Morgan include *Earthworm Selling and Shipping Guide; Earthworm Feeds and Feeding;* and *The Worm Farm*.
- Websites (use an Internet search engine in addition to www.bae.ncsu.edu/people/faculty/sherman/vermiculture/directory-by-state.html)
  - Worm growers
  - Vermiculture clearinghouses
  - Vermicomposting experts
  - Listserves on vermicomposting and composting
- Agencies (use an Internet search engine to find updated contact information)
  - State and local offices of Cooperative Extension
  - State solid waste agencies
  - State composting councils
  - U.S. Composting Council (www.compostingcouncil.org)
  - State recycling associations

- National Recycling Coalition (www.nrc-recycle.org)
- Solid Waste Association of North America (SWANA) (www.swana.org)

While gathering information, set up a small-scale system by buying or building a worm bin. This will enable you to learn first-hand what it is like to raise worms as you discover the challenges and demands of maintaining the system. Refer to the Extension publication *Worms Can Recycle Your Garbage* (http://www.bae.ncsu.edu/people/faculty/sherman/ag473-18.html) for instructions on getting started. Once confidence is gained in raising earthworms, expand the operation.

An important issue to address is compliance with state and local regulations. Many city, county, and state governments classify earthworm farming as agriculture for zoning purposes. Check with local government agencies for the zoning classification and any restrictions. Find out if a business license, permit, or resale license is required. Contact the state solid waste management agency and the state Department of Agriculture and Consumer Services to inquire if permits are required for raising worms, using particular feedstocks, and selling worms and/or vermicompost. If food residues and yard debris are to be imported as feed for the worms, a permit from the state solid waste agency likely will be required. Obtaining this type of permit can be a costly and time-consuming process. In North Carolina, contact Ted Lyon, Solid Waste Section, Division of Waste Management, N.C. Department of Environment and Natural Resources, (919) 733-0692, ext. 253. If vermicompost is to be sold, contact Danny Turner, Fertilizer Section, N.C. Department of Agriculture and Consumer Services, (919) 733-3933, ext. 219.

Some new growers choose to sign contracts with earthworm wholesalers who sell breeder stock and promise to buy their offspring back. Many people are attracted to this arrangement because they will already have a steady market for earthworms. Those considering becoming a contract grower should check the wholesaler's reputation with the state attorney general (and other states, if possible) and try to talk to the wholesaler's customers. The Federal Trade Commission has a fact sheet, “Franchise and Business Opportunities,” with tips for investigating a business before investing with it

(http://www.ftc.gov/bcp/conline/pubs/invest/franchse.html). Even if a wholesaler is reputable, something unexpected could cause that company to go out of business, and then the worm grower's sole market would disappear. It is wise in any business to have backup plans for markets and other contingencies.

Growing earthworms in conjunction with livestock operations is often a successful way to diversify. Raising earthworms in the waste products of live stock and then feeding the animals with crops that have been enhanced with worm castings completes a nutrient cycle. Many rabbit growers have developed a second income from the sales of earthworms by placing worm bins directly beneath the rabbit cages where the worms automatically receive manure as feed.

Choosing whether to set up a worm-growing operation indoors or outdoors depends on climate, the type of system to be used, available finances, and goals for worm production. As mentioned earlier, redworms tolerate temperatures between 55° to 80° F. The closer the temperature is to the extremes, the less active the worms will be at feeding and reproducing. For maximum earthworm production, temperatures should be maintained between 60° and 70° F. To achieve this level may require providing some sort of shelter or insulation that can hold heat in the winter and cool the system during the summer.

Outdoor beds should be located in a well-shaded spot or under an open-shed roof. Indoor beds should be placed where there is adequate drainage and ventilation.

Ensure that water and electricity can be supplied to the site. Plenty of water is needed to keep the worm beds moist. Electricity is needed for lighting and temperature control, such as fans to cool the worm beds and auxiliary heating systems for warmth. Lights are the most effective method for preventing worms from leaving their bins.

Earthworm beds may be constructed from many materials, including lumber, concrete or cinder blocks, brick, concrete, or hollow tile. Do not use cedar, redwood, or other aromatic lumber for the beds, as they contain tannic acid and resinous saps that are

harmful to earthworms. Furthermore, do not use pine, as it soaks up water and softens, allowing earthworms to eat right through it.

Earthworm growers sometimes choose to use the following items as beds, as they can be obtained for free or inexpensively: half barrels of steel or wood, discarded refrigerators, old livestock water tanks partly buried, washing machine tubs, or other large metal or wooden containers. If any of these containers have a solid bottom, holes should be drilled in them for drainage. The frames or containers can be partially buried in the soil to help control temperature. Moles eat earthworms, so if they are common in the area, it will be necessary to install bottom coverings or screen linings in the beds.

The most convenient width for the short sides of an earthworm bed is 3 feet. For length, worm growers generally construct beds of at least 8 feet. If beds are longer than 8 feet, some growers like to install dividers every 8 to 10 feet for ease in dividing, harvesting, cleaning, or feeding. Others prefer not to use dividers.

Bed depth should be 12 to 24 inches. If continuous freezing or excessively hot temperatures occur in the area, consider building beds 12 to 24 inches below ground where the constant ground temperature will keep the worms from freezing or overheating.

The ideal distance between beds is 3 feet. This allows room for manually or mechanically operated equipment to be used between the beds for feeding, harvesting, or cleaning.

The lengthwise direction of the earthworm beds and their shelters should parallel the prevailing winds. For example, if the wind generally blows from west to east, the beds should be laid out in a west-east direction. This will prevent intense winds from hitting the largest part of the shelter and will help prevent covers, if they are used, from blowing off.

As described earlier, under certain conditions, earthworms have a tendency to crawl away from their beds. Many growers seek to prevent worms from migrating or at least try to capture them before they crawl away or perish. Some growers keep lights on over the beds all night and on rainy or foggy days. Others fit fine screens over the beds or install ledges extending at least 1.5 inches over the rim of the beds. Others pile moist manure, castings, compost, or old carpet next to the bins to capture worms that have crawled out.

Although beds and bins are most commonly used by worm growers, some choose other methods, such as windrows, the wedge system, or continuous-flow reactors.

Windrows are linear piles on the ground containing feedstocks up to 3 feet high. They are being used extensively both in the open and under cover, but require either a lot of land or large buildings.

The wedge system is a modified windrow system that maximizes space and makes harvesting easier because there is no need to separate worms from vermicompost. Organic materials are applied in layers against a finished windrow at a 45-degree angle. The piles can be inside a structure or outdoors if they are covered with a tarp or compost cover to prevent leaching of nutrients. A front-end loader can be used to set up a windrow 4 to 10 feet wide by whatever length is appropriate. The windrow is started by spreading a 12- to 18-inch layer of organic materials at one end of the area being used. Up to one pound of redworms may be added per square foot of windrow surface area. Subsequent layers of 2 to 3 inches of organics are added weekly, although 3- to 6-inch layers can be added in colder weather. After the windrow reaches 2 to 3 feet deep, the next layers are added at an angle against the first windrow. Worms in the first windrow will eventually migrate toward the fresh feed. Organic materials are added to the second pile until it reaches the depth of the first one, and then a new windrow is started. Worms will continue to move laterally through the windrows. After 2 to 6 months, the first windrow and each subsequent pile may be harvested.

Continuous-flow reactors have raised beds with side walls and mesh bottoms. The mesh floor openings are usually either 2 inches by 4 inches or 2 inches by 2 inches. When the system is being set up, a few layers of newspapers are laid on top of the mesh to prevent the bedding from falling through. Approximately 12 inches of bedding are spread on top of the newspapers. Earthworms are placed on top of the bedding at a rate of 1/2 to 1 pound per square foot of surface area of the bed. Feedstocks are added in layers on top of the bed. Finished vermicompost is harvested by scraping a thin layer from just above the grate, and letting it fall into a chamber below. These systems can be relatively simple and manually operated or fully automated with temperature and moisture controls. For maximum efficiency, they should be under cover.

Bedding Materials

Practically any organic residue, including plant wastes and most bulky animal manures, may be used for bedding. Horse and rabbit manures are considered ideal bedding materials. Some growers prefer to mix sandy loam topsoil with the bedding material, but this is not necessary. It also increases handling time and costs and may even reduce yields.

Earthworm bedding should retain moisture, remain loose, and not contain much protein or organic nitrogen compounds that readily degrade. These compounds would be quickly degraded with the release of ammonia, and this might temporarily increase the pH of bedding material to 8 or higher, which is not good for the worms.

The bedding material will heat up in the beds if it has not already substantially decomposed or if it contains excessive amounts of readily degradable carbohydrates. These conditions can cause the worms to die. Hence, materials of this type should be composted, or aged beyond the heating stage by forming them into piles. Supplemental nitrogen can be added if needed in the form of inorganic nitrogen fertilizers, blood meal, chicken manure, or urea at the beginning of the composting process (about 1/2 to 1 pound of nitrogen to 100 pounds dry-weight bulky residue). Moisten the piles and turn them periodically to enhance aeration and to incorporate material on the edges and top into the

middle of the piles. After the heating stage has passed, the material may be placed in the beds to a depth of 8 to 10 inches.

After worms are added, keep the bedding moist but not soggy, and turn it once every 2 or 3 weeks to keep it loose and aerated. The bedding should be replaced about every 6 months by removing the top 5 or 6 inches (where most of the worms are) and harvesting the remaining worms, as described below. Then remove the remaining old bedding, which has been converted to castings, and pile it for other uses. Fill the bins with new bedding, add worms, and resume feeding.

Feeding Worms

Earthworms will consume animal manures, compost, food scraps, shredded or chopped cardboard or paper, or almost any decaying organic matter or waste product. Horse, rabbit, swine, dairy, or steer manures are excellent feeds. Poultry manure is not recommended as it is too high in nitrogen and mineral.. If feeds are low in nutrients, they must be supplemented with high protein or nitrogen materials such as grains, mashes, and cottonseed meal. Feeds containing high amounts of carbohydrate or woody residues should be composted beyond the heating stage. The feed and supplements can be applied straight or mixed with 20 to 30 percent horse manure or aged pine sawdust or shavings and spread on top of the bedding about 1 inch deep.

When using manure as feedstock or bedding, always test its suitability for the earthworms. The same goes for any organic material in question. Place the material in a container along with about a dozen worms and observe their behavior over the next 12 to 24 hours. If the worms consume the material, it's fine, but if they crawl away or die, it's not suitable. Composting the material may solve the problem. Continue to experiment with the substance until deciding whether it should be fed to the worms.

Feed the worms regularly, once or twice a week. Set the feeding schedule and amount of feed according to the rate of consumption of the last feeding and the condition of the worms and beds. When most of the feed has been consumed, it is time to feed again.

If too much feed is added, the beds may overheat or become anaerobic (oxygen-deprived) or too acidic. Adding calcium carbonate and mixing the bedding can alleviate these problems. If the worms do not appear to be growing bigger or producing offspring, more protein may be needed in the feed. Add grains, mashes, or cottonseed meal.

Harvesting

Harvest the earthworm beds regularly, about every 30 days, to optimize worm production. Thinning the population provides more feed and space for the remaining worms and keeps the bedding loose and porous so the worms can move more easily to eat and reproduce.

Harvesting Beds and Bins

Harvesting beds or bins may be accomplished by several methods. A commonly used technique is called "table harvesting." Place a table or board covered with a waterproof plastic sheet next to or across the worm bed frame. Next to it, place one or two containers with about 2 inches of pre-soaked bedding for the harvested worms. Using a pitchfork or three-pronged garden tool, carefully lift the top 4 inches of bedding (which contain most of the worms), and place it on the harvesting board. Make sure that either brilliant sunlight or a bright light is shining overhead to drive the worms deeper into the bedding to escape the light. Gently remove the top inch of the bedding pile. Wait a few minutes for the worms to burrow deeper, and then repeat the process until eventually mostly a solid mass of worms remains. Place the worms in the containers with the pre-soaked bedding.

Another method is to make a box with wooden sides and a mesh bottom and put manure or watermelon in it. Place the box on top of the worm bed and earthworms will crawl through the mesh bottom to eat the food. Then simply pick up the box and either set up a new bed or package the worms for sale.

A similar but more elaborate box method captures more worms and grades them as they are harvested. Build 4 square boxes 2.5 to 3 feet long, using 1-inch by 4-inch lumber. Staple or nail a different size wire screen to each box with the following size openings: 1/4-inch, 3/16-inch, 1/8-inch, and 1/16-inch. Put moist bedding and worm food in each box. Place the boxes in sequence with the largest screen size on the bottom, and put the boxes either on the bed to be harvested or slightly buried in it. After several days of keeping the bedding properly moistened, remove the boxes to find earthworms in each box according to size, with the largest worms trapped in the bottom box and the smallest ones in the top. This technique works because earthworms head for the surface to feed.

Another simple harvesting method is to set a plastic sheet with fresh manure on top of the worm bed. A significant number of worms will crawl onto the sheet, and it can be lifted off the bed.

Harvesting Windrows

Worm growers with long 2-foot high windrows typically use a front-end loader to remove the top 6 to 8 inches of material, where most of the worms can be found. This material is deposited in a new windrow. Then the remaining castings are scooped up and screened, using a mechanical harvester.

Harvesting Wedge Systems

This system is basically self-harvesting because worms in the first, oldest windrow will migrate toward the fresh feed in the newer windrows. After 2 to 6 months, the first windrow and each subsequent pile can be harvested.

Harvesting Continuous-Flow Reactors

Activate a hand-operated crank or a hydraulic system to pull a bar across and just above the grill, scraping off a thin layer of finished vermicompost that falls through the widely spaced bars to the chamber or floor below.

Mechanical Screening

Worm farmers operating on a mid to large scale use a mechanical worm harvester. These devices may use a vibrating or shaking flat screen, but the most common types are trommels, which are rotating cylinders with screen mesh sides of varying sizes. A 1/4-inch screen is the most commonly used. The average trommel used in the vermiculture industry is 8 to 10 feet long and 2 to 3 feet in diameter. A small electric motor mounted on one end of the cylinder turns it. As the cylinder rotates, the material inside rolls across the screen as it moves from the input end to the output end. This forward motion is accomplished by tilting the harvester at an angle. As the material rolls, anything smaller than the holes in the screen falls through, and the rest continues until it comes out the output end. At the output end, a cone may be installed that separates most of the worms from the other material that did not fall through the screen. Commercial trommel screens used for harvesting worms typically cost between $1,600 and $3,500. Some growers choose to build their own trommel screens at a fraction of the cost of a new one.

Grading and Counting

Earthworms are sold by weight or by count. There are two grades, bed-run (worms of all sizes) and bait-size (worms 2 1/2 inches or longer when drawn up and with bodies at least 1/8 inch in diameter). Breeding stock are large earthworms with a fully developed clitellum. If worms are to be sold for bait or breeding stock, they need to be sorted from the rest by hand; this is best accomplished while harvesting. Put the smaller worms immediately back into the beds, and count the larger ones as they are placed into containers or set them aside for weighing. Most growers pick out the desired size or type of earthworms by hand to ensure uniformity.

Instead of hand-counting worms, many growers use a sample count and weighing method. This involves hand-counting 1,000 worms of one grade (bed-run or bait-size) and placing them on a scale that weighs in pounds and ounces. Make sure the scale is set at zero (*i.e.*, adjust for the weight of the container) before putting any worms on the scale. A 10 percent overcount is considered good business in the earthworm industry, so add another 100 worms to the 1,000 on the scale. Record the weight in ounces so that a single

unit of measurement is used instead of two (pounds and ounces). Continue this method of measurement for the other grades of worms to be sold so that you end with a standard weight for 1,000 worms of each grade, including overcount. Thus, the worms will no longer need to be counted by hand, except to recheck base weights periodically to ensure their accuracy.

Packaging and Shipping

Earthworm growers use a variety of packaging methods and containers, but most of the successful ones use containers specially designed for holding and shipping worms. These containers may be purchased from various suppliers, including earthworm growers, wholesalers, or distributors. Containers range in size from half-pints (holding 50 bait-size worms) to gallon cartons holding 1,000 bait-size or 1,500 to 2,000 bed-run earthworms. To retain moisture and to discourage the worms from eating the containers, the cartons should be made of wax-coated cardboard or plastic and have small holes for air. Earthworms should always be stored in cool, well-shaded areas. Shipping boxes should be securely fastened with heavy shipping tape, and clearly marked on the outside: LIVE EARTHWORMS. HANDLE WITH CARE. DO NOT EXPOSE TO EXTREME HEAT OR COLD.

To help keep the worms moist and alive, pack them in moist bedding. Canadian sphagnum peat moss is considered by many to be the best material for shipping worms. Other types of peat moss may be too acidic. The peat moss should be soaked in water for at least 24 hours and then squeezed by hand to remove excess water. This produces a damp, but not soggy, packing material that will keep the worms comfortable for up to two weeks. If the peat moss is too wet, it could cause acid buildup. Some agricultural lime can be sprinkled on the peat moss to reduce acidity and bring the pH level to 6.5. Pack the shipping container about half full of peat moss and then add the worms.

Worm growers typically ship earthworms by ground transportation, using either United Parcel Service (UPS) or the U.S. Postal Service (USPS). Bear in mind that UPS does not make Saturday or Sunday deliveries, and USPS does not deliver on Sundays. Therefore,

always ship worms at the beginning of the week so they do not end up spending the weekend where they could be harmed by temperature extremes. As a courtesy, notify customers when their shipments leave and when they should expect delivery.

Before getting into shipping, find out how other growers in the area do it, and ask UPS and USPS how packages are handled to determine the best method of shipment. Try shipping a small amount of worms to a family member or friend to find out how they survive the trip. Planning ahead can help avoid having to replace lost inventory.

Earthworm Pests

Earthworm pests are birds, rats, snakes, moles, mice, gophers, toads, and other insects or animals that feed on worms or molest them. Arthropods such as mites and ants are probably of the greatest concern to earthworm growers.

Mites

Mites are natural inhabitants of manures and similar organic materials. All worm beds contain small populations of mites, which under certain conditions may reach extremely high levels. If worm beds are not cared for properly, acidity can build up and create conditions that allow mites to thrive. Routinely check pH and add agricultural lime if the pH is less than 6.8.

White or Brown Mites

White or brown mites are not predaceous and tend to feed only on decaying or injured worms. During infestations, however, these mites can devour much of the food in earthworm beds, depriving worms of needed nutrients. This increases worm growers' costs and time spent feeding worms. Mite populations at high levels also can cause worms to stay deep in the beds and not come to the surface for feeding, resulting in poor growth and reproduction.

Red Mites

The red mite is parasitic to earthworms. It attaches itself to the worm and sucks its blood or body fluid. Red mites also are capable of piercing and sucking fluids from egg cocoons. These mites first appear as small white or gray clusters resembling mold. Magnification will reveal clusters of juvenile red mites in various stages of development. The adult red mite, which is smaller than the white or brown mite, has an egg-shaped body, is bright red, and has eight legs.

Mite Prevention

The best control for earthworm mites is prevention. Proper care of worm beds can prevent a harmful buildup of mites. Bed conditions ideal for worm production are not conducive to high mite populations. Conversely, beds with high mite populations are being improperly managed for optimum worm production. One or more of the following conditions are usually associated with high mite populations:

Too much water—Beds that are too wet create conditions that are more favorable to mites than worms. Avoid excessively wet beds by adjusting watering schedules, improving drainage, and turning bedding frequently.

*Overfeeding—T*oo much food can cause an accumulation of fermented feed in worm beds and lower the pH of the beds. Adjust feeding schedules so that all feed is consumed within a few days. Modify feeding schedules as the seasons (and temperatures) change because worms consume less food in colder temperatures. Maintain beds around a neutral pH 7; use calcium carbonate to adjust the pH level.

Excessively wet or fleshy feed—Vegetables with high moisture content can cause high mite populations. Limit the use of such feed, and if high mite populations are discovered, discontinue the use of this feed until mite populations are under control.

Mite Removal

Several methods have been suggested for removing mites from earthworm beds. Bear in mind that any type of mite removal, physical or chemical, will only be temporary unless worm bed management is altered to make conditions less favorable for mites. The following techniques range from low- to high-intensity measures.

Method #1—Uncover the worm beds and expose them to sunlight for several hours. Reduce the amount of water and feed. Mites will not like this environment and they may leave the worm beds.

Method #2—Place moistened newspapers or burlap bags on top of the beds, and remove the paper or bags as mites accumulate on them. Repeat this procedure until mite populations are substantially reduced.

Method #3—Place pieces of watermelon or cantaloupe rind or potato slices on top of the worm beds. Mites are attracted to the sweetness of the rinds or peels and will accumulate on them. The rinds or peels can then be removed and dropped in water or buried.

Method #4—Water heavily, but do not flood, the worm beds. Mites will move to the surface, and worms will stay below the surface. Use a hand-held propane torch to scorch the top of the beds and kill the mites. Take appropriate safety precautions when using the torch. This procedure may be repeated several times, at three-day intervals, if needed.

*Method #5—U*se a light dusting of soil sulphur to kill the mites. After soaking the worm bed with water and causing the mites to surface, apply a rate of 1/16 ounce of sulphur per square foot of bed surface. Sulphur will not harm the worms, but in time, it may increase the acidity of the bed and reduce earthworm populations.

Popular literature on mite removal from earthworm beds is somewhat contradictory. In the past, chemical pesticides have been used in worm beds. However, it is now known that some pesticides have the potential to harm humans, and recommendations for such treatments are not given here. Although newer, safer, miticides exist, sufficient scientific research has not been conducted in worm beds to merit mention at this time.

Ants

Several species of ants may occasionally be a problem or annoyance to worm growers. Ants are attracted to high-concentrate feed in worm beds, and some species are reported to feed on eggs and small worms. Physical barriers can be placed around worm beds to keep ants out. Ants can be controlled with baits and insecticidal sprays outside the bins, but take precautions to prevent injury to the worms.

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Raising Fresh Fish in Your Home Waters

by: Brenda Bortz, Jack Ruttle, and Marc Podems

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RAISING FRESH FISH IN YOUR HOME WATERS.

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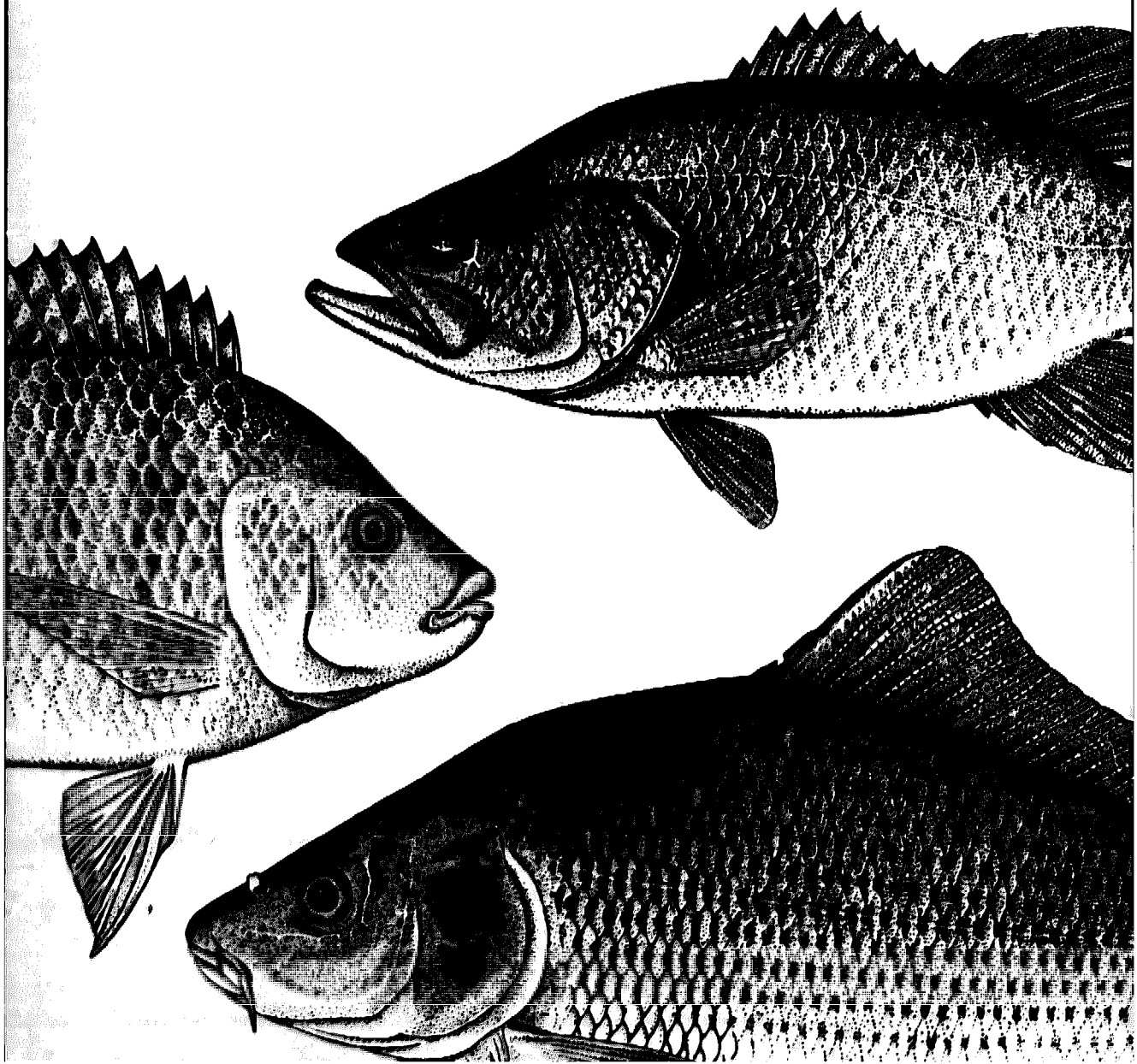

WHY BE A FISH FARMER

Not many people think of fish as a potential crop. But that's just what carp, catfish, trout, and bass are. Till recently, fish has been a wild food in this country—hunted and caught in open waters, then taken home or to market. But all that is changing. Wild stock is being depleted by overfishing and contaminated by industry, and the cost of fresh and frozen fish keeps climbing.

Luckily, there's a happy ending to this fish story. In other lands people have been stocking, breeding, feeding, and harvesting fish for centuries. And more recently, American scientists have begun to domesticate desirable native species like trout and catfish.

Putting this knowhow to work, commercial farms now raise huge numbers of fish much like agribusiness grows cattle and chickens. At the other extreme, country people still enjoy the farm pond—stocked for recreation and occasional meals, but not truly cultured.

Now, though, there's a middle ground. It's a backyard fish culture, a method that lets you grow fish like a garden crop. Like the foods you grow in soil, the fish in your water garden will need regular attention and feeding or fertilization. Cared for in this way, a pond the size of a modest swimming pool can supply enough fish for a family. And a typical farm pond can yield enough to have plenty left over for sale.

Backyard fish vs. barnyard animals For many people, a crop of fish can also turn out to be the best choice in livestock. Highly digestible and low in fat, fish are rich in protein. And their protein comes closer to meeting the body's needs than meat protein does.

Since fish are cold blooded, they don't burn food just to keep warm. Which means they are one of the most energy efficient livestock around. And unlike barnyard animals, they're absolutely quiet and odorless. Since there's no pen or manure pile to offend the neighbors, raising fish is an almost invisible way to grow some of your own meat in town or in the suburbs.

CREATING A BALANCED AQUATIC HABITAT

Just like organic gardening, fish culture involves working with a whole living system. The water that will be your growth medium is much more than the equivalent of nourishing garden soil. It's also the atmosphere that provides life-giving oxygen. Many forces interact in this total environment, and as a beginner in aquaculture you'll want to know about those that directly affect fish.

Swimming silently in small, gem-like ponds, fish are welcome neighbors just about anywhere.

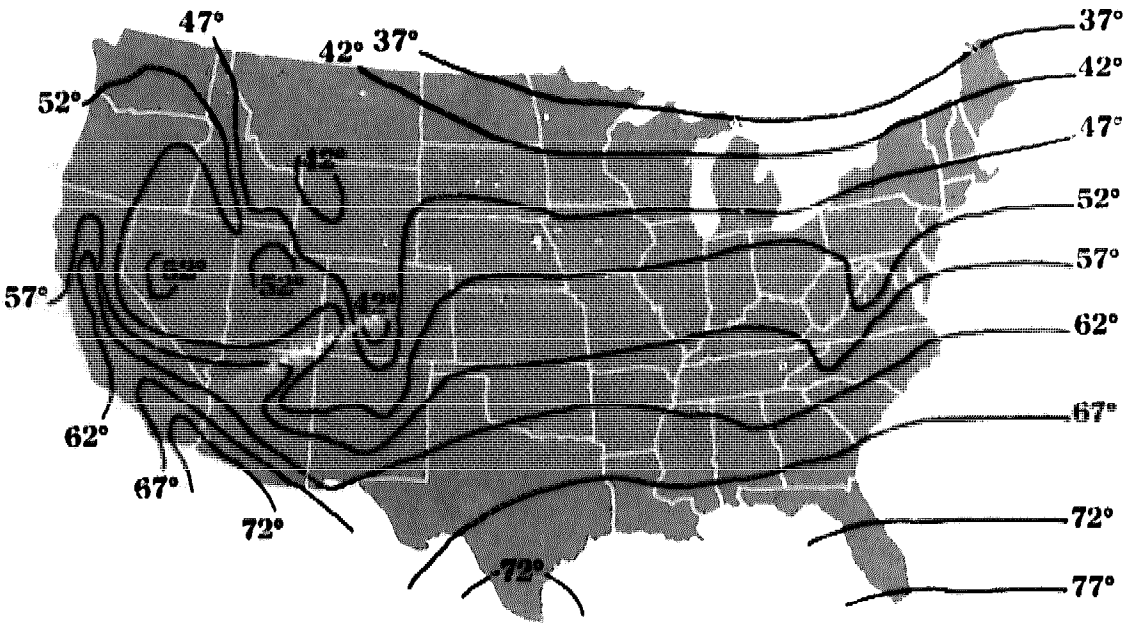

Figure 1. Approximate temperature of groundwater in the United States at depths of 30 to 60 feet.

Clean water is a must in fish culture, and fortunately the water in most farm ponds, rural streams, springs, and wells is naturally clean. Keep in mind, though, that the kind of water best for fish farming is far from crystal clear. A healthy bloom of algae is vital to a high-yielding system, and these microscopic pea green to ruddy brown plants can make water look soupy.

If you suspect, however, that your water source contains man-made pollutants, you should have it analyzed. Your county Agricultural Extension Agent or your state's Fish and Game Commission people can tell you how to do this.

You must also be alert to natural sources of trouble. Even ordinary soil aided by erosion or the rooting of ducks can foul water too much for the fishes' liking. In heavily stocked ponds, droppings from the fish themselves can get thick enought to clog their gills with tiny particles. Unconsumed bits of food can do the same thing. Happily, these problems aren't common—especially when other organisms in the pond are doing their work.

Temperature is crucial. Because fish are cold blooded animals, they can be grown only when and where the climate and water supply cooperate to provide water temperatures within their growing range. Moreover, each kind of fish favors a specific temperature range. Some flourish only in cold waters. Others won't grow and reproduce well unless the water is very warm.

The water temperature you will have to work with can be closely tied to the temperature of your water source. If your source water flows fast from an underground supply, its temperature will be roughly the same as that of the groundwater in your area. (See Fig. 1.) On the other hand, if your source water trickles from below ground rather than gushes, it will be warmed somewhat as it passes slowly through the ground below the frost line.

Air temperature also greatly influences pond water temperatures. As a rule of thumb, water temperature in a pond tends to approach the average air temperature. To get a good idea of what that is, scan the table of average monthly temperatures for your area. (Get this from the nearest U.S. Weather Bureau. Or look it up at the library in *The Climatic Atlas of the United States* or in a good almanac or encyclopedia.)

Since pond water responds slowly to changes in air temperature, the water temperature in your pond will be slightly behind the temperature rise in spring and the drop in fall. For the same reason, pond water is usually cooler than the hottest air during the day and warmer than the coolest air at night.

The deeper the pond, the less the change in water temperature between night and day. In small ponds, however, water temperature can change a fair amount on a summer's day and will follow seasonal changes in air temperature more closely. This means that to be on the safe side in choosing fish, you should know both average monthly air temperatures and the approximate highest temperature your pond water is apt to reach in the summer. (Fish Commission people can help you with that estimate.)

As all this suggests, each region has a growing season for fish. Though pond size, source-water temperature, and climate affect the length of this season, it will correspond roughly to the frost-free period for gardening in your area. How close it comes you'll have to determine from experience.

Growing season aside, the natural life that establishes itself in your pond will go on to some extent all year round. Though any fish will be dormant in winter, algae will grow a little. Water temperture will control the rate of all activity at any time. A very rough rule is that the speed of life processes in fish and algae doubles with each 15°F rise in temperature.

Oxygen is vital to high yields in fish culture. Unlike air, water has very little ability to hold oxygen. In 5 parts of air, 1 part is oxygen. But in 1 million parts of water, only 10 are oxygen. And so the availability of oxygen is often what puts a limit on how much life a pond can support.

Some of the oxygen used up by pond life is replaced from the air. Cooler water will hold more oxygen than warm water. So when oxygen levels fall below the norm at a given temperature, oxygen molecules move into spaces in the water from the air above it. At 50°F water will hold 11.3 ppm (parts per million) of oxygen. AT 60°F the saturation point is 9.6 ppm, at 70°F—9 ppm, at 80°F—8 ppm, and at 90°F—7.4 ppm.

Now it's much easier for relatively shallow ponds of 3 to 5 feet in depth to maintain these full oxygen levels naturally. That's because shallow ponds have a large surface area compared to volume, so a larger portion of water is in contact with the air.

Wind also can help greatly. First, by making ripples or waves, it magnifies the surface area of a pond. Second, wind steadily brings fresh air into contact with the water, thus stepping up the rate of oxygen exchange from rich to depleted areas. (Larger ponds take advantage of wind best, because they give moving air more chance to kick up waves.)

In addition to air, another source charges water with oxygen. It's the process of photosynthesis. Whenever oxygen is used up in the water by bacteria breaking down organic matter—or by higher forms of animal and plant life—carbon dioxide

is produced. This abundant gas, together with sunlight and water, is used by plants to make their food via photosynthesis. And so for each molecule of carbon dioxide plants take in, they return a molecule of oxygen to the water.

The most important plants contributing oxygen to water are algae, and under ideal conditions algae and still or moving air will keep a pond supplied. But the amount of oxygen a cultivated pond will need depends on how much fish you plan to grow in it. Theoretically at least, your goal in fish farming ought to be first, to find the amount of fish that the oxygen in your water can support, and beyond that, to find ways to make the algae population healthier so it can donate more oxygen.

But all this is easier said than done, for many factors make it difficult to count on a fixed amount of oxygen from algae. Each of the many types makes oxygen at a different rate. Too, it's impossible to control which species will get into your pond, or to tell how to create the conditions that desirable types will like. Moreover, for no apparent reason the dominant species in your pond may change slowly as the season progresses.

Another variable is the weather, for the rate of photosynthesis depends directly on the sun. Typically, the oxygen levels in your pond will change even on a clear day. By mid-morning the algae will be hard at work, and there will be plenty of oxygen. By early afternoon the dissolved oxygen will be at maximum concentration. Your pond should stay saturated with oxygen nearly to sunset. When the temperatures are right at those times, you can be sure the fish

A relatively shallow pond fully exposed to sun and wind has a good chance of maintaining high oxygen levels.

are feeding actively and growing well, even though you can't see them in the pea soup-green water.

At sunset, natural oxygen production stops, but oxygen use by all pond life goes on. By the next morning, oxygen levels will be low but tolerable for the fish, and at sunrise the water again will begin to be charged by the algae.

On a cloudy day, of course, the algae will generate much less oxygen, and there will be much less to tide over the pond population at night. Cool weather also will slow photosynthesis slightly.

The food chain is another major force at work in the aquatic environment. As the term implies, all life in the water is linked together. And every plant and animal is destined to be eaten by the being on the next higher level of the chain. Interestingly, a creature's source of food rather than its size is what fixes its position on the food chain. Because algae make their food from gas, light, and water, they are at the first level. And because some very large fish feed directly on algae and tiny animals called zooplankton, these big fish are themselves quite low on the food chain.

In a farmed pond, it's these plankton feeders that will grow best with the least attention to supplementing the natural foods in the pond. That's because like grass in a pasture, cropped-off algae can grow back rapidly, whereas amphibians and other forms of higher life eaten by nonplankton feeders are replaced much more slowly.

Pond fertility is determined not just by oxygen and temperature levels, but by the amounts of mineral nutrients available to support algal growth. If your system contains a well-balanced supply of nitrogen, potassium, phosphorus, and other minerals in the form of fertilizer supplied by nature or by you, there will be a rich bloom of algae. And the algal population will expand until all free nutrients are absorbed in balanced amounts.

But there can be an excess of nutrients. For example, algal growth can get so thick that the surface layer keeps light from algae below and starves it. When this happens, decay organisms thrive on the dead algae, increasing until they exhaust the oxygen supply. Then more dieback occurs, other organisms are favored, and the cycle can continue.

Working with the food chain is a big must in raising fish in quantity. In a mature pond left on its own, life will reach a balanced state. Changes in dominant species and in oxygen levels will be gradual. But that is not the case in fish culture.

Man-made ponds are frequently very young ecosystems, with most of their life concentrated in just a few types of organisms. Furthermore inputs like large quantities of fish and feed have immediate effects on the natural food chain and on the demand for oxygen. Still, any healthy pond requires a balance. You might say that fostering and maintaining a man-made balance is the science of fish farming.

To practice this science successfully, you have to regulate all amounts of fish, feed, fertilizer, and oxygen. The idea is to keep them in right relation to each other and all else in the pond. Here are some tips gleaned from experience that might make your job a little easier.

Feeding and Fertilizing: Since some fish can thrive on fast-growing plankton and may need no extra feed, it might seem ideal to stock these species and encourage lush algae growth by adding fertilizer. Oxygen production would be high, and the fish would keep the algae from overgrowing. Realistically, though, most

FERTILIZER

PLANKTON

LARGEMOUTH BASS

BLUEGILLS

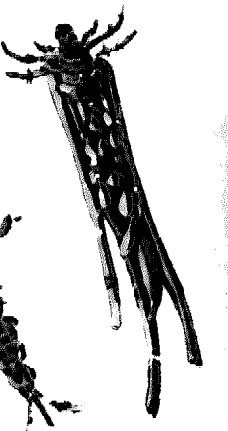

CADDIS FLY LARVAE

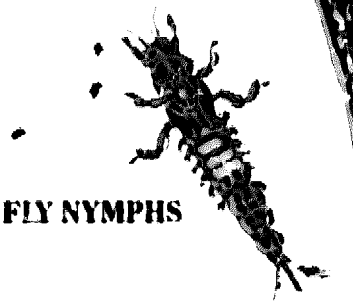

DRAGON FLY NYMPHS

MAY FLY NYMPHS

FROGS

WORMS

CRAYFISH

readily available species mostly eat organisms higher on the food chain and will quickly deplete your pond's natural foods. For all of these fish, you'll need commercial feed blends — readily available from livestock feed suppliers. Actually, to get bumper crops of *any* fish, supplementing natural foods is nearly always essential.

The next point to remember is that feeding at productive rates stimulates rapid growth and higher waste levels. Since more oxygen will be needed by the fast-growing fish and to ready the system to absorb their wastes, you might need to fertilize with manure. The life-giving nutrients thus provided will multiply algae, zooplankton, and bacteria. These will feed on the detritus and provide more oxygen and feed for the fish.

To determine if you do need to add fertilizer, there is a simple test you can make. If your algae are adequate, they should be so thick that you can't see any deeper than 15 to 18 inches into the water. To find out if this is so, mark the inches off on a yard-long stick and nail a tin can lid to the zero end. Then push the lid straight down into the water until it just vanishes from sight. Next pull the stick out and check the high water mark.

If the lid is visible past 18 inches you should fertilize with manure. For each acre of pond surface, use 500 pounds of fertilizer. (At that rate a 225-square-foot pond — that's 15 feet by 15 feet — would require 2½ pounds.) Put the weighed manure in burlap bags, and place them in the water anchored to poles. If the weather is warm and moderately sunny, a healthy bloom of algae should grow in 2 weeks.

Check with your dipstick regularly. Add more manure if needed, but be careful not to overdo it or you'll have to cope with dieback and stagnation.

Floating and sinking pellets sized for various fish are available from supply dealers.

Manuring will be most successful in ponds where warm water fish will grow. In large ponds with water temperatures between 50°F and 60°F, you may have trouble getting a thick bloom of algae even if you add much manure. But then the trout and other cold water species you would grow there prefer cooler water anyway.

Aerating: You can supplement oxygen contributed by air and algae by paying attention to the type of water enclosure you choose, to its design, and to mechanical devices that help oxygen exchange. For instance, by impounding a section of stream with a dam or netlike fence, you can make a fish farm that is always being supplied with freshly oxygenated water. (Tumbling, rolling fast-moving water breaks into waves and splashes that take more oxygen from the air.)

If you do farm a stream or brook, however, you won't easily reap the benefits of fertilization, for the manure will be washed far downstream. The same thing can happen to your fish food unless you devise a stationary feeder that can resist the current. Remember that your wasted feed or fertilizer is pollution for your neighbor downstream. And that adding these materials without being sure of their effects and destination is illegal as well as wasteful.

A better system would be to tap a portion of the stream water via a pipe or ditch. You might route it through a small pond built nearby, then back to the stream. Though the same potential problems exist, this kind of setup is more easily controlled. You can regulate the amount of water and rate of flow. And when storms swell the stream with water, mud, and debris, you can disconnect your enclosure.

Using the power of the stream you can increase oxygen by creating a small waterfall or spillway over rocks. This way you can charge a

small amount of incoming water as it enters a relatively large pool. This water also will bring in some oxygen-making algae and some fish foods. If the enclosure is much larger than the stream and much of the water remains within it for a week or so, you might encourage more algae with low level fertilization.

To take full advantage of aeration by wind, make the surface area larger rather than deepen the water when you want to increase your pond's volume. Also, avoid locations where trees or buildings will keep wind or sun from the surface. The water surface shouldn't lie too far below the banks either — especially in small ponds.

In some parts of the country mechanical aerators may be necessary if you're stocking and feeding a pond for higher production. The amount of supplementary aeration you need will depend upon your pond's natural oxygen levels — linked, of course, to wind and photosynthesis — and on the quantity of fish you've stocked per cubic foot of water.

Though mechanical aerating easily removes any doubts about adequate oxygen, you'd best start small, for the cost of the aerator and the power to run it easily can become one of your biggest expenses in fish culture. In very small ponds try bubbling aerators — the kind often used in aquarium tanks. They are cheap and use little power. In a 400-square-foot pond, try two with four aeration tubes on each. In a larger pond, you might have to use surface aerators, which churn or spray the water. Figure on 1 horsepower of aerator for every surface acre of water.

Even if your stocking rates are modest, you may find it necessary to boost your pond's oxygen during "the dog days" of summer. The reason is that in sunny and very hot weather algae begin to grow much more vigorously than usual. Then when cloudy and perhaps slightly cooler weather sets in for a few days, oxygen production drops suddenly. Since the very high oxygen demand of the expanded population can't be met, some pond life will die.

This is the time when fish kills are most common, and in some places they occur regularly once or twice a season. The problem is worse at night and is heightened by decay of the dead algae. In a situation like this, a 1/20 h.p. aerator may supply enough oxygen to support several hundred pounds of fish, using just

A pond can be filled from a neighboring stream, as this one is. If extra oxygen is needed, use a lift pump.

four kilowatts of power a day. At 3 cents a kilowatt hour, 12 cents a day is a small price to pay for tiding your fish through. Another remedy if oxygen levels become perilously low is to harvest some fish. This will quickly reduce the demand on the oxygen source.

PUTTING IN A FISH POND

One of the missions of the Soil Conservation Service is to help people build ponds that will last. SCS staffers will gladly help you assess possible sites and soil and provide literature and advice on pond design. They should also know of experienced local builders if your project is too big for you to do yourself.

Many states have laws that regulate the use of water and the design and construction of ponds. Some require that plans for a dam be approved by a state agency before a construction permit is granted. So before you start building a pond, find out what laws apply locally.

Prior to talking with anyone at the Soil Conservation Service, you'll want to give your situation some thought. Here are some major aspects to consider and some techniques you might find useful.

Selecting a site: To fill your pond and replenish water lost by evaporation and seepage, locate it near a dependable source of good water. Possible sources are springs, wells, streams, and the runoff from rain. Runoff is the least dependable, and in

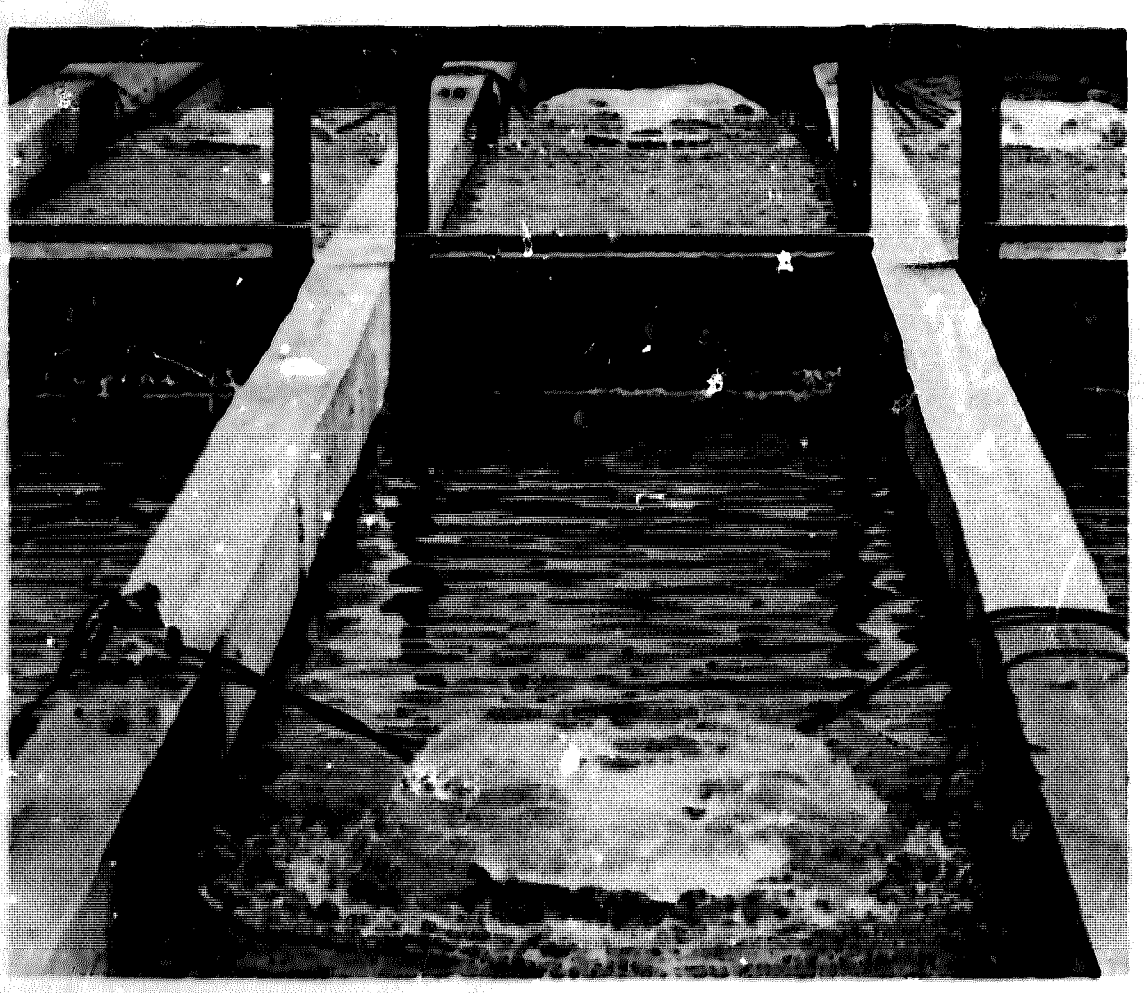

Through forceful mixing action a surface aerator speeds the migration of oxygen molecules from air to water.

areas of light rainfall a pond filled by runoff must be oversized to carry the fish through drought.

The soil at your site must be able to hold water, or you'll have to seal the pond artificially. Clay and silty clay are good for ponds, and sandy clay sometimes holds water adequately. But areas with rock outcroppings, limestone, shale ledges, or gravel require sealing.

For a good preliminary soil test, wet a handful with just enough water to dampen. Then squeeze. If the soil holds its shape after you open your hand, it's probably good for a pond.

There are two basic types of ponds. Impounding ponds are best suited to hilly areas. They use dams or banks of earth to block off the opening between two banks or slopes and are usually easier to build because less earth must be moved. Most of the reservoir created is above the natural ground level, though the size or depth can be increased by excavation.

Excavated ponds are pits dug below the pond surface, usually where land is fairly flat. There is no definite rule for choosing between the two types. But if the land surrounding your site slopes more than 4 percent, an impounding pond is likely to work.

To determine the slope, drive a stake into your site at the highest point you expect the water to reach. Then drive another stake in about 10 feet downhill. Using a carpenter's level, tie some string or rope level between the two stakes. Measure the height of the string from ground level on each stake. Substracting the smaller height from the greater, divide by 10. Your answer is the percentage of slope. (See Figure 2.)

Designing the pond: Generally, build your pond as large as you can, for big ponds are easier to manage, though small ponds are cheaper to build. Allow at least 10 cubic feet of space for every pound of fish you expect to harvest. To get 100 pounds, you'll need a pond with at least 35 feet of surface and a depth of 3 feet.

By the way, waters less than a yard deep do not make efficient use of surface area. Too, weeds grow best in shallow water. In addition to increasing oxygen demand, they provide young fish with protection from predators. This increases the chances for overpopulation and stunting. On the other hand, water at a depth of over 15 feet contains little oxygen since algae don't grow well over 10 feet down. The most productive depth is between 3 and 10 feet, and the most convenient shape for harvesting with nets is a rectangle.

Constructing the pond: After clearing the site, outline the perimeter with stakes and string. Excavate by hand, backhoe, or bulldozer, making the bottom slope from 2 to 5 percent to improve drainage. Install a series of pipes and trenches to carry off excess water from heavy rain safely and to drain the pond for harvest. (If your pond is small, you can use a pump or syphon.)

(To connect a stream to your pond for a ready supply of water, install a tube or dig a channel. Or use a sump pump. Filter the stream water before it enters the pond with a good material such as saran screen, style MS-904 (manufactured by National Filter Media Corporation, 1717 Dixwell Ave., New Haven, Conn. 06514).

If your water flow is light, make the screen into a "sock" and place it over the end of the inlet pipe. For a heavier flow, use a rigid filter or floating box. (Saran filters, which are fine enough to stop all but the smallest of wild fry, must be cleaned periodically.)

Your next step is to build the dikes and dams. Make them wide enough to withstand the pressure of the pond

$$B - A = C$$

$$\frac{C}{D} = \% \text{ of slope}$$

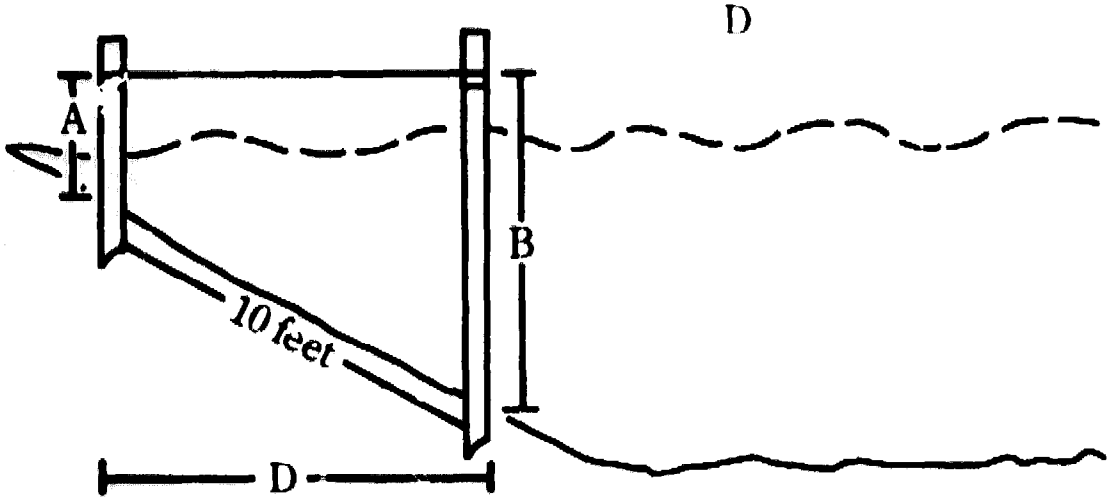

water. A wall should be shaped so that the base is at least twice as wide as its total height. The top should be at least as wide as its total height and at least 20 inches higher than the water. And the walls should be tapered gradually from top to base. When you finish, plant grass on them.

Sealing the pond: Before sealing, thoroughly compact the sides and bottom with special equipment. For small ponds, you can make a tamping tool by attaching a square flat board to a pole.

For a simple, low cost sealant for a small pond, try gley, or biologic plastic. Developed for sealing ponds in the U.S.S.R., gley has been used successfully by the New Alchemy Institute in Costa Rica. Making it is a lot like composting. First, cover the bottom and sides of the pond thoroughly with pig manure. Then completely cover the manure with freshly-cut grass, green leaves, and flattened cardboard cartons. Then add a layer of soil and firmly tamp down all three layers. Wait 3 weeks before filling the pond.

You can also seal small ponds with polyvinyl sheets, sold in many sizes by swimming pool dealers. To determine the length of sheeting you need, add twice the maximum depth of the pool to the length. For the width, add twice the maximum depth to the width. Then add 1½ feet all around to allow plenty of overlap.

Dig a shallow 10- to 12-inch-wide trench around the perimeter of the pond. Put the liner in the pond, pulling it moderately taut, and evenly cover it with 6 inches of soil. Place the edges in the trench and cover them with soil to hold them down and protect them from deteriorating in sunlight.

For large ponds, bentonite is the most commonly used sealant. It is available in 50-pound bags through some ceramic dealers. You'll need 8 pounds for each square foot if your soil is very sandy and 2 to 4 pounds for soil with more clay. If possible, consult your Extension Agent for an evaluation of your soil porosity and bentonite needs.

But if you have to establish application rates for yourself, a distributor of the clay suggests that you punch holes in the bottom of a container, put in a couple inches of your subsoil and compact it lightly. Then add a small, measured amount of bentonite and work it lightly into the surface. Add water to see if this amount seals. If it doesn't, continue adding measured amounts of clay until seepage stops. Then estimate your pond's requirements by using the same ratio of surface area to quantity of bentonite that worked in the small container. (To be on the safe side, add 15 percent more bentonite.)

STOCKING YOUR SYSTEM

The best times to stock fish are early spring and late fall. Then cooler temperatures reduce the rate of metabolism so the fish move more slowly and need less oxygen. They are easier to handle and there is less chance that any will die.

Consult your state's Fish Commission for lists of local commercial hatcheries. It's even possible that the Fish Commission or Soil Conservation Service in your state will provide fish free from state hatcheries.

If a species is readily available locally, it may be well adapted to your growing conditions. Certainly it will be the cheapest to buy. If by chance you can't find the fish you want nearby, you'll find many sources for all the species described here listed in the *Commercial Fish Farmers Buyers' Guide* (available for $2.50 from Subscription Service, P.O. Box 4922, Manchester NH 03105). You may order fish from these dealers via air express. Be sure to learn the exact time the fish will leave the hatchery and make arrangements to meet them at the airport no matter what time they arrive.

Keep in mind that the fish you choose must be suited to your climate. In selecting from the catalog that follows, you should (1) estimate the highest water temperature in your pond in the summer, (2) identify the species that can tolerate that temperature, (3) estimate the average water temperature that will prevail over most of your growing season, (4) narrow your list to fish that do well at that temperature, and (5) determine the length of your growing seasons *w* the fish you've chosen so you can decide what size to stock.

Yearling fish, which are 3 to 8 inches long, have a better chance than smaller fingerlings to survive and reach edible size in one season. Though growing time and stocking rates vary with each species and the climate, a good rule of thumb is that at least 10 cubic feet of water is necessary to grow each pound of fish and that yearlings will take at least 6 months to mature. You can also assume that 40 percent of each pound you harvest will be lost when you clean the fish.

Bentonite makes a good sealer for large ponds.

A CATALOG OF FISH

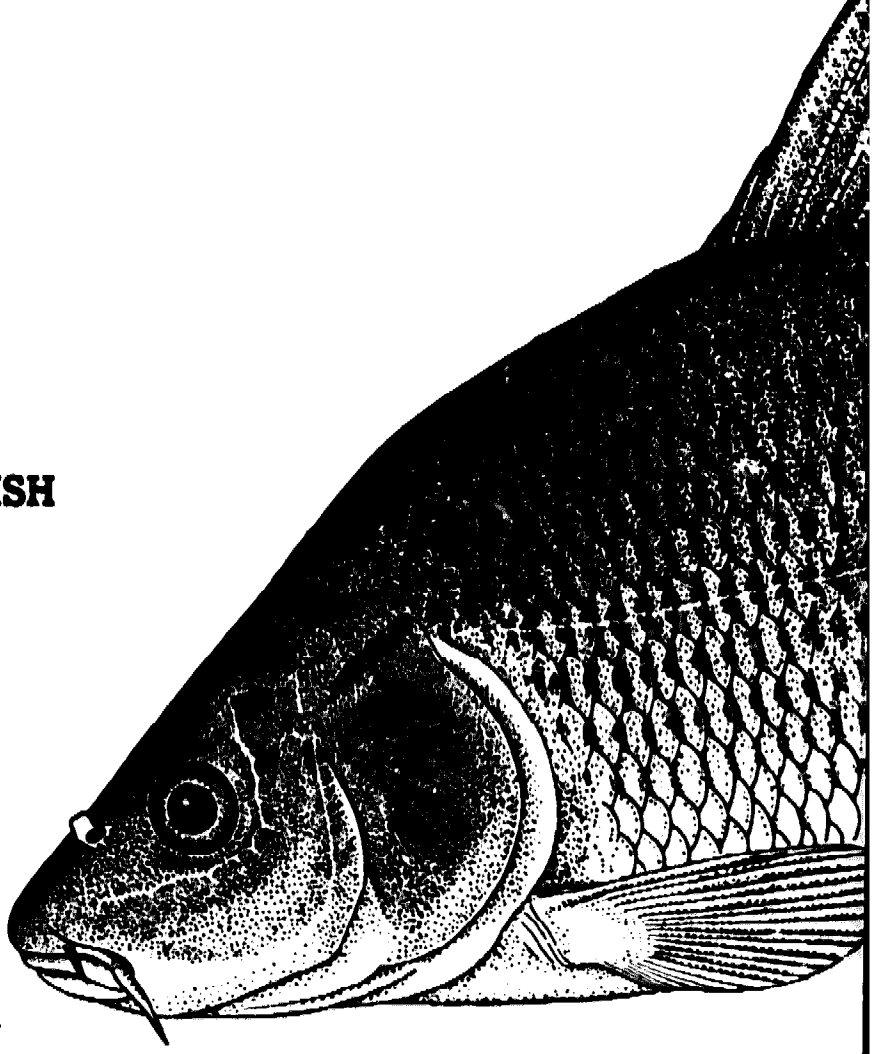

THE CARP FAMILY

Common Carp *(Cyprinus carpio).* A special variety developed for hardiness and productivity is called Israeli (or Mirror) Carp.
Grass Carp or **White Amur** *(Ctenopharyngodon idella)*
Bighead Carp *(Aristichthys nobilis)*
Silver Carp *(Hypophtinalmichthys molitrix)*
Oxygen: Can tolerate as few as 0.5 ppm. Grow best with 4 ppm and more.
Temperature: Can withstand great fluctuations. Best growth in water between 80°–85°F, but do well anywhere between 70°–90°F. Below 50°F they don't feed.
Ammonia: Can tolerate as much as 1.2 ppm.
pH: Slightly alkaline (7.5) is best, but stand as much as 9.
Hardness: Usually takes care of itself. At least 50 ppm of calcium and magnesium ions is recommended.
Turbidity: Can tolerate high level of suspended solids.
Hardiness: All very hardy. Strongest cultivated fish *re* resisting disease, adjusting to low oxygen levels.

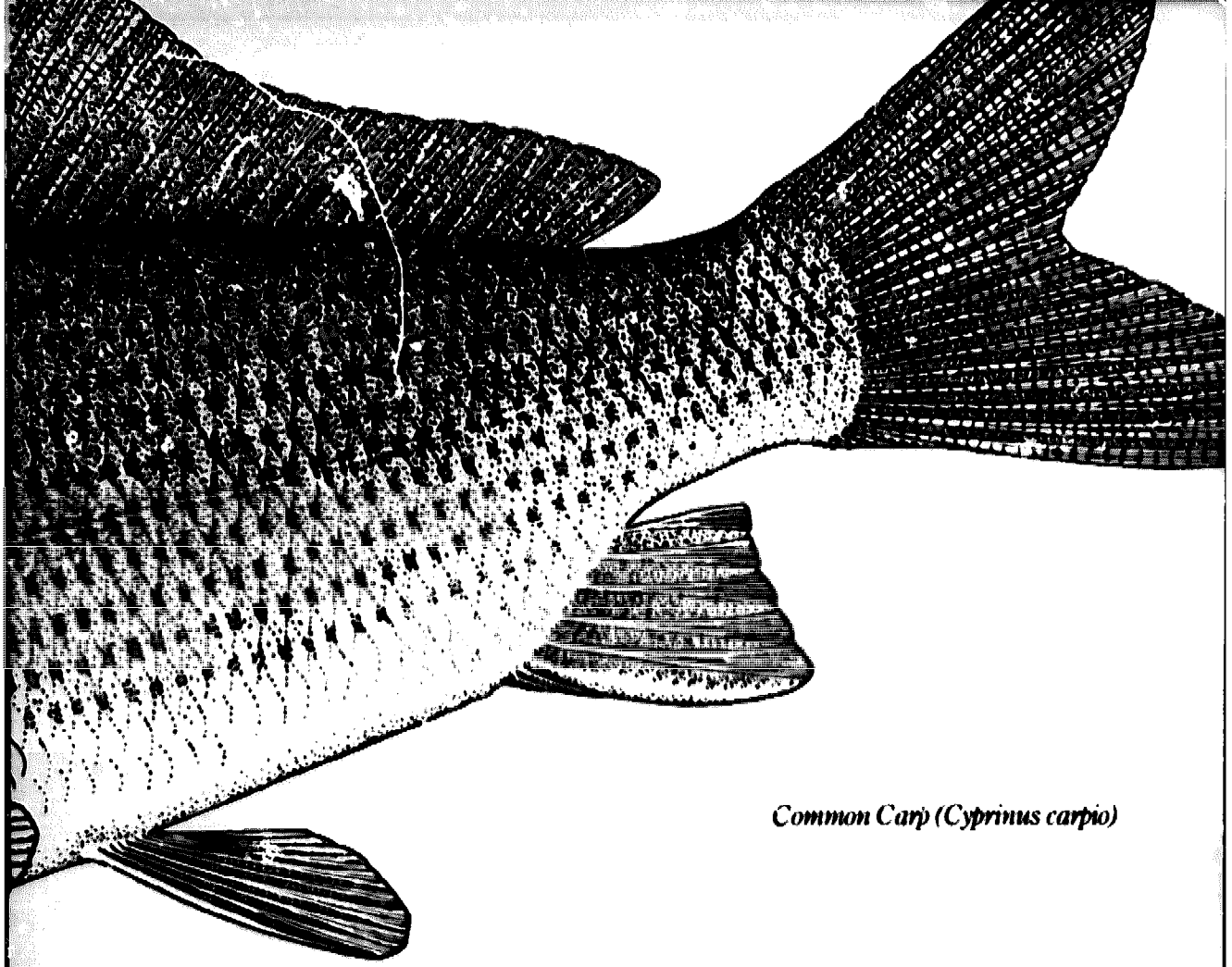

Common Carp (Cyprinus carpio)

Feeds: All eat low on food chain and forage well. Common carp eat pond bottom organisms and partially digested feed in detritus, including fecal matter of other fish. Grass carp feed on aquatic plants, including pond scum formed by filamentous algae. They will readily eat garden vegetable wastes, grass clippings, weeds, and fresh cut hay. Both common and grass carp also eat supplemental feeds like potatoes, soybeans, cottonseed meal, and oats. Bighead carp feed on zooplankton and silver carp eat phytoplankton. No information available on feed utilization.

Growth rate: Efficient growers. With adequate food, 1-inch fish reach edible size of 1–2 pounds in 7–9 months. 6–8 inch fish may mature in only 5 months.

Stocking: Can be combined with other fish to use more of pond's natural food supply and increase total harvest. Won't compete much with other species for food. Can help make pond more productive by controlling plankton growth. Combining four kinds of carp makes one of most productive low energy systems yet tested, yielding up to 3000 pounds per surface acre. Each specie also can be raised alone. For harvest in one season, stock 6–8 inch fish, no more than 500 per surface acre. With longer time to harvest, stock up to 4000 1–2 inch fish.

Availability: Easiest to obtain from hatcheries in South. Wild strains of common carp can be netted from lakes and rivers throughout country. Other species illegal in many states, but not in Arkansas and Mississippi.

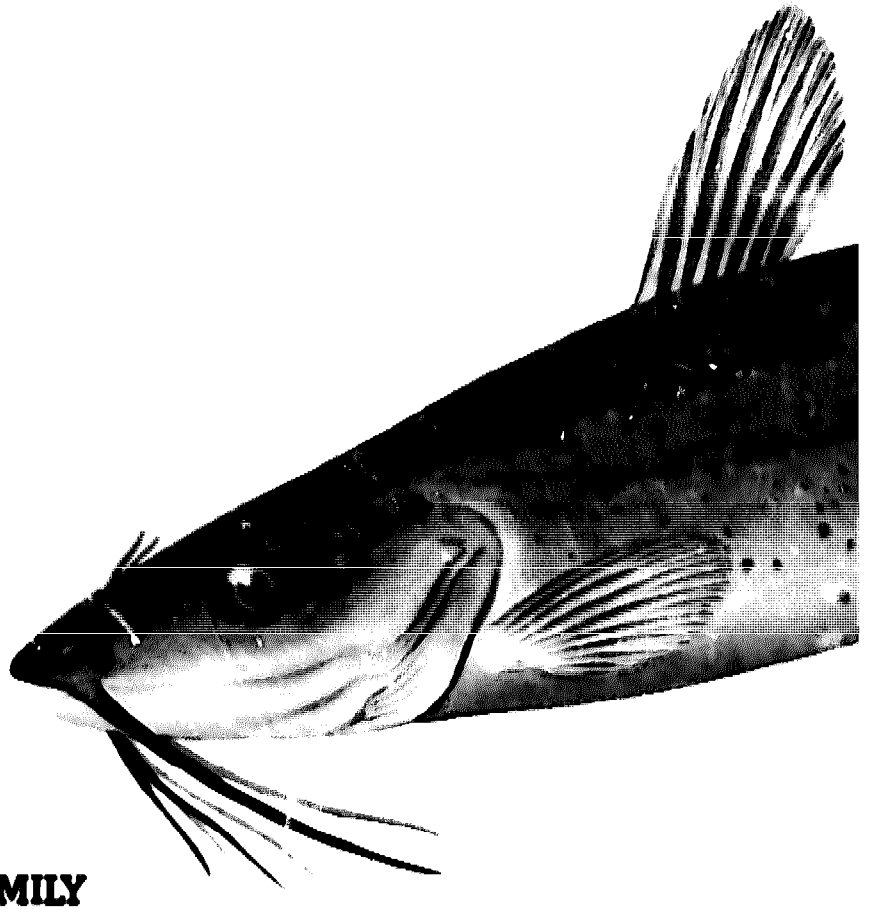

THE CATFISH FAMILY

Channel Catfish *(Ictalurus punctatus)*
Brown Bullhead Catfish *(I. nebulosus)*
Black Bullhead Catfish *(I. melas)*
Yellow Bullhead Catfish *(I. natalis)*

Oxygen: Grow well at more than 4 ppm. At less than that, may not eat, thus weakening resistance to diseases and parasites.

Temperature: Grow most efficiently between 70°–90°F. Below 60°F growth stops.

Ammonia: Keep below 1 ppm. 2 ppm can be lethal.

pH: Slightly alkaline (7.5) is best. Can stand up to 9.

Hardness: At least 50 ppm of calcium and magnesium ions recommended.

Turbidity: Tolerate high level of suspended solids from natural and artificial sources. Like common carp, spend much time in muddy water on pond bottom.

Hardiness: Can contract bacterial infections, viruses, or parasitic diseases if oxygen, ammonia, and temperature levels not maintained. Have normal mortality rate of 7–13 percent when conditions ideal.

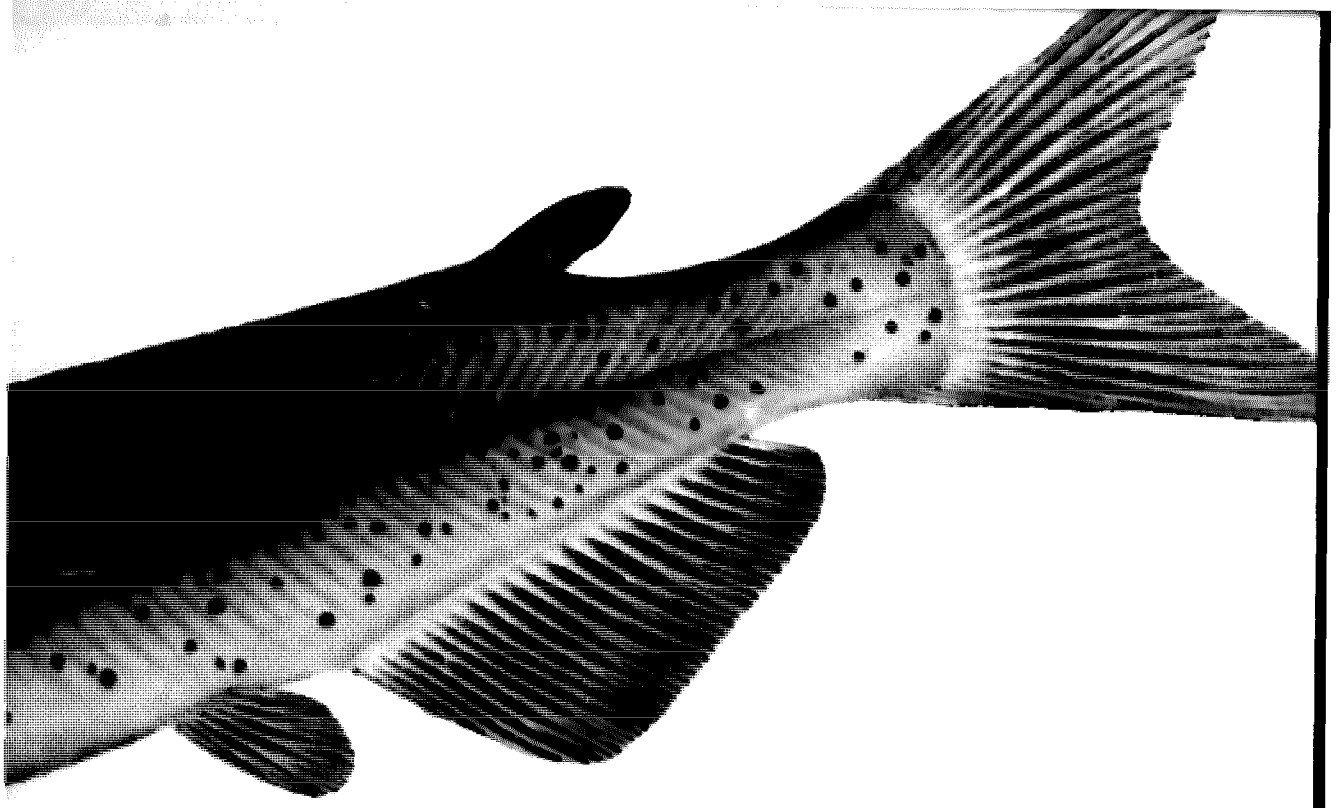

Channel Catfish (Ictalurus punctatus)

Feeds: Natural diet includes aquatic insects, crayfish, bluegills and other small fish, frogs, and some filamentous algae. For rapid growth, supplement with commercial pelleted catfish feeds. Will also grow on kitchen-waste blends if protein content is about 30 percent and fat levels kept low.

Feed utilization: May use 1–3 pounds of feed to produce 1 pound of meat. In intensive culture may convert feed as efficiently as 2 or 1½ pounds feed to 1 pound fish. Require more feed to gain weight when larger than 1½ pounds.

Growth rate: Can reach edible 1-pound size in 6 months if fed regularly.

Stocking: Will compete for limited food supply with other species that eat insects, amphibians, or small fish. Some catfish species tend to be bottom feeders so might compete little with species that feed nearer the surface. When prolific fish like bluegill are grown with catfish, young will provide extra food for catfish. For edible fish in one season, stock about 2000 6-inch fish per surface acre. For longer growing periods stock 1–2 inch fingerlings at 5,000 per surface acre. If stocking with bass and bluegills, use 100–200 catfish per surface acre. They must be the same size as the bass or the larger fish will eat smaller.

Availability: Can be purchased in most states in South and in a few in North.

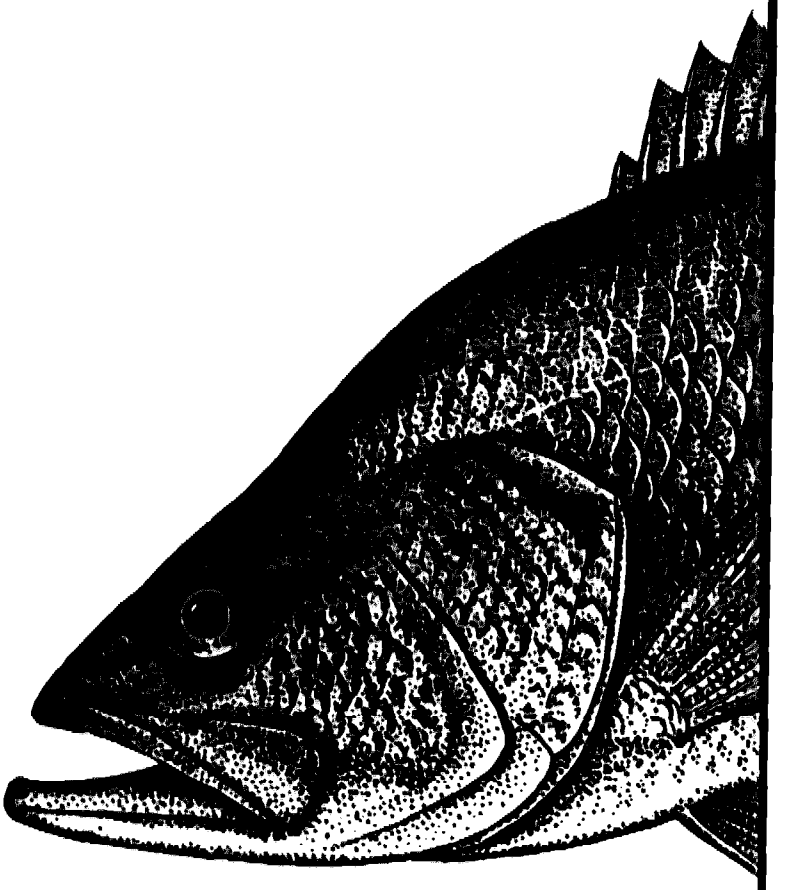

THE SUNFISH FAMILY

Largemouth Bass *(Micropterus salmoides)*
Bluegill *(Lepomis macrochirus)*
Hybrid Sunfish (male *L. machrochirus* crossed with female green sunfish, *L. cyanellus*)

Oxygen: can tolerate no fewer than 2.5–3 ppm. Best growth at 5–8 ppm.

Temperature: Optimum is between 73°–77°F. Above 80°F and below 68°F growth declines significantly.

Ammonia: No more than 1 ppm.

pH: Slightly alkaline (7.5) is best. Can take up to 9.

Hardness: At least 50 ppm of calcium and magnesium ions recommended.

Turbidity: Should have clear water. Especially important because they eat live food and must be able to see it. They also reproduce only when water is relatively clear.

Hardiness: Fairly hardy within limits of good water quality. But require relatively high levels of oxygen for active feeding and prefer narrow temperature range.

Feeds: Chiefly feed on invertebrates like insect larvae, water fleas, adult insects, algae, freshwater shrimp, small crayfish, and snails. Also eat young amphibians and small fish. In summer may turn to plants because of lack of animal foods. Bluegills also eat pelleted chows and food scraps. Bass must be trained to eat pelleted feeds. No information available on feed utilization.

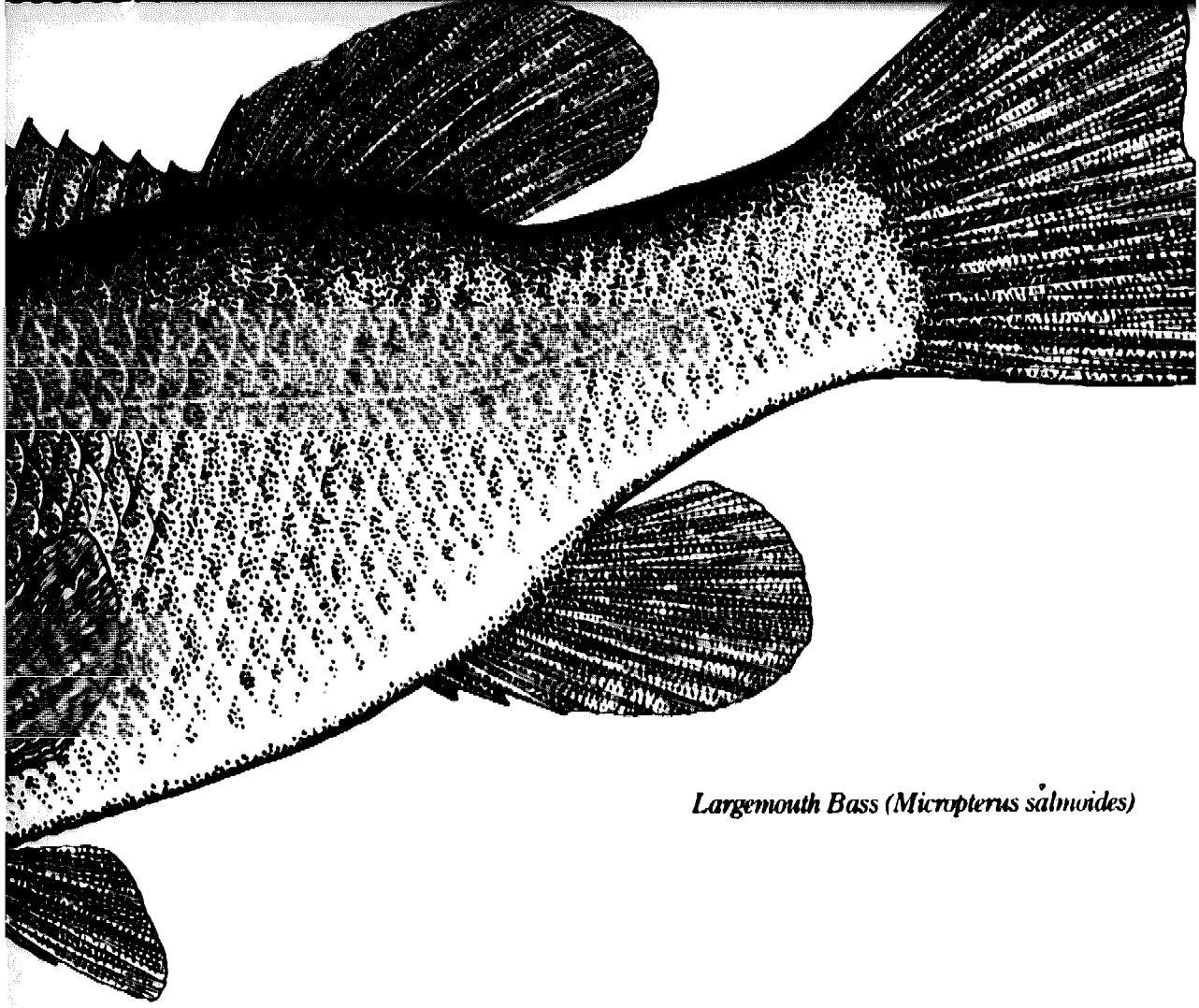

Largemouth Bass (Micropterus salmoides)

Growth rate: May reach eating size of 1 pound in 6–9 months if supplemental feed given. Otherwise can take up to 6 years.

Stocking: Bluegills reproduce so rapidly that often growers get weight of fish planned for, but all the fish are too tiny to clean and cook. One solution: stock hybrid sunfish, which do not reproduce well. Or stock bluegills with larger fish that will feed on extra fry.

The bass-with-bluegill combination is popular. But be sure the pond will maintain temperatures at which the bass feed, or the bluegills will overpopulate and the bass will be too sluggish to chase down the fry. Also, don't harvest too many bass, lest you interrupt reproduction and reduce the number of predators needed to keep bluegills in check. Do harvest the bluegills fairly heavily.

Recommended stocking rates are 100 bass to 800–1000 bluegills per surface acre. (These rates may be low since they are based on untended pond culture.) As you harvest both species by fishing, maintain this 8 or 10 to 1 weight ratio. If stocking only hybrid sunfish, put in 1000–2000 5-inch fish per surface acre when feeding to harvest in one season. For longer time to harvest, stock same number of 1-inch fish.

Availability: Hatcheries in almost all states raise some kind of sunfish.

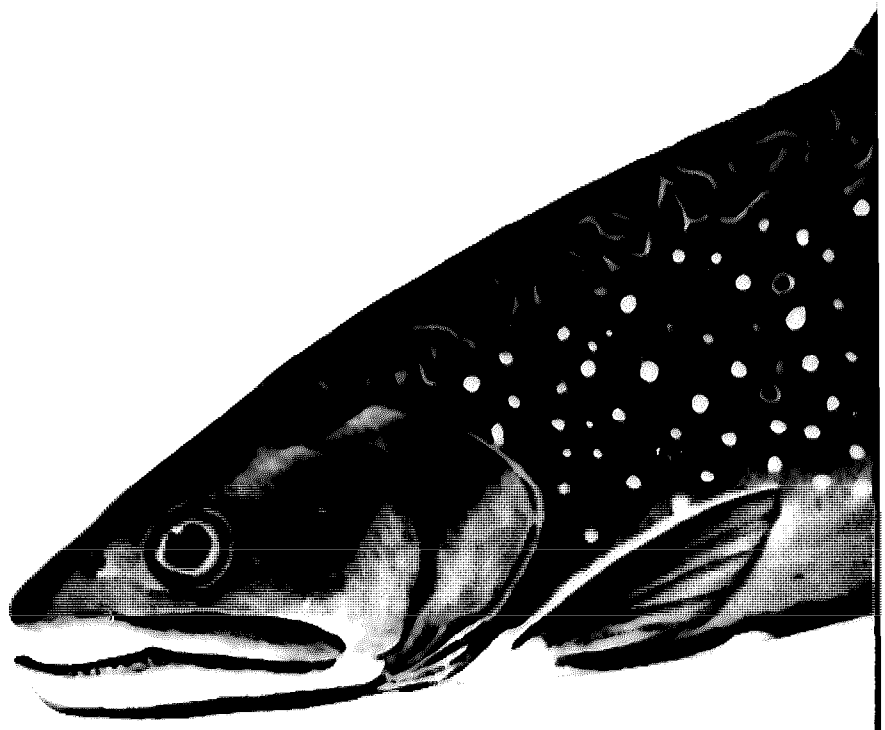

THE TROUT FAMILY

Brook Trout *(Salvelinus fontinalis)*
Brown Trout *(Salmo trutta)*
Rainbow Trout *(Salmo gairdneri)*

Oxygen: At least 5 ppm for good growth. Growth declines greatly if level below 5 ppm.

Temperature: 50°–60°F is OK, but 58°–60°F is best. Severely stressed above 70°F.

Ammonia: Over .7ppm is harmful.

pH: Can live in water from 6 to 8.

Hardness: Hard water (50–250 ppm calcium and magnesium ions) produces trout more economically than soft water.

Turbidity: Must have clear water to feed and breathe easily.

Hardiness: More susceptible to diseases and gill and liver tissue damage than most warm water species. If ideal conditions provided, death rate still from 2–13 percent.

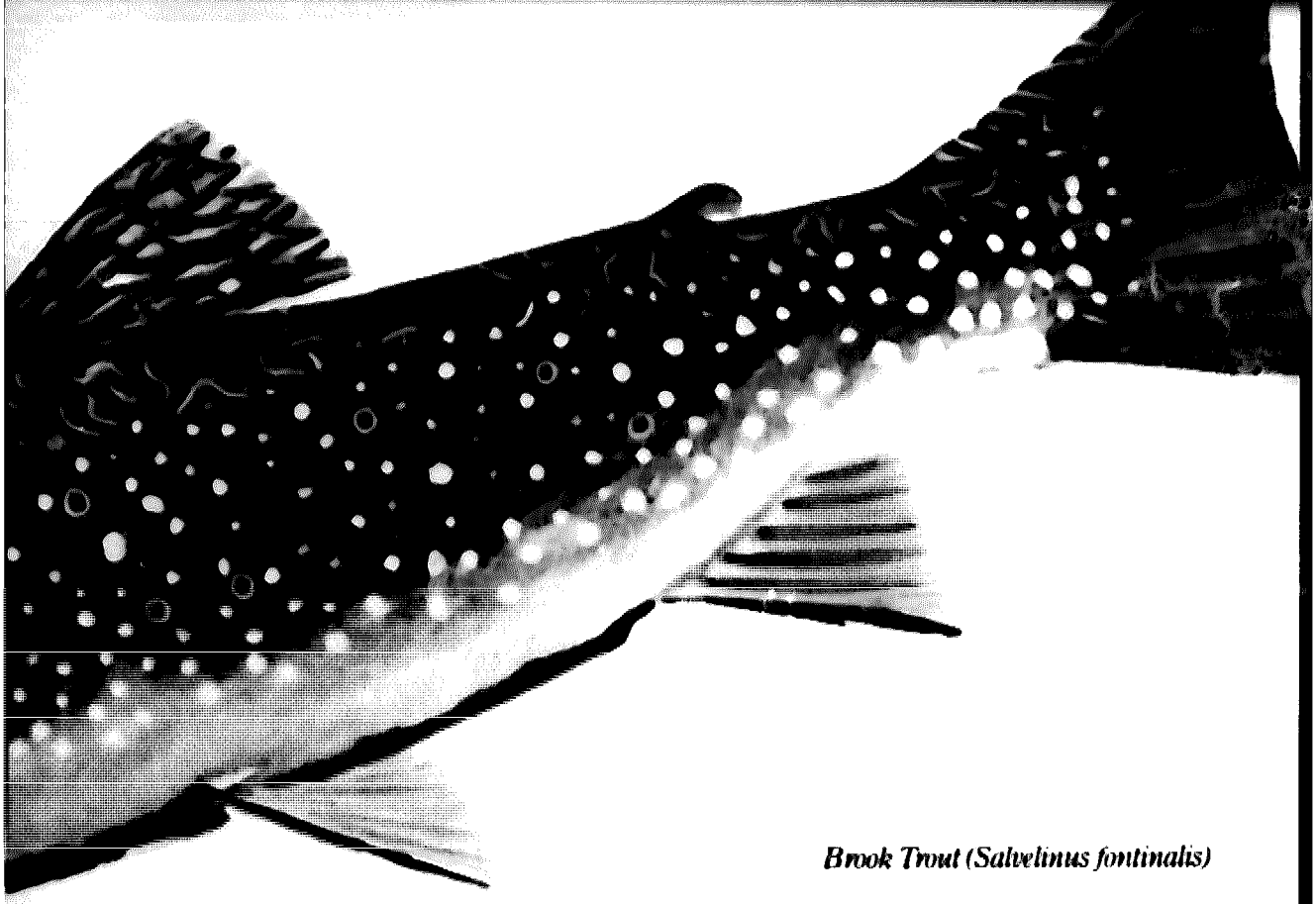

Brook Trout (Salvelinus fontinalis)

Feeds: Eat high on the chain. Mostly live foods. Natural feeds include insects, larger crustaceans, snails and leeches, and some plankton. For fast growth when stocked densely, need high protein pelleted trout chow supplement (35 percent protein for fish over 3 inches, up to 45 percent for smaller fish). Will eat 1–12 percent of body weight depending on their size and water temperature.

Will overfeed, which makes for fatty livers and less hardy fish. In general, lower the feeding rate as they get larger and/or as the water temperature goes down.

Feed utilization: Need about 2 pounds of feed to produce 1 pound of meat. About 1/3 of total feed must be protein.

Growth rate: Yearlings given extra food may reach 1-pound eating size in 6 months. Without supplemental feed, will take 3–4 years.

Stocking: Usually not compatible with other species because of extremely high demand for oxygen and feed. Usually raised in flowing water. Stocked lightest of all species listed here. A surface acre will grow only a few hundred pounds of mature trout. To harvest in one season, stock no more than 2000 yearlings per acre.

Availability: Grown by most hatcheries in northern half of U.S.

THE TILAPIA FAMILY

Java Tilapia *(Tilapia mossambica)*
Blue Tilapia *(T. aurea)*
Nile Tilapia *(T. nilotica)*

Tilapia are one of the most important food fishes throughout the world. At least 14 different species have been raised in both small and large ponds. Their popularity stems from the fact that they are hardy, easy to breed, rapid growers, and good tasting.

Since they are tropical fish, in all but the warmest regions of the U.S., tilapia have to be brought in for the winter and perhaps kept in a heated pond. Because they reproduce prolifically, it is quite possible to stock a few and end up with a pondful of tiny fish. If they survive the winter and reproduce, their rapid spreading can threaten other fish populations. Many states have outlawed them because of this.

Oxygen: Can survive as few as 2ppm, partly because of unique ability to breathe oxygen from the air.
Temperature: Thrive in water from 64°–90°F. From 61°–50°F can survive but are lethargic. Below 50° most die.
Ammonia: Will tolerate a very high level, surviving in ponds with large amounts of organic matter.
Hardiness: Highly resistant to both diseases and parasites, and thrive within a fairly wide range of water quality factors.
Feeds: Some prefer large plants (garden wastes or grass clippings) while others like blue tilapia are adapted to feed on plankton. To make an artificial blend for blue tilapia, try mill flour sweepings and finely ground grain. A good homemade mixture is

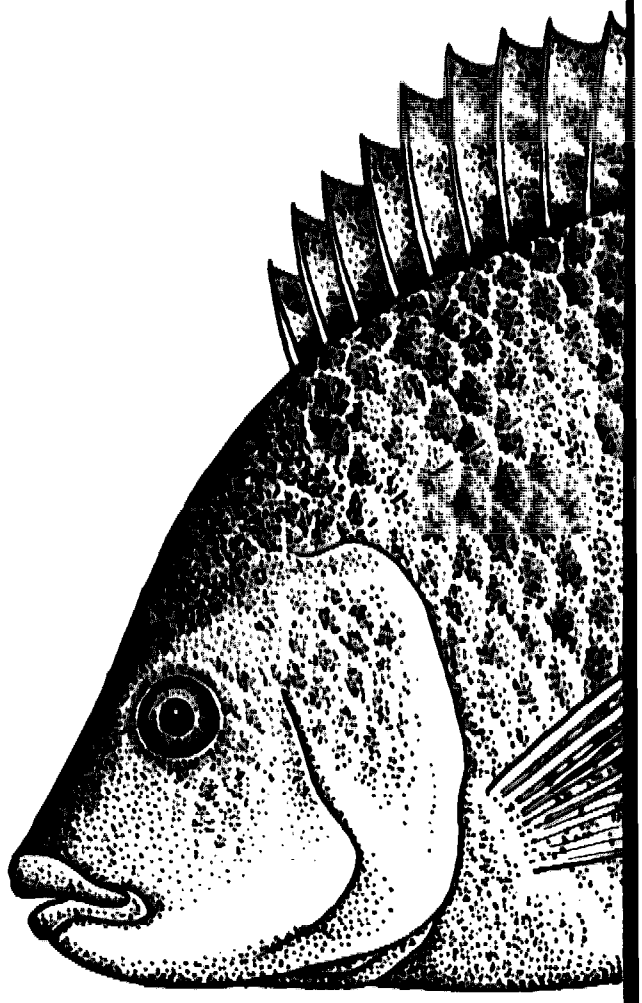

35 percent coffee pulp, 24 percent corn, 20 percent molasses, 10 percent bran, 10 percent cottonseed meal, and 1 percent urea. They also take pelleted feeds.

Java tilapia feed mainly on plankton but do eat all kinds of plants and vegetable feeds such as soybean or grain meal. If there is no plant food, they will accept animal food.

Nile tilapia reportedly feed on plankton, higher plants, and animal food.

Feed utilization: Blue tilapia consume less than their weight in pelleted feeds in growing to eating size. The rest of that weight comes from natural feeds. No information is available on other two species.
Growth rate: Varies greatly with stocking densities, frequency of reproduction, and available food. Fingerlings should reach eating size of at least 1/3 pound in 1 year of growing time if sexes raised together, but can grow to this size in as little as 4

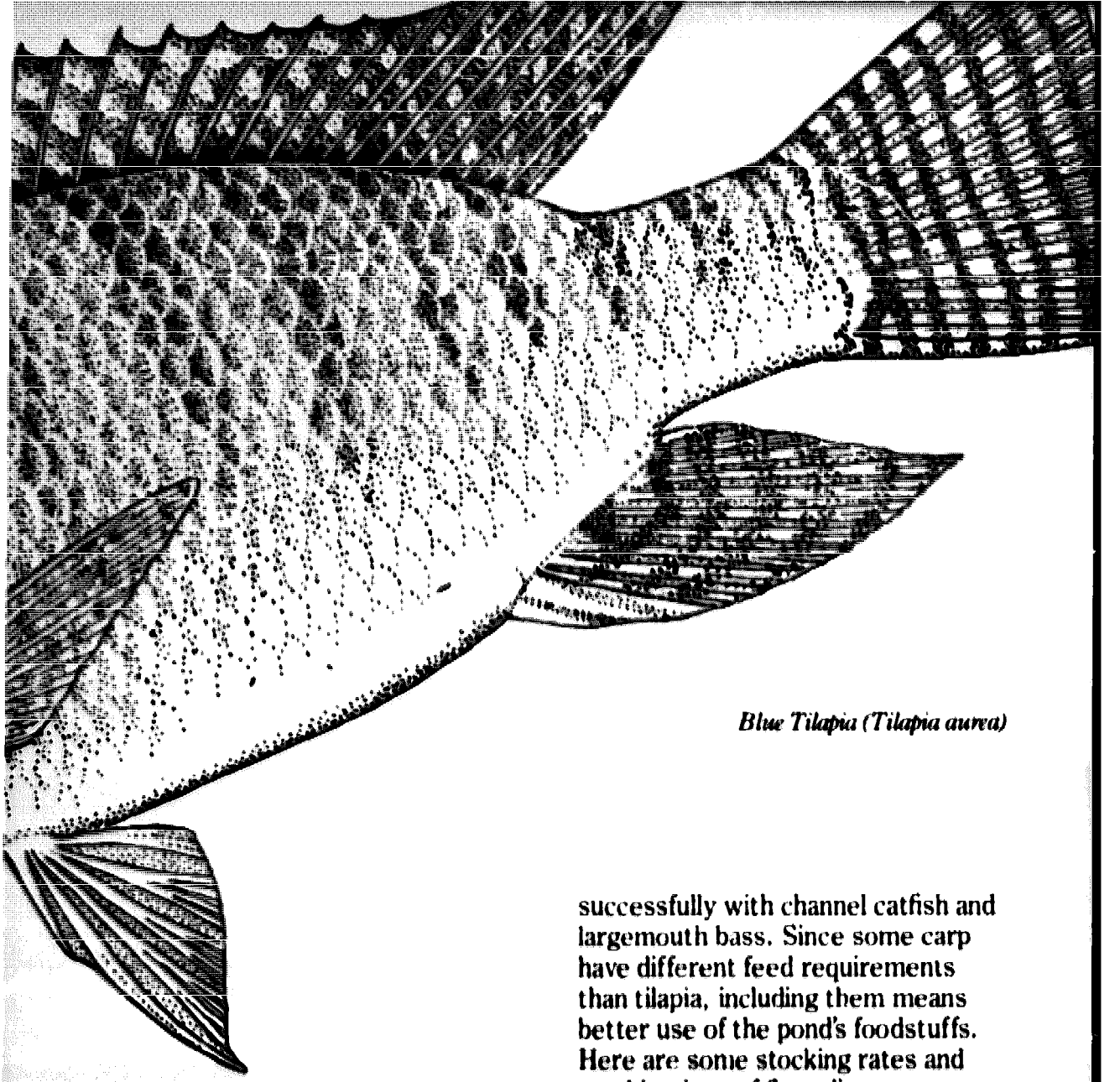

Blue Tilapia (Tilapia aurea)

months. Under ideal conditions java tilapia may reach nearly 1 pound in one year. In salt water, may grow to 1 pound in 8 months. Try to obtain all males: they grow two to three times faster than females.

Stocking: Easiest to manage when grown with larger predators which will feed actively on tilapia young. Since tilapia tolerate such a wide range of water quality, be sure the predator chosen will be vigorous over most of the tilapia's growing season. If you overstock, all fish in pond will be crowded and stunted. For monoculture it's possible to get sterile hybrids or stock of all one sex so that reproduction is impossible.

Java and nile tilapia can be raised successfully with channel catfish and largemouth bass. Since some carp have different feed requirements than tilapia, including them means better use of the pond's foodstuffs. Here are some stocking rates and combinations of fingerlings per surface acre for polycultures yielding edible fish in one season: 1000 tilapia, 500 channel catfish, and 100 largemouth bass OR 1000 Java tilapia, 1000 Nile tilapia, and 200 largemouth bass OR 600 tilapia, 1200 common carp, 506 silver carp, 150 grass carp, and 60 largemouth bass.

For monoculture, stock from 2000-8000 fingerlings per surface acre, depending on intensity of supplemental feeding, aeration, and periodic harvesting. Fish will be edible in one season.

Availability: Most commonly raised by commercial dealers in Alabama, Arkansas, California, Idaho, and Oklahoma.

CARING FOR YOUR FISH

Before they come you'll want to make some preparations. For instance, when you order your fish, you should also order your fish chow at a farm supply store. A variety of chows are available for all kinds of fish, and there are floating or sinking pellets sized for fish of different lengths. But don't buy too much feed at one time since the nutritive value starts to decline after 3 months.

While you wait for your fish, you might want to build a feeder. This device will let you monitor food intake. It also allows you to observe your fish and perhaps net them for an occasional check or harvest.

Here are instructions for a feeder that holds both floating and sinking feeds. Using 4 1x3x12" pieces of wood, put together a square inner frame. Then use 2 1x3x26" pieces of wood and 2 1x3x36" pieces to build a rectangular outer frame.

You can attach the inner frame of a homemade feeder to the end of the outer frame with good-sized loops of nylon string.

After painting both frames for durability, staple a 34x44" piece of screening onto the outer frame so it forms a concave catch basin. Next, hinge the inner frame to the inside of a narrow end of the outer frame.

Tying a 5-foot length of heavy nylon string to the opposite end of the inside frame, attach a small float to the other end of the string so you can remove the feeder from the pond easily.

Finally, place a stone in the end of the catch basin which has the float. The rock should be just heavy enough to sink the catch basin so it's at a 45° angle to the surface. Sinking feeds placed in the floating inner frame will drop onto the catch basin. Floating feeds will stay in the upper frame.

Since fish are sold by numbers of sized individuals and not by weight, you will also need some sort of bathroom scale or heavy-duty hanging meat scale to figure out feeding rates and monitor growth. A dip net and large buckets also would be useful. You might also want to make provisions for a supplementary aeration system. To locate suppliers for such fish care musts, check with the Fish Commission. Or consult the very complete *Commercial Fish Farmers Buyers' Guide*.

About 6 weeks or so before you get your fish, you also will want to order some simple water testing materials. Use them and an outdoor thermometer to start checking water quality at least 2 weeks before you stock the pond.

To take temperature readings, tie the thermometer to a wooden float so it hangs about a foot below the float in 3 feet of water. For a good reading, keep it in the water for several minutes, then retrieve and read it rapidly. Record all readings regularly in a notebook along with other observations on the health of the pond.

If your pond has supported fish successfully before, the pH is proba-

To lessen stress during stocking add pond water to the holding tank gradually before you move the fish.

bly all right, for 50 percent of the bodies of water in the U.S. have a pH of under 7.6 and 95 percent are under 8.3. Hardness also usually takes care of itself. In fact, moderately high hardness levels are desirable, increasing fishes' resistance to several toxins. If you're unsure about pH or hardness, though, arrange for tests through the Agricultural Extension people.

The tests for oxygen and ammonia you'll need to do yourself, both before and after stocking. Complete kits cost under $25 and are easy to use, but you can put together your own and save some money. In addition to a thermometer, to do oxygen tests you'll need O_2 #1 powder pillows, O_2 #2 powder pillows, O_2 #3 powder pillows, an O_2 collection bottle, a plastic measure, a mixing bottle, clippers (optional), and PAO titrant. For ammonia testing, buy the colored disc for ammonia, a disc holder, two test tubes, and Nessler reagent. All these materials can be ordered from Hach Chemical Company, P.O. Box 907, Ames, Iowa 50010.

If your initial oxygen level readings are too low for the fish you'll be stocking, fertilize the pond at the rate suggested earlier. And keep testing.

Ammonia is most likely to be a problem after fertilizing and stocking. A reading of over 3 ppm is approaching toxicity. But as the algae multiply, they should adjust to ammonia levels and absorb steadily what the fish produce.

In case your water quality doesn't reach acceptable levels as stocking time nears, remember to inform the hatchery to delay shipping.

When your fish come there's a sequence you should follow to help them adjust smoothly to a new aquatic environment. First, transport them from the hatchery or airport in a tank or plastic bag containing cool water. If the trip is more than an hour, aerate the water by forcing air through it or splashing it. Disturb the fish as little as possible, for the entire stocking period is stressful for them and they will be somewhat weakened.

A rapid temperature change will stress them even more, so when you get home, measure the water temperatures in the container with the fish and in the pond. Then add pond water to the container slowly so its temperature is brought up to pond temperature gradually. Or you may be able to put the container into the pond and let it reach pond temperature without exchanging water. The entire process should take no more than an hour.

Your next move should be to fill a 5-gallon bucket partly with pond water and weigh it. Then add fish and take another reading. The difference is the weight of your fish. You'll need to know the total weight of the fish you're stocking to calculate how much to feed them initially and how much they've grown at harvest time.

You'll also want to disinfect your fish to remove any external parasites they might carry from the hatchery. Fill a container with pond water and mix in 2½ pounds of salt for each 10 gallons of water. Transfer the fish to this solution and leave them in it for two or three minutes—less if they're stressed. This treatment removes the mucous coating and with it the parasites. (The fish will quickly secrete a new coating.)

While the fish are still in the salt solution, drain off some of it and dilute what remains with more pond water. Do this a few times so salt won't be entering the pond with the fish. Then slowly ease the fish into the pond.

Feeding: Try feeding just a little after stocking, and when the fish start eating actively, begin your regu-

lar feeding rate, putting in food at the same time every day.

As a general rule, fish should have 3 percent of their total weight in feed every day. Weighing the fish on arrival will tell you only the initial feeding rate. From then on you must estimate how much they have grown and how much more you need to feed them. Do this and change the ration accordingly once a week.

As a rule of thumb, assume that fish grow a pound of flesh for each 2 pounds of feed. So to get the ration for each second-week feeding, take half the weight of the first week's total feed (half because 2 pounds feed becomes 1 pound of fish), and calculate 3 percent of that. Adding that number to the first week's daily ration will give the new daily ration. For the third week, begin with the total for the second week.

For example, if you stock 10 pounds of fingerlings, they should get .3 pounds of pellets each day for the first week, or a total of 2.1 pounds. So at the beginning of the second week, you can assume the fish have gained 1.05 pounds. Round that down to 1 pound for convenience. Since 3 percent of 1 is .03, add that to the .3 pound daily ration for the first week, and you'll see that the fish get .33 pound of feed daily for the second week. For the third week, begin with 2.3 pounds (the previous weekly total), assume the fish gained 1.1 pounds, and so on.

Always remember it's better to underfeed slightly than overfeed, since uneaten food is consumed by other organisms, especially bacteria, and will raise the oxygen demand of the pond. Besides, you want the fish to forage. So when you see unconsumed feed, cut back on the feeding rate. And clean excess out of the feeder regularly.

It's possible, by the way, to raise common carp and catfish on a feed formulated from a careful blend of tablescraps. In Rodale trials, the growth rates of fish fed this way were about the same as those of same-species fish given commercial feeds. The homemade blend was made by putting high-protein food scraps (50 percent of total scraps), high-carbohydrate food scraps (25 percent of total scraps), and vegetable trimmings and wastes high in moisture, vitamins, and fiber (25 percent of total) through a food grinder. Fatty foods were carefully avoided.

Restaurants are a likely source for ample amounts of such kitchen scraps, which can be gathered, ground, and refrigerated one-week's-worth at a time. If you do blend your own feeds, try to use fresh material so the vitamins are adequate. It would also be good to add a balanced vitamin feed supplement, available at farm supply stores.

Feed your fish daily until a day or so before harvest. Then withhold food to let their digestive tracts empty. Fish can go without supplemental feeding for a week or more with no ill effects if you should need to be away. The only problem is that they won't grow without feeding and may lose some weight.

Making observations and changing the routine: Regular water quality checks are the only way to prevent problems for your fish and to learn about pond dynamics. For the first 2 weeks after stocking, you should record temperature and oxygen levels in the water and air temperature and amount of sunlight once each day. You'll find oxygen and temperature readings at the end of the day to be higher than those taken soon after dawn.

Ammonia also should be checked daily after stocking or fertilization until levels drop to the tolerable range. After that, a weekly check will do.

After the critical first weeks, you should monitor temperature and oxygen at least every other day. As you learn the workings of the pond, patterns will begin to emerge, and in several months you will come to recognize and anticipate the interactions of sunlight, temperature, algae, and fish. When you are able to tell the early signs of trouble, you will be able to get by with less testing.

According to the test results you get, you'll be changing your pond management somewhat. For example, you may learn that in your pond it is best to feed in the afternoon when oxygen levels are higher. If morning feedings are your practice, you may come to omit feedings on days that promise to be cloudy (in anticipation of low oxygen levels).

Here are some general principles you can use in adjusting management to water quality:

1. Fish feed more heavily as the water temperature moves toward the higher end of their optimum range.
2. Greater activity and heavy feeding consume oxygen faster.
3. Water holds less oxygen at higher temperature.
4. Withholding feed when oxygen approaches the lower limit decreases activity and reduces the need for oxygen.
5. Feeding must stop when fish don't eat because the water is too warm; otherwise, feed will raise the oxygen demand at a time when the fish need more oxygen than usual.
6. Additional fertilizer can be helpful when the oxygen levels and algal population are low.

Daily checks on water quality are essential during the first weeks of aquaculture.

Harvesting: It is simplest and most efficient to stock fish of the same size and harvest them all at once. Of course, this requires that you have the means to clean and freeze them all promptly since fish spoils fast. Ideally, you should take fish when they reach the minimum size for harvesting. As they get larger, their rate of growth slows and they require more food just to be kept alive. Harvesting a few at a time is more like fishing—it's fun, but time consuming, too.

If it suits your needs best, you can maintain fish in a deep pond over the winter quite safely. They won't need any feed after water temperature drops below their ideal range, and they won't grow. The only danger is that the water may become depleted of oxygen if the surface freezes over for very long. And of course very small ponds can freeze solid, which is lethal.

You can harvest most easily with large nets. There are two types. Gill nets allow you to take only fish of edible size. The mesh size should be large enough to allow undersized fish to swim through and to catch the others by the gills. Seines, on the other hand, take out all the fish. They are made of stronger fibers and have smaller mesh sizes.

Most ponds can be harvested with nets no longer than twice the width of the pond. The width of the net should be 33 to 50 percent larger than the depth of the water. A net dealer will be able to tell you the right size for your pond.

When you're ready to harvest, it's most convenient to let most of the water out of the pond. But remember to leave enough so that the fish can breathe. They will be concentrated in a small area and will become very active.

Begin netting when the water is about waist high. The trick is to posi-

tion the netting when you start so that it covers the pond from bank to bank and crosses the very bottom so no fish can get around it. When it's in position, begin to draw the ends along the perimeter of the pond so that they will meet opposite the starting point.

At the same time, people standing at the meeting point should begin drawing in the bottom ropes. Slowly the net will become a large bag holding all the fish. They can then be scooped up with large buckets and transferred to holding containers to await cleansing and freezing.

For high quality meat, keep your catch in the holding tank for about a day after harvest. The fresh clean water will cleanse the fish of mud and algae, which can give them a "pond water" taste. Put the tank in a cool or shady place, then flush it with spring or well water until it's filled with new water. You should also aerate the water enough to maintain the fish in good condition.

Treating troubles that may arise despite your best efforts is part of the challenge of aquaculture. Here are a few common problems and some solutions.

Muddy water can be caused by run-off or by wave action against the bank. Erosion can be stopped only by good soil conservation practices on the watershed, and you may have no control over such matters. However, if waves are eroding your banks in windy weather, protect them with a layer of gravel or rock (riprapping). If clay particles are suspended in the water, you may be able to get them to settle by adding gypsum at the rate of 12 pounds to every 1000 cubic feet of water.

Disease or parasites may be the culprit if a fish dies or the fish stop eating even though water quality (temperature, oxygen, ammonia levels) has been fine. If this is the case and you have a dead fish that appears unmutilated by an animal, wrap it in plastic, refrigerate it, and notify the Fish Commission people. They will determine the cause of death and recommend treatment if any is possible.

Leaks can grow into a very serious problem. You should determine the cause immediately, calling on the Soil Conservation Service for help if necessary. Some small leaks can be stopped with extra sealing in the form of plastic sheets or bentonite clay granules. Severe leakage may require partial draining of the pond for repairs.

Muskrats can cause leaks if they begin to burrow into the dam sides. Burrows usually begin 6 to 18 inches below the water line. When you see them in the area, protect the banks by laying wire mesh several feet above and below the water line. Or you can do riprapping with very large stones. Also remove cattails and other aquatic plants that muskrats feed on.

Wild fish will compete with your fish for food and oxygen and may carry disease. If they are in a stocked pond, harvest all the fish, discard the undesirables, then drain the pond dry to make sure that all the wild fry are destroyed. Another method is to kill all fish with rotenone, then wait 6 weeks before restocking to make sure the rotenone has biodegraded completely. To protect your pond from wild fish, be sure to use very fine mesh screens or netting (as described earlier) to filter any water entering from a stream.

Raccoons and mink may prey on your fish. The only solution is to shoot or trap them.

Position the net so that it covers the pond from bank to bank and crosses the very bottom.

FIGURING OUT COSTS

Fish you grow yourself can cost as little as $.25 a pound or as much as $3 a pound. Obviously, knowing the economics before you get under way is a good idea. It will help you to keep your input and outcome in balance and prevent you from underestimating expenses and later finding it impossible or very costly to continue what you've started

Calculating what your fish will cost in advance is easy. First, estimate the length of the active growing season, the volume of productive water you have, and how much fish will grow there. When you have projected the total weight of the fish you expect to harvest, reduce it by 40 percent to allow for losses in cleaning. Next, figure how much you will spend to produce that quantity of dressed fish.

Some things you will pay for only once. These initial costs include the pond, water testing supplies, nets, boots, aerator(s), holding tanks, pumps and such. Though these items will add up to a lot of money, only a portion of what you pay for each one can be figured fairly into the cost of your first crop of fish. That amount is based on how long the item will be used. So estimate the life of each item and divide its total cost by the number of harvests you will make in that time.

Other inputs like feed, fingerlings, and power and transportation costs are purchased every time you begin a new season. So you must charge the entire expense of such items against the one crop they produce.

Once you have an annual charge for each long-life item, add them and add that total to the total for your seasonal inputs. Next divide the planned-for weight of dressed fish into that total. The result is the approximate price you'll be paying per pound of ready-to-eat fish.

MORE READING

Books:

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Farm Pond Harvest. Professional Sportsman's Publishing Company, RR 2, Momence, IL 60954.

Fisheries. American Fisheries Society, 5410 Grosvenor Lane, Bethesda, MD 20014.

The Progressive Fish-Culturist. United States Government Printing Office, Washington, DC 20402.

Government Booklets:

The following are available from the United States Government Printing Office, Washington, DC 20402.

Catfish Farming. Farmers' Bulletin No. 2260. $.40.

Trout Ponds for Recreation. Farmers' Bulletin No. 2249. No charge.

Warm Water Fish Ponds. Farmers' Bulletin No. 2250. No charge.

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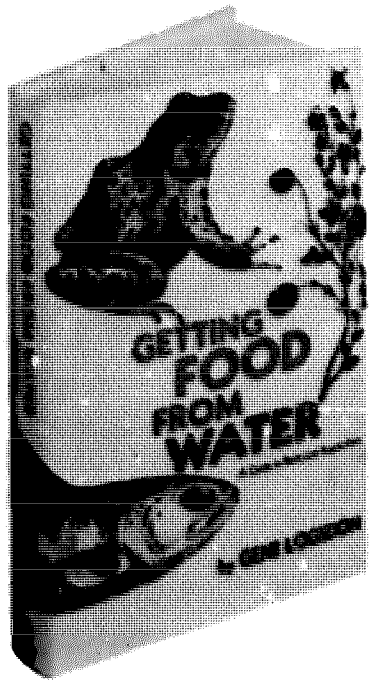

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Our new LSS-100C Aerator turns your pool or pond into a growing medium that is loaded with life-giving oxygen. The energy efficient 1/20 horsepower motor pumps over 60 gallons per minute—transferring enough atmospheric oxygen to help satisfy the requirements of over one hundred pounds of active, growing fish.

With aerator.

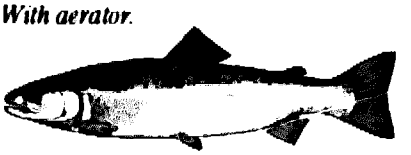

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The LSS-100C helps your fish grow faster. And larger.

Tests show that fish production may be increased up to nine-fold with the addition of aeration—and with much better food conversion percentages—when raised in aerated waters as opposed to no aeration at all.

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So a Rodale LSS-100C Aerator is a dollar-wise investment that can quickly pay for itself by increasing production. And by making it possible to grow more fish in an area which might normally be too small.

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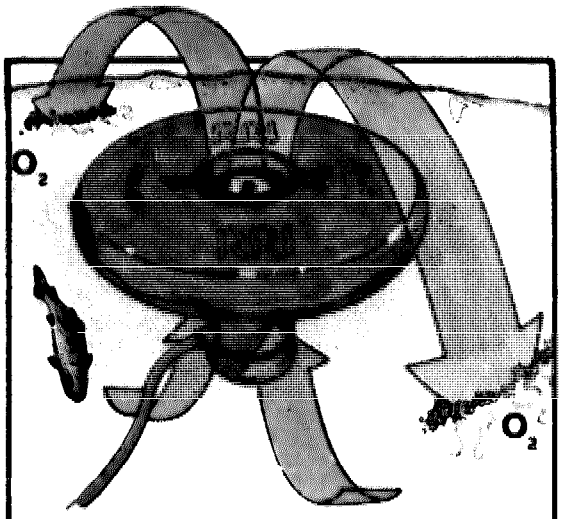

- Heavy-duty, long-lasting, construction covered by our one-year limited warranty**
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- Allows greater populations in smaller areas
- Helps fish grow larger and faster *naturally!*
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But don't think your profits will go bubbling away in big energy bills. Because the LSS-100C has been designed with energy-saving in mind. Our new capacitor-type motor is energy-efficient. We've found that it costs roughly one-half cent per hour to operate.* And round the clock operation is necessary only in special cases.

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So if self-sufficiency is an idea that appeals to you, help turn that idea into a reality with a Rodale LSS-100C Aerator — the energy-efficient oxygen machine that can help make backyard fish farming "pan out" for you!

**Details of our warranty available upon request.
*Actual costs may vary due to difference in local electrical rates.

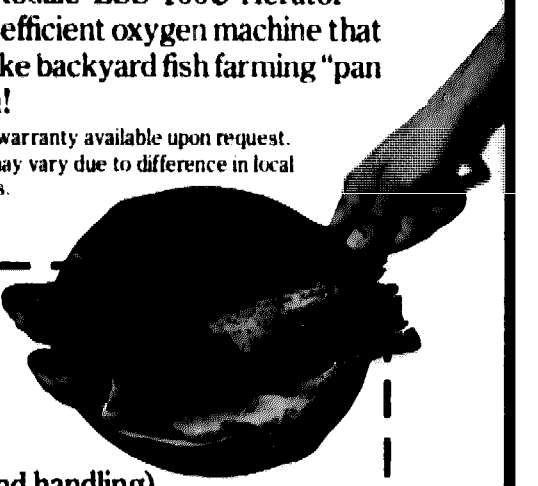

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Raising Goats For Milk and Meat

By Rosalee Sinn

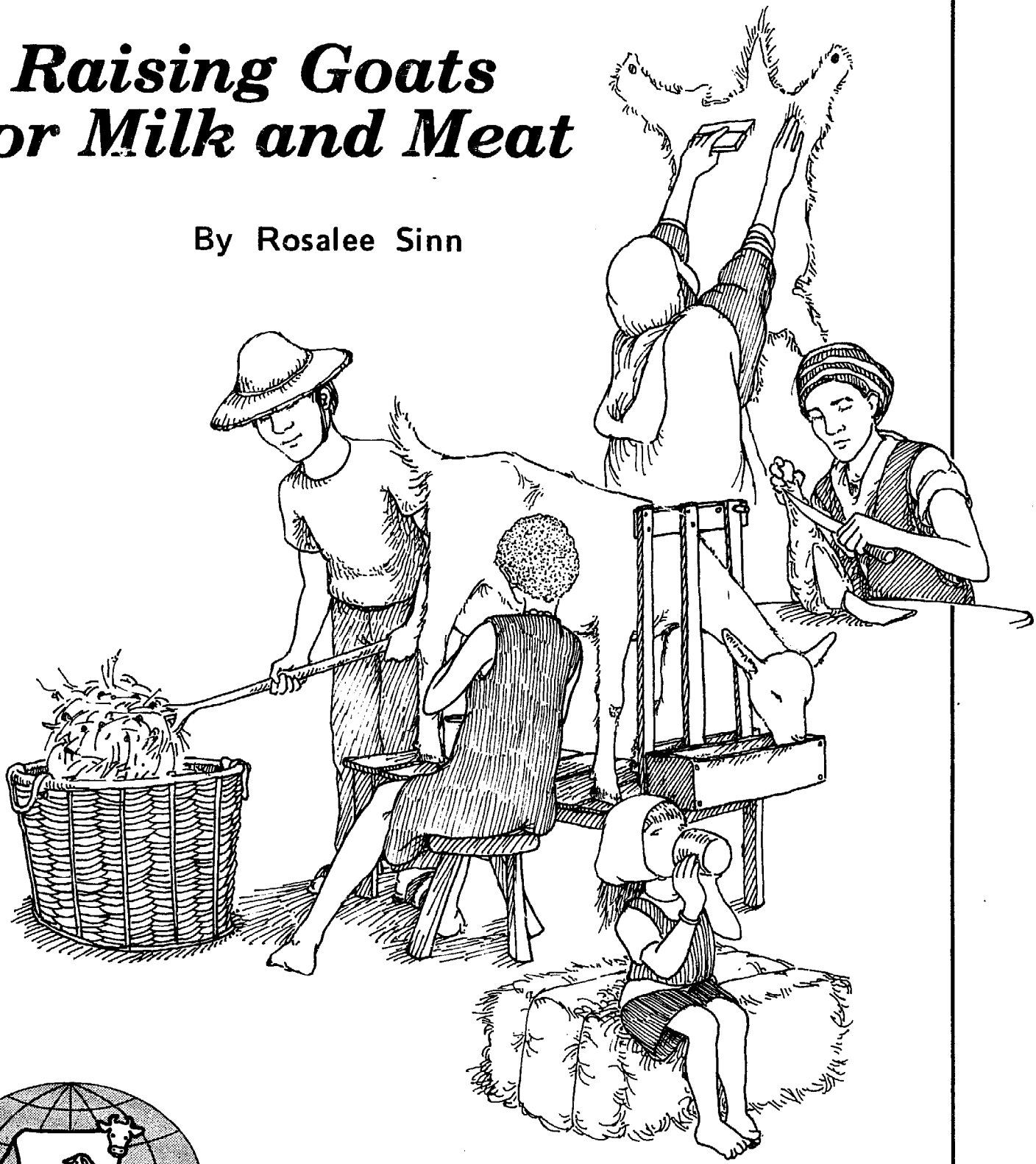

A HEIFER PROJECT INTERNATIONAL TRAINING COURSE

Rosalee Sinn is the Northeast Director for Heifer Project International. She has selected, processed and shipped thousands of goats for HPI to program areas located in dozens of developing countries and in rural areas of the United States. She has visited goat projects in Central America and the Caribbean and has taught dairy goat management courses in Cameroon, West Africa. This manual was originally written for training courses in Cameroon. It has been revised for more universal use.

Raising Goats for Milk and Meat

Rosalee Sinn

A Heifer Project International Training Course

Heifer Project International

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This book is dedicated to the small farmers in the Northwest Province of Cameroon, West Africa. I am indebted to them for their encouragement in my early attempts to formalize this training manual and for their willingness to work with me in discovering anew the benefits of goat husbandry.

- Rosalee Sinn

MEMO TO TRAINING INSTRUCTORS

This manual is directed toward persons in rural development areas. Educational backgrounds will vary. Most people in the course will have backgrounds in either livestock or crop farming.

The focus of the manual is on European breeds of dairy goats. However, we recognize that in many areas there are crossbreds which may have been upgraded to milk animals. The material in the manual is applicable to native (local) milk animals as well.

The manual has been field tested in Cameroon, West Africa. Some of the management procedures are adapted from those experiences.

The manual may reflect different procedures than those used in your particular area. During the training sessions you will want to give additional information which is appropriate to your situation.

GENERAL PROCEDURES

1) Read the entire manual. Identify those areas which you will want to adapt or change.

2) Review each lesson.

3) Identify words that need clarification.

4) Decide on tasks, "hands-on" experiences, and arrange for animals, equipment and supplies needed.

Note: A filmstrip is available to accompany the course. Write Heifer Project International, Box 808, Little Rock, AR 72203

RAISING GOATS FOR MILK AND MEAT

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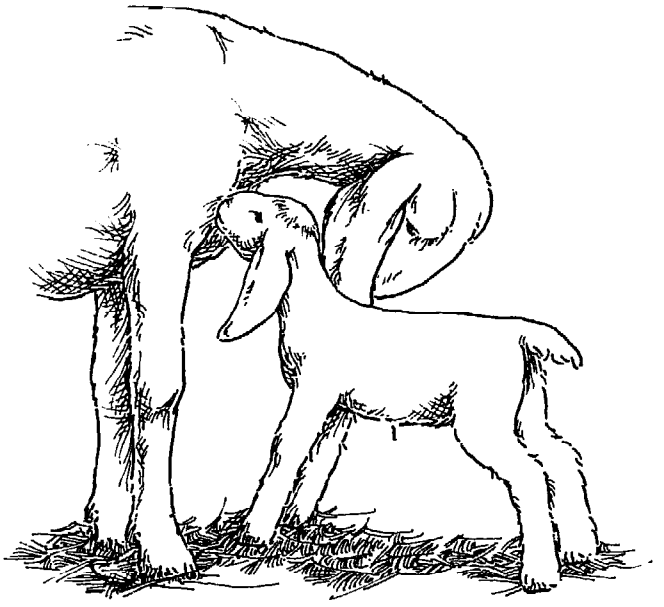

Rosalee Sinn
Northeast Director
Heifer Project International

Illustrations by:
Barbara Carter,
Randolph, Vermont

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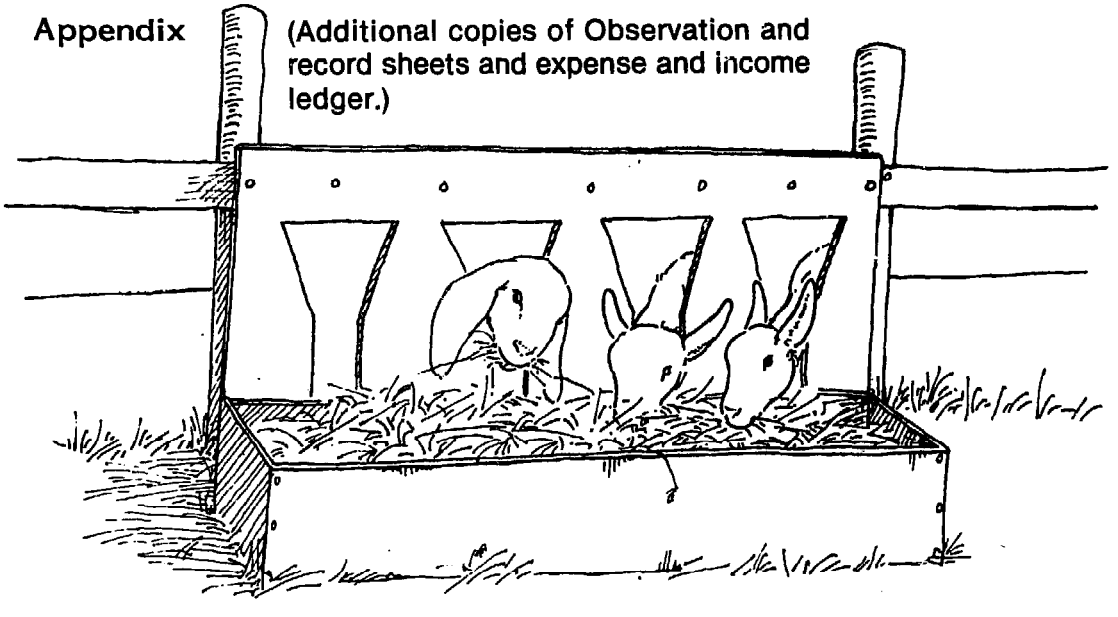

RAISING GOATS FOR MILK AND MEAT

INTRODUCTION

PURPOSE

The purpose of this course is to provide a guide to learning basic care and management of dairy goats. It is directed toward persons in rural development areas. It is designed to be used in a classroom situation. The ideal classroom setting will provide for "hands-on" experiences with goats. If possible, plan to have a yearling doe, a lactating (milking) doe, a mature buck and two kids present during the instruction period.

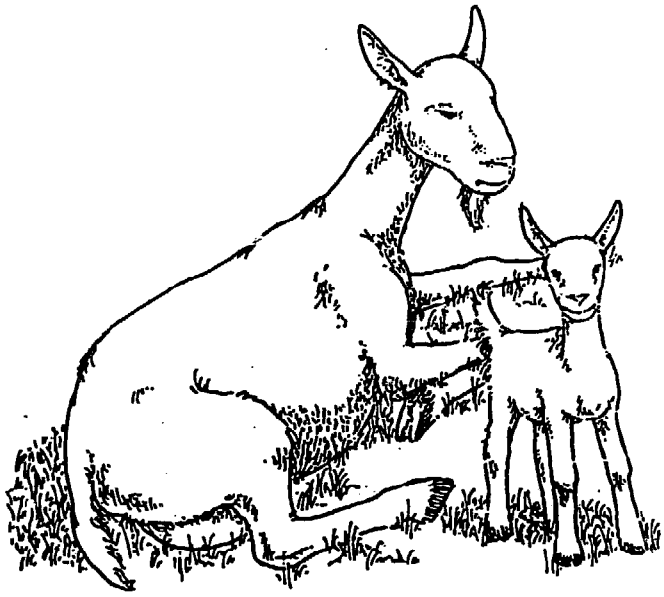

Experience with and observation of goats during the training course is important. Good management begins with basic knowledge and daily observation. Observation at special times such as estrus (heat period), and breeding, parturition (birth) or during illness is critical. While all areas of management cannot be observed during the training course, students may be invited to return to the training center or visit another goat breeder at the other significant periods.

Information on forages, feed by-products and climate may vary in each situation. However, most of the material in this manual is applicable regardless of location.

The course can also be used by an individual student, utilizing the advice and assistance of other goat breeders, extension personnel and local veterinarians.

HISTORY OF GOATS

Goats have been used as a source of meat and milk since the earliest days of recorded history. They were first domesticated about ten thousand years ago in the Tigris-Euphrates Valley in Southwestern Asia. Goats are mentioned two hundred times in the Bible. Moses ordered the altar cloths in the Tabernacle woven of silk and goat hair. In 1981, the goat population of the world was reported at 445 million.

The goat has been traditionally raised for meat and milk. The fact that goats are comparatively small animals and cost very little for maintenance has led goat farming to be popular among small scale farmers.

Goats have some advantages over other animals. They are widely adapted throughout the world. They thrive and reproduce in tropical or cold climates and in humid as well as dry regions.

Their small size compared to cattle permits them to be maintained on a limited area of land. Goats transform feeds left behind by other species into meat, milk and fiber. They will consume a wide variety of grasses, weeds and leaves and small branches of bushes and trees. Goats also serve as scavengers, consuming discarded leaves, peelings and roots of vegetables, husks of corn, citrus and banana peelings and other waste plant residues that would otherwise cause pollution. About two-thirds of the feed energy used in producing these animals comes from substances which are undesirable, indigestible and inedible by humans.

Goats play a positive role in environmental protection, clearing away undesirable plant species. They reduce bush encroachment in rangeland areas.

Their small size makes them ideal for family milk and meat production. The milk is sufficient to contribute to the nutrition of children without having storage problems associated with the larger supplies from cattle. The meat can be consumed by a family before it spoils in warm climates where no refrigeration is available.

In addition to meat and milk, goats make important contributions to the world's supply of skins and of by-products such as blood and bone meal, horns and fertilizer. Goats in the developing nations contribute about 75% of the world's supply of goat skins.

There are negatives too. Uncontrolled grazing and or too many goats directly cause deterioration of rangelands. Goats are probably not the initial cause of rangeland deterioration, but they may be the primary culprit during the later stages of destruction. Uncontrolled goats can be destructive of household and neighborhood crops.

Goats have had and will continue to have an important role in agricultural development and food production on small farms around the world.

VOCABULARY

Buck:	Male Goat
Sire:	Father
Wether:	Castrated Male
Doe:	Female Goat
Dam:	Mother
Kid:	Young goat under six months of age
Kidding:	Giving birth
Doeling:	Female goat 6 to 12 months old
Buckling:	Male goat 6 to 12 months old
Yearling:	Any goat 12 to 24 months old
Purebred:	Both sire and dam belong to the same breed
Crossbred:	Sire and dam are of different breeds
Bush Goat:	Sire and dam are of unknown breeds (local goat)
Colostrum:	The first milk coming after kidding
Lactation Period:	Time during which milk is given
Gestation Period:	Time doe carries young before birth

REVIEW OF BREEDS

Most of the dairy goats in use today originated in the Middle East. There are some 60 recognized breeds. The vast majority of these are multipurpose animals.

The JAMNAPARI of Northern India is a dual purpose goat that has undergone some selection for milk production. Its coat color is white with patches of tan or black often on the head. It has a large convex face and large pendulous ears. The average milk yield is 160-200 kg over 210-240 days. The maximum yield is reported at 544 kg in 250 days.

Grade Jamnapari female goat, Surabaja, Indonesia

The BEETAL is a large spotted black goat of the Punjab in India. It has large pendulous ears, a Roman nose and wattles usually present on both sides of the lower neck. Milk yield averages 140-230 kg in 150-225 days. Maximum yield reported for a Beetal is 592 kg in 177 days.

The BARBARI, Often called the dwarf milk goat, is a white or spotted fawn goat of Northern India. The ears are small and erect. They are considered prolific breeders. Milk production is lower, averaging 100-700 kg in 200-250 days.

The DAMASCUS is a red goat of the eastern Mediterranean region. The does are polled or horned and have tassels hanging from the lower neck. Milk production is usually highest during the sixth lactation. Average milk yield ranges from 400 to 500 kg over a lactation of 238-263 days.

The SUDANESE Nubian originated in East Africa. It has the typical Nubian convex face with large ears. Color markings vary. Average milk yeilds are low, about 1-1.25 kg per day, but usually only 60 kg per lactation.

The BLACK BENGAL is an interesting breed since it has a number of outstanding features. These goats are found in Bengal, India and in the northern part of East Pakistan where they are very widely distributed. The breed is economically important because in addition to its production of meat of high quality, it also produces a skin for which there is considerable demand. The skin is used extensively for making high quality shoes.

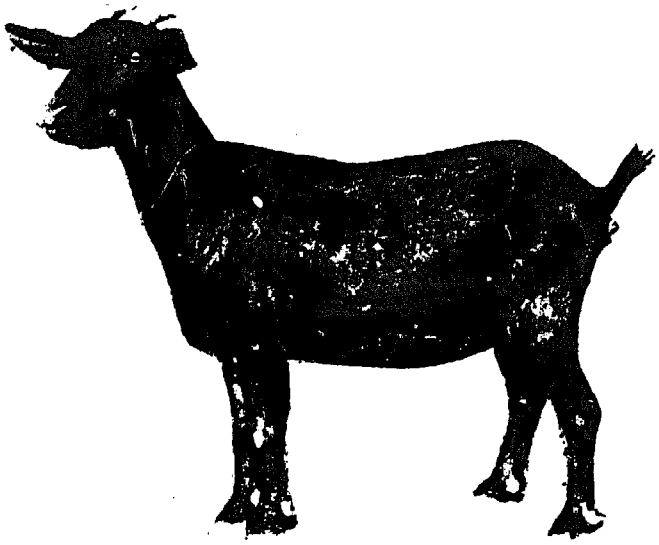

West African Dwarf goats; the doe on the right had 12 kids and reared 11, in 4 kidding at intervals of 6 months.

DWARF GOATS with disproportionately short legs, which are often bent, occur in and near the tropical forest belt in West and Central Africa. A typical example is the Fonta Djallon or WEST AFRICAN DWARF GOAT. These are about 50 cm in height and 20 kg in weight. Growth rate and milk yield are very low, but twin and triplet births are common and they breed at all times of the year. They are used almost exclusively for meat production. Dwarf goats are Tsetse fly resistant.

EUROPEAN - USA BREEDS - "EXOTICS"

European Breeds were introduced to the United States and other areas as the quickest means for increasing milk production. These breeds are generally above average in size with mature does weighing 45-55 kg and bucks 60-75 kg. Milk production ranges from 350-900 kg in a 300 day lactation.

Four European breeds - Saanen, Nubian, Alpine and Toggenburg - will be the focal point for this course. They will be considered both as purebred producers and for their potential in crossing with local goats such as the African Dwarf.

SAANEN - Average lactation
800-900 kg in 275-300 days.*

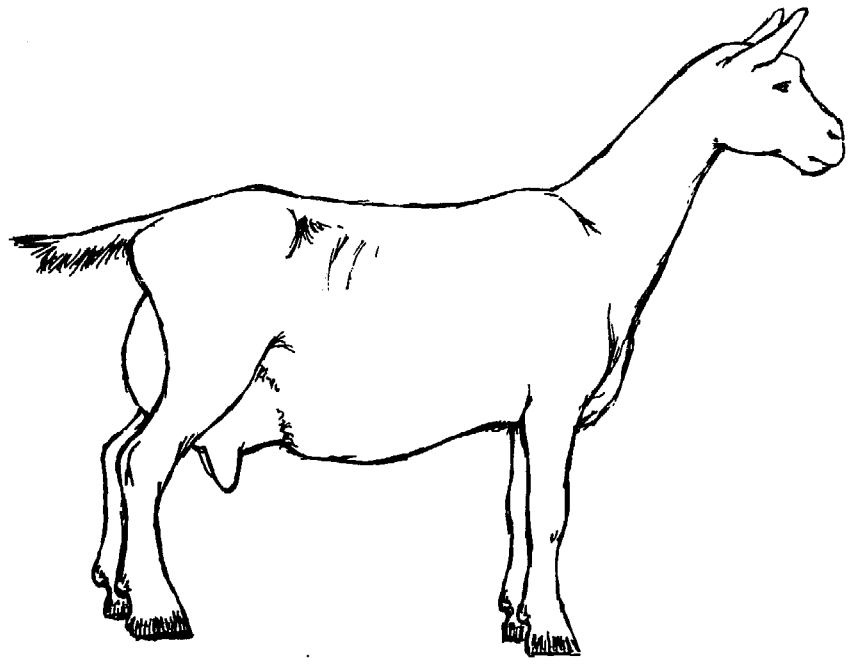

The Saanen is a large animal of strong bone. The breed originated in Switzerland with records indicating that the first imports to the United States were in 1904. It is an all white or creamy-colored animal. The face is straight, the ears are upright and alert. The hair is short and fine. Saanens are vigorous animals and high producers.

* Milk production figures indicate amounts which will be high for animals receiving limited protein and energy supplements. On the other hand, they will be low for herds on heavy concentrate diets.

ALPINE - Average lactation
600-900 kg in 250-305 days.

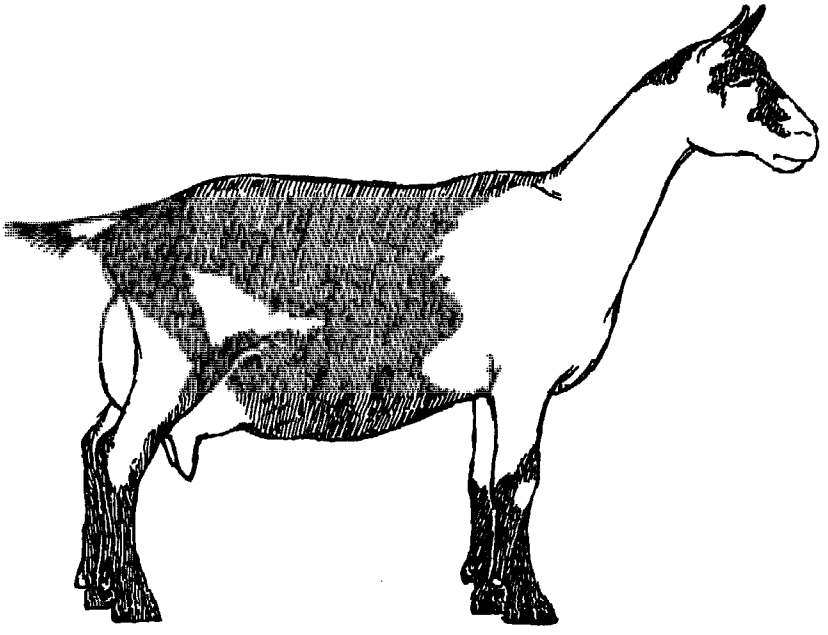

The French Alpine originated in the French Alps, and most goats of the Alpine type were imported to the United States from France. They are medium to large in size and are hardy and adaptable animals, thriving in many climates. The face is either straight or slightly dished. The color patterns can vary. The French Alpine is described in the following terms:

Cou Blanc - (coo blanc) this means literally "white neck" - the frontquarters are white and the hindquarters are black, with black or gray markings on head.

Cou Clair - (coo clair) the literal translation is "clear neck" - frontquarters are tan or off-white, or a shading to gray with black hindquarters.

Cou Noir - (coo nwah) literally "black neck" - black frontquarters and white hindquarters.

Sundgau - (sundgow) black with white markings such as belly and facial trim.

Pied - spotted or mottled.

Chamoisee - (shamwahzay) brown or bay - often with black face, dorsal stripe, feet and legs. On a buck this is spelled chamoise.

TOGGENBURG
Average Lactation - 600-900 kg 275-305 days

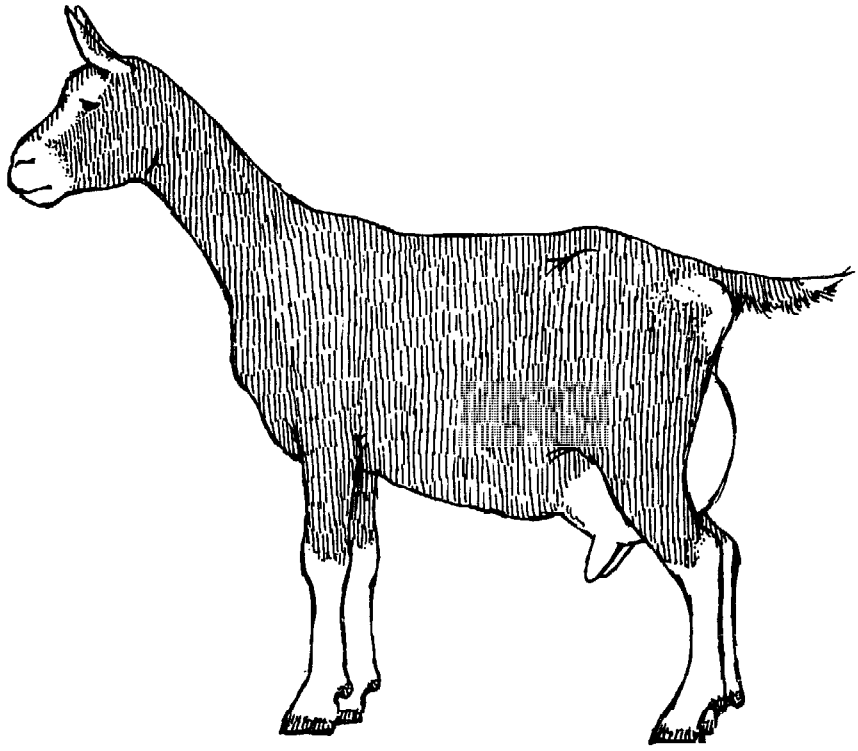

The Toggenburg is a Swiss breed from the Toggenburg Valley in Switzerland. It has been called the oldest breed of Switzerland and was one of the first to be imported to the United States. It is a medium size and sturdy in appearance. The hair is usually short to medium and is fine and soft. However, some individuals have a heavy hair coat. The color varies from light fawn to dark chocolate. The distinct white markings are two white stripes down the face from above each eye to the muzzle; hind legs white from hocks to hooves; forelegs white from knees downward with dark below the knee acceptable; a white triangle on either side of the tail; a white spot may be at root of wattles* or in that area if no wattles are present. The ears are erect and carried forward. The nose is straight or slightly dished.

* Wattles are small appendages, usually hanging from the neck of a goat, but may appear anywhere about the head and neck. They do not appear on all goats and are hereditary. They serve no purpose and are often removed during the first few weeks as they are subject to getting caught in fences, etc. (see goat on page 14)

NUBIAN - Average lactation
700-900 kg in 275-300 days.
Milk has high butterfat content.

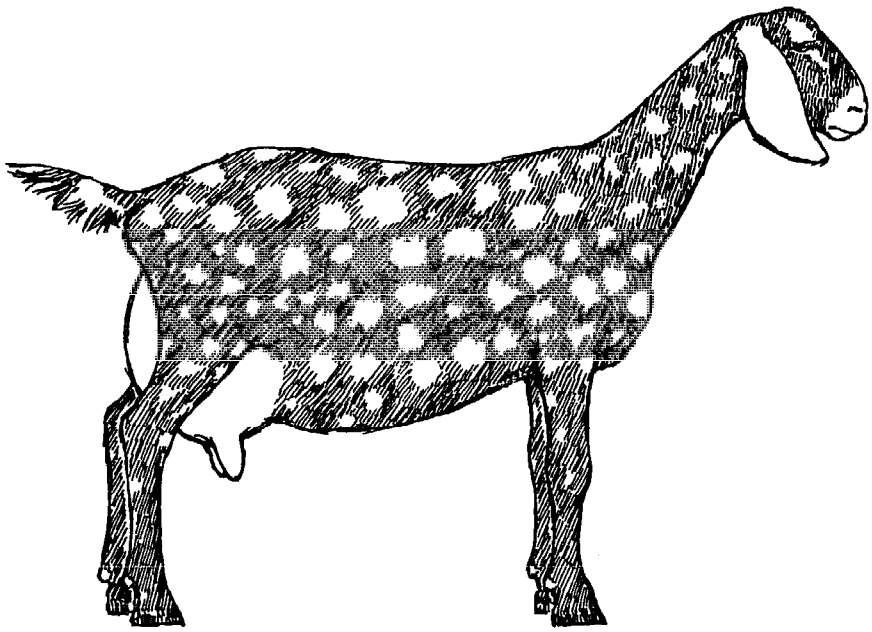

The Nubian is a relatively large, graceful dairy goat. It is said to be of Oriental origin. Its distinguishing characteristic is the head. The profile between the eyes and the muzzle is strongly convex, creating its Roman nose. The ears are long, wide and pendulous. They lie close to the head at the temple and gently flare out and forward. The hair is short and glossy. The colors vary greatly, with black, tan or red colors predominating. Any color or pattern is acceptable.

Nubians often adjust more readily to extreme heat.

BREED SIZE STANDARDS

Breed	Min. Height Mature Does		Min. Weight Mature Does		Min. Height Mature Bucks		Min. Weight Mature Bucks	
Alpine	76.2 cm	30"	61.3 kg	135 lbs	81.2 cm	32"	77.2 kg	170 lbs
Nubian	76.2 cm	30"	61.3 kg	135 lbs	81.2 cm	32"	77.2 kg	170 lbs
Saanen	76.2 cm	30"	61.3 kg	135 lbs	81.2 cm	32"	77.2 kg	170 lbs
Toggenburg	66.0 cm	26"	54.5 kg	120 lbs	71.1 cm	28"	68.1 kg	150 lbs

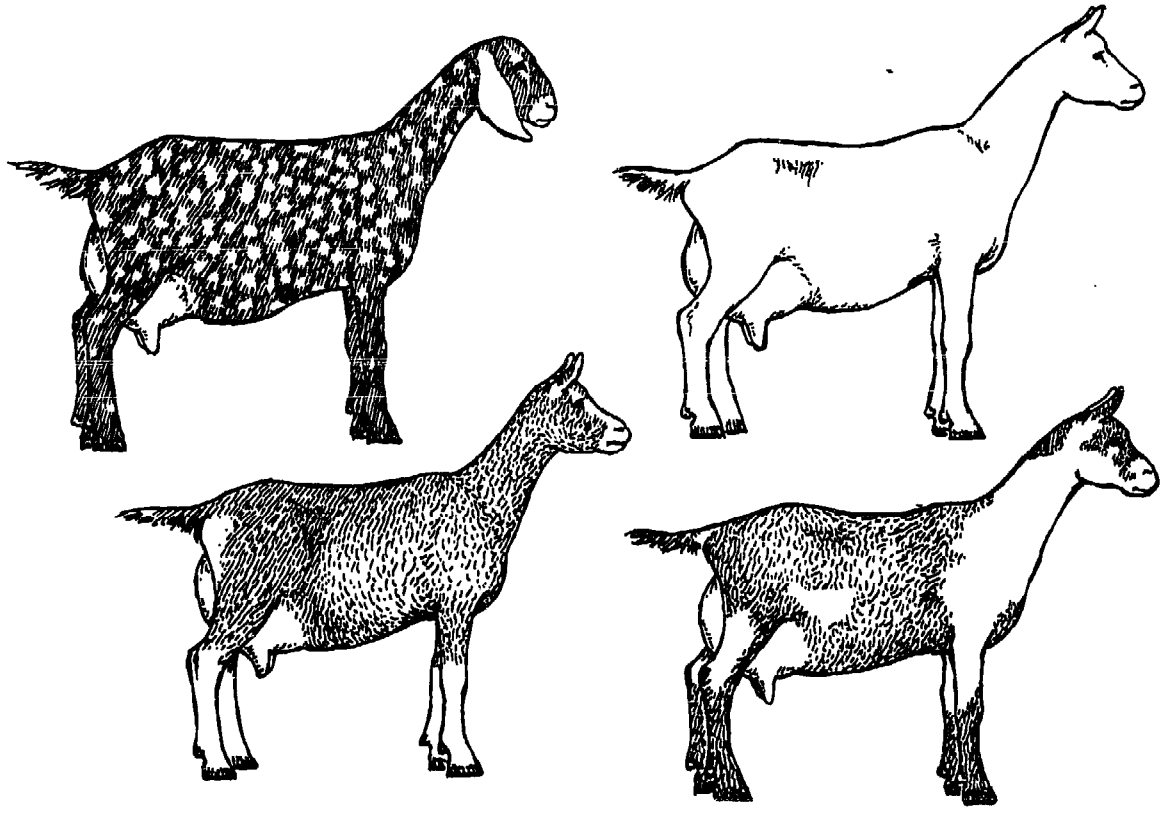

LESSON I - INTRODUCTION TO DAIRY GOATS

1) What are the benefits of owning a dairy goat?

a) Nutritional - While forty-nine per cent of the world's population drink goats' milk, eighty per cent of children in rural areas do not have milk or milk products. A dairy goat will help provide milk for good health in children and adults. Dairy goat milk provides protein and calcium. The fat in goats' milk is in smaller pieces than in cows' milk and is easier to digest. It is very good for people who have stomach (gastric) problems and for babies, small children and older people. One or two goats produce enough milk for a family. Since the milk can be used in a day, refrigeration is not required. Pasteurization of the milk is recommended, particularly in areas where regular tests for Tuberculosis and Brucellosis are not available for the animals.

- What is Protein? Protein in our diet builds strong bones, teeth, hair and muscle.

- What foods are high in protein? Beans, meat, eggs, and milk -- milk, meat and eggs are complete proteins. Beans eaten with rice make a more complete protein.

- What is Calcium? Calcium is a mineral used to make bones and teeth. Without it children get weak, have crooked bones and bad teeth. Older people who do not have enough calcium in their diet have bones that break easily. Children often complain of "growing pains."

- What does one liter of goats' milk a day provide?
  --all the protein a child needs to age six
  --60% of the protein a child needs to age 14
  --half the protein a child age 14-20 needs
  --all the calcium a child to age 10 needs
  --almost all the calcium a child age 10-18 needs
  --all the calcium old people need

- What does goat meat provide? Good nutrition - plenty of protein and important vitamins and minerals.

b) Economic - If you care for your dairy goat properly and give her plenty of green chop (forage), she will give you at least a liter of milk every day for 300 days each year. She will also give you one or two kid goats each year which you can sell, use for meat or raise for additional milk producers. If you give your dairy goat rice bran, wheat bran, cottonseed cake or other protein supplements, she will give more milk. If you have extra milk you can make cheese to eat or sell. You can also sell the horns and skin from your goats.

c) Fertilizer - If you put the manure and urine collected from your goats on your garden, it will improve the soil and make the garden grow better. You can put the manure directly on your garden and mix it into the soil or put the manure in a bucket, cover with water and the next day pour the "tea" on your plants.

Whey is the by-product of cheesemaking. It can be fed to pigs or chickens. Whey can also be used to fertilize your crops. Put approximately 2.54 cm or 1 inch of whey on the first year. Individual applications can be put at half this amount. Do not put on growing foliage. Whey is a complete fertilizer similar to manure. Apply whey to the same crops you would apply manure. Apply at rates consistent with nitrogen needs.

d) Pleasure - Holidays and special occasions are times when goat meat is appreciated. Children and adults enjoy goats. They are affectionate, intelligent and energetic. They enjoy climbing on rocks. They like to go for walks with the person who cares for them. Goats are easier to keep clean than cows.

2) What are the problems of owning a dairy goat?

a) She must be fed plenty of green chop (forage) at least twice a day. A mature goat needs to have green feed before her as often as possible to produce plenty of milk.

b) A dairy goat needs plenty of water - 6-8 liters a day.

c) A dairy goat needs milking twice a day - morning and evening. You will get more milk if you milk your goat twice a day than if you only milk once.

d) A dairy goat who is not tethered (tied) may get into your garden or even worse your neighbor's garden. If she is not tied, she needs a fenced paddock. If you tie your goat you need to move her several times each day.

e) You will have to care for your goat when she is sick.

f) You will need to find a good buck to breed her once a year.

g) You will have to find someone to care for her while you are away.

3). How does a dairy goat differ from a local (bush, country) goat?

a) local goats range freely

b) local goats receive no supplements

c) local goats have no special shelter

d) local goats produce only enough milk to raise the kids.

4) Identify the parts of the goat's body.

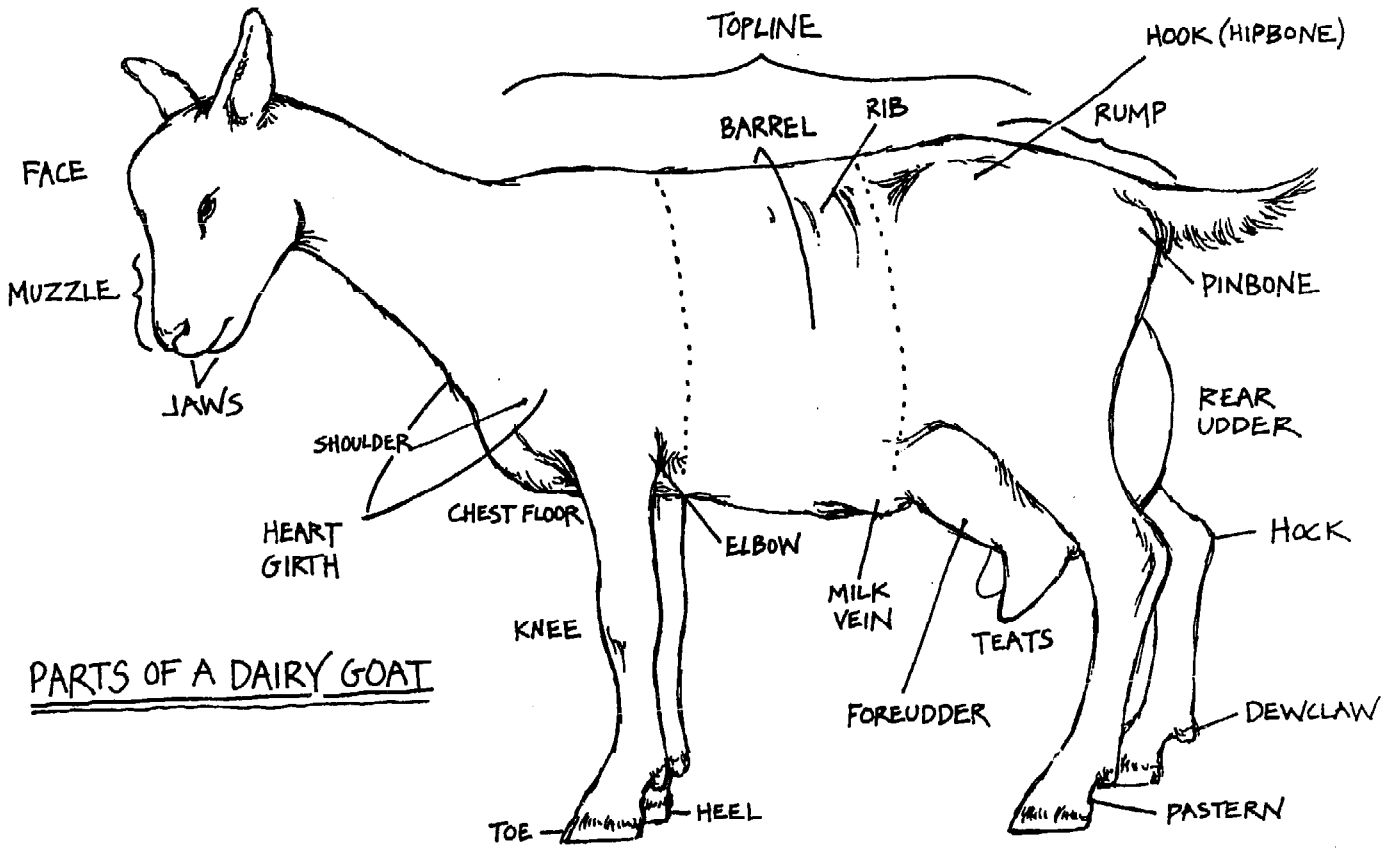

PARTS OF A DAIRY GOAT

USE THE DIAGRAM BELOW TO PRACTICE IDENTIFYING THE PARTS OF A GOAT'S BODY:

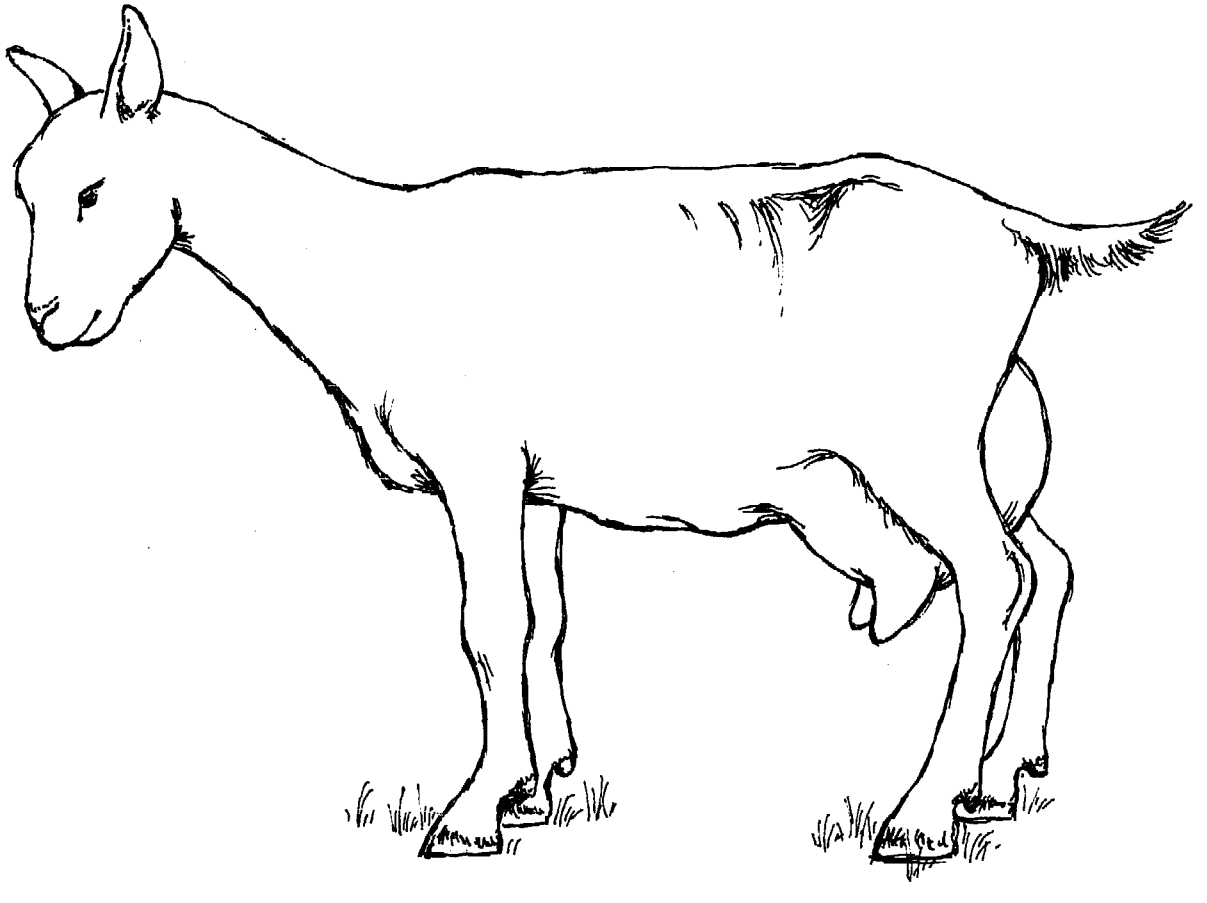

6) How do you select a good dairy goat?

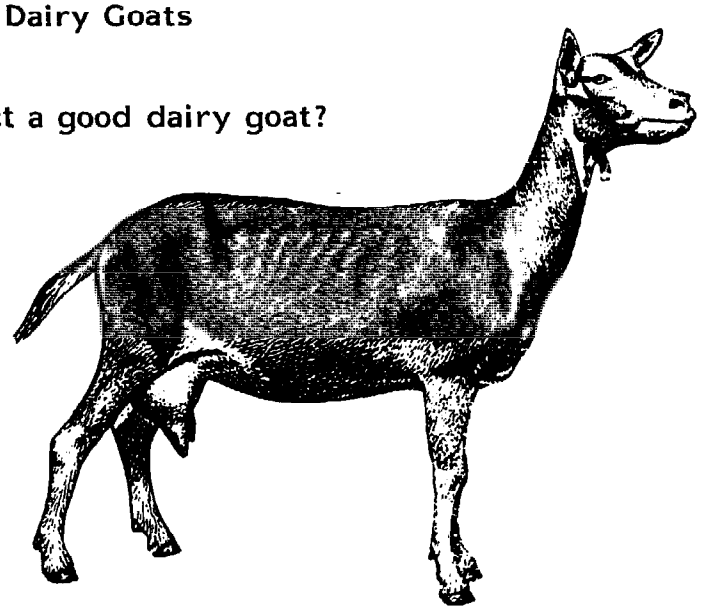

The goat pictured above has excellent dairy qualities.

a) a dairy doe (female) should have feminine characteristics. She should have fine features - not like a male - not coarse.

b) straight top line - feel individual vertebrae - sharp withers not fat

c) long rump - not too steep

d) wide chest - plenty of space for lungs to breathe and heart to pump blood

e) bright sleek coat

f) plenty of capacity for feed and kids; open ribs

g) large heart girth

h) straight legs - hips prominent, pins sharp

i) strong muzzle - jaw not undershot or overshot

j) loose, pliable coat

k) alert, bright eyes

l) she should walk soundly with no trace of a limp

m) a dairy goat's udder should blend smoothly with the body wall and be securely bound across the entire upper surface. It is carried well forward, sloping gently into a gradual upward curve. The rear udder attachment is high, wide, firm and strong. It is firmly fastened at a wide escutcheon.

Here are examples of a good udder

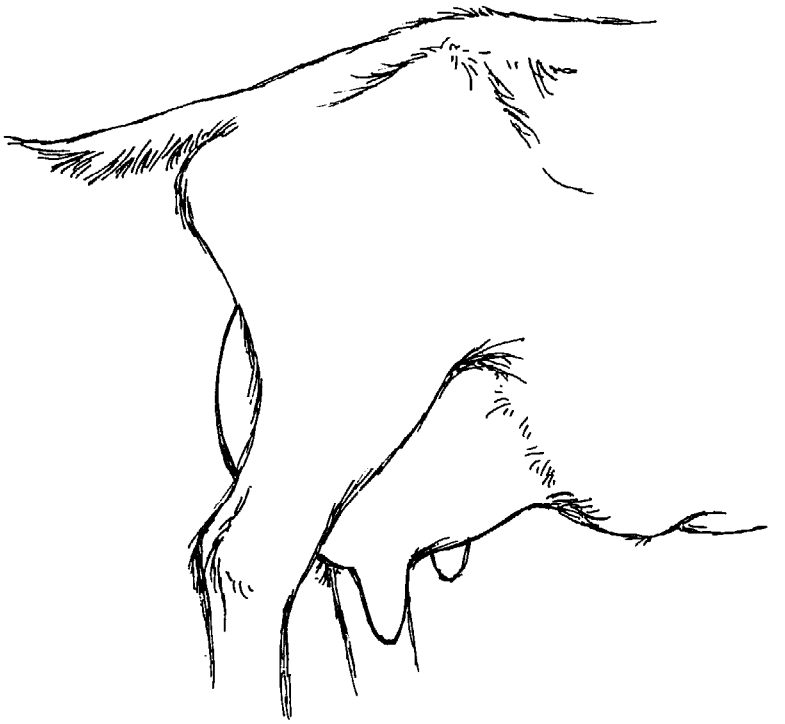

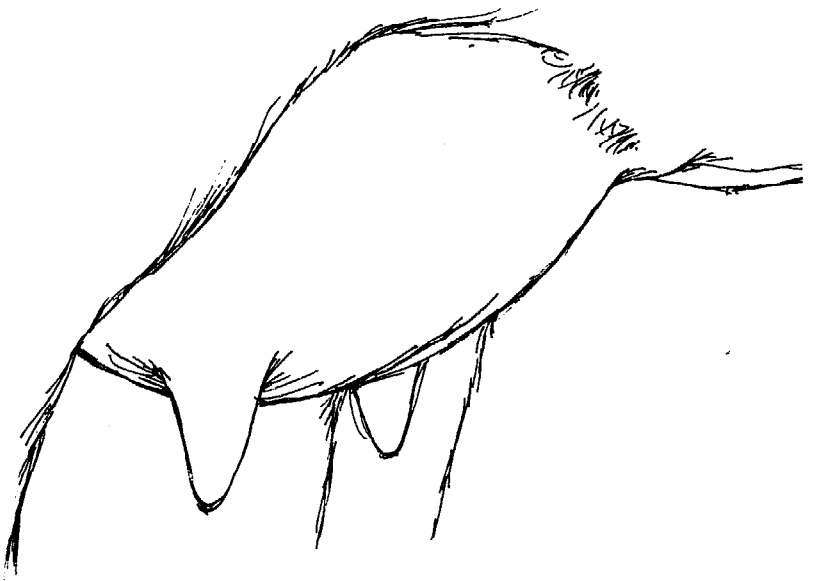

Look for good conformation in your bucks.

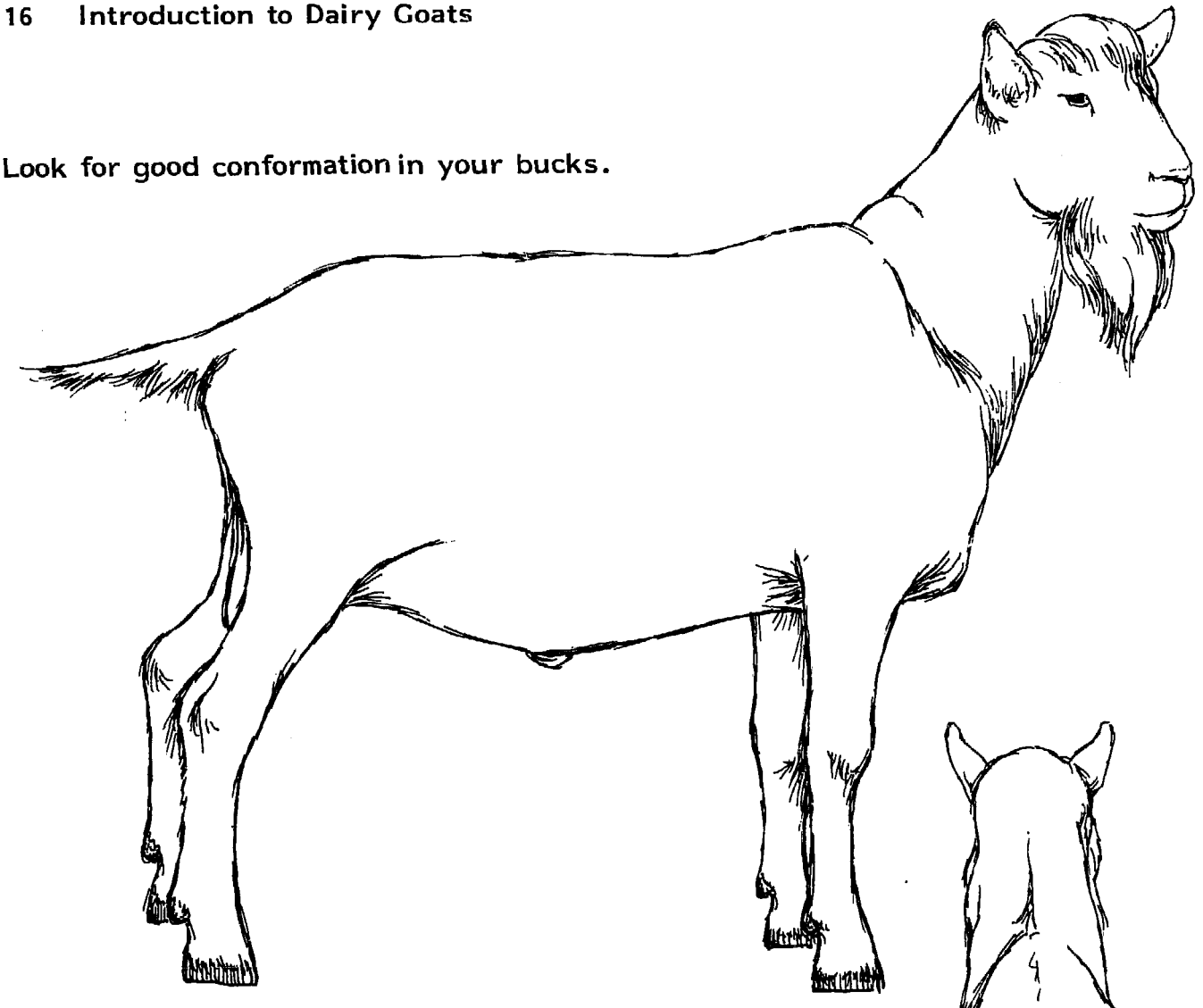

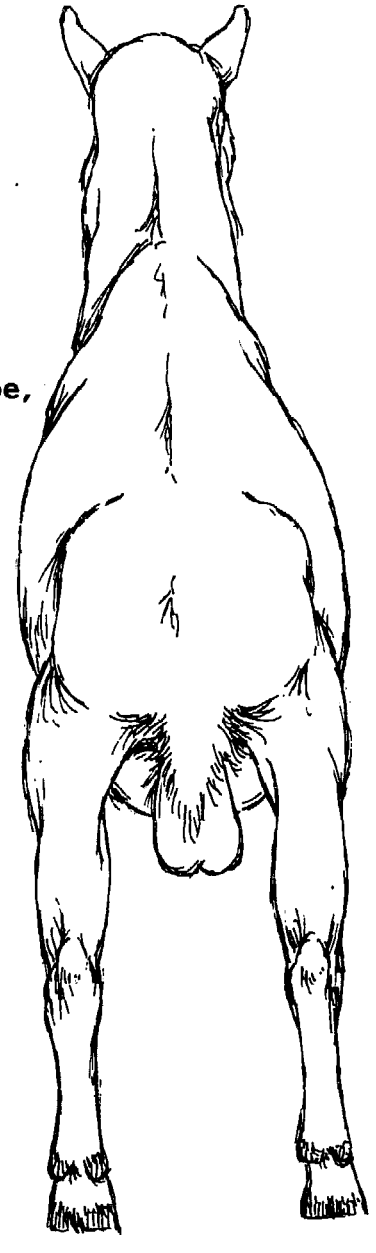

7) Evaluating Bucks - When you select a buck to breed your doe, be sure he is in good health.

   a) The buck should be masculine. His head should be medium in length. He should have a broad muzzle with large open nostrils. His eyes should be bright.

   b) His back should be strong and straight. His rump long, wide and nearly level. He should have strong legs and feet. His legs should be wide apart and squarely set.

   c) The buck should have two testicles of appropriate size. Visible parts of the reproductive system should show no evidence of disease or disability.

   d) Two rudimentary teats of uniform size should be squarely placed below a wide, arched escutcheon.

   e) A buck should have dairy character and show animation, general openness and freedom from excess tissue. He should have a large body capacity to provide ample digestive capacity, strength and vigor.

8) Determining the Age of Goats

Sometimes when we look at a dairy goat, it is helpful to know the age. We can determine this by looking at the goat's teeth.

Goats have no teeth in the upper jaw. The lower jaw has eight front teeth. Toward the back of the mouth goats have large teeth called molars to chew the grass.

The front teeth are small and sharp in animals less than one year of age. At about one year, the center pair of teeth will drop out and are replaced by two large permanent teeth. At about two years, two more large front teeth appear, one on each side of the first two yearling teeth. The three to four year old has six permanent teeth. The four to five year olds have a complete set of eight permanent teeth in front.

After this age, the approximate age can be told by the amount of wear in the front teeth. As the animal gets older, the teeth spread apart and finally become loose and some drop out. At this age the animal begins to lose its usefulness as a grazing animal. It may be kept and fed specially prepared feeds if the animal is still capable of reproduction. (Colby, Dairy Goats, Breeding, Feeding, Management)

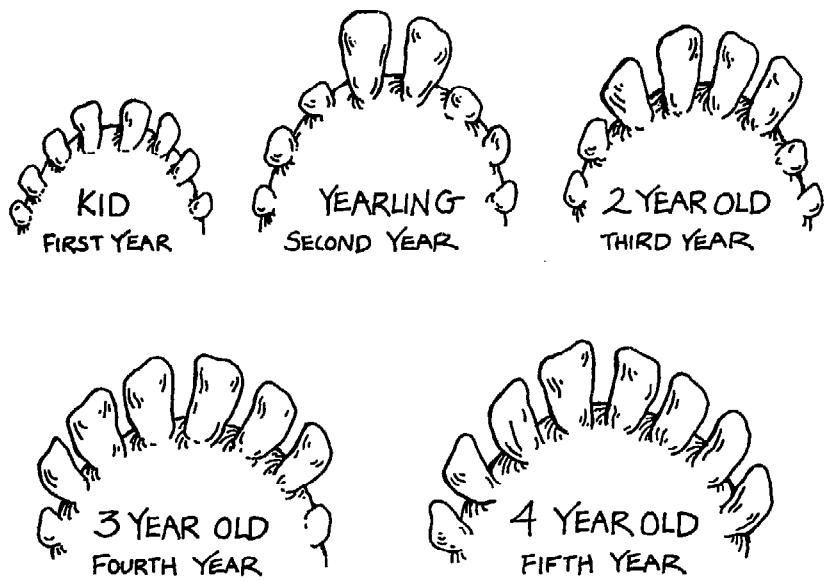

9) To determine the weight of a goat, measure the goat around the heart girth. Pull the tape tightly.

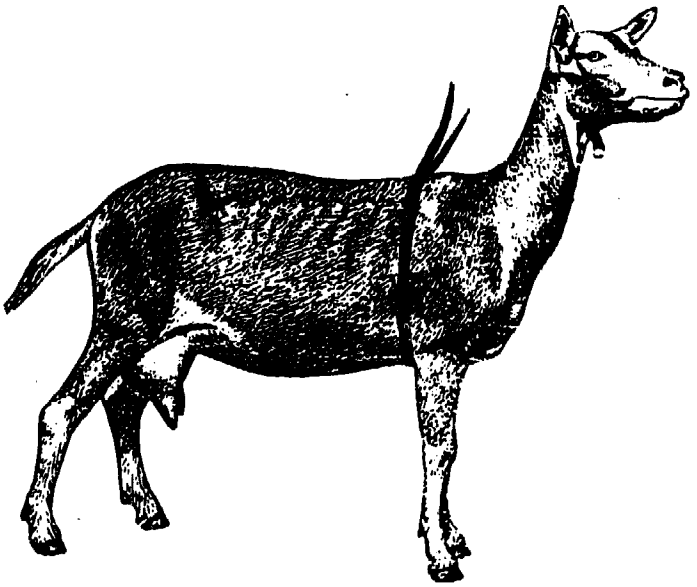

WEIGHT CHART

Inches	Centimetres	Pounds	Kg.
10-¾	27.3	5	2.27
11-¼	28.6	5-½	2.49
11-¾	29.9	6	2.73
12-¼	31.1	6-½	2.95
12-¾	32.4	7	3.17
13-¼	33.7	8	3.63
13-¾	34.9	9	4.08
14-¼	36.2	10	4.54
14-¾	37.5	11	4.99
15-¼	38.7	12	5.44
15-¾	40.0	13	5.90
16-¼	41.3	15	6.80
16-¾	42.7	17	7.71
17-¼	43.8	19	8.62
17-¾	45.1	21	9.52
18-¼	46.4	23	10.43
18-¾	47.6	25	11.34
19-¼	48.9	27	12.24
19-¾	50.2	29	13.15
20-¼	51.4	31	14.06
20-¾	52.7	33	14.97
21-¼	53.9	35	15.87
21-¾	55.3	37	16.78
22-¼	56.5	39	17.69
22-¾	57.8	42	19.05
23-¼	59.1	45	20.41
23-¾	60.3	48	21.77
24-¼	61.6	51	23.13
24-¾	62.9	54	24.49
25-¼	64.1	57	25.85
25-¾	65.4	60	27.21

Inches	Centimetres	Pounds	Kg.
26-¼	66.7	63	28.57
26-¾	67.9	66	29.93
27-¼	69.2	69	31.29
27-¾	70.5	72	32.65
28-¼	71.7	75	34.01
28-¾	73.0	78	35.37
29-¼	74.3	81	36.73
29-¾	75.6	84	38.10
30-¼	76.8	87	39.46
30-¾	78.0	90	40.82
31-¼	79.4	93	42.18
31-¾	80.7	97	44.00
32-¼	81.9	101	45.80
32-¾	83.2	105	47.62
33-¼	84.5	110	49.89
33-¾	85.7	115	52.15
34-¼	87.0	120	54.42
34-¾	88.3	125	56.69
35-¼	89.5	130	58.96
35-¾	90.8	135	61.22
36-¼	92.1	140	63.49
36-¾	93.4	145	65.76
37-¼	94.6	150	68.08
37-¾	95.9	155	70.29
38-¼	97.2	160	72.56
38-¾	98.4	165	74.83
39-¼	99.7	170	77.10
39-¾	101.0	175	79.37
40-¼	102.2	180	81.63
40-¾	103.5	185	83.90
41-¼	104.8	190	86.17
41-¾	106.1	195	88.44

Adapted from Ralston Purina Company.

GROWTH RECORDS

It is important to keep growth records. This helps you to determine if kids are developing properly.

Age	Kg	Lbs
Birth	3.8	8
1 mo.	9.4	21
2 mo.	14.4	32
4 mo.	25.6	57
6 mo.	32.8	73
12 mo.	48.6	108
18 mo.	61.4	136
21 mo.	64.8	144

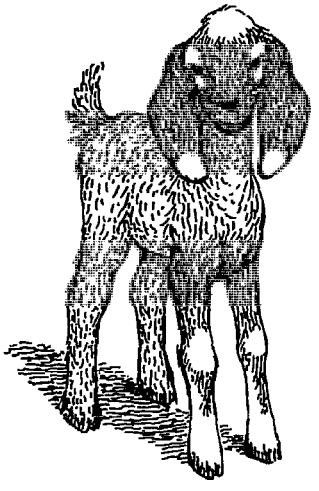

Although these figures are not necessarily offered as the "ideal", they should give you some indication as to average growth patterns.

Source: Adapted from Dairy Goat Journal, April 1971

TASKS FOR LESSON 1:

1) Work with another person to identify the parts of a goat's body.

2) Use the teeth chart to determine a goat's age.

3) Select a goat and use the observation sheet.

OBSERVATION SHEET

Additional Observation Sheets will be found at the end of the manual.

Name of goat to be observed _____

Tag Number (if any) _____ Tattoo _____ Sex _____

Breed _____ Age _____

If Female: Bred _____ Open _____ Date Due to Kid _____

If Male: Check testicles to be sure both are descended. Check general condition of reproductive organs.

Current Feeding Schedule _____

Weight _____ Compare with projected weights on Page 19 of Manual.

Treated for parasites _____ When _____ Medication _____

Each day observe the following and record:

1) General Appearance

2) Activity Level

3) Legs and Hooves

4) Any external problems such as abcesses, parasites, etc.

5) Condition of eyes, nose, mouth

6) Condition of feces (droppings) - pellet-like, ploppy, loose, diarrhea

7) Milk Production - if lactating _____ kilos per day

_____ liters per day

Any signs of mastitis

8) Eating habits

9) Check any of the following signs of illness:

_____ off feed	_____ standing off from group
_____ dehydration	_____ abnormal temperature
_____ limping	_____ pale mucosa around eyes and in mouth
_____ blindness	_____ heavy mucous in nose or mouth
_____ diarrhea	_____ no sign of cud chewing
_____ runny eyes	_____ swelling at any point in body
_____ circling movements	_____ hair falling out or rough in appearance
_____ clots or bloody milk	

LESSON II - HOUSING, FEEDERS AND CONTAINMENT

I) HOUSING

Housing for your goats should have a dry floor and good ventilation. The housing should protect your goats from the sun and rain.

Stilted housing is common where rainfall is heavy and goats need protection against possible waterlogging. In this type of housing the floor of the pen is raised about 1-1.5 meters above ground level. This facilitates easy cleaning and collection of manure and urine. Slatted floors are one of the components of this type of housing.

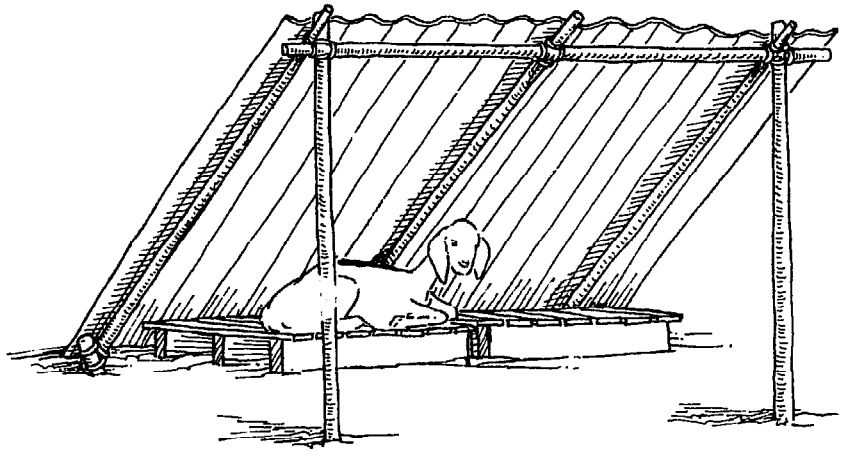

The ground-level house with a dirt floor takes several forms. It may be a lean-to type of building. In this type of housing the buildings are about 2-3 meters high, sloping to about 1-1.5 meters behind. The floor can be made out of rough concrete, but more commonly is packed clay or earth. If you put a drainage ditch around the housing, it will keep the floor dry during heavy rains. If you use a dirt floor, make pallets or sleeping benches for your goats to rest on.

Whatever the type of housing, it must be light, well-ventilated, and easily cleaned. Materials must be suitable to local conditions.

(Above paragraphs adapted from C. Devendra - Goat Production in the Tropics.)

Housing for bucks should be separate from the does. Having a buck near the milking area will give the milk a bad taste. His building can be small, but he should have an outside pen and dry floor. He can also have a pallet to sleep on and should have appropriate mangers and feeders.

Kids should be separated from the doe by the age of two weeks. Up to six weeks of age, they can be kept in one meter boxes which have solid sides. These should be cleaned daily, but are good in that they keep the kids from drafts. The kids should have small mangers and feeders.

Each mature goat needs:

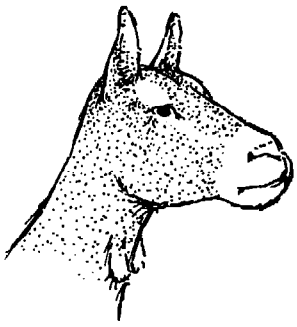

1.5 meters by 1 meter of space
shelter from rain, heavy winds and too much sun
a dry floor - well drained soil works well
- a slatted floor should be wide enough for manure to fall through, but narrow enough that a goat's legs do not get caught
- housing designed for easy manure removal
- good ventilation. Hot air rises, so make openings high to prevent drafts
- a pallet or sleeping bench
- exercise

2) MANGERS AND FEEDING EQUIPMENT

The most important thing about the manger is that it keeps the green chop, hay or vegetable cuttings off the ground so that they will not be contaminated. There are many different kinds of mangers. They must be built suitable to the goat's size and in such a way that the goats cannot contaminate them with their feet.

Slatted Feeder

If slatted feeders are too high above the goat's head, the dust from the hay can irritate the goat's eyes. There will always be some waste in this type of feeder as the hay which falls on the ground will be wasted. Put a bar on the top. Otherwise the goats may sleep in the feeder.

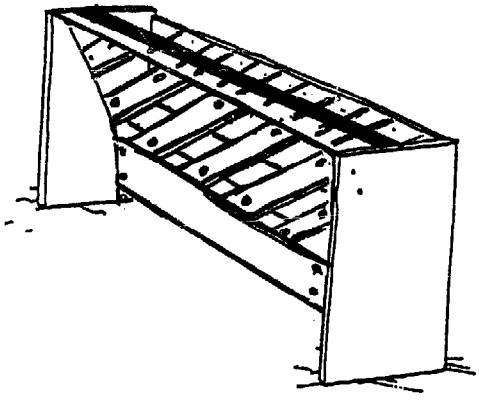

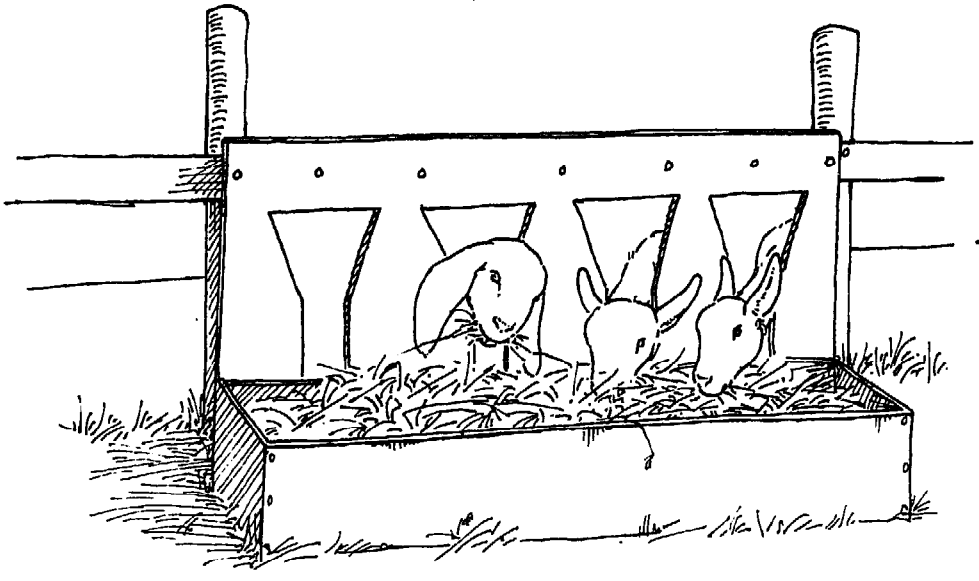

Keyhole Feeder

Keyhole feeders prevent contamination of the feed. Waste is further prevented if a box can be placed on the opposite side from the keyholes.

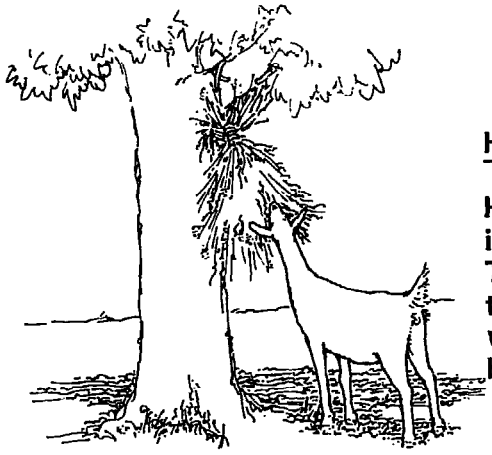

Hay Can Be Tied

Hay can be tied to the pen or on a tree branch if you do not have a manger or keyhole feeder. The important thing is that the hay is kept off the ground. Be sure the rope is tied in such a way that when the hay is gone the goat cannot be strangled by the rope.

Water Buckets

Water buckets are very important. They should be kept clean and should be low enough to be reached by small animals. For larger animals hanging the buckets above the ground keeps the water from being soiled. Water buckets can also be placed outside the pen with access through keyhole opening.

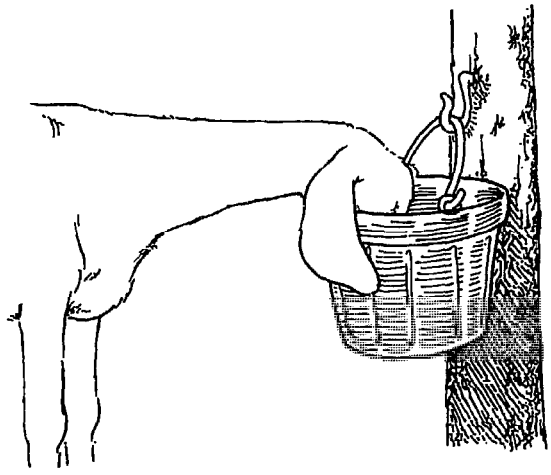

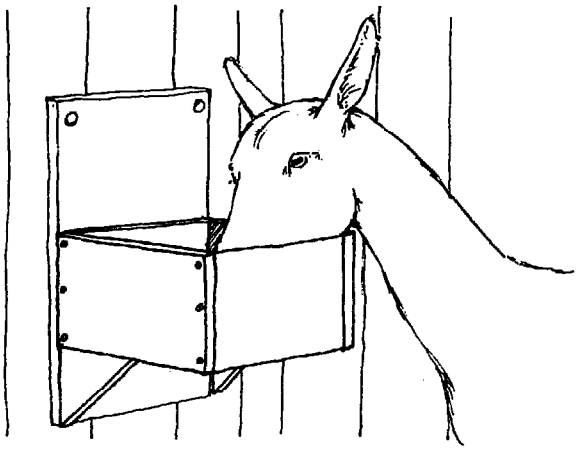

Salt Boxes

Mineral salt should be offered free choice and be kept in a container which is off the ground. This can be a small wooden box. If mineral salt is not available, then give common salt to your animals.

3) CONTAINMENT

Fencing must be strong and high enough to contain a goat. Wire fencing is expensive so you will probably want to make your fences from bamboo or other small timbers. A living fence can be planted. The top of the fence often can be cut and used for forage. Leucaena (Ipil-Ipil) is one example.

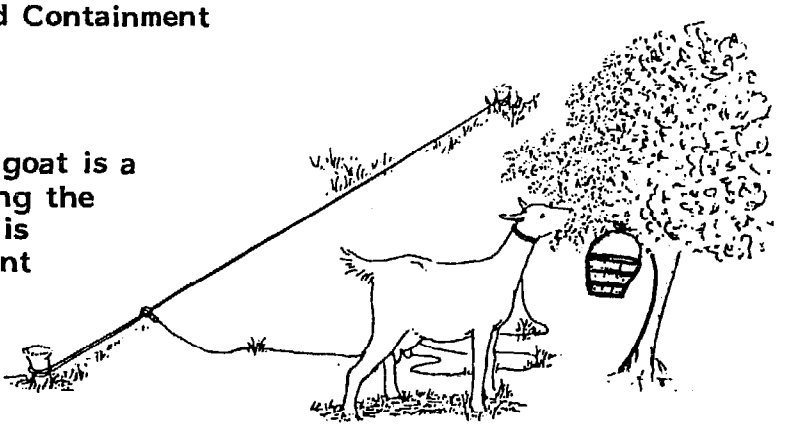

Tethering or tying a goat is a popular way of keeping the animal. When a goat is tethered it is important to see that the goat can get into the shade and be moved often so that it can get enough feed. A running tether is one which has a long wire or rope staked at both ends. The tether is attached with some kind of ring. This gives the goat opportunity to forage in a wider area.

Be sure water is available.

Do not tether your animal if dogs or wild animals may attack.

Be sure to check for any poisonous plants.

Herding

There may be times when you want to herd your goats so they can get different varieties of forage.

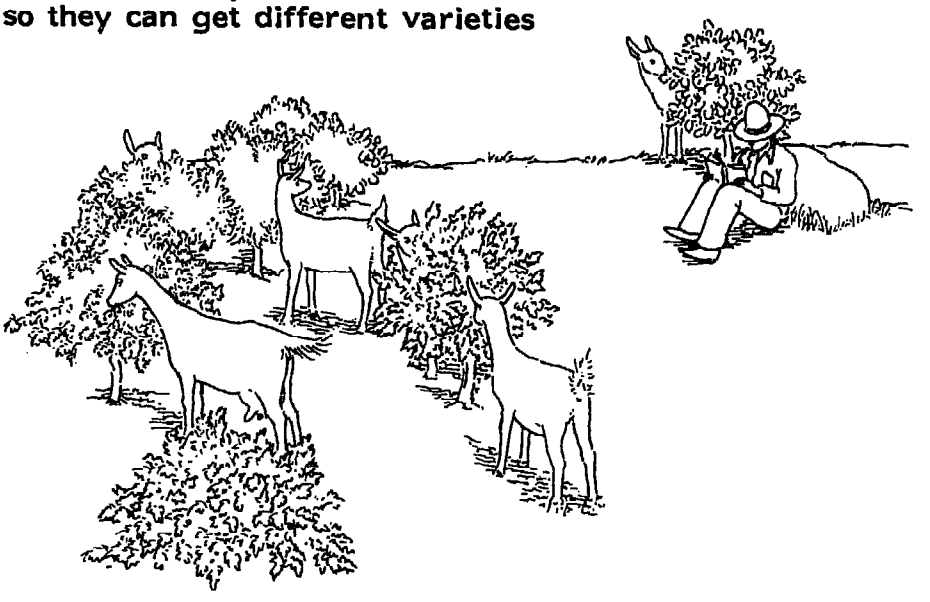

4) MILKING EQUIPMENT

You will need the following equipment and supplies for milking your goat:

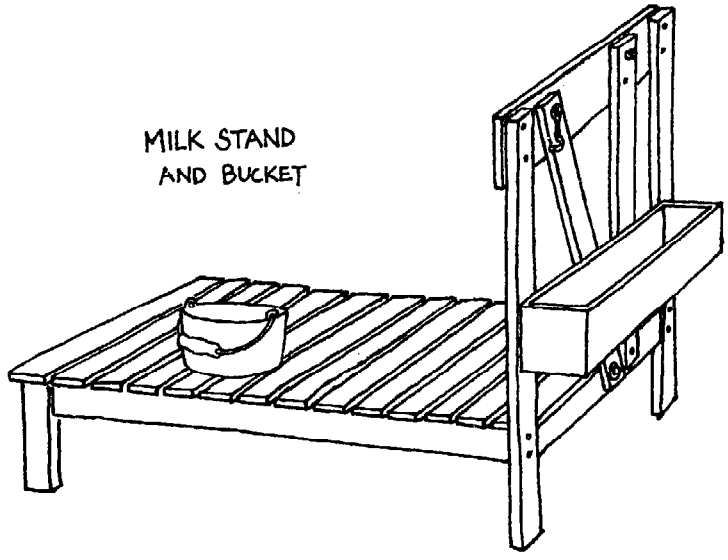

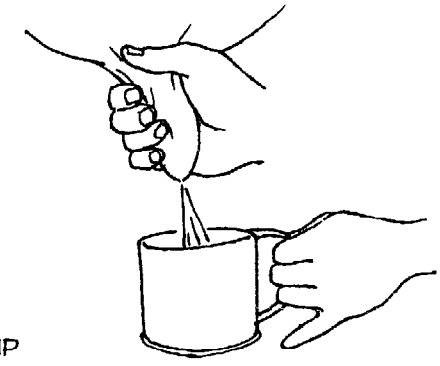

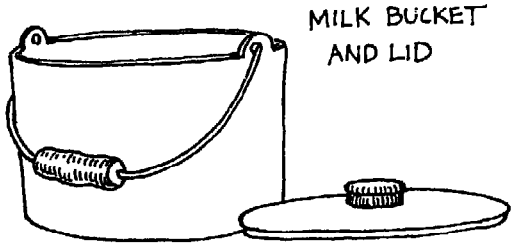

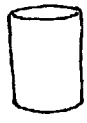

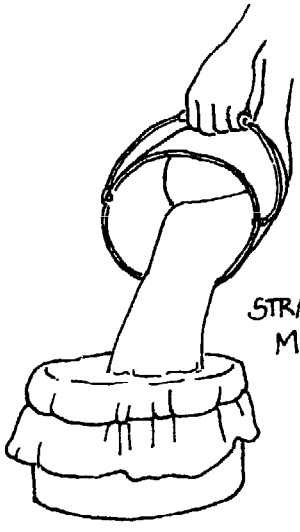

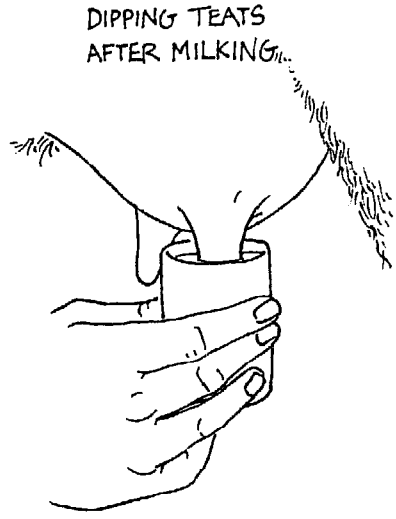

TASKS FOR LESSON II:

1) Describe the housing you plan for your goats. Indicate materials which will be needed. Tell about the kind of containment you will provide - fencing or tethering.

2) Draw a sketch of the housing, feeders and mangers you plan.

3) List the other equipment and supplies you will need for keeping your goat such as milk stand, etc.

LESSON III - FEEDING

The dairy goat requires five major classes of nutrients - energy, protein, minerals, vitamins and water. Fiber is also important in the diet.

Dairy goats are energetic, inquisitive and versatile in the art of food gathering. They can consume large amounts of browse (tree leaves, bushes, twigs, etc.) in contrast to cattle and sheep who prefer grasses and legumes.

Their mobile upper lip enables them to discriminately select favored parts of plants. Goats chew their food more completely than cattle and therefore can obtain a higher per cent of digestible material from their diet.

1) The Ruminant Digestive System

Goats are ruminant animals. This means they chew their cud. Cows are ruminants. Sheep are ruminants. Ruminants are animals with four stomachs. This means they can eat grasses and feeds that are not digestible by one stomach animals. A pig and a chicken have only one stomach. Their digestive system is called monogastric.

To feed, the goat grips the grass or forage with the upper jaw and teeth in the lower jaw and jerks its head to pull out the grass.

It does not chew the grass, but swallows it and the grass goes into the first stomach (rumen).

Grass comes back into the mouth to be chewed for a long time. This is called "chewing the cud." Then it goes to the second stomach (reticulum) and to the third stomach (omasum) and fourth stomach (abomasum).

Ruminants can eat grass, bush, corn stocks and all kinds of products that humans and single stomach animals cannot eat. They then transform these roughages into milk and meat which provide protein, calcium, vitamins and minerals for human growth.

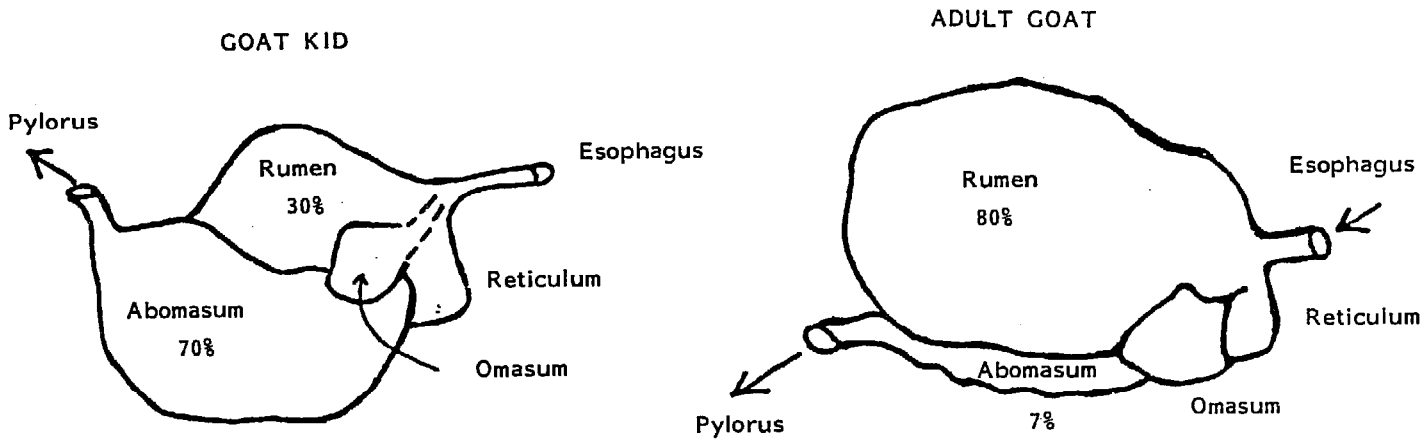

The RUMEN is the largest of the compartments and contains many microorganisms which supply enzymes to break down fiber. It is often called the fermentation vat. Protein and B Vitamins and also Vitamin K are all produced in the rumen.

The RETICULUM is the second stomach and is just below the entrance of the esophagus into the stomach. Actually, the reticulum is part of the rumen, being separated by a partial wall. The lining of the reticulum looks like a honeycomb.

The OMASUM consists of hanging layers of tissue. The large surface area of these folds permits absorption of moisture from feed as it passes into the fourth stomach.

The ABOMASUM is considered the true stomach. It contains hydrocloric acid and enzymes that break down feeds into simple compounds that can be absorbed by the stomach walls and the intestines.

2) Feeding the Newborn

COLOSTRUM is the most important ingredient for a newborn kid's diet. This is the first milk produced by the doe. It is usually very thick and may be pale yellow in color. It is rich in antibodies which protect young kids against disease. Newborn kids should have colostrum within the first hour after birth.

<u>Normal Program</u>

First Week . . . . . Leave kids with doe
Second Week . . . . . Take kids from doe and bottle or pan feed.
Give ½ liter (1 pint or 2 cups) of milk three times each day.
Put protein supplements, hay and water near the kids and they will soon learn to eat and drink well.

Third and Fourth Week . . . . . Two liters of milk divided into three feedings, along with protein supplement, hay and water.

Fifth and Sixth Week . . . . . Continue to feed 2 to 2½ liters of milk divided into three feedings.

Seventh Week . . . . . Decrease number of feedings to two

Eighth and Ninth Week . . . . . Same as seventh

Ninth to Twelfth Week . . . . . Decrease milk slowly to once a day. Wean kid.

4 cups = about 1 liter

If your doe is penned and the kids are left with the doe, you may want to make a creep feeder for the kids. This is a space in the fence that the kids can pass through to get feed and water and green chop, but which the doe cannot reach.

The kids should weigh about 15 kilos at the weaning age of three months.

CAE Prevention Program (See also P. 79)

At Birth . . . . . Take kids from doe immediately. Do not let kid suckle. Do not let doe lick kids. Towel dry.

Feed kid(s) at least 2 ounces heat treated colostrum within one hour of birth.

Continue to feed colostrum at 4-hour intervals during first day.

First Week . . . . . Give ½ liter (1 pint or 2 cups) pasteurized milk or milk replacer 3 times each day.

Second through Twelfth Week . . . Follow feeding schedule in normal program using pasteurized milk.

Keep kids away from physical contact with adult goats.

HOW TO HEAT TREAT COLOSTRUM

Fill stainless steel thermos with water that has been heated to 131°F.

Seal for 1 hour. The water should still be at 131°F or a few degrees higher when removed from thermos.

Heat colostrum to 131°F. Watch carefully. Do not exceed 131°F or you will kill antibodies.

Pour water out of thermos.

Pour in heated colostrum.

Seal for one hour.

Refrigerate or freeze in another container for future use.

How to Feed a Kid When It Is Taken From the Doe

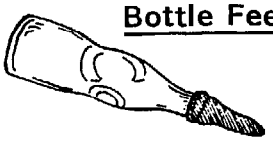

Bottle Feed - a baby bottle or Coke or Fanta bottle will do. Be sure the bottle and nipple are clean at every feeding.

Pan Feed - you can teach the kid to drink from the pan by sticking your finger in the milk and letting the kid suck your finger or by putting the kid's mouth into the milk. Pan feeding is often easier and there is less contamination. Wash the pan with soap and water and sun dry after every feeding.

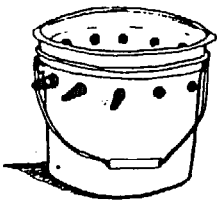

Bucket Nurser - As your goat herd grows and you have many kids, you may want to make a bucket nurser. This takes a plastic bucket, some kind of plastic tubes and nipples. You can feed up to 8 kids at a time. However, it is very important that the tubes, nipples and bucket be kept very clean. Place bucket in some kind of sturdy frame at correct height.

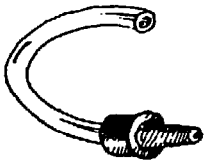

Lambar Nipples - Australian-made natural rubber nipples for lambar-style feeders. Flange on back holds tube which reaches into milk. Nipple fits through 5/8" hole which should be placed 7" above bottom of bucket.

Order from Caprine Supply, 6657 Woodland, Shawnee, Kansas, U.S.A. 66218.

Multiple Bottle Nurser - You can make a similar nurser to hold bottles with nipples.

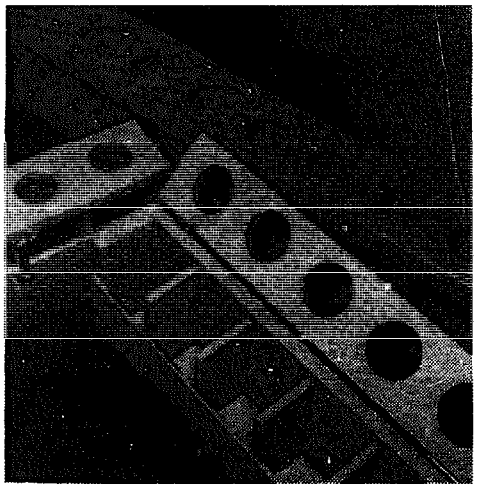

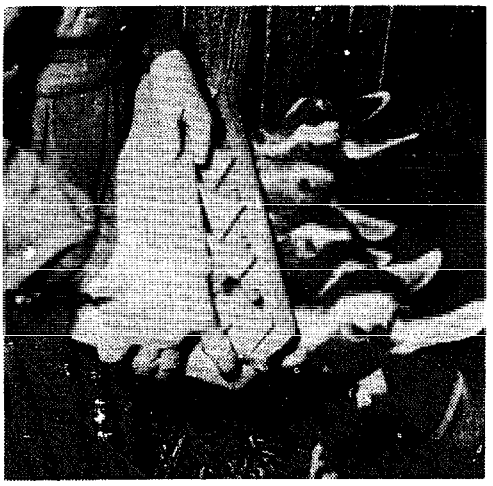

Pictures courtesy of Benedictine Nuns, Mont-Laurier, Quebec, Canada

Taking the Kids From the Doe at Night Provides Extra Milk for Your Family

You may choose to leave the kids with the doe until they are weaned. However, you may still want a small amount of milk for your family.

Take the kids from the doe each evening and place them in a 1 x 1 meter enclosure with solid sides. This prevents unhealthy drafts.

Each morning, milk out the doe and save that milk for your family to drink. Put the kids back with the doe. Repeat this procedure each day.

Milk Replacers

If the doe should die or be unable to produce enough milk for her kids, you will need to use a substitute for the doe's milk. Try to get colostrum from another doe to give to the kid. In some locations milk replacers made especially for goats are available. If these are not available, use powdered milk or cow's milk. In the early stages you may want to dilute it with about 10% water.

3) Feeding the Weaned Kid Up to One Year

The important thing is to provide enough feed that a kid will grow well. Be sure the kid gets plenty of good mixed hay, browse or pasture, plus a protein supplement, mineralized salt and water.

4) Feeding the Mature Goat

A dairy goat will produce best on a diet of plenty of green chop and at least one-half kilo of 16% protein concentrate (feed) a day.

A mixture of green chop and legume hay is excellent for dairy animals. Legume hay is hay made from special grasses and plants high in protein. Lucerne (alfalfa), Desmodium spp. (silverleaf desmodium, greenleaf desmodium), clover, beans, peas and groundnuts are legumes.

Remember if you tether (tie) your goat or have her in a pasture, be sure your goat has access to shade and water. Remember, goats are browsers, not grazers, although they will eat grass. An area with low bushes is ideal for your goat.

You can also feed your dairy animal trimmings from your vegetable garden - beets, cassava leaves, cabbage leaves and bean vines. Be careful of green potatoes, tomato and potato vines; they contain solanin, which is toxic. You can also give your goat beans, groundnuts or bambara groundnuts, sunflower seeds and banana peels. Do not feed too many banana peels as this can cause diarrhea.

ALWAYS GIVE YOUR ANIMAL MORE GREEN CHOP (FORAGE, BROWSE) THAN SHE CAN EAT. BE SURE THAT IF YOU ARE CUTTING AND CARRYING THE GREEN CHOP TO YOUR ANIMAL THAT IT IS PLACED IN A MANGER OFF THE GROUND. YOU CANNOT FEED TOO MUCH GREEN CHOP.

WATER IS ONE OF THE MOST IMPORTANT INGREDIENTS OF A DAIRY GOAT'S DIET. BE SURE SHE RECEIVES 6-8 LITERS OF CLEAN WATER EACH DAY. IF THE WATER IS CONTAMINATED BY FECES OR OTHER FOREIGN MATTER, YOUR GOAT WILL NOT DRINK IT.

Protein and mineral supplements are recommended.

Cottonseed cake is a good protein supplement. One kilo of cottonseed cake will provide your goat with adequate protein for four days. Wheat bran and rice bran contain good amounts of protein, although they are generally referred to as energy feeds.

Goats require calcium and phosphorus in their diet. Bone meal is high in calcium. Alfalfa, timothy, red clover, mulberry, kudzu, elephant grass (napiergrass), seaweed (kelp) and dried citrus pulp are also good sources of calcium. Orchardgrass, sudangrass, rice bran, wheat bran and oats are good sources of phosphorus. Many tropical grasses are low in phosphorus.

Be sure your goat has salt in her diet. Mineralized salt is best. Iodized salt will provide needed amounts of iodine. Common table salt can be used if prepared mixes are not available. Make a salt box and put in loose salt for your goat to eat free choice. Salt blocks are also acceptable.

Vitamin E and selenium should be provided in areas where these are deficient. Most of the other minerals your goat requires will be supplied in the forages your goat eats.

5) Feeding the Milking Doe

Rations for the milking doe should contain 14-16% crude protein. Feed requirements are greatly increased during lactation. If you feed a prepared concentrate, feed .5 kilo of concentrate for each 1.5 kilo of milk produced. High quality hay will provide extra protein.

If you feed the milking doe on the milk stand, leave her on the stand for about five minutes after you finish milking so that she will consume additional protein supplements or concentrate.

6) Feeding the Pregnant Doe

When a doe is three months pregnant you should stop milking her. The kids inside the doe will be growing the fastest and requiring the most nutrition during these final weeks.

If you have been feeding legumes (clover, alfalfa) which are high in calcium, it is best to replace these with grass hay at least three weeks prior to kidding to help prevent milk fever. This forces the animal to mobilize her own body stores and prepare for lactation.

A fat doe will have trouble kidding.

Be sure the goat gets mineralized salt and water during these critical times.

7) Feeding the Breeding Buck

Proper feeding is very important for the breeding buck. High quality hay in large quantity will help maintain and grow the buck at a reasonable cost. When not being used for breeding, good pasture alone will maintain the buck in good health.

Two weeks before and during the breeding season gradually build up to ½ kilo of concentrate or some kind of protein supplement twice each day. Plenty of water and exercise is also important for the breeding buck. Never let a buck become fat or sluggish or this may cause him to be sterile. Excessive gain when the buck is inactive may cause overweight. A buck needs only 12-14% protein in his diet. After the breeding season, reduce concentrate feeding.

8) Compositions of nutrients in a goat's total diet should be:

14-16% Protein
11% Digestible Protein
63% TDN (Total Digestible Nutrients)
16-18% Fiber
.6-1.0% Calcium
.4-.5% Phosphorus
(The ideal calcium/phosphorus ratio for milking does is 1.5:1)

9) Examples of Feeds

ENERGY FEEDS -	Barley, oats, corn, bran, beetpulp, milo, wheat
PROTEIN FEEDS -	Peas, beans, cottonseed cake or meal, soybean meal, linseed meal, brewers grains
CALCIUM FEEDS -	Bone meal, elephant grass, citrus pulp
PASTURE/LEGUMES - GRASSES	Hay (alfalfa, grass, clover), silage (alfalfa, grass, corn), roots (sugar beets, yucca) and garden refuse free from chemical residue
COMMERCIAL FEEDS -	Concentrates, mineral mixtures

10) Hay Storage

During the rainy season and during the extreme part of the dry season, you will want to cut hay (forage) and bring into your barn or shelter to dry and store for your animals. Cut forages or grasses for hay in the early bloom stage of maturity. Try to cut the hay during rain-free weather. Leave to dry one or two days before baling or stacking.

Hay which contains too much moisture will mold and be unsuitable for feeding. You can store the hay for many weeks and it will make management of your animals easier during times when it is difficult for your animals to graze.

Elephant grass grows well in many places. If this is cut when it is young, it makes good hay. Sudangrass may also be used.

11) Silage

Silage is less palatable to goats then hay, but may have storage advantages. Silage is hay which is cut into small pieces and stored in airtight conditions until fermentation occurs. Corn silage is made by chopping the stalk and the ear. Corn silage is an acceptable feed, but should be combined with other forages and a protein supplement. Grass and legume silage are fed extensively to goats in Norway and France.

Small amounts of silage may be cut and stored in plastic bags. After cutting, press silage tightly into the bag. Press out all of the air and tie the opening. Each time you feed, press out the air.

Larger amounts of silage may be stored in a trench silo. Your livestock extensionist can advise you on proper proceedures.

12) Forages and Grasses

On the following pages are photographs of various forages. This is not an exhaustive list. You will want to add the forages from your area.

In Central America, Mulberry leaves, Confrey and Ramio are widely used. In the Caribbean, Acacia is an important forage plant. The following are used in West Africa.

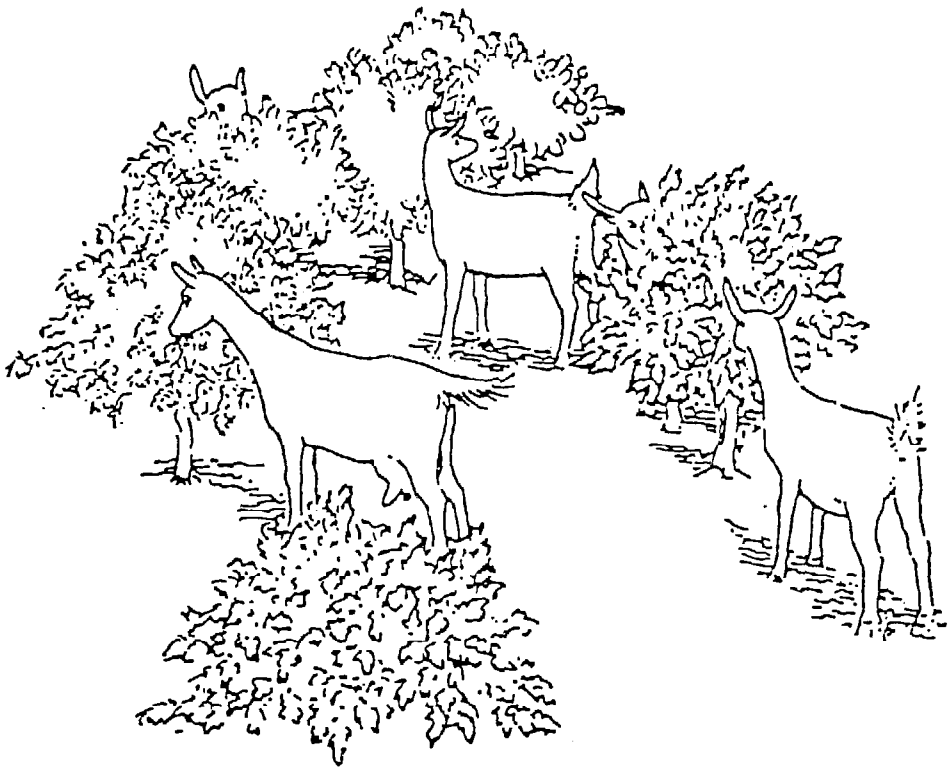

Photos by Barbara Needham
Forage Specialist - Martin Djakari

STYLO or BRAZILIAN LUCERNE

Alfalfa-like perennial. Mixes well with grasses. Palability low in rainy season, but readily eaten in dry season. Young plants best. A legume.

DESMODIUM spp.

Prostrate creeping perennial or annual with small leaflets of pink, blue and purple flowers. For grazing, but not as desirable as others. A legume.

PENNISETUM PURPUREUM
Elephant grass, Napiergrass, Uganda grass

High yielding, tall erect perennial grass with thick stems. Tolerant of short drought, but not waterlogging. Prefers deep soils of moderate to heavy texture. Used for hay, silage and potential grazing. Contains some calcium.

TRIPSACUM LAXUM
Guatemala grass, Honduras grass

Tall broad-leafed perennial. Grows tall. Is a good crop for dry season. Grows in humid areas, but not suited for grazing. Can be used as green chop or hay. More persistent, but less nutritious than Elephant Grass.

HYPARRHENIA RUFA
(Jaragua Grass or
Thatching Grass)

Palatable forage before tussocks form. Can be used as hay. Flowering stands must be mowed or burned.

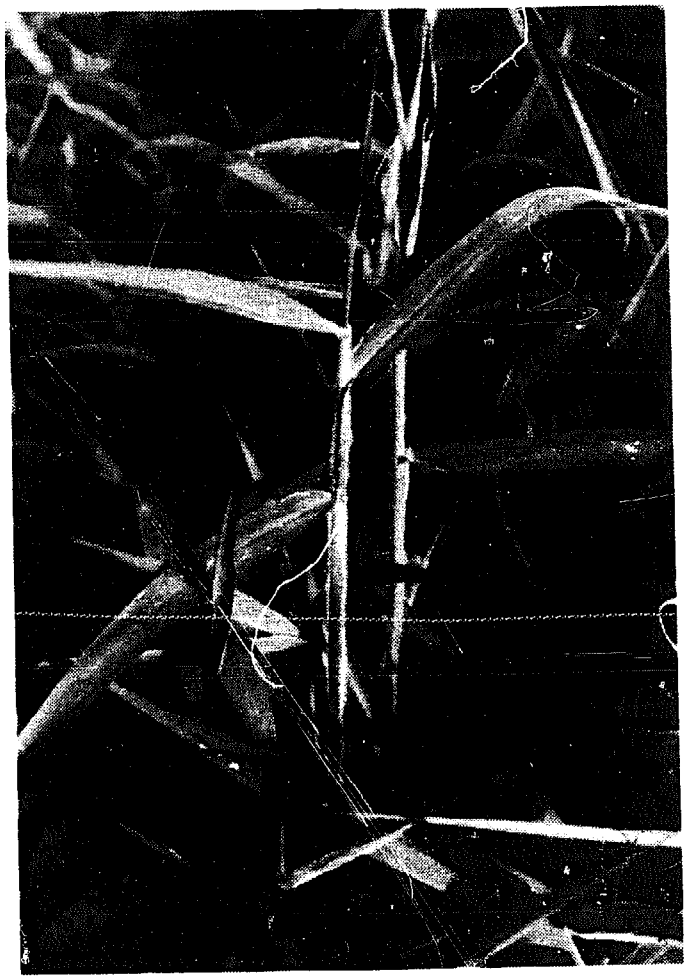

CYMBOPOGAN spp.
Oil grass

Hardy, upright perennial - bunchgrass with many leaves. Seed heads resemble oats. Well adapted to light textured soils suitable for pasture or hay.

PENNISETUM CLANDESTINUM
Kikuyu grass

Excellent pasture - contains high levels of digestible protein through maturity. Stocking rates should be light until grass is well established. Vigorous, aggressive, perennial grass. Prefers well-drained soils - drought resistent.

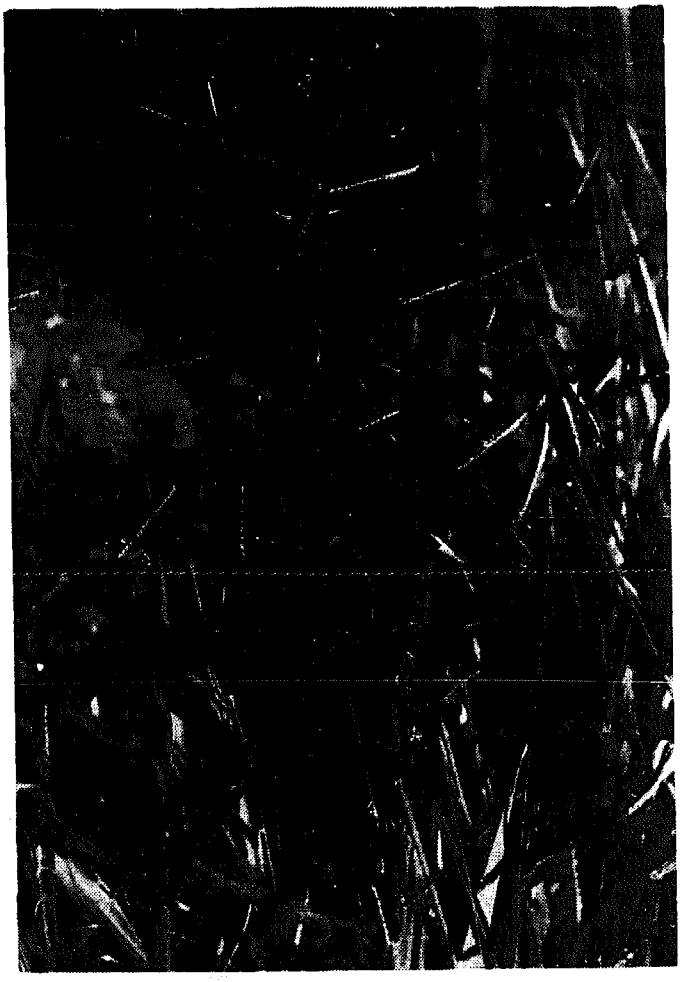

BRACHIARIA spp.

Tufted perennial with erect or sub-erect stems.

13) PROTEIN SUPPLEMENTS	% Dry Matter	% Digestible Protein	% TDN	% Calcium	% Phosphorus
Cottonseed Cake	93.5	14.9	90.0	.14	.67
Rice Bran	90.7	8.4	58.9	.07	1.59
Soybean Meal	91.3	46.6	71.2	.29	.65
Brewers Grain	91.0	19.1	60.3	.27	.48
Groundnuts (peanuts)	91.5	42.7	70.3	.20	.65

Comparative Feeding Value of Selected Feedstuffs

Feedstuff	% Dry Matter	% Crude Protein	% Dig. Protein	% Total Dig. Nut.	% Fiber	% Cal.	% Phos.
Legume hays:							
Alfalfa, ave. anal	90	15.9	11.7	51	27	1.38	.20
Alfalfa, early cut	89	17.7	13.4	51	25	1.28	.23
Alfalfa, mature	91	12.0	8.4	50	35	1.07	.16
Alfalfa, dehy, pel.	92	17.5	12.7	56	24	1.33	.24
Peanut (few nuts)	91	9.9	6.1	51	30	1.12	.15
Cowpea	90	15.6	10.6	52	26	1.22	.31
Soybean	90	14.4	9.7	50	30	1.10	.24
Velvet bean	87	12.9	7.9	56	31	1.10	.22
Clover, white	90	19.0	13.9	57	22	1.71	.29
Non-legume hays:							
Coastal bermuda	91	11.1	6.9	50	28	.35	.17
Common bermuda	91	9.0	4.6	45	26	.40	.19
Sudan grass	91	10.0	5.2	52	28	.56	.29
Johnson grass	90	8.6	4.7	54	30	.63	.26
Oat, headed	90	8.0	4.6	51	29	.26	.24
Cottonseed hulls	91	3.8	.0	43	43	.14	.08
Peanut hulls	92	6.1	1.5	19	54	.24	.06
Grains:							
Barley	88	12.2	9.6	73	5.0	.04	.33
Corn, # 2 yel.	89	8.7	6.7	82	2.0	.02	.34
Milo	89	10.6	7.5	78	2.3	.03	.28
Oats, all anal.	89	12.1	9.6	68	10.9	.06	.33
Wheat	88	14.9	11.9	78	2.5	.03	.38
Molasses, cane	75	3.9	1.1	55	-	.78	.09
Cottonseeds	92	21.7	14.9	90	18.2	.14	.67
Wheat bran	89	15.2	11.7	63	10.4	.11	1.26
Protein Feeds:							
Cottonseed meal	91	41.0	31.3	66	12.3	.18	1.11
Soybean meal	91	46.7	42.0	73	2.3	.33	1.11
Peanut meal	92	48.7	43.8	71	6.3	.20	.63
Linseed meal	91	35.9	31.2	72	8.8	.39	.84
Bean, pinto	90	22.6	17.2	79	4.0	.13	.46
Cowpea seed	89	23.8	19.5	76	5.0	.09	.44
Pasture/Range:							
Alfalfa, ave.	24	4.7	3.5	14	6.4	.46	.06
Coastal bermuda	31	4.6	3.4	21	8.8	.35	.17
Common bermuda	39	3.6	unkn	23	10.5	.40	.13
Honeysuckle	41	4.1	2.7	23	9.4	. 40	.19
Oat, immature	16	2.5	unkn	10	4.0	unkn	unkn
Ryegrass, Ital.	26	3.8	1.6	15	6.2	.17	.11
Sudangrass, Ave	27	3.4	2.2	17	8.4	.19	.09
Milk:							
Goat, fresh	13	3.5	unkn	17	.0	.13	.11
Cow, fresh	13	3.6	3.4	17	.0	.12	.10
Ewe, fresh	19	6.4	unkn	26	.0	.21	.12

POULTRY LITTER - an optional protein for your goats.

The manure from poultry houses where birds are maintained on litter is designated as "poultry-house litter".

Poultry litter may be successfully fed to goats and other ruminants as a protein supplement. It may contain up to 23% digestible protein. Nutrient composition varies due to bedding, number of birds, etc. Litter from replacement pullets or ongoing layer house programs is best suited. Bedding should not be too deep. Select the litter from well agitated areas when the birds have been on it for at least ten weeks. These are usually within a short distance from the feeders.

The litter may be fed immediately or stockpiled for 4-6 weeks. If you stockpile the litter, it must be out of the rain and well ventilated. Do not cover with plastic. Feed less of your regular concentrate and mix from 10-50% litter in with the concentrate. On a maintenance program you can feed only poultry litter and green chop with no other concentrate.

* Loss of amonia through evaporation lowers the protein content of the poultry litter.

COMPOSITION OF BROILER LITTER

Dry matter (%)	84.7
Composition of dry matter	
Crude protein (%)	31.3
True protein (%)	16.7
Digestible protein (%)	23.3
Percent digestibility (%)	74.6
Crude fibre (%)	16.8
Ether extract (%)	3.3
NFE (%)	29.53
DE (sheep) (kcal/kg)	2440
ME (sheep) (kcal/kg)	2181
Total digestible nutrients (sheep) (%)	72.5
Ash (%)	15
Calcium (%)	2.37
Phosphorus (%)	1.8
Potassium (%)	1.78
Copper (mg/kg)	98
Iron (mg/kg)	451
Manganese (mg/kg)	225
Zinc (mg/kg)	235
Magnesium (%)	0.44

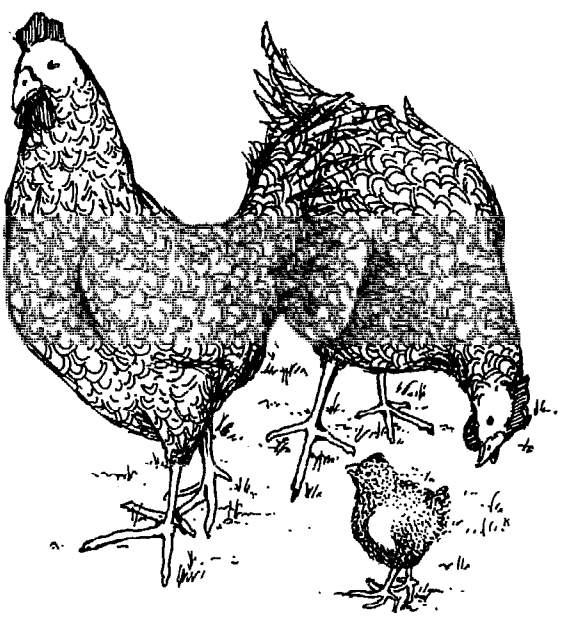

(Source: Bhattacharya and Taylor, 1975)

14) HUSBANDRY SYSTEMS

a) Extensive Production

Extensive husbandry systems are those which provide least protection from the natural environment and involve a minimum of labor. In regions where climatic conditions are favorable and predators are not too numerous, animals may be left free to graze on natural pastures without fencing or housing, being herded into enclosures only when required. The most extensive system in the tropics is bush or range grazing with housing at night and during the rains. It is generally accepted that goats, although hardy in other ways, are intolerant of wet or damp conditions and under such circumstances they are reputed to be particularly susceptible to pneumonia and in the case of milk goats, mastitis.

b) Intensive Production

The most intensive form of production involves continuous housing or "zero grazing". This provides maximum protection from the adversities of difficult environments and gives complete control over the destructive aspects of the goat's feeding habits. It is ideal for dairy goats under tropical conditions and perfect for small family herds. It makes no use of the independent feeding habits of the goat, but cheap materials such as crop wastes, industrial wastes and vegetable peelings can be utilized. Where small numbers are concerned, it is more economical of labor than herding them in the bush and very convenient for the control of feeding and mating. The system is suited to high-producing animals and exotic breeds and their crosses are more likely to be successful on zero grazing than on any other system.

c) Semi-Intensive Systems

This term covers all degrees of compromise between range management and zero grazing, but usually involves controlled grazing of fenced pastures with supplementary concentrate feeding. Tethering commonly replaces fencing.

When tethering is used care must be taken that there is no possibility of strangulation. Shade must be always available, with drinking water and shelter from rain provided when required. It is essential to change the place of tethering every day so that fresh herbage and a variety of plants can be obtained by the animal.

The great advantage of permitting some grazing, whether free or tethered is that it gives the goat an opportunity to supplement the diet provided for it under zero grazing and to do some selective feeding to overcome dietary deficiencies.

Above paragraphs from C. Devendra, Goat Production in the Tropics

15) MANAGING GOATS DURING WET AND DRY SEASONS

Wet Season - Browsing for your animals may need to be limited during the rainy months. Parasites live in the moist grasses and can reinfect your animal easily. In tick infested areas, you will need to spray or dip your animals in insecticide twice a week during the rainy season. Bring the animals into a shelter during the heavy rains and let them browse when it is not raining. You may need to bring hay and green chop to them if they are unable to browse long enough to get adequate feed.

Dry Season - At the beginning of the dry season forage will be plentiful. This is probably the best time for kids to be born and to develop your milking animals. As the season grows longer, there will be fewer bushes and grasses for the animals to browse. For this reason, early in the dry season you may want to cut and store hay to use when it is not plentiful. Also, in tick infested areas spray or dip your animals at least once a week, twice a week if ticks are abundant.

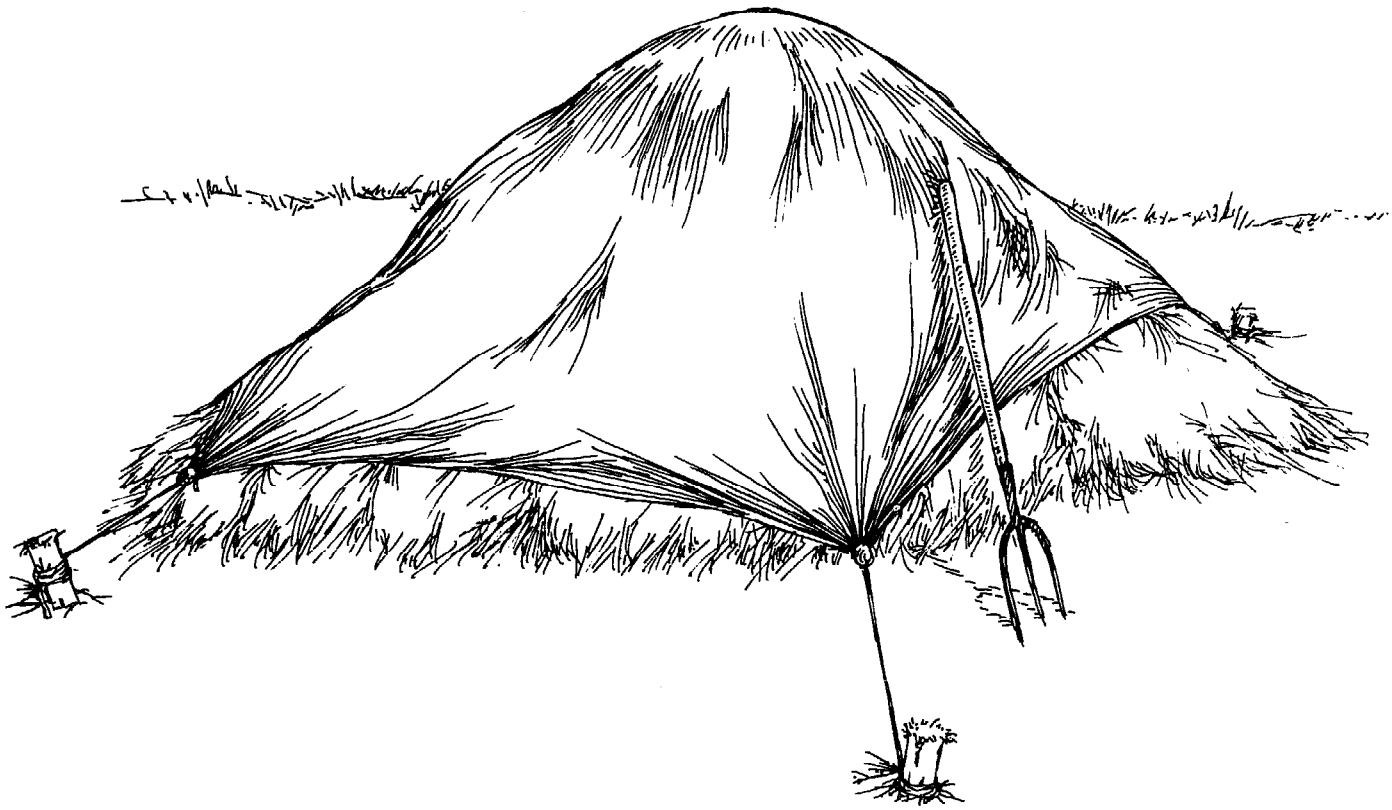

TASKS FOR LESSON III:

1) Practice feeding kid goats with both a bottle and pan.

2) Identify forages and grasses available in your area and collect samples.

3) List the feed resources available to you and write a formula for a good goat ration utilizing forage, pasture and supplements.

LESSON IV - BREEDING AND CROSSBREEDING

1) BREEDING THE DOE

In the Northern Hemisphere goats are, on the average, seasonal breeders. The normal breeding season is August to March. There may be some individuals who cycle at other times during the year, particularly if a buck is introduced or artificial lighting is used.

In tropical climates, goats cycle year round. It is, however, recommended that you breed your does to kid at the beginning of the dry season, as feed will be abundant and both kids and lactating animals will perform well.

The heat (estrus) period lasts from 12-48 hours and ovulation occurs 24-36 hours after the onset of the heat period. The doe should be bred the last half of the estrus. General advice is to breed the second day and repeat in twelve hours if she is still in heat.

The estrus cycle is 17-23 (average 21) days, with older does having shorter cycles.

A doe should be 7-10 months old, or better yet 36-41 kg (80-90 lbs.) before breeding.

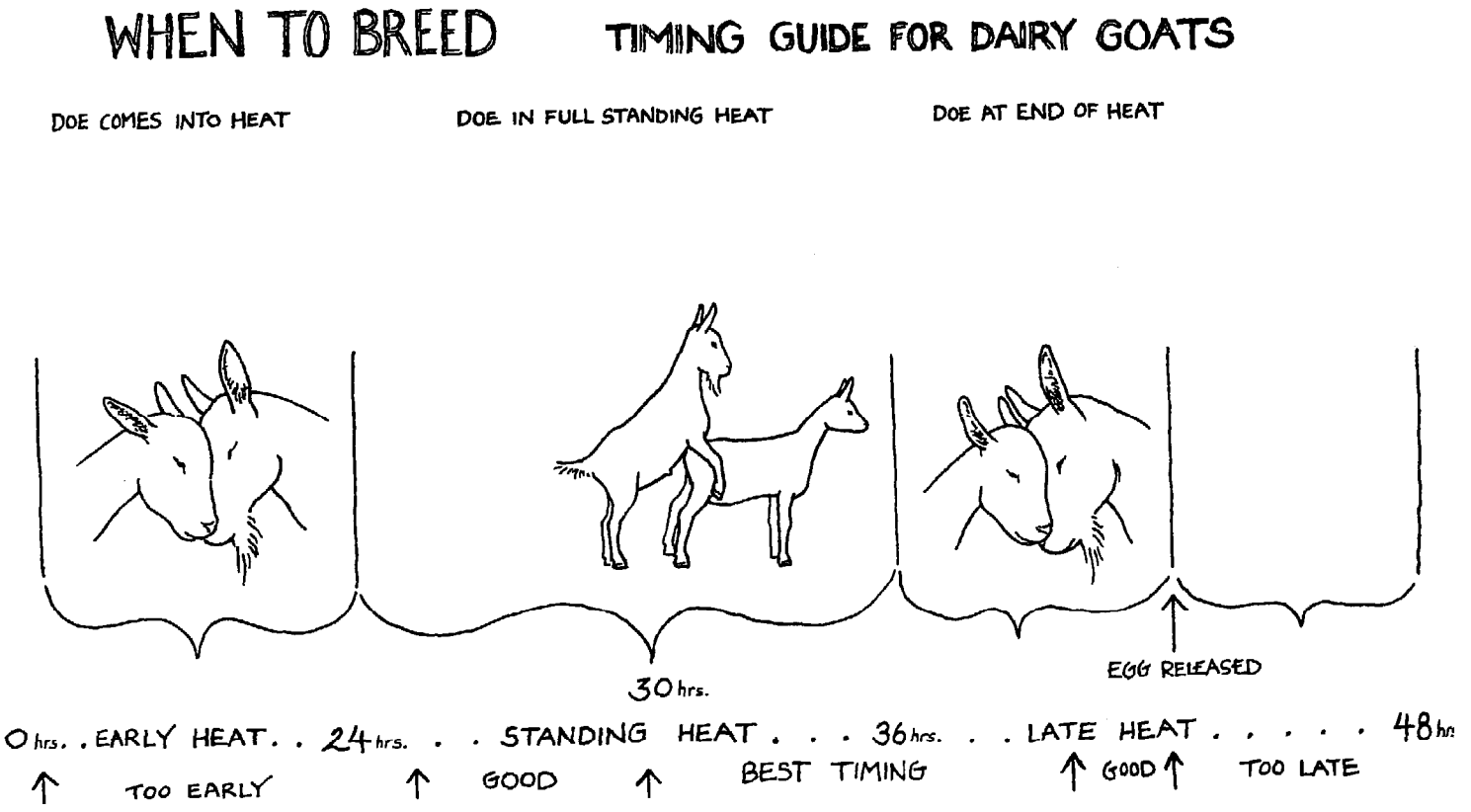

2) SIGNS OF ESTRUS (heat)

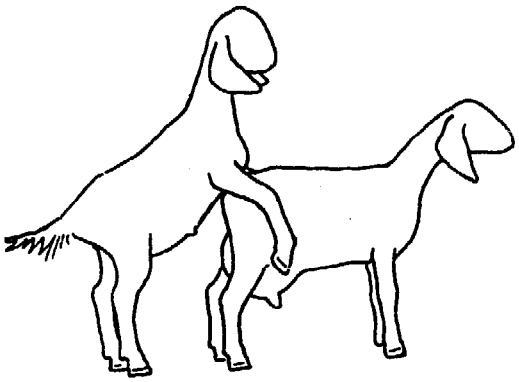

Swelling and redness of the vulva
Mucous discharge
Flagging of the tail
Nervousness and bleating
Mounting and being mounted by other goats
Frequent urination

Does come into heat for the first time at a very early age. As stated earlier, it is best to wait until the doe is 7-10 months old and weighs 36-41 kg (80-90 lbs.).

You can "flush" your doe 2-3 weeks before planning to breed. This increases the number of ovulations. To do this you might feed extra concentrate or protein supplement. If you carefully watch and record heat dates, then you can estimate the next period at which you wish to breed. You are more likely to have multiple births if the doe has been flushed. A doe should always be gaining weight when she is bred, but should not be fat.

It is also a good practice to worm your doe a few weeks before you plan to breed.

Decreasing light and temperature helps bring a doe into heat. Shorter days trigger heat cycles.

If the doe fails to show a strong heat, you can either place her with a buck or rub a rag on a buck's head (behind horn area where musk glands are located) and bring the rag to the doe once a day. Keep the rag in a covered jar.

Good nutrition is also essential for both the doe and the buck at the time of breeding. A good buck can serve two does a day and 4-5 does a week.

The introduction of a buck or its smell at the beginning of the season will often bring the whole group into heat in about eight days. Most goats will cycle even without the buck's presence.

3) CROSSBREEDING

When unrelated goats are mated, the system is known as crossbreeding. First cross progeny are usually superior to their parents. This is known as hybrid vigor.

Crossbreeding is used to improve the productivity of local animals. Using an exotic buck to breed a native doe will produce strong, vigorous offspring. These offspring will have increased production potential.

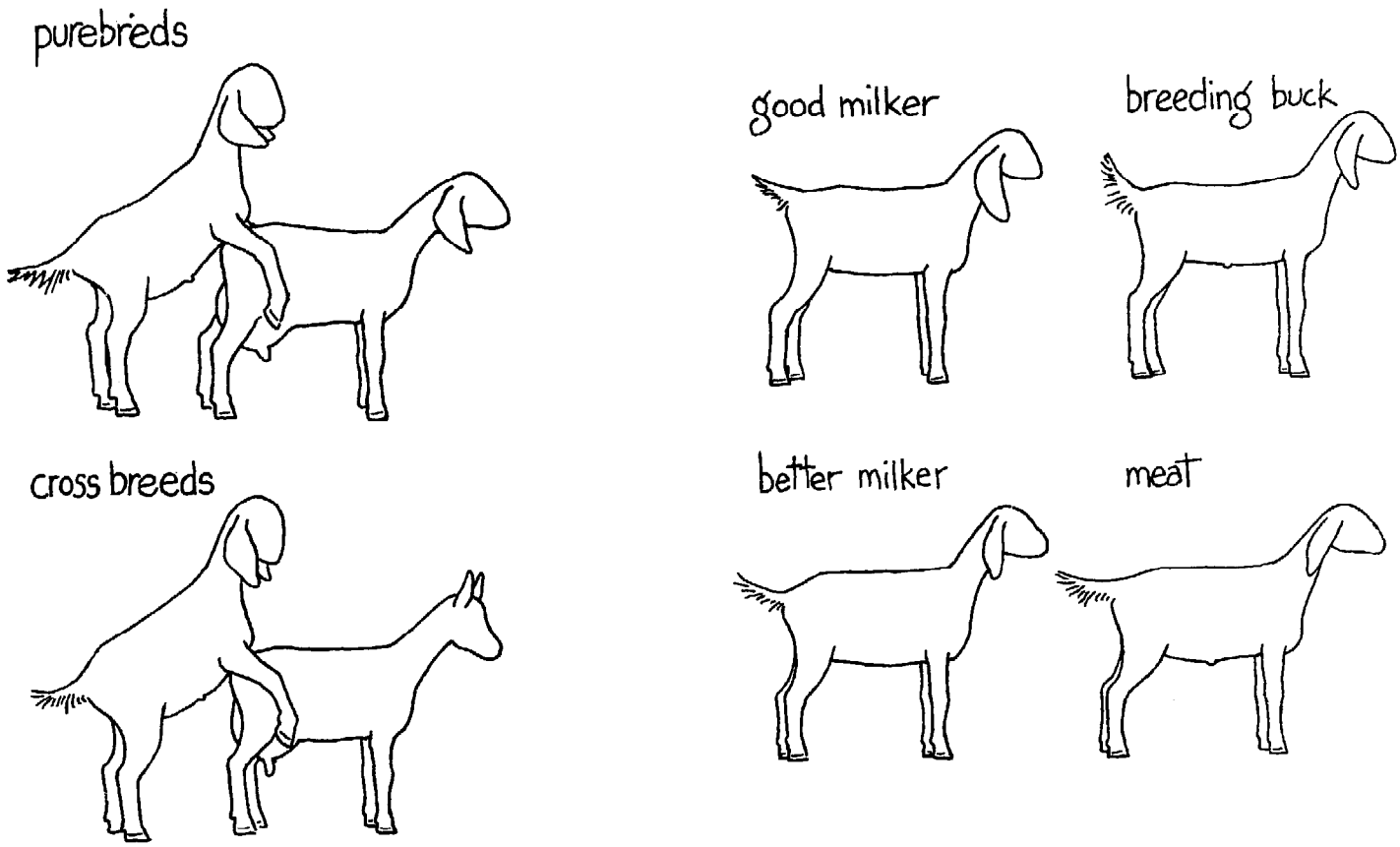

4) SELECTING A BUCK

The buck you use is one-half your herd.
The buck should be better than your best doe.

Look for a buck who will reinforce your does' strong points and at the same time does not possess any of their major faults.

a) Be sure the buck is in excellent health.

b) In selecting your buck for milk production, be sure that the dam (mother) of the buck gives as much or more milk than the mother of the doe.

c) Feed the buck .5 kilo of concentrate per day and plenty of green chop during the breeding season. If you cannot get concentrate or other protein supplements, be sure he has all the green chop he needs and let him browse extensively.

d) If you are breeding for purebred kids, select a buck of the same breed as your doe.

e) If you are crossbreeding, it is best to breed a native doe to an exotic buck.

f) For increased vigor you may also want to breed two exotic goats of different breeds, i.e., Nubian and Toggenburg.

g) Do not breed two hornless animals (hornless at birth). If you breed two hornless animals, the genitals of the kids may not be normal.

5) CARING FOR THE PREGNANT DOE

Protein supplements are important during the dry period (non-lactating period). The kids are growing fast at this time.

If you are feeding legumes (clover, alfalfa) which are high in calcium, it is best to replace these with grass hay at least three weeks prior to kidding to help prevent milk fever. This forces the animal to mobilize its own body stores and prepare for milking.

If available, give the doe a Clostridium Perfringens C & D vaccination and tetanus toxoid three weeks prior to kidding. If possible give Vitamin E and Selenium during the dry season to prevent white muscle disease. There is also good indication that Selenium plays an important role in enhancing female reproduction.

It is also good to worm your doe two weeks prior to kidding.

REPRODUCTIVE ORGANS OF BUCK

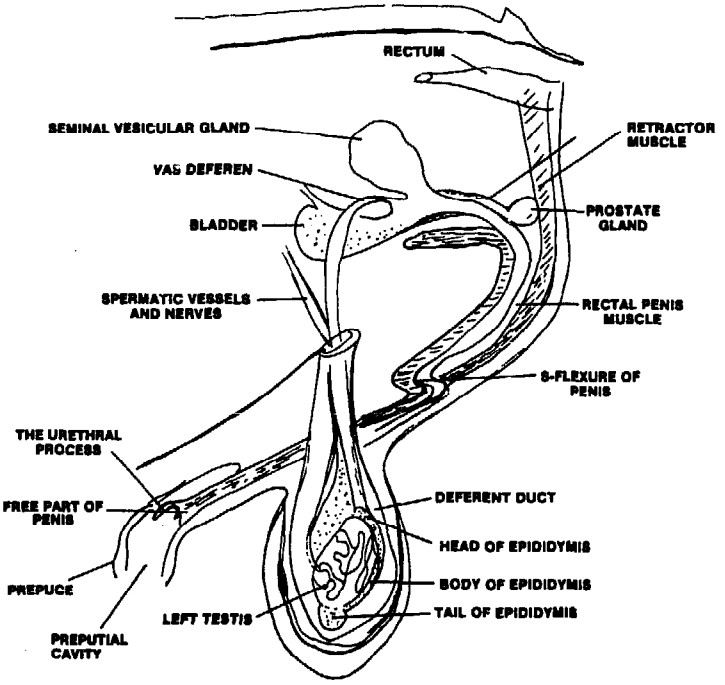

REPRODUCTIVE TRACT OF DOE

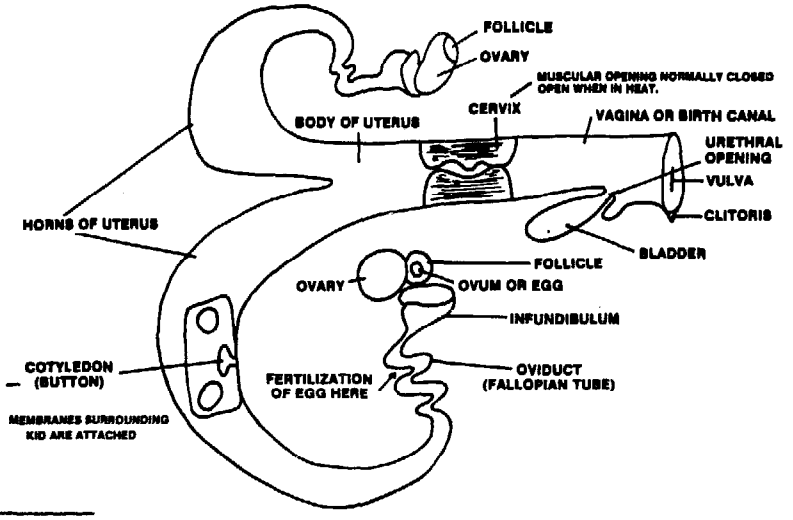

Source: University of Guelph, *Independent Study: Dairy Goat Production*.

GESTATION TABLE

Breeding Date		Kidding Date		Breeding Date		Kidding Date	
January	1	May	30	July	5	December	1
	6	June	4		10		6
	11		9		15		11
	16		14		20		16
	21		19		25		21
	26		24		30		26
	31		29	August	4		31
February	5	July	4		9	January	5
	10		9		14		10
	15		14		19		15
	20		19		24		20
	25		24		29		25
March	2		29	September	3		30
	7	August	3		8	February	4
	12		8		13		9
	17		13		18		14
	22		18		23		19
	27		23		28		24
April	1		28	October	3	March	1
	6	September	2		8		6
	11		7		13		11
	16		12		18		16
	21		17		23		21
	26		22		28		26
May	1		27	November	2		31
	6	October	2		7	April	5
	11		7		12		10
	16		12		17		15
	21		17		22		20
	26		22		27		25
	31		27	December	2		30
June	5	November	1		7	May	5
	10		6		12		10
	15		11		17		15
	20		16		22		20
	25		21		27		25
	30		26		31		29

Source: *Penn State University, Dairy Goat Correspondence Course No. 105.*

TASKS FOR LESSON IV:

1) Observe does to detect possible heats.

2) Select bucks you feel are best for breeding with specific does.

3) Breed animals if possible.

LESSON V - KIDDING

1) PREPARATION FOR KIDDING

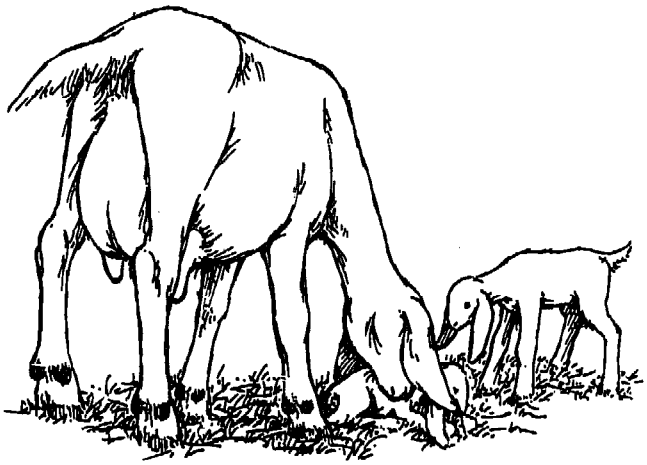

It takes 146-156 days after breeding for the doe to kid. Two weeks before kidding prepare the kidding pen. It is important that the pen be clean and have fresh bedding.

Be sure to have a bottle of iodine and a soft towel near the pen to use at the time of birth.

About a week before kidding, the doe's udder will bag up and become larger and fill with milk. Several days before you expect the doe to kid, put her in a clean kidding pen with plenty of bedding. Give her grass hay, a protein supplement and water.

DO NOT LEAVE THE WATER BUCKET IN THE PEN WHILE YOU ARE NOT WATCHING. IF YOU LEAVE THE WATER IN THE PEN, THE DOE MAY DROP THE KID IN THE WATER AND IT WILL DROWN. BRING THE WATER TO THE DOE SEVERAL TIMES EACH DAY.

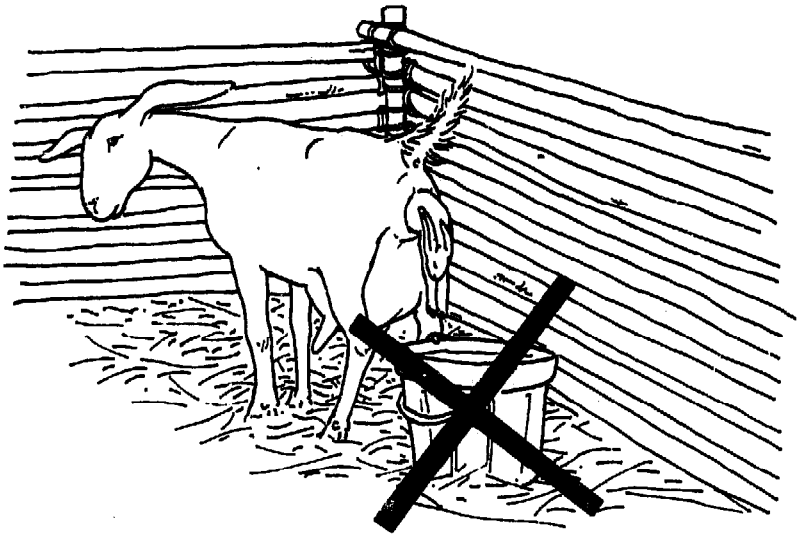

Once you see signs of kidding, stay with your goat. You cannot help if you are not there.

Kids can be felt on the right side of the doe. As long as you can feel the kids moving, they probably won't be born for at least 12 hours.

2) SIGNS OF KIDDING

- Doe is restless and paws the bedding
- Doe appears hollow on either side of the tail
- In a group of animals she may stand off by herself
- She will show a great display of affection
- There will be a discharge from the vulva

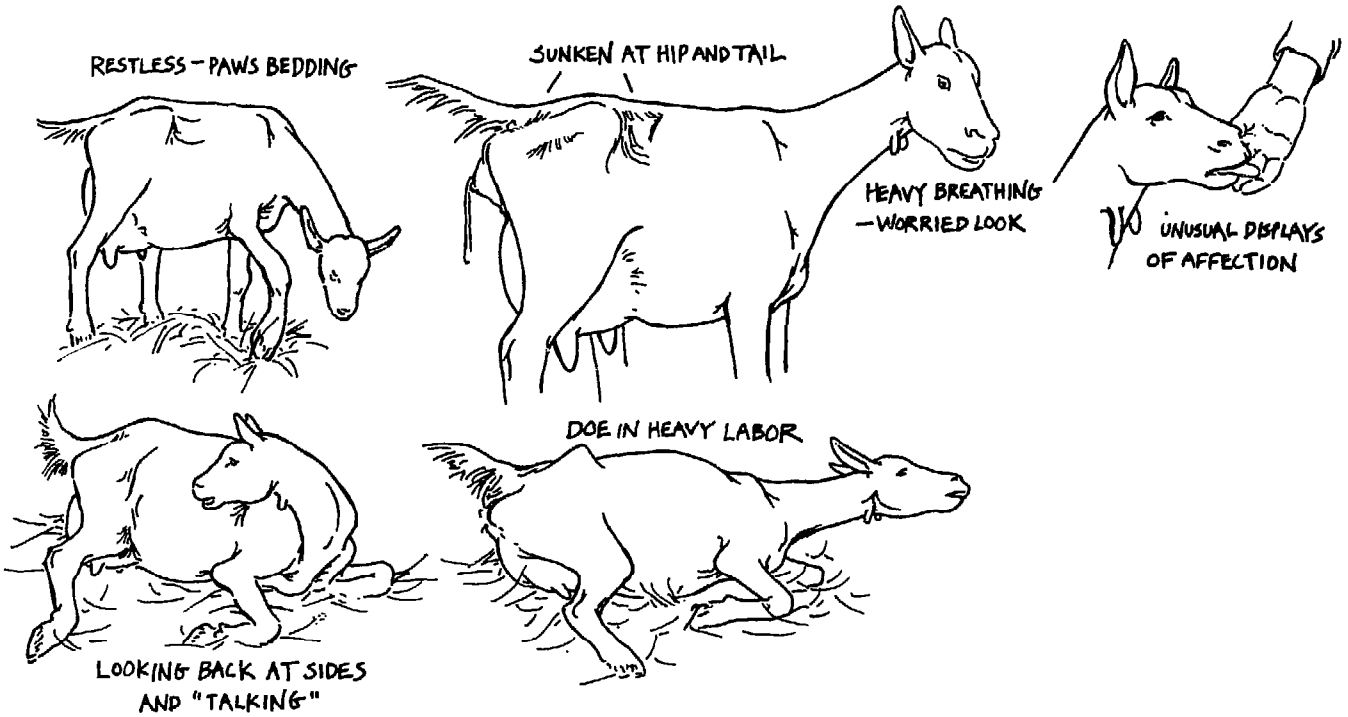

After the water sac breaks, the doe will have a long discharge hanging from the vulva. The kid should start appearing within one hour.

3) NORMAL DELIVERY POSITIONS

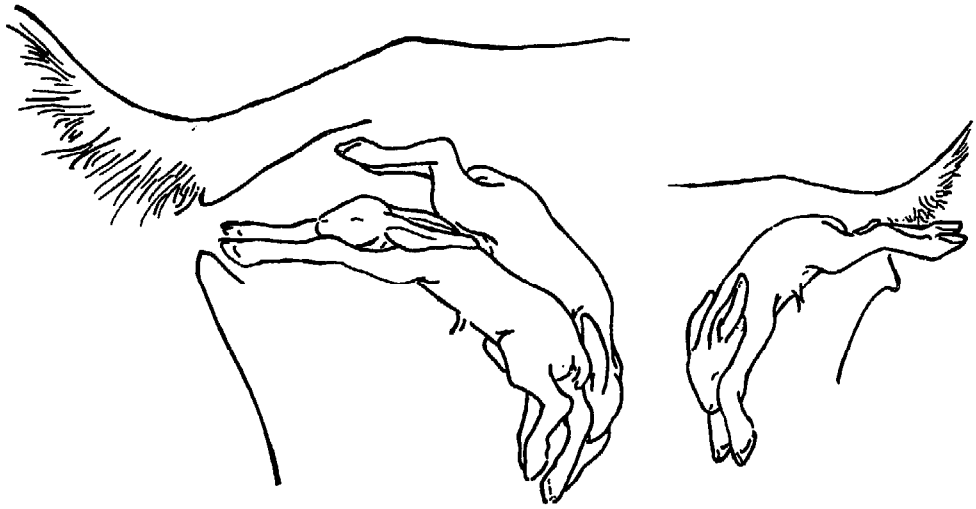

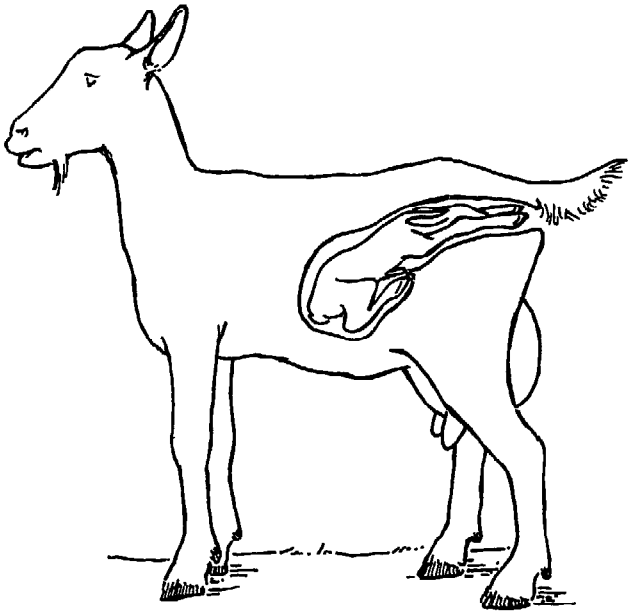

There are two normal delivery positions. The nose diving between the front legs or with both hind legs together and the dew claws up. The kid should be right side up, face down.

4) ABNORMAL BIRTH POSITIONS

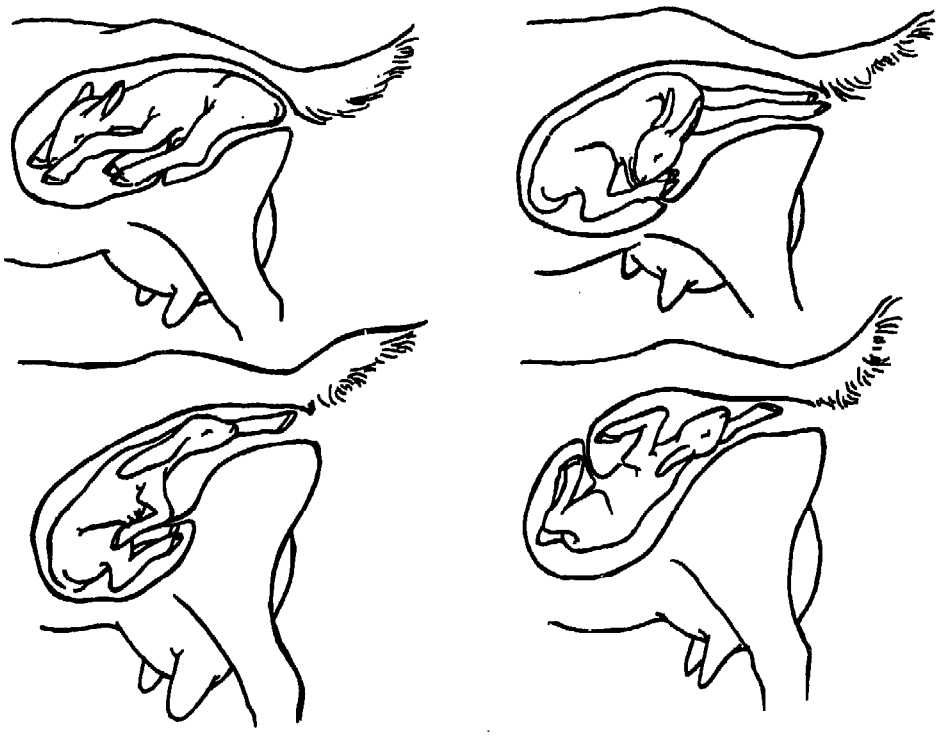

NEVER PUSH THE HEAD BACK IN ONCE THE SAC OVER THE NOSE IS BROKEN OR YOU WILL SUFFOCATE THE KID.

Front legs back - Reach inside the doe next to the kid's neck and follow it to the kid's chest and then to the elbow of one front leg. Hook the front leg with a finger and gently pull it forward and straight. Try the other front leg. Rock one shoulder and then the other gently out of the doe. Pull with the doe, not against her. Wipe off the kid's nose with a clean cloth. Clear its mouth with your finger and get it breathing. Towel the kid dry with fast strokes.

Legs present, but head twisted back - Push legs back into uterus. Slide hand into uterus and grasp head with palm of hand and hold head steady while bringing legs into diving position. Guide head with palm of hand and fingers until it enters pelvic area.

Breech presentation - rump first. Try to rotate the animal into the normal positions, perhaps hind legs first, dew claws up.

THE KID SHOULD BE BORN WITHIN ONE HOUR AFTER HARD LABOR BEINGS. IF THIS DOES NOT OCCUR, WASH THE DOE OFF WITH A MILD SOLUTION OF SOAP AND WATER. WASH YOUR HAND AND PUT IT GENTLY INSIDE TO FIND OUT WHAT IS GOING ON. HAVE SOMEONE HOLD THE GOAT IF POSSIBLE. MOVE THE KID UNTIL IT IS IN A NORMAL BIRTH POSITION.

HELPING WITH A DIFFICULT BIRTH

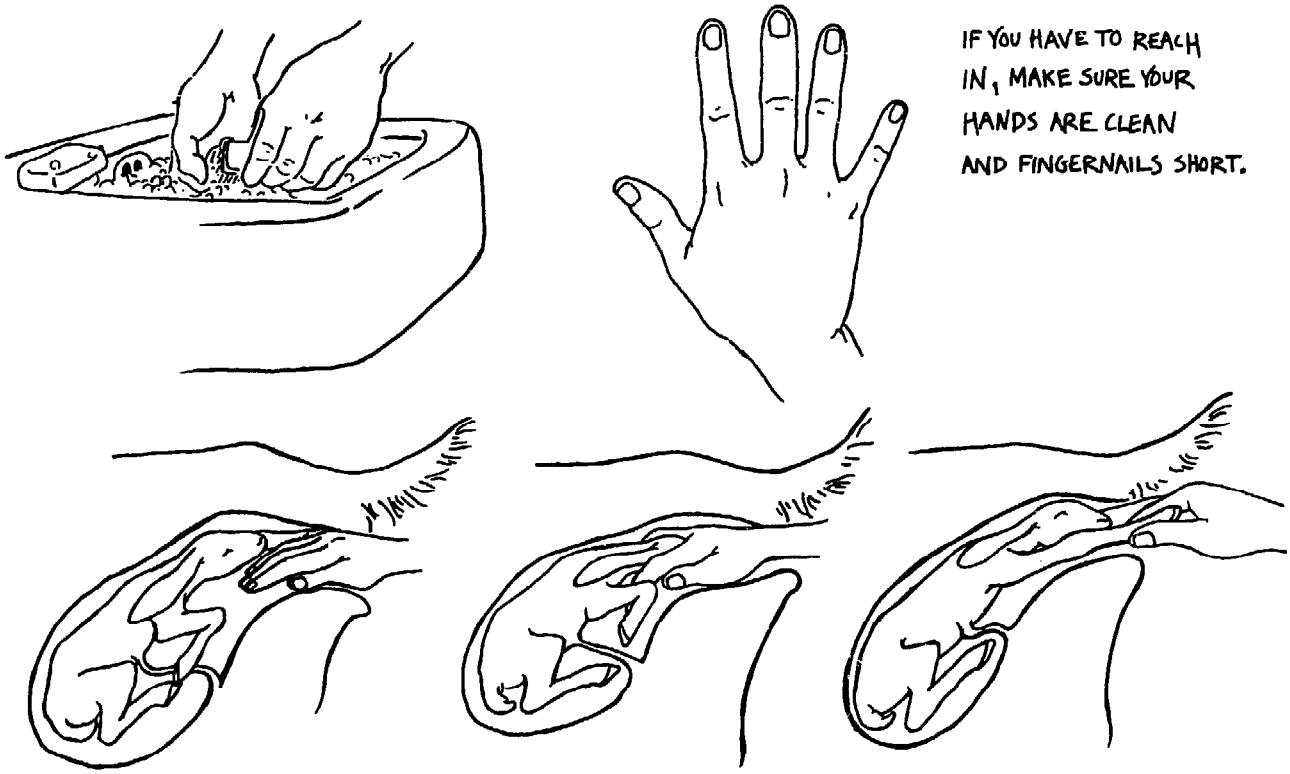

5) GENERAL PROCEDURES

Try to let the cord break naturally so all the blood in it flows into the kid. If sac is not broken, you can break it for the doe.

Dip the cord in 7% iodine to prevent deadly germs from moving up inside the kid's body. Cover the navel with a small container containing iodine. Turn the opening against the kid's body and hold for one minute.

Clean mucous out of nose, throat and mouth. A straw up the nose provokes sneezing which helps clear the airways.

If the kid appears lifeless, swing it by its hind legs - fast and hard. Give it short hits with your fingers in the middle of the heart. Try artificial respiration.

THE FIRST MILK (COLOSTRUM) CONTAINS ANTIBODIES WHICH PROTECT THE KID FROM DISEASE. GIVE THE KID COLOSTRUM WITHIN 15 MINUTES AFTER BIRTH, AND CONTINUE COLOSTRUM FEEDING FOR AT LEAST 24 HOURS AT 4 HOUR INTERVALS.

If you have decided to guard against CAE (Caprine Arthritis Encephalitis) you will want to have heat-treated colostrum available for immediate use. If frozen, be careful to thaw in warm water only to avoid killing antibodies. (Temperature of water should not be more than 131°F). If you are not following a CAE management program, you can let the kids suckle.

The Birth Process

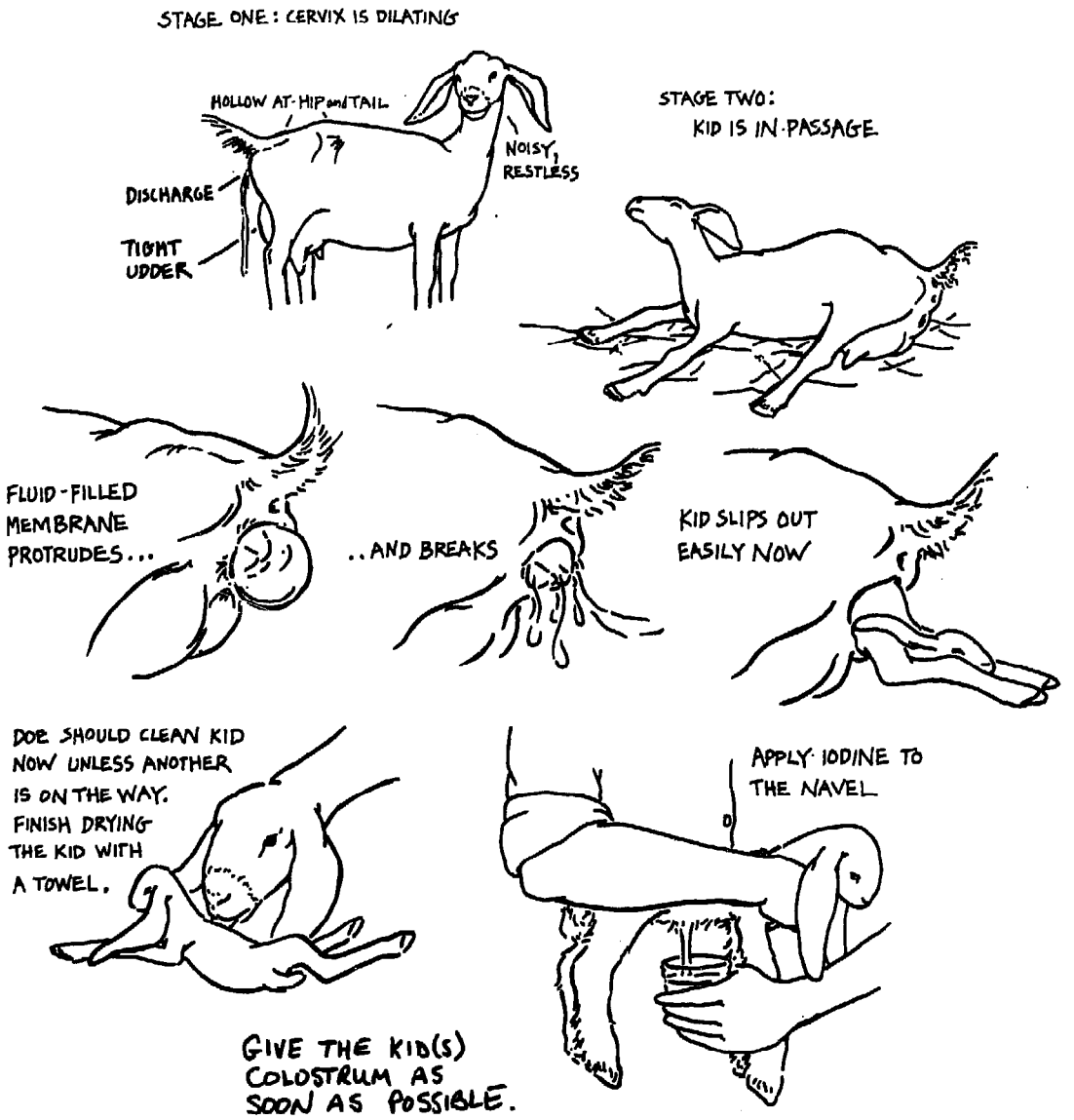

Photos by Rosalee Sinn

Taken at LaFiesta Farm,
Paso Robles, California,
U.S.A.

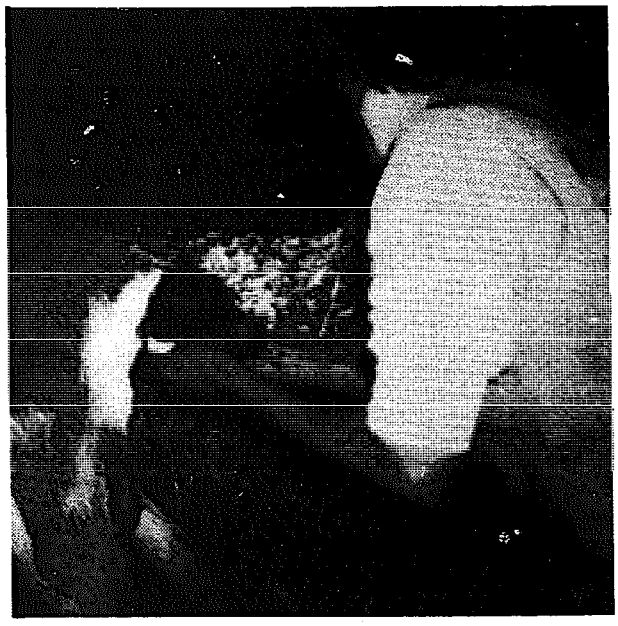

6) DISBUDDING/DEHORNING - Should be done 3 days to 2 weeks of age.

Disbudding and dehorning may not be widely practiced outside of the United States. However, it is highly recommended. Dehorning prevents goats that are tethered from getting tangled in bush or fencing. It also prevents injuries due to fighting among goats.

Equipment needed:

a metal rod which is fairly thick - about 1 cm in diameter (3/4")

the metal rod should have a handle on it which will not conduct heat

a hot fire

a person to help or a disbudding box

It is wise to give the kid an anti-tetanus shot prior to dehorning.

Heat the iron until it is red hot. Place the kid in the disbudding box and sit on top of the box, or have your helper hold the kid tightly between his/her knees, exposing the head. Feel for the horn buds. Place the hot iron firmly and directly over the horn bud. Do not be timid. Hold firmly for 10-20 seconds, pushing against the head and turning the iron. The hotter the iron, the shorter the time. A copper colored ring is a good sign of successful disbudding. Release the animal. You may give the kid a bottle of warm milk following the dehorning.

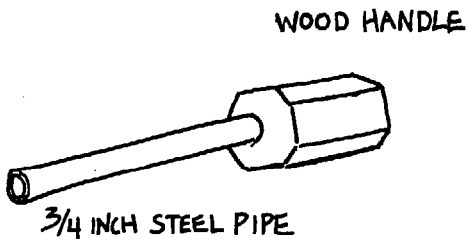

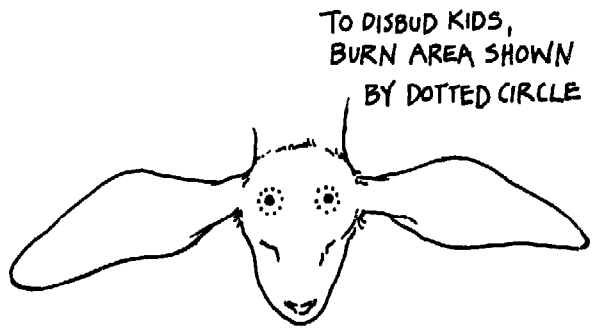

Build Your Own Disbudding Box

Use ¼" plywood or masonite, nails, wood screws and glue for assembling.

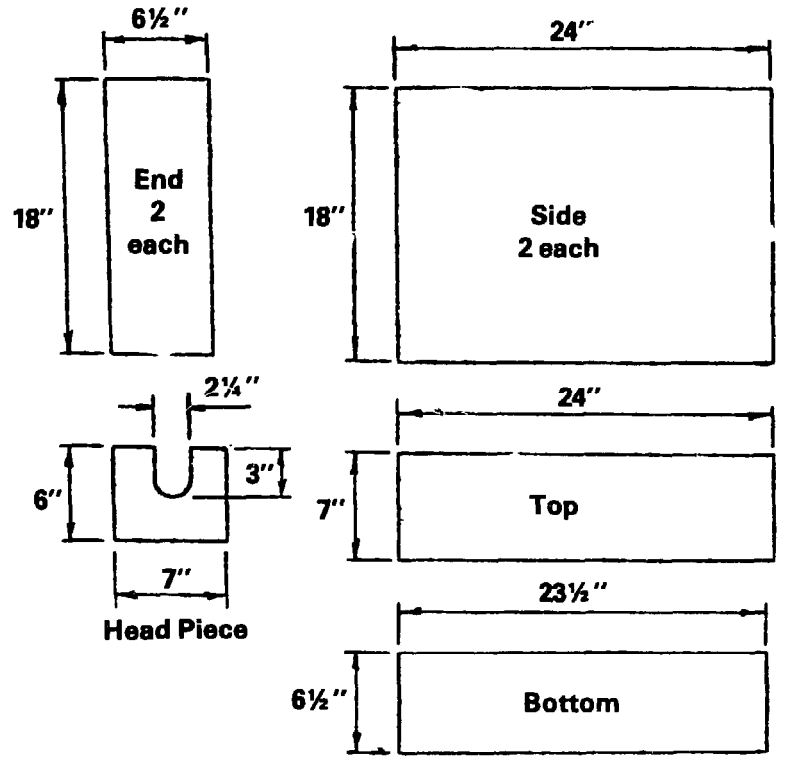

by **Jan Kelley**
Dimondale, Michigan

As goat owners, we all have developed techniques for restraining goats while disbudding. These restraint techniques are usually a direct result of burning either yourself or the goat in an inappropriate place.

And with today's economics, more owners are opting to "do it themselves" rather than pay a large vet bill.

This disbudding box effectively solves restraint and inadvertent burning problems. Its rather large size can accommodate most kids. Bedding will raise the box floor, as many of the kids I disbud are too young to have grown to 18 inches high at the shoulders. I do encounter very large kids and the bedding can be removed to suit each individual goat's height.

The box was designed by Gordon Millis of Mason, Michigan, who was the disbudding "king" of our area for years. Using his basic design, I have added a flexible handle on top, and hooks and eyes on the front sides to hold the top down. The hook and eye arrangement make transport and carry an easy proposition.

To use this box, you straddle the top so you are directly over the goat. With one hand, I steady the head, holding the lower jaw and muzzle, while applying the hot iron.

I then remove the hair cap making sure the area is clear and clean, and do the opposite side in the same manner. Everyone varies this technique to suit their needs, but restraint need never be a problem using this disbudding box.

I use a screwworm aerosol spray around the wound area to discourage flies. You may also wish to use a topical antibiotic powder and/or tetanus antitoxin injection which is quite inexpensive. Some 500 disbuddings later, I've lost one kid to tetanus. However, he was quite valuable. If you think tetanus might be a problem on your farm use your own judgement and/or consult with your veterinarian. □

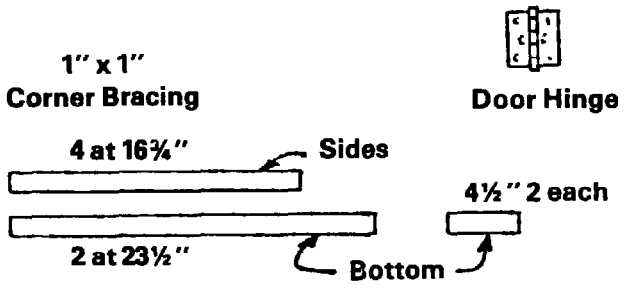

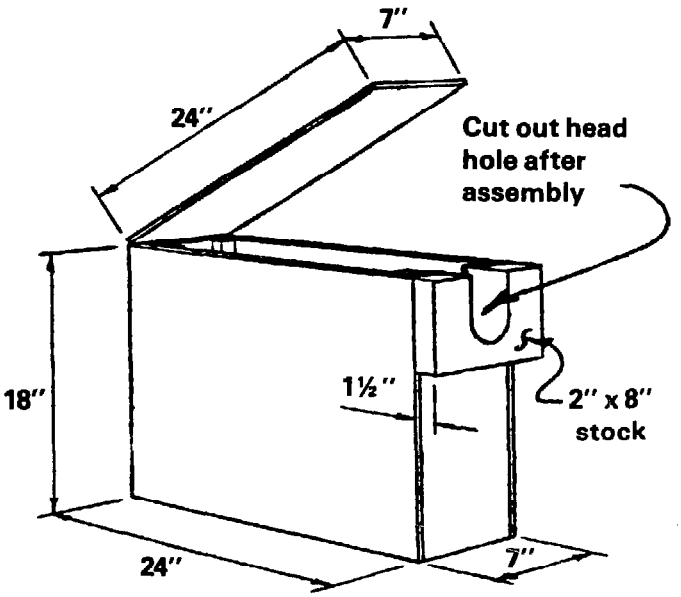

7) HOW TO CARE FOR GROWING KIDS

A feeding schedule for kids through the weaning stage is given under the section on feeding. Your management system will tell you whether or not you will hand feed the kids milk (with bottle or pan) or leave them with the does until weaned. Good nutrition is most important. From the first day kids should be offered green chop and protein supplements as well as salt and water. Provide these in feeders in an area where the doe cannot get to them. Kids are extremely active and need plenty of exercise.

If you want some milk for your family prior to weaning the kids, separate the kids from the doe at night. Milk the mother out first thing in the morning and return the kids to her. This method works best when you have decided to leave the kids with the doe until they are weaned. (This would not be practiced in a CAE prevention program.)

Here is the growth chart for kids once again:

Age	Kg	Lbs
Birth	3.8	8
1 mo.	9.4	21
2 mo.	14.4	32
4 mo.	25.6	57
6 mo.	32.8	73
12 mo.	48.6	108
18 mo.	61.4	136
21 mo.	64.8	144

KID BOX KEEPS KIDS WELL

When kids are under one month and separated from doe, place them in a box with solid sides which is 1 meter square. Change bedding each day. Even if they are outside in the day, putting them in the "kid box" at night keeps them out of cool drafts. Three kids per box.

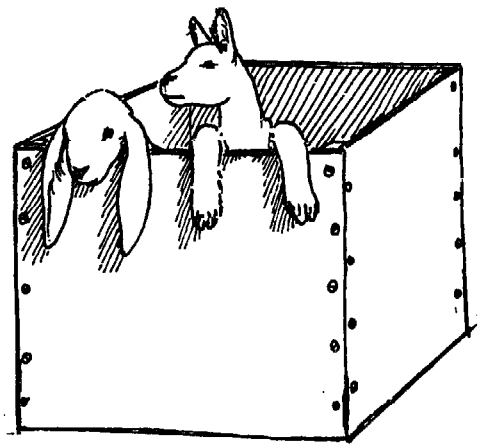

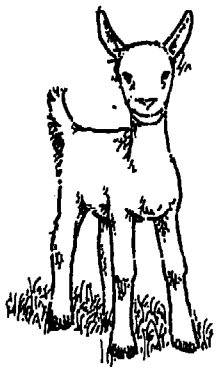

8) CASTRATION AND VASECTOMY OF BUCKS

You will want to keep your finest bucks to sell as breeding animals or to keep for your own herd. However, it is best to castrate or vasectomize the bucks you plan to use for meat. You can do this anytime from two weeks to two months. However, you will get better growth if you wait until nearer two months.

Materials needed:

- tetanus anti-toxin shot is recommended prior to either method
- sharp knife, razor blade or scissors that have been sterilized
- alcohol
- iodine
- soap and water
- person to help

Procedure:

Place the materials needed on a clean surface. Wash your hands with soap and water. Dip the scrotum in either alcohol or iodine.

Castration - Cut off lower third of scrotal sac (holding it taut) and push testicles out through the opening. Gently pull the testicles until the cord is severed. Dip scrotum in iodine. Release kid.

Cut off tail of Epididymis - Grasp lower end of scrotum with forefinger and thumb and pull it taut. Cut off lower third of scrotum. Push testicles through scrotum. You will see two ball-shaped protrusions, one at the end of each testicle. Cut these off. Dip scrotum in iodine. Release kid.

The advantage of this method is that the buck will be sexually active and can be used as a teaser buck.

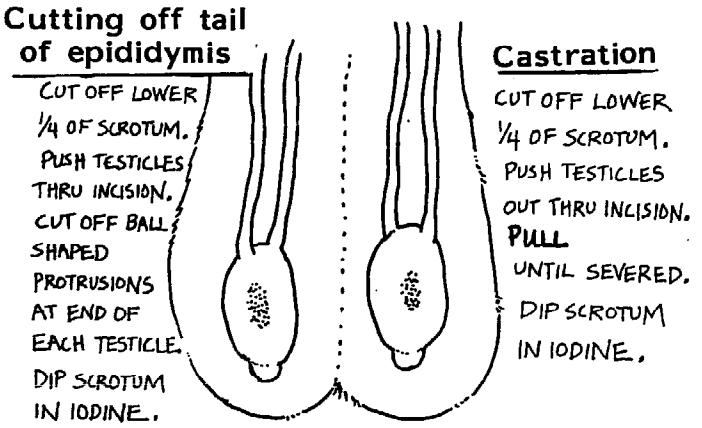

9) HEALTH CARE FOR KIDS

3-4 Weeks - Vaccinate

Tetanus
Soremouth (Be cautious when vaccinating as the disease is transmissible to humans.)
Enterotoxemia (over-eating disease)
Use Clostridium Perfringens C & D if available

1 Month

Worm with Thibenzole or check with vet for alternative wormer
Remember internal parasites (worms) will take important nutrition from your animal.
Coccidiosis is often present in kids. Diarrhea is one of the signs.
The following treatment has been used successfully:
At one month, two months and three months of age administer Amprol in proper dosage for 4 days.
Sulmet and other Sulfa based drugs also effective.
External Parasites
In areas where ticks are present spray with Supona solution or other treatment once a week in dry season, twice a week in rainy season.

Signs of Illness:

Temperature
Off Feed
Diarrhea
Mucous Discharge from Nose
Heavy breathing - respiratory problems.

TASKS FOR LESSON V:

1) Dehorn Kids

2) Castrate Buck Kid

3) Vasectomize Buck Kid

4) Vaccinate for soremouth, tetanus and enterotoxemia

LESSON VI - CARE OF THE MILKING DOE
MILK PRODUCTS

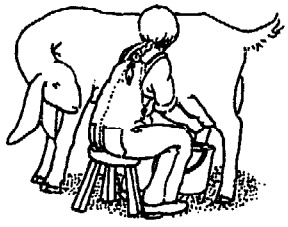

Good Nutrition is the single most important thing you can provide for the milking doe. If she has adequate feed, plenty of water, proper health care and exercise, she will provide milk 305 days a year, plus one or two kids every year. Caring for her properly will provide a great deal of satisfaction.

1) MILKING

a) Equipment and Supplies (see illustrations on page 25)

- A milking stand (optional)
- A milk bucket - a two liter pail is fine. Stainless steel or enamel is best. Any deep container can be used
- 2 cups - one for examining the milk prior to milking
  one for teat dip
- A filter or strainer if available or a clean cloth for straining the milk
- A pan for pasteurizing the milk
- A container for the milk
- A bucket of cold water to cool the milk
- Teat dip - may be either 2% iodine or a solution of 50% bleach and 50% clean water.
- Soap and water
- Clean cloths

BE SURE ALL OF THE EQUIPMENT YOU USE IS CLEAN: THAT IT HAS BEEN WASHED WITH SOAP AND WATER AND AIR OR SUN DRIED. COVER THE EQUIPMENT WHEN NOT IN USE WITH A CLEAN CLOTH.

b) Proper Milking Procedures

Put some feed in a bucket or in the feed container attached to the milking stand.

Wash your hands.

Bring the goat to the milking location and tie her or put her on the milking stand.

If the goat's udder is dirty, wash it with soap and water and dry with a clean towel. If the goat's udder is clean and free of manure and dirt you do not need to wash it. Brush away loose hair or dirt.

Direct the first milk from each teat into a cup. Examine the milk. If the milk is clear and good, you are ready to proceed. This first squirt also clears bacteria out of the teat canal. If you see stringy or lumpy milk or blood in the milk, this is an indication of sickness or mastitis. Do not use the milk if this occurs. DO MILK OUT THE UDDER AND DISCARD THE MILK. Ask your extension person or veterinarian about proper treatment.

Place the pail under the goat.

Grasp the teat with your thumb and index finger together to trap the milk in the teat.

Gently, but firmly, bring pressure on the teat with your second finger forcing the milk down further. The third finger does the same and then the little finger.

Bump the udder and massage it and you will get more milk.

Do not drag (pull) or jerk down on the udder. Use a steady pressure and loosen your grip before you squeeze again. It should take approximately five minutes to milk the doe.

When you are finished milking, dip each teat into the teat dip. Let the doe remain on the stand until the teats are dry and return her to her pen.

MILK THE DOE TWICE EACH DAY - MORNING AND EVENING - ON A REGULAR SCHEDULE. Twelve hours apart is ideal, but this can vary according to your schedule. The important thing is that you milk at approximately the same time each day. Record the milk production. (There is a chart in the Record Section of this manual.)

PROPER MILKING PROCEDURES

WASHING THE DOE'S UDDER BEFORE MILKING

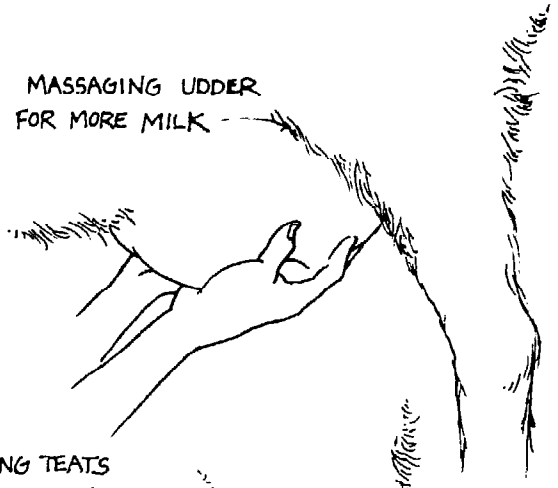

MASSAGING UDDER FOR MORE MILK

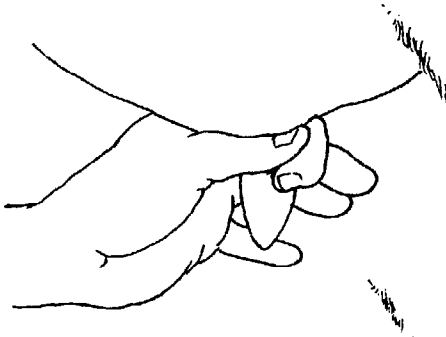

TRAPPING MILK IN TEAT BY CLAMPING AT TOP WITH THUMB AND INDEX FINGER

DIPPING TEATS AFTER MILKING

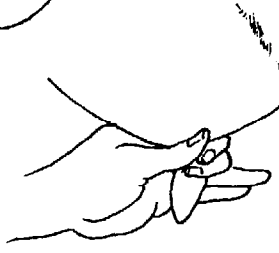

SQUEEZING MILK DOWN BY ADDING LOWER FINGERS
- DO NOT LOOSEN THUMB AND INDEX FINGER -

ALL FINGERS SQUEEZING FIRST SQUIRT INTO THE TEST CUP

DO NOT MILK LIKE THIS

2) HOW TO CARE FOR THE MILK

Strain the milk through a filter or cloth into a clean container. This will remove any hair or other dirt that has fallen into the milk.

Pasteurize the milk. Place the milk on the stove and bring it almost to the point of boiling. Hold for one minute. If you have a thermometer you can use these guidelines:

63° C	145° F	for 30 minutes
72° C	161° F	for 15 seconds
100° C	212° F	for 0.01 second (boiling)

(Feeding pasteurized milk to kids helps with control of diseases like CAE and Johne's.)

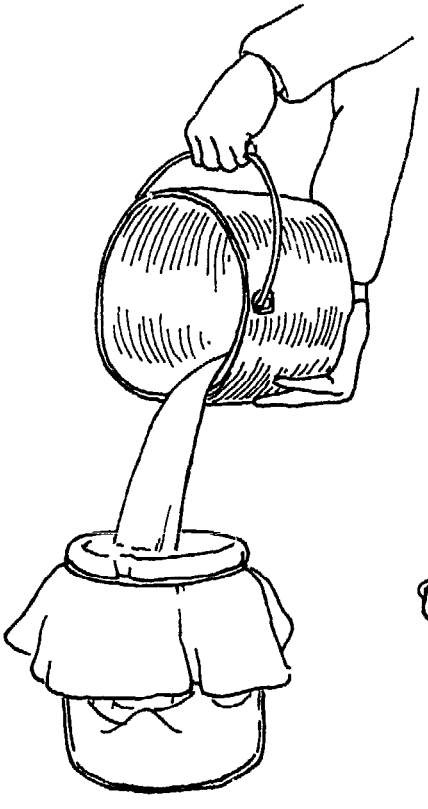

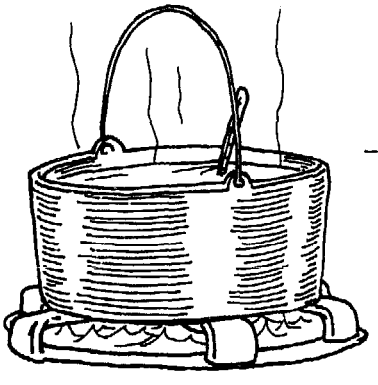

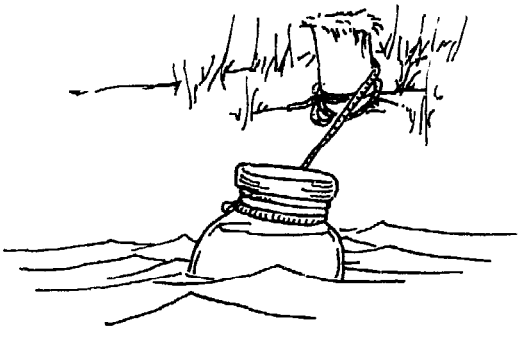

Pasteurized milk should remain sweet for several days even without refrigeration.

Place the milk in a clean container. If you have a jar with a tight cover this is good. Place the container in a bucket of cold water or in a stream to cool. If you have a refrigerator, the milk will stay good for at least a week.

IF POSSIBLE HAVE YOUR VETERINARIAN TEST YOUR DOES FOR BRUCELLOSIS AND TUBERCULOSIS EACH YEAR.

3) DRYING OFF A DOE

Stop milking the doe when she is three months pregnant. Her udder will become hard, but gradually the milk will stop and she will not produce any more. If she is too uncomfortable you can milk her out again, but be sure to milk her out completely.

It is important to dry off the doe because during the last two months the kids are growing fast inside the doe and need the sustenance of her body.

The doe needs a 12% protein feed at this time. Add a few drops of iodine to the drinking water each day toward the end of pregnancy. Keep nutrition high. Avoid abrupt dietary changes.

4) MASTITIS

Mastitis is an infection of the udder caused by bacteria. Good sanitation is the best way to prevent mastitis. This includes using teat dip after each milking.

Hard udders are occasionally seen when a doe kids. These are not necessarily mastitic. Usually having the kid nurse and milking the udder out will relieve this condition.

Mastitis is characterized by heat, pain and swelling of the udder. You may find hard knots in the udder, see some discoloration and abnormal qualities in the milk. Milk may be almost normal or may be watery and pale, dark yellow and thick, chunky, greenish or bloody.

Antibiotics for insertion in the teat are available. Use only one-half the dosage for a cow. Divide between teats, insert and massage. Milking the udder out at one or two hour intervals and applying hot packs will help. When treating with antibiotics allow the recommended withdrawal time before using milk for human consumption.

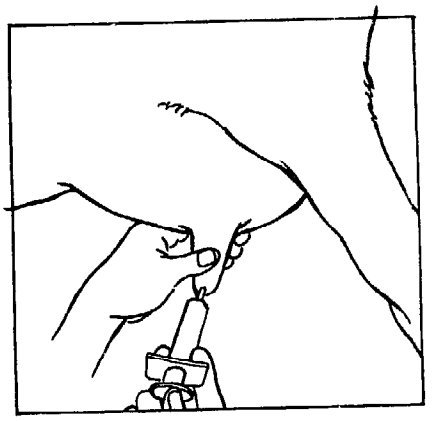

5) MILK PRODUCTS

Yogurt

a) Heat one liter of milk to just below the boiling point for one minute. This wipes out bacteria.

b) Cool the milk for 45 minutes to just above body temperature. The milk should feel warm, but not hot, on the inside of your wrist.

c) Put two tablespoons of plain fresh yogurt or dry yogurt into the lukewarm milk. Be sure these are generous spoonfuls. Stir gently, but well. Mix thoroughly with milk.

d) Pour the inoculated milk into a clean jar or jars. Put on covers. Put containers in a large pot. Put a tight cover on the pot. Wrap pot with heavy towel or blanket and set aside away from drafts. You can also place the pot in the sun.

e) Leave 4-8 hours. When yogurt is ready, put in a cool place.

Soft or Cottage Cheese

Use two liters of milk.

Bring goat milk to just under a rolling boil, stirring so it will not stick or burn. Remove from fire, keep stirring and add drop by drop 8 teaspoons vinegar or lemon juice. Strain curds at once. The acidity of the vinegar or lemon juice will determine how much you add. If curds do not form, add a little more.

Use the whey (left from the curds) for drinking or cooking.

Pressed Cheese

Use 7.5 liters or 2 gallons of milk. Heat to 63° C or 145° F. Cool to lukewarm immediately by setting in cold water. Add about 1/4 cup yogurt or buttermilk. Stir well. Dissolve 1/8 of a rennet tablet in 1/4 cup cold water. Add to milk and stir well. Let set until firm or when you insert a knife it comes out clean. Cut curd in 1/4 inch strips up and down and crosswise until you have small pieces. Let stand until all the whey has separated from the curd - at least 1/2 hour to 1 hour. Stir, strain through a cheese cloth or other similar cloth. Squeeze out as much moisture as possible and press overnight. Keep in cool place.

Semi-hard Goat Cheese (takes 2 hours)

Into an 8 liter pot (2 gallons), pour 6 liters or 1.5 gallons of just drawn goat milk. (Do not cool milk - this gives cheese a rubbery texture.) Add 1 cup buttermilk, stir. (Yogurt can also be used.) Dissolve 1/2 of a rennet tablet in 1/4 cup of cold water, crush with spoon. Add rennet solution to warm milk, stir for one minute.

Let stand in a warm place until a firm curd forms, about 45 minutes. Use a long knife to cut curd into cubes two ways, vertically and at an angle. Warm slowly, about 20 minutes (very low heat) to about 42° C or 110° F stirring frequently with a spoon to keep curds from sticking together.

Pour curds and whey into a cloth lined strainer. Drain curds. Add 1 tsp salt and mix with hands. Add herbs if desired. Squeeze out whey by twisting cheese cloth. When firm remove from cloth and wrap in plastic. Ready to eat.

Other Cheeses

You can make a mold out of any round container with holes in it or use a cloth. The mold should hold at least 1 kilo of curd. Piece the container so the whey can drain away from the curd.

You can make a press out of a jar full of water or any other weight that will fit on top of your mold. The weight should be 1-2 kilos.

It is important to have a fine mesh cheese cloth or other cloth to strain the whey from the curd. Be sure that your cloth and all containers are clean. You may even want to sterilize the pans and cloth by boiling in water before using.

Many cheeses require a culture - yogurt or buttermilk. They also require rennet (liquid or tablet). Rennet goes a long way and your culture, once developed, can be saved from a previous batch.

Here are some additional recipes. Note that the temperatures are in Fahrenheit (F). Experiment with your own special cheese. It will provide important protein and good nutrition for your family.

Ricotta Cheese

If you have the ambition, you can use the whey to make some ricotta. It's wonderfully easy.

Take two quarts of whey and heat it until a creamy substance rises to the top. Pour in three cups of milk and heat it until it is scalding. Then stir in 3½ tablespoons of vinegar or lemon juice. Stir briskly until the curd floats, keeping it very hot, not boiling.

Remove the curd to a strainer as it rises and drain it for 7-8 hours at room temperature. Salt to taste and place in cool place. If you prefer to save the whey for another time, it will keep for about a week in a cool place.

Brousse Cheese Recipe

Heat one gallon of milk to 90° F in a sterilized, stainless steel or enameled pan immersed in a larger pan of water. (Heat goat's milk only to 85° F). Stir in thoroughly 1 tablespoon of cheese starter culture (or 1 tablespoon of either buttermilk or yogurt). Cover pan and leave for 30 minutes at same temperature. Dissolve 1/4 rennet tablet in 1/4 cup cooled, sterilized water and add to milk, stirring for one minute. Cover pan again and leave undisturbed at the same temperature for one hour until curd is set.

Cut curd carefully into 1/2 inch cubes and let rest for 10 minutes. Slowly raise temperature to 120° F (this should take about an hour) and gently stir curds with stainless steel spoon (or your clean hands), bringing curds up from the bottom and carefully cutting any that are over 1/2 inch cubes. Curds will gradually lose their cube shape as they release whey. When they finally look like very large curd cottage cheese, ladle them into a sterilized cheese cloth placed over a strainer in a larger bowl.

Gather corners of cloth and hang cheese to drain over a bowl to catch the whey for an hour or two. Empty curds from cloth into a clean dry bowl and break up into small clumps, working about 2 teaspoons of coarse salt into the curds.

Place salted curds into the sterilized Brousse mould, pressing them down firmly with stainless steel spoon or ladle. Cover top of cheese with a circle of cheese cloth and set mould on an overturned bowl set in a larger bowl to catch the whey. After about an hour, fill a 2 pound coffee can (or similar jar) with water and place on top of cheese to press it.

In about two hours or so, gently remove cheese from mould and carefully replace it in the mould - upside down. Replace weight and continue pressing process. Turn cheese every few hours until it has taken on the neat, symmetrical shape of the mould, wipe dry with a clean cloth and place on a clean folded towel at room temperature to dry and form a rind. Turn occasionally to allow even drying. After 24 hours, cheese may be placed in cool place for 3 to 5 days to age before cutting.

(From the New England Cheesemaking Supply Co., P. O. Box 85, Ashfield, MA 01330)

HOW TO MAKE YOUR OWN RENNET

Rennet is the ingredient that causes the curd to set. It is important to have rennet to make hard cheese.

Method 1)

Go to the slaughter house and ask for the fourth stomach (Abomasum) of a calf or young goat.

Clean and salt the stomach and hang it up to dry in a cool place. Store it where the dust will not get on it.

The day before you are to make cheese, break off a small piece of the dried stomach (about the size of your hand). Put in a small container and cover with cooled, sterilized water. Leave for at least three hours.

Add 1/4 cup of this solution to the milk when you are ready to form the curd.

Keep the leftover solution in a cool place. Use within three days.

> Note: You can sterilize water by boiling it for 15 minutes and cooling.

Method 2)

If a calf or a kid goat is slaughtered or dies and is not more than two days old, the stomach will contain colostrum.

Take the colostrum out and save it. Clean the stomach carefully. Return the colostrum to the cleaned stomach. Tie off the opening. Hang in a cool place to age. When the contents are like butter or margarine, it is ready to use. Keep as cool as possible.

Use 1/2 teaspoon to set 8 liters of milk. Mix the colostrum in 1/4 cup cool water.

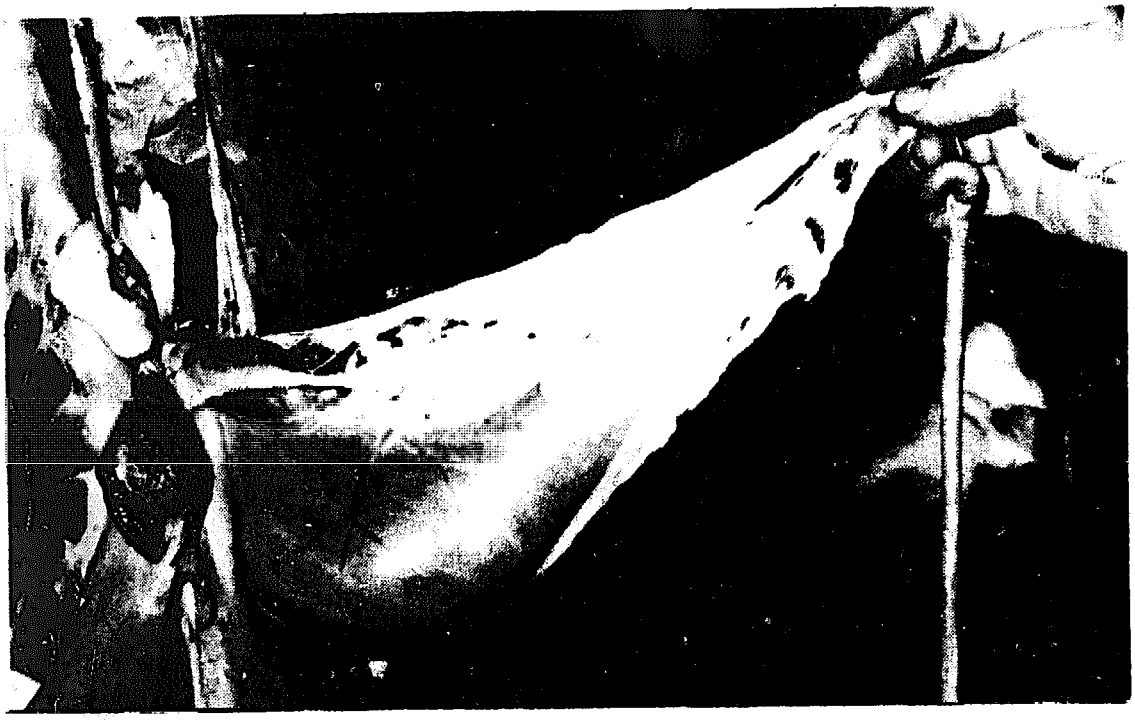

DOMESTIC RENNET

Use abomasa from kids that have been fed exclusively on milk (i.e., slaughtered when roughly 1 month old).

On receiving the abomasa, clean the outside portions, remove excess fat, close one of the two openings on each abomasum with a well-tied knot. Insert a pipette or straw into the other end and blow up like a balloon. Knot the end to keep the abomasum blown up. Dry in a dry, well-ventilated area for 2-3 days. Once the abomasa have dried, they keep for several months.

Rennet - 2 abomasa

- Cut the abomasa into 5-cm (¼-inch) wide strips.
- Add 500 ml water, 45 ml coarse salt, a pinch of boric acid.
- Let steep for 5 days at roughly 12°C (55°F). Stir 2 or 3 times during this period. Leave covered.
- Add 250 ml water and 15 ml coarse salt.
- Pour.

  Pour first through an ordinary strainer, then through cheesecloth. Next pour through 3 thicknesses of cheesecloth. Repeat the last operation.

DIRECTIONS *for* Farmhouse Cheese

1 WARM THE MILK. Pour 2 gallons of milk into a stainless steel or enameled pot, set in a sink of warm water, stir and warm the milk to 90°F.

2 RIPEN THE MILK. Add 2 ounces of cheese starter culture and stir in well, yet gently. Cover pot and leave for 45 minutes to ripen at 90°F.

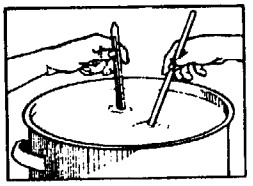

NOTE: If you plan to add cheese color, do it at this point - before the rennet is added.

3 ADD CHEESE RENNET. Dissolve completely one quarter of a cheese rennet tablet in a quarter cup of cooled, sterile water, breaking and crushing with back of spoon as you stir. Stabilize temperature of milk at 90°F. by regulating water temperature in sink outside cheese pot. Protect the pot from drafts. Add rennet solution and stir in thoroughly for one minute with a stainless steel spoon or ladle. Top-stir (if using cow's milk) ¼ inch with back of ladle for another minute to keep cream from rising.

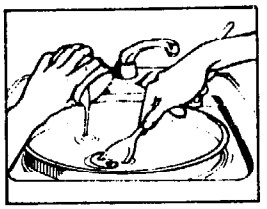

4 LET SET 'TIL CURD "breaks clean". Let covered pot stand **undisturbed** until a firm curd forms (30 to 45 minutes). Test firmness with your finger. When it "breaks clean", it is ready to cut.

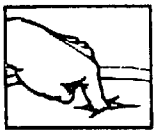

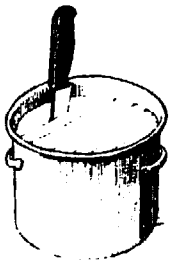

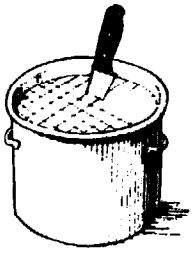

5 CUT CURDS 4 WAYS. Cut the curds into small (½ inch) cubes with a long-bladed knife or spatula. The blade must be long enough to reach all the way to the bottom of the pot without immersing the handle. Start at one side of the pot and cut vertical, parallel lines in the curd, ½ inch apart. Turn the pot 90° and cut again at right angles to the first cuts. Then, with the knife at a slant, using the original lines in the curd, cut at a 45° angle in both directions. Your aim is to cut the entire curd into ½ inch cubes.

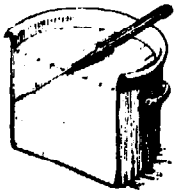

When the curd is all in cubes, gently stir them, turning them over, bottom to top, cutting any pieces of curd that are still too big.

6 SCALDING THE CURD:

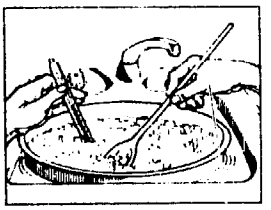

Run some hotter water into the sink outside of the pot and raise the temperature of the curds slowly to 100°F. The temperature must not rise more than 2° every 5 minutes. This should take 30 minutes, and you should stir gently as you cook. The curd pieces will shrink in size as the heating continues. The whey will increase as the curds decrease in size.

7 DRAINING THE WHEY Cover the pot and let the curd settle for 5 minutes, then pour off the whey into another pot (*save it for Ricotta or Mysost*). Pour the curds into a cheesecloth-lined colander.

8 HANG CURDS TO DRAIN: Knot one corner of the cloth around the other three corners and hang the bag of curds to drain for one hour at 70°F.

9 SALTING THE CURDS: Pour the drained curds into a scalded bowl and break them up with your fingers (gently) into walnut sized pieces. Mix in thoroughly 2 tablespoons of cheese salt for each 4 pounds of curd.

10 MOULDING AND PRESSING THE CURD

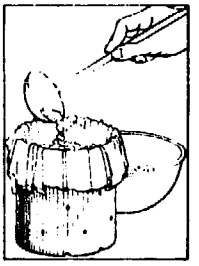

Scald and cool your mould and cheesecloth. Line mould with cheesecloth and put curds into the mould, folding cheesecloth neatly over the top when it is full.

Put the round follower on top of the curds and place under 20 pounds pressure for 10 minutes.

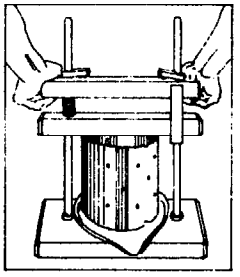

Then turn the mould upside down and replace the follower on top and increase pressure to 30 pounds for another 10 minutes.

Repeat twice more at 10 minute intervals and increase pressure by 10 pounds each time you turn the cheese. The last time, leave cheese under 50 pounds pressure for 14 to 16 hours.

11 FINISHING THE CHEESE: Remove the cheese from the mould and carefully peel away the cheesecloth, taking care not to rip the surface of the cheese. Air dry the cheese at room temperature on a cheese mat until a rind has developed and surface is dry. Turn several times a day. After 3 to 5 days, it will be ready to wax.

12 WAXING AND CURING THE CHEESE: Paint melted cheese wax (or paraffin - in a pinch) on a cool, dry cheese. Use a small, real-bristled paint brush kept just for this purpose. Wax must always be melted in a double boiler to reduce danger of fire. Cover cheese completely. Cure your **Farmhouse Cheese** at 50°F for at least three months. It's flavor will be even better after six months. Turn the cheese daily for 2 weeks, and occasionally after that until it is eaten.

COMPOSITION OF MILK

	Solids/not Fat	DM	Protein	Fat	Lactose	Mineral
Goat	8.9	12.6	3.4	3.8	4.1	0.8
Cow	9.0	12.2	3.2	3.6	4.7	0.7

The following values were compiled by Charles A. Parry, PhD., McLean, Virginia.

ITEM All Items Per Liter		Breast Milk	Goat's Milk	Cow's Milk
Energy	Kcal	710	670	660
Protein	gm	11	32	42
Fat	gm	38	40	37
Carbohydrate	gm	68	46	49
Calcium	mg	340	1290	1430
Phosphorus	mg	140	1060	1120
Sodium	meq	7	15	27
Potassium	meq	13	46	45
Iron	mg	.5	1	0.5
Zinc	mg	3.5	2.4	3.5
Chloride	mg	375-450	1200	1050
Magnesium	mg	46	100-145	120
Vitamins				
A	i.u.	2000	2074	1500
B_1	mg	0.160	0.400	0.440
B_2	mg	0.360	0.1840	0.2100
B_3 (Niacin)	mg	1.47	1.9	1.0
B_6	mg	0.100	0.70	0.640
B_{12}	mcg	0.3	0.6	4.3
Pantothenate	mg	1.84	3.4	3.5
Folacin	mcg	52	6	55
Biotin	mcg	8	39	31
Choline	mg	90	150	121
Inositol	mg	330	210	110
C	mg	43	15	21
D	i.u.	22 22	24	14*
E	i.u.	1.8	—	0.4
Essential Fatty Acids, per 100 gm of Milk Fat			4.1	2.6
Percent Fat Globules Less Than 3 dram			63	43

* Not Fortified

Note: Actual values given vary over a considerable range. Reasonable values within ranges have been chosen as being representative.

TASKS FOR LESSON VI:

1) Build a Milking Stand

2) Learn Proper Milking Techniques

3) Pasteurize Milk

4) Make Cheese

LESSON VII - HEALTH CARE FOR YOUR GOATS

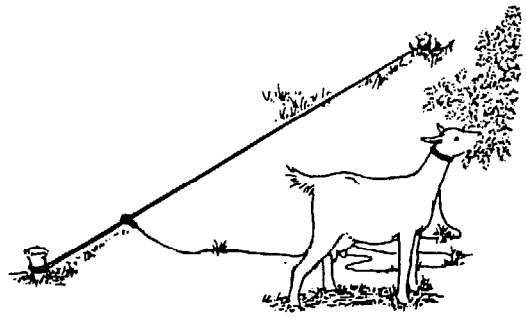

A HEALTHY GOAT

- eats well
- has a shiny coat
- is free of disease
- has strong legs and feet
- chews its cud
- is sociable
- has eyes that are bright and clear

NORMAL PHYSIOLOGICAL DATA FOR A GOAT

. Temperature	38.7° - 40.2° C 101.7° - 104.5° F
. Heart (pulse) rate	70-80 per minute, faster for kids
. Respiration rate	12-15 per minute, faster for kids
. Rumen movements	1 to 1.5 per minute
. Onset of heat (estrus)	7-12 months
. Length of heat	12-48 hours
. Heat cycle	17-23 days - average 21 days
. Length of gestation	145-156 days - average 150 days

SIGNS OF ILLNESS

- off feed
- standing off from group
- dehydration (Pull skin out from body. If skin sticks to itself and does not slip back easily, animal is dehydrated.)
- abnormal temperature
- pale mucosa around eyes and in mouth
- diarrhea
- heavy mucous in nose and mouth
- no sign of cud chewing
- limping
- runny eyes
- blindness
- swelling at any point in body
- hair falling out or rough in appearance
- circling movements
- clots or blood in milk

GOOD HEALTH CARE BEGINS WITH

- daily observation
- good nutrition which includes green chop (hay and forage), protein and energy supplements and plenty of water
- sanitation - clean pens, feeders and water buckets
- exercise
- a vaccination program - tetanus toxoid, soremouth, enterotoxemia (over-eating disease)
- parasite control for internal and external parasites
- regular hoof trimming

PREVENTATIVE HEALTH PROGRAM

The following preventative health program is recommended:

PREGNANT DOES

Vitamin E and Selenium - 60 days before kidding

Clostridium Perfringens C & D - 3 weeks before kidding

Tetanus Toxoid - 3 weeks before kidding

KIDS: 3 weeks to 3 months of age

Tetanus Toxoid	1/2 cc - 2 shots two weeks apart Annual booster
Contagious Ecthyma (Soremouth)	Vaccinate under tail or in bare skin under front leg at point of elbow. Be sure to check in 3 days for a take. Revaccinate every two years in heavily infected areas.
Clostridium Chauvoei Septicum-Novyi-Sordellii Perfringens Types C & D Bacterin	Protection against enterotoxemia, (over-eating disease), blackleg, malignant edema, black disease and clostridium sordellii infections. Give at 1 month, 6 weeks, 5 months of age. Annual booster

NEW ANIMALS COMING INTO HERD SHOULD ALWAYS BE VACCINATED.

GOOD HEALTH CARE BEGINS WITH DAILY OBSERVATION. Approach your goat as an individual. Be aware of any changes in her environment. Be gentle.

HOOF TRIMMING

While it is possible for goats on a rough terrain to wear down their hooves, most will need trimming at regular intervals. The diagrams below show the proper trimming method. Use either shears such as the Burdizzo Hoof Trimming Shear or a sharp knife.

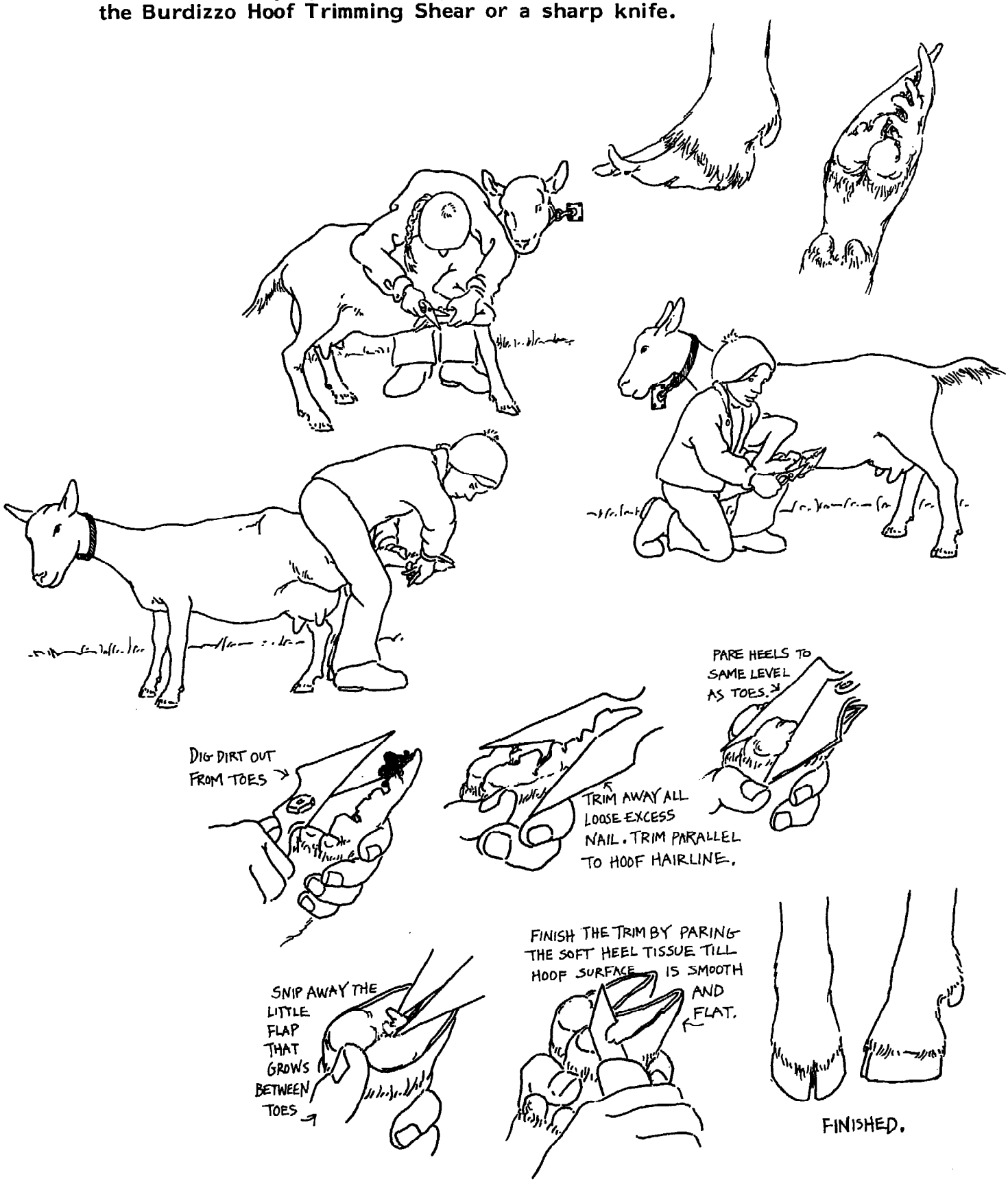

HOW TO TAKE A GOAT'S TEMPERATURE

Normal Temperature is 38.7° - 40.2° C
101.7° -104.5° F

Wipe thermometer with antiseptic solution - alcohol, iodine or bleach.
Shake the thermometer down to below normal, with a quick snap of the wrist.
Be sure not to hit anything as the thermometer breaks easily.
Insert the mercury end of the thermometer into the goat's rectum.
Wait for two minutes.
Remove thermometer, wipe clean and read.
Shake down again.
Wipe with antiseptic before storing.

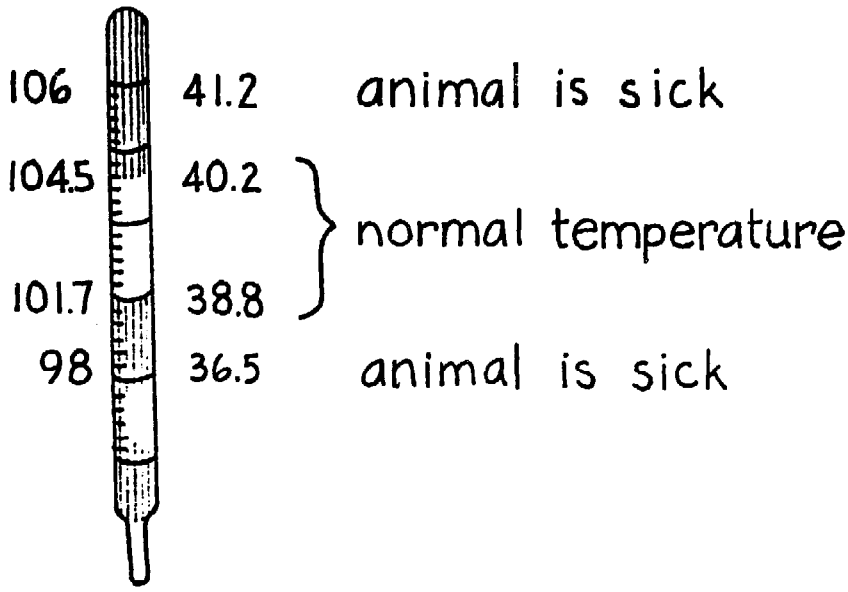

HOW TO DRENCH AN ANIMAL

Liquid medication can be given as a drench.
You will need a dose syringe or a Fanta, Coke or beer bottle.

Measure the correct amount of drench.
Keep goat's head in normal position.
Place end of syringe or bottle in left side of mouth on back of tongue.
Slowly pour drench into esophagus.

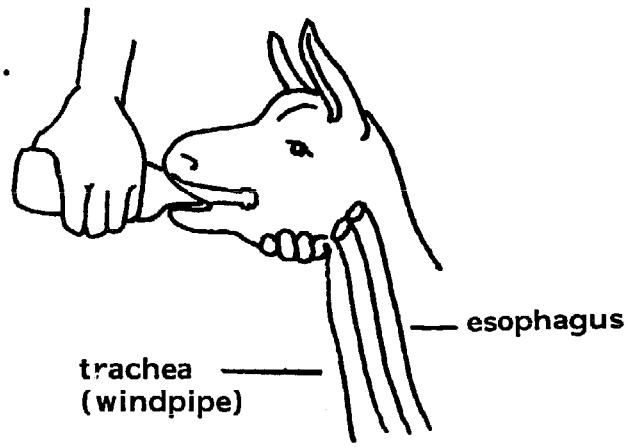

HOW TO GIVE AN ANIMAL A BOLUS

It is easier to give an animal a bolus if you have a tube made especially for this purpose or you can make one yourself by using two pieces of plastic pipe which can slide into each other - about 2 cm.

Remove bolus from container in proper dosage. Break bolus if needed.

Insert bolus in end of balling gun or tube. Hold tube upward to prevent bolus from dropping out.

Put tube in left side of goat's mouth.

Push plunger forward forcing bolus into esophagus.

Hold goat's mouth closed and stroke throat downward until bolus is swallowed.

HOW TO GIVE AN INJECTION

1) I.V. or Intravenous - Should be performed only by a veterinarian!

2) I.M. - Intramuscular

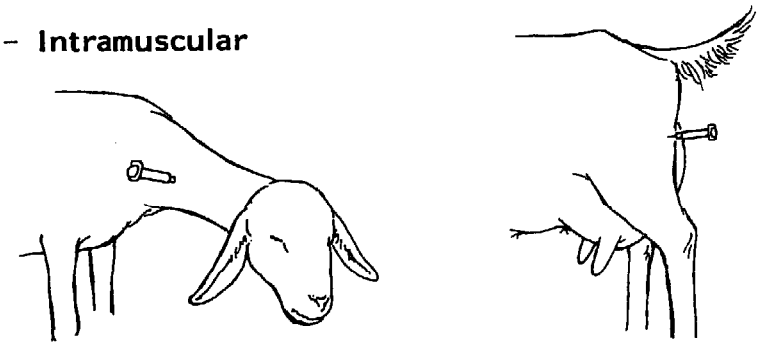

Use 20 gauge 1" needle for adult goats; 20 or 22 gauge 1" needle for kids. Insert needle to hub in thigh or in heavy part of neck. Draw back on plunger to aspirate for blood. If blood flows into syringe, withdraw needle and replace in another site.

3) SubQ. or Subcutaneous

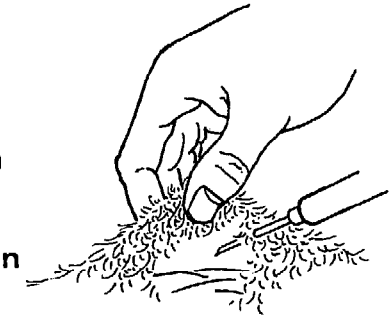

Use same size needles as for I.M. injections. Lift the loose skin of the flank or underneath leg and insert needle at an acute angle. Aspirate for blood as with I.M. If performed properly, a bleb should appear under the skin as the plunger is depressed.

NOTE: ALWAYS USE A STERILE NEEDLE AND SYRINGE WHEN GIVING INJECTIONS. BOIL NEEDLES AND SYRINGES IN WATER FOR 20 MINUTES TO STERILIZE.

ALWAYS CHECK DOSAGE FOR SPECIES AND WEIGHT OF ANIMAL.

GUIDE TO COMMON GOAT DISEASES

The following is only a partial list of diseases affecting goats. Your veterinarian is your best source for diagnosis and treatment, but in the absence of a vet, these guidelines will be helpful.

HEALTH PROBLEM	SIGNS	PREVENTION AND TREATMENT
NON-INFECTIOUS		
ANEMIA	Listless, lack of energy, pale mucosa around eyes, pale gums.	Improve nutrition. Treat for parasites. Add iron to diet.
ABORTION	Loss of fetus.	Abortions may occur in 15% of gestations. Injury, such as butting, is a major cause of abortion. Poor nutrition and mineral deficiencies can cause abortion, along with viral and bacterial infections.
BLOAT	Swelling of paunch, shows on left side.	Prevent rapid filling on legume pastures. Drench with palm oil or mineral oil. Keep animal on feet and moving. Feed dry non-legume grass to animal before putting out on legume pastures.
KETOSIS	Lack of appetite. Occurs in late pregnancy or shortly after kidding. Normal temperature, animal prefers hay to grain - incoordinate. Sweet smelling breath.	Preferred Treatment: propylene glycol, if available. Or give sugars, honey or syrup. Prevent obesity in early pregnancy. Increase plane of nutrition in last two months of pregnancy.
NAVEL ILL	Lameness, stiffness, swollen joints, fever in newborn kids. Fatal if not treated.	Prevent by sanitation at birth and dipping navel with 7% iodine at birth. If infected give Pen-strep injections, plus broad spectrum antibiotic in milk.
TETANUS	Sawhorse stance, prolapse of third eyelid, stiffness. Enters through wounds.	Vaccinate with tetanus toxoid or if not vaccinated, give tetanus anti-toxin at onset of disease. Give large doses of penicillin.

HEALTH PROBLEM	SIGNS	PREVENTION AND TREATMENT
CONTAGIOUS AND INFECTIOUS		
ABCESSES Caseous lymphadenitis	Swollen lymph nodes commonly occuring under jaw and ear, in front of shoulder, on flank, above udder or scrotum or above hock. The nodes may be warm and swell 3-5 cm or larger. Contain greenish, cheesy pus.	Avoid contaminated feeds. Can be contracted through breaks in skin, insect bites, etc. Spread by contact. Treat by surgical lancing, irrigate with 7% iodine. Burn all material from abcess. Treat daily until healing occurs.
BRUCELLOSIS	Goats show only vague symptoms: occasional mastitis; lameness of feet, loose stools, does may abort in final 4-6 weeks of pregnancy. Rare in goats.	In goats caused by Brucella melitensis; only rarely do other species of Brucella affect goats. Disease spreads when goats eat contaminated feed or lick infected material from the reproductive track. Organism transmitted to humans through drinking raw (unpasteurized) milk from infected animals. No treatment for infected animals. Vaccine used to control spread of disease. Goats should be tested yearly.
CAPRINE ARTHRITIS ENCEPHALITIS (CAE)	A viral disease. Goats develop weakness in rear legs, stumble and later cannot rise; they have no fever and eat well. Signs usually appear between one and two years. Older goats exhibit swollen joints and severe arthritis.	Transmitted most likely through colostrum and milk. Also spread by prolonged direct contact. Taking kids from doe and feeding heat-treated colostrum has been effective for prevention. (See Page 29.) A high percentage of goats tested show a positive titer, but actual clinical diagnosis of the disease is not as widespread.

HEALTH PROBLEM	SIGNS	PREVENTION AND TREATMENT
CONTAGIOUS AND INFECTIOUS (continued)		
COCCIDIOSIS	Most often seen in young kids. Affects digestive system and causes unthrifty condition and death. Persistent diarrhea, bloody feces or white feces may be present.	Give Amprol solution for 4 days at correct dosage. Treat with scour medication. Give electrolyte solution of 1 tsp. table sale, 1/4 tsp. baking soda, 4 oz. glucose (karo syrup), 2 quarts water. Give solution free choice. Sulmet also good treatment.
CONTAGIOUS ECTHYMA Soremouth	Lesions begin as small red spots in corners of mouth and become larger scabby areas. May also affect nostrils, eyelids and mouth. Scabs last 1-4 weeks. If in kids it may spread to teats of doe and prevent nursing.	Vaccinate kids at two weeks of age. Revaccinate every two years. Infected goats are said to be immune. Separate infected animals. Area in which animals are housed and pastured will be contaminated for up to 10 years.
DIARRHEA	Loose stools. Sign of another primary problem. May be caused by worms, coccidiosis.	Take off feed for 1 day. Give electrolyte solution. Give kaopectate. Serious diarrhea - treat with amprolium or sulfa drugs.
ENTEROTOXEMIA Overeating Disease	Convulsion, sluggish, staggers, loss of appetite, diarrhea, death within 24 hours. Usually affects animals in good condition.	Vaccinate at least once a year. Good feeding practices. No effective treatment.
FOOT ROT	Lameness, inflamation and swelling of foot. Dermatitis commonly seen between toes.	Trim feet. Keep in dry lot and under sanitary conditions. Remove abcess between toes and destroy. Bathe infected area in copper sulfate solution, Chloramphenicol, formaldehyde or a solution of 75% bleach, 25% water. Advanced cases should be given heavy doses of penicillin.

HEALTH PROBLEM	SIGNS	PREVENTION AND TREATMENT
CONTAGIOUS AND INFECTIOUS (continued)		
HEMORRHAGIC SEPTICEMIA Shipping Fever	Fever, cough, discharge.	Most often encountered during periods of stress. Vaccination available. Give 1 week prior to stress, i.e. transporting. Nasalgen effective. Treat with antibiotics.
MASTITIS	Inflammation of udder. Hard knots. Bloody, thin or stringy milk. Caused by bacterial infection.	Milk udder out several times each day. Apply hot compresses. Use appropriate antibiotic in teats.
PINK-EYE Kerato-Conjunctivitis	Tearing of eyes in early stages. Inner eyes will be red. In advanced stages cloudiness appears and sometimes total blindness.	Administer lacribiotic or other salve which contains neomycin, polymycin and/or a Terra-Cortril Opthalmic Suspension - twice each day. Keep animals out of direct sunlight. Apply a patch to severely infected eyes. Do not touch eye with tube while treating. Powders available, but often irritate eye.
PNEUMONIA	Nasal discharge, tongue out, rapid exaggerated movements of ribs, raspy sounds from lungs; temperature may be normal to high.	Bad ventilation is most often cause; also drafts and over-crowding. It may be a secondary infection following shipping fever. May result in death. Treat with Tetracycline, Oxytetracycline, Tylosin or Pen-strep.

HEALTH PROBLEM	SIGNS	PREVENTION AND TREATMENT

PARASITES

Good nutrition is the best prevention for any type of parasite problem along with good sanitation, rotating pastures and feeding hay and other forage in racks off of the ground.

Parasites rob important nutrition from your animals and treatment and prevention are extremely important in the productivity of your herd.

EXTERNAL PARASITES

LICE	Animal will pick at hair, hair coat will look out of condition.	Treat with powders or spray solution such as Coral, Toxaphene, Lindane.
EAR MITES	Dead skin in ear.	Mix cresyl with oil and rub in skin and clean ears once a week for 3 weeks.

TICKS

Ticks are a serious problem and a good program of management must be used to prevent fatal diseases.

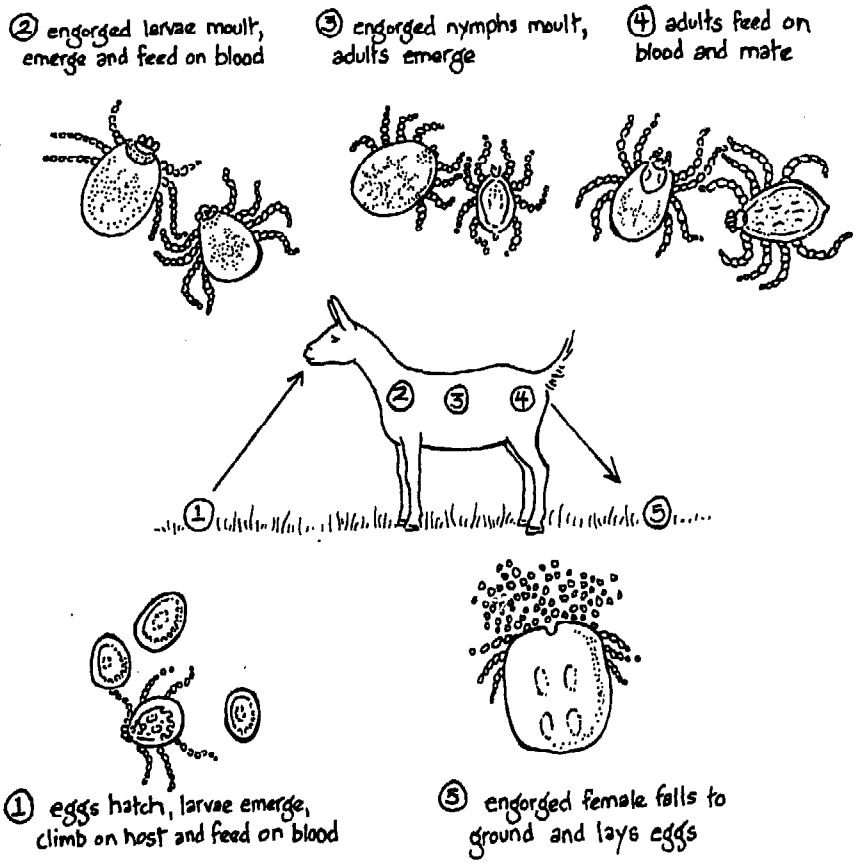

HEALTH PROBLEM	SIGNS	PREVENTION AND TREATMENT
TICKS AND TICK-BORNE DISEASES (continued)		
ANAPLASMOSIS	White mucosa, anemia high temperature, animal is weak and slow. Abortion common. Wide-spread in African countries.	Prevention by regular dipping or spraying. Spray or dip animals twice weekly in rainy season, once weekly in dry season. 10 cc Supona mixed with 16 liters water effective. Be sure feet and head are treated. Infected animals need good nursing care. Oxytetracycline (3-5 mg/kg body weight) should be administered daily.
HEARTWATER	Animal does not eat. High temperature. Continual movements of limbs, head, ears, tongue and jaw. Eventual convulsions and death.	Prevention by regular dipping or spraying described above. Administer Oxytetracycline or Sulphadimidine intravenously.

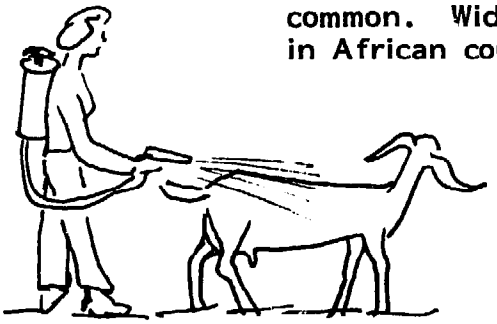

Note: Other products for spraying or dipping
Sevin, Lindane, Melathion, Asuntol

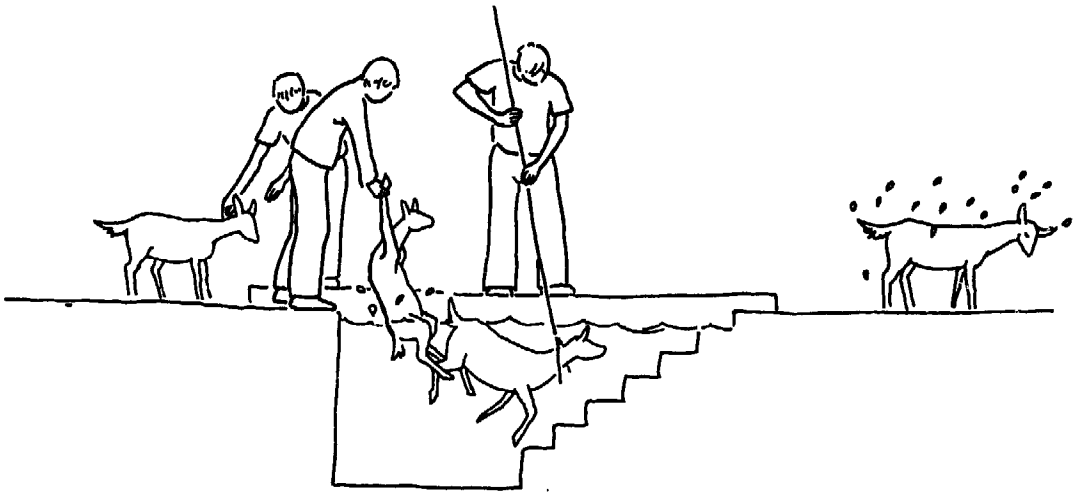

HEALTH PROBLEM	SIGNS	PREVENTION AND TREATMENT
OTHER SKIN PROBLEMS		
MANGE	Hair falls off, skin dry and flaky.	Apply red oil mixed with cresyl.
RINGWORM	Round scaly area with thin hair coat. Spreads rapidly. Highly contagious.	Thorough scrubbing with disinfectant. Treat with iodine or rub on thibendazole paste. Isolate infected animal.
INTERNAL PARASITES		
STOMACH WORMS INTESTINAL WORMS TAPEWORMS LUNGWORMS LIVER FLUKES	Unthrifty animal Anemia Pot-bellied Weight loss Diarrhea Pale Mucosa Pale Gums	The following products should be used after reading the instructions on the product label. Be sure to note the product use with pregnant and/or lactating animals. Albendazole - (Valbazen) Stomach worms, Intestinal worms, Tapeworms, Flukes (Do not use in first 45 days of pregnancy.) Ivermectin - (Equalan) Stomach worms, Intestinal worms, Lungworms, Tapeworms, Flukes and external parasites Fenbendazole - (Panacur, Oxfendazole) Stomach worms, Intestinal worms, Tapeworms Lavamisole - (Tramisol) Stomach worms, Intestinal worms, Lungworms Thiabendazole - (Thibenzole, TBZ, Omnizole) Stomach worms, Intestinal worms. In heavily infected areas, worm goats every four weeks. Give second dose 2-3 weeks later and repeat in 4 weeks. Alternate wormers.

LIFE CYCLE OF TYPICAL STOMACH WORM

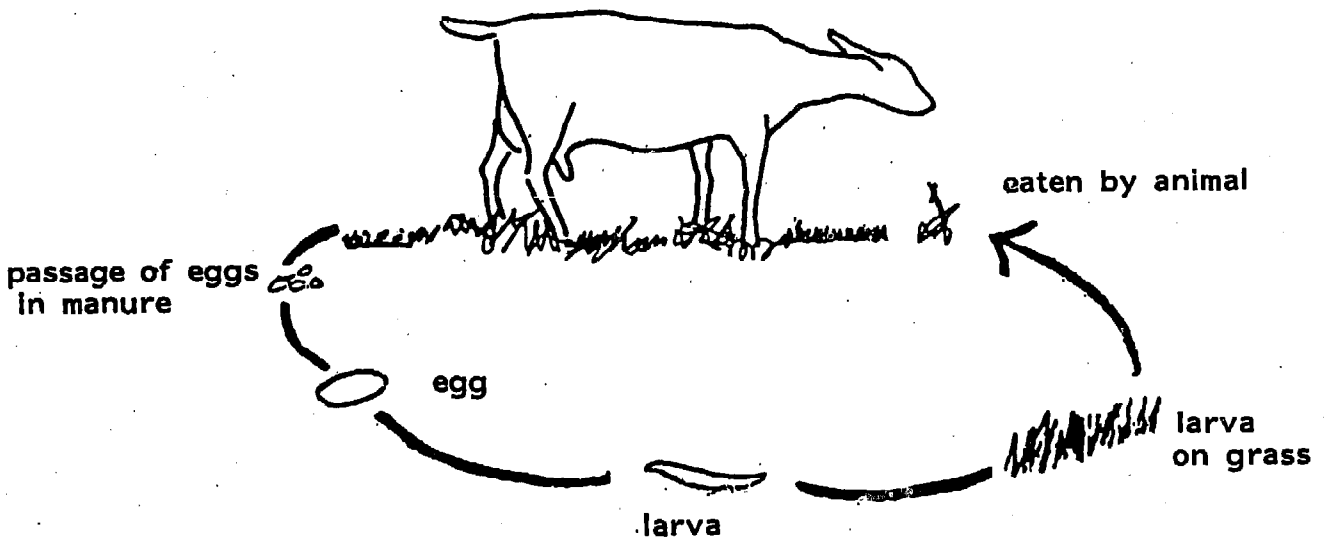

The cycle for the Tapeworm and Liver Fluke is similar except the intermediary host for the Tapeworm is a mite and for the Liver Fluke a snail.

LIFE CYCLE OF LIVER FLUKE

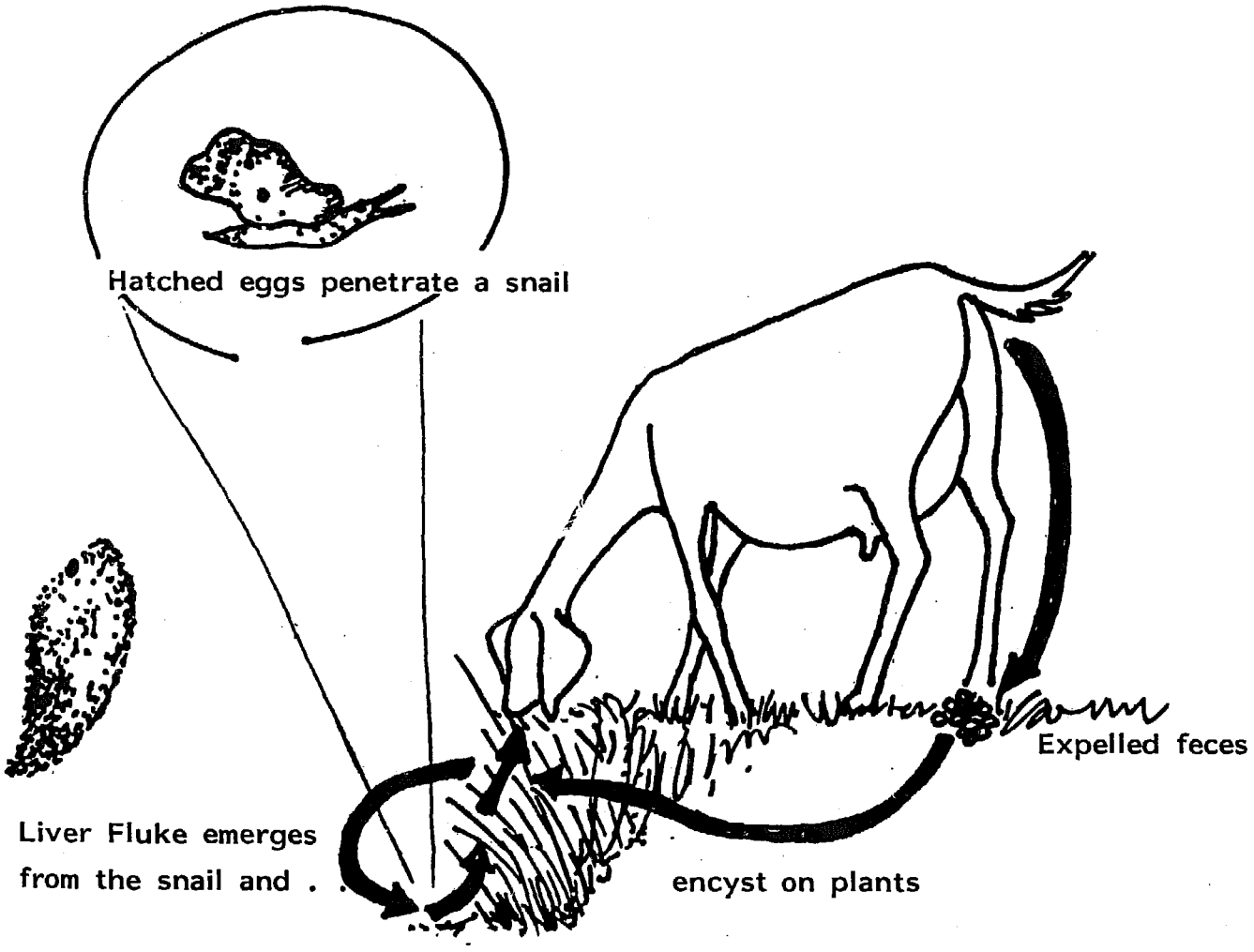

ITEMS AND MEDICATIONS YOU WILL NEED TO KEEP YOUR GOAT HEALTHY

Thermometer	
Disposable Syringes	3 cc and 5 cc are most used
Needles	20 and 22 gauge
Wounds	Vaseline, Cresyl, 3% Hydrogen Peroxide, Iodine
Foot Rot	Copper Sulphate, Bleach or Formaldehyde
Scours	Kaopectate, Electrolytes
Coccidiosis	Amprol
Respiratory Illness (pneumonia)	Terramycin, Oxytetracycline
Wormers	Thibenzole, Albendazole, Panacur, Omnizole, Tramisol
Teat Dip	Iodine, Bleach
Tick Spray	Supona, Sevin
Buffers	Bicarbonate of Soda, Palm Oil, Mineral Oil
Disinfecting	Alcohol, Iodine

PANACUR (FENBENDAZOLE)

AMPROL SOLUTION (CO-RID)

MINERAL OIL

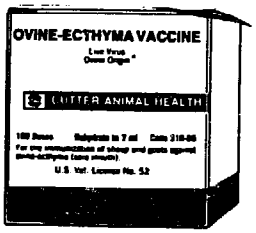

OVINE ECTHYMA VACCINE

NOLVASAN SUSPENSION

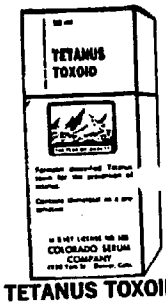

TETANUS TOXOID

TASKS FOR LESSON VII:

1) Temperature taking

2) Giving Medication by Bolus

3) Giving Medication by Drench

4) Giving I.M. and SubQ Injections

LESSON VIII - RECORD KEEPING

RECORDS ARE VERY IMPORTANT

THEY TELL YOU ABOUT YOUR GOAT

- what your goat is eating
- about your goat's health
- time of breeding
- the date and number of kids
- accurate record of milk production

EACH GOAT NEEDS HIS OR HER OWN INDIVIDUAL RECORD

KEEP A PAGE IN A NOTEBOOK OR A CARD ON EACH GOAT

Sample records are a part of this lesson. You may want to use these or adapt them to meet your own needs.

KEEP A RECORD OF YOUR GOAT'S VALUE AND SALES YOU MAKE	KEEP A RECORD OF ALL YOUR EXPENSES FOR YOUR GOAT
- milk and meat for your family - sale of milk or cheese - sale of offspring	- feed - health care and medications - breeding fees - equipment

THE DIFFERENCE BETWEEN THESE TWO COLUMNS WILL TELL YOU THE VALUE OF YOUR GOAT.

DAIRY GOAT RECORD SHEET

breed	reg. no.	born
name	tattoo no.	dehorned
color		

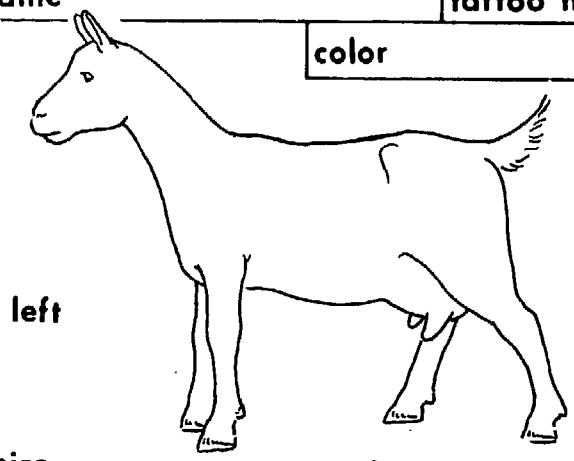

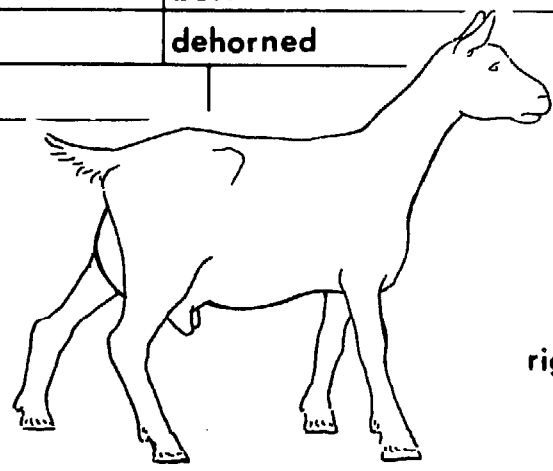

sire	no.	sire	no.
		dam	no.
dam	no.	sire	no.
		dam	no.

LACTATIONS

freshening age	total days	lbs. milk	B.F.	%

ORIGIN

farm reared	purchased from	
date	cost	date died

KIDDING

bred	due	kidded	no. in litter		sire	comments

HEALTH

date	condition	treatment	date	condition	treatment

DAIRY GOAT RECORD SHEET

breed	reg. no.	born
name	tattoo no.	dehorned

color

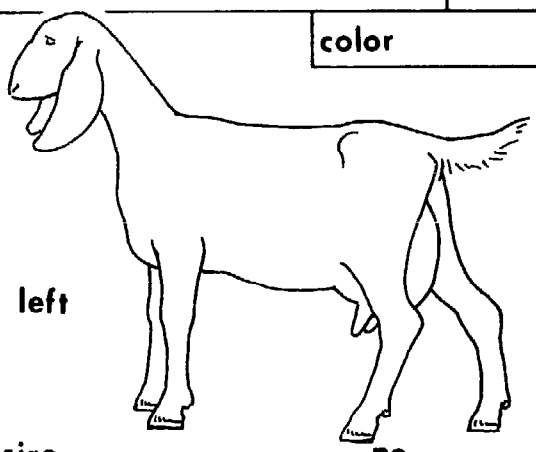

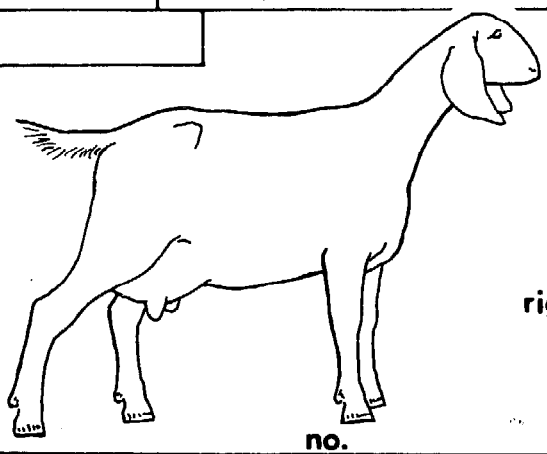

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LACTATIONS

freshening date	total days	lbs. milk	B. F.	%

ORIGIN

farm reared	purchased from	
date	cost	date died

KIDDING

bred	due	kidded	no. in	litter	sire	comments

HEALTH

date	condition	treatment	date	condition	treatment

BUCK RECORD SHEET

breed	reg. no.	born
name	tattoo no.	dehorned
color		

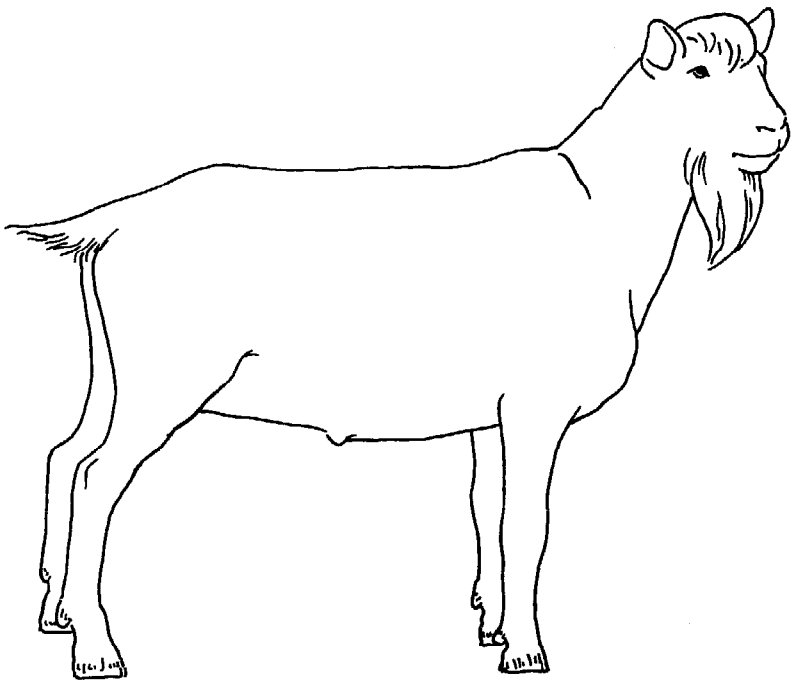

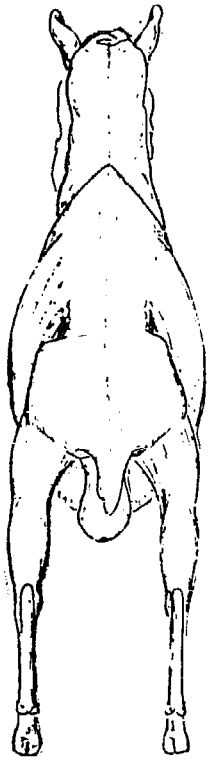

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BREEDINGS

DATE	DOE

BREEDINGS

DATE	DOE

ORIGIN

farm reared	purchased from	
date	cost	date died

HEALTH

date	condition	treatment	date	condition	treatment

BUCK RECORD SHEET

breed	reg. no.	born
name	tattoo no.	dehorned

color

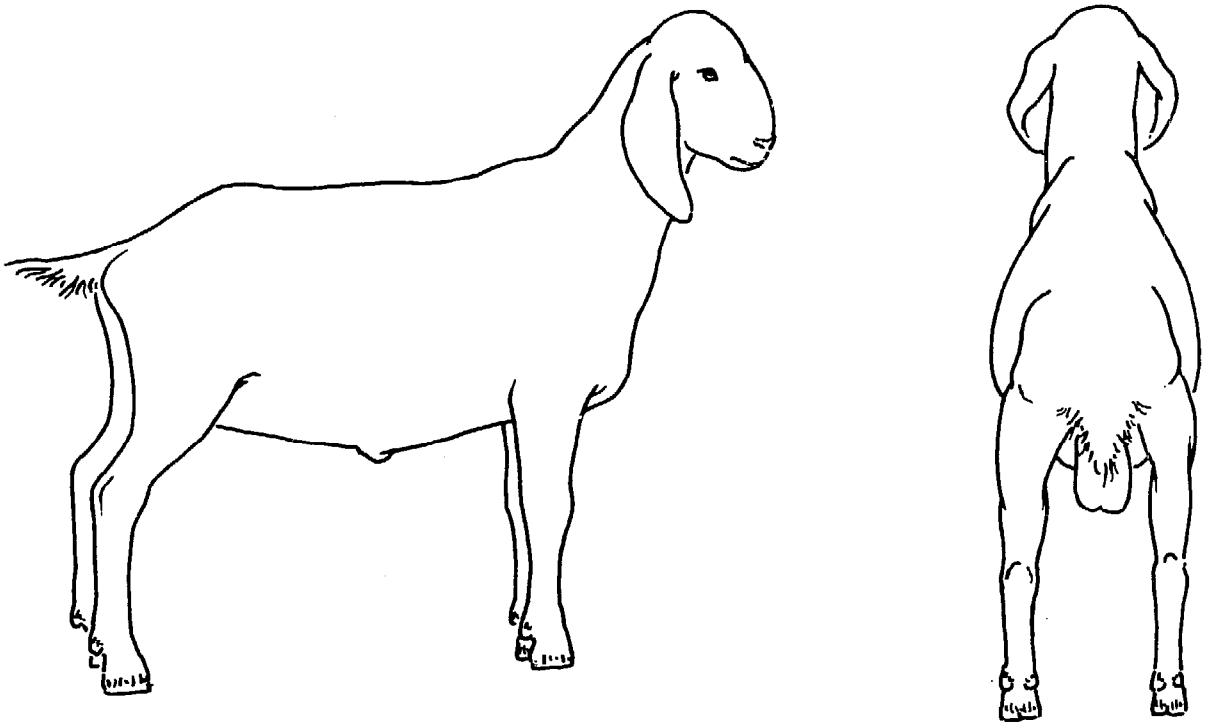

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BREEDINGS

DATE	DOE

BREEDINGS

DATE	DOE

ORIGIN

farm reared	purchased from	
date	cost	date died

HEALTH

date	condition	treatment	date	condition	treatment

INDIVIDUAL DAILY MILK RECORD

Name of Goat _____ Year _____

No. _____

Weigh milk and record in kilos or lbs. If no scale, measure after straining and record in liters or quarts.

Day	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Total
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INDIVIDUAL DAILY MILK RECORD

Name of Goat _____ Year _____

No. _____

Weigh milk and record in kilos or lbs. If no scale, measure after straining and record in liters or quarts.

Day	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Total
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INDIVIDUAL DAILY MILK RECORD

Name of Goat _____ Year _____

No. _____

Weigh milk and record in kilos or lbs. If no scale, measure after straining and record in liters or quarts.

Day	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Total
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DAILY HERD MILK RECORD

Put Day of Month in Box																			
Goat's Name and No.	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	Total
Total																			

TASKS FOR LESSON VIII:

1) Record Daily Milk Production

2) Record Herd Milk Production

3) List the items your goat will provide which will have value

4) List the expenses you anticipate for your goat

LESSON IX - SELECTING AND SLAUGHTERING GOATS FOR MEAT

CULL ANIMALS

1) Not suitable for breeding, i.e. animals with genetic defects. Note: If abnormal conditions are evident, further inspection by a qualified person, such as a veterinarian, would be advisable. Diseased animals should not be slaughtered for consumption.
2) Surplus breeding stock
3) Unthrifty animals
4) Poor producers
5) Older animals

HANDLING OF ANIMALS PRIOR TO SLAUGHTER

1) Withhold feed of all kinds - both hay and grain - for 24 hours prior to slaughter.

2) Do provide plenty of water.

3) Place animals in a clean, well-bedded area.

4) Do not excite animals prior to slaughter.
Do not pinch hide or beat with a stick because you will bruise the meat and it will spoil more quickly.

SLAUGHTER IN THE COOL OF THE DAY. IF REFRIGERATION IS NOT AVAILABLE, PLAN TO SLAUGHTER ONLY ANIMALS THAT CAN BE EATEN IN 24 HOURS. Otherwise, you may want to preserve meat by salting, drying, etc.

PREPARATION FOR SLAUGHTER

Plan to slaughter in an area with a concrete floor or put legs on your slaughtering cradle to keep the animal's carcass clean.

Make a Hanging Stick

Make a Slaughtering Cradle

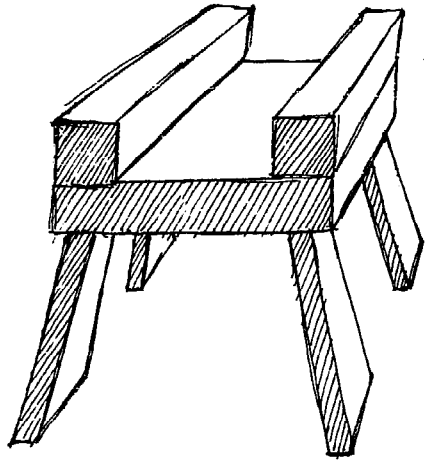

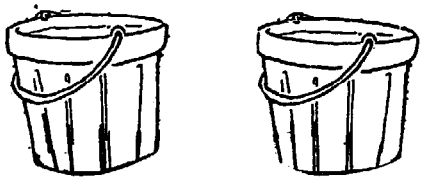

Have plenty of cold water available.

EQUIPMENT

Hammer or Pistol (for stunning, if preferred)

Sharp knife and sharpening stone
Steel for putting edge on the knife

Rack to hang hide on
Meat Saw (if available)

Container for Blood

SLAUGHTERING

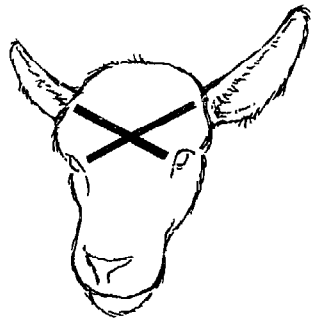

1) Halter animal. Hold at about 6" distance.

2) Draw an imaginary cross between ears and eyes. Where the cross intersects is the place to strike the stunning blow. Use small blunt instrument like a hammner or pistol. Animal will probably not die, only be stunned.

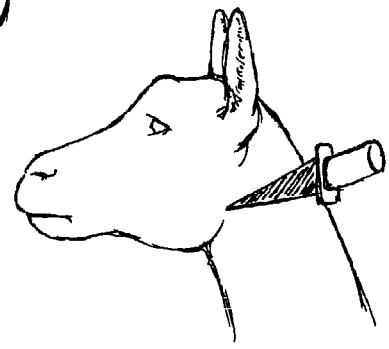

3) Put the stick knife in below the ear and at the base of the jaw. Stick through to other side. Cutting edge should be pointed out. Speed is important. Let the blood flow freely. When you are sure animal is through bleeding, pull chin back until you can see neck bones. Sever windpipe, sever head.

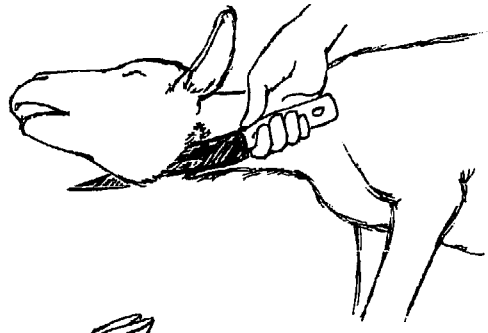

4) Let animal bleed a couple of minutes until it has quit thrashing.

5) Put animal into cradle on its back, head down. Wait until reflexes have stopped.

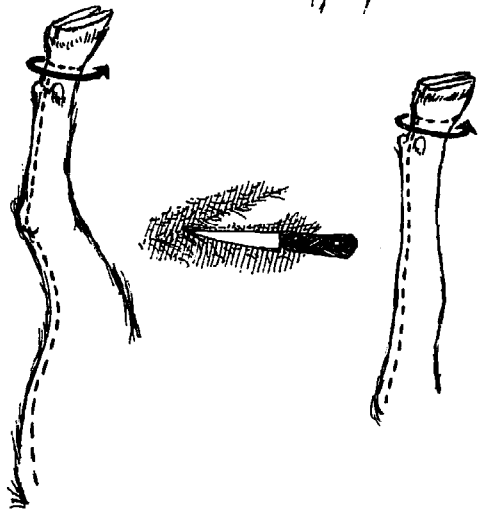

6) Ring each hoof between hoof and declaw with knife. Run point down back of each front leg. On rear legs run knife all the way up leg to rectum. Go just through the skin. As you begin to trim skin away, the dew claw becomes holding point.

7) Separate skin from pastern area. Jerk hide down to hock holding onto dew claws.

8) Now jerk up to crotch. Do both sides.

9) Separate tissue from severed line in crotch. Leave scrotal or mammary tissue in hide. Separate flap of skin from rectum to leg.

10) Front end. Do same as far as knee. Jerk it to top of arm.

11) Draw knife across sternum from armpit to armpit. Go right under skin. Do not cut meat. At the point line crosses brisket, go from there to throat and open.

12) Begin working back the skin to the armpits.

13) Now you have skinned front end - exposing throat, front portion of each shoulder and at legs.

Once you have separated hide off legs at the break joint, sever the foot from the leg. (The break joint is only present in animals under a year of age.) Otherwise, remove foot at ball joint.

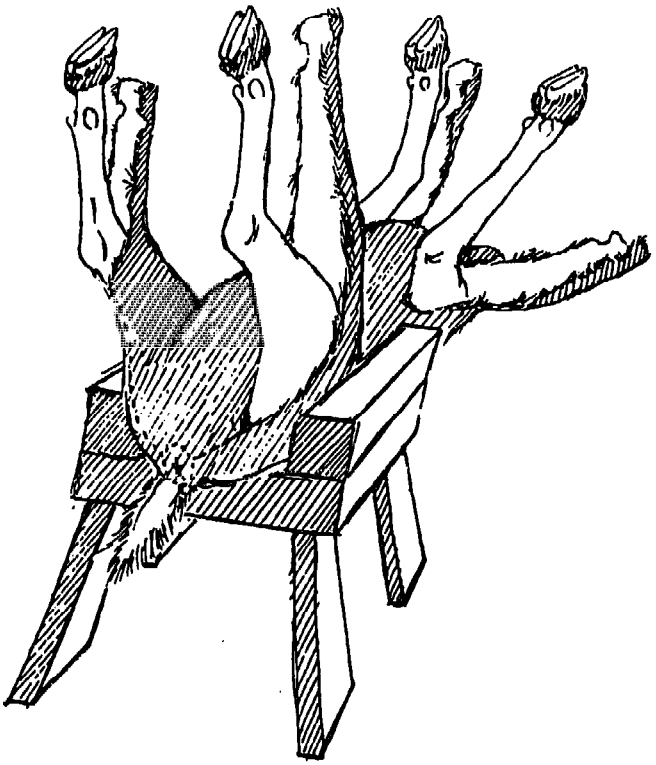

14) Take knife and open skin from sternum to crotch. In male remove penis.

15) Work hide back to each side using fingers. Try to keep thin layer of muscle on the carcass. It is important to keep carcass intact. The entire stomach is now exposed.

16) Put in the hanging stick through hock between the achilles tendon and lower section of thigh.

17) Suspend hanging stick from tree. Hoist animal off of cradle so it is hanging.

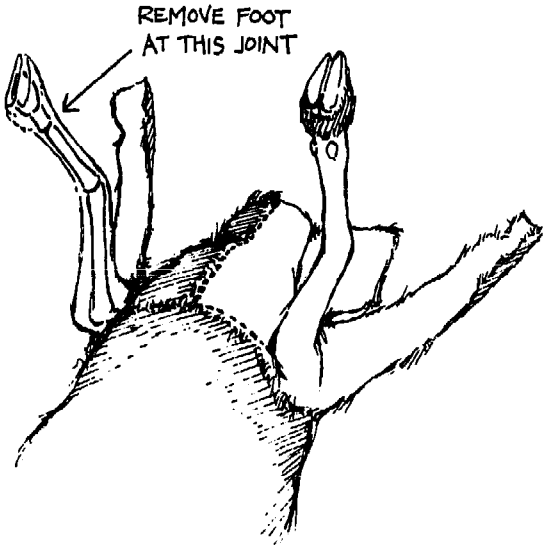

IMPORTANT: RINSE HANDS ANYTIME YOU TOUCH HIDE AND THEN MEAT.

18) Cut from throat to sternum, through sternum from middle of belly through throat. Chest cavity is exposed.

19) Work with fingertips and knife when necessary, working hide over rump. As you approach tail, grasp tail base and pull skin off.

20) At this point strip back with fingernails and knuckles trying to keep all muscle on carcass, going right down backbone. Strip right off. Again, keep subcutaneous muscle attached to carcass and not hide. Pull off. Lay hide on rack.

21) Go to front. Wash carcass. Pour bucket of clean water over it.

22) Put in knife at crotch - blade side toward you. Put finger behind dull side of knife and push finger and knife down toward navel and eventually to sternum. Guts will fall forward.

23) Reach into the crotch and draw the rectum through pelvic arch.

23) Ring the rectum with knife. Tie it off. Reach into the crotch and draw the rectum through pelvic arch.

24) Pull bladder free and let this go with guts. Leave kidneys in kidney fat at back side of body.

25) Approaching thoracic cavity, spleen will be on left hand side. Pull loose - discard. At this point you will see liver on the right. Grab base of gall bladder and strip from liver, leaving liver in body cavity.

26) You will see bottom of esophagus. Tie this off. Cut this and guts will fall loose on the ground.

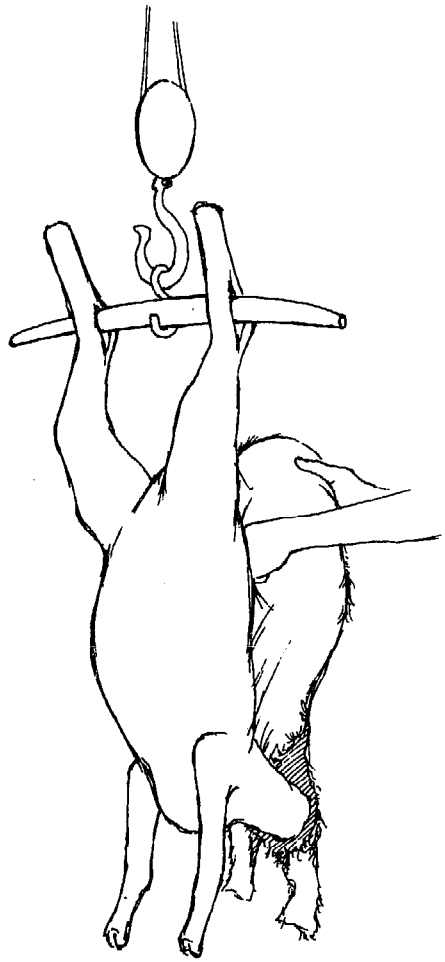

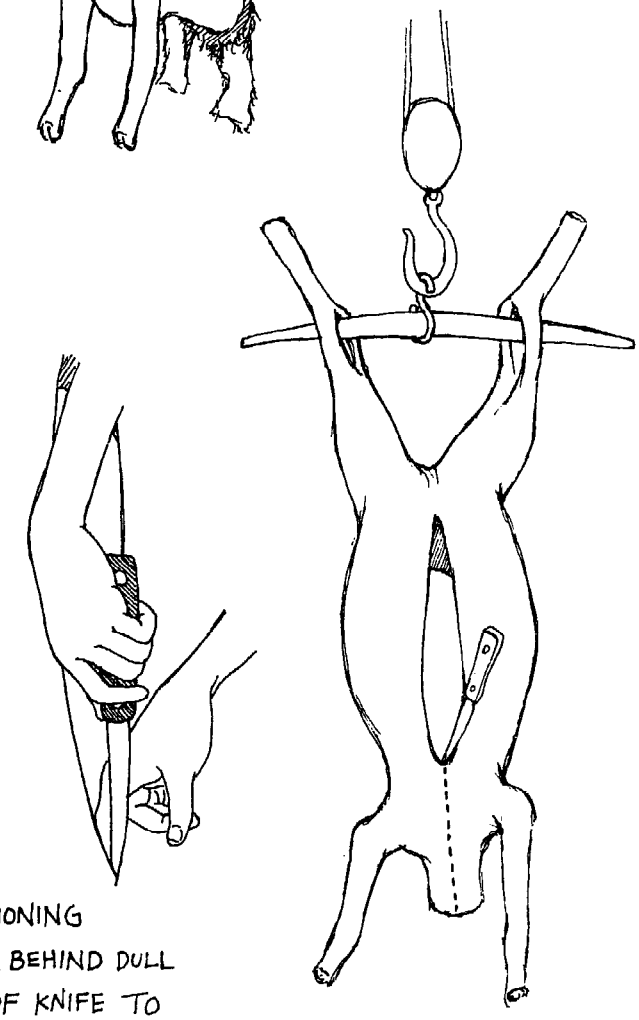

POSITIONING FINGER BEHIND DULL EDGE OF KNIFE TO PROTECT STOMACH FROM PUNCTURE

27) As you look at kidneys and liver, you will see beneath them a distinct red and white line (diaphram). This band separates the thoracic cavity from the abdominal cavity. Run knife along muscular strip (red and white line) and cut to sternum on each side. Grasp in center and pull away from muscle supporting liver. Do not take out.

28) Heart, lungs, windpipe and esophagus (pluck) will be in the material you are dragging away. Remove pluck, opening the throat the full length of the chest cavity.

29) Thoroughly wash carcass inside and out.

30) Remove tongue from head and any other parts of head you wish to use, such as brains, etc.

31) Keep the meat in a cool place or throw cold water on it periodically. If you are going to leave hanging for any length of time, wrap in a clean cloth.

32) Cut in desired pieces. Edible by-products would include liver, heart, tongue, kidneys, brains. If you have use for casings, for sausage, the small and large intestines could be salvaged.

33) All inedible visera should be buried or disposed of in a sanitary manner.

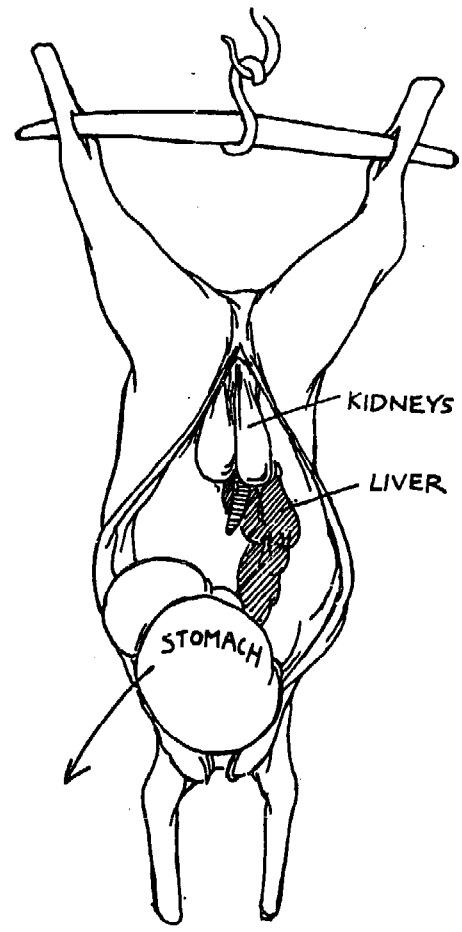

CONVERSION TABLE

1 milliliter (ml) = 1000 microliters
1 liter (l) = 1000 ml

To convert liters (l) to ounces (oz), pints (pt), quarts (qt) and gallons (gal):

¼ l = 8½ oz
½ l = 1 pt 1 oz
1 l = 1 qt 2 oz
4 l = 1 gal 7 oz
10 l = 2¾ gal
25 l = 6¾ gal

50 l = 13¼ gal
100 l = 26½ gal

To convert ounces (oz), pints (pt), quarts (qt), and gallons (gal) to milliliters (ml) and liters (l):

1 oz = 29.6 ml
2 oz = 59.2 ml
3 oz = 88.8 ml
4 oz = 118.4 ml
5 oz = 148 ml
6 oz = 177.5 ml
7 oz = 207 ml
8 oz = 236.6 ml
1 pt = 473.2 ml
1 qt = 946 ml (or 0.946 l)
2 qt = 1.893 l
3 qt = 2.839 l
4 qt = 3.785 l

Temperature

To convert Centigrade (C) to Fahrenheit (F)

C	F
36	96.8
36.5	97.7
37	98.6
37.5	99.5
38	100.4
38.2	100.8
38.4	101.1
38.6	101.5
38.8	101.8
39	102.2
39.2	102.6
39.4	102.9
39.6	103.3
39.8	103.6
40	104
40.2	104.4
40.4	104.7
40.6	105.1
40.8	105.4
41	105.8
41.2	106.2
41.4	106.5
41.6	106.8
41.8	107.1
42	107.5

Note: To reduce degrees F to degrees C, subtract 32, then multiply by ⅝. To reduce degrees C to degrees F, multiply by ⅝ then add 32.

Weights

1 gamma = 1 microgram (mcg)
1,000 mcg = 1 milligram (mg)
1,000 mg = 1 gram (gm)
1,000 gm = 1 kilogram (kg)
1,000 gm = 1 kg = 2.2 lb

To convert ounces (oz) and pounds (lb) to grams (gm) and kilograms (kg):

1 oz = 28.3 gm
2 oz = 56.7 gm
3 oz = 85 gm
4 oz = 113.3 gm
5 oz = 141.6 gm
6 oz = 170 gm
7 oz = 198.3 gm
8 oz = 226.6 gm
9 oz = 255 gm
10 oz = 283.5 gm
11 oz = 311.8 gm
12 oz = 340 gm
13 oz = 368.3 gm
14 oz = 396.6 gm
15 oz = 425 gm
16 oz (1 lb) = 453.6 gm
1 lb = 453.6 gm
2 lb = 907.2 gm
3 lb = 1.4 kg
4 lb = 1.8 kg
5 lb = 2.3 kg
10 lb = 4.5 kg
50 lb = 22.7 kg
100 lb = 45.4 kg
1,000 lb = 453.6 kg
2,000 lb = 907.2 kg

Linear Measure

1 millimeter (mm) = 0.04 inch (in.)
1 centimeter (cm) = 0.4 in.
1 decimeter = 4 in.

1 in. = 2.54 cm
1 foot (ft) = 30.48 cm
1 yard (yd) = 91.44 cm

10 mm = 1 cm
100 cm = 1 meter (m)
1000 m = 1 kilometer (km)

⅛ in. = 3 mm
¼ in. = 6 mm
½ in. = 11 mm
¾ in. = 18 mm
1 in. = 2.5 cm
2 in. = 5 cm
3 in. = 7.5 cm
4 in. = 10 cm
5 in. = 12.5 cm
6 in. = 15 cm
7 in. = 17.5 cm
8 in. = 20 cm
9 in. = 22.5 cm
10 in. = 25 cm
11 in. = 27.5 cm
12 in. = 30 cm

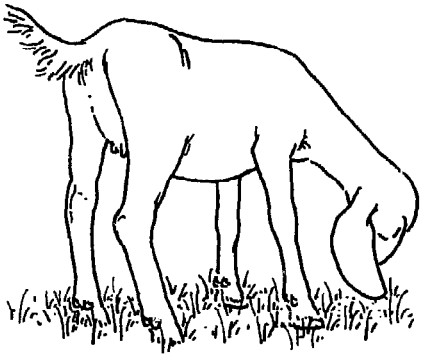

Goat milk weighs approximately 8.5 lb. (1.02 Kg) per gallon (L) at room temperature.

The weight will vary as it depends on the specific gravity of the milk. The higher the fat content of the milk, the lower is the specific gravity, thus the lower the weight per gallon of milk.

Milk freezes at approximately 30°F (-1°C)

QUICK REFERENCE CONVERSION

Inches	1	2	3	4	5	6	7	8	9	10
Centimeters	2.54	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40

Centimeters	1	2	3	4	5	6	7	8	9	10
Inches	.39	.79	1.18	1.57	1.97	2.36	2.76	3.15	3.54	3.93

Pounds	1	2	3	4	5	6	7	8	9	10
Kilograms	.45	.91	1.36	1.81	2.27	2.72	3.18	3.63	4.08	4.53

Kilograms	1	2	3	4	5	6	7	8	9	10
Pounds	2.20	4.41	6.61	8.82	11.02	13.23	15.43	17.64	19.84	22.02

UNITS OF CAPACITY LIQUID MEASURE

Units		Fluid Ounces	Liquid Pints	Liquid Quarts	Gallons	Milliliters	Liters
1 fluid ounce	=	1	0.062	0.031	0.007	29.573	0.029
1 liquid pint	=	16	1	0.5	0.125	473.176	0.473
1 liquid quart	=	32	2	1	0.25	946.352	0.946
1 gallon	=	128	8	4	1	3,785.306	3.785
1 cubic inch	=	0.554	0.034	0.017	0.004	16.387	0.016
1 cubic foot	=	957.506	59.844	29.922	7.480	28,316.846	28.316
1 milliliter	=	0.033	0.002	0.001	0.000	1	0.001
1 liter	=	33.814	2.113	1.056	0.264	1,000	1

UNITS OF CAPACITY DRY MEASURE

Units		Dry Pints	Dry Quarts	Pecks	Bushels	Liters	Dekaliters
1 dry pint	=	1	0.5	0.062	0.015	.550	.055
1 dry quart	=	2	1	0.125	0.031	1.101	.110
1 peck	=	16	8	1	0.25	8.809	.880
1 bushel	=	64	32	4	1	35.239	3.523
1 cubic inch	=	0.029	0.014	0.001	0.000	0.016	0.001
1 cubic foot	=	51.428	25.714	3.214	0.803	28.316	2.831
1 liter	=	1.816	0.908	0.113	0.028	1	0.1
1 dekaliter	=	18.161	9.080	1.135	0.283	10	1

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Appendix

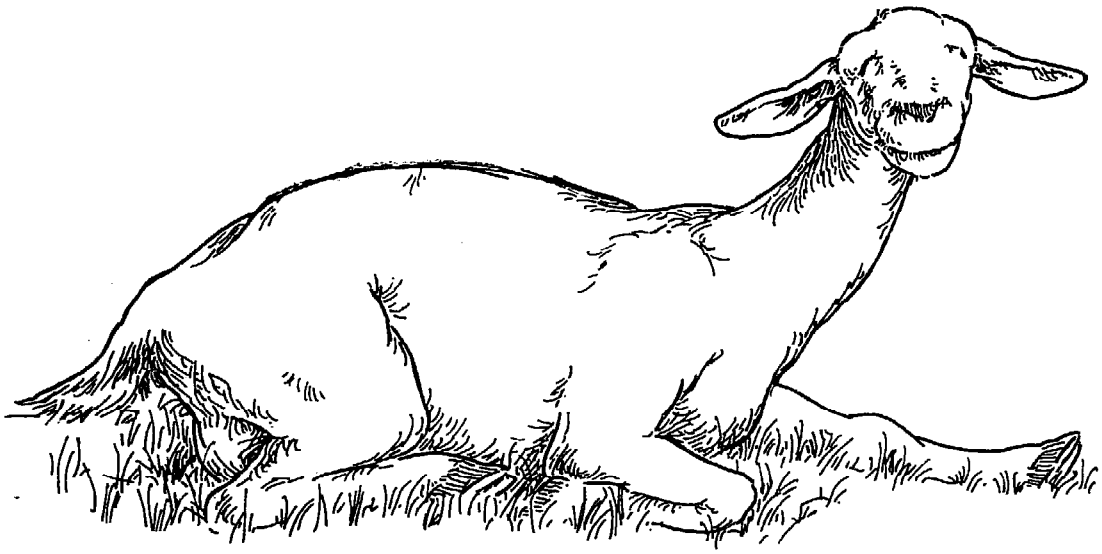

OBSERVATION SHEET

Name of goat to be observed _____

Tag Number (if any) _____ Tattoo _____ Sex _____

Breed _____ Age _____

If Female: Bred _____ Open _____ Date Due to Kid _____

If Male: Check testicles to be sure both are descended. Check general condition of reproductive organs.

Current Feeding Schedule _____

Weight _____ Compare with projected weights on Page 19 of Manual.

Treated for parasites _____ When _____ Medication _____

Each day observe the following and record:

1) General Appearance

2) Activity Level

3) Legs and Hooves

4) Any external problems such as abcesses, parasites, etc.

5) Condition of eyes, nose, mouth

6) Condition of feces (droppings) - pellet-like, ploppy, loose, diarrhea

7) Milk Production - if lactating _____ kilos per day

_____ liters per day

Any signs of mastitis

8) Eating habits

9) Check any of the following signs of illness:

_____ off feed
_____ dehydration
_____ limping
_____ blindness
_____ diarrhea
_____ runny eyes
_____ circling movements
_____ clots or bloody milk
_____ standing off from group
_____ abnormal temperature
_____ pale mucosa around eyes and in mouth
_____ heavy mucous in nose or mouth
_____ no sign of cud chewing
_____ swelling at any point in body
_____ hair falling out or rough in appearance

OBSERVATION SHEET

Name of goat to be observed _____

Tag Number (if any) _____ Tattoo _____ Sex _____

Breed _____ Age _____

If Female: Bred _____ Open _____ Date Due to Kid _____

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_____ diarrhea
_____ runny eyes
_____ circling movements
_____ clots or bloody milk
_____ standing off from group
_____ abnormal temperature
_____ pale mucosa around eyes and in mouth
_____ heavy mucous in nose or mouth
_____ no sign of cud chewing
_____ swelling at any point in body
_____ hair falling out or rough in appearance

DAIRY GOAT RECORD SHEET

breed	reg. no.	born
name	tattoo no.	dehorned

color

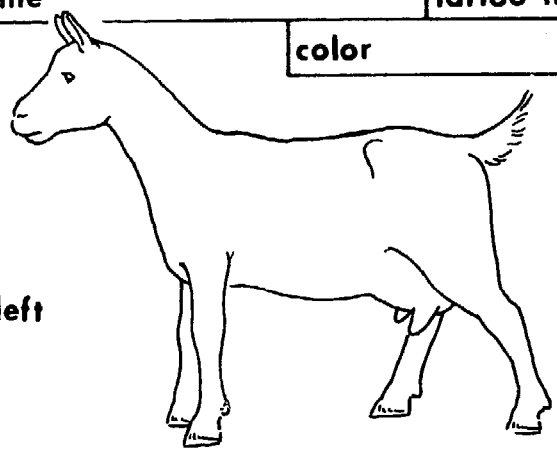

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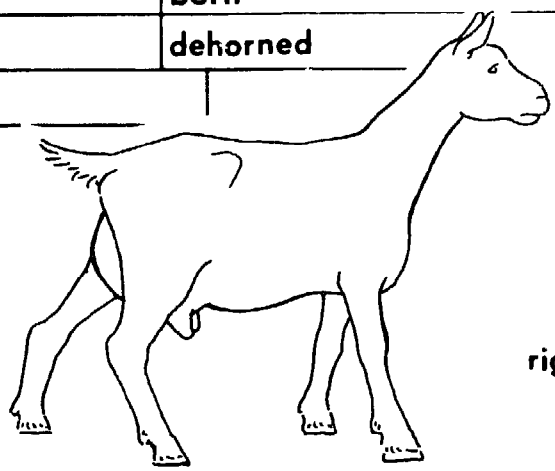

right

sire	no.	sire	no.
		dam	no.
dam	no.	sire	no.
		dam	no.

LACTATIONS

freshening date	total days	lbs. milk	B. F.	%

ORIGIN

farm reared	purchased from	
date	cost	date died

KIDDING

bred	due	kidded	no. in litter		sire	comments

HEALTH

date	condition	treatment	date	condition	treatment

BUCK RECORD SHEET

breed	reg. no.	born
name	tattoo no.	dehorned

color

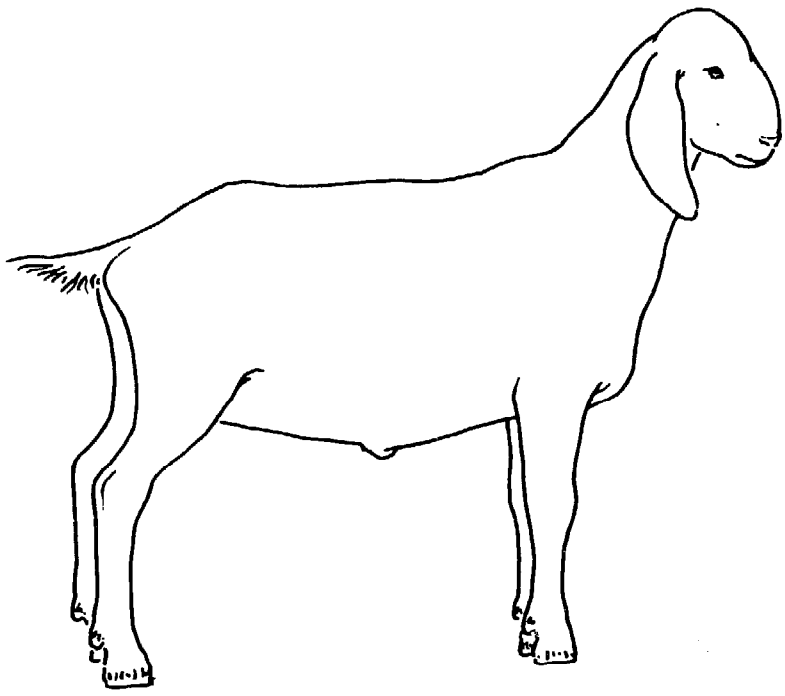

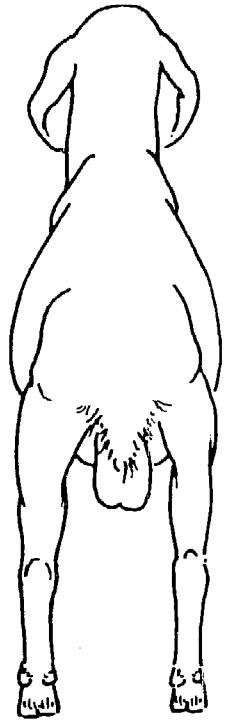

sire	no.	sire	no.
		dam	no.
dam	no.	sire	no.
		dam	no.

BREEDINGS

DATE	DOE

BREEDINGS

DATE	DOE

ORIGIN

farm reared	purchased from	
date	cost	date died

HEALTH

date	condition	treatment	date	condition	treatment

INDIVIDUAL DAILY MILK RECORD

Name of Goat _____ Year _____

No. _____

Weigh milk and record in kilos or lbs. If no scale, measure after straining and record in liters or quarts.

Day	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Total
	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	
1																									
2																									
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30																									
31																									
Total																									

INDIVIDUAL DAILY MILK RECORD

Name of Goat _____ Year _____

No. _____

Weigh milk and record in kilos or lbs. If no scale, measure after straining and record in liters or quarts.

Day	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Total
	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	
1																									
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HERD MILK RECORD

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Founded in 1944, Heifer Project has since provided assistance to people in more than 100 countries.

The purpose of Heifer Project International is to assist small farmers achieve a better living through more efficient use of human and natural resources.

The method is to introduce genetic improvement in livestock and to demonstrate and teach proper management.

Distribution of Heifer Project livestock is made without regard to race, creed or political origin, and in a manner which requires the recipient to share the increase.

Projects are designed so as to be self-supporting and perpetuating. To accomplish this, plans and agreements are made with indigenous organizations.

The program of Heifer Project International is supported by voluntary contributions from thousands of individuals, churches, youth groups, businessmen, farmers and others who believe in the aims and objectives of Heifer Project.

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Raising Healthy Cattle Under Primitive Conditions

By: James Carlson, D.V.M.

Published by: Christian Veterinary Mission
Division of World Concern
Box 33000
Seattle, WA 98133

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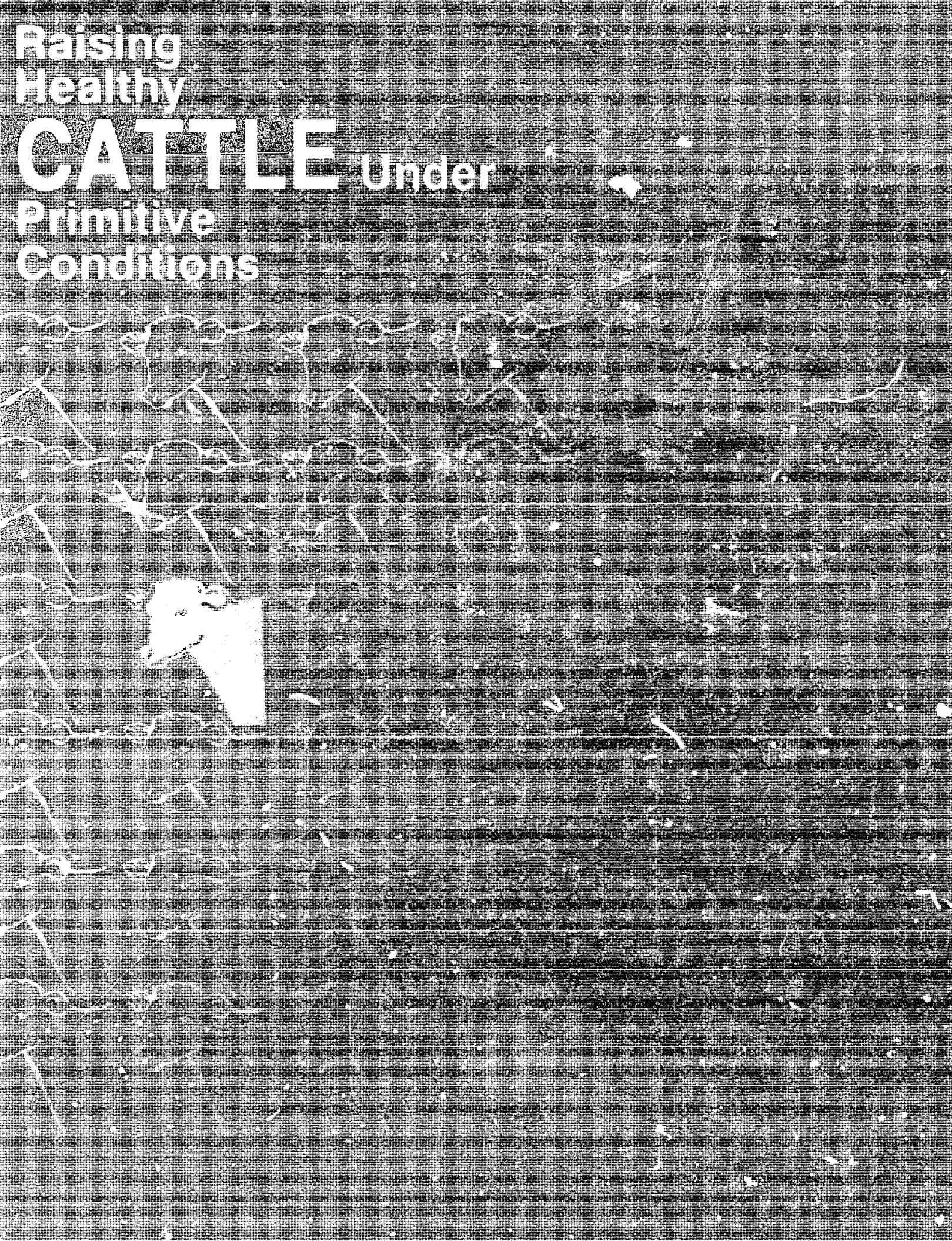

Raising Healthy Cattle Under Primitive Conditions

by

JAMES CARLSON, D.V.M.

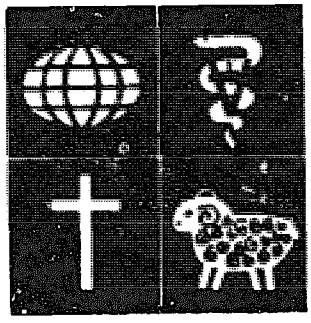

Christian Veterinary Mission

A Publication of Christian Veterinary Missions

Division of World Concern

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THIS IS AN EXPERIMENTAL FIRST EDITION

It can be improved with your help. If you are a veterinarian, veterinary technician, animal husbandry worker, missionary, development worker or anyone with ideas or suggestions for ways this booklet could be changed to better meet the needs of your people, please write to the authors at Christian Veterinary Mission., 19303 FreMont Ave. N., Seattle, WA 98133

Thank you for your help.

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Section I

Introduction

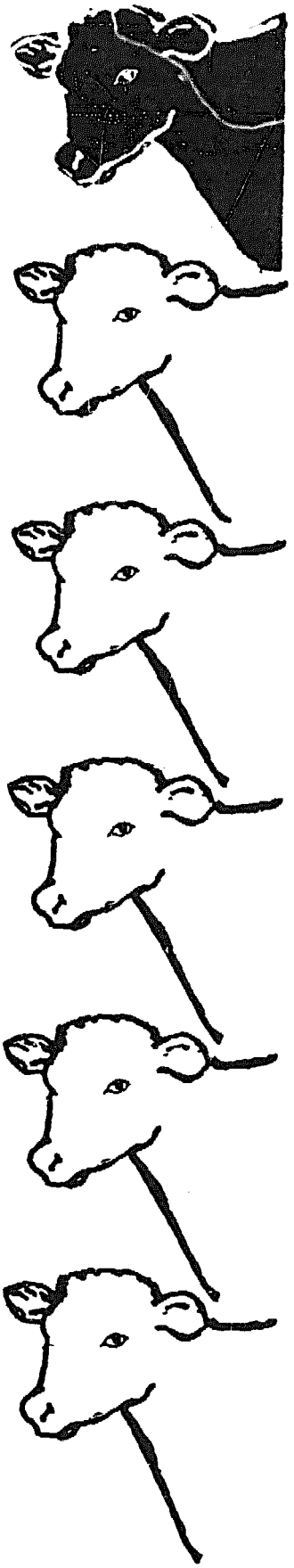

BACKGROUND

This booklet was provided by Christian Veterinary Missions to provide basic information concerning beef cattle for missionaries, small farmers, and agricultural workers. Topics discussed are Facilities and Handling, Nutrition, Management, Diseases and Poisonings. There also is a section in the back which gives instructions on consulting by mail where more information is needed or a specific problem exists.

The author has practiced Veterinary Medicine in a rural community for fifteen years. In addition, he has done veterinary and nutritional consultation work. Currently he is involved in a livestock and farming enterprise with his family. He has made several short-term missionary tours to Haiti.

Because this is an experimental first edition, it can be improved with your help: **Any suggestions concerning changes or improvements for future editions are welcome and appreciated.** Please send your comments to Christian Veterinary Missions.

INTRODUCTION

Beef cattle play an important role in the life of small farmers in developing countries. They are an important source of nutrition providing useable protein and also in combating problems such as iron deficiency anemia. Because of the unique ruminant digestive system, beef cattle can utilize forage and marginal grazing systems to provide useable protein, carbohydrates, minerals and vitamins for man. These feedstuffs would not otherwise be used. They also provide farm power for traction and transportation. In addition to numerous by-products such as leather, the manure is an excellent source of fertilizer and fuel for cooking.

In many countries beef cattle serve as a savings account for schooling, marriages, religious activities, etc. The loss of one cow could equal the loss of an entire families' income for one year. Therefore, proper management and disease prevention and control are directly linked to the farmer's livelihood and well-being.

Projections indicate that by the year 2000 the world will need 80 percent more beef than in 1970.

Developing countries are expected to increase their numbers of cattle by 41 percent and their output of meat by 90 percent to keep up with population demands. These increases will require a substantial improvement in the management of their beef herds.

This book is intended to assist in an understandable manner the small farmer, missionary, or agricultural worker who applies proper management and disease control techniques for beef cattle. It is not intended to replace the services of a veterinarian if available.

Section 2

FACILITIES AND HANDLING

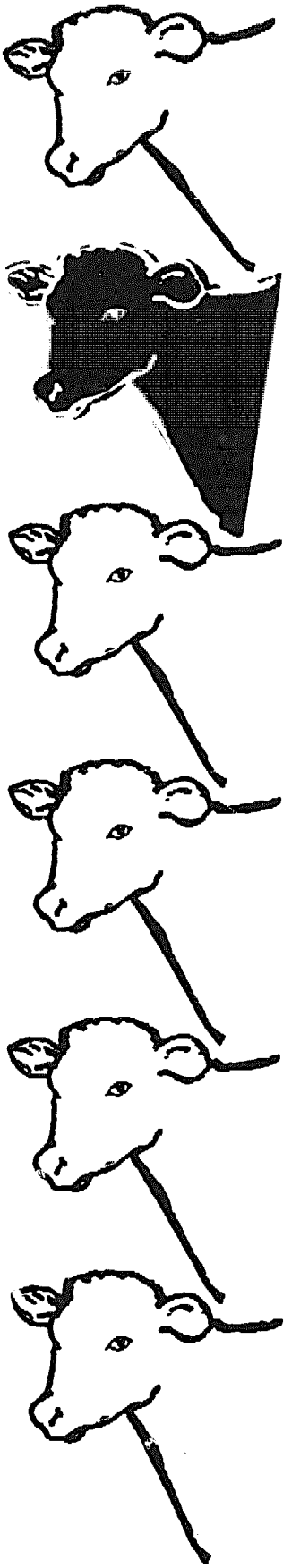

Restraint

In the handling of beef cattle it is important to keep in mind the large size of these animals and the potential for human injury. Cows and bulls can pose special problems in this area. Always remember cattle can kick to the side as well as behind their body.

There is also the risk of injuring the animal with improper restraint measures. Some reasons for restraint involve the following: dehorning, castration, branding, treatment of wounds, treatment for infection, treatment of foot problems, calving difficulties, blood sampling, etc.

Whenever cattle are to be handled while standing, the easiest and best solution is to have a crush or chute. The width of the crush should be 70 cm with height of 150 cm.

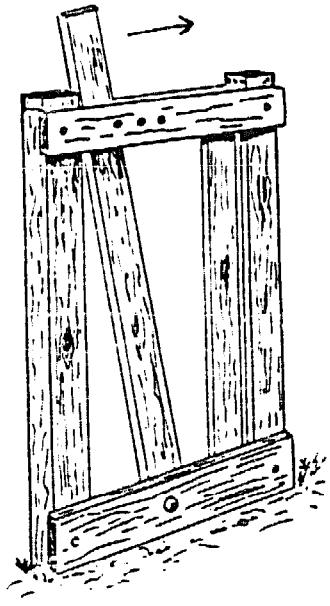

Close-up of simple Head catch. The middle board is pulled closed and a pin inserted into the hole.

One important thing to bear in mind with a crush or chute is: If there is any obstruction beneath the animal's neck (and if it would lie down) this will cause the air supply to be shut off and the animals will suffocate in a matter of seconds. Thus if the animal should lie down in the headgate, the head catch should be released immediately and the animal removed from the chute.

If a crush or chute is not available, the animal will have to be restrained with a rope tied to an immovable object such as a tree or post. A halter can be made from a rope as follows:

Cow

TEMPORARY ROPE HALTER

A rope loop fastened with a bowline knot is placed around the cow's neck.

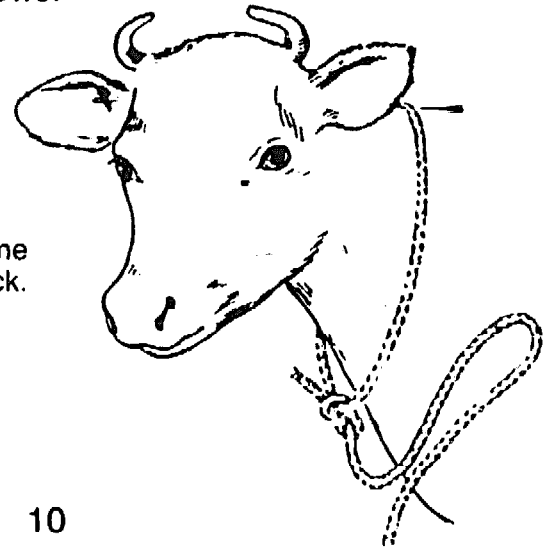

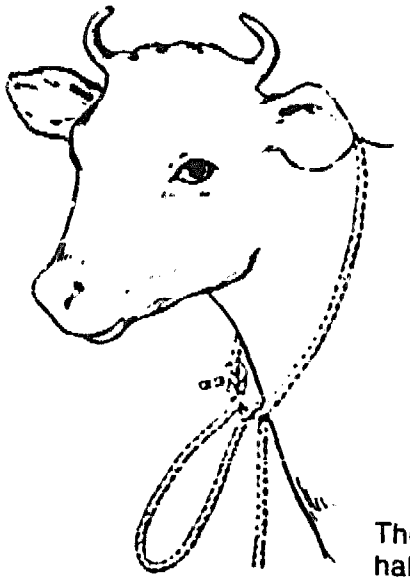

A bight in the standing part passed through the loop and over the nose.

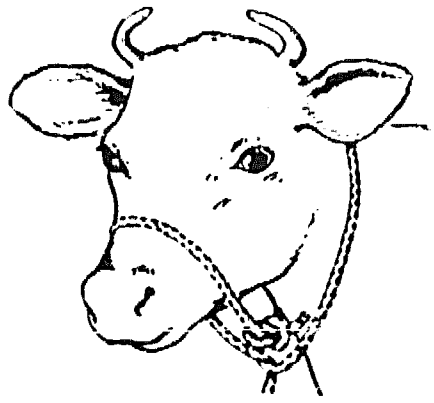

The nose piece should be pulled tight when the halter is in use.

Fig. # 2 (FAO Manual—1983)

One should never place a rope around the neck and tighten it up tight as the animal will suffocate from lack of oxygen. The rope could also be placed around the horns of the animal. A nose lead as illustrated below is also a very efficient means of restraint.

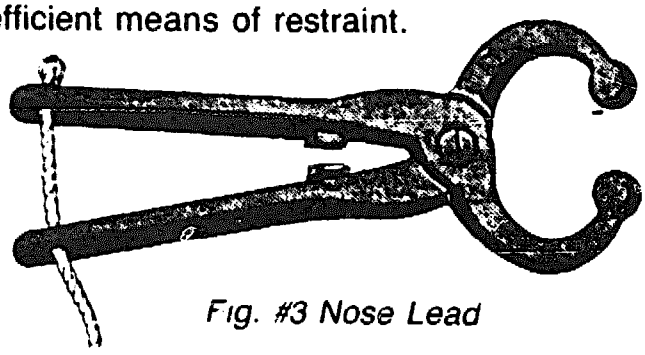

Fig. #3 Nose Lead

If a nose lead is not available, one may grasp firmly the bridge of the nose with the thumb and forefinger.

A tail restraint is also a very effective method to direct the animal's attention away from another part of its body i.e. castrating, treating udder, etc. One should stand to the side of the cow to avoid being kicked.

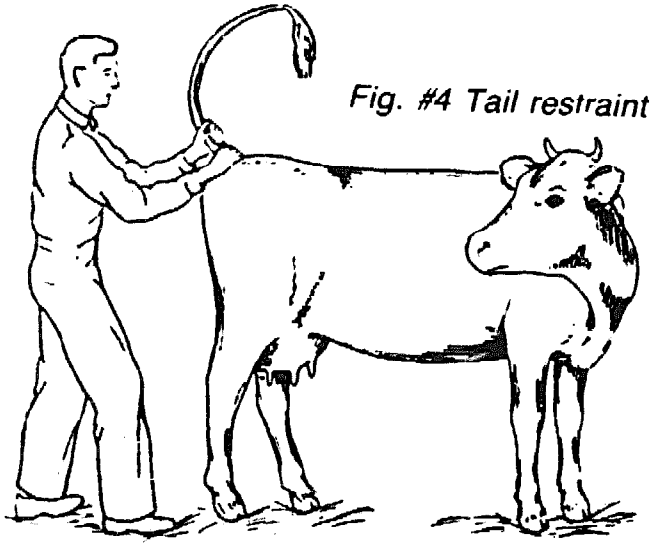

Fig. #4 Tail restraint

Casting—This involves laying the cow down and securing with ropes. Reasons for casting a cow or bull might be for surgery, examination and treatment of the feet and legs, wound treatment, etc. There are two methods that can be employed:

Casting—Burley Method-Find a soft area or bedding to lay the animal down. Secure the cow with a good halter and position a 40-foot piece of rope as shown in the diagram with the center over the top of the shoulders.

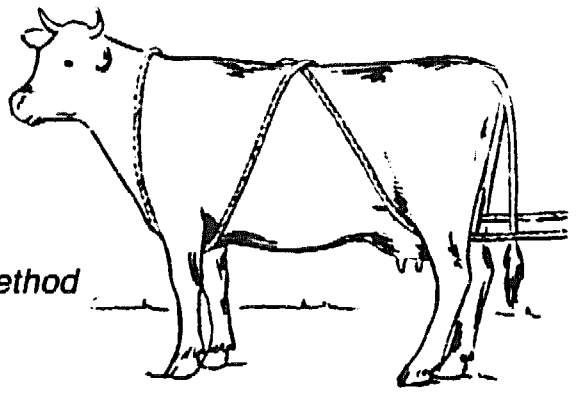

Casting
Fig. #5 Cow with Burley Method

When the ends of the rope are pulled, the cow will lie down. Flex the back legs and make a half hitch around the fetlock and several figure 8's between fetlock and hock. The front legs can be secured with another rope.

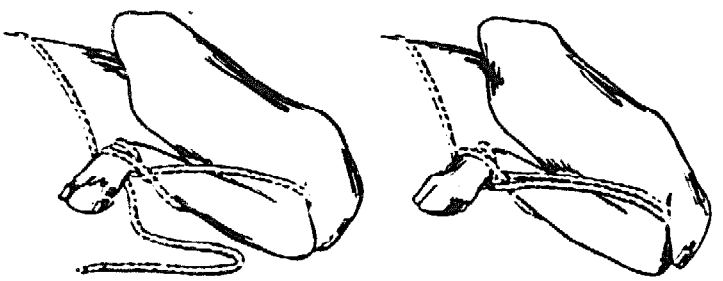

Fig. #6 Securing the legs

Casting—Rope Squeeze Method

Secure the cow with a good halter and make a loop around the cow's neck or horn using a bowline knot which will not slip. Continue placing the rope around the animal as shown in the picture.

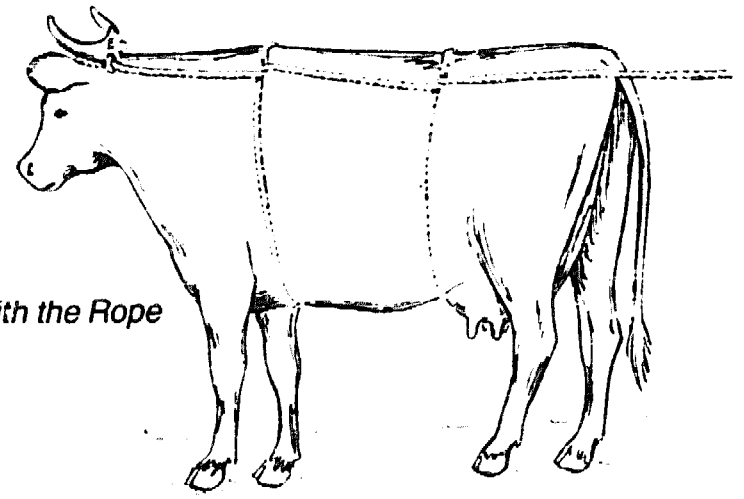

Fig. #7 Casting cow with the Rope Squeeze Method.

Pulling the rope will force the cow to lie down. Then the legs can be tied to each other with ropes or stretched outward to immovable objects. Care should be taken if the rope is placed around the animal's neck so it is not too tight for proper breathing.

Local anesthetics such as lidocaine can also be used for surgical procedures and relief of pain. General anesthetics and tranquilizers can be used in the place of or in combination with ropes for casting.

Feeding Equipment

Other equipment needed for handling beef cattle would be a feeder for hay and a feeder for grain and mineral. If hay or grain is to be fed, it should be in a feeder. This eliminates waste of feed and also helps so internal parasites are not spread as readily.

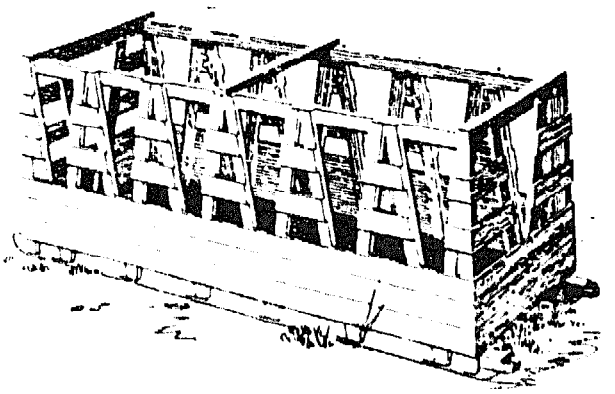

Fig. #8 Hay Feeder (Colo. State University Bulletin #469)

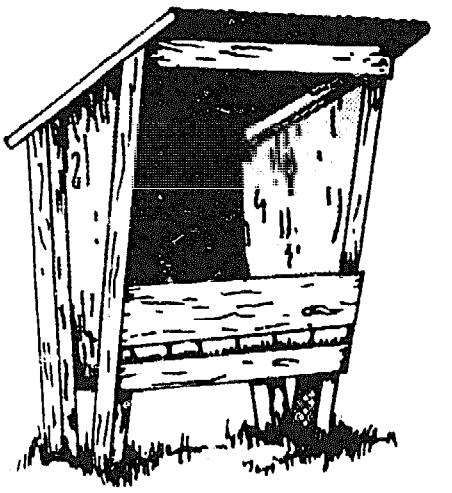

Fig. #9 Mineral feeder (Colo. State Univ. Bulletin #469)

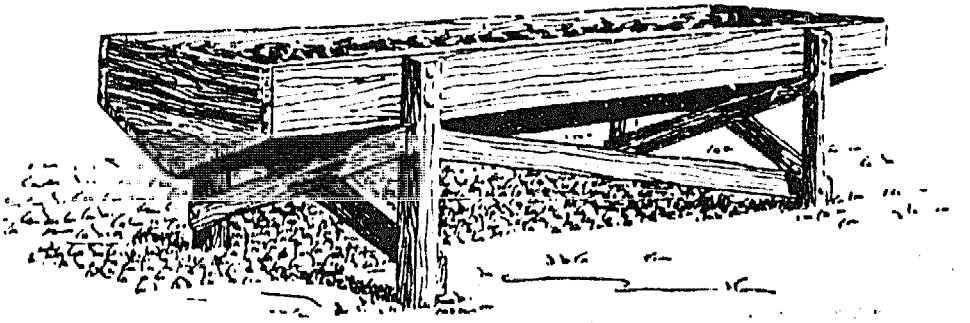

Fig. #10 Feed Bunk (Colo. State Univ. Bulletin #469)

Section 3

Digestion and Nutrition

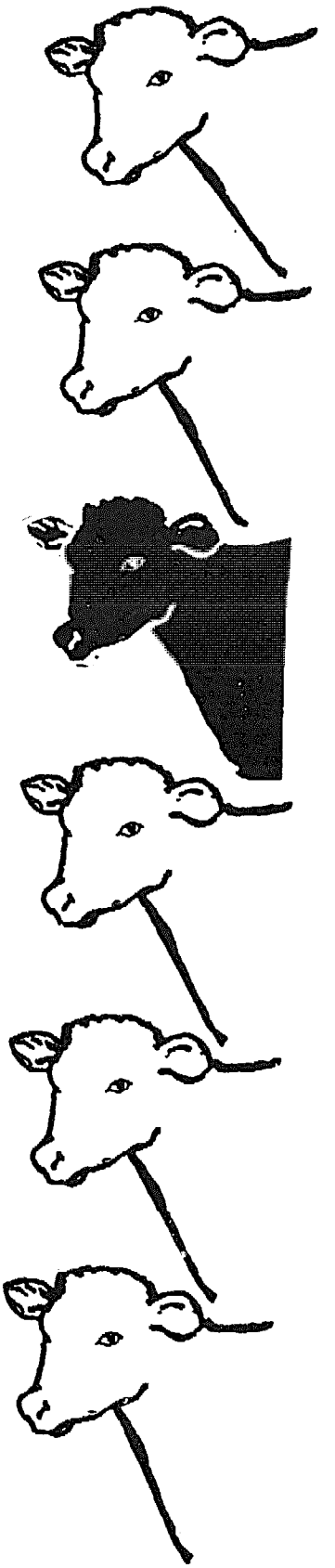

What Makes Animals Function

Animals eat, move about, reproduce, and gain weight because of the various organ systems in the body. Organs are well defined parts of the body which perform particular functions. These organs may be divided into Skeletal, Muscular, Digestive, Respiratory, Circulatory, Lymphatic, and Urogenital systems.

Skeletal System

This system contains bones and supporting structures for the body.

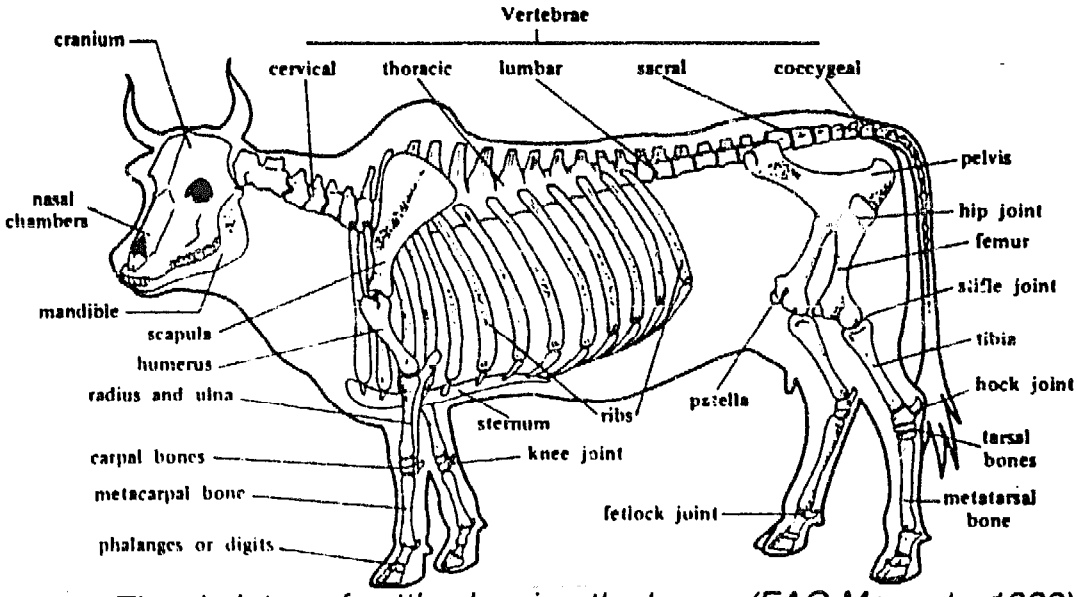

Fig. #11 The skeleton of cattle showing the bones (FAO Manual—1983)

Muscular System

This system contains all of the separate muscles which cause movement. These muscles cover the skeleton and are of great economic importance in meat-producing animals.

Digestive System

This system runs from the mouth to the rectum and includes the liver and pancreas. It converts the food into a useable form and excretes the unuseable remains. This system will be studied more closely in the next section.

THE INTERNAL ORGANS OF THE COW (Right side)

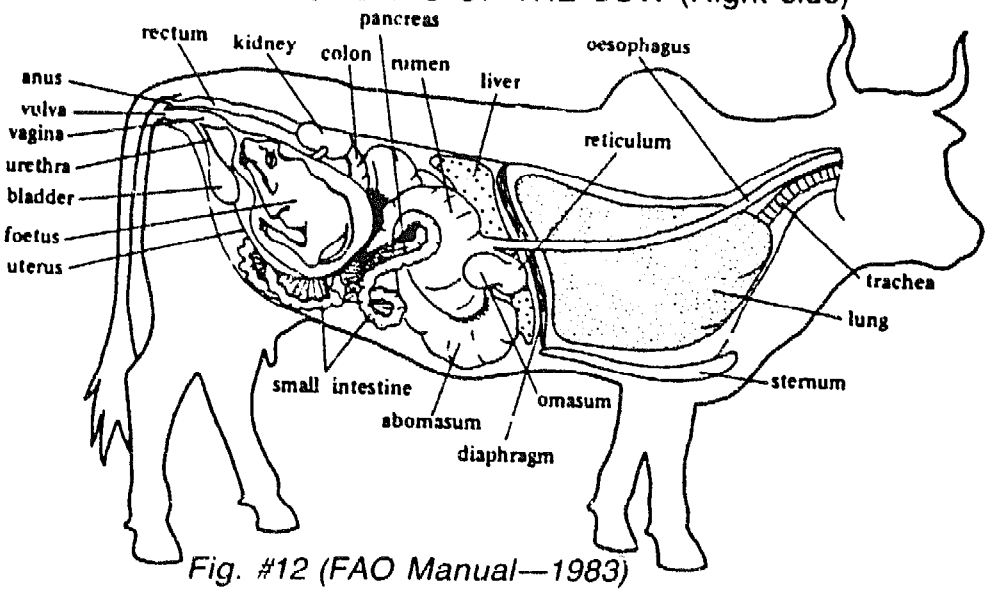

Fig. #12 (FAO Manual—1983)

THE INTERNAL ORGANS OF THE COW (Left side)

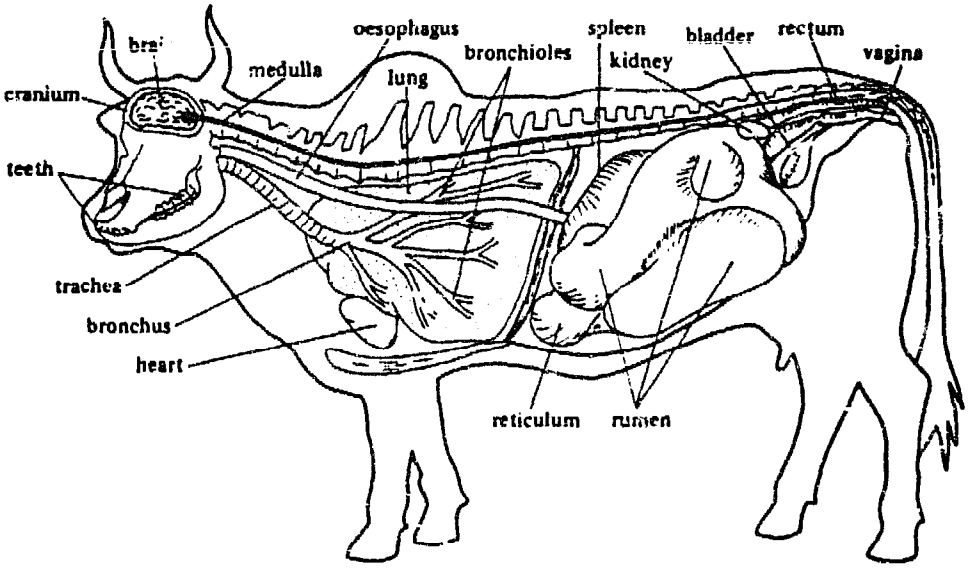

Fig. #13 (FAO Manual—1983)

Respiratory System:

This system consists of the nasal passages, trachea, and the lungs. The nasal passages and trachea take in the air and oxygen needed for the body functions. The oxygen is absorbed into the blood in the lungs and the carbon dioxide is exhaled.

Circulatory System

This organ system is made up of the heart, arteries, and veins. The heart pumps blood to all parts of the body. Arteries carry blood from the heart, and veins bring the blood back to the heart.

CIRCULATION AND BLOOD VESSELS

Arteries carry blood FROM the heart. Veins carry blood TO the heart.

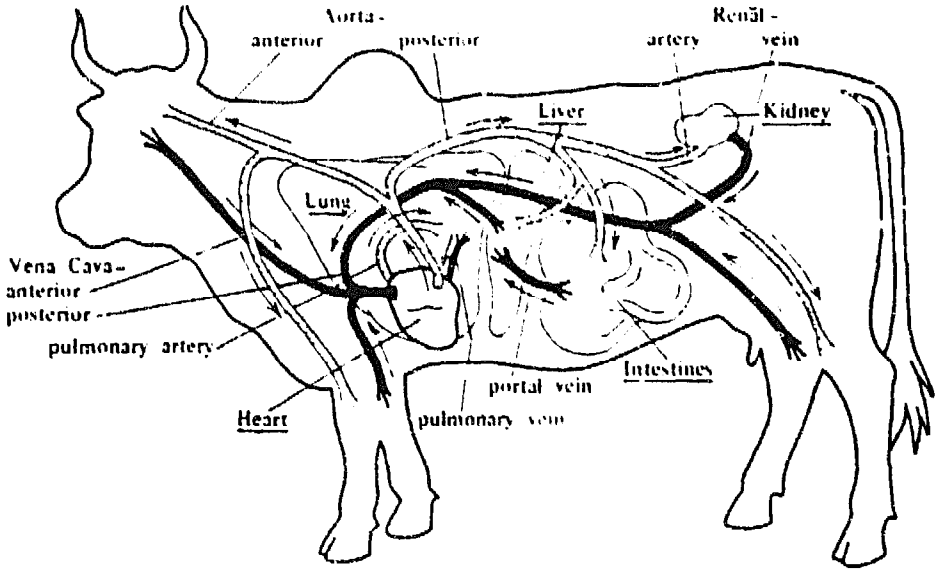

Fig. #14 (FAO Manual—1983)

The blood in its passage around the body picks up oxygen from the air in the lungs and nutrients from food in the intestines. The blood then transports nutrients and oxygen to the cells throughout the body. It brings back to the lungs carbon dioxide formed in the tissues. Waste materials formed during body processes or metabolism are carried to the liver for processing and to the kidneys for filtration and excretion in the urine.

The blood is made up of red blood cells, white blood cells and plasma. The red blood cells contain hemoglobin and carry oxygen throughout the body. They are formed in the bone marrow. The white blood cells help protect the body against disease by engulfing and ingesting micro-organisms. These cells are mainly formed in the lymph nodes. The plasma contains the other cells in the blood and contains over one half of the volume. Other functions which the blood provides is the regulation of body temperature and transportation of hormones from the glands to various organs.

Lymphatic System

This system is actually part of the circulatory system and acts as the middleman between the blood and tissues in feeding the body. The vessels of this system collect the lymph (colorless fluid from plasma) through the vessel walls and pass it back to the veins through the lymph nodes which filter bacteria.

The Nervous System

The nervous system is responsible for coordination and control of all the activities of the body. This system is made up of the brain, spinal cord, and nerves which are distributed throughout the body.

Urogenital System

The urinary system consists of the kidneys, bladder, urethra (urinary tube). The kidneys filter the blood separating out wastes and concentrating the urine. The male and female genital organs are discussed in a later section.

Ruminant Digestion

Ruminants are defined as cloven-footed, cud-chewing mammals with multi-compartment stomachs. Ruminants such as cattle are unique since they have a special digestive system for tearing down the complex carbohydrates and proteins in plant materials. They convert low quality, high fiber feedstuffs to meat and milk, rich in proteins, minerals and vitamins. The primary part of this digestive system is the large fermentation vat called the rumen. This is what makes ruminant digestion different from other animals.

The first problem in digesting feedstuffs is to reduce the particle size. This is accomplished initially by the cow chewing her feed enough to swallow it. Once in the rumen, the feed is thoroughly saturated with rumen fluids which soften the plant materials and start to break them down. The more resistant plant materials are sent back to the mouth to be rechewed during the cud-chewing or ruminating process. This is a longer and more thorough chewing than the initial one during the eating stage.

The next phase is the process of fermentation and the rumen provides the ideal conditions for this process. The rumen is maintained at

a desirable temperature, flooded with water and saliva, populated by millions of bacteria and protozoa, and constantly mixed by contractions of the rumen muscles. The micro-organisms attack the small particles of feed and use them for their own growth or convert them into soluble forms which can be absorbed through the rumen wall into the blood stream. The semi-solid food continues through the reticulum, omasum, abomasum (true stomach), and the small intestine where micro-organisms and glandular secretions breakdown proteins, carbohydrates, and fats into simpler substances which can be absorbed through the stomach and intestinal walls. Digestion continues in the small intestine and the first part of the large intestine. What is left of the food then passes through the cecum, colon, and rectum where it is excreted.

STOMACH OF THE RUMINANT (from right side) SHOWING DIRECTION OF FLOW OF FOOD.

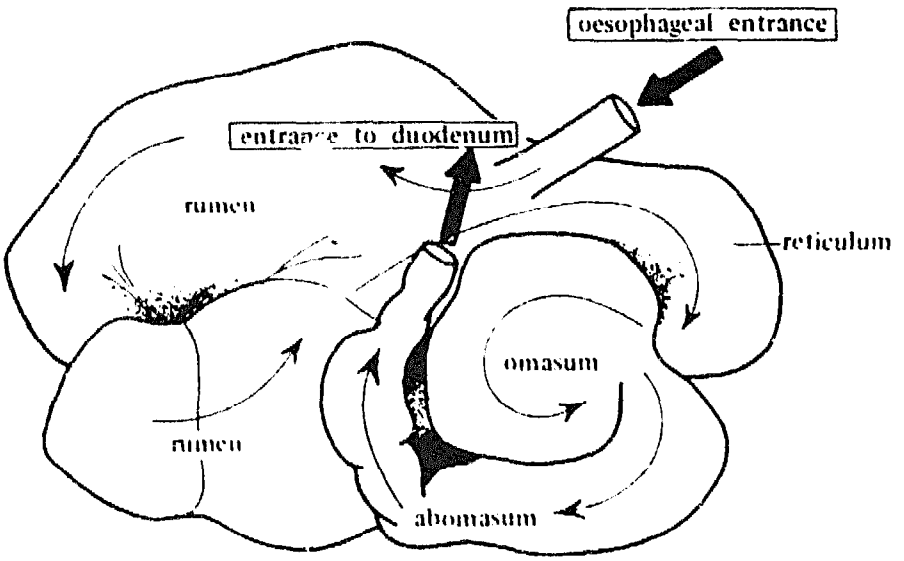

Fig. #15 (FAO Manual—1983)

Because ruminants can subsist on roughage (grass, bowse, legumes, hay, and straw) they do not normally compete with people for food.

Feed Nutrients

Nutrients are substances needed in the feed of animals. The elements of nutrition are:

1) water
2) energy (carbohydrates and fats)
3) protein
4) minerals
5) vitamins

ENERGY	PROTEIN
The fuel that keeps the body functioning, warm, and able to move about.	The building materials used by the body.

MINERALS	WATER
CALCIUM PHOSPHORUS Make up large part of teeth and bones and a small but important part of the body tissue. Help in regulating body functions.	Over half of the body composition. Aids in carrying out and regulating body processes.

Fig. #16

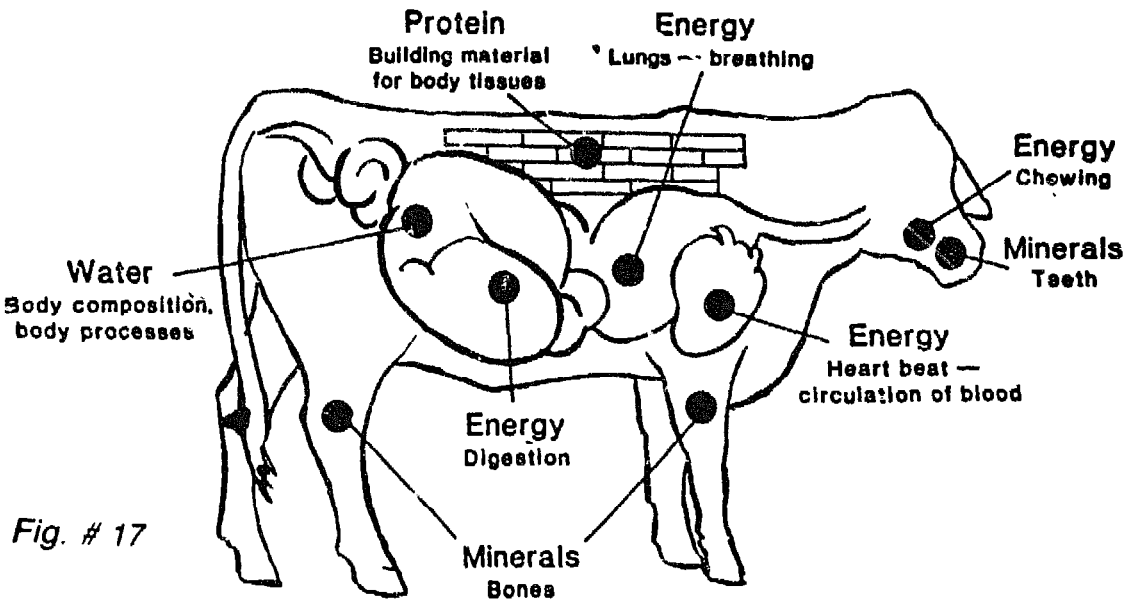

Fig. # 17

Water

This essential nutrient makes up over one half of the body composition. Water is essential for carrying out and regulating body processes. Feed intake of cattle is related to water intake. In other words, if the intake of water is hindered, the feed intake will also decrease. Under average conditions animals should consume:

1-1.5 gal. water/100 lb. body weight/day

or

4-6 liters water/50 kg. body weight/day

Water consumption depends on air temperature, humidity, feed source, body size, activity of animal, and quality of water. Sources of water

are the water consumed and also from the water in feeds. Young plants may contain up to 90% water and mature plants may contain 10% water. Animals which are not supplied with enough water eat less feed, their blood thickens, their performance and productivity suffer, and they gradually die from dehydration. Zebu cattle require less water than European cattle. Cattle should be allowed to drink at least two times per day.

Estimated Daily Water Needs of Cattle

Species	Weight (kg)	Condition	Approximate daily water needs (liters)
Cattle	50	Growing	5 to 6
	100	Growing	8 to 9
	150	Growing	12 to 14
	200	Growing	17 to 19
	300	Growing	23 to 25
	450	Fattening	30 to 34
	450	Pregnant	30 to 38
	550	Lactating	38 to 50
	500	Grazing	20 to 30

Energy

Energy gives the body power, similar to fuel in an engine. This power may be used to move the animal, to keep it warm, and to aid in the processes of growth, reproduction, and breathing. Cattle get their energy from the feed they consume—milk, grass, hay, grains, etc. Energy is divided into classes—carbohydrate and fat.

Carbohydrates consist of fiber, starches, or sugars. These substances provide heat and energy for the bodily functions. When excess carbohydrate is taken in, it is stored as fat by the animal.

Fats can be in the form of plant fats such as soybean oil or peanut oil and animal fats such as talow. Fats provide more energy than carbohydrates. Fat occurring within the animal provide insulation and a protective covering of the internal organs.

Protein

Protein is used by the body to make muscles (meat), to make milk, and to make repairs of worn-out or damaged tissues. Thus, a growing calf needs a lot of protein because it is building new muscles. A mother cow must get enough protein so she can produce milk for her calf. The protein is provided by the feed sources—grazing and hay. If the sources do not provide enough protein, a supplement will have to be added. Small calves get most of their protein from milk. If excess protein is fed, it will be used for energy.

Crude Protein is a measurement of protein content of feeds and is derived by multiplying the per cent nitrogen times 6.25.

Crude Protein = % N x 6.25

Because of the rumen fermentation, cattle can take lower quality protein such as that found in roughage and convert it into higher quality useable protein. They can also use non-protein nitrogen such as urea. This product, however, requires energy such as that found in grains for it to be utilitzed. Urea should never be used without a high energy source such as grains, or it can be toxic.

Minerals

Minerals are used to make bones, teeth, muscles and blood. They are necessary in some chemical reactions that take place in the body. Most of the mineral source comes from plant materials. However, often a deficiency will exist of one or more minerals and a mineral supplement will have to be fed. Calcium and phosphorus are necessary for bone formation and should be given in a ration of 1-2 parts calcium to 1 part phosphorous. Bone meal and dicalcium phosphate are excellent sources of calcium and phosphorous. Limestone provides calcium but not phosphorous. These sources are often mixed with salt 50 - 50. Trace minerals of zinc, copper, molybdenum, potassium, selenium, etc. are deficient in certain areas and may need to be supplemented. (See mineral supplement page 31.)

Vitamins

Vitamins have many different functions includiing being necessary to allow cattle to make proper use of other feeds they eat. Baby calves get vitamins from their mother's milk. As cattle grow older their stomachs develop and many of the vitamins are produced right in the stomach. Green forages provide vitamin A and vitamin E; whereas, sunlight provides a form of vitamin D. If these and other vitamin requirements are not adequate, then they must be supplemented in the feed or by injection.

For best results in beef cattle production, it is helpful to add supplemental protein, energy, and minerals to the animals' diet. However, if it is not feasible economically to add protein or energy, one should still add supplemental minerals.

Formulating Diets

Feeding livestock to achieve maximum production at minimal cost is the goal of all beef cattle producers. Properly fed animals are also much healthier and able to resist disease. These production levels are achieved when an appropriate amount and balance of calories, protein, minerals, and vitamins are fed. The amount and quality of the feedstuffs consumed affects animal performance.

Nutritional factors that are major concerns in cattle rations are water, dry matter (D.M.), energy (T.D.N. or N.E.), protein (C.P.), calcium (Ca), phosphorous (P), and vitamin A. These nutrients are most likely to be critical under most conditions.

The term **dry matter** (D.M.) describes the amount of feed an animal eats in one day with all water removed. A certain amount of D.M. is essen-

tial to satisfy an animal's appetite and promote rumen functioning. A cow will need to consume more of a very succulent or wet feed as compared to a dried one in order to take in the same amount of dry matter.

Energy in a ration is the most important factor limiting production. All feeding standards and ration formulations are based on some measure of energy. It accounts for the highest proportion of expense compared to other nutrients because of the quantities needed. Energy is expressed in calories, kilocalories (Kcal), or megacalories (Mcal). Energy value of feeds, Metabolizable Energy (M.E.) may be described as Net Energy (N.E.) or Total Digestible Nutrients (T.D.N.). N.E. is the most precise and reliable measure of energy that is converted to animal tissue. T.D.N. is an older method of calculating energy and is not quiet as accurate as N.E.

Feed Intake

In order to properly formulate rations one must be able to estimate what the feed intake should be. One factor which affects feed intake is the body weight of the animals. Most animals **will consume between 2 and 3 % of the body weight in dry feed per day.** Younger animals usually consume more feed per pound of body weight than older animals. Cattle in the later stages or pregnancy or after calving need considerably more feed to maintain their body condition. Livestock consuming feeds high in water will have to consume more total weight of feed to meet their dry matter requirements. Cattle consuming feeds which are high in energy (grains) will consume less volume of feed because of the high calorie content of the feed. Other factors which increase consumption are cold temperatures and hard work (draft animals). Some conditions that decrease consumption are high external temperatures, high humidity, crowding, excessive handling, and sickness. Nurtient requirement tables will have expected dry matter intakes.

Before one begins to formulate a balanced diet, we need to establish 2 things:

1) nutrient requirements of the animals
2) nutrient content of the locally available feedstuffs

Nutrient requirements may vary according to size, age, sex, growth rate, reproductive status, and work expected. Usually animals will first use nutrients to maintain basic body functions; then they will use additional nutrients for growth, milk production, pregnancy, etc. These nutrient requirements will depend upon production goals. There are a number of tables available which list nutrient requirements of cattle. Among these are the tables of the National Research Council of the U.S. National Academy of Sciences.

Nutrient Requirements for Growing-Finishing Steer Calves And Yearlings (Nutrient Concentration In Diet Matter)

Weight[b] (kg)	(lb)	Daily gain[c] (kg)	(lb)	Minimum Dry Matter Consumption (kg)	(lb)	Roughage (%)	Total Protein (%)	Digestible Protein (%)	NE_m[1] (Mcal/kg)	(Mcal/lb)	NE_g[1] (Mcal/kg)	(Mcal/lb)	ME[1] (Mcal/kg)	(Mcal/lb)	TDN[d,f] (%)	Ca (%)	P (%)
100	220	0	0	2.1	4.6	100	8.7	5.0	1.17	0.53	—	—	2.0	0.91	55	0.18	0.18
		0.5	11	2.9	6.4	70-80	12.4	8.3	1.35	0.60	0.75	0.23	2.2	1.00	62	0.48	0.38
		0.7	1.5	2.7	6.0	50-60	14.8	10.7	1.60	0.71	1.00	0.43	2.5	1.13	70	0.70	0.48
		0.9	2.0	2.8	6.2	25-30	16.4	11.8	1.81	0.82	1.18	0.54	2.8	1.27	77	0.86	0.57
		1.1	2.4	2.7	6.0	.15	18.2	13.3	2.07	0.94	1.37	0.62	3.1	1.41	86	1.04	0.70
150	331	0	0	2.8	6.2	100	8.7	5.0	1.17	0.53	—	—	2.0	0.91	55	0.18	0.18
		0.5	1.1	4.0	8.8	70-80	11.0	7.0	1.35	0.60	0.75	0.23	2.2	1.00	62	0.35	0.32
		0.7	1.5	3.9	8.6	50-60	12.6	8.5	1.60	0.71	1.00	0.43	2.5	1.13	70	0.46	0.36
		0.9	2.0	3.8	8.4	25-30	14.1	9.7	1.81	0.82	1.18	0.54	2.8	1.27	77	0.61	0.45
		1.1	2.4	3.7	8.2	-15	15.6	11.1	2.07	0.94	1.37	0.62	3.1	1.41	86	0.76	0.54
200	441	0	0	3.5	7.7	100	8.5	4.8	1.17	0.53	—	—	2.0	0.91	55	0.18	0.18
		0.5	1.1	5.8	12.8	80-90	9.9	6.0	1.25	0.56	0.60	0.27	2.1	0.95	58	0.24	0.22
		0.7	1.5	5.7	12.6	70-80	10.8	6.8	1.40	0.64	0.78	0.35	2.3	1.04	64	0.32	0.28
		0.9	2.0	4.9	10.8	35-45	12.3	8.2	1.70	0.78	1.10	0.50	2.7	1.22	75	0.47	0.37
		1.1	2.4	4.6	10.1	—15	13.6	9.3	2.07	0.94	1.37	0.62	3.1	1.41	86	0.59	0.43
250	551	0	0	4.1	9.7	100	8.5	4.8.	1.17	0.53	—	—	2.0	0.91	55	0.18	0.18
		0.7	1.5	5.8	12.8	55-65	10.7	6.7	1.56	0.71	0.95	0.43	2.5	1.13	70	0.31	0.28
		0.9	2.0	6.2	13.7	45-50	11.1	7.1	1.64	0.74	1.02	0.46	2.6	1.18	72	0.35	0.31
		1.1	2.4	6.0	13.2	20-25	12.1	8.0	1.81	0.82	1.18	0.54	2.8	1.27	77	0.43	0.35
		1.3	2.9	6.0	13.2	—15	12.7	8.5	2.07	0.94	1.37	0.62	3.1	1.41	86	0.50	0.38
300	661	0	0	4.7	10.4	100	8.6	4.8	1.17	0.53	—	—	2.0	0.91	55	0.18	0.18
		0.9	2.0	8.1	17.9	55-65	10.0	6.2	1.56	0.71	0.95	0.43	2.5	1.18	70	0.27	0.23
		1.1	2.4	76	16.8	20-25	10.8	6.8	1.81	0.82	1.18	0.54	2.8	1.27	77	0.33	0.29
		1.3	2.9	7.1	15.6	—15	11.7	7.6	1.98	0.90	1.31	0.59	3.0	1.36	83	0.41	0.32
		1.4a	3.1	7.3	16.1	—15	11.9	7.8	2.07	0.94	1.37	0.62	3.1	1.41	86	0.42	0.34
350	772	0	0	5.3	11.7	100	8.5	4.8	1.17	0.53	—	—	2.0	0.91	55	0.18	0.18
		0.9	2.0	8.0	17.6	45-55	10.0	6.1	1.64	0.74	1.02	0.46	2.6	1.18	72	0.25	0.22
		1.1	2.4	8.0	17.6	20-25	10.4	6.5	1.81	0.82	1.18	0.54	2.8	1.27	80	0.29	0.25
		1.3	2.9	8.0	17.6	—15	10.8	6.9	1.98	0.90	1.31	0.59	3.0	1.36	83	0.32	0.28
		1.4a	3.1	8.2	18.1	—15	10.9	7.0	2.07	0.98	1.37	0.62	3.1	1.41	86	0.34	0.29
400	882	0	0	5.9	13.0	100	8.5	4.8	1.17	0.53	—	—	2.0	0.91	55	0.18	0.18
		1.0	2.2	9.4	20.7	45-55	9.4	5.7	1.64	0.74	1.02	0.46	2.6	1.18	72	0.22	0.21
		1.2	2.6	8.5	18.7	20-25	10.2	6.3	1.81	0.82	1.18	0.54	2.8	1.27	80	0.27	0.25
		1.3	2.9	8.6	19.0	—15	10.4	6.5	2.07	0.98	1.37	0.62	3.1	1.41	86	0.29	0.26
		1.4a	3.1	9.0	19.8	—15	10.5	6.6	2.07	0.98	1.37	0.62	3.1	1.41	86	0.29	0.26
450	992	0	0	6.4	14.1	100	8.5	4.8	1.17	0.53	—	—	2.0	0.91	55	0.18	0.18
		1.0	2.2	10.3	22.7	45-55	9.3	5.5	1.64	0.74	1.02	0.46	2.6	1.18	72	0.19	0.19
		1.2	2.6	10.2	22.5	20-25	9.5	5.7	1.81	0.82	1.18	0.54	2.8	1.27	80	0.23	0.22
		1.3	2.9	9.3	20.5	—15	10.4	6.3	2.07	0.98	1.31	0.62	3.1	1.41	86	0.26	0.25
		1.4d	3.1	9.8	21.6	—15	10.0	6.1	2.07	0.98	1.37	0.62	3.1	1.41	86	0.26	0.23
500	1102	0	0	7.0	15.4	100	8.5	4.8	1.17	0.53	—	—	2.0	0.91	55	0.18	0.18
		0.9	2.0	10.5	23.1	45-55	9.1	5.3	1.64	0.74	1.02	0.46	2.6	1.18	72	0.18	0.18
		1.1	2.4	10.4	22.9	20-25	9.2	5.5	1.81	0.82	1.18	0.54	2.8	1.27	80	0.19	0.19
		1.2	2.6	9.6	21.2	—15	10.0	6.0	2.07	0.98	1.31	0.62	3.1	1.41	86	0.22	0.22
		1.3d	2.9	10.0	22.0	—15	9.7	6.0	2.07	0.98	1.37	0.62	3.1	1.41	86	0.22	0.22

[a]The concentration of vitamin A in all diets for finishing steers is 2,200 iu/kg of dry diet.

[b]Average weight for a feeding period.

[c] Dry matter consumption, ME and TDN allowances are based on NE requirements and the general types of diet indicated in the roughage column. Most roughages will contain 1.9-2.2 Mcal of ME/kg dry matter and 90-100 percent concentrate diets are expected to contain 3.1-3.3 Mcal of ME/kg.

[d]TDN was calculated by assuming 3.6155 Mcal of ME per kg of TDN.

[e]Most steers of the weight indicated, and not exhibiting compensatory growth, will fail to sustain an energy intake necessary to maintain this rate of gain for an extended period.

[f]Due to conversion and rounding variation, the figures in these columns may not be in exact agreement with a similar energy concentration figure calculated from the data of Table 1.

(Adopted from National Academy of Sciences—1976)

Nutrient Requirements for Beef Cattle Breeding Herd (Nutrient Concentration in Diet Dry Matter)

Weight[b] (kg)	Weight[b] (lb)	Daily gain[c] (kg)	Daily gain[c] (lb)	Minimum Dry Matter Consumption (kg)	Minimum Dry Matter Consumption (lb)	Roughage (%)	Total Protein (%)	Digestible Protein (%)	NE_m[1] (Mcal/kg)	NE_m[1] (Mcal/lb)	NE_g[1] (Mcal/kg)	NE_g[1] (Mcal/lb)	ME[1] (Mcal/kg)	ME[1] (Mcal/lb)	TDN[d,f] (%)	Ca (%)	P (%)
Pregnant Yearling Heifer – Last Third of Pregnancy																	
325	716	0.4d	0.9	6.6	14.5	100c	8.8	5.1	1.09	0.49	0.38	0.17	1.9	0.86	52	0.23	0.23
		0.6	1.3	8.5	18.7	100	8.8	5.1	1.09	0.49	0.38	0.17	1.9	0.86	52	0.21	0.21
		0.8	18	9.4	20.7	85-100	9.0	5.3	1.24	0.56	0.60	0.27	2.1	0.95	58	0.23	0.21
350	772	0.4d	0.9	6.9	15.2	100	8.8	5.1	1.09	0.49	0.38	0.17	1.9	0.86	52	0.22	0.22
		0.6	1.3	8.9	19.6	100	8.8	5.1	1.09	0.49	0.38	0.17	1.9	0.86	52	0.21	0.21
		0.8	1.8	9.4	20.7	85-100	8.8	5.1	1.24	0.56	0.60	0.27	2.1	0.95	58	0.22	0.21
375	827	0.4e	0.9	7.2	15.9	100	8.7	5.0	1.09	0.49	0.38	0.17	1.9	0.86	52	0.21	0.21
		0.6	1.3	9.3	20.5	100	8.7	5.0	1.09	0.49	0.38	0.17	1.9	0.86	52	0.20	0.20
		0.8	1.8	11.6	25.6	85-100	8.7	5.0	1.17	0.53	0.50	0.23	2.0	0.91	55	0.20	0.20
400	882	0.4d	0.9	7.2	15.9	100	8.7	5.0	1.09	0.49	0.38	0.17	1.9	0.86	52	0.21	0.21
		0.6	1.3	9.7	21.4	100	8.7	5.0	1.09	0.49	0.38	0.17	1.9	0.86	52	0.20	0.20
		0.8	1.8	11.6	25.6	85-100	8.7	5.0	1.17	0.53	0.50	0.23	2.0	0.91	55	0.19	0.19
425	937	0.4d	0.9	7.8	17.2	100	8.8	5.1	1.09	0.49	0.38	0.17	1.9	0.86	52	0.20	0.21
		0.6	1.3	10.1	22.3	100	8.7	5.0	1.09	0.49	0.38	0.17	1.9	0.86	52	0.20	0.20
		0.8	1.8	12.1	26.7	85-100	8.7	5.0	1.17	0.53	0.50	0.23	2.0	0.91	55	0.18	0.18
Dry pregnant mature cows—Middle third of pregnancy																	
350	772	–	–	5.5	12.2	100e	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
400	882	–	–	6.1	13.4	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
450	992	–	–	6.7	14.8	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
500	1102	–	–	7.2	15.9	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
560	1213	–	–	7.7	17.0	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
600	1323	–	–	8.3	18.3	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
650	1433	–	–	8.8	19.4	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
Dry Pregnant mature cows—Last third of pregnancy																	
350	772	0.4d	0.9	6.9	13.9	100e	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
400	882	0.4	0.9	7.5	15.4	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
450	992	0.4	0.9	8.1	16.5	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
500	1102	0.4	0.9	8.6	17.9	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
550	1213	0.4	0.9	9.1	19.0	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
600	1323	0.4	0.9	9.7	20.3	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
650	1433	0.4	0.9	10.2	22.4	100	5.9	2.8	1.09	0.49	–	–	1.9	0.86	52	0.18	0.18
Cows nursing calves—Average Milking ability—First 3-4 months postpartum																	
350	772	–	–	8.2	18.1	100b	9.2	5.4	1.09	0.49	–	–	1.9	0.86	52	0.29	0.29
400	882	–	–	8.4	19.4	100	9.2	5.4	1.09	0.49	–	–	1.9	0.86	52	0.28	0.28
450	992	–	–	9.3	20.5	100	9.2	5.4	1.09	0.49	–	–	1.9	0.86	52	0.28	0.28
500	1102	–	–	9.8	21.6	100	9.2	5.4	1.09	0.49	–	–	1.9	0.86	52	0.28	0.28
550	1213	–	–	10.5	23.1	100	9.2	5.4	1.09	0.49	–	–	1.9	0.86	52	0.27	0.27
600	1323	–	–	11.0	24.2	100	9.2	5.4	1.09	0.49	–	–	1.9	0.86	52	0.25	0.25
650	1433	–	–	11.4	25.1	100	9.2	5.4	1.09	0.49	–	–	1.9	0.86	52	0.25	0.25
Cows Nursing calves—Superior Milking Ability—First 3-4 months postpartum																	
350	772	–	–	10.2	22.4	100b	10.9	6.4	1.17	0.53	–	–	2.0	0.91	55	0.42	0.39
400	882	–	–	10.8	23.8	100	10.9	6.4	1.17	0.53	–	–	2.0	0.91	55	0.42	0.38
450	992	–	–1	11.3	24.9	100	10.9	6.4	1.17	0.53	–	–	2.0	0.91	55	0.40	0.37
500	1102	–	q–	11.8	26.0	100	10.9	6.4	1.17	0.53	–	–	2.0	0.91	55	0.39	0.36
550	1213	–	–	12.4	27.3	100	10.9	6.4	1.17	0.53	–	–	2.0	0.91	55	0.37	0.35
600	1323	–	–	12.9	28.4	100	10.9	6.4	1.17	0.53	–	–	2.0	0.91	55	0.36	0.34
650	1433	–	–	13.4	29.5	100	10.9	6.4	1.17	0.53	–	–	2.0	0.91	55	0.35	0.35
Bulls, growth and maintenance (moderate activity																	
300	661	1.00	2.2	8.8	19.4	70-75	10.2	6.3	1.40	0.64	0.78	0.35	2.3	1.04	64	0.31	0.26
400	882	0.90	2.0	11.0	24.2	70-75	9.4	5.6	1.40	0.64	0.78	0.35	2.3	1.04	64	0.21	0.21
500	1102	0.70	1.5	12.2	26.9	80-85	8.8	5.1	1.32	0.60	0.70	0.32	2.2	1.00	61	0.18	0.18
600	1323	0.50	1.1	12.0	26.4	80-85	8.8	5.1	1.32	0.60	0.70	0.32	2.2	1.00	61	0.18	0.18
700	1543	0.30	0.7	12.9	28.4	90-100h	8.5	4.8	1.17	0.53	0.50	0.17	2.0	0.91	55	0.18	0.18
800	1764	0.00	0.0	10.5	23.1	100h	8.5	4.8	1.17	0.53	–	–	2.0	0.91	55	0.18	0.18
900	1964	0.00	0.0	11.4	25.1	100h	8.5	4.8	1.17	0.53	–	–	2.0	0.91	55	0.18	0.18
1000	2205	0.00	0.0	12.4	27.3	100h	8.5	4.8	1.17	0.53	–	–	2.0	0.91	55	0.18	0.18

(a) The concentration of vitamin A in all diets for pregnant heifers and cows is 2,800 u/kg dry diet; for lactating cows and breeding bulls, 3,900 u/kg.
(b) Average weight for a feeding period.
(c) Dry matter consumption, ME and TDN requirements are based on the general type of diet indicated in the roughage column.
(d) Approximately 0.4 = 0.1 kg. of weight gain/day over the last third of pregnancy is accounted for by the products of conception.
(e) Average quality roughage containing about 1.0-2.0 Mcal ME/kg dry matter.
(f) 5.0 = 0.5 kg of milk/day.
(g) 10 = 1 kg. of milk/day.
(h) Good quality roughage containing 2.0 Mcal ME/kg dry matter.

(From National Academy of Sciences—1976)

The next step involves selecting available feeds and their **nutrient content**. The nutrient content of available feedstuffs is evaluated by laboratory analysis. If a laboratory is unavailable or impractical to use, one can use various feed-composition tables to determine the nutritive value of feeds. These feed values vary according to maturity at harvest, moisture, soil, climate, and storage conditions.

TABLE 4

Composition of Common Feeds (Dry Matter Basis)

Feedstuff	Dry Matter	Total Protein	ME Mcal/Kg	TDN	Calcium	Phosphorus
Dry Roughages[b]	%	%	%	%	%	
Alfalfa hay	89	18.5	2.06	60.0	1.16	0.20
Babiagrass hay	90	8.7	1.75	51.0	0.48	0.18
Bermudagrass hays						
Ahera	87	9.7	-	54.0	0.39	0.21
Coastal	90	10.5	1.77	56.0	0.41	0.20
Common	89	9.0	1.73	51.2	0.40	0.18
Midland	90	10.7	52.0	0.34	0.30	
Tift 44	87	11.7	58.0	0.42	0.22	
Corncobs	90	2.7	1.70	46.6	0.12	0.04
Cornstover	87	5.9	2.13	58.6	0.49	0.09
Cottonseed hulls	90	4.3	1.48	41.1	0.16	0.10
Fescue hay	89	9.5	1.95	52.5	0.43	0.31
Grass-clover hay (65-35%)	90	11.8	2.17	55.6	0.87	0.30
Lespedeza hay	91	13.8	2.10	54.0	1.15	0.25
Oat hay	89	9.0	2.21	60.8	0.25	0.23
Orchardgrass hay	89	10.6	2.06	57.8	0.38	0.33
Peanut hay	91	11.3	2.20	61.9	1.31	0.28
Peanut hulls	91	7.4	.71	20.7	0.27	0.07
Sorghum (grain) hay	89	13.2	2.13	58.3	0.56	0.31
Soybean hay	91	15.1	1.88	52.0	1.25	0.30
Wheat straw	90	3.6	1.74	47.7	0.17	0.08
Silages[b]						
Alfalfa silage	38	17.2	1.95	56.6	1.04	0.26
Corn silage	35	8.0	2.53	65.5	0.30	0.22
Grass-legume silage	37	13.8	2.02	55.0	1.13	0.25
Sorghum (grain) silage	30	8.2	2.13	56.5	0.26	0.15
Small grain silage	26	10.1	2.13	58.0	0.36	0.25
Concentrates						
Barley	89	13.0	3.00	81.0	0.09	0.47
Cane molasses	75	4.3	2.75	91.0	1.19	0.11
Corn	89	8.5	3.29	91.0	0.02	0.35
Cottonseed meal	91	41.4	2.68	75.8	0.18	1.32
Cottonseed (whole)	92	24.9	3.29	91.0	0.15	0.73
Milo	89	10.9	3.00	81.2	0.04	0.33
Oats	89	12.7	2.75	76.4	0.11	0.39
Poultry litter	89	24.5	3.29	56.0	2.23	1.78
Soybean meal (44%)	89	45.8	3.07	84.0	0.34	0.70
Soybean meal (49%)	90	49.9	2.93	87.0	0.29	0.70
Soybean hulls	91	12.1	1.88	75.0	0.49	0.21

Composition of Common Feeds (Dry Matter Basis)

Feedstuff	Dry Matter	Total Protein	ME Mcal/Kg	TDN	Calcium	Phosphorus
Dry Roughages[b]	%	%	%	%	%	
Soybeans (whole)	92	41.7	3.4	91.0	0.27	0.65
Urea	100	279.6	—	—	—	—
Wheat	89	13.4	3.18	91.0	0.06	0.39
Mineral Sources						
Dicalcium phosphate	96	—	—	—	23.1	18.6
Defluorinated rock phosphate	100	—	—	—	33.0	18.0
Ground limestone	100	—	—	—	38.0	0.02
Sodium tripolyphosphate	96	—	—	—	—	25.9
Steamed bone meal	95	12.7	—	15.8	30.5	14.3

a Values can be converted to as-fed basis by multiplying by the dry matter percent.

b Nutrient content of harvested roughages can vary greatly. Forage analysis should always be obtained.

Table #4 (Georgia Extension Service - Bulletin #715)

TABLE 5

Composition and feeding values of selected cereal grains, their milling by-products, tubers, and molasses, dry-matter basis.

Feed	CP (%)	NE_m NFE (%)	NE_g (Mcal/kg)	ME (Mcal/kg)	Ca (%)	P (%)
Maize *(Zea mays)*						
White dent	10.0	80.8	1.90	1.26	.02	.30
Bran	11.3	71.9	1.92	1.28	.06	.73
Sorghum *(Sorghum bicolor)*						
Grain	11.2	80.5	1.88	1.25	.03	.34
Rice *(Oryza sativa)*						
Rough, with hulls	9.7	70.8	1.30	.64	.07	.030
Bran, 6-12% fiber	13.8	48.7	1.92	1.28	.12	1.51
Polishings	14.0	58.6	2.03	1.37	.05	1.48
Wheat *(Triticum aestivum)*						
Grain	13.6	77.7	1.84	1.22	.08	.45
Bran	15.0	60.4	1.69	1.13	.13	1.38
Middlings	1.87	65.2	2.06	1.40	.10	.91
Sweet potato *(Ipomoea batatas)*						
Tubers, mixed	4.1	87.6	1.60	.99	.15	.15
Cassava *(Manihot* spp.)						
Whole	4.6	83.4	1.54	.92	.10	.15
Sugarcane *(Saccharum officinarum)*						
Molasses	5.4	74.0	1.15	.41	1.09	.12

Table #5 (Winrock International — 1985)

TABLE 6

Composition of selected protein feeds, dry matter basis.

Feed	CP (%)	NE_m (Mcal kg)	NE_g (Mcal/ kg)	Ca (%)	P (%)
Coconut *(Cocos nucifera)*					
Meal, solvent extracted	24.4	1.46	.84	.19	.66
Cottonseed *(Gossypium* spp.)					
Meal, solvent extracted	44.2	1.48	.86	.35	1.09
Soybean *(Glycine max)*					
Meal, solvent extracted	51.9	2.01	1.35	.34	.70
Sunflower *(Helianthus* spp.)					
Meal, solvent extracted	37.9	1.08	.28	.47	.83
Leucaena *(Leucaena leucocephala)*					
Browse, dough stage	23.4	1.77	1.15	1.40	.22
Shad *(Gliricidia sepium)*					
Browse, midbloom	19.9	1.44	.82	.67	.19
Wisteria *(Sesbania grandiflora)*					
Browse, 43-56 days	27.5	1.80	1.17	1.60	.53
Urea[a]	281.0				

[a] Urea contains 45% N that, when multiplied by 6.25, yields 281% crude protein equlivalent, not protein.

(Table #6 Winrock International - 1985)

Tropical forages mature more rapidly than forages in temperate zones. They have lower levels of protein, minerals, energy, and higher levels of crude fiber. Forages high in crude fiber are digested slower and this causes the animal to eat less feed. Another problem with forages grown in the tropics is the high water content which reduces the energy intake. To reduce the forage's water content, thereby increasing the dry matter content, one can:

—cut grasses for green chop in the mornings
—allow the grass to wilt in the sunshine
—feed the dried grass in the evening or the next day

As you can see, raising beef cattle in the tropics presents special management problems.

Diet Formulation Example

The following diet formulation is taken from *Winrock International Technotes #22:*

The mathematics of balancing a diet are simple. Let's go through an example of how to do this for a 400-kg penned cow that it not lactating but is in the middle trimester (third) of pregnancy.

Step 1: Determine which feeds are available and record their composition. The cow owner has a small plot of molassesgrass from which

he cuts fresh forage by hand daily after about 50 days of growth. The farmer also has a limited supply of sugarcane molasses. The nutrient composition of these two feeds is as follows:

	% DM	Mcal/ % TDN	kg ME	% CP	% Ca	% P
Molassesgrass 50 days' growth, fresh	22	53	1.9	9.0	.63	.54
sugarcane molasses	77	53	1.92	5.4	1.09	.12

The dry matter (DM) content will influence how much of the feed the animal will voluntarily eat each day. Cattle generally eat 2% to 3% of their weight in dry matter each day if they are performing a major function such as producing milk or growing rapidly. This cow will need to consume more of a very succulent feed as compared to a drier one in order to take in the same amount of dry matter. Both total digestible nutrients (TDN) and metabolizable energy (ME) are measures of energy content on a dry matter basis. The crude protein (CP), calcium (Ca) and phosphorous (P) levels are also listed (because these are essential nutrients).

Step two: Record the animal's requirements. The information listed here is from the tables mentioned previously and has been obtained from many scientific feeding studies. It may not be exactly right for this cow, but it will be close.

Animal class	kg DM	kg TDN	Mcal ME	g CP	g Ca	g P
Cow, 400 kg, middle one-third pregnancy	7.5	3.6	13.1	525	13	13

Step three: Begin to formulate the diet with the information from the previous steps. In order to keep costs down, let's attempt to balance the feed nutrient content with the animal's needs using only the forage, molassesgrass. The cow will eat at least the equivalent of 7.5 kg/day dry matter of this succulent forage. By multiplying the values from step one by 7.5 kg/day, we see that if the cow eats only fresh-cut molasses-grass, her nurtient intake will be:

	kg DM	kg TDN	Mcal ME	g CP	g Ca	g P
Molassesgrass provides	7.5	3.975	14.25	675	47.25	40.5

Step four: Evaluate the diet. This diet contains more than enough of each nutrient for the cow. Obviously, then the farmer will not need to purchase or use any molasses. Because the diet has an oversupply of most nutrients, the farmer can somewhat reduce the amount of feed he gives the cow and still meet her needs. The farmer should also supply salt and, if available, a trace mineral mixture for free-choice consumption.

Step five: Convert the diet from a dry matter to an as-fed basis,

especially in the case of fresh forages. The molassesgrass is 22% dry matter. So, for this cow to consume 7.5 kg. of dry matter, she must eat 34.9 kg/day (7.5 kg ÷22%) of molassesgrass as it is cut from the plot. In some cases, where animal nutrient requirements are high and the available forage is low in dry matter, it is not physically possible for the animal to consume the amount of fresh food necessary. In such cases, it would be wise to wilt the forage, or to add a drier and higher energy feedstuff.

To summarize then, the tools you need to formulate livestock diets include 1) some idea of the nutritional requirements of the animals you are feeding; 2) a list of some of the feedstuffs you have available, and 3) a knowledge of the feedstuff composition. Formulate the diet on a dry matter basis, evaluate the diet by comparing the animal dietary requirement with the composition of the formulated diet, and make adjustments as needed. Finally, convert the diet to an as-fed basis as it will be based on forage plus perhaps some supplemental (calories or protein) concentrates.

Economic Comparisons of Feed

In addition to examining the nutrient content of feeds, we need to consider the price of feeds also. Costs per unit of dry matter, per unit of crude protein, or per unit of energy are most useful for comparing the true costs of feeds.

If one could get a dry feed for the same price per kg as you could get it fresh, which would be the best buy? Obviously, the dry feed would be the best buy because you would not have to pay for the weight of the water.

Because feeds differ in weights per pound, bushel, or kg and in nutrient concentration, they should not be purchased solely on the basis of price per weight measure (pound, bushel, kg). The following formula compares feeds on a cost per weight of nutrient basis using pounds as the weight measure: (bushels or kilograms could be substituted for pounds by using the appropriate conversion tables).

$$\text{Cost (\$/lb. of nutrient)} = \frac{\text{Cost per 100 lb. feedstuff}}{\text{\% nutrient in feed stuff}}$$

Example: A farmer needs to purchase a protein supplement of either soybean meal (45.8% protein) at $220/ton (2000 lb.) or cottonseed meal (41.4% protein) at $180/ton. Which supplement would be the best buy?

Soybean meal would convert to $11/100 lb. and cottonseed meal would convert to $9/100 lb.

Soybean meal cost/lb. protein = $11/45.8 =$.24/unit of protein

Cottonseed meal cost/lb. protein = $9/41.4 = $.22/unit of protein

Thus the cottonseed meal should be the best buy based on cost per unit of protein.

Mineral and Vitamin Supplements

Salt or sodium chloride is necessary for body cells to function, for saliva production, and it stimulates the appetite. Either loose salt or block **salt should be available to cattle at all times.** The average requirements

for a mature cow are 40-50 gm/per day.

Minerals are nutrients needed in small amounts for the proper functions of the body. A lack of required minerals results in decreased growth and production. Minerals are found in plants that the animal consumes, but these plants may not contain enough of all the minerals needed. Plants grown in areas of high rainfall i.e. tropics, have lower levels of minerals. Mineral deficiency signs include loss of condition and/or hair, abortion, diarrhea, anemia, loss of appetite, and a craving for dirt, wood, or bones.

The kind and amount of minerals supplemented will vary from region to region based upon soil conditions. **Calcium and phosphorus are the minerals most often deficient and usually need to be supplemented.** Then, based upon the region, the other minerals may need to be provided.

TABLE 7

Suggested mineral requirements (dry basis).

	Beef cattle	Lactating dairy cows
Macroelements		
calcium (%)	.28	.52
phosphorus (%)	.25	.36
magnesium (%)	.1	.2
potassium (%)	.65	.8
sodium (%)	.08	.18
sulfur (%)	.1	.2
Microelements		
cobait (ppm)	.1	.1
copper (ppm)	8.0	10.0
iodine (ppm)	.5	.5
iron (ppm)	50.0	50.0
manganese (ppm)	40.0	40.0
molybdenum (ppm)	--	--
selenium (ppm)	.2	.1
zinc (ppm)	30.0	40.0

Adapted from McDowell (1985). Note: The true requirements will range higher and lower because of various dietary and animal factors.

Most minerals are mixed with salt to provide for a better consumption. To calculate the amount of mineral supplied daily from a mineral mixture, multiply the percentage of mineral element in the mixture times the intake of the mixture and divide by the total dry matter intake of the animal. Mineral mixtures should be placed in areas where cattle congregate or at watering supplies.

Vitamins, like minerals, are supplied by the plant; but in some instances, need to be supplemented. They are required for growth, transportation of energy in the body, and other body functions. Whether to supplement these vitamins depends upon regional conditions as well as production expectations. Vitamin A is the one that is more often supplemented either in the feed or water or by injection. Vitamin A re-

quirements for beef cattle are 3000 I.U./100 lb. (6600 I.U./100Kg) body weight. If the cattle are not eating green feed or a legume, vitamin A should be supplemented. The other vitamins—D, E, K, B, C—may need to be supplemented in lesser amounts.

Feeding the Cow After Calving

One of the most important goals for the beef cattle producer is to have a calf per cow per year. With a gestation period of 285 days, the cow has 80 days to recover from the calving cycle and rebreed. First-calf and second-calf heifers are especially difficult to rebreed in this time period. The reason is that the younger animal is still growing herself, nursing a calf, and getting ready to breed all at the same time. The time period between calving and the first heat cycle (conception time) is directly related to the "nutritional status" of the animal. Thus proper nutrition is most important at this time.

After calving dry matter requirements increase by 49%, energy requirements increase by 45%, and protein needs increase by 140%. Therefore, it is important that cows which have calved be separated and fed appropriately, increasing the energy and protein levels. In some instances and especially with younger animals, addition of a grain concentrate and/or protein supplement is necessary at this post-calving period. Phophorous levels are also very critical. Other suggestions for feeding cows after calving include using young, tender grasses to replace mature forages. Also, adding legumes either by interceding in grass pasture, as green chop, hay, or silage can be very beneficial. In order for cows to breed after calving, they need to be gaining weight.

Pasturing Forage

In order to plan ahead, a farmer will need to know how many livestock his pasture will carry. This would depend upon a number of factors including size and age of animals to be pastured, rainfall, amount of forage produced, and type of pasture.

In the humid tropics approximately .5 hectacres are needed to support one cow per year. In drier areas approximately 10 hectacres will be needed per year. Cattle which are approximately one year old will need one half as much pasture as mature cows.

The amount of forage available during the year varies according to the season. Thus, one might not have enough cattle grazing pasture during the rainy season, but will hopefully have enough forage to sustain the animals through a dry season. It's desirable to have some extra hay or forage on hand to be prepared for drought conditions which occur periodically.

Because pastures are usually the cheapest feed source available, any efforts made to upgrade and improve pastures are beneficial. The first step in deciding what improvements should be made is to take a soil test. This will help one determine what plant nutrients must be added to improve productivity of the pasture. Sometimes lime will need to be applied which adds valuable nutrients such as calcium, magnesium, and phosphorous. According to the soil tests, nitrogen, phophorous, sulphur, and other types of fertilizers may be used to provide needed nutrients.

Another method of upgrading pastures is to clear all brush and tree growth. Then one can plant various grains and/or legumes. The choice of grasses will depend on the climate and the expectations of the pasture. It is also important to control weeds growing in the pastures. Cattle will usually eat grasses and weeds will go unchecked using up valuable nutrients and moisture. Weeds can be controlled by clipping (mowing) and the use of herbicides (weed killers.)

Prevention of overgrazing also helps in the control of weeds as well as having a good stand of grass to compete with the weeds. **Cross-fencing** pastures allows grazing one part of the pasture down, and then moving the cattle to another part, allowing the first part to make a second growth for later grazing.

When pasturing cattle, make sure there is a good water source available as well as salt and mineral.

Hay Production

To provide extra feed needed during dry seasons, one can use surplus grass or legumes to produce hay. This provides a more constant supply of nutrients so animals can be carried through seasons of low forage production. Hay production involves cutting these grasses and legumes during the wet season and storing them for later feeding.

It is usually best to cut the forage before the plant flowers. By doing the harvesting at this stage, one can get the maximum yield and still have high quality hay. If the hay gets too mature, the quality of the hay decreases and also the livestock will not eat it as well.

The sickle, knife, and scythe are the and tools used for cutting forage for hay. A scythe is usually the fastest. Cut the growing plants after all dew has evaporated from the leaves, usually by mid-morning. Leave the forage on the ground to dry for about one day. (This time may lengthen if the forage is extremely wet or is rained on.) Do not let the forage get too dry or risk getting rained on. After the forage has properly dried, it should be gathered into piles with a hay rake or a 3-4 tine fork. As soon as possible it should be moved to a storage area close to where it will be fed. Animals may be used to pull carts to transport the hay from the field to the feeding area.

The hay should be handled carefully to avoid losing the leaves. The hay stacks should be located in a well-drained area and fenced to keep stray animals out. The stacks should have a peak in the center so the rain will run off and can be up to 10 m. tall. It is even better if there could be some sort of cover over the top of the stack.

Whenever possible, try to schedule hay cutting between rains. Hay that is rained on before it is stored loses many of its nutrients.

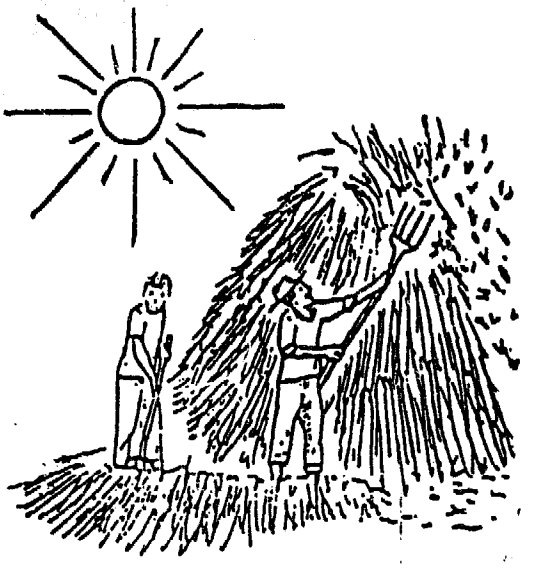

If possible stack the hay close to the feeding area.

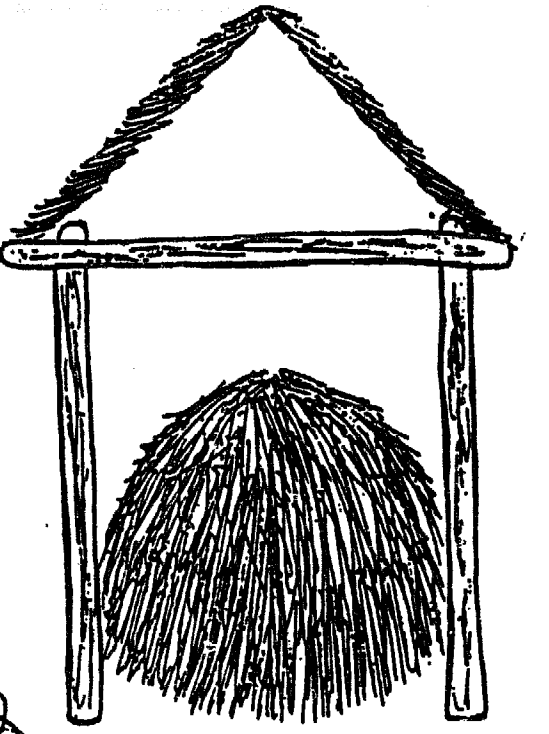

A cover over the hay will prevent spoilage.

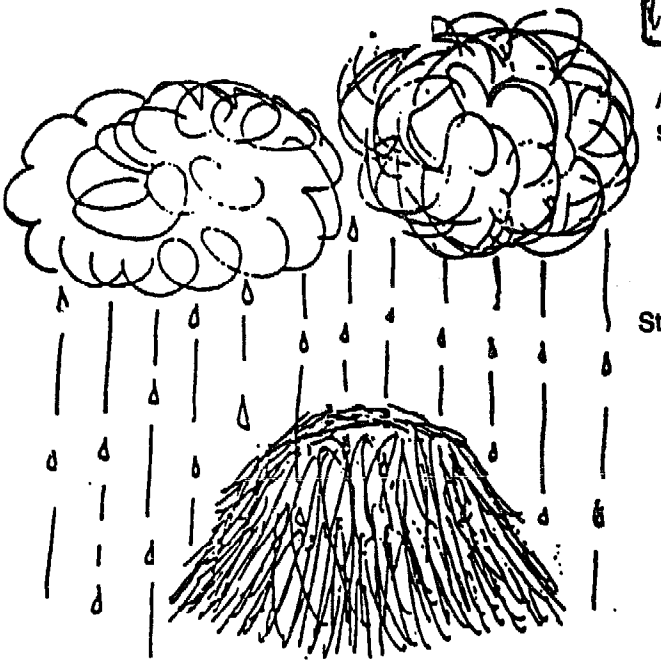

Stack the hay so it will shed water.

Drawings donated by Maureen Birmingham, D.V.M.

Section 4

Management

MANAGEMENT OF BEEF CATTLE

This section will concentrate on management practices to successfully raise beef cattle. If one wants to keep one or more cows, he must consider the following:

1. Do I have enough forage and water for the animals?
2. Do I have facilities to keep the animals?
3. is there someone in the family to tend to the animals? (feed and water)
4. Do I have access to a bull for breeding?
5. Can I provide minerals and additional feed if needed?
6. How will I market the beef?

Aging Beef Cattle

The age of cattle is estimated by the front teeth. The eruption of the front teeth occurs as follows:

1. First pair - 1.5-2 years
2. Second pair - 2-2.5 years
3. Third pair - 3-3.5 years
4. Fourth pair - about four years

THE ERUPTION OF TEETH IN ZEBU CATTLE

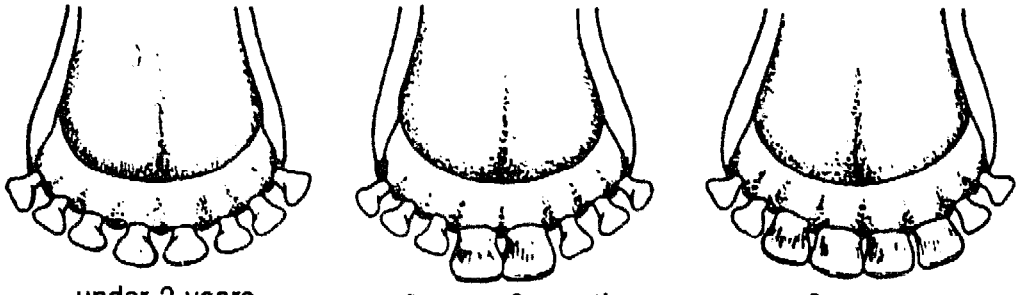

under 2 years | 2 years 3 months | 3 years

The small teeth are the temporary or milk teeth which fall out. The large teeth are the permanent incissors.

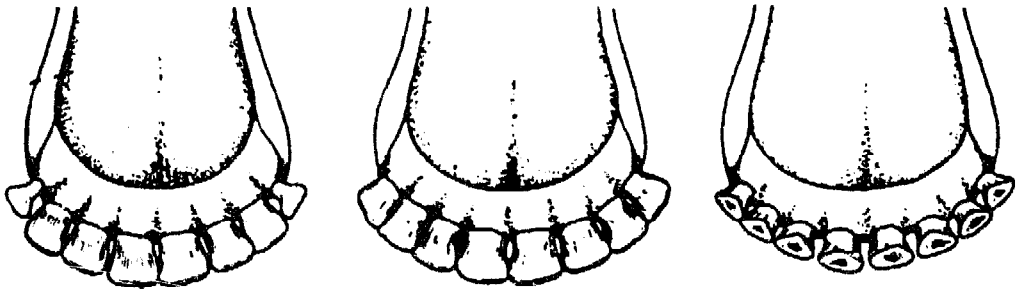

3 years 6 months | about 4 years old (4 pairs of permanent incissors | old animal. 4 pairs of permanent incissors in wear.

The teeth of exotic and improved breeds erupt slightly earlier but considerable variation occurs between all breeds and types of cattle of the same ages.

Fig. #18 (FAO Manual—1983)

Estimating the Weight of An Animal

Most producers will not have a scale available, so determination of approximate weight is necessary. Weight estimation is needed for determination of drug dosages, check on feeding practices, and the determination of market times.

The only equipment needed for this procedure is a metric tape measure. The formula for making this calculation is:

heartgirth (cm) x heartgirth (cm) x body length (cm)
divided by 10,840

By using this formula, you will get the approximate body weight. The following steps will help you with the procedure:

Step 1: **Measure heartgirth.** This is the distance around the chest at a point just behind the shoulder blade, down over the ribs, and under the body behind the elbow. Place the measuring tape completely around the animal, tighten snugly and record the number.

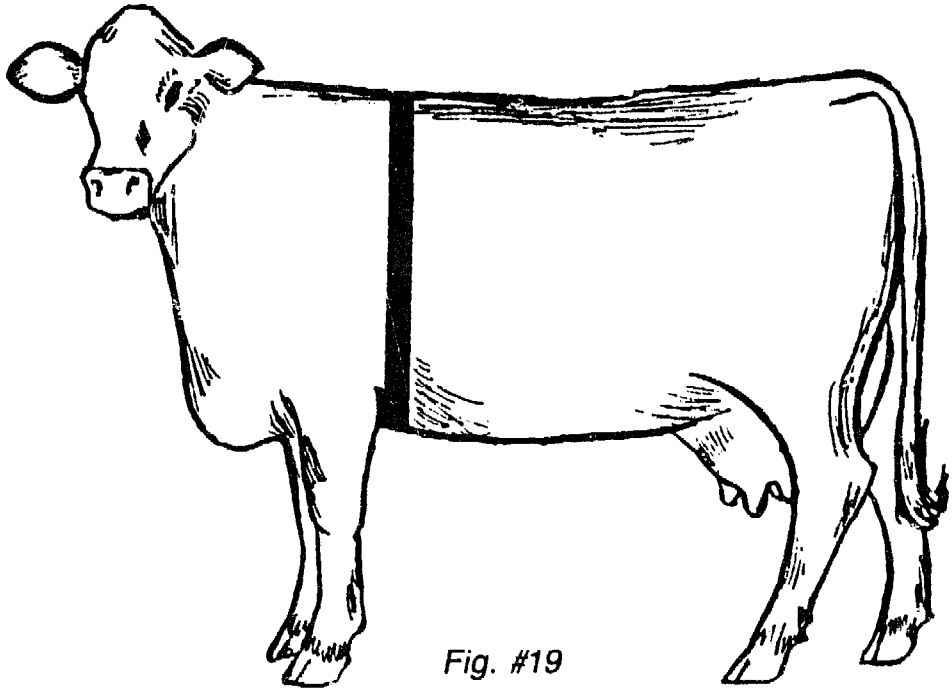

Fig. #19

Step 2. **Measure body length.** This is the distance from the point of the shoulder (the most forward part of the shoulder) to the pinbone (the rear most part of the rump.) Pull the tape snugly and record the number.

Step. 3 **Apply the formula.** Assume an animal has a heartgirth of 170 cm and a body length of 144 cm.

170 x 170 x 140 divided by 10,840.
170 x 170 equals 28,900
28,900 x 140 equals 4,046,000
4,046,000 divided by 10,840 equals 373 kg. or the approximate weight.

Another method to estimate weight is to measure the heartgirth and use the table below for determining weight in kg.

Table 1. Estimated Live Weights of Dairy Cows from Heart Girths

Heart girth cm	Weight kg	Heart girth cm	Weight kg	Heart girth cm	Weight kg	Heart girth cm	Weight kg
140	255	160	328	180	409		
142	264	162	338	183	420		
145	273	165	348	185	431		
147	282	168	358	188	442		
150	291	170	368	190	453		
152	300	173	378	193	464		
155	309	175	388				
157	319	178	399				

(Winrock International 1985)

Identifying Animals

Reasons for marking of individual animals include: proof of ownership, keeping track of an animal for production history, as a marking for quarantine, or as a record of immunization. Cattle can be identified by a number of different methods.

1. **Branding** can be done by the use of a hot iron. The animal should be restrained in a chute or tied with ropes. The iron is heated red hot and applied to the hide for approximately 3 seconds. The animal should be dry before being branded. If the iron is left on the hide too long, it will burn through and could result in screwworm infestation. This can be prevented with an insecticide repellant.

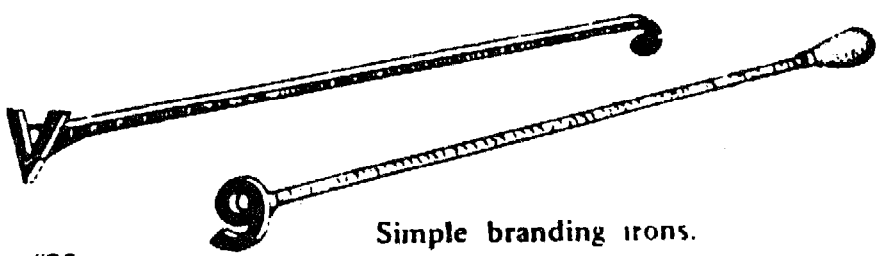

Simple branding irons.

Fig. #20

2. **Ear Clipping** is accomplished by trimming a notch out of the ear.
3. **Tatooing** of the ears is done by a special instrument that places letters or numbers in the skin of the inside ear. These numbers are dyed with ink.
4. **Ear Tagging** involves placing metal or plastic tags in the ear. These tags can have numbers or letters on them.

Selection of A Bull

Selection of sires is the most important way to upgrade one's herd. The bull contributes 50 percent of the genetic potential to the offspring and his daughters go on to become replacement females. It is projected that the bull can contribute up to 80 percent of the genetic material in a herd over a period of time. Traits commonly selected for include birth weight, weaning weight, yearling weight, milking ability of offspring, carcass traits, etc.

Table 9 Chart Heritability Traits

Sire Selection

Heritability Estimates of Some Economically Important Traits*

Trait	Heritability (%)
Calving Interval (Fertility)	10
Birth Weight	40
Weaning Weight	30
Cow Maternal Ability	40
Feedlot Gain	45
Pasture Gain	30
Efficiency of Gain	40
Final Feedlot Weight	60
Conformation Score:	
Weaning	25
Slaughter	40
Carcass Traits:	
Carcass Grade	40
Ribeye Area	70
Tenderness	60
Fat Thickness	45
Cancer Eye Susceptibility	30

From Gregory, 1969. Beef cattle breeding. USDA Ag. Inf. Bull. No. 286 (Revised)

Quite often in attempts to upgrade a cow herd, bulls are brought in from other areas to be used in crossbreeding. This is when the parents of different breeds are mated together, i.e., Brahma and Charlois. This results in an increase in gain, fertility, and thriftiness. However, when animals from temperate climates are brought into tropical regions, this sometimes results in disappointment. The problem is that the newly arrived animal cannot adapt to the climate change. These animals also do not have resistance to ticks, tsetse fly, etc. An animal brought into a tropical region for breeding purposes should be heat tolerant, capable of resisting local diseases, and tolerant of varying planes of nutrition.

Inbreeding is the mating of related animals. For example, a bull is mated with one of his daughters. This is generally **not recommended** because the undesirable traits of these individuals are increased in their offspring. These characteristics might include death, dwarfism (miniature calves), hydrocephalus (water on the brain), spastic, or lacing coordination, deformed joints, and double muscling. They may also have cleft palate (imperfectly closed top of mouth), curved spine, and either bent or extended legs, as a result of inbreeding. These calves either die immediately after birth or develop abnormally. Thus, livestock producers need to avoid breeding animals which are closely related to each other.

In selecting a bull, one should examine the overall confirmation and appearance of the bull. Pay close attention to the feet and legs for soundness. The testicles should be of the same size with a firm consistency. The larger the testicles, the better fertility the bull will have. The distance around the testicles should be over 30 cm. for yearling bulls. Mature bulls

should measure 36-40 cm. Note the reproductive organs in the diagram below.

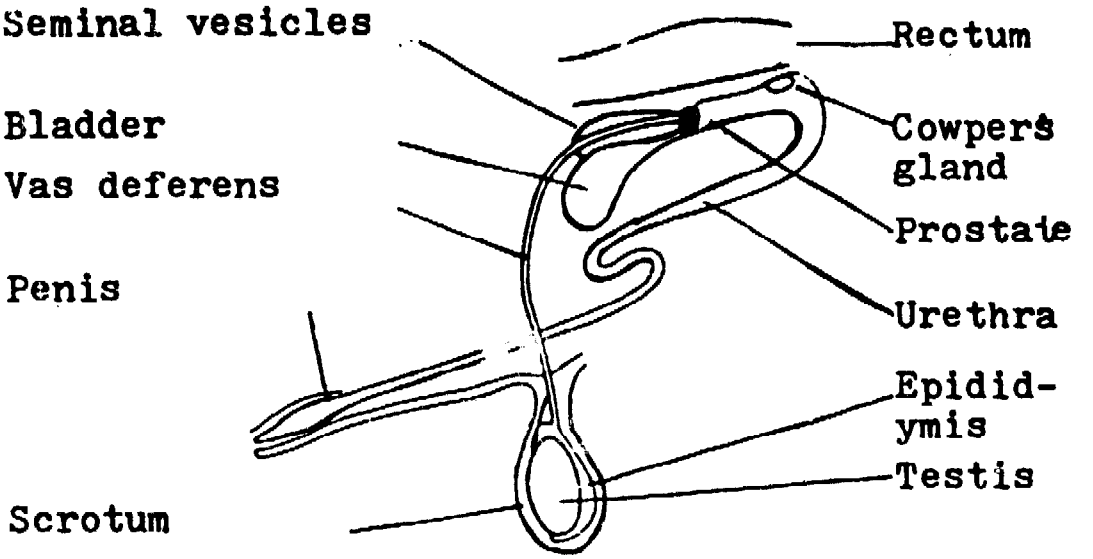

Fig. #21 Male reproductive organs

The sperm is produced in the testis and stored in the seminal vesicles until ejaculation. Outside temperature (excess heat or cold) can influence the quantity and quality of the sperm. Also, presence of fever or infection can reduce the number of sperm.

A one to two-year old bull, **given the proper nutrition,** should be able to breed 10-15 cows in a 60-day season. A mature bull should be able to breed 15-20 cows in a 60-day season. If a bull is fed well and does not have to roam a pasture to breed cows, he can breed even more cows than mentioned above. The best way to analyze a bull's reproductive ability is the collection of semen and evaluation by trained person.

Artificial insemination is the process of collecting semen from superior bulls, diluting, and freezing it in liquid nitrogen and then transporting it. This semen is then used to breed cows instead of natural breeding with a bull. The advantages are the use of genetically superior bulls at a nominal cost, elimination of spread of veneral disease, and elimination of cost and maintenance of a bull. The disadvantages are the cost of the semen and the time and management involved in heat checking and breeding. This procedure can be carried out by trained personnel. It should be attempted only where excellent management and nutrition is practiced.

Selection of a Female

Selection of females is also very important and there are many traits to consider in this process. The first might be the fertility or reproducing ability of the animal. This is determined by its parents as well as enviromental factors—namely, nutrition. Different breeds are known for their reproductive abilities. One also needs to consider the size of the animal. We don't want a heifer or cow so small that she will have trouble delivering the calf; but, on the other hand, a very large cow will require too much feed to maintain her production. Other characteristics to consider would be structurally correct feet and legs and a sound udder.

Reproduction

The cow will only accept the bull when she is in "heat" or estrus. With proper nutrition and health, the estrus cycle occurs every 21 days and lasts approximately 18 hours. Ovulation, or the release of the egg from the ovary, occurs approximately 11 hours after the end of the estrus or heat period. Thus, it is best for a cow to be exposed to the bull at the end of the heat period rather than the at beginning. The level of nutrition has a very large effect upon the frequency of heat cycles. In order for a cow to cycle following calving, she needs to be gaining weight.

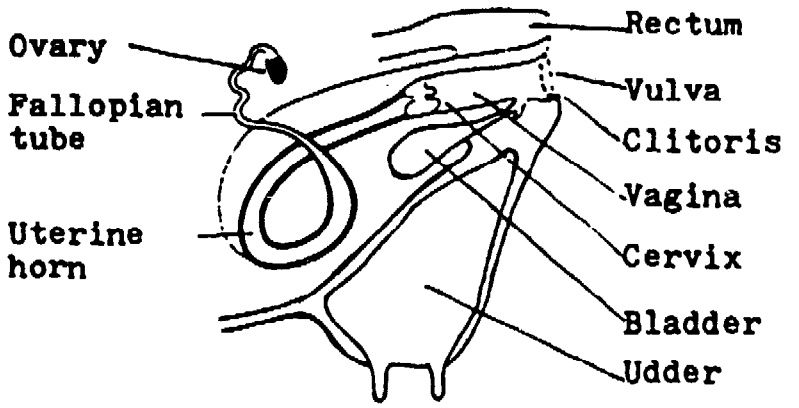

Fig. #22 Female reproductive organs

THE REPRODUCTIVE ORGANS OF THE COW.

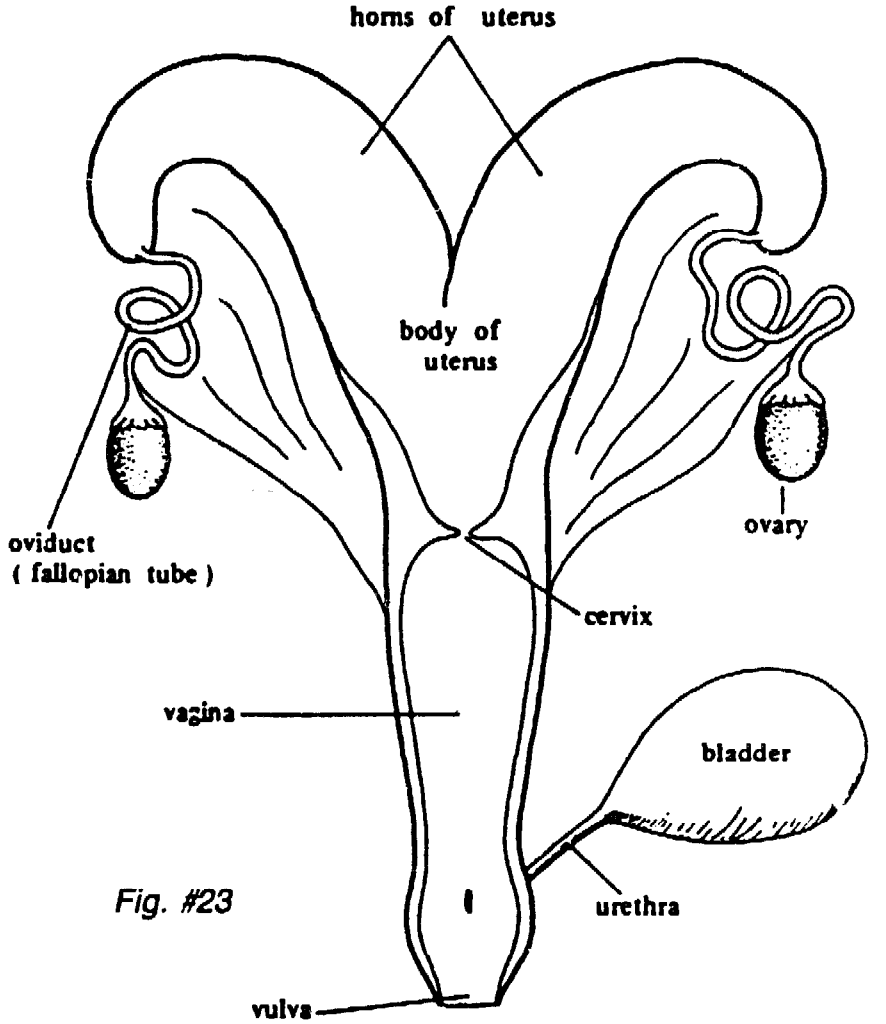

Fig. #23

The signs of heat in a cow are: bellowing, restlessness, the cow mounting or being mounted by another, and a slight discharge of mucus from the vagina. The cow will often seek out the bull.

PUBERTY	LENGTH OF ESTRUS CYCLE	LENGTH OF HEAT PERIOD
6-24 mo.	18-24 days (avg. 21)	4-24 hr. (avg. 18)

When the male mates with the female, he deposits his ejaculate in the vagina. There are thousands of sperm cells present in the ejaculate. Some of the sperm cells pass through the cervix and into the uterus. Fertilization takes place in the fallopian tube and the egg is fertilized by only one sperm. The fertilized egg then moves into the uterus and becomes attached to one of the horns of the uterus. The fetus becomes enclosed in a sack called the placenta. It receives its nutrition through the umbilical cord and transfer of nutrients from the mother's blood.

Care of the Cow Before Breeding

The first heat cycle for a heifer will occur at six months up to 2-3 years depending on nutrition and breed. Heifers should not be bred before 1 year of age for proper structural development. If a cow does not receive the proper feed after calving, it will take considerable time for her to come into heat for re-breeding. A cow may lose weight for 3-6 weeks following calving and thus it is important to feed a cow well during this period. The preferred length of time between calving and re-breeding is 1-3 months. However, with poor nutrition, this time may be lengthened to 1-2 years. The most difficult time for a cow to settle is after her first calf as she is still growing, milking, and trying to re-breed.

Before breeding is also the best time to give any vaccinations. Recommendations for vaccination will be given in a later section.

Pregnancy Diagnosis

Where possible, determination of pregnancy is most valuable and beneficial. This could be done by a veterinarian or trained technician by manual examination of the uterus through the rectal wall. Also, if the animals can be observed closely, the absence of estrus within 24 days after exposure to a bull would indicate likely pregnancy.

Because feeding cows which aren't pregnant is expensive, pregnancy diagnosis is important.

Caring for The Cow at Calving Time

The gestation period (length of pregnancy) for the cow averages 285 days or about 9½ months. As birth of the calf approaches, the udder becomes enlarged with milk and there is a marked loosening of the region of the tail head, and pin bones. The vulva also swells and enlarges. When these signs occur, the cow needs to be observed three or four times per day in the event assistance is needed for delivery of the calf. Just before the cow delivers, she will produce a water sack 15-25 cm. in diameter. This sack will break and usually within two hours the cow will deliver by herself. If the cow is in **severe labor for more than two hours** , it should be examined by a veterinarian or experienced personnel. Before examin-

ing the cow, clean off the vaginal area with water. Also, be sure to use ample lubrication of soapy water on the hands and arms. Use of an O. B. glove or sleeve is recommended before examination of a cow.

Conditions Requiring Assistance at Birth

1. **Large Calf-Normal Position**
   Normally, the front feet and the head will come out of the vulva first. If the cow cannot deliver the calf by herself, assistance will be needed. Ropes should be attached to both legs, and be sure to attach the rope above the fetlock or joint as you may dislocate the joint or break a leg. You should have one or two strong men to pull the calf. If it is an especially difficult pull, a rope can be attached around the back of the ears and through the mouth to provide another point of traction. **Do not pull straight out on the calf,** but rather pull at an angle downward toward the back legs of the cow. If one pulls straight back on the legs, the calf could be caught by the hips in the pelvic canal of the cow and would be very difficult to deliver.

Fig. #24—Correct presentation of calf—note location of ropes above the Fetlock and also the direction of pull (downward).

Fig. #25—THE POSITION OF THE FETAL CALF IN LATE GESTATION

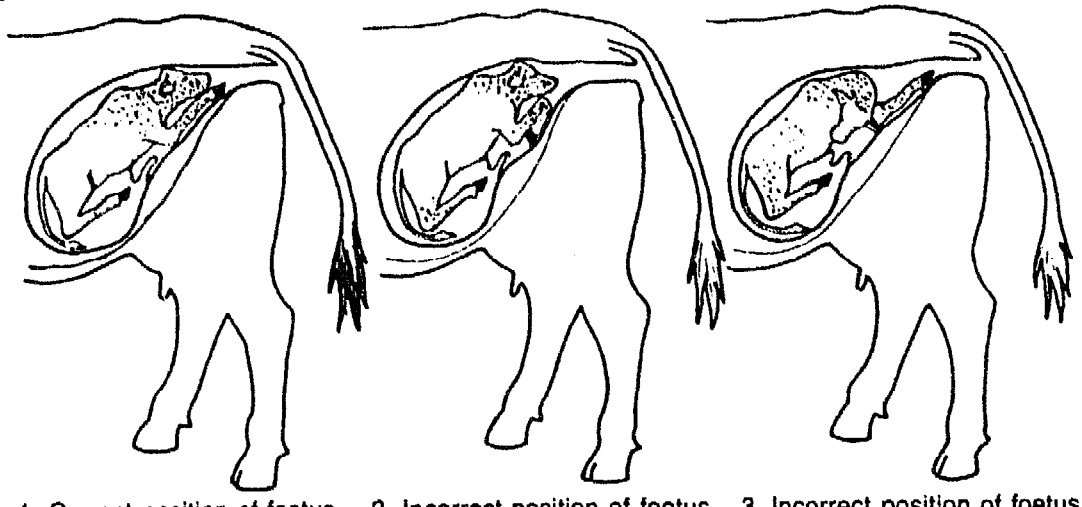

1. Correct position of foetus, (forelegs and muzzle correctly placed.)
2. Incorrect position of foetus, (showing forelegs bent back)
3. Incorrect position of foetus, (showing head twisted back)

2. **Backwards Calf**
If the legs are turned with the dewclaws facing upward the calf is probably backwards. About 5% - 10% of calves will come backwards and usually will require assistance. Attach the ropes to the hind legs and pull as described previously. In this position, the umbilical cord will break before the calf can breathe; so once the pulling is started, it is very important to get the calf out quickly. Often the calf will have fluid in the lungs. To help in this situation, the calf should be raised up by the hind legs and swung back and forth upside down to drain the fluid out of the lungs. Sometimes it helps to hang the calf upside down for 2 or 3 minutes to drain the fluid and stimulate breathing.

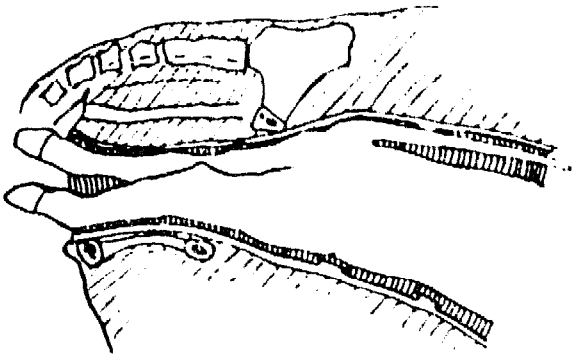

*Fig. #26—**Backwards presentation:** always check that the tail is not being forced into the roof of the vagina as it is in this diagram. It should be lying between the hind legs during the birth.*

(FAO Manual—1983)

3. **Breech Calf**
A small percentage of calves will be positioned in a **tail-first** position which is impossible for the cow to deliver by herself. In this position, a local anesthetic block in the spinal cord is most helpful to keep the cow from straining while manipulations are performed. Very carefully, the calf needs to be pushed forward so that the backlegs can be located and pulled out into the birth canal. Then the calf can be pulled as a normal backwards calf. The danger in this procedure is in tearing a hole in the uterus with one of the back legs while bringing it into position.

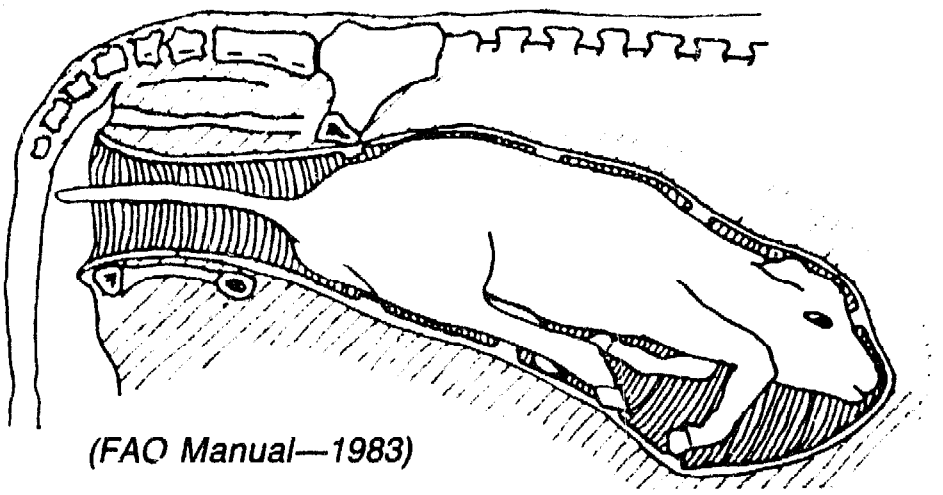

(FAO Manual—1983)

*Fig. #27—**Breech presentation:** the calf is coming backwards but with both legs forward so that only the tail is felt in the vagina. Because there is nothing dilating the vagina the cow often does not strain, and consequently many breech births may go unnoticed for several hours and produce a dead calf.*

4. **Headback Position**
   In this position the legs are preceding into the birth canal normally but the head is bent to one side or the other. Carefully push the calf back into the uterus and grasp the head with a rope snare or by the nose and pull it up into the canal. It may be helpful to put one leg back into the uterus to allow more room to work. (See figure 25.)

5. **Legback Position**
   In this position one leg fails to come into the birth canal. As before, push the calf back while at the same time pulling the leg into the canal. (See figure 25.)

   If the above procedures do not result in a successful delivery, the only alternative is a **Caesarean Section** which must be done by a qualified person.

As the calf reaches the ground, clear any placenta or mucus from the nose and mouth. Breathing can be stimulated by throwing cold water on the head or by tickling the end of the nostril with a piece of hay or straw. Slapping the side of the chest with the flat of the hand will also stimulate breathing.

Care of A Calf Immediately Following Birth

After the calf is breathing normally, apply iodine to the naval cord to prevent naval infection. The cow should be allowed to lick the calf as soon as possible as this stimulates breathing and helps dry off the calf. **If the calf does not nurse within six hours after birth, the cow will have to be milked and the colostrum (first milk) fed to the calf.** The colostrum is highly nutritious and also contains antibodies. The antibodies are the only source the newborn calf has to fight off infection. Calves that do not receive adequate colostrum will have a much higher death rate, more scours, and more pneumonia. The newborn calf's stomach can only absorb the antibodies during the first hours of life and thus, the importance of receiving the colostrum within the first hours of life and thus, the importance of receiving the colostrum within the first six hours.

Special Problems Following Birth

Uterine Prolapse: Occasionally, immediately following birth, a cow will continue straining and the entire uterus will be pushed out. This occurs usually after a difficult and prolonged labor. This is an emergency because the cow can go into shock and die quickly. The major problem in treating this condition is to keep the cow from straining while the uterus is replaced. The injection of a spinal block of local anesthetic will relax the cow. In addition, a rope tied tightly around a cow's abdomen just ahead of the udder helps to stop the straining. Also, with the cow lying down, one can tie a rope to the hind legs and secure the rope to a stationary object overhead such as a tree limb. With steady pressure the hind quarters should be elevated by 1-3 feet. This procedure gets the uterus off the ground so that cleaning is easier, makes it easier to replace the uterus into the cow, and keeps the cow from straining.

The uterus should be washed off with clean water and soap. Slowly and carefully the uterus should be replaced into the cow. Once the uterus

is inside the cow, it must be turned inside out by pushing gently with a closed fist into each uterine horn. At this time an antibiotic should be administered into the uterus. The vulva should then be sutured to prevent another prolapse. Also an antibiotic should be given to the cow for 4 or 5 days. Treatment of this condition requires trained personnel.

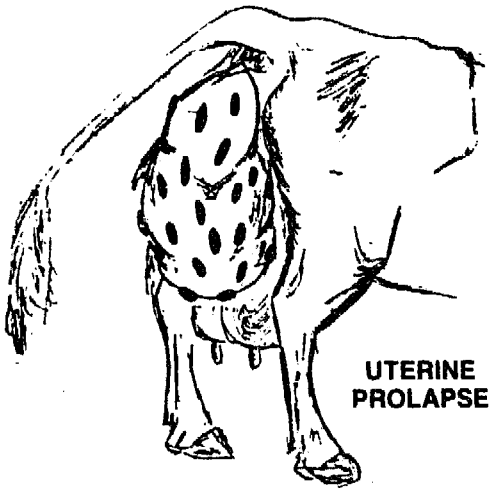

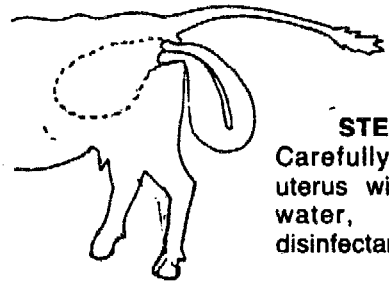

STEP 1
Carefully wash uterus with soap, water, and disinfectant.

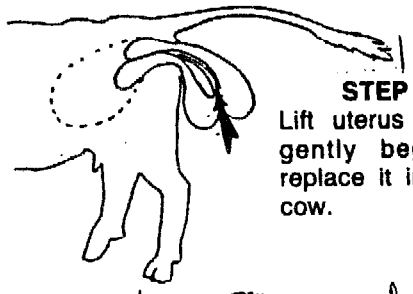

STEP 2
Lift uterus up an gently begin to replace it into the cow.

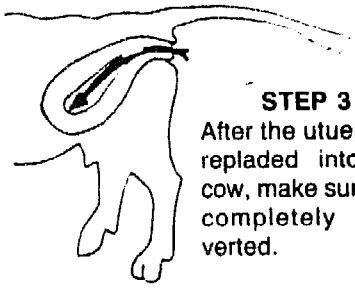

STEP 3
After the utuerus is repladed into the cow, make sure it is completely inverted.

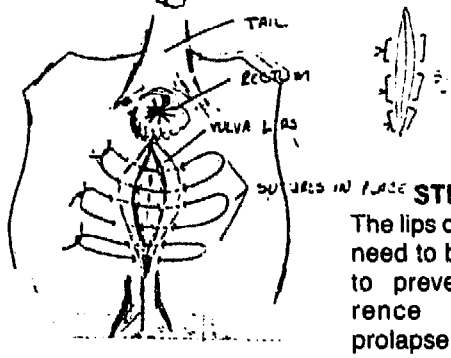

STEP 4
The lips of the vulva need to be sutured to prevent recurrence of the prolapse.

Retained Placenta

Sometimes the placenta will remain attached to the uterus longer than 24 hours. If this occurs, the cow should be watched closely for signs of infection. These signs include listlessness and loss of appetite. If the cow doesn't show signs of infection, it is best to leave the cow alone and let it fall off on its own. If the placenta has not been shed after 3 days, it is best to give the cow some antibiotics daily. If it is deemed that removal is necessary, a gloved hand should be lubricated and inserted into the uterus. With careful manipulation the placenta is removed. Following removal of the placenta, antibiotics should be administered into the uterus.

Nerve Paralysis

Sometimes following a difficult delivery of a large calf, the cow cannot get up. This usually results from damage to nerves in the pelvic canal. The cow may attempt to stand, but one or both legs slide outwards. The treatment for this condition is to tie the legs together with a rope above the hocks. Also, the cow should be rolled into a different position every 12 hours. If the cow cannot stand within 2 weeks, the chances of recoverv are slim.

Managing Nursing Calves

In certain cases where the mother cow may die or be used for milk production, a baby calf may be raised without the mother's milk. In these cases, it is still very important that the calf receive colostrum within 6 hours of birth. While whole milk is the best choice of milk, other substitutes might be goat's milk or milk replacers. Milk replacers should contain 22% protein and 10% fat. It is best to feed the calf with a nipple bottle 1-2 liters 2-3 times per day. Do not overfeed the calf as this causes scours and intestinal upset. Keep the calf hungry. Provide water and a small amount of concentrate or grain free-choice. After 6-8 weeks on the bottle, the calf can be gradually switched to hay and grain.

A few management procedures should be performed after birth and before weaning:

1. **Castration**
   If the male calf is not to be kept as a bull it is best to castrate it early. There is practically no stress or bleeding when done at this time and the calves are easier to handle. Before castration or dehorning it is best to vaccinate the animals for blackleg and malignant edema.
   The best method of castration, on young animals up to six months, is with a clean sharp knife. Secure the animal with ropes or a crush. First, use a mild disinfectant and water to clean off the scrotal area. Then grasp the end of the scrotum, pull it tight, and cut off the lower ⅓ of the scrotum. After exposure of the testicle, a steady pull on it will break the spermatic cord inside the body cavity and very little bleeding occurs. If there is any fatty tissue hanging out of the scrotum, it needs to be trimmed away with a knife or scissors. **The use of a screwworm fly repellant is recommended every 2-3 days following the castration until the wound heals.** Exercise of the calf is recommended for 1-2 weeks following castration to help prevent infection.

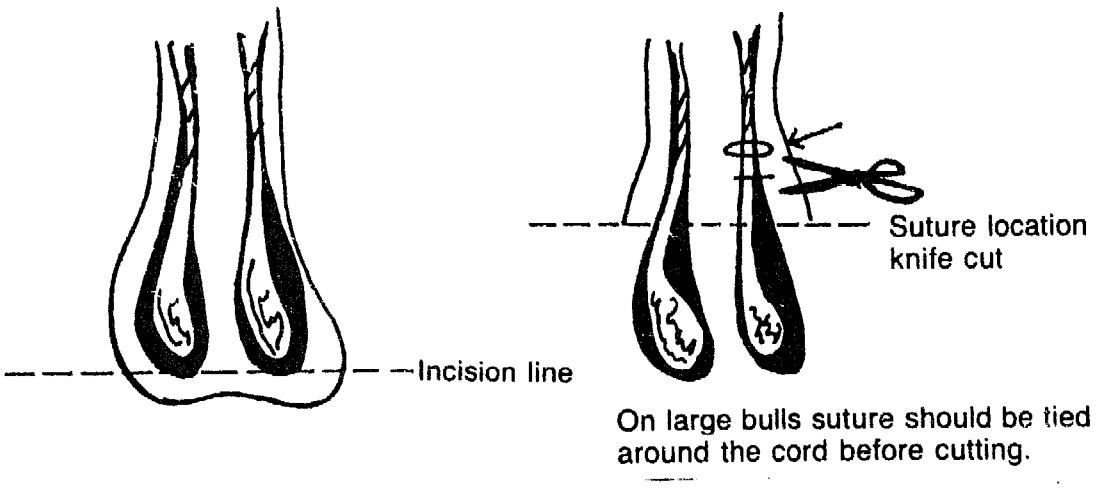

Fig. #29 Castration technique. View from rear of scrotum.

Another method involves the use of a **Burdizzo** which crushes the spermatic cord without cutting or wounding the scrotal skin. (See figure 30.) The advantage of this method is that there is no bleeding or chance of infection or screwworm infestation. The crushing of the cord stops the blood flow to the testicles and they wither away. Careful attention should be taken in making sure the cord does not slip sideways from the jaws of the burdizzo when crushing. Each cord should be crushed separately.

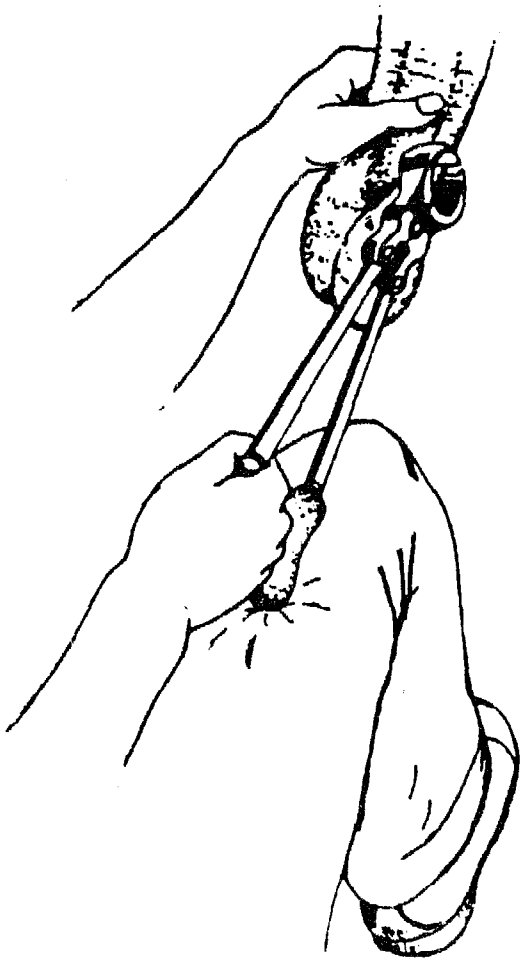

Fig. #30
Proper use of a Burdizzo

An **emasculator** can be used on older animals instead of cutting the cord with a knife. This decreases blood loss. If this instrument is unavailable, tie a piece of suture (catgut) around the cord tightly and cut the cord 1-2 cm. below the suture. (See figure 29.)

If there is considerable bleeding 15-25 minutes after the castration, the bleeding will have to be controlled. This can be done by application of cotton into the scrotum and/or suturing the wound closed. The cotton and/or sutures should be removed in 24 hours and the wound treated with antibiotics, fly repellant and penicillin injections for infection. If there is considerable swelling 1-2 days afterwards, penicillin should be administered again.

2. **Dehorning**
   The reason for dehorning is to keep cattle from injuring humans and one another with their horns. If dehorning is desired, it should be done at an early age. Several methods are available which include a hot iron, paste of caustic soda, mechanical dehorners, or

a saw. The method of choice for baby calves in a warm climate is a hot iron. As soon as the horn button appears, the red hot iron is applied to the horn. The end of the iron should be hollowed out so that its sides go down around the button. It should be held on the horn for a few seconds to kill all the horn cells. The advantage of this method is there is not bleeding. However, it cannot be used on animals over four months of age. Caustic paste can be applied to a calf's horn that is 1-10 days old. One disadvantage of this method is that, in rainy weather the paste gets into the calf's eyes. Also, oftentimes the cow will lick the paste off diminishing its effectiveness. Mechanical methods of dehorning are used primarily on older animals. It is necessary to control the bleeding following these procedures. A small amount of bleeding can be controlled by applying cotton directly into the recess where the horn used to be. To control heavier bleeding, the vein can be pulled with a forceps or a hot iron can be used to cauterize the bleeding vessel. As with castrating, it is most important to use a fly repellant for screwworms and maggots.

DEHORNING CATTLE

Dehorning instruments:

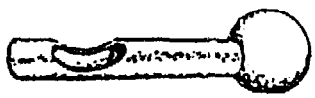

Tube dehorner for calves up to 1-year old.

Hot iron dehorner for calves up to 4-5 months old.

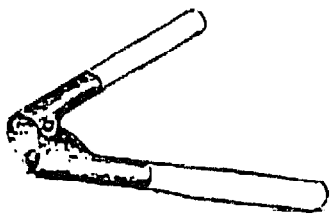

Barnes dehorner for older cattle

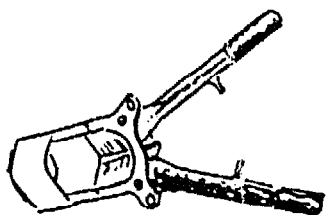

Keystone dehorner for older cattle

Dehorning saw (used only for dehorning)

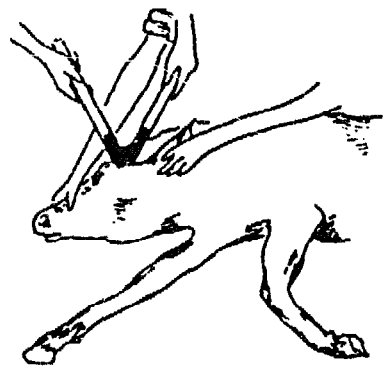

Using a Barnes dehorner on a calf

Dotted lines indicate ¼-inch of skin to be removed along with the horn butt to prevent regrowth. This is true for both calves and older cattle.

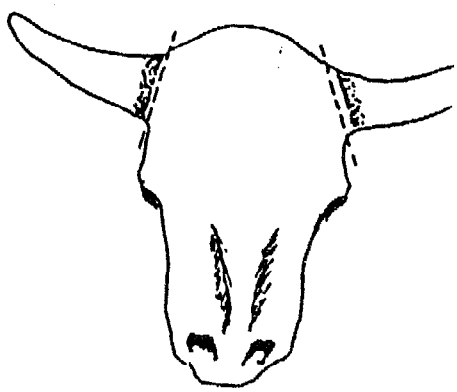

3. **Implants**
The use of hormonal implants increases weight gain by 10%. These are implanted into the ear of the animal according to individual implant instructions. These can be given as early as 1-2 months of age but should not be given within 100 days of slaughter. The implants will last for 100-200 days depending on the type of implant. These should not be used on breeding animals:

Medical Kit

Specific equipment is needed for proper examination and treatment of animals and should include the following:

1) strong rope and/or halter
2) nose tongs—handy if available-not necessary
3) rectal thermometer
4) soap and disinfectant for cleaning and treating wounds
5) container for water and disinfectant
6) cotton, sponges, or clean rags for cleaning wounds
7) bandage material of some sort
8) surgical instruments—knife, forceps, tweezers, surgical needles, and suture of some sort
9) syringe and needles
10) wound dressing of some kind
11) tick and screwworm medication
12) antibiotics—such as penicillin
13) dewormer
14) medication for allergic reactions

Using Drugs Properly

Drugs as chemical substances work in the treatment of disease. They generally have strong actions and can have serious side effects. Precautions need to be followed when using drugs and these include:

1) Be sure to select the proper drug to treat the problem at hand. A drug which is effective for one disease may be totally worthless in the treatment of another disease.
2) Read label warnings and follow directions, observing expiration dates of medicine.
3) Be sure to give the correct dosage. If too low or too high a dose is given, the drug could cause a serious reaction (possible death) in the animal.
4) Use cleanliness and sterility in administering the medication. Boiling the syringes and needles in water for 15 minutes is best. Chemical disinfection is also used.
5) Store medications properly, usually refrigerated and out of the sunlight.

Drugs can be administered in a number of ways depending on directions given on the label. These include:

1) orally as bolus- administered with a pill or balling gun
2) orally as a paste- administered with a syringe or caulking gun

3) orally as a drench- administered with a dose syringe, bottle or tube
4) intramuscular injection- given by needle in large muscle areas or hind legs or shoulder
5) subcutaneous injection- given under the skin, usually in the neck region. Use a shorter needle ½-1" long and direct needle at an angle. Certain drugs such as pencillin should never be given into a blood vessel; so always pull back on the plunger of the syringe just before injecting a drug to be sure you're not in a vein. When giving I.M. or S.Q. injections and the needle is in a vein, blood will show in the syringe and a different injection site needs to be found.

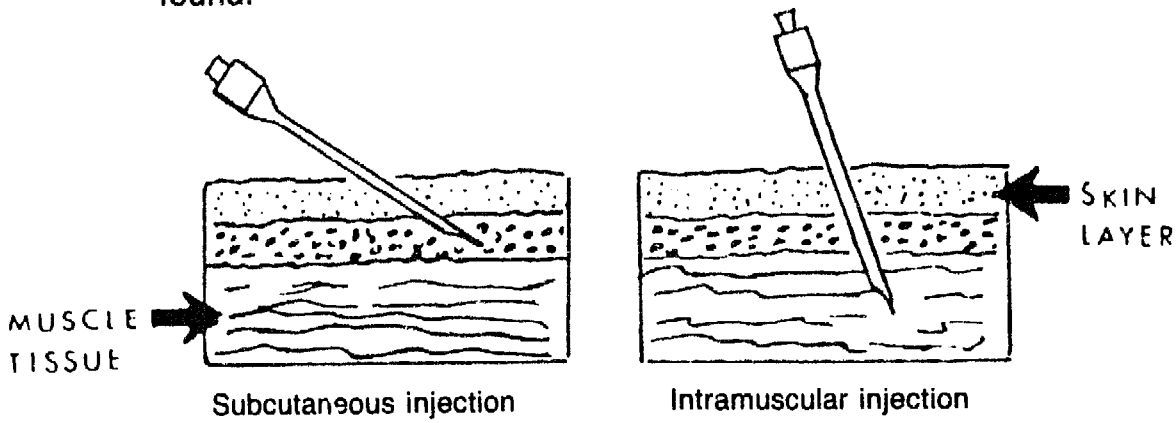

Fig. #32

6) intravenous injection- given directly into the vein; either jugular or tail vein
7) intra-peritoneal injection- given by administering the drug directly into the abdominal cavity
8) administered in the feed or water

Be very careful not to inject oneself with a needle. Also, never give any medication by any route other than what is recommended by the manufacturer.

Figuring Drug Dosages

The effectiveness of most drugs is dependent to a large degree on proper dosage given periodically so as to maintain a proper concentration in the blood. The dose varies depending on the concentration of the drug and the weight of the animal. Units of measure include:

International Unit (I.U.)- arbitrary measure of drug activity against micro-organisms in the laboratory; used for older antibiotics such as penicillin .

Milligram (mg)- 1/1000th gram- metric measure of weight

Milliliter (ml)- 1/1000th liter- volume measure

Cubic Centimeter (cc)- volume measure; 1 cc is equal to 1 ml

Kilogram (kg)- weight measure; equals 2.2 pounds.

To determine the proper amount of injectable drug given an animal, one has to convert the dose in units or mg per lb. or kg of body weight into volume (ml) to give. We need to know three things:

1) Weight of animal: This can be estimated with the help of a heart-girth measurement and expressed in lb. or kg. Remember

there are 2.2 lb. in each kg.

2) Concentration of the drug: This information is found in the package label and is expressed as units/ml or mg/ml.
3) Dosage per lb. body weight of per kg body weight: This information is found on the package label or insert and is expressed in mg/lb or mg/kg.

Example: a farmer has a 700 lb. (318 kg) cow and needs to give a dose of tetracycline. The dose level is 5 mg/lb and the concentration of the drug is 100 mg/ml. How many ml or cc should he give?

1) write down pertinent figures:
   weight of cow- 318 kg (700lb)
   dose level- 11mg/kg (5mg/lb)
2) figure total dose in mg for weight of cows:
   weight multiplied by dose equals total mg.
   312 kg x 11 mg/kg equals 3500 mg
   (700 lb x 5 mg/lb equals 3500 mg)
3) figure out how many ml it takes for total mg needed:
   because there are 100 mg in each ml you will divide total mg by the concentration:
   3500÷100=35ml (cc)
   100 mg/ml

This is the amount you would give to the cow.

Proper Use of Antibiotics

Antibiotics are substances that are used to inhibit or kill microorganisms (germs). They are the most commonly used drugs to treat disease and are also the most misused drugs. They are very effective when used properly. Some points to consider are:

1) An antibiotic is a substance which can be harmful to life. Misuse can harm the animal being treated.
2) The choice of an antibiotic depends on accurate diagnosis of the disease problem.
3) Antibotics are effective against bacterial infections. They are **not** effective against viral and protozoan infections.
4) Antibiotics can be used alone or in combination with other antibiotics. However, certain combinations of antibiotics tend to work against each other and should be used only under the recommendation of a veterinarian.
5) Effectiveness of antibiotics depends on giving the proper dose, repeated at the proper time (ex. 12-24 hr.), and given for a recommended time (ex. 3-5 day). If the proper concentration of the drug is not maintained in the blood then, the antibiotics usefulness is diminished considerably. Usually one has to give more than one dose of the antibiotic. If antibiotics are given for too long of a period they may kill the normal bacteria in the rumen causing digestive upsets. Always read and follow the label and dosage instructions carefully.
6) Some bacteria can become resistant to antibiotics. This is likely to occur when antibiotics are used over a long period of time

or when they are used in too low of a dosage level.

7) Antibiotics are most effective against acute (sudden) infections where bacteria are growing rapidly.
8) Withdrawal periods are listed on product labels. These are the number of days that the antibiotic exists in the meat or milk after the last injection. Their guidelines must be strictly observed.
9) Antibiotics can be added to feed or water for treating or preventing disease.
10) A good guideline for telling if the antibiotic is effective in treating a disease is to observe the rectal temperature. It will usually be elevated in the disease condition and should fall back to the normal range (38-39.5 C) after antibiotic treatment. Continue treating the animal at least 48 hours after the temperature has dropped. If the temperature does not drop after 24 hours, then another antibiotic should be tried or the diagnosis re-elevated.

The following section on antibiotics contains excerpts from the Stockman's Veterinary Guide, Lee Newman D.V.M.

Sometimes animals are allergic to certain medications or vaccines. This is called **anaphylactic shock** and usually occurs almost immediately following injection of the drug. The symptoms observed are nervousness followed by severe depression, glassy or puffy eyes, increased slobbering, and grinding of the teeth. Rapid shallow breathing, muscle tremors, sweating, and staggering can also be observed. Convulsions and death can occur very quickly without treatment. Treatment consists of injections of epinephrine, corticosteroids (azuim, or dexamethazone) and antihistimines. These drugs should be available and need to be administered as soon as allergic symptoms are observed.

Section 5

Diseases

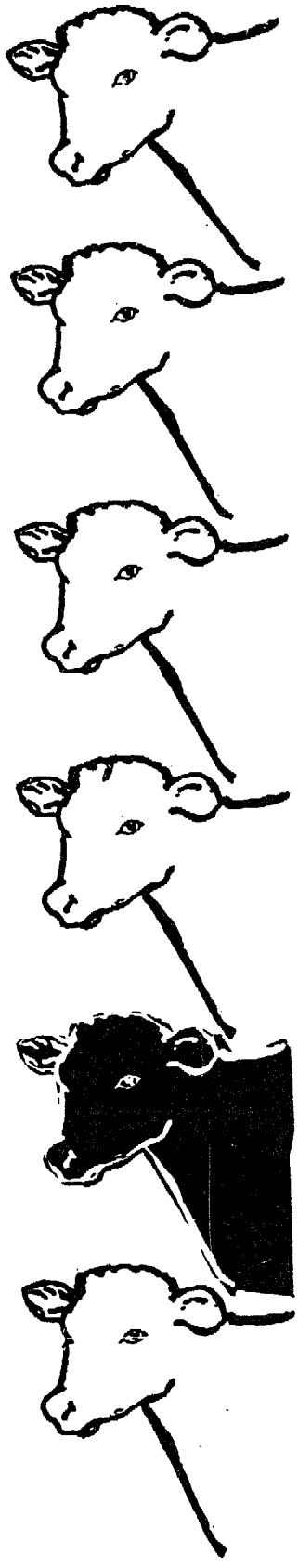

Diseases

Disease may be defined as any change from the normal function of the body. The causes of disease are bacteria, viruses, protozoa, parasites, fungi, poisons, trauma and nutritional deficiencies.

Bacteria, viruses, and parasites are living organisms which live inside or outside of the affected animal. There are numerous infectious agents that can be spread from animal to animal. They are spread by (1) biting insects, (2) direct contact between well animals and sick animals, and (3) indirect contact through blood, secretions, and excretions of diseased animals. Non-infectious diseases would include trauma, deficiencies and poisons which do not not spread from animal to animal.

Bacteria

Bacteria are single-celled organisms which are individual discrete forms of life. Given ideal conditions of warmth, nutrients, and mositure, most of them can also multiply outside of the animals' body. Under adverse conditions some bacteria can turn themselves into a very resistant spore which can survive for many years. The classic example is anthrax whose spores exist in the soil for up to 40 years. Other examples of bacterial infections include mastitis, blackleg, tetanus, navel ill and calf diptheria.

Viruses

Viruses are smaller than bacteria and can be seen only with special microscopes. Unlike bacteria, they cannot multiply outside of the animal's living cells. Once inside the animal, viruses penetrate the animal's cells and use these metabolic processes for their own purposes. Viruses are usually quite selective in the sites they choose to infect. Examples of disease viruses cause are rinderpest, African swine fever, and foot and mouth disease.

Protozoa

Protozoa belong to the animal kingdom and are larger than bacteria. One difference between protozoa and bacteria is that in some diseases the protozoan organisms undergo part of their reproductive cycle in an intermediate host such as a tick or fly. Examples of protozoan disease caused in this way are East Coast Fever and Redwater Tick Fever. Examples of protozoan diseases with no intermediate host are cocciciosis and trypanosomiasis.

Rickettsia

Rickettsia are bacteria that multiply only in living cells. Examples of these are anaplamosis and heartwater which are transmitted by ticks.

Parasites

Parasites are organisms that live on or in a host animal but contribute nothing in return and derive nutrients from the animal. Ectoparasites, living on the outside of animals, include ticks, mites, fleas, and lice. Endoparasites, living inside the animal, are flukes, flatworms, and roundworms.

Fungi

Fungi are members of the vegetable kingdom. Ringworm is an example of a disease caused by a fungus.

Bacteria and viruses invade the body in various ways, mainly through digestive, respiratory, genitourinary tracts, and skin. The ability of the infective agent to cause disease depends upon the virulence of the host.

Factors Affecting Whether An Animal Becomes Ill

Not all animals that are exposed to a disease agent will become ill. Many factors are involved in the disease process including:

a) **pathogenicity of infectious agent-** this refers to the ability of the organism to invade the host's body. Some agents are highly infectious; whereas others need special conditions to cause illness.

b) **age of the animal-** very young and very old animals are more susceptible to disease.

c) **nutritional status-** animals which are in poor physical condition due to inadequate nutrition are much more likely to get sick. Also, some nutritional deficiencies are directly responsible for disease.

d) **parasites-** animals heavily infected with internal or external parasites are much more susceptible to infection.

e) **weather conditions-** extreme weather conditions have considerable influence over disease processes.

f) **stress-** conditions such as shipping fatigue, excessive labor, etc. can predispose animals to disease.

g) **immune status-** whether an animal has been previously exposed to an illness or has been vaccinated or received immunity from its mother affects the susceptibility to an illness.

h)**other factors-** sex, breed, sanitation, and management.

Diagnosis of Disease

Certain thoughts should be kept in mind in determining first if an animal is sick and then the reason for the sickness. First, it is important to get a history of the illness and the animals involved from the owner. Some questions that need to be asked are: the number of animals involved, contacts with adjacent animals, addition of new animals to a herd, changes in weather conditions, treatment methods applied, etc. Usually the more questions asked, the easier it is to arrive at a diagnosis. The second thing is the surroundings in which the affected animals live. For example, lice and flukes favor marshy areas; leptospires flourish in damp soil; and dirty surroundings favor disease-carrying insects and parasites. Often the cause of various poisonings or nutritional diseases can be detected by examination of the surrounding area.

The final determination of a disease is done by inspection of the sick animal. First, look at the animal from a distance noting the posture, alertness, and the general attitude of the animal. An animal standing with its legs tucked underneath, with its head down, and ears drooping, is obviously depressed. If the animal is laying down, this may indicate a more serious illness. In observing from a distance one should note whether the breathing is labored, presence of a cough, if there is any lameness, or signs of diarrhea or straining, and if the animal is gaunt or full. An animal

not eating or drinking normally is usually sick.

Upon closer examination of the animal, the rectal temperature should be checked. This is accomplished by gently inserting a thermometer into the rectum and holding it there for two minutes. Be sure to shake the thermometer down to 94 °F before using. **The normal temperature of cattle or buffalo varies from 101 °F to 102.5 °F or 38 °C to 39.5 °C.** This may increase by up to 1 °F for younger animals, or those animals under stress from excessive heat. An increase in body temperature usually indicates an inflammatory process is taking place and antibiotics are indicated. **The normal respiration rate (breathes per minute) for adult cattle is 15-20 respirations per minute.** The pulse can be checked with a stethoscope or under the jaw on the facial artery and should be 40-60 beats per minute for adults. Pulse and respiratory rates increase with exercise, excitement, hot weather, and illness. Younger animals will normally have increased respirations and pulse compared to older animals. The haircoat should be examined as well as checking for nasal and eye discharge, the presence of ticks, and/or lice, and also the condition of the teeth and gums. The gums can give an idea of the blood circulation in the animal. Normally, they should be bright pink:, whereas, paleness would indicate poor circulation, shock, or heavy parasite infection. One should also check for any swellings around the eyes, naval, neck, etc. By thrusting a closed fist into the left upper flank region, you can count the number of times that the rumen contracts. This should be 2-3 times per minute in a healthy cow. Rumen movement less than 2-3 minutes suggests a more serious illness. Also, the muzzle or nose should be clean and wet as opposed to a dirty nose with discharge.

After examination of the animal one needs to make a diagnosis based upon the history and the signs of the illness. Specific diseases will be covered later in the section with treatment suggestions. If possible, it is sometimes helpful to submit samples to a laboratory for analysis. Blood samples, tissue samples, and feed samples can be collected by a qualified personnel. It is also worthy to remember that certain diseases such as rabies or anthrax can be transmitted to man. Thus, until a definite diagnosis is made precautions should be taken to protect one's safety.

Prevention of Diseases

When an infectious disease invades an animal's body, the animal will be susceptible to it and the disease process occurs or the animals will be able to reject the disease. As we have mentioned previously, the animal's ability to resist disease is dependent on a number of factors. One of the most important of these factors is within the animal itself—the immune system. This complex system allows the animal to fight off certain infections before they can be harmful.

The immune system is made up of antibodies which circulate throughout the body via the bloodstream. These antibodies seek out and destroy invading organisms. They are produced as a result of previous exposure to the disease or by a vaccine. Vaccines contain disease organisms which have been modified so they give only a mild attack of the disease which makes the animal resistant to the disease.

Vaccination is the processs of introducing an infection in animal

by using an altered form of a disease agent. Types of vaccines include:

toxoids—prepared from toxins (poisonous substances secreted by bacteria)

bacterins—bacteria that have been inactivated but will usually give disease protection for up to twelve months. (An example is blackleg bacterin.)

live bacterial suspensions- produce a longer lasting immunity than bacterins but are also more dangerous to use. (An example is brucellosis strain 19.)

modified live virus- vaccines are live virus that have been modified to not cause disease in the host animal. These vaccines produce an effective and longer lasting protection.

antiserum- agents which contain ready-made antibodies. These are used sometimes in the treatment of certain viral and bacterial diseases. The duration of protection is quite short.

Vaccines are not available for all diseases. Where they are available for diseases specific to certain areas, they afford a very economical protection. It is considerably more effective and less expensive to **prevent** a disease rather than treat it. Vaccines should always be **refrigerated** and **protected from the light.** Specific vaccinations will depend on diseases in your area.

Other management factors important in the prevention of disease include cleanliness of the environment the animal lives in and the nutritional state of the animal. **A healthy well fed animal can resist diseases much better than one that is weak, due to improper nutrition.** Also, **the presence of parasites makes the animal much more susceptible to disease or infection.**

Diseases

The following section contains a brief summary of various diseases that can affect cattle. It is not possible in a manual such as this to describe in detail every illness that affects cattle. This section is divided into viral diseases, bacterial diseases, protozoal and rickettsial diseases, tick-borne diseases, parasitic diseases, and miscellaneous diseases.

Diagnosis and treatment should be carried out by trained personnel when available. Post-mortem exam (examination of dead animal to determine the cause of death) and collection of laboratory samples would be best done by qualified people. Some definitions of common terms are:

acute—having a sudden onset

chronic—having a long duration

incubation period—refers to length of time from exposure to a disease until the signs of the disease become apparent.

Viral Diseases

Foot and Mouth Disease—

(Afta Epizootica, Afthosa Fievre', Aphteuse)

Nature and Occurrence

Foot and mouth disease (F.M.D.) is a highly contagious disease of predominantly cattle and other cloven-footed animals. It can affect cat-

tle, buffalo, pigs, sheep, goats, and many wild species. Cape buffalo have been shown to act as carrier animals. This disease occurs in almost all of the tropics and especially in South America, Africa, and Asia. It is not present in North America, Australia, or New Zealand.

Although F.M.D. does not cause a high death loss, the reduced production of affected animals and also rapid spread of the infection make it a very serious disease.

The disease is spread chiefly by the contents of the blisters (on the nose, tongue, mouth, udder, and feet) bursting. It is also spread by the milk, urine and nasal discharge, conveying the infection directly from a sick animal to those that are healthy. The infection can also be spread by birds and meat products. It is more prevalent in cooler seasons of the year.

Symptoms

The incubation period (time from exposure to observation of sickness) is usually 3-8 days. The symptoms in older animals and in lean animals are not as severe as in younger animals or better conditioned animals. Also, the symptoms are not as severe in African or Creole cattle as in temperate-zone breeds. Symptoms include: high temperature, loss of appetite, formation of vesicles (small blister-like swellings) on the tongue, dental pad between the claws and around the hooves. The vesicles soon rupture, becoming ulcers in the mouth, resulting in drooling and difficulty in chewing. The animals will become lame and the hooves will fall off sometimes. Vesicles will also form in the udder and teats and milk production will diminish. In younger animals the heart muscle cells are destroyed and take on a yellowish look (tiger heart). These animals either-die or are poor doers. Most animals recover spontaneously in 7-14 days.

Diagnosis, Treatment and Control

Rapid accurate diagnosis of F.M.D. is essential. Vesicular Stomatites resembles F.M.D. and requires laboratory analysis to differentiate the two. If F.M.D. symptoms occur the proper governmental authorities should be contacted immediately.

Treatment with disinfectants and protective dressings will sometimes shorten the life of the disease.

Control is by slaughter or mass vaccination depending on governmental policy. If vaccination is attempted, the vaccine should be prepared from the same sub-type of virus that is causing the outbreak. Vaccination is usually repeated every six months.

Vesicular Stomatitis

(Sore Mouth, Stomatite Vesiculeuse Contagiuse)

Nature and Occurrence

Vesicular Stomatitis (V.S.) affects horses, cattle, and pigs. The symptoms and lesions are the same as F.M.D. It affects far fewer numbers of animals and there is virtually no death loss as compared to F.M.D. It is present in virtually all countries.

Symptoms

The incubation period is generally three days followed by fever and vesicle formation in the inner cheeks and tongue. Foot and teat lesions

are rare and recovery takes place in 3-4 days.

Diagnosis, Treatment and Control

As mentioned previously, it is impossible to tell V.S. from F.M.D. and thus, governmental authorities should be notified if suspicious symptoms occur. Treatment is not usually attempted as recovery is rapid and complete. Standard hygience procedures are recommended as well as isolation of sick animals for control. A vaccine is available but not extensively used.

Malignant Catarrhal Fever

(Malignant Head Catarrh, Snotsiekte)

Malignant Catarrhal Fever (M.C.F.) is a fatal infection of buffalo, cattle, and deer. Sheep, goats, and wild ruminants like the wild beasts do not show symptoms but are thought to spread the disease particularly at the time of parturition (birth). The disease is cause by a herpes virus and occurs sporadically world-wide. Its prevalence is particulaly high in East, Central, and South Africa.

Symptoms

The incubation period ranges from 1-4 months. Symptoms can vary but many include discharge from the nose and eyes, inflammation of the mouth, high temperatures, loss of condition, emaciation, difficulty in breathing, opacity, (cloudiness of the eyes) sometimes with blindness, and peeling and thickening of the skin. Depression is severe, and the lymph nodes on the outside of the body are clearly swollen. Diarrhea may occur. Nervous signs, particularly lack of coordination, may be severe. Most affected animals will die 4-12 days after the onset of the disease.

Diagnosis, Treatment and Control

Diagnosis is based on symptoms and post-mortem lesions which include inflammation and ulceration of the esophagus and stomach and swelling of the kidney, liver, and lymph nodes. There is no treatment and control measures include keeping cattle and buffalo separate from wild game, sheep, and goats. Acutely ill cattle do not spread the disease to healthy animals.

Rinderpest (Cattle Plague, Peste Bovina)

Nature and Occurrence

Rinderpest (R.P.) is a highly infectious and usually fatal disease of ruminants and pigs. In the past, this disease has been the world's most destructive disease of cattle. R. P. is presently confined to East and West Africa, the near East, and Asia. The virus is transmitted in oral and nasal secretions, feces, and expired air.

Symptoms

The incubation period is 3-15 days and the characteristic signs occur in the mucous membranes. First there is a high fever followed by depression and the animal going off feed. The membranes of the mouth and eyes are intensely inflammed. Hemorrhagic patches and ulcers are seen on the mucous membrances with the presence of ropy, foul-smelling salvia. There is a purulent discharge from the nostrils with coughing and rapid breathing. Diarrhea begins 1-2 days after the appearance of mucous lesions. The death loss approaches 100%.

Diagnosis, Treatment, and Control

R.P. may be confused with M.C.F. however, M.C.F. does not usually display the intestinal lesions and diarrhea. B.V.D. can also be confused with R.P. Laboratory diagnosis of lymph tissue may be used for confirmation.

Treatment is ineffective. For control there is a vaccine available which gives life-long immunity. In areas where R.P. is a problem, all susceptible animals should be vaccinated upon reaching 6 months of age. In areas where wild game are present, it is difficult to eliminate the disease.

Bovine Virus Diarrhea (Mucosal Disease)

Nature and Occurrence

Bovine Virus Diarrhea (B.V.D.) is a disease of domestic and wild ruminants. The occurrence is world-wide with younger animals affected more than older animals. The infection rate can be very high, but the death rate is low.

Symptoms

The symptoms of B.V.D. resemble very closely that of R.P., F.M.D., and M.C.F. There is a high body temperature very early which decreases to normal or subnormal later in the disease process.

The incubation period lasts 1-3 weeks with fever ulcers of the mouth, and diarrhea. Pregnant animals abort 3-6 months after infection, or they can give birth to calves which exhibit neurologic abnormalities.

Diagnosis, Treatment, and Control

Laboratory diagnosis may be needed to distinguish B.V.D. from the other viral mucosal diseases. There are erosions and ulcers along the entire digestive tract.

Treatment is usually unsuccessful.

Control can be achieved by vaccination and keeping a closed herd.

Cow Pox (Variola)

Nature and Occurrence

Cow Pox is a mild viral disease affecting cattle which can be transmitted to man. This virus attacks the cells of the skin and is usually spread during milking of dairy cattle.

Signs

Cow Pox affects hairless areas of the body usually the teats and the sides of the udder. Infection begins as a blister with yellowish fluid which break and fill with pus. Scabs eventually will form leaving a characteristic "pock" mark. The lesions in the teats prevent calves from nursing, and milking is difficult. The incubation period is 3-5 days with the lesions disappering after about two weeks.

Diagnosis, Treatment and Prevention

Characteristic signs in hairless areas are helpful in diagnosis. It should be remembered that this disease can be transmitted to humans.

Treatment involves keeping the lesion clean while applying a sulphonamide or antibiotic ointment.

There is a vaccination available but is seldom used due to the mild nature of the disease. Disinfection of equipment and hands during milking is the best method of control.

Warts (Papillomaas or Fibromas)

Warts appear as fleshy lumps and are caused by viruses. They appear more predominantly in 6 month to 2-year-old cattle. Most cases will recover spontaneously without treatment. In certain wart locations (ex. teat or penis) the warts can be removed surgically. There are vaccines available to prevent and treat warts or an autogenous vaccine can be prepared. An autogenous vaccine is made by preparing a vaccine from the acutal warts removed from the animal and injecting this solution. If these warts are quite numerous or large, they may develop a bacterial infection.

Fig. #34—Warts on the head and neck. These normally disappear spontaneously, but vaccines can be used. (Veterinary Book for Farmers—R. W. Blowey 1985)

IBR Syndrome (Infectious Bovine Rhinotracheitis—I.B.R.)

(Infectious Pustular Vulvovaginitis— I.P.V.)

Nature and Occurrence

I.B.R. and I.P.V. show different clinical signs of the same infection in ruminants. The cause is a herpes virus and the occurrence is worldwide. The IBR syndrome is characterized by fever and inflammation of the nasal passages and trachea. The IPV syndrome is characterized by fever and vulvovaginitis. Recovered animals from both syndromes often remain carriers. IBR spreads by close contact with sick animals via airborne transmissions. IPV spreads venereally.

Signs

The incubation period of IBR is usually less than one week. The clinical signs are a sudden high fever, loss of appetitie, runny eyes, and nasal discharge. Abortion is very common among pregnant animals. Unless there is a secondary bacterial infection, most animals recover com-

pletely within two weeks.

The IPV syndrome is manifested by low grade fever, congestion of the lining of the urogenital tract, swelling and discharge from the vulva, and the formulation of pustules in the vagina. The vaginal irritation is intense. As with IBR, complete remission of signs occurs within two weeks. Bulls can develop an infection of the outer lining of the penis.

Diagnosis, Treatment and Prevention

Diagnosis is based upon clinical signs, large nuumber of animals affected, and recovery from infection. Diseases which might be mistaken for IBR are FMD, RinderPest, MD and MCF.

A live virus vaccine is available and effective for prevention of the disease. **It should not, however, be given to pregnant animals.** It will cause the cow to abort. Treatment is used for prevention of secondary infection.

Rabies (Hydrophobia, Lyssa, Rage)

Nature and Occurrence

Rabies is a fatal disease which affects the nervous system of all animals and man. It is transmitted by infected saliva of affected carnivores (dogs, cats, rats, skunks, foxes, hyenas, mongoose, bats, etc.) Cattle are commonly infected and the distribution is world-wide except for the British Isles, Australia, and New Zealand. Rabies is most common in Third World Countries. According to the U. S. Communicable Disease Center, in 1983 there were more cases of rabies reported in cattle than dogs and cats.

Signs

The incubation period is from 3-8 weeks up to 6 months. In dogs and hyenas the first symptoms are marked changes in behavior. The animal may become nervous and aggressive and saliva drools from the mouth. The mode of transmission is usually a bite from an infected animal or contact with the saliva of such an animal.

Cattle will become restless and excited, their voice will change, and there may be considerable bellowing. Later there is a grinding of the teeth and drooling of saliva. Finally there is a weakness in the hindquarters and paralysis.

Diagnosis, Treatment, and Prevention

Diagnosis is very important due to possibility of infection in man. If rabies is suspected in an animal the proper health authorities should be notified for a definitive diagnosis. There is no treatment for rabies once the symptoms have begun and it is close to 100% fatal. There are adequate vaccines for all animals and man. In cattle vaccines are usually used only in the face of outbreak.

BACTERIAL DISEASES

Anthrax (Fievre Charbonneuse, Carbunco Bacteridiano)

Nature and Occurrence

Anthrax is an acute infectious disease of all warm-blooded animals and man. Its occurrence is world-wide and seems more predominant in tropical countries. Cases are seen more commonly during moist rather than dry periods of the year.

The infection is caused by a large bacillus which is transmitted by eating contaminated animal products or drinking of contaminated water. The organism can also enter the body through inhalation or through a wound. Anthrax forms highly resistant spores which are believed to remain infective for 10-20 years in the soil. These spores are also highly resistant to standard disinfectants.

Symptoms

After an incubation period of 1-10 days, most animals are usually found dead without any signs of previous illness. Death occurs very rapidly after the first symptoms occur. These are high fever, muscle tremors, labored breathing, staggering, and convulsions. Frequently, there are bloody discharges from the nose and anus.

Diagnosis, Treatment and Prevention

If an animal dies suddenly with no previous symptoms of illness, anthrax should be suspected and no post-mortem examination should be attempted. For diagnosis, a blood smear should be obtained from the ear or tail. (See figure #35) A vaccine is available for use in endemic area. Only high quality vaccines should be used as inferior vaccines can actually cause the disease. Extreme caution should be taken to not eat meat from suspected anthrax animals as this can result in human deaths. This should be strained with Giemsa-Wright, or Leishman stains and examined in a laboratory for large encapsulated bacteria or spores.

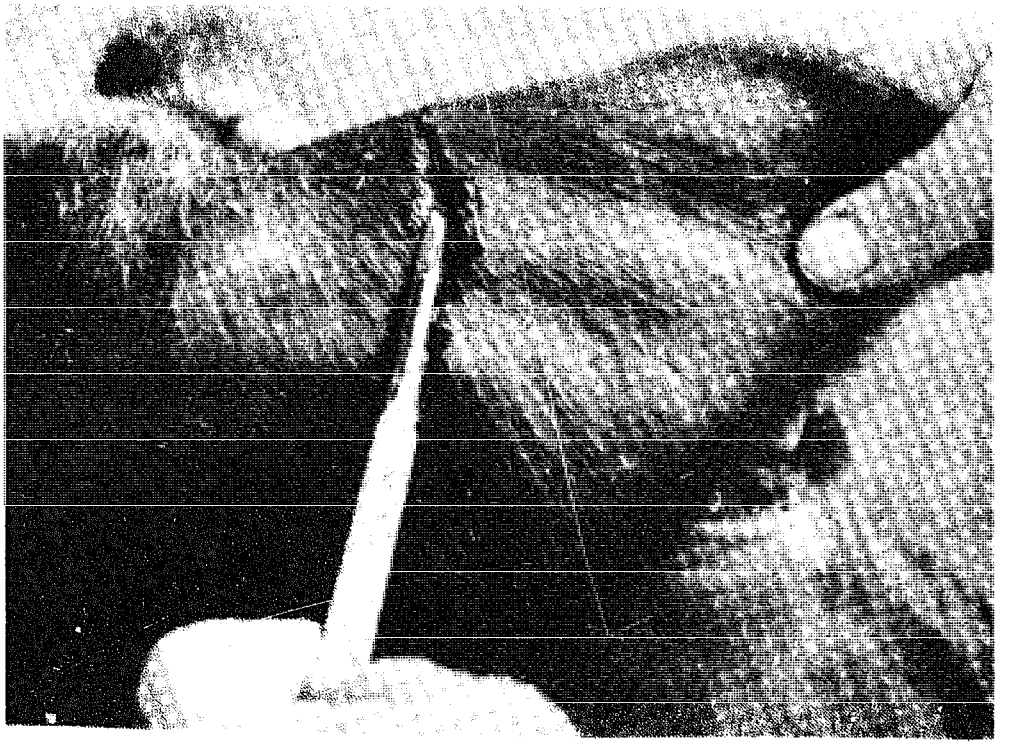

Fig. #35 Collection of a blood smear from a dead animal. (Veterinary Book for Farmers—Blowey, 1985).

Post-Mortem

Bloating and decomposition occur rapidly. Should the carcass be opened by mistake, the spleen would be enlarged and filled with tarry pulp. The blood would be dark and unclotted. Often snake bite, lightning

strike, or bloat are confused with anthrax.

Treatment of exposed animals is sometimes attempted using penicillin. Carcasses should be either burned or buried and the exposed area treated with quick lime. Anything coming in contact with the dead animal should be burned. The premises should be fenced off and all animals and man kept out.

Clostridial Diseases

Nature and Occurrence

Clostridial diseases are caused by a group of organisms called **Clostridium.** These organisms produce very potent poisons (exotoxins) which are damaging to cattle. Most clostidial species form **spores** which during unfavorable environments can survive in the soil for long periods of time.

It appears that clostridial organisms are present in about every region of the world. Usually clostridial infections are very severe and occur suddenly resulting in rapid death. Treatment is usually unsuccessful, but good vaccines are available for prevention of the disease.

Blackleg (Black Quarter, Quarter Ill, Charbon Symptomatique, Felon, Carbunco Symtomatico)

Cause: Clostridium Chauvoeli

Blackleg is most common in younger animals 6 months to 2 years old. It probably invades the body through a break in the skin or mucous membrane. It is characterized by a severe inflammation and death of muscle tissue in the heavily muscled parts of the body as a result of toxin formation.

Many times animals are just found dead with no signs of sickness. If symptoms are observed they include lameness, swelling on the upper leg which crackles on touch due to gas under the skin, severe depression, high temperature, and death. There may also be bloody discharges from the nose and anus before and after death.

Treatment is usually unsuccessful; however, large doses of penicillin may be helpful in early cases. Because this disease closely resembles anthrax, a post-mortem should not be attempted, but qualified personnel contacted for diagnosis. A blood smear from the affected muscle tissue will tell this disease from anthrax.

Prevention should be the main objective in outbreaks of the disease. A very effective vaccine is available and can be given as early as 2 weeks of age with annual booster injections.

Malignant Edema (Gangrenous Septicemia)

Cause: Clostridium Septicum

Malignant edema is closely related to blackleg but usually occurs following a wound. There is swelling around the wound, high fever and depression, followed by death. There is a jelly-like hemorrhagic fluid in the swellings.

Diagnosis and treatment are the same as in blackleg. Vaccination is the best method of prevention as well as proper treatment of wounds.

Cleanliness and disinfection during castration and obstetrical procedures is also beneficial for prevention of the disease.

Acute Cervical Hemorrhagic Edema
Cause: Clostridium Sordelli

This condition is similar to malignant edema except it is not associated with a wound infection. The animals show an elevated temperature, depression, incoordination, and death with 6-24 hours. Post-mortem lesions involve swelling and dark hemorrhage in the neck region. Treatment is usually unsuccessful with penicillin, the drug of choice. A vaccine is available for prevention.

Tetanus (Lockjaw, Tetanos)
Cause: Clostridium Tetani

Tetanus is a fatal toxicosis of all domestic animals and man. The organisms frequently enter the body through wounds, such as castration infections and deep puncture wounds. The course of the disease is usually 3-10 days.

The first signs of the disease are muscular stiffness and spasms. The tail and ear muscles are erect while the muscles of the jaw hold it tightly closed (lockjaw).

Consequently, the animal cannot eat or drink. These animals are very sensitive to sound, light and movement. They may assume a saw-horse stance.

If started early, treatment is sometimes successful. This includes injection of tetanus antitoxin (if available), thorough cleaning and disinfection of the wound, and large doses of antibiotics (penicillin). Prevention involves cleanliness when doing any surgical procedures such as castration and proper care of wounds. There is also an effective vaccine available. Any person working with animals should also have a current tetanus vaccination.

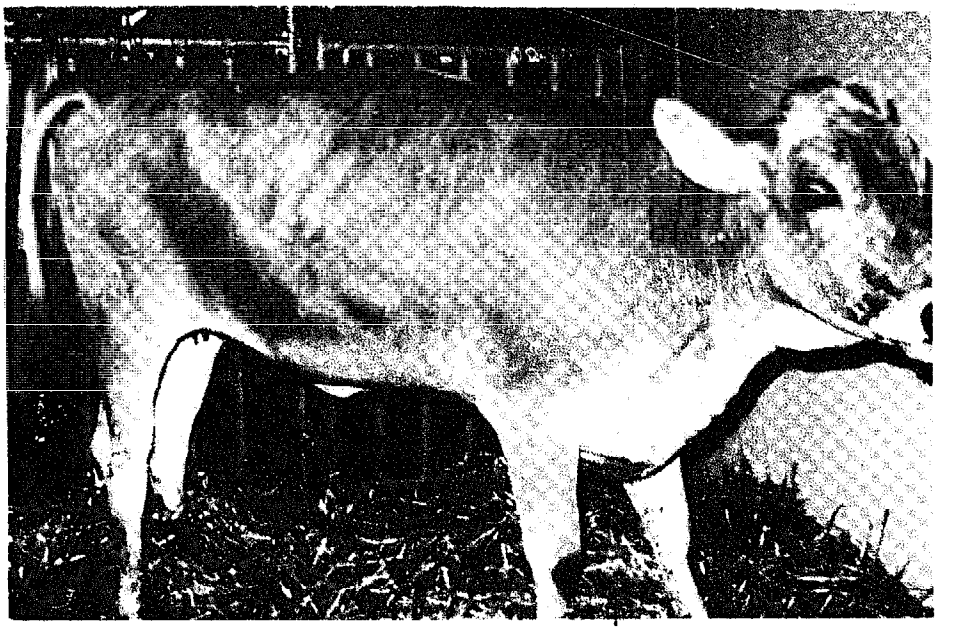

Fig. #36 Cow with tetanus. Animal exhibits "pump handle" tail and straight-legged posture. (Veterinary Book for Farmers—Blowey, 1985).

Botulism (Lamziekte Disease)
Cause: Clostridium Botulinum

Botulism is a fatal paralytic disease caused by eating contaminated feed or water containing the organism. This organism proliferates in decaying animal and vegetable material. Where animals are mineral deficient and are apt to chew bones with decaying flesh on them, the disease is common.

Signs of the disease are staggery gait, difficult swallowing, drooling of the mouth, eyes that stare, paralysis of the tongue, lips, throat, and legs, and general weakness. The animal goes down with labored respiration and dies in 1-4 days.

Treatment is ineffective and prevention consists of proper disposal of all carcasses, provisions of fresh water, and correcting any mineral deficiency. Vacicnation is available for problem areas.

Enterotoxemia (Overeating Disease)
Cause: Clostridium Perfrigens Type D

This disease often takes on two forms:

1) affecting nursing calves
2) affecting cattle on full feed or concentrate

In nursing calves the symptoms include bloating, severe abdominal pain, diarrhea, depression, fever, and death within a few hours. Often the calves are found dead with bloat. This disease usually occurs after a storm where calves can't nurse for some time and then take on a large amount of milk.

Treatment involves Cl. Perfrigens antiserum, antistamine, and antibiotics. A vaccine is available.

Signs for cattle on a high concentrated ration are sudden death within 1-2 hours following consumption of a large volume of feed. Prevention involves vaccination, lowering the concentrate level of the feed, regular feeding times, and feeding low-level antibiotics.

Black Disease (Infectious Necrotic Hepatitis)
Cause: Clostridium Novyi Type B

Black disease has a high death rate and causes a severe liver infection. Signs include high fever, depression and death within a short amount of time. Post-mortem inspection reveals large amounts of parasitic fluke infections.

Treatment is usually unsuccessful, but antibiotics can be used in high doses and a vaccine in available.

Bacillary Hemoglobinuria
Cause: Clostridium Hemolyticum

Bacillary hemoglobinuria has a high death rate and similar signs as Black disease. Other symptoms involved would be reddish urine (red water) and jaundice (yellowing of the mucous membranes). Treatment and control are the same as Black disease.

Hemorrhagic Septicemia

(Pasteurellosis, Shipping-Fever, Cattle Fever)

Hemorrhagic Septicemia (H.S.) is caused by a Pasteurella species

which is present in the nasal passages of healthy animals. Oftentimes, the presence of stress (weather change, parasites, nutritional and mineral deficiency, dust transportation, etc.) along with a virus (IBR and/or Pi3) weaken this animal and it is susceptible to Pasteurella infection.

The disease is of world-wide distribution occurring sporadically in some countries. It affects cattle, buffalo, sheep, goats, reindeer, and wild ruminants. Buffalo appear highly susceptible to the disease. In tropical regions it is seen frequently during the rainy season. Younger animals are more susceptible than older animals.

Symptoms

In some cases no symptoms are seen but the animal dies suddenly. Symptoms most often observed would include depression, high fever, off feed, diarrhea (sometimes bloody), and swelling of the throat, head, brisket, legs, or tailhead. There is labored respiration with runny eyes, nose, and persistent cough. The course of the disease can be acute or chronic.

Diagnosis, Treatment and Prevention

Post-mortem lesions would include a severe broncho-pneumonia, hemorrhages under the skin, on the intestines, and in the heart. There is often a sticky yellow fluid in the body cavities and the swollen tissues. Diseases which may be confused with pasturellosis include contagious bovine pleuro-pneumonia, MCF, and IBR.

If caught in the early stages, treatment is often effective. Antibiotics recommended would include a combination of tetracyclines and sulphonamides. If an animal is suspected of coming down with the disease its temperature should be checked for diagnosis. Early recognition and treatment of the infection is most important.

Vaccination is available for prevention as well as elimination of conditions which cause stress on the animal such as excessive work, overcrowding and poor environmental and feeding conditions.

Contagious Bovine Pleuropneumonia (Peri-Pneumonia)

Nature and Occurrence

Contagious Bovine Pleuropneumonia (CBPP) is caused by a small bacterial Mycoplasma Mycoides. It is highly infectious and causes a severe infection of the lungs.

This disease is widespread in certain tropical regions of Africa, Australia, Asia, and Latin America. CBPP affects cattle and buffalo. It is spread by material coughed up by an infected animal. Recovered animals remain chronic shedders of the infection. The incubation period is 1-4 weeks.

Symptoms

Symptoms characteristic of CBPP are characteristic of pneumonia and pleurisy. These include fever, coughing (dry and painful), and labored breathing. There is depression, loss of appetite, and swelling in the throat region. As the disease progresses, the haircoat becomes dull, constipation alternates with diarrhea, and finally the animal goes down. The affected animal appears to be in considerable pain and they stand with their elbows out. The course of the disease may be from 1-7 weeks.

Post-mortem lesions include a marbled appearance of the lungs possibly affecting only one side. There is also an inflammation of the membrane covering the lungs and thoracic cavity.

Diagnosis, Treatment and Prevention

Diagnosis is accomplished by typical signs, port-mortem lesions, and laboratory analysis of lung tissue or serum.

The drug of choice for treatment is tylosin (tylan), but treatment should not be initiated without governmental supervision.

Control is based upon four methods: slaughter, blood testing, quarantine, and vaccination.

A veterinarian should be informed if CBPP is suspected.

Diphtheria (Bacillary Necrosis)

Nature and Occurrence

Diphtheria is an acute (fast-acting) high infectious disease which primarily affects young calves. It is caused by the bacteria. Fusiformis Necrophorus. The disease can spread rapidly especially in housed animals. The disease occurs world-wide and can affect calves as early as three days old.

Symptoms

The calf will refuse and there is coughing, salivation, high temperature, and the development of rough, greenish-yellowish deposits on the mucous membranes of gums, cheeks, palate, and tongue. These deposits are firmly attached to the underlying tissue and have a foul-smelling odor. There is a swelling of the face with affected calves drooling and frothing at the mouth. When examined, these calves may have a mass of partially chewed feed at the front of the tongue with an ulcer underneath.

The calves will often **breathe extemely noisily** with a snoring sound but they are not particularly depressed. If left untreated the disease can progress into pneumonia.

Diagnosis, Treatment and Prevention

The classical symptoms along with examination of the mouth should lead to an accurate diagnosis. Pnuemonia is most often confused with diphtheria. In pneumonia the calf will be very sick with rapid but quiet respiration.

Treatment with antibiotics in combination with sulphonamides is usually quite effective if treatment is started early. Coarse feed or feed with thorns should be avoided. A preventative vaccine is not available.

Fig. #37 Calf with diphtheria—note the swelling of the cheeks on the left. (Veterinary Book for Farmers—Blowey 1985)

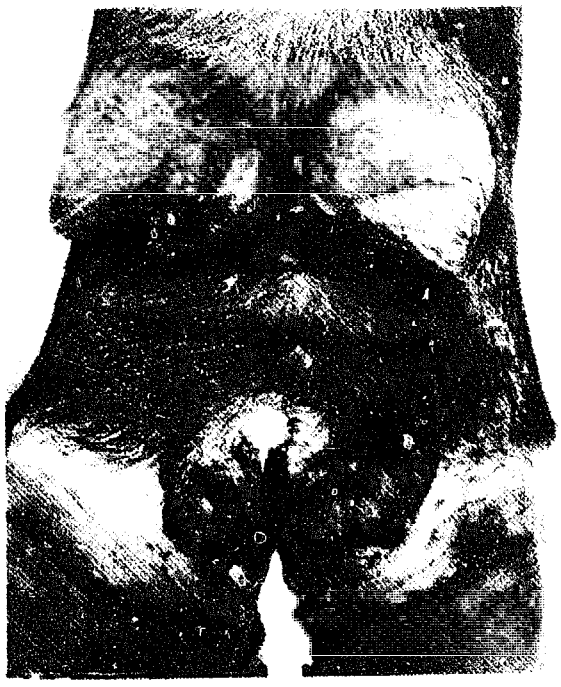

Fig. #38 Foot rot—the most common form of lameness in cattle. (C.S.U. Extension Bulletin—536)

Footrot(Foul in the Foot, Panartium, Pietin)

Nature and Occurrence

Footrot is an infection of the feet caused by a number of organisms but chiefly **Fusiformis Necrophorus.** This organism lives in the soil and gains entrance to the foot upon injury or wet conditions.

Symptoms

Affected animals will be lame on usually just one foot. The area just above the hoof becomes inflamed and swells. Swelling can also develop in the interdigital spaces (between claws). As the disease progresses, abscesses will break out just at the hoof line and drain. In later stages the tendons and joints can become infected at which point treatment is usually unsuccessful. The animals will tend to lay down and there is a rapid loss of condition.

Diagnosis, Treatment and Prevention

Diseases often confused with footrot would be sole abscesses, infections and inflammation of the upper joints of the leg, and foot and mouth disease. The characteristic swelling above and between the hooves should distinguish most other lameness. If started early, treatment is fairly successful with best results obtained by using a combination of tetracyclines (terramycin) and sulfonmides. In animals where there is a lot of diseased tissue, this should be trimmed away surgically and treated with an antibiotic ointment or copper sulfate and wrapped with a bandage. Animals may also be walked through a 2-5% solution of copper sulfate, 4% formaldehyde solution, or a mixture of powdered copper sulfate and slaked lime. Movement of animals to dry ground may sometimes help in the control of the disease.

Calf Diarrhea (An Overview)

Calf diarrhea is the number one cause of death losses in newborn calves. The specific causes of calf scours are **E. Coli, Salmonella Species, Corona, and Roto Viruses, B.V.D. Virus, cocidiosis,** and nutritional causes. Usually a stress such as adverse weather conditions, transportation, change in the feeding schedule, etc. will precipitate an outbreak of scours.

Thus a combination of stress and the presence of a virus or bacteria or both, cause the animal to have diarrhea. More fluid is lost in the feces than is replaced by the mouth and the animal becomes dehydrated. The blood becomes thicker and more difficult for the heart to pump and poor circulation develops. The extremities (tips of ears, feet, mouth, and nose) become cold and the body temperature drops. At this point the calf goes into shock and usually dies.

When diarrhea is first observed, treatment should be the first priori-

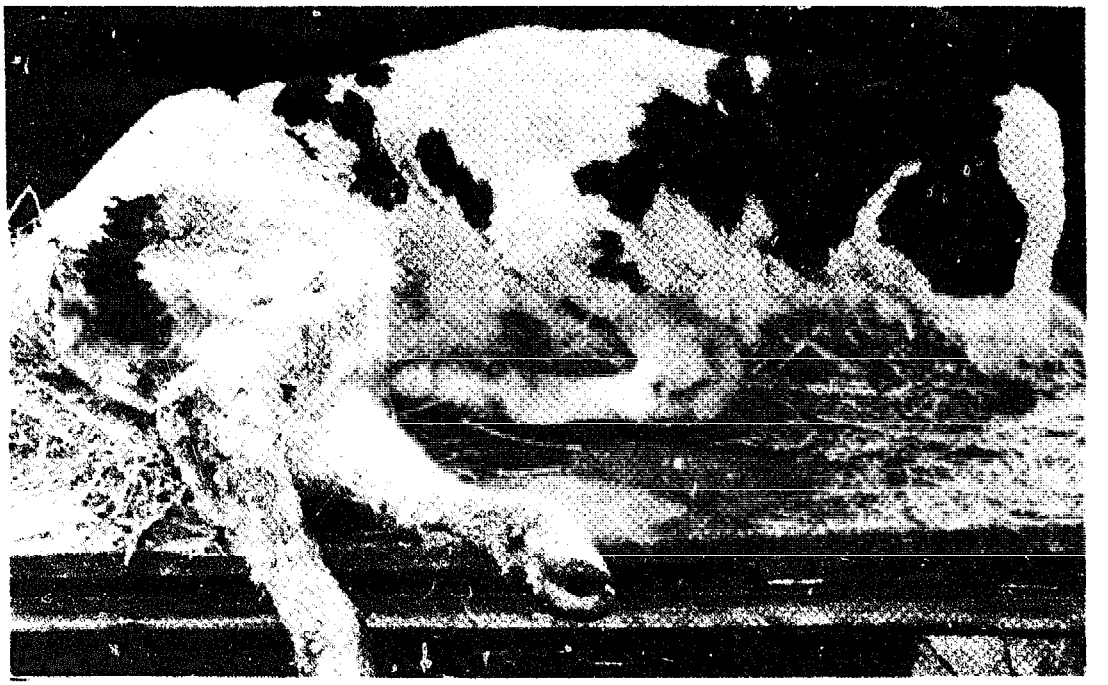

Fig. #39 Depression and weakness in a calf with severe diarrhea. (Cornell University)

priority followed by diagnosis of actual cause of the diarrhea and then prevention.

Treatment consists of four steps:

1. provide fluids (This is to counteract the massive loss of fluids in the feces.)
2. replenish salts and nutrients (Excessive water in the feces carries with salts and other nutrients that normally would be absorbed in the small intestine.
3. administer antibiotics
4. withholding milk (The intestine can no longer absorb milk.)

Several commercial preparations are available to be mixed with water and administered orally for fluid and nutrient dehydratio. If these products

are not available, one can mix up his own oral supplement as follows:

1¾ oz fruit pectin (sugar, honey, or corn syrup can be substituted if fruit pectin is unavailable)

1 tsp. salt

2 tsp. baking soda

1 can beef consomme (meat broth soup) add warm water to make 2 quarts

Two quarts should be fed orally 2-3 times daily. Provide fresh water at all times and continue with supplement for 24 hours after diarrhea ceases. If the calf is too weak to nurse the supplement from a bottle, it can be administered with a stomach tube or fluid feeder.

If the calf is in shock or unable to move, subcutaneous (under the skin) or intravenous fluid therapy with sterile solutions may be required.

In deciding on the choice of antibiotics to use, a culture and sensitivity to the fecal material or tissues is helpful, if lab facilities are available. If lab facilities are unavailable, the response to treatment is the next best alternative. Tetracyclines, sulfonamide, neomycin, and nitrofuozones are commonly used antibiotics for the treatment of scours.

Prevention of calf scours involves a number of procedure including:

1) Make sure the newborn calf receives colostrum within six hours after birth so it can have antibodies to fight infection.
2) Separate calves with diarrhea from other calves to minimize the spreading of infection.
3) Pay strict attention to cleanliness of the environment the calf lives in.
4) try to keep the calf dry and warm with clean bedding.
5) Vaccines are available to prevent scours in some cases such as viral scours and E. Coli.
6) Maintain the proper nutrition level with regular feeding schedules.

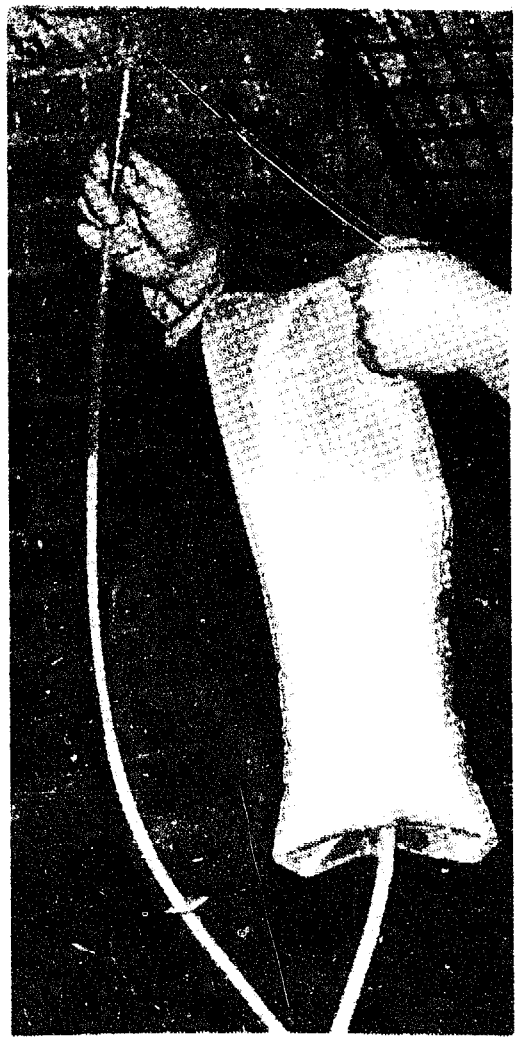

Fig. #40 Dispensing bag filled with colostrum. The stomach tube part is held in the operator's right hand.

The specific causes of scours will be covered in the next section.

Colibacillosis (Infectious Dysentery, White Scours)

Nature and Occurrence

Colibacillosis is an infectious disease of calves caused primarily **by E. Coli.** It enters the calf via the mouth or the navel cord. It usually occurs within the first week of life. Lack of colostrum and feeding milk in excessive quantities predisposes calves to colibacillosis.

Symptoms

The feces are very watery and white or yellow in color with a foul odor. The animal is depressed and rapidly becomes weak because of the diarrhea.

Diagnosis, Treatment and Prevention

If the disease is recognized early, the infection can be treated. If, however, dehydration and depression are severe treatment is unsuccessful. For treatment follow the 4-point plan outlined in the calf diarrhea section. Vaccination for prevention may be helpful given to the calf at birth or the mother before giving birth.

Calf Paratyphoid (Salmonellosis)

This infection of calves is caused by Salmonella bacteria. It usually affects calves between 5 and 12 weeks of age. This disease occurs world-wide.

Symptoms

Symptoms include yellowish, watery diarrhea along with depression. This is preceded by a fever of 103-106°F. Fresh blood may be present in the feces. Usually a large number of calves are affected and the mortality (death rate) is high.

Diagnosis, Treatment and Prevention

Diagnosis can be confirmed by culture of the liver and lymph nodes. The liver, on post-mortem exams, will be swollen and the kidneys will have a mottled appearance.

Treatment involves fluid therapy and antibiotics as outlined in the general section on scours. Chloramphenicol gives good results for treatment. Also, there is a vaccine available for prevention.

Salmonella bacteria can cause diarrhea in man and even death in young children. Careful attention should be made to washing hands and clothes after handling calves with diarrhea.

Roto and Corona Virus Infection

These viruses cause diarrhea in calves less than 2-3 weeks old. Often times **E. Coli.** is also involved and severe dehydration and death losses are involved. Diagnosis involves viral cultures of the feces. If viral infections are diagnosed, there is a modified live virus vaccine available for prevention.

White Diarrhea in Buffalo Calves

This disease is seen in young buffalo calves and cause a high death loss. It does not respond to antibiotic therapy. The cause of this disease is **Ascaris Vitulorum.** Piperazine is used for treatment and prevention given at 30 days of age with a follow-up treatment at 60 days of age.

Brucellosis (Contagious Abortion, Bang's Disease, Undulant Fever, Epizootic Abortion)

Nature and Occurrence

Brucellosis is an infection of cattle and buffaloes affecting the reproductive organs. The causal organism is **Brucella Abortus** which is shed in the placenta and can remain infective for up to 2 years. The organs affected are the uterus, fetus, fetal membranes, udder, and testicle.

The disease occurs world-wide and is spread by contamination from the afterbirth, fetal fluid, aborted fetuses, vaginal discharges, and milk.

Practically all animals including man are susceptible and the incubation period ranges from 14 days to 2 months. In man the disease is called Undulant Fever. Man is usually infected by drinking milk from affected animals or by handling infected afterbirth or discharges. The symptoms are acute fever, followed by relapses of fever, sweating, weakness, etc.

Some suggestions for prevention are:

1) Have all cows blood tested before mixing into a new herd.
2) All membranes and fetal material should be burned and clothes disinfected.
3) Milk should be boiled before drinking, and great care should be made to keep from contaminating small cuts on the hands and arms.
4) Use of plastic gloves when doing obstetrical procedures

If brucellosis is suspected, governmentql authorities should be notified for diagnois and prevention.

Vibriosis (Bovine Genital Campylabacteriosis)

Nature and Occurrence

Vibriosis is a general disease of cattle caused by Campylobacteria. It is a venereal disease in that it is spread at mating or by artifical insemination with contaminated semen. The disease occurs world-wide and is characterized by abortions and low fertility in the cows.

Symptoms

The main signs are reduced fertility and low calving rates. The abortion rate is generally low. The fetus generally dies early with cows coming into heat at 6-12 weeks after mating. The early fetus is usually either reabsorbed by the cow or aborted unnoticed. The disease may clear up in infected females but will affect younger animals not previously exposed. The infected bull will spread the disease but shows no symptoms.

Diagnosis, Treatment and Prevention

Vibriosis can be suspected based upon history but can only be confirmed by laboratory tests. These tests are sometimes difficult under field conditions and also inconclusive. Differential diagnosis includes brucellosis, trichomoniasis, and leptospirosis.

Treatment of cows is not advised, but bulls can be treated with antibiotic sheath washings. Vaccination is available for prevention, and also artificial insemination with uninfected bulls can be used to prevent the disease from spreading.

Advice from local health authorities is best for prevention and control.

Leptospirosis

Nature and Occurrence

Leptospirosis affects almost all domestic animals as well as man. It is caused by various **Leptospira** species. This disease occurs world-wide and is spread by contact with infected urine. Rats act as important carriers.

Symptoms

The signs of disease vary greatly but may include high fever, abortions, reduced milk production, blood in the milk and urine, and also jaundice or yellow-color in mucous membranes. Post-mortem signs include enlarged yellowish liver and kidneys.

Diagnosis

Diagnosis involves laboratory analysis of blood and urine samples. Antibiotic treatment with tetracyclines and/or penicillin is effective if started early. Recovered animals may continue to be carriers of the disease for sometime.

Where leptospirosis is a major problem, vaccination is available. Elimination of rats and rodents is beneficial in controlling the spread of the disease.

Tuberculosis (Pearl's Disease, Phthisis, Consumption)

Nature and Occurrence

All mammals (warm-blooded animals), including man are susceptible to this disease. It occurs world-wide and is of great economic importance in some regions of the tropics.

In cattle, tuberculosis is widespread in Angola, Zaire, Argentina, Chile, Dominican Republic, Honduras and Mexico.

Zebu cattle appear to be more resistant to tuberculosis than European breeds.

The method of transmission is either by inhalation (breathing) or infected droplets from coughing of an affected animal or orally (by mouth) through infected discharges. The course of the disease is usually chronic (long term) and the incubation period is quiet long.

Symptoms

The symptoms vary according to the site of the infection. Whenever there is an unexplainable loss of condition accompanied with a swelling of the lymph nodes, T.B. should be suspected. The milk yield will be reduced and hard nodules can be felt in the udder.

If the intestines are involved, there will be diarrhea. If the animal is infected by inhalation, the lungs will be involved and it will develop a progressive chronic cough.

The infection is characterized by the formation of tubercles which vary from a few millimeters to 10cm in diameter. They are filled with pus or calcified deposits.

Affected animals gradually become thinner and often die. Other times, the disease is diagnosed only at slaughter.

Diagnosis, Treatment and Prevention

Diagnosis in the live animal is by a **tuberculin test** involving injection of tuberculin into the skin of the suspect animal. In the infected animal

there is a reaction to the tuberculin and a resultant swelling. In the dead animal the presence of tubercles in the lungs, liver, intestine, or udder are evidence of the disease. Laboratory examination of the infected lymph nodes is also used for diagnosis.

Treatment should not be attempted and infected animals should be destroyed. Testing and disposal of reactors is the only method of control. There is no effective vaccine available.

Because man is susceptible to this disease, great care should be taken to avoid contact with infected meat, milk, or tissues.

Lumpy Jaw and Wooden Tongue

(Actnomycosis, Actinobacillosis)

Nature and Occurrence

These diseases are caused by **Actinomyces Bovis**—lumpy jaw, and **Actinobacillus Lignieresi**—wooden tongue in combination with other pus-producing bacteria. These organisms live normally in the mouth and skin of animals and gain entry to the body through wounds.

Lumpy jaw usually affects the bony tissues of the head (upper and lower jaws). Whereas, the organism causing wooden tongue affects the soft tissues of the head and tongue. These diseases occur world-wide and can also affect man. The incidence of disease is quite low.

Symptoms

There is usually a swelling on the upper or lower jaw, or the tongue will enlarge. This swelling will increase in size over weeks and months. Eventually there will be an eruption at the skin surface where pus oozes out. These eruptions often heal over and break out elsewhere on the lesions. The animal will experience difficulty in eating and chewing. In wooden tongue, the tongue will protrude from the mouth making eating and drinking virtually impossible. Due to the interference with eating, the animal will lose condition.

Diagnosis, Treatment and Prevention

The diagnosis is quite easy due to the evident clinical signs. It is important, however, to distinguish whether the bony tissues are involved. If the upper or lower jaw bones are infected then treatment is very difficult and in many cases impossible. If the soft tissues or tongue are infected, then treatment is highly successful. If the swelling is localized then it should be disinfected and drained surgically, flushing the wound daily with a dilute iodine solution. If the wound is not localized or if the tongue is affected, antibiotics such as streptomycin and/or sulofonamides along with sodium iodine I.V. should be given.

Fig. #41 Lumpy Jaw affecting a calf. (Stock Diseases—Bayer)

If the lesion is draining, then appropriate fly control methods should be administered.

Control methods involve keeping sharp awns or grass beards out of the feed source.

Steptothricosis (Dermatophilosis, Cutaneous Actinomycosis, Senkobo Disease)

Nature and Occurrence

This disease causes a chronic dermatitis (skin infection) and scab formation in cattle damaging the hide and causing a loss of condition in affected animals. It affects cattle in many tropical countries particularly West Africa, the Far East, and the Latin American countries.

The cause of the disease is **Dermatophilus Congolensis.** It spreads from one animal to another through injuries to the skin and bites of ticks and flies. It occurs more commonly during the rainy season.

Symptoms

Skin lesions occur primarily on the back, sides, belly, inside of legs, face, and ears. They appear first as papulles (small skin enlargements) which ooze serum. These form scabs which can extend over a large area of the body.

Animals seriously affected lose condition, become weak, and can actually die from starvation.

Diagnosis, Treatment and Prevention

Diagnosis is based upon clinical signs and the seasonal incidence of the disease. Laboratory examination of affected skin and scabs can confirm the diagnosis.

Treatment with aureomycin injections along with bactericidal washes of the lesions helps in some cases.

Control involves keeping affected animals separate from other animals. Also, frequent dipping to protect from ticks and flies helps. Removal of thorn bushes from grazing areas is also beneficial.

Pinkeye (Infectious Bovine Keratoconjunctivitis, Infectious Ophthalmia)

Nature and Occurrence

This disease causes an inflammation of the outer layer of one or both eyes. It is caused by **Moraxella Bovis**. The occurrence is world-wide. Animals recently introduced into an area are more susceptible.

The disease is spread by either direct contact or insects.

Symptoms

Initially there is increased watery discharge from the eyes followed by cloudiness of the eyes and swelling of the eyelids. The animal becomes oversensitive to light and the discharge becomes thicker. The outer covering of the eye may ulcerate and even rupture. Untreated cases can result in blindness.

Diagnosis, Treatment and Control

This disease affects only the eyes which distinguishes it from other viral diseases such as IBR, BVD, and MCF which affect other parts of the animal as well as the eyes.

Treatment should be started early and involves direct application of

antibiotics to the eye. Affected animals should be kept in a dark place away from sunlight and flies.

Control of flies and ticks can help in the spread of the disease. There is a preventive vaccine available for severe outbreaks.

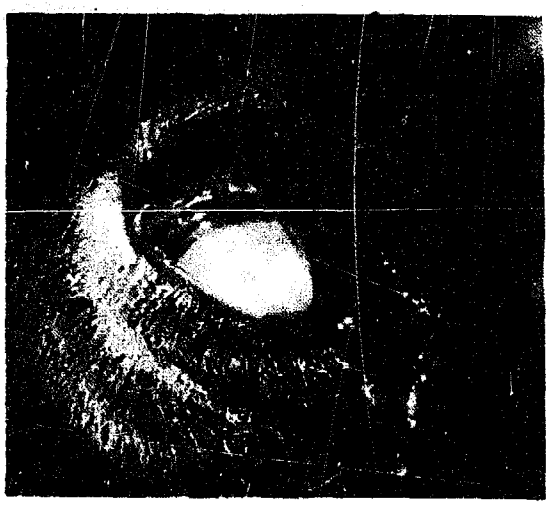

Fig. #42 A case of pinkeye. (Stock Diseases—Bayer)

Diseases Caused by Protozoa and Rickettsia

Tick-Borne Diseases

In many developing countries tick-borne diseases represent the greatest threat to development of the livestock industry.

Ticks are a group of parasites which cause major losses of productions through their blood-consuming ability and transmission of other diseases. These disease are transmitted by the tick's habit of moving from one host to another between blood meals carrying the disease with them. The second method of transmission is for the disease itself to pass through one of the stages of the tick. Examples of diseases transmitted by ticks include East Coast Fever, Heartwater, Babesiosis, Anaplasmosis, etc. Other losses attributable to ticks include skin and hide damage. Skin damage caused by ticks permits entry of other parasites like screwworms. Tick paralysis can also be caused by certain ticks.

Ticks are distributed world-wide, but occur principally in tropical and sub-tropical countries. Before feeding on the blood of their hosts, they are usually flat but when enlarged with blood they are spherical. Ticks are capable of taking in many times their own weight in blood. Each tick may suck out .3ml of the animal's blood.

The tick family is divided into two groups: soft ticks, which infest birds, and **hard ticks**, which infest animals and man. The hard ticks (Ixodid) have a hard shell covering the whole upper surface of the male and a small area of the female. From the color and other characteristics of this shield, ticks can be identified. All ticks have four pairs of legs and a round body.

During development the tick passes through the stages of egg, larval, and nymph before it becomes an adult. The eggs are laid on the ground. The larval (small tick with 3 pair of legs) then emerge from the eggs and climb up on grasses and shrubs attaching themselves to passing animals. According to their method of further development they are divided into one, two, or three host ticks. A one-host tick goes through all stages of development on one animal. For two-host ticks, the larval develop into nymphs on the first host, then drop off, molt into adults, and become attached to a second host. Three-host ticks attach themselves to a different animal at each stage of development, dropping off and molting into the next stage on the ground.

When the female tick has mated and engorged itself with blood it drops to the ground where it lays 2,000 to 20,000 eggs and then dies. This entire life cycle may take from a few months to several years. It is important to know in controlling ticks whether the tick is a one-, two-, or three-host tick.

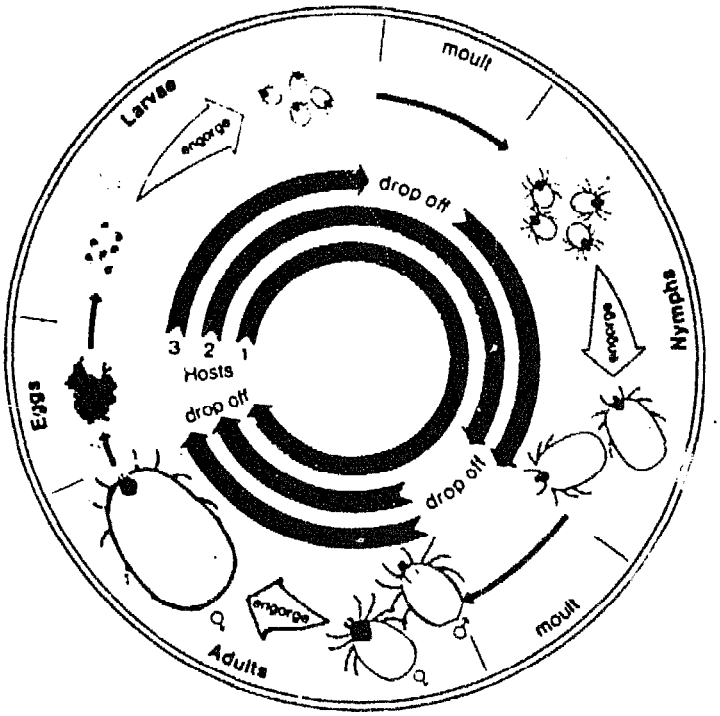

Fig. #43 Cycle of development of one or more host ticks. (Stock Diseases —Bayer)

Ticks are generally controlled by the immersion of animals in an application of a chemical (acaracide) capable of killing the ticks. A one-host tick stays on the animal longer than the two- and three-host ticks and consequently, the dipping interval can be longer for one-host ticks than for two- and three-host ticks. The strength of the dips can also be varied.

Common One-Host Ticks:

Boophilus Decoratus (Blue Tick)
found in South, East and Central Africa, and Central and South America
transmits Babesiosis and Anaplasmosis

Boophilus Annulatus (North American Cattle Tick)
found in Egypt, Western Asia, Central America,
transmits Babesiosis

Boophilus Microplus (Blue Cattle Tick)
found in Australia, Asia (S.E.), Central and South America, and South Africa—transmits Babesiois, Anaplasmosis and Theileriosis

Common Two-Host Ticks

Rhipicephalus Evertsi (Red-Legged Tick)
found in Central and Southern Africa
transmits East Coast Fever and Babesiosis

Rhipicephalus Bursa
found in Africa and Southeast Asia
transmits Babesiosis, Anaplasmosis and Theileriosis

Hyaloam Truncatum (African Bont-legged Tick)
found in Africa
transmits sweating sickness in calves

Common Three-Host Ticks

Rhipicephalus Appendiculatus (Brown Ear Tick)
found in Central, East and South Africa
transmits East Coast Fever, Corridor Disease, and Babesiosis

Amblyomma Hebracum (Bont or Heartwater Tick)
found in tropical regions
transmits Heartwater

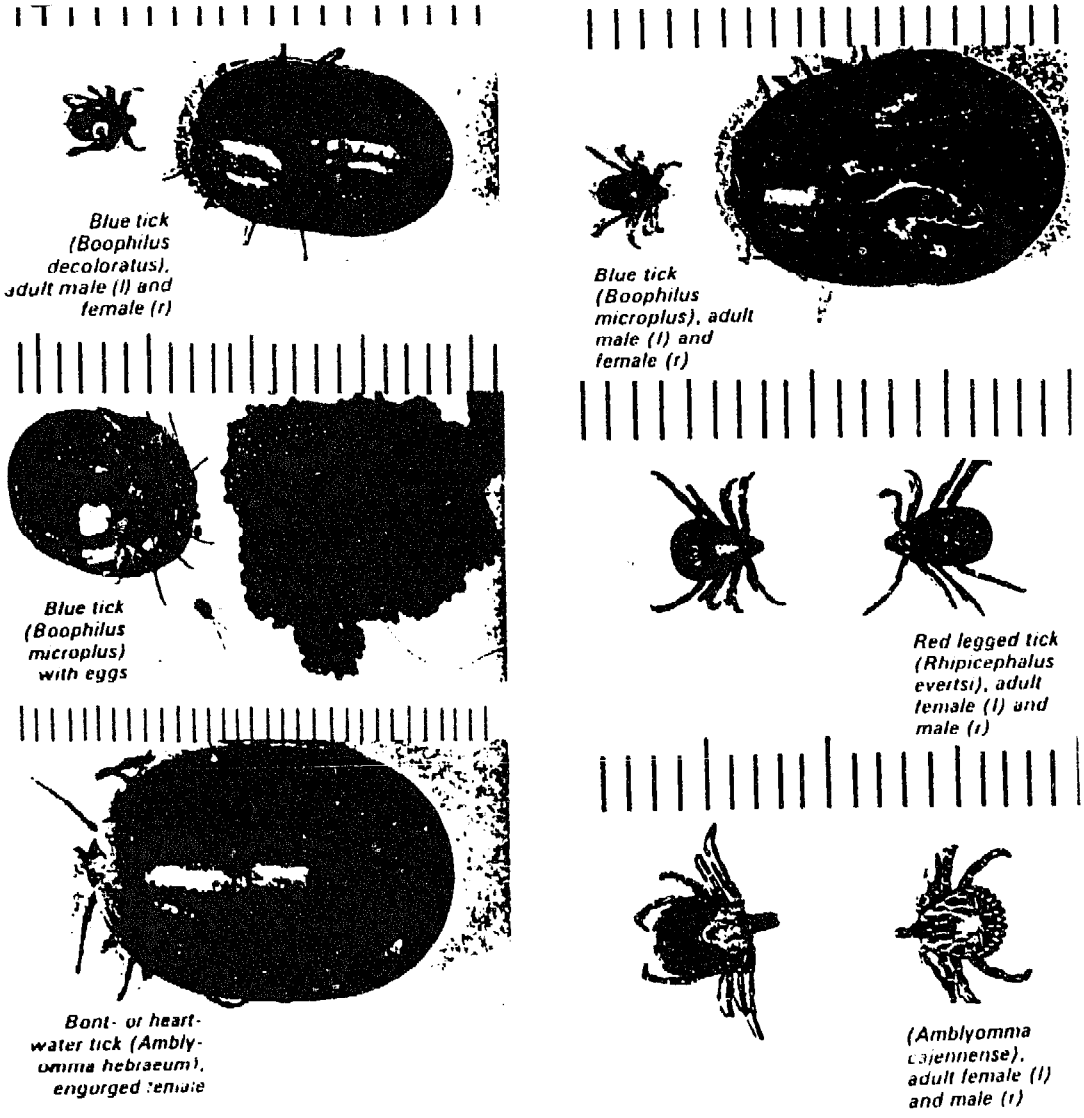

Fig. #44 (Stock Diseases—Bayer)

Tick Control

Tick-borne diseases differ from many other diseases in that young animals are more tolerant than older animals to these diseases. Thus, when animals are exposed to a sufficient number of infected ticks early in life they suffer a mild infection, recover, and develop a resistance to further infection. They remain, however, carriers of the disease. If com-

plete tick control cannot be achieved in an area, calves need to be exposed to moderate numbers of infected ticks so they can build up resistance. In areas where tick control is good or certain ticks are not present, calves will grow up susceptible to tick-borne diseases. If these animals are moved to an infected area or control breaks down there is the potential for severe losses in adult animals.

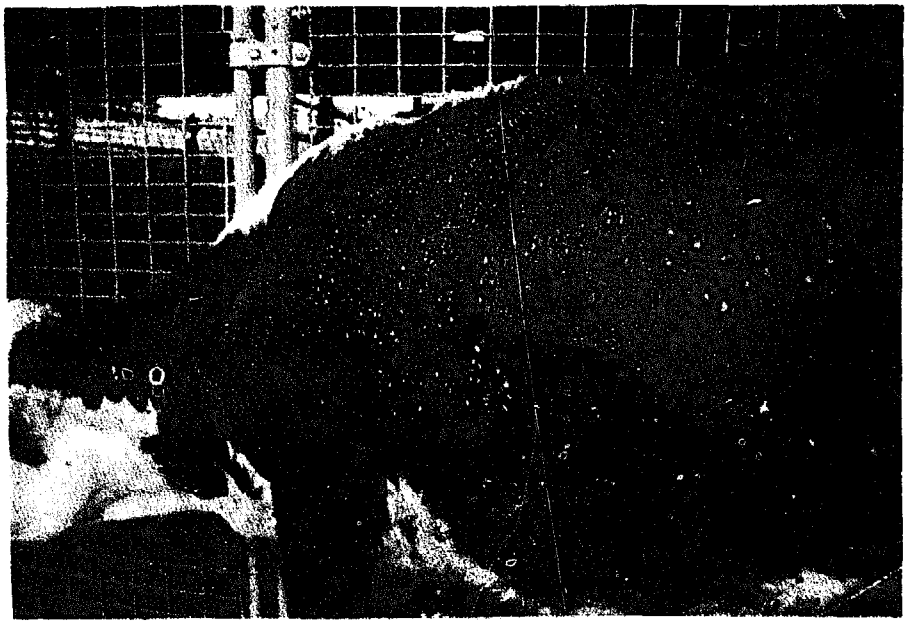

Boophilus microplus— artificial infestation

The only effective way of controlling ticks and the diseases they transmit is by dipping or spraying them in an acaracidal solution (chemical which kills ticks). In many countries the government supervises tick control measures.

Excellent recommendations for treatment and control have been developed by the Food and Agriculture Organization. These recommendations include dipping, operation of dipping tank, measuring tank capacity, maintaining dip fluid strength, spraying, hand spraying, hand dressing, frequency of treatments, and acacridides. These can be obtained by writing to Director, Publications Division, Food and Agriculture Organization of the United Nations, Via delle Terme di Carocalla, 00100 Rome, Italy.

Protozoan and Rickettsial Dieseases Transmitted by Ticks

Anaplasmosis (Gall-Sickness)

Nature and Occurrence

Anaplasmosis is caused by rickettsia which live in red blood cells. It is widely distributed throughout the tropical, sub-tropical, and temperate areas. Anaplasmosis is transmitted primarily by ticks and biting flies. It can also be spread by non-sterilized instruments and needles during dehorning, tatooing, and vaccination. The incubation period is 30-40 days.

after the animal is bitten by an infected tick. The animals at greatest risk are those newly introduced into an area or foreign breeds.

Symptoms

The disease is more prevalent in summer and early fall. Initially there is an increase in the body temperature. The animal is depressed, off feed, mucous membranes are pale to yellow, and the lymph nodes are enlarged. The urine is dark yellow and constipation may be present. There is a high death rate especially in older animals. If death results it is usually 3-4 days following the onset of sickness.

Post-mortem lesions include a general yellow color to the internal organs. The spleen, liver, kidneys, and gall bladder are enlarged. Hemorrhages occur on the heart and intestines.

Diagnosis, Treatment and Control

Diagnosis is based upon clinical signs, post-mortem lesions, and laboratory analysis. Blood smears can reveal the anaplasma parasite in the red blood cells. Babesiosis can often be confused with Anaplasmosis.

Treatment can be successful if started early using tetracyclines (terramycin) or imidicarb.

Control involves treatment of ticks and vaccination. Also, because this disease can be transmitted by needles and surgical equipment great care should be taken when treating and vaccinating animals. A fresh needle should be used for each injection in areas where the disease exists.

Babesiosis (Redwater, Piroplasmosis, Tick Fever)

Nature and Occurrence

Babesiosis is caused by a protozoan parasite that is spread by carrier ticks. It causes extensive breakdown of the red blood cells resulting in anemia and jaundice (yellowing of skin). The distribution of the disease is world-wide wherever ticks are located. Ticks from the **Boophilus** species and most commonly incriminated. Other **Babesia** species affect horses, dogs, pigs, and sheep.

The disease commonly occurs in animals 6-12 months old which have not had previous exposure. Cattle living in an affected area are protected by antibodies developed at a young age. The protozoan parasite passes from one generation of ticks to another by transovarian transmission. They are then passed on to susceptible animals through the blood-sucking habits of carrier ticks. Carrier cattle also provide a source of infection for ticks. As in Anaplasmosis imported cattle are especially susceptible to the disease.

Symptoms

Symptoms include a sudden high fever of 106°F (41°C) or higher approximately 10-12 days after the bite of a tick. The animal is depressed, off feed, with anemic mucuous membranes, and later yellow mucous membrances. Due to the anemia, breathing is rapid and the heartbeat is strong and fast. The animal becomes weak and may develop nervous symptoms. The breakdown of the red blood cells produces hemoglobin which often stains the urine red. The untreated animal will die in 2-3 days as the disease may become chronic.

Post-mortem lesions include a very large spleen. The organs are

either very pale colored or yellowish. The urine is pink or red. The presence of a fever associated with red urine, anemia, and jaundice are highly suggestive for babesiosis.

Diagnosis, Treatment and Control

Diagnosis is best accomplished by examination of a blood smear which demonstrates the Babesia organisms. Diseases which are often confused with babesiosis include rabies due to the nervous symptoms and Anaplamosis.

Drug therapy, if given early in the course of the disease, can produce dramatic results. Drugs commonly used are Pirevan, Phenamidine, Isothionate, Amicarbolide (Diampron) or Diminazene acoturate (Berenil). Because there is a small margin of safety between a therapeutic dose and a toxic dose, careful consideration should be given to the dosage label recommendations. Animals with advanced cases of the disease should be given a blood transfusion along with drug therapy. One problem with therapy is that the drug totally eliminates the parasites from the blood. Thus no immunity can develop and the animal is once again susceptible to the disease.

Control of the diseases involves three factors: elimination of the tick carrier, elimination of the protozoan parasite, and control by premunition. Elimination of the ticks and thus, the Babesia is discussed under tick control. Premunition involves vaccination of susceptible cattle with blood from donor animals which are carrying the disease.

Products Used to Successfully Treat Babesiosis

Compound or Compound Group	Proprietary Name	Chemical Description*
Acridine derivatives		
Acriflavine hydrochloride (Euflavine, Trypaflavine)	Gonacrine[a]	A mixture of 3.6-diamino-10-methylacridinium chloride and 3.6-diamino acridine hydrochloride
Azo-Naphthalene dyes		
Trypan Blue	Congo Blue Niagara Blue	3.3¹-[(3.3¹-dimethyl[1.1¹-biphenyl]-4.4¹-diyl)bis(azo)]bis [5-amino-4-hydroxy-2.7-naphthalene disulfonic acid] tetrasodium salt
Diamidine derivatives		
Aromatic		
Diminazene diaceturate	Berenil[b] Ganaseg[c]	4.4¹-diamidinodiazoaminobenzene diaceturate
Pentamidine diisethionate	Lomidine[a]	4.4¹-diamidinodiphenoxypentane di(beta-hydroxyethane sulfonate)
Phenamidine diiisethionate	Lomadine[a]	4.4¹-diamidinodiphenylether di(beta-hydroxyethane sulfonate)
Cardanilide:		
Amicarbalide diisethionate	Diampron[a]	3.3¹-diamidinocarbinilide diisethionate
Imidocarb dipropionate	Imizol[d]	3.3¹-bis(2-imidazolin-2yl) cardanilide dipropionate
Quinoline derivatives		
Quinuronium sulfate	Acaprin[e] Akiron Pirevan Piroplasmin Babesan[f]	6.6;-ureylenebis(1-methylquinolinium)bis(Methosulfate) N.N¹-di-6-quinolinylurea

FOOTNOTES:

[a] May & Baker Ltd., Dagenham, England.
[b] Farbwerke-Hoechst AG, Frankfurst, West Germany.
[c] Squibb Mathieson, E.R. Squibb & Sons de Mexico, Mexico City, Mexico.
[d] Burroughs Wellcome & Co. Ltd., London, England.
[e] Ludabel Farbenfabriken, Baver, Leverkusen, West Germany.
[f] Imperial Chemical Industries Ltd., Macclesfield, Cheshire, England
* Obtained when available from the Merck Index, Ninth Edition, 1976.

Relative Efficacy of the More Commonly Used Babesiacidal Compounds

	Diminazene	Imidocarb	Amicarbalide	Phenamidine	Quinuronium	Trypan blue	Pentamidine
Cattle:							
Babesia bigemina	++++	++++	++++	++	+++	++	++
B bovis	+++	+++	++	++	++	—	
B divergens	++	+++	++		+	—	
Horses:							
B. caballi	+++	++++	+++	+++	++	++	
B. equi	++	+++	+	++	—	—	
Sheep:							
B. motasi	+++		+++		+	+	
B. ovis	+	++			+	—	
Swine:							
B. trautmanni				++	++	++	
B. perroncitoi	+++				++	—	

Table #9 (Diseases and parasites in the tropics - HTB Hall)

Tick Paralysis

Nature and Occurrence

Tick paralysis is caused by the absorption of toxins (poison) from the salvia of feeding ticks. It causes a paralysis of man and domestic animals. This disease can occur anywhere that ticks are located but is a serious problem in North America, Australia, Africa, and India. It predominantly affects cattle under one year of age.

Symptoms

The first signs are barely noticed but include a worried look and slight staggered movements. As the disease progresses, there is an ascending paralysis. The animal first drags its hind legs, then cannot get up, and finally dies from paralysis of the breathing muscles.

Diagnosis, Treatment and Control

Diagnosis includes a paralysis with the presence of ticks and recovery of the animal, if the ticks are removed. Prompt removal of ticks by hand, followed by treatment of an acaracide, is recommended. Recovery may be complete in a matter of hours after removal of ticks or it may take a few days. Prevention and control involve tick control using acaracides and also avoidance of known tick-infested areas.

Protozoan Diseases Transmitted By Flies

Trypanosomiasis (Nagana, Sannare, Sleeping Sickness, Chagas Disease)

Nature and Occurrence

This disease is caused by a protozoan organism called a trypanosoma (T. Congolense, T. Vivax) and is spread by blood-sucking flies (Tsetse fly). These trypanosomes undergo part of their reproductive cycle in an intermediate host-tsetse fly. When the fly bites an infected animal the trypanosomes in the blood of the animal enter the salivary gland of the fly and multiply. Before the fly can breed, it must have a feed of blood and thus, spreads the disease to another animal. When it feeds on the blood of a susceptible animal it infects this animal with trypanosomes via the salvia. The tsetse fly is about the same size as an ordinary house fly. It often picks up the trypanosomes from wild game such as the warthog and giraffe. These animals are immune to the disease but transmit it to humans (sleeping sickness) and animals (nagana). All species of domestic animals are susceptible to the infection.

African tryanosomiasis is caused by a blood parasite transmitted through the bite of the TSETSE FLY when it feeds.

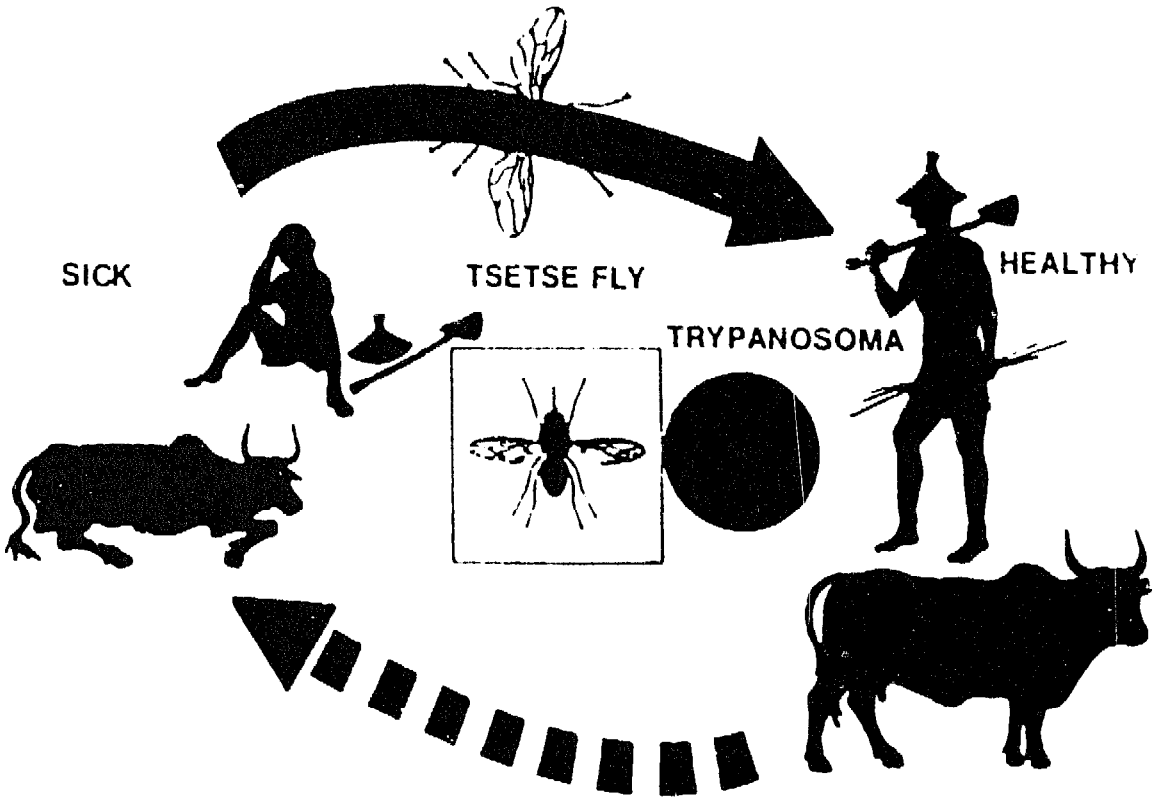

As well as man and cattle, the disease also affects camels, horses, sheep, goats, pigs, and dogs.

Table #10-A

(FAO Program for control of African Animal Tryspanosomiasis.)

The area most affected by trypanosomiasis is central Africa. It also occurs in Central and South America. Legions of tsetse flies control over 4.5 million square miles of some of Africa's choicest land (an area larger that the continental U.S.A.). Thirty-five million Africans and many millions of cattle live under threat of the disease. If tsetse infected areas could be reclaimed for cattle production, Africa's annual meat production could be doubled. Needless to say, trypansosmiasis is one of the most awesome problems affecting Africa today.

This disease which occurs in almost 9 million km² of the savannah and forest areas of the African continent . . .

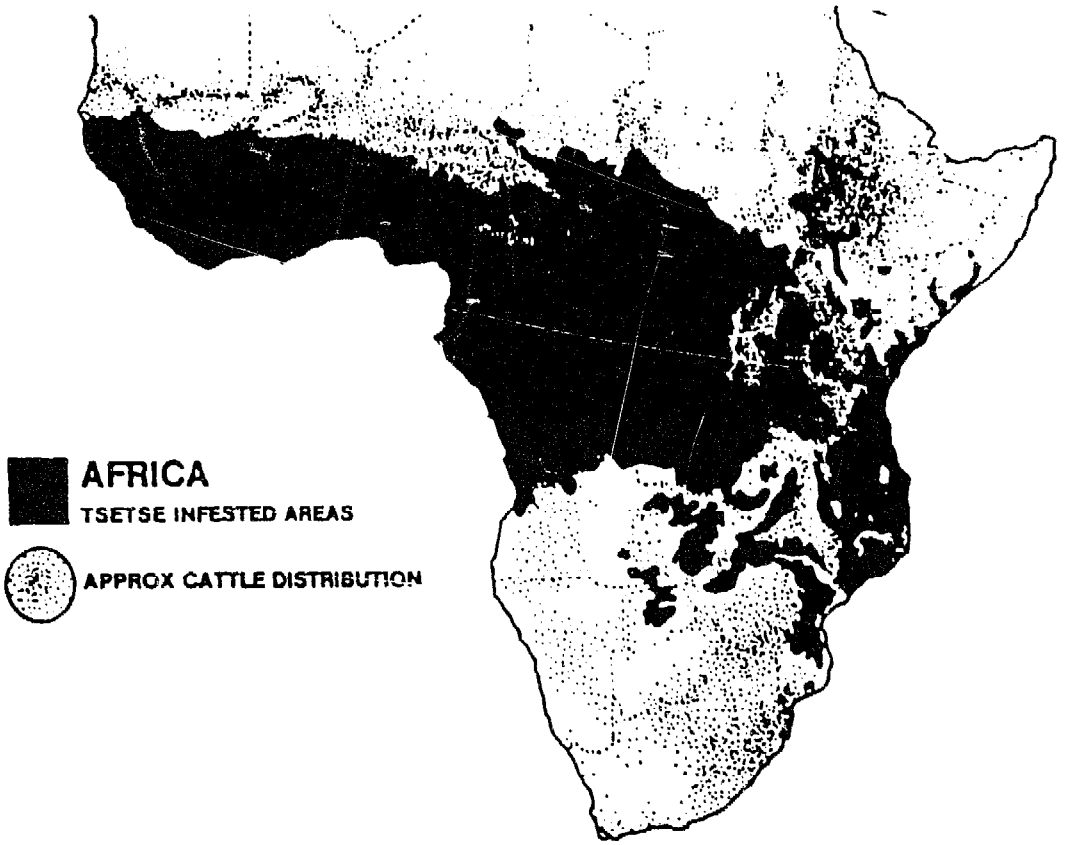

. . . is spread by the TSETSE FLY and limits the production of livestock and agriculture in most of these areas.

Table #10-B

(FAO Program for control of African Animal Trypanosomiasis.)

Symptoms

The time period between the bite of an infected tsete fly and infection generally takes 5-7 days. Symptoms then develop gradually over several weeks. The animals are dull and depressed and their appetite is greatly diminished. Body weight and condition deteriorate as well as milk production. There may be a slight discharge from the eyes which have sunken appearance. There is a fever and enlargement of the lymph glands. One sign is anemia and a paleness of the mucous membrances of the mouth and conjunctiva. Many animals die within a few weeks; whereas, other animals will recover spontaneously or many linger for years. Abortions and still-births occur frequently.

Fig. #46 The effect of trypanosomiasis on a naturally-infected N'Dama yearling. The animal is stunted and has a characteristic nagana pose. (Veterinary Book for Farmers, Blowey—1985)

Post-mortem examinations reveal a carcass that is in very poor condition with paleness to the organs due to the anemia. The spleen and lymp nodes will be enlarged.

Diagnosis, Treatment and Control

Diagnosis involves symptoms, history of the herd and location, and blood smears. Either a stained smear of examination of a fresh smear of blood will demonstrate the parasite. Positive diagnosis can be made only by a smear examination.

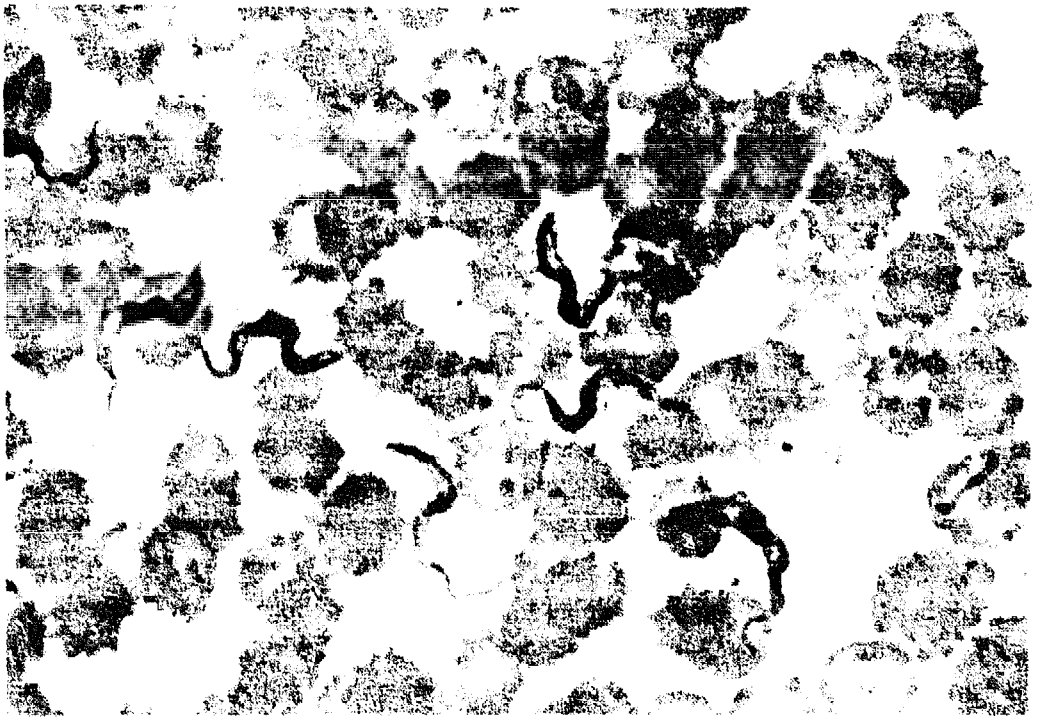

Fig. #47 A microscopic view of trypanosomes in the blood of an infested animal. (FAO)

Treatment involves proper rest and nutrition to minimize loss from the disease. Drugs recommended for treatment include:

Diminazeve Aceturate (Berenil)
Homidium Chloride (Novidium)
Isometamidium Chloride (Somorin)
Quinapyramine Sulphate (Antrycide)

It is best to follow a veterinarian's instruction as to the use and dosage of the drugs. Insufficient dosage may lead to resistance of the Trypanosome to the drug.

Control measures involve:

(1) **treatment** of animals with drugs to control the prarasite
(2) **vector control** by reducing or eliminating the tsetse fly
(3) **trypanotolerant livestock** resistant to the disease

Tsetse control involves insecticide spraying and biological control. The insecticide spraying is done by ground crews, helicopter and airplanes. This can be a very effective method of control if a large area is covered and multiple sprayings are accomplished. Biological control involves the release of sterile laboratory-reared males. Because the tsetse female mates only once in her life, this process is effective if a large number of sterile male flies are released. The second method of biological control involves the release of specific pests or diseases of the tsetse fly. The third method of biological control is by setting up traps which contain an attractant which attracts the flies and traps them at the same time. Another method of over-all control is the increased use of trypanotolerant cattle. These cattle, by natural selection, have developed a natural resistance to trypanosomiosis. These breeds include the **humpless** West African breeds of N'Dama from Zaire, Baoule' from Ivory Coast, and Race Locale from Togo. European and Zebu cattle are more endangered by this disease. No one method of control will eliminate this disease, but a **combination** of the above methods will greatly reduce the effects of the trypanosomiosis.

Protozoan Diseases Spread Without An Intermediate Host

Coccidiosis

Coccidiosis is caused by a protozoa which lives inside the cells of an infected animal's intestinal tract. It occurs world-wide but is more important where animals are confined in small areas. Younger animals which have recently been stressed are most susceptible. The death rate is usually low; however, outbreaks can occur with many animals affected. The source of infection is the manure from affected or carrier animals. Infections occurs when cattle, eat or drink manure contaminated feed or water.

Symptoms

The most characteristic sign is foul-smelling, dark, watery manure. Severely affected animals develop watery diarrhea with clots of blood and shreds of mucous lining from the intestinal tract. These animals will lose their appetites, become depressed and dehydrated, lose weight, and go off feed. Straining is quite common.

Untreated animals may die in the acute phase or later from secondary infection. If the animal survives the severe phase, it may recover

but with significant weight loss. Cattle can also suffer central nervous system disorders from coccidiosis. These animals show muscular tremors, convulsions, and bending of the neck and head. These animals usually die withing 24 hours after symptoms first appear. Post-mortem signs show hemorrhages of the intestinal tract.

Diagnosis, Treatment and Control

Diagnosis is made by symptoms and microscopic examination of manure for coccidial oocysts. Treatment involves the isolation of sick animals. Drug therapy involves gut sulfas like sulfaguanadine, ionphores and Amprolium. Control involves the used of Deccox and Amprolium to prevent the disease. Sanitation measures of not feeding cattle on the ground and maintaining clean water supplies are also important. Pasture rotation and avoidance of overcrowding are helpful.

PARASITES

Ectoparasites

As stated earlier, ectoparasites live outside of the host animal. Ectoparasites commonly involving cattle include ticks, mites, flies and lice. Since ticks were covered in an earlier section, we will deal primarily with mites, flies and lice.

Mites

Mites have four pairs of legs like ticks but are much smaller. They are important because they cause various types of mange in cattle. Mange causes an inflammation of the skin as the mites burrow into the skin. These mites occur widely throughout the world. Their entire life cycle is usually spent on one animal.

Demodectic Mange is caused by **Demodex Falliculorum.** It affects most domestic animals and man. The parasite lives deep in the hair follicles and sebaceous glands of the skin. The infection is very slow in developing and the initial signs are thickening of the skin and the loss of hair. Itching may develop into abscesses. These mites can be demonstrated by skin scraping and examination under a microscope. Treatment is very difficult. Rotenone preparations of 2% in oil may be beneficial. Ivermectin injections can also be helpful. Antibiotics are helpful in the event of abscess formation.

Sarcoptic Mange is caused by **Sarcoptes Scabei** and is spread by direct contact with infected animals. This mite burrows deeply into the skin causing itching, scratching and skin infection with the formation of fluid leaking from the sores.

Treatment involves cleansing the lesions with soap and water and dipping the animals in gammexane (lindane), limesulphur (2% calcium, polysulphide), coumaphos (Co-Ral), and 5% solution toxaphene. Dipping at weekly intervals is suggested until the signs disappear. Ivermectin (Ivomec) injections are also very effective.

Flies

Flies are characterized by only one pair of wings. Their economic importance results from their attacking a group of animals and irritating them by biting. The animals will not eat or drink because they are distracted by the flies and subsequently lose condition. Flies can also

transmit disease, i.e. tsetse fly. Other flies of economic importance include the warble fly and screwworm fly.

The **warble fly** or heel fly lays its eggs on the lower part of the back legs of cattle. The eggs hatch into a larva which penetrates the skin and migrates throughout the muscle tissue of the animals body. The larva locates underneath the skin on the back of the animal and forms a maggot or grub. This maggot then penetrates through the skin damaging the hide and completing the life cycle. Warble flies most generally occur in colder climates and can be prevented with organophosphate insecticides (Co-Ral, Warbex, or Neguvon) as a dip or pour-on.

Screwworm flies occur commonly in Central and Latin America. These female flies deposit their eggs on the edges of wounds. The eggs hatch into maggots which burrow into the flesh causing abscesses and eventual death to the animal if not treated. The process can occur in a matter of days. Control involves treating all wounds and surgical procedures (castration and dehorning) with cleanliness using disinfectants and insecticide fly repellants or screwworm pastes. Elimination and control of flies is also helpful using sterile male flies and insecticide preparations.

Lice occur in colder climates and are more common on poorly fed cattle. They are more frequently located around the ears, neck and base of the tail. Because they suck blood, untreated animals become anemic and lose weight. Treatment involves insecticides and tick-control medications.

Internal Parasites

Internal parasites are referred to as helminths and are divided into two groups, the flatworm and the roundworm. The flatworms are further divided into flukes and tapeworms. Internal parasites have varying effects on animals; they parasitize ranging from no effect at all to loss of condition and eventual death. They live inside the animal as opposed to external parasites which live on the skin.

Roundworms

Nature and Occurrence

Roundworms or nematodes cause damage to cattle in two ways: blood-sucking and causing inflammation and damage to the gut lining. The large stomach worm (Haemonchus) and brown stomach worm (Ostertagia) bury themselves in the stomach wall and feed upon blood. The worms suck a few drops of blood and then move to another location. The tiny cuts continue to bleed after the worm moves on and also serve as routes of bacterial infection. In addition, the brown stomach worm causes disruption of digestion by reducing stomach acidity and causing a severe diarrhea. Among the parasites which cause damage to the surface of the gut, the small stomach worm (Trichostrongylus) and the cooperids (Cooperia) are most common. The worms disturb digestion in the stomach and disrupt absorption of vital nutrients in the intestine. Lowered feed efficiency and poor weight gains are frequent results. Diarrhea is another common effect. The mature female worms living in the gut of the animal produce large numbers of eggs which pass out of the animals with the manure. The warmth and moisture of the manure cause the eggs

to hatch and develop into larvae. These larvae migrate into the grass. If the cow or calf graze contaminated grass of forage, the parasites are ingested and the animals are infected with roundworms.

Symptoms

The destructive effects of these parasites are more severe in younger animals. Usual signs include loss of appetite, loss of weight and condition, dull haircoat, constipation or diarrhea. The resulting anemia is characterized by pale mucous membrances, depression and possible "bottle jaw" (accummulation of fluids under the skin of the lower jaw). The animal may also have a potbellied appearance.

Diagnosis, Treatment and Control

Diagnosis involves examination of the animals, history, and fecal examination. Because the parasites are quite small, a microscopic examination of the feces is best. A common method involves the floatation method whereby a small amount of feces is mixed with a sugar or salt solution. Because most parasite eggs will float to the top and fecal debris settles out, this method is highly reliable. The top layer of solution is examined microscopically and the parasite eggs identified. Most animals living in temperate or tropical climates are infected with roundworms and should be routinely treated.

In choosing products to treat nematodes, one must keep in mind the following: availability, effectiveness of the product, types of worms controlled by the product, ease of administration, safety, and length of residues for slaughter animals. Products available to treat nematodes include:

Ivermectins (Ivomec-Merck) an injectable given subcutaneously 1 ml/50 kg body weight

Benzimidazoles (Thibenzole-Merck) (Fenbendezole-Safe-Guard-Hoechst Agri Vet) these are available as feed pre-mixes, oral suspensions, pastes, boluses, and crumbles

Imidazathiazoles (Levasale-Pitman Moore) (Tramisol-American Cyanamid) these are available as boluses, drench, gel, in feed, or as an injection

Organophosphates (Baymix-Haver-Lockhart) (Halox, Loxan, Wellcome, JenSal) these are available as a feed pre-mix, boluses, or drench

Phenothiazine (Tefenco-West-Argo) this drug is available to be mixed with the feed (Febantel-Bayer)

Morantel Tartorate (Rumatel, Nemater-Pfizer) this drug is available as a pre-mix or a bolus.

Strict following of manufacturer's recommendations as far as dosage and time before slaughter is recommended. **Guidelines as to types of treatment and frequency of treatment will vary from region to region, but one guideline might be the following: deworm cows every 6 months and deworm calves every 3 months. The changing of the type of wormer from year to year is suggested to keep the worms from building up a resistance to one type.**

Overstocking of pastures contributes greatly to internal parasitism because it enhances the movement of parasites from animal to animal.

Adult cattle are the source of worm eggs which develop into larvae and infect young animals. Therefore, separation of cattle by age group as much as possible is helpful in controlling parasitism. Larvae require moisture for their development and migration; therefore, properly drained pastures encourage parasitism. Rotation of pastures so they are free of cattle 4-6 months can help greatly in controlling parasites in young cattle. For cattle in a dry lot, frequent removal of manure and care that it does not contaminate feed and water will also contribute to the control of parasites.

Lungworms

The lungworm parasite lives in the air passages of the lung causing irritation, mucous production, and secondary bacterial infection. The disease occurs most frequently in younger calves. Common clinical signs include rapid and shallow breathing. Infected animals may have a loose cough which is made more severe by excercise. Animals with heavy infections tend to lose condition and may stand with their head extended and mouth open with saliva drooling from the mouth.

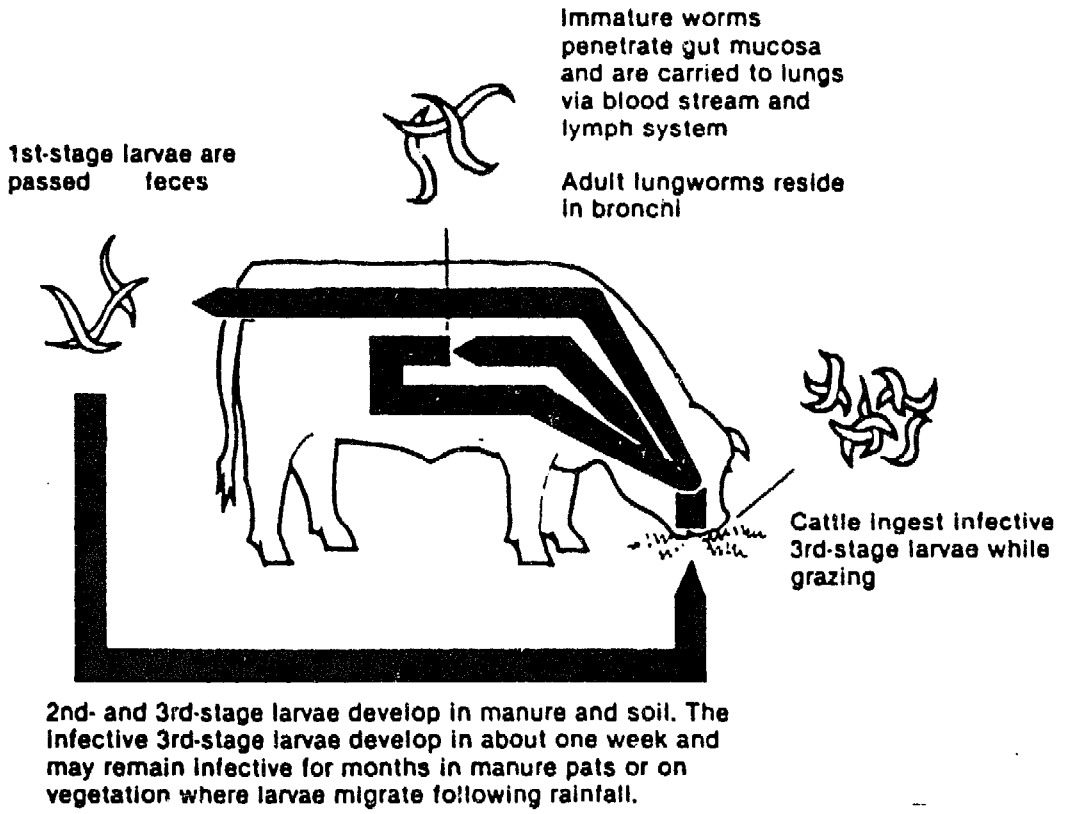

The life cycle of *Dictyocaulus viviparus*, the lungworm of cattle.

Fig. #48 (Stock Diseases—Bayer)

Diagnosis is based upon clinical signs, post-mortem diagnosis, and demonstration of larvae by the Baermann technique. The most acceptable treatment is levamisole (Ripercal, Tramisol, Levasole) given orally or subcutaneously. Since this parasite does not persist on the leaves of grass or soil for long periods of time, a two-month interruption of grazing is enough to free a field of the parasite. Treatment of infected cattle before going to a clean pasture reduces the number of larvae shed and aids

in keeping calves free of the infection. Separation of calves from older animals aids in protecting them from heavy exposures.

Liver Flukes

Nature and Occurrence

Liver flukes (Fasciola Hepatica and Fasciola Gigantica) occur in many tropical countries. The disease they cause is rarely fatal but causes serious losses due to damage to the liver and bile duct. The flukes are flat, unsegmented, leaf-shape parasites 20-50 mm long and 12 mm wide. They are greyish-brown in color. Fluke eggs pass out of the cow with the feces. In moist areas these eggs hatch into an intermediate stage which requires snails for further development. After 1-2 months in the snail, the fluke lives on water vegetation. After being eaten with the vegetation, the young flukes penetrate the gut wall, migrating in the gut cavity, and finally penetrate the liver. In the liver the fluke causes serious tissue damage and reaches maturity in the bile duct where it releases eggs which pass out of the cow's body with feces to start the cycle again. Infection takes place in damp, marshy, or swampy areas where snails are found.

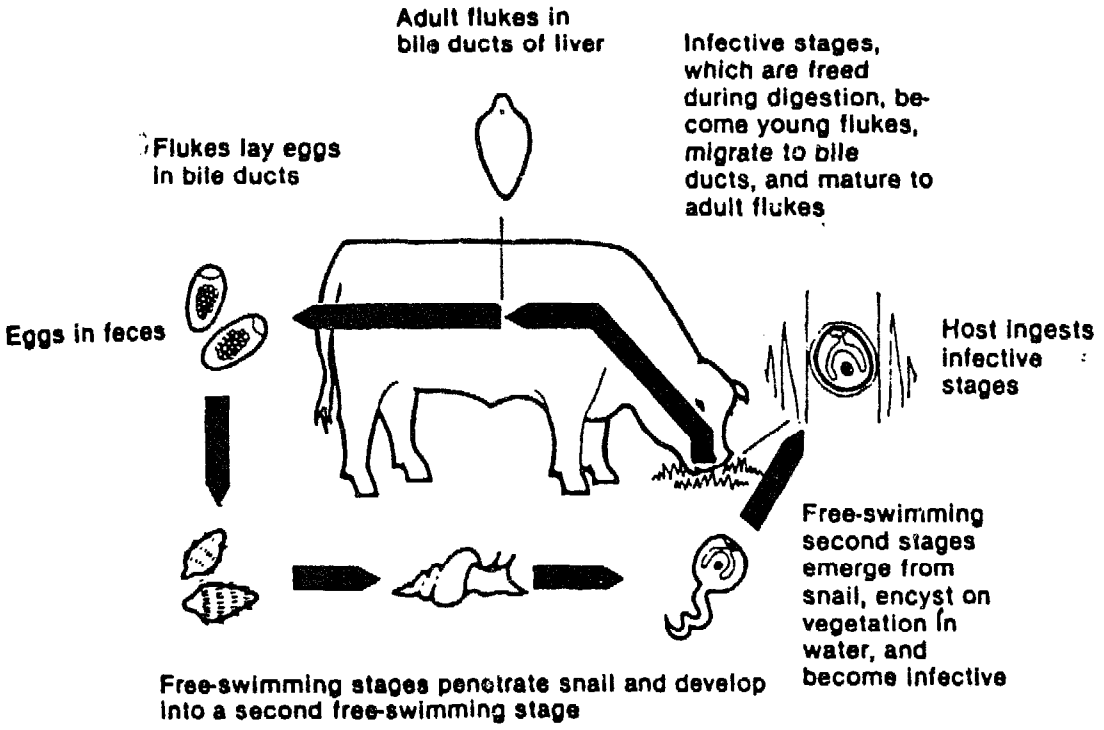

Life cycle of *Fasciola hepatica*, the common liver fluke of cattle.

Fig. #49 (Stock Diseases—Bayer)

Symptoms

The liver fluke affects cattle by the damage which it does to the liver. This organ has large reserves of tissue and tolerates large numbers of flukes without obvious clinical signs. Signs commonly seen are anemia, unthriftiness, bottle jaw, and reduced milk flow. Post-mortem signs indicate severe damage to bile ducts and liver.

Diagnosis, Treatment and Control

Diagnosis is based upon a history of fluke disease in a herd pastured in moist areas with heavy snail populations and showing clinical signs.

To confirm the diagnosis, a fecal examination needs to be done. Because the eggs are heavy a fecal sedimentation test needs to be done rather than a fecal floatation test. Also, egg production does not take place until severe liver damage has already occurred.

Treatment is often difficult because drugs strong enough to treat the parasite are also toxic to the animal. Drugs which have been used are carbon tetrachloride and hexachlorethlene. A newer drug Clarsulon (Curatrem-Merck) is also available now as a treatment.

Since the disease requires the snail as an intermediate host, it can best be prevented by elimination of exposure of cattle to the snail. This can be done by drainage to remove water necessary for the snail's environment and fencing cattle away from areas where the snail lives.

Tapeworms

Tapeworms (Cestodes) are long, segmented, flat, white worms. These worms may be several meters in length and each segment has a number of eggs. Tapeworms occur in most animals and man and are usually located in the small intestine. They require an intermediate host to complete their life-cycle. Cattle act as intermediate hosts for human tapeworms **(Taenia Saginata and Taenia Solium)**. Tapeworms which affect cattle are **Moniezia Expansa** and **Thysanosoma Spp.** Their effects are minimal compared to the other worms, but they do utilize nutrients from their hosts resulting in possible weight loss and malnutrition. Treatment of these parasites is rarely justified.

Non-Infectious Diseases

Lameness

The symptoms of lameness are obvious with a limp or carrying of one or more legs. Footrot was discussed earlier and other lameness conditions will be discussed here: **Sole Abscess** is hard to differentiate from footrot. There is usually less swelling above the hoof area and usually no drainage of the hoof area. It is caused by an abscess within the hoof wall which is often hard to distinguish. Treatment involves casting the animal and probing the hoof area to locate the abscess. Once it is located, the hoof area needs to be cleaned and pared with a knife, the abscess drained and treated with antibiotics, and wrapped with a bandage.

Another common cause of lameness is **arthritis** or inflammation of joint tissue. This condition can affect one or more joints and is either infectious or non-infectious. The signs are a swelling of the joint accompanied by possible heat and a pronounced lameness. If the cause is infectious or bacterial, antibiotics are recommended as well as rest. Infectious arthritis is seen more often in younger animals and may be accompanied by a rise in body temperature. Non-infectious arthritis is usually caused by trauma either directly to the joint or by twisting motion to the leg causing a sprain or strain. Treatment involves complete rest and confinement and soaking or bandaging to reduce the swelling.

Another common cause of lameness is either a **cut** or **puncture wound** to the hoot or leg area. Nails or wire or string around the leg are common causes of these wounds. Treatment involves removal of the cause if needed, thorough cleansing, application of antibiotic ointment, possible bandaging, and rest. Antibiotic injections are also helpful.

Laminitis or **founder** occurs when there is an abrupt change in feed, usually from a high fiber ration to a high energy (grain) or protein ration. This primarily affects the two front feet which have elongated hooves and are very tender. The affected animal moves painfully and prefers to lie down. Treatment is usually unsuccessful.

Bloat (Hoven)

Bloating occurs in ruminants when gas accumulates in the rumen and the animal cannot get rid of it. This may be caused by rapid gas formation, paralysis, or obstruction of the esophagus. Normally the animal gets rid of this gas by belching. Some nutritional causes of bloat include grazing legume pastures which ferment rapidly and also rapid consumption of cereal grains.

Symptoms

Symptoms of bloat are: the left side of the animal may be greatly enlarged; the animal will stand with its feet apart, mouth open, and drooling; the animal will have difficulty breathing to the point of gasping; the animal will eventually lie down and die due to inability to breathe.

If the animal is having difficulty breathing, it is considered an emergency and needs immediate attention. This involves puncturing the rumen with a knife, scissors, or trocar. The knife or trocar is inserted through the skin in the left side at a point halfway between the last rib and the point of the hip and the same distance below the lumbar vertebrae. The instrument should be directed with force downwards. If a knife or scissors are used, a hallow tube or piece of bamboo should be inserted in the opening to allow air to escape. If the animal is excited or stressed considerably before removal of the gas, this greatly increases the chances of losing the animal.

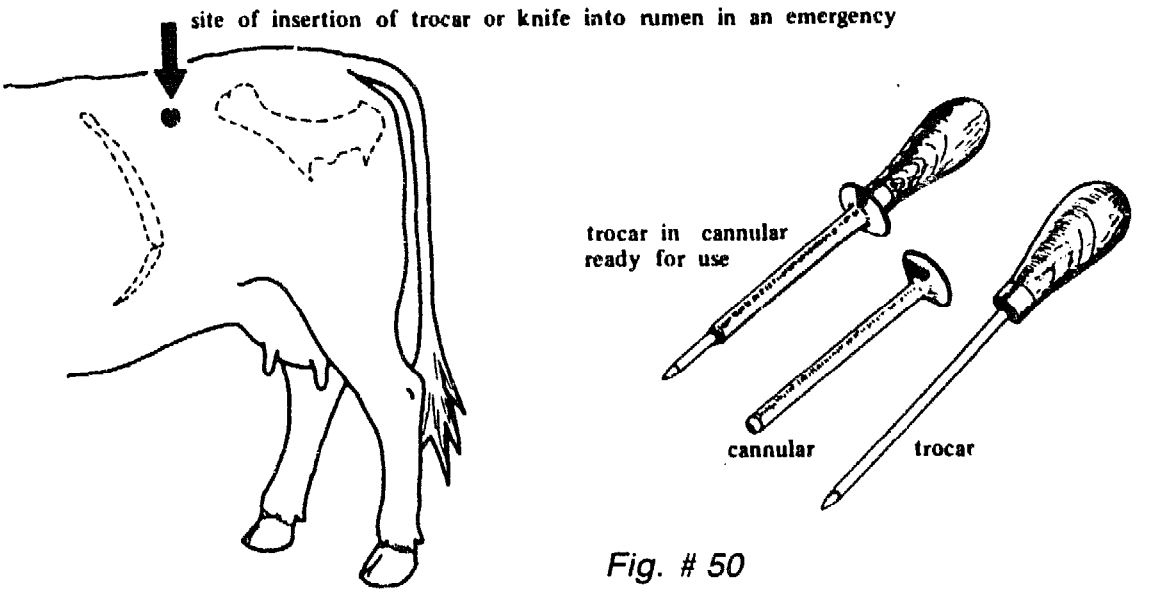

Fig. # 50

USE OF TROCAR AND CANNULAR IN CASES OF BLOAT

Sometimes cattle will have a frothy bloat as opposed to a grassy bloat. This occurs when air is trapped in numerous bubbles which will not pass through a stomach tube or trocar. The only solution in these cases is to

administer medications which will dissolve the air bubbles. These might include 10 gm household detergent dissolved in water, 100 ml formalin in 2 liters water, 2-4 liters of linseed oil, or mineral ol adminstered orally.

If the affected animal is still not breathing normally, any of the following methods may be tried:

(1) walk the animal to help belching
(2) tie a thick rope or block of wood in the mouth to encourage chewing and belching
(3) stand the animal uphill
(4) pass a stomach tube to relieve the bloat

Esophageal Obstruction (choke)

"Choke" occurs when foreign objects such as potatoes, apples, beets, etc. become lodged in the esophagus or food tube. The symptoms are the animal may stand away from the others with its head stretched forward and mouth slightly open. The animal will be drooling and may be bloated. It usually cannot eat or drink.

Treatment involves blocking the mouth with a block of wood between the teeth and fishing the obstruction out with a looped wire or hand. Or if this is unsuccessful, you may attempt to push the obstruction on into the stomach with a stiff tube. Great care must be observed with either of these procedures as tearing or rupture of the esophagus is usually fatal.

Urinary Calculi (Waterbelly)

This occurs most always in castrated males. It is caused by the formation of caluli (small mineral deposit stones) in the bladder and subsequent lodging in the urethal tube (penis). This causes the urine to back up and bladder enlarges and may rupture.

If the condition is noticed before the bladder ruptures, the animal will be seen acting very uncomfortable, wringing the tail, standing up, and lying intermittently, and straining. If the condition is noted after the bladder or penis rupture, the animal will be seen dull and depressed with a large swelling underneath the skin of the belly or within the abdominal cavity.

This condition is treated surgically by redirecting the penis to discharge above the scrotum. This must be done by a qualified person. Prevention involves keeping plenty of water available for cattle and also the proper mineral balance.

Lightning Strike

This condition occurs during a thunderstorm with severe lightning. The signs generally seen are a dead animal or group of animals, sometimes lying on top of a hill or near some trees. One may also find scorch marks on adjacent trees, marks along the ground, or burns on the animal itself. Post-mortem examination usually shows no significant lesions.

Hardware Disease (Traumatic Pericarditis)

In this disease the animal will consume pieces of wire or metal in their eating process. These metal pieces will locate in the second stomach (Reticulum) and may penetrate into the heart sac causing a severe in-

fection. The symptoms are depression, off feed and milk production. They stand with the back slighty arched; they may be reluctant to move, and there may be a grunting sound. The body temperature may be elevated slightly.

Treatment involves the use of a cattle magnet administered orally along with antibiotics. Also, the wire may be removed surgically by a veterinarian in valuable animals.

Naval Ill (Joint Ill, Umbilical Infection)

Naval ill is generally seen in calves during their first week of life. Early, the calf's naval cord will be enlarged and painful with a purulent odor. Later the calf's temperature will be raised and he will be depressed and reluctant to move. The joints in the legs may be swollen.

Treatment involves the use of daily antibiotic infections. If the joints become swollen, the condition is very difficult to treat. Prevention is accomplished by treating the naval cord with iodine upon birth and also ensuring that the birth takes place in clean surroundings.

Abortion

Abortion occurs when a fetus dies and is expelled from the uterus for a variety of causes. If early fetal death occurs, the fetus is usually reabsorbed in the uterus and nothing else is seen. With the absence of infectious disease the abortion rate can approach 2%. Rates higher than this may indicate the presence of an infectious disease or toxicity problem. Diseases which are commonly involved in abortions are: Brucelosis, Vibrosis, IBR, BVD, Leptospirosis, Fungal Infections, and Salmonellosis. High nitrates in feed sources can also cause abortion.

Positive diagnosis of the cause of the abortion would have to be determined by a laboratory. So if the entire fetus cannot be submitted to the laboratory, samples of the lung, kidney and liver from a fresh fetus should be collected and frozen before delivery to the laboratory. Also, blood samples from the cow that aborted may be helpful. Even under the best conditions only about 50% of abortions are diagnosed by a laboratory.

Mastitis (Mammitis)

Mastitis is any inflammation of the udder. It occurs in all countries and breeds but is more prevalent in dairy breeds. The usual cause is the entrance of bacteria into the udder by the teat opening. The symptoms are a swollen, tense, hot and painful udder. The milk flow is diminshed and the milk is discolored and sometimes stringy. One or more quarters may be affected and they will feel hard and knoblike. In severe cases the cow will have an elevated temperature, go off feed and lose condition.

Treatment, if started early is usually successful. This involves completely milking the affected quarter or quarters and then injecting antibiotics. The antibiotics are applied into the teat canal with a special needle or syringe. The needle or syringe needs to be thoroughly disinfected as does the end of the teat before applying the antibiotic. Analysis of the milk by a laboratory can help in deciding which antibiotic to use. Prevention involves keeping cows in clean dry surroundings and disinfection of teats, hands, and equipment at milking time. In herds where

mastitis is a persistent problem, the teats of all cows should be dipped in a cup containing a chlorine-type disinfectant immediately after they have been milked.

Vaginal and Rectal Prolapse

These conditions can occur together or separately. A vaginal prolapse can occur either immediately before calving or afterwards. Only the vagina and cervix are everted as opposed to a uterine prolapse where the uterus also everts. This condition is much less serious than a uterine prolapse but requires attention. If left unattended for any length of time, the cow will strain because it cannot urinate and also may result in a rectal prolaspe. A rectal prolapse can occur by itself and is when 4-8 inches of rectum evert.

Both of these conditions require a trained professional to correct. The animal will have to be given an epidural anesthetic injection (spinal block) to relieve straining and pain. Then the vagina and/or rectum will need to be everted and sutured to prevent recurrence.

General Wound Treatment

Oftentimes, animals are injured from sharp horns, bites, wire cuts, kicks, or sharp objects such as knives or machetes. These injuries are oftentimes infected with bacteria.

The first concern in treating any wound is to stop the bleeding if it has not stopped by itself. This can be done by these steps:

(1) direct pressure on the wound with a clean cloth or bandage (This pressure may need to be applied for considerable length of time until bleeding stops)

(2) tie a rope or a cord above the wound to cut off the blood circulation (This is a temporary solution as you stop the bleeding)

(3) clamp the bleeding vessel with forceps or tweezers and then tie a piece of suture (Fishing line or strong sewing thread will also work) around the vessel and tie tightly with 3 overhand knots.

The first concern in treating a wound is to cleanse it. Clean water can be used initially. If there is long hair on the edge of the wound it should be trimmed. Be very careful to remove all hair, dirt, straw, etc. from the wound as these will retard healing. Next, apply a mild disinfectant (alcohol, iodine, or 2 teaspoons salt in ½ litre of water) as cleansing is repeated. If the wound is less than 12 hours old and has well-defined edges, it may be sutured.

After the wound is clean, daily treatments with antibiotic powder or ointments is best. Sufanilamide or Nitrofurazone works good for this. A clean bandage, changed every 2-3 days is excellent. **Never** use salt or pine tar in a wound as these destory tissue and are extremely painful.

Another problem to be avoided is a screwworm infestation of the wound. THis can be avoided by thorough cleaning of the wound and application of screw repellant, tick grease (grease plus asuntal powder) or Stockholm tar applied around the edge of the wound to prevent flies from laying eggs.

In treating **puncture wounds** where something has penetrated the skin and muscle, antibiotics should be given by injection. Oftentimes, the

skin will close over the wound and it cannot drain causing an internal infection. If drainage can be established by opening the wound with a knife, this should be done. The wound should then be kept open and treated with disinfectants or antibiotics. Tetanus is a consideration in puncture wounds.

If wounds are severe involving joints, large blood vessels, or tendons, some animals may have to be slaughtered. Animal bites to cattle should be treated with caution because of the possibility of rabies developing.

Treatment of Abscesses

Abscesses develop as a result of a small puncture wound and the growth of pus-producing bacteria. These result in round swellings developing anywhere from the jaw, to the back, and/or to the feet. The animal needs to be secured by ropes or a crush and examined. If possible, one should tap the abscess with a 14-16 gal. needle to determine if the abscess is ready to open. If pus drains out of the needle the abscess should be lanced with a knife. Always open the abscess at the lower most point of the swelling so that it will drain well. Cut a triangle-shaped opening approximately 1-2 cm across with a sharp knife. Throughly rinse out the abscess with disinfectants and apply screwworm repellant until the wound heals.

Treatment of Broken Bones

The decision of whether to slaughter an animal with a broken leg depends on several factors. If there is any bone penetrating the skin, infection will develop and the only alternative is to slaughter the animal. Also, if the animal with the broken leg is an adult or weighing over 200 kg, the chances of the bone mending is considerably diminished. In a younger and lighter animal if the bone can be stabilized and the animal confined, the bone can mend properly.

If the choice is made to try to treat the fracture, the animal needs to be kept quiet and secured either with ropes or a crush. The primary concern is to stabilize or immobilize the leg so the bones can fuse back together. Any movement at the site of fracture keeps the bones from mending. Thus the joint above and below the fracture should not move.

If plaster of paris or comparable cast material is available, this works best to immobilize the bones. If sufficient padding of cotton or other material is available, splint boards, broom sticks, or metal pipes can be taped in place for support. The supporting material must be strong enough to stabilize the leg but not too heavy and bulky. Be sure to align the bones correctly while applying the splint. The supporting material may need to be changed periodically due to sudden lameness or pressure sores developing. Leave the splint material in place for a minimum of 6 weeks. If the bones are kept perfectly aligned with rigid material and the animal is kept confined, the bones should heal in a younger animal.

Malnutrition

Malnutrition probably ranks as the number 1 cause of death and loss of production in Third World countries. This is understandable considering that the people are malnourished as well. However when the animals are properly cared for they can better provide for the needs of the people — meat, milk, or work.

It is most important to provide first enough forage and then to see that the forage is properly balanced for protein, energy, vitamins and minerals. (Refer to nutrition section)

Meeting the livestock's nutritional needs is especially difficult in the dry seasons. This is where hay production is needed for times of low forage availability.

Internal and external parasites also play a large role in the malnutrition complex. Even if cattle are provided with all the necessary nutrients parasites can cause the animal to be malnourished. Specific guidelines for control are given in the section on parasites.

Plant Poisoning

Plant poisoning is especially common in tropical areas. Usually a high temperature and high humidity favor the growth and development of the poisonous principle. Lack of good grazing (drought) causes animals to eat poisonous plants which they might not otherwise consume. Also, younger animals are usually more susceptible to poisonous plants.

The symptoms resulting from plant poisoning vary according to the type of plant involved. These symptoms vary from hyper-excitability to dullness, convulsions, skin blistering, jaundice, etc. Generally, however, the symptoms of dullness, abdominal pains, and possible nervous signs may indicate poisoning. If you suspect a certain plant poisoning, it is hard to identify this specifically even if laboratory facilities are available. One should be careful not diagnose plant poisoning unless the specific poisonous plant is seen.

Because there are no specific antidotes for most plant poisonings, general treatments to prevent absorption and treat the symptoms are recommended. Oxidizing agents such as potassium permanaganate deactivates some poisons. Charcoals will absorb many poisons whereas limewater or alum prevent the poisons from being absorbed. Linseed oil, cottonseed oil, or mineral oil relieve irritation and speed the removal of poison from the body. Convulsions are treated with sedatives (ex. barbituates) while paralysis and depression are treated with stimulants.

Control involves avoidance of areas with poisonous plants. Also careful management to avoid over-grazing of pastures is important. Remember prevention is the best way to avoid losses due to plant poisoning.

Some common plants and plant materials:

Lantana Shrub—Animals show jaundice and severe skin infection
Jequirity—Asia, Australia, South America; symptoms: blood poisoning
Castor Oil Plant—symptoms: blood poisoning and convulsions
Lillies—acute digestive upset and convuisions
Tribulus—variable symptoms and localities
Oleander (Ceylon Rose)—Diarrhea and convulsions
Salanines—(thron apples) - dullness and depression
Milkweed—widespread in tropical areas
Mexican Poppy— weakness and labored respiration
Ground-Nut Meal—toxic with the presence of a fungus
Bracken Poisoning—anemia and hemorrhage

Ragwort—severe straining
Yew Tree—immediate death
Acorn and Oak Leaves—dullness and diarrhea

Common Mineral and Chemical Poisonings

Arsenic

This element was commonly used in dips and sprays. It causes severe gut inflammation leading to abdominal pain, colic, and scouring. Treatment involves 60-120 gm of sodium thiosulphate given as a drench in a liter of water

Copper

Copper poisoning usually results with improper cooper supplementation or spraying plants with copper salts. Symptoms usually occur following long periods of intake and include jaundice, pain, and blood in the urine. Treatment involves removal of the source and are symptomatic.

Lead Poisoning

Sources of lead poisoning might include old paint, lead plates from batteries, oil, etc. Symptoms are blindness, excitability, alternated with dullness, abdominal pain, constipation, and possible death. Treatment includes 100 gm magnesium sulphate (epsom salts) by mouth.

Creosote (Diesel, Paraffin)

Symptoms are dullness, abdominal pain, and convulsions. Lower levels of consumption cause poor haircoat and reduced growth. Treatment involves removal of the source.

Nitrates

Nitrates can accumulate in plants during periods of drought and/or lack of sunlight. Also, heavy fertilization causes plants to accumulate large quantities of nitrates. These plants are then consumed by cattle and the nitrates cause symptoms of panting, gasping, bloat, etc. Death can occur very rapidly and the blood is brownish colored. Abortions may result in pregnant animals. Treatment includes I.V. administration of 5% methylene blue.

Insecticides

The two main groups of insecticides which cause poisoning are Chlorinate Hydrocarbons and Organophosphates. Chlorinated Hydrocarbons include DDT, BHC (louse powder), and Dieldrin. Symptoms of excitability and muscle spasms can occur quite suddenly. Treatment is symptomatic to control convulsions.

Organophosphorus insecticides, (such as occurs in grub and tick control medication) fly repellants, cattle wormers, and many crop chemical are common causes of poisoning. The symptoms are salivation, abdominal pain and diarrhea with possible convulsions. Atropine is recommended for treatment.

Moldy Feed

When feeds are stored under unsatisfactory conditions, especially high humidity and high temperature, molds may grow. Many of these molds are not harmful if consumed; however, some molds may produce

toxins which produce poisoning. Symptoms range from decreased appetite and depression to abdominal pain, diarrhea, and even death. Treatment involves removal of the contaminated feed.

Snakebite

Snakebite is a common occurrence is many tropical countries. Animals are usually bitten on the face or legs when grazing. Diagnosis includes demonstration of puncture marks on the face or legs, severe swelling at the site of the bite, depression and possible sudden death. The severity of the bite depends upon the location the bite, size and type of snake, and the amount of venom injected. The treatment involves rest and administration of antibiotics to counteract infection.

Malnutrition

Malnutrition accounts for more loss of production and death loss than any other single factor. Correction of cause involves better feeding and management, which does cost money, but yields much better returns.

MINERAL AND VITAMIN DEFICIENCIES

In order to obtain optimum health, it is necessary that proper amounts of minerals and vitamins be provided. The requirements and needs are discussed in the section on nutrition and we will only discuss the specific deficiencies in this section. These deficiencies usually arise as a result of animals kept in areas where soils are deficient or because of overstocking and/or poor quality feed. These deficiencies can be corrected by supplying the deficient minerals in the form of a supplement or lick.

Acute Calcium Deficiency (Milk Fever, Hypocalcemia, Puerperal Paresis)

Acute calcium deficiency usually occurs in high producing cows in good condition that are receiving a high protein diet. It usually occurs after the second lactation period. Most cases occur during the first 3 days following calving.

After a short period of excitement, the cow shows weakness of the hind quarters and loses its appetite. The cow is generally found lying down and very depressed with the neck bent sideways. The eyes are half closed and the body temperature may be below normal.

Treatment involves the administration of 500-1000 ml of Calcium-phosphorous solution intravenously. This should be given slowly and response is usually quite rapid. Proper mineral supplementation prior to calving helps to eliminate this disease.

Fig. # 51
Milk fever, the neck is bent sideways, a characteristic sign. (Stock Diseases — Bayer)

Calcium and Phosphorous Deficiency

Most tropical soils have a low phosphorous content and consequently grasses growing on them are deficient in this mineral. Even the young growing stage of a plant may be lacking in phosphorous, and this level

will drop even further during maturity stages or drought.

An inadequate intake of calcium causes weakened bones, slow growth, low milk production and severe deficiences, and convulsions. Phosphorus deficiencies result in fragile bones, general weakness, weight, loss, stiffness, reduced milk production and chewing of wood, rocks or bones. A phosphorous deficiency can result in chewing of bones leading to botulism. Under conditions of extreme phosphorous shortage, cattle may go for years without producing a calf or even coming into estrus.

Calcium and phosphorous deficiencies can be overcome by supplementation in the diet. Di-Calcium phosphate is an example of a mineral supplement to prevent these deficiencies.

Cooper and Molybdenum Deficiency

In this condition there is usually a deficiency of copper and an excess of molybdenum. Symptoms involve change in the haircoat (loses color especially around the eyes), irregular breeding, incoordinaton and scouring. In some areas of severe deficiency, animals may collapse and die due to heart failure.

Diagnosis is made by clinical signs and laboratory analysis of blood and/or liver. This deficiency can be prevented by licks containing copper, supplementation of fertilizer to soil, or injections.

Fig. # 53
Hair color changes as a result of copper deficiency. The darl color is normal when animals receive adequate copper. (Courtesy Bernardo Jorge Carillo, C.I.C., INTA, Castelar, Argentina.)

Cobalt Deficiency (Engoatic Maramus, Nakuruitis)

Like many deficiencies, this one only occurs in certain areas of the world. Symptoms include a gradual loss of appetite and decreased growth rate. This is followed by extreme depression, depraved (abnormal) appetite, severe anemia and death Diagnosis is by laboratory analysis of blood and/or liver samples. Supplementation involves treatment of the soil or pasture with cobalt or feeding or drenching animals individually.

Fig. #54 Cobalt deficiency. The top left photo shows a cobalt-deficient heifer that had access to an iron-copper-salt supplement. Note the severe emaciation. The top right photograph is the same heifer fully recovered with an iron-copper-cobalt salt supplement while on the same pasture. (Florida Experiment Station Bulletin 699, 1965. R. B. Becker, J. R. Henderson and R. B. Leighty, University of Florida, Gainesville, Florida, U.S.A.)

Sodium Chloride Deficiency

This is a very common deficiency in tropical areas. The signs are a craving for salt demonstrated by licking of wood or soil. The cattle will be restless, drink more water, lose weight, become unthrifty, have a rough haircoat, and the eyes will be dull. The easiest method of diagnosis is to provide a source of salt with granular or block salt. Supplementation of salt can lead to a rapid and full recovery from the signs of deficiency. **Salt should be provided at all times for grazing animals.**

Iodine Deficiency (Goiter)

This deficiency occurs on all continents. It is characterized by stunted growth, loss of hair, abortion and decreased reproductive performace. The thyroid gland is enlarged, helping to make diagnosis. Prevention involves using iodized mineral supplements.

Selenium Deficiency (White Muscle Disease)

This deficiency is widespread occurring more in young animals. The affected animals are often born weak and may die shortly after birth. If able to move, they are stiff. The muscle of the legs and head can be examined following death and reveals very pale to white color. Because there is a relationship between selenium and vitamin E, these substances can be supplemented to prevent this deficiency.

Magnesium Deficiency (Grass Tetany, Grass Staggers and Hypomagnesemia)

This condition occurs when nursing cows and sometimes calves graze young green forage in the spring. Small grain and rye grass pastures are often involved. Associated with the disease are low levels of magnesium and high levels of protein and potassium. The symptoms resemble milk fever and include nervousness, lack of coordination, muscle spasms, staggering and death. Treatment involves administration of magnesium solutions intravenously. This therapy results in immediate response to treatment. Prevention involves supplementing Magnesium Oxide in the feed or included in salt as a 10-15% mixture.

Vitamin A Deficency

This deficiency occurs when animals do not receive enough green feed and during dry conditions, when feeds may contain low levels of vitamin A. Vitamin A deficiency is characterized by a decreased fertility. There is a lowered resistance to infection and a deformity of bones. Treatment and control involves supplementation of vitamin A by either injection or feed supplementation. A rich source of vitamin A is fish liver oil.

Vitamin D Deficiency (Ricketts, Osteomalacia)

Ricketts affects young animals and is caused by a deficiency of vitamin D. There is an incomplete calcification of boney tissue resulting in a deformity of the ends of the long bones. The animal finds standing painful, it stumbles, moves stiffly and rises with difficulty.

Osteomalacia occurs in adult animals and results from a decalcification of mature bones which become brittle. The symptoms are stumbling, lameness and difficulty in rising. The animal will often lick wood, walls, bricks, carcasses, manure, etc. There is a rapid loss of condition.

Treatment and prevention involve supplementation of vitamin D and calcium-phosphorous preparations.

Section 6

Consultation

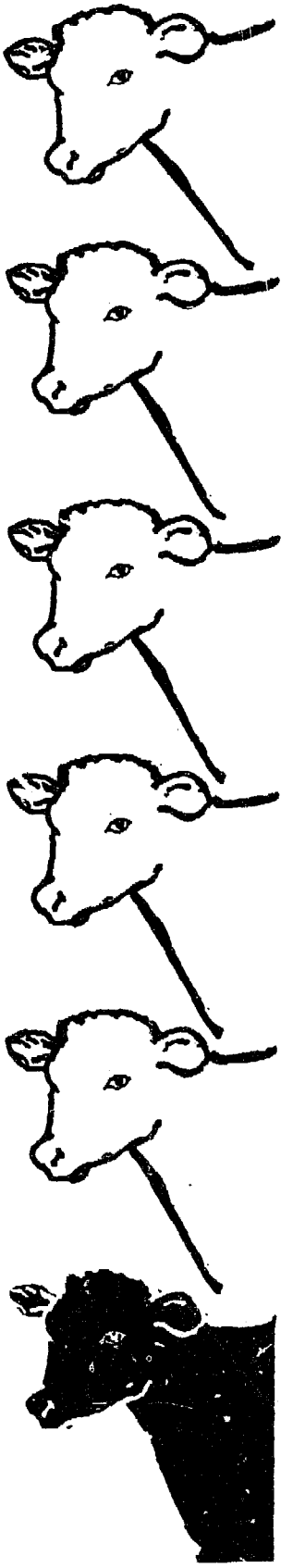

If specific problems arise whereby more information is needed, the author is available for consultation by mail. One should, however, first try to seek information from local sources such as veterinarians, extension workers, universities, etc. If additional information is needed please provide the following:

1) **Farm Location**
   a. country
   b. state or province
   c. distance and direction

2) **Climate by Season**
   a. temperatures, rainfall and variations by season

3) **Description of the Area** where farm is located (example: mountainous, swampy, or tropical)

4) **Description of the Farm**
   a. acres in farm
   b. total number of cattle on farm by age group (example: cows, bulls, calves, yearling)
   c. other animals on farm
   d. crops grown on farm

5) **Management Practices**
   a. nutrition in detail—feeds consumed, grazing practices, minerals and salt
   b. water source
   c. general condition of animals (thin, poorly cared for, presence of parasites, etc.)
   d. worming, insect control, and vaccination procedures

6) **Sickness**
   a. describe the specific problem and symptoms in detail (body temperature, appetite, etc.)
   b. number of animals affected, by age
   c. number of animals died, by age
   d. length of time problem observed
   e. is the problem worse in certain seasons
   f. length of time sickness noted until death
   g. what are the after-affects if the animals recover
   h. describe treatments used and results

7) **Any Other Observations**

mail to: CVM, World Concern
Box 33000,
Seattle, Washington 98133, USA

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1) **Dr. E. Goodman** - Clemson University for resource information, practical tips and proofreading.
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   a. University of Arizona - Stockman's Veterinary Guide - Lee Newman, D V.M.
   b. Clemson University
   c. Colorado State University
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   e. University of Georgia
   f. Mississippi State University
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   h. North Carolina State University
8) United States Department of Agriculture

Special thanks to my wife Pat for her help and support. Also special thanks to Marilyn Beckler and Joanna Radel for their assistance with typing. Rhonda Miller is to be commended for her typing and artistry.

Household measure equivalents to some common dosage forms:

1 teaspoonful = 5 cc (ml)

3 teaspoonful = 1 tablespoonful

1 tablespoonful = 15 cc

2 tablespoonful = 30 cc = 1 fluid ounce

2 cups = 1 pint = 16 fluid ounces = 500 cc (approx.)

1 cup = 8 ounces

2 pints = 1 quart = 32 fluid ounces

1 quart = approx. 1 liter (1000 cc)

1 liter = 1000 ml (cc)

4 quarts = 1 gallon = approx. 4000 cc

1 pt. = approx. 1 pound of fluid

1 cup = approx. 250 cc

1 ounce = 30 cc

METRIC MEASUREMENTS

1 millilter (ml) = 1 cubic centimeter (cc)

1000 ml = 1 liter

1 gram = 1000 milligrams (mg)

1 kilogram = 2.2 pounds (lb)

1 ounce = approx. 30 grams

1 pound = 16 ounces = 454 grams

THE AUTHOR

JAMES CARLSON, D.V.M., graduated from Colorado State University in 1974 with a Doctor of Veterinary Medicine degree. He has practiced in a rural community in Colorado for the past fifteen years. In addition, he has done veterinary and nutritional consultation work.

Dr. Carlson, who has made several short-term missionary tours to Haiti, is currently involved in a livestock and farming enterprise with his family.

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Raising Healthy GOATS Under Primitive Conditions

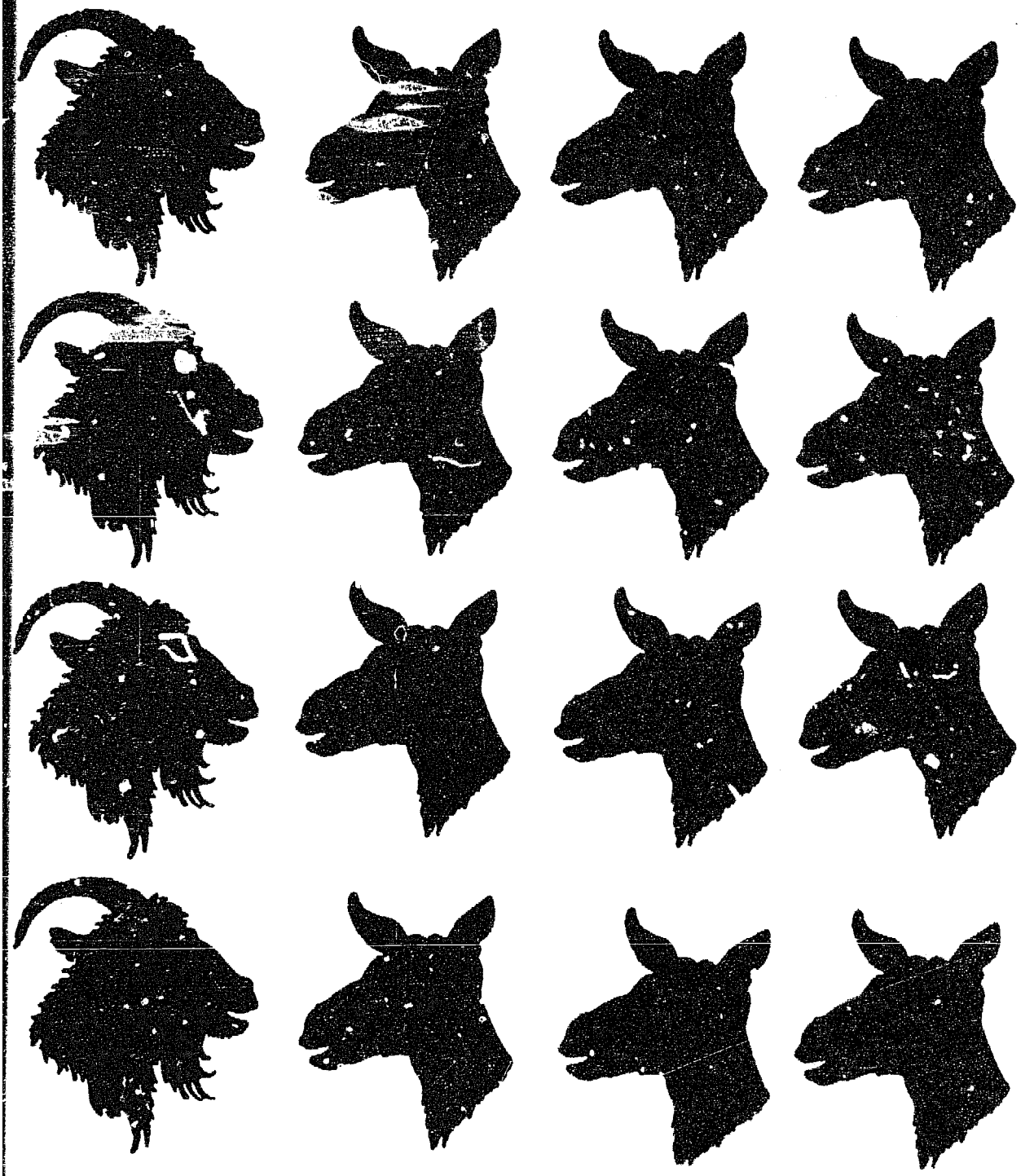

HEALTH CARE OF GOATS

BY

ROBERT A. VANDERHOOF V.M.D.

A Publication of Christian Veterinary Mission
Division of World Concern

Box 33000
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USA

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It can be improved with your help. If you are a veterinarian, veterinary technician, poultry producer, animal husbandry worker, missionary, development worker or anyone with ideas or suggestions for ways this booklet could be changed to better meet the needs of your people, please write to the authors at Christian Veterinary Mission, a division of World Concern.

Thank you for your help.

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I am indebted to my wife, Margaret, who encouraged me in the compiling of this book.

A special thanks to Diane Goldman of San Luis Obispo and Lisa Mates, Visalia, CA, for typing this manuscript, and to Cyndee Willis of Atascadero for help and advice in the preparation, and to Mr. Steve Taylor of Atascadero for his excellent illustrations all through the book.

Dr. M. A. Hammarlund is a veterinarian in Riverside, California, who has special interest in goats as a food animal. He is a graduate of Kansas State University and did graduate study in animal pathology at Colorado State University. In addition to his practice, he has traveled to the Philippines, Bolivia and Costa Rica to assist in various programs. He carefully reviewed the final manuscript for which I owe him my gratitude.

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FOREWORD

My sincere desire in preparing this booklet is that it will serve to be readily used as a reference and aid in the raising of goats. Veterinary information and assistance are in short supply or non-existent in many areas of the world. The author has endeavored to write this booklet in a brief style. Touching on the most important diseases and conditions and providing appropriate dosages, treatments and recommendations.

The writer of this booklet has been in veterinary practice for 45 years, taking care of both large and small animals. After graduating from the University of Pennsylvania, School of Veterinary Medicine, he was intimately associated with his father introducing and developing the Polled Hereford breed of beef cattle in California. His 6000 acre cattle ranch was located at Woodlake, California in the foothills of the High Sierra range of mountains.

The author has traveled to Haiti, helping with veterinary work, as well as Mexico, and to Havasupai Indians down in the grand Canyon of Arizona. He also made a trip to Israel in 1968.

He is presently in active veterinary practice in Central California at Woodlake, and much of his time is spent on working with small ruminants (sheep and goats).

This manual is dedicated to people (providing hope and encouragement) who must by necessity derive their sustenance from the milk and meat of the goat.

Robert A. Vanderhoof, V.M.D.
880 No. Valencia
Woodlake, Ca. 93286

Section I

Overview of General Information

I. OVERVIEW OF GENERAL INFORMATION

Goats were among the earliest animals to be domesticated. Most countries of the world have used goats as a source of meat and milk since the earliest days of recorded history.

Goats play a positive role in environmental protection and destruction by clearing away certain plant species. The dairy goat is an ideal family dairy animal. It is friendly, alert, intelligent, socially inclined and manageable.

Goat populations are large in mountainous areas where they thrive on grass and browse (brush). This animal is very helpful to people in small, hilly, dry countries.

As well as having an important role in agriculture, goats can contribute significantly in improving the health of many, e.g. the infant suffering from allergy to mother's or cow's milk, and raise the standard of living as well as the economy.

GOAT PRODUCTS

The most important goat products are milk, cheese, butter, meat, mohair and leather. Meat from goats is called chevon. Usually wethers (castrated males) are used for meat about weaning time.

TERMINOLOGY

Caprine - Latin designation for goats.
Buck - male goat
Doe - (pronounced do) female goat
Buckling - young male
Doeling - young female
Kid - young goat
Kidding - birthing process

BREEDS

As to breeds of goats, the most prominent in America are:

Nubians - originate from the Near East and have large Pendulant ears and slightly Roman noses. They produce milk with the highest butterfat, about 4 to 5%. They come in various colors and patterns.

Alpine - are from the French-Swiss area. They have upright ears and come in various colors.

Oberhaslie - are from the alpines and are solid brown.

Saanen - are the largest bodied of the breeds and are nearly all white. They produce the most milk, with probably the lowest butterfat content, about 3%. They have upright ears.

Toggenburg - a Swiss breed with distinct and constant markings of gray and white. They have upright ears.

La Mancha - originated in Spain. Their outstanding feature is a real short ear. This breed comes in various colors and patterns. They are very docile and loveable animals and are good milkers.

Angora - are not classed as a dairy or meat producing goat, but are raised for their distinctive mohair. They are white, have upright ears, and their horns are left intact.

Pygmy Goat - are vey small and are sometimes used for their milk and/or meat. They are mainly raised as curiosities and as pets.

ORIGINATION AND NATURE OF GOATS

Goats originate from warm, dry desert areas and mountainous terrain. Goats can stand more heat than sheep. They have a strong dislike for being in water and are reluctant to feed in the rain, so they should have shelter for loafing and feeding.

STRESS

Goats are particularly affected by stress such as hauling, surgical operations, very hot weather, too much rain, shows and sales, etc. Stress will often trigger an attack of a disease or parasitism.

WATER

One must have a constant supply of clean, fresh water. Goats are very fastidious. Dirty water, strange tasting water, or water that is too warm or too cold can cause a lower water consumption which can contribute to certain diseases.

HERD HEALTH: Vaccinations, Worming and Supplements

Preventive medicine is the key. Particular attention should be paid to nutrition, housing, sanitation and vaccination. Since goats are the most aggressive of all farm animals and have the most strict social order, they need relatively more feeding space than other species of animals. They should have 1½ to 2 ft. per head for feeder space. "Social Order" is important. The shy animal can actually starve to death by being pushed away from its feed by the other goats.

RECOMMENDED SCHEDULE FOR WORMING, VACCINES, ETC. FOR GOATS

The annual series of treatments for a good preventive medicine program for goat-worming, (antihelminthics), vaccinations and supplements should be considered. The following schedule is recommended.

	Breeding, 4 weeks prior to	Kidding, 8 4 weeks prior	Kids weeks of age 1	2	6	10	12
Antihelminthics	D,B	D,B			K		
Chlamydia	D,B						
Clostridium D,C	D,B	Y D	K	K	K	K	
Coccidiostat (varies)			K				
Soremouth			K				
Tetanus toxoid		Y D		K	K		
Vitamins A, D	D,B	D,B			K		
Vitamin E, selenium	D,B	D,B		K			

D=does B=bucks Y=yearlings K=kids

Clostridium perfringens types C and D (overeating disease) and tetanus toxoid combination vaccine is available and may be used in place of just Clostridium C, D, using the same schedule. The 5- or 7-way clostridial vaccines may be necessary in some problem areas, but the cost is 5 to 6 times greater and vaccine reactions may be a problem when this cattle vaccine is used in goat.

Tetanus protection is essential at the time of disbudding. Does vaccinated by this program pass immunity through their colostrum to the kids. Kids fed cow's colostrum should receive Clostridium perfringens type C and D antitioxin and tetanus antitoxin at disbudding. Thereafter, kids may be put on the same vaccination program as recommended above.

Soremouth vaccine is used only on premises with recurrent infections. Vaccinated kids become contagious, so animals should not be sent to other herds until the scabs are gone. See "Soremouth" under Chapter XII.

The worming schedule recommended above is for animals maintained on dry lots. Those on irrigated pasture will require more frequent worming.

A coccidiostat for kids should be continued from 1 week of age until 2 to 4 weeks after weaning; the actual schedule will be determined by manufacturer's labeled recommendations.

Section 2

Normal Goat Physiological Data and Tables

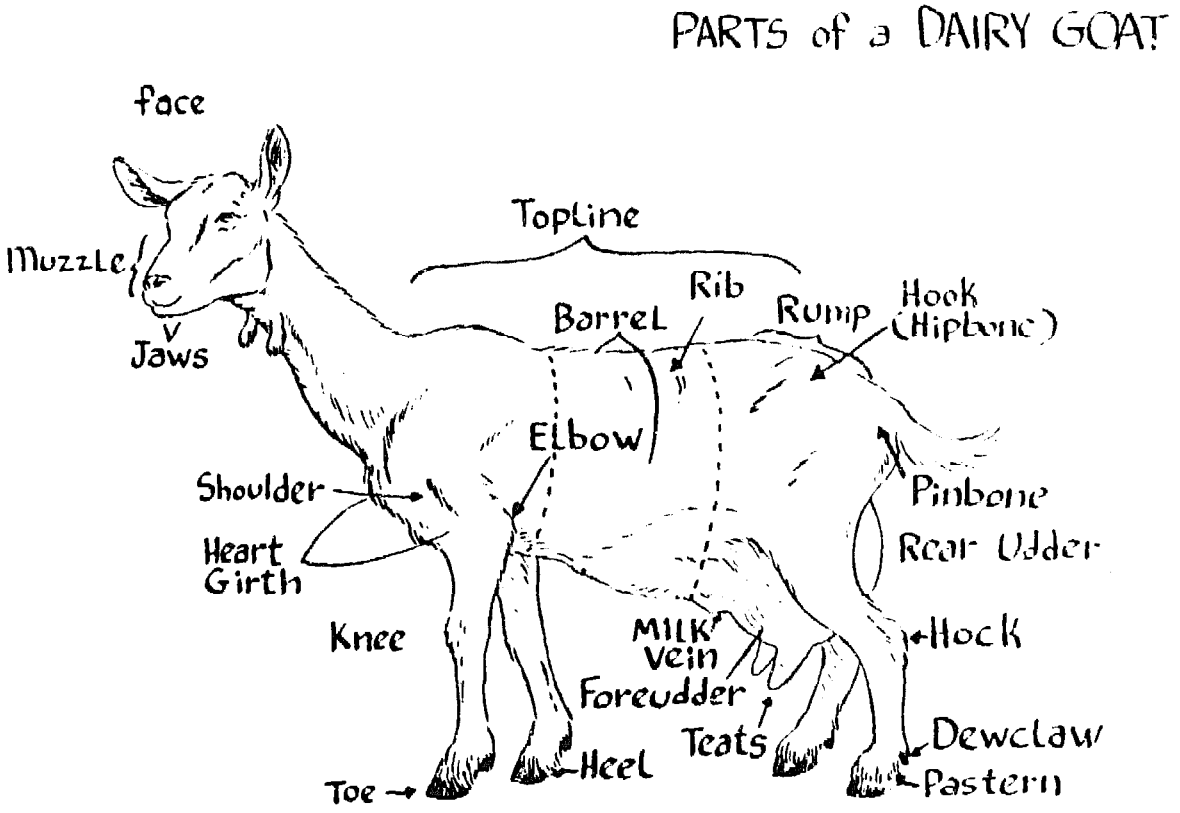

II. NORMAL GOAT PHYSIOLOGICAL DATA AND TABLES

Rectal temperature: 104 degrees + or - 1 f. 40 degrees C.
Heartbeat (pulse) rate: 70 to 80 per minute, faster for kids.
Respiration rate: 12 to 15 per minute, faster for kids
Rumen movements in and out: 1 to 1.5 per minute
Onset of heat when (estrus) first starts: 7 to 12 months of age, depending on nutritional regime.
Length of the heat period: 12 to 48 hours—average about 1 day.
Heat cycle (estrous cycle) (length of time between heat periods): 17 to 23 days—average 21 days.
Length of pregnancy (gestation): 148 to 156 days—average 150 days.

The total blood volume in the goat is 60 to 70 ml of blood per kilogram of body weight. If ⅓ of the blood volume is lost in a short time, shock ensues and death may result.

A. TEMPERATURE

Temperature Conversions=Rectal

	F	C
Subnormal	100.4	38.0
	101.3	38.5
	102.2	39.0
Normal*	103.1	39.5
	104.0	40.0
	104.9	40.5
Slight Fever	105.8	41.0
	106.7	41.5
High Fever	107.6 or higher	42.0

Conversion of Celsius to Fahrenheit: F=(x9/5)+32
Conversion of Fahrenheit to Celsius: C=(F-32)x5/9

*The body temperature is related to stress, exercise, and the environmental temperature. If the goat is excited, has been severely exercised, or if it is a very hot, humid day, let the animal calm down and retake the temperature.

B. GESTATION TABLE

(length of pregnancy average=150 days)

Breeding Date		Kidding Date		Breeding Date		Kidding Date	
January	1	May	30	July	5	December	1
	6	June	4		10		6
	11		9		15		11
	16		14		20		16
	21		19		25		21
	26		24		30	26	
	31		29	August	4		31
February	5	July	4		9	January	5
	10		9		14		10
	15		14		19		15
	20		19		24		20
	25		24		29		25
March	2		29	September	3		30
	7	August	3		8	February	4
	12		8		139		
	17		13		18		14
	22		18		23		19
	27		23		28		24
April	1		28	October	3	March	1
	6	September	2		8		6
	11		7		13		11
	16		12		1816		
	21		17		23		21
	26		22		28		26
May	1		27	November	2		31
	6	October	2		7	April	5
	11		7		12		10
	16		12		17		15
	21		17		22	20	
	26		22		27	25	
	31		27	December	2		30
June	5	November	1		7	May	5
	10		6		12		10
	15		11		17		15
	20		16		22		20
	25		21		27		25
	30		28		31		30

Source: Penn State University, Dairy Goat Correspondence Course No. 105

To estimate the weight of a goat, measure the goat around the heart girth (pull the tape lightly) and consult the following chart:

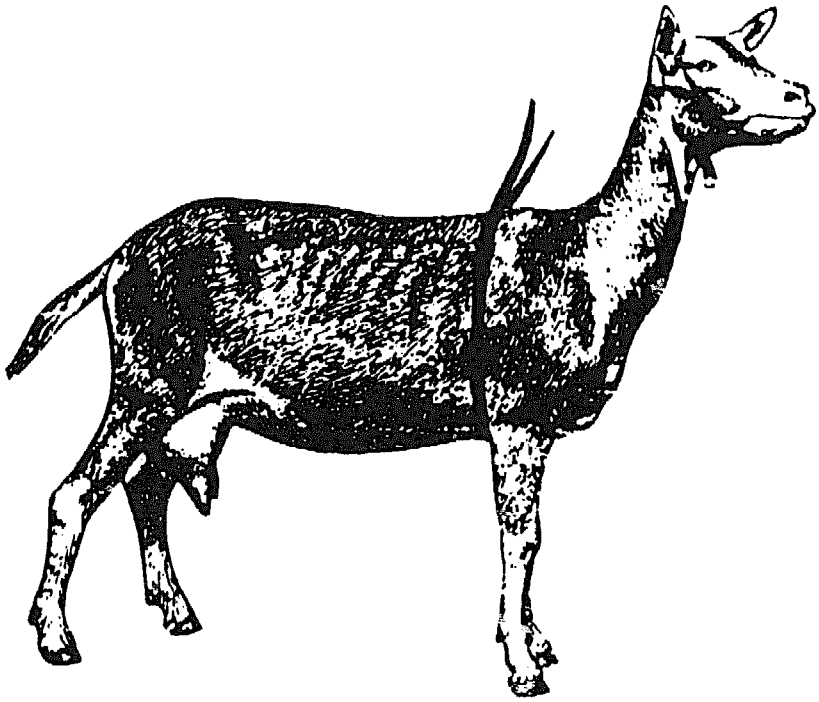

C. WEIGHT CHART

Inches	Centimeters	Pounds	Kg.
10¾	27.3	5½	2.27
11¼	28.8	5½	2.49
11¾	29.9	6	2.73
12¼	31.1	6½	2.95
12¾	32.4	7	3.17
13¼	33.7	8	3.63
13¾	34.9	9	4.08
14¼	36.2	10	4.54
14¾	37.5	11	4.99
15¼	38.7	12	5.44
15¾	40.0	13	5.90
16¼	41.3	15	6.40
16¾	42.7	17	7.71
17¼	43.8	19	8.62
17¾	45.1	21	9.52
18¼	46.4	23	10.43
18¾	47.6	25	11.34
19¼	48.9	27	12.24
19¾	50.2	29	13.15
20¼	51.4	31	14.06
20¾	52.7	33	14.97
21¼	53.9	35	15.87
21¾	55.3	37	16.78
22¼	56.5	39	17.69

22¾	57.8	42	19.05
23¼	59.1	45	20.41
23¾	60.3	48	21.77
24¼	61.6	51	23.13
24¾	62.9	54	24.49
25¼	64.1	57	25.85
25¾	65.4	60	27.21
26¼	66.7	63	28.57
26¾	66.7	66	29.93
27¼	69.2	69	31.29
27¾	70.5	72	32.65
28¼	71.7	75	34.01
28¾	73.0	78	35.37
29¼	74.3	81	36.73
29¾	75.6	84	38.10
30¼	76.8	87	39.46
30¾	78.0	90	40.82
31¼	79.4	93	42.18
31¾	80.7	97	44.00
32¼	81.9	101	45.80
32¾	83.2	105	47.62
33¼	84.5	110	49.89
33¾	85.7	115	52.15
34¼	87.0	120	54.42
34¾	88.3	125	56.69
35¼	89.5	130	58.96
35¾	90.6	135	61.22
36¼	92.1	140	63.49
36¾	93.4	145	65.76
37¼	94.6	150	68.08
37¾	95.9	155	70.29
38¼	97.2	160	74.83
38¾	98.4	165	77.10
39¼	99.7	170	79.37
39¾	101.0	175	81.63
40¼	102.2	180	83.90
40¾	103.5	185	86.17
41¼	104.8	190	87.30
41¾	106.1	195	88.44

Adapted from Ralston Purina Company

Section 3

Owners Examination for Sickness

III. OWNER'S EXAMINATION FOR SICKNESS

One should be able to recognize a sick goat in the early stages of a disease process.

Most diseases take from 3 to 5 days to cause death or spread to others.

Early diagnosis is essential.

It is helpful to use a notebook or clipboard to record all salient observations to aid in a proper diagnosis.

All goats should be observed at least daily.

Check for any animals that are lagging behind the herd, have a poor appetite, diarrhea, limping, breathing hard or fast, grunting, grinding of teeth, or other unusual behavior.

Examination Checklist (Make List)

1. Look at animal from a distance. Note the general condition and age of the goat. Can it stand and walk normally? Can it see (bumping into objects)? Does it exhibit signs of pain? Is it bloated? Are there swollen areas? Count respirations per minute (in and out).

2. Approach the animal. It should be held by an assistant by the neck or body. Do not run or fight goat to get excitable as will cause false temperature and respiration. The goat can be laid down on its side if it struggles.

3. Temperature. Shake down the thermometer. Insert into goat's rectum and leave for 1½ minutes.

4. Place your fingertips in front of left hip to feel rumen activity. It should move in and out about 1 to 1½ times per minute. If rumen sounds slushy, water-filled or distended with gas—note, could be bloat, or an overloaded rumen from overeating grain.

5. Place fingertips on both sides of lower rib cage to feel for heartbeat and heart rate. The pulse can also be detected inside the upper rear leg. Count for 1 minute.

6. Roll back eyelids and lips of mouth to observe color of mucous membrane. Pink is normal; white could indicate anemia (lack of adequate number of red blood cells). Check color inside the vulva. "Angry" red: high fever; a serious malady, possibly.

7. Straddle the animal and feel over goat's body for swellings or signs of pain.

8. Check for blindness. Move a hand toward the eye to detect blinking.

9. Note any unusual sounds, wheezing, coughing = respiratory problems. Grinding teeth or grunting = general body pain in the chest or abdomen.

10. Check all body openings to determine diarrhea, excessive salivation, or runny nose and whether clear or cloudy. Examine for crusty or runny eyes.

11. When examining a lactating (nursing) doe, always check the udder. Look for clots, or bloody or any off color abnormal milk. Feel for hard lumps, heat or signs of painful udder.

12. Detect any abnormal sounds of the abdomen and chest areas. A stethoscope should be used or place your ear against the goat's chest or abdomen.

13. Use the skin pinch test to determine roughly the degree of dehydration if the animal is very sick.

Skin ridge formed 5% = moderate

Skin ridge persists for length of time 10% = serious—will probably not live long

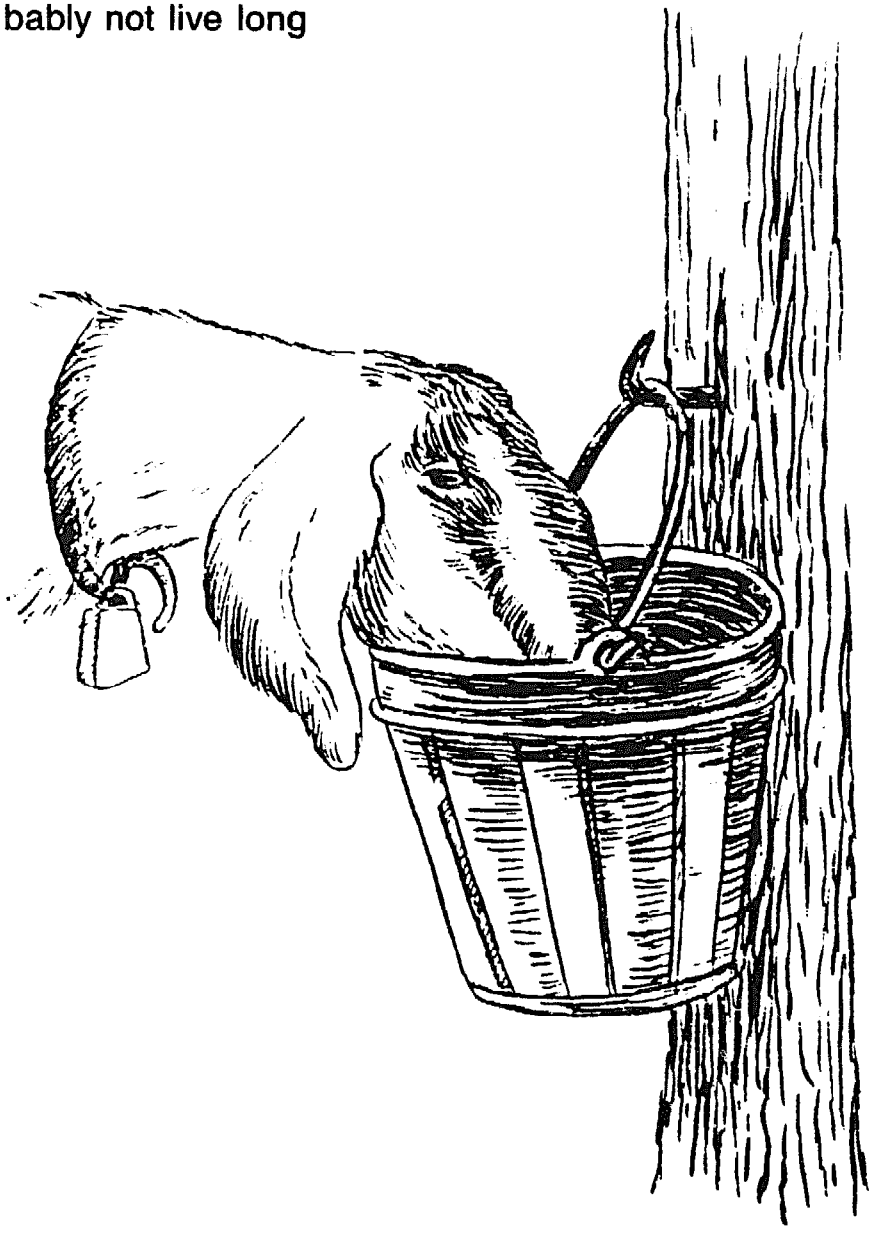

14. Condition of skin and hair coat is a good indicator of general health. Examine hair condition for roughness, lack of luster, hair ends split and turned up—"scroungy looking." This often is caused by parasitism. Sickness can be the cause also as well as mineral/vitamin deficiency.

15 Have animals been transported recently? How far and from where?

16. Condition of pasture. Were insecticides or herbicides used? If so, what and when?

17. What are feeding, grazing/browsing habits? Is there need for roughage in the diet?

18. Goats can have ear mites causing shaking of head.

19. Examine feet. Hooves should not be overgrown. Hooves will have a characteristic odor if have infection. This is known as foot rot.

20. Examine all joints by palpation (by feeling with your fingers).

21. Mammary glands (the udder or "bag")—examine for lumps and whether one side is warmer than other. Examine teats for patency (being open) in lactating (milking) animals, especially right after they give birth.

GOOD HEALTH PROGRAM

1. Good nutrition is essential. Hay and pasture and browse for forage, protein and energy supplements and plenty of fresh water.
2. Exercise.
3. Adequate internal and external parasite control.
4. An adequate vaccination program.
5. Daily observation.
6. Plentiful fresh water supply.
7. A supply of clean loose salt (course granulated) and minerals. Do not use salt blocks for goats; they will probably not get enough.

Section 4

Emergencies and Preventive Management

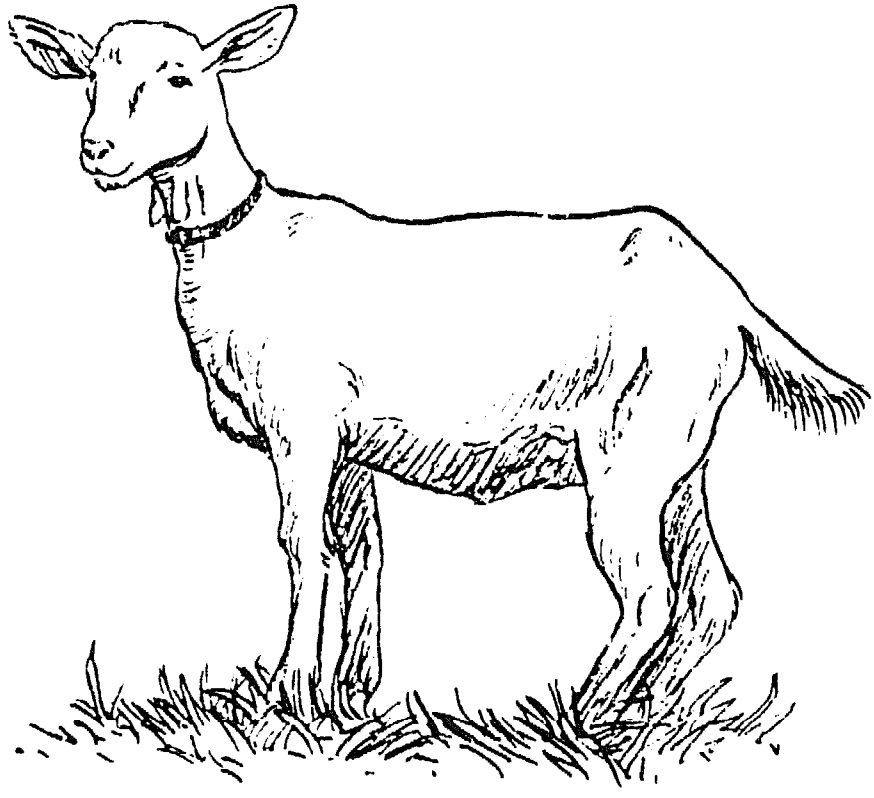

IV. EMERGENCIES AND PREVENTIVE MANAGEMENT

No matter how careful you are as a goat owner/breeder and how well managed your premises are, there will be veterinary emergency situations.

All of the items below should probably require veterinary assistance.

EMERGENCIES

a) Rectal temperature that is very high = 106 degrees F or very low and depressed temperature = 100 degrees F or less could mean impending death. If temperature is taken on a hot day with an animal that is struggling, it's temperature might conceivably be 106 degrees F. So must allow for this. Goats do not generally deal calmly with pain or stress.

b) Difficulty in breathing—open mouth, panting or difficult inhaling.

c) Wounds that penetrate a joint or tendon sheath. Immediate attention is necessary.

d) Eye infections or wounds that can cause permanent damage and blindness.

e) Shock. Typical signs are:

1] cold extremities, warm or cool body
2] pale mucous membranes, pale gums, white of the eye
3] rapid, weak heart beat and rate
4] loss of skin elasticity
5] subnormal body temperature, shivering
6] recumbent animal, too weak to get up
7] causes of shock frequently apparent; for example, watery diarrhea, severe hemorrhage, adverse reaction to a drug.

f) Birth of a very weak or premature kid that has become seriously chilled. Should provide a source of warmth. Place in warm water bath if its body temperature is below 96 degrees F, 36 degrees C, until normal temperature is restored, then dry thoroughly and quickly. Energy - give colostrum or milk.

g) Tremors, convulsions, coma. Use vitamin B_1 - ½ cc IM.

h) Bloat - Make a small incision through skin on the left side—above flank on the **left** side between the last rib and the hip. Insert the trocar through incision, on into paunch (rumen) by directing instrument toward the opposite (right) front foot. Remove the trocar, leaving metal sheath in place (in rumen) to allow the escape of the accumulated gas.

i) Uterine prolapse.

j) Wounds, especially that penetrate the chest or abdominal cavities. Cover completely and tightly. Veterinary assistance advised.

k) Difficult urination—straining, dribbling, blood tinged urine or complete absence of urine. Usually caused by urinary or bladder stones.

l) Nervous symptons, e.g., circling, sudden blindness, tilted head,

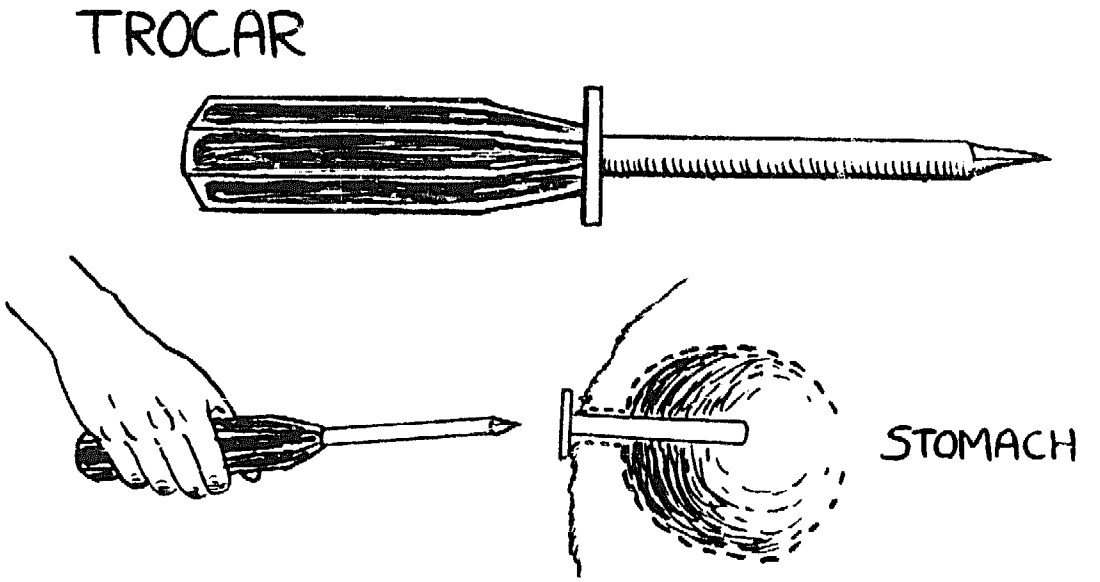

and "star gazing"—probably nervous system affected. Inject Vitamin B_1 - ½ to 1 cc IM.

m) Abdominal distress—grinding teeth, distended abdomen and kicking abdomen—offer water, no food.

n) Abnormal feces—absence of feces, changes in color and consistency, mucous or blood in feces, diarrhea which rapidly dehydrates the animal, especially the young. See previous pages on kid diarrhea.

o) Uncontrolled bleeding—employ a pressure bandage. Wrap the bleeding wound with bandage or any available cloth sufficiently tight to stop the hemorrhage.

p) Pinkeye—can be contagious. Remove any foreign body. Use and eye antibiotic, e.g., Tetracycline, Chloromycetin, etc.

q) Poisoning (See section on poisons below).

PREVENTIVE MANGEMENT

a) Keep all concentrates (grain, pellets, etc.) under lock! Goats are smart enough to open some latches. An overloaded stomach can cause death.

b) Use good, adequate fencing to prevent dog or wild animal attacks. Avoid barbed wire to prevenent lacerations or fractures.

c) Keep wire, pieces of metal or glass, etc., out of your goat pens and watch out for projecting nails or bolts.

d) Provide adequate space for each animal, especially when there are aggressive and dominant animals in your herd. This is important when there is an age or size difference in the herd.

e) It can be dangerous to pen goats with larger species of livestock, e.g., cattle or horse, even though some goats seem to keep horses company and vice versa.

f) Keep animal off roads. Honk your horn if you come upon any animal or bird in the roadway.

g) Avoid sudden changes in feed to prevent diarrhea.

h) Always provide a clean fresh source of water, especially during freezing weather.

i) It pays to regularly inspect your goat housing area and management practices for harmful details. Do not assume that everything is all right!

j) Keep poisonous plants and chemicals out of premises.

Section 5

Recommended Veterinary Medical Supplies and Equipment

V. RECOMMENDED VETERINARY MEDICAL SUPPLIES AND EQUIPMENT

1. Rectal thermometer (keep in cool or cold place).
2. Roll of absorbent cotton, adhesive tape and gauze pads, gauze rolls, Ace bandage and/or Vetrap.
3. Hypodermic syringes and needles.
4. Baking soda, magnesium sulfate (epsom salts), and mineral oil.
5. Antibiotics, e.g., Combiotic (Pfizer), Liquamycin LA 200 (Pfizer), Chloromycetin eye ointment, and an antibiotic, e.g., Neomycin or Sulfamethazine.
6. Antibacterial solutions, e.g, Betadine Solution and Betadine Scrub (a soap).
7. Scalpel (a surgical knife).
8. Epinephrine (Adrenalin).
9. Dexamethasone (Azium—a cortico—steroid)
10. Hoof shears.
11. Hoof knife.
12. Sulfa compounds for use in drinking water.
13. Trocar.
14. Thiamin Hydrochloride (Vitamin B_1) for neurological symptoms.
15. Cyanocobalamin (Vitamin B_{12}) - to improve appetite; to combat anemia.
16. Bo-SE-(Selenium-Vitamin E combination).
17. The Merck Veterinary Manual. Published by: Merck and Co., Inc., Rahway, N.J., USA.

Note: See Appendix I—Listing of Pharmaceutical Companies.

Section 6

Poisons

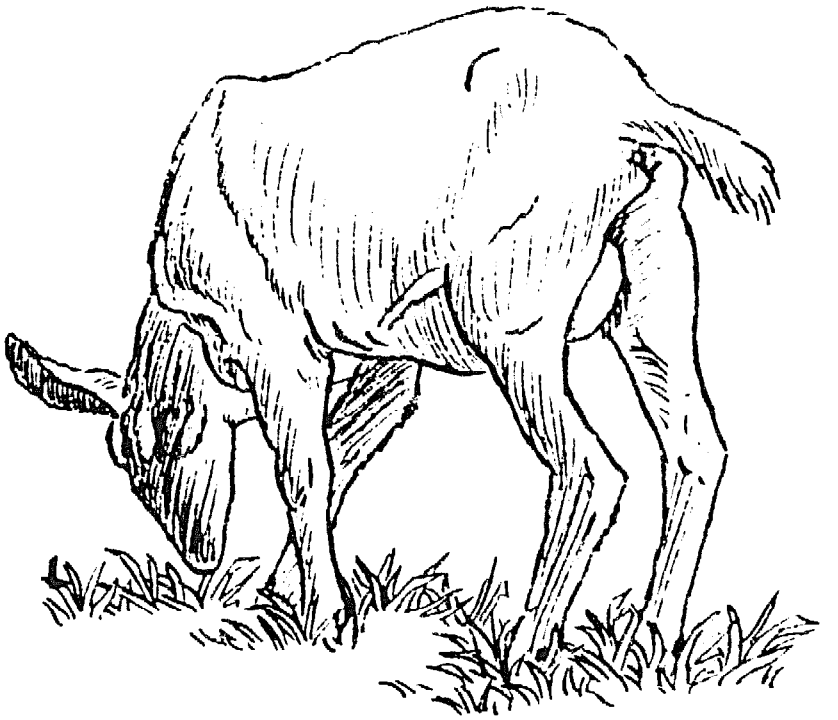

VI. POISONS

PLANTS

Goats are browsers and tolerate more bitter-tasting plants than will other species. The natural behavior of the wild goat, eating only those plants chosen by the doe leader, results in few plant poisonings. Kids raised away from the herd will not learn this protective behavior. The backyard goat, especially one confined in a small wooded area or allowed into the flower garden, is at risk. Goats lacking salt or natural browse may be more apt to eat deadly plants. Also to be avoided is the practice of discarding garden or hedge clippings within reach of the inquisitive goat. The best way to protect a goat from a tree or vice versa is to wrap chicken wire two or three times around the trunk to a height of 6 feet. The wire will need to be adjusted every 5 years or so as the tree grows.

GENERAL RULE: Animals generally will not eat poisonous plants if there is plenty of grazing and forage available to them.

The following is a partial list of plants known or suspected to be poisonous to goats:

Belladonna—Atropa (Deadly Nightshade)—has killed goats; incoordination, convulsions, loss of function of stomach.

Buttercup—Ranunculus—reported in goats; oral tissues fiery red. Salivation, diarrhea, abdominal pain.

Castor beans and plant.

Cocklebur—Xanthium—seed leaves contain hydroquinone; vomit, depression, heavy breathing, unsteady gait, head thrown back and rigid.

Cyanide Poisoning—Johnson grass/Sudan grass/sorghum—new growth after damage to the plant, e.g., freezing and drought or herbicide application (less than 1 foot high) produces HCN, (hydrocyanic acid), a very quick acting poison also known as prussic acid. Symptoms: respiratory distress, blue mucous membranes, muscle tremors, convulsions, death. Animal's tissues are usually bright red.

Locoweed—Astragalus—loco reported in goats results in loss of condition, staggering, ataxia, constipation.

Milkweed.

Oak—Quercus—acorns or buds contain tannins. Symptoms: abdominal distress, gaunt, weak, constipation or diarrhea. Large numbers of acorns will poison goats quite readily.

Oleander—all parts of the plant are toxic and there is no treatment.

Poison Hemlock—Conium—reported in goats; nervousness, trembling, staggering, weak pulse, cold extremities, coma, death.

Poison oak—goats and cattle eat and relish poison oak without any ill effects. It seems that the milk from such a doe is perfectly okay to use.

Potato parings—Poisonous principal = solanin. Nervous or

digestive disorder, diarrhea, paralysis, dyspnea, weak pulse, death.

Rhododendron, Mountain laurel—Kalmia—froth, vomit, depression, stagger, colic, grind teeth.

Rhubard—Rheum—oxalates in blade toxic to all classes of livestock; danger if leaves thrown to animals. Treat with fluids and calcium.

Water Hemlock—Cicuta—"all livestock" - roots and shoots, especially in spring when loose in ground; frothing at mouth, violent convulsions, death.

Plants Which Cause Photosensitivity—(reaction to sunlight). The important plants involved in this group are buckwheat, alsike clover, rape, St. John's wort, and to a lesser extent, ladino and white clover. With the exception of St. John's wort, all of the plants are quite palatable and nutritious. White-skinned animals eating enough of these plants (those that produce lush growth in ideal weather are the worst) in bright sunny weather develop anything from sunburn to severe slouching of the white-skinned areas.

There are three basic requirements for development of photosensitivity when goats eat these plants: the animals must have white skin, the animals must eat a minimum quantity of the plants, and they must be exposed to bright sunlight for at least one-half day all at the same time.

CHEMICAL AND MINERAL

Arsenic—insecticides and weed-killers are the major sources. Signs are usually severe gastroenteritis (inflammation of stomach and intestines) and abdominal pain, fetid diarrhea and death.

Chlorinated Hydrocarbons—Benzene hexachloride group; includes lindane, dieldrin, chlordane. These chemicals are found in the meat and excreted in the milk for a long time after exposure. Young goats are quite susceptible; a .15% dip twice at 4 day intervals has been reported to kill; more than .3% is toxic to adult goats. Young, emaciated (thin), or lactating (milking) animals are more susceptible. Signs usually appear within 24 hours and include neuromuscular (nerve and muscle) disorders; apprehension, hypersensitivity, blepharospasm (twitching of the eyelids), muscle faciculations (trembling movement), and spasms, increased salivation and chewing movements, convulsions and death due to respiratory failure (failure of lung function). Sometimes severe depression is noted instead. Wash with cold water to remove further toxin from the skin and then lower the body temperature (if convulsing).

Haloxon—in sheep and cattle posterior paralysis may appear suddenly or several weeks after worming.

Lead—sources include paint cans, licking painted boards, car batteries, used car oil and certain automotive lubricants, and boiled linseed oil. Poisoning is rare in goats, which are much more resistant to lead than are cattle. Symptoms: Loss of appetite, dullness, diarrhea or constipation.

Organophosphates—used for external and internal parasite control in various animal species. Signs of toxicity are salivation and excessive tears, open-mouth breathing, protrusion of tongue, colic, abdominal pain, pupillary (closing down of the eyes) constriction, stiffness, staggering gait, bloat, and death due to respiratory failure. Toxic compounds include trithion, diazinon, coumaphos (Co-Ral), fenthion, malathion, and Ronnel (fenchlorphos). 100 mg/kg is the maximum safe oral dose of fenchlorphos in goats.

Phenothiazine—may cause abortion. Red colored milk and urine may result.

Ethylene glycol (Prestone)—antifreeze draining from automobile radiator. Animals will drink because it is sweet. Causes irreparable damage to the kidneys and then death.

Salt—poisoning may occur if animals eat too much because they were previously deprived of salt or if they drink saline water. Signs are thrist, salivation, and GI (stomach and intestinal) disturbance.

OTHER

Allergies—Caused by insect or spider stings, injections, or applications of certain medications to the skin.

Snake bites—venom (poison) will cause an extensive swelling of surrounding tissue.

As with all species, prevention of poisons is essential. Remove any remaining poison, prevent further absorption; wash if on surface.

Section 7

Digestive System

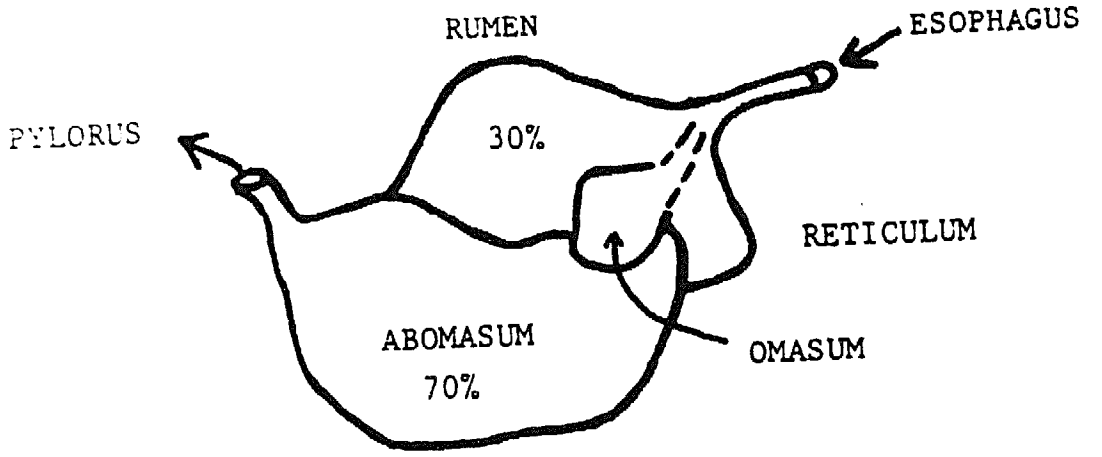

GOAT KID

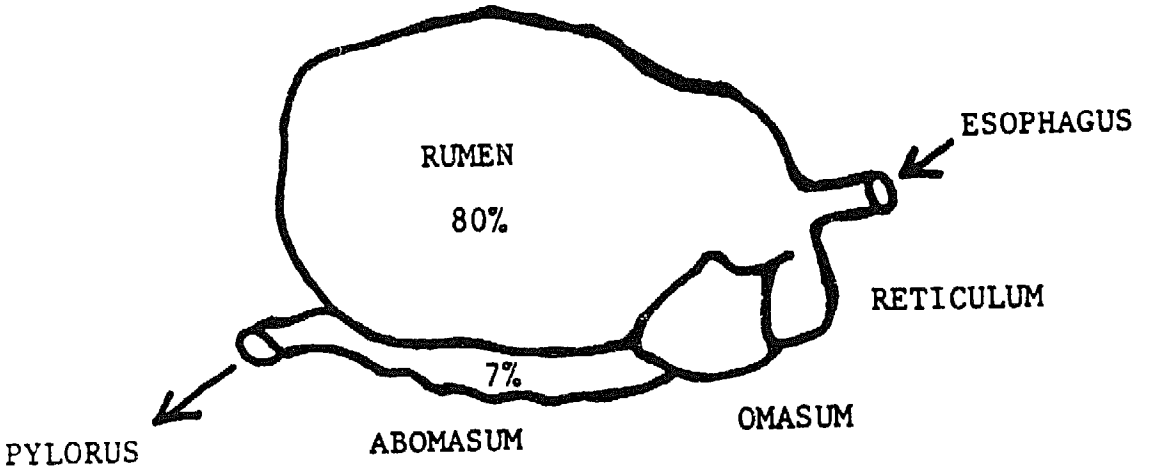

ADULT GOAT

The four stomach compartments of young and adult goats, showing relative changes in dimensions from pre-ruminant to ruminant status. Drawing courtesy of D. L. Ace, Pennsylvania State University.

VII. DIGESTIVE SYSTEM

A Brief Anatomy and Physiology of the Gastrointestinal (G.I.) Tract of the Ruminant

The small ruminants, goats and sheep, are like the cow in that they have four stomachs; the rumen or paunch, reticulum, omasum, and abomasum. The foundation for good goat feeding is an understanding of rumen function.

The first stomach, or rumen, where microorganism digestion takes place, is virtually a large fermentation vat with a capacity of 3 to 5 gallons, where the ground or chewed up hay and grain with water is attacked by billions of beneficial bacteria and protozoa. These "bugs" break down the tough plant fibers so they can be digested, and also manufacture all the vitamins except vitamin A and possibly vitamin E. They also make a number of the amino acids—the precursors, beginners of the formation, of protein—for the animal.

Gas is formed in the rumen constantly, so the animal must belch about every 20 minutes. If not, it will bloat, fill up with gas, and die by suffocation in about ½ to 1 hour. The animal obtains vitamin A from green plants or hay and it is stored in the liver for a 3- to 6-month period.

Herbivores (plant-eating animals) manufacture copious amounts of saliva, enabling them to swallow and digest dry grasses and foliage. (A cow can produce 2 to 3 gallons of saliva per day). Goats and sheep chew their cud while resting—regurgitating a small amount of ingesta from the first stomach, chewing it 30 to 40 times, then swallowing. The cud travels into the second stomach, the reticulum, where it is mixed with juices and macerated, and ground up (this is the "honey comb" stomach). Food then travels into and through the third stomach, the omasum "manyplies" where it is further macerated and ground up still finer. Then into the fourth stomach, the abomasum—or the true stomach—which is shaped much like ours. This is where much of the enzyme digestion takes place before passing on into the small and large intestines for additional digestion. Nutrients are picked up by the bloodstream all along the GI tract, mostly the intestines.

When a ruminant fails to chew its cud, it is usually a sign that peristalsis (movement) of the GI (stomach-intestinal) tract has ceased. All food, but not water, should be withheld until this condition has been rectified. Many animals can be simply cured this way. After animal again becomes hungry, then hay and concentrates should be added back gradually in small increments over the next 2 or 3 days, resuming the normal ration.

In normal peristalsis, put your ear to left side of abdomen of animal, over the rumen, and you should hear bubbling, gurgling sounds in-

side. If impacted, there is very little or no sound.

Rumen stimulation:

1. Torumen—a dried yeast powder
2. Acidophilus bacteria in an oral paste
3. The cud material can be transferred to another animal by reaching into the mouth of a healthy ruminating animal and retrieving the mass. Dilute with water and drench a sick animal with this.

The digestive system of goats and all other ruminants is designed physiologically to handle forages with a minimum of grain, fruits, etc. Too many dairy goat owners feed their animals diets which would be more appropriate for pigs—too much grain and not enough forage.

A kid or lamb won't start chewing its cud until its rumen develops—as soon as they start eating hay. They are really a monogastric animal at birth. Goats of any age will eat more feed and waste less if they are fed small quantities at frequent intervals.

DIGESTION

Goats are fastidious eaters and can distinguish bitter, salt, sweet, and sour. They have a higher threshold for bitter than cows, but probably lower than camels. They have a pronounced sweet taste. They reject salt at concentration of 5 gm/100 ml. Goats do more browsing than other ruminants; they may spend 46% of the day eating and may cover 6 miles per day while foraging. They tend to strip a pasture. Goats eat more species of plants than do sheep. Goats eat to keep warm and stop eating to prevent hypertoxemia (overeating)

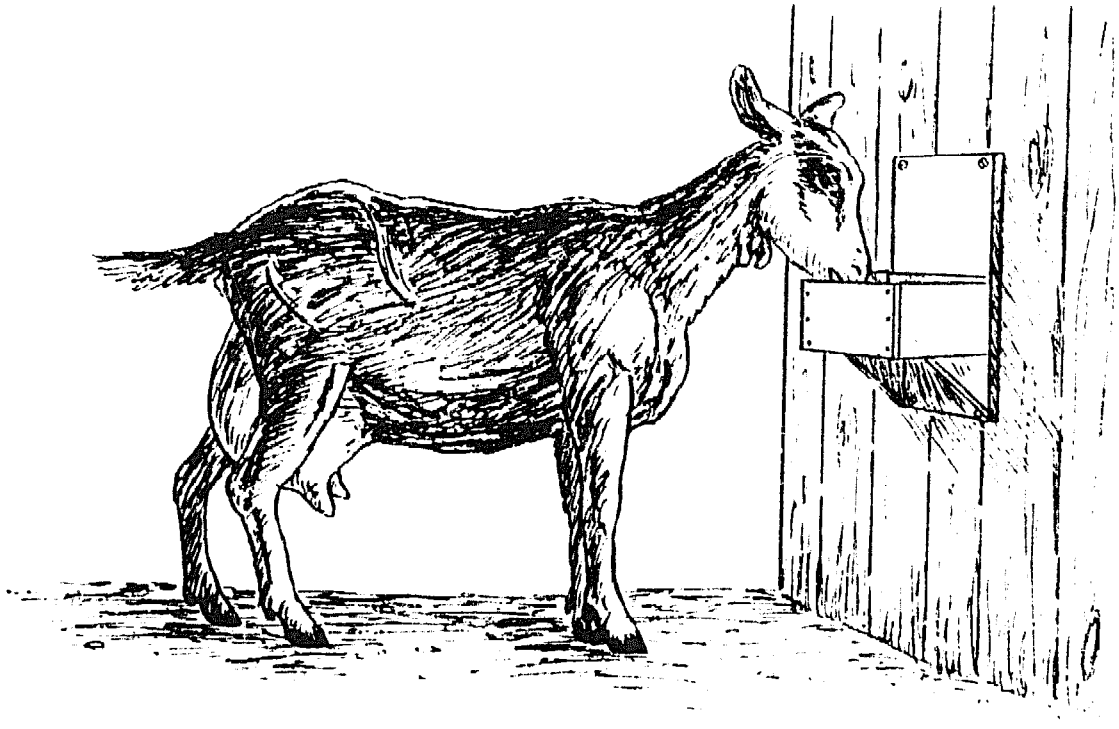

FEEDING

The goat is related to the deer. Since it is a browser rather than a grazer, it would rather reach up than down for food. The goat also craves variety. Coupled with this is the goat's natural curiosity and nothing is safe from at least a trial taste.

Anything hanging, like clothes on the line, is just too much for a goat's natural instinct. Rose bushes and pine trees are high in vitamin C and goats love them. Leaves, branches, and bark of young trees are a natural part of the goat's diet. Their digestive tract is especially adapted to consuming leaves and brush and will do better if allowed access while feeding hay and grain.

Allow goats to graze or browse in the pasture for 8 hours per day. If you have no fenced pasture, tether in grassy places. Use of "zero" pasture management is very workable and recommended. See under Chapter X.

Feed concentrates for readily available source of energy and protein. They especially need this if they are young and growing, or if they are milking does, or for bucks that are breeding, or if you want to fatten wethers for butchering.

Provide a salt supply. Keep it clean, as goats are fastidious and won't like dirty salt. Salt blocks for licking will do, but animals can get more salt if in granular form.

Section 8

Nutrition

VIII. NUTRITION

Note: The differentiation between concentrates (cereal grains for the most part) and roughages (hay, pasture, and browse) must be understood. Roughages consist of the entire plant and are higher in fiber than concentrates.

ESSENTIALS FOR A BALANCED AND PALATABLE RATION

1. Storage and age of forage: goats steadfastly refuse to eat must or dusty hay. Such hay usually contains a tremendous amount of mold. Most molds in hay, if not downright toxic, are an irritant to the digestive tract or the respiratory tract when ingested.

2. Quality of protein: Good hay—alfalfa hay. Three or four different kinds of grain. A wide variety is advisable.

3. Palatability: Feeds must be well liked. Should be from a variety of sources—3 to 7 different plant sources. Forage intake can often be greatly improved in goats being fed the best of hays if some supplementary green forage is fed at least once daily. Hand harvested green legumes, surplus vegetables from the garden, surplus fruits like apples or pears, comfrey, turnips, pumpkins, etc. are welcome additions to the daily diet as they apparently improve digestion and appetite for the stable diet.

4. Minerals: Calcium and phosphorus are the two essentials—"Ca" and "P". Ca from legume hays, e.g., alfalfa. P from wheat bran and oil meals. All livestock need salt, preferably loose, instead of blocks.

5. Essential vitamins: Vitamins A and D are most imporant for livestock. Vitamin A from green grass and hay—the brighter the better. Old alfalfa hay or sun damaged—depleted of vitamin A. Vitamin D supplied by the sun curing of hay and exposure of animal's skin to sunlight.

6. Bulkiness or fiber: Roughage is essential for all ruminants. Grain mixture should not be out of proportion to the roughage. Half or more of the diet should be roughage. About 30% concentrates (grain) is desirable. A goat may eat as much as 11% of her body weight as dry matter per day. Five to eight pounds dry matter per 100 lbs body weight per day is a common capacity. Increased fiber is necessary in cold weather to maintain body temperature. Too little fiber predisposes to entertoxemia. Clostridium perfringens organisms are always present in the digestive tract, but rapid overgrowth and toxin (poison) production occurs with high grain feeding or sudden changes in diet. Goats that suddenly engorge on grain are also prone to toxic indigestion, with severe metabolic acidosis (acidic condition of the system), dehydration, and a splashy (fluid present) in rument. Vigorous fluid and electrolyte (chemicals of the body) replace-

ment will be needed to save these animals. Dry matter must be adequate. Animals can graze on succulent new growth grass and actually lose weight because of the high water content.

7. Variety: Goats prefer many more species of plants than sheep or cows. They like elm, ash, hazel, willow and oak; also briars, ivy, pigweed, thistles, nettles, dock, mulberry leaves and bananas. Browsing habits result in a higher mineral uptake because the species eaten have deeper roots than do grasses. Variety improves palatability. There are many good forage crops in addition to alfalfa, such as peavine, lespedeza, improved bermuda, clover, timothy, etc.

8. Right amount for mature goat: A mature goat will require anywhere from three to ten pounds of hay per day depending on type, quality, waste, and other factors. Give grain according to amount of milk produced. For lactating (milking) animals, the protein content of the concentrate ration should be about 16% of the roughage. With less protein in hay, more must be added to the concentrate. For dry does, 12% protein is sufficient. The watchfulness by the herdsman is essential. General Rule: Whatever each animal can clean up in 15 minutes is about right.

RATION CHART

Ration for a milking doe fed good alfalfa hay.
12.6% digestible protein.

Corn	31 pounds
Oats	25
Wheat bran	11
Linseed oil meal	22
Cane molasses	10
Salt	1

Ration for milking a doe fed good alfalfa hay.
12.6% digestible protein.

Barley	40 pounds
Oats	28
Whaeat bran	10
Soybean oil meal	11
Cane molasses	10
Salt	1

Ration for a milking doe fed non-legume hay.
21.2% digestible protein.

Corn	11 pounds
Oats	10
Wheat bran	10
Corn gluten feed	30
Soybean oil meal	24
Cane molasses	10
Salt	1

Ration for a milking doe fed non-legume hay.
21.2% digestible protein

Barley	25 pounds
Wheat bran	10
Soybean oil meal	25
Linseed oil meal	15
Salt	1

Ration for dry does and bucks.
9.6% digestible protein.

Corn	58 pounds
Oats	25
Wheat bran	11
Soybean oil meal	5
Salt	1

Ration for dry does and bucks.
10.1% digestible protein.

Barley or wheat	51½ pounds
Oats	35
Wheat bran	12½
Salt	1

9. Succulents: Greater production and condition are gained from succulent feeds throughout year. Root crops are good for goats, especially beets, turnips, cabbages, and carrots.

10. Water

a. Water is the most important of all feeds for animals. It is impossible to have production efficiency and healthy animals where water quality is poor. Production in low-producing, poor reproducing, health-problem dairy herds is often improved tremendously by providing a new or better source of water. Goats are more fussy about fouled water than any other animal. Slightly fouled water can reduce water intake tremendously and correspondingly cut milk production.

b. Water and shade are necessary. Place water troughs near and around goat sheds and pens. Hard water (high calcium, low phosphorus) may cause an increase in male infertility. Warming the water has been advised if feeding much concentrate. A dry diet with restricted water supply will fatten a goat. Adding salt to the water or the diet will increase the milk yield, but should only be done if the goats are too fat. Some breeders feed molasses water to the goats: ½ cup molasses in 12 quarts water is given routinely for its tonic effect. Molasses also helps to prevent ketosis (a disease in which the body burns up its own fat).

c. Every encouragement should be given to lactating (milking) goat to drink large quantities of water. Milk is more than 85% water, so must have water for adequate milk supply.

11. Metabolic (functions of the body) cycle: A sudden drop in milk yield and appetite occurs naturally in the fall. The production decreases to less than two quarts and the goat gains weight when the appetite again increases. A dry, high fiber diet is needed at this time. Does vary in production while cycling, and another decline occurs after the breeding season. Keep the goats thin during the first half of gestation, then increase feed as the fetus grows rapidly. Restricted water, a dry diet, and irregular milking will help to dry off a goat that doesn't do so by herself. Increase feed to last 8 weeks ("steaming up") to avoid pregnancy toxemia (poisons in the blood). Introduce moist feed the last few days before kidding and return to a drier diet 3-4 days after kidding. A good milker will lose weight the first 4 months of lactation. A common problem is overfeeding grain to does in late lactation. Goats store fat preferentially in the abdominal cavity and by the time fat is grossly obvious, the internal deposits are subtantial.This can lead to problems at kidding and to pregnancy toxemia.

12. Cost: A grain mix which will furnish the most digestible nutrients and the most protein per dollar to balance the roughage will be the most economical.

A dry or pregnant doe will usually consume 1½ pounds grainfeed daily.

It is generally considered that 6 to 8 goats can be kept on the feed required for 1 cow.

Generally 500 pounds of hay and 450 pounds of grain are required for each mature goat per year.

If a doe does not receive sufficient Ca) (calcium) and P (phosphorus) in her ration while pregnant, these elements will be drawn from her bones and teeth in favor of the developing fetus.

Dry does—should be fed free choice hays—½ high quality oat hay and ½ high quality alfalfa with 1 lb of grain per day. If very fat, reduce to ½ lb grain and cut down the alfalfa.

Milking does—(refer to the table above) feed ½ lb of grain per pound of milk. Increase the grain up to ¾ lb as long as production increases, then back off the grain when milk production reaches a peak. By the fifth month of lactation, as little as 1 lb of grain to 4 to 5 lbs of milk may be fed. Expect does to lose weight during lactation. Pelleted feeds do not decrease butterfat content in goat's milk as they do in cattle.

OVERVIEW OF MINERALS

Seven major mineral elements are required by the mamallian body and constitute 60 to 80% of all inorganic matter in the body. These are calcium, magnesium, sodium, potassium, phosphorus, sulfur, and chlorine. These chemicals constitute what is known as electrolytes and are measured in milligrams per ml or lbs. One begins to see why electrolytes in the blood and cells are so important to maintain at the correct level.

Trace mineral elements are also found in the body and in extremely small amounts. They are very essential and are measured in ppm (parts per million). At least eight of these are iron, copper, iodine, manganese, cobalt, zinc, molybdenum, and selenium, and are especially important for good fertility.

Some "newer" mineral elements and their body requirements:

Chromium (Ci) = < 0.1 ppm
Nickel (Ni) = .03 to 3.0 ppm
Vanadium (V) = 0.1 ppm
Tin (Sn) = 1.5 to 2 ppm
Flourine (F) = 2.5 ppm
Silicon (Si) = 5 to 100 ppm

The microflora (plant life) and microfauna (animal life) of the goat rumen action initiate the breakdown of feedstuffs, especially the weedy portion.

With carbohydrates—grasses, hay, etc., cellulose (fiber) is further broken down into glucose by cellulose enzymes.

"Pica" = depraved appetite. Caused by deficiency of minerals and feed. Symptoms: chewing sticks, bones, stones, etc., loss of flesh, rough hair coat, or stiffness of body. Treatment: Make sure the ration contains the essential minerals, carbohydrates (corn, barley, wheat)

and proteins (oil meals made from cotton seeds, flax seed, soybeans, etc.).

MINERALS PROPORATION

The calcium-phosphorus ratio is very important in nutrition. Dry does and bucks require a 1.5 to 1 ratio and lactating does require a 2 to 1 ratio.

Alfalfa hay often has a Ca:P of 5:1. This results in articular (joint) Ca deposits—especially manifested in bucks that have Ca deposits in their joints. Does are not affected as much as they seem to eliminate Ca in their milk.

Prevention: Mix oat hay and grains to balance out the ration.

Symptoms of Calcium deficieny:

1. "Milk fever" (paralysis).
2. Nerves are affected.
3. Bone structure is impaired.

Symptoms of Phosphorous deficiency:

1. Tendency to produce offspring only every other year.
2. Reduced milk production—a shorter milking period.
3. Bone disease manifestation and deformities.
4. Dental problems.

POSSIBLE MINERAL MIXES THAT MIGHT BE PREPARED LOCALLY:

Mix No. 1—Equal parts—ground limestone (or oyster shell)
—steamed bone meal
—traced mineralized salt (or iodized salt)

Mix No. 2.—Equal parts—ground limestone (or oyster shell)
—DiCalcium phosphate
—trace mineralized salt (or iodized salt

Mix No. 3—Equal parts—ground limestone (or oyster shell)
—Deflourinated Rock Phosphate
—trace mineralized salt (or iodized salt)

Mix No. 4—Equal parts—steamed bone meal or DiCalcium phosphate
—trace mineralized salt

TRACE ELEMENTS

Iodine (I) deficiency—Availability is dependent on soil content, being highest in soils that hold moisture well, such as peats, clays, and humus-rich soils. Seaweed meal is high in iodine, or iodized salt may be fed. A milliliter of tincture of iodine painted on the skin of the nursing doe once a week will prevent goiters in the kids, but would not be necessary with an appropriate diet.

TRACE ELEMENTS DEFICIENCIES

Iodine. Absolutely essential for body functions in trace amounts for all animals and humans. Necessary for the manufacturing of thyroxine by the thyroid gland.

Symptoms of a deficiency:

1. Enlarged neck—thyroid gland
2. Kids born hairless or covered with small, fine hair.
3. Kids covered with thick, scaly skin.
4. Kids stillborn.

Treatment: See under text above on "Iodine Deficiency".

Iron (Fe) deficiency does not seem to be a problem with goats and sheep.

Salt. Be sure that salt is available for goats at all times. Use loose salt, as goats usually don't like the trace mineral blocks. The salt must be kept clean because goats, being so fastidious, will refuse it if dirty. Adult goats will eat about 10 grams of salt per day.

VITAMIN DEFICIENCIES

Hypovitaminosis A (lower than normal) = a deficiency of vitamin A.

Treatment: Green pasture or forage. Vitamin A injections. Vitamin deficiences are sometimes a problem in marginal quality. Forage areas and multivitamin injections are especially valuable to sick and weak animals.

Selenium (Se) and vitamin E (T): SeT = selenium tocopherol (tocopherol) is the chemical name for vitamin E). SeT deficiency syndrome. Until recently, little information as to the importance of Se and T has been known. Now they are known as essential elements. In soils, selenium (a metal and one of the elements) is often in short supply, so crops and grass are often deficient. This situation is widespread in most livestock producing areas. Selenium and vitamin E are absolutely essential for maintaining healthy livestock.

MISCELLANEOUS OBSERVATIONS ON NUTRITION

Overstocking and overgrazing pastures lead to serious health problems:

1. Animals not able to obtain enought TDN (Total Digestible Nutrients).
2. Leads to severe intestinal parasite problems.
3. Especially harmful to the growth of good pasture grasses.
4. Causes extensive soil erosion.

Anorexia—loss of appetite.

Treatment: 1. Inject vitamin B 12 intramuscularly 2 or 3 times per week, using about ½ ml. IM.

2. There is currently acidophilus (beneficial) bacteria available in the form of a paste and is given orally, or use soured milk.

Section 9

Housing and Fencing

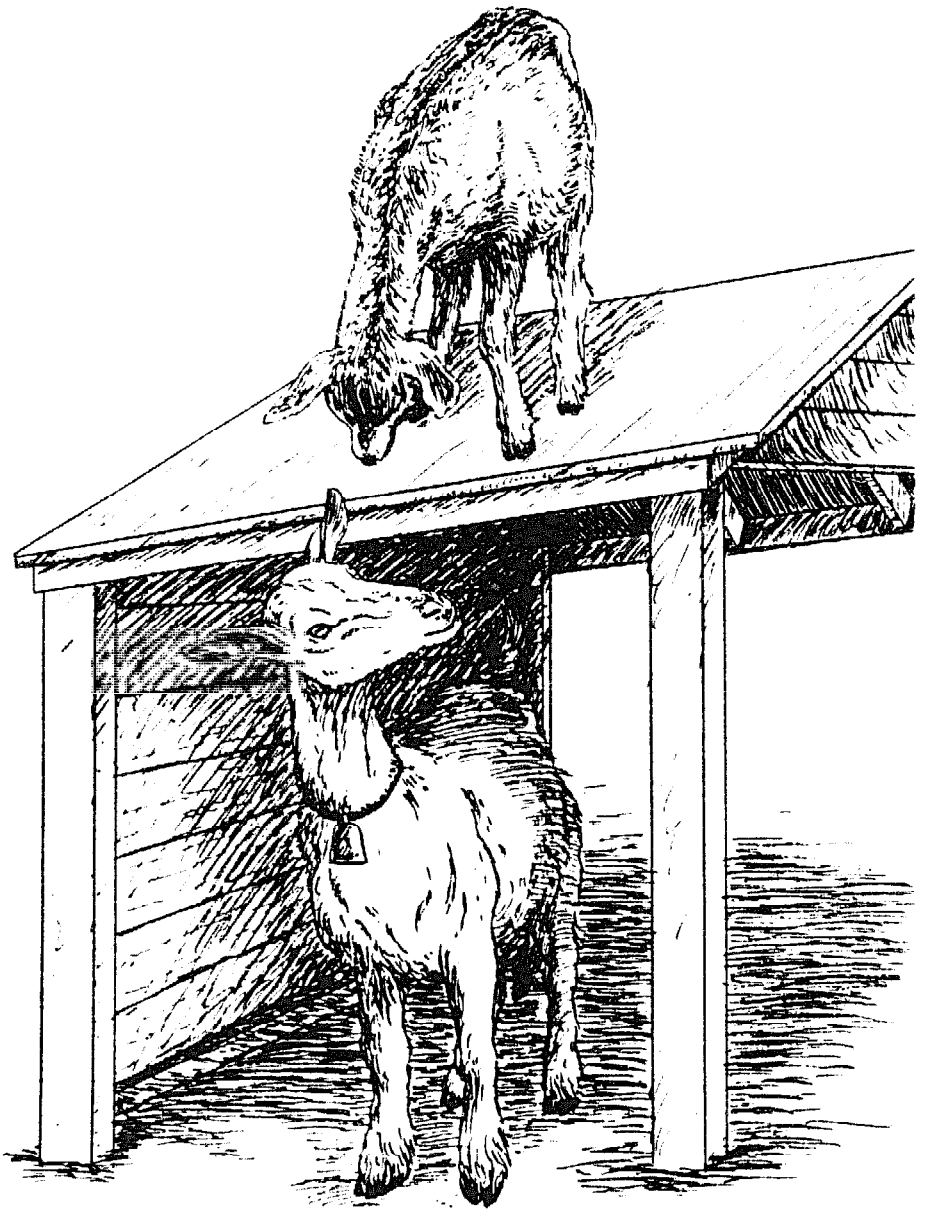

IX. HOUSING AND FENCING

The majority of goats in this country are managed much the same as dairy cows. They require milking twice daily and usual length of lactation of 305 days. This allows a 60-day dry period for the doe to replenish her body stores of nutrients before the next lactation. When a doe kids, or "fresheris," it is common practice to remove the kids and raise them separately from their mothers.

Goats require protection from the elements. The shelter provided need not be elaborate but it must keep the animals clean and dry and away from drafts. Many older buildings can be adapted to cut costs. During the summer months, it is important to provide a shady area with adequate air circulation for the goats and to control flies.

Adequate space is essential for housing dairy goats to prevent aggressive does from monopolizing feed bunks and limiting production of timid does. Each doe should have 15 square feet.

Feeders should be designed to discourage animals from wasting feed and to prevent feed from being contaminated with manure. Provide enough space for all animals to eat at one time. Outside, each doe should have at least 30 square feet of drylot for exercise area if pasture is not available.

There are two main methods of housing dairy goats: (1) shed type or loose housing and (2) tie stalls or individual confinement. Some use a combination system, stalls for milking does and loose housing for the yearlings and kids.

LOOSE HOUSING

Also called Zero Pasture Management. This has many advantages and some disadvantages. These may be summarized as follows:

Advantages:

1. Exercise resulting from the freedom is desirable.
2. Daily handling of manure is minimal or possibly eliminated, especially when slat floors are used.
3. Manure pack, when kept dry, provides heat and comfort.

Disadvantages:

1. Boss goats, especially when horned, may cause injury.
2. There will be much riding when a doe is in heat.

The floor should be bedded regularly with dry straw, wood shavings or ground corn cobs to absorb moisture. Feeding stanchions can serve as one side of the building. Stanchions permit one to control intake of feed.

Goats are able to unlatch many types of latches, so must be secured properly.

CONFINEMENT HOUSING

This allows goats to be cared for so they do not become a nuisance by destroying gardens and trees.

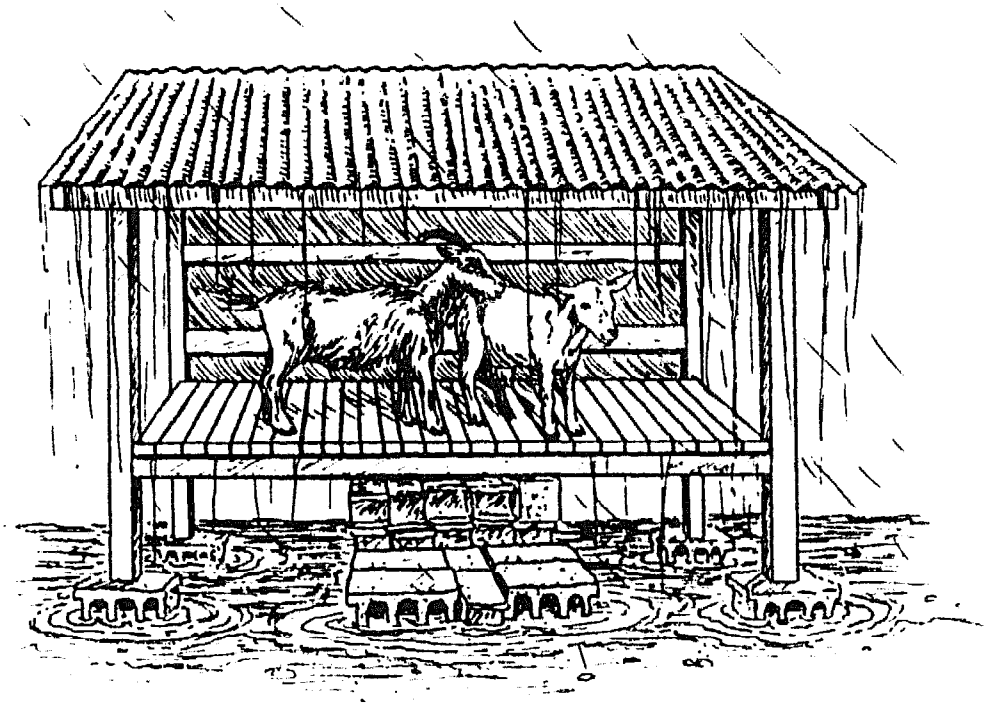

BABY KID HOUSING

Open or partially open shed-type housing with raised wood slat-floored pens off the floor at least fifteen inches provides dry draft-free quarters for kids. Pens should have three solid sides with the front side opening to the stall floor. Feeding, nursing and watering facilities should be placed outside the pen, accessible through keyholes for sanitation, necessary to prevent parasite and other disease problems caused or aided by contaminated feed. Bedding provided baby kids should be of inedible or unpalatable material such as sawdust, shavings, shredded fodder, shredded straw, or sugar cane begasse. Pens for newborn kids should be provided with heat lamps in cold climates. These can be used until newborn kids are thoroughly dry and they have been given a few feedings of colostrum.

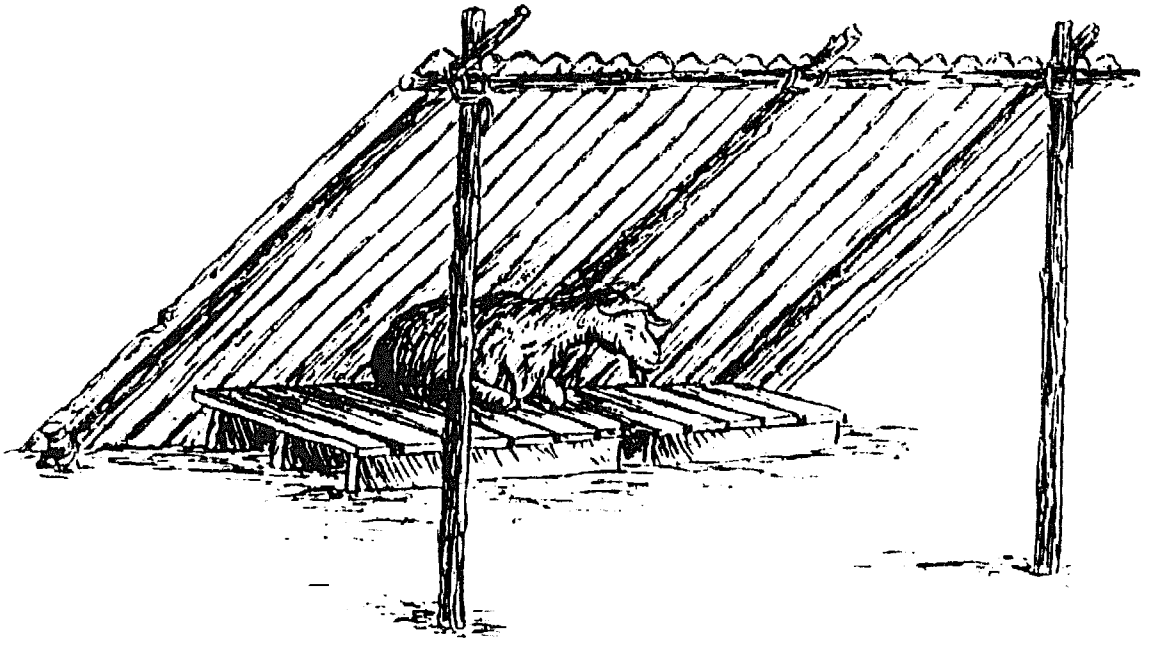

HERD SIRE HOUSING AND MANAGEMENT

The most important requirement for housing buck dairy goats is complete separation from the female members of the herd. Open shed housing with drop-down panels for summer weather is best. Bucks require only shelter from rain and a dry place to lie down. Several bucks can share the same area if at least 40 square feet of pen space and 100 square feet of yard space is allotted for each. For housing one mature buck, the use of an open shed six feet by eight feet is adequate. The tethering arrangement allows the buck to exercise and at the same time keeps him under constant control. Bucks with horns may be held by a collar. Hornless bucks should be held with a sturdy heavy leather halter. A simple open-fronted shade with a drop down panel on the rear wall for better summer ventilation will provide adequate shelter.

Deep bedding should be used inside the shed. A heavy utility pole guy wire should be stretched close to the surface of the ground between the building and an automobile axle driven its entire length into the ground at a point distant from the building. The length of wire can be as long as 200 feet and the longer the better. A turnbuckle should be used on the wire to keep it stretched tightly. A small bull ring to which is attached a swivel and about 6 feet of light chain should slide along the wire. If the tether wire is placed close to the ground surface, it is easy to mow the grass around and over it to keep the yard in good shape.

The feeding facility provides for water, grain and hay feeding from the side away from access to the buck. This feeding facility should be placed so that the buck will have access to it but will not be able to move around it or get into it. Lengths of pipe keep the buck out of grain and water buckets and the hay rack is also made out of pipe to prevent the buck from chewing it. This buck housing arrangement is ideal for large fractious bucks. Opportunity for exercise and observation will keep bucks healthier and more contended.

FENCING

Goats are adventurous and are natural climbers, and efforts should be made to control them; the ultimate control would be high-tensile, electric fence. Goats stand and push on other fences and can be very destructive. Hazards that might contribute to broken legs and strangulations should be removed. Tethering goats is potentially dangerous since they are vulnerable to dog attacks, and if chained too close to another goat, invariably one will strangle. Goats chew on painted surfaces, and lead poisoning is a potential hazard in old barns. An efficient layout of pens, easy access to well-designed feeders and effective control will minimize management-related problems.

It is virtually impossible to confine bucks with any other fence less than six feet high unless it is unclimable. The doe should be taken to the buck pen for mating.

BEDDING

Inedible or unpalatable bedding is to be preferred over edible types. Sawdust, mill shavings, peanut hulls, shredded corn fodder, sugar cane bagasse, straw or poor quality hay are desirable forms. The drier the bedding material are, the better.

Section 10

Pasture Management

X. PASTURE MANAGEMENT

GRASSES, FORBS, AND BROWSE

Goats do well on what they have, provided they are given the chance to choose. Although their nutrient requirements exceed those of most other livestock species, goats succeed while others fail. The reason for this success is that goats are particular. They consume the best parts only.

NUTRITIONAL VALUES OF GRASSES, FORBS, AND BROWSE PLANTS

Even though grasses are usually considered the most desirable type vegetation for livestock production, forbs, and browse plants (weeds and vines, shrubs, and trees) often contain higher levels of nutrients. Leguminous forbs and browse, for example, commonly contain more than 25 percent crude protein, whereas perennial grasses seldom exceed 15 percent in crude protein content.

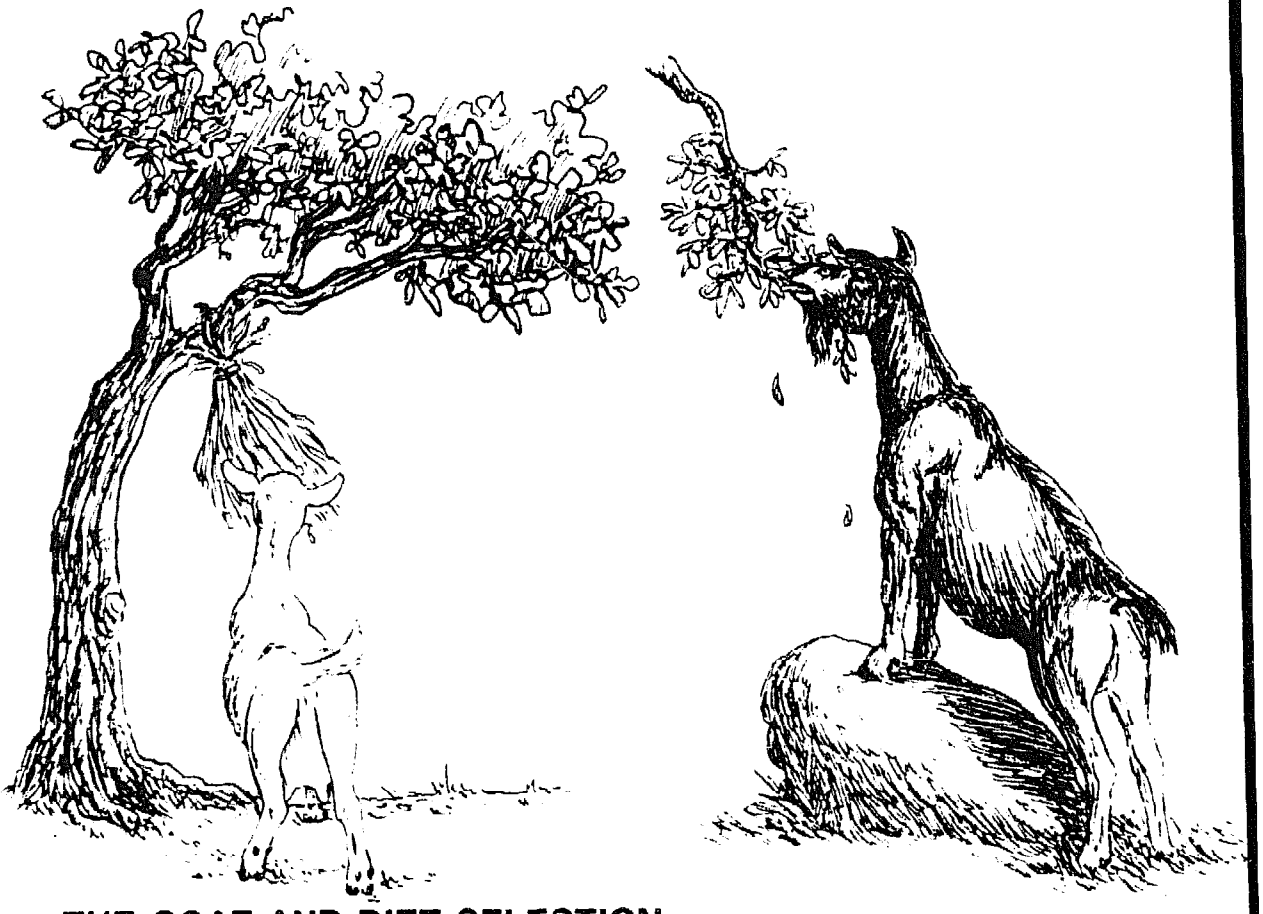

THE GOAT AND DIET SELECTION

Goats are agile and have exaggerated control of their mouth parts, allowing them to be very selective for diet. They are able to stand on their hind legs and climb rock cliffs and low growing trees to gain access to relished plants and plant parts that are unavailable to other livestock species. Goats have a mobile upper lip, effective in nipping off plant parts very selectively. As a result, the goat's diet is very diver-

sified, consisting of small components of a large number of plant species. Very simplified vegetation, an all-grass meadow, for example, does not provide good nutrition for goats over a long period of time. Goats need access to a wide variety of plants in order to exercise diet selection, as different plants increase and decrease in nutritional value with seasonal changes.

THE GOAT AS A BRUSH CONTROL TOOL

Many of the browse species have invaded or become overabundant in old, abandoned fields or on range and pasturelands following prolonged grazing by other livestock species. These invading species, collectively called "brush", often can be suppressed or eradicated using goats. Goats are effective as brush control tools, when the following requirements are met:

1. The brush is either low-growing or is reduced to low growth by mechnical means.
2. The brush species is preferred by goats.
3. Goats can be concentrated in large numbers for a relatively short period, then removed for a extended period.

Each time the goats are concentrated, they consume the leaves and the twigs of the brush species, as well as a substantial portion of the grasses. When the goats are removed, the grasses recover more quickly than the brush. After several sequential grazing and rest periods, the brush is reduced to a density easily controllable, with a few goats included in the grazing herd. This method of brush control has proven successful in several regions of the United States, as well as at many locations around the World.

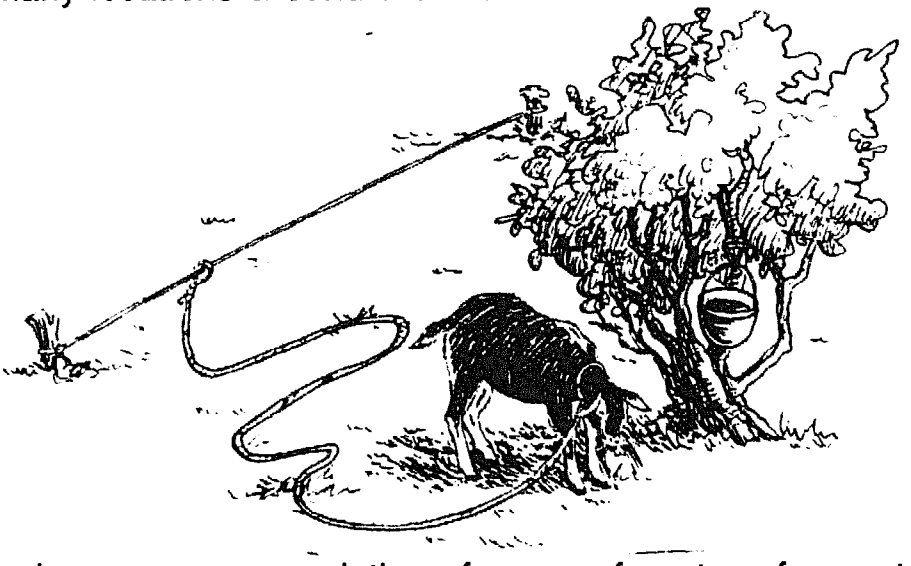

Summing up recommendations for use of pasture for goats: put young stock and dry stock on unimproved pastures and shrubby or weedy lots; they will make good use of this material. As long as they are not forced by starvation to eat poisonous plants, they will usually avoid them. Coarse, woody forage is excellent for young animals to develop good rumen function. After milking does have completed a lactation in which they were fed relatively large amounts of grain highly

digestible hay, browse of any kind is highly desirable to restore both rumen capacity and function to prepare them for the next lactation.

When goats are placed in improved pastures, they waste much more feed than they eat. It is much better to harvest the material daily and feed it to the herd in a feeder which will prevent the animals from contaminating the forage.

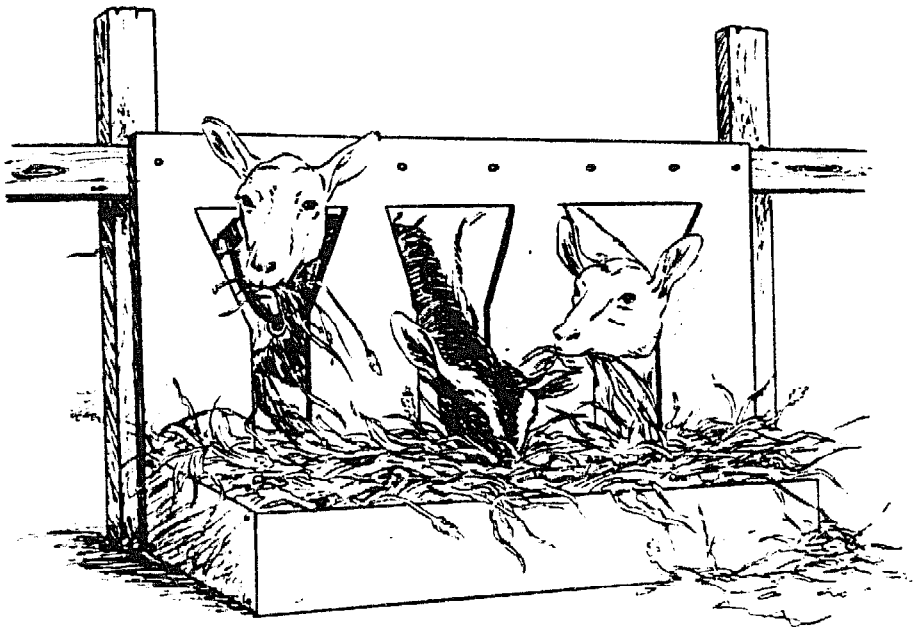

PASTURE MANAGEMENT

Permanent grass pastures are exceedingly difficult ot manage for prevention of internal parasite problems. Rotation of animals using small areas which will furnish two-week periods of grazing is infinitely better than allowing animals continuous use of a large area. The individual areas can be managed using strip grazing with an electric fence. After animals are moved to a new area, the grazed area should be mown as short as possible and soil and grass stubble given full exposure to the sun. This effectively destroys worm larvae and provides new growth of fresh succulent forage for the next grazing period. The size and number of paddocks for grazing will be determined by the species of forage, the usual rainfall, and the number of animals. If pasture growth exceeds the need for grazing, nearly mature material can be removed for hay.

ANNUAL FORAGES

Use of annual grasses (piper sudan grass, annual brome grass, etc.), cow peas, and clovers are excellent means for furnishing goats palatable nutritious forage. Feeding them as green forage results in much less waste than allowing the animals to graze. Comfrey, kidzu and other perennial forage crops can best be utilized by hand harvesting them and feeding them in fence line feeders. When feeding green forage and especially broad-leaved species such as comfrey, be cautious about feeding large amounts during when the weather may interfere with normal growth of the plants. Periods of cold dark

wet weather or periods of hot dry weather may sufficiently alter the nitrate levels or produce other toxic nonprotein substances in the forage.

ZERO PASTURE MANAGEMENT

It is a program of confinement with goats, usually on elevated, slatted floors. Forage is brought to the goats. This is an improved way of caring for goats.

Section II

Metabolic And Non-Infectious Diseases

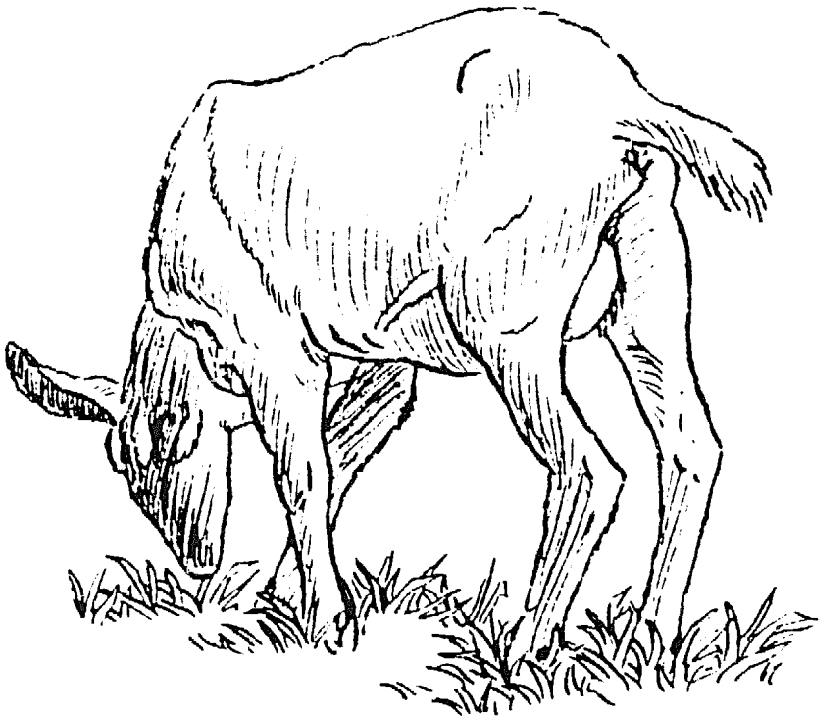

XI. METABOLIC (MALFUNCTION OF BODY PROCESSES) AND NON-INFECTIOUS DISEASES

ANEMIA

Is a deficiency of circulating red blood cells thereby depriving body tissues of the proper amount of oxygen. Symptoms: Listless, weak, lack of energy, blanched, whitened mucous membrane such as around the eye ball and the gums of the mouth. These should be a pink color when healthy.

Cause:

1. Internal parasites - attached to inside of stomach or intestines and sucking blood.
2. External parasites - attached to skin and some suck blood.
3. Severe hemorrhage - bleeding.
4. A blood disease - like anaplasmosis - destroys red blood cells.

ALLERGIES

Symptoms: Severe generalized symptoms such as sudden collapse, coma, and death may appear from allergies or insect stings. Less severe and more common symptoms may include respiratory distress (difficulty in breathing), heart irregularities, excessive saliva flow from the mouth or tears from the eyes, mild to severe itching, lumps (hives) that appear on the skin suddenly, hair standing erect, swelling of tissues with fluid retention (edema), and red areas on the skin.

Cause/Transmission: An allegery is the reaction to a substance (usually a protein) with which it has had previous contact and to which the body has developed an immune sensitivity. Many substances can cause allergic reactions with varying degrees of severity. Common causes of allergies are feeds, infection, applications to the skin, and insect bites. Some examples are pollens or other plant proteins, insect stings, many drugs and biological substances such as antisera, vaccines, or antibiotics. Many times the allergic reaction is dose related: small doses cause small reactions and large doses cause severe shock or even death. These reactions can occur almost immediately after contact or up to 3 weeks later.

Treatment: Immediately remove the animal from its surroundings because the allergen usually is nearby. If the suspected allergen was applied to the skin, wash the animal with soap and water. (Protect yourself from the suspected allergen. Doses of antihistamines and corticosteroids injected or taken orally usually produce a dramatic response, completely reversing or greatly reducing the severity of the allergy. To prevent further recurrence, do not place the animal in the same environment or use the same products.

BLOAT

Is gas forming in the rumen from overeating lush clover-type pasture of grain.

Treatment: 1. Fashion a wooden bit, e.g., piece of a broom handle; attach a cord or leather strap from each end back around head. Place in mouth crosswise like a horse bit so that animal will fight it with mouth and tongue. Then hold animal upright and shake or dance him up and down.

COLOSTRUM

Because the doe's first milk, called colostrum, is high in antibody level, it is very important for the kid to nurse soon after birth. It should receive about 10% of its body weight in colostrum the first day of life. This would amount to nearly 236 ml (½ pint) for the average-sized kid.

PHYSICAL INJURY/WOUNDS/BURNS/FRACTURES

Goats are often injured in fights with dogs, predators, and other goats, Usually, with a little help, the animal will heal itself. First, bleeding should be stopped. This can normally be done by applying mild pressure. Second, clean the wound with mild soap and water or hydrogen peroxide. Remove all dirt, hair, and trash. Be gentle so as not to cause renewed bleeding. Next, apply an antibiotic ointment, cream, or powder to the area. Finally, apply a bandage if the damaged area is large, and give antibiotic injections daily for a week, e.g., Penicillin or Combiotic. Most wounds do not require bandaging. Protect from fly infestation (screw worms).

Also clean and protect burned areas with an ointment. Use a saline or salt solution, 1 teaspoon salt per pint of water, for cleaning and do not damage the burned area. If no antibiotic ointment is available, butter or cream will help. Any cream medication you would use on yourself.

If the wounds or burns are severe and large areas of skin are destroyed, the goat probably should be slaughtered.

Fractures and and dislocations sometimes are seen when goats fight or get entangled in fences, feeders, or other equipment. Usually, it is best to slaughter as soon as possible after the break occurs.

POLIOENCEPHALOMALACIA

Usually a brain disturbance from bad feed. No treatment available. But Vitamin B_1 (Thiamin hydrochloride) can be injected I.M. or S.C. for possible improvement. Use 1 cc daily for several days.

General Treatment: Inject Bo-SE into any sick animal—½ cc to kids; 1½ to 2½ cc to adults.

Section 12

Infectious And Contagious Diseases

XII. INFECTIOUS AND CONTAGIOUS DISEASES

ANAPLASMOSIS

Symptoms: Anemia is the most common symptom. Anemic animals have poor appearance and do not milk or reproduce well.

Cause/Transmission: This blood parasitic disease of goats is caused by the rickettsia Anaplasma ovis. The disease is usually passed from animal to animal by infected ticks, bloodsucking flies, and blood-contaminated needles and surgical instruments. Infected animals that show no symptoms of the disease are carriers of the organism. The disease is fairly common in areas where anaplasmosis occurs in cattle.

Diagnosis requires a laboratory examination for the organism inside the red blood cells.

Treatment/Prevention: tetracycline drugs are recommended for prevention and treatment. Suggested treatment is based on cattle-dosage control at 4 mg/kg intramuscularly every 30 days with the 200 mg/cc oxytetracycline, or administered orally in feed at 20 to 30 mg per head per day on a continuing basis. Control of flies and ticks will help, as will sanitation of instruments used for castration, etc. Severe stress also tends to increase the risk of an anaplasmosis outbreak.

BABESIOSIS

Symptoms: Goats usually show no outward clincial signs of Babesia infection. Diagnosis same as for Anaplasmosis.

Treatment/Prevention: Administer acaprin or dimenazine aceturate (Berenil). Control and prevention are based on controlling ticks with dips or sprays. See Chapter XV for illustration on dipping and spraying.

BRUCELLOSIS

This disease in goats is known as Malta Fever, caused by Brucelia melitensis.

Symptoms: 1. Does may abort in final 4-6 weeks of pregnancy. Severe placentitis (inflammation of the after birth tissue).

2. Males may have swollen joints and testicles.

3. The germ is shed in the urine, milk, and vaginal discharge for 2 to 3 months, and can cause infection in people (undulant fever).

Warning: Do not use the "Strain 19" vaccine that is used for cattle on goats as there is a danger of giving them the disease.

CAE (Caprine Arthritis Encephalitis)

A viral contagious disease of goats of all breeds, ages and sexes. CAE causes encephalitis (brain symptoms) in the young goats and arthritis (inflammation of the joints) in the adults.

It is transmitted from the infected doe to the kid through the col-

colostrum (first milk). There is no treatment or vaccine at present. The only prevention is pasteurization of the colostrum.

CASEOUS LYMPHADENITIS - "CL" (abcesses)

Probably the most common ailment in goats. Cause: a bacteria. Symptoms and treatment: Swelling on the body, usually around the neck that turn into abcesses that will rupture unless lanced. If they are opened surgically, which should be done, the resulting pus should be caught in a rag or paper and burned to prevent premises contamination. The abcesses should be flushed out with hydrogen peroxide or betadine (a "tamed" iodine preparation) and left open to heal.

Prevention: There is no vaccine and the injection of antibiotics, like penicillin, does not have much effect. Keep animals under treatment—isolated from the flock for about 2 weeks until wounds completely heal.

CHLAMYDIAL DISEASE

An abortion producing disease caused by a very small bacteria.

CONTAGIOUS AGALACTIA (MYCOPLASMA) AND ARTHRITIS

Cause/Transmission: Contagious agalactia is a disease of goats caused by mycoplasma agalactia. The organism is found in milk, urine, feces, and eye and nasal fluids for several months after infection. Spreading may occur when an uninfected goat contacts these secretions.

Treatment/prevention: Helpful antibiotics are tetracycline or tylosin given intramuscularly. The death rate can reach 20% of the infected animals. A vaccine is available in some countries.

CONTAGIOUS CAPRINE PLEUROPNEUMONIA

Cause/Transmission: Contagious caprine pleuropneumonia is caused by Mycoplasma sp. and is commonly seen in Africa, Asia, the Mediterranean, and has been reported in Mexico. The disease is spread by contact with an infected animal.

Treatment/Prevention: Same as for contagious agalactia.

CONTAGIOUS ECTHYMA - (SORE MOUTH) = "CE"

Disease of sheep and goats, worse in goats, caused by a virus highly resistant to drying. Virus has remained viable for at least 12 years on premises of an outbreak, and is worldwide.

Symptoms: Incubation of 2 to 3 days. Papules, vesicles, pustules, and scabs.

1. Small blisters on lips and gums, eyelids, nostrils, tongue, and palate, raised proliferative tissue under scabs.
2. Rupture and form scabs over inflammed, raised areas.
3. Kids—lesions develop on gums of incisor teeth and then refuse to nurse, but when they do they spread infection to teats of doe, producing:
    a. infection in doe and up teat canal—mastitis.
    b. lesions on feet and genitals of bucks and does.

c. unthrifty condition and slow growth.
d. in feedlot lambs, 3 to 7 months old.

4. Most common in August, September and October.

Transmission: goats and sheep should not be exhibited in fairs, sales, and shows if there is a chance of exposing other animals.

Immunity: Goats that have an attack are highly immune thereafter.

Prevention: A vaccine is available, but should not be used if there is no history of the disease on the premises. If one starts using, must vaccinate all newcomers to premises. Adults are usually immune for 5 years after vaccination.

Treatment: The scabby material is removed, then treat wounds with hydrogen peroxide or chlohexidrine solution.

Precaution: This disease serves as a good example why there should be veterinary inspection and clearance or rejection prior to all shows and fairs. In vaccination and treating lesions, rubber or plastic gloves should be worn. Humans can become infected, producing very painful lesions, inflammation of hands auxillary lymph nodes, persisting for weeks.

ENTEROTOXEMIA - OVEREATING DISEASE

It causes sudden death. Cause: Overeating—too much grain.

Prevention: Vaccination 2 to 3 times a year with Clostridium perfringens type C and D vaccine and prevent overeating. Kids should be vaccinated at 3 to 4 weeks of age and then boostered at 6 to 7 weeks then again at 6 months. Revaccinate adults every 6 months.

TUMORS

The goat is not especially prone to tumors—both benign and malignant being quite rare. However, about 1% of the Angora goat population does have skin cancer—usually in the form of pedunculated (hanging) growths on the side of the vulva or under the tail.

Skin warts are known to affect the Saanen breed of milk goats occasionally. Wart growth are found mainly on milking goats that are whiter in color than others, and nearly all parts of the body are affected. Often these growth will develop into malignant tumors.

Some tumors can be removed surgically by a veterinarian.

EYE INFECTIONS - PINKEYE

Cause: A bacteria.

Transmission: Dusty conditions. Flying insects.

Treatment: antibiotic ointments, such as Terramycin or Chloromycetin ointment or Tylan eye powder.

Prevention: There is now a vaccine available. Protect from flies.

FOOT AND MOUTH DISEASE (APHTHOUS FEVER)

Symptoms: Symptoms of foot and mouth disease in goats are usually less severe than those seen in cattle. Goat symptoms include dullness, fever, and small blisters on the mouth and tongue that break

and leave small pits. Small blisters also will appear between the toes and on the feet. These areas turn pale and then peel off, leaving erosions and sores between the toes. The affected animals are very lame. The same type of blisters and erosions appear on the teats. Affected animals will not eat, and if the feet are very sore, will not stand. Sometimes the first symptoms are sudden death in kids, with abortions in the adults. Ministries and Departments of Agriculture require that FMD be reported, if suspected. Diagnosis is based on symptoms and laboratory confirmations. The disease should be differentiated from goat pox, and contagious ecthyma.

Cause/Transmission: Foot and mouth disease is caused by a virus that has seven types and over 60 subtypes. It is widespread over much of the world. The disease is spread by swallowing the virus on feed or by inhaling or getting virus particles in the eyes from virus-laden air. Spread by recovered carrier cattle, sheep, goats, and hogs, foot and mouth disease can occur for a year or longer after the symptoms are gone. There is some evidence the virus can be spread through the air by winds.

Treatment and Prevention: There is no effective treatment. Vaccination can be made as a preventative measure against the type that occurs locally. Some countries use the eradication method—all exposed and sick animals are destroyed, then burned, or buried.

FOOT ROT

Cause: Two bacteria working together.

Transmission: Wet, soggy ground or damp manure-filled areas.

Prevention: A vaccine is available. Welcome labs.

Treatment: Antibiotic injections. Close, deep, and severe hoof trimming. Foot baths. Zinc Sulphate solution and copper sulfate solution. This malady will be addressed in more detail in this text. See Chaper XVII.

HEARTWATER DISEASE

An infectious, non-contagious disease of ruminants found in areas infested by ticks of the genus Ambloyomma: regions of Africa, and the islands of Madagascar, Reunion, Manrituis and Caribbean.

Symptoms: High fever
Tear formation
Convulsions
Loss of appetite
Depression
Exaggerated blinking of eyes
Chewing movements
Prostration

Prevention and Treatment:
Control tick infestation
Tetracyclines at 10 to 20 mg/kg of body wt.
*A second and third treatment may be necessary.

HYDROPHOBIA - (rabies)

A rare but always fatal viral infection conferred by a bite and salvia from an infected animal.

Symptoms: Excitation, depression, paralysis, coma and death.

Prevention: A relatively new and improved rabies vaccine that can be used on all classes of livestock. There is a new and improved vaccine for humans, also.

MELIOIDOSIS

Cause/Transmission: Caused by the bacterium Pseudomonas pseudomallei, meliodosis is most commonly seen in South East Asia, but also occurs in most other areas of the world. Infection is due to the contamination of wounds with soil containing the organism. Spread from animal to animal or animal to man is unlikely.

Treatment and Prevention: Older animals sometimes recover but may get sick again when under stress. If you do decide to treat, use tetracycline, chloramphenicol, or sulfa drugs. No vaccine is available. As a precaution, healthy animals should be kept away from areas where the disease has occurred.

Human Health Concerns: Although unlikely, human infection may occur as a result of swallowing the organism. Parts or products from infected animals should not be used for human food unless the animal recovers completely.

MYCOPLASMA

Cause: A very small bacteria that can cause the following diseases and is spread through colostrum (the first milk): Pneumonia, Mastitis = inflammation of the udder, Polyarthritis = more than one joint affected with inflammation , Abortion= birth before term, usually dead, pinkeye, diseases of the central nervous system (spinal cord and brain). Two of the above that are probably most devastating to the goat owner are mastitis and abortions.

Prevention: Pasteurization of the colostrum and giving to the newborn before they nurse the doe. Colostrum is pasteurized at 131 degrees F (56 degees C) for 1 hour. If the temperature varies 1 or 2 degrees below, the mycoplasma will not be killed and if above 131 degrees the colostrum will be ruined.

Treatment: Culling the affected animals. There is no vaccine.

NAVEL ILL

Cause: Filthy premises. Contamination of the umbilicus (navel cord) at birth or shortly afterwards—from unsanitary kidding quarters.

Symptoms: Infection and pus in the joints; acute lameness; internal abscesses; retarded development.

Prevention: good management. Clean kidding premises. Soak the umbilical (navel) stump with tincture of iodine 7%, just once. Inspect the umbilicus in 4 to 5 days for signs of infection.

Treatment: Wide spectrum antibiotics, like penicillin, streptomycin, Oxytetracycline injected IM. About 5 ml daily for 1 week.

PESTE DES PETITS RUMINANTS

Symptoms: A sudden rise in temperature, up to 106 degrees F (41 degrees C), is seen in goats that appear dull and restless. They have a dull coat, a dry muzzle with a clear discharge, very little appetite, and reddening around the eyes. There may be some red or raw areas in the mouth. Diarrhea, dehydration, emaciation and collapse sometimes occurs. Pneumonia may develop as a complication. Most infected goats die within 8 to 10 days.

Several other diseases have similar symptoms, thus laboratory diagnosis should be made using blood and culture tests. It has been reported to 10 to 90% fatal in goats.

Cause/Transmission: The disease is caused by a virus and has been reported only in West Africa. It is transmitted by direct contact with sick animals or with areas where sick animals have been recently kept. All tissues and fluids from sick animals contain the virus and are considered infectious.

Treatment/Prevention: There is no effective treatment. A vaccine that will protect sheep and goats for about 1 year is available in some areas.

RABIES—See under Hydrophobia

RESPIRATORY DISEASE

Cause: Stress from:

1. Overcrowding - excess dust.
2. Chilling - sudden temperatue changes, especially newborn kids.
3. Weaning.
4. Long distance hauling.
5. Poorly ventilated barns.
6. Malnutrition.
7. Feed changes.
8. Parasitism.
9. Worming.

Symptoms:

1. Nasal discharge.
2. Anorexia, reduced appetite, weight loss.
3. Accelerated breathing and heart rate.
4. Fever.
5. Depression.
6. Coughing.
7. Reluctance to move.
8. Paleness or anemic.
9. Cyanosis of mucous membrane.
10. Gray-blue lymph nodes
11. Finally shock and then death.

Treatment of respiratory disease:

1. Treat early in course of disease and for sufficient length of time.

2. Use the appropriate antibiotic drug given in adequate doses, (e.g., Pencillin-Streptomycin, Tylosin, Oxytetracycline).

3. Use the most suitable antibiotic. Include a sulfa drug, e.g., Sulfamethazine (use simultaneously with antibiotics). Some are available for drinking water.

In general, antibiotics should be continued for 3 days after temperature is normal.

Separate sick animals from the healthy. Isolate recently shipped or hauled animals for 2 to 3 weeks so sick animals can be treated early. Careful nursing of the young should not be overlooked.

Adequate colostrum should be given to the newly born. A colsotrum bank should be maintained. Keep frozen. Milk carton make handy containers.

Overcrowding should be avoided. Need 14 square feet per pregnant animals, including following birth.

RIFT VALLEY FEVER

Symptoms: High abortion rate occurs in adults and high death losses among very young animals. Sick animals show a rapid rise in temperatue and a rapid, weak pulse. Gait is unsteady. Sores sometimes appear on the tongue and cheeks. Milk production rapidly decreases. Death losses are extremely high for young lambs, kids, calves, and puppies. Adult goats suffer a 10 to 20% death loss.

Cause/Transmission: Goats are affected by this virus-caused disease, transmitted primarily by mosquitoes. Ticks have also been identified as carriers. The disease is seen primarily on the African continent, usually during the wet season.

Treatment/Prevention: There is no effective treatment. Prevention consists of housing animals in insect-proof buildings or moving them to highlands away from insects. A vaccine is available; however, it is a live-virus vaccine and will cause abortions in pregnant animals and deformities in the fetus.

Human Health Concerns: Humans are infected both by insects and by handling animals and tissues affected with this virus. Meat from infected animals should not be eaten. In humans, the disease is not usually fatal but does cause a long, 7 to 10 day flu-like disease that is very delibitating and painful. A vaccine is available for use in humans.

SALMONELLOSIS DYSENTERY

An acute contagious disease of goats, not uncommon. Two forms, enteric and abortion. Death rate severe in spite of vigorous treatment. Triggered often by high stress factors.

Diagnosis: Difficult because symptoms are similar to other diseases.

1. Severe watery black or bloody scours with putrid odor.
2. Mortality very high in young kids.
3. Normally does not occur with older animals unless stress-

ed, e.g., transportation or temporary feed reduction or passage through a sales barn or auction market.

4. Abortion.

Prevention: These are only effective means of control:

1. Strict sanitation.
2. Avoid management changes.
3. Recovered animals often become chronic carriers for many months and serve as a source of infection to others.

Treatment:

1. Only effective if started early in course of disease.
2. Administer large quantities of electrolytes, e.g., Gatorade orally, or human oral rehydration fluids.
3. Administer large doses of broad spectrum antibiotics, e.g., Oxytetracycline 2cc.

TETANUS - LOCKJAW

Cause: An anaerobic bacteria (one that cannot live in the presence of oxyen). This bacteria produces a toxin (poison) that attacks the nervous system and eventually the brain. This disease is easy to prevent but difficult to cure. The bacteria are found everywhere, the world over, and especially in manure of animals.

Symptoms: Usually are produced in 10 days after infection.

1. Muscle spams, convulsions.
2. Head thrown back and legs stretched out rigid.
3. Death, in 3 to 10 days.

Mode of Contamination:

1. Castration (especially by elastrators which are heavy rubber bands that are applied above the testicles).
2. Wounds produced by shearing, disbudding, dehorning, tail docking, or any wound.
3. Untreated navel cord.

Treatment:

1. If early enough in course of the disease, the wound can be debrided (cleaned surgically) and packed with gauze soaked with antiobiotic.
2. Antibiotics, systemically e.g., Penicillin-Streptomycin, SQ or IM or IV.

Prevention:

1. Protection for about 1 year to vaccination with tetanus toxoid. About a 9 day period is required to build up immunity.
2. Immediate protection by inoculating with tetanus antitoxin which lasts for 2 weeks.
3. Use these two at a time of surgical procedure. Both kinds can be given intramuscularly or subcutaneously simultaneously.
4. There is a vaccine available that has both Clostridium perfringens type C and D, and tetanus toxoid, all in one.
5. When using the tetanus toxoid, a booster inoculation should be given about 45 to 60 days following the initial vaccination,

then an annual booster thereafter.

6. Employ clean techniques on the animal and the instruments when doing any surgical procedure.

7. Keep animal quarters clean and free of wire, broken glass, nails in boards.

TICK-BORNE FEVER

It is also called Tick-Borne Encephalitis. It is caused by a virus, and affects goats, sheep and cattle as well as rodents. It is found in European countries and is carried by a tick, Ioxides ricinus. It can also be transmitted through milk.

Section 13

Reproduction

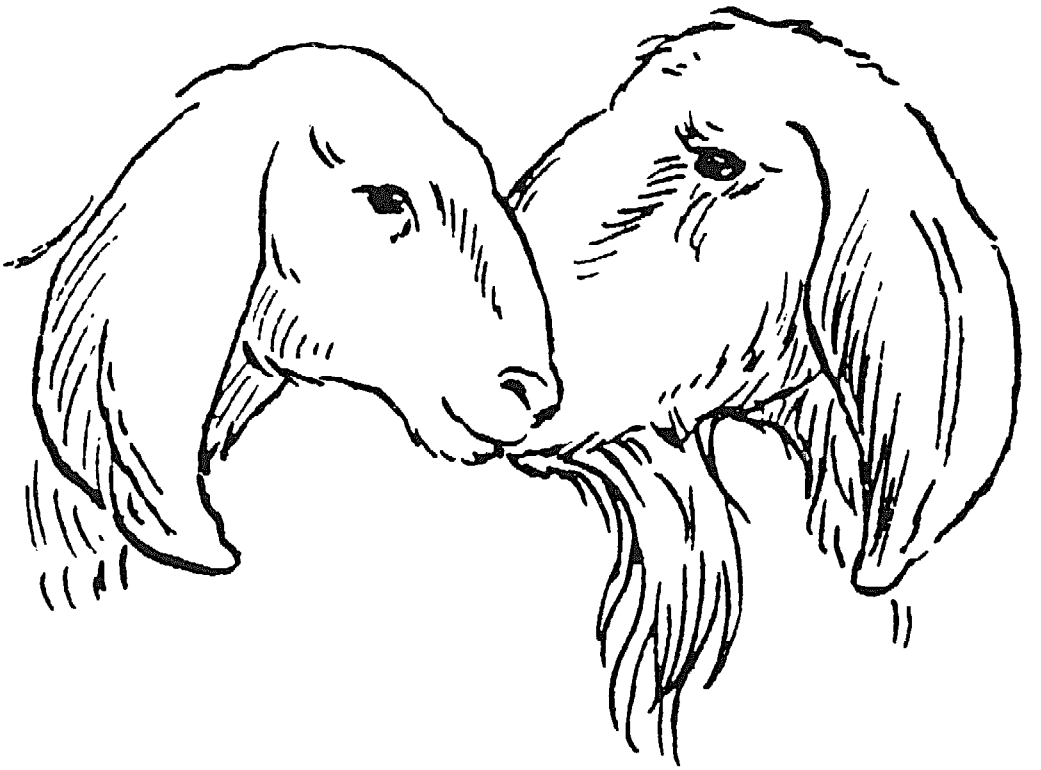

XIII. REPRODUCTION

Goats are considered short-day breeders—estrus (heat) is brought on and increases with decreasing light. Estrus does are usually mated with bucks at onset of estrus and then at 12 hour intervals until heat subsides. The most fertile period for bucks and does in the northern hemisphere is late August through January.

In the Northern Hemisphere, most goats cycle during October, November, December, and January. They may fail to come in heat until the winter solstice (December 21), but some does cycle until March 1. There is breed variation and much individual variation as to when they start cycling. Individual variation is greater than breed variation.

The length between the caprine (goat) estrus cycles is 18 to 24 days. Nubians tend to have the longest cycles, often extending from July to March.

The duration of estrus is 24 to 96 hours, but average is 40 hours. Standing heat is usually 12 to 24 hours, but can be as short as a few hours.

Goats near the equator cycle year round, and two kid crops a year are possible. In temperate latitudes they are seasonally polyestrous (having more than one heat). Silent heats are common at the beginning and end of the season. Decreasing light and temperature helps to bring a doe into heat. The introduction of a buck or its smell at the beginning of the season will often bring the whole group into heat., in an average of 8 days. Most goats will eventually cycle even without the buck's presence. A doe occasionally shows heat when she is already pregnant, but rarely will goats come into estrus after being bred (successfully). Gestation is 150 (145-155) days.

A doe will be in heat for 24 to 96 hours (average 40) but may stand only 12-24 hours. Signs of estrus include:

1. Swelling and redness of the vulva, followed by a clear discharge which becomes white by the end of the estrus.
2. Uneasiness.
3. Tail switching.
4. Continuous bleating.
5. Frequent urination.
6. Riding and standing are less common than with cows. A doe that is not in heat will resist pressure on her lower back and attempts to grab her tail. The doe should be bred the last half of estrus. General advice is to breed the second day and repeat in 12 hours if she is still in heat. The does' milk production will decrease during estrus, and she should be segregated from the herd to maintain tranquliity. If the doe fails to show strong heat, one trick to try is to rub a rag on a buck's head, keep the rag in a covered jar, and offer it to the doe

once a day. When in heat, she will follow the jar all over the barn. In cold weather, the buck jar may need to be heated to improve its aroma.

Although goats come into heat when they are about 3 to 4 months old, a doe should be 7 to 10 months old, or better yet, 80 to 90 pounds before breeding. Underweight doelings are often anestrous (without heat) or have silent heats.. If they do become pregnant, they will produce fewer kids than the average well-grown doe. Fertility and twinning can be increased by flushing (increasing energy feed, not protein) for two weeks before breeding. Also, statistically more kids result from breeding on the second heat of the season than the first.

Rectal temperature regarding kidding: For about a week before kidding, the doe's temperature will be above normal, about 103 degrees or above, but approximately 24 hours before birth it falls below normal. This can be very useful.

Dehorned and descented bucks are not as efficient breeders. Most does will ovulate by the 10th day after introduction of the buck. A thin clear mucous discharge becomes thicker after ovulation.

FALSE PREGNANCY

It is also called pseudopregnancy or pseudocyesis, or cloudburst. The goat is the only ruminant that has this condition. It is fairly common and usually occurs following breeding. It is also common in anestrus or non-pregnant does. Some even come into lactation. The condition is a hydrometra (water in the uterus) and usually terminates at the doe's approximate due date, with "delivery" of a large volume of cloudy fluid. In about 50 percent of these does, subsequent pregnancies are normal.

Treatment: The use of prostaglandins such as Lutylase or Estrumate can be used to terminate pseudopregnancy.

RETAINED PLACENTAS (after birth = fetal membranes), R.P.

Placentas normally drop quite rapidly after parturition (birth) in several hours. If retained after 12 hours, should get a little concerned.

Treatment: Leave the R.P. alone. Give an antiobiotic parenteraly to combat toxicity in the doe and the possible development of laminitis (Founder—feet become engorged with blood and very painful.) Does will sometimes contract tetanus from an R.P., so protect with tetanus antitoxin. R.P. should normally fall out in 2 to 3 days.

Prevention: Bo-Se injected intramuscularly several times through the year.

BUCK EVALUATION FOR BREEDING SOUNDNESS

1. Examine for general or total health.
2. Their structural (anatomical) soundness—locomotion.
3. Teeth.
4. Feet—should be trimmed if necessary.
5. Examine reproductive apparatus—penis, prepuce, and testicles.

a) Palpate (feel) testicles for size, e.g., 30 centimeters total circumference a minimum. Also check for consistency and symmetry. (The two halves should be approximately the same size.

b) Spermatogenesis (ability to produce sperm) is highly correlated with testicle weight and size, therefore, 35 to 38 cm. circumference would be better.

c) Bucks are rendered sterile or partially sterile for about a 60 day period after sickness, fever, or transportation.

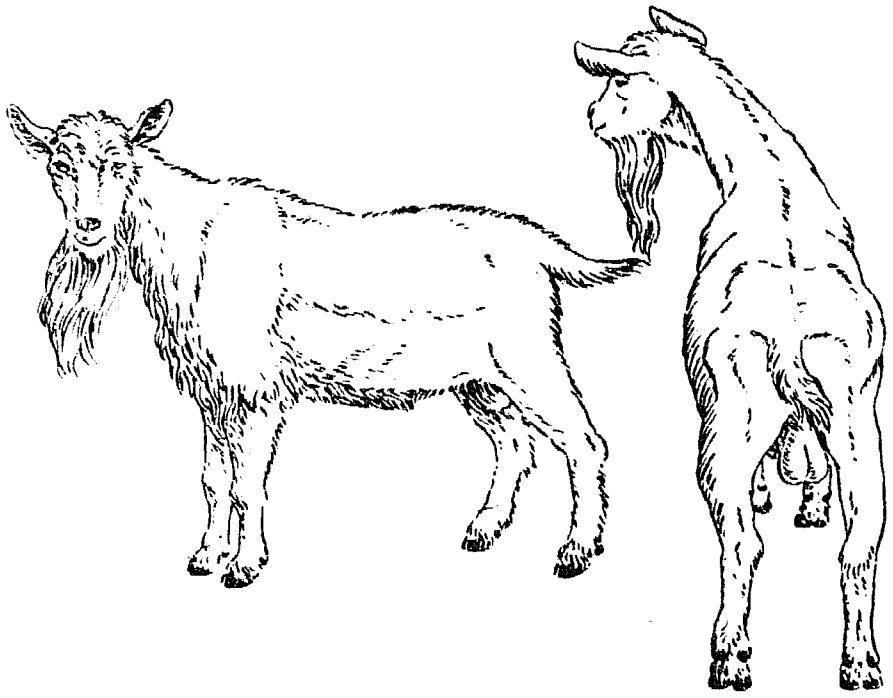

6. Small testicles (30 cm. down to 25 cm. should be culled) that are soft, small, or hardened and asymmetrical (different size). The epididymis (the cord leading from top to bottom of testicle) can and should be palpated.

7. Stress—shipping, high temperatures, or sickness will affect breeding efficiency. Sperm cycle of formation in testicle is about 50 days, and 11 to 15 for sperm to pass up into tract, about 60 days total.

8. Semen evaluation by microscopic examination of spermatazoa.

9. A mature buck can service 30 to 40 females if the breeding season is evenly spread from August through March, and if not more than two does are to be serviced per day.

10. A buck kid starts pestering the does at 8 weeks of age. By three months he may serve does that he can mount and reach, but not until 6 or more months can he inseminate them. It is advised to separate young bucks from young females.

11. The young buck should not be pressed into full service until the second breeding season.

12. Do not allow him to run with the herd. He can be dangerous, vicious and will attack you.

13. Any doe in heat may be serviced, 5, 10, or 20 times. This is a waste of energy for the buck and may be physically harmful for the

doe. A doe too young to be bred may become pregnant.

14. The buck should be in a pen with an exercise area located 200 feet away from the does and the fence should be at least 6 feet high.

15. Fecal examination for internal parasites by use of a magnifying glass, or microscope to detect the eggs of worms.

MULTIPLE BIRTHS

The usual or average number of kids per parturition (birth) is two, but often have three or not uncommon to have four, occasionally five. A herd of 30 does or more kidding should produce 200%.

ARTIFICIAL INSEMINATION (placing semen directly into uterus)

The doe is inseminated 1 to 12 hours after onset of estrus (heat).

REPRODUCTIVE FAILURES

There are many known and unknown reasons for reproductive failures in the doe. Some of these are as follows:

1. Infertile sperm from the buck.
2. Abnormal egg from the doe.
3. Hormone malfunction such as retained corpus luteum—yellow body, located on the ovary and produces a hormone that prevents abortion.
4. Overfat condition of doe can prevent conception (pregnancy).
5. Cyst(s) on the ovary.
6. Very hot weather may prevent conception or cause the fertilized egg to be aborted (die and pass out of the body).
7. In isolated cases, malnutrition (improper feeding) or lack or protein, deficiency of the mineral phophorous and the lack of vitamin A can prevent normal reproduction and abortion.
8. A normal fetus may be aborted due to the female being injured by other animals or being bumped in a narrow door opening.

BREEDING

Buck kids should be separated from doelings at 3 months of age. Bucks are old enough for light service at 6 to 12 months. Bucks should not be used for extensive or heavy service until 18 months of age.

Bucks should not be left to run in the same pen as does. Bucks will worry does resulting in reduction of milk and buck odor may taint the milk.

Both sexes will breed better if they are gaining in condition or weight after being thin. Nubians, especially, tend to get fat during their dry season. Fat goats have more trouble getting bred and also with difficult or abnormal birth.

PARTURITION

Signs of Approaching Kidding

1. Uneasiness and restlessness.
2. Lying down and getting up.
3. Pawing and bedding.
4. Bloating.

5. A mucous discharge will cause the tail and genital area to be moist.

6. The water bag may appear or there may be just a slight gush of fluids. (Sometimes the sac will break before it is visible.) When this sign appears, kidding is near.

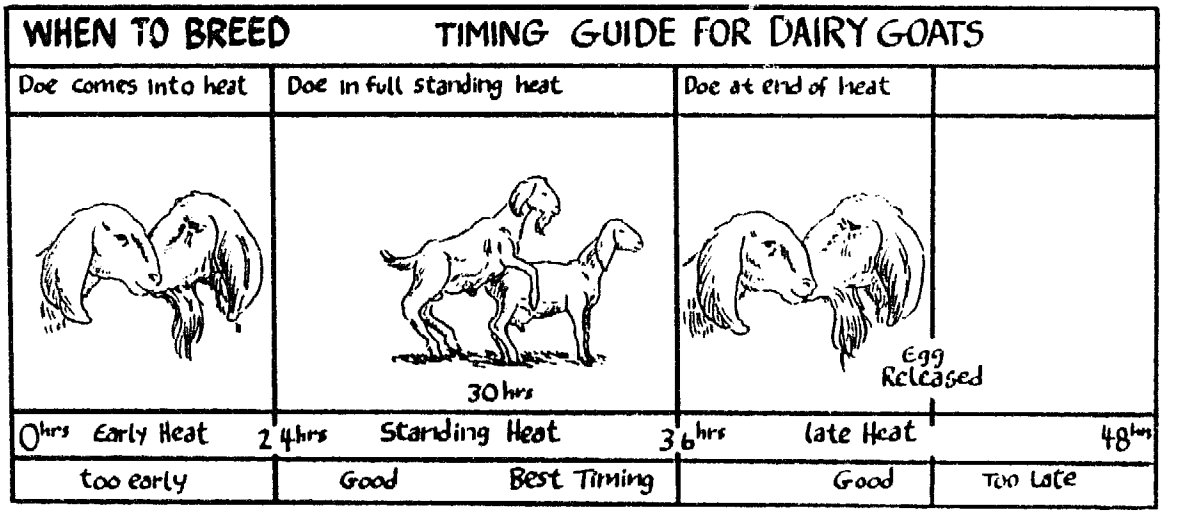

KIDDING DOES

1. Provide adequate exercise for the doe right up to kidding.

2. Feed additional grain during last month of pregnancy to allow doe to gain weight and provide fetal growth.

3. Confine the doe to the maternity pen prior to kidding.

a) The maternity pen should be clean and freshly bedded with straw and with no obstacles to injure the doe or kids at the time of parturition.

b) Clean the doe before putting her in the pen. The long hairs around the hindlimbs, perineum (area under the tail), and udder should be clipped to make clean-up easier after kidding.

c) Don't put water bucket in kidding pen. Doe sometimes will push kid into water and drown.

Attendance at kidding is life saving and cleanliness is very important. The fetus acquires the capacity for extrauterine life only shortly before term, and may die in utero if parturition is unduly delayed. As kidding time approaches, the udder rapidly enlarges, the pelvic legaments relax around the tail head, and the vulva becomes greatly enlarged. Eight to 12 hours before birth, the cervix begins to dilate and the cervical mucus plug will be in evidence, as a tan, sticky substance smeared about the hind parts of the doe. This first stage of kidding lasts 1 to 6 hours. If progress stops, a vaginal exam with clean, will lubricated hands is in order.

Normally the fetus enters the birth canal and the doe starts an abdominal press. The chorioallantoic sac is ruptured and the unbroken amniotic sac (water bag) is then forced through the vulva. Delivery of the kids usually occurs in a short time once the water bag can be viewed. Kids may be presented either with their front feet forward (nor-

mal) or in posterior presentation where their rear feet are presented first. The doe may rest between each kid for a short period of time. Most does are best left alone during parturition. Interference with parturition of does kidding for the first time may result in the doe rejecting the kids. It is important that does lick the kids as soon as possible after they are born as this indicates her acceptance of them. Dystocias (difficult births) are rarely encountered.

If labor is prolonged for more than one hour with no progress, a vaginal exam is again indicated. With multiple births, more than one fetus may be lodged in the pelvis. Careful sorting is necessary before delivery is possible. The goat's uterus is very fragile and prolonged manipulation may result in uterine rupture. "Ring womb" occurs, when, with prolonged labor, the cervix begins to contract, making delivery impossible. Caesarean sections are done with overlarge fetuses, monsters, "Ring womb" and other dystocia that might threaten the doe's life.

After parturition, the doe should begin to lick the kids, and she may eat part of the fetal membranes. There is no evidence for benefit or harm from ingestion of the fetal membranes. Normal kids will start trying to stand up immediately and should be on their feet and nursing within a short period of time. It is important that kids nurse the doe as soon as possible after birth in order to get the first milk or colostrum. It may be necessary occasionally to help weak kids to nurse. Kids' navels should be dipped in iodine solution. Retention of the fetal membranes, a condition not uncommon in cows, seldom occurs in goats. A retained placenta should be treated conservatively with the exposed portions clipped off. The placenta is discharged naturally 3-5 days if not normally expelled within 6 hours after kidding. Systemic antibiotics are indicated only if the doe shows signs of illness.

Thorough disinfection of pens after each delivery and especially after problems is important for successful reproductive management. Colostrum feeding should be continued to kids beyond the first hours after kidding for three days. Excess colostrum can be frozen successfully for later use in the kiddings. The fresh doe will normally discharge a deep red, mucus-like material called lochia for 7 to 14 days postpartum. Abnormal is a large amount of bright red blood, foul-smelling exudate, or pus.

a) Know when to assist or seek the advice of a knowledgeable person.

b) Does assisted in birth when the uterus is entered by the hand should be treated with intrauterine antibiotics. A sulfa bolus or pill placed in the uterus, after parturition process is completed is necessary.

KID CARE AT PARTURITION

1. The kid born during a normal parturition seldom needs human help to survive.

2. Kids born during dystocias or difficult birth may need help. The most important thing is to clear the mucus out of the mouth and start

the kid breathing. Hold the kid by the back feet with head down and swing and shake to clear throat of mucus. Touch, tickle, or pinch the nose to provoke sneezing. Pinch hard on the skin between the toes or on the ears or the tail. This will usually make a kid scream and in order to scream, it must breathe in first. A kid which is not breathing well, will not inflate its lungs properly and will be a candidate for pneumonia.

3. Assist the doe in cleaning and drying kids that are to be dam raised; or remove bottle fed kids immediately after birth and towel them dry. They don't really need a heat lamp other than just drying off the kid.

4. Remove the placenta (afterbirth) and discharges as they are expelled by the doe. Prompt treatment for does with retained placenta would be 2 to 4 ml. of Oxytocin or Ergonovine maleate solution injected IM or SQ every 4 hours until afterbirth is expelled.

5. Examine does inside the uterus that show anxiety with straining after kidding.

6. Strip milk out of the udder, saving the colostrum to feed the kids and also check for mastitis.

Water buckets should be removed when parturition is imminent to avoid drowning the kids. The kids are usually born withing 1½ hours after the water bag breaks. If the doe doesn't kid in half an hour, it may help to have the owner put her on a slope with her front end downhill for 1 hour, then release her to let her try again. If the kid is presented wrong, this allows it to fall back in and rearrange itself. Any manual assistance given should be very gentle because the uterus is relatively thin-walled and can rupture or tear. Attendant's hands should be washed with soap and clean water. Often a kid can be delivered with one leg still back.

It is of paramount importance that parturition (birth) takes place in a clean, draft-free and sheltered environment to reduce the chance of infection in the newborn. A rule of thumb: 14 square feet minimum for the pregnant doe and increased after birth. Weaned kids need a minimum of 4 to 5 square feet each.

About a week to 10 days before kidding, add a tablespoon of whole flax seed and 2 tablespoons of Red Wheat Bran to the doe's grain ration. It is a mild and lubricating laxative of the bowels, making kidding easier. Also, give wheat bran mash and warm drinking water to doe after kidding.

REPRODUCTIVE ORGANS OF BUCK

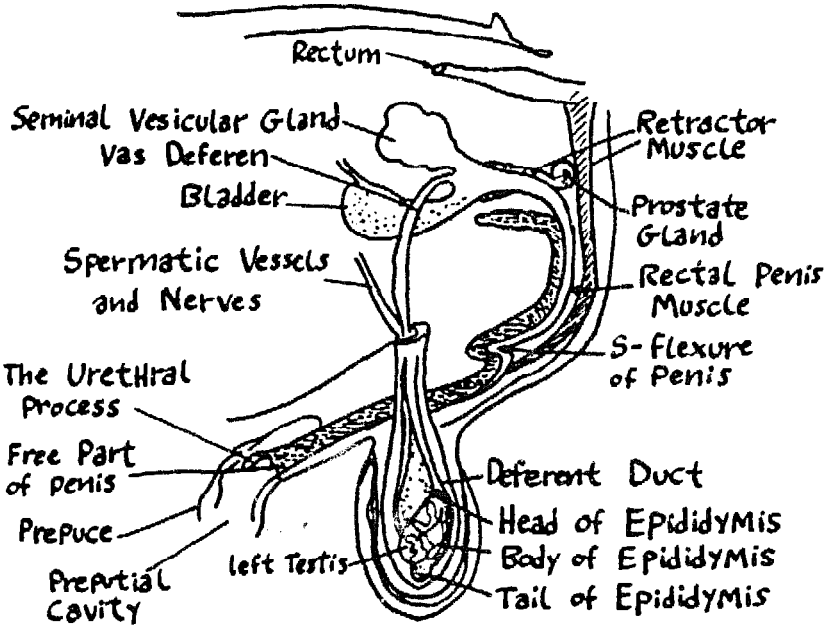

REPRODUCTIVE TRACT OF DOE

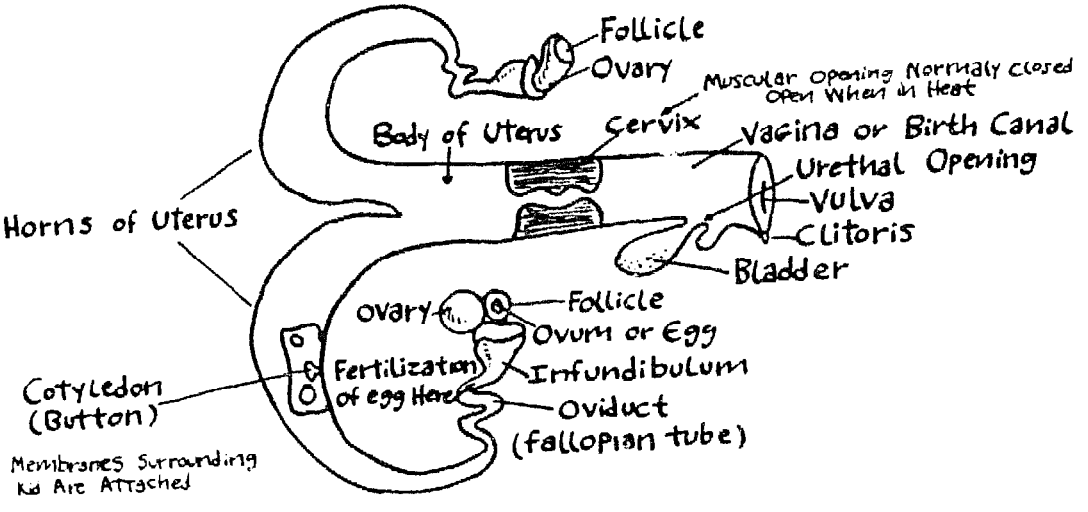

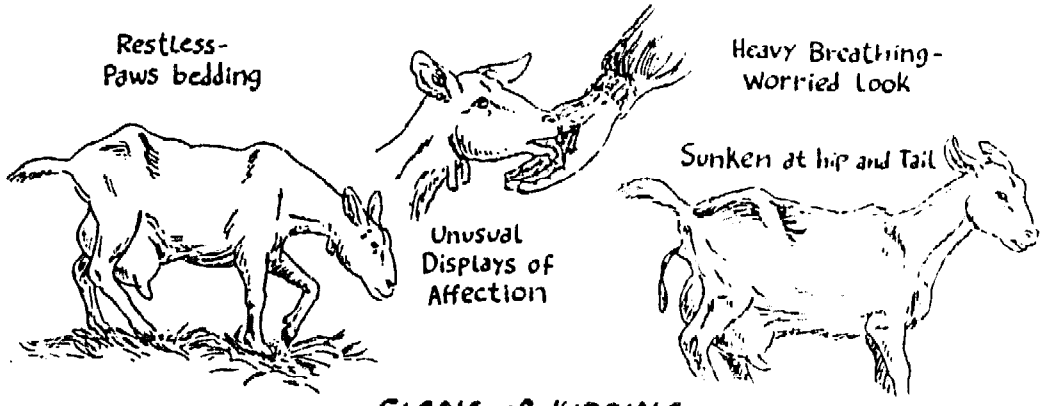

SIGNS of KIDDING

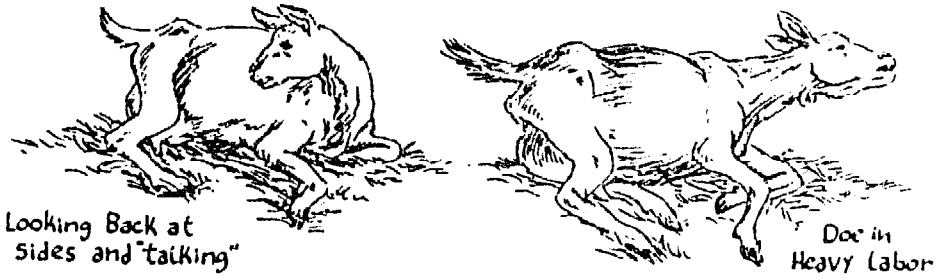

The Birth Process

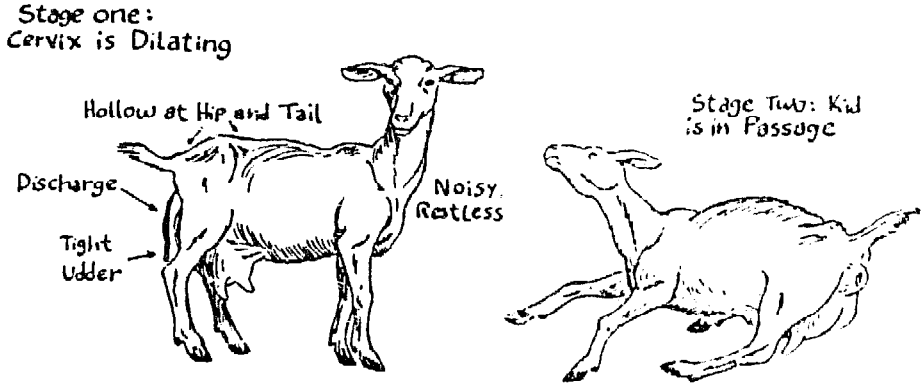

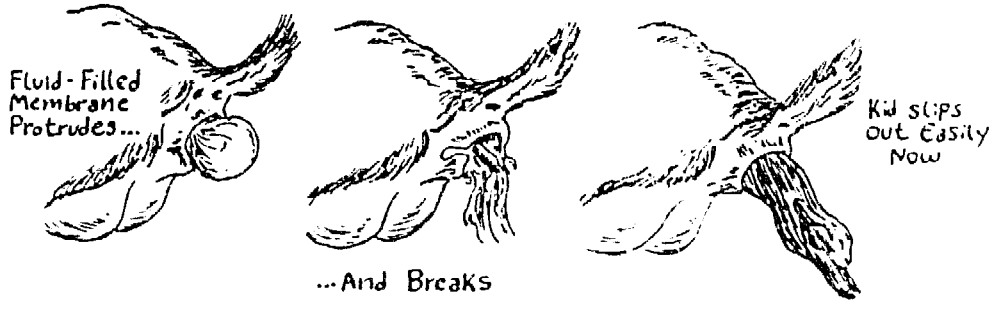

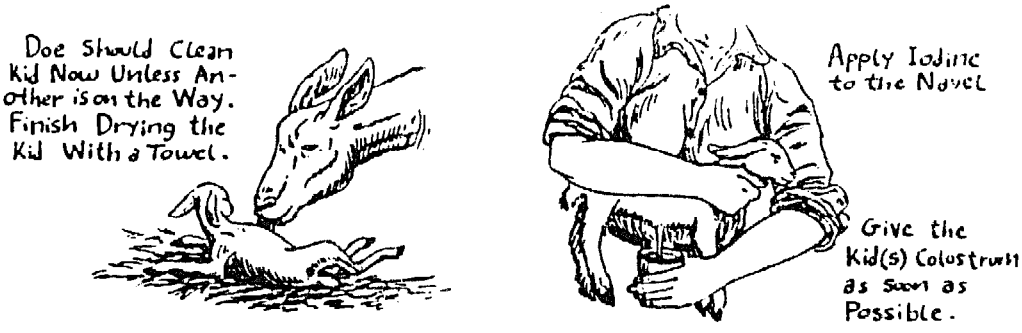

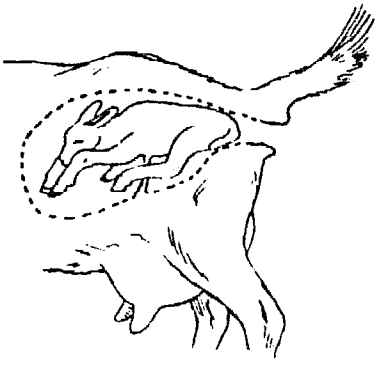

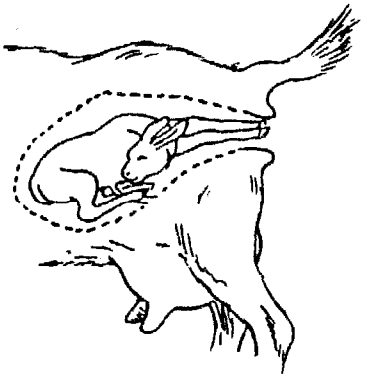

ABNORMAL BIRTH POSITIONS

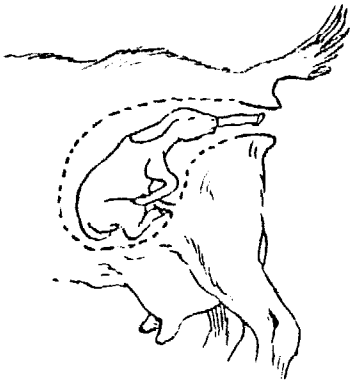

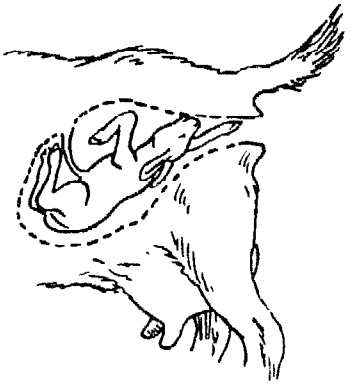

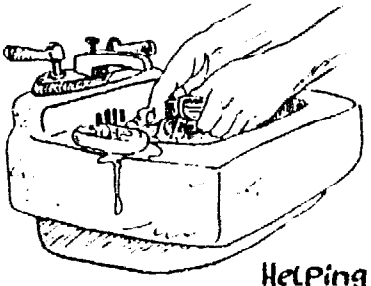

Helping With A Difficult Birth

If You Have To Reach In, Make Sure Your Hands are Clean and Fingernails Short.

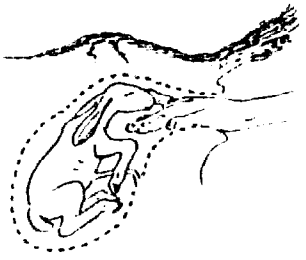

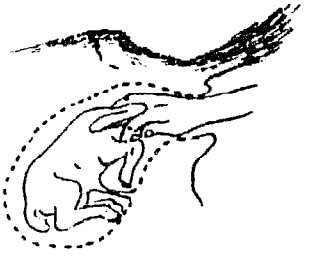

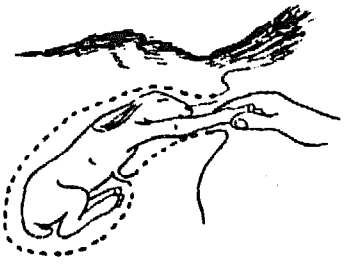

Section I 4

The Udder And Milk Production

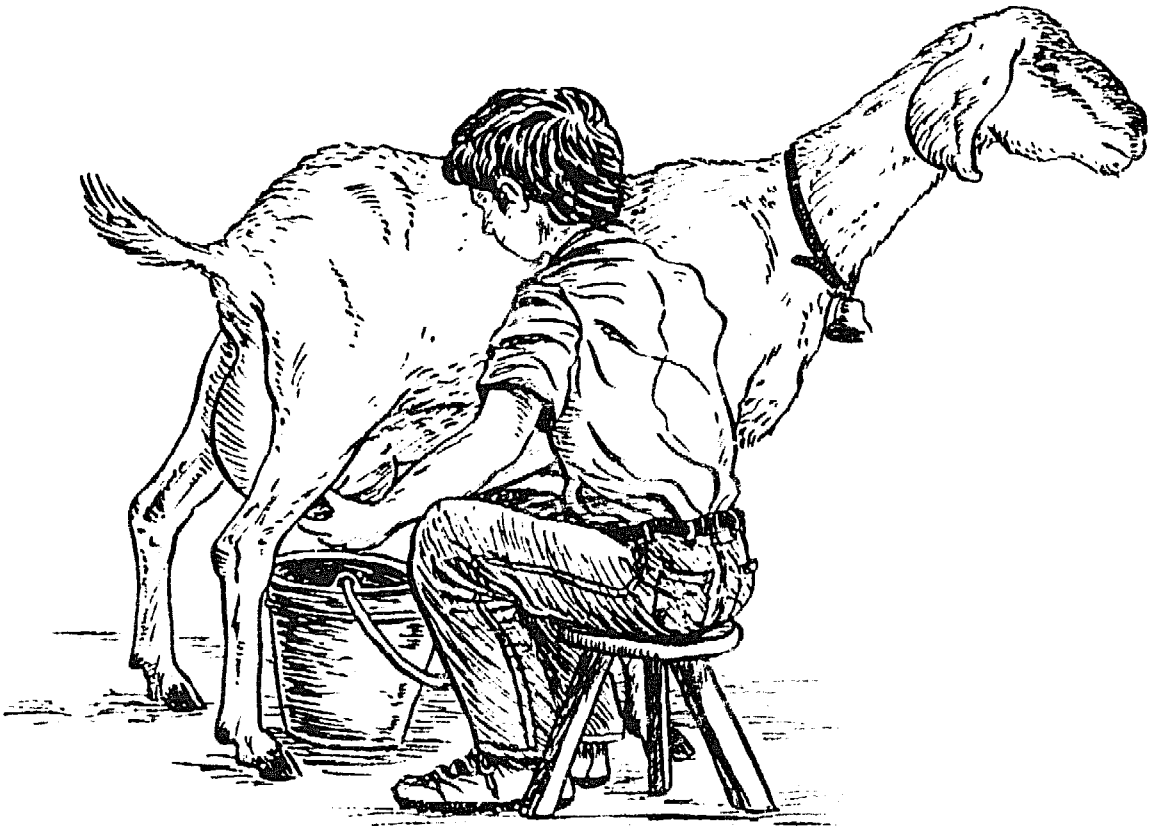

XIV. THE UDDER AND MILK PRODUCTION

Many doctors prescribe goat's milk for a number of maladies such as stomach ulcers and liver problems. But goat's milk is not a medicine. It is a very excellent food.

The great majority of goats are raised for milk and are managed much the same as dairy cows. They require milking twice daily and the usual length of lactation (milk production) is 305 days. This allows a 60 day dry period for the doe to replenish her body stores of nutrients before the next lactation.

When a doe kids or "freshens", it is a common practice to remove the kids and raise them separately from their dams.

An average dairy goat will give about six to ten pounds of milk a day, and should be milked twice a day at approximately 12-hour intervals. A milking parlor or an area away from the main barn is needed for this purpose. The basic equipment needed to obtain milk for home use is a milking stand, clean bucket, sanitizing solution, teat dip, and milk strainer.

To avoid mastitis, does should be milked in an area free of dust and insects. Wash and dry each doe's udder thoroughly, using a separate disposable paper towel. Milk the first few squirts of milk into a strip cup or special container to check for abnormal milk.

Screen for mastitis and milk those animals after all others have been milked. Discard the mastitis milk. Any doe that has chronic mastitis is quite likely to infect other does and should be culled.

After the does have been milked, the milk should be run through a strainer to remove foreign material. Then it should be chilled to 50 degrees F (10 degrees C) or less within 30 minutes of milking and held at that temperature until use.

Compostion of Milk

	Goat	Cow	Human
Fat%	3.8	3.67	3.6-4.7
Lactose%	4.54	4.80	7.18
Ash%	.55	.65	.21
Protein%	3.21	3.50	1.19
Vit B1 ugm/100ml	68	45	17
Calories/100ml	70	69	68
Cholesterol mg/100ml	17-39	7-10	

The supply of milk normally rises quites rapidly after kidding in response to the rapid growth demands of the young. The peak of production is commonly reached about two months after kidding. From the peak, the milk production curve gradually slopes downward.

Age of the doe is a factor in milk production, the peak coming in the fourth or fifth year.

Milking procedures are similar to those for cows. Sanitation and general cleaniness are important. An elevated wooden stand aids

cleaniliness and spares the back of the milker. The best milk pails are seamless stainless steel and are hooded to keep out debris. A strip plate, strainer, and filter discs are also helpful. A goat can be milked by hand in 7-8 minutes.

DISEASES OF THE UDDER

Mastitis—Inflammation of the mammary glands from any cause. Mastitis produces changes in the milk secreting tissues.

Symptoms:

1. A straddling walk may be one of first signs.
2. Milk can have clots or stringiness and reduced amount.
3. The udder is warm, swollen, hard, and usually painful and milk is off-color.

Causes: injuries

Treatment:

1. Most mastitis is responsive to penicillin via intramammary infusions and intramuscular injections of the same for 5 to 7 days. First sterilize the end of teat well with a disinfectant, e.g., Betadine solution.
2. Frequent milking every 1 to 2 hours and massaging the affected half is very often sufficient treatment. Warm compresses or packs applied frequently are also helpful.

Prognosis (Outcome): Guarded for recovery. Poor.

Good Udders

SUPERNUMERARY TEATS

A common problem is extra teats, double teats, and fish-tail teats with double orifices. Extra teats can be snipped off easily when young.

PROPER MILKING MANAGEMENT

1. Sanitation. Prevent infections between animals.
   a) Use separate disposable paper towels or cloth towels for each

animal—not a communal rag.

b) Milker's hands should be washed between each milking.

2. Teat dipping. Recommended for goats.

a) Organic iodine preparations, like Betadine, are best. Caution: iodine based preparations that have been accidentally frozen will cause severe irritation if used. Teats should be dipped following milking in an approved iodine solution, 5,000 to 10,000 ppm which is a ½% to 1% solution. These iodine compounds should have glycerol or lanolin incorporated. "Bovidine" or Betadine is one of the best aids in preventing the spread of mastitis.

3. Management.

a) Every effort should be made to prevent healthy does from becoming infected by using good santitation. Clean dry bedding areas are also important.

b) Treatment for an animal that is already infected must be tried, but if not successful, it should be culled.

PASTEURIZATION

Pasteurizing equipment should be monitored carefully. Use a good thermometer.

Regular method: 145 degrees F (62 degrees C) for 30 minutes.

IMPORTANT DAIRY FACTS

1. Don't infuse the udder with irritating injectable, e.g., tetracycline hydrochloride which will cause udder to react violently.
2. The milking doe requires 3 times the amount of feed of a non-milking goat.
3. Be regular in both milking and feeding—this will teach the goat to be regular in her milk let-down.
4. Keep buck away from milking doe.
5. Only let the buck stay with the milking doe a short period of time as milk will absorb the male goat odor.

Heavy producers sometimes are milked three times a day, especially if the doe has leaking teats.

Doe at her best: production will be increased each year until about the fifth year. The average life of a normal goat is considered to be 10 to 12 years.

UDDER IMPETIGO

Staphylococcus aureus infection is quite common. Erroneously called Goat Pox. People can become infected. Produces tiny ferruncles (pimples) with deep pussy abscesses in the skin. They are painful, extending deep into skin lays, and constitutes a very nasty situation in the dairy goat. Use Nolvassan Ointment until it clears up. Do not use water or a water preparation, which seems to cause them to spread. This disease is contagious and can spread to the whole herd.

Treatment: Dry pimple type: one time copper Napthenate Fort Dodge ointment followed by daily application of an ointment. The bovine udder infusion, e.g., "Dry Clox," cloxacillin benzathine Fort Dodge is effective.

CARE OF THE MILK EQUIPMENT

Mostly pails and buckets are used. Only a few have milking machines. Most people fail to appreciate the importance of scrupulously clean equipment.

After cleaning equipment with detergent, follow with chlorine rinse around 200 parts/million, which would be 0.2 ml per liter (which is approximately one quart). Chlorine solution is inactivated by organic material, e.g., Manure. So be sure there is no milk in buckets.

Iodine, 50 ppm or 0.05 ml per liter (quart), is satisfactory. Not as inactived as much as chlorine in presence of organic material. Can use the color of the iodine solution as a measure of strength.

Detergent—use a good detergent in the quantity recommended and "elbow grease". Always maintain the temperature of cleaning solutions. If below 105-110 degrees F (40-44 degrees C), can have a reprecipitation of fat in bucket.

Filter pads—to pour milk through. Cloth can be used or a manufactured special filter paper. This is important to remove any foreign material that dropped into milk while milking.

Cleanliness—clean the animals prior to milking. Wash udder with an iodine rinse. The milkers should wash their hands.

HANDLING MILK

Cleanliness—cover milk in the bucket, prevent dirt and flies from contaminating.

Temperature—it is very important to cool the milk immediately to inhibit bacterial growth.

MILK OFF FLAVORS

Off flavors are a serious problem with goat milk.

1. Off flavor is present in the milk as it comes from the udder.

a) Food flavors—voltile odors may be aborsbed from the GI (stomach-intestinal) tract and pass via the blood system to the udder. Onions, cabbage, turnips, and some weeds such as burdock are examples. If they are to be fed, feed small amounts immediately after milking, certainly no less than 4 hours before the next milking. The problem may occur in only one goat even though the whole herd is on the same diet. Odors from a dirty facility may be inhaled and reach the milk.

b) Conditions of health—off flavors may be secondary to systemic illnesses, including indigestion and metritis (inflammation of the uterus). Mastitis is a very important cause. A salty taste may develop, especially near the end of lactation. Occasionally a goat's milk will go off flavor each time she comes into heat.

2. Off flavor can develop while milk is standing. The udder should be washed and dried before each milking. This also stimulates milk "let down".

a) Bacterial action—the milk should be collected and stored in clean, sterilized utensils. Cool rapidly; pour the milk into pre-colled

containers and rush it to the refrigerator. Without refrigeration, milk should be consumed promptly.

b) Chemical action—Never mix raw and pasteurized or hot and cold raw milk.

c) Some goats always have poor-tasting milk, for which no correctable cause is found. This may be hereditary; the trait seems to run in certain families.

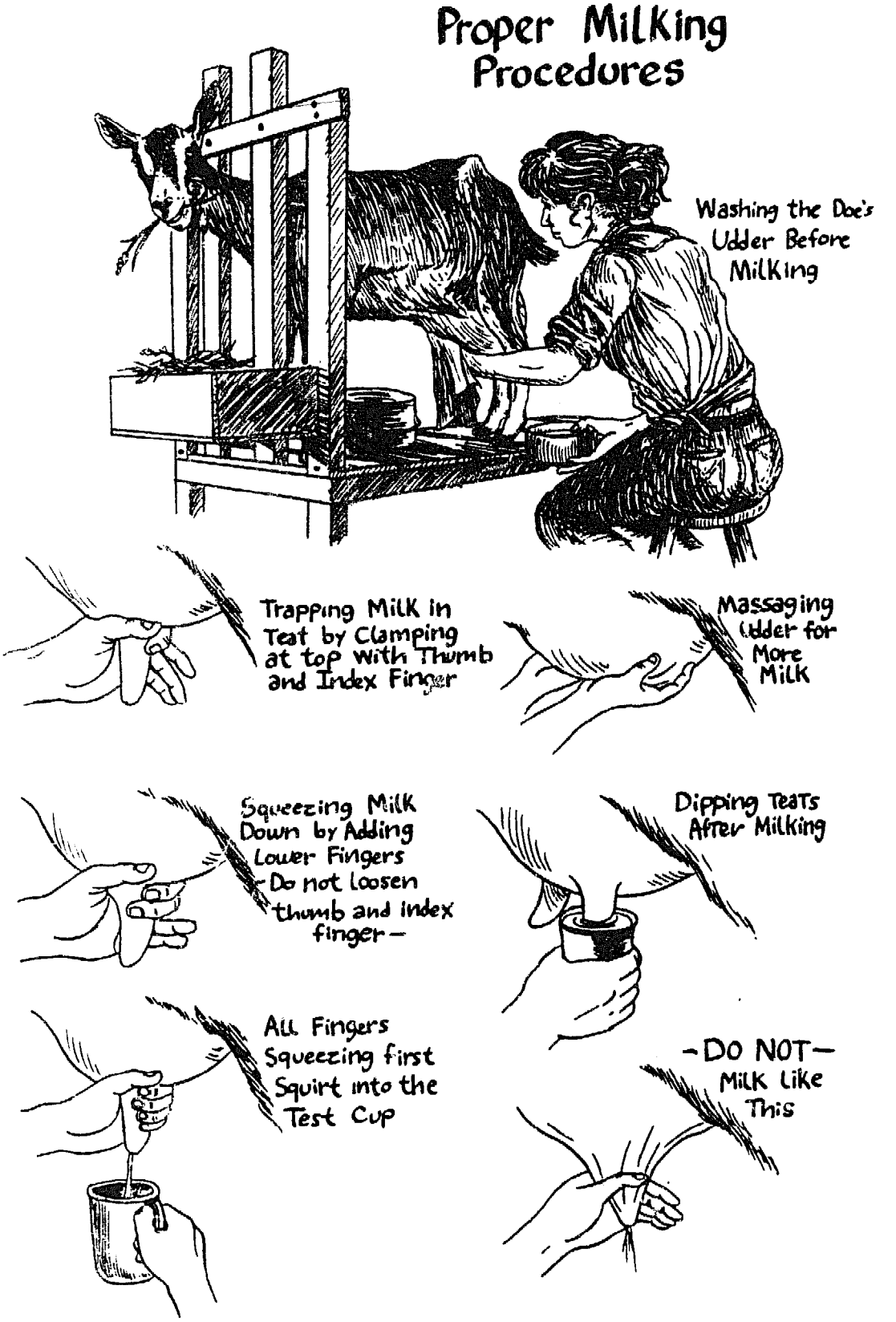

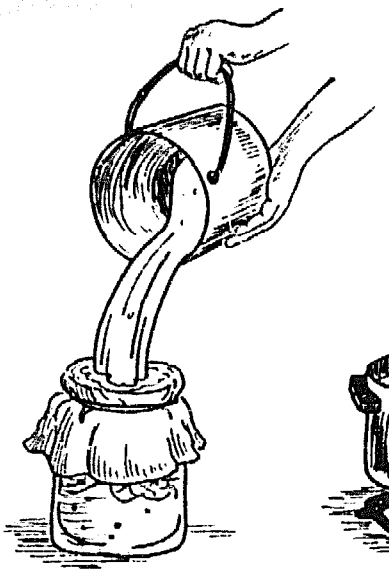

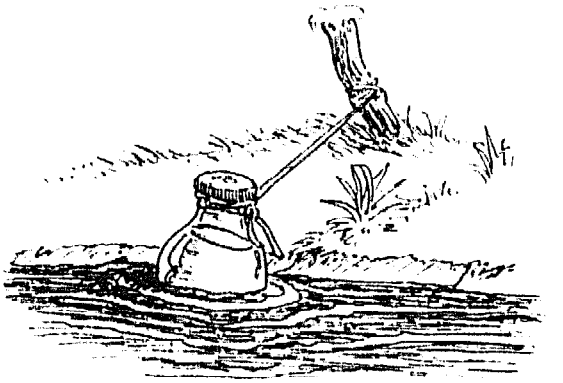

MILKING EQUIPMENT

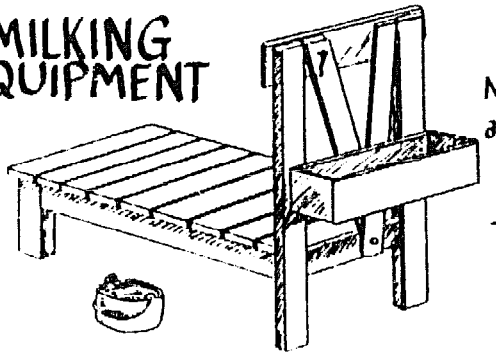

Milk Stand and Bucket

TEAT DIP CUP

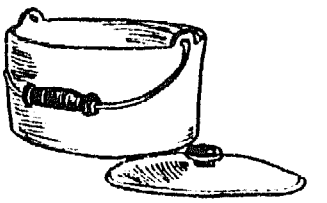

Milk Bucket and Lid

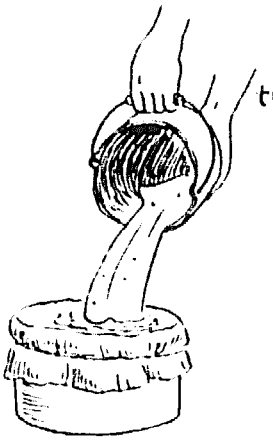

Straining the Milk through Cloth

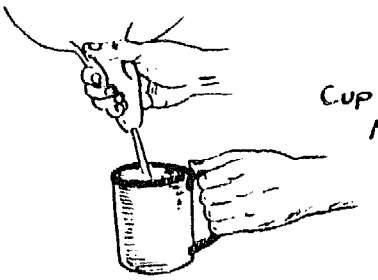

Cup for Testing Milk

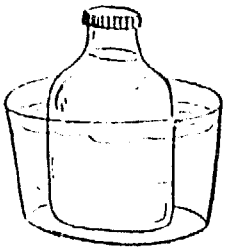

Cooling the Milk

Dipping Teats After Milking

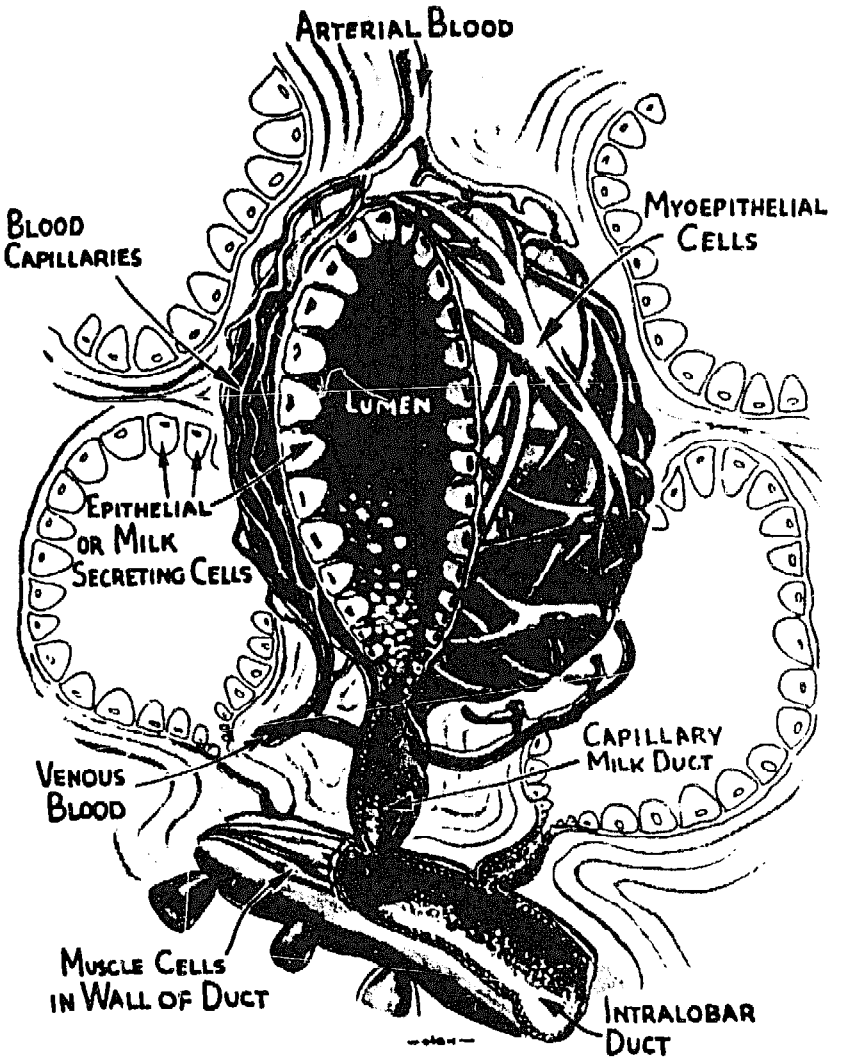

An alveolus opened showing secretory cells, blood supplies, ducts and muscle cells. Drawing courtesy of Babson Bros. Co., Oakbrook, Illinois.

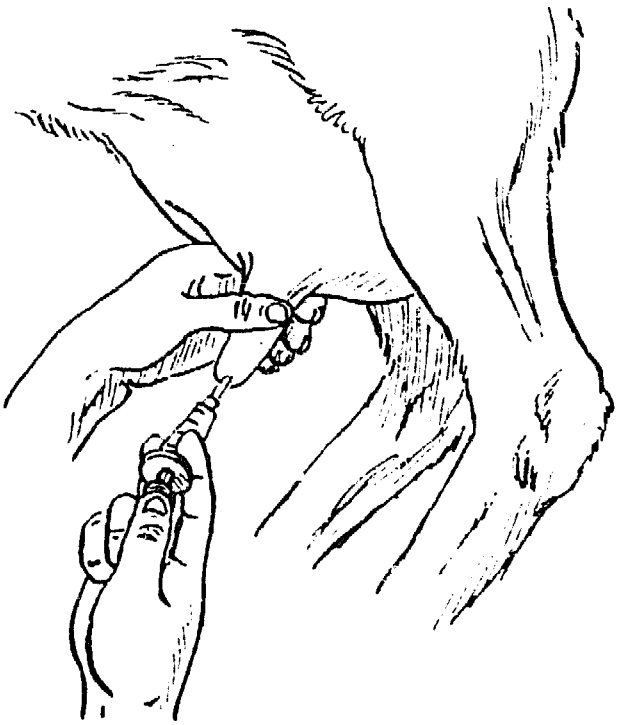

Section 15

Parasites

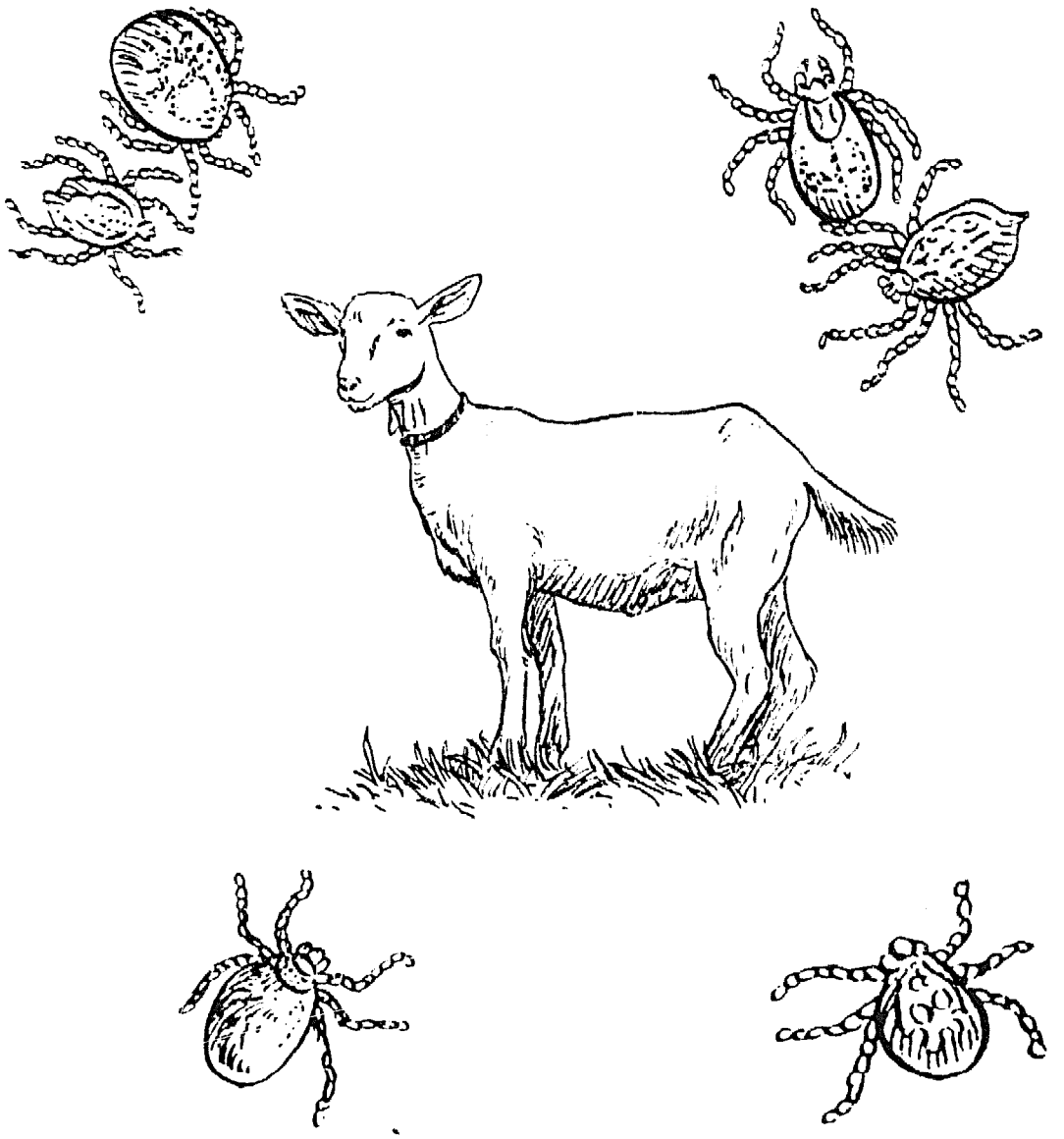

XV. PARASITES

EXTERNAL PARASITES (live on outside of body)

EAR MITES—Psoroptic cuniculi, very common in ears of dairy goats. The mite lives deep in the ear canals.

Symptoms: Head shaking, ear scratching, scabs in ears, and trying to put a foot in ear. Carry head to one side or tip head or walk in circles. La Manchas can have severe infestations. May be a discharge from the ear and may see whitish scaly exudate in ear.

Treatment: cattle screw-worm (eartick medicine) sprays containing lindane. Preparations used on dogs and cats for ear mites, e.g., Rotenone = 1 part to 3 parts mineral oil, and work down into ear. Mitox - Carbaryl N-Methylcarbamazine (Sevin). Goats don't like to have ear manipulated. Best to treat again in 2 weeks. Ivermectin might have some effect.

FLEAS—are sometimes a problem in kids, but condition is rare. Usually acquire from barn cats. Treatment: Sevin, Lindane Spray, and other flea preparations used for dogs and cats.

FLY STRIKE—Massive egg deposits, rapidly hatch into maggots.

Treatment: Fly repellents, e.g., pine tar. Diesel starting fluid will work immediately to kill maggots. The main ingredient is ether. Also straight ether or chloroform.

Maggots are very devastating to goats. As few as 2 or 3 under the skin can sometimes cause death.

BITING LICE—Bovicola caprae or demalinia are less common and are large enough to see with a magnifying glass, especially on the back and neck. They are yellow orange to brown in color and have broad head. They live on scales of dandruff and skin. They burrow into hair follicles. Usually cause severe prurites (itching). Will see more in the winter and spring months.

Treatment: None are approved for lactating animals. Coumaphos, (Co-Ral) .03% dust, or "pour on" (pour on small amount on back of animal). This is good and especially safe for kids. Clip hair—renders insecticide more efficient. Dust with Co-Ral powder or apply a solution 1 lb of 25% Co-Ral powder in 100 gallons of water—spray on. Repeat treatment in 10 to 14 days. Ivermectin is effective for sucking lice but not biting lice.

In treating external parasites, Malathion or Sevin used. Particularly good for biting lice in Angora goats. Can also mix Co-Ral in with this.

SUCKING LICE—Linognathus stenopsis, larger than biting louse. Lice live on the animal. They have no intermediate host. Lice are introduced to the herd by new animals or from a show. Inspect "new" goats closely for lice when introducing to your premises. Mostly found in winter and spring. Prevalent on sides of neck and underline around udder. Can see nits (small, developing or baby lice) in the hair (brown). They spend their entire life cycle on the goat. They are visible to the

naked eye; they have a narrow head and are bluish in color. They pierce the skin to feed and are heavy blood suckers. They can cause severe anemia, even fatal, especially in kids. A heavy infestation can kill a young goat. They may have central nervous system (incoordination) signs and are very weak from anemia (blood loss) and cannot tolerate stress. Tend to multiply more rapidly on young, sick, or debilitated animals. They may hibernate (become inactive) in skin folds and crevice during hot summer months, then have a sudden appearance in cool weather.

Treatment: Ivermectin or Co-Ral Spray, and repeat in 10 to 14 days as this is their life cycle span. Premises don't need treatment.

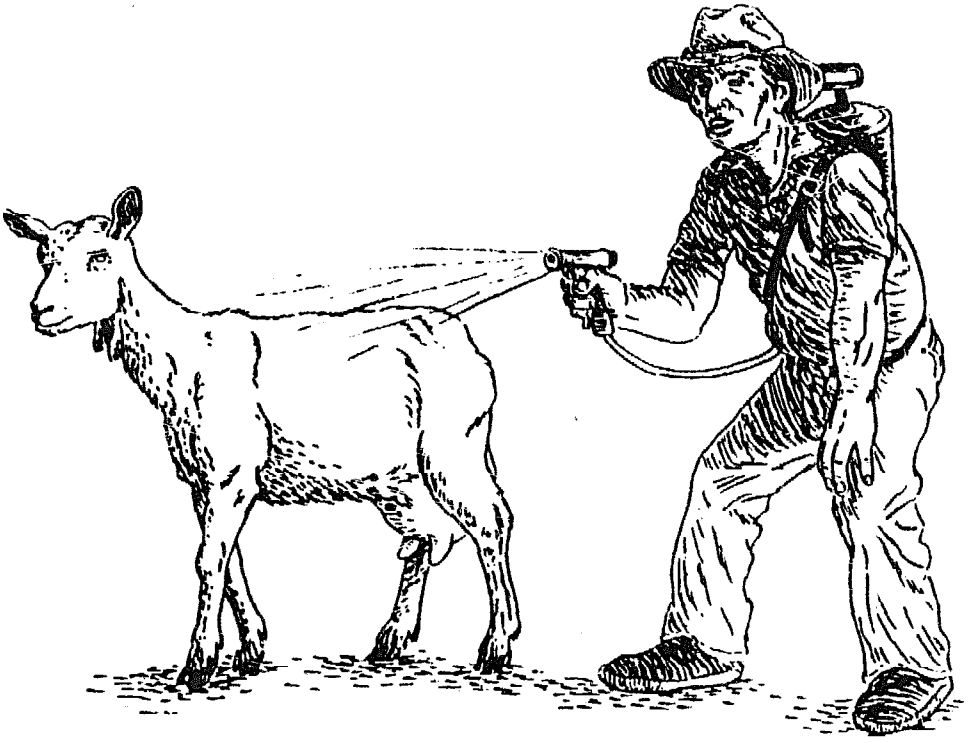

MANGE—is caused by very small mites not visible to the naked eye which belong to the spider family (they have eight legs). They burrow into the layers of the skin and spend their life-cycle there.

Chorioptic Mange Mite—Symptoms:

1. Severe itching
2. Hair loss, primarily on legs, belly, and udder.

Treatment: Coumaphos, spray twice, 14 days apart.

DEMODECTIC MANGE—Demodex Caprae

These mites invade hair follicles and sebaceous (oil) glands, causing loss of hair and abscesses. Normally the disease is limited to many small tiny nodules, especially on the brisket, lower neck, forearm, and shoulder, but the problem may generalize (become widespread).

NOSE BOTS—Oestrus ovis

Common in goats housed with sheep.

Symptoms:

1. Chronic discharge from nose (both sheep and goats).

2. Snuffling (both sheep and goats)
3. Goats may try to hide indoors during hot fly season.
4. Larvae live within the sinuses of the head.

Treatment: Ivermectin

RINGWORM

A fungus. There are several species and all are contagious. Body distribution—head, ears, neck, generally. Mostly are scaly circular lesions—grey short-hair areas—hair shafts broken off short, Highly contagious.

Treatment: 10% thiabendazole (TBZ) in glycerine. Apply topically (on outside of body). Iodine is effective but tends to burn the skin and stain. Thorough scrub in medication. Isolate infected animal(s).

SARCOPTIC MANGE—Scabies

Causes sarcoptic mange which is a very serious disease. May be a reportable disease.

Symptoms:

1. Skin is denuded of hair and the skin is thrown up in ridges or wrinkles. The face and ears are affected first.
2. Then it spreads to rest of body.
3. Emaciation
4. Intense itching
5. Redness and even bleeding
6. Scaling and thickening of skin.

Treatment: neguvon 0.2% once weekly for 4 weeks. Ivermectin. Co-Ral, spray several times.

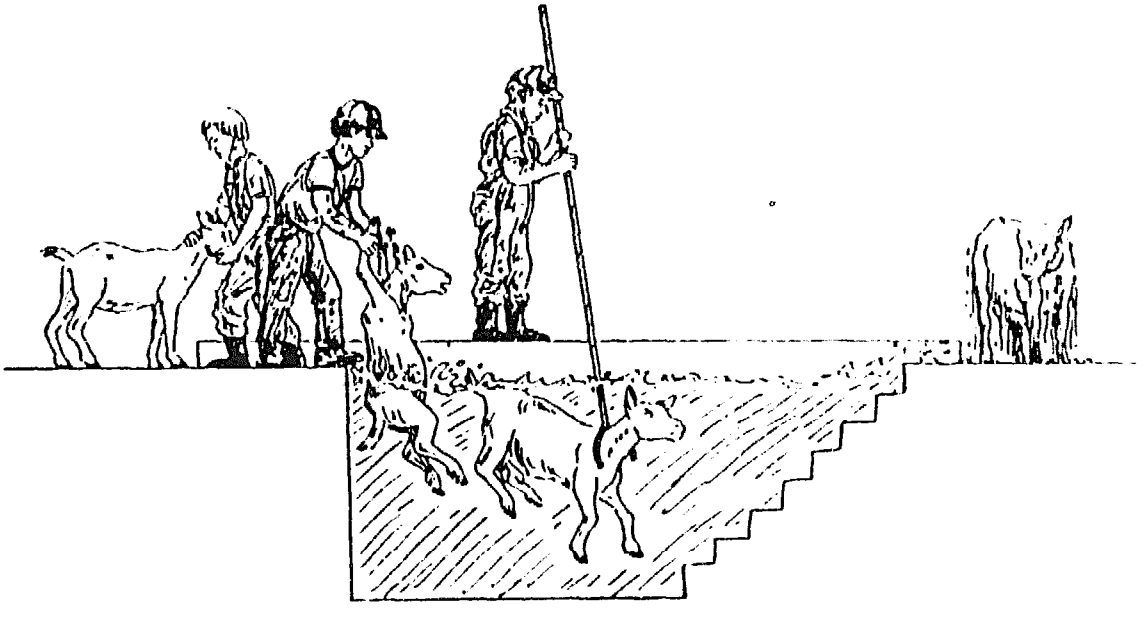

INTERNAL PARASITES

A major problem in goats and an important cause of anemia (blood loss). Most can be diagnosed by fecal examination. Two major symptoms in advanced cases: rapid heart beat and labored breathing.

LUNG WORMS

Live in the air passages of the lungs. They can be ¾ to 2½ inches long. Their presence increases the animal's susceptibility to pneumonia with coughing.

Treatment:

Ripercol or Levamisol—2 ml per 100 lbs body weight SQ.
Ivermection—1 ml per 110 lbs body weight SQ.

STOMACH AND INTESTINAL WORMS

Also called Hair worms, they live in the stomach and intestines and are blood suckers.

Symptoms:

blackish green diarrhea, depression, abdominal pain, weight loss, dehydration and death.

Treatment: Ivermectin and Levamisol.

Kids are highly susceptible and most adults are resistant and rarely develop clinical (obvious) signs, but can remain carriers and shedders of the worm eggs.

TAPEWORMS

Not life-threathening like other parasites. Not a big problem but maybe underestimated. One type lives in bedding and in soil. Flat, white, segmented ribbons live in the small intestine and are passed in the feces.

Symptoms:

1. Segments of tape worm may be found hanging on the hair in perinneal area (under tail) or in the feces.
2. A slight diarrhea.

Treatment: Mebendazole (Telmin) and Fenbendazole (panacur).

Albendazole—most effective, but must have permission to use.
Ivermectin is not effective.

LIVER FLUKE

Flat worms, must have a snail in pasture (usually a body of water—a lake) that carries the metacercariae (young developing fluke)—waits on encystment inside a capsule on the vegetation and is consumed by host.

Symptoms:

1. Emaciation, anemia, lethargy, weight loss. It is estimated that an adult fluke ingests .3 to .5 ml of blood per day, so 150 flukes could be taking 45 to 95 ml of blood from the animal per day.
2. Cause inflammation and tissue death as they migrate through the liver.
3. Distended painful abdomen.
4. May cause disease in goats that share their pasture with deer.
5. Decreased milk production.
6. Bottle jaw (swelling under the jaw).

Prevention:

1. Good nutrition

2. Snail control—drain or fence off marshes
3. Treat marshes or ponds with copper sulfate to kill snails.

Treatment/Control:

Control:

1. Fecal flotation test: A microscopic examination for worm eggs in the feces should be checked several times a year.
2. All new goats, or goats returning from fairs or breeding on different premises, should be quarantined until determined to be free of internal parasites.
3. Manure control—use adequate feeders, waterers, where animals can't defecate onto the feed.
4. Pature management:
   a) Do not overstock the field, paddock, or pasture.
   b) Mow the grass frequently if possible so the grass is exposed to direct sunlight—this stops development of many parasites.
   c) Keep deer out of pastures if feasible.
   d) Include both goats and sheep in the same deworming program.
   e) "Safe pasture". Alternate or rotate pastures with cattle and horses as they don't have the same species of parasites in their systems.

Treatment: Flukes are not susceptible to most wormers. Albendazole is the drug of choice if available. Deer and snail population should be kept separate from goats.

1. Deworm goats in late fall and move to safe pasture. Repeat again in late spring or 2 weeks before kidding.
2. "Periparturient rise" in parasites = parasites will reproduce rapidly around kidding time and infect the kids. So treat all does 2 weeks before kidding. Repeat every 3 weeks for 3 more treatments.
3. Moving goats to a safe pasture after worming is very helpful in maintaining a reduced parasite load.

COCCIDIOSIS

An intestinal disease of young animals caused by a protozoa. One of the most frustrating parasitic infections encountered by the goat owner. Coccidia can be considered one of the leading killers of young goats under 4 months of age. The life cycle is complex. Kids born in the spring are the most vulnerable and clinical sign appear 4 to 8 weeks after exposure.

Treatment: "Corid" 9.6% solution in drinking water at 16 oz. per 100 gallons for 5 days. Then use solution of 8 oz. per 100 gallons for 21 days.

Reworm daily for 5 to 7 days.

"Bovatec" can be incorporated in a pre-creep feed.

Symptoms:

1. A high percentage of kids are affected.
2. Weakness.
3. Not eating—loss of appetite.
4. Losing weight, chronically poor gains.

5. A watery diarrhea with blood and straining, but usually rare. It will sometimes be a gray-green color.

6. Dehydration.

7. Rough hair coat.

8. Anemia.

9. Sudden death—can be high if not treated, but usually around 10%.

Coccidia infection may be acquired from contaminated water and feed or pasture or by licking contaminated wool or hair of an infected animal. The well fed animal is just as susceptible to coccidia as the malnourished one.

If a kid is weak and unthrifty, consider coccidiosis. The severity of symptoms depends upon how many occysts are ingested. The majority recover but will have a setback in growth and decreased performance. Even though immunity develops, the animal may continue to shed occysts for the rest of its life.

Prevention:

1. Pasture rotation
2. Raise kids on elevated, slatted floors or pens.
3. Avoid small grassy areas for exercise.
4. Clean environment = dry, clean lots. Keep clean of manure or dirty bedding and compost this if possible.
5. Isolate sick and newly acquired individuals
6. Separate kids from adults.
7. To aid in the prevention of coccidiosis in artifically reared dairy goats, the kids should be put in small, age-matched groups in outside portable or elevated pens that are moved to clean ground periodically.
8. Arrange and establish feeders so that neither kids nor adults can contiminate feed with their manure. Prevent the kids from jumping into the feed troughs.
9. Stressful situations: (must be kept to a minimum)
   a) Avoid overcrowding
   b) Avoid changes in surroundings
   c) Avoid sudden changes in feed
   d) Avoid travel as much as possible
   e) Lessen hot weather effects by using shades, barns, etc.
   f) Weaning can be a stressful situation.
   g) Stress allow the propagation of the coccidia to gain a foothold in the animal.

If a herd problem with coccidia exists, start the kids on a coccidiostat, (a medicine that inhibits coccidia growth) one to two weeks before introducing them to older animals. Maintain them on the coccidiostat for 6 weeks.

Coccidiostats: Amprolium, Lasalocid, Sulfamethazine, Deccoquanate, Nitrofurazone, or Rumensin.

Amprolium—"Corid"

SUMMARY OF INTERNAL PARASITISM

Is one of the most important problems of all animals. Goats are the most susceptible of all livestock species to parasitism. Contaminated feed and water are the major problems. To produce goat milk from healthy animals with a low level of parasitism, it is best to keep them in the dry lot—feed them through the fence with a keyhole feeder—green forage and avoid fecal (manure) contamination in the feed and water. That's the best way to control internal parasites in goats.

PARASITE CONTROL IN GENERAL

Do's:

1. Do maintain clean, dry, warm housing.
2. Do keep available supply of fresh water.
3. Do rotate pastures.
4. Do keep kids separate from adults.
5. Do feed well balanced diet in adequate amounts.
6. Do discuss problems with your animal health advisor.
7. Do observe goats daily.

Don't:

1. Don't mix other livestock with goats.
2. Don't have feeders where animals can climb into them.
3. Don't allow water supply to become contaminated with droppings or bedding.
4. Don't graze in swampy areas.
5. Don't mix newly purchased goats with herd until proper isolation (about 4 weeks) is observed and vaccinations are done. (Quarantine.)

LIFE CYCLE OF TICK

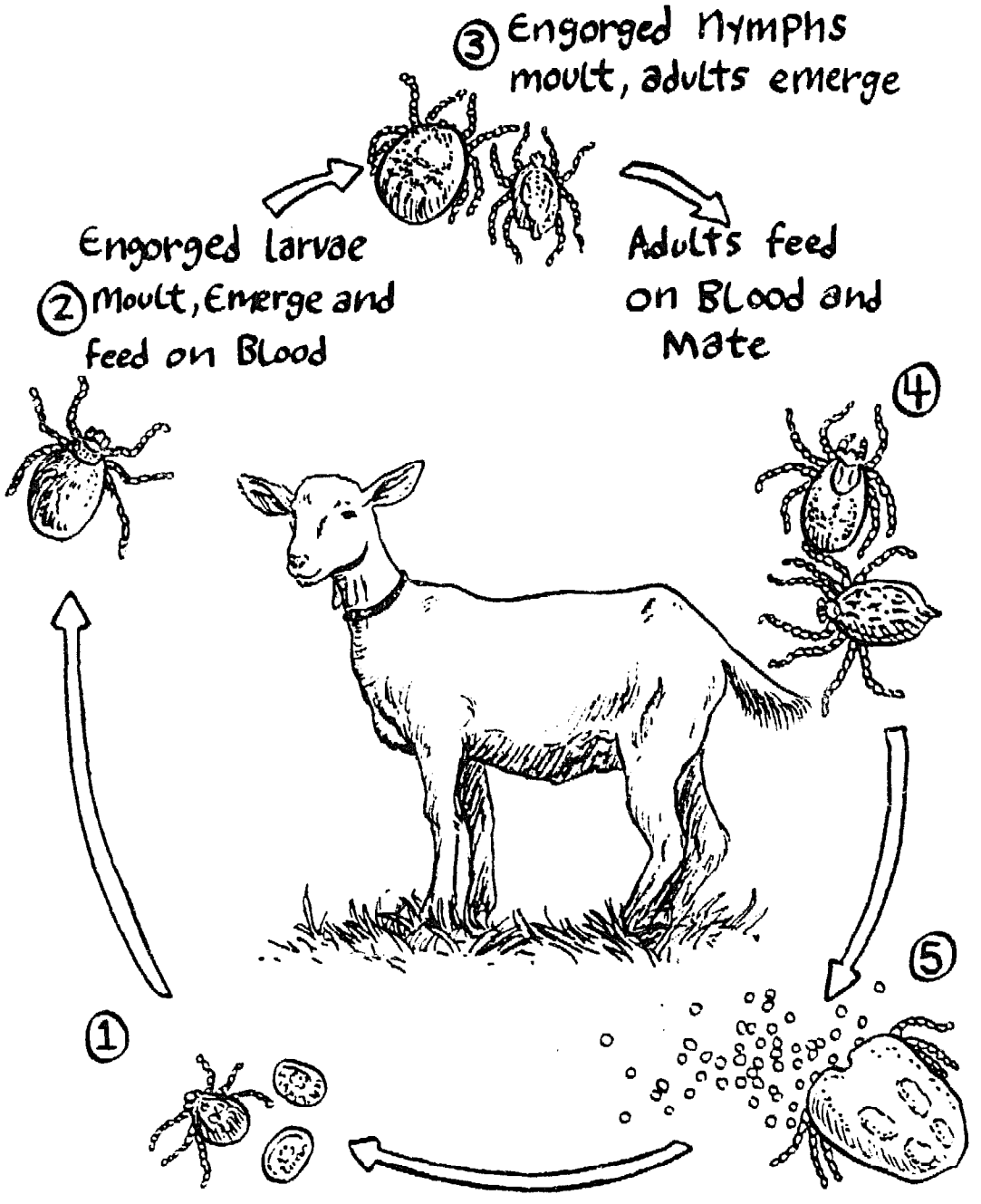

TICKS

Ticks are a serious problem and a good program of management must be used to prevent fatal diseases, such as Anaplasmosis and Heart-water disease.

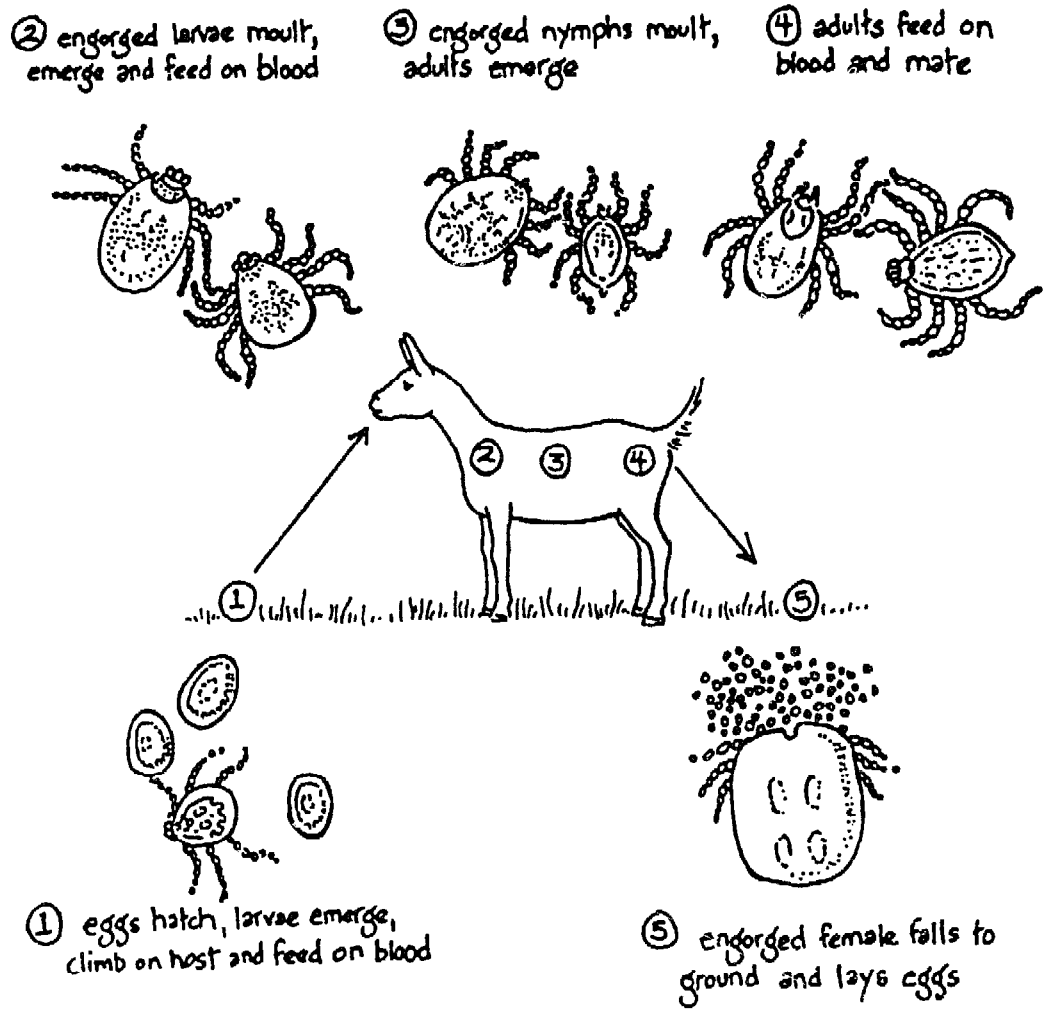

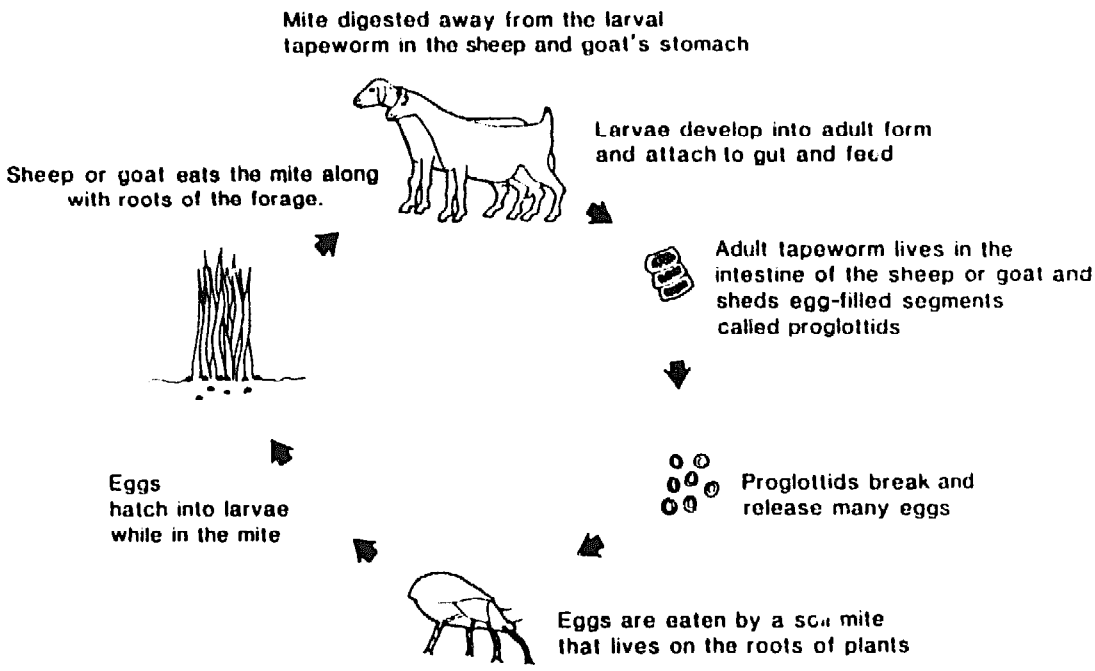

Typical Life Cycle of the Tapeworm

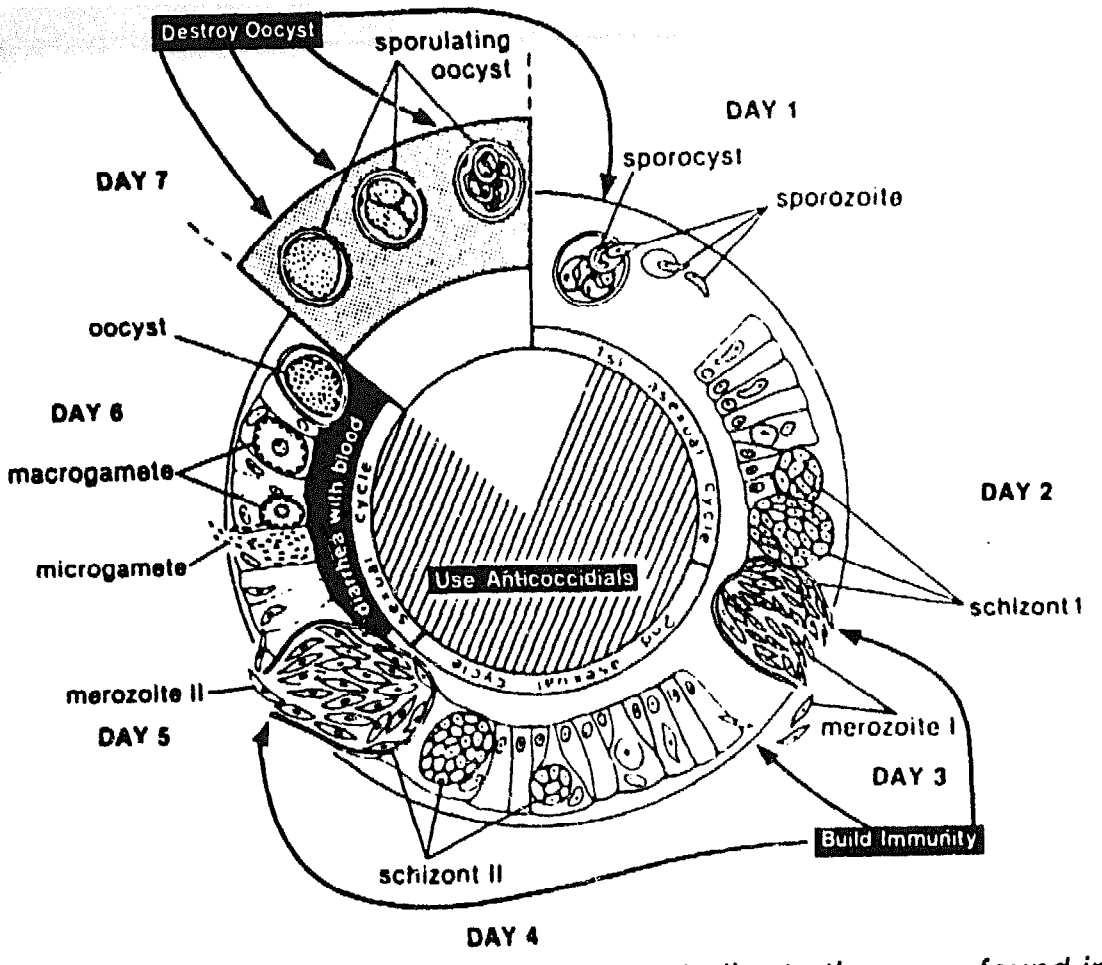

Life cycle of ovian coccidiaa (E. tenella) similar to the ones found in goats; showing where anticoccidial drugs are effective. Drawing courtesy of Feedstuffs Publishers, Minneapolis, Minnesota, November 1, 1982, 22.

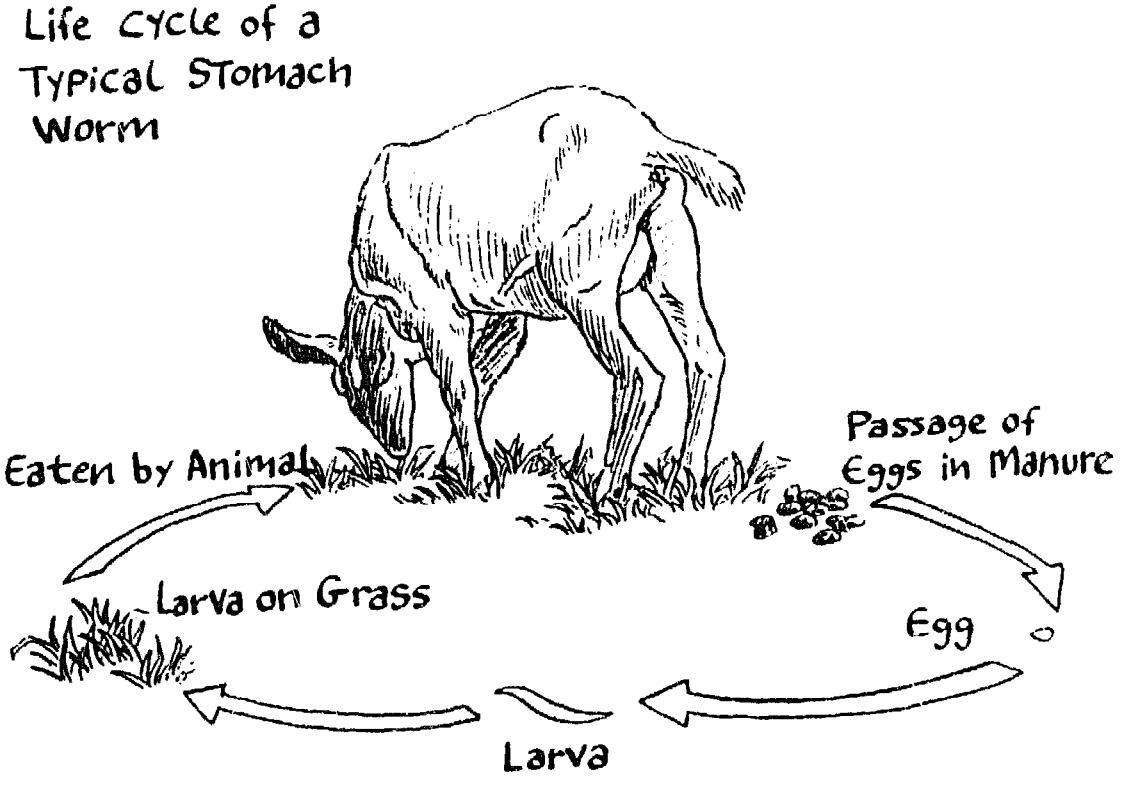

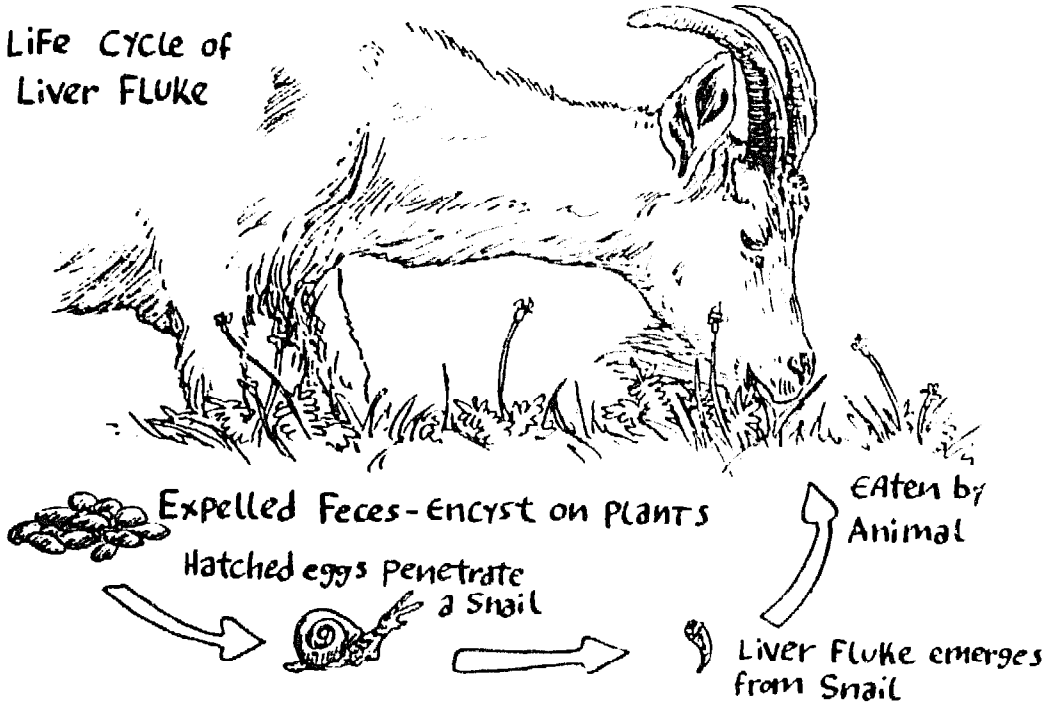
Life Cycle of
Liver Fluke
Expelled Feces - Encyst on Plants
Eaten by
Animal
Hatched eggs Penetrate
a Snail
Liver Fluke emerges
from Snail

Section 16

Diseases of the Kid

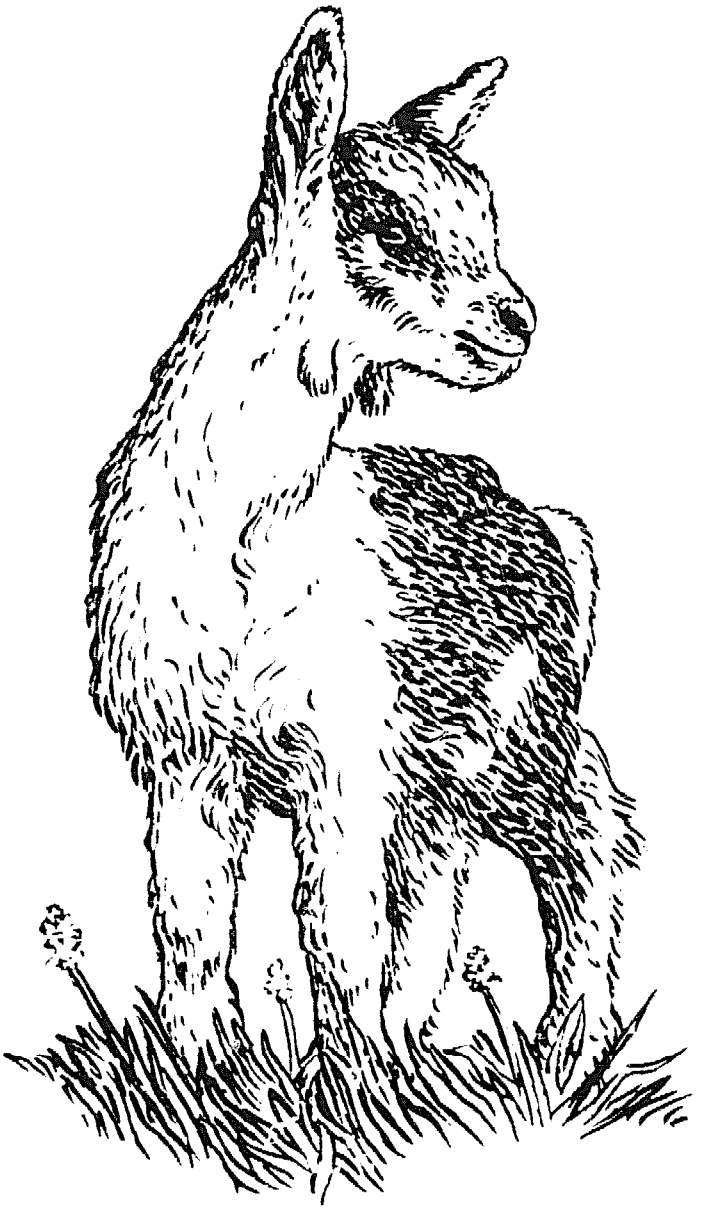

XV1. DISEASES OF THE KID

FEEDING KIDS

Most dairy goat kids are taken from their dams at birth and bottle fed. The first meal for a newborn kid should be colostrum. This is the first milk that a doe produces, and it contains antibodies to protect the young kid from infection until its own immune system can take over. Quite often, goat raisers simply let the kids nurse their dams for their first meal. The milk a doe produces for three days after freshening is not acceptable for human use.

Kid goats may be raised on goat milk, cow milk, or commercial milk replacer. A kid should be started on 5-6 oz. three times a day. Within three weeks they should be able to consume a pint three times a day.

Kids can be weaned as early as six weeks of age if they are eating other feed well. They will start to nibble at hay leaves by about one week of age if hay is available to them. They should be offered a very palatable concentrate ration if available after about three weeks of age.

Sometimes does are allowed to raise their own kids. In this situation, the does should be checked daily to make sure their udders are being emptied of milk. If not, the doe's udder may become lopsided or she may be in danger of contracting mastitis. Some producers lock the kids up at night, milk the does in the morning, then turn the kids back in with their dams during the day to reduce bottle feeding and milking.

If the kid fails to suck and get milk, it must be helped. It may be necessary to open its mouth and milk the teat into it.

If you want to milk the mother doe for home uses, do not allow the kid to stay with the doe during the night time. Put the kids in a separate pen and allow it to be with the doe only during the day.

DISBUDDING NEONATAL (Newborn) KIDS

Horns can be a source of injury to other animals or to humans, especially if they are on the buck, however in some areas the horns should be left intact to allow protecting against predators. Some goats are hornless. Examine for horn buds.

1. Do as early as 2 days old, as horn grow extremely fast.
2. Inoculate with tetanus antitoxin, half of a vial that contains 1500 units.
3. Best to use an electric disbudding iron made for goats and when heated the end must reach a cherry-red color. Apply heated disbudder iron over horn button for about 5 seconds, and not more than 7 seconds, let head cool for 15 to 20 seconds and remove the horn cap and re-burn over the bloody stump to prevent the growth of scurs. Don't be too aggressive. Be sure the burned area is at leat ¼ to ½ inches from the base of the horn bud—if not, scurs will grow. Caution: if head is overheated there can be brain damage. Can destroy

the musk patches or scent glands at the same time. Scent glands are slightly posterior (toward rear) and medial (toward the middle) from horn buttons. It hot iron is applied for too long a period of time, there is danger of producing a "post dehorning encephalitis" (brain damage) caused by burning the suraface of the brain.

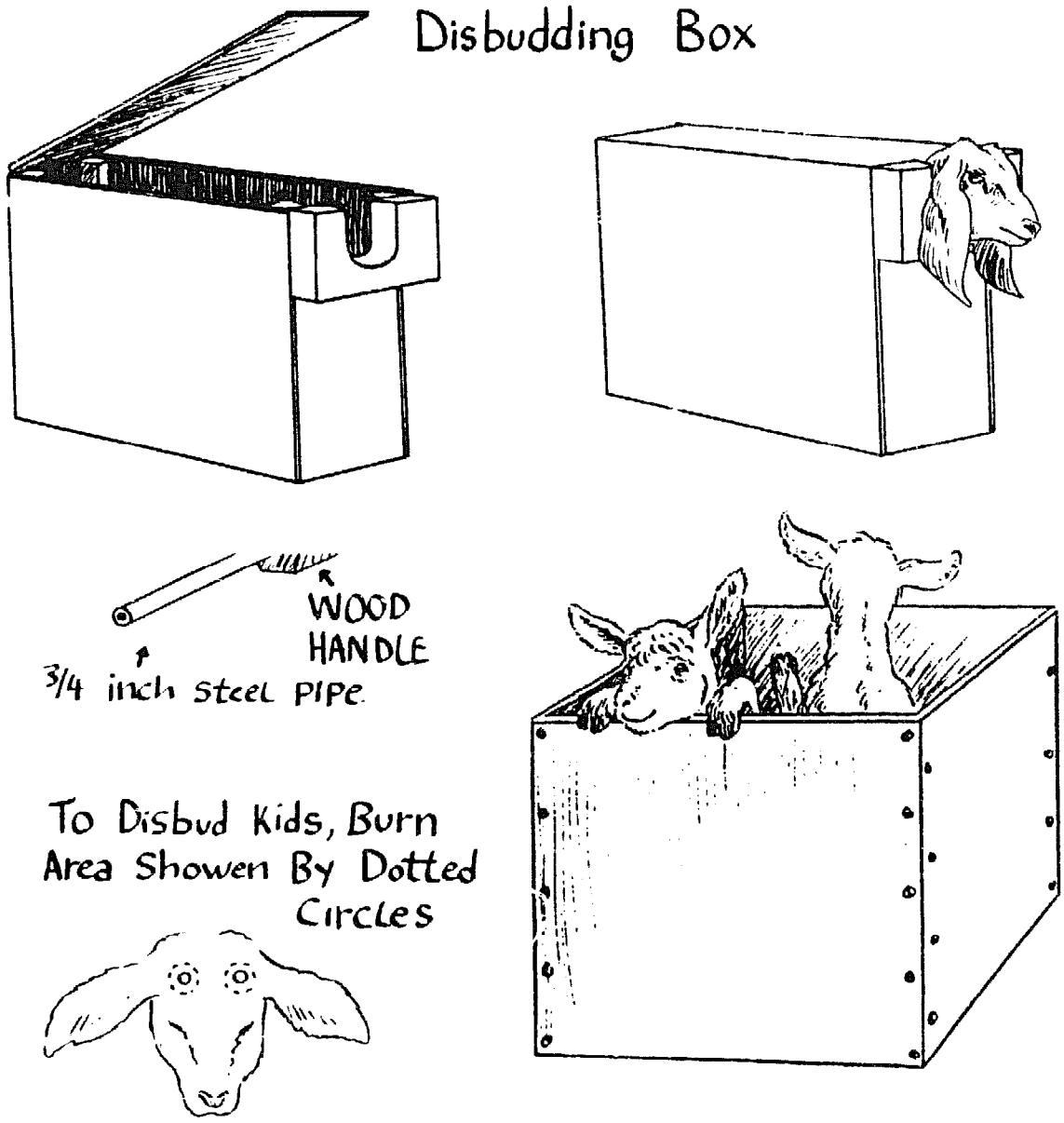

PNEUMONIA PREVENTION

Can grab newly born kid by hind legs and swing it around in order to throw fluids out of lungs. Use an infant rubber syringe or ear syringe to extract fluid from nose. If weak or not breathing, can use artifical respiration. Close one nostril and blow into other one to inflate lungs.

If extremely cold, the kids may be suffering from hypothermia (subnormal body temperature). Put this baby kid in a bathtub of warm water, 104 degrees F (40 degrees C). This is the fastest method of raising their body temperature to normal. Heat lamps are also used, but be careful of burning kid. They can be rolled in a blanket; held

close to a person's body and rubbed or put next to heated rocks.

Contracted (tightened) tendons causing "knuckling over" are quite common, but usually will be self correcting in several days.

WEAK AND STARVING KIDS

1. Usually need heat and food.
2. In their very weak condition they will often eat dirt and hair.
3. Be sure they are getting milk when nursing—does rarely could have plugged teats. Kid's tail will wag if getting milk.
4. Or give oral electrolytes. Several commercial preparations are available, like Pedialyte or Gatorade, or try the following home-made formula; which can be given by mouth or stomach tube.

2 teaspoons of common table salt. (10 grams)

1 teaspoon of baking soda (sodium bicarbonate) (5 grams)

8 tablespoons of crystalline dextrose, honey, or white corn syrup (not cane syrup). (120 grams).

Mix in 1 gallon of warm water. (4 liters).

MANAGEMENT OF NEWBORN KIDS

Feeding young stock. The kid should be fed as much as it wants in 6 feedings per day during this time. Nipple feeding is more natural but pan feeding from the beginning simplifies feeding and sterilizing procedures. The milk must be at body temperature. By two weeks of age, the kid will be drinking up to 2 quarts of milk a day; this is the maximum amount to be fed kid of any age. At two weeks old, add good roughage and a mineral lick or clean dirt to supply iron and copper. Normal growth rate is 0.5 lbs gain per day. The kid can be weaned as early as 5 weeks of age or 20 pounds. Extra goat milk may be frozen for as long as a year or fed back to the doe. Colostrum may be frozen in ice cube trays (one cube per kid) to provide for emergencies when the mother's colostrum may not be available. Cow colostrum is better than nothing. Cow's milk may be substituted freely for goat's milk in raising kids. Scours (diarrhea) in the young kid may be caused by dirty utensils, cold milk, or overfeeding. Kids that become cold and weak need special care. Keep them warm and give high energy food, such as honey and sugar.

When kid diets are changed, it should be done gradually. They should be bottle fed so that the sucking reflex is maintainted. Goat's milk is the best diet, especially in the first 4 weeks. Can use cow's milk after the first 4 weeks.

A common feeding practice which prevents kids from learning to eat grain and forage is too frequent feeding of milk and feeding too much milk. Twice-daily feeding is adequate for kids after they are three days old and a practical maximum of two pounds of milk daily should be set for animals to be reared as herd replacements. As kids approach weaning age, gradually adding warm water to the milk they are fed will provide them with necessary fluids for rumen development and ease the stress of weaning them. Grain and hay feed to young

kids should be selected for them mainly on the basis of palatability. Hay which may appear to the feeder to be the best quality may not be as palatable or acceptable as other hay.

Kids can be weaned after 8 weeks. 12 to 16 weeks is more natural and they do better. Gradual weaning is often most practical.

Cold or chilling stress can be a significant cause of early mortality in newborn kids and presumably a risk factor for the subsequent development of pneumonia. Cold wind can be particularly devastating.

Animals at high risk or becoming weak (stressed) include multiple births, premature, or limp and weak kids; and those born to dams in poor condition. Those animals with moderate hypothermia (35 to 39 degrees C, approximately 96 to 100 degrees F) should be dried, given an additional ration of colostrum, or fed milk substitute and removed to shelter. Hypothermia (under 37 degress C, 98.6 degrees F) is best treated by artifical warming. A water bath of 104 degrees F (40 degrees C) is probably the fastest method to restore body temperatures to normal. Coats can be made from T-shirts, sweaters, or jackets to help conserve body heat.

KID/LAMB SCOURS

A very effective precaution against diarrhea in kids = regularity in feeding milk that has been heated to the right or body temperature. Or, if colostrum is available, the use of which will control stubborn scours. Bovine colostrum can be used at the rate of approximately 5% of body weight of the kid. First, take off or remove food entirely or reduce drastically for a day. Antibiotics: Neomycin—use orally for a general rule of thumb for scours.

Other useful drugs:

Gentocin (a wide spectrum antibiotics)

"Vetisulid" (a sulfa)

"Albon" (a sulfa) Sulfadimethoxine

"Val Syrup" (Fort Dodge) an excellent product for pediatric use.

"Probiotic"—a lactaobacillus preparation. This is excellent in restoring normal level of microorganisms in the digestive tract.

"Kaobiotic" (Upjohn) Kaolin-pectin with neomycin.

This is an excellent preparation, usually very effective and safe.

When the feces firms up then the animal can go back on feed, but gradually! Try not to have on full feed until 3 to 5 days.

1. Dehydration of the body is of prime concern. Use pinch test (the degree and length of time the skin stays pinched is the degree of dehydration) for rough determination of the degree. Use oral rehydration fluids.

NURSING AND FEEDING KIDS

When the tail is wiggling, it means he's getting milk.

Kids should have access to hay and a grain-based creep feed as early as 1 week of age. They can be weaned when they are readily

eating a large handful of grain per day; this should occur approximately 5 weeks of age, and no later than 8 weeks of age.

MANAGEMENT PROCEDURES

Navels of kids should be treated immediately following birth with iodine. Check them for birth defects. Disbud kids at 3 days to 2 weeks of age, preferable iwth a hot iron made for that purpose. Castrate buck kids and remove accessory teats from doe kids, and give tetanus antitoxin.

Selenium/vitamin E shots should be given in areas where the deficiency occurs. Give immunizations for enterotoxemia and tetanus at 4 and 6 weeks of age. Anticoccidial drugs may be necessary in some herds. Start a record with health, reproduction, production and disposition information on each kid.

To administer fluids use the oral route.

To determine between stillbirth and living birth. If the dead kid or lamb was living when born and walked on its feet, the thin seal covering the sole of the hoof will be broken or disturbed, while if the animal was born dead or aborted, this seal should be intact.

WETHERS (CASTRATED MALES)

Wethers fed on substantial amounts of grain are prone to develop urinary calculi. Reducing grain consumption, adding ammonium chloride to the diet, keeping the Ca:P ratio around 2:1, and keeping the magnesium level low will help.

CONTROLLING COCCIDIOSIS IN KIDS

Kids with coccidiosis, usually over 4 weeks of age show slight diarrhea, diagnosis can be made by fecal microscopic examination.

For treatment use sulfa (sulfamethazine) on kids while on milk. When 2 to 3 weeks of age, put sulfa in their milk once daily for 7 days then stop and repeat in 2 weeks. Can repeat this treatment. Another critical period is when kids are not on such a preventative program, stressed at weaning.

Amprolium (Corid) is effective very early in the life cycle of this disease. If used, should be given to kids early in life—on for 3 weeks and off for 2 weeks.

Deccox—used as a continous treatment by adding to feed. Available in bulk form in a soybean meal base so it can be mixed at home. Deccox a wide margin of safety. Start kids on it in their grain mix. The kids have to consume the grain to get this medication.

Section 17

Foot Diseases

XVII. FOOT DISEASE

LAMENESS

Lameness among goats is one of the most common problems faced by producers, and can lead to other complications if not treated and controlled.

PROBLEMS OF HOOVES

These involve horny areas of the foot and its associated structures.

Causes—bruising from rough ground or stones, punctures from sharp objects, laminitis (inflammation beneath the hoof wall) usually caused by stress or dietary changes, wet conditions, separations of the white line (white line disease), poor hoof trimming practices, foot rot-causing bacteria (Fusobacterium necrophroum and Bacteriodes nodosus), and various viruses including foot-and-mouth virus.

When hooves are not properly trimmed, the feet become distorted and misshapen and the foot develops pockets and crevices. If foot rot bacteria gets into the hoof, these pockets can harbor the infection for long periods.

Infectious causes like bacteria and certain viruses are introduced into the flock by addition of new animals, and then spread by both indirect and direct contact.

Treatment: Examine the feet and depending on the cause, trimming, footbaths, in disinfectants, antibiotics, and even vaccination may be indicated.

For prevention, avoid exposure of animals of sharp objects and wet conditions, and regularly trim hooves. If infections causes have been diagnosed in your area, avoid additions of new animals when possible.

TRIMMING OVERGROWN HOOVES

Tools for trimming:

1. Pocketknife or a jackknife with medium size blade. Must be sharp.
2. A hoof knife—used on horses.
3. Foot rot shears.
4. Hoof nippers.
5. File or rasp.

Frequency: The normal goat on soft bedding needs frequent trimming. Monthly examination and attention is best.

Instruction: Trim the wall so that it is parallel to the coronary band and does not roll over the sole. The soft heel may need to be shortened to prevent the spreading of the toes.

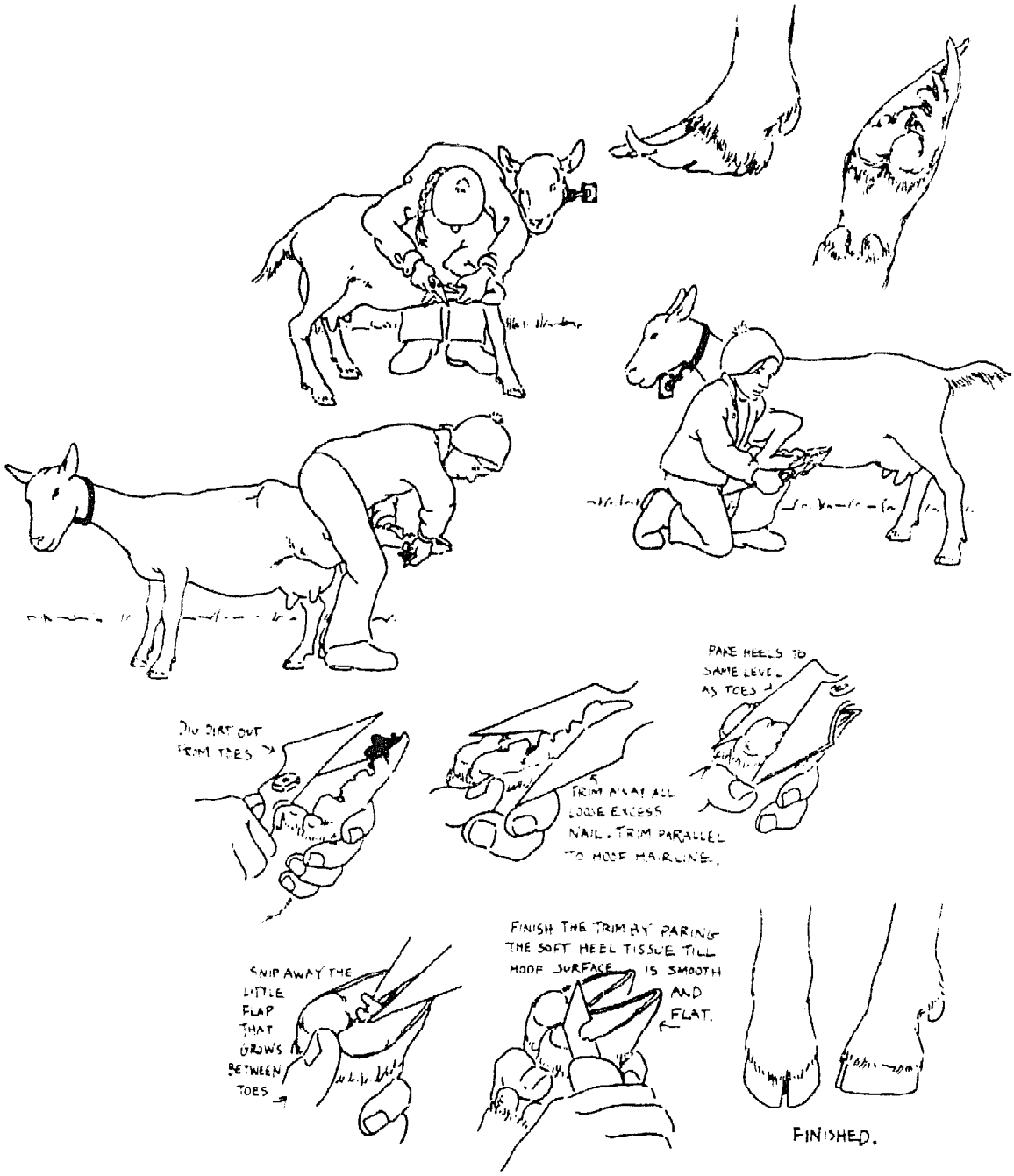
DIG DIRT OUT FROM TOES
TRIM AWAY ALL LOOSE EXCESS NAIL. TRIM PARALLEL TO HOOF HAIRLINE.
PARE HEELS TO SAME LEVEL AS TOES
SNIP AWAY THE LITTLE FLAP THAT GROWS BETWEEN TOES
FINISH THE TRIM BY PARING THE SOFT HEEL TISSUE TILL HOOF SURFACE IS SMOOTH AND FLAT.
FINISHED.

Section 18

Slaughtering Goats for Meat

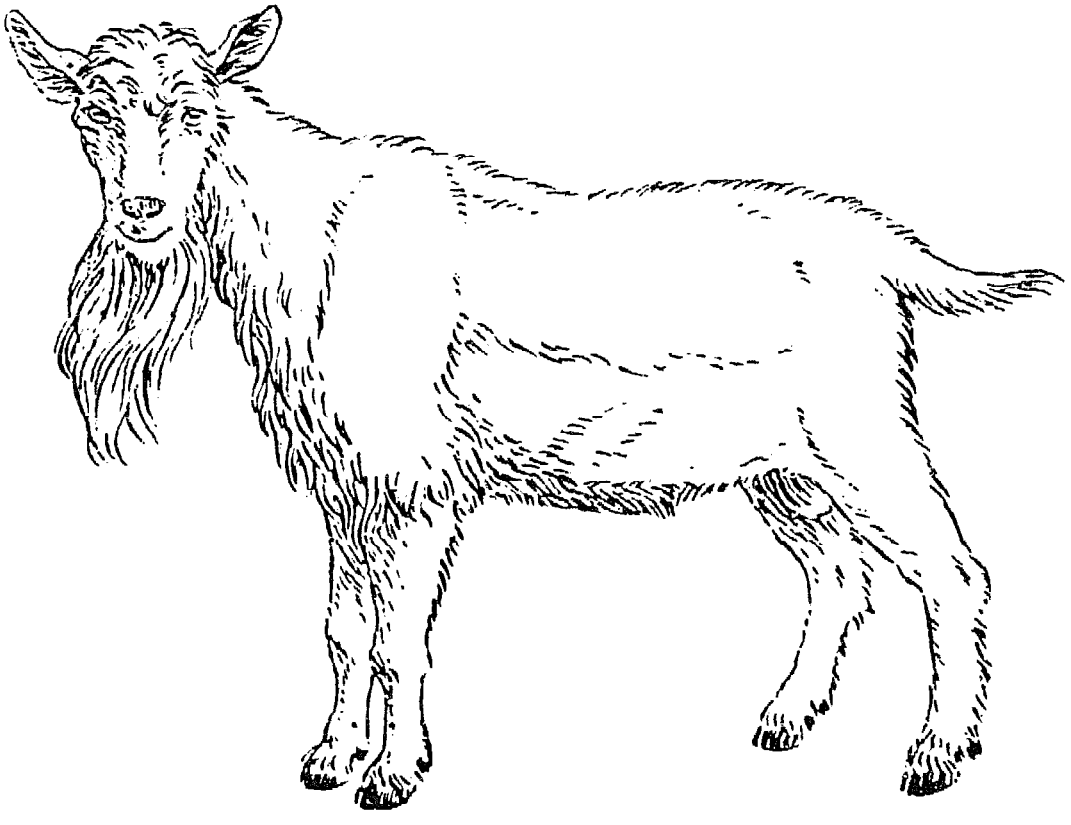

XVIII. SLAUGHTERING GOATS FOR MEAT

SELECTING ANIMALS

A listing follows of those animals which could be slaughtered.

1. Not suitable for breeding, i.e., animals with genetic defects.

Note: If abnormal conditions are evident, further inspection by a qualified person, such as a veterinarian, would be advisable. Diseased animals should not be slaughtered for human food.

2. Surplus breeding stock
3. Unthrifty animals
4. Poor producers
5. Older animals
6. Male kids that have been castrated.

HANDLING OF ANIMALS PRIOR TO SLAUGHTER

1. Withhold feed of all kinds—both hay and grain—for 24 hours prior to slaughter.
2. Do provide plenty of water.
3. Place animals in a clean, well-bedded area.
4. Do not excite animals prior to slaughter. Do not pinch hide or beat with a stick because you will bruise the meat and it will spoil more quickly.

Slaughter in the cool of the day. If refrigeration is not available, plan to slaughter only animals that can be eaten in 24 hours. Otherwise, you may want to preserve meat by salting, drying, etc.

PREPARATION FOR SLAUGHTER

Plan to slaughter in an area with a concrete floor or put legs on your slaughtering cradle to keep the animal's carcass clean.

Make a Hanging Stick

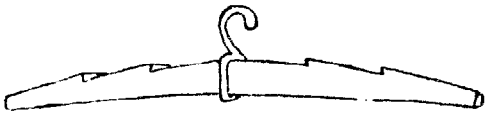

Make a Slaughtering Cradle

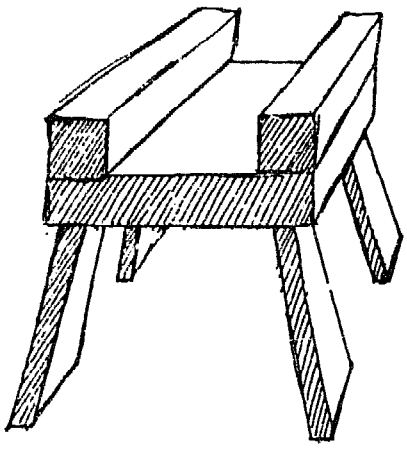

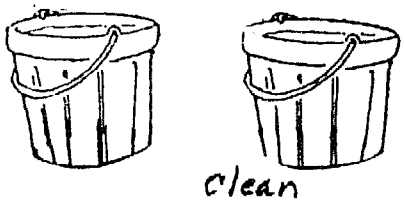

Have plenty of cold water available.

EQUIPMENT

1. Hammer or pistol (for stunning, if preferred).
2. Sharp knife and sharpening stone, or sharpening steel for put-

ting edge on the knife.

3. Rack to hang hide on; neat saw (if available).
4. Container of blood.

SLAUGHTERING

1. Halter animal. Hold about 6" distance.

2. Draw an imaginary cross between ears and eyes. Where the cross intersects is the place to strike the stunning blow. Use small blunt instrument like a hammer, or shoot with a pistol. Animal will probably not die, only be stunned.

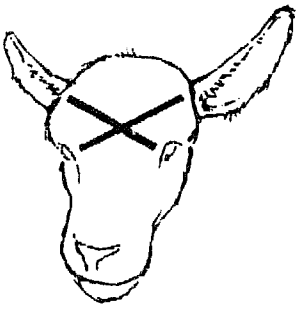

3. Put the stick knife in below the ear and at the base of the jaw stick through to other side. Cutting edge should be pointed out. Speed is important. Let the blood flow freely. When you are sure animal is through bleeding, pull chin back until you can see neck bones. Sever windpipe, sever head.

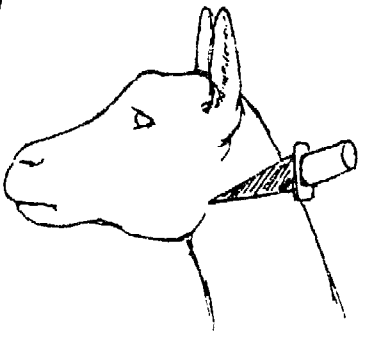

4. Let animal bleed a couple of minutes until it has quit thrashing.

5. Put animal into cradle on its back, feet up. Wait until reflexes have stopped.

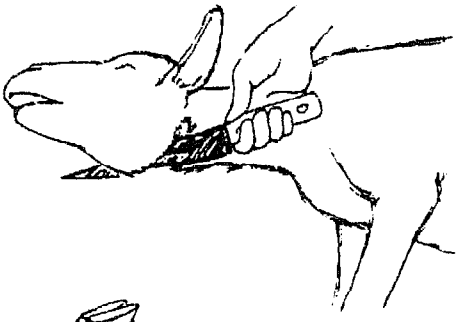

6. Ring each hoof between hoof and declaw with knife. Run point down back of each front leg. On each legs run knife all the way up leg to rectum. Go just through the skin. As you begin to trim skin away, the dew claw becomes holding point.

7. Separate skin from pastern area. Jerk hide down to hock holding onto dew claws.

8. Now jerk up to crotch. Do both sides.

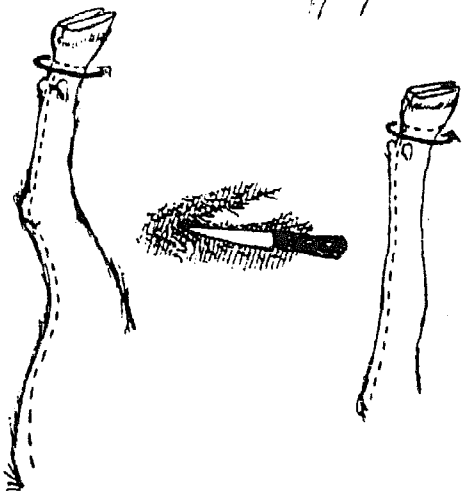

9. Separate tissue from severed line crotch. Leave scrotal or mammary tissue in hide. Separate flap of skin from rectum to leg.

10. Front end. Do same as far as knee. Jerk it to top of arm.

11. Draw knife across sternum

from armpit to armpit. Go right under skin. Do not cut meat. At the point line crosses brisket, go from there to throat and open.

12. Begin working back the skin to the armpits.

13. Now you have skinned front end - exposing throat, front portion of each shoulder and at legs.

Once you have separated hide off legs at the break joint, sever the foot from the leg. (The break joint is only present in animals under a year of age). Otherwise, remove foot at ball join.

14. Take knife and open skin from sternum to crotch. In male remove penis.

15. Work hide back to side using fingers. Try to keep thin layer of muscle on the carcass. It is important to keep carcass intact. The entire stomach is now exposed.

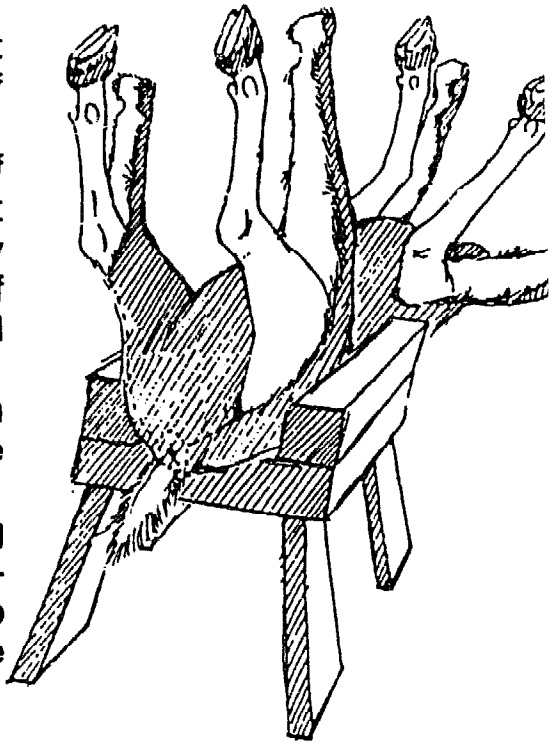

16. Put in the hanging stick through hock between the achilles tendon and lower section of thigh.

17. Suspend hanging stick from tree. Hoist animal off of cradle so it is hanging.

Important: Rinse hands anytime you touch hide and then meat.

18. Cut from throat to sternum, through sternum from middle of be ly through throat. Chest cavity is exposed.

19. Work with fingertips and knife when necessary, working hide over rump. As you approach tail, grasp tail base and pull skin off.

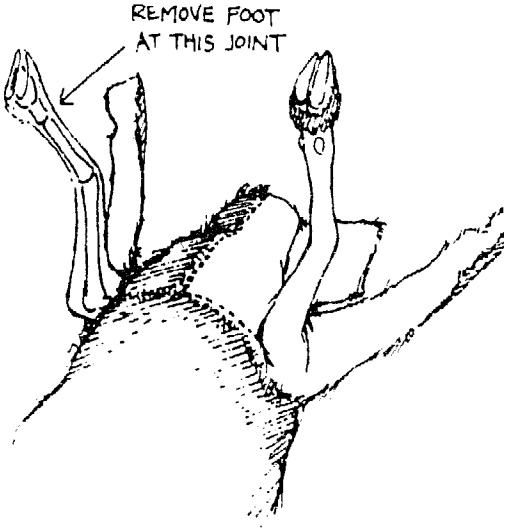

20. As this point strip back with fingernails and knuckles trying to keep all muscle on carcasss going right down backbone. Strip right off. Again, keep subcutaneous muscle attached to carcass and not hide. Pull off. Lay hide on rack.

21. Go to front. Wash carcass. Pour bucket of clean water over it.

22. Put in knife at crotch - blade side toward you. Put finger behind dull side of knife and push finger and knife down toward navel and eventually to sternum. Guts will fall forward.

23. Reach into the crotch and draw the rectum through pelvic arch.

24. Ring the rectum with knife. Tie it off. Reach into the crotch and draw the rectum through pelvic arch.

25. Pull bladder free and let this go with guts. Leave kidneys in kidney fat at back side of body.

26. Approaching thoracic cavity, spleen will be on left hand side. Pull loose - discard. At this point you will see liver on the right. Grab base of gall bladder and strip from liver, leaving liver in body cavity.

27. You will see bottom of esophagus. Tie this off. Cut this and guts will fall loose on the ground.

28. As you look at the kidneys and liver, you will see beneath them a distinct red and white line (diaphram). This band separates the thoracic cavity from the abdominal cavity. Run knife along muscular strip (red and white line) and cut to sternum of each side. Grasp in center and pull away from muscle supporting liver. Do not take out.

29. Heart, lungs, windpipe and esophagus (pluck) will be in the material you are dragging away. Remove pluck, opening the throat the full length of the chest cavity.

30. Thoroughly wash carcass inside and out.

31. Remove tongue from head and any other parts of head you wish to use, such as brains, etc.

32. Keep the meat in a cool place or throw cold water on it periodically. If you are going to leave hanging

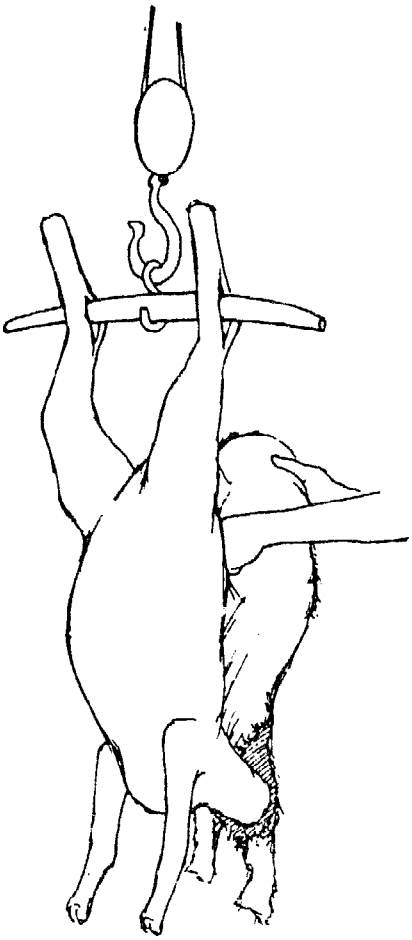

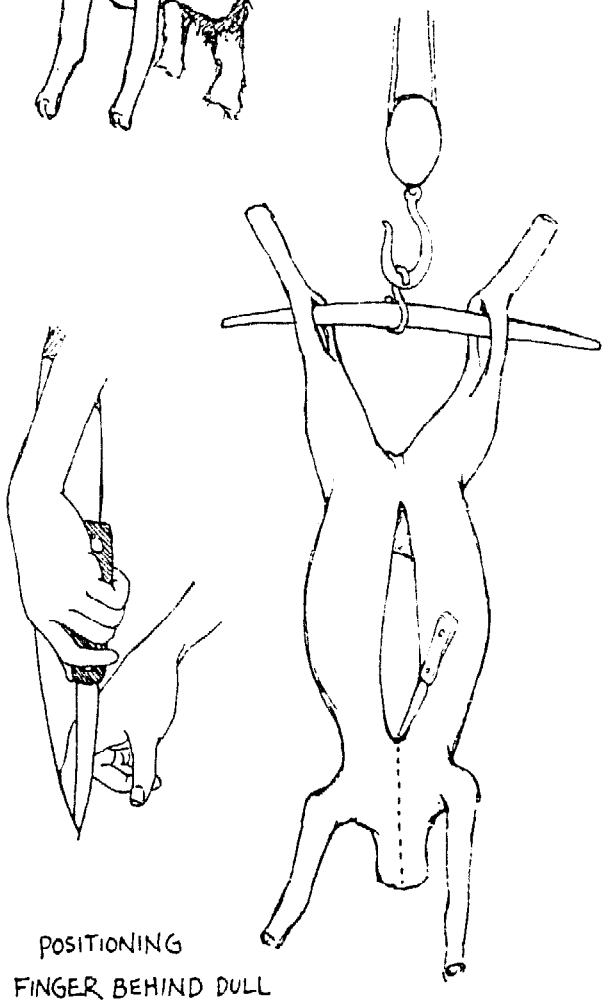

POSITIONING FINGER BEHIND DULL EDGE OF KNIFE TO PROTECT STOMACH FROM PUNCTURE

for any length of time, wrap in a clean cloth.

33. Cut in desired pieces. Edible by-products would include liver, heart, tongue, kidneys, brains. If you have use for casings, for sausage, the small and large intestines could be salvaged.

34. All inedible visera should be buried or disposed of in a sanitary manner.

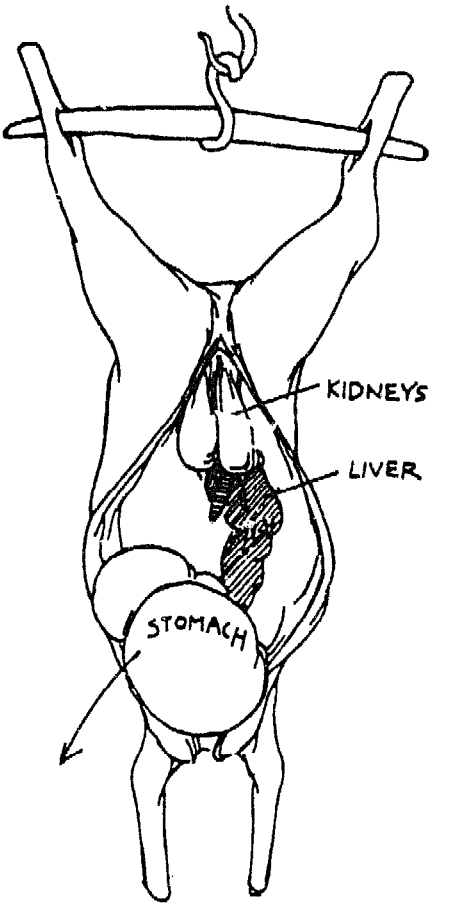

Section 19

Miscellaneous

XIX. MISCELLANEOUS

COMMERCIAL GOAT PRODUCTS

CREAM

If sold as such, an outlet is also needed for skim milk. Goat cream is pure white in color, and is colored yellow with annatto for commercial sale. The smaller fat globules make separation of the cream harder; the size of the globules also decreases as lactation advances. The cream rises so slowly that a small cream separator is useful.

BUTTER

A delicacy in Greece and Cyprus. Natural souring is usually satisfactory if one is careful and clean; otherwise, use a dairy butter starter.

CHEESE

The market is not large in this country, but the demand is increasing. Cheese is cheaper and nutritionally superior to many meat protein sources. Cheese making is a very precise science, requiring careful control of acidity and temperature. The American Dairy Goat Association booklet has several recipes. Cheese has long been a practical way to store and market goat's milk when the herd is on an inaccessible mountain pasture.

CHEVON

This is goat meat. It tastes somewhat like lamb, mutton, and venison, but lacks the fat. Young kids are popular with some ethnic groups at Easter, and are slaughtered at 4 to 6 weeks of age. Castrated kids grow and taste better; descenting at least one month before slaughter is also recommended.

SKINS

Morocco leather is derived from longhaired goats of cooler climates. Suede kid shoe leather comes from 9-18 month castrated and adult goats of warmer areas. True kid skins, from animals 1-6 months old, are used in a limited market for high class glove making. Dry kid weight about 14 ounces, hides from adult females weigh 1½-2 lbs, and those from adult males weigh 3-5 lbs.

GOAT HAIR

Coarse hair is used for tent cloth, carpet and rug making. Mohair, from Angora goats, is mainly produced in the U.S., South Africa, and the eastern Mediterranean. Angora fleece develops poorly where annual rainfall exceeds 20 inches. Cashmere wool is the fluffy undercoat of goats living at high altitudes in the Himalayas. It is combed from the goat. The fleece is of poor quality in mild climates.

ANGORA GOATS

Smaller in size and weight than the dairy goat. They are raised to produce Mohair which yields a higher price than wool, especially from

the older kids. Horns are left on this breed. They are white. The males, except those that are saved for bucks, are castrated at 8 to 10 months of age or earlier. Angora kids are weaned at about 3 months of age.

SOME COMMON SURGICAL PROCEDURES

1. Castration. Castrates are known as wethers in both sheep and goats. Can be performed during the first week of life along with disbudding. Be sure to disinfect the area with Betadine (a tamed iodine solution) first. Be sure to inoculate with tetanus antitoxin.

METHODS:

a) Elastration—Very widely practiced. There is danger of tetanus. This method is probably more painful and takes a longer time. It consists of applying a strong rubber band at the base of the testicles which is left there until the testicles fall away.

b) Knife or scalpel—regular surgery; probably the method preferred by most veterinarians. The lower third of the scrotum (sack) is cut off. Place pressure on the testicles above the cut area and force the testicles out of the cut end of the sack. Each testicle should then be grasped, pulled out as far as possible, and cut off. A sharp knife or scissors can be used for this process. Do not handle any tissue that remains in the goat as infection is very likely to occur.

Young kids can be castrated without anesthesia. Following castration, each kid should receive 500 to 750 (IU) of tetanus antitoxin (T.A.T.). If castration, disbudding, and de-scenting are done at the same time, only one dose of T.A.T. is necessary. An antibiotic powder may be applied to the scrotal area. If screwworms are a problem, always apply an insecticide or a fly repellent to the wound. A sitting assistant can hold the kid firmly between his knees with the head down and the scrotal area exposed.

c) Burdizzo—probably the best method, as there is no external bleeding, so no fly attraction, but must be carefully and accurately performed. This is an instrument that pinches and crushes the spermatic cord and blood vessels leading to the testicles without breaking the skin.

Mature bucks—must use anesthesia (putting to sleep) as goats are more subject to shock. An emasculator should be used. Antibiotics should be given afterwards. Tetanus antitoxin is to be given if never inocualted for tetanus before.

If animal is to be used for meat, castrate before 2 months of age.

2. Dehorning and de-scenting. Older or mature animals. Horns are an important problem in goat herds. They are the most vicious of our domestic animals in relation to one another. They hurt and injure each other with their horns; they damage one another bad enough when they are dehorned.

A FORMULA FOR A GOOD ANTISEPTIC AND HEALING COMPOUND

Used tail docking (removing), castration, or any wound:

1 lb Nitrofurazone dressing
1 lb Sulfanilamide powder
2 tablespoons wettable Co-Ral powder (25%)

Mix enough nitrofurazone solution to make a thick paste.

VACCINATION TECHNIQUES

Sterilizing Instruments, Syringes, and Needles

Clean instruments with soap and water after using and before sterilization. Scrub away all grease, blood, and tissue, then rinse with clean water. To sterilize, boil in clean water for 15 to 20 minutes. Cold sterilization involves soaking the clean instruments in Nolvasan or one of the quaternary ammonium disinfectants at the proper dilution and adequate time. Read label carefully. Soak instruments at least 60 minutes before using, but several hours would be better.

Do not use wet chemicals sterilization for syringes and needles. Residue in the syringe and needle from the disinfectant can cause irritation to the animal and can inactive some vaccines. Boil syringes and needles instead.

INJECTION SITES

The following abbreviations are for the corresponding type of injection and the site on the goat as described.

Intramuscular (IM)—injected deep within a major muscle mass, such as that in the hind leg or on the shoulder. It should be given with a 20, 19, 18 gauge, 2.5 to 4 cm (1 to 1½ inch) needle, pointed straight into the muscle. Before injecting the drug, always withdraw on the syringe plunger to make sure you have not hit a blood vessel. If this happens, blood will flow into the syringe. To correct, simply replace the needle in the muscle in a different site.

Subcutaneous (SC or SQ)—injected under the skin, usually in the neck or behind the shoulder. Usually a 1 to 2.5 cm needle is inserted at an angle through the skin. So that you do not stick yourself, pick up the skin with your fingers and insert the needle through the skin while it is pointed away from your fingers.

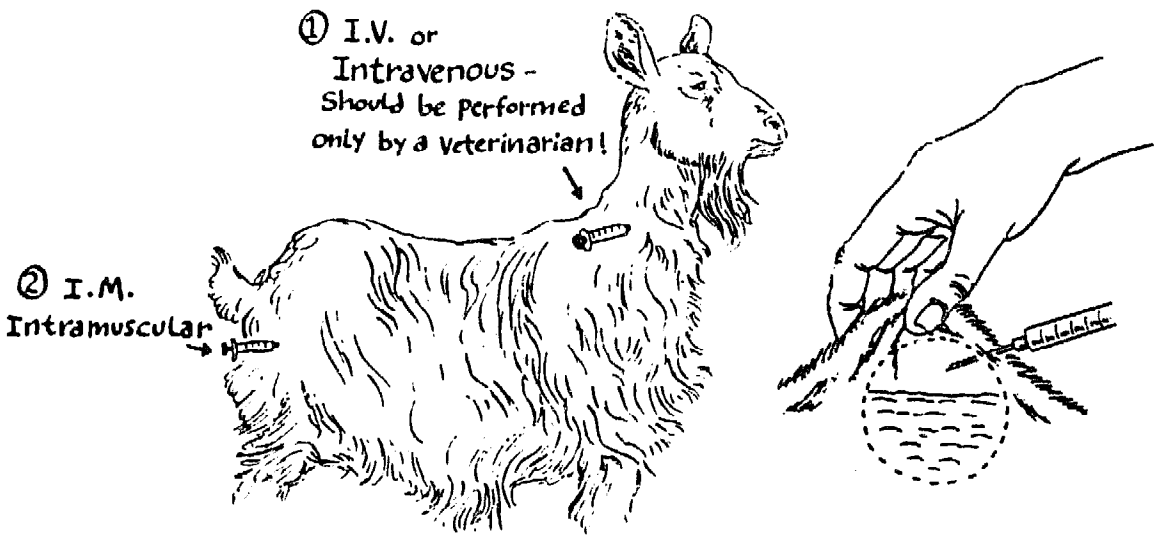

Intravenous (IV)—injected into a vein, usually the jugular or neck vein as in the illustration. This procedure takes some skill and practice. Become thoroughly familiar with the method before attempting to use it. The vein must be blocked with one hand near the shoulder to enlarge it and make it visible. Usually a 4 cm, 18 gauge needle is used for IV injections. All IV injections should be given slowly, using only products specifically approved for this method.

Intramammary—injected within the milk gland, into the end of the teat through the natural opening. Always wash the teat end with soap and water and wipe it with alcohol or Betadine before injection. Use only sterile, blunt, teat infusion needles or "throw-away" mastitis medicine applicators. Unclean material entering the teat will cause mastitis.

SC or SQ = subcutaneous = under the skin
ID = intradermal = within the layers of the skin
IV = intravenous = into a vein
IP = intraperitoneal = into the abdomen cavity
IM = intramuscular = into a muscle

VACCINATION

1. Vaccine should be sterile and "in date" (not expired). Every time the needle punctures the rubber top of vaccine vial, bacteria are introduced into vial.
2. Keep vaccine cold (refrigerated) (but not frozen) to reduce bacterial growth.
3. Best to use sterile needle for each animal. Or, at least, clean the needle with alcohol before each use. Some disease can be transmitted by "dirty" needles, e.g., anaplasmosis.
4. Give manufacturer's recommended dosage.
5. Restrain animal. A moving, struggling goat can cause tissue damage from a flaying needle.
6. Where to vaccinate. Vaccinations usually cause swellings on goats, no matter where they are placed.
   a) Back (posterior) to scapula (shoulder blade). SC = subcutaneously (under the skin). Flatten out the swelling and rub in well to disperse the vaccine. Will still have a good chance of forming a swelling, at best.
   b) Be careful about vaccinating goats in the rump or rear leg region as you might strike a nerve or blood vessel, especially with very thin animals and kids.
7. Skin should be cleansed with Alcohol or Betadine before giving the injection.

EQUIPMENT AND PROCEDURES FOR GIVING MEDICINE BY MOUTH

Drenching—Most goats will swallow liquids placed into the mouth if their head is held slightly upward. A dose syringe or a bottle with

a rubber hose attached will work well. If using dose syringe with a long nozzle or tube, be careful to place tube in the side of mouth—between teeth and facial wall. This will prevent the danger of forcing liquid down the windpipe into the lungs, causing pneumonia.

Place the end of the tube to the side of the tongue. Be careful not to injure the inside of the mouth.

Bolus or Pill Administration—A small balling gun is used to give pills or boluses to goats. The small guns are passed into the mouth over the hump on the tongue, and the plunger is gently pushed down taking care not to injure the mouth. Goats will often reject blouses, and they must be given again. Be patient. Do not overextend the head or the bolus may go down the windpipe. Apply a lubricant to the bolus before administering. It can be dipped into mineral oil or molasses for ease of swallowing. Pills can also be crushed and given in a small amount of tasty food.

BUCKS TOGETHER:

It is dangerous to turn two mature bucks in together in the same pen suddenly. If raised together, it can be fairly safe if young, but if full grown they still can be dangerous to each other.

DENTAL

Examine mouth carefully with a flashlight. Look for grass awns or other foreign bodies. Look for abscessed teeth or sharp teeth cutting into the cheek. Floating (rasping or filing) the molars may be necessary occasionally, as with horses, if they start quidding (dropping chunks of food out of mouth) or salivating.

CULLING

It is vital to the overall productivity of the herd. Some goats will fall heir to "wasting disease" of which there is no treatment, and so should be eliminated. Examples of some causes: Johne's Disease, nerve problems, arthritis from CAE, etc.

ENVIRONMENTAL INSULTS

1. Sunburn. Light-skinned goats, like people, will often suffer when first turned out in the spring. Teats and udder can especially be damaged by sunburn. Prevention: Turn animals out into sunlight gradually and provide shade.

2. Light sensitization. Usually from 2 or 3 factors of which both must be present.

a) A white or unpigmented skin that is sensitive to ultraviolet rays.

b) Ingestion of certain plants that sensitizes the white skin to the damage by ultraviolet rays such as:

Saint-John's-wort
Alsike clover

c) Possibly a third factor: genetic predisposition (tendency) to the condition.

Photosensitization (sensitive to light): Edema (swelling) of lips, face, and ears is a common sign.

Treatment: confine animal to barn or remove the offending plants.

3. Frostbite. Exposure of wet extremities to freezing. Newborn kids may have tips of their ears frozen, especially Nubians. Prevention/Treatment: tape ears up over head to improve blood circulation and prevent edema of the ear.

4. Urine scald. During breeding seasons, bucks will urinate on themselves, their legs and beard, etc. This often causes loss of hair. Treatment: hair should be clipped and skin washed with mild soap and then rinsed with sodium bicarbonate. Then coat the skin with petroleum jelly.

5. Fly strike (maggot formation). From a wound or accumulated feces under tail, that attracts flies to lay their eggs. Clean wounds and rectal area with hydrogen peroxide.

6. Predation: Provide adequate protection.
   a) Domestic large dogs running in packs.
   b) Wild carnivora, e.g.. coyotes, bobcats, mountain lions.

Section 20

Goat Raising in The Semi-Arid Tropics

XX. GOAT RAISING IN THE SEMI-ARID TROPICS

The term "semi-arid" describes restricted rainfall areas in warmer regions closer to the equator. Goat production is highly linked to the dry tropical conditions of the world.

Goats' feeding behavior is related directly to plant preference and plant part selectivity. The agility and dexterity combined with anatomical characteristics and distinctive rear limb articulations uniquely enable them to fit adequately to grazing conditions and respond satisfactorily when good quality pastures are used. The native vegetation in most areas seem to be adequate for meat and skin-type goats. However, it is known that this type of grazing is not adequate to sustain lactating dairy goats unless some sort of energy and protein supplement is made available. Tropical legunes have proved to be of great nutritive value for dairy goats.

LATERITE

In many tropcial areas of the world, because of erosion and other factors, soil changes to aluminum and ferric hydroxide and becomes brick-hard and usually red. It contains very little organic matter where land is cleared for cash crops, after 2 to 3 years it tends to solidify upon exposure to air. This forms a brick-hard layer that is known as laterite. One promising solution to this problem could well be found in a plant known as leucaena.

LEUCAENA

Providing protein-rich forage for cattle and goats is just one of the many uses of this so-called miracle plant, leucaena. Leucaena can also provide fire wood, timber, posts, raw material for pulp and paper, and many other products within a relatively short period of growth. It can do all this while improving the properities of soil such as laterite—increasing nitrogen content, loosening compacted soil and penetrating deep to bring nutrients to the surface. Its leaves are small and decompose rapidly to produce soil humus.

Leucaena leucocophala is one of ten species within the genus. It is called ipil-ipil in the Philippines, Kao Hoale in Hawaii and lamtoro in Indonesia. A fast-growing tree, leucaena usually begins to function as a legume within 3 months of being planted. Like other legumes, it acquires the capacity to take its nitrogen supply from air when nitrogen-fixing bacteria rhizobia—in the soil infect its roots and form nodules. The resulting nitrogen compounds enrich the surrounding soil to the benefit of leucaena and any surrounding plants.

A problem exists with this plant. It is toxic to animals if their diet consists of 30 percent or more of leucaena. The function of the thyroid gland is impaired, resulting in goiter formation. If the ration is main-

tained at less than 30 percent leucaena, the rumen can detoxify the mimosine (toxic principle) and provide an excellent food supply relatively high in protein and calcium, similarly found in other leguminous feeds, e.g., alfalfa.

GOAT PRODUCTION AND MANAGEMENT IN BRAZIL

In the Sertao desert area of northeast Brazil:

1. Major problem: uncertain feed supply
2. The primary product from the goat in northeast Brazil is meat production
3. Goat milk and skins or hides are second.
   a) The size and the extent of defects in skins determine their value.
4. Although human food of animal origin is produced more efficiently through milk than through meat, relatively few goats are milked in Brazil.
5. One of the main problems in goat production is cost of fencing. Some have used solar powered electric fences.
6. Mixed rations for milking goats—Algaroba pods used as replacement for corn.

GOAT PRODUCTION IN SUCHAN PROVINCE, CHINA

Sichuan is one of the largest provinces in the People's Republic of China, situated in the southwestern part of the country on the upper reaches of the Yangtze River. The Chengdu Plain forms the Sichuan Basin. It has been known as the "land of Abundance," and has a population of 102 million people. Goats are an important "cash livestock" in Sichuan. By the end of 1985, there were 5.4 milion goats that produced 24.3 million kg. of mutton and 3.7 million kg. of milk, annually. Goat hides have long been an important export resource of Sichuan Province.

There are six native breeds of goats in Sichuan and generally speaking have a medium-sized body, high production of mutton and hides, good reproductive performance, good adaptability and relatively low milk production.

European breeds were introduced in 1936, namely, Saanean, Toggenburg, and Nubian into Chengdu Province. Size, body weight, milk and meat production have increased as they were mixed in with the native goats. The dairy goat has become the main economic resource of the small farmer.

CHILE - GOAT IMPROVEMENT

The breeding of dairy goats started in Chile around 1555 with animals from Peru and later, Argentina. Intensive inbreeding produced with low production of milk and meat. From 1930 to 1955, several importation of European breeds such as Nubian Saanen were made, dispersing these breeds throughout the country. The Saanen goat better resists the cold conditions of the South of the Chile.

As these European breeds are mixed in with the native goats,

tolerance to local climate and feeding conditions will be developed.

The goal is to improve size, milk, milk fat, and meat production while maintaining resistance to local conditions.

GOAT PRODUCTION FOR SMALL HOLDERS IN SOUTH INDIA

The Goat population of India grew from 47 million in 1951 to over 71 million today, with a 43 percent turnover (278,000 tons of meat) for consumption.

Landless peasants can raise several goats, feeding them grasses and legumes from roadsides.

Milk and meat production from goats often represents a significant improvement in nutrition and income for landless people.

Constraints to goat production for these farmers include climatic problems, infertility, disease, access to land and feed, and lack of understanding of appropriate husbandry practices.

Goat milk is primarily consumed by the farmer's family but some is sold. Prices are based on fat tests.

Goats are providing nutrition and income to small farmers throughtout India.

GOAT MEAT PRODUCTION IN FIJI

Feed is readily available in Fiji, with grass pastures able to maintain three to four goats per acre. There is also a good supply of coconut meal, maize, sorghum, broom corn seed, wild tapioca, rice straw and molasses.

Major debilitating diseases have not so far occurred. Important restrictions regarding health are strict. The primary concern of producers is that of internal parasites.

GOAT PRODUCTION IN HONDURAS

The health and nutrition status of children has been substantially improved by the introduction of goats to families. It has been determined that, under the prevailing conditions, goats do not impose additional constraints to the rural family. The major drawback of these projects is the lack of "outside" bucks, causing a degree of inbreeding. To avoid such problems, three breeding centers have been implemented, with either Anglo-Nubian, French Alpine or Saanen bucks.

GOAT PRODUCTION IN HAITI

Fifty percent of the land is too steep, too dry, and too rocky for cultivation, however, it is suitable for a wide variety of grains and legumes, and for reforestation. Leucaena—a nitrogen fixing legume—would provide excellent feed for goats and at the same time help restore a more fertile soil.

Increased production of meat and milk from goats would directly benefit the nutritional status of Haitians. Both protein and calories are in short supply.

The malnutrition of children under five years of age is extremely high. Haiti has the lowest per capita supply of animal protein compared to Central and South American countries—only 7.1 grams per

day.

It has been shown that a few ounces of milk each day will improve the well being and nutritional status of children.

Loose herding and tethering are the predominant goat production systems in Haiti. In the loose herding system, the animals roam about uncontrolled in rural and urban areas, subsisting on whatever feed and/or food refuse they can find. A large majority of goats in Haiti are kept under the loose herding system. Tethering—tying the animal with a 10 to 12 foot rope and moving its location when the surrounding feed is exhausted—is more common in areas where row crops or gardens are planted. It is doubtful that under either production system the goats can fulfill their nutrient requirements; particularly in a situation such as Haiti.

PROBLEMS IN RAISING GOATS IN KENYA

1. Insufficient amounts of adequate quality feed on a year round basis. On small farms, the demand for human food crops takes priority over production of feed of livestock.
2. Tick-borne diseases, such as anaplasmosis, trypanosomosis, heartwater. Control measures: dipping or spraying - not commonly practiced because of cost and lack of assistance.
3. The need for more time for the animals to forage and graze; also milking animals need more access to drinking water.
4. Socioeconomic constraints: many would rather produce goats for status symbol—for capital storage—and secondarily for production.
5. Lack of status in keeping goats - instead of cattle.

GOAT PRODUCTION IN THE PHILIPPINES

FEEDING

Goats are provided with good roughage in the feeders every day. Rotation grazing is also practiced in control internal parasites and be able to maintain more animals per hectare.

Napier grass and ipil-ipil (50:50) are used as "cut and carry" roughage (ipil-ipil is the native Philippine name for the leucaena plant). Rice straw, corn, and sorghum silage are also used for feeding.

BREEDING

Sixty days after kidding, the doe is bred. Breeding is repeated 12 hours later. Ninety days after breeding, stop milking the doe. Sixty days later, the doe will give birth again. Using this system of breeding, the does will kid at least twice a year. Purebred does will average three kids per year.

Artificial insemination (A.I.) with frozen semen is also being practiced, but only on does treated with hormones. Does are inseminated twice per estrus period.

Purebred does are not bred until reaching a weight of 36 kgs. or until they are 8 months old.

HOUSING

It has been accepted that the confinement method of raising goats in the Philippines is efficient and economical.

Basically, a goat house or shed must be built to provide shelter for the animals against the elements and from other animals. Goats prefer to stay in elevated places. Houses, therefore, must be provided with elevated sleeping areas. It must be well ventilated, well drained and easy to clean. Feeding racks should be provided. To give accessibility to both animals and the caretaker, flooring should be inclined by about 30 to 40 percent to facilitate drainage and cleaning.

Separate cages or housing should be provided the lactacting does, dry does, baby kids, and growing kids and the buck. The bucks' cages must be placed far enough away, but still visible to the does.

A loafing area beside the goat houses must be provided (100 to 150 sq. m. per 50 head), complete with feeding racks and water troughs. This must be continuous along the goat house to allow them to loaf outside when preferred.

Any building material will do depending on financial and availability, but the flooring must always be cemented to facilitate drying the floor.

FENCING

A five foot high hog wire is one of the cheapest fencing available. Posts must be staked every two meters. Goats are fond of pounding their feet on the fences and scraping their bodies, so fences must be sturdily built.

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C. Devendra and G. B. McLeroy
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APPENDIX I
LISTING OF PHARMACEUTICAL COMPANIES

American Cyanamid Co.
One Cyanamid Plaza
Wayne, NJ 04740 USA
Phone: 201-831-2569
Tetracycline Hydrochloride
Sulfamethazine

Colorado Serum Co.
4950 York St.
Denver, CO 80216
Phone: 303-295-7527
Vaccine: Clostridium Perfringens Type C and D
Tetanus Toxoid

Fort Dodge Laboratories, Inc.
800 Fifth St.
Fort Dodge, IA 50501
Phone: 515-955-4600
Vaccine: "Anaplaz" for Anaplasmosis, Tetanus Toxoid and Tetanus Antitoxin
Medication: Antibiotic preparation for udder infusions
Disinfectants: Nolvasan Solution

Haver-Mobay Corporation
American Health Division
Shawnee, KS 66201
Phone: 913-631-4800
Insecticide: Co-Ral

Merck-MSD Agvet
Division of Merck & Co., Inc.
P.O. Box 2000
Rahway, NJ 07065
Phone: 201-855-3800
Worming Products: Corid and Ivamec
Antiseptics: Furacin Dressing and Furacin Soluble Powder

Pfizer, Inc.
U.S. Animal Health Operations
235 E. 42nd St.
New York, NY 10017
Phone: 212-573-1298
Antibiotic: Combiotic, Liquamycin LA-200, and Terramycin Ophthalmic Ointment

Pitman-Moore, Inc.
421 E. Hawley St.
Mundalein, IL 60060
Phone 312-566-2600
Worming Prep.: Levasole
Eye Medication: Chloromyectin and Vetra Chloracin

Rhone-Poulenc Animal Nutrition
500 Northridge Road
Suite 620
Atlanta, GA 30350
Phone: 800-727-4433
Worming Prep.: Deccox

Scheuring Animal Health
1011 Morris Avenue
Union, NJ 07083
Phone: 201-558-4000
Medication: Bo-SE
Eye Medication: Gentocin Durafilm

Techamerica Veterinary Products
Fermenta Animal Health
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Raising Healthy Pigs Under Primitive Conditions

by Dr. D.E. Goodman

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Raising Healthy PIGS Under Primitive Conditions

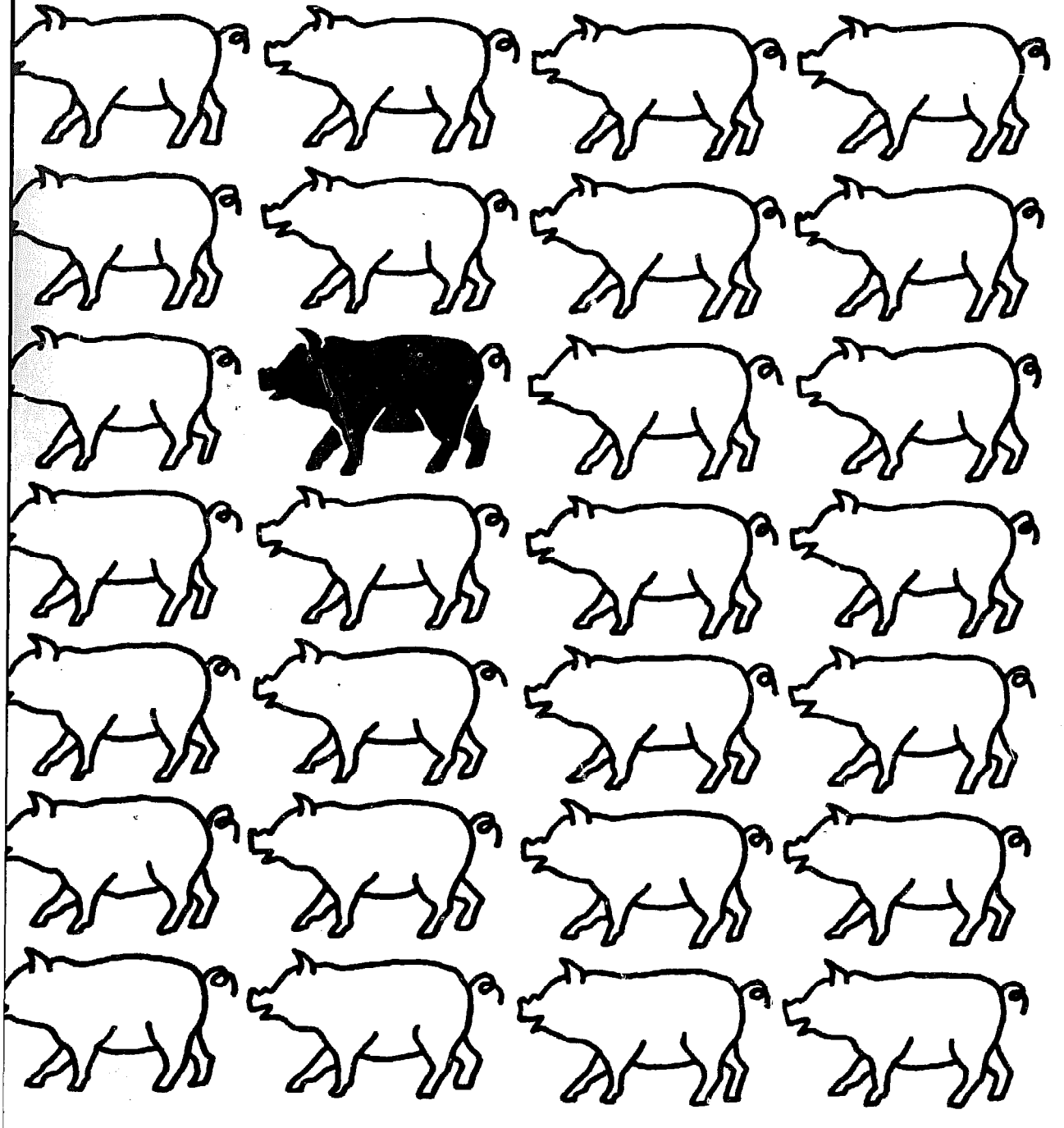

Dr. D.E. Goodman, Christian Veterinary Mission
vision of World Concern

Raising Healthy Pigs Under Primitive Conditions

by

Dr. D. E. Goodman
Turbeville, South Carolina

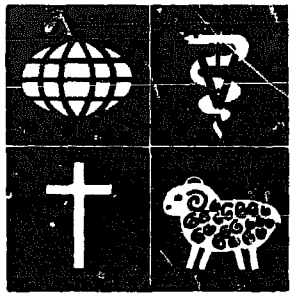

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THIS IS AN EXPERIMENTAL FIRST EDITION

It can be improved with your help. If you are a Veterinarian, Veterinary Technician, Animal Husbandry Amateur, Missionary, Development Worker, or anyone with ideas or suggestions for ways this booklet could be changed to better meet the needs of your people, please write to the author at Christian Veterinary Mission, a division of World Concern.

Thank you for your help.

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Section 1

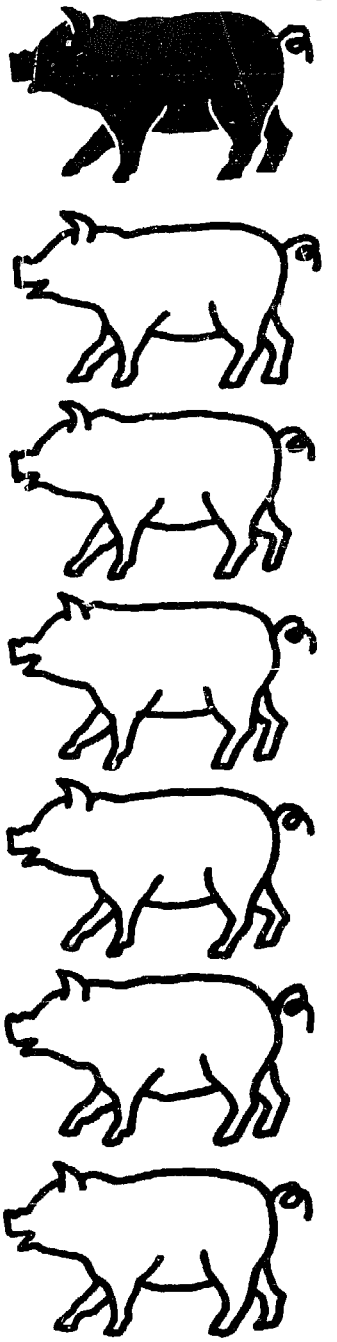

Background

This booklet was prepared by Christian Veterinary Missions as an aid to those working in areas where information and assistance needed by small farmers is limited. Hopefully, this booklet will aid you in working with people in your area in order to raise healthier animals and improve the standard of living. It also provides you with a means of consulting by mail on special livestock problems.

The author of this booklet has traveled widely, and has lived and worked in underdeveloped areas of the world. He has also made several short-term missionary tours in those areas. He has had extensive experience with small scale pig production and livestock veterinary practice, as well as disease control and swine health consulting work. He is presently Supervisor of Animal Health Programs for Clemson University Livestock-Poultry Health Division and Diagnostic Laboratory.

This booklet is purposely written in discussion style for the sake of a broad background understanding, and contains only the minimum of hard facts and tables.

These suggestions, when used with adjustments for local conditions and a common sense approach to problem solving, could be a big help to those in your area.

Introduction

Pigs are grown in almost all inhabited areas of the world with the exception of Arctic and sub-Arctic areas, and some extreme desert climates. They have proven to be adaptable to wide ranges of climate and production systems — from the very primitive to the highly sophisticated.

Pigs have also proven themselves able to thrive on a variety of foodstuffs. This makes them very desirable as a source of protein and cooking fat in otherwise deficient areas.

Also, they can aid in land clearing and slash-burn systems by eating roots, seeds, vegetation, and seedlings of young trees. Their manure (fecal waste) may serve as a source of fertilizer as well.

With the exception of areas with religious or cultural taboos against eating pork, the flesh of pigs is much in demand. It is a highly nutritious food and is totally safe to eat if a few basic sanitation and cooking practices which are outlined in this booklet are followed.

The fact that pigs can be grown on small acreage and their exceptional reproductive ability makes them very desirable. One pregnant female managed properly can soon be the basis of a small herd which can supply much needed food and income for the family. This can often be done at very little expense, if good judgment is used. Hopefully, this booklet will help you assist those in your area to do that.

Section 2

A Healthy Environment

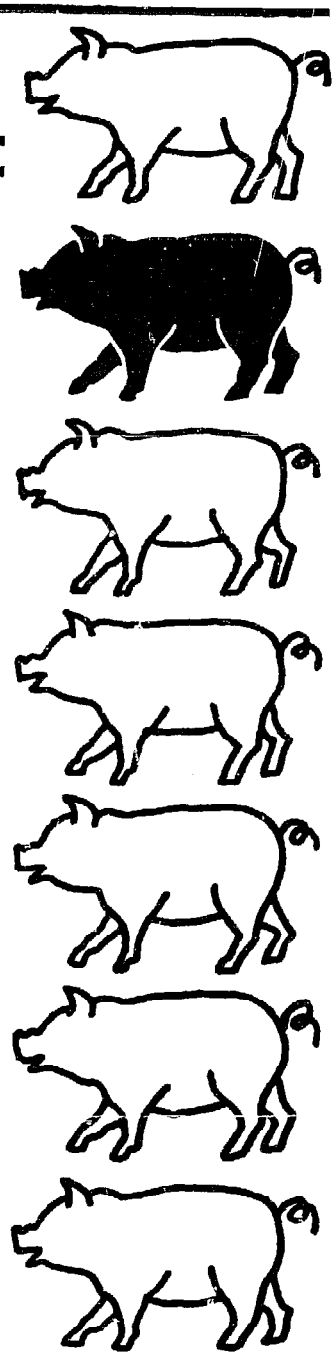

ENVIRONMENT PART I

Living Conditions

Environment (Living Conditions)

Protection from adverse weather conditions is an important consideration in raising pigs. Although they have adapted to wide variations of local climate, they still need protection from extreme heat and cold, cold rain, cold wind, and snow.

Swine suffer more from hot weather than any other livestock. They have no sweat glands in their skin which provides a natural cooling system for other animals that can perspire and who are cooled by the evaporation of this moisture from their skin. Also, the heavier fat layer beneath the skin tends to hold body heat. For these reasons it is necessary that we furnish protection from heat or allow pigs to use their native instincts to stay cool.

Protection from extreme heat can be just as important as protection from extreme cold. Prolonged exposure to bright sunshine or in poorly ventilated buildings may cause pigs to become overheated and can bring on respiratory problems (colds and pneumonia) and reproductive (breeding) problems. Exposure to extreme cold without protection from wind, rain, and snow often leads to severe respiratory problems in all ages, as well as slowed growth and reproductive problems.

Generally 50° to 80° is the best temperature range for adults. Baby pigs have a poorly developed temperature regulating response and need more warmth than do adults (around 80° - 90° F. for the first three or four weeks). These, however, are only rough guidelines. Native pigs often have adapted very well over a period of time to most extremes of local climate if given some protection or if they are allowed to use their natural instincts.

Sows, with their great maternal instincts, have a remarkable ability to protect their baby pigs from temperature extremes by farrowing in protected areas and making beds of dried vegetation. By using their natural instincts and their ability to adapt, plus a few basic management suggestions, healthy pigs can be grown almost anywhere that humans live. Pigs may survive extremes of weather without shelter; however, their health is often impaired and stunting, poor reproduction, and weak animals occur and protection becomes unsatisfactory.

In areas where temperatures often drop below freezing or chilling wind and rain occur, some type of temporary (movable) or permanent shelter or housing will be needed. At the minimum, a roof and three sides are needed to protect against wind and rain. The open side should face the sun for warmth.

In tropical or subtropical areas where temperatures are often above 80° F. some type of natural shade (tree cover) or permanent or

temporary (movable) shelter will be needed. Thatch, straw, wood, or bamboo roofed, **open-sided shelters** are often all that is necessary if adequate natural shade is not available. Tin or other metal may be used for the roof, but tends to be hotter than other coverings. The framework can be made from discarded lumber, bamboo, or poles cut locally from the more rot and insect resistant trees.

On pastures and in dirt pens sows and boars will need around 15 square feet of shelter built with the roof sloped and approximately five feet high. Sows with pigs need twice this much sheltered area. Growing-fattening animals on pasture or dirt pens need 10 square feet of sheltered area.

Temporary (movable) shelter is much to be preferred over permanent structures because they can be moved to prevent build up of filth which causes sanitation problems and leads to disease and parasite difficulties. They are also less expensive and are easier to build.

Canvas or plastic sheets over a temporary framework can be used in emergencies such as protecting a sow and her newborn baby pigs.

Pigs should be pastured on land that is as well drained as possible with some tree cover for wind and shade protection. Mud wallows and low wet areas soon become unsanitary and can be a source of disease and parasite problems. For this reason, pigs should be given shade and fresh water; otherwise, they should be moved often.

Wallow areas where animals are allowed to escape extreme heat by laying in shallow water or mud is a natural method of keeping animals cool. However, it should be used as a last resort and when other methods are not feasible because the poor sanitation leads to disease and parasite problems.

Running streams may bring disease germs from nearby farms. This is another reason why it is a good idea to keep pigs out of these areas and give them fresh water.

Pasture and pen rotation, where pigs are frequently moved to an area not recently used and recently used areas are allowed to rest is almost a necessity if we are to raise healthy pigs without serious trouble from disease and parasites. **Pens and pastures can be used again 6-12 months later.** This also applies to dirt lots as well.

If land is greatly limited or large number of animals are being raised, permanent housing with floors may be necessary. However, sanitation problems from the build up of manure and filth without adequate waste disposal systems usually leads to serious health problems. Therefore, permanent housing should be build only as a last resort in most situations. Temporary shelters built for one or two adults, or several (one litter) small animals can be moved by a few people or may be built on pole runners and pulled to a clean area.

Pigs can be raised satisfactorily on a few acres if only a small amount

is used at a time, and if the animals are frequently moved. **It is almost certain that pens, pastures, or open land used continuously for as little as two years will have developed health problems from disease or parasites, and should not be used again for 6-12 months for pigs.**

More details on housing are given in the section on buildings and equipment.

Often in your area there will be someone who has, over a long period of time, acquired experience and has been able to successfully grow pigs under local conditions. Careful observation of his methods may give you clues that you can pass along to others. You should also contact any livestock specialists in your area for assistance (government workers or others).

In summary, the ideal pig living conditions are high, well drained land, with animals frequently moved to unused land and allowed natural or artificial protection from weather extremes.

SPECIAL NOTE I: In some areas vampire bats may bite animals, causing infections and spreading rabies. If they are a problem in your area, animals must be protected at night. Screened or boarded enclosures, or some source of light such as candles, lamps, etc., usually prevent the problem. In such areas pigs may be turned out during the day and protected at night.

SPECIAL NOTE II: Sows should farrow on the cleanest ground; newborn pigs are very susceptible to disease, and infections and parasites do their most serious damage to pigs under 8-10 weeks old. **There are further details on this in later chapters.**

SPECIAL NOTE III: Another important consideration is that pigs be prevented from having contact with human fecal waste. This is to prevent the spread of certain parasites and diseases that can be real problems. **This is covered in more detail in the section on parasites.**

ENVIRONMENT PART II

The Big Decision:
Fencing, Tethering, Running Loose or Buildings

The Big Decision — Fencing, Tethering or Buildings

1. Totally Primitive — pigs allowed to run loose.
2. Tethering.
3. Pen or pasture with fencing and sheds.
4. Buildings.

Fencing, Tethering or Buildings

One of the most difficult decisions in pig production is to decide what type or combination of facilities to use. There are advantages and disadvantages to each.

Major considerations include the farmer's experience with pigs, cost and availability of building supplies and equipment, size of farm, climate, method of feeding and others.

1. **Primitive** — animals run loose, no buildings and no fences or only a few small pens.

Advantages — no cost for buildings and fences.
— less feed cost — animals forage for themselves with small amounts of other foods.
— less experience with pigs needed.
— less time needed to care for animals.

Disadvantages — wild animals may harm pigs, especially newborn.
— can't assist with farrowing problems and help when sick. Sow at farrowing time and sick animals are often hard to find.
— animals may stray and come in contact with other pigs and become sick from disease.
— may damage crops.
— may come in contact with human waste and develop parasite problems. This would only be practical in isolated areas with no other farms closeby. However, it could be done in seasons when no crops are grown and animals are confined during the growing season.

2. **Tethering** — animals tied to control their movement.

Advantages — less costly than fences and still control animals' movement.
— no unwanted crop damage.
— no contact with human waste.
— no contact with other pigs and less exposure to disease.
— keep pigs out of low wet areas where parasites

and disease are a problem.

Disadvantages — takes time to train pigs to the tether. Start with younger animals.
— much time needed. Animals are usually moved to grazing area during daylight and brought back near the family at night. **On hot days they can only graze early in the morning and late in the afternoon and have to be moved often.**

Description of Tether Harness — Basically a shoulder harness similar to a dog harness and made from leather strapping or cloth webbing. It has to be long enough to encircle the body behind the front legs at the chest with **one strap** and **another** around the neck in front of the front legs and short pieces to connect the two at the sides. Fit the harness over the pig's neck, cross it under the chest and wrap around the body. Attach the tether, preferably a chain (or rope) to the harness under the chest and tie to a tree, post, or ground anchor. It has to be adjustable for growing pigs or several sizes are needed.

In some areas a simple neck harness is used. It can be made of the same material and consists of one strap around the neck fixed so it cannot tighten and choke the animal. It is then attached to the chain or rope. With this type neck harness, pigs should be trained from a very young age to get used to it. In most primitive situations this type tether might be more practical than the one shown in the illustration.

3. **Pen or Pasture with Fencing and Shade Fences**

A. Woven Metal wire is very good, but is too expensive for most primitive farms. It is also difficult to move and pens and pastures may be used too long and build up parasite (worm) and disease germs.

B. Wooden fencing made from poles or scrap lumber are most often used on primitive hog farms. They are easier to construct and little or no cost of materials. They do not last as long as metal wire, but this is no problem since they should be moved often.

C. **Barbed Wire Does Not Work Well for pigs.**

Fencing Advantages — control movement of animals.
— assist at farrowing time and when sick.
— only minimal experience with pigs needed.

Disadvantages — cost of fence and shed if materials have to be purchased.
— buildup of disease germs and parasites unless moved often.

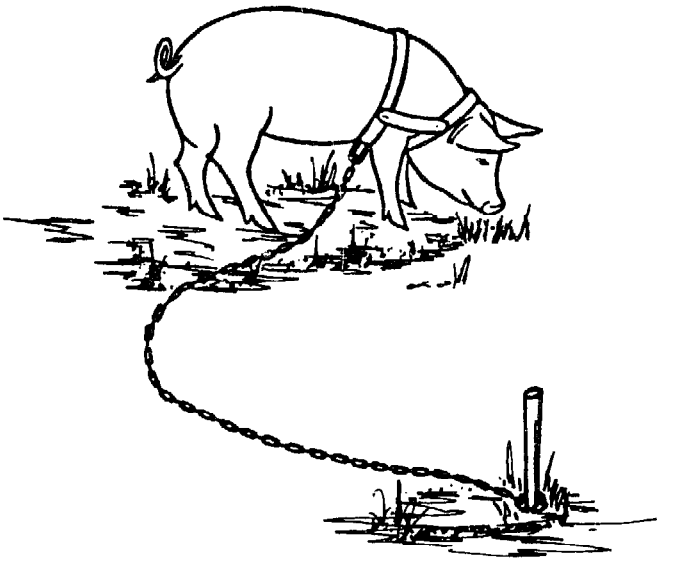

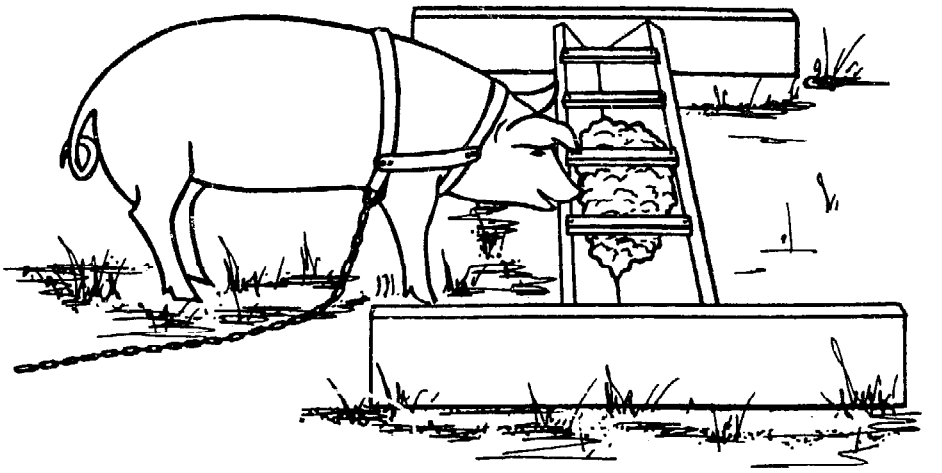

"Drawings of Use of Tether Harness on Pigs"

From: USDA Leaflet 537

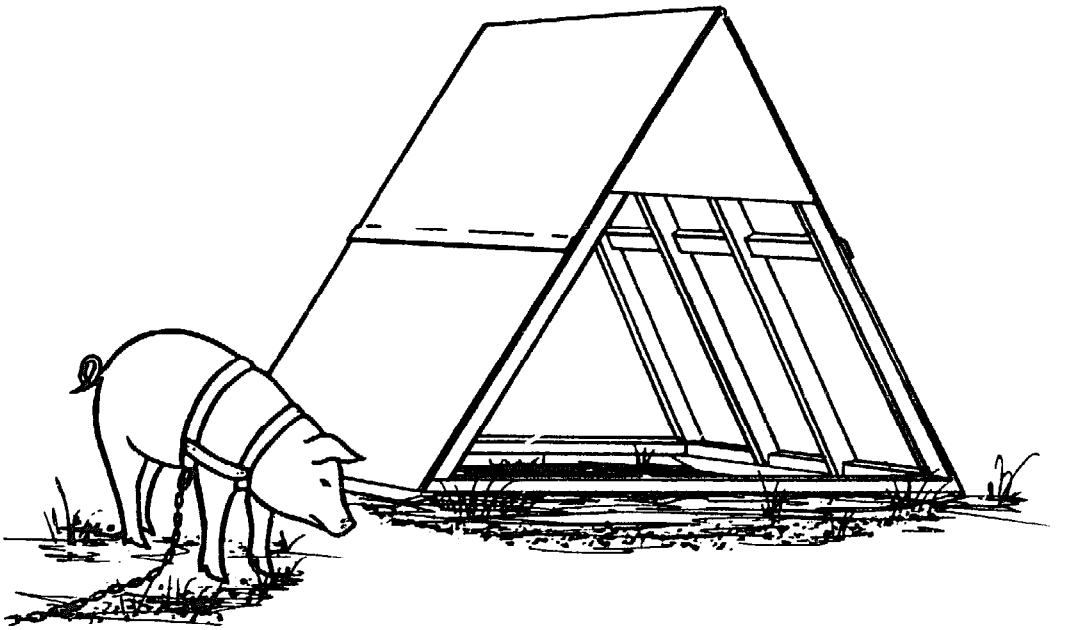

"Drawing of pig with Tether Harness and movable A-Frame Shed"

From: USDA Leaflet 537

Summary:

The most practical system for primitive farms is a combination of tethering and allowing pigs to run loose.

Example: — Tethering at farrowing time and growing season for crops.
— Run loose in non-crop season.
— This is probably the best combination in most cases.

Example: — Pen or enclosed pasture during farrowing time and crop growing season.
— Run loose during non-crop season.
(This would be another combination)

Example: — Large pen or pasture most of the day, night.
— Tether animals for other grazing during part of the day.

Example: — Pen-Pasture during farrowing and baby pig time.
— Tether during crop season.
— Loose during non-crop season.

4. **Buildings** — Other than temporary sheds as already described.

There are few practical reasons for using buildings in primitive pig production.

Advantages — Ease of handling animals when confined in small areas, especially at farrowing time and sickness.
— protection from extreme weather, **mainly cold weather.**
— less land used.

Disadvantages — cost of buildings and equipment.
— farmer needs more experience in raising pigs.
— sanitation problems from buildup of filth often lead to disease problems.
— baby pigs in buildings **with floors** will have a serious anemia problem unless precautions are taken. **See Notes in Baby Pig Section of Reproduction.**
— enclosed buildings are often too hot for animals' comfort and good health.

SKETCHES OF FENCING

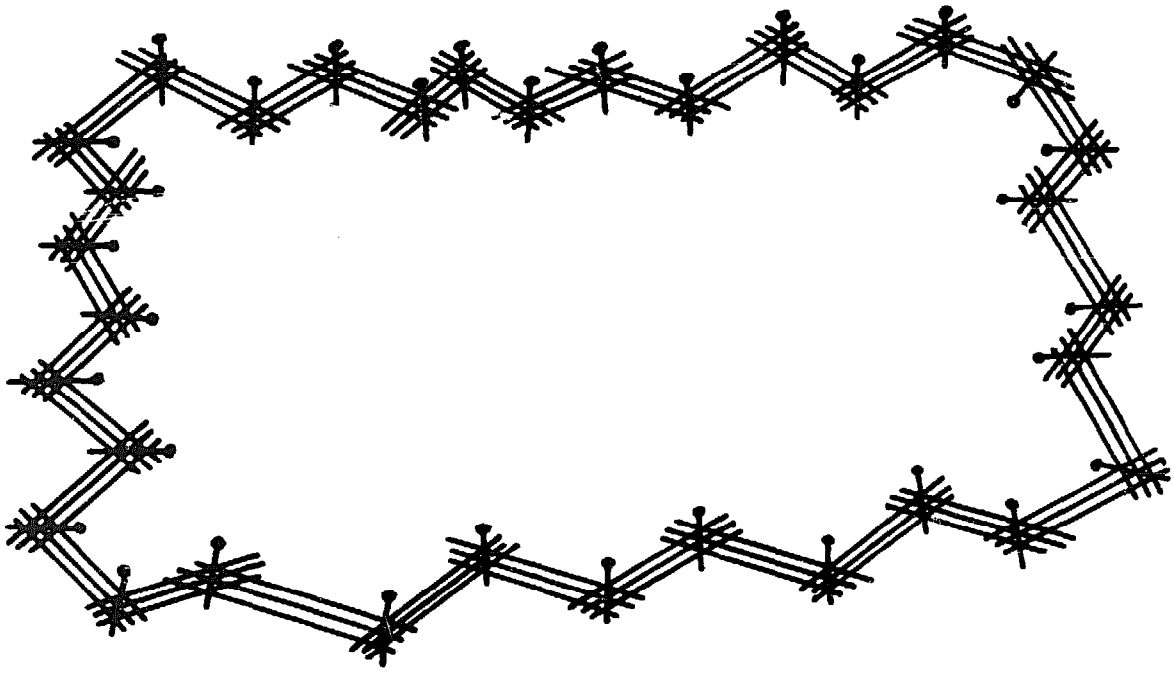

"Sketch of pole or split-rail Fence"

This uses long poles or split-rails around 10 feet long. They are laid horizontally and overlap each other at the ends. For maximum strength the ends must cross at an angle. An upright pole in the angle adds more strength. The poles may be attached to each other with nails, wire, or strong vines. For many reasons this type fencing is often used in primitive livestock production.

FENCING MATERIALS

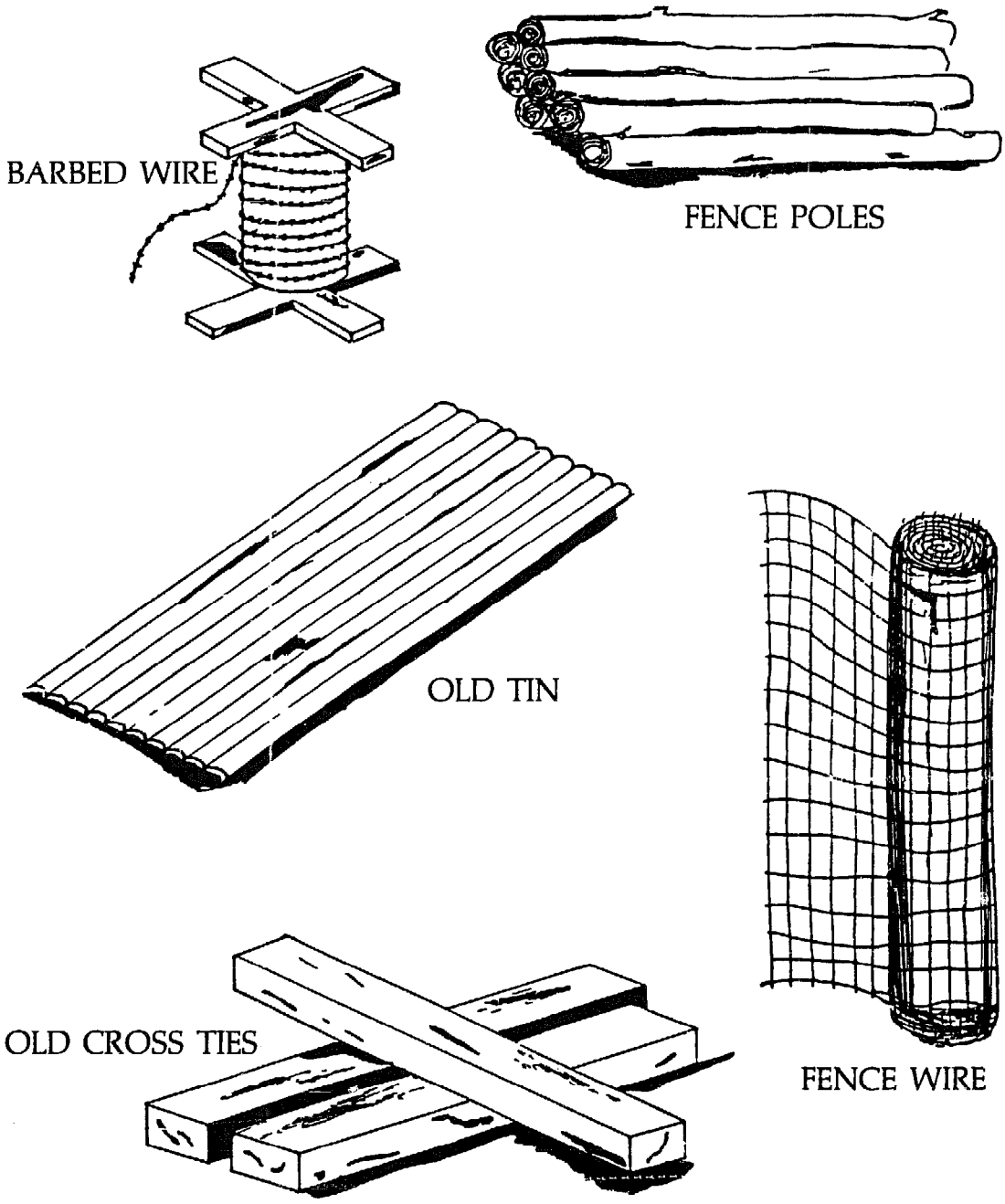

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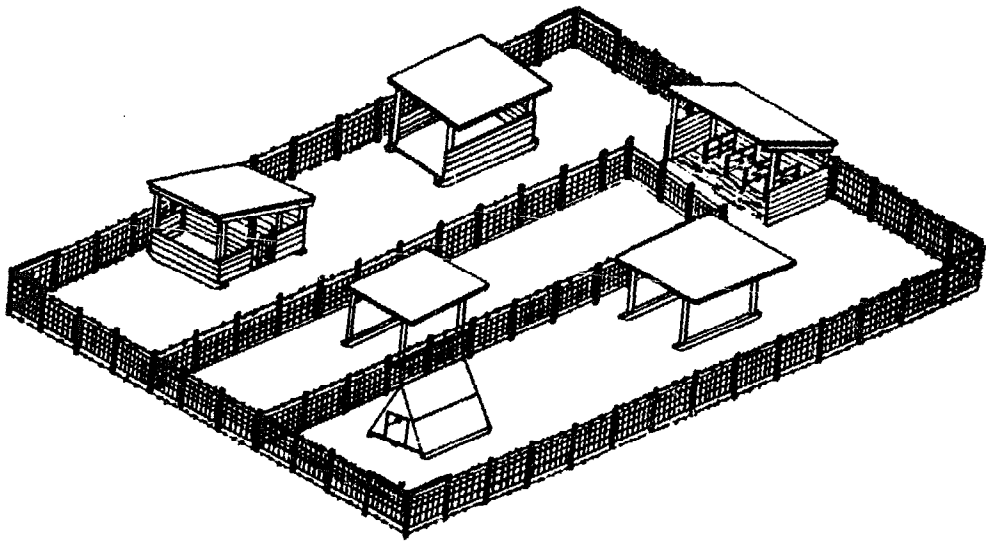

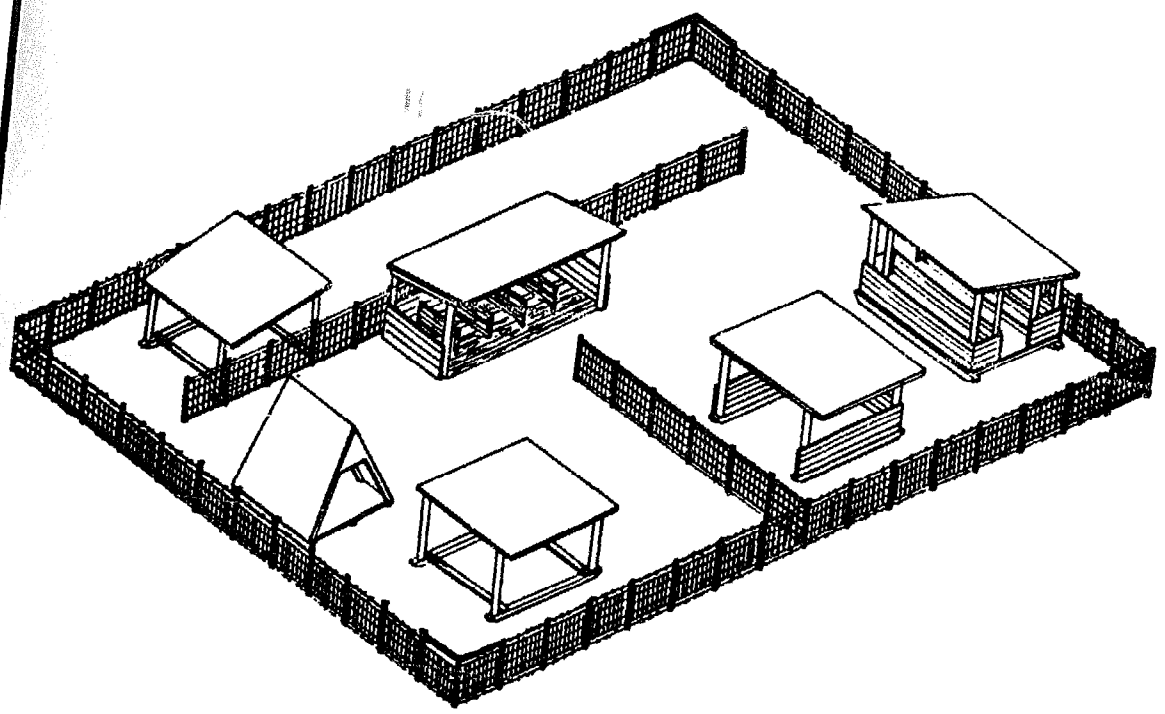

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ENVIRONMENT PART III

Buildings and Equipment

feeders & waterers

PORTABLE FEED BUNKS

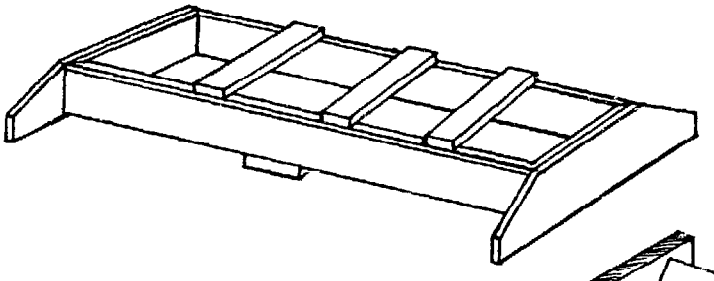

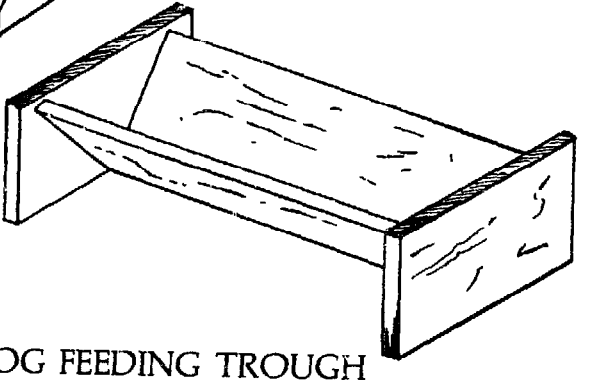

HOG FEEDING TROUGH

FEED OR WATER TROUGH
FROM OLD TRACTOR TIRE
OR TRUCK TIRE

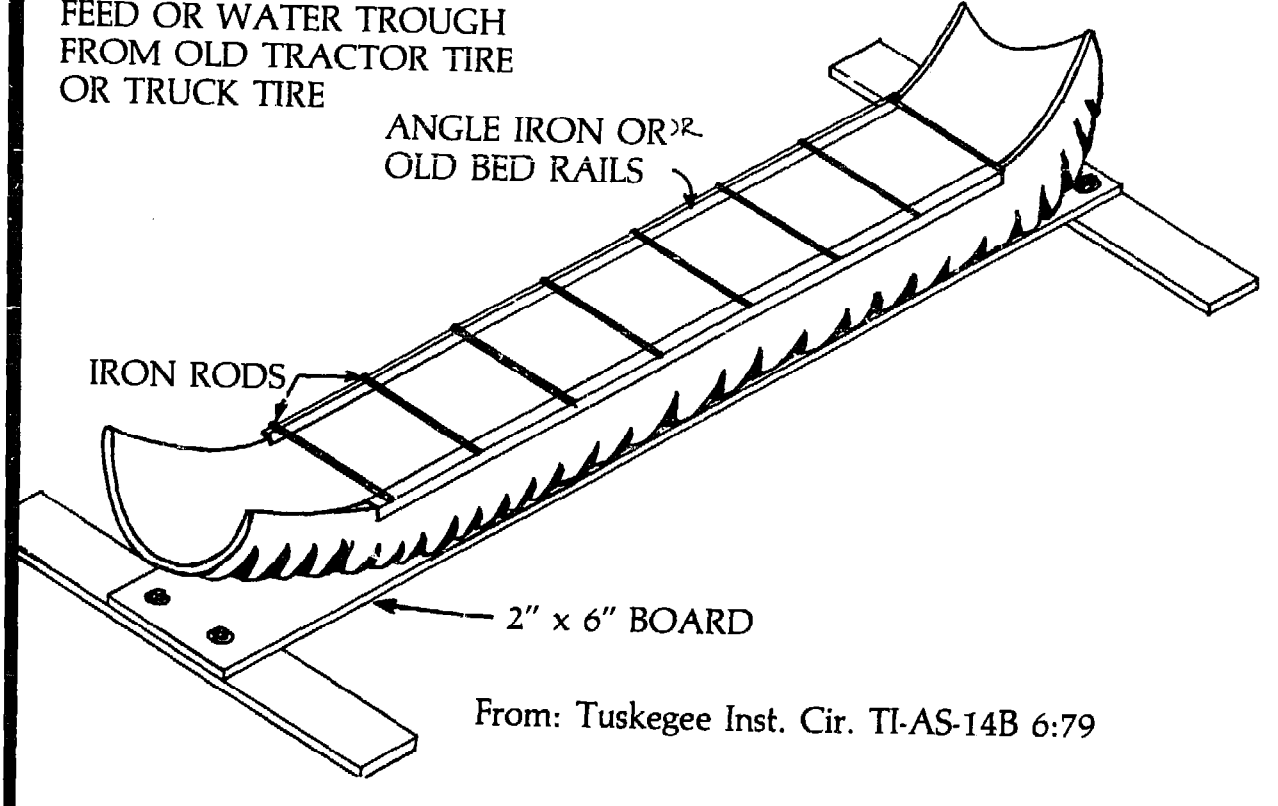

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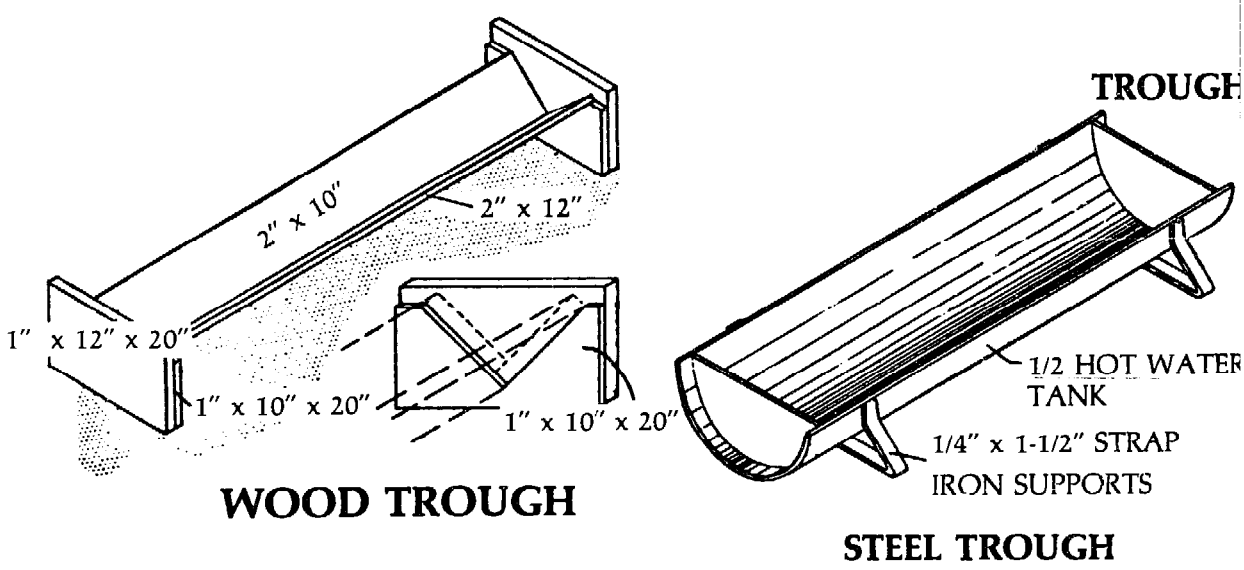

"Drawings of Feed and Water Troughs for Pigs"

From: Clemson University Agri. Eng. Circular 205

FEEDERS OR WATERERS

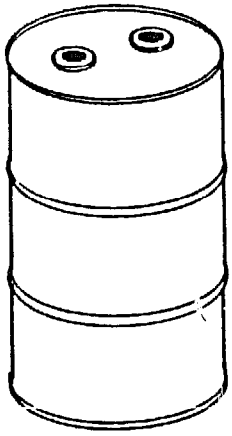

FEED OR WATER TROUGHS
FROM RECYCLED OIL DRUM
55 GAL. OIL DRUM

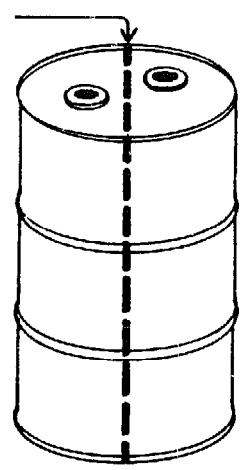

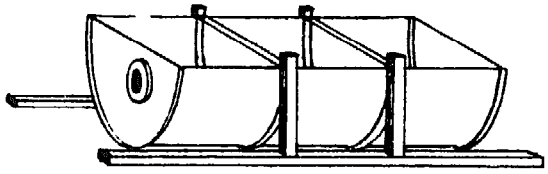

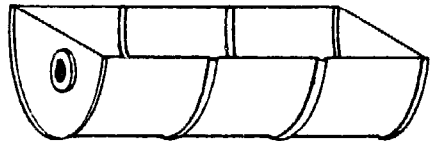

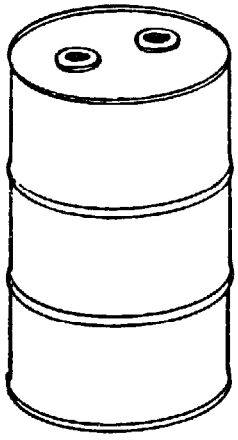

OLD OIL DRUM
CUT IN THIRDS

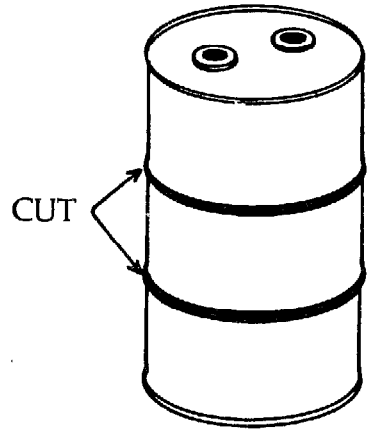

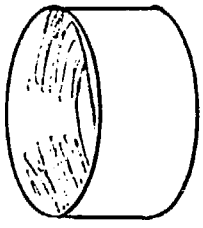

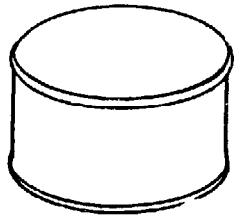

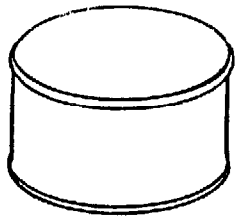

From: Tuskegee Inst. Cir. TI-AS-14B 6:79

farrowing houses

A ONE-JACKET HOUSE

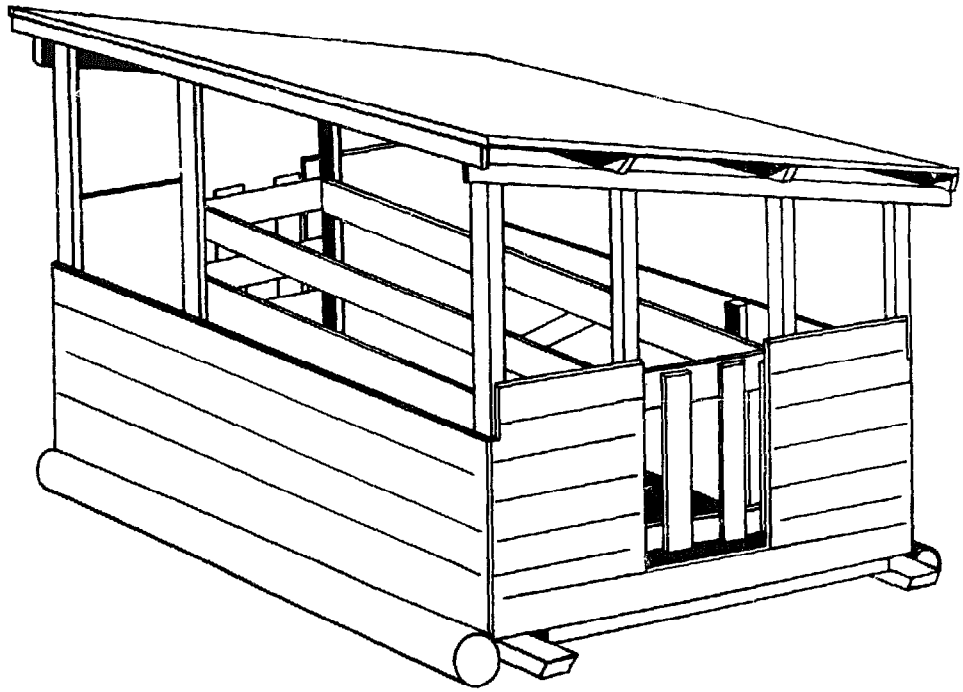

CROSS SECTION

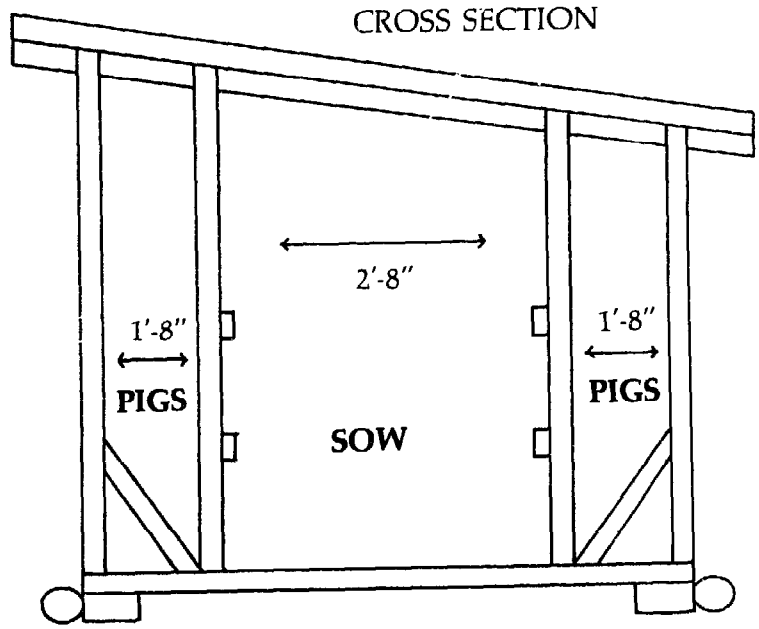

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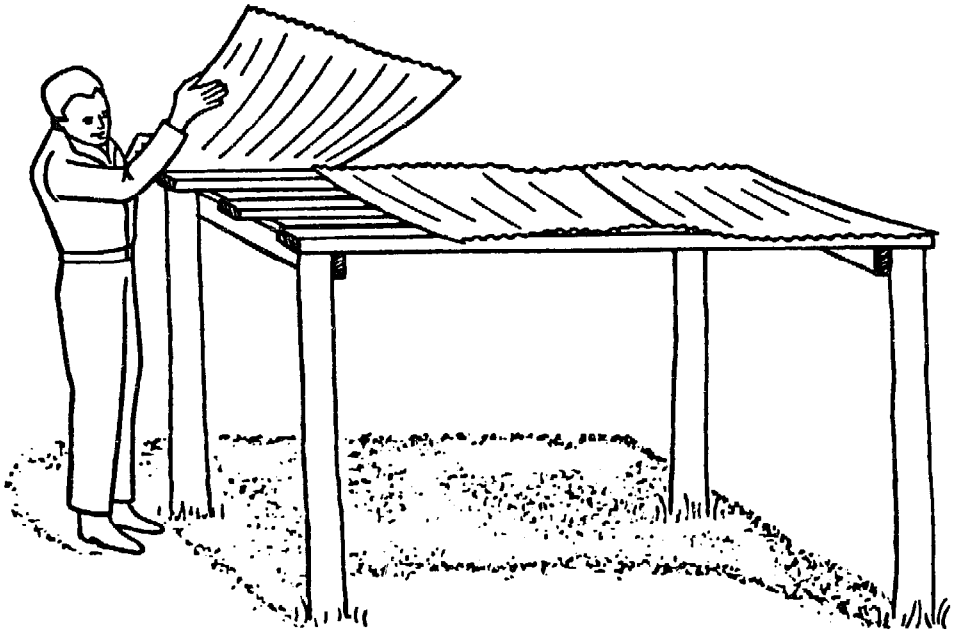

"Drawing of Temporary Shed made from Poles and Scrap Building Material.
Thatch or straw would also work well if roof were more steep."

From: USDA Leaflet 537

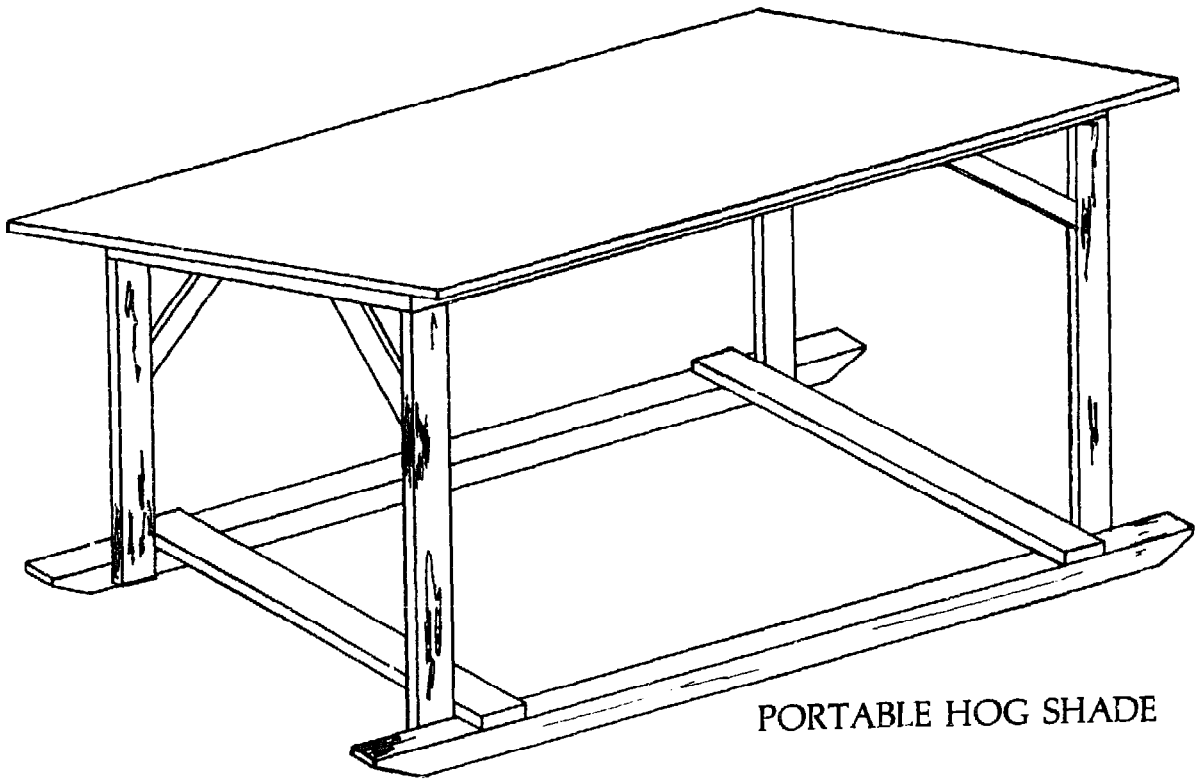

PORTABLE HOG SHADE

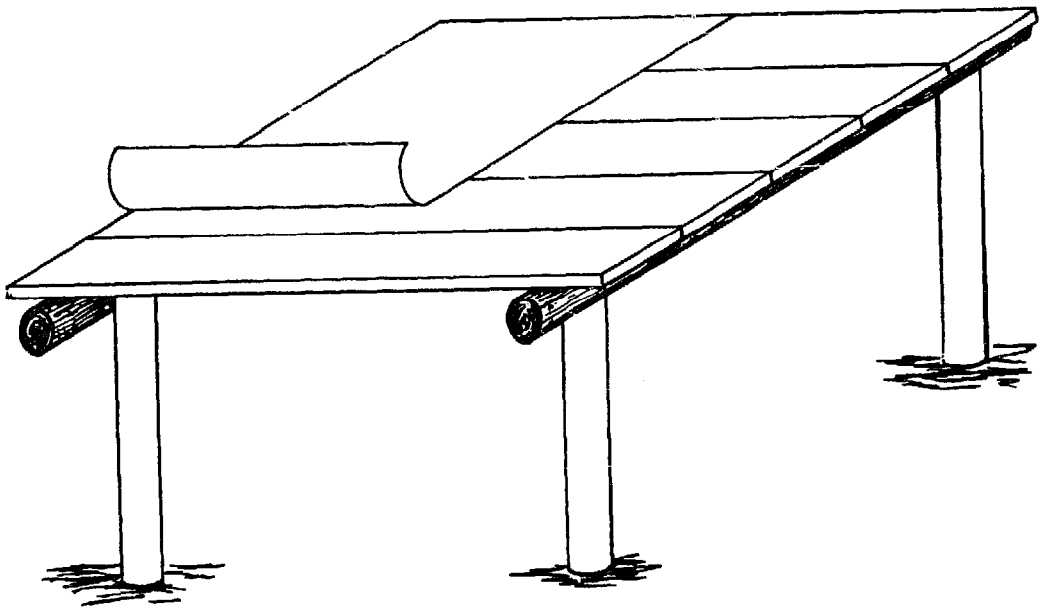

STATIONARY HOG SHELTER

From: Tuskegee Int. Cir. TI-AS-14B 6:79

AGRI. ENG. CIR. 205

NOV., 1948

A-TYPE HOG HOUSE

BILL OF MATERIALS

2 - 2" x 6" x 8'-0" RUNNERS
7 - 1" x 6" x 8'-0" BRACES
10 - 1" x 3" x 12'-0" BATTENS & CLEATS
10 - 1" x 8" x 12'-0" SIDING
1 - 2" x 4" x 10'-0" GUARD RAIL
2 LBS. 8d COMMON NAILS
1 LB. 6D COMMON NAILS
1 PC. 24" TAR PAPER 7'-0" LONG

PREPARED BY
G.H. STEWART, LEADER
AGRICULTURAL ENGINEERING EXTENSION WORK
AND
A.L. DURANT
EXTENSION LIVESTOCK SPECIALIST
COOPERATING

CLEMSON AGRICULTURAL COLLEGE
Cooperating with
UNITED STATES DEPARTMENT OF AGRICULTURE
EXTENSION SERVICE
D.W. Watkins, Director
Clemson, South Carolina

DISTRIBUTED IN FURTHERANCE OF THE ACTS OF CONGRESS OF MAY 8 AND JUNE 30, 1914.

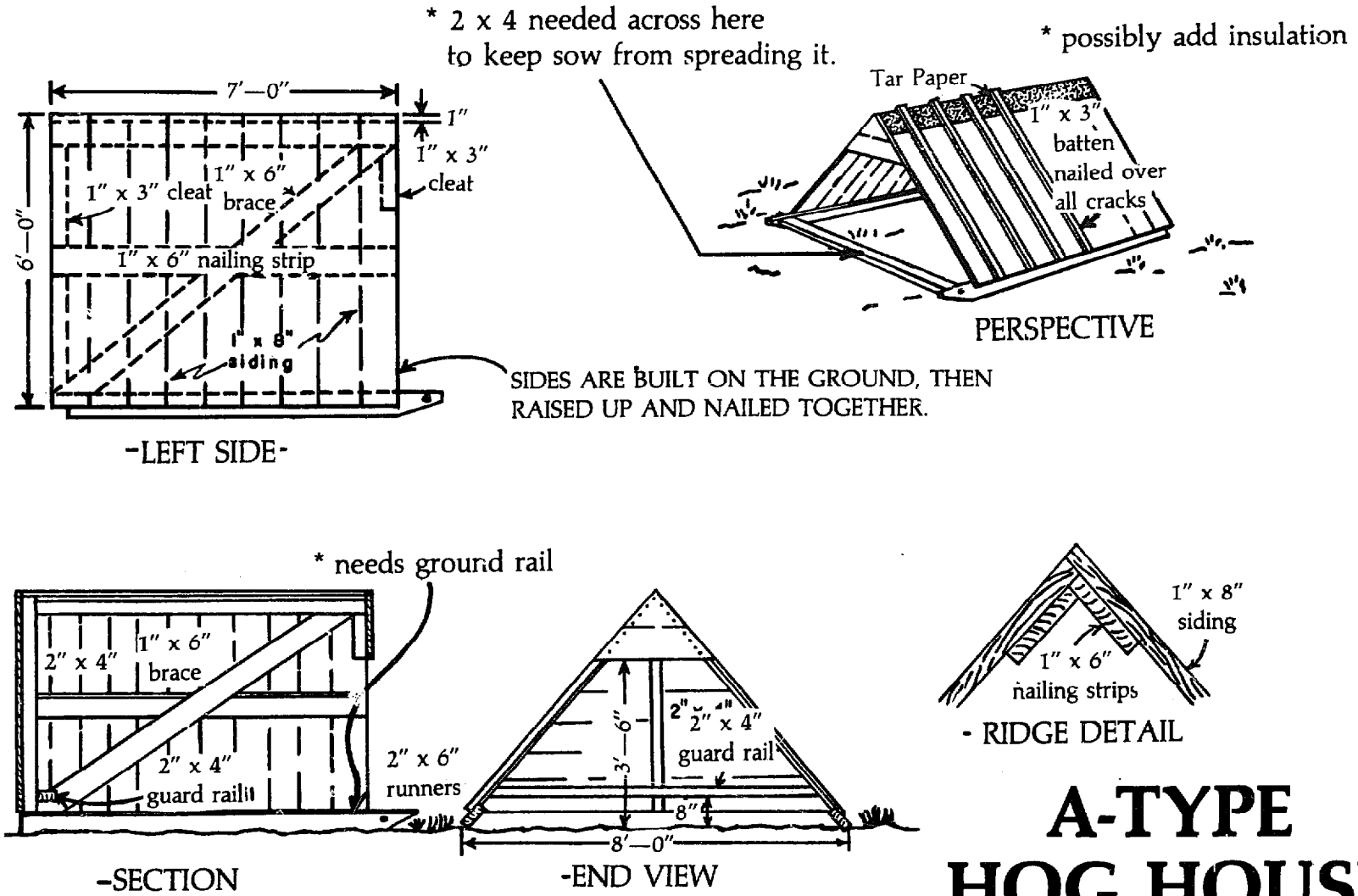

A-TYPE HOG HOUSE

A FEED MIXER

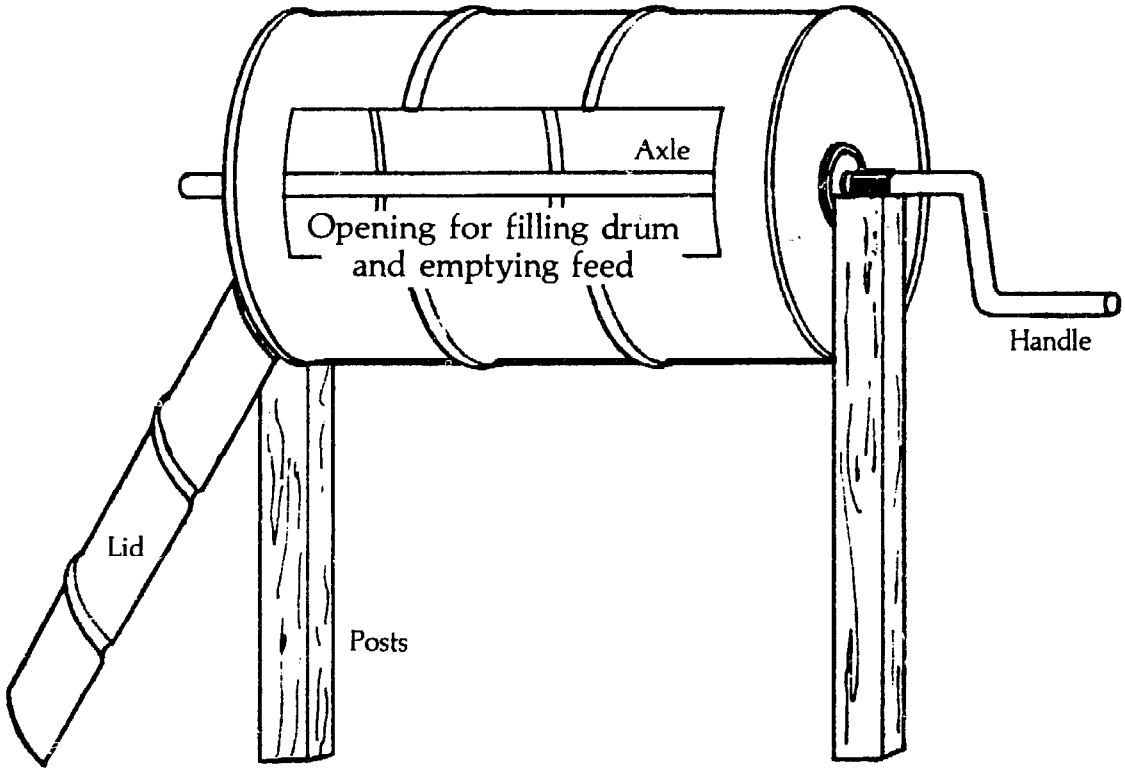

The 200 lb. mixer
made from a 44 gallon drum

Section 3

Nutrition

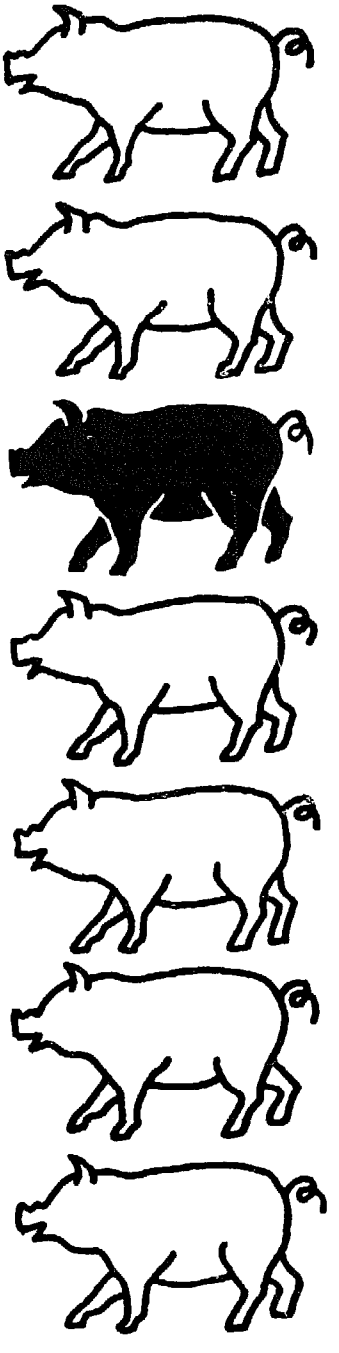

Nutrition — Food and Water For Growth and Health

In this booklet we will greatly emphasize nutrition because so many aspects of an animal's health are affected by nutrition, and because pigs are able to consume and often thrive on a wide variety of foodstuffs. Many of these foods are in a surplus seasonally, are very inexpensive in certain areas, or are not nutritious or appetizing for humans and consequently may be wasted if not fed to pigs. Also, there are many times when grain and occasionally purchased ingredients fed along with these other products to pigs will often result in a great increase in protein and cooking fat available to humans. This protein and cooking fat would probably not be otherwise available if it were not for some of the unique characteristics of pigs.

Like humans, pigs have a simple stomach of relatively small size. Since pigs are omnivorous (like man) they are able to utilize food of both animal and plant origin. This gives us many options in feeding pigs that we do not have in feeding cattle, sheep, and goats.

Pigs are also able to utilize forages, grass, and other grazing much better than is generally believed and this gives us options that help extend other foodstuffs in the diet.

Nutritional needs of the animal are influenced by size, age, pregnancy, nursing pigs, climate, soil type, and many other factors. These nutrition suggestions are offered as information only, and **should be used on the basis of the animal's needs but with the realization that local conditions and the owner's circumstances will dictate a great degree of flexibility in feeding pigs.** For this reason, the author has extensively researched the subject to find as many as possible of the foodstuffs that pigs can consume. Also, visits to existing hog farmers in your area may help you discover other satisfactory foodstuffs for pigs.

The key to pig nutrition is understanding that different classes of foods must be combined for a balanced ration since no one feed provides all required nutrients. (California)

There are five classes of feeds for hogs:

Carbohydrates and fats: These are mainly grains, but include dried (and fresh) fruit, yams, potatoes, molasses, and fats. Vegetables and garbage are also included, but are less desirable. Foods in this group give energy which is used daily in body processes, stored as fat, and used for milk production. They make up the bulk of pig diets, around 80% of the total.

2. **Protein:** This is supplied by a number of animal and fish by-

products, and oil seeds. Good grazing supplies much protein, and grains contain a small amount. Protein provides for growth and builds tissues (muscle and lean meat).

3. **Minerals (including salt):** These are supplied by sources such as ground limestone, steamed bone meal, and salt. These are necessary for bone and tissue growth, and for body functions.

4. **Vitamins:** These are needed in small amounts for growth, reproduction, and body functions. They are **necessary** for good health. Vitamins are supplied mainly by good grazing, but small amounts come from protein sources and fresh fruits and vegetables.

5. **Water:** A fresh, plentiful, and constant source of water is needed for good health.

1. Carbohydrates and Fats:

A. **Grain:** In areas where corn can be efficiently produced, it is a staple of hog rations. However, any grain can be fed, as well as grain by-products and substitutes. Often grain is expensive or is not available locally. Small amounts, however, used along with other inexpensive ingredients will greatly extend them and will balance the ration. This method can be cost effective and can increase the protein and cooking fat available to humans. Also, in the isolated areas where transportation of farm products is difficult, meat and animals are often more easily sold.

1. **Corn:** Corn is an ideal hot feed, but, **as with all grain products,** needs to be balanced with a little extra protein and minerals for best results. Yellow corn has more vitamins and is preferred.

2. **Wheat:** This grain is similar to corn and is an ideal hog feed. Cost and availability, however, mean that little is used as hog feed (it should also be balanced with protein and minerals.)

3. **Oats:** Also a good hog feed and less expensive than wheat. Because of its high fiber content, it is better for adults than young animals. It works best when mixed with other grain, especially for young animals. Hulled oats are a good feed for young pigs.

4. **Barley:** Is almost as good as corn, but **must be crushed or ground.**

5. **Rye:** A satisfactory hog feed if it is ground or crushed.

6. **Grain Sorghums:** These include milo, millet, kafit, etc. and are similar to corn in feed value to pigs, if crushed or ground.

7. **Triticale:** A relatively new hybrid which is a cross between wheat and rye is satisfactory as pig feed. Except for short periods, it should not constitute over 50% of the total diet.

8. **Wheat Bran and Wheat Middlings:** These are similar in feed value to wheat, and can be fed to pigs, if available, at a reasonable cost. These are better fed to animals over 100 pounds, and should

not make up more than one-fourth of the total ration, except for short periods. These are the milling by-products.

9. Other grain or feed milling by-products, including floor sweepings, may be fed to pigs, but there is an element of risk if other chemicals are stored in the same building.

NOTE: All of these grains, except corn, should be ground, crushed, or soaked for pig feed. Corn can be fed without grinding. See **Details** in the section on **Food Preparation.**

B. Rice Products:

1. **Rice:** Rough or paddy type; it is a good pig feed, but only if it is ground or cooked. It is better for use with older animals. Cost and availability limit its use in pigs except for special circumstances. It can be used to extend other inexpensive products in order to produce protein and fat. Older hogs do well on rice stubble.

2. **Rice Bran and Polish:** A good pig feed if mixed with other grain and a little protein. Do not feed as the only carbohydrate source except for short periods. The high fat content causes rancidity to develop quickly.

C. **Grain Substitutes:** These are best used to replace part of the grain, but can be used as the only source. As with other products, they need to be balanced with minerals, a little protein, and grazing or cut forage, if possible.

1. **Potatoes:** Cull or surplus potatoes are occasionally fed to pigs. If cooked they can replace part of the grain in the diet.

NOTE: Sprouts may be dangerous. Remove before feeding. Dehydrated potatoes also work well.

2. **Yams (sweet potatoes):** These are a good grain substitute. Do not feed as the only carbohydrate source except for short periods of time. Do not feed molded or rotten potatoes or sprouts. If yams are not grown in your area, suggest it be tried. Cooking improves their value. It takes 3-4 pounds to replace a pound of corn.

3. **Manioc (Cassava-Manihot-Yucca):** These can be used as a grain substitute. **It can be poisonous to humans and animals.** Heavy peeling and boiling seems to prevent this problem. A practical guideline is to prepare it as is done for human food. This is a food that seems to be cheaply and easily grown in many areas with a warm climate, and should probably receive more attention as a pig food.

4. **Cassava Meal:** A manufactured product is a satisfactory grain substitute in pigs if available at a reasonable cost.

5. **Molasses:** Can replace part (1/3) of the grain, but should not not be used as the only carbohydrate except for short periods. Molasses should **not** make up more than 10% of the diet of young pigs, 20%-

30% in growing animals. Cane molasses is best, beet molasses fair and citrus molasses less desirable.

6. **Sugar:** Same as for molasses.

7. **Tubers:** Root crops, artichokes, beets, and turnips, and any other root vegetable eaten by humans is a satisfactory pig feed. These are not highly nutritious, but pigs like them, and then can extend the diet somewhat. Carrots are better than any others.

8. **Cull Vegetables** (overripe or surplus): Cucumbers, watermelon, tomatoes, pumpkin, lettuce, cabbage, squash, and others locally available, are not highly nutritious, but can extend the diet. They should not be the only food for nursing sows and young animals. They are better used in larger growing animals.

9. **Cull Fruits** (overripe or surplus): Coconut, ripe bananas, pineapple, pineapple bran, avocado (without seeds), pears, apples, peaches, papaya, and breadfruit are satisfactory for up to 1/3 of the diet, or higher for short periods. They should not be the only food for nursing sows and young animals as they are too low in energy supply. Any other fruit available locally should be looked into as a pig feed. **Bananas** can be utilized in several forms, but they are more appetizing if allowed to ripen. Green bananas are somewhat bitter and pigs will eat less of them than they will eat if ripe. Ripe bananas may be fed whole with peelings. Green bananas may be made more appetizing by cooking them. Bananas are often in a surplus, and may be available free or at a very low cost. In such areas they should receive more attention as a food for pigs. Bananas and breadfruit are among the best grain substitutes for pigs.

NOTE: Vegetables, potatoes, and fruit should be cut into small pieces for better digestion and to prevent choking.

10. **Dried Fruit:** Cull raisins, dried figs, prunes, dates, apples, etcetera, can be fed to pigs. They should be limited to 1/3 of the diet except for short periods. This is one method of preserving surplus or inexpensive food for later use when it is out of season.

11. **Citrus Fruit and Pulp:** There is often a surplus of this at harvest time, and it can prove to be an inexpensive feed or culls may be free. Information for other fruit applies here. They can be fed with the peelings. Those with a sweeter taste such as oranges or tangerines are preferred over lemons, limes, and grapefruit.

12. **Kiawa Bean Meal:** If dried and ground or crushed, this is a satisfactory pig feed for up to 1/3 of the ration. It is high in fiber and is best fed to non-nursing animals.

13. **Copra:** This is coconut oil meal and is a satisfactory carbohydrate-grain replacer for up to 1/3 of the diet. It is not very appetizing to pigs and should be mixed with other food for better results. Molasses works well with copra.

14. **Babassu Oil Meal:** A manufacturing by-product of the Brazilian palm. It is similar in food value to that of Copra for pigs.

15. **Tamarind Seed:** Has been fed satisfactorily in India, as a grain-carbohydrate source, though details are not available.

16. **Incubator Waste Eggs:** This is a good source for pigs that is often available around egg hatcheries. They are a reasonably satisfactory food for pigs, but **only if cooked and in small amounts.**

Caution: No grain or seed of any kind (including oil seeds such as peanut, soybean, and cottonseed) which has been treated with **chemicals for planting** should be fed to animals or humans. **All seed treatment chemicals are harmful.**

Caution: Leucaena — An unusual, fast growing Leguminous Tree has leaves and seeds that have been used for livestock feed. However, there **may be a problem** in feeding it to pigs. Do not feed it to pigs unless local experience with it has proven satisfactory. This is especially true in pregnant and nursing females.

17. **Bagasse:** Sugar cane pulp, a manufacturing by-product. While not a very desirable grain substitute, can be used in small amounts, (not over 15%) in the ration of larger growing animals. (See Sample Ration 13). It is best used with molasses. It has very little feed value for pigs and would only be used as a last resort.

D. **Waste Kitchen Fat:** Lard and tallow and cooking oils. All of these are good energy sources and work well in swine rations. They should not be the only energy source. Fat stimulates nursing sows to give more milk and it is richer in fat. It should be supplemented with other carbohydrate and protein and minerals. Food grade vegetable oil such as a peanut, soybean, and sunflower works well.

E. **Bakery Waste:** Stale bread, dough, cake, etc., is occasionally available free or is inexpensive and often not appetizing to humans or is a surplus. It is similar in food value to grain and can replace it. Protein and minerals are also needed to balance it. If very dry, it should be moistened.

Caution: Before feeding, **always remove plastic and paper wrappers.**

F. **Garbage Feeding:** Garbage can also be a grain substitute - carbohydrate source. It is usually animal or vegetable source food discarded from the human food supply. Business, institutional and military garbage is far superior to household garbage, though both are satisfactorily fed. As with any grain - carbohydrate source, protein and minerals should also be fed. Because of poor nutrient balance, garbage **alone** should not be fed to the very young or nursing adults: it is best fed to growing animals. Because **it often contains meat and bone scraps it may spread disease and parasites (Trichina & Tapeworms) that affect humans and animals. Boiling for 30**

minutes is considered an adequate safeguard. It also improves the food by blending it and softening it. As a last resort, if cooking is impossible, try to remove meat and bone scraps or cook these separately. Also, remove plastic, paper, metal foil, etc.

Particular attention should be paid to slaughter house waste as a source of disease and parasites. **Always cook these well before feeding.** Good quality garbage with meat scraps may be fed without added protein to growing animals; however, they will grow faster and healthier with more protein. Garbage always needs to be supplemented with minerals, including salt. This is especially true in pregnant and nursing animals. Garbage alone is not a satisfactory food for pigs under 8-10 weeks old. In order to do well they need some regular carbohydrate-grain produce and added protein. **Feeding household food waste to pigs is often a recommended practice in primitive situations.**

Animals confined in a small area and fed garbage will greatly benefit if **freshly cut green grazing food is also fed to supply vitamins.**

Environmental Note: Because of many factors, garbage feeding soon becomes unsanitary and pigs generally suffer from more health problems. Rotation of pens and pastures on at least a 6-12 month system is a great help in growing healthier animals.

G. **Forages - Green Grazing:** Grazing is an inexpensive source of nutrients that is usually available and should be utilized if at all possible wherever swine are grown. In many areas it is available year around. In non-nursing adults it can replace part of the carbohydrate-grain and protein. Grazing is especially helpful for pregnant animals and is almost a necessity unless a well-balanced highly nutritious diet is fed. Legumes such as clover, alfalfa and others are high in protein and do well with no added nitrogen fertilizer. If local conditions are suitable they should be grown even if in small patches. **However, any (non-poisonous) green vegetation is helpful.**

If grazing is of high quality or in limited supply it may be better to **cut it and bring it to animals** rather than damage it by grazing. Any excess can be dried like hay for future use.

In many countries, local experimentation has developed greatly improved strains of local grasses that are more nutritious and resistant to disease and insects. Also, imported grasses may have been introduced that are much better than local forage. In either case, seeds or cuttings of these should be started from the original planting.

While commercial fertilizer is often too expensive or transportation is too costly, there may be some situations where cost will allow their use. Yields are greatly increased with fertilization and foods are much

more nutritious. In many cases small amounts of fertilizer will increase yields more than enough to be cost-effective. In other areas, soil testing will have indicated that single ingredients such as phosphorus or potassium alone will greatly help. They are much less expensive than complete fertilizers.

Grazing with access to wooded areas allows swine to supplement their diet with grubs, earthworms, roots, seeds, acorns, berries and occasional small rodents.

2. **Protein:**

Grain and grain substitutes do not contain protein in sufficient amounts to satisfy the needs of swine. Therefore, some feed high in protein needs to be added as often as possible. Failure to do this causes slowed growth, stunting and many health problems.

Although the usual commercial products are costly, there are often local sources of some type of protein which can be grown or purchased at reasonable cost. The numerous possibilities listed here well prove that to be true.

A. **Plant Sources of Protein:**

1. **Soybean Meal** is 40-44% protein and is the ideal pig plant protein. **As with all plant protein sources it should be supplemented with vitamins and minerals. It should not be over 1/2 of total ration.** Cooking soybeans for 30 minutes at 280° F. or 138° C. will destroy a chemical that interferes with digestion and should be done if at all possible. Any cooking such as parching or boiling is a big help.

2. **Peanut Meal:** 47% protein, is a good protein source. It is a better ration if some meat protein is also fed. Peanuts can also be fed raw to pigs and in the hull.

3. **Linseed (Flax) Meal:** 35% protein. Information as for peanut meal applies here but should only be fed in limited amounts or short time. It should not make up more than 1/3 of the added protein. It has a laxative affect and small amounts are good for sows.

4. **Cottonseed Oil Meal:** 35% is a good source of protein for swine but unless specially processed it is **dangerous to swine** because of a chemical called gossypol. It is mentioned here because cotton is grown in many areas and may be available at low cost. **If care is used** — small amounts, **not over 10%** of a normal ration may be fed if animals are closely observed. It is better if a little animal protein is also fed.

5. **Copra (Coconut Meal):** 21% protein — rates as a protein **and** carbohydrate-grain source. It is better if a small amount of meat protein is also fed.

6. **Field Peas:** 23% protein — are a good source of protein for swine. They are usually grazed but they are more efficient and there

is less waste if hand picked. They may also be dried for later use and cooked for swine. They supply carbohydrate as well and since they require little fertilizer and in many areas can be grown year-round, they should receive more attention as a swine feed. They yield well on small patches and are also a good human food. **The dried peavine bush makes excellent hay.**

7. **Navy, Lima and Other Edible Beans:** 23% protein. They supply protein and energy. They **have** to be cooked or they are toxic (poisonous) and salt added or they are not appetizing to swine. **Caution — Hulls of some beans, if wilted, are poisonous and should not be fed. Caution — Raw velvet beans are not safe for pigs** and not totally safe if cooked.

8. **Alfalfa** (Green) or Hay (Chopped Fine) is an excellent source of protein, vitamins and minerals for swine. It is usually high priced but even in small amounts is an excellent swine feed at up to 10% of total ration. Newer varieties show promise of being grown in many areas not formerly suitable. Suggest that it be tried in your area.

9. **Sunflower Seeds:** Can be source of protein for swine, though not as suitable as others. It is a better feed for adults since it is high in fiber, but can be fed to all ages except baby pigs.

Sunflower Meal:25-45% protein is better than seeds and is satisfactory for all ages.

10. **Safflower Meal:** Low in protein (20%) but is a fair protein source up to 10% of total diet.

11. **Sesame Meal:** 44% protein. If this is used as the protein source some animal-fish protein is also needed.

12. **Feather Meal:** (By-product of poultry processing). It is not a good protein source for swine, but is available in some areas and should be used if inexpensive. It is best used to extend other protein.

13. **Brewers Grain:**(By-product of beer processing) and Distillers Grain (By-product of Alcohol production). It is a satisfactory source of protein for swine if available and reasonably priced. They have the same limitation as the grain from which they were produced.

14. **Emergency Plant Protein Sources:** Very poor source of protein for pigs.

a. **Tung Nut Meal** — must have been detoxified for pig feed. It is not palatable unless fed in small amounts and mixed well. It might best be used in emergencies or for a short time.

b. **Kapok Oil Meal** — another manufacturing by-product that can be used as a protein for pigs. It is much less desirable than others but can be used. It is best used to extend a more desirable protein.

c. **Palm Kernel Oil Meal** or **Cake** — a manufacturing by-product that is not a very appetizing nor highly nutritious protein source for pigs. However, it can be used in small amounts when no other

protein is available.

d. **Rubber Seed Meal** — a manufacturing by-product of the Para-Rubber Tree, containing 25% protein, can probably be used in small amounts in pigs. Heat treatment seems to reduce the Toxic Hydrocyanic (Prussic) Acid. **Caution:** Hemp Seed Meal is a poor protein source for pigs and **possibly dangerous.**

B. **Meat-Fish Sources of Protein**

1. a. **Meat and Bone Scraps**
   b. **Meat Meal and**
   c. **Tankage**

All of these are meat processing by-products. These generally run 45-60% protein and are an excellent protein source for swine. If any of these products have not been cooked in processing, they should be cooked as for garbage. It also supplies minerals.

2. **Blood Meal** — 80% protein — another meat processing by-product that is a good protein source for swine. It is best used when other protein is also fed and is of most value in larger growing animals.

3. **Fish Meal** 50-70% protein, one of the best protein sources for swine and one of the most appetizing for swine. High cost limits its use in most areas. However, in some areas it is available at a cost that makes its use in swine a possibility. It is especially good to get young growing pigs off to a good start and to extend lesser quality protein. It does not give pork a fish taste.

Cooked Fish or Fish Scraps — Locally caught fish or fish scraps, if cooked, can be fed to swine as an excellent source of protein. In many areas this could satisfy the protein needs of swine. Fish species not appetizing to humans can be used in swine. If not well cooked by boiling (and in the case of larger fish, also crushed or ground) bones may be a problem. In some areas fish might also be a source of disease and parasites if not well cooked. By-products of processing seafood other than fish can also be used in swine rations. These would include scraps from fresh processing, as well as shrimp and crab meal, shark and tuna meal.

C. **Dairy Product Sources of Protein**

1. **Surplus whole or skim milk and buttermilk** — These are excellent sources for swine and very appetizing. They would be of the most value in nursing sows and baby pigs but also are very good in growing animals. Even in small amounts they stimulate nursing sows to give more milk and help young pigs to get a good start. In areas where crop farming is not practical and grazing for cattle (and goats) is plentiful and cheap, milk could become a surplus and could be efficiently used in swine diets. This would be especially true in areas

with many cattle and few people or where transportation of milk is impractical. **Surplus goat milk could be used for swine.**

2. **Whey** — By-Product of cheese making. Though low in protein it is easily digested. It has about half the food value of skim and buttermilk, but should be used if available at reasonable cost.

3. **Vitamins:** These are only needed in small amounts, but are necessary for good health, growth and reproduction. They are not used as a source of protein or energy, but are essential for normal body functions. The vitamins most often deficient in swine rations are Vitamin A, B Complex, and B_{12}. Vitamin A is produced from carotene which is found in green and yellow feeds such as grasses and yellow corn or carrots. The B complex vitamins are found in green feeds and grain and B_{12} in animal and fish products. In advanced swine production systems swine are fed commercially produced vitamins. This is a necessity, where swine are raised on concrete or in confinement buildings.

High cost, transportation problems, and heat inactivation necessitate that a practical and inexpensive solution to providing vitamins to swine be found. The answer to this is the knowledge that the 14 vitamins swine require are generally available in feed if some of the different categories are regularly fed. Also some are produced by normal micro-organisms in the intestine. This means grain or grain by-products and plant and animal (or dairy) protein sources need to be fed regularly. Many of these are also available in forages being grazed or cut and brought to animals. Fruits and vegetables, especially those with yellow color, also provide vitamins and should be fed as often as possible. Any source of fish or fish by-product or animal protein, even if only occasionally, is a big help in providing vitamins.

Under most primitive production systems, forage of good quality grazed or cut and fed to swine, or dried for later use will adequately provide vitamins if animals are fed a reasonably well balanced diet. **This is a simple and inexpensive way of providing vitamins, that is usually available.** If good quality forage is not available, use any green grass or other vegetation, if palatable and not poisonous.

4. **Minerals:**

These are inorganic elements that are essential for many vital functions and are major components of the skeleton. Calcium, phosphorus, sodium and chlorine (salt) are the ones needed in larger amounts. Iron, zinc, iodine, selenium, copper and manganese are also needed, but in minute amounts.

Calcium and available phosphorus are too low in the usual carbohydrate-energy sources to satisfy the needs of swine, especially pregnant and nursing females.

Also, almost all of the usual foodstuffs are deficient in salt.

Practically all feeds contain some minerals. The combination of feeds being fed determine the amount of extra minerals needed. Because pasture and grasses harvested for forages have more mineral than seeds and their by-products, **swine fed on pasture need less additional minerals.** Also, they can obtain some of their mineral requirements directly by **rooting in the soil,** particularly iron and other minor elements.

We have to understand that the mineral content in grain and forage-pasture depends to some extent on this **amount in the soil.** Where topsoil is limited, in areas with very heavy rainfall, in areas naturally deficient in certain minerals, and on land that has long produced crops with poor replacement of minerals we can expect that foodstuffs grown will contain lesser amounts of minerals. This **almost always** means that we have to provide **additional minerals** since one or more of the above conditions prevails in most areas and swine will not grow or reproduce well without adequate minerals.

Where a complete mineral mix (calcium, phosphorus, salt and minor elements) is available and at affordable cost it should be fed since only small amounts are consumed daily. In other circumstances, a practical solution can usually be found if one has a basic understanding of the problem.

A good trace mineralized salt will supply salt and the minor elements — all that is needed except calcium and phosphorus.

Calcium is the principle component of Limestone (Lime) which is often available and the usual source of calcium. It may contain magnesium also.

Steamed bone meal is a good source of calcium and phosphorus and often used. **Defluorinated rock Phosphate** is a good source of phosphorus and calcium. **Raw rock phosphate** with the **fluorine not removed is poisonous to swine. Dicalcium phosphate** also contains both calcium and phosphorus and works well for pigs. **Caution** — Do not use lime that has been heated or has had other ingredients added as for cement or mortar mix. Protein supplied from animal sources also provides a source of calcium and phosphorus. **Possible Mineral Mixes** that might be prepared locally.

Mix No. 1 — Equal parts — ground limestone (or oyster shell)
— steamed bone meal
— trace mineralized salt (or iodized salt)

Mix No. 2 — Equal parts — ground limestone (or oyster shell)
— DiCalcium phosphate
— trace mineralized salt (or iodized salt)

Mix No. 3 — Equal parts — ground limestone (or oyster shell)
— Defluorinated Rock Phosphate
— trace mineralized salt (or iodized salt)

Mix No. 4 — Equal parts — steamed bone meal or DiCalcium phosphate
— trace mineralized salt

This mix is not as good as numbers 1-3 mixes, but can be used for pigs.

Mix No. 5 — Another mineral mix that can be used, though not as good but simple and inexpensive is:

— 80 pounds of wood ashes and
— 20 pounds of trace mineralized salt

All of these mixtures should be fed free-choice to all ages daily, in boxes or feeders protected from rain; unless they are being fed as a complete ration containing minerals. If no other minerals are available **wood ashes** can be fed. However, they are best used to extend other better quality minerals. It can be fed at one teaspoonful daily per 100 pounds bodyweight and seems to also have a small beneficial effect in controlling intestinal worms. Also, bone meal or mixed minerals can be fed daily at one teaspoonful per 100 pounds body weight. In many areas there are cattle or poultry operations who are using home-made or commercial mineral mixes who will help other farmers. Although these are slightly different from the needs of pigs, they are preferable to doing without. Also, they might help you obtain certain ingredients such as trace mineralized or iodized salt.

Ground Oyster Shells (clam shells, coral, coquina or any seashell) (or mussel-fresh water shells) can be used when lime (limestone) is needed. Ground oyster shell is usually available wherever poultry are grown, but needs to be more finely ground for pigs.

Fish in the diet will provide iodine if fed often and also other minerals such as calcium and phosphorus.

Selenium is a mineral needed by animals, but in extremely minute amounts. It is deficient in most coastal flatlands, river valleys that flood and most areas with high rainfall. Trace mineralized salt often contains selenium and would be preferred, if available.

Note — Animal bones are often available and they can be **finely ground** or crushed by hand or a hammer mill. They should be **thoroughly cooked**, preferably in steam to kill germs. Fresher bones are better for these purposes. They are good sources of calcium and phosphorus.

Note — Trace mineralized salt contains iodine and minor elements and is less costly to transport than complete mineral mix with calcium and phosphorus. It can then be mixed with the calcium and phosphorus source. If trace mineralized salt is not available, use iodized salt rather than plain salt. **See later notes on Adding Iodine to Salt in the discussion on salt.**

Note — Commercial trace minerals without salt may be available.

They could be mixed with salt and the calcium and phosphorus sources for a complete mineral by following the label directions. Since only very small amounts are used, transportation costs would be small.

A simple homemade mixer adequate for mixing minerals is described in the **discussion on salt** and there is a **drawing in the section on Buildings and Equipment.**

Calcium and Phosphorus Deficiencies are usually seen as swollen joints and arthritis in all ages, but is much more noticeable in young growing pigs a few weeks after weaning. Sows often show weakness and paralysis in rear legs and reproductive problems and poor milking is common.

Mineral needs are very great in animals being fed grain alone and no protein.

They are less critical in animals on good grazing and in animals fed on animal or fish protein.

Salt is the one mineral which swine always need. It may be fed loose or in blocks, or mixed into the ration. In most primitive systems it is fed loose, preferably in a free choice mineral mix. If not fed as part of a mineral mix, Trace mineralized salt or at least iodized salt should be used. It should be fed daily or as often as possible. Health problems may arise if hogs go very long without salt. Also, they may overeat salt when it becomes available with serious consequences if they have long been without it. Salt or mineral mixes should be kept covered to protect from rain. **Water dissolves salt and pigs may consume too much.** If salt is fed in a complete ration with a grain-carbohydrate source and protein, it should be used at 0.5% rate, equivalent to 1/2 pound in 100 pounds of feed or 10 pounds in a ton of feed. **If fed this way, do not give other salt.** Animals should always have access to plenty of fresh water. **Swine on complete feed with salt have to have water constantly available.**

Since iodine is so important and iodized or Trace mineralized salt may not be available, the following information is given.

Sources of iodine for mixing with salt

Potassium iodide Sodium iodide Calcium iodate	(readily available to livestock but will leach or evaporate from salt blocks)
	Pentacalcium orthoperiodate (PCOP) is equal to above in availability, but will not be lost as rapidly from blocks. Used when exposed to rainfall.
	EDDI (ethylenediamine dihydriodide) — also useful for livestock. Less problem with moisture.

Potassium iodide is less desirable because of moisture problems, but is often available, even in remote areas. Drug stores often stock it or can order it; also try chemical supply companies.

EDDI is an iodine containing preparation that is often fed to cattle and might be available through feed dealers or possibly from cattlemen. It is not an expensive product and because of the very small amount used it can well be justified. An advantage is its moisture tolerance.

The following table provides a list of iodine containing preparations and amounts to use in mixing with salt.

	Amount of Product to Add to Salt to provide 0.007% Iodine		
	% I	mg/kg	gm/100 lbs.
Potassium iodide	76	92	4.2
Calcium iodate	65	108	4.9
Sodium iodate	85	82	3.7
EDDI	79	87	3.9
PCOP	26	270	12.3

Conversions:

1 ounce = 28.35 grams
1 gram = .03527 ounces
1 kg. = 2.2 lbs.
1 lb. = .454 kg.

In known iodine deficient areas, especially if goiter is seen, the amount of iodine may be doubled in salt or even tripled. The larger amount may also be easier to mix.

Note 1: Iodine or Trace minerals can be mixed with salt in small containers but the high dilution factor makes this very difficult. A clean oil drum (usually a 60 gallon barrel) with a steel rod through the center and a handle on it suspended on a pole frame makes an adequate mixer for this purpose and for mixing small amount of feed and mineral mixes. **(See Drawing in section on Buildings and Equipment).**

Caution — Containers previously used for gasoline and oil are safe if thoroughly cleaned with soap and water or steam. **Never take a chance on a container that may have contained poisonous chemicals. They cannot be cleaned well enough to be safe.**

Note 2: If there is no other way to provide iodine, it can be furnished by dissolving one ounce of potassium iodide in one gallon of water and feeding each sow one tablespoonful of the solution on her feed once each week. This is **only as a last resort in known iodine deficient areas. Do not overdose!**

Iodine Deficiency in pigs is seen as goiter (greatly swollen glands in the throat below the ears) of newborn and very young baby pigs

and lack of hair in pigs. Animals also do not grow and reproduce well.

Pigs with symptoms of a **salt deficiency** will be seen licking boards and do not grow and reproduce well.

5. **Water:**

Water is the most important nutrient required by swine, yet it is one of the most neglected aspects of swine production.

Since water is so important the following table is given for information. For their size, swine require a surprisingly large amount of water.

Weight of Hog	Gallons Water Per Day
50 lbs.	Up to 1.0
100 lbs.	Up to 1.5
150 lbs.	Up to 2.0
200 lbs.	Up to 2.5
250 lbs.	Up to 3.0
Pregnant Sow	Up to 3.0
Lactating — Sow with nursing pigs (Milk is around 80% water)	Up to 6.0
Weanling Pig	Up to 0.5

In extremely hot weather they may need even more water. Swine should have water constantly available if possible, or at least several times daily. Swine given fresh water instead of ground (surface) or pond or stream water will have much less parasite and disease problems.

However, regardless of the source it must be frequently available. Homemade inexpensive troughs and other suitable containers for water are shown in the section on Buildings and Equipment. Surprisingly, pigs prefer clean fresh water to dirty surface water.

6. **Methods of Feeding Pigs:**

Pigs may be fed in a number of ways. The farmer may combine methods to fit his situation. For example, he might hand feed limited amounts of protein and grain and graze on good quality forage.

A. **Self-Feeding** — requires a feeder in which feed is placed and pigs are allowed to eat at will. This is usually done where larger groups of growing animals are being fed. Sows should **not** be self-fed; they will become too fat and have trouble with farrowing and milking. Self-feeding is not practical in most primitive situations or where only a few animals are being fed. Its advantage is in saving labor. A **drawing** of a self-feeder is shown in the section on Buildings and Equipment.

B. **Hand-Feeding** — is done with small groups and where one wants to limit feed to sows. Small amounts are fed one or more times daily in troughs or other containers. Animals are fed no more than

the amount they will consume at the time. There is much less waste and a healthier situation where feed is placed in troughs or other containers rather than on the ground. Hand-feeding takes more time and labor than self-feeding, but no expensive equipment. This is the commonest method of feeding in small operations and under primitive conditions.

C. **Gleaning** — is a good and simple way to fatten animals. **After harvest,** pigs are turned out to clean up waste grain, rice, peas, beans, and other crops. The stubble or other remains alone may be adequate, but extra protein is usually needed. Gleaning is also good for pregnant sows. Animals under 3 months of age will not do well on stubble. Nursing sows will need additional grain and protein in most situations. This feeding method saves time otherwise lost and should be used in almost all circumstances following harvest.

Hogging Down — is similar to gleaning and is a way of letting pigs harvest their own feed. It saves labor, but is not as efficient as other methods because some feed is lost. This method may be used for almost any crop except soybeans. Some additional protein should be also feed unless animals are on beans or peas which contain adequate protein. Sows and fattening animals over 3 months of age do well but younger animals do not do as well. There is less waste of feed if a small area is used until all the feed is gone and then another area is used. Smaller animals often cannot reach the food and one or more older pigs should be in the group to help break plants down. **Water** should always be available closeby to animals gleaning or hogging-down crops.

Labor saving is the primary advantage in hogging-down crops. The loss of feed is too great to justify its use in most cases.

E. **Pasturing-Grazing** — as already mentioned is good for all ages, especially pregnant and nursing sows and young pigs. If forage is plentiful this is best, but it can be wasteful. In many cases, it is best to cut it and bring to the animals. Grazing animals get sunlight and exercise, plus moderate amounts of carbohydrate and protein as well as vitamins and minerals.

Nursing sows will need additional grain and protein and pregnant sows will do better with it.

F. **Hay-Dried Forage** — is a method whereby excess forage is preserved by drying for use at a later time. This evens out the food supply between better growing seasons and poor growing seasons, and it saves on the cost of purchased ingredients. While not efficient users of dried forage as are ruminants, older pigs can use it to greatly extend grain-carbohydrate and protein source foods. It also contains minerals and vitamins. The forage should be cut for hay near the time of maximum growth, but while still tender and green. It should be

dried as rapidly as possible. This often means that it has to be protected from daily rains and then placed out in the sunny part of the day or dried under sheds.

G. **Creep Feeding** — this is a method that provides nursing pigs with feed that is not accessible to the sow. It is a method that introduces baby pigs to solid food and greatly reduces the shock of weaning. The sow's milk production begins to decrease when the pigs are around 3 weeks of age. Creep-feeding helps offset the lessening milk flow and helps pigs grow faster. A small shallow trough or other container is placed in a small enclosure with an opening only large enough for baby pigs to enter.

Finely ground feed, initially mixed with milk if possible, for a day or two, is fed to baby pigs in the creep area starting at 2-3 weeks of age. When pigs are eating well, milk is not necessary, but is still a great help if available. **Bread scraps can be fed instead of ground food.** Do not let milk spoil, it can make pigs sick. Clean troughs often if milk is fed. There is more information in the **section on Baby Pig Management,** and sample rations 1-3 at the end of the section on Nutrition.

Food Preparation for Pigs:

1. **Grinding (or crushing)** — For small grains, such as wheat, oats, barley, sorghums such as milo and millet. This is almost a necessity for efficiently growing swine. Baby pigs have to have ground grain. Corn can be fed whole in older animals, but has to be ground for baby pigs. Other small grains can be fed whole, but not as efficiently. Hammer mills are most often used for grinding, but are not available in many areas. Small portable hand grinders used for making corn meal and flour are available in many areas. They are slow, but satisfactory. In very primitive situations, mortar and pestle is often used for a few sows and baby pigs.

2. **Soaking** is a poor alternative to grinding small grains to improve digestibility of small grains. It is not as good as grinding. Grain is placed in clean water in a container and fed after soaking 24 hours. Feed soaked over one day may ferment and cause problems.

3. **Cooking Grain or Forage** — does not improve digestibility, and is **not recommended.** However, rice products need to be cooked.

4. **Cooking Potatoes and Bean and Peas** — This does increase food value and **is recommended.** Potatoes may be cooked with dry heat or steamed or boiled. They should then be cut into small pieces or ground into meal. **Beans** should be steamed or boiled to eliminate the bitter taste and are more digestable if ground or crushed before feeding. **Soybeans have to be well cooked.**

5. **Grinding or Chopping Hay or Dried Vegetation** allows

pigs to make better use of it and **should be done.**

6. **Chop fruit** and vegetable into small pieces to avoid choke and aid in greater consumption.

Feeding a Balanced Ration:

Pigs require a balanced ration for good health, growth and reproduction. Daily or as often as possible, the following categories of foodstuff should be fed.

1. A grain-carbohydrate source or grain substitute.
2. A protein source, plant and/or animal.
3. Mineral and salt source — preferable free-choice.
4. Vitamin source — usually green forage.
5. Adequate Water — at all times.

A highly detailed discussion of balanced rations for pigs is beyond the scope of this booklet. However, the following guidelines should be a big help.

1. Generally the diet of pigs should contain around 75-80% grain-carbohydrate (or grain substitute) sources and 20-25% from protein sources with minerals and salt fed free choice or mixed in feed and at least some green forage being grazed or brought to animals, or fed dried as hay.

2. In most primitive situations, grazing will of necessity replace much of the grain-carbohydrate and protein source feeds even though growth and reproduction suffer as higher amounts are fed.

3. Also grain-substitute feeds will be necessity at times replace much of the grain in the ration. Again this is done at the sacrifice of fast growth and reproduction often is not as efficient.

4. Better quality feed (more grain and protein) should be fed to nursing sows and baby pigs.

5. Poorer quality food can be fed with less problems to larger growing animals.

6. Protein source foods should not make up over 1/3 of the diet.

7. Commonly used grains — corn, oats, wheat, barley, rye and sorghums contain around 7-8% protein. However, this is not enough for pigs to do well without at least some additional protein.

Grain alone with no additional protein can be fed to larger growing animals with slowed growth often the only consequence; however, vitamins and minerals should be provided. Grain with good quality grazing for large growing animals is often satisfactory except for slightly slowed growth rate. Grain alone is **not** adequate for nursing sows. Grain with good quality grazing is better, but additional protein is needed. Also, vitamins and minerals should be fed.

8. Fruit and vegetables should not make up over 1/3 to 1/2 of the total diet, if possible. However, conditions often dictate greater use

of these. The higher amounts would be best used in larger growing animals rather than in sows and baby pigs.

See other notes on feeding in the **Section on Management.**

Caution — Avoid sudden changes in type (source) and amount of each ingredient in the ration. Serious digestive upsets and other health problems may occur. This is especially true of high percentage protein source foods.

Pregnant and nursing sows and baby pigs are especially sensitive to sudden diet changes.

To prevent problems gradually add newer ingredients or increase regular ingredients by small amounts over several days.

Feeding Pregnant Sows

Pregnant sows should gain 40-75 pounds between breeding and farrowing. This will vary according to her size, and condition (amount of body fat) at breeding. If she is extremely fat or too thin at farrowing time she will often have problems delivering the baby pigs and not give enough milk. While good grazing will supply part of her carbohydrate and protein needs, she still needs at least 1/4 to 1/2 pound of protein source food per day and some grain or grain substitute in order to produce normal pigs and milk well. The pregnant sow needs a constant source of minerals and vitamins also, if the unborn pig's skeleton is to develop normally. If possible, grain and protein should be increased slightly the last month of pregnancy.

Feeding the Nursing Sow:

Sows should gradually be fed increasing amounts of food from the day after farrowing until on full-feed at around 10-14 days after farrowing. **If possible**, an approximate 80% Grain Source - 20% Protein Source ration should be fed or as close to this as possible, starting with 1-2 pounds per day and increasing by one pound per day to full feed, (all she will eat daily). Sows fed too much the first few days after farrowing may produce too much milk and cause digestive upsets in the baby pigs. Good quality grazing is a big help to the nursing sow and can replace part of the grain-protein source foods and is advised for most primitive production systems. However, in order to milk well some added grain and **protein source foods are needed.** Even in small amounts they are a big help. Never let the nursing sow and baby pigs use old contaminated lots and pastures. This helps prevent worm problems.

Fruits and vegetables, with the exception of a few such as bananas, pumpkin, coconut and breadfruit are too low in food value to feed to nursing sows except in small amounts and in emergencies. A constant supply of fresh water is necessary if sows are to milk well. Remember: The nursing sow is in a very nutritionally stressful period. Use good

judgment! About a week before weaning, gradually reduce the sow's ration to decrease milk flow. This will help dry up her milk and lessen chances of udder (breast) injury.

Feeding Baby Pigs:

When pigs are 2-3 weeks old they will eat a little grain. They will accept it better if it is ground and mixed with milk. Bread scraps in milk also work well. The food should be placed in a **creep** area as previously described. As pigs become older and nearer weaning they should receive small amounts of the protein they will later consume. Milk is not necessary in the feed after pigs are eating well, but if it is plentiful it should be continued. Give pigs only what they will consume daily; the food will soon spoil.

Creep feeding is not inconsistent in primitive pig production systems; in fact, it is one of the most recommended management practices in raising healthy pigs. The creep feeding area should be located convenient to the baby pigs, preferably near their shelter and close to a source of water.

Feeding the Grower Finishing Pig:

This is the age between weaning and market or home butchering. It deserves special consideration because a high percentage of feed used in the operation is used during this time. It is also a time in the pig's life when we have many options to consider in feeding these animals. As previously mentioned in feeding pigs of other ages, a ration based on 75-80% grain-carbohydrate source and 20-25% protein source foods with salt and minerals and green forage (or dried) is the preferred ration. However, the pigs of this age have less critical nutritional needs than pregnant or nursing sows and baby pigs. Although growth will be slowed and health problems may occur, this is the age that is most often fed on the grain-carbohydrate substitutes and garbage.

Surplus or inexpensive fruits and vegetables can be fed in larger amounts to this age pig than others.

In almost all primitive situations this age pig should be grazed on some form of green forage or have it brought to them. Good quality forage can greatly offset the deficiencies that would otherwise occur if a balanced diet were not being fed.

Sample Rations:

Under primitive production systems there will be **very few times** when complete rations using ground ingredients will be fed. However, there might be circumstances where this information would be useful. A few sample rations follow. There are many others that could be used, based on other ingredients mentioned previously.

1. **Sample Ration No. 1** — Creep feed for baby pigs

   75 pounds corn — finely ground
   25 pounds protein meal — preferably part or all from animal or fish
   1/2 pound trace mineral salt
   1/2 pound ground limestone
   1/2 pound steamed bone meal or
   DiCalcium Phosphate or
   Defluorinated Rock Phosphate

This is a very simple but adequate ration.

2. **Sample Ration No. 2** — Creep feed for baby pigs

   58 pounds corn, finely ground
   22 pounds soybean meal or other oil seed meal
   5 pounds Tuna or other fish meal
   3 pounds wheat middlings
   10 pounds molasses or sugar
   1/2 pound trace mineral salt
   1/2 pound ground limestone
   1/2 pound steamed bone meal or
   DiCalcium Phosphate or
   Defluorinated Rock Phosphate

3. **Sample Ration No. 3** — Creep feed for baby pigs

   60 pounds corn
   20 pounds soybean meal
   5 pounds dried skim milk, milk replacer or mix other ingredients in milk
   15 pounds sugar or molasses
   1/2 pound trace mineralized salt
   1/2 pound ground limestone or finely crushed oyster shell
   1/2 pound steamed bone meal or
   Difluorinated Rock Phosphate

In all creep rations, wheat or oats may be substituted for corn with little difference. Other grains such as barley, rye and sorghum do not work as well in baby pig rations, but may be used if available and are finely ground.

4. **Sample Ration No. 4** — Pregnancy Ration — Hand Fed

   79 pounds grain
   18 pounds soybean oil meal
   1 pound ground limestone or finely ground oyster shell
   1 pound steamed bone meal or Defluorinated Rock Phosphate or DiCalcium Phosphate
   1/2 pound Trace mineral salt

5. **Sample Ration No. 5** — Pregnancy Ration — Hand Fed

82 pounds grain
8 pounds soybean oil meal
7 pounds fish meal
Minerals and salt as in Ration No. 4

6. **Sample Ration No. 6** — Pregnancy Ration — Hand Fed

24 pounds grain
20 pounds molasses
25 pounds pineapple bran
5 pounds fat
17 pounds soybean meal
7 pounds fish meal
1/2 pound steamed bone meal
1/2 pound Trace mineralized salt

Special Note: Where minerals and salt are being fed free-choice, eliminate them from all above rations.

7. **Sample Ration No. 7** — Nursing Sow Ration

78 pounds grain
19 pounds soybean meal
1/2 pound Trace mineral salt
1 pound steamed bone meal or Defluorinated Rock Phosphate or DiCalcium Phosphate
1 pound ground limestone

8. **Sample Ration No. 8** — Nursing Sow Ration

82 pounds grain
11 pounds soybean meal
5 pounds fish meal
1/2 pound Trace mineral salt
1/2 pound steamed bone meal or Defluorinated Rock Phosphate or DiCalcium Phosphate
1/2 pound ground limestone or finely ground oyster shell

9. **Sample Ration No. 9** — Nursing Sow Ration

57 pounds grain
20 pounds molasses
15 pounds soybean meal
4 pounds fish meal
2 pounds meat and bone meal
1/2 pound ground limestone or finely chopped oyster shell

10. **Sample Ration No. 10** — Growing Ration — Low Protein

87 pounds grain
10 pounds soybean meal

1/2 pound Trace mineral salt
1 pound steamed bone meal or DiCalcium Phosphate or Defluorinated Rock Phosphate
3/4 pound ground limestone or finely ground oyster shells

This is an example of a simple grain-soybean meal ration.

11. **Sample Ration No. 11** — Growing Ration — Medium Protein

60 pound grain
12 pound soybean meal
4 pounds fish meal
2 pounds meat and bone meal
20 pounds molasses
1/2 pound Trace mineral salt
1/4 pound ground limestone or finely ground oyster shell
1/4 pound steamed bone meal, DiCalcium Phosphate or Difluorinated Rock Phosphate

This ration is more complex with several protein sources.

12. **Sample Ration No. 12** — Growing Finishing Ration — High Protein

61 pounds grain
17 pounds soybean meal
3-1/2 pounds fish or tuna meal
2-1/2 pounds meat-bone meal
15 pounds molasses
1/2 pound Trace mineral or iodized salt

This ration shows an example of using molasses and several protein sources.

13. **Sample Ration No. 13** — Growing Finish Ration —

30 pounds soybean meal
5 pounds Tuna or fish meal
48 pounds molasses
10 pounds bagasse pulp
5 pounds vegetable oil or other edible fat
1/2 pound Trace mineral or iodized salt
1/2 pound steamed bone meal or Defluorinated Rock Phosphate or DiCalcium Phosphate

Special Notes:

1. Where minerals and salt are being fed free choice, eliminate them from above rations.

2. These rations are based on assumption that animals are grazing or being hand fed green forage or good quality hay.

3. Generally animal-fish and plant source protein may be interchanged in rations with little or no adjustments. However, animals

grow and reproduce better and are healthier when some of each is fed. When animal or fish protein is substituted for plant source protein, less is needed, around 10-20% less.

4. Cooked soybeans (preferably with dry heat) that are crushed or ground may be substituted for soybean meal in these sample formulas. They should be used at a slightly higher level, around 20% more than soybean meal. The additional fat in the cooked beans helps nursing sows produce more milk. It also would help balance out a ration that was deficient in grain-carbohydrate. Since soybeans can be grown in many areas and require very little commercial fertilizer, growing them and home-cooking for swine feed would seen to be a good idea.

Caution: Since cooked soybeans contain more fat, the rations made from them spoil more quickly. The ration should be made often and in small amounts.

Although extensively researched, there are many other potential food sources available for pigs. A little imagination and a few dollars spent on a small scale experiment could possibly mean a breakthrough of great importance in your area. The author would appreciate hearing about other foods used for pigs. He will also be happy to furnish more information on nutrition in pigs.

Section 4

Management Practices

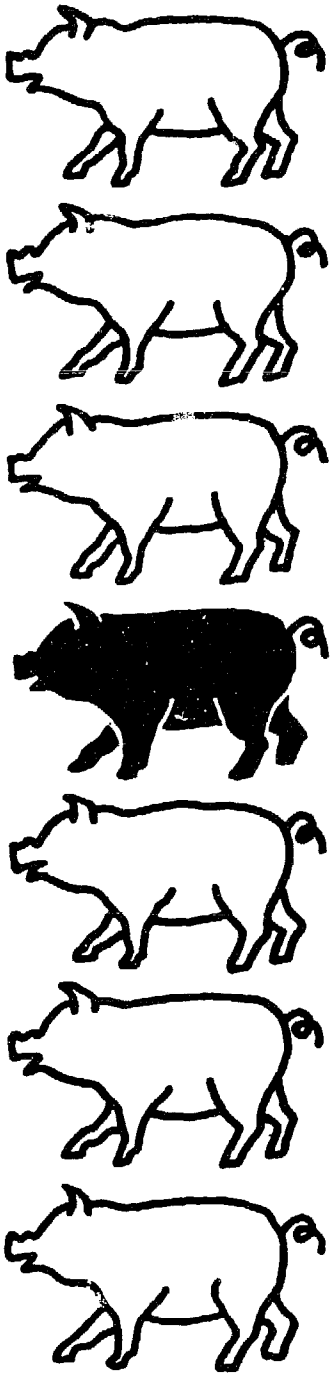

Reproduction

Covers Management Practices from Breeding through Farrowing

A. **Selection of Young Females (Gilts) for Breeding Animals**

Look for the following:

1. Select females from **best milking mothers** (dams).
2. Select females from **largest litters.**
3. Select **larger faster growing** females of litter.
4. Females **free from obvious defects** such as hernias, lameness and other health problems.
5. Females with **at least 10 well developed**, well spaced teats (preferably 12 teats). None of the teats should be "blind" (non-functional teats) which do not protrude as do normal teats.
6. Be of **Desired Body Type.**
   a. Short blocky fat type animals if cooking fat is in demand.
   b. Long, lean, muscular type animals if lean meat is much in demand.
   c. In most situations, the preferred body type is a compromise between the first two types.
6. **Purchase** from herds with as few health and disease problems as possible. **Purchase** virgin females that have never mated with a boar. This greatly lessens the chances of her introducing one of the diseases that cause reproductive problems.

B. **Selection of Males (Boars) for Breeding Animals**

1. He should have the rugged masculine appearance of a male.
2. Free from hernias, lameness and other health defects.
3. Two large, well-formed testicles.
4. From a large litter.
5. Fastest growing males of the litter.
6. Not related to your females — preferably from a different herd than your females.
7. From herds that are as disease free as possible in the area.
8. Body type as referred to in female selection.

If no good quality boars are available in the immediate area it may be necessary to look elsewhere. In most countries there are herds with high quality breeding animals. The high cost of these animals and transportation problems may make it impossible for most primitive operations to obtain them. There are foundations and organizations that can help, such as Heifer Project in Little Rock, Arkansas, and many

church groups as well. The male pigs from one high quality boar can then go into other herds and improve them.

One good male can help genetically as much as many females, at much less cost.

Always purchase **virgin boars** if possible. This greatly lessens the chances of introducing disease. This is especially true if we are purchasing higher priced animals.

Blood Tests For Purchased Breeding Stock — Purchase of virgin females and males from herds with no known disease problems is always a good idea. An even better safeguard would be blood tests for diseases such as Brucellosis. However, this is only possible where there is a veterinarian in the area.

C. **Physiology of Swine Reproduction — An Understanding**

Swine are not seasonal breeders. This means that their reproductive cycles are not directly affected by seasons. However, in areas with more extremes of winter and summer, they often tend to farrow more in spring and fall with milder weather. Generally the gilt from her first heat (estrus) or the sow after weaning her pigs will continue to cycle regularly until she becomes pregnant, or is nursing pigs or develops a health problem.

1. **Heat (Estrus)** The 2 or 3 day period when the female will accept the male in the mating act. It is seen as a swelling of the vulva (external female genitalia) and a sudden show of interest by the male. It is the only time the female will accept the male.

2. **Heat Cycle (Estrus Cycle)** The interval between heat (estrus) periods. It averages 19-21 days, but may vary by another day or two.

3. **Ovulation** — release of the ova (egg) by the **ovary** (female sex glands) so that it can be fertilized by the male's sperm. Ovulation generally occurs the second day of heat. That day and the next day are when mating (breeding) should take place for best conception (fertilization of ova by sperm).

4. **Conception** — fertilization of ova by sperm following the mating act.

5. **Female Puberty** — Time of the first heat period and first desire to mate with the male. It varies by breed, size, nutritional conditions, other health factors and by climate. It may be as early as 6 or 7 months or as much as a year of age.

6. **Male Puberty** — Time of their first desire and ability to mate with the female. It is generally a month or so earlier than in the female but varies because of the same factors.

Breeding (Mating) Methods — There are two methods of breeding (mating): hand breeding and pen breeding.

In **Hand-breeding** — the male is kept separate from females.

When the female is noticed in heat she is brought to the male for breeding. The advantages of this are that the male may serve more females and is not left with the pregnant females. (There is a chance that the male may injure the females if left with them). The disadvantage is that someone has to closely observe the females for heat daily and extra labor is required in moving the female to be bred. It requires someone experienced in observing heat.

In **Pen-Breeding** — the male stays with the females. The advantages are that the male will find the female in heat and no labor is required in moving the female. The disadvantages are that the male may injure pregnant females and that he cannot serve as many females. This is **because of its simplicity the method usually used in primitive systems.** If a herd is successful and gets larger than a few females and one boar then hand-breeding is often used.

Age to first breed females — as previously mentioned in notes on puberty, the age of the first heat varies because of many factors. However, it is rare to breed gilts under 8 months of age. Some gilts do come in heat earlier but unless they are fully grown should not be bred until they are 8 months old. In most primitive situations, gilts grow slowly and reach puberty late and are bred later.

Gilts bred when too small will not grow to the normal size and often have trouble at farrowing time.

Age to first breed males — Young boars are usually not bred before 8-10 months of age. Those that reach puberty may be bred occasionally, but litter size is often small and conception is poor.

Time of Year to Breed Females — Left on their own swine will breed year around. However, where there are distinct seasons they tend to farrow more in the spring and fall. Since baby pig survival is best in least severe weather, it is a good idea to breed sows to farrow during these times. In areas with heavy rainfall at one season, it is a good idea to avoid farrowing during that time. In areas with little seasonal changes the time of year to farrow would not be of importance unless there were some other factors such as seasonal market demand or transportation problems.

State of Heat to Breed Females — The best time to breed the females is on the second day of heat. If she is still in heat on the third day, breed her again. Conception is much better with two matings. Of course, where the boar is running with the females he usually breeds them several times.

Breeding Sows After Weaning — Sows generally come into heat 3-7 days after pigs are weaned and they are mated at that time. If they are too thin they should not be bred on the first heat. They need time to put on some flesh before being bred. Occasionally, a sow will come into heat when pigs are 2-3 weeks old and still nursing. They should

not be bred at this heat.

Length of Pregnancy (Gestation in Swine) — The length of pregnancy in swine averages 114 days with up to 3-4 days variation; earlier or later. An easy way to remember it is the often heard "three months — 3 weeks and 3 days." For example, a sow bred on January 1 will farrow around April 24. It is important to keep good breeding records in order to give the sow some special care the week prior to farrowing.

Managing Pregnant Females — Basically, we must remember that the pregnant animal is an expectant mother. The life of the pig begins at conception and the ration fed the pregnant sow is extremely important, (refer to previous notes in nutrition section on feeding of pregnant animal).

After she is obviously pregnant, not coming into heat on the 19-21 day cycle and showing sign of udder enlargement, she should not be allowed to run with the boar.

The unborn pig, especially early in pregnancy, can be affected if the sow becomes overheated. For this reason she should be given good protection from extremes of heat and should not be overly exerted as in moving her or excited by other animals.

If at all possible, the pregnant female should be allowed to graze and on the best forage available. The nutritional value of the green forage and the exercise both help her develop healthy pigs.

Care of the Male — The male should be fed very much like the pregnant female. He needs to stay in a medium state of flesh, not too fat or not too thin. Boars too thin will not be able to perform well and those too fat tend to be lazy and poor breeders. The boar should be fed very much the same as pregnant females. However, if he is breeding sows often he may lose weight. If this happens he should be fed more to keep him in the medium state of fleshing.

When there are no females to breed, he should be kept separate from the other pigs. He needs at least a quarter of an acre so he can get exercise, with adequate protection from extreme weather. He should be able to graze or green food should be brought to him to supplement his other food.

His pen or pasture should be moved occasionally to prevent health problems.

Boar Use — The boar can breed more females in a given period as he grows older. Males under 1 to 1-1/2 years of age should be used to breed no more than 2 or 3 females per week. As they become older, they can be used to breed more females, up to as many as six per week, if they do not come into heat at the same time. In most primitive situations where there are only a few sows, it would be rare for him to be bred too often. One mature boar should be enough for 10-12

sows.

When weaning pigs from sows, do not wean several sows at one time if there is only one boar. They will come in heat about the same time and the boar may be overworked and small litters may be the result.

Protection from heat is very important. Extreme heat has the effect of killing sperm in males for around 30 days and females will not conceive. Avoid undue exertion in moving and handling and provide protection from extreme heat. A boar that has been sick with a high fever usually cannot effectively breed for 30 days.

Tusk Removal in Boars — Most boars develop long protruding teeth at the corner of the mouth called tusks. They become larger as the boar grows older and can be very dangerous to the farmer and his family and to other pigs. Usually by the time the boar is one and a half years of age they have to be removed. To remove the tusks the boar is restrained by way of a rope tied around the upper jaws behind the tusks and the rope tied to a post or tree. Then large nippers such as bolt cutters, or a saw is used to remove the part of the tusk above the gum line. Try not to damage the gum. This may have to be repeated later.

Sharing Boars by Different Farmers — This is a situation where necessity, too few sows on one farm to justify a boar or the cost of the boar mean that two or more farmers must use the same male. There is a considerable risk because there are diseases that he can spread. However, where the farms are closeby each other or where animals often intermingle, the diseases may have already spread.

There is one situation where the boar should not breed females from other farms. This is when a superior male is brought in to improve the pigs in a community. He should also be kept away from pigs running loose.

Health Tests For Breeding Animals — There are several breeding diseases that can be very serious and boars and sows should be tested if there is anyone available to do it. Blood samples are tested at laboratories and some can be done on the farm. If possible, animals should be tested prior to purchase. (See Other Information in Health Section).

Preparation For Farrowing (Delivery of Baby Pigs) — Decide how you want to handle sows at farrowing.

Farrowing Methods:

1. **Pasture Farrowing** — sows and baby pigs are left on their own.

   Advantages — no facilities required.
   — no labor involved.

   Disadvantages — can't assist with farrowing problems.
   — can't help newborn pigs.

— more pig deaths result from bad weather and wild animals.

2. **Pen Farrowing** — sows moved to small pen with a shed for days before farrowing.

Advantages — can help sows and baby pigs if they need assistance.
— some weather protection.
— temporary facilities can be moved, (and should be moved) to lessen diseases and parasites.
— more pigs saved.

Disadvantages — facilities required.
— need slightly more experienced help.

This would be the system most practical for primitive locations.

3. **Farrowing in Buildings** — with floors

Advantages — sow closely confined and easy to help with
— pigs can be better protected from weather.

Disadvantages — cost of facilities.
— need experienced help
— sanitation problems often lead to sickness
— have to prevent baby pig anemia (see Note) on Baby Pigs later.

Signs of Approaching Farrowing Time

2-3 weeks before farrowing — udders (breasts) becoming noticeably enlarged.

5-7 days before farrowing — vulva (external genitalia) noticeably enlarged.

24-48 hours before farrowing — milk appears in teats.

12-24 hours before farrowing — sow becomes very nervous and restless and carries dried vegetation to make a bed.

Assisting with Farrowing — Old sows seldom need help with farrowing. However, gilts often need help with their first litter. If a pig lodges in the pelvis bones (birth canal) it soon dies, usually in 30 minutes unless delivered. If it remains there more than an hour or two the next pig also dies. If a pig lodges for 12-24 hours the other remaining pigs die and often the female also dies.

A clean, well greased hand and arm can often reach the lodged pig. Grasp the feet if possible and remove the pig with the least possible force. If the feet cannot be grasped, use the head. Often the first pig is the problem and others follow normally when it is removed.

A woman because of her small hands can often assist far better than a man.

Caution: Always wash and disinfect hands after assisting in

farrowing or handling newborn pigs. Never assist in farrowing if there are cuts or bad scratches on your hands. Rubber gloves are much better to reduce risk of human infections that can occur.

Fetal Membrane (Afterbirth) — contrary to the opinion of the uninformed, these should **not** be fed to sows; rather, they should be burned or buried soon after all pigs are delivered.

Feeding the Lactating Sow (Nursing Pigs) — Refer to notes in Nutrition Section.

Helping the Newborn Pig — The degree of involvement with helping the newborn pig will vary with the skill of the owner and the facilities. However, newborn pig survival is much greater when as many of these as possible are done.

On Arrival — remove from membrane.
- wipe mucus from mouth and nose with a clean cloth.
- clip the navel cord 1-2 inches long with scissors and spray or dip in iodine. **Wait about 20 minutes to do this.** If the cut cord bleeds excessively, tie it with cotton string or fish line.
- if weather is cold, dry pigs off with a clean cloth soon after delivery. You may also put them in a box or basked lined with straw until all pigs are delivered, but not longer than 2-3 hours.
- they must nurse as soon as possible to get colostrum (milk in udders at birth that gives protection from infections).
- needle teeth are very sharp teeth often found at the front corners of the mouth, both upper and lower, in newborn pigs. They can damage the udder of the mother if not removed. Small wire cutters or pliers with side wire cutters work well. Only the outer half is removed; do not injure the gum.

Iron Deficiency Anemia in Baby Pigs — An unhealthy condition in baby pigs called **baby pig anemia** (lack of blood) is common in baby pigs who do not have access to soil the first few weeks of life. It is caused by a lack of iron and copper which is **essential for blood formation.** Since sow's milk is deficient in both of these minerals, baby pigs **must have additional amounts** or their chances of survival are very poor. Soil usually contains adequate amounts and the baby pigs almost from the first day will eat soil. If they are housed in buildings with floors they do not have access to soil and a method **must be found** to provide iron and copper.

The simplest solution is to bring soil to the pigs and place it in

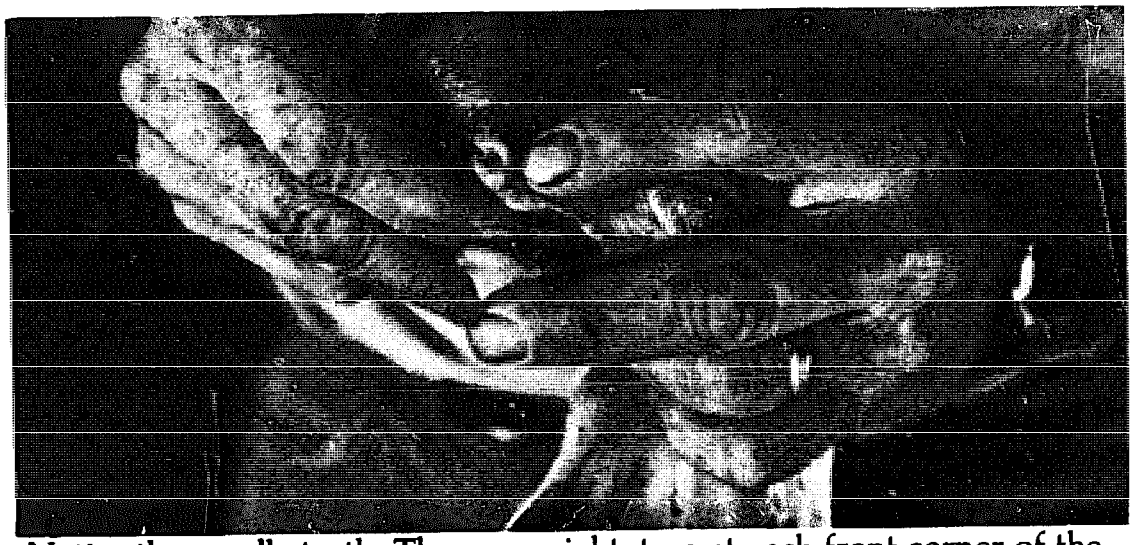

Notice the needle teeth. There are eight: two at each front-corner of the upper and lower jaws.

Method for trimming needle teeth of a newborn pig.

The pig's mouth after its needle teeth have been trimmed.

a small container for each litter of pigs. **This adequately solves the problem** but soil should come from an area that **pigs have not had access to.** This prevents spread of parasites and disease germs to the pigs. This dirt should be replaced often.

There are commercial injectable and oral products available for pigs and solutions to apply to the sow's udder, but these are costly and often not available.

Anemic pigs have very poor resistance to infections, do not grow well and many will die if an iron source is not provided by the end of the first week. It should be provided by the third or fourth day of age.

Pigs born on the ground should not have an anemia problem.

Feeding The Baby Pig — (See Notes in Section on Nutrition).

Castrating (Testicle Removal) The Baby Pig — Pigs are castrated for several reasons: to prevent an unpleasant taste and odor in meat, to prevent the nuisance of the boars not needed for breeding, and some people think castrated males grow faster.

Under most primitive conditions male baby pigs should be castrated around 2-4 weeks of age. Pigs withstand castration much better while nursing than after weaning.

The operator should be careful to have his hands and knife clean (and disinfected if possible). The scrotum (skin over testicles) should also be washed (and disinfected), as well as the knife.

Hold the testicle firmly between the fingers and thumb and make an incision through the skin and into the testicle with a sharp knife. The incision should be parallel to and 1/4 to 1/2 inch off the midline of the scrotum. Separate the testicle from the surrounding tissue, pull it away with the attached spermatic cord and cut it off near the body. Remove the other testicle in the same manner. Be sure the incisions are low enough for good drainage when the pig is standing; this speeds healing.

After the operation, blood should be washed from the skin near the incision. Blood will attract flies and infection may result and insect larvae such as screwworms may infest the wound.

Wound spray of liquid (with fly repellant) applied around the wound is even better.

Often in the community, there is someone with experience in castrating pigs. His techniques should be observed. However, some of these mentioned suggestions might well be an improvement.

Keep the recently castrated pigs from dirty wallow areas and other unsanitary conditions until wounds heal.

Common Mistakes in Castration are failure to clean and disinfect prior to the operation, incisions too small for drainage, incisions too high for drainage, wet and unsanitary living conditions before healing

and waiting until pigs are past weaning age.

There are many satisfactory **disinfectants** including iodine, alcohol, very weak solutions of chlorine laundry bleach, hydrogen peroxide, mercurochrome and any human disinfectants available.

Weaning — Separating Nursing Pigs From Their Mother. This is one of the greatest stress periods in the pig's life. It is also a time of considerable stress on the sow.

In the natural state, sows usually wean the pigs themselves and when pigs are around 8-10 weeks old.

In modern operations with confinement rearing, baby pigs are often weaned as early as 3-5 weeks of age. However, in **primitive situations,** without expensive buildings and sophisticated rations, **this is neither or wise to do.** Since sow's milk is the natural food for baby pigs it should be used as much as possible. This means leaving pigs on the sow until around 8 weeks of age. The quantity of milk starts decreasing at around 3-4 weeks after farrowing. Baby pigs should be started gradually on solid food at 10-14 days of age and fed increasing amounts as they grow older and as sow's milk is decreasing. If they are eating solid food well, there is much less digestive shock at weaning and fewer health problems in general. **(There is much more information on feeding Baby Pigs in the Nutrition Section.)**

The nursing sow should have her food gradually decreased starting about a week prior to weaning. This will greatly lessen her milk production and lessen the chances of udder problems following weaning.

Sow Weaning Problems — If, as occasionally happens, the udder becomes distended with milk a day or so after weaning, pigs can be allowed to nurse a few minutes every other day.

If the udder becomes "caked," (hard to the feel and often with a hot feeling), a simple remedy is to massage it daily with comphorated oil, a common human remedy for bruises. If the sow should also lose her appetite, she probably has an udder infection and fever. In this case she will need to be treated with antibiotics — (See Health Section).

Baby Pig Weaning Problems — These can usually be prevented by the following:

1. Continue pigs on feed they are already used to before weaning. By not changing the feed we avoid one stress that often causes problems. After a week or so the feed can gradually be changed.

2. Remove the sow and leave the pigs in their familiar surroundings for several days. This is a simple way to prevent another stress problem.

Weaning Age For Two Litters Per Year — Under most primitive conditions two litters per sow per year is feasible. Consider that pregnancy length in the sow is almost 4 months and that sows come in heat a few days after weaning pigs. This means no later than

8 week weaning of baby pigs for two litters per sow per year. this is also a very good time for the sow and baby pig.

A Big Decision — One or Two Litters Per Year Per Sow — While 2 litters per year should be tried for in most cases, there will be instances where 1 litter may be more practical. One situation would be where for various reasons, food for pigs is very limited at certain seasons. Sows might be on a maintenance ration and unable to sustain a normal pregnancy, and nurse pigs adequately. In that case, sows should be bred to become pregnant and farrow during the highest level of nutrition.

Another circumstance would be when one season of the year is a long period of extreme weather. Maintenance of pregnancy and baby pig survival might be very poor.

Raising Orphan Pigs — Orphans pigs become a problem when the mother sow dies, is sick and not giving milk or occasionally when the sow has too many pigs and some must be taken away (generally over 12 in the litter).

Cow's milk is a satisfactory food for the newborn pig. Human baby bottles can be used but cleaning and sterilizing are a big problem. Pigs will usually drink from a shallow pan. They must be fed six times a day for the first two weeks, then gradually reduced to three times a day. At around 10-14 days, small amounts of bread scraps or cracked grain can be added and gradually increased and the milk decreased over the next several weeks. **Goatmilk is less desirable,** but may be used.

Another possible solution is to move pigs to sows with very small litters. This will only work if the orphan pigs are within a few days of the age of the other pigs. Very often the sow will reject the orphan pigs. This may be overcome by wetting the orphan pigs' backs with milk or a human skin medication, both of which would have an odor that would confuse the sow as to which were the orphan pigs.

SECTION ON THE GROWER-FINISHER (FATTENING ANIMAL)

A. General

After pigs have made the adjustment of weaning, they have passed the most critical stages of their life.

The Grower-Finishing-Fattening period is the period between that time and the time when they reach the desired slaughter or market weight.

It is that stage in their life when if given reasonably adequate nutrition and protection from extreme weather they should reach market or slaughter weight with very few problems.

It is the age when there are less critical nutritional and environmental needs. **However, the fewer of these compromises that we have to make the faster growing and healthier these animals will be.**

B. Nutrition of the Grower-Finisher Animal

This is well covered in the Section on Nutrition. The important point is to keep in mind that the needs of the pregnant and nursing sow and baby pigs must come first if the amount and quality of food are in limited supply. This age animal may be stunted by inadequate nutrition but has a much better chance of surviving.

If food is plentiful they should be allowed to consume all that they will.

C. Environmental Consideration of the Grower-Finisher Animal

This was covered in general in the Section on Environment. However, there are a few things to keep in mind.

1. Where higher, well drained land is limited or land has been heavily used by pigs for a long period of time, this age animal could better tolerate the less satisfactory conditions.
2. Also, where natural or man-made protection from extreme weather is limited this age animal can better tolerate these conditions.

However, every possible effort should be made to provide satisfactory living conditions so that animals will be healthy, fast growing and the operation be efficient. Animals subjected to excessive environmental stress will not efficiently use food, will grow very slowly and develop health problems.

D. Length of Time to Reach Slaughter Weight

This will vary according to nutrition, environment, disease and health conditions and the genetic makeup of the animal. Well bred animals on a balanced ration and satisfactory living conditions often reach slaughter weight as early as 6-7 months of age. Under less satisfactory conditions it may take as long as 12 months and unhealthy animals may never reach that point.

Factors in Growth Rate — The major limiting factor in growth rate under most primitive conditions is a lack of protein in the diet and failure to control internal parasites (worms) and environmental stress.

Other factors often involved are mineral deficiencies and other nutritional problems and many health and disease problems.

E. Castrating Older Pigs

As we mentioned earlier in the Section on Baby Pigs, castration should be done prior to weaning. However, for various reasons this

may not have been done. It can be done at later times, but the risk is greater. The major problem is blood loss from the larger blood vessels and the greater risk of infection. Blood loss can be prevented by tying off the blood vessels leading to the testicle with a material such as small fishing line. This is a necessity in the case of older mature boars no longer needed for breeding purposes.

F. **Internal Parasite (Worm) Treatment and Control**

Worm treatment and control is a necessary practice if we are to produce healthy pigs. This topic is covered on pages 92-96.

G. **External Parasites (Insect) Treatment and Control**

Another factor in producing healthy pigs is insect treatment and control. This topic is covered on pages 98-101.

Section 5

Health Problems In Pigs

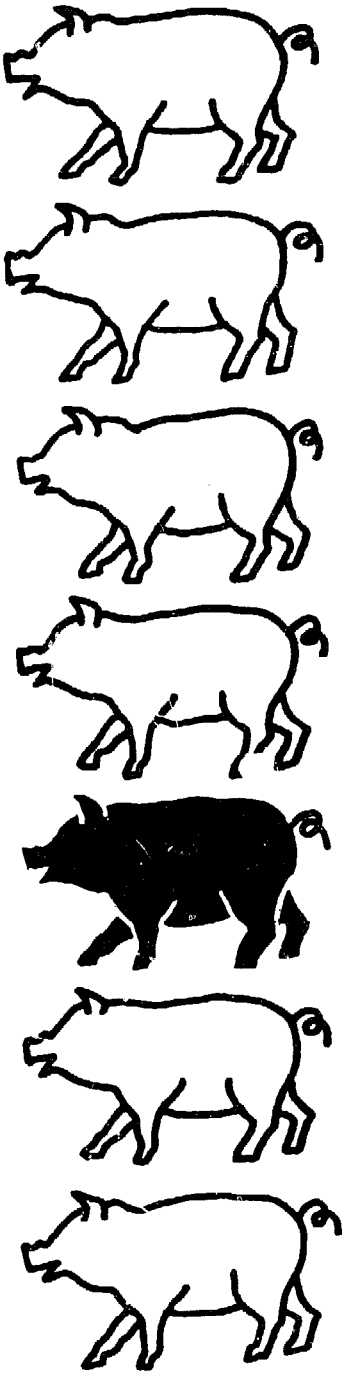

I. General Considerations in Prevention of Health Problems In Pigs

Health problems are costly to the farmer by way of reproductive problems, poor baby pig survival, stunting and death. Very often stunted, slow growing animals are a major economic problem because they continue to eat but take a long time to reach market or slaughter weight, and some never reach that point.

Veterinarians are often not available for assistance and medications to treat sick animals, even if available, are often very costly. Sick animals that are treated successfully and recover usually are stunted and often take longer to reach slaughter weight.

For those and many other reasons the farmer should try to prevent health problems if at all possible.

This booklet will concentrate on an understanding of the potential problems and ways to prevent them. A detailed description of all possible diseases is beyond the scope of this booklet; however, a few of those that deserve particular attention are discussed.

A. **Sanitation,** or cleanliness, is the first rule in profitable livestock farming. The commonly held idea that pigs are naturally dirty and prefer muddy wallow holes, dirty pens, stagnant drinking water and swampy pastures is wrong. In fact, that belief has led to many unnecessary and serious health problems in pigs.

We must realize that wherever there is fecal material (animal waste-manure) there are almost always germs and worm eggs.

We must also realize that germs and worm eggs survive well where there is moisture and a lack of sunlight. This means that anything we can do in the way of a good sanitation program will go a long way toward preventing many health problems.

The following are suggestions for **Basic Sanitation.**

1. Locate pens and pastures on **highest, well drained land.**

2. **Rotate** pens and pastures often, leave them unused and allow germs and worm eggs to decrease. **Nursing sows and baby pigs should be** placed on **cleanest land** (longest without pigs on it).

3. **Food and water** should be placed in troughs or containers. Otherwise, pigs may ingest germs and worm eggs from soil as they obtain food and water.

4. Buildings should be cleaned often with soap and water and soiled bedding material replaced. As the buildings are emptied they should also be cleaned well. (**See later notes on Disinfectants**).

Temporary (moveable) building should be moved often. This is a great help in reducing the number of germs and worm eggs that pigs are exposed to. **We simply move the buildings and leave the filth.**

Since buildings with floors are so hard to adequately clean and disinfect, they should only be used under certain conditions such as in areas with extreme cold weather. See earlier notes in Environment Section.

Disinfectants (Germ killing chemicals) for use around pig facilities:

Commonly available products:

1. **Lye** — sodium hydroxide. Mix one pound in 10 gallons of water; it kills most germs, but is dangerous to use if precautions are not taken. Because it can cause skin burns and serious problems to eyes and internally, it should be used with care. Use rubber gloves and boots, if possible.

2. **Household Chlorine Bleach** diluted according to directions the bottle is also a satisfactory germ killer. **Also use with care.**

There are also **many** commercial disinfectants available; however, they are costly and in most primitive situations their use is not practical. In other cases the sanitation measures previously outlined are usually satisfactory.

Note: If feed or water containers have been disinfected, they should be rinsed well prior to being used again.

B. **Nutrition:** This was well covered in the **Section on Nutrition.** However, one cannot overemphasize the importance of adequate amounts and a well balanced ration in maintaining good health and resistance to infection.

Weather Stress: Protection from extremes of hot and cold weather, whether by natural or artificial means, is very important in maintaining good health and resistance to infection. Weather stress can lower resistance and lead to serious problems. **Refer to earlier Notes in The Environment Section.**

D. **Vaccinate,** if possible, for diseases that are a problem in the area. Consult with University Agricultural Staff or Government Veterinarians or others knowledgeable on animal health in your area. Often they can help locate a source of vaccine and demonstrate their use. **There are also General Notes in the Disease Section later.**

E. **Treat for Parasites** — While this will be covered in detail in the **Section on Parasites,** it is well to emphasize the importance of parasite control in maintaining health and resistance to infection. **Parasite (worm and insect) prevention, control and treatment are major factors in good health.**

II. Understanding The Normal Healthy Pig and Recognizing Signs of Health Problems (Symptoms)

The more that we know about the basic nature of the pig, the more likely we are to raise healthy pigs.

If we are to recognize the sick pig we must first know how the normal healthy pig acts.

Pigs should be observed more as a group than as individuals because most diseases and other conditions generally affect several animals. They should be observed while quiet, rather than when we are working with them and moving them.

A. **Disposition** — The normal pig is a very curious, alert animal that will constantly be poking around and interested in observing any approach to the pen by people or other animals.

The sick pig will appear dull and listless with a lack of curiosity. Often he is reluctant to get up and move around even if forced to and may be weak and uncoordinated.

B. **Appetite** — Lack of appetite is one of the earliest and most consistently recognizable signs of sickness. It is often a sign of fever from infection, and disease.

C. **The recent bowl movement** (fecal material) is also a good indication of a health problem. A hard consistence often means fever. Loose consistency (diarrhea) usually means an intestinal problem and most often an infection. It is also often caused by **intestinal worms.** At times it may be caused by **nutritional** problems such as sudden changes in the diet. Various poisons may also cause diarrhea.

D. **Normal Respiration** (breathing) is a smooth in and out movement by the muscles of the rib area. Any interruption of that smooth pattern such as a jerky movement, coughing, or sneezing is an indication of a possible respiratory problem. The normal respiratory rate (breaths per minute) in the pig ranges from **10-18 per minute.** A rate in excess of that usually indicates a problem.

Bronchitis is a mild respiratory problem usually indicated by a faster than normal respiratory rate and a slight change in breathing patterns. A slight couch also is common and sneezing may be seen. It is a symptom of a mild lung problem.

Pneumonia is a more severe respiratory problem as evidenced by a very noticeable interruption in the breathing pattern and a much faster respiratory rate and often there is a harsh cough. It is a symptom of a severe lung problem.

Discharges from the nose and eyes are also recognizable signs of respiratory problems and often occur at the same time.

Respiratory problems have **many causes.** The most likely is chilling and overheating. Lungworms often damage lung tissue and allow germs to cause an infection. Pneumonia and bronchitis often follow a high fever from other infections. Generally unhealthy pigs from parasitism and nutritional problems often develop respiratory problems.

E. **Normal Temperatures** in the pig is 102-103 ° F. When environmental temperature is very high the normal pig's temperature may

be as much as 103.5° F.

Fever is a higher than normal body temperature. It is usually the response of the body to an infection and is a sign that the body defenses are responding to that infection. Under normal environmental conditions a body temperature over 103.5° F. is considered to be a sign of fever. During very hot weather a body temperature over 104° F. is considered to be a sign of fever. **Body temperature in the pig is checked by using a rectal thermometer held in the rectum for at least 3 minutes.** The animal has to be very tightly restrained during this procedure.

Checking the body temperature is a simple procedure that should be used often when we have sick pigs. It is a fairly reliable indicator of whether or not we are dealing with infection-disease.

F. **Color of the mucous membranes** (lining of mouth and nose and inner eyelid) are often a good indication of health problems. The normal healthy color is reddish-pink. A pale to white, bleached out color indicates anemia (lack of blood). Baby pig anemia was previously discussed in the Baby Pig and Reproduction Section.

There are many causes of anemia, especially parasites and nutrition. Lcterus (jaundice) — an orange to yellow color may be seen. It is an indication of a number of conditions: infections, blood parasites and poisons that destroy blood cells.

G. **Problems with Locomotion** (movement) show up in several ways:

Arthritis — sore, stiff, swollen joints and a reluctance to get up and move around — usually caused by mineral deficiencies, also infections, diseases as Erysipelas and injuries.

Foot Problems — sore, swollen feet and a reluctance to place weight on affected limb — usually caused by injuries, infection and diseases such as Foot and Mouth Disease.

"Downer" animals — (animals completely unable to get up) — This is usually seen in pregnant and nursing sows and most often is caused by a mineral deficiency. It may also be caused by a severe back injury.

Weakness and Uncoordination — are usually secondary to other serious conditions such as infection, disease, poisoning, etc.

III. Major Categories of Health Problems and Their More Probable Causes:

A. **Reproductive Problems** as evidenced by poor conception, and late abortion, weak and stillborn pigs and small number of live healthy pigs farrowed.

Causes: 1. **General Poor Health** Boar and Females

a. **Nutritional** problems such as a poorly balanced

ration and deficiencies of necessary nutrients.

b. **Parasites** — failure to prevent and treat.

c. **Chronic Diseases** such as non-fatal pneumonia and diarrhea.

2. **Stress of high environmental temperatures** on Boar and females.

3. **High Fever** in Boars and Females from infection and major diseases.

4. **Reproductive Diseases** such as Brucellosis and Leptospirosis and others.

5. Boars or females too young at breeding time and mating (breeding) boars too often in a short period of time.

6. **Injuries** to pregnant females.

7. **Failure** to assist at farrowing time.

B. **Poor Baby Pig Survival** — as evidenced by deaths and severe stunting in baby pigs.

Causes: 1. **Poor Milking in Sows** — one of major causes.

a. **Nutritional Problems** — prior to farrowing while nursing pigs. **(See Notes on Nutrition of Pregnant and Nursing Sows). This is the cause.**

b. **Fever** in the sow usually causes milking problems.

c. **Udder infection** causes milking problems and milk may make pigs sick.

d. **Heat stress** on the sow as in poorly ventilated buildings and anytime the sow is not given protection from high environmental temperature will probably cause milking problems.

2. **Scours** (Diarrhea — (Loose bowel movement) — another major cause.

a. **Poor sanitation** in the farrowing area often leads to infections and is a major cause of scours.

b. **Milking Problems** in the sow often cause scours.

c. **Chilling** results in loss of resistance to infection.

d. **Baby Pig Anemia.**

e. **Internal parasites** — worms.

3. **Intestinal Diseases** — Bacterial and Viral infections such as Salmonellosis, TGE, and others.

4. **Pneumonia** — respiratory problems caused by most of the same causative factors of scours, especially chilling.
5. **Major Diseases** — Hog Cholera, Erysipelas, Foot and Mouth Disease and others which cause high death losses in all ages.
6. **Failure to provide solid food** to supplement the **sow's milk. This can contribute** to slowed growth and less resistance to infection. It also adds to the stress of weaning.
7. **Weaning Stress** is often a major cause of health problems. It was well covered in the **Baby Pig Section with Reproduction.**

C. **Stunting** — slowed growth in the growing - fattening animal after weaning. It may be a minor problem where the animal takes longer to reach slaughter weight or such a severe problem that animals will never reach that point. **It is one of the most common and serious economic problems to a swine farmer.**

Causes: 1. **Nutrition** — The major cause in most cases. It may from a lack of food in general but most often is caused by a **lack of protein in the diet.**

2. **Parasites** — internal parasites (worms) are the other major cause of stunting in most cases. This be covered in detail in **The Parasite Section.**
3. **Continuation of Any Baby Pig Problems** that weakened but did not kill. Often the lung damage from pneumonia, intestinal damage from worms and scours and liver damage from worms causes long term effects leading to stunting.
4. **Non-Fatal Diseases and Infections** such as Pneumonia and Diarrhea that cause long term effects in survivors.
5. **Environmental Stress** such as extremely hot or cold weather with poor protection.
6. **Non-Fatal Poisoning.**

D. **Major Death Losses** in animals after weaning.

Causes: Major Infectious Diseases such as Hog Cholera, Erysipelas, Foot and Mouth Disease and African Swine Fever.

2. **Common Infections** such as Pneumonia and Diarrhea in animals not adequately treated for these common problems. Inadequate nutrition, and parasites often are the cause of the already weak animals.

3. **Poisoning** — There are many potential causes of poisoning in swine and while not a common problem it is serious when it does occur. Treating poison cases is expensive and results are usually poor.

IV. Internal Parasites and Their Role in Health Problems of Pigs.

Internal Parasites (worms) and External Parasites (insects) are a major cause of health problems in pigs. Because they are so serious we need to have a good background knowledge of these parasites, the problems that they cause and how to prevent them and treat animals for them.

A. **Getting to Know the Worms** — Pigs are parasitized by many species of worms. Their ordinary living conditions, low wet unsanitary areas and rooting in soil, favor survival and spread of worms. All the species of worms that infest pigs are major or contributing factors to stunting, poor utilization of foodstuffs, lowered resistance to disease and general poor health. They come in various sizes from the thread-line strongyloides to the pencil size ascaris. They are located in:

1. The **stomach and intestine:**

   Ascaris — Large roundworm.

   Oesophagostomum — Nodular worm.

   Strongyloides — Threadworm.

   Trichuris — Whipworm.

   Hyostrongylus — Red stomach worm.

   Ascarops — Thick stomach worm.

   Macracanthorhynchus — Thorny Head Worm

   Spiruroids — several species, (Ascarops, Physocephalus, Gongylonema) of small stomach and intestinal worms that migrate through the liver and cause intestinal irritation and stunting.

There are other stomach and intestinal worms in various parts of the world that parasitize pigs but they are usually similar to the ones being discussed.

2. Three species of **Lungworms** infest swine: two species of **Metastrongylus** and one species of **Choerostrongylus.**
3. In the kidney area, **Stephanurus**, the **kidney worm** of swine, is often a serious problem. They also cause severe liver damage.
4. **Flukes:** Any type of flatworm are common in

many parts of the world, usually low wet swampy areas.

Fasciola — common liver fluke

Paragonimus — liver fluke

5. **Tapeworms and Trichina** are under some circum- **a possible danger to humans** and will be discussed separately.

B. **The effect of worms on a pig's health** depends on the species of worm and its location in the body.

Stomach and Intestinal Worms cause irritation to the lining of these areas and lead to digestive upsets, diarrhea, poor food utilization and stunting. Some species of these cause damage to the liver and lungs by immature stages migrating through the body. All of these effects are very serious in the baby pig.

Lungworms develop in the small air passages of the lungs and set up an irritation which interferes with normal lung function and causes severe stunting. This irritation also often leads to bronchitis and pneumonia.

Kidney Worms in their immature stages migrate through the liver and cause severe damage. They then migrate to the kidney area and cause severe irritation. Since the liver and kidney are such important organs, this irritation causes the animal to be stunted and unthrifty.

Liver Flukes cause damage to the liver by irritation and blocking bile passages. Liver damage leads to stunting and general unthriftiness and poor resistance to disease.

Lung Flukes cause irritation to the lungs and secondary effects similar to lungworms.

C. **Life Cycle of the Worms**

All of these worms pass part of their life cycle **outside the pig's body. Knowing this is the key to prevention and control,** we try to interrupt the life cycle and prevent spread from an infested animal to a healthy animal.

All of these worms have adults in the body who lay microscopic eggs that are eventually passed out of the body in fecal waste (stomach and intestinal worms), coughed up, swallowed and passed in the fecal waste (lung worms and lung flukes) and through the urine (kidney worms).

The next animal becomes infested by taking in these eggs in food or water contaminated with manure or urine from an infested animal. This is true of all worms except lungworms whose intermediate stage is in the earthworm and flukes whose intermediate stage is in snails and crayfish.

Ascaris and Strongyloides may also infest the unborn pig.

Eggs of strongyloides and kidney worms may hatch in very wet soil and the immature stages penetrate through the skin into the body.

D. **Prevention and Control of Worms in Pigs**

This is based on our knowledge of the life cycle of these worms and the fact that they all pass part of their life cycle outside the pig. It is also based on our knowledge that food and water contaminated with fecal material and urine are the primary method of spread.

1. **Good Basic Sanitation** — as previously discussed in detail.

2. **Pasture and Pen Rotation** where pigs are often moved from one area to another to allow the eggs in the soil to decrease. This is especially true when low, wet swampy areas are used for pigs.

3. **Separate Newborn Pigs and Their Mothers** away from other pigs to decrease chances of becoming infested at an early age.

4. **Farrow Sows and Keep Baby Pigs on Cleanest and least used land.** This is a major consideration. Worms cause their most serious damage to the youngest pigs and the longer we can prevent or minimize infestation the better chance the pig has of remaining healthy.

5. **As much as is practical, keep pigs away from low, wet, swampy areas** where worm eggs survive so well. This also lessens the chances of eggs hatching and immature stages penetrating the skin. This is also the area where earthworms, snails and crayfish, which are intermediate hosts of lungworm and flukes, are usually found. **If low, wet land must be used for pigs, move them often to areas not recently used.**

6. Provide fresh water in clean troughs or other containers. This lessens the chances of contamination with fecal material and urine.

7. Feed grain, ground food, garbage and all others possible in **clean troughs** or other **containers.**

8. **Worm Treatment Medication:** This lessens the number of adult worms who can lay eggs and lessens the chances of contaminating the food and water. **It is also one of the most necessary practices in raising healthy pigs.**

9. Prevent pigs from access to human and dog fecal waste to lessen chances of becoming parasitized by tapeworms and trichina. Also cook garbage well always.

E. **Medication — Worm Treatments**

There are a number of medications. Some of these are effective against many species of worms (Broad Spectrum Wormers) and others only available against one or two species. Generally the Broad Spectrum wormers should be used if available. Conditions that favor

one species of worm often are satisfactory for others and most often pigs are infested with several species.

In some areas the farmer may have a choice of several worm medications. In other areas the choice may be limited and in some areas he may have to improvise by using products more suitable to cattle, sheep or chickens. For that reason a large number of products are listed and also the fact that worm treatment is almost **a necessity** in raising healthy pigs.

Dosages are not given because these medications come in differing forms and strengths. **ALWAYS FOLLOW DIRECTIONS ON THE CONTAINER FOR PROPER USE.** Chemical names are given first, then brand name and manufacturer in parenthesis. These may vary in different areas of the world.

1. **Broad Spectrum Wormers** — Most often used if available

a. **Fenbendazole** ("Panacur"-Hoechst AG) is effective against a number of stomach and intestinal worms and kidney worms.

b. **Levamisole** ("Tramisol," "Levasole"-Ripercol, American Cyanamid Co.) is effective against most stomach and intestinal worms and its effectiveness against lungworms makes it very desirable. It also has an effect on kidney worms.

c. **Dichlorvos** ("Atgard"-Shell) is effective against most stomach and intestinal worms and is one of the few effective against whipworms which can cause severe diarrhea.

d. **Febantel** ("Rintal"-Bayer) is effective against a number of stomach and intestinal worms. If fed in feed over a long time it is effective against lungworms and whipworms.

e. **Citarin-L, Concurat-L** (Bayer) is effective against a number of stomach and intestinal worms as well as lungworms and whipworms.

2. **Other Commonly Used Pig Wormers**

a. **Piperazine** is effective against two of the most common intestinal worms, Ascaris and Oesophagostomum. Poultry farms often use this product and they might help you locate it. Use it if one of the Broad Spectrum Group is not available.

b. **TBZ** — (Thibenzole-Omnizole-Merck) for use in baby pigs at one week of age with a serious worm problem. Cattle and sheep farms use this. It can be used in older animals if no others are available.

c. **Pyrantel** (Banminth-Pfizer) is effective against Ascaris Oesophagostomum. It is often used if Broad Spectrum products are not available.

d. **Phenothiazine** is a cattle and sheep product that has been used in pigs. **It often makes pigs sick** and should not be used if others are available. Also, it is only effective against the two most common intestinal worms. **Do not use in pregnant sows.**

e. There may be other satisfactory products available in certain parts of the world. **Always follow directions closely.**

f. **Neguvon** (Bayer) is an animal medical product sometimes used in pigs, but **not** recommended. Dosage is critical, especially in young pigs. It should **not** be used if others can be found. The experience of others using it might be helpful.

F. **Treatment Schedules**

1. **Normal Circumstances** — no major stunting
   a. Pregnant Sows — 1-2 weeks before farrowing with a drug **approved** for this — do not use a drug not approved for pregnant sows.
   b. Pigs a few days after weaning — **ABSOLUTE**
   c. Repeat 3 weeks later in pigs.

2. **Severe Stunting problems** — slowed growth
   a. TBZ or Rintal in baby pigs one week old.
   b. Broad Spectrum wormer at 5-6 weeks old.
   c. Repeat in 3 weeks — after weaning.
   d. Sows 1-2 weeks before farrowing with an approved drug. Also in sows after weaning, before rebreeding.

However, worm treatment in herds with severe problems is very costly. Prevention and control measures as already discussed should be followed to reduce the need for heavy medication.

B. **Drug Forms and Notes on Use of Worm Medicines**

1. **For a few pigs**
   a. Powder or crushed tablets in small amount of feed.
   b. **Tablets** are difficult to administer to pigs, especially older animals.
   c. **Drenches** — often used, but care is needed to prevent strangulation.
   d. **Skin Pour-On** preparations work well, but are not usually available.

2. **Water Medication** mixed in drinking water is mostly used for large groups. **Access to any other water has to be prevented.**

3. **Injections** work well, but experience is needed. Syringes and needles are costly and must be sterilized. This means they are rarely used in small operations.

H. **Worm Treatment Drugs Approved For Pregnant Sows**

1. Dichlorvos (Atgard)
2. Levamisole (Tramisol)
3. Citarin L, (Concurat)
4. Rintal

5. TBA (Thibenzole-Omnizole) only if no others are available and problems are severe.

I. **Flukes** — are unusual flat, leaf shaped worms that parasitize many animals. In pigs, several species of lung and liver flukes infest pigs. Lung flukes cause damage similar to lung worms that leads to bronchitis, pneumonia and severe stunting. Liver flukes damage the liver and also cause stunting.

Flukes in pigs are usually found only where animals have access to low, wet, swampy areas. This is because intermediate stages outside the pig require crayfish or snails as part of the life cycle. Since snails and crayfish are found in low, swampy areas the obvious control and prevention is to limit access by pigs to those areas.

There are **no** practical and **safe** way to **treat** pigs infested with flukes.

J. **Worms in Pigs That May Affect Humans**

1. **Tapeworms** — The **pork tapeworm, Taenia solium** affects swine in the intermediate stage while the adult stage is in humans. The intermediate stage in swine is a small blister appearing lesion in various organs and muscles. Humans are infested by eating raw or slightly cooked pork products. In the human the intermediate stage develops into a full grown tapeworm that causes health problems in humans. Segments from the adult worm pass in human feces.

Pigs become infected when they have access to human fecal waste by rooting in soil or when their food and water are contaminated.

Control and prevention are by limiting access of pigs to human feces by good sanitary practices by humans and by cooking all pork well done for human consumption.

The **Hydatid Tapeworm**, Echinococcus granulosus, is a tapeworm that infests pigs in the intermediate stage and dogs in the adult stage. Occasionally humans become infested by eating raw or improperly cooked pork. Control includes preventing **dogs from straying through hog pens and pastures** and preventing dogs from eating raw pork products. The practice of giving dogs **raw pork scraps at butchering** time should not be allowed.

2. **Trichina (Trichinella spiralis)** is the worm parasite of pigs most often thought of as causing a problem in humans. The Trichina are microscopic worms in the muscle meat of pigs. Humans become infested when they **eat raw or improperly cooked pork.** Dogs and other meat eating animals also become infested by eating dead pigs or pork scraps. Control and prevention in pigs and later problems in humans is done by cooking garbage and preventing pigs from access to human and dog feces. Dead pigs should be buried or burned.

Always cook all pork products well done if used by humans.

This is the worm parasite in pigs which has caused most of the reluctance to human consumption of pork. By following the few suggestions outlined previously, pork should be completely safe for humans.

V. External Parasites (Insects) That Affect Pigs

A. **External parasites** of pigs include those parasites that live on the outside of the pig and usually on or in the skin. Some of these, lice and ticks, are easily seen but mange mites are microscopic and their presence is noted by a severe skin irritation. They cause problems by skin irritation, often severe, that may lead to skin infection as germs enter the broken skin. They also may spread germs from animal to animal and carry a malarial type blood parasite. Ticks and lice are blood suckers and contribute to anemia problems. All contribute to stunting and poor health.

1. **Lice** (Hematopinus suis) is the most often noticed insect problem of pigs. They are usually found around the head, neck and between the legs. The adults are 1/8 to 1/4 inch long, greyish-black in color and easily seen on white pigs, but less easily seen on black pigs. Pigs with lice are often restless, and **scratch** a lot and skin may be irritated. Affected pigs are usually unthrifty.

The adults lay eggs on the same pigs and the life cycle repeated as eggs hatch and immature stages grown to maturity. They may move to another pig as they lie side by side or when a pig scratches them off on a pole or wall and they later get on another pig.

Treatment involves use of sprays, dips, dusts or pour-on insecticidal chemicals approved for use on pigs. Treatment should be repeated in 2-3 weeks. **This is one of the most often required management practices in raising healthy pigs. A Table of Insecticides approved for pigs follows at the end of this Section.**

2. **Mange** is the common name for a skin infection caused by mites of two species. **Sarcoptes** and **Demodectes.** They are too small to be seen without magnification. They burrow into the skin, most often around the head, neck and shoulders and cause a severe irritation. It is first seen as a reddening of the skin, later severe and followed by scabs. They are first seen around the ears and later over the face, neck and other parts of the body. The severe irritation and scratching caused by the mites is usually followed by skin infection and a stunted unhealthy pig.

Mange mites live their entire life on the pig and the life cycle is repeated in the skin. They may spread to other pigs by direct contact or when scratched off on a post or wall and later get on other pigs.

Treatment is difficult because the mites are in the skin. Spraying or dipping is necessary and must be repeated in 10-15 days. **Insecticides**

that kill mange mites and are approved for pigs are listed at the end of this Section.

3. **Ticks** of several species affect swine. Ticks commonly found on cattle, sheep, dogs and wild animals may affect swine. Ticks do not spend their entire life cycle on an animal. At various stages of their life cycle they drop off on bushes and small trees and later attach to another animal. This makes them important in the spread of diseases. They also are blood suckers and cause skin irritation.

Treatment for ticks is by using **Toxaphene, Sebacil or Bacdip or Lindane** dip or spray as listed in the following Section on Insecticides.

B. **Insecticides Approved For Use on Pigs**

1. **Co-Ral** — 25% wettable powder. Mix 1 pound in 50 gallons water for lice.

2. **Co-Ral** — 1% Dust. 1 ounce per animal for lice.

3. **Ciodrin** — 13.1% Emulsifiable concentrate — 3-1/3 pints to 50 gallons water for lice.

4. **Korlan** 5% Granules. Apply 1/2 pound to 100 sq. feet of bedding for lice.

5. **Korlan 24E** — Mix 2 quarts in 50 gallons water for lice. **Can be used on baby pigs.**

6. **Lindane** — 20% Emulsifiable Concentrate. Mix 1 pint in 50 gallons water for mange, lice and some effect on ticks. **Do not use on baby pigs less than 30 days old.** Wait 30 days untii slaughter after use.

7. **Lindane** — 12.4%. Mix 1-1/2 pints in 50 gallons of water. For mange, lice, and some effect on ticks. **Do not use in baby pigs less than 30 days old.** Wait 30 days until slaughter after use. Lindane is generally available; it has many uses.

8. **Malathion** — 4-5% Dust. Apply 1/4 to 1/2 tablespoonful per animal. It is good for lice and fair for mange. It **can be used on baby pigs.** This product has many uses and is generally available.

9. **Malathion** — 57% Emulsifiable Concentrate. Mix 2 quarts in 50 gallons water for mange and lice.

10. **Sevin** (carbaryl) 5% dust is a very safe and generally available product that is used for lice in pigs. Do not use on baby pigs less than 30 days of age.

11. **Methoxychlor** — 24% Emulsifiable Concentrate. Mix 1 gallon in 50 gallons of water for lice.

12. **Rabon** — 3% Dust. Use 3-4 ounces per animal.

13. **Toxaphene** — 60% Emulsifiable Concentrate. Mix 3 pints in 50 gallons of water. Effective for mange and lice. **Effective for Ticks.**

14. **Bacdip (Bayer) — spray, dip and paint on for all external** parasites of pigs, especially ticks.

15. **Sebacil** (Bayer) — spray on pigs for lice and ticks.

16. **Odylen** (Bayer) — pour on, paint on for mange and lice.

17. **Neguvon** (Trichlorfon — Bayer) — pour on for external parasites in pigs.

18. **Tiguvon** (Fenthion-Bayer) — pour on for lice in swine. **Okay for use on pregnant and nursing sows.** Wait 14 days until slaughter.

19. **Used Motor Oil** — an old home remedy, is effective against lice in swine. It should be used in small amounts poured or painted on the shoulders and neck behind the ears. **This is somewhat risky because oil may contain harmful chemicals. It should be used as a last resort only and when no others are available.**

20. There may well be other insecticides approved for swine that are available in your area. **Follow Directions Closely.**

C. **Notes on Use of Insecticides in Pigs**

1. **Insecticides are potentially dangerous drugs much more so than other drugs used in animals. Always follow directions closely, especially mixing and dilution.**

Be especially careful when using insecticides **on sows** just **prior to farrowing** and while **nursing** their baby pigs. Pigs may ingest insecticide as they nurse and serious problems may result. Also, use with care **on baby pigs.** Lice are usually the only insect problem before 5 weeks of age. Mild dusts such as 4-5% Malathion are safest. Use others **only if label contains directions for baby pigs.**

VI. Diseases of Swine

It is not within the scope of this booklet nor would it serve a real purpose to go into great detail on all the diseases of swine. Earlier parts of this section on Health Problems which describe more common problems are more useful in most circumstances.

Also, diagnosis of most major diseases is difficult even for experienced veterinarians with laboratory assistance. Treatment is expensive, drugs are often hard to find and results often are poor with resulting death losses and stunting in survivors.

Prevention of Health Problems Through previously mentioned guidelines should be our goal.

A. **Hog Cholera** (Swine Fever) is a highly contagious and highly fatal disease of pigs caused by a virus. It is generally considered the worst disease of swine in the world. Though eradicated in some countries it is still a very serious problem in many areas.

Affected animals are first noticed by their lack of appetite which

is caused by the high fever. Soon after this they become weak and depressed. Many develop diarrhea and death follows in a high percentage of affected animals. Recovered animals are often weak and unthrifty.

This disease spread rapidly through an area where many farms have pigs. Keeping animals closely confined to prevent contact with other pigs is a good idea. Also, keep pigs away from streams because the virus may travel from farms with sick pigs.

If the disease is known to be in an area and cases are frequent it would be advisable to vaccinate if possible for it.

If it has not been diagnosed, but sickness that is suspicious of it does occur, try to get help in diagnosing it. In most countries, government or university veterinarians are available for help in disease outbreaks and they should be advised of suspicious cases in an area.

B. **African Swine Fever** is a very serious disease of pigs which in many respects is similar to hog cholera. Laboratory tests are needed to differentiate between the two diseases.

Until the past 10-15 years this disease only occurred in the continent of Africa. However, it is now widespread with outbreaks in parts of Europe, South America and the Caribbean.

Other information on Hog Cholera applies here. Suspicious cases should be reported to government veterinary authorities.

C. **Foot and Mouth Disease** (Aftosa) is a very serious disease in pigs as well as other livestock. It is also very contagious and rapidly spreads through an area. The fact that other livestock are involved allows it to spread through an area more easily.

The disease is usually not hard to diagnose. The combination of vesticles (hard thick blisters) inside and outside the mouth, snout, feet and udders is very likely to attract attention. These lesions later become red and raw as vesticles rupture.

Animals become very lame and are reluctant to eat because of the sore mouth.

Death losses are usually not great but the stunting and general poor health in survivors causes great economic loss to the farmer.

Vaccines are available and should be used if possible in areas with frequent outbreaks.

Suspicious cases should be reported to government veterinary authorities.

D. **Erysipelas** — is a bacterial disease of pigs which occurs worldwide. It is considered one of the major diseases of swine, but it is not as contagious in its spread through an area as the previous viral diseases.

It occurs in two forms. One is a highly fatal condition which results in deaths in 24-72 hours in affected pigs. Pigs develop a very high fever, sore swollen joints, are reluctant to move, but usually remain

alert until near death.

The other form manifests itself by a chronic arthritis or raised reddish diamond shaped areas of skin. Stunting is the problem associated with this form of Erysipelas.

Vaccines are available and should be used, if possible, on farms with previous problems. It often recurs on the same farm.

E. **Brucellosis** (Bangs Disease) (Infectious Abortion) is a major reproductive disease of pigs and occurs worldwide. It is caused by a bacteria that affects the reproductive organs of adult males and females.

It causes poor conception, early and late abortions, weak and still-born pigs and small litters. However, animals are not noticeably sick. It is usually brought into a herd by infected breeding stock who in turn infect others. An infected male may spread it to sows and from an infected sow to others. Often laboratories are not closeby but if possible, newly purchased animals should be blood tested prior to purchase.

Sharing boars is often a necessity, but this may spread the disease.

It also spreads within a herd when sows have an abortion and at farrowing time.

F. **Leptospirosis** — is another reproductive disease caused by bacteria and is worldwide. It causes a widerange of reproductive problems similar to Brucellosis. Animals are rarely visibly sick.

Strains of this bacteria are found in other livestock, wild animals, dogs and rate. All of these may cause problems in pigs. This makes it difficult to control.

The organism is found in the kidney and passes from the body in urine and may be spread to other animals as urine contaminates drinking water. This is especially true of animals drinking from ponds or small streams. As with Brucellosis, blood tests are available. There are very effective vaccines available to prevent this disease.

G. **Pox (Pig Pox)** is a disease of pigs found worldwide and caused by a virus. It is noticed as clean blisters on the skin most often between the legs and under the abdomen. Blisters turn into dark raised areas that disappear within a week to 10 days. The condition is most often seen in pigs under 3 months old.

Deaths are rare. However, the virus does lower resistance and common pneumonia and diarrhea may follow.

Section 6

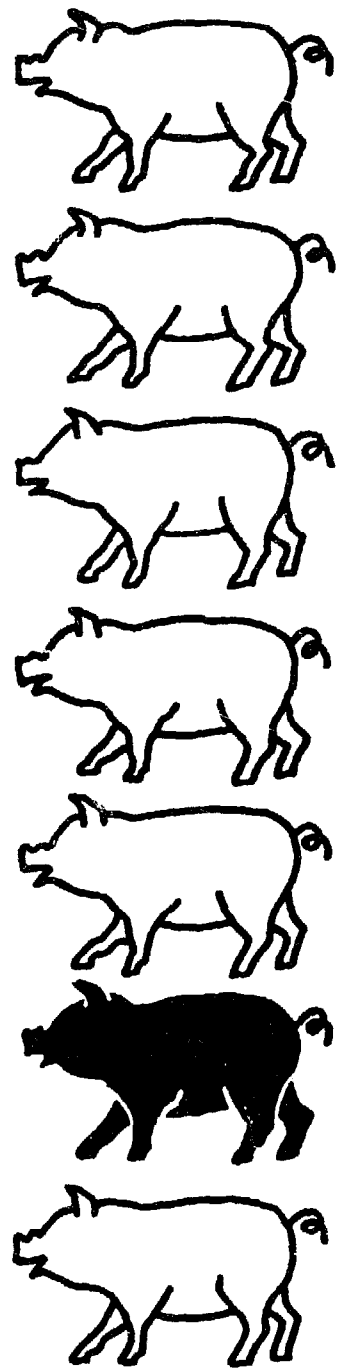

Since this booklet cannot cover all possible aspects of health and production practices in primitive pig raising, Christian Veterinary Missions is providing in this section a method whereby you may obtain additional information on pig problems in your area.

The following is a general outline of information needed.

1. **Farm Location**
   1. Country
   2. Area of Country — State or Province
   3. Distance and direction from nearest large city

2. **Climate By Season**

   Ex. — Winter, December-February, Cool with heavy rains daily
   Rest of year — hot and dry

   Give seasonal extreme temperatures and amounts of rain, if possible.

3. **Description of Area** where farm is located

   Ex. — High mountain plateau, sparsely populated.
   Ex. -- Small farms, densely populated area near large city.
   Ex. — Rangeland with low swampy areas near streams.
   Ex. — Tropical island with coconut and sugar cane plantations.

4. **Description of Farm** in great detail

   a. **Terrain**

      Ex. — Low, uncleared land with small amounts of well drained cropland being farmed.
      Ex. — High mountain valley.

   b. Total Acres in Farm_____.
   c. Acres in crops_____.
   d. List crops grown by season_____ _____.
   e. Acres used for pigs_____.
   f. Acres used for other livestock_____.
   g. Number of pigs on farm —
      Baby pigs_____.
      Growing Animals_____.
      Adult Females — Sows_____.
      Adult Males — Boars_____.
   h. List other livestock and poultry on farm.
   i. Describe method of confinement, tethered, fenced, running loose, etc.
   j. Describe all buildings and sheds; age and condition.
   k. Distance to nearest farm with pigs.
   l. Do neighboring pigs run loose?

5. **Management Practices**

a. Sanitation — good, bad or fair, describe.
b. Nutrition — in great detail.
— what foods are fed and to each age group.
— how much of each is fed.
— seasonal variation.
— include minerals and salt.
c. Drinking Water
Source — well, stream, pond
How supplied — trough, etc.
d. How are animals protected from extremely hot and cold weather.
e. List worm and insect control practices and drugs; what, when, how much, how used.
f. Vaccines used; what, when, how.
g. Weaning age.
h. How many years experience does farmer have in raising pigs.

6. **Describe Sickness in Great Detail**

a. How long has the problem been observed in the herd _____?
b. Does it have a seasonal pattern, describe it.
c. Are other pigs in area sick?
Has it been diagnosed?
d. What ages are affected?
e. What percent of pigs are affected, by age.
f. What percent of affected pigs die, by age.
g. Average number of days from first sickness noticed until death.
h. Are survivors stunted, mild or severe.
i. Is reproduction affected? _____. Describe.
j. Is appetite affecte? _____. Describe.
k. Body temperature while sick.
l. Describe all symptoms in great detail.
m. Describe treatments used and results.

7. **Any Other Observations.** Remember, no detail is too trivial to be of great importance.

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Section 7

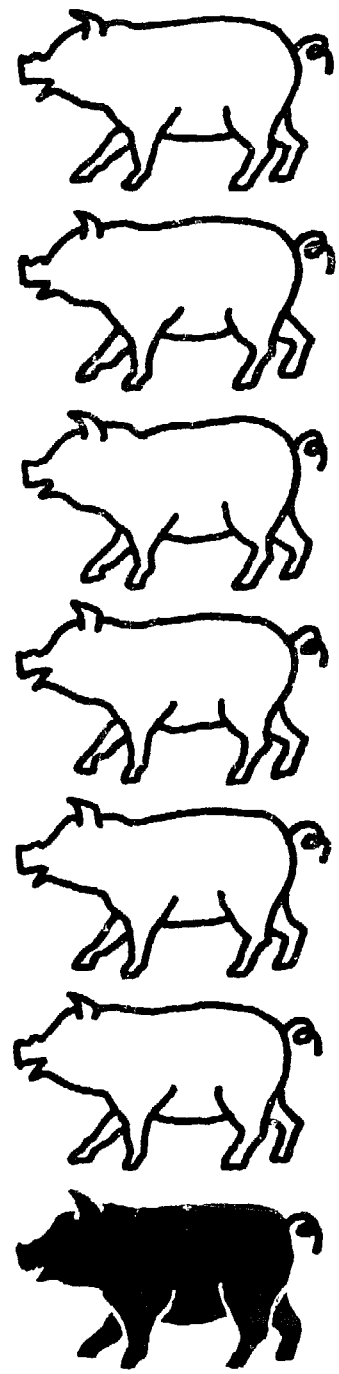

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Sources of Information:

1. Agricultural Extension Service of State Universities as follows:

   A. Auburn University, Alabama
   B. University of California
   C. Colorado State University
   D. University of Florida
   E. University of Hawaii
   F. University of Illinois
   G. Iowa State University
   H. University of Kentucky
   I. Mississippi State University
   J. Montana State College
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   M. North Dakota State University
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O. Purdue University, Indiana
P. Clemson University, South Carolina
Q. Tuskegee Institute, Alabama
R. University of Tennessee
S. Utah State College
T. Virginia Polytechnic Institute
U. University of Georgia

2. **United States Department of Agriculture**

3. Farm and Livestock Magazines:

   A. Hog Farm Management

   B. National Hog Farmer

   C. Pig America

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Raising Healthy Poultry Under Primitive Conditions

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Raising Healthy Poultry Under Primitive Conditions

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Dr. W. Malcolm Reid Dr. Gene M. Pesti
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Thank you for your help.

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Section I

Introduction

Introduction

More people raise poultry than any other food-producing animal. They may begin as a hobby for pleasure, to produce their own food, or for profit. This booklet may be regarded as a primer on essential methods of keeping poultry healthy. Suggestions are made on how to expand into a small-scale poultry farm under primitive conditions.

Since chickens are the most common domesticated bird raised on farms, villages and even in towns or cities, they will be used to illustrate poultry management which may also apply with some modifications for ducks, geese, turkeys, guinea fowl, quail, and pigeons. Some contrasts between chickens and other species are made in Section 9.

Many poultry producers have started by rearing a few birds as pets. Associated income, which was at first regarded as "pin-money", may grow into plans for a larger commercial enterprise. Optimistic hopes for financial returns may mislead the producer into too rapid expansion if careful planning has not taken place.

The best advice: "Start small the first year and let financial success govern your rate of expansion. Keep careful records!" Many financial failures have come from attempts to start with large flocks without knowing the best sources and costs of high-producing chicks, feed, methods of disease prevention, or marketing. This booklet may assist small-scale poultry operators as they expand into a successful commercial enterprise. Large scale poultry production is a specialized agricultural industry which will require further study of more detailed textbooks (See Section 10).

Section 2

Getting Started - Securing Stock

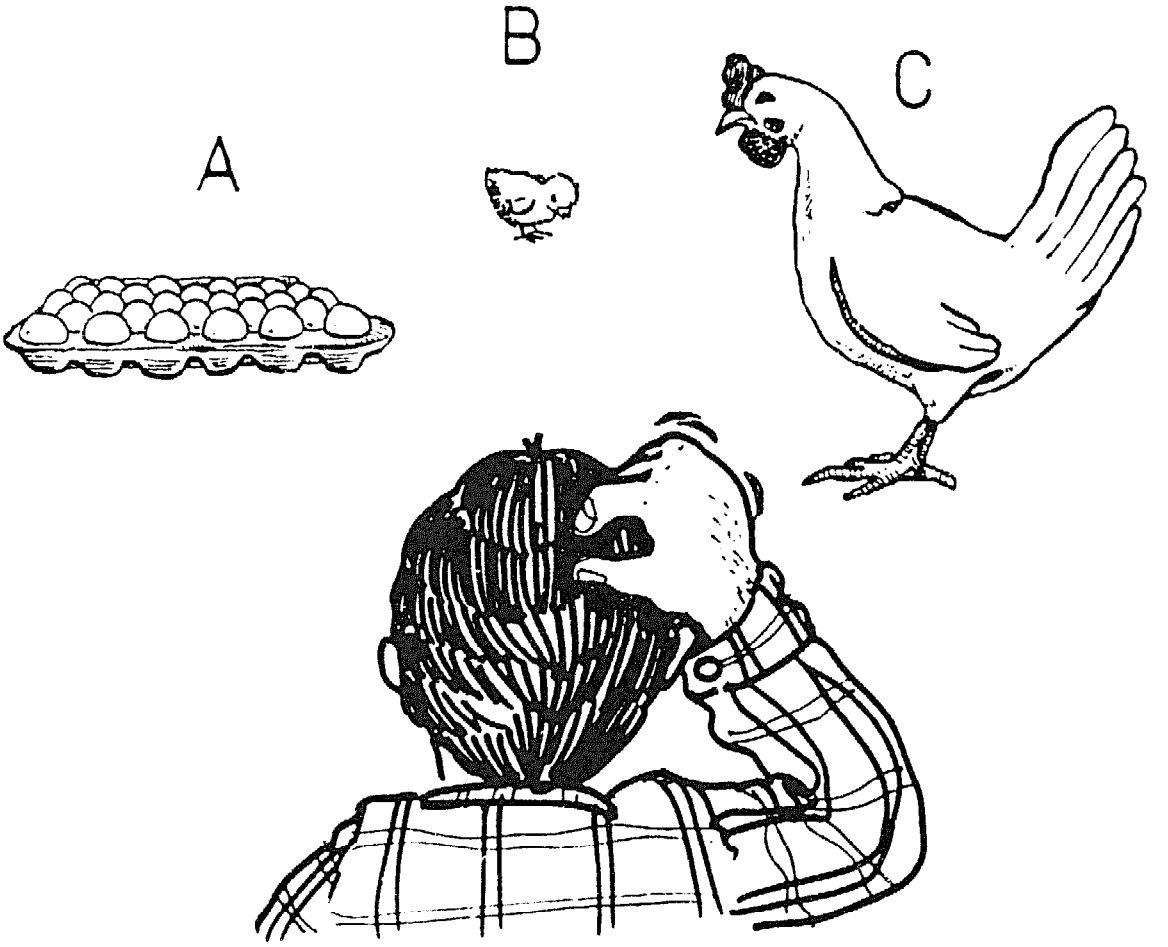

Which one shall I order?

GETTING STARTED - SECURING STOCK

Chickens are conveniently purchased and moved to new locations at four different stages in their lives:

1) As day-old baby chicks. This is the most common method of starting or restocking a poultry operation. Advantages: Since day-old chicks are nourished by stored yolk for 2 or 3 days, they do not require food or water during shipment to new quarters. Disadvantages: during shipment there is danger of smothering if overheated or getting chilled in freezing temperature. Although newly hatched baby chicks require more heat than humans, groups of 25 generate sufficient heat to be comfortable in a cardboard shipping box if some ventilation holes are provided and moderate room temperatures can be maintained. Watering and feeding will be necessary if shipments are delayed more than 3 days.

2) Purchase of hatching eggs secured from good breeding stock makes another convenient method of getting started. Although eggs may be easily broken if insecurely packed, temperature changes are less critical than with baby chicks. The producer must be prepared to incubate the eggs as soon as they are received. Hatching eggs cannot be stored for much longer than a week even if maintained at the optimum temperature of 10°C (50°F).

Natural incubation requires availability of a "broody" hen, turkey, duck or other bird. Although numbers of eggs set under a hen may be limited to 12-14, other birds sometimes incubate larger numbers of eggs. Hatching still larger numbers of chicks requires use of a mechanical incubator for artificial incubation. Success with this method is dependant upon skill and care of a the hatchery operator. If eggs from disease-free stock are obtained, care must be taken to prevent contamination by eggs or fowls from other sources. Percentage of hatch depends upon egg fertility, nutrition of the dam, condition of the egg shell, genetic constitution of the parents, egg storage time and temperature before incubation.

3) Purchase of started chicks three weeks or more of age saves the beginner from supplying equipment and the time-consuming tasks associated with brooding. These include use of artificial heat, initiation of chicks into feeding and drinking and sometimes early vaccinations.

4) Purchase of started pullets ready to lay at about 20 weeks of age relieves the customer of numerous rearing tasks. Advantages: males and inferior female culls are eliminated before purchase. Males are often destroyed as day-old chicks in the hatchery after sexers have examined the vent under strong light or by noting genetic feathering differences inherited from selected parent lines. Vaccination and other disease prevention procedures may have been accomplished. Disadvantage: added costs are usually charged an a per bird basis for these services.

Section 3

Types of Chickens
Breeding Practices

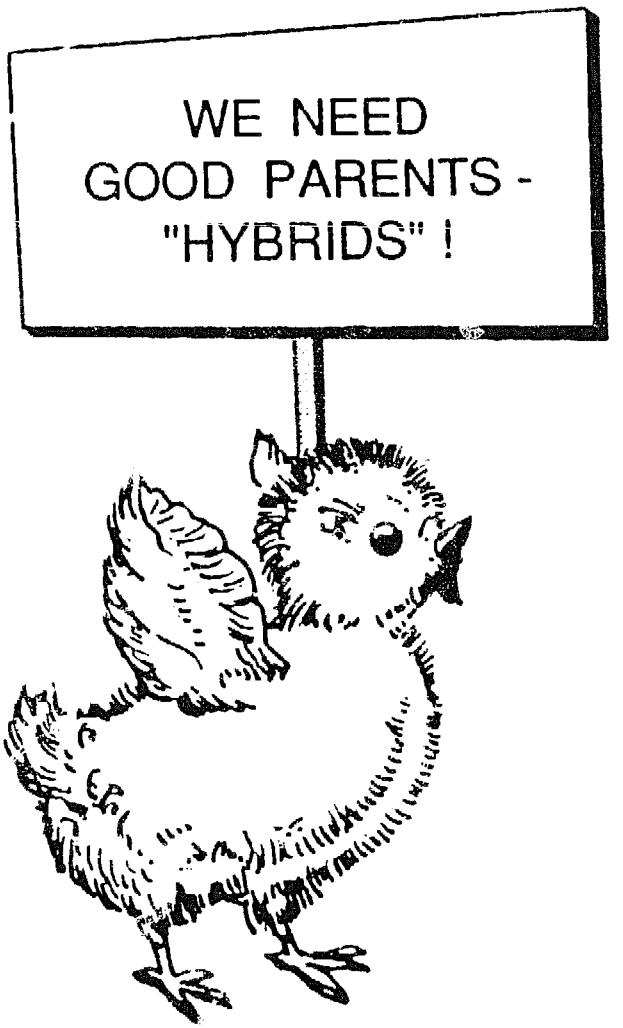

TYPES OF CHICKENS AND BREEDING PRACTICES

Poultry producers generally make a choice in selecting their stock from three types of birds:

Dual-purpose chickens are reared to produce both eggs and meat. Most young males are sacrificed after 2 or 3 months for meat while females are maintained for a year or more to produce eggs. Females are also salvaged for meat after egg production declines. Dual-purpose birds are generally preferred for backyard flocks, while larger commercial poultry producers generally specialize in either meat or eggs.

Egg-layer strains have been selected for good egg production. Surplus males are often eliminated on hatch-day after sexing since they are usually genetically inferior for meat production. Spent females may be salvaged for meat after their egg production drops below 50%. Their salvage value is minimal because of their small size.

Meat chickens, often known as broilers or fryers, are reared from strains selected for rapid growth. Both male and female lines are selected from parent stock which produce rapid meat production. Some of these hybrid strains produce a bird weighing 2 kilos (4.4 lbs.) in 7 weeks after being fed less than 4 kilos (8.8 lbs.) of a well-balanced diet.

Primary breeding companies with hybrids. Specialized breeding organizations have developed feed-efficient strains of these three types of chickens. They are produced by cross-breeding techniques and go by the general name of "hybrids". This cross breeding brings about gene combinations which excel in production of eggs or meat over that of either parent. Superior qualities produced by new gene combinations are attributed to "hybrid vigor". These hybrid strains are now so popular with modern poultry producers that they have abandoned use of such dual-purpos breeds as Rhode Island Reds, New Hampshire, Cornish, or Barred Plymouth Rocks. Improved hybrid strains of White Leghorns produce white eggs while brown or tinted egg strains usually have some White Leghorn ancestry.

These breeding companies require years of work to test dozens of strains and hundreds of progeny. Certain inbred or synthetic strains which combine well are then selected to become the great-grandparents or grandparents of chicks sold to poultry producers. Strain crosses known as the male and the female lines are established and sold separately to hatchery organizations which rear them together as their "breeder flocks". All hatching eggs are derived from such breeders.

Poultry producers purchasing these hybrid chicks have at first been reluctant to pay for the necessary increased cost for these hybrid

chicks. However, if the purchase price of feed consumed is also calculated, the cost of the hybrids is more than compensated for. Unfortunately this nybrid vigor is rapidly lost by interbreeding the hybrid birds. The producer needs to renew the male and female lines of breeder stock in each generation.

Names of many of these hybrid strains are now recognized by poultry producers on a world-wide basis. Broiler strains are often named for the breeder organizations such as Arbor Acres, Cobb, H & N, Hubbard, Indian River, Peterson, Pilch, Ross, Shaver, Vantress, and Vedette. Some of the egg-type strains have been produced by Babcock, HyLine, DeKalb, Hisex, and Tatum. Names of some dual-purpose strains would include: DeKalb-Warren 6-Sal-Link (USA), Hardy sex-linked (USA), Kabir (Israel), Label (France), Nera sex-linked (Japan), Parks Hybrids, and Stino's White Baladi (Egypt).

Dual-purpose breeds are still preferred in many parts of the world where brooding hens are used to hatch and start chicks. A running debate has continued in many countries on whether to select native breeds or imported hybridized stock. Advantages sometimes cited for native breeds include: disease resistance inherited from long natural exposure, and local customer preference for these more "tasty" and "chewy" birds. Differences in taste may be due to scavenged feedstuffs such as garlic, insects, herbs, and manure. Slow growth probably produces the more "chewy" meat. National pride has sometimes influenced local decisions. Imported disease-free hybrids may grow faster, have better feed conversion, and produce more eggs. Natural inbreeding of backyard flocks results in low productivity for both meat and eggs.

By introducing imported males to breed with native hens, some of the advantages of hybrid vigor can be inexpensively incorporated in village-wide programs where producers are still dependant upon natural hatching and brooding. A happy "marriage" of improved egg production, growth and disease resistance from the males and local characteristics is thereby achieved. The program calls for elimination of all native cocks and substituting the surplus males coming from imported lines which have been selected for high productivity. Better egg and sometimes better meat production has been reported from such programs in Egypt, Ghana and India. The imported male chicks are inexpensive as they are otherwise often discarded in the hatchery.

Section 4

Housing and Equipment

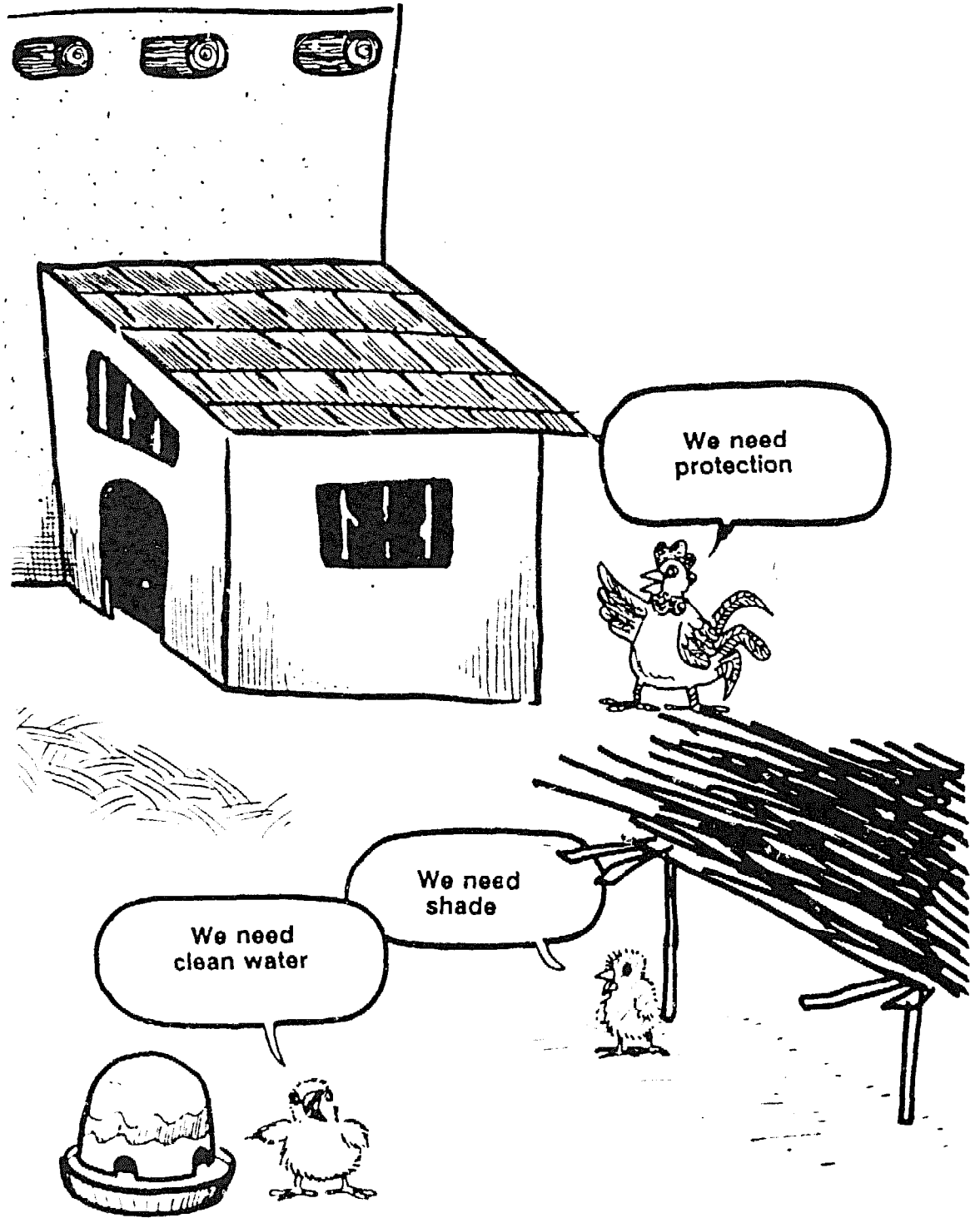

HOUSING AND EQUIPMENT

A. Housing is considered essential to protect chickens from predators, rain, wind, and temperature extremes. Although the ancestral jungle fowls roost in trees at night, mortality losses are often high. Nocturnal attacks from dogs, cats, rats, owls, hawks and other predators may destroy even adults chickens. Protective housing is very desirable (Fig. 1-4). If properly constructed and managed the house may also protect against the spread of diseases and parasites. Satisfactory houses have been built from wood, stone, concrete, adobe, brick, bamboo, and sheet metals. Materials available and designs used vary so greatly from different areas that detailed plans may best be secured from local authorities. Several essentials need to be considered before building a house.

Fig. 1. Free range management

Fig. 2. Night shelter for partially controlled range

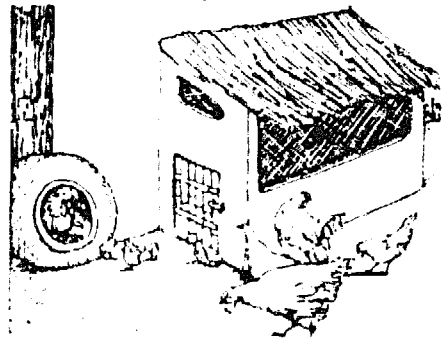

Fig. 3. Gable chicken house

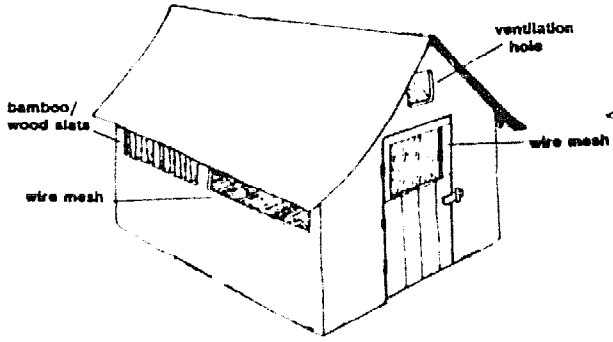

Fig. 4. Deep litter house for confinement rearing

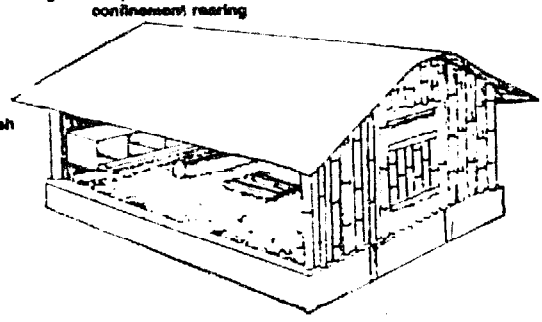

1) Location. The house needs to be properly oriented to 1) protect against wind but permit some air movement, 2) prevent too much heat from the sun, and 3) to insure sufficient drainage to prevent wet floors. In hot climates available shade and roof overhang may need consideration. In the northern hemisphere windows are often oriented to leave an open southern exposure. If built in deep valleys there may be insufficient air circulation. Objectionable odors or houseflies breeding in poultry houses have forced some poultry units to move from developing suburbs.

2) Temperature Control. Temperature extremes in hot and cold weather create stressful conditions in poultry houses. Over heating of drinking water may be dangerous in hot climates. Frozen waterers create special problems in cold weather. Specialized construction plans adapted to local conditions may be available from local experts.

3) Ventilation. Air movement within the house is essential to prevent smothering (Fig. 3). Chickens need more fresh air per unit of body weight than any other class of livestock. Wide open sides or windows may be desired in hot climates. Air movement should not be blocked by bushes or other buildings. Ventilators and/or fans may be essential in large commercial houses.

4) Insulation. Health of poultry is often promoted by insulating roofs and sidewalls against both cold and hot weather. Advice on materials and engineering recommendations should be sought locally before building large houses.

5) Moisture Control. Large quantities of water are consumed by chickens. Layers may require more than a liter per day in hot climates. In humid climates high humidity may result in wet droppings which cause disease problems. Adequate drainage in the house floor may assist in moisture control. To prevent moisture problems some producers have selected management programs using slatted or wire floors.

6) Space. Crowded chickens are unhappy and unproductive. Minimum requirements for birds housed in a moderate climate with plenty of ventilation are as follows: 15 birds per square meter up to 6 weeks of age, 5 birds per square meter up to 16 weeks, and 3 to 4 birds per square meter for older birds. Higher temperatures, excess humidity, or wet litter increase required floor space requirements. In cages, 10 to 20 layers may be placed per square meter of floor space. Larger white and brown egg layers require proportionately greater floor space, as calculated by weight.

7) Framing. Availability of local materials and construction methods will determine the type of framing. Internal pillars may be required to support the roof against heavy wind or snow. Special strength is required over doors, windows and if tile roofing is used.

8) Roof. The roof should be entirely rainproof. Thatch, sheet metal, tile, shingles or wood covered by roll roofing materials may be used. An overhang of up to one meter on the south side (northern hemisphere) may provide shade in summer but permit sun to enter the house during winter. The amount of overhang to give this advantage varies with the latitude.

9) Floor. Although concrete floors with embedded wire mesh to keep rats out are desirable, more houses have dirt or heavy clay floors because of expense. Adequate drainage should be planned. Types of floors vary with different management systems which include deep litter, and suspended floors made of slats or wire. Convenient clean-out systems for manure need to be considered.

10) Animal and Bird Protection. Nocturnal protection against dogs, cats, rats, weasels, owls and day-time protection against wild animals, hawks and eagles should be planned. Wire mesh is often

used. Although foraging in pasture may be satisfactory during the day, greater protection is usually required at night.

B. Waterers. *Chickens of any age should never be left without clean, cool water!* Chickens need water every 15 to 20 minutes. Making certain that water supplies are adequate is one of the most important jobs of the caretaker. Waterers adapted for various ages of chickens are illustrated (Fig. 5). The simplest waterer is a tin can inverted into a soup or pie plate (Fig. 6). Punch a hole about 1.5 cm (0.5 in.) from the open end of the tin can. Fill the can with water and cover it with the plate. With one hand on the plate and one on the tin can, quickly invert both. The position of the punched hole and the vacuum in the tin can will regulate the water level in the plate. Smaller cans are suitable for chicks but larger ones must be substituted as growing birds require more water.

Waterers

Fig. 5. Chick waterer

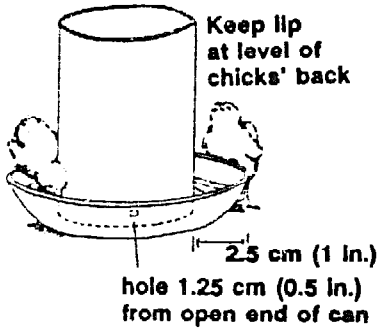

Fig. 6. Parts of waterer

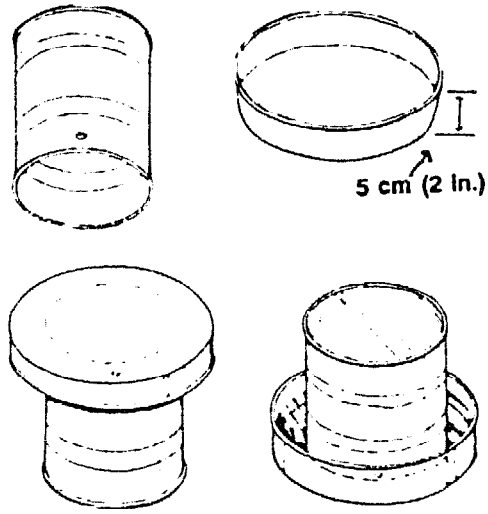

Fig. 7. Clay waterer

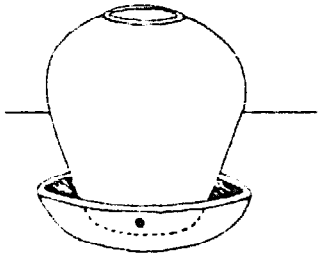

Fig. 8. Bottle waterer

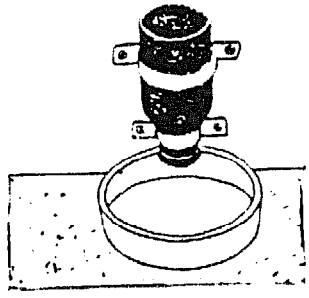

Fig. 9. Gourd waterer

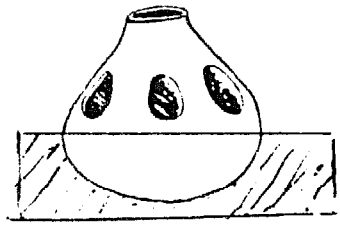

Fig. 10. Slat holder

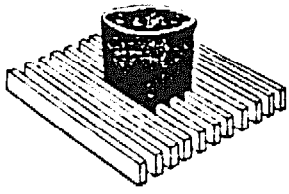

Fig. 11. Waterer suspended to keep litter dry

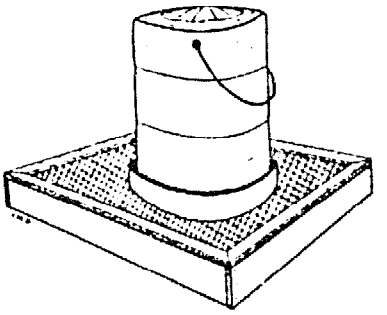

Fig. 12. Automatic waterer

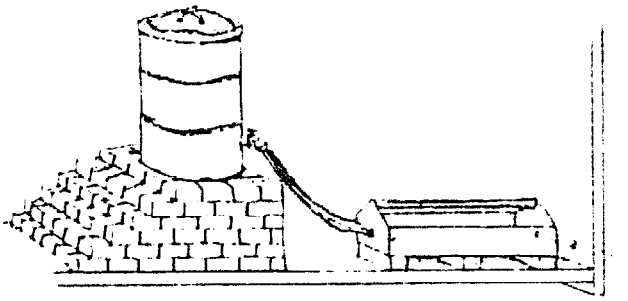

Other waterers can be fashioned using a clay pot and shallow plate with a hole or groove in the lip (Fig. 7). A removable bottle strapped to the wall or a stand can be adjusted at a convenient height above a dish (Fig. 8). A gourd submerged in the ground for stability has holes of convenient size cut in the sides (Fig. 9).

Various automatic devices have been invented to preclude refilling waterers so frequently (Fig. 12). Illustrated is one built with a clean 50 gallon oil drum connected to a galvanized sheet metal trough 10 cm (4 in.) high. Flow of inlet water into the drinker is adjusted by a faucet and an overflow pipe leading outside the house. The top of the waterer needs to be protected by a spinner (a bar that rotates so chickens cannot roost on it). All waterers need frequent checking to see that water is constantly available but that no overflow goes into the litter. To keep the litter dry, each waterer is often placed on a flat board between slats (Fig. 10) or suspended on a wire-floored platform 9 cm (3 1/2 in.) above the litter (Fig. 1).

Slime molds begin to grow in waterers if they are not washed frequently. This should not be allowed to happen. A long handled brush is often used to clean out debris. Waterers need periodic cleaning with a brush. Some authorities suggest that this be done daily.

C. Feeders. Providing a continuous supply of feed for chickens is one of the major tasks of the poultry producer. Elongated trough-type feeders with overhanging lips on both sides may be constructed of wood, metal or bamboo (Figs. 13-20). Sufficient linear feeder space along the trough should be provided for all birds to feed at once. Otherwise timid birds may starve to death while others resort to cannibalism. Suggestions on linear space/bird: chicks 0-8 weeks 2.5 cm (1 in.), 9-16 weeks 7.6 cm (3 in.), breeder pullets 10.2 cm (4.0 in.), layer hybrids 3.8 cm (1.5 in.), caged layers and turkeys 7.6 cm (3.0 in.), ducks 5.0 cm (2 in.), and geese 6.4 cm (2.5 in.).

Feeders

Fig. 13. Chick feeder

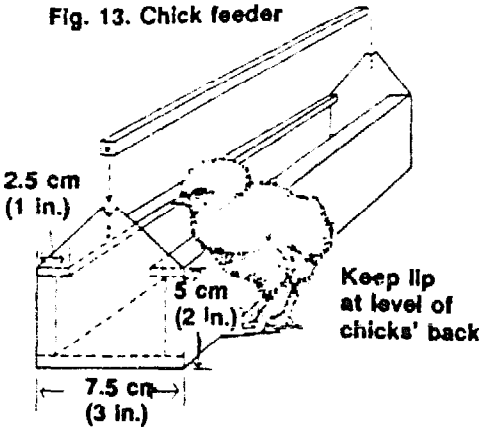

Fig. 14. Older chick feeder

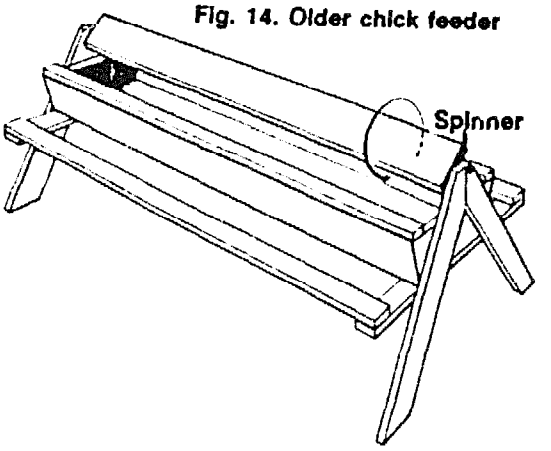

Fig. 15. Hanging feeder

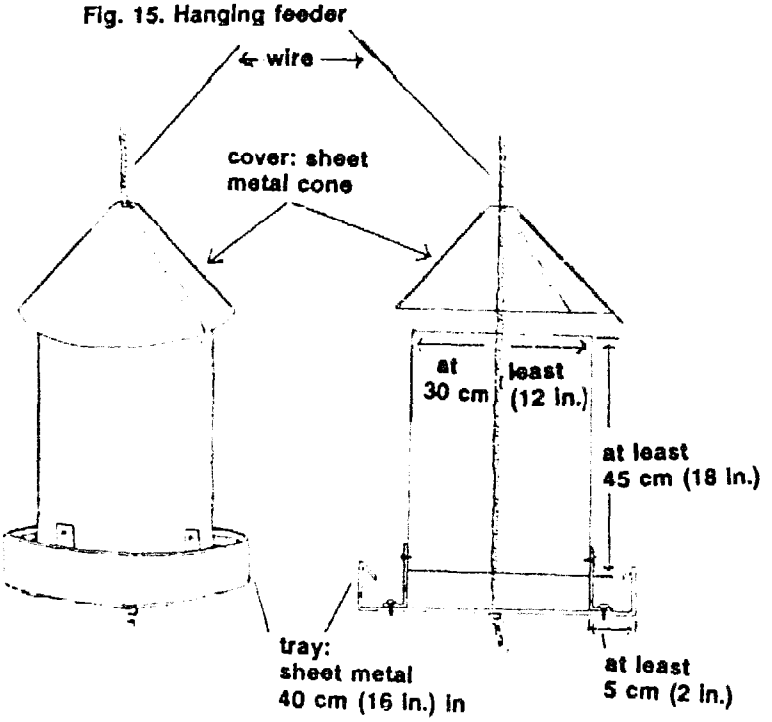

Fig. 16,17,18. Lip overhang

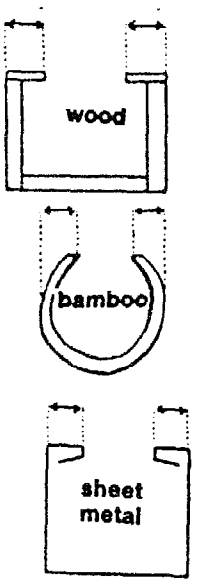

Fig. 19. Hanging feeder - bamboo

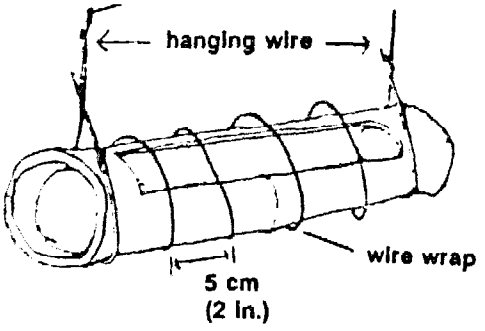

Fig. 20. Stationary feeder - bamboo

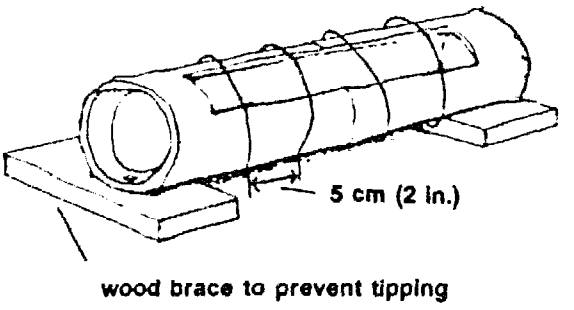

D. Cages. Craftsmen can fabricate cages if supplied with welded wire mesh with wire 2 mm (1/8 in.) in diameter. For the frame and dividers wire size is spaced 2.5 x 5 cm (1 x 2 in.). A piece cut 3.66 m x 1.5 m (12 x 5 ft.) provides the form for 3 colony cages or 16 double cages (Figs. 21 and 22). Four dividers plus end pieces cut 40 x 45 cm (16 x 18 in.) will make three colony cages or 17 for 16 double cages spaced 22.8 cm (9 in.) apart. A flexible metal wire is used to bind the dividers to the frame. The front is made from wire mesh with larger openings (5 x 10 cm, 2 x 4 in.). Doors may be cut in as indicated in Fig. 23. Floors should slant downward 7.6 cm (3 in.) back to front so eggs will roll through a 5 cm (2 in.) gap in the front and rest upon the upturned floor for easy collection (Fig. 26). Bamboo or slats may be substituted for wire floors (Figs. 24, 25). Feeders and waterers may be made of sheet metal or bamboo and hung tightly to the front of the cage. Spacing is important to prevent spillage of water or feed. Double cages accommodate 2 layers each while colony cages permit 6 if they have been severely debeaked.

A system of double hanging is illustrated (Fig. 27). A correct slant of 7.6 cm (3 in.) to the floor is required to permit eggs to roll out without damage (Fig. 26).

Making Wire Cages

Fig. 21. Feeder and waterer location

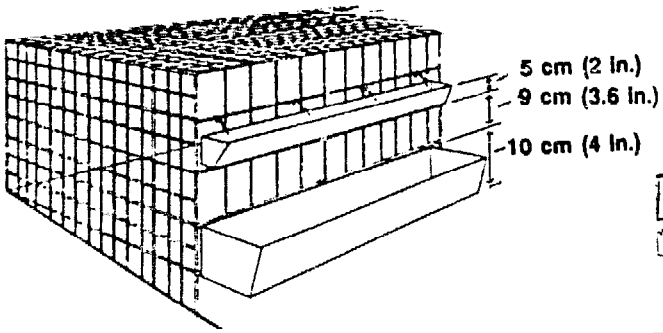

Fig. 24. Floors may be slatted

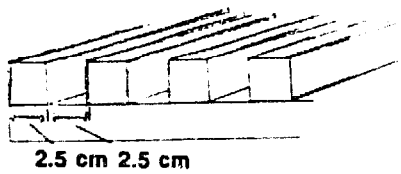

Fig. 25. Floors may be bamboo

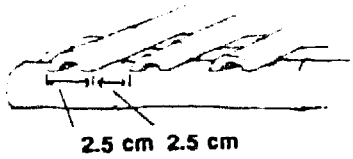

Fig. 22. Form for cage from wire mesh

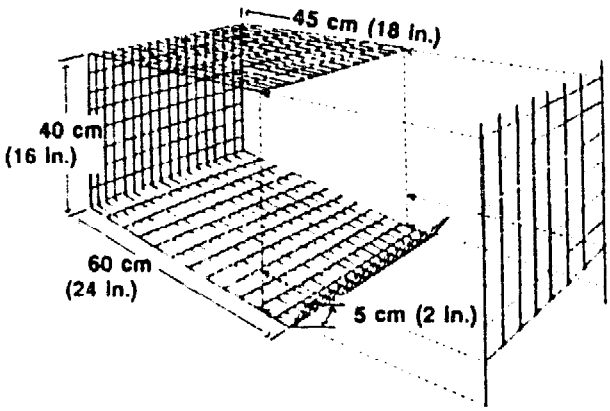

Fig. 26. Slanted floor for egg roll out

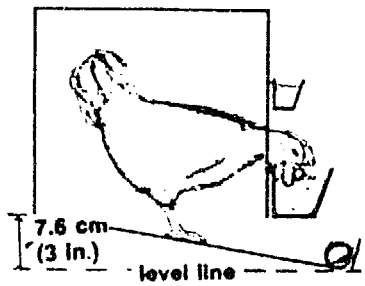

Fig. 23. Cage front and sliding door

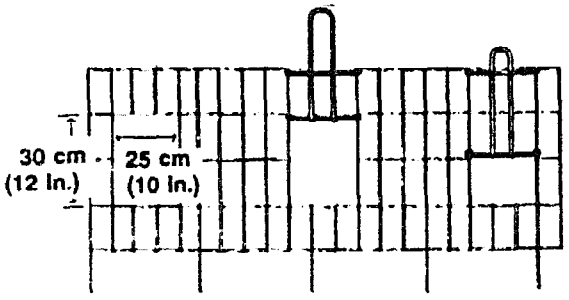

Fig. 27. Four cages hung staggered from ceiling

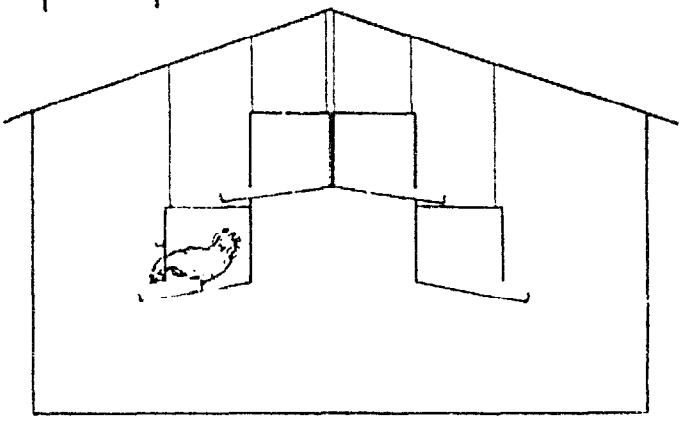

Section 5

Management

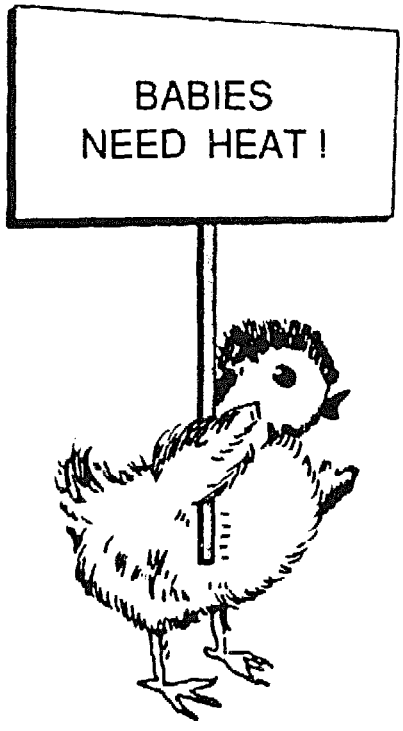

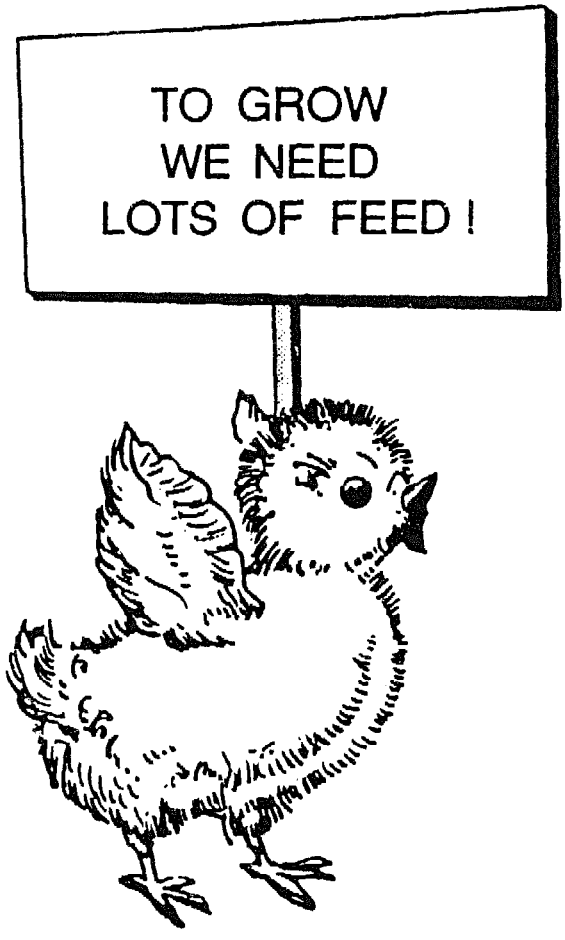

MANAGEMENT

A. Incubating and Hatching. New poultry producers must choose between natural incubation of fertile eggs with broody hens or using an incubator. Natural incubation under broody hens or substitute turkeys, ducks, capons or geese requires little care from the poultry producer. However, it severely limits flock size and growth, and presents the possibility of disease transmission which may be controlled in artificial incubation programs. Most commercial poultry producers have come to rely upon a hatchery industry which has developed methods of artificially hatching large numbers of eggs.

Home-constructed incubators are still used for small flocks in some areas where the commercial hatchery business is not well developed. If a constant supply of electricity or kerosine is available, inexpensive incubators can be purchased or constructed which will hatch small numbers of eggs (Fig. 28). For chicken eggs the incubator must contain a thermostat (Fig. 29) which can be adjusted to maintain a constant temperature of 39.4°C which is the approximate temperature of naturally incubated eggs. Relative humidity should be maintained between 45 and 65% by use of water pans and adjusting the air flow. Chicks begin to hatch at 21 days and are often stronger if left unassisted. Although a few stragglers may live if given assistance, they are often too weak to survive. A small still-air, 50-egg capacity electric incubator can be built using a heat lamp with temperature regulated by a gas-filled thermostat. Eggs should be "turned back and forth" about 4 times a day during the early weeks of incubation. Mark each egg with an "x" to judge a turn of 45° each time but do not rotate.

Fig. 28. A homemade incubator

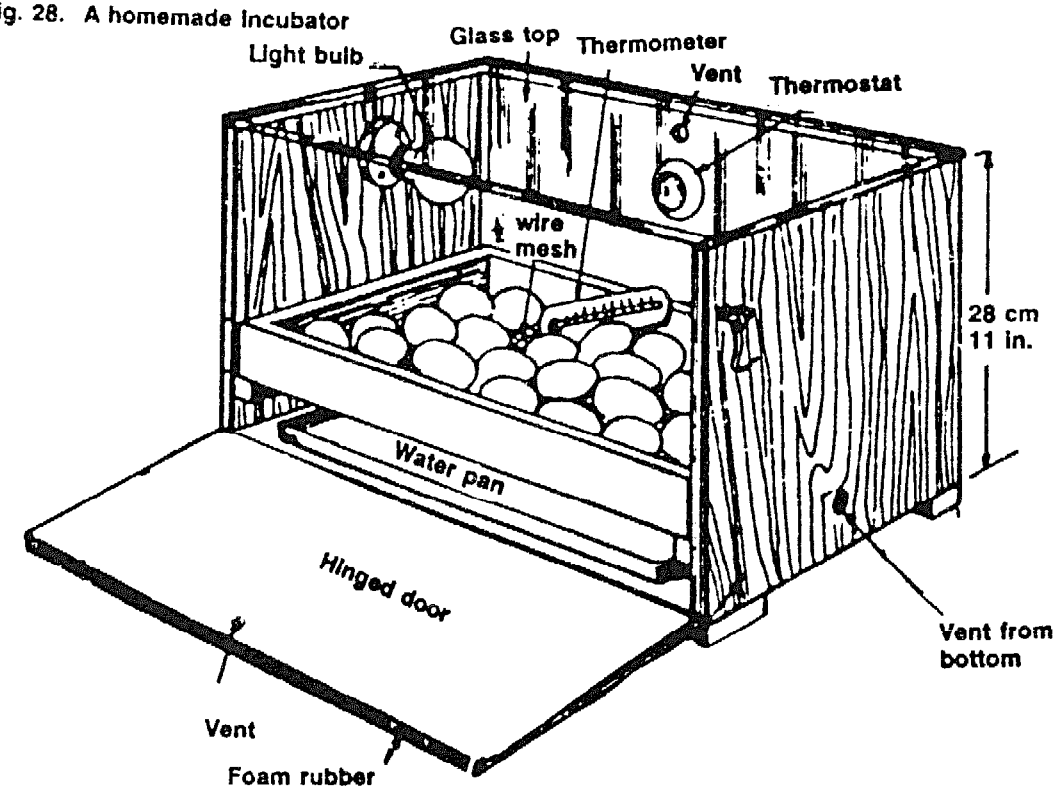

Fig. 29. Gas filled thermostat

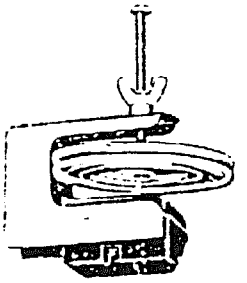

Fig. 30. Egg candler

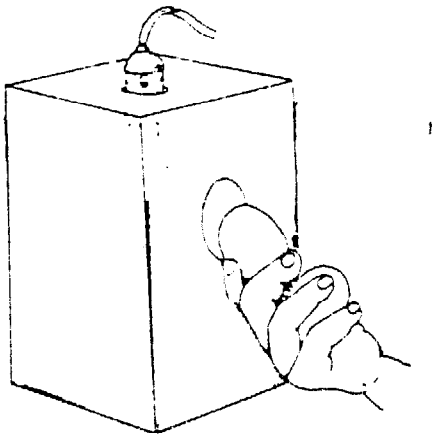

Fig. 31. Size of air cell after 7, 14, 18 days of incubation

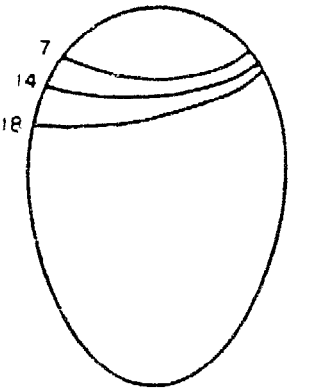

Since mechanical failures with home operated equipment are frequent, most poultry producers have come to rely on commercially operated hatcheries which employ mammoth forced draft incubators. These are designed to mechanically turn the eggs several times a day. Temperature should be maintained between 37.5 and 37.6 degrees with 50 to 60% relative humidity. For the nineteenth and twentieth days, the temperature should be dropped to 36.1 to 37.2% with an increase in relative humidity to 75% just before the highest rate of hatching is reached. These recommendations depend on the type of incubator and size of the eggs being hatched, so pay careful attention to manufacturers recommendations. A back-up alarm system may automatically start a standby electric generator in case of power failure. Each incubator may well be provided with filtered air to prevent bacterial contamination from other incubators within the hatchery. Eggs are transferred from the incubator to a hatching unit on the 18th day of incubation.

A good commercial hatchery will supervise disease control on the breeder farm to prevent introducing diseases into the hatchery. Hatchery-transmitted diseases have been costly in the past. Thus the older custom of accepting hatching eggs furnished by individual breeders sometimes known as "custom hatching", has been discontinued. A thorough washing and disinfecting of equipment is essential for sanitary clean-up after each hatch. Services for vaccination, debeaking and sexing are often provided along with supervision of the breeder farms to prevent egg-transmitted diseases such as pullorum and mycoplasma. Most of the newly hatched chicks are sold and delivered directly to the customer at one day of age. Some hatcheries brood and sell started chicks or pullets.

B. Candling Eggs. Progress in the developing embryo during incubation can be observed by rotating an egg in a beam of light. A simple candler can be made by putting a 3 cm (1-1/8 in.) hole to a can or box holding a 15-50 watt light bulb (Fig. 30). A flash light or narrow

beam of sunlight in a dark room may also be used. Normal shrinkage of the air cell during incubation is shown (Fig. 31). If the airsac is more than 1 1/4 cm (1/2 in.) deep, the egg is probably spoiled.

Infertile eggs (white shells only) can be detected after 4-5 days of incubation. Two or three days longer may be required for tinted or brown eggs. If thin blood vessels may be seen as emerging from a dark red spot, the egg is fertile and the chick developing. If yolks and whites are clear the eggs remain edible, although laws prohibit their sale in some countries. Candling is also possible at 18 days while eggs are being transferred to the hatcher. Infertile eggs remain clear, contaminated eggs are detected by a darkened embryo inside and the absence of an air cell.

C. Brooding. If baby chicks are artificially hatched, the producer must assume the task of the mother hen in a role known as brooding. The attendant takes on serious responsibility for hourly attention during the critical early stages in the life of a flock of chicks. Constant inspection during the first two days may determine the difference between success and failure of a flock. In many countries women demonstrating maternal instincts do the best job of brooding during the critical first weeks. Three necessities must be constantly attended to: heat, feed and water.

Heat for a brooder may be provided by electricity (Fig. 32-33), gas (Fig. 34), kerosene (Fig. 37), charcoal (Fig. 35) wood, coal, straw, or solar heat. Preparations include testing and adjusting the heat source 24 hours before the chicks arrive. The old rule of thumb for maximum brooder temperature has been 35 °C (95 °F) for the first week, and a decrease of 2.8 °C (5 °F) for each succeeding week until 21 °C (70 °F) is reached. Lethargic breeds of chicks require more heat than genetically active breeds. Thus some authorities suggest a starting temperature of 30-35 °C, varying with breeds. A range of temperatures in the brooding area gives chicks a choice in selecting an optimum temperature.

Types of Brooders

Fig. 32. Light bulb brooder

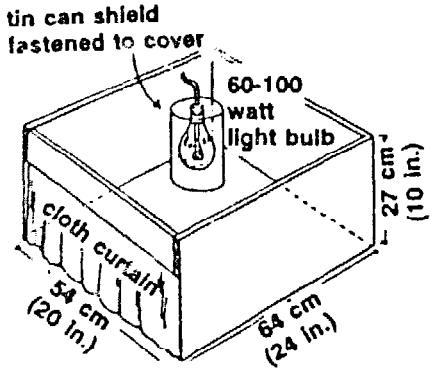

Fig. 33. Infra-red heat lamp

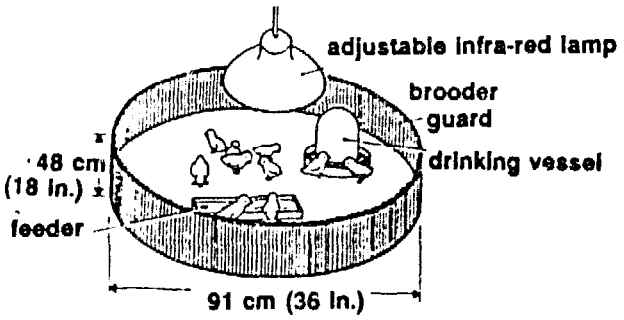

Fig. 34. Gas brooders with hood

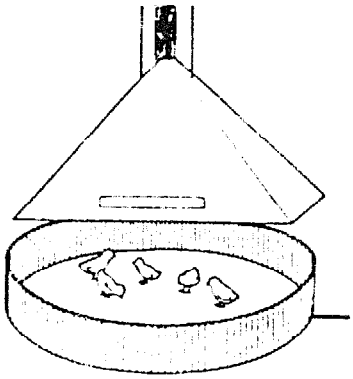

Fig. 35. Oil barrel - charcoal

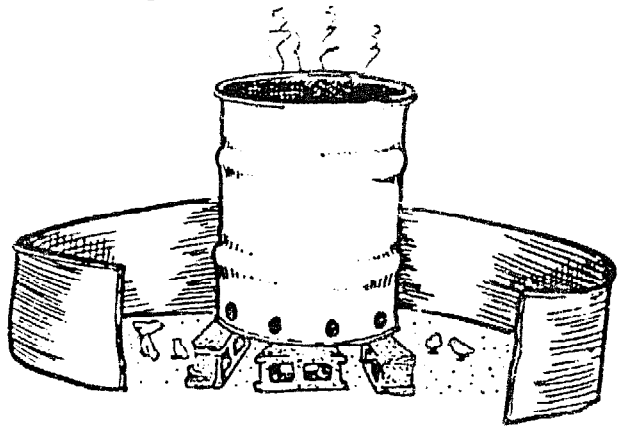

Fig. 36. Basket brooder

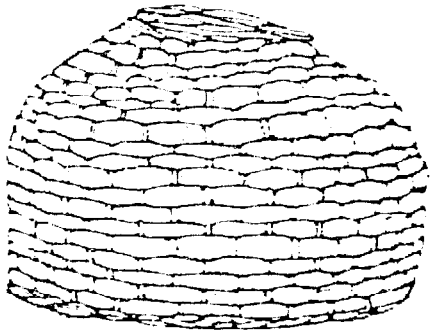

Fig. 37. Kerosine brooder

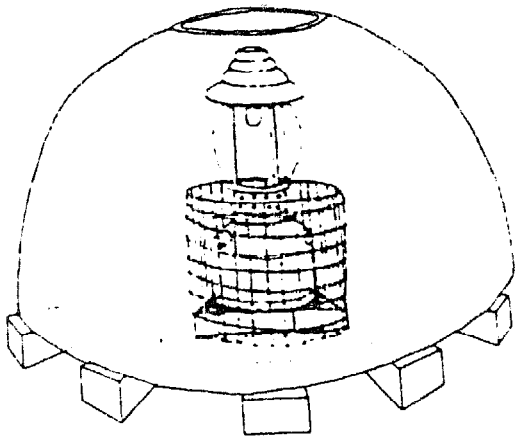

An inverted box-type brooder with a protected light bulb hanging 20 cm (8 in.) from the floor furnishes a satisfactory brooder for about 50 chicks (Fig. 32). A confined area outside will permit chicks to run outside through the cloth curtain. An infra-red light bulb adjusted to hang 45 cm (18 in.) from the floor is a good heat source for small numbers of chicks (Fig. 33). A hood, which is usually constructed of sheet metal, may be hung or suspended by small posts or bricks with the edge 10-12 cm (3-4 in.) above the floor. Basket brooders may be constructed with a kerosine lamp propped up on bricks as a heat source. Caution to prevent fires is required with any heat source.

For the first week a cardboard ring known as a "chick guard" or "brooder guard" is often placed beyond the rim of the brooder to prevent chicks from wandering too far from the heat source (Figs. 33-35). An experienced observer will be guided in temperature regulation by the chick behavior (Figs. 38-41). Less experienced care-takers should frequently record the temperatures indicated by a thermometer located at the level of the chicks' backs. If chicks are huddled together and making the chirping sounds of discomfort, more heat may be necessary. If chicks are distributed in a ring as far possible

from the heat source, less heat should be furnished (Fig. 40). Constant attention for young chicks is especially important because outside temperature changes alter the amount of supplemental heat necessary.

Brooder Management

Fig. 38.
Chicks too cold. Lower lamp.

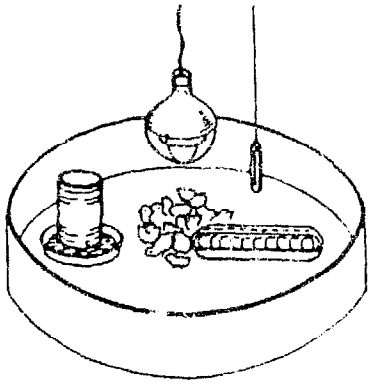

Fig. 39.
All is well; conditions just right.

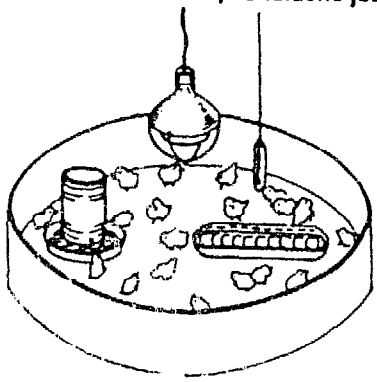

Fig. 40.
Chicks too hot. Raise lamp.

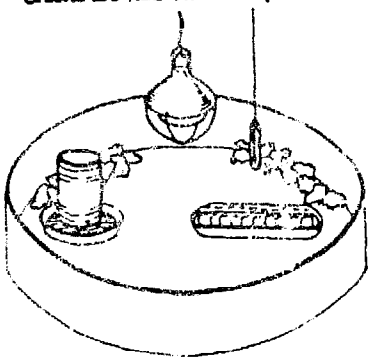

Fig. 41
Cold draft. Plug it up.

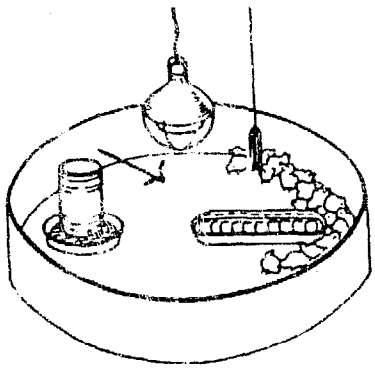

Fig. 42. Feed and water placement within brooder guard. Arrangement of 4 waterers and box lids (temporary) to be replaced by feeders.

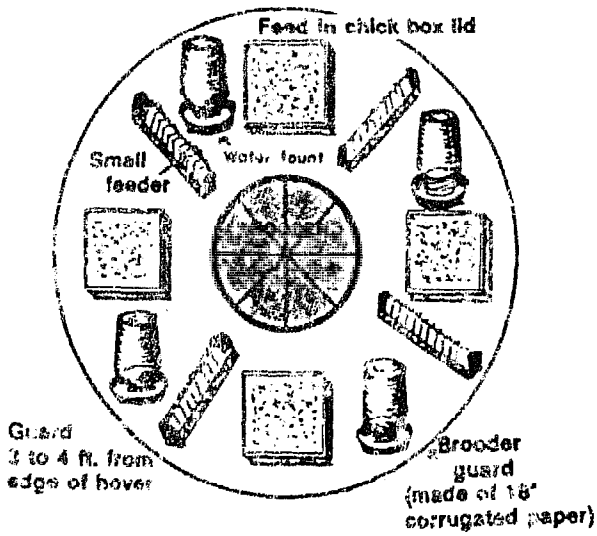

Feed must be presented in a manner that will attract the curious chick during its first day of brooding. Mixed mash, or crumbles spread out on newspapers or an inverted box top is frequently used. Four feeder and 4 watering stations are often placed alternately just inside the brooder ring (Fig. 4). Place baby chicks right on tope of the feed. During the first week temporary box-top feeding stations are gradually replaced with 4 small chick feeders. Each 100 chicks requires 2.5 m (199 in.) of feeding space.

Water must be found by each chick during the first day even if some must be picked up by hand and their beaks inserted in the water. During the first 2 weeks no chick should be more than 1 m (3 ft.) from a waterer and thereafter not more than 3.5 m (10 ft). Daily requirement of water for 100 chicks approximates 2 liters during the first week. Size of the waterers will need to be increased as the chickens grow (Figs. 5-12). One hundred hens in lay may require 36 liters or more per day. Spillage on to the litter needs to be guarded against (Figs. 10-11).

D. Rearing. Use of added heat in brooders may be discontinued after 3 weeks, or earlier in warm climates. The producer has a choice of different systems of management. The flock may be reared on free range (Fig. 1), limited range (Fig. 2), in pens, in cages or in confinement within houses (Fig. 3 and 4).

Advantages of range rearing include 1) reduced feed costs as birds secure much of their own diets by scavenging for green fodder, insects, and by scratching in manure from large animals, and 2) reduced housing costs. Disadvantages include 1) loss from predators, and 2) it requires close flock shepherding. A limited range requires less flock supervision.

Advantages of pen rearing include more protection from weather and predators. Disadvantages include the cost and responsibility for furnishing all essential nutrients in the feed and cost of complete feeding, fencing, and problems arising from wet pens in rainy weather which may result in disease and parasite problems.

Cages save space and if suspended to avoid contact with droppings, birds may be protected against some diseases and tick parasites. They have a higher initial cost and require a convenient manure disposal system.

Confinement rearing permits greater protection against predators and may prevent disease if sanitary measures exclude visitors, older chickens, pets, or fomites. All essential nutrients must be furnished in the feed. Recommended space per bird should be 650 sq. cm (100 sq. in.) for the first 5 weeks, and increased to 2,750 sq. cm (3 sq. ft) as it reaches maturity. The floor is usually covered with 5 to 10 cm (2-4 inches) of litter. Type of litter selected depends

upon local availability and cost. Preferred materials include: peat moss, chopped oat, rice, or wheat straw, softwood or hardwood chips, sawdust (only after 4 weeks), shredded corn stalks, ground corn cobs (some danger from molds), broadleaf leaves, rice, peanut or coffee bean hulls, shredded sugar cane stalks, newspapers, and sand (last choice). Poor quality litter requires somewhat greater floor space to stay dry. If litter becomes wet due to leakage of waterers or rain, wet material should be replaced. Fine grass, straw or hard particles of incompletely ground feedstuffs may cause a blockage known as "crop-bound" (Fig. 43). If such chickens are otherwise healthy they should be sacrificed for meat since there is no practical remedy to relieve this condition.

Fig. 43. Crop-bound chicken

Fig. 44. Killing a chicken for a post mortem examination

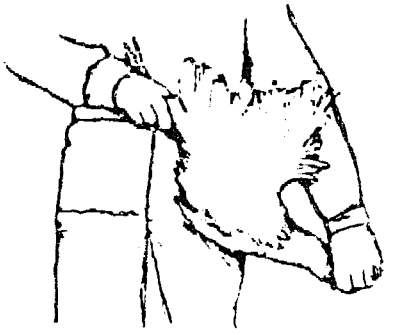

Fig. 45. Metal cone for weighing

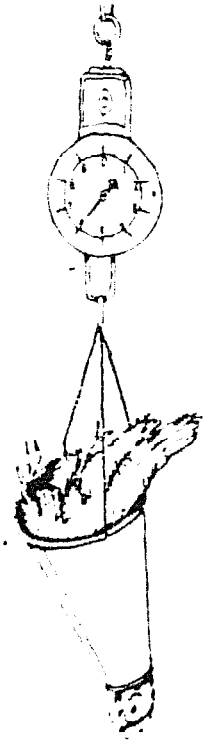

Fig. 46. Zones for debeaking

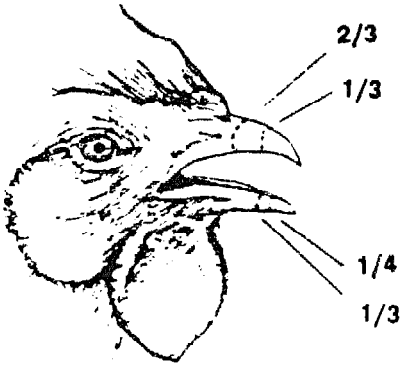

Fig. 47. A catching hook

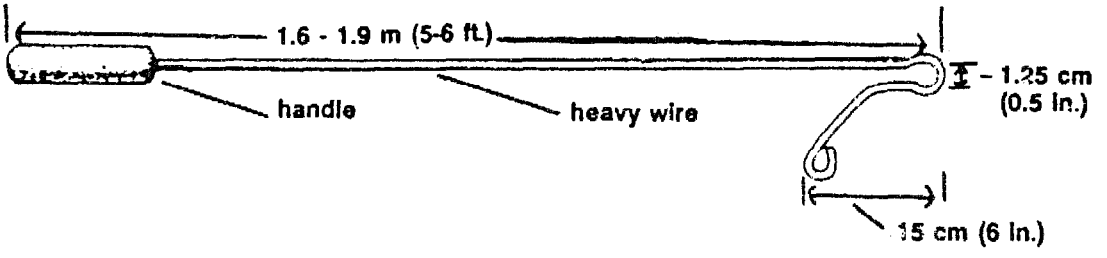

Cannibalism. Debeaking is a method of cutting or burning off the tip of the upper and lower beaks (Fig. 46). If properly done this minor operation prevents cannibalism which is a bad habit of pecking at feathers or injured areas of other birds. Some broiler and layer producers order debeaking of all birds at the hatchery. For broilers, only about 1/3rd of the top beak is removed. For layers which will be alive longer, 1/3rd to 2/3rds of the upper and 1/4th to 1/3rd of the lower beak is removed. Scissors or a sharp knife may be used if a debeaking machine is not available. Dip the freshly cut beak into feed if bleeding occurs. With birds on the range equal amounts of each beak should be removed only after the onset of cannibalism. Cutting too deep into the nares should be avoided.

Other methods of preventing cannibalism are sometimes required. At the first sign of feather pulling or blood the victims should be removed from the pen. Raising the birds in very dim light, a practice known as "dark house brooding" is an effective means of preventing cannibalism. This requires a windowless house, fan ventilation, and dim light furnished by a few small light bulbs. At least .5 foot candles (5.4 lux) of light must be provided. Care is critical in placement of feeders and waterers to prevent birds from becoming dehydrated and losing weight in the dark.

E. Layers. Debates continue over which is the best management system for layers. Free-range provides access to sunlight (which prevents rickets) and gives birds access to green fodder. Eggs from such sources have sometimes sold at a premium because of increased pigmentation in egg yolks. However, general production costs are considerably higher than eggs produced with confinement rearing. Scavenging for feed on range may save some costs for feed. Partial restriction by fencing provides increased protection but may also increase exposure to diseases and parasites if pens get wet.

Confinement rearing on litter in floor pens, on elevated slatted floors (Fig. 52), or in cages is now widely practiced. This requires a feed source which is nutritionally fully balanced. Capital investment for housing is lower with litter on floor pens than cages. Cages conserve space, facilitate egg collection, save on labor costs but are expensive to install. Manure accumulations under cages or raised slatted floors sometimes creates housefly problems as they breed in damp manure.

Additional lighting applied at the proper time in the life cycle of hens may greatly increase egg production. With leghorn types the optimum time to increase lighting exposure is usually at 20 weeks of age. With dual-purpose breeds 21 weeks and broiler breeders 22 weeks is often the best time. Instructions in management guides often provided by breeding organizations should be closely followed. These instruct on weight of the pullet (Fig. 45) at the time increased light is to be applied. Add one hour of light each week until 15 hours total

is reached. Egg size may remain small if increased lighting occurs too early. Switching lights on and off during the night is another management program sometimes used to stimulate feed consumption and rate of growth of broilers. In large commercial operations light switches are controlled by time clocks.

Another factor in numbers of eggs produced is the regular daily collection. If a yard hen is permitted to keep her eggs in the nest, her production may be limited to 30 eggs per year in two clutches of 12-15 each. If collected daily she may lay 120 eggs. If 15 hours of daylight are provided she may lay 250 eggs.

Nests. With floor-pen management nests should be provided for layers before they begin to lay. They may be constructed of wood (Fig. 48), sheet metal, wire mesh, clay, mud bricks, or woven mats (Fig. 50). Individual nests should provide a space of about 0.12 cubic m (1 cubic ft.). They may be placed on the floor (Fig. 48), on stilts (Fig. 49) or against the wall and in the darkest part of the house (Fig. 51). They should be lined with fresh litter and kept clean to prevent production of dirty eggs. If tiered or hung above the floor, nests should be provided with a perch in front. Colony nests, which may be used by several birds at one time, may be satisfactory if they are four times the size of a single nest.

With large slatted floor houses, nests are arranged for the convenience of the caretaker (Fig. 52).

Nests

Fig. 48. Individual wooden nest on floor

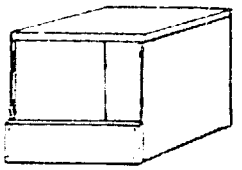

Fig. 49. Double nest of wood on stilts

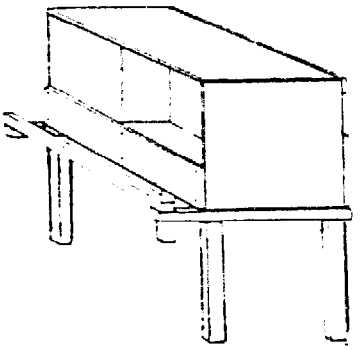

Fig. 50. Basket made of reeds and clay

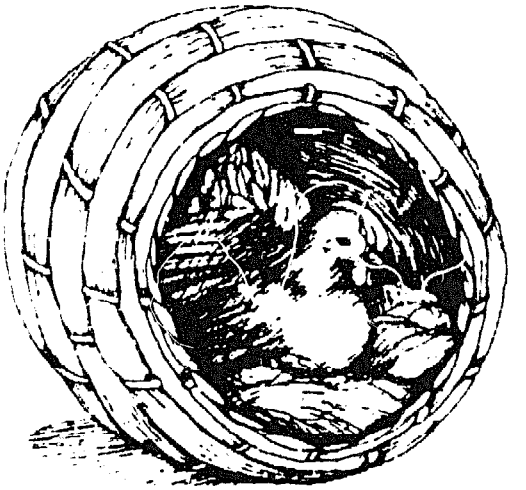

Fig. 51. Nests hung against the back wall. Perch is hinged for night closure

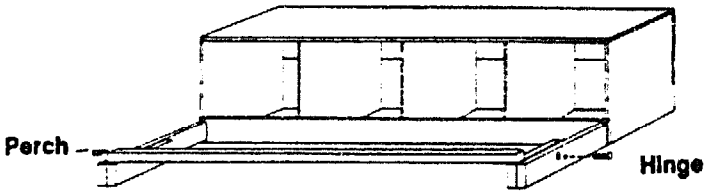

Fig. 52. Slatt-litter house with convenient egg collection

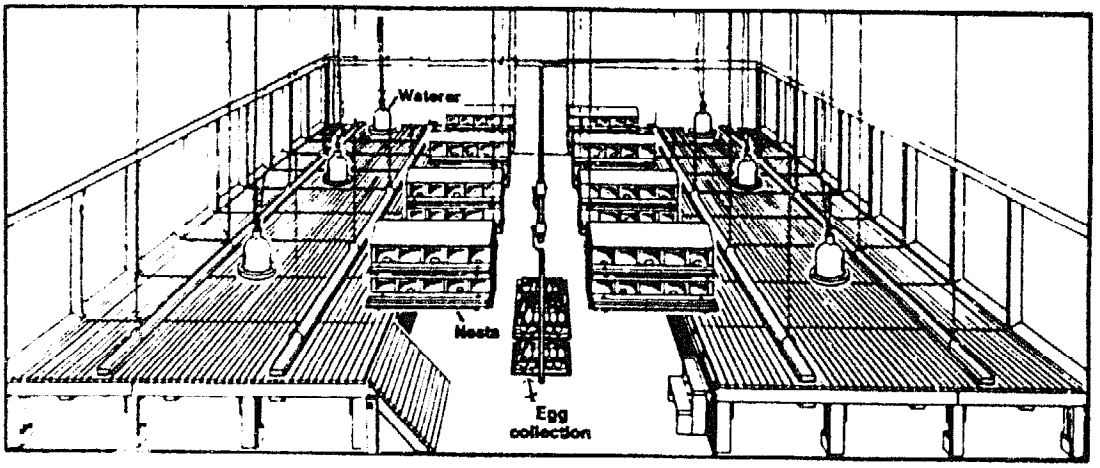

Eggs should be collected frequently and stored in a cool place to prevent rapid deterioration in quality. Some producers make 3-5 collections a day in hot weather. Eggs held at 37 °C (99 °F) drop drastically in quality after 3 days while they may keep 100 days at 3 °C (37 °F). Three degrees may be best for long term storage, but 10 °C (50 °F) is fine for shorter periods. These guides are for commercial eggs only.

Hatching eggs require special care and should not be kept more than about 10-14 days.

Roosts. Since birds traditionally sleep in trees, they are comfortable if the producer provides roosts. However, roosts are unnecessary. Hens require about 20 cm (9 in.) of roost space per bird. Roosts do concentrate droppings which may be salvaged for fertilizer. If roosts are built, house design should be planned for ease in cleaning out droppings.

Culling is the practice of removing non-layers from a flock. Considerable savings in feed costs can be effected by periodically catching and removing unproductive birds from the flock. However, caution in selection is suggested since birds which have recently molted may recover their ability to lay after a period of rest. A "catching hook" (Fig. 47) facilitates their recovery. Signs of a non-layer are a shriveled, pale, scaly comb, yellow pigment in the eye ring and the beak, dry rough wattles, small, round, yellow (Fig. 54), puckered vent (Fig. 56) with space between the two pubic bones for only 1 finger (Fig.

58), and 2 fingers between the pubic and breast (keel) bones. Note that the reference to pigmentation applies only to genetically yellow skinned birds receiving yellow pigments in the feed. In contrast, active layers have large, red, waxy combs, bleached eye ring and beak, soft and smooth wattles (Fig. 53), large, oval, moist, bleached vent (Fig. 55), with room for 3 fingers (Fig. 57) between pubic and 5 fingers between pubic and breast bones. Since even good layers may sometimes take 2-3 week pauses between clutches, caution is necessary to prevent the accidental selection of some potential good layers.

Layers vs. Non-layers

Fig. 53. Hen in lay

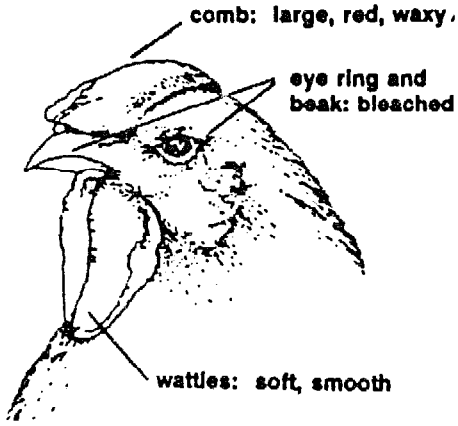

Fig. 54. Non-layer

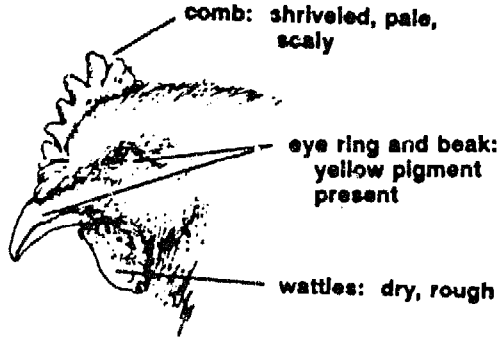

Fig. 55. Hen in lay

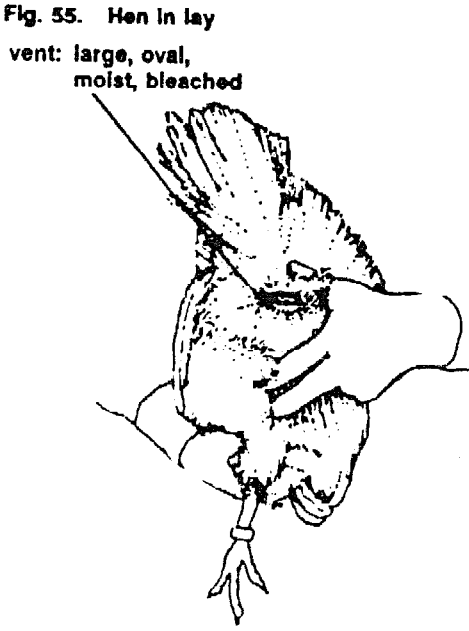

Fig. 56. Non-layer

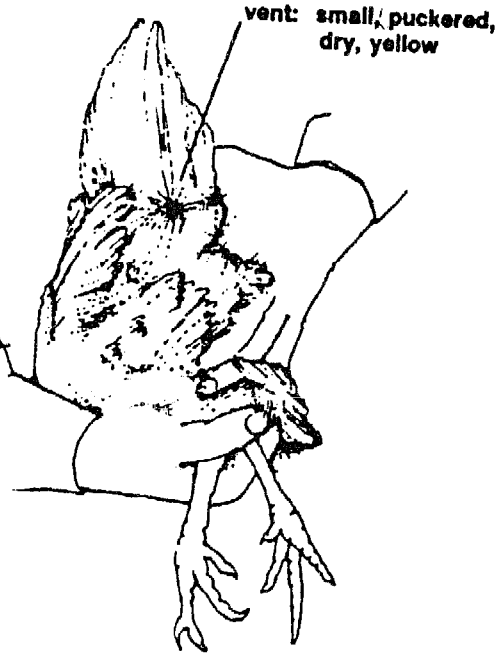

Fig. 57. Hen in lay: 3 fingers

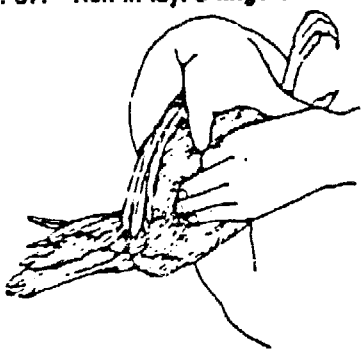

Fig. 58. Non-layer: 1 finger

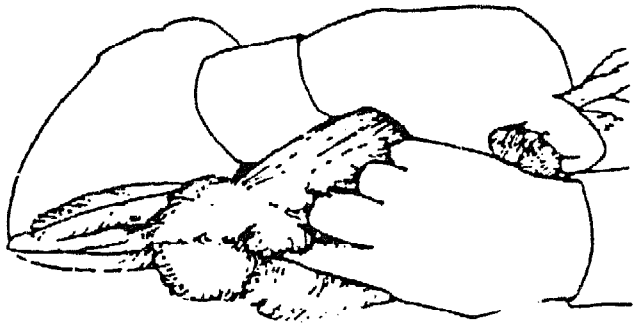

F. Breeders. Each of the commercial breeding establishments selling male or female parent stock provides a manual with suggestions for rearing their birds to obtain optimum production of meat or eggs in the offspring. To judge maturity rate, birds are selected at frequent intervals to be weighed as flock samples (Fig. 45). Placing the bird in a cone-shaped metal container head first is a convenient method. Different directions are sometimes given for feeding and rearing male and female lines. Since the price of these breeders as baby chicks may be several times the cost of other chicks, all management suggestions are usually closely followed.

G. Records. Daily records should be made on charts conveniently located within the poultry house. Ruled lines with the calendar date on a card or paper attached to a clipboard are suggested. These should include space to record mortality, date of delivery of chicks, feed delivery date and source, feed consumption, daily egg production and records of any management or disease problems. Although this chore is distasteful to many poultry producers, these records become invaluable in planning for future poultry projects and disease control programs.

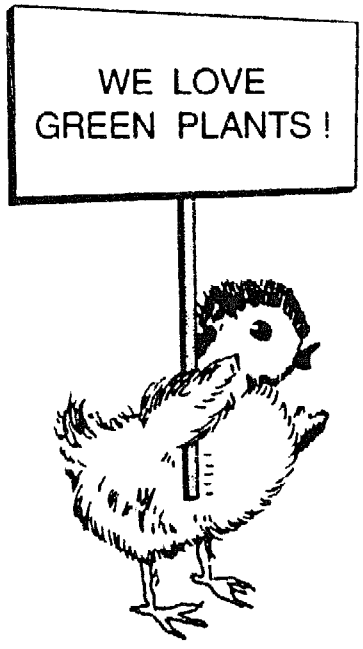

Section 6

Nutrition

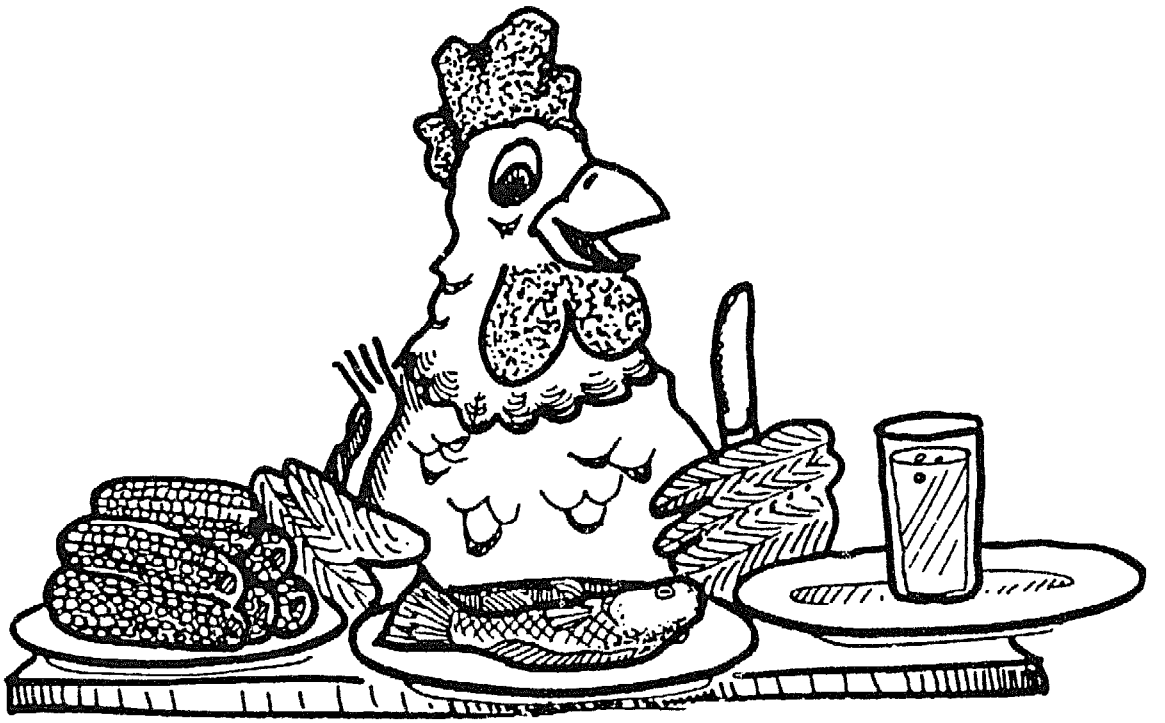

Energy

Proteins

Minerals

POULTRY HEALTH PROGRAMS

A. Prevention versus Treatment. PREVENTION IS THE KEY TO CONTROL OF POULTRY DISEASES. The poultry producer may think first of a drug treatment in case of a disease outbreak. Such a response, learned from treating human ailments, starts with the wrong premise for control of poultry diseases. He/she needs to remember: 1) drugs are expensive, 2) treatment must involve the entire flock, 3) to catch each bird individually requires much effort if treatment is given by mouth or injection, 4) if given by feed or water special mixing equipment may be required, 5) specific medication is generally successful only after a specific disease has been accurately diagnosed, 6) too long a delay frequently occurs before treatment can be instituted 7) indiscriminate use of antibiotics leads to the establishment of resistant strains of bacteria. Prevention is generally accomplished by:

1) Vaccination for specific diseases such as Newcastle, and fowl pox.

2) Blood testing breeder hens to locate and eliminate carriers of such diseases as pullorum and chronic respiratory disease (CRD). Chicks should be purchased only from blood-tested pullorum mycoplasma-free breeders.

3) Providing nutritionally balanced feeds complete with essential vitamins, minerals, amino acids, and energy to prevent nutritional deficiency diseases.

4) Feeding recommended levels of anticoccidial drugs to broilers if available for the first two months to prevent coccidiosis losses. Some recommended high levels for breeders or layers may prevent sufficient exposure to permit oocysts and prevent protective immunity.

5) Enforcing sanitary rules as:

a) Never introduce older birds into a young flock.

b) Prevent visitors (including neighbors), wild flying birds, rodents and especially other poultrymen from entering poultry houses.

c) Avoid visiting neighbor's flocks and returning to your own without a complete change of footwear and clothing.

d) Keep dirty crates, egg cartons, feed sacs and other contaminated items from poultry houses.

e) Establish an "All in, all out" rule to keep birds of one age together.

f) Practice a sanitary clean-up and waiting period (2-week minimum) before introducing a new flock to previously used pens. Exposure to direct sunlight kills many organisms.

g) Promptly remove dead birds and dispose of them by burning, deep burial or a specially constructed deep pit. Composting methods in tight containers has proved successful if large numbers of birds must be disposed of.

NUTRITION

A. Introduction to Poultry Nutrition and Feeding

If poultry is permitted to forage in open fields or barnyards, birds usually manage to obtain enough of a balanced diet to survive. A household flock of 10 to 20 birds may require no feed in addition to to table scraps, green fodder and insects from nearby gardens. Slightly larger flocks survive better if fed a few handfuls of corn or other grain. Encouraged by the income from the sale of these scavenger flocks, the planner may be tempted to greatly expand flock size, sometimes forgetting that this may require the purchase of most of the feed. Plans must be made to provide a balanced diet with prospects for enough financial return to justify the added expense.

The producer may be well-advised to start small and increase flock size gradually after some experience with feeding and marketing poultry. Commercial producers calculate that 50 to 70 percent of the expense of producing chickens is due to the cost of the feedstuffs. Thus advance planning for a reliable supply of feed is necessary. As birds grow, their feed requirements increase each day. "Full feeding", a practice of keeping feed in front of the birds at all times, is often recommended. Estimates should be made on the total feed requirements to rear the flock to market age. Weight of feed required will be at least 2 or more times the expected market weight of fast-growing meat birds. A feed conversion ratio (feed weight divided by market weight of the birds) of 2 is considered good for broilers. To obtain such a ratio requires 1) good broiler breeder stock 2) a nutritious and well-balanced diet 3) good management and 4) disease control. The sale value of the bird minus the cost of the feed may be more important than the feed conversion ratio. Less expensive feed sometimes leads to slower growth but a greater profit.

Many poultry producers have lost all profits due to flock starvation when essential feedstuffs have unexpectedly disappeared from the market. Other losses, which may go undetected by the producer, occur due to nutritional deficiency diseases. Since grain products constitute the bulk of many mixed poultry feeds, competition with human food supplies becomes a major consideration. The enterprising poultry producer usually expends considerable effort in locating inexpensive feed ingredients which are unsuitable for human consumption.

Although the backyard producer has come to think of grain as the ideal supplement for scavenging chickens, a variety of feed ingredients is essential if chickens are to be raised in confinement. To insure rapid growth and egg production most commercial producers have come to rely upon a nutritionally balanced mixed feed given as mash, crumbles, or pellets.

B. Ingredient Sources to Meet Nutrient Needs:

For optimal performance some 40 different chemical substances,

or nutrients, have been identified as essential in the diet. A brief summary of six classes of ingredients is presented here:

1. Feedstuffs Rich in Energy. Hunger is the driving force which stimulates a chicken to eat and satisfy its energy requirement. Energy is required for muscular activity to carry on chemical processes like digestion and for producing heat. The feed ingredients must be proportionately balanced with energy-containing foods to supply all nutrients in proper ratios.

Feedstuffs providing energy are often subdivided into three categories: carbohydrates, fats (lipids) and proteins. Although surplus proteins do furnish energy, their need to satisfy growth requirements plus their added cost makes them too expensive to consider for energy alone. Carbohydrate sources may be subdivided into starches, sugars and cellulose (a fibrous plant tissue). Starches and sugars usually furnish a major portion of the energy requirements. These are usually supplied by feeding grains. Although celluloses (indigestible fibers) may be a major constituent of the feed, they are not utilized by poultry. Fats or oils provide an added energy reserve. If measured by weight they produce more than twice the energy yielded by carbohydrates or proteins. The energy value of feeds is usually expressed in terms of kcal or Joules per unit of feed. Both are metric system units for expressing energy, kcal are specific measures of heat energy. One cal = 4.184 Joules = heat required to raise 1.0 gram of water one degree C. Fats yield about 9 kcal per gram, while carbohydrates and proteins yield about 4 kcal of metabolizable energy for each gram.

Feedstuffs Which Contribute to Energy Needs

Corn (Maize). This cereal is the preferred energy source in many poultry diets and often constitutes as much as 60 to 70% of the ration. Corn based diets must be supplemented for deficiencies with certain amino acids, vitamins and minerals. Yellow corn is preferred over white if yellow pigmentation of egg yolks or skin color is preferred by consumers.

Wheat Although frequently more expensive than corn, wheat may be used up to 70% of the diet. By-products of flour manufacturing such as wheat middlings and bran may also be used. Bran contains considerable fiber which cannot be used by poultry, but is a source of some vitamins.

Other grains are also supplied as energy sources. Each one has somewhat different nutritional properties. *Sorghums (milo, millet, kafir corn), barley, and oats* are frequently used. Crushing or grinding is usually recommended and in some feedstuffs husks should be removed if possible.

Rice screenings are sometimes included in poultry rations after lighter husks have been removed. Such products must be fed while fresh after winnowing.

Cassava (manioc) roots contain large quantities of starch and may be incorporated in levels up to 25% of mixed feeds after drying to remove toxic hydrocyanic acid.

Potatoes and yams (sweet potatoes) have been used as a short-term energy substitute for grain products.

Molasses may be used in levels up to 5% as a carbohydrate source.

Cane juice has been used at 60% in broiler diets. Cane juice and molasses are valuable sources of energy, but they contain almost no protein.

Fats - oils and tallow from plant or animal sources are sometimes added to mixed feeds to supplement energy supplies. Between 3 and 6% of the ration is generally recommended.

The birds energy intake needs to be in balance with the protein and other nutrient intakes for the optimum utilization of the diet for meat and egg production.

2. Feedstuffs Rich in Proteins and Amino Acids. All new body cells of a baby chick are synthesizing distinctive new proteins from as many as 20 different amino acids. Amino acids, the building blocks of proteins, are derived from plant and animal feedstuffs. Some amino acids cannot be synthesized by chickens (arginine, lysine, histidine, leucine, isoleucine, valine, methionine, phenylalanine, tryptophan, and threonine). They are called essential, or indispensable, amino acids and must be present in each poultry ration. Other amino acids can be synthesized only in some situations (cystine, glycine, serine and tyrosine).

General signs of amino acid or protein deficiencies include growth depression, abnormal feather development, decline in egg production, and especially reduced egg size in laying hens. Deficiency of the amino acid lysine causes lack of pigment deposit in black or reddish colored feathers. One-third of the protein in a hen's diets may come along with energy from the grain source. The key to protein feeding is to compliment the chosen grain source. Most grains are low in lysine and high in methionine, so the best protein supplements are likely to be legume and/or animal protein meals, which are high in lysine and low in methionine.

Feedstuffs Which Contribute to Protein Needs

1) Plant Sources. Soybeans and Soybean oil meal. Soybean protein is rich in lysine, and therefore an excellent compliment to grain proteins. Soybeans must be cooked or heat treated to destroy growth-inhibiting substances. Heat processed whole beans make an excellent high protein (36%), high energy, supplement. Meals with the oil removed are excellent protein supplements containing approximately 44-49% protein.

Peanut Meal (Groundnut) may contain 47% protein but is deficient in some amino acids, particularly lysine, methionine and cystine.

Cottonseed Meal may contain up to 43% protein but a toxic compound ("gossypol") must be removed by special treatment before it is fed. If the meal is not treated growth depression occurs in chicks and egg yolks are discolored.

Meals from *sunflower, safflower, sesame, tung nut, kapok oil, palm kernel, rubber seed, copra, field peas, navy, lima, winged,* and *other beans* together with *brewers* and *distillers by-products* have been used for protein supplementation. Each product can be fed at low levels, but all have limitations which need to be considered in feed formulation. The amounts of these meals that may be economically fed are dependent on the source of each ingredient. The best approach is to buy from a reliable source, and learn from trial and error how much of each ingredient can be fed. If the source and quality of an ingredient changes, the birds response may also change.

2) Animal Sources. Meals made from fish, meat, blood, offal (visceral wastes), and *feathers,* contain varying levels of essential amino acids and minerals. Phosphate supplements are often expensive and animal protein meals are usually good sources of available phosphorous. Surplus dairy products such as milk and whey are also good sources of scarce amino acids and some essential minerals. Buttermilk is an excellent supplement to grain-based diets; it increases palatability and adds nutrients. It may be poured on the feed in the trough. To prevent mold formation, add only enough for a few hours consumption in hot climates, and not more than will be consumed in one day, even in cool climates.

3) Synthetic Amino Acids. Two amino acids, lysine and methionine, that often limit the nutritional quality of feedstuffs, are now available at competitive prices as feed supplements from commercial manufacturing processes. Synthetic methionine hydroxy analog is also available as an economic methionine source for poultry. This analog is quickly converted to methionine in the bird's body, taking advantage of waste nitrogen available in the bird.

Other Ingredients

Many other ingredients may be included in poultry diets if available at reasonable prices. These include grain crops and animal and plant by-products. Each contains different amounts of protein, energy, vitamins and minerals. Examples: bananas, carob pods, coconut products, copra meal, cowpeas, dried dates, gram, horse beans, alfalfa (lucerne) meal, lupins, lobster waster, manioc, millet, molasses, palm kernel cake, pineapple leaf meal, rice bran, rice paddy, simsim (sesame) cake, snails, sweet potatoes, dried worm meals,

and yucca products.

3. Vitamin Supplements. Some 13 different vitamins are required to produce healthy chickens. Deficiency symptoms (Table 1) sometimes indicate the absence of one specific vitamin, but more frequently, these symptoms indicate shortages of several vitamins and/or minerals.

TABLE 1. SIGNS OF VITAMIN DEFICIENCIES AND NATURAL SOURCES

Vitamin	Signs of Deficiency	Rich Sources
Vitamin A retinol	"nutritional roup" ataxia, eye infections, urate deposits, reduced egg production poor hatchability	green forage corn gluten meal yellow corn (carotene) fish oil
Vitamin D	rickets, soft bones, poor growth, feather- reduced egg production	chicks in sunlight synthesize this vitamin
Vitamin E tocopherol	"crazy chick disease" encephalomalcia, edema, muscular dystrophy poor hatchability	alfalfa meal, vegetable oils wheat germ
Vitamin K	hemorrhaging, poor blood clotting	alfalfa green pasture fish meal
Vitamin B_1 thiamin	"star gazing" loss of appetite, weight loss, convulsions laying stops	leafy feedstuffs milk and grain products oil seed meals
Vitamim B_2 riboflavin	curled toe paralysis, reduced growth and hatchability	alfalfa, green grass milk by-products fermentation products
Pantothenic acid	dermatitis of feet, poor growth and feathering, lesions of mouth, eye lids	alfalfa, green grasses, milk products distillers' fermentation products
Nicotinic acid niacin Vitamin B_6	slipped tendon (perosis) hock enlargement poor feathering dermatitis poor growth & coordination, convulsions	wheat middlings corn gluten meal alfalfa milk products soybean meal meat and fish meals
Biotin	poor growth, dermatitis in feet, mouth, eyes, slipped tendon, reduced hatchability	green pasture soybean meal, grains, dried yeast milk products

Folacin folic acid	poor growth slipped tendon anemia, poor feathering and hatchability	leafy vegetables
Choline	slipped tendon="perosis" poor growth and egg production	fish and milk products soybean meal
Vitamin B_{12}	anemia, poor growth and hatchability animal manures	fish and animal by-products

Many of the vitamins are readily available in grains, green fodder or natural fermentation products if scavenger management is used. The B complex vitamins appear in yeasts and fermented animal manures. Supplemental B complex vitamins and vitamin A are sometimes furnished in small poultry operations by providing cut-up green fodder. Although vitamins from this source deteriorate rapidly, they may be preserved by drying. For this reason alfalfa meal is often used as a feed supplement. The poultry producer should be on the lookout for milk by-products such as whey and brewery waste products when vitamin supplements are needed.

The alternative to natural feed sources for vitamins is the inclusion of a concentrate as a feed supplement. Most of the vitamins are inexpensively produced from chemical processes or from fermentation waste products. Concentrates of vitamins as well as trace mineral additives are available commercially. Shipping charges are low since only small quantities are required. For example a typical premix added at the rate of 0.05% of the diet provides (per kg/diet): vitamin A, 5,500 IU; vit. D_3 1100 ICU; vit. E, 11 IU; riboflavin, 4.4 mg; Ca pantothenate, 12 mg; nicotinic acid, 44 mg; choline Cl, 220 mg; vit. B_{12}, 6.6 mcg; vit. B_6, 2.2 mg; menadione, 1.1 mg; folic acid, 0.55 mg; d-biotin, 0.11 mg; thiamine, 2.2 mg (as thiamine mononitrate); and an antioxidant to increase the vitamin stability. Purchase of such a premix should be seriously considered by any poultry producer who must mix his/her own feed.

4. Mineral Supplements. Nine or more inorganic elements are often lassified as essential minerals. They must be supplemented to the diet if absent from the major feedstuffs. Calcium, phosphorus, sodium, potassium and chloride must be present in relatively large quantities. Potassium is generally available from practical ingredients, while sodium and chloride are provided by salt. Calcium and phosphorous supplements need to be carefully balanced. Suggested feed levels for calcium are 0.9 to 1.0% for pullet starter and broiler feeds, and 3% for layer feeds. Since large quantities of these minerals, with costly shipping charges, are required, a local supply of limestone and bone

meal is desirable. Calcium and phosphorus are necessary for good bone structure and egg shells. An absence of either, or a vitamin D deficiency, causes a condition of soft bones called rickets. A balance of 2 parts of calcium to 1 part of available phosphorus should be maintained for growing chickens. Two-thirds of the phosphorous from plant materials is considered non-available. Layers need no more than 0.32% available phosphorus. Cooked or pasteurized hatchery waste containing egg shells has been used as a source of calcium. Crushed limestone or oyster shells are often provided in separate containers so hens may supplement their diet by free choice of calcium. This practice is unnecessary if layer feed formulation is properly balanced.

TABLE 2. SIGNS OF DEFICIENCIES IN ORGANIC ELEMENTS AND FEED SOURCES

Inorganic Elements	Deficiency Signs	Feed Sources
calcium	rickets, soft bones thin egg shell growth retardation	oyster shell ground limestone (low or no fluorine) bone meal
phosphorus (phosphates)	rickets reduced egg production thin egg shells	cereals bone & fish meals defluorinated phosphates milk products
sodium	poor growth cannibalism	common salt animal products
potassium	poor growth	plant feedstuffs
iron	anemia	plant & animal products
manganese	slipped tendon (perosis) "star-gazing"	rice hulls wheat middlings
selenium	severe anemia exudative diathesis poor egg production	fish meals brewers yeast
iodine	goiter	fish meal brewers yeast

Several other inorganic mineral elements are required in minute quantities (Table 2). Since these "trace" elements are light in weight they may be shipped inexpensively in trace-mineral premixes. Recommended levels have been established for iron, iodine, zinc, manganese, copper, magnesium and selenium. The trace mineral status of feedstuffs is highly dependent on the quantity present in the soils in which they were grown. When all the feed ingredients in a diet come from one geographic region, the chance of trace mineral deficiencies in animals is greatly increased. Other trace elements which may be important under special conditions include fluoride, nickel, tin, and vanadium.

Diseases caused by trace mineral deficiencies include: iron—anemia, iodine--goiter, and zinc—enlarged hock joints. The absence of dietary selenium causes a disease condition with appearance of gelatinous green pustules under the skin ("exudative diathesis"). This condition appears in limited areas of the world. In other areas selenium levels are high enough to prove toxic to large animals. Feedstuffs grown in soils containing low selenium levels require added traces at the level of 0.2 mg per kilogram of diet. A typical mineral premix used at the rate of 0.05% to the diet would add in mg per kilogram of diet: Manganese, 60; Zinc, 50; Iron, 30; Copper, 5; Iodine, 1.5; Selenium, 0.1. Wood ashes often provide many of the trace elements in scavenger poultry management.

Supplying insoluble grit in the form of small stones has sometimes been recommended for confinement rearing to assist the gizzard in grinding feedstuffs. However many feeding trials indicate that this practice is no longer considered necessary when feed ingredients are routinely ground. Scavengers or yard chicken will search out their own grit sources.

5. Water. Chickens require free access to clean, preferably cool drinking water at all times. All growth, body maintenance, activity, and egg production requires water. Water makes up 85% of the body weight of a chick. Although chicks can survive for several days or even weeks without feed, a 20% weight loss due to water deprivation results in death. Molting may be induced by short periods of water deprivation (1 to 2 days). Complete water deprivation may result in death in less than one day in hot weather. Water requirements are greatly increased for body cooling during hot weather. After initiation of the panting reflex, water losses from the lungs are greatly increased.

Chickens are particularly sensitive to poisoning with common salt if it is accidentally introduced in the water or added in excess amounts to feed. Water contamination from cadmium, chromium, copper, mercury and zinc should also be monitored. Using water from wells high in chloride may cause permanent change in hens resulting in poor quality of egg shells.

A condition known as "flushing" can result when hens are deprived of water for short periods in hot weather. Overconsumption after access to water is resumed resulting in diarrhea.

6. Non-nutritive feed additives. Since mixed feeds are universally used in large commercial poultry enterprises, the inclusion of non-nutritive substances as feed additives is a convenient method of insuring a uniform intake. These additives, which are manufactured, distributed and advertised by commercial companies, are sold as concentrates diluted by feedstuff carriers. They include: 1) medications: antibiotics, anticoccidials, insecticides and vermicides; 2) growth producing factors such as certain organic arsenicals; 3) chemical preservatives such as antioxidants to prevent rancidity in fats; 4) antifungal agents to pre-

vent molds from producing toxic substances; 5) detoxicants such as ferrous sulphate to reduce the toxicity of gossypol; and 6) yellow pigments ("carotenoid products") to color skin and egg yolks when consumers have expressed a preference.

To protect human health all of these additives must pass stringent governmental safety tests before their use is permitted as feed additives.

C. Sources of Poultry Feeds. The aspiring poultry producer faces three possible choices for finding a suitable feed source: 1st) prepare his/her own feeds from locally available grains and supplementing with as many natural feedstuffs as possible; 2nd) mix feeds using locally secured grains plus protein supplements and adding imported concentrates which contain essential mineral and vitamin supplements; or 3rd) rely upon a poultry feed manufacturer to supply nutritionally balanced feed for each class of poultry. If a reasonably-priced mixed feed is available, the small poultry producer may develop a good working relationship with a reputable dealer. Producers may best rely on a mutual exchange and trust developed with a feed dealer. Feed manufacturers may employ a nutritionist to guide in feed formulation. Production comparisons with different diets should be encouraged by the poultry producer and the feed manufacturer. Results should be compared using two or more feedstuffs under identical conditions. More than one trial may be required and statistical comparisons should be considered before firm conclusions are warranted.

D. Feeding Systems. Producers with a few scavenging birds may first want to supplement their birds' diet. Green feeds may be grown in season for birds on range. Chickens, turkeys and other fowl will harvest them directly, or they may be cut, dried and stored for feeding to birds in cages. Green pastures are excellent, high protein, high vitamin, feeds for all types of poultry. The importance of storing water (damming streams, irrigation, winter crops) to keep pastures green and growing out of season cannot be overemphasized. Alfalfa, clover and many local grasses make excellent forage crops. Energy and mineral supplements are usually required to improve performance by range birds. Scavenging birds can be given grain or concentrate premixes made by mixing grain with some protein and mineral supplements. Concentrates for range fed birds may contain the energy and vitamin and mineral levels of mixed feeds. The protein supplement is left out if the birds are consuming plenty of high protein, growing plants.

Poultry may be fed a small amount of a concentrate feed and then all of a cheap, bulky feed that they will eat. Rice bran with rubber seed meal or palm kernel cake can make an adequate supplement to banana or cassava wastes fed ad libitum.

If the market for chicken meat or eggs is adequate to justify ex-

pansion, the producer may consider mixing his/her own feed. There are advantages to using a large number of ingredients in any formula, thus making available a good balance of amino acids and adequate vitamin levels more likely. If commercial vitamin and trace mineral supplements are not available, reasonable levels can often be achieved with local ingredients. Animal by-products, milk by-products like whey and buttermilk, milling products like wheat bran and middlings, all make good vitamin-rich ingredients for poultry feeds. Finally, if available, complete mixed feeds may be purchased.

E. Quality Assurance. More important than the type of any ingredient used is its quality. Corn may be universally recognized as an excellent feedstuff for poultry. However, corn with certain types of mold growing on it can be deadly. The value of any feedstuff should be determined by it's ability to promote growth or egg production. Possible growth inhibiting contaminates in ingredients always need to be considered. These include weed seeds, molds, vermin pellets (which may also carry disease with them), toxic chemicals, unusually high levels of one nutrient in a certain ingredient (like high calcium in fish meal), and insect larvae. **Buyer Beware!**

F. Formulas for Feed Rations. A new poultry producer faced with feeding problems for the first time frequently asks: "What feed formula should I use?" From thousands of successful formulations, there can be no simple answer. Possible feedstuffs vary in content of nutritional constituents, availability in different areas, and cost. Formulas for chickens are often classed as starter, grower, finisher, layer, or breeder rations and they vary with breeds, climate and other classes of poultry. Large manufacturers may change formulation daily or weekly depending upon cost and the availability of substitute ingredients.

Several years of study in poultry nutrition are required to formulate a feed which includes all essential ingredients and is cost competitive. More is known about the nutrition of poultry than any other animal including man. Most large feed companies employ a nutritionist who makes use of computer technology in formulating a least-cost ration. Such formulas are often considered confidential. References on feed formulation (Section 10) provide outlines of the essential tools required.

G. Sample Feed Formulas. Beginning poultry producers may want to start with a simplified feed formula like one of those listed below. Ingredients are listed in percentages which may be weighed out in kilos or pounds. If chicks are kept indoors 1/2 kg of stabilized cod liver oil or a commercial vitamin supplement must be added to each 100 kg of feed.

H. Feed Mixing and Delivery. After the feedstuffs required in the formula are assembled, the laborious task of feed mixing can be undertaken. Some ingredients are ground in a hammer mill to provide a fine meal. Bulky ingredients may be poured out on a concrete slab

and lesser ingredients, including premixes, are placed on top. Premixes include vitamins, minerals or anticoccidial drugs are used in small quantities. Your own premixes may be prepared by diluting the essential additive with 1-5 kilos of corn or another ingredient. This mixture is blended by turning several times in a closed container (Figs. 59, 60 and 61) or in a plastic bag. All ingredients are turned over several times with a shovel, hoe, or in a feed mixer. As the enterprise grows, mixing the larger quantities of feed may require a mechanical mixer. A hand crank or an electric motor should rotate the drum for several minutes to assure thorough mixing. Rations are usually fed as a dry mash. More sophisticated feed mills use heat and pelleting machinery to produce crumbles or pellets which improve growth and feed efficiency. Although some mixed feed can be stored for a month or two, speed of deterioration of nutrients varies with different ingredients and holding environments. In hot climates some ingredients begin to deteriorate within a week.

Feed Mixers

Fig. 59. Tumble mixer with hand crank. Excellent as a premixer with a 5 gallon can. A 50 gallon oil drum can mix up to 50 kilos of feed

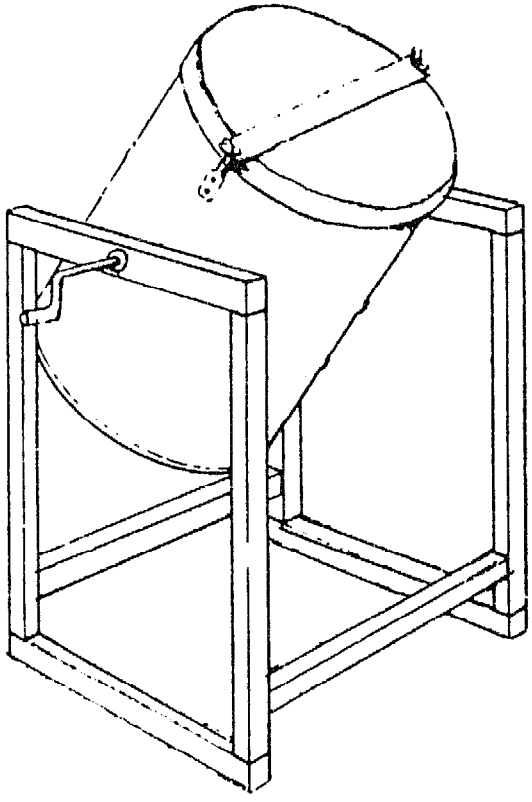

Fig. 60. End view of the same mixer

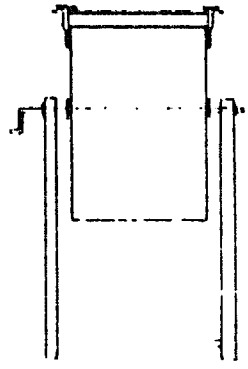

Fig. 61. Another mounting for a clean 50 gallon oil drum requires a specially fabricated locking door

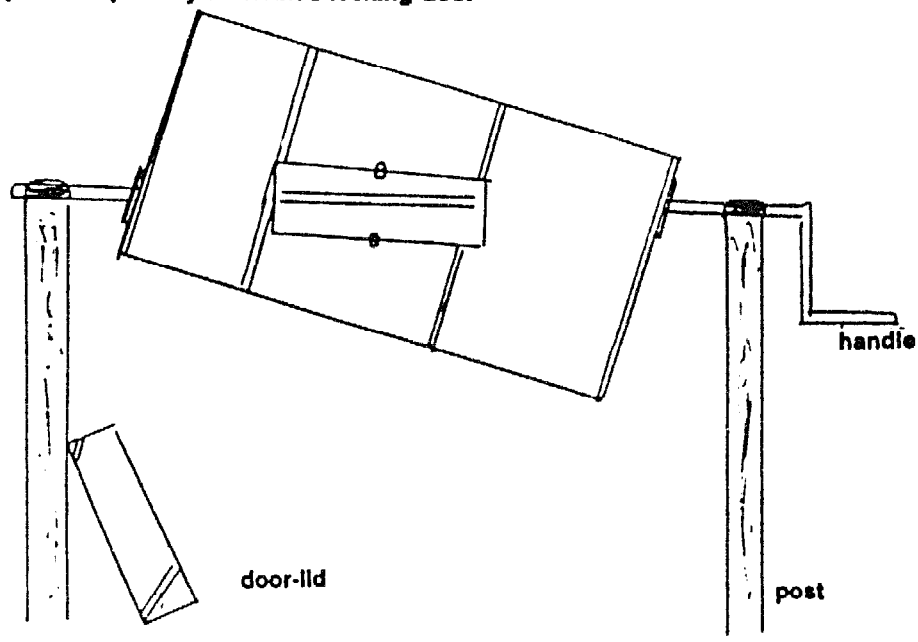

Many poultry producers have come to rely upon feed manufacturers to purchase and assemble the ingredients. Specialized heavy equipment is employed to mix and bag the feed. Bulk delivery systems may save expense and labor if storage bins and good roads are available. Unfortunately many producers have been disappointed when substitution has been made in the feed formula by the manufacturer. A loss of reputation is often the best control over the unreliable substitutions sometimes made in a feed mill. Governments sometimes require tags indicating minimal ingredient levels within the bag.

Many aids for transporting the feed to the premises and into the house have been devised. Feed wastage needs to be guarded against. A common rule with a trough-type feeder: "never fill the feeder more than half full".

SAMPLE RATIONS FOR EGG LAYING OR DUAL PURPOSE CHICKENS

Ingredients	Starter A Weeks:1-8	Starter B 1-8	Grower 9-20	Layers 20+
	Percentage			
Ground or finely cracked grain	49.5	29.5	49.5	21.5
Grain milling by-products	20.0	20.0	-	25.0
Wheat bran or rice bran	-	15.0	30.0	15.0
Soybean oil or legume seed oil meal	10.0	-	5.0	15.0
Meat, fish, poultry scraps or meals	10.0	10.0	10.0	10.0
Alfalfa or other dried forage	5.0	5.0	-	5.0
Ground nut, sesame cotton seed meal	-	15.0	-	-
Dried whey or distillers by-product	3.0	3.0	5.0	-
Steamed bone meal or geed grade phosphate	-	2.0	-	3,0
Salt	.5	.5	.5	.5
TOTAL	100	100	100	100

SAMPLE RATIONS FOR COMMERCIAL BROILER PRODUCTION

Ingredients	Starter Weeks: 1-3	Grower-Finisher 3-10	Withdrawal last week
	Percentage		
Ground or finely cracker grain	58.65	63.15	68.20
Soybean, or legume seed meal	31.00	22.50	16.50
Corn gluten meal 65%	3.00	4.00	
Meat, fish, poultry scraps or meals	5.00	5.00	5.00
Fat (feed grade)	3.00	4.00	4.00
Crushed limestone or oyster shells	.65	.65	.65
Feed grade phosphate	1.25	1.25	1.25
Salt	.25	.25	.25
Methionine supplement	.15	.15	.10
Trace mineral mix and vitamin premix	.05	.05	.05
TOTAL	100	100	100

SAMPLE RATIONS FOR LAYING CHICKENS FED IN SRI LANKA

Ingredients	Chicks (0-8 weeks)	Chicks (8-18 weeks)	Layers
	Percentage		
Tambagalla (sorghum)	239.5	44.5	41.5
Rice bran	7.0	23.0	19.5
Fish meal	10.0	12.0	8.5
Coconut meal	25.0	20.0	18.5
Gingelly *(Sesamum indicum)* cake	12.0	-	2.0
Shell grit	-	-	6.5
Salt	0.5	0.5	0.5
TOTAL	100.0	100.0	100.0
Added per 100 kg:			
Potassium iodide (g)	0.14	0.145	0 0.145
Choline chloride (21.7%) (g)	555	530	540

SAMPLE RATIONS FOR LAYING CHICKEN FED IN ZAIRE

Ingredients	Starter Week: 1-8	Grower 8-24	Layers 24+	Layer Concentrate*
	Percentage			
Maize, ground	33.0	40.0	40.0	20.0
Millet, ground	22.0	15.0	20.0	18.0
Rice, dehulled, ground	11.0	-	-	-
Rice, paddy, ground	-	10.0	10.0	10.0
Fish meal	7.5	7.0	3.0	4.0
Meat meal	-	-	3.0	5.0
Skim milk, powder	5.0	6.0	-	-
Yeast, dried	3.0	1.0	1.0	-
Groundnut cake meal	9.0	12.5	12.0	25.0
Alfalfa meal	7.5	5.0	7.0	12.0
Dicalcium phosphate	0.5	1.0	0.5	2.0
Oyster shells	1.0	2.0	3.0	3.0
Salt	0.5	0.5	0.5	1.0
TOTAL	100	100	100	100

*To be fed free choice with a grain.

SAMPLE RATIONS FOR LAYING CHICKENS FED IN URUGUAY

Ingredients	Layers	Chicks
	Percentage	
Ground maize	40.0	40.5
Ground wheat	5.0	20.0
Sorghum	3.0	-
Ground barley	20.0	16.0
Bran	10.0	-
Meat meal	7.0	15.0
Ground sunflower cake	10.0	7.0
Oyster shells	4.0	1.0
Salt	1.0	0.5
TOTAL	100	100

Section 7

Poultry Health Problems

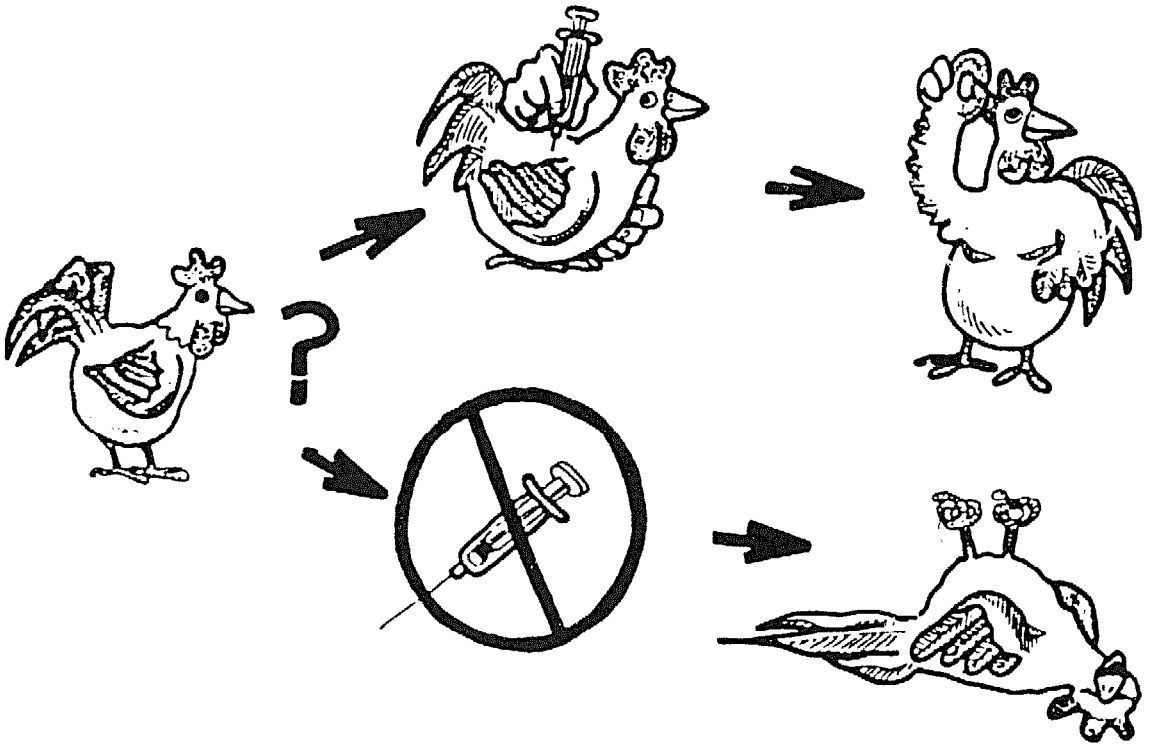

POULTRY HEALTH PROGRAMS

A. Prevention versus Treatment. PREVENTION IS THE KEY TO CONTROL OF POULTRY DISEASES. The poultry producer may think first of a drug treatment in case of a disease outbreak. Such a response, learned from treating human ailments, starts with the wrong premise for control of poultry diseases. He/she needs to remember: 1) drugs are expensive, 2) treatment must involve the entire flock, 3) to catch each bird individually requires much effort if treatment is given by mouth or injection, 4) if given by feed or water special mixing equipment may be required, 5) specific medication is generally successful only after a specific disease has been accurately diagnosed, 6) too long a delay frequently occurs before treatment can be instituted 7) indiscriminate use of antibiotics leads to the establishment of resistant strains of bacteria. Prevention is generally accomplished by:

1) Vaccination for specific diseases such as Newcastle, and fowl pox.

2) Blood testing breeder hens to locate and eliminate carriers of such diseases as pullorum and chronic respiratory disease (CRD). Chicks should be purchased only from blood-tested pullorum mycoplasma-free breeders.

3) Providing nutritionally balanced feeds complete with essential vitamins, minerals, amino acids, and energy to prevent nutritional deficiency diseases.

4) Feeding recommended levels of anticoccidial drugs to broilers if available for the first two months to prevent coccidiosis losses. Some recommended high levels for breeders or layers may prevent sufficient exposure to permit oocysts and prevent protective immunity.

5) Enforcing sanitary rules as:

a) Never introduce older birds into a young flock.

b) Prevent visitors (including neighbors), wild flying birds, rodents and especially other poultrymen from entering poultry houses.

c) Avoid visiting neighbor's flocks and returning to your own without a complete change of footwear and clothing.

d) Keep dirty crates, egg cartons, feed sacs and other contaminated items from poultry houses.

e) Establish an "All in, all out" rule to keep birds of one age together.

f) Practice a sanitary clean-up and waiting period (2-week minimum) before introducing a new flock to previously used pens. Exposure to direct sunlight kills many organisms.

g) Promptly remove dead birds and dispose of them by burning, deep burial or a specially constructed deep pit. Composting methods in tight containers has proved successful if large numbers of birds must be disposed of.

B. Classification of Diseases of Chickens. Diseases of chickens with a few examples may be classified under seven different causes: 1) bacteria (fowl cholera, coryza, fowl typhoid, mycoplasma, pullorum); 2) virus (fowl pox, Newcastle, infectious bronchitis); 3) internal parasites (tapeworms, roundworms); 4) external parasites (lice, mites, ticks); 5) protozoa (coccidia, blackhead); 6) fungus (fungus infections and toxins produced by molds); 7) nutritional deficiency (rickets, see Section 6).

1) Bacterial diseases. Bacteria from infected birds may be demonstrated by culturing, staining and examination with a light microscope. Various types of selective media are used to demonstrate pathogenic species. Several important bacterial diseases are now controlled or eradicated from poultry flocks in many countries. Control of pullorum disease, also known as "bacillary white diarrhea", is a good example of cooperative disease control. It causes a chalky-white diarrhea and severe mortality in newly hatched chicks. The liver, heart or lungs may show enlargement and reddish spots. Since it is transmitted chiefly to chicks through eggs from infected hens and chick to chick during hatching, blood testing of all breeder flocks and removing carriers over a period of years has almost eradicated this disease in many countries. Through voluntary effort good hatcheries have systematically carried out this blood-testing program with a minimum of governmental supervision. A person buying baby chicks should request only pullorum-clean stock. Fowl typhoid, caused by another bacterium belonging to the same genus (Salmonella), is likewise detected and controlled in a similar manner.

More recently mycoplasmosis, caused by a much smaller bacterium belonging to the genus *(Mycoplasma)*, has become a breeder farm-hatchery-controlled disease. It is sometimes known as "air sac disease" or CRD (Chronic Respiratory Disease) which causes coughing, sneezing and pus formation in the air sacs. Chicks derived from Mycoplasma-infected breeders are susceptible to secondary bacterial infections. These infections are more prevalent after vaccination or other stresses. Once newly hatched chicks are mycoplasma-clean, more sanitary precautions are required to keep the disease from reinfecting flock premises than in the case of pullorum disease. An eradication approach is required to eliminate mycoplasmosis.

2) Viral diseases. Although viruses are so small they can be demonstrated only with an electron microscope, their presence or absence may be detected by blood testing the flock. Since treatment with antibiotics is not successful, emphasis is placed on vaccination. Before starting a vaccination program seek help from local veterinarians, poultry health experts, or poultry extension agencies

on sources of vaccine and need for vaccination against specific diseases. They will know the local needs which vary greatly in different areas. Vaccines successful in some areas may be ineffective in others due to differences in strains and manufacturing methods. They will be aware of precautions necessary to prevent accidental introduction of new diseases if live-virus vaccines are to be used. Some examples of diseases controlled by vaccination:

Newcastle (Raniket Disease in Asia) is often the most feared disease by poultry producers throughout the world. Symptoms include sneezing, gasping, tremors, paralysis, and decreased egg production. Mortality may be as high as 100%. Vaccinating all the birds in a village or area has been successful in controlling this disease. Useful vaccine strains vary in different areas and may be administered by individual injection, via drinking water, or incorporated into pelletted feeds.

Marek's disease vaccine is used on practically every broiler, breeder and commercial egg pullet in the hatcheries in the USA. This vaccination prevents leg paralysis and a cancerous-type of tumor on the internal organs of young chickens.

Fowl pox, a highly contagious disease, is readily transmitted from one bird to the next by mosquitoes. Scabs or ulcers form on the comb, wattles, around the eyes, and in the mouth and throat. Vaccine is often administered by inserting a specially designed needle into the wing web. Care must be taken to prevent feathers from removing the vaccine from the needle. Protection requires mosquito control and vaccinating birds which are likely to be exposed.

Other vaccination programs. Vaccination is also practiced to prevent: Infectious Bronchitis, Infectious Laryngotracheitis, Avian Encephalomyelitis, and Infectious Bursal Disease ("Gumboro"). Somewhat different vaccination programs have been used with the bacterial diseases Infectious Coryza, Fowl Cholera, Fowl Typhoid (never in breeders) as well as the protozoan disease causing Coccidiosis. Methods of administration vary with each disease and type of vaccine. Always follow vaccine manufacturers recommendations on methods of vaccine storage and administration.

3) Internal Parasites (roundworms, tapeworms, flukes) frequently appear during post mortem examinations. The producer may be unduly alarmed by the presence of a single or a few parasites recovered from the digestive system or other parts of the body. Harmless host-parasite relationships have developed after many generations of exposure to parasites. However, crowding or other rearing practices sometimes produce heavy infections which require corrective measures. Control efforts should first be directed to breaking the life cycle to reduce reinfections. A few management changes may make this possible. Treatment to reduce the parasite load may be also be desired.

Piperazine removes the intestinal roundworm if given in water or feed (Fig. 62). Problems with heavy loads in successive crops of broilers have been eliminated by giving monthly treatments for several months. Since the recently hatched young worms do more damage than adults, benefits come largely from eliminating adult females producing eggs. The dosage should be calculated at the rate of 50 to 200 mg of piperazine per bird depending on the body weight. Piperazine preparations are available as various salts so that dosage needs to be adjusted to include only the piperazine portion. Best results come from water medication when birds are thirsty thus assuring high drug levels in the gut. Suggestions for identifying and controlling some worm parasites are presented in Table III.

Fig. 62. Large roundworms and cecal worms

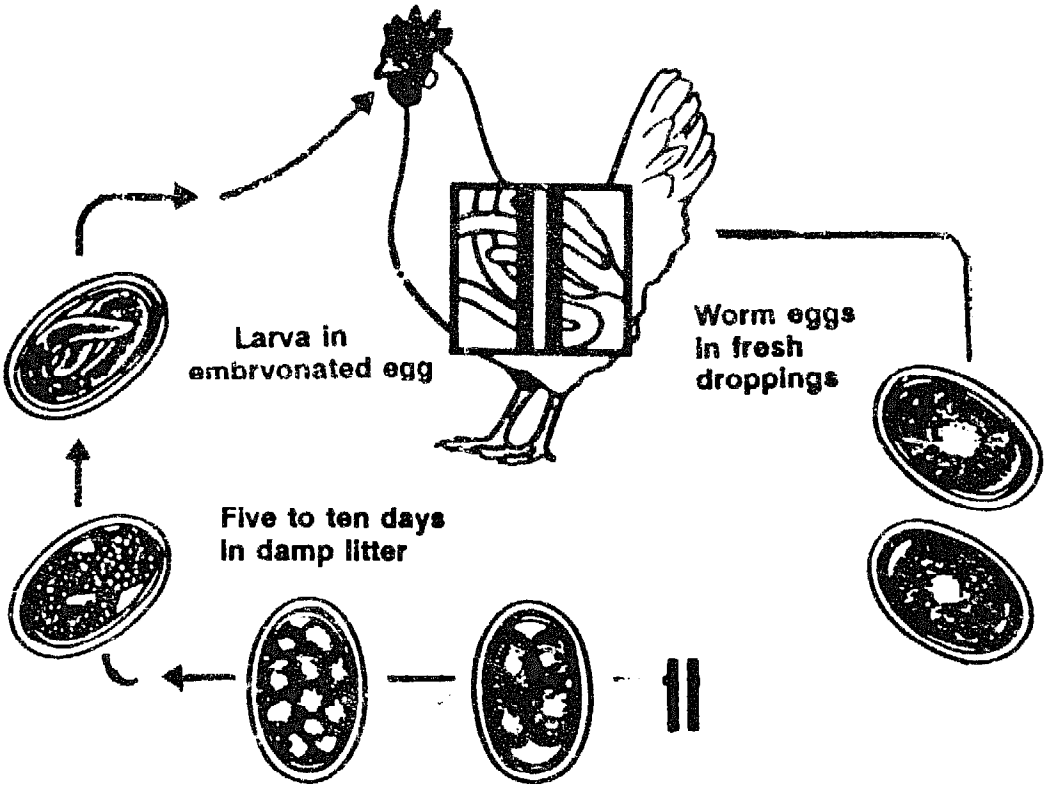

Break the life cycle || by treating the birds to remove adult female worms or remove infective embryonated eggs in litter

TABLE 3. Control of worm parasites.

Parasite	Location	Prevention	Treatment
Roundworm (Nematoda) intestinal worm (Ascaridia) 5-10 cm long	Upper small intestine	Treat monthly to remove female worms laying eggs	Piperazine in drinking water 50-200 mg/bird; birds need to consume medicated water rapidly (water starve before treatment)
Cecal worm *(Heterakis)* 0.5-1.5 cm long	Cecum	Prevent turkeys from ranging with chickens; worms transmit the protozoan parasite of blackhead	Phenothiazine 0.5-1 g/bird 0.5-1.5 cm long Levamisole™ 16 mg/lb body wt. (worm removal will not prevent blackhead)
Capillarids, hair-like roundworms often laced deep in tissues (Capillaria spp.)	Crop, esophagus, intestine	Sanitation to prevent eggs from being consumed; control insect intermediate hosts control if involved in life cycle	Administer in the feed 0.0009-0.0013% Hygromycin B or 0.004% Coumaphos
"Gape worm", red worms male and female joined in Y formation. Causes choking in turkeys and chickens	Trachea	Sanitation, confinement rearing, move from earthworm infested ranges.	Experimental drugs will remove but none are approved or practical Levamisole 16 mg/lb (not approved in USA)
Tapeworms (Cestoda) several species each with a different intermediate host	Intestine	Identify the species; break the life cycle by control of the intermediate host	Butynorate (approved in USA in combination with piperazine and phenothiazine treatment often caused more damage than the tapeworm)
Flukes (Trematoda) flatworms - dozens of species - leaf-like	Any organs of the bird	Break the life cycle which usually involves a snail host	None

4) External parasites such as *northern fowl mites, young ticks, lice,* and *fleas* may be recognized while handling birds. Others such as *roost mites, adult soft ticks* and *bed bugs* feed periodically at night and will not be seen in daytime. They may be discovered by deep probing in cracks or crevices with a sharp instrument near roosting areas.

Mites, distinguished by the presence of 8 legs, often build to destructive numbers that cause blood loss and emaciation. Northern fowl mites, which live continuously on the bird, may blacken the vent region when in large numbers. The roost mite may go unnoticed as it hides between the cracks in daylight. Both may be controlled by dusting, dipping or spraying with insecticides directly on birds or the premises.

Lice: several species of lice may be found hidden among the feathers on the neck, under the wings, or around the vent. A few isolated specimens, which feed largely on feathers need not cause great concern. Heavy infestations may call for dipping, spraying or dusting with insecticides.

Fleas are occasionally found in numbers warranting treatment. The stick-tight flea becomes rather permanently attached in clumps around the face. Use insecticides as directed for mites.

Bed Bugs large concentrations of this former human pest sometimes occur in poultry houses. They may be controlled by using insecticides as directed for mites.

Ticks. The "soft tick" may cause severe blood losses and transmit diseases. Larval ticks (6 legs) with a diameter of 1-3 mm remain on the bird and may be found under the wings engorged with blood. Much larger adults (8 legs) up to one cm long hide in cracks around roosting areas. Larval ticks are treated on the bird while the premises must be treated for control of adults.

Chiggers are microscopic larvae of mites which penetrate the skin of turkeys causing blister-like lesions. Although they drop off after two or three weeks, lesions cause carcass disfigurement. For prevention avoid using weed-infested ranges for turkeys.

Mosquitoes may transmit diseases, cause significant blood losses and irritation prevents normal egg production. Control measures require destruction of larvae found in standing water near poultry houses.

Blackflies transmit a malaria-like disease particularly destructive to turkeys and ducks. These gnat-like flies breed in running streams making control difficult. Areas where blackflies are common are generally unsuitable for turkey development.

Houseflies and other nuisance flies may multiply around poultry establishments and produce severe public relation problems. Moist litter under cages provides an ideal breeding area for fly larvae. Improper management of manure has brought on legal closure of some

farms by troubled neighbors. Although large numbers of flies may be killed by use of poisoned baits (Bomyl™, Erythrosine™, Methomyl™), efforts directed at adults are generally less effective than treating larvae in manure. Various chemicals may be added to manure. Larvadex™, is a feed additive which gets in the manure through the feed. Keeping manure piles dry by preventing leaks from roofs or waterers is a good precautionary measure. Birds themselves usually prevent larval development if they have access to scratch in the manure where larvae are present.

Chemical control of external parasites using insecticides has long been practiced. With large flocks, insecticides may be applied directly on the bird by dusting, or high pressure sprays. Spraying, fogging, or dusting is used in houses or on litter. Some producers use nest or dusting box treatments.

With small flocks birds may be individually dipped by submerging them in a tub containing a suitable insecticide. In the USA only 8 of 90 effective drugs have been approved for direct use on birds. Use of chlorinated hydrocarbons (eg. Lindane), although highly effective against external parasites, is strictly forbidden. Long use of an insecticide often makes further use ineffective due development of drug resistant insects.

Currently approved insecticides in the USA include:

Carbaryl (Sevin™)—1 lb. 5% dust on 100 birds or 40 sq. ft. of litter; 1-2 gallons of 0.5% spray applied to 1000 sq. ft of litter or 1 gal./100 sprayed directly on the birds. Used for control of mites, lice, fleas, ticks and bed bugs.

Cycromazine (Larvadex™)—5 parts/million in mixed feed for fly larvae control. Used as a "feed through" feed additive.

Dichlorvos (DDVP™, Vapon™)—0.5% diluted spray on manure for fly larvae control.

Malathion (Cythion™)—4 or 5% dust, 1 lb./100 birds, or 50 sq. ft. applied to litter, 1-2 gals. diluted spray (0.5]/1000 sq. ft. Same directions as Carbaryl. Extended use has reduced effectiveness in many areas.

Nicotine Sulfate (Black Leaf 40™)—painted on roosts for roost mite control. Caution: Note restrictions and directions on label; toxic on skin of birds or operator.

Permithrin (Ambush™, Atroban™, Ectiban™, Permaban™, Praemix™, Pounce™)—1 lb/100 birds 0.25% dust; 1 gal diluted spray to 100 birds. For control of mites, lice, fleas, ticks and bed bugs.

Stirofos (Rabon™, Tetrachlorvinphos)—1 lb. 3% dust/300 birds; 1 gal diluted spray/100 birds or 1000 sq. ft. litter. Effective for direct use on all external parasites.

Producers must follow all label restrictions on the use of any

insecticide.

5) Protozoan Diseases

Coccidiosis is a much feared disease caused by parasitic protozoa which invade the intestine causing diarrhea (which is sometimes bloody) and sudden mortality. Infection results when the bird picks up large numbers of oocysts from the litter (Fig. 63). These microscopic oocysts, which are very resistant to disinfectants, are found almost everywhere chickens are raised. Exposure to a few oocysts at a time gradually induces a protective immunity in many flocks. Thus severe coccidiosis is rare if birds are widely disbursed on range, but is common under crowded conditions. Although potent anticoccidial drugs have been discovered, these are used for prevention rather than for treatment which is usually initiated too late to prevent losses.

Fig. 63. Life Cycle of Coccidia and Severity of Infection

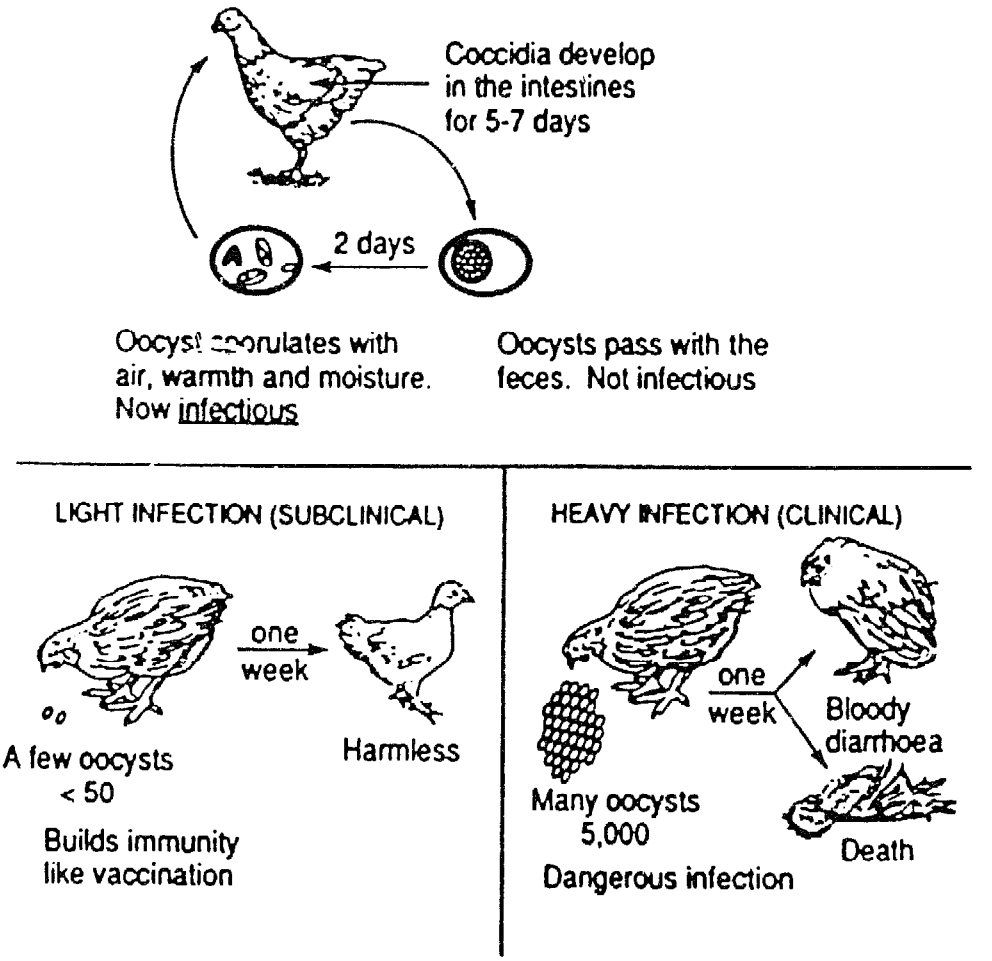

Feed manufacturers usually select one drug to be incorporated in broiler feeds on the basis of price and effectiveness against the several strains and species of coccidia in the area. After extended use resistant strains of coccidia appear so that the drug used is often rotated. Higher levels are sometimes avoided for floor breeders or

layers and discontinued at 8 weeks to permit some natural exposure and immunity development. Anticoccidials currently available with a recommended percentage for broilers in mixed feed:

1. **Amprol™** (amprolium) [MSD-AGVET]—0.0125%
2. **Butynorate** (Tinostat™) [Salsbury]—0.0375% (for turkeys)
3. **Clopidol™** (metichlorpindol) [Rhome-Poulenc]—0.0125%
4. **Halofuginone** (Stenerol™) [Hoechst-Roussell]—0.0003%
5. **Lasalocid** (Avatech™) [Hoffmann-La Roche]—0.0075-0.0125%
6. **Madurimicin** (Cygro™) [Cyanamid]—0.0005-0.0006%
7. **Monensin** (Elancoban™) [Elanco]—0.01-0.0125%
8. **Narasin** (Montiban™) [Elanco]—0.006-0.008%
9. **Nicarbazin** (Nicarb™) [MSD-AGVET]—0.0125%
10. **Salinomycin** (Nicrazin™, BioCox™, Coxistat™, Sacox™) [Kaken, Agri-Bio, Pfizer, Hoechst]—0.0044-0.0066%
11. **Sulfaquinoxaline** (SQ™ [MSD-AGVET]—0.0125% (no longer approved in USA)
12. **Zoalene™** (DOT, Zoamix™) [Salsbury]—0.0125%

Blackhead (Histomoniasis) is a protozoan disease causing ulcers on the liver and cecum and yellow feces. The disease is transmitted through the eggs of the cecal worm to chickens and turkeys. The worm is common in chickens but they are relatively resistant to the disease. Turkeys are much more susceptible to blackhead than chickens. The cardinal rule for prevention—"never rear turkeys with chicken".

6. Fungi or molds. A form of plant life identified by presence of large numbers of microscopic spores and filaments, may cause disease directly or produce toxins harmful to poultry. One genus *(Aspergillus)* common in wet litter sometimes invades lungs causing greenish-yellowish nodules. Fungi which grow in stored feeds high in moisture content may produce toxins (eg., aflatoxin). Dampness which produces conditions favorable for fungal growth in poultry house litter and in stored feedstuffs should be avoided.

C. Mortality. Some mortality is to be expected during growing and laying periods. An excess of over one percent per month indicates serious problems which may require veterinary assistance if available. Remove sick and dead birds from the house. Dead birds should be buried deep, burned or placed in a disposal pit to prevent dogs or wild animal from transmitting disease from the carcasses.

D. Post Mortem (Autopsy) Examinations. With serious disease problems the services of a veterinary diagnostic laboratory should be consulted if available. If unavailable the producer may be able to make a tentative diagnosis after making a post mortem examination. Diagnostic laboratories prefer to receive a few live birds taken as typical flock samples. Rapid post mortem changes often obscure

diagnostic signs if dead birds are submitted. Live birds may be painlessly killed by stretching the neck while the head is bent back around the thumb (Fig. 44). Lesions or color changes will be more easily recognized if normal birds have been previously observed while dressing or processing them (Figs. 64,65,66).

Anatomy of Chickens

Fig. 64. External features

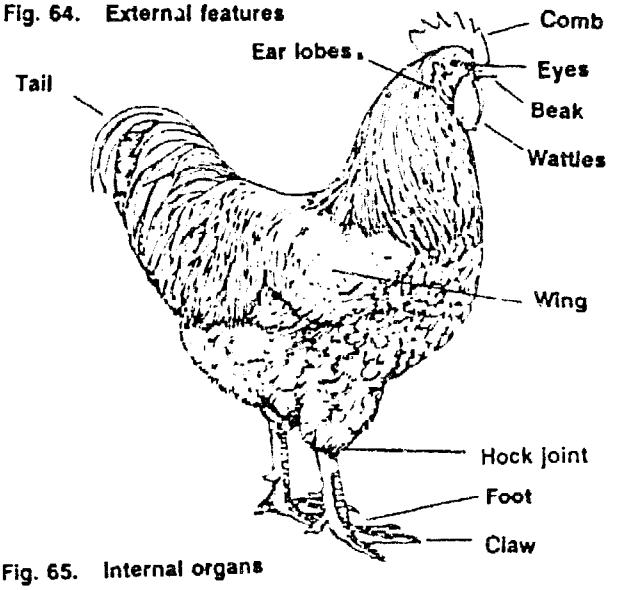

Fig. 65. Internal organs

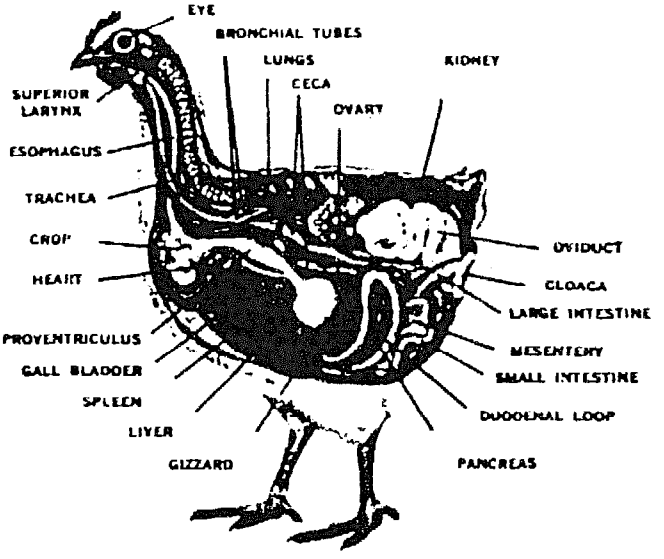

Fig. 66. Digestive system

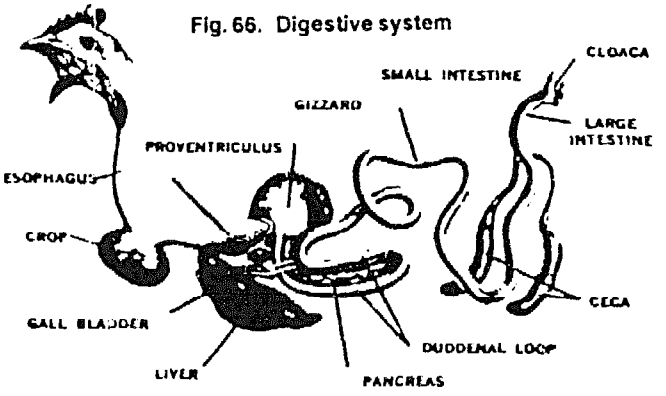

First examine the birds externally. Look between the feathers for mites, ticks, lice or fleas. Watch for skin lesions in nonfeathered areas, which may indicate fowl pox. Cut open the mouth, esophagus and crop looking for active bleeding, ulcers, rough surfaces, abnormal lumps or excess mucus. To examine internal organs make a cut through the skin from the vent to the tip of the breast (keel) bone revealing the viscera. The cut is continued forward on each side through the ribs and breast muscles using heavy scissors. The legs are then pushed out and down from the body until they become disjointed at the hip and lie flat. The keel bone is then raised revealing the heart, lungs, and digestive tract. After removing the entire digestive tract examine the crop, esophagus, proventriculus, gizzard, intestines and ceca both internally and externally for ulcers, bleeding, parasites and other signs of disease (Fig. 66). The liver, heart, kidneys, reproductive organs, and lungs should be examined for abnormal color, spots, or pus pockets. Trachea and lungs are examined for excess mucus, plugs, hemorrhage, inflammation, and consolidation of the lungs (pneumonia). Muscles should be examined for discoloration or lesions. Search for swellings of nerves especially under muscles of the thigh, wings and neck. Watch for soft bones and abnormal lumps for tumors or rickets.

An excellent diagnostic guide listing changes in color and lesions organ by organ is available in The HyLine Redbook. Typical lesions may be recognized after study of colored illustrations in Salsbury's Manual of Diseases of Poultry or The Diseases of Poultry (see Section 10 for book listings).

Drug treatments. Poultry producers waste large sums of money on medication treating undiagnosed disease conditions with little financial return in flock improvement. Drugs have a valid use in treatment of certain diseases after a specific diagnosis has been made by competent diagnostic laboratories. Drugs available in different countries differ greatly. Listed below are drugs sometimes recommended with some technical names of diseases which may be diagnosed. Both dosages and any withdrawal recommendations must be exactly followed.

Blackhead (histomoniasis)—Furazolidone Furoxone (nf-180™, Furox™ (0.022%=200 g/ton), Nitrasone (Histostat-50™) (0.01875%) in feed for prevention; dangerous for ducks, and geese. Although Dimetridizole and Ipronidazole are effective, they are no longer legal in USA.

Cholera, fowl—sulfa drugs in water, Oxytetracycline (Terramycin™), Aureomycin™, Novobiocin, Lincomycin, Spectinomycin™ in feed.

Chronic Respiratory Disease (CRD)—Chlortetracycline, Ery-

thromycin, Furoxone or Furazolidone, Oxytetracycline, Spectinomycin, Tylosin. Culture and sensitivity tests are particularly heloful (effective in producing mycoplasma free breeder flocks by egg dipping).

Coccidiosis—for preventive drugs see part 5 above.

Colibacillosis—E. coli (Furazolidone) or Tetracycline antibiotics in feed, Neomycin and Erythromycin are partially effective. Culture and sensitivity tests are better than indiscriminate use in breeders.

Coryza, infectious—Erythromycin, sulfa drugs, Penicillin and Tetramycin.

Enteritis, ulcerative (Quail disease)—Furoxone (Furazolidone), Chlortetracycline, or Bacitracin in feed, Streptomycin in water or feed.

Erysipelas in turkeys—Penicillin, Streptomycin, or Tetracyclines—may increase carrier rate in turkeys—intramuscular.

Insecticides. See part 4 above.

Salmonellosis—Furoxone, Furazolidone, Sulfonamides.

Staphylococcosis—Novobiocin, Erythromycin, Tetracyclines, Streptomycin; Culture and sensitivity tests desirable.

Worm parasites—piperazine, Wormal™, Hygromycin B™, Levimisole™ (not approved in USA; each species should be identified before drug recommendation is made).

All of these drugs have definite limits on maximum and/or optimum dosage to prevent toxicity. Each had appropriate lengths of treatment, and number of days for withdrawal before birds may be slaughtered for human consumption. In the United States changing regulations for feed medication are updated annually in the Feed Additive Compendium.

E. Diagnosis of Disease Problems. An accurate diagnosis may be more important for future planning than for immediate therapy. Complete diagnosis often involves visiting the flock, a post mortem laboratory examination, microscopic examinations, blood tests, bacterial or egg embryo subculturing, and inoculation tests made on clean birds.

An experienced poultry producer can often detect the early onset of a disease by quietly observing flock behavior. The first sign of a disease outbreak is often a decrease in feed or water consumption. The observer should watch for huddling, wet or bloody feces, listen for coughing, sneezing or gasping, and notice any distinctive odors. Layers may show reduced egg production.

F. Predators, Rodents, and Other Pests

The poultry producer may have serious problems with predators such as hawks, owls, cats, foxes, weasels and other wild animals. At night flocks may be partially protected by providing tight buildings for confinement. Wild birds should be excluded by covering all open-

ings with wire mesh. Legs of cages may be protected against crawling pests by furnishing sheet metal shields (Fig. 67) or by placing each leg in a can containing kerosine.

Fig. 67. Bamboo cage house with a thatched roof. Note the protective barriers on the legs to keep out rodents and snakes

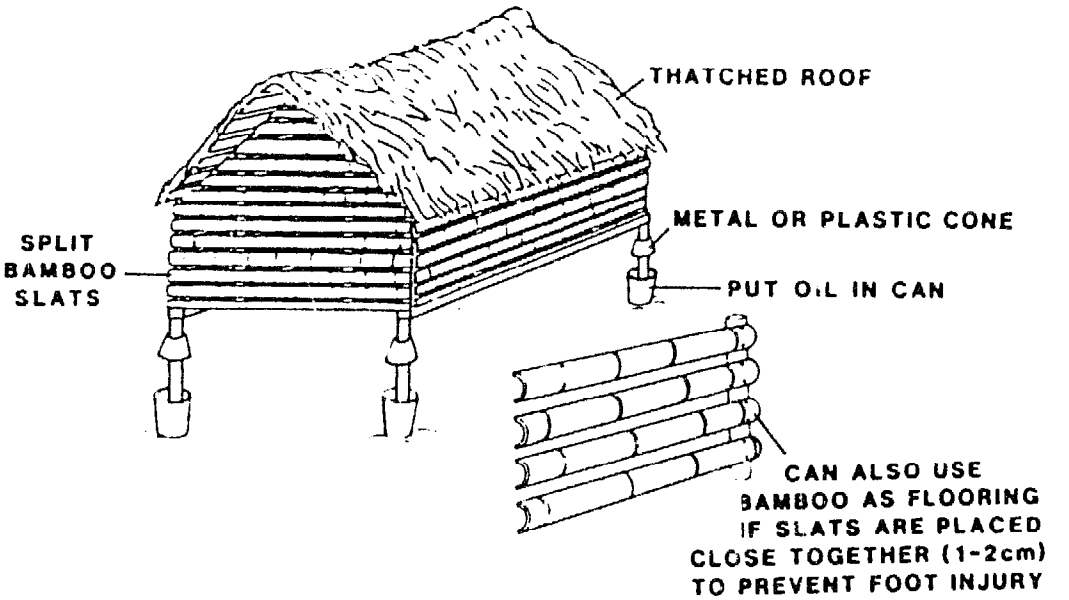

Rats, mice and other rodents are often attracted by feed and may eat sufficient quantities to produce economic losses. Their presence may go unnoticed by the producer since they feed mostly at night. Since trash, weeds, and junk around the house provide hiding places, they should be removed. Rats may be killed by baiting, fumigating, trapping or shooting. Several kinds of baits are frequently available for control. One type illustrated by WarfarinTM kills rats by preventing blood coagulation. Although harmless to chickens, caution is called for around children, pigs, dogs and cats. Follow published directions to attract pests and to avoid hazards to humans.

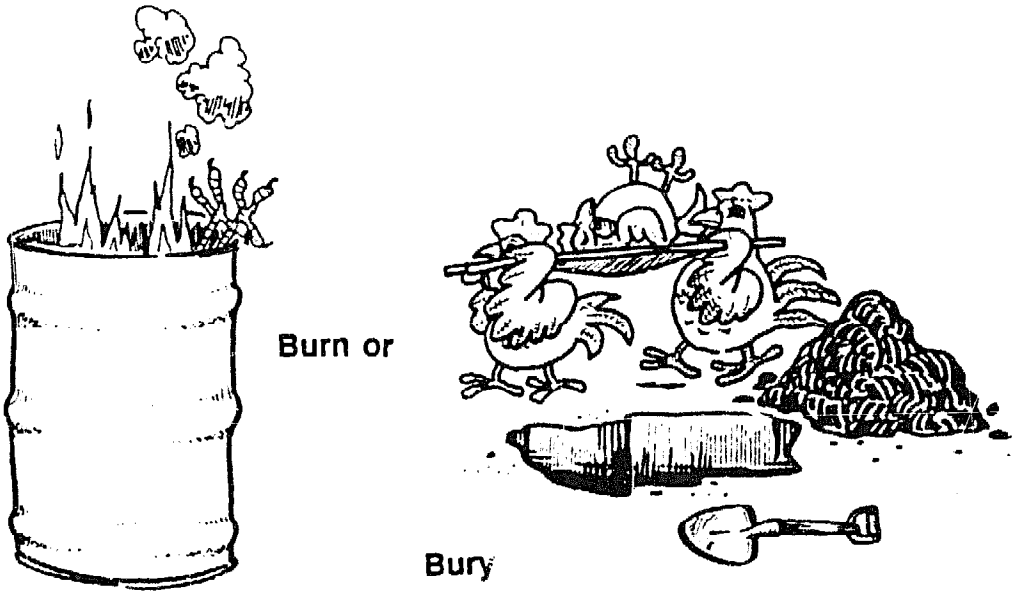

Section 8

Marketing

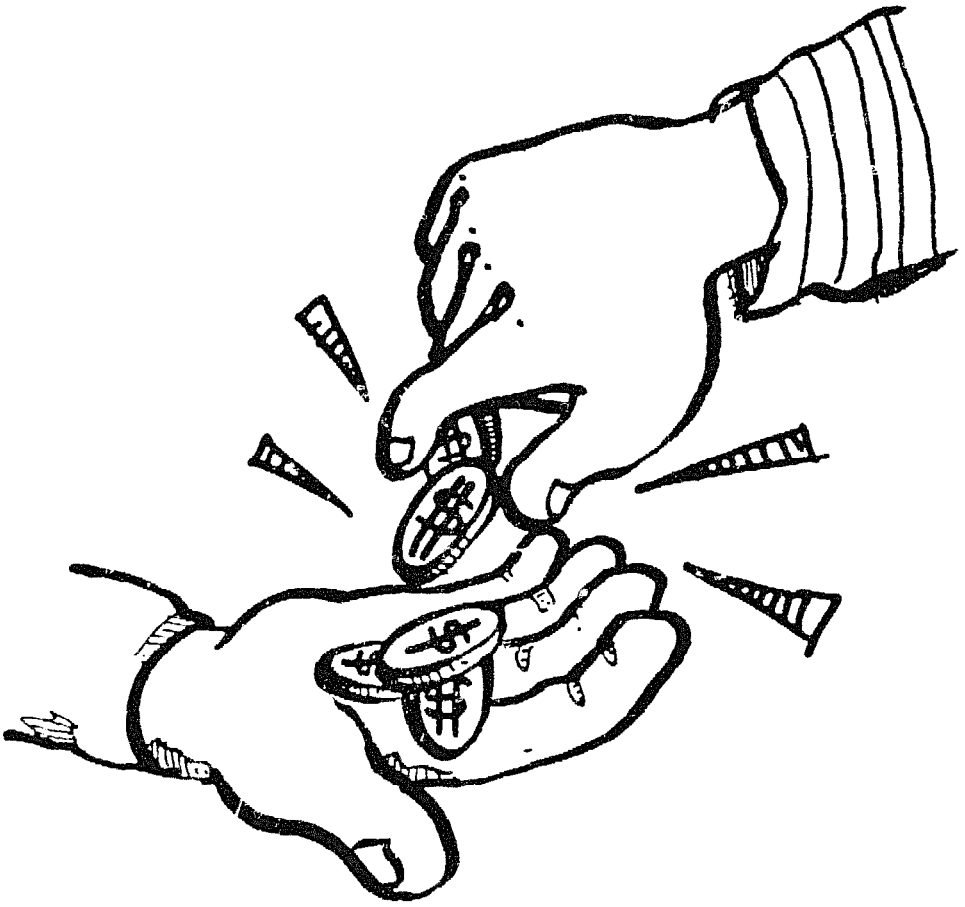

MARKETING

A thorough study of the potential poultry market must precede any plans to expand production. Both eggs and meat are perishable commodities so storage and transportation to market are major factors in success. Financial failure often occurs if prices drop or the method of transporting products to market is cut off.

A. Eggs. Egg quality diminishes rapidly at higher temperatures or if left in the sun. In hot weather some producers gather eggs as frequently as 5 times a day and move them to cool storage. Ideal storage temperature is 4 to 13 °C (40 to 50 °F). Since refrigerators are seldom available under primitive conditions, temporary cool storage is sometimes improvised by using a cave or burying eggs in a clay pot in a shaded area. They may be placed on straw or a mat and covered with a damp cloth or straw. Soil around the pot should be moist without standing water.

Three other methods of storing eggs for home consumption may prolong their keeping qualities. 1) Oil in the form of a thin film will prolong quality for three weeks or longer if stored under 10 °C. Eggs should be dipped in a light mineral or cooking oil such as coconut oil. The oil temperature should be about 11 °C higher than room temperature. If reused, the oil should be filtered and sterilized by heating to 116 °C. 2) Water glass. Eggs are maintained in solution of one part water glass (sodium silicate) to 5 parts of previously boiled but cooled water. Eggs keep for several months if covered and stored in a cool place. 3) Lime water solution is made by mixing 2.3 kg of finely powdered quick lime with 6 liters of boiled but cooled water. After the solution has settled overnight eggs may be stored for more than a month.

Soiled eggs may be cleaned by rubbing them lightly with fine sandpaper, emery cloth or steel wool. Washing is generally discouraged as it may cause bacterial contaminants to be drawn inside the egg through the shell. Since eggs vary greatly in size, they are sometimes sold by weight. In the United States they are graded by weight into 5 sizes: small 35-42 grams, medium 43-49 g, large 50-56, extra large 57-63 g and jumbo 65 g and over. Defective eggs may be detected by candling to remove egss with cracks, blood spots, mold, rot, or parasites using candling methods (Section 5). Attractive packaging in cardboard or plastic containers serves for protection and customer appeal.

B. Meat. Carcass quality deteriorates so rapidly at room temperature that chickens are frequently sold live and dressed by the customer. Although cooking kills all harmful bacteria in chicken meat, "food poisoning" due to bacterial growth may occur if there is extended

storage of either cooked or raw poultry meat at room temperature. Refrigeration methods of preserving dressed poultry has revolutionized the poultry industry. With assembly-line procedures, elaborate processing plants use mass production methods of dressing, storage, and shipment. Broilers may be shipped on ice for thousands of miles by refrigerated trucks. If frozen they may be held for several months and shipped by boat around the world. Development of these large scale methods has resulted in great reductions in the price and availability of poultry meat. Since the risk of spoilage is reduced by shipping freshly frozen birds, this method is preferred in some countries.

C. Financing. Enlarging a poultry enterprise usually requires financial assistance in the form of short-term or long-term loans. Small poultry farmers generally have had good records for loan repayments. Possible funding sources would include:

a. International agencies. The World Bank, Oxfam, U.S./A.I.D., UNICEF and others agencies sponsor rural development programs with funding assistance.

b. Others. Cooperatives, banks, credit unions, women's groups, chick suppliers, feed manufacturers, integrated poultry companies, and local money lenders may be good credit sources for capital funds required in building facilities. They may also finance short term loans to purchase chicks and feed.

c. Government agencies. In the USA federal and state agricultural loan programs have been established through administrative or agricultural extension networks. Secondary school (4H or FFA in the USA) poultry projects have often initiated young people into careers with the poultry industry.

D. Contracts. Lenders may work out purchase agreements with growers. Drawing up specific management and repayment schedules may help to overcome lender reluctance. Details may include: records of past experience, a current balance sheet, projected income statement, chronological management plan, schedule for visits by advisory personnel, and a marketing and repayment plan.

Section 9

Other Kinds Of Poultry

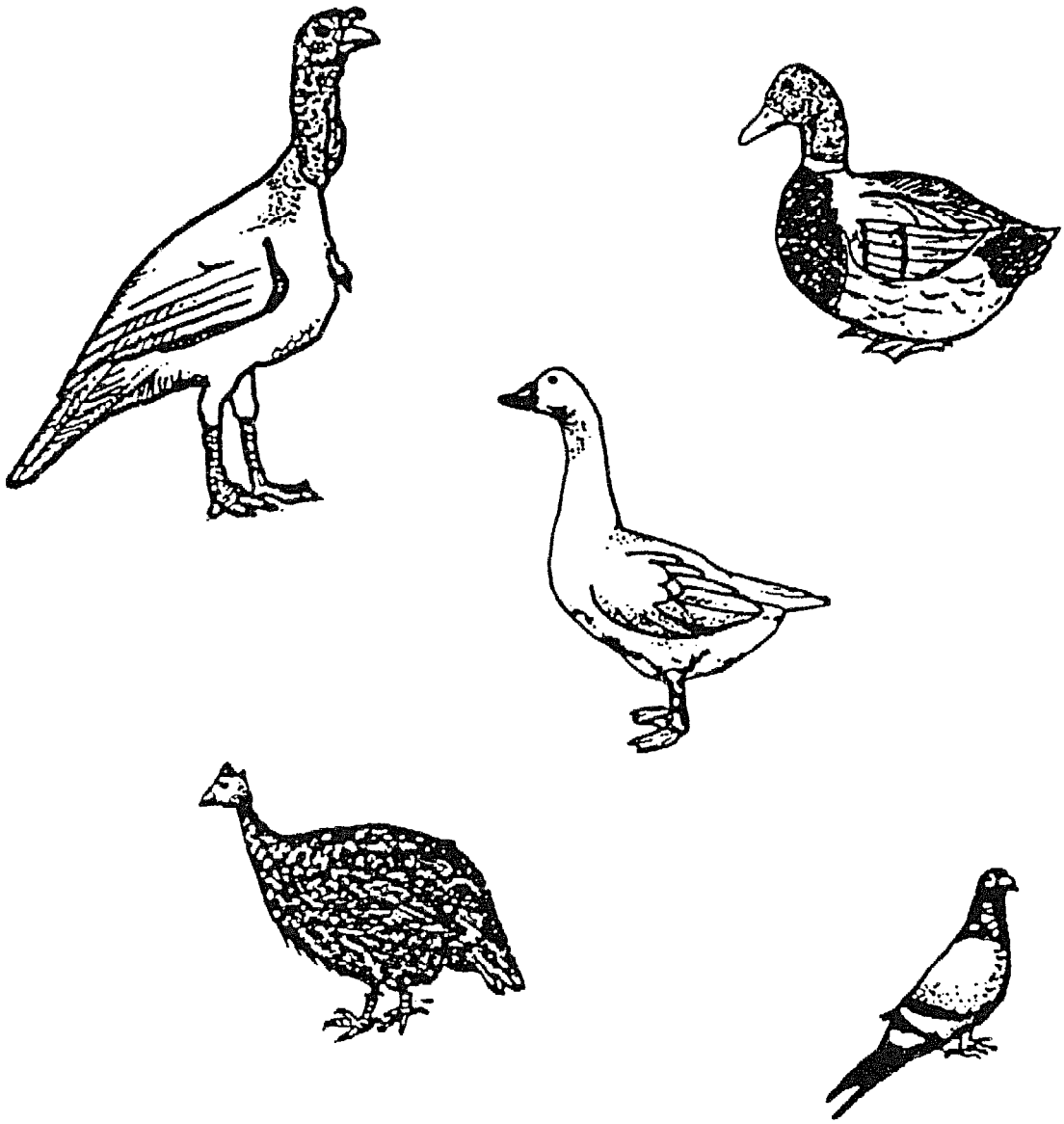

OTHER KINDS OF POULTRY

A. Ducks. Domestic ducks are often easier to care for than chickens. They are hardy, disease-resistant, versatile and their meat is popular with expert cooks. Three of the principal breeds raised for meat are the White Pekin, popular in United States, Aylesbury, popular in England, and Muscovy which originated in South America. The larger Muscovy, often classed with geese, is popular in villages.

If there is a local market for duck eggs, Indian Runner and Khaki Campbell breeds may lay up to 350 eggs per year. Due to the strong taste of duck eggs, local acceptance varies widely in different areas. Duck eggs are larger than chicken eggs but they may spoil if kept longer than a week under less than ideal conditions.

Ducks can be raised using the same equipment as chickens. Waterers should be deep enough for them to submerge their heads (also true of geese). At least one drake should be kept for six females although many villagers have adopted a 1:2 ratio. Ducks for breeding do not require a pond or stream to lay, but they may produce better if water is provided. Duck eggs take 28 days to hatch and ducklings require added heat at 32°C (90°F) for the first week after hatching. They should be kept dry and warm for 4 weeks. They do well on starter pellets but wet mash fed twice a day is preferred by some raisers. On range they forage for themselves feeding on grasses, insects, snails, slugs, and require but an occasional handful of grain. In some areas they require little supplemental feed as they range over large farm areas. Night confinement is desirable to collect eggs which are mostly laid at night or early in the morning. In some parts of the world duck pens are erected over water so the droppings can fertilize fish ponds. Ducks should not be held by the legs but by the wings or neck. Since both ducks and geese are difficult to pluck, a system of dipping freshly killed carcasses in hot melted wax has been devised. After the wax is hardened, feathers are rapidly removed together with the wax.

B. Geese. Domestic geese are raised for their meat, large eggs, feathers, and sometimes their ability to weed crops or act as watch dogs. They are large, hardy, aggressive, noisy birds that need little attention when mature. Geese may live for 30 years. They are preferred by some because they may be hardier than ducks and subsist largely on grass. Of nine recognized breeds, African and Chinese do best in the tropics. No brooder is needed for goslings, but they should be kept warm and dry for the first few weeks. In the presence of the mother no outside shelter is required unless weather is extremely cold. Lock up goslings at night to protect them from predators. Although they like to swim, they do not need water to breed. Ideally, starter feed for geese should contain 20 to 22 percent protein in pellet form. They

can go to range at 2 to 6 weeks. If pasture is plentiful, geese do not need more than 1 kg (2 lbs.) of supplemental feed per bird in a week for satisfactory growth.

C. Guinea Fowl. Meat of guinea fowl is prized in some countries for its wild gamebird-like taste. They are valued for watch dog services on some farms. Guineas are wilder than other poultry, hide their nests, and do not take to confinement rearing as well as chickens. They should be left in the nest to attract the females back again. A broody hen makes a better mother than a female guinea fowl. Keets (hatchlings) are hatched after 28 days of incubation. Ideally they are started on 24% protein diets which can be reduced to 15% protein in the grower mash. Eggs are somewhat smaller than hen's eggs and their production is usually limited to less than 100 per year. In some areas a market demand for guinea eggs has developed. If fed late in the afternoon they may return to shelter for the night. At 18 weeks of age they may weigh up to 1.5 kg (3½ lbs.) when marketed for meat.

D. Turkeys. Originally a hardy bird of the North American forests, domesticated turkeys have been bred for large size and as an inexpensive meat source. The two most common breeds, Bronze and Whites, have difficulty in reproducing because of the heavy weight of the males and their poor fertility. Poults are prone to panic and can break their necks by running into fences, or they may pile up and suffocate each other. They may drown themselves in a low dish of water or jump into a bucket of water. They may starve if not encouraged to start eating. A caretaker can attract them to food by finger tapping on a board making a pecking sound near the feed. Bright colors such as red will attract them to feeders or waterers.

Turkeys frequently suffer from a disease known as blackhead. Signs include yellow feces with large rounded lesions on the liver. The causative agent, a protozoan parasite, also mildly affects chickens. The protozoan parasite is usually transmitted via a cecal worm - a nematode about one centimeter long which lives in the cecum, or blind sac at the lower end of the intestine. Heavy losses in turkeys are prevented by following the rule: *"never raise turkeys and chickens together"*. Coccidiosis, although due to different species from chickens, may require preventive methods similar to those of chickens.

One gobbler (tom) is needed for each four or five hens. However, with artificial insemination, only one is needed for each ten hens. Poults need 28% protein in the starter feed which may be reduced to 20% in grower and 15% in finisher feed.

Until recently turkeys have been known as a luxury bird raised largely for festive occasions. Their large size, 8 to 15 kg (18-35 lbs.) has limited carcass storage without refrigeration. Development of smaller breeds, confinement rearing, together with deboning and cut

up processing, has greatly increased market demand. They are now competitive with beef and broilers to satisfy a growing demand for meat.

E. Pigeons. Once established, a pigeon colony can be practically self-sustaining. Larger breeds such as White King and Giant Homer are preferred to the common Rock Pigeon which throngs city parks.

A breeding pair will produce ten or more squabs (young pigeons) each year, two at a time. Squabs are usually eaten when 25 to 30 days old when completely feathered, but before they begin to fly. Any waterproof house will do for housing if protected against cats, dogs, snakes and rats. In Egypt, especially designed shelters, or cotes, are built for recovery of the manure, which is more valuable for fertilizer than the harvest of squabs.

F. Quails. Quail meat and quail eggs are sometimes featured on menus of fancy hotels to satisfy a demand for a wild-bird taste. Both the bob white quail and the much smaller Japanese quail (Coturnix coturnix japonica) are raised commercially. They are generally reared in confined batteries. The Japanese quail are more prolific since they grow to breeding maturity in 6 weeks.

Section 10

Further Information
Acknowledgements

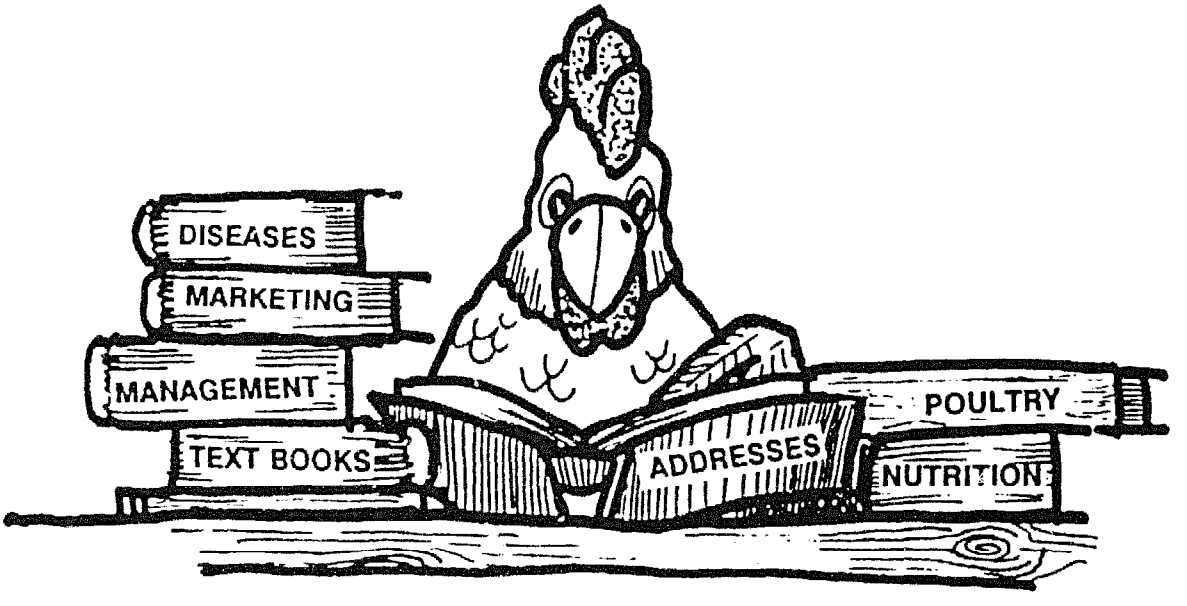

OTHER INFORMATION

A. Glossary—Definitions of Poultry Related Terminology

Abscess - a localized collection of pus within a cavity usually surrounded by inflamed tissue.

Acute - a short and severe course as applied to a disease.

Additive - an ingredient added to a basic feed mix.

Agglutination test - serological test to determine antibody levels; example: used to detect *Salmonella pullorum,* the agent causing pullorum disease.

Air cell - air space in egg between shell membranes due to CO_2 and H_2O evaporation.

Air sacs - part of bird respiratory system (lungs, air sacs, bones).

Albumen - egg white.

Albumin - class of water soluble proteins

Allantois - extra-embryonic membrane in an egg

Amino Acid - one of the organic acids which form the building blocks from which proteins are built.

Anemia - a condition in which there is a deficiency in hemoglobin content or number of red blood corpuscles.

Antibiotic - a chemical substance produced by microorganisms which has the ability to destroy bacteria or other microrganisms.

Antioxidant - A chemical feed additive used to protect certain nutrients from oxidation.

"As hatched" = "Straight run" - unsexed birds from a hatchery; half males and half females, generally used with broilers - rarely layers.

Aspergillosis - a diseased condition cause by a specific fungus present in damp litter.

Bacteria - one-celled, microscopic plants some of which are beneficial while others cause diseases.

Bacterin - similar to a vaccine, but protects against bacterial diseases; produced from dead organisms.

Billing - a pecking action of poultry spilling out feed from a feeder.

Breed - a selected, closely related group of birds having a common ancestry.

Broiler - a chicken marketed for meat at 6-12 weeks of age.

from getting chilled.

Brooder - heat distributing equipment use for young chicks

Brooder Ring (hover guard or chick guard) - a small wall usually made of cardboard used around a brooder to keep chicks from geeting chilled.

Broody - condition of a hen which is ready to set on a clutch of eggs.
Bursa=bursa of Fabricious - A sac or pouch in the connective tissue located just inside the vent.
Candle - to examine the contents of an egg by beaming a strong light source (from a candler) through the contents.
Cannibalism - a bad habit of chickens pecking on themselves or other birds. Feather pulling is often the first sign of trouble.
Cecum - a blind pouch at the junction of the small and large intestine.
Chick - young, unsexed chicken.
Chigger - larval mites which cause intense itching in humans, blisters on turkeys.
Chronic - a disease condition of long duration in contrast to acute.
Cloaca - the common chamber into which the intestinal, generative, and urinary tracts discharge.
Clutch - a group of eggs laid in a series without missing a day; a group of chicks hatched by a broody hen.
Coccidiosis - a protozoan disease causing losses in chickens or turkeys. The parasites are called coccidia
Coccidiostat (anticoccidial) - A drug which inhibits development of coccidia usually administered in the feed.
Cock - male, 1 year or older.
Cockerel - male, less than 1 year of age.
Comb - a fleshy head projection.
Concentrate - A feedstuff especially rich in distinctive nutrients.
Confinement - A system of management wherein birds are kept in an enclosure.
Congestion - an excessive accumulation of blood.
Crest - tuft of feathers on head.
Crop - an enlargement of the esophagus in front of the chest.
Crumbles - a preparation consisting of medium size granules prepared from pelleted feed.
Custom hatching - hatching for hire - once popular - now discontinued in the USA to prevent disease transmission in the hatchery.
Cull - a bird no longer useful for production purposes. Also used as a verb: to cull.
Debeak - removal of a portion of the beak by use of a hot iron or scissors.
Disease - any deviation from a condition of health.
Disinfectant - a chemical agent used in killing microorganisms.
Dub or dubbing - comb removal - to prevent physical (cage) or damage

from freezing.
Dusting - natural activity of birds rolling in dirt or dust to remove parasites.
Extension - adult education, especially farming methods.
Feces - droppings excreted from the digestive tract.
Feed efficiency - the ratio derived by dividing the weight of feed consumed by the body weight of the bird.
Floor eggs - eggs laid on floor versus cage or nest - undesirable.
Floor pen - a pen where chicks are usually reared on litter in contrast to cage operations.
Floor layer - hen which lays floor eggs.
Fluff - Soft downy feathers in masses on certain parts of fowls.
Fryer - Broiler - young chicken, 6-12 weeks of age, of either sex that has tender meat, a soft pliable smooth skin and a flexible breastbone.
Full-feeding (ad libitum) - having feed in front of animals at all times.
Fumigate - a procedure using fumes to disinfect a given area.
Fungi =Molds - lower forms of plant life which invade tissue such as combs of poultry. They may produce toxins in feedstuffs.
Germinal disc - little white spot on yolk =site the new embryo.
Giblets - edible viscera (gizzard, liver, heart and neck).
Hackles - narrow pointed feathers on neck.
Haugh units - method of measuring internal egg quality on broken-out eggs (wt. of egg and albumen height).
Hock Joint - Joint in lower leg just above the foot.
Hover or brooder - canopy or cover of a brooding device that supplies or retains heat for brooding chicks.
Hen - female greater than 1 year of age (or in lay).
Hybrid - offspring from parents of different breeds, varieties or species.
Hybrid Vigor, (heterosis) - an increased vigor or capacity for growth often occuring in crossbred animals or plants.
Incubation - the process of maintaining eggs under conditions favorable for the development of the embryos.
- insures peace.
Infection - a contamination with any disease-producing substance such as bacteria or viruses.
Inflammation - a condition in which tissues manifest sweling, redness, heat and pain.
Integration - combinations of different poultry operations under one management (e.g., hatching, rearing, processing).
Internal layer - an egg released from the ovary which misses the

journey down the oviduct; yolk is retained iin the body cavity.
Keel bone - the breast bone to which breast muscles are attached.
Lesion - an abnormal structural change in an organ due to injury or disease.
Litter - absorbent material placed on the floor of a chicken house.
Marek's disease - a cancer-type disease affecting younger chicks.
Metabolic - the chemical and physical process going on in living tissues.
Meat spots - eggs which contain pieces of hen tissue in the albumen.
Nares - nostrils.
Necropsy or autopsy - to perform a post mortem examination.
Newcastle disease - a serious virus disease causing high mortality.
Nick - genetic combinations of male and female lines which produce desired characteristics in offspring.
Oil gland=preen gland=uropygial gland - at base of tail used by bird to oil feathers, preening; removed during processing.
Oocyst - an egg-like structure which is the infectious stage causing coccidiosis.
Parasites - live organisms which invade tissues or live at the expense of other organisms sometimes causing diseases.
Peck order - established social order in flocks - insures peace.
Pellet - a formed large granule of mixed feed prepared by heat treatment in the feed mill.
Pipping - embryo breaks shell and starts to hatch, egg is then called a pip.
Post mortem=autopsy=necropsy - examination of a dead bird in an attempt to determine the cause of death.
Poult - unsexed turkey chick.
Premix - a blended mixture of such ingredients as vitamins or minerals combined with a small quantities of a carrier to facilitate transfer to a bulk mixer.
Protozoa - one-celled organisms belonging to the animal kingdom.
Proventriculus - the glandular stomach of birds.
Pullet - young hen less than one year old.
Ration - the diet of an animal.
Replacement stock - Young birds brought in to replace worn-out breeders or layers.
Rickets - a disease caused by vitamin D deficiency resulting in soft bone structure.
Salmonella - a genus of bacteria containing species which cause

digestive disturbances in humans or in birds (eg. pullorum disease).
Self-feeder - an automatic feed hopper that lets feed down as the bird eats.
Set - to start eggs for incubation under a hen or in an incubator.
Sexer - an expert at determining the sex usually done by examining the vent on day-old birds using a strong light.
Sexing - determining the sex, usually done on day-old birds.
Sign - Any objective evidence of an abnormality such as coughing, sneezing or vomiting.
Species - a distinctive category in animal or plant classification constituting a subclass under genus.
Straight run - Unsexed chicks or poults as they come from the hatchery.
Strain - A closely related group of birds within the same breed.
Stress - a stimulus which may lower resistance to disease such as chilling, moving, or loud or frightening sounds.
Supplement - a feed additive used to improve the nutritive balance.
Toxin - a poisonous substance produced by certain bacteria or fungi, and proteins from animal or plant sources.
Trachea - the thin-walled air tube.
Tumor - new tissue produced by abnormal cellular growth which is unrelated physiologically to neighboring cells.
Vaccine - usually a suspension of killed or modified live organisms used to protect against a specific infectious disease.
Vent - the common outlet for the urinary and digestive tracts of birds.
Virus - an infectious agent too small to detect with light microscopes, but usually demonstrated under electron microscopes; many diseases of poultry are caused by viruses.
Viscera - the internal organs in the body cavity.
Vitamin - an organic compound required in the diet that plays an essential role in body metabolism.
Wattles - a fleshy often bright colored piece of skin hanging from the throat of birds.

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Dr. David J. Farrell, The University of New England, Department of Biochemistry, Microbiology and Nutrition, Armidale, N.W.S. 2351, Australia.

Dr. J. David French, Extension Poultry Veterinarian, College of Agriculture, The University of Georgia, Athens, GA 30602.

Drs. Henry L. Fuller, Leo S. Jensen, Hardy M. Edwards, Jr., Department of Poultry Science, The University of Georgia, Athens, GA 30602.

Dr. D. Earl Goodman, Tubeville, SC 29162.

Dr. Maxcy P. Nolin, Jr., Department of Entomology, The University of Georgia, Athens, GA 30602.

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D. Authors.

W. MALCOLM REID
Professor Emeritus of Poultry Science (Parasitology)
Department of Poultry Science
University of Georgia, Athens, Georgia 30602
Telephone number: (404)542-0412 FAX number: (404)542-1827

B.S., 1932, Monmouth College
M.S., 1937, Kansas State University
Ph.D., 1941, Kansas State University
D. Sci., 1950, Monmouth College

Alumni Foundation Distinguished Professor of Poultry Science 1964
Fellow of the American Association for Advancement of Science 1954 and of the Poultry Science Association 1974.
Special Service Award of the American Association of Avian Pathologists
Dr. Reid has made consultation trips to 29 countries at the request of governmental agencies or pharmaceutical companies. Research activity at the University of Georgia included publication of some 300 papers related to parasite control with special emphasis on coccidiosis and worm parasites. He is coeditor of three editions of the Diseases of Poultry published by the American Association of Avian Pathologists. As Head of U. S. Aid project in Egypt (1952-1955) he planned importation of 130,000 baby chicks as layer stock to Egypt which was distributed widely in villages in Egypt. He held a "shuttle" missionary appointment to Bolivia in 1986 with the Christian Veterinary Mission.

GENE M. PESTI
Assosiate Professor of Poultry Science and Animal Nutrition
Department of Poultry science
University of Georgia, Athens, GA 30602
Telephone number: (404) 542-1351 FAX number: (404) 542-1827
B.S.A., 1972, The Ohio State University
M.S., 1976, Auburn University
Ph.D., 1980, University of Wisconsin-Madison

Dr. Pesti teaches poultry husbandry, economic management, and nutrition to undergraduate and post-graduate students. His research activity includes some 80 papers related to nutrition and management of poultry, and he has authored bulletins and computer software for undergraduate instruction. In 1987 he was a Visiting Research Fellow at the University of New England in Armidale, N.S.W., Australia.

M. A. HAMMARLUND
Consulting Poultry Veterinarian
P. O. Box 7698
Riverside, CA 92513
Telephone (714) 687-2373
B.S., 1953, Kansas State University
D.V.M. 1973, Kansas State University

Dr. Hammarlund is a practicing veterinarian in Riverside, California with special interest in diseases of poultry. He is a veterinary graduate of Kansas State University. Before locating in California he was employed at the Ralston Purina Co. in St. Louis, Missouri, doind poultry disease research. Dr. Hammarlund held a "shuttle missionary appointment to Bolivia in 1989 with the Christian Veterinary Mission

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Thank you for your help.

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Section I

Acknowledgements
Introduction

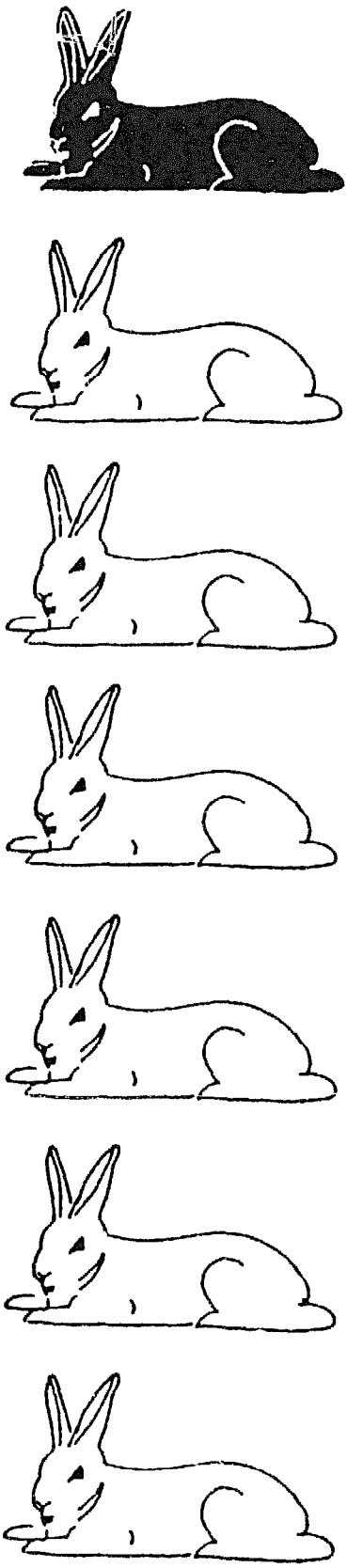

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INTRODUCTION

Many developing countries have populations which are suffering from protein deficiencies. As a means of alleviating this need for protein, government agricultural research centers and Christian Veterinary Missions are encouraging the production of fish, poultry, swine, some rodents such as capybara and guinea pigs, and rabbits by small family units or villages.

This text will outline essential information required for rabbit production. Some of the specific advantages for raising rabbits are: They do not compete for grains used for human consumption, since they can reproduce and grow on low-grain, high-forage diets; unlike chickens, they can be successfully raised on a diet consisting largely of forage, plants, grasses and shrubs; and because they are small animals, these food substances can be easily collected by a small family or village unit. Another advantage is that rabbits can use these sources of protein more efficiently than most other animals and they have a high feed conversion ratio. Weanling rabbits can gain one kilogram of body weight for each 2.5-4.0 kilograms of plants they eat. For beef cattle on a similar diet, 12-15 kilograms of feed are required per kilogram of body weight. This means that a hectare of alfalfa can produce at least five times more rabbit meat as compared to cattle raised under similar circumstances. In many areas of the world the keeping of large animals for meat is not feasable. This is primarily due to their large feed and space requirements, the long time taken to reach slaughter weight, and the problem of using a large amount of meat at once when refrigeration and electricity are lacking. In these instances, the rabbit has the distinct advantage of serving as a 'biological refrigerator', since the meat from one animal can be quickly consumed without the need for storage. Another advantage of the rabbit is its high reproductive rate and its ability to thrive on weeds, tropical forages, vegetables leaves and tops, and table scraps. Twelve good does, producing five litters each year, and raising seven fryers to the litter, will produce 420 fryers per year for the table. At a 50% average dress out, they will produce somewhere between 385 and 475 kilograms of high quality white meat, which is enough to satisfy the needs of an entire village for a year.

Because there is a pressing need for protein in millions of people living in predominantly rural environments where forages are plentiful, Christian Veterinary Missions (CVM) highly recommends following the outlines presented in this text regarding raising healthy rabbits. As competition for grain intensifies between humans and livestock, it is possible that rabbits will assume an increasingly important role as a source of food.

Section 2

Housing, Equipment And Furniture

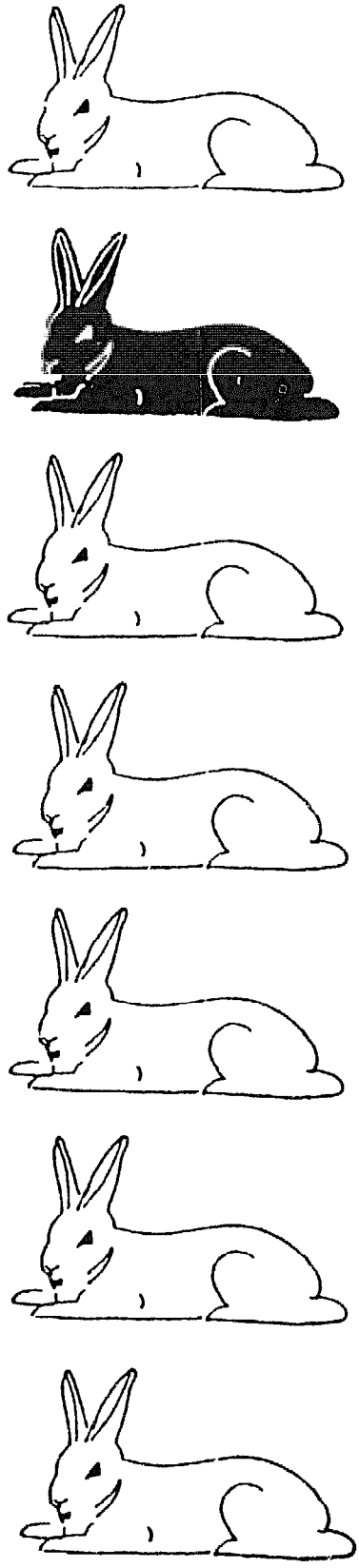

HOUSING, EQUIPMENT AND FURNITURE

Permanent rabbit caging should be constructed before the arrival of the first rabbits. This avoids the situation where temporary housing becomes, by default, the permanent housing for the rabbitry.

The site of the rabbit hutches should have fresh air circulation and good drainage. Outdoor hutches can be the best means of meeting the fresh air requirement and, if located properly, even dirt floors can be adequately drained. Outdoor hutches with free air flow and dirt under the cage flooring also cuts down on fly problems.

EQUIPMENT:

Rabbits are housed in hutches made of a variety of materials. A simple house can be built using a wood frame with a solid wood roof and floor. The sides of the cage may be covered with a chicken wire mesh and the floor can be covered with hay for bedding. If welded wire is available in a fine mesh, this is preferred over wood as a flooring material (Figures 1 and 2).

Commercial rabbitries often use hanging, or quonset-style cages in an open sided building with a solid floor (Figure 3). Cages should be constructed of 14-16 gauge wire. The sides and top can be 2.5cm x 5.0cm mesh and the floor wire should be 1cm x 2cm. The average height for all cages is 51cm; whereas, the floor area should be 75cm x 75cm if the young are removed at four weeks of age, and 75cm x 91cm if the young are removed at six weeks of age. Young does, prior to their first breeding, can be kept in a floor space of 38cm x 75cm cages. Individual breeding bucks should be housed in 75cm x 75cm cages with a floor space of 75cm x 75cm. Wire bottom cages which allow the feces to fall through are superior to solid bottom cages as they help control coccidiosis (Figure 4).

The rabbit building, which is required for larger operations can be open sided in warmer climates. The side toward the prevailing winds should be closed. Even in areas with some cool or cold weather, a one sided building with curtains made of plastic or some other material can be used. In a completely enclosed building, a ventilating system delivering 14 to 20 air changes per hour is required and can defeat the economics of rabbit raising. In either case, abundant ventilation is of tremendous value in controlling snuffles (see disease section).

In many areas of the world bamboo can be used to construct the flooring, sides and roof on a wood frame rabbit hutch (Figure 5). Although not as effective as wire, split bamboo can be used to form slatted floors and walls. Because rabbits like to chew, the rounded sides of split bamboo should be placed on the inside of the hutch. It is also important

to place the split bamboo slats close enough together to prevent injury to the feet. Usually a 1-2cm spacing is adequate.

A more permanent hutch can be made with a wooden frame and wire mesh (Figure 6). The wire between should be 2.5cm x 5 cm wire mesh or 1cm hardware cloth. The hutch dimensions can vary, but the depth should be no longer than the owner's arm length. Generally, 75cm wide and 91-122cm deep is the ideal size. The roof should provide at least 15cm of overhang. Roof construction can be a solid sheet of plywood, metal, several boards or straw thatch. If wood is used, the roof should be covered with some type of shingle msterial. Also note that multiple cages can be built, with two adjoining cages sharing a common wall (Figure 7).

If materials such as hinges are not available for a cage door, cages can be built with removable tops (Figure 8). Some method, such as hook-and-eyes, should be used to secure the top in position. Scrap lumber and 2.5cm poultry wire mesh are useful for hutch construction. Wood-framed hutches should be built with the wire mesh covering placed on the inside of the wood frame to help prevent the rabbit from chewing up the caging (Figure 9).

All-wire cages can be used in any covered type of building, such as a pole barn or open pole shed. The all-wire indoor cage is ideal for large operations, as it helps reduce disease problems. All-wire cages can be easily sanitized by using a propane hand torch plus a brush. If this equipment is not available, a thorough scrubbing with soap and water followed by a chlorine bleach or weak lye rinse is adequate. Periodically, following cleansing, the cages should be set in the sun for 2-3 days.

In order to construct a wire cage you need 5.5 meters of 60cm wide wire. Roof and floors are cut out to be 60cm x 90cm (Figure 10). Next remove one piece 60cm x 60cm for a door. The remaining wire (300cm x 60cm) can be shaped into a rectangle (60cm x 90cm and 60cm high). The top and bottom are then attached using J-clips, or other small metal or wire fasteners. Finally cut a 45cm square hole along one of the long sides. Attach the 60cm x 60cm piece as a door over the 45cm square hole. This provides 5400 square centimeters of floor space. A doe with young rabbits requires more floor space (6500-7500 square centimeters), especially if the young rabbits are to be left with the doe until they reach butchering size (2 to 2.5 kilograms).

Keep outdoor cages raised off the ground and note the placement of buckets of oil around the base of each leg and/or metal cones, which can be attached around the legs (Figure 5). These tips help prevent access by rats, mice, or other rodents and snakes. In warm areas, an open sided pole barn is best to allow adequate air circulation around the rabbit cages (Figure 11). If other livestock are housed near the rab-

bitry, the rabbits should be screened from the livestock. A pig or goat may frighten a nervous doe and cause her to abandon her litter.

In hot areas it is important to control the temperature. When the temperature in the hutch exceeds 30 °C it is essential to provide additional cooling measures. One simple method of shading the rabbitry is to make an awning framework covered with thatched material, moistened cotton, or burlap feed bags. Of course, trees and vines should be used whenever possible to shade the rabbitry. Large rabbitries in enclosed buildings often require roof sprinklers and electric fans; however, these techniques are often expensive.

Gravel or sand floors under the caging is recommended. Loose dirt will also work to help reduce humidity and ammonia levels. Concrete under caging is not recommended unless it is to be cleaned several times daily. However, concrete can be effectively used for alley ways between the rows of cages in the larger rabbitry.

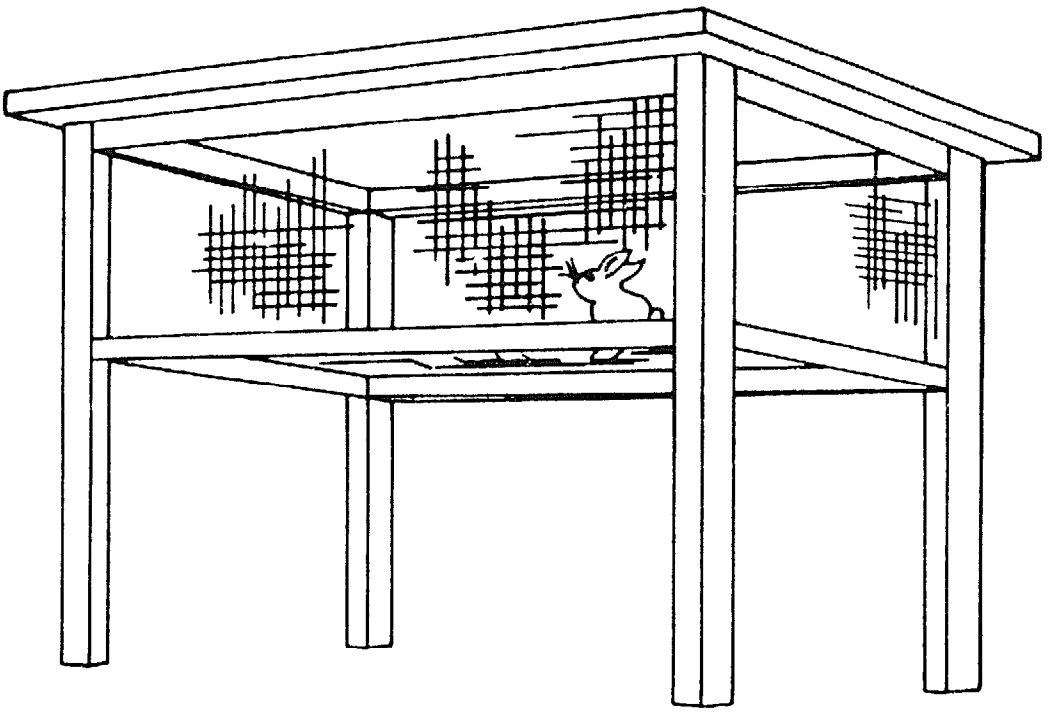

Figure 1. Wood frame hutch with wire sides and floor (Redrawn from Kanable, Raising Rabbits)

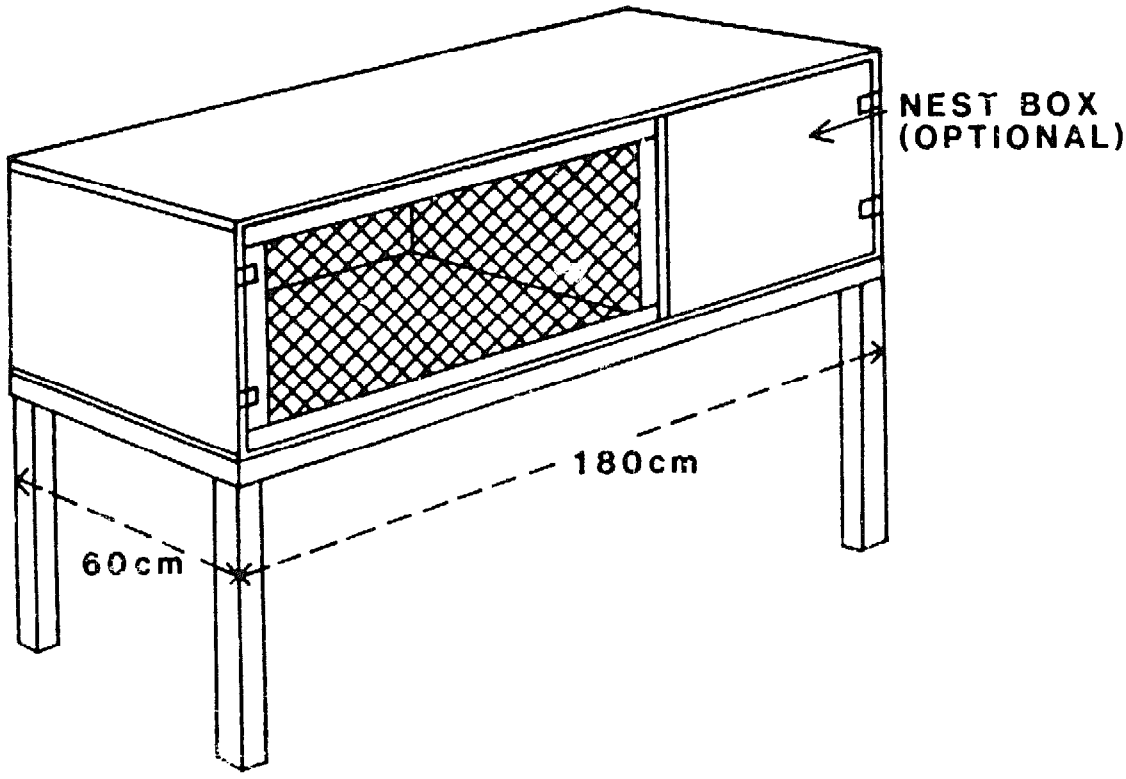

Figure 2. Wood frame hutch with solid floor and nest box

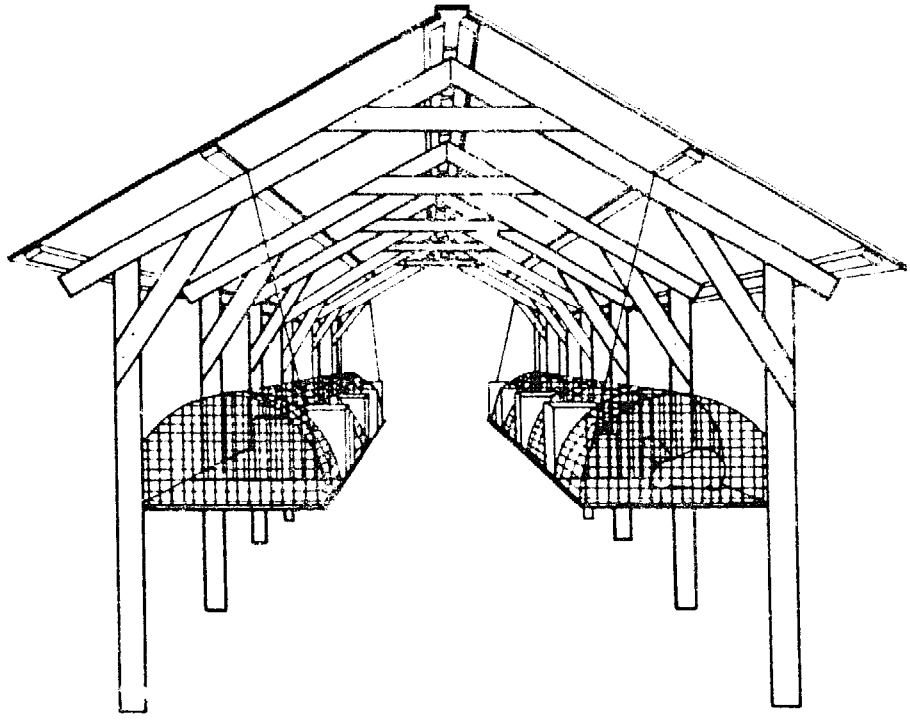

Figure 3. Hanging wire quonset style cages in open building

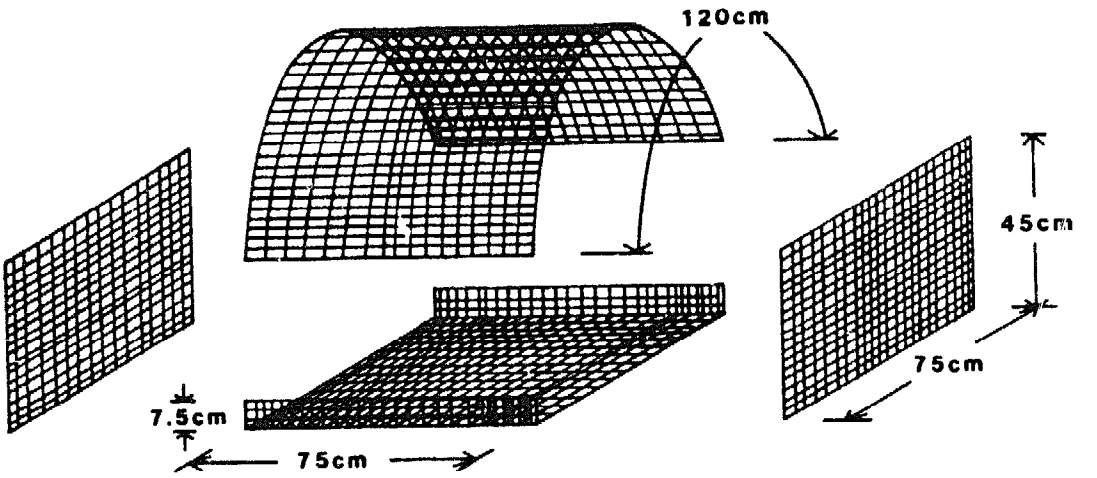

Figure 4. Construction of Quonset style rabbit cages (Redrawn from D.J. Harris)

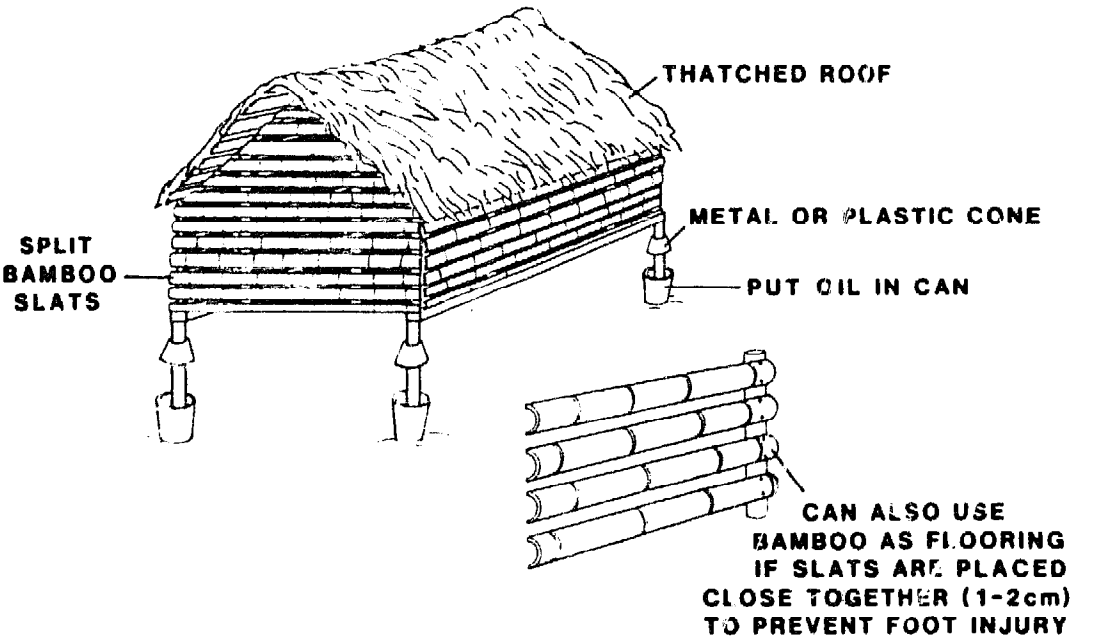

Figure 5. Bamboo hutch with a thatched roof. Note the protective barriers on the legs to keep out rodents and snakes.

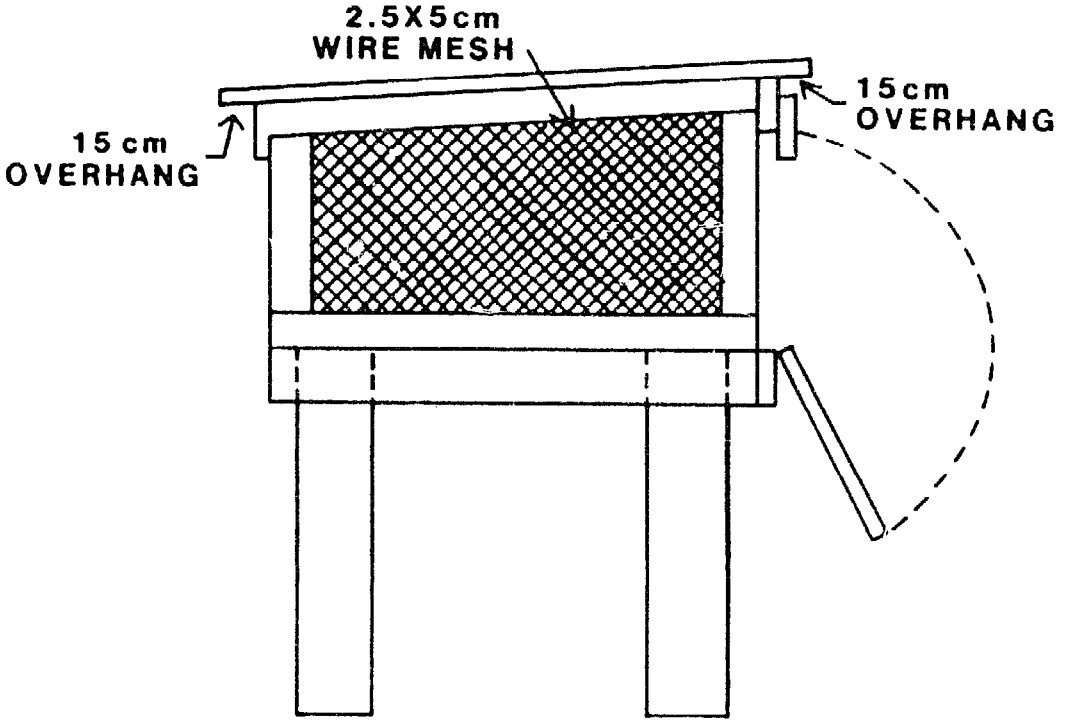

Figure 6. Wood frame hutch with wire mesh sides and roof overhang
(Redrawn from Kanable Raising Rabbits)

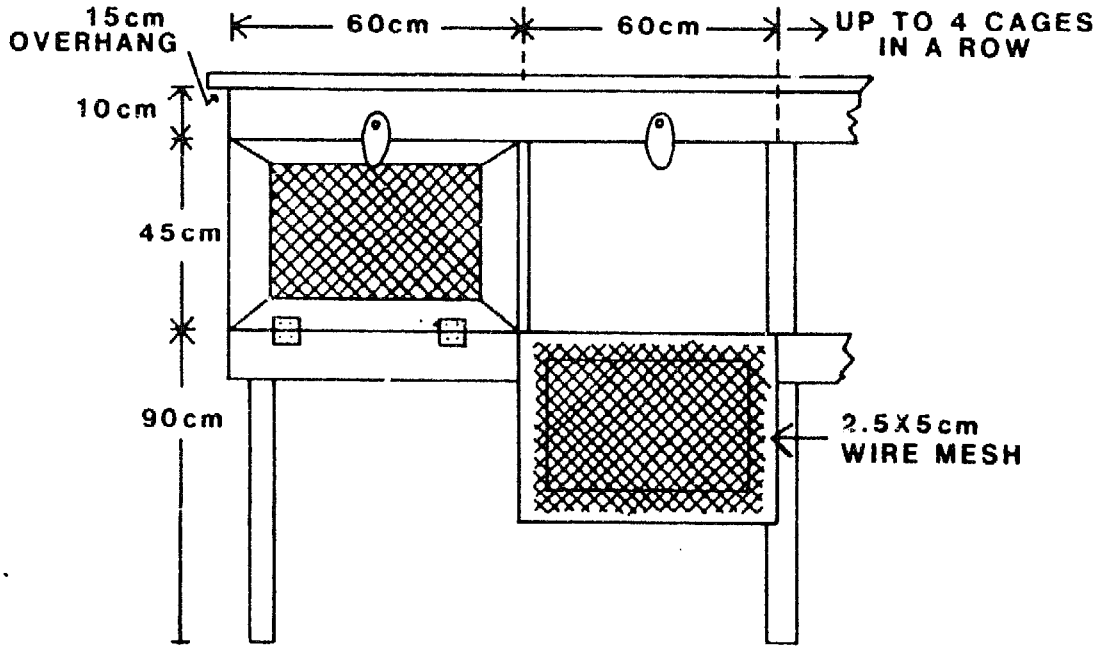

Figure 7. Model illustrates multiple hutch construction
(Redrawn from Kanble, Raising Rabbits)

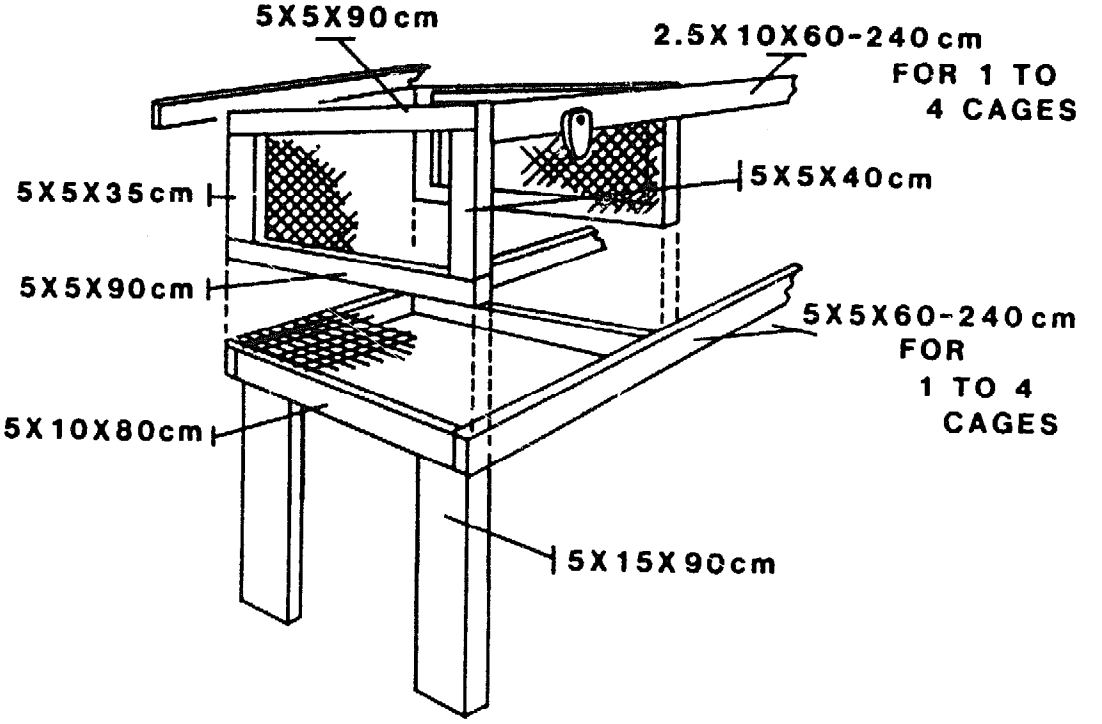

Figure 8. Model illustrates hutch construction with removable top (Redrawn from Kanable Raising Rabbits)

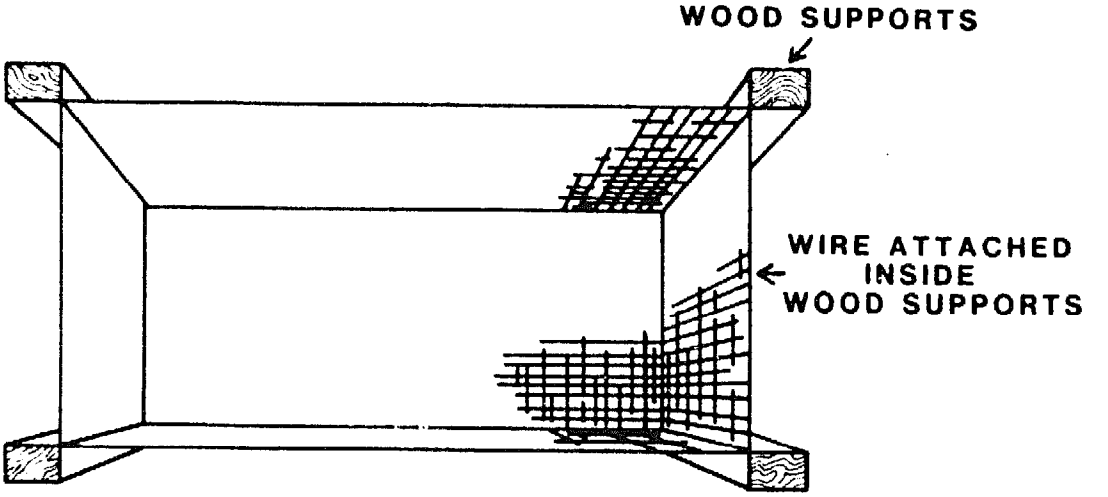

Figure 9. Overhhead view of cage showing position of wire

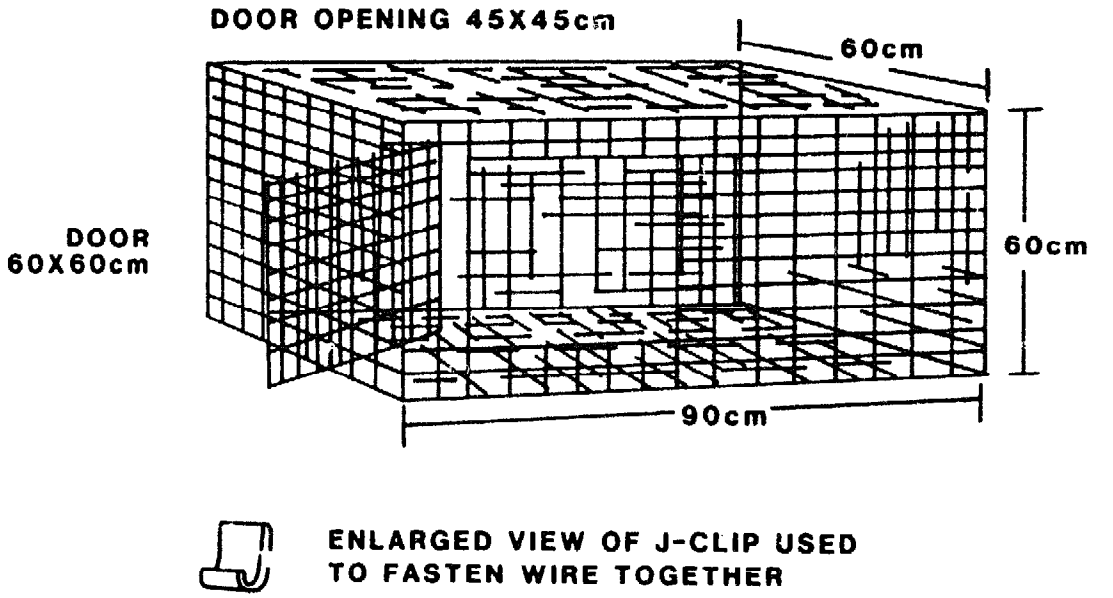

Figure 10. All wire cage construction

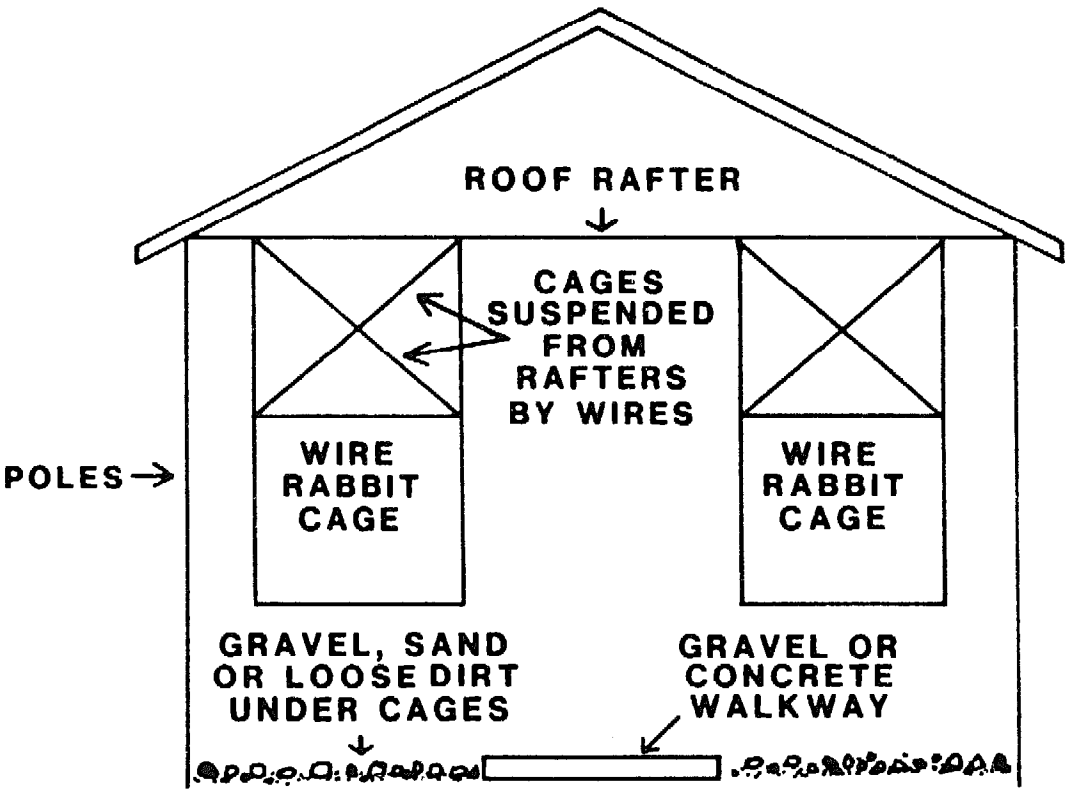

Figure 11. Open-sided pole barn with hanging cages

FURNITURE:

Nest Box:

There are a number of nest box designs, but basically all designs try to provide the doe with some seclusion for kindling (giving birth to the young) and to provide protection for the young rabbits. The nest box should be large enough to prevent crowding, but not too large to prevent the young from remaining close together. Good ventilation is required in warmer climates, while some protection from wind is required in cooler climates.

Box-type: The box-type nest box can be constructed of a variety of scrap wood materials such as shipping crates, etc. The corners should be covered with metal to prevent the doe from gnawing on these areas. Basic dimensions shown in Figure 12 are for a 3.5-5.5kg doe. Adjustments in the size can be made for larger or smaller does. A good doe should provide a warm nest of wool groomed from her body or from nesting material provided (such as straw), so that her young rabbits can survive temperatures as low as -25 °C. Lids and floors should be screwed in place to allow nest box to be removed and cleaned between litters (Figure 13). Extra insulation can be provided by placing corrugated cardboard as a liner along the inside of the nest box. An alternate method is to place the nest box within a corrugated cardbord box and use straw to line the space between the nest box and the cardboard box.

Nail-keg: The nail-keg nest boxes can make use of an item sometimes available for free in the community. A 30cm diameter keg is required for a doe weighing over 5.5kg, while a 25cm diameter keg is adequate for a 3.5kg doe. The required drain holes, ventilation holes and door are shown in Figures 14 and 15. Boards nailed to the front and rear of the keg will prevent it from rolling.

Open-box type: When plywood is available a more open wood nest can be built for use in warmer climates (Figure 16). The bottom can be either solid or wire window screen material. The screen bottom has the advantage of keeping both the babies and the doe cooler by providing more ventilation. If a solid bottom is used, 3-4 holes should be drilled in the bottom to provide drainage. The sitting board at the back of the box provides the doe with a place to rest and observe her young without having to be in among them.

Wire nest box: In some warm tropical areas the sides and bottom of the nest box can be constructed entirely of wire and the top is left open. The purpose of this type of nest box is to provide adequate ventilation while confining the young to one small part of the cage.

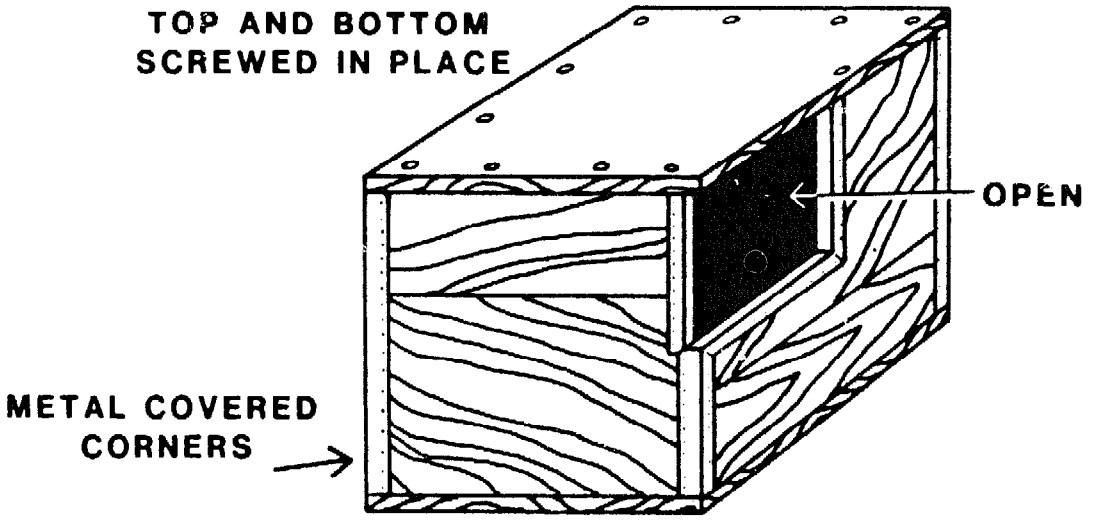

Figure 12. Nest box construction using wood with metal covered corners
(Redrawn from Farmers' Bulletin 1730, USDA)

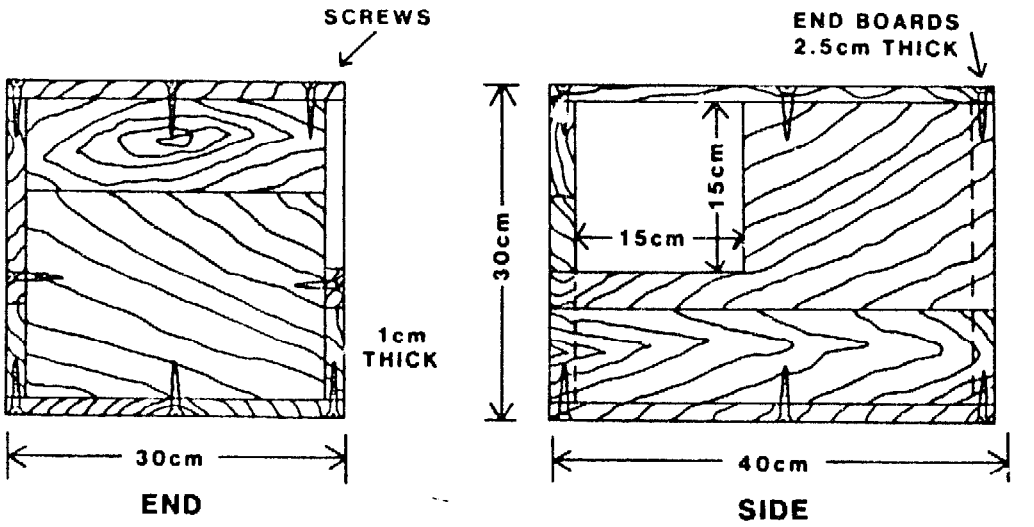

Figure 13. Nest box construction detailed for ease in cleaning
(Redrawn from Farmers' Bulletin 1730, USDA)

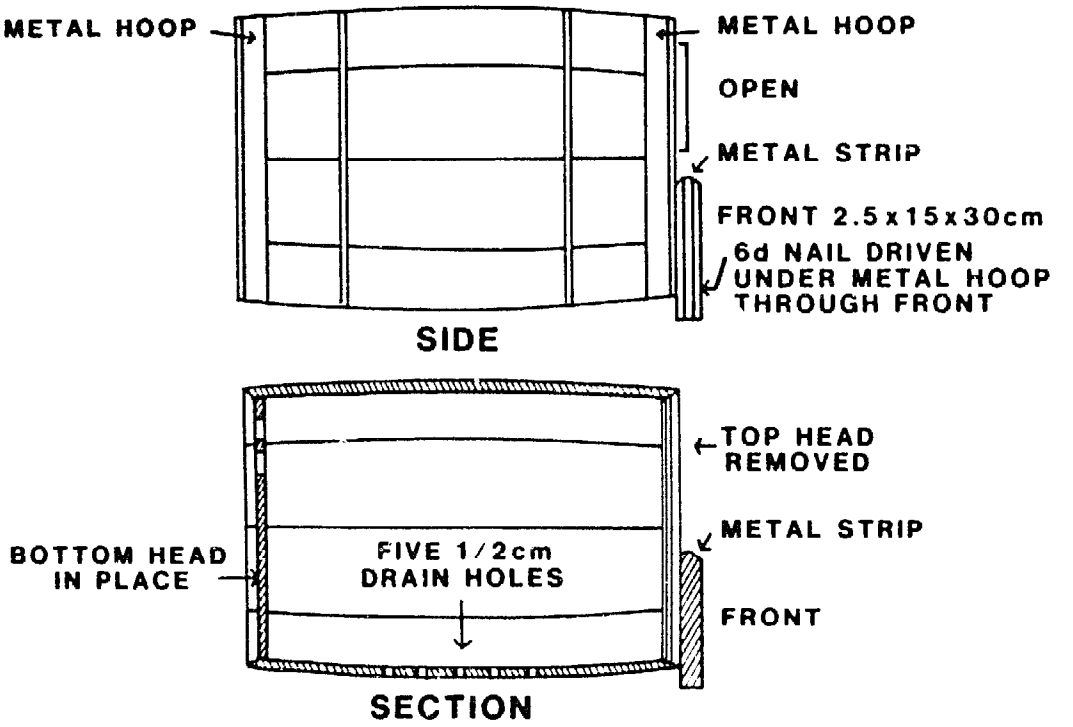

Figure 14. Nail-keg hutch
(Redrawn from Templeton, Ashbrook and Kellog, Rabbit Raising, Conservation Bulletin 25, USDI)

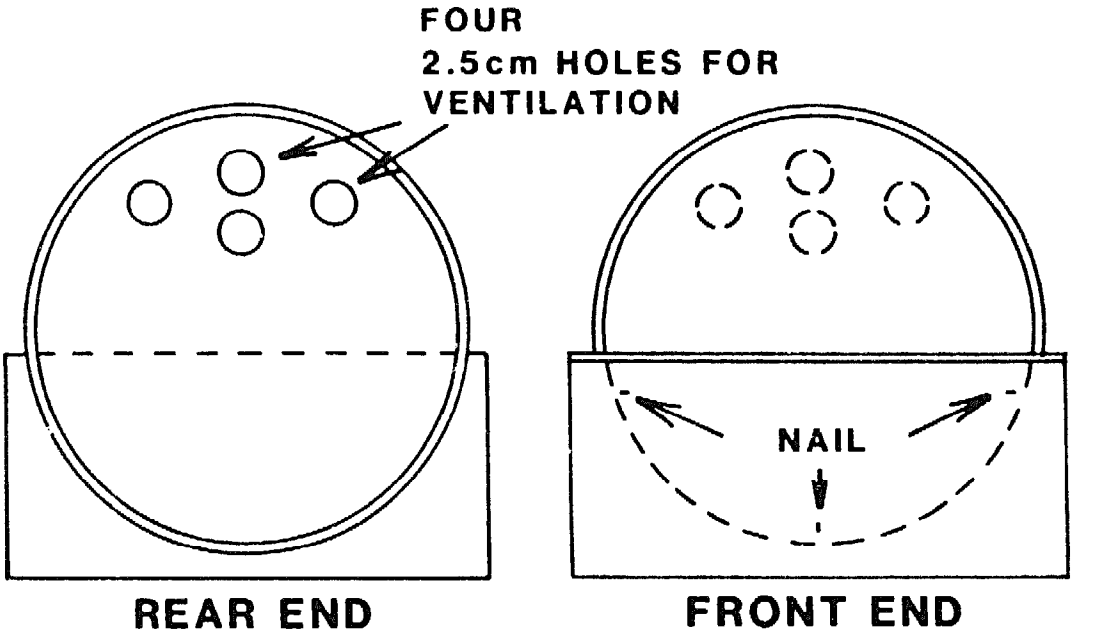

Figure 15. Nail-keg hutch with wood supports to prevent it from rolling
(Redrawn from Temoleton, Ashbrook and Kellogg, Rabbit Raising, Conservation Bulletin 25, USDI)

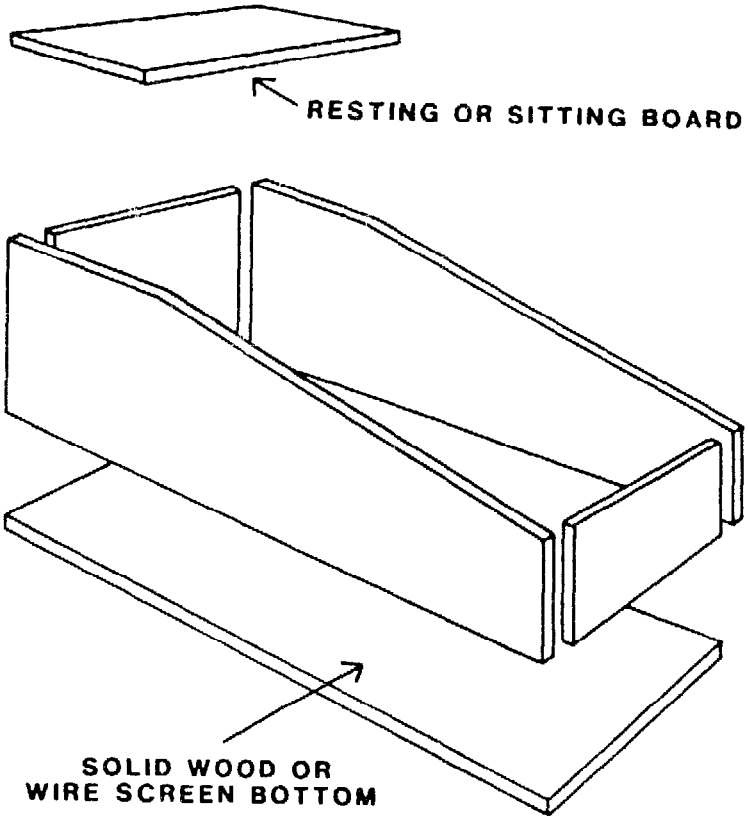

Figure 16. Open wood nest box
(Redrawn from Kanable, Raising Rabbits)

WATERING DEVICES:

Rabbits require clean water at all times. A doe and her offspring can drink four liters of water daily. Several watering systems, from simple equipment for small farmers to automatic systems for larger operations, can be used.

Crocks:

Two liter pottery crocks are still one of the easiest and least expensive ways for watering rabbits. The crock needs to be fastened to the front of the hutch with part of the crock extending into the hutch. Fasten the crock so that the rabbits will not tip it over. Clean and disinfect the crocks at least weekly.

Coffee Cans:

Cut-down coffee cans or other types of large cans will work in place of crocks, but are tipped over more easily by the rabbits. Therefore, it is necessary to securely fasten them to a board or the cage. Again, if part of the can extends out beyond the cage it can be refilled easily. Cans should be cleaned and disinfected weekly, and replaced as soon as they begin to show rust.

Soda Bottle and Cans:

A further modification of the can watering device is to wire the can inside the hutch. Then wire a large soda bottle on the outside of the hutch with the bottle neck extending into the water in the can (Figure 17).

Plastic Jugs:

A simple watering device can be made from a four liter plastic jug such as those used for various cleaning agents (bleach or soap). Be sure to rinse the container thoroughly, then mount a drinking valve in the heavy plastic material near the bottom of the jug (Figure 18). The jug is then placed on a tray attached to the cage. A wire loop helps secure the jug in place. By retaining the jug's plastic screw-cap, the water supply can be protected from contamination by dust or vermin. This system is also useful for medicating a single rabbit. The medication is added to the water in a measured quantity and there is little waste as encountered in the more open systems described previously. The drinking valve would have to be purchased from a rabbit or poultry supply company.

Automatic-Watering Systems:

Automatic systems eliminate the need for washing and refilling of water containers daily and deliver a constant supply of clean, fresh water. The system starts with a pressure-reduction tank on the incoming water line. The tank is equipped with a float valve feeding into a supply pipe that leads to the watering unit for each hutch. The tank should be about 30cm higher than the highest point in the piping system

in order to maintain a good water flow. Tanks as small as four liters can be used where there is no problem with sediment in the water and no danger of freezing in cold weather. Small tanks have the advantage of maintaining a cool, fresh water supply due to the constant turnover. The tank should be connected to the watering pipes by a flexible hose in order to allow for adjustments in tank height. If the tank is too high, the system will be under too much pressure and the rabbit will not be able to trip the valves in their hutches; and, if the pressure is too low, the valves will leak or drip.

The water valve for the rabbit should be located 22.5cm above the hutch floor for large breeds and 18cm above the floor for smaller breeds. To minimize problems from dripping water valves, locate the valves just outside the hutch and cut a hole in the hutch wall large enough to allow the rabbit to stick its head through and drink.

The piping from the tank to the cages can be either a flexible rubber-type hose such as a garden hose or plastic (PVC) piping (except the first section near the tank as noted above). Drinking valves would have to be obtained from a commercial source of rabbit or poultry supplies. Additional valves for bleeding air from the system should be located at any high point in the piping. A valve to drain the system should be located at the system's lowest point (Figure 19).

Rabbits quickly learn to use the system. Even young rabbits readily adapt to the system providing they are large enough to reach the drinking valve. If young rabbits are not large enough to reach the drinking valve, be sure to supply their fresh water needs by adding a crock or other device they can reach. When a hutch has been unoccupied for a few days, make sure the drinking valve is working properly before introducing a new rabbit, as minerals and sediment in the water can cause the valve to stick.

In cold climates you must protect the system from freezing. If the hutch and all piping are in a heated enclosure there should be no freezing problem; otherwise, heating cables sold for wrapping house pipes can be used on the rabbit piping. Another alternative for short cold periods is to keep the water in the system moving by allowing water to dribble from the drain valve at the low end of the system.

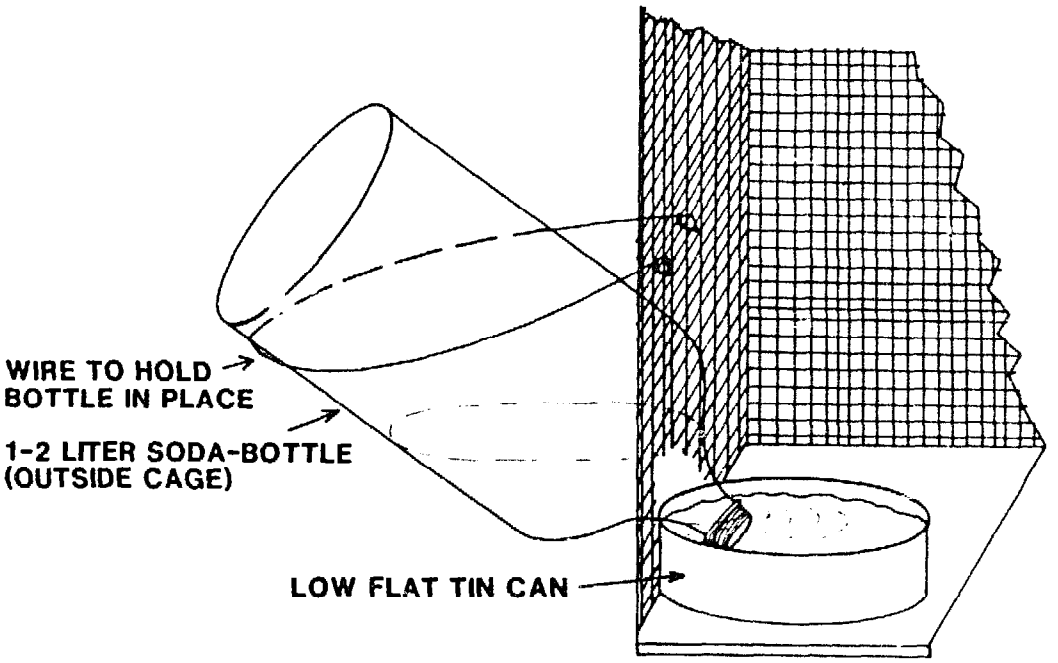

Figure 17. Cut-away view of soda-bottle waterer
(Redrawn from Kanable, p. 31)

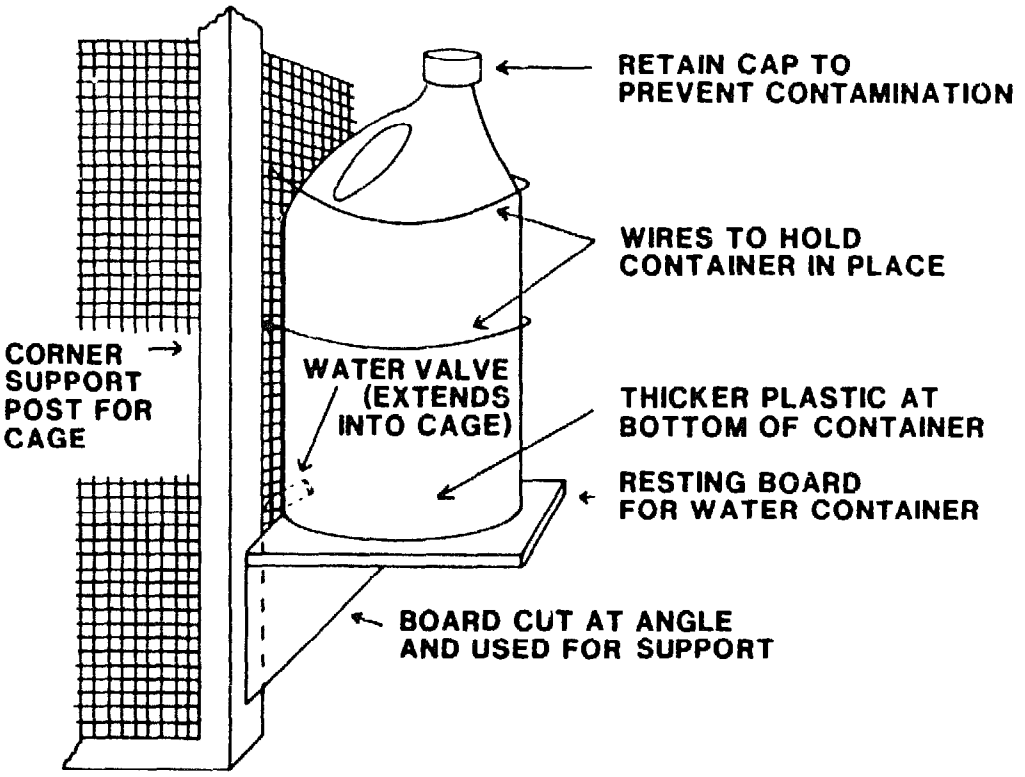

Figure 18. Plastic jug watering device
(Redrawn from Kanable, Raising Rabbits)

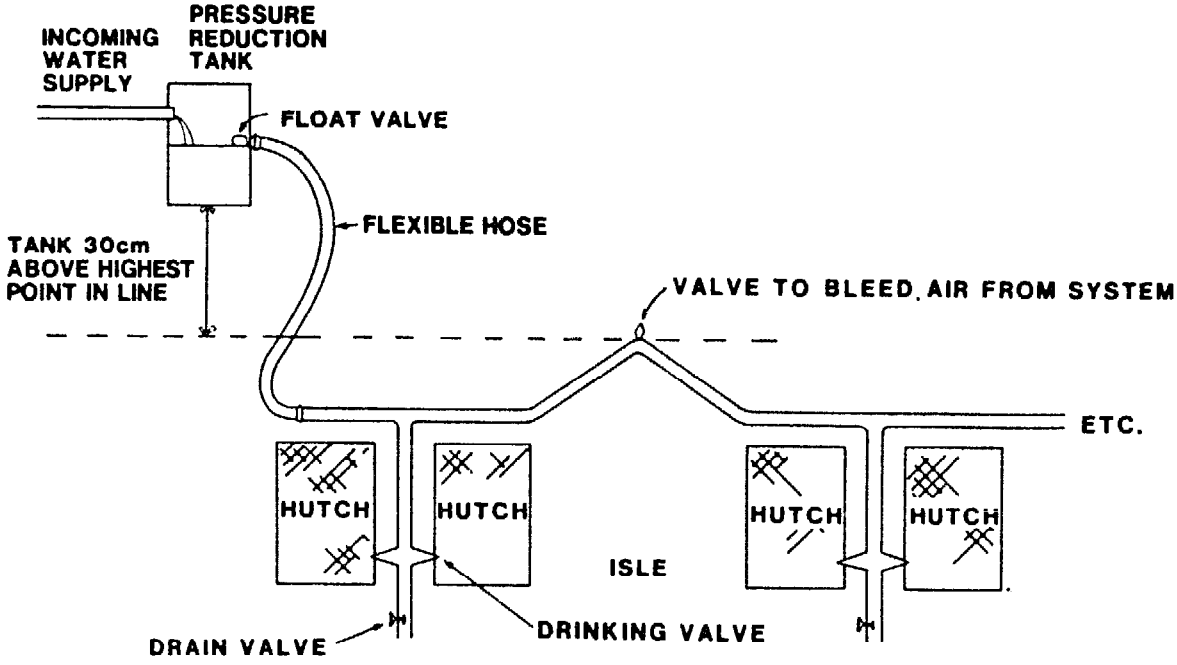

Figure 19. Automatic watering system for large rabbitry.

FEEDERS:

Feeders vary from small, homemade devices to manufactured hoppers for pelleted food. For the small rabbit farmer, homemade feeders are the most practical and least expensive alternative. The simplest feeders are those using a pottery crock or tin can similar to the equipment used to hold water.

Tin can feeder:

Take a one-pound coffee can or similar size tin can, and with tin snips cut down one side to within 5 cm of the bottom. Next, cut half-way around the can staying parallel with the bottom (Figure 20). Now flatten the cut section and fasten the overlap inside the remaining section of the can using rivets or solder. Bend the lower portion of the can over to reduce the possibility of the rabbit cutting itself on the can. The feeder can be wired to a cage wall to prevent tipping (either inside or outside the cage, Figure 21).

Feed troughs:

Hay mangers and feed troughs help keep food off the floor of the cage where it can be trampled and lost. Mangers and troughs also save time in feeding. A simple feed trough (Figure 22) can be built from wood and 24-gauge galvanized metal. The trough guide is made from two wood blocks approximately 2cm thick (9cm x 21cm in length and width) and covered on the flat surface with pieces of galvanized metal (to stop chewing). Next, cut two pieces of galvanized metal 11.75cm wide and 30cm long or longer. The length of these pieces can vary and will determine the length of the feeder, but both pieces should be the same length. Now cut five pieces of 2cm x 4cm boards to 30cm length (or the same length as the previous galvanized pieces). The 2cm x 4cm boards are attached at their end points to the galvanized covered 9cm x 21cm board using wood screws (Figure 22). Then the 11.75cm x 30cm galvanized pieces are formed into two half-circles and placed between the 2cm x 4cm x 30cm pieces (Figure 22). These two half-circles can be attached to the wood 2cm x 4 cm supports with wood screws. A guard to prevent small rabbits from sitting in the feed trough can be constructed from a piece of iron 0.5cm x 2cm x 30cm to which 0.5cm iron rods are attached at 7.5cm intervals. The wire rods need to be 17cm long to cover the feed trough area, and are attached at their midpoint to the flat iron pieces (Figure 23). The flat iron piece is then attached with wood screws to the center 2cm x 4cm wood suport for the two troughs.

Hay manger:

A manger can be constructed from 26-gauge galvanized metal and 16-gauge 2.5cm mesh wire (Figure 24). Galvanized metal sides and ends are attached to the 16-gauge 2.5cm mesh wire with 2.5cm long metal clips and rivets (pop rivets or similar devices). Hay can then be placed in the manger and not be contaminated by feces and urine, as it would be if just placed in the bottom of the cage. If the length and width dimensions used for the manger are the same as those used for the feeding trough, the manger can sit on top of the trough thus conserving cage space (Figure 25).

Oil-can feeder:

A four compartment feeder can be constructed out of a five gallon (20 liter) oil or gas can. The can should be cleaned thoroughly, then two openings are cut in the front and two in the rear. (Figure 26). The openings are 7.5cm x 10cm and are located 10cm from the bottom of the cage. Hem (turnover) a 0.5cm section around the edge of each hole to create a smooth surface. The inner partitions can be built of wood. Two partitions the same size as the inside dimensions of the can are needed (Figure 27). Notching these in their center for half their length will allow them to interlock. The four angled pieces can be made now, also taking their dimensions from the inside compartments. The cut-out portions of these pieces allow food to drop down to the feeding area inside the openings. A piece of 26-gauge galvanized metal can be used to build a top for the feeder. The corners are cut and turned down for 2-1/2cm (Figure 28). If an oil or gas can is not available, the feeder can be constructed entirely of galvanized metal.

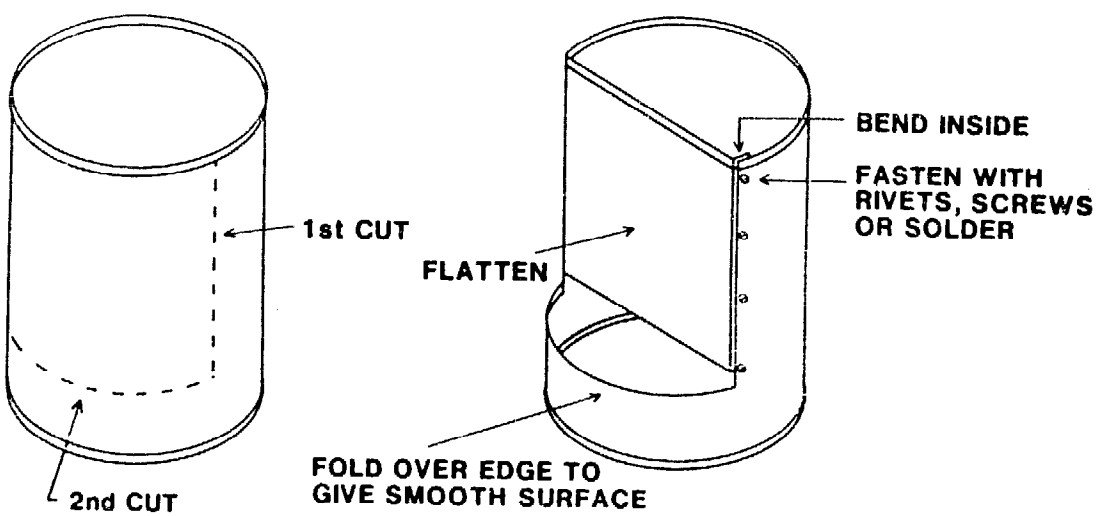

Figure 20. Tin-can feeder
(Redrawn from Kanable, Raising Rabbits)

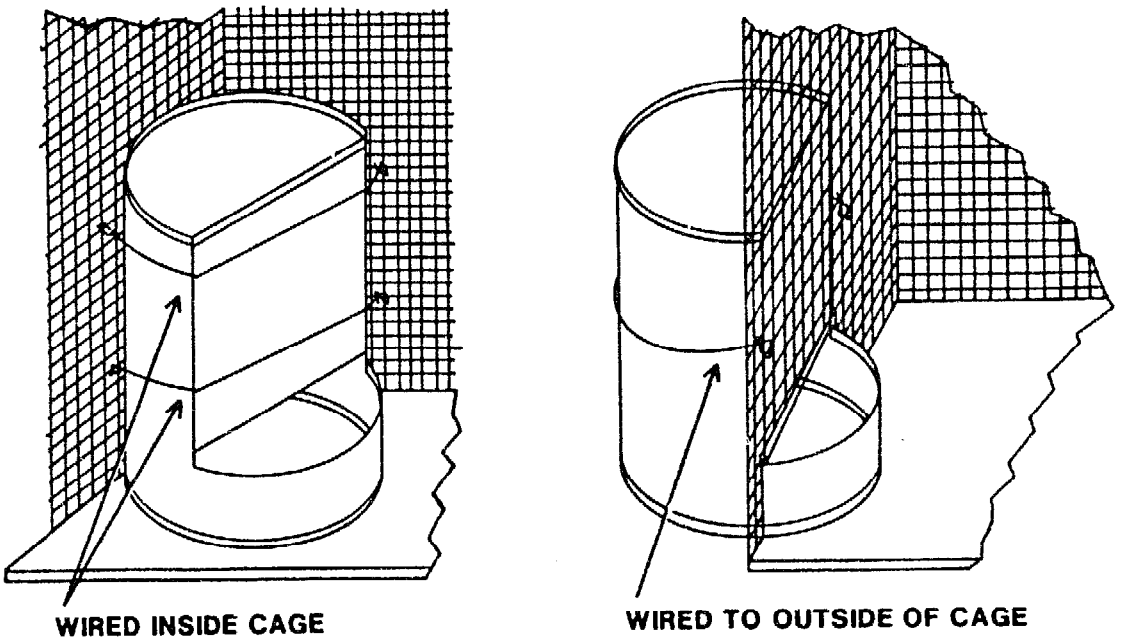

Figure 21. Tin-can feeder attached to cage or hutch

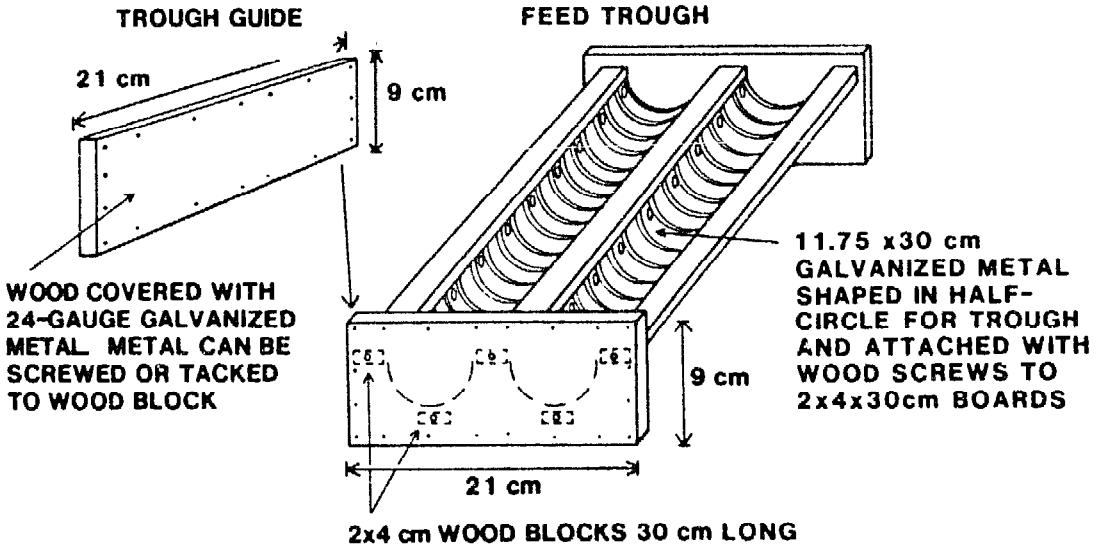

Figure 22. Wood and galvanized metal feed trough
(Redrawn from Farmers' Bulletin 1730, USDA)

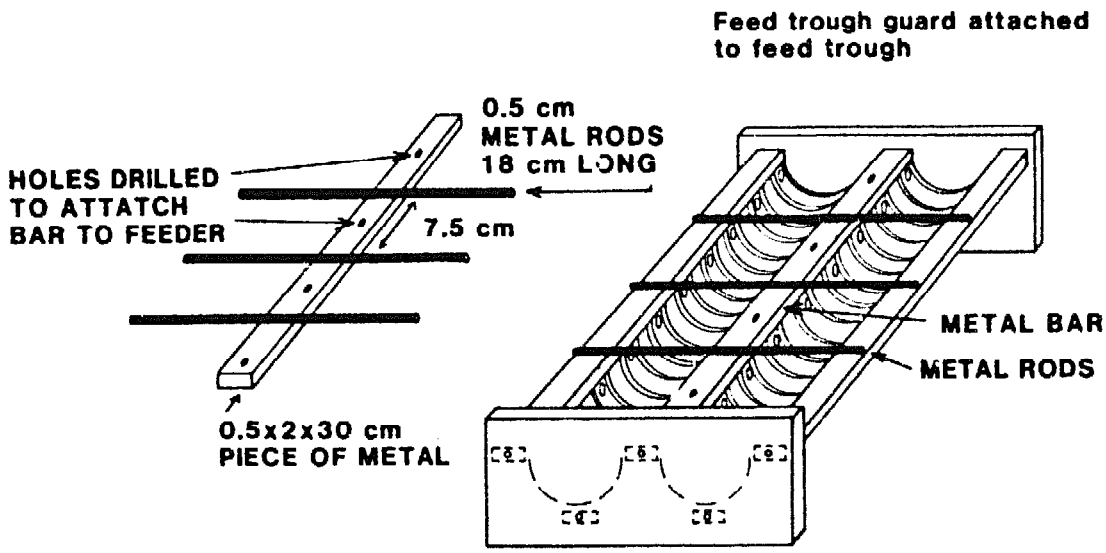

Figure 23. Feed trough guard
(Redrawn from Farmers' Bulletin 1730, USDA)

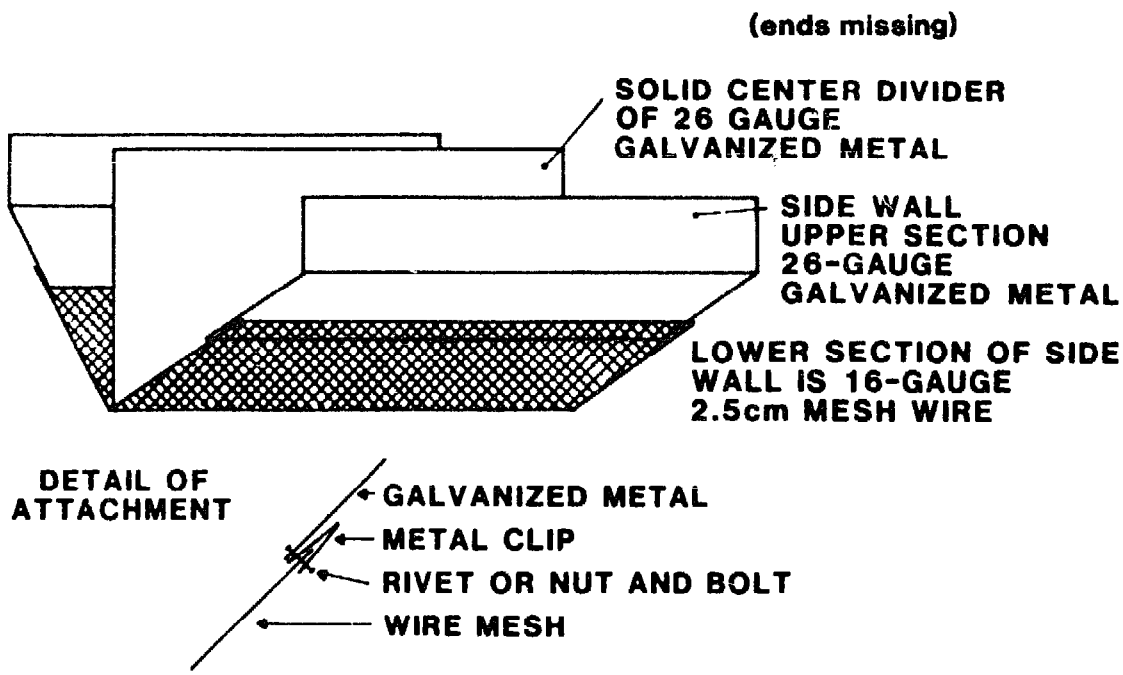

Figure 24. Cut-away view of hay manger (ends missing)
(Redrawn from Farmers' Bulletin 1730, USDA)

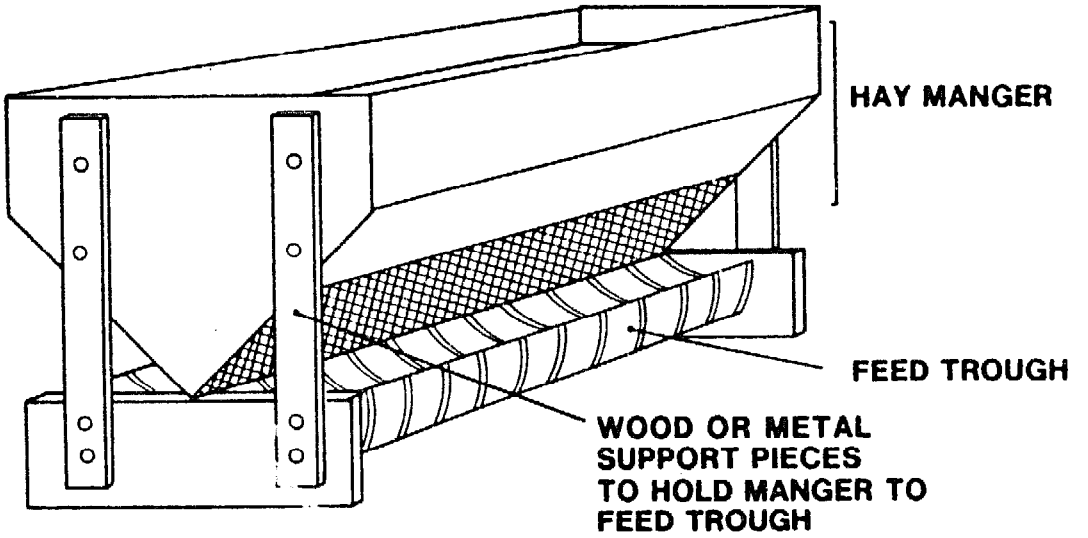

Figure 25. Hay manger on top of feed trough
(Redrawn from Farmers' Bulletin 1730, USDA)

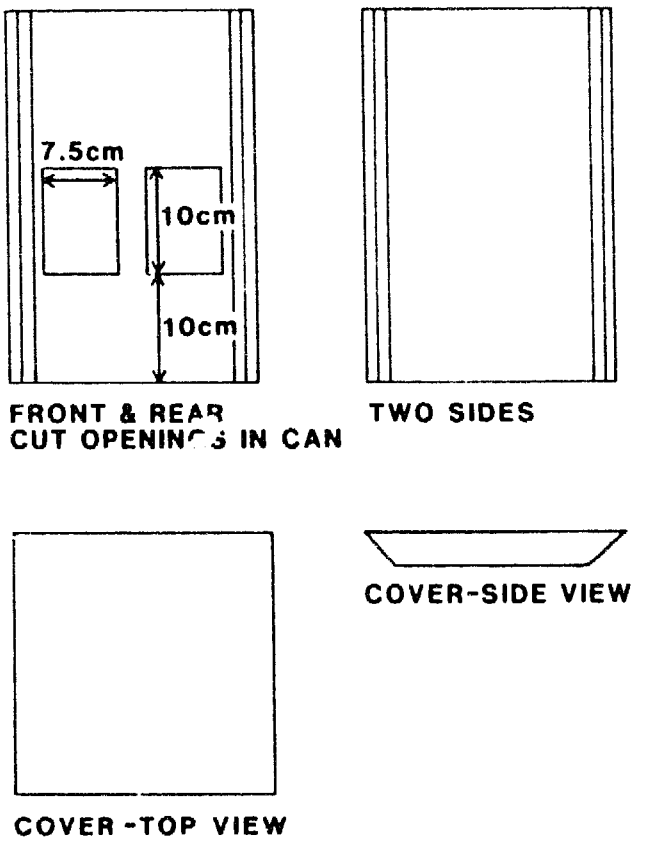

Figure 26. Self-feeder made from 5-gallon oil can
(Redrawn from Conservation Bulletin 25, USDA)

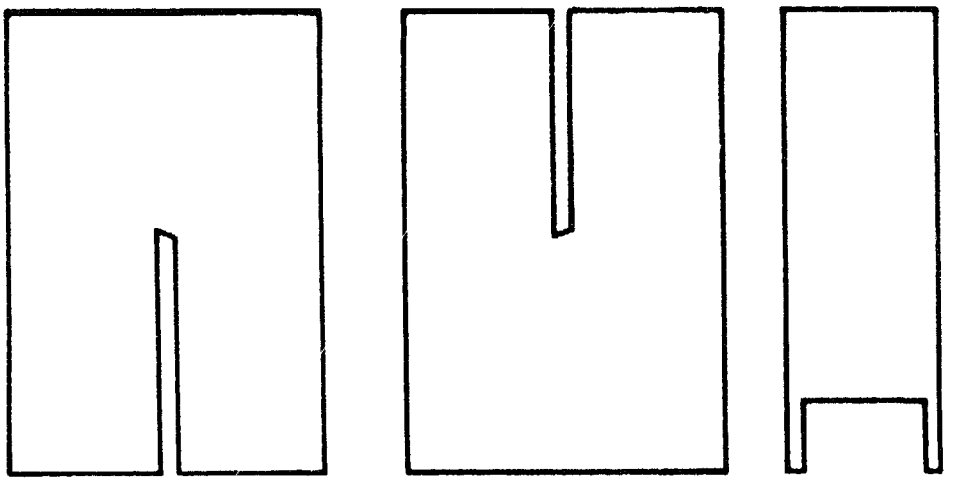

1. MAIN PARTITIONS

2. HOPPER PARTITIONS (MAKE 4)

Figure 27. Partitions for 5-gallon self-feeder
(Redrawn from Conservation Bulletin 25, USDA)

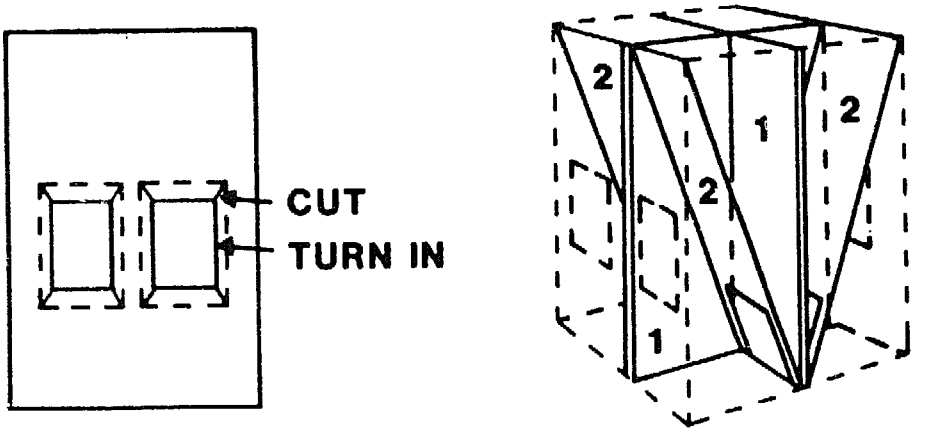

HEM OPENINGS IN CAN

CUT-AWAY SHOWING ASSEMBLY OF PARTITIONS 1 AND 2

Figure 28. Oil can feeder partitions and openings
(Redrawn from Conservation Bulletin 25, USDI)

CARE OF RABBITS DURING EXTREME HEAT

During unusually warm weather the two most important requirements for rabbits are shade and good air circulation. In addition, rabbits should have a good supply of fresh water.

Newborn litters and pregnant does, especially those near kindling, are most susceptible to heat stress. Signs of heat stress include extreme restlessness in early stages and, in young animals, rapid respiration, excessive moisture around the mouth, and small hemorrhages on nostrils. Place a rabbit suffering from heat stress in a quiet, cool, well-ventilated location. Wet the rabbit or give it a cloth soaked in wet water to lie on. When using an overhead sprinkler or another method, wet the tops and any solid sides of the hutch. The resulting evaporative cooling will reduce the temperature in the hutch by 3-8 °C.

Section 3

Breed Selection
Rabbit Wool Production

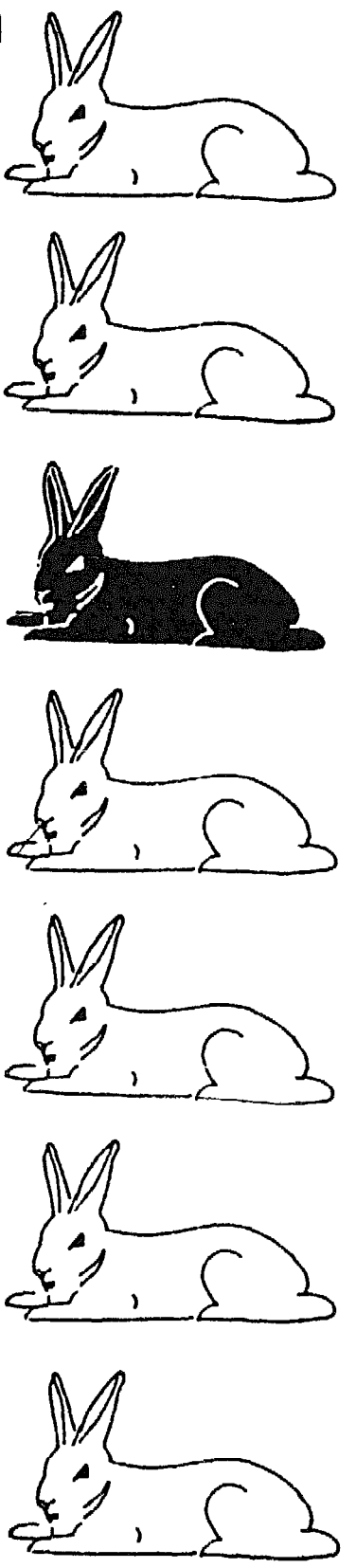

BREED SELECTION

After the hutch is constructed, the rabbits can be obtained from another farmer or from a commercial breeder. Different breeds can be selected for various characteristics. Mature rabbits of the smaller breeds, such as the Netherlands dwarf, weigh 1.5kg to 2kg (3-4 pounds) and large breeds 6kg to 7kg (13-16 pounds). The medium and large breeds are most suited for meat and fur production. New Zealand, Californian, Champagne d'Argent, Chinchilla and Flemish Giant are excellent breeds for meat production (Table1). While the white breeds such as New Zealand and Californian are the most desirable for fur production, the New Zealand white is also the breed used most often for meat. The Californian is the second most common meat breed.

Often rabbit raisers will cross Californian bucks and New Zealand does. One buck can service 2 to 10 does, and the breeds or crossbreeds are not critical for the small backyard producers. Of more importance is trying to obtain healthy rabbits initially. Rabbits that come from different sources should be housed in separate quarters for 30 days before introducing them to other animals in the rabbitry.

Table 1. SOME COMMON BREEDS OF RABBITS USED FOR MEAT AND FUR PRODUCTION (Farm Agriculture Handbooks No. 309, USDA)

BREED	DESCRIPTION	WEIGHT (KG)	USES
Chinchilla	Rabbit that resembles the chinchilla in coloration	4.5.5	fur and meat
Californian	White body with darker nose, ears, feet and tail	3.6-4.7	fur and meat
Champagne d'Argent	Undercoat dark slate blue, surface coat blue-white or silver, long black guard hairs	4-5.5	meat
Flemish Giant	Gray, tan, black, white	10+	meat
New Zealand	White, reddish-brown, black	4-5.5	meat and fur (white color only)

RABBIT WOOL PRODUCTION

Angora rabbits are raised primarily for their fur or wool. Wool on this variety of rabbit will grow at the rate of about 2.5cm per month. Usually the wool is trimmed from the rabbit at three month intervals with total production being about 450 grams per year. The wool is valued for its fluffiness, softness and warmth, but usually has to be blended with other fibers to give it a better strength and durability. The Angora rabbit can, of course, be used as a dual purpose animal for both meat and wool production in those areas with cooler temperatures favoring this type of rabbit.

Herd bucks and does are kept in individual hutches, but extra rabbits can be kept in groups or colonies. Castration of bucks in the colony is necessary to prevent unwanted breeding and to help prevent fighting among the bucks.

Because of their thick coats, Angora rabbits should be handled periodically to determine how thin or plump they are, and adjust their feed accordingly. Self-cleaning types of floors for the hutches and colonies are recommended to keep the wool as clean as possible. Also, it is a good idea to shear animals just prior to mating to decrease matting and loss of wool during pregnancy.

Shearing can be accomplished with a hairbrush that has a single row of steel bristles and a pair of barber's scissors. Electric clippers can also be used if available.

Section 4

Reproduction

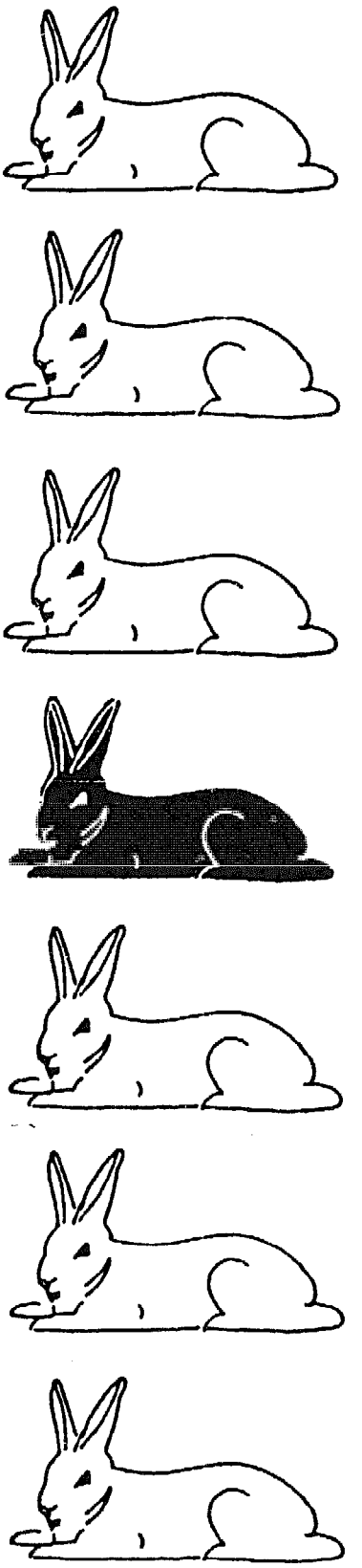

REPRODUCTION

INTRODUCTION

In planning a breeding program for rabbits, concepts that have been shown to work in the breeding of other domestic livestock should be applied in the rabbitry.

Gene Pool:

The initial foundation stock provides a pool or group of hereditary units commonly called genes. Genes are found on specific locations on the chromosomes (small thread-like bodies found in the center or nucleus of every cell). There are 22 pairs of chromosomes in the rabbit, one chromosome of each pair comes from each parent (via egg or sperm). Hereditary characteristics are transmitted from one generation to the next by this method.

Selection:

Selection is the process of a planned breeding to produce offspring with a desired trait or traits. Selection depends upon the initial quality of the gene pool and a proper environment to allow the animal to grow to its maximum potential (i.e. an environment that has adequate food and water plus adequate cage space, so that the young rabbits are not stunted).

Outbreeding or Crossbreeding:

Outbreeding or crossbreeding is the mating of unrelated rabbits.

Advantages: Offspring are usually more fertile and they display increased vigor and growth (desirable in animals for meat production). It produces a maximum number of unlike genes in one animal.

Disadvantages: Later generations show a great amount of variation and can have little commercial value.

Inbreeding:

Inbreeding is the mating of closely related individuals.

Advantages: It maintains uniformity of the rabbit population over several generations.

Disadvantages: It can result in undesirable recessive genes causing a decrease in vibility and reproductive fitness of future generations of rabbits. Sterility, mortality and undesirable abnormal variations occur in greater numbers.

Generally, it is desirable that the initial stock of rabbits be of the highest quality and contain the maximum number of favorable genes.

If the size of the rabbitry is small, and especially if there is only one buck used, it would be highly desirable to bring new, unrelated females into the rabbitry to periodically increase the gene pool and avoid extensive inbreeding.

PHYSIOLOGY OF RABBIT REPRODUCTION:

Heat (estrus):

Rabbits do not have a regular estrus cycle as do some domestic animals. Rather the doe (female rabbit) remains in heat (estrus) for long periods unless she is bred. The follicles on the ovary remain active for 12 to 16 days before regressing. When these active follicles regress, others become active to take their place. There may be a short period (1 to 2 days) between regression of one set of follicles and the onset of activity of another set when the doe is sterile.

Ovulation:

Ovulation (the process of a large ovarian follicle breaking away to become an egg) occurs about ten hours after mating. The male's sperm have moved through the female's reproductive tract to a point where they will meet with and enter (fertilize) the egg.

Development of Fetus:

The fertilized egg grows and becomes the young fetus. In highly fertile strains an average of ten eggs are shed, while in the strains of lower fertility only 4-5 eggs may be shed. The average gestation period for the rabbit is 30 to 33 days (range of 28 to 35 days).

BREEDING METHODS:

Age to Breed:

Smaller breeds develop more rapidly and are sexually mature earlier. Normally bucks are one month older than does before the first breeding. In general, medium weight (4-6 kilograms) rabbits are first bred at 5-6 months and giant breeds (10 kilograms) at 8-10 months. A doe to be bred should always be placed in the bucks' cage. In order to prevent back injury, it is important to carry the rabbit in the correct manner (Figures 29 and 30). The rabbits should be observed for 15 to 20 minutes and if no breeding or fighting takes place it is best to try another buck or try again the next day.

Pregnancy Detection:

Pregnancy can be accurately determined by palapating the abdomen at 12-14 days after mating.

1. Hold the ears, fold of neck and shoulder skin in the left hand (or right hand for left-handed persons).

2. Place the right hand under the abdomen and in front of the pelvis; place the thumb on one side and the fingers on the other side of the abdomen.
3. Slip the tissues of the abdomen between thumb and fingers, feeling (gently) for several marble-size (2cm diamter) forms.
4. CAUTION: Do not palpate with too much pressure as the uterus can be damaged or a fetus torn loose from the uterine wall. This can result in a toxic abortion with loss of the fetuses and possibly the doe.
5. Experienced rabbit owners may be able to palpate pregnant does as early as seven days post mating. If by day sixteen no fetuses are palpated, the doe should be rebred.

Kindling (giving birth to young):

Place a nest box in the cage on day 27 (after mating). The doe will remove some hair and make a nest for the young with the hair and any bedding material provided. One to two days before kindling the doe will reduce her food consumption. Feeding a small amount of green plant material at this time is helpful. Kindling usually occurs at night, and afterwards the doe may be restless. Try not to disturb her until she quiets down.

Complications at Kindling: Complications are rare. Both anterior and posterior (or breach presentations are considered normal; however, if it is determined that the doe is not having strong contractions it may be necessary to give 0.2-3 U/kg of Oxytocin (Table 3). Because of the stress of kindling, does are more susceptible to diseases at this time. Pneumonia is the most frequently seen secondary problem in kindling does. Depending on the cause of the penumonia, antibiotics may be effective in treating the condition (Table 3).

Caked Breasts: This condition develops in does if their milk is not removed. The tissues around the teats become enlarged and hard. Later the ends of the teats becomes tender. Treatment is to rub lanolin on the area and massage the teats, strip the milk from these teats, or allow the young to nurse on the teats affected.

Mastitis: The breast is congested and warm to the touch. Often the skin over the swollen breast is red or purple, and the teats are discolored. Usually mastitis is due to a bacterial infection and can be contagious causing illness in the nursing bunnies. Broad spectrum antibiotics can be used for treatment. Do not let bunnies nurse on infected breasts.

Large Litters: Does may care for 9-10 young, but litters of up to 18 are possible. If there is another doe with a small litter, it is possible

to take some of the young from the large litter and introduce the young to a doe with a small litter. Usually the litters should be within 3-4 days-of-age of each other.

Dry does: The young will starve in 2-3 days if the doe has no milk to nurse them. Using a foster mother may prove useful.

Cannibalism of Young: The doe normally severes the umbilicus and ingests the placenta. Canniblism may be due to an inadequate diet, hereditary factors or a result of disturbance of a nervous doe.

Weaning:

Young rabbits can be weaned at eight weeks of age, and the weight of the young should average 2 kilograms/rabbit. Weaning as early as five weeks is possible.

SEX DETERMINATION IN YOUNG RABBITS

Hold the rabbit around the chest with your left hand and hold the front legs forward alongside the head. Turn the rabbit over on its back while holding the hind legs with the right hand. Now use the first two fingers of the right hand to depress the tail. Then move the thumb up to carefully depress the sex organs exposing the pink mucous membranes. The buck will have a penis with a rounded tip, while the female will have a membrane that protrudes and forms a slit with a small hole near the anus end (Figure 31). Young rabbits can sometimes be sexed as early as one week, but sexing rabbits at weaning is such more practical.

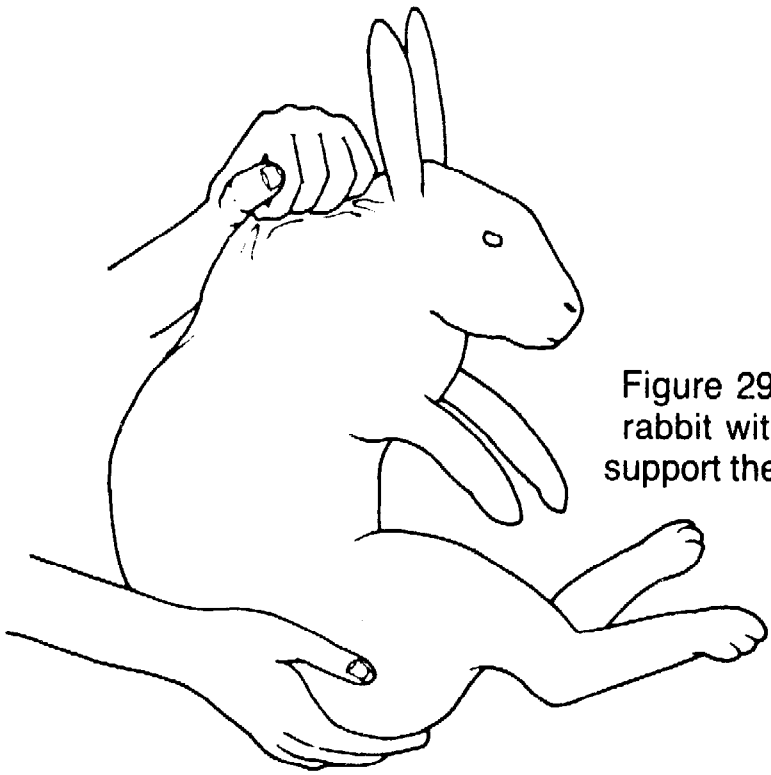

Figure 29. Rabbit restraint—Lift a rabbit with two hands and always support the posterior end of the body.

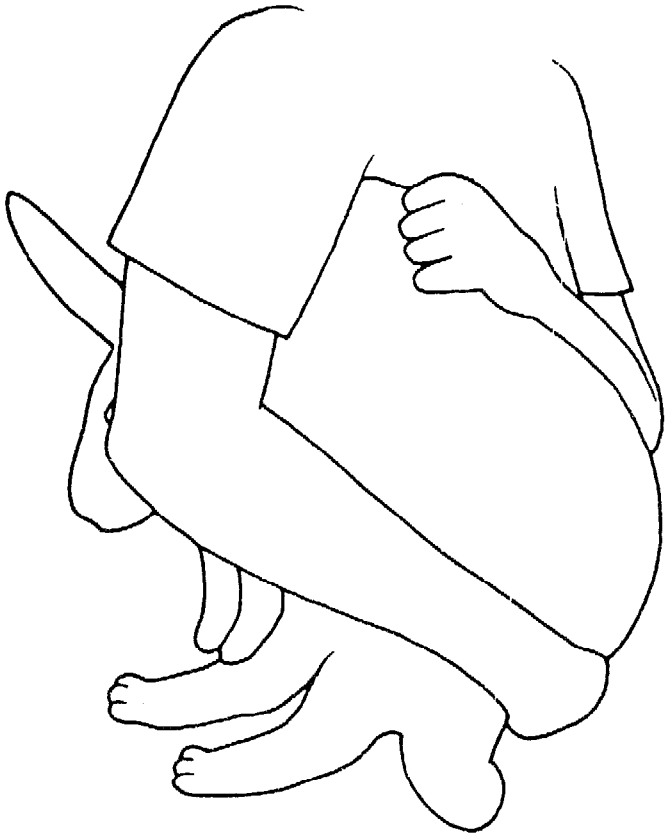

Figure 30. Proper method for carrying and supporting a rabbit to prevent injury

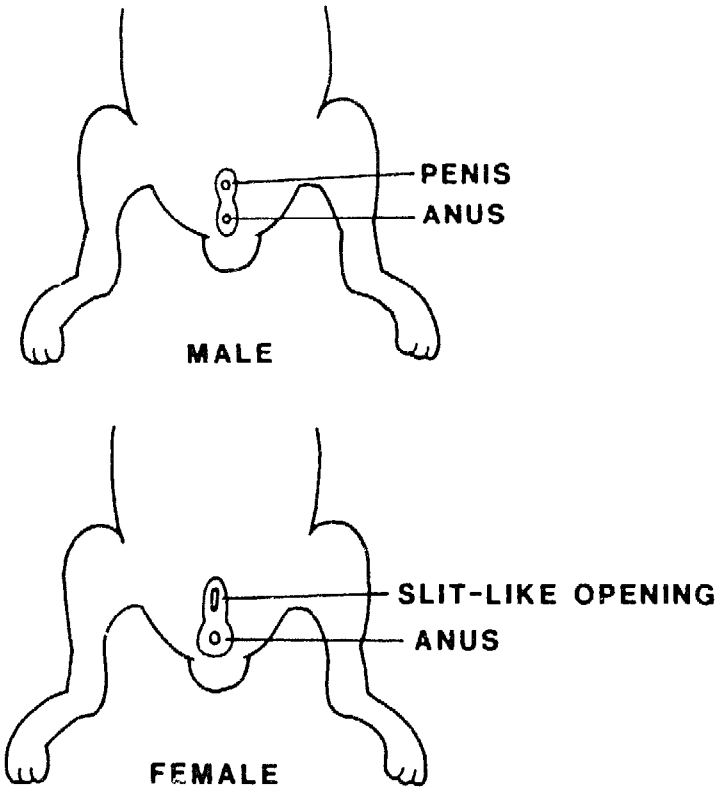

Figure 31. Sexing young rabbits

Table 2. NORMATIVE PHYSIOLOGICAL VALUES

MEASUREMENT/ COMPONENT	RABBIT New Zealand Whites Oryctolagus cuniculus	MEAN	MEAN Male	MEAN Female
Humidity	50%			
Recommended room temperature	68°F.			
Begin consumption of dry feed	21 days			
Daily food consumption (adult)	5 oz.			
Water requirements	200-850 ml/day			
Adult male, weight	2000-7000 gms	3000 gms		
Adult female, weight	2500-8000 gms	3500 gms		
Female breeding age	5-6 months			
Male breeding age	6-7 months			
Estrus cycle	Polyestrus			
Gestation, average	31 (28-35) days			
Birth, weight	80-120 grams			
Litter, size, average	1-18	7-9		
Weaning age	8 weeks			
Life expectancy (years)	5-12 years			
Respiratory rate		51.0		
Tidal volume (ml)		21.0		
Minute volume (liter/min)		1.07		
Whole blood volume		-----		
Plasma volume		38.8		
Erythrocyte volume		-----[b]		
Whole blood pH		7.35		
Heart rate (beats/min)		-----[b]		
Temperature		39.5°C		
Erythrocytes (RBC)	4-6.7		6.7	6.31
Hemogblobin (Hb)			13.9	12.8
Mean corpuscular volume			62.5	63.1
Mean corpuscular hemoglobin			20.7	20.3
Mean corpuscular hemoglobin concentration			33.5	32.3
Hematocrit (PCV)	39-42		41.5	39.8
Sedimentation rate			2.0	1.75
Platelets			480.00	450.00
Leukocytes (WBC)	5.2-12		9.00	7.90
Neutrophils			46.0	43.4
Eosinophils			2.00	2.00
Basophils			5.00	4.30
Lymphocytes			39.00	41.80
Monocytes			8.00	9.00

Table 3. DRUGS AND DOSAGES

DRUGS	DOSAGES
ANTIMICROBALS	
1. Ampicillin	10-25 mg/kg BW, I.M., b.i.d., 5-7 days. 22-44 mg/kg of body weight (B.W.) per os in divided doses for 10 days.
2. Cephalothin	12.5 mg/kg B.W., I.M. q.i.d. for 6-8 days.
3. Chloromycetin palmitate	50 mg/kg B.W. per os t.i.d. for 7-10 days
4. Chloromycetin succinate	30 mg/kg B.W., I.M. s.i.d. for 5-7 days.
5. Gentamycin	4 mg/kg B.W. s.i.d., I.M. for 5-7 days.
6. Penicillin	60,000 I.U. per kg B.W., b.i.d. I.M. for 7-10 days.
7. Benzathine Penicillin G and Procaine Penicillin G	**Flocillin** (Bristol). 1 cc/2.25 kg B.W., I.M. or S.Q. every other days for 10 days **or** 42,000-84,000 I.U./kg B.W., S.Q. once each week.
8. Tetracycline or Oxytetracycline	30-100 mg/kg B.W. per os daily in divided doses, **or** 400-1,000 mg/liter of drinking water. Examples: -Cosa-terramycin (Pfizer) 2 teaspoons (500 mg) per pint. -Polyotic (American Cynanamid) 2.5 teaspoons (500 mg) per pint. -Panmycin Aquadeops (Upjohn) 50 mg per kg B.W. per os b.i.d.
9. Sulfadimethoxine (Albon, Sulmet)	75-100 mg/kg B.W., P.O. s.i.d. for 7 days.
10. Sulfamethazine or Sulfamerizine	100 mg per kg B.W., daily per os. **Examples:** (1) 40 ml (5 gm) of a 12-½% solution per gallon of drinking water. (2) 5 ml of 12½% solution per pint of drinking water. (3) Dilute 1 ml of 12½% stock solution with 49 ml of water. Give 0.5 ml per 30 gms of B.W. (4) Dilute 10 ml of a 12½% stock solution with 40 ml of water. Give 10 ml b.i.d. to an adult 5 kg rabbit as an oral drench. Treat for 3-5 days, skip 3 days and repeat treatment.

Table 3. DRUGS AND DOSAGES (continued)

DRUGS	DOSAGES
11. Furazolidone (Furoxone)	Use -12 teaspoons (200 mg/tsp.) per pint of drinking water for 7-10 days, 2.5/100 lbs. of feed or 50g/ton of feed.
12. Nitrofurazone (Furacin)	100 mg/1,000 ml drinking water for long term therapy **or** 9 g/gal drinking water for 5-7 days.
13. Sulfaquinoxaline	225 gm/ton of feed or 0.05% in water for 10 days.
ANTIFUNGAL AGENTS:	
1. Griseofulvin	**Oral dosages:** 2.5 mg/100 B.W., s.i.d. for 14 days or 25 mg/100 gm B.W. once every 10 days until lesions disappear. **Fulvicin** UF (Schering): Mix once 25 mg tablet with 10 ml of water and give 1 ml of suspension per kg B.W. s.i.d. until lesions disappear.
PARASITICIDES:	
1. Fenbendazole	50 ppm in the food for 5 days.
2. Niclosamide (Yomesan)	150 mg/kg B.W. P.O., repeat treatment in 14-21 days.
3. Phenothiazine	1 g/50 gm molasses-treated feed.
4. Piperazine citrate	100 mg/100 ml drinking water for 1 day, repeat treatment in 14-21 days.
5. Piperazine powder	25 mg/kg B.W. P.O. 1 ml/7 kg B.W. P.O. for 5 days.
6. Amprolium 9.6% (Corid)	309 ml in 20 liters of water and treat for 2 days, then use 15 ml in 20 liters of water for 4 days. Repeat in 2 weeks.
7. Dimetridazole (Emtryl)	0.025% solution prepared using 45g active ingredient /50 gallon of drinking water.
8. Benzyl benzoate	Use as a 2-5% dust (dilute in talcum powder).
9. Ivermectin	0.1-0.2cc S.Q. of a 1 to 100 dilution in propylene glycol.
10. 10% Ammonia solution	Used on caging following a thorough cleaning with hot water, a detergent to kill Coccidial oocysts.
11. Mitox	Place 6-8 drops in each ear every 3 days for 2 weeks. Repeat as necessary.

Table 3. DRUGS AND DOSAGES (continued)

DRUGS	DOSAGES
OTHER DRUGS:	
1. Oxytocin	0.2-3 u/Kg B.W., S.Q.
2. Calcium gluconate 10%	5-10 ml P.O. **or** 3-5 ml I.V.
3. Chlorination of drinking water	Use 1.5 ml of 5.25% sodium hypochlorite solution (Chlorox) per 2 gallons of drinking water (200 ppm of free chlorine) use daily.
4. Accidification of drinking water	Use 3.0 ml of 1.0N hydrochloric acid per pint of drinking water. Give a ph of 2.4.

Key for Table 3: I.M.—intramuscular injection
I.V.—intravenous injection
S.Q.—subcutaneous
Per of or P.O.—oral dose
mg—milligrams
gm—gram
kg—kilogram
B.W.—body weight
s.i.d.—one daily dose
b.i.d.—two daily doses
t.i.d.—three daily doses
four daily doses

Section 5

Nutrition

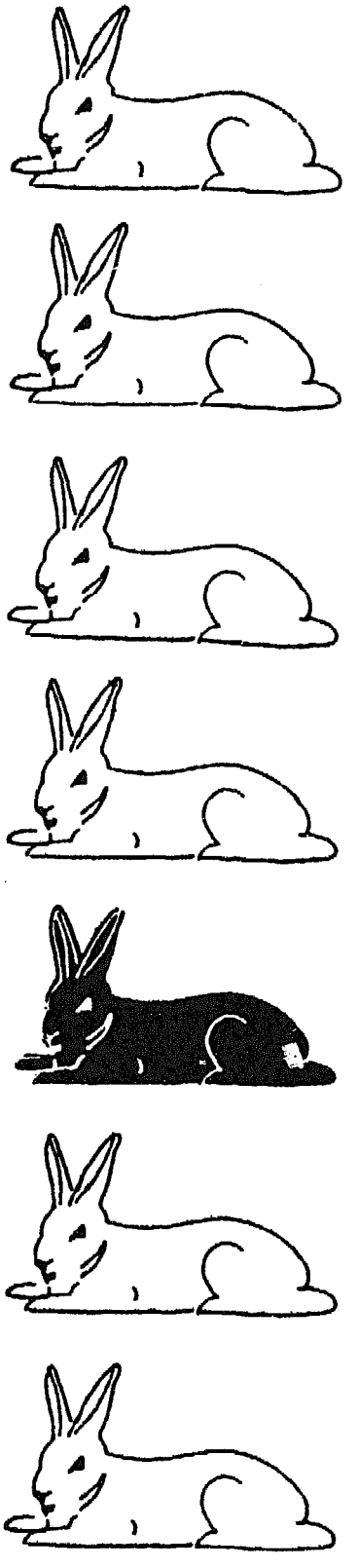

NUTRITION

Although it has been said that rabbits can be fed any left-over food product, this is only true if specific nutritional levels are not met. Different foods contain different levels of those substances, which an animal uses to build its body, reproduce and produce energy. These substances are called nutrients, and there are basically five types of nutrients: Carbohydrates, proteins, vitamins, minerals and water.

Rabbits are herbivorous, monogastric animals with a unique large intestine. The potential of rabbits as meat producing animals is related in part to their ability to utilize fibrous feedstuffs that cannot be effectively consumed by man. In developing countries, rabbits can be raised to convert available forages and feed by-products into high quality human food. Rabbit meat is high in protein and low in fat, cholesterol and sodium.

The ability of the rabbit to gain weight on a small amount of feed is very good. Several studies have reported a feed to gain ratio of less than 4 to 1, on a high alfalfa diet. This is much lower than the feed to gain ratio of most other animals on a grain diet.

In the United States of America, the majority of rabbit feed utilized is pelleted. The use of pelleted feed has several advantages, including the reduction of dust, east of handling, and prevention of animals from sorting through the feed and eating only the more palatable feedstuffs. Rabbits prefer a pelleted form or diet over the unpelleted form when given a choice. They have a higher growth rate compared to rabbits fed the same diet in an unpelleted form. Also, there is more feed spillage and wastage with the unpelleted diet. However, in situations where pelleted feed is impractical and/or too expensive, the feeding of unpelleted diets may be utilized with satisfactory results.

The rabbit's intestine is sensitive to many factors, such as pH, starch content and osmolarity. With this in mind, feed changes should be done gradually, over a four-to-five day period in order to allow growth of normal organisms required for digestion. This is especially important in the four-to-twelve-week old rabbit. During the diet change, old and new foods should be combined, gradually increasing the amount of new diet while decreasing the amount of old diet.

DIETARY REQUIREMENTS:

CARBOHYDRATES:

Carbohydrates (starch) are a major source of energy and are important for growing, reproduction, lactation, keeping warm and several other

body functions. Food sources which are high in starch include pasture grasses, bananas, cassava, potatoes, hay, and grains such as corn and cereals. Energy requirements for the rabbit have been estimated to be 2500 Kcal of digestible energy per kilogram of diet for growth, gestation and lactation. Approximately 2100 Kcal of digestible energy per kilogram of diet is required for maintenance.

One can divide carbohydrates into two main categories: 1) readily available carbohydrates (RAC) and 2) carbohydrates that are associated with fiber. The feeding of diets high in RAC can result in carbohydrate overload of the hindgut. The starch component in high energy grain diets such as corn and other cereal grains may pass through the small intestine relatively undigested and serve as a substrate for bacterial growth in the cecum, which is a large pouch off the large intestine. Finely ground ingredients predispose to the development of this situation. Starch in the cecum allows proliferation of **Clostridium spiroforme** which produces an iota toxin resulting in a fatal intestinal poisoning called enterotoxemia. Maintaining dietary crude fiber levels of at least 12-15% has been shown to minimize the occurrence of this disease.

Indigestible dietary fiber is also important for maximum growth rate and to prevent hair chewing. Rabbits fed low fiber, high energy diets have reduced grains and more pronounced fur chewing. Fur chewing may lead to increased problems from gastric trichobezoars (hair balls). Generally, a diet of 16 to 20% crude fiber is recommended for rabbits. Some evidence exists that particle size of the fiber is important (ie. finely ground alfalfa is less effective than coarsely ground or checked alfalfa). Diarrhea will be seen with dietary fiber levels that are less than 6%. Although fiber is an important component of a rabbit's diet, too much fiber may also cause problems. Digestion of fiber in the rabbit is much lower than in practically any other animal. It has been suggested that high dietary fiber levels, over 22%, may predispose a rabbit to develop cecal impaction.

FATS:

Fats, like carbohydrates, are also a major source of energy in a diet. Because fats are easily digested, rabbits like to eat fatty foods. A dietary fat content of 2% is generally thought to be adequate for rabbits, although dietary fat levels as high as 25% have been fed without adverse effects.

PROTEIN:

Proteins are important in maintenance, growth, reproduction and milk production. These dietary components are found in cereals, grains, by-products of oil crops such as coconuts, soybeans, peanuts and in young

green grass, green legumes and hay. Protein requirements for rabbits are 15 to 16% for growth and 18 to 20% for lactation. There is some evidence that bacterial synthesis of protein in the cecum contributes to the amino acid requirements of adult rabbits. It is thought that bacterial synthesis of protein makes only a minor contribution to the amino acid needs of growing rabbits. It is important to remember that the amino acids found in proteins are the building blocks of the body; therefore, protein quality of the diet is important in rabbit nutrition.

Even though 18-20% protein is necessary for optimal growth rate and performance for lactating does, lactating does can be fed diets containing 16-17% protein. At the lower dietary protein level, there is not a great deal of difference in doe productivity. The economic advantages, particularly in back-yard rabbitries, of the lower protein diet may off set the slightly reduced performance.

Protein deficient diets may result in inadequate milk production and poor growth of newborn rabbits, cannibalism and increased fur chewing.

VITAMINS:

Vitamins are substances that activate all body processes. Domestic rabbits require vitamins A, D, E, K and the B vitamins. Supplementation of the diet with vitamin C is not necessary. Generally speaking, a diet consisting of 30 to 60% good quality dried forage will meet the rabbit's requirements for the fat soluble vitamins (A, D, E and K). Vitamin D is also obtained from the sunlight.

Rabbits produce two kinds of feces, a soft, mucous form at night and a firm pellet during the day. The soft night feces are ingested directly from the anus. This practice is called coprophagy. The night feces may consist of 30 to 80% of the total daily excreta. Night feces have a similar protein, ash and fiber composition as day feces but have a much higher concentration of niacin, riboflavin, pantothenic acid and vitamin B_{12}. These B vitamins are synthesized by bacteria in the cecum. The practice of coprophagy provides sufficient B vitamins to meet the rabbit's daily requirements.

MINERALS:

Minerals are substances which must be presented in the diet for the proper building of bones and teeth. Like vitamins, mineral requirements of rabbits are easily satisfied by a good quality diet consisting of 30-60% dried forage. The major consideration regarding mineral nutrition is an adequate calcium: phosphorus ratio. Generally speaking, a calcium level of 0.40-0.45% and a phosphorus level of 0.22-.037% will be sufficient for growth and gestation. During lactation rabbits need higher levels, 0.775% calcium and 0.50% phosphorus. Most forages and feeds

contain minerals; however, salts are often added to the diet to supplement the needs for minerals.

WATER:

Clean, cool water should be provided for rabbits at all times. Water helps keep the animal cool in hot weather, but more important is the fact that water is essential for the animal to keep its body tissues alive and healthy. An animal's body is made up of 70% water and the rest is just minerals and ash.

DIETARY COMPONENTS:

GRAINS:

Except for a diet of barley, there is no real advantage to feeding diets consisting of grains over commercially available pelleted diets. However, if pelleted diets are not practical and/or affordable, grain may be a satisfactory component or supplement to a rabbit's diet. If home grown grains are available and are not needed for either human or other animal consumption, they may be used successfully as a component of the rabbit's diet.

Other grains that have been fed to rabbits include buckwheat (10% protein) and wheat (soft, 11-13% protein). It has been suggested that one can mix together equal parts of crushed wheat (or oats or corn) and barley, milo, rye, rice or other grain sorghums to feed dry does, young rabbits or herd bucks.

FORAGES:

While alfalfa is the most commonly used forage-addition to rabbit diets in the United States, research has also been done on the use of other forage materials. Forages are cheap and abundant year round in tropical countries. A recent study examined the use of woody legumes, non-woody legumes and grasses as dietary additions for the rabbit. Grasses were 6 weeks old, legumes were cut at the flowering stage and forages were hand-chopped to 1-1.5cm prior to feeding. Forages were wilted overnight and/or steam-pelleted. In general, the woody legues had the highest nutrient composition, digestibility and palatability. Regardless of which type of forage, one must supplement with a concentrate diet to improve nutrient intake. This is especially true for grasses, as most tropical grasses have very little nutritional value except as a source of indigestible fiber. It is important to note that the digestibility values of calcium in most grasses, and phosphorus in most forages, are negative. The following is an alphabetical listing of forages that have been examined as components of rabbit diets.

Alfalfa - : The protein content of alfalfa deteriorates as the plant grows older. Prebloom alfalfa hay has approximately 19% protein content and early bloom alfalfa hay has approximately 16% protein content. Alfalfa hay, like other legume or grass hays, may be fed free choice in a hay manger or rack on the side of the cage. All hays (and other feeds) should be completely free of molds. Alfalfa is also available in pellet and meal forms. In fryer studies, the use of sun-cured alfalfa meal has yielded better performance when compared to dehydrated alfalfa meal. Sun-cured alfalfa meal is also more palatable than dehydrated alfalfa meal.

Bermuda grass - Bermuda grass is reportedly toxic to rabbits and therefore, is not recommended as a forage source.

Black Locust - Black locust, also called common acacia or false acacia, is a fast-growing, leguminous tree that is readily adapable to a variety of soils and climates. The young trees can be repeatedly cut so that they grow in a shrubby form from which the leaves are easily harvested. The crude protein level in the leaves is 23%. One study compared the use of dried black locust leaves as the forage component (40% of the diet) of a pelleted diet to the use of alfalfa forage. Average daily gains with black locust leaves were approximately 12 g/day less than those obtained by rabbits fed alfalfa. Average daily gains were still in an acceptable range and no mortality, diarrhea or other adverse effects were reported following the feeding of black locust leaves. Black locust leaves may also be fed fresh to rabbits.

Butterfly pea - The crude protein level of butterfly pea, a tropical forage, is 17.2%. Average daily gains using butterfly pea as 40% of the diet are similar to those seen with alfalfa diets.

Calliandra sp - This has been used as a forage component of rabbit diets in Indonesia.

Cassava - The crude protein content of cassava is 24.7%. Average daily gains are approximately 10 g/day less than with similar diets utilizing alfalfa as the forage component. The cassava tuber is used as human food and rabbits may be fed with the leaves, a by-product of this human vegetable/crop production. Cassava leaves have been fed to rabbits in Indonesia. **Manihot utilissima**—grown in Nigeria, is another form of cassava, which has a crude protein of 32% and 18% crude fiber.

Cassia tora - This tropical forage has a 14.9% crude protein level, when fed to rabbits as 40% of the diet, average daily gains were 5-7 g/day less than those achieved by rabbits ingesting a similar diet of 40% alfalfa.

Comfrey - Comfrey, a leafy forage plant, may be fed as a fresh green during the growing months or dried and fed as as a hay during the winter months. Comfrey is a good protein source, comparable to alfalfa; however, the digestibility of the protein in comfrey is only about 70% of the digestibility of alfalfa protein because it is bound to fiber. Comfrey is lower in fiber compared to alfalfa and has about double the ash content. Comfrey also contains allantoin and has been reported to alleviate diarrhea in young rabbits.

Corn plant - Whole corn plant pellets, prepared by harvesting the entire corn plant, dehydrating it and pelletin_ it, have been fed to rabbits. The pellets are low in protein (6.2%), crude protein, and high in fiber.

Gliricidia sp. - This has been used as a forage component of rabbit diets in Indonesia.

Grass Hay - Various grass hays such as Prairie, Timothy, Johnson and Sudan may be fed to rabbits. Grass hays contain less protein than legume hays and the diet will probably need an added protein source.

Guinea grass - Guinea grass is a tropical forage with 13.1% crude protein level. Compared with a diet of 40% alfalfa, average daily gains with guinea grass were 5-7 g/day less.

Elephant grass - Elephant grass has a 13% crude protein level and a 30% crude fiber level.

Kentucky blue grass - Kentucky blue grass clippings were fed to rabbits, 10% of the diet, and average daily gains were similar to those seen with alfalfa. The grass clippings were obtained from a sod farm. The young, tender clippings proved to be a good high protein forage for rabbits.

Kudzu - Kudzu is a rapidly growing, coarse, hairy, stoloniferous vine that is native to China and Japan. It is best adapted to drained loam soils of good fertility. Kudzu can be used to prevent soil erosion, as a pasture plant, and also as a hay. Uncontrolled, it may overgrow other vegetation, and can become a pest. Compared to alfalfa, at 10% of the diet, average daily gains were about 8 g/day less but were still at an acceptable level. Kudzu, as a forage, is palatable and may be especially useful in tropical or warm countries where no alfalfa is available.

Leucaena - is a tropical leguminous tree producing high protein (greater than 30% crude protein) leaves. Trees can be kept in the shrubby form by repeated cutting. It has been fed successfully to rabbits at levels of 20-30% of the diet, in dried form, with

average daily gains of 37 g/day. The digestibility of dry matter and protein is reduced as the **Lecaena** level in the diet is increased, resulting in poor feed/gain ratios. Urine of rabbits fed **Leucaena** is deep red to black in color. The origin and significance of the urinary pigments is presently unknown. **Leucaena** may also be fed fesh, in the green form. It is important to note that **Leucaena** contains an amino acid, mimosine, which has been toxic for rabbits that were fed Leucaena as the sole forage. In this group of rabbits, various reproductive problems, poor growth and hair loss were seen.

Pawpaw leaves - Pawpaw leaves have a 35% crude protein level and 8.8% crude fiber.

Perennial peanut - Florigraze rhizoma is a warm-season, tropical, perennial forage legume, adapted to well-drained soils. The plant is a native of South Africa. When substituted for alfalfa, 40% of the diet, rabbits had similar rates of gain. Some rabbits had diarrhea for the first few weeks on this diet; however, this eventually resolved.

Red clover hay - Red clover hay, approximately 13% protein content, may be used to feed rabbits.

Rice straw - Rice straw has been fed to rabbits at either 20 or 20% of the diet. Growth rate is approximtely 35 g/day.

Sesbania - is a forage plant that has been utilized to feed rabbits in Indonesia.

Spanish clover - Spanish clover contains 21.4% crude protein. When fed to rabbits, 40% of the diet, the average daily gains are equal to or slightly greater than gains seen with rabbits on a 40% alfalfa diet.

Styloanthes quinesis - is a tropical forage with 15.8% crude protein. Rabbits fed diets of 40% **S. quinesis** have average daily gains of approximately 33.5 g/day, which is 7-8 g/day less than gains of rabbits fed a 40% alfalfa diet. It should be noted that there is a 50% incidence of diarrhea and a 30% mortality rate in rabbits receiving **S. quinesis** compared with a 20% diarrhea and a 20% mortality in the alfalfa diet rabbits.

Sugarcane - Sugarcane has a 4.8% crude protein level and 21% crude fiber.

Sunflower leaves - Fed as 40% of the diet, sunflower leaves result in poor growth and hair loss problems. Sunflowers contain a phenolic substance, chlorogenic acid, which binds protein and reduces its availability. Hair loss in rabbits fed sunflower leaves is thought to be due to increased fur chewing caused by an in-

duced protein deficiency. Sunflower leaves appear to have poor potential as feedstuff for rabbits.

Sweet potato vines - have been used to feed rabbits in Indonesia.

Talfairia - Talfairia has a 22% crude protein level and 13% crude fiber.

Talinum - Talinum has a 22% crude protein level and 11% crude fiber.

Vetch - Common vetch, approximately 17% protein, may be used as a legume hay in rabbit diets.

Water peanut - In China, water peanut is grown along pond banks. It is collected in the morning, allowed to wilt on mats and then fed later in the day to rabbits. Approximately 70% of the rabbits' diet consist of water peanut, the remainder of the diet is composed of a variety of weeds and forages.

Wheat straw - Rabbits fed a diet of either 20 or 30% wheat straw had a growth rate of 35-40 g/day.

Winged bean - Winged bean, approximately 18.8% crude protein, fed to rabbits as 40% of the diet results in average daily gains of 10 g/day less than alfalfa. There is a high incidence of diarrhea when rabbits are fed winged bean. It is felt that the diarrhea plus low growth rate may suggest that winged bean contains compounds which interfere with nutrient utilization. Winged bean is a tropical forage. The bean pod has been used as human food, thus rabbits can be fed a by-product of vegetable/crop production.

SEEDS:

The following is an alphabetical list of seeds that have been examined as components of rabbit diets.

Amaranthus - Seed heads of both black and white species of amaranthus have been fed to rabbits. Both types resulted in poor average daily gains. Feeding of seed heads from the black-seeded amaranthus resulted in an 80% mortality rate due to a possible hepatotoxin.

Barley screening - Rabbits fed a diet of 20% barley screenings, as a fibre source, have average daily gains equal of superior to rabbits fed a similar diet with 22.5% dehydrated alfalfa.

Canola meal - Canola meal or low glucosinolate rapeseed meal is a good replacement for soybean in rabbit diets.

Cottonseed - Rabbits fed a diet of 43% cottonseed have no significant differences in gain compared with rabbits fed a soybean meal diet. Cottonseed meal, prepress solvent extracted, has been fed to fryers as 4, 8.2, 10 and 16.5% of the diet. No adverse

effects attributable to the cotton seed meal were noted as assessed by rate of gain, mortality or feed efficiency. No effects on the semen of bucks fed 20% cottonseed meal for 150 days were noted. At these levels cottonseed does not appear to have adverse effects on male rabbit fertility. Long term studies on does need to be done.

Flax - A diet of 30% flax seed has been fed to rabbits. No significant differences in gains are noted between rabbits fed flaxseed and a soybean meal diet.

Lupin grain - Diets of 7, 14, and 21% lupin grain, 40% crude protein, have been fed to rabbits. No significant differences in average daily gain or feed intake are seen in rabbits fed lupin grain as compared to soybean diet.

Maize (corn) bran - Maize bran has 11.2% crude protein and 7.8% crude fiber.

Peas - Peas, 26-27% crude protein, have been fed to rabbits as 30% of the diet. No significant differences in average daily gain or feed intake are seen in rabbits fed peas and those fed soybean meal.

Rice and wheat bran - Rice and wheat bran are excellent sources of protein and energy for rabbits. Wheat bran contains approximately 16% protein and 10% fiber plus vitamin E.

Safflower - Rabbits fed a 34% safflower diet have no significant differences in gain compared to rabbits fed soybean meal.

Soybeans - Soybean meal contains approximately 45 to 48% protein. It may be added to rabbit rations at a percentage of 5 to 7% of the total ration. Adding too much soybean meal can cause digestive problems in rabbits, especially young rabbits.

Soybean hulls - Rabbits fed a 10% soybean hull diet as a fiber source have average daily gains that are statistically equal or superior to a diet of dehydrated alfalfa.

MISCELLANECUS CATEGORY:

The following is an alphabetical list of various supplements and components of rabbit diets.

Banana and Plantain leaves - Mixtures of banana and plantain leaves have been fed to weanling rabbits. The leaves, comprising 30% of the diet, were fed either fresh, dry or half and half. No difference in performances were seen between fresh or dry leaves with average daily gains of about 20g. Banana leaves are 20% crude protein and 24% crude fiber. Plantain leaves are 18% crude protein and 20% crude fiber.

Beet pulp - Rabbits fed a 15% beet pulp diet, as a fiber source, have average daily gains that are statistically equal or superior to those of rabbits that are fed dehydrated alfalfa.

Blood meal - Blood meal has 24.3% crude protein and 24% crude fiber.

Brewers grains - Dried brewers grains contain 28% crude protein and 18% crude fiber.

Brewers yeast - Dried brewers yeast contain 46.3% protein and 12% crude fiber.

Cabbage - Fresh cabbage leaves have been fed into weanling rabbits in which 5, 15, and 25% levels replaced corn in the diet. Average daily grains were 13.2, 18.1 and 12.4 g/day respectively.

Citrus pulp - Dehydrated lemon and orange citrus pulps have been fed to weaning rabbits as 20% of the diet, replacing 20% corn in the diet. Digestibility of the citrus pulp is similar to the corn diet. Gains with the citrus pulp diet were about 20 g/day compared to 24 g/day with corn.

Corn husks - Corn husk contains 2.6% crude protein and 31.6% crude fiber.

Cottonseed cake - Cotton seed cake contains 22.4% crude protein and 25% crude fiber.

Copper - Conflicting literature reports exist on whether or not the addition of copper to rabbit diets is beneficial. One study examined the effects of 100, 150 and 200 ppm copper sulfate in diets that were low (14%), medium (18%) and high (22%) in protein. This study found that growth was significantly enhanced at 200 ppm copper sulfate for the low and medium protein levels, but not the high protein level diet. This suggests that as dietary protein levels increase, the effects of adding copper to the diet decreases. The mechanism of action is unknown; however, cupric ions activate pepsin, an enzyme involved in protein utiliztion, which may be part of the reason for the growth promoting effect of supplemental copper. Another study did not show any effect on weight gains when copper (250 ppm) was added to the diet. Some studies have also suggested that dietary supplementation with copper has some protective effect against diarrhea and mortality in 4 to 10 week old rabbits. Other studies have not supported this finding.

Goat's milk - One study gave rabbits free choice pellets and goat's milk. Rabbits given goat's milk consumed less than half the amount of pellets eaten by those control rabbits receiving water and pellets ad lib. When excess milk is available, the cost of feeding rabbits could be reduced by giving milk instead of water.

Palm Kernel Meal - Palm kernel meal contains 21% crude protein and 10% crude fiber.

Peanut Cake - Peanut cake contains 52% crude protein and 5% crude fiber.

Peanut hulls - Peanut hulls contain 5.7% crude protein and 31.8% crude fiber.

Poultry broiler finisher pellets - Poultry boiler finisher pellets (18% crude protein) can be fed in limited quantities along with free choice grass to produce rabbit meat at a cost comparable or less than that of fresh chicken and pork. A study in Trinidad fed each doe 80 g/day for day 1-23 of gestation and 100 g/day the last 8 days of gestation. The schedule for concentration feeding from kindling to weaning at 28 days was: 120 g/day first 7 days then 120 g + 10 g/kit/day for the next 21 days. Fryers are offered 30 g/day the first week post weaning and this amount was increased by 10 g every 7 days, until the animal was 9 weeks old. Animals 9 weeks of age and older received 80 g/day of the concentrate.

Poultry manure - Dried poultry manure contains 26% crude protein and 18.6% crude fiber.

Rabbit manure - Dried rabbit manure contains 36.7% crude protein and was fed in one study as 10-15% of the total diet. Average daily gains of rabbits fed manure were similar to those fed alfalfa. Rabbits fed manure had a decreased incidence of enteritis. If rabbit manure is treated with alkali, the crude protein level is 0.4% and the digestible content is 1970 Kcl/kg (vs. 772 Kcal/kg pre-treatment) which is similar to alfalfa.

Rice husks - Rice husks contain 5.2% crude protein and 43.2% crude fiber.

Urea - Urea has potential as an inexpensive substitute for low protein in rabbit diets. Experimental studies have reported somewhat variable results. Early studies, using weanling rabbits, showed no beneficial effects of the addition of urea to a low protein diet. More recent studies have shown that a urea diet does not support body weight gain and nitrogen retention as well as soybean meal diet in adult animals; however, fryers appear to utilize urea more efficiently than adult animals. With fryers, gain is actually slightly superior with a urea diet as compared to a soybean meal diet. Coprophagy is essential for normal utilization of dietary crude protein in both young and mature rabbits.

Vegetable leaves and tops - Various vegetables and vegetable leaves have been fed successfully to rabbits. These include collard leaves, carrots and carrot tops, dandelions, potatoes and potato peels, turnips, sweet potatoes, parsnips, English pea and green bean vines. Raw potato peels are high in Vitamin B_6.

Zeolite - Zeolite is a buffering compound, crystalline alumino silicate, with ion exchange properties. Addition of zeolite to the

diet in either 1.5% or 3% has resulted in significant decreases in mortality due to enteritis.

TYPES OF DIETS:

Although many individual food products have been discussed in this section, there may be a commercial supplier of concentrated feeds in the area. If rabbit chow is not available, one may substitute a pelleted pig grower ration or even a pelleted chicken feed. It is especially helpful to use the commercial products as a supplement to the natural foods during the rapid growth periods of the young, during the last ten days of pregnancy, and during lactation. Some recommended rates for using the commercial supplements are: 90g per day for growing young; 90g per day during pregnancy; 150g per day during first 3-4 weeks of lactation; add 10g more per kg during the last few weeks of lactation (1-ounce = 28.25 grams).

Generally one diet is used for the entire herd. However, the protein and energy requirements for lactation are higher than for growth. If only one diet is used for all rabbits, for example, a diet suitable for a lactating rabbit, then fryers will receive excess protein and the high energy level may induce diarrhea. If a diet adequate for fryers is fed to all rabbits then one may see decreased productivity in does.

It has also been suggested that at least two diets could be advantageously used for fryers. One diet would be a high fiber weaning diet and the second diet would be a high energy finishing diet. More research needs to be done in order to develop optimal diets for various production phases.

Section 6

Rabbit Diseases

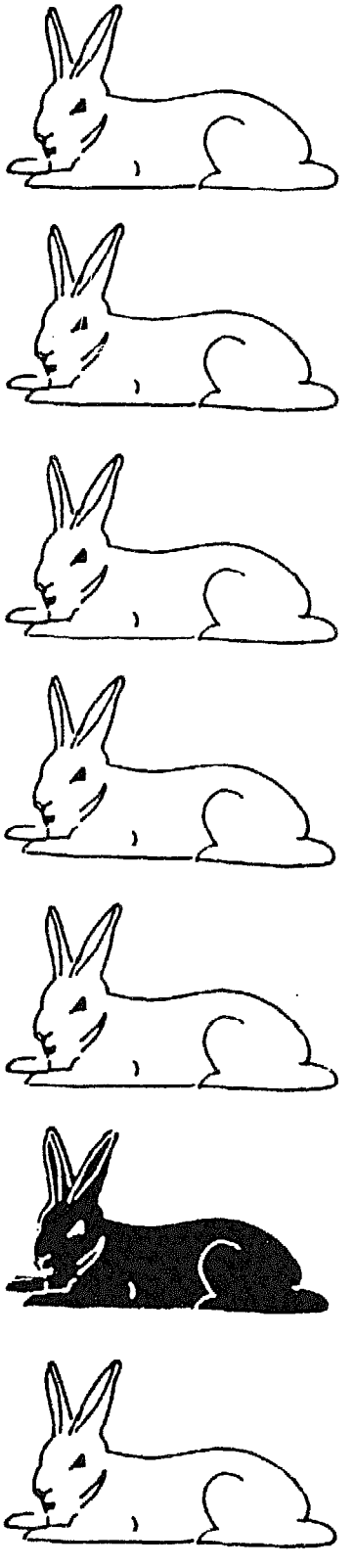

RABBIT DISEASES

Obviously, one of the most devastating and discouraging aspects of rabbit production is disease. The term disease is used here in the broad sense of various illnesses, disorders or ailments, which may cause poor performance, sickness, other abnormalities, or death. Disease states may result from infection by microorganisms and parasites (infectious diseases) or from injury, poison, and functional or metabolic disorders (noninfectious diseases). Rabbits may be affected by both classes, but the infectious diseases are of more concern.

The success or failure of a rabbit operation is probably dependent upon the owner's ability to keep disease at a minimum. Most diseases occur because of management mistakes or lack of knowledge. Mortality in many herds averages 20% or more of all animals born. The total loss of rabbits due to disease in the United States averages 20-25%; this includes kits born dead, nest box death, fryer deaths, and the loss of does and bucks. In other areas of the world it seems reasonable to expect that death losses would be at least this high. This section will discuss bacterial, viral, fungal, parasitic, hereditary and miscellaneous diseases often seen in the rabbitry.

When well fed and properly housed in draft free sanitary hutches, rabbits will live relatively free of disease; however, the best cure is always prevention. Because medications are not always available, the following paragraphs will discuss natural animal medicines and their reported uses in preventing and curing common rabbit ailments.

Many wild animals have an innate ability to choose what is needed to get well. Old time rabbit breeders have used this information to discover natural medications with which animals in the wild treat themselves.

Feeding the leaves of plantain, dandelion, or the leaves and bark from elm trees once or twice a week may help keep a rabbit herd from developing any need for more drastic chemical drugs. These natural materials appear to be effective in preventing common scours (diarrhea) that sometimes afflict the very young rabbit.

The bark and the limbs of the sassafras tree also appears to relieve digestive upsets in newborn rabbits. Once the bark is all eaten from the piece of sassafras, it is not uncommon to see the doe place the wood in her water bowl allowing the wood to seep into the water making tea. Breeders have felt that either the bark or the tea is helpful in preventing diarrhea.

It has also been shown that dry leaves of certain trees may have about the same effect as green leaves. The dry leaves may be gathered when they are fresh, clean and free of mold, decay and insects. Rabbits seem

to prefer the leaves of oak, elm, sassafras and willow trees. Apparently the bark of the willow tree also contains substances that are beneficial to rabbits.

Blackberry leaves have long been considered an excellent cure for scours. Because the rabbit is highly susceptible to chemical toxicities, it is very important to never use the leaves, bark, grass clippings or berries that have been sprayed with insecticides or herbicides.

Another natural remedy for diarrhea or scours in rabbit herds has been the use of apple cider vinegar. Apparently the apple cider contains large amounts of potassium, which may be the major beneficial ingredient for rabbits. The apple cider vinegar is diluted to 5% acidity, and one or two tablespoons are added to a gallon of fresh clean drinking water. The vinegar treated water is then given daily over a period of two to three months. Some breeders have claimed that giving rabbits this water vinegar daily will also control coccidiosis. Other breeders have actually reported that the apple cider vinegar in the drinking water will increase the reproductive rate of rabbits in a rabbitry.

Apple cider vinegar has also been shown to improve the rabbits' coats, giving them a healthier sheen even in hot months when rabbits are likely to be shedding at least some of their heavy fur. Improvement in rabbit coats is probably due to the acidity of the vinegar, which can effect the pH balance of the skin and give the hair folliciles a healthier base in which to grow.

Another natural remedy which has been used to combat a lack of protein in the diet is feeding the product comfrey. Comfrey contains most of the amino acids that are the building blocks of protein, plus it contains the curative substance allantoin which is commonly used in many medications. Comfrey is fed as a fresh green plant during growing months or it may be dried and fed during the winter months. Like alfalfa, it should be fed as fresh as possible to have the greatest effect, but drying the summer crop for winter use is as practical as using other hays. It offers more extensive benefits with regular use. Many rabbit breeders have reported that their rabbits are very seldom sick with colds, numerous rabbits suffering from various types of diarrhea have cleared up, and those suffering from run down conditions due to a heavy breeding schedule and nursing, have all been shown to improve or disappear after the feeding of comfrey. Recent studies have indicated that comfrey may have some carcinogenic activity; therefore, it is recommended that this food source be used with discretion.

In raising rabbits you may come in contact with some unusual methods for treating diseases. One such medication is pekoe tea given in the drinking water. This substance has been shown to be effective against some bacterial diseases such as Tyzzer's disease. One large tea bag is diluted in one gallon of water, cooled and given to sick rab-

bits as drinking water. The tanic acid in the tea apparently is effective in killing many bacterial diseases. The weak tea has also been shown to clear up cases of ordinary diarrhea when given with clean, bright straw to eat.

As in many other animals, stress is known to produce or precipitate diseases in rabbits. Common stresses include such things as extreme heat in the summer, cold in the winter, and noises of various kinds. Perhaps the greatest stress placed upon the rabbit is lack of proper sanitation. Living in filthy quarters can stress any animal, including those much larger and stronger than the rabbit. Accumulation of manure and urine create an ammonia gas in the building. This in turn causes a severely oppressed air quality which has its effect on the respiratory system of the rabbit. As with heat, those carrying or nursing young and little rabbits are the most susceptible. When the rabbitry operator can smell ammonia gas in the rabbitry, damage has already been inflicted on the lungs, nasal passages, and bronchial tubes of the rabbit.

DISEASE DIAGNOSIS:

As a rabbit raiser, you should become very familiar with the normal appearance and physiological characteristics of a rabbit. Refer to Table 2 for physiological parameters. Rabbits suffering from a disease usually exhibit some characteristics which make them appear or act differently from healthy animals. The following clinical signs are indications of a disease or abnormality, and each should be evaluated carefully:

1. Failure to eat
2. Abnormal breathing
3. Discharges from the eye and nose
4. Loss of weight
5. Diarrhea
6. Listlessness
7. Blood in excretions
8. Skin lesions
9. Fever
10. Increased pulse rate
11. Increased respiratory rate
12. Change in color of mucous membranes

Close observation of clinical signs while the rabbit is living may allow for diagnosis. Other diseases cannot be diagnosed without a necropsy examination, and in some cases, special techniques. A necropsy should be performed by a veterinarian as soon as possible after death, since tissues degenerate rapidly and examinations several hours after death are of little value unless the carcasses are preserved. Refrigeration can be used to delay tissue decomposition if necropsies must be performed at a later date.

COMMON DISEASES:

The following diseases are grouped as: (a) miscellaneous and noninfectious diseases and ailments, (b) hereditary diseases, (c) viral diseases, (d) bacterial diseases, (e) fungal diseases and (f) parasitic diseases—external and internal parasites.

MISCELLANEOUS AND NONINFECTIOUS DISEASES:

Canabalism:

Most cases of canibalism, which is the act of one rabbit eating another rabbit, are the result of the diet being inadequate in either quality or quantity, or because the does are disturbed following kindling. In a breeding program it is essential that the doe be provided with adequate housing and diet in order to prevent this condition. Does which continue to destroy their litters should be culled from the breeding population.

Heat Prostration:

In tropical climates, care should be taken to prevent rabbits from getting too hot and collapsing. Adult animals suffering from heat may be relieved by spraying them with water or placing a wet burlap feed sack on the cage floor for the animals to rest on. Bedding and fur should be removed from the nest box to allow free circulation of air in boxes with infants. Other techniques which may be used in high temperature climates are: overhead water sprinklers to help reduce the air temperature by evaporation, aluminum roof sheds to help reduce the air temperature by evaporation, aluminum roof sheds to help reflect the heat, and burlap bags soaked in water may be hung from the edges of the roofs to shade and cool the air.

Clinical signs of heat prostration are increased respiratory rate, depression, and evidence of a bloody discharge from the mouth and the nose. Mortality rates can be high unless environmental temperatures can be reduced below 33°C (92°F). Pregnant does are most often affected, and young rabbits in the nest box are particularly susceptible when there is excessive bedding and little ventilation.

Broken Back:

Spinal fracture is an injury which may occur if the rabbit kicks excessively when the rear legs are not properly supported. Paralysis may extend from the middle of the back resulting in an animal that cannot use its back legs. The animal moves with its front legs and drags the hind quarters. Often times the urinary bladder may become greatly enlarged giving the animal a bloated appearance.

Other conditions which may produce spinal injury include using a tattoo short for the size of the animal or injuries which may occur at night

when predator animals invade the rabbitry. A rabbit with a dislocated spine usually cannot be treated and should be destroyed. Sometimes, if the spinal cord has not been too severely damaged partial recovery may occur.

Sore hocks:

Although the scientific name for this disease is Pododermatitis, the name sore hocks is much more descriptive of the inflamed bare spots, devoid of fur, which are found on the bottom surface of the hind legs. Severe cases will develop secondary infections with Staphylococcus organisms producing abcesses. If a rabbit walks with an unusual motion or of the rabbit sits with more weight on the front feet than normal, the disease sore hocks should be suspected. Although both front and hind feet may become involved, the animal usually throws more weight to the front feet due to the painful hocks of the infected hind feet.

A genetic predisposition for this disease occurs in certain strains of rabbits. If the animal is inherently nervous, excitable, and is active with excessive foot stomping, this may contribute to the development of sore hocks. Also, larger breeds seem to have a higher incidence compared to smaller breeds. Since there is an inherit predisposition to this disease, it is obvious that rabbits with a habitual tendency towards sore hocks should not be used as breeders. Environmental factors which may be involved in this disease include the type of wire on the cage floor, the cleanliness of the cage floor, and the condition of the cage floor. Filthy caging and improper housing can easily be corrected by proper management.

The use of ointments, sprays, and many other medications will produce temporary improvement in rabbits suffering with sore hocks. Placing the rabbit on a soft flooring such as sawdust may also help the feet to heal. Unfortunately when the rabbit is returned to its original housing or his treatment regime is discontinued, the condition will usually reappear. Most rabbitries believe it is more economical to cull the rabbit, and avoid using this animal for breeding stock.

Malocclusion:

Malocclusion and tooth overgrowth result when, (for genetic, dietary, infectious, or traumatic reasons) open rooted teeth do not meet properly and are therefore not worn down as they would normally. In the rabbit, the teeth commonly involved are the incisors, which, if not constantly worn down, will grow approximately 10 cm (4 inches) per year. Malocclusion in the rabbit is probably an autonomous recessive (inherited) trait involving an abnormally short upper jaw. Since buck teeth are also an inherited characteristic, the number of rabbits carrying the nose with the medial aspect of the fore feet resulting in a wetting and matting of fur on the feet.

undesirable gene will increase in a breeding colony unless specific culling is carried out to eliminate these animals. There is no cure for this condition other than culling. Temporary treatment involves cutting away the excessive growth using heavy scissors or wire cutters. This will allow the young to eat and obtain slaughter weight. The teeth will continue to grow during this period and repeated trimming may be required in two to three weeks.

Hairballs (Trichobezoars):

Many rabbits ingest small amounts of hair during the normal practice of grooming. Several rabbits in a hutch may eat body fur, eyelashes, and whiskers. Accumulation of hair within the stomach is thought to be attributed to the inability of the rabbit to vomit and the small pyloric lumen, which predisposes to hair accumulation in the stomach. In either case the fur mixes with the stomach contents and forms a firm ball which cannot pass through the pyloric valve between the stomach and the small intestine. Causes for this condition include hairloss; lack of dietary fiber; protein, copper, or a magnesium deficiency; abnormal grooming behavior; and excessive shedding of a naturally long hair coat.

Clinical signs for hairballs include anorexia, weight loss, agalactia, depression, absence of feces and eventually death in three to four weeks from starvation and metbolic abnormalities. Diagnosis is often times difficult but usually can be made using palpation and/or radiography.

Although routine treatment with mineral oil (10cc at a time) on a monthly basis may prevent hairballs, the formation of a ball too large to pass out of the stomach cannot be treated by this method. A wetting agent, dioctyl sodium sulfosuccinate 5% in propylene glycol or one of several flavored laxatives and lubricate preparations, can also be used. Of recent interest is the use of a digestive enzyme (papain) and/or pineapple juice, which may break down the fiber particles and allow for passage of the hairball. Surgical removal of the hairball can be used as a last resort. Postoperative care should include fluids, antibiotics, and hay or calf manna. Unfortunately, recurrences are common. Even though there is no effective method of treatment, many breeders feel that a 15% fiber level is probably the minimum that should be fed to either growing or producing rabbits. Apparently the increased fiber content in the diet helps prevent the formation of hair balls.

Coprophagy:

This is a normal characteristic of the rabbit in which it actually eats its own fecal pellets, and this usually occurs at night. Fermentation of feces in the large intestine supplies an abundance of certain B vitamins to the fecal pellets, probably improves the quality of the protein in the soft pellets, and improves fiber breakdown by bacterial action. The rabbit

actually takes three soft pellets from the vent as they are passed and reingests them. It is thought that this second passage of food through the digestive tract allows for increased nutritive values to be derived from the food. Coprophagia can occur during the day, although it is usually a night practice and should not be interpreted as a disease or an indication of a depraved appetite.

Yellow Fat:

Some rabbits develop a very dark yellow deposition of fat. This is a genetic trait determined by a recessive gene which prevents the reduction of the xanthophyll pigment to a colorless product. This is not a disease condition; however, it is often an objectionable trait because consumers prefer white fat in meat rabbits. The only solution is to cull those breeders producing this yellow fat syndrome.

Wet Dewlap:

The dewlap is a loose fold of skin under the neck, which is very large in female rabbits. During warm weather, rabbits will tend to drink large amounts of water and this may predispose this area to excessive moisture. If this dewlap remains damp, the fur will discolor and may develop a secondary bacterial infection. Usually the hair will turn green and the skin will become inflamed beneath the matted fur.

Treatment involves clipping away the matted fur and treatment of the skin with an antibiotic ointment. The removal of water crocks, fixing leaking sipper tubes and, in general, providing for a dry environment will usually prevent this condition.

Hutch Burn:

The reproductive organs and teats are very sensitive to urine and fecal contamination. These tissues are easily irritated and may have brownish crusts covering the area with a bloody exudate. This condition is often confused with rabbit syphilis or vent disease.

Treatment involves warm compresses, the application of camphor oil and massage to remove the milk. If the teat and its milk gland are severely caked it may be necessary to lance it and thoroughly irrigate the tissues with hydrogen peroxide. Topical and systemic antibiotics are also recommended. Often times this condition will predispose the female to subsequent mastitis, which is a severe disease of the milk glands.

HEREDITARY DISEASES:

Buphthalmia (Congenital or Infantile Galucomma):

This eye condition initially appears as an increase in the size of the eye with a gradual cloudiness and a bluish color on the surface of the eye. The eye soon becomes more milky white in color, enlarges and

there is increased blood supply to the surface of the eye. Eventually the eye is so opaque that blindness results. Because this is thought to be inherited, it is best to remove these animals from the breeding colony.

Hydrocephalus:

This is almost always a condition which is first noticed as an enlargement of the head at birth and then quickly worsens as the animal grows. Usually the young die within a short period of time. Although many reports describe this as an inherited trait, it has also been shown that a lack of vitamin A in the diet of the pregnant doe may be correlated with hydrocephalus.

Splay leg:

This condition is similar to the hip dysplasia found in certain breeds of dogs and it is thought to be an inherited condition. Affected rabbits cannot move the involved limbs(s) toward the body resulting in a 'splay leg' appearance for the animal. Again, because of the potential genetic involvement, all affected animals should be removed from the breeding program.

VIRAL DISEASES:

Rabbit Pox:

Rabbit pox is a severe, highly fatal disease that can occur with or without clinical lesions. It is caused by a pox virus which is closely related to the vaccinia virus and it is transmitted through nasal secretions.

Clinically, animals are febrile and they have a profuse watery diarrhea, enlarged inquinal and popliteal lymph nodes and cutaneous skin lesions. The skin lesions are usually seen as a rash covered by a crusty exudate. Blepharitis, keratitis and a purulent conjunctivitis are often present. Mortality is highest in the unweaned young where it may approach 75% in epizootics.

Vaccination with vaccinia virus is recommended for susceptible colonies in the face of an outbreak.

Myxomatosis:

This is an infection of cottontails which can easily enter rabbitry colonies by means of mosquito transmission. Myxomatosis is also called 'Big Head Disease' because of the swelling produced around the eyes, ears, lips and nose. Clinically there is swelling around all body orifices and the ears may become so edematous that they become heavy and pendulous. Diagnosis is usually made on the basis of the clinical signs described and over 80% of the animals will die in 10-12 days.

Histological examination of the affected tissues is used to confirm this diagnosis. Some attempts have been made to vaccinate infected colonies with an attenuated rabbit fibroma virus or a modified-live myxomatosis virus.

Rabbit Papilloma:

This is a DNA virus belonging to the Papilloma virus group which usually causes papilloma type lesions in the cottontail but has also been isolated from domesticated rabbits. The most common sites for these well keratinized papillomas are the eyes and eyelids.

As these wart-like lesions increase in size they are easily scratched or knocked off leaving an open wound which heals without complications.

It is thought that transmission from the wild cottontail to the domestic rabbit is accomplished via insects such as mosquitos and ticks. The obvious measure is to protect the animals from these arthropod vectors.

BACTERIAL DISEASES:

Pasteurellosis:

One of the most serious problems observed in rabbitries is pasteurellosis caused by **Pasteurella multocida**. This disease results in economic losses through deaths, failure to gain weight, culling of sick animals, and in some cases failure of affected rabbits to reproduce. Rabbits are more susceptible to infection with **Pasteurella multocida** than most other laboratory animals, and several clinical forms of the disease occur. This disease can manifest itself in a number of different ways, such as metritis (infection of the uterus), orchitis (infection of the testicles), mastitis (infection of the mammary glands), conjunctivitis (infection of the eye), sinustitis (infection of the sinuses), and subcutaneous absesses. Of all these conditions, sinusitis (snuffles), is by far the most common. Severe snuffle problems have forced many rabbitries out of business and cut the profits of most large rabbitries.

Snuffles is most often seen in rabbitries with poor ventilation. The rabbitry is usually over crowded and excessive manure build-up under the cages is common. The odor of ammonia from the breakdown of rabbit urine is often detected. All of these factors put a considerable amount of stress on the rabbit's respiratory system. The mucous membranes of the nasal sinus become infected by bacteria in the inspired air or by direct contact with infected animals or contaminated objects. The clinical disease is characterized by nasal discharge (mucous or pus). Infection of the paranasal sinuses probably results in a lifelong infection in most cases. Infection may be clinically silent for varying periods of time with intermittent periods of mucopurulent nasal discharge. The discharge may be wiped from the

nose with the medial aspect of the fore feet resulting in a wetting and matting of fur on the feet.

Snuffles is extremely contagious to other animals in the herd. The other forms of pasteurellosis mentioned previously generally begin appearing after snuffles is noticed. The devastating aspect of **Pasteurella multocida** is that it has been shown to spread throughout the body by several routes including: a) the nasolacrimal duct to the conjunctival sac; b) via the trachea to the lungs; c) by the eustachian tube to the middle ear and subsequently to the inner ear, meninges, and brain; d) via blood to organs and tissues throughout the body; and e) by lumphatics to lymph nodes and the blood stream. Rabbit mortality surveys have shown that the greatest single cause of death in mature animals is pneumonia following an upper respiratory disease with snuffles. Signs of pneumonia are depression, labored breathing, bluish eye color in albinos, and a nasal discharge. The body temperature is usually above normal.

Many times infected females will not reproduce and are therefore culled from the herd and slaughtered. Necropsy usually reveals an infected uterus (**pyometra)** which can be traced back to a single buck with a chronic infection of testicles. **Orchitis** is an infection of the testicles. The testicle becomes enlarged and contains an abscess. Pus can be seen when the testicle is cut open. As described above, the infection is transmitted to does by infected bucks during breeding.

Pasteurella multocida is the causative organism found in the majority of abscesses seen in rabbits. Abscesses are usually seen in the subcutaneous areas and occur when the pasteurella organism invades a break in the skin due to a scratch, cut, or sore. Abscesses can also occur internally. Although abscesses can be lanced, drained and treated with a penicillin-strepomycin antibiotic, it is probably best to cull such rabbits from the herd immediately Treated rabbits often show a recurrence of the problem and may well act as carriers of the pasteurella organism.

Middle ear infection of one or both ears causes filling of the tympanic cavity with a purlent exudate. If the process spreads to the inner ear, the equilibrium of the animal is disturbed and a head tilt or wryneck results. Again treatment is not effective and rabbits with this condition should be culled from the herd. There is nothing wrong with the meat from these rabbits, they can be safely eaten.

Conjunctivitis or weepy eyes is a condition which is often seen in rabbits in the nest box and sometimes in older does. It can be caused by several different bacteria; however, the usual cause is **Pasteurella multocida.** Infection of the eye usually occurs as a result of extension of the infection of the nasal cavity (snuffles). Antibiotic opthalmic oint-

ment containing penicillin or chloromycetin are particularly effective in treating this disease (Table 3). If the infection persists or returns, a blocked tear duct can be anticipated which will require a veterinarian's care to correct.

When the organisms enter the blood stream, an overwhelming **septicemia** may develop. Tissue changes usually occur very rapidly in the heart, spleen, and upper digestive track resulting in the death of the animal within a very short time. A lack of clinical signs and the short duration do not allow time for suitable treatment of this condition.

Because nearly all of the pasteurella isolates are sentitive to penicillin, individual cases can be treated with a daily injection of procaine penicillin 60,000 IU/kg of body weight for ten days. Although it is usually best to cull sick animals from the herd, in some instances it may be necessary to treat the condition on a herd basis. The addition of a broad-spectrum antibiotic to the water such as 300 mg/liter of tetracyline or the use of a feed additive sulfaquinoxaline, at 225 gm/ton of feed or furizolidone at 50 gm/ton of feed, may produce beneficial results. Other antibiotics which have been used include: Sulfamethazine, sulfamerazine, ampicillin, cephalothin, gentamycin and chloromycetin (Table 3). Recurrence of clinical signs frequently accompanies cessation of treatment. It is **recommended** that treated animals **should not** be used for human consumption for a period of at least 72 hours following treatment.

Because pasteurellosis is very difficult to treat and exists in a carrier state, the success of a rabbitry is dependent upon the prevention of pasteurellosis from entering the colony. A good preventive medicine program will rely on the following: 1) The purchase of breeding and replacement stock from healthy suppliers which are free of pasteurella, 2) Providing a clean environment with adequate sanitation and the prevention of fecal contamination and ammonia buildup in the environment, 3) When the premises become severely contaminated it may be necessary to purchase pasteurella-resistant rabbits, and experimental work is now being conducted to develop a streptomycin-dependent live **Pasteurella multocida** vaccine for the prevention of rabbit pasteurellosis. Further testing is necessary to determine the value of this vaccine.

Tyzzer's Disease:

This disease is found in mice, rats, hamsters, gerbils, rabbits, guinea pigs, horses, cats, dogs and several wildlife species. **Bacillus piliformis** is the causative organism.

Transmission is usually by the fecal-oral route, although in-utero transmission has been demonstrated experimentally. A big problem with this disease is that infectious spore-like bodies may survive a year or more in bedding, soil, or contaminated feed. Some form of stress, such

as overcrowding or extremes in temperature, is usually needed to precipitate this disease.

The clinical signs for Tyzzer's disease can be either acute or chronic. Signs of the acute form in weaning or stressed animals are diarrhea, listlessness, anorexia, dehydration and death within 48 to 72 hours. Subclinical infections are very common resulting in carriers within a colony which continue to shed organisms. Chronically infected animals exhibit weight loss, rough hair coat and eventually death.

Pathological lesions include necrosis in the wall of the cecum and focal necrosis in the liver and heart. Acute deaths result in edema, congestion, hemorrage and focal ulceration of the intestine. The intestine is often atonic and filled with a yellowish fluid. The hepatic, intestinal and myocardial foci, which are so characteristic for this disease, probably arise via an embolic shower of organisms from a primary infection in the intestine.

Diagnosis is usually made on the basis of clinical signs and demonstrations of the organisms in liver cells. Many times these organisms will give the appearance of a 'pile of sticks'. A complement fixation test has been effective in diagnosing this disease in Japan.

Treatment is usually not effective as the acute cases die before a therapeutic program can be initiated. Oxytetracycline in the drinking water at 0.1 g/l for 30 days has been effective in suppressing outbreaks (Table 3).

Tularemia:

This is an infectious disease of wild animals and man that is caused by **Francisella tularensis.** Tularemia is rare in domesticated rabbits unless they are exposed to wild animals, birds, rodents, deer flies and ticks. Transmission can be by direct contact, aerosol, or biting arthropods. Organisms can be found in the tissues, blood and feces of infected animals.

Tularemia produces an acute speticemia which usually results in death within one week. Necropsy lesions include pulmonary congestion and numerous small white necrotic foci in the liver and spleen. Diagnosis is based on these necropsy findings and isolation of the organism. This agent is extremely hazardous to man and must be handled with extreme caution in the laboratory. Treatment is not indicated due to the public health hazard. All infected animals should be euthanatized and their carcasses burned.

Spirochetosis:

This disease is caused by **Treponema cuniculi**. It has been erroneously called 'rabbit syphilis , although this disease is not the same as 'human syphilis'.

The accidental use of infected bucks will quickly spread this disease

through a colony. Lesions involve crusty, dry, scaly or edematious sores on the nose, mouth, ears and genitalia. Lesions around the vent easily become irritated from urine and poor sanitation and have resulted in the term 'Vent disease'. The organism is sensitive to arsenicals and penicillin. A single intramuscular injection of 100,000 units of penicillin is the recommended treatment (Table 3).

Listeriosis:

This disease is caused by Listeria monocytogenes. It exhibits three clinical forms: (1) a blood-born infection in young animals, (2) a brain infection in adults, and (3) a uterine infection and fetal mortality in pregnant does.

Clinical signs include loss of weight, incoordination, convulsions, nasal discharge, uterine discharge and abortion. The most consistent lesion at necropsy is liver necrosis which produces small pinpoint necrotic foci resembling Tyzzer's Disease and Tularemia. Pregnant does and does which have recently kindled are the most susceptible. Diagnosis is usually made at necropsy and so treatment is of little value. If a diagnosis is made, sick animals may be treated with tetracycline or penicillin. Females recovering from this disease are often sterile. This disease is transmissable to man and a positive diagnosis should be reported to the local health authority.

Enterotoxiemia, Rabbit Diarrhea Complex, Mucoid Enteropathy:

Young rabbits often show a variety of enteric conditions ranging from constipation to a profuse watery diarrhea. Although no one has clearly defined one cause for all these enteric disorders, a number of distinct infectious entities may be involved. These include a number of agents such as **Bacillus piliformis,** Salmonella, colibacillosis, intestinal coccidiosis and a clostridial enterotoxemia.

This disease complex usually occurs in 7-10 week old rabbits which have just been weaned and placed on a new diet. Clinical signs include loss of appetite, increased thirst, diarrhea, rapid weight loss, grinding of the teeth, bloated abdomen and a stained anus area with light green to brown feces and mucous. Diagnosis can only be confirmed on necropsy by finding goblet cell hyperplasia. There is no specific treatment due to the uncertainty of an etiology for this disease complex; however, increased roughage in the diet has been shown to reduce the incidence of this disease.

FUNGAL DISEASE:

Ringworm is produced by two main groups of fungi, **Trichophyton** and **Microsporum**. These fungi cause patchy areas of dry, crusty, thickened skin. Lesions are usually found on the nose, ears, eyelids and feet of nursing young where it can produce desvastating results.

Single lesions are also found in the adult, but they are much less severe. Diagnosis is made by finding fungi in skin and hair scrapings and by culture. Treatment involves a thorough cleaning of all nest boxes and nesting materials with a strong detergent, hot water, chlorine bleach and/or a lye water rinse, cleaning up the nursing mothers with soap and water, and putting all diseased animals on griseofulvin at a dosage of 12 mg/lb/day for two weeks (Table 2). This disease is also transmissable to man and should be reported to the local health authority.

PARASITIC DISEASES:

External Parasites:

The most common external parasite of rabbits is **Psoroptes cuniculi**, which produces ear mange or canker. The mites live in the ear canal producing a brown, waxy material, which soon forms a dark crusty covering composed of mites, dried blood, and cellular debris. If not treated the ear may lose its vascular supply and actually slough or fall off the head. Contrary to some beliefs, external ear mites do not produce a middle ear infection.

Treatment for ear mites can involve commercial products such as Mitox (Norden Laboratories, P.O. Box 80809, Lincoln, Nebraska, 68501), or a 0.25% suspension of Lindane in mineral oil. Approximately 6-8 drops of this suspension or Mitox should be placed in the ear and massaged every third day for two weeks. Mineral oil by itself will tend to suffocate the mites and can provide a fairly effective treatment. The most effective treatment is to use Ivermectin injectable (Merk and Company, Inc., Rahway, New Jersey, 07065). This product has not been approved for rabbits in the United States, but it is very effective (Table 3).

Wild rabbits may have infestation with ticks of the genus **Haemophysalis**. Most housing facilities are sufficient to break the life cycle and so they are usually not a problem in domesticated rabbits. Another parasite of the wild rabbit is the Cuterebra fly. Grub worms hatch from fly eggs and burrow into the skin to form warbles. These larvae, sometimes three quarters of an inch long, can be removed by enlarging the opening in the skin and pulling them out with a tweezer. The wound is then cleaned with an antiseptic.

Internal Parasites:

Without a doubt, the most common parasitic disease in rabbits is coccidiosis. The most severe intestinal forms are **Eimeria magna** and **Eimeria irresidua**. These parasites produce diarrhea, poor appetite, weight loss and sometimes death. Diagnosis is dependent on finding the oocysts in the feces on micrscopic examination. Control of intestinal coccidiosis is directly related to management practices which minimize

fecal contamination of feed, water and hutch floors. Most breeders use wire bottom floors and it has been shown that agitation of the floor on a daily basis will increase the flow of feces through the floor and thus greatly reduce the incidence of coccidiosis. Cages may also be soaked in a 10% ammonia solution, which will kill the oocysts (Table 3). In many cases this is all that is necessary to break the life cycle of the parasite; however, if further treatment is required amprolium, sulfaquinoxaline, sulfamerazine, and sulfadimethoxide have been proven to be effective (Table 3).

One species of coccidia, **Eimeria stiedae**, is known to attack the liver and is therefore very pathogenic. This parasite enters the body through the intestine, but it soon migrates to the bile ducts of the liver. On necropsy, the liver will have charateristic white, circular nodules on its serosal surface. Control measures are the same and are the most effective means of regulating this parasite. Medications will provide temporary relief as before, but the parasites will soon reinfect the colony if the life cycle is not broken.

Tapeworms:

The rabbit tapeworm, **Cittotaenia variabilis,** is a flat ribbon shaped parasite which usually causes little or no problem in low numbers. However, if excessive numbers are reached they can produce diarrhea and weight loss. Good sanitation will usually control this problem. Medications used have included Praziquante and Niclosamide (Table 3),

The dog releases eggs of the tapeworm **Taenia pisiformis** in its feces and is thus a source of infection for the rabbit. These larvae enter the digestive tract, migrate through the liver leaving white scars and eventually form small fluid-filled cysts (cysticerci) in the abdominal cavity. There is no treatment for the larval from and so control is accomplished through good management.

Roundworms:

Three roundworms are seen in the rabbit. **Obeliscoides** is a very slender, reddish colored stomach worm and **Trichostrongylus** is a similar parasite in the small intestine. These two parasites are usually not a problem and if they are present they can be easily controlled with good sanitation. The third roundworm is **Passalurus ambiguus**, a pinworm living primarily in the cecum. These parasites are glistening white, about one half inch long and they rarely cause any disease problems. Again, management practices will usually break the life cycle. All roundworms can be effectively treated with piperazine citrate at a dose of 100 mg/100 ml of drinking water for one day. This treatment must be repeated in 14-21 days. Other drugs which have been used include phenothiazine and fenbendazole (Table 3).

Section 7

Sanitation Program Slaughtering And Dressing

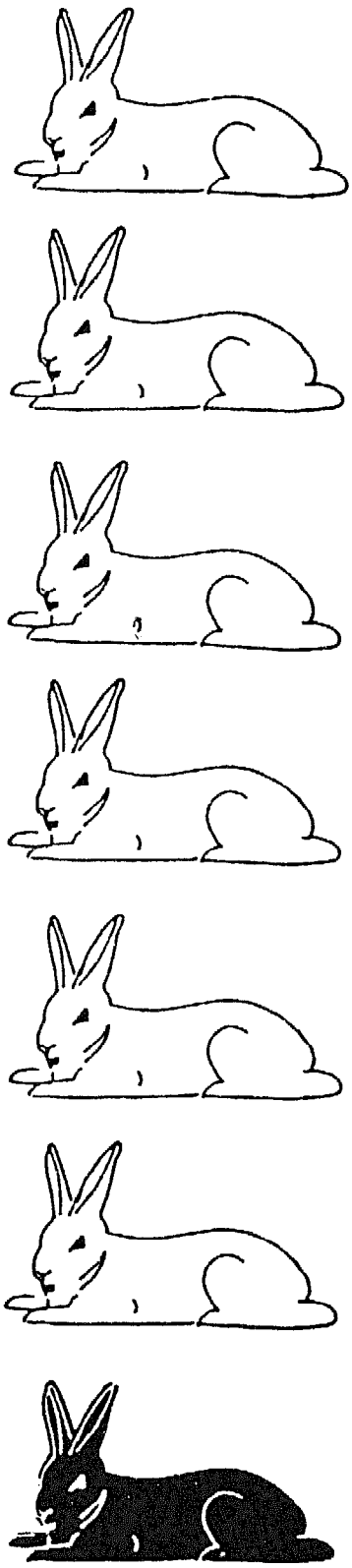

Sanitation Program

An essential part of disease prevention and reproduction is a good daily sanitation program. Environmental factors such as the proper type of hutch and shelter construction, and a routine program for cleaning and maintenance are particularly important. Ideally, cages should be cleaned daily with a wire brush to remove loose hair and manure. Following a thorough scrubbing, the cages should be brushed or sprayed with a chlorine bleach solution (one ounce of chlorine bleach per quart of water). The combination of scrubbing and using a bleach solution is an effective way to control coccidiosis and enteritis. The build-up of calcium carbonate deposits may be reduced by rinsing these areas with a weak acid solution, i.e. vinegar. Be sure to clean water and food bowls daily.

Avoid overcrowding of the rabbits. Build the hutches in an area which has good drainage, fresh clean water and adequate sunlight. Avoid damp, poorly ventilated areas as this will only reduce the animals resistance to disease and infection.

Because feed may act as a mechanical carrier for infection, be sure it is stored in a dry, vermin-proof container, such as a metal can with a sealed lid on it. Also, properly designed feed hoppers are necessary for any good sanitary program. Avoid scattered feed in the rabbitry, as this will only serve to attract insects, mice, rats and birds. Of course, all of these are potential carriers of disease.

Once a month, soiled hutches or cages should be removed from the rabbitry and thoroughly disinfected. In addition, pens or buildings housing infected animals should also be disinfected. One agent, which acts as both a cleaner and disinfectant, is lye or caustic soda. One 13-ounce can of lye can be dissolved in 15 gallons of water or one pound makes about 20 gallons of disinfectant. Care must be taken to avoid getting this lye solution on painted surfaces, clothing, aluminum or the skin of rabbits and man.

Sunlight is also an effective disinfectant; however, the exposed equipment must be thoroughly cleaned of all debris prior to exposure as the sun has very little penetrating power. When possible, a cement slab, exposed to the direct rays of the sun, provides a good place to disinfect movable equipment. Other methods which can be used include a variety of commercial chemical disinfectants, live steam and dry heat such as that produced by the direct flame of fire. Care must be taken when using any of these agents to avoid human injury.

In addition to maintaining the suggested sanitation and disinfection practices, the daily inspection and handling of sick animals is important. A good preventive medicine program would include:

1) Purchase only healthy animals. Never bring diseased animals into your rabbitry. Quarantine all new animals for thirty days before introducing them into your colony.
2) Isolate all sick animals in a completely separate area. If the animal cannot be readily cured, it is probably best to destroy these animals and bury or burn the carcasses.
3) Be sure to care for healthy animals prior to servicing the diseased animals. This will prevent carrying organisms into your healthy colony.
4) Mark all pens which contained diseased animals. Be sure to thoroughly clean and disinfect these cages with a 2% lye solution (one pound of lye in 5½ gallons of water) before placing new rabbits in them.

Slaughtering and Dressing

The rabbit that is ready for slaughter can be quickly and humanely killed by delivering a quick, sharp blow to the base of the skull. An alternate method is to dislocate the neck by holding the rabbit up by the hind feet, then pulling the head in a quick upward snap.

The carcass then can be suspended by the hind legs by slitting the skin between the tendon and the tibia. Hooks, nails or rope can be used to tie the legs and then suspend the rabbit from an overhead beam, tree limb, etc. (Figure 32).

Next, cut the neck to allow free bleeding or remove the head. The tail is removed and a cut is made from one hock to the other. The skin is cut completely around the hock area. Next cut through the skin around the anus and genital area extending this cut to the cut running from leg to leg (Figure 33).

The edge of the skin is now separated from the carcass and, starting at the legs, pull inside-out over the body. The front legs are removed at the carpus (wrist) before the skin from the body is pulled over this area. Likewise, the head should be removed from the body if not already done. Fat should be left on the carcass. The entire hide is then pulled off the rabbit and remains flesh side out (this is referred to as a cased skin). The cased skin can be stretched over a wood or wire form for drying (Figure 34).

Now remove the internal organs. First make a cut through the muscle on the midline of the abdomen from below the anus to the end of the sternum (breastbone). Then cut the cartilage alongside the breastbone, opening the chest area. Pull the intestines out of the body cavity, using your knife to cut any tough attachments.

Remove the liver, heart and lungs. The gallbladder will lie to one side of the center of the liver. It is necessary to remove the gallbladder from the liver if the liver is to be saved and eaten, as fluid leakage from the gallbladder can give the liver an unpleasant taste.

After removing the internal organs, the carcass should be rinsed in cold water for a short period not to exceed 15 minutes. This helps remove any hair or blood on the meat and cleanse the carcass.

Next, the carcass can be cut into sections (Figure 35). Remove the front legs by cutting from the underneath side of the legs, up through the shoulder. Likewise, cut the hind legs free at the hip. Now cut down to the vertebrae just behind the last ribs. Then bend the spine back to locate a space between the vertebrae and cut there to separate the carcass in two. Cut the ribs from the backbone (vertebrae) on each side to make two rib sections. The pelvic area can, likewise, be split in two or left as one large piece.

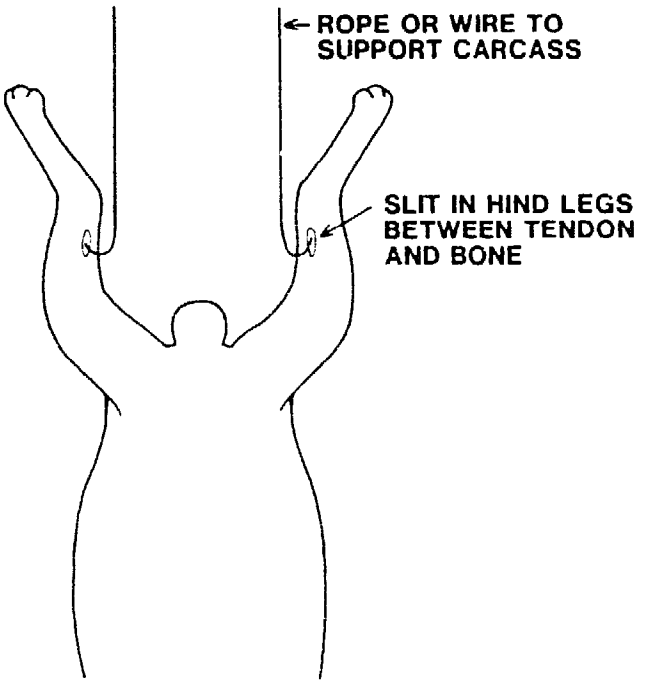

Figure 32. Suspending carcass by hind legs

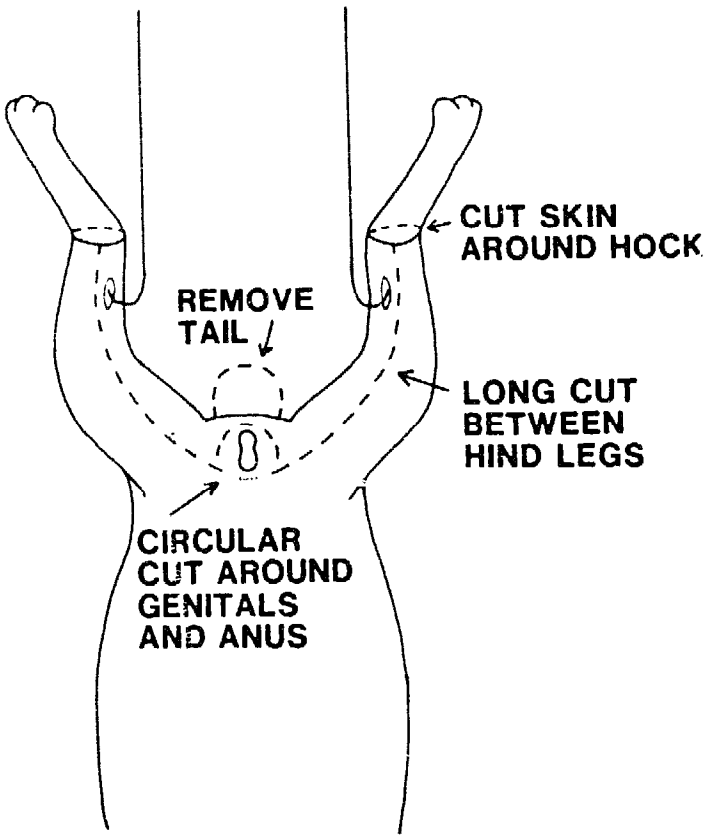

Figure 33. Dotted lines show proper cuts for hide removal

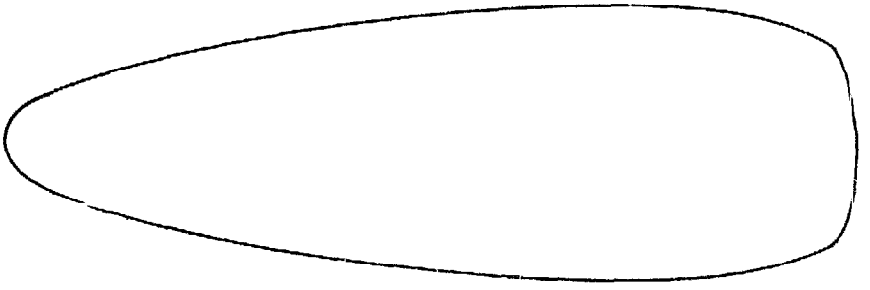

Figure 34. General shape for wood or wire form for drying cased pelt

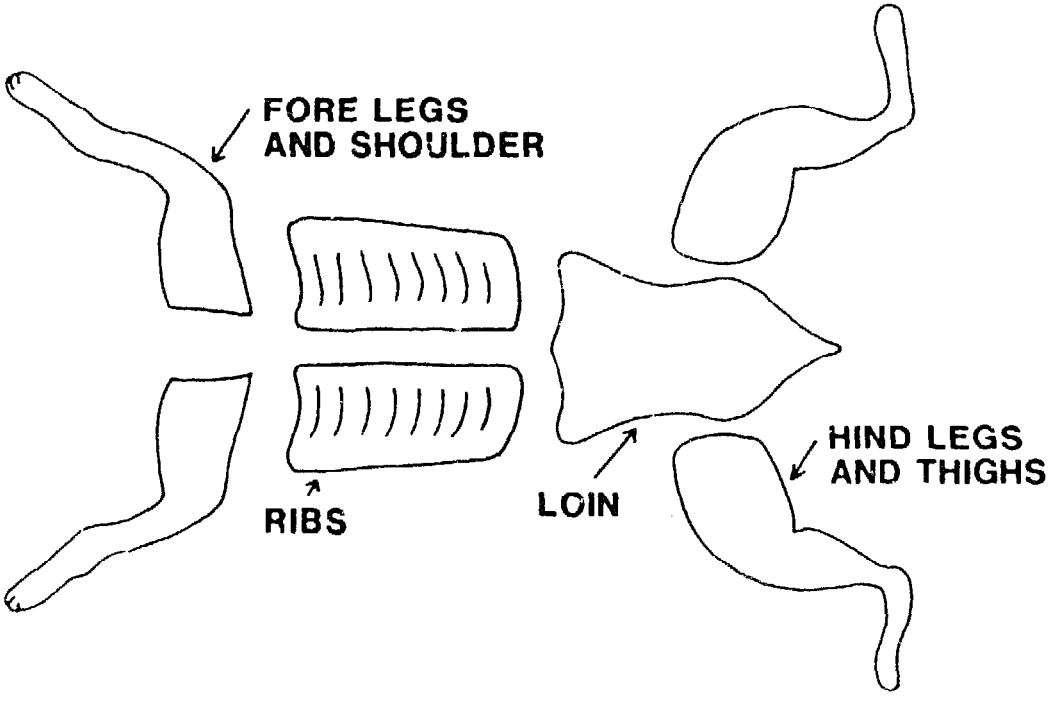

Figure 35. Method of dressing rabbits for marketing

THE AUTHORS

W. Sheldon Bivin

Professor of Laboratory Animal Medicine
Chief, Laboratory Animal Resources
Head clinician for Laboratory, Zoo, Exotic and Marine Mammals
Director, Wildlife and Raptor Rehabilitiation Unit
Louisiana State University
School of Veterinary Medicine
Baton Rouge, Louisiana 70803
Telephone number: (504) 346-3145

B.S., 1962, Kansas State University
D.V.M., 1964, Kansas State University
Ph.D., 1971, University of Missouri

Diplomate-American College of Laboratory Animal Medicine

Dr. Bivin is a Professor in the Department of Veterinary Clinical Sciences. He serves as Chief of Laboratory Animal Resources in the School of Veterinary Medicine and is Director of Laboratory Animal Medicine for the Louisiana State University main campus. He is also Director of a state supported wildlife and Raptor Rehabilitation Unit housed at the School of Veterinary Medicine. His duties include teaching courses to veterinary students on the diagnosis, therapy and control of diseases of laboratory, zoo, exotic and marine mammals. He and his staff of four veterinarians also provide all of the clinical expertise required to care for several thousand research animals used on the L.S.U. campus.

Kathleen A. Murray

Clinical Veterinarian
Merck, Sharp and Dohme Research
W42-2
West Point, Pennsylvania 19486
Telephone number: (215) 661-6984

B.S., 1977, University of Rochester
D.V.M., 1982, Purdue University
M.S., 1984, Pennsylvania State University

Diplomate-American College of Laboratory Animal Medicine

Dr. Murray was a clinical veterinarian at Louisiana State University at

the time this text was written. She is now a clinical veterinarian with Merck, Sharpe and Dohme. In this capacity she is responsible for the health care and surgical expertise required to manage several thousand research animals.

Glenn H. Olsen

Clinical Veterinarian and Researcher
Patuxent Wildlife Research Center
United States Federal Wildlife Service
Laurel, Maryland 20708
Telephone number: (301) 498-0264

B.S., 1969, University of Illinois
D.V.M., 1971, University of Illinois
M.S., 1980, University of Massachusetts
Ph.D., 1983, University of Massachusetts

Dr. Olsen was a clinical veterinarian at Louisiana State University at the time this text was written. He is now doing basic research on Wildlife and providing veterinary care for a wide variety of wildlife housed at the Center.

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STOREY A GARDEN WAY PUBLISHING BOOK

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A Garden Way Publishing Book

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INTRODUCTION

The incentive to write this book resulted from the many recent requests for information about the small poultry flock. During the nearly 20 years the author has been associated with poultry extension education never has there been the interest in the small family flock that currently exists.

For years we have witnessed the development of a large, highly automated, and specialized poultry industry. This revolution has taken place at the expense of the small poultry flock because of diminishing profits and problems of marketing for small flock owners. Now, very suddenly, there has developed a renewed interest in raising a few chickens, turkeys or waterfowl. Why this sudden turnabout?

The desire to produce fresh eggs and poultry for the family probably ranks high among the reasons for starting a small flock. However, a few birds may also provide family members with an excellent chore responsibility, a hobby, or even a source of limited income. Whatever the reason, success in such a venture requires a knowledge of poultry husbandry and many other related subjects.

The need exists for a handy reference manual which contains complete and practical information for the small poultryman or prospective

poultryman. This book is written with that need in mind. It treats practically all phases of poultry production and processing and includes sections on chickens, turkeys and waterfowl.

One chapter attempts to help answer the question, "Should I Raise A Poultry Flock?" and includes a discussion of the possible types of poultry projects and some of the advantages and disadvantages of each. The section which will probably interest the larger number of readers is the one on the laying flock, since this seems to be the project that is of interest to most people. Much of the chapter centers around questions the author is frequently asked. It therefore covers topics such as types and sources of stock, management and feeding practices, housing and equipment needs. It contains plans for small poultry houses, poultry furniture, a small incubator and others. One section is devoted to meat bird production. Other sections treat turkey and waterfowl production. Information is presented on such skills as culling, debeaking, caponizing, egg care, egg grading and poultry processing. To enhance the value of the book as a handy reference, it includes lists of additional reading materials, sources of supplies and equipment, as well as the addresses of poultry specialists at the State Universities and the State Poultry Diagnostic Laboratories.

Since the book does include information on more than one species, and many of the subjects discussed required references to other subjects, some repetition was unadvoidable. Then too, it was felt that repetition might be helpful to those readers who have an interest in only one section of the book or who have time to read only one section at a time. However, cross references are used to prevent as much duplication as possible.

Although intended primarily as a guide and reference for prospective poultrymen and small flock owners, *Raising Poultry the Modern Way* does also have value as a text or supplement for practical poultry production courses or science projects in the schools.

Leonard S. Mercia

1

SHOULD I RAISE POULTRY?

Today, the care of a small poultry flock can be a rewarding experience as a hobby, to help fill the family refrigerator or freezer, or to sell. Modern poultry keeping can also be an enriching experience. With good husbandry and flock management the poultry project can be a source of efficiently produced food. Commercially produced poultry feeds can be supplemented to some extent with table scraps, green garden crops, and lawn clippings — up to one third of the nutritional requirements of the flock. The selection of the right stock for your particular type of project will help provide optimum results, whether it involves laying birds, broilers, roasters, capons, turkeys, waterfowl, or others. Moreover, surplus eggs and poultry may be sold at a healthy profit.

We are currently experiencing a resurgence of interest in the production of food at home. Often the responsibility for the care of the poultry project is given to the younger members of the family. This can be a well-rounding experience for young people, fostering a basic knowledge of such things as egg care, incubation, feeding and management of growing birds and, if properly undertaken, the development of such important skills as record-keeping, and money management.

A valuable by-product of the poultry project which is frequently overlooked is the manure. Poultry manure is high in fertilizer value and is an excellent fertilizer for the garden or a valuable addition to the compost pile.

The modern commercial poultry industry is perhaps best characterized as being a very highly specialized, highly commercialized, agricultural industry. It is no longer a small business on many farms, but a large business on fewer and fewer farms. The keys to success in the commercial poultry business are frequently bigness and efficiency. The necessary capital investment is high; there are some pitfalls in the business, and a profitable market for large volume production is nearly essential if the enterprise is to be successful.

Small poultry enterprises with a few hundred or a few thousand birds can be profitable if the products can be marketed at a substantial margin direct to stores, restaurants, hospitals, institutional users, or direct to consumers. Even the small family flock can return a profit when products are marketed direct to the housewife at a substantial markup. These outlets, too, are not always free of problems. Competition for markets is keen, and profit margins sometimes erode. Moreover, there is the problem of providing a volume of sizes, quality and service that is often difficult for the small producer who sells to the wholesale outlets.

If you plan to sell your products and make a profit, you need to study the market potential in your area carefully. Without profitable markets any poultry enterprise is almost certainly doomed to failure.

Before starting a poultry flock, check the local zoning ordinances. Animal projects are not permitted in certain residential areas. A possible problem might involve your neighbors. Poultry flocks can bring about such problems as odors, flies, rats or mice. There is the possibility of complaints about noise, especially if there are adult males in the chicken flock. Nothing manages to anger neighbors more than the early morning crowing of a rooster. Good management will prevent many of these nuisances, but it is well to research thoroughly all possible problems before embarking upon your own poultry project.

Should you decide to raise poultry, it is, in most instances, a seven-day-a-week job. There are the daily management chores to be done — feeding, watering, collecting eggs and checking the birds.

Types of Poultry Projects

the laying flock

The Laying Flock is the most popular type of poultry project. Good stock properly managed will lay eggs throughout the year. Laying birds should start laying at 22-24 weeks of age. The length of their laying cycle is normally 12 to 14 months. Any stock that is bred for high egg production is suitable for the laying flock. A good laying bird, under good management conditions, should lay 19-20 dozen eggs during a laying cycle. Then too, there is the possibility of an occasional meal of fowl when poor producers are culled from the flock.

meat chickens

Specialty meat-type birds such as capons and roasters are particularly suited to small flock enterprises. Broilers, as a general rule, cannot be grown on the small farm as economically as they can be grown commercially. Broilers are young chickens used for frying, broiling or roasting and are usually about eight weeks of age when processed. Commercial broilers are scientifically bred to produce meat efficiently. Very few broilers are now produced as a by-product of egg production.

Roasters are 3-5 month old chickens that weigh 5 pounds or more. Capons are castrated males grown for 6-7 months to weights of 7 pounds or more. The costs of raising these chickens to heavier weights are considerably higher than the costs of raising broilers. These tender-meated, well-finished birds are, however, sought after and demand a much higher price-per-pound in the market.

turkeys

Turkey production makes an excellent project for fun or profit. Although it was once thought to be hazardous and difficult to raise turkeys, this is no longer true. Thanks to the available modern-day drugs and management know-how, the turkey enterprise is not now a particularly

hazardous one. Still, there are certain precautions which have to be observed. Blackhead disease is a possible problem, and turkeys should be reared separately from chickens to avoid problems with this disease. It is possible to raise turkeys either in confinement or on range.

A turkey project can be an excellent one for the young or old. It can provide an excellent responsibility and learning experience for young people, and with good stock, good management and marketing, a profit can be realized. Turkeys can be raised in virtually any type of climate successfully if they receive the proper management and nutrition and are protected against diseases, predatory animals and exposure to extreme weather conditions.

Turkey production has the added advantage of being a relatively short-term project since it requires only about 5 months to prepare for the poults, grow them, process and market them and clean the facilities in preparation for the next flock.

Fresh native turkey, properly dressed, is hard to beat for juiciness and flavor, so it is a natural for the production of food for home consumption.

waterfowl

Like other phases of the poultry industry, there are farms that have specialized in commercial production of ducks and geese. There are also many small flocks raised to occupy the farm pond or as a hobby or sideline to other farm enterprises. Ducks and geese make an excellent hobby, and many are raised for exhibition purposes or multiplied for sale as ducklings or goslings.

Ducks and geese, which are well-finished, are a nutritious and tasty food. Some of the breeds of ducks, surprisingly enough, surpass some chickens in egg-laying ability.

Rearing waterfowl is relatively easy. The young are quite hardy, and by following reasonable management and feeding programs, such a project can be a successful and profitable one. Ducks and especially geese are great foragers and can pick up a great deal of their nutritive requirements during the warm weather months in the form of green feed, insects and worms. In confinement they can cause damp litter conditions, unless special waterers and management procedures are observed.

2

POULTRY HOUSING AND EQUIPMENT

The type of poultry house will vary with the type of project and how you plan to get started. For example, baby chicks and turkey poults require tighter, more comfortable housing than do older birds. If you plan to begin the project with started birds, then the house may not have to be as tight or as well-insulated. In warm climates the house may have open sides enclosed with poultry netting. It may be equipped with adjustable awnings for use during inclement weather. Waterfowl require very little in the way of housing as adults. However, young ducklings and goslings, though relatively hardy, will need good housing during the early brooding period.

The type of house will also depend, to a certain extent, upon the management system you use. Some differences in design and size might be needed to accommodate different types of equipment and furniture. Cages may be utilized for laying flocks, and thus the building construction and design must be considered before building to insure that the equipment fits into the building. Material-handling chores such as feeding, cleaning, watering and gathering eggs should also be considered when planning the poultry house.

The poultry house need not be elaborate or expensive. An old building can frequently be remodelled to accommodate a small flock of poultry. Sometimes a pen can be built within a large existing structure that will function quite well for small flocks. Remodelling of old buildings for large production units is seldom advisable. Though some old structures are suitable for the production of broilers, pullets, or turkeys, most are not readily adapted to the efficient handling of birds. While material-handling chores for young growing birds are not so critical, it is an important consideration for large laying projects.

There are basically two types of poultry housing. One type is designed for floor management systems, the other for cage systems.

Floor housing, sometimes called litter or loose housing, allows the birds free access to the poultry house or pens within the house. The advantages of the floor system are that it permits flexibility in the use of the house. It can be adapted for brooding and growing or managing most any type of poultry flock including broilers, roasters, capons, layers, turkeys or waterflowl. This system is well suited for the small farm or family flock, and most of our consideration will be given to this type of housing.

A word about cages. This is the system most frequently used by commercial egg producers today. There are several reasons for its popularity. Floor space requirement per bird is less, thus reducing per bird cost of housing. Cage systems are readily adapted to labor saving in materials handling. The use of automatic feeders and waterers, the belt collection of eggs and manure-handling devices are a natural with cages. Another important advantage of cage units is that eggs do not have to be collected as frequently because of the egg roll-a-way feature. Cage housing and management systems permit the care of more birds per man than does the floor system. For the most part we find that cage facilities offer better control of parasites and eliminate many of the troublesome litter-borne diseases that we sometimes find with floor birds. Most breeding farms still use the floor systems of housing for the mating of the breeders and the production of fertile eggs. Breeding cages are available, and may be successfully used for light breeders.

The requirements for a poultry house, or poultry pen, are that it provide a clean, dry, comfortable environment for the birds throughout the year. If young birds are to be brooded in the house, it must be built well enough to permit a comfortable environment and efficient use of fuel. It must be tight enough to prevent drafts on the birds and help maintain a uniform temperature economically. Poultry facilities should have floors which can be easily cleaned and disinfected. Most poultry pens or buildings

should provide for ventilation to control moisture in the pens, remove gases and conserve or dissipate heat. In the northern climates the houses should have insulation in both the sidewalls and ceilings. Piped-in water is desirable but may create problems in severely cold climates, especially in the small flock situations where body heat is not sufficient to keep the pen temperatures above freezing. It is possible to correct this particular problem through the use of electric heat tapes. Houses should have artificial light to provide the right lighting program for both layers and growing stock. The poultry house should be strong enough to withstand high winds and snow-loads if necessary. The house plan (*Figure 1*) is for a small flock and provides room for storage of feed and supplies.

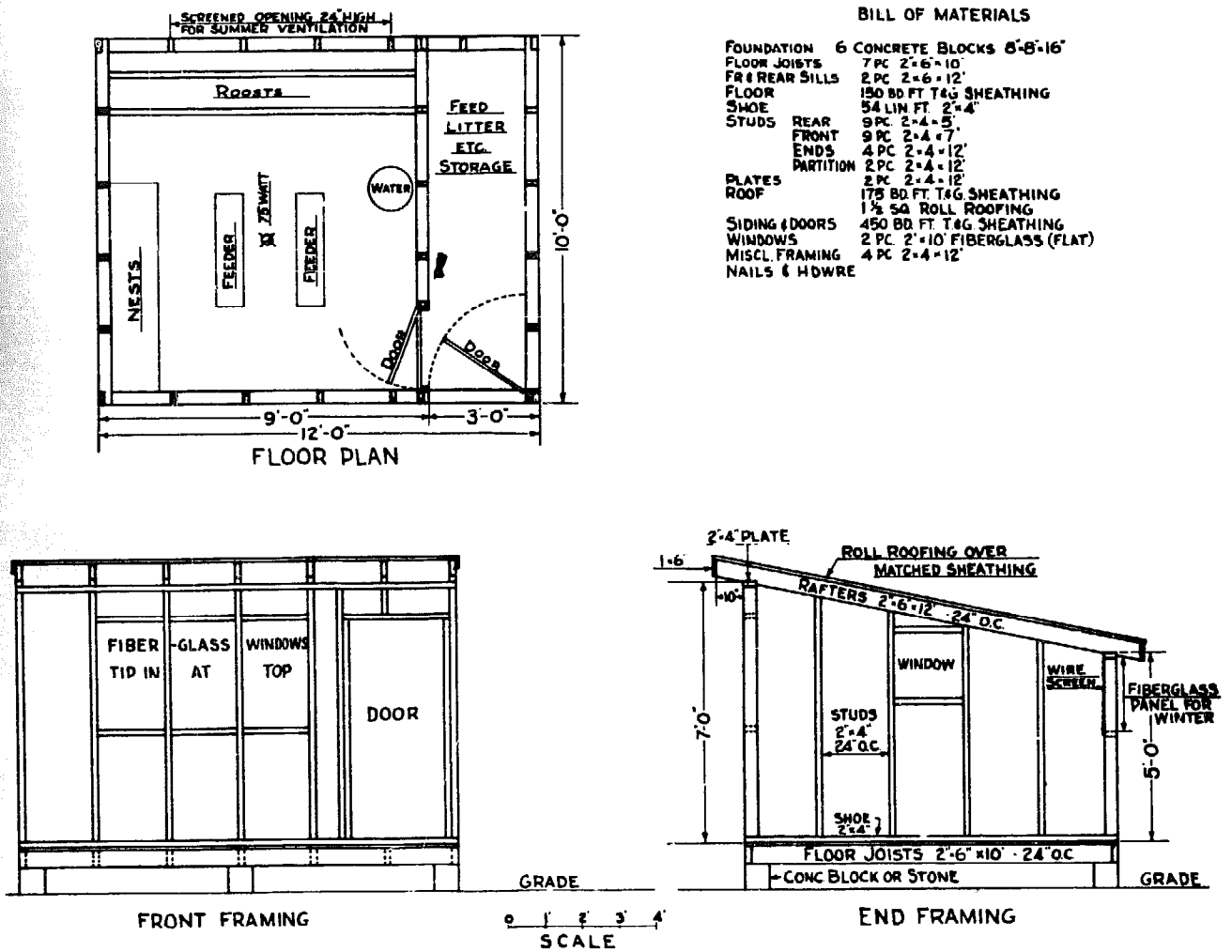

(*Figure 1*)

COOPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS
AGRICULTURAL ENGINEERING DEPARTMENT
UNIVERSITY OF NEW HAMPSHIRE
AND
UNITED STATES DEPARTMENT OF AGRICULTURE COOPERATING

POULTRY HOUSE - 10'×12'		
N H	NO 64-4	SHEET 1 OF 1

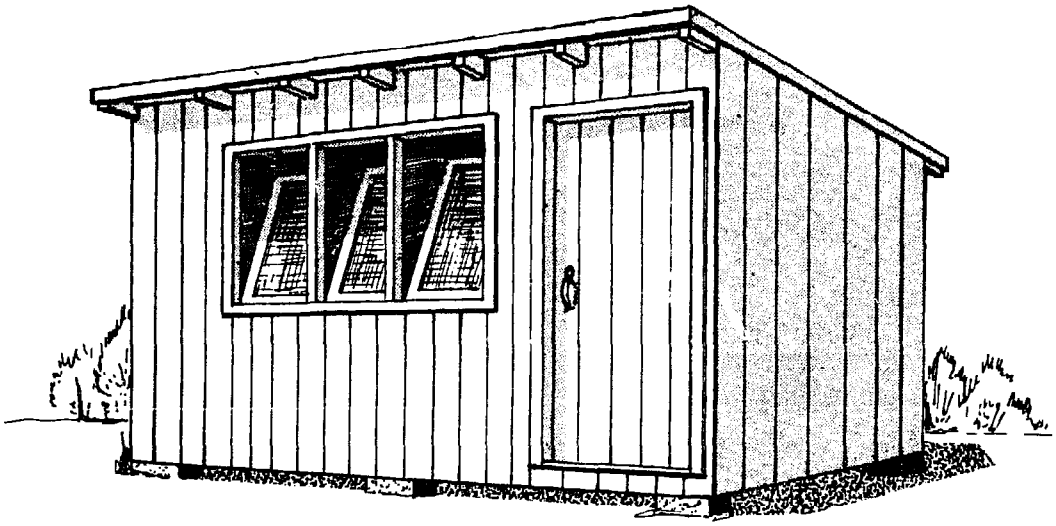

(Elevation of Figure 1)

Selecting A Site For The Poultry House

When selecting a site for a poultry house consider the soil drainage, air movement, location of the dwelling and the water supply. Remember there is the possibility of such problems as odors, flies, rats and mice. Good soil drainage assures dry floors which will help prevent wet litter, dirty eggs, disease, or other problems.

The poultry house should be located where the prevailing summer winds will not carry odors to the dwelling. The site should be large enough to provide for expansion, if this should seem advisable in the future. The location of access roads, electric lines, future buildings and yards should also be considered.

A site on relatively high ground with a south or southeast slope and good natural drainage is desirable. The location of a poultry house at the foot of a slope where soil or air drainage is poor, or where seepage occurs, is unwise.

If the house is located on a hillside the site should be graded so as to carry surface water away from the building. In some instances, tile drains will be necessary to adequately carry the water away from the foundation of the building.

In areas of severe winter weather, most of the windows should be in the front of the building, the house should face south to take advantage of the

sunlight. The pen will be warmer, litter drier and the birds more comfortable. The closed or back side of the house should provide maximum protection against the northwest wind. Where the prevailing winter storms are from the west, however, the house should be oriented to face east. Wider houses are often placed with their long dimensions north and south so as to provide lighting on both sides. If the house is oriented with the front window area to the south, solar heat can be controlled by the width of roof overhang so as to provide shade in the summer months when the sun is high on the horizon, and permit sunlight in the pens in the winter when the sun is low.

space requirements

The size of the poultry house will depend upon the type and number of birds to be housed as well as the management system to be used. Various age groups and species of birds require different amounts of floor space for optimum results. If the house is designed for a laying house, and a cage management system is to be used, the size of the building will depend upon the dimensions of the cages, the type of cage, as well as the number of birds to be housed per cage. In addition to that space needed for the birds, there should always be some additional space for storage of feed, supplies and equipment.

The floor space requirements vary according to the type of project, the size or age of the birds and the management system in use (*Table 1*).

insulation and ventilation

The removal of moisture from the building is one of the main problems with keeping poultry. The moisture in fresh-voided manure is 70-75%. Then too, there is the respired moisture and moisture in the incoming air which must be taken care of.

Insulation will provide optimum bird comfort and avoid excessive moisture problems if the heat is adequate. In most areas of the United States the poultry house should be insulated. The purpose of insulation is to conserve heat in the cold climates and to keep out the heat in warm climates. It should be pointed out that light colored reflective roof and wall surfaces are helpful in keeping the pens cooler in warm climates. Since warm air carries more moisture than cold air, insulation serves to conserve heat in cool climates to not only provide bird warmth, but also to permit

TABLE I

FLOOR SPACE REQUIREMENTS FOR POULTRY

Type of Bird		*Floor Space (Square feet)
Chicks	0-10 weeks	.8 — 1.0
	10-maturity	1.5 — 2.0
Layers	Brown Egg	2.0 — 2.5
Layers	White Egg	1.5 — 2.0
Layers	Meat-Type Breeders	2.5 — 3.0
Broilers	0-8 weeks	.8 — 1.0
Roasters	0-8 weeks	.8 — 1.0
Roasters	8-12 weeks	1.0 — 2.0
Roasters	12-20 weeks	2.0 — 3.0
Turkeys	0-8 weeks	1.0 — 1.5
Turkeys	8-12 weeks	1.5 — 2.0
Turkeys	12-16 weeks	2.0 — 2.5
Turkeys	16-20 weeks	2.5 — 3.0
Turkeys	20-26 weeks	3.0 — 4.0
Turkeys	Breeders (Heavy)	6.0 — 8.0
Turkeys	Breeders (Light)	5.0 — 6.0
Ducks	0-7 weeks	.5 — 1.0
Ducks	7 weeks maturity	2.5
Ducks	Breeders (Confinement)	6.0
Ducks	Breeders (Yarded)	3.0
Geese	0-1 week	.5 — 1.0
Geese	1-2 weeks	1.0 — 1.5
Geese	2-4 weeks	1.5 — 2.0
Geese	Breeders (yarded)	5.0

*Many factors determine the floor space requirements including the type of management system, the type of house, the number and kind of bird, the climate and even the management the birds receive.

removal of moisture from the building. It is important to keep the litter dry and to prevent the buildup of ammonia in the house. Excessive ammonia can be detrimental to the birds and uncomfortable for the operator.

It was once thought that only housing in the northern climates need be insulated. The development of the so-called controlled environment house for high density operations has changed this philosophy, and we now find more of this type of housing being built in the south as well as in the northern climates, particularly for cage management systems. Controlled environment houses are windowless structures, with artificial light and fan ventilation.

Climate influences poultry house design, especially for the small flock. The farm building zone map (*Figure 2*) shows the four basic climatic zones in the United States, based on January temperatures and relative humidity.

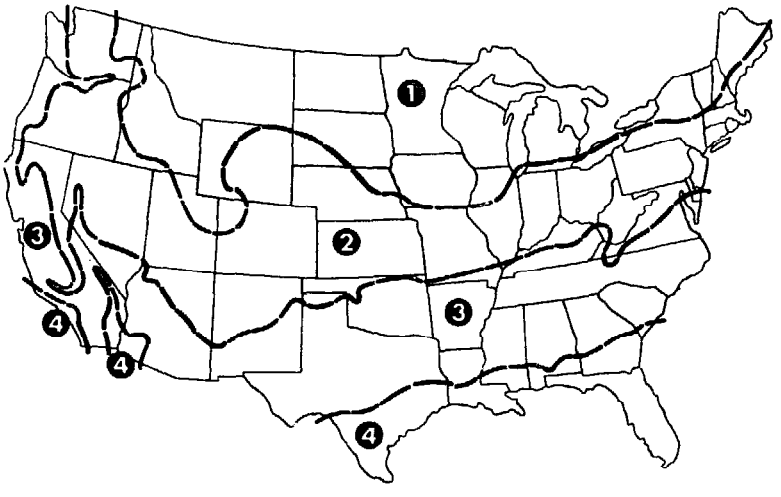

(Figure 2)

In the northern part of the United States the small flock,(less than a few hundred birds), is not without its special problems. Even the well insulated poultry house may not provide optimum conditions during severe winter weather unless artificially heated. It is essentially impossible or highly impracticable to insulate buildings well enough to conserve the heat given off by a small number of birds. Frozen waterers, frozen pipes or even frozen combs may result, causing a drop in egg production. Cold buildings also cause excessive feed consumption. Well insulated pens within large existing buildings may be one answer to some of the above mentioned problems, especially if other animals are housed in the building and help provide some of the warmth within the structure. Houses that are well protected from the wind are also much easier to keep warm and comfortable in winter weather. *Table 2* gives the recom-

mended insulation values for poultry houses in the different climatic zones. The resistance or insulation values of various building materials is shown in *Table 3*.

TABLE 2

RECOMMENDED MINIMUM INSULATION VALUES FOR POULTRY HOUSES BY ZONES

Location	R-value	
	Walls	**Ceilings**
Zone 1:		
Colder parts	8-10	10-15
Warmer parts	6	12
Zone 2	5	10
Zones 3 and 4	2	5

Insulation value (R-value) is defined as the number of degrees difference in temperature between the inside and outside surfaces of a wall that will permit 1 British thermal unit (B.T.U.) of heat to pass through 1 square foot of the wall per hour.
Source: *USDA*

In zone 4, laying houses may be built with wire walls which can be covered with curtains during cool or windy weather. In zone 3 uninsulated houses with large openings in the front are frequently used. These are usually equipped with windows or plastic curtains for use in the cold or stormy weather.

TABLE 3

R-VALUES OR INSULATION VALUES OF VARIOUS BUILDING MATERIALS

Material	Thickness in Inches	Resistance or R-Value
Air space	3/4-4	.91
Asbestos cement board	1/4	.13
Blanket Insulation (Glass or Rock Wool)	1	3.70
Blanket Insulation (Glass or Rock Wool)	2-1/2	9.25
Blanket Insulation (Glass or Rock Wool)	3	11.10
Building Paper		Negligible
Cinder block	8	1.73
Concrete	10	.80
Concrete block	8	1.11
Fill Insulation		
Shavings	3-5/8	8.85
Shavings	5-5/8	13.70
Sawdust	3-5/8	8.85
Sawdust	5-5/8	13.70
Fluffy Glass Fiber, Mineral or Rock	3-5/8	13.40
Homosote	1/2	1.22
Insulation Board (Typical Fiber)	1/2	1.52
Insulation Board (Typical Fiber)	25/32	2.37
Plywood	3/8	.47
Sheathing and Flooring (Softwood)	3/4	.92
Shingles (Asphalt)		.15
Shingles (Wood)		.78
Siding (Drop)	3/4	.94
Siding (Lap)		.78
Surface (Inside)		.61
Surface (Outside)		.17
Window (Single Glass)		.10
Window (Double Glass in Single Frame)		1.44

ventilation

The purposes of ventilation are to provide bird comfort by removing moisture and ammonia from the building, to provide an exchange of air, and to control the environmental temperature in the pen.

There are two types of ventilation systems commonly used in poultry houses: the natural or gravity system and the forced-air system.

The gravity system may utilize windows, special slot inlets, or flues to provide air movement. The incoming cool air replaces the warmed, moisture laden air going up through flues in the ceiling or through the top of opened windows. If flues are used in cold climates, they must be insulated to prevent condensation of moisture which drips back into the pen. Flues must also extend well above the roof to provide the necessary draft to remove the warm, moisture laden air. This approach to ventilation works satisfactorily in an insulated house where inlets or windows are properly adjusted. The gravity method of ventilation has been gradually replaced as the size of poultry operations have increased. The need to open and close windows with changes in temperatures and wind conditions is a very time-consuming chore. Maintenance of the windows is also time-consuming and costly.

Forced-air ventilation gives the best control of air movement. Fans are used to move out the warm, moisture laden air and ammonia, and bring in cool air for bird comfort. Fan capacity is determined by the type, age, and number of birds in the house. For example, a house to be used for 2,000 growing or laying birds would be designed with a fan capacity of from 500 to 10,000 cubic feet per minute (cfm). This flexibility of air movement can be accomplished with either multiple fans, two-speed fans, or a combination of both. It permits a small amount of air movement for young chicks or for cold weather conditions, and a larger volume of air movement for older birds or warm weather conditions.

In cold climates 5 cfm would be too much air movement for bird comfort, so the ventilation rate is cut back to a lesser rate by the use of thermostats which control the fans. In cold climates the optimum temperature for all but young birds under 6-7 weeks of age is approximately 55° F. Fans should not be allowed to cycle on and off at frequent intervals. Fan cycling occurs when the pen temperatures are cooled down too quickly by over-ventilating. The maximum amount of moisture is not removed from the pens, and the birds are exposed to uncomfortable temperature conditions when this occurs. Fan cycling can be prevented with proper thermostat settings, and by restricting the air inlets in cold weather, to maintain a rather definite relationship between pen temperature, incoming air, and exhausted air. In the warm months the inlets are opened wide to permit a maximum flow of air for removal of moisture and ammonia and for cooling the birds. Houses for the small flock can usually be ventilated satisfactorily through the windows.

management systems

There are essentially three types of management systems used for the care of poultry. The one most widely used, until a few years ago, was the floor or litter management system. This is still the most popular method for small flocks, breeder flocks, growing birds, broilers, roasters, turkeys and waterfowl. This system permits the birds freedom of the entire pen or building. Litter materials such as wood shavings, ground corn cobs, sawdust, sugar cane or finely chopped straw are used on the floor. In addition to the necessary feeding and watering equipment, this system may utilize nests or roosts or dropping pits, depending upon the type of bird housed.

Another type of management system utilizes slats or wire mesh as the floor. This system has been used for laying birds, turkeys and waterfowl. The entire floor is slats or wire. No litter is used and roosts are not required. The bird's droppings fall through the wire or slats into a pit and are generally cleaned out periodically or when the birds are removed. A variation of this method incorporates either slats or wire and a litter section. The feeders and waterers are usually placed over the wire or slat sections, and the fecal material drops into a shallow or deep pit. The pit and the slatted or wire section are usually located in the center of the pen with a litter section on each side. This system has several advantages, in that the birds spend approximately 75% of their time on the slats or wire sections eating and drinking. Therefore, the majority of the droppings go into the pits, helping to keep the litter sections dry. This greatly simplifies the job of ventilating the building and results in cleaner litter and cleaner nests and eggs. The same types of feeders, waterers and nests are used for litter floor houses as for the slat or wire-floor houses.

The third type of management system utlizes cages. As mentioned earlier, cages have become the most popular means of managing market egg birds. Most of the large commercial laying houses are now equipped with wire cages. Cages have sloped floors so that eggs roll to the front for easy collection. Since the birds can't set on the eggs, they need not be collected as frequently. Cages are also coming into use to brood pullets to be housed in laying cages.

TABLE 4 APPROXIMATE SPACE

Type of Bird	Age (Weeks)	Brooder Hover-Type
Chicks (including broilers and pullets,	0-2	7 sq. in.
	2-6	7 sq. in.
	6-maturity	discontinue
Layers (all mash systems)	22-market	discontinue
(mash & scratch system)		discontinue
Light Roasters	0-2	7 sq. in.
	2-6	7 sq. in.
	6-maturity	discontinue
Heavy Roasters and Capons	0-2	7 sq. in.
	2-6	7 sq. in.
	6-13	discontinue
	13-maturity	discontinue
Turkeys	0-2	12 sq. in.
	2-4	12 sq. in.
	4-6	12 sq. in.
	6-16	discontinue
	16-market	discontinue
Ducks	0-2	12 sq. in.
	0-4	12 sq. in.
	4-	discontinue
Geese	0-2	12 sq. in.
	2-4	12 sq. in.

REQUIREMENTS (PER 100 BIRDS)

Infrared Lamps	Feeder	Waterer
2	One feeder lid to 10 days	20" or 2 — 1 gal.
	or	
	100"	
2	200"	40" or 3 — 1 gal.
discontinue	300"	96" or 1 automatic
discontinue	400"	96" or 1 automatic
discontinue	360"	96" or 1 automatic
2	One feeder lid to 10 days	20" or 2 — 1 gal.
	or	
	100"	
2	200"	40" or 3 — 1 gal.
discontinue	300"	40" or 3 — 1 gal.
2	One feeder lid to 10 days	20" or 2 — 1 gal.
	or	
	100"	
2	200"	40" or 3 — 1 gal.
discontinue	300"	40" or 3 — 1 gal.
discontinue	400"	96" or 1 automatic
2-3 depending on outside temp.	One feeder lid to 10 days or 192"	36" or 4 — 1 gal.
2-3 depending on outside temp.	288"	72" or 5 — 1 gal.
2-3 depending on outside temp.	384"	96" or 1 automatic
discontinue	480"	120" or 1 automatic
discontinue	600"	120" or 1 automatic
3-6 depending on outside temp.	100"	20" or 2 automatics
3-6 depending on outside temp.	150"	50" or 4 automatics
discontinue		50" or 4 automatics
3-6 depending on outside temp.	100"	20" or 2 automatics
3-6 depending on outside temp.	150"	50" or 4 automatics
discontinue		50" or 4 automatics

Furnishing The Poultry House

Furnishings for the poultry house depend upon the type and size of the project. If it is a growing type project the major requirements will be brooding equipment, feeders and waterers. A laying bird project will require feeders, waterers, nests, roosts and a broody coop for birds that go broody. If laying cages are used, then no nests, roosts or broody coops are needed.

The equipment need not be fancy. Feeders and waterers should be designed so as to service the birds efficiently with a minimum of waste or spillage. There must be enough equipment to give each bird an equal chance to utilize it. The amount of equipment required varies with the type of bird, age and size *(Table 4. See Preceding Pages).*

Equipment can be purchased from local feed and farm supply outlets or from mail order houses and farm equipment concerns (See Sources of Supplies and Equipment Section, page 205). For the small poultry operation much of the equipment may be homemade or purchased second-hand.

feeders

Feeders should be large enough to supply the flock's needs for a day or more without wasting feed. Proper feeder design is an important consideration in avoiding feed waste. The use of an anti-roost device, such as a reel or a spring-loaded wire on top of the feeders, will help to prevent waste. A lip on the side of the feed hopper will prevent birds from beaking out feed. Feed hoppers should never be filled more than 1/3 to 1/2 full to avoid feed waste. The size, height, and the construction of the feeder is very important if feed waste is to be kept to a minimum. To minimize feed waste, troughs should be made so that the height can be adjusted as the birds grow. The alternative is to change to a larger feeder as the birds become larger. Less feed is wasted if the lip of the feeder is level with the top of the bird's back. Some of the feeders commonly used and wooden feeders you can build are shown in *Figures 3* through *3e* on pages 22 and 23.

waterers

Birds of all ages should have access to plenty of clean, fresh water. Bear in mind that water is one of the cheapest sources of nutrients, and over one-half of the bird's body is water. Eggs are composed of about two-thirds water. Water is a very vital ingredient for all of the bird's body functions.

Water consumption depends upon the environmental temperature, age and species. Laying birds will drink about 2 pounds of water for every pound of feed consumed. In extremely hot weather water consumption may amount to 4 pounds for each pound of feed eaten.

For young chicks the waterers can be one-gallon glass jars with plastic bottoms. These are easy to clean. As the birds become older these should be exchanged for larger metal fountains or troughs. Older birds can be watered in open pans, pails or troughs. The containers may be equipped with a float to make them automatic.

If running water is piped to the house you may want to consider buying an automatic water fountain. The cost is usually not excessive, the amount of labor required is reduced and a constant supply of fresh water is available at all times. A homemade waterer (*Figure 4*) may be made from a gallon oil can. *Figures 4a* and *4b* show types of waterers commonly used for small flocks of poultry.

A fountain should be placed on a platform *(Figure 5)* or water stand, covered with a 1" x 2" mesh welded wire. The platform can be made of 2" x 4" material 30" to 36" square. For best results, it should be raised 3" to 4" higher than the depth of the litter. Better still, it can be placed over a drain if available. This arrangement will lessen he amount of wet litter surrounding the fountain and also help to keep litter material out of the fountain.

brooders

If day old birds are to be started, some type of brooder (heat source) will be needed. Enough brooder space must be provided so that every bird can get under the heat source as needed.

Brooders may be the hover-type heated by gas, oil, electricity, wood or coal. Infrared lamps work very well for small flocks and have the added advantage of enabling you to observe the chicks at all times.

FEEDERS

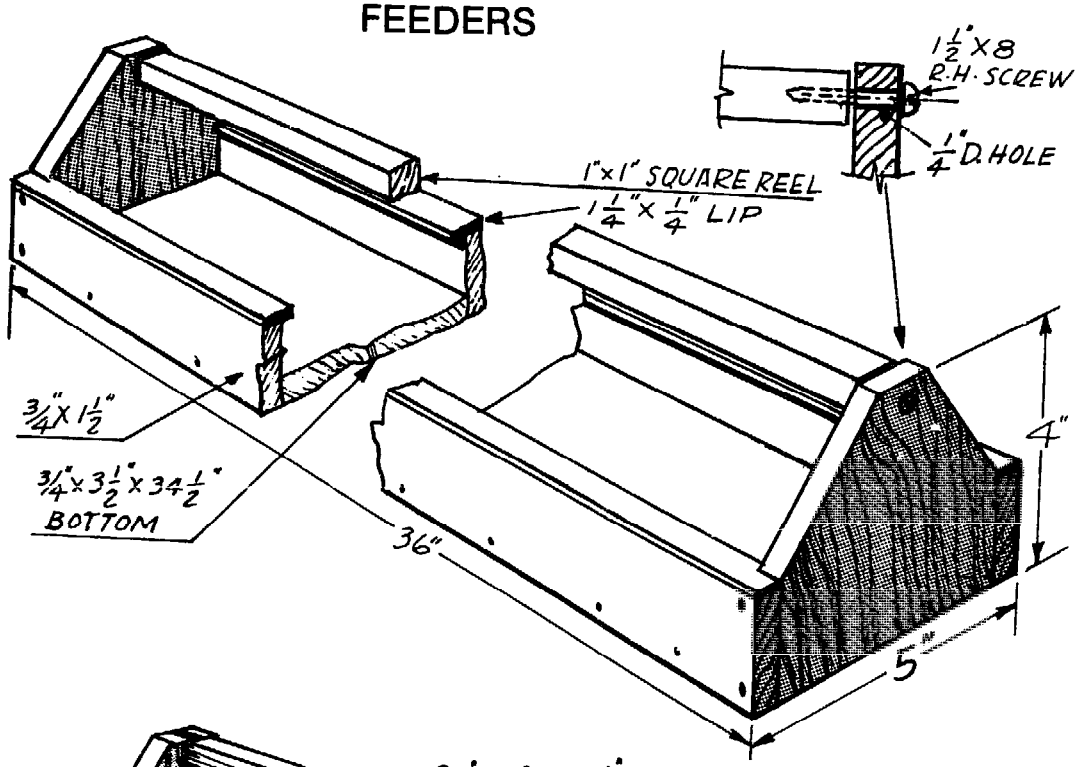
1½"X8
R.H. SCREW
¼" D. HOLE
1"x1" SQUARE REEL
1¼"X¼" LIP
¾"X1½"
¾"X3½"X34½"
BOTTOM
36"
4"
5"

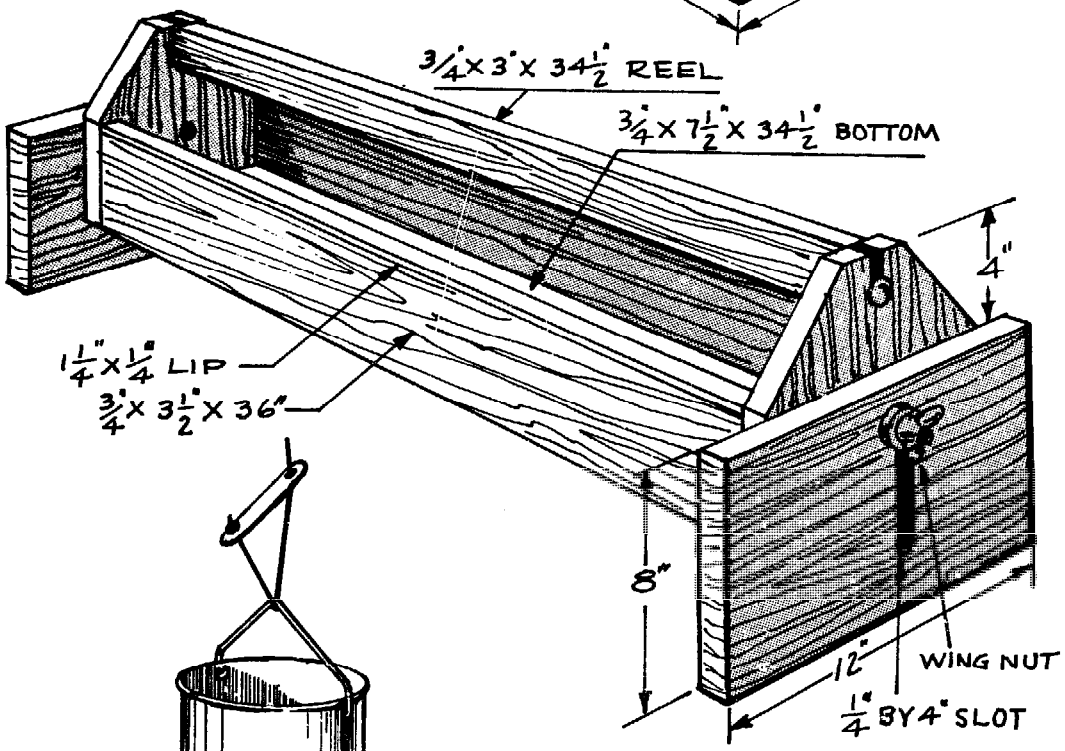
¾"X3"X34½" REEL
¾"X7½"X34½" BOTTOM
4"
1¼"X¼" LIP
¾"X3½"X36"
8"
12"
WING NUT
¼" BY 4" SLOT

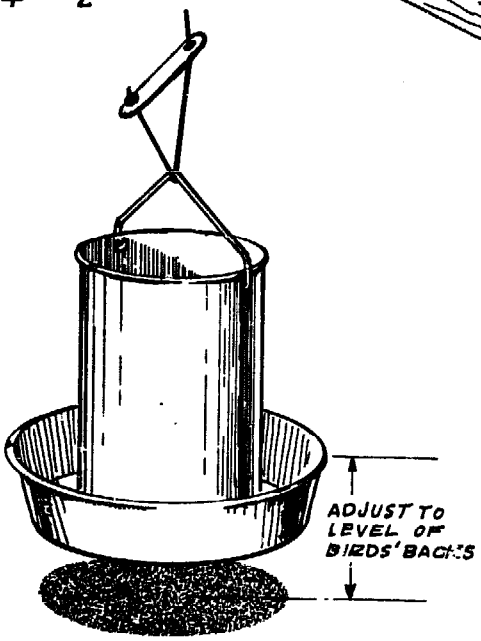
ADJUST TO
LEVEL OF
BIRDS' BACKS

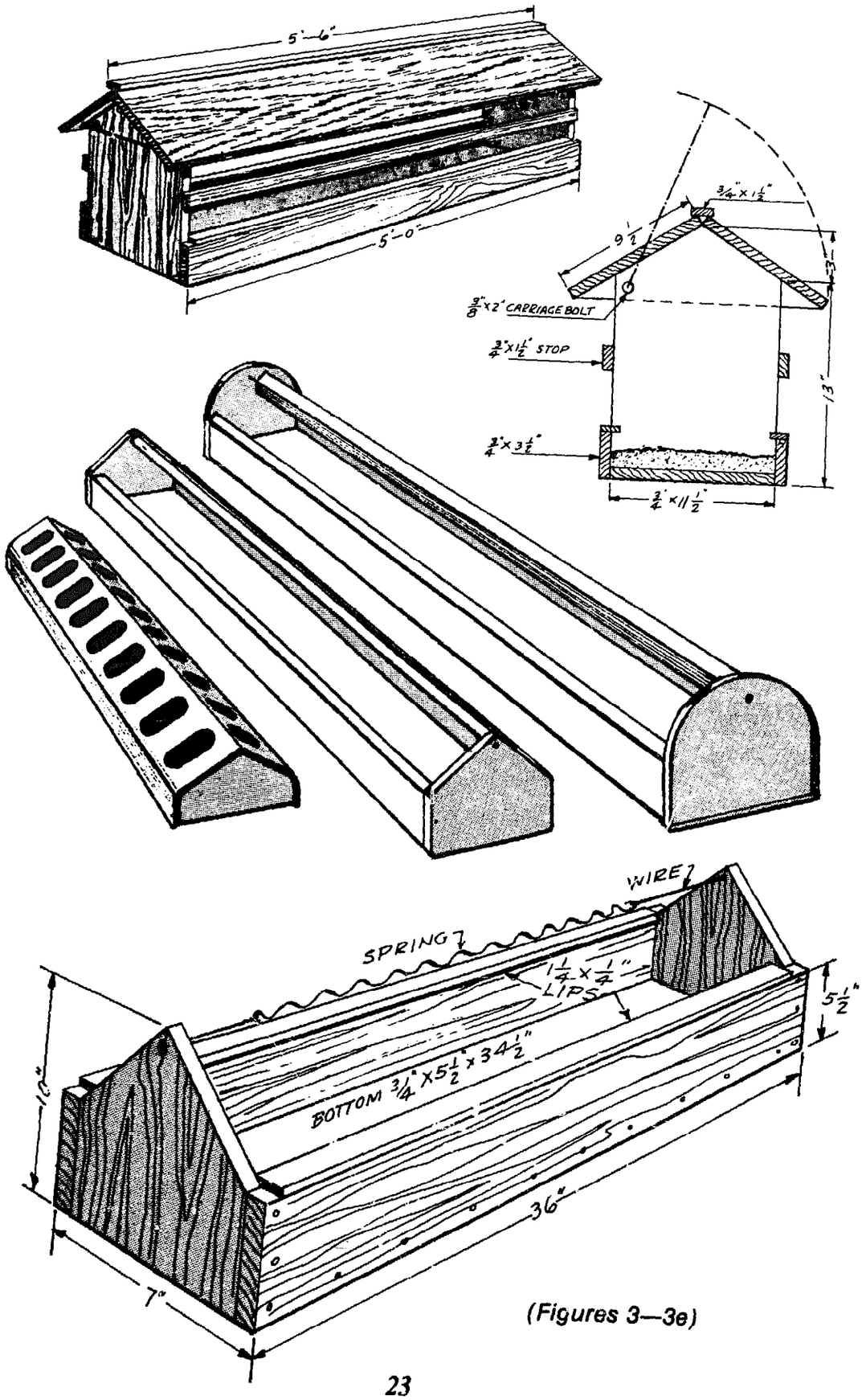
5'-6"
5'-0"
3/4" x 1 1/2"
9 1/2"
3"
3/8" x 2" CARRIAGE BOLT
3/4" x 1 1/2" STOP
13"
3/4" x 3 1/2"
3/4" x 11 1/2"
WIRE
SPRING
1 1/4" x 1/4" LIPS
5 1/2"
BOTTOM 3/4" x 5 1/2" x 34 1/2"
12"
36"
7"

(Figures 3—3e)

WATERERS

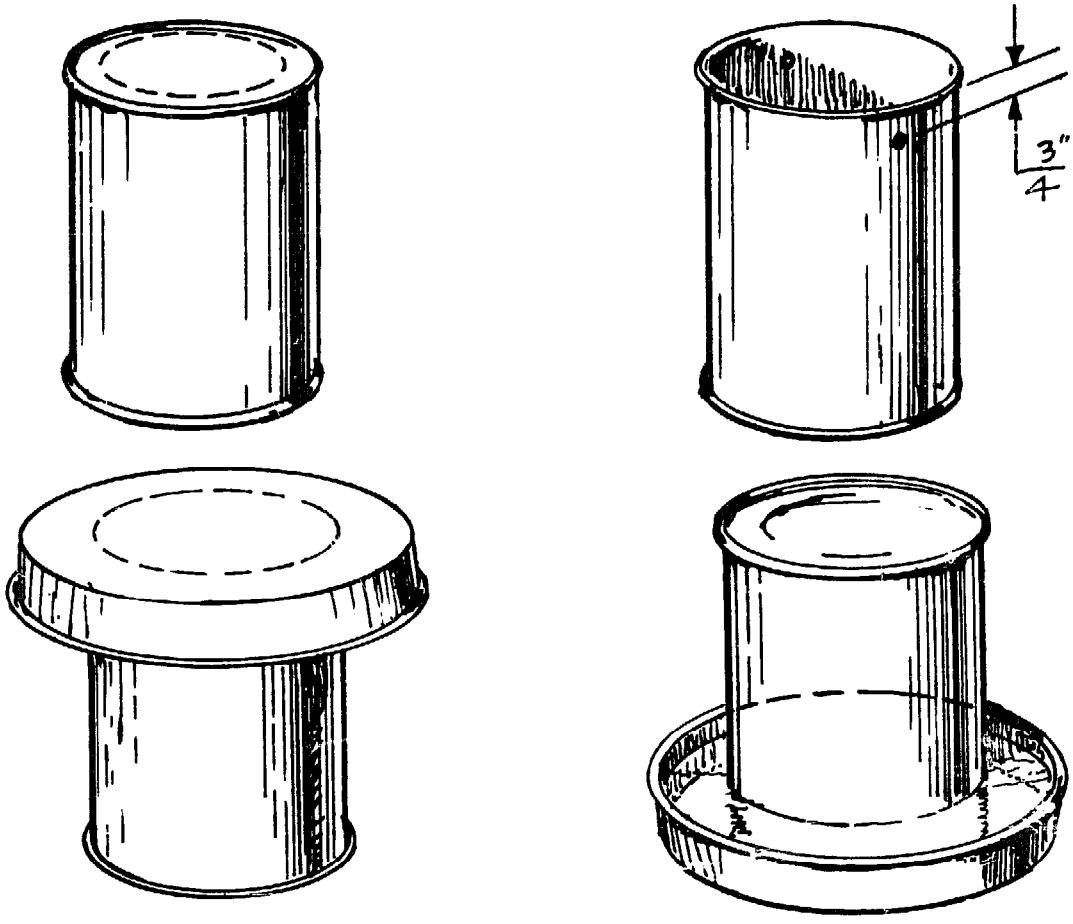

(Figure 4. Homemade Waterer made from a gallon oil can and a pan.)

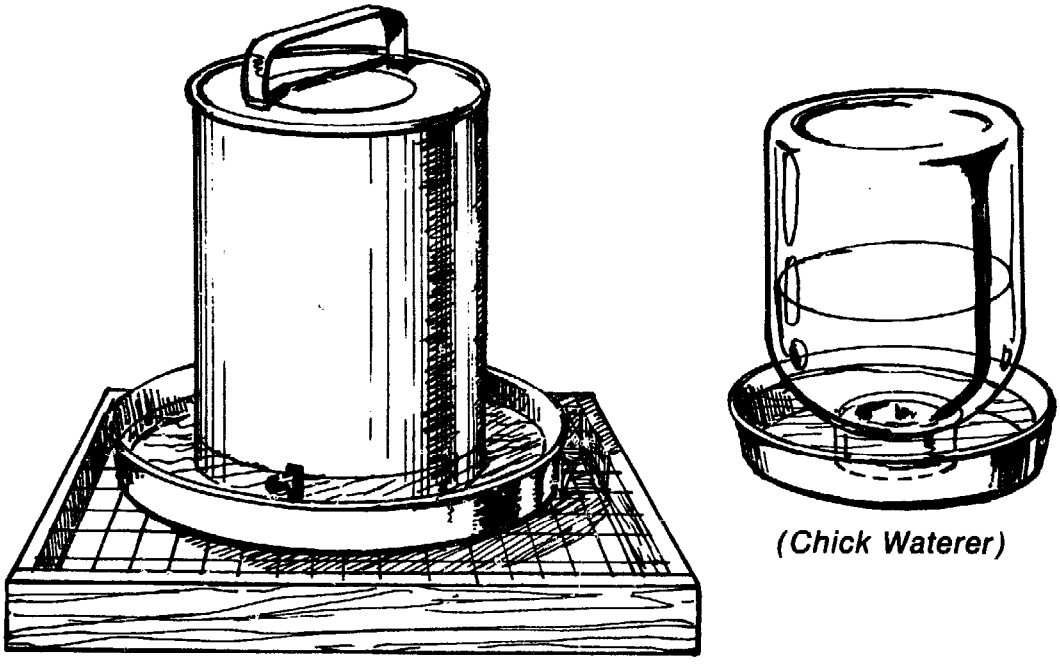

(Chick Waterer)

(Figure 4a. Waterer for older birds.)

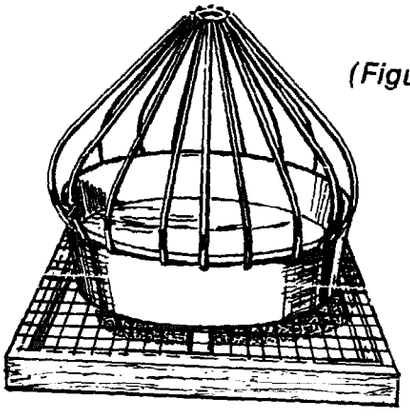

(Figure 4 b. Waterer suitable for laying birds.)

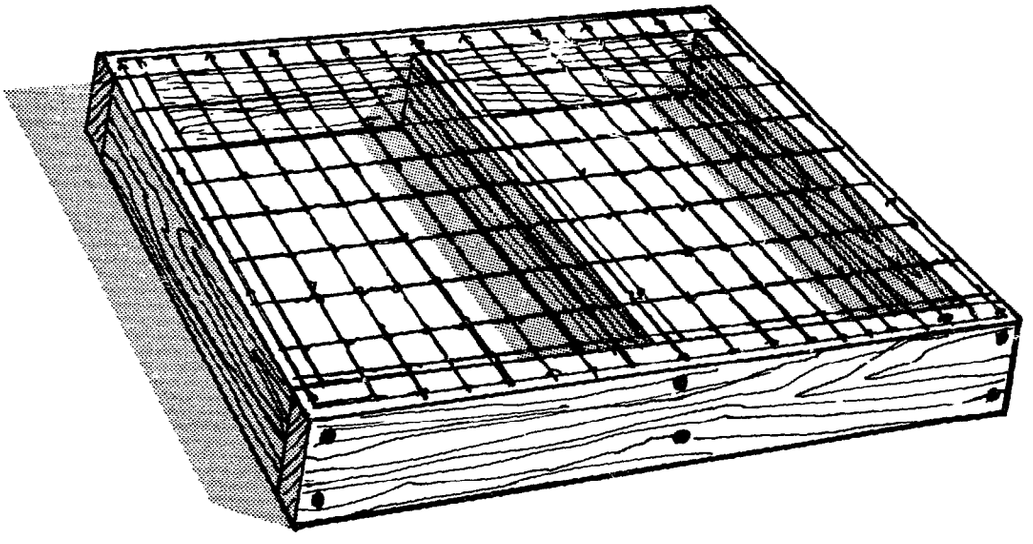

(Figure 5. Wire Water stand.)

Figure 6 shows an infrared brooder with guard. *Figure 6a* is a plan for a homemade electric brooder for a small flock. The typical hover-type *(Figure 6b)* reminds one of a flying saucer. It is usually suspended from the ceiling by chain or cable.

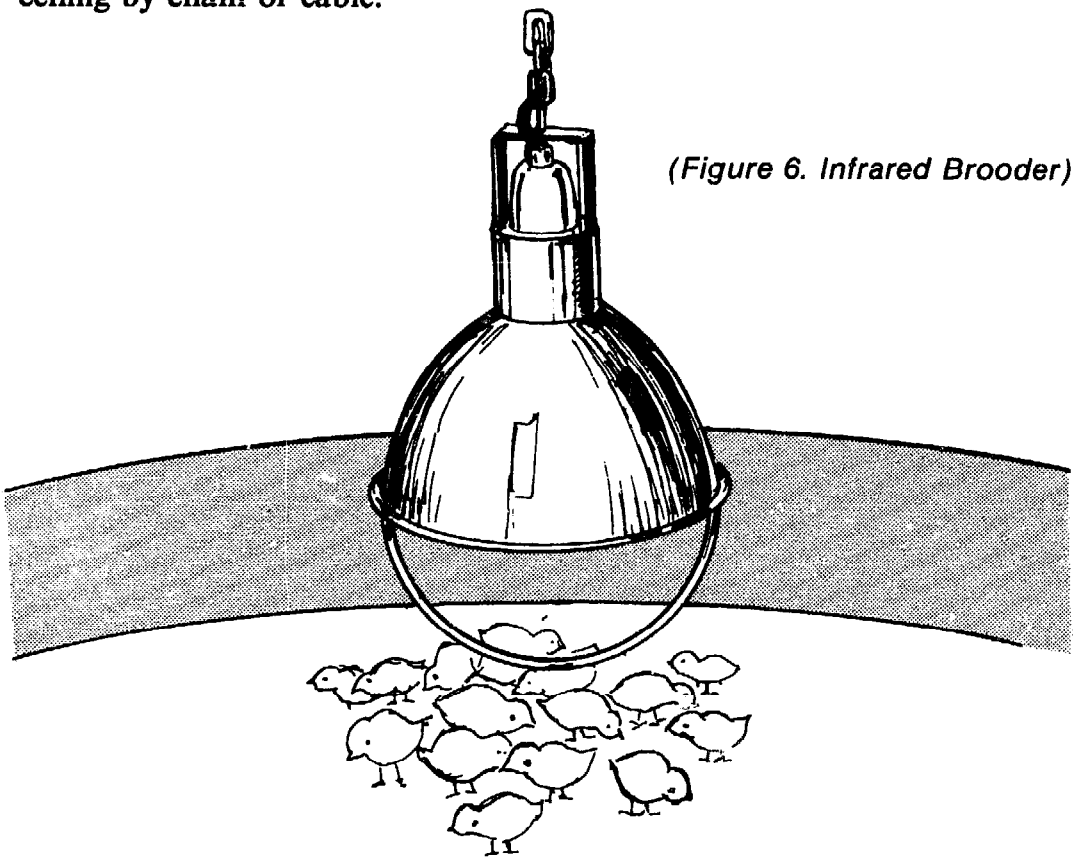

(Figure 6. Infrared Brooder)

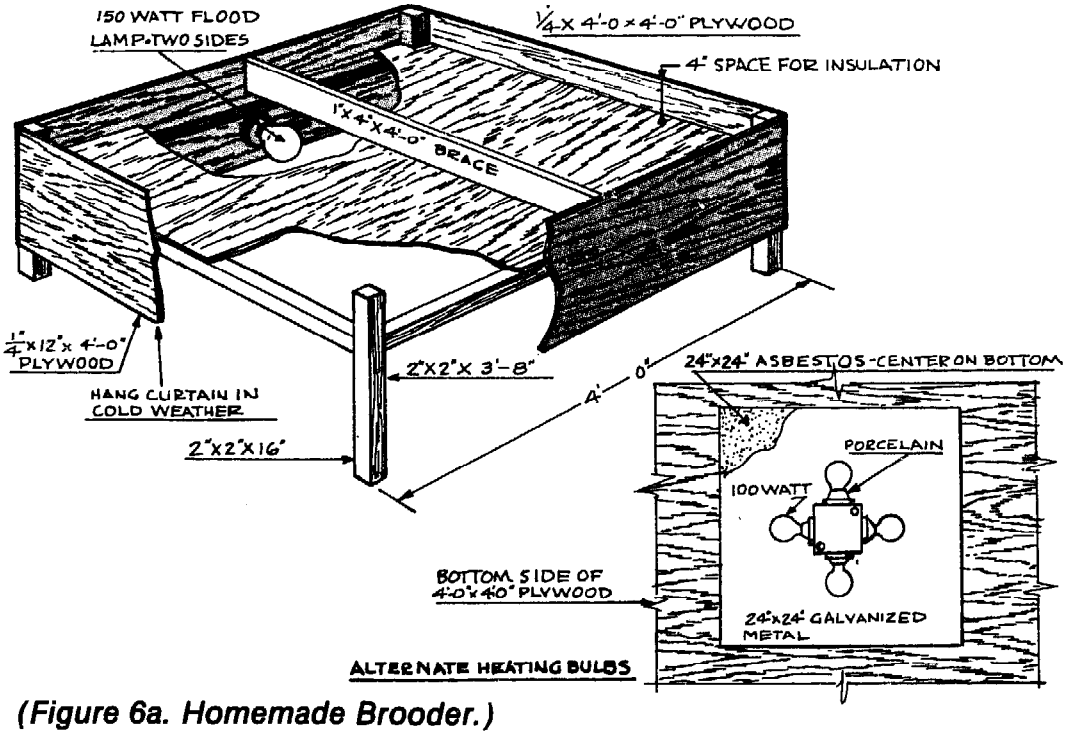

(Figure 6a. Homemade Brooder.)

(Figure 6b. A hover-type brooder)

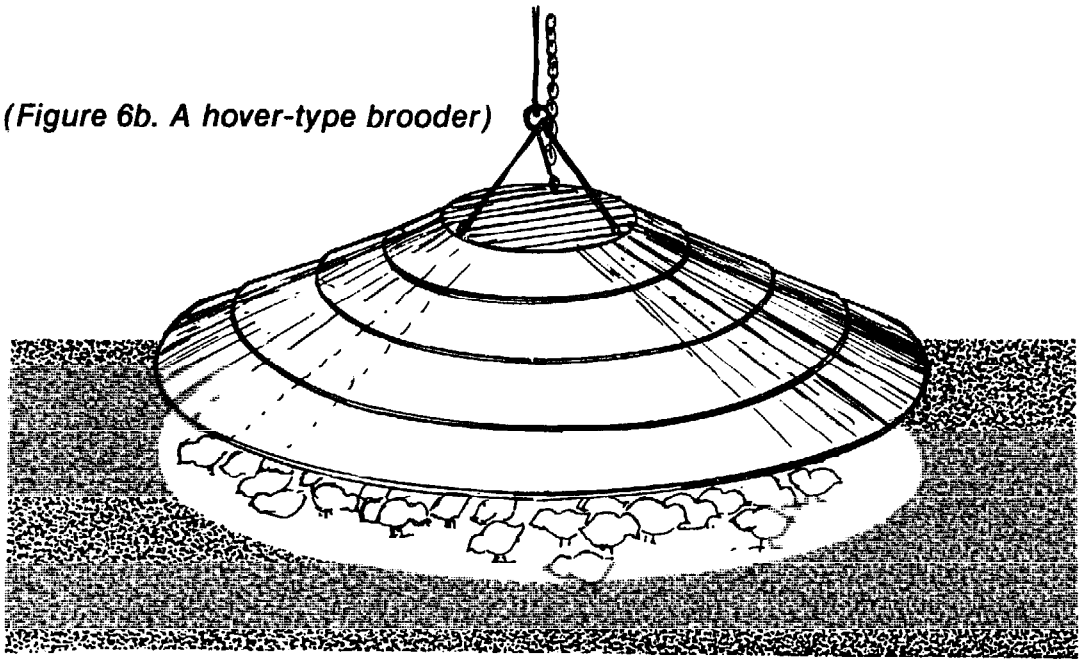

roosts

Roosts are not essential but are recommended for most small-laying flocks. Roosts should not be used for broilers or other meat birds. They may cause breast blisters. Roosts are used for turkeys but not waterfowl. Pullets should have 6"-8" of roost space per bird. If the layers are expected to roost they must be trained at an early age, or it will take considerable time to train them to use the roosts in the laying house.

There are several types of roosts. One of the more common types is the dropping pit with perches on the top of it (*Figure 7*). This type of roost is designed to accumulate droppings underneath for several months. This, naturally, keeps a large amount of the moisture out of the litter. If properly constructed and screened in around the top and sides, it will prevent the birds from getting into it. The nesting material and litter stays cleaner. Dropping pits are usually located either in the center of the building or at the rear of the building. These are normally the more comfortable areas in the house. The dropping pit should be designed so as to facilitate culling and so that it can be easily moved for cleaning. In larger units the dropping pits should be narrow enough to facilitate easy catching or culling of birds at night.

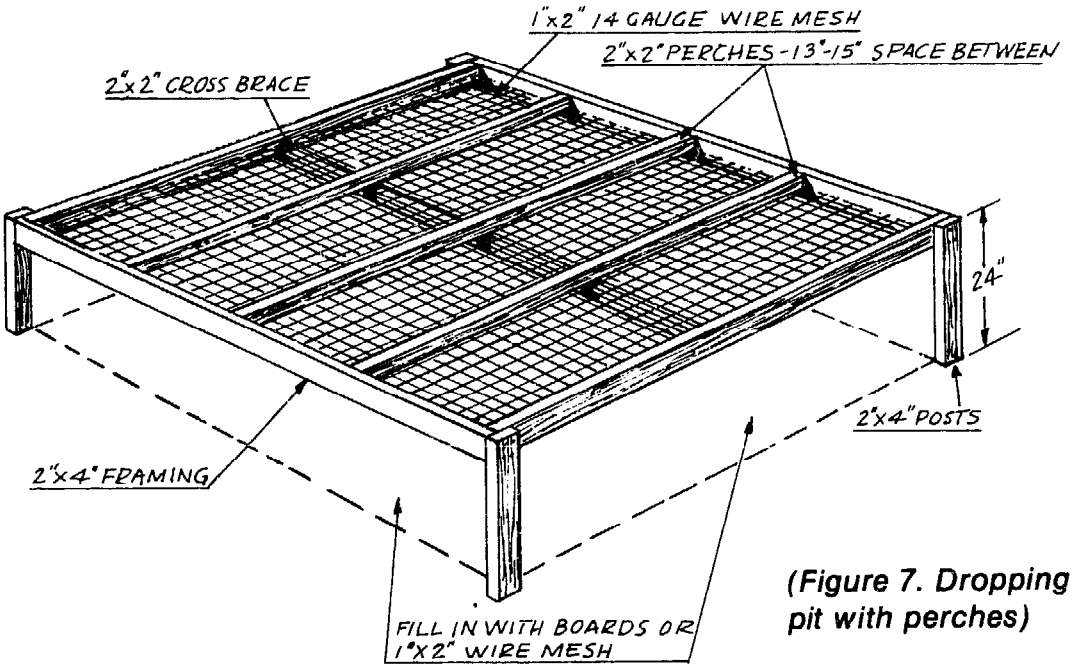

(Figure 7. Dropping pit with perches)

Another roosting method uses a dropping-board. The typical dropping-board is usually mounted on the wall at the heighth of about 2½ feet. The open space under the dropping-board provides additional floor space for the birds. The roosts are located above the dropping-board and the perches are hinged to the wall so they can be raised when the dropping-board is cleaned. This method is not as desirable as the dropping-pit type and is not recommended unless floor space is at a premium.

The roosts or perches should be of 2" x 2" stock, rounded or bevelled on the upper edges, so as to prevent injury to the breast and feet. For small breeds, allow 8" of perch space per bird is needed. Large breeds should have 8 to 10" of perch space. Roost perches are usually spaced 12"-15" apart.

nests

An adequate number of well designed nests with clean nesting material should be provided for the laying hens. They can be either individual or community-type nests. One individual nest, or one square foot of community nest, should be provided for each four laying birds. Individual nests (*Figure 8*) should be at least one-foot square and one foot high. Community nests (*Figure 8a*) can be almost any size but must be provided with at least two openings, 9" x 12" for every 20 square feet of nest space.

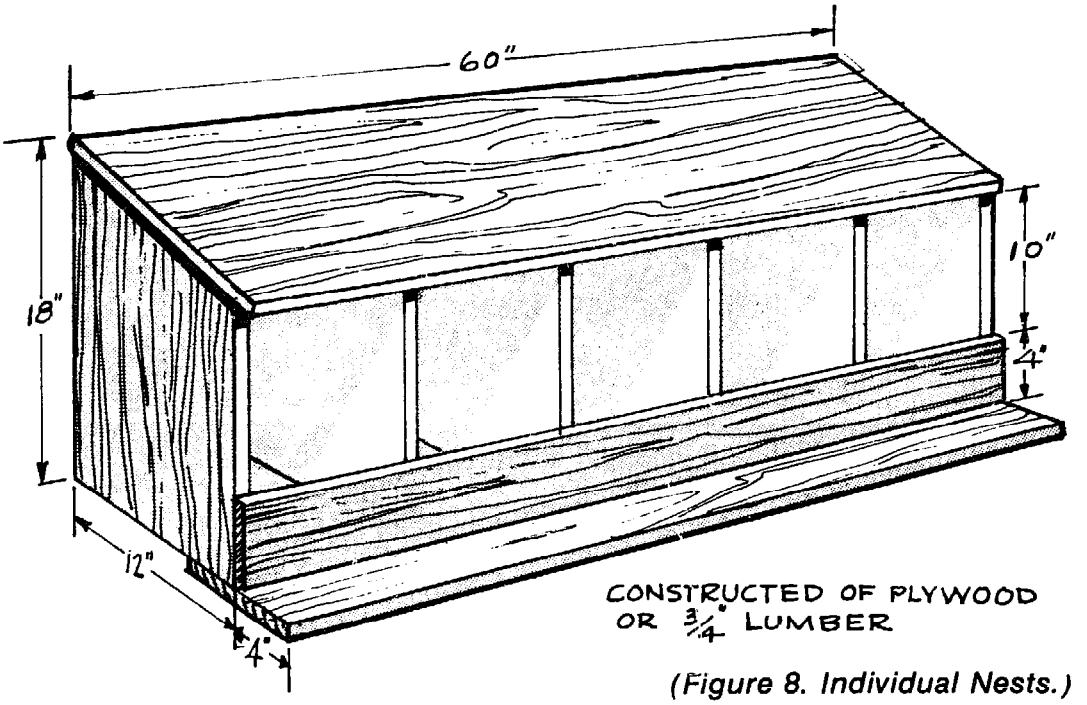

(Figure 8. Individual Nests.)

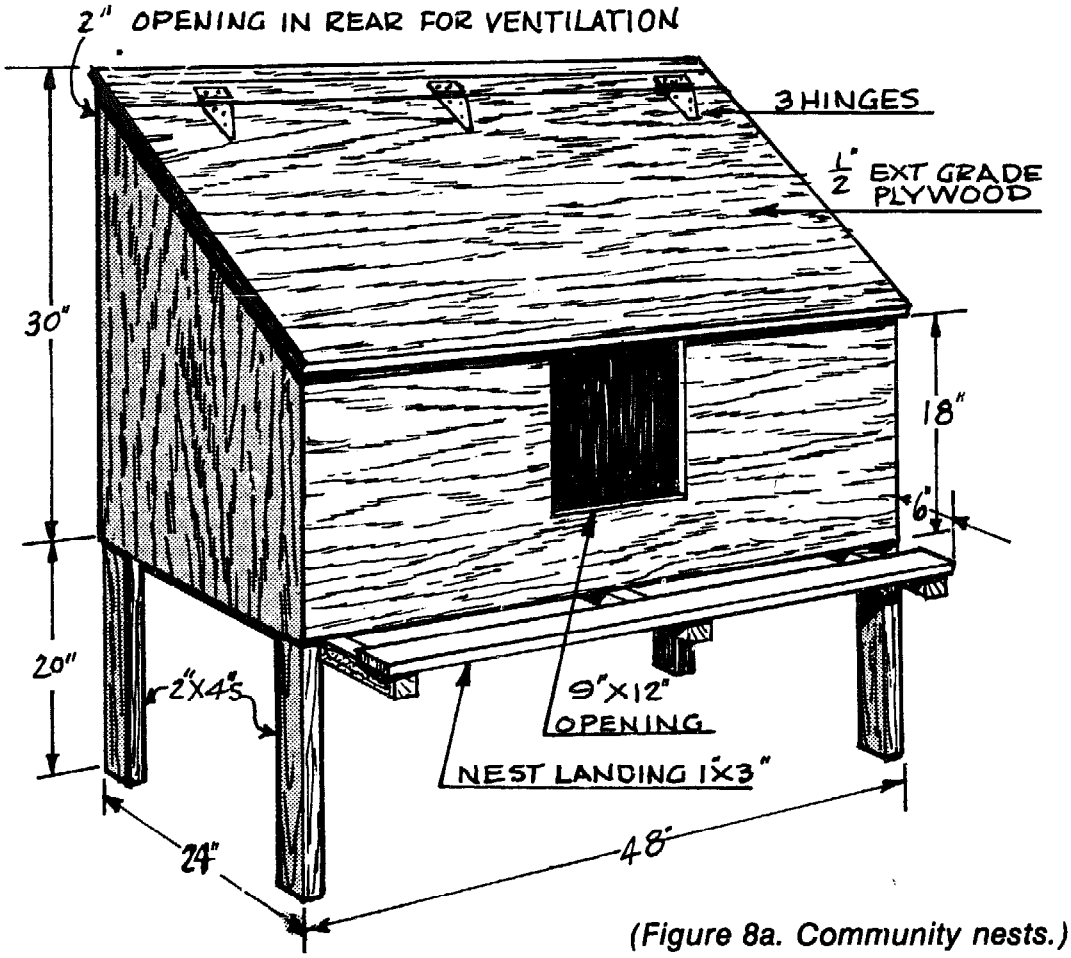

(Figure 8a. Community nests.)

As an aid to getting the birds into the nests, they can be darkened by covering two-thirds of each nest entrance with a cloth flap. A landing board should be placed below the nest openings to provide easy access to the nests. The nests should be located approximately 2 feet from the floor or surface of the litter.

Commercially-made nests are also available from agricultural supply houses and specialized equipment dealers. Some of these people offer a nest, either a community or individual type, with a roll-a-way feature. After the eggs are laid, they roll out to the front or back of the nest into an egg tray where they can be easily gathered. A word of caution about this type of nest: it's excellent in theory, but birds must be trained to use it and, more often than not, a large percentage of the eggs are laid on the floor rather than in the nest.

Nests should be cleaned frequently, as the nest material becomes dirty. Since several hens use the community-type nest at one time, ventilation of the nest is very important. For this reason a 2″ wide opening at the top of the nest is provided to allow heat to escape.

cages

Laying birds may also be housed in wire cages. Cages may be located in an open building or in closed fan-ventilated housing. As mentioned earlier, cages simplify the management of layers, but birds in cages are more susceptible to the effects of extreme weather conditions. Therefore, they must be protected from wind, cold and, particularly, from hot weather.

Cages (*Figure 9*) are usually constructed of 1″ x 2″ welded wire, the floor is constructed with a slope of approximately 2 inches per foot, so that eggs will roll out onto the egg tray. Feed and water is provided in troughs usually located on the outside of the cage. Water cups located inside the cage are also sometimes used.

There are several types of cages available, most of which are quite satisfactory. They come in several sizes but should not exceed 20 inches in depth for best results. Cages 12 inches wide and 18 inches deep are very popular. Research has indicated that three brown-egg birds or four Leghorn-type birds can be placed in a 12 x 18 inch cage with good results.

Several types of cages are satisfactory. They include the stair-step, the double-deck with dropping boards, colony and single-deck. Stair-step cages are available in two arrangements, either full or modified. Some

commercial producers are also moving toward a triple deck or even a four-deck modified stairstep-cage system to enable them to house more birds in a given area.

The use of cages cannot be justified in many of the very small laying flock enterprises. However, there are situations in which they can be used to good advantage. We have helped plan several small cage units for flocks of three or four hundred birds, utilizing an existing building or pen space more efficiently than could have been accomplished using a floor system. In these small units the birds are usually watered automatically, but the feeding, egg collection and cleaning are manual chores.

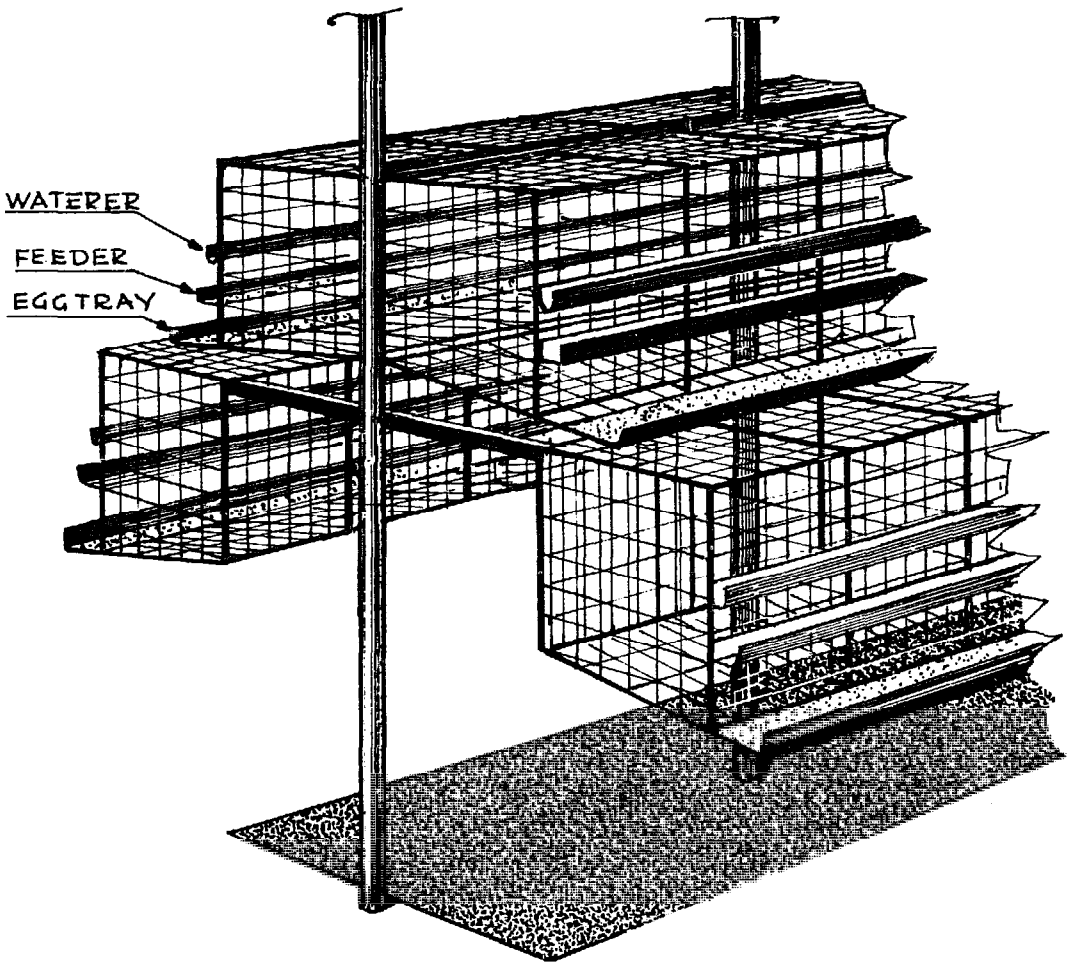

(Figure 9. Full Stair-step cage)

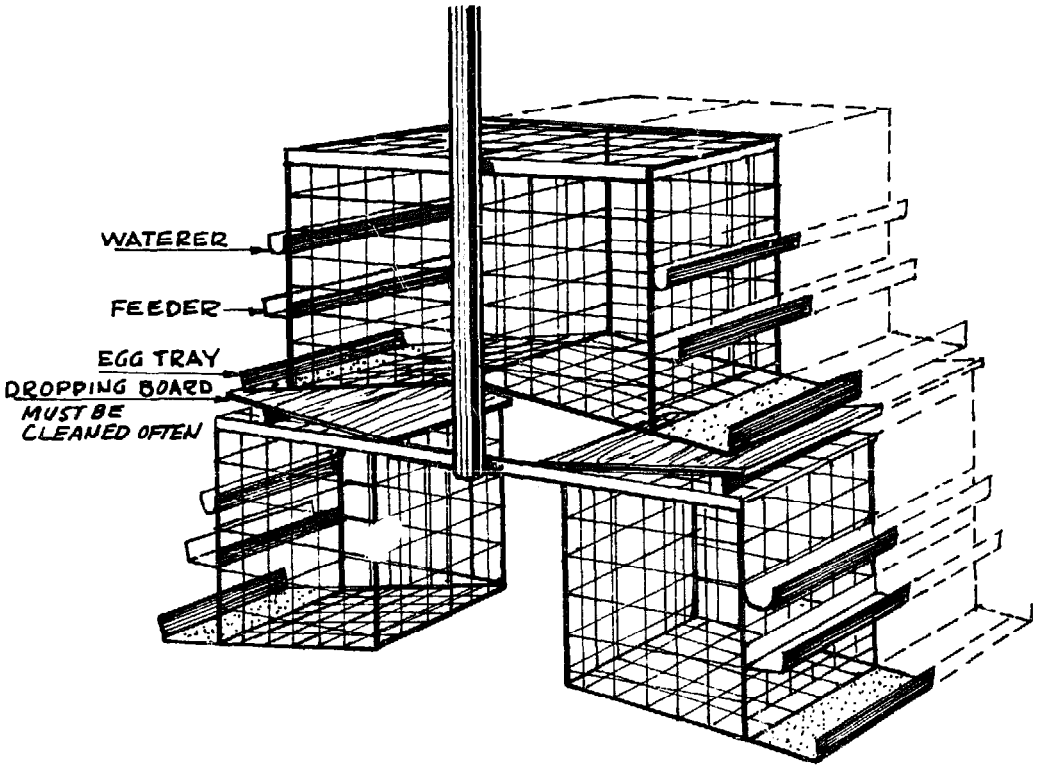

(Figure 9a. Modified Stair-step cage)

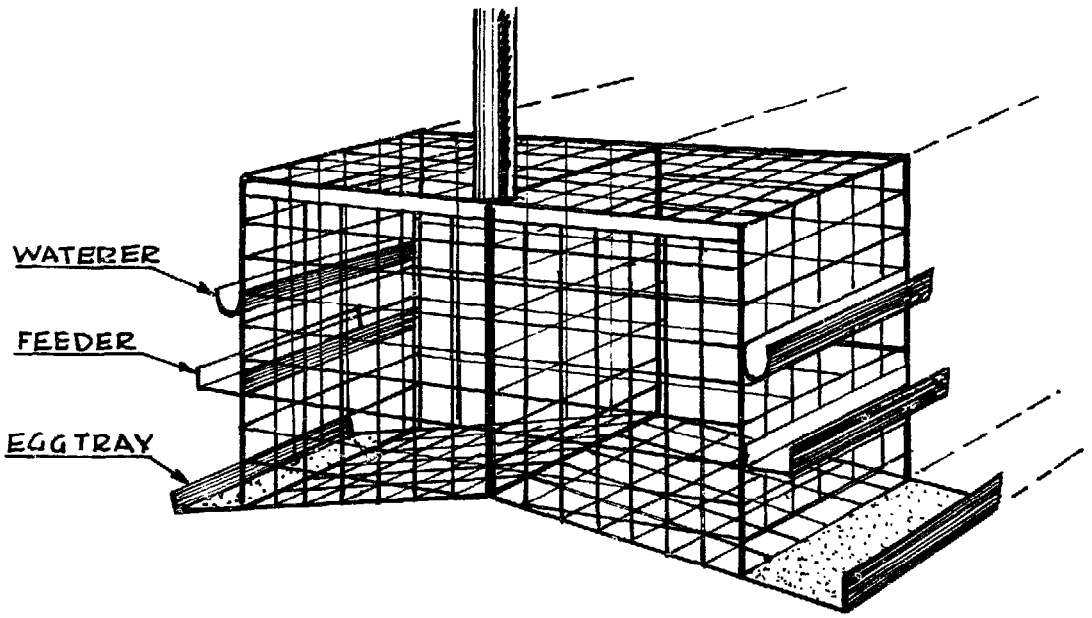

(Figure 9b. Single-deck cage)

3

STARTING THE LAYING FLOCK

The laying flock can be started in a variety of ways. You can set eggs under a broody hen or in a small incubator. Either day-old chicks or started pullets may be purchased. One questionable method of starting is to purchase second-year layers. These are birds that have laid for a year. Production is not as good for second year layers, egg quality may be poor and they may stop laying, go into a molt (shed old feathers and grow new ones) soon after moving. One of the simplest and best ways of starting the laying flock is to buy started pullets. This avoids the need for equipment and the care involved in incubating eggs and brooding chicks. You can buy started pullets from commercial growers at 19 to 20 weeks of age. Sometimes it is possible to buy a few surplus pullets from a local poultryman in your area. Pullets should be debeaked to avoid feather picking and cannibalism. Ten to 15 birds will normally provide the average family with enough eggs. Unless surplus eggs can be marketed easily you should not produce more than the family needs.

Before buying birds, decide whether you want white or brown eggs. Egg shell color does not affect food value, but it does influence the market price, since there is a definite preference in various areas of the country. In most sections of the United States, white shell eggs sell for slightly more

than the brown shell eggs. In the New England area, or so-called Boston market area, brown eggs are preferred and the situation is reversed.

Birds that lay white eggs usually weigh in the vicinity of 4 to 4½ pounds at maturity. Representatives of these breeds and varieties are the Leghorns, first generation Leghorn strain crosses or hybrids — all of which are good egg producers but not so good for meat.

The medium weight breeds, American Breeds, lay brown eggs. The mature weight of these birds is usually between 5 and 6 pounds, thus making them more desirable as meat birds. Most of the medium weight, brown egg producing layers are crosses of American breeds, such as the Barred Plymouth Rock and the Rhode Island Red. There are several of these crosses, all of which are good egg producers. There are several pure breeds such as the Rhode Island Reds, White Plymouth Rocks and New Hampshires, which can be used as dual purpose breeds, that is for meat and eggs. However, they may not do as well as the crosses which have been bred especially for meat or egg production.

Stock that is bred for high egg production or for meat production is best suited for the home flock. To get the project off to a good start, purchase well bred healthy chicks or started pullets. One of the mistakes that is frequently made is the purchase of chicks from distant hatcheries. Sometimes the conditions to which chicks are exposed when being transported over long distances are less than desirable. They may be chilled or overheated, leading to early losses and a poor producing flock. It is usually best to purchase chicks or started pullets from a reputable nearby hatchery or producer that has stock bred for efficient production. Traits that should be considered, when purchasing chicks or pullets, include liveability, early feathering and feed efficiency, freedom from disease, rate of growth, egg production and egg quality. Much valuable information can often be obtained by talking with poultry producers in your area. They can frequently tell you from experience which breeds and strains have the above characteristics and the most reputable hatcheries and pullet growers from which stock can be obtained. Another means of evaluating stock is to consult the random sample egg production and meat production test reports. Random sample egg and meat production tests are conducted in several states. These tests are designed to test the entries of production stocks for the various economic production traits. The test reports provide information to help evaluate the performance of laying stock or meat stock offered for sale by the participating breeders and hatcherymen.

The United States Department of Agriculture annually publishes a report on these production tests. Copies of the publication, which contains records of all stocks entered in the performance tests in the United States and Canada, may be obtained by writing to the Poultry Research Branch, Animal Sciences Research Division, Agricultural Research Service, United States Department of Agriculture, Beltsville, Maryland.

One of the first steps toward getting disease-free chicks is to buy the stock from hatcheries that blood test their breeders for pullorum-typhoid. Hatcheries which operate under the National Poultry Improvement Plan do blood test their breeding flocks for these diseases. Both of these diseases are passed from the infected hen to the chick through the egg.

If a nearby hatchery has stock with good production capabilities and is disease free, it is best to get your chicks locally to minimize the shipping time and avoid the possibility of prolonged exposure to extremes of temperature and poor handling. It is usually much easier to get adjustments from a nearby hatcheryman in the event that problems arise. Chicks should be ordered at least four weeks in advance of the date you would like to start them, and started pullets should probably be ordered close to six months before they are needed. Your County Extension Agent or Extension Poultry Specialist can help you select sources of stock. (See page 198 for Directory of State Poultry Specialists.)

Buying Your Chicks

The importance of selecting the right stock should be re-emphasized here. After deciding on the breed or strain you want, be sure to buy healthy stock from hatcheries which have a U.S. pullorum-typhoid clean status. Buy the best chicks you can buy. Cheap chicks may cost you more in the end than those that cost most in the beginning. Poor results with growth or liveability can soon erase any savings that you may have made in the purchase of chicks.

Be sure to buy chicks which are bred for the purpose for which they are to be used. If you are interested in starting with a flock of laying birds, get chicks from a source which is known for having birds with high egg production records. There are great differences among types of birds, insofar as egg size, egg production, feed efficiency, liveability and many other economic traits are concerned.

In the New England area, production birds that lay brown eggs are primarily the sex-link crosses. There are about three or four birds of this type offered for sale in New England. They are known as sex-link crosses,

because the breeds that are mated result in male chicks of one color and female chicks of another color. These can be sexed by feather color at day-of-age, thus eliminating the cost of vent sexing. Some of the breeders of inbred crosses, noted mainly for their white-egg birds, also have inbred crosses which produce brown eggs.

When buying chicks for laying stock the usual practice is to purchase sexed pullets. This is because the cockerels of the best laying stocks are apt to be poor meat producers. It is usually not wise to try to grow them for meat.

If you are planning to raise meat-type birds, it is recommended that you order the birds which are bred for the production of meat. Only birds bred for meat production should be raised as broilers, capons or roasters.

Stock that is bred for the production of meat has the ability to grow rapidly with a minimum of feed consumption. Feed consumption represents at least 60% of the total costs of producing poultry meat. Thus feed cost becomes an important consideration. Also, birds that are bred for meat tend to mature with a better finish, are tenderer and more juicy. Then too, the meat bird stocks are primarily white feathered, which results in a much better dressed appearance in the absence of dark pinfeathers.

when to start the chicks

The time to start chicks may depend upon the type of housing you have and the type of brooding equipment available. Chicks started in the winter commence laying in the early summer, but may go into a neck molt and take a vacation the following winter. On the other hand, pullets, which are hatched in late winter or early spring, start to lay in the summer when egg prices are normally highest. Those raised late in the spring will not start laying until late fall when egg prices are usually lower.

Probably the best time for most small flock producers to buy their chicks is in late March, April and May, especially those in the northern climates. Chicks started at that time do not need cold weather brooding facilities. Moreover, the pullets will start laying in early fall and will continue laying for a full 12-month cycle.

4

BROODING AND REARING YOUNG STOCK

The Brooder House

Brooding facilities can affect the degree of success one has in growing chicks. As indicated earlier, an expensive building is not necessary, but the facility should be built so that it will brood chicks efficiently.

One of the features of a good brooder house is structural soundness to withstand high winds and snowloads in winter areas. It should be of tight construction, with sufficient insulation against drafts, and easy to maintain a uniform temperature economically. It should have a ventilation system to control moisture and gases, yet still able to conserve or dissipate heat. Lastly, it is desirable to have some degree of light control in the house. The main equipment needs include the feeders, waterers and brooders. Roosts may be used for replacement pullets.

Equipment

feeders

Commercial or homemade feed hoppers are satisfactory for use in brooding chicks. Probably the commercial hoppers are easier to clean and cause less feed waste.

waterers

It is possible to make water fountains using oil cans, or juice cans in combination with tin plates. This can be done by making two holes on opposite sides of the can about ¾" from the lip. The can is then filled with water the plate placed on top, the can and plate is then flipped over to provide a waterer that maintains its own water level. See *Figure 4* for details on making this waterer.

A small wire platform underneath each fountain helps to keep the water clean, keep the shavings out of it and also prevents the litter from becoming too damp around it.

Probably the best watering devices are the commercial one-gallon fountains. Commercial poultry producers frequently use the gallon fountains in combination with automatic waterers. They gradually move the gallon fountains close to the automatics. They are thus able to convert to the automatic waterers as early as 10 days of age. Once the chicks are drinking well from the automatic waterers, the fountains can be removed gradually and additional automatic fountains added until they have three to four eight-foot waterers per 1,000 birds.

In small flock situations, two one-gallon waterers are usually good for 100 birds for up to 2 weeks. From the second through the sixth week, there should be at least two 2 or 3-gallon waterers, and from 8 to 10 weeks, one 5-gallon waterer per 100 birds.

brooders

To provide the necessary heat some type of brooding device is required. Infrared lamps are an excellent source of heat for brooding small flocks of chicks *(Figure 6)*. The initial cost of equipment is relatively small, and the lamps are excellent for supplying heat to the chicks, par-

ticularly in the late spring, summer, or early fall months. The infrared lamp is suspended approximately 18″ above the litter. One 250 watt bulb is sufficient to brood up to 75 chicks. Even though the number of chicks may be small, it is wise to use at least 2 bulbs in case one fails.

Many small flocks are brooded with homemade brooders utilizing electric light bulbs as the heat source. It is possible to construct simple hovers (canopies) of plywood and canvas, or some similar material, which can be suspended from the ceiling or supported by legs *(Figure 6a).*

Other brooders which are manufactured commercially are fired by oil, gas, electricity, wood or coal. These have a hover to keep the heat down at the floor level *(Figure 6b).* Such brooders are excellent for flocks of 100 chicks or more. Some of them are rated at a capacity in excess of 750 chicks. The initial cost of these units is considerably more than either the infrared lamp or the homemade brooder. Each chick needs a minimum of 7 square inches of hover space or its equivalent.

Each type of brooder has certain advantages. The infrared bulb has the advantage of enabling the operator to see the chicks at all times. Where the hover-type brooder is used, it is more difficult to observe the chicks. On the other hand, the hover-type brooder is best for cold weather brooding and is less expensive to operate.

The type of equipment that is selected will depend, to a certain extent, upon the cost and availability of fuel and the extent to which it is to be used. Whatever brooder stove you use, it should have the capacity to heat adequately and a means for controlling the temperature accurately.

roosts

Roosts should not be used for broilers, roasters or capons. They can cause breast blisters or breast deformities. In fact, few people use roosts even for growing replacements. Those who want their birds to roost in the laying house feel that it is necessary to train the pullets to roost in the brooder house. If roost perches are to be used in the brooder house, they should be enclosed with poultry netting so as to prevent the chicks from coming in contact with the droppings. They should be constructed so as to provide easy access for the birds. Frequently, they are slanted from the floor to the wall much like a ladder.

5

BROODING MANAGEMENT

Preparation Of The Brooding Quarters

Getting the chicks off to a good start is very important. Probably no other part of the enterprise deserves more planning and advance preparation than does the starting of baby chicks. The modern brooder house should be clean and disinfected or fumigated at least two weeks before the chicks arrive. If this is not done, the chicks may be exposed to certain poultry diseases which can lead to mortality and poor results. First sweep or wash down cobwebs, dirt and dust, then use a good disinfectant. There are a number of good commercial preparations available. They should be used according to the manufacturers recommendations. Some of them require that the house stand idle for a period of time and be thoroughly aired before the chicks arrive. Failure to observe these precautions may cause the chicks to have severely burned feet and eyes.

After the brooder house has been cleaned and disinfected, it should be allowed to dry thoroughly before putting in new litter. When the floor is dry, it should be covered with 2"-4" inches of litter material. The litter material serves to absorb moisture and to insulate the floor for comfort of the birds. Several different materials may be used for litter. Wood shavings are among the most commonly used, whenever available. Other materials include sawdust, or shavings and sawdust, rice hulls, sugar cane, peanut hulls and ground corn cobs.

When chicks are extremely hungry upon arrival they may try to eat the litter before learning to eat feed. If you have reason to believe that the chicks have been hatched for two or three days when they arrive, it may be a good idea to put paper over the litter for the first 3 or 4 days until they learn to eat. When chicks are received soon after hatching, it is not necessary to do this.

The brooders should be started a day or two before the chicks are due to arrive. This will assure that the equipment is operating properly and is adjusted to the correct temperature. A chick guard should be used to confine the chicks to the source of heat. It will also help to prevent drafts on the chicks under the brooder. A corrugated cardboard guard, approximately 12" high is good for this purpose during cool weather. For warm weather brooding the guard may be made of poultry netting. It should form a circle around, and about 3 feet from, the brooder. The guard is usually removed after 10 days or so, depending upon the weather and conditions within the house. The chick guard keeps the chicks confined to a given brooder and also prevents migration and overcrowding of some brooders if more than one brooder is used in the brooding facility.

Fill the feeders and waterers several hours before the chicks arrive. The water will be at room temperature when the chicks arrive, and encourage them to drink. The feed trays and water fountains should be spaced uniformly around the brooder and close to the hover (*Figure 10*). One method that is frequently used to get chicks to eat, when first put under the hover, is to place a small amount of feed on either new egg filler flats or on inverted chick box lids. The type of lid that is used is the one without the slots or holes for ventilation. Chicks instinctively peck at anything at the same level as the surface upon which they are standing. Therefore, they will learn to eat more readily if feed is provided in this manner for a day or two. Chicks that are slow to catch on to the fact that feed is in front of them are attracted by the noise made by the others that have found the feed and are pecking on the cardboard. This gets the chicks off to a good start and eating well.

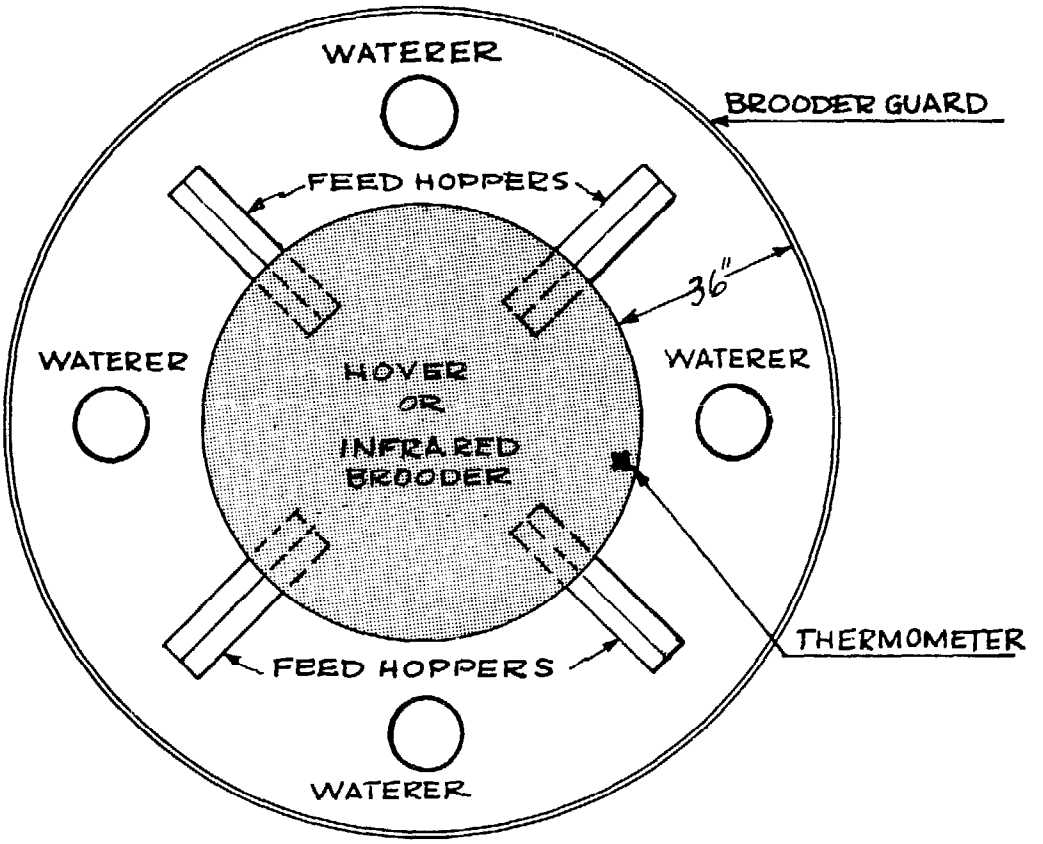

(Figure 10)

brooder management

Brooding temperature is very important. The recommended temperature at the start is 90-95° F. A rule of thumb to remember is: reduce the temperature 5° each week until the chicks no longer need heat. It is often stated that the best thermometer, to gauge the most comfortable temperature, is to watch the chick itself *(Figure 11)*. After the chick reaches 7 days of age this is probably true. If the chicks huddle close to the heat source you can be reasonably sure that the operating temperature is too low. If, on the other hand, the birds are located in a circle, way outside the heat source, you should assume that the temperature is too high. During the day the chicks should be evenly distributed around the entire brooding area, with some of the chicks underneath the heat source. Temperature readings should be taken at the outside edge of the brooder at the chick level. One important factor for the successful brooding of chicks is the maintenance of good litter conditions. When litter conditions get out of hand and become too wet, disease problems can result. Wet, dirty litter can harbor many disease organisms which affect poultry. In

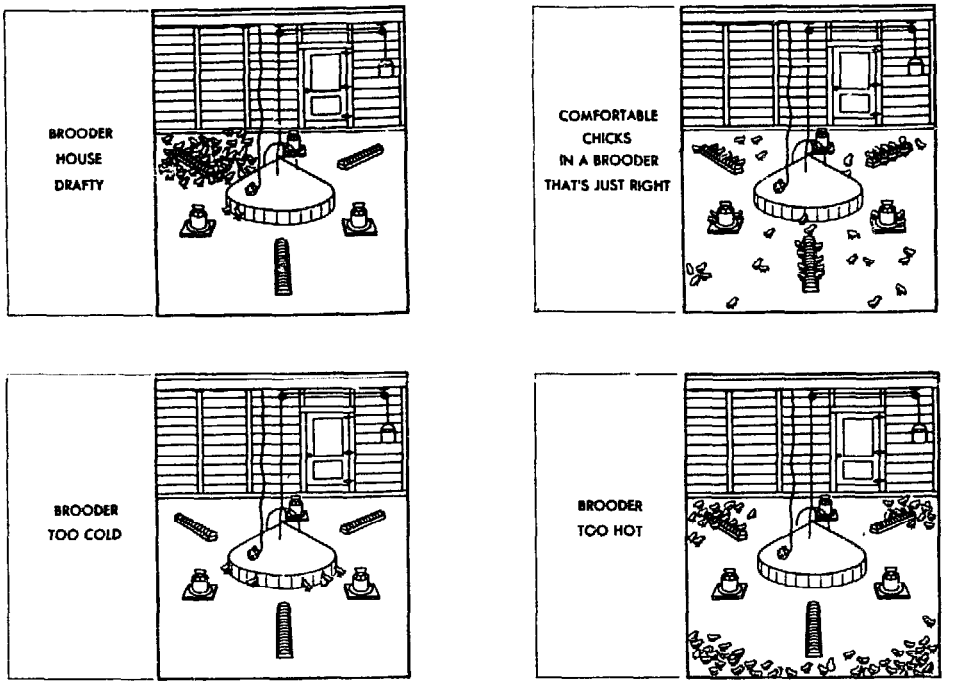

(Figure 11. Brooder Management)

the case of replacement pullets, it is desirable to have a certain amount of moisture in the litter (30-35%) to enable sporulation of oocysts and the subsequent development of an immunity to coccidiosis during the growing period. However, an excessively wet litter, especially during warm periods, can bring about a clinical case of coccidiosis and result in what we term a coccidiosis break, which requires treatment.

One of the common problems experienced with meat birds is breast blisters — swellings or external sores on the skin of the breast — which seriously detract from the dressed appearance of the carcass. These are quite common in flocks of capons and roasters. Excessively wet, caked or dirty litter is frequently blamed for breast blisters. Since perches are not used for broilers or meat birds, the birds must bed down in the litter. It is important that the litter depth be maintained and that it is kept dry and fluffy enough to cushion the body and avoid all contact with the floor. Furthermore, it is essential that it be reasonably clean to avoid soilage of the breast feathers, skin irritations and breast blisters.

General Feeding Programs

The recommended modern feeding programs for meat birds and for laying bird replacements vary widely. Broilers and other meat birds are fed a high energy diet throughout the growing period. In the production of

meat birds, the goals are rapid growth, heavy weights and efficient feed conversion. Replacement pullets, on the other hand, are started on medium-to-high-energy starter rations for the first 6 to 8 weeks; then they are changed to a grower diet to accommodate their changing dietary needs. Meat bird chicks and replacement pullets which are reared on litter are normally started on a diet containing a coccidiostat. A higher level of coccidiostat is used for meat birds to prevent coccidiosis, a disease common to chickens reared on the floor. The coccidiostat is usually fed throughout the growing period in the case of the meat birds to protect them against a coccidiosis outbreak and to obtain maximum growth and efficiency. Replacement pullets are fed a lower level of coccidiostat in the starter diet. This enables them to develop an immunity to coccidiosis by 6 to 8 weeks of age, and this immunity protects them throughout the remainder of the growing period and the laying period.

Diets for meat birds, particularly broilers and turkeys, are usually somewhat better fortified with vitamins and growth-promoting factors. They sometimes contain antibiotics. The protein level of meat bird diets, at least during the first several weeks, is higher than for replacement birds. Another difference is that feeding programs for meat birds do not include scratch grains during the growing period. Occasionally, heavy meat birds are fed corn the last two weeks of the growing period to improve their finish just prior to dressing or marketing. Frequently a special finishing diet is used for this purpose. Some growers of meat birds prefer the crumbles or pellets to the mash form because of less feed waste and increased feed consumption. However, crumbles and pellets cost more, and there is also the tendency for birds fed on crumbles, and particularly pellets, to feather-pick or become cannibalistic.

Some broiler or roaster feeds contain feed additives that must be removed several days prior to slaughter. The withdrawal period varies with the type of drug. For the last several days the birds are fed on a special feed without the additives. Some drugs used for the treatment of diseases are administered through the feed. Definite withdrawal periods are required for these drugs prior to slaughter. Always follow the recommendations of the feed company printed on the feed tag.

feeding and management of layer replacements

Replacement chicks for layers are started on a diet very similar to the broiler diet; however, the energy and protein content are usually slightly lower. The protein is 20 to 21%. Chicks to be raised for layers are normally

fed a starter for 6-8 weeks and then changed to a grower diet.

As with other animals, the growth rate diminishes as the birds become older. Therefore, the protein requirement is less later in the growing period and the grower diet is formulated with somewhat less protein than the starter.

Several feeding programs are used from the 6-8 week period to housing. However, the two basic systems are the all-mash diet with approximately 15% protein or a mash and scratch diet. For a number of years it was felt that it was best to full-feed growing replacements. Today, more and more growers are using some form of feed restriction to delay sexual maturity, yet permitting the development of a healthy pullet. Other growers are using lighting programs to delay sexual maturity. No doubt the simplest and best procedure for the small flock manager is to full-feed the growing pullets. When feed is restricted, there must be adequate equipment and good management to avoid problems.

why delay sexual maturity?

Birds that commence to lay too early or that are too fat at the onset of production frequently do not perform as well as slower-maturing birds. They are inclined to lay fewer and smaller eggs and are more prone to prolapse of the uterus and higher mortality.

Birds on a full-feed program that are grown in the off-season (under conditions of increasing day-length) should receive a controlled lighting schedule to delay sexual maturity. This method, if done correctly, usually produces the most economical gains and more uniform birds with fewer social problems or vices.

There are several restricted feeding programs. One of the fairly common ones is the use of a 15 or 16% protein diet of medium energy. The exact diet depends upon the type of bird. Usually some physical restriction is used. It can be a skip-a-day program, or a specific amount of feed can be fed daily depending upon the weight and age of birds. The restriction requires attention to certain details. For example, it requires about 50% more feed space for a restricted feeding program to assure that all birds get feed. Then too, restricted programs tend to increase feather pulling and cannibalism and may increase the nervousness of the flock.

A feeding program which is still used, to a considerable extent, is a combination of the grower concentrate with a grain such as oats. After 8 weeks the oats can be gradually added to the grower diet until proportions

of approximately one-half grower concentrate and one-half oats is reached. Some producers permit the birds to free-choice feed the mash and oats. Grit should be used when a whole grain is fed. A hard insoluble grit, not a soluble grit such as calcite crystals, should be used. Use a medium or pullet size grit to approximately 12 weeks of age and the hen size, or coarse, for the remainder of the growing period. Grit must be present in the gizzard to enable birds to grind the fibrous material so that it can be utilized and absorbed in the intestines.

Other restriction programs now receiving some attention for delaying sexual maturity in pullets, are high-energy, low protein-type diets and low lysine diets. Good pullets can be grown on most of these programs. Check with your feed company, and the breeder of the stock which you purchase, to determine which system he recommends.

Heavy breeds have a tendency to acquire more fat than the lighter breeds and crosses of egg-producers. These birds, and heavy broiler breeders, for hatching egg production are commonly put on a restricted program, usually an all-mash diet.

Range-Rearing

Under some conditions range-rearing or yarding can still be recommended. It may be possible to save some on the cost of feed and still grow good healthy pullets. Practically all broilers and most meat birds are reared in confinement, so as to have absolute control of the feed intake, more rapid and efficient growth and better finish. As mentioned earlier, rapid growth and early maturity, are not desired in replacement birds, so range-rearing or yarding may be used for replacement pullets.

Range-rearing was once a very popular method of growing young stock during warm weather. There is no question that excellent pullets can be grown on range. Good range-reared birds usually have excellent shank color, beautiful feathering, and are inclined to be big-framed birds having health and vigor. Why, then, have many producers gone to confinement-rearing?

Losses from predators, the increased labor requirements in feeding and caring for the birds, are probably two of the biggest reasons for getting away from range-rearing of pullets. Predators such as foxes, coons and even hawks and owls can be a real problem where birds are kept on range. Then there is the expense of building fences and range shelters and their upkeep. If the birds are to be yarded you can perhaps utilize the brooder house for shelter, thus avoiding the need for special range shelters. The

choice of whether to range or confine birds will depend upon a number of factors, such as the size of flock, the labor situation, and the land and housing facilities available. *Figure 12* shows a range shelter suitable for about 100 pullets.

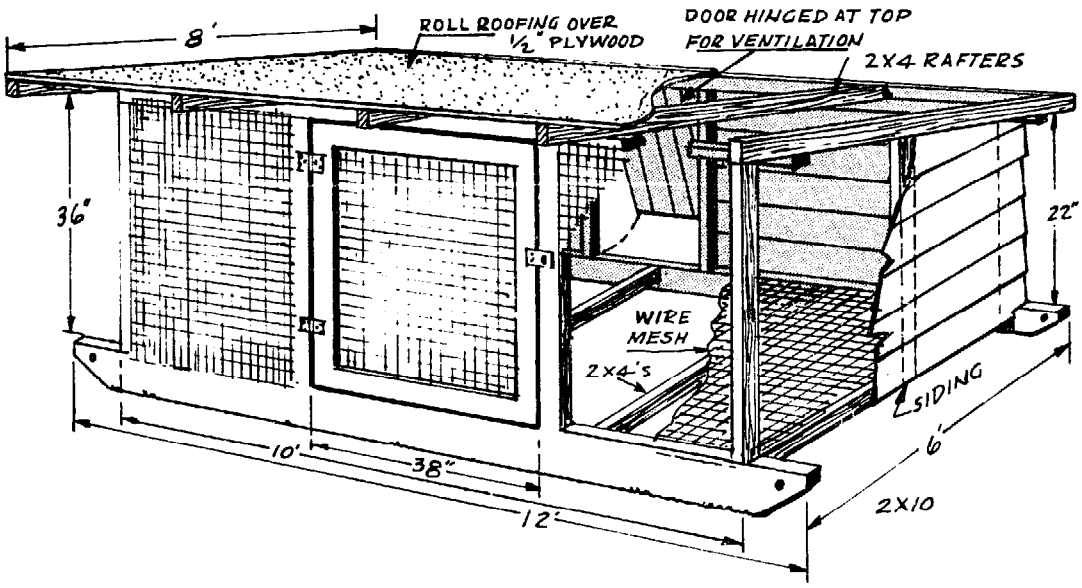

(Figure 12. Range Shelter)

A good range properly managed will yield a good supply of forage for growing pullets. Some of the grasses and legumes that are most satisfactory for poultry range include ladino clover, Kentucky blue grass and brome grass. This type of range permits feeding of a grower diet on a restricted basis and makes the birds forage for a portion of their nutrient intake. The range should be kept clipped to be most palatable and kept in a sanitary condition that is, prevent bare spots and mud holes.

Range shelters and equipment should be moved occasionally when the ground around them becomes bare, so as to keep the birds out of the mud. It is desirable to change range areas so that a given area is not used every year. This may help to avoid disease problems. Capillaria worms are one of the problems experienced on wet muddy range.

Covered feeders are recommended when birds are fed on range. They will help prevent feed loss from wind and rain. A covered range feeder is shown on page 23.

It requires an acre of good range to properly handle 400-500 pullets. Range-rearing is limited to the warm seasons of the year or to the areas which have warm climates.

Small flocks of layers, pullets, roasters or capons are frequently provided a yard. The yard is a fenced-in area attached to the brooder house or some other shelter. A yard permits more birds to be kept in a given floor area and may help prevent management problems such as cannibalism or feather picking. Its use in the cold climates is pretty much restricted to the warm months.

Where yards are used, the feeding and watering equipment is usually left in the house. If covered feeders are used some of the feeding may be done in the yard.

The same hazards may exist with yards as with range or pasture. Disease may be a consideration where the same yard is used year after year. Ideally the yard area should be moved each year. Predators may also be a problem. Layers which are permitted to yard may hide their eggs in areas outside the house. In wet weather the eggs may be excessively dirty. It is usually best to confine the laying flock for optimum results.

Vaccination

Several vaccines are available to prevent outbreaks of some of the troublesome poultry diseases. Some of the common ones available for immunizing birds are for infectious bronchitis, Newcastle disease, laryngotracheitis, fowlpox and cholera. In some areas, all of these diseases are a problem. Newcastle and bronchitis can be problems anywhere, and fowlpox is prevalent in many areas. In northern New England we don't see fowlpox very often and do not recommend vaccination for it. The same has been true for laryngotracheitis. Vaccination programs should be established on the basis of those diseases which are prevalent in the particular area. Commercial producers routinely vaccinate for Newcastle and bronchitis in all areas of the United States and, in some areas, also vaccinate for fowlpox and cholera on a routine basis. Vaccination recommendations in various areas, therefore, will differ, and the individual program should be developed to handle the disease situation in the particular area.

Some of these vaccinations come early in the chick's life, the Marek's vaccination, for example, administered at day of age, usually at the hatchery. Incidentally, it is advisable to purchase chicks that have been vaccinated for Marek's disease. Marek's disease did, for many years, take a tremendous toll on growing birds. With the advent of the Marek's vaccine, mortality has been cut to a very negligible rate. Other vaccinations are

administered at various times during the growing period and may require booster shots during the laying period.

There are two basic types of vaccines, those which produce a temporary immunity and those which produce a solid or permanent immunity which will protect the birds for the remainder of their lives. The virus vaccines producing a temporary immunity are usually of low virulence, or, in some cases, have no apparent affect on the birds when administered. The virus of vaccines producing a permanent immunity are of a more severe virulence and therefore, will produce more marked or serious symptoms of sickness.

There are two types of vaccines on the market with regard to method of application. There are those that are applied to individual birds and those that are applied to the flock on a mass basis. Two of those that are applied on a mass basis are vaccines for Newcastle and infectious bronchitis. These may be applied as a spray, dust, or in the drinking water. Those vaccines that are used on a mass basis are mild vaccines of low virulence.

Contact your Poultry Diagnostic Laboratory or Poultry Specialist at your State University. Local industry service people and County Extension Agents can also be helpful. Some vaccines are not permitted in certain states. Vaccination of small flocks is not recommended in many areas.

Because there are so many factors to consider, and so many variable conditions from farm to farm, no set vaccination program can be recommended here that will best suit all farms. The program should be planned to meet the needs of the given area. It should be planned well in advance of the brooding and rearing season, and be scheduled so that all the birds that are to be placed in laying houses will have been vaccinated well before the time they are ready to lay. This will give them sufficient time to fully recover from the stress of vaccination and avoid any carry-over effects there might be on egg production or egg quality.

Feather Picking And Cannibalism

Both feather picking and cannibalism are rather common vices which can develop in the brooder house and may be carried on into the laying house. A similar type of problem is toe picking which can start in a flock of chicks soon after they are put down under the brooder.

The exact cause of these vices is not always evident. Some factors that are thought to contribute to them are poor nutrition, overcrowding, or

other faulty management practices. Overheating the birds, lack of floor, feed and water space, or even overlighting, are all thought to be factors. Sometimes the problem will occur even with apparently good management.

At the first sign of feather picking, action should be taken to stop it immediately. When blood is started the birds frequently pick each other apart and losses can be severe. In some flocks, the problem can be corrected by a change in management — providing more feed, water, or floor space, better ventilation, cutting back on the light, or any number of things that will improve the birds comfort or change environmental conditions.

In the case of small flocks, anti-pick ointments applied to the birds have been somewhat successful in curtailing the problem. Plastic and metal devices known as "specs" can also be used. "Specs" are mounted on the top beak and are designed to obstruct the bird's forward vision. Sometimes these devices catch on the poultry furniture and come off or partially unattach. The most widely-used, and probably the most satisfactory method of cannibalism control, is to debeak the birds. Many producers debeak their birds routinely to prevent picking problems.

Chicks can be debeaked at day old at the hatchery, using a precision debeaking machine. The beaks tend to grow out again. To be safe, most producers debeak again before the birds are put into the laying house. Unless the job is done properly, debeaking at day of age can result in chick mortality due to starve-outs.

A number of producers are now debeaking at 7 to 9 days of age. Special adaptors for debeaking machines make this a precision job. If done properly, this usually holds and the job need not be done again. Debeaking can be done at any age to correct a picking problem. However, it is best done before the birds start to lay and should be done by 16 weeks of age.

Debeaking involves cutting off slightly more than one-half of the upper beak and blunting the lower beak. The upper beak should be shorter than the lower beak, making it difficult for the bird to grasp feathers or skin. A temporary debeaking job can be done in the absence of a debeaking machine. This is done by the removal of a small portion of the upper beak with nippers or dikes. The beak soon grows out and the procedure needs to be repeated.

A debeaking machine has an electrically heated blade that cuts and cauterizes at the same time to avoid bleeding. Properly debeaked growing and adult birds are shown in *Figures 13* and *13a*.

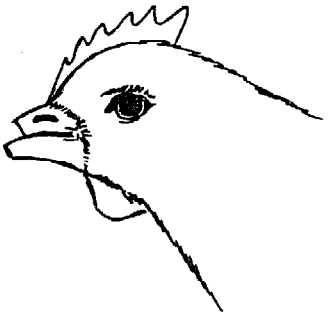

(Figure 13. Properly Debeaked Pullet)

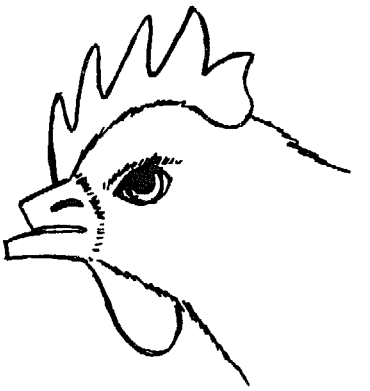

(Figure 13a. Properly Debeaked Adult Bird)

Lighting Programs For Young Stock

The first three days to a week, the birds should be provided with 24 hours of light. During this time they get used to their surroundings and learn where the heat, water and feed are.

After this time the chicks should be put on a controlled lighting program unless hatched during the April to August period. All pullet chicks grown in windowed houses and hatched between April and August can be exposed to natural daylight, because daylight length will be decreasing during the latter part of the growing period, thus delaying maturity. The rule of thumb to follow is never expose replacements to an increasing light day during the growing period. Pullets subjected to a constantly increasing photoperiod during the growing period come into production too early. Egg size and production suffers, and a high incidence of prolapse of the uterus may result.

After the first three days to a week, pullets raised in a light-tight windowless house may be put on a constant 8 hour light day. This lighting program will reduce problems with vices and delay sexual maturity. Pullets will come into production with more uniformly large egg size and better production when the light period is held constant or reduced to delay maturity.

Pullets raised in windowed houses are exposed to natural light conditions and must be treated differently. Those pullets hatched between September 1 and March and grown in windowed houses should receive a step-up, step-down lighting schedule. This lighting schedule is planned by determining the amount of natural daylight the pullets will receive when they reach 22 weeks of age. To this length of day is added 7 hours to give the starting length of light period. This light period is the total of

the natural light supplemented by artificial light. This light period is provided for the first week and stepped-down 20 minutes each week until the birds reach 22 weeks of age. At 22 weeks the light is stepped-up one hour to stimulate egg production. Each week the light period is increased by one hour until a total of 15 or 16 hours are provided. There is no need of providing more than a 16 hour light day.

costs of growing pullets

Many factors affect the costs of production. The most flexible cost will be the cost of feed. Where home-grown grains are available or a range rearing program is used, substantial savings may be made and the costs will vary from those shown in *Table 5*.

TABLE 5

ESTIMATED COST OF RAISING PULLET REPLACEMENTS TO 22 WEEKS*

Item	Brown-Egg Pullet	White-Egg Pullet
Chick Cost	$ .34 — .42	$ .36 — .50
Feed Cost at $.08 per pound	1.68	1.36
Brooding Cost	.03	.03
Litter and Miscellaneous	.03	.03
	$2.08 — 2.16	$1.78 — 1.92

Assumptions: Mortality 8%, 21 pound Feed Consumption for Brown-Egg Birds, 17 pound feed consumption for White-Egg Birds full-fed. Costs will vary depending upon quantities purchased, feed program, feed prices and other factors.

**Interest on average investment, labor and overhead (depreciation, insurance, and taxes) are costs of producing commercial pullets not normally considered in small flock situations. The approximate costs of these items are: interest — 7.5¢ — 10.0¢, labor — 14¢, overhead — 23¢ — 31¢.*

6

MANAGING THE LAYING FLOCK

Preparing The Laying House

The laying house should be thoroughly cleaned between flocks — this means the removal of manure, and brushing down the cobwebs and dust from walls and ceilings. Any repairs that are needed should be done at this time. Wet cleaning is best, but dry cleaning is satisfactory.

After the house is cleaned it should be sprayed with a disinfectant. The equipment should also be cleaned and disinfected at this time. Some of the common disinfectants include creosol solutions, hypochlorites and the phenol or carbolic acid preparations. Use disinfectants according to the manufacturer's recommendations.

When the house has been disinfected, the roosts, dropping boards or pits, and the nests should be painted with carbolinium or a red mite paint. It is advisable to treat the floors with carbolinium once each year. Carbolinium is not only a disinfectant but a wood preservative, and it makes future cleaning much easier. A similar cleaning and disinfecting program should be used for the brooder house and equipment.

A word of caution. Carbolinium is an excellent material but must be used correctly. Allow a minimum of two weeks for the house to dry and air

out before the birds are put in. The material can be injurious to the birds' feet and eyes. After the house has had an opportunity to dry, the litter can then be added.

litter

Provide approximately 6 to 8 inches of clean, dry litter material. Although the availability and cost are factors in determining litter to be used, some of the more commonly used materials are shavings, sawdust, a combination of shavings and sawdust, ground corn cobs, and sugarcane. These are all excellent litter materials.

To help maintain the litter in a satisfactory condition, it is recommended that a built-up litter be used. Built-up litter should be started early in the fall before cold weather sets in. Start with 4"-5" of clean litter and gradually add to it. Fresh litter is added until a depth of 9"-12" is reached. It is usually not necessary to change the litter during the laying year. Removal of the wet spots from time to time is usually all that is required.

Built-up litter insulates the floor and provides warmth for the birds. Due to the decomposition and fermentation processes heat is actually produced in the litter. It also absorbs moisture from the feces.

The same litter should not be used more than one year. Infestations of both internal and external parasites can result. Then, too, it is necessary to remove the litter to properly clean the house.

When warm weather arrives, it is the practice of some producers to replace the built-up litter with new litter. This provides cooler, more comfortable, conditions during hot weather.

In cold weather it is usually necessary to stir the litter regularly to keep it from packing and to permit it to aerate and dry.

feeding the layers

Laying birds require a diet containing from 16 to 18% protein. Actually the requirements vary during the laying cycle. Protein intake needs to be higher during the early laying period, because that is when egg production peaks and the birds are still growing. As egg production diminishes, the protein requirement decreases.

Protein is expensive, so commercial producers frequently phase-feed their layers, that is, use three different protein levels during the laying

period. They may start with an 18% diet and, at approximately 4 months of production, reduce the level to 16%. When the layers fall below 60-65% production the protein content of the feed is dropped to 15%.

Many factors affect feed intake of the birds. With changes in feed consumption, protein intake changes, so feeding layers is not a simple task if you are aiming for optimum production. Some of the factors which affect feed intake include:

(1) Management factors such as feed hopper and floor space.
(2) Environmental temperatures, both warm and cold.
(3) Calorie content of the diet.
(4) Variations in egg production.
(5) Flock health or stress factors.

Most small flock owners prefer to use a simple feeding program, one which utilizes one type of feed and which can be full-fed to the layers. In these situations a 16 to 17% all-mash diet is normally used.

all-mash feeding

The simplest and most foolproof approach to feeding layers is to feed a complete all-mash laying ration and keep it in front of the birds at all times. It is less bother, is adaptable to mechanical feeding and provides a more nearly balanced diet for the layers, assuming there is enough feeder space available.

grain and mash feeding

Some producers still prefer to use a grain and mash system of feeding. Grains are frequently fed in the form of so-called "scratch feed" containing corn, wheat and oats. It is often thought to be somewhat easier to maintain a high feed consumption with the grain and mash systems. Grains are also well liked by the birds and they eagerly consume them when they are provided. Some producers feed a large part of the daily allowance of grain before the birds go to roost. During cold weather this gives them a reserve supply of energy for warmth and will help keep them more comfortable while on the roost during the night. Grains are high in energy and are digested more slowly than mash, thus providing more warmth over a longer period of time. Grit must be provided when hard grains are fed.

The portions of mash to grain vary with the protein content of the

mash and also the type of layer. Usually a 20-21% mash is kept before the birds at all times. Light breeds such as Leghorns, on a grain and mash program, are fed equal amounts of grain and mash, or perhaps slightly less grain than mash. Heavy breeds have a tendency to become too fat if they receive too much energy, and therefore, may receive only 40% grain and 60% mash. In some instances, if a high energy type mash is used, it would be necessary to decrease the amount of grain to 30% of the total diet. It is important to prevent laying birds from getting too fat. Excessive fat is not conducive to high egg production.

One of the problems encountered with the mash and grain system is to feed in the proportions that will provide the correct protein intake of approximately 16 percent. Production problems can frequently be traced to a low total intake of protein when a mash and scratch system is being used.

The protein content of most scratch grains is approximately 9 to 10%. If, for example, equal proportions of an 18% laying mash and scratch grains are fed, the total protein intake will be approximately 13.5 to 14%. This will not support optimum egg production — at least during the early part of the laying cycle. Most high energy complete laying mashes can be safely supplemented with grain at the rate of 1 or 2 pounds per hundred birds per day. Follow the manufacturer's recommendations.

Grain may be fed on top of the mash or in the litter if litter conditions are reasonably dry and clean. When birds scratch for grains it helps to aerate the litter and maintain it in better condition.

free choice or cafeteria style

This method uses a high-protein mash containing from 26-40% protein, with grain and calcium supplement kept before the birds at all times. The chief advantage of this method is that it enables a producer to use local grain or grain produced on his farm. It is also a simpler system than hand-feeding grain. The mash concentrate is fed in one hopper, and the grains are fed in individual hoppers. The bird actually balances its own nutrient intake, hopefully.

Other Feeding Programs

For small flock situations fresh kitchen scraps, garden products and even surplus milk can be fed to layers. Feeding of these various materials

can substantially reduce the amount of purchased grain required. The amounts of these materials should be limited to what the birds can clean up in 5 or 10 minutes. If too much of this sort of material is fed to the birds, the nutritive intake can be diluted to the extent that they don't get the right amount of protein and other nutrients for body maintenance and the production of eggs. Milk should be given to the birds in plastic or enamel containers and not in galvanized containers.

Care should be taken in the choice of table scraps given the birds. Spoiled meat and materials like fruit peelings, onions and other strong flavored foods may give a bad taste to the eggs and should not be fed to the birds. Potato peelings can be fed to chickens if they are cooked. Vegetable peelings and green tops of vegetables are good. Green feeds are satisfactory for layers, and those that may be used for laying birds are similar to those recommended for growing birds. When a complete laying mash is supplemented with table scraps and other materials, grit and calcium supplements should be provided the birds. Egg shells are a good source of calcium and may be crushed and fed back to the laying flock. A simple or "Natural Laying Hen Diet" for those who want to mix their own ration, can be found on page 212.

TABLE 6

FEED CONSUMPTION PER DAY PER 100 LAYERS AND FEED PER DOZEN EGGS VARIOUS LEVELS OF PRODUCTION

Percent Production	Feed for Leghorn-Type Bird — 4 Pounds		Feed for Brown-Egg Bird — 5 Pounds		Feed for Brown-Egg Bird — 6 Pounds	
	Pounds		Pounds		Pounds	
	Per Day	Per Doz.	Per Day	Per Doz.	Per Day	Per Doz.
0	15.8		18.6		21.2	
10	16.7	20.1	19.6	23.6	22.1	26.6
20	17.6	10.5	20.4	12.2	22.9	13.7
30	18.4	7.4	21.3	8.5	23.9	9.6
40	19.3	5.8	22.2	6.7	24.7	7.4
50	20.2	4.8	23.1	5.5	25.6	6.1
60	21.1	4.2	24.0	4.8	26.5	5.3
70	22.0	3.8	24.9	4.3	27.5	4.7
80	22.9	3.4	25.8	3.9	28.1	4.2
90	23.8	3.2	26.7	3.6	29.2	3.9

Based on Card, L.E., and Nesheim, *Poultry Production — Tenth Edition.*

feed consumption of layers

Feed consumption varies with the body weight and rate of production *(Table 6)*. A certain amount is used for body maintenance. This amount corresponds with the amount consumed at "0" production. As a rule of thumb to estimate feed consumption at various levels of egg production, add to the amount of feed required for maintenance ("0" production) 1 pound of feed for each 10% of egg production.

Birds eat to satisfy their energy requirements, so the feed consumption will vary with environmental temperatures. They will eat more in cold weather. To insure optimum feed consumption, provide 4 linear inches of feeder space per layer.

calcium supplements and grit

Calcium is one of the most important minerals needed in the feeding of layers. Hens need calcium for egg-shell formation. About 10% of the total weight of the egg is shell. The shell is almost 100% calcium carbonate. Hens in heavy production require calcium in relatively large quantities.

Most of the high energy complete laying mashes today contain 3 to 3½ % calcium depending upon the time of year. Under most circumstances, this appears adequate to produce eggs with sound shells.

When laying birds get well into their laying cycle and shell quality begins to deteriorate, or during periods of extremely hot weather when shell quality may suffer, additional calcium seems to be indicated. In these cases, producers frequently add extra calcium to the diet in the form of oyster shells. Some types of birds, particularly the light laying strains of birds that have relatively small calcium reserves, need calcium supplementation earlier in the laying cycle than some of the heavier types of birds. When to, and not to, feed supplemental calcium is still somewhat of a controversial subject. There are those who feel that the most satisfactory way of meeting the variable individual requirements of layers is to supplement the calcium that is in the laying mash. This is done by feeding separately hen-size oyster shell or calcite crystals, both of which are soluble.

For those feeding systems other than the complete laying mash system, a supplemental feeding of calcium is to be recommended.

In addition to a source of calcium, a hard insoluble grit should be fed in many instances. Insoluble grit, such as granite grit, maintains its sharp edges in the digestive system and in essence takes the place of teeth. It is frequently thought that it is not necessary to feed grit to layers that are fed an all-mash type of diet. It is assumed that everything the birds consume in the laying diet is already finely ground and, therefore, needs little or no further grinding. Where birds are kept in cages, this is probably true.

However, birds that are housed in a floor management system, frequently eat feathers, litter and nesting material. Under these circumstances grit, if available, enables the gizzard to grind the fibrous material so that it can be moved on through the digestive system. Any feeding program other than the all-mash system of feeding, should incorporate grit so that coarse grains can be utilized by the digestive system.

There are a number of types of grit and shell hoppers available on the market. These are usually divided into two compartments, so that both grit and the source of calcium can be fed from the same hopper. It is a relatively simple project to construct a hopper which will serve equally as well. In those situations where grit and calcium material is needed, the hopper should be kept full at all times.

watering

Birds need plenty of clean, cool water at all times if they are to produce well. Water makes up a large portion of the hen's body and is a major constituent of the egg. Water helps to soften the feed and aids in its digestion, absorption and assimilation. If hens are deprived of water for only a short time, egg production will suffer. Dirty water and watering equipment may discourage water consumption and is a potential source of disease infection. The water supply should never be permitted to freeze for an extended period. If the house temperature cannot be maintained at a level to prevent freezing, then an electrical immersion heating unit can be installed in the drinking fountain. Heating units should be thermostatically controlled. Laying birds normally drink in pounds approximately twice as much as the feed they consume. During hot weather they will consume substantially more than this amount. One inch of the trough-type waterer per bird should be provided, or one round waterer per 100 birds. One pan-type waterer is usually adequate for the small family flock. Waterers should be cleaned and filled with fresh water daily. The water consumption of layers is shown in *Table 7.*

TABLE 7

WATER CONSUMPTION OF LAYERS BASED ON ENVIRONMENTAL TEMPERATURE

Temperature	Gallons Per 100 Layers Per Day
20-40° F	4.2-5.0
41-60° F	5.0-5.8
61-80° F	5.8-7.0
81-100° F	7.0-11.6

Source: *New England Poultry Management and Business Analysis Manual — Bulletin 566*

floor space

In well insulated, mechanically ventilated houses Leghorn type layers can be housed at the rate of 1¼ to 1½ square feet per bird. Heavier brown egg birds should be given 1½ to 2 square feet per bird. In those houses where gravity ventilation is used, that is, ventilation through the windows or slots, slightly more floor space should be given. The normal recommendation is a minimum of 1½ to 2 square feet for Leghorns and 2 to 2½ square feet for brown egg birds. Actually, in a well insulated house cold weather ventilation is somewhat simplified if there are more birds, since they supply more heat. When feeders and waterers are located over a dropping pit, the floor area per bird can be reduced below the amounts previously mentioned. However, with each additional reduction in floor space per bird, additional feeding, watering, nesting and roosting space must be provided. The birds should not have to travel more than 15 feet to reach either feed or water.

nests

Provide at least one individual nest or one square foot of community nest space for each four hens. Nesting material should be replenished as needed and be kept clean and dry. This is very important in preventing dirty, cracked and broken eggs. The nest should be a minimum of 2 feet from the floor or litter. If floor eggs are a problem at the onset of production, it is advisable to place the nests on the floor and gradually raise

them as the birds become accustomed to using them. One of the common problems with small flocks is egg-eating. When the nests are poorly constructed or without litter, or the eggs are not gathered frequently enough, breakage occurs, and this habit is much more likely to get started.

egg gathering

Eggs should be gathered two or three times a day. Frequent gathering reduces the number of dirty eggs and improves the egg quality. It also reduces the possibility of birds developing the habit of egg-eating. Very often, it is difficult for small flock owners to gather the eggs as frequently as is desirable. Having plenty of nests, keeping them clean and with plenty of litter will help prevent broken or dirty eggs. When the flock owner has to be away during the day, and the eggs will not be collected, it is possible to have the lights come on earlier in the morning, so that part of the eggs will be laid earlier and can be gathered before leaving for the day. Once egg-eating commences it is a difficult habit to stop. Probably one of the best methods of preventing it is to debeak the birds and to increase the frequency of egg collection. Eggs not gathered during the day are also subject to freezing in cold weather.

lighting

The use of artificial light in the poultry house is not to give the hens more time to eat. It is the stimulation of the light itself that makes them lay more eggs. The light stimulates the pituitary gland through the eye. This gland, in turn, secretes hormones that stimulate the ovary of the hen to lay eggs.

Laying birds need about 14 hours of light daily. In the northern part of the United States, darkness exceeds the amount of daylight during many of the fall and winter months. Beginning on August 15th, the birds need to receive extra light to give them a 14-15 hour day. During the months of November, December and January, when the days are shortest, they will need 5 hours of supplemental light. The lights may be turned on in the morning or in the evening. A combination of both morning and evening lights may be used, as long as the birds have at least 14 hours of light each day. With small flocks it is a task to turn the lights off each night, or to get up early enough to turn them on in the morning. The best way to solve this problem is to use a time clock which automatically turns the lights off and

on at the desired time. This generally gives satisfactory results. As soon as the natural day length reaches 14 hours again, the lights can be discontinued.

The lights should be ordinary 40-60 watt incandescent bulbs. To get the most efficient use of the light wattage a reflector can be used. This will frequently permit the use of lower wattage bulbs. One light fixture should be installed for each 200 square feet of floor area or less. A distance of 10 feet between lights generally gives good distribution of light for the birds. A rough rule of thumb for light intensity is one-foot candle at the feeder level. One bulb watt per 4 square feet of floor space will usually provide 1 foot-candle if the bulb is 7 to 8 feet from the litter and has a reflector. During the first week or two of the lighting period, it may be necessary to catch and place some of the birds on the perches if they do not get on the roost of their own accord when it's time for *lights out.*

ventilation

During cold weather all of the ventilation should be from one side of the poultry house. Preferably the south. Windows that drop down from the top or tip in are best for winter ventilation, in the absence of fan ventilation. The windows should be adjusted according to the weather. When the house tends to be stuffy, and the ammonia fumes are strong, the house needs more ventilation. The house should never be closed tight, even on cold nights. It is always well to leave at least some of the windows slightly cracked.

In the warm, summer months or in warm climates, ventilation will help cool the house. If you can open up both sides of the house, it will increase the air movement, help keep the birds cool and maintain better egg production.

rodent and bird control

Rats and mice like chicken feed. If there is a place for them to hide in the chicken house they will do it. They enjoy living in piles of refuse, the double walls of buildings, old stone foundations, in dropping pits, under deep litter or under the floors, and many other hiding places. Good housekeeping will help to reduce the problem with rats and mice.

Anticoagulant rat poisons and other types of poisons have been very helpful in getting rid of rat problems. For anticoagulant-type poisons to be

effective, rodents must consume it for several days. If birds are housed in an old building that has plenty of hiding places, it may be best to set up a permanent bait station or stations, and keep bait in them at all times.

It is desirable to screen wild birds out of the chicken house, if possible. Wild birds are vectors of some of the common diseases and parasites of poultry.

culling and selection

Good production-bred chickens will lay well for approximately a year if they are well managed. The culling of healthy birds that go out of production for just a short time is not advisable, unless a chicken dinner is in order. After the birds have laid for nearly a year, the non-layers may be culled out, dressed and used at home or sold. Usually the entire flock should be replaced after 12 to 14 months of production. On occasion it is necessary — and advisable — to sell hens that are still laying at a reasonable rate, to make room for the new flock of pullets.

In culling, there are two distinct things that one has to learn. One is how to distinguish between a layer and non-layer. The other is to determine with a reasonable degree of accuracy, how long the bird has been either in or out of production. After one has acquired the ability to do these two things, he can do a reasonably good job of culling a flock of layers.

With the beginning and termination of laying, changes take place in the head, the abdomen and the vent. To determine whether or not a layer is in production, all three of the body parts should be carefully examined to make an accurate judgment. The examination of one of these parts alone will not provide the whole answer.

When birds are in laying condition their combs and wattles are enlarged, bright red and waxy in appearance. The vent is large and moist and the pubic or pin bones are wide apart to physically permit the egg to be laid. The spread of the pubic bones of the laying bird will be about three fingers wide. The abdomen will be soft and pliable.

When birds are not laying, the combs and wattles may be small, pale and scaly in appearance, the vent dry and puckered. The pubic bones may be close together (one or two fingers width) and the abdomen hard and shallow.

The characteristics of layers and non-layers and high and low producers are presented in *Table 8*.

To determine how long a bird has been in production, or out of production, one must consider two factors, namely, the degree of bleaching of pigment and the molt.

TABLE 8

CHARACTERISTICS OF LAYERS AND NONLAYERS

Character	Laying Hen	Nonlaying Hen
Comb	Large, red, waxy, full	Small, pale, scaly, shrunken
Wattles	Large, prominent	Small, contracted
Vent	Large, moist	Dry, puckered
Abdomen	Full, soft, velvety, pliable	Shallow or full of hard fat
Pubic bones.	Flexible, wide open	Stiff, close together

CHARACTERISTICS OF HIGH AND LOW PRODUCERS

Character	High Producers	Low Producers
Vent	Bleached, large, oval, moist	Yellow, dry, round, puckered
Eye Ring	Bleached	Yellow-tinted
Beak	Bleached or bleaching	Yellow or growing yellow
Shanks	Pale yellow to white, thin, flat	Yellowish, round, full
Head	Clean-cut, bright red, balanced	Coarse or overrefined, dull, long, flat
Eyes	Prominent, bright, sparkling	Sunken, listless
Face	Clean-cut, lean, free from yellow color and feathers	Sunken or beefy, full, yellowish, feathered
Body	Deep	Shallow
Back	Wide. Width carried out to pubic bones	Narrow, tapering, pinched
Plumage	Worn, dry, soiled	Smooth, glossy, unsoiled
Molt	Late molter	Early molter
Carriage	Active and alert	Lazy and listless

Source: *Culling For High Egg Production,* Vermont Agricultural Extension Service Circular 115RU.

Pigmentation

The yellow pigmentation found in all yellow-skin breeds and varieties of chickens is a pigment called xanthophyl. Yellow corn, a major constituent of the poultry diet, is the principal source of this pigment. If a pullet has been properly fed when it comes into the laying house, she will

carry a considerable amount of pigmentation in all parts of her body. When she commences to lay, the pigment present in the skin and in other parts of the body is gradually lost. The reason for this loss is that the pigment is diverted to the yolks, giving them their yellow color. As long as the bird is in production, it continues to lose this yellow color from the various parts of its body. Hens that are thoroughly bleached out are usually high producers. When the bird stops production, the pigment reappears in the various parts of the body. The return of pigmentation is one of the first clues that a bird is out of production.

There is a very definite order of bleaching of the body parts as the birds commence to lay — the vent, the eye ring, the ear lobe, the beak, the shanks and feet. The order of bleaching and the approximate time required to bleach the various parts of the body are given in *Table 9*.

TABLE 9

ORDER OF BLEACHING AND TIME REQUIRED WHEN BIRDS ARE IN CONTINUOUS PRODUCTION

Body Part	Time Required
Vent	Few Days
Eye Ring	2 to 3 Weeks
Ear Lobe	3 to 4 Weeks
Beak	6 Weeks
Shanks	2 to 5 Months

vent

The first noticeable change occurs in the skin around the edges of the vent. Within a few days after production commences, the yellow color around the vent disappears.

A yellow vent indicates that a bird is not laying. A whitish, pinkish or bluish white vent indicates that a hen is laying.

the eye ring

The eye ring starts to bleach soon after the vent. In 2 to 3 weeks after the onset of production, the eye ring usually loses its yellow pigment. By that time, the bird has probably laid 10 to 12 eggs.

the beak

The yellow color leaves the beak next. It leaves the base of the beak first, and the fading continues toward the tip. It takes approximately 6 weeks of continuous production for complete bleaching. By that time usually 30 to 40 eggs have been laid.

The lower beak bleaches more rapidly than the upper beak. Fading of color can be readily seen in the lower beak. When the dark pigment "horn" appears on the upper beak, the lower beak can be used as a basis for judging the degree of pigmentation loss. Barred Plymouth Rocks and Rhode Island Reds frequently carry this dark pigment.

the shanks

The bleaching of the shanks occurs last and is an indicator of long-term production. Bleaching of the shanks takes from 4-5 months of continuous production. She must lay from 120-140 eggs to be completely bleached. It is not possible to pick a bird as a layer or non-layer on the basis of bleached or yellow legs unless she has been in production for 4 or 5 months.

When the bird stops laying, pigmentation returns to the different parts of the body in the same order that it bleached out.

By observing the degree of pigmentation, one can tell rather accurately how well a bird is laying. It should be taken into consideration that the feeding program, breed, and flock health are factors which can also affect pigmentation.

The Molt

Once each year birds renew their plumage. This process of replacing old feathers with new ones is called molt. Hens usually go through their annual molt in the late summer, the fall, or early winter months. Factors which determine the time of the molt are (1) time of the year that the bird was hatched, (2) the individual bird or breeding and (3) management stresses to which the bird is exposed. Where bleaching is most helpful in determining layers from non-layers during the first eight or nine months of

production, the molt is most useful during the last several months of production.

When a bird starts her molt she goes out of production and, normally, will not come back into production until shortly before the molt is completed or just after it is completed. The pattern depends, to a certain extent, upon the type of management and feeding program to which she is exposed. Some laying birds start their molt early in the fall after eight or nine months of production and are called early molters. Others lay for 12 or 15 months before they molt and stop production. In fact, some of our modern day strains of layers have to be force-molted to get them out of production. This procedure provides them with an opportunity to rest, renew their feathers and return to production. Hens that complete at least 12 months of production before molting are referred to as late molters and are the most desirable birds to have in the flock.

When using the molt to cull or select hens, the primary (flight) feathers of the wing are used. There are usually ten of these feathers, arranged in a group, extending from the short axial feather in the center of the wing to the tip.

The fact that the primary feathers are dropped and renewed in a definite order makes the use of the molt a fairly accurate means of estimating how long a bird has been out of production and how long it will take her to go through her complete molt. It is also possible to determine whether she is a slow molter or a rapid molter by observing the way in which she has dropped and is renewing the primary feathers. A typical slow-molting bird will drop one primary at a time over an extended period, whereas a rapid molting hen will drop more than one at a time and drop them more frequently. In some of the better strains of laying birds, the hens will drop a group of several primaries and then, very shortly after, drop more and thus go through the complete molt in a relatively short period of time and be back in production. Approximately 6 weeks are required to grow a primary feather. Usually the slow molter stops production before or at the time they start their wing molt. They very seldom lay through a molt. Thus, the slow molter that drops one primary at a time will be out of production for many weeks and would be a like candidate to be culled from the flock. Many of the rapid molting birds will lay for a period of time after they start to renew their primary feathers. Some of the good laying strains of birds will renew half or more of their primaries before they finally stop laying. *Figure 14* shows the different stages of molt in fast and slow molting birds.

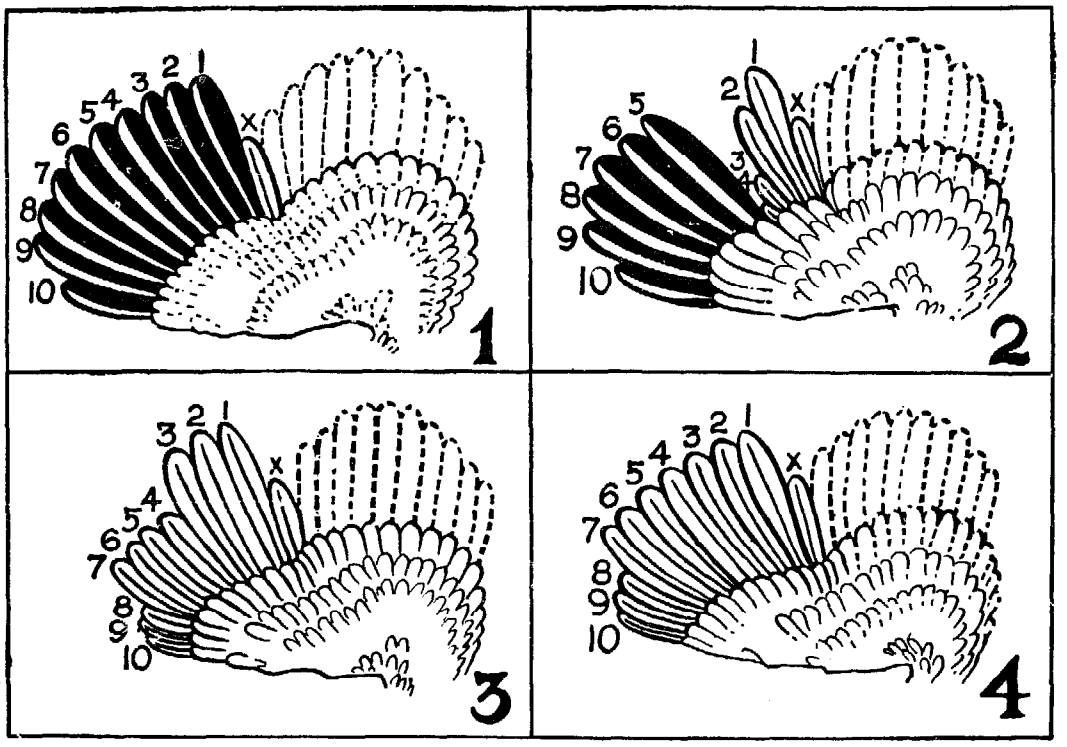

(Figure 14. Wings during different stages of molt. Top left (1) shows the 10 old primary feathers (black), and the secondary feathers (broken outline), separated by the axial feather (x). Top right (2) shows a slow molter at six weeks of molt, with one fully grown primary and feathers 2, 3, and 4 developing at two-week intervals. In contrast, 3 (lower left), a fast molter, has all new feathers. Feathers 1 to 3 were dropped first (now fully developed); feathers 4 to 7 were dropped next (now four weeks old); and feathers 8 to 10 were dropped last (now two weeks old). Two weeks later (4, lower right), feathers 1 to 7 are fully grown. Fast molt took 10 weeks, compared to 24 weeks for slow molt (South Dakota Extension drawing.)

force molting

Toward the end of the laying cycle, egg production is at a relatively low level. Interior and exterior egg quality are poorer, particularly if the tail end of the cycle coincides with hot weather. At this point some producers force molt or recycle the flock if it has been a good flock.

Force molting gives the layers a rest for about 8 weeks. After the rest, egg production increases but not to the level of the pullet year. It may reach 88-90% of the pullet year production level. Egg quality, both exterior and interior, recovers substantially.

Recycled layers usually lay profitably for only 6-9 months. Egg size is large, feed consumption and mortality is higher and the overall egg quality is lower than during the pullet year.

The big reason for force molting is to beat the high cost of pullet depreciation which may be 8 to 10 cents per dozen depending upon the pullet cost and fowl or salvage value. If force molted birds are to be profitable to the commercial producer, there must be a market for the extra-large eggs. The profitability of the practice is still under investigation. Most producers feel that it is better to replace the flock at the end of the first laying cycle.

Force Molt Procedure*

Day 1	Decrease lights to 8 hours per day in light-tight houses or no-natural-light in window houses. Remove all feed and water.**
Day 3	Provide water
Day 8	Provide growing mash — 40% normal consumption level.
Day 22	Restore lights to pre-molt level and full feed laying ration.

** *An alternative method, particularly during periods of hot weather, is as follows:*

Day 1	Decrease lights to 8 hours per day in light-tight houses or no-artificial-light in window houses. Remove feed but provide water free choice.
Day 8	Provide growing mash — 40% normal consumption level.
Day 22	Restore lights to pre-molt level and full feed laying ration.

* From *New England Poultry Management and Business Analysis Manual,* Bulletin 566.

broodiness

Poultry geneticists have done a great deal to eliminate the natural tendency for laying birds to become broody. There will, however, still be an occasional bird in floor management systems that will become broody. If the bird is permitted to stay in the nest, she will remain broody and will not eat and drink properly during this time, and a loss in body weight and egg production will result. If broody hens are removed from the nest as soon as they are discovered, the loss of egg production can be reduced substantially.

The best procedure for breaking up broody birds is to place them in a broody coop — constructed with a wire or slatted bottom to discourage setting and inactivity. The broody coops are usually suspended from the ceiling in the pen or outside the pen, and the birds are provided with plenty of feed and water. Birds exposed to this type of treatment can usually be put back with the flock in four or five days.

flock health

Flocks that are well managed and fed a well-balanced diet do not frequently experience disease problems. If one bird dies now and then it is probably nothing to become alarmed about. If a number of birds become sick, respiratory symptoms appear, or they look droopy, go off feed or stop laying — it is then time to find out why.

If a disease outbreak occurs, the cause should be determined as soon as possible. First signs are frequently a change in feed and water consumption. If you do not recognize the disease or parasite, take or send some of the live birds showing symptoms to the nearest poultry diagnostic laboratory. Poultry diagnosticians prefer live birds showing symptoms. Dead birds sent to the laboratory should be kept cool so that they do not arrive at the laboratory in a decomposed condition. It is helpful to poultry diagnosticians to know the flock history. Relate the symptoms you have observed in the flock, the number of birds affected, the number of birds that have died, source and size of the flock, feeding program, age of the flock and any other information that you think will be helpful to them.

To control disease on the farm, incinerate dead birds, or put them into a disposal pit and remove all obviously sick chickens from the flock. It is

sometimes best to kill them and dispose of the carcasses. If, however, the birds are to be treated, put them in a separate pen or hospital pen — as far away from the other birds as possible.

The old adage — "an ounce of prevention is worth a pound of cure" — certainly applies to poultry flock health. If you are successful in buying or raising good healthy pullets, they are properly vaccinated, placed in cleaned and disinfected quarters, given enough feeder, water and floor space and are fed a well balanced diet, you are well over the hurdle with regard to disease or production problems.

Chickens are creatures of habit; any sudden changes can cause them stress. This is true of layers in peak production and those nearing the end of their laying cycle. Any change in feed or management should be done gradually to avoid stress problems.

Birds should be vaccinated for such diseases as infectious bronchitis, Newcastle disease, fowl cholera, laryngotracheitis and fowlpox, if these are a problem in your area. A good laying-flock manager checks for both internal and external parasites and immediately commences control measures as indicated. The screening of windows, doors and other points of entry for wild birds will help to prevent some disease and parasite problems.

The immediate disposal of dead birds, by burying or incinerating is recommended. Check local and state ordinances concerning the disposal of dead birds in your area. Some types of incinerators are not approved in certain states.

Cannibalism, feather pulling and egg eating are habits which are sometimes hard to stop once they get started. Birds commence these vices usually as a result of faulty management or environment. This trait is more common in some breeds of chickens than in others. Different types of feed may also cause these problems. Crumbles and pellets can bring on the picking problem when fed instead of mash. The birds fulfill their intake needs more quickly on pellets and have time to get into mischief. Proper debeaking is usually the answer when those problems commence. Actually the birds should be properly debeaked by 16 weeks of age so that it doesn't have to be done after the birds come into production. Debeaking after production commences can cause a production slump.

Frozen combs are one of the small flock hazards in cold climates. The combs of some breeds and varieties, such as the Single Comb White Leghorn, and the males of many breeds, have large combs. These are quite easily frozen in cold housing and can cause lowered egg production and a reduction of egg fertility in mated flocks. When severely frozen, the top of

the comb becomes discolored and eventually may slough off. Naturally there are sore heads, and feed consumption may be discouraged by grills or reels on feeding and watering equipment.

This problem can be avoided by dubbing the birds. The best time to do this is at the hatchery or the farm at day of age. It is done with a pair of manicure scissors. The comb is cut off close to the head, giving a closely cropped comb at maturity, one which is less likely to be frozen or injured. White Leghorns that are to be put in laying cages are frequently dubbed to avoid injury which may occur from the cage wires. Dubbing can be done to older birds, at which time both the comb and wattles are cut with dull shears. Considerable bleeding occurs in older birds.

records

Record keeping is not only interesting but necessary if you want to know what the flock is doing and the costs and returns involved. Records need not be complicated but merely contain information on daily egg production, mortality, culling, feed consumption, the quantity and value of poultry and eggs eaten and sold.

Records may be kept on a calendar or on a pen record obtainable from most feed companies. You can make your own pen record. At the end of the month the information can be transferred from the pen record to a permanent record. These records should be analyzed each month and at the end of the year. Records should be filled in each day to be accurate. Without good records it is hard to tell if you should continue in business or buy your eggs and poultry at the store.

costs of egg production

Budgets for small flocks can vary substantially from the budget information in *Tables 10* and *11*. Overhead costs, interest and labor are frequently not considered in the small flock situation. Bird depreciation may vary considerably. The fowl may be processed and used at home, or sold, and would thus be valued at the consumer price instead of the farm price for fowl which is relatively low. Feed price is another variable. Small flock owners normally buy their feed in small quantities at a price well over that paid by the commercial producer. Feed prices also will depend upon the feeding program, the geographical area and other factors.

The two budgets are based on the following assumptions:

Birds housed at 22 weeks of age, sold at 73 weeks of age. (51 weeks of production).

Annual mortality 12%
Eggs per hen housed 221

Feed per 100 daily

Brown-egg birds 26 pounds (92.8 pounds annual)
White-egg birds 23 pounds (92.1 pounds annual)

TABLE 10

COST PER DOZEN ANALYSIS — WHITE EGGS

Item	Cost (Cents)
Feed (4.19 pounds) at 8.00 per cwt.	33.52
Bird Depreciation	10.00
Overhead	1.77
Other	1.68
Interest	0.71
Labor	1.74
Total	49.42

Based on information from the *New England Poultry Management and Business Analysis Manual, Bulletin 566.*

TABLE 11

COST PER DOZEN ANALYSIS — BROWN EGGS

Item	Cost (Cents)
Feed (4.75 pounds) at 8.00 per cwt.	37.84
Bird Depreciation	8.50
Overhead	2.26
Other	2.01
Interest	0.87
Labor	1.78
Total	53.26

Based on information from the *New England Poultry Management and Business Analysis Manual, Bulletin 566.*

7

THE PRODUCTION OF FERTILE EGGS

A rooster is not needed in the laying flock. The hens will lay just as well without him. Some individuals do, however, like to mate their flock of layers to merely produce fertile eggs. Others plan to perpetuate a breed or strain of bird as a hobby, for exhibition purposes, or for a number of other reasons.

If flocks are mated for the production of eggs for hatching, it is well to check on state regulations. Some states require that all hatching egg flocks be blood-tested for Salmonella Pullorum and Salmonella Typhoid. Blood testing is supervised by employees of the official state agency that administers the National Poultry Improvement Plan in the state. For further information on blood test requirements, check with your State Department of Agriculture, State Extension Poultryman or County Extension Agent.

As is the case with other laying flocks, careful feeding and management, good housing and proper equipment, all apply to hatching egg production. Good feeding and management are important if one is to get a good hatch of healthy chicks from the eggs.

Preliminaries

selecting stock

Select a source of stock that is healthy and bred to meet the specifications you have set, whether it is feather color, body size, egg production, meat production or a combination of these characteristics.

mating

A hatching egg flock of Leghorn or Leghorn-type birds should contain about 6-7 males per 100 pullets. Heavier breeds, such as the Rhode Island Red and the Plymouth Rocks are mated at the rate of 8 males per 100 pullets. The ratio of males to pullets in some of the commercial hatching egg flocks may vary from this ratio substantially, due to anticipated mortality, morbidity or other special problems with the males.

If you are trying to perpetuate a breed, the breeding stock should be selected to conform to those characteristics, desirable for that breed or variety, as outlined in the American Standard of Perfection. The American Standard of Perfection is issued by the American Poultry Association. It describes the various classes, breeds and varieties of poultry which are recognized as Standard-Bred. Primary breeders select for numerous economic characteristics, including production, production efficiency, egg size, egg quality, liveability and many others.

If yearling hens are to be mated, force them out of production to permit approximately an eight week rest before they commence laying hatching eggs. The same force molting procedure is used as outlined in *Chapter 5*.

The flock should be mated at least 2 weeks before hatching eggs are to be saved.

feeding and management of breeders

In addition to producing eggs efficiently, breeding stock should produce eggs that hatch well and produce vigorous chicks. Breeder flocks should be fed a diet that has additional vitamins and minerals for high fertility and hatchability. For best results then, the breeding flock should be

fed a specialized diet, formulated for hatching egg production. These are known as breeder rations.

The management of a breeding flock is very similar to a market egg flock. Most of the management recommendations given in the preceding chapter on Laying Flock Management, therefore, need not be repeated in this chapter. Only the basic differences between breeder flock and laying flock management will be mentioned.

One of these basic differences is the management system required. It was mentioned in the preceding chapter that there are several management systems available for laying birds. Among those mentioned were the cage system, the combination slats and litter, the all slat or the combination wire and litter, or all wire, or the conventional litter management approach.

Cage management systems for breeding birds are relatively uncommon. This is because of the difficulty in designing cages so that birds can mate with good results. Where cage systems are used it is usually necessary to artificially inseminate the females. This is not a difficult task where small flocks are involved, but is much more time consuming than the conventional floor pen matings.

While some of the other management systems have been used with some degree of success, there are a number of problems involved with systems other than the littered floors. This is particularly true with the heavier birds that appear to be inherently lazy and don't want to lay well in the nest. For example, the all slat floors or even the slat and litter management systems have often produced a high percentage of floor eggs or eggs layed on the slats. This can cause dirty eggs, broken eggs, and the loss of eggs through the slats. It is probably best not to use wire floors for mated flocks, particularly the heavy breed flocks, because of the incidence of foot and leg problems and the relative difficulty of the birds to mate.

lighting the breeders

Light is important not only for the stimulation of egg production in breeding flocks, but it also increases the semen output of the males. Lighting schedules were outlined in *Chapter 6, Managing the Laying Flock.* Light schedules vary with the type of house and very careful attention to the lighting schedule should be given.

Hatchability of fertile eggs is affected by many factors. Shell quality is one of these factors. The longer the bird is in production, the poorer the shell quality. Shell quality is affected not only by the length of time the birds

have been laying, but also the time of year, temperature, diet and genetics. Birds that have been force molted and are in a second year of egg production invariably show shell quality deterioration much more rapidly than during the first laying cycle.

Tremulous or loose air cells also affect the hatchability of eggs. Use care in handling eggs to prevent tremulous or loose air cells. Eggs that have been cracked very seldom hatch, so care should be taken to produce as few cracks as possible and to make sure that cracked eggs are not set in the incubator.

Eggs
gathering and care of hatching eggs

Hatching eggs should be gathered 3 to 4 times a day. When temperatures are extremely hot or cold, they should be gathered more frequently. Eggs should not be left in the nest overnight.

Eggs should be cleaned as soon after gathering as possible. Unless they can be washed properly, they should not be washed but rather dry-cleaned by sanding or buffing. Hand-buffing devices are available for this purpose.

Eggs should be washed at a temperature of 110°-115° F. in water containing an approved detergent-sanitizer. They should not be immersed in the wash water for more than 3 minutes. The eggs should be dried and moved to cold storage. Improperly cleaned eggs frequently become contaminated and may explode during incubation.

The eggs should be stored at a temperature of 50-60° F. Lower storage temperatures may reduce hatchability. The temperature of the average household refrigerator runs below that recommended for storing hatching eggs. For best results, the relative humidity should be 75%.

Eggs that are cracked, have thin shells, shells with ridges or that are excessively dirty or abnormal in size or shape should not be kept for hatching. Excessively large or small eggs are often infertile or won't hatch and should not be set in the incubator.

For best results, hatching eggs should not be stored for more than 10 days to 2 weeks before they are set. They should be stored in filler flats or egg cartons with the small end down. Eggs that are to be held for several days prior to hatching should be held in a slanted position (approximately 35°) and turned at least twice each day. One simple method of turning eggs is to prop one end of the egg carton or case up on an object at an angle of about 35°. Then just shift ends with the container at least twice each day.

Incubation: types of machines and operating temperatures

There are two types of incubators in use today. These are the forced-draft and the still-air machines. The one most frequently used in commercial hatcheries is the forced-draft machine. This type of incubator has fans which force the air through the machine and around the eggs. For most types of eggs the incubator temperature of the forced-draft machine is set at 99½° F. to 99¾° F.

Most of the still-air incubators in use today are quite small. They are made to hold from one to 100 or more eggs. Still-air machines do not have fans. They depend upon gravity ventilation through vents on the top and bottom of the machine. The operating temperature of the still-air machine is higher than for the forced-draft incubator. It ranges from 101½ to 102¾° F. depending on the type of eggs being incubated. Actually good results may be obtained using a constant 102° F. temperature. The temperature may vary between 100° and 103° F. without hurting the embryos if the temperature does not stay at these extremes.

humidity

Humidity in the incubator varies from 83° to 88° F. (wet bulb thermometer) depending on the type of eggs. This level of humidity is maintained until the last 3 or 4 days before hatching, and then is increased to 90-95° F. (wet bulb).

The humidity in small incubators is provided by moisture evaporation pans. The evaporation pan has to be kept full at all times. When adding water, add warm water (110° F.) so as not to reduce the incubator temperature for an extended period of time. If the humidity in the machine needs to be elevated, a large sponge, placed in the evaporation pan, will help to increase the moisture level. More pan space also helps.

During the incubation period (19 days), eggs should lose about 11% of their original weight through evaporation. A loss of more than this amount is detrimental. The amount of evaporation is controlled by proper humidity. The relative humidity level for chicken eggs should be 50-55% for the first 18 days (83°-87° F. wet bulb reading) and 65% (89°-90° F. wet bulb reading) during the last three days. If humidity is too low, close the vents part way, or add to the moisture evaporation surface. If humidity is too high, permit more ventilation.

Figure 15 shows the approximate size of the air cell when evaporation is normal. By candling the egg at various stages of incubation, this can be used as a rough guide to control humidity in the absence of a wet bulb thermometer. The candling procedure and candling light are covered in the section on candling.

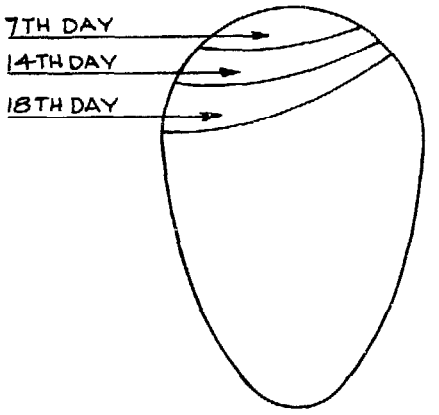

(Figure 15. Air cell size at various stages of incubation.)

ventilation

Ventilation is very important in the incubator. Without it the embryos will suffocate. For machines with adjustable vent opening, the openings are usually cracked open at the start and are gradually opened to permit more ventilation toward the end of the incubation period. Follow the manufacturer's directions, or if using a homemade machine, experiment until the best results are obtained. The room where the incubator is located should be ventilated, yet not drafty.

turning the eggs

While eggs are incubating they should be turned at least four times a day. This is to prevent the embryo from sticking to the shell membrane. Large machines may include automatic or mechanical turning devices. If the eggs are not turned during the night, they should be turned late in the evening and early in the morning. If the eggs are set on their ends they should be slanted at about 30°. If they lie flat in the tray they should be turned from one side to the opposite — in other words, 180°. One method of making sure that all eggs are turned is to put an "X" on one side of the egg and an "O" on the other, in pencil. When turning the eggs make sure all the "X's" or "O's" are on top. Discontinue turning after the 18th day for chicken eggs or 3 days prior to hatching for eggs of all other species.

candling

Normally, the eggs are candled three days prior to hatching and the infertiles removed. Candling is done in a dark room using a special light. *Figure 16* shows a candling light which can be easily made at home. If the eggs are infertile, they will appear clear before the candling light. The fertile eggs will permit only light through the large or air cell end of the egg. The rest of the egg will be black or very dark in color. The eggs may be candled earlier in the incubation period. At 72 hours the early fertiles will have the typical blood vessel formation, looking much like a spider.

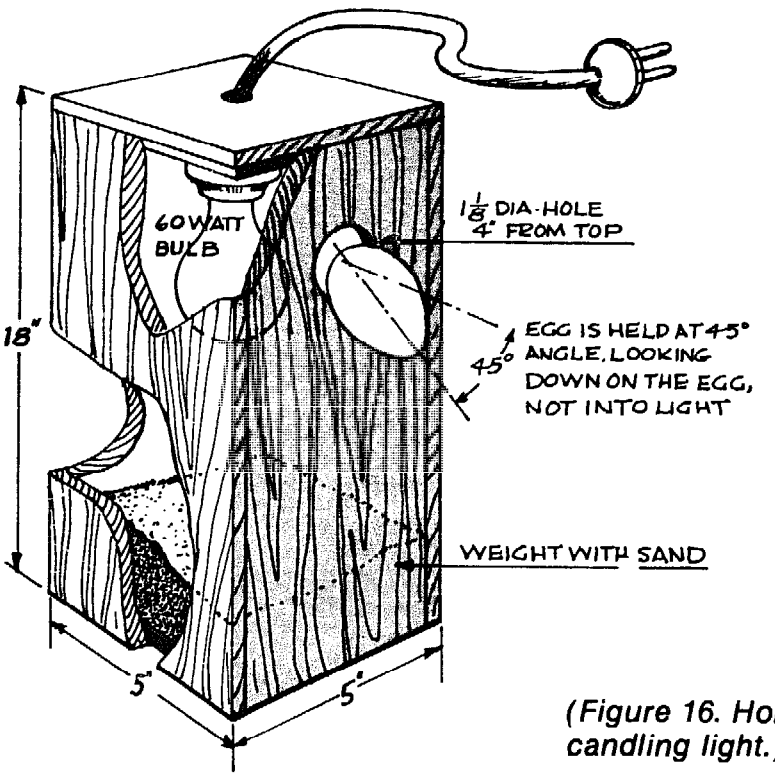

(Figure 16. Homemade candling light.)

After the eggs hatch, leave the young birds in the incubator for approximately 12 hours until they are dried and fluffy before removing them. The young can survive without food and water for 72 hours, but the sooner they are put on feed and water, the better.

Table 12 contains incubation trouble shooting information.

Table 13 lists the incubation period for eggs of various species.

TABLE 12

INCUBATION TROUBLE CHART

Symptom of Trouble	Probable Cause	Suggested Remedies
Eggs Clear No blood ring or embryo growth.	1. Improper mating. 2. Eggs too old. 3. Brooding hens too thin. 4. Birds too closely confined.	1. 8 to 10 vigorous males per 100 birds. 2. Eggs set within 10 days after date laid. 3. Keep hens in good flesh.
Eggs Candling Clear But showing blood or very small embryo on breaking.	1. Incubator temp. too high. 2. Badly chilled eggs. 3. Breeding flock out of condition (frozen combs, chicken pen, etc.) 4. Low vitamin ration.	1. Watch incubator temp. 2. Protect eggs against freezing temp. 3. Do not set eggs from birds with frozen combs or with contagious diseases. 4. Feed fish oil and alfalfa.
Dead Germs Embryos dying at from 12-18 days.	1. Wrong turning. 2. Lack of ventilation. 3. Faulty rations.	1. Close temp. regulation. 2. Plenty of fresh air in incubator room and good ventilation of machines. 3. Feed yellow corn, milk, alfalfa meal and fish oil.
Chick Fully Formed But dead without pipping.	1. Improper turning. 2. Heredity. 3. Wrong temperature.	1. Turn eggs 4 times daily. 2. Select for high hatchability. 3. Watch incubator temp.
Eggs Pipped Chick dead in shell	1. Low avg. humidity 2. Low avg. temperature. 3. Excessive high temp. for short period.	1. Keep wet bulb temp. from 85-90° F. 2. Maintain proper temp. throughout hatch. 3. Guard against temp. surge.

TABLE 12 (Continued)

Symptom of Trouble	Probable Cause	Suggested Remedies
Sticky Chicks Shell sticking to chick.	1. Eggs dried down too much	1. Carry wet bulb temp. at 85° F. between hatches.
	2. Low humidity at hatching time.	2. Increase wet bulb reading to 88-90° when eggs start pipping.
Sticky Chicks Chicks smeared with egg contents.	1. Low avg. temperature.	1. Proper operating temp.
	2. Small air cell due to high avg. humidity.	2. Increase ventilation and lower humidity.
Rough Navels	1. High temp. or wide temp. variations.	1. Careful operation.
	2. Low humidity.	2. Proper humidity.
Chicks Too Small	1. Small eggs.	1. Set nothing under 23 oz. eggs.
	2. Low humidity.	2. Maintain proper humidity.
	3. High temperature.	3. Watch incubator temp.
Large Soft Bodied Chicks	1. Low avg. temperature.	1. Proper temperature.
	2. Poor ventilation.	2. Adequate ventilation.
Mushy Chicks	1. Navel infection in incubator.	1. Careful fumigation of incubator between hatches.
Short Down on Chicks	1. High temperature.	1. Proper temperature.
	2. Low humidity.	2. Careful moisture control.
Hatching Too Early With bloody navels	1. Temperature too high.	1. Proper control of temp.
Draggy Hatch Some chicks early, but hatch slow in finishing.	1. Temperature too high.	1. Proper operation.
Delayed Hatch Eggs not starting to pip until 21st day, or later.	1. Avg. temp. too low.	1. Watch temp., check thermometers.

TABLE 12 (Continued)

Symptom of Trouble	Probable Cause	Suggested Remedies
Crippled Chicks	1. Cross beak — heridity.	1. Careful flock culling.
	2. Missing eye — abnormal.	2. Matter of chance.
	3. Crooked toes — temp.	3. Watch temperature.
	4. Wry neck — nutrition (?)	4. Not fully known.
Excessively Yellow	1. Too much formaldehyde, fumigation.	1. Follow directions on fumigation program.

Source: *Embryology and Biology of Chickens, University of Vermont*

TABLE 13

INCUBATION PERIODS FOR VARIOUS SPECIES

Species	Days
Chicken	21
Duck	28
Muscovy duck	33-37
Turkey	28
Goose	30-32
Guinea	26-28
Pheasant (Ring Neck)	23-24
Mongolian Pheasant	24-25
Ostrich	42
Pigeon	16-20
Japanese Quail	17
Bobwhite Quail	23
Peafowl	28

Constructing A Small Incubator

A small still-air or forced-draft incubator can be constructed quite easily and inexpensively *(Figure 17)*. There are several ways to make them. If the incubator is to be used for demonstration purposes, the top or one side can be made of glass, so that the hatching process can be observed. Some excellent, still-air incubators have been constructed from styrofoam coolers. Others have been made from cardboard boxes, or fabricated from plywood.

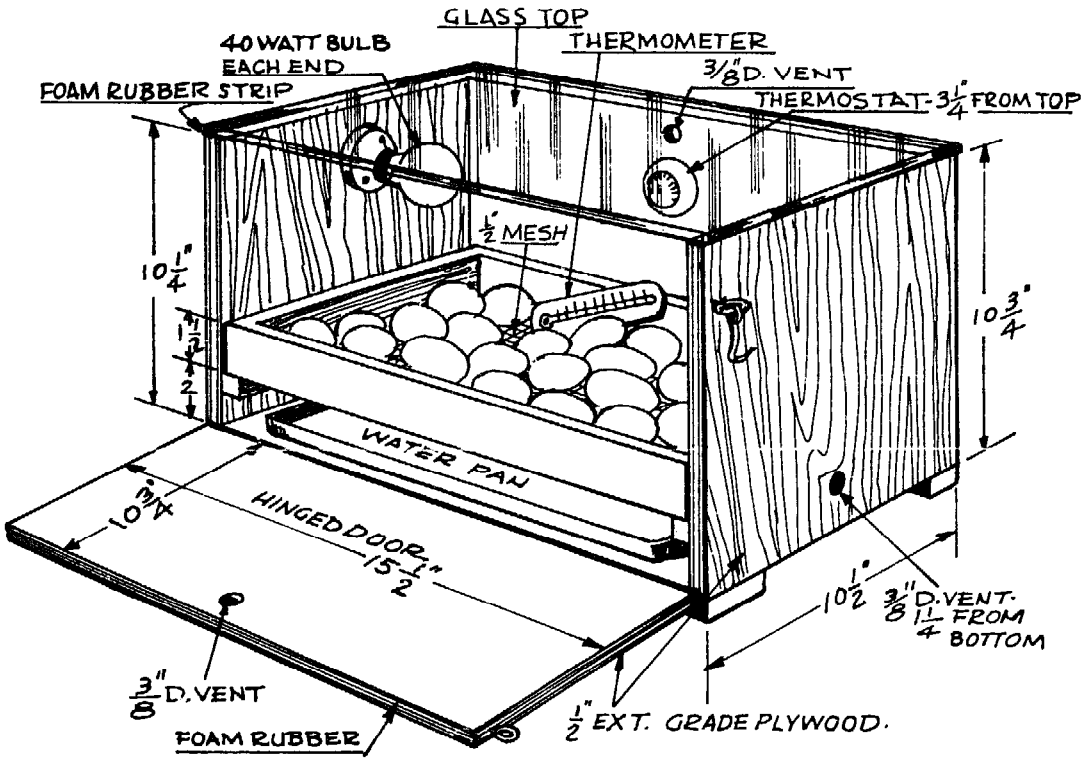

(Figure 17. Homemade incubator.)

Some commercial concerns offer incubator plans and kits for sale, and, of course, some companies also sell incubators. A list of these concerns selling incubators and incubator parts may be found in the section, *Sources of Supplies and Equipment.*

natural incubation

The first requirement for hatching eggs naturally is a good setting hen. Many of our modern-day chickens have had the broodiness characteristic bred out of them. Some of the breeds that are usually good brooders are the Rhode Island Reds, Plymouth Rocks, Wyandottes and Orpingtons. Don't use birds with long spurs. They are likely to trample the chicks. Select a calm bird. She will be less likely to break eggs in the event that she becomes frightened.

Provide a suitable nesting box, one which is roomy and deep so that she will have plenty of room to change her position, turn the eggs, and be comfortable. Select a spot for the nest where it will be quiet, away from dogs or other predators and disturbances. Darken the nest area and provide feed and water close by. The bird should be free of lice or mites before setting her.

A medium sized hen can cover 9 or 10 eggs, a large one 15 eggs. The same birds can cover only 6 or 7 turkey eggs, 9 to 11 duck eggs and 4 to 5 goose eggs. Bantams normally cover 8 or 9 of their own eggs.

It may be advisable to try the bird on dummy or artificial eggs for a few days to see if she is a persistent brooder. Take her off the eggs a few times. If she gets back on the nest each time, then put the hatching eggs under her.

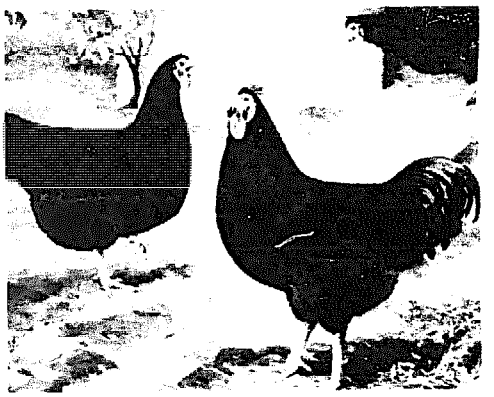

*Rhode Island Reds**

*Single Comb White Leghorns**

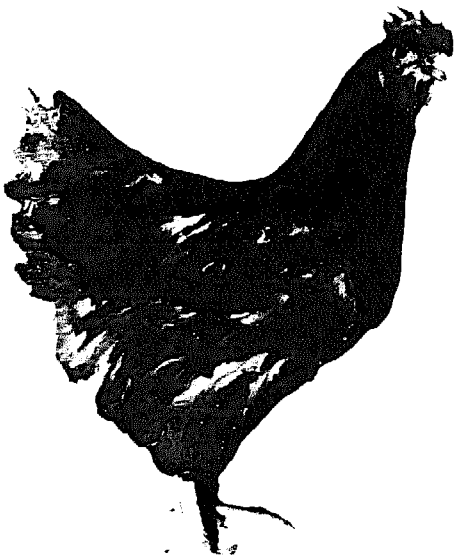

Sex-Sal layer
(Popular brown egg
New England crossbred)

*Source: *Poultry Tribune, Mount Morris, Illinois*

8

MEAT BIRD PRODUCTION

Birds grown for meat include, broilers, roaster, capons, turkeys and waterfowl. Turkeys and waterfowl seemed important enough in themselves to warrant separate chapters. Thus, they are covered in *Chapters 9* and *10*.

Most meat type birds, and particularly broilers, were once produced as a by-product of chick replacements for egg production. Chicks were purchased as straight run, that is approximately 50% cockerels and 50% pullets. The cockerels were separated from the pullets at about 10 to 14 weeks of age and marketed as broilers or fryers or carried on to heavier weights as roasters. Males that were to be used as capons were taken out, or separated from the pullets, at about 5 or 6 weeks of age, surgically caponized and carried through to marketing time. Today these cockerels are destroyed at the hatchery, in most instances, because they are relatively inefficient producers of meat.

For top performance, birds that are to be grown for meat should be selected from those sources that have outstanding broiler birds. Today's broiler chick is a very highly specialized bird. It is not a good egg producer but very efficient as a producer of meat. Broiler chicks are usually crossbreds or hybrids and the parent stock that produces the chicks are usually

of White Cornish and White Plymouth Rock breeding. White feathers are preferred in meat birds for the ease of dressing and for better carcass appearance. The Cornish White Rock crosses give chicks that have white or predominently white feathers and also produce chicks with meaty breasts, large legs and with rapid, efficient growth characteristics. The dressed birds have excellent conformation and market appearance.

Breeders are continually improving their stocks. When buying a broiler chick or any chick that will be used for meat production, check the growth rate and feed conversion of available stocks in your area. Contact your State Poultry Extension specialist or County Agent. It pays to start with the best chicks one can get. Chick cost is a small portion of the total costs of producing a pound of poultry meat.

Table 14 presents information on broiler growth, feed consumption and feed conversion. Water consumption data is presented in *Table 15*. The costs of broiler production are shown in *Table 16*.

Most all meat type birds are sold as day-old chicks. A possible exception is the started capon which may be purchased at 4-5 weeks of age from a hatchery or dealer.

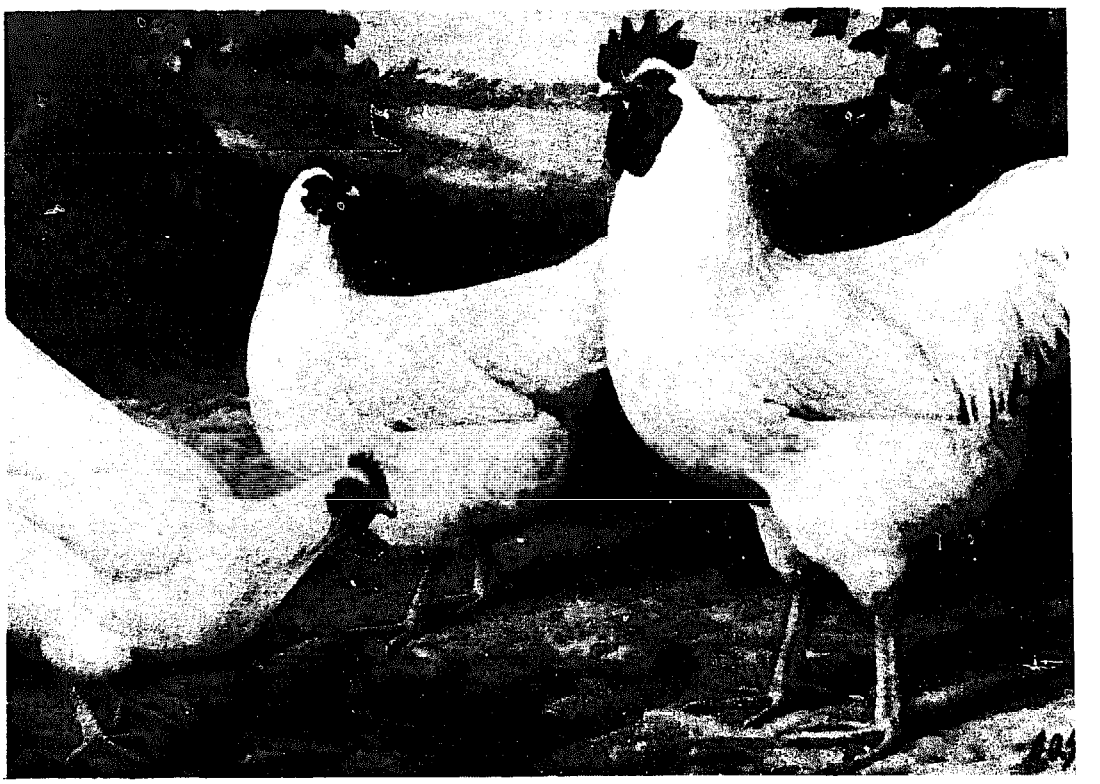

White Plymouth Rock chickens

Source: *Poultry Tribune, Mount Morris, Illinois*

TABLE 14

STANDARDS FOR BROILER GROWTH
AND FEED CONSUMPTION

Week	Live Weight — Pounds Cockerels	Pullets	Mixed Sexes	Gain over preceding week — Mixed sexes (pounds)	Feed per broiler for the week — Mixed sexes (pounds)	Feed to date — Mixed sexes (pounds)	Feed conversion to date — Mixed sexes*
1	.27	.25	.26	.17	.29	.29	1.11
2	.61	.54	.57	.31	.43	.72	1.26
3	1.09	.95	1.02	.45	.72	1.45	1.42
4	1.66	1.41	1.53	.51	.94	2.39	1.56
5	2.24	1.89	2.06	.53	1.07	3.46	1.68
6	2.91	2.42	2.67	.61	1.26	4.72	1.77
7	3.66	3.00	3.33	.66	1.45	6.18	1.86
8	4.38	3.58	3.98	.65	1.62	7.79	1.96

***Feed conversion = Pounds of feed consumed divided by the live weight**
Based on information from the *New England Poultry Management and Business Analysis Manual, Bulletin 566* (Revised).

TABLE 15

WATER CONSUMPTION OF BROILERS

Age in Weeks	Gallons Water per 100 birds Weekly	Daily
0-1	7.0	1.0
1-2	10.3	1.5
2-3	17.3	2.5
3-4	22.5	3.2
4-5	25.7	3.7
5-6	30.2	4.3
6-7	34.8	5.0
7-8	38.8	5.5

Source: 1972-73 *New England Poultry Management and Business Management Manual — Bulletin 566.*

TABLE 16

ESTIMATED PER BIRD COSTS OF BROILER PRODUCTION*

	Cents
Chick cost	16-20
Brooding	02-03
Feed (7.79 lbs. at .08)	62-62
Litter & Misc.	02-04

Total Per Bird: 82-89 cents

*Interest on average investment, labor and overhead (depreciation, insurance and taxes) are included in the costs of producing commercial broilers but frequently omitted in small flock situations. The approximate costs of these items are: interest — 2¢, labor — 2¢, and overhead — 6¢.

Housing And Equipment Needs

Meat-type birds can be grown either in confinement or on range. However, most broilers are grown in confinement. For at least the first several weeks they have to be confined to the brooder house. Since the males may be dressed as early as the sixth week it usually doesn't pay to move them to range. The best growth results are obtained by rearing in confinement.

Roasters and capons are sometimes grown on range or yarded. This is satisfactory where housing is scarce, but growth and finish may be sacrificed by so doing. Meat birds usually do better when confined and receiving a full feed of a specialized ration designed for rapid growth and efficient conversion.

floor space

Meat birds should receive at least ½ square foot per bird until the chicks are two weeks old and one square foot per bird between the second and tenth week. Heavy meat birds such as capons and roasters from 10 to 20 weeks of age should have 2-3 square feet of floor space per bird. When meat type birds are kept over 20 weeks they should have a minimum of 3 square feet per bird and more if available.

feed and water space

The chicks may be fed in box lids for the first 5 to 10 days, or chick-size feeders may be used at the rate of 1″ per chick. At 3 to 6 weeks, they should have 2″ of feeder space per chick and at 7-12 weeks, 3″. Birds to be carried on as roasters should be provided with 4″ of feeder space per bird for the remainder of the growing period.

Water should be provided at the rate of 20″ of hopper space or two 1 gallon waterers per 100 chicks up to 3 weeks of age. From the third week they should have a 4 or 5 foot trough per 100 chicks or two large fountain type waterers.

The feed hopper should not be filled more than ½ full to avoid feed waste. The feeders should be adjusted so that the lip of the hopper is at a

level with the bird's back. Adjustable hanging tube feeders are excellent for growing birds. Three tube-type feeders will normally accommodate 100 birds.

housing requirements

General housing requirements — the requirements for cleanliness, sanitation, litter, the arrangement of feeding and watering and brooding equipment — are all much the same as those described for brooding replacement pullets in *Chapter 4*. Roosts are not recommended for brooding meat birds. Roosting can cause such problems as crooked breast bones and breast blisters.

Lighting meat birds is somewhat different than lighting replacement birds. Enough light should be provided the broiler chick to enable it to move about and see to eat and drink. Actually, it is desirable to keep activity at a reduced level for the most efficient feed utilization. The intensity of illumination at the level of the chick should be about ½ of a foot candle. It is sometimes difficult to keep this level of lighting in housing with windows. Birds that receive a higher intensity are more prone to cannibalism, increased activity and possible piling and smothering. One bulb watt per 8 square feet of floor space will normally provide ½ foot candle intensity. This is when the bulb has a reflector and is 7 to 8 feet above the floor.

Many broiler producers use a continuous-light program. This may be somewhat hazardous. In the event of a power failure, the birds may panic and pile. A light-day of 14 hours is usually sufficient. If the birds are given enough light to enable them to consume adequate feed and water, it is not usually necessary to provide more than 14 hours. When the weather is exceptionally hot, it may be an advantage to use a 16 hour light day to provide additional feeding time during the cooler hours of the morning or evening.

management systems for meat birds

Although some research work is being done to develop cage equipment for broilers and other meat birds, the recommended management system is still the conventional floor litter system. Cage growing offers several advantages but, thus far, the disadvantages

outweigh these advantages. More breast blisters, leg and foot problems, crooked keels, poor growth and feed efficiency are problems which may result with cage management systems of growing meat birds.

The windowed house or controlled environment houses are used for meat birds depending upon the climate, the size of flock and other factors. Ventilation and ventilation systems are the same as those for other types of growing houses. In most areas concrete floors are required for proper cleaning and sanitation and to avoid disease and parasite problems. The cleaning and sanitation requirements are the same for meat birds as for other growing stock.

disease control

Disease prevention is vitally important to a broiler growing program. Unlike birds that are grown for egg production, or meat birds such as the roasters or capons, broilers have only an 8 week growing period. If the birds become sick in the middle of the growing period, the time in which the disease can be treated and brought under control is relatively limited, and the overall flock results can be severely affected. It is, therefore, important that a disease control program for broilers be one of prevention rather than treatment.

Vaccination recommendations for meat birds vary with the area. It is probably well to plan to have the chicks vaccinated for Marek's disease, especially if the disease has been prevalent in your area. Marek's vaccine is usually administered at the hatchery. Some broiler growers do not vaccinate for other diseases, because they practice isolation and sanitation practices and feel that these programs will prevent most disease outbreaks.

Before establishing a vaccination program for meat birds, be sure to check with poultry pathologists or other people who are knowledgeable about the possible disease exposure situation in the area. When broilers or other meat birds are vaccinated for other than Marek's disease, it is normally Newcastle disease or infectious bronchitis.

It is very important to prevent outbreaks of coccidiosis in meat birds particularly during the broiler stage. Outbreaks of coccidiosis normally occur early in the chick's life and can damage the intestinal lining. This prevents the normal absorption of food materials in the intestinal tract. Outbreaks of coccidiosis can cause poor growth and feed conversion, or — in severe cases — mortality and morbidity.

Drugs called coccidiostats are normally used in the feeds to either reduce the infection of coccidiosis or to completely suppress it. When pullets are grown for a floor management system of housing layers, the starter feeds and grower feeds contain low levels of a coccidiostat which permits the birds to have a low level of infection and build up immunity to the disease. Birds that are grown on the floor and are to be housed in cages — where they won't be exposed to fecal material and contained sporulated oocysts — are given a type of coccidiostat, or dosage of coccidiostat, in the diet to prevent infection altogether.

Since the growing period for broilers is so short, and so much emphasis is placed on fast efficient growth, the usual procedure is to control coccidiosis during the growing period. Better growth results are obtained if infection is prevented. Most roaster and capon growers use a coccidiostat throughout the growing period.

Even though the birds are on a preventive level of coccidiostat, at times there are outbreaks of the disease due to excessively wet litter or other factors. The method of treating these outbreaks is covered in the section on flock health, *Chapter 13.*

feeding programs for meat birds

The goal of the feeding program for meat birds is to get as much growth as quickly as possible. This is unlike feeding replacement pullets where we are interested in delaying sexual maturity. Meat birds must have access to full feed at all times, and they should be encouraged to eat as much as possible, with as little waste as possible. A number of small flock owners permit capons and roasters to yard or range. Though overall performance may be somewhat less, excellent birds can be grown this way. The cost may be somewhat less also, because the chickens forage for a part of their food intake.

It is important to feed meat birds a ration that is designed to give rapid growth and good feed conversion. They should be started on a broiler feeding program. The complete feeding program includes two or possibly three different rations. Some companies recommend a program which begins with a broiler starter the first five weeks. The starter contains about 22% protein and a coccidiostat. This feed is replaced with an 18% broiler finisher from 5 weeks up to 5 days prior to marketing. At this time they would be shifted to a final feed of 17%, but containing no coccidiostat. Where this feeding program is used, it should be stressed that the birds

should be checked very carefully for coccidiosis if they are to be held beyond the 5 day period. It may become necessary to treat for coccidiosis if the birds are held more than 5 days prior to dressing or marketing.

Where birds are to be held over as light roasters for 4 to 5 weeks beyond the broiler period, they can be fed a 20% broiler finisher diet. This may be fed up to within 2 to 5 days prior to dressing or marketing, depending upon the type of coccidiostat used. Some coccidiostats must be withdrawn several days prior to slaughter.

Where birds are fed as capons or heavy roasters, they should be fed a lower protein and higher energy diet from the ninth or tenth week to marketing. The protein level should be approximately 16%. Some feed company programs call for feeding a roaster finisher from the sixth week to 2 days before marketing, at which time a feed containing no coccidiostat is used for the remainder of the period.

Capon Production

Male chickens, sometimes castrated or caponized to make them fatten more readily, are called capons. Capons are not only more tender than cockerels but bring a much better market price. Capons are normally grown to be marketed during the Thanksgiving-Christmas holiday seasons at which time they bring premium prices.

Up to possibly 20 weeks of age the capon and the cockerel weigh about the same. Afterwards, the capons gain weight more rapidly than cockerels. When cockerels show spur and comb development and are called stags, their flesh toughens. Toughness of the flesh does not occur in capons. When cockerels are a year old, and are classed as old cocks, they bring a very low price, and their flesh is very tough. On the other hand, capons have very tender flesh, and if kept beyond the age when they are normally marketed, or dressed-off, the flesh remains tender.

Unlike the cockerel, the capon has a very quiet disposition, is very docile and seldom crows. After caponization, the comb and wattles cease growing, the head looks pale and small, and the hackle, tail and saddle feathers grow to be unusually long.

selecting a breed for caponizing

Broiler stocks with white plumage and yellow skin, are preferred for

meat bird production. White Plymouth Rocks, New Hampshires and crosses of these breeds or those crosses involving White Cornish and White Rock Crosses are generally used. Caponizing small birds, such as Leghorns, or the small representatives of the American breeds, just does not pay.

when to caponize

Since capons are in the biggest demand during the Thanksgiving to March period and take 24-25 weeks to grow and finish properly, the best time to caponize is in late spring or early fall.

Caponizing used to be done at 5-6 weeks of age. With our faster growing broiler strains of birds, it is now desirable to caponize at approximately 4-5 weeks of age before they become too large, when the operation is more difficult. Some hatcheries or dealers specialize in selling 4-week old capons that have been caponized as early as 10 days. It is possible to caponize older birds up to 8 weeks; it is best, however, to do it earlier.

the caponizing operation

Feed and water should be withheld from the birds for 24 hours before the operation. The bird's intestines should be almost empty to prevent them from obstructing the operation. When the birds are removed from feed and water, they should be kept in wire or slat-bottom coops to prevent them from eating litter or other materials.

Good light is mandatory during the operation. Direct sunlight is best; a strong electric light with a reflector can, however, serve indoors.

A barrel or box can be used as an operating table. When a large number of birds are to be caponized, a table of convenient height is recommended.

During the operation, the birds can be restrained by a second operator who holds the bird outstretched on its side. A caponizer can do the operation single-handedly by restraining the birds with weighted cords tied to the legs and wings. These cords should be about 2 feet long and weighted with 1 pound weights. The cockerel's legs are securely tied by the use of a half-hitch in one cord. Both wings are held together near the shoulder joint with a half hitch in the other cord. The weights are hung over the edge of the

operating table, and the bird is stretched out. The cords should be so arranged that it is easy to adjust the bird and turn it over without disturbing the weights.

methods

The operation can be done with one incision or two incisions. Most operators find it easier to remove the upper, or nearer testicle, then turn the bird over, make a second incision on the other side of the body for removing the other testicle. If both testicles are removed through the one incision, it is best to remove the lower one first; otherwise, bleeding from the upper may obscure the lower.

It is very important not to rupture the artery which runs just behind the testicles. If the artery is ruptured the chicken will bleed to death in seconds. Usually if feed and water have been withheld, the artery presents no problem.

The instruments which are needed for the operation are: a sharp knife, a rib spreader, a sharp pointed hook and the testicle removers, or forceps *(Figure 18)*. The operation should be performed as quickly as possible to reduce stress on the bird.

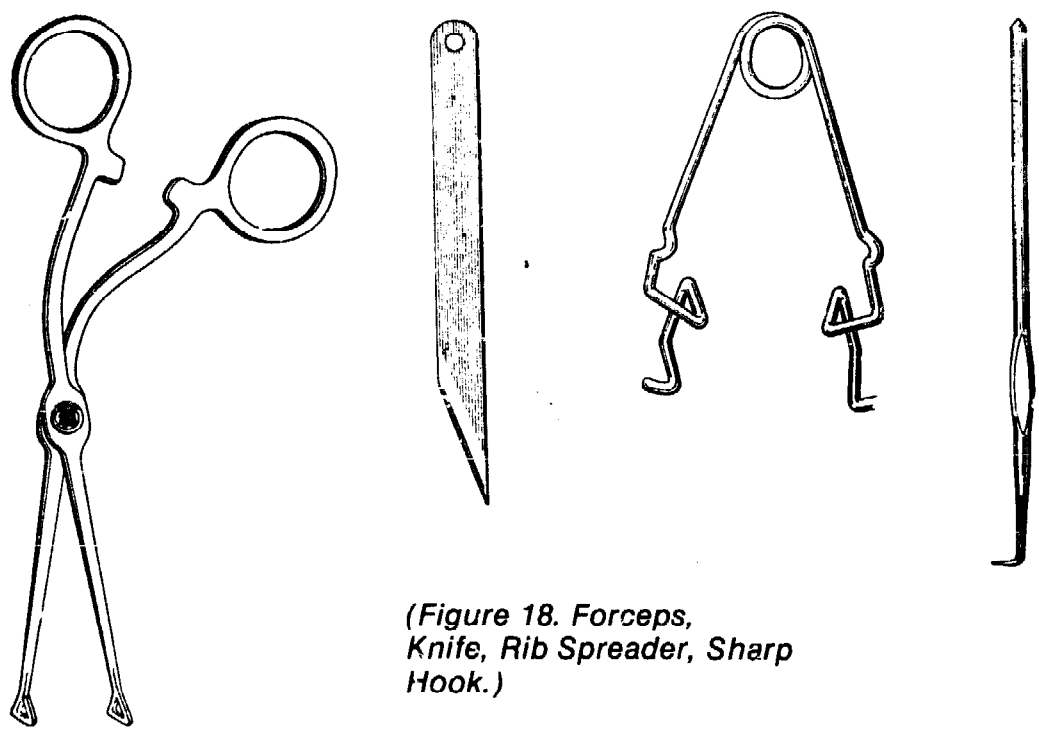

(Figure 18. Forceps, Knife, Rib Spreader, Sharp Hook.)

Moisten and remove the feathers from a small area over the last two ribs, just in front of the thigh; with one hand, slide the skin flesh down toward the thigh and hold it in that position. This will prevent cutting into the muscle and causing excessive bleeding. The cut is made between the last two ribs *(Figure 19)*. The incision should be lengthened in each direction until it is about ¾" to 1" long.

The spreader is then inserted into the incision to spring the ribs apart *(Figure 20)*. The intestines will be visible beneath a thin membrane. This membrane should be torn open with the hook. This procedure will expose the upper testicle. It is usually yellow in color but may be dark colored. It is about the size and shape of a navy bean and is located up close to the back bone and just below the front end of the kidney. If the intestines are empty, once they are pushed aside, it is quite easy to see the lower testicle. It is in the same position as the upper one, but on the other side of the backbone.

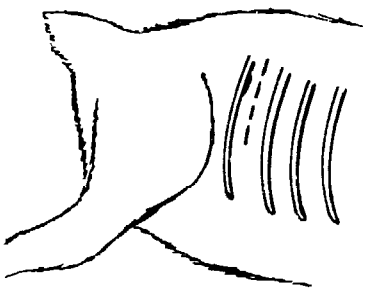

(Figure 19.)

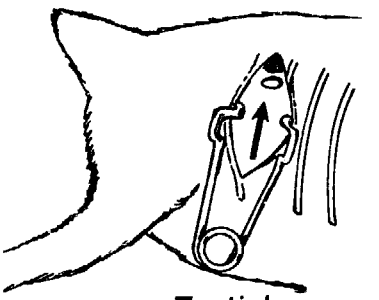

Testicle
(Figure 20.)

The forceps are used to grasp the testicle and it is important that the artery be avoided at this point. The entire testicle must be removed with a slow twisting motion, tearing it away from the spermatic cord to which it is attached. Unless both testicles are removed from the same incision, the bird is turned over, and the same operation is performed on the other side. It is not necessary to stitch the incision, since when the skin and flesh are released, they will slide back over the incision and cover it.

slips

Frequently, when the caponizing operation is performed for the first time, a number of birds will become what are known as slips. A "slip" is neither a cockerel nor a capon. A slip develops when a part of the testicle is not removed during the operation. This small piece of testicle often grows

to a considerable size. Slips have the same restless disposition as cockerels and they grow and fatten little, or no better, than a cockerel. Thus slips are not as highly valued for meat purposes and do not bring as good a price if sold. Inexperienced operators may expect up to 50% slips; experienced operators can expect about 5% or less.

losses in caponizing

Occasionally, even the best operators will kill some birds during the caponizing operation. However, this loss seldom exceeds 5%. Inexperienced caponizer frequently kill several birds, but gradually losses are reduced as they gain experience. Any birds that are killed during the operation may be dressed and eaten.

Speed develops with experience. An experienced caponizer can do up to four birds per minute. It is wise for the beginner to practice, at first, on slaughtered birds to acquire some skill before attempting to caponize a live bird. Caponizing is somewhat of a stress on the birds, so some commercial caponizers inject the birds with an antibiotic solution just prior to the operation. Some capon growers administer the antibiotic solution in the drinking water for 2 or 3 days, beginning 4 or 5 days prior to the operation. Antibiotics should not be given by way of the drinking water within two days of the operation. Some antibiotics tend to cause the intestines to balloon, thus increasing the possibility of damage to the intestine and making it more difficult to spot the testicle.

care and feeding of caponized birds

Caponized birds should be separated from other chickens and kept separated during the growing period. Air puffs or wind puffs may develop after the operation. Wind puffs are caused by air which gathers under the skin. This air should be released by pricking the skin with a needle or knife and pressing it out. Usually within ten days after the operation, the incision is fully healed.

Breast blisters are often a problem with capons. They are likely to appear when the capons are about half-grown and the incidence may increase as the birds become heavier. The birds may develop breast blisters from roosts, especially those with narrow perches or from resting on board, concrete, or wire floors. Litter should not be permitted to become caked or

excessively wet but should be kept soft, loose and dry. Roasters or capons should not be permitted to roost.

During the growing period, the birds should be supplied with a growing feed which contains approximately a 17% protein. The growing stage is very important because during this period leg problems may occur. Capons, if pushed too hard for rapid growth during the early growing period, may have insufficient bone development to hold up the body weight. Most cockerels that are to be used for capons are actually broiler males. This stock has been selected for rapid growth and males should reach 3½ to 4 pounds in body weight at 8 weeks of age. They are normally marketed at these weights. When we use these birds for capon production it is expected that they will grow to about 9 or 10 pounds live weight in approximately 20 weeks. Some of the birds will not have strong enough legs to support these heavier weights if growth is too rapid early in the growing period. It is, therefore, well to keep this in mind when selecting a feeding program for capons. Some growers restrict feed, and thus the growth rate, from about 6-10 weeks of age to prevent this problem in light roasters. Feeds especially formulated for capons take this problem into consideration. Broiler rations, however, are high energy feeds that are designed for maximum growth and may create the leg problems if fed throughout the growing period. For heavy roasters, it is suggested that a lower energy diet be used from approximately 8 to 13 weeks.

Leg weaknesses also contribute to the breast blister problem. This problem can be very serious, because it detracts from the dressed appearance of the birds. Birds that do have a weak leg problem exhibit a tendency to sit down much of the time. The keel bone is constantly in contact with the litter and the incidence of blisters is increased, especially if litter conditions are poor. Other factors that affect the incidence of breast blisters include the type of equipment used, overcrowding, genetics, loading and handling methods and others. Birds can receive bruises and skin irritations by bumping into equipment or by being pushed and shoved or mishandled.

Capons may be grown in confinement with a yard provided or on range. Downgrading often seems higher in the case of confinement reared birds. The reason for this is that confined birds are usually pushed to higher weights more quickly. There is also a greater possibility of crowding and injuries when birds are confined.

Range birds, however, seem to have higher mortality. A lot of this is probably due to predator losses. Birds on range should be provided with shelters. Often, shelters with wire floors and perches are used. These may

cause breast blisters. Wire floors and perches should be covered, and preferably litter used on the floor of the shelters. Shade is important for birds on range. This is especially true during the hot weather seasons, or in warm weather climates. The range should be clean and provide a short succulent forage to be most valuable. If good range is provided, feed costs can be substantially reduced. Birds on range should be provided with range feeders that prevent the feed from being blown away or getting wet and subsequently moldy. Adequate feeder and watering space is important regardless of whether the birds are reared on range or in confinement. Approximately 4″ of feeder space and 1″ of watering space per bird is required.

When finishing capons, the birds should be pushed for maximum gains and efficiency after they reach an age of 13 weeks. The protein levels of the feed can be reduced to approximately 15 or 16%, and the energy level increased to obtain maximum yet efficient weights, as well as to get the birds in good market condition in terms of fat cover, fleshing, and pigmentation.

chemical caponizing

Dienesterol Diacetate (Lipamone) may be used to produce chemical capons. Lipamone is added to the finisher diet and is fed to the birds for the last 3 or 4 weeks prior to slaughter. This program is often used for birds that are to be slaughtered as light roasters at 12-14 weeks. Lipamone-fed birds seem to have more fat beneath the skin and, therefore, the bird is more tender and succulent and has an improved flavor.

Another program which we have used in Vermont for a number of years makes use of a product which is relatively easy to administer, and yields essentially the same end results as surgical caponizing. A steroid paste (Esmopal) is administered with a special gun which meters the correct amount of material through a needle. The implant is injected just under the skin alongside the comb. This material is manufactured by the Mattox and Moore Company, Indianapolis, Indiana, and comes in a 50-dose cartridge. Birds so injected take on much the same appearance as surgical capons. The comb and wattles become pale and small, and the birds become quiet and somewhat more docile than untreated birds.

when to implant

Once the birds are implanted, a minimum of 6 weeks time must have elapsed before they can be slaughtered for human consumption. Birds should be 5 weeks of age before implanting. Those injected at 5 weeks of age must be at least 11 weeks of age when slaughtered. It is absolutely necessary to plan the marketing or slaughtering program. At the end of 6 weeks following the implant, birds must be slaughtered or re-implanted, because the steroid material is completely absorbed by that time, and they will begin again to appear and act like cockerels.

In trials conducted at the University of Vermont, Bioresearch Center, birds were implanted at 5 weeks, again at 11 weeks and slaughtered at 17 weeks. Live weights of 9½-10½ pounds were reached. If heavier market weights are desired the birds could, for example, receive the first implant at 7 weeks, a second at 13 weeks and be slaughtered at 19 weeks. With this program some birds can be slaughtered as light roasters at 11 or 12 weeks of age or they can be reimplanted and carried on to heavier weights. Feed consumed is approximately 38 pounds per bird at 17 weeks. Implanting costs approximately 12 cents per bird on the 17-week program. Estimated costs of production of roasters and capons is shown in *Table 17.* Care and feeding of the chemical roasters is the same as for capons.

TABLE 17

APPROXIMATE PER BIRD COSTS OF PRODUCING CAPONS AND ROASTERS*

Item	Cost
Chicks	$ .16 — $ .20
Brooding	.02 — .03
Feed, 38 lbs. at $.08-.09	3.04 — 3.42
Litter and Miscellaneous	.04 — .05
Cost of Esmopal or Surgical Caponizing	.12 — .20
	Total: $3.38 — $3.90

*Interest on average investment, labor and overhead (depreciation, insurance and taxes) are included in the costs of producing commercial roasters but frequently overlooked when grown in small flocks. Estimated costs of these items are: interest — 7¢, labor — 12¢, and overhead — 17¢.

9

TURKEY PRODUCTION

Before you launch into the production of turkeys, even on a small scale, you should be aware of the costs of production. The turkey poult costs substantially more than does a chick and, of course, turkeys consume considerably more feed than do growing chicks. Thus the cost of producing turkeys is considerably higher. *Table 18* presents the costs involved in raising a small flock of turkeys.

Getting Started

The turkey enterprise can be started in one of several ways. You can purchase hatching eggs and incubate them, or purchase day-old poults. One may also buy breeding stock, but this is a rather expensive way to begin. If hatching eggs are purchased, it requires equipment for incubating; if breeding stock is purchased it is not only expensive to buy the birds but also to maintain them. Normally, most small flocks of turkeys are purchased as poults from a hatchery.

There are several varieties of turkeys, but those that are most important commercially are the Broad Breasted Bronze, the Broad

TABLE 18

ESTIMATED PER BIRD COSTS OF RAISING HEAVY ROASTER TURKEYS

Item of Cost	Amount
Poult	$ .75 — $1.00
Feed (75.5 lbs.)	6.04 — 7.55
Brooding, Electricity, Litter, Misc.	.15 — .20
	Total: $6.94 — $8.75

Assumptions: Small flock, their feed costs are relatively high, poult costs are usually high, all feed purchased, no labor, overhead, or interest costs included.

Breasted White, and the Beltsville Small White. Until quite recently the Bronze was the most popular variety.

The Bronze has good growth rate, confirmation, feed conversion and about all of the qualities demanded by the turkey industry. Its basic plumage color is black, and it has dark colored pin feathers, a distinct disadvantage that has led to its replacement by the Broad Breasted White.

The Broad Breasted White was developed in the early 1950's from crosses of the Broad Breasted Bronze and the White Holland variety. In some areas of the country it is now difficult to find the Broad Breasted Bronze, because the current demand is so great for the Whites.

The Small White looks very much like the Large White from the standpoint of color and body conformation. It is a much smaller turkey which was developed at the Beltsville Agricultural Research Center in Maryland. Its body weight has tended to increase in recent years through selection by breeders.

Properly managed and fed the Beltsvilles reach good market condition in 15 to 16 weeks and make excellent turkey broilers. They also make good medium roasters if held to 21 to 24 weeks. They are not as efficient converters of feed as the Large Whites but usually cost somewhat less as poults. Their main disadvantage is the difference in feed required to reach the same weights as the large turkeys.

When buying poults you should select a strain that is known to yield good results. As is the case with chickens, the poults should originate from sources that are U.S. pullorum-typhoid clean, and preferably from breeder flocks having no history of sinusitis, or air-sac infection. Consult your state poultry specialist, your county Agricultural Extension Agent, or some other knowledgeable person for advice on sources of good turkey poults in your area.

Place your order for poults well in advance of the delivery date, so as to be sure to get the quality of stock you want. Birds should be ordered to arrive so as to permit 24-28 weeks for growing the large breeds and 18-22 weeks for smaller breeds. It is sometimes difficult to obtain small lots of turkeys delivered from the hatchery. However, it may be possible to pick the turkeys up at the hatchery or, perhaps, have a nearby producer order a few extra poults for you. Poults that are shipped express are subject to chilling and overheating. Buy the poults as close to home as possible.

housing requirements

Small flocks of turkeys are normally started in the warm months of the year so housing doesn't have to be fancy. However, the brooder house should be a well-constructed building that is easily ventilated. If a small building is not available a pen can be built within a large building. The pen should have good floors that can be readily cleaned. The insulation required will depend upon the climatic conditions as well as the time of year the poults are to be brooded. A well-insulated building can save energy and brooding costs. Young turkeys must be kept warm and dry, so a well insulated and ventilated house is important in cool climates, particularly with large flocks.

The brooder house should have windows which slide down or tilt in from the top. These are best for ventilation. The windows should be located in the front and back of the house. Usually one square foot of window area to each 10 square feet of floor area is adequate.

Confinement rearing of turkeys is most frequently used by the small grower. Where predators or adverse weather conditions are likely, or where there is limited range area, confinement rearing is preferred. Some producers yard their birds within fenced-in areas using the brooder house as the shelter.

Sun porches were once very popular with turkey growers. Some producers still use them. The porches are attached to the brooder house or shelter. The floor of the porch is made either of slats or wire. They are frequently elevated to provide a space underneath for the accumulation of droppings and an easy access for cleaning. Porches are fenced in on the top and sides. Coarse mesh wire is used on the top to avoid snow loading. Porches have several advantages in that they help to acclimate the birds to the weather conditions prior to going on range. This helps to reduce

stampeding on the range during wind or rain storms. The porches also acclimate them to changes in temperature to which they are exposed on range.

The heavy breed turkeys today are not grown on wire or slated porches as much. Breast blisters, foot and leg problems tend to develop particularly on wire. Light type turkeys may still be grown on porches. A modification of the porch approach is the use of paved yards or yards with a gravel or stone surface.

Large turkey production units sometimes use windowless, controlled environment houses. These buildings are thoroughly insulated to provide maximum efficiency in the use of heat during brooding and to provide comfortable well-ventilated conditions for the birds.

Ventilation systems for turkey housing are designed essentially the same as for chicken houses. Many of them use fan ventilation with the same type of inlet but a larger ventilating capacity. Fan systems are designed to move from ¾ to 1 cubic foot per minute at ⅛ inch static pressure per pound of turkey expected at maturity. If you plan to go into the turkey business on a commercial scale, contact your State Extension Poultry Specialist for help in designing the facilities.

preparing the brooder house

The brooder house should be cleaned between broods. This means completely removing all the old litter and thoroughly washing the floors, sidewalls, ceilings and equipment. The building and equipment should be disinfected with a material such as cresilic acid. Some of these materials can cause foot burn or eye injury. To prevent disinfectant injury to the poults, make sure that the house has an opportunity to dry for about 2 weeks prior to the time the poults are put in the house.

After the building is thoroughly dry, 3″ to 4″ of litter should be put down on the floor. Some of the common litter materials which are suitable for use are wood shavings, sugarcane, ground corn cobs, peatmoss or vermiculite. The litter may be covered or uncovered. Some producers cover the litter with paper to prevent litter-eating for the first week. If the litter is covered, a rough paper should be used. A slippery surface can cause leg weakness and crooked feet. The litter should be evenly distributed over the floor and free of mold and dust. Very coarse litter material can also contribute to leg disorders.

In small brooder houses, corners should be rounded with small mesh

wire to prevent piling. Turkeys may pile when frightened or when the house is drafty or floor temperatures low.

floor space

Use one square foot of floor space per poult up to 8 weeks of age. From 8-12 weeks the floor space should be increased to 2 square feet per poult, and from 12-16 weeks two and one half square feet should be the minimum allowance. Mixed sexes which are to be kept in confinement during the entire growing period should receive 4 square feet per bird. If the flock is all toms, they should receive 5 square feet or, if all hens, 3 square feet is adequate. For light type turkeys, or for turkeys housed in controlled environment housing, the floor space requirements may be somewhat less than the above recommendations.

brooders

Several types of brooders are suitable for brooding poults. Gas or electric are probably the best suited for small flock situations. If hover type brooders are used, allow approximately 12-13 square inches of hover space per poult started. A brooder that is rated for 250 chicks will be adequate for only about 125 turkeys. When hover type brooding is used, a 7½ watt light bulb should be used to attract the poults to the heat source. Each brooder should be equipped with a thermometer which can be easily read. Infrared brooders are satisfactory for small turkey flocks.

If infrared bulbs are used for brooding, provide 2 or 3,250 watt bulbs per 100 poults. Infrared lamps should be hung about 18 inches from the surface of the litter initially. They can be raised 2 inches per week until 24 inches above the litter. The brooder ring or guard should be 8-10 feet in diameter. Care should be taken to avoid splashing water on infrared bulbs. This may cause them to break unless they are the Pyrex-type. Ideally, the temperature outside the heat source or the hover area should be approximately 70° F. to provide maximum comfort for the poults.

brooder guards

Brooder guards should be used to confine the birds to the heat source and to prevent drafts on the poults.

Management of the brooder guard varies, depending upon the design of the house and the climatic or seasonal conditions. Where non-insulated housing is used during fairly cool weather, an 18 inch brooder guard for each stove is recommended. For warm weather brooding a 12 inch brooder guard is satisfactory. The brooder guard should be located 2-3 feet from the edge of the hover and be gradually moved out to a distance of 3 to 4 feet. After 7 to 10 days the brooder guard can be removed. At this time the poults are normally allowed free access to the brooder house. If poults are brooded early in the season, or in cold climates, and the brooder house is quite large, it may be necessary to partition off part of the house at the start and enlarge the area as necessary.

feeding equipment

The first feed for the poults can be supplied to them on new egg filler flats, on chick box lids, or in small chick feeders. Turkeys sometimes have a visual problem and have difficulty finding the feed and water. When this occurs there may be starve-outs or dehydrated poults. Bright colored marbles placed on top of the feed or in the water containers will often attract the poults to the feed and water. Oatmeal or fine granite grit sprinkled very lightly over the feed, once or twice a day for the first 3 days, may also help to get them eating. Unless the litter is covered with a paper, don't fill the feeder so full that it will overflow. This can lead to the practice of eating litter. For poults from 7 days to 3 weeks, use small feeders at the rate of 2 inches of feeder space per bird. From 3 weeks to market, the poults should be furnished with large feeders about 4 inches deep at the rate of 3 inches of feeder space per bird. Hanging tube-type feeders can also be utilized. The amount of tube type feeding space can be determined by multiplying the diameter of the feeder pan by 3 1/7 to obtain the number of inches of feeder space available. In figuring feeder space remember to multiply the hopper length by 2 if the poults are able to use both sides of the feeder. Thus a 4 foot trough feeder actually provides 8 linear feet of feeder space.

water space

Poults can be started on either glass fountain type waterers or automatic waterers. From 1 day to 3 weeks the poults should have access to

3, one or 2 gallon fountains per 100 poults. From 3 weeks to market they should have 2, 3 or 5 gallon fountains per 100 poults, or one 4 foot automatic waterer.

Changes of equipment, both feeders and waterers, should be made gradually so as not to discourage feed or water consumption.

brooding the poults

When the poults arrive the brooder house should be completely ready for them. The feeding equipment should be arranged and the brooder guards set up (See *Figure 10).* The brooders should have been in operation for approximately 24 hours to get them regulated and to get the building warm.

If hover type brooders are used, the temperature should be 100° F. for white birds, 95° F. for Bronze. This temperature reading is taken under the hover approximately 7 inches from the outer edge and 2 inches above the litter, or at the height of the poults' backs. Be sure to check the accuracy of the thermometer you are using before the poults arrive. The hover temperature should be reduced 5° weekly until it registers 70 or 75° F. or equals the outside temperature. If the weather is warm during the brooding period, heat may be shut down during the day after the first week. Heat during the evening hours will be required for a longer period. Normally, little or no heat is required after the sixth week, depending upon the time of year, the weather conditions and the housing. Watch the poults as a guide when checking or adjusting temperatures *(Figure 11).*

Important: Feed and water the poults as soon as possible after hatching. As each poult is taken from the box, dip its beak in water and then in the feed. This will help to get it started on feed and water.

lighting

High light intensity should be provided the poults for the first 2 weeks of brooding in all types of houses to prevent starve-outs. Ten to 15 foot candles of light should be used day and night. This will require 200 watt bulbs spaced 10 feet on centers. A small 7½ to 15 watt attraction light bulb should be installed under each brooder hover. After the first two weeks in

window houses, use dim lights at approximately ½ foot candle during the night hours. The dim lights will help to prevent, or discourage, piling and stampeding.

roosts

Roosts are seldom used for brooding turkeys though they may help to prevent piling at night. Roosts do not normally cause breast blister problems with turkeys. If roosts are used in the brooder house they may be of the step ladder type, allowing about 3 linear inches of perch space per bird. The roosts perches are made of 2 inch round poles or 2" x 2" or 2" x 3" material, with the lowest perch located about 12 inches above the litter. Each succeeding perch is 4-6 inches higher. The perches should be beveled or rounded on the edges to prevent injury to the breasts. Each bird should have 6 linear inches of roosting space by the end of the brooding period. The bottom and the ends of the roosts should be screened so as to prevent the poults from gaining access to the droppings. Birds usually begin to use the roosts at about 4-5 weeks of age.

Usually where birds are grown in complete confinement roosts are not used. Since the birds bed down on the floor, litter conditions should be kept in good condition to prevent breast blisters, soiled and matted feathers, off-colored skin blemishes on the breast. Good litter conditions also help to maintain sanitary conditions and prevent disease problems.

Roosts which are used on range should be constructed of 2" poles or 2" x 4" material laid flat with rounded edges. The roosts perches should be spaced 24" apart and located approximately 3 feet off the gound. If placed in a house or shelter, the roosts may be slanted to conserve space. Where an outdoor roosting rack is constructed, all roosts perches should be built on the same level. This type of roost should be built of fairly heavy material to prevent breaking when the weight of the birds is concentrated in a small area. Ten to 15 inches of perch space, per bird, is required for the large type birds and 10 to 12 inches for small type turkeys.

feeding

One of the soundest pieces of advice that can be given to a turkey grower is to select a good brand of feed and follow the manufacturers recommendations for feeding the birds.

Two basic feeding programs for growing turkeys are available. One is the all mash system and the second is a protein supplement plus grain system. Nutrient requirements of turkey poults vary with the age. As the birds become older the protein, vitamin and mineral requirements decrease and the energy requirements increase.

An insoluble grit such as granite grit should be fed the first 8-10 weeks. Whenever grains are included in the diet or if the birds are on range they should receive an insoluble grit to enable them to grind and utilize the grains and fibrous materials.

Recommendations for feeding, and the number of feeds offered, vary considerably between feed companies. One of the simpler types of feeding programs recommends a 28% starting diet with a change to 21% growing diet and finishing with a 16% protein diet. Other commercial concerns offer and recommend 5 or 6 different diets during the growing period. Again, buy feed from a reputable feed company and follow their recommendations. Under most circumstances the diets should include a coccidiostat and, in most instances, there should be a blackhead disease preventative drug incorporated in the feed.

Feed and water should be kept before the birds continuously. Pelleted mash can be fed after the first 4 weeks. Most growers feed a nutritionally complete starting mash. However, green feed can be utilized for small flocks where labor requirements are of little concern. Tender alfalfa, white Dutch clover, young tender grass or green grain sprouts all chopped into short lengths and fed once or twice daily are good for the poults. Wilted or dry roughage feeds should not be permitted to remain before the poults. These can cause impacted or pendulous crops.

Turkey starter diets can be purchased ready-mixed. They can be home or custom-mixed according to recommended formulas, or a concentrate can be used and mixed with ingredients such as ground corn and soybean meal. For the most part, small producers will find it best to feed a ready-mixed complete starter diet.

Growing diets, fed to the poults from 8 weeks to maturity, may be in mash or pellet form. They may include either loose or pelleted mash plus whole or cracked grain — sometimes referred to as scratch grains. A commercial concentrate may also be purchased and combined with ground grain or with soybean meal and ground corn in the proportions recommended by the manufacturer. Once again the small grower will find it advantageous to use a complete ready-mixed mash when the birds are reared in confinement. If the birds are on range, a complete feed, preferably

TABLE 19

GROWTH RATE AND FEED CONSUMPTION FOR HEAVY AND LIGHT ROASTER TURKEYS AND BROILER FRYERS

	BROAD BREASTED BRONZE AND BROAD BREASTED LARGE WHITES				SMALL WHITES OR BROILER-FRYER-ROASTERS			
	Live Weight Pounds		**Total Cumulative Feed Required Pounds**		**Live Weight Pounds**		**Total Cumulative Feed Required Pounds**	
Age Weeks	**Toms**	**Hens**	**Toms**	**Hens**	**Toms**	**Hens**	**Toms**	**Hens**
2	.55	.53	.6	.53	.5	.45	.6	.55
4	1.4	1.2	2.1	1.8	1.5	1.3	2.25	2.0
6	2.5	2.0	4.8	3.8	2.9	2.3	4.5	3.8
8	4.0	3.5	8.8	7.7	4.6	3.6	8.0	6.7
10	5.4	5.2	16.2	14.1	6.9	5.3	13.0	10.6
12	8.2	7.0	25.0	21.0	9.4	7.1	20.2	15.7
14	11.0	9.0	34.3	28.0	11.8	8.5	28.0	21.7
16	14.0	11.0	43.8	34.2	14.2	9.8	36.1	28.2
18	16.9	13.0	52.9	40.3	16.4	10.9	45.2	34.9
20	19.7	14.8	62.5	49.0	18.5	11.8	56.0	41.7
22	22.4	16.3	74.0	57.7				
24	25.2	17.3	87.3	64.0				
26	28.0		103.0					
28	30.6		120.0					
Total	**30.6**	**17.3**	**120.0**	**64.0**	**18.5**	**11.8**	**56.0**	**41.7**

Based on material by M. L. Scott, *Turkey World,* 1970.

in pellet form, supplemented with good range, grains and insoluble grit makes a sound feeding program. Growth rate and feed consumption information for heavy and light roaster turkeys is presented in *Table 19.* Water consumption information is presented in *Table 20.*

TABLE 20

DAILY WATER CONSUMPTION OF TURKEYS

	Gallons Per 100 Birds	
Age in Weeks	**Large Turkeys**	**Small Turkeys**
1	1	.7
2	2	1.5
3	3	2.5
4	4	3.5
5	5	4.0
6	6	4.5
7	7.5	5.0
8	9.5	5.5
9	11.0	6.5
10	12.5	7.0
11	14.0	7.5
12	15.0	8.0
13	16.0	9.5
14	16.5*	10.5
15	17.0*	12.0
16	16.5*	13.0
17	16.5*	—
18	16.5*	—
19	16.5*	—
20	16.5*	—

Dr. Salisbury Laboratories

*Consumption will vary from 15 weeks to maturity from 14.0 to 19.0 gallons per 100 birds per day depending upon the temperatures.

range-rearing

It is possible to reduce the cost of rearing turkeys by putting them on range. This is especially true if the diet can be supplemented with home grown grains. Turkeys are good foragers and if good green feed is available

on the range this will help to supplement the diet and reduce the cost of the feeding program.

Range-rearing is not without its problems. Losses are possible from soil born diseases, insects, thieves, adverse weather conditions, and predators. Because of these several factors confinement rearing, which tends to minimize these losses, has quite rapidly replaced range rearing in some areas.

Portable range shelters which can be moved to various areas of the range are preferred with layer flocks. The shelter should provide about 1½ square feet of floor space per bird. It should be equipped with roosts, or slat floors with the slats located 1½ inches apart.

Normally, turkey poults can be put out on the range at 8 weeks of age. The flock should be well-feathered, especially over the hips and back, before they are put on range. Check the weather forecast for several days before putting the birds on range. It is best to move them in the morning. This helps to get the birds used to range conditions without losses.

A range area that has been free of turkeys for at least one year and preferably for two years, is desirable. Poorly drained soil on the range should be avoided. Stagnant surface water may be a factor in turkey disease outbreaks. A temporary fence can be used to confine the flock to a small area of the range. The fence can be moved once a week, or as often as the range and weather conditions indicate. Artificial shade should be provided if there is no natural shade. Several rows of corn planted along the sunny side of the range area provides good shade and will also provide some feed as it matures. About one acre of good pasture is required for 250 turkeys. If range shelters are used, it is well to move them every 7 to 14 days depending upon the weather and the quality of range. The feed and watering equipment should also be moved as needed to avoid muddy and bare spots.

It is possible to use a combination of confinement and range-rearing by providing a permanent shelter such as a barn with fenced-in range areas around the barn. These fenced-in areas can be used on an alternate basis every year or two.

Range crops will depend upon the climate, soil and the range management. Many turkey ranges are permanently seeded, others are a part of a crop rotation plan. As part of a 3 or 4 year crop rotation, legume or grass pasture and an annual range crop such as soybeans, rape, kale, sunflowers, reed canary grass and sudan grass, have been used successfully. Sunflowers, reed canary grass and sudan grass provide green feed and also shade. For permanent range, alfalfa, ladino clover, blue grass, brome grass and others are very satisfactory.

Where feeders are to be used outside, they should be waterproof and windproof so that the feed is not spoiled or blown away (See *Figure 21).* The feeders should be placed on skids, or be small enough so that they can be moved by hand. Trough-type feeders are inexpensive and relatively easy to construct. Specialized turkey feeding equipment can also be purchased. To prevent excessive feed waste, all feeding equipment should be designed so that it can be adjusted as the birds grow. The lip of the feed hopper should be approximately on line with the bird's back to prevent waste, and the feed level in the hopper should be kept at about half to prevent waste. Pelleted feeds are less likely to be wasted on range. Provide two 10-foot feeder troughs per 100 birds if the flock is hand fed each day. When bulk feeders are used, feeder space should conform to the equipment manufacturers recommendations. Provide one 4-foot automatic trough

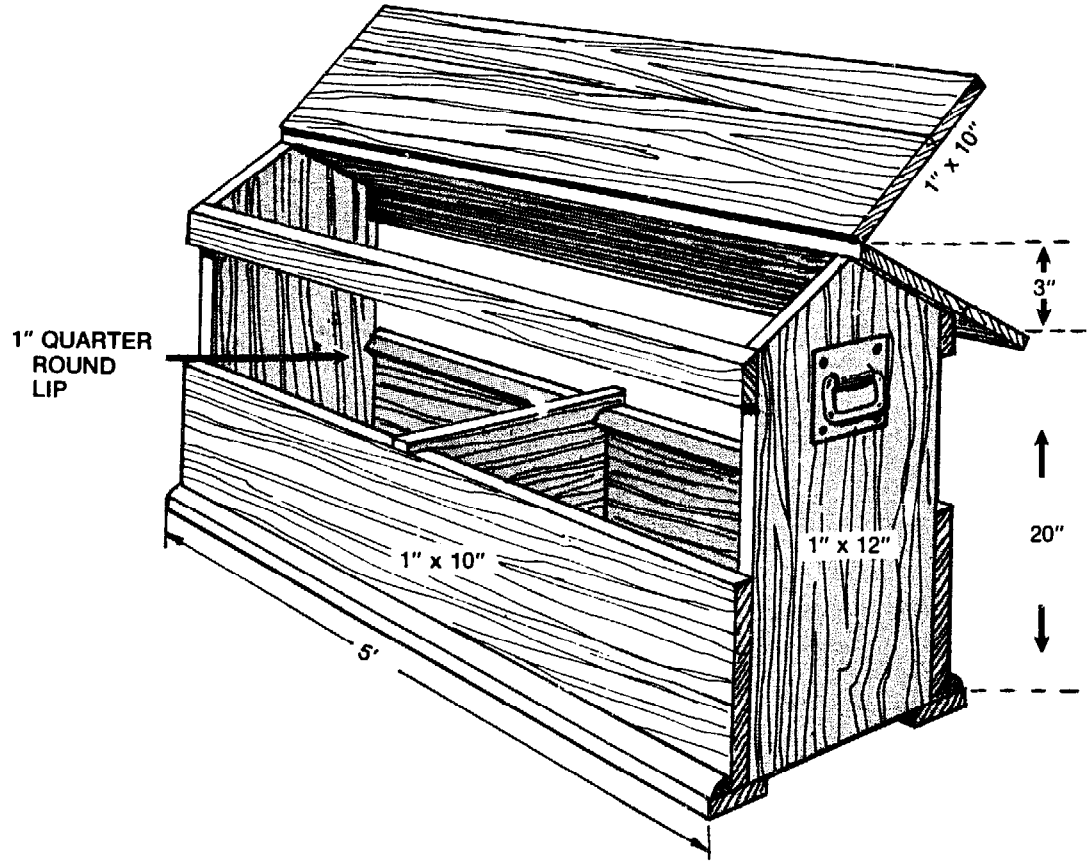

(Figure 21. A Range Feeder.)

waterer or the equivalent per 100 birds. The waterers should be cleaned daily and disinfected weekly. If possible, the waterers should be shaded with portable or natural shade.

The range shelters should provide roosting space and cover for the birds during adverse weather and hot sun *(Figure 22).* During the hot period of the year, particularly when birds are close to marketing time, it is advisable to pull extra shelters onto the range to provide more shade for the birds when natural shade is not available.

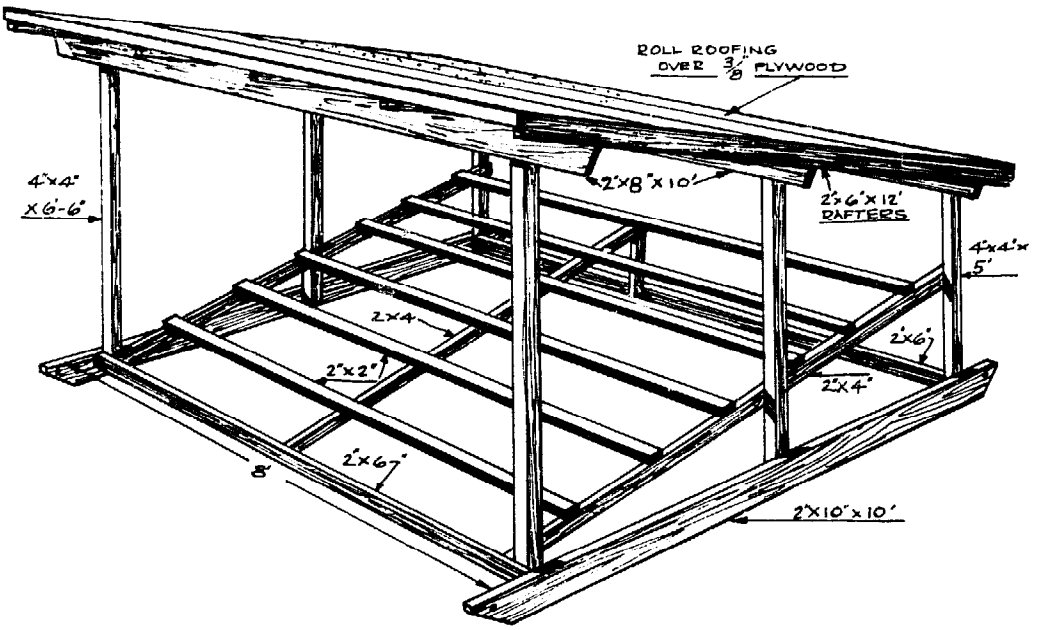

(Figure 22. A Turkey Range Shelter.)

debeaking

It is recommended that the poults be debeaked when they are from 2-5 weeks of age. Delaying beyond this period makes it difficult to handle the heavier birds and excessive feather picking may occur. To prevent cannibalism and feather pulling, debeaking should be regular practice before noticeable picking occurs.

The poults should not be debeaked at day of age at the hatchery, as this can interfere with the birds ability to eat and drink and may cause starveouts and dehydrated birds. The debeaking job is done with an electric debeaker and about ½ of the upper beak should be removed, being careful not to cut into the nostril. When birds are debeaked it is

necessary to make sure that the feed and water levels are deep enough for the debeaked birds. See *Figure 23* for correct debeaked appearance of turkeys.

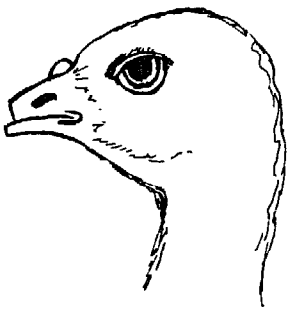

(Figure 23. Properly debeaked young turkey.)

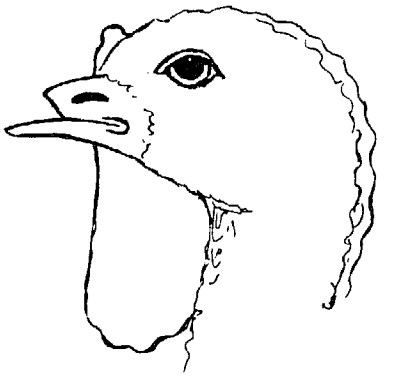

(Figure 23a. Properly debeaked adult turkey.)

desnooding

The snood (a fleshy appendage on the top of the head back of the beak) is sometimes removed. Removal of the snood helps to prevent head injuries as a result of fighting or picking, and may prevent erysipelas infection from getting started in the flock. The snood may be removed at day old by pinching between the finger and thumb nail. It may be cut with finger nail clippers or scissors up to approximately 3 weeks of age.

wing clipping or notching

The wing feathers of one wing are sometimes cut off with a sharp knife to prevent the birds from flying, if on range. Wing notching, or the removal of the end segment of one wing with a debeaker, is another method sometimes used to prevent flying on range. Wing notching can be done with an electric debeaker from day of age up to 10 days of age. Wing clipping and wing notching are not used as much as they once were because of injuries resulting when the birds attempt to fly. This may cause carcass bruises and detract from the dressed appearance.

toe clipping

Toe clipping is frequently done to prevent scratches and tears of the skin on the bird's backs and hips. It is especially helpful where birds are crowded or nervous, but appears to help even when birds are on the range. The two inside toes are clipped so that the nails are completely removed. Surgical scissors or an electric debeaker may be used. This should be done at the hatchery.

general management recommendations

Young poults should be isolated from older turkeys. Care should be taken not to track disease organisms from the older stock to the younger stock. A good control program for mice and rats should be followed. These rodents are not only disease carriers but also consume large quantities of feed. Rats can kill young poults. Ideally, no other avian species such as chickens, game birds or waterfowl should be on the same farm. However, with the medications available today, it is possible to grow small flocks of turkeys where other types of birds are kept, if they are kept separate. It is still somewhat risky. If abnormal losses or disease symptoms occur, birds should be taken promptly to a disease diagnostic laboratory for diagnosis. One of the first symptoms of a disease problem is a reduction in feed and water consumption. Without good records on daily feed consumption it is difficult to detect changes in feed intake. Dead birds should be disposed of immediately in a sanitary manner, by incinerating or by use of a disposal pit.

With good management, the turkey grower should be able to raise 95% of the turkeys started to maturity. With high poult costs and feed costs, mortality can become very costly, especially when birds are lost towards the latter part of the growing period.

Depending upon the disease exposure in the given area it may be necessary to vaccinate the poults for such diseases as Newcastle, fowlpox, erysipelas, or fowl cholera. In planning a vaccination program for your flock, check with the poultry diagnosticians at your state laboratory, your County Extension Agent, or some other knowledgeable person. Frequently small flocks are not vaccinated.

Medication is effective in reducing losses from such diseases as

coccidiosis and blackhead when used in the feed at preventive levels. Antibiotics and other drugs are of value in preventing and treating diseases, but such medications should not be used as a substitute for good management.

the production of turkey hatching eggs

Occasionally there are individuals who want to mate a few turkeys for the production of hatching eggs. The turkey breeding flock is not only somewhat more difficult to manage than the chicken breeding flock but is considerably more expensive. The cost of growing the bird to maturity is several dollars *(Table 18)*, and the amount of feed required to maintain the hens and toms during the holding and breeding periods is also substantial *(Table 21)*.

TABLE 21

FEED CONSUMPTION OF TURKEY BREEDERS
(POUNDS PER BIRD PER DAY)

Type Turkey	Hens	Toms
Large	.60	1.00
Medium	.45	.75
Small	.35	.65

Source: *Turkey Production AGR Handbook No. 393 U.S.D.A.*

selecting the breeders

Those turkeys to be kept as breeders should be started about 8 months before egg production is desired. Those that come into production at too early an age lay small eggs. Fertility tends to be poorer in small eggs.

Select only the best birds as breeders. Look for candidates with good, full breasts, (those with no protruding keel bones). Select for strong, straight legs, straight keel bones, and straight backs. Use only those birds that are healthy and vigorous for breeders.

mating

One tom per 20 hens is adequate for the light type breeders. Medium turkeys can be mated at the ratio of 1 tom per 18 hens. Large turkeys require 1 tom for 16 hens. A few extra toms should be kept to replace poor mating birds or those that die.

lighting

The usual procedure is to commence lights on the toms about 4 to 5 weeks prior to mating. The toms need this light period to stimulate them to produce sperm. The hens should receive light about 3 weeks prior to the onset of egg production.

A 13 to 14 hour light period, artificial and natural combined, should be used. A 50 watt bulb for each 100 square feet of floor space is adequate. A time clock can be used to bracket the natural daylight hours with artificial light.

egg production

Turkeys are not as good layers as most chickens. Heavy strains may be expected to produce 40 to 50 eggs during the season. Medium turkeys lay 50-70 eggs per hen and the small strains 85 to 100 eggs per bird.

First year egg production is best. After the first year, production diminishes at the rate of approximately 20% each succeeding year. Egg size increases with age and hatchability tends to decrease.

mating habits

Females will not mate until they commence egg production. Toms must be ready for semen production when the hen is ready to mate. The toms strut most during the mating season. When the hen is ready to mate she approaches the tom of her choice. The hen squats near the tom and the male mounts her and copulation usually takes place. Some toms may never mount the hen, others may mount but not complete the insemination. When the male performance is not satisfactory, the hen may become disinterested and not mate for a period of time. If this happens, low fertility can result.

fertilization

Fertilization of the egg takes place in the upper part of the oviduct. Sperm are stored there for several days to several weeks and can fertilize eggs up to 3 weeks after insemination. Storage life of the sperm shortens as the birds become older.

artificial insemination

Some breeder hens are fertilized totally by artificial insemination. Others are artificially inseminated on a supplemental basis to improve fertility where natural mating proves to be less than satisfactory.

The semen used for artificial insemination is obtained by milking the toms. Semen can be collected from the toms 2 or 3 times per week. The tom is stimulated by stroking its abdomen and pushing the tail upwards and toward the head. The male copulatory organ enlarges and partially protrudes from the vent. By gripping the rear of the copulatory organ with the thumb and forefinger from above and fully exposing the organ, the semen is then squeezed out with a short sliding downward movement. The males soon become trained and ejaculate easily when stimulated. The semen is collected in a small glass beaker or a stoppered funnel. The tom yields 2/10 to 5/10 of a cubic centimeter. The semen should be clear and free of fecal material. Some producers withhold feed and water from the toms for 8-12 hours to help avoid fecal contamination of the semen.

Semen should be used within 30 minutes. About 1/40 cc of semen per hen is adequate. Usually good fertility will result when hens are inseminated 2 times at 4 day intervals at the onset of egg production. Insemination every 2 or 3 weeks thereafter is usually desirable unless fertility is high in the mated flock.

The hen is inseminated by exposing the opening of the oviduct and inserting a small syringe without needle into the oviduct about 1½ inches. The oviduct is exposed by pushing outward and exerting pressure on the abodmen, while at the same time forcing the tail upward toward the head. The oviduct can be exposed or protruded only in those hens that are in laying condition.

broodiness

Broodiness is an inherited characteristic. Turkeys are inclined to be more broody than most breeds of chickens. Some strains of turkeys are more broody than others. It is difficult to identify broody turkeys. If the birds are found on the nest in the early morning or evening it is safe to assume they are broody. Broody birds should be driven into a broody pen or yard and left there for about five days. The birds should be fed and watered in the broody pen. Dark spots and areas where they can rest should be eliminated. No nests should be provided. Slat or wire floors are best for broody pens. One or more toms in the pen will tend to keep the hens on their feet and discourage broodiness. Hens usually want to mate a few days after they go broody so this practice may also improve fertility.

Broodiness may be discouraged by moving the birds to different areas, by providing roosts and chasing birds off the nest when the eggs are gathered. Gathering eggs several times each day may also help prevent broodiness.

housing

Buildings which are used for brooding young stock are satisfactory for breeders. Confinement is preferred to range management where unfavorable weather is common or where there are predators that may be a problem. The houses should be well insulated and ventilated for maximum comfort in cold or warm weather. The floor can be cement, asphalt or wood. It should be covered with a good litter. Houses should be thoroughly cleaned and disinfected between flocks.

More floor space is required for breeders. Usually 6 to 8 square feet per bird is recommended. Where only females are housed 5 to 6 square feet is adequate for large turkeys and 4 to 5 for small ones.

In warm climates or where winters are mild, breeders may be given access to fenced range or yard. They should have a shelter to protect them from bad weather and predators. The range area should be well drained and provide about 150 square feet per bird. Where a yard is used, allow 4 to 5 square feet of area per bird. The shelter should be equipped with roosts and provide at least 4 square feet of floor space per bird. The feeders, waterers and the broody pen are best located inside the shelter.

nests

Provide one nest for every 5 birds. Nests should be located in a dark area of the house. They should be available prior to the time egg production starts so the hens will get used to them.

Some breeders prefer tie-up or trap nests but open type nests may be used. Nests should be 2′ x 2′ if they are the manger or open type. If nests are placed outside the shelter they should be protected by a roof.

feeding

Breeders should be put on a special turkey breeder diet one month before egg production is expected. Feed according to the manufacturers instructions. All-mash diets are preferred but mash and grain diets are satisfactory if fed in the right proportions. If too much grain is fed in relation to the mash, egg production and hatchability may be reduced. If used properly this method has the advantage of making use of home-grown grain without having to grind or mix it. Home-grown grains can be used in an all-mash program by grinding and mixing with a concentrate at home or having them mixed elsewhere.

Mash or concentrate may be in a pelleted form. There is less waste with pelleted feeds, particularly if fed on range. An insoluble grit or gravel should be available for confinement breeders. When the birds are fed and watered out-of-doors the equipment should be moved frequently to avoid muddy spots and possible sources of disease.

Six linear inches of feeder space should be provided for large turkeys and 4½ linear inches for the small birds.

Provide two automatic waterers per 100 birds. One linear inch of water space per hen is adequate. Turkeys normally consume 2 pounds of water for every pound of feed. Lack of water can be more harmful to the birds than the lack of feed.

care of eggs

Eggs should be gathered at least 3 times per day, more frequently if the birds tend to crowd certain nests. Frequent gathering will help to avoid breakage, dirty eggs and possibly frozen eggs.

If eggs are cleaned they must be cleaned properly, using a detergent sanitizer made for egg washing. A washing temperature of 110° to 115° F. is recommended. Excessively dirty eggs gathered in hot, wet weather may easily become contaminated. Contaminated eggs often explode in the incubator.

If eggs are to be held before incubating they should be turned daily. When eggs are turned and held under good storage conditions hatchability may be good for two weeks. Eggs can be placed in filler-flats or cartons. The container can be elevated at one end to slant the eggs about 30°. At least once each day, shift ends with the container and elevate the opposite end. Hatchability will be improved if this is done.

flock health

The hens should be debeaked when placed in the breeding pens. Remove about one-half of the upper beak *(Figure 23)*. Feed and water levels should be maintained at a height that will permit the debeaked birds to eat and drink.

Some states require that breeders be blood tested for Salmonella pullorum and Salmonella typhoid and possibly other diseases such as infectious sinusitis, paratyphoid and PPLO (pleuro-pneumonia-like infection.) Follow the recommendations of your County Agent, State Extension poultry Specialist or diagnostic laboratory.

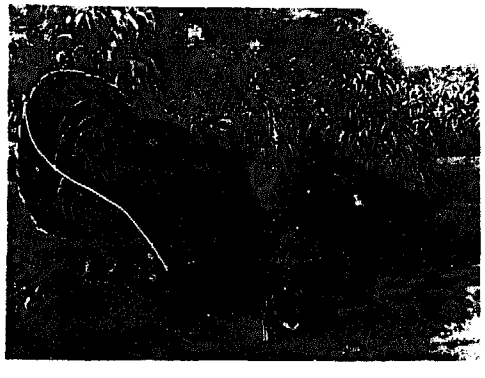

Bronze Turkeys

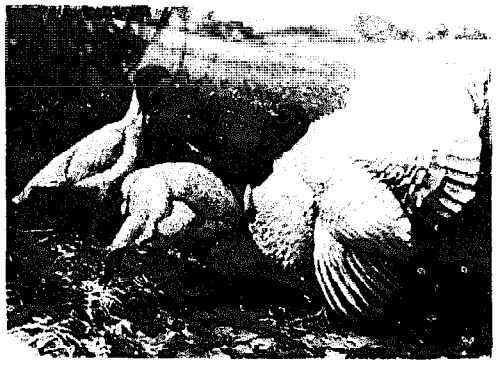

Broad Breasted White Turkeys

Source: *Poultry Tribune, Mount Morris, Illinois.*

10

WATERFOWL PRODUCTION

Waterfowl can be raised with relative ease. They are hardy and not subject to as many diseases as are other types of poultry. Numerous small flocks of waterfowl are grown to grace a small pond, as a hobby, or for exhibition. Not to be overlooked is the fact that properly finished and dressed, waterfowl are excellent for food. A number of people, in fact, prefer waterfowl to other types of poultry for the Thanksgiving and Christmas holidays.

Breeds Of Waterfowl

ducks

There are several breeds of ducks available. The breed one selects will depend upon the purpose for which they are to be raised. If ducks are to be kept for meat purposes, then the best choices include the White Pekin, the Aylesbury, the Rouen and the Muscovy ducks. If they are to be kept for ornamental purposes, or for hobby or exhibition purposes, the small ducks may better fit the bill. Included in this group are the White and Grey Calls,

the Wood duck, Mandarin, and Mallard. If the interest is in a breed of ducks which produce eggs, then the choice should be the Khaki Campbells or the Indian Runners.

Meat Breeds

white pekin

The White Pekin is well suited for the production of meat. It produces good quality meat and reaches a market weight of about 7 pounds in approximately 8 weeks. It is a large, white feathered bird. Its bill is an orange-yellow color, its legs and feet a reddish-yellow color and it has a yellow skin. The adult drake weighs 9 pounds, the adult duck 8 pounds.

The White Pekin is a fairly good egg producer. The average yearly egg production reaches approximately 160 eggs. It is a poor setter and seldom raises a brood of ducklings.

aylesbury

The Aylesbury originated in England and, like the White Pekin duck, is a good meat bird. It reaches market weight in about 8 weeks. The Ayelsbury has white feathers, white skin, a flesh colored bill, light orange legs and feet. The eggs are tinted white. The adult drake weighs 9 pounds, the adult duck 8 pounds. It lays somewhat fewer eggs than the White Pekin and is also a poor setter.

muscovy

There are several varieties of Muscovies, the white being the most desirable for market purposes. They produce meat of excellent quality and taste, when marketed before 17 weeks of age. They are relatively poor egg producers but good setters. The adult drakes weigh 10 pounds, the adult ducks 7 pounds. Muscovies have white skin.

rouen

The Rouen duck reminds one of the Mallard. It has the same striking

color patterns as the Mallard but is much larger. The adult drake weighs 10 pounds, the adult duck 9 pounds. Its pigmented plumage gives it a less desirable dressed appearance. It is excellent for home consumption, where the dressed appearance is not so important.

Egg Producing Breeds

khaki campbell

The Khaki Campbells were developed in England. Several varieties of the Khaki Campbell ducks have been selected for high egg production. The egg production of some of these varieties is reported to average close to 365 eggs per duck in a laying year. It is interesting to note that this is a higher rate of production than the highest producing strains of chickens.

The male has a brownish bronze lower back, tail coverts, head and neck, and the rest of his plumage is khaki. The beak is greenish black and the legs and toes brown. The adults weigh only 4½ pounds, thus the Khaki Campbell is not known for the production of meat.

the indian runners

Although the Indian Runners originated in the East Indies, their egg production qualities were developed in Europe. They are second only to the Khaki Campbell in egg production. There are three Indian Runner varieties, the White Penciled, Fawn, and White. All of these varieties have orange to reddish-orange feet and shanks. The males and females weigh approximately 4½ pounds. They are not good meat birds.

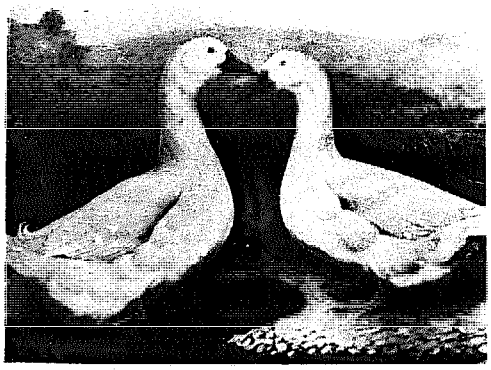

Pekin Duck

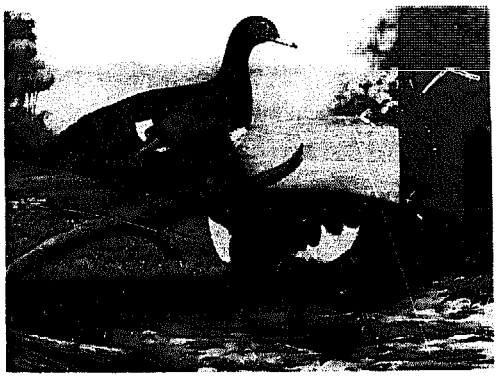

Colored Muscovy Ducks

Source: *Poultry Tribune, Mount Morris, Illinois*

Breeds Of Geese

The most popular breeds for meat production are the Toulouse, Emden and African geese. Other common breeds in the United States include the Chinese, Canada, Buff, Pilgrim, Sebastipole and Egyptian.

In choosing a breed one should consider the purpose for which they are to be raised. Geese may be raised for either meat or egg production or as weeders for show birds, or as farm pets. Some of the cross breeds, such as the cross between the white Chinese male with the medium sized Emden female, usually results in fast growing white geese of good market size.

toulouse

The Toulouse has a broad, deep body and is loose feathered, a characteristic which helps give it its large appearance. The plumage is dark grey on the back, gradually shading to a light grey edge with white on the breast and white on the abdomen. The bill is pale orange and the shanks and toes are a deep reddish orange.

emden

The Emden is a pure white goose. It is a much tighter feathered bird than the Toulouse and, therefore, appears more erect. Egg production averages from 35-40 eggs per bird. The Emden is a better setter than the Toulouse and is one of the most popular breeds for meat. It grows rapidly and matures early.

african

The African has a distinctive knob on its head. The head is a light brown, the knob and bill are black and the eyes dark brown. The plumage is ash brown on the wings and back and a light ash brown on the neck, breast and underside of the body. It is a good layer, grows rapidly and matures early. It is not as popular for meat production because of its dark beak and pin feathers.

chinese

The Chinese are smaller than the other standard breeds. There are two varieties, the brown and the white. Both varieties mature early and are better layers than are the other breeds. They average from 40-65 eggs per bird annually. The Chinese grows rapidly. It is a very attractive breed and makes a desired medium sized meat bird. It is very popular as an exhibition and ornamental breed.

canada goose

The Canada Goose is the common wild goose of North America. The weight of the Canada Goose ranges from about 3 pounds for the lesser Canada Goose to about 12 pounds for the giant or greater Canada Goose. The Canada is a species different from other breeds of geese. It can be kept in captivity only by close confinement, by wing clipping or pinioning the wings. They may be kept only by permit which must be obtained from the Fish and Wildlife Service of the United States Department of Interior in Washington, D.C.

The breed does not have the economic value of other breeds of geese, they mate only in pairs, are late maturing, and lay very few eggs.

pilgrim

The Pilgrim is a medium sized goose and is good for meat production. The males and females of this breed can be distinguished by feather color. In day old goslings the male is a creamy white and the female is grey. The adult male remains all white and has blue eyes. The adult female is grey and white and has dark hazel eyes.

buff

This has only fair economic qualities as a market goose and only a limited number are raised for meat. The color varies from the dark buff on the back to a light buff on the breast and from light buff to almost white on the under part of the body.

sebastipole

The Sebastipole is a white ornamental goose which is very attractive because of its soft plume-like feathering. The breed has long curved feathers on its back and sides and short curled feathers on the lower part of the body.

egyptian

This is a long-legged but very small goose. It is kept primarily for ornamental or exhibition purposes. Its coloring is mostly grey and black with touches of white, reddish brown and buff.

Getting Started

Those who wish to raise a small flock of ducks or geese can best get started by the purchase of day-old ducklings or goslings. This eliminates the need for keeping breeding birds and incubating the eggs. Day old stock is available in most areas of the country. A list of those hatcheries selling waterfowl is printed in the National Poultry Improvement Plan, Hatchery list. This can be obtained by writing to the United States Department of Agriculture in Washington, D.C. Other good sources of information concerning the availability of young birds include the state Extension Poultryman and the County Extension Agent in your area.

brooding and rearing

As is the case with other types of poultry, waterfowl need to be put on feed and water as soon as they are placed under the brooder. Young ducklings, and particularly young goslings are somewhat more hardy than are chickens and turkeys. However, they do need to be kept where it is warm, dry, and free of drafts. Most any type of building that will provide these conditions is suitable for brooding ducklings or goslings. The building should be designed so that it can be ventilated without chilling the birds.

The brooder house should be cleaned and disinfected well before the time the birds are to arrive. When they arrive, the house, the litter, the feeding and watering equipment and the brooder stove should be ready. The brooder should be operating at least one day before the birds arrive. The first day a brooder guard should be placed approximately 2 feet from the hover. It should be gradually moved back and entirely removed at about 7 days. The brooder guard will confine the birds to the brooding area and prevent huddling and chilling before they are able to adjust to the location of the heat source.

Waterfowl may be started on wire, slat or litter floors. The most practical method is to start them on litter floors. Wood shavings, sawdust, chopped straw or peat moss are all good litter materials. The material to be used should be free of mold, since moldy litter can cause mortality. The proper equipment arrangement for brooding is shown in *Figure 10.*

The birds should have adequate floor space. Ducklings need ½ square foot of floor space per bird the first week, ¾ of a square foot the second and 1 square foot the third week. If they are to be housed in confinement this space allotment will need to be increased to 2½ square feet by the time they reach 7 weeks of age. Goslings will need more floor space. They should have ½ to ¾ of a square foot of floor space the first week and 1 to 1½ square feet the second week. The amount should be increased slightly until they go on range. They can be placed on range when 2 to 4 weeks of age. No shelter is needed but some type of shade should be provided. Ducklings normally need supplementary heat for approximately 4 weeks. During warm weather or in warm climates, heat may be needed for just the first two or three weeks. Goslings usually can get by without heat after 2 weeks of age. Waterfowl feather very rapidly and thus do not require as long a brooding period as do baby chicks. Any brooder unit suitable for brooding chicks or turkeys is satisfactory for ducklings or goslings. Electric, gas, oil, coal or wood burning brooder units are all suitable.

Infrared heat lamps are excellent for brooding small groups of birds. One infrared lamp for up to 30 birds is satisfactory. To determine the number of ducklings or goslings a hover type brooder will accommodate, cut the brooder's rated chick capacity in half. They require 13 to 14 square inches of hover space per bird.

The brooder temperature should be in the vicinity of 85-90° F. the first week, and reduce approximately 5° per week during the next few weeks. The behavior of the young birds is the best guide to the temperature required (See *Figure 11).* When the temperature is too hot, the birds will crowd away from the heat. High temperatures may result in slower weight

gains and slower feathering. When the temperature is uncomfortably cold the birds will tend to huddle together under the brooder or, perhaps, crowd into corners. When a hover-type brooder is used, a night light will tend to discourage crowding; where infrared brooders are used, enough light is provided to make extra light unnecessary. When the temperature is just right the birds will be well distributed over the floor and using all the feeders and waterers.

Keep clean drinking water in front of the birds at all times. Hand-filled water fountains or automatic waterers may be used. Place the water fountains on wire or slatted platforms or over a screened drain. This will help to keep the litter dry. The waterers should be of the type that the birds cannot get into. Waterers should be cleaned daily.

Waterfowl should have access to range or a yard when old enough to tolerate the weather conditions. Ducklings will manage nicely on range at 4 weeks of age unless the weather is cold. Goslings can be placed out-of-doors at 2 weeks of age weather permitting. They need shade and cannot tolerate chilling rains until they are well feathered on the back. When birds reach 5-8 weeks of age they need shelter only during extreme weather conditions. Most commercial growers provide ponds for their birds at approximately 5 weeks of age. However, waterfowl can be raised without swimming water.

As with other types of poultry, feather pulling can be a problem with ducks. If this vice starts, the birds should be given additional space. It may be necessary to debill the birds if the problem continues. This is done by nipping off the forward edge of the upper bill with an electric debeaking machine.

feeding and watering space

Several types of feeders are satisfactory for waterfowl. Feed hoppers, such as those used for chickens and shown in *Chapter 2, Figures 3* through *3e,* work well. Small feeders can be used until the birds are two weeks of age. Large feeders should be used for older birds and breeding stock. Feed hoppers that are used outdoors should be covered to protect the feed from wind and rain. A range feeder designed for chickens or turkeys will work well. A plan for a range feeder is also shown in *Chapter 2.*

To start ducklings and goslings off it is well to use chick box covers, shallow pans, or small chick feeders. Hanging tube-type feeders are excellent. One of these with a pan circumference of 50″ is suitable for 50 ducklings or 25 goslings for the first two weeks.

Pans or troughs are satisfactory waterers. They should be equipped with wire guards or grills to prevent the birds from playing in them and spilling water. The waterers should be placed over low wire covered frames, and preferably, over drains to prevent the litter from getting too wet. A water stand which is satisfactory for waterfowl is shown in *Figure 5.* Increase the size and number of waterers as the birds become older. Approximately 4′ of trough is good for 250 young waterfowl for the first few weeks. The waterer should be wide enough to permit the bird to dip its bill and head into it.

feeding

Some commercial feed companies formulate rations specifically for ducks and geese. However, in a number of areas specially prepared rations will not be available. It is possible to mix your own feed. But before doing so, write to your Extension Poultry Specialist for formulas. If feeds for ducks are not available, they may be started on crumbled or pelleted chick starter for the first 2 weeks. Pellets are recommended because they are easier to consume. They also reduce waste, and do not blow around like mash when used out of doors. Feed conversion is usually better with pellets. However, the lack of pelleted feed should not discourage a grower who wishes to produce ducks or geese on a small scale. Satisfactory results can be obtained with mash. If a chick starter is used, it is desirable that the starter not contain any drugs which may be harmful to the ducklings. The use of a medicated feed is not usually necessary. Coccidiosis is not nearly the problem in ducklings that it is in chickens, though it does affect some flocks.

Ducklings and goslings do well on a starter diet that contains 22% protein. At 2 weeks of age thay can be changed to a 15 to 18% protein diet. If a special grower diet is not available a chick grower is satisfactory. When ducks are to be dressed as green ducks, that is at 7-9 weeks of age, this diet can be fed for the full period. In addition to a pelleted grower ration, cracked corn or other grains are often included in the diet for goslings. Feed should be kept before the birds at all times, and an insoluble grit provided. Grit enables the gizzard to grind fibrous material so that it can be passed on and further digested in the intestine. Ducks are not as good foragers as geese but may be put on pasture at 4 weeks of age if to be kept beyond the 7 to 9 week period. Feed consumption and liveweight information for ducks and geese are shown in *Tables 22* and *Table 23.*

TABLE 22

AVERAGE LIVEWEIGHT, FEED CONSUMPTION AND FEED CONVERSION RATIOS OF WHITE PEKIN DUCKLINGS AT DIFFERENT AGES MIXED SEXES

Age	Liveweight	Feed Consumption Weekly	Feed Consumption Cumulative	Feed/lb of weight gain to date
weeks	lb.	lb.	lb.	lb.
1	0.60	0.50	0.50	0.83
2	1.68	1.64	2.14	1.27
3	2.98	2.55	4.69	1.57
4	4.01	2.55	7.24	1.81
5	5.13	3.27	10.51	2.05
6	6.19	3.57	14.08	2.27
7	6.96	3.87	17.95	2.58
8	7.54	3.39	21.34	2.83

Source: *Cornell University*

TABLE 23

GROWTH RATE AND FEED CONSUMPTION OF WHITE CHINESE, EMBDEN GOSLINGS

	Confinement-reared			Range-reared		
Age	Avg wt per gosling	Cumulative feed consumption per gosling	Feed per lb. of gosling to date	Avg wt per gosling	Cumulative feed consumption per gosling	Feed per lb. of gosling to date
weeks	lb	lb	lb	lb	lb	lb
3	3.3	5.25	1.75	3.3	5.25	1.75
6	8.1	17.32	2.22	7.8	12.60	1.68
9	10.8	34.92	3.32	10.1	19.97	2.03
12	12.3	47.54	3.96	11.6	30.62	2.71
14	12.8	56.09	4.48	11.8	38.10	3.31

Source: *Duck and Goose Raising, Ministry of Agriculture and Food — Ontario*

The Breeding Flock

If a breeding flock is to be kept the prospective breeders may be selected at about 6-7 weeks of age. A few extra should be selected at that time to allow for culling in the future. Birds selected for breeders should then be placed on a breeder developer diet, a diet containing less energy than the starter or grower diets. Frequently the breeder developer diet is fed on a restricted basis to prevent the birds from becoming too fat. Birds that are too fat will lay fewer and smaller eggs. Where a diet is fed on a restricted basis, have plenty of feeder space or spread the pellets over a wide area to make sure that all of the birds get their share.

To obtain optimum fertility, it is best to feed a special breeder diet. Breeder birds should be switched to the special diet a month prior to the date of anticipated egg production. If a breeder developer diet is not available, a growing ration can be fed during this time.

selecting and mating the breeder flock

Ducks to be used as breeders are usually selected from the spring hatched birds. They may be selected at 6 to 7 weeks of age. It is possible at that time to differentiate the males from the females by their voices. The females honk and the males belch. (See the section on sex differentiation for further information). The ratio of drakes to ducks is normally 1 to 6. A few extra should be selected to take care of mortality or to permit further selection during the growing period.

Breeders should be selected for vigor, body weight, conformation, and feathering as well as breed characteristics. Although ducks demonstrate some selectivity in mating they are essentially polygamous in their mating habits.

Geese are somewhat different in their mating habits. Some breeds tend to be monogamous, the Canada Goose being an example. Layer breeds mate better in pairs or trios, and the ganders of some of the smaller breeds may accept 4 or 5 females. When selecting geese for the breeding flocks, select for body size, rate of growth, liveability, egg production, fertility and hatchability as well as breed characteristics.

housing and managing the breeder flock

Housing for waterfowl does not have to be as tight as that for chickens and turkeys. The pen should be well lighted, well ventilated and supplied with plenty of dry litter. Waterfowl, and especially geese, prefer to be outside even during severe winter weather. Insulated buildings are not too important. A simple shed, a small house or an area within an existing barn can be used as a breeder pen. If more than one trio occupies a shelter it should be divided to prevent fighting.

Dirt floors may be used but cement or wood floors are easier to clean and disinfect. Litter materials that are used for brooding are satisfactory for the breeders. The litter should be kept dry. Wet and caked areas should be removed and dry litter added from time to time as required. Floor space requirements vary depending upon the type of bird and whether or not a yard is available. Ducks in confinement need 5 to 6 square feet per bird and 3 square feet when a yard is provided. Geese having access to a yard should have 5 square feet per bird in the house. Up to 40 square feet per bird should be provided in the yard.

Windows and doors should be left open during the daylight period to allow adequate circulation of air. Good ventilation is also needed at night to prevent over-heating during hot periods and to reduce condensation during the winter. Supplementary heat is not necessary.

The birds will make their own nests in the litter and lay about anywhere in the house. They prefer a somewhat secluded spot. Simple nest boxes can be provided in rows along the wall. The nests should be 12″ wide, *18″* deep and 12″ high. Nests for large geese should be 24 inches square. Some prefer to not partition the nests at all. The tops and fronts of the nests are open. Straw and wood shavings make good nesting materials. The nesting material should be kept clean to prevent dirty and soiled eggs. One nest is adequate for every 3 to 5 breeders.

The pens may be kept drier if the watering devices are placed outside the house. Ducks and geese can go without water overnight, provided they do not have access to feed. When permitted to eat without available water they can choke to death on the feed. If the birds are locked in the house overnight with no water, the feeders should be empty or closed. If the birds are watered in the house, again, the water supply should be placed above a screened drain.

Yards should slope gently away from the house to provide good drainage. Mud holes and stagnant puddles of water are sources of diseases and parasites. Manure will accumulate in the yard, so it should be cleaned occasionally. The frequency of cleaning will depend upon the number of birds and the size of the yard. Large flocks are normally provided 75 square feet of yard space per bird.

Ducks have the tendency to run in circles if startled in the dark. This is a more serious problem with large flocks. An all night light should be used in the house if stampeding is a problem. One 15 watt bulb for each 200 square feet of floor space is adequate to prevent this.

The breeders should not be brought into full production before they reach 7 months of age. If production starts sooner there will be a problem of small eggs and low hatchability. Fourteen hours of light will stimulate them to produce in the fall and winter months when the days are short.

Females should be lighted three weeks before production. The males should be prelighted 4 to 5 weeks prior to mating. Pre-lighting will help fertility. The lamps used for preventing stampeding in duck pens will also stimulate egg production. However, larger bulbs give better light stimulation.

Ducks are much better layers than geese. They lay more eggs over a longer period of time. Geese tend to lay every other day but may lay 2 or more successive days. Daily gathering of eggs will help to discourage broodiness (the urge to set) and an accompanying pause in production. Separating broody birds from their mates and confining them with feed and water will sometimes discourage broodiness.

The birds should reach a peak of production at approximately 5 or 6 weeks after the onset of lay. The rate of production will depend upon the breed, the feeding program and the management they receive. Older geese make better breeders than the young ones. The geese lay more eggs their second year and 2 year old ganders tend to yield better fertility. Geese will lay until they are about 10 years old. Ganders may be kept as breeders for 5 years.

egg gathering and care

Ducks lay most of their eggs during the night and early morning hours. The eggs should be collected early so as to prevent them from getting soiled and cracked. The birds should be kept in the house each day until the eggs are laid. Eggs that are laid outside may freeze during severely cold

weather, killing the embryos. The eggs can also be badly soiled if laid outside. Eggs that are dirty should be washed soon after gathering. The wash water should be warmer than the eggs. The recommended wash water temperature is 115° F. If cold water is used it will cause the egg contents to contract, and bacteria and other organisms may be drawn through the pores of the shell and contaminate the egg contents. This can cause the eggs to explode in the incubator. The eggs should be washed in a detergent sanitizer which may be obtained from an agricultural supply house. The washing time is 3 minutes. The maufacturer's directions for use should be followed.

Badly misshaped, abnormally small or large eggs, or eggs that have been cracked, should not be saved for incubation. Chances are they will not hatch. The eggs should be stored at a temperature of 55° F. and a relative humidity of 75%. If hatching eggs are to be stored for more than a week prior to incubation, they should be turned daily. This will prevent the yolks from sticking to the shell membranes causing a reduction in hatchability. Eggs should be stored on egg filler flats or egg cartons. One end of the container may be propped up at an angle of 30°. Each day change ends with the container. Eggs that are stored for 2 weeks or longer decline in hatchability quite rapidly.

incubation

The incubation period for most domestic ducks is 28 days. The Muscovy requires 35 days. The Canada and Egyptian geese require 35 days, all other geese 30 days.

It is possible to incubate waterfowl eggs by natural means in small flocks. A goose will cover 9 or 10 eggs and a duck 10 to 13 eggs. While the Muscovy duck is a good setter, most other breeds of ducks are not. If available, a broody hen may be used and will cover 4-6 goose eggs, or 9-11 duck eggs. The nest should be placed where the hen won't be disturbed during the incubation period. A nearby source of feed and water should be provided for the setting hen. Where hens are used to incubate waterfowl eggs, the early hatched should be removed from the nest as soon as they are hatched and placed under a brooder. This will prevent the hen from leaving the nest before completion of the hatch, or trampling some of the young if she becomes restless.

The nest may be placed on the ground, or inside a building. Turkey hens and Muscovy ducks are larger and better than chicken hens for hatching duck and goose eggs. Ten to twelve goose eggs can be set under a turkey or duck, depending upon the size of the bird. Hens should be treated for lice before the eggs are set.

When chicken or turkey hens are used for setting, it is necessary to add moisture. The eggs should be sprinkled with luke warm water during the incubation period and the nest and straw should be placed on the ground or on a grass covered turf. This helps to increase the moisture. Some growers indicate that if the eggs are lightly sprinkled, or dipped in lukewarm water for half a minute daily during the last half of the incubation period they hatch much better. If ducks or geese have access to water for swimming no additional moisture is needed. If a setting hen does not turn the eggs they should be marked with a crayon or pencil and turned daily by hand. Usually the hen will turn them.

Artificial incubation is used extensively for hatching waterfowl eggs. In the large forced-draft machines a temperature of 99¼ to 99¾° F. is usually used. For the incubation of duck eggs the wet bulb thermometer reading during the incubation period should be 86-88° F. and during the hatching period 92° F. Since the humidity requirements are so much higher for waterfowl eggs than for chicken eggs, the two should not be set in the incubator at the same time.

In the small still air incubators the temperature should be 100½° F, 101½°F, 102½°F and 103°F respectively, for the first, second, third and fourth weeks of incubation. However, satisfactory results may be obtained by running the machine at an even 102° for the entire period. The thermometer reading should be taken at the top of the egg. The eggs in a still-air machine are set in a horizontal position, usually, and are turned 180 degrees on each turn. The eggs should be turned 3-4 times daily. The moisture requirements are the same for goose and duck eggs.

The eggs may be candled 4 to 6 days after incubation starts. Candling is done by passing the egg over an electric candling light in a dark room. The living embryo of the egg will appear as a dark spot at the large end of the egg near the air cell. From this dark spot radiates blood vessels giving a spider-like appearance. Embryos that have died will appear as a spot stuck to the shell membrane and no radiating blood vessels will be apparent. Infertile eggs will appear clear. The infertile egg should be removed from the incubator, along with any cracked eggs that are detected.

Usually the eggs are candled three days prior to hatching. At this time, the fertile eggs will appear dark, except for the large air cell end. The

infertiles will be clear. Turning of the eggs should be discontinued three days prior to the end of the incubation period. From that time to hatching, the eggs should not be disturbed other than to open the incubator to add water.

Since the hatching period for waterfowl tends to be spread out over several hours the large commercial hatcheries frequently take the birds out of the machines as they are hatched and dried. However, it is necessary to prevent chilling of the newly-hatched watefowl and it may be better for the small producer to keep the incubator closed until the hatch is complete.

Some ducklings appear to need help from the shell. Conditions in small machines are sometimes difficult to control so this practice may be justified. However, birds that are helped from the shell probably should not be used for breeding stock as heredity may be a factor responsible for this condition.

sex differentiation of waterfowl

In general, the determination of sex in ducks is somewhat easier than for geese. The drakes usually have larger bodies and heads and the males have a soft throaty quack, while females have a loud, distinct, harsh quack. Also the main tail feathers on the mature drake are curled forward and not on the ducks. In colored breeds of ducks, the males are more brilliantly colored than are the females.

Characteristics which are used to distinguish between the adult male goose and the female goose are the longer neck and a somewhat coarser and larger head, as well as the larger body of the male. There are differences in the voice between sexes, though these are somewhat difficult to determine. The African and Chinese geese have knobs on their heads. The knobs of the male are larger than those of the female. In immature stock these differences are hard to distinguish. Even in the mature geese, there are cases where there are oversized females and undersized males. The Pilgrim breed can be sexed from day-old to maturity by the use of plumage color. The color of the male is light or white and the female is a dove grey.

sexing goslings and ducklings

There are occasions when it becomes desirable to be able to sex goslings and ducklings at an early age. The vent sexing of day-old ducklings and goslings is very similar. The sexing is done in a warm room using a strong light, so that the reproductive organs can be easily seen. (See *Figures 24, 25* and *26).*

(Figure 24. Sexing day-old waterfowl.)

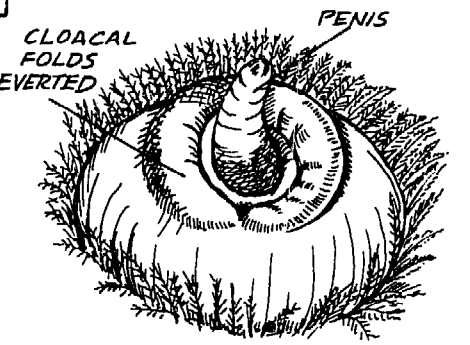

(Figure 25. Appearance of the male genital organ.)

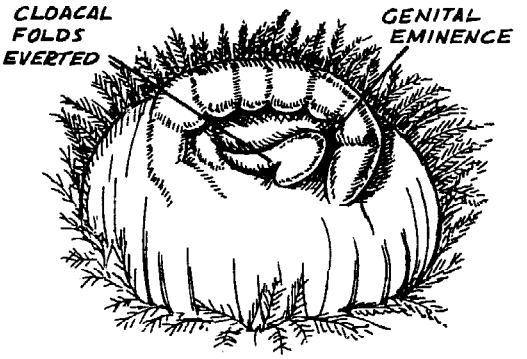

(Figure 26. Appearance of the female genital organ.)

sexing adult geese

The bird is held over the bended knee or a table — on its back — with the tail pointed away from you. The tail end of the bird is moved out over the edge of the knee or the table so it can be readily bent downwards. Then the index finger is inserted into the cloaca about a half an inch and moved around in a circular manner several times to enlarge and relax the sphincter muscle which closes the opening. Then pressure is applied directly below and on the sides of the vent to expose the sex organs.

range for geese

During warm weather, geese can be put on range as early as the second week. A good share of their feed can be forage after they are 5-6 weeks of age. Geese are better foragers than are ducks. They tend to pick out the young tender grasses and clovers. They reject alfalfa and narrow leafed tough grasses and select the more succulent clovers and grasses. Geese should not be fed wilted poor quality forage.

It takes approximately an acre of range to support 20-40 geese, depending upon their size and the quality of the pasture. A 3 foot woven-wire fence will confine the geese to the grazing area.

Where good quality pasture is available, the amount of pelleted ration may be restricted to about 1 to 2 pounds per goose, per week, until the birds are 12 weeks of age. The amount of feed should be increased as the supply of good forage decreases, or when the geese reduce their consumption of grass. If the birds are being grown to market as meat, they should receive pellets on a free-choice basis after they are 12 weeks of age, even though on range. Geese may be fed pellets, mash or whole grains. For the first 3 weeks they should receive a 20-22% protein goose starter preferably in the form of pellets. Less waste occurs with pelleted feeds. After 3 weeks of age feed a 15% goose grower in the form of pellets. If a specialized grower diet or starter diet for geese is not available then the equivalent chick starter and grower can be utilized. Again, the diets need not contain coccidiostats or other medications.

Mash or whole grains can be fed alone, or they can be mixed at a 50-50 mash to grain ratio. At 3 weeks of age a mash to grain ratio of approximately 60-40 may be used. The proportions should be changed

gradually during the growing period until, at market age, the geese are receiving a 40-60 ratio of mash to grain. Depending upon the quality and quantity of available range, these ratios may be adjusted up or down slightly. For maximum growth it is important that mash and grain mixtures provide a nutrient intake of approximately 15% protein, the same as the all-mash diet. Insoluble grit should be available to the geese throughout the growing period.

geese as weeders

Geese will eat many noxious weeds and are thus used as weeders for certain crops without seriously harming the crop. Geese are good weeders in orchards and for crops such as strawberries, sugar beets, corn, cotton and nursery stock.

For best results the goslings should not be more than 6 weeks old when started as weeders. Shade should be provided and waterers spaced throughout the field. The weeder goslings should be kept hungry. A light feeding of grain at night is enough and the amount is varied, depending upon the availability of weeds and grass in the crop which is being weeded.

If placed in a field before the weeds get a head start, 6-8 goslings properly managed can control the weed growth on one or possibly two acres of strawberries. After the fruit begins to ripen it is best to move the goslings to other crops, or put them on range, and fatten for market. A fence 30-36″ high serves to confine the goslings to the area to be weeded. Any pesticide, or insecticides that are used on adjoining tree crops, should not contaminate the weeds and grasses that are to be eaten by the goslings.

feathers

Duck and goose feathers have value. If properly cared for they may be a source of extra income, or they may be used at home. The feathers are used mainly by the bedding and clothing industries. It usually requires 5 ducklings or 3 goslings to produce one pound of dry feathers.

The feathers may be sold to specialized feather processing plants or a small producer can wash and dry them for home use. The feathers may be washed by using a soft lukewarm water to which has been added either a detergent or a little borax and washing soda. Following the washing, rinse, wring the moisture out and spread out to dry.

11

HOME PROCESSING OF EGGS AND POULTRY

Egg Processing

Eggs, as they come from the nest, vary in several respects. They vary in size, shape, cleanliness, shell texture, interior quality, and some will be cracked and checked. If the right management, the right environmental conditions, the proper feed has been provided a healthy flock, then the majority of the eggs will be of good quality. If the family consumption of eggs keeps up with the production of the birds, then there won't be too many problems with quality differentiation or quality preservation. However, on occasion some flocks produce more eggs than can be consumed by the family and some of them have to be sold. Eggs are sold on the basis of size and quality, and thus it is necessary to understand a little bit about egg quality determination and egg size requirements.

egg quality

The quality of an egg never improves after it is laid. Quality diminishes with time and the rate depends upon how the eggs are treated. To best

understand what happens to egg quality, a knowledge of the structure and the various parts of an egg is essential.

There are four basic parts to an egg, namely the shell, the shell membranes, the albumen and the yolk (*Figure 27*). Fastened to the shell are two membranes. It is between these two membranes that the air cell is formed usually at the large end of the egg. When the egg is first laid this air cell is non-existent, but with the cooling and contraction of the egg contents, the air cell begins to appear a short time after the egg is laid. Since the shell is porous, moisture can escape from the egg, so the air cell enlarges as the egg is held for a period of time. The rate at which the air cell increases in size depends upon the holding conditions.

A relative humidity of 75% in the cooler will keep the evaporation to a minimum. The yolk of a high quality egg is very near the center of the egg. On the surface of the yolk is a small white spot known as the germinal disc or germ spot. It is at this point that fertilization takes place. Whether the egg is fertile or infertile, the germ spot looks exactly the same. In other words, it is not possible to tell with the naked eye whether or not an unincubated egg is fertile. The yolk and the germ spot are enclosed by a thin membrane known as the viteline membrane.

The albumen or white of the egg is made up of alternate layers of thick and thin albumen. Surrounding the yolk is a thin layer of very dense albumen called the chalazeferous layer. From this layer of dense albumen extend the fibrous or cord-like structures called chalazae. These extend out towards the ends of the egg and are anchored in another layer of thick albumen. The chalazae tend to keep the yolk near the center of the egg.

Between the chalaziferous and outer layer of thick albumen there is an inner layer of thin albumen. If an egg is broken out and the thick albumen surface is cut, some of the thin albumen can be seen merging with the thick albumen.

After the egg is laid, a number of changes take place as far as the interior quality is concerned. The rate at which this takes place depends upon how the egg is handled. As mentioned earlier when an egg is laid there is no air cell, but as the contents cool and contract the air cell becomes apparent. A further increase in the size of the air cell is dependent upon the rate of evaporation of moisture from the egg. The rate of evaporation depends upon the thickness and texture of the shell as well as the temperature, relative humidity of the storage area and the length of the storage period. Air cell size is an important factor in grading eggs but actually has no significance as far as eating qualities are concerned.

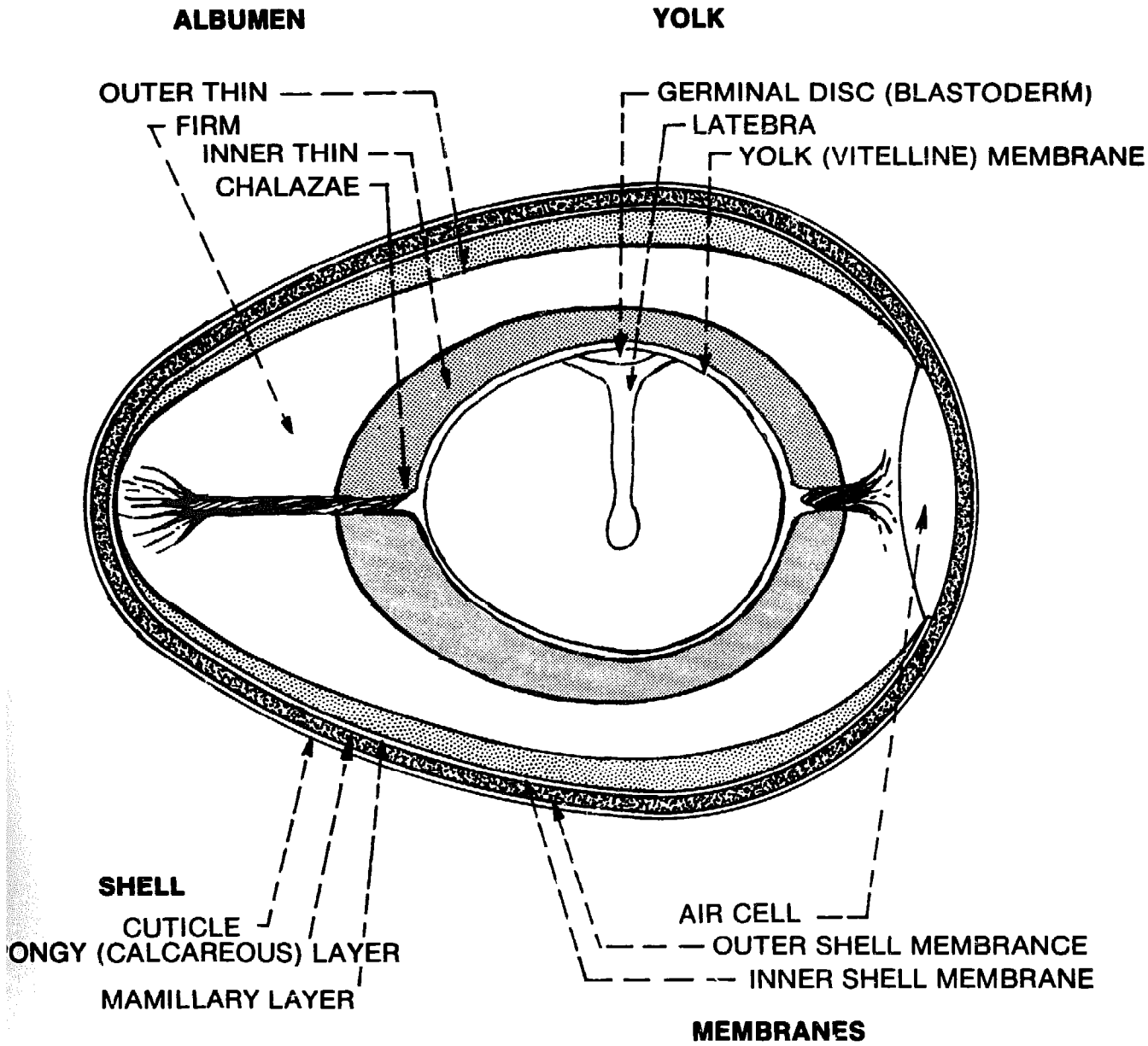

(Figure 27.)

During the holding period a change takes place in the thick albumen. It gradually breaks down into thin or watery albumen. If the egg is stored long enough, eventually there will be no evidence of thick albumen left. As a result of these changes, when eggs are broken out into a pan, the contents seem to spread over a large area and the yolk has a flattened and enlarged appearance. Most individuals frown on this type of egg because it is a sign of poor quality. An egg of high quality, when broken out, will have a large amount of thick albumen adhering to the yolk. The yolk will be upstanding and practically spherical in shape. When broken out, the egg will occupy a much smaller area in the pan. If a high quality egg that is hard-cooked is cut in two, the yolk will be well centered and the air cell small. With the low

quality egg the yolk may be close to, or touching the shell membrane and the air cell quite large.

Egg quality can be determined relatively easily with the use of a candling light. Candling is the process of twirling the egg before a light in a dark room. When a low quality egg is candled the yolk shadow will be plainly visible and off-center. The egg contents move about very rapidly when the egg is twirled. When an egg is of high quality the yolk appears centered, the shadow is only slightly visible, and the contents of the egg don't move as easily. Thus, candling is a fairly effective means of determining interior egg quality.

The standards of quality for individual shell eggs are set up by the United States Department of Agriculture *(Table 24).*

It should be noted that blood spots or meat spots are permissible in C grade eggs providing the single defect, or the total of several defects, is not more than ⅛" in size. Eggs containing blood or meat spots, not within these tolerances, are classified as inedible eggs.

Blood spots in the egg are usually found on the surface of the yolk. They may vary in size from a small speck to a large clot with some of the blood diffused throughout the entire albumen. Blood spots are caused by the rupture of one or more small blood vessels in the yolk follicle at the time of ovulation or in the oviduct during egg formation.

Meat spots are either blood spots which have changed in color, due to chemical action, or tissue that has sloughed off the oviduct of the hen during egg formation. Possibly 2% of the eggs produced contain blood or meat spots.

In addition to the interior quality factors which we have discussed, there are also exterior quality factors which must be considered. The more important exterior egg quality factors include condition or soundness of the shell and cleanliness. Leakers, dented cracks, and eggs with rough or thin shells, can be detected during processing without candling. Blind checks or hairline cracks can be seen during candling. Dirty and stained eggs should not be packed if to be marketed.

Weight classes of shell eggs *(Table 25)* are set up by the United States Department of Agriculture. The system uses the weight in ounces per dozen. For example, a single egg weighing 2 ounces is called a 24 ounce egg because a dozen of this size egg weighs 24 ounces. Uniformity of size in a market pack of eggs is important and there should be no more than a 3 ounce variation between each dozen. Small individual egg scales or larger automated scales are available for sizing eggs.

TABLE 24

SUMMARY OF UNITED STATES STANDARDS FOR QUALITY OF INDIVIDUAL SHELL EGGS (Specifications for Each Quality Factor)

Quality Factor	AA Quality	A Quality	B Quality	C Quality
Shell	Clean Unbroken Practically Normal	Clean Unbroken Practically Normal	Clean to very slightly stained Unbroken, may be slightly abnormal	Unbroken May have slightly stained areas Moderate stains permitted of less than ¼ of shell surface Prominent stains or adhering dirt not permitted.
Air Cell	⅛ inch or less in depth May show unlimited movement, may be free or bubbly	3/16 inch or less in depth May show unlimited movement, may be free or bubbly	⅜ inch or less in depth May show unlimited movement, may be free or bubbly	May be over ⅜ inch in depth May show unlimited movement, may be free and bubbly
White	Clear and Firm	Clear and reasonably firm	Clear, may be slightly weak or thin	May be weak and watery Small blood spots or clots may be present* *(aggregating not more than ⅛ inch in diameter)

(Continued on p. 148)

Table 24 (cont'd)

Quality Factor	AA Quality	A Quality	B Quality	C Quality
Yolk	Outline only slightly defined Practically free from defects	Outline may be fairly well defined Practically free from defects	Outline may be well defined May be slightly enlarged and flattened May show definite but not serious defects.	Outline may be plainly visible May appear dark, enlarged and flattened before candling light. May show clearly visible germ development, but no blood due to such development. May show other defects which do not render the egg inedible. Small blood clots or spots (aggregating not more than ⅛ inch in dia.) may be present.

TABLE 25

UNITED STATES WEIGHT CLASSES FOR CONSUMER GRADES OF SHELL EGGS

Size or Weight Class	Minimum Net Weight Per Dozen	Minimum Net Weight per 30 Dozen Case	Minimum Weight for Individual Eggs at rate per Dozen
	Ounces	Pounds	Ounces
Jumbo	30	56	29
Extra Large	27	50 1/2	26
Large	24	45	23
Medium	21	39 1/2	20
Small	18	34	17
Peewee	15	28	—

Source: *Egg Grading Manual Agricultural Handbook No. 75*

care of eggs on the farm

As stated earlier, immediately after the egg is laid the quality begins to deteriorate. The sooner the egg is removed from the nest, cleaned, cooled and packed, the better it is. Some of the management recommendations that will lead to higher quality eggs are listed as follows:

1. Keep the birds confined.
2. Gather eggs frequently, at least three times a day.
3. If eggs must be cleaned, clean them immediately after gathering.
4. Dry clean slightly dirty eggs.
5. Cool eggs as quickly as possible.
6. Maintain an egg storage room temperature of 50-55° and a relative humidity of 75%.

cleaning eggs

If eggs are to be washed, they should be washed at a temperature of 110-115° F. in clean water, with an approved detergent sanitizer. Washing time should be no more than 3 minutes. If the eggs are rinsed following the washing, they should be rinsed with a water containing a detergent sanitizer and then dried and cooled. Slightly soiled eggs may be dry cleaned with an abrasive material such as emery cloth, fine sandpaper on a hand buffer, or steel wool.

On commercial egg farms the washing and sizing of eggs is done with large automated equipment. Smaller operations may use immersion washers. The eggs are immersed in warm detergent sanitizer which is agitated to clean the eggs.

Poultry Processing

At best the job of processing poultry is a messy one. Ideally there should be two rooms available for the processing procedure. One for killing and picking the birds, and the other for finishing, eviscerating and packaging. If this is not possible, then the killing and plucking should be done in one operation. The room should then be cleaned and the birds

drawn and packaged as a second operation. This procedure will make the whole operation far more sanitary.

care before killing

Birds should be starved for about 12 hours before they are to be killed. This will give ample time for the crop and intestines to empty. Starving the birds makes the job of eviscerating much cleaner and easier. Birds that are to be starved should be removed from the pen and put into coops containing wire or slat bottoms, so that they do not gain access to feed, litter. feathers or manure.

Care should be taken in catching and handling the birds to prevent bruising. They should be caught by the shanks and not be permitted to flop their wings against equipment or other hard surfaces. This will help prevent bruising and poor dressed appearance. After the birds are caught, keep them in a comfortable, well ventilated place prior to killing. Overheating or lack of oxygen can cause poor bleeding resulting in bluish, discolored carcasses.

(Figure 28.)

(Figure 29.)

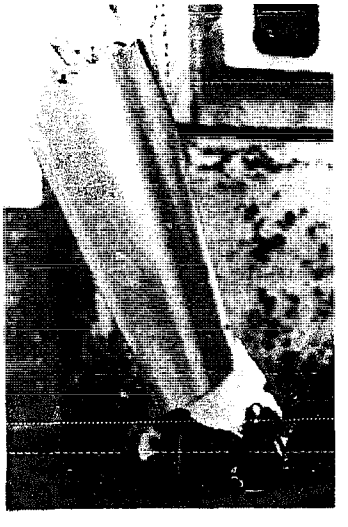

(Figure 29a.)

Equipment Required

the shackles or killing cones

When only a few birds are to be dressed, a shackle can be made from a cord with a block of wood 2″ x 2″ square, attached to the lower end *(Figure 28).* A half-hitch is made around both legs and the bird suspended upside-

down. The block of wood prevents the cord from pulling through. Commercial dressing plants use wire shackles which hold the legs apart and make for easier plucking. Some producers make their own shackles out of heavy-gauge wire *(Figure 29).* Other people prefer to use killing cones which are similar to funnels. The bird is put down through the funnel with its head protruding through the lower end. This restrains the bird and prevents some of the struggling which often leads to bruising or broken bones *(Figure 29a).*

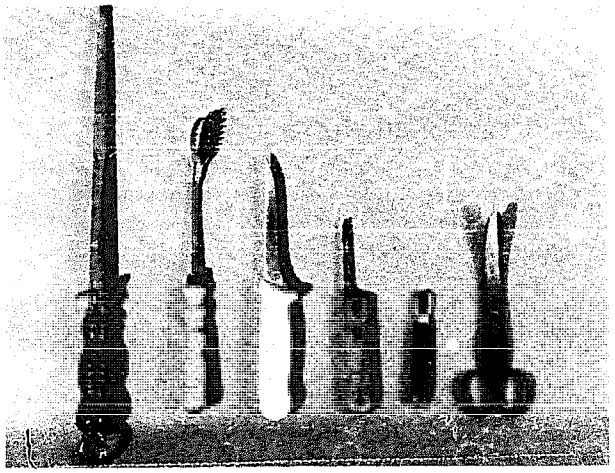

These tools make lighter work of dressing poultry.

the knives

About any type of knife is satisfactory for dressing poultry. There are specialized knives for killing, for boning, and for pinning. Six-inch boning knives work very well. If the birds are to be brained then a thin sticking knife should be used.

scalding tank

Where only a few birds are to be dressed, a 10-20 gallon garbage can, or any other clean container of suitable size, is satisfactory. Where considerable dressing is done a thermostatically controlled scalding vat is preferred.

thermometer

Accurate temperatures are important for certain types of scalding. You should have a good rugged dairy thermometer, or some other type of floating thermometer which accurately registers temperatures between 120-212° F.

weight or weighted blood cup

A weight or weighted blood cup attached to the lower beak of the bird will prevent it from struggling and splashing blood around. The weight may be made from a window weight and attached to the lower beak by means of a sharp hook. The blood cup is not used when killing funnels are available.

killing

The bird should be suspended by its feet with a shackle, or placed in a killing cone. The head is held with one hand, it is pulled down for slight tension to steady the bird. With a sharp knife the jugular vein is severed by cutting into the neck just back of the mandibles. This can be done by inserting the knife into the neck close to the neck bone turning the knife outward and severing the jugular. It may also be done by cutting from the outside. Another method which is sometimes used, is to cut the jugular vein from inside the mouth. Using this method the bird hangs with the breast toward the operator. The head is held firmly with the thumb and first finger at the ear lobes. A slight pull with pressure causes the beak to open. The knife is then inserted into the mouth, so that the point can be felt just back of the left ear lobe as you face it. It will be opposite for left-handers. With a slight pressure and drawing outward towards the opposite corner of the mouth the jugular vein is cut at the junction of the connecting vein running across the back of the throat *(Figure 30).* Warning: the head should be held so that the fingers do not get in the way.

During the bleeding process the birds should be restrained by holding the head until the bleeding and flopping stops, or a weight is attached to the lower beak. The wings or legs should not be grasped tightly so as to restrict the flow of blood from these parts. A poor-appearing dressed carcass will result if the bleeding is incomplete.

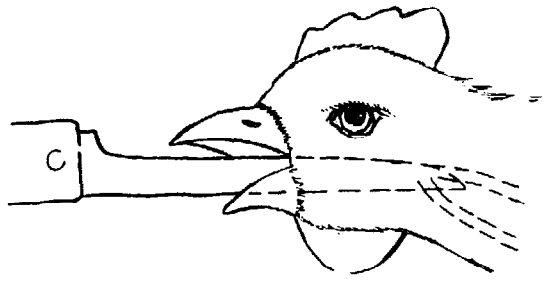

(Figure 30.)

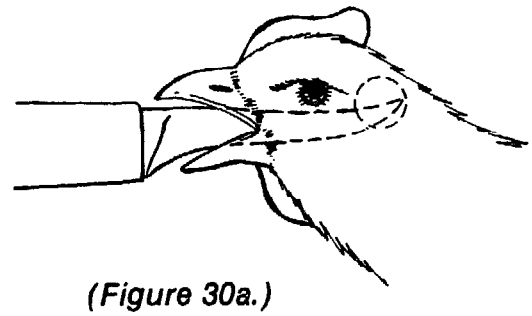

(Figure 30a.)

debraining

Debraining loosens the feathers so that it is easier to pluck the birds. It is done after the jugular vein is cut. Debraining is done when the birds are to be dry-picked, but may also be done when the birds are to be semi-scalded to make the removal of feathers easier.

The knife is inserted through the groove or cleft in the roof of the mouth and pushed through to the rear of the skull where it pierces the rear lobe of the brain *(Figure 30a)*. The knife is then given a quarter-turn. This kills the bird and loosens the feathers. A characteristic squawk and shudder indicates a good stick. If the front portions of the brain are pierced it may cause the feathers to tighten. This procedure requires considerable practice before the operator becomes proficient.

Picking

In general, there are four methods of removing feathers from birds. They are the hard scald, the sub-scald, the semi-scald and dry picking.

hard scald or full scald

This method is probably used more commonly on the farm than any others. The hard scald uses 160°-180° temperatures for 30-60 seconds. After the bird is sloshed up and down in water at this temperature, the feathers are removed very easily. With this method the time the bird is scalded depends upon the temperature of the water and the age of the birds. It should be only long enough so that the feathers can be pulled easily. This method would conceivably be used only for older birds and possibly waterfowl. Hard scalding makes for fast easy picking but destroys the protective covering of the skin. The hard scald causes a dark, crusty, blotchy, appearance and results in poorer keeping quality.

the sub-scald

The sub-scald uses a temperature of 138-140° F. for 30-75 seconds. This method causes a break-down of the outer layer of skin but the flesh is not affected as in hard scalding. The main advantage of the sub-scald is the

PROCESSING PROCEDURE

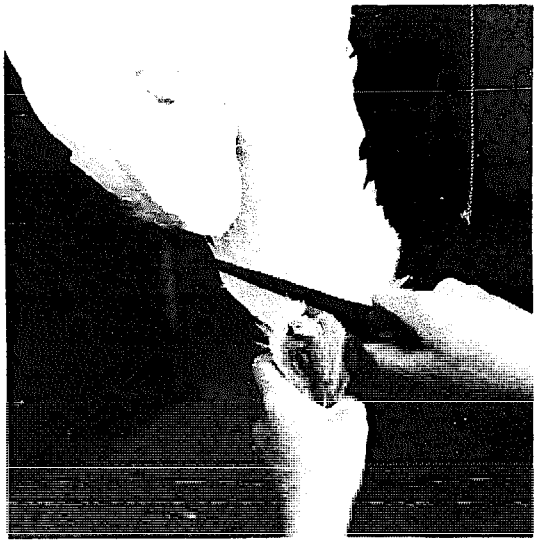

1. *Make cut at least 2" long at the base of the skull.*

2. *Follow time-temperature recommendations carefully.*

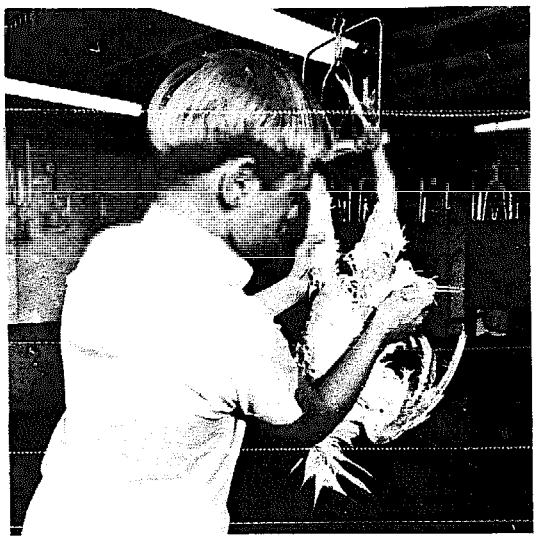

3. *Use a rubbing action with the thumb while picking.*

4. *Don't burn skin when using bottle gas torch.*

All photos in this chapter courtesy of the Pennsylvania State University College of Agriculture Extension Service.

easy removal of feathers and a uniform skin color. However, the skin surface tends to be moist and sticky and will discolor if not kept wet and covered. This method is frequently used for turkeys and waterfowl. The water temperature for scalding ducks is normally 135-145° F. and for geese from 145-155° F. The length of the scald is from 1½ to 3 minutes.

semi-scald

With the semi-scald the bird is sloshed up and down in water at a temperature of 125-130° F. Generally a water temperature of 128-130° for 30 seconds gives satisfactory results. The temperature and time varies with the age of the birds. Older birds require a higher temperature and a longer time.

Semi-scalding of poultry softens and spreads the fat beneath the surface of the skin. This improves the appearance of the dressed bird. Over-scalding is caused by too high a temperature for too long a time. This method is generally used for young birds such as broilers, fryers, roasters and capons.

One other technique may be utilized in connection with the semi-scald or the sub-scald, and this is known as wax picking. After the birds are scalded they are dipped in hot wax. After they are removed from the wax they are dipped in cold water to solidify the wax. The bird is coated with wax and the feathers and pin feathers become imbedded in it, so that when the wax is stripped from the carcass, the feathers and pinfeathers are easily pulled out. This method is commonly used in dressing waterfowl. It is not so frequently used when dressing chickens or turkeys.

A modification of the above described wax picking method is sometimes used for dressing waterfowl. Parafin is added to the scald water to form a thick floating layer. The bird is held in the scalding vat for the required length of time and then removed slowly so that a layer of parafin adheres to the feathers. The parafin is given an opportunity to solidify and is then stripped off carrying with it many of the feathers and pin feathers which are normally hard to pull.

Waterfowl feathers tend to resist thorough wetting during the scalding process. A little detergent in the scald water will help solve this problem and make the job of picking somewhat easier.

pinning and singeing

Pinfeathers, the tiny immature feathers, are best removed under a slow stream of cold tap water. Use a slight pressure and a rubbing motion. Those that are difficult to get can be removed by using a pinning knife or dull knife. Applying pressure, the pinfeathers can be squeezed out. The most difficult may have to be pulled.

Chickens and turkeys usually have a few hair-like feathers left following the plucking operation. These hairs can be removed by singeing with an open flame. Singeing equipment is available commercially for large operations but for small units a small gas torch or a gas range work well. The birds are easily singed by rotating the defeathered bird in the flame.

Eviscerating

After the carcasses are picked and singed, they should be washed in clean, cool, water. As soon as they are washed they are ready to be eviscerated. Some prefer to cool the poultry before eviscerating and cutting it up, because it is somewhat easier and cleaner to do after it is cooled. Others eviscerate and then cool by placing the birds in ice water or cool water which is constantly replenished. There are many methods of drawing poultry. The following methods are not the only ones but are satisfactory. Neatness and cleanliness are essential if a satisfactory job is to be done.

The tools needed for drawing poultry are a sharp stiff-bladed knife, a hook if the leg tendons are to be pulled and a solid block or bench upon which to work. All equipment and working surfaces should be clean. A piece of heavy parchment paper, or meat paper may be laid on the working surface and changed as necessary.

eviscerating roasting chickens, turkeys and waterfowl

Roasters, turkeys and capons are usually stuffed and roasted so the drawing procedure is the same for all.

It is desirable when eviscerating turkeys to remove the tendons from the drumsticks before removing the shanks and feet. By cutting the skin along the shank, the tendons extending through the back of the leg may be exposed and twisted out with a hook or a special tendon puller, if one is available.

The shanks and feet should be cut off straight through or slightly below the hock joint, leaving a small flap of the skin on the back of the hock joint. This will help prevent the flesh on the drumstick from drawing up and exposing the bone during the roasting process. The oil sac on the back near the tail should be cut out, as it sometimes gives a peculiar flavor to the meat. This is removed with a wedge-shaped cut.

To remove the crop, windpipe, gullet and neck, cut the head off, and slit the skin down the back of the neck. Separate the skin from the neck and then, from the gullet and windpipe. Follow the gullet to the crop and remove by cutting below the crop. The loose skin then serves as a flap which folds over the front opening and permits stuffing the bird without sewing. The neck is cut off as close to the shoulders as possible. A pair of pruning shears are handy for this purpose. The flap of skin is then folded back between the shoulders and locked in place by folding the tips of the wings over it.

The vent is loosened by cutting around it. This should be done carefully to avoid cutting into the intestine. The viscera are removed through a short horizontal cut approximately 1½-2 inches below the cut made around the vent. The horizontal cut should be about 3 inches long. The lungs, liver and heart attachments are carefully broken by inserting the fingers through the front opening. The intestines are loosened from the rear opening by working the fingers around them and breaking the tissues that hold them in the body cavity. The viscera are removed through the rear opening in one mass by inserting two fingers through the rear opening and hooking them over the gizzard cupping the hand and using a gentle pull and slight twisting motion.

Remove the gonads (ovaries and testes). The gonads are attached to the backbone. They can be removed quite easily by hand. Surgical capons should not have gonads unless they are "slips".

The lungs are attached to the ribs on either side of the backbone. These can be removed by using the index finger to break the tissues attaching the lungs to the ribs. Merely insert the finger between the ribs, and scrape the lungs loose. The lungs are pink and spongy in appearance.

After all the organs have been removed, wash inside with a hose or under a faucet. Also wash the outside removing all adhering dirt, loose skin, pin feathers, blood or singed hairs. Hang the birds so as to drain the water from the body cavity. Twenty minutes should be adequate to thoroughly drain the birds.

trussing

A properly trussed bird makes for a nicer appearance. It also conserves the juices and flavors during the roasting process. One method is to place the bird on its back and draw a string across the shoulders and over the wings. It is then crossed over the drumsticks, brought under the back, drawn tightly and tied at the base of the tail.

Another method of trussing is to place the hock joints under the strip or bar of skin between the vent opeining and the cut from which the viscera was removed. The neck flap is drawn back between the shoulders and the wingtips are folded over the shoulders and serve to hold the skin.

The same procedures are used for killing and eviscerating waterfowl.

cleaning the giblets

Remove the gall bladder — the green sac attached to the liver — without breaking it. If the gall bladder is broken while removing the viscera, or cleaning the liver, it will likely give a bitter, unpleasant taste to any part with which it comes in contact as well as causing a green discoloration.

If the gizzard is cool and care is used, it may be cleaned without breaking the inner lining. Cut carefully through the thick muscle until a light streak is observed (do not cut into the inner sac or the inner lining). The gizzard muscle may then be pulled apart with the thumbs and the sac, and its contents removed unbroken.

eviscerating broilers and fryers

The method used for drawing broilers and fryers is very similar, except that fryers are usually cut up into more pieces. Both can be drawn the same as roasters but the usual method is to split and cut up the fryers.

The first operation is to cut off the legs at the hock joint. Remove the oil sac at the base of the tail and cut off the neck. Place the bird on its side, neck toward the operator, and the back of the bird toward the cutting hand. Split the bird with a single cut down the backbone or, if preferred, two cuts can be made along either side of the backbone and the backbone and neck stripped out. The cuts along the backbone should be made with a stiff bladed knife and just deep enough to sever the ribs. The vent is cut out, and the viscera then removed from the bird.

To remove the breast bone, simply make a small cut in the cartilage toward the front of the breast bone. By applying a downward pressure on both sides of the bone with the thumbs and snapping it, the breast bone can be pulled out. Broilers are usually left whole or in halves and fryers, quartered.

1. Use boning knife to remove feet at hock joint.

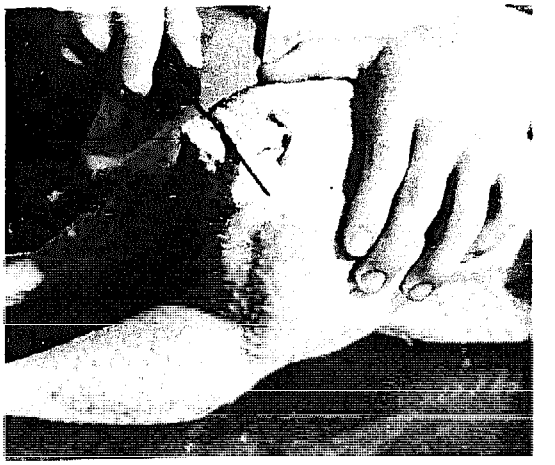

2. Cut deeply into tail and remove oil gland.

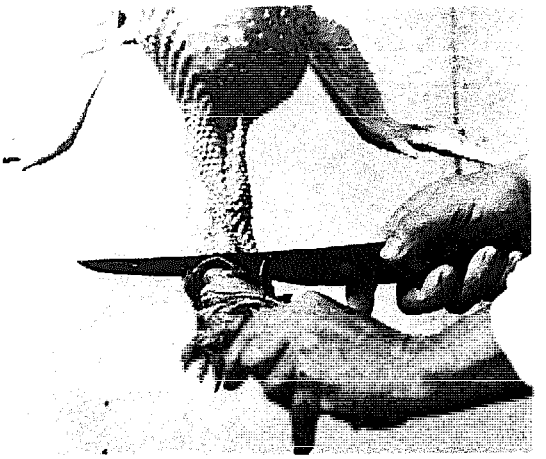

3. Cut off head between the head and the first neck vertebra.

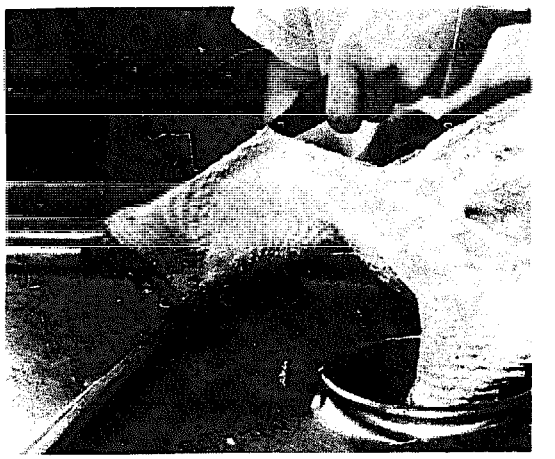

4. Split neck skin from shoulders to the Atlas joint.

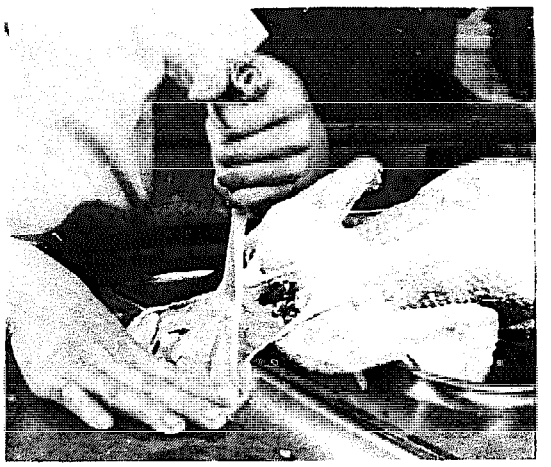

5. Pull out trachea, esophagus, and crop.

6. Cut around neck bone, double neck, and twist off.

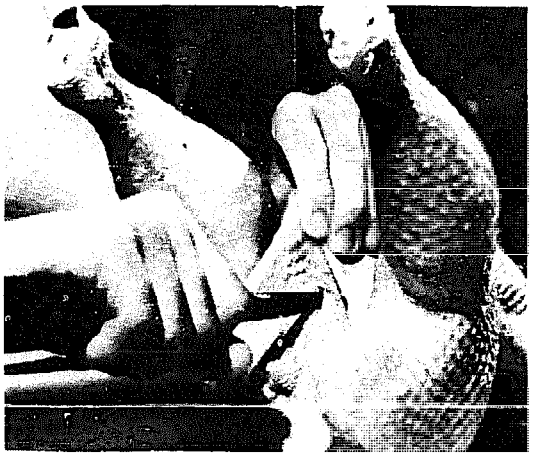

7. *Midline cut: Pull up abdominal skin, then cut . . .*

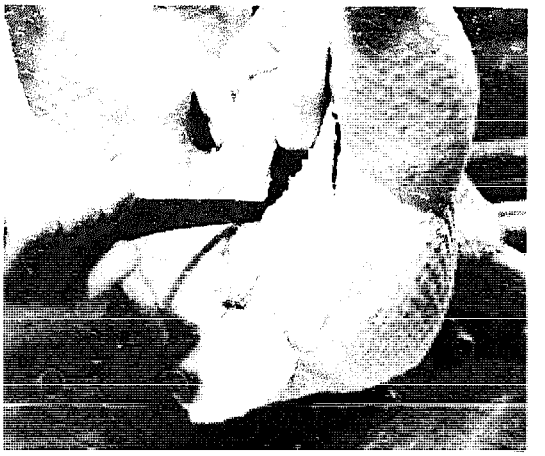

8. *. . . Through skin and down toward tail.*

9. *Cut around vent, avoiding cut into intestines.*

10. *Remove vent and large intestine, and discard.*

11. *The completed midline cut, for broilers, small roasters.*

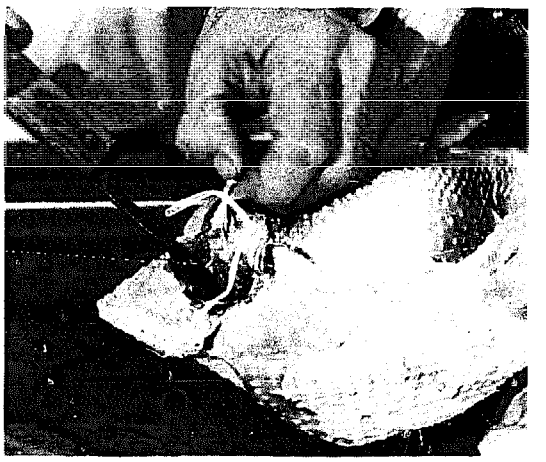

12. *Bar cut: cut halfway around vent, then . . .*

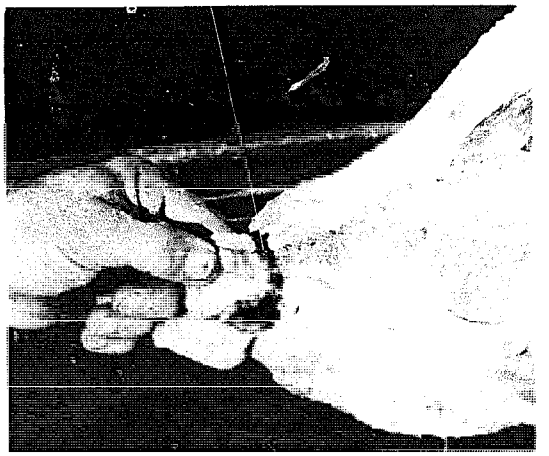

13. . . . Using finger as guide, cut with shears to free vent.

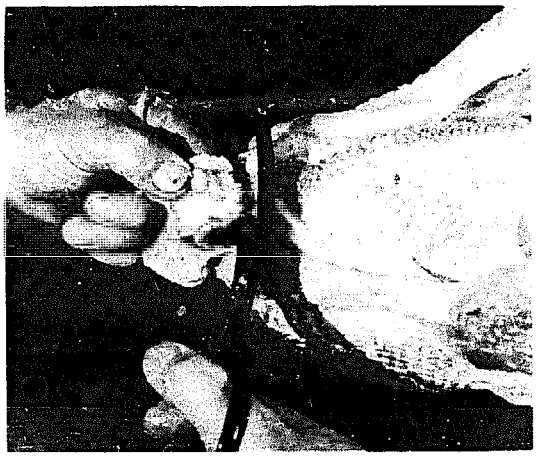

14. When making this cut, avoid cutting large intestine.

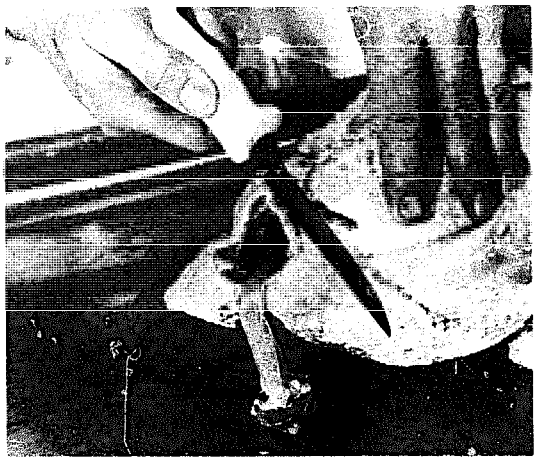

15. Pinch skin up and make 3" horizontal cut.

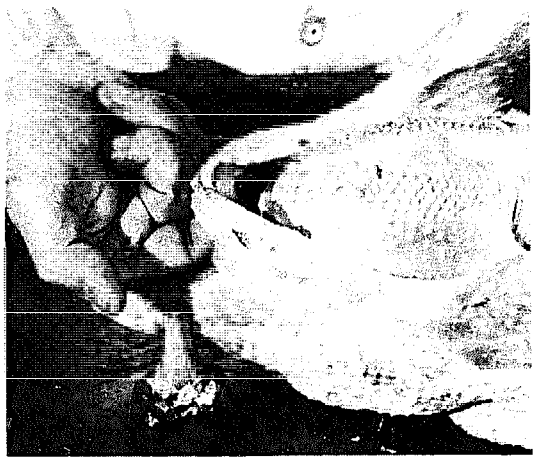

16. This cut leaves a "bar" of skin 1½-2" wide.

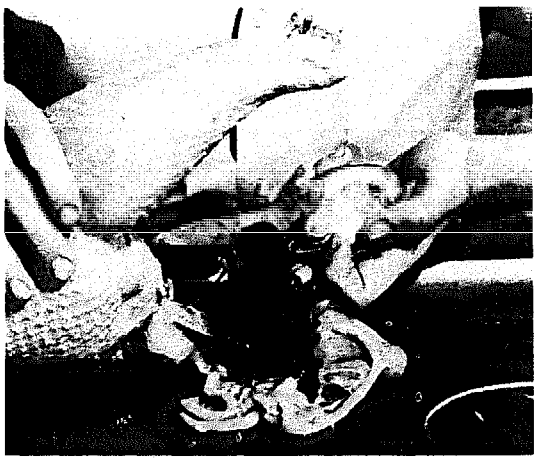

17. Pull out entrails and save giblets and liver.

18. Pinch gall bladder from liver at neck of bile duct.

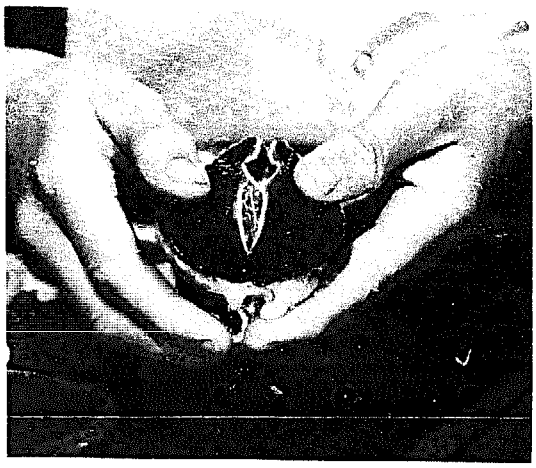

19. *Cut through yellow lining of gizzard, and separate.*

20. *Peel and discard yellow lining and gizzard contents.*

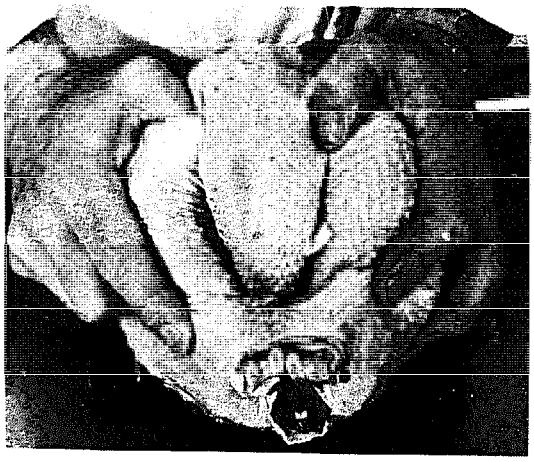

21. *Tuck tail, then legs under bar strap.*

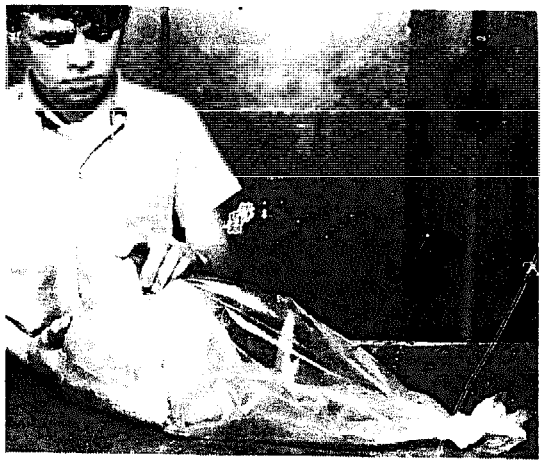

22. *To air truss, place bird in plastic bag.*

23. *With hose, draw air out of bag until bird is air trussed.*

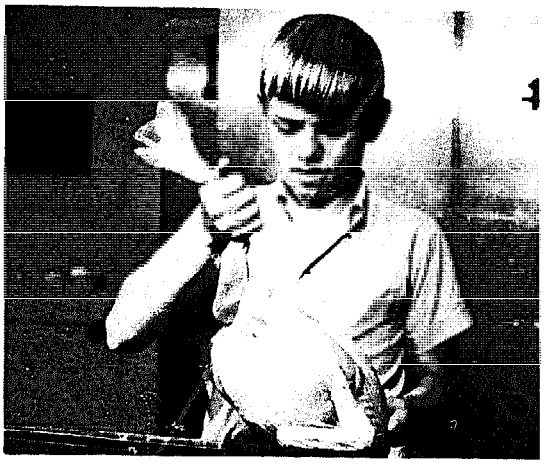

24. *Twist mouth of bag four times, double, and secure.*

eviscerating fowl

Fowl or old laying hens may be drawn similar to roasters and turkeys. However, they are too tough for barbecuing, roasting or frying and are usually cut up for stewing or fricasse. One method of cutting-up fowl is as follows: Remove the head, neck, crop, gullet and windpipe as described under roasting chickens, turkeys and capons. Next remove the feet, oil sac, wings and legs. A slight cut is made on both sides of the body of the bird to the rear and below the breast, cutting to the backbone. The fowl is then broken apart by bending back the breast. The breast, back and neck, and liver are then cut away leaving the viscera in one mass. The breast may be split into halves if desired. The drumsticks and thighs are separated by cutting through the second joint above the hock joint. The giblets are cleaned as described earlier.

chilling and packaging

It is important that the body heat be removed from the birds as soon as possible after killing. If the cooling is done slowly, bacteria can develop, causing spoilage and undesirable flavors.

If birds are to be air-dried, the air temperature should be from 30-35° F. to cool the birds properly. The time required to cool the carcasses depends on the size of the birds and the temperature of the air. It may vary from 6½ hours for a 3 pound fowl to 10 hours for a 7 pound male bird.

Water cooling of poultry can be used when air temperatures are above 35° F. If the birds have been dressed in scalding temperatures that are too high, or for too long a period of time, the air-dried birds may show a blotchy, discolored appearance of the skin. When the hard scald is used water cooling is the preferred method of cooling the carcasses. Dressed birds should be cooled in pails or tanks of ice water or cold running water. The important factor is to maintain a constant temperature of 34-40° F. To cool the birds to an internal temperature of 36-40° F. requires 5-10 hours in the water, depending again, upon the size of the carcass.

In the case of cut-up poultry, the birds may be cut up immediately after dressing, thrown into cold water and cooled in a much shorter time. It should again be noted that it is much easier and cleaner to draw or cut up poultry after it has been cooled.

Birds should be cooled and aged for approximately 8-10 hours. If

eaten or frozen immediately after dressing, the carcasses will be tougher than if aged for a period of time.

Remove the carcasses from the running water or ice water and hang them up to dry for 10-30 minutes before packaging. Every effort should be made to get all of the water out of the body cavity of the bird before putting it into the bag.

The giblets should be wrapped in a square sheet of wax paper or a sandwich size plastic bag. Giblets can be stuffed into the body cavity. The giblets should be wrapped well, so that if they spoil the carcass will not be affected.

There are two types of bags available for poultry — one is the common plastic bag; the other is the so called cryo-vac bag. The cryo-vac bag is a shrinkable bag and one that adheres closely to the bird after shrinking in boiling water. It makes a much nicer appearing package. It also helps to reduce the amount of water loss during the freezing process. However, good plastic bags are available and will do a satisfactory job of maintaining quality in frozen dressed poultry. The bags should be highly impermeable to moisture to prevent dehydration in freezer storage, which causes toughness.

Birds to be bagged should be thoroughly trussed and then inserted front end first into the plastic bag. The bag should be excessively large. After the bird is in the bag, the excess air can be removed by applying a vacuum cleaner or by inserting a flexible hose into the top of the bag and applying a vacuum. Merely keep the bag snug around the hose or vacuum

TABLE 26

PROCESSING YIELDS — POULTRY

Type	Approximate % Yield Live-to-Eviscerated
Broilers and Fryers	75
Roasters	76
Fowl — Leghorn-Type	68
Fowl — Heavy-Type	70
Turkeys — Heavy-Roasters	80
Turkeys — Light-Roasters	78
Ducks	70
Geese	68-73

Source: *New England Poultry Management and Business Analysis Manual*

cleaner then suck the air out of the bag. Twist the bag several times and secure it with a wire-tie or rubber band.

Fresh-dressed, ready-to-cook poultry has a shelf life of approximately 5 days. It should be refrigerated at a temperature of 29-34° F. If it is to be frozen, it should be frozen by the third day after it is dressed and chilled. Poultry to be frozen should be chilled to below 40° F. before placing in the freezer.

The weight losses from live to dressed weight vary with the type, age and size of bird *(Table 26)*.

state and federal grading and inspection

Processors of poultry and eggs that are to be sold off the farm are subject to the Poultry Products Inspection Act and the Egg Products Inspection Act. There are exemptions for small producers. Check into them if you have questions. For information on grading and inspection programs and how they affect you, contact your State Department of Agriculture.

12

FLOCK HEALTH

Disease is not normally much of a problem with small flocks, but there are several diseases that can possibly affect your flock. It was emphasized earlier that an ounce of prevention is worth a pound of cure. If you purchase stock from a good clean source, follow a sound sanitation program, use a good feeding program and provide a comfortable house with ample dry litter and plenty of fresh air, you will have gone a long way toward keeping your flock healthy.

It should be realized that losses will occur in any flock. Commercial flock owners expect a monthly mortality of approximately ¾ to 1%. However, a disease in the flock is usually manifested by a drop in feed and water consumption, a drop in egg production and sick or dead birds. When it is apparent that a disease is present in the flock, seek the advice of a person who is a trained poultry diagnostician. It is not advisable to use drugs or antibiotics indiscriminately. Sometimes this will do more harm than good and the only result may be a waste of money.

For the list of diagnosticians in your area consult the list at the back of this text. When birds are submitted to a State Diagnostic Laboratory, a sample of the flock problem should be submitted. The sample should include two or more sick birds, or recently dead birds. Care should be taken

to preserve dead specimens by cooling or freezing so as to prevent decomposition. An early diagnosis and fast treatment is always recommended for a quick solution to poultry disease problems.

There are many poultry diseases but only the more common ones will be discussed in this text. These will not be discussed in great detail because this text is intended mainly for the small flock situations. There are many excellent texts on poultry diseases if more in-depth information is desired.

Many of the diseases which will be described are common to both chickens and turkeys. To avoid duplication, these will be covered in the one section. Those diseases that are peculiar to or more important in waterfowl will be covered in the section on Diseases of Waterfowl.

Diseases

aspergillosis or brooder pneumonia

Aspergillosis is a disease of young birds including chicks, turkeys and ducks. Symptoms include, dumpy-acting birds, rapid breathing, gasping, and possibly inflamed eyes.

The disease is caused by a fungus which is inhaled by the birds, usually from moldy litter or feed. On post mortem, yellowish-green nodules may be found on the lungs, in the trachea, bronchi, and viscera. There is no treatment known. However, further spread of the infection may be prevented by culling the sick birds and cleaning and disinfecting the house and equipment thoroughly. Musty litter or feed must be carefully removed from the building to prevent further spread of the disease.

blackhead or histomoniasis

Blackhead is caused by a protozoan parasite. It is infrequently found in chickens but is a very common disease of turkeys of all ages. Since it can affect both chickens and turkeys, and chickens may act as an intermediate host for the organism causing blackhead, it is commonly felt to be rather risky to keep chickens and turkeys on the same farm. The term blackhead is misleading, because this symptom may or may not be present.

Cecal worm eggs can harbor the organism over long periods of time and when picked up by the turkeys infect the intestines and liver. Mortality may reach 50% if treatment is not started and the infection checked immediately. Symptoms may be droopiness and dark heads, brownish

colored and foamy droppings. Inflamation of the intestine and ulcers on the liver may be seen upon autopsy. The incidence of the disease and its severity is dependent upon the management and sanitation programs used. Management factors such as sanitation of the brooding facilities, rotation of the range areas, and segregating young birds from old birds help to prevent outbreaks. Segregation of turkeys from chicken flocks is very helpful in preventing problems with blackhead.

Blackhead drugs are commonly added to the feed to prevent outbreaks and may be used to treat blackhead infections.

bluecomb

The cause of bluecomb is not known. It affects both chickens and turkeys, it can hit birds at any age but usually affects chickens and pullets early in the laying cycle. Mortality can be heavy. When an outbreak occurs in laying chickens or laying turkeys, egg production is severely affected.

Characteristic symptoms include a loss of appetite, darkening of the head and a watery diarrhea. The birds get listless and drink excessive amounts of water.

Antibiotics given in the drinking water usually result in a dramatic recovery when treatment is started early.

bumblefoot

Bumblefoot is the swelling of the foot involving the foot pad and the area around the base of the toes. It is thought to be caused by injuries resulting from bruising, a penetration of wire or thorns or other sharp objects with which the feet come in contact. Organisms such as E. Coli, Streptococcus and Staphylococcus have been isolated from the puss material found in the swollen area.

Equipment should be designed so that the birds do not get foot punctures from wire or nails. A deep dry litter is helpful in preventing this condition, especially in those areas in front of high roosts or nests which require that the birds jump to the floor.

Birds with severely swollen feet, or birds that are very lame should be removed from the flock. Some birds may recover if the scab over the swollen area is removed and the core is squeezed out. The foot should then be washed with an antiseptic.

fowl cholera

Fowl cholera is caused by a bacterium. It is a highly infectious disease of all domestic birds including chickens, turkeys and ducks.

The birds become sick rapidly and may die suddenly without showing external symptoms. They may appear listless, feverish, drink excessive amounts of water and show a diarrhea.

Post mortem findings include red spots or hemorrhages on the surface of the heart, lungs, intestines or in the fatty tissues. The birds may have swollen livers (a cooked appearance) with white spots. Treatment with sulfonamides such as sulfaquinoxalene, sulfamethazine and others are currently recommended. Sulfaquinoxalene in the feed at the .33% level for 14 days is considered to be one of the best treatments. Antibiotics are sometimes injected at high levels.

Sanitation in the poultry house, range rotation and proper disposal of dead birds help to prevent cholera outbreaks. In problem areas, birds may need to be vaccinated.

chronic respiratory disease: mycoplasma gallisepticum

Chronic respiratory disease is an infectious and contagious disease affecting birds of all ages. It is prevelent in all areas of the country. It is caused by a pleuro-pneumonia-like organism. It affects chickens, turkeys and ducks.

C.R.D. is a respiratory disease affecting the whole respiratory system, especially the accessory lungs or air sacs. It is not a killer but can cause considerable morbidity, especially if treatment is not undertaken soon and secondary invaders avoided.

In young birds the signs are rattling, sneezing and sniffling; In older birds, the condition may go unnoticed. When the condition becomes complicated, there may be a nasal discharge, a foamy exudate from the eyes. There may be difficult breathing, lack of appetite and a drop in egg production in producing birds. Young birds may be somewhat stunted and unthrifty.

Post mortem findings include, cloudy air sacs with cheesy exudates, mucus in the nasal passages, trachea and lungs.

Transmission is through the hatching egg, through the air and via

infected equipment, feed bags, and other means.

Several of the antibiotics are used to treat the disease and may be administered in the drinking water, the feed or by injection. These currently include tetracycline, tylosin and spectinomycin and others.

Stress appears to play a key role in triggering the disease. Thus, good environmental conditions and good management are important.

infectious bronchitis

Infectious bronchitis is caused by a virus. It spreads very rapidly and hits birds of all ages and is found in chickens. It may cause up to 50% mortality in young chicks and 5-10% in adult birds. It affects the reproductive organs of young birds thus affecting future performance.

Symptoms include sneezing and coughing. Egg production drops to nearly zero in laying birds and the eggs become misshapened, soft shelled, chalky or porous and light in color in the case of brown eggs. The interior egg quality is also affected.

Post mortem findings may be inflamed nasal passages with cheesy plugs in the lower trachea and bronchi. There is no known treatment for infectious bronchitis. Treatment with antibiotics for 3 to 5 days is usually recommended to ward off secondary invaders.

Control of infectious bronchitis is accomplished through a vaccination program. Vaccines may be administered by mass methods or individually by nasal or ocular drops. Mass methods of vaccination include drinking water, dust, or spray. The manufacturer's recommendations should be followed in the use of any of these products. Bronchitis vaccine is frequently given in combination with Newcastle vaccine.

coccidiosis

Coccidiosis is primarily a problem in chickens and turkeys, though on rare occasions it may be found in flocks of ducks. Coccidiosis is a very common disease of poultry and is caused by a protozoan parasite, coccidia. The birds expose themselves to the disease by picking up sporulated oocysts in fecal material and litter. It should be assumed that all flocks

grown on litter are exposed to the disease. Birds grown on wire are not exposed to droppings and normally don't become exposed to coccidiosis.

Coccidia are host specific, that is, the coccidia that affect chickens do not affect turkeys. About 9 species of coccidia affect chickens. Of these nine, three cause most of the problems. Different species affect various parts of the digestive tract. Six species are known to infect turkeys, but only two of these commonly cause problems.

Symptoms of coccidiosis are ruffled feathers, unthriftiness, head drawn back into the shoulders, an appearance of being chilled and a diarrhea which may be bloody with some forms. If permitted to go unchecked, considerable mortality, morbidity, and poor flock results may occur.

On post mortem, lesions and hemorrhages may be seen in the various parts of the intestine, depending upon the species involved.

The disease may be prevented by feeding coccidiostats in the growing diet and permitting the bird to build an immunity or completely controlling by feeding a preventative level of coccidiostats.

Treatment involves the use of sulfonamids or other coccidiostats as prescribed by a diagnostician or service man.

infectious coryza

Infectious coryza is a respiratory disease of chickens caused by a bacterium. It spreads rapidly from bird to bird and is thought to be triggered by a stress. Mortality may be high but is usually low. Symptoms include an involvement of the sinuses and nasal passages with a nasal discharge and swelling of the face. Egg production drops in laying flocks.

Post mortem findings usually include congested nasal passages and fluid-filled tissues of the face and wattles.

Old birds are carriers and should not be mixed in with young birds, but either sold or kept isolated from growing flocks. Sulfonamids are frequently used for treating Coryza.

erysipelas

Erysipelas is primarily a disease of turkeys. It may affect ducks and rarely affects chickens. It is caused by a bacterium. Swine, sheep and man are also susceptible.

Symptoms are swollen snoods, bluish purple areas on the skin, and congestion of the liver and spleen. Birds may become listless, have swollen joints and exhibit a yellowish-green diarrhea. It is primarily a disease of toms because of injuries during fighting. The erysipelas organism readily enters through skin breaks.

Erysipelas is considered to be a soil-borne disease and contaminated premises are assumed to be the primary source of infection.

The disease responds to penicillin. Tetracycline is also effective. Control requires good management and sanitation.

fowl pox

Fowl pox is found in many areas of the country. It is caused by a bacterium and spread by contact with infected birds or by such vectors as flies and mosquitos or wild birds. There are two forms of fowl pox. The dry or skin-type and the wet or throat-type. The same organizm causes both. The disease affects both chickens and turkeys.

Birds with fowl pox have poor appetites and look sick. The wet pox causes difficult breathing, a nasal or eye discharge, yellowish, soft cankers on the mouth and tongue. With the dry pox, the birds develop small greyish white lumps on the face, comb and wattles. These eventually turn dark brown and become scabs.

On post mortem, cankers may be found in the membranes of the mouth, throat and windpipe. There may be occasional lung involvement or cloudy air sacs.

There is no treatment for the disease itself, though an antibiotic may help to reduce the stress of the disease.

The only means of control is through administering a vaccine. This is recommended in those areas where fowl pox is a problem.

laryngotracheitis

Laryngotracheitis is a viral disease. It spreads very rapidly. It may be airborne, spread by contact or by carrier birds. It affects all ages of chickens and pheasants. Its affect on birds under four weeks is mild, but may be very severe in adult birds. Mortality in some cases may be as high as 60%. It causes egg production to drop but has no affect on egg quality.

Signs of the disease include coughing and sneezing and, as the disease

progresses, the birds find it difficult to breath. The neck is outstretched when the birds inhale and this may be accompanied by a cawing sound. A bloody mucous may be expelled when the birds cough and sneeze.

On post mortem examination the throat, trachea and larynx are very inflamed and swollen. There is frequently a bloody mucus or yellowish, false membrane in the trachea. Severe inflammation of the larynx and trachea are in evidence and occasional cheesy plugs are found in the trachea. No treatment for laryngotracheitis is effective. In those areas where the disease is a problem, a vaccination program should be followed.

After an outbreak of laryngotracheitis, some birds are carriers. These birds are a possible source of infection for non-immune birds.

lymphoid leukosis

This disease has caused serious economic losses to the poultry industry for many years. Most forms of lymphoid leukosis occur in the older birds or laying flocks. Mortality from this disease is seldom a problem in the young. Infected birds begin to develop tumors of the internal organs, particularly the liver, and slowly lose weight and eventually die. Acute death losses are not common with lymphoid leukosis but occur a few at a time over a long period of time.

There is no known treatment for the disease and it remains a perplexing problem for the poultry industry. Although isolation brooding, and clean brooding facilities are recommended, these management practices have proved to be ineffective in controlling lymphoid leukosis.

marek's disease

Marek's disease is a disease of chickens caused by a herpes virus. The disease takes many forms and affects many areas of the body, including the muscle, nerves, skin and intestines. Birds over two weeks of age may be affected. It can cause losses of 30% or more in pullet flocks up to the time of housing.

There is no treatment for Marek's Disease and the best control measure is by vaccination of the baby chicks. This is usually done at the hatchery.

newcastle disease

Newcastle disease is widespread. It is acute, highly contagious, and found in chickens, turkeys, ducks and geese. It is a respiratory disease caused by a virus. It causes high mortality in young flocks. Production in laying birds frequently drops to zero.

Newcastle spreads rapidly through the flock causing gasping, coughing and hoarse chirping. Water consumption increases and a loss of appetite occurs. Infected birds tend to huddle and exhibit signs of partial or complete paralysis of the legs and wings. The head may be held between the legs or on the back with the neck twisted.

The disease is transmitted in many ways. It can be tracked in by people, brought in with chickens from another premise or on dirty equipment, feed bags or by wild birds which gain entrance to the pen.

Post mortem findings may include congestion and hemorrhages in the gizzard, intestine, and proventriculas. The air sacs may be cloudy.

There is no effective treatment, though antibiotics are normally given to keep down secondary invaders. Vaccination is recommended in most areas of the country, and can be administered individually or on a mass basis. Recommendations vary with the area and the type of bird. Newcastle disease vaccines can be administered intranasally, ocularly, or by wing-web. On a mass basis it can be given alone or in combination with infectious bronchitis — in the drinking water, or in the form of a dust or spray. Manufacturers' recommendations should be followed for use of the product. The vaccination program should be that which is recommended for the area and the type of bird that is to be grown.

omphalitis

Omphalitis is caused by a bacterial infection of the navel. It occurs when the navel doesn't close properly following hatching. It is found in young chicks and turkey poults and may be caused by poor incubator or hatchery sanitation, chilling or overheating.

Birds with omphalitis are weak and unthrifty and tend to huddle together. The abdomen may be enlarged and feel soft and mushy. The navel is infected. The area around the navel may be a bluish-black in color. Mortality may be high for the first four to five days.

There is no treatment for the disease. Most of the affected chicks die the first few days. No medication is needed for the survivors.

paratyphoid

Paratyphoid is an infectious disease of chickens, turkeys, ducks and other birds and animals. It is caused by one or more of the salmonella bacteria. There are several types but Salmonella typhimurium is one of the most common in poultry and it accounts for over half of the typhoid outbreaks in poultry flocks. Transmission may be from the hen through the egg and to the chick. The organism is also found in fecal material of infected birds.

The disease is primarily one of young birds, but older birds may also be affected. In young birds mortality may run as high as 50%. Some birds may die without showing symptoms, while others show signs of weakness, loss of appetite, diarrhea and pasted vents. Birds may appear chilled and huddle together for warmth. In older birds there is a loss of weight, weakness, loss of egg production and diarrhea.

On post mortem of young birds, there may be unabsorbed yolk sacs, small white areas on the liver, inflammation of the intestinal tract, congestion of the lungs, and enlarged livers. Older birds usually show no lesions, though a few may show white areas on the liver.

Sulfamerazine, nitrofurans and some of the antibiotics may reduce losses, prevent secondary invaders, and increase appetite.

Control is through sanitation and isolation of the flock from sources of infection such as wild birds, birds from other flocks, contaminated feed and equipment.

pullorum

Pullorum is an infectious disease of chickens, turkeys and some other species. It is found all over the world. Pullorum is highly fatal to birds under two weeks of age. It is caused by a bacterium, salmonella pullorum.

Mortality begins at 5-7 days of age. The birds appear droopy, huddle together, act chilled and may show diarrhea and pasting of the vent. It is sometimes called white diarrhea.

Salmonella pullorum is spread mainly from the hen to the chick

through the egg. It spreads rapidly through transmission on chick down in incubators and hatchers.

Post mortem findings in infected chicks include dead tissue in the heart, liver, lungs and other organs and an unabsorbed yolk sac. In adult birds there are discolored and misshapen ova; the heart muscle may be enlarged and show greyish-white nodules. The liver may also be enlarged, yellowish-green and coated with exudate. One of several types of blood tests help to establish a positive diagnosis for salmonella pullorum..

Sulfamethazine and sulfamerazine are effective in reducing mortality. Nitrofurans may also be effective in reducing mortality but will not cure the disease. Medication may hinder diagnosis.

Flocks which have recovered from salmonella pullorum should not be kept for replacements or breeding purposes unless they have been blood tested and found to be free of the disease.

Infectious sinusitis: mycoplasma gallisepticum

Infectious sinusitis is a disease of turkeys and is caused by the same organism that causes chronic respiratory disease (CRD) in chickens.

It is transmitted through the eggs from carrier hens. As in the case of CRD, stress is thought to lower the poults resistance to the disease.

Symptoms are nasal discharge, coughing, difficult breathing, foamy secretion in the eyes and swollen sinuses, accompanied by a drop in feed consumption and loss of body weight. Air sac involvement may be in evidence on post mortem.

Antibiotics and antibiotic-vitamin mixtures will help. Individual treatment with injectible penicillin and streptomycin in the sinuses is recommended.

Infectious synovitis: mycoplasma synoviae

Synovitis is an infectious disease of chickens and turkeys. It is caused by a pleuro-pneumonia-like organism (PPLO). At first it was identified as a cause of infections of the joints, but more recently it has been identified with a respiratory disease. The disease can affect birds of all ages. It is found in all areas of the United States and is a serious problem, particularly in broiler flocks.

Symptoms include lameness, hesitancy to move, swollen joints and

foot pads, loss of weight and breast blisters. Some flocks show signs of the respiratory problem. Dying birds may show a greenish diarrhea.

Upon post mortem examination, swelling of the joints and a yellow exudate, especially in the hock, wing and foot joints, is in evidence. Internally, the birds may show signs of dehydration and enlarged livers and spleens. Birds showing the respiratory involvement are not easy to spot. On post mortem examination, the air sacs may be filled with liquid exudates.

The most common means of transmission is through infected breeders. Poor sanitation and management practices also contribute. Treatment is prescribed for market egg flocks. Breeder flocks with infectious synovitis should probably be disposed of. It can be passed on to their offspring. Antibiotics yield some results. These should be given by injection or in the drinking water. Some prefer to use both simultaneously for best results.

fowl typhoid

Fowl typhoid is caused by a bacterium, salmonella gallinarum. It affects chickens, turkeys, ducks and other species of birds. The disease may be present wherever poultry is grown.

Affected birds may look ruffled, droopy and unthrifty. Other symptoms may include pale combs and wattles, loss of appetite, increased thirst and a yellowish-green diarrhea.

On post mortem, the liver may have a mahogany color. The spleen may be enlarged and there may be pinpoint necrosis in the liver and other organs. There may be pinpoint hemorrhages in the fat and muscle tissue and evidence of enteritis.

Prevention, treatment and control are the same as for pullorum disease.

Diseases Of Waterfowl

Waterfowl raised in small flocks very seldom have disease problems. Where waterfowl are kept in large numbers, and concentrated in relatively small areas, disease may be more prevalent. Some breeds of waterfowl exhibit more resistance to diseases than others. For example, the Muscovy duck appears to be more resistant to diseases common to the Pekin and Runner.

Only the more common diseases of waterfowl will be considered in this section. It should again be emphasized that when disease problems occur it is well to get a reliable diagnosis from a poultry diagnostician.

amyloidosis

This is one of the common diseases of adult ducks and geese. Amyloidosis is also called wooden liver disease and can be quite readily recognized by the hardness of the liver. Mortality may reach as high as 10% in some flocks. The cause of the disease is not known and there is no known cure. Upon post mortem there are frequently large accumulations of fluids within the body cavity.

aspergillosis or brooder pneumonia

This disease was discussed earlier under chicken and turkey diseases. The causes and control measures are the same for waterfowl.

botulism

Botulism occurs in both young and adult waterfowl and in other types of poultry. It is caused by the bacteria, clostridium botulinum. This organism grows in decaying plant and animal material. Birds feeding on material containing the toxins produced by the bacteria lose control of their neck muscles. For this reason it is sometimes referred to as "limber neck". Infected waterfowl may drown if swimming water is available to them. The maintenance of dry, clean, facilities, the removal of decaying vegetation, or spoiled feed, will usually prevent this disease. A mixture of epsom salts, at the rate of one pound per 5 gallons of water, has been reported as an effective treatment.

fowl cholera

Fowl cholera has been discussed earlier under chicken and turkey diseases. The disease also attacks ducks and geese. The control and treatment for fowl cholera in waterfowl is the same as for other birds.

coccidiosis

As mentioned earlier, coccidiosis is a very infrequent problem with ducks. The species causing the disease in ducks is different from those causing the problem in chickens and turkeys. Control and treatment is the same as for treatment of other species of birds.

duck virus enteritis or duck plague

This disease affects ducks, geese, swans and other aquatic birds. It is caused by a virus that is transmissible by contact. It commonly occurs where water is available for swimming. The disease has affected ducks in commercial flocks in the eastern United States.

Signs of the disease are watery diarrhea, a nasal discharge and general droopiness. The symptoms develop 3-7 days after exposure. Death frequently results in 3 or 4 days. Generalized hemorrhages in the body organs may be seen on post mortem.

There is no satisfactory treatment. Only strict sanitation and the rearing of ducks in pens with access to drinking water will greatly reduce and help control the disease.

The exposure of domestic ducks to duck virus enteritis from migratory waterfowl can be avoided by keeping the susceptible ducks in houses or in wire enclosures.

keel disease

Keel disease occurs in young ducklings the first few days after hatching. Affected birds appear thin and dehydrated.

Fumigation of the hatching eggs, and a thorough washing and fumigation of the hatcher between hatches, are recommended to reduce the number of bacteria to which the young ducklings are exposed. Clean, warm, brooding facilities and good feed and fresh water will also help control the disease.

new duck disease or infectious serositis

New Duck disease is one of the most serious diseases affecting ducklings. It is caused by a bacterium. The symptoms resemble those of chronic respiratory disease of chickens. The first signs of the disease are sneezing and loss of balance. Losses up to 75% have been recorded. Death often is due to water starvation, rather than to the primary infection. Antibiotics and sulfa drugs have been used with some success.

virus hepatitis

Virus hepatitis outbreaks can cause 80-90% mortality in flocks of young ducklings. It is a highly contagious disease and strikes ducklings from 1-5 weeks of age.

Vaccination of the female breeding stock will prevent this disease. Antibodies produced by the vaccinated laying ducks are passed on through the egg to the young ducklings.

Parasites Of Poultry

Although there are many parasites of poultry, relatively few of them are of major importance. Some of the parasites live inside the bird, while others live on the outside. Certain of the external parasites affect growth and egg production. Some of the internal parasites can cause setbacks in weight gains, loss of egg production and even deaths if the infestation is severe. A few of the intestinal parasites harbor other disease organisms which are harmful to chickens and turkeys.

Internal Parasites

large roundworm

A light infestation of roundworms probably does little damage to the bird. However, when worms become numerous the birds can become unthrifty and feed conversion can suffer. The worms themselves seldom

cause mortality but when present with other diseases may cause an increase in mortality.

The large roundworm is 1½" to 3" long. It is found in the middle of the small intestine and causes setbacks in weight gains and a loss of egg production in adult birds. The piperazine compounds are used to treat roundworms, and can be given in the water, in the feed, or in capsule form.

Birds infect themselves with the roundworm by picking up the egg from feces, the litter or other infested materials. It is, therefore, desirable to keep the litter as clean as possible to prevent the birds from picking up the eggs. Birds on wire floors or in cages do not have worms.

capillaria worm

The capillaria worm is a very small worm ½" to 1½" in length. It inhabits the upper part of the intestine, including the esophagus, crop and occasionally the ceca. It can cause inflammation of the intestines, diarrhea, weakness and, in laying birds, lowered egg production. It is very difficult to see capillaria worms with the naked eye, and so sometimes their presence is overlooked on autopsy. Capillaria worm infestations prevent the efficient utilization of Vitamin A in the bird. Frequently the treatment rations are supplemented with additional Vitamin A. Hygromycin added to the diet has been reported to be helpful in some cases. Capillaria has the same direct life cycle as the roundworm. The embryonated egg is picked up from the litter by the bird. The earthworm is also an intermediate host. Sanitary conditions are very important for the control of capillaria worms. It is very difficult to get rid of them where dirt floors are used in poultry buildings.

cecal worm

The life cycle of the cecal worm is similar to that of the large roundworm. These worms are found in the ceca instead of the small intestine. Their length is ½" to ¾". By itself it probably has little economic significance in chickens, but its eggs harbor the organism which causes blackhead disease of turkeys. In severe infestations, cecal worms may contribute to a somewhat unthrifty condition in the birds, weakness and emaciation. It is rather hard to treat because most of the intestinal contents

bypass the ceca during the process of digestion. Phenothiazine or hygromycin B have been used successfully as treatments.

gizzard worm

The gizzard worm is reddish in color about ½"-1" in length. It is found under the lining of the gizzard and it impairs digestion due to the damage to the gizzard. No treatment is known, but the disease may be controlled by avoiding exposure of the birds to such intermediate hosts as grasshoppers, beetles, weevils and other insects.

gape worm

The gape worm attacks the bronchi, trachea and lungs. It can cause pneumonia, gasping for breath or even suffocation. High mortality may occur in young birds, especially turkeys and pheasants. The treatment of choice is to dust with barium antimonal tartrate, given at the rate of one ounce per 8 cubic feet of pen space for fifteen minutes. The earthworm is an intermediate host. The gape worm is y-shaped and red in color.

tape worm

There are several species of tape worms varying in size from microscopic to 6-7" long. They are flat, white and segmented. They inhabit the small intestine and cause a loss of weight, and a loss of egg production in adult laying birds. Treatment recommended for tape worms is dibutyltin dilaurate. This drug is sold in combination with piperazine and is effective in the removal of tape worms. One caution should be observed in the use of this material. It should be used only for severely infected flocks and should not be fed to laying birds.

The effective control of internal parasites depends primarily upon a program of cleanliness and sanitation. Parasitic eggs can remain viable in the soil for more than a year. This makes it important for producers to practice rotation of poultry runs or yards and if possible, to keep them clean and under cultivation to prevent the birds from picking up the parasites.

External Parasites

lice

Lice are chewing or biting insects that cause birds considerable grief. With severe infestations, egg production, growth and feed efficiency can suffer. They cause an irritation of the skin with a scab formation.

Lice spend their entire lives on the birds. They will die in a matter of a few hours if they get off the bird. The eggs are laid on the feathers where they are held with a glue-like substance. The eggs hatch in a few days to 2 weeks. Lice live on the scales of the skin and feathers. There are several types of lice which attack poultry. They include the body louse, shaft louse, wing louse, large chicken louse and the brown chicken louse. The body louse is one of the most common lice of poultry and usually affects older birds. The lice and its nits (eggs) are seen on the fluff, the breast, under the wings and on the back. The head louse attacks the feathers of the head and seems to be most harmful to young birds.

Materials which may currently be used to treat lice are carbaryl, malathion, or co-ral. These should be used according to the directions on the label. The birds should be examined frequently for signs of a reinfestation.

Mites

northern fowl mite

Northern fowl mites are a reddish dark brown in color. They are found around the vent, the tail and the breast of the birds. These mites live on the birds at all times. They may be seen on eggs in the nest when there is a severe infestation. They attack the feathers, suck blood, cause anemia, loss of weight and loss of egg production. Materials recommended for treatment of northern fowl mite are carbaryl or co-ral. Use according to the manufacturer's directions.

red mites

Red mites are not found on the birds during the daytime. Red mites feed during the night time. They may be seen on the underside of roosts,

cracks of the wall or seams of the nest during the daylight hours. Other signs are salt and pepper-like trails under roost perches or clumps of manure on the furniture. Red mites are blood suckers. They cause irritation, loss of weight, loss of egg production, and anemia. Laying birds may refuse to use infested nests. The red mite may be treated with the same materials as those used for northern fowl mite. Use according to the manufacturer's recommendations.

depluming mite

The depluming mite burrows into the skin and causes an irritation at the base of the feather. In an attempt to relieve the itching, the bird pulls out feathers until they may be nearly naked in cases of severe infestation.

To control the depluming mite, use a dip containing 2 ounces of sulfur and 1 ounce of soap per gallon of water. The birds should be dipped so as to wet the feathers to the skin. Dip only on warm days. The treatment should be repeated in 3 or 4 weeks if necessary.

the tropical chicken flea

This flea clusters on the comb, wattles and earlobes and around the eyes of the bird. It causes irritation to the membranes of the eye and may cause eventual blindness and death. It causes a loss of weight and lowered egg production. Use carbaryl (sevin) in dust or spray form according to the recommendations on the label.

fowl tick or blue bug

The fowl tick is a flat, egg-shaped, reddish-brown bug. It resembles the ticks. The adults are nocturnal feeders. They cause a loss of appetite, a loss of body weight, and lowered production. Loss of blood may result in anemia. The ticks may also carry diseases. Heavy infestation may lead to so-called tick paralysis.

Malathion spray applied at the rate of 1 gallon per 1,000 square feet

of building surface is the recommended treatment. Use according to the Manufacturer's recommendations.

the bed bug

The bed bug is a brown or yellow-red bug found under roosts and in cracks and crevices. The bugs are nocturnal feeders. They do not remain on the birds during the daylight hours. The birds pull out their own feathers in an effort to relieve the intense itching caused by the bed bugs. The treatment for this parasite is the same as for the northern fowl mite.

scaly leg mites

This mite is microscopic in size. It burrows into the skin of the legs, under the scales and may occasionally attack the comb and wattles. It may cause the birds to go lame or be crippled for life. There is evidence of scales and crusts on the legs, and the legs may be swollen. Scaly leg mite is not common where proper sanitation is practiced.

Treatment is on an individual bird basis. Dip legs in a mixture of 1 part kerosene plus 2 parts raw linseed oil.

chiggers

The chigger that attacks poultry is the same red mite that attacks man. Birds that are infested with chiggers may become droopy and emaciated. Chiggers attach themselves to the skin of the bird in clusters under the wings and on the back and neck. They may cause abcesses and inflamed areas. Birds may even die with severe infestations.

One aid in controlling chiggers is to keep the grass and weeds on range or in the yards cut short. The range may also be dusted with 1% malathion at the rate of 40 pounds per acre.

precautions for drug and pesticide use

Drugs and pesticides should be used with caution. To get optimum

production results from poultry, the use of a drug or pesticide is sometimes indicated. However, before they are used make certain of the problem and then use the material of choice according to recommendations. Never use a material that is not registered for use on poultry.

Neither drugs nor pesticides are intended as substitutes for good preventive management. They work best when used in combination with good sanitation and sound management practices. Early diagnosis and treatment of disease or parasite problems is to be recommended.

Agencies of the federal government have set up definite withdrawal periods and tolerance levels for various materials used in poultry. The Food and Drug Administration, for example, has set minimum periods of time certain drugs must be withdrawn prior to poultry slaughter. These withdrawal periods vary from 1 or 2 days up to several days and are subject to change from time to time. Maximum tolerances for residues of certain materials are also established. Some insecticides can be used around poultry but not directly on the birds or on the eggs or in the nests. Some pesticide materials cannot be used within a certain number of days prior to slaughter. Frequency of use is also an important consideration with some materials.

Withdrawal periods and tolerances, as mentioned above, do change, and accepted treatment materials change, so the specific precaution for use of various materials will not be dealt with here. However, it is hoped that the point has been strongly made that drugs and insecticides should be used discriminately, following all the precautions on the label for the use of a given material. Improperly used, they can be injurious to man, animals and plants.

Store all drugs and pesticides in the original containers in a locked storage area. Keep them out of the reach of children and animals. Avoid the prolonged inhalation of sprays or dusts, and wear protective clothing and equipment where recommended. Be Safe!

Nutritional Diseases

A number of diseases of poultry may be caused by nutritional deficiencies or imbalances. With the well formulated diets on the market today, nutritional problems are very infrequent. Therefore, a thorough discussion of nutritional diseases will not be undertaken. However, to point out the importance of good nutrition, it may be well to just mention a few of the more common nutritional diseases.

rickets

Rickets is caused by a deficiency of Vitamin D3. Birds with rickets appear to be weak, have stiff swollen joints, soft beaks, soft bones of the leg and enlarged rib bones. A deficiency of phosphorous can also cause rickets.

perosis

Perosis is a leg weakness usually caused by a deficiency of manganese in the diet. Choline, niacin and biotin may also have a role. With this deficiency, most chicks will respond to manganese fortification in the feed.

encephalomalacia

Encephalomalacia or Vitamin E deficiency is commonly called "crazy chick disease" because it causes staggering, uncoordination, and paralysis of affected chicks. Vitamin E deficiency causes a part of the brain to degenerate. Positive diagnosis of this disease requires a study of the brain tissues.

curly toe paralysis

Curly Toe Paralysis is caused by a riboflavin deficiency in the feed. The birds become unthrifty and uneconomical. One or both feet may be affected. Additional fortification of the feed with riboflavin will help to prevent further development of this disorder.

nutritional roup — vitamin A deficiency

Birds that are deficient in Vitamin A become very unthrifty. Exudates may form in the eyes and nostrils and whittish pustules develop in the mouth, esophagus and crop. Mortality in young poultry can be very high if the deficiency is not corrected. Adult birds exhibit reduced production, lowered hatchability and decreased livability in the offspring. Yellow corn, legumes, grasses and fish oils are good sources of Vitamin A.

Predators

rats and mice

Rats and mice are a common problem on poultry farms. They like poultry feed, eat it, and destroy it. They may destroy feed bags if they are not hung up where they cannot get at them. They destroy insulation in poultry buildings and are carriers of disease. A few rats or mice will quickly produce a large population if not controlled.

Rats and mice like hiding places. Given places to hide in or around the chicken house, they will set up housekeeping. They like to inhabit the space between double sheathed walls, stone foundations, under floors and in and around junk. Good housekeeping will help to eliminate hiding spots and prevent rodent problems.

Trapping can be helpful where the populations of rats and mice are small. Keeping a cat in the area will also help to control them. However, baiting is the best way of handling large populations.

The anti-coagulent baits are the most effective means of erradicating rats and mice. Anti-coagulents cause the rodents to bleed to death internally after they have consumed the bait for several days.

To be effective, bait stations *(Figure 31)* need to be set up near walls, burrows and paths that the rats and mice tend to follow. These bait stations need to be kept full of fresh bait — but no more than they will eat in 2 or 3 days. If bait gets old and musty, they will not touch it. Fresh water should be located near the baiting stations to increase consumption of the bait.

Ideally, grain should be stored in rat and mouse proof bins or containers. Covered galvanized garbage cans are excellent for storing feed for small flocks.

other predators

Although rats and mice are the biggest nuisance to small flocks, one should be aware of other possible problems.

At times, dogs and cats may raid the poultry yard or house. Cats can be a problem if they gain access to a pen of young chicks. Occasionally dogs get into the poultry house or poultry yard and manage to kill young or adult birds. Usually, the real loss comes from piling of the birds and subsequent suffocation due to fright.

Foxes and raccoons frequent areas where chickens are kept. The work

of a fox can frequently be identified by the signs of hair on the fence, or a hole where he crawled through. He usually kills several birds, and frequently leaves them behind partially buried. When the raccoon comes to visit he tends to eat the crops out of the birds, and some heads may be missing. Given the opportunity, he returns every fourth or fifth night to get more.

Owls also like chicken. Where one or two birds are killed every night and the heads and necks are missing, an owl may be the problem.

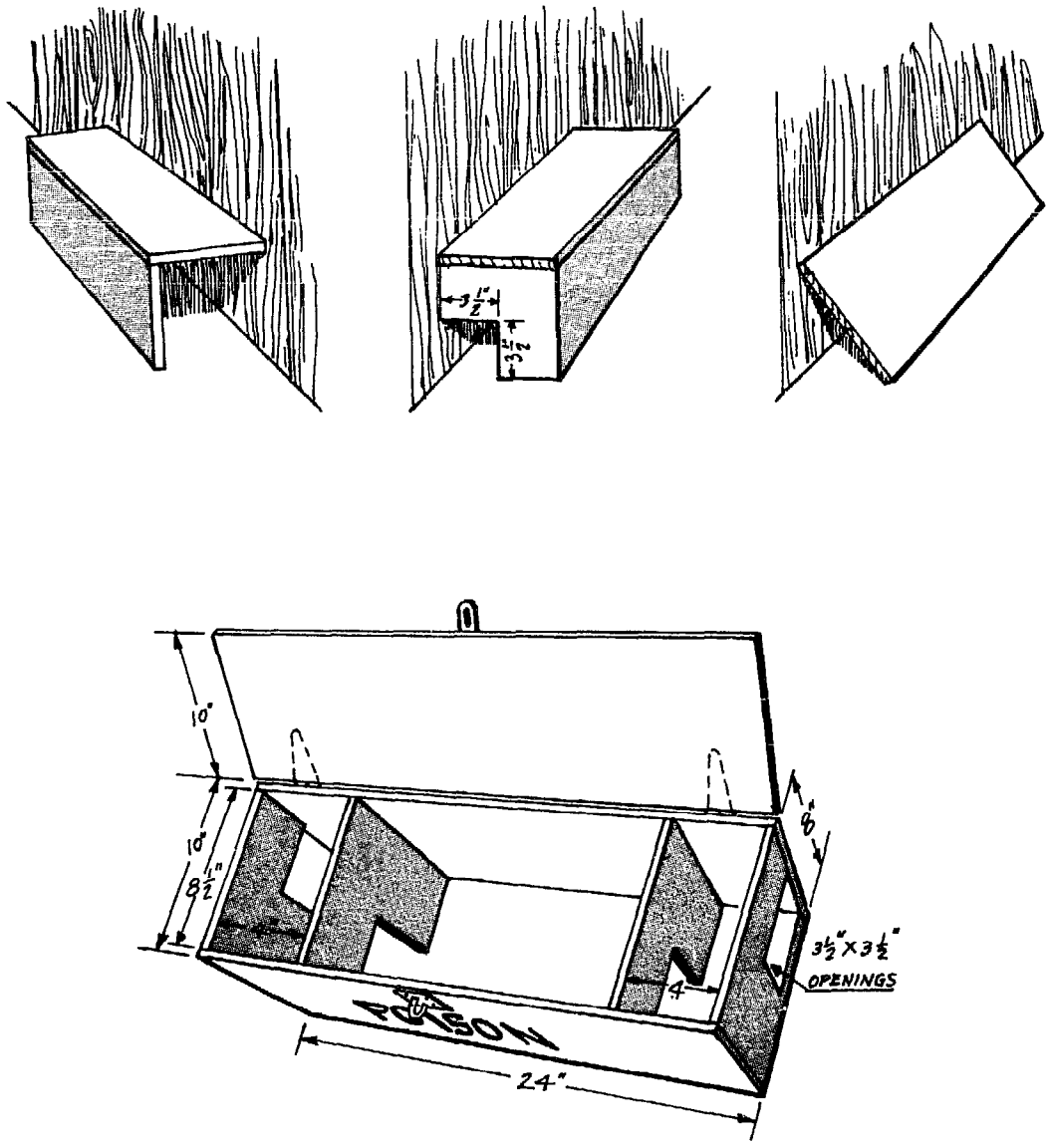

(Figure 31. Various types of bait stations.)

When birds are killed occasionally and are badly beaten, a dog problem is indicated. If several birds are killed on an irregular basis, it may also be the work of a mink or weasel, in which case there will be small bites around the neck and head.

Confinement-rearing has prevented many of the losses from predators. When birds are ranged or yarded they should be closed in a shelter at night. If range shelters are used, the space beneath the shelter should be screened. The installation of an electric fence a few inches above the ground may serve to discourage some predators.

List of Diagnostic Laboratories by State

ALABAMA

State of Alabama Veterinary Diagnostic Laboratory
P.O. Box 127
Albertville, Alabama 35950

State of Alabama Veterinary Diagnostic Laboratory
P.O. Box 2209
Auburn, Alabama 36830

State of Alabama Veterinary Diagnostic Laboratory
192 Boswell Street
Elba, Alabama 36323

ALASKA

Alaska State Federal Laboratory
P.O. Box 807
Palmer, Alaska 99645

ARIZONA

Department of Animal Pathology
University of Arizona
Tucson, Arizona 85721

ARKANSAS

Arkansas Livestock and Poultry Commission Diagnostic Laboratory
2915 South Pine
Little Rock, Arkansas 72204

Arkansas Livestock and Poultry Commission Diagnostic Laboratory
Highway 71 N. Box 766
Springdale, Arkansas 72764

CALIFORNIA

California Department of Agr. Veterinary Lab. Services
2789 South Orange Avenue
Fresno, California 93725

California Department of Agr. Veterinary Lab. Services
1500 Petaluma Blvd. S.
Petaluma, California 94952

California Department of Agr. Veterinary Lab. Services
3290 Meadowview Road
Sacramento, California 95823

San Diego County Veterinary Laboratory
5555 Overland Avenue
San Diego, California 92123

California Department of Agr. Veterinary Lab. Services
P.O. Box 255
San Gabriel, California 91778

Poultry Pathological Laboratory
P.O. Box P
Turlock, California 95380

COLORADO

Colorado State University, Animal Disease Diagnostic Laboratory
Ark. Valley Br. Sta.
Rocky Ford, Colorado 81067

CONNECTICUT

Department of Animal Diseases
Box U-89
University of Connecticut
Storrs, Connecticut 06268

DELAWARE

Avian Disease Laboratory
Route 2, Box 47
Georgetown, Delaware 19947

Eastern Shore Laboratory
P.O. Box 657
Laurel, Delaware 19956

Sterwin Laboratories Incorporated
Millsboro, Delaware 19966

Dept. of Animal Science and
Agricultural Biochemistry
University of Delaware
South College Avenue
Newark, Delaware 19711

FLORIDA

Dade City Diagnostic Laboratory
P.O. Box 1031
Dade City, Florida 33525

Kissimmee Animal Disease
Diagnostic Laboratory
P.O. Box 460
Kissimmee, Florida 32741

Live Oak Diagnostic Laboratory
P.O. Drawer O,
Live Oak, Florida 32060

Miami Springs Diagnostic Laboratory
8701 N.W. 58th Street
Miami, Florida 33166

GEORGIA

Veterinary Pathology
Georgia Department of Agriculture
19 Hunter Street SW
Atlanta, Georgia 30334

Georgia Poultry Laboratory Number 2
P.O. Box 349
Canton, Georgia 30114

Georgia Poultry Laboratory Number 4
1126 Lamar Street
Dalton, Georgia 30720

Georgia Poultry Laboratory Number 1
P.O. Box 148
Oakwood, Georgia 30566

North East Georgia Poultry
Laboratory
Box 37
Royston, Georgia 30662

Georgia Poultry Laboratory Number 6
Coastal Pl. Expt. Sta.
Tifton, Georgia 31794

HAWAII

Hawaii Dept. of Agr., Veterinary
Laboratory Branch
1428 South King Street
Honolulu, Hawaii 96814

IDAHO

Idaho Livestock Disease Control
Laboratory
P.O. Box 7249
Boise, Idaho 83707

ILLINOIS

Regional Diagnostic Laboratory
235 North Walnut Street
Centralia, Illinois 62801

Peoria Regional Diagnostic
Laboratory
P.O. Box 1078
Peoria, Illinois 61601

Laboratories of Veterinary
Diagnostic Medicine
University of Illinois
Urbana, Illinois 61801

IOWA

Veterinary Diagnostic Laboratory
Iowa State University
Ames, Iowa 50010

Dr. Mayfield Laboratories
Incorporated
1209 South Main St.
Charles City, Iowa 50616

Salsbury Laboratory
(Veterinary Services)
2000 Rockford Road
Charles City, Iowa 50616

Diagnostic Laboratory, Fort Dodge
Laboratory Inc.
800 5th Street N.S.
Fort Dodge, Iowa 50501

KANSAS

Veterinary Diagnostic Laboratory
College of Vet. Med.
Manhattan, Kansas 66502

KENTUCKY

Kentucky Dept. of Agr., Animal Diagnostic Laboratory
North Drive
Hopkinsville, Kentucky 42240

Dept. of Veterinary Science Diagnostic Laboratory
University of Kentucky
Lexington, Kentucky 40506

Central Kentucky Animal Disease Laboratory
RR 6 Newtown Pike
Lexington, Kentucky 40505

LOUISIANA

W.E. Anderson Livestock Diagnostic Laboratory
P.O. Box 1276 Plank Road
Baton Rouge, Louisiana 70821

Central Louisiana Livestock Diagnostic Laboratory
Route 1 Box 51-F
Lecompte, Louisiana 71346

Northwest Louisiana Livestock Diagnostic & Research Laboratory
Robeline Rd. Box 4297 N.S.U.
Natchitoches, Louisiana 71457

MAINE

University of Maine Animal Pathology Diagnostic & Research Laboratory
Hitchner Hall
Orono, Maine 04473

Maine Poultry Consultants
Box 262
Waterville, Maine 04901

MARYLAND

Animal Health Department Laboratory
RFD
Centreville, Maryland 21617

Animal Health Department Laboratory
P.O. Box 1234
Frederick, Maryland 21701

Animal Health Department Laboratory
12 South Third St.
Oakland, Maryland 21550

Animal Health Department Laboratory
P.O. Box J
Salisbury, Maryland 21801

MASSACHUSETTS

Dept. of Veterinary and Animal Sciences

Paige Laboratory
University of Mass.
Amherst, Mass. 01002

Avian Diagnostic Laboratory
240 Beaver Street
Waltham, Mass. 02154

MICHIGAN

Veterinary Diagnostic Laboratory
Michigan State University
East Lansing, Michigan 48823

Michigan Dept. of Agr. Laboratory Division
1615 S. Harrison Road
East Lansing, Michigan 48823

Escanaba Laboratory, Michigan Dept. of Agriculture
305 Ludington Street
Escanaba, Michigan 49829

MINNESOTA

University of Minnesota, Vet. Diagnostic Laboratory
St. Paul Campus
St. Paul, Minnesota 55101

MISSISSIPPI

Veterinary Diagnostic Laboratory, Mississippi Board of Animal Health
2531 North West St.
Jackson, Mississippi 39201

MISSOURI

Veterinary Medical Diagnostic Laboratory
University of Missouri
Columbia, Missouri 65201

Ralston Purina Veterinary Laboratory
Veterinary Department
Checkerboard Square
St. Louis, Missouri 63188

MONTANA

State of Montana, Livestock Sanitary Board Diagnostic Laboratory
P.O. Box 997
Bozeman, Montana 59715

NEBRASKA

Harris Laboratories Incorporated
P.O. Box 80837
Lincoln, Nebraska 68502

Diagnostic Laboratory, Department of Veterinary Science
University of Nebraska
Lincoln, Nebraska 68503

Veterinary Science Laboratory
University of Nebraska
North Platte Station
North Platte, Nebraska 69101

NEVADA

Animal Disease Laboratory
Nevada Department of Agriculture
350 Capitol Hill Ave.
Reno, Nevada 89502

NEW HAMPSHIRE

Veterinary Diagnostic Laboratory
University of New Hampshire
Durham, New Hampshire 03824

NEW JERSEY

Rutgers Poultry Diagnostic Laboratory
Thompson Hall
New Brunswick, New Jersey 08903

New Jersey Health Diagnostic Laboratory
John Fitch Plaza
Trenton, New Jersey 08625

Rutgers Poultry Health Laboratory
2569 Landis Avenue
Vineland, New Jersey 08360

NEW MEXICO

State Federal Cooperative Laboratory
P.O. Box 464
Albuquerque, New Mexico 87103

NEW YORK

Cornell University, Duck Research Laboratory
Box 217 Old Ctry. Road
Eastport L.I. New York 11941

Department of Avian Diseases
N.Y. State Vet. College
Ithaca, New York 14850

Regional Poultry Disease Laboratory
88 Prince Street
Kingston, New York 12401

NORTH CAROLINA

Livestock and Poultry Disease Diagnostic Laboratory
Box 5658 Western Blvd.
Raleigh, North Carolina 27606

NORTH DAKOTA

North Dakota State Veterinary Diagnostic Laboratory
North Dakota State University
Fargo, North Dakota 58102

OHIO

Ohio State University, Dept. Veterinary Clinical Sciences, Clinical Pathology Laboratory
2578 Kenny Road
Columbus, Ohio 43210

Ohio Department of Agriculture,
Animal Disease Diagnostic
Laboratory
Reynoldsburg, Ohio 43068

OKLAHOMA

State Federal Laboratory
50 Northeast 23 Street
Oklahoma City, Oklahoma 73105

College of Veterinary Medicine
Oklahoma State University
Stillwater, Oklahoma 74074

OREGON

Oregon State Veterinary
Diagnostic Laboratory
Oregon State University
Corvallis, Oregon 97331

State Federal Veterinary Laboratory
635 Capitol St. N.E.
Salem, Oregon 97310

PENNSYLVANIA

Regional Poultry Diagnostic
Laboratory
Pennsylvania Department of
Agriculture
Doylestown, Pennsylvania 18901

Southwest District Diagnostic
Laboratory
R. 1. Evans City, Pennsylvania 16033

Poultry Diagnostic Laboratory
New Bolton Center
Kennett Square, Pennsylvania 19348

Whitmoyer Laboratories Incorporated
19 N. Railroad Street
Myerstown, Pennsylvania 17067

Pennsylvania Dept. of Agriculture,
Bureau of Animal Industry
Laboratory
Summerdale, Pennsylvania 17093

Regional Diagnostic Laboratory
R 92 South
Tunkhannock, Pennsylvania 18657

Poultry Diagnostic Laboratory,
Pennsylvania State University
Wiley Laboratory
University Park, Pennsylvania 16802

Animal Disease Diagnostic Laboratory
Animal Disease Building
University Park, Pennsylvania 16802

PUERTO RICO

Puerto Rico Animal Diagnostic
Laboratory
P.O. Box E
Dorado, Puerto Rico 00646

RHODE ISLAND

Diagnostic Laboratory Dept. of
Animal Pathology
University of Rhode Island
Kingston, Rhode Island 02881

SOUTH CAROLINA

Clemson University,
Livestock Laboratory
P.O. Box 1771
Columbia, South Carolina 29201

SOUTH DAKOTA

Animal Disease Research and
Diagnostic Laboratory
South Dakota State University
Brookings, South Dakota 57006

TENNESSEE

Poultry Service Laboratory
Knoxville, Tennessee 37901

C.E. Kord Animal Disease Laboratory
P.O. Box 40627 Mel. Sta.
Nashville, Tennessee 37204

TEXAS

Texas A and M University,
Poultry Disease Laboratory
FM 108 Box 84
Gonzales, Texas 78629

UTAH

Utah State University Veterinary Diagnostic Laboratory
Utah State University
Logan, Utah 84321

Branch Veterinary Laboratory
Utah Agricultural Experiment Station
P.O. Box 1068
Provo, Utah 84601

State Chemist Office and State Federal Cooperative Laboratory
412 Capitol Building
Salt Lake City, Utah 84114

VERMONT

Animal Pathology Laboratory
Hills Science Building
University of Vermont
Burlington, Vermont 05401

VIRGINIA

Department of Veterinary Science
Virginia Polytechnic and State University
Va. Polytech. Inst.
Blacksburg, Virginia 24061

Division of Animal Health and Dairies Regulatory Laboratory
116 Reservoir Street
Harrisonburg, Virginia 22801

Division of Animal Health and Dairies Regulatory Laboratory
Ivor, Virginia 23866

Division of Animal Health and Dairies Regulatory Laboratory
Box 4191
Lynchburg, Virginia 24502

Division of Animal Health and Dairies Central Laboratory
1 North 14 Street
Richmond, Virginia 23219

Division of Animal Health and Dairies Regulatory Laboratory
234 West Shirley Avenue
Warrenton, Virginia 22186

Division of Animal Health and Dairies Regulatory Laboratory
Box 436
Wytheville, Virginia 24382

WASHINGTON

Department of Veterinary Pathology
Pullman, Washington 99163

Poultry Diagnostic Laboratory
Western Washington Research & Experiment Center
Puyallup, Washington 98371

WEST VIRGINIA

State Federal Cooperative Animal Health Laboratory
RM B 86 Capitol Bldg.
Charleston, West Virginia 25305

West Virginia Regional Animal Health Laboratory
Box 568
Moorefield, West Virginia 26836

West Virginia University, Division of Animal & Veterinary Sciences
Agricultural Science Building
EV. Camp.
Morgantown, West Virginia 26506

WISCONSIN

Regional Animal Health Laboratory
1418 LaSalle Avenue
Barron, Wisconsin 54812

Murphy Diagnostic Laboratory
124 South Dodge Street
Burlington, Wisconsin 53105

Central Animal Health Laboratory
6101 Mineral Pt. Rd.
Madison, Wisconsin 53705

WYOMING

Wyoming State Veterinary Laboratory
Box 950
Laramie, Wyoming 82070

Addresses of Extension Poultry Specialists by State

ALABAMA

Auburn University, Auburn, Alabama 36830
102 Federal Bldg. P.O. Box 15, Cullman, Alabama 35055

ARIZONA

Agricultural Science Building, Univ. of Arizona, Tucson, Arizona 85721

ARKANSAS

University of Arkansas, P.O. Box 391, Little Rock, Arkansas 72203
University of Arkansas, Dept. Animal Sci. R-C123, Fayetteville, Arkansas 72701

CALIFORNIA

University of California, Department of Avian Sciences, Davis, California 95616
University of California, 306 Agricultural Extension Building, Riverside, California 92502
P.O. Box 1411, Modesto, California 95353
Agr. Res. & Ext. Center, 9240 S. Riverbend Ave., Parlier, California 93648
Suite 202, 21160 Box Springs Rd., Riverside, California 92507
566 Lugo Avenue, San Bernardino, California 92415
Building 4, 5555 Overland Avenue, San Diego, California 92123
Room 100-P, Mendocino Avenue, Santa Rosa, California 95401
684 Buena Vista St., Ventura, California 93001
1000 S. Harbor Blvd., Anaheim, California 92805

COLORADO

Colorado State University, Fort Collins, Colorado 80521

CONNECTICUT

University of Connecticut, Storrs, Connecticut 06268
Agricultural Center, Haddam, Connecticut 06492
24 Hyde Avenue Rt. 30, Rockville, Connecticut 06066
562 New London Turnpike, Norwich, Connecticut 06360

DELAWARE

University of Delaware, RD 2, Box 48, Georgetown, Delaware 19947
Agr. Hall, Newark, Delaware 19711

FLORIDA

University of Florida, Gainesville, Florida 32603
Chipley, Florida 32428

GEORGIA

University of Georgia, Athens, Georgia 30602
Calhoun, Georgia 30701
Oakwood, Georgia 30566
Tifton, Georgia 31794

HAWAII

University of Hawaii, 1825 Edmondson Rd., Honolulu, Hawaii 96822

IDAHO

University of Idaho, Moscow, Idaho 83843

ILLINOIS

University of Illinois, 322 Mumford Hall, Urbana, Illinois 61801

INDIANA

Purdue University, Lafayette, Indiana 47907

IOWA

Iowa State University, Kildee Hall, Ames, Iowa 50010

KANSAS

Kansas State University, Leland Call Hall, Manhattan, Kansas 66506

KENTUCKY

University of Kentucky, Lexington, Kentucky 40506
Somerset Community Col., 808 Monticello Rd., Somerset, Kentucky 42501
1270 Montgomery Avenue, Ashland, Kentucky 41101

LOUISIANA

Louisiana State University, Knapp Hall, Baton Rouge, Louisiana 70803

MAINE

University of Maine, Hitchner Hall, Orono, Maine 04473
P.O. Building, Belfast, Maine 04915
P.O. Building, Lewiston, Maine 04241
Federal Bldg. Rm. 209, Rockland, Maine 04841

MARYLAND

University of Maryland, Dept. of Poultry Science, College Park, Maryland 20742
Broiler Sub-Station, RFD 5, Salisbury, Maryland 21801

MASSACHUSETTS

University of Mass., 314 Stockbridge Hall, Amherst, Massachusetts 01002

MICHIGAN

Michigan State University, 113 Anthony Hall, East Lansing, Michigan 48823
Coop Extension Service, P.O. Box 79, Zeeland, Michigan 49464

MINNESOTA

University of Minnesota, St. Paul, Minnesota 55101

MISSISSIPPI

Mississippi State University, P.O. Box 5425, Mississippi State, Mississippi 39762
Box 9714, Jackson, Mississippi 39206

MISSOURI

University of Missouri, Columbia, Missouri 65201
RDI Bldg., Belcrest & E. Trafficway, Springfield, Missouri 65802

NEBRASKA

University of Nebraska, Lincoln, Nebraska 68503

NEW HAMPSHIRE

University of New Hampshire, 55 Pleasant St., Rm. 331, Concord, N.H. 03301
Kendall Hall, Durham, New Hampshire 03824

NEW JERSEY

Rutgers — The State University, CAES P.O. Box 231, New Brunswick, New Jersey 08903

NEW MEXICO

New Mexico State University, Dept. Poultry Sci., Box 3P, Las Cruces, New Mexico 88001

NEW YORK

Cornell University, Rice Hall, Ithaca, New York 14850
249 Highland Ave., Rochester, New York 14620
380 Federal Building, Syracuse, New York 13202
Coop Ext. Regional Office, Martin Rd., Voorheesville, N.Y. 12186

NORTH CAROLINA

North Carolina State University, P.O. Box 5307 Scott Hall, Raleigh, N.C. 27607

NORTH DAKOTA

North Dakota State Univ. Stevens Hall, Rm. 218A, Fargo, North Dakota 58102

OHIO

Ohio State Univ., 2120 Fyffe Road, Columbus, Ohio 43210
2120 Fyffe Road, Columbus, Ohio 43210 (Ohio State Univ.

OKLAHOMA

Oklahoma State University, Stillwater, Oklahoma 74074

OREGON

Oregon State University, Poultry Sci. Dept., Corvallis, Oregon 97331

PENNSYLVANIA

Pennsylvania State University, University Park, Pennsylvania 16802

PUERTO RICO

University of Puerto Rico, Rio Piedras, Puerto Rico 00928

RHODE ISLAND

University of Rhode Island, Kingston, Rhode Island 02881

SOUTH CAROLINA

Clemson University, Clemson, South Carolina 29631
P.O. Box 378, York, South Carolina 29745
P.O. Box 1711, Columbia, South Carolina 29201

SOUTH DAKOTA

South Dakota State University, Brookings, South Dakota 57006

TENNESSEE

University of Tennessee, P.O. Box 1071, Knoxville, Tennessee 37901

TEXAS

Texas A & M University, College Station, Texas 77843
Res. & Ext. Center, Box 220, Overton, Texas 75684

UTAH

Utah State University, Logan, Utah 84322

VERMONT

University of Vermont, Burlington, Vermont 05401

VIRGINIA

Virginia Polytechnic Institute, Blacksburg, Virginia 24061

WASHINGTON

Washington State University, Pullman, Washington 99163
Western Washington, Res. & Ext. Center, Puyallup, Washington 98371

WEST VIRGINIA

West Virginia University, Morgantown, West Virginia 26506

WISCONSIN

University of Wisconsin, Dept. Poultry Sci., Col. of Agr. & Life Sci., 1675 Observatory Dr., Madison, Wisconsin 53706

WYOMING

University of Wyoming, Univ. Station, P.O. Box 3354, Laramie, Wyoming 82071

WASHINGTON, D.C.

Extension Service — USDA, Room 5509 South Building, Washington, D.C. 20250

Directory of Poultry Publications

A number of U.S.D.A. and State Extension publications on poultry production and marketing are available and may be obtained by contacting the local County Extension Agent and State or Area Poultry Extension Specialists. The addresses of the Poultry specialists, by states, are given in a preceding section. A partial list of trade publications and books follows:

TRADE PUBLICATIONS

Broiler Industry, Garden State Building, Sea Isle City, N.J. 08243 — Monthly

Egg Industry, Garden State Building, Sea Isle City, N.J. 08243 — Monthly

Feedstuffs, 2501 Wayzata Blvd., Minneapolis, Minn. 55404 — Weekly

Poultry Digest, Garden State Building, Sea Isle City, N.J. — Monthly

Poultry Meat, Watt Publishing Co., Mount Morris, Illinois 61054 — Monthly

Poultry Tribune, Watt Publishing Co., Mount Morris, Illinois 61054 — Monthly

The Poultry Times, P.O. Box 1338, Gainsville, Georgia 30501 — Weekly

Turkey World, Watt Publishing Co., Mount Morris, Illinois 61054 — Monthly

BOOKS

Commercial Chicken Production Manual, Mack O. North, 1972. The AVI Publishing Co. Inc.

Diseases of Poultry, Biester & Schwartz, 5th Edition, 1965 Iowa State University

Farm Poultry Production, Wilson and Card, Interstate

Marketing Poultry Products, Benjamin, Gwin, Faber and Termohlen, 5th Ed. 1960 Wiley

Modern Waterfowl Management and Breeding Guide, Oscar Grow 1972, American Bantam Assoc.

Sources of Supplies and Equipment

Many of the supplies and equipment needs for the small poultry flock can be found at local feed store, hatchery or other agricultural supply outlets. Some of the large mail order houses such as Sear's and Ward's also handle agricultural supplies

As an aid to locating sources of certain items not readily available in some areas, a partial list of supplies and equipment and possible sources is included below.

Space would not permit a complete listing of products nor company names. There is no intent to recommend one source over another.

Bags — Dressed Poultry

Dow Chemical Co. Flexible Packaging Sales, James Savage Building., Midland, Michigan 48640

W. R. Grace and Co., Cryovac Division, Box 464, Duncan, South Carolina 29334

Gordon Johnson Industries, 2519 Madison Ave., Kansas City, Missouri 64108

Mobil Chemical Co., Plastics Div. Tech Center, Macedon, New York 14502

Bands — Identificiation — Leg and Wing

Gey Band and Tag Co. Inc., P.O. Box 363, Norristown, Pennsylvania 19401

National Band & Tag Co., 721 York Street, Newport, Kentucky 41071

Brooders

Anderson Box Co., P.O. Box 1851, Indianapolis, Indiana 46206

Beacon Industries, Inc., 100 Railroad Ave., Westminster, Maryland 21157.

Bramco Products, Mariette St., Canton, Georgia 30114

Brower Manufacturing Co., Box 1123, Quincy, Illinois 62301

Lyon Electric Co., 3425 Hancock St., P.O. Box 81303, San Diego, California 92138

Shenandoah Mfg. Co. Inc., Edom Rd., P.O. Box 839, Harrisonburg, Virginia 22801

Big Dutchman, A div. of U.S. Industries Inc., 200 N. Franklin St., Zeeland, Michigan 49464

Cages

American-Can, Div. of Jamesway Co. Lts., P.O. Box 156, Bowling Green, Ohio 43402

Anderson Box Co., P.O. Box 1851, Indianapolis, Indiana 46206

Big Dutchman, A div. of U.S. Industries Inc., 200 N. Franklin St., Zeeland, Michigan 49464

Diamond International Corp., 23400 Haggerty Road, Farmington, Michigan 48024

Chore-Time Equipment Inc., P.O. Box 518, Milford, Indiana 46542

Cannibalism Supplies and Equipment — Specs

Gey Band and Tag Co. Inc., P.O. Box 363, Norristown, Pennsylvania 19401

Kuhl Corporation, Box 26, Flemington, New Jersey 08820

National Band & Tag Co., 721 York Street, Newport, Kentucky 41071

Cannibalism Supplies and Equipment — Debeakers

Lyon Electric Co., 3425 Hancock St., P.O. Box 81303, San Diego, California 92138

Cannibalism Supplies and Equipment — Ointments and Paints

Eastern Laboratories Inc., 1483 Washington Ave., Vineland, New Jersey 08360

Vineland Laboratories Inc., 2284 E. Landis Ave., Vineland, New Jersey 08360

Caponizing Instruments

Mattox & Moore Inc., 1503 E. Riverside Dr., Indianapolis, Indiana 46202

Thomas Equipment & Supply Co., 5505 Langley Rd., Houston, Texas 77016

Catching Hooks

Holland Co., Inc., 208 Market St., Box 645, Lexington, North Carolina 27292

Thomas Equipment & Supply Co., 5505 Langley Rd., Houston, Texas 77016

Disinfectants

Carbola Chemical Co. Inc., Natural Bridge, New York 13665

The Diversey Corp., 212 E. Monroe St., Chicago, Illinois 60606

The Dow Chemical Co. Agri. Products, Box 1706, Midland, Michigan 48640

Hess & Clark, Div. of Rhodia Inc., 7th & Orange, Ashland, Ohio 44805

Pfizer Inc., Agri. Div., 235 E 42nd St., New York, N.Y. 10017

Salsbury Laboratories, Charles City, Iowa 50616

Vineland Laboratories Inc., 2285 E. Landis Ave., Vineland, New Jersey 08360

Whitmoyer Laboratories Inc., Sub. of Rohn & Haas Co., Myerstown, Pennsylvania 17067

Egg Baskets — Gathering

Barker Equipment Co., Div. Conco Inc., P.O. Box 111, Mendota, Illinois 61342

Big Dutchman, A div. of U.S. Industries Inc., 200 N. Franklin St., Zeeland, Michigan 49464

Brower Mfg. Co., Box 1123, Quincy, Illinois 62301

Kuhl Corporation, Box 26, Flemington, New Jersey 08820

Egg Candlers — Hand

Big Dutchman, A div. of U.S. Industries Inc., 200 N. Franklin St., Zeeland, Michigan 49464

Brower Mfg. Co., Box 1123, Quincy, Illinois 62301

Egg Cartons

Anderson Box Co., P.O. Box 1851, Indianapolis, Indiana 46206

Continental Packaging Corp., 555 North Michigan Ave., Kenilworth, New Jersey 07033

Diamond International Corp., Diamond Fiber Products Div., 733 Third Ave., New York, N.Y. 10017

Keyes Fibre Company, 160 Summit Ave., Montvale, New Jersey 07645

Packaging Corporation of America, 300 W. Main St., Griffith, Indiana 46319

Egg Cases and Filler Flats

Anderson Box Co., P.O. Box 1851, Indianapolis, Indiana 46206

Peter Berg & Company Inc., 917-19 Fifth St., N., Minneapolis, Minnesota 55401

Brooklyn Egg Case Co., Rt. 17 Box A., Harris, New York 12742

Diamond International Corp., Diamond Fiber Products Div., 733 Third Ave., New York, N.Y. 10017

Packaging Co. of California, 2900 San Pablo Ave., Berkeley, California 94702

Packaging Corporation of America, 300 W. Main St., Griffith, Indiana 46319

Egg Scales — Small

Brower Manufacturing Co., Box 1123, Quincy, Illinois 62301

Beacon Steel Products Co., Inc., Box 600 Westminster, Maryland 21157
W. Kent Co., 13145 Coronado Dr., North Miami, Florida 33161
National Poultry Equipment Co., Box 238, 615 Wells Ave., N. Renton, Washington 98055

Egg Washers — Small

Big Dutchman, A div. of U.S. Industries Inc., 200 N. Franklin St., Zeeland, Michigan 49464
National Poultry Equipment Co., Box 238, 615 Wells Ave., N. Renton, Washington 98055

Egg Washing Detergent — Sanitizers

Big Dutchman, A div. of U.S. Industries Inc., 200 N. Franklin St., Zeeland, Michigan 49464
Brower Manufacturing Co., Box 1123, Quincy, Illinois 62301
Kuhl Corporation, Box 26, Flemington, New Jersey 08820
National Poultry Equipment Co., Box 238, 615 Wells Ave., N. Renton, Washington 98055
Proctor & Gamble Agr. Chemicals, Sales Dept., Box 599, Cincinnati, Ohio 45201
Vineland Laboratories Inc., 2285 E. Landis Ave., Vineland, N.J. 08360

Fans — Ventilation

Aerovent Fan & Equipment Inc., 5530 Pennsylvania Ave., Box 9007, Lansing, Michigan 48909
Amer-Can, Div. of Jamesway Co. Ltd., P.O. Box 156, Bowling Green, Ohio 43402
Big Dutchman, A div. of U.S. Industries Inc., 200 N. Franklin St., Zeeland, Michigan 94964

Feeders & Waterers

Amer-Can, Div. of Jamesway Co. Ltd., P.O. Box 156, Bowling Green, Ohio 43402
Beacon Industries, Inc., 100 Railroad Ave., Westminster, Maryland 21157.
Big Dutchman, A div. of U.S. Industries Inc., 200 N. Franklin St., Zeeland, Michigan 49464
Bramco Products, Marietta St., Canton, Georgia 30114
Brower Manufacturing Co., Box 1123, Quincy, Illinois 62301
H. D. Hudson Mfg. Co., 154 E. Erie St., Chicago, Illinois 60611
Shenandoah Mfg. Co. Inc., Edom Rd., P.O. Box 839, Harrisonburg, Virginia 22801

Incubators — Small

Brower Manufacturing Co., Box 1123, Quincy, Illinois 62301
Jamesway, Div. of Butler Mfg. Co., 104 W. Milwaukee Ave., Ft. Atkinson, Wisconsin 53538
Humidaire Incubator Co., 217 W. Wayne St., New Madison, Ohio 45346
Lyon Electric Co., 3425 Hancock St., P.O. Box 81303, San Diego, California 92138
Petersime Incubator Co., Gettysburg, Ohio 45328
Robbins Incubator Co., Box 899, Denver, Colorado 80201

Knives — Poultry Dressing

Barker Poultry Equipment Co., P.O. Box 368, 802 South Madison Ave., Ottumwa, Iowa 52501
W. Kent Co., 13145 Coronado Dr., North Miami, Florida 33161
Thomas Equip. & Supply Co., 5505 Langley Rd., Houston, Texas 77016

Pickwick Company, P.O. Box 756, 1120 Glass Rd. N.E., Cedar Rapids, Iowa 52406

Nests

Amer-Can, Div. of Jamesway Co. Ltd., P.O. Box 156, Bowling Green, Ohio 43402

Anderson Box Co., P.O. Box 1851, Indianapolis, Indiana 46206

Brower Manufacturing Co., Box 1123, Quincy, Illinois 62301

Kuhl Corporation, Box 26, Flemington, New Jersey 08820

Shenandoah Mfg. Co. Inc., Edom Rd., P.O. Box 839, Harrisonburg, Virginia 22801

Poultry Pickers, Scalders

Ashley Machine Inc., Box 2, Greensburg, Indiana 47240

Barker Poultry Equipment Co., P.O. Box 368, 802 South Madison Ave., Ottumwa, Iowa 52501

W. Kent Co., 13145 Coronado Dr., North Miami, Florida 33161

Pickwick Company, P.O. Box 756, 1120 Glass Rd. N.E., Cedar Rapids, Iowa 52406

Thermostats — Mercury or Open Contact

Aerovent Fan & Equipment Inc., 5530 Pennsylvania Ave., Box 9007, Lansing, Michigan 48909

Beacon Industries, Inc., 100 Railroad Ave., Westminster, Maryland 21157.

Big Dutchman, A div. of U.S. Industries Inc., 200 N. Franklin St., Zeeland, Michigan 49464

Chick Master Incubator Corp., 3212 W. 25th St., Cleaveland, Ohio 44109

Diamond International Corp., 23400 Haggerty Road, Farmington, Michigan 48024

Petersime Incubator Co., Gettysburg, Ohio 45328

Thermostats — Wafer

Brower Manufacturing Co., Box 1123, Quincy, Illinois 62301

Lyon Electric Co., 3425 Hancock St., P.O. Box 81303, San Diego, California 92138

Shenandoah Mfg. Co. Inc., Edom Rd., P.O. Box 839, Harrisonburg, Virginia 22801

A. R. Wood-Northco, Box 218, Lucerne, Minnesota 56155

Water Warmers

Brower Manufacturing Co., Box 1123, Quincy, Illinois 62301

H. D. Hudson Mfg. Co., 154 E. Erie St., Chicago, Illinois 60611

Wax-Defeathering

Du Bois Chemicals, Du Bois Terrace, Cincinnati, Ohio 45202

Gainesville Machine Co. Inc., P.O. Box 1258, Gainesville, Georgia 30501

Gordon Johnson Industries, 2519 Madison Avenue, Kansas City, Missouri 64108

National Wax Co., 3650 Touhy, Skokie, Illinois 60076

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Mercia, L. S., *Lighting Replacements and Layers,* Vermont Extension Service, University of Vermont, Burlington, Vt.

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Ota, Hajime, *Housing and Equipment for Laying Hens,* Misc. Publication 728, Agr. Research Service, U.S.D.A.

1974-75 *Poultry Management and Business Analysis Manual,* Bulletin 566, Cooperative Extension Services, Extension Poultrymen in New England.

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Raising Livestock on Small Farms, Farmers Bulletin No. 2224, U.S.D.A.

Ridlen, S. F., and Johnson, H.S., *4-H Poultry Management Manual — Unit 1,* Cooperative Extension Service, University of Illinois, Urbana, Ill.

Talmadge, Dan W., *Brooding and Rearing Baby Chicks,* Published by the Cooperative Extension Services of the Northeast.

Warren, Richard, *4-H Laying Flock Management,* 4-H Circular 79, Published by the Cooperative Extension Services in New England.

GENERAL FEED REQUIREMENTS FOR DIFFERENT TYPES OF BIRDS AT VARIOUS AGES

Type of Bird		Type Feed	Percent Protein	Lbs/100 Birds	
				White Egg	Brown Egg
Chickens:					
Pullets	0 — 8 wks.	Starter	20	280	364
	8 — 12 wks.	Grower	17	308	392
	12 — 22 wks.	Grower or Developer	14	1064	1289
Layers	22 + wks.	Layer	17	23	25
Broilers or Fryers	0 — 4 wks.	Starter	22	200	
	5 — 7 wks.	Grower	20	500	
	7 — 8 wks.	Finisher	18	100	
Roasters	0 — 4 wks.	Starter	22	200	
	4 — 13 wks.	Grower	16	1200	
	13 — market	Finisher	14	1000	
Turkeys:					
Small	0 — 7 wks.	Starter	28	600	
	7 — 18 wks.	Grower	20	3000	
Large	0 — 8 wks.	Starter	28	1000	
	8 — 16 wks.	Grower	20	3000	
	16 — 24 wks.	Finisher	14	3500	
Ducks: (White Pekin)					
For Market	0 — 2 wks.	Starter	22-24	214	
	2 — 4 wks.	Grower	18-20	510	
	4 — 8 wks.	Finisher	16-17	1410	
For Breeders					
	0 — 2 wks.	Starter	22-24	214	
	2 wks. maturity	Grower	18-20	*	
Geese: (White EMBDEN OR Chinese)					
	0 — 3 wks.	Starter	20-22	525	
	3 — 14 wks.	Grower	15	5600	
	14 wks. to market (24-30 wks.)	Grower	15		

*Ducks and particularly geese are good foragers. From approximately 3 weeks of age with good forage available, savings of up to 35% in feed consumption can be realized.

A "NATURAL" LAYING HEN DIET

To be fed as all-mash to medium size layers kept in floor pens

Ingredient	Amount (lbs.) Per 100 lbs.	Amount (lbs.) Per Ton
Yellow corn meal	60.00	1200
Wheat middlings	15.00	300
Soybean meal (dehulled)	8.00	160
Maine herring meal (65%)	3.75	75
Meat & bone meal (47%)	1.00	20
Skim milk, dried	3.00	60
Alfalfa leaf meal (20%)	2.50	50
Iodized salt	0.40	8
Limestone, grd. (38% Ca)	6.35	127
Totals	100.00	2000

Calculated Analysis	"Natural" Laying Laying Hen Diet (per pound)	Recommended (N.E.C.C.)* Nutritionists (per pound)
Metabolizable energy Cal./lb.	1252	1292
Protein	16.07%	16%
Lysine	0.79%	0.74%
Methionine	0.31%	0.29%
Methionine & cystine	0.55%	0.54%
Fat	3.67%	3.33%
Fiber	3.15%	2.51%
Calcium	2.77%	2.75%
Total phosphorus	0.53%	0.50%
Available phosphorus	0.44%	0.42%
Vitamins (units or mgs./lb.)		
Vitamin A activity (U.S.P. units/lb.)	5112	5290
Vitamin D (I.C.U.)		1000
Riboflavin (mg.)	1.36	1.38
Pantothenic acid (mg.)	3.89	4.05
Choline Chloride (mg.)	411	500
Niacin (mg.)	17.46	16.95

The birds *must* receive *direct* sunlight to enable them to synthesize vitamin D. Unfortified cod liver oil can be fed in place of sunlight to supply vitamin D. The amount of cod liver oil would depnd upon the potency of the oil — the need is for 1000 (I.C.U.)** per pound of feed.

(Prepared by Dr. Richard Gerry, Department of Animal & Veterinary Sciences, University of Maine, Orono, Maine)

*New England College Conference nutritionists

**International Chick Unit

POULTRY MANURE INFORMATION

Manure Production

Layers: 25 pounds per 100 per day with normal drying.
Four-tenths of a cubic foot per 100 per day.
Moisture content 75-80% as defecated.
Pollution load — 7 to 12 layers equal one human.
Weight of a cubic foot of poultry manure at 70% moisture is approximately 65 pounds.

Broilers: Manure and litter per 100 birds
8 weeks equals 400 pounds or 11.2 cubic feet at 25% moisture.

Fertilizer Value of Poultry Manure*

			Pounds per Ton	
	Moisture %	**Nitrogen**	**Phosphorous**	**Potash**
Fresh Manure	75	29	10	8
Stored Manure	63.9	24	13	16
Broiler Litter	18.9	72	25	30
Layer litter	22.1	50	23	36
Slurry (Liquid)	92.0	22	12	7

When nitrogen is worth 25¢ per pound, phosphorous 15¢ per pound and potash 8¢ per pound the values per ton of poultry manure are:

Fresh Manure	$9.39
Stored Manure	9.23
Broiler Litter	24.15
Layer Litter	14.86

Other elements of plant food contained in poultry manure include calcium, magnesium, copper, manganese, zinc, chlorine, sulphur, and boron.

*Based on information from Univ. of New Hampshire *Bulletin 444 — Farm Manure — 1966.*

Glossary of Terms

Abdomen Area between the keel and pubic bones.

Air Cell Air space usually found in the large end of the egg.

Albumen The white of the egg.

American Breeds Those breeds developed in America and having common characteristics such as, yellow skin, non-feathered shanks, red earlobes. All lay brown eggs except the Lamonas which produce white eggs.

Axial Feather The short wing feather between the primaries and secondaries.

Baby Chick Newly hatched chick before it has been fed or watered.

Bantam Diminutive fowl. Some are distinct breeds, others are miniatures of large breeds.

Beak Upper and lower mandibles of chickens, turkeys, phesants, peafowl, etc.

Bean Hard protuberance on the upper mandible of waterfowl.

Bill The upper and lower mandibles of waterfowl.

Blood Spot Blood in an egg caused by a rupture of small blood vessels usually at the time of ovulation.

Breast The forward part of the body between the neck and the keel bone.

Breast Blister Enlarged discolored area or sore in the area of the keel bone.

Breed A group of fowl related by ancestry and breeding true to certain characteristics such as body shape and size.

Broiler-Fryer Young chickens under 12 weeks of age of either sex, that are tender-meated with soft, pliable smooth-textured skin and flexible breastbone cartilage.

Brooder Heat source for starting young birds.

Broody Maternal instinct causing the female to set or want to hatch eggs.

Candle To determine the interior quality of an egg through the use of a special light in a dark room.

Cannibalism The habit of eating other birds in the flock.

Capon A castrated male fowl having undeveloped comb and wattles, and longer hackles, saddle and tail feathers than the normal male.

Chalazae White, twisted rope-like structures which tend to anchor the egg yolk in the center of the egg, by their attachment to the layers of thick albumen.

Chalaziferous layer Thin layer of thick white surrounding the yolk and is continuous with the chalazae.

Cloaca The common chamber or receptacle for the digestive, urinary and reproductive systems.

Cock A male bird over 12 months of age.

Cockerel A male bird under 12 months of age.

Coccidiostat A drug used to control or treat coccidiosis disease.

Comb The fleshy prominence on the top of the head of fowl.

Crop An enlargement of the gullet where food is stored and prepared for digestion.

Crossbred The first generation resulting from crossing two different breeds or varieties or the crossing of first generation stock with first generation stocks resulting from the crossing of other breeds and varieties.

Cull A bird not suitable to be in a laying or breeding pen or not suitable as a market bird.

Culling The act of removing unsuitable birds from the flock.

Debeak To remove a part of the beak to prevent feather pulling or cannibalism.

Drake Male duck.

Dub To trim the comb and wattles close to the head.

Duck Any member of the family Anatidae and specifically a female.

Duckling The young of the family Anatidae.

Ear Lobe Fleshy patch of skin below ear. It may be red, white, blue or purple, depending upon the breed of chicken.

Embryo A young organism in the early stages of development, as before hatching from the egg.

Face Skin around and below the eyes.

Flight Feathers Primary feathers of the wing, sometimes used to denote the primaries and secondaries.

Follicle Thin, highly vascular ovarian tissue containing the growing ovum.

Fowl Term applied collectively to chickens, ducks, geese, etc. or the market class designation for old laying birds.

Gander Male goose.

Germinal Disc or Blastodisc Site of fertilization on the egg yolk.

Gizzard Muscular stomach. Its main function is grinding food and partial digestion of proteins.

Goose The female goose as distinguished from the gander.

Gosling A young goose of either sex.

Gullet or Esophagus The tubular structure leading from the mouth to the glandular stomach.

Hackle Plumage on the side and rear of the neck of fowl.

Hen A female fowl more than 12 months of age.

Hock The joint of the leg between the lower thigh and the shank.

Horn Term used to describe various color shadings in the beak of some breeds of fowl such as the Rhode Island Red.

Hover Canopy used on brooder stoves to hold heat near the floor when brooding young stock.

Infundibulum or Funnel Part of the oviduct which receives the ova (egg yolks) when they are ovulated. Fertilization of the egg takes place in the infundibulum.

Isthmus Part of the oviduct where the shell membranes are added during egg formation.

Keel Bone Breast bone or sternum.

Litter Soft, absorbent material used to cover floors of poultry houses.

Magnum Part of the oviduct which secrets the thick albumen or white during the process of egg formation.

Mandible The upper or lower bony portion of the beak.

Meat Spots Generally blood spots which have changed in color due to chemical action.

Molt To shed old feathers and regrow new ones.

Oil Sac or Uropygial Gland Large oil gland on the back at the base of the tail — used to preen or condition the feathers.

Ova Round bodies (yolks) attached to the ovary. These drop into oviduct and become yolk of the egg.

Oviduct Long glandular tube where egg formation takes place and leading from the ovary to the cloaca. It is made up of the funnel, magnum, isthmus, uterus and vagina.

Pendulous crop Crop that is usually impacted and enlarged and hangs down in an abnormal manner.

Plumage The feathers making up the outer covering of fowls.

Poult A young turkey.

Primaries The long stiff flight feathers at the outer tip of the wing.

Pubic Bones The thin terminal portion of the hip bones that form part of the pelvis. Are used as an aid in judging productivity of laying birds.

Pullet Female chicken less than 1 year of age.

Recycle, or force molt To force into a molt with a cessation of egg production.

Relative Humidity The percentage of moisture saturation of the air.

Replacements Term used to describe young birds which will replace an old flock.

Roasters Young chickens of either sex, usually 3 to 5 months of age, that are tender-meated with soft, pliable, smooth textured skin and with a breastbone cartilage, somewhat less flexible than the broiler-fryer.

Roost A perch on which fowl rest or sleep.

Secondaries The large wing feathers adjacent to the body, visible when the wing is folded or extended.

Sex-linked Any inherited factor linked to the sex chromosomes of either parent. Plumage color differences between the male and female progeny of some crosses is an example of sex-linkage. Useful in day old sexing of chicks.

Shell membranes The two membranes attached to the inner egg shell. They normally separate at the large end of the egg to form air cells.

Slip A male from which all of both testicles were not removed during the caponizing operation.

Snood Fleshy appendage on the head of a turkey.

Sperm or spermatozoa The male reproductive cells capable of fertilizing the ova.

Spur The stiff, horny process on the legs of some birds. Found on the inner side of the shanks.

Standard-bred Conforming to the description of a given breed and variety as described in the American Standard of Perfection.

Sternum The breast bone or keel.

Stigma The suture line or non-vascular area where the follicle ruptures when the mature ovum is dropped.

Strain Fowl of any breed usually with a given breeder's name and which has been reproduced by closed-flock breeding for 5 generations or more.

Testicles or testes The male sex glands.

Trachea or Windpipe That part of the respiratory system that conveys air from the larynx to the bronchi and to the lungs.

Undercolor Color of the downy part of the plumage.

Uterus The portion of the oviduct where the thin white, the shell and shell pigment are added during egg formation.

Vagina Section of the oviduct which holds the formed egg until it is laid

Vent or Anus Is the external opening from the cloaca.

Vitelline membrane Thin membrane which encloses the ovum.

Wattles The thin pendant appendages at either side of the base of the beak and upper throat, usually much larger in males than in females.

Windpuffs Air trapped under the outer skin as a result of rupturing the air sacs during caponization.

Xanthophyll One of the yellow pigments found in green plants, yellow corn, fatty tissues and egg yolks.

Yolk Ovum, the yellow portion of the egg.

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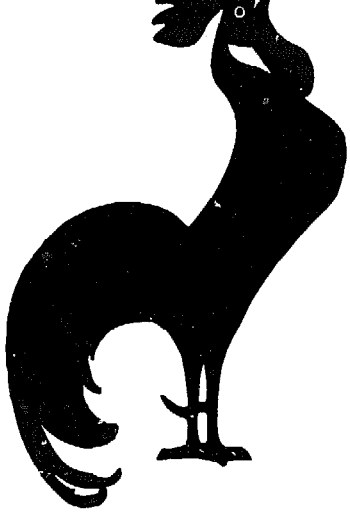

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Leonard S. Mercia is a native Vermonter. At the University of Vermont he majored in Agriculture and furthered his education at Ohio State University. Later, he worked with the Ohio Poultry Improvement Association as Assistant Field Manager for three years. He returned to Vermont in 1954 as Extension Poultryman.

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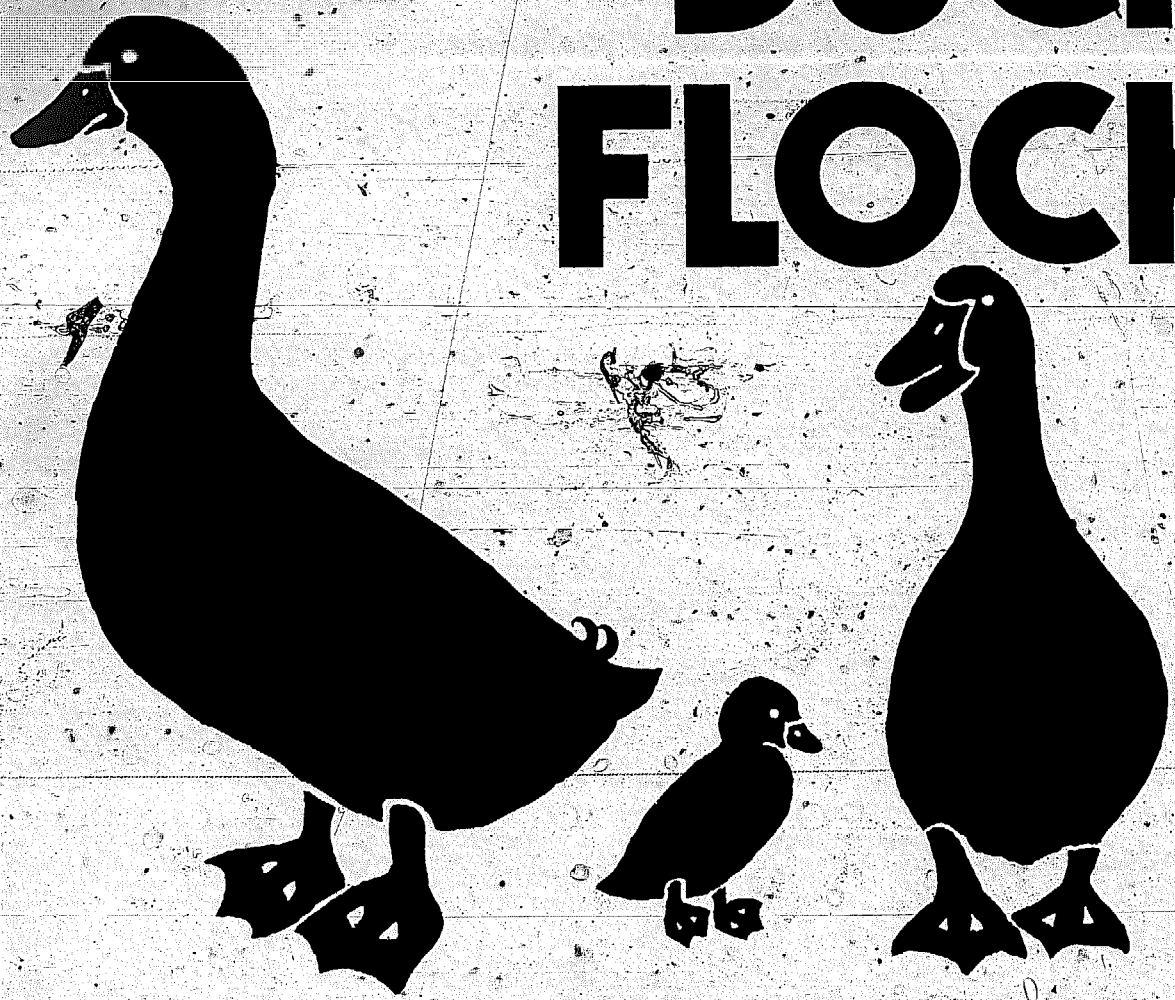

RAISING THE HOME DUCK FLOCK

A Complete Guide

Dave Holderread

Illustrated by Millie Holderread

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Dedicated to Mom—

the one who took me
—as a young child—
on walks through nature,
teaching me to smell the flowers
and listen to the song of birds. . .

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Foreword

Hobbyists, homesteaders and commercial duck raisers alike will find this book a handy reference. It is based on the author's longtime experience and supplemented with data from current scientific research. All aspects of small-scale duck husbandry are presented in an orderly, understandable form. Whether you are a beginner with a first-time pet, or a commercial operator wishing to formulate or mix your own feed, *Raising the Home Duck Flock* can provide the information you need.

AL HOLLISTER
Department of Poultry Science
Oregon State University
Corvallis, Oregon

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*Henry K. Miller, Lebanon, Pa., American Poultry Association licensed

*Deceased

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And most of all, to Millie, my wife and best friend, for patience and encouragement throughout this project, for weighing feed and birds and keeping records on a number of experiments, for proofreading and typing the manuscript, and for the best part of the book—the sketches.

Introduction

In our world, approximately 25 percent of the human population suffer from serious nutritional deficiencies. Every day, including today, thousands die of starvation and diseases related to malnourishment. Many of us find these facts distressing as well as difficult to comprehend. And yet, they are a stark reality.

The problem of producing sufficient food is complex and many-faceted. There are no easy solutions. However, it has become obvious that modern agribusiness with its impressive arsenal of insecticides, herbicides, chemical fertilizers, monstrous machinery and large, specialized farms is not the ultimate answer we once thought it was.

The inability to produce and distribute adequate quantities of food is not the only shortcoming of current agricultural technology. In many cases production methods are depleting soil fertility and polluting our land, water and air at a dangerous rate, the quality of some of its products is questionable and vast numbers of small farmers are being strangled out of existence.

Growing numbers of people are becoming convinced that if we are to improve both the quantity and quality of food and at the same time restore our environment to a healthy condition, the emphasis must move back to smaller, less specialized farms. A practical result of this conviction is the increasing number of persons who are raising a major portion of their food.

Due to their size, efficiency and adaptability, poultry are the most popular type of small stock raised by homesteaders and backyard farmers. In many countries, chickens are the most common fowl kept. However, after raising and studying the various types of domestic poultry, I believe that for many situations, ducks are the most practical bird available. In a world of limited space and resources, the practicality of raising ducks becomes obvious as one recognizes the unique abilities of these waterfowl to utilize foodstuffs that normally go unharvested, control harmful insects, slugs, snails and unwanted aquatic plants, thrive under harsh conditions with limited shelter, resist diseases and parasites, and produce food efficiently.

While several good publications on waterfowl are available for the exhibitor and commercial producer, literature prepared specifically for the home flock owner is limited. *Raising the Home Duck Flock* is an attempt to provide a comprehensive handbook that clearly outlines the information needed by backyard farmers to raise ducks efficiently and with the least number of frustrations.

Because my experience with ducks has been limited to tropical Puerto Rico and the Pacific Coast of the United States, I lack firsthand knowledge in caring for waterfowl in other regions. To help bridge this gap, veteran poultry breeders and hatchery people from across North America were corresponded with or interviewed in laying the groundwork for this book.

In various sections of the text, the material presented was obtained from work conducted through the vocational poultry program at Academia Menonita Betania in Aibonito, Puerto Rico. The studies carried out at Betania were specifically designed for gathering information which would be pertinent to the small, home poultry flock.

Although this manual emphasizes the practical aspects of ducks, I hope you will also learn to appreciate the beauty and entertainment they have to offer. Over the past twenty years, ducks have added a great deal of color to my daily life, as well as having provided food and clothing. I trust they'll do the same for you.

DAVE HOLDERREAD

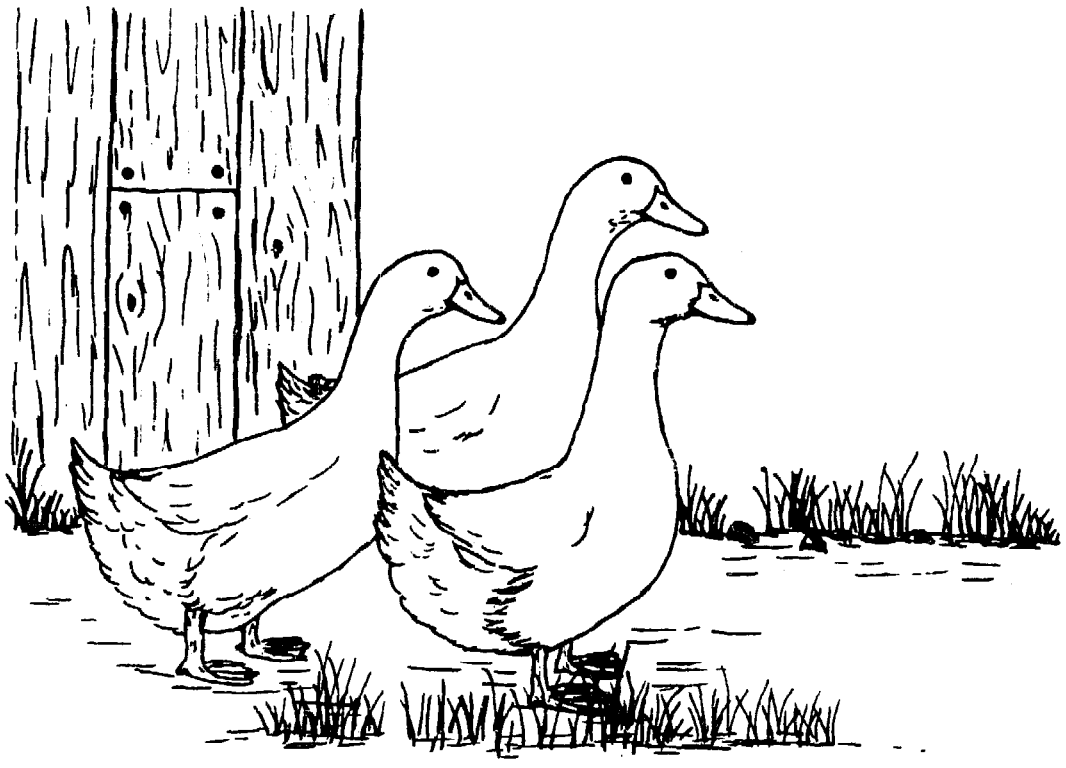

CHAPTER 1

Why Ducks?

The popularity of ducks is increasing in many areas of the world. It appears that the rest of us are beginning to understand what Europeans and Asians have known for centuries—ducks are one of the most *versatile* and *useful* of all domestic animals.

For the home poultry flock, we're looking for birds that produce meat and eggs efficiently, require minimal care and shelter, can find a good portion of their own food, destroy weed seeds and insects, don't need to be vaccinated and otherwise pampered, and add a touch of beauty and interest to our lives. For many situations, it's difficult to find a better all-purpose bird than *the duck*.

EASY TO RAISE

People who have kept all types of poultry generally agree that ducks are the easiest domestic bird to raise. Along with guinea fowl and geese, ducks are incredibly resistant to disease. While chickens usually must be vaccinated for communicable diseases and regularly treated for worms, coccidiosis, mites

and lice, duck keepers can normally forget about these inconveniences. Even when kept under poor conditions, small duck flocks are seldom bothered by sickness or parasites.

TABLE 1
GENERAL COMPARISON OF POULTRY

Bird	*Raisability*	*Disease Resistance*	*Special Adaptations*
Coturnix Quail	Good	Good	Egg and meat production in extremely limited space.
Guinea Fowl	Fair-Good	Excellent	Gamy-flavored meat; insect control; alarm. Thrive in hot climates.
Pigeons	Good	Good	Message carriers; meat production in limited space. Quiet.
Chickens	Fair-Good	Fair-Good	Eggs; meat; natural mothers. Adapt to cages, houses or range.
Turkeys	Poor-Fair	Poor-Fair	Heavy meat production.
Ducks	Excellent	Excellent	Eggs; meat; feathers; insect, snail, slug, aquatic plant control. Cold, wet climates.
Geese	Excellent	Excellent	Meat; feathers; lawn mowers; "watchdogs"; aquatic plant control. Cold, wet climates.

RESISTANT TO COLD, WET AND HOT WEATHER

Mature waterfowl are practically immune to wet or cold weather and better adapted to cope with these conditions than are chickens, turkeys, guineas or quail. With thick coats of well-oiled feathers, ducks can remain outside in the wettest weather. While chickens have protruding combs and wattles that must be protected from frostbite, and bare faces that allow the escape of valuable body heat, ducks are more completely clothed and are able to winter comfortably outdoors with only a windbreak, even when temperatures fall below 0°F. Ducks also do well in hot climates if they have access to plenty of shade and drinking water. During torrid weather, bathing water is beneficial.

INSECT, SNAIL AND SLUG EXTERMINATORS

Nurturing a special fondness for mosquito pupae, Japanese beetle larvae, potato beetles, grasshoppers, snails and slugs, ducks are extremely effective in controlling these and other pests. In the midwestern United States, ducks are used to reduce plant and crop damage during severe grasshopper infestations. In areas plagued by liver flukes, ducks can help correct the problem by consuming the snails which host this troublesome livestock parasite.

Under most conditions, two to six ducks per acre of land are needed to get rid of Japanese beetles, grasshoppers, snails and slugs. To free bodies of water of mosquito pupae and larvae, six to ten ducks should be provided for each acre of water surface. The breeds of ducks in the egg and bantam categories are the most active foragers, making them the best exterminators.

PRODUCTIVE

Ducks are one of the most efficient producers of animal protein. Indian Runner and Campbell duck hens selected for egg production lay *better* than the best egg strains of chickens, averaging 275 to 325 eggs per hen per year. Furthermore, duck eggs are 20 to 35 percent larger than chicken eggs. Unfortunately, in many localities, strains of ducks that have been selected for top egg production are not as readily available as egg-bred chickens. Meat-type ducks that are raised in confinement are capable of converting 2.6 pounds of concentrated feed into one pound of bird. If allowed to forage where there is a good supply of natural foods, they can do considerably better. The only domestic animal commonly used for food that has better feed conversion is the chicken broiler with a 2.1:1 ratio. See Tables 2 and 3 for a comparison of the producing abilities of all types of poultry.

TABLE 2
COMPARATIVE EGG PRODUCTION OF POULTRY

Bird	*Egg Weight per Dozen* ounces	*Annual Egg Production* #	pounds	*Annual* Feed Consumption* pounds a	b	*Feed to Produce 1 Pound of Egg* pounds	*Efficient Production Life of Hens* years
Duck, Campbell	31.0	288	46.5	110	140	2.4-3.0	2-3
Quail, Coturnix	5.5	306	8.8	—	22	2.5	1
Chicken, Leghorn	24.0	240	30.0	85	95	2.8-3.2	1-2
Duck, Pekin	40.0	156	32.5	145	175	4.5-5.4	2-3
Goose, China	66.0	72	24.8	130	185	5.2-7.5	4-8
Guinea Fowl	17.0	78	6.9	45	65	6.5-8.7	1-2
Chicken, Broiler	25.0	144	18.8	125	130	6.6-6.9	1-2
Turkey, Lg. White	38.0	90	17.8	180	200	10.1-11.2	1-2

Based on the egg yields of good stock fed concentrated feeds and managed for efficient production. Egg size, egg production and feed conversion of poultry are highly dependent upon the quality of the birds and the care they receive.

*Represents the quantity of feed that the average hen consumes from the day she commences laying until a year later.

a—For hens that are free to roam and forage.

b—For hens raised in confinement.

TABLE 3
COMPARATIVE MEAT PRODUCTION OF POULTRY

Bird	*Optimum Butchering Age* *weeks*	*Average Live Wt. at Butchering* *pounds*	*Feed Consumption* *pounds*	*Feed to Produce 1 lb. of Bird* *pounds*
Chicken, Broiler	8	4.0	8.5	2.1
Duck, Pekin	7	7.0	19.0	2.7
Turkey, Lg. White	16-20	17.0	55.0	3.2
Goose, China	12-20	10.0	35.0	3.5
Quail, Coturnix	6	.4	1.5	3.8
Guinea Fowl	12-18	2.3	11.0	4.8
Duck, Campbell	10-14	4.0	22.0	5.5
Chicken, Leghorn	18-22	3.3	20.0	6.1

Based on meat yields of quality stock which were fed concentrated feeds, kept in confinement and managed for efficient production. Growth rate and feed conversion are highly dependent on the quality of the birds and their care.

EXCELLENT FORAGERS

Ducks are energetic foragers, capable of rustling 15 to 100 percent of their own living. Along with guineas and geese, ducks are the most efficient type of domestic poultry for the conversion of food resources that normally are wasted, such as insects, weed plants and seeds, into edible human fare.

AQUATIC PLANT CONTROL

Ducks are useful in controlling unwanted plants in ponds, lakes, and streams, improving conditions for many types of fish. In most situations, twelve to twenty birds per acre of water are required to clean out heavy growths of green algae, duckweed (Lemna), pondweed (Potamogeton), widgeon grass (Ruppia), muskgrass (Chara), arrowhead (Sagittaria), wild celery (Vallisneria), and other plants that ducks consume. Once the plants are under control, four to ten ducks per acre will usually keep the vegetation from taking over again.

In bodies of water having plants submerged more than two feet, or when it is desirable to clean grass from banks, four to eight geese per acre of water surface should be used along with the ducks. (For geese to be effective, they must be confined to the pond and its banks with fencing.) Waterfowl are *ineffective* in checking the growth of tropical plants such as water lettuce and water hyacinth.

GARBAGE DISPOSAL

Ducks will eat almost anything that comes out of the kitchen or root cellar. They relish vegetable trimmings, table and garden leftovers, canning and fruit juice refuse, most kinds of deteriorated produce, and stale baked goods. To make it easier for these broad-billed fowl to eat firm vegetables and fruits, place apples, potatoes, beets, turnips, etc. on an old board and crush them with your foot.

In the poultry program in Puerto Rico, we supplied a flock of forty Rouen ducks that were on pasture and had access to a five-acre pond, with nothing but leftovers from the school cafeteria. These garbage-fed birds remained in good flesh and showed no signs of poor health, although they produced 60 percent fewer eggs than a control group that was provided concentrated laying feed along with limited quantities of institutional victuals.

USEFUL FEATHERS

The down and small body feathers of ducks are valuable as filler for pillows and as lining for comforters and winter clothing. (See Appendix F, page 157.)

VALUABLE MANURE

A valuable by-product of raising ducks is the manure they produce. Duck manure is an excellent organic fertilizer that is high in nitrogen. The innovative Orientals have taught us another use for this "waste." They herd their duck flocks through rice fields to eat insects and pick up stray kernels of grain. The birds are then put on ponds where their manure provides food for fish.

GENTLE DISPOSITIONS

Rather shy, ducks are seldom aggressive towards humans. Of the larger domestic birds, they are the *least* likely to inflict injury to children or adults. In the twenty years I have worked with ducks, the only injuries I've sustained have been small blood blisters on my arms and hands—received while attempting to remove eggs from under broody hens—and an occasional scratch when the foot of a held bird escaped my grasp. If you do get scratched by the claws of a bird, prompt washing of the wound with rubbing alcohol will lessen the chance of infection.

DECORATIVE AND ENTERTAINING

Together with their many practical attributes, ducks are decorative and entertaining. A small flock of waterfowl can transform just another pond into a center of attraction and provide hours of entertainment.

TABLE 4
COMPARISON OF DUCKS AND CHICKENS

Characteristic	*Ducks*	*Chickens*
Housing requirements	Minimal	Substantial
Height of fence to keep confined	2-3 feet	4-6 feet
Susceptibility to predators	High	Moderately high
Resistance to parasites and disease	Excellent	Fair
Resistance to hot weather	Good	Good
Resistance to cold weather	Good	Fair
Resistance to wet weather	Excellent	Poor
Foraging ability	Good-Excellent	Fair-Good
Scratching in dirt	None	Considerable
Probing in mud with bills or beaks	Considerable	None
Incubation period	28 days	21 days
Hatchability of eggs in incubators	65-90 percent	70-90 percent
Cost of day-olds in lots of 25	Ducklings double the price of chicks	
Starter feed—min. protein needed	16 percent	18 percent
Layer feed—min. protein needed	15 percent	15 percent
Age hens commence laying	20-24 weeks	20-24 weeks
Eggs laid per hen per year (wt.)	32-52 lbs.	22-34 lbs.
Feed to produce 1 pound of eggs	2.4-3.8 lbs.	2.8-4.0 lbs.
Part of diet hens can forage	10-25 percent	5-15 percent
Light required for top production	14-16 hours	14-17 hours
Annual mortality rate of hens	0-3 percent	5-25 percent
Efficient production life of hens	2-3 years	1-2 years
Protein content of eggs	13.3 percent	12.9 percent
Fat content of eggs	14.5 percent	11.5-12.5 percent
Cholesterol content of eggs	.884 percent	.494-.638 percent
Flavor of eggs	Similar; ducks sometimes stronger	
Feed to produce 1 pound of bird	2.5-3 lbs.	2-2.2 lbs.
Age to butchering	7-12 weeks	8-20 weeks
Typical plucking time	3-15 minutes	2-10 minutes
Color of meat	All dark	Light and dark
Protein content of flesh	21.4 percent	19.3 percent
Fat content of carcass	16-30 percent	5-25 percent
Cholesterol content of carcass	0.07 percent	0.06-0.09 percent
Usefulness of feathers and down	Excellent	Fair

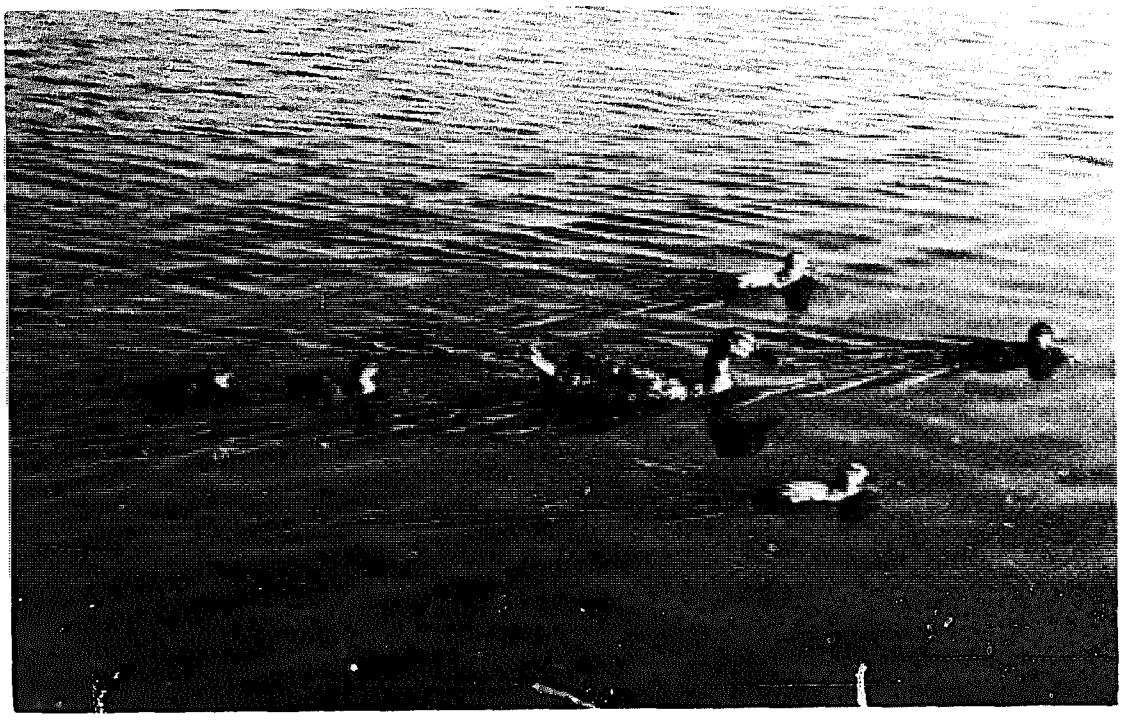

A domestic Mallard hen with ten-day-old ducklings.

I can still remember the first ducks I had as a young boy. Because our property had no natural body of water, I fashioned a small dirt pond in the center of the duck yard. After filling it with water, I watched as my two prized ducklings jumped in and indulged in their first swim. They played and splashed with such enthusiasm that it wasn't long before I was as wet as they were. And then—much to my delight—they began diving, with long seconds elapsing before they popped above the surface in an unexpected place. I was "hooked," and continue to be intrigued by the playfulness, beauty and grace of swimming waterfowl.

CHAPTER 2

Some Points to Consider

Despite the versatility and usefulness of ducks, there are several factors you should be aware of and understand. In some situations another type of fowl may prove more suitable.

NOISE

Many people find the quacking of ducks an acceptable if not pleasant part of nature's choir. However, if you have close neighbors, the gabble of talkative hens may not be appreciated or tolerated. Some breeds are noisier than others. A small flock consisting of one of the calmer breeds will be quiet if not frightened or disturbed frequently. Drakes are almost mute, and for the control of slugs, snails and insects in town or suburb, they work fine.

PLUCKING

Most people find that plucking a duck is more time-consuming than defeathering a chicken. But then, most of us who have had the privilege of dining on roast duck agree that it is time well spent. Furthermore, duck feathers are much more useful than chicken plumes. With good technique and a little experience, it is possible to reduce the picking time to three minutes or less.

POND DENSITY

Having large numbers of ducks on small ponds or creeks encourages unhealthy conditions and can result in considerable damage to bodies of water. One of the feeding habits of ducks is to probe the mud around the water's

edge for worms, roots and other buried treasures. A high density of ducks will muddy the water and hasten bank erosion. On the other hand, a reasonable number of birds (15 to 25 per acre of water) will improve conditions for fish, control aquatic plant growth and mosquitos, and will not significantly increase bank erosion.

GARDENS

Putting a few ducks (the bantam breeds are best due to their small size) in a garden is a good method of controlling slugs, snails and insects. However, to prevent the birds from doing more harm than good, the following guidelines must be observed:

1. Don't let birds in until the crops are well started and past the succulent stage.
2. Keep ducks out when irrigating or when the soil is wet.
3. Fence off tender crops such as lettuce, spinach, cabbage and green beans.
4. Remove birds when low-growing berries and fruits are ripe.
5. Limit the number of ducks in a medium-sized garden to two or three adults.

MEAT AND EGGS

All types of poultry provide good food. However, there are variations in the flavor, texture and composition of the meat and eggs produced by the diverse species. There are also differences in dietary needs and likes and dislikes of food among people. If you are seriously considering producing duck meat or eggs but have never cooked or eaten them, I recommend that you sample duck products before starting your flock. (This practice is wise before investing time and resources in any type of unfamiliar animal for food.) The following observations are presented to help you evaluate your first encounter with duck cuisine:

1. The flavor of meat and eggs from ducks whose diet included fish or fish products is often strong and *not* typical of good duck.
2. Ducklings which have been raised in close confinement and pushed for top growth (e.g., Long Island Ducklings) are much fatter than ducks which have foraged for some of their own food and have grown at a

slower pace. The high fat content of quick-grown duckling makes its meat exceptionally succulent and provides valuable energy for persons who live in cold climates or who get strenuous physical exercise. However, many of us get limited exercise and our bodies do not need the large quantity of fuel provided by fat ducklings. For this reason, I feel

TABLE 5
APPROXIMATE COMPOSITION OF VARIOUS MEATS

Description	*Calories per 100 grams*	*Protein percent*	*Fat percent*
Chicken: raw			
Fryers			
Total edible	155	17.3	7.4
Flesh only	107	19.3	2.7
Roasters			
Total edible	239	19.2	17.9
Flesh only	131	21.1	4.5
Mature hens and cocks			
Total edible	298	17.4	24.8
Flesh only	155	21.6	7.0
Turkey: raw			
Total edible	218	20.1	14.7
Flesh only	162	24.0	6.6
Duckling: domestic, raw			
Total edible	326	16.0	28.6
Flesh only	165	21.4	8.2
Duck: wild, raw			
Total edible	233	21.1	15.8
Flesh only	138	21.3	5.2
Rabbit: raw			
Flesh only	162	21.0	8.0
Pork: raw			
Carcass (medium-fat class)			
Total edible	513	10.2	52.0
Composition of trimmed lean cuts, ham, loin, shoulder and spareribs (medium-fat class)			
Total edible	308	15.7	26.7
Beef: raw			
Carcass			
Total edible			
Choice grade	379	14.9	35.0
Good grade	323	16.5	28.0
Total edible, trimmed to retail levels			
Choice grade	301	17.4	25.1
Good grade	263	18.5	20.4
Round			
Total edible	197	19.5	12.5

Information from *Handbook of the Nutritional Contents of Foods.*

TABLE 6
APPROXIMATE COMPOSITION OF EGGS

Kind of Egg	*Protein percent*	*Fat percent*	*Cholesterol* mg/gm of egg*	*Calories per 100 gms*
Chicken, Commercial Egg	12.9	11.5	4.94-5.50	163
Chicken, Commercial Broiler	—	—	6.38	—
Quail, Coturnix	11.5	10.9	8.44	186
Turkey	13.1	11.8	9.33	170
Duck	13.3	14.5	8.84	191
Goose	13.9	13.3	—	185

Information from *Handbook of the Nutritional Contents of Foods* and "Cholesterol Content of Market Eggs," *Poultry Science Journal.*

*Young hens produce eggs with less cholesterol than old hens.

Note: Dashes indicate that information was not available.

that quick-grown duckling should be eaten only in limited quantities. See page 82 for ways to produce lean ducks.

3. Duck eggs have a higher cholesterol content than the average chicken egg. As with fat in meat, the amount of cholesterol in eggs seems to be affected by the diet and life-style of the producing bird. Hens that are active and forage for a portion of their diet *may* produce eggs lower in cholesterol.

   When eggs are eaten in moderation (we limit our weekly intake to four to six eggs per person), the difference in cholesterol between duck and chicken eggs probably is insignificant for healthy people who get adequate exercise and eat sensibly—lots of high fiber and uncooked foods while going easy on the meats.

4. Duck eggs are excellent for general eating and baking purposes. When fried in an open pan, the whites of duck eggs are often firmer than those of chicken eggs. We prefer to steam-fry our duck eggs (see Appendix E, page 153) for a softer textured egg white. While it is often said that duck eggs are unsatisfactory for meringues and angel food cakes, we have not found this statement to be true. In fact, one of our favorite treats for special occasions is whole wheat angel food cake made with duck egg-whites. (See Appendix E.)

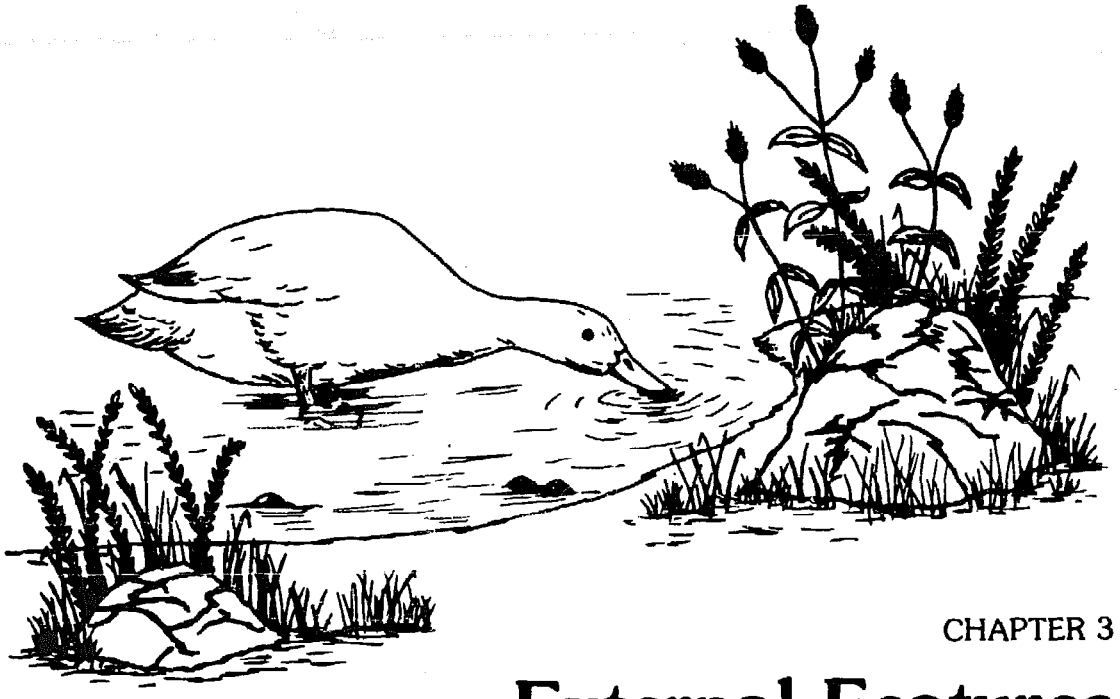

CHAPTER 3

External Features

Ducks are masterfully designed, down to the smallest detail, for an aquatic life. Being acquainted with the external features of ducks is a useful management tool and will deepen your appreciation for these waterfowl. I suggest that you take a few minutes to familiarize yourself with the accompanying nomenclature diagram.

BODY SHAPE

For stability and minimal drag while swimming and diving, the lines of the body are smooth and streamlined; the underbody is wide and flat.

FEATHERS

Endowed with an extraordinary abundance of feathers, particularly on the underside of their bodies, ducks can swim in the coldest water and remain comfortable. Soft, insulating down feathers close to the skin are covered by larger contour feathers. Several times each day, ducks faithfully preen and oil their feathers. A water repellent is produced by a hidden oil gland at the base of the tail. As a duck preens, it frequently squeezes the nipple of the oil gland with its bill and spreads the excretion onto its feathers.

WINGS

Ducks have long, pointed, rather narrow wings—except Muscovies, whose wings are broad and rounded. Most domestic breeds have lost their ability to

fly, although Muscovies, Calls, East Indies and domesticated Mallards have retained their flying skills to varying degrees.

TAILS

Muscovies have squarish tails that are 4 to 6 inches long. Other ducks possess shorter, pointed rudders. Excluding the Muscovy, mature drakes have several curled feathers in the center of their tails.

BILL

Long and broad, duck bills are well adapted for collecting food from water, catching flying insects and rooting out underground morsels. With nostrils located near the head, ducks can dabble in shallow water and breathe at the same time. Due to hormonal changes in their bodies, duck hens with yellow or orange bills frequently develop dark spots or streaks on their bills when they begin to lay. These blemishes are not a sign of disease. Some waterfowl breeders believe they are an indication of high egg production.

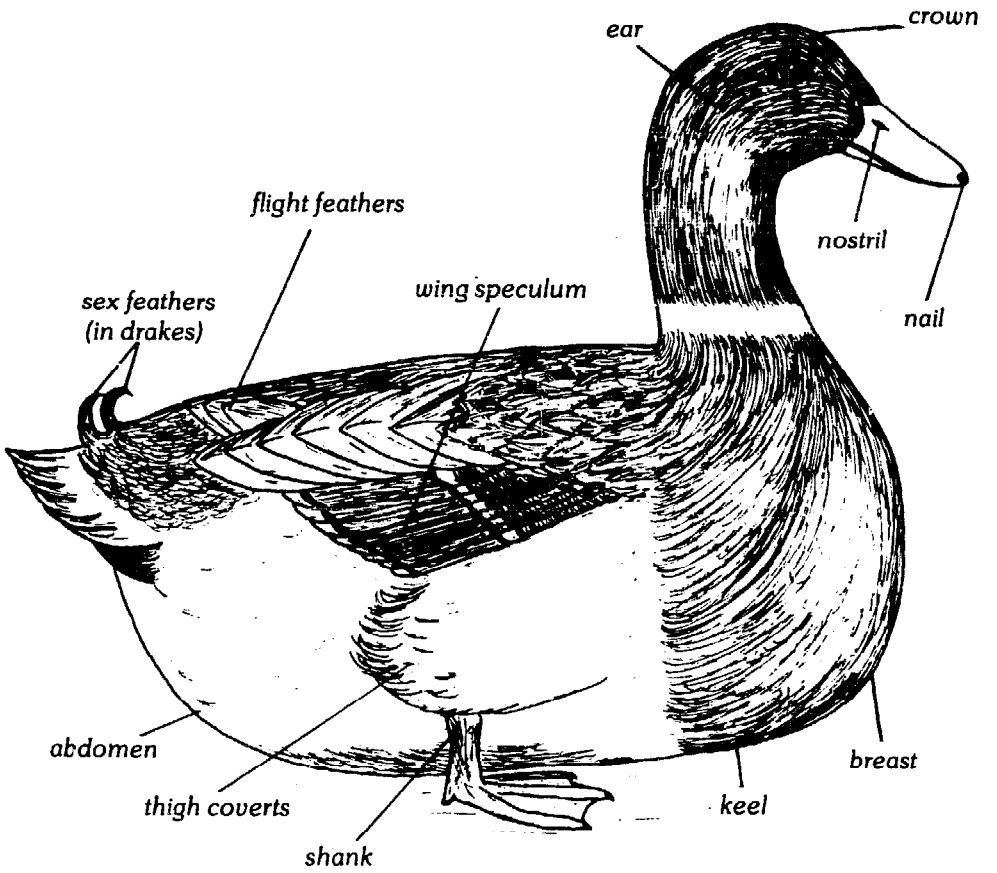

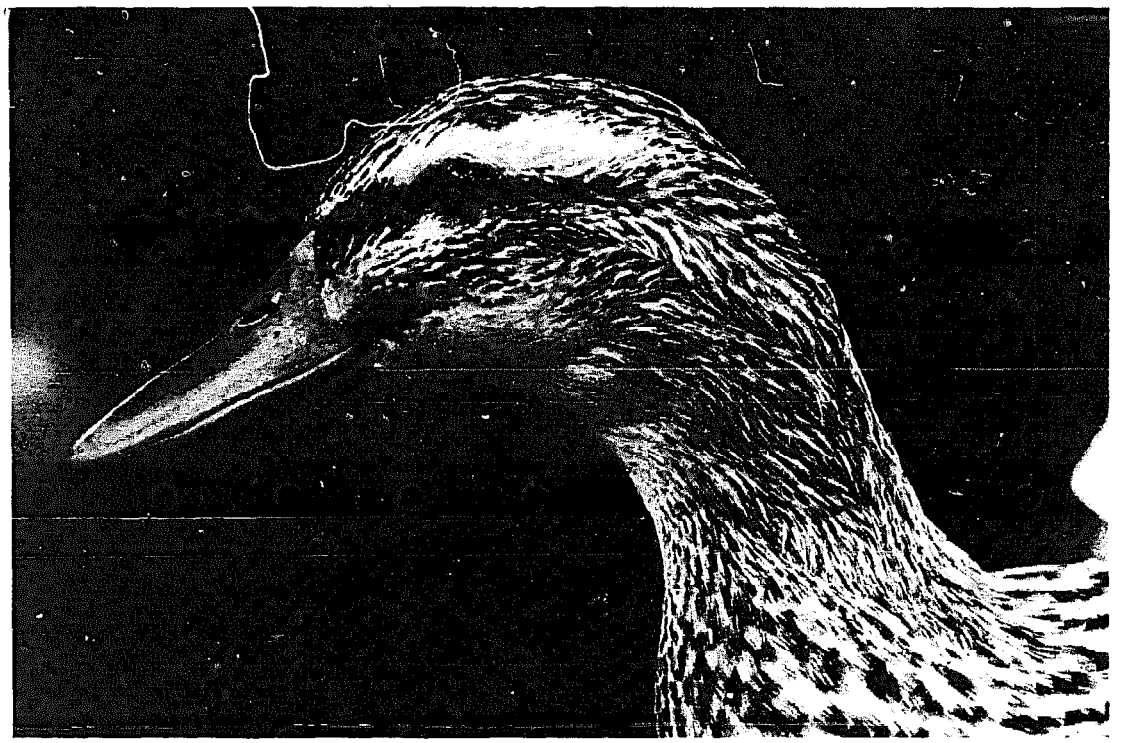

With their long, broad bills, ducks are adept at catching flying insects, straining minute plants and animals from water and probing in mud. The hooked nail at the end of the bill is used for nipping off tough roots and stems.

EYES

The vision of ducks is much sharper than our own. Due to the location of their eyes, ducks can see nearly 360 degrees without moving their heads. This feature makes it possible for a feeding duck to keep a constant lookout for danger.

FEET AND LEGS

With webbed toes and short legs, ducks are not exceptionally fast on land, but are highly skilled swimmers, preferring to escape danger by way of water. The legs of ducks are injured more readily than those of chickens. Therefore it is advisable to pick them up by the neck and/or body.

BACK

Normally a duck's back is long and straight. In some of the larger breeds—particularly Aylesburies and Rouens—there is a tendency toward arched backs. These humped backs can be a serious problem since ducks with this

fault often have low fertility or are sterile. When selecting breeding stock, avoid individuals with excessively curved backs.

KEEL

Ducks that are heavily fed and selected for large size and fast growth often develop keels. This appendage is a fold of skin that hangs from the underbody, and in extreme cases may run the entire length of the body and brush the ground as the bird walks. A well-developed keel is a breed characteristic of Aylesburies and Rouens, while it is not preferred on any other breed.

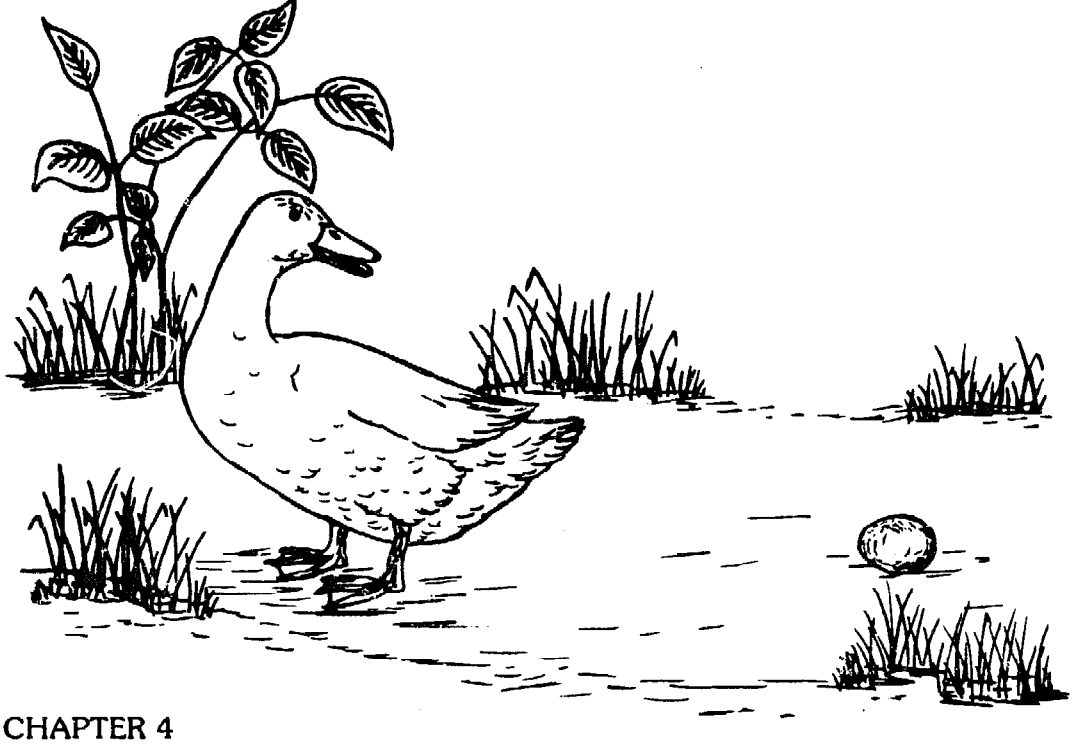

CHAPTER 4

Behavior

Just as you and I have distinct personalities, so each duck has its own peculiarities and habits. However, ducks follow behavioral patterns which you should understand if you're going to do a good job of raising them.

PECKING ORDER

This bird law regulates the peaceful coexistence of the duck flock. The number one bird in the flock can peck or dominate all others, the number two bird can dominate all but number one, the number three bird can dominate all but numbers one and two, and on down the line until we reach the last individual who dominates no one

If you introduce a new bird into an established flock, the existing pecking order is threatened and normally this results in a power struggle which may evoke fighting. Unless the conflict is causing serious injury to the participants, you should not intervene, remembering that the roughhousing is necessary for the future peace of the flock.

FEEDING

The natural diet of ducks consists of approximately 90 percent vegetable matter (including seeds, berries, fruits, nuts, bulbs, roots and succulent grasses)

and 10 percent animal matter (such as insects, mosquito larvae, snails, slugs, leeches, worms, and an occasional small fish or tadpole). Sand and gravel are picked up to serve as grinding stones in the gizzard. Ducks feed by dabbling and tipping up in shallow water, drilling in mud and foraging on land. While ducks eat considerable quantities of tender grass, they're not true grazers as are geese.

SWIMMING

Skillful and enthusiastic swimmers from the day they hatch, ducks will spend many happy hours each day bathing and frolicking on water if it is available. However, ducks of all types and ages (particularly Muscovies and ducklings) can drown if their feathers become soaked and they are unable to climb out of the water. For this reason, ducks must be allowed to swim only where they will be able to exit easily. It is a good idea to keep ducklings out of water until they are four weeks old. Ducks can be raised successfully without swimming water. Most of the ducks we've raised have had only drinking water.

MATING

Ducks will pair off, although domesticated drakes normally mate indiscriminately with hens in a flock. If you raise several breeds and wish to hatch purebred offspring, each variety needs to be penned separately three weeks prior to and throughout the breeding season.

In single male matings, a drake can usually be given two to five hens, although males sometimes have favorites and may not mate with the others. In flock matings, one medium or heavyweight breed male should be allowed for every three to six hens, while one drake of the lightweight breeds should be provided for every four to seven hens. For good fertility, hens need to be bred by drakes at least once every four or five days. A few eggs which have been laid as long as two weeks after copulation may hatch.

Ducks prefer to mate on water, but most breeds can copulate successfully on land. Several of the large breeds, especially deep-keeled Aylesburies and Rouens, have higher fertility if they have access to swimming water at least eight inches deep.

NESTING

Domestic duck hens frequently lay their eggs at random on the ground, and occasionally even while swimming. When a nest is made, it is a shallow depression in the ground, lined with twigs, grass and leaves. If eggs are left in

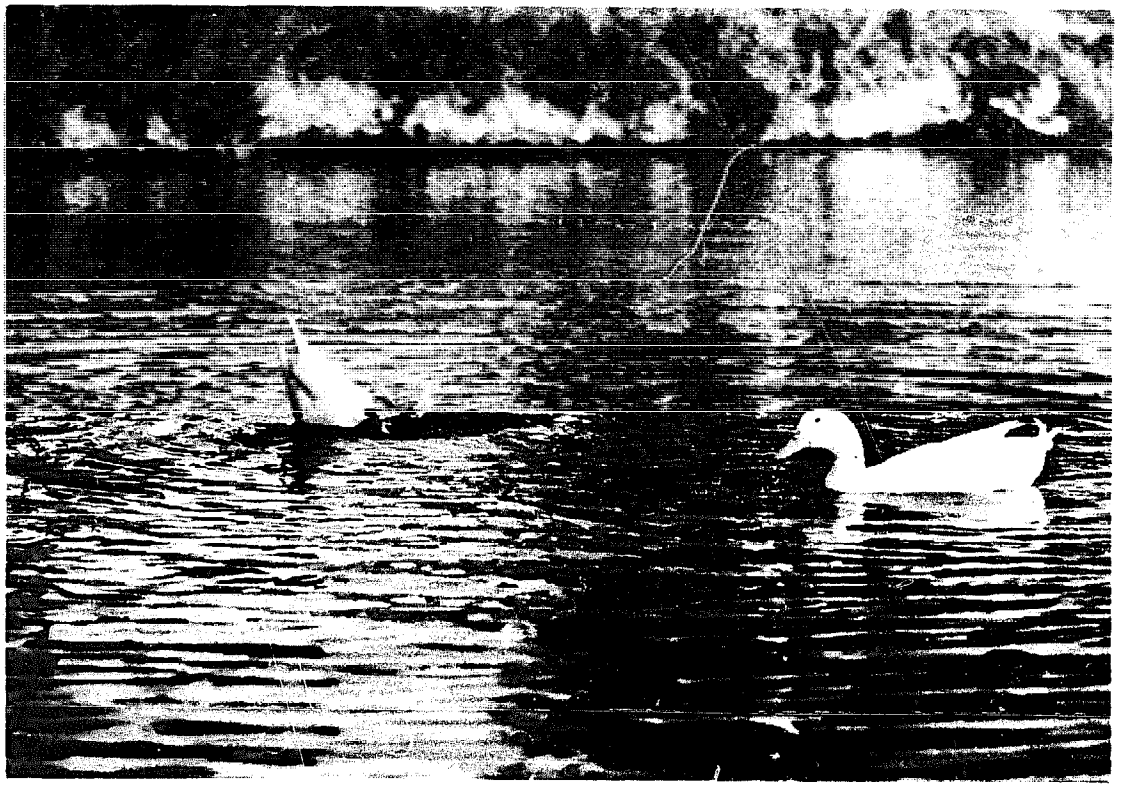

Mallards and their derivatives frequently tip up when feeding in water.

the nest for natural incubation, the hen will pluck down from her breast for added insulation.

FIGHTING

Ducks get along together well and rarely fight. If a new bird is introduced into a flock, there will be a short period of chasing, pushing and wing slapping, but normally such conflicts subside quickly. Adult ducks seldom inflict injury to one another if there is not an excessive number of drakes in a flock during the breeding season. As a rule, drakes will not fight among themselves if there are no females around.

LIFE EXPECTANCY

Ducks live a surprisingly long time when protected from accidental deaths. It is not unusual for ducks to live and reproduce for six to eight years, and there are reports of exceptional birds living twenty to thirty years. However, few ducks die of old age (except for those special pets!) since fertility decreases after one or two years and egg production normally declines significantly after three or four years, and their owners do not consider it economical to keep them past this age.

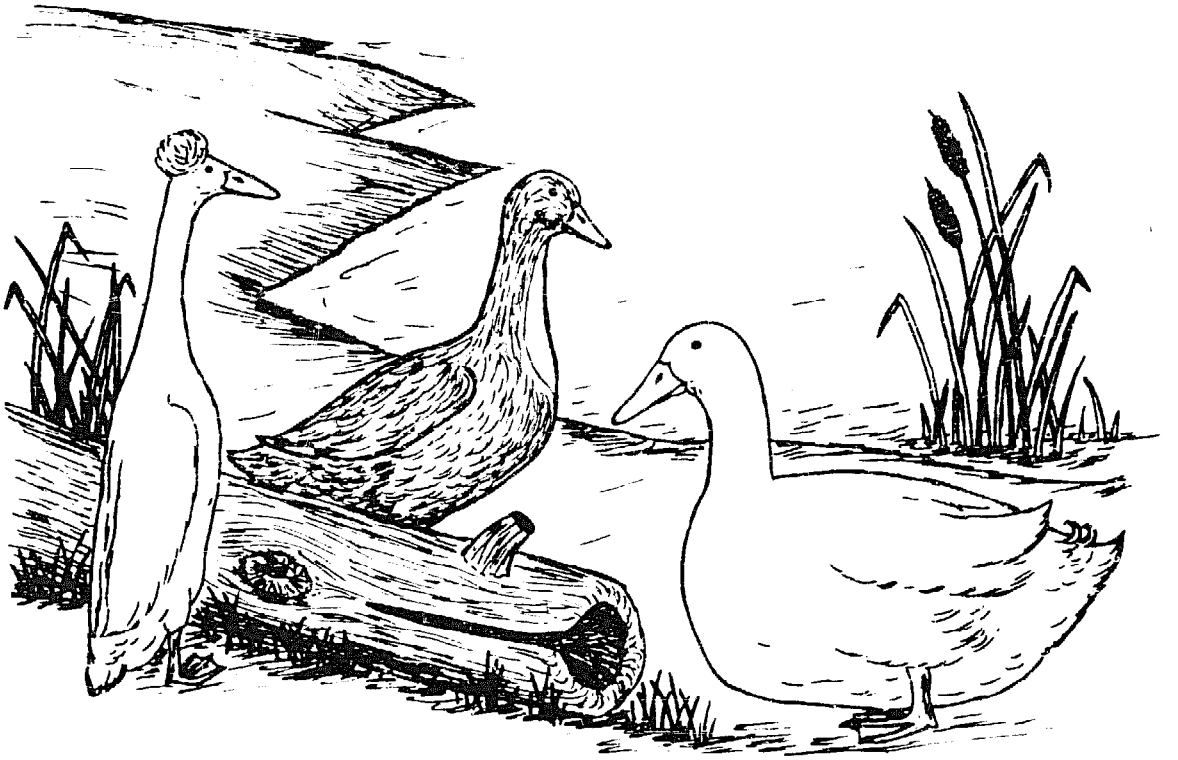

CHAPTER 5

Selecting a Breed

Choosing an appropriate breed for the home flock can be fun and will play an important role in the success or failure of your duck project. Unfortunately, novices often assume that a duck is a duck and acquire the first web-footed bird they find that quacks. This mistake frequently results in expensive eggs or meat, needless problems and a discouraged duck keeper. Investing a little time at the *outset* in acquainting yourself with the basic characteristics, attributes and weaknesses of the various breeds will go a long way toward eliminating unnecessary disappointments.

SOME CONSIDERATIONS

The following questions are designed to help you identify the features needed in birds for your flock. You may find it helpful to jot down your answers and then keep them handy as you compare the breeds.

Purpose

What is your main purpose for raising ducks? Is it for eggs, meat, feathers, insect and slug control or a combination of these and other aims?

Location

Where are you located? Some breeds are noisier than others—a fact which should be taken into consideration when you have close neighbors. Talkative breeds (Calls and Pekins in particular) also attract more predators.

Management

How are you going to manage the flock? Will they be confined to a small pen or be given freedom to roam over a large area? Will you provide all of their feed, or will they forage for a good portion of it themselves?

Color

What plumage color is best adapted to your situation? Aside from personal preferences, color is significant for several practical reasons. The pin feathers of light-plumaged birds are not as visible as those with dark plumage, making it easier to obtain an attractive carcass with light-colored ducks when they are butchered for meat. On the other hand, dark birds are better camouflaged, making them less susceptible to predators. Also, if there is no bathing water available, colored ducks maintain a neater appearance than white ones.

Availability

What breeds are available either locally or by mail order? Some breeds are rare, making them more expensive and difficult to obtain.

THE BREEDS

Over the years, waterfowl breeders in various parts of the world have developed distinctive types of ducks. As these local ducks became uniform in size, shape and color, they were given names and recognized as separate breeds. Those breeds which have proven to be the most useful and widely accepted have survived.

Today, most of the purebred ducks being raised in North America belong to one of sixteen breeds. Many of these breeds consist of several varieties that are distinguished from one another by the color or pattern of their plumage. For convenience, the breeds are divided into four main categories: egg, meat, general purpose and bantam.

Egg Breeds

Ducks that are bred primarily for high egg production are small, exceptionally active, non-broody, and often are more high-strung than other breeds. Despite their diminutive size, they lay a greater number of eggs than larger

TABLE 7
BREED PROFILES

Category	Breed	Weight in Pounds M	Weight in Pounds F	Yearly Egg Production	Egg Size per Dozen Ounces	Mothering Ability	Foraging Ability	Availability
Egg	Bali	5.0	4.5	150-250*	30-36	Poor	Good	Poor
	Campbell	4.5	4.5	250-325+	28-34	Poor	Excellent	Good
	Runner	4.5	4.0	225-325+	30-36	Poor	Excellent	Good
Meat	Aylesbury	9.0	8.0	35-125	36-42	Fair	Fair	Fair
	Muscovy	12.0	7.0	50-125	44-50	Excellent	Excellent	Good
	Pekin	9.0	8.0	125-175	38-42	Poor	Fair-Good	Excellent
	Rouen	9.0	8.0	35-150	36-44	Fair	Fair-Good	Excellent
General Purpose	Cayuga	8.0	7.0	100-175	34-38	Good	Good	Fair
	Crested	7.0	6.0	100-175	34-38	Fair	Good	Fair
	Magpie	6.0	5.0	125-225	30-36	Poor	Good	Poor
	Orpington	8.0	7.0	150-250	30-36	Poor	Good	Fair
	Swedish	8.0	7.0	100-150	34-40	Good	Good	Fair
Bantam	Australian Spotted	2.5	2.2	25-100*	22-30	Excellent	Excellent	Poor
	Call	1.8	1.6	25- 75	18-24	Excellent	Excellent	Good
	East Indie	2.0	1.8	25-125	18-28	Excellent	Excellent	Fair
	Mallard	2.8	2.4	25-125	24-30	Excellent	Excellent	Excellent

Information presented in this profile is based on the average characteristics of each breed. Actual performance of individuals may vary considerably from the norm.

*Estimates

hens, while consuming a lot less feed. Excellent foragers, they are capable of picking up much of their own food, and are outstanding for the control of insects, snails and slugs. While all ducks enjoy swimming water, the egg breeds are more at home on land than most. If *efficient egg production* is your principal goal, one of these breeds should be given top priority.

Bali. In my opinion, the Bali is the most unusual of all breeds. With their dignified, yet comical appearance, they can bring a smile to the face of even the most serious-minded person. One of the oldest of domesticated ducks, they originated on Bali and other Indonesian islands. Waterfowl historians generally agree that this breed and Indian Runners are closely related; the Runner was probably developed from the Bali.

The erect carriage of the Bali is accentuated by a long body that is somewhat heavier than that of the Indian Runner. Resting snugly on the head of an ideal Balinese is a medium-sized globular crest. As with Crested ducks, the ducklings of this breed hatch out both plain-headed and crested. Most Bali raised in North America are white, although khaki brown is the common color in their homeland.

While Bali are good layers, they are so scarce outside their homeland that they have not been selectively bred for egg production. However, if you can locate specimens, it is a practical and fascinating breed with which to work.

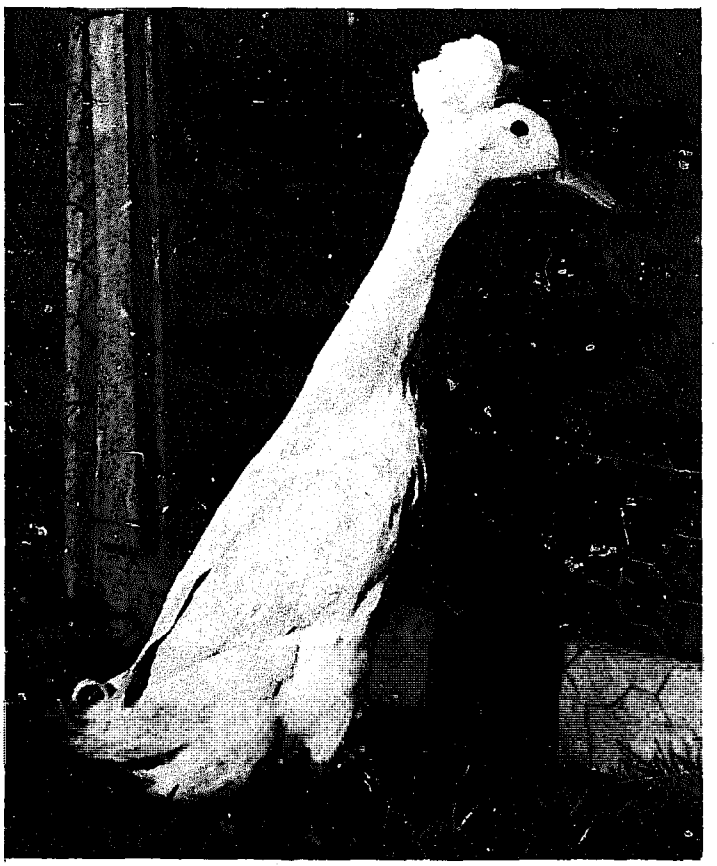

A White Bali drake. Notice his thicker neck and heavier-set body when compared with the Indian Runners on page 25.

Campbells. Mrs. Adele Campbell of Glouchester, England, is given credit for having developed the colorful Khaki Campbell in about 1900. It is believed that Indian Runners, Mallards and Rouens were used in its creation. Egg-bred Campbells are the best layers of all ducks. There have been reports of individuals producing 360 or more eggs in a calendar year, although flock averages of 275 to 340 are more typical. Campbell eggs have superb texture and flavor and pearly white shells.

Here is an appropriate place for a word of caution: If you want good egg yields, make certain you acquire authentic Campbells that have been selected for high egg production. The laying ability of birds in some hatchery flocks has been allowed to deteriorate, and much too often crossbreeds are being sold as Campbells.

Today, there are three varieties of Campbells—White, Dark and Khaki. While the Khaki is generally considered by far the most common, a substantial number of so-called Khakis more accurately are Darks. Khaki Campbell drakes have green or bluish-green bills, greenish-bronze heads and backs (brownish-bronze in these sections is preferred for exhibition), with the remainder of the plumage being an even shade of khaki tan that is similar in color to withered grass. Ducks have dark brown or greenish-black bills, and except for seal brown heads, the plumage should be a warm shade of khaki brown. When compared to Khakis, Dark Campbell females display deeper

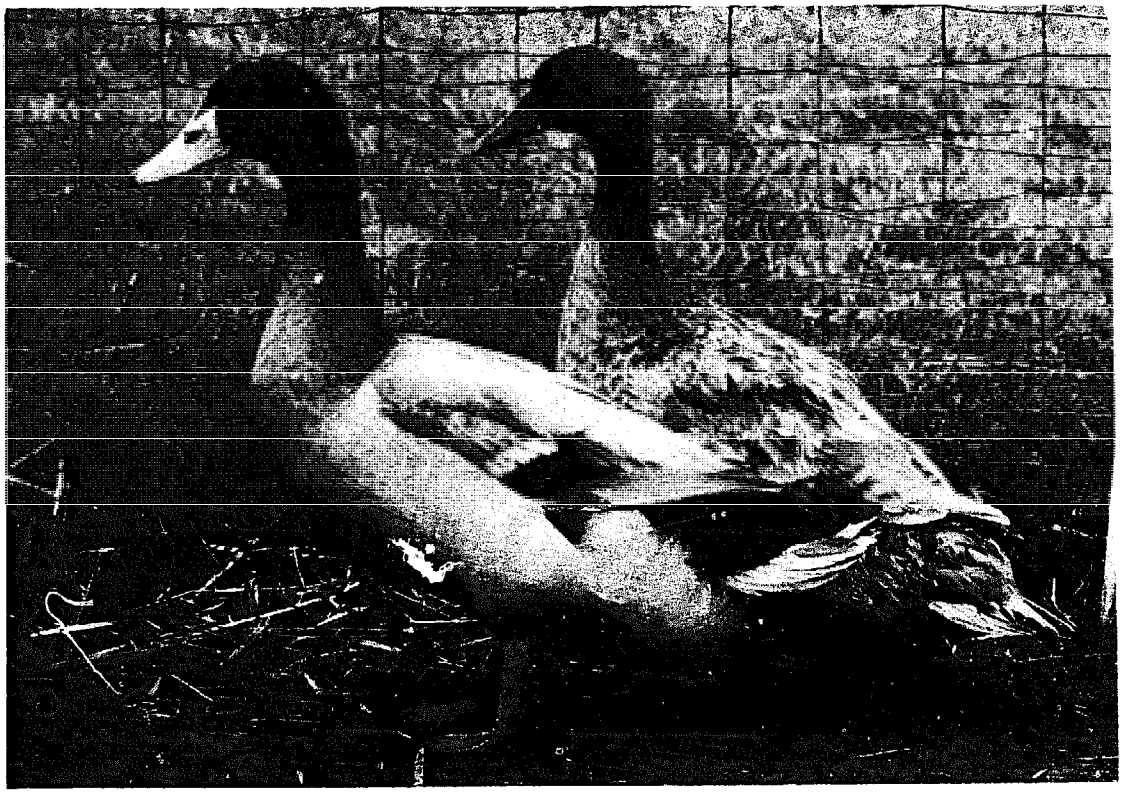

Pair of egg-bred Khaki Campbells exhibiting the good length of body that is needed for top egg production. Owned by Mother Hen Farm, Corvallis, Oregon.

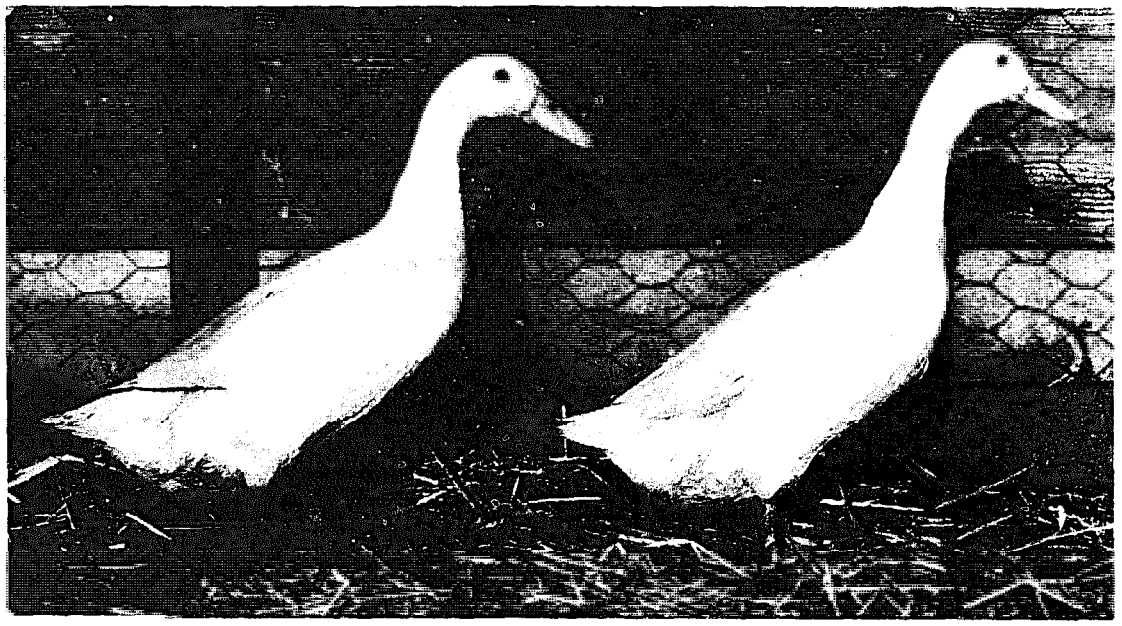

White Campbell females. This variety can be distinguished from other white ducks by their trim heads, medium size, and spry carriage, which is roughly 35 degrees above horizontal. Owned by Wilbur and Dave Holderread, Corvallis, Oregon.

shades of brown while males have brighter greenish-black heads and backs. Due to a sex-linkage factor, when Khaki drakes are mated to Dark ducks, their offspring are color-coded and can be sexed at hatching time by the hue of their down—males are dark, females are light.

Until recently, White Campbells were rarely heard of in North America. During the last several years, however, a number of waterfowl breeders have been distributing this useful variety nationwide. In our experience, Whites are as productive and hardy as their colored counterparts. Plumage color is silky white and feet are orange. The bill color of egg-bred White Campbells normally is pink in ducklings and pink or yellowish-pink in adults.

Campbells are extremely hardy and active, and will forage over a large area. Of all breeds of true ducks, they seem to have the least desire to swim. Campbells are also one of the quieter breeds, although this characteristic does vary among different strains. When dressed for meat, they provide a medium-small carcass that is lower in fat than most large ducks. The colored varieties have excellent camouflage and are pretty, especially when seen against the backdrop of a green pasture. For the home flock, I consider Campbells to be the best duck—and in many situations, the best bird—for the efficient production of eating eggs.

Indian Runners. Because of their long, slender bodies and vertical posture, this breed is often called the *Penguin duck.* Unlike most ducks, Indian Runners do not waddle—they run. Aided by their fast gait and active disposition, Runners are one of, if not the best foragers of all domestic breeds.

Many colorful varieties have been developed in this popular breed, including White, Penciled, Fawn and White, Solid Fawn, Blue, Black, Chocolate,

Indian Runners showing upright carriage, slender bodies, wedge-shaped heads and high-set eyes typical of the breed. A pair of Fawn and Whites are in the background, Whites in foreground. Owned by Henry K. Miller, Lebanon, Pennsylvania.

Buff, Khaki and Gray (same markings as the Mallard). The first three varieties are the most common.

The White, and Fawn and White Runners are the best layers since they have been selected more carefully for egg production than the other varieties. Runner eggs are white, tinted, green or blue, and average two ounces larger per dozen than those of Campbells.

Although Indian Runners are not as large as breeds traditionally used for meat, they are popular with people who desire a small, lean meat-bird. Second only to Campbells in egg production, Runners are a good breed for the home duck flock, being practical as well as highly entertaining. In fact, watching the astonished expressions on people's faces the first time they see Indian Runners stroll by is a pretty good reason for keeping a few.

Meat Breeds

The meat breeds can be identified by their large sizes, calm dispositions and fast growth rates. As a group, they are easy to keep confined, do not wander far from the feeding area and, with the exception of the Pekin, are less vocal than most smaller ducks. These birds are ideally suited for the efficient production of large roasting ducks. Due to their hearty appetites and only fair laying abilities, it is not practical to keep them solely for the production of eating eggs.

Aylesbury. This massive pure white duck is a native of England. The body carriage of Aylesburies is horizontal and their well-developed keels nearly touch the ground. They possess unusually long, straight bills which are pinkish-white. Their skin is white, in contrast to the yellow skin of most other breeds. Hens lay white, tinted or green eggs.

Aylesburies are slow moving, *exceptionally tame* and make large, fat roasting ducks when well-fed on concentrated feed. For top fertility and hatchability, breeders must have swimming water and should be fed a ration that contains 18 to 20 percent protein and is well fortified with vitamin-rich substances such as alfalfa meal and cod-liver oil or a vitamin premix. Generally, Aylesburies are not quite as hardy and vigorous as most other breeds.

Muscovy. A native South American, this duck is definitely a bird of a different feather. In fact, it is not considered a true duck by many waterfowl breeders, and has been grouped with them for lack of a better classification. Muscovies will cross with other ducks, but the resulting offspring are usually sterile.

Muscovies have many distinguishing features. Their faces are covered with rough, red skin, and drakes have a fleshy knob at the base of their bills. Both sexes display narrow head crests which can be elevated and lowered at will.

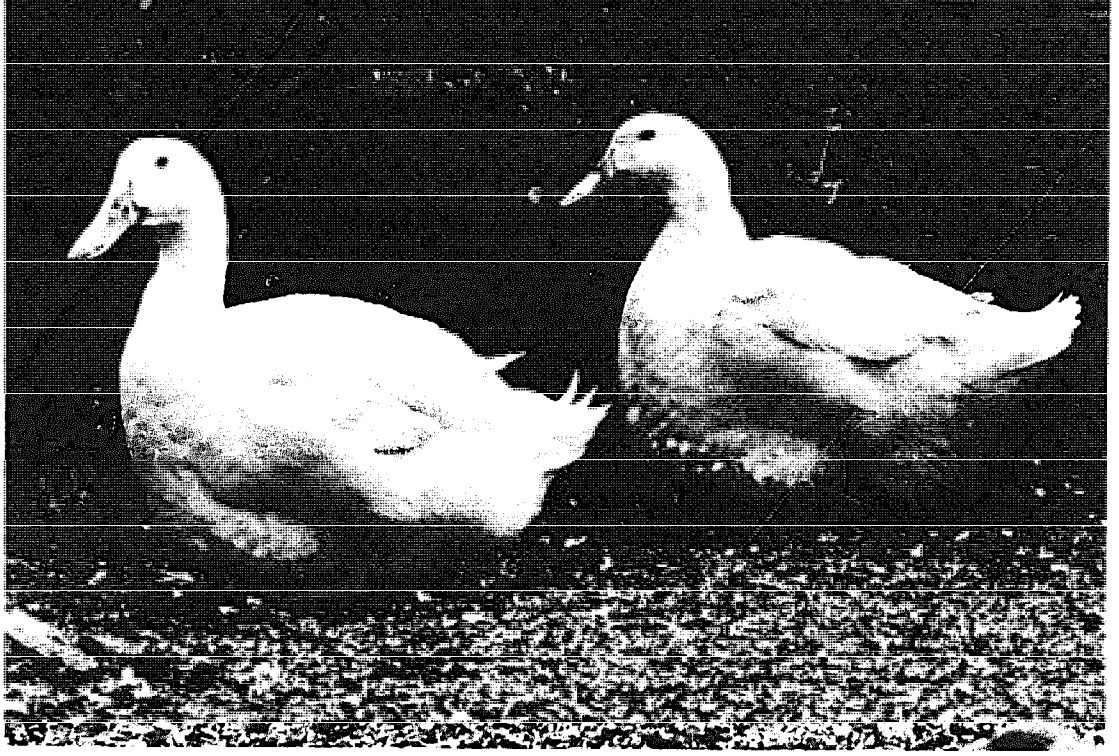

A pair of deep-keeled Aylesburies, popular in England where white-skinned fowl are preferred for meat. Owned by Henry K. Miller.

Hens are practically mute and the voices of males resemble a muffled hiss. Drakes are nearly twice as heavy as their mates and have larger facial skin patches, making it easy to distinguish the gender of mature birds.

While Muscovies do swim, their feathers are not as water repellent as those of genuine ducks. When forced to remain on water for more than a brief length of time, they can become soaked and drown. They require more protection from wet and cold weather than other ducks.

Muscovies often roost on buildings and walls. The hens are strong fliers, but drakes frequently become so ponderous that they cannot get airborne without the aid of a strong headwind or an elevated perch.

Muscovies are excellent foragers and can utilize larger quantities of grass than true ducks. In mild weather, ducklings that are brooded artificially can be put out on pasture at three to six weeks of age. If good quality forage is available, pastured ducklings require only light feedings of grain or pellets once daily. When raised in this manner, they'll average five pounds for hens and ten pounds for drakes at sixteen to twenty weeks of age.

The jumbo white or tinted eggs laid by the Muscovy require thirty-three to thirty-five days to hatch. Hens are dedicated natural mothers—with the exception of some production-bred white strains—and normally bring off large broods. It is not unusual to see Muscovy hens with fifteen to twenty ducklings in tow. They bravely protect their young, and have been known to ward off marauding predators such as foxes, cats and dogs.

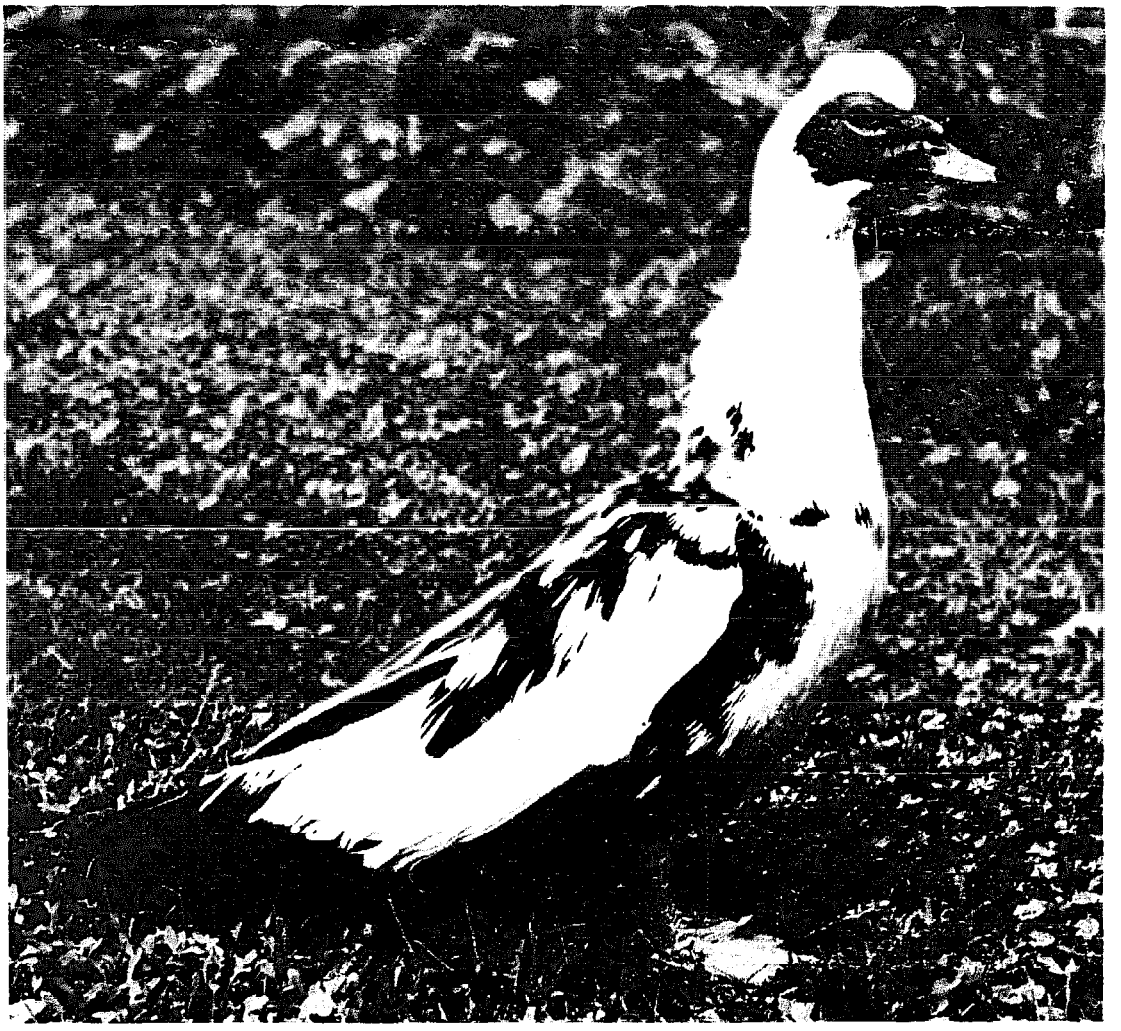

A Black and White Pied Muscovy drake with his head crest elevated.

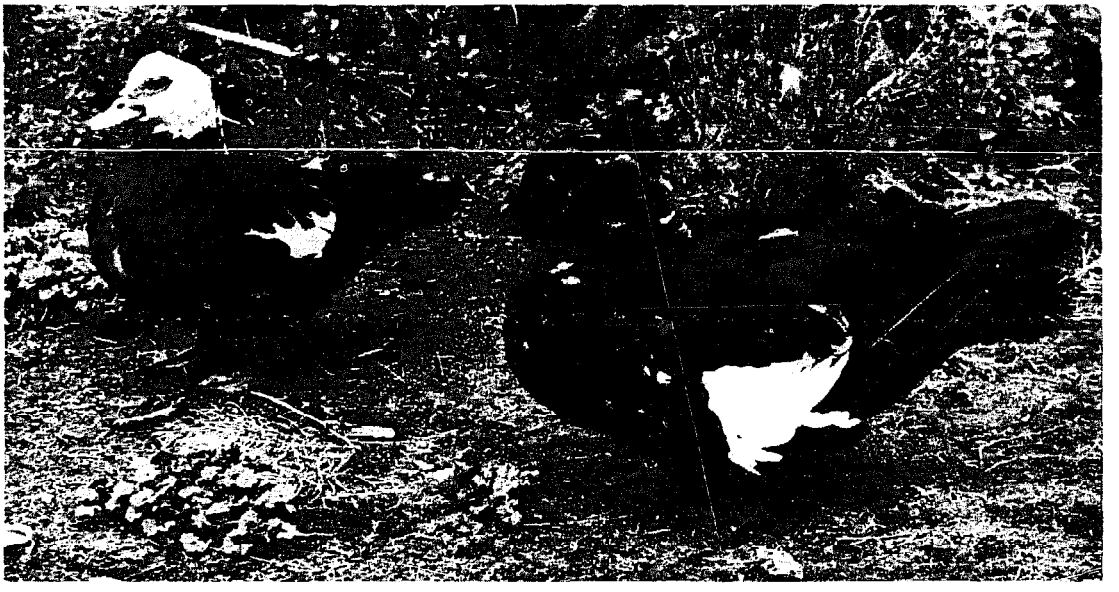

A White-headed Muscovy duck and Colored drake displaying his white forewings which are characteristic of Colored varieties. Owned by Mrs. Richard Moon, Bend, Oregon.

Muscovies are highly prized for their meat and are easier to pick than true ducks. They have exceptionally broad, well-muscled breasts and are one of the leanest of all waterfowl. We have found that when their meat is used in stews it is hard to distinguish from beef, while cured and smoked Muscovy is similar to lean ham.

The two most common varieties of Muscovies are the White and Colored, with the latter's plumage being iridescent greenish-black throughout, except for white forewings. Other varieties include Blue, Chocolate, Silver, Buff and Pied.

This breed is not considered attractive by many people, but they are hardy and quiet, and capable of foraging for much of their keep. If you want a meat-bird that requires minimal care and feed, it is doubtful that there's a better choice available than the Muscovy. An added bonus our family has found with this breed is that we don't become overly attached to them—making it less of an emotional strain on butchering day.

Pekin. Recognized worldwide as the fastest growing of all ducks, Pekins are hatched in greater numbers than all other meat type breeds combined. These hardy ducks were introduced into Europe and the Americas from China in the 1870s. Pekins are attractive as well as practical, and frequently

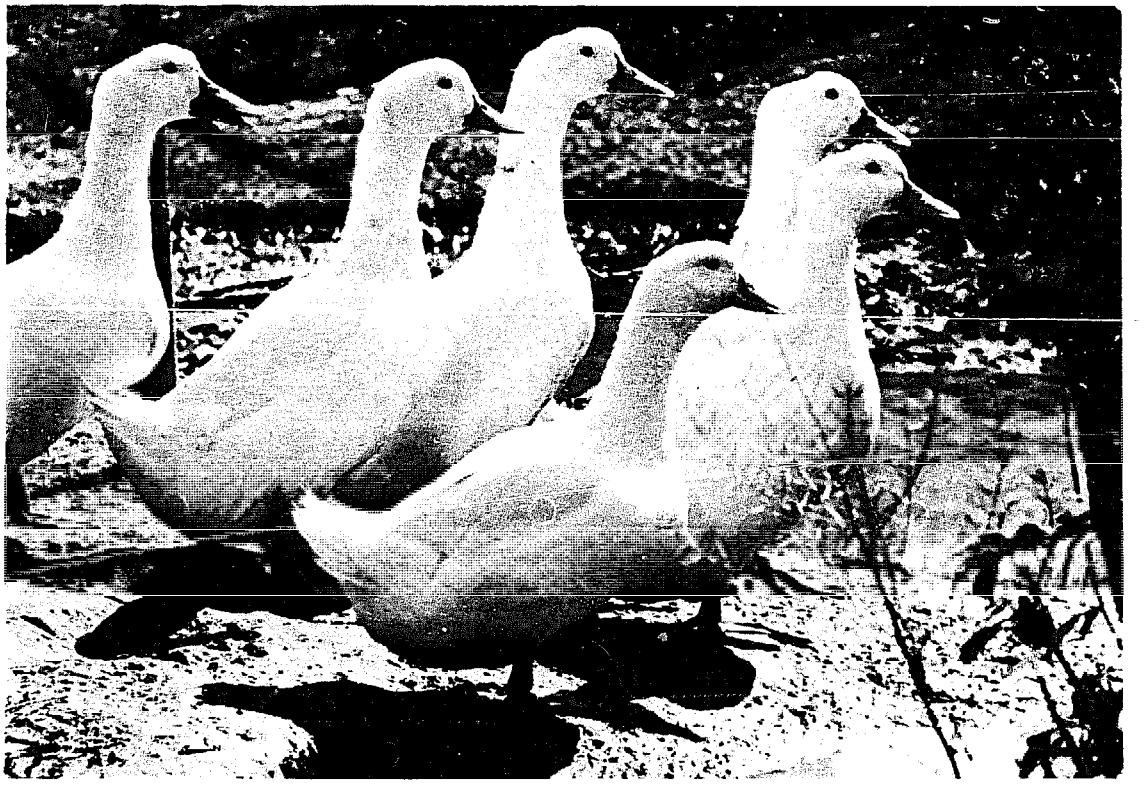

A group of seven-week-old Pekins. Note typical breed characteristics of large, high-crowned heads, rather upright carriage and elevated tails.

are kept on ponds "just for pretty." Their creamy-white plumage is offset nicely by bright orange bills and reddish-orange feet. Hens lay white or tinted eggs.

The Pekin is the best breed for the production of "green" ducklings. When managed properly, they are capable of weighing seven pounds at seven weeks of age. One objection some people have to this breed is the exceptionally high fat content of their carcasses and the talkativeness of the hens.

Rouen. France was the original home of the imposing Rouen. Their large, deep bodies and handsome plumage have helped them gain wide popularity. They have retained the basic color pattern of the Mallard, although the plumage of the Rouen typically is several shades darker than their wild ancestors. Hens lay eggs in various shades of blue, green and tinted white.

Rouens combine beauty with good meat qualities. They do not grow quite as rapidly as Pekins, making them less practical for raising as "green" ducklings. Rouens are better suited for situations where they can forage for a substantial portion of their food, receiving just enough grain or concentrated feed to keep them in good condition. They can be dressed at ten to twelve weeks or five to six months when they are well-matured and in full feather.

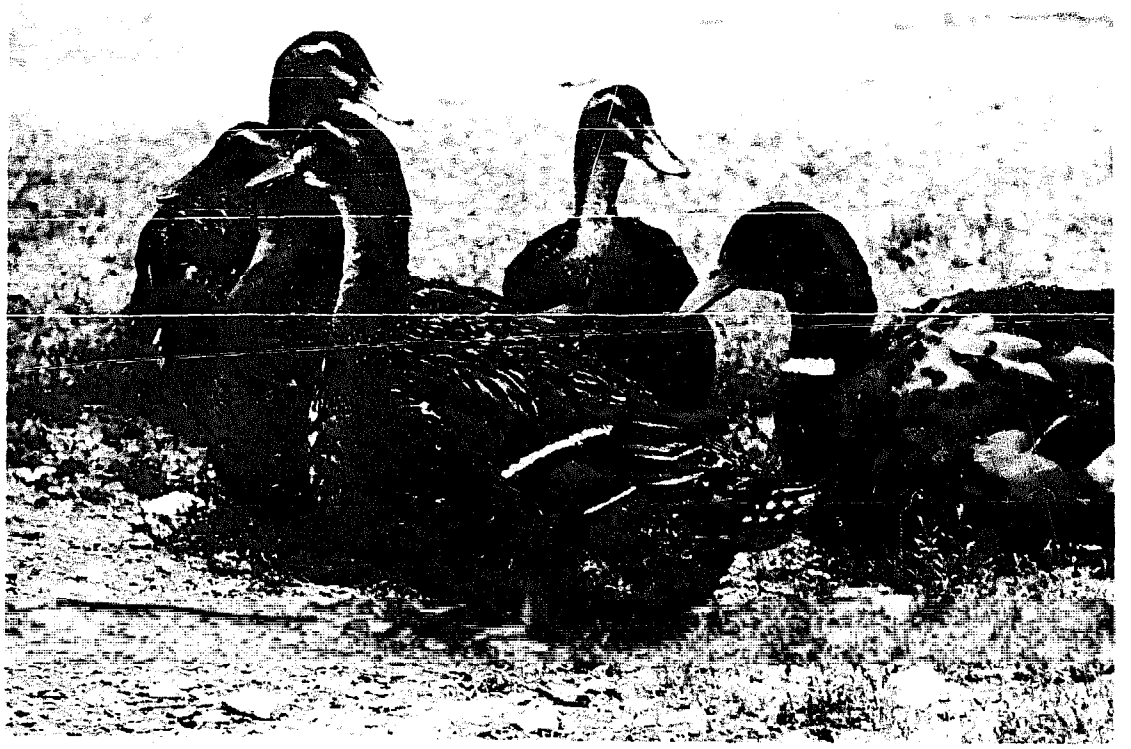

Deep-keeled standard-bred Rouens photographed in midsummer after the drake had commenced the eclipse molt. Owned by Marcus L. Davidson, Bath, Pennsylvania.

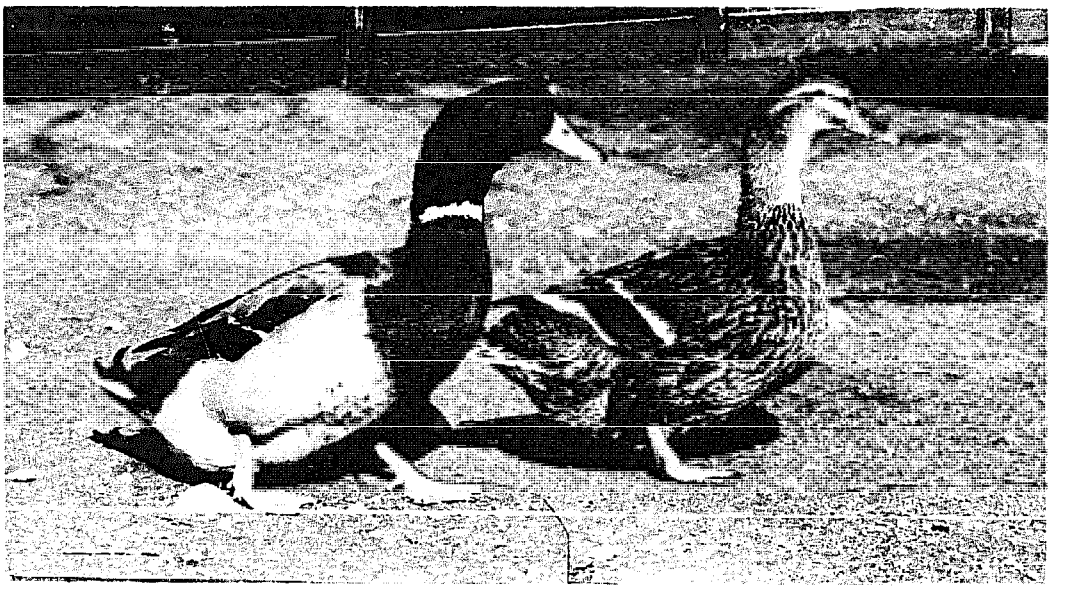

A pair of production-bred Rouens. The drake has just begun the eclipse molt, as evidenced by the sprinkling of dark feathers on his gray underside.

General-purpose Breeds

This category includes a colorful assortment of medium weight breeds that are capable of furnishing a good supply of both meat and eggs for your kitchen. Not being the outstanding layers that egg-type ducks are, nor as fast growing as Pekins, these breeds are the most practical where they can rustle a good portion of their food. The fastest growing strains make good prospects for the production of ten- to twelve-week-old roasting ducklings. These breeds are active foragers and will add color and interest to your duck flock.

Cayuga. One of three breeds of ducks that can claim North America as its native land, the Cayuga is thought to have been developed from ducks raised in the region of Lake Cayuga, New York.

The distinguishing feature of this attractive bird is its brilliant green-black plumage. A common problem in breeding Cayugas is that the brightest colored individuals (particularly hens) frequently acquire white feathers as they age. To keep this problem under control, the breeder of Cayugas can select good green-colored drakes with no white feathers (be sure to check under the bill) and mate them with hens that had no white feathers as young birds. Hens with just a hint of brown under their bills and wings often produce ducklings with solid black color.

In keeping with her ebony plumage, the hen produces her first eggs of the season encased in a black or dark gray film that fades to light gray or blue as the season progresses. Ducklings have glossy black feet and bills, and black down with just a trace of yellow on the breast.

An old Cayuga duck with good solid black plumage. Owned by Maurice Clark, Toledo, Oregon.

Cayugas are one of the hardiest and quietest of all breeds. However, their black plumage makes it difficult to obtain an attractive carcass when they are butchered at a stage when they have pin feathers. (When pin feathers are present, we solve the problem by skinning the bird. This procedure is more healthful, since most of us don't need the skin's extra fat in our diet.)

Crested. A large, round head crest gives this regal bird its name. Over the years that domestic ducks have been raised, specimens with small tufts have frequently appeared in many countries. These tufted ducks were improved through selective breeding in various parts of the world, including Europe and North America, resulting in the Crested duck as we know it today.

A curious trait of Crested ducks is that the size and shape of the crest still varies a great deal, and up to one-third of all ducklings lack the head adornment. This phenomenon is the result of a lethal gene that causes the premature death of embryos that carry two genes for crest. The only ducklings that can hatch are those which have only one gene for crest or else have two genes for normal (no crest). Due to this condition, the average hatchability of Crested duck eggs is approximately 25 percent less than for other medium-sized breeds.

The most common variety is White, but Crested ducks are also bred in Gray (Mallard color), Black, Blue and Buff. Hens lay blue, green, tinted or white eggs.

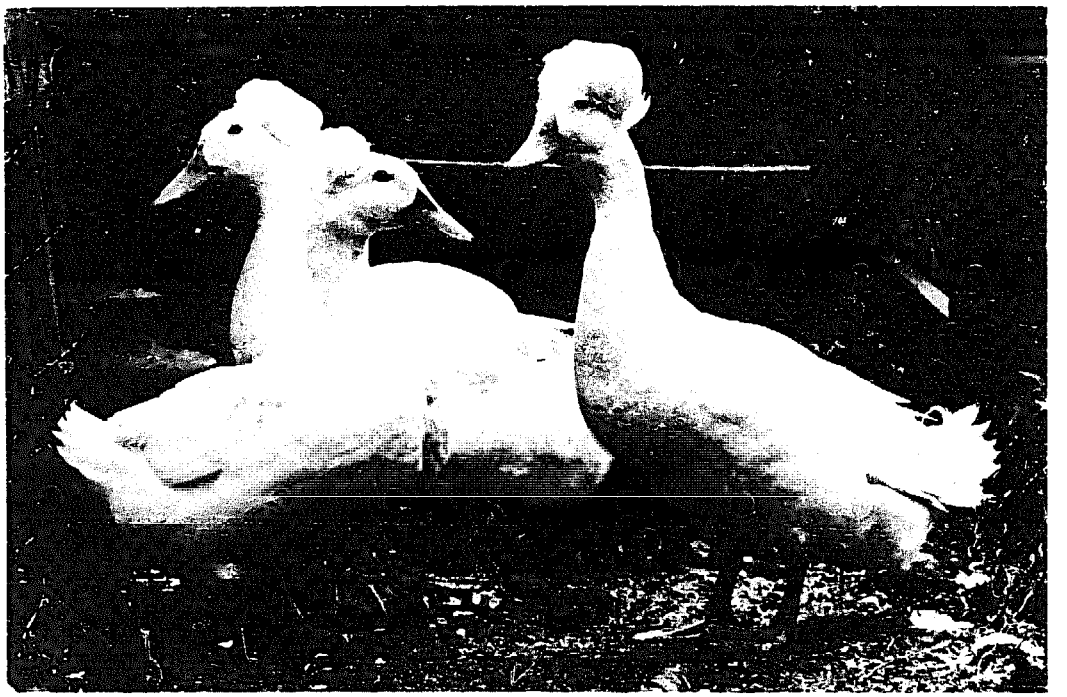

A trio of White Crested ducks. While none of these birds possesses large, round crests, they produced a good percentage of ducklings with head adornments that approached the ideal. Owned by Henry K. Miller.

Crested ducks are fast growing and highly decorative and the ducklings that hatch are strong and vigorous. Despite the disadvantage of having lower than normal hatchability, they are still a popular and practical breed.

Magpie. The name of this striking Welsh breed refers to its distinctive markings. The plumage is predominately white, offset by two colored areas that include the back (from the shoulders to the tail) and the crown of the head (see photo, page 34). The most common variety is Black, with a limited number of Blues and Duns also being raised. Breeding well-marked Magpies is a real challenge.

While Magpies are scarce, the few people raising them have found this duck to be productive and practical. Hens lay tinted or bluish-colored eggs and are among the best layers of the general purpose breeds. Magpies dress off cleaner than solid, dark-colored birds. This breed is an excellent duck for persons interested in helping to preserve a rare breed of waterfowl.

Orpington. William Cook of Kent, England, was the originator of the Orpington ducks. According to available records, they were introduced into North America in the early 1900s.

Five varieties of Orpingtons have been developed over the years—Buff, Blue, Silver, Black and Chocolate. The last four varieties all have white bibs on their chests. The Buff—which is solid colored—is the only variety com-

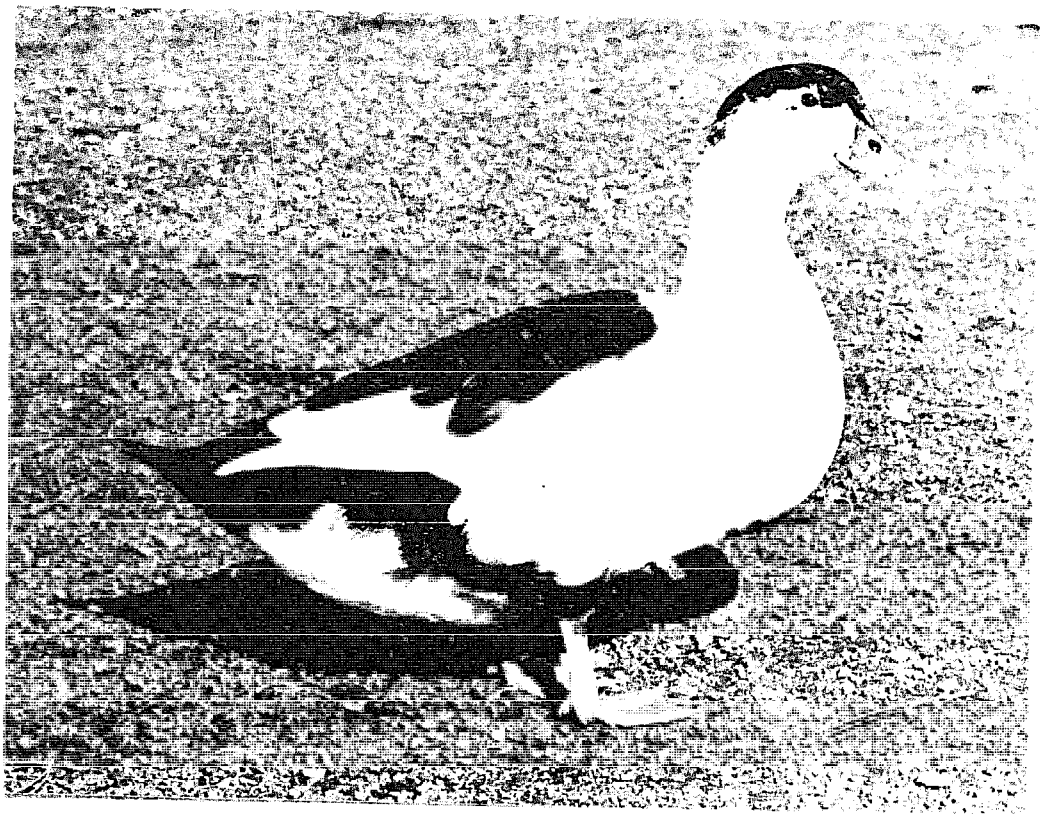

A Black and White Magpie duck. Ideally, black feathers do not extend down onto the thigh coverts, and bills are clear orange or yellow without green spots.

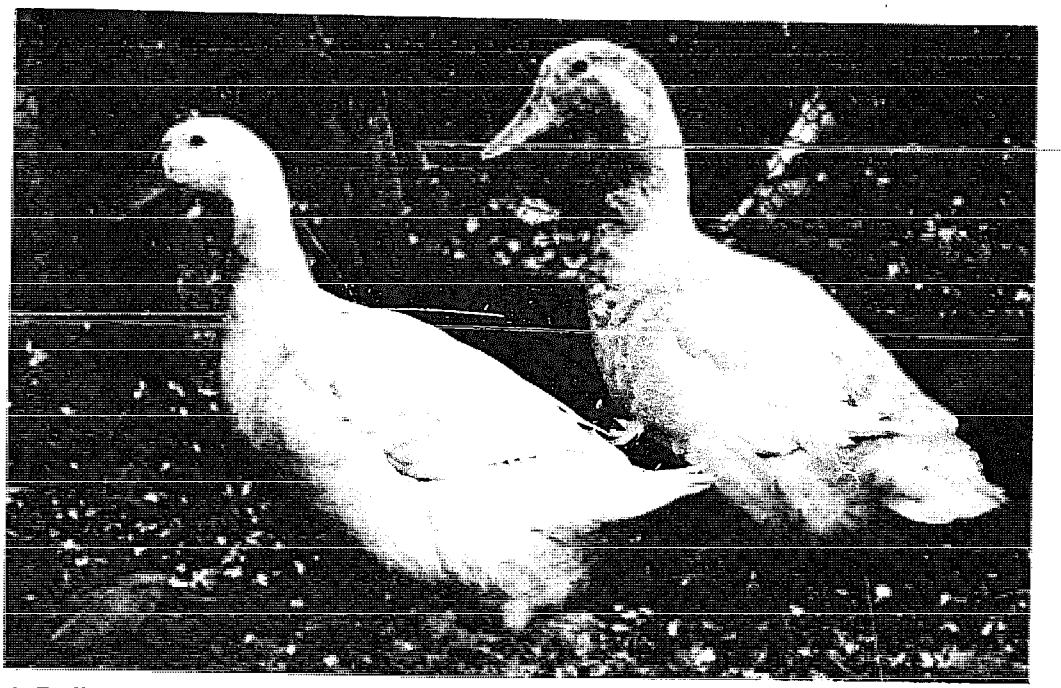

A Buff Orpington duck and drake possessing good length and depth of bodies, characteristics that are needed for heavy meat and egg production. Owned by Henry K. Miller.

monly raised today, and it is often referred to simply as the Buff duck. It is a pretty shade of fawn buff which does not become soiled as easily as white plumage, and yet is light enough that pin feathers are not unsightly when this variety is dressed for meat.

Orpington hens lay white or tinted eggs, and along with Magpies, are the best egg producers among the medium and large breeds. Many experienced waterfowl raisers consider the Buff Orpington the best choice when a single breed is desired that will provide both a steady supply of eating eggs and large roasting birds.

Swedish. Although their name would indicate otherwise, Swedish are believed to have been developed in Germany. They are bred in three varieties: Blue, Black and Silver. All varieties have white bibs that extend from under the bill to halfway down the breast. Ideally, the two outermost flight feathers on each wing are white.

While the color of the Blue variety is pretty, it is not the bright blue seen in some cage or wild birds, but rather is a subtle gray-blue shade. Blue Swedish hatch out only partially true to color, with approximately 50 percent of the ducklings being blue, 25 percent black and 25 percent silver or white splashed.

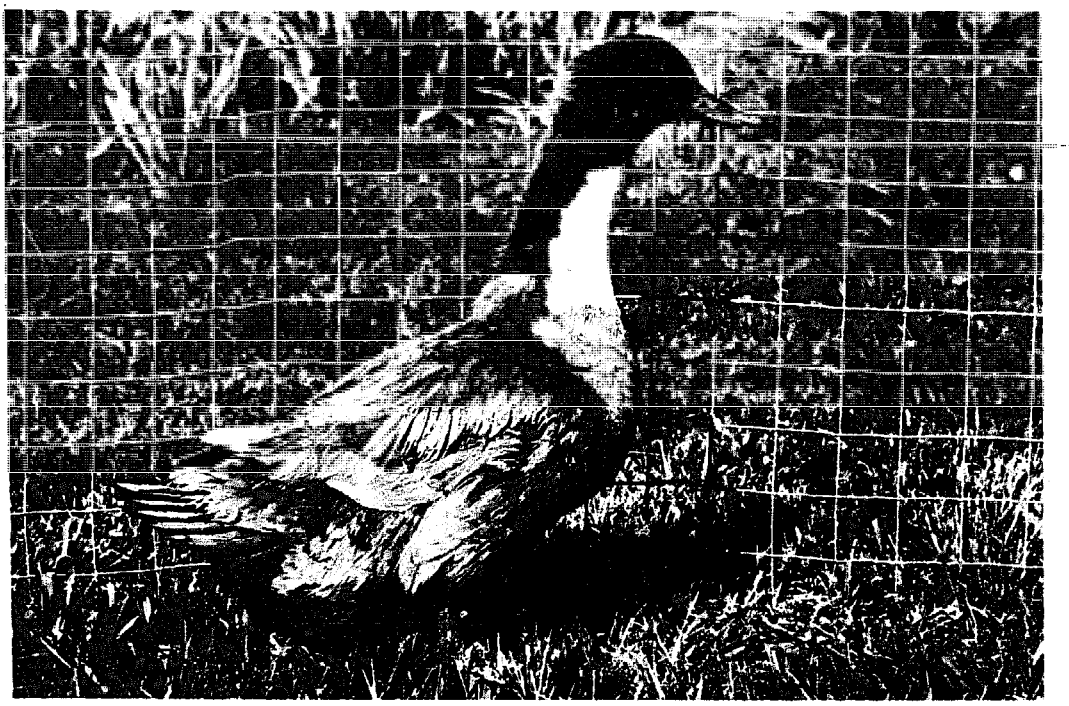

A Blue Swedish duck with typical color, but smaller than standard bib. Owned by Perrydale Acres, Amity, Oregon.

Hens lay blue, gray or tinted eggs. Swedish are extremely hardy, and are one of the most active foragers among the larger breeds. People who are intrigued by the principles of color inheritance find the Blues especially interesting to raise.

Bantam Breeds

These birds are the miniatures of the duck family and in the past have been valued primarily for their esthetic qualities. However, they are good spring layers if eggs are gathered daily, and their meat is exceptionally fine textured and has outstanding flavor. Highly adaptable, they thrive in limited space under close confinement, or can be allowed to roam at large. A patrol of several bantam ducks per acre of land provides an effective means of keeping insects and slugs under control. These breeds require a minimal quantity of grain or pelleted feed to supplement their gleanings. To obtain top egg production and hatchability (particularly under artificial incubation) it is often helpful to supply bantam ducks with a breeder ration containing 20 percent protein and fortified with 10 to 25 percent more vitamins than recommended for other breeds. Hens are excellent natural mothers.

Australian Spotted. This handsome bird is seldom mentioned in poultry literature and infrequently advertised for sale. Nevertheless, they have been bred for at least fifty years, and are an established breed.

Apparently the Australian Spotted ducks kept in North America were created separately by several master waterfowl breeders. According to John C. Kriner, Jr. of Orefield, Pa., he and Stanley Mason developed this breed in the 1920s, and exhibited them for the first time in 1928. The late Henry K. Miller of Lebanon, Pa. was breeding and showing Spotted ducks of his own creation more than thirty-five years ago.

Typical body shape is intermediate between the long, racy wild Mallard and the short, compact Call. Coloration of the Australian Spotted varies, but in general, it is reminiscent of Mallards, with the striking difference being that the Australian drake displays conspicuous reddish-brown spots on his sides and back, a snowy chest and white flight feathers. The plumage of the female has an attractive frosted appearance with a liberal scattering of black or brown spots. Hens produce pale blue, greenish-buff or white eggs.

The Australian Spotted is a colorful and hardy little bird. It is often difficult to locate a source that offers stock for sale.

Call. These tiny birds are the *smallest* of all domestic ducks, but make up for their lack of size with loud, persistent voices. In the era when live decoys were used in duck hunting, the English breeders were developing Calls for their talkativeness.

An Australian Spotted drake exhibiting well-marked sides. According to his owner, Henry K. Miller, this specimen should have a longer bill and a more streamlined head.

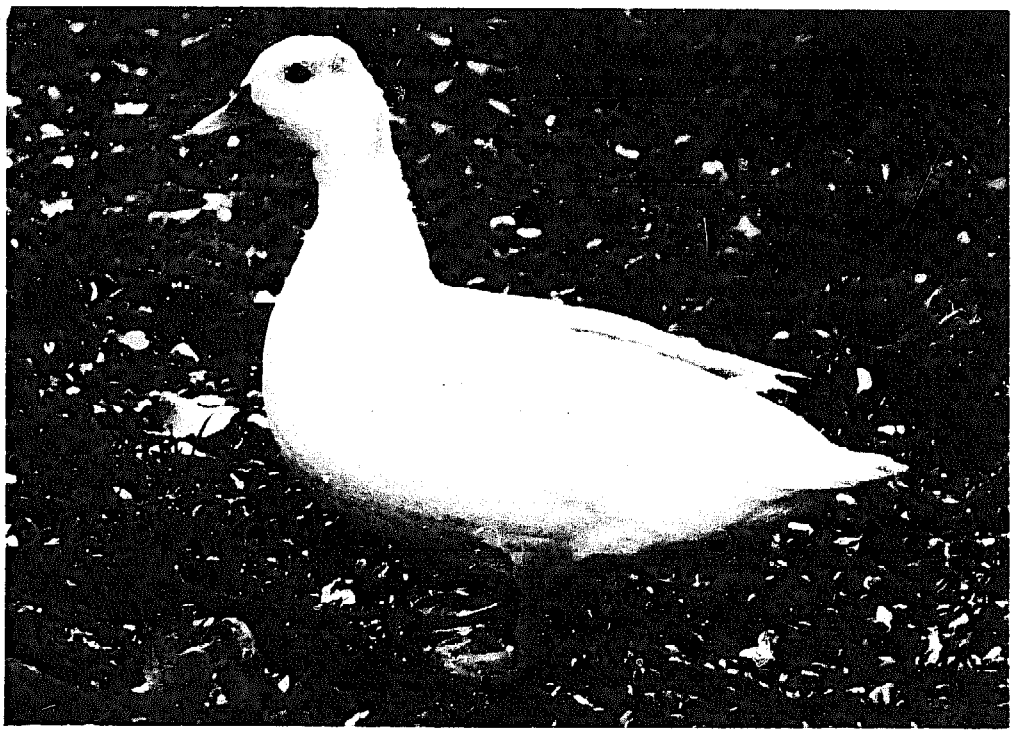

A White Call duck showing typical characteristics of short bill and horizontal carriage. She was photographed at the end of the breeding season when her head was not as large and round as normal. Owned by Henry K. Miller.

Plump, bowl-shaped bodies, short bills and large round heads are typical characteristics. Calls are bred in two common varieties: Gray and White. The Gray variety has the same color combinations as the Mallard, while the Whites are pure white with bright yellowish-orange bills, shanks and feet. Several rare varieties, including Blue, Buff, Golden, Aleutian and Spotted, are also being raised by waterfowl fanciers.

Call hens lay green, blue or tinted eggs. Newly hatched ducklings often are not as sturdy as the young of other breeds; therefore, some breeders have found it helpful to start them on a diet of quick-rolled oats, with finely chopped greens sprinkled on their water. When the ducklings are five to six days old, the oats can gradually be replaced with starting crumbles so that by two weeks of age, they are receiving 100 percent crumbles. Once started, Call ducklings are hardy and easily raised. The delightful, friendly Call duck is the most popular of the bantam breeds.

East Indie. It is believed that this breed originated in the United States, although English waterfowl breeders are given credit for its refinement. East Indies are usually a trifle larger than Calls, and exhibit a somewhat racier body conformation.

A group of East Indies with two old hens displaying white age feathering. Note the longer bills and racier type than typical for Calls. Owned by Henry K. Miller.

The iridescent green-black plumage of the Black East Indie cannot be described satisfactorily and live specimens must be seen in bright sunlight before their beauty can be fully appreciated. The brilliance of their feathers is *unequaled* by any other black domestic fowl. The same mating procedures are necessary as with the Cayugas to keep the occurrence of white feathers under control.

The first eggs of the laying season are black or dark gray, gradually changing to light gray or blue as the season advances. Hens are surprisingly good layers for such a small bird, and the ducklings are vigorous and hardy *if* they are out of a strain that is not overly inbred.

In our experience, East Indies reproduce extremely well under natural conditions with minimal care. If the ducklings are butchered at eight to ten weeks of age when in full-feather, they produce an attractive carcass that is just the right size to serve as a dinner for two.

Mallard. This wild species frequents most countries in the Northern Hemisphere, and is believed to be the parent stock of all domestic duck breeds, with the single exception of the Muscovy. Mallards readily adapt to domestication and in four or five generations of heavy feeding in captivity will in-

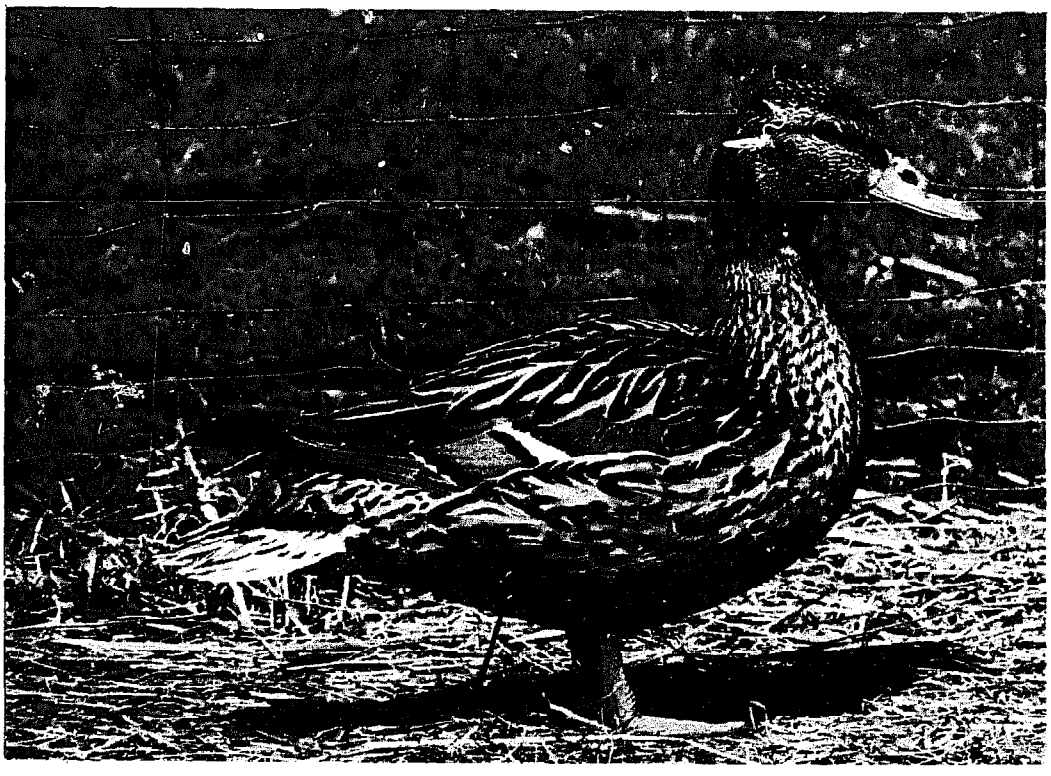

Mallard duck displaying her wing speculum, black and white wing-bars and intricately penciled body plumage. Authentic Mallard hens possess only one facial streak, while less typical birds often exhibit two. Owned by Dave and Millie Holderread.

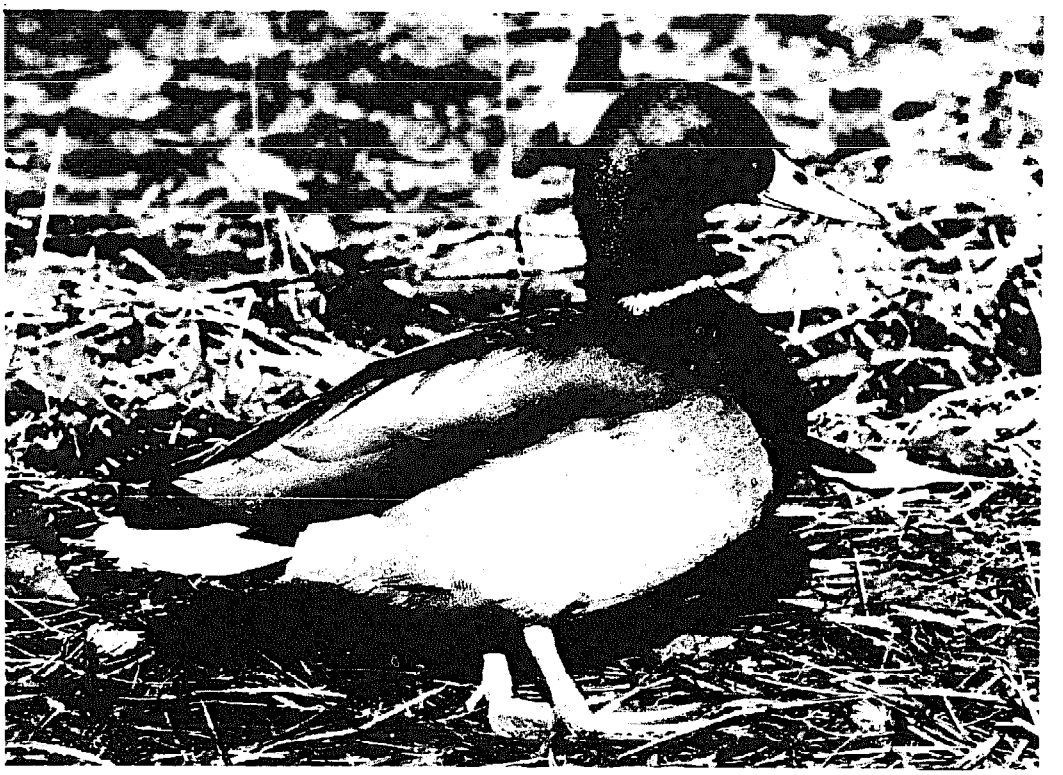

Mallard drake in a relaxed pose with head feathers ruffled. He exhibits the long, slender bill, teardrop-shaped body and centrally placed legs typical of authentic specimens. Owned by Dave and Millie Holderread.

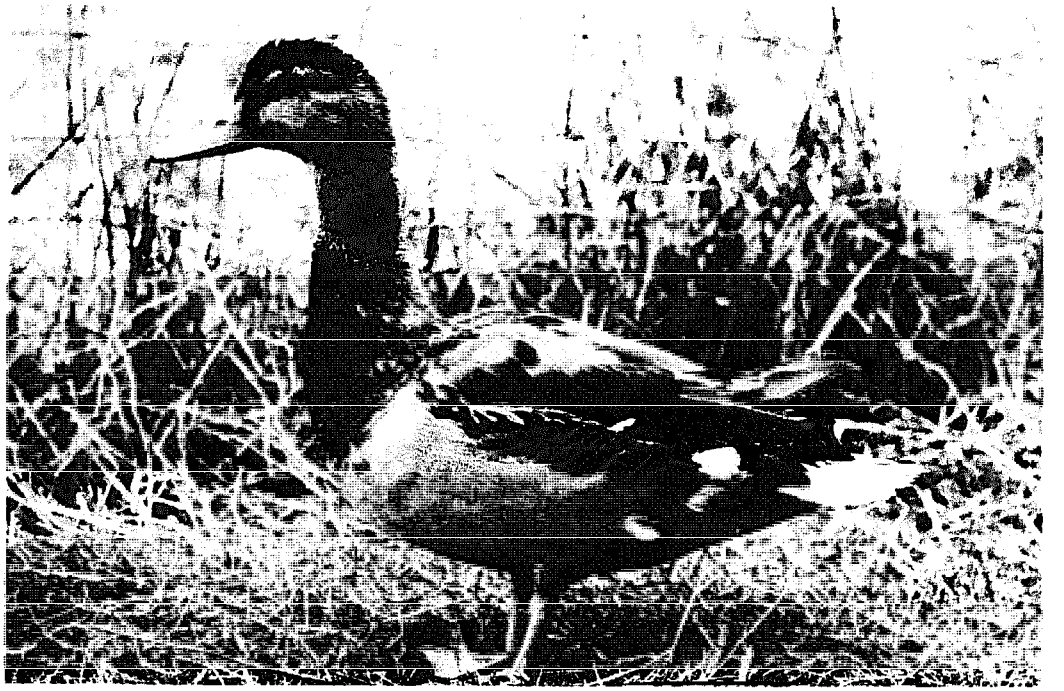

At seventeen weeks of age this Mallard drake has begun to replace his juvenile plumage with the bright colors of adulthood. To provide camouflage as long as possible, young males acquire their iridescent green heads and white neck collars last.

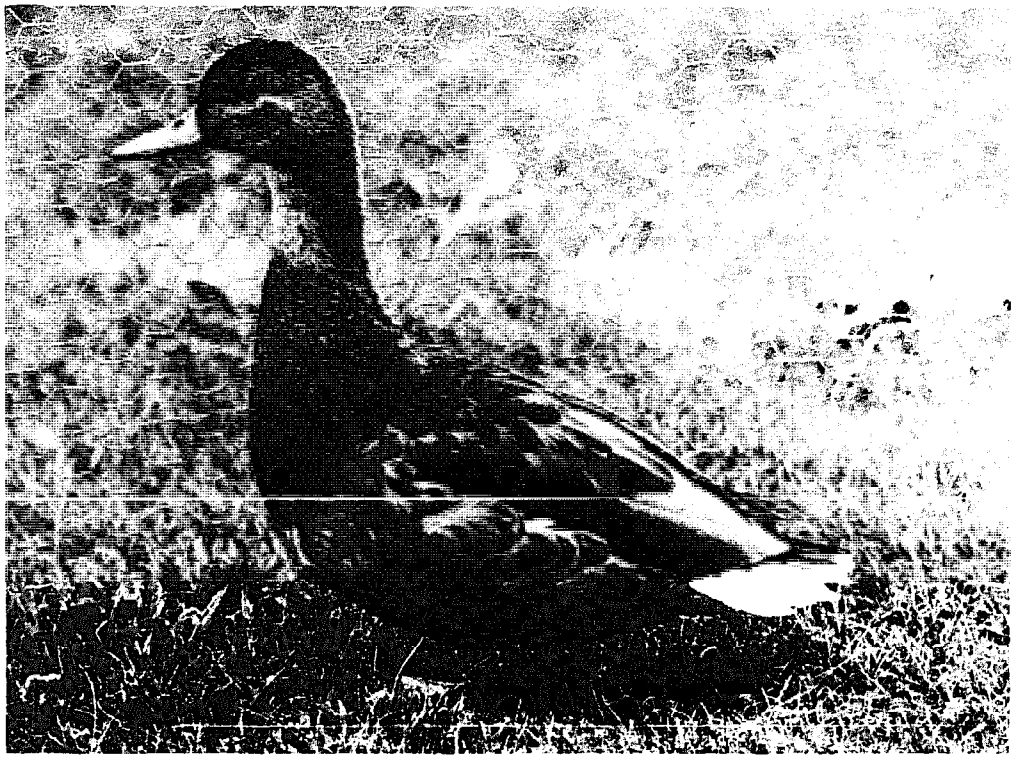

The same Mallard drake as shown to the left, photographed four months later in midsummer when he was in full eclipse plumage. By fall he will again sport the flashy nuptial plumage that makes the Mallard one of the most beautiful ducks.

crease dramatically in size and lose much of their desire and ability to fly. To preserve the streamlined type and outstanding foraging ability of the authentic Mallard, it is necessary to feed them judiciously and select breeders that most closely resemble the wild greenheads. (To legally capture wild Mallards or gather their eggs, a federal permit is required. However a permit is not needed to raise or sell domesticated Mallards.)

The Mallard drake is one of the *most beautiful* of all waterfowl with his iridescent green head, white neck collar, chestnut breast, silver underbody, blue wing speculum and reddish-orange feet. Except for her iridescent blue wing speculum, the hen's plumage is a mellow, though attractive, combination of almond and golden browns, with dark brown and black penciling. Besides the normal colored stock, there exist rare varieties that include the White, Snowy, Buff, Blue, Silver and Crested Mallards.

Along with Muscovies, genuine Mallards are the most self-reliant of all breeds. The hens are outstanding mothers and will hatch a high percentage of their greenish-buff or bluish eggs if not molested repeatedly while nesting. When there is an abundant supply of natural foods, hens are capable of raising their broods with little or no supplementary feed.

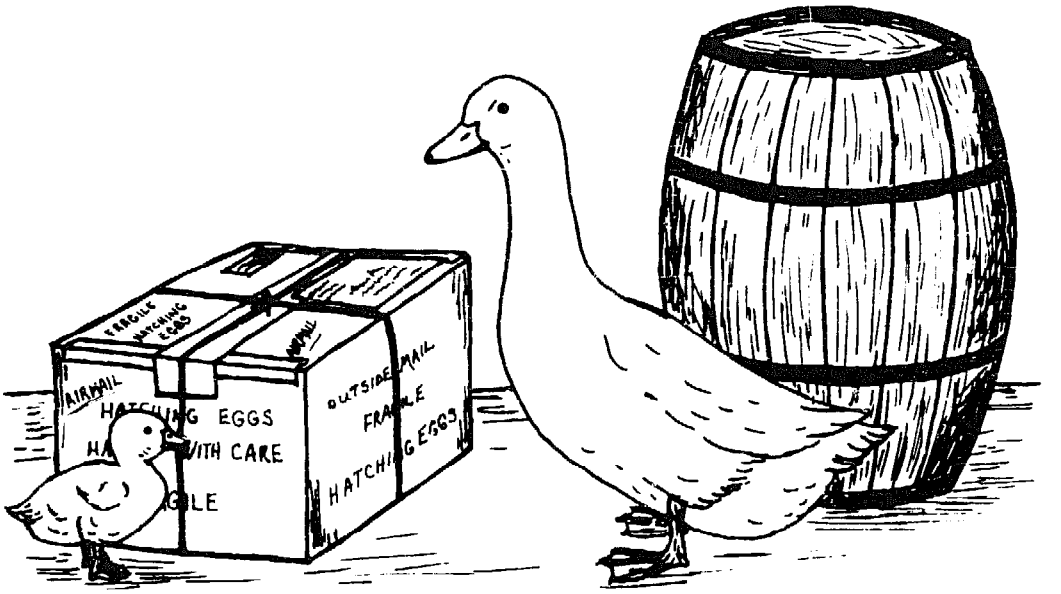

CHAPTER 6

Acquiring Stock

Having selected the breed or breeds you want to raise, the next step is locating suitable stock. The importance of starting with good quality birds cannot be overemphasized. The productivity, growth rate and size of ducks within the same breed varies a good deal. If your duck project is going to be economically practical and free of unnecessary problems, healthy and productive birds are essential.

PRODUCTION-BRED VS. STANDARD-BRED STOCK

Egg and meat producing characteristics are given first priority in production-bred ducks, with less concern for perfect color or shape. On the other hand, standard-bred birds are used for showing in competition and are painstakingly selected for color, size and shape, with production abilities often given second priority. Normally, standard-bred stock is priced higher than production-bred stock.

In some breeds of ducks, the productivity and growth rate of exhibition strains are equal to or better than the commercial stock that is commonly sold by hatcheries. However, production-bred strains of Aylesburies, Rouens, Campbells and Runners are more practical for the home flock than are standard-bred birds of these breeds.

HATCHING EGGS

If a good dependable setting hen or incubator is available, you may wish to buy hatching eggs to start your flock. Some advantages of this method are that hatching eggs normally sell for one-third to one-half of the prices of day-old ducklings, and you get to experience the fun of waiting for and witnessing the hatch. Some disadvantages are that eggs vary in their fertility, they may be broken or internally damaged if they must be shipped, and it is impossible to know just how many ducklings will hatch.

If you receive a shipment of hatching eggs that are insured or COD for postage, open the package in the presence of your postal carrier to check for breakage and to count the number of eggs received. If a substantial number of eggs are broken or there are fewer eggs than you paid for, the postal carrier will provide a claim report.

Unless you know that the eggs are over two weeks old when you receive them, higher hatchability can often be obtained if shipped eggs are held at 55° to 65° F. for six to twelve hours prior to being placed in the incubator. Older eggs are best set promptly upon their arrival.

DAY-OLD DUCKLINGS

Purchasing day-old ducklings is the most popular method of starting a duck flock. They are more widely available than hatching eggs or adult stock. Ducklings are sturdy and can be shipped thousands of miles successfully. While living in Puerto Rico, we received hundreds of ducklings from distances of over 3000 miles, and the mortality rate was well under 1 percent.

Ducklings are occasionally sold sexed, but normally are available only straight run. Theoretically, unsexed ducklings run 50 percent drakes and 50 percent hens. Practically, there may be 10 to 25 percent more drakes than hens or vice versa, particularly when ducklings are purchased in lots of twenty-five or less.

When ordering ducklings, give your telephone number (or a neighbor's, if you don't have a phone) and instruct the shipper to include it on the shipping label. If you live on a long rural route, ask your local postmaster to hold the ducklings at the post office and phone you upon their arrival so you can pick them up promptly. When a shipment is received, open the box in the presence of the postal employee and check the condition of the ducklings and count the live birds. If the quantity of live ducklings you receive is significantly fewer than the number you paid for, the postal carrier should provide a claim report.

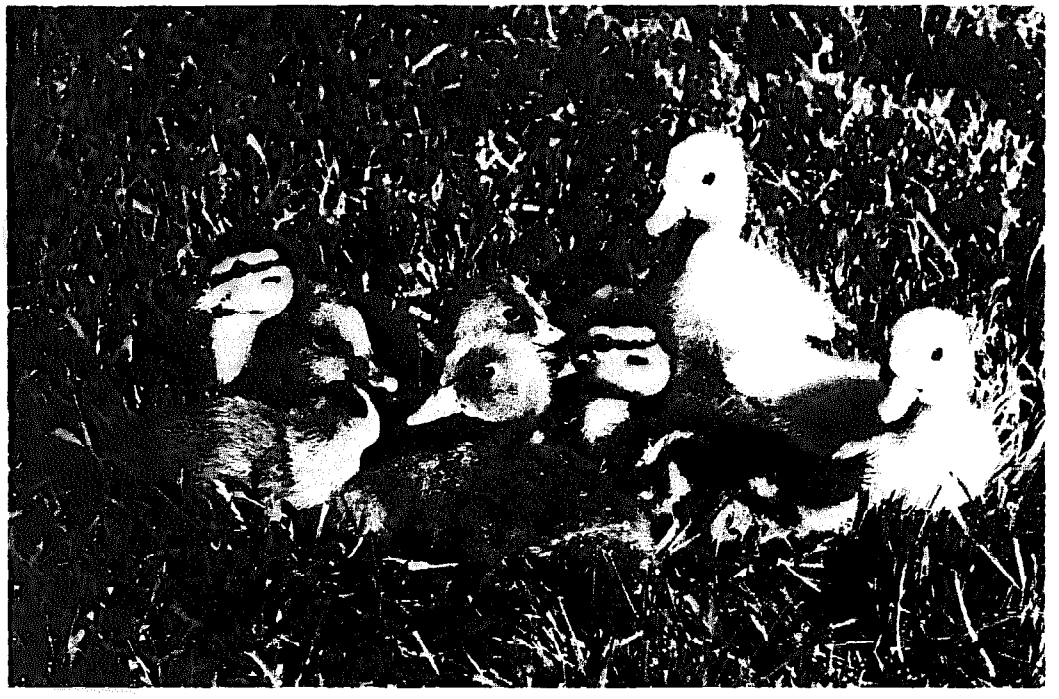

Day-old Khaki Campbell, Mallard and White Indian Runner ducklings several hours after being taken out of the incubator.

Care of Shipped Ducklings

The first twenty-four hours after ducklings arrive are *critical*. The birds should be given drinking water, food and rest as soon as possible. As you take the little ones from the shipping box and place them in the brooder, dip each of their bills in lukewarm water to help them locate the drinking fountain. They should be checked frequently the first day, but do not handle or disturb them more than absolutely necessary.

BUYING MATURE STOCK

The quickest way to obtain a producing duck flock is to purchase mature birds. Poultry farms and hobbyists often have adult stock available. Because the productivity of ducks normally decreases significantly after their third or fourth year, it is preferable to acquire birds that are not over one or two years of age.

When possible, it is advantageous to acquire ducks locally since you'll save on transportation costs, and the ducks will be seen at the time of purchase. If a problem arises at a later date, it will be convenient to communicate with the seller. However, waterfowl adapt quickly to new climates and are readily shipped, so you need not hesitate ordering from out-of-area breeders and hatcheries if the birds you want are not available locally.

Some good places to look for ducks or addresses of sources follow: feed

stores; agriculture fairs; university poultry or animal science departments; agriculture extension services; classified ad sections of poultry, farm and gardening magazines, and local newspapers; and Appendix G (The Duck Breeders and Hatchery Guide) in this book.

HOW MANY

The ideal number of ducks for your flock will depend on the purpose you have for raising them, the breed raised and the environmental conditions to which the birds are exposed.

To estimate the number of hens needed for a laying flock, calculate the total number of eggs you will need over a year's time. Divide this number by the average number of eggs a hen of the breed you are going to raise will lay during a year. Keep in mind that the figures given in the Breed Profile Chart (page 21) for the yearly egg production of the various breeds are for hens that are fed concentrated feeds and exposed to no less than fourteen hours of light daily during the laying season. Egg production is reduced by 30 to 60 percent if concentrated laying feeds are not utilized and by 30 percent or more if artificial lighting is not used to lengthen the short days of fall, winter and spring. (See Table 18, page 105).

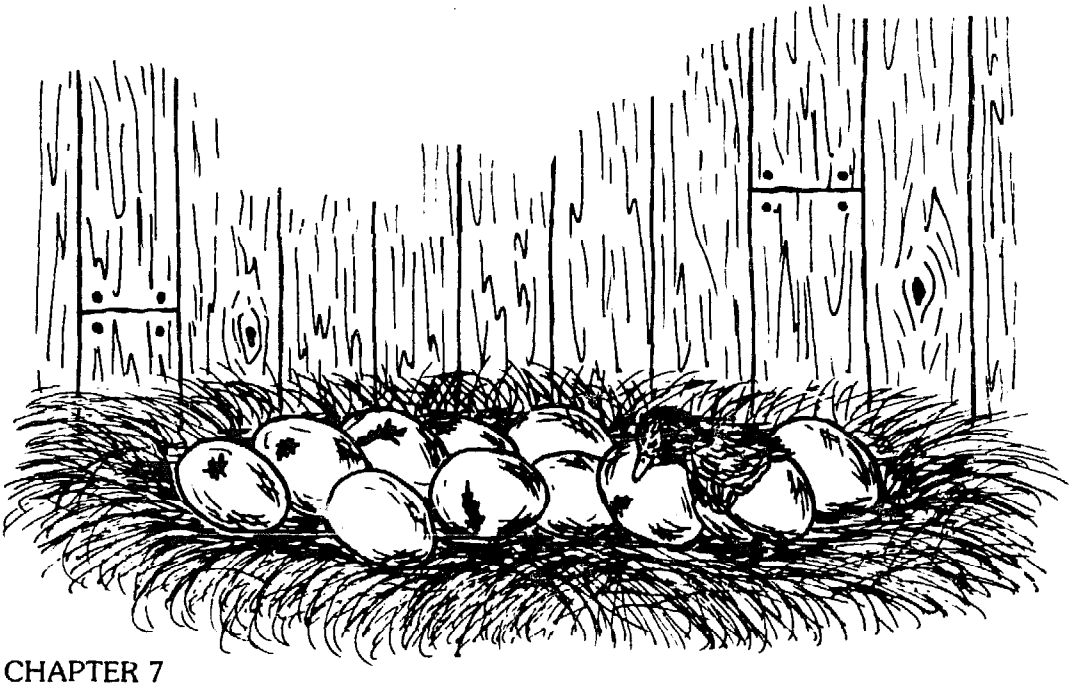

CHAPTER 7

Incubation

For many of us who own poultry, the incubation and hatching of eggs is the most fascinating phase of raising birds. When holding an egg in one's hand, it is difficult to comprehend that inside the shell there exists every element necessary for the beginning and growth of a new life. In fact, when a fertile egg is laid, an embryo several thousand cells in size has already formed. If stimulated by warmth and movement, that tiny spark of life will grow, break from the shell and present itself as a new generation of ducks!

HATCHING EGGS

Gathering

Eggs that are going to be incubated by a foster hen or in an incubator should be gathered at least twice daily to protect them from predators and prolonged exposure to the elements. Hatching eggs must *always* be handled gently so that the diminutive embryo is not injured or the protective shell cracked. Rolling eggs over and over, jolting them sharply or handling them with dirty hands—all can destroy fertility.

Cleaning

Eggs that are nest-clean hatch the best. Lightly soiled eggs should be wiped with a clean cloth or fine sandpaper. Dirty eggs need to be washed as soon after gathering as possible.

Washing has several negative effects on duck eggs: it removes the cuticle (a protective film on the shell that reduces dehydration and screens out pollutants); it can lower hatchability slightly; and it makes it necessary to raise the humidity level during incubation by 5 to 10 percent. Nonetheless, it is preferable to wash dirty eggs rather than set them uncleaned, since contaminated eggs create an unsanitary condition under the hen or in the incubator and frequently explode during incubation.

When eggs are washed, always use clean water that is 10° to 25°F. warmer than the eggs. Washing with dirty water spreads contaminants from egg to egg, while cold wash water forces filth deeper into the shell pores. In situations where it is practical, use a hatching egg disinfectant in the wash water.

Selecting

Not all fertile eggs are suitable for hatching. Those used for setting should have normal shells and be average to large in size. Extremely large eggs often have double yolks and seldom hatch. Any eggs having irregular characteristics or the slightest crack are best used for food. Valuable eggs with small cracks can sometimes be saved by placing a piece of tape over the fracture.

Storing

Proper care of eggs *prior to setting* is just as important as correct incubation procedures. In working with owners of small poultry flocks, I have found that careless handling of eggs before incubation is one of the leading causes of bad hatches. It must always be kept in mind that no matter how faithful a setting hen is or how carefully the incubator is regulated, a poor hatch will result if the embryos have been weakened or killed during the holding period.

Where. Eggs must be stored away from direct sunlight in a cool, humid location. Cellars and basements are ideal places; refrigerators are usually too cold.

Position. The position in which eggs are stored prior to incubation has little effect on hatchability. The results of a study involving thousands of duck and goose eggs showed no significant difference in the hatchability of eggs stored on their sides, vertical with the air cell up or vertical with the air cell down. However, when eggs are stored in twelve-egg cartons or thirty-egg flats (twenty-egg turkey flats are best for large duck eggs), less breakage occurs if the eggs are positioned with their large end up.

Temperature. The ideal storage temperature for hatching eggs that are held for ten days or less seems to be 55° to 65° F. If eggs are kept for a longer

time, a temperature of 48° to 52° F. will produce better hatches. Because wide temperature fluctuations reduce the vitality of embryos, it is wise to store eggs where the temperature stays at a fairly constant level. In a study of the effects of storage temperature on hatchability in duck eggs that were stored five to seven days, the following results were obtained:

Storage Temperature	*Hatchability Percentage*
38°-40° F.	61
60°-62° F.	73
76°-82° F.	42

Turning. Duck eggs that are held five days or less show little improvement in hatchability when turned during the storage period. On the other hand, when eggs are stored longer than five days, the hatch can be increased 3 to 15 percent by turning them daily while they're being saved for incubation. If eggs are stored in egg cartons or flats, they can be turned by leaning one end of the container against a wall or on a block at an angle of 30° to 40° each day alternating the end that is raised.

Length of storage. Ordinarily, the shorter the storage period is, the better the hatch. A few eggs that have been held four weeks or longer may hatch, but for good results, the general rule is not to keep eggs for more than ten days before setting them. The negative effect of long storage periods on hatchability can be seen in the results obtained from a test involving several thousand eggs.

Length of Storage	*Hatchability Percentage*
1-7 days	71
8-14 days	64
15-21 days	47
22-28 days	18

Incubation Period

The normal incubation period for Mallards and their derivatives is twenty-seven to twenty-eight days, while Muscovies require approximately a week longer—thirty-three to thirty-five days. High temperatures during storage or incubation cause premature hatches, while long storage periods and low incubation temperatures result in late hatches.

Average Fertility

It is unusual for all eggs in a large setting to be fertile. The average fertility for heavyweight breeds is 85 to 95 percent and for lightweight birds, 90 to 98 percent. See Table 9, page 62, for common causes of poor fertility.

Average Hatchability

The hatchability of artificially incubated duck eggs often is 5 to 10 percent lower than for chicken eggs. Still, good setting hens frequently hatch every fertile duck egg they incubate. Under artificial incubation, the average hatchability falls between 65 to 85 percent of all eggs set, or 75 to 95 percent of the fertile eggs. See Table 9, page 62, for common causes of poor hatchability.

NATURAL INCUBATION

When you wish to hatch a moderate number of ducklings, natural incubation is often the most practical. A good setting hen is a master at supplying the precise temperature, and instinctively knows just how often eggs need to be turned. She also serves as a ready-made brooder, eliminating the need to supply an artificial source of heat.

Choosing Natural Mothers

The Breed Profile Chart (see page 21) under the heading of Mothering Ability, indicates the average capability of the various breeds as natural mothers. Duck eggs can also be hatched by goose, turkey and chicken hens. The breeds of chickens that make the best foster mothers are Silkie or common barnyard bantams and large Old English Games, Orpingtons and Cochins.

Clutch Size

Duck hens normally cover eight to fourteen (Muscovies sixteen to twenty) of their own eggs. Some hens lay such large clutches that they cannot incubate the eggs properly. In this situation, the oldest eggs—those that are the dirtiest—should be removed, leaving only the number that the hen can cover comfortably. Eggs must be positioned in a single layer to hatch well, never stacked on top of one another. If too many eggs are in a nest, the result will be a poor hatch or a complete loss.

Care of the Broody Hen

Setting hens are temperamental and should not be disturbed by people or animals. It is advantageous to isolate the broody from the rest of the flock with a temporary partition. This precaution will keep other hens from attempting to lay in the broody's nest and disrupting the incubation process. Unlike chickens, duck hens and their nests usually *cannot* be moved.

To remain healthy during her long vigil on the nest, the hen must eat a balanced diet, have clean drinking water, and be protected from the hot sun. Feed and water containers should be placed several feet from the nest so that the hen must get off to eat and drink. A leave of absence from the nest for five to ten minutes once or twice daily is essential to the hen's good health and will not harm the eggs.

When chicken or turkey hens are used to hatch duck eggs, they should be treated for lice and mites several days before their setting chores commence. It is usually necessary to sprinkle waterfowl eggs with lukewarm water several times each week when turkey or chicken hens are employed.

Multiple Broods

Muscovies—and occasionally hens of other breeds—will frequently bring off two broods a year or up to three in mild and tropical climates. Multiple broods can be encouraged by feeding hens extra feed in the early spring and by removing the ducklings at one to four weeks of age.

ARTIFICIAL INCUBATION

There are circumstances when an incubator is useful. Unlike setting hens, incubators can be used any season of the year, and come in such a wide range of sizes that any number of eggs, from one to thousands, can be set simultaneously or on alternate dates.

On the other hand, incubators must be attended to periodically each day to check the temperature and humidity, and to turn the eggs if this function is not performed automatically. The hatchability of eggs is lower and the number of crippled or weak young higher under artificial incubation than when the natural method is used. Also, electric incubators are at the mercy of power failures unless a gasoline generator is available.

Types of Incubators

Incubators are made and sold in a wide range of sizes and shapes, with varying degrees of automation. They can be divided into two basic types: the still-air (gravity flow) and the forced-air.

Still-air. These models, available with electric or oil heat, closely approximate natural conditions by having the heat source above the single layer of eggs, causing the upper surface of the eggs to be warmer than the lower portion. Still-air incubators are simple to operate, dependable, nearly maintenance-free and are manufactured with capacities of 20 to 400 eggs. We have

used four models of still-air machines and have had excellent results with each. In my opinion, they are the best incubators for the small home poultry owner.

Forced-air. These incubators are equipped with fans or beaters which move warmed air to all surfaces of the eggs, and normally have multiple layers of egg trays. Forced-air machines are available with capacities of twelve to many thousands of eggs, and when compared to still-air incubators, are better suited to automatic turning of eggs, and take less floorspace for larger quantities of eggs. They are also more complicated, require greater maintenance and sell for higher prices.

Homemade. With a little ingenuity and a lot of persevering care, satisfactory hatches can be obtained in a homemade incubator consisting of a cardboard or wooden box and light bulbs for heat. More elaborate incubators, complete with heating elements and thermostats, can also be crafted in the home shop. (Kits for making small incubators are manufactured by the Lyon Electric Company. See Appendix H for the address.) In emergency situations —such as a hen deserting her nest—it is possible to hatch eggs in an electric frying pan or heating pad.

Where to Place the Incubator

Incubators perform best in rooms or buildings where the temperature does not fluctuate more than 5° to 10° F. over a twenty-four hour period. Consistent temperatures are especially important for still-air incubators, which should be located in a room with an average temperature of 60° to 70° F. *Do not* position your machine where it will be in direct sunlight, or near a window, heater or air conditioner.

Leveling the Incubator

Incubators, particularly still-air models, must be level to perform well. If the incubator is operated while askew, the temperature of the eggs will vary in different areas of the machine, causing eggs to hatch poorly and over an extended period of time.

Operating Specifications

Manufacturers of incubators include a manual of operating instructions with their machines. This guide should be carefully read and followed. The operating instructions often cannot be adapted from one machine to another with good results, particularly if one is a still-air model and the other a forced-air. If

you acquire a used incubator which does not have an instruction booklet, manufacturers are usually willing to send a new manual if you send them a request with the model number of your machine.

The following is a summary of the basic incubation requirements of duck eggs.

Setting the eggs. Start the incubator *at least* forty-eight to seventy-two hours ahead of time and make all necessary adjustments of temperature, humidity and ventilation before the eggs are set. People frequently put eggs in machines that are not properly regulated, thinking they can make fine adjustments after the eggs are in place. This practice is a serious mistake since one of the most critical periods for the developing embryo is the first four or five days of incubation.

Prior to being placed in the incubator, duck eggs need to be warmed up for five or six hours at a room temperature of 70° F. If cold eggs are set without this warming period, water condenses on the shells, and yolks occasionally rupture.

For high percentage hatches, it is *essential* that eggs are incubated in the correct position. Always set them on their sides with the large end (air cell) slightly raised. When duck eggs are set with the air cell lowered, their chances of hatching are decreased by up to 75 percent. Set only the number of eggs that fits comfortably in the tray, without crowding or stacking them on top of one another. If at all possible, do not disturb eggs during the first twenty-four hours they are in the incubator.

Temperature. In still-air machines the correct temperature is 101.5° F., 102° F., 102.5° F., and 103° F. for each consecutive week. If you do not fill the incubator with one setting, but add a few eggs each week, a constant temperature of 102° to 102.5° F. should be maintained. It is essential that thermometers be positioned properly in still-air incubators or an incorrect temperature reading will be given. The top of the thermometer's bulb must be level with the top of the eggs. *Do not* lay the thermometer on top of the eggs since this practice will give a warmer temperature reading than actually exists at the level of the eggs. Forced-air machines are maintained at several degrees lower, 99.5° to 99.75° F., since all sides of the egg are warmed equally.

The temperature must be watched closely the last seven to ten days of incubation. During this period, an increase in temperature is often experienced, and the thermostat may need to be adjusted slightly each day to keep the eggs from overheating. Lowering the temperature by 1° to 1.5° F. for the final two days is beneficial, since ducklings generate considerable internal heat in their struggle to free themselves from their shells.

It is a good idea to use thermometers designed specifically for incubators, as they have greater accuracy than utility models and are easier to read.

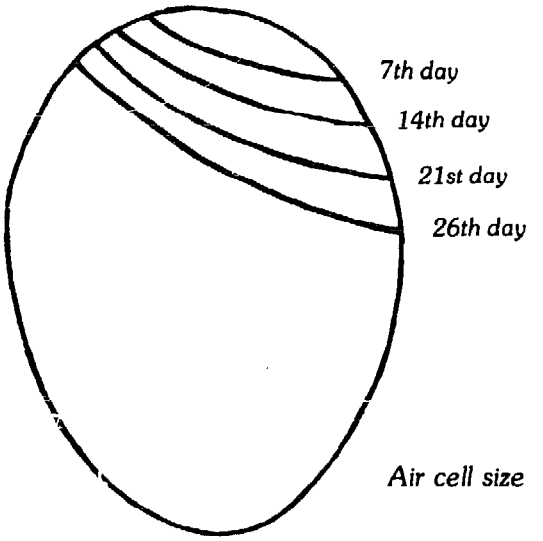

Humidity. To have a large number of strong ducklings hatch, the contents of the eggs must gradually dehydrate the correct amount. When dehydration is excessive, the embryos are puny and weak, making it extra tough for them to break out of the eggs. Conversely, inadequate moisture loss results in chubby embryos that have difficulty turning within the egg and cracking all the way around the shell.

The rate at which the contents of eggs dehydrate is regulated by the quantity of moisture in the air of the incubator. Moisture is usually supplied by water evaporation pans. To control humidity, the water surface area is increased or decreased, and the amount of ventilation regulated.

If your incubator is equipped with a wet-bulb thermometer or hygrometer, the correct reading on these instruments during the incubation period is 84° to 86° F., which is equal to a relative humidity of 55 percent. When eggs have been washed prior to incubation, the above figures may need to be raised to 88° to 90° F. on the wet-bulb thermometer or 65 percent on the hygrometer. Throughout the hatch (the last three days of incubation), the relative humidity should be increased to approximately 75 percent, or 92° to 94° F. on the wet-bulb thermometer.

While the hygrometer is a useful instrument for measuring the humidity level in incubators, the *best* indicator of whether the contents of the eggs are dehydrating at the correct rate is the size of their air cells. The air cell's volume can be observed by candling the eggs. On the seventh, fourteenth and twenty-first days of incubation, the average air cell volume should be approximately the same size as those in the accompanying illustration. If the air cells are too large, increase the moisture in the incubator by adding more water surface and/or decrease the amount of ventilation, being careful not to reduce the airflow so severely as to suffocate the embryos. If the air cells are too small, decrease the water surface area and/or increase the ventilation.

Due to variations in egg size and shell quality, the humidity requirements of duck eggs can vary considerably from one breed to another. Small eggs dehydrate faster than larger ones. When eggs from various breeds are incubated together, eggs from some breeds may dehydrate properly while others dry down excessively or not enough. In this situation, I have found it helpful if all the eggs from the breeds whose eggs dehydrate the slowest are washed prior to setting them, while the eggs from the breeds whose eggs dehydrate faster are not washed.

Ventilation. The developing embryo needs a constant supply of fresh air, which is provided through vent openings in the sides and tops of incubators. The amount of ventilation required is relatively small, but extremely essential to the well-being of the imprisoned ducklings. Ventilation demands increase at hatching time.

Turning. Incubating eggs must be turned to exercise the embryo and relieve stresses. Some eggs will hatch if you turn them just once every twenty-four hours, but turning three times daily at approximately eight-hour intervals is the *minimum* for high percentage hatches. For best results, duck eggs need to be rotated at regular hours and revolved at least one-third of the way around at each turning. Some studies indicate that turning eggs a full 180° improves hatchability. Eggs must be turned gently to avoid injury to the embryo. Turning should begin twenty-four to thirty-six hours after the eggs are set, and be discontinued three days before the scheduled hatch date.

When eggs are turned manually, it is helpful to mark them with an X and an O on opposite sides with a wax or lead pencil. Liquid inks—such as those in felt-tipped pens—should not be used, since they clog shell pores and can poison the embryos. After each turning, all eggs should have the same mark facing up.

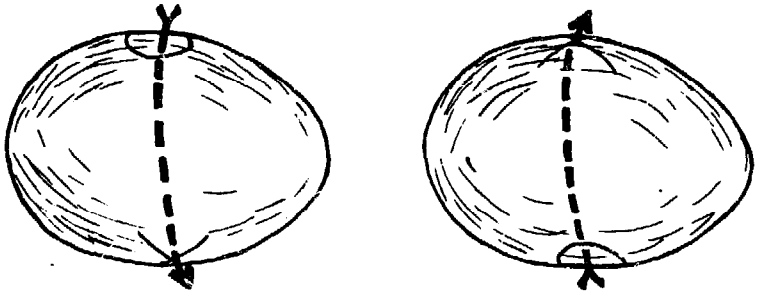

First turning is in this direction; next time, turn egg the opposite way.

Cooling. For best results when using still-air incubators, eggs should be cooled once daily—except during the first week and last three days of incubation. (Satisfactory hatches are obtained in forced-air machines without cooling.) When the room temperature is 65° to 70° F., the trays of eggs should be removed from the machine and cooled five minutes a day the second week, eight minutes daily the third week, and twelve minutes the first four days of the fourth week.

If you're like me, you will occasionally get sidetracked and forget the eggs as they cool. While they will hatch if left without heat for up to twelve hours once or twice during incubation (except during the first week and the last five days when low temperatures are disastrous), repeated over-cooling will retard growth and can be fatal. To avoid this problem, I borrow our kitchen timer and set it for the appropriate number of minutes at the beginning of each cooling period.

If you ever find that the temperature in the incubator is excessively high by more than 2° F., *immediately* cool the eggs for ten minutes and make adjustments to correct the problem.

Sprinkling. To prevent the egg membranes from drying out and becoming tough during the hatch, it is sometimes necessary to spray or sprinkle duck eggs with warm water forty-eight and again twenty-four hours before the calculated hatching time. While waterfowl breeders and incubator manufacturers frequently recommend that duck eggs also be wetted daily throughout the incubation period, good results can be obtained without this time-consuming chore if proper humidity levels are maintained throughout the incubation and hatching period. However, in tabletop incubators, the water evaporation pans often are so small that sufficient humidity cannot be maintained, and better hatching results in these machines are usually obtained when duck eggs are sprayed once daily from the 7th to 28th day of incubation. A convenient method is to use a discarded spray bottle that has been cleaned and filled with warm water.

Candling

The best time to candle duck eggs to check fertility is on the seventh day of incubation, unless they have dark-colored shells; then waiting until the tenth day is advantageous. If eggs are candled prematurely, it is more likely that fertile eggs will be accidently discarded.

Eggs are candled in a darkened room with an egg candler or flashlight. On the seventh day, fertile eggs reveal a small dark spot with a network of blood vessels branching out from it, closely resembling a spider in the center of its

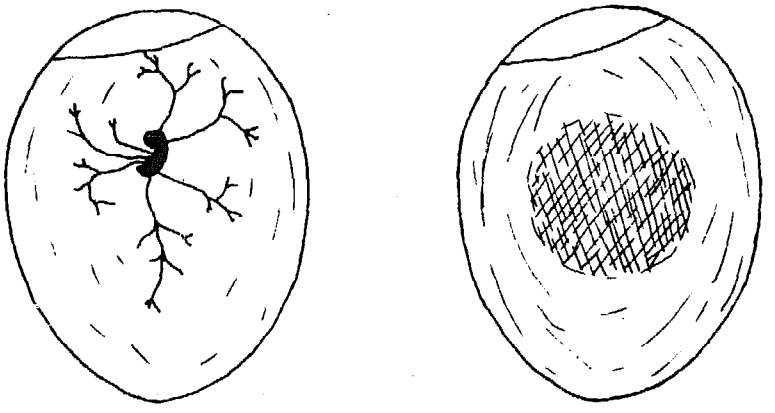

Fertile egg (left) and infertile egg (right) on the seventh day.

web. Infertile eggs are clear with the yolk appearing as a floating shadow when the egg is moved from side to side.

Sometimes embryos begin to develop, but perish within several days. When this happens, a streak or circle of blood is visible in an otherwise clear egg. Contaminated and rotten eggs often exhibit black spots on the inside of the shell, with darkened, cloudy areas floating in the egg's interior.

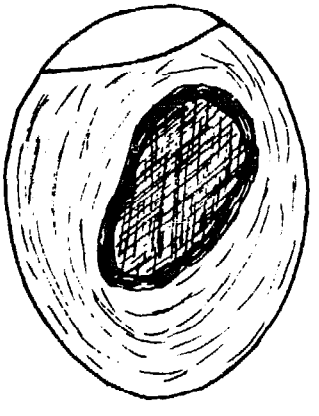

Blood ring—embryo has died.

All eggs not containing live embryos should be removed from the incubator when candled on the seventh or tenth day. Contaminated and rotting eggs give off harmful gases and frequently explode, covering the other eggs and the incubator's interior with putrid smelling goo that is difficult to clean up.

Uses for Infertile Eggs

Eggs that are infertile when candled on the seventh day of incubation are useful as a feed supplement for ducklings, adult poultry and other livestock such as pigs, cats and dogs. When fed to poultry or pets, eggs should *always* be hard-boiled and mixed with other feed. Feeding uncooked eggs can cause

a serious biotin deficiency or result in birds and animals robbing nests to satisfy their appetite for raw eggs.

Eggs that have cloudy contents or dark blotches on the interior of the shell due to contamination are not suitable for livestock food. Rotten eggs should be disposed of where animals and birds will not have access to them.

THE HATCH

All the time and effort invested in producing and incubating eggs is rewarded by the hatch. Those first muffled chirps of the ducklings are sweet music.

Normally the first eggs will be pipped forty-eight hours prior to the hatch date. Ducklings require twenty-four to forty-eight hours to completely rim the shell and exit. Newly hatched birds are wet and exhausted, and should remain in the incubator four to twelve hours while gaining strength and drying off.

If your incubator is equipped with adjustable air vents, they should be regulated to give hatching ducklings additional air. However, do not open them so wide that an excessive amount of warm air escapes and the humidity drops. During the hatch, you may find it necessary to place extra water containers in the machine to maintain an adequate level of humidity with the increased air circulation. Evaporation pans should be covered with screen or hardware cloth to make *certain* that the ducklings cannot drown.

After most of the ducklings are hatched, the relative humidity can be lowered to 50 percent (82° to 84° F. on the wet-bulb thermometer) so they will fluff out properly.

Removing Ducklings From the Incubator

When the ducklings are dry, it is time to remove them from the incubator. Before opening the machine, have a clean container—with sides no less than six inches high—prepared with soft bedding. While transferring the ducklings, work quickly and gently, discarding empty shells and pipped eggs containing birds that are obviously dead. During this operation, the room temperature should not be below 60° F. Any ducklings that are still wet can be left in the incubator for several additional hours.

Help-Outs

At the end of the hatch a number of live ducklings may be still imprisoned within partially opened shells. Most of us find it hard to ignore these and wish to help them out. Assistance can be given by carefully breaking away the shell just enough so that the duckling will be able to exit under its own power.

While some birds that are assisted from the shell develop into fine specimens, a large percentage of them are usually handicapped by a deformity or weakness. When it is understood that the hatch is a fitness test given by nature to cull out the weak and deformed—protecting them from facing a life for which they are unprepared—we can take a more realistic view of helping ducklings from the shell.

It is a good idea to mark all help-outs so they are not used as breeders unless they exhibit exceptional qualities as mature birds. Indiscriminate use of such ducklings for breeding can lower the vitality of subsequent generations. (See Marking Ducklings, page 88.)

Incubator Sanitation

While the incubator supplies the correct conditions for the embryo to develop, it also provides an excellent environment for the rapid growth of molds and bacteria. Consequently, it is essential that the incubator be kept as clean as possible.

At the conclusion of *each* hatch, clean and disinfect the incubator. If the eggs are set to hatch at various times, the water pans should be emptied, disinfected and returned with clean, warm water, and the duckling fuzz removed from the incubator with a damp cloth or vacuum cleaner.

At the end of the hatching season, thoroughly clean the incubator and store it in a dry, sanitary location.

FUMIGATION

On the average homestead, where relatively few eggs are set and hatched artificially each year, fumigation is normally not required for satisfactory hatching results. However, when eggs are set and hatched continuously over a period of time and the incubator cannot be thoroughly cleaned and disinfected between each hatch, the bacteria count within the machine will soar, resulting in reduced hatchability of the eggs and more deaths among the ducklings that do hatch. When continuous setting and hatching of eggs is practiced, a sound fumigation schedule will usually improve your results.

When to Fumigate

Table 8 gives a fumigation schedule. Of the five fumigations listed, numbers 1, 2 and 5 are usually sufficient. Number 1 is not as necessary if, promptly after they are gathered, eggs are washed with warm water to which a hatching disinfectant has been added.

TABLE 8
FUMIGATION SCHEDULE

Type of Fumigation	Amount of Fumigant per Cubic Ft. of Air Space		Length of Time Air Vents Should be Closed	Correct Conditions for Fumigation	
	Potassium-Permanganate	Formalin (37.5%)		Minimum Air Temp.	Minimum Humidity
1. Immediately after eggs are gathered and cleaned	0.6 grams	1.2 cc	20 minutes	70° F.	70%
2. Within 16 hours after eggs are set	0.4 grams	0.8 cc	20 minutes	99.5° F.	55%
3. 60 hours prior to end of incubation period	0.4 grams	0.8 cc	20 minutes	98° F.	65%
4. 30 hours prior to end of incubation period	none	0.5 cc	none	98° F.	65%
5. Empty incubators at beginning and end of season & between settings	0.6 grams	1.2 cc	3-12 hours	99° F.	55%

1. Fumigation number 1 should be carried out in a tight cabinet that has a fan for circulating the fumigation gas. Eggs should be placed on wire racks, in wire egg baskets or on clean egg flats. The sooner this fumigation takes place after the eggs are laid, the more effective it will be.

2. Fumigation number 2 takes place in the incubator within the first sixteen hours after the eggs are set, but not before the temperature and humidity have had a chance to normalize. Between the 24th and 120th hours of incubation, embryos go through a critical period. If eggs are exposed to formaldehyde gas during this time, the developing ducklings can be weakened or killed. However, when continuous setting is practiced in the same incubator, eggs can be fumigated several times during the course of the incubation period *if* they are not fumigated during this critical period.

3. When eggs are transferred to a separate machine for the hatch, fumigation number 3 can be employed to control outbreaks of omphalitis, a bacterial infection of the navel in newly hatched birds. To prevent damage to the lung tissue of the ducklings, fumigate *before* the eggs are pipped.

4. Fumigation number 4 is normally applied *only* when number 3 does not control omphalitis.

5. Prior to the first setting of the season, between hatches and at the end of the hatching season, fumigation number 5 should be used after incubators have been thoroughly washed and disinfected.

To be effective, a fumigation schedule should be designed and followed. Haphazard fumigating is of little value and is a waste of time and money. Under no circumstances should fumigation replace other sanitation procedures.

Procedures

The fumigation agent is formaldehyde gas which is produced by pouring liquid formalin over dry potassium-permanganate crystals. While formaldehyde gas is highly toxic, fumigation will destroy harmful bacteria and disease organisms without harming the eggs, the incubator or you, the operator, if the correct procedures are followed.

Step 1. Calculate the airspace within your incubator by multiplying the width times the depth times the height.

Step 2. Close all ventilation openings.

Step 3. Warm up incubator until it is operating at normal temperature and humidity levels for incubation.

Step 4. Measure out the correct quantity of potassium-permanganate into a dry earthenware, enamelware or glass container—*never* use metallic receptacles—having a capacity at least ten times the total volume of the ingredients, and place it in the incubator.

Step 5. Without leaning over the container, pour the correct amount of formalin over the potassium-permanganate and quickly shut the incubator door. The chemical reaction of these two substances begins within seconds. To prevent damage to your mucous membranes or burns on your skin, *never* combine these chemicals outside of the incubator or while holding the mixing vessel.

CAUTION

Formaldehyde gas is toxic to small and large organisms alike. When fumigating, follow instructions carefully and do not take chances that endanger your health.

Step 6. After the correct allotment of time, open the air vents to exhaust the formaldehyde gas. Thirty minutes to several hours after, remove the fumigation container and dispose of the residue in a safe location where children or animals cannot get into it.

If ducklings are fumigated thirty hours before the end of the incubation period (fumigation 4 in Table 8), no potassium-permanganate is used. Rather, sufficient cheesecloth is used to absorb the formalin and then hung in the incubator, allowing time for total evaporation. Position the cloth so that it *does not* touch the eggs or restrict air circulation.

INCUBATION CHECKLIST

1. Provide adequate nests furnished with clean nesting material.
2. Gather eggs in morning to protect them from temperature extremes.
3. Handle eggs with clean hands or gloves and avoid shaking, jolting or rolling them.
4. Store eggs in clean containers in a cool, humid location, and turn them daily if held longer than five days.
5. Set only reasonably clean eggs with strong shells.
6. Start incubator well in advance of using. Make adjustments of temperature, humidity and ventilation before eggs are set.
7. When filling the incubator, position eggs with their air cells slightly raised, and do not crowd eggs on tray.
8. Try not to disturb eggs during the first twenty-four hours they are in the incubator.
9. Gently turn eggs at least three times daily at regular intervals from the second to twenth-fifth day (second to thirty-second for Muscovies).
10. Operate still-air incubators at 101.5° to 103° F., and forced-air machines at 99.5° to 99.75° F. during the incubation period.
11. Maintain relative humidity at 55 percent (a wet-bulb reading of 84° to 86° F.) for first twenty-five days (thirty-two for Muscovies) of incubation.
12. When using a still-air machine, cool eggs five minutes a day the second week, eight minutes daily the third week, and twelve minutes the first four days of the fourth week.

TABLE 9: PINPOINTING INCUBATION PROBLEMS

Symptoms	*Common Causes*	*Remedies*
More than 10 or 15 percent clear eggs when candled on seventh day of incubation	1) Too few or too many drakes 2) Old, crippled or fat breeders 3) Immature breeders 4) Breeders frequently disturbed 5) No swimming water for mating 6) First eggs of the season 7) Late season eggs 8) Medication in feed or water 9) Eggs stored more than ten days	1) Correct drake to hen ratio 2) Young, active, semi-fat breeders 3) Use breeders seven months or older 4) Work calmly around breeders 5) Swimming water for large breeds 6) Don't set eggs laid first week 7) Don't set eggs when males molt 8) Avoid medicating breeders 9) Set fresher eggs
Blood rings on seventh to tenth day	1) Faulty storage of eggs 2) Irregular incubation temperature	1) Proper storage prior to setting 2) Adjust machine ahead of time.
Ruptured air cell	1) Rough handling or a deformity	1) Handle and turn eggs gently
Yolk stuck to shell interior	1) Old eggs which haven't been turned regularly during storage	1) Turn eggs daily if they are held for more than five days
Dark blotches on shell interior	1) Dirt or bacteria on shells causing contamination of the inner egg	1) Wash eggs soon after gathering with water and disinfectant
More than 5 percent dead embryos between seventh and twenty-fifth day of incubation	1) Inadequate breeder diet 2) Highly inbred breeding stock 3) Incorrect incubation temperature 4) Periods of low or high temperature 5) Faulty turning during incubation	1) Supply balanced diet 2) Introduce new birds to flock 3) Check accuracy and position of thermometer 4) Check temperature frequently; don't overcool eggs 5) Turn at least three times daily
Early hatches	1) High incubation temperature	1) Lower incubation temperature
Late hatches	1) Low incubation temperature	1) Raise incubation temperature
Eggs pip but do not hatch; many fully developed ducklings dead in shells that aren't pipped	1) High humidity during incubation 2) Low humidity during incubation 3) Eggs chilled or overheated during last five days of incubation 4) Low humidity during the hatch causing egg membrane to dry out 5) Poor ventilation during hatch 6) Disturbances during hatch	1) Decrease amount of moisture 2) Increase amount of moisture 3) Protect eggs from temperature extremes during this period 4) Last three days, raise humidity to 75% and sprinkle eggs daily 5) Increase air-flow during hatch 6) Leave incubator closed
Eggs pipped in small end	1) Eggs incubated in wrong position	1) Position eggs with small end lower than the large end
Sticky ducklings	1) Probably low humidity during incubation and/or hatch	1) Increase amount of moisture
Large, protruding navels	1) High temperature 2) Excessive dehydration of eggs 3) Bacteria infection	1) Lower temperature; check thermometer 2) Increase humidity level 3) Improve sanitation practices
Dead ducklings in incubator	1) Suffocation or overheating	1) Increase ventilation during the hatch and watch temperature carefully
Spraddled legs	1) Smooth incubator trays	1) Cover trays with hardware cloth
More than 5 percent cripples other than spraddled legs	1) Inadequate turning during incubation 2) Prolonged periods of cooling 3) Inherited defects	1) Turn eggs a minimum of three times daily 2) Don't forget eggs when cooling 3) Select breeders free of defects

13. Lower the incubator temperature 1° to 1.5° F. for the hatch.
14. Increase the relative humidity to 75 percent (a wet-bulb reading of 90° to 94° F.) for the hatch.
15. Sprinkle eggs with lukewarm water forty-eight and twenty-four hours prior to the scheduled hatch date.
16. Do not open incubator except when necessary during the hatch.
17. Leave ducklings in machine until they are dried.
18. Clean and disinfect incubator after each hatch.

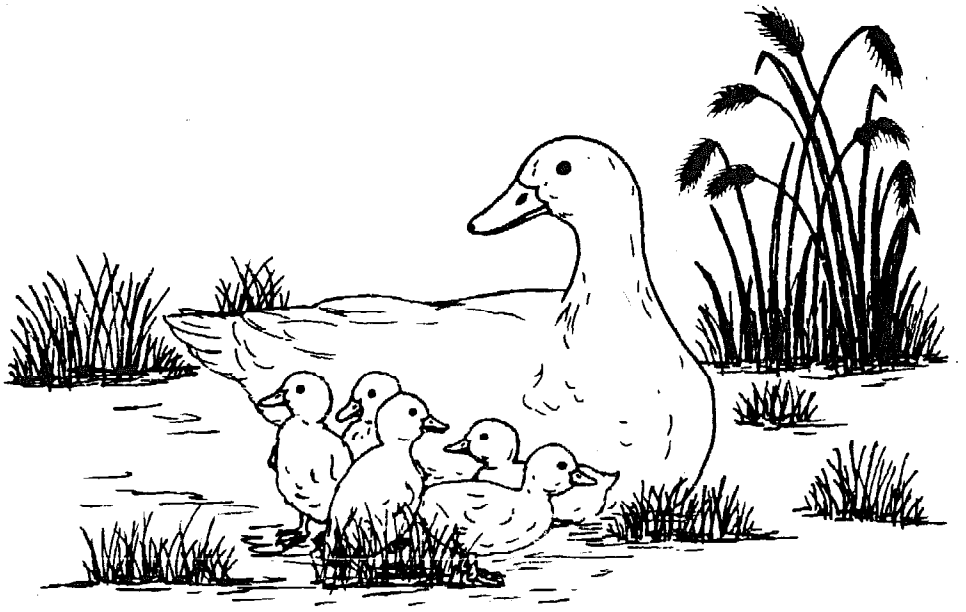

CHAPTER 8

Rearing Ducklings

The downy young of all types of poultry are charming, and day-old ducklings are no exception with their bright eyes, tiny wings and miniature webbed feet. Aided by shovel-like bills, they are soon eating an amazing quantity of food, all the while growing at an equally astounding rate. In only eight to twelve weeks, a newly hatched duckling is transformed into an adult duck.

BASIC GUIDELINES

Of all domestic fowl, the young of ducks are the easiest to raise. It is common for every duckling in a brood to be reared to adulthood without a single mortality. They withstand less than optimum conditions well—although that is no reason to mistreat or neglect them. If you put into practice the following management guidelines, raising ducklings will be a pleasant and trouble-free task.

Keep them warm and dry and protect them from drafts. Ducklings that are cold lose their appetites, and when wet, they chill rapidly and will die if not dried and warmed promptly. Drinking water containers should be designed so that ducklings cannot enter and become excessively wet.

Maintain them on dry bedding that provides good footing. Many internal parasites, molds and disease organisms thrive in damp and filthy bedding. Smooth, slick floors are the leading cause of spraddled legs.

Supply fresh, nonmedicated feed that provides a balanced diet. A proper diet is essential for disease resistance and fast growth. Feed that is moldy or contains medication can cause stunted growth, sickness and death. (See Medication Poisoning, page 126.)

Provide a constant supply of fresh water. Ducklings suffer a great deal when drinking water is not available, particularly right after they have eaten.

Furnish adequate floor space and fresh air. Forcing ducklings to live in crowded conditions is one of the leading causes of feather eating and disease.

Protect them from predators. Tame and wild predatory animals and birds find unprotected ducklings easy prey. The clumsy feet of humans and large animals also snuff out the lives of many young birds.

NATURAL BROODING

For the home poultry flock, natural brooding has many advantages. It eliminates purchasing or constructing special brooding equipment and supplying artificial heat. When allowed to range, hen-mothered ducklings learn to forage for their food at a young age, and will be nearly self-sufficient if there is a plentiful supply of insects, tender grass and wild seeds and fruits. Ducklings can be brooded by duck, turkey, bantam or large chicken hens.

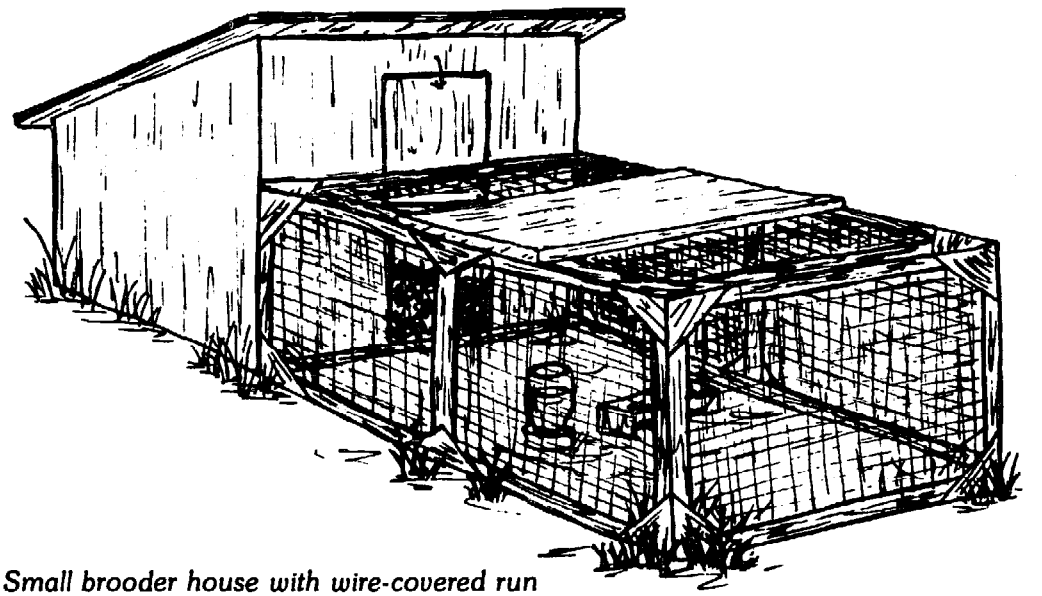

Small brooder house with wire-covered run

A day-old Mallard exhibiting the bold black and yellow markings that are typical of all gray varieties of ducklings.

By two weeks of age, the down color has faded and feathers can be felt protruding from her tail and sides.

Managing the Hen and Her Brood

The best management practice in dealing with a hen and her brood of ducklings is to bother them as *little* as possible. Your main concern is to protect them from predators and to keep the ducklings from becoming soaked during their first several weeks of life outside the shell.

Free-roaming turkeys and chickens often leave ducklings stranded, so it is a good idea to pen these foster hens with their broods in a dry building or pen for the first two weeks. There the entire family will be protected from rain, cold winds, predators and rodents, and concentrated feed can be supplied to help them get off to a fast start.

The same procedures are recommended for duck hens and their broods, although it is normally safe to give them freedom in a large pen not occupied by other fowl after the ducklings are several days old. Duck hens are not as likely to jump or fly over barriers such as fences and leave the little ones behind.

Confine hens and their broods in a secure pen or building each night until

At four weeks, feathers cover the face, shoulders, underbody and tail, and have begun to appear on her back.

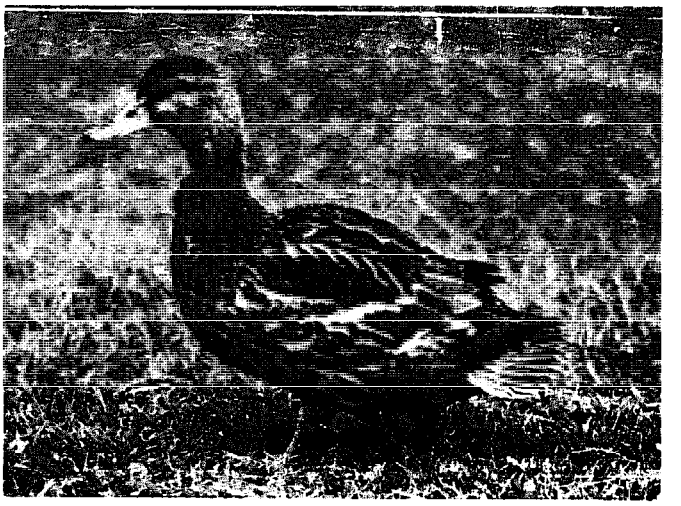

Now eight weeks old, the once soft, cuddly duckling is fully feathered and nearly the size of her parents.

the ducklings are six to eight weeks old. This significantly reduces the possibility of losses to predators.

Hens can be aggressive towards strange ducklings and may injure or kill them. Don't confine two or more hens together with their broods, particularly during the first week or two.

Allowing a new brood in with an established flock can also be dangerous for the young ones, especially when ducks are penned in close confinement and the strange ducklings may threaten the territorial boundaries of the adults. If your flock of ducks is permitted to roam freely, ducklings may not be bothered. In any case, newly hatched ducklings should be allowed with adult birds *only* if you can be on hand to remove them if a problem develops.

Giving Hens Foster Ducklings

Sometimes it is desirable to give hens foster ducklings to brood. If a hen already has young, the foster ducklings should be approximately the same size

and color as her own. Hens who set, but for one reason or another do not hatch any ducklings—or chicks in the case of a chicken hen—often will accept a foster brood. Giving ducklings to a chicken hen that has chicks of her own usually does not work out, but it can be attempted in an emergency situation. To lessen the possibility of rejection, it is advisable to slip foster ducklings under their new mother after dark.

Novice duck raisers sometimes lock a hen (which has been setting for a short time, or not at all) in a pen with ducklings and expect her to mother them. Almost without exception these attempts fail and frequently result in ducklings being brutally attacked. Unless an exceptional hen is discovered, it is not wise to give foster ducklings to hens that have not set their full term.

The number of ducklings a hen can brood depends on her size and the weather conditions. Typically, a duck hen can successfully brood eight to twelve of her own young. Bantam hens can handle six to eight ducklings, large chickens twelve to eighteen, and turkey hens up to twenty-five. The most important factor is that all the ducklings can be hovered and warmed at the same time.

Excellent natural mothers, Muscovy ducks normally bring off large broods.

ARTIFICIAL BROODING

If a broody hen is not available or you are raising a large number of birds, it will be necessary to brood ducklings artificially. When sound management practices are used, this method produces good results.

The Brooder

Brooders provide warmth for the ducklings during the first four to six weeks after they hatch. Brooding equipment can be purchased from stores handling poultry supplies or can be fabricated at home with a minimum of skill and cost.

Battery brooder. This brooder is an all-metal cage which is equipped with a wire floor, removable dropping pan, thermostat, electric heating element, and feed and water troughs. They can be purchased and used in individual units or stacked on top of one another. Battery brooders are commonly used for starting chicks, but can also be used for brooding ducklings up to an age of two to six weeks, depending on the breed. While new units are expensive, this type of brooder requires limited floor space, is easily cleaned, protects young birds from predators and provides sanitary conditions.

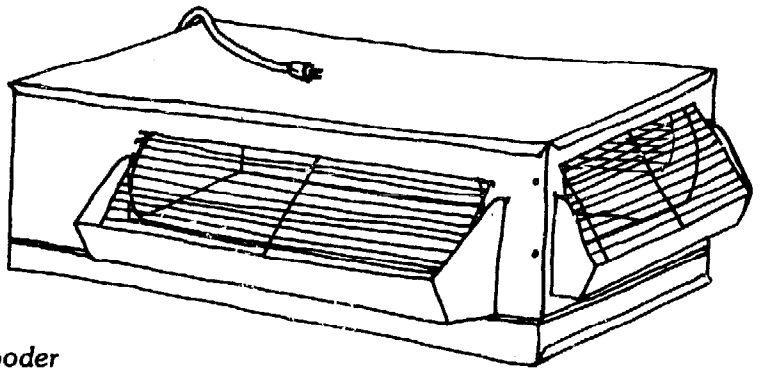

Battery brooder

Hover brooder. Available with gas, oil or electric heat, this brooder consists of a thermostatically controlled heater which is covered with a canopy. The brooder is supported with adjustable legs or suspended from the ceiling with a rope and is easily set to the proper height as the birds grow. Water fountains and feeders are placed around the outside of the canopy where the ducklings drink, eat and exercise in cooler temperatures. Hover brooders are available in sizes which are rated at 100 to 1000 chick capacity. The number

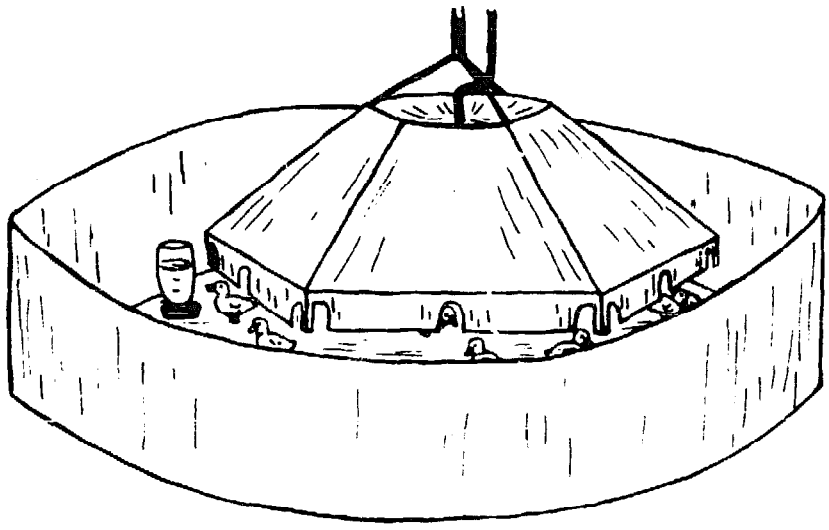

Hover brooder and draft guard

of ducklings under each unit should be limited to 50 to 60 percent of the given capacity for chicks.

Heat lamp. A simple method for brooding ducklings is with 250-watt heat lamps. Suspended eighteen to twenty-four inches above the litter, each lamp will provide adequate heat for twenty to forty ducklings, depending upon the size of birds and the outside temperature. We always use at least two lamps just in case one burns out.

When heat lamps are used, *extreme care* must be taken to prevent fires. These lamps must *never* be hung with the bottom of the bulb closer than eighteen inches from the litter, or so that any part of the bulb is near flammable material such as wood or cardboard.

Homemade brooder. A few ducklings can be brooded with a light bulb that is positioned in a box or wire cage. Recent research indicates that blue bulbs are best since they reduce the incidence of feather eating and are gentler on the ducklings' eyes.

The wattage required depends on the size of the box and the room temperature. I prefer to use several forty-watt bulbs rather than a single larger one. The box or cage must be big enough to allow ducklings to move away from the heat when they desire. When bulbs of over forty watts are used, they must be located out of the reach of ducklings. To prevent fires or the asphyxiation of ducklings from smoke produced by smoldering materials, even bulbs of low wattage *must not touch* or be close to flammable substances.

A light reflector and clamp make a safe and inexpensive "hover brooder." They are available at hardware stores and, while not used for brooding, come

in handy around the shop and house. The reflector can be clamped to the side of a cage or box and will brood up to a dozen ducklings. As the young ones grow, the heat source can be adjusted to the correct height.

A variety of homemade brooders with more permanent qualities can also be crafted. Hover-type brooders can be built with a plywood or sheet-metal canopy and porcelain light fixtures. Better still is the washtub brooder built and used by a retired coal miner friend of ours. He outfitted an old zinc washtub with several light fixtures and three adjustable legs. With just a little work and a lot of ingenuity, he had a safe brooder that gave dependable service for many years.

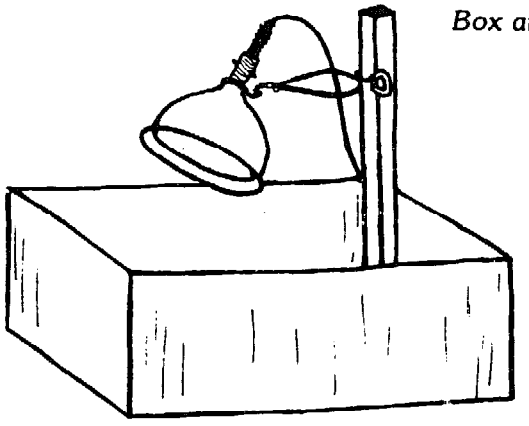

Box and reflector lamp

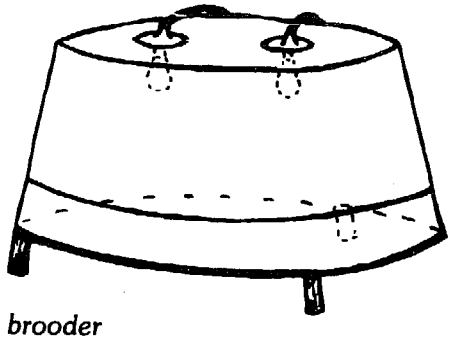

Homemade washtub brooder

Draft guard. The use of a draft guard around hover brooders and heat lamps is recommended for the first week or two. The guard protects ducklings from harmful drafts and prevents them from wandering too far from the heat and piling up in corners. Commercially produced guards constructed of corrugated cardboard can be purchased and used several times. Homemade guards can be fashioned with twelve-inch boards or welded wire that is covered with burlap or paper feed sacks. The guard should form a circle two or three feet from the outside edge of the hover brooder canopy.

Heat

Ducklings require less heat than chicks. Under the brooder the temperature should be held at approximately 90° F. the first seven days, and then lowered 5° each successive week. Once ducklings are six to eight weeks old and well-feathered, they can withstand temperatures down to 50° F. or lower, but must be protected from *drastic* temperature fluctuations.

The actions of the ducklings are a better guide to the correct temperature than a thermometer. If ducklings are noisy and huddle together under the heat source, they are cold and additional heat should be supplied. When they stay away from the heat, or pant, they are too warm and the temperature needs to be lowered. The proper amount of heat is being provided when ducklings sleep peacefully under the brooder or move about freely, eating and drinking.

Even at the start of the brooding period, it is *extremely* important that ducklings are able to get away from the heat source when they desire. Overheating is almost as damaging to ducklings as chilling.

Brooding Without Artificial Heat

If you're in an area not served by electricity or have chosen to live without it, you can still brood ducklings. One technique is to keep ducklings in a box near the stove or furnace until they are large enough to be put outside. If you use this method, be careful not to place the container too close to the heat, which could overheat the ducklings or, worse yet, start a fire.

Another procedure that works satisfactorily in mild weather is to utilize the body heat given off by the ducklings to warm themselves. A well-insulated box is the basic equipment needed. The floor of the container should be covered with two to four inches of dry bedding such as clean rags, chopped grass, straw or sawdust. If a fine bedding such as sawdust is used, cover it with cloth or burlap the first several days to prevent ducklings from harming themselves by eating the particles of wood.

The top and sides of the box must be draped with a layer of old towels, blankets, or burlap bags. Be sure that the little ones have sufficient air to prevent suffocation. Since heat rises, the ducklings will stay warmer if the "hot box" you design has a maximum of six inches of headroom after the bedding is in place. Also keep in mind that the smaller the inside area is, the cozier the occupants will be.

A small door should be made in the side of the brooder box where the ducklings can exit to eat and drink. They soon learn to go back inside when they're chilly, although you'll probably need to give them a helping hand the first day or two.

FLOOR SPACE

When ducklings are started on litter, allow a minimum of .75 square feet of floor space per bird for the first two weeks, 1.75 square feet until four weeks of age, 2.75 square feet until six weeks, and 3 to 5 square feet per bird thereafter. At three to four weeks of age, give ducklings access to an outside

pen or yard during mild weather, allowing 10 square feet of space per bird. This additional space will help keep the inside bedding drier and reduce sanitation problems.

LITTER

Ducklings consume a huge volume of water so it is *exceedingly important* that a thick layer of absorbent, mold-free litter (or wire flooring) is used to keep the brooding area from becoming sloppy. Shavings, sawdust, peanut hulls, peat moss, crushed corncobs, flax or chopped straw can be used for bedding.

Begin with three to six inches and add new litter as required. Soggy and caked bedding should be removed whenever it appears and replaced with dry material. A daily stirring of litter is advantageous, particularly if the density of ducklings is high. In warm weather, flies will become a problem if the quality of the litter is allowed to deteriorate.

YARDS AND PASTURES

Ducklings can be given access to a yard or pasture as soon as they are comfortable outside. The exercise, fresh air and sunlight are beneficial to their health. They will also eat substantial quantities of tender grass which reduces their feed consumption and enriches their diets with vitamins and minerals. Ducklings *cannot* eat mature, dry or coarse grasses.

When allowed outside, ducklings should be put under cover each time it rains until they are five to six weeks old. After this age, a simple shelter is adequate protection.

WATER

Swimming Water

It is not necessary to have swimming water for ducklings, even though they thoroughly enjoy going for a paddle within hours after hatching. Even when ducklings are brooded by a duck hen, it is safest to keep them out of water until they are at least two weeks old.

To protect ducklings from drowning, all water containers which they can enter should have gently sloping sides with good footing to allow tired and wet swimmers to exit easily. If you supply swimming water in receptacles having steep or slick sides, an exit ramp *must* be provided if drowning losses are to be avoided. Drowning and becoming soaked and chilled while swimming are the leading causes of duckling mortalities in home duck flocks.

Aylesbury, Pekin, Rouen and White Call ducklings of various ages enjoying a small pond made by mortering together a row of cinder blocks across a creek on Boyd Smith's farm in Kunkletown, Pennsylvania.

Drinking Water

To thrive, ducklings must have a *constant* supply of drinking water. Drinking fountains should be designed so that young ducklings *cannot* get into the water. To lessen the possibility of ducklings choking to death, the water should be deep enough to allow them to submerge their bills and dislodge particles of food which frequently become stuck in their throats and nostrils.

Sufficient receptacles should be provided so their contents are not quickly exhausted and the ducklings left without water. Placing water containers on screen-covered platforms is a big help in keeping the watering area dry and sanitary. Waterers should be rinsed out daily.

NUTRITION

The importance of a *sound* feeding program cannot be overemphasized. Nutrition is probably the most neglected phase of management in many small home flocks. Nearly half of the small duck flocks I observe exhibit nutritional deficiencies that can be avoided if the following recommendations are implemented.

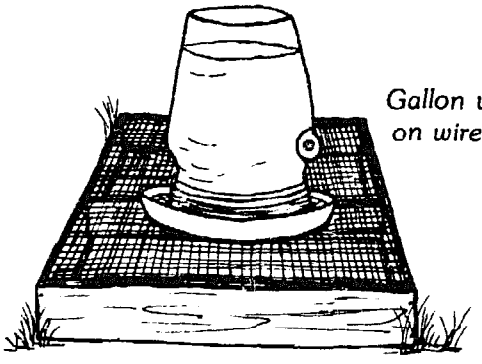

Gallon water fountain on wire-covered platform

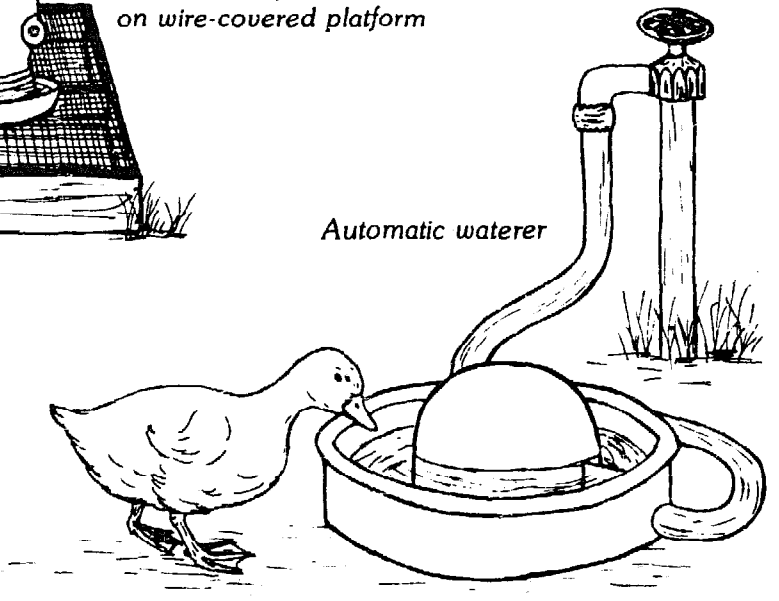

Automatic waterer

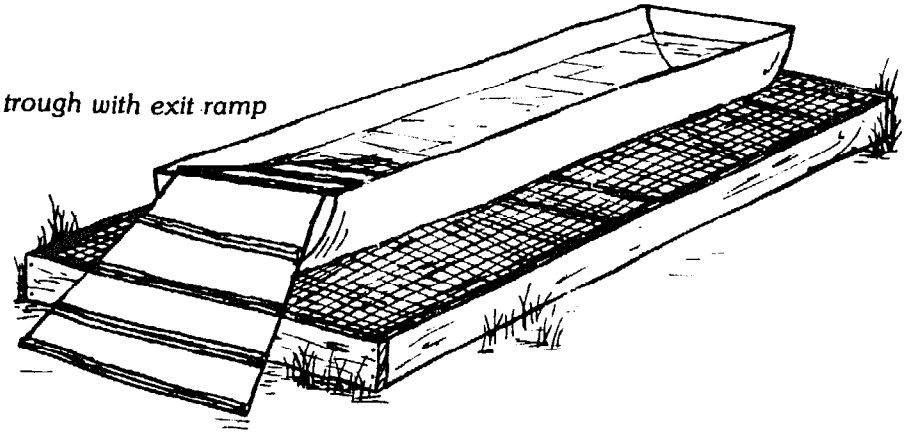

Water trough with exit ramp

The rate at which ducklings grow is in direct proportion to the *quantity* and *quality* of the feed they consume. For maximum growth they need a diet that provides 20 to 22 percent protein up to two weeks of age, and 16 to 18 percent protein from two to twelve weeks.

To stimulate fast growth, ducklings should be allowed to eat all the feed they want up to two weeks of age. After this time, you can limit them to two or three feedings daily, when they should be given all the feed they can clean up in five to ten minutes. When month-old ducklings have access to succulent pasture, they can be limited to one feeding daily. Giving the birds their meal in the evenings will encourage them to forage throughout the day.

For the first several weeks, small pelleted (3/32″) or coarse crumbled feed is preferred; thereafter, larger pellets (3/16″) will give the best results. Duck-

lings choke on fine, powdery mash when fed dry and up to 25 percent of the feed is wasted. If used, finely ground feed is better utilized when it is moistened with water or milk to a consistency that will form a crumbly ball when compressed in your hand. A new batch should be mixed up at each feeding to avoid spoilage and food poisoning.

TABLE 10
SUGGESTED FEEDING SCHEDULE FOR DUCKLINGS

	0-2 Weeks	*2-7 Weeks*	*7-20 Weeks*
Type of Duckling	*Pounds of 20% Starter Feed per Bird Daily*	*Pounds of 18% Grower Feed per Bird Daily*	*Pounds of 16% Developer Feed per Bird Daily*
"Green"	Free choice	Free choice	
Small Breed	Free choice	Free choice 5 min. twice daily	0.15-0.25
Egg Breed	Free choice	Same as above	0.20-0.30
Medium Breed	Free choice	Same as above	0.25-0.35
Large Breed	Free choice	Same as above	0.30-0.40
Muscovy	Free choice	Same as above	0.20-0.40

The quantity of feed required by ducklings is highly dependent on the availability of natural foods, climatic conditions and the quality of feed (e.g., birds require larger amounts of high fiber foods than low fiber foods to meet their energy requirements).

Feeding Programs

The feed program you employ should be designed to fit your situation and goals, and most likely will be a combination of two or more of the following options.

Natural. Ducklings, particularly Muscovies and Mallards, which are brooded by their natural mothers, are capable of foraging for most of their own ration if there is an abundant supply of insects, wild seeds and succulent plants. Ponds, lakes, sloughs, marshes and slow-moving brooks are excellent sources of free food for ducklings. In most situations it is advisable to supply ducklings concentrated feed for at least the first ten to fourteen days to get them off to a good start.

Grains. Small whole grains such as wheat, milo, kafir or cracked corn can be fed to ducklings after they are several weeks old. Grains by themselves are *not* a balanced diet. Ducklings need tender greens and an abundant supply of insects or another protein supplement. They cannot be expected to remain healthy and grow well on a diet consisting exclusively of whole, cracked or rolled grains.

Home Mixed. It may be practical to mix your ducks' feed if the various ingredients are available at a reasonable price. The formulas given in Tables 11 and 12 are examples of the types of feed that can be mixed at home. While these rations are not as sophisticated as commercially prepared feeds, they will give good results in most situations *if* they are mixed properly and the instructions are closely followed. If a vitamin:mineral premix (carried by many feedstores) is used, the rations in Table 13 can also be home-blended. For instructions on how to formulate rations using locally available foodstuffs, see Appendix A, page 135.

Special equipment is not needed to mix duck feed. For small quantities the ingredients can be placed in a large tub and combined with the hands or a stick. Another method is to pile the measured components in layers on a clean floor and mix with a shovel. A cement mixer or old barrel mounted on a stand and outfitted with a handle, door and ball bearings can be used for larger quantities. More important than the method used for mixing is that the ingredients are blended *thoroughly*. During warm weather, no more than a four-week (three weeks or less if ground grains are used) supply of feed should be prepared at a time.

TABLE 11
HOME-MIXED STARTING RATIONS (0 to 2 WEEKS)

Ingredient	*No. 1 Small Quantity*	*No. 2 Large Quantity*
Yellow commeal	11 cups	62 lbs.
Soybean meal (44% protein)	3½ cups	17 lbs.
Wheat bran	2 cups	2 lbs.
Meat and bone meal (50% protein)	½ cup	4 lbs.
Fish meal (60% protein)*	½ cup	2 lbs.
Alfalfa meal (17.5% protein)	½ cup	2 lbs.
Dried skim milk or calf manna	½ cup	3 lbs.
Brewer's dried yeast	1½ cups	7¼ lbs.
Dicalcium phosphate (18.5% P)	1 tbsp.	½ lb.
Iodized salt	1 tsp.	¼ lb.
Totals	20 cups	100 lbs.
Cod liver oil**		
Chopped succulent greens	Free choice	Free choice
Sand or chick-sized granite grit	Free choice	Free choice
Chick-sized oyster shells or crushed dried egg shells	Free choice	Free choice

* If fish meal isn't available, use 4½ cups soybean meal and 10½ cups cornmeal in formula #1, or 20 lbs. soybean meal and 61 lbs. cornmeal in formula #2.

** If birds do not receive direct sunlight, which enables them to synthesize vitamin D, sufficient cod liver oil must be added to these rations to provide 500 International Chick Units (ICU) of vitamin D_3 per pound of feed.

TABLE 12
HOME-MIXED GROWING RATIONS (2 to 12 WEEKS)

Ingredient	*No. 3 Corn Base (pounds)*	*No. 4 Wheat Base (pounds)*	*No. 5 Milo Base (pounds)*
Cracked yellow corn*	75.00	—	—
Whole soft wheat	—	79.00	—
Milo (grain sorghum)	—	—	76.00
Soybean meal (50% protein)	9.00	5.00	8.00
Meat and bone meal (50% protein)	4.00	4.00	4.00
Alfalfa meal (17.5% protein)	3.00	3.00	3.00
Dried skim milk	3.00	3.00	3.00
Brewer's dried yeast	5.00	5.00	5.00
Dicalcium phosphate (18.5% P)	0.10	0.10	0.10
Limestone flour or oyster shells	0.65	0.65	0.65
Iodized salt	0.25	0.25	0.25
Total (lbs.)	100.00	100.00	100.00
Cod liver oil**			
Sand or chick-sized granite grit	Free choice	Free choice	Free choice
Chopped succulent greens (eliminate when pasture is available)	Free choice	Free choice	Free choice

* Whole corn can be used after the birds are 4 to 6 weeks of age.
** See Table 11.

Commercial. In some localities premixed starter and grower feeds for ducklings are available. When these feeds are used, the instructions should be followed. If rations specifically formulated for ducklings are not available, use the corresponding nonmedicated mixes recommended for game birds, turkeys or chickens. The first two are preferred, but chicken feeds usually give satisfactory results if they are fortified with additional niacin.

You may want to have a local feed mill mix your feed if enough ducklings are raised to make it practical. The formulas given in Table 13 are for complete rations that will provide a balanced diet *if* mixed properly and not stored for more than four weeks (less in hot weather). Ration numbers 6, 7, and 8 are to be fed to ducklings up to two weeks of age, and numbers 9, 10 and 11 from two to twelve weeks.

Niacin Requirements

Young waterfowl require two or three times more niacin in their diet than chicks. (See Niacin Deficiency, page 126.) When ducklings are raised in confinement on a ration that is deficient in niacin—such as commercial chick feeds—a niacin supplement should be added to their feed or water.

TABLE 13
COMPLETE RATIONS FOR DUCKLINGS (PELLETED)

Ingredient	*No. 6 Corn Base Starter (lbs/ton)*	*No. 7 Wheat Base Starter (lbs/ton)*	*No. 8 Milo Base Starter (lbs/ton)*	*No. 9 Corn* Base Grower (lbs/ton)*	*No. 10 Wheat* Base Grower (lbs/ton)*	*No. 11 Milo* Base Grower (lbs/ton)*
Ground yellow corn	1385	—	—	1570	—	—
Ground soft wheat	—	1425	—	—	1607	—
Ground milo (grain sorghum)	—	—	1377	—	—	1575
Soybean meal solv. (50% protein)	430	360	425	295	270	330
Fish meal (60% protein)	40**	40**	40**	—	—	—
Meat and bone meal (50% protein)	80	80	80	80	40	40
DL-Methionine (98%)	2.00	2.75	3.25	1.50	2.00	2.50
Stabilized animal fat	25	40	30	—	20	—
Soybean oil	—	14	5	—	10	—
Dicalcium phosphate (18.5% P)	6.25	5.25	6.25	8.00	17.00	18.00
Limestone flour (38% Ca)	6.00	7.00	7.75	20.00	9.00	9.50
Iodized salt	5.75	6.00	5.75	5.50	5.00	5.00
Vitamin:mineral prefix	20	20	20	20	20	20
Totals (lbs.)	2000	2000	2000	2000	2000	2000
Vitamin:Mineral Premix						
Vit. A (millions of IU/ton)	8.0	9.5	9.5	5.0	6.5	6.5
Vit. D_3 (millions of ICU/ton)	1.0	1.0	1.0	.8	.8	.8
Vit. E (thousands of IU/ton)	5.0	15.0	15.0	2.0	12.0	12.0
Vit. K (gm/ton)	2.0	2.0	2.0	2.0	2.0	2.0
Riboflavin (gm/ton)	6.0	6.0	6.0	4.0	4.0	4.0
Vit. B_{12} (mg/ton)	8.0	8.0	8.0	4.0	4.0	4.0
Niacin (gm/ton)	50.0	50.0	50.0	40.0	40.0	40.0
d-Calcium pantothenate (gm/ton)	6.0	3.0	3.0	4.0	2.0	2.0
Choline chloride (gm/ton)	300.0	—	300.0	200.0	—	200.0
Folic acid (gm/ton)	.5	.5	.5	.5	.5	.5
Manganese sulfate (oz/ton)	9.6	9.6	9.6	9.6	9.6	9.6
Zinc oxide (80% Zn, oz/ton)	3.2	3.0	3.2	3.2	3.0	3.2
Ground grain to make 20 lbs.	+	+	+	+	+	+
Totals (lbs.)	20.0	20.0	20.0	20.0	20.0	20.0
Calculated Analysis						
Crude protein (%)	20.2	19.6	20.1	16.4	16.1	16.4
Lysine (%)	1.05	1.00	1.03	.76	.73	.75
Methionine (%)	.46	.44	.46	.37	.33	.35
Methionine + cystine (%)	.76	.76	.76	.62	.63	.61
Metabolizable energy (kcal/lb)	1424	1366	1416	1426	1362	1410
Calorie:protein ratio	70	70	70	87	85	86
Crude fat (%)	4.7	4.7	4.2	3.5	3.3	2.6
Crude fiber (%)	2.3	2.4	2.3	2.3	2.4	2.3
Calcium (%)	.76	.78	.80	.93	.63	.64
Available phosphorus (%)	.41	.41	.42	.36	.36	.37
Vit. A (IU/lb)	4912	4750	4750	3535	3250	3250
Vit. D_3 (ICU/lb)	500	500	500	400	400	400
Riboflavin (mg/lb)	3.73	3.76	3.76	2.64	2.66	2.66
Total niacin (mg/lb)	41	51	46	31	43	37

* To convert into breeder-developer rations, substitute the following quantities of vitamins for those listed under the vitamin:mineral premix: 1 gm of vit. K; 3 gms riboflavin; 30 gms niacin; and 100 gms choline chloride in the corn and milo base rations.

** If fish meal is not available, use an additional 50 lbs soybean meal solvent (50% protein) and subtract 10 lbs of grain.

KEY: IU = International Units; ICU = International Chick Units; gm = gram; mg = milligram; kcal = kilocalories

Niacin can be purchased in tablet form at drug stores, and is a common ingredient in poultry vitamin mixes. Adding 5 to 7.5 pounds of livestock grade brewer's yeast per 100 pounds of chicken feed (or two to three cups of yeast per ten pounds of feed) will also prevent a niacin deficiency in ducklings.

Green Feed

The daily feeding of leafy greens to ducklings fortifies their diets with essential vitamins and minerals, reduces feed consumption and lowers the possibility of cannibalism. Tender young grass (before it joints), lettuce, chard, endive, watercress and dandelion leaves are excellent green feeds.

Ducklings will eat their salad *only* if it is tender and fresh. When greens are placed on the floor of a brooder, they soon wilt and are trampled and soiled. By putting the chopped feed in the ducklings' water trough, it remains succulent and clean, and the ducklings spend many contented hours dabbling for the bits of greenery.

Grit

Coarse sand or small granite grit should be kept before ducklings at all times. Grit aids the gizzard in grinding, helping birds to get the most out of their feed.

Feeders

For the first day or two, feed should be placed in containers where the ducklings cannot help but find it. Jar lids, shallow cans and egg flats are excellent for this purpose. Once the ducklings have located their feed and are eating well, they should be fed in trough feeders to reduce wastage.

Feeders can be purchased or constructed at home out of scrap materials. Homemade troughs should be designed so they do not tip over as ducklings jockey for eating space. To keep birds out of the feeder, a spinner can be attached across the top.

Sufficient feeder space needs to be provided to insure that each duckling receives its share. When limiting feedings to one or two daily, supply adequate trough space so that each bird can eat without having to struggle for its portion of the meal. By filling troughs no more than *half full,* you can significantly reduce the amount of feed that is wasted.

Creep Feeding

When ducklings are brooded by hens and run with the flock, it is sometimes desirable to feed the young birds separately from the adult ducks. This is done

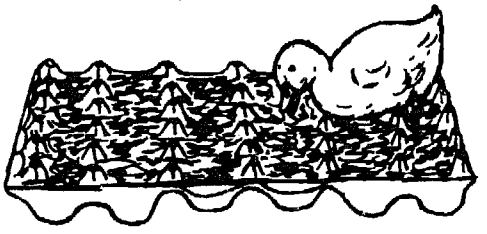

Egg flat feeder

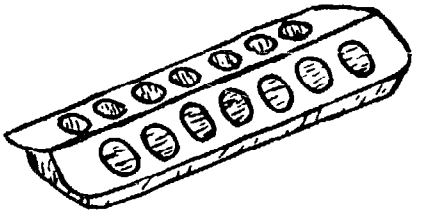

Covered feeder for small ducklings

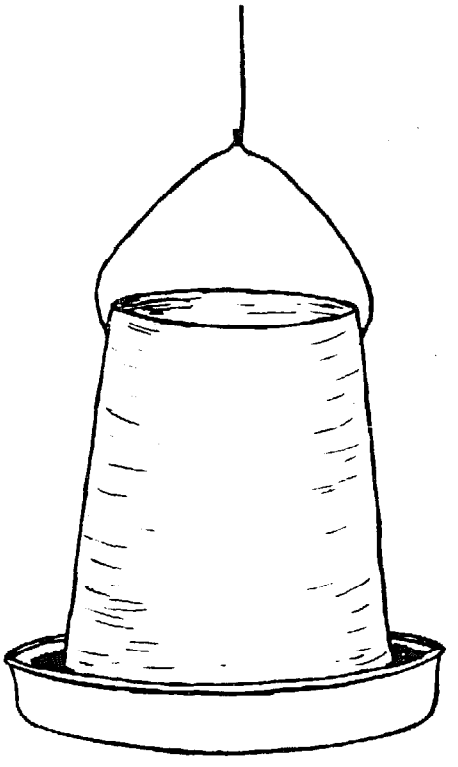

Hanging feeder for larger ducklings and adults

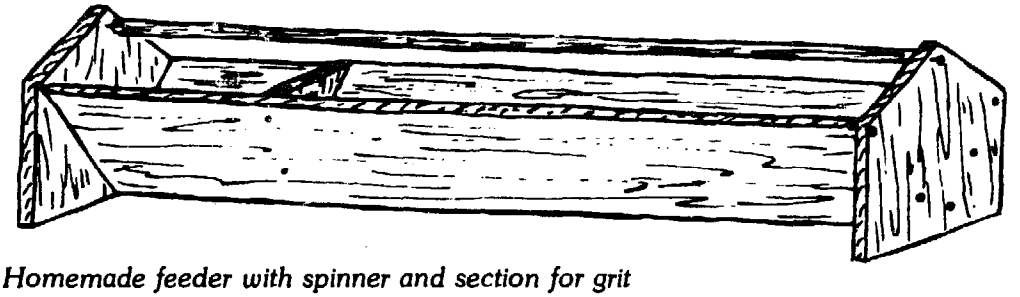

Homemade feeder with spinner and section for grit

by devising a creep feeder, where ducklings can eat without competing with grown birds.

The basic component of the creep feeder is a doorway large enough for only ducklings to pass through and gain access to the feed trough. The doorway panel can be placed across a corner of the duck yard or in the entrance of a shed.

Mature ducks can squeeze through smaller holes than is generally realized, and I have found that there is a tendency to make the slots too large. Dimensions for the portals will vary according to the breed raised, and you will probably need to do a little experimenting to find what size works best for your

ducks. However, as a general rule, a space four inches square is satisfactory when breeds weighing seven to nine pounds are kept. For smaller breeds, such as Mallards, the passageway needs to be approximately three inches square to keep the old birds from entering and chowing with the youngsters.

MANAGING "GREEN" DUCKLINGS

"Green" ducklings are the equivalent of broilers in chickens. These birds are managed to produce the quickest possible growth in the shortest period of time on the least quantity of feed. The breed best suited for this practice is the Pekin. With good management, they are capable of weighing seven pounds at seven weeks of age on approximately twenty pounds of feed.

To stimulate fast growth, "green" ducklings must have limited exercise, a continuous supply of high-energy, concentrated feed, and twenty-four hours of light daily. They are ready to be butchered as soon as their primary wing feathers are developed. If held beyond seven or eight weeks, their feed conversion decreases *rapidly* (see Table 14) and they'll commence to molt, making it hard to pick them until they are fourteen to sixteen weeks of age.

PRODUCING LEAN DUCKLINGS FOR MEAT

The major drawback of raising ducks for meat is the high fat content of their carcasses. While many people enjoy the succulency of quick-grown duckling meat, recent medical research strongly indicates that many of us need to reduce the amount of fat in our diets. There are several management practices that can be used to produce leaner ducklings.

One method is to use a high protein grower ration that contains an energy:protein ratio of 65:1 or less (see Appendix A, page 135). While ducklings fed such rations do not gain *weight* as rapidly as birds given feed with a wider energy:protein ratio (88:1 is normally recommended), the actual amount of *meat* will be almost identical.

A second method, which is more effective and practical for the small flock owner, is to raise a breed other than Aylesbury or Pekin; Muscovies, Mallards, Indian Runners and Campbells are generally considered the leanest. Then, rather than pushing ducklings for the fastest possible growth, they should be allowed to forage for a portion of their food. The birds should be given just enough feed to keep them healthy and growing well. When butchered at twelve to twenty weeks of age, the fat content of birds raised in this manner is similar to that of wild ducks (see Table 6, page 11). In a trial involv-

TABLE 14
TYPICAL GROWTH RATE, FEED CONSUMPTION AND FEED CONVERSION OF PEKIN DUCKLINGS RAISED IN SMALL FLOCKS

Treatment	*Age (weeks)*	*Live Weight (pounds)*	*Feed per Bird (pounds)*	*Feed per lb. of Bird (pounds)*
Fed free choice on a 20% protein, 1400 kcal/lb ration from 0 to 2 weeks; then fed 16% protein, 1400 kcal/lb ration from 3 to 12 weeks. Exposed to 24 hours of light daily and raised in confinement.	5	5.07	10.85	2.14
	6	6.10	14.52	2.38
	7	6.85	18.43	2.69
	8	7.43	22.36	3.01
	9	7.87	26.52	3.37
	10	8.36	31.43	3.76
	11	8.58	36.47	4.25
	12	8.43	40.55	4.81

ing thirty Rouen drakes from a production-bred strain, we found that when this method was employed, even these large meat birds produced carcasses that were no more fatty than roasting chickens.

SEXING DUCKLINGS

Over the years, I have been told many secret methods for sexing day-old ducklings. However, when tested, many of these techniques have proven to be only 50 percent accurate at best. To my knowledge, the following methods are the most trustworthy procedures for sexing live ducklings.

Vent Sexing

The *only* sure way to sex ducklings of all breeds before they are six to eight weeks old is by examining the cloaca. While it is much easier to vent sex waterfowl than land fowl, this procedure still requires practice, an understanding of the bird's physiology, and care to avoid permanent injury to the bird. Too often, persons attempt to sex ducklings without first acquiring the needed skills, injuring the birds or wrongly identifying the gender.

At best, a written account on sexing ducklings is a poor substitute for a live demonstration by an experienced sexer. I *highly recommend* that you have a knowledgeable waterfowl breeder show you how to vent sex ducks before trying it yourself.

While ducks of all ages can be sexed by this method, I suggest that novices practice on birds that are two to three weeks old. At this age, ducklings are

easily held and their sex organs are large enough to be readily identified. As birds reach maturity, the sphincter muscles which surround the vent become stronger, making it more difficult to expose the cloaca. Extremely young ducklings are usually harder for the beginner to hold for sexing, and the sex organs are tough to identify until a person knows what to look for. There are three points to keep in mind when vent sexing ducklings:

1. Young ducklings are *extremely* tender and clumsy fingers can kill the bird or permanently injure the sex organs.
2. A bird has not been sexed *until* the cloaca has been exposed. People often assume that if they can't find a penis after applying a little pressure to the sides of the vent, the bird is a hen. However, a duckling cannot be identified as a hen until the cloaca has been inverted and no penis is evident.
3. The sex organs of ducklings are tiny, so it is *essential* that birds be sexed outside on a sunny day or under a bright light.

After studying the accompanying illustrations, you should be able to sex ducklings if the following steps are carefully implemented. There are several methods for holding birds for sexing, but I'll describe only the way I find most comfortable.

Step 1. Hold the bird upside down with its head pointed toward you. If the duck is large, its neck and head can be held between your legs.

Step 2. Use the middle and/or index finger of your right hand to bend the tail to a position where it is almost touching the bird's back.

Step 3. Push the fuzz or feathers surrounding the vent out of the way so you can see what you are doing.

Step 4. Place your thumbs on either side of the vent and apply pressure down and slightly out.

Step 5. Use your index finger of the right hand to apply pressure down and out on the backside of the vent. This inverts the cloaca and exposes the sex organs.

If it's a drake. If the duckling you are sexing is a male, a corkscrew-shaped penis will pop up near the center of the cloaca. (You must look carefully, since sometimes only the tip of the penis will be visible.) In drakes only a few days old, the penis is extremely small and almost transparent. By the time

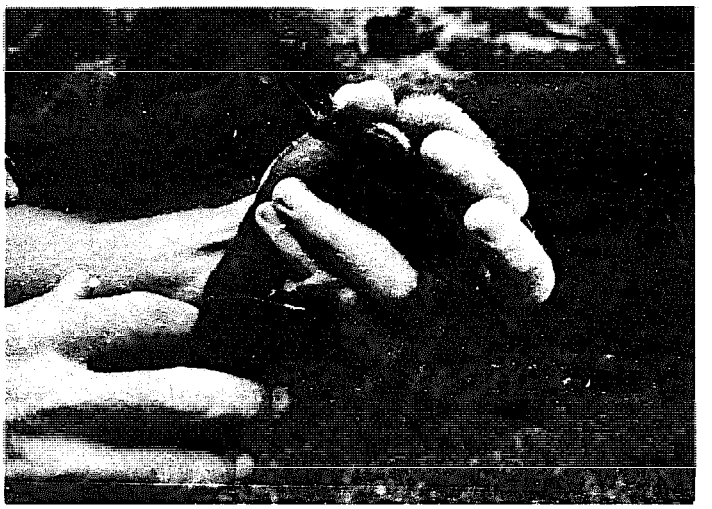

Vent Sexing
the Small Duckling

1. Vent sex young ducklings under good lighting. Hold the bird upside down with its head pointed toward you and double its tail back with an index finger.

2. With the legs out of the way, position your thumbs on opposite edges of vent and place free index finger just behind the vent. To invert the cloaca, simultaneously apply pressure down and out with thumbs and index finger.

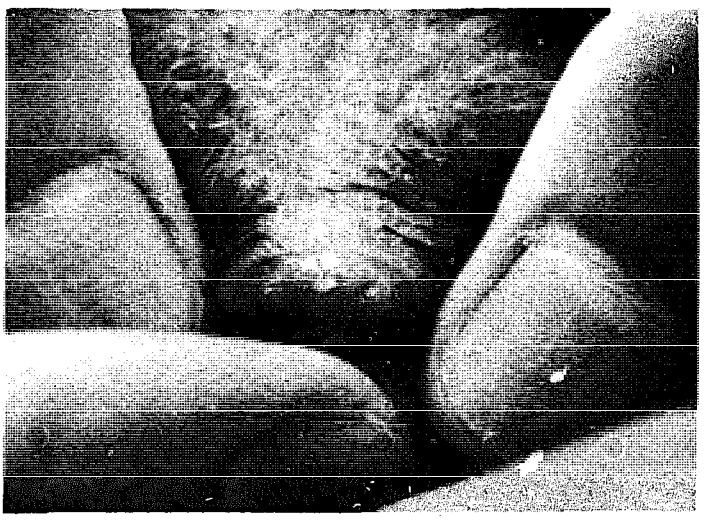

3. Almost transparent, the penis of a week-old drake is visible in the center of the inverted cloaca. A duckling cannot be identified as a hen until the cloaca is inverted as shown and no penis is present.

Vent Sexing the Older Bird

1. A convenient method for restraining large ducks for sexing is to turn the bird upside down and hold its neck between your legs.

2. After bending the tail back, push aside the feathers surrounding the vent, position your thumbs on the sides and your index finger on the back of the vent, and invert the cloaca by applying pressure down and out.

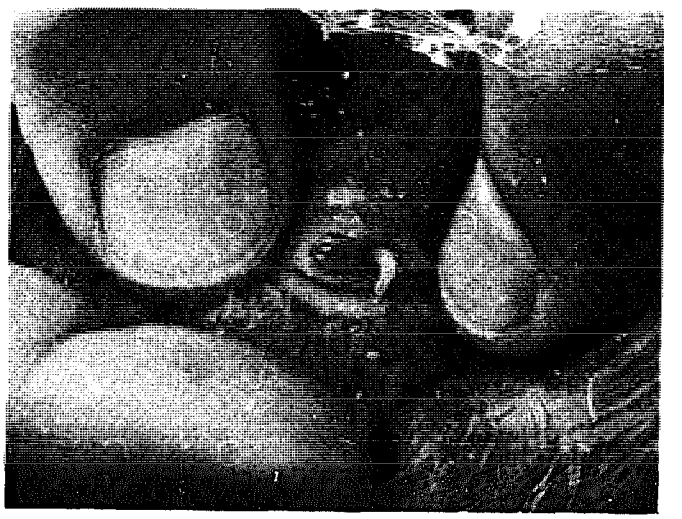

3. The cloaca and penis of an eight-week-old drake. If the cloaca is inverted sufficiently to expose the two dimples visible in this photo and still no penis is evident, it can be assumed that the bird is a hen.

males are a couple weeks of age, their sex organs are easier to see because of their larger size and deeper white or yellowish color.

If it's a hen. Should you have a hen, no penis will be visible when the cloaca is inverted. In hens that are more than several weeks old, the female genital eminence is often visible as a small, dark (usually gray) protuberance that resembles an undeveloped penis.

If you have difficulty. The most common problem encountered by unexperienced sexers is getting the cloaca inverted. If this is your problem, make sure that:

1. You have the bird's tail bent back double as in the illustration.
2. You are applying pressure down and out simultaneously with both your thumbs and the right hand index finger.

As with most skills, your speed and accuracy in sexing will improve with practice. If you get discouraged on your initial attempts, wait a few days until you have regained your confidence and then try again.

Sexing by Voice

By five to eight weeks of age, hens of most breeds can be distinguished by their voices. To sex birds by this method, catch each duckling individually, and as it protests its predicament, listen carefully for the hen's distinctive quack.

Sexing by Bill Color

It is possible to sex purebred ducklings of some varieties by their bill color as early as six weeks of age. In gray varieties such as Mallards and Rouens, the bill of a drake will normally turn dull green while that of a hen becomes dark brown and orange. The hen in most other colored varieties has a darker bill than the drake. This method cannot be used reliably on some crossbred ducklings since variation in bill color can be a sign of genetic differences rather than gender.

Sexing by Plumage

Drakes do not acquire their adult nuptial plumage until they are four to five months old. However, in many colored varieties, there are sufficient variations in the juvenile feathering of drakes and hens that it is possible to differentiate the sexes of ducklings that are five to eight weeks old. In gray varieties

such as Mallards and Rouens, the feathers of the crown of the head and back often are darker and have less brown penciling in drakes than in hens.

MARKING DUCKLINGS

It is sometimes desirable to mark certain birds so they can be easily distinguished from the rest of the flock. Several methods can be utilized, including the use of leg or wing bands, and the notching and perforating of the webbing between the duckling's toes. I prefer to use bands since they do not permanently disfigure the duck.

Bands and toe punches are available from poultry equipment suppliers and feed stores. When leg bands are applied, care must be taken to use rings that are large enough to permit *free* circulation of blood to the feet.

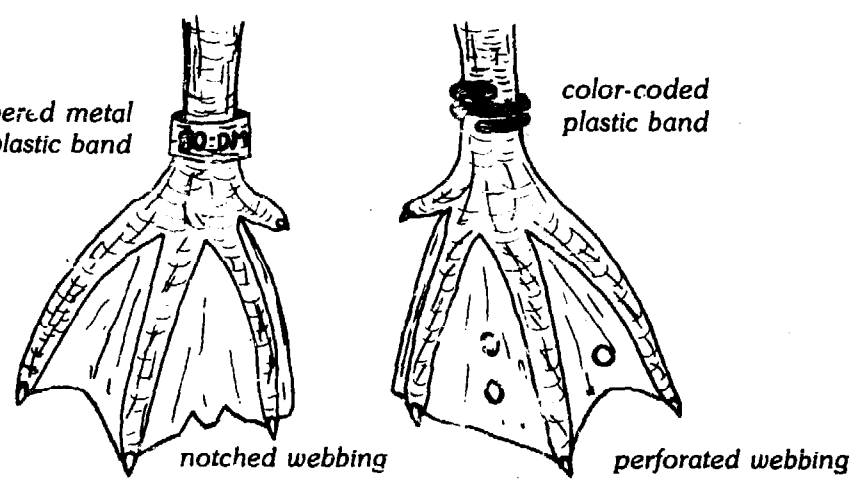

Marking birds for easy identification

REVIVING WATERLOGGED DUCKLINGS

If you raise ducks, there's a good chance that you'll have at least one case of ducklings becoming soaked. In this condition, the little ones chill and quickly lose mobility. However, they can often be revived if you take *immediate* action, even when there is scarcely any movement left in their bodies.

The first step is to rub down the waterlogged birds with a soft cloth. Then put them in a warm (90° to 95°F.) place such as under a brooder or heat lamp, being careful not to *overheat* them.

Once they are up and around, provide feed and lukewarm drinking water. Keep the ducklings isolated until you are sure they have regained sufficient strength to be returned to their broodmates.

BROODING DUCKLINGS WITH OTHER BIRDS

Many of us who have duck flocks also raise other poultry. Consequently sometimes we're brooding ducklings and other birds at the same time. To save space and equipment, it is tempting to brood the various species together.

However, the young of ducks, geese, quail, guineas, chickens and turkeys have unique habits, temperaments, growth rates and management requirements that can cause serious problems when birds are raised in mixed groups. While it is not impossible to brood ducklings with other young poultry—goslings and ducklings get along fairly well—many problems are avoided and each grows better if they are brooded separately.

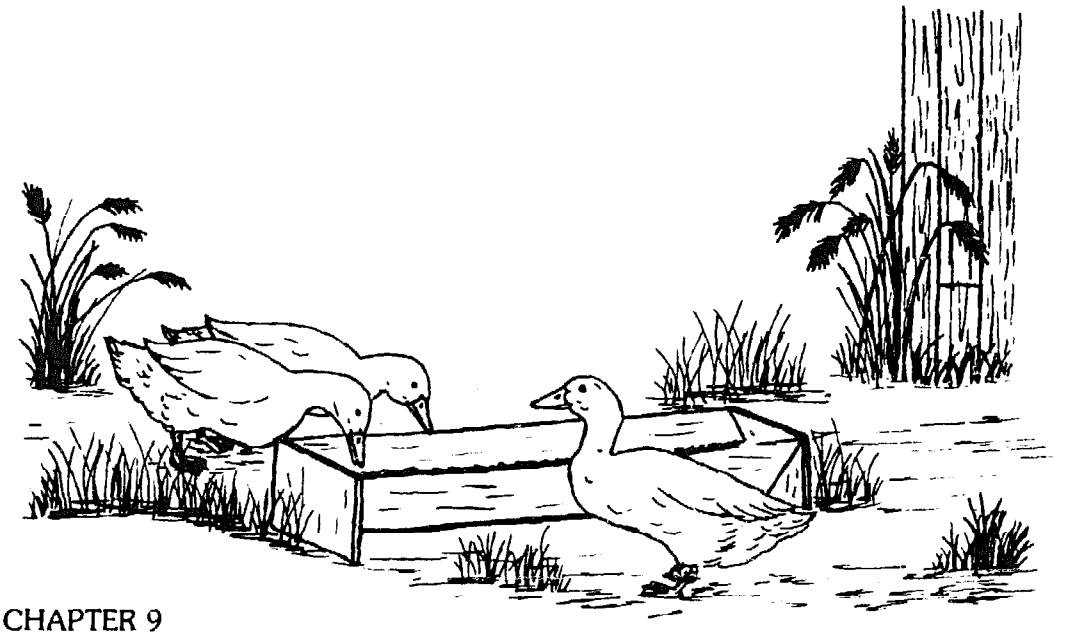

CHAPTER 9

Managing Adult Ducks

Adult ducks do not require a lot of time-consuming care or specialized facilities. By using common sense and being observant, novices can manage ducks successfully.

BASIC GUIDELINES

The most common error made with ducks is trying to raise them like chickens. For good results, every type of bird must be managed somewhat differently.

Protect your birds from predators. Ducks raised in small flocks seldom die from disease or exposure to severe weather, but quite a number are lost to predators. Every night, they should be penned up in a building or a securely fenced yard.

Supply a balanced diet and avoid medicated feeds. Following close behind predators, improper nutrition is the second leading cause of problems encountered by duck keepers.

Provide a steady supply of drinking water. Ducks do not thrive if they are frequently left without water.

Furnish suitable living conditions. Keeping ducks locked up in yards covered with deep mud and stagnant waterholes is an invitation for trouble.

Do not disturb them more than necessary. Waterfowl thrive on tranquility.

When catching, do not grab or carry them by their legs. The legs and feet of ducks are easily hurt.

HOUSING

Ducks require minimal housing. Unlike chickens, they prefer to stay outside day and night in most weather. In mild climates it is possible to raise ducks without artificial shelters. A windbreak made of straw bales will provide sufficient protection to keep ducks comfortable in regions where temperatures occasionally dip to 0°F. A more substantial shelter is needed in areas where extremely low temperatures are common.

Because waterfowl normally perch on water or the ground at night, the main reason for housing ducks in mild weather is to protect them from night-wandering predators (see Appendix C, page 147). A tight fence at least four feet high enclosing the yard is enough to stop many predators. However, in areas where thieves such as weasels, mink, raccoons, owls and wild or domestic cats are common, it is much safer to close ducks in a varmint-proof building or pen at nightfall.

If you do not have an empty building that can be converted into a duckhouse, an inexpensive shed-like structure can be constructed. In the illustration, a practical duckhouse is shown. This type of shelter is portable and can be used for either ducklings or adult birds.

Since ducks are short, there is no need to have the walls of the duckhouse more than two feet high at the lowest point, except for your convenience in

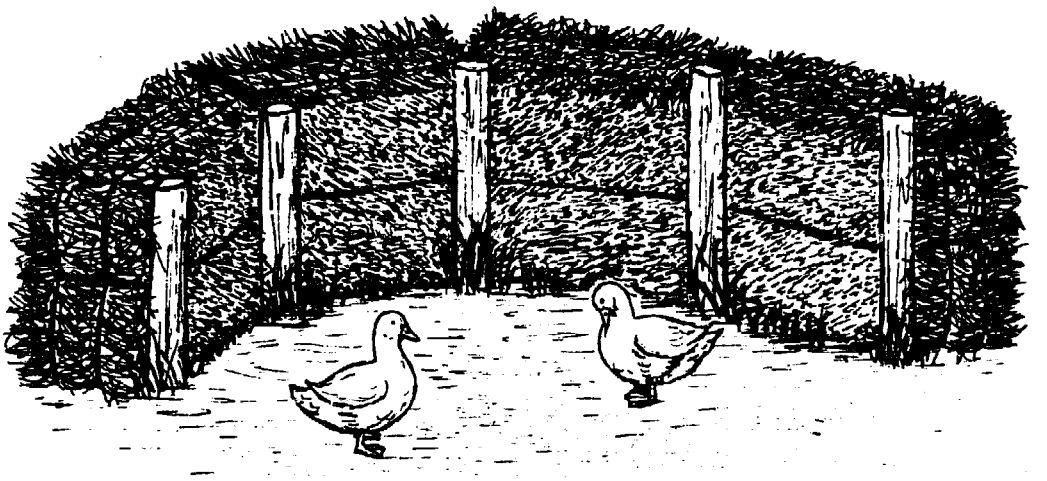

Windbreak made of straw or hay bales

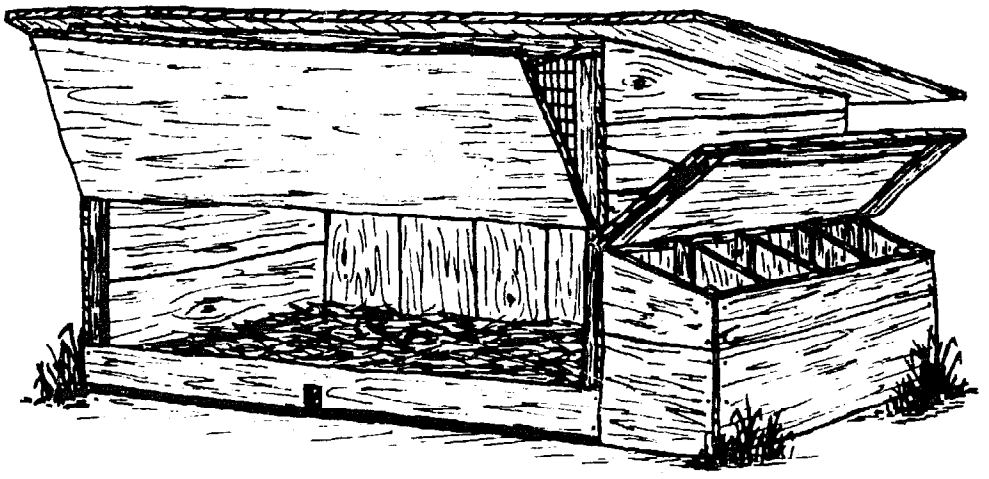

Practical duckhouse with attached nests

gathering eggs and cleaning out old litter. By having the nests attached along the outside and outfitted with a hinged top, eggs can be gathered without entering the shed. Three solid walls and a wire front are recommended except in regions with severe winters, where it is better to have a closed front. Good ventilation is essential though, even in cold climates, since ducks fare poorly if they are forced to stay in stuffy, damp quarters.

Dirt or sand floors are preferred to cement or wood floors in duck buildings. To insure good drainage, place the shed on a slope or build the floor up four to eight inches above ground level with dirt, sand or bedding. If the duckhouse is located in a low spot, water will accumulate, making it impossible to keep the litter dry.

When ducks are housed only at night, allow at least 2.5 to 4 square feet of floor space per bird. If you anticipate keeping your ducks inside continuously during severe weather, a minimum of six to eight square feet of floor space should be provided.

Cold Weather Housing

Ducks are well-prepared to remain comfortable in freezing weather with their thick garb of feathers and down. Nonetheless, feed consumption can be reduced and egg production increased if ducks are protected from the severity of bitter northern winters, particularly at night when the birds are inactive.

Insulated quarters. Insulating a small duckhouse is inexpensive and can mean the difference between few or many eggs during the long winter months. If the duckhouse has double wall construction, air spaces can be filled with sawdust, chopped straw or a commercially prepared material.

Another satisfactory way to insulate shelters is to stack straw bales against the outside walls from ground level to the roof.

Deep litter. A thick layer of bedding in the duckhouse keeps ducks off cold floors and reduces the penetration of cold from the ground during periods of low temperatures. The deep litter system actually goes one step further by producing heat through decomposition of the litter and manure. This system has been tested in cold climates and has been found to increase winter egg production by up to 20 percent. It also eliminates the need to clean out duckhouses more than twice yearly, and produces excellent organic matter for the home garden.

To employ the deep litter method, follow these three steps: (1) cover the duckhouse floor with four to six inches of dry bedding; (2) periodically stir the bedding and add fresh material to keep the floor in good condition; and (3) clean out the old litter each spring. Because the litter will accumulate to a depth of eighteen to thirty inches, the walls of duckhouses where this system is used need to be approximately four feet high.

The Duck Yard

Most serious duck raisers have a fenced yard where birds are locked in at nighttime, or continuously if space is limited. The ideal yard has a minimum of ten to twenty-five square feet of ground space per duck, natural or artificial shade, a slope that provides good drainage, and a surface that is free of stagnant waterholes and deep mud.

If the soil on the land where you live has poor drainage, the duck yard should be covered with pea gravel, sand, straw, wood shavings or leaves, with the center of the yard built up higher than the outside edges. When choosing a location for your duck yard, keep in mind that a dense population of birds can kill young trees due to the high nitrogen content of duck manure.

Keeping Ducks on Wire Floors

Adult ducks can be kept in houses or hutches with wire-covered floors or in elevated, all-wire cages. The main advantage of this system is that birds can be maintained in extremely limited space without problems of sloppy litter or muddy yards. Some disadvantages are that feed consumption is higher since the birds cannot forage, foot problems can develop (particularly among the larger breeds), and life is less enjoyable for the ducks.

To prevent lameness, wire mesh used on floors should not have openings larger than 1 inch by ½ inch. However, if finer mesh is used, manure may not pass through, causing buildup problems. A minimum of two square feet of

floor space per bird should be allowed, with double or triple this amount being recommended when feasible.

Bedding

Ducks can withstand wet weather, but they should *never* be forced to stay in muddy, filthy yards or buildings. The floors of buildings should be covered with several inches of absorbent litter. In muddy or snow-covered yards, mounds of bedding four to six inches thick should be provided to give ample space where all ducks can roost comfortably. Add new layers of clean bedding as needed.

Shade

Ducks must have access to shade in hot weather. They are a cool-weather bird and suffer if forced to remain in the sun at temperatures above 70°F. When ducks are confined to a yard lacking natural shade, a simple shelter should be provided which will supply adequate shade for all birds residing there. Feed troughs can also be located under this cover to protect the feed from exposure to the elements.

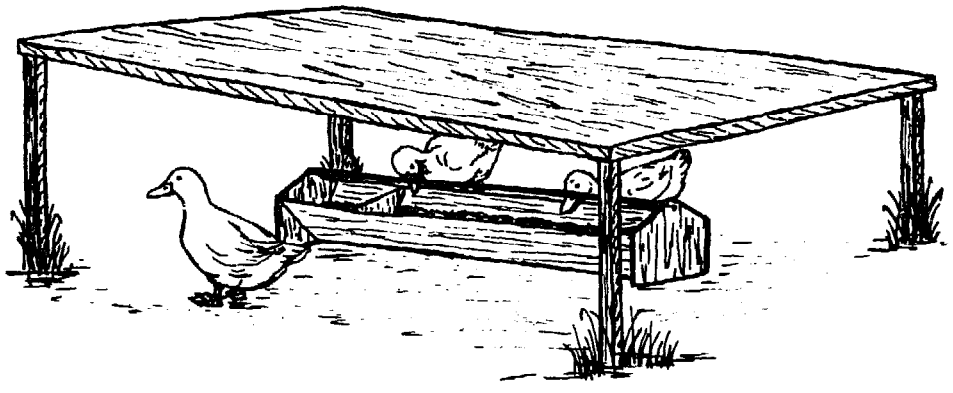

A simple shelter provides shade and protects feed from sun and rain.

Nests

Clean eggs hatch better and retain their freshness for eating longer than eggs that must be washed. Having adequate nests for your hens will help produce clean eggs and reduce the chances of eggs being broken. So that hens are familiar with them, install nests two weeks before you expect the first eggs. One nest for every four or five hens is sufficient.

For medium to large hens, nests approximately a foot square and twelve inches high are recommended. Duck nests are placed on the ground and do

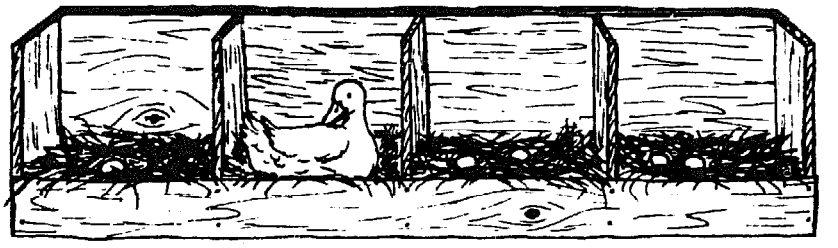

Indoor nests

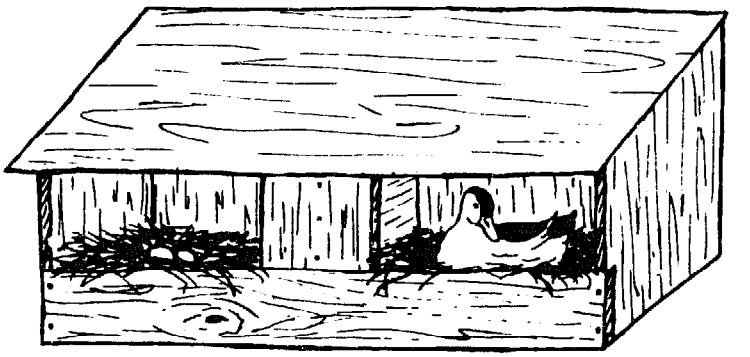

Outdoor nests

not need solid bottoms. If nests are inside buildings, they do not require a top. Covering the nest bottoms with burlap aids in the production of clean eggs. Keeping nests well-furnished with clean, dry nesting material such as sawdust or straw will encourage hens to use them and result in fewer broken or soiled eggs.

Portable Panels

Lightweight panels constructed from 1″ × 2″ or 1″× 4″ lumber and chicken netting frequently come in handy. They can be used to divide pens, for isolating hens that are setting or have young, as a catch pen in a large yard, and for small pens that can be moved around to utilize grass in different areas of the home place. To retain most breeds of ducks, the panels only need to be two or three feet high. Panels that will be used to impen day-old ducklings should be covered with 1″ × 1″ chicken netting.

SWIMMING WATER

Ducks enjoy swimming, and add charm and interest to lakes, ponds and brooks. Where natural bodies of water do not exist, small earthen or cement ponds can be constructed. It is advantageous to design them for easy drainage and cleaning. A four-inch-deep layer of sand or gravel around the

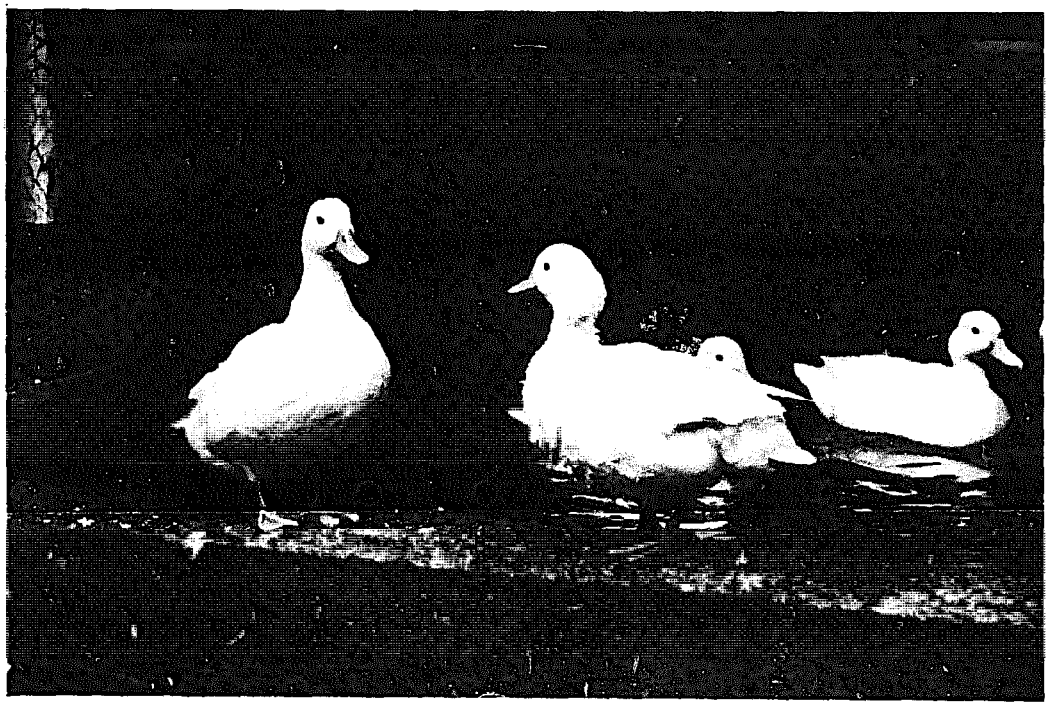

White Calls taking it easy on a small cement pond.

perimeter of a pond is helpful in keeping ducks from tracking in mud and drilling with their bills.

Contrary to popular belief, ducks can be raised successfully without water for swimming. In fact, there are some advantages in having only drinking water. If a small pond is overcrowded, sanitation problems often arise. Ducks must *not* be allowed to swim in or drink filthy, stagnant water.

DRINKING WATER

Ducks must have a *constant* supply of reasonably clean drinking water. So the birds can wash out their nostrils, waterers should be designed to provide water that is at least three inches deep. Buckets, dishpans and hot water tanks cut in half vertically make satisfactory drinking containers for adult ducks. For a pair or two of birds, a one-gallon tin can will suffice.

Because ducks frequently wash their bills, drinking water would need to be changed many times daily to be kept clear. While such repeated changing is not necessary, the water should be replaced several times weekly and must never be allowed to become putrid.

To keep unhealthful mudholes from developing around watering areas, water fountains should be placed on wire-covered platforms. For additional protection, a pit twelve to twenty-four inches deep can be made underneath the platform and filled with gravel.

During cold weather when there is soft snow, ducks can sustain themselves

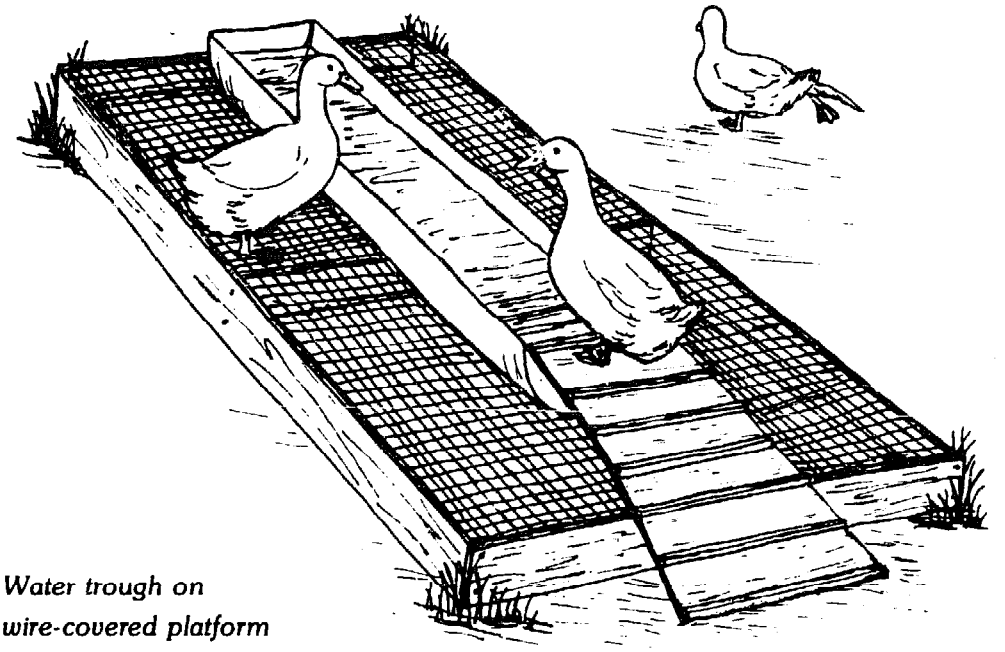

Water trough on wire-covered platform

for a time by eating the icy crystals. However, it is preferable to give them warm drinking water twice daily when the temperature is cold enough to freeze all available liquid.

RAISING DUCKS ON SALT WATER

Ducks can be raised successfully in marine areas. Most ocean bays and inlets are teeming with an abundant supply of plant and animal life that ducks relish. Because domestic ducks have a lower tolerance for salt than do wild sea ducks, sweet drinking water should be supplied at all times. Birds that are raised for meat on marine waterways need to be confined in a pen or yard and fed a grain-based diet for two to four weeks prior to butchering to avoid fishy-flavored meat.

NUTRITION

Feed is the single most expensive item in raising ducks, normally representing 60 to 80 percent of the total cost. Finding ways to save on feed expenditures will significantly decrease the cost of your duck project.

For top egg production, ducks must be fed an adequate amount of concentrated feed having 16 percent crude protein. Three weeks before the first eggs are expected and throughout the laying season, a laying ration should be fed

free choice or twice daily. (See Table 15 for recommended daily feed allowances.) Duck hens lay the best when they are in a semi-fat condition, but excessive fatness is harmful and must be avoided. A sudden change in the diet of hens that are laying normally results in a sharp decline in egg production, throwing hens into a premature molt from which it will take six to ten weeks to recover.

TABLE 15
SUGGESTED FEEDING SCHEDULE FOR ADULT DUCKS

	Holding Period When Birds Are Not Producing	*3 Weeks Prior to and During Laying Season*	*2 Weeks Prior to Butchering Mature Ducks*
Size of Duck	*Lbs. of 12-14% Protein Feed per Bird Daily*	*Lbs. of 16% Protein Feed per Bird Daily*	*Lbs. of High-Energy Feed per Bird Daily*
2-3 lbs.	0.15-0.25	0.20-0.30	Free choice
4-5 lbs.	0.20-0.30	0.30-0.40	Free choice
6-7 lbs.	0.25-0.35	0.40-0.50	Free choice
8-9 lbs.	0.30-0.45	0.45-0.60	Free choice
Muscovy	0.30-0.40	0.40-0.60	Free choice

The quantities of feed that you need to supply ducks are highly dependent on the availability of natural foods, the climatical conditions and the quality of feed (e.g., birds require larger amounts of high fiber foods than low fiber foods to meet their energy requirements).

While not in production, mature ducks can be given a maintenance ration containing 13 to 14 percent crude protein, and fed just enough to keep them in good condition. The quantity of feed required by birds is highly affected by the weather. During cold periods, ducks must eat considerably more feed than when temperatures are moderate.

Fish by-products such as fish meal are excellent sources of high-quality proteins, and are used in many commercially prepared poultry feeds. These ingredients are excellent for immature birds and adult breeders that produce hatching eggs, but laying hens that supply eating eggs must be given feeds that are low in (less than 4 percent), or do not contain, fish products.

Feeding Programs

In formulating a feed program for your adult duck flock, try to find ways to obtain a high degree of productivity while utilizing food resources that normally go unharvested.

Natural. The least expensive way to feed ducks is to make them forage for their food. This option is limited to situations where wild and natural foods are

in abundant supply and when top egg production is not important. It must be remembered that the quantity of natural feed fluctuates widely during the various seasons of the year. While there may be periods when ducks can find most and possibly all of their own feed, there will probably be times when most of their food will need to be supplied in the form of grain and mixed rations. Ducks must *never* be allowed to deteriorate and become thin due to lack of feed. Negligence in this area can permanently damage their productivity.

Grains. Whole grains, by *themselves*, are not a complete poultry feed. However, if ducks are given a protein concentrate (see Appendix A, page 135) or can forage in waterways or pastures, a supplement of grain will often satisfy their dietary needs, particularly when the birds are not in production.

Ducks are not as fond of oats and barley as they are of other grains. But these two grains are good waterfowl feeds and the birds will learn to eat them if forced to do so.

Corn is a high energy grain and an excellent feed for cold weather and for fattening poultry—if you desire fat meat. During hot weather, the diet of ducks should not consist of more than 60 to 80 percent corn. If waterfowl are fed too much corn during exceptionally hot weather, egg production drops and health problems can arise.

Home mixed. It may be practical to mix your own feed if the various ingredients are available at a reasonable price. Mixing a home ration for ducks is simpler than for chickens. All ingredients for chicken feeds need to be finely ground; otherwise the birds will pick out the grains and leave the finer particles. This problem is usually not encountered with ducks since they tend to scoop up their feed rather than picking it up one kernel at a time. (See pages 77-78 for methods of mixing feed.)

The formulas in Table 16 are examples of the type of feeds that can be mixed at home for small flocks of ducks. If a commercially prepared vitamin:mineral premix is used, the rations in Table 17 can be prepared at home as well. The suggested ingredients can be substituted with similar products that are more readily available in your area. (See Appendix A, page 135 for instructions on how to formulate rations.)

Commercial. The simplest way to provide ducks with a balanced diet and stimulate top production is to purchase commercially mixed concentrated feed. These rations are formulated to insure a proper balance of carbohydrates, fats, proteins, vitamins, minerals and fiber.

In many localities, feeds manufactured specifically for breeding and laying ducks are not available. Nonmedicated turkey and chicken feeds can be used in place of duck mixtures. (Chicken rations usually need to be supplemented

TABLE 16
HOME-MIXED RATIONS FOR ADULT DUCKS

*Ingredient**	*No. 12 Holding* pounds	*No. 13 Holding* pounds	*No. 14 Layer* pounds	*No. 15 Layer* pounds
Whole milo or yellow corn	82.00	—	60.00	24.00
Whole soft wheat	—	86.00	9.00	48.00
Soybean meal (50% protein)	8.00	4.00	7.00	4.50
Meat and bone meal (50% protein)	—	—	4.00	4.00
Alfalfa meal (17.5% protein)	4.00	4.00	4.00	4.00
Dried skim milk	—	—	2.00	2.00
Brewer's dried yeast	5.00	5.00	7.00	7.00
Oyster shell	0.25	0.50	6.40	5.90
Dicalcium phosphate (18.5% protein)	0.50	0.25	0.30	0.35
Iodized salt	0.25	0.25	0.30	0.25
Cod liver oil**				
Totals (lbs.)	100.00	100.00	100.00	100.00

*The addition of 3 to 5 pounds of livestock grade molasses to each 100 pounds of mixed feed reduces waste.
**If birds do not receive direct sunlight, which enables them to synthesize vitamin D, sufficient cod liver oil must be added to these rations to provide 400 International Chick Units (ICU) of vitamin D_3 per pound of feed.
Note: These rations are best suited for situations when birds have access to pasture.

with additional niacin. See page 78.) Ducks waste less feed if they are fed *pellets* rather than crumbles or mashes.

If you are raising a large number of ducks, it may be economical to have a local feed mill custom-mix your duck feed. In Table 17, feed formulas that we have used successfully for a number of years are given.

Because wheat is our most abundant and cheapest grain here in the Northwest, we use it as the base for our rations. In your locality, other grains may be lower priced and they should be used. Your grain dealer can help you formulate a feed that best utilizes available resources.

Growing Duck Feed

It is possible to raise a good portion of the feed required by a flock of half a dozen ducks on a 25′ × 25′ plot of land. Field corn yields large quantities of ears that are easily harvested and shelled by hand or broken in two and thrown to the ducks to shell for themselves. Grains such as wheat and rye provide fall and spring grazing and, when the seeds are mature, the ducks can be allowed into the patch for a short time daily to harvest their own feed. Grain sorghums such as kafir and milo produce large seed heads that can be hand harvested and stored whole.

A large assortment of natural crops is available for planting in and around bodies of water. Some of the favorites of ducks include wild celery, wild rice,

TABLE 17
COMPLETE RATIONS FOR ADULT DUCKS (PELLETED)

Ingredient	*No. 16 Corn Base Holding* lbs/ton	*No. 17 Wheat Base Holding* lbs/ton	*No. 18 Milo Base Holding* lbs/ton	*No. 19 Corn Base Breeder* lbs/ton	*No. 20 Wheat Base Breeder* lbs/ton	*No. 21 Milo Base Breeder* lbs/ton
Ground yellow corn	1612	—	—	1415	—	—
Ground soft wheat	—	1667	—	—	1460	—
Ground milo (grain sorghum)	—	—	1630	—	—	1421
Soybean meal solv. (50% protein)	265	190	255	302	236	295
Meat and bone meal (50% protein)	—	—	—	80	80	80
Alfalfa meal (17.5% protein)	40	40	40	40	40	40
Stabilized animal fat	—	30	—	—	20	—
Soybean oil	—	5	—	—	15	—
DL-Methionine (98%)	—	1.25	1.25	1.00	1.50	2.00
L-Lysine (50%)	—	1	—	—	—	—
Dicalcium phosphate (18.5% P)	28	27	27	12	10	12
Limestone flour (38% Ca)	30.00	13.75	21.75	125.00	112.50	125.00
Iodized salt	5	5	5	5	5	5
Vitamin:mineral premix	20	20	20	20	20	20
Totals (lbs.)	2000	2000	2000	2000	2000	2000
Vitamin:Mineral Premix						
Vit. A (millions of IU/ton)	5.0	6.0	6.0	8.0	9.0	9.0
Vit. D_3 (millions of ICU/ton)	0.8	0.8	0.8	1.0	1.0	1.0
Vit. E (thousands of IU/ton)	—	10.0	10.0	10.0	20.0	20.0
Vit. K (gm/ton)	1.0	1.0	1.0	2.0	2.0	2.0
Riboflavin (gm/ton)	3.0	3.0	3.0	6.0	6.0	6.0
Vit. B_{12} (mg/ton)	4.0	4.0	4.0	8.0	8.0	8.0
Niacin (gm/ton)	30.0	30.0	30.0	50.0	50.0	50.0
d-Calcium pantothenate (gm/ton)	2.0	1.0	1.0	6.0	3.0	3.0
Choline chloride (gm/ton)	100.0	—	100.0	300.0	—	300.0
Folic acid (gm/ton)	—	—	—	0.5	0.5	0.5
Manganese sulfate (oz/ton)	9.6	9.6	9.6	9.6	9.6	9.6
Zinc oxide (80% Zn, oz/ton)	3.2	3.0	3.2	3.2	3.0	3.2
Ground grain to make 20 lbs.	+	+	+	+	+	+
Totals (lbs.)	20.0	20.0	20.0	20.0	20.0	20.0
Calculated Analysis						
Crude protein (%)	14.2	13.6	14.1	16.3	15.8	16.2
Lysine (%)	0.63	0.60	0.63	0.77	0.72	0.75
Methionine (%)	0.26	0.26	0.26	0.33	0.33	0.32
Methionine + cystine (%)	0.50	0.53	0.49	0.58	0.58	0.57
Metabolizable energy (kcal/lb.)	1419	1359	1405	1322	1278	1306
Calorie:protein ratio	100	100	100	81	81	81
Crude fat (%)	3.3	3.4	2.5	3.2	3.6	2.6
Crude fiber (%)	2.6	2.8	2.7	2.6	2.7	2.7
Calcium (%)	0.95	0.64	0.77	2.99	2.75	3.00
Available phosphorus (%)	0.35	0.36	0.35	0.40	0.39	0.41
Vit. A (IU/ton)	5240	4678	4678	6610	6178	6178
Vit. D_3 (ICU/ton)	400	400	400	500	500	500
Riboflavin, (mg/lb)	2.17	2.21	2.20	3.73	3.76	3.76
Total niacin (mg/lb)	25	38	32	35	46	41

KEY: IU = International Units; ICU = International Chick Units; gm = gram; mg = milligram; kcal = kilocalories

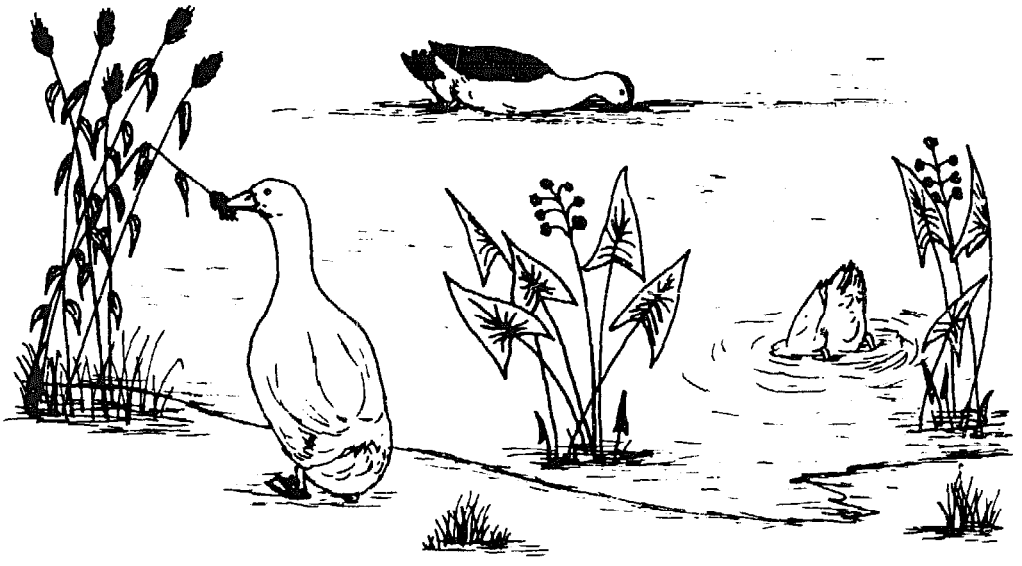

wild millet, small bulrush, smartweed and chufa tubers. Addresses of nurseries specializing in natural game bird crops can be found in hunting and outdoor magazines. Ducks also enjoy and benefit from vegetable and fruit produce that cannot be used in the kitchen.

Pasture

While ducks can be raised in barren yards or pens, they enjoy succulent vegetation when it is available. Good quality forage lowers their feed consumption by approximately 10 percent and lessens the possibility of vitamin deficiencies. Ducks cannot eat mature pasture (except the seeds), so it should be mowed occasionally to encourage new growth.

Orchards are an excellent location for duck pastures. The vegetation smothers out noxious weeds and provides a protective and attractive ground cover. Ducks significantly reduce the numbers of harmful insects in orchards and clean up diseased and windfall fruits.

There are a variety of grasses and legumes that make good permanent pasture for ducks. The main requirements are that the plant thrives in your region and that it produces succulent forage. A mixture of Perennial Rye grass and one of the clovers such as New Zealand White, Lodino or White Dutch will provide good grazing in many localities. Your local agriculture extension service specialist can give advice on what varieties do well in your climate.

Feeding Insects to Ducks

Insects are a bountiful source of high-quality protein. While ducks of all ages are accomplished bug hunters, their consumption of winged insects can

be increased by burning a low-wattage bulb twelve to eighteen inches above ground level in the duck yard at night. As the insects swarm around the light, the birds have hours of leisurely dining.

Utilizing Surplus Eggs and Milk

Eggs and milk are excellent sources of nutrition for poultry. Being "complete" foods, they are particularly valuable in home-mixed rations to help insure that birds are receiving a balanced diet. In general, when egg and/or milk are added to the diet of ducks, they grow better, have glossier plumage and lay more eggs.

The only practical way to feed liquid milk to ducks is to mix small quantities into a dry ration. When milk is given in pans or buckets, ducks play in it, covering themselves and the surrounding area with the sticky stuff. Under these conditions, food poisoning and eye infections often develop.

Eggs should *always* be hard-boiled before they are given to poultry. Feeding raw eggs can result in a biotin deficiency and often leads to birds eating their own eggs. To avoid spoilage, milk and eggs should not be mixed with the duck ration until feeding time.

Feeding Leftovers

Kitchen and garden refuse must be fed to producing birds in moderation. Leftovers normally are high in starch, fiber and liquid, and low in most other nutrients. Hens cannot lay well if their minimum requirements for protein, minerals and vitamins are not being ingested.

Grit and Calcium

To digest their feed to the best advantage, ducks need to have a continuous supply of granite grit, coarse sand or small gravel. Four weeks prior to, and throughout the laying season, hens need to have their diets supplemented with calcium if they are going to lay strong-shelled eggs. Most manufactured laying feeds contain the correct amount of calcium, but when grains or home mixes are used, a calcium-rich product such as egg shells, oyster shells or ground limestone should be fed free choice.

Feeders

Because adult ducks are often fed a limited quantity of feed, sufficient feeder space must be allowed so that *all* the birds can eat at one time without crowding. Otherwise, less aggressive and smaller ducks may be pushed aside and not get their full share.

Approximately six lineal inches of feeder space should be allowed per bird. Ducks can eat from both sides of most feeders, so a trough five feet long provides ten lineal feet of feeder space which is sufficient for a flock of twenty birds. V-shaped troughs, with spinners mounted along the top to keep birds out, are easily constructed and provide sanitary eating conditions.

Finishing Roasting Ducks

When ducks have been forced to forage for much of their feed during the growing period, they can be fed grain or finishing pellets free choice for two or three weeks prior to butchering. If they have ranged widely, it is advantageous to pen them in a restricted yard (allowing a minimum of twenty-five square feet per bird) during the finishing period. This time of heavy feeding and restricted exercise will encourage the ducks to gain weight rapidly, resulting in a larger carcass and succulent, tender meat.

THE LAYING FLOCK

Most duck hens lay before 8 in the morning. So that eggs are not lost in fields or bodies of water, it is a good practice to confine the laying flock to a yard or building at night.

When ducks are penned up at nighttime, they *must* have access to drinking water if feed is in front of them. Otherwise, they will suffer from thirst and may choke to death.

Unless eggs are going to be used for hatching, there is no need to have drakes. Hens lay better without frequent mating activity, and nonfertile eggs store longer than fertile ones.

Lighting Needs

When top egg production is desired during the short days of fall, winter and early spring months, duck hens, like chickens, *must* be exposed to artificial lighting. A minimum of fourteen hours of light daily is required to keep duck hens laying well. It is essential that the length of daylight *never decreases* while hens are producing, or the rate of lay will be severely diminished. Even a reduction of only fifteen to thirty minutes per twenty-four hour period for several days can negatively effect heavily producing hens.

By using an automatic time switch that turns lights on before daybreak and off after nightfall, hens can be exposed to fourteen to sixteen hours of light daily. Another method is to leave a light burning all night long. Since ducks become frightened quite easily at night and may wear themselves out by milling about, this system has the advantage of keeping them calm and quiet.

TABLE 18
TYPICAL EFFECTS OF MANAGEMENT ON EGG PRODUCTION

	Annual Egg Production per Hen		
Treatment	*Domestic Mallards*	*Commercial Rouens*	*Khaki Campbells*
Fed whole or cracked grains Given access to pasture & pond Exposed to natural day length	25-40	50-65	75-150
Fed 16% protein laying pellets Given access to pasture Exposed to natural day length	50-75	75-100	175-225
Fed 16% protein laying pellets Given access to pasture Exposed to 16 hours light daily	85-125	125-150	275-325

However, egg production is normally lowered slightly when hens are exposed to twenty-four hours of continuous light daily, in contrast to fourteen to sixteen hours.

To prevent premature egg production, the amount of light young hens are subjected to needs to be watched carefully. When pullets are exposed to excessive light or increasing day lengths between the ages of twelve to twenty-two weeks, they will begin to lay before their bodies are adequately mature. Early laying (before twenty weeks of age) can result in a shortened production life, smaller and fewer eggs, and greater possibility of complications such as prolapsed oviducts.

The intensity of light required to stimulate egg production is relatively low (approximately one foot-candle at ground level, which usually equals one bulb watt per four square feet of floor area). When ducks are confined to a building or shed at night, one forty- to sixty-watt incandescent bulb six feet above ground level will provide adequate illumination for each 150 to 250 square feet of floor space. In outside yards, one 100-watt bulb with a reflector per 400 square feet of ground space is recommended.

We use the following lighting schedule with good success on hens that are hatched in March through July, and I recommend it if you desire maximum efficiency and production.

Age	*Hours of Light Daily*
0-8 weeks	24 hours.
8-22 weeks	Natural day length.
22 weeks	Add 2 hours of artificial light to natural day length.
23 weeks	Add 15 minutes of light weekly until 15 or 16 hours of total light is reached. Maintain a constant level until hens stop laying or they are force molted.

Identifying Producing Hens

Shortly before production commences, and throughout the laying season, the abdomens of hens swell noticeably. Hens that are in production can be identified by their large, moist vents and wide-spread pubic bones. As the season progresses, the color of the bills of high-producing hens fades. This phenomenon is especially noticeable in ducks with orange bills.

Encouraging Hens to Use Nests

To encourage duck hens to lay where you want them to, place dummy eggs in nest boxes several weeks before the beginning of the laying season. While nest eggs can be purchased, I have found that turning them out on a lathe is an enjoyable rainy day project. You do not have to worry about making them exactly the correct shape and size. Painting the wooden eggs makes them last longer and easier to clean. Any color will be accepted by the hens,

TABLE 19
IDENTIFYING PROBLEMS IN THE LAYING FLOCK

Symptom	*Common Cause*
Thin or soft-shelled eggs	Usually a vitamin D_3 deficiency; also high temperatures, abnormal reproductive organs or calcium deficiency.
Eggs decrease in size	A gradual decrease in size is common as the laying season progresses. However, excessive environmental stresses and dietary deficiencies accentuate the problem.
Odd-shaped eggs	Temporary malfunction of the reproductive organs; in some cases, abnormal oviducts.
Pale yellow yolks	A diet lacking carotene, which is supplied by products such as yellow corn and green plants. Hens fed wheat-based rations without access to pasture or greens usually produce anemic-colored eggs.
Bright orange-red yolks	Diets high in corn and/or green feeds.
Blood or meat spots in egg interior	Internal hemorrhage. Eggs fit for eating.
Blood on shell exterior	Ruptured blood vessel at the cloaca opening. Frequently occurs when young hens begin laying.
The back of head and neck bare of feathers; in extreme cases, skin is lacerated and scabby	Too many drakes, which results in excessive mating activity. Drakes sometimes have favorite hens.
Hens go into a premature molt	A sudden change in diet or lighting; birds frequently left without water; onset of hot weather.
Eggs lost in bodies of water, pastures or hidden nests	Hens not locked in a pen or small yard at night, or are turned out before 8 or 9 A.M.

but white or light-colored shades have the advantage of being more visible to birds.

Production Life of Hens

With good management, small breed pullets begin laying at twenty to twenty-four weeks, while large breed pullets require twenty-four to thirty weeks. Duck hens lay the greatest number of eggs in their first year of production, but normally show only a minor decrease in productivity during the second and third year when eggs are larger in size. Good hens often produce some eggs until they are four to eight years old.

Breaking Up Broody Hens

When hens become broody, their egg production falls off or ceases. To induce broodies back into production, isolate them in a well-lit pen without nests or dark corners, and provide drinking water and feed. In these surroundings, hens normally lose their maternal desires in three to six days and can be returned to the flock. Because broodiness seems to be contagious, remove hens from the flock *promptly* when they show the first signs of wanting to set.

Force Molting

Each year ducks lose their feathers and replace them with new ones. Hens normally do not molt while they are laying since their bodies cannot support the strain of growing feathers and forming eggs at the same time. Under natural conditions, this arrangement works out fine; the hen lays in the spring, hatches and broods her young until they are able to fend for themselves, and then she molts, with her new garb being ready for the cold winter months.

When pullets of the egg breeds are managed for top egg production, they begin laying at twenty to twenty-four weeks of age which typically is in the fall of the same year they are hatched. With proper management, hens will lay throughout their first winter, the following spring and summer and into the fall months without molting. By this time their feathers are worn and will not provide ample protection from the low temperatures and wet weather of their second winter. Because it is feasible to keep duck hens for up to three years, it is a good practice to force molt them at the end of their first and second years of production.

The laying flock should be force molted when egg production is down—normally during the hot summer months—and when they will have sufficient time to replace their feathers before the cool, wet weather of fall. Because

ducks require six to ten weeks to molt and begin laying again, they should be force molted in June or July in most localities.

Hens are thrown into a molt by sudden changes in their diet and environment. The following schedule is suggested as a simple method for force molting the home duck flock.

1st day:	Discontinue artificial lighting and remove all water and feed.
2nd day:	Provide drinking water but no feed.
4th day:	Commence feeding again, but substitute the laying ration with .25 pounds of grain (preferably not corn) per bird per day. This feed allotment is for hens weighing four to five pounds.
8th day:	Switch to a 17 to 18 percent protein grower ration to insure a healthy growth of new feathers. Supply .25 to .33 pound of feed per bird per day.
28th day:	Gradually replace grower feed with laying ration, and supply a minimum of fourteen hours of light.

SELECTING BREEDERS

To maintain the productivity of the home flock, ducks that are to be used as breeders must be chosen carefully. In selecting breeding stock, only birds displaying the following characteristics should be retained: robust health, strong legs, good body size and freedom from deformities. If purebred ducks are raised, breed characteristics for typical size, shape, carriage, color and markings should also be considered.

The following deformities and weaknesses are highly inheritable and will occasionally show up in duck flocks. Birds with any of these faults *should not* be kept for reproduction.

Weak legs. While this problem can usually be traced to nutritional deficiencies, weak legs can also be inherited. Genetic leg weakness is often indicated by birds hobbling about with one or both legs twisted slightly outward or birds whose legs give out quickly after walking short distances.

Crooked toes. One or more toes are bent sharply at an unnatural angle, making this disfigurement easily identified.

Slipped wing. Probably the most common deformity seen in ducks, slipped wings are identified by wingtips that stick out from the sides rather than folding smoothly against the body. (See page 128.)

Wry tail. Rather than pointing straight back as is normal, wry tails are constantly cocked to one side.

Roach back. A deformed spinal column causes a humped and shortened back.

Kinked neck. This condition can be the result of an injury or from forcing tall ducks such as Indian Runners to remain in low boxes for extended periods of time (e.g., when they are shipped). Crested ducks exhibit necks with severe crooks just behind the head more than other breeds.

Crossed bill. When a duck has this defect, the upper mandible is usually bent to the side and not aligned with the lower mandible.

Scoop bill. Scoop-bills have an unnaturally deep, concave depression along the top line of the bill.

Blindness. Certain strains of poultry, particularly some of those that are highly inbred, show a high incidence of clouded or white pupils. Some birds will exhibit this fault at hatching time, while in others, it may not develop for several months or years.

CATCHING AND HOLDING DUCKS

Ducks *must be handled with care* since their legs and wings are injured easily. When catching, avoid running them on rough ground or where they will trip over feed troughs and other obstacles. It is advantageous to walk waterfowl into a small catching pen or V-shaped corner rather than having a wild chase around a large yard.

Never grab ducks by their legs or wings. Rather, grasp them securely but gently by the neck or with one hand over each wing to subdue them, and then slide one hand under the breast and secure the legs. When the bird is lifted from the ground, its weight should be resting on your forearm with its head pointed back between your body and arm, and its wings pinned against your side. When the wings and feet are held securely, there is little possibility that either you or the duck will be injured. Small and medium-sized ducks can be picked up and held with a thumb over each wing and the hands encircling the body.

Special precautions should be taken when handling Muscovies. They are surprisingly powerful and have long, sharp claws. When handling any type of bird, hold them away from your face to eliminate the possibility of injury to your eyes.

A safe and convenient method for catching ducks is to grasp the bird gently by the neck.

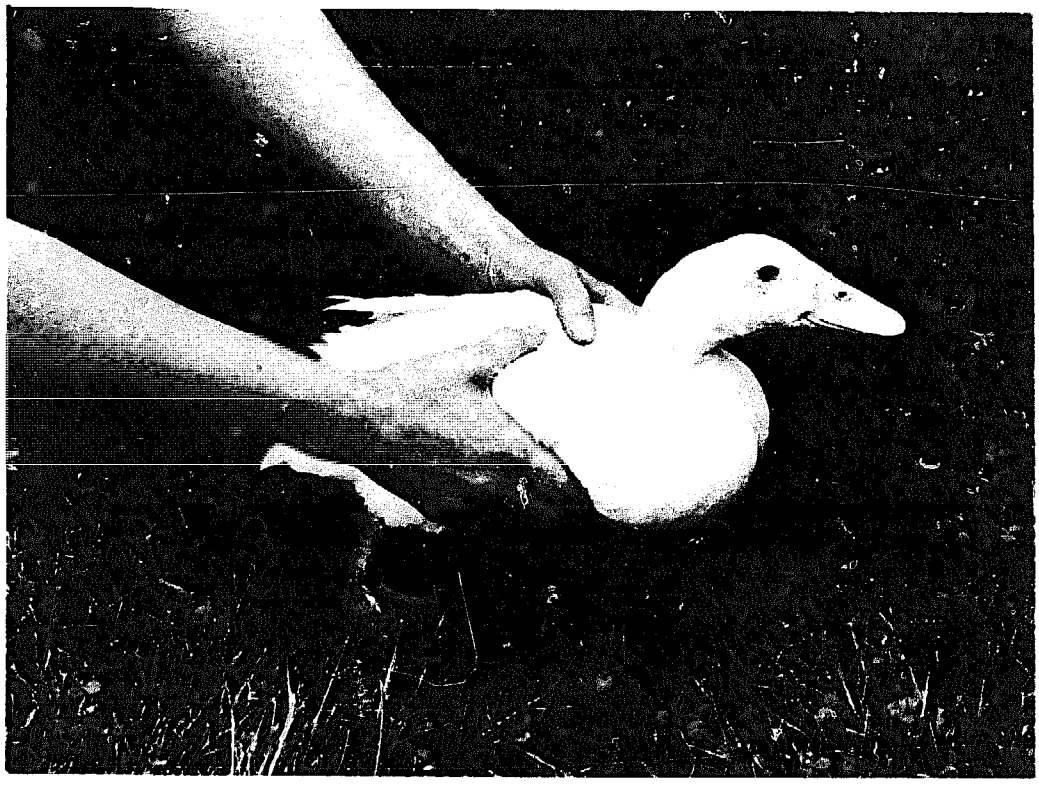

Small and medium-sized ducks such as this young White Campbell can be caught and held with a thumb over each wing and the hands encircling the body.

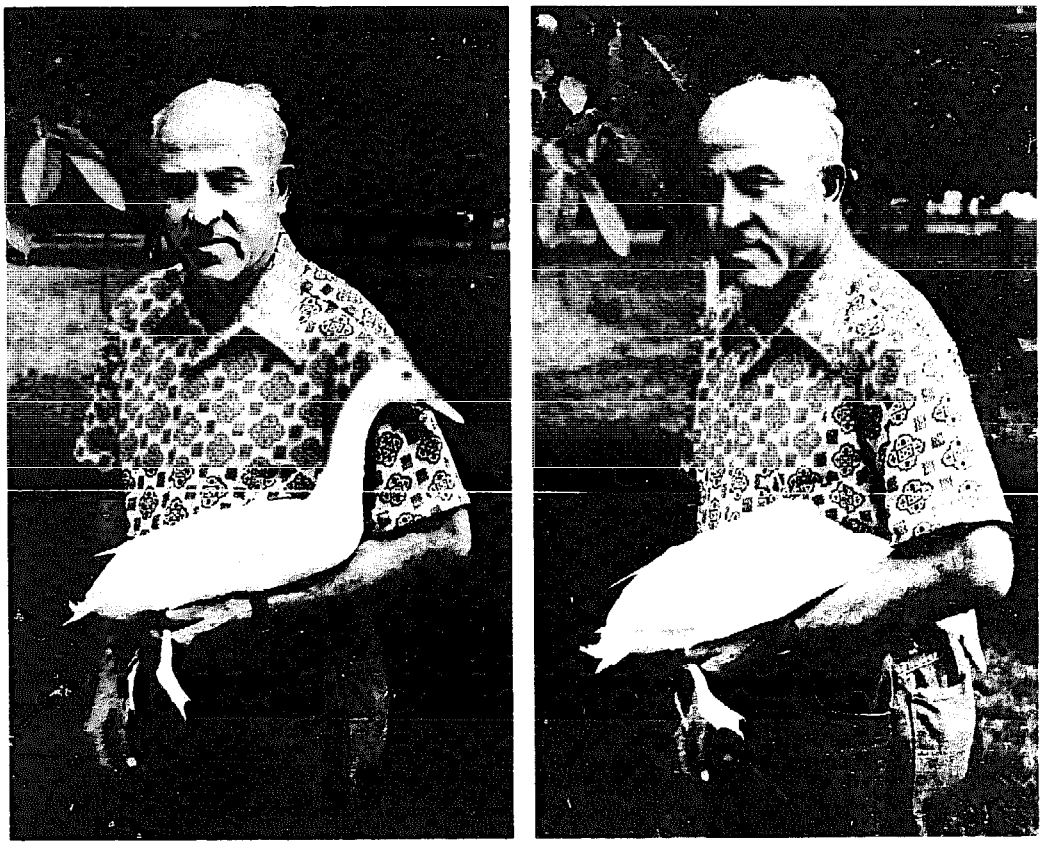

My father demonstrates two methods for holding ducks that are comfortable and safe for both the bird and the holder.

DEALING WITH AGGRESSIVE BIRDS

Ducks are not aggressive by nature. On rare occasions, however, a bird will develop a belligerent disposition and make a nuisance of itself by pecking and wing-slapping the legs of anyone who approaches too near. This problem is usually the result of ducks being teased and harrassed and can be avoided by teaching your birds to trust you.

Rehabilitating a rogue duck requires patience and an understanding of his nature. Many people aggravate the problem by kicking or striking back at pursuing birds. This action challenges the duck and stimulates it to fight harder. I have found that when a bird makes threatening advances, the best strategy is to ignore it and quietly go about your business, being careful not to make sudden moves. While some persons find this advice hard to follow, it usually works like magic. Without a stimulus to fight, the bird quickly loses interest and goes on its way.

If you happen to run into a hard-core rascal who refuses to mellow, you'll have to decide whether to put up with it or enjoy duck stew!

DISTINGUISHING THE SEX OF MATURE DUCKS

The gender of adult ducks is easily recognized by secondary sex characteristics such as voice, feather formation, plumage color and body size. The voices of drakes resemble a hoarse whisper, in contrast to the quacking of hens. Except during the molt, drakes display ... ral curled tail feathers, which hens lack. In colored varieties, drakes are brighter than hens, although for approximately two months each year, males undergo an eclipse molt during which time both sexes are similarly colored.

Muscovies are practically mute, although the hens can quack weakly. Drakes lack the curled tail feathers of true ducks, and the two sexes are similar in color. However, the sexes can be readily identified by the drakes' larger size and the hens' smaller facial skin patch.

CLIPPING WINGS

To keep flying ducks from wandering, it may be necessary to clip their wings. This is easily and painlessly accomplished by cutting the main flight feathers of one wing with tin shears or heavy-duty scissors. So that birds do not look unbalanced, the two outermost flights can be left intact. Once a year ducks molt their wing feathers and replace them with a new set. To keep them grounded, trim their wings annually.

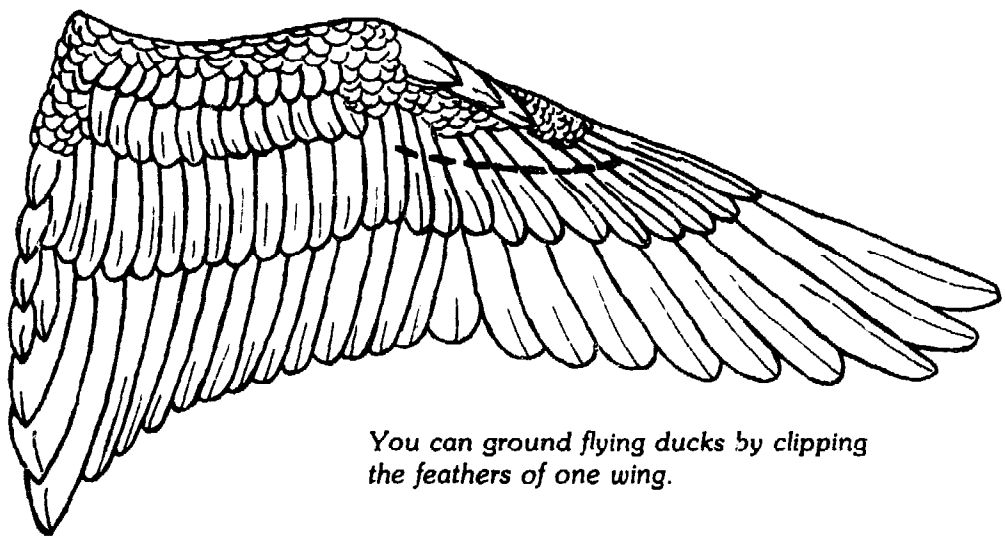

You can ground flying ducks by clipping the feathers of one wing.

HANDLING MANURE

Fortunately, the handling of duck manure does not need to be a back-breaking chore. If you plan ahead, the birds will spread much of their droppings directly onto the land where it is needed.

In the fall of the year, after the garden crops have been harvested, a portion of, or the entire garden can be converted into the duck yard. A layer of bedding such as cornstalks, leaves or straw should cover the ground to a depth of at least three to four inches. This covering not only keeps the ducks out of mud, but it also protects the dirt from being packed down and provides an excellent environment for earthworms and soil-enriching microorganisms.

In the spring, the partially decomposed bedding and manure can be worked into the soil. In gardens where this method has been used, lush crops of vegetables and fruits have flourished with minimal use of commercial fertilizers.

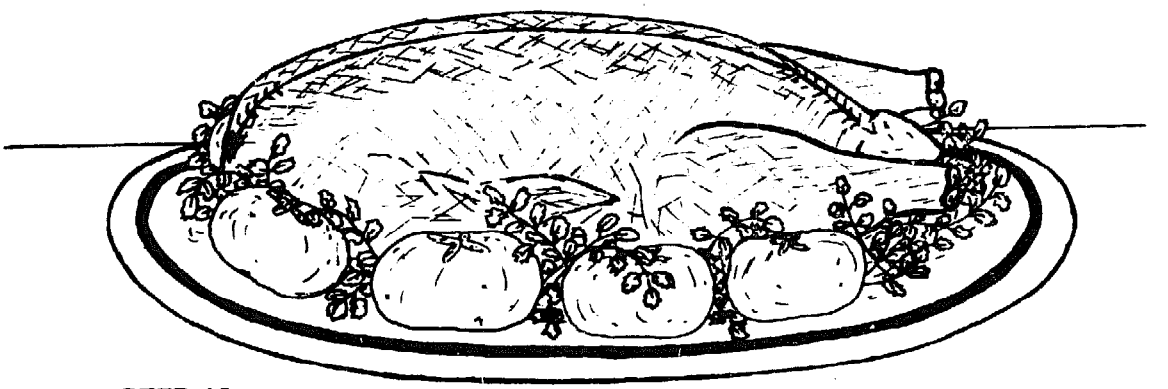

CHAPTER 10

Butchering

One of the main reasons ducks are raised is for their excellent meat. While they can be taken to a custom dressing plant to be butchered, this service is often expensive and robs you of the satisfaction of preparing your own food.

Cleanliness throughout the butchering process is essential to curb contamination and spoilage of meat. All cutting utensils should be sharp—dull knives are a waste of time as well as unsafe.

WHEN TO BUTCHER

One of the most time-consuming parts of the butchering process is the removal of the feathers. To make this job as simple as possible, butcher ducks when they are in full-feather. If a duck is slaughtered when it is covered with pin feathers, a picking job that normally takes three to five minutes can develop into a frustrating, feather-pulling marathon.

Depending on the breed and management, ducklings are normally in full-feather at seven to twelve weeks of age, except Muscovies, which require fourteen to sixteen weeks to feather out. Within a short time—sometimes a matter of days—ducks go into a heavy molt, replacing their juvenile garb with adult plumage. If ducklings are not dressed before this molt commences, butchering is best delayed for six to ten weeks when their adult plumage will have been acquired. The flesh of ducks is not in prime condition while they are molting.

Prekilling Preparations

Ducks should be taken off feed four to six hours prior to killing, or the night before if they are going to be dressed early the following morning. To avoid

excessive shrinkage, drinking water should be left in front of the birds until they are slaughtered.

Killing

For most of us, the least enjoyable task in raising ducks is killing them on butchering day. But for those of us who raise our own meat, it is a necessary chore.

There are several ways of dispatching ducks. The simplest and most impersonal method is the ax and chopping block. It is advantageous to have a device (such as two large nails driven into the block to form a V) on the chopping block to hold the bird's head securely in place. A sharp cutting edge on the ax is a must. As soon as the head is removed, the bird should be hung by its legs to promote thorough bleeding and to prevent it from becoming bruised or soiled from thrashing about on the ground.

A second method for killing is to suspend the live duck head-down with leg shackles or in a killing cone. Grasp the bill firmly with one hand; with the other stun the bird with a stout stick. With a sharp knife, cut the throat about an inch below the base of the bill, on the left side, severing the left jugular vein. The head provides a convenient handle if the duck is going to be scalded.

To avoid discolored meat in the dressed product, it is vital that ducks are bled *thoroughly* before they are processed further.

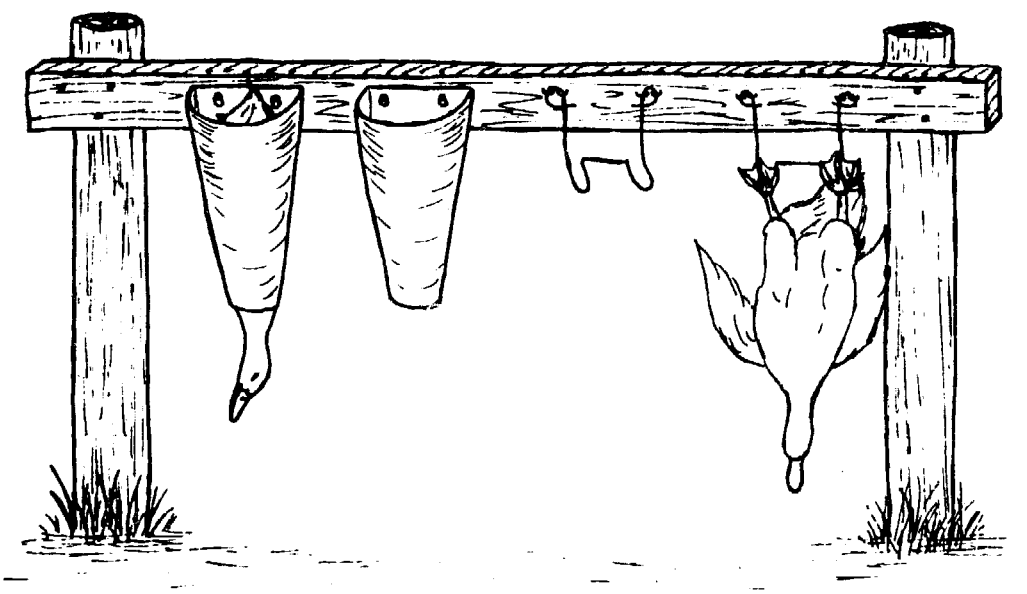

Killing cones and leg shackles

PICKING

The sooner a duck is picked after it is bled, the easier the feathers will come out.

Dry Picking

The best quality feathers for filler material and the most attractive carcasses are obtained when ducks are dry picked. Novices often find this method unbearably slow. Veterans, on the other hand, can dry pick a duck clean in three minutes or less. One secret for success is to extract feathers in the same direction they grow. Pulling feathers against the grain invariably results in torn skin. For a better grip, lightly dust the duck with resin, or periodically moisten your hands with water. The large plumes of the wings and tail need to be plucked out one or two at a time.

Because feathers and down float in every direction when waterfowl are dry picked, choose a setting that is free from drafts. Picking into a large plastic garbage bag and covering the floor around the plucking area with newspapers are helpful in keeping feathers under control.

Scald Picking

The most common method for defeathering ducks is to scald them prior to picking. The only equipment needed is a large container in which to submerge an entire duck, and a forked branch (or a 1″ × 2″ × 24″ board with a large nail driven in at an angle near one end) which is used to hold the bird under water.

To scald, hold the duck by its feet and wedge the neck into the fork of the stick. Then dip the bird up and down in water that is 125° to 145° F., making certain that the water penetrates through to the skin. To improve the wetting ability of the scalding water, a small amount of detergent can be added.

The scalding time for ducks varies from one to three minutes, depending on the age of the bird and the temperature of the water. Mature ducks require longer and hotter scalds than ducklings. If you find that the feathers are still difficult to remove after the initial scald, the bird can be redipped. Overscalding causes the skin to tear easily and discolors the carcass with dark blotches.

Ducks should be picked immediately after scalding, starting with the wing and tail feathers. Because the feathers are going to be hot, have a bucket of cold water nearby to dip your hands into occasionally.

If your first attempts at scald picking poultry do not produce carcasses that are as attractive as those that are processed commercially, don't get discouraged. Your results should improve once you've gained a little experience.

Feathers from scalded ducks are of good quality when handled correctly (see Care of Feathers, page 120).

Wax Picking

A popular variation of the scalding method is to dip rough-picked ducks in hot wax. Even when birds with a moderate number of pin feathers are butchered, this procedure can produce clean carcasses in a short time. Paraffin or a mixture of one part beeswax to one part paraffin can be used. There are also products such as Dux-Wax which are made specifically for this purpose and are available from poultry supply distributors. (See Appendix H, page 164.)

When wax is used, ducks are scalded without detergent in the water, and rough-picked by removing the large tail and wing feathers and 50 to 90 percent of the body plumage. Prior to scalding, place a container of solidified wax in a large receptacle of hot water where it is melted and heated to a temperature of 150° to 165° F. *Extreme care* must be taken when working with hot wax to avoid burns and fires.

Rough-picked ducks are partially dried and then dipped into the hot wax several times. Spray with cold water or wait long enough between each dunking to allow sufficient congealing to build up a good layer of wax. If only a few birds are being dressed, you may find it simpler to melt a small container of wax to be poured over the carcasses.

Submerging the waxed duck in cold water causes the wax to harden and grip the feathers. The wax and feathers are then stripped off together, resulting in a finished product that is clean and attractive. Birds that are extra pinny can be rewaxed.

Used wax can be recycled by melting it and skimming off the feathers and scum, and boiling out any existing water.

SINGEING

After ducks are picked, long hair-like filament feathers usually remain. The simplest way to remove these filoplumes is to pass the carcasses quickly over a flame, being careful not to burn the skin. A jar lid with a thin layer of rubbing alcohol in the bottom gives the best flame I know of for singeing. Alcohol burns tall, cleanly and odor-free. Newspapers (do not use colored sheets) loosely rolled into a hand torch, gas burners and candles can also be used.

SKINNING

Ducks can be skinned rather than picked. Some advantages of this technique are that ducks with pin feathers can be dressed as easily as those in full-feather

and some people find skinning less time-consuming than picking. Because skin is composed largely of fat, skinning significantly reduces the fat content of the dressed duck.

The major drawbacks of this method are that skinned carcasses lose much of their eye appeal when roasted whole, special precautions must be taken in cooking the meat to prevent dryness, some flavor is lost and a higher percentage of the bird is wasted.

To prepare a duck for skinning, remove its head, feet and the last joint of each wing. With the bird resting on its back, slip the blade of a small, sharp knife under the skin of the neck, and slit the skin the length of the body, cutting around both sides of the vent. The final step is to peel the skin off, which requires a good deal of pulling. Over stubborn areas, a knife is needed to trim the skin loose.

EVISCERATING

Ducks can be drawn immediately after they have been defeathered, or they can be chilled in ice water for several hours or hung in a cool (33° to 36° F.) location to ripen for six to twenty-four hours. Chilling the carcasses first has the advantage of making the cleaning procedure less messy, while aging before eviscerating produces stronger-flavored meat, which is preferred by some people.

With the bird resting on a clean, smooth surface (we use our dishrack drainboard), remove the feet, neck and oil gland, making certain that *both* yellowish lobes of the oil gland are cut out. Then make a shallow three-inch-long horizontal incision between the end of the breastbone and the vent, being careful not to puncture the intestines that lie just under the skin.

Through the incision insert your hand into the body cavity and gently loosen the organs from the inside walls of the body, and pull them out. Cut around the vent to disconnect the intestines from the carcass. The gizzard, heart and liver should be cut free and set aside before the unwanted innards are discarded.

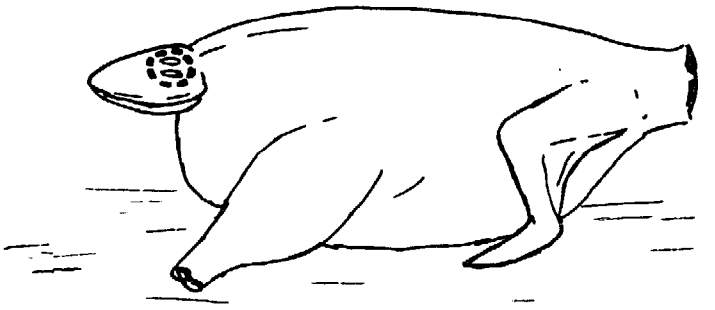

Cutting out the oil gland

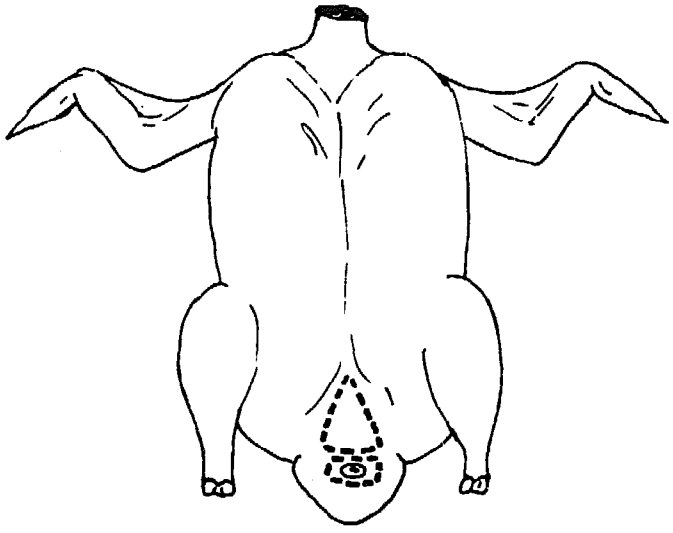

Cutting bird for eviscerating
. . . above and around vent

The esophagus (ducks do not have true crops) and windpipe are well-anchored in the neck and require a vigorous pull to remove them. The pink, spongy lungs are located against the back among the ribs and can be scraped out with the fingers if you desire.

To clean gizzards, cut around their outside edge and then pull the two halves apart. The inner bag with its contents of feed and gravel can then be peeled away and discarded. The final step is to rinse the muscular organ with water.

The gall bladder, a small green sac, is tightly anchored to the liver and should be removed *intact* since it is filled with bitter bile. A portion of the liver must be cut off along with the gall bladder so bile does not spill onto edible meat.

Unwanted feathers and body parts make excellent fertilizer and should be buried near a tree or in the garden. *Do not feed raw innards to cats and dogs. If you give uncooked entrails to your pets, they can develop a taste for poultry* and may kill birds to satisfy their cravings.

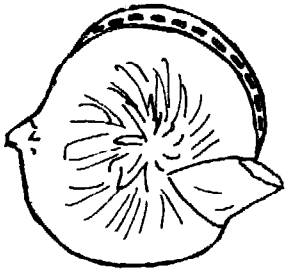

Cutting open gizzard

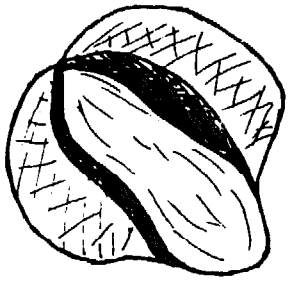

Taking out contents

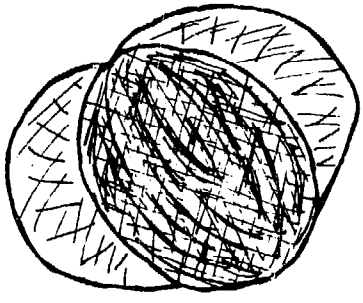

Cleaned gizzard

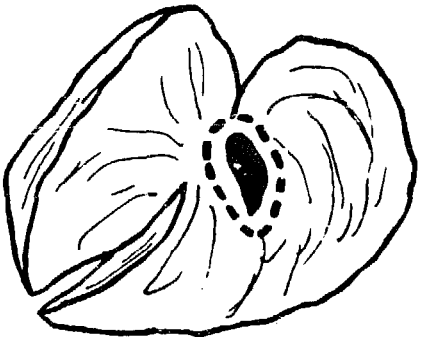

Incision to remove green gall bladder from liver

COOLING THE MEAT

After all the organs have been removed, thoroughly wash the carcass and chill it to a temperature of 34° to 40° F. as soon as possible. If meat is cooled slowly, bacteria may grow, causing spoilage and unpleasant flavor. Poultry can be chilled in ice water or air-cooled by hanging the carcasses in a refrigerator or in a room with a temperature of 30° to 40° F.

PACKAGING AND STORING MEAT

After the body heat has dissipated from the carcasses, they should be sealed in airtight containers. If the meat was chilled in water, it should be allowed to drain for ten to twenty minutes before it is packaged. To retain the highest quality in meat that is going to be frozen, suck the air from plastic bags with a straw or vacuum cleaner before sealing. To produce the tenderest meat, poultry must be aged twelve to thirty-six hours at 33° to 40° F. before it is eaten or frozen.

CARE OF FEATHERS

Duck feathers are a valuable by-product of butchering. If you plan to save the feathers, keep the down and small body feathers separate from the large stiff plumes of the wings, tail and body as the slaughtered birds are being picked.

When ducks are scalded prior to picking, the feathers need to be washed with a gentle detergent, rinsed thoroughly in warm water, and spread out several inches thick on a clean, dry surface or loosely placed in cloth sacks and hung in a warm room. Stir the wet feathers daily to fluff them and insure rapid drying. Once they are well-dried, feathers can be bagged and stored in a clean, dry location. (See Appendix F, page 157, for instructions on how to use feathers.)

BUTCHERING CHECK LIST

1. Remove the ducks' feed four to six hours before they are killed.
2. Sharpen all cutting tools.
3. When catching ducks prior to butchering, keep them calm and handle them carefully to avoid discolored meat due to bruises.
4. Hang slaughtered ducks in killing cones or by their feet to avoid bruising or soiling the meat and to insure thorough bleeding.
5. Remove feathers as soon as possible after birds are bled.
6. Singe off filament feathers.
7. Trim out the oil gland from the base of the tail.
8. Cut off feet and shanks at hock joints; remove neck.
9. Make a horizontal incision between the vent and the end of the breastbone, and gently lift out innards.
10. Set aside the heart, gizzard and liver before disposing of unwanted innards.
11. Pull out the windpipe and esophagus from the neck/chest area.
12. Extract the lungs from between the ribs.
13. Rinse the carcass thoroughly with clean, cold water.
14. Clean the gizzard and carefully remove the gall bladder from the liver.
15. Chill dressed duck to an internal temperature of 40° F.
16. Bury unwanted body parts, entrails and feathers in the garden or near a tree.
17. Age the meat for twelve to thirty-six hours at 33° to 40° F. prior to cooking or freezing.
18. Package and freeze the meat, or enjoy a festive banquet of roast duck.

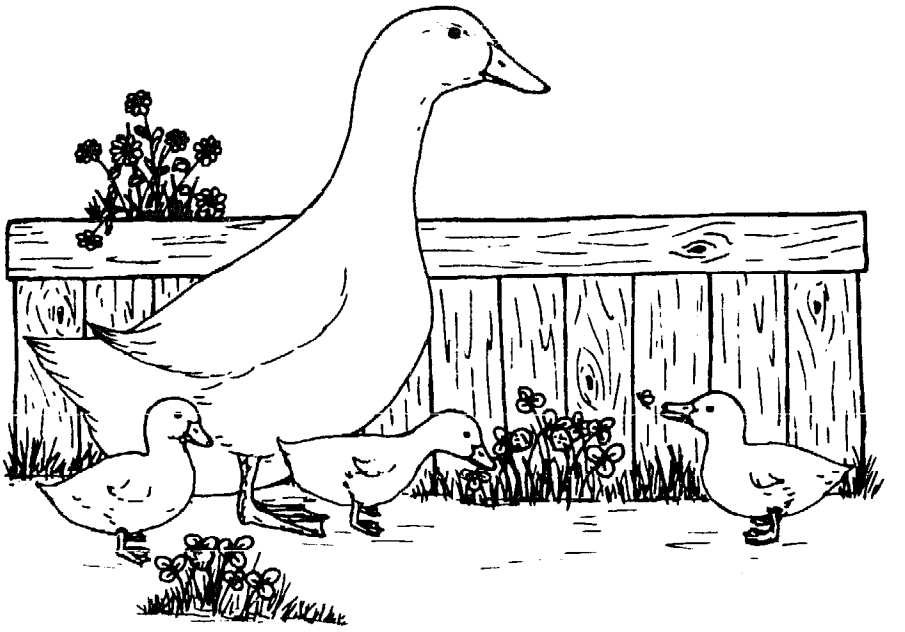

CHAPTER 11

Health and Physical Problems

Ducks in small flocks are rarely bothered by poor health. When problems do arise, they can often be traced to diet deficiencies, although stagnant drinking water, medicated feeds, moldy bedding, or overcrowded and filthy conditions can also be the source of illness.

If a problem does appear and you are unable to diagnose the trouble, advice should be sought *at once* from an experienced duck breeder, veterinarian or animal diagnostic laboratory. Waiting to see if an ailment will cure itself can be fatal for the duck.

Sick or injured birds should be isolated in a dry, clean pen, and provided a balanced diet and clean drinking water. Remove dead birds *immediately* to avoid the possibility of attracting predators and, in the case of communicable disease, to curb the likelihood of infecting healthy ducks. Bury carcasses deep enough that they will not be dug up by scavengers.

The following ailments are the ones that are the most common in small duck flocks. Nearly all of these conditions can be diagnosed and treated at home.

BOTULISM

Cause. This deadly food poisoning is caused by a toxin commonly found in decaying animal and plant matter. Botulism most frequently strikes when

the weather has been dry and water levels in ponds and lakes drop, leaving decaying plants and fish exposed where ducks find and eat them. Ducks can contract botulism if they are given spoiled canned foods from the pantry.

Symptoms. A few hours after eating poisoned food, birds may lose control of their leg, wing and neck muscles. Body feathers frequently loosen and are easily extracted. Ducks that are swimming when paralysis of the neck develops often drown before they are able to climb out on land. Dying birds may slip into a coma several hours before expiring. Botulism kills in three to twenty-four hours, although in mild cases, birds may recover in several days.

Treatment. Confine ill ducks to a clean yard and provide fresh drinking water *immediately*. Assist any birds that cannot drink on their own. Giving a laxative consisting of a half-cup molasses in each gallon of drinking water for approximately four hours, or individual doses of one-half to one teaspoon of castor oil, often helps. Epsom salts—one pound per five gallons of drinking water—has also been recommended as an effective treatment. A vaccine has been developed, but is rather expensive and often difficult to obtain on short notice. Every effort must be made to locate the source of the poisoning so that future problems can be avoided.

Prevention. Bury carcasses of dead animals and clean up rotting vegetation. Do not let your ducks feed in stagnant bodies of water during dry periods.

EVERSION OF THE OVIDUCT

Cause. This ailment can be the result of a hen straining to lay an unusually large egg or can be caused by oviduct muscles being weakened due to premature or high egg production or obesity. Unfortunately this disorder occurs most frequently among the best layers.

Symptoms. A hen with this problem is easily identified by her droopy appearance and the expelled oviduct protruding from her vent.

Treatment. An ailing hen can be saved only if she is discovered within several hours after the oviduct is dislodged and *prompt* action is taken. Even then, her chances of healing are marginal.

To treat, wash the oviduct thoroughly with clean, warm water. Apply an antiseptic ointment, then gently push the organ back into place. Confine the hen in a clean pen for several days. To give the muscles a chance to heal, the hen should be fed small quantities of feed that will discourage laying.

Hens that are not valuable enough for treatment should be killed immediately and dressed for meat or buried. Left unattended, they will suffer a slow, painful death.

Prevention. Do not push pullets to begin laying before they are mature (twenty to twenty-four weeks) and make sure hens are not excessively fat. To

keep the oviduct of high-producing hens healthy and lubricated, mix cod liver oil (one teaspoon per bird) with the feed one day a week.

FEATHER EATING

Cause. Cannibalism is most prevalent among ducklings, especially Muscovies, that are brooded artificially. It can be the result of high brooding temperature, excessive light, overcrowding, an unbalanced diet, insufficient quantities of feed or lack of roughage.

Symptoms. Birds pull out and eat one another's feathers.

Treatment. At the first sign of feather eating, check brooder temperature, reduce the intensity of light (using blue bulbs often helps), and provide ducklings with sufficient space, a balanced diet, adequate quantities of feed and tender green foods such as grass, clover and dandelions.

Prevention. Correct brooding temperature; dim, colored lights; sufficient floor space; a balanced diet and the daily feeding of greens eliminate this disgusting problem.

FOOT PROBLEMS

Cause. The bottoms of the feet of waterfowl are more tender than those of land-dwelling birds such as chickens. Foot problems can be the result of ducks bruising the pads of their feet or from spending much of their time on dry, hard surfaces without having access to bathing water. However, the most common cause, although not usually recognized, is a dietary deficiency in biotin, pantothenic acid or one of the other vitamins or minerals that are important in maintaining healthy skin.

Symptoms. Large corns and rough calluses develop on bottoms of feet. In severe cases, deep, bleeding cracks are evident and/or the pads of the feet swell and become infected (commonly known as bumble foot), causing the bird to go lame.

Treatment. If it is suspected that the problem is the result of a deficient diet, supplement the bird's rations with a vitamin premix or feedstuffs, (such as brewer's dried yeast, whey, dried skim milk or alfalfa meal), that are rich in vitamin A, biotin and pantothenic acid.

If the foot is inflamed, open the callus with a sharp, sterilized instrument, remove the pus or core, and disinfect the incision with rubbing alcohol. Place the duck in a clean pen that is bedded down with a thick layer of straw. Provide a balanced ration, green feed and at least a small container (a dish pan will suffice) of bathing water. The daily washing, disinfecting and application of a moisturizer may facilitate healing.

Rough, cailoused feet such as these are often the result of a diet deficient in biotin, pantothenic acid and/or riboflavin.

Prevention. Ducks who receive a balanced diet seldom develop foot problems. Access to succulent pasture and bathing water reduces its occurrence.

HARDWARE DISEASE

Cause. Nails, bits of wire or pieces of string are swallowed by birds. When ingested, these objects often impact or puncture some portion of the digestive system.

Symptoms. Birds slowly lose weight, stop eating and sit with eyes partially closed, apparently in severe pain. When a post-mortem is performed, the hardware is often found lodged in the esophagus or gizzard.

Treatment. There is no practical remedy for hardware disease, unless the problem is a crop (esophagus) impaction, often called pendulous crop, caused by ingestion of string or tough green feed. In this case the crop can be slit open and the object removed. Afterwards, limit food intake until muscle tone returns.

Prevention. Never leave nails, wire or string where birds can reach them. Unfortunately, it takes only *one* misplaced nail to cause the death of a valuable bird. Whenever hardware is being used in an area to which birds have access, every effort should be made to retrieve bits and pieces that are dropped.

MALNUTRITION

Cause. Malnutrition can be caused either by an incomplete diet or an insufficient quantity of feed. It occurs most frequently when birds are raised in buildings or grassless yards and are fed nothing but grains or inadequate chicken rations.

Symptoms. In ducklings, malnutrition can be detected by stunted growth, wide variation in body size, retarded feather development, leg weakness and emaciated birds with little resistance to disease or parasites. Adult ducks that are undernourished produce poorly, have rough-looking feathers, may be thin and are susceptible to disease and parasites.

Treatment. Provide an ample quantity of food that supplies a balanced diet. (See Nutrition, Chapters 8 and 9.)

Prevention. Do not try to save money by starving ducks or by using a cheap feed that does not furnish a complete diet. If you are feeding grains, make sure the birds have access to a plentiful supply of grass and insects, or a protein, vitamin and mineral concentrate.

MEDICATION POISONING

Cause. Ducks are frequently poisoned when fed medicated chicken or turkey feeds. The problem seems to stem from the fact that in proportion to their body weight, ducks eat more feed than land fowl, getting an overdose of the medication. If ingested in the correct dosages, these drugs do not affect ducks any differently than chickens or turkeys.

Symptoms. Birds (usually ducklings that are brooded in close confinement) lose their appetites, become weak, have stunted growth or die suddenly.

Treatment. At the first sign of any of these symptoms, switch to a nonmedicated ration. If medicated feeds must be used, dilute the potency of the drug by providing an abundant supply of succulent greens and mix rolled, cracked or small, whole grains with the feed.

Prevention. Unless you have no other choice, do not use medicated rations, particularly if the birds are not able to forage some of their own nourishment.

NIACIN DEFICIENCY

Cause. Ducklings are maintained on a diet deficient in niacin.

Symptoms. Birds develop weak or bowed legs, and often show stunted

growth. (Rickets, sometimes confused with niacin deficiency symptoms, is caused by a vitamin D_3 deficiency.)

Treatment. Ducks exhibiting mild symptoms of a niacin deficiency can usually be cured by the immediate addition of a niacin supplement (see Niacin Requirements, page 78) to their feed or drinking water. In severe cases, ducklings may become so crippled that they are worthless and must be destroyed.

Prevention. When allowed to forage in pastures and bodies of water where there is an abundant supply of insects, ducklings are seldom bothered by this malady. If raised in close confinement, they must be fed a niacin-rich diet.

PARASITES, EXTERNAL

Cause. Lice and mites seldom multiply on waterfowl, particularly those with access to bathing water, in large enough numbers to cause ill effects. However, ducklings that are hatched and brooded by chicken or turkey hens can harbor heavy infestations of external parasites.

Symptoms. Parasites are visible on birds if you look closely, particularly on the head and wings, and around the vent and oil gland. Infected ducks lose weight, grow slowly and are anemic.

Treatment. Use olive oil, pulverized dried tobacco leaves or a commercial preparation such as Sevin Dust or Malathion. To be effective, these products need to be worked into the feathers of the head, neck, wings, upper tail and vent. When you are dusting with an insecticide, be *extremely* careful not to contaminate water or feed with the poison.

Prevention. Provide bathing water or treat birds before lice or mites are present in large enough numbers to be harmful. Turkey and chicken hens used as foster mothers for ducklings should *always* be treated for lice.

PARASITES, INTERNAL

Cause. Healthy ducks consume such large volumes of water that worms are usually flushed out of their digestive systems faster than the parasites can reproduce. Worms are usually a problem only when ducks have access to stagnant water and crowded ponds or small streams, or when they are forced to live in a filthy environment.

Symptoms. An infestation of worms retards growth, lowers feed conversion and reduces egg production. In severe cases, these symptoms are accompanied by a loss of body weight and eventually death.

Treatment. Poultry worm medications that are added to the drinking water are readily available. Some people have suggested diatomaceous earth and

chewing tobacco as alternative remedies. Because many of the wigglers will be passed alive, the ducks should be closed in a small pen for twenty-four hours after being wormed. The bedding should then be cleaned up and disposed of, preferably by burning.

Prevention. Provide fresh drinking water and reasonably sanitary living quarters. As a precaution, birds can be routinely wormed once or twice yearly.

PHALLUS PROSTRATION

Cause. A wild drake normally pairs off with a single hen and is sexually active for a relatively short period of time each spring. Under domestication, males are frequently mated with two to seven hens and breed over an extended season. This unnaturally long mating season, or possibly a genetic weakness, occasionally causes a drake to lose the ability to retract his penis.

Symptoms. The penis—a 1½-inch long, coiled organ—protrudes from the bird's vent.

Treatment. Under most circumstances, a drake with this disability should be killed *immediately*. If the bird is valuable and his problem is discovered before the penis has become infected or dried out, there is a possibility of recovery. To treat, wash and then disinfect the organ with an antibacterial ointment and isolate the drake where he has clean swimming water. Keep the bird in isolation and apply the ointment daily until he is fully recovered, which may require several weeks or longer.

Prevention. The best safeguard is to have an extra drake so that if one develops this prostration, you'll have a backup male for breeding purposes.

SLIPPED WING

Cause. A genetic weakness, diet deficiency or extremely fast growth can cause slipped wings.

Symptoms. The tip of one or both wings folds on the outside of the pinion, rather than resting smoothly against the bird's sides.

Treatment. When prompt action is taken, it is sometimes possible to repair slipped wings of ducklings by folding the feathered limb in the correct position and taping it shut. Because the wing will become stiff from disuse, the bandage should not be left on for more than four or five days at a time.

Prevention. The occurrence of slipped wing can be reduced by using only normal-winged breeding stock, and by making sure ducklings consume a

A Black Swedish duck with slipped wings.

balanced diet. Birds with this deformity are fine for meat or the production of eating eggs.

SPRADDLED LEGS

Cause. Spraddled legs are usually the result of smooth incubator trays or brooder floors where ducklings have poor footing, but this problem can also be the result of a birth defect.

Symptoms. Birds are crippled by weak legs that slide out from under them as they try to walk.

Treatment. Severe cases of spraddled legs are difficult to correct. Ducklings with mild cases are sometimes rehabilitated by placing them on a rough surface that gives good footing—wood excelsior pads as used in chick boxes, grass turf or coarse burlap are excellent for this purpose. Tying a short piece of yarn between the duck's legs for two or three days is also helpful. When hobbles are used, don't tie them so tightly that blood circulation to the feet is restricted.

Prevention. Slick surfaces on which ducklings walk must be covered with a

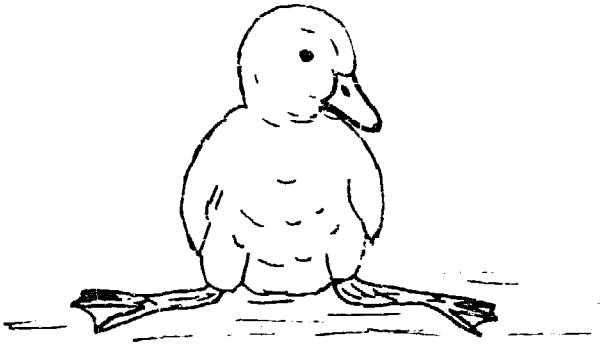

Spraddled legs

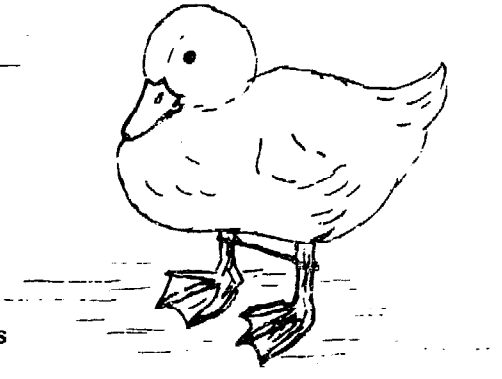

Hobbled legs

rough material such as wire hardware cloth or burlap for the first week after the birds hatch.

STICKY EYE

Cause. In their natural habitat, ducks consume foods high in vitamin A, pantothenic acid and biotin, and have access to clean bathing water. Under domestication, waterfowl are often raised on diets deficient in vitamins and are supplied water in shallow containers which do not permit the birds to rinse their eyes. The result is that ducks raised in confinement are susceptible to ophthalmia, a low-grade infection in one or both eyes which is referred to as sticky eye.

Symptoms. A yellowish discharge mats down the feathers around the eye and may cause the eyelids to stick shut. Sticky eye is most prevalent among ducklings that are raised indoors.

Treatment. As soon as opthalmia is detected, ducks should be fed fresh greens and given a vitamin supplement until the problem clears up. Providing clean drinking water deep enough for the birds to submerge their heads, and the daily application of a medicated eye ointment speed the recovery in some cases. If sticky eye is not cured promptly, the infection can linger for the duration of the bird's life and cause blindness.

Prevention. If ducklings are raised in confinement and not fed a ration formulated specifically for waterfowl, fortify their diets with a vitamin premix or

Adult drake with a chronic case of sticky eye

other substances (such as alfalfa meal, brewer's dried yeast or green feed) that are high in vitamin A, biotin and pantothenic acid. Disinfect water containers weekly.

APPENDICES

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APPENDIX A

Formulating Duck Rations

Feed mills often have someone on their staffs who is trained in formulating livestock and poultry feeds. However, with the aid of a hand calculator and by using the information in this appendix, you should be able to devise good duck rations that utilize readily available local ingredients. While ration formulation requires several hours of work, it can save you considerable money on your feed bill.

The purpose of this section is to present the basic nutrient requirements of ducks and explain how to formulate rations. If you are interested in the whys of nutrition, see Appendix I, page 166, for sources of information.

USING THE FORMULA CHART

The formula chart (see Table 22) is a convenient and orderly means by which rations can be computed. Ingredients and their values for protein, energy, fiber, etc., are taken from Table 21 (or similar chart) and written or typed into the proper columns of the formula chart. The percentage (which should be expressed as a decimal, e.g., 73 percent wheat ÷ 100 = .73) at which each ingredient is going to be included in a ration is then multiplied times the various nutrients of the ingredient.

Once the protein values have been calculated for each ingredient, they should be added up to see if the protein content of the ration compares favorably with the recommendations given in Table 20. Once the proper protein content has been obtained, the values for energy, fat, fiber, minerals, vitamins and amino acids should be computed and compared with Table 20.

CONVERTING KILOGRAMS TO POUNDS

In many publications containing information showing the average composition of feedstuff for poultry (similar to Table 21), the values for the various nu-

trients are given in kilograms. If you'd rather work in the American Standard rather than the Metric system of weights and measures, a conversion must be made. One kilogram equals 2.2 pounds, so to convert amounts per kilogram to amounts per pound, *divide* by 2.2. Example: Wheat has approximately 3,120 kcal/kg of metabolizable energy, which if divided by 2.2 gives 1418 kcal/lb of ME. (If you want to work in the metric system, the values in Tables 20 and 21 must be converted from pounds to kilograms by multiplying by 2.2.) Those values that are given in percentages, (such as protein, calcium, phosphorus, etc.), *remain the same* no matter which system is used.

COMPUTING THE CALORIE:PROTEIN RATIO

Birds eat primarily to meet their energy needs. To guard against over-or-under-consumption of protein by ducks, rations must have the proper calorie-to-protein ratio (see Table 20). To compute this ratio, divide the metabolizable energy (kcal per pound of feed) by the protein percentage of the ration (e.g., 1278 kcal of energy ÷ 15.8 percent protein = 80.9).

THE PHOSPHORUS:CALCIUM RATIO

In order for ducks (particularly young ones) to utilize phosphorus and calcium effectively, these two minerals must be included in feeds in the proper proportions. An imbalance of phosphorus and calcium can result in stunted growth, rickets and other bone deformities, and in acute cases, lead to death.

For ducklings and non-producing adults, the correct ratio of total phosphorus to calcium is in the range of 1:1 to 1:1.5 (P:Ca), with 1:1.2 considered ideal. For laying birds, the ratio should fall between 1:4 and 1:5.

To compute the phosphorus:calcium ratio of a ration, divide the amount of calcium by the quantity of total phosphorus. Example: A starting ration contains .80 percent calcium and .65 percent phosphorus (.80 ÷ .65 = 1.2 which is equal to a P:Ca ratio of 1:1.2).

USING A PROTEIN CONCENTRATE

In many instances, the simplest method for preparing a balanced and economical ration at home is by mixing a commercial protein concentrate with locally grown grains. If fortified with additional niacin, concentrates formulated for chickens normally work satisfactorily for ducks as well.

To calculate the proportions of concentrate to grains that should be used, Pearson's Square Method can be employed. Example: You have a concen-

trate that is 40 percent protein and [illegible] to blend it with soft wheat (approximately 10 percent protein) to get a 16 percent protein laying ration.

10% protein in wheat		24 parts of wheat
	16% protein desired	
40% protein in the concentrate		6 parts of concentrate

To obtain the correct proportions of wheat and concentrate needed, subtract the small number from the larger on each diagonal (i.e., 16 − 10 = 6 parts concentrate and 40 − 16 = 24 parts wheat). Then divide the parts of each by the total number of parts and multiply by 100 to get the percentage at which each ingredient should be used:

$6 + 24 = 30$ total parts
$6 \div 30 = .2 \times 100 = 20$ percent of protein concentrate needed
$24 \div 30 = .8 \times 100 = 80$ percent of wheat needed

TABLE 20
RECOMMENDED NUTRIENT LEVELS FOR COMPLETE DUCK RATIONS (PELLETED)[1]

(Expressed as a percentage or amount per pound of feed)

Nutrient	*Starter 0-2 Wks.*	*Grower-Finisher 2-7 Wks.*	*Breeder Devel-oper*	*Breeder Layer*	*Holding Ration*
*Metabolizable energy (kcal/lb)[2]	1400	1400	1400	1300	1400
*Energy:Protein ratio	70	88[3]	88	81	100
*Fat, minimum (%)	3.0	2.5	2.0	2.0	1.5
*Fiber, maximum (%)	4	5	6	6	7
*Protein, minimum (%)	20	16	16	16	14
Amino Acids:					
Arginine (%)	1.25	1.00	1.00	0.95	0.83
Glycine + serine (%)	1.12	0.90	0.90	0.85	0.74
Isoleucine (%)	0.44	0.35	0.35	0.30	0.26
Histidine (%)	0.88	0.70	0.70	0.65	0.57
Leucine (%)	1.63	1.30	1.30	1.20	1.05
*Lysine (%)	0.94	0.75	0.75	0.70	0.62
*Methionine + cystine (%)	0.75	0.60	0.60	0.55	0.48
*Methionine (%)	0.44	0.35	0.35	0.30	0.26
Phenylalanine + tyrosine (%)	1.63	1.30	1.30	1.20	1.05
Phenylalanine (%)	0.88	0.70	0.70	0.65	0.57
Threonine (%)	0.75	0.60	0.60	0.55	0.48
Tryptophan (%)	0.24	0.19	0.19	0.17	0.15
Valine (%)	1.00	0.80	0.80	0.75	0.66
Vitamins (fat soluble):					
*Vitamin A (IU)	4750	3250	3250	4750	3250
*Vitamin D_3 (ICU)	500	400	400	400	400
*Vitamin E (IU)	12	8	8	15	8
*Vitamin K (mg)	1.0	0.5	0.5	1.0	0.5

[1]Nutrient levels shown in this table apply only to the energy level specified. For rations containing different energy concentrations, compensations in the quantities of amino acids, vitamins and minerals should be made to guard against over- or under-consumption of these nutrients. If your ration has a lower energy level than given in this table, the amounts of the other nutrients can likewise be reduced to avoid waste. Example: Your ration has an energy level of 1260 kcal/lb, which is 90% of 1400 kcal/lb (1260 ÷ 1400 = .9 × 100 = 90%). Therefore, all nutrients can be reduced by approximately 10% and the birds will still ingest the proper quantities of all nutrients.

[2]The energy concentration given is only an example. The energy concentration of rations may vary from 1000 to 1500 kcal/lb, provided the concentration of each nutrient per unit of energy remains the same. The energy level chosen should be the one at which least cost per unit of energy is achieved.

[3]To produce ducklings with less fat, the energy:protein ratio can be lowered to 65 or less.

[4]Most of the niacin in plants is unavailable to birds.

[5]Rations based on wheat, milo or barley are often deficient in linoleic acid, necessitating the addition of an ingredient rich in this fatty acid, such as one of the vegetable oils.

Nutrient	Starter 0-2 Wks.	Grower-Finisher 2-7 Wks.	Breeder Devel-oper	Breeder Layer	Holding Ration
Vitamins (water soluble):					
Thiamine (mg)	1.25	1.25	1.25	1.25	1.25
*Riboflavin (mg)	3.75	2.25	2.25	3.75	2.25
*Pantothenic acid (mg)	7	6	5	7	5
*Niacin, available (mg)[4]	35	30	25	35	25
Pyridoxine (mg)	1.45	1.45	1.45	1.65	1.45
Biotin (mg)	0.09	0.06	0.06	0.09	0.06
*Choline (mg)	800	700	450	450	450
Folacin (mg)	0.35	0.20	0.20	0.25	0.20
*Vitamin B_{12} (mg)	0.006	0.005	0.004	0.004	0.004
Linoleic acid (%)[5]	01.0	0.8	0.8	1.0	0.8
Minerals:					
*Calcium, minimum (%)	0.70	0.60	0.60	2.75	0.60
*Calcium, maximum (%)	1.00	1.00	1.00	3.00	1.00
Phosphorus, total (%)	0.65	0.60	0.60	0.65	0.60
*Phosphorus, available (%)	0.40	0.35	0.35	0.40	0.35
Potassium (%)	0.4	0.4	0.3	0.2	0.2
*Sodium (%)[6]	0.17	0.14	0.14	0.14	0.14
Chlorine (mg)[6]	400	400	400	400	400
Copper (mg)	2.0	1.5	1.5	2.0	1.5
Iodine (mg)	0.20	0.20	0.20	0.18	0.18
Iron (mg)	40	20	20	30	20
Magnesium (mg)	275	275	275	275	275
*Manganese (mg)	25	25	25	20	20
Selenium (mg)[7]	0.06	0.06	0.06	0.06	0.06
*Zinc (mg)	15	15	15	15	15

[6]These recommendations are for birds receiving low salt drinking water. The salt content of rations should be reduced if drinking water contains above average levels of sodium chloride.

[7]Grains grown in areas where the soil is of volcanic origin, often are deficient in selenium.

*Denotes the nutrients that are of greatest concern when formulating rations. Usually, if these are balanced, the others will be satisfactory.

Note: Information in this table was adapted from Extension Stencil #25 (1969) "Duck Rations," and updated information, (1972 and 1973) with permission of Cornell University Duck Research Laboratory; and from *Nutrient Requirements of Poultry*, 7th revised ed., (1977), pages 30 and 33, with the permission of the National Academy of Sciences, Washington, D.C.

KEY: IU = International Units
ICU = International Chick Units
mg = milligram
kcal = kilocalories

TABLE 21
AVERAGE COMPOSITION OF SOME COMMONLY USED FEEDS FOR POULTRY

Line No.	Feedstuff	Protein %	Energy kcal/lb	Crude Fat %	Crude Fiber %	Calcium %	Total Phosphorus %	Avail. Phosphorus %	Sodium %	Manganese mg/lb
	Alfalfa meal, dehydrated									
1	17% Protein	17.5	622.73	2.0	24.1	1.44	0.22	0.22	0.12	13.6
2	20% Protein	20.0	740.91	3.6	20.2	1.67	0.28	0.28	0.13	19.2
3	Barley	11.6	1200.00	1.8	5.1	0.03	0.36	0.11	0.04	—
4	Barley, Pacific Coast	9.0	1190.91	2.0	6.4	0.05	0.32	0.10	0.02	7.4
5	Corn, yellow	8.8	1559.09	3.8	2.2	0.08	0.28	0.08	0.02	2.3
6	Corn, Gluten meal, 41%	41.0	1336.36	2.5	7.0	0.23	0.55	0.16	0.07	4.0
7	Cottonseed meal, solvent	41.4	1090.91	0.5	13.6	0.15	0.97	0.35	0.04	9.1
8	Dicalcium phosphate	—	—	—	—	21.00	18.50	18.50	1.20	54.5
9	Distiller's dried solubles (corn)	28.5	1331.82	9.0	4.0	0.35	1.33	0.39	0.26	33.5
10	DL-Methionine, 98%	—	—	—	—	—	—	—	—	—
11	Feather meal, hydrolyzed	86.4	1072.73	3.3	1.0	0.33	0.55	0.55	0.71	9.5
12	Fish meal, herring	72.3	1450.00	10.0	0.7	2.29	1.70	1.70	0.61	2.1
13	Fish meal, menhaden	60.5	1281.82	9.4	0.7	5.11	2.88	2.88	0.41	15.0
14	Limestone, ground	—	—	—	—	38.00	—	—	0.06	112.5
15	Meat and bone meal	50.4	890.91	8.6	2.8	10.10	4.96	4.96	0.72	6.4
16	Meat meal	54.4	909.09	7.1	8.7	8.27	4.10	4.10	1.15	4.4
17	Oats	11.4	1159.09	4.2	10.8	0.06	0.27	0.08	0.08	19.6
18	Oats, West Coast	9.0	1186.36	—	11.0	0.08	0.30	0.09	—	17.3
19	Oyster shell	0.9	18.18	—	—	37.26	0.07	0.07	0.20	58.0
20	Salt, iodized	—	—	—	—	—	—	—	38.91	—
21	Sorghum, grain (milo)	8.9	1531.82	2.8	2.3	0.03	0.28	0.09	0.04	6.2
22	Soybean meal, solvent 50%	50.8	1131.36	1.1	2.9	0.29	0.65	0.20	0.01	20.9
23	Soybean meal, solvent 44%	44.0	1013.64	0.8	7.3	0.29	0.65	0.20	0.26	13.3
24	Soybean meal, dehulled	48.5	1109.09	1.0	3.9	0.27	0.62	0.19	0.25	19.5
25	Wheat, bran	15.7	590.91	3.0	11.0	0.14	1.15	0.35	0.05	51.5
26	Wheat, hard	14.1	1272.73	1.9	2.4	0.05	0.37	0.11	0.04	14.5
27	Wheat, middlings	16.0	818.18	3.0	7.5	0.12	0.90	0.28	0.12	53.6
28	Wheat, soft	10.2	1418.18	1.8	2.4	0.05	0.31	0.10	0.04	10.8
29	Whey, dried	12.0	863.64	0.8	0.2	0.97	0.76	0.76	0.48	2.8
30	Yeast, brewer's, dried	44.4	904.55	1.0	2.7	0.12	1.40	0.41	0.07	2.4

TABLE 21-Continued

Line No.	Zinc mg/lb	Vit. A IU/lb	Vit. D_3 ICU/lb	Vit. E mg/lb	Vit. K mg/lb	Riboflavin mg/lb	Pantothenic Acid mg/lb	Total Niacin mg/lb	Choline mg/lb	Vit. B_{12} mg/lb	Lysine %	Methionine %	Cystine %
1	10.9	83909	—	56.82	4.0	6.2	11.4	17.3	637	.0018	0.73	0.23	0.20
2	11.4	101000	—	65.46	4.7	6.9	15.5	18.2	645	.0018	0.87	0.31	0.25
3	7.7	—	—	9.09	—	0.8	3.6	25.0	450	—	0.40	0.17	0.19
4	6.8	—	—	9.09	—	0.7	3.2	21.8	470	—	0.29	0.13	0.18
5	4.5	1318	—	10.00	—	0.5	1.8	10.9	282	—	0.24	0.20	0.15
6	9.1	11955	—	9.09	—	0.8	4.5	22.7	421	—	0.78	1.03	0.65
7	37.3	—	—	—	—	1.8	3.2	18.2	1333	—	1.71	0.52	0.64
8	13.6	—	—	—	—	—	—	—	—	—	—	—	—
9	38.6	500	—	18.18	—	7.7	9.5	52.7	2201	—	0.90	0.50	0.40
10	—	—	—	—	—	—	—	—	—	—	—	98.00	—
11	24.5	—	—	—	—	1.0	4.5	12.3	405	.0355	1.67	0.42	4.00
12	60.0	—	—	10.00	—	4.5	7.7	42.3	2412	.1832	5.70	2.10	0.72
13	66.8	—	—	3.18	—	2.2	4.1	25.0	1389	.0473	4.83	1.78	0.56
14	—	—	—	—	—	—	—	—	—	—	—	—	—
15	42.3	—	—	.46	—	2.0	1.9	20.9	907	.0318	2.60	0.65	0.25
16	46.8	—	—	.46	—	2.5	2.3	25.9	944	.0309	3.00	0.75	0.66
17	7.7	—	—	9.09	—	0.5	—	5.5	430	—	0.50	0.18	0.22
18	—	—	—	9.09	—	0.5	5.9	6.4	436	—	0.40	0.13	0.17
19	—	—	—	—	—	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—	—	—	—	—	—
21	6.4	—	—	5.46	—	0.5	5.5	18.6	205	—	0.22	0.12	0.15
22	20.5	—	—	2.23	—	1.4	6.2	9.9	1265	—	3.19	0.74	0.83
23	12.3	182	—	.96	—	1.3	7.3	13.2	1270	—	2.93	0.65	0.69
24	20.5	—	—	1.50	—	1.3	6.8	10.0	1241	—	3.18	0.72	0.73
25	60.5	—	—	6.14	—	2.1	14.1	84.5	855	—	0.59	0.17	0.25
26	14.1	—	—	5.73	—	0.6	4.5	21.8	495	—	0.40	0.19	0.26
27	68.2	—	—	18.41	—	1.0	5.9	44.5	654	—	0.69	0.21	0.32
28	12.7	—	—	6.00	—	0.5	5.0	25.9	455	—	0.31	0.15	0.22
29	1.4	—	—	.09	—	12.3	20.0	4.5	622	.0105	0.97	0.19	0.30
30	17.7	—	—	—	—	16.8	49.5	203.6	1811	—	3.23	0.70	0.50

Note: Information in this table was reproduced from *Nutrient Requirements of Poultry*, 7th revised ed., (1977), pages 42-45, with the permission of the National Academy of Sciences, Washington, D.C.

TABLE 22
SUGGESTED FORMAT FOR FORMULA CHARTS

Formula #: 19 Type of Ration: Corn Base Breeder Calorie:Protein Ratio: 81.3:1

Ing. #	Ingredient	% in Mix	Protein %	Protein Amt.	Met. Energy kcal/lb	Met. Energy Amt.	Calcium %	Calcium Amt.	Total P %	Total P Amt.	Avail. P %	Avail. P Amt.	Vit. A IU/lb	Vit. A Amt.
5	Corn, yellow	.7075	.008	.06226	1559	1102.9925	.0002	.0001415	.0028	.001981	.0008	.000566	1318	932.485
22	Soybean meal, solv. 50%	.151	.508	.076708	1131	70.781	.0029	.0004379	.0065	.0009815	.002	.000302		
15	Meat and bone meal	.04	.504	.02016	891	35.64	.1010	.00404	.0496	.001984	.0496	.001984		
1	Alfalfa meal, dehy., 17%	.02	.175	.0035	623	12.46	.0144	.000288	.0022	.000044	.0022	.000044	83909	1678.18
10	DL-Methionine, 98%	.0005												
8	Dical. Phosphate, 18.5% P	.006					.21	.00126	.185	.00111	.185	.00111		
14	Limestone flour	.0625					.38	.02375						
20	Salt, iodized	.0025												
V/M	Vit. & Min. premix	.01											400000	4000.
	Totals	1.00		.162628		1321.8735		.0299174		.0061005		.004006		6610.665

Ing. #	Vit. D ICU/lb	Vit. D Amt.	Vit. E mg/lb	Vit. E Amt.	Vit. K mg/lb	Vit. K Amt.	Riboflavin mg/lb	Riboflavin Amt.	Total Niacin mg/lb	Total Niacin Amt.	Lysine %	Lysine Amt.	Methionine %	Methionine Amt.	Cystine %	Cystine Amt.
5			10.0	7.075			.46	.3219125	10.91	7.71175	.0024	.001698	.0020	.001415	.0015	.0010612
22			2.2	.3322			1.36	.20536	9.86	1.48886	.0319	.0048169	.0074	.0011174	.0083	.0012533
15			.4	.016			2.00	.08	20.91	.836	.0260	.00104	.0065	.00026	.0025	.0001
1			56.8	1.136	3.95	.079	6.18	.1236	17.27	.346	.0073	.000146	.0023	.000046	.0020	.00004
10													.98	.00049		
8																
14																
20																
V/M	50000	500	500	5.0	100	1.0	300	3.0	2500	25						
T		500		13.5592		1.079		3.7308725		35.38261		.007709		.0033284		.0024545

APPENDIX B

Symptoms of Vitamin and Mineral Deficiencies in Ducks

Vitamin	Deficiency Symptoms*
VITAMIN A	Retarded growth; general weakness; staggering gait; ruffled plumage; low resistance to infections and internal parasites; eye infection; lowered production and fertility; increased mortality. (Adult birds develop symptoms slower than ducklings.) *Sources*: Fish-liver oils, yellow corn, alfalfa meal, fresh greens.
VITAMIN D_3	Retarded growth; rickets; birds walk as little as possible, and when they do move, their gait is unsteady and stiff; bills become soft and rubbery and are easily bent; thin-shelled eggs; reduced egg production; bones of wings and legs are fragile and easily broken; hatchability is lowered. *Sources*: Sunlight, fish-liver oils, synthetic sources.
VITAMIN E	Unsteady gait; ducklings suddenly become prostrated, lying with legs stretched out behind, head retracted over the back; head weaves from side to side; reduced hatchability of eggs; high mortality in newly hatched ducklings; sterility in males and reproductive failure in hens. *Sources*: Many feedstuffs both of plant and animal origin, particularly alfalfa meal, rice polish and bran, distiller's dried corn solubles, wheat middlings.

Summarized from *Nutrient Requirements of Poultry*, 7th revised edition (1977), pages 11-20, with the permission of the National Academy of Sciences, Washington, D.C.

* The deficiency symptoms are given in the sequence they normally evidence themselves.

Note: While work on vitamin and mineral deficiencies in poultry has been limited largely to chickens and turkeys, I have observed many of these symptoms in ducks.

VITAMIN K	Delayed clotting of blood; internal or external hemorrhaging which may result in birds bleeding to death from even small wounds. *Sources*: Fish meal, meat meal, alfalfa meal, fresh greens.
THIAMINE	Loss of appetite; sluggishness; emaciation; head tremors; convulsions; head retracted over the back. *Sources*: Grains and grain by-products.
RIBOFLAVIN	Diarrhea; retarded growth; curled-toe paralysis; drooping wings; birds fall back on their hocks; eggs hatch poorly. *Sources*: Dried yeast, skim milk, whey, alfalfa meal, green feeds.
NIACIN	Retarded growth; leg weakness; bowed legs; enlarged hocks; diarrhea; poor feather development. *Sources*: Dried yeast and synthetic sources. (Most of the niacin in cereal grains is unavailable to poultry.)
BIOTIN	Bottoms of feet are rough and calloused, with bleeding cracks; lesions develop in corners of mouth, spreading to area around the bill; eyelids eventually swell and stick shut; slipped tendon (see also choline and manganese deficiencies); eggs hatch poorly. *Sources*: Most feedstuffs, but especially dried yeast, whey, meat and bone meal, skim milk, alfalfa meal, soybean meal, green feeds. (The biotin in wheat and barley is mostly unavailable to poultry. If raw eggs are fed to animals, avidin—a protein in the egg-white—binds biotin, making it unavailable.)
PANTOTHENIC ACID	Retarded growth; viscous discharge causes eyelids to become granular and stick together; rough-looking feathers; scabs in corners of mouth and around vent; bottoms of feet rough and calloused, but lesions are seldom as severe as in a biotin deficiency; drop in egg production; reduced hatchability of eggs; poor liveability of newly hatched ducklings. *Sources*: All major feedstuffs, particularly brewer's and torula yeasts, whey, skim and buttermilk, fish solubles, wheat bran, alfalfa meal.
CHOLINE	Retarded growth; slipped tendons (see also biotin and manganese deficiencies). *Sources*: Most feedstuffs but especially fish meal, meat meal, soybean meal, cottonseed meal, wheat germ meal. (Evidence indicates that choline is synthesized by mature birds in quantities adequate for egg production.)

VITAMIN B_6	Poor appetites; extremely slow growth; nervousness; convulsions; jerky head movements; ducklings run about aimlessly, sometimes rolling over on their backs and rapidly paddling their feet; increased mortality. *Sources*: Grains and seeds.
FOLACIN	Retarded growth; poor feathering; colored feathers show a band of faded color; reduced egg production; decline in hatchability; occasionally slipped tendon. *Sources*: Green feeds, fish meal, meat meal.
VITAMIN B_{12}	Poor hatchability; high mortality in newly hatched ducklings; retarded growth; poor feathering; degenerated gizzards; occasionally slipped tendon. *Sources*: Animal products and synthetic sources.

Mineral	Deficiency Symptoms*
CALCIUM AND PHOSPHORUS	Rickets; retarded growth; increased mortality; in rare cases, thin-shelled eggs. *Sources*: Calcium—oyster shells and limestone. Phosphorus—dicalcium phosphate, soft rock phosphate, bone meal, meat and bone meal, fish meal. (Most all feedstuffs have varying amounts of calcium and phosphorus, but typically only about one-third of the phosphorus in plant products is available to birds.)
MAGNESIUM	Ducklings go into brief convulsions and then lapse into a coma from which they usually recover if they are not swimming; rapid decline in egg production. *Sources*: Most feedstuffs, especially limestone, meat and bone meals, grain brans. (Raising either the calcium or phosphorus content of feed magnifies a deficiency of this mineral.)
MANGANESE	Slipped tendon in one or both legs; retarded growth; weak egg shells; reduced egg production and hatchability. Slipped tendon (also known as perosis) is first evidenced by the swelling and flattening of the hock joint, followed by the Achilles tendon slipping from its condyles (groove), causing the lower leg to project out to the side of the body at a severe angle. (Perosis can also be the result of biotin or choline deficiencies.) *Sources*: Most feedstuffs, especially manganese sulfate, rice bran, limestone, oyster shell, wheat middlings and bran.

CHLORIDE	Extremely slow growth; high mortality; unnatural nervousness. *Sources*: Most feedstuffs, especially animal products, beet molasses, alfalfa meal.
COPPER AND IRON	Anemia. *Sources*: Most feedstuffs, including fresh greens.
IODINE	Goiter (enlargement of the thyroid gland); decreased hatchability of eggs. *Sources*: Iodine. Iodized salt contains such small quantities of iodine that it cannot be relied upon to provide sufficient iodine.
POTASSIUM	Rare, but when it occurs, results in retarded growth and high mortality. *Sources*: Most feedstuffs.
SODIUM	Poor growth; cannibalism; decreased egg production. *Sources*: Most feedstuffs, but especially salt and animal products.
ZINC	Retarded growth; moderately to severely frayed feathers; enlarged hock joints; slipped tendon. *Sources*: Zinc oxide and most feedstuffs, especially animal products.

APPENDIX C

Predators

One of the most frustrating experiences for the owner of ducks is to lose valuable birds and eggs to predators. The seriousness of this problem varies a great deal from one location to another. It is a good idea to talk with poultry keepers in your area to learn what kind of problems they have encountered and what precautions are necessary to minimize losses.

There are various species of wild and domestic animals that will prey upon ducks. Of the domestic type, dogs—and to a lesser extent, cats—are notorious for the damage they can inflict on poultry flocks. The first time one of these pets shows an interest in your ducks, they must be disciplined *immediately* if future troubles are to be avoided.

Some of the wild creatures that cause duck raisers grief are rats, ground squirrels, weasels, mink, skunks, raccoons, opossum, foxes, coyotes, turtles, snakes, crows, ravens, magpies, jays, gulls, hawks, falcons and owls. Because these animals—with the possible exception of rats—are essential in maintaining the delicate balance of nature, we must not attempt to eliminate them, but rather, need to respect them and give poultry sufficient protection so that hungry predators passing by will not be able to dine at the expense of our birds.

SECURITY MEASURES

Ducks roost on the ground, making them most vulnerable at night. Because many predators have nocturnal habits, a small building or fenced yard where ducks can be locked in after dark is a *must* in most localities. If you try to raise ducks without penning them up nightly, I can predict with almost 100 percent accuracy that your flock will be ravaged sooner or later.

A sturdy woven wire fence at least four feet high goes a long way in keeping ducks safe while they sleep. In areas where determined hunters such as raccoons and opossum are present, electric fencing can be used in combination with woven wire fences to make yards safer after sundown. To be the most effective, two strands of electric wire need to be utilized. One strand should run around the outside of the woven wire four inches above the

ground, while the second strand should be installed a couple of inches above the top of the fence.

If weasels, mink, owls and cats (wild or domestic) are prevalent in your locality, at nighttime it will be expedient to pen your ducks in a shelter having a covered top as well as sturdy sides. Some predators will dig under fences or dirt floors of houses to gain entrance to impenned birds. Burying the bottom six to twelve inches of fences that encircle yards or covering the floors of duckhouses with wire netting will keep out excavators.

Because setting hens and ducklings are especially vulnerable to predation, extra care must be taken to provide them with secure quarters. Setting hens should be encouraged to nest in shelters that can be closed at night. When hens do nest in the open, panels four feet high can be set up around them to provide protection.

IDENTIFYING THE CULPRIT

If you do lose birds or eggs, it is helpful to be able to identify the culprit in order to remedy the situation. Once predators discover a convenient source of food, they often return at *regular* intervals if permitted to do so. The following is a brief guide to help you recognize the work of some of the more common predators, with suggestions on how to stop their thievery.

Dogs

Telltale signs. A number of ducks, sometimes the entire flock, badly maimed. Check for large holes under or through fences, and clumps of dog hair caught on wire.

Stopping losses. Strong fences at least four feet high.

Cats (wild or tame)

Telltale signs. Crushed eggs held together by shell membranes. Birds disappear without a trace, or only a few feathers or clumps of down are found in a secluded spot where the animal fed.

Stopping losses. Keep ducklings in wire-covered runs until they are two to four weeks old. Domestic cats are intelligent enough that they can be taught fairly easily not to molest poultry. When a pet cat is seen stalking your birds, let the tabby know *immediately* that the ducks are off limits. Throwing a rolled up newspaper at the offending animal will usually get the message across. If you have problems with stray cats, a live trap may be needed.

Foxes

Telltale signs. Foxes are fastidious hunters and normally leave little evidence of their visits. Usually they kill just one duck at a time and take the bird with them or partially bury it nearby. (Foxes have been known to go on

rampages, killing thirty or more birds at a time and scattering carcasses over a quarter-mile area.) You might be able to find a small hole under or through fences, or a poorly fitted gate or door pushed ajar.

Stopping losses. Tight fencing at least four feet high with two strands of barbed or electric wire, and close-fitting gates. Foxes will squeeze or dig under fences that are not flush with the ground.

Raccoons

Telltale signs. End of eggs bitten off, or crops (esophagus) eaten out of dead birds—possibly heads missing. Usually returns every fourth or fifth night.

Stopping losses. Fences four feet high with two strands of electric wire, or lock birds at night in shelter with covered top and sides.

Skunks

Telltale signs. Destroyed nest with crushed shells mixed with nest debris.

Stopping losses. Gather eggs daily. Encourage setting hens to nest in shelters that can be locked up at night, or set up panels around hens that are nesting in the open.

Opposum

Telltale signs. Smashed eggs and birds that are badly mauled.

Stopping losses. At night, lock birds in a shelter with covered top and sides.

Mink and Weasels

Telltale signs. Young ducklings disappear or larger birds killed, evidently for amusement, with small teeth marks on head and neck.

Stopping losses. At nighttime, lock the birds in a shelter that is covered with ½-inch wire hardware cloth. As incredible as it seems, mink and weasels can pass through holes as small as 1 inch in diameter.

Snapping Turtles and Large Fish

Telltale signs. Ducklings disappear mysteriously while swimming.

Stopping losses. If your ducks frequent bodies of water that host turtles or large fish such as northern pike and large mouth bass, keep ducklings away from the water until they are two to four weeks old.

Snakes

Telltale signs. Nest appears untouched, but some or all eggs are missing.

Stopping losses. Encourage setting hens to lay in covered nest boxes.

Rats

Telltale signs. Eggs or dead ducklings pulled into underground tunnels.

Stopping losses. Until ducklings are three to six weeks old, at night put them in a pen that has sides, top and floor that are covered with ½-inch wire mesh. Rat populations should be kept under control with cats or traps.

Crows, Jays, Magpies and Gulls

Telltale signs. Punctured eggs or shells scattered around base of an elevated perch such as a fencepost or tree stump. These birds also occasionally steal newly hatched ducklings.

Stopping losses. Provide covered nest boxes and gather eggs several times a day. Keep ducklings in wire-covered runs until they are at least two weeks old.

Hawks

Telltale signs. Ducklings disappear during daylight without a trace or only a few scattered feathers or clumps of down.

Hawks are probably falsely accused of stealing poultry more often than any other predator. Because the large, soaring hawks (buteos) are so visible, people mistakenly assume these winged hunters are the cause of every missing barnyard fowl. Actually, the hawks we need to worry about are the ones that are seldom seen by the casual observer; the accipiter family which includes the Goshawk, Cooper's Hawk and Sharp-shinned Hawk. The accipiters are secretive—sticking to trees—and hunt from low altitudes. They can be identified by their short, round wings and long tails. If you do occasionally lose ducklings to hawks, your frustration may be reduced if you'll remember that the average hawk eats 200 to 300 rodents yearly.

Stopping losses. Keep ducklings in wire-covered runs until they are two to four weeks old.

Owls

Telltale signs. One or more ducks killed nightly with head and neck eaten.

Stopping losses. At night, lock ducklings and adult ducks in a shelter covered with 1″ × 1″ wire netting. Some of the smaller species (such as Screech Owls) can squeeze through 2″ × 2″ wire mesh.

APPENDIX D

Storing Eating Eggs

Several methods can be used for short or long term storage of eating eggs. Whichever mode you use, keep in mind that the quality of eggs decreases *rapidly* when they are exposed to temperatures above 60° F., sunlight, dry air or contamination due to soiled or cracked shells. Infertile eggs can be stored longer than fertile ones.

Dirty eggs should be washed with warm water soon after being gathered, and used within one or two weeks. Warm water opens the shell pores, drawing out filth that would remain embedded if a cold bath were used.

NATURAL STORAGE

Nest-clean, strong-shelled duck eggs can be held for two or three weeks without refrigeration if they are placed in a cool (below 60° F.) humid, dark nook. Cellars, pumphouses, garages and unheated basements often meet these requirements.

REFRIGERATION

Under refrigeration (34° to 40° F.), eggs can be kept safely for up to six weeks. By sealing freshly laid eggs in plastic bags, their refrigeration life can be lengthened to two months.

FREEZING

Freezing is an excellent way to save surplus eggs for seasons when production slacks off. By following strict sanitation precautions in preparing waterfowl eggs for the freezer, we have been able to keep them for over twelve months successfully. However, because frozen eggs of any type can harbor bacteria that may cause acute intestinal infections, it is safest to store them *no more* than six months and restrict their use for baked or long-cooked foods.

Select only fresh, nest-clean eggs for freezing. Wash them with warm water, and then break into a boiled mixing bowl. Blend the whites and yolks with a fork, being careful not to beat in air bubbles. To prevent the yolks from becoming excessively thick during storage, add either one teaspoon of salt or one tablespoon of honey to each pint of eggs.

The last step is to pour the batter into thoroughly clean ice cube trays or freezer containers, leaving ½ inch headroom to allow for expansion. If ice trays are used, remove the egg cubes soon after they are frozen solid, seal them in a clean container and place immediately in the freezer.

Once frozen eggs are thawed, they should be used within twenty-four hours. *Do not* refreeze thawed eggs.

APPENDIX E

Duck Recipes

There are many ways duck can be fixed to taste great. Unfortunately, duck cookery is ignored or passed over lightly in most cookbooks. So with a lot of help from Millie, I'd like to share a few of our favorite recipes.

FRIED DUCKLING

1 duckling, cut up into pieces
flour
salt
pepper

Dust pieces of duckling with flour. Season with salt and pepper. Fry in lightly greased skillet over medium-low heat for 1½ hours. Turn pieces as necessary to brown evenly.

Remove fat from skillet as it fries out of duck. Use drippings for gravy.

Serves 4 to 6.

ROAST DUCKLING

1 whole 4½-5 lb. duckling
salt
pepper
stuffing

Rub inside of duck cavity with salt. The duck may be roasted with or without stuffing. Fasten opening with skewers and lace closed with strong thread or thin string.

Place duckling uncovered on rack of roasting pan. Roast in preheated oven at 325° F. for 2½ to 3 hours, until skin is crisp and brown and flesh is tender.

Serves 4 to 6.

STEAM-FRIED DUCK EGGS

Put eggs into medium-hot, lightly greased skillet. Pour a small amount of hot water around eggs and place lid on skillet. Steam-fry for several minutes until egg-white is set. Serve immediately.

DUCK STEW

In a large kettle:

Sauté:	1-2	cloves garlic, minced
	2	tbsp. butter or margarine
Add:	1-2	cups leftover duck meat, in chunks
	3	medium-sized potatoes, diced
	4	carrots, sliced in ½-inch pieces
	1	large onion, wedged
	1	cup shredded cabbage
	2	cups tomatoes

Cover with vegetable or meat stock. Season with salt, pepper, paprika and desired herbs. Cook over medium-low heat till vegetables are crispy tender. Add water if necessary to keep vegetables covered.

Add:	1	cup peas, green beans or limas
	2-3	celery stalks, in chunks
	1	cup corn

Heat to boiling point (or longer if fresh or frozen beans are used). If you prefer a thicker stew, add a paste of flour and water. Serve with fresh, warm homemade bread.

Serves 6 to 8.

BARBECUED DUCKLING

1 whole 4-5 lb. duckling
salt
pepper

Have plenty of hot coals ready. Season inside cavity of duckling. Fasten bird securely to rotisserie rod (or pole, if you're cooking it over an open pit). Salt and pepper outside of duckling. Position bird 6 to 12 inches from coals. Relax and enjoy the aroma as the duck sizzles and cooks for 2½ to 3 hours.

When done, serve piping hot with sauerkraut, mashed potatoes, and homemade bread.

Serves 4 to 6.

USING GIBLETS

Livers: We like them made into patties. Grind up (or blend) raw livers, along with onion, green pepper and a slice of bacon for extra flavor. Add an egg, a little flour; season with salt and pepper. Spoon into lightly greased skillet and fry on both sides till brown.

Hearts and gizzards: Bake them while you're using the oven anyway. Slice and use on pizza—they're delicious! Use hearts and gizzards to make gravy that tastes yummy over pancakes or on mashed potatoes.

STIR-FRIED VEGETABLES AND DUCK

Combine in small bowl and set aside:

1-2 tbsp. cornstarch
1 tsp. salt
1 tbsp. honey
3 tbsp. soy sauce
1½ cups stock or water

Cut raw vegetables (enough to make 5 cups) such as the following, in any combination: asparagus, broccoli, cabbage, carrots, cauliflower, green beans or zucchini. Set vegetables aside, grouping according to cooking time.

Heat in skillet:

4 tbsp. cooking oil
Add: 2-3 cloves garlic, minced
1 large onion, sliced in thin wedges
½-1 cup leftover duck, cut in strips or chunks

Stir-fry over medium-high heat for 3 to 5 minutes. Add longest cooking vegetables, such as cabbage, carrots and green beans, continuing to stir-fry. As soon as they begin to tenderize, add faster cooking vegetables. If necessary, add more oil. When vegetables are crispy-tender—and still have their bright color—add soy sauce mixture. Cook, while stirring, till sauce is clear. Serve *immediately* over hot rice.

Serves 4 to 6.

Note: Have all other meal preparations finished when you begin with this part—it takes a lot of last-minute work!

HOMEMADE NOODLES

¾ cup whole wheat flour
¾ cup unbleached white flour
1 tsp. salt
1 tsp. fat or margarine
4 duck egg yolks (or 2 whole eggs), slightly beaten

Combine flours and salt. Rub fat into dry ingredients to form coarse crumbs. Add eggs to form a stiff dough. Knead 25 strokes on floured board. Divide dough into three parts and roll each as thin as possible.

Then, if you have a hand noodle slicer, cut at this point, then dry strips in warm oven.

Otherwise, spread rolled dough on a cloth and allow to partially dry; then roll dough as a jelly roll and cut thinly.

Use immediately or store in refrigerator or freezer.

Makes approximately 12 ounces.

DEL'S DELIGHTFUL OMELET

4 duck eggs
pepper
2 tbsp. butter or margarine
chopped vegetables, such as onion, zucchini, tomato, eggplant, green or red pepper, mushrooms, broccoli
cheddar cheese, shredded alfalfa sprouts

Beat eggs. Melt butter in skillet and add egg mixture. Add your choice of vegetables and season with pepper.

Cook slowly till underside is *barely* brown. Flip, then sprinkle cheese on top. When egg has set and cheese has melted, serve with sprouts.

Serves 4 to 6.

WHOLE WHEAT ANGEL FOOD CAKE

Mix: 1 cup sifted whole wheat flour
¾ cup packed brown sugar

Crush and mix sugar lumps.

Beat together until stiff but glossy:

1½ cups duck egg-whites (8-10 eggs)
1½ tsp. cream of tartar
¼ tsp. salt
1 tsp. vanilla
½ tsp. almond flavoring

Add: ¾ cup packed brown sugar to beaten whites, ¼ cup at a time, beating well after each addition.

Fold in flour with a large spoon, sifting a little over the top, folding in lightly with a down-up-over motion. When well-blended, pour into an ungreased 10-inch angel food cake pan. Bake at 375° for 45 to 60 minutes; touch the top gently to see if cake is done.

Invert pan and cool cake thoroughly. Remove from pan.

Option: Substitute ¼ cup carob powder for an equal amount of flour and omit almond flavoring.

APPENDIX F

Using Feathers and Down

Those soft feathers and down that were carefully saved at butchering time can be used in making a variety of handy items. And as the prices of manufactured down-filled articles continue to spiral upward, home-grown feathers are becoming more practical all the time.

While all ducks produce good-quality plumage, the down of Muscovies is less desirable than that of the breeds derived from Mallards. Large breeds such as Aylesbury, Pekin and Rouen will produce 2½ to 3½ ounces of down and small feathers per bird. Mature ducks have more down than ducklings that are seven to twelve weeks old, and birds have more down in the late fall after cold weather has set in than during the warm months of summer.

PLUCKING LIVE DUCKS

People frequently ask about plucking live ducks for down. While ducks usually survive such treatment, this practice places a great deal of stress on the birds and reduces their productivity. If ducks are live-plucked, taking the following precautions will reduce the negative effects it has on the birds.

1. Pick the birds only once a year during the late spring or early summer after they have begun their natural molt. At this time, their feathers will be loosened in the follicles, and the plumes can be removed with less pain to the birds.
2. Pull out only small pinches of feathers and down at a time to keep from tearing the bird's skin.
3. Take feathers only from the underside of the duck.
4. Remove a maximum of 50 percent of the feathers from the plucked area, and do not leave any bare patches.
5. Do not let the birds swim for two or three weeks, or until they have grown new feathers.

PILLOWS

A tightly woven cloth, such as down-proof ticking, is essential to keep down and feathers from working their way out of the pillow. Double stitched seams should be used to keep the exits closed.

Small, soft body feathers need to be mixed with down to make pillows more resilient. A pillow filled with just down is too weak to hold its shape well. An excellent ratio is 75 percent down and 25 percent feathers, although good pillows can be obtained with a mixture of half down and half feathers.

COMFORTERS, QUILTS AND SLEEPING BAGS

A down-filled coverlet—what a way to keep warm on cold winter nights! Not only are they delightful, but also efficient. Millions of people around the globe are still being warmed by feathers as they sleep.

The tops and bottoms of comforters, quilts or sleeping bags must be lined with down-proof material. To keep the down and feathers distributed evenly, channels five to six inches wide need to be made. Leave one end of the channels open for stuffing.

If the large plumes of the wings, tail and body have been discarded at picking time, feathers and down can be used in the same ratio they come off the bird. As each channel is filled, sew the opening shut by hand; then finish the edges with binding.

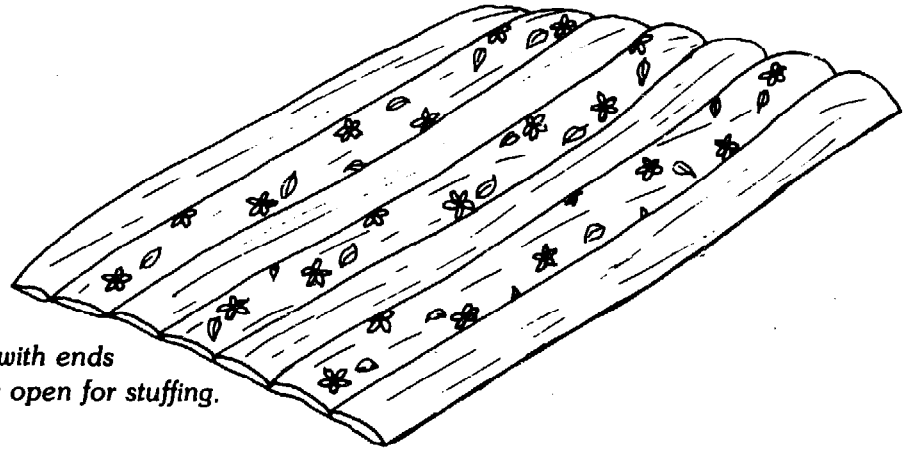

Comforter with ends of channels open for stuffing.

CLOTHING

As in comforters, you will need to make channels to keep the warmth spread around. For parkas, vests, etc., make the channels narrower, approximately two to three inches wide. Remember to use down-proof lining, and to make those seams double so that none of the down escapes. To keep clothing as lightweight as possible, use 75 to 90 percent down, with small quantities of body feathers.

APPENDIX G

Duck Breeders and Hatchery Guide

The Duck Breeders and Hatchery Guide was prepared to help you locate sources of ducks. This list is not exhaustive. Please keep in mind that the information is dated, and details such as addresses, stock sold, and so on may change with time.

While attempts have been made to include only reliable sources, I am *not* endorsing the quality of stock or service given by the following firms. Some hatcheries sell crossbred ducklings under purebred labels. If you are interested in acquiring a specific breed, ask potential sources if they *guarantee* their stock to be pure-blooded.

Three additional sources for addresses of duck breeders are *Feather Fancier* and *Poultry Press* (see Appendix I, page 166, for addresses) and the breeders directory of the Society for Preservation of Poultry Antiquities. The directory is available from the society's secretary (James Rice, Route 3, Greenwood, Wisconsin 54437) for $5 per copy.

When writing to poultry breeders and hatcheries, always have the courtesy to enclose a stamp. Some hatcheries and brokers will send their catalogues only if you send a dollar (which is refunded with your first order) along with a request for particulars on the stock they carry.

Code: Hatcheries with no asterisk offer production-bred stock, while those with one asterisk sell standard-bred ducks. Two asterisks indicate that both production-bred and standard-bred birds are available.

California

Blohm's, 54 Blanca Lane, [illegible]onville, CA 95076—Ph. (408) 724-6743
Ducklings in Khaki Campbell; Pekin; Rouen.

Hockman's, Box 7187, San Diego, CA 92107—Ph. (714) 222-6983
Ducklings in Khaki Campbell; White Muscovy; Pekin; Rouen; Mallard.

Metzer Hatchery, 25870 Old Stage Rd., Gonzales, CA 93926—Ph. (408) 679-2355
Ducklings in Khaki Campbell; Fawn & White Runner; White Muscovy; Pekin; Rouen; Ca[illegible]; Buff Orpington; Swedish; Mallard.

Connecticut

*Charles Herrman, 610 Center St., Manchester, CT 06040
Hatching eggs and ducklings in Khaki Campbell; White, Fawn & White Runner; White Muscovy; Pekin; White Crested; Swedish.

Florida

**John Thiele, Box 1545, Hobe Sound, FL 33455—Ph. (305) 546-4675
Ducklings and mature stock in Khaki Campbell; White, Fawn & White, Black Runner; Pekin; Rouen; Cayuga; White Crested; Buff Orpington; Swedish; White, Gray Call; East Indie.

Morris Hatchery, 8900 S.W. 80th St., Miami, FL 33173—Ph. (305) 271-8982
Ducklings in Pekin; Rouen; Mallard.

Illinois

*Stephen F. Gerdes, Rt. 1, Toluca, IL 61369—Ph. (815) 452-2534
Hatching eggs, ducklings and mature stock in Khaki Campbell; White, Fawn & White, Penciled, Solid Fawn, Blue, Black, Chocolate, Buff, Gray Runner; Aylesbury; White, Colored, Blue, Chocolate, Silver, Buff Muscovy; Pekin; Rouen; Cayuga; White, Gray, Black Crested; Magpie; Buff Orpington; Swedish; Australian Spotted; White, Gray Call; East Indie; Gray, White, Snowy, Golden Mallard.

Louisiana

*Clark's Bayou Bird Farm, Star Rt., Box. 192½, Princeton, LA 71067—Ph. (318) 949-2294
Mature stock in White, Black Runner; Blue Muscovy; White Crested; Swedish; East Indie; Gray, White, Golden, Crested Mallard.

Massachusetts

*Roger A. Sanford, 832 Pine Hill Rd., South Westport, MA 02790—Ph. (617) 636-2533
Hatching eggs and ducklings in White Runner; Pekin; Rouen; White, Gray Call; East Indie.

Minnesota

Leuze's Waterfowl Hatchery, Rt. 5, Willmar, MN 56201
Ducklings in Rouen.

**Neubert Hatcheries, P.O. Box 1239, Mankato, MN 56001
Hatching eggs, ducklings and mature stock in Runner; White, Colored Muscovy; Pekin; Rouen; Crested; Gray, White Mallard.

Pietrus Hatchery, 112 E. Pine St., Sleepy Eye, MN 56085—Ph. (507) 794-3411
Ducklings in White Muscovy; Pekin; Rouen; White Mallard.

Sobania Hatchery, Rt. 6, Little Falls, MN 56345
Ducklings in Khaki Campbell; Pekin; Rouen; White, Gray Crested; Buff Orpington; Gray, White Mallard.

**Stromberg's, Fifty Lakes Rt., Pine River, MN 56474
Hatching eggs, ducklings and mature stock in Khaki Campbell; Runner; Muscovy; Pekin; Rouen; Cayuga; Crested; Buff Orpington; Swedish; Mallard.

**Sunny Creek Farms & Hatchery, Rt. 2, Red Lake Falls, MN 56750—Ph. (218) 253-2211
Hatching eggs and ducklings in Khaki Campbell; White, Fawn & White, Penciled Runner; Aylesbury; White, Colored, Blue Muscovy; Pekin; Rouen; Cayuga; White Crested; Buff Orpington; Swedish; White, Gray Call; East Indie; Mallard.

*Duane Urch, Rt. 1, Box 48, Owatonna, MN 55060—Ph. (507) 451-6782
Hatching eggs, ducklings and mature stock in Khaki Campbell; White, Fawn & White, Penciled Runner; Aylesbury; White, Colored, Blue Muscovy; Pekin; Rouen; Cayuga; White Crested; Buff Orpington; Swedish; East Indie.

Missouri

Cackle Hatchery, P.O. Box 529, Labanon, MO 65536—Ph. (417) 532-4581
Ducklings in Khaki Campbell; Pekin; Rouen.

Crow Poultry & Supply, Box 339, Windsor, MO 65360
Ducklings in Pekin; Rouen.

Heart of Missouri Poultry Farm, P.O. Box 954, Columbia, MO 65201—Ph. (314) 442-3534
Ducklings in White Muscovy; Pekin; Rouen; Mallard.

*Zillich Poultry Farm, Rt. 1, Mercer, MO 64661—Ph. (816) 875-2572
Hatching eggs and ducklings in Penciled, Black, Blue, Buff Runner; Pekin; Cayuga; Swedish.

North Dakota

Magic City Hatchery, P.O. Box 1771, Minot, ND 58701—Ph. (701) 839-3726
Ducklings in Pekin; Rouen.

Ohio

Pilgrim Goose Hatchery, Creek Rd., Williamsfield, OH 44093
Ducklings in Runner; Aylesbury; Pekin; Rouen; Cayuga; Buff Orpington; Swedish.

Pruden Hatchery, Rt. 84 & Meyers Rd., Geneva, OH 44041—Ph. (216) 466-1773
Ducklings in Pekin; Rouen; Mallard.

Ridgway Hatcheries, Inc., LaRue, OH 43332
Ducklings in Pekin; Rouen; Mallard.

**Ronson Farms, P.O. Box 12565, Columbus, OH 43212—Ph. (614) 486-6219
Ducklings and mature stock in Khaki Campbell; White, Fawn & White, Penciled, Gray Runner; White, Colored Muscovy; Pekin; Rouen; Cayuga; White Crested; Buff Orpington; Swedish; White, Gray Call; East Indie; Mallard.

Oklahoma

Country Hatchery, Box 747, Wewoka, OK 74884—Ph. (405) 257-3250
Ducklings in Pekin; Buff Orpington; Swedish; Mallard.

Oregon

Mother Hen Farm & Hatchery, 3810 NE Hwy. 20, Corvallis, OR 97330—Ph. (503) 752-6520
Hatching eggs and ducklings in White and Khaki Campbell; White Runner; Mallard.

**Northwest Farms, P.O. Box 3003, Portland, OR 97208—Ph. (503) 653-0344
Hatching eggs, ducklings and mature stock in Khaki Campbell; White, Fawn & White, Penciled Runner; Aylesbury; White, Colored, Blue Muscovy; Pekin; Rouen; Cayuga; White, Gray Crested; Buff Orpington; Swedish; White, Gray Call; East Indie; Mallard.

Shank's Hatchery, P.O. Box 429, Hubbard, OR 97032—Ph. (503) 981-7801
Ducklings in Pekin; Mallard.

Pennsylvania

Clearview Hatchery, Gratz, PA 17030—Ph. (717) 365-3234
Ducklings in Khaki Campbell; White Muscovy; Pekin; Rouen; Cayuga; Crested; Buff Orpington; Swedish; White Call; East Indie; Mallard.

*Feather Edge Farm, Rt. 1, Cochranton, PA 16314
Hatching eggs, ducklings and mature stock in Khaki Campbell: Pekin; Cayuga; White, Black Crested; Buff Orpington; White Call.

Hoffman Hatchery, Gratz, PA 17030—Ph. (717) 365-3407
Ducklings in Khaki Campbell; Fawn & White Runner; White Muscovy; Pekin; Rouen; Cayuga; Buff Orpington; Swedish; Mallard.

**Willow Hill Farm & Hatchery, Rt. 1, Box 100, Richland, PA 17087—Ph. (717) 933-4606
Ducklings and mature stock in Khaki Campbell; White, Fawn & White, Penciled Runner; White Muscovy; Pekin; Rouen; Cayuga; White, Gray, Black, Blue Crested; Buff Orpington; Swedish; White, Gray Call; East Indie; Mallard.

South Dakota

Inman Hatchery, 3000 Third Ave., S.E., Aberdeen, SD 57401—Ph. (605) 225-8122
Ducklings in Pekin; Rouen.

Washington

Harder's Hatchery, Rt. 101, Box 316, Ritzville, WA 99169—Ph. (509) 659-1423
Ducklings in Khaki Campbell; Pekin; Rouen.

Wisconsin

Abendroth's Hatchery, Rt. 2, Box 200, Waterloo, WI 53594—Ph. (414) 478-2053
Ducklings in Khaki Campbell; Fawn & White, Penciled Runner; White Muscovy; Pekin; Rouen; Cayuga; White Crested; Buff Orpington; Swedish; Gray, White Mallard.

*Halbach Poultry Farm, 305 S. Third St., Waterford, WI 53185—Ph. (414) 534-6405
Hatching eggs, ducklings and mature stock in Khaki Campbell; White, Fawn & White, Penciled, Black, Gray Runner; Aylesbury; Pekin; Rouen; Cayuga; White Crested; Buff Orpington; Swedish; White, Gray Call; East Indie.

Canada

Berg's Hatchery, Box 603, Russel, Manitoba ROJ 1WO
Ducklings in Pekin; Rouen.

Canadian Poultry Supplies, Rt. 2, Lindsay, Ontario K9V 4R2
Hatching eggs, ducklings and mature stock in Khaki Campbell; White, Fawn & White, Penciled, Black Runner; Aylesbury; White, Colored, Blue Muscovy; Pekin; Rouen; Cayuga; White, Black Crested; Black, Blue Magpie; Buff Orpington; Swedish; White, Gray Call; East Indie; Mallard.

Miller Hatcheries Ltd., 260 Main St., Winnipeg, Manitoba R3C 1A9—Ph. 943-6541
(Branch offices in Regina, Saskatoon, North Battlefield, Edmonton)
Ducklings in Pekin; Rouen.

Springhill Hatchery, Neepawa, Manitoba ROJ 1HO
Ducklings in Pekin.

Pardo's Hatchery, Rt. 3, Blenheim, Ontario
Ducklings in Pekin; Rouen.

Webfoot Farm & Hatchery Ltd., Elora, Ontario NOB 1SO—Ph. (519) 846-9885
Ducklings in White Muscovy; Pekin; Rouen.

Puerto Rico

Aibonito Hatchery, Ruta 2, Buzon 490, Aibonito, PR 00609—Ph. (809) 735-8585
Ducklings in several breeds.

APPENDIX H

Sources of Supplies and Equipment

One of the advantages of ducks is that a minimum of special equipment and supplies is required in order to raise them successfully. However, there may be times when you'll need an incubator, a few bands, some picking wax, etc., but cannot find a local source for these products. For this reason, the following firms are listed.

COMPLETE INVENTORY

Burkey Co.
P.O. Box 29465
San Antonio, TX 78229
Ph. (512) 696-0706

Canadian Poultry Supplies
Rt. 2
Lindsay, Ontario
Canada K9V 4R2

College Poultry Supplies
287 College St.
Toronto, Ontario
Canada M5T 1S2
Ph. (416) 924-5598

Foy's Supplies
Box 27166
Golden Valley, MN 55427

Gragne Bros. Supplies
2883 Woodland Circle
Allison Park, PA 15101
Ph. (412) 443-2486

Marsh Manufacturing, Inc.
14232 Brookhurst St.
Garden Grove, CA 92643
Ph. (714) 534-6580

Northwest Farms, Inc.
P.O. Box 3003
Portland, OR 97208
Ph. (503) 653-0344

Rocky Top Poultry Supply
P.O. Box 1006
Harriman, TN 37748
Ph. (615) 882-8867

Ronson Farms
P.O. Box 12565
Columbus, OH 43212
Ph. (614) 486-6219

Sidney Shoemaker Poultry Supplies
3091 Lincoln-Gilead Twp. Rd. 124
Rt. 3
Cardington, OH 43315
Ph. (419) 864-6666

Stocklin Supply Co.
738 S.E. Lincoln
Portland, OR 98124
Ph. (503) 234-0897

Strecker's Poultry Supply
Rt. 3, Box 365-K
Arroyo Grande, CA 93420

Stromberg's
50 Lakes Route
Pine River, MN 56474
Ph. (218) 543-4223

Valentine Equipment Co.
9706 S. Industrial Drive
Bridgeview, IL 60455
Ph. (312) 599-1101

INCUBATORS AND BROODING EQUIPMENT ONLY

Brower Manufacturing Co.
Box 5722
Quincy, Il 62301

Hockmans
12659 Devonshire
San Diego, CA 92107
Ph. (714) 222-6983

Leahy Manufacturing Co.
406 W. 22nd St.
Higginsville, MO 64037
Ph. (816) 584-2641

The Humidaire Incubator Co.
217 W. Wyne St.
New Madison, OH 45346
Ph. (513) 996-3001

Oak Ridge Manufacturing Co.
Veyo, UT 84778
Ph. (801) 673-9190

Superior Incubator Co.
4734 Sanford
Houston, TX 77035
Ph. (713) 729-2109

APPENDIX I

Suggested Reading

MAGAZINES AND NEWSPAPERS

Backyard Poultry, Jerome D. Belanger, publisher, Rt. 1, Waterloo, Wisconsin 53594. $7 yearly. A monthly publication devoted to the small flock owner, which carries articles on most types of poultry.

Countryside, Jerome D. Belanger, editor and publisher, Rt. 1, Waterloo, Wisconsin 53594. $9 yearly. Authoritative monthly magazine for small farmers. Regular features on poultry with question and answer department.

Feather Fancier, Corey R. Herrington, editor and publisher, P.O. Box 239, Erin, Ontario, Canada NOB 1TO. $6 yearly, 50¢ for sample. Monthly paper devoted to standard-bred poultry, pigeons and pet stock. Good source for addresses of Canadian poultry breeders and hatcheries.

Poultry Press, Robert F. DeLancey, editor and publisher, Box 947, York, Pennsylvania 17405. $5 yearly, 50¢ for sample. Monthly paper with articles on poultry shows, club news, and breeding and management tips. Good source for addresses of waterfowl breeders and hatcheries throughout North America.

BOOKS

Light Weight Camping Equipment and How to Make It, by Gerry Cunningham and Margaret Hansson. Available from Gerry Division of Outdoor Sports Industries, 5450 North Valley Hwy., Denver, Colorado 80216. Gives patterns and instructions for making down-filled clothing.

Nutrient Requirements of Poultry, 7th revised edition (1977), National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C. 20418. An informative though brief manual on poultry nutrition. Highly recommended for persons who desire a working understanding of poultry nutrition and who plan to formulate rations.

Poultry Feed Formulas, Department of Animal and Poultry Science, Ontario Agricultural College, University of Guelph, Guelph, Ontario, Canada. Contains information on ration formulation for most types of poultry and includes 28 duck rations using various feedstuffs.

Modern Waterfowl Management and Breeding Guide, by Oscar Grow. Available from American Bantam Association, P.O. Box 610, N. Amherst, Massachusetts 01059. $12. Contains detailed information on the origin, history and breeding of most breeds and species of domestic and semi-domestic ducks, geese and swans. 359 pages, numerous illustrations, hardback.

Successful Duck & Goose Raising, by Darrel Sheraw. Available from Stromberg Publishing Co., Pine River, Minnesota 56474. $5.95. Most comprehensive book available on selecting and mating standard-bred waterfowl. 208 pages, 225 pictures, paperback.

Standard of Perfection for Domesticated Land Fowl and Water Fowl, American Poultry Association, Inc., Box 70, Cushing, Oklahoma 74023. $12. Describes in detail all varieties of large chickens, bantams, turkeys, ducks and geese recognized by the American Poultry Association. Of special interest for persons who raise pure-bred poultry. 600 pages, over 200 illustrations, hardback.

APPENDIX J

Organizations

International Waterfowl Breeders Association; Lyle Jones, Secy., 12402 Curtis Rd., Grass Lake, MI 49240. Dues $3. Sponsors meets at shows and sends out newsletters (2-4 pages).

Associated Breeders of Campbell Ducks; Rick Luttman, Secy., 7909 Lynch Rd., Sebastopol, CA 95472. Dues $3. An active organization that sends out quarterly newsletters (6-8 pages) containing information on all aspects of breeding and managing Campbells for exhibition and egg production.

American Poultry Association, Inc.; Allen D. Fitchett, Exec. Secy., Box 70, Cushing, OK 74023. Dues $4. For breeders of all poultry. Membership includes newsletter and yearbook (112 pages in 1977) containing articles and advertisements from leading poultry breeders.

American Bantam Association; Fred P. Jeffery, Secy., P.O. Box 610, N. Amherst, MA 01059. Dues $5. For breeders of bantam chickens and ducks. All members receive the A.B.A. quarterly newsletter, and new members are sent a free copy of the A.B.A. yearbook (212 pages in 1977).

Society for Preservation of Poultry Antiquities; James K. Rice, Secy-Treas., Rt. 3, Greenwood, WI 54437. Dues $5. Members receive S.P.P.A. Breeder Directory (last issue contained 97 pages and listed 184 poultry breeders throughout North America) and quarterly newsletters (6-12 pages) with information on all types of rare poultry.

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Glossary

Bantams: The miniature breeds of ducks.

Biotin: A vitamin found in most feedstuffs (see Appendix B, page 143 for symptoms of a deficiency).

Breed: A subdivision of the duck family whose members possess similar body shape, body size and temperaments and the ability to pass these characteristics on to their offspring.

Breeder ration: Feed used for the production of hatching eggs.

Breeding stock: Adult birds used to produce young.

Broody Hen: A hen that wants to set on eggs. When a hen is broody, her personality undergoes a marked change; she spends much time on the nest, ruffles her feathers when molested, pecks at intruders and quacks incessantly while off the nest.

Concentrated feed: Feeds that are high in protein, carbohydrates, fats, vitamins and minerals, and low in fiber.

Culling: The removal of inferior (crippled, deformed, diseased, low-producing) birds from the flock.

Drake: The male duck.

Duck: In general, any member of the Anatinae family; it is often used specifically in reference to females of the duck family.

Ducklings: Young ducks up until feathers have completely replaced their baby down.

Eclipse molt: A four- to six-week period each year, usually in mid-summer, when the bright plumage of colored adult drakes is replaced with subdued colors similar to those of the hens. This molt occurs for camouflage while the flight feathers are being replaced.

Embryo: The young bird before it emerges from the egg shell.

Esophagus: The tube in which food passes from the mouth to the digestive tract. (Ducks do not have true crops.)

Feed conversion: The ability of birds to convert feed into body growth or eggs. To calculate feed conversion ratios, divide pounds of feed consumed by pounds of body weight or eggs.

Fertility: In reference to eggs, the capability of producing an embryo. Fertility is expressed as a percentage that equals the total number of eggs set minus those that are infertile, divided by the total number set, times 100.

Full-feathered: When a bird has a complete set of feathers.

Gizzard: The muscular organ that grinds the food eaten by birds.

Green ducklings: Young ducks that are managed for fast growth and then slaughtered at seven to eight weeks of age.

Growing ration: Feed that is formulated to stimulate fast growth in ducklings over two weeks old.

Hatchability: The ability of eggs to hatch. Hatchability can be expressed as (1) a percentage of the fertile eggs set (total number of ducklings hatched divided by the number of fertile eggs set, times 100) or (2) a percentage of all eggs set (total number of ducklings hatched divided by the total number of eggs set, times 100).

Hen: The female duck.

Hygrometer: An instrument designed to measure the amount of moisture in the air.

Laying ration: Feed that is formulated to stimulate high egg production.

Lethal gene: A gene that causes the premature death of a developing embryo.

Maintenance ration: Feed used for adult ducks that are not in production.

Molt: The natural replacement of old feathers with new ones.

Niacin: A B-complex vitamin (nicotinic acid). Niacin deficiency causes bowing of the legs.

Nuptial plumage: In colored varieties of ducks, the bright breeding plumage of males exhibited during fall, winter and spring.

Pin feathers: New feathers that are just emerging from the skin.

Pip: The first visible break the duckling makes in the egg shell.

Post-mortem: The thorough examination of a dead bird, usually to determine the cause of death.

Production-bred: Ducks that have been selected for top meat and/or production.

Purebred: Ducks of a specific breed that have not been crossed with other breeds for many generations.

Relative humidity: The ratio of the quantity of water vapor in the air to the greatest amount possible at a given temperature. Therefore, 100 percent relative humidity is total saturation, while 0 percent would indicate the complete absence of moisture.

Roasting chickens: Broilers that are kept beyond eight or nine weeks of age—often up to six months. They attain live weights of 8 pounds or more.

Setting hen: A broody hen that is in the process of incubating a nest of eggs. This term is also sometimes used to identify a hen that has successfully hatched eggs in the past.

Standard-bred: Ducks that have been stringently selected over many generations according to the ideal that is set forth in the Standard of Perfection.

Standard of Perfection: A book containing pictures and descriptions of the physical characteristics desired in the perfect bird of each recognized breed and variety of poultry.

Starting ration: A high-protein feed used the first couple of weeks to get ducklings off to a good start.

Straight run: Young poultry that have not been sexed.

Variety: A subdivision of the breeds. In ducks the varieties within a breed are identified by their plumage color or markings.

Waterfowl: Birds that naturally spend most of their lives on and near water. This term is often used in specific reference to ducks, geese and swans.

Wet-bulb thermometer: A mercury thermometer that has a tubular wick, with one end fitted over the thermometer's bulb and the other end inserted into a container of water. This instrument is used to measure the relative humidity in the incubator.

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Ducks are the homeowner's friends.
They will:

- **Eat Japanese beetles, grasshoppers, snails, slugs and mosquitoes.**
- **Clean unwanted plants from ponds and lakes.**
- **Eat up all table and gardening leftovers.**
- **Produce an abundance of valuable nitrogen-rich manure.**
- **And most important, provide you with low-cost meat and eggs.**

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Dave has raised ducks since his boyhood days, and he's taught hundreds in this country and Puerto Rico through vocational poultry programs. He knows ducks, and he knows how to teach his subject.

"Hobbyists, homesteaders and commercial duck raisers alike will find this book a handy reference. It is based on the author's longtime experience and supplemented with data from current scientific research. All aspects of small-scale duck husbandry are presented in an orderly, understandable form. Whether you are a beginner with a first-time pet, or a commercial operator wishing to formulate or mix your own feed, **Raising The Home Duck Flock** can provide the information you need."
— AL HOLLISTER Dept. of Poultry Science Oregon State University

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Hydraulic Rams For Off-Stream Livestock Watering

Cooperative Extension Service/The University of Georgia
College of Agriculture and Environmental Sciences/Athens

The benefits of off-stream watering are numerous. Watering livestock away from the water source can improve water quality, animal health, animal productivity, pasture utilization and manure distribution. As both pasture management techniques and pressure to protect the environment intensify, producers are being forced to look for new and better ways to water their livestock.

Recent cattle grazing studies show that off-stream watering significantly reduces stream bank erosion and lowers the amount of nutrients, sediment, and fecal bacteria entering the water source. In fact, many scientists feel that off-stream watering is a cost effective alternative to stream bank fencing.

For maximum production and pasture utilization, animals need plenty of water. By providing animals with easy access to water, off-stream watering helps insure that water is not a limiting factor to animal weight gains. These additional water sources also open up pasture management options, like rotational grazing, which can increase pasture carrying capacity and/or enhance forage utilization.

From the standpoint of animal health, some diseases are spread by animals coming into contact with urine and/or feces discharged from infected animals. Also, studies have shown that the incidence of foot rot and mastitis are greater among cattle herds that are allowed to enter wet, muddy areas. Off-stream watering helps solve these problems, by allowing

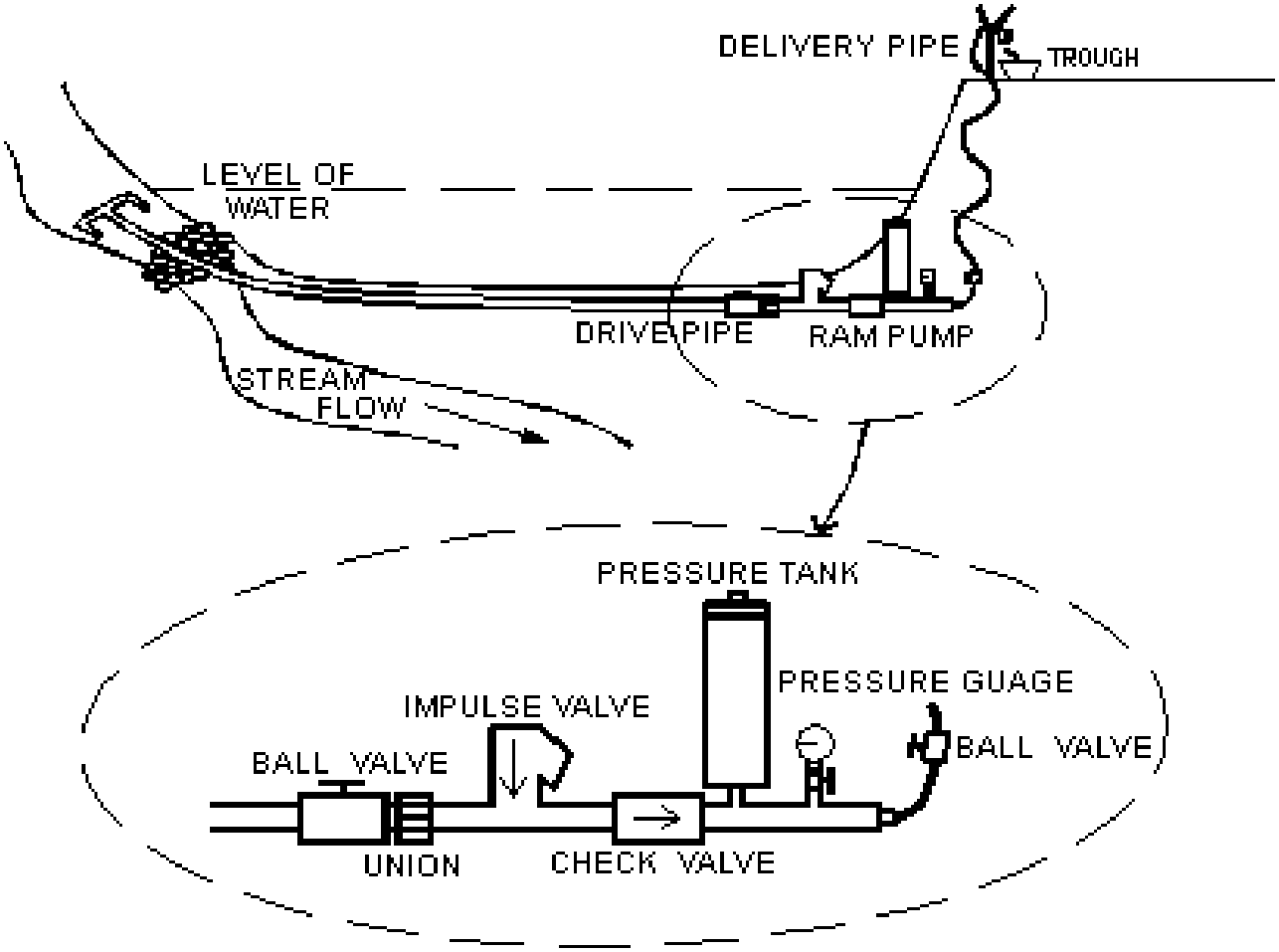

Figure 1. Hydraulic Ram Installation

producers to remove cattle from many of the areas that harbor disease organisms.
Were it not for the initial cost of setting up watering systems, escalating energy costs, and limited access to electricity, off-stream watering would probably be far more widespread than it is today. The hydraulic ram pump overcomes many of these obstacles. It is a motorless, low flow rate pump that uses flowing water as an energy source to operate the pump. Hydraulic rams are ideal for use where small quantities of water are required, such as for livestock watering.

PRINCIPLE OF OPERATION

A hydraulic ram uses the kinetic energy of falling water to pump water. The mechanics of the hydraulic ram are pictured (Figure 1) and described below. Water from a spring, creek, artesian well, or stream flows down the drive pipe and out through the impulse valve until its velocity is sufficient to close the valve. The sudden closing of the impulse valve forces a moving column of water to pass through a check valve and into the pressure tank. The momentum of the flowing water compresses the tank's air-bladder until the pressure of the trapped air is so great that the bladder begins to rebound, pushing water back down and out of the pressure tank. Water flowing out of the pressure tank forces the one way check valve to close which diverts all water flow through the delivery pipe to its destination. The closing of the check valve also creates a slight vacuum, which permits the impulse valve to reopen, and the pumping cycle begins again.

Table 1. Daily Water Requirements

Livestock (drinking)	gallons/animal/day
Milking cow	25-45
Dry cow	12-30
Calf	6-12
Beef animal	1.5/100 lbs. weight
Hog	4
Horse	10-15
Sheep	2
100 Chickens	4-5/100 birds
100 Turkeys	18/100 birds

PUMP SELECTION

A ram's size must be selected to produce a required flow rate while generating enough pressure to lift the water to the desired elevation. The fall from the water supply source to the ram must be at least 2 feet and the minimum flow of water needed is roughly 1-2 gallons per minute (gpm). The relationship between pump output and water source can be expressed as:

$$Q = \frac{V \times F}{E} \times 0.60 \text{, where:}$$

Q = pumping flow rate (gpm)
F = vertical fall of the drive pipe (ft)
V = available flow through drive pipe (gpm)
E = vertical distance or eleveation that the water will be raised (ft)
0.60 = efficiency of a ram installation
** Each of these parameters is further defined below**

Note: The length of the delivery pipe is not considered in this equation because friction losses are normally small due to low flow rates. However, if the discharge pipe is extremely long or if the flow rate is high, friction losses in the delivery pipe will affect pump flow rates.

Pumping Flow Rate (Q)

Before installing a ram pump, you need to have an estimate of your water requirements. Use Table 1 to determine water requirements. Multiply the number of animals that the pump will serve by the daily water requirement for that animal in order to determine a total daily water requirement in gallons. Next, divide that number by 1440 to determine desired pumping flow rate (Q) in gallons per minute.

Measuring Available Water Flow (V)

If the flow of water from the source is small it can be measured by timing how long it takes to fill a bucket of known capacity with water from the supply source. However, for larger flows it may be necessary to use a weir or flow meter to measure available water. This measurement should be taken during the driest season of the year. Be sure that the flow (V) is calculated in gallons per minute.

Vertical Fall (F) & Lift Elevation (E)

The fall from the supply source to the ram can be determined using a leveling instrument or by using a carpenters level securely fastened to the top of a pole (*See Figure 2*). Starting at the proposed ram sight, place the pole-level on the ground and observe where the line of sight hits. Continue in this manner until you reach the level of the source. Add the measurements together to obtain the vertical fall of the water (F) in feet.

The same procedure can be used to determine lift elevation (E). In this case, measure from the proposed ram sight up to the point of discharge.

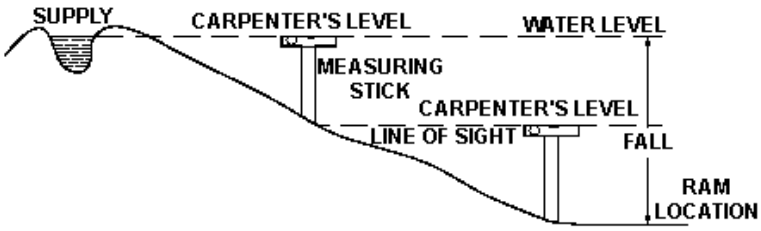

Figure 2. Determining Vertical Fall (F) and Lift Elevation (E) Using a Carpenter's Level

INSTALLATION & CONFIGURATION

Matching Rams to Available Water Flow

Hydraulic rams come in drive pipe sizes from 3/4" to 8" diameters, delivery pipe sizes from ½" to 4" inch diameters, and drive water requirements of $^3/_4$ to 400 gpm. Table 2 can be used as a guide in matching new pump size to available water flow.

Foundation

The ram should be bolted or securely fastened to a very stable and level foundation.

Source

The water source should be screened to prevent trash from entering the drive pipe and clogging the ram.

Drive Pipe

The drive pipe is probably the most important part of a ram installation. It carries the water from the source to the ram and contains the pressure surge.

- ✦ Should be galvanized steel or at least schedule 40 PVC

Table 2. Hydraulic Ram Specifications

Drive Pipe Diameter (inches)	Delivery Pipe Diameter (inches)	Min. Intake (gpm)	Max. Intake (gpm)
¾	½	¾	2
1	½	1½	6
1¼	½	2	10
1½	¾	2½	15
2	1	3	33
2½	1¼	12	45
3	1½	20	75
4	2	30	150
6	3	75	400
8	4	400	800

- ✦ Should be as straight as possible. Minimize bends and avoid elbows.
- ✦ Should be at least one size larger than delivery pipe
- ✦ Should be watertight and rigidly anchored
- ✦ The upper end of the drive pipe should be installed at least one foot under water in order to avoid whirlpools from forming and sucking air into the drive pipe

Determining Drive Pipe Length

Recommendations for drive pipe length are based on empirical data from systematic experiments. Calvert (1958) found that the output and stability of a ram installation depend on the ratio of drive pipe length (L) to diameter (D). He found that hydraulic rams will work satisfactorily if L/D is between 150 and 1000.

For example, to determine the minimum length of a drive pipe that has a 1½ inch diameter: L/D = 150, so D x 150 = L, or 1½" x 150 = 225" (18.75'). To calculate the maximum length for this same drive pipe: L/D = 1000, so D x 1000 = L, or 1½" x 1000 = 1500" (125').

When drive pipe length falls outside of this range both performance and stability are impaired. Increasing the drive pipe length within this range produces no change

in waste or output, but it does lower the beat frequency (fewer beats per minute.) Practical aspects such as valve wear, fatigue of pipe fittings, and the amount of noise generated all favor a low beat frequency, and hence a longer drive pipe than the minimum necessary for good performance.

Supply Pipe and Stand Pipe

If you have to go downstream for a great distance in order to obtain adequate vertical fall, a stand pipe and a supply pipe will need to be installed between the water source and the drive pipe with a tee joint *(see Figure 3).* The supply pipe and stand pipe will not be exposed to as much stress as the drive pipe. Therefore, the strength of the materials used in their construction is not as critical. It is not imperative that these pipes run on a straight incline. However, it is essential that they be sized to carry more water than the ram can use, so that air is not sucked into the drive pipe.

Supply Pipe

- Can be made from any material that will stand up to the pressure exerted by the water source
- Must be at least one size larger than the drive pipe
- Should run on a straight incline where possible
- The top of the supply pipe should be installed with a screen that is at least one foot under water

Stand Pipe

- Can be made from any material that will stand up to the pressure exerted by the water source
- Must be at least two sizes larger than the supply pipe
- The top of the stand pipe should be at least a few inches above the level of the water at the source of supply

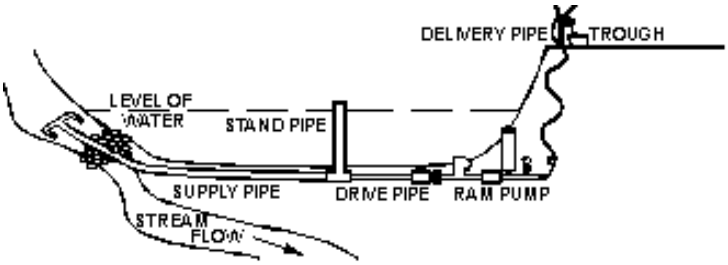

Figure 3. Hydraulic Ram With a Distant Supply

Delivery Pipe

- Can be made from any material that will stand up to the pressure of the water leading to the watering trough.
- Avoid right angled elbows wherever possible.
- To avoid excessive pressure losses due to friction, make sure that the diameter of the delivery pipe is large enough so that the velocity of the water running through it does not exceed 5 feet per second.

$$\text{Velocity} = \frac{Q}{2.45 \times D^2} \quad \text{where:}$$

Q = pumping flow rate (gpm)
D = inside diameter of delivery pipe (in)

Drain Tile

The total amount of vertical fall can often be greatly increased by sinking a ram pump deep into the ground and extending drainage tile to divert unused water. A frost pit or well casing can be used to bury a ram, but a drain tile is essential to carry off the waste water.

Installation of Two or More Rams

Rams are often installed in batteries or groups if a single pump does not meet the water requirement, or if available flow in the water source varies during the year. If two or more rams are installed alongside each other, each ram must have its own drive pipe, but all of them can pump into one common delivery pipe of sufficient size to carry the water (*see Figure 4*).

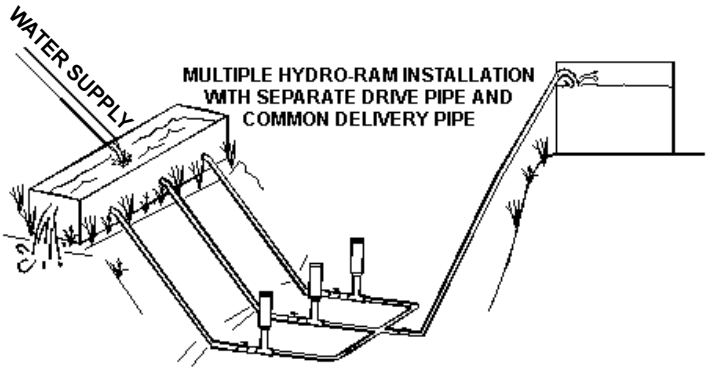

Figure 4. Installation of Hydraulic Rams in a Battery

Installation of a Ram Behind a Dam

Water from lakes, ponds and springs can be pumped by placing a ram on the backside of a dam. The water for the ram's operation can either be piped directly through the dam, or it can be siphoned over the dam. Because the pipe in a siphon system is bent, it should

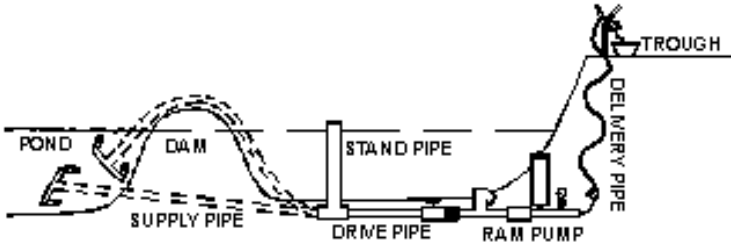

be treated like a supply pipe. Therefore, a stand pipe should be installed between the siphon and the drive pipe with a tee joint (*see Figure 5*).

Figure 5. Installation of a Ram behind a Dam

STARTING A RAM PUMP

- If there is a valve between the ram and the drive pipe open it
- If there is a valve between the ram and the delivery pipe it should be closed
- Push down on the impulse valve for two seconds and release. Repeat this step until the ram begins to work automatically
- When the pressure in the storage tank reaches 10 - 20 psi, the valve between the ram and the delivery pipe should be opened slowly. A gauge installed between the pressure tank and the ball valve on the delivery pipe is useful for making these pressure readings *(see Figure 1)*.

HYDRAULIC RAM SIZING DATA SHEET

The following data sheet can either be used to help you correctly size a ram pump yourself, or you can fill it out and send it to a manufacturer, so that they will have the information needed to size it for you.

Site Characteristics:
1. Available supply of water (gpm)

_____

2. Vertical Fall (ft)

_____

(Measure the amount of vertical fall in feet from the water level of the source supply down to the level of the foundation on which the ram will rest.)

3. Distance from source of supply to ram (ft)

_____

4. Vertical distance or elevation that water will be raised (ft)

_____

5. Distance from the ram to the watering trough (ft)

_____

6. Total daily water requirement (gallons)

_____

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903-743-5555

Folk Water Powered Ram Pumps, Inc.
2770 White Court, N.E.
Conyers GA 30207
770-922-4918

Rife Hydraulic Engineering Mfg. Co.
P.O. Box 367
Wilkes-Barre PA 18703
1-800-227-8511
The Ram Company
247 Llama Lane
Lowesville VA 22967
1-800-227-8511

Mention of these companies does not constitute any endorsement by The University of Georgia nor does it imply any exclusion of other companies that provide similar goods or services.

ACKNOWLEDGEMENTS

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Watt, S.B. 1978. A Manual on the Hydraulic Ram for Pumping Water. Intermediate Technology Publications, Southampton Row, London WC1B 4HH, UK.

This publication (Misc. Engineering Publication #ENG98-002) was prepared by:

Frank Henning: Special Extension Agent, Water Quality

Mark Risse, Ph.D.: Public Service Assistant and Agricultural Pollution Prevention Specialist

William Segars, Ph.D.: Professor of Agronomy, and Extension Water Quality Coordinator

1785

The University of Georgia

Printed March, 1998

Ram pump plans

http://www.clemson.edu/irrig/equip/ram.htm

Home-made Hydraulic Ram Pump

Pump Plans	Assembly Notes	Performance	Links
How It Works	Operation	Test Installation	

This information is provided as a service to those wanting to build their own hydraulic ram pump. The data from our experiences with one of these home-made hydraulic ram pumps is listed in Table 4 near the bottom of this document. The typical cost of fittings for an 1-1/4" pump is currently $120.00 (U.S.A.) regardless of whether galvanized or PVC fittings are used.

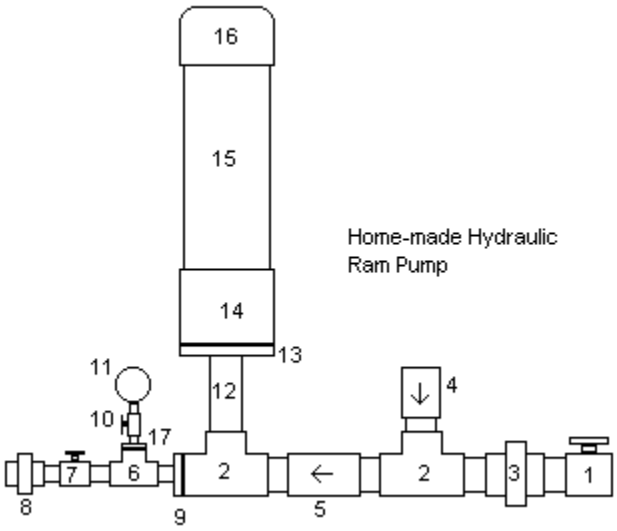

Click here to see a picture of an assembled ram pump

Table 1. Image Key

1	1-1/4" valve	10	1/4" pipe cock
2	1-1/4" tee	11	100 psi gauge
3	1-1/4" union	12	1-1/4" x 6" nipple
4	1-1/4" brass swing check valve (picture)	13	4" x 1-1/4" bushing
5	1-1/4" spring check valve	14	4" coupling

6 3/4" tee
7 3/4" valve
8 3/4" union
9 1-1/4" x 3/4" bushing
15 4" x 24" PR160 PVC pipe
16 4" PVC glue cap
17 3/4" x 1/4" bushing

All connectors between the fittings are threaded pipe nipples - usually 2" in length or shorter. This pump can be made from PVC fittings or galvanized steel. In either case, it is recommended that the 4" diameter fittings be PVC fittings to conserve weight.

Conversion Note: 1" (1 inch) = 2.54 cm; 1 PSI (pound/square inch) = 6.895 KPa or 0.06895 bar; 1 gallon per minute = 3.78 liter per minute. PR160 PVC pipe is PVC pipe rated at 160 psi pressure.

Click here to see an image-by-image explanation of how a hydraulic ram pump works

Click here to see a short mpeg movie of an operating ram pump
*(**Note - this is a 6.2 mb movie clip**. On slower systems (11 mbps, etc.), it will load "piece-meal" the first time. Allow it to finish playing in this fashion, then press the play button again to see it in full motion with no "buffering" stops. Dial-up users may have to download the file to see it - simply right-click on the link, then select "Save Target As..." to save it to your computer. Downloading may take considerable time if you are on a slower dial-up system.)*

Assembly Notes:

Pressure Chamber - A bicycle or "scooter tire" inner tube is placed inside the pressure chamber (part 15) as an "air bladder" to prevent water-logging or air-logging. Inflate the tube until it is "spongy" when squeezed, then insert it in the chamber. It should not be inflated very tightly, but have some "give" to it. Note that water will absorb air over time, so the inner tube is used to help prevent much of this absorbtion. You may find it necessary, however, to drain the ram pump occasionally to allow more air into the chamber. *(The University of Warwick design (link below, pages 12-13) suggests the use of a "snifter" to allow air to be re-introduced to the ram during operation. Their design, however, is substantially different from the one offered here and provides a location (the branch of a tee) where the addition of a snifter is logical. This design does not. Also, correctly sizing the snifter valve (or hole as the case may be) can be problematical and may allow the addition of too much air, resulting in air in the drive pipe and ceasing of pumping operation. For these reasons we have elected not to include one in this design.)*

According to information provided by the University of Warwick (UK) (http://www.eng.warwick.ac.uk/dtu/pubs/tr/lift/rptr12/tr12.pdf , page 14), the pressure chamber should have a minimum volume of 20 times the expected delivery flow per "cycle" of the pump, with 50 times the expected delivery being a better selection. The chart below provides some recommended minimum pressure chamber sizes based on 50

times the expected delivery flow per "cycle." Note that larger pressure chambers will have not have any negative impact on the pump performance (other than perhaps requiring a little more time to initially start the pump). Some of the lengths indicated are quite excessive, so you may prefer to use two or three pipes connected together in parallel to provide the required pressure chamber volume. Well pump pressure tanks will also work well - just make sure they have at least the minimum volume required.

Table 2. Suggested Minimum Pressure Chamber Sizes
(Based on ram pumps operating at 60 cycles per minute.)

Drive Pipe Diameter (inches)	**Expected Flow Per Cycle** (gallons)	**Pressure Chamber Volume Required** (gallons)	**Length of Pipe Required for Pressure Chamber (for indicated pipe diameter)** (lengths are in inches)							
			2 inch	2-1/2 inch	3 inch	4 inch	6 inch	8 inch	10 inch	12 inch
3/4	0.0042	0.21	15	11	7	--	--	--	--	--
1	0.0125	0.63	45	32	21	--	--	--	--	--
1-1/4	0.020	1.0	72	51	33	19	--	--	--	--
1-1/2	0.030	1.5	105	74	48	27	--	--	--	--
2	0.067	3.4	--	170	110	62	27	16	--	--
2-1/2	0.09	4.5	--	230	148	85	37	22	14	--
3	0.15	7.5	--	--	245	140	61	36	23	16
4	0.30	15	--	--	--	280	122	72	45	32
6	0.80	40	--	--	--	--	325	190	122	85
8	1.60	80	--	--	--	--	--	380	242	170

(Note - it is quite difficult to push a partially-inflated 16 inch bicycle inner tube into a 3 inch PVC pipe. Due to this we suggest the pressure chamber be a minimum of 3 inches in diameter.)

A 4" threaded plug and 4" female adapter were originally used instead of the 4" glue-on cap shown in the image, This combination leaked regardless of how tightly it was tightened or how much teflon tape sealant was used, resulting in water-logging of the pressure chamber. This in turn dramatically increased the shock waves and could possibly have shortened pump life. If the bicycle tube should need to be serviced when using the glue cap design, the pipe may be cut in half then re-glued together using a coupling.

Valve Operation Descriptions - Valve #1 is the drive water inlet for the pump. Union #8 is the exit point for the pressurized water. Swing check valve #4 is also known as the "impetus" or "waste" valve - the extra drive water exits here during operation. The

"impetus" valve is the valve that is operated manually at the beginning (by pushing it in with a finger) to charge the ram and start normal operation.

Valves #1 and #7 could be ball valves instead of gate valves. Ball valves may withstand the shock waves of the pump better over a long period of time.

The swing check valve (part 4 - also known as the impetus valve) *can* be adjusted to vary the length of stroke (please note that maximum flow and pressure head will be achieved with this valve positioned vertically, with the opening facing up). Turn the valve on the threads until the pin in the clapper hinge of the valve is in line with the pipe (instead of perpendicular to it). Then move the tee the valve is attached to slightly away from vertical, making sure the clapper hinge in the swing check is toward the top of the valve as you do this. The larger the angle from vertical, the shorter the stroke period (and the less potential pressure, since the water will not reach as high a velocity before shutting the valve). For maximum flow and pressure valve #4 should be in a vertical position (the outlet pointed straight up).

Swing check valve #4 should always be brass (or some metal) and not plastic. Experiences with plastic or PVC swing check valves have shown that the "flapper" or "clapper" in these valves is very light weight and therefore closes much earlier than the "flapper" of a comparable brass swing check. This in turn would mean lower flow rates and lower pressure heads.

The pipe cock (part 10) is in place to protect the gauge after the pump is started. It is turned off after the pump has been started and is operating normally. Turn it on if needed to check the outlet pressure, then turn it back off to protect the gauge.

Drive Pipe - The length of the drive pipe (from water source to pump) also affects the stroke period. A longer drive pipe provides a longer stroke period. There are maximum and minimum lengths for the drive pipe (see the paragraph below Table 2). The drive pipe is best made from galvanized steel (more rigid is better) but schedule 40 PVC can be used with good results. The more rigid galvanized pipe will result in a higher pumping efficiency and allow higher pumping heights. Rigidity of the drive pipe seems to be more important in this efficiency than straightness of the drive pipe.

Drive pipe length and size ratios are apparently based on empirical data. Information from University of Georgia publications (see footnote) provides an equation from Calvert (1958), which describes the output and stability of ram pump installations based on the ratio of the drive pipe length (L) to the drive pipe diameter (D). The best range is an L/D ratio of between 150 and 1000 (L/D = 150 to L/D = 1000). Equations to use to determine these lengths are:

Minimum inlet pipe length: L = 150 x (inlet pipe size)

Maximum inlet pipe length: L = 1000 x (inlet pipe size)

If the inlet pipe size is in inches, then the length (L) will also be presented in inches. If inlet pipe size is in mm, then L will be presented in mm.

Drive Pipe Length Example: If the drive pipe is 1-1/4 inches (1.25 inches) in diameter, then the minimum length should be L = 150 x 1.25 = 187.5 inches (or about 15.6 feet). The maximum length for the same 1-1/4 inch drive pipe would be L = 1000 x 1.25 = 1250 inches (104 feet). The drive pipe should be as rigid and as straight as possible.

Stand pipe or no stand pipe? Many hydraulic ram installations show a "stand pipe" installed on the inlet pipe. The purpose of this pipe is to allow the water hammer shock wave to dissipate at a given point. Stand pipes are only necessary if the inlet pipe will be longer than the recommended maximum length (for instance, in the previous example a stand pipe may be required if the inlet pipe were to be 150 feet in length, but the maximum inlet length was determined to be only 104 feet). The stand pipe - if needed - is generally placed in the line the same distance from the ram as the recommended maximum length indicated.

The stand pipe must be vertical and extend vertically at least 1 foot (0.3 meter) higher than the elevation of the water source - no water should exit the pipe during operation (or perhaps only a few drops during each shock wave cycle at most). Many recommendations suggest that the stand pipe should be 3 sizes larger than the inlet pipe. The supply pipe (between the stand pipe and the water source) should be 1 size larger than the inlet pipe.

The reason behind this is simple - if the inlet pipe is too long, the water hammer shock wave will travel farther, slowing down the pumping pulses of the ram. Also, in many instances there may actually be interference with the operation of the pump due to the length of travel of the shock wave. The stand pipe simply allows an outlet to the atmosphere to allow the shock wave to release or dissipate. Remember, the stand pipe is not necessary unless the inlet pipe will have to be longer than the recommended maximum length.

Another option would be to pipe the water to an open tank (with the top of the tank at least 1 foot (0.3 meter) higher than the vertical elevation of the water source), then attach the inlet pipe to the tank. The tank will act as a dissipation chamber for the water hammer shock wave just as the stand pipe would. This option may not be viable if the tank placement would require some sort of tower, but if the topography allows this may be a more attractive option.

Click here to view sketches of these types of hydraulic ram pump installations
(loads in 70 seconds over 28.8 modem)

Operation:

The pump will require some back pressure to begin working. A back pressure of 10 psi or more should be sufficient. If this is not provided by elevation-induced back pressure

from pumping the water uphill to the delivery point (water trough, etc.), use the 3/4" valve (part 7) to throttle the flow somewhat to provide this backpressure.

As an alternative to throttling valve part 7 you may consider running the outlet pipe into the air in a loop, and then back down to the trough to provide the necessary back pressure. A total of 23 feet of vertical elevation above the pump outlet should be sufficient to provide the necessary back pressure. This may not be practical in all cases, but adding 8 feet of pipe after piping up a hill of 15 feet in elevation should not be a major problem. This will allow you to open valve #7 completely, preventing stoppage of flow by trash or sediment blocking the partially-closed valve. It is a good idea to include a tee at the outlet of the pump with a ball valve to allow periodic "flushing" of the sediment just in case.

The pump will have to be manually started several times when first placed in operation to remove the air from the ram pump piping. Start the pump by opening valve 1 and leaving valve 7 closed. Then, when the swing check (#4) shuts, manually push it open again. (The pump will start with valve 7 closed completely, pumping up to some maximum pressure before stopping operation.) After the pump begins operation, slowly open valve 7, but do not allow the discharge pressure (shown on gauge #11) to drop below 10 psi. You may have to push valve #4 open repeatedly to re-start the pump in the first few minutes (10 to 20 times is not abnormal) - air in the system will stop operation until it is purged.

The unions, gate (or ball) valves, and pressure gauge assembly are not absolutely required to make the pump run, but they sure do help in installing, removing, and starting the pump as well as regulating the flow.

Pump Performance:

Some information suggests that typical ram pumps discharge approximately 7 gallons of water through the waste valve for every gallon pressurized and pumped. The percentage of the drive water delivered actually varies based on the ram construction, vertical fall to pump, and elevation to the water outlet. The percentage of the drive water pumped to the desired point may be approximately 22% when the vertical fall from the water source to the pump is half of the elevation lift from the ram to the water outlet. It may be as low as 2% or less when the vertical fall from the water source to the pump is 4% of the elevation lift from the ram to the water outlet. Rife Hydraulic Engine Manufacturing Company literature (http://www.riferam.com/) offers the following equation:

$$0.6 \times Q \times F/E = D$$

Q is the available drive flow in gallons per minute, F is the fall in feet from the water source to the ram, E is the elevation from the ram to the water outlet, and D is the flow rate of the delivery water in gallons per minute. 0.6 is an efficiency factor and will differ somewhat between various ram pumps. For instance, if 12 gallons per minute is available to operate a ram pump (D), the pump is placed 6 feet below the water source

(F), and the water will be pumped up an elevation of 20 feet to the outlet point (E), the amount of water that may be pumped with an appropriately-sized ram pump is

0.6 x 12 gpm x 6 ft / 20 ft = 2.16 gpm

The same pump with the same drive flow will provide less flow if the water is to be pumped up a higher elevation. For instance, using the data in the previous example but increasing the elevation lift to 40 feet (E):

0.6 x 12 gpm x 6 ft / 40 ft = 1.08 gpm

Table 3. Typical Hydraulic Ram specifications *(Expected water output will be approximately 1/8 of the input flow, but will vary with installation fall (F) and elevation lift (E) as noted above. This chart is based on 5 feet of lift (E) per 1 foot of fall (F).)*

Drive Pipe Diameter (inches)	**Delivery Pipe Diameter** (inches)	**At Minimum Inflow**		**At Maximum Inflow**	
		Pump Inflow (gallons per minute)	**Expected Output** (gallons per minute)	**Pump Inflow** (gallons per minute)	**Expected Output** (gallons per minute)
3/4	1/2	3/4	1/10	2	1/4
1	1/2	1-1/2	1/5	6	3/4
1-1/4	1/2	2	1/4	10	1-1/5
1-1/2	3/4	2-1/2	3/10	15	1-3/4
2	1	3	3/8	33	4
2-1/2	1-1/4	12	1-1/2	45	5-2/5
3	1-1/2	20	2-1/2	75	9
4	2	30	3-5/8	150	18
6	3	75	9	400	48
8	4	400	48	800	96

Table 4. Test Installation Information

Drive Pipe Size	1-1/4 inch Schedule 40 PVC
Outlet Pipe Size	3/4 inch Schedule 40 PVC
Pressure Chamber size	4 inch PR160 PVC
Pressure Chamber Length	36 inches
Inlet Pipe Length	100 feet

Outlet Pipe Length	40 feet
Drive Water (Inlet) elevation above pump	4 feet
Elevation from pump outlet to delivery outlet	12 feet

Click here to see pictures of the test installation (loads in 38 seconds over 28.8 modem)

Table 5. Trial 1 Performance Data

	Expected Performance	**At Installation (5/17/99)**	**After Installation (with water-log) (5/21/99)**	**After Clearing Water-log (6/20/99)**
Shutoff Head	5 to 17 psi	22 psi	50 psi	22 psi
Operating Head	10 psi	10 psi	10 psi	10 psi
Operating Flow Rate	0.50 to 1.00 gpm	0.28 gpm	1.50 gpm	0.33 gpm

Note that we used a 4" threaded plug and a 4" female adapter for our test pump (instead of the recommended 4" glue cap (#16) shown in the figure). Two days after installation the pump air chamber was effectively water-logged due to leakage past the threads of these two fittings, which was shown by the pronounced impulse pumping at the outlet discharge point. If the pump were allowed to remain waterlogged, it would shortly cease to operate - and may introduce damage to the pipe or other components due to pronounced water hammer pressure surges.

The large range of expected values for shutoff head is due to the unknown efficiency of the pump. Typical efficiencies for ram pumps range from 3 feet to 10 feet of lift for every 1 foot of elevation drop from the water inlet to the pump.

Hydraulic Ram Web Sites

Bamford Pumps
CAT Hydraulic Ram Tipsheet
Green and Carter
Lifewater Rams
NC State's EBAE 161-92, "Hydraulic Ram Pumps"
RamPumps.com
Rife Rams
Schott Solar Electric
University of Warwick (UK) Ram Pump Publications

University of Warwick (UK) Ram pump system design notes

Some information for this web page - and the initial information concerning construction of a home-made hydraulic ram pump - was provided by University of Georgia Extension publications #ENG98-002 and #ENG98-003 (both Acrobat "pdf" files) by Frank Henning. Publication #ENG98-002 also describes the pumping volume equations for hydraulic ram pumps.

Last modified on 10/15/07
This page created and maintained by Bryan Smith,
Clemson University Cooperative Extension, Laurens County.

How a Hydraulic Ram Pump works

The concept behind the ram idea is a "water hammer" shock wave. Water has weight, so a volume of water moving at a certain speed has momentum - it doesn't want to stop immediately. If a car runs into a brick wall the result is crumpled metal. If a moving water flow in a pipe encounters a suddenly closed valve, a pressure "spike" or increase suddenly appears due to all the water being stopped abruptly (that's what water hammer is - the pressure spike). If you turn a valve off in your house quickly, you may hear a small "thump" in the pipes. That's water hammer.

Here's how the hydraulic ram pump actually works, step-by-step:

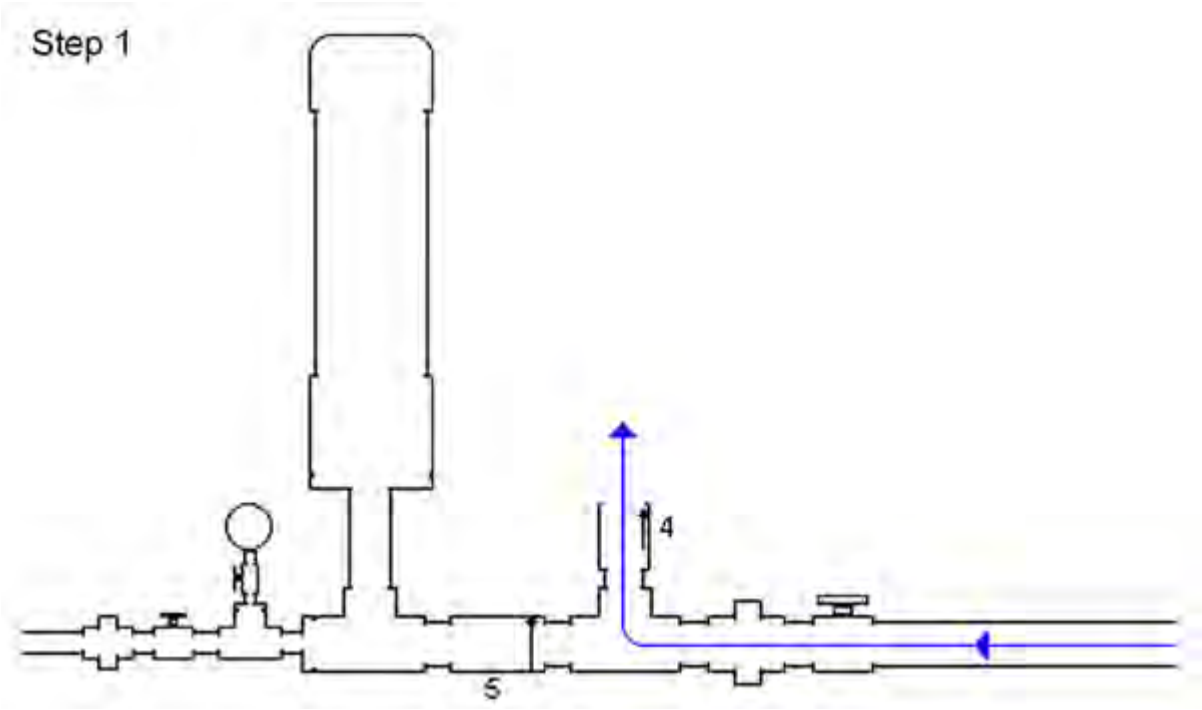

(1) Water (blue arrows) starts flowing through the drive pipe and out of the "waste" valve (#4 on the diagram), which is open initially. Water flows faster and faster through the pipe and out of the valve. (Click here to see an actual image of an operating ram pump for this step.)

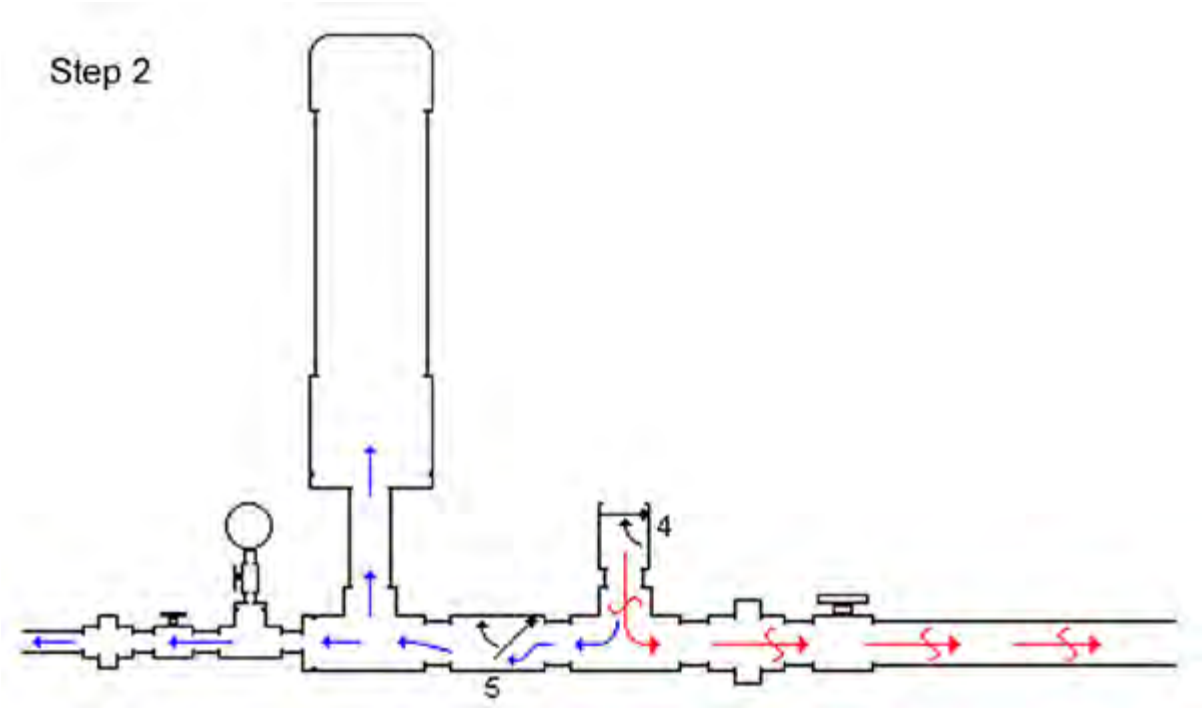

(2) At some point, water is moving so quickly through the brass swing check "waste" valve (#4) that it grabs the swing check's flapper, pulling it up and slamming it shut. The water in the pipe is moving quickly and doesn't want to stop. All that water weight and momentum is stopped, though, by the valve slamming shut. That makes a high pressure spike (red arrows) at the closed valve. The high pressure spike forces some water (blue arrows) through the spring check valve (#5 on the diagram) and into the pressure chamber. This increases the pressure in that chamber slightly. The pressure "spike" the pipe has nowhere else to go, so it begins moving away from the waste valve and back up the pipe (red arrows). It actually generates a very small velocity *backward* in the pipe. (Click here to see an actual image of an operating ram pump for this step. Note the drops of water still falling to the ground in the image.)

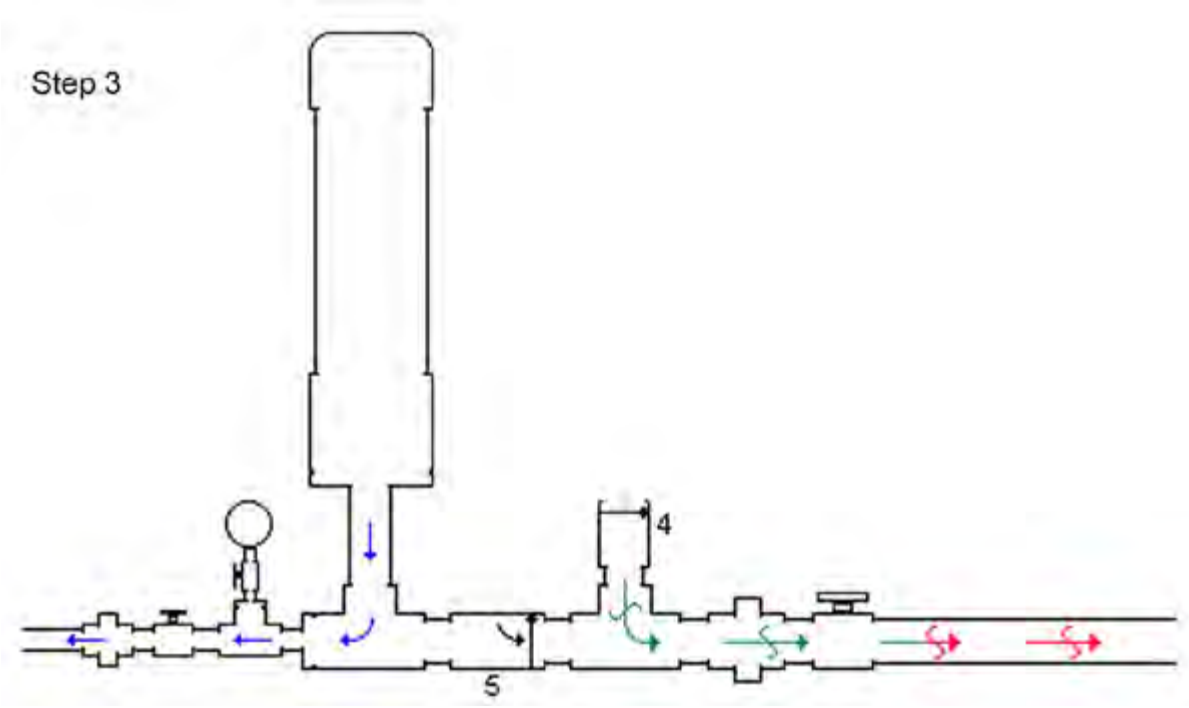

(3) As the pressure wave or spike (red arrows) moves back up the pipe, it creates a lower pressure situation (green arrows) at the waste valve. The spring-loaded check valve (#5) closes as the pressure drops, retaining the pressure in the pressure chamber.

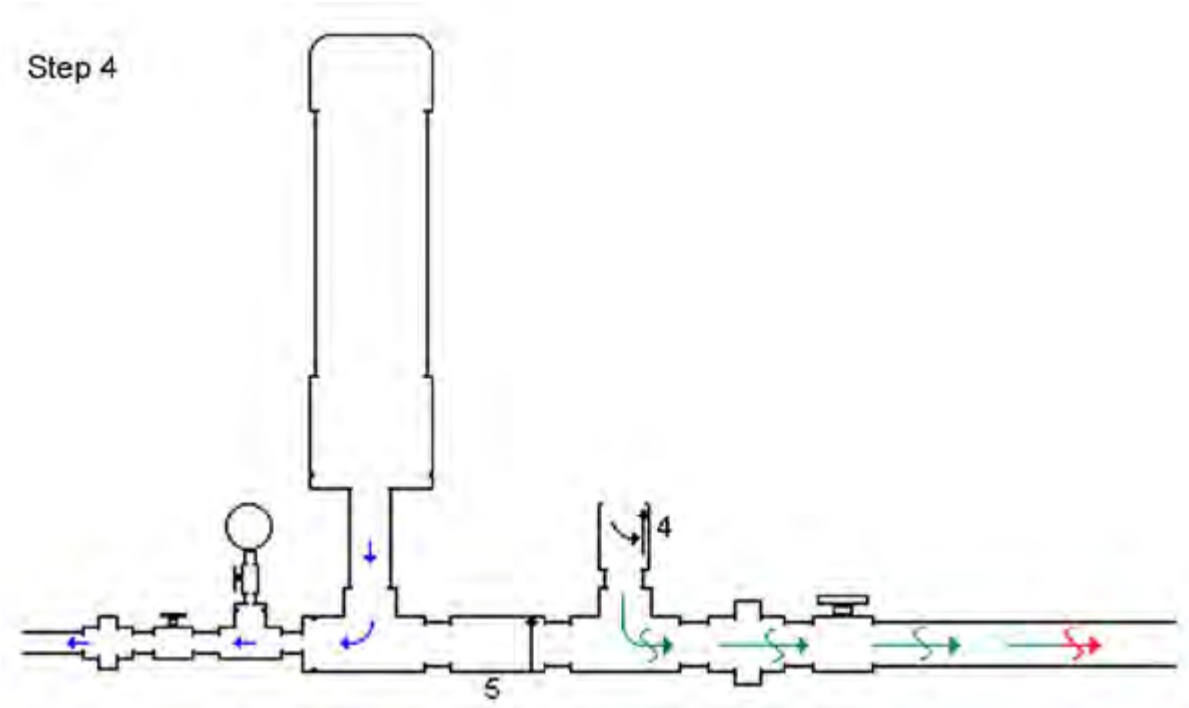

(4) At some point this pressure (green arrows) becomes low enough that the flapper in the waste valve (#4) falls back down, opening the waste valve again. [(Click here to see an actual image of a ram pump for this step.)]

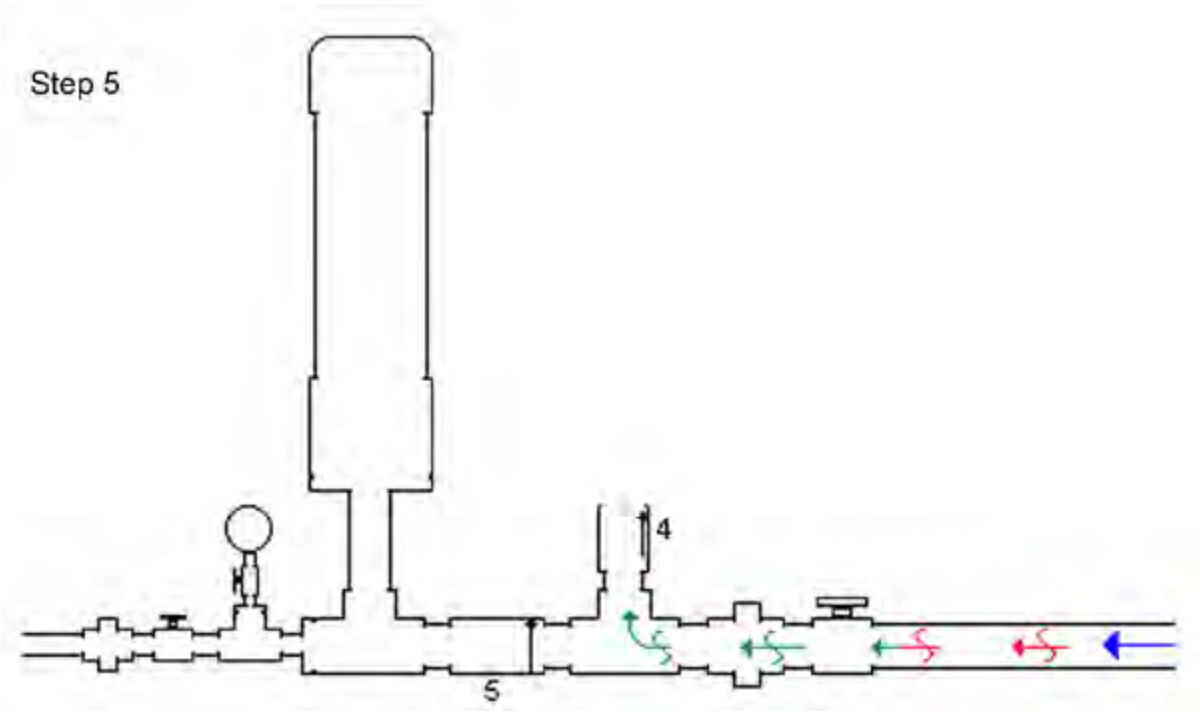

(5) Most of the water hammer high pressure shock wave (red arrows) will release at the drive pipe inlet, which is open to the source water body. Some small portion *may* travel back down the drive pipe, but in any case after the shock wave has released, pressure begins to build again at the waste valve (#4) simply due to the elevation of the source water above the ram, and water begins to flow toward the hydraulic ram again.

(6) Water begins to flow out of the waste valve (#4), and the process starts over once again.

Steps 1 through 6 describe in layman's terms a complete cycle of a hydraulic ram pump. Pressure wave theory will explain the technical details of why a hydraulic ram pump works, but we only need to know it works. (One American company has been manufacturing and selling hydraulic rams since the 1880's). The ram pump will usually go through this cycle about once a second, perhaps somewhat more quickly or more slowly depending on the installation.

Each "pulse" or cycle pushes a little more pressure into the pressure chamber. If the outlet valve is left shut, the ram will build up to some maximum pressure (called shutoff head on pumps) and stop working.

The ram is quite inefficient. Usually 8 gallons of water must pass through the waste valve for each 1 gallon of water pumped by the ram. That is acceptable for a creek or

river situation, but may not be a good option for a pond that does not have a good spring flow.

Hydraulic Ram Pump System Sketches

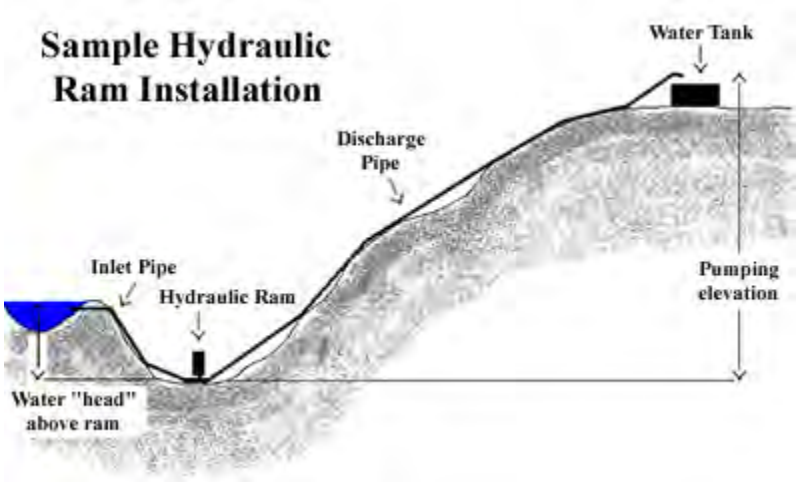

Figure 1. This installation is the "normal" ram system where the inlet pipe is less than the maximum length allowed. No stand pipe or open tank is required.

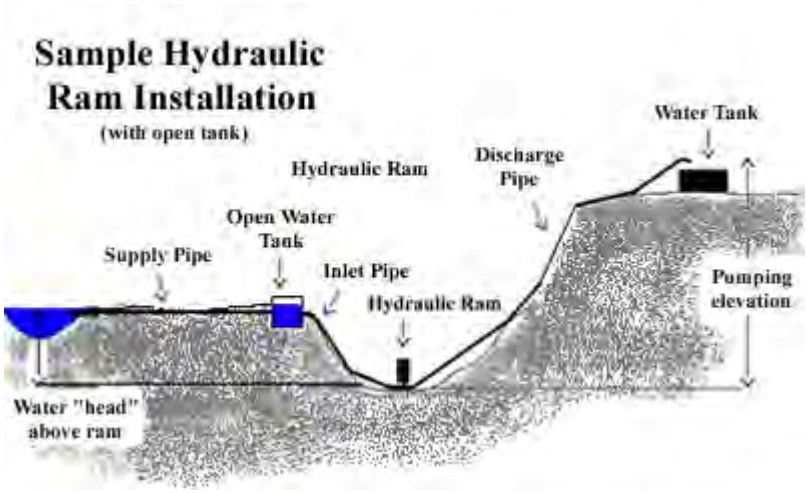

Figure 2. This installation is one option used where the inlet pipe is longer than the maximum length allowed. The open water tank is required to allow dissipation of the water hammer shock wave.

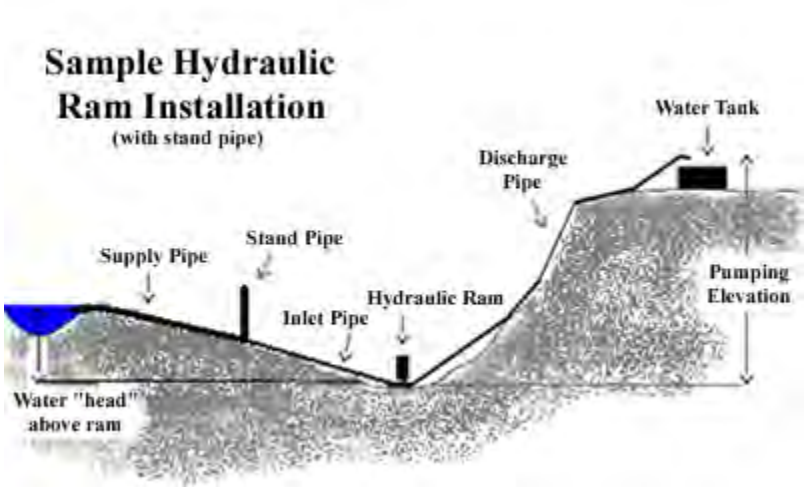

Figure 3. This installation is another option used where the inlet pipe is longer than the maximum length allowed. The stand pipe (open to atmosphere at the top) is required to allow dissipation of the water hammer shock wave.

Home-made Hydraulic Ram Test Installation

Figure 1. The ram pump installed and operating. Note the water exiting the waste valve and the rock used to hold the pump upright and anchor it.

Figure 2. The 1-1/4 inch Schedule 40 PVC drive pipe supplying the ram pump. Note the curves in the pipe due to the geometry of the stream channel. The pump worked quite well despite the lack of straightness of the pipe.

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http://www.homepower.com/article/?file=HP97_pg140_QandA_2

Q&A: Ram Pump

By Michael Welch

Oct/Nov 2003 (#97) pp. 140-141

Intermediate Level

Ram Pump

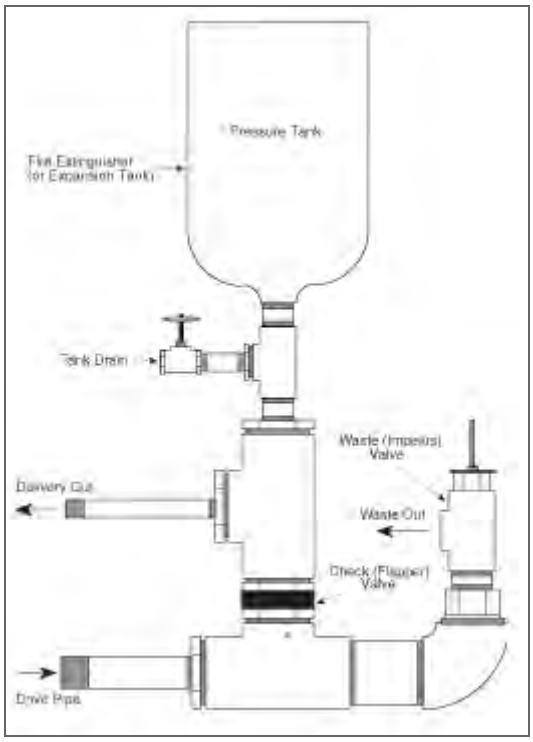

Dear Home Power, I live in northeast Scotland. I was very interested in an article you had in your magazine on how to build your own ram pump using basic plumbing fittings and a fire extinguisher (HP41). My water supply at present is fed to our house by a #2 Blake Hydram pump, which requires between 2.5 and 5 imperial gallons per minute falling 6 or 7 feet to enable it to pump to a height of 137 feet. This has worked reasonably well until now. The water supply has reduced to 2 imperial gallons per minute and the pump is 50 years old and has seen a lot of wear and tear. I can still manage to get it to pump to around 75 feet.

I endeavored to fabricate my own pump using your detailed instructions. Using the same flow rate and working fall, I got it to pump to a height of just under 60 feet. Do you think that the output I have obtained is reasonable and I'm expecting too much, or have I done something wrong somewhere? The only feature that differs in the pump I put together is that I used an expansion tank rather than a fire extinguisher.

I would appreciate any advice you could offer, since my house is becoming one of the driest places in Scotland. Regards,

Ian Black • via email

Hi Ian, I am really surprised to hear that you can only reach 60 feet with that pump, whereas the Blake was pumping to 137 feet. Actually, I am more surprised that you got that much pumping height from such a low drive head, even with the Blake. It must be a very nice pump.

Something may be amiss with the homebuilt pump. That pump successfully moved water to a height of 150 feet, but also had a drive head of greater than 20 feet at the time. Here are two things to check. First, the design of the waste (impetus) valve leaves much to be desired. If you are using the original design for this, I would not be surprised if it was trying to close a bit crooked since there is not enough of a guide for the stem. That would leave a small gap, and possibly reduce the amount of power the pump has. Also, the flapper valve inside can be a problem. We found that it would cup into the hole when it closed, losing efficiency. What we did to fix this was to put a large washer (called fender washers in the U.S.) that spanned the entire hole on top of the flapper, with a bolt all the way through, and a washer smaller than the diameter of the valve seat underneath. This increased the efficiency of the unit quite a bit.

It seems to me that the Blake should still be able to pump to the same height, except with fewer gallons per day, when adjusting it down to your lower flow rate from your source. Are you sure nothing else is wrong? Check for:

- Obstruction of the drive pipe or impetus valve inner area
- Corrosion in the drive pipe
- Leaks or cracks of the internal valve
- Water filling the bell, reducing the effective air chamber to the point that it will not work.

Michael Welch • Home

Ram pumps

Ram pumps can only be used in situations where falling water is available, which restricts them to use in three main applications:

- Lifting drinking water from springs in valleys to settlements on higher ground.
- Pumping drinking water from clean streams that have significant slope.
- Lifting irrigation water from streams or raised irrigation channels.

Water ram

Ram pumps are water pumping devices that are powered by falling water. The pump works by using the energy of a large amount of water falling a small height to lift a small amount of that water to a much greater height. In this way, water from a spring or stream in a valley can be pumped to a village or irrigation scheme on the hillside. Wherever a fall of water can be obtained, the ram pump can be used as a comparatively cheap, simple and reliable means of raising water to considerable heights.

Ram pumps have a cyclic pumping action that produces their characteristic beat during operation. The cycle can be divided into three phases: 'Acceleration', 'delivery' and 'recoil'.

Acceleration
When the impulse valve is open, water accelerates down the drive pipe and discharges through the open valve. The friction of the water flowing past the moving parts of the valve causes a force on the valve acting to close it. As the flow increases it reaches a speed where the drag force is sufficient to start closing the valve. Once it has begun to move, the valve closes very quickly.

Delivery
As the impulse valve slams shut, it stops the flow of water through it. The water that has been flowing in the drive pipe has considerable momentum, which has to be dissipated. For a fraction of a second, the water in the body of pump is compressed causing a large surge in pressure. This type of pressure rise is known as water hammer. As the pressure rises higher than that in the air vessel, it forces water through the delivery valve (a non-return valve). The delivery valve stays open until the water in the drive pipe has almost completely slowed down and the pressure in the pump body drops below the delivery pressure. The delivery valve then closes, stopping any back flow from the air vessel into the pump and drive pipe.

Recoil
The remaining flow in the drive pipe recoils against the closed delivery valve, rather like a ball bouncing back. This causes the pressure in the body of the pump to drop low enough for the impulse valve to reopen. The recoil also sucks a small amount of air in through the snifter valve. The air sits under the delivery valve until the next cycle when it is pumped with the delivery water into the air vessel. This ensures that the air vessel stays full of air. When the recoil energy is finished, water begins to accelerate down the drive pipe and out through the open impulse valve, starting the cycle again.

Efficiency and Power

The power required to raise water is proportional to the water's flow rate multiplied by the height through which it is lifted (in a ram pump q x h). Similarly, the power available from falling water is proportional to its flow rate multiplied by the distance dropped (Q x H). A ram pump works by transferring the power of a falling drive flow to a rising delivery flow.

By definition Efficiency = output power/input power = qh/QH.

Efficiency is always less than 1. It is useful to know the efficiency because we can use it to predict the delivery flow of a system and to compare two different pumps. Rearranging the equation above gives the formula:

Delivery flow (q) = QHn/h

To obtain a good delivery flow, the efficiency of the pump should be high, there should be a large drive flow, and the delivery head should not be too many times the drive head. The value of system efficiency to put into the formula depends upon many factors including the design of the pump and the system being used.

Suitable Areas

Although all watercourses slope downwards to some degree, the gradient of many is so shallow that many kilometres of feed pipe or canal would be needed to obtain a fall of water large enough to power a ram pump. Ram pumps can be made to run with drive heads of less than one metre but they are not normally considered viable unless heads of two metres or more are available. If it would take a long length of feed pipe or canal to achieve this head, a ram pump system would be prohibitively expensive. The best geographical area for ram pumps is one that is hilly, with rapidly dropping watercourses and, ideally, springs.

In some areas of the world good regional records of rainfall and flow from springs and in watercourses are kept in government offices and libraries. In others, another agency may have carried out recent relevant studies. If any hydrological studies are available for the region in which you plan to install ram pump systems, you can save time, effort and costly mistakes by consulting the records and using their findings in your site design.

After potential sites have been identified, they must be surveyed. The survey yields information about its dimensions and the materials required to construct the site as well as, when more than one site is surveyed, yielding a cost and performance comparison.

Designing a good drive and pump layout is crucial to achieving good system performance and limiting the amount of maintenance required. The aim is to be able to achieve a large head of water between the drive tank and pump, while using a short drive pipe to connect them. The best and cheapest sites are those where the land falls rapidly, allowing all pipe work to be short.

Life and Reliability

Imported ram pumps operated at fairly low throughput have proved extremely reliable in some developing countries. Some have run without stopping for ten years or more in systems supplied with clean water from a reservoir. This outstanding reliability has had a curious side effect - when such pumps finally stop the beneficiaries have no recall of their source, no knowledge of how to maintain them and no access to spare parts. Failures in ram pump systems often occur outside the pump itself - blockage of filter screens, damage to pipes, sedimentation of pipes and tanks etc. Poorly located drive pipes sometimes show perforation due to a process called cavitation.

Pumps made in local workshops are less durable than some of the imported machines made of cast iron, but their lower price usually makes them better value than either imported ram pumps or other pumps of comparable throughput. They also have the advantage of being locally repairable with ready access to spare parts.

Ram pumps run unattended for long periods, so running faults can go unattended for days or weeks. This can lead to expensive failures. For example, blockage of the output for long periods can cause fatigue failure of components (unless a costly pressure relief valve is fitted). The historical high reliability of ram pumps may reflect in part the social circumstances of their traditional use on large farms or mission stations where regular checks are made. The routine supervision of village systems may be much poorer and great care should be taken to ensure adequate caretaking.

Tuning to Suit Site Conditions

Any particular ram pump is normally capable of running under quite a wide range of conditions. Most manufacturers quote operating ranges of drive head (H), drive flow (Q) and delivery head (h) for each pump size and give some indication at a particular site. In situations where the water source has a larger flow than that required, each pump can be tuned to use as much drive water as possible to ensure minimum capital costs. When there is a limited amount of drive water available, the impulse valve has to be tuned to make the most efficient use of that water to produce the best possible output. At many sites there is a seasonal variation in the drive flow available and this is accommodated by varying the pump tuning or varying the number of pumps in use.

Economic Factors

One of the greatest benefits of ram pump systems is that they have extremely low running costs. There is no input of expensive petroleum fuels or electricity, making the systems very inexpensive to operate. The purchase cost of a pump, however, is usually only a fraction of the capital cost of a system: drive and delivery pipe work are usually the most expensive parts. Ram pump systems can be subject to economies of scale. For example, where there is enough drive flow, having several pumps at one site gives a lower unit cost then if the same pumps were installed at separate sites. In situations of plentiful drive flow, buying one large pump may be cheaper than buying several smaller ones, although this option does have disadvantages: having a single large pump involves a loss of system flexibility across a range of flows and if the pump needs maintenance or fails, 100% of the delivery is

lost. With several smaller pumps, a pump can fail or be stopped for maintenance without stopping the entire delivery flow.

Prices of ram pumps available today vary enormously. If a pump is imported the costs of shipping and customs duty may significantly increase the actual cost of the pump to its users.

Social Factors

The significance of social factors to any development project cannot be over-emphasised. This is particularly true of community water supplies, which involve every member of the community on daily basis. A large amount of written material is available highlighting the importance of community involvement and detailing examples of participation in project initiation, design, management, and finance. It is strongly recommended that anyone exploring the possibility of initiating a community water supply should obtain some of the available literature and give great attention to the social aspects of the project. Good engineering is only one part of sustainable, economic and equitable water supply system. Without complete community involvement, even a water supply system that is technically perfect is likely to encounter serious problems and may fail altogether.

Adequate community involvement is particularly important during the period of system appraisal and design, and is dependent on good communication. When sufficient time and care is invested in producing a widely acceptable design, ram pump technology can be very appropriate to rural areas and be capable of true village-level operation and maintenance.

http://www.wot.utwente.nl/publications/articles/rampumps.html

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Hydraulic Rams -- Computer Simulation and Optimum Design

Although the hydraulic ram pump has been around for roughly 200 years, its design has been largely left to trial and error. Here is a computer-aided method for improving performance. Y.C. Chiang, Ali A. Seirig, Mechanical Engineering Department, University of Wisconsin, Madison, Wis.
-- From *Computers in Mechanical Engineering*, January 1985 (with thanks to Kirk McLoren)

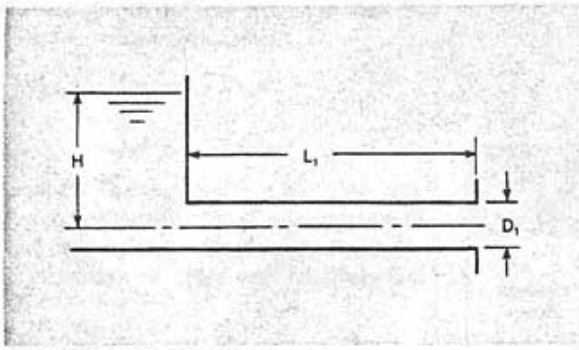

Fig. 2 Model of the drive pipe.

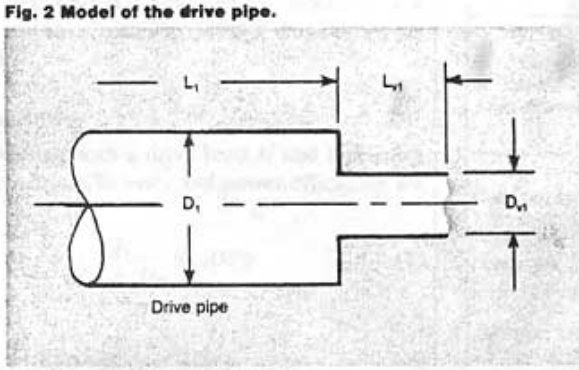

Fig. 3 Model of the waste valve.

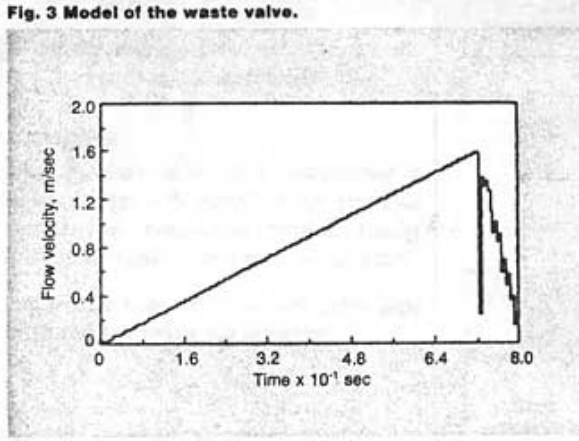

Fig. 4 Velocity time history in the drive pipe for example 1 (full cycle).

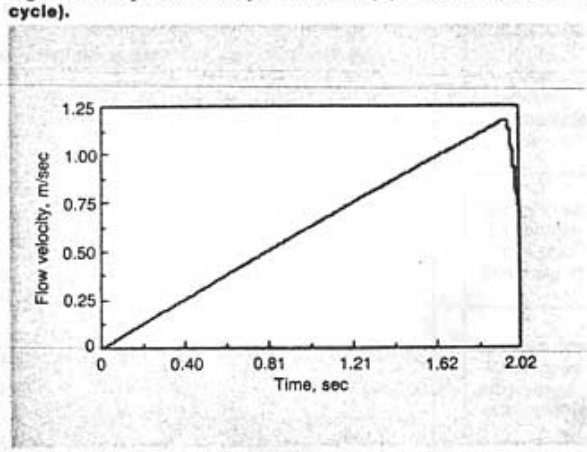

Fig. 5 Velocity time history in the drive pipe for example 2 (full cycle).

pipe [1–4] are rather incomplete and are usually derived from empirical experience rather than comprehensive experimentation or theory. In this article we will present a general method for the analysis and optimum design of hydraulic rams for any application. The technique used is the computer-aided analysis we introduced in the previous issue of *CIME* [5].

Modeling the Hydraulic Ram

A hydraulic ram is composed of five main parts: the drive pipe, waste valve, delivery valve, air vessel (or surge tank), and delivery pipe. To apply our scheme for analyzing fluid transients to the hydraulic ram, we must develop simplified models of the individual parts as follows:

Drive pipe. The drive pipe, with a drive head H, can be modeled as a pipeline connected to a reservoir of head H upstream, as shown in Figure 2.

Waste valve. We model the waste valve as a short pipe with variable diameter. The length of this pipe, L_{v1}, is taken equal to the stroke of the disk valve. The diameter, D_v, is then set to vary from 0 to the diameter of the drive pipe, D_l, in order to describe the change from the fully closed to fully opened valve. The model of the waste valve is shown in Figure 3.

If the relative valve opening τ is defined as

$$\tau = \left(\frac{D_v}{D_1}\right)^2 \tag{1}$$

Then,

$$D_v = D_1\sqrt{\tau} \tag{2}$$

The valve opening is controlled by the movement of the valve disk, which can be determined from:

$$\ddot{x} = -g + \frac{A_d}{M_v}\left(C_v\frac{1}{2}\rho V_1^2 + P_1 - P_2 + L_{v1}\rho g\right) \tag{3}$$

where: A_d is the effective area of the valve disk; P_1 and P_2 are pressures at the drive-pipe side and free side, respectively; V_1 is the flow velocity at the end of the drive pipe; M_v is the mass of the valve; and C_v is the valve coefficient, assumed to be 1.0.

By integrating equation (3), we can determine the value of τ according to the following equations:

$$\begin{aligned} \tau &= -x/L_{v1} && \text{for } -L_v < x < 0 \\ \tau &= 0 && \text{for } 0 < x \\ \tau &= 1 && \text{for } x < -L_v \end{aligned} \tag{4}$$

Delivery valve. Modeling of the delivery valve is similar to that of the waste valve. The equation of motion for the delivery valve can be written as:

$$\ddot{x} = -g + \frac{A_d}{M_v}\left[C_v\frac{1}{2}\rho(V_1^2 - V_2^2) + P_1 - P_2 + L_{v2}\rho g\right] \tag{5}$$

where V_1 and V_2 represent the velocity for the drive-pipe side and the surge-tank side, respectively.

The relative opening of the delivery valve can then be determined from the following relationships:

$$\begin{aligned} \tau &= x/L_{v2} && \text{for } -L_{v2} < x < 0 \\ \tau &= 0 && \text{for } 0 < x \\ \tau &= 1 && \text{for } x < -L_{v2} \end{aligned} \tag{6}$$

Surge tank (air vessel). The impedance of the surge tank is generally selected to be relatively small in comparison to that of the drive and delivery pipes. To simplify the analysis, we model the surge tank as a pipe with relatively low impedance.

Delivery pipe. The delivery pipe can be modeled as a pipeline connected to a reservoir with a head h at the downstream end.

Ram Performance

For a ram operating with a drive head H and a delivery head h, the volumetric efficiency and power efficiency are defined as:

$$\eta_v = \frac{Q_d}{Q_w + Q_d} \times 100\% \tag{7}$$

and

$$\eta_p = \frac{Q_d h}{Q_w H} \times 100\% \tag{8}$$

where Q_w and Q_d are the average flow rates through the waste valve and the delivery valve, respectively.

Numerical Examples

These pipe models for the ram are then incorporated in the pipeline transients program discussed in the previous issue. We will consider two examples to check the results of our model against those obtained by other investigators.

Example 1: the hydraulic ram with straight drive pipe analyzed in [4] with the following parameters:

$H = 3.54$ m
$h = 24.38$ m
$D_1 = 0.0262$ m
$L_1 = 15.04$ m

The additional data necessary for our analysis are assumed to be:

$D_2 = 0.2$ m
$L_2 = 0.5$ m
$D_3 = 0.0262$ m
$L_3 = 5.01$ m
$M_1 = 0.1$ kg
$M_2 = 0.25$ kg
$L_{v1} = 0.02$ m
$L_{v2} = 0.02$ m
$C_1 = 1443$ m/sec
$C_2 = 117$ m/sec
$C_3 = 1433$ m/sec
$A_{v1} = 0.00054$ m^2
$A_{v2} = 0.00054$ m^2

Table I
Performance of Ram In Examples 1 and 3
(H = 3.54 m, h = 24.38 m)

Performance of ram	Cycles per min.	Pump rate cc/sec	Volumetric efficiency η_v	Power efficiency η_p
Iversen's results	85.0	22.8	8.48%	58.39%
Our results from example 1	75.0	39.6	9.14%	69.3%
Optimum case for straight drive pipe (example 3)	52.4	66.2	11.50%	89.4%
Optimum case for stepped drive pipe (example 3)	50.6	73.7	12.14%	95.1%

Table II
Performance of Ram In Examples 2 and 4
(H = 0.65 m, h = 1.30 m)

Performance of ram	Cycles per min.	Pump rate cc/sec	Volumetric efficiency η_v	Power efficiency η_p
Baz's experimental data	24.0	26.0	3.36%	6.95%
Our results from example 2	29.6	28.66	4.15%	8.663%
Optimum case for straight drive pipe (example 4)	59.5	29.98	9.00%	19.77%
Optimum case for stepped drive pipe (example 4)	47.9	54.35	23.9 %	62.7%

The velocity time history in the drive pipe is shown in Figure 4. Table I compares the computed performance of the ram with Iversen's analytical results [4], which were obtained from the usual one-dimensional unsteady-flow approximation. The differences in the two sets of results point out that we lack enough information for a true comparison.

Example 2: hydraulic ram with a straight drive pipe operating with a low drive head and investigated experimentally by Baz and others [6]. The ram has the following characteristics:

$$H = 0.65 \text{ m}$$
$$h = 1.3 \text{ m}$$
$$D_1 = 0.0381 \text{ m}$$
$$L_1 = 10.0 \text{ m}$$

The other data necessary in the analysis are taken as:

$$D_2 = 0.2 \text{ m}$$
$$L_2 = 0.4 \text{ m}$$
$$D_3 = 0.0381 \text{ m}$$
$$L_3 = 5.0 \text{ m}$$
$$M_1 = 0.25 \text{ kg}$$
$$M_2 = 0.1 \text{ kg}$$
$$L_{v1} = 0.025 \text{ m}$$
$$L_{v2} = 0.025 \text{ m}$$
$$C_1 = 1443 \text{ m/sec}$$
$$C_2 = 117 \text{ m/sec}$$
$$C_3 = 1433 \text{ m/sec}$$
$$A_{v1} = 0.00114 \text{ m}^2$$
$$A_{v2} = 0.00114 \text{ m}^2$$

Figure 5 shows the velocity time history in the drive pipe for this example. Comparison of the ram performance from our analysis and from the experimental data in [6] is shown in Table II. Better correlation is evident in this case.

Example 3: an optimum design of the hydraulic ram in example 1. Given in this case that the values of all variables are the same as those in the first example, we must determine the design parameters for M_1, M_2, D_2, and D_3 that maximize the ram's volumetric efficiency. The following constraints are imposed on the design:

$$0.2 \text{ kg} < M_1 < 1.5 \text{ kg}$$
$$0.1 \text{ kg} < M_2 < 0.5 \text{ kg}$$
$$0.03 \text{ m} < D_2 < 0.3 \text{ m}$$
$$0.015 \text{ m} < D_3 < 0.05 \text{ m}$$

Values for $M_1 = 0.1$ kg, $M_2 = 0.25$ kg, $D_2 = 0.2$ m, and $D_3 = 0.0262$ m, which correspond to example 1, are chosen as the initial base point for the search. Following the optimum search procedure described in the previous issue, the optimum solution gives these design parameters: $M_1 = 0.769$ kg, $M_2 = 0.1$ kg, $D_2 = 0.1053$ m, and $D_3 = 0.05$ m. The performance characteristics for the optimum design are shown in Table I for comparison.

Layered (or laminated) materials or elastic bars with variations in impedance have been shown to produce attenuation or amplification of the stress wave when subjected to impact or blast loading [7–10]. We use this concept in the optimum design of the ram by generating an optimal shape for the drive pipe in order to produce further improvement in the efficiency. A drive pipe with five equal segments is assumed in this case and the diameters corresponding to the optimum design are found to be:

$$l_1 = 3.01 \text{ m} \quad d_1 = 0.0579 \text{ m}$$
$$l_2 = 3.01 \text{ m} \quad d_2 = 0.0527 \text{ m}$$
$$l_3 = 3.01 \text{ m} \quad d_3 = 0.0262 \text{ m}$$
$$l_4 = 3.01 \text{ m} \quad d_4 = 0.0315 \text{ m}$$
$$l_5 = 3.01 \text{ m} \quad d_5 = 0.0262 \text{ m}$$

The ram characteristics for this design are improved, as shown in Table I.

Example 4: optimum design of a hydraulic ram operating in low heads. The data for this example are the same as those used in example 2. The parameters obtained for the optimum design with a straight-drive-pipe ram are $M_1 = 0.05$ kg, $M_2 = 0.50$ kg, $D_2 = 0.012$ m, and $D_3 = 0.381$ m.

The optimum shape of a five-segment drive pipe corresponding to the optimum ram are also found to be:

$$l_1 = 2.0 \text{ m} \quad d_1 = 0.032 \text{ m}$$
$$l_2 = 2.0 \text{ m} \quad d_2 = 0.0381 \text{ m}$$
$$l_3 = 2.0 \text{ m} \quad d_3 = 0.0603 \text{ m}$$
$$l_4 = 2.0 \text{ m} \quad d_4 = 0.0032 \text{ m}$$
$$l_5 = 2.0 \text{ m} \quad d_5 = 0.0032 \text{ m}$$

The performance characteristics for the stepped drive are a significant improvement, as shown in Table II. ■

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Renewable Energy Fun
and
Water HomePower do-it-yourself projects!

Spanish text of Gert Breur's ram-pump
Gert Breur's water-powered suction ram-pump
New - Simple water-pump made even simpler: Rope-pump

The Breur ROC-ON Ram pump

The large 2inch water-powered RAM pump is able to drive water up to more than 100 meters altitude, while it needs a flow of between 2 and 10 meters level to run. Best operation: delivery less than 10 times altitude of flow. Delivery output volume approximately 10% of flow through Ram. For more info on Ram pumps, go to the WOT homepages: WOT - Working group on Development Technology.
Breur has also developed a small ram pump, so easy to assemble and understand, that the main principle of operation should be clear to anyone that has assembled one. Furthermore, it uses standard "garden" materials except for some pressure tube. Bill of material should be less than $50 even with high-quality materials. I have put up a shopping list below (translated from Dutch, so I hope you understand). Below are the pictures of the assembled pump with numbers, to get an idea. I have made "exploded-view" photos, see further below. I hope they allow you to assemble the parts more easily.

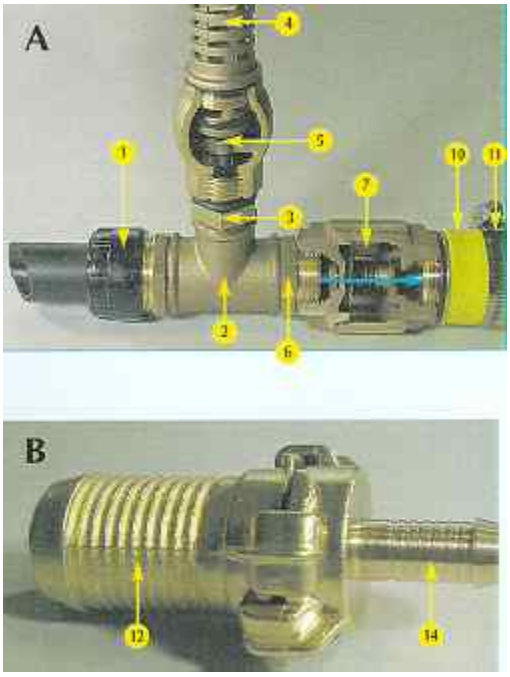

The Breur low-cost 3/4inch Ram pump

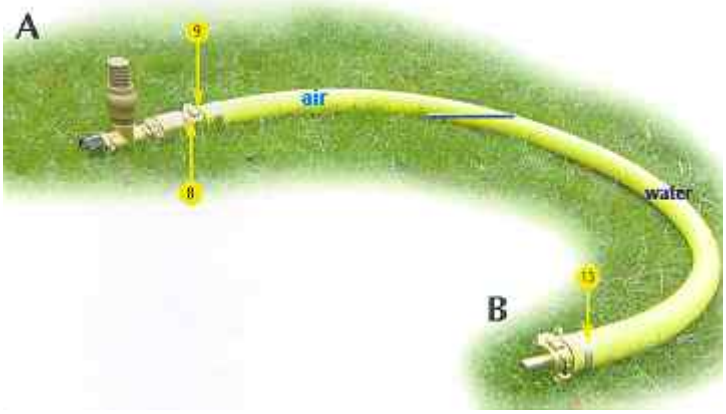

The bottom picture shows the ram (A) and the delivery (B). Make sure the delivery is situated LOWER than the RAM, because the tube in between must stay partially filled with air for correct (smooth & efficient) operation.

Shopping List:
1. Clamp-connection SIMPLAST WISA 25 x 3/4inch thread
2. T-joint brass 3/4 inch inside thread
3. Brass reducing coupling 1 inch to 3/4 inch outside thread
4. Foot valve brass 1 inch inside thread (ball shape and used in reverse direction)
5. O-ring nitrilrubber 6.0 mm x 1.5 mm (to regulate pump frequency)
6. Brass reducing coupling 1 inch to 3/4 inch outside thread
7. Spring-loaded check valve brass 1 inch inside thread "EUROPA"
8. (optional) brass quick-connect coupling "GEKA" 1 inch outside thread
9. (optional) Hose quick-connect brass coupling "GEKA" 1 1/4 inch
8+9 may be replaced by brass converter from 1 inch thread to 1 1/4 inch hose coupling.

10. Pressure tube TRICOFLEX 1 1/4 inch x 150 cm (more than 10 bar)
11. Hose clamp "JUBILEE" stainless steel 30-40 mm
12. Hose quick-connect brass coupling "GEKA" 1 1/4 inch
13. Hose clamp "JUBILEE" stainless steel 30-40 mm
14. Hose quick-connect brass coupling "GEKA" 1/2 inch
Not numbered items: Enflontape 12 mm x 0.1 mm or fibre "WURTH" (like for central heating installations)
Further the drive-pipe is not specified, this is either a rigid (metal!) pipe or (easier and therefore preferred) tylene tube, also used in drinking water installations. The diameter must be at least as much as the ram, so 3/4 inch. The length is expected to be several meters, from water-supply to ram.

NOTE that the drive pipe water inlet) is not shown above, it should be connected to the open end of the T-joint. A self-wound spring for the waste-valve is shown on the photo, this is necessary when this valve doesn't point upward.

Considerations: If the water comes out the dilivery in sharp pulses, then there is no air in the thick pressure tube. Disconnect it and fill it with air, the ram will run more efficient and smooth.

The drive heigth should be at least half a meter, but the ram cannot pump up high in that case. No more than 10 meter supply is recommended, or the pressure might get too high when the delivery is blocked.

If the ram doesn't start when water runs through it or it doesn't seem to be very efficient, the O-ring on the stem of the waste valve might be changed (taken away or one more added). Another reason can be that the waste-valve must point upward, or you must spring-load it. Otherwise the valve doesn't open itself. Some experimenting is required to get the best operation.

Multiple rams might be connected parallel (each have its own drive pipe and a common delivery, connected at B) and this will increase both delivery and reliability. Also when the amount of input flow decreases (season), some rams can be shut down while still some water is delivered by the others. One big ram will completely stop. Another important factor: maintenance can be done one ram at a time.

WARNING! If the ram is used to pump more than 20 meters high, the thin delivery tube must also be able to withstand this pressure! Be careful when disconnecting the delivery output, because the full pressure is present even when the ram has stopped! Drain the delivery tube or make (add) a pressure release valve that can be opened safely.

Ram with a shadow of fertility. **Water** means life and growth.

Pictures above can be downloaded as zipped bitmaps: ram.zip (warning: 1331 kB!)

Last update: Feb 24, 2000
Webmaster: Cor van de Water

DISCLAIMER:

The information on this page is presented in good faith of its usefulness and applicability, however no guarantees can be given that the information is correct and no responsibility is assumed in case the use of it results in damage. The applicant should treat the information with care, because it serves as illustration and description only.

The information is free of copyrights and fees (as far as we know) and can be used for private as well as commercial use. A notification of successful ram installation is appreciated. The WOT has set up a mailing list to share knowledge about ram-technology. Please indicate in your mail if you want to be included in the mailing list.

http://www.geocities.com/ResearchTriangle/System/7014/index.html

Gert Breur's water-powered suction ram-pump

Gert Breur's water-powered ram-pump also sucks up water!

The well-known ram pump, invented two centuries ago by Montgolfier, can lift water to high altitude using the energy of a larger amount of water falling only a few feet. The Dutch inventor Gert Breur has added only one valve to the original two-valve ram, creating a novel design which can still pump water up, but also sucks water from a lower level into the main drive stream. One possible application for this pump is at a piece of land which is the lowest point around, gathering water and becoming too wet for use. With a stream passing by at a higher level, this ram can be powered to lift the water up from the land into the stream. At the same time the ram can pump up water from the stream to a higher level, for irrigation or drinking. The water pumped up from the lower level is not mixed with the water which is pumped to the higher level, because it enters the ram after the impulse valve. See picture 2 for reference.

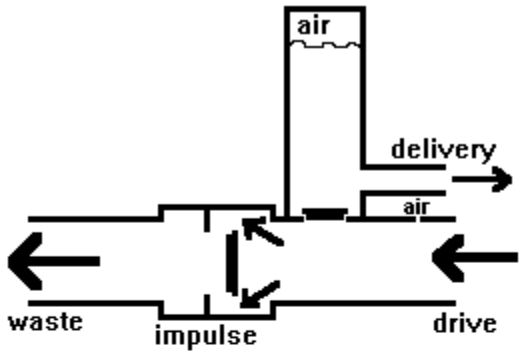

Figure 1a Acceleration

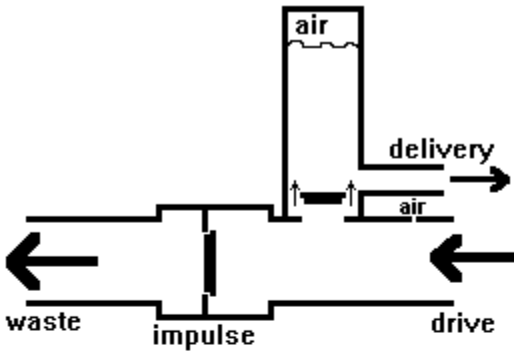

Figure 1b Compression

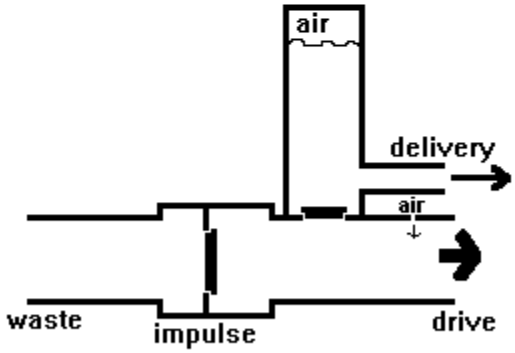

Figure 1c Recoil

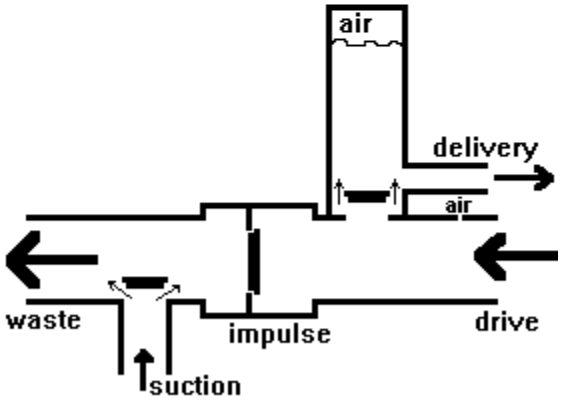

Figure 2 ram suction pump
Compression/Depression

The principle of Gert Breur's Ram pumps

Gert Breur has been experimenting with different materials to make the ram according his design criteria. These are:
- Simple operation, so everyone can grasp the working principle by looking at the parts and assembling them.
- Construction simplicity, so everyone can assemble one in a matter of minutes. Maintenance by local people is the goal.
- Easily obtainable materials, no special parts, so independence from suppliers. Local hardware store or garden centre should provide most or all material.
- No fees, no royalties. The inventor does not want to earn money, he wants people to enjoy the availability of clean water, saving lives and decreasing diseases. Therefore construction drawings and shopping list are free available, distribution is encouraged.

Common characteristic of all ram pumps is the operation using hydro power: a running stream or at least a waterlevel difference is needed. No electric, oil, gas or other energy is needed. This makes the operational cost very low: only the maintenance. Since the operating principle is so simple that local people can maintain the ram, this further reduces opertional cost. Combined with the use of standard materials for the Breur ram, this is an ideal choice for developing countries and for the many environmental aware do-

it-yourselfers that want running water at their residence, but want to use renewable energy to bring it there.

Operation principle of the basic ram pump:
The cycle consists of three phases, see figure 1.
a. Acceleration Phase
Water running through the ram increases in speed until the flow through the impulse valve causes enough pressure difference to close it.
b. Compression Phase
The moving water causes a high pressure inside the ram, which opens the delivery valve until the movement of the water has stopped.
c. Recoil Phase
Depending on the type of ram, some air enters the ram during the recoil of the water, this air adds to the 'pressure bubble' in the delivery output, smoothing the operation of the ram. Fresh air is needed if this air can escape during the operation of the ram. At the end of the cycle the impulse valve is opened by its spring and a new cycle starts.

Operation principle of Gert Breur's suction ram pump: See figure 2. The same phases as in figure 1 apply for this ram. Additional action occurs in phase b: Compression/Depression Phase. The water that already passed the impulse valve causes a low pressure when it closes (vacuum). This opens the third valve, sucking in a small amount of water until the main water flow has been stopped, so the pressure rises and the third valve closes.

More information on the ram pumps of Gert Breur can be found at the Working Group On Development Techniques (WOT). This is a volunteer organisation of the University Twente, the Netherlands. They are advising developing countries on the use of Renewable Energy, preferably by knowledge transfer of the technology, so local support is guaranteed.

contact address:
WOT
Vrijhof 206
P.O. Box 217
7500 AE Enschede
the Netherlands
tel: +31 53 489 2845
fax: +31 53 489 2671
e-mail: wot@tdg.utwente.nl
http://www.student.utwente.nl/~wot

Last update: April 11, 1999
Webmaster: Cor van de Water

The Gravi-Chek pumps have been tested by the Center for Irrigation Technology at the California Agricultural Technology Institute. There are three models available, providing water at rates from 20 to 16,000 gallons per day, depending on the installation.

Easy to use:

- Lightweight (35 lbs. or less), easy to carry and install in remote areas.
- Quick start up, no energy costs.
- Little or no maintenance.

Efficient and powerful:

- Running water supplies pumping energy.
- Durable, only two moving parts.
- Made from tempered marine aluminum

THE MOTORLESS WATER PUMP

Water flows through the drive pipe into the pump and out through the waste gate. The buoyant ball will be pulled down by the flow of water and block the waste gate.

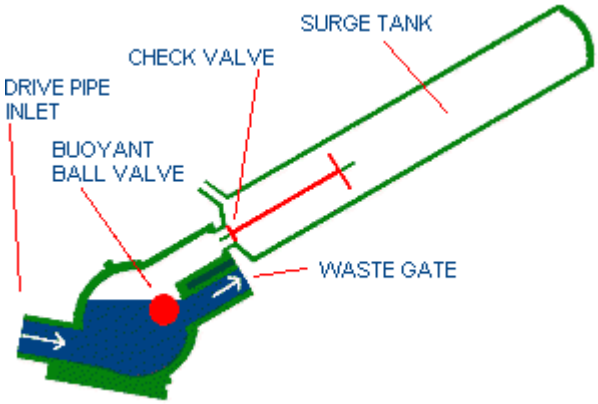

Here the ball has blocked the waste gate. The incoming water forces the spring loaded check valve open, allowing water to fill the surge tank, compressing the air in the tank.

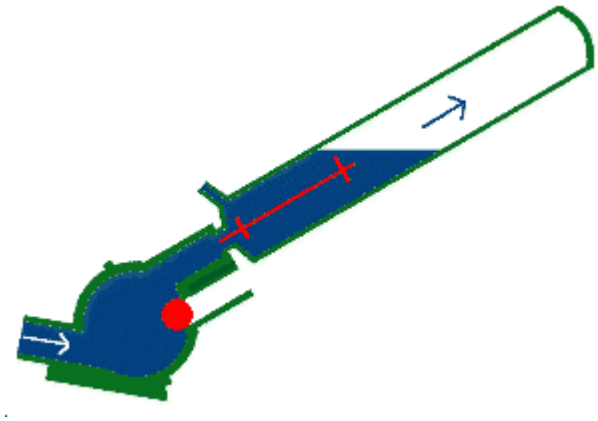

When the pressure in the surge tank equals the pressure in the drive pipe, the water from the drive pipe can no longer flow into the pump, a ãbounce-backä effect happens. The check valve shuts and the compressed air in the surge tank forces water in the tank up to where it is needed. The bounce back causes the water to briefly flow back up the drive pipe, unseating the ball valve and letting the cycle begin again.

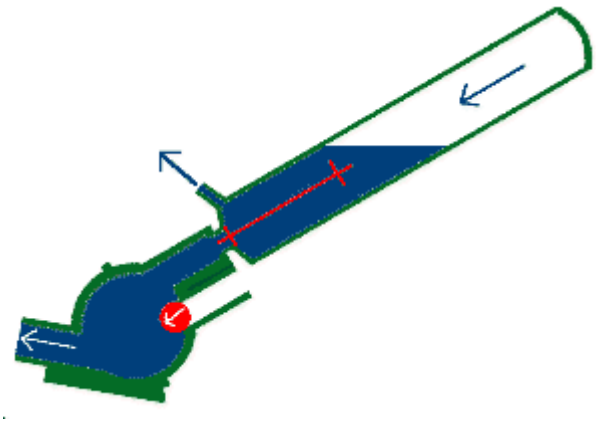

http://www.gravi-chek.com/index.html

---

http://journeytoforever.org/at_waterpump.html

Water-powered water pumps

Hydraulic ram water pumps use downhill water pressure to pump water much higher than it started, with no other power needed. A 20ft fall is enough to push water 150 feet above the source or more. Or as little as a 2ft fall between the water source and the pump at a flow rate of 1 to 3 gallons per minute is enough to pump water 20ft higher than the source -- as much as 4,000 gallons a day, depending on the model.

No modern magic this -- ram pumps were invented more than 300 years ago. A more recent variation is the High Lifter pump, which uses different principles to do the same thing. Ram pumps are noisy, high lifters are silent and can work with less water, but the water has to be clean and grit free, while the ram pump is not so fussy.

Folk hydraulic ram pump

These pumps can be expensive. **Home Power** magazine has had several good articles on the pumps, including designs and instructions for a cheap ram pump you can build yourself using off-the-shelf materials and a recycled fire-extinguisher. See: **Hydraulic Ram Pump** -- adapted from "A Manual for Constructing and Operating a Hydraulic Ram Pump" by Kurt Janke & Louise Finger, "Homebrew", Home Power #41, June / July 1994. Digital back issues can be bought online:
http://www.homepower.com/

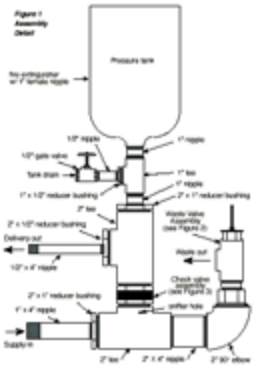

Build your own ram pump

High Lifter pump maker Alternative Energy Engineering is now part of solar electric company Applied Power Corporation.
http://www.solarelectric.com/
More information on the High Lifter Pump
http://www.solarelectric.com/products/level3_179.htm

More information about **High Lifter** pumps from supplier Mark Snyder Electric -- Application & Installation, How High Lifters Work, Question & Answer, Not a Ram Pump (the differences). Also sells ram pumps.
http://www.marksnyderelectric.com/catalog/waterpoweredpumps.html

Fleming Hydro-Ram pumps are powerful, lightweight, practically maintenance-free, and cheaper. From The Ram Company:
http://www.theramcompany.com/

The **Bamford "Hi-Ram Pump"** is a simple, low-cost, self-powered water pump using new patented technology. The principle is similar to conventional ram pumps, but its construction and characteristics are different. The heart of the pump is a stainless steel adjustment tube, and a free-floating high-impact plastic ball. It is quickly adjusted using alternative tubes, and the plastic ball gives quiet operation. While much higher outlet pressures are possible, the 25 mm (1 inch) pump can lift about 1500 litres of water daily to a height of 20 metres, using 2 to 3 metres drive head and 20 litres a minute inlet flow. The pump will operate when totally underwater. It can be made to supply compressed air or to provide a direct mechanical output to drive other devices, and can also act as a suction pump. Made with an eye to the needs of developing countries. Priced from about US$125.
http://www.bamford.com.au/rampump/

Hydraulic Rams -- Computer Simulation and Optimum Design

Although the hydraulic ram pump has been around for roughly 200 years, its design has been largely left to trial and error. Here is a computer-aided method for improving performance. Y.C. Chiang, Ali A. Seirig, Mechanical Engineering Department, University of Wisconsin, Madison, Wis.
-- From *Computers in Mechanical Engineering*, January 1985 (with thanks to Kirk McLoren)

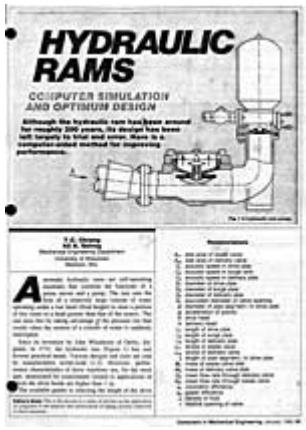

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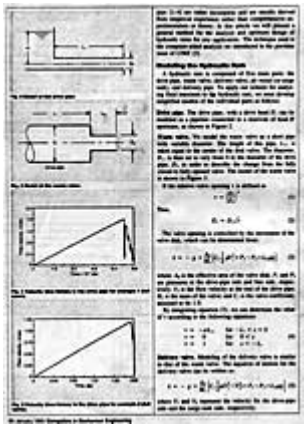

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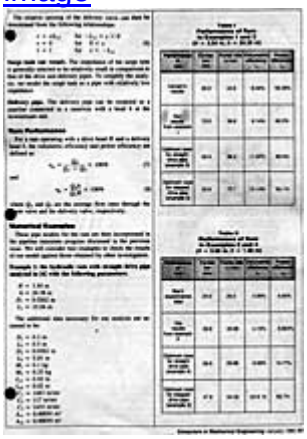

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Good overview of ram pumps and their uses and restrictions from the **Working Group On Development Techniques** (WOT) in Holland (also rope pumps, windmills):
http://www.wot.utwente.nl/documents/articles/rampumps.html

Dutch engineer **Gert Breur's** ram pumps are simpler, and they not only pump, they can also suck water up from a low-lying area into a stream. Breur has also developed a small ram pump, easy to assemble, using standard "garden" materials except for some pressure tube. Materials list, numbered pictures and "exploded-view" photos show you how.
http://www.wot.utwente.nl/documents/articles/breurram/index.html

More about Gert Breur's water-powered suction ram pumps, including Spanish text; also rope-pump and more:
http://www.geocities.com/ResearchTriangle/System/7014/index.html

Updated ram design from **Gravi-Chek** -- The Gravi-Chek pump is the newest

technology available in the ram pump industry. The Gravi-Chek pumps have been tested by the Center for Irrigation Technology at the California Agricultural Technology Institute. There are three models available, providing water at rates from 20 to 16,000 gallons per day, depending on the installation
http://www.gravi-chek.com/

Hydraulic ram pumps -- 6-page Technical Brief, Practical Action (Intermediate Technology Development Group, ITDG), Acrobat file, 190 K
http://www.itdg.org/html/technical_enquiries/docs/hydraulic_ram_pumps.pdf

Overview of ram pumps (and hand pumps) with some useful diagrams, from the (ahem) "**Sourcebook of Alternative Technologies for Freshwater Augmentation in Small Island Developing States**/Part B - Technology Profile/2. Technologies Applicable To Very Small, Low Coral Islands/ 2.1 Freshwater Augmentation Technologies/2.1.3 Pumps":
http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8d/pumps.asp

Ram Pump System Design Notes from the Development Technology Unit, School of Engineering, University of Warwick, UK: Online papers -- Introduction to hydraulic ram pumps, how ram pumps work, instructions for use and manufacture, designs, plans and drawings; also low-cost handpumps.
http://www.eng.warwick.ac.uk/DTU/lift/index.html

Another ram pump overview, more diagrams, equations, tables:
http://www2.ncsu.edu/eos/service/bae/www/programs/extension/publicat/wqwm/ebae161_92.html

Lifewater Canada -- Hydraulic ram pumps and Sling Pumps. Lots of great information at this site.
http://www.lifewater.ca/ram_pump.htm
See also Handpumps Resources -- Handpumps and water well drilling training for safe drinking water:
http://www.lifewater.ca/

Designing a Hydraulic Ram Pump -- US AID Water for the World Technical Notes
http://www.lifewater.org/wfw/rws4/rws4d5.htm

"All About Hydraulic Ram Pumps--How and Where They Work", Don R. Wilson, 1994 (updated), Atlas Pubns, ISBN 0963152629 -- This book explains in simple terms and with illustrations how the ram pump works, where it can be set up, and how to keep it going. The second section of the book gives step-by-step plans for building a fully operational Atlas ram pump from readily available plumbing fittings that requires NO welding, drilling, tapping or special tools. The final chapter shows how to build an inexpensive ferro-cement water storage unit with up to 15,000 gallon capacity. From Grove Enterprises, Inc.

http://www.grove.net/~atlas/

Rife Hydraulic Engine Mfg. Co. Inc. has specialized in pumping water without electricity or fuel for over 117 years -- one of the original Water Ram manufacturers and the oldest. Manufacture 19 different models of ram pumps, pumping up to 500 ft vertically and producing up to 350,000 gal/day. Rife also manufactures the Slingpump, which works on the flow of a stream, creek or river and can lift water up to 82 ft vertically and up to one mile away, 24 hours a day with no maintenance.
http://www.riferam.com/

Needed by African farmers: simple water pumps -- Finding sufficient water for irrigation is one of the major challenges facing farmers in sub-Saharan Africa, where only 4% of arable land is irrigated, severely constraining agricultural productivity in a region where an estimated one third of the population is chronically undernourished. Locally produced low-cost treadle pumps instead could make an important difference and could boost food security in the region significantly, says a new report, "Treadle pumps for irrigation in Africa". Treadle pumps make it easier for farmers to retrieve water for their fields or vegetable gardens, and they are cheap and easy to handle. If pumps are produced locally, they can also create jobs and income.Many African farmers are still irrigating very small plots of land using bucket-lifting technologies, which are slow, cumbersome and labour intensive. Treadle pumps are far more efficient and user-friendly. They can be used in a comfortable way, the farmer stands on the treadles, pressing the pistons up and down, lifting up to five cubic metres per hour (5,000 litres).
http://www.fao.org/news/2001/010103-e.htm

Practical Action books

Prototype ram pump in India -- built for one-tenth the commercial price

"Manual on the Automatic Hydraulic Ram for Pumping Water" by Simon B. Watt, 1978, Practical Action (Intermediate Technology Development Group, ITDG), ISBN 0903031159
Assumes no specialised knowledge of hydraulics, needs access only to basic machine tools and a few common engineering materials. Describes how to make a hydraulic ram from mild steel, some nuts and bolts and two rubber disks. Part One contains details of how to make and maintain a small hydraulic ram on a suitable site, Part Two takes a more technical look at ram performances and design considerations and also contains a useful bibliography. Excellent, clear plans for making your own hydraulic ram water pump from standard pipe fittings.
http://developmentbookshop.com/product_info.php?ref=13&products_id=239&affiliate_banner_id=1

"Hydraulic Ram Pumps: A guide to ram pump water supply systems" by T.D. Jeffrey, T.H. Thomas, A.V. Smith, P.B. Glover and P.D. Fountain, Practical Action, ISBN 1853391727
Step-by-step instructions on designing, installing and operating hydraulic ram pumps. Illustrations and diagrams, details of a pump designed for a local manufacture, notes for

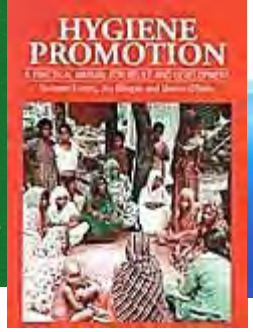

those developing their own model.
http://developmentbookshop.com/product_info.php?ref=13&products_id=235&affiliate_banner_id=1

"How to Make a Rope and Washer Pump" by Robert Lambert, 1989, Practical Action, ISBN 1853390224
How to make a simple, cheap pump which can raise water 18 feet from a stream or well at an output of 1 litre per second. Designed to irrigate small plots. A rope is pulled up through a pipe by means of a pulley wheel -- an old tyre. Fixed to the rope are flexible rubber washers (cut from another tyre) slightly narrower than the pipe; as the washers are pulled up through the pipe water is drawn up and discharged at the top. Rope and washers pass around the pulley wheel and return to the bottom of the pipe. Clever!
http://developmentbookshop.com/product_info.php?ref=13&products_id=236&affiliate_banner_id=1

"How to Make and Use the Treadle Irrigation Pump" by Carl Bielenberg and Hugh Allen, Practical Action, ISBN 1853393126
The treadle irrigation pump is able to lift up to 7,000 litres of water per hour using the power of the human body, and can be made locally at low cost in small-scale metalworking shops. Its acceptance in Bangladesh where it was first developed in 1984 is extraordinary, with over 500,000 pumps estimated now to be in use. The current design in this manual has evolved from the Bangladesh original into a fully portable pump with both lift and pressure capacity and is especially good for use in permeable soils where water cannot easily be distributed through channels.
http://developmentbookshop.com/product_info.php?ref=13&products_id=298&affiliate_banner_id=1

Water Lifting Devices: A Handbook, Third Edition, Peter Fraenkel and Jeremy Thake, Practical Action, ISBN 9781853395383
Updated and expanded new edition of Water Pumping Devices, long the authority on the subject. Detailed review of the water-lifting technologies available to smallholders for irrigation, along with new information covering drinking water for humans and livestock. Overview of the entire spectrum of pumps and water lifting devices for small-scale applications and a basis for comparing and choosing between them. Comprehensive single source of practical information.
http://developmentbookshop.com/product_info.php?ref=13&products_id=681&affiliate_banner_id=1

Designing a Hydraulic Ram Pump

Technical Note No. RWS.4.D.5

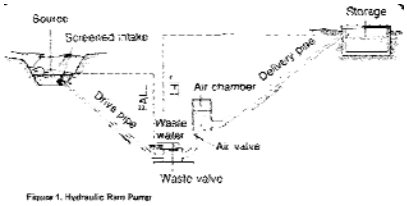

Figure 1. Hydraulic Ram Pump

[Index | Bottom]

A hydraulic ram or impulse pump is a device which uses the energy of falling water to lift a lesser amount of water to a higher elevation than the source. See Figure 1. There are only two moving parts, thus there is little to wear out. Hydraulic rams are relatively economical to purchase and install. One can be built with detailed plans and if properly installed, they will give many trouble-free years of service with no pumping costs. For these reasons, the hydraulic ram is an attractive solution where a large gravity flow exists. A ram should be considered when there is a source that can provide at least seven times more water than the ram is to pump and the water is, or can be made, free of trash and sand. There must be a site for the ram at least 0.5m below the water source and water must be needed at a level higher than the source.

Factors in Design

Before a ram can be selected, several design factors must be known. These are shown in Figure 1 and include:

1. The difference in height between the water source and the pump site (called vertical fall).
2. The difference in height between the pump site and the point of storage or use (lift).
3. The quantity (Q) of flow available from the source.
4. The quantity of water required.
5. The length of pipe from the source to the pump site (called the drive pipe).
6. The length of pipe from the pump to the storage site (called the delivery pipe).

Once this information has been obtained, a calculation can be made to see if the amount of water needed can be supplied by a ram. The formula is: D=(S x F x E)/L Where:

D = Amount delivered in liters per 24 hours.
S = Quantity of water supplied in liters per minute.
F = The fall or height of the source above the ram in meters.

E = The efficiency of the ram (for commercial models use 0.66, for home built use 0.33 unless otherwise indicated).
L = The lift height of the point of use above the ram in meters.

Table 1 solves this formula for rams with efficiencies of 66 percent, a supply of 1 liter per minute, and with the working fall and lift shown in the table. For supplies greater than 1 liter/minute, simply multiply by the number of liters supplied.

Table 1. Ram Performance Data for a Supply of 1 liter/minute
Liters Delivered over 24 Hours

Working Fall (m)	Lift - Vertical Height to which Water is Raised Above the Ram (m)											
	5	**7.5**	**10**	**15**	**20**	**30**	**40**	**50**	**60**	**80**	**100**	**125**
1.0	144	77	65	33	29	19.5	12.5					
1.5		135	96.5	70	54	36	19	15				
2.0		220	156	105	79	53	33	25	19.5	12.5		
2.5		280	200	125	100	66	40.5	32.5	24	15.5	12	
3.0			260	180	130	87	65	51	40	27	17.5	12
3.5				215	150	100	75	60	46	31.5	20	14
4.0				255	173	115	86	69	53	36	23	16
5.0				310	236	155	118	94	71.5	50	36	23
6.0					282	185	140	112	93.5	64.5	47.5	34.5
7.0						216	163	130	109	82	60	48
8.0							187	149	125	94	69	55
9.0							212	168	140	105	84	62
10.0							245	187	156	117	93	69
12.0							295	225	187	140	113	83
14.0								265	218	167	132	97
16.0									250	187	150	110
18.0									280	210	169	124
20.0										237	188	140

Components of Hydraulic Ram

A hydraulic ram installation consists of a supply, a drive pipe, the ram, a supply line and usually a storage tank. These are shown in Figure 1. Each of these component parts is discussed below:

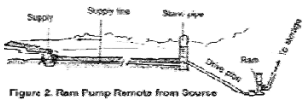

Figure 2. Ram Pump Remote from Source

Supply. The intake must be designed to keep trash and sand out of the supply since these can plug up the ram. If the water is not naturally free of these materials, the intake should be screened or a settling basin provided. When the source is remote from the ram site, the supply line

can be designed to conduct the water to a drive pipe as shown in Figure 2. The supply line, if needed, should be at least one pipe diameter larger than the drive pipe.

Drive pipe. The drive pipe must be made of a non-flexible material for maximum efficiency. This is usually galvanized iron pipe, although other materials cased in concrete will work. In order to reduce head loss due to friction, the length of the pipe divided by the diameter of the pipe should be within the range of 150-1,000. Table 2 shows the minimum and maximum pipe lengths for various pipe sizes.

Table 2. Range of Drive Pipe Lengths for Various Pipe Diameters

Drive Pipe Size (mm)	Length (meters)	
	Minimum	Maximum
13	2	13
20	3	20
25	4	25
30	4.5	30
40	6	40
50	7.5	50
80	12	80
100	15	100

The drive pipe diameter is usually chosen based on the size of the ram and the manufacturer's recommendations as shown in Table 3. The length is four to six times the vertical fall.

Table 3. Drive Pipe Diameters by Hydram Manufacturer's Size Number

Hydram Size	1	2	3	3.5	4	5	6
Pipe Size (mm)	32	38	51	63.5	76	101	127

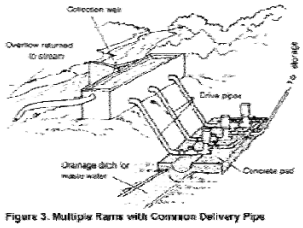

Figure 3. Multiple Rams with Common Delivery Pipe

Ram. Rams can be constructed using commercially available check valves or by fabricating check valves. They are also available as manufactured units in various sizes and pumping capacities. Rams can be used in tandem to pump water if one ram is not large enough to supply the need. Each ram must have its own drive pipe, but all can pump through a common delivery pipe as shown in Figure 3.

In installing the ram, it is important that it be level, securely attached to an immovable base, preferably concrete, and that the waste-water be drained away. The pump can-not operate when submerged. Since the ram usually operates on a 24-hour basis the size can be determined for delivery over a 24-hour period. Table 4 shows hydraulic ram capacities for one manufacturer's Hydrams.

Table 4. Hydram Capacity by Manufacturer's Size Number

	Size of Hydram								
	1	2	3	3.5	4	5X	6X	5Y	6Y
Volume of Drive Water Needed (liters/min)	7-16	12-25	27-55	45-96	68-137	136-270	180-410	136-270	180-410
Maximum Lift (m)	150	150	120	120	120	105	105	105	

Delivery Pipe. The delivery pipe can be of any material that can withstand the water pressure. The size of the line can be estimated using Table 5.

Table 5. Sizing the Delivery Pipe

Delivery Pipe Size (mm)	Flow (liters/min)
30	6-36
40	37-60
50	61-90
80	91-234
100	235-360

Storage Tank. This is located at a level to provide water to the point of use. The size is based on the maximum demand per day.

Sizing a Hydraulic Ram

A small community consists of 10 homes with a total of 60 people. There is a spring l0m lower than the village which drains to a wash which is 15m below the spring. The spring produces 30,000 liters of water per day. There is a location for a ram on the bank of the wash. This site is 5m higher than the wash and 35m from the spring. A public standpost is planned for the village 200m from the ram site. The lift required to the top of the storage tank is 23m. The following are the steps in design.

Identify the necessary design factors:

1. Vertical fall is 10m.

2. Lift is 23m to top of storage tank.

3. Quantity of flow available equals 30,000 liters per day divided by 1,440 minutes per day (30,000/1,440) = 20.8 liters per minute.

4. The quantity of water required assuming 40 liters per day per person as maximum use is 60 people x 40 liters per day = 2,400 liters per day.
2,400/1,440 = 1.66 liters per minute (use 2 liters per minute)

5. The length of the drive pipe is 35m.

6. The length of the delivery pipe is 200m.

The above data can be used to size the system. Using Table 1, for a fall of 10m and a lift of 80m, 117 liters can be pumped a day for each liter per minute supplied. Since 2,400 liters per day is required, the number of liters per minute needed can be found by dividing 2,400 by 117:

2,400/117 = 20.5 liters per minute supply required.

From item 3 above, the supply available is 20.8 liters per minute so the source is sufficient.

Table 3 can now be used to select a ram size. The volume of driving water or supply needed is 20.5 liters per minute. From Table 4, a No. 2 Hydram requires from 12 to 25 liters per minute. A No. 2 Hydram can lift water to a maximum height of 150m according to Table 4. This will be adequate since the lift to the top of the storage tank is 23m. Thus, a No. 2 Hydram would be selected.

Table 3 shows that for a No. 2 Hydram, the minimum drive pipe diameter is 38mm. Table 2 indicates that the minimum and maximum length for a 40mm pipe (the closest size to 38mm) is 6m-40m. Since the spring is 35m away, the length is all right. Table 5 can be used to select a delivery pipe 30mm in diameter which fits the supply needed, 20.5 liters per minute.

http://www.lifewater.org/resources/rws4/rws4d5.htm

HYDRAULIC RAM PUMP SYSTEM DESIGN AND APPLICATION

Dr. Abiy Awoke Tessema
Head, Equipment Design
Research, Development and Technology Adaptation Center
Basic Metals and Engineering Industries Agency, P.O. Box 1180, Addis Ababa, Ethiopia
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ABSTRACT

Hydraulic ram pumps are water-lifting devices that are powered by filling water. Such pumps work by using the energy of water falling a small height to lift a small part of that amount of water to a much

greater height. In this way, water from a spring or stream in a valley can be pumped to a village or irrigation scheme on the hillside. The main and unique advantage of hydraulic ram pumps is that with a continuous flow of water, a hydram pump operates automatically and continuously ***with no other external energy source - be it electricity or hydrocarbon fuel****. It uses a renewable energy source (stream of water) mid hence ensures low running cost. It imparts absolutely no harm to the environment Hydraulic ram pumps are simple, reliable and require minimal maintenance. All these advantages make hydraulic ram pumps suitable to rural community water supply mud backyard irrigation in developing countries. In this paper, different aspect of designing a hydraulic-rain pump system is discussed. Application and limitation of hydraulic-ram pump is presented. Alternative technologies which compete with hydraulic ram pump, are highlighted. Finally, the Research, Development and Technology Adaptation Center (RDTAC) work on hydraulic-rain pump is presented and discussed.*

Introduction
Hydraulic Ram Pump System
Working Principle of Hydraulic Ram Pumps
Applications and Limitations of Hydraulic Ram Pumps
Considerations in Hydraulic Ram Pump System Design
Hydraulic Rain Pump Design Considerations
RDTAC's Work on Hydraulic Ram Pumps
Hydraulic Ram Pump Development Work of RDTAC
Conclusion

INTRODUCTION

Ram Pumps have been used for over two centuries in many parts of the world. Their simplicity and reliability made them commercially successful, particularly in Europe, in the days before electrical power and the internal combustion engine become widely available. As technology advanced and become increasingly reliant on sources of power derived from fossil fuels, the ram pump was neglected. It was felt to have no relevance in an age of national electricity grids and large - scale water supplies. Big had become beautiful and small-scale ram pump technology was unfashionable. In recent years an increased interest in renewable energy devices and an awareness of the technological needs of a particular market in developing countries have prompted a reappraisal of ram pumps. In hilly areas with springs and streams, the potential for a simple and reliable pumping device is large. Although there are some examples of successful ram pump installation in developing countries, their use to date has merely scratched at the surface of their potential.

The main reason for this being, lack of wide spread local knowledge in the design and manufacture of ram pumps. Hence, the wide spread use of ram pumps will only occur if there is a local manufacturer to deliver quickly; give assistance in system design, installation, and provide an after-sales service.

HYDRAULIC RAM PUMP SYSTEM

Hydraulic Ram Pumps are water pumping devices that are powered by falling water. The pump works by using the energy of a large amount of water falling a small height to lift a small amount of that water to a much greater height. In this way, water from a spring or stream in a valley can be pumped to a village or irrigation scheme on the hillside. Wherever a fall of water can be obtained, the ram pump can be used as a comparatively cheap, simple and reliable means of raising water to considerable heights.

The diagram in Fig. 1 shows all the main components of a hydraulic ram pump system. Water is diverted from a flowing river or taken from intake structure of a spring. A drive tank is usually built between the ram pump and the intake to insure constant flow of water to the ram pump. The ram pump lifts part of the water coming through the drive pipe to a higher level at the delivery tank. A pump house is built to protect the ram pump and fittings from theft or accidental damage.

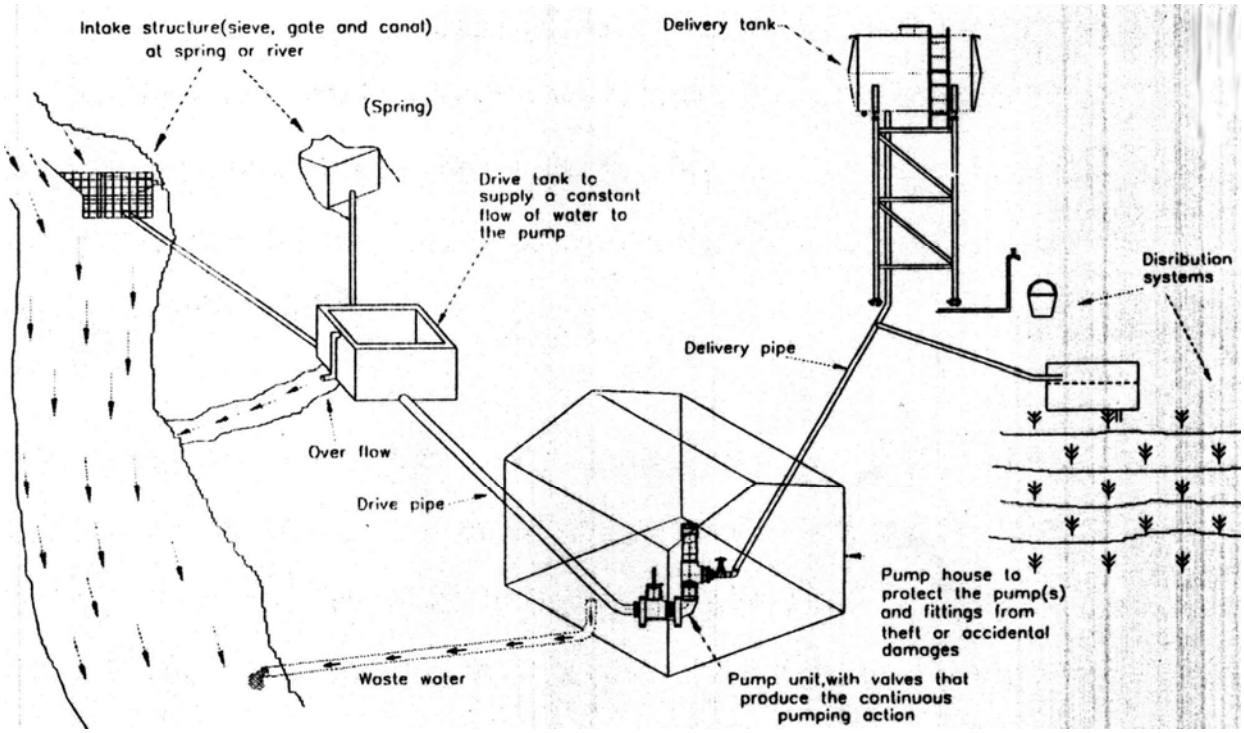

Fig. 1 Components of a Hydraulic Ram Pump Station

WORKING PRINCIPLE OF HYDRAULIC RAM PUMPS

Although hydraulic ram pumps come in a variety of shapes and sizes, they all have the same basic components as shown in Fig. 2. The main parts of a ram pump are Hydram body, Waste value snifter valve, delivery valve, air chamber and relief valve. Ram Pumps have a cyclic pumping action that produces their characteristic beat during operation. The cycle can be divided into three phases; acceleration, delivery and recoil.

Acceleration - When the waste valve is open, water accelerates down the drive pipe and discharges through the open valve. As the flow increases it reaches a speed where the drag force is sufficient to start closing the valve. Once it has begun to move, the valve closes very quickly.

Delivery - As the waste valve slams shut, it stops the flow of water through it. The water that has been flowing in the drive pipe has considerable momentum which has to be dissipated. For a fraction of a second, the water in the body of the pump is compressed causing a large~ surge in pressure. This type of pressure rise is known as water hammer. As the pressure rises higher than that in the air chamber, it forces water through the delivery valve (a non-return valve). The delivery valve stays open until the water in the drive pipe has almost completely slowed and the pressure in the pump body drops below the delivery pressure. The delivery valve then closes, stopping any back flow from the air vessel into the pump and drive pipe.

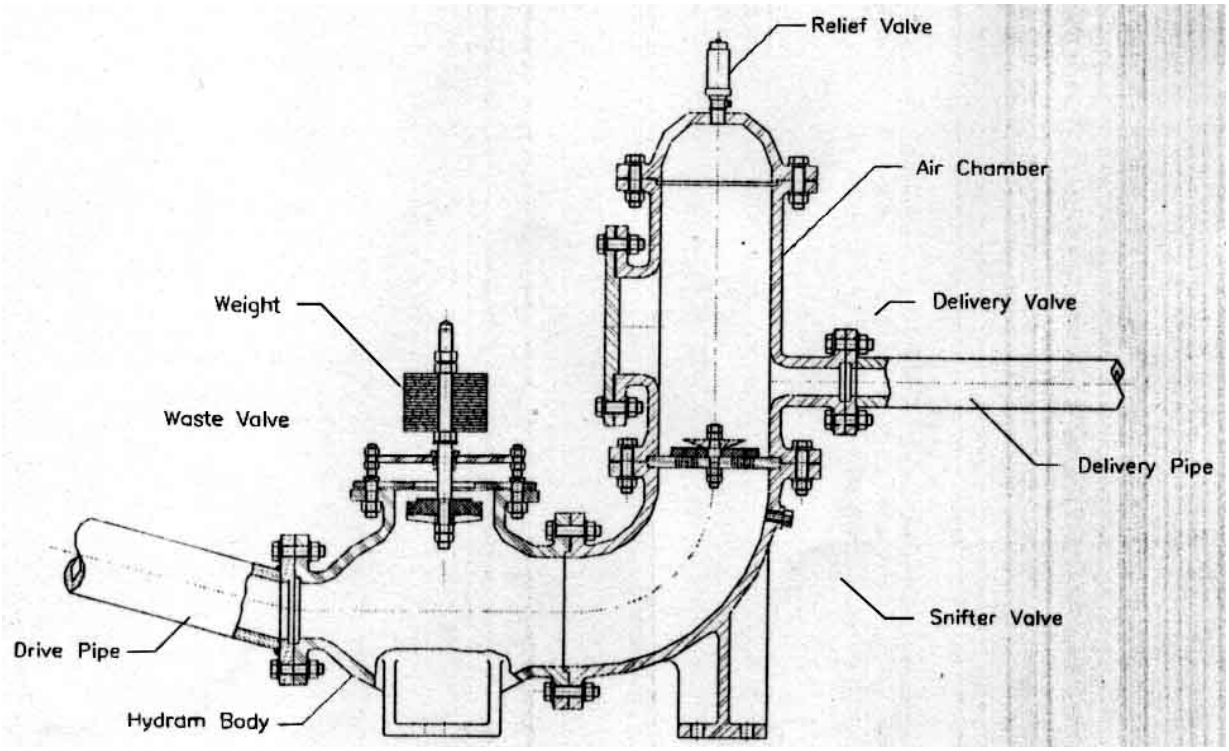

Fig. 2 Hydraulic Ram Pump

Recoil - The remaining flow in the drive pipe recoils against the closed delivery valve - rather like a ball bouncing back. This causes the pressure in the body of the pump to drop low enough for the waste vale to reopen. The recoil also sucks a small amount of air in through the snifter valve. The air sits under the delivery valve until the next cycle when it is pumped with the delivery water into the air vessel. This ensures that the air vessel stays full of air. When the recoil energy is finished, water begins to accelerate down the drive pipe and out through the open waste valve, starting the cycle again. Throughout the cycle the pressure in the air vessel steadily forces water up the delivery pipe. The air vessel smoothes the pulsing in flow through the delivery valve into an even outflow up the delivery pipe. The pumping cycle happens very quickly, typically 40 to 120 times per minute.

During each pumping cycle only a very small amount of water is pumped. However, with cycle after cycle continuing over 24 hours, a significant amount of water can be lifted. While the ram pump is operating, the water flowing out the waste valve splashes onto the floor or the pump house and is considered' waste' water. The term' waste' water needs to be understood. Although waste' water is not delivered by the ram pump, it is the energy of this water that pumps the water which is delivered.

APPLICATIONS AND LIMITATIONS OF HYDRAULIC RAM PUMPS

For any particular site, there are usually a number of potential water lifting options. Choosing between them involves consideration of many different factors. Ram pumps in certain conditions have many advantages over other forms of water-lifting, but in others, it can be completely inappropriate. The main advantages of ram pumps are:

- Use of a renewable energy source ensuring low running cost
- Pumping only a small proportion of the available flow has little environmental impact

- Simplicity and reliability give a low maintenance requirement
- There is good potential for local manufacture in the rural villages
- Automatic, continuous operation requires no supervision or human input.

The main limitations are:

- They are limited in hilly areas with a year-round water sources
- They pump only a small fraction of the available flow and therefore require source flows larger than actual water delivered
- Can have a high capital cost in relation to other technologies
- Are limited to small-scale applications, usually up to 1kW, but this requires economical and other considerations.

Specific situations in which other technologies may prove more appropriate are:

- In terrain where streams are falling very rapidly, it may be possible to extract water at a point above the village or irrigation site and feed it under gravity.

- If the water requirement is large and there is a large source of falling water (head and flow rate) nearby, turbine-pump sets can provide the best solution. Many ram pumps could be used in parallel to give the required output but at powers over 2kW, turbine-pump systems are normally cheaper.

- In small-scale domestic water supply, the choice can often be between using a ram pump on a stream or using cleaner groundwater. Surface water will often need to be filtered or treated for human consumption, increasing the cost of a system and requiring regular filter maintenance. Under these conditions, to select a hydram pump, economical considerations compared to other technologies has to be looked at.

http://home.att.net/~africantech/ESME/hydram2/HydRam2.htm

CONSIDERATIONS IN HYDRAULIC RAM PUMP SYSTEM DESIGN

The following factors need to be considered in hydraulic Ram pump system design.

- Area suitability (head and flow rate)
- Flow rate and head requirement
- Floods consideration
- Intake design
- Drive system
- Pump house location
- Delivery pipes routing
- Distribution system

For these considerations reference 1 is a good guide.

HYDRAULIC RAM PUMP DESIGN CONSIDERATIONS

- Manufacturing considerations - A choice between casting and welding method of manufacture has to be made. Cast ram pumps are less susceptible to corrosion and have longer life. On the other hand, cast ram pumps are costly and cannot be made in a simple rural setting workshop. Usually, for low and medium sized ram pumps welding method of manufacture is preferred because of simplicity and less cost.

- Maintenance and service life considerations - The critical parts that require frequent maintenance are bolts, studs and nuts. Therefore, it is usually preferable to have stainless steel bolts, studs and nuts, even though they are costly and difficult to source.

- Material availability

- General considerations
    - Shape of hydram has little effect on performance
    - Valve design considerations. The correct design of valves is a critical factor in the overall performance of ram pumps. Hence, this needs special consideration.
    - Strength considerations. This determines thickness of hydram body and air chamber.
    - Others - such as size of air chamber, size of valves, tuning devices need special considerations. Reference 2 is a good guide for design of hydraulic rain pump dimensions.

RDTAC'S WORK ON HYDRAULIC RAM PUMPS

Adami-Tulu Hydraulic Ram Pump Maintenance - During performance follow up of hand pumps developed by RDTAC and installed around Ziway, a station of hydraulic ram pumps which were installed about forty years ago were discovered. Five hydraulic ram pumps in this station were used to supply water to a ranch located about 20 km away. However, the then status of the pumps was that only one out of five pumps was operational. The following parts of the hydram pump station were in need of maintenance.

- Drive pipe - The drive pipes of the hydram station were 6" galvanized steel pipe. These drive pipes, due to long years of service, have been corroded and leak at many points. The drive pipes were replaced by new galvanized steel pipes. Flanged connections were made for ease of maintenance.

- Threaded parts of the hydram body (see Fig. 3). - The threaded parts of the hydram body were out of use due to corrosion. As a result, this required re-threading of the hydram body for fixing valve parts securely.

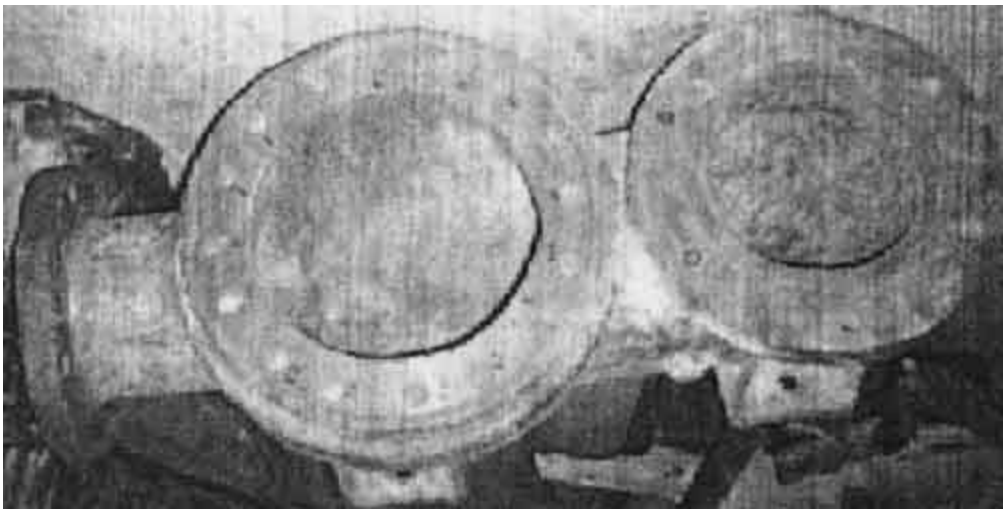

Fig. 3 Hydraulic Ram Pump Body

- Bolts, studs and nuts - These elements are the ones which had been replaced often during the service life of hydrams. Hence, the studs were made out of stainless steel and others were electro-galvanized for longer maintenance free operation.

- Waste valve perforated disk (see Fig. 4) - This part is made of bronze to prolong its life against corrosion. However, it was discovered that it is damaged mostly due to wear. The part needed to be cast out of bronze, machined and drilled. The bronze casting was made by subcontracting it to private foundries. Casting of the part without cavitation (porosity) had been a difficult task. The valve needed to be re-cast again and again to get it to acceptable quality standard.

- Waste valve-retaining ring (see Fig. 4) - Some of the retaining ring was broken due to repeated fatigue loading and corrosion. Hence, they were replaced as new.

- Rubber parts - Besides bolts and nuts, these parts were the ones which needed to be replaced often. When found, all the delivery and waste valve rubber parts were damaged due to wear and tear. To manufacture them, a rubber mold was designed and manufactured. Addis Tyre Enterprise made the rubber valve parts to the required standard using the molds.

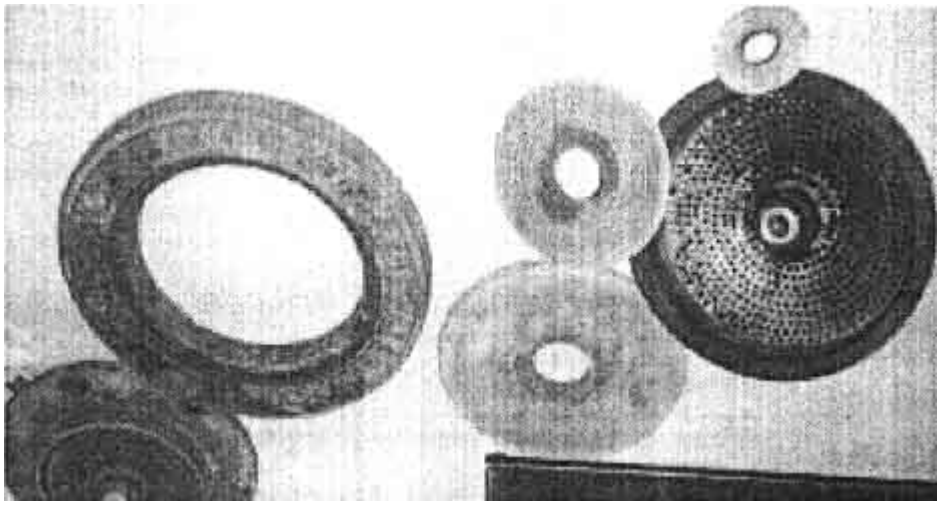

Fig. 4 Waste Valve, Retainer Ring and Rubber Parts of Adami-Tulu Hydraulic Ram Pump

- Other - Parts such as diversion canal gate, header pipes, intake valves were re-designed and manufactured.

The hydram pumps after renovated successfully are shown in Fig. 5.

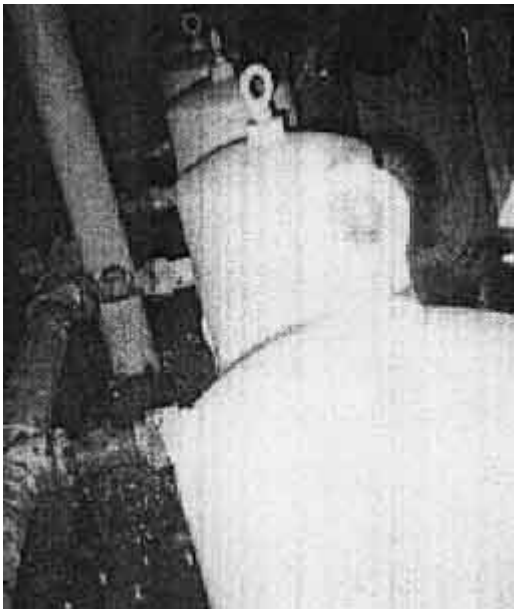

Fig.5 Renovated Adami-Tulu Hydraulic Ram Pumps

HYDRAULIC RAM PUMP DEVELOPMENT WORK OF RDTAC

Design - The design of hydraulic ram pump developed by RDTAC is shown in Fig. 2. The pump was 4" drive pipe designed to supply 80 litre/mm at a head of 45 m. This is sufficient for a village of 500 people and their cattle. In the design, casting technology was preferred for the main parts of the hydraulic ram pump for resistance to corrosion and long term maintenance free operation. Parts which are more prone to failure as a result of corrosion were made out of stainless steel or bronze based on experience obtained from the Adami-Tulu hydram maintenance project. Bolts and nuts were designed to be electro-galvanized. Parts of the hydram, the body, elbow and air chamber were made in separate pieces to facilitate easy handling during transportation and machining operation. Provisions for stroke and weight adjustment has been incorporated. The waste valve was designed for simple and less costly manufacturing method.

Fig. 6 RDTAC's Hydram installed At Adami-Tulu

Manufacturing - The hydraulic ram pump parts were manufactured in the RDTAC workshop, RADEL Foundry Pvt. Ltd. Company, Addis Tyre Enterprise and Gelan-Metal Products Factory. RADEL made all the casting parts. Addis Tyre Enterprise has made all rubber parts by moulds manufactured in RDTAC. Gelan Metal Products Factory performed electro-galvanization on bolts, studs and nuts. All the machining and welding of the hydraulic ram pump parts were made in RDTAC.

Installation - The hydraulic ram pump was installed in the pump house of Adami-Tulu hydraulic ram pump with the permission of the Abernosa Ranch (see Fig. 6). Existing civil work such as diversion canal, drive tank and pump house at Adami-Tulu was used for the project. This has resulted in considerable financial, time and labor saving. A delivery pipe of 2" was installed for 0.8 km from the pump house to a reservoir tank which is located in Dodicha Woreda (Oromia Region, Arsi Zone).

Performance - By now, the hydraulic ram pump successfully provides water for drinking and backyard irrigation. See Fig. 7.

Fig.7 Water Supply System at Dodicha Woreda, Arsi Zone, Oromia Region from RDTAC's Hydram

CONCLUSION

The following conclusions can be made from RDTAC's project work on Hydraulic Ram pumps.

- There is broad prospect of utilizing the country's abundant surface water run off potential for various purposes or requirements using locally designed and manufactured hydraulic ram pumps and other similar appropriate technologies.

- To disseminate hydrams at potential sites throughout the country, there is a need to create awareness through training and seek integrated work with rural community, government institutions like water, energy and mines bureau of local regions and non-governmental organizations.

- Hydraulic Ram pumps made by casting have many advantages, but they could be expensive. In addition, considering the cost of civil work and pipe installation, the initial investment could be very high. To reduce cost of hydrams made by casting, there is a need for standardization. Standardizing hydram pump size will also have an advantage to reduce cost of spare parts and facilitate their easy access when they are needed.

- The use of appropriate means of treating river water should be looked at in conjunction with any development project of domestic water supply using hydrams.

ACKNOWLEDGEMENT

RDTAC would like to take the opportunity to express its sincere appreciation to the Ethiopian Science and Technology Commission for the unreserved assistance and encouragement rendered.

Hydraulic Ram Pumps

Prepared by:
Gregory D. Jennings, PhD, PE
Extension Specialist

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A hydraulic ram (or water ram) pump is a simple, motorless device for pumping water at low flow rates. It uses the energy of flowing water to lift water from a stream, pond, or spring to an elevated storage tank or to a discharge point. It is suitable for use where small quantities of water are required and power supplies are limited, such as for household, garden, or livestock water supply. A hydraulic ram pump is useful where the water source flows constantly and the usable fall from the water source to the pump location is at least 3 feet.

Principles of Operation

Components of a hydraulic ram pump are illustrated in Figure 1. Its operation is based on converting the velocity energy in flowing water into elevation lift. Water flows from the

source through the drive pipe (A) and escapes through the waste valve (B) until it builds enough pressure to suddenly close the waste valve. Water then surges through the interior discharge valve (C) into the air chamber (D), compressing air trapped in the chamber. When the pressurized water reaches equilibrium with the trapped air, it rebounds, causing the discharge valve (C) to close. Pressurized water then escapes from the air chamber through a check valve and up the delivery pipe (E) to its destination. The closing of the discharge valve (C) causes a slight vacuum, allowing the waste valve (B) to open again, initiating a new cycle.

The cycle repeats between 20 and 100 times per minute, depending upon the flow rate. If properly installed, a hydraulic ram will operate continuously with a minimum of attention as long as the flowing water supply is continuous and excess water is drained away from the pump.

System Design

A typical hydraulic ram pump system layout is illustrated in Figure 2. Each of the following must be considered when designing a hydraulic ram pump system:

1. available water source
2. length and fall of the drive pipe for channeling water from the source to the pump
3. size of the hydraulic ram pump
4. elevation lift from the pump to the destination
5. desired pumping flow rate through the delivery pipe to the destination.

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A hydraulic ram pump system is designed to deliver the desired pumping flow rate for a given elevation lift. The range of available flow rates and elevation lifts is related to the flow quantity and velocity from the water source through the drive pipe. The mathematical relationship for pumping flow rate is based upon the flow rate through the drive pipe, the vertical fall from the source through the drive pipe, and the vertical elevation lift from the pump to the point of use. These variables are illustrated in Figure 2. Equation 1 is used to calculate pumping rate:
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where:

Q=pumping rate in gallons per day (gpd)
E=efficiency of a hydraulic ram pump installation, typically equal to 0.6
S=source flow rate through the drive pipe in gallons per minute (gpm)
L=vertical elevation lift from the pump to the destination in feet
F=vertical fall from the source through the drive pipe in feet.

To convert the p~umping rate expressed in gallons per day(gpd) to gallons per minute(gpm), divide by 1440. The following example illustrates an application of Equation 1.

Example.
A hydraulic ram will be used to pump water from a stream with an average flow rate of 20 gpm up to a water tank located 24 feet vertically above the pump. The vertical fall through the drive pipe in the stream to the pump is 4 feet. Assume a pumping efficiency of 0.6. What is the maximum pumping rate from the hydraulic ram pump?

In this example, E = 0.6, S = 20 gpm, L = 24 feet, and F = 4 feet. The resulting pumping rate, Q, is calculated as:

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The maximum pumping rate delivered by the hydraulic ram pump operating under these conditions is 2880 gallons per day, or 2 gallons per minute.

The example shows how the pumping rate, Q, is directly related to the source flow rate, S. If S were to double from 20 gpm to 40 gpm, the resulting pumping rate would also double to 5760 gpd, or 4 gpm.

The example also shows how the pumping rate, Q, is inversely related to the ratio of vertical elevation lift to vertical fall, L/F. If L were to double from 24 feet to 48 feet, the lift to fall ratio, L/F, would double from 6 to 12. The resulting pumping rate would decrease by half to 1440 gpd, or 1 gpm.

Table 1 lists maximum pumping rates, Q, for a range of source flow rates, S, and lift to fall ratios, L/F, calculated using Equation 1 with an assumed pumping efficiency, E, of 0.6. To illustrate the use of Table 1, consider a hydraulic ram system with S = 30 gpm, L

= 150 feet, and F = 5 feet. The calculated lift to fall ratio, L/F, is 30. The resulting value for Q is 864 gpd, or 0.6 gpm.

Table 1. Maximum pumping rates for a range of source flow rates and lift to fall ratios assuming a pumping efficiency of 0.6.

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Hydraulic ram pumps are sized based upon drive pipe diameter. The size of drive pipe selected depends upon the available source water flow rate. All makes of pumps built for

a given size drive pipe use about the same source flow rate. Available sizes range from 3/4-inch to 6-inch diameters, with drive pipe water flow requirements of 2 to 150 gpm. Hydraulic ram pumps typically can pump up to a maximum of 50 gpm (72,000 gpd) with maximum elevation lifts of up to 400 feet.

Approximate characteristics of hydraulic ram pumps for use in selecting pumps are listed in Table 2. The recommended delivery pipe diameter is normally half the drive pipe diameter. For the system described in the example above, the available source water flow rate is 10 gpm. From Table 2, a pump with a 1-inch drive pipe diameter and a 1/2-inch delivery pipe diameter is selected for this system.

Table 2. Hydraulic ram pump sizes and approximate pumping characteristics.
Consult manufacturer's literature for specific pumping characteristics.

<!--[if !supportEmptyParas]--> <!--[endif]-->
-------Pipe Diameter------- ---------------Flow rate--------------

<!--[if !supportLineBreakNewLine]-->

<!--[endif]-->
Min. Drive Min. Discharge Min. Required Source Maximum Pumping

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-----------inches---------- ---------gpm-------- ------gpd------
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3/4	1/2	2	1,000
1	1/2	6	2,000
1 1/2	3/4	14	4,000
2	1	25	7,000
2 1/2	1 1/4	35	10,000
3	1 1/2	60	20,000
6	3	150	
72,000			

Installation

The location of the water source in relation to the desired point of water use determines how the hydraulic ram pump will be installed. The length of drive pipe should be at least 5 times the vertical fall to ensure proper operation. The length of delivery pipe is not usually considered important because friction losses in the delivery pipe are normally small due to low flow rates. For very long delivery pipes or high flow rates, friction losses will have an impact on the performance of the hydraulic ram pump. The diameter of the delivery pipe should never be reduced below that recommended by the manufacturer.

To measure the available source water flow rate from a spring or stream, build a small earthen dam with an outlet pipe for water to run through. Place a large bucket or barrel of known volume below the outlet pipe, and measure the number of seconds it takes to fill the container. Then calculate the number of gallons per minute flowing through the outlet. For example, if it takes 30 seconds to fill a 5-gallon bucket, the available source water flow rate is 10 gpm. The lowest flow rates are typically in the summer months. Measure the flow rate during this period to ensure that the year-round capacity of the system is adequate.

Purchasing a System

Prices for hydraulic ram pumps range from several hundred to several thousand dollars depending on size and performance characteristics. Contact manufacturers to determine prices and ordering specifications. Send the information listed in Table 3 to the manufacturer to assist in sizing your system properly.

Table 3: Information to provide to the manufacturer for sizing your system.

```
<!--[if !supportEmptyParas]--> <!--[endif]-->
<!--[if !supportEmptyParas]--> <!--[endif]-->
1.      Available water supply in gpm   _________
2.      Vertical fall in feet measured from the source
        water level to the foundation on which the ram
        pump will rest   _________
3.      Distance from the water source to the ram
        pump in feet   _________
4.      Vertical elevation lift in feet measured from
        the ram pump foundation to the highest point to
        which water is delivered   ________
5.      Distance from the ram pump to the destination tank
        in feet   _________
6.      Desired pumping flow rate to the destination tank
        in gpd   _________
```

This fact sheet adapted from materials prepared by the California, Florida, and South Carolina Cooperative Extension Services.

Distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Employment and program opportunities are offered to all people regardless of race, color, national origin, sex, age, or disability. North Carolina State University, North Carolina A&T State University, U.S. Department of Agriculture, and local governments cooperating.

http://www.bae.ncsu.edu/programs/extension/publicat/wqwm/ebae161_92.html

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http://www.i4at.org/lib2/hydrpump.htm

Hydraulic Ram Pump

A hydraulic ram or impulse pump is a device which uses the energy of falling water to lift a lesser amount of water to a higher elevation than the source. See Figure 1. There are only two moving parts, thus there is little to wear out. Hydraulic rams are relatively economical to purchase and install. One can be built with detailed plans and if properly installed, they will give many trouble-free years of service with no pumping costs. For these reasons, the hydraulic ram is an attractive solution where a large gravity flow exists. A ram should be considered when there is a source that can provide at least seven times more water than the ram is to pump and the water is, or can be made, free of trash and sand. There must be a site for the ram at least 0.5m below the water source and water must be needed at a level higher than the source.

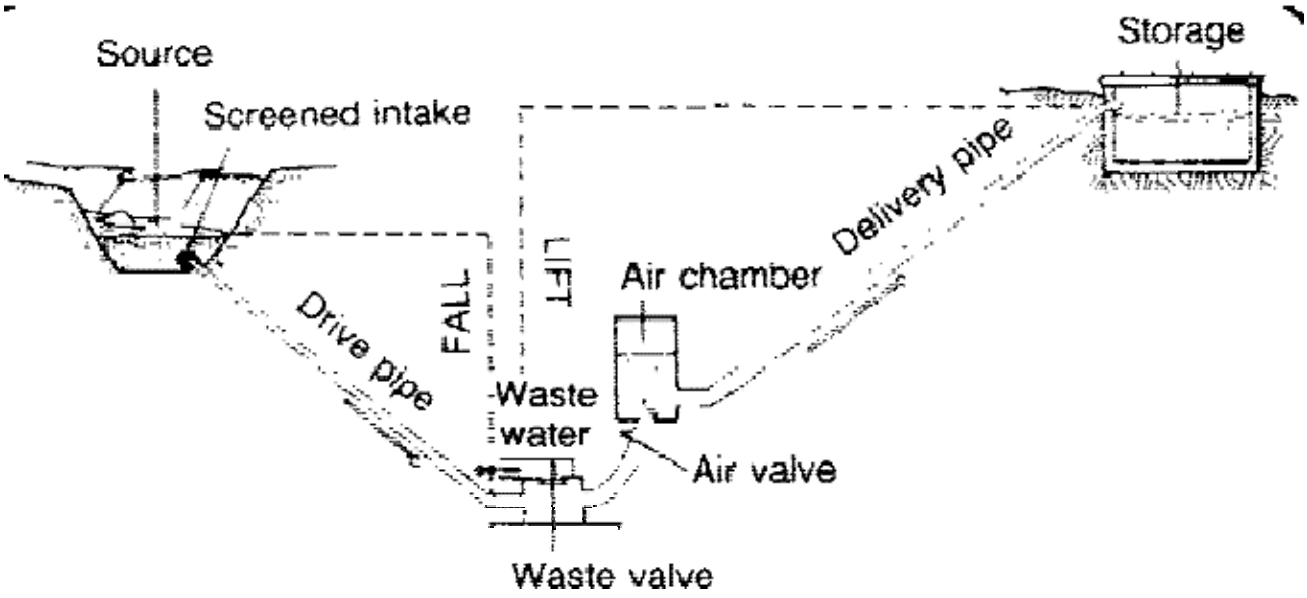

Figure 1. Hydraulic Ram Pump

Factors in Design

Before a ram can be selected, several design factors must be known. These are shown in Figure 1 and include:

1. The difference in height between the water source and the pump site (called vertical fall).
2. The difference in height between the pump site and the point of storage or use (lift).
3. The quantity (Q) of flow available from the source.
4. The quantity of water required.

5. The length of pipe from the source to the pump site (called the drive pipe).
6. The length of pipe from the pump to the storage site (called the delivery pipe).

Once this information has been obtained, a calculation can be made to see if the amount of water needed can be supplied by a ram. The formula is: D=(S x F x E)/L Where:

D = Amount delivered in liters per 24 hours.
S = Quantity of water supplied in liters per minute.
F = The fall or height of the source above the ram in meters.
E = The efficiency of the ram (for commercial models use 0.66, for home built use 0.33 unless otherwise indicated).
L = The lift height of the point of use above the ram in meters.

Table 1 solves this formula for rams with efficiencies of 66 percent, a supply of 1 liter per minute, and with the working fall and lift shown in the table. For supplies greater than 1 liter/minute, simply multiply by the number of liters supplied.

Table 1. Ram Performance Data for a Supply of 1 liter/minute
Liters Delivered over 24 Hours

Working Fall (m)	Lift - Vertical Height to which Water is Raised Above the Ram (m)											
	5	**7.5**	**10**	**15**	**20**	**30**	**40**	**50**	**60**	**80**	**100**	**125**
1.0	144	77	65	33	29	19.5	12.5					
1.5		135	96.5	70	54	36	19	15				
2.0		220	156	105	79	53	33	25	19.5	12.5		
2.5		280	200	125	100	66	40.5	32.5	24	15.5	12	
3.0			260	180	130	87	65	51	40	27	17.5	12
3.5				215	150	100	75	60	46	31.5	20	14
4.0				255	173	115	86	69	53	36	23	16
5.0				310	236	155	118	94	71.5	50	36	23
6.0					282	185	140	112	93.5	64.5	47.5	34.5
7.0						216	163	130	109	82	60	48
8.0							187	149	125	94	69	55
9.0							212	168	140	105	84	62
10.0							245	187	156	117	93	69
12.0							295	225	187	140	113	83
14.0								265	218	167	132	97
16.0									250	187	150	110
18.0									280	210	169	124
20.0										237	188	140

Components of Hydraulic Ram

A hydraulic ram installation consists of a supply, a drive pipe, the ram, a supply line and usually a storage tank. These are shown in Figure 1. Each of these component parts is discussed below:

Supply. The intake must be designed to keep trash and sand out of the supply since these can plug up the ram. If the water is not naturally free of these materials, the intake should be screened or a settling basin provided. When the source is remote from the ram site, the supply line can be designed to conduct the water to a drive pipe as shown in Figure 2. The supply line, if needed, should be at least one pipe diameter larger than the drive pipe.

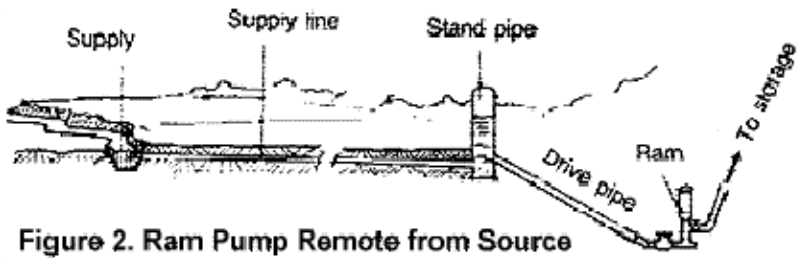

Figure 2. Ram Pump Remote from Source

Drive pipe. The drive pipe must be made of a non-flexible material for maximum efficiency. This is usually galvanized iron pipe, although other materials cased in concrete will work. In order to reduce head loss due to friction, the length of the pipe divided by the diameter of the pipe should be within the range of 150-1,000. Table 2 shows the minimum and maximum pipe lengths for various pipe sizes.

Table 2. Range of Drive Pipe Lengths for Various Pipe Diameters

Drive Pipe Size (mm)	Length (meters)	
	Minimum	Maximum
13	2	13
20	3	20
25	4	25
30	4.5	30
40	6	40
50	7.5	50
80	12	80
100	15	100

The drive pipe diameter is usually chosen based on the size of the ram and the manufacturer's recommendations as shown in Table 3. The length is four to six times the

vertical fall.

Table 3. Drive Pipe Diameters by Hydram Manufacturer's Size Number							
Hydram Size	1	2	3	3.5	4	5	6
Pipe Size (mm)	32	38	51	63.5	76	101	127

Ram. Rams can be constructed using commercially available check valves or by fabricating check valves. They are also available as manufactured units in various sizes and pumping capacities. Rams can be used in tandem to pump water if one ram is not large enough to supply the need. Each ram must have its own drive pipe, but all can pump through a common delivery pipe as shown in Figure 3.

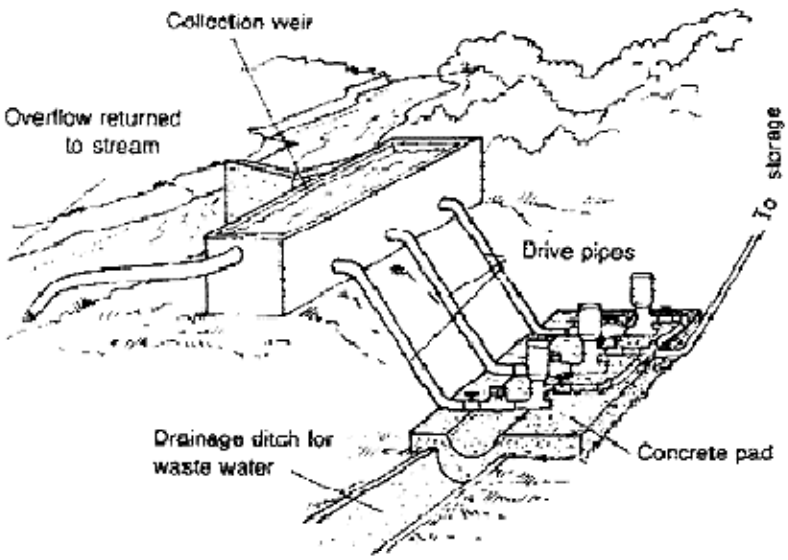

Figure 3. Multiple Rams with Common Delivery Pipe

In installing the ram, it is important that it be level, securely attached to an immovable base, preferably concrete, and that the waste-water be drained away. The pump can-not operate when submerged. Since the ram usually operates on a 24-hour basis the size can be determined for delivery over a 24-hour period. Table 4 shows hydraulic ram capacities for one manufacturer's Hydrams.

Table 4. Hydram Capacity by Manufacturer's Size Number									
	Size of Hydram								
	1	2	3	3.5	4	5X	6X	5Y	6Y
Volume of Drive Water Needed (liters/min)	7-16	12-25	27-55	45-96	68-137	136-270	180-410	136-270	180-410
Maximum Lift (m)	150	150	120	120	120	105	105	105	

Delivery Pipe. The delivery pipe can be of any material that can withstand the water

pressure. The size of the line can be estimated using Table 5.

Table 5. Sizing the Delivery Pipe	
Delivery Pipe Size (mm)	Flow (liters/min)
30	6-36
40	37-60
50	61-90
80	91-234
100	235-360

Storage Tank. This is located at a level to provide water to the point of use. The size is based on the maximum demand per day.

Sizing a Hydraulic Ram

A small community consists of 10 homes with a total of 60 people. There is a spring l0m lower than the village which drains to a wash which is 15m below the spring. The spring produces 30,000 liters of water per day. There is a location for a ram on the bank of the wash. This site is 5m higher than the wash and 35m from the spring. A public standpost is planned for the village 200m from the ram site. The lift required to the top of the storage tank is 23m. The following are the steps in design.

Identify the necessary design factors:

1. Vertical fall is 10m.

2. Lift is 23m to top of storage tank.

3. Quantity of flow available equals 30,000 liters per day divided by 11,440 minutes per day (30,000/11,440) = 20.8 liters per minute.

4. The quantity of water required assuming 40 liters per day per person as maximum use is 60 people x 40 liters per day = 2,400 liters per day.
2,400/1,440 = 1.66 liters per minute (use 2 liters per minute)

5. The length of the drive pipe is 35m.

6. The length of the delivery pipe is 200m.

The above data can be used to size the system. Using Table 1, for a fall of 10m and a lift of 80m, 117 liters can be pumped a day for each liter per minute supplied. Since 2,400 liters per day is required, the number of liters per minute needed can be found by dividing 2,400

by 117:

2,400/117 = 20.5 liters per minute supply required.

From item 3 above, the supply available is 20.8 liters per minute so the source is sufficient.

Table 3 can now be used to select a ram size. The volume of driving water or supply needed is 20.5 liters per minute. From Table 4, a No. 2 Hydram requires from 12 to 25 liters per minute. A No. 2 Hydram can lift water to a maximum height of 250m according to Table 4. This will be adequate since the lift to the top of the storage tank is 23m. Thus, a No. 2 Hydram would be selected.

Table 3 shows that for a No. 2 Hydram, the minimum drive pipe diameter is 38mm. Table 2 indicates that the minimum and maximum length for a 40mm pipe (the closest size to 38mm) is 6m-40m. Since the spring is 35m away, the length is all right. Table 5 can be used to select a delivery pipe 30mm in diameter which fits the supply needed, 20.5 liters per minute.

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http://www.atlaspub.20m.com/kits.htm

Atlas Ram Pump Constructon

The Atlas ram pump will pump water from a flowing source of water to a point above that source with no other power required.

A full description of how to build and install an Atlas Ram Pump is contained in the 'The Original' book
Hydraulic Ram Pumps, How and Where They Work'

Home Hydraulic Ram Pumps Crayfish Farming Red Claw Crayfish Farming

Atlas Ram Pump Parts

The Atlas Ram Pump parts shown here shows everything needed to build the Atlas Ram. Only the concrete for the base and PVC glue is needed. The drive and delivery pipes are not part of the detail. The plans now call for heavy-duty US made valves (Simmons, 400 psi) although other brands can be used, and larger clack valves as well. The air dome uses Heavy Duty 220 psi PVC well casing. The cost of the parts is about $75-$100 at most hardware stores.

Check valve to clack valve Conversion Pack

PARTS ARE NOW AVAILABLE

Check / Tank Mount Unit

The check / tank mount unit shown to the right is the only fabrication required in the design. Made by molding a 1" galvanized street ell inside of a 2" street ell with fiberglass or epoxy resin. This allows a lower profile & center of gravity, and gives standard pipe threads for both the check valve and the pressure tank (air dome).

The check / tank mount unit shown to the right is available from Atlas Publications.
The price is $45 each + $8.00 shipping (Up to 3 units);
The conversion pack is included with each unit free of charge.
Please note the conversion pack is for the 1" Simmons check valve only.

Send check or MO to:

Atlas Publications
P.O. Box 265
Murphy, NC 28906

Or use this handy PRINTABLE ORDER FORM

The best check valves to use are made by Simmons Manufacturing and are available from amazon.com (see below)
They are called Brass in-line spring loaded check valves, are rated at 400 psi, and the bushing need not be replaced by the plastic sleeve mentioned in the book.

For a detail of the clack valve conversion process, see pgs. 22 & 23 of the book clik HERE.

SIMMONS CHECK VALVE ORDERING
(use your BACK button to return from these pages)
Silicon Bronze Lead Free Check Valves; Silicon Bronze Cast Poppet, Female Pipe Thread.

SIMMONS MFG CO #503-SB, 1", 1.1 pounds. Price: $16.08
This is the valve for the check valve, part # 11, pg.9 in the book,
and for the clack valve for a 1" Ram.
Click here to view and/or order: Simmons 1" Check Valve

SIMMONS MFG CO #504-SB, 1-1/4", 1.5 pounds. Price: $22.05
Can be used for a clack valve for a 1 1/4" Ram.
Click here to view and/or order: Simmons 1 1/4" Check Valve

SIMMONS MFG CO #505-SB, 1-1/2" 1.8 pounds. Price: $30.08
Can be used for a clack valve for a 1 1/2" Ram.

Click here to view and/or order: Simmons 1 1/2" Check Valve

SIMMONS MFG CO #506-SB, 2", 3.6 pounds. Price: $48.65
Can be used for a clack valve for a 2" Ram.
Click here to view and/or order: Simmons 2" Check Valve

NEW! Online store for the best selection of Brass Check Valves!

There are a lot of other suitable check valves available online,
some quite a bit less expensive than Simmons.

Click on this link to go to our online store for a selection. ..Brass Check Valves

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(LEFT) This is the Base...the 'base fittings' with fiberglass reinforced concrete ('quick-wall') molded around them, ready for the valves, tank and drive pipe to be attached. After completing this step, it is only a matter of attaching the fittings and air dome. Drive pipe attaches on the left, clack valve on the first hole from the left, check valve and air dome attach on the hole to the right.

Completed pump!!

Here is a picture of a 2" Atlas Ram Pump, assembled.
The only difference from a 1" Atlas Ram is the size of the clack valve (brass colored). This 2" check valve (converted to a *clack valve*) is quite expensive, and usually the 1" pump is sufficient (sometimes more than) for most applications.
The Drive pipe attatches at the left of the base and delivery pipe on the right out of the 'T' fitting.
One of the most efficient and inexpensive Hydraulic Ram Water Pumps available today, simple to build and easy to keep running!

This book includes assembly instructions for the ram pump, simple plans for a ferro-cement water storage tank, as well as complete set-up and maintenence information.

The book ***'The Original! HYDRAULIC RAM PUMPS how and where they work'*** contains complete plans and instructions for assembling the pump, and explains in simple terms and with illustrations how the ram pump works, where and how it can be set up, and how to keep it working year after year with a minimum of time and energy for upkeep. With this book, the Atlas Ram is now easier to build, more reliable and efficient than ever, with NO welding, drilling, tapping or special tools needed. The design has evolved to a point where low maintenance and long term reliable service is almost certain, even by a novice. A great resource for self-reliant types, homesteaders, alternative energy users or anyone curious about this 'old-tech' device that has been around for so long and works so well. The final chapter shows how to build an inexpensive ferro-cement water storage tank up to 15,000 gallon capacity.

Also included is the authors personal e-mail for any questions...
The book is US $10.95 + $1.00 shipping
(Canadian & overseas orders, go to Amazon, see below)

Some people have a ram pump for a summer cabin, shut the pump off for the winter when they leave...and set it back up when they return. Here's a review by one of them...

Ernie Samson writes again: "Hi, it is Ernie Samson again. I just set our pump up for the year, and it is working wonderfully... thought you would like to know. Everyone who comes and sees it working can't believe how well it works! Thanks again!"

INFORMATION.

Questions? Feel free to e-mail for specific information about this pump, parts, ram pump applications.

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Send check or MO for $11.95 per book to:
(please indicate which book)

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Murphy, N.C. 28906

Shopping Cart

Brass Check Valves

Here are the most popular check valves for the Atlas Ram Pump.
We have checked all over and this is the best online site for ordering these Check Valves.

Simmons #503SB 1" Bronze CHK Valve
$17.90
This is the best valve for the Atlas Ram Pump (400 psi).You need 2 per pump, unless you want a larger clack valve.

Merrill Mfg. CVR100 Brass Check Valve
$10.34
Merrill Mfg. 1" Brass Check Valve, tapered self cleaning valve seat. Delrin guide bearing for the poppet stem.

2 Pack of TC2502 1 IN. BRASS CHECK VALVE
$25.22
By FLOTECH. Slightly less expensive option to the Simmons valve, pack of 2, needed for a 1" Atlas Ram

Merrill Mfg. CVR125 Brass Check Valve
$14.55
Merrill Mfg.1-1/4" Brass Check Valve, for a larger CLACK Valve. Abrasion resistant O-ring, tapered self-cleaning valve seat. ...

Merrill Mfg. CVR150 Brass Check Valve
$16.07
Merrill Mfg.1-1/2" Brass Check Valve, for a larger CLACK Valve. Abrasion resistant O-ring, tapered self-cleaning valve seat. D...

Merrill Mfg. CVR200 Brass Check Valve
$30.06
Merrill Mfg. 2" Brass Check Valve, for the largest CLACK Valve. Abrasion resistant O-ring, tapered self-cleaning valve seat. D...

CAMPBELL MANUFACTURING CV-5T BRASS CHECK VA...
$23.75
Campbell-1 1/4" Brass Check Valve. 200 PSI, Neoprene O-ring, Non-corroding delrin stem guide, Stainless steel springs.

Valve, Check - Spring (Brass) 1"

OEM 1" check valve, less expensive option to the Simmons valve

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http://www.atlaspub.20m.com/rampg.htm

WHAT IS A RAM PUMP?

The hydraulic ram pump is a reliable, old-time water pump that works just as well today as ever. **Ongoing research indicates the Great Pyramid may actually have been a**

gigantic ram pump..built to pump drinking water to public water fountains in the cities above the Nile flood plain! (Pyramid Pump) Often called a water ram, one of these simple devices can **pump water from a flowing source of water (spring, creek, river, etc.) to any point above the source, *and this without any power requirement* except the force of water moving downhill,** contained inside a 'drive pipe'. This rugged and dependable device is typically installed today at remote home sites and cabins that are off the power grid and would otherwise be without a water supply. Sometimes a ram is used as a backup water system, or for watering livestock, gardens, decorative lily ponds, water wheels or fountains. Simply because a ram uses no power opens up a world of possibilities for using water that would otherwise flow on downstream,wasted. All that is really required is the surface water source. The water has to be moving...not much, but some. The creek need not be large either - 4 gallons per minute is the minimum.

TYPICAL RAM PUMP SETUP

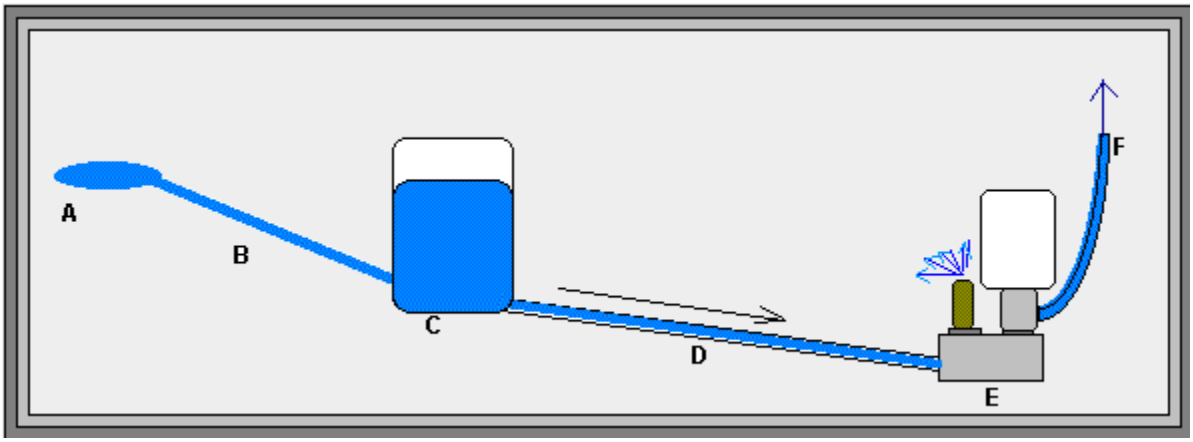

(A) Water source; can be a river, stream, spring, or pond.
(B) Supply pipe. Goes from the source to the collection barrel downstream (below the source).
(C) Collection barrel or intake barrel. The water is collected here. Water level stays at the level of the source.
(D) Drive pipe. About 100 ft. long; brings the water to the pump and provides the power to the pump, somewhat like a battering ram. Probably the least understood and most important part of the ram pump system. Typically black plastic pipe, 1" to 2" dia., generally matched to the size of the clack valve on the pump.
(E) Ram Pump. Starts and stops the movement of the water column in the drive pipe through the clack valve (gold colored). Also redirects a portion of the water (10%-15%) to the pressure tank through the internal check valve or one-way valve. This portion leaves the pump and rises to the end use area through the...
(F) Delivery pipe which goes to the storage tank, garden, house...wherever the water is needed. Typically of 1/2" or 3/4" black plastic pipe.

ATLAS RAM PUMP CUTAWAY

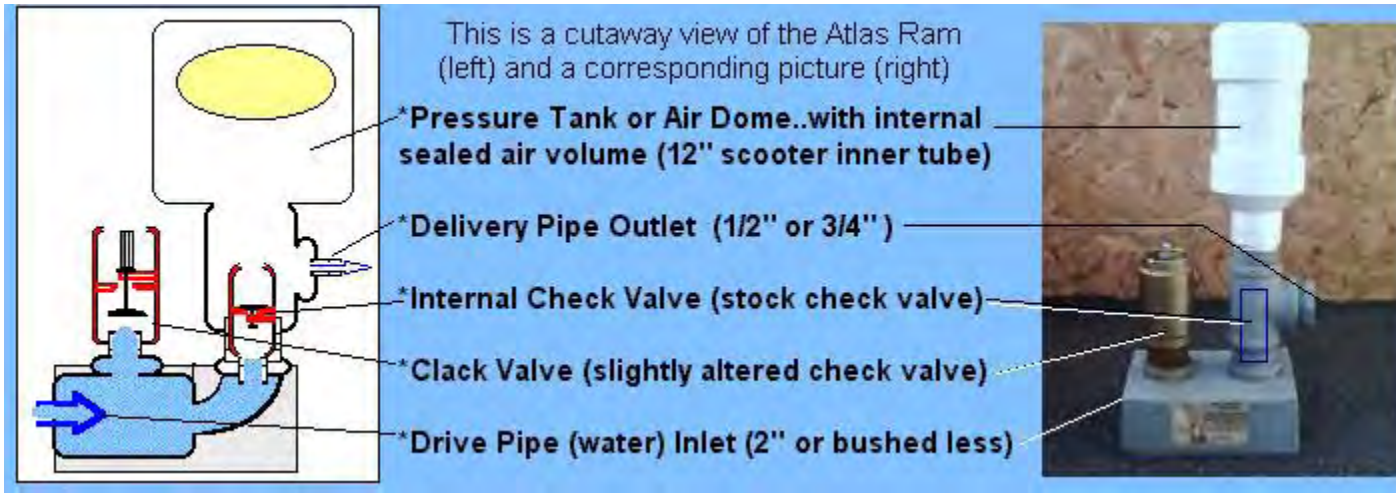

ABOUT THE ATLAS RAM PUMP

The Atlas Ram Pump is the simplest and most efficient low flow / fall ram pump available today. Designed to be simple to build-- with NO drilling, tapping or welding involved in its construction; the materials and fittings are readily available at most hardware stores. (LEFT) The Atlas Ram Pump...water enters from the right through the drive pipe, delivery out the left. 'Waste' water out the clack valve (brass). (RIGHT) The Atlas Ram is compact, rugged and easily carried.

(LEFT) The 'air dome' or 'pressure tank' removes easily to

access the 'sealed air volume'. The air dome is of heavy-duty 220 psi PVC well-casing. (RIGHT) The sealed air volume, in this case a 12" scooter inner tube, eliminates the possibility of an air-logged or water-logged condition inside the air dome. This promotes the overall reliability and efficiency of the Atlas ram pump.

(LEFT) The tank-mount 'tee' fitting removes easily to access the check valve. This is rarely if ever needed, unless to remove debris if the intake screen is breached.

(RIGHT) The clack valve removes easily for checking or maintenence, very rarely needed also.

To place an order for this book, send check or MO for $10.95 + $1.00 shipping per book (Canadian & overseas orders, go to amazon.com, see below)to:
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http://www.judyofthewoods.net/ram_pump.html

Low cost, low flow, home made hydraulic ram pump (no welding required)

If you have a water supply (spring, brook or river) below the point where you need the water, and the source is higher than the lowest part of the property, then a hydraulic ram pump may be the solution. Hydraulic ram pumps are powered by a portion of the water running through it. If the cost of a commercial pump puts you off, or the water volume is too little to operate the pump, you can make one to suit your conditions at very little cost. There are two excellent books published by Intermediate Technology on making your own ram pump. One is "Hydraulic Ram Pumps: A Guide to Ram Pump Water Supply Systems" by T.D. Jeffrey, T.H. Thomas, A.V. Smith, and P.B. Glover. The other is "A Manual on the Hydraulic Ram for Pumping Water" by S. B. Watt. I would recommend you get both; they do complement each other. They also explain how to design and build the whole system. The pumps featured in the books do require welding and threading equipment, and the smallest pump has a 2" diameter body which requires a fair amount of water to operate. However, the principle also works on a smaller scale, and I have made a pump from standard brass 28 mm compression fittings, with 28mm, 22 mm and 15 mm pipe (all readily available) and with soldering equipment. It is not scientifically worked out, but it works and is about as efficient as a commercial pump, and it takes the elbow grease out of pumping by hand or the expense and complications of an electric pump. I don't know what the maximum lift would be with a pump this size, but in a test with my own it pumped water approximately 15 - 20 feet up with a drive head of about 5 - 6 feet. Even in such a small pump the pressure is enormous, and I believe it could pump water much higher. This pump also works on relatively small volumes of water. Even the smallest commercial pump requires large volumes of water to power it, making a ram pump unsuitable for many situations, where this smaller pump would still be able to operate. I have even operated the pump on about 25 gallons a day during a dry summer by running it intermittently from a holding tank. However, the pump only delivers about one 10th of the volume, wasting the rest, so I only ended up with about two gallons out of that tank. It also required manually opening and closing the stop cock or some complicated automated system (self-siphoning may be a possibility I have not yet tested, but the tight pipe bends may hinder the flow too much).

I built this pump nearly 12 years ago, and did not take pictures during the build. Due to limited material choice, some parts have corroded, and some of the information is based on memory, so the instructions are a little incomplete, but hopefully there is enough information to build your own. A lot of the measurements for this pump were indeed rule of thumb - "that looks about right", and it worked. Of course, your thumb may differ in size from mine, but you get the idea.....

click to enlarge, and drag corners
for large annotated pictures go to my Flickr page

How the hydraulic ram pump works

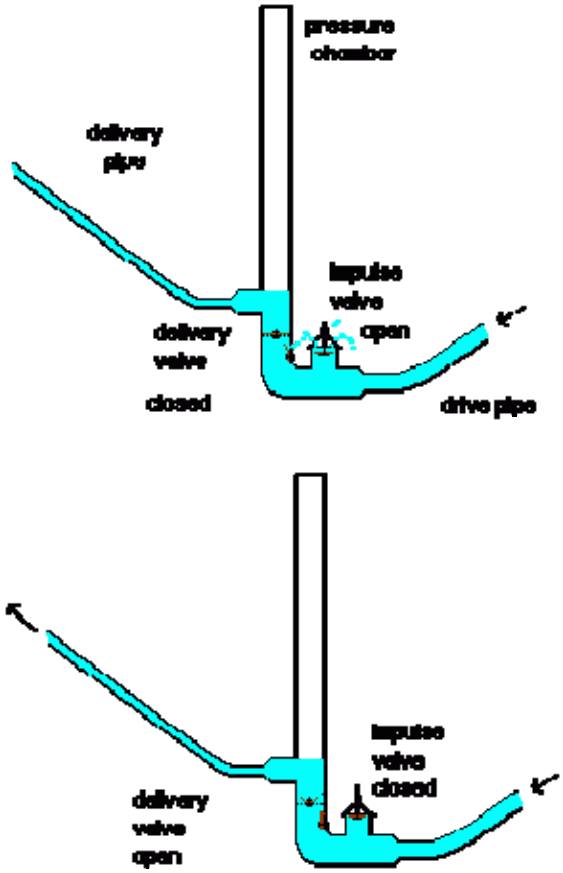

Water enters the ram from the thick drive pipe and runs out of the impulse valve, which is held open by a spring (or weight in larger pumps). As the momentum increases, the pressure of the water will drag the impulse valve shut. This creates a shock wave inside the ram body, pushing water past the delivery valve (a non-return valve). As the pressure subsides the impulse valve opens and the cycle begins again. This takes place more than 100 times a minute, depending on the head pressure and tuning of the impulse valve, and each pulse pushes up a small quantity of water through the thinner delivery pipe. The air chamber cushions the flow. The tiny snifter valve below the chamber allows a small quantity of air into the air chamber with every pulse to replace air lost into the deliver pipe. A small squirt of water will come out on the recoil.

Building the pump

Materials

approx. 1 meter of 28 mm copper pipe for body and pressure chamber
22 mm copper pipe for supply pipe
15 mm copper pipe for delivery pipe
connectors as needed
two 28 mm compression 'T's
one 28 mm compression elbow
one 28 mm solder blank end (optional) one 15 mm ball valve
one 28 mm to 15 mm reducer (solder type)

one 28 mm to 22 mm reducer (solder type)
flat piece copper for valves (pipe cut open and hammered flat on metal surface)
small bore pipe to form guide for impulse valve
inner tube for delivery and snifter valves and mounting shock absorbers
rubber and copper disk (psst! don't tell Her Madge - a coin) for impulse valve
tiny nut and bolt cut from earth connector of light switch for snifter valve flap
two nuts and bolts for the impulse and the delivery valve (brass or s/s)
a steel spring removed from a cabinet ball and spring closure (brass would be better if found) for the impulse valve
1/2 tea strainer (wire globe type) clipped to tank outlet
approx 1 ft of 22 mm i/d reinforced automotive rubber pipe as shock absorbing section in supply pipe
two hose clamps for above
one 20 gallon tank as buffer and filter at spring
one 22 mm tank connector
two exhaust pipe brackets to hold pump body to base
section of steel I-beam for base
concrete to hold pump base
solder, flux

Note on fittings - these compression fittings are typical for the UK, and are somewhat different from those available in other countries. Your fitting may look different, but should still work. It is important to use threaded fittings, as the rubber gaskets in the pump body would be damaged when assembling a pump made with solder fittings. Threaded fittings also allow access to the inside of the pump in case of debris entering it, or to replace worn gaskets. Although I used joint tape, it is probably not necessary, as a slight seepage is of no consequence in the pump setting, and the amount of water lost miniscule.

You may be able to obtain the short length of pipe and fittings for the body from a plumber doing a remodeling job. If you buy new materials, shop around. I have bought the fittings at an agricultural iron mongers for about one third the price a builder's merchant charged! The most difficult thing to obtain is the right size brass nuts, bolts, and spring. DIY shops have very little choice - if you get the right length bolt, it may be too thin. You may be able to scavenge them from some old electrical equipment, as did I, if only I could remember what from. Make sure it is solid brass as any plating will soon wear off. Valve gaskets can be cut from inner tube, preferably car tube, as it makes flatter gaskets. Avoid seams. The spring for the impulse valve came from a cabinet ball snap closure. It was just the right size and tension, but made of galvanized wire, which did not last long. You may be able to make one from s/s or brass wire. This is the part which needs some experimentation.

Delivery and snifter valve assembly

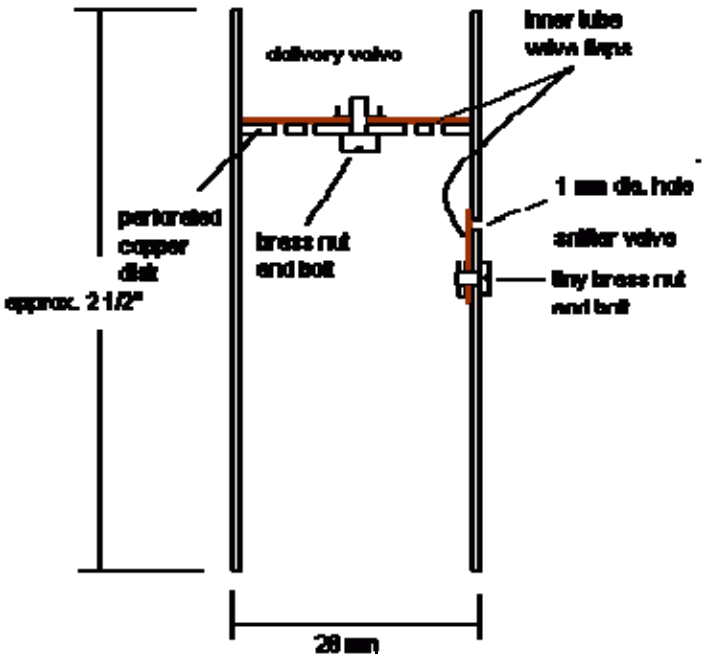

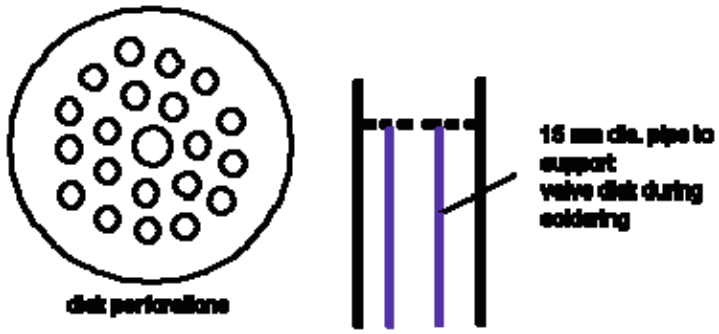

Cut a disk of sheet copper (a piece of opened up pipe, hammered flat) to fit inside the approx. 2 1/2 inch section of 28 mm pipe. Drill one hole in the center to take a small bolt, and holes all around to allow as much water through as possible, but not so many to weaken the disk. Leave a solid edge for the gasket to overlap enough to prevent leakage. File the holes clean with a round needle file and rub surface with abrasive paper to prevent sharp edges and to ensure the gasket makes good contact. Solder the disk into the pipe about 1/2 inch below the edge. Rest the disk on a piece of 15 mm pipe cut to the hight of the disk position. Keep it to the center and avoid excess solder, or you will solder this pipe to the disk too.

Drill a 1 mm diameter hole about halfway down the pipe, and clean the edges. Drill another hole about 1/4 inch below, making it the size of a tiny bolt. Cut a small flap of inner tube to cover the 1 mm hole and extend beyond the bolt hole, and cut a small hole in the rubber for the bolt. Attach the rubber flap with the bolt and nut. If you can't find a tiny brass nut and bolt, you can improvise with the small grub screw and the threaded counterpart of the earth terminal of a redundant plastic electrical socket. The threaded brass block should be sawn in half to reduce drag.

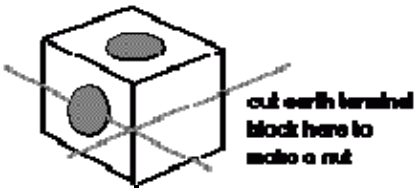

Cut a disk of inner tube to fit snuggly inside the pipe, but not touching the pipe, as the flap must be able to move freely. Cut a small hole in the center and bolt it on top of the metal valve disk with a small washer between the gasket and the nut.

Impulse valve assembly

This one is more tricky to make, and will need some experimenting and improvising with available materials. I will describe the one I made, but there are many ways of doing it. The main principle is a rigid disk with a rubber surface (for good contact) on a guided support which allows the disk to travel in a straight line. The disk is held away from the opening with a spring or weights, which should not prevent the shock wave from slamming the valve shut. The valve disk should be smaller than the inside diameter of the valve body to allow water to pass around it to exit from the outlet holes which need to be big enough to allow the water to pass through with as little resistance as possible to build up momentum. In practice this is a compromise between the disk size and the outlet holes. If the outlet holes are too big, then the disk would have to be correspondingly big to cover the holes in the shut position, thereby allowing little water to pass around the disk when open. The area of the holes should be about equal to the area of the space around the disk, taking into account a small area where the disk overlaps the outlet plate to ensure a tight seal.

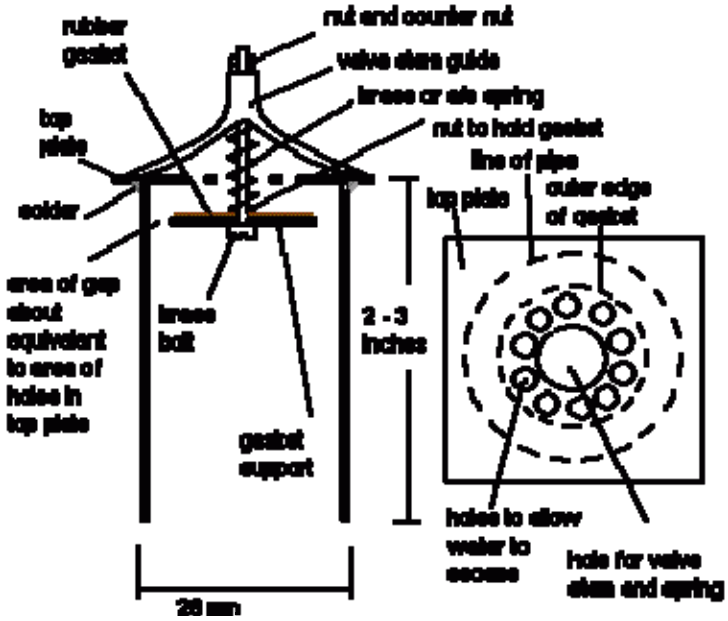

Cut a section of 28 mm pipe to about 2 - 3 inch length. Make a flat piece of copper to cover the top which overlaps the edge to give a sufficient mounting surface for the valve stem guide. Shape is not important, though square is probably easier, unless you already happen to have a suitable round disk. Drill a large enough hole in the center to allow the spring to pass through without catching the edge, and drill more smaller holes around this big one, using the above thumb formula. I am not sure why I did not make a larger hole instead. The reason may have been drill size. I suppose, one large hole should work as well, as long as it is a smaller than the valve disk

to allow the sealing overlap. Make sure the holes and surface are smooth. Solder a frame to the top of the plate to hold a piece of tube just big enough to allow the bolt to pass through and guide it in a straight line. I happen to have had some thin copper tube scavenged from a gas installation of an old caravan. There were two diameters, one fitted snuggly inside the other. The inner was just big enough for the bolt (taking into account that the thread will be filed off the bolt inside the guide tube), but did not have enough substance to split it into four extended legs to support it above the plate, but the larger tube served that purpose. I then soldered the legs to the top plate. The guide tube should also be small enough for the spring to but against it, and not slip inside. The height should allow for the spring to be in the relaxed position with the valve disk about the same distance below the top plate in the open position as the space around the disk. It should also allow room for compression of the spring when the valve shuts, i.e. the spring should also be long enough to allow this compression without the bunched up wires crowding the small space between the guide and the top of the plate, which would happen with a short and tightly coiled spring. To assemble the valve drop a copper or brass disk onto the bolt head followed by a rubber disk, a washer and a nut to secure the disks. Measure the length of the spring and the guide tube and file the thread off the bolt for this length to prevent snagging, and leave thread on the last section for the nut and counter nut. Drop the spring onto the bolt and feed the bolt from inside the valve body through the center hole and the guide tube and secure the bolt in place with the nut and counter nut.

Assembling and installing the pump

Assembling is very easy, just follow the diagram. One point to watch out for is the location of the snifter valve. When inserting the deliver valve assembly between the elbow and 'T' make sure the snifter valve is on the **opposite side of the delivery pipe exit** to prevent the air being lost up the delivery pipe. The top of the pressure chamber can be capped with a blank end or simply hammered flat, bent over like a toothpaste tube, and sealed with solder run into the joint. It is critical that there is enough water to power the pump, as any reduced flow would simply trickle out of the open impulse valve without causing the shock wave to slam it shut. The pipes need to be filled and no air should enter the pipe. It is also important that no debris enters the pump as it can easily jam the valve open. Some kind of intake tank is advisable, and a filter at the tank exit. I used a 25 gallon plastic tank and clipped one half of a s/s fine wire mesh tea strainer (the wire globe type with sprung handle) over the tank connector nut - just happened to be perfect fit. The water also came from a covered spring with very little debris entering it. The drive pipe needs to be as straight as possible, with any bends kept very gradual. Stop cocks must not hinder the flow, therefore a ball valve would be best suited. The jolt of the valve slamming shut creates a fair amount of pressure in the pipe, and it needs to have some shock absorbing section of strong reinforced rubber hose in the upper section. The pump body must be fixed to a base rigidly, but with some cushioning. I clamped the pump to a section of 'I' beam which is embedded in concrete, and used exhaust pipe clamps, cushioned with some inner tube wrapped around the pump body. There is a stop cock on both pipes entering and leaving the pump. For the longer delivery pipe Medium Density Polyethylene is best suited for longer sections, and can easily be joined at or near the stop cock with a copper to MDPE adapter.

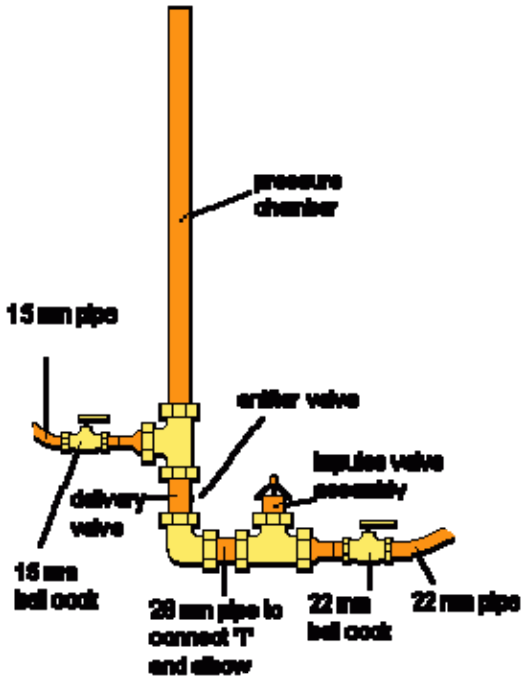

20th WEDC Conference: Colombo, Sri Lanka, 1994

Disseminating ram-pump technology

Dr. Terry Thomas, Warwick University, UK

FOR BOTH IRRIGATION and domestic supply, gravity feed is not always possible: water often needs lifting. The power to lift a flow of water can conveniently be expressed as

power =

constant x mean x flowrate x height lifted

duty x efficiency

where 'duty' is a time fraction (pumping hours per day) and 'efficiency' is a product of the efficiencies of the hydraulic circuit, the pump and the prime mover. Pipes are sized to give tolerable hydraulic efficiency and pumps are chosen to match the hydraulic

conditions and the energy source available. Duty can also be varied to achieve better matching of the prime mover to the hydraulic circuit: high duties such as continuous 24-hour operation result in low power requirements and cheap piping (see Box on next page).

Whilst in general the power for water-lifting can come from engines, electrical mains, animals, humans or renewable (climatic) sources, in the particular context of rural areas in poor countries the choice is more constrained. In many such countries there are virtually no rural electrical mains, engines pose problems of both fuelling and maintenance, draught animals may be unavailable or difficult to apply to water lifting, renewables are erratic, complex and import intensive. Therefore human-powered lifting and transporting of water is still common, despite the very high cost of human energy (US$ 2 to 20 per kW hour).

Of the renewables, water power has the longest history, and under favourable conditions is the easiest to use. Several Asian and Latin American countries have developed the capability of building hydro-power systems. Although sites where power can be economically extracted from falling water are rather rare, they generally occur in the same terrain (mountainous) as the greatest water-lifting needs. The use of water power to pump water is therefore an interesting option. Figure 1 shows the main ways of doing this and illustrates the relative simplicity of the hydraulic ram-pump system. A typical such system is shown in Figure 2.

Ram-pumps (invented 200 years ago) are still manufactured in over ten countries and were once commonplace in Europe, The Americas, Africa and some parts of Asia. They have however been largely displaced by motorized pumping in richer countries, whilst in developing countries their use is concentrated in China, Nepal and Colombia. Ram-pump technology is not trivial: designing systems that are reliable, economic and durable (e.g. against flood, theft, silt ....) takes some experience. Generally, in rural areas of developing countries, this skill has been lost since about 1950, and the intermediaries that used to connect ram-pump manufacturers to pump users have disappeared. Old systems lie broken for lack of fairly simple maintenance: new systems are few.

For various reasons, discussed later, the potential for using ram-pumps seems to be increasing worldwide. Working, primarily in Africa, since 1985 the Development Technology Unit of Warwick University has identified several obstacles to this potential being realized, and has been trying to remove them. This paper records that experience.

The niche of the ram-pump

In suitable terrain, ram-pumps can be used to provide low-power unsupervised pumping. Typical individual ram-pumps can deliver 10 to 200 watts for lifting water; several small pumps can be operated in parallel to feed a single delivery pipe, larger pumps are available from some manufacturers. The power requirements of rural water lifting are illustrated by the following examples, which all assume pipe head losses are 10 per cent of lift. The powers quoted are 'water watts' assuming 24 hours pumping.

domestic supply to a prosperous house 5W

(500 litres per day lifted 75m)

village supply 62W

(l0 000 litres per day lifted 50m)

irrigated garden (0.5 hectare) 87W

(35 000 litres per day lifted 20m)

As the ram pump's system efficiency including its drive pipe is 50 per cent to 75 per cent, the hydro-power inputs for the examples above need to be up to twice the figures shown. The ram-pump is therefore well power-matched to these applications. These inputs are obtained at comparatively low drive heads - typically 10 per cent of the delivery head - so the drive flows to ram-pumps are typically twenty times their delivery flows. (In the examples above the drive flow would be typically 7, 140 and 500 litres per minute respectively). This high flow requirement is clearly a constraint on location. On the positive side, however, no ram-pump user can extract more than a small fraction (e.g. five per cent) of any source flow, the bulk of it being passed on downstream to other users: this has some social advantages.

Three other technical constraints require mention. Firstly there is only a limited range of head ratios (delivery height divided by drive head) of 5 to 30 over which a ram-pump is efficient and economic. Secondly neither drive head nor delivery head should exceed the particular pump's rating (often 20m and 100m respectively, but much less for cheap plastic ram-pumps). Thirdly it must be acceptable that the water lifted is derived from - and hence is of the same quality as - the drive water: a ram-pump cannot derive energy from a dirty stream to pump water from a different (cleaner) source.

Disregarding social and organizational factors, we can therefore describe the technical niche of the ram-pump as moist hilly rural areas where there is no mains electricity but a need for lifting water from streams or springs. The source must be of adequate quality and have a flow many times that to be lifted.

The problem of minor technologies

One of the more accessible concepts from 20th Century physics has been that of 'critical mass'. If the mass of a radioactive material or the size of an organization is below some threshold its activity dies away; above that threshold the activity sustains itself and may even grow. For most technologies there is similarly a critical scale of application below which the activities needed to sustain it may die away. Such activities include manufacture of components, training of new users and specialist maintenance.

In the case of ram-pump systems, specific skills are needed in manufacture, system design, installation and operation. The skills are not especially high and overlap those needed to manufacture, install etc. other devices. Sometimes such skills are preserved in inanimate form. Thus many ram-pump manufacturers employ steel castings whose foundry patterns were made decades ago. Documents preserve design procedures. Existing installations are available as models for new systems. The critical throughput to sustain commercial manufacture is perhaps 50 pumps per year, it is usually achieved via selling into more than one country. A throughput of only one or two new systems a year might sustain system design and installation skills in a general water contractor. However, a specialist installer might need to put in at least 20 pumps a year to survive.

In reviving an old technology or introducing a new one, the 'critical mass' throughputs need to be estimated. If they are higher than the area of sales or of installer operation can sustain, any intervention to promote the technology will ultimately fail. More important, if the likely demand is thought to be close to such a threshold of sustainability it is worth effort to lower the threshold.

With the technology of hydro-electricity we are used to having separate organisations making turbines, designing systems, building them and operating them. Maintenance may require a fifth agency. Even though some of these organisations operate internationally via local agents, such complexity entails uncertainties that tend to raise the critical size for each of them. Micro-hydropower utilisation has lagged behind its apparent economic potential for these reasons in most countries. Ram-pumping faces similar difficulties.

Often there is a key agency that effectively leads the others involved in a technology. For example a manufacturer of equipment may set up training for its installers, users and maintainers; alternatively a consultant may co-ordinate and supplement the existing skills of the other parties. A low value rural technology does not lend itself to the latter approach.

Experiences in Africa

The author and his DTU colleagues have been trying to revive ram-pump usage in Africa since 1985. An early analysis suggested that foreign (e.g. European) manufacturers selling a few pumps a year via agents could not and would not provide adequate training for local installers. Moreover imported pumps are expensive and difficult to source spares for. In colonial times there were few technical alternatives for water lifting to plantations, mission hospitals and large schools and it was worth the cost of bringing a ram-pump installer from another continent. Today that is an unacceptably expensive option for a village or farm needing pumped water or for a small-scale pumped irrigation scheme.

In the absence of a design consultant (again unlikely for this scenario), the options for sustainability appeared to be

either to build up the design capability of installation contractors

and/or to encourage local manufacture by an organisation also capable of providing back-up to installers.

The DTU chose the 'and' option, first spending several years in developing simple and cheap pump designs suitable for provincial manufacture and codifying system design and installation procedures. Since 1990 the DTU has been training both producers and installers from nine African and one Asian country, usually using its demonstration centre in the Eastern Highlands of Zimbabwe. There is an ongoing debate about what is the right level of manufacturing technology (hand tool, workshop with electricity, factory), whether manufacture and installation should be undertaken by the same organization, whether low-lift irrigation or high-lift water supply should be given priority, whether installer training should be directed towards governmental, NGO or private organizations and what fraction of possible sites are 'easy' sites suitable for beginners to tackle.

The results have been mixed. Easy sites (with modest lifts, plentiful water, favourable stream geometry and well-organised customers) are perhaps only a few percent of technically feasible sites. The process of system design has proved intimidating to technicians for whom even sizing a pipe for gravity flow is at the limit of their understanding. The input of (expatriate) man and woman power to bring an installation organisation up to the level of competence and confidence to stand alone with this technology has been expensively high. The 'successes' have been with unusually well-resourced NGOs. Commercial manufacture, for example in Kinshasa (Zaire) and Mutare (Zimbabwe) has been started but self-sustaining manufacturer-installer arrangements have not been developed. Of some 30 pumps installed, too many have been 'demonstrations' rather than built to meet real water needs.

Clearly training on courses alone is not enough. Installers and manufacturers need to be visited and helped/encouraged with production of their first systems. A ram-pump has a certain 'something-for-nothing' magic about it that impresses onlookers and causes any installation to yield many enquiries from neighbouring villages or farms. However the technology's uncertainties, using very cheaply produced pumps in the hands of novice installers, makes it much easier to apply to individual 'rich' farms or institutions than to villages or communal dry-season gardens.

Ram-pump technology has a fascination for enginers and users out of proportion to its current commercial importance. The DTU's 1992 book on system design must have sold more copies worldwide than there have been new systems built! A 1993 day school on ram-pumps in Sri Lanka attracted fifty engineers but so far has resulted in no new systems.

Prospects

Ram-pumping will never be a major technology comparable with motorized pumping from rivers or hand pumping from boreholes. Its particular niche is described above: worldwide there is a potential for between perhaps 10 000 and 200 000 systems. Much of

that potential lies in areas where there are currently no system design skills. Availability of pumps need not be a major problem (despite the DTU's local manufacture strategy in Africa), since even though good imported machines cost over $10,000 per kilowatt the pump itself rarely accounts for more than 40 per cent of system costs.

Certain trends worsen the prospects for ram-pumps. Worldwide, water sources are becoming both dirtier and weaker. Some historical ram-pump systems no longer operate because of declining drive flow. Clean spring water is usually associated with very low power levels - in Rwanda for example, the DTU had to design for 80 metre lifts from drive flows under 10 litres per minute, which is on the limits of the technology.

Factors increasing likely demand are the movement of rural populations uphill (under population growth pressures), the expansion in micro-irrigation, the introduction of local ram-pump manufacture (especially in South America) and the availability, apparently for the first time in decades, of both trustable handbooks and training courses.

In Africa the prospects for ram-pump usage seem to depend largely on the confidence of potential installers. Despite much individual innovation there, Africa is not a continent where organizations readily take risks with unknown technology. Elsewhere in the developing world continuation of the current slow expansion of ram-pump usage will depend upon developments in photo-voltaic pumping, its most immediate rival.

The scope for technical improvement of a simple device already used for 200 years is rather small. However, modern materials may permit the pressure vessel (required to smooth the pulsating flow through the delivery valve into a steady flow up the delivery pipe) to be replaced by a pressured bladder. This will allow pumps to be operated slightly under water which has advantages for both efficiency and reliability. Understanding of the causes of erratic pump behavious and of inefficiency is now better than in the past, which designers of pumps and 'trouble-shooters' of systems can draw upon. It is not possible to totally design away temperamental behaviour, during for example system start-up, but its incidence can certainly be reduced.

For the ram-pump to fully occupy its niche, efforts must continue both to simplify the design of reliable systems and to propogate design skills. Although water-powered pumping will never attain the simplicity of drop the suction pipe in the stream and switch on that motorized pumping offers, as users of a renewable energy source, ram-pumps may have time on their side.

http://info.lut.ac.uk/departments/cv/wedc/papers/thomas2.html
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¾” RAM PUMP PLANS
AS BUILT BY ROD LAVOIE
USING ALL STOCK PARTS FROM THE HOME DEPOT

1. 1 ¼”x100FT ROLL PVC PIPE
2. 1 ¼” MALE PIPE ADAPTER
3. 1 ¼” GALV COUPLING
4. 1 ¼” x 1” GALV BUSHING
5. (2)-1”x ¾” GALV BUSHING
6. (4)- ¾”x2” GALV NIPPLE
7. (2)-¾” GALV TEE
8. (2)-¾” BRASS SWING CHECK VALVE
9. ¾”x6” GALV NIPPLE
10. 1 ½”x1” GALV BUSHING
11. ¾”x ½” GALV BUSHING
12. ½” HOSE SPIGOT
13. 1 ½” FEMALE PIPE ADAPTER-SCHED 40
14. 1 ½”x10’ SCHEDULE 40 PIPE (I USED 5’)
15. 1 ½” SCHED 40 GLUE CAP
16. 4”x12”- ¼” MESH GALV SCREEN

ASSEMBLY NOTES: View is from top. Inlet pipe has red stripe. Screen is over inlet of drive pipe. Inlet pipe starts between two rocks in stream where water flows fastest. Outlet hose is green. Top check valve arrow points down, bottom points right. White air chamber is 5 feet long, and pitched up, but not necessarily vertical. Entire unit lays in stream bed. Pump is pitched up slightly to help bottom check valve close. Swing check valves have a flapper swinging on a pin. They have no spring. For normal operation, they must be mounted with the large hex cap up. Mounting it upside down allows water to flow backwards through it, until the velocity picks up the flapper and slams it closed. This creates the pressure pulses. Start pump by opening waste valve with finger. All air must be removed from drive pipe for proper operation. Removing the waste valve may help. Do not use wrenches to tighten fittings. Rotating the tee with the waste valve adjusts flow. The delivery hose can be removed for flushing. An inlet valve may be added if no rocks are expected to be available to stop flow for service, but I haven’t tested the valves with shock waves. Showers are healthy and refreshing ,too. Pressure is not too high. If part substitutions are necessary, just remember that you are trying to create and use the shock waves created when you suddenly stop a column of flowing water. Bigger parts make a bigger pump. Lighter parts make a lighter pump.

PERFORMANCE DATA:

HEAD- 40 INCHES OVER 100 FEET, LIFT- 10 FEET ABOVE PUMP, FLOW- 27 GALS PER HOUR, WILL VARY WITH LIFT, PRESSURE AT 10 FEET- 15 PSI, WILL ALLOW WATER TO BE PUMPED HIGHER.

COST- ABOUT $80.00 FOR PUMP, $24.00 FOR 3 LIGHT DUTY 50 FOOT DELIVERY HOSES.

DTU

Ram pump programme

Computerised ram pump calculators
A short user guide

TECHNICAL
10
RELEASE

DTU Ram Pump Programme

Computerised calculator programmes

These programmes are supplied as "Freeware", which means that the DTU reserves no copyright. You can copy and distribute the programmes as much as you like — as long as you do not charge any money for doing so. Please do not change the programme code in any way.

Although every effort has been made to ensure that this software performs correctly and that its documentation is accurate, the DTU accepts no liability whatsoever for errors contained herein or incidental consequences resulting from the use of this material. Disks are checked for viruses before leaving the DTU, but no guarantee of non-infection can be made after the first use.

Microsoft Windows is a trademark of Microsoft Corp®.

Hardware requirements

The minimum hardware requirement for these programmes is an IBM compatible PC with an 8088 processor. If you have the minimum requirement, only the DOS programme DOSPUMP will run. Although all three programmes should work on an IBM compatible machine with an 80286 processor running Windows 3, we recommend that the Windows programmes are used on an IBM compatible machine with at least an 80386 SX processor and four megabytes of RAM that is using Microsoft Windows 3.1 (or later versions).

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1. Calculator Installation

There are three programmes on the 720k 3.5" disk inside the cover of this book. Two of them must be installed on a hard disk and run under Microsoft Windows®. The third programme runs under DOS and can be run from the floppy disk drive or installed onto a hard disk.

The two Windows programmes are:

WINPUMP
PUMPDATA

The DOS programme is:

DOSPUMP

You will not need to use both the Windows and the DOS programmes because they do the same thing. If you have a version of Microsoft Windows® on your computer, do not bother to install DOSPUMP as well as the other programmes.

1.1 Installing the Windows ram pump programmes

To install the ram pump programmes that run under Microsoft Windows® insert the disk in the floppy disk drive, then type the letter identifying the drive, followed by a colon (:).

For example:

A:

Then press the [Return] key.

The [Return] key is also called the [Enter] key and often has an arrow on it, like this ↵.

Type **PWIN** followed by the letter identifying the hard disk drive being used, a colon (:) and a backslash (\), and the directory name **DTUPROGS**, which is where the programmes will be installed.

For example:

PWIN C:\DTUPROGS

Then press the [Return] key.

When the programmes have been installed, a message appears advising you that installation is complete and telling you to press any key to continue.

Press the space bar.

The Windows programmes have now been copied to your hard disk, but Microsoft Windows® does not know this. The next stage of installation tells Microsoft Windows® that they are there and installs them as icons at the Microsoft Windows® Programme Manager screen.

To do this, type the letter identifying the hard disk drive where the programmes have been copied, followed by a colon (:).

For example:

C:

Then press the [Return] key.

Type **CD\DTUPROGS** and press [Return] to change to that directory on your PC.

Type **SETUP** and press the [Return] key.

Microsoft Windows® starts and the DTU programme installation window appears. The DTU programme installation window has two buttons:- OK and EXIT.

Use the mouse to click on the OK button to start the installation.

The programmes are installed in a few seconds with progress being shown in the bar above the control buttons. A programme group called DTU programmes is created under Microsoft Windows' Programme Manager, and the DTU Windows programmes are installed there with these icons.

1.1.1 To run the Windows DTU calculator programmes — WINPUMP and PUMPDATA

Start Microsoft Windows® and click the mouse on the icon for the programme that you want. Click twice quickly (using the left mouse button) to run the chosen programme.

1.2 Installing the DOS DTU ram pump calculator programme — DOSPUMP

To install the ram pump calculator that runs under DOS, insert the disk in the floppy disk drive, then type the letter identifying the drive, followed by a colon (:).

For example:

A:

Then press the [Return] key.

Type **PDOS C:\DTUPROGS**

When the programmes have been installed, a message appears advising you that installation is complete and telling you to press any key to continue.

Press the space bar.

If you do not have a hard disk, the programme can be run from the floppy disk.

1.2.1 To run the DOS DTU calculator programme — DOSPUMP

There are two ways to run this programme — from the hard disk or the floppy disk.

Running from the hard disk	Running from the floppy disk
Type the letter identifying the hard disk drive where the programmes have been copied, followed by a colon (:). For example: C: Then press the [Return] key. Type **CD\DTUPROGS** and press [Return] to change to that directory on your PC. Type **DOSPUMP** and press [Return] to start the programme.	Put the floppy disk into the drive, then type the letter identifying the floppy disk drive, followed by a colon (:). For example: A: Then press the [Return] key. Type **DOSPUMP** and press [Return] to start the programme.

2. Using the DTU programme WINPUMP

When you click on WINPUMP the ProRam window opens. This window is used to enter variables to work out the equation: $E\ (Eta) = \frac{q\ h}{Q\ H}$.

This is the ProRam window:

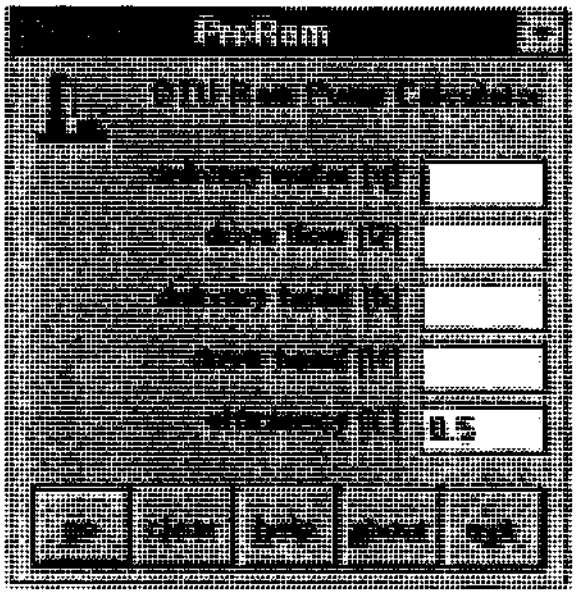

Winpump is used by filling in any four of the variables for a ram pump system, (Q,q,H,h, and E) and clicking on the GO button. The missing variable is then provided for you.

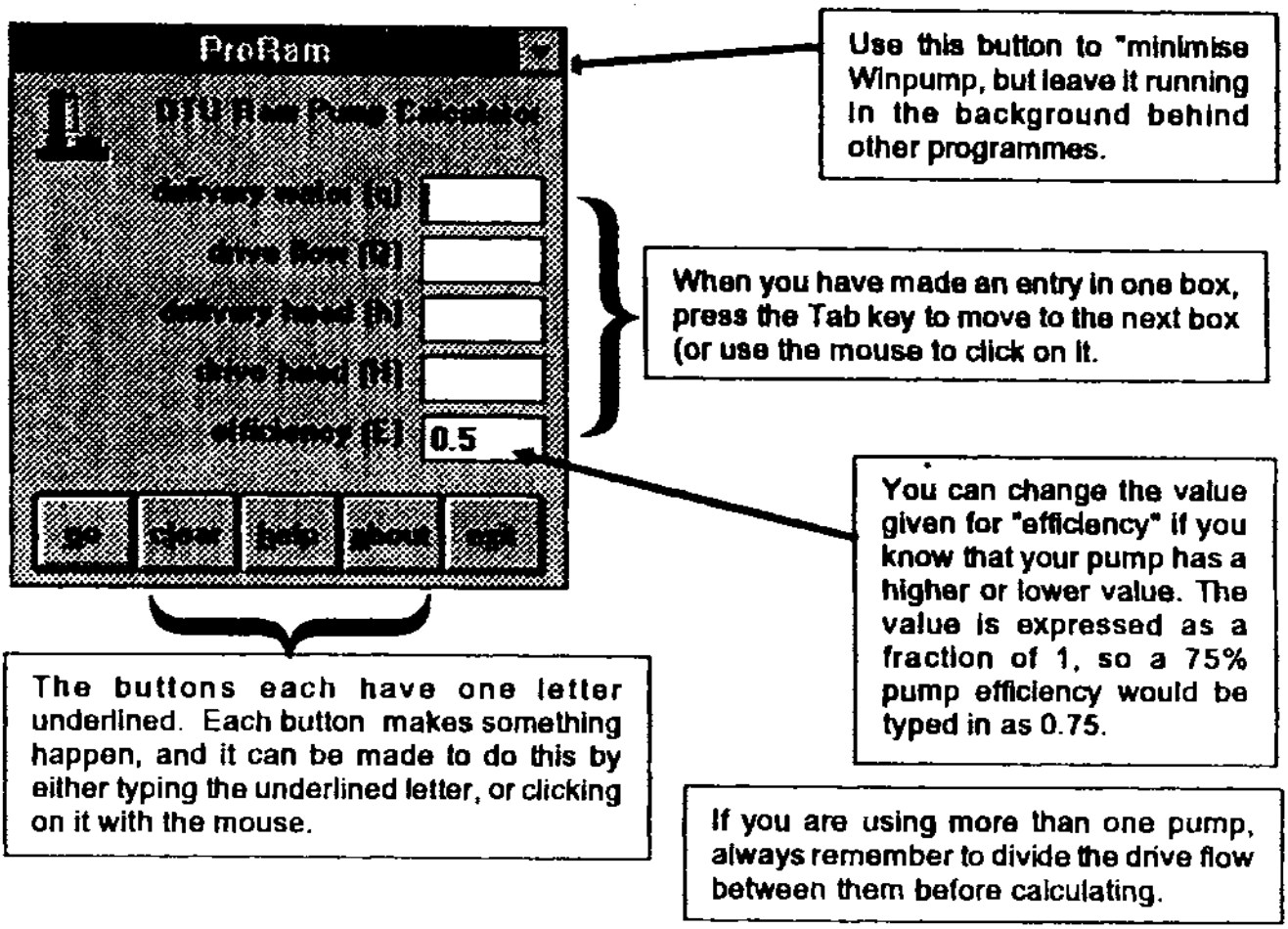

When you have made one calculation and wish to make another, click on the "clear" button. All the values will disappear, except for 0.5, which is the default pump efficiency.

If you want to know the pump efficiency of an existing system, delete the entry for efficiency and fill in the other variables, then click on the GO button.

To leave WINPUMP, click on the "exit" button, of type the letter X.

WINPUMP's usefulness is limited, but it can be very handy for making quick calculations of the effect of changing parts of a system's design. For example, you can quickly find out what difference it would make to the delivery flow if you added a metre to the drive head or reduced the drive flow.

An example is when a system design is actually going to deliver more water than is needed and by varying the entries for drive head and delivery head we can see whether we could save money on the drive pipe, or deliver to a point high enough above the originally planned delivery tank for the excess to be usefully gravity fed to a garden plot.

DOS users will find that the DOSPUMP programme is a very similar calculator to WINPUMP. It looks different because it runs under DOS, but it does the same things.

3 Using the DTU programme PUMPDATA

When you click on PUMPDATA the DTU Ram Pump Data Generator window opens. This window is used to enter variables to work out the equation

$$q = \frac{\eta Q H}{q h}$$

for a wide range of conditions. All possible answers within the ranges given are calculated. The range of results can then be sorted and printed.

This is the DTU Ram Pump Data Generator window:

A range of values for the Drive Head (H), Drive Flow (Q) and Delivery Head (h) are calculated for a particular pump efficiency. If you know the efficiency of the pump in use, begin by changing the efficiency value (which is given as 0.5 or 50% by default).

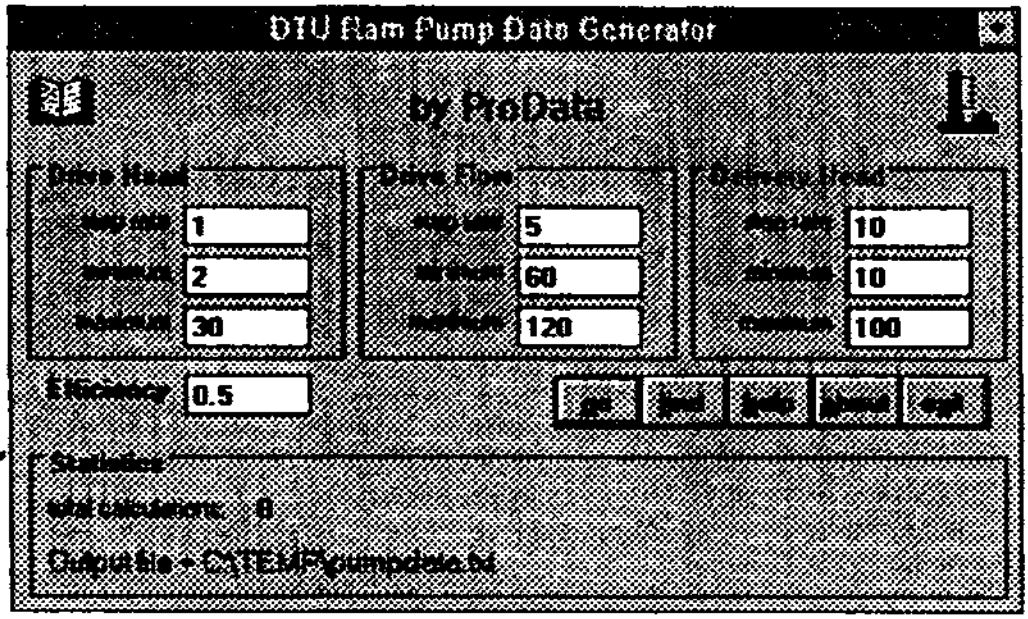

When the efficiency has been set, the "Drive Head" figures are entered (in Metres).

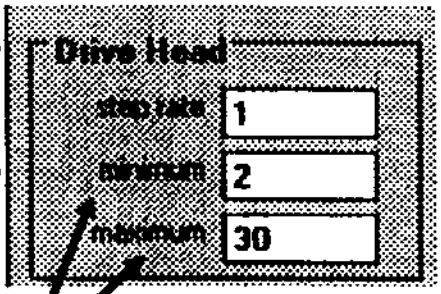

The "step rate" is the amount by which the value is advanced for each set of recalculations. For example, with a step rate of 1, the Drive Head will be calculated for every value between the minumum of 2 and the maximum of 30 (whole numbers only). If the step rate is changed to five, the minimum number will be advanced in fives to the maximum.

Change the step rate to a bigger figure to reduce the number of calculations carried out if your computer is very slow.

Change the minimum and maximum Drive Head to those available at the site being calculated.

When the "Drive Head" range has been set, the "Drive flow" figures are entered (in litres per minute).

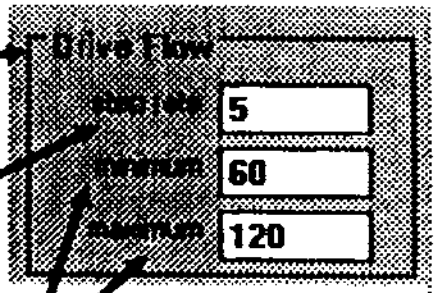

The "step rate" is the amount by which the value is advanced for each set of recalculations. For example, with a step rate of 5 as shown, the Drive flow will be calculated in fives from the minumum of 60 to the maximum of 120 litres per minute. If the step rate is changed to 10, the number will advance in tens from the minimum to the maximum.

Change the step rate to a bigger figure to reduce the number of calculations carried out.

Change the minimum and maximum Drive flow to those available at the site being calculated. If a single flow is known, type that flow into both the minimum and the maximum boxes.

When the "Drive flow" range has been set, the "Delivery Head" figures are entered (in metres).

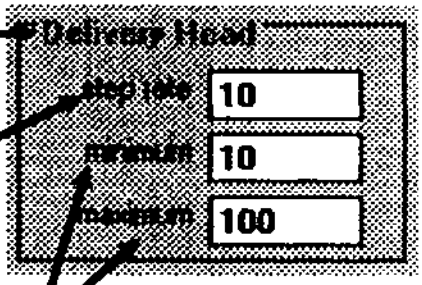

The "step rate" is the amount by which the value is advanced for each set of recalculations. For example, with a step rate of 10 as shown, the Delivery Head will be calculated in tens from the minumum of 10 to the maximum of 100 metres. If the step rate is changed to 20, the number will advance in twenties from the minimum to the maximum.

Change the step rate to a bigger figure to reduce the number of calculations carried out.

Change the minimum and maximum Delivery Head to those available at the site being calculated.

After setting the Step rates and the maximum and minimum entries for Drive Head (H), Drive Flow (Q) and Delivery Head (h) at a site, click on the "go" button to start making calculations.

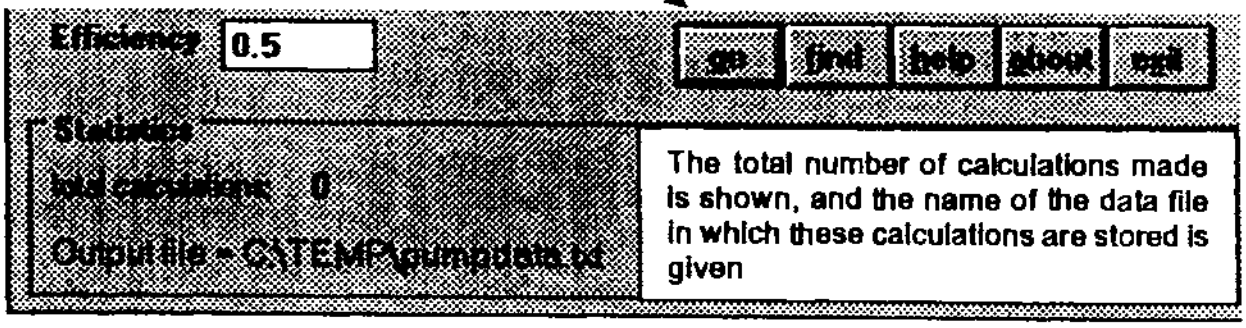

The total number of calculations made is shown, and the name of the data file in which these calculations are stored is given

3.1 Looking at the results

When the calculations have been made, they are saved in the file called "pumpdata.txt" on your hard disk. You can look at this using a wordprocessor or other programme if you want to. To look at the calculations in this programme, and to select restricted ranges to look at, click on the "FIND" button to open the PUMP DATA QUERY window.

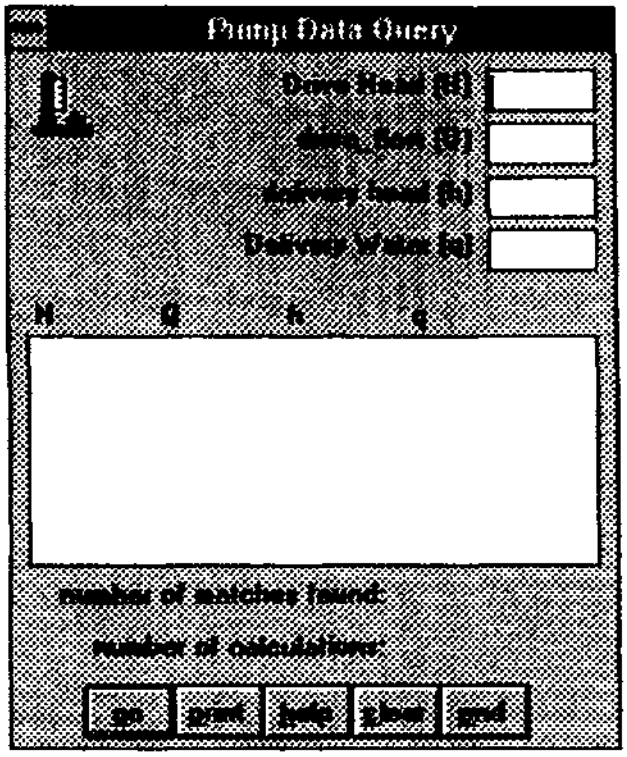

Asking the calculator a question

A Query is simply a question. You can ask to see the data for a restricted set of variables, or for all. To see all, just click on the GO button without putting anything in the boxes.

To see a restricted part of the calculations you have just made at the DTU Ram Pump Data Generator window, make at least one entry in the boxes alongside Drive Head, Drive Flow, Delivery Head and Delivery Flow.

For example, if you wanted to see how much drive flow would be needed at a site with a known drive head, delivery head and required delivery flow, type the known values in the boxes and click on the GO button.

EXAMPLE

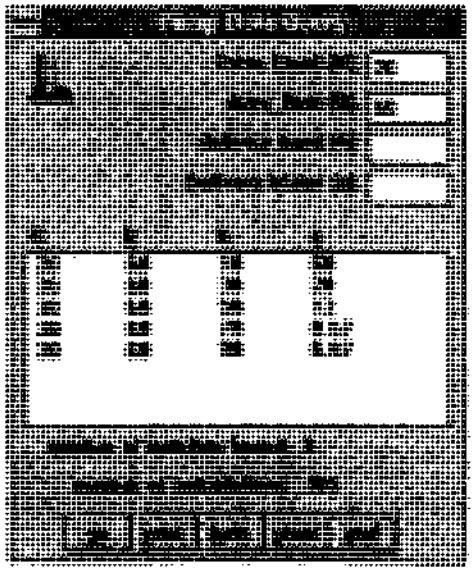

In this example, a drive head of 20 metres was possible but the drive flow was restricted to 60 litres per minute. We wanted to know how much water could be pumped to a range of heights. The step rate for the delivery head had been given as 20 metres at the DTU Ram Pump Data Generator window, so only five calculations for delivery head were made for its range of between 10 and 100 metres.

Notice how it is possible to generate silly answers if you are not careful. The first calculation in the list shows a Drive Head of 20 metres and a Delivery Head of only 10 metres — gravity feed!

Printing the result

To print the information you have found, simply click on the PRINT button. Make sure that your printer is attached and turned on, with paper in it before trying to print anything.

It can be useful to print a range of calculations for a particular site before visiting it. For example, you might know that the site must deliver 10 litres a minute before the client will be interested, you might also know the efficiency of the pump to be installed, and the fact that there is plenty of drive water (120 litres a minute or more). You may also know that the delivery head is at least 50 metres. If you then find all possible combinations of drive Head and Delivery Heads of 50 metres or more that give a delivery flow of 10 litres a minute or more, this would be useful to have with you when assessing a site.

Asking another question

If you want to find the answer to another question, click on the CLEAR button to clear your first question and its answers from the window. Then type in the relevant values for your new question and click the mouse on the GO button.

Leaving the PUMPDATA programme

When you have finished making your calculations, click the mouse on the END button to close the DTU PUMPDATA programme.

4 Using the DTU programme DOSPUMP

Refer to section 1.2.1 To run the DOS DTU calculator programme - DOSPUMP to start the programme from your hard disk or from the floppy disk provided.

This is what appears on the DOSPUMP main screen.

```
DTU Ram Pump Calculator by ProData

Q=Drive Flow: q=Delivery Water: H=Drive Head: h=Delivery Head: E=Efficiency

Which variable to calculate: Q, q, H, h, E, ?=help, X to quit
```

Type which one of the five variables, Q, q, H, h, and E you want to calculate.

☛ *Be careful to type "Q","H" and "E" as upper case letters and "q" and "h" as lower case letters.*

WINPUMP users will find that the DOSPUMP programme is a very similar calculator. Because it runs under DOS its appearance is different, but it does the same things as WINPUMP.

Whichever variable you select, a window will open asking you to enter a value for the other variables, one at a time. For example, if you type "q", the window shown below opens prompting you to give a value for E (the pump efficiency).

```
DTU Ram Pump Calculator by ProData

Q=Drive Flow: q=Delivery Water: H=Drive Head: h=Delivery Head: E=Efficiency

Which variable to calculate: Q, q, H, h, E, ?=help, X to quit

Delivery Water
enter value for E:
```

You are asked for each of the other four variables in turn, and when you have entered them (press [Return] after each entry), the programme displays the missing value lower on the screen. An example is shown below.

```
DTU Ram Pump Calculator by ProData

Q=Drive Flow: q=Delivery Water: H=Drive Head: h=Delivery Head: E=Efficiency

Which variable to calculate: Q, q, H, h, E, ?=help, X to quit

Delivery Water
enter value for E: 0.6
enter value for H: 5
enter value for Q: 90
enter value for h: 60

the value of q is  4.50

Again? (y)es or (n)o:
```

When you have entered all the variables, a window at the bottom of the screen a message prompts:

"Again? (y)es or (n)o:"

Type the letter Y to clear the screen and calculate a result for another set of variables.

Type the letter N to close DOSPUMP.

DTU

Ram Pump Programme

AN INTRODUCTION TO HYDRAULIC RAM PUMPS
(and the DTU range)

TECHNICAL
16
RELEASE

An introduction to hydraulic ram pumps

This Technical Release explains briefly what ram pumps are, how they work, and how you might select them. It finishes with a catalogue of the current DTU designs of pump for local manufacture in developing countries.

Contents

What a ram pump does

The parts of a ram pump

The ram pump cycle

The parts of a ram pump system

When to use ram pumps

Choosing which ram pumps to use

The DTU range of ram pumps

A much fuller description of how to design and install ram pumps systems can be found in the book *Ram pumps and the design of ram pump systems*, DTU, UK 1995, which is available from the DTU at the address on the back cover of this Technical Release. A list of Working Papers and other Technical Releases, several of which refer to ram pumps, can also be found on the back cover of this Technical Release.

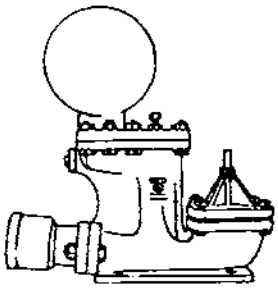

AN EASTON RAM PUMP
UK

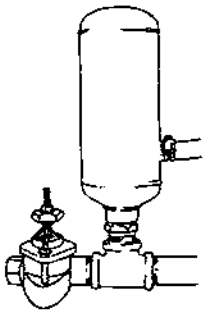

A GAVIOTAS RAM PUMP
Columbia

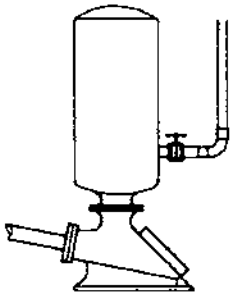

A "PREMIER" RAM PUMP
India

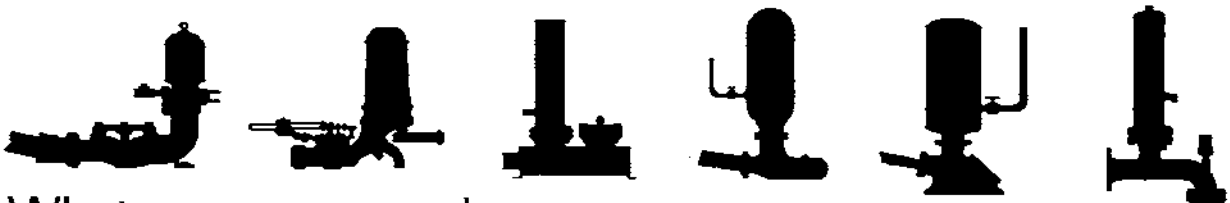

What a ram pump does

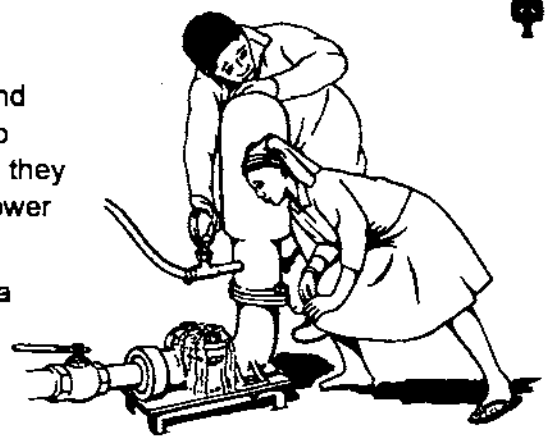

Some ram pumps are made from many parts and look very complicated. Others look too simple to work. Whether they look simple or complicated, they all work in the same way and they all get the power to run in the same way.

Many people are surprised when they first see a ram pump working. They think that it is driven by a hidden motor, or by magic. They watch it pumping and are amazed.

Every kind of pump needs a source of power. They can be powered by people or animals, the wind, falling water, electricity , or fuels such as diesel and petrol. The source of power is often separate from the actual water pump and the two can be joined together by, for example, a shaft. The ram pump uses the power of falling water and there is no separate motor or mechanism that turns the pump. This is why a well designed ram pump can look much simpler than some other pumps. It *is* a very simple machine, although the reasons for it working well are not simple at all.

The drawing below may help you to understand how much simpler a ram pump system is than other ways of using water power to pump water.

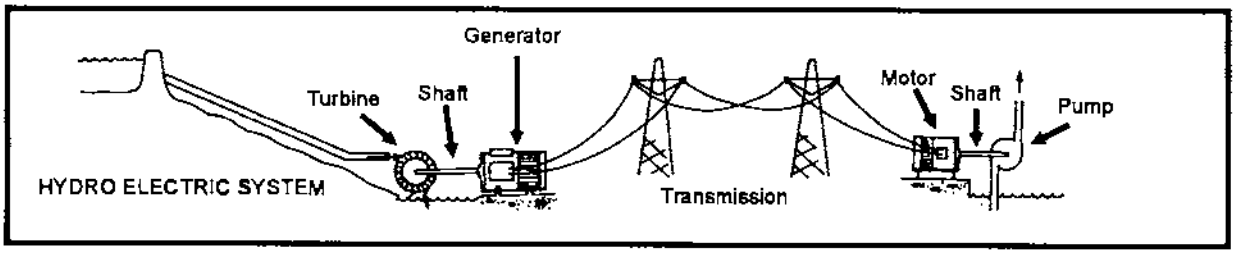

THREE DIFFERENT WAYS TO USE WATER POWER TO PUMP WATER

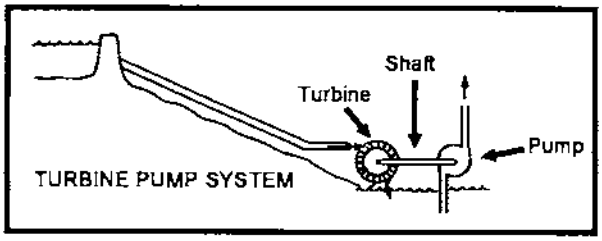

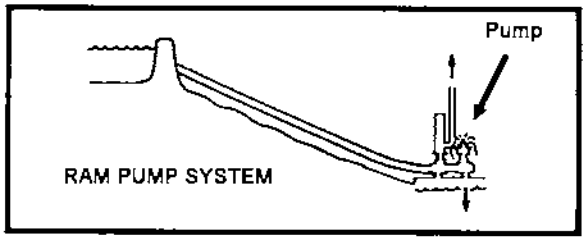

As far as we know, the ram pump was first discovered or invented 200 years ago. Since then it has been rediscovered many times.

Water is diverted from a spring or river and flows down a sloping drive pipe, gathering speed like a rock rolling downhill. As the water gathers speed it gathers energy. The faster it goes the more movement-energy it has. If you are hit by a small rock rolling slowly downhill it will stop without hurting you very much because it does not have much movement-energy. If you are hit by the same rock rolling very quickly downhill it will hurt a lot because it has a lot of movement-energy.

At the bottom of the sloping drive pipe is the ram pump and the water is flowing out through its main valve. The valve closes and the water is suddenly stopped. The movement-energy in the water becomes pressure-energy. Pressure-energy is what all pumps use to lift water. It pushes some of the water into the delivery pipe.

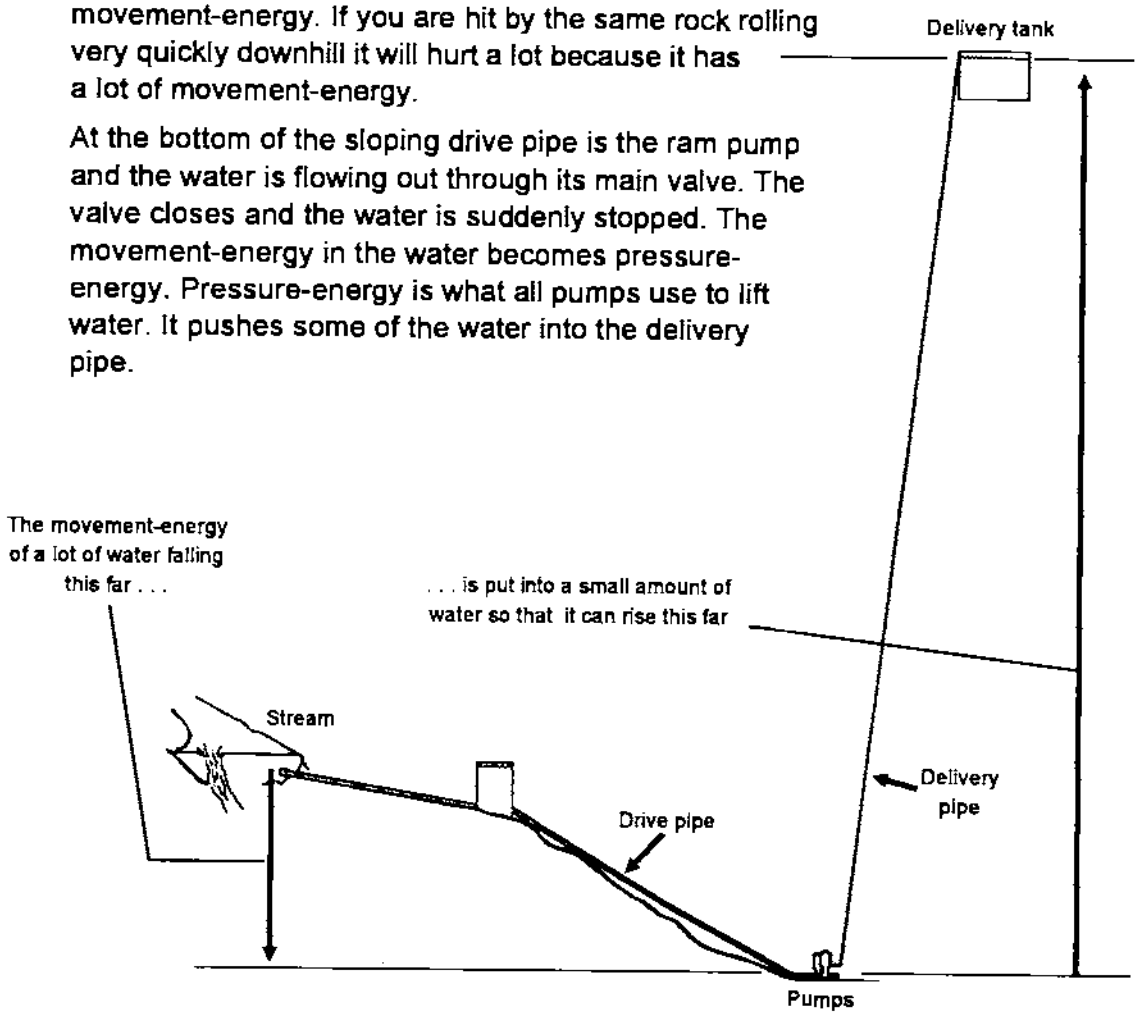

SKETCH OF A RAM PUMP SYSTEM

The movement-energy of all the water falling down the drive pipe is put into a small part of that water. The small part of water then has enough pressure energy in it to be 'delivered' to the place where it is needed.

All ram pumps need a lot of water falling down a pipe to provide the energy they use, and they only pump a small amount of the water. This is why they can only be used in places where there is more water than you need to pump. Usually, each pump will pump about 5 to 10% of its drive water. The rest goes back into the stream for other people to use.

The parts of a ram pump

Ram pumps come in many different shapes and sizes but they all have the same basic parts. They all have two main valves, which are an impulse valve and a delivery valve. They also have an air vessel of some kind.

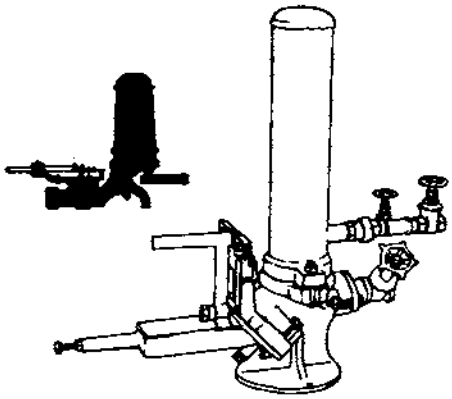

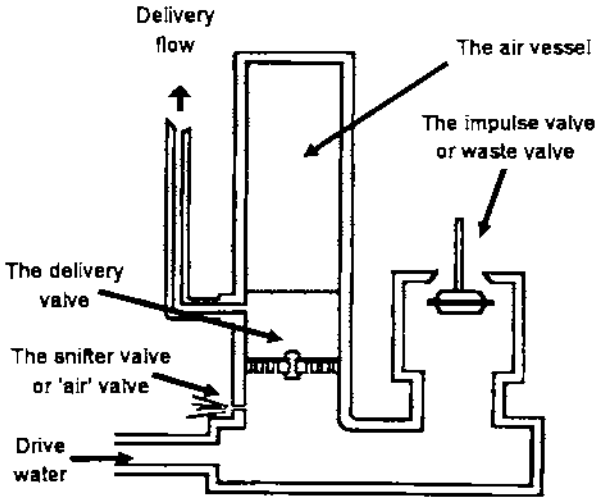

A DRAWING OF A RAM PUMP CUT IN HALF

Most pumps have an air vessel that is slowly filled with air by the snifter valve when the pump is started. The air acts as a shock absorber, absorbing the high pressure surges of the pump. A few modern pumps have an air vessel that is closed by a rubber diaphragm, like the Platypus pump shown on page 12. The pump operator pressurises the air vessel by pumping in air in the same way as you would pump up an inner-tube for a tyre. The diaphragm takes away the need for a snifter valve.

Some ram pumps have the air vessel and the impulse valve the other way around from the pump in the drawing so that the drive water reaches the impulse valve first. Some big ram pumps have more than one impulse valve working together to get the same effect.

A few pump makers build ram pumps that keep the water that is pumped separate from the drive water. This allows you to pump clean water from a nearby spring while using the power of dirty water from a river or stream. These are sometimes called 'compound' rams. The pumps are more complicated and expensive than ordinary ram pumps, so they are not covered in this Technical Release.

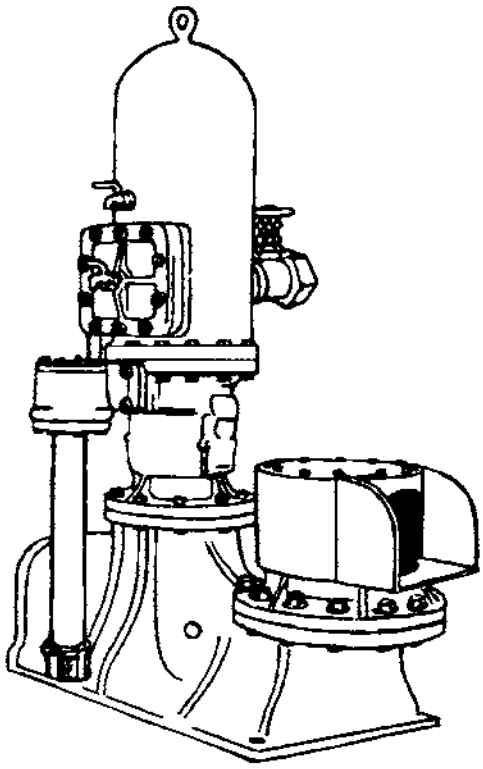

A LARGE GREEN AND CARTER 'COMPOUND' RAM PUMP

The ram pump cycle

Ram pumps have a pumping cycle. The last part of each cycle is the first part of the next, so the pump keeps on working.

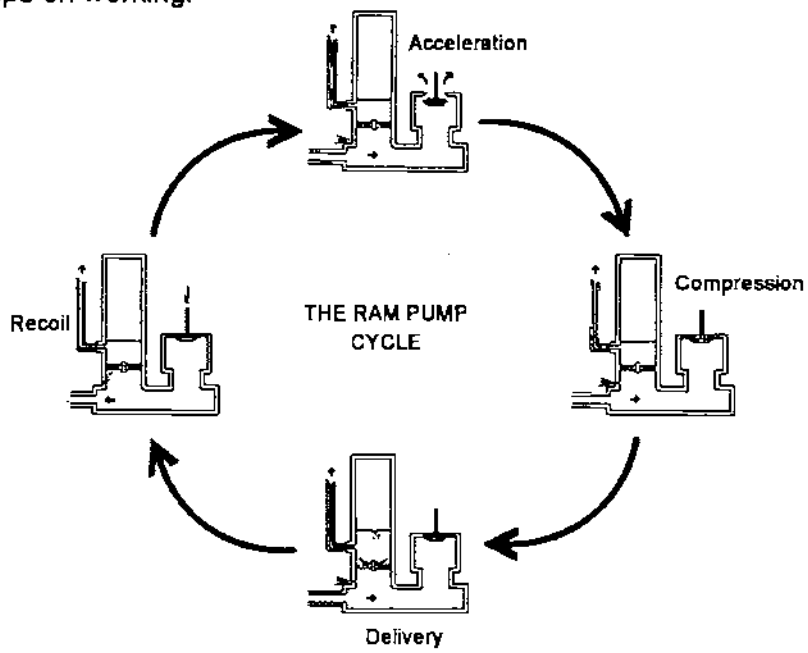

Each cycle happens very quickly, often about once a second. This means that there is no time to see what is happening. The time each stage takes is usually measured in 'milliseconds', which are thousandths of a second. A mosquito flaps its wings about 1000 times a second, so a millisecond is roughly the time it takes for a mosquito to flap its wings once.

It is easiest to explain how the ram pump cycle works by dividing it into four stages called ***Acceleration, Compression, Delivery*** and ***Recoil.***

In the explanation that follows the pump is cycling 60 times a minute, or once a second. The time that each stage takes is given in flaps of a mosquito's wings. Because the cycle takes one second, there are a total of 1000 flaps of the mosquito's wing.

Acceleration (about 900 flaps of a mosquito's wing)
When the impulse valve on the pump is open, water flows down the drive pipe and comes out through the open valve. The water flowing past the open valve drags past it, trying to close it. The flow down the drive pipe and out through the impulse valve gets faster and faster. As it gets faster, it drags harder on the valve until it is strong enough to drag it closed.

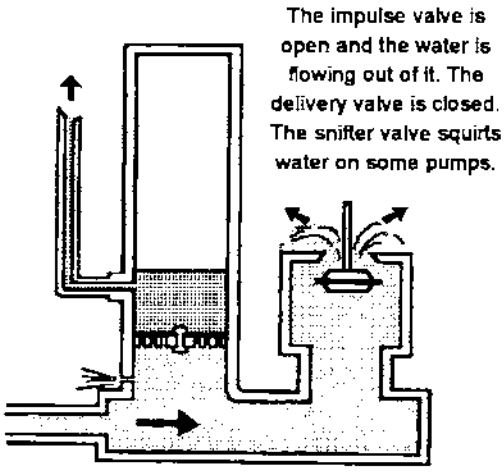

ACCELERATION

Compression (1 or 2 flaps of a mosquito's wing)
When the impulse valve shuts, the water flowing down the drive pipe cannot come out through it. At the moment the valve closes, the water is travelling very fast and suddenly it has nowhere to go. As it got faster, it gathered movement-energy like the rock rolling down a hill. The movement-energy changes to pressure-energy as it compresses the water in the body of pump. It is as if each small part of the water is bumping into the one ahead as they rush to come down the pipe and escape. As a result there is a sudden rise in pressure that is sometimes called "water-hammer". The pressure rises to a level much higher than the pressure in the pump's air vessel.

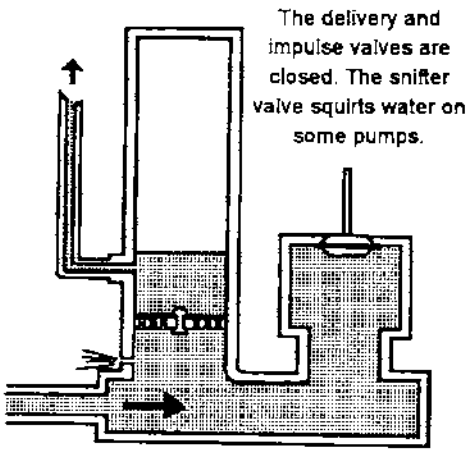

COMPRESSION

Delivery (about 50 flaps of a mosquito's wing)
Because the pressure rises higher than the pressure in the air vessel, the delivery valve is pushed open and water flows through it. The pressure in the pump body drops quickly to equal the pressure in the air vessel. The water coming down the drive pipe slows down and the pressure in the pump body drops. As soon as the pressure falls enough to be lower than the pressure in the pump's air vessel, the delivery valve closes. The delivery valve is a one-way valve, which stops water flowing back from the air vessel into the pump.

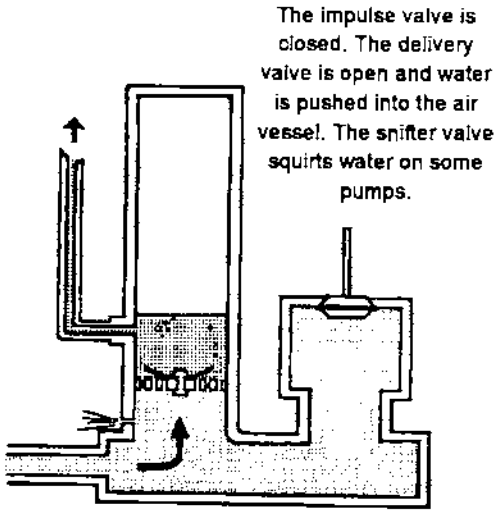

DELIVERY

Recoil (about 50 flaps of a mosquito's wing)
When the delivery valve closes, there is still some pressure in the pump body and drive pipe. The valves in the pump are closed, so the only direction in which the water can move is back the way it came. The water coming down the drive pipe has stopped, so the pressure-energy can be released by moving back up the drive pipe. The water in the pump body bounces back a little way up the drive pipe. This bouncing back makes the pressure in the pump body fall low enough for the impulse valve to reopen. On some pumps the impulse valve includes a spring to help it reopen, on some they reopen because of their own weight. The low pressure in the pump body means that a small amount of air is sucked through the snifter valve. The air waits under the delivery valve until the next cycle when it will get pushed into the pump's air vessel. This makes sure that the air vessel always stays full of air.

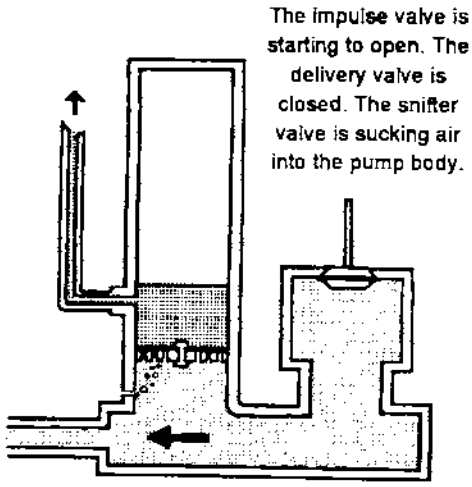

RECOIL

Very quickly, the pressure left in the pump body is released by bouncing back up the drive pipe. When the bouncing back is complete, water begins to flow down the drive pipe again. This is where the cycle started, and the water **Accelerates** down the drive pipe through the open impulse valve.

During each pumping cycle only a small amount of water is pumped. Most of the movement-energy harvested from a large amount of water is transferred into a small amount of water. The high pressure in the pump body pushes water through the delivery valve and into the air vessel. It provides the power to push the small amount of water much farther uphill than the big amount of water fell downhill.

Throughout each pumping cycle the pressure in the pump's air vessel is steadily forcing water up the delivery pipe. The air vessel smoothes the pulses of water coming through the delivery valve into a steady flow up the pipe to the delivery tank.

While a ram pump is working, water flows out of the impulse valve and splashes onto the floor of the pump house. This happens during the 'acceleration' phase of each cycle. It is the splashing water and the noise of the "water hammer" that people notice when they see a working ram pump. The water splashing out is often called 'waste' water. Although 'waste' water is not delivered by the ram pump, it is the movement-energy harvested from this water that pumps the water that is delivered. A better name for 'waste' water would be 'used' water. The noise varies from pump to pump. Pumps with impulse valves that have no moving metal parts are the quietest, but they can still disturb people who live nearby. This is because of the water hammer "drumming" in the drive pipe.

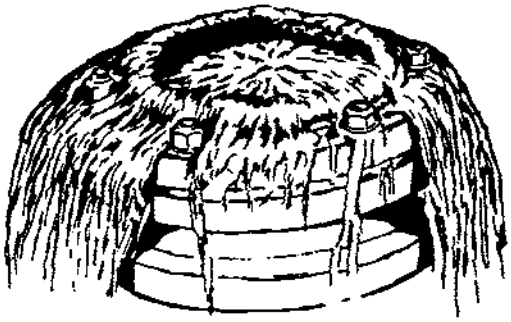

THE IMPULSE VALVE OF A BLAKES RAM PUMP
This has no moving metal parts. It pulses gently and is fairly quiet

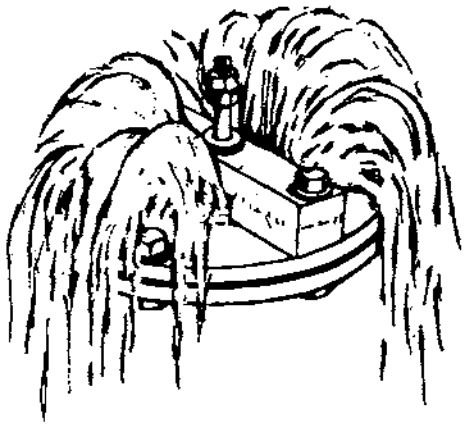

THE IMPULSE VALVE OF A DTU M8 RAM PUMP
This splashes and is noisy.

The parts of a ram pump system

A ram pump does not work alone. It has to be part of a system to deliver water. The drawing here shows the main parts of a typical ram pump system. To install one you will need to know how to build dams and water tanks and have basic plumbing skills.

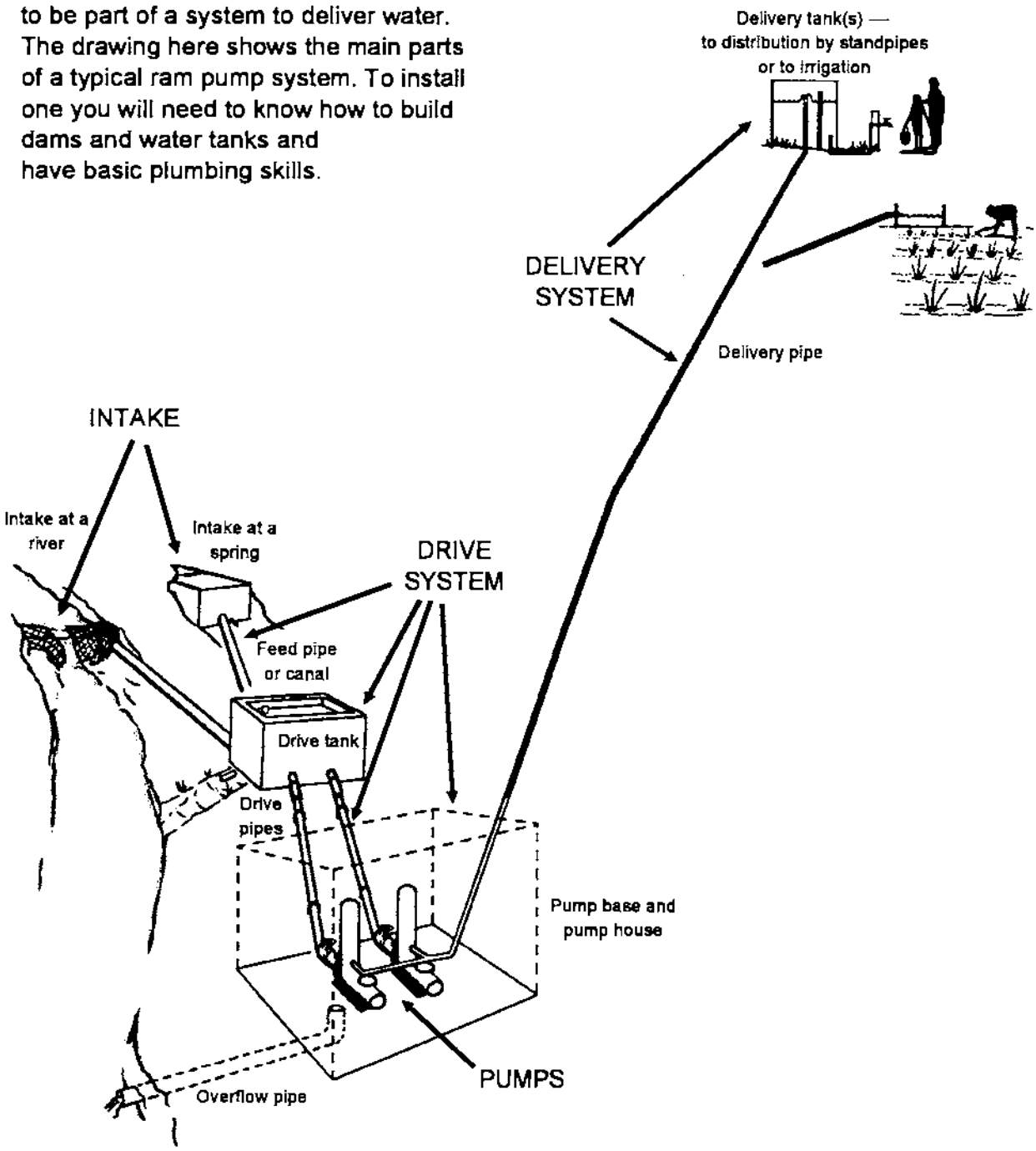

THE MAIN PARTS OF A RAM PUMP SYSTEM

As you can see, ram pump systems can have more parts than some other water pumping systems. This means that they may be more expensive to install. The main advantages of using ram pumps are that they can often be maintained by the users and cost little to maintain and nothing to run.

When to use ram pumps

Ram pumps can only be used where water flows downhill and where there is much more water flowing than you want to pump. They are usually used to lift water from springs or streams in hilly areas. Sometimes they are used for irrigation, but more often they are used for community water supplies.

There is a limit to how high a ram pump can lift. This varies from pump design to pump design. Some pump makers make unrealistic claims for their pumps. Generally, ram pumps with up to 4" drive pipes can deliver a useful amount of water to heights of up to 100 meters. Some pumps cannot pump this high, so check a pump's instructions before choosing which pump to use.

In most cases it is important that the pumps work all year round. They cannot do this if the springs or streams from which they get their water run dry or get very low in the dry season.

A ram pump system is very cheap to run but it does need care and maintenance. The people using the system must be committed to its maintenance and understand how to do it.

The water supplied by any water system to a community must be distributed in a way that meets the people's needs and is seen to be fair. The people must be involved in planning the system, especially the way the water is distributed. They must also be prepared and able to pay for occasional replacement parts.

So, ram pump systems can be useful when there are the following things.

- A flow of water that is dropping quite quickly. It does not have to be flowing steeply in the stream or river. The system designer can usually make the water do that.
- A source of water that has a much bigger flow than you want to pump.
- A source of water that does not get very low or dry up at some times of year. This applies especially to irrigation systems because the time they are needed is usually the time when the water is lowest.
- A place for the pumps that is not more than 100 meters below the place where the water must be delivered.
- A willingness for system care and maintenance to be provided by the community that uses the water.
- A community involved in planning and paying for the system.

If a site meets these conditions, it is probably worth carrying out a site design survey. A design survey will give a good idea of the amount of water that can be delivered and how much a system will cost.

When you are installing a community supply, remember that many sources of water are not safe to drink. Springs are usually safe but water from streams and rivers is usually not safe to drink. The water must be filtered or boiled before you use it. Slow sand-filters that clean the water can add quite a lot to the cost of a system.

Choosing which ram pump to use

Ram pumps have been made for general sale for well over a hundred years. Many of the early designs were much stronger than they needed to be. Some were also more complicated than they needed to be. A few of the pumps made early in this century are still being used around the world. Many pumps made fifty years ago are still working even though the makers may have stopped selling them a long time ago.

Some of the traditional ram pump makers are still in business at the time this is written. The most famous is perhaps John Blake in the UK. The basic design of their pumps has been so successful that it has been copied by a number of makers from China to Africa.

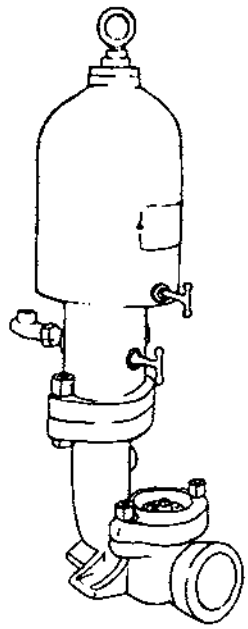

A SMALL 'JOHN BLAKE' RAM PUMP, UK

Buying ram pumps from traditional makers can be very expensive if they have to be imported. Although some run for years without needing spare parts, others need them frequently. It can be expensive and difficult to get the spare parts and advice you will need. The only way to avoid the spare parts problem is to buy pumps that are made locally or arrange to have your own pumps made. You are probably reading the Technical Release to help solve the problem of lack of advice.

Recently, a number of small engineering firms have started to make ram pumps to meet local demand. Be warned that some of these businesses do not understand ram pumps very well and their pumps can be poorly designed and made. Try to see an example of the pump installed and working before buying one.

If you want to make your own ram pumps, several designs are freely available from European organisations. The DTU believes that its own range of designs are the easiest to make in small workshops and give the best performance.

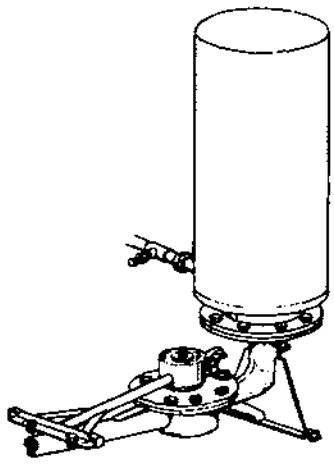

A 'DCS' RAM PUMP
Nepal

Ram pumps vary a great deal in size, but a single ram pump does not normally pump a lot of water. If a lot of water is needed, two or three pumps are usually installed and they are all left working constantly. For example, if a single pump delivered 5 liters of water a minute to a tank, it would deliver 7,200 liters of water each day. If three pumps were side by side in the system, they could deliver together 21,600 liters of water each day.

Some pump makers produce a range of pump sizes so that you can choose from it a single pump that will deliver enough water for your needs. If you know that the pumps are very reliable and easy to tune, it can be sensible to just use a single pump. If you are buying pumps that are locally made and do not have a well known reputation, it is better to buy two smaller pumps than one big one. Then, when a pump needs to be maintained or repaired, the other pump will keep working and some water will be delivered.

Buying a pump

Which pumps you buy will depend on which pumps you can get.
You will need to find out these things from the maker's instructions:

- The size of the pump's drive pipe. This is the pipe's internal diameter (ID).

  ☛ *If you choose a pump with a drive pipe bigger than 4" you should get the manufacturers to help design the system.*

- The pump's maximum and minimum drive flow. This is the most drive water it can use, and the least drive water it can use.
- The pump's maximum "feed" or "drive" head. This is the highest feed head that it can use.
- The pump's maximum delivery head. This is the highest that it can pump to.

The instructions also tell you the pump efficiency. It is always useful to know a pump's efficiency but unfortunately pump maker's claims about efficiency are not often reliable.

Imported pumps

If you can afford to buy imported and well known pumps, that may be the best choice. They often cost five to ten times as much as a locally made copy, and between ten and twenty times as much as a pump you make yourself. There are so many ram pumps available for import that it is not possible to assess them here, but most well known names give good and reliable service. Remember that all pumps will need spare parts eventually, and some imported spares are very expensive. If you are installing a system for someone else, remember to make sure that *they* will be able to get the spares when they need them. There are many ram pumps around the world that no longer work because the people who installed them have left the area. After some time the pumps needed parts and the users had no idea how to get them.

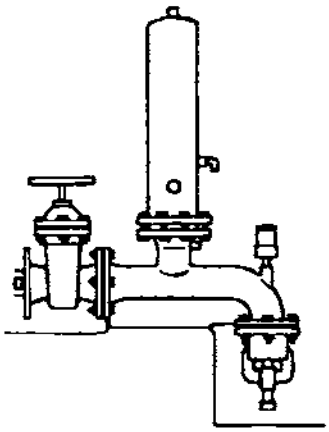

A PFISTER AND LLANGHAUS RAM PUMP, Switzerland

Locally made pumps

There are advantages if you buy from a maker that can be contacted easily when spare parts are needed. Try to make sure that the maker has been in business for some time so that they are still likely to be in business when the spares are needed. Locally made copies of pumps may need a spare part much more frequently, but if the spares are cheap and easy to get, that is not usually a problem. Check any pump that is locally designed very carefully.

The drawing on the right is of a pump made by Jandu plumbers in Tanzania. It is based on a heavy cast-iron John Blake design. Notice that it has two impulse valves so that it can use more drive water and harvest more energy to pump the delivered water.

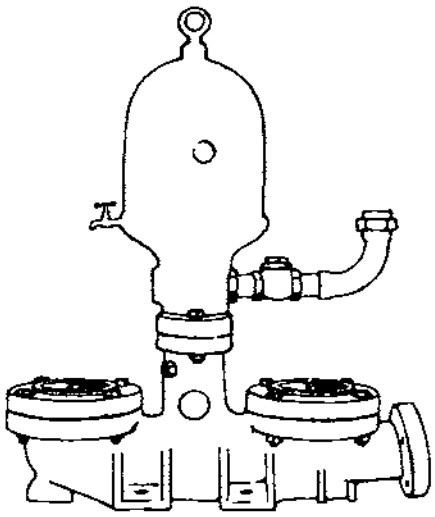

A JANDU PLUMBERS TWIN-IMPULSE RAM PUMP Tanzania

What to look for in a pump

With any make of pump, the first thing to check is that the makers give the pump's operating ranges. Do not buy pumps that do not include some instructions that tell you the operating ranges. Even if the pump is good, you will not know how to design the system properly and it may let you down.

- Look at the whole pump. If it looks very complicated with lots of small parts, it is probably more likely to break down.
- Check that the pump is well made. Inspect any welds carefully to see if they are fairly regular and not lumpy.
- Look at the hole or holes around the impulse valve where the water comes out. The combined area of those holes should be at least as big as the hole inside the drive pipe. If it is not, the drive pipe is bigger than it need be and the pump is badly designed. Some pumps with a body that is screwed together from pipe fittings have this problem. Surprisingly, some of the best known pumps also have it. If it is the only thing wrong with a pump it can be ignored.
- Look for any parts that look as if they may bend or break easily and avoid these designs if you can. Pay special attention to the impulse valve arrangement, which has to open and close millions of times a year.
- Check that the impulse valve moves up and down freely and appears to seal. If it has a spring or lever arrangement, make sure it is protected against rust.
- Check that the air vessel is made from thick steel. Usually 3mm is thick enough. If possible, check that the air vessel has been painted or galvanised inside and out.
- Avoid pumps that have already started to rust. They may be old stock, or carelessly made. If the nuts and bolts are rusty it may make the pump hard to maintain. When a pump is being used, the water will wear paint away from some parts very quickly. Those parts will not rust much because the moving water will keep them clean.
- Check that the pump includes a way to attach it firmly to a base or cradle. Pumps made from cast iron often have feet with holes for bolts. Pumps made using pipe fittings may use "U" bolts.
- Look at any rubber parts carefully. If the rubber is starting to perish the pump may be old stock and the rubbers will need to be replaced soon.
- Check that the pump has a snifter valve. It may be a small hole or a valve and is usually in the body of the pump just below the delivery valve. Very rarely the air vessel is made with a diaphragm inside like the Platypus pump shown below. These can be pumped up like a car tyre and do not need a snifter valve. All other pumps must have one. If they do not they can be dangerous.
- Make sure that you can buy spare parts easily.

The Platypus pump has an inflatable air vessel and is designed to run completely under water.

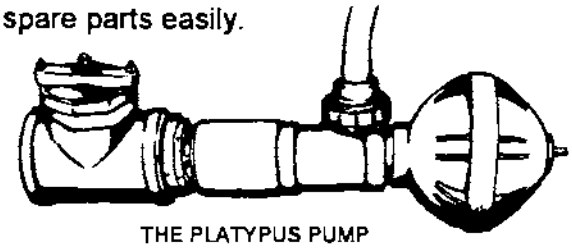

THE PLATYPUS PUMP
Australia

Using an old ram pump

If you have found an old pump that you want to use, contact the makers before deciding to do so. If the makers do not make the pumps any more, you may not be able to get spare parts. Also, you may not be able to find out the operating ranges of the pump.

Engineers may be confident that they can make any part that needs to be replaced. Be warned that the rubber parts on European ram pumps are nearly always made from a very special compound and the pump will not work reliably with anything less.

Making a ram pump in a small workshop

There are two big advantages in making the pumps or having them made in a local workshop. The first is that spare parts are easily made and so always available. The second is that the pumps cost so little in the first place. In the case of the DTU designs, the pumps are made from materials that are cheap and easy to get, so the spare parts are also cheap.

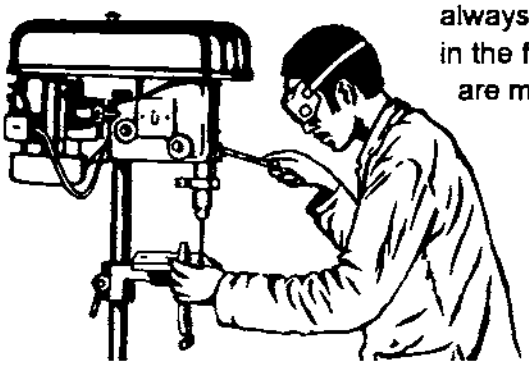

There are also disadvantages in making the pumps or having them made in a local workshop. The workshop must have a skilled metalworker to make the pumps or they will almost certainly be unreliable. Also, using cheap and available materials means that some small parts wear out and need to be replaced quite often.

The DTU S2 pump shown in this drawing is built from steel pipe and plate that is widely available around the world. This pump has a high efficiency. It can be made in a small workshop that has welding facilities, a gas cutting torch and a pillar drill.

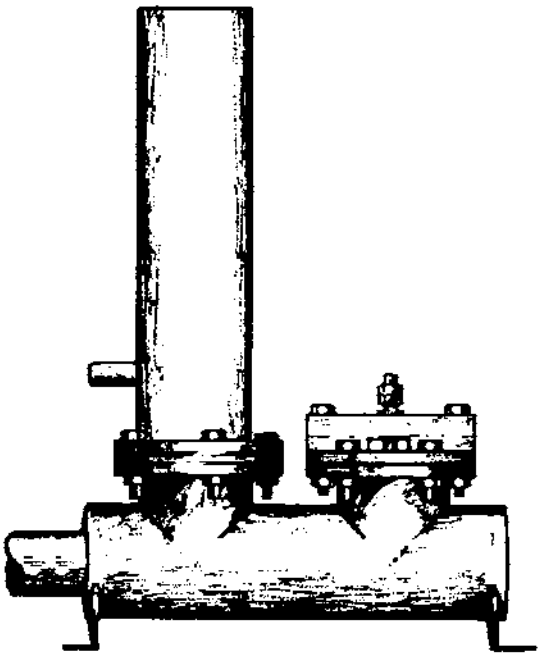

THE DTU S2 RAM PUMP

The DTU range of ram pumps

Since 1988 the Development Technology Unit has been developing designs for ram pumps. These have been intended to enable small industries in developing countries to manufacture reliable pumps using commonly available materials. The pumps are much cheaper than imported ones but their lives are shorter. Indeed, it is assumed that they will need and get some maintenance over their working lives. Parts most likely to wear out have been made easy to copy and replace.

Three pumps are described briefly here. All are latest versions of pumps used in Africa and Asia for some years. Two are of steel (for respectively 1" and 2" galvanised iron drive pipes) and one is of plastic the P90 (for use with 90mm plastic pressure pipe) The P90 could be made entirely with hand tools. The S1 and S2 require simple power tools (welder, pillar drill) and the skills to go with them. Whilst a lathe or gas cutter are also required to make the steel pumps, the operations involving these machines are so few and simple that they could be sub-contracted to an urban machine shop at little expense.

TABLE OF PUMP CHARACTERISTICS

	S1	S2	P90
Material (mainly piping)	Steel	Steel	PVC or ABS
Drive flow range (in liters per minute)	20 — 60	40 — 120	100 — 360
Drive pipe size (high drive flows)	1"	2"	90mm
Drive pipe size (low drive flows)	¾"	1½	90mm
Maximum delivery head in meters	80	100	20
Maximum drive head in meters	15	15	3
Typical delivery flow in liters per minute	½ — 10	1 — 20	3 — 40
Typical life (assuming minor repairs)	5 years	5 years	2 years

Note that if two pumps are used in parallel, the drive flow and delivery flow of the system will be doubled

S1 pump. This small pump is normally used to supply drinking water to a house or small group of houses. The drive flow is usually taken from a spring.

S2 pump (formerly M8). This medium size pump can be used for water supply to a village or institution, or to irrigate gardens or to water cattle. Its drive flow is usually taken from a large spring or a small stream.

P90 pump. This large pump is mainly used for irrigation, drawing its drive water from a (diverted) stream or drop-structure in a canal.

For full details of each pump see other DTU Technical Releases:
TR 11: The DTU S1 ram pump
TR 12: The DTU P90 ram pump
TR 14: The DTU S2 ram pump.

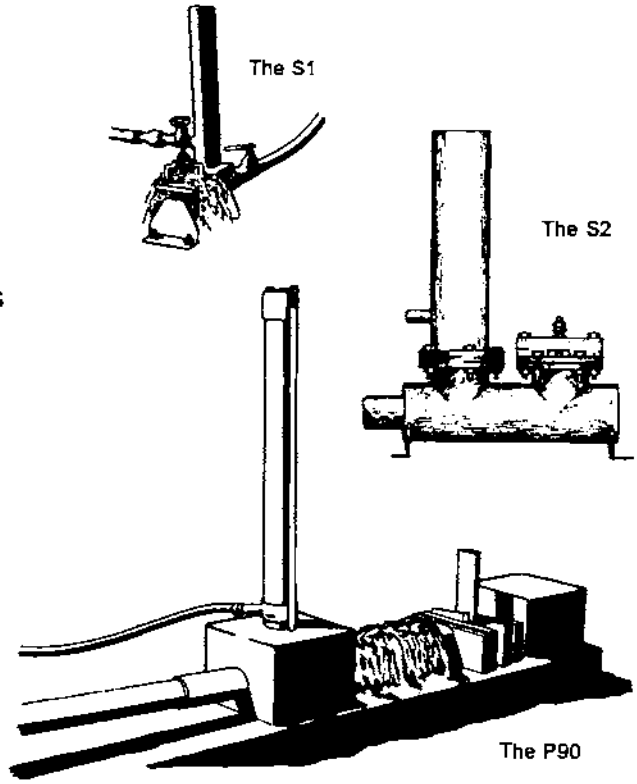

DTU

Ram Pump Programme

HOW RAM PUMPS WORK

TECHNICAL

15

RELEASE

How ram pumps work

This Technical Release explains what is happening inside working ram pumps. It shows how changes in the design of a ram pump system can change its performance. It will be useful to anyone who is designing ram pump systems and to anyone who is tuning ram pumps to give the best performance.

This section begins with a few examples of simple systems and introduces the words that are used later. It also shows the way that the water flowing through pipes can be shown on a graph. Even if you are already understand terms such as *terminal velocity* in pipes, you should read all of this part so that you know the way that we are using the words.

Falling water

Head

In the drawing here there is a reservoir of water behind a dam. A small pipe passes through the bottom of the dam and runs down the hill. At the end of the pipe there is a tap which is closed. The height from the water level in the reservoir to the tap is called the *head.*

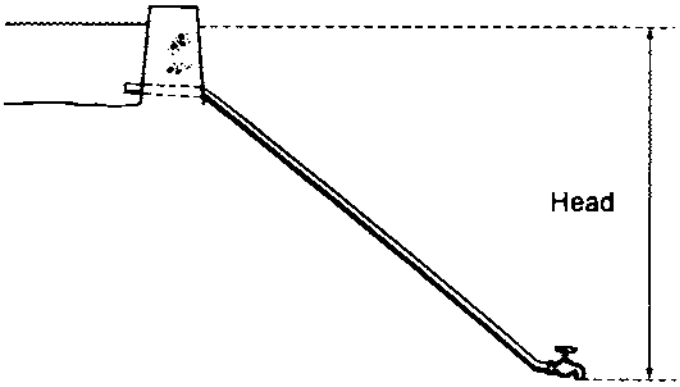

When the tap is opened, water starts to flow down the pipe and out through it. It flows slowly at first, but speeds up very quickly. After a short time the water reaches its maximum speed and the flow becomes steady. If the tap is left open, water will of course continue to flow steadily down the pipe from the reservoir and out through the open tap.

A graph can be drawn to show how the water coming out through the tap gets faster at first, and then flows at its maximum rate. The graph alongside shows what happens. Imagine that a stop-watch was started as soon as the tap was opened and the speed of the water in the pipe was measured every hundredth of a second. The graph has the speed of the water flowing through the pipe marked on the side axis. The time that has passed is marked along the bottom axis.

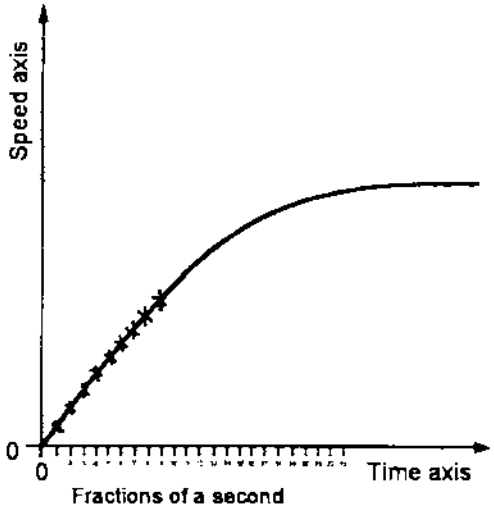

Before the tap was opened and the stop watch was started, there was no water coming through the tap. That is why the graph starts when the "Time" is zero and the "Speed" of the water in the pipe is also zero.

At first the line on the graph goes up very quickly. As the water flows it rubs against the sides of the pipe. This rubbing is usually called *friction*. As the water gets faster, the friction becomes bigger and stops the speed of the water from increasing as quickly. This is shown on the graph by the curve of the line getting flatter and flatter. After a while, the water is flowing as fast as it can and the line on the graph is flat. This shows that the water is continuing to flow out of the tap at the same speed.

A larger head

In this drawing there is a water supply with a reservoir and three pipes and taps. The pipes are labeled as the original, second and third systems. In the second system it is further downhill to the tap (the *head* is bigger than in the original system). When the tap on No.2 is opened, the water will flow down the pipe and out through the tap more quickly. The line showing speed against time would rise more steeply on a graph. This is because the reservoir is higher above the tap than it was on System 1, so there is more pressure pushing the water down the pipe and out through it.

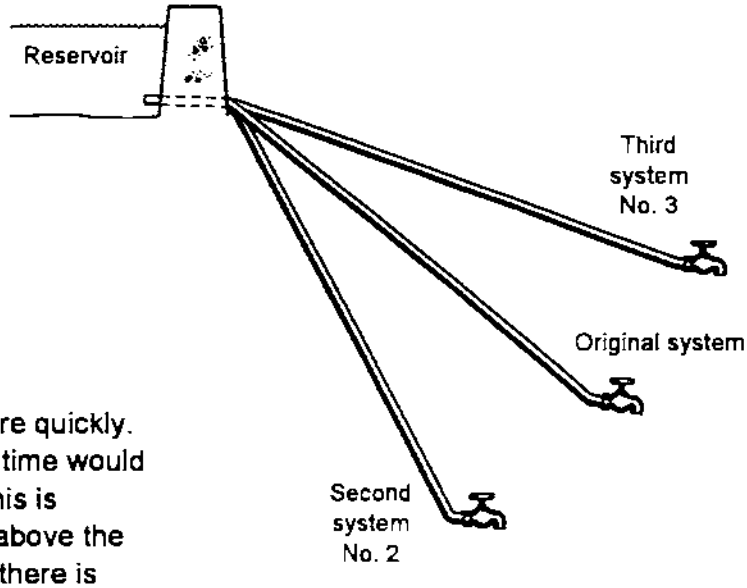

As the water gets faster the friction between it and the wall of the pipe gets greater. The curve of the line on the graph begins to flatten out. When the water is flowing as fast as it can, the line on the graph is flat. Because the *head* in the second system is greater than the *head* in the first, the water flows faster in the second. This is shown on the graph at the top of the next page.

A smaller head

For the third system, the drop from the reservoir to the tap (the *head*) is much less than in the original system. When a graph of System number 3 is drawn, the line on the graph showing speed against time does not rise as sharply and flattens out at a lower speed. This is because there is less pressure pushing the water down the pipe and out through the tap. The speed of the water when it reaches a steady flow is the slowest of the three examples.

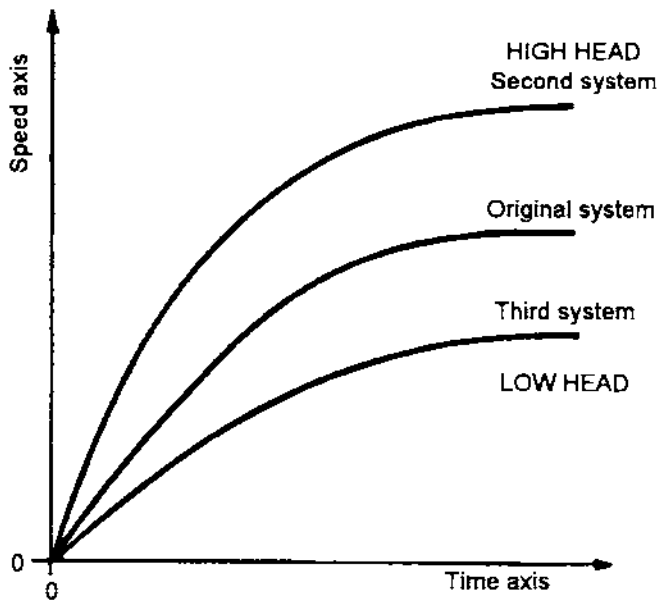

Acceleration

The rate of increase in speed is called the *acceleration*. When the tap is first opened, the speed of the water increases very quickly, so the *acceleration* is very high. As the water flows more quickly there is more friction and the line on the graph flattens out. This shows that the water is still accelerating but that the rate of acceleration is becoming lower. When the water is flowing as fast as it can, there is no more acceleration and the line on the graph is flat. This maximum speed is called the *terminal velocity*. In this case, the word *"terminal"* is used to mean *"as much as possible"*. *"Velocity"* is really just another name for *"speed"*. *"Terminal velocity"* just means *"top speed"*.

In the drawing below another pipe is installed from the reservoir. The new pipe is called System number 4. The pipe is the same diameter as the first one, but it is much longer. The height from the reservoir to the tap (the *head*) is the same. When the tap of this new system is opened, the water accelerates down the pipe and out through the tap. Because the water has to flow through a longer pipe there is more friction to slow it down, so its *terminal velocity* is not as fast.

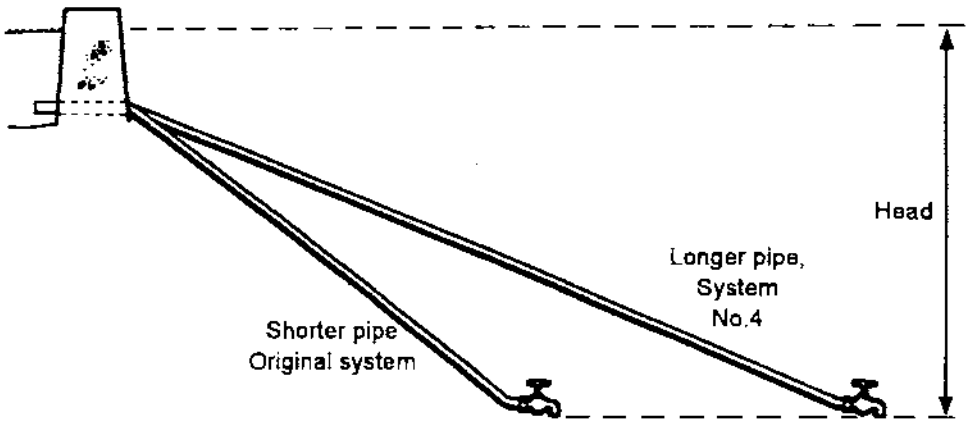

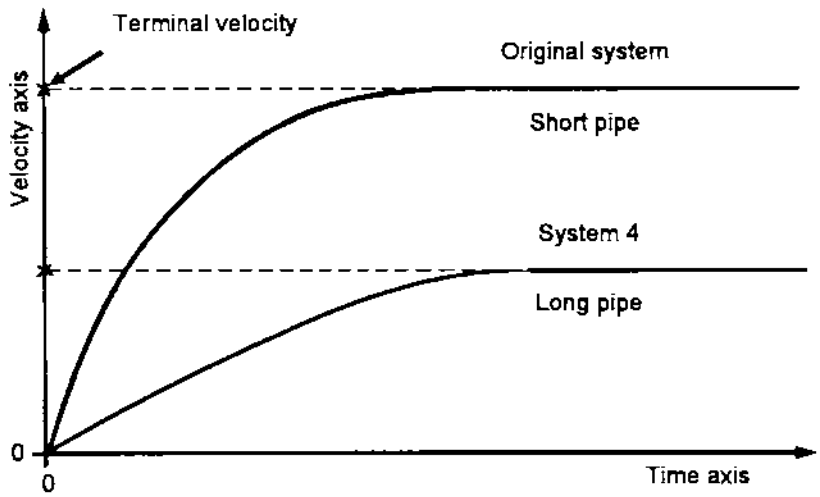

On the graph of this example above, the original system is also shown. The line on the graph flattens out at a lower speed and in a longer time.

If any one of the pipes in these systems was replaced by a pipe with a bigger internal diameter, the graph would change. This is true even if the bigger pipe were the same length and ran along the same route. When the acceleration of the water was measured again, you would find that the water reached a faster *terminal velocity*. This is because the larger pipe would have less friction. In a bigger pipe, there is more room for the water to pass through without touching the sides.

How ram pumps use the water

In the drawings of Systems 1 to 4 there was a reservoir at the top of a pipe with a tap at the bottom. From now on the reservoir is replaced by a tank and the tap on the end of the pipe is replaced by a ram pump.

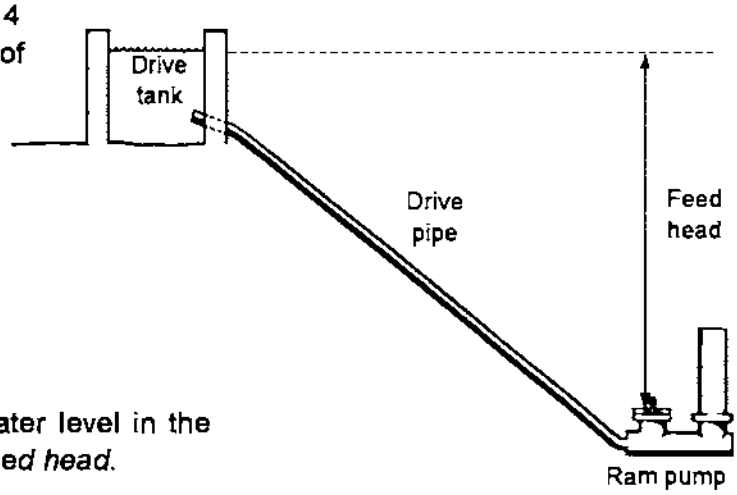

Feed head

The drop in height from the water level in the tank to the pump is called the *feed head*.

Closure velocity

When the ram pump is not working and the impulse valve is closed, there is no water coming through it. When the impulse valve is pushed down, water begins to come out through the open valve, getting faster as it accelerates down the pipe. The force of the water flowing around the impulse valve tries to lift it closed but the weight of the valve keeps it open. The force of the water trying to close the valve gets bigger and bigger.

When the force trying to close the valve becomes bigger than the weight, the valve starts to move upwards. All impulse valves will close when the drive water reaches the right velocity. What that velocity is will depend on how the impulse valve on the particular pump is tuned. The water accelerates down the pipe and out through the impulse valve until it reaches the *closure velocity* and the valve closes.

A graph can be used to show the increasing velocity in the system just as it was for the examples with the tap. If the impulse valve was held open and water allowed to flow out for a long time the graph would show it reaching a *terminal velocity* just as before. The shape of the line on this graph would depend on the feed head, the pipe diameter, the pipe length and the amount of friction through the pump. If the pump was operating normally, the impulse valve would close when the velocity reached the *closure velocity*. This point can be marked on the graph.

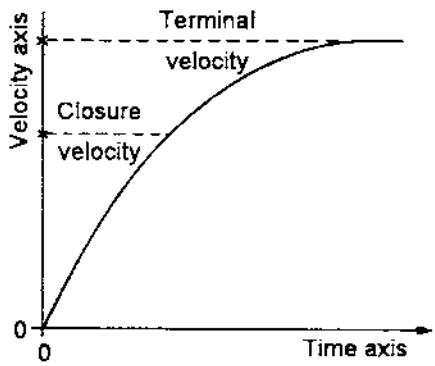

At any ram pump site the settings of the impulse valve (the stroke length and the valve weight) will decide how big the *closure velocity* is. A valve with a small weight and a short stroke has a low closure velocity. It will close when the water reaches only a low velocity. A valve with a large weight and a long stroke will need a much higher velocity to make the valve close. The *closure velocity* of the pump can be changed by making adjustments to the impulse valve — in other words, by *tuning* the pump.

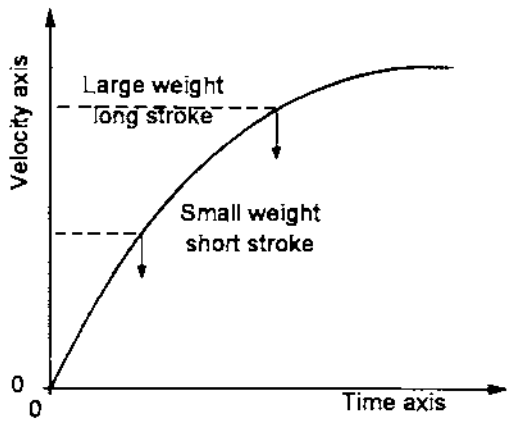

The time it takes for the water to reach the *closure velocity* can be worked out using the same graph. This is done by drawing a straight line across from the Velocity (Speed) axis at the *closure velocity* until it reaches the line on the graph. Another line is drawn from this point straight down to the bottom of the graph where it hits the Time axis. The scale on the Time axis can then be read to find out how long it takes to reach *closure velocity*.

You can see that if the pump has a high *closure velocity*, it will take a long time for the valve to close. If the stroke of the impulse valve was reduced, the velocity needed to close the valve would also be reduced and the time it would take to reach the new *closure velocity* would be less. So, reducing the length of the impulse valve stroke on a pump will make it work faster.

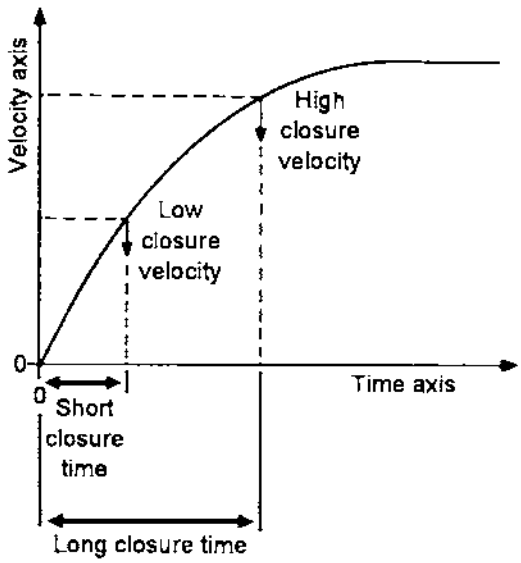

Closure velocity and waste flow

When a pump has a high *closure velocity* a lot of water will flow through the impulse valve before it shuts. This water is often called the *waste flow* for one cycle and can be represented by the area under the graph that has been shaded.

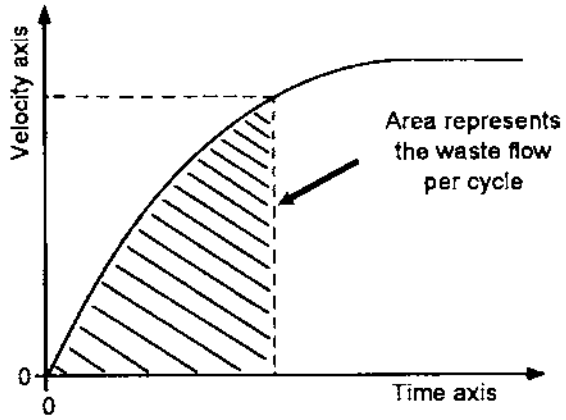

By shortening the length of the impulse valve stroke, the pump can be made to work faster and the *closure velocity* will be lower. The area representing the *waste flow* on the graph will be smaller, showing that the amount of water flowing through the pump (the *waste flow*) has gone down.

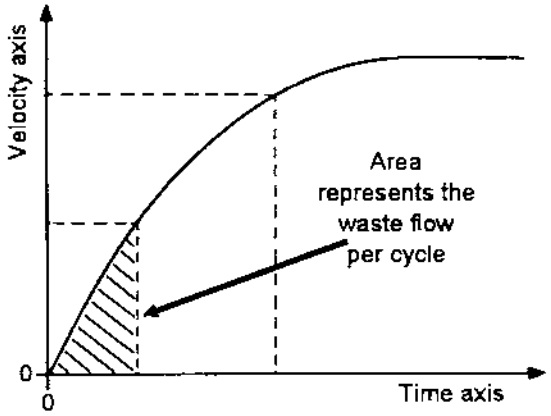

Closure velocity and feed head

You saw earlier with the reservoir, pipe and tap that when the head from the reservoir to the tap was increased, the acceleration was faster and the line on the graph rose more steeply. If the *feed head* of the ram pump system is increased, the line on the graph also rises more steeply.

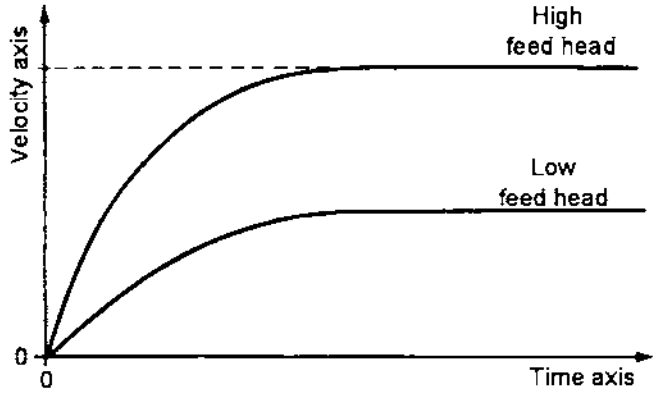

If the same ram pump system was given a different feed head, the *closure velocity* for the system would stay the same as long as the same pump was used and its tuning was not changed. The area under the line on the graph for the system with the higher feed head would be much less, showing that the waste flow was smaller. It would also take less time to reach the *closure velocity*, so the pump would work faster.

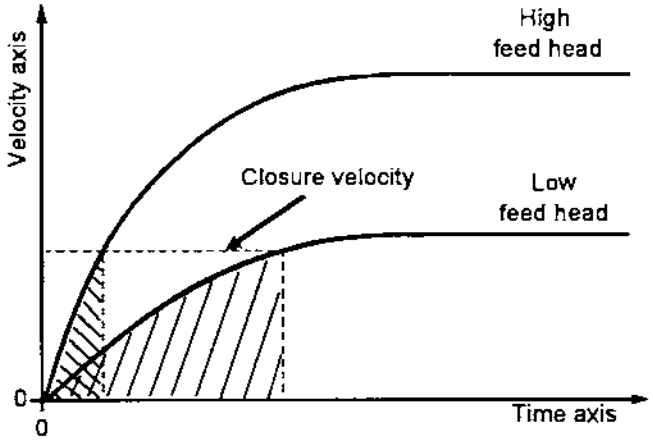

Water delivered from a ram pump

When the impulse valve on a ram pump closes, the water flowing down the drive pipe and through the pump has nowhere to go. The velocity of the water drops very quickly. As the velocity of the water drops, the energy of the moving water is turned into pressure energy. The more the velocity of the water drops the more the water pressure inside the pump rises.

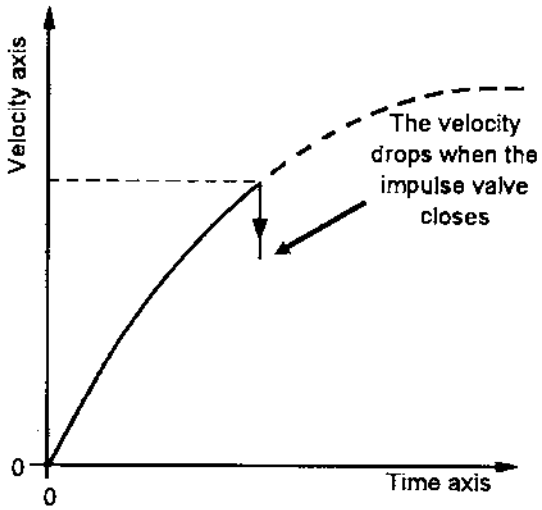

Delivery head

The velocity of the water continues to fall until the pressure in the ram pump is higher than the pressure in the air vessel. The pressure in the air vessel will depend on the height from the pump to the top of the delivery pipe. The height from the pump to the top of the delivery pipe is called the *delivery head*.

When the *delivery head* is high, there has to be a big drop in the velocity before the pressure in the pump is bigger than the pressure in the air vessel.

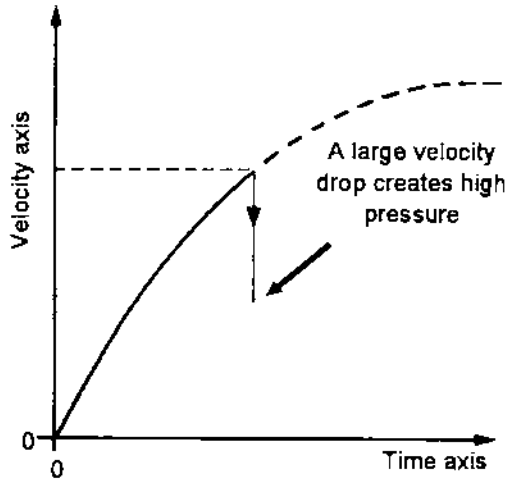

When the *delivery head* is small, the velocity only has to drop a small amount before the pressure in the pump is higher than the pressure in the air vessel.

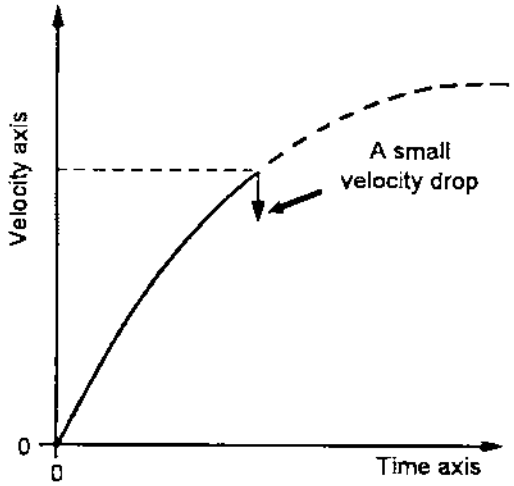

If the delivery head is very high, the closure velocity may be too small. When it is too small, there is not enough velocity to turn into pressure energy when the impulse valve closes. The pressure in the pump rises, but not enough to reach the delivery pressure. The water loses all of its velocity but the delivery valve does not open. The impulse valve may then open again and water flow through, allowing the velocity of the water to increase until the impulse valve closes again. When this happens a pump can work with the impulse valve opening and closing but without the delivery valve opening, so no water is pumped.

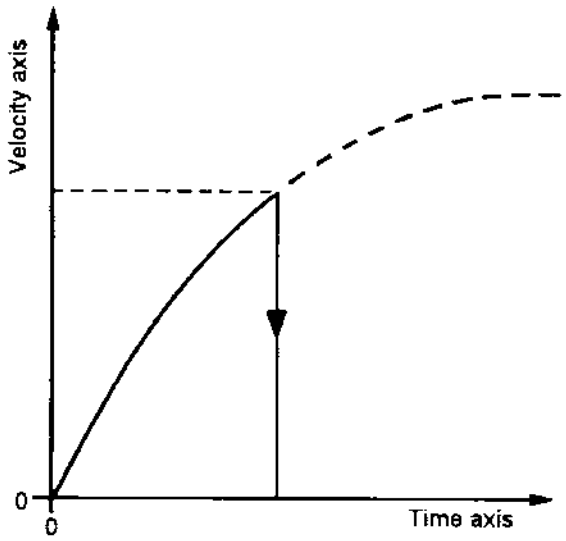

Delivery pressure

When the pressure in the pump is greater than the pressure in the air vessel, the delivery valve opens. Water flows through the delivery valve and into the air vessel. The water has lost velocity and gained pressure. It flows at the lower velocity into the air vessel. Water will continue to flow through the delivery valve at this velocity for a certain period of time. The amount of time will depend on the time it takes for a shock wave to travel up the water in the drive pipe to the drive tank and back down to the pump again.

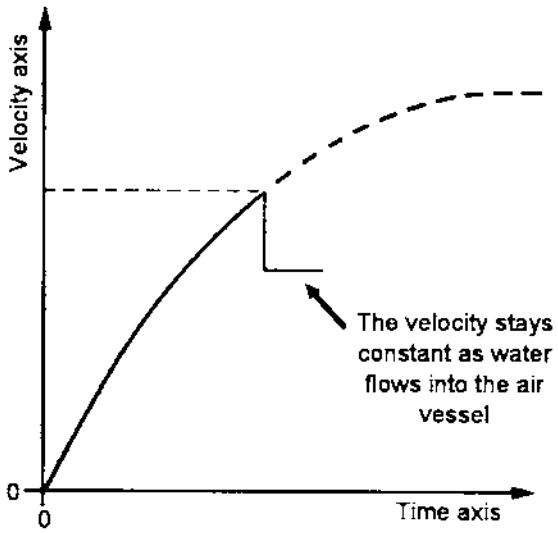

This is more fully explained in the box on the next page. It is not necessary to understand all the details so you can miss out the box if it seems too complicated. All you need to know is that the water flows through the delivery valve at the reduced velocity for a certain period of time. The length of time will depend on the length of the drive pipe. If the drive pipe is short the period of time will be short. If it is long then the period of time that the water flows through the delivery valve will be longer. Remember that the pump is likely to be cycling every second or so, so the periods of time are all only fractions of a second.

More advanced explanation

When the impulse valve closes, the water moving inside the pump suddenly slows down. When the first bit of water starts to slow down, its pressure rises. The water behind it also slows down and its pressure also starts to rise. Pressure rises along the drive pipe as all the water slows down and its pressure rises.

Try to imagine a line between the water in the pipe that has slowed down and the water that is still moving at full speed. This imaginary line travels very quickly from the impulse valve up the drive pipe to the drive tank. On one side of the line the water has slowed down and the pressure has risen. On the other side the water is still moving at closure velocity. This imaginary line is at the front of a "shock wave". The drop in velocity of the water across this shock wave is the same as the drop in velocity needed to open the delivery valve.

The shock wave travels at very high speed (usually over 1000 meters per second) up the drive pipe until it reaches the drive tank. The drive tank acts a bit like a mirror that turns things around and reflects them back. It is a low pressure shock wave which travels back down the drive pipe towards the pump.

The time taken for the shock wave to travel from the pump to the drive tank and back again will depend on the length of the drive pipe and the speed of the shock wave. The pressure in the pump, and the velocity of the water flowing through the delivery valve will remain constant until the shock wave has gone up the drive pipe, been reflected and come back down to the pump. The graph below shows that the velocity of water in the pump stays constant for a set period of time. The time will depend on how long it takes the shock wave to go up and down the drive pipe.

When the shock wave in the drive pipe has returned to the pump, the velocity of the water drops again. This keeps the pressure in the pump high enough to push water through the delivery valve into the air vessel. The second velocity drop is twice as much as it was the first time.

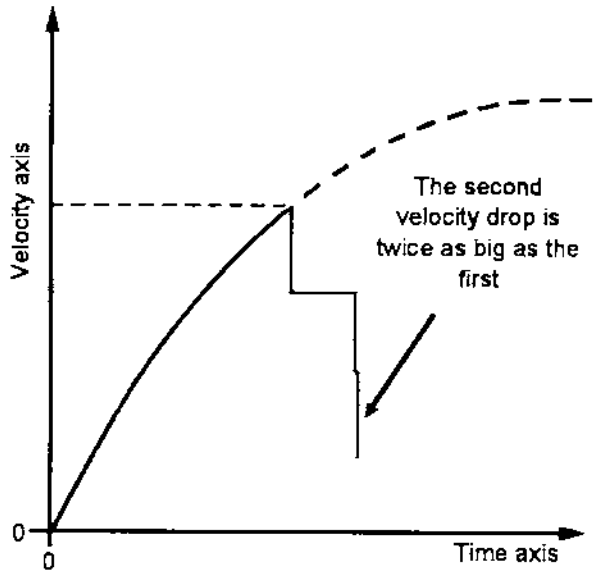

More advanced explanation

When the reflected shock wave reaches the pump the velocity there drops due to the lower velocity of the water *behind* the shock wave. It immediately drops again to recreate the pressure needed to keep the delivery valve open. Both of these drops in velocity are the same size as the first velocity drop when the impulse valve closed.

Water continues to flow through the delivery valve at the reduced velocity. It flows for the same amount of time as before, while the second shock wave travels up to the drive tank and back again.

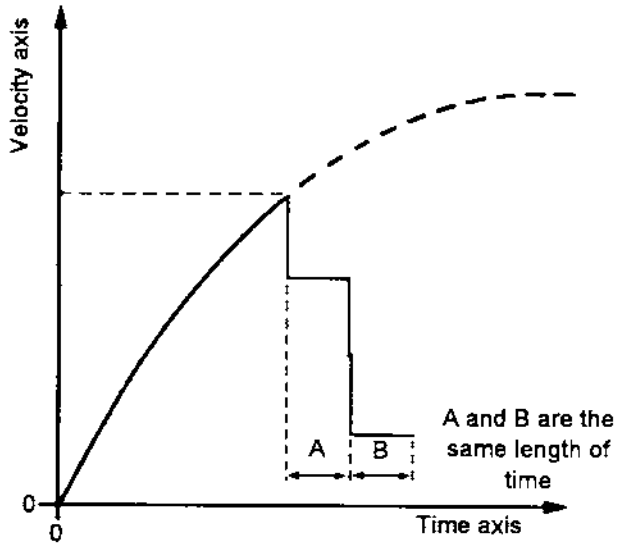

More advanced explanation

The second part of the second drop in velocity produces another increase in pressure that keeps the pressure in the pump greater than the pressure in the air vessel. Water flows through the delivery valve at the lower velocity. The increase in pressure starts another shock wave that travels up the drive pipe. The second shock wave is also reflected by the drive tank and another low pressure shock wave travels back down to the pump. Water continues to flow from the pump into the air vessel until the reflected shock wave reaches the pump.

Each time a shock wave comes back to the pump, the water's velocity drops again and a new shock wave travels up the drive pipe. Water continues to flow into the air vessel at the reduced velocity. The velocity in the pump continues to step down in this way until there is not enough velocity left to make another full step.

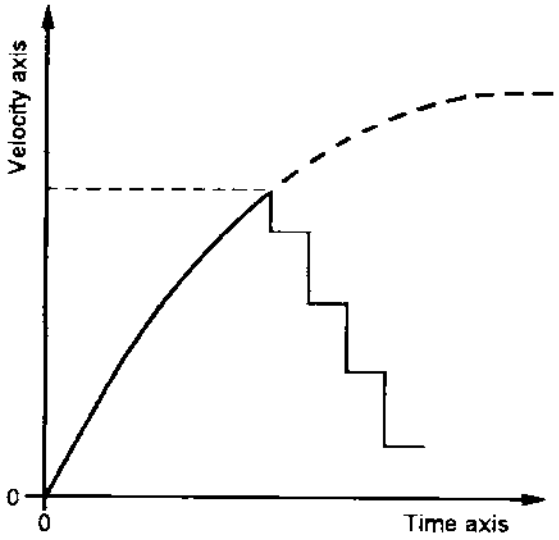

Recoil

When there is not enough velocity left to make one complete step the pressure can no longer stay high enough to keep the delivery valve open, so it shuts. The water in the system is still moving with a low velocity down the drive pipe. The impulse and delivery valves are both closed so the water has nowhere to go. The water bounces back up the drive pipe towards the drive tank. The water is like a spring that is pushed against a wall so that it compresses and then is suddenly let go. It opens up and flies away from the wall.

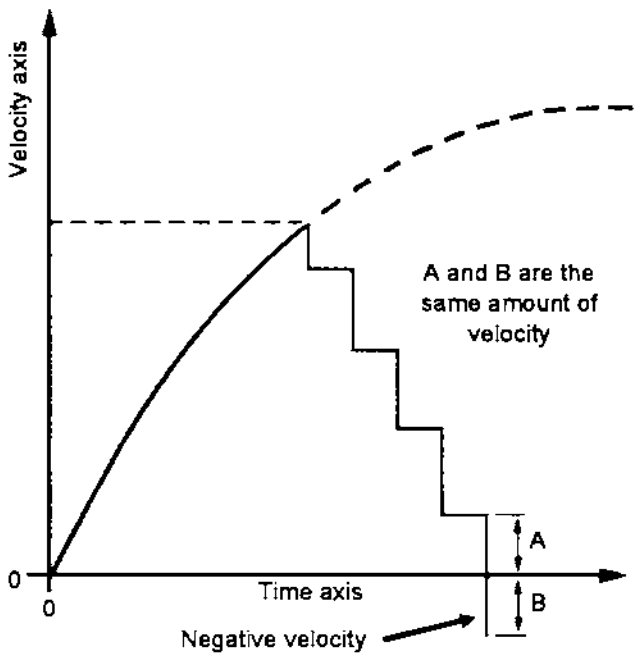

As the water moves away from the pump it has a negative velocity, so the line on the graph goes under the base (under 0 on the Velocity axis). The negative velocity will be the same size as the positive velocity that was left when the delivery valve closed. When the water has a negative velocity it moves away from the pump towards the drive tank.

The negative velocity is shown where the line on the graph goes below 0 on the Velocity scale. The water flowing back up the drive pipe slows down and stops, then the line on the graph crosses back over the Time axis. After that, the impulse valve has reopened and the water begins to accelerate down the drive pipe. The line on the graph rises in the same way as before. The section of the graph below the line is called the "recoil" stage of the pump's cycle.

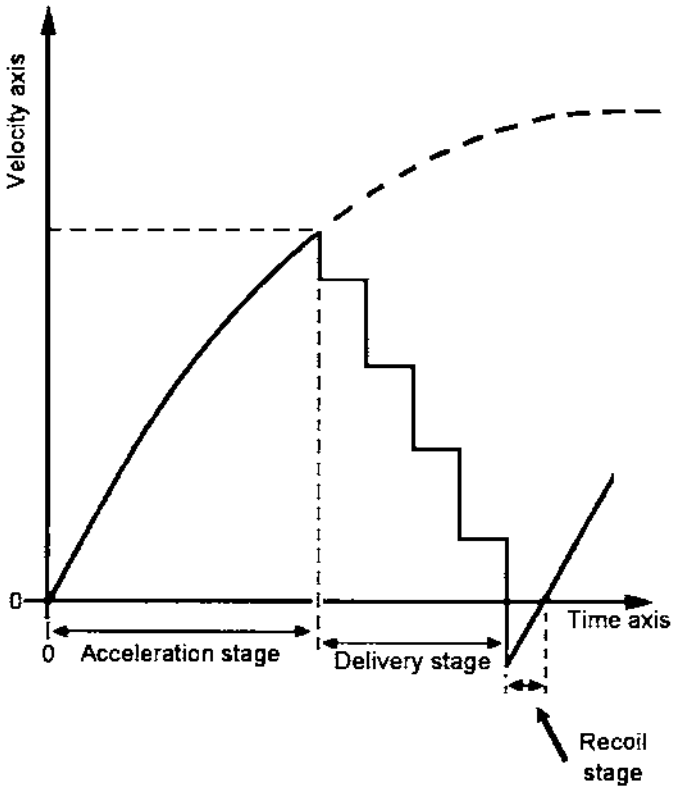

When the delivery valve closes and the water in the pump *recoils* back up the drive pipe, it is actually flowing away from the pump. This leaves a low pressure or vacuum in the pump. The low pressure lets the impulse valve drop open with its own weight.

When the water has stopped recoiling, it starts to flow down the drive pipe and out through the open impulse valve again. It accelerates down the drive pipe and through the open valve as it did at the start of the pumping cycle.

The pump cycle

To make the operation of the pump easier to understand the pump cycle can be divided into three stages. They are called the *acceleration, delivery and recoil* stages. There is a very short pressurisation stage as well, but that can be ignored. The graph at the bottom of the previous page shows how these stages refer to different parts of the cycle.

As the pump continues to operate, the same cycle is repeated. The water accelerates down the drive pipe and out through the impulse valve until the velocity of the water reaches closure velocity. Then the stages of delivery and recoil occur before the cycle starts again. The graph can be used to see the time taken for each cycle and work out how fast the pump is operating.

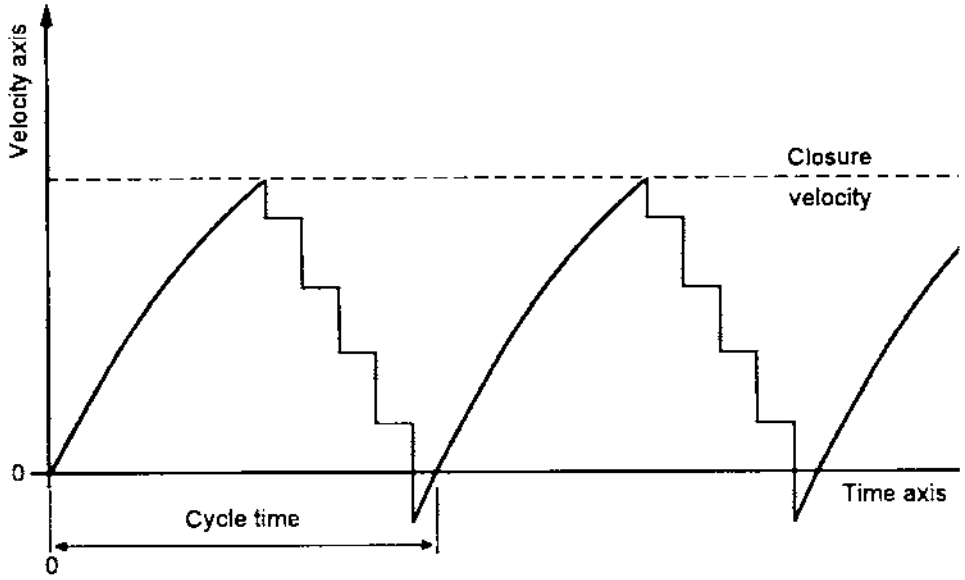

The impulse valve closes and the pump beats every time the line on the graph reaches closure velocity. For a pump working at 60 cycles a minute, the "cycle time" would be 1 second.

Delivery flow

You saw on page 6 how the amount of waste flow could be represented by shading the area under the line on the graph. In the same way, the amount of water flowing from the pump into the air vessel can be represented by the area under the graph during the delivery stage. This is called the *delivery flow* per cycle.

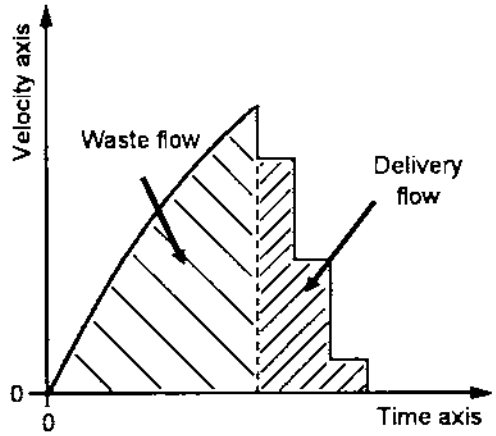

When the area under the falling part of the graph is large it means that there is a large *delivery flow*. Two things increase this area. One is increasing its height. The other is increasing its width either by having more steps or by having longer steps.

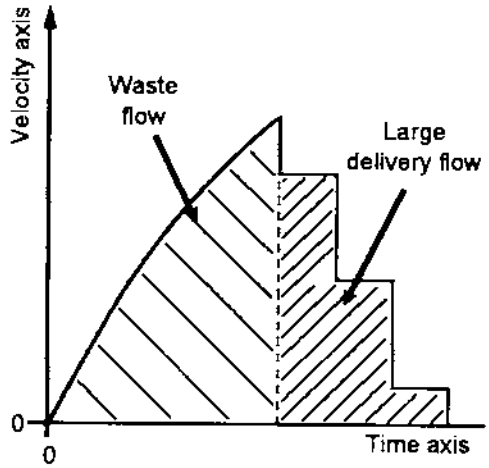

Systems with a low delivery head will only need a small drop in velocity to deliver water. The delivery stage will have many small drops in velocity before all the velocity is used up. The large area under the line on the graph shows that a large amount of water will be pumped with each cycle.

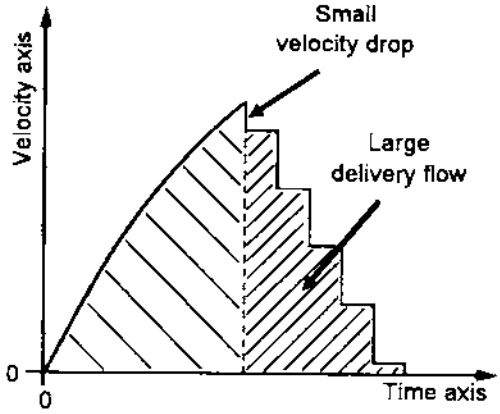

If the delivery head of the same system was increased, the acceleration of the water and the closure velocity would be the same but the drop in velocity required to reach the delivery head would be much higher. The graph shows that there would be a few large drops in velocity during the delivery stage of the cycle. The area under the graph during the delivery stage would be much smaller, showing that the flow through the delivery valve was small. Much less water would be pumped with each cycle.

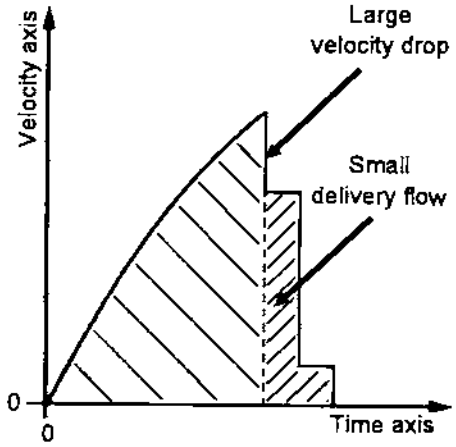

More advanced explanation

Because the drive pipe is the same length in both of the systems just described, the time taken for a shock wave to travel from the pump to the drive tank and back again would be the same. So the flat sections of the graphs, showing when the water is flowing at a steady velocity through the delivery valve, would each last the same length of time. The delivery stage of the pump cycle in a system with a low delivery head would be longer than it would be in the same system with a higher delivery head. The acceleration time would be the same in both cases and the time for the recoil stage would be very small. When the delivery head is increased, the length of the delivery stage is reduced and the pump operates faster.

Getting the best delivery flow

This is explained using an example. Suppose you are asked to design a ram pump site on a stream where the flow of water in the dry season is quite small. There is an obvious ram pump site but it only has a small drop, so the feed head would also be small. If a pump was installed there, the acceleration of the water would be quite low and so the graph would not rise very steeply. The impulse valve of the pump could be adjusted to use all the water available in the stream. With a low feed head, the acceleration and closure velocity would also be low. The pump would not deliver much water.

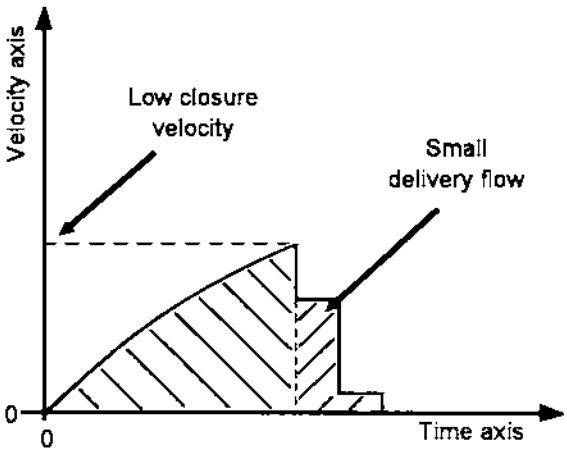

The owner of the site says that he needs more delivered water than the proposed site would give, so you have to look more carefully at the site design. Suppose that you find that you can double the feed head without too much trouble. Normally the drive pipe length will also double. By keeping the closure velocity the same, the feed flow will hardly change. The delivery head would be increased by an amount equal to the extra feed head, but this has little effect on the flows. Although the drops in velocity would be about the same as before, the steps are twice as wide and much more water would be delivered.

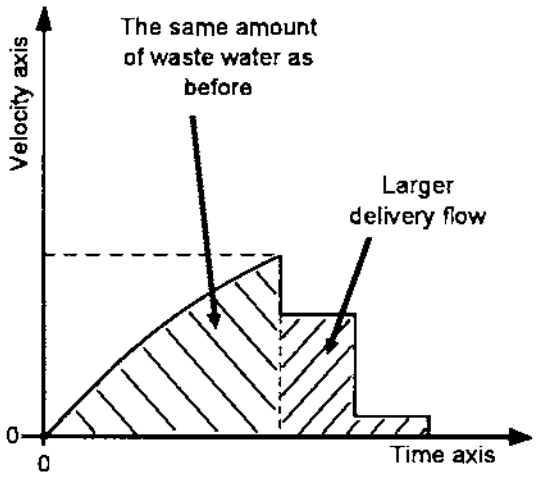

If the same site has plenty of water available in the rainy season, you could recommend changing the tuning of the impulse valve when the stream is full so that the closure velocity was increased. The valve would then take longer to close and much more water would flow through it. The delivery head would be the same as before so the drops in velocity would be the same size. Because the closure velocity would be higher there would be more drops in velocity during the delivery stage and more water would be pumped.

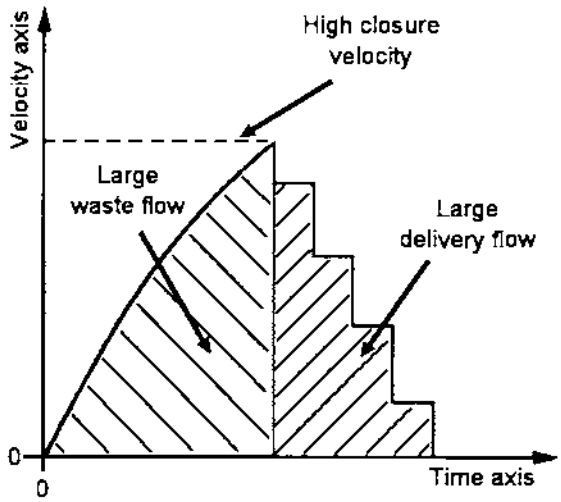

More advanced explanation

As the closure velocity is increased (by changing the settings of the impulse valve) three things happen:

- the drive flow per cycle increases a lot
- the delivery flow per cycle increases a lot
- the pump works a little more slowly (fewer cycles per minute)

The overall effect is to increase both the delivery flow per minute and the drive flow per minute.

When the closure velocity is in the steep section of the line on the graph, increasing the closure velocity will increase the delivery flow per cycle and the total water delivered by the pump.

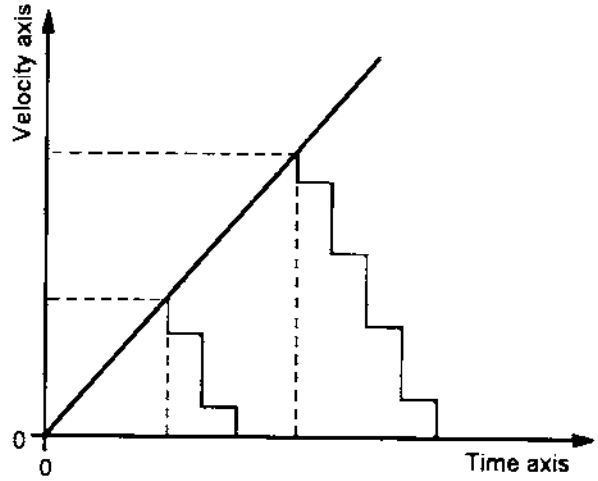

If the impulse valve was tuned so that the stroke was very long or the weight very heavy, the closure velocity would be in the flatter section of the line on the graph. The drive flow through the pump would increase a lot but the delivery flow would change very little. The time taken for each cycle would also increase so that there would be fewer cycles per minute. The pump would become less efficient and would actually pump less water per minute.

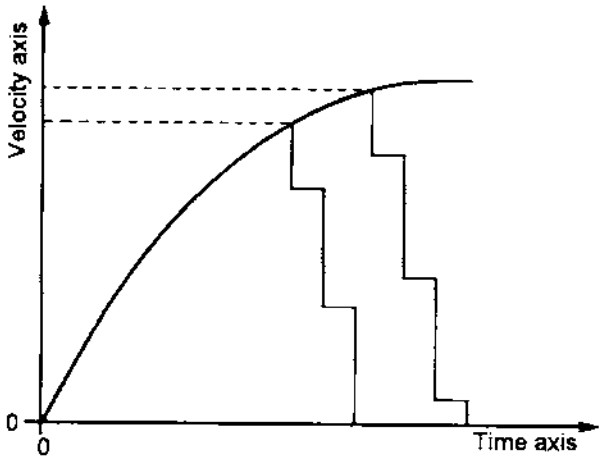

Increasing the weight and stroke of the impulse valve too much would stop the valve from closing at all. This is because the valve cannot close when the velocity needed to close it is more than the terminal velocity of the water through the pipe.

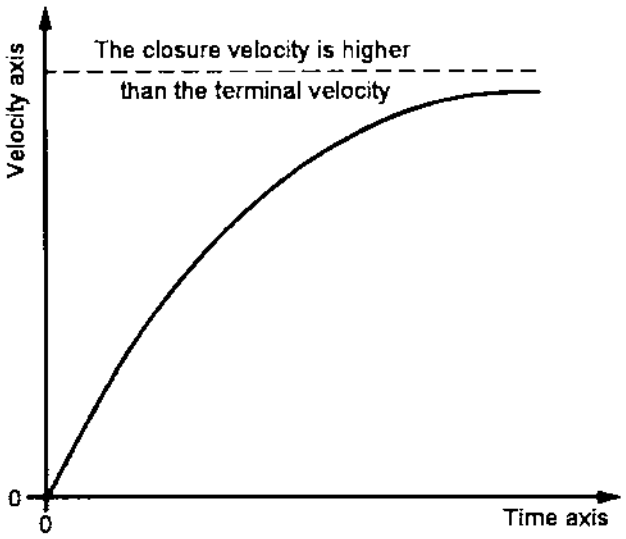

The following DTU Technical Releases give further information about ram pumps.

TR 11: The DTU S1 ram pump

TR 12: The DTU P90 ram pump

TR 14: The DTU S2 ram pump

TR 16: An introduction to hydraulic ram pumps (and the DTU range)

DTU

Ram Pump Programme

DTU S2 PUMP

TECHNICAL

14

RELEASE

DTU TECHNICAL RELEASE NO.14 : THE DTU S2 PUMP

INTRODUCTION

This Technical Note is in four parts.

The first part (1 page) is a 'Stop Press' UPDATE containing amendments (dated November 1998) to the original which was written in 1995.

The second part (4 pages) is a summary of the pump's design and performance, suitable for copying, laminating and posting in the pump house.

The third part (20 pages numbered 1-20) is a detailed description of how to use the drawings to make an S2 pump. It should be read in conjunction with the amendments mentioned above.

The fourth part is a set of 16 drawings, of which Nos. 11a, 13, 14 and 14a have been added as amendments and offer alternatives to earlier drawings.

The 'Status' of this pump is that several dozen have been made, mostly in Africa, but that none has been run continuously for years on end. The pump is not a 'very-long-life' design although, in normal applications and incorporating the amendments in the UPDATE, continuous use should require only occasional replacement of worn parts. The Drawings deliberately do not precisely define the materials to be used, because the design is supposed to be somewhat adaptable to what is available. If all the metal parts are of mild steel, corrosion will cause some problems - especially affecting nuts and bolts and the impulse valve stem. If possible these parts should be made of stainless steel.

It is not the intention of the Development Technology Unit to undertake further development of this pump. However the Unit's Director would be happy to receive any comments from the field about its performance or any suggestions for further 'UPDATES'.

Development Technology Unit, School of Engineering, Warwick University,
Coventry, CV4 7AL, UK
tel +44 1203 523122, fax 418922, email at dtu@eng.warwick.ac.uk,
web at http://www.eng.warwick.ac.uk/dtu

TR14 UPDATE - November 1998

Since this Technical Release was written in 1995, based mainly on field experience in Zimbabwe and Zaire, the DTU has obtained further experience with this S2 model of ram pump. The following modifications derive in particular from observations during extended testing in Staffordshire, England during Summer 1998. The modifications are expressed as variants on the production procedure of the (original) pages that follow. Extra drawings have been added (Dwgs. 11A, 13, 14 and 14A).

1) [*Problem of steel washer cutting into delivery valve rubber disc*]
   Refer to page 14 - Making the S2 pump delivery valve.

Fit a rubber washer, made from the same material as the valve disc and of the same diameter as the steel washer, between the steel washer and delivery valve disc.

2) [*Wear and tilting wobble of impulse valve stem*]

Refer to page 12 - Making the S2 pump impulse valve - and to old Drgs Nos.9, 11a & 12 and new Drawing No.11a.

Fit a second (upper) stage to the impulse valve guide. This requires that a longer valve stem and longer guide bolts are made/used than those shown in drawing number 12. The plain section of the valve stem is 50 mm longer (i.e. 100 mm overall length), the bolt shank is 50 mm longer (i.e. 130 mm long).

If a *new* two stage guide is to be used then the assembly should be welded together *before* the holes are drilled. However if the second stage of the guide is fitted *as an addition to/modification of* an existing impulse valve, then (to ensure correct location and operation of the valve itself) any welding should only be undertaken *after* the impulse valve is fully assembled and bolted to the pump body, as detailed on pages 17 to 18.

3) [*Problem of delivery valve gasket blowing out midway between the clamping bolts*]

Refer to old Drawing No.3 & new Drawing No.13

New gasket size, internal diameter = 95 mm, outside diameter = 165 mm. Using the internal diameter of the gasket shown in Dwg.13, which is a little smaller than that of the flange in Drg. 3, ensures that it protrudes slightly inside the flange. This wider gasket is primarily required between the air vessel and delivery valve plate, but can also be used between delivery plate and pump body and in the impulse valve.

4) [*Problem of rusting bolts*]

Thoroughly grease all bolts prior to assembly and use nuts or washer/nut combinations that extend to the end of the bolt threads, leaving almost no thread exposed. Of course if stainless steel bolts and nuts are available and affordable, they should be used in preference to plain steel.

5) [*Problems in aligning pump with drive pipe*]

If possible, the drive pipe, pump and cradle should be assembled in situ within the shuttering for the concrete base *prior* to any concrete being poured

6) [*Problems with marking out delivery valve plate for drilling*]

Refer to old Dwg. Nos. 5, 6 & 7 and new Drgs. Nos. 14 & 14a.

An alternative layout of holes in the delivery valve plate is to have them in parallel staggered rows as shown in Drawing number 14. The delivery valve rubber disc now flexes as a butterfly's wings and has to be retained by a bar or rod held in position by two bolts (rather than the original single central bolt) - see Drawing 14A. Slightly inferior pump output may be experienced (due to more back-leakage before the delivery valve recloses) but this layout is easier to mark out and make, so there is less chance of having too thin a wall between adjacent holes. As before, care should be taken to not so tighten the bar-retaining bolts that the valve rubber disc no longer lies flat on the valve plate. The nuts on these bolts should if possible be self-locking or held on with a locking compound such as 'Locktight'. The alternative of using a second locknut on each bolt is not so good.

7) [*Problems with silting up of intake pool*]

Ram pumps driven by water drawn from immediately below springs, or from large reservoirs, have little problem with silting. Pumps drawing water from behind small dams (e.g. 400mm high) on streams may experience major silt problems, with the 'pool' silting up by as much as 300mm after a single storm. Drawing all drive water through silt will almost certainly overload the silt-settling capacity of the drive tank. There is no easy way of automatically keeping such a pool silt-free and such locations are therefore not suitable for ram pumps unless someone is on site to apply frequent manual desilting procedures to both pool and drive tank.

DTU S2

hydraulic ram pump

The name "S2" stands for a Steel pump with a drive pipe up to 2" in diameter.
The S2 replaces the DTU M8 pump

The DTU S2 hydraulic ram pump is a steel machine, using a 1.5" or 2" diameter galvanised drive pipe, that can lift water up to a height of 100 meters. It was designed for village water supply but may also be used for irrigation, and is being used successfully in many African countries. The pump has been designed to be made in small workshops with welding equipment and a pillar drill. A lathe can be useful but is not essential.

A ram pump is powered by falling water. Water from a stream or spring is diverted and dropped through a drive pipe into the pump. The power of the falling water is used to pump some of the water where it is wanted. The amount of power in the falling water limits how high you can pump, and how much water you can pump. Generally, the more water you drop and the further you let it fall, the more power there will be.

In areas where the water source flow varies greatly during the year, more than one pump can be installed, all sharing the same delivery pipe as shown in the drawing below.

Distribution system, for domestic or irrigation use. A tank is always recommended.

Delivery pipe, rising all the way along its length (no ups and downs). The pipe should be buried where possible and protected if it has to be above ground.

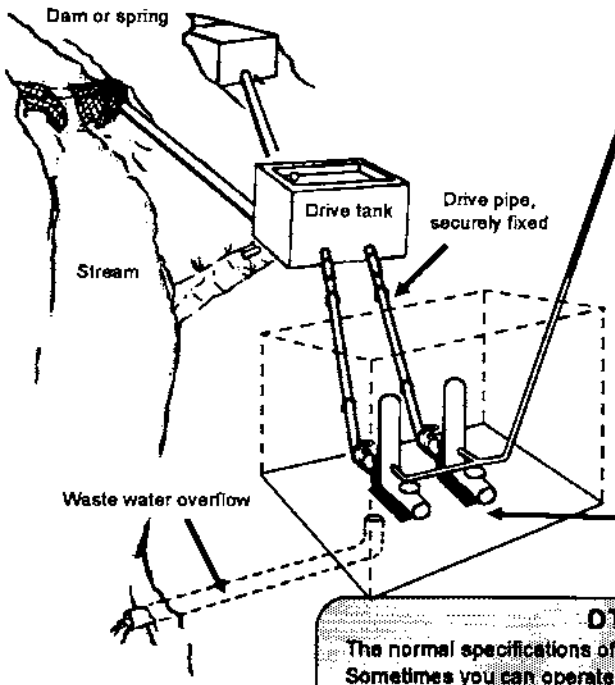

Use 25mm diameter plastic pressure pipe for the delivery pipe if there is one pump in the system, and one size larger if there are two.

The DTU S2 can be locally made
Is easy to maintain
and cheap to run!

DTU S2 ram pump specifications

The normal specifications of the DTU S2 ram pump are given here.
Sometimes you can operate pumps outside these limits, but they may not work well.

drive head range	—	2 to 15 meters
drive flow range	—	40 to 120 liters a minute
drive pipe material	—	Galvanised iron
drive pipe diameter	—	1.5" for flows from 40 to 80 liters a minute
drive pipe diameter	—	2" for flows from 60 to 120 liters a minue
delivery head range	—	up to 100 meters
typical delivery range	—	1 to 25 liters a minute
delivery pipe diameter	—	25mm

DTU S2 PUMP: USER INSTRUCTIONS

AN EXPLODED VIEW OF THE DTU S2 PUMP

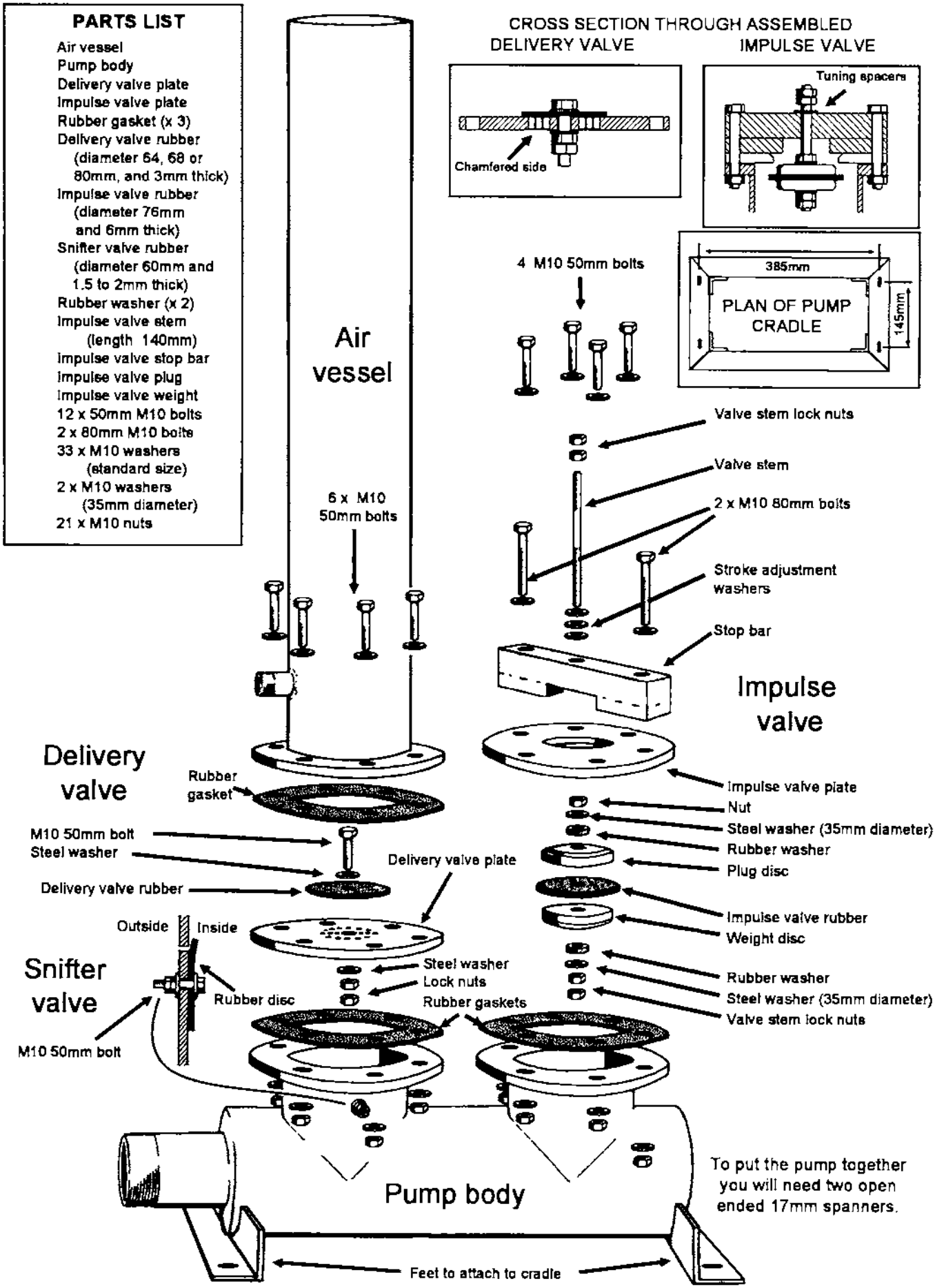

Installation notes

The DTU S2 pump should be installed in a properly designed system. To prevent vibration causing breakages, it should be firmly bolted to a steel frame (called a pump cradle) that is half buried in a concrete base. The cradle is usually made from 40 x 40mm angle iron and will vary in size depending on the number of pumps installed. Hole locations for just one pump are shown on the previous page.
All pipes in the system should be supported firmly, and buried where possible. The drive and delivery tanks should be constructed on good foundations by experienced tradesmen. Pipe joints to the drive tank should allow the pipes to move slightly without damaging the tank walls or leaking badly.

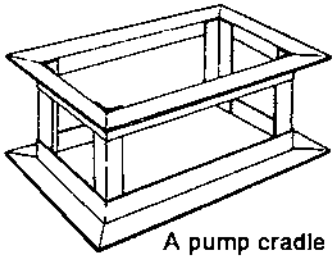
A pump cradle

Starting and stopping the ram pump

Although ram pumps often start very easily, they can be awkward the first time they are run.
To start the pump:

1. Make sure that any valve fitted on the delivery pipe is open and then open the drive pipe velve. Water will flow out of the open impulse valve until it suddenly shuts. If it reopens automatically, the pump should continue to run on its own. If it does not, you must prime the delivery system as described in Step 2 alongside.
2. Push down on the top of the impulse valve stem with your foot to reopen it (wear strong boots). Again, water will flow out of the open impulse valve until it suddenly shuts, then push down immediately to re-open the valve. Keep helping the valve to re- open until it will do so by itself.

To stop the pump, hold the impulse valve stem up to close it or shut the valve at the bottom of the drive pipe.

Tuning for best performance

The DTU S2 can be tuned to adjust performance. This is done by changing the up and down movement of the impulse valve, which is usually set to around 15mm. Tuning is usually done to achieve either the maximum delivery flow or the most efficient use of the drive water available.

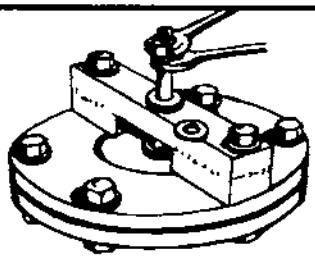

Maximum delivery
When there is plenty of drive water available, the pump can be tuned to deliver as much water as possible. To do this, remove all washers from the impulse valve stem so that the velve has as much up and down movement as possible (about 20mm).

WARNING: - this also puts the pump parts under greater stress and makes them wear more quickly.

Low drive flow
If the pump uses more water than is available it will soon stop. If this happens it must be tuned to use less. The impulse valve should be tuned down to use 90-95% of the water available from the source. To tune the pump down, add washers onto the impulse valve stem so that the valve has less up and down movement. The shorter the stroke, the smaller the amount of drive flow needed, and the less water is delivered. The minimum stroke length is around 10mm.

Routine maintenance

While the pump is running normally, a visit should be made once a week to check that bolts are tight and that there are no leaks. Once a month an inspection of the whole system should be carried out. It is also recommended that a log book is kept to record the checks and repairs that have been made.

Monthly maintenance check list (without stopping the pump):

1. Inspect all the joints to check for leaks.
2. Check if there is sufficient air in the air vessel. This can be done by listening carefully to the pump. If there is insufficient air in the air vessel, the pump will be much louder than usual. This means that the snifter valve is probably blocked and will need to be cleared. If a bleed screw is fitted, when opening it, air or a small amount of water followed by a rush of air means the air level is OK. If only water emerges, then again the snifter valve will have to be checked for blockage.
3. Clean any filters installed in the system.
4. Remove excess silt or debree from tanks or from behind the intake dam or weir if necessary.
5. Walk along all pipes looking for damage. Also, inspect the tanks for leaks, particularly at pipe joints.

Pump repair

If the pump stops or it delivers less water than usual, it may require adjustment or repair.

Look at the pump and if there is no obvious fault start it again if you can. Watch the pump and listen for irregular pumping or unusual noises. A worn impulse valve, for example, is usually obvious because water squirts through when the valve is closed. Some parts of your rem pump may need occasional replacement. the frequency of this will depend on how hard the pump is working and on the cleanliness of the drive water.

Tools you will need:

2 x 17mm ring/open end spanners to disassemble and assemble the pump
2 x Adjustable wrenches - to loosen a union joint on the delivery pipe (if fitted)

Taking the pump apart

Depending on the fault it may be necessary to disassemble the impulse valve and/or the air vessel. Before attempting to take apart the pump:

1. Make sure that the drive pipe valve is closed and the impulse valve is open. This will allow you to work on the impulse valve ONLY.
2. Depressurise the air vessel.

WARNING - Before attempting to remove the air vessel, always release the pressure in it slowly. An ideal system will have a gate valve or one-way valve and a union fitted between the air vessel and the bottom of the delivery pipe and the optional bleed screw fitted to the air vessel. With the pump stopped, close the gate valve in the delivery pipe to stop it draining back. If a one-way valve is fitted it will close automatically. Then loosen the bleed screw to release the pressure in the air vessel. If none of the above are fitted, the only other way to release the pressure in the air vessel is to loosen each of the air vessel flange bolts one turn at a time until the water and air escapes through the join at the flange. You will certainly get wet this way.

Checks

1. Check the delivery valve rubber for wear and blockage of the valve holes. Check that the lock nuts on the valve bolt are tight.
2. Check that the snifter valve is in good condition.
3. Remove the impulse valve and check the impulse valve rubber and the rubber washers for wear. Check that the nuts on the valve stem are tight and check for excessive wear of the stem. Replace parts if necessary.
4. Check the pump body is firmly bolted down, then reassemble the pump, ensuring that all bolts are greased.

Putting the pump back together

Assembly of the pump is shown in the exploded view drawing, but the following important points need to be kept in mind:

1. Assembling the delivery valve
   Put together the delivery valve plate, the rubber and the bolt. Make sure the side of the plate with the chamfered holes is on the opposite side to the rubber, and that the rubber is on top.

   Screw on the first nut until it is finger tight and then undo it by one turn. Care must be taken not to overtighten the bolt and nuts as this will affect the performance of the valve. Next, screw on the other nut and tighten it up against the first. Use the spanners to tighten them firmly together. This will lock them together, and also allow a small up-and-down movement of the bolt and rubber.
2. Assembling the snifter valve
   Put the 'shaped' bolt and washer together, feed the bolt through the valve rubber, then push this through the pump body. Make sure that the shaped curve of the bolt head and washer align with the curvature of the body.

   Screw on the first nut until it is only finger tight. If the nut is on too tight the rubber will curl away from the pump body and will need to be slackened off slightly. Then screw on the second nut and tighten the two nuts firmly together using the spanners. Then check that the rubber has not distorted. If it has, slacken the nuts half a turn and tighten the outer one again.
3. Assembling the air vessel/delivery valve/rubber gaskets
   Align the delivery valve, air vessel, pump body and rubber gasket mounting holes and feed through the bolts. Make sure the delivery valve is the correct way up (the valve rubber facing upwards) and then tighten the nuts by hand. Use the spanners to tighten each nut and bolt a little at a time, working around the flange. This will draw the assembly together evenly.
4. Assembling the impulse valve
   The first parts to assemble are the valve stem, discs and rubbers. Screw on a nut to the longer threaded end of the stem up to the end of the thread. Push a steel washer on up to the nut, then add a rubber washer. Follow this with the valve plug disc, with the chamfered side towards the nut. Slide the valve rubber up against this, then the weight disk with the chamfered side facing away from the rubber. Follow this with another rubber washer and a steel washer. Screw a nut up them until it is finger tight. Thread on another nut and use the spanners to tighten the nuts together. This part of the assembly is sometimes known as the valve plug.

   Hold the impulse valve plate and the velve plug together, with the chamfered side of the plate opposite to the side against which the valve rubber presses. Slide the stop bar onto the top of the stem and thread a nut loosely on the stem.

   Align the valve assembly, pump body and rubber gasket and feed through the flange bolts. The two longer bolts feed through the cross-bar as well.

   Thread on the six nuts by hand, then use the spanners to tighten the four shorter bolts that hold down the valve plate. Again care must be taken to ensure that these nuts are tightened evenly. The next step is to make sure the closed valve plug is centred in the valve plate hole before tightening down the two remaining nuts that secure the stop bar. To check the alignment, open and close the valve manually turning the valve plug to make sure it does not catch on the hole in the valve plate.

Now you only need to set the stroke length of the valve for the pump to be ready for use.

Spare parts to keep on the site

- impulse, delivery and snifter valve rubbers
- an impulse valve stem
- a few spare M10 nuts, bolts and washers

The Development Technology Unit (DTU)
Department of Engineering
University of Warwick,
Coventry CV4 7AL UK
Tel: 44 (0)1203 523122
FAX: 44 (0)1203 418922

Making a DTU S2 ram pump

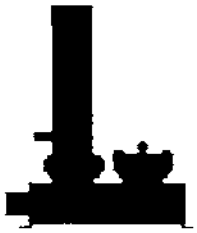

When you have decided to make a pump, the first thing you must do is make photocopies of the DTU S2 ram pump design drawings in Technical Release number 14b. The copies can be used in the workshop and it will not matter if they get dirty or are damaged. Some of the drawings can also be used as templates.

It will be useful to have the copies of the design drawings beside you as you work through this Technical Release. The pump's normal operating ranges are on the first drawing.

The manufacture process is presented under the following headings.

- **The parts of the pump**
  This introduces the main parts of the DTU S2 pump.

- **Tools required**
  The DTU S2 pump was designed to be made in small workshops with limited tools. This section describes the tools recommended. We have assumed that you are a workshop technician who already knows how to use the tools.

- **Guides and Templates**
  Simple guides and templates are useful, so we have included descriptions of guides and templates, and suggest ways of making them.

- **Materials needed to make a DTU S2 ram pump**
  A "shopping list" of the materials that you will need is given on page 6. This can be photocopied and taken with you when you buy materials.

- **A step by step guide to manufacture**
  The process of manufacture is described in detail under this heading. It begins with making the pump body and air vessel, and goes on to cover the valves and the pump cradle.

- **Assembly and testing**
  Putting the valves together properly is very important, so the process of assembly is described. The description includes some suggested ways of checking that they work properly.

- **Spare parts**
  This explains which spare parts to supply with a pump. It points out which parts you should expect to wear out or fail.

- **Optional addition**
  The addition of a "bleed" screw in the air vessel can make it easier to find out what is wrong with a pump when it does not perform properly. It can also make the pump easier to maintain. The "bleed" screw is described under this heading.

The parts of the pump

The picture here shows the main parts of a DTU S2 ram pump. There are five, apart from the risers and flanges. The pump's recommended operating ranges are given in the box.

1 The pump body
2 The air vessel
3 The impulse valve
4 The delivery valve
5 Feet to attach the pump to the cradle.

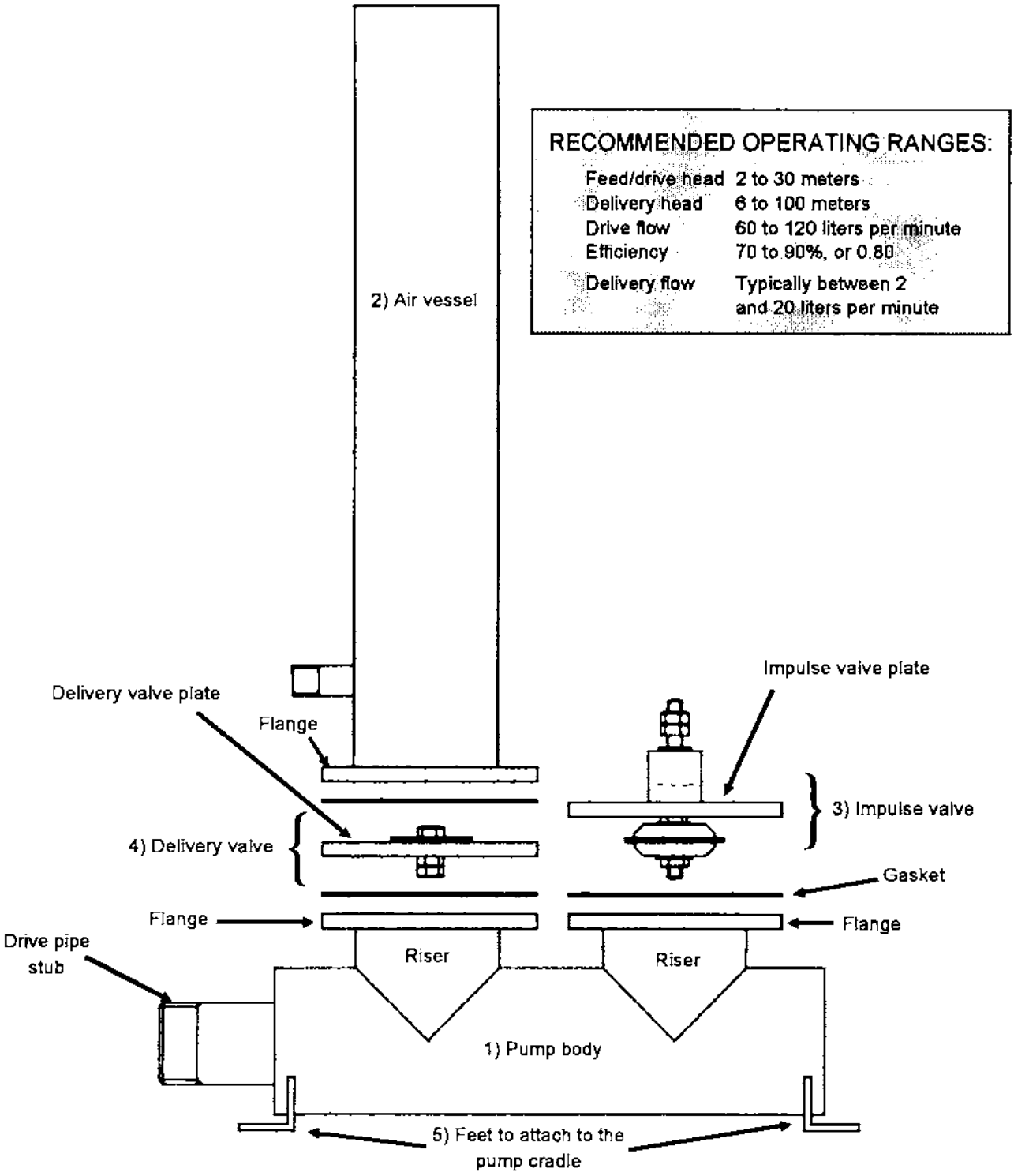

Tools required

DTU S2 ram pumps can be made in a workshop with welding facilities, a drill, a hacksaw and files. It is hard work making them with as few tools as this. It is also hard to make the pumps to a high enough standard. Cutting and filing the parts by hand will take a very long time and it may not be possible to make the parts accurately. Do not plan to make more than one pump unless you have access to some other power tools.

Most small workshops do not have a lathe, but many do have a gas cutting torch. Many also have a bench-grinder and a hand-held angle grinder. The step-by-step manufacturing guide that follows assumes that the pump is being made using a gas cutting torch, an arc-welder, a pillar-drill and grinding machines. Some parts of this guide will be useful to people who are making the pumps using other tools. A lathe can be useful for making parts of the impulse valve when one is available.

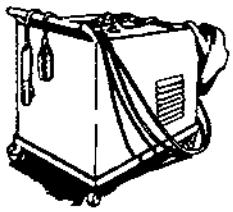

Arc welder

To cut circles accurately with a cutting torch, a centre pivot can be bought or made. The one shown here was made in the workshop where it is used.

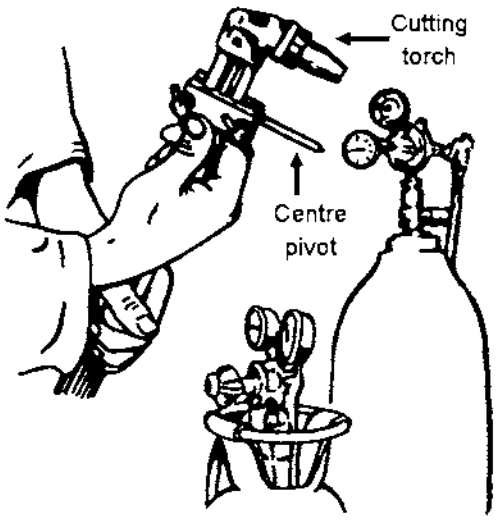

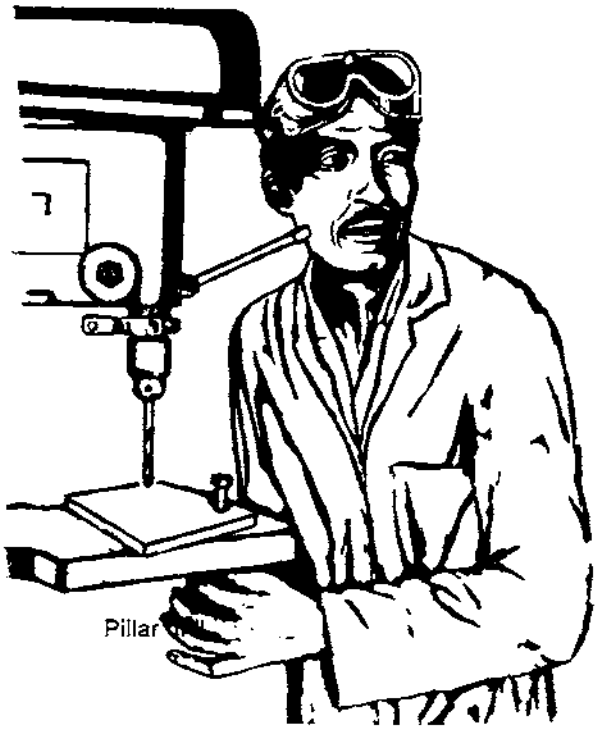

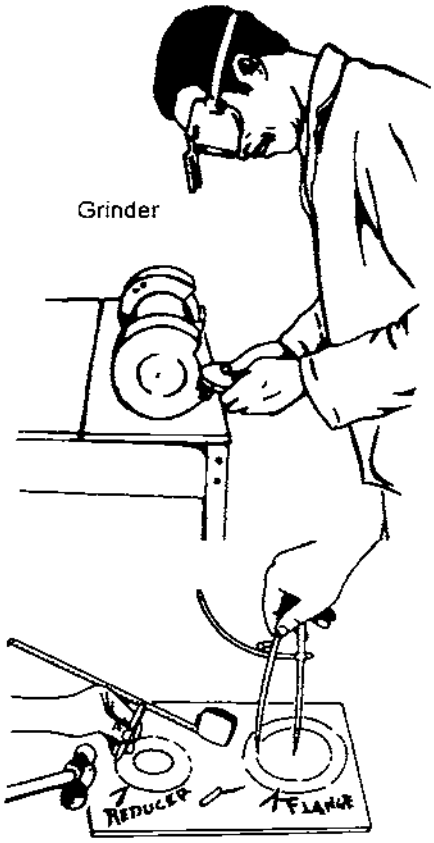

You will also need chalk, a scriber, a measuring tape, dividers, a centre punch, files, a 10mm hole punch, an M10 tap and die, drill bits, two 17mm spanners, goggles, gloves, PTFE tape, a setsquare, a feeler-gauge and a hammer.

Guides and templates

When you are planning to make a number of pumps, it is worth making a few guides or templates or guides to help when marking up, cutting and drilling.

Guides for marking out the pump body

Use a short piece of PVC pipe of the same size as the pipe to be marked. Cut the PVC pipe along its length and push it over the steel pipe. Hold it in place and use it as a guide to score a line around the pipe.

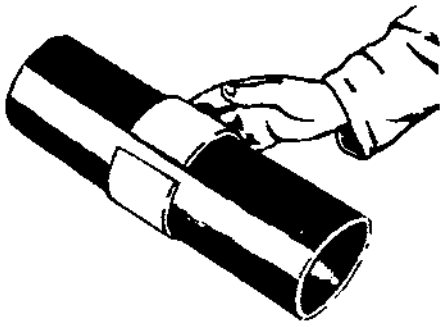

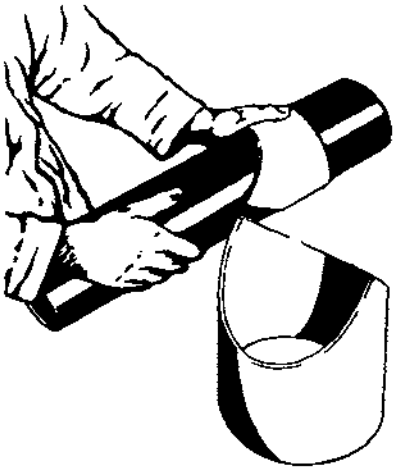

A "V" notch template like the one shown on the left can be made using thin plate (1mm) or PVC pipe. This is a guide for marking up the notches cut into the pump body and for the risers that fit into the notches.

When you have scored the line in the right place you can make it easier to see by rubbing chalk over it. Scored lines can be very hard to see through the protective goggles used when cutting. Use a centre punch to mark dots along the scored line. Use the punch about every 5mm.

It is very important to mark up clearly. If you do not, you may not cut a straight line with the torch and so you may have to start again.

Flange and valve plate template

Design drawings number 3, 5, 6, 7, and 10 can be copied and used as templates. If you want to make a lot of pumps it is probably worth making a a steel template for the flanges. If you do not have access to a lathe, consider having the template made for you in another workshop.

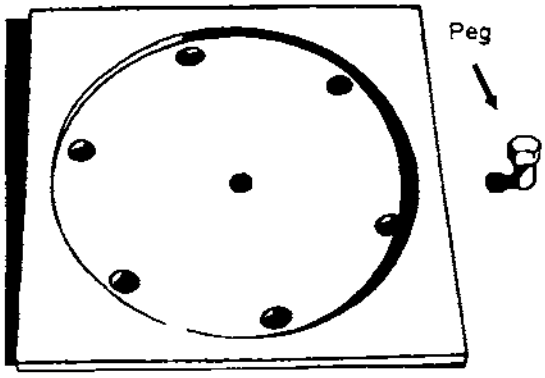

The template can be recessed with a lathe so that the flange drops into it when it is the right size. The example shown is recessed and has a ring of large holes around the outside. The example shown also provides a pattern for the bolt holes on the flanges and both valve plates.

When the first hole in the outer ring has been drilled a "peg" made by cutting a bolt is put into the hole to prevent the disc turning inside the template.

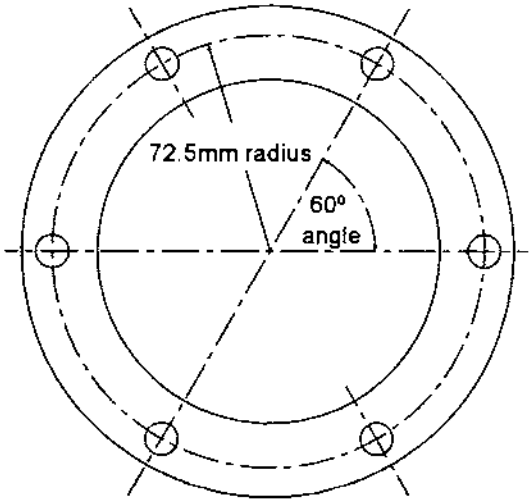

A simple template like this can be made using thin plate

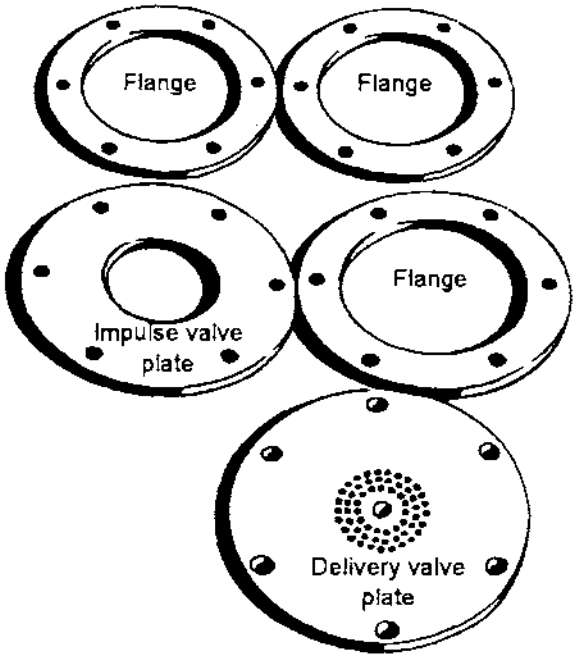

You must drill the flange holes equally spaced and at the correct radius. If you do not, the flanges may not bolt together, or may only bolt together one way around.

Some people simplify the making of flanges by stacking them and drilling them together. Although this will always mean that the holes line up, it can mean that only the holes that were underneath each other when they were drilled line up. When the pump is put together is it important that the holes align whatever way around the parts are turned. Either take great care marking up each flange and be sure that the centre-punch marks are perfectly positioned before drilling, or use a template.

Materials needed to make a DTU S2 ram pump

STEEL	Size	No. of	Length/area	Notes	✔
STEEL PIPE	4" (105mm internal diameter)	1	1350mm	The outside diameter of 4" pipe is 115mm. The wall thickness should be 5mm.	
STEEL PLATE	10 or 12mm	1	330 x 500mm	Do not use plate less than 10mm thick.	
STEEL BAR	25 x 25mm	1	165mm	If this is hard to find, make some by welding together a stack of thinner 25mm wide bars.	
STEEL BAR	25 x 15mm	1	165mm		
STAINLESS OR MILD STEEL ROD	10mm	1	280mm	If this is not available, mild steel reinforcing bar will do. This includes enough to make a spare impulse valve stem to supply with the pump.	
RUBBER	Size	No. of	Area	Notes	
GASKET RUBBER (inner tube)	Car or small truck	1	825 x 170mm	Make sure that it has not perished. This includes enough to make two spare flange gaskets to supply with the pump.	
IMPULSE VALVE RUBBER	6mm	1	152 x76mm	Offcuts of conveyor belt and shoe sole material have been used in the past . This includes enough to supply a spare of each with the pump.	
DELIVERY VALVE RUBBER	3mm	1	160 x 80mm		
NUTS & BOLTS	Size	No. of	Length	Notes	
BOLTS	M10	1	30mm	These must be stainless steel or galvanised. The 4 x 40mm bolts, nuts and washers to hold the pump to the cradle are included. Extra nuts and washers are needed for the valve stem and are included in the totals. The totals also include a few spares that you should supply with the pump.	
BOLTS	M10	10	40mm		
BOLTS	M10	8	50mm		
BOLTS	M10	3	80mm		
NUTS	M10	28			
WASHERS	M10	40			
CONSUMABLES				Notes	
WELDING RODS	The amount you use will vary according to your skills.			Select rods to give good penetration on the 5mm walls of steel pipe and on 10mm steel plate.	
GAS				For the cutting torch.	
PRIMER (PAINT)				Either have the parts of the pump galvanised or paint it. In most cases it is easiest to paint it	
ENAMEL PAINT					
THINNERS					

✎ Photocopy this table and tick off the materials as you get them so that you know you have everything you need before you start.

A step by step guide to manufacture

Before starting, decide which delivery valve template you will use. This will depend on the delivery head at the site where the pump is to be installed. If you do not know where the pump will be installed, use drawing number 5, which is the standard design.

Cutting the pump parts

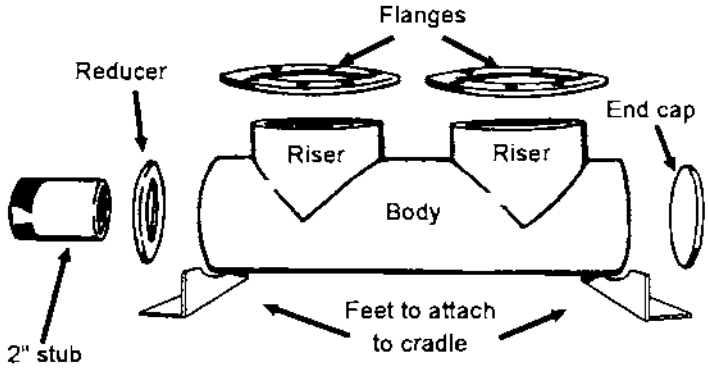

All the cutting for this pump can be done with a cutting torch. To save grinding and to minimise scrap, the metal cut from the centre of the flanges is used as the ends of the pump body. The ends are called the "Reducer" and the "End cap". The pump body is made from steel pipe with an internal diameter of 105mm (4" pipe). The length shown on the S2 design drawings is 365mm.

The discs of steel that fall out when the flanges are cut will fit inside the pump body, but are not big enough to cover the ends. So the ends are welded about 5mm inside the body. This should leave enough overlap to weld neatly to.

The feet are cut from 40 x 40mm angle iron. A curve that fits the pump body is cut out of one side of the angle iron.

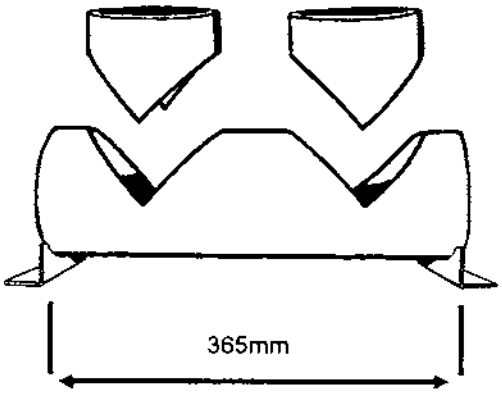

The body is cut from a length of pipe by using the PVC pattern to score a line around the pipe. Mark it with chalk if it does not show up clearly, then go over the line with a centre punch to make sure it can be seen when cutting.

Skilled use of the cutting torch can result in the cut parts falling apart with clean edges. Even then, they will probably need to be tided up a little with a file or a grindwheel.

It is necessary to have a clean cutting nozzle on the torch, and to set the gas pressures appropriately.

If the pipe being used is galvanised, it can help to grind away the galvanise from the area to be cut. It is not worth using galvanised pipe for the pump body unless it is easy to get because a lot of the galvanised protection burns away by the time the pump is finished.

The fumes given off by burning Zinc galvanising are poisonous and should not be breathed.

Cutting the S2 pump risers

The risers are made from the same pipe as the pump body. They are welded into "V" notches cut into the pump body. Both the risers and the notches can be marked up using the "V" notch pattern or template. At its shortest point, each riser should be no less than 30mm high. At its longest point it should be 87.5mm high.

Remember to go over the scored lines with a centre punch to make them easier to see.

Use an angle grinder or a bench-grinder to clean up the cuts so that the parts fit together properly. A gap of up to 2mm can be filled with weld.

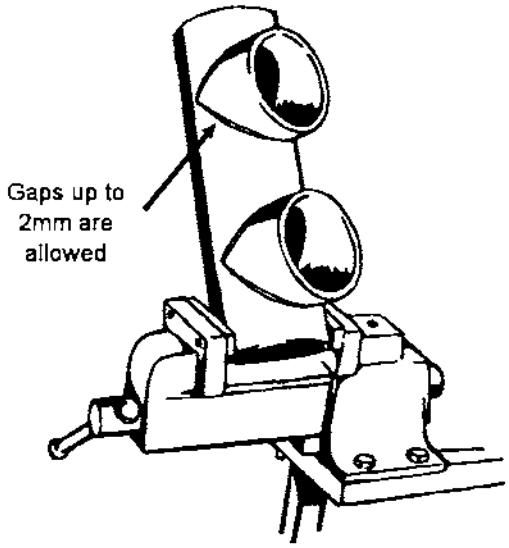

Place the risers in the pump body and grind them to fit. It can be useful to mark the risers and the notches, then grind each riser to fit a particular notch.

Cutting the S2 air vessel body

The air vessel body is cut from the same 105mm (4") pipe as the pump body. The length should be 800mm. This size will always be big enough, so do not change it. A ¾" hole should be cut (or drilled) with its centre 85mm from one end of the pipe. This is where the delivery pipe stub is attached.

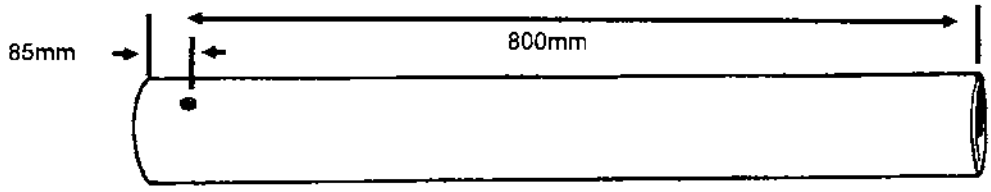

Cutting the S2 pump flanges and plates

The S2 pump body has two flanges and two pump body ends. The ends are called the "End cap" and the "Reducer". The "End cap" is the inner circle cut from a flange. The "Reducer" is the inner circle cut from a flange with another hole cut in the middle of it. The "Reducer" reduces the pipe size from the 4" pump body to the 2" drive pipe, so the inside hole is cut to take a stub of 2" pipe. The S2 air vessel has one flange and one end cap.

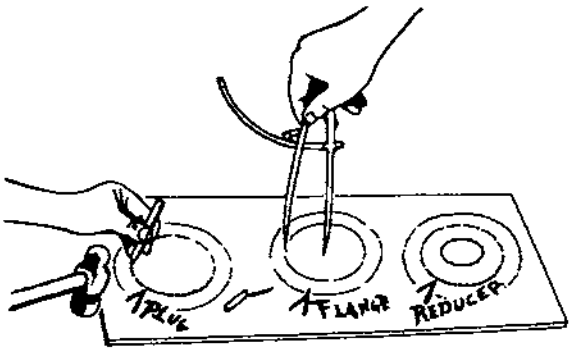

Mark up the flanges carefully, and cut the outer circle first. It can be useful to tack-weld the edge of the first circle to the workbench to make it easy to cut the second circle.

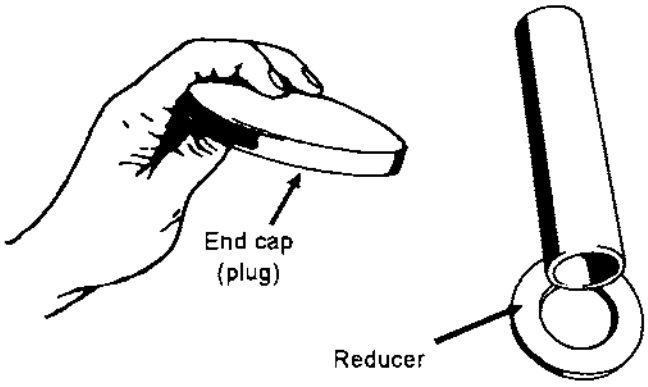

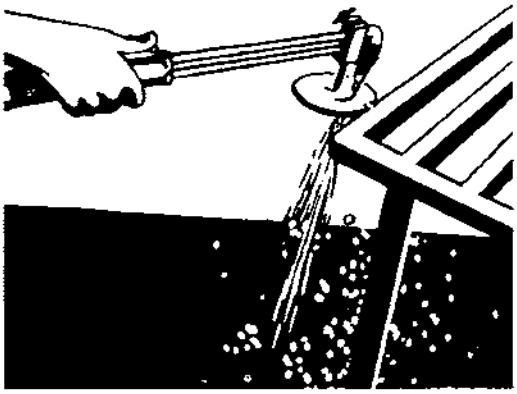

Drilling the flanges and valve plates

It is wise to make a template before drilling the flanges. Use a photocopy of design drawing number 3 as a template. Put it over the disc to be drilled, then use a centre punch to mark the hole centres through the paper template. To make the template last longer, glue it to thin cardboard before you use it.

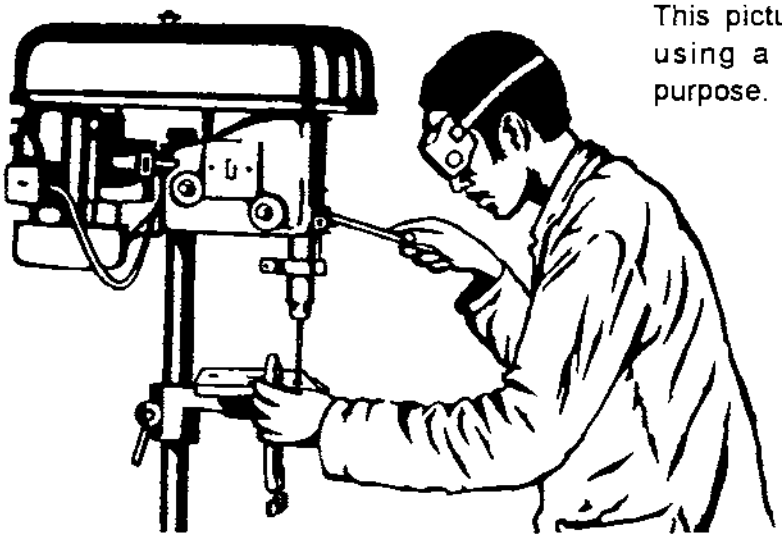

This picture shows a flange being drilled using a steel template made for the purpose.

Notice that the holes are drilled before the flanges are welded to the pump body.

Welding the S2 pump body

When the parts of the pump body and air vessel have all been cut they must be welded together. The following pictures show a suggested order in which to weld the parts. This order can be changed to suit the person doing the welding. It is important that the welder be skilled because the welds must be strong and not leak under pressure.

1 Tack-weld the risers onto the body, making sure that their tops are level.

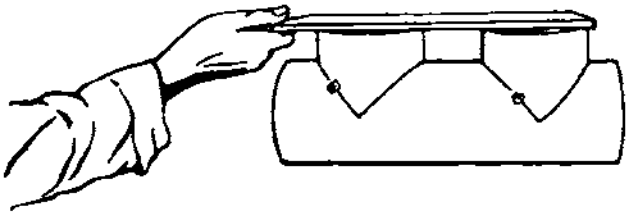

2 Weld the risers all the way around on the outside of the body.

3 Weld the end cap and the reducer 5mm inside the ends of the pump body.

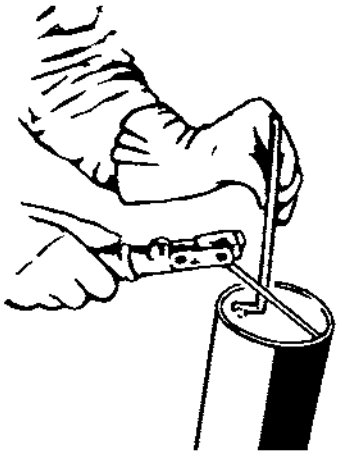

If the ends are a loose fit, tack a rod to them and hold them in place while tack-welding them. Then weld all the way around.

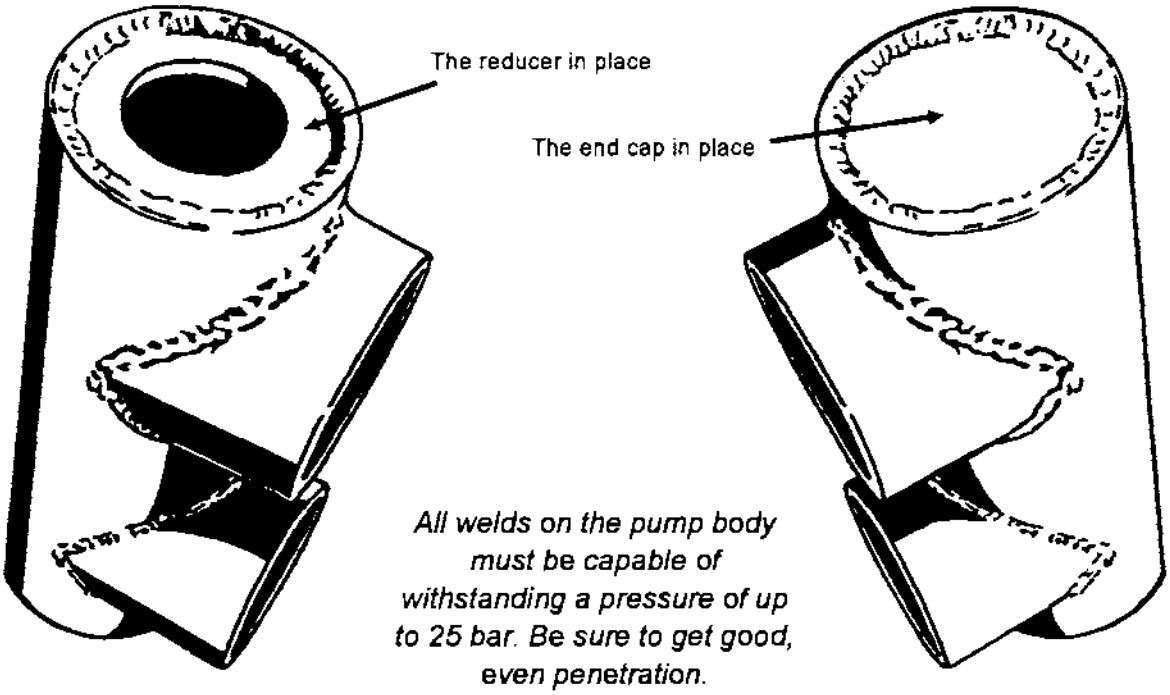

All welds on the pump body must be capable of withstanding a pressure of up to 25 bar. Be sure to get good, even penetration.

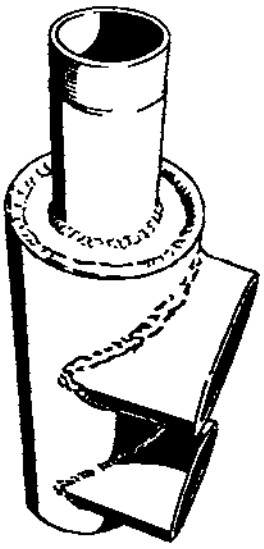

4 Weld the stub of the 2" drive pipe into the hole in the reducer. Cut a thread on one end of the stub before cutting it from a length of pipe.

5 Tack-weld the flanges onto the risers and make sure that the flanges are level, then weld all the way around.

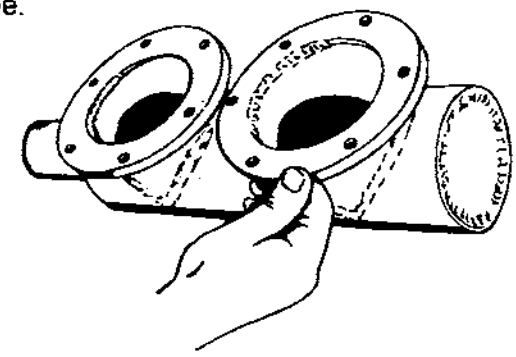

Make sure that the flange holes are not in line with the pump body.

They should be offset like this.

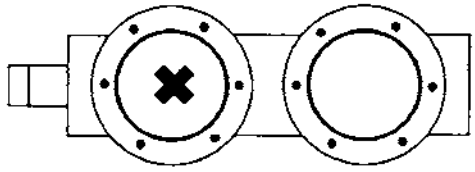

Flange hole alignment

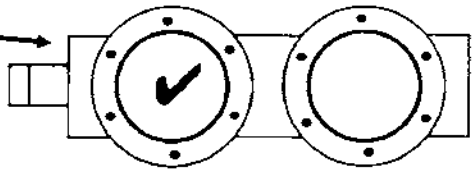

The impulse valve stop bar can later be bolted to the flange in any of the three possible positions, A, B, or C.

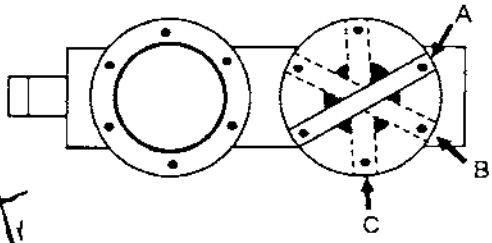

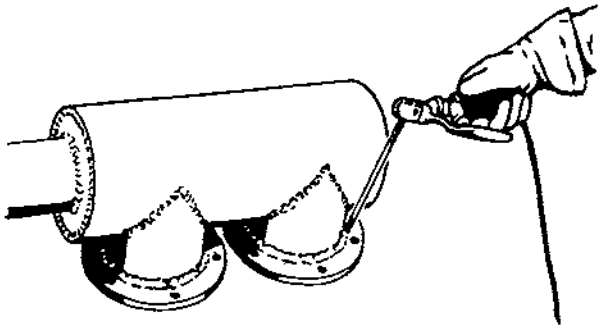

6 Turn the pump body over and weld around the flanges on the other side.

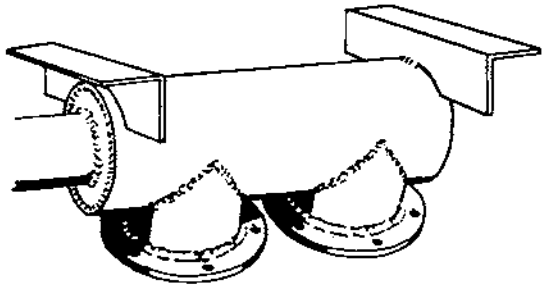

7 Tack-weld the angle iron feet to the bottom of the pump body, 5mm in from each end. Make sure that they are both level, then weld them on both sides.

Welding the S2 pump air vessel

8 Weld the air vessel End cap in place, 5mm below the top of the air vessel.

9 Weld the air vessel flange in place, being sure to get it level. Weld it inside and outside.

10 Weld the delivery pipe stub into the hole in the air vessel. Cut a thread onto the stub before you cut it from the end of a length of pipe.

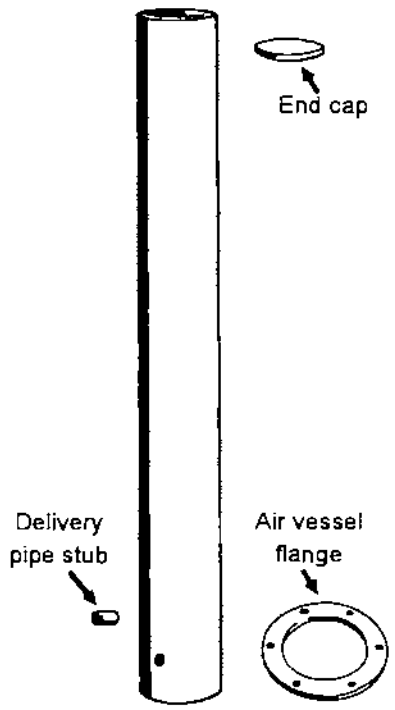

Making the S2 pump impulse valve

The valves are the most important parts of these pumps. They must be made accurately or the pump will not be as efficient as it should be and may be unreliable. If they are made carelessly, the pump may not work at all.

The valve stem rises and falls as the pump works. When it falls it pushes the plug down to allow water to flow through the central hole in the impulse valve plate. When it rises it pulls the plug up to almost block the hole, and the rubber makes a final seal.

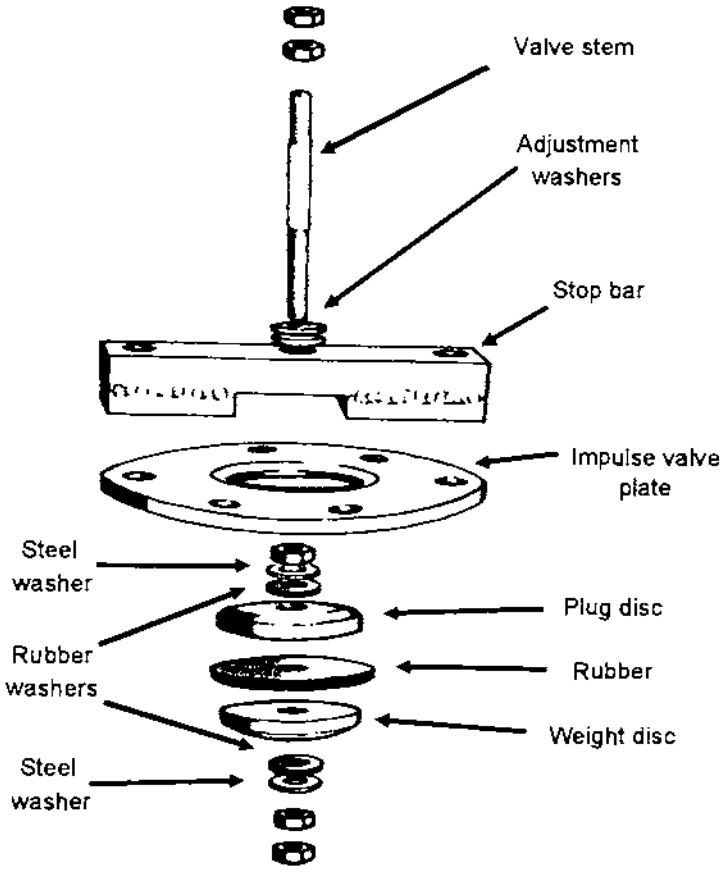

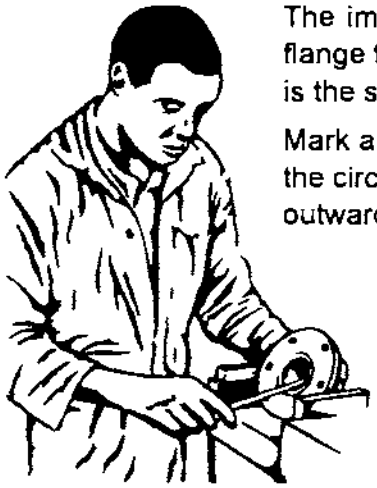

The impulse valve plate is a disc of 10 or 12mm steel plate. Use the flange template to drill holes around the outside. The outside of the disc is the same size as a flange (165mm diameter).

Mark a circle with a radius of 33mm from the centre of the disc and cut the circle out. Use a file to chamfer one side of that hole so that it slopes outward at 45°. The chamfer should be 5mm deep.

The stop bar is a 165mm length of 25mm square steel, with two 58.5mm lengths of 15 x 25mm bar welded to it. The bar is drilled to fit on top of the impulse valve plate.

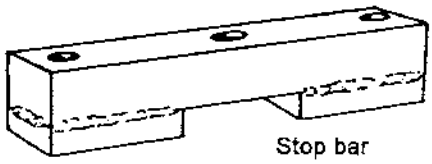

It is important that the holes are drilled upright through the bar, so use a pillar drill when you can.

Lathe alternative

Drill the holes in the stop bar and cut the threads on the valve stem with a lathe when you can.

People prefer their pumps to look good, so it is often worth grinding away any excess weld on the stop bar using a grindwheel. In the drawing alongside, a hand-held grinder is held in a vice to make a temporary bench-grinder. If you do this, make sure that the grinder is held firmly.

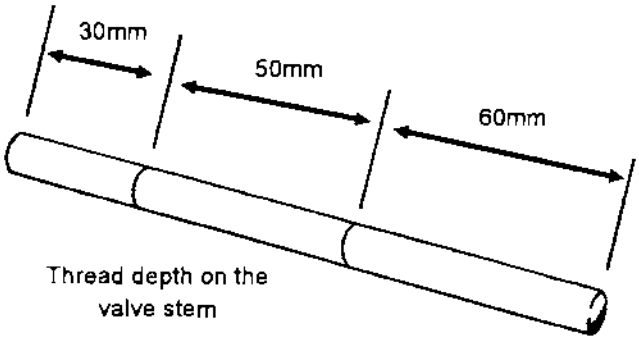

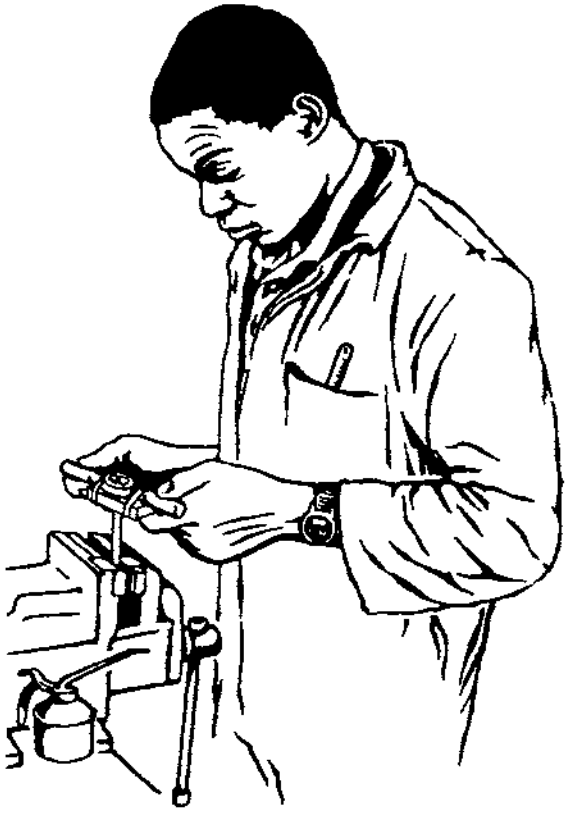

The valve stem is 140mm of 10mm stainless or mild steel bar. If plain bar is not available, reinforcing bar can be used, but it may not last as long. The bar must be straight. A slightly bent bar may break quickly when the pump is being used.

The stem must be threaded at each end. The depth of the thread is greater at the bottom than the top.

The impulse valve plug and weight discs are identical. When they are put onto the valve stem, the second is put on upside down.

Cut two 60mm disks from the same 10 or 12mm steel plate that you used for the Impulse valve plate, then drill a hole of 11mm diameter in the centre of each. It is important that the holes are straight.

One edge of each valve disc must be chamfered with a 45° angle. The chamfer should only be 3mm deep, leaving 7mm of the edge straight.

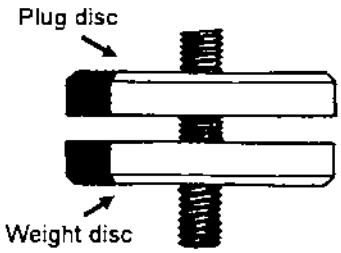

Making the S2 pump delivery valve

This is a simple flap valve. The delivery valve rubber is pushed up when the pump reaches delivery pressure, and flaps closed when the pressure drops. When the rubber is bent up, water flows through the small holes into the air vessel and into the delivery pipe.

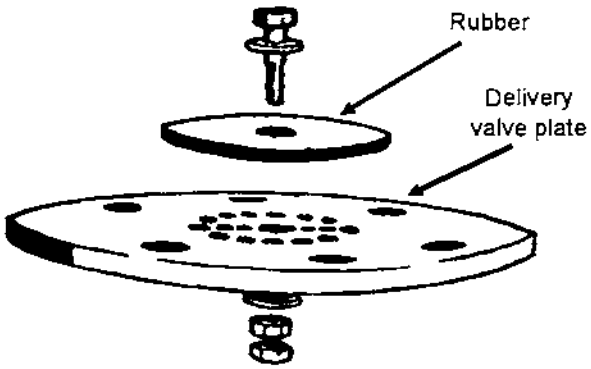

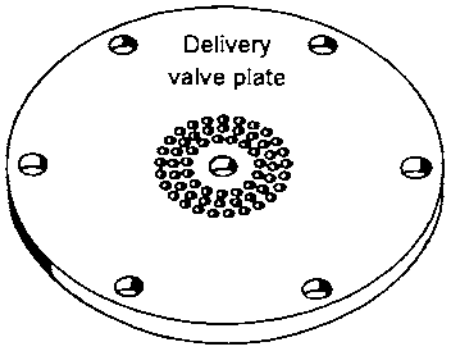

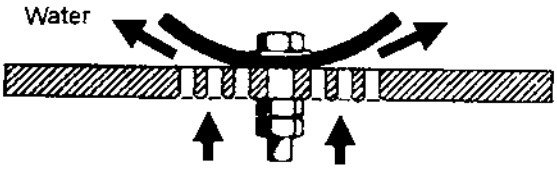

CROSS-SECTION THROUGH A DELIVERY VALVE WITH THE RUBBER OPEN

The delivery valve plate is cut from the same 10 or 12mm plate used for the flanges. You should have already chosen which of the design drawings numbers 5, 6 and 7 to use as a template. Punch through the template to mark out the holes. The central rings of holes allow water to pass through when the valve is open. To increase the flow through these holes, chamfer them using a larger drill bit (6 - 8mm) on one side of the valve plate.

The chamfered side must be underneath when the valve is put together.

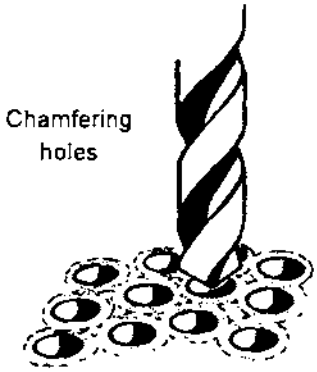

Making the S2 pump snifter valve

The snifter valve is a small flap valve in the riser furthest away from the drive pipe stub. When the pump is running, it allows a little air into the pump body. The air is pumped through the delivery valve with the water and keeps the level of air in the air vessel constant.

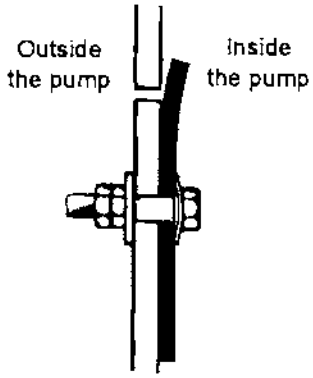

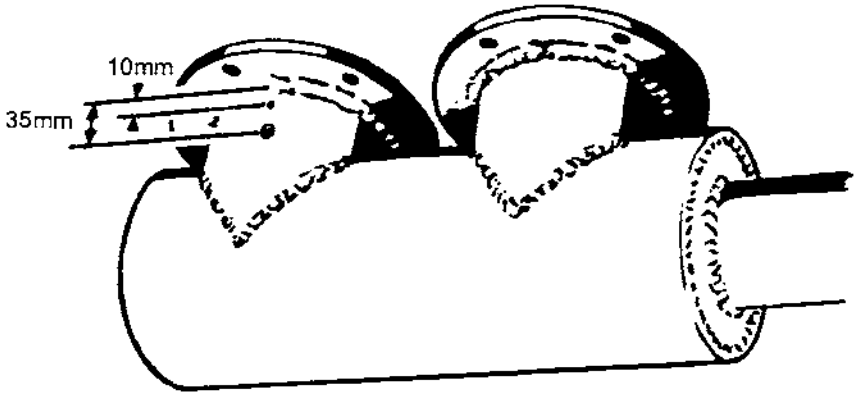

Drill a 1 or 2mm diameter hole in the riser 10mm below the bottom of the flange, (or 20mm below the top of the flange, which is the same thing). Drill a 10mm diameter hole 25mm below the first hole. The 1 or 2mm hole is the hole that air will come through.

The rubber flap inside the pump body must sit flat against the side of the riser. Because the riser is curved, you must file away parts of the bolt head and bend a washer as shown in the drawing. Then, when the bolt is tightened, the rubber flap will be able to sit flat. Be careful not to tighten the bolt enough to distort the rubber. Usually it is enough to tighten the nut with your fingers, then lock another against it using spanners.

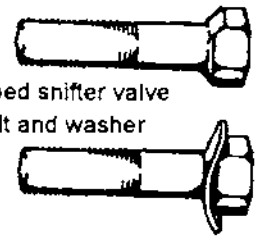
Shaped snifter valve bolt and washer

It is very important for the air in the air vessel to remain at a constant level, so it is essential that the snifter valve is fitted and working properly. If it does not work properly, the pump will be less efficient, and may even be damaged.

Rubber parts

You will need valve rubber and flange gasket rubber to complete an S2 pump.

Flange gaskets are usually made using old inner tube rubber. Make sure that it is not so old that it has started to perish, and try to select an area where it is more or less the same thickness. On some tubes, especially those made for big wheels, the rubber can be twice as thick in some places as others. Using the flange template as a guide, cut the big circles using a sharp knife. The bolt holes should be punched out using a 10mm hole punch. This leaves clean holes on which the threads of the bolts do not catch.

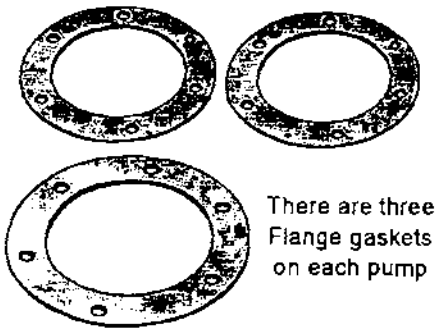
There are three Flange gaskets on each pump

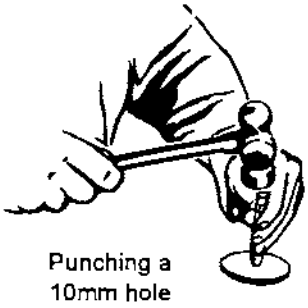

Punching a 10mm hole

Delivery valve rubber

Impulse valve rubber

Inner tube rubber can also be used for the snifter valve rubber disc.

The large impulse valve rubber must be stiff but the delivery valve rubber has to bend easily. The impulse valve rubber should be about 6mm thick. Thicker rubber will probably be all right, but do not use thinner rubber. The delivery valve rubber should be about 3mm thick. Delivery valve rubber can also be used for the small impulse valve rubber washers above and below the impulse valve discs. We have used rubber made for shoe repairs and offcuts of conveyor belt when we cannot buy rubber sheet easily.

The pump cradle

You should not make and sell a pump without including a pump cradle. If a ram pump is not securely fixed during use, it will break, and may break the connecting pipework too.

It is important that you use steel strong enough to hold the pump firmly, and that the cradle is buried in a strong concrete base. The pump tries to vibrate when operating and will soon shake itself loose from an insecure base.

Use 40mm angle-iron, about 5mm thick, to make the cradle. It can be extended to support two pumps when needed.

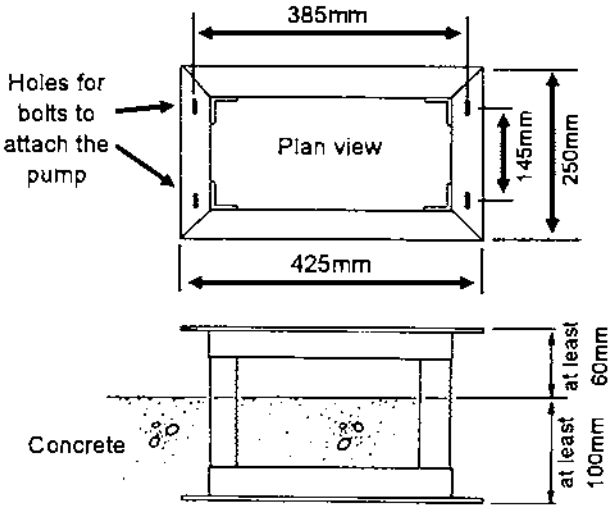

SECTION THROUGH A CRADLE INSTALLED ON A CONCRETE BASE

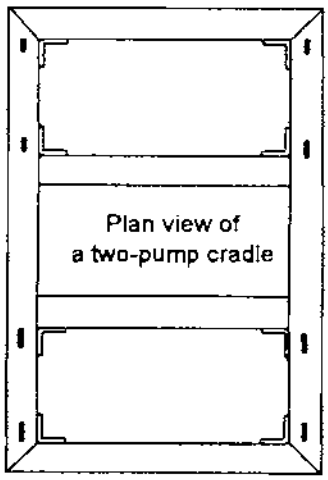

The pump is attached to the cradle by the angle iron feet that you have welded to the bottom of the body. Notice that the holes are slotted so that the pump can be moved from side to side slightly to allow for small mistakes in drive pipe alignment. The cradle must stand up from the concrete far enough to make it easy to reach the fixing nuts.

Assembly and testing

Putting the pump together properly is very important. The process of assembling the valves is described here, including some simple ways of testing them. Paint all the metal parts you have made before you assemble them for the final time. You may like to assemble them loosely before painting to check that everything is OK. To make the pump last longer, it should be painted inside and out with a metal primer, then a good enamel paint.

Assembling the impulse valve

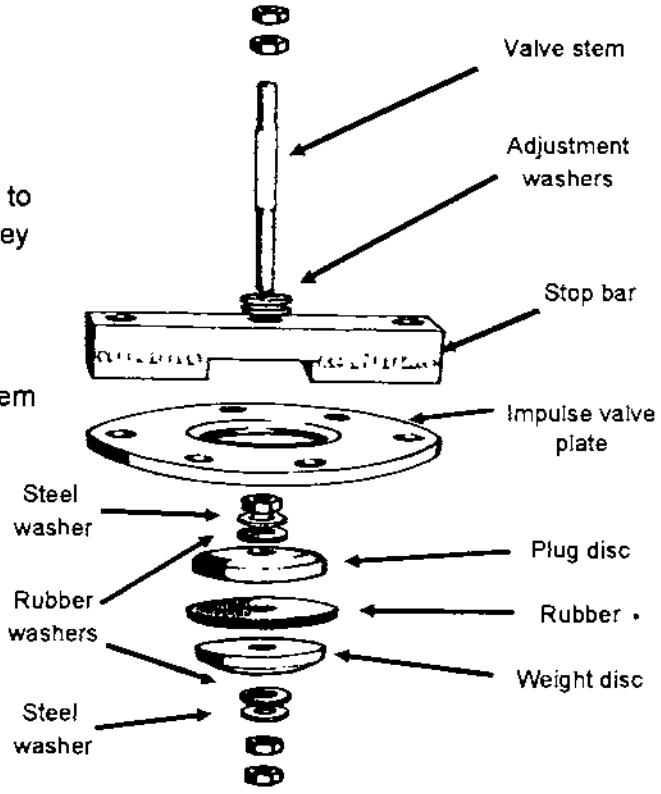

The impulse valve design drawings, numbers 9, 19, 11 and 12, are also templates. Start by holding each part against the drawing of it on the template to check that the dimensions are right. If they are not right, either adjust them or make them again.

When the parts are all the right size, thread a nut onto the end of the valve stem that has a longer thread. This will be the bottom of the valve stem. Screw the nut to the end of the thread and use a spanner to lock it there. Then push a steel washer and a rubber washer up to the nut. Put the plug disk onto the stem, with the chamfered edge towards the nut and washers already there. Then push the impulse valve rubber over the stem up to the plug disc. Put the weight disc over the stem with the chamfered edge facing away from the valve rubber. Then push a rubber washer and a steel washer up to the weight disc. Thread on a nut up to the washer. Thread it on finger tight. If you use a spanner, do not tighten it so that it squashes the rubber washers. Hold the nut with a spanner and use another spanner to lock a second nut against it. The valve stem should look like the one in the drawing below.

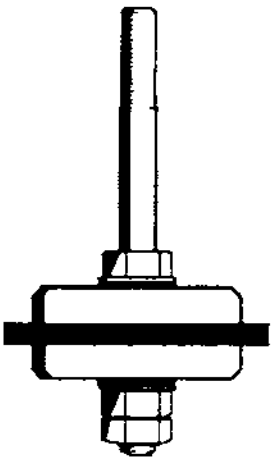

Push the stem up through the Impulse valve plate and through the stop bar. Drop two washers over it and thread on two nuts. Lock them lightly against each other. They should be adjusted when the pump is installed, so do not over-tighten them.

When the valve has been assembled, bolt it to the pump with a rubber gasket between the impulse valve plate and the flange on the pump. The impulse valve goes on the riser furthest away from the drive pipe stub. Tighten all the bolts on the flange except the two holding the stop bar in place. Put nuts on these but leave them finger tight.

Check that the impulse valve can move freely up and down without the plug disc catching on the sides of the hole in the Impulse valve plate. If it does catch, push the stop bar away from the side that catches. The stop bar has a small amount of movement between the bar and the threads of the bolts holding it.

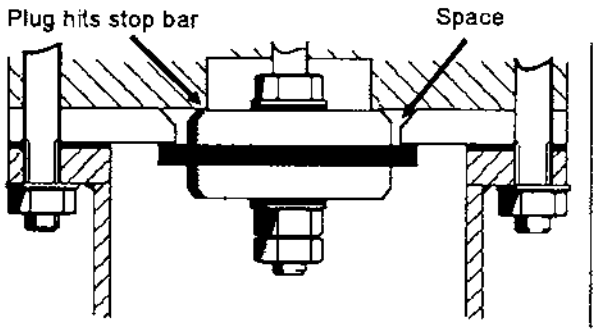

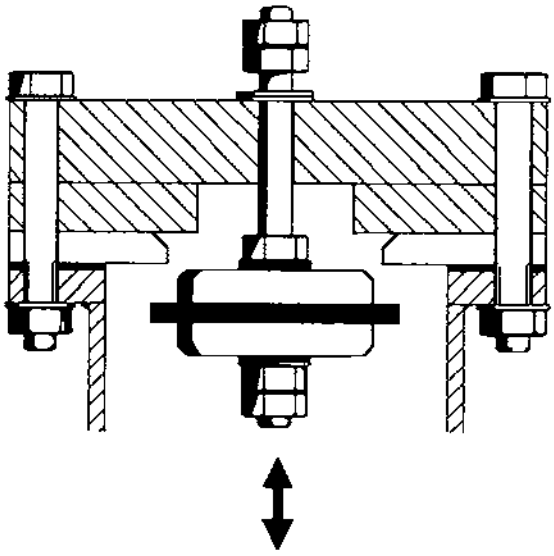

There should be a space all the way around between the side of the plug disc and the Impulse valve plate. If the pump has been made exactly to the measurements, the space will be 3mm. If it is less than 1mm, you should take the valve apart and check the parts against the templates. If the plug disc is too large you may be able to make it smaller. If the hole in it is not in the centre, you will probably have to make another. If the hole in the impulse valve plate is too small or not round, you may be able to file it out. Do not file it so that the hole is bigger than 66mm as shown in design drawing number 10. The plug disk must also hit the stop bar all the way around. Turn the plug disk to make sure that this is so.

Assembling the delivery valve

The delivery valve must be assembled so that the nuts are tight on the bolt, but the bolt has some up and down movement. This is shown on the drawing below. When the bolt head is pressed down against the washer and rubber on top of the delivery valve plate, there should be a gap on the underside of 1 to 2mm between the plate and the washer.

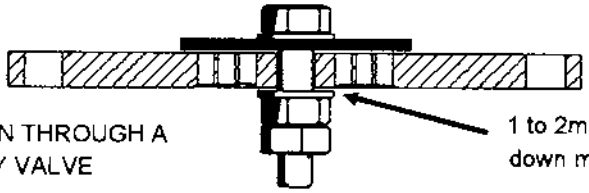

CROSS SECTION THROUGH A DELIVERY VALVE

To assemble the valve put a washer over a 40mm M10 bolt and push it through the delivery valve rubber. Make sure that the rubber moves freely on the bolt. It the hole in the centre was cut out with a hole punch, it should move freely up and down. If the rubber distorts when it is pushed over the bolt, you must make the hole in the middle bigger. This can sometimes be done with a round file or a stick with emery paper wrapped around it.

Check that there are no rough edges on the holes in the delivery valve plate then push the bolt through it. The chamfer on the delivery valve holes should be on the underside of the plate, away from the bolt head. Push on a washer and thread on a nut, leaving 1 to 2mm up and down movement in the bolt. Use a feeler-gauge if you have one, or do up the nut with your fingers until it starts to get tight, then unscrew it one full turn. Use spanners to lock a second nut against the first, then check that there is still enough up and down movement. It should be at least 1mm and not more than 2mm.

Assembling the snifter valve

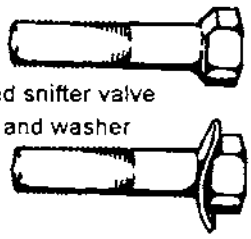

Shaped snifter valve bolt and washer

The snifter valve rubber must sit flat against the inside curve of the riser below the delivery valve. To make this happen you must shape a nut and washer as shown on page 15.

Make sure that there are no rough edges on the inside of the two holes you have drilled through the riser on the pump body. Even a small burr can stop the valve working properly. Also make sure that the holes have not been blocked by paint.

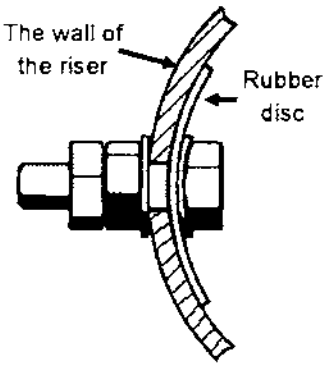

CROSS SECTION of the snifter valve assembly from above

To assemble the valve, push the rubber over the bolt up against the shaped washer. Make sure that the rubber moves freely on the bolt. It the hole in the centre was cut out with a hole punch, it should move freely up and down. If the rubber distorts when it is pushed over the bolt, you must make the hole in the middle bigger. Then push the bolt through the riser on the pump body. Make sure that the rubber disc covers the small snifting hole in the riser. Be sure to use a disc of rubber rather than a smaller flap. If the disc turns it will still cover the snifting hole.

Push a washer over the thread outside the pump body and thread a nut onto it. Holding the head inside the pump, tighten the nut half a turn with spanner. Check that the rubber disc has not distorted. If it has, slacken the nut off until the rubber disc sits flat against the riser. When the disk sits flat and there is no play in the nut and bolt, use spanners to lock a second nut against the first.

Spare parts

It is important that you make the pump parts carefully to match the dimensions given on the design drawings. Then, if a part needs to be replaced, it can be made from the drawings and taken to the pump. If the parts are made carelessly, the pump may have to be brought to the workshop so that you can make a part that fits.

The DTU S2 ram pump costs much less than any commercial pump we have seen. It is made using materials and tools that are widely available. The disadvantage of this is that some parts will wear out or fail more quickly than they do on expensive pumps. The parts that have failed in the past are the rubber discs and the valve stem. You should make spares of these and supply them with the pump. A valve stem made from stainless steel usually lasts a lot longer than a stem made from mild steel. After the pump has been taken apart a few times it may also need a new flange gasket. The head or the thread on a bolt or nut may also get damaged, so the pump should be supplied with a few extra nuts, bolts and washers of the right size.

Provide these spares with each pump:

- a spare impulse valve stem;
- spare impulse and delivery valve rubbers;
- 2 spare flange gaskets.
- 1 spare 40mm M10 nut and bolt;
- 1 spare 80mm M10 nut and bolt;
- 2 spare 50mm M10 nuts and bolts;
- 4 spare M10 nuts and 6 spare washers.

If the impulse valve discs are not made carefully with their holes in the centre, the valve plug disk may not turn freely in the hole in the valve plate. It may not strike the stop bar on both sides all the time when the valve plug is turned through 360°. This may also happen if the hole in the middle of the stop bar is not drilled absolutely vertically through it. If you find these faults, you must make the parts again.

Optional addition

The addition of a "bleed" screw in the air vessel can make it easier to find out what is wrong with a pump when it does not perform properly. It can also make the pump easier to maintain.

Many commercially available pumps have a bleed screw on the air vessel. The screw is opened to check that there is enough air in the air vessel, and to let out the water when there is too much. It is also a useful way of letting the pressure out of the air vessel when you want to take it apart for maintenance.

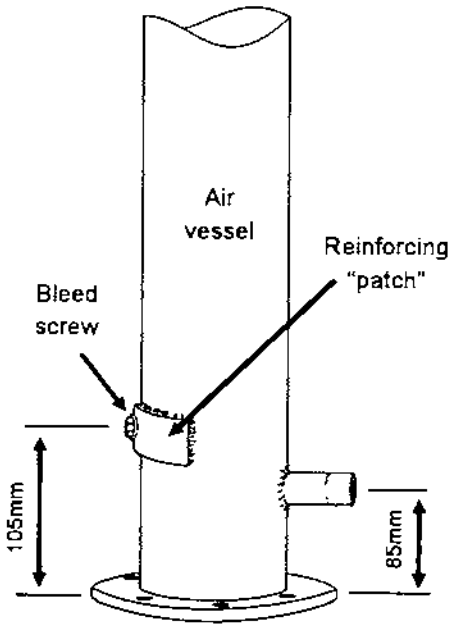

The bleed screw should be position just above the delivery pipe stub on the other side of the air vessel.

The pressure in the air vessel can get very high, so the bleed screw and its thread must be made carefully to prevent it leaking. To make the thread longer and more secure, a "patch" cut from the same 4" pipe as the air vessel should be welded over the area first. Then you drill a hole through the patch and the wall of the air vessel. Cut a thread in the hole so that an M10 bolt will screw into it.

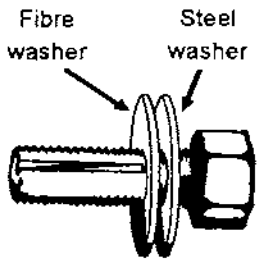

The thread on the bolt used should be 30mm long. Holding the head of the bolt in a vice, use a hacksaw to cut a shallow slot along the threads. Do not cut more than 1mm deeper than the bottom of the thread. When the hacksaw blade hits the bolt head, stop. The bolt should look like the one in the drawing alongside. You will need to use a steel and a fibre washer under the bolt head to make a good seal.

To bleed air or water from the air vessel, simply undo the bolt a few turns until air starts to hiss out, or water to spray out.

DRAWINGS

1	An Exploded View of the DTU S2 Pump
2	DTU S2 Pump Body
3	DTU S2 Pump Flange
4	DTU S2 Air Vessel
5,6,7	Delivery Plates 1, 2 & 3 *[Original]*
8	Snifter and Delivery Valve Assemblies
9	Impulse Valve Assembly
10	Impulse Valve Plate
11	Impulse Valve Stop Bar *[Original]*
11a	Two-Stage Impulse Valve Stop Bar / Guide *[Amendment]*
12	DTU S2 Impulse Valve Discs and Stem
13	DTU S2 Gasket *[Amendment]*
14	Plate for Alternative Delivery Valve *[Amendment]*
14a	(Alternative) Delivery Valve Rubber and Retaining Bar *[Amendment]*

DTU S2 pump
Design drawings

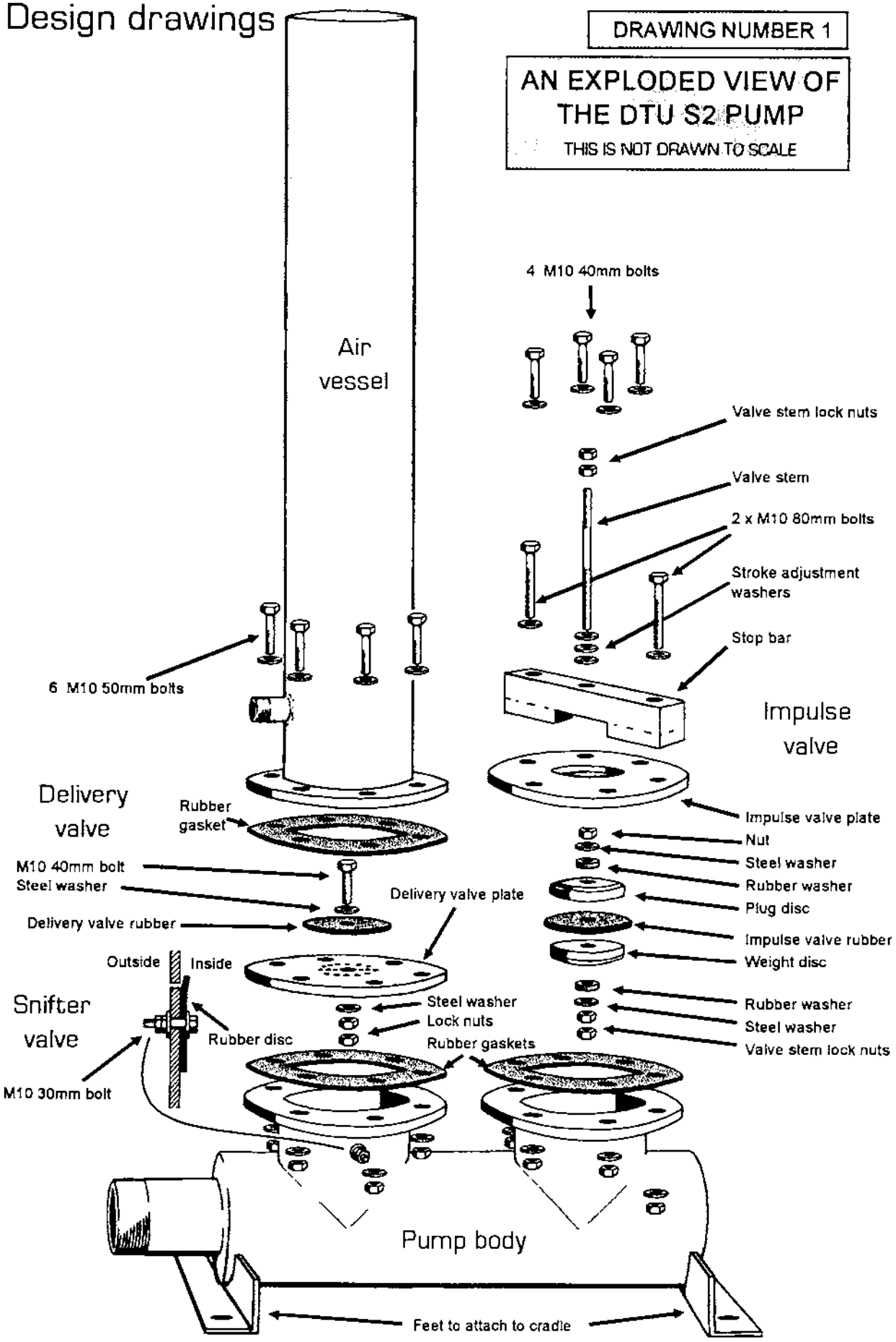

CROSS SECTION THROUGH THE MIDDLE OF THE PUMP BODY
that is from A to A on the plan drawing below

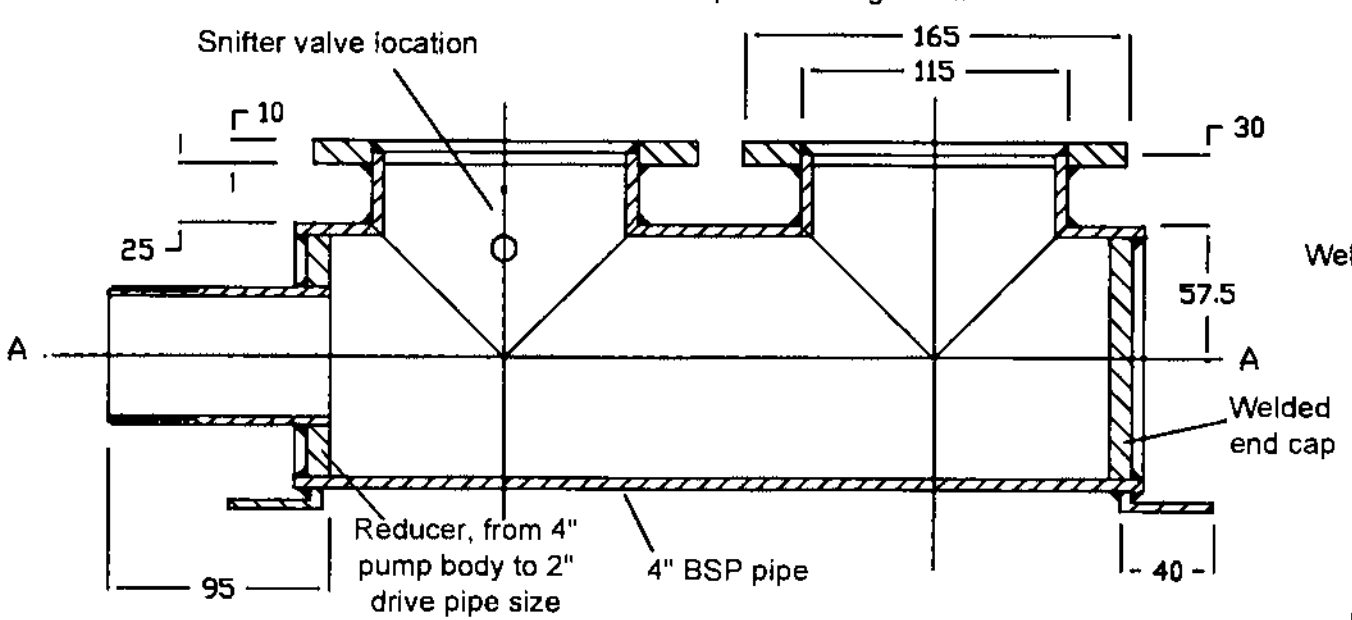

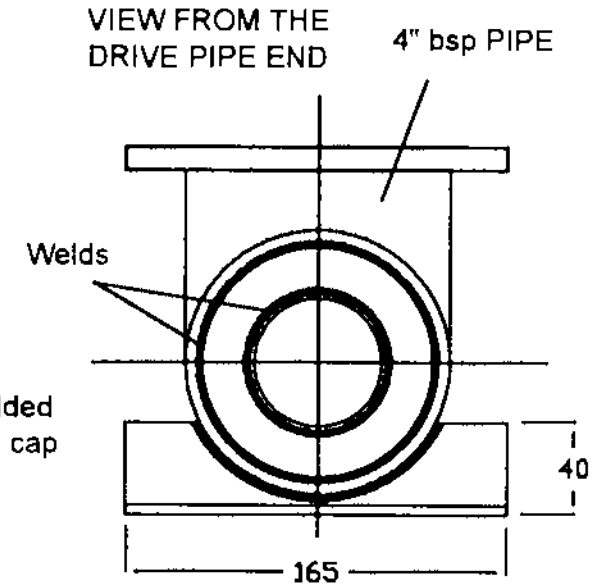

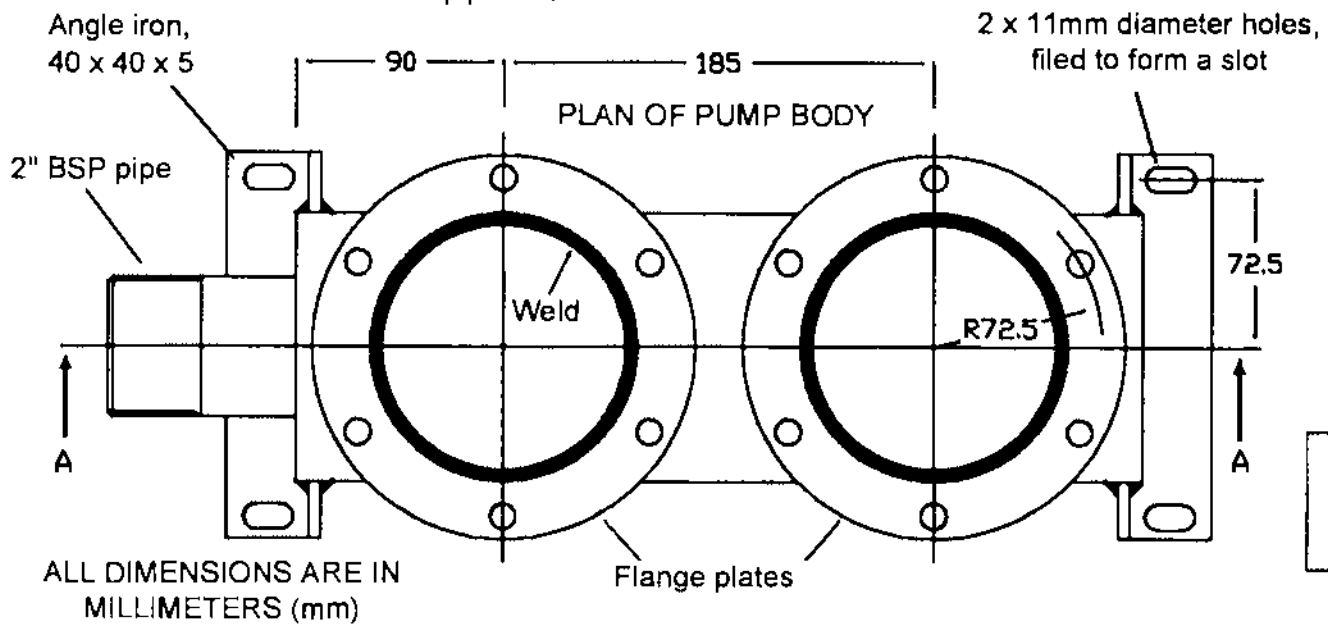

MATERIALS

PIPE: the pipe used is mild steel with a 4" (115mm) outside diameter and an inside diameter of 105mm.

PLATE: the plate is mild steel either 10 or 12mm thick.

ANGLE IRON: use 40 x 40mm angle iron, about 5mm thick. Use bigger angle iron if this size is hard to get.

ALL THE JOINTS SHOULD BE WELDED

DRAWING NUMBER 2

DTU S2 pump body

NOT DRAWN TO SCALE

DTU S2 PUMP FLANGE

DRAWING NUMBER 3

see also Drawing No 13

PLAN VIEW OF A FLANGE

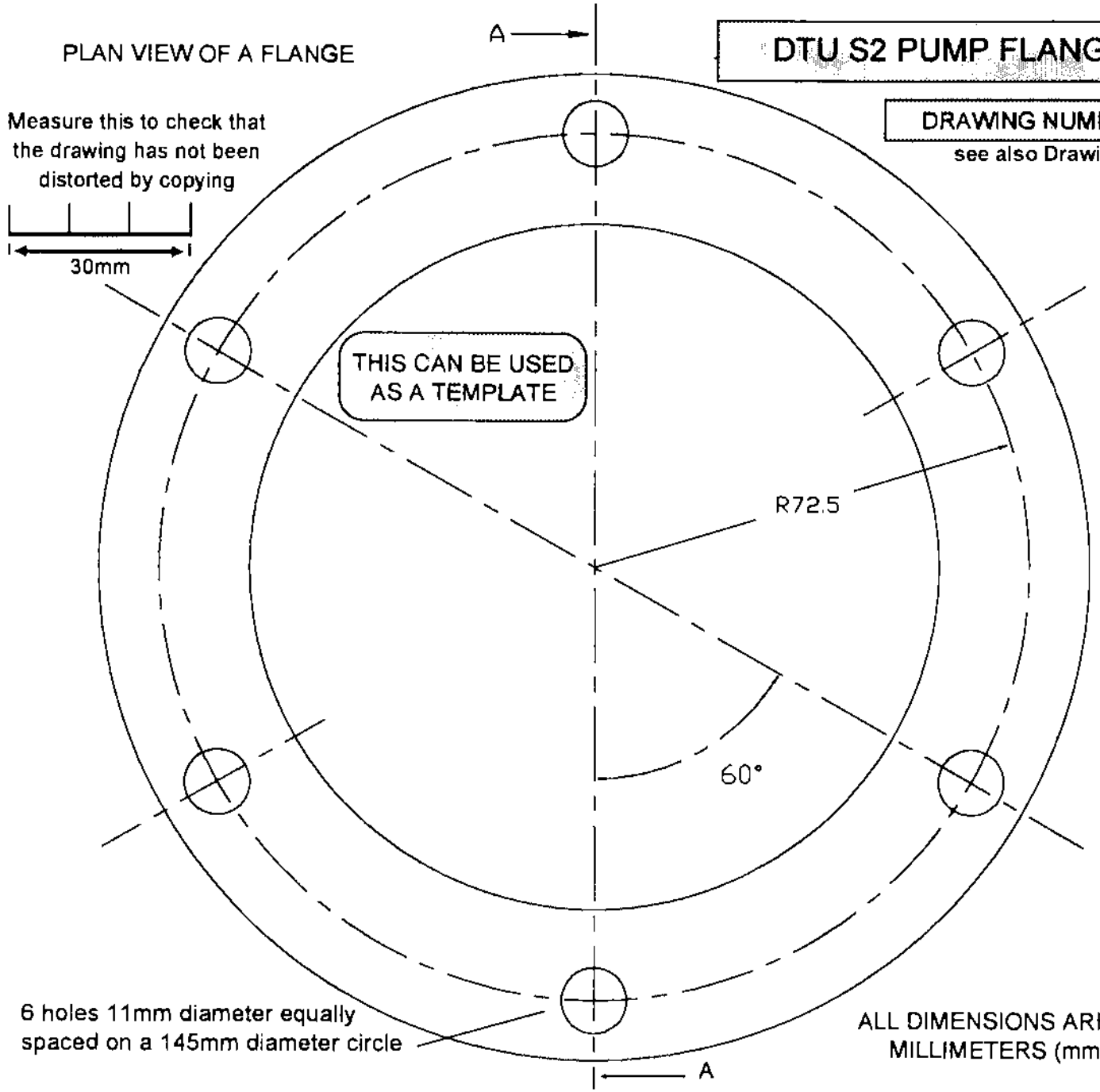

ALL DIMENSIONS ARE IN MILLIMETERS (mm)

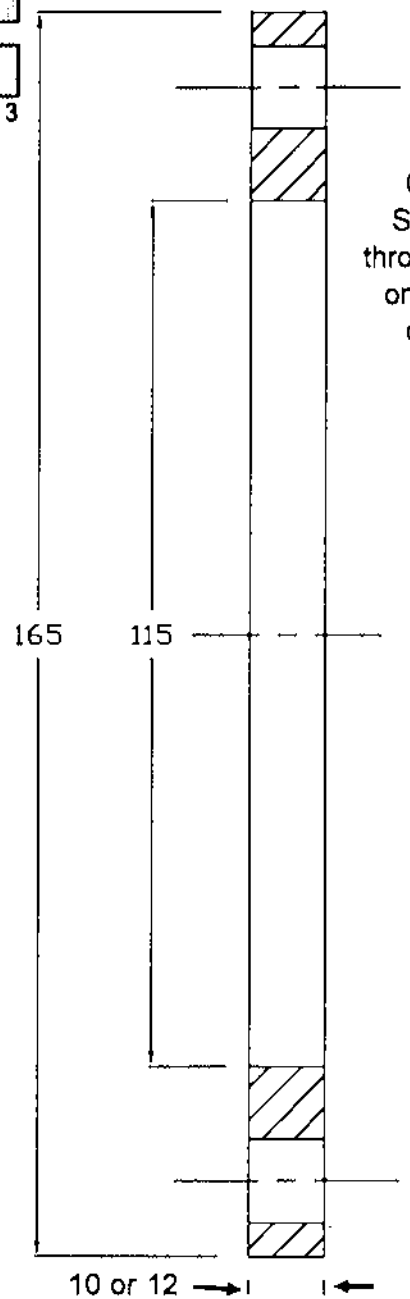

CROSS SECTION through A to A on the plan drawing

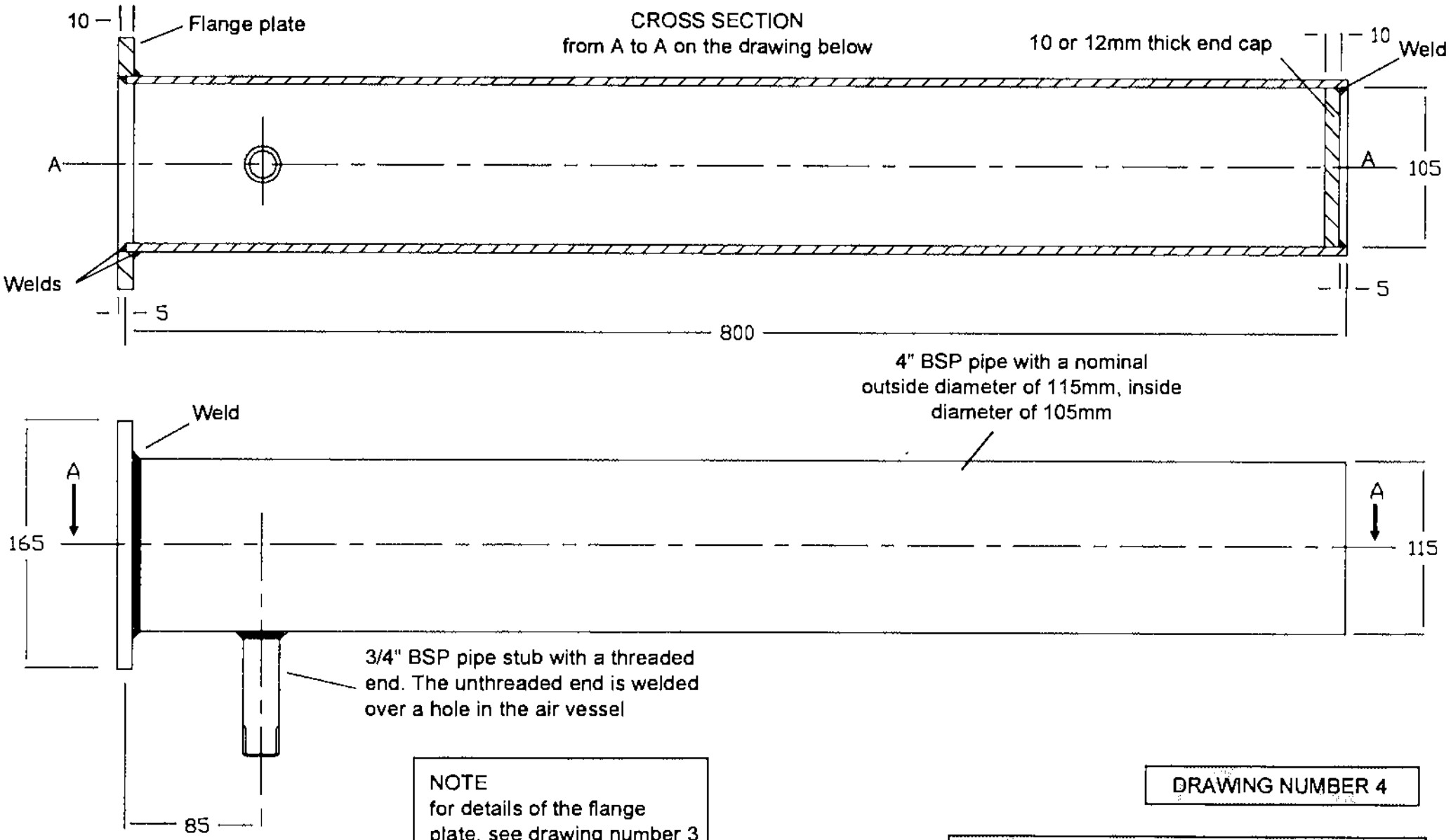

NOTE
for details of the flange plate, see drawing number 3

ALL DIMENSIONS ARE IN MILLIMETERS (mm)

DRAWING NUMBER 4

DTU S2 AIR VESSEL

NOT DRAWN TO SCALE

DELIVERY VALVE PLATE 1

Suitable for delivery heads over 75 meters
DRAWN TO SCALE: 1:1

DRAWING NUMBER 5

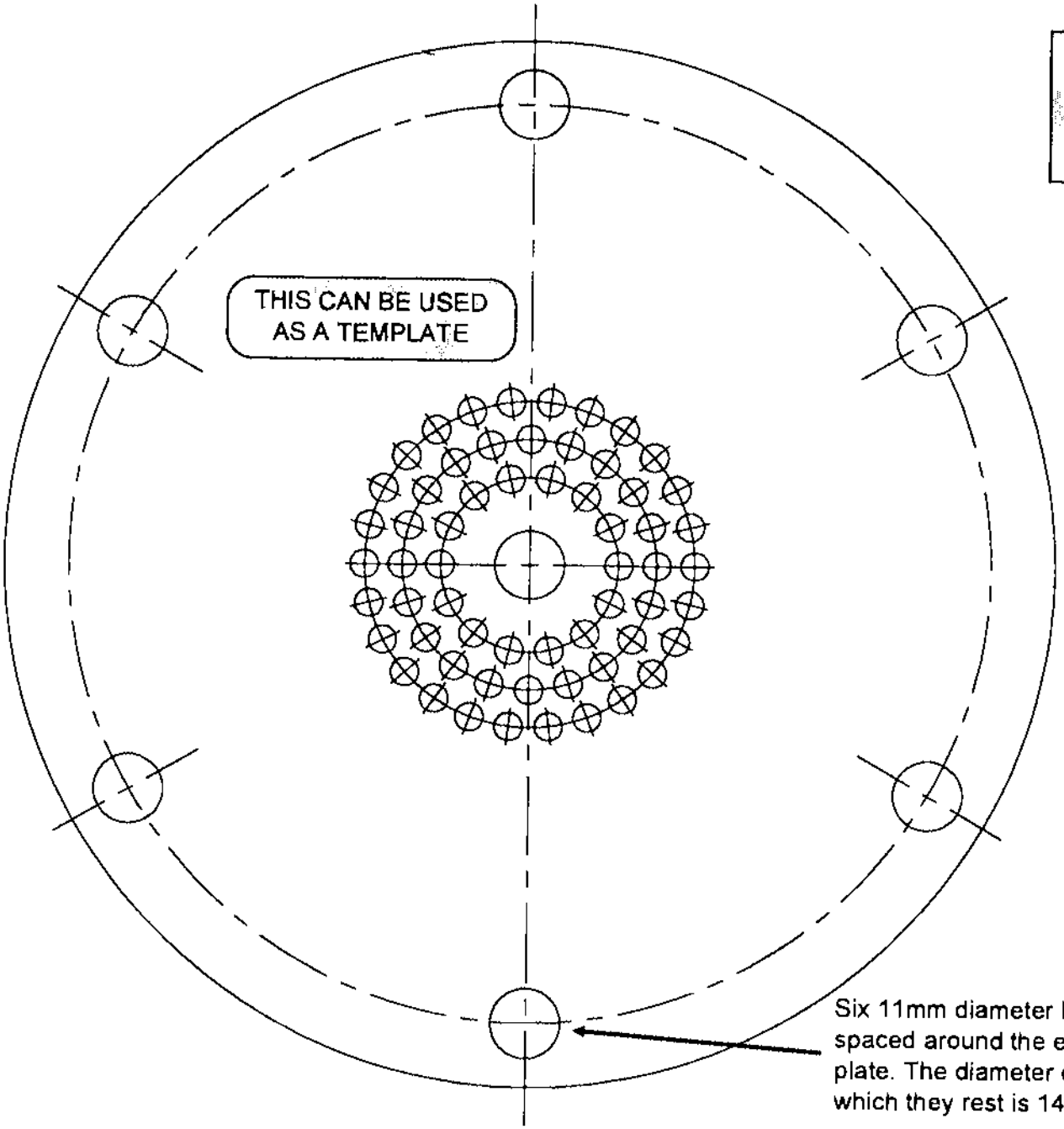

NOTES

The centre hole is 10.5mm in diameter.

The rings of holes are 4.5mm in diameter. They are equally spaced on circles drawn from the centre with a radius of 14, 20 and 26mm. All these holes must be deburred and chamfered on one side. The chamfered side will be the underside of the delivery valve.

The valve rubber diameter is 64mm and it should be at least 3mm thick.

The plate should be 165mm in diameter and 10 or 12mm thick.

Six 11mm diameter holes are equally spaced around the edge of the valve plate. The diameter of the circle on which they rest is 145mm.

Measure this to check that the drawing has not been distorted by copying

Six 11mm diameter holes are equally spaced around the edge of the valve plate. The diameter of the circle on which they rest is 145mm.

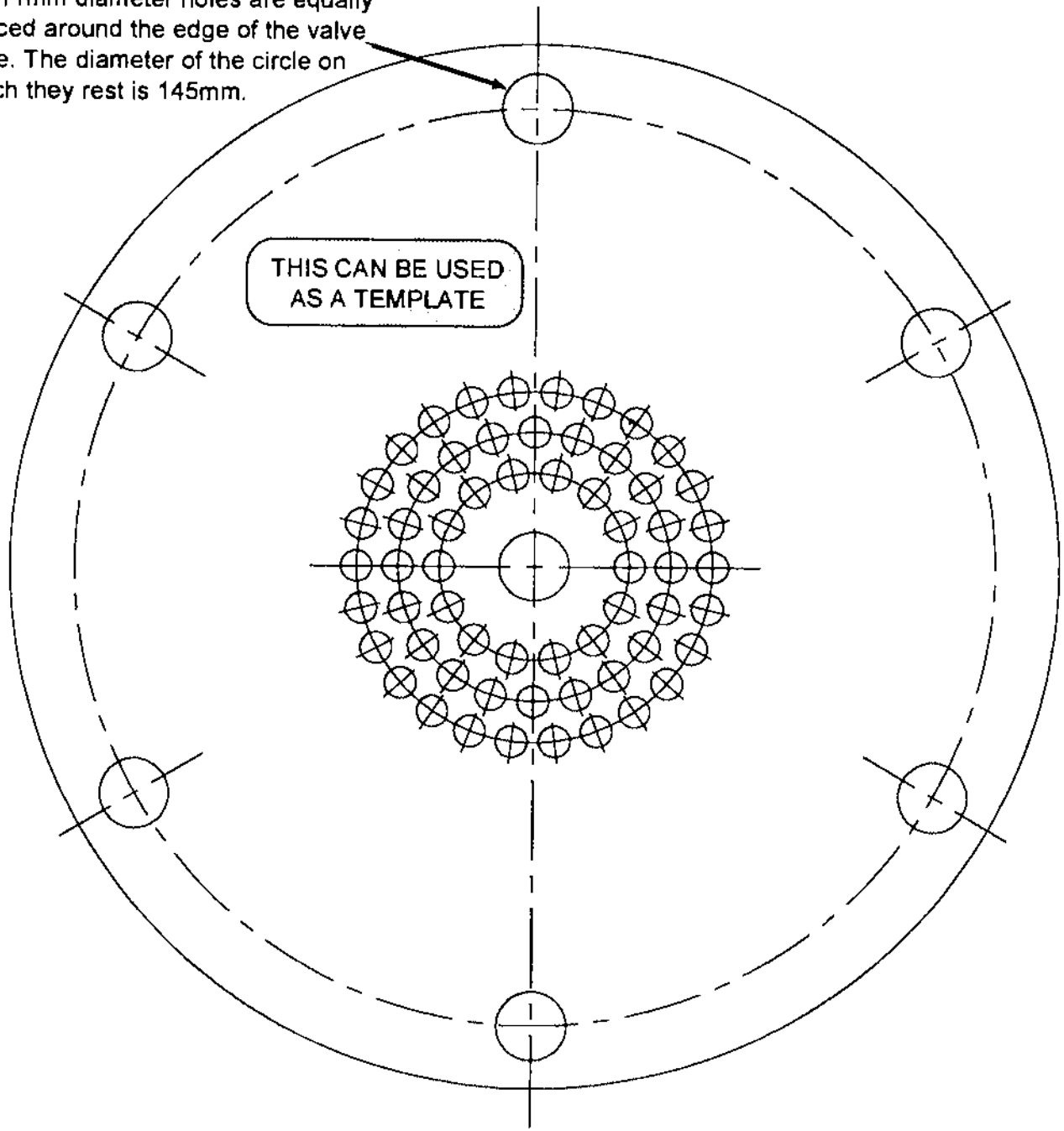

Measure this to check that the drawing has not been distorted by copying

NOTES

The centre hole is 10.5mm in diameter.

The rings of holes are 5mm in diameter. They are equally spaced on circles drawn from the centre with a radius of 15, 21.5 and 28mm. All these holes must be deburred and chamfered on one side. The chamfered side will be the underside of the delivery valve.

The valve rubber diameter is 68mm and it should be at least 3mm thick.

The plate should be 165mm in diameter and 10 or 12mm thick.

DRAWING NUMBER 6

DELIVERY VALVE PLATE 2

Suitable for delivery heads of 35 to 75 meters

DRAWN TO SCALE: 1:1

DELIVERY VALVE PLATE 3

Suitable for delivery heads up tp 35 meters
DRAWN TO SCALE: 1:1

DRAWING NUMBER 7

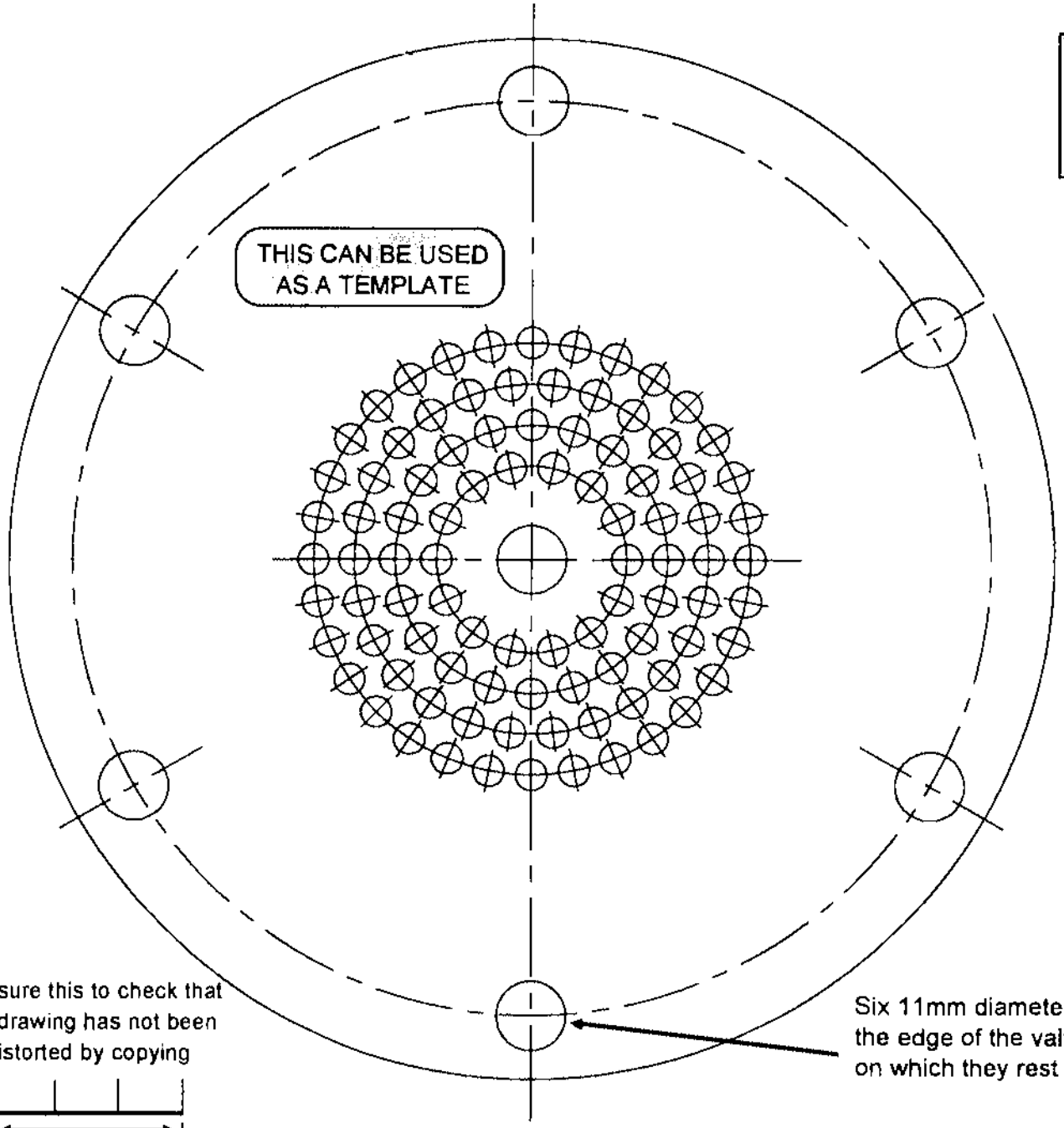

NOTES

The centre hole is 10.5mm in diameter.

The rings of holes are 5mm in diameter. They are equally spaced on circles drawn from the centre with a radius of 15, 21.5, 28 and 34.5mm. All these holes must be deburred and chamfered on one side. The chamfered side will be the underside of the delivery valve.

The valve rubber diameter is 80mm and it should be at least 3mm thick.

The plate should be 165mm in diameter and 10 or 12mm thick.

Six 11mm diameter holes are equally spaced around the edge of the valve plate. The diameter of the circle on which they rest is 145mm.

Measure this to check that the drawing has not been distorted by copying

30mm

CROSS SECTION THROUGH THE SNIFTER VALVE ASSEMBLY

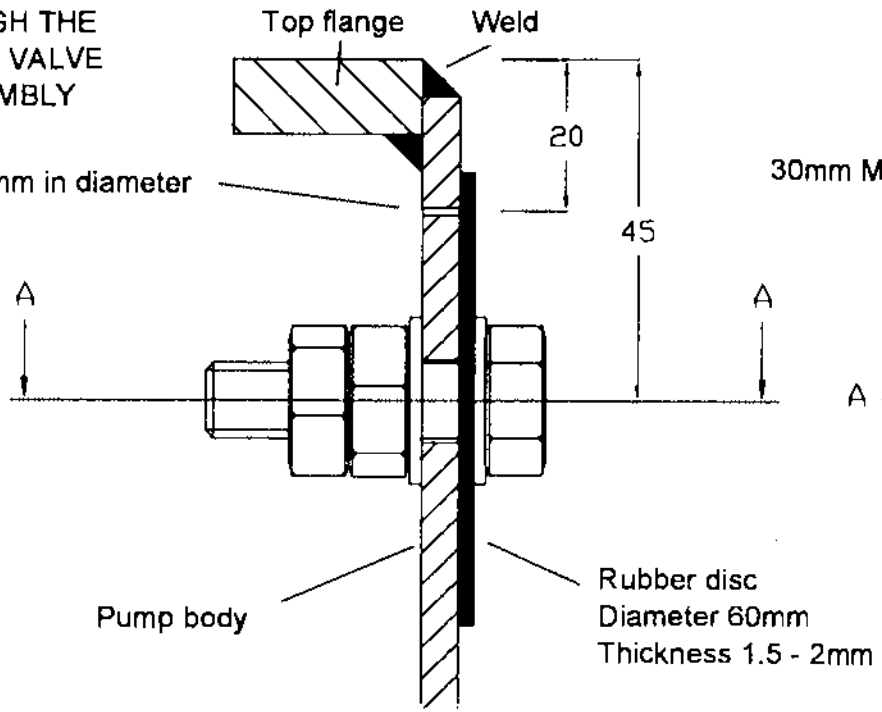

PLAN VIEW CROSS SECTION
that is from A to A on the assembly drawing

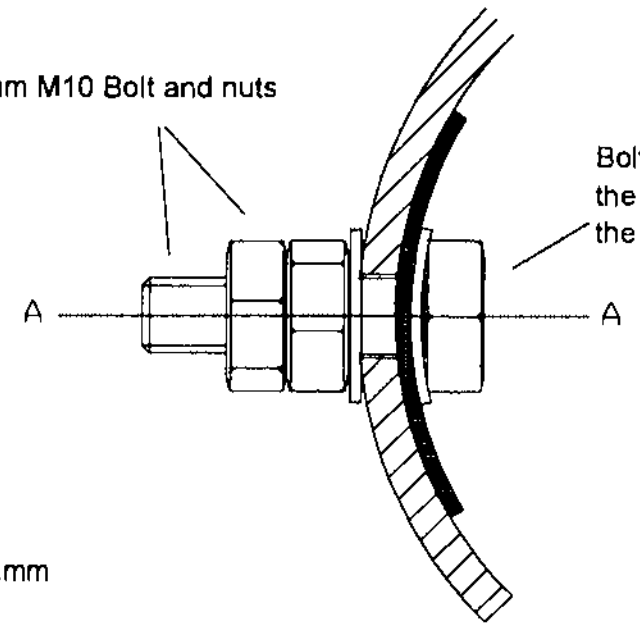

Measure this to check that the drawing has not been distorted by copying

CROSS SECTION THROUGH THE DELIVERY VALVE ASSEMBLY

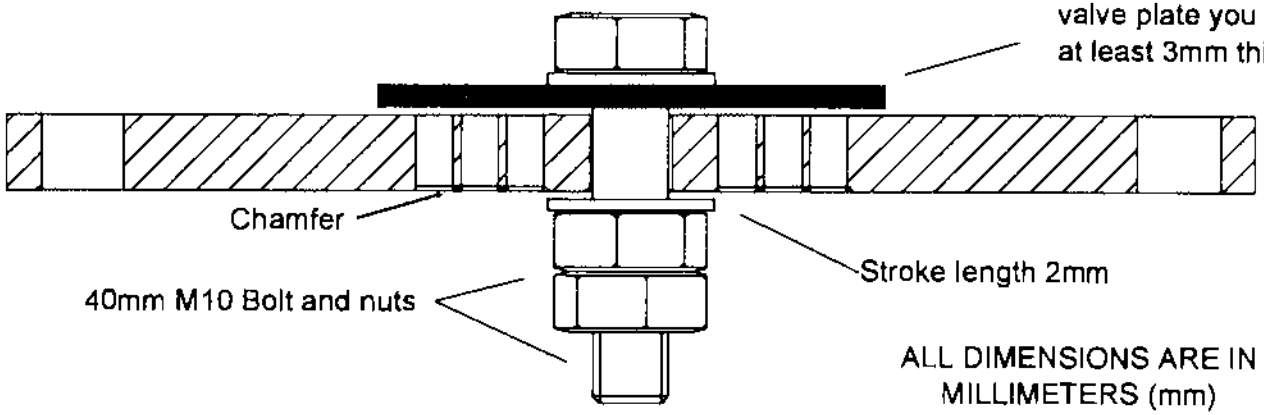

ALL DIMENSIONS ARE IN MILLIMETERS (mm)

DRAWING NUMBER 8

SNIFTER AND DELIVERY VALVE ASSEMBLIES

DRAWN TO SCALE: 1:1

IMPULSE VALVE ASSEMBLY

DRAWN TO SCALE: 1:1

DRAWING NUMBER 9

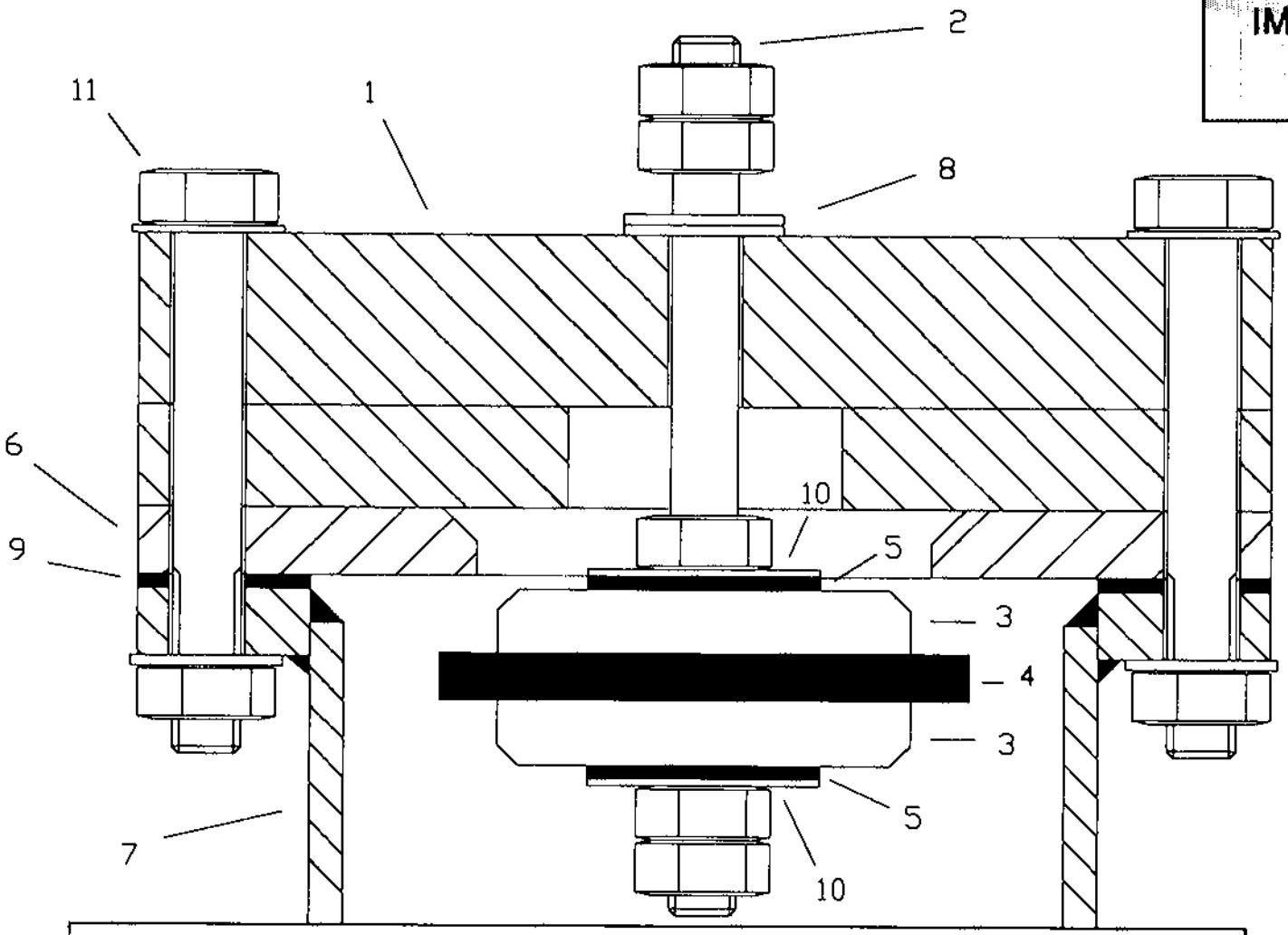

PARTS LIST

1 - Stop bar
2 - Valve stem
3 - Valve disc (x2)
4 - Rubber disc
5 - Rubber washer (x2)
6 - Valve plate
7 - Pump body
8 - Stroke adjustment washers
9 - Rubber gasket
10 - Large steel washers, about 35mm in diameter (x2)
11 - M10 Bolts, nuts and washers

BOLTS

M10 x 80mm (x2)
M10 x 40mm (x4)

NOTES

The rubber disc (4) is 76mm in diameter and 6mm thick. Do not use a larger disc.

The rubber washers (5) are made to the same diameter as the steel washers (10) and can be 1.5 to 3mm thick.

The rubber gasket (9) can be 1.5 to 3mm thick and is cut to match the pump body flange. Drawing number 3 can be used as a template.

Measure this to check that the drawing has not been distorted by copying

30mm

ALL DIMENSIONS ARE IN MILLIMETERS (mm)

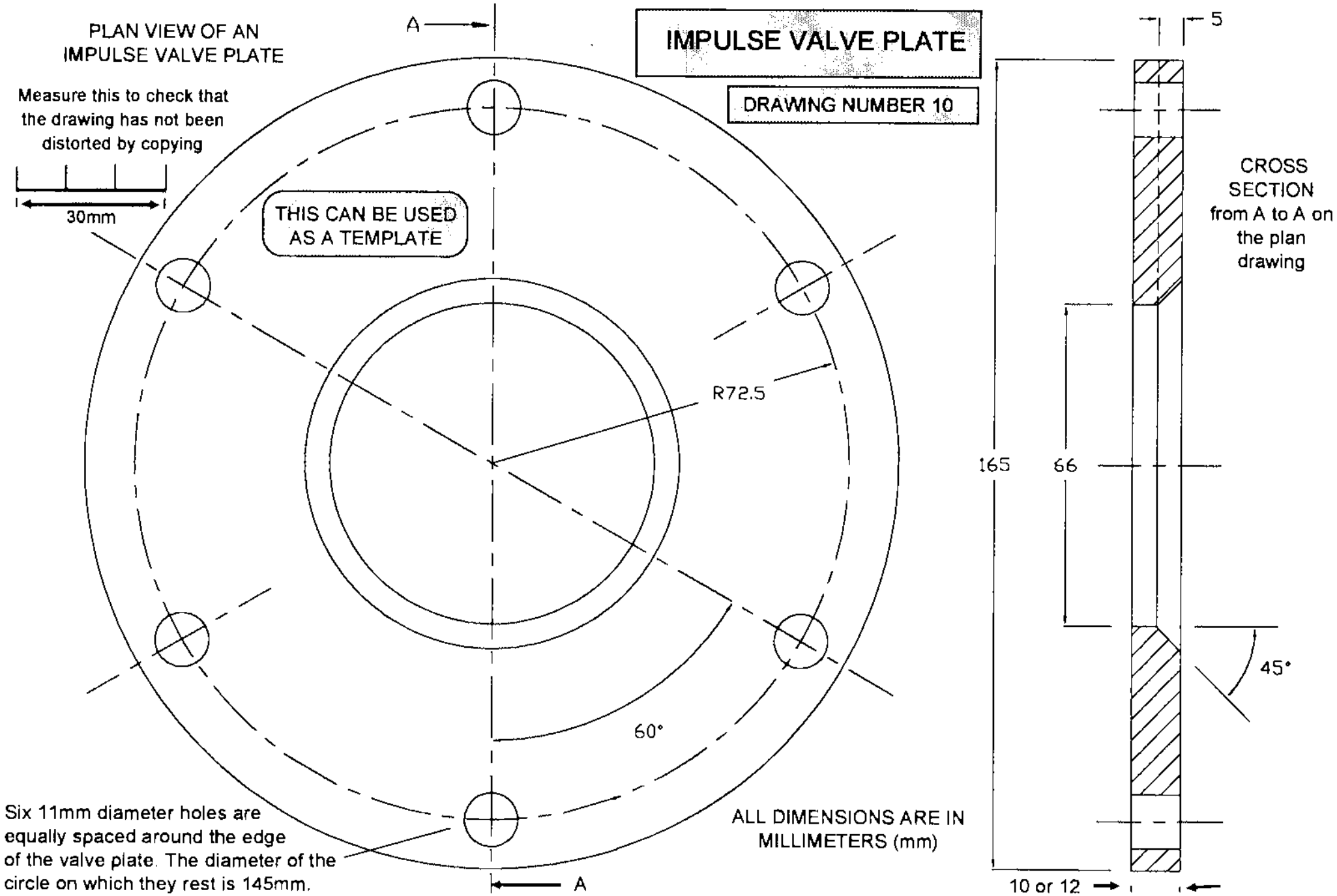
PLAN VIEW OF AN
IMPULSE VALVE PLATE
Measure this to check that the drawing has not been distorted by copying
30mm
THIS CAN BE USED AS A TEMPLATE
A
A
R72.5
60°
Six 11mm diameter holes are equally spaced around the edge of the valve plate. The diameter of the circle on which they rest is 145mm.
ALL DIMENSIONS ARE IN MILLIMETERS (mm)
IMPULSE VALVE PLATE
DRAWING NUMBER 10
5
165
66
45°
10 or 12
CROSS SECTION from A to A on the plan drawing

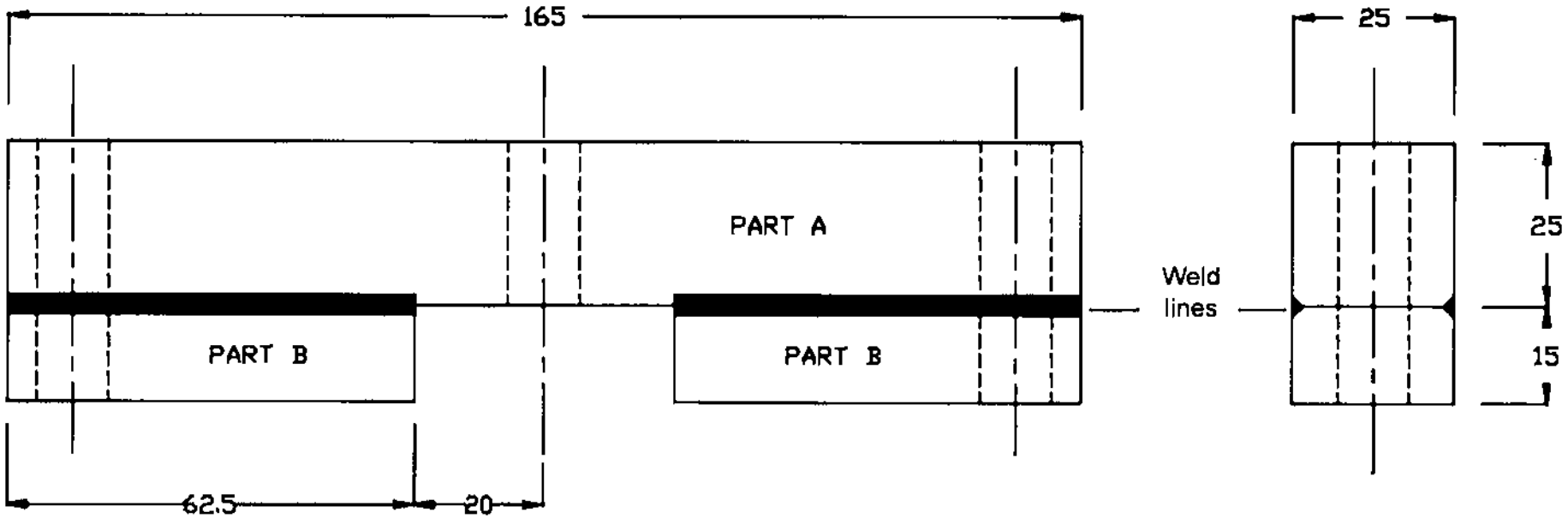

ALL DIMENSIONS ARE IN MILLIMETERS (mm)

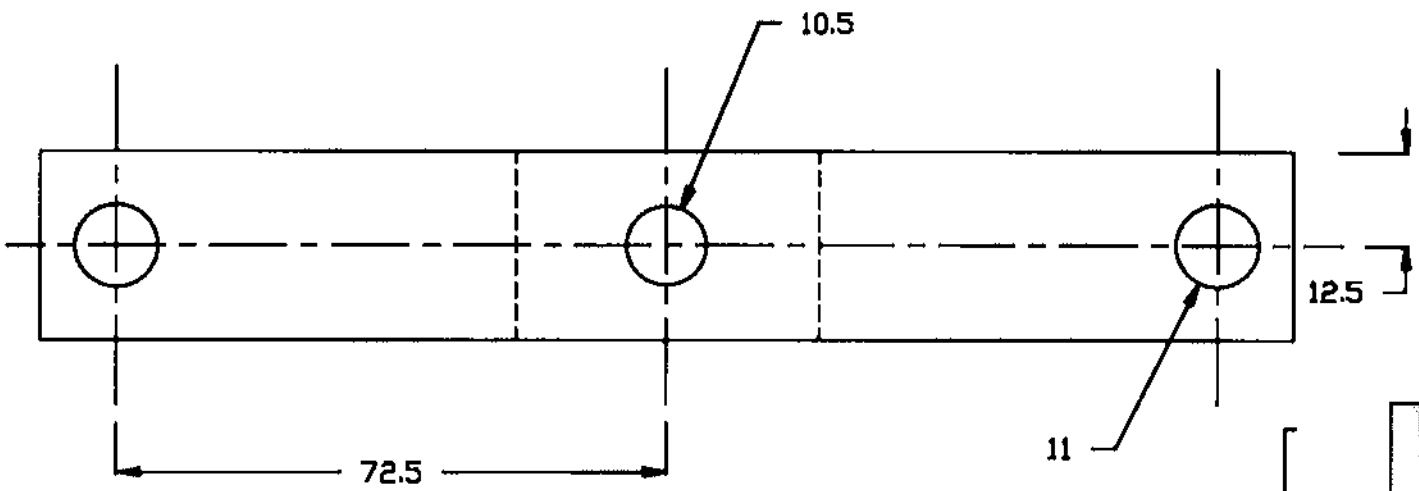

Measure this to check that the drawing has not been distorted by copying

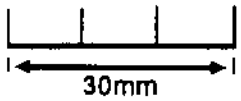

IMPULSE VALVE STOP BAR

DRAWN TO SCALE: 1:1

DRAWING NUMBER 11

NOTES

If you cannot get the right size of bar, the height of Part B must be a minimum of 15mm. Part A should be 25mm high, but sizes down to 20mm can be used. The width of Parts A and B should be 25mm but a width down to 20mm can be used.

Make the bar from mild steel. Only use stainless if it is available and you have the tools.

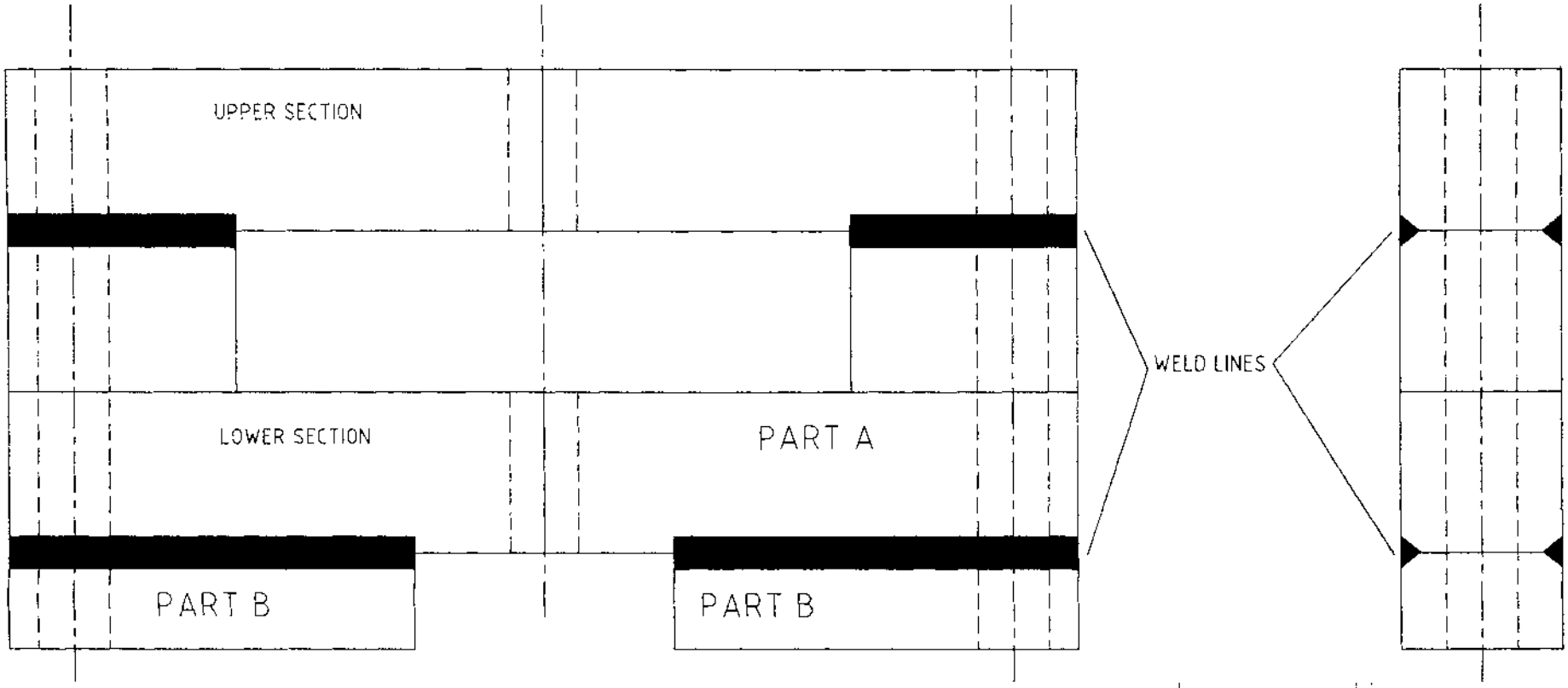

Lower section as per drawing No. 11
Upper from 25' x 25 mm and drilled to match lower assembly

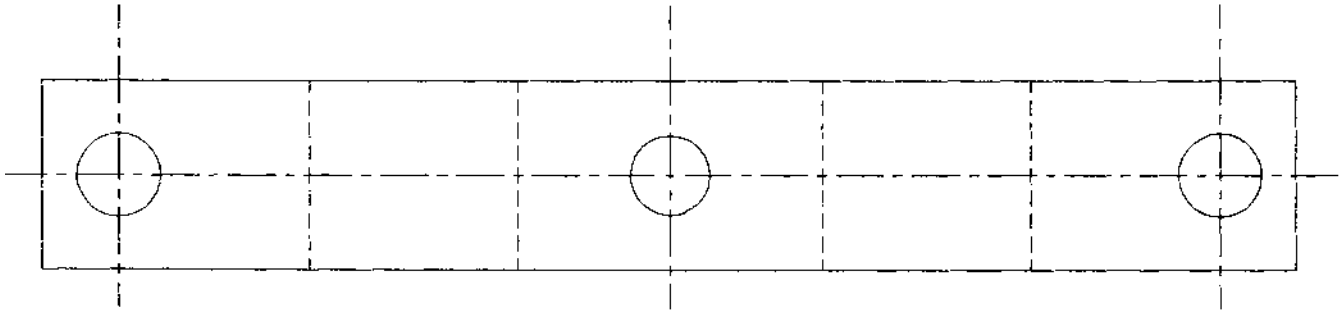

Outer Holes 11.0 mm dia. Middle Hole 10.5 mm dia.

TWO STAGE IMPULSE VALVE STOP BAR/GUIDE

DRAWING NUMBER 11a

DRAWN TO SCALE 1:1

PLAN OF AN
IMPULSE VALVE DISC
Two of these are needed
for each valve

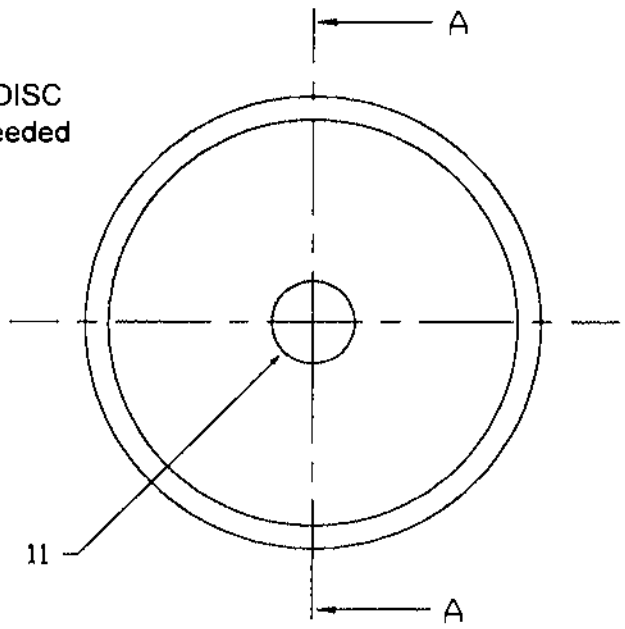

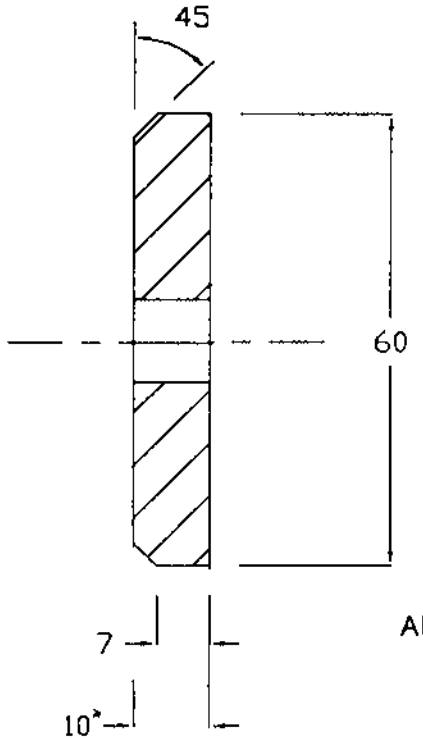

CROSS SECTION
From A to A on the
Plan drawing

ALL DIMENSIONS ARE IN
MILLIMETERS (mm)

IMPULSE VALVE STEM

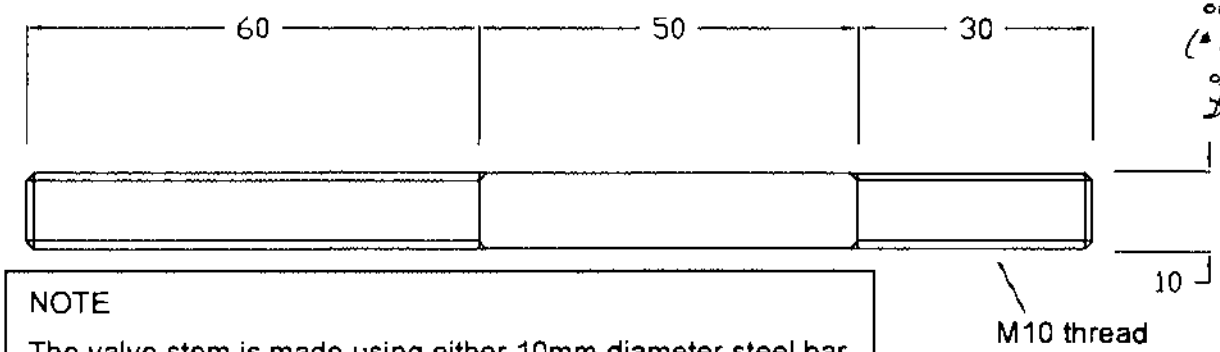

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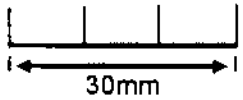

NOTE

The valve stem is made using either 10mm diameter steel bar or 10mm diameter reinforcing bar. Use stainless if you can.

The thread is hand turned using an M10 x 1.5 die.

DTU S2 IMPULSE VALVE DISCS AND STEM

DRAWN TO SCALE: 1:1

DRAWING NUMBER 12

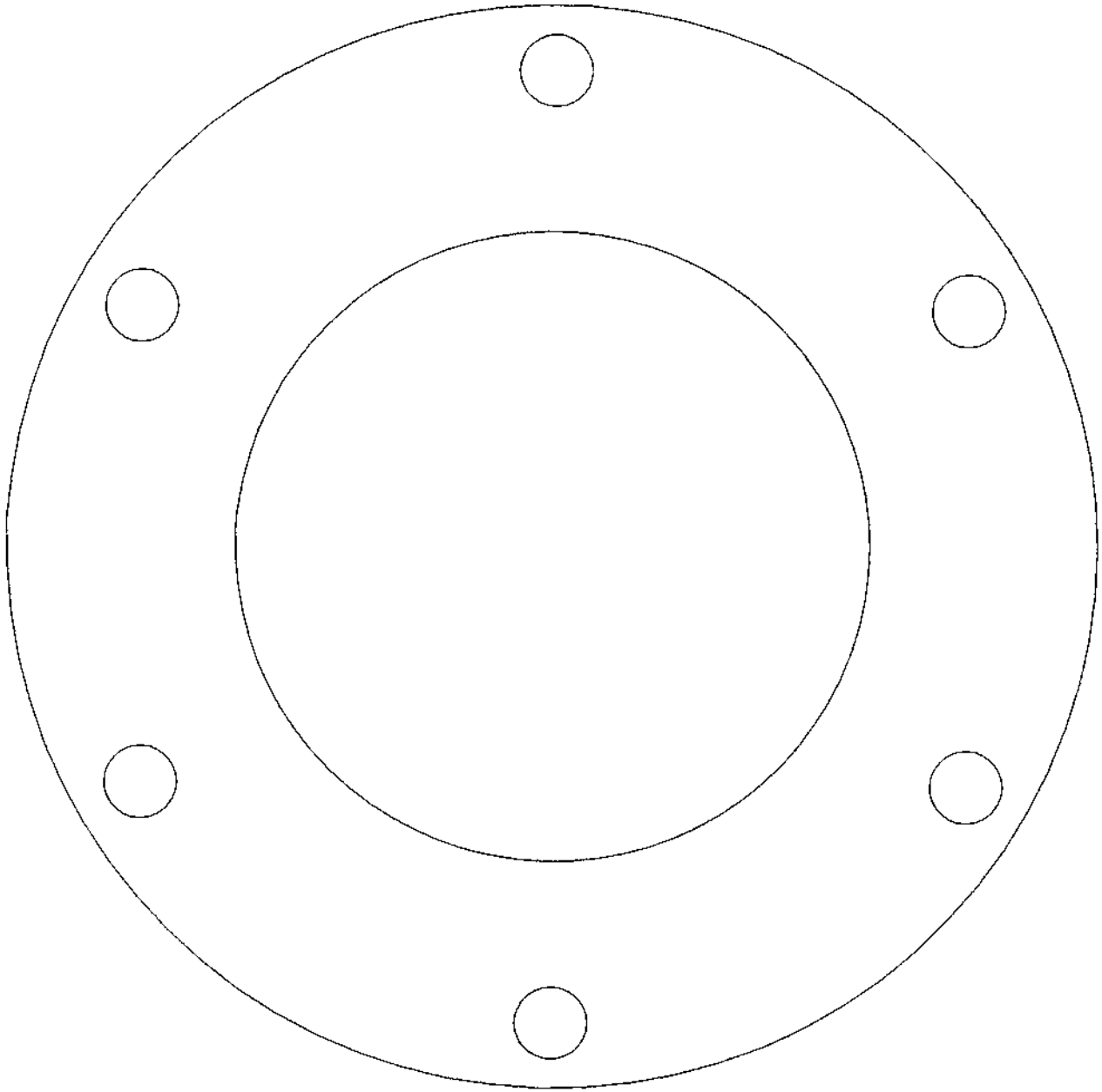

Inner diameter 96.0 mm
Outside diameter 165 mm

DTU S2 GASKET

DRAWING NUMBER 13
DRAWN TO SCALE 1:1

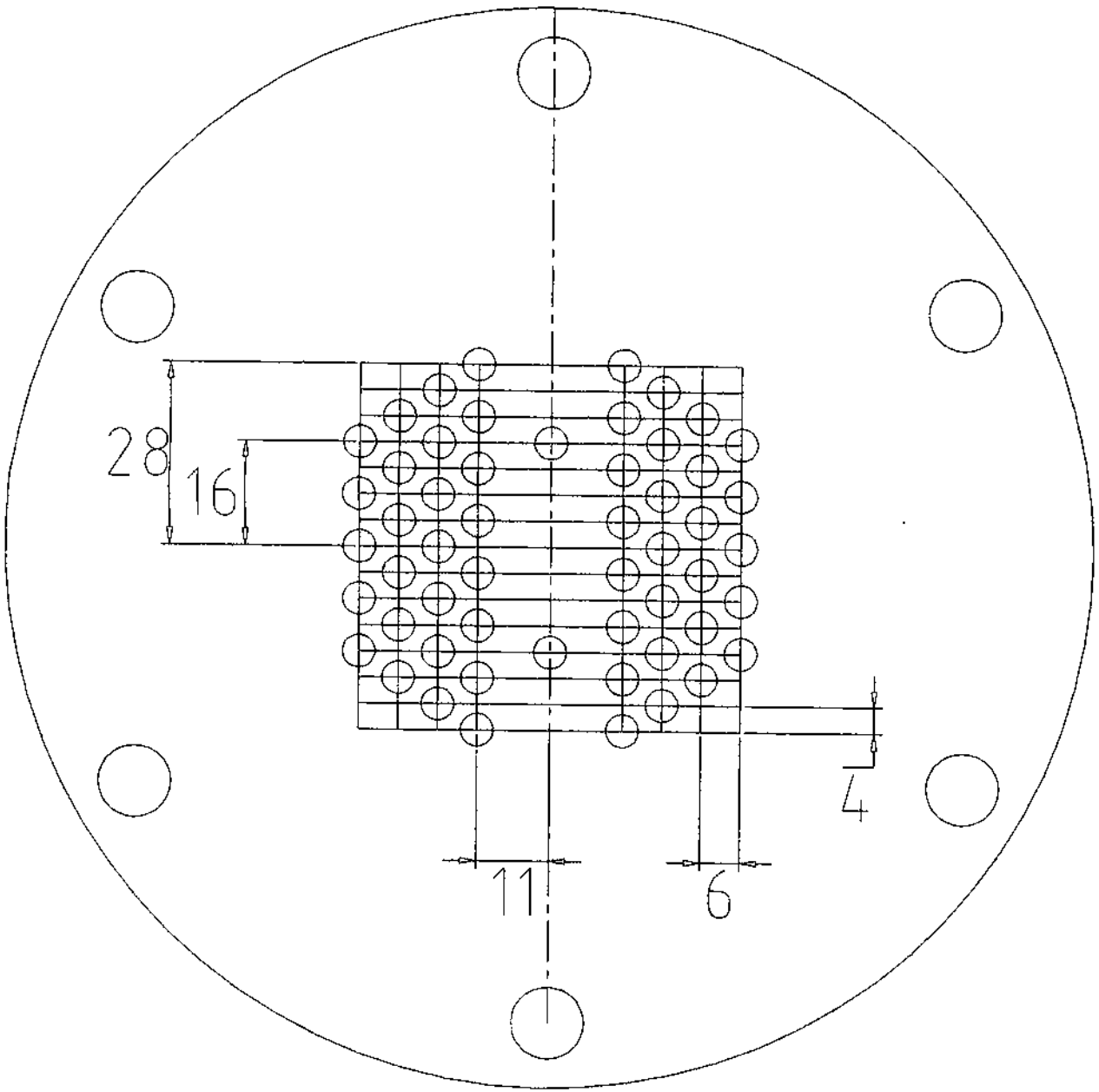

Delivery Holes 52 off
4.5 mm dia. High Head
5.0 mm dia. Low Head

Centre Holes
5.0 mm dia.

PLATE FOR ALTERNATIVE DELIVERY VALVE

DRAWING NUMBER 14

DRAWN TO SCALE 1:1

Steel Retaining Bar
5 mm thick
10 mm wide

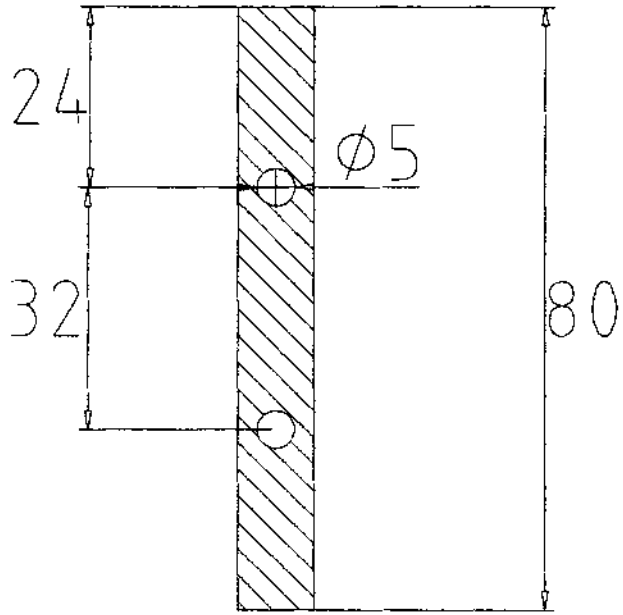

Delivery valve rubber
Diameter 82 mm
3 mm thick for low heads
6 mm thick for high heads

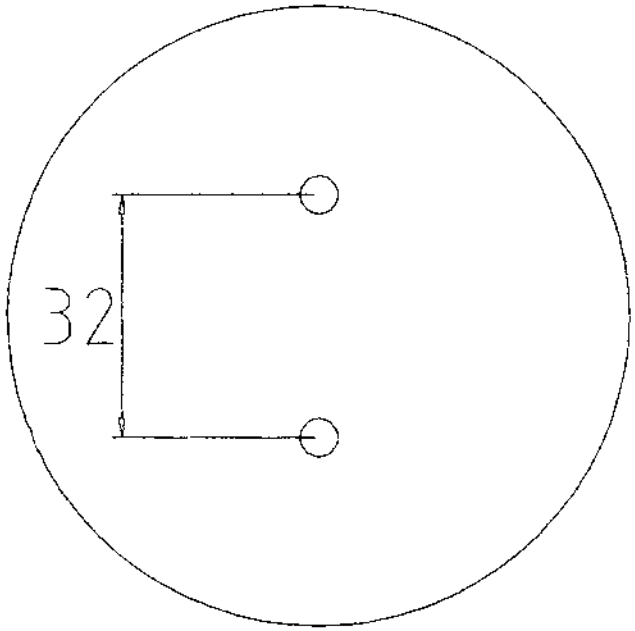

DELIVERY VALVE RUBBER AND RETAINING BAR
FOR ALTERNATIVE DELIVERY VALVE

DRAWING NUMBER 14a
DRAWN TO SCALE 1:1

Hydraulic Ram Pump
Research Programme

NEW DEVELOPMENTS IN HYDRAULIC RAM PUMPING

Technical Release 13

1996

Development Technology Unit
School of Engineering, University of Warwick

This technical release has been written more for ram pump enthusiasts, researchers and manufacturers than for installers and users. It describes the main current trends in system and pump design.

1 GENERAL TRENDS

The ram pump is a 'mature' technology. Over the last two centuries pump designs have stabilised and many variations to the basic configuration (of drive pipe, pump, pump house and delivery pipe) have been tried. One might think that no further significant change was likely in the ram pump itself or in the system in which it is used. However there are changes occurring in both pumping needs and in materials.

Before the invention of petrol engines or the arrival of electricity on farms, the ram pump was in many locations the only feasible way of lifting water from streams or springs to neighbouring hillsides. In consequence a high cost was tolerated; strong but expensive pumps made from cast steel, gunmetal and brass were used. Today there are more alternatives, so that ram pumping can only hold its 'market share' in water supply for humans and for cattle by becoming cheaper and simpler.

All over the world water is getting scarcer and dirtier. In consequence ideal sites for rarn pumping - where a large flow of clean water drops steeply - are becoming fewer. Quite often the water requires cleaning if it is to be used for domestic purposes. There are various possible responses to this problem of polluted drive flow. One is to filter the delivery flow. A second is to use an indirect ram pump that permits falling dirty water to power the raising of clean water from a nearby source. A third is to concentrate on applications like cattle watering and irrigation where water quality is less important.

Filtering and disinfection are well understood, and the technical options for applying them are increasing in number. The availability of only one or two watts of electricity, say from a small photo-voltaic panel, now enables chemical or ultra-violet sterilisation to be performed at a household or village scale. Adding such processes to a ram pumping system may require other design adjustments, for example those to permit delivery flow only in day light hours.

Indirect pumping is a technique known for a hundred years or more. Indirect pumps are still manufactured but they are complex and hence costly. They have more wearing parts than normal ram pumps and they require a source of clean water close to the dirtier flow that drives them. One might argue that to require such elaboration in system installation and maintenance is to head in the wrong direction. Field experience suggests that the use of ram pump technology is already severely limited by people thinking it is 'too complicated'.

It is the authors' experience, mostly in an African context, that even after a 3 weeks' training course many water technicians do not have the confidence to survey, design and install a ram pump system. The design rules seem complex and they fear making any mistake that might cause a system to fail. Yet systems do occasionally fail - through wear and corrosion, insufficient drive flow or flood damage, siltation or blockage, theft or malicious damage. It is not possible to build a perfect system.

With petrol-engine pumping at its simplest, the user carries the pump to site, drops a suction hose into the water source, rolls out the delivery hose and starts the pump. With electric powered pumping using mains, photo-voltaics or transported batteries, the procedure is a little more complex. Ram pumping is more complex again. There has therefore been a growing interest in simplifying the technology, especially in order to serve irrigation operated by peasant farmers.

2 SIMPLER PUMPS

A pump normally comprises an adjustable impulse valve, a (non-return) delivery valve, a pressure vessel to smooth out the pulsating delivery flow and an anchorage or cradle. Where 'free' air is the buffering medium in the pressure vessel (which must be vertical to work properly), a third ('snifter') valve is needed to replenish this air.

Simplifications can take a number of forms, but the main ones of current interest are

- removing the mechanism to adjust the drive flow,
- replacing 'free' air by 'contained' air,
- simplifying the anchorage of the pump and its attachment to drive pipe and delivery.

Removing the tuning mechanism of course removes all the benefits of tuning, namely the ability to adjust the pump to match the drive flow locally available. Under some circumstances, especially when only a small fraction of stream flow is needed, there is no great merit in being able to tune. Where a manufacturer produces a range of pumps it is normal for each step up in size to correspond to a two or three fold increase in maximum drive flow. An untuned pump is effectively permanently set to its maximum (or 'rated') drive flow. Thus using such pumps singly will restrict the drive flow, and hence delivery, to one of a few widely spaced values. If however several (say three) identical pumps, or two pumps of different size, are used in parallel, it is usually possible to get within 25% of any ideal drive flow. In fact there are four distinct alternatives to on-site tuning for matching pumps to available flow, two of them applicable when the system is installed and two when it is in use.

During *installation* the drive flow capacity of a system can be roughly selected by choosing the right number and size of pumps to be run in parallel. Alternatively pump(s) can be used that are 'preset' to a particular drive flow. This lower level of adjustability not only simplifies pump design (e.g. it can be provided by having two or three different weights of impulse valve), but removes the possibility that the user completely mistunes his pump. Such mistuning through operator ignorance is quite common in high technology systems as well as in the simple ram pump ones we are discussing here.

During *operation*, there may be a need to respond to a fall in available stream flow. If pumps are not tunable this can only be done by reducing the number of pumps in operation or by running them all intermittently. Using the 'three same size pumps' or 'two different size pumps' arrangement recommended above, it is possible to follow any changes in stream flow by changing the number of pumps in use. Intermittent operation by contrast can be used with only a single pump but requires much more operator activity and also a reservoir capable of storing at least 2 hours drive flow. In practice intermittent operation, where the user turns on the pump when the reservoir is full and off when it is empty, is very rare. It could become more common where small-farm irrigation is the pumping application. Technically it should also be possible to use a self-priming siphon to achieve intermittent operation without human intervention: the authors know of no example of this being done.

Given the desirability of having more than one pump running in parallel for reliability reasons, the relative rarity of requiring very close matching of system drive flow to stream flow (often extremely variable) and the likelihood of mistuning by inexperienced operators - we may expect to see more simple pumps that are untunable or are tuned ('preset') only during manufacture.

Using "contained " air to buffer the pulsations in delivery flow has real advantages over using a conventional air vessel. By "contained" air or "air packet" we mean air in a bladder or closed-cell foam. Normal commercial pressure-surge limiters in water pipelines use diaphragms to separate the air from the water, however such diaphragms are difficult to make and to seal and are therefore expensive. By contrast closed-cell foam such as bubble-wrap has already been used in a number of small ram pumps. The advantages of substituting air packets for the free air of a conventional pressure vessel are several. The containing chamber need no longer be vertical, air cannot be lost through tiny holes in welds or fittings, the snifter valve is no longer necessary, the pump can be operated under water. Disadvantages are the possible fatigue failure of the air-containment materials, slow loss of air through the walls of bladders or foam and the significant reduction in air volume at start up.

Consider a conventional air vessel of volume 10 litres in a pump delivering to 90 meters. Initially, before start-up, the air is at atmospheric pressure (1 bar). At start-up the absolute pressure rises rapidly to 10 bar (9 bar 'gauge') as the air is warmed and compressed. It then cools until its volume is about 1 1itre, namely one tenth of its initial value: the air vessel is now nearly full of water. Over a period of

hours however the air is replenished via the snifter valve to its original volume of 10 litres. The pump may run rather noisily until this has taken place.

If however a closed air packet replaces the conventional free air, there is no replenishment mechanism, so throughout the run time it remains at 1 litre. It therefore is necessary to provide an air packet whose initial volume is equal to:

> V_{init} = air volume required in operation (V_{op}) × delivery pressure in bars absolute.

(Note that 10 meters delivery head corresponds to 2 bars absolute, 20 meters to 3 bars etc.)

Recent research and experimentation suggest that the air volume in operation (V_{op}) can safely be as little as twice the volume of water delivered per cycle. [The pump efficiency does not fall significantly compared with when V_{op} is large, and the overpressure of about 30% is usually also tolerable from a fatigue point of view.] An irrigation pump may only lift to 20 meters, so initial air volume V_{init}, is only 3 times V_{op}, whereas a domestic supply pump may lift to 80 meters (V_{init} = 9 times V_{op}) or higher. We would therefore expect this air compression problem to be more severe with high-lift pumps. However as the delivery head is increased (while the drive head and drive flow are kept constant) the volume delivered per cycle goes down. The combination of these effects means that for a given size of pump, the appropriate initial air packet size does not vary much with delivery head. In practical terms, the minimum initial packet size relates to pump size roughly as shown in Table 1:

This table indicates an initial air packet volume, and therefore vessel size, equivalent to 1 m of drive pipe (or less length of a larger diameter) should be sufficient: this is a tolerable size.

With an air packet, pump design can be simplified to essentially an impulse valve followed by a packet-enclosing horizontal tube entered via the non-return delivery valve. This results in a fairly compact design of pump that can be placed under water to maximise drive head and to reduce noise. Although there are some particular problems that can arise when operating under water – for example sucking debris in through the impulse valve, increased vulnerability of flood damages and difficulty of access for tuning – in many situations the advantages outweigh the disadvantages.

As materials further improve we may expect more ram pumps to incorporate air packets or even a diaphragm instead of traditional air vessels.

Simplifying the pump attachment is a particular requirement for irrigation use where ram pumps and even drive pipes may be removed at night and will certainly need to be removed at the end of the dry season. The shock forces on pumps when they are in use are large, so any anchorage has to be sturdy. Already it is usual to bolt pumps onto a permanent (i.e. concreted-in) cradle. There is now interest in providing clip-on arrangements both between pump and cradle and between pump and drive pipe, rather than using nuts, bolts or wedges.

3 NEW MATERIALS, LOWER COSTS AND HIGHER PERFORMANCE

Materials For long-life pumps, traditional construction materials are largely suitable. By contrast, new materials have particularly found their place in cheap ram pumps of modest but adequate performance. During the last twenty years metal piping has largely been superseded by plastic, especially PVC, ABS and HDPE. It is therefore

Table 1

Drive pipe size (ID)	mm	25	50	75	100
Assumed driveflow	litres/min	25	100	250	500
Packet size (for *drive* head of 2 meters)	litres	0.15	0.60	1.50	3
of 6 meters)	litres	0.45	1.80	4.50	9
Volume of I meter of drive pipe for comparison	*litres*	*0.5*	*2.0*	*4.4*	*8*

tempting to use these rust-proof and easily worked materials for constructing ram pump bodies. Unfortunately the poor stiffness, fatigue strength and sunlight resistance of plastics poses problems.

The water-hammer effect that underlies ram pump operation is dissipated in very elastic, or worse energy absorbing, materials. For this reason we try to avoid accumulation of air in drive pipes and we look for a high level of wall stiffness in them. The maximum height a ram pump can deliver to is approximately $h_{max}=\nu\ C_{dp}/g$. Where ν is the maximum water velocity in the drive pipe and C_{dp} is the velocity of sound in that water. It can be shown that for an infinitely stiff pipe, C_{dp}/g is about 140 meters height per meter/second, in a steel pipe it is typically 120 but in a plastic pipe it is only about 30.

[The formula normally used is:

$$C_{dp} = C\sqrt{\frac{1}{1+\frac{DG}{tE}}}$$

Where C is the velocity of sound in water, D and t the diameter and thickness of the plastic pipe, G the stiffness of water and E the stiffness of the plastic.]

This effect shows itself in a plastic system being only able to deliver to about 30% the height of an all-steel system. For really high head deliveries steel drive pipe is essential. For delivery height under 50 meters, plastic drive pipe is adequate

All materials show 'fatigue' in that a loading that they can tolerate easily if it is applied only a few times may cause failure if applied millions of times. In a ram pumping system, the pump and drive pipe experience between 15 million and 100 million pressure pulses per year, so fatigue failure is a real danger. For plastic drive pipes it is usually sufficient to select a pipe pressure rating of 3 times the delivery pressure. For plastic pumps, fatigue failure is so likely that either they are metal reinforced or they are restricted to use with very low delivery heads. Apparently no one is making pumps out of glass reinforced plastics (GRP) despite this material having suitable stiffness and fatigue performance.

Injection moulded plastics are used in centrifugal pumps and hand pumps. They could be used for ram pumps too, but the small production runs do not at present justify the high tooling costs. A few experimental pump bodies have even been made of concrete whose inertia may act as a substitute for strength in the face of sudden forces. The material is cheap, though heavy, but the problems of getting really high densities and of sealing the joints between concrete sections have apparently defeated concrete pump designers.

Certainly the use of simple plastics in small or low-lift ram pumps is now well established alongside that of metals for higher lifts. It seems unlikely that more complex materials or processes will be soon employed to make these devices.

Lower costs come from use of fewer, cheaper or 'easier' materials, from mass production and from design simplifications. Understanding of ram pumps is better than in the past and this had led to a few design changes leading to lower costs.

Mass production of complete pumps is constrained by small markets, while attempts to assemble the pumps from mass-produced fittings have not generally led to either high performance or to much lower costs. Fittings are not cheap if used in any number: pumps made from them are generally clumsy and have too many parts.

For fabricated steel pumps the now ready availability of square section tubing offers simplification of design and assembly compared with traditional round tubing. Square tubing is not efficient at containing high pressures but this is not normally a problem at all but the highest delivery heads. Fabrication is better suited to some pump-using countries than employing iron casting, machining, forging or threaded connectors. Welded joints can be opened again if necessary by cutting them out with an angle grinder

Probably the greatest need for cost cutting is in irrigation applications. If a siphon drive pipe could be developed (requiring the pump to be submerged), the installation costs of irrigation pumps could be reduced substantially. Some effort is being applied to designing essentially portable systems for use with dams as low as 500 millimeters, where the pump and its drive pipe can be quickly disconnected from anchorage and dam respectively.

High performance takes various forms, such as higher efficiency, higher delivery head, quieter operation and greater durability. It seems that little theory was used in the past when designing either

pumps, or complete systems. Today ram pumps have something of a fascination for analysts so that there are several publications that aid high-performance design. For example the main sources of inefficiency are well documented and it is not hard to devise an economical system with an overall efficiency as high as 70%.

In Nepal, the Andes, Rwanda and elsewhere there is some need for pumps that lift as high as 200 meters, well beyond the limit of normal machines. The procedures and materials for achieving very high heads are known, but so far the market for such pumps has been too small to cover the costs of fully developing them. DCS, Butwal in the Himalayas have reached 180 meters lift with some reliability.

Quiet operation has been traditionally achieved by placing pumps and drive pipes underground. For years some pumps (for example the Blake's machines) have used rubber impulse valves in otherwise metal systems to reduce noise. The move towards plastic drive pipes may lower efficiency a little, but it beneficially converts high-frequency 'clanging' into less intrusive low-frequency 'thumping'.

Only in the area of durability can one find no significant improvement. Perhaps the lifespan of cheap pumps has increased a little from its former low level, but it is still far below that achievable with traditional 'over-designed' machines.

DTU

Ram Pump Programme

DTU P90 PUMP

TECHNICAL
12
RELEASE

DTU P90

The name "P90" stands for a Plastic pump with a drive pipe of 90mm in diameter.

hydraulic ram pump

The P90 is a plastic-bodied hydraulic ram pump designed mainly for the irrigation of vegetable gardens from streams running nearby. Each pump, used continuously day and night, can irrigate 0.2 to 0.6 hectares (½ to 1½ acres). If it is run only in daylight hours, it will only irrigate half the area. The P90 may be used for furrow irrigation, hose irrigation and watering by bucket from a storage pond at the top of a field. It does not give enough pressure for irrigation using water cannons or automatic sprinklers. The P90 can also be used for pumping drinking water, but only as high as twenty meters. For greater heights use steel-bodied pumps.

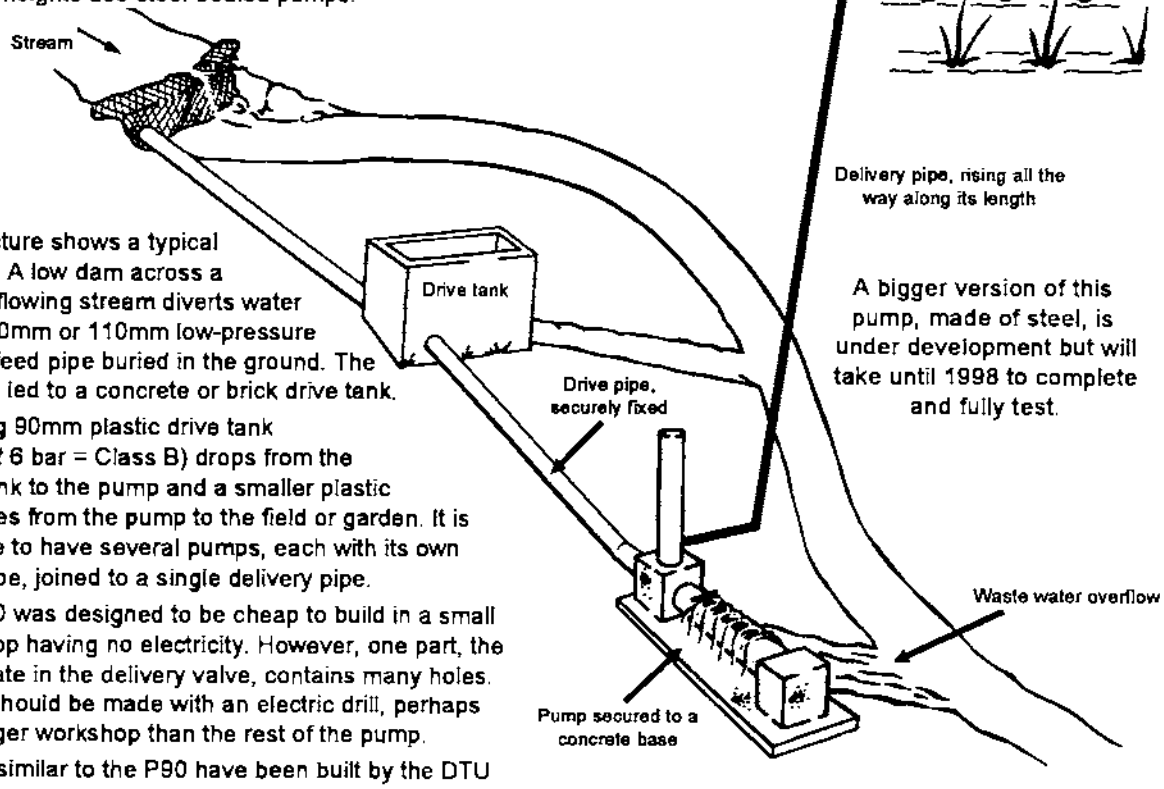

This picture shows a typical system. A low dam across a rapidly flowing stream diverts water into a 90mm or 110mm low-pressure plastic feed pipe buried in the ground. The water is led to a concrete or brick drive tank.

A strong 90mm plastic drive tank (*at least* 6 bar = Class B) drops from the drive tank to the pump and a smaller plastic pipe rises from the pump to the field or garden. It is possible to have several pumps, each with its own drive pipe, joined to a single delivery pipe.

The P90 was designed to be cheap to build in a small workshop having no electricity. However, one part, the steel plate in the delivery valve, contains many holes. These should be made with an electric drill, perhaps in a bigger workshop than the rest of the pump.

Pumps similar to the P90 have been built by the DTU in several countries. Although the DTU believes the P90 will operate for two years, only one pump trial (in Zimbabwe) has been run for that long.

A bigger version of this pump, made of steel, is under development but will take until 1998 to complete and fully test.

DTU P90 ram pump specifications

The normal specifications of the DTU P90 ram pump are given here. Sometimes you can operate pumps outside these limits, but they may not work well.

drive head range	—	up to 3 meters
drive flow range	—	100 to 360 liters a minute
drive pipe material	—	PVC or ABS (*at least* 6 bar or Class B)
drive pipe diameter	—	90mm
delivery head range	—	up to 20 meters
typical delivery range	—	3 to 40 liters a minute
delivery pipe diameter	—	25mm

The DTU plastic irrigation pump

Most ram pumps being manufactured are designed to supply water for domestic use because the low flows produced and the costs generally make ram pump systems unsuitable for small-scale crop irrigation. Sufficient water for 1000-1500 people, for example, would only irrigate a plot of around 1 hectare! Some very large bore (12") ram pumps have been built to supply water for irrigation but the capital costs of such schemes restricts their application. In many parts of the world there is a large potential for low-lift, low-cost irrigation of small garden plots to improve yields, allow alternative crops to be grown and increase crop security in unpredictable weather conditions.

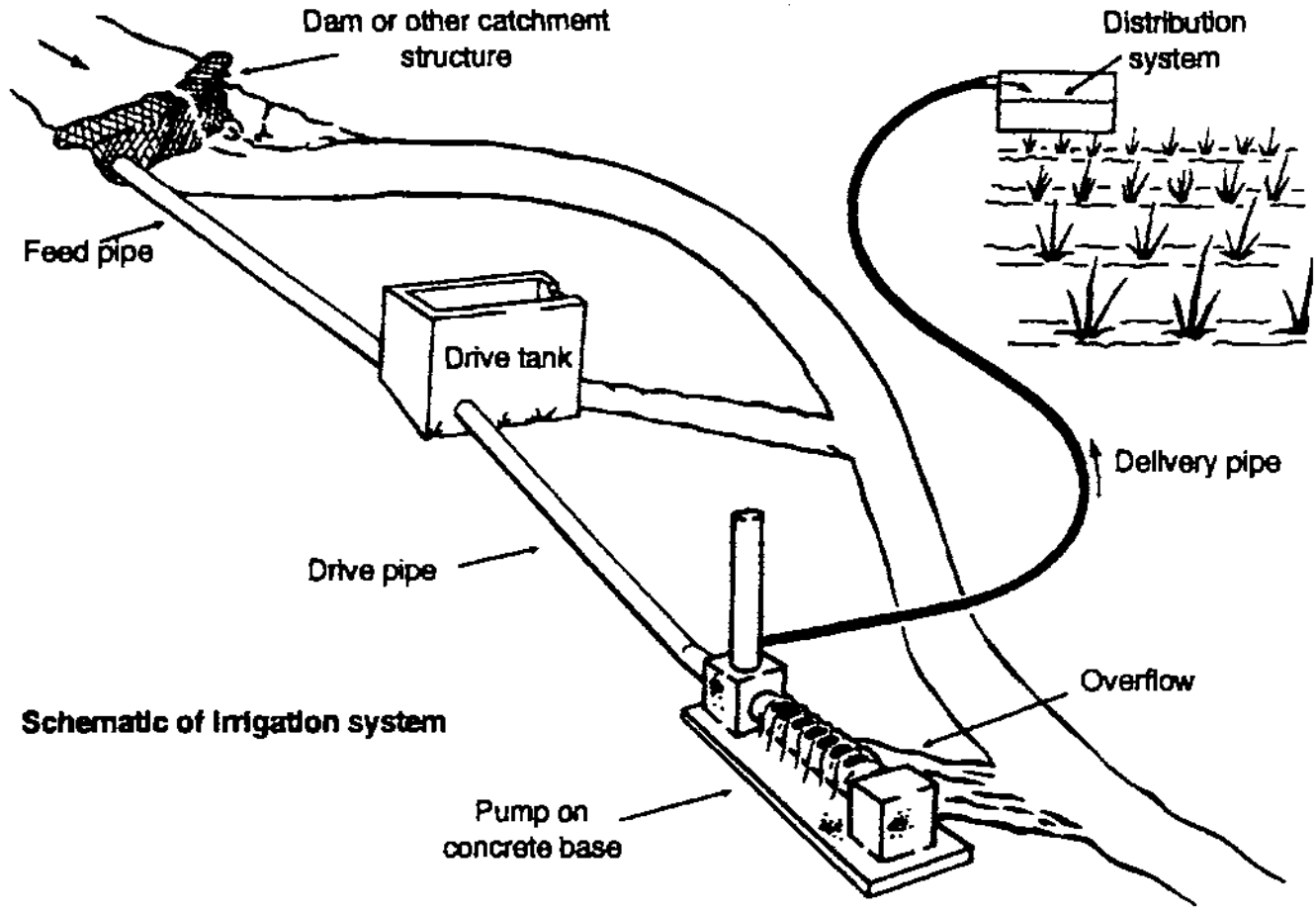

Schematic of irrigation system

The material the DTU selected as the only viable alternative to steel is plastic pipe. PVC 110mm (4") diameter pipe is now widely available in many developing countries and provides the scale of flow necessary for small-scale irrigation.

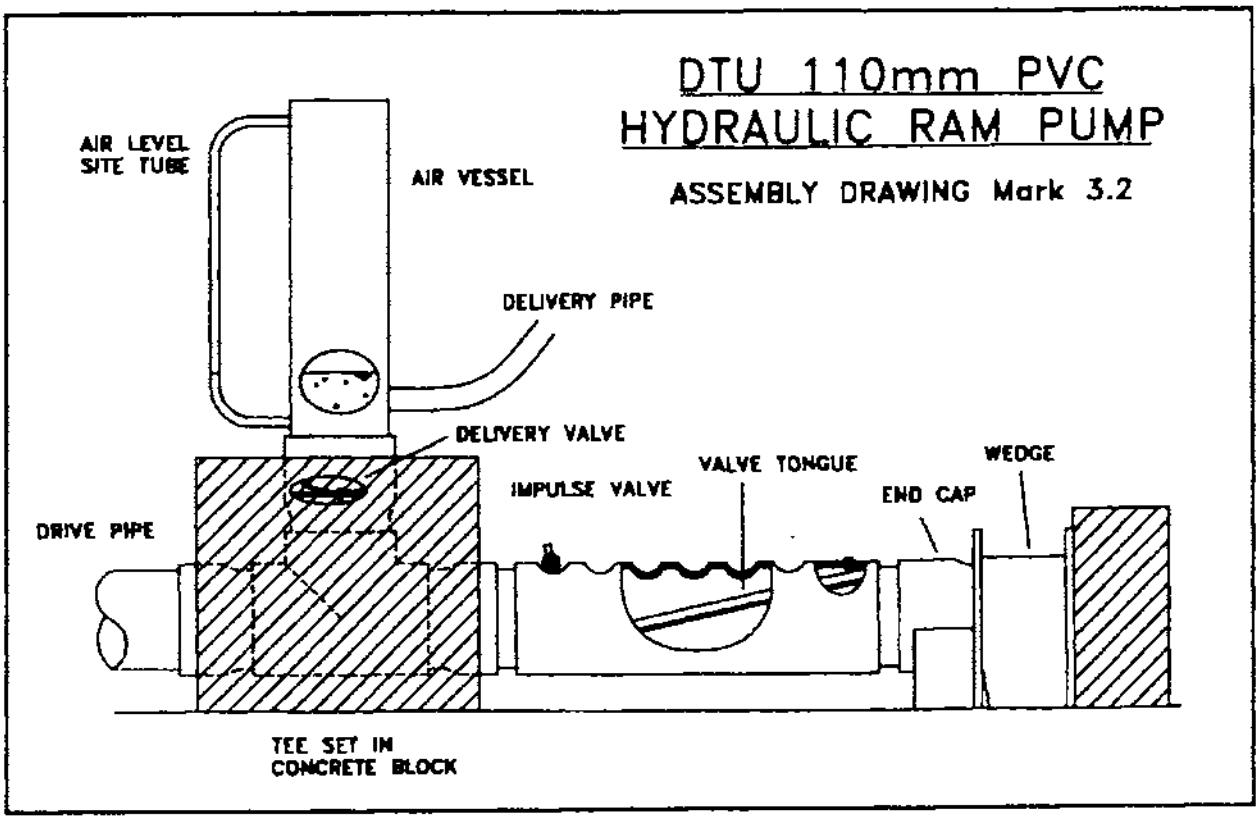

The DTU pump has the following specification:

- all major parts can be manufactured from 110mm pipe (with a minimum of other materials such as bolts, rubber, etc.);
- all parts can be manufactured using hand tools in small rural workshops;
- the system can be maintained by the user and all parts are capable of simple replacement in case of wear, damage or theft;
- designs have been extensively tested for performance and endurance (including extensive field tests);
- pumps should be easy to tune to suit a broad range of site conditions.

It meets the following performance specifications:

1. The drive head (fall of water) can be between 1 and 3 metres.
2. The drive flow available can be between 3 and 7 litres/second.
3. The maximum delivery head is 12m.
4. The energy efficiency exceeds 50%.

At 2 metres drive head, maximum delivery to 15 metres is 35,000 litres per day, adequate to irrigate ⅔ of a hectare.

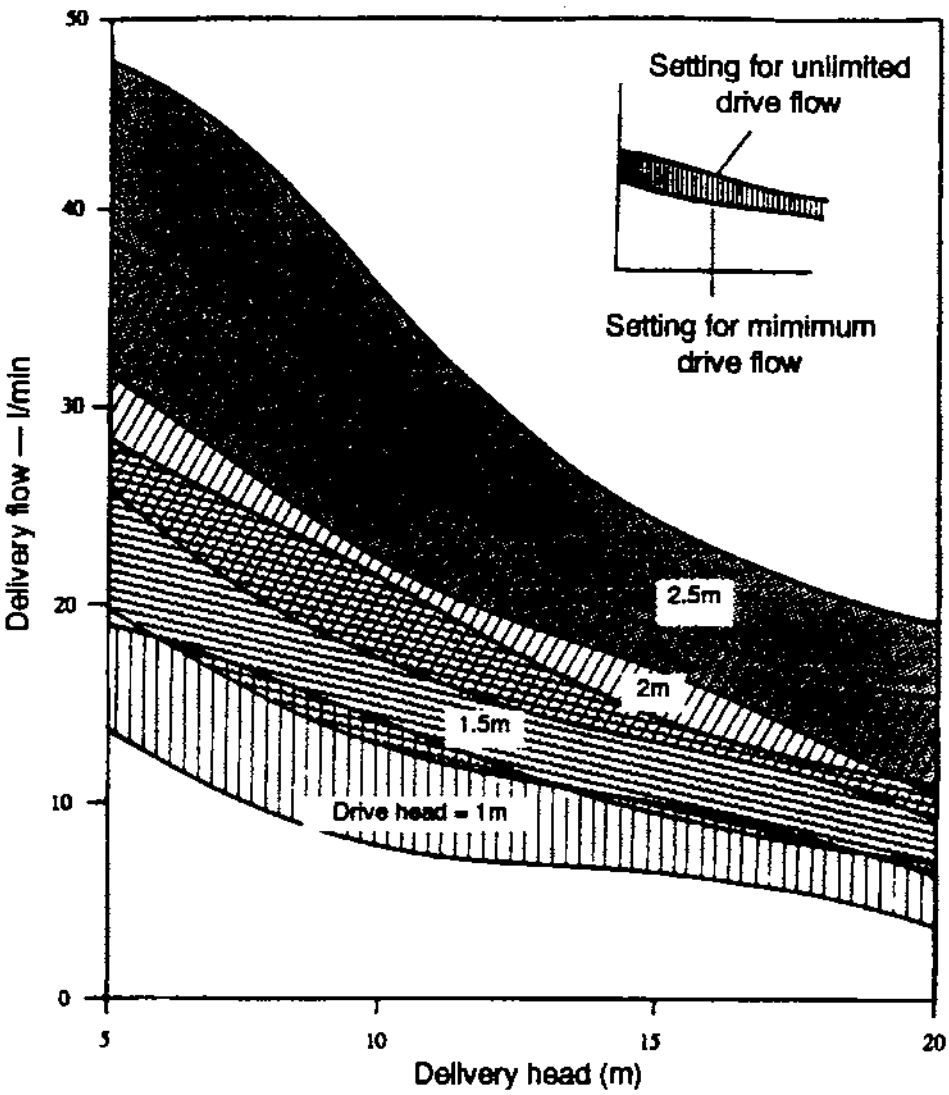

DTU PVC ram pump — Typical performance data

The shaded areas on the performance data chart above indicate the normal operating range for different values of drive head.

Pump designs have been developed over a number of years with increasing performance and component life. Plastic pipe is more prone to fatigue failure than steel, reducing the life of some components to two years. The current design has been extensively tested in Zimbabwe but is still (1993) at the proving stage of development.

Manufacturing notes

The first DTU ram pump to be built using plastic materials was tested in 1986 as part of an undergraduate project. It was constructed largely from standard PVC drain pipe fittings with a wooden impulse valve. The major interest in the use of plastic for ram pumps stemmed from the low cost of materials and the ease of manufacture using plastic components. There was some question initially whether the thin PVC material would withstand the continual fatigue loading and simply break under the first cycles. With the success of this first design, research was continued on its development and the horizontal axis impulse valve was introduced. Since then laboratory tests and field trials have significantly refined the design of the pump and produced data concerning its durability and pumping limitations.

Plastic ram pumps can provide a cheap and simple means of supplying water to elevations of less than 15m. The scale of flow produced and the limitations on their pumping head make them ideal for local manufacture and use for small scale irrigation in developing countries.

This Working Paper details the design of the M3.2 pump. It lists each component and describes any significant features and considerations. Drawings of all the components are also included along with some graphs showing the typical performance of the pump.

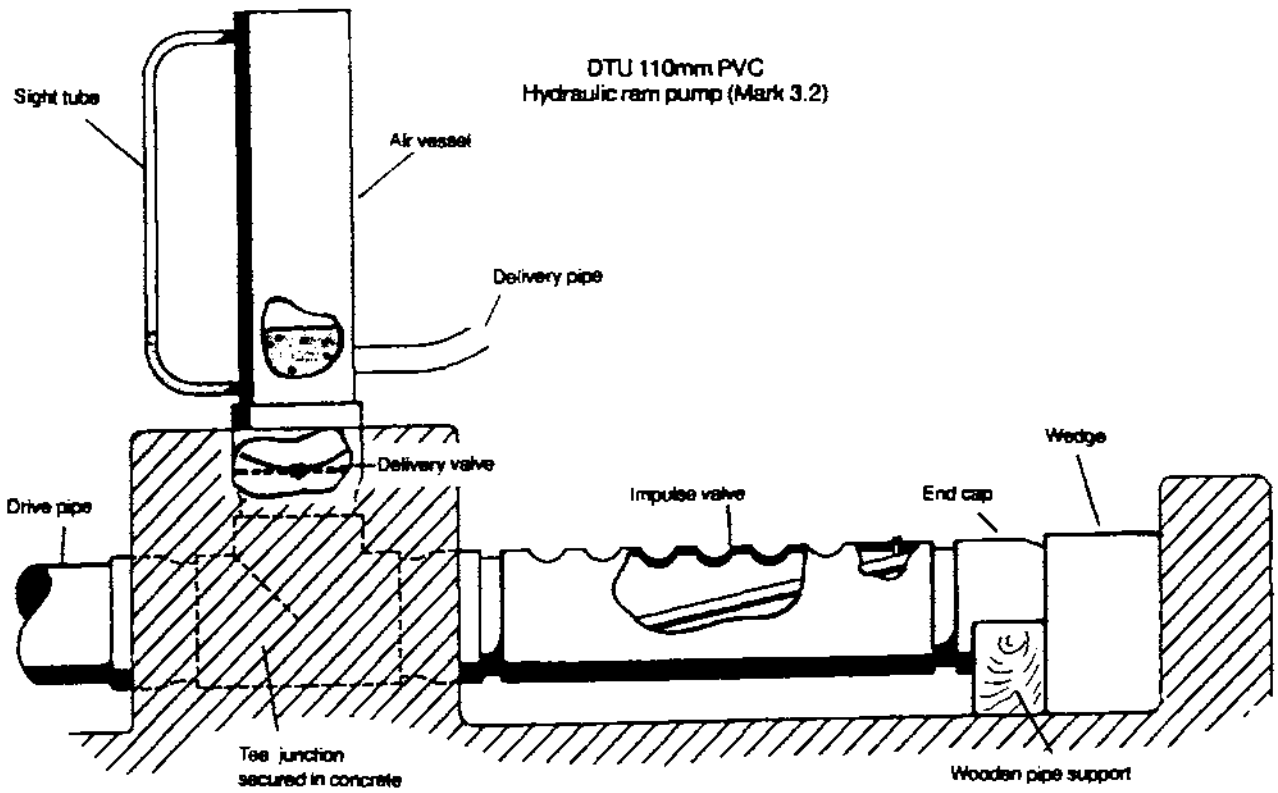

Impulse Valve

The design of impulse valve on the DTU M3.2 is unique amongst current ram pump designs. It aims to achieve a flow area through the valve equal to, or greater than, the area of the drive pipe whilst using the drive pipe material for its construction. This greatly simplifies the materials required for pump construction and reduces the need for steel components.

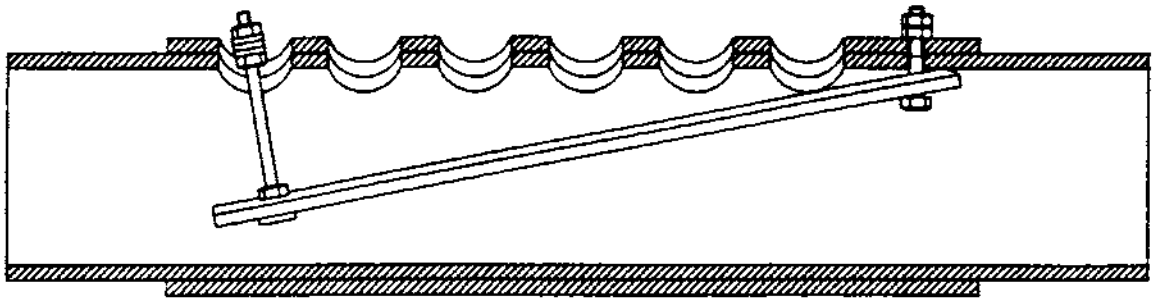

The M3.2 impulse valve

The valve operates under conditions similar to those that cause the aerodynamic lift of an aircraft wing. The velocity of the water flowing over the top of the tongue and out to waste, creates a slightly lower pressure on the top side than that underneath it. As the water accelerates, this pressure differential across the tongue increases until it is sufficient to begin to close the valve. As the tongue rises the velocity over it is increased, which in turn increases the pressure differential, causing the valve to close faster and further increasing the velocity. In this way the tongue accelerates and closes very rapidly producing the sudden deceleration of the water necessary to raise the pressure in the pump body to the delivery pressure.

The valve design works well using PVC materials due to its slight flexibility. When the valve closes the subsequent pressure rise actually flexes the tongue ensuring a good seal even though the tongue may not fit perfectly to the valve body. The same valve design has been tried using steel pipe material but was found not to work well as the tongue could not easily be contoured to the exact shape of the inside of the valve body and didn't have sufficient flexibility to deform under the normal working pressure. Provided that the tongue of a PVC pump fits sufficiently well to just operate it will deform over a number of days of operation until it seals properly.

The development of the this design from the basic concept has taken some time in using different configurations; hole sizes, spacing, valve length and in finding a design with sufficient strength to withstand the continual loading. PVC is not a material recommended for use in situations where a high fatigue loading is likely. Its use would therefore not normally be advisable in ram pumps where there is a highly fluctuating load from the pressure transients in the pump and drive pipe. Research has shown that provided the delivery pressure is kept within recommended limits, the pump and pipe material are sufficiently thick, and the pump well manufactured with no potential stress concentrators, that the normal fatigue loading experienced is well within the tolerance of the material. A Working Paper is available from the DTU detailing the research and findings of work undertaken on fatigue in PVC.

Impulse Valve Design and Manufacture Notes

1) Great care is needed in the manufacture of the holes in the valve body to ensure that there are no small cuts, indentations or cracks from the initial shaping of the holes. Once the holes have been roughly shaped they should be carefully filed until they are completely smooth to the touch and show no visual defects. This will help prevent the formation and propagation of cracks.

2) The tongue hinge is a potential source of rapid wear of the PVC material used both for the tongue and the valve body. The hinge is simply a bolt about which the tongue has some freedom to move. To prevent wear of the tongue, the hole that goes through it is lined with a piece of metal, either a small section of pipe with the correct I/D or a specially fabricated liner made from sheet steel.

3) On two occasions impulse valve cracks were found running down the valve parallel to the pipe axis at the upstream end that was pushed into the tee piece. These cracks were caused by the valve being wedged too hard into the tee piece socket. This created a significant additional hoop stress at that end of the valve and led to a crack propagating from some small imperfection in the first valve hole back to the end of the pipe. The main cause of this problem was the method of wedging the impulse valve into the tee piece against the concrete end block. It is possible to prevent this type of cracking by wedging the impulse valve more carefully. However this does not provide a fool proof solution and still allows the possibility of valve failure. The simplest method of preventing this problem is to shorten the length of the pipe that can fit into the tee socket so that the double skin of the impulse valve butts up against the tee before the valve is pushed in too tight.

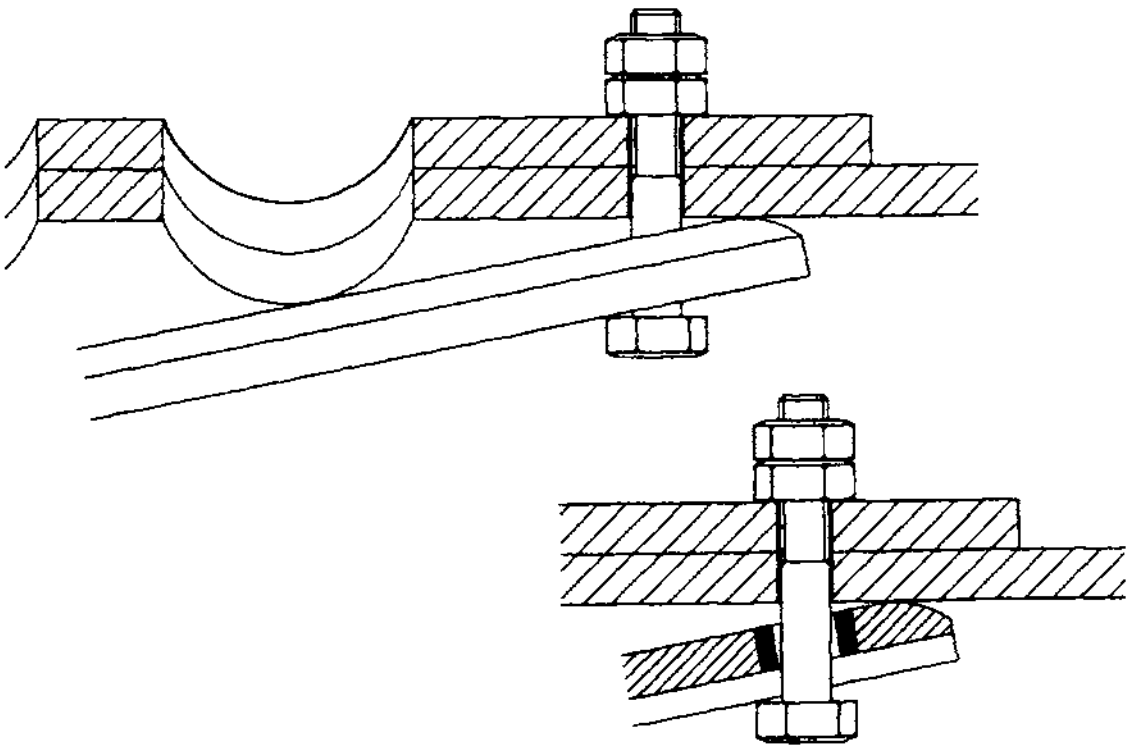

Diagram showing hinge arrangement of impulse valve tongue

Delivery Valve Design

The delivery valve for a low cost ram pump must satisfy all of the following requirements;

1) produce good performance by; opening quickly with a low pressure differential across it; have a low resistance to flow through it; allow little backflow by closing quickly with a small pressure differential.

2) have an acceptable working life with any disposable rubber parts lasting a minimum of 6 months.

3) be cheap and simple to manufacture.

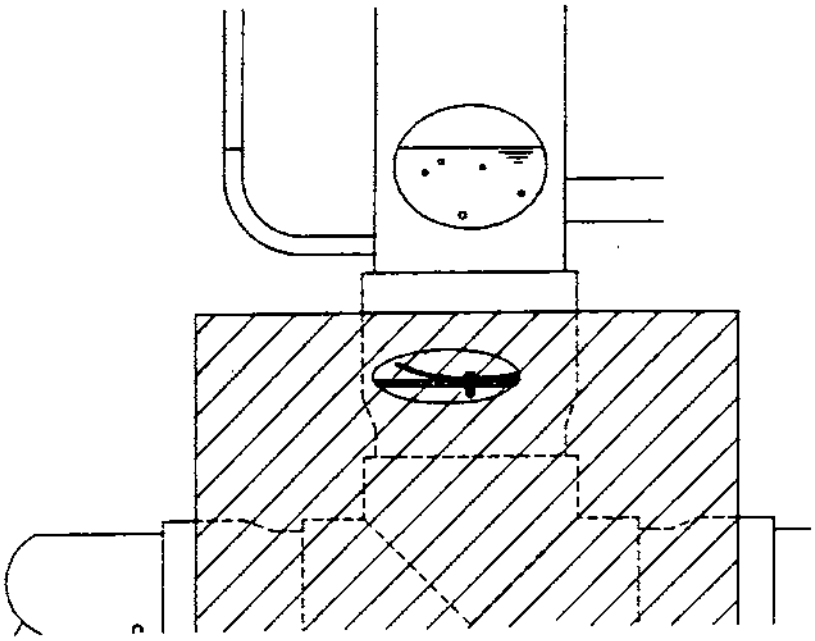

Position of the Delivery Valve

Laboratory tests have been carried out on a number of different types of delivery valve to assess their performance. These were simply designed to compare the throughput of the valve under a controlled set of conditions. Backflow of water through the valve from the air vessel during the period of recoil had been found to be significant on tests of steel ram pumps, reducing the delivery flow by up to 40% in the worst cases. With identical impulse valve settings, the delivery head and flows were measured for 5 different delivery valves. The results of the tests are shown in the following graphs.

The original flap type delivery valve proved to give the best performance over a wide range of conditions with two thicknesses of rubber to increase the rigidity of the valve. The rubber used in the tests was 3mm thick commercial sheet. One thickness of rubber gives lower performance due to its lower response to closure allowing more backflow to occur. Increasing the number of rubbers above 2 also reduces the delivery flow as the resistance of the valve to opening increases and the friction through the valve during delivery reduces the flow. Unfortuneately the quality and availability of rubber sheet varies enormously around the world and it is important to be able to make use of locally available materials to guarantee access to spare parts. Good quality inner tube from truck wheels is often the most available and reliable source of rubber. It is recommended that a number of thicknesses be used to make the total thickness of rubber between 4 and 6mm. Some experimentation with the materials available is advised. measuring performance with varying amounts of rubber to find an optimum and assess the rubbers' vulnerability to tearing and stretching.

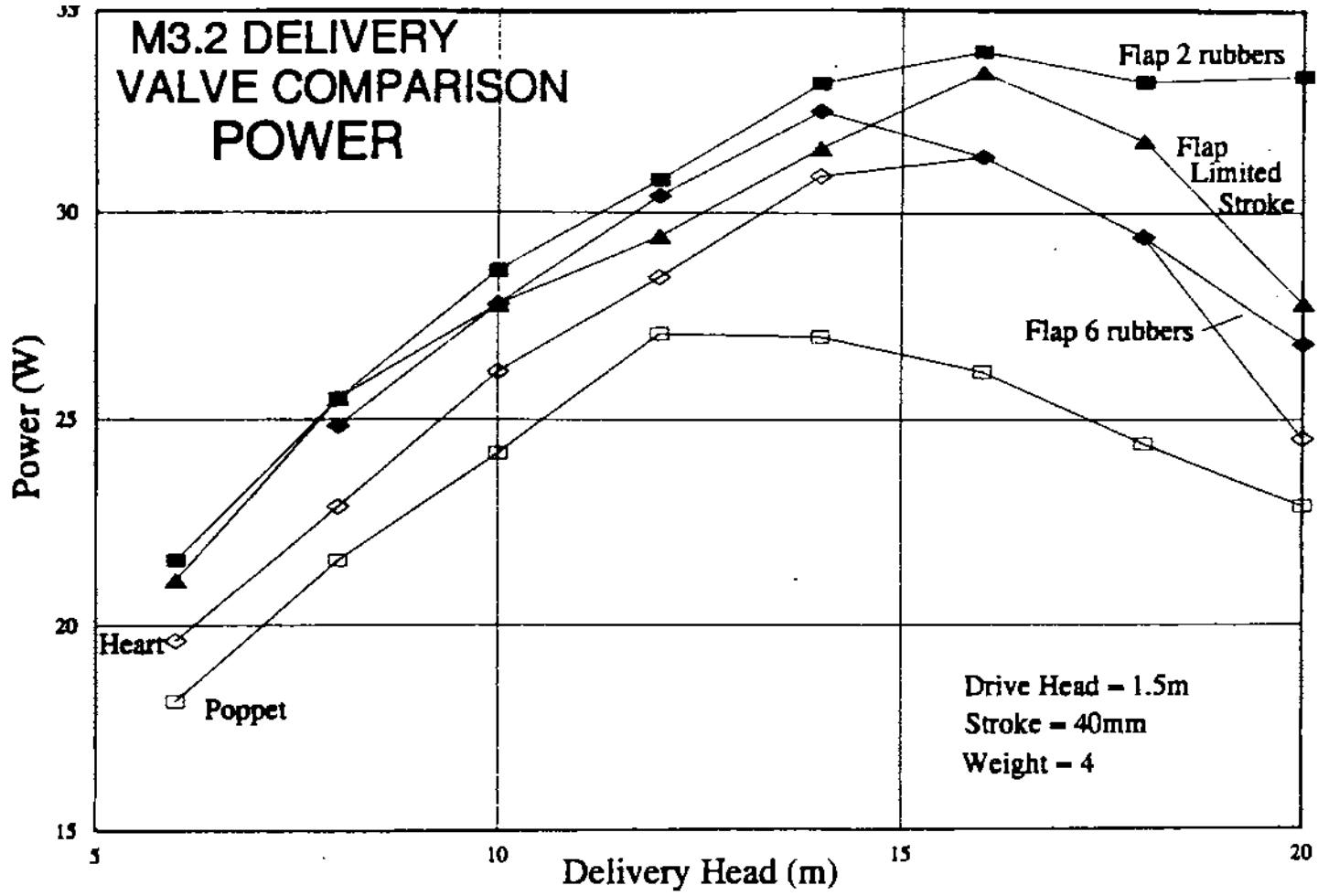
M3.2 DELIVERY
VALVE COMPARISON
POWER
Flap 2 rubbers
Flap
Limited
Stroke
Flap 6 rubbers
Heart
Poppet
Drive Head = 1.5m
Stroke = 40mm
Weight = 4
Power (W)
Delivery Head (m)
15
20
25
30
5
10
15
20

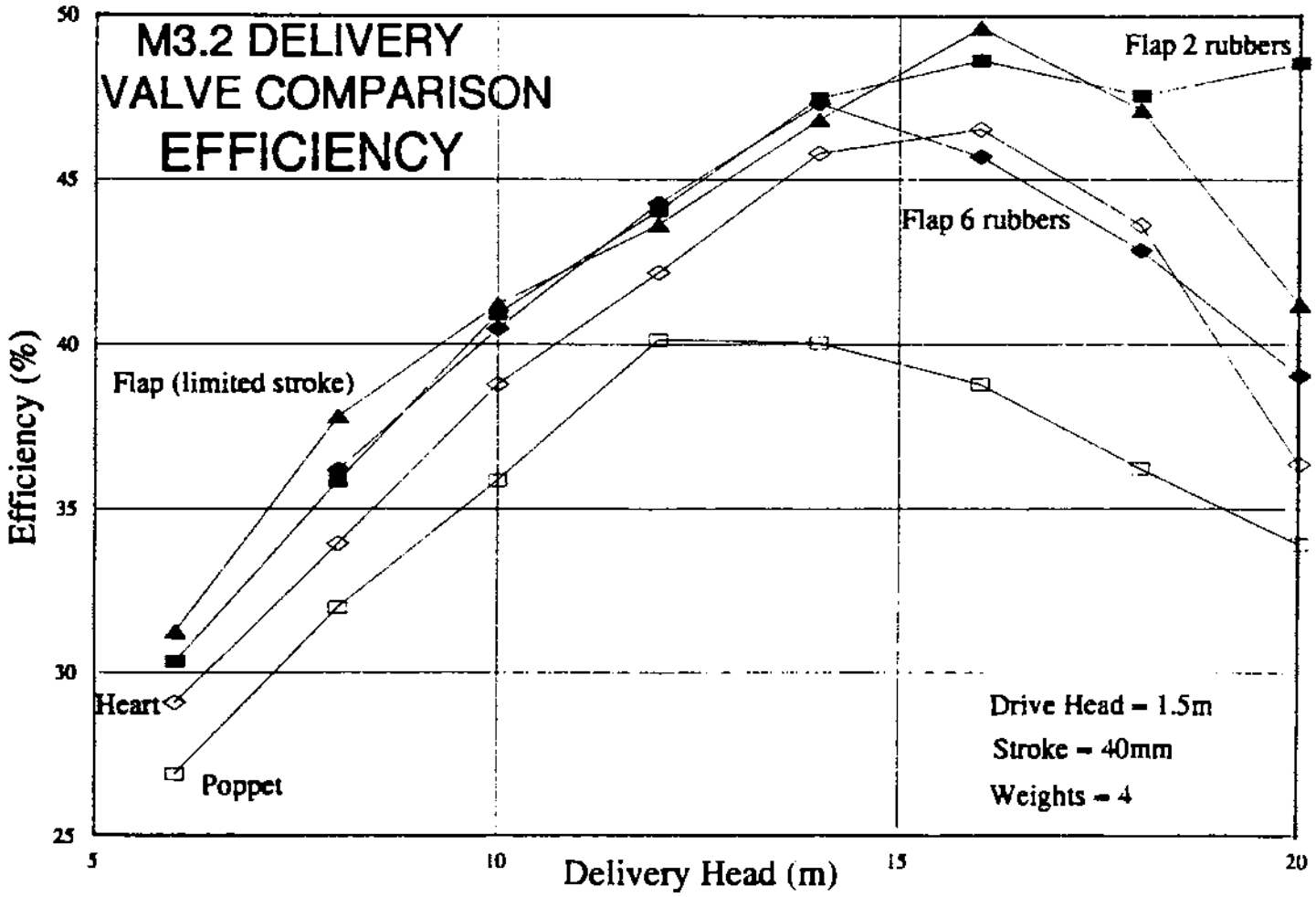
M3.2 DELIVERY
VALVE COMPARISON
EFFICIENCY
Flap 2 rubbers
Flap 6 rubbers
Flap (limited stroke)
Heart
Poppet
Drive Head = 1.5m
Stroke = 40mm
Weights = 4
Efficiency (%)
Delivery Head (m)
25
30
35
40
45
50
5
10
15
20

One problem experienced with the standard flap type valve, that has been extensively used, is splitting of the rubber at the point where it is clamped. The continual movement of the valve has often been found to lead to a stress related failure at the point about which the rubber trys to hinge. This occurs most frequently when the retaining bolt holding the valve rubber is over tightened, compressing the rubber. Using a curved washer reduces the problem by not having a sharp edge about which the rubber bends and eventually is cut. The rubber instead follows a more gentle curve along its length reducing the likelihood of stress concentration and splitting of the rubber.

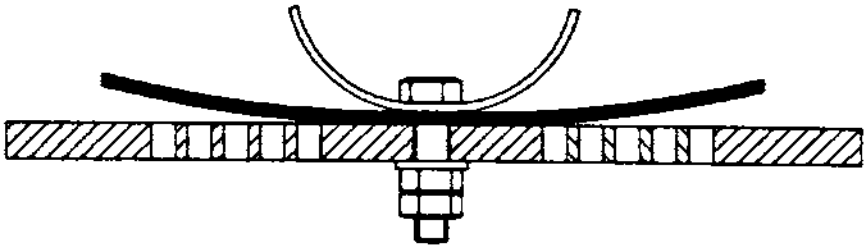

Diagram showing curved washer used in delivery valve.

Another important factor in manufacturing the rubber discs is the cutting of the central hole. This must be done cleanly with no ragged edges or flaws where cracks could start and then spread with the continual movement and stretching of the rubber. To do this it is recommended that a hole punch be bought or manufactured ensuring holes with clean edges can be accurately and repeatably made.

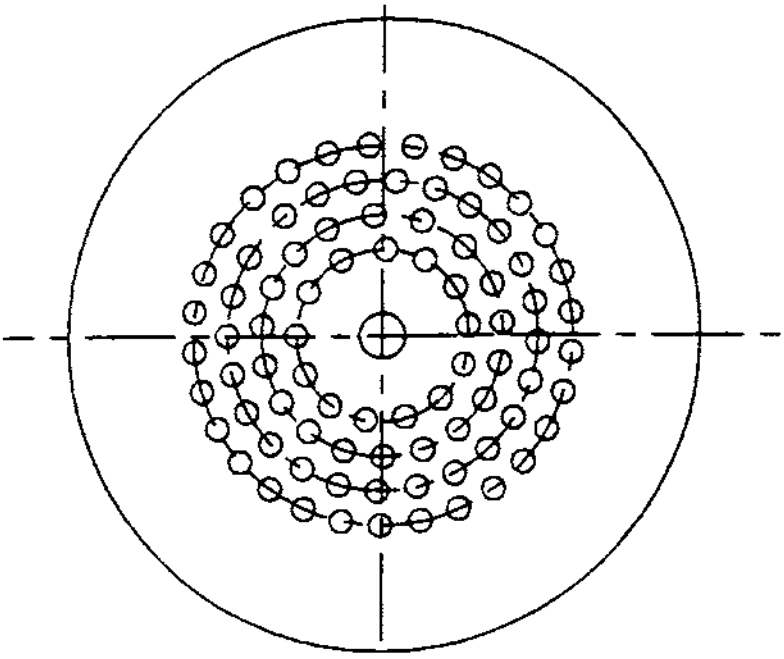

Diagram showing arrangement of delivery valve holes

The valve disc itself should be manufactured from steel plate with a minimum thickness of 3mm (10 swg) and preferably be up to 6mm. The arrangement and size of the holes in the plate is important for a number of reasons;

1) The hole size must be large enough to allow high flows with little resistance.

2) The hole size must be small enough to prevent the pressure of water in the air vessel from pushing the rubber into the holes thus deforming it and causing potential cracks.

3) The radius from the center in which the holes are confined needs to be as large as possible to maximise throughput but limited to allow sealing of the rubber around the outside of the valve plate.

4) The holes should not be too close together to prevent cracking of the valve disc between holes due to the continuous fatigue loading.

Valve plates using thick plastic material have been tested in an attempt to do without the need for a metal component. The life of such discs however was found to be too short under the loading experienced.

Marking out and accurately driling the arrangement of the large number of holes required in the valve plate can be an arduous and time consuming process. If a number of pumps are to be made it is well worth making a jig, both to cut down on the time taken and to ensure accuracy. Under the manufacturing aids section there is a drawing of one design of a valve plate jig. It ensures both the accuracy of the circumference of the plate and the accuracy of the spacing and number of holes.

Snifter Valve

During operation of the pump, air will be constantly taken into solution at the air/water interface in the air vessel. This slowly reduces the amount of air in the air vessel leading to inefficient operation and pressure spikes significantly higher than the static delivery head. Air therefore has to be constantly and reliably introduced into the air vessel to replenish that being lost in order to keep the air vessel full and the pump working at peak efficiency. This is done by the snifter valve allowing air to enter into the body of the pump each time the pressure recoil opens the impulse valve. The slight negative pressure during the recoil phase of the cycle draws air in through the snifter valve. It is placed to enable the air to travel to the under side of the delivery valve waiting to enter the air vessel at the next delivery cycle.

There are a number of types of snifter valve that have been used on ram pumps over the years. The main design considerations are that the valve is reliable and lets in the correct amount of air each cycle. On initial start-up of the pump the volume of air in the air vessel (at atmospheric pressure) is compressed as the delivery pressure builds up. The flow of air into the air vessel from the snifter valve needs to be sufficient to re-fill the air vessel over a period of time. If too much air is entering through the snifter, the air vessel will fill up quickly and then the excess air will simply be taken up the delivery pipe where it may create problems of air locks. The snifter therefore needs to be large enough to allow sufficient air to ensure replenishment of the air vessel but not so large that the delivery pipe has a large amount of air travelling in it.

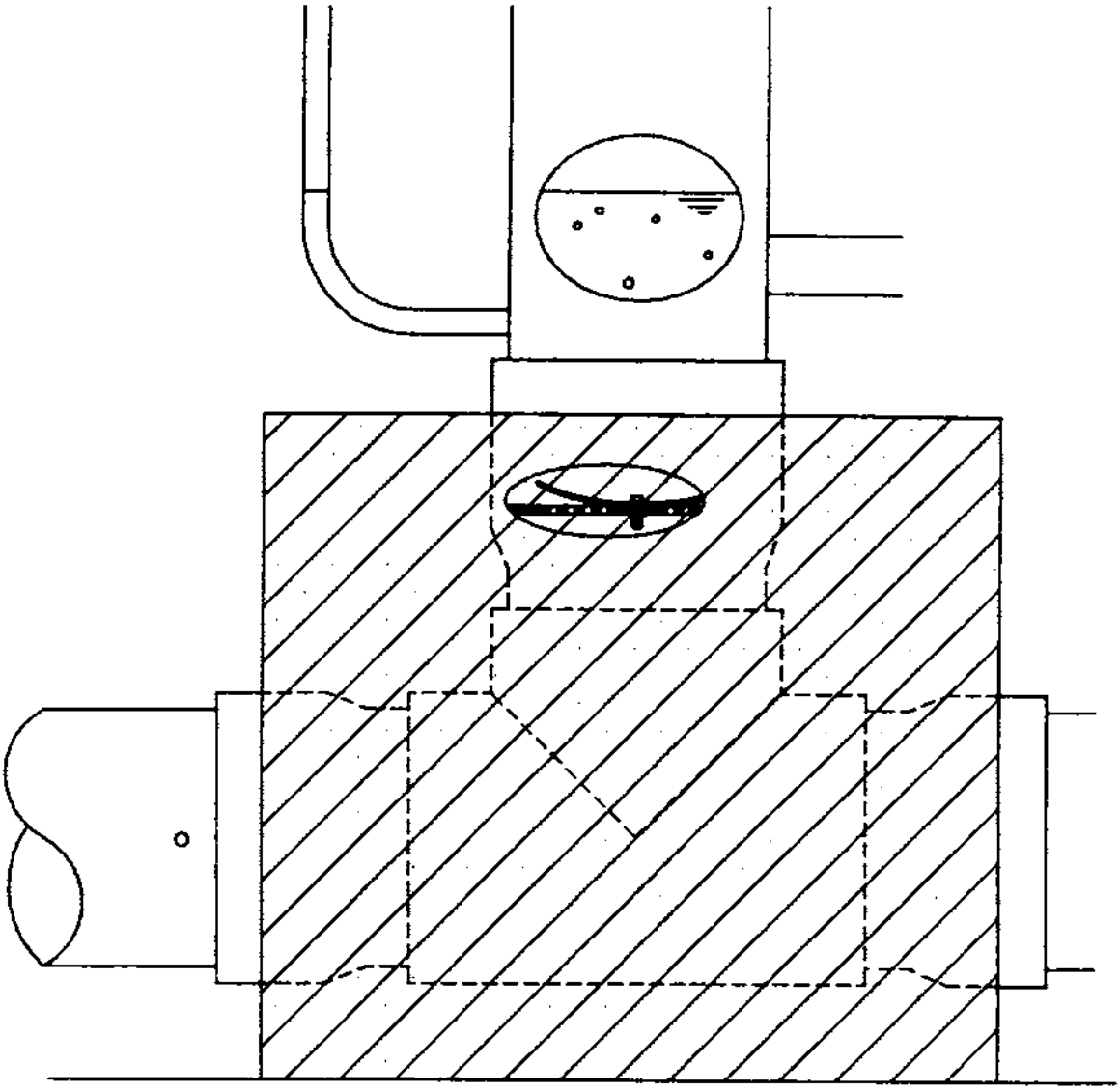

The simplest type of snifter is a hole drilled in the pump body close to the underside of the delivery valve. In the DTU M3.2 the best place for this is just upstream of the tee piece that connects the drive pipe to the pump. A small jet of water will squirt through the hole with the pressure inside the pipe until the recoil cycle occurs when air will be sucked through the hole into the pipe. As the water accelerates beginning the next cycle, some of the air rises up and sits under the delivery valve. This snifter hole should be drilled in the side of the pipe after the pump has been started for the first time.

Use the following procedure;

1) On initial start-up of the pump allow it to settle and stabalise at the system delivery pressure.

2) Make a note of the level of the air in the air vessel using the air sight tube.

3) Drill a 1.5mm dia hole in the tee/pipe as specified above.

4) Wait for 30 mins to 1 hour to see if the amount of air changes. If the air level continues to increase until it reaches the top of the delivery pipe connection, then the snifter valve is probably about the right size. If the amount of air remains constant or reduces then increase the hole diameter to 2mm. Repeat this process until the hole is big enough to allow the air level to drop down to the delivery pipe connection.

Air Vessel Size.

Over the years that ram pumps have been used there have been a number of different theories proposed and used to design air vessels. One purpose of the air vessel is to turn the intermittent flow through the delivery valve into a steady, continous flow up the delivery pipe. The air vessel provides the pump with a constant head to pump against, limits the size of the damaging pressure spikes, and removes the inefficiencies associated with intermittent flow in the delivery pipe. The size of the air vessel therefore should ensure that conditions (ie pressure) in the air vessel are little affected by the sudden inflow of water each cycle coming through the delivery valve. The volume of air in the air vessel therefore should be at least 20 and preferably nearer 50 times the expected delivery flow per cycle. An air vessel with a volume many times that of the water entering per cycle will experience little change in conditions at each delivery. Pumps running to low heads with large delivery flows therefore actually require air vessels larger than ones pumping smaller flows to high delivery heads.

For example; A pump delivering 30 l/min and operating at 60 cycles per minute has a flow per cycle of 0.5 litres. The minmum air vessel volume for this case should be 20 x 0.5 = 10 litres.

The design of the DTU M3.2 110mm PVC pump is attempting to use the fewest number of components possible. The air vessel has therefore been restricted to the same 110mm pipe used in the rest of the pump. This pipe typically has an internal cross sectional area of around 7500mm^2 and therefore a 130mm length of pipe is required per litre volume of air vessel. The maximum expected delivery flow under normal conditions is 0.5 litres per cycle requiring a 10 litre air vessel that is 1300mm long.

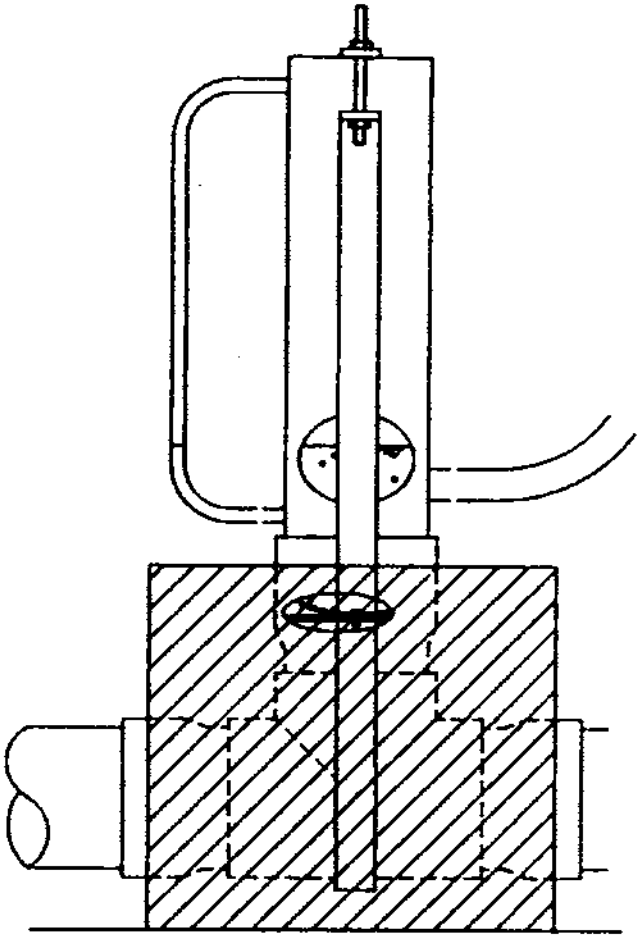

Sight tubes on an air vessel provide a very simple way of checking the level of air and therefore the effectiveness of the snifter valve. A number of problems have been encountered with the manufacture and use of air vessels that are worth mentioning:

1) Small bore, 'see-through' plastic tubing is not always easy to find.

2) Most tubing that is available deteriorates over a few months, becoming cloudy so that it is very difficult to distinguish the water level inside. Fitting a sight tube is still worthwhile under these circumstances as it is during commissioning of the pump and sizing the snifter valve that the sight tube is most useful.

3) Making connections onto the air vessel can be quite difficult. Reinforcing strips of pipe can be used over areas where the connections are to be made to increase the wall thickness of the pipe for glueing or threading.

Air Vessel Strap

The air vessel has to be held down to prevent the pressure inside it blowing out from the tee piece. The concrete block holding the tee piece makes a good solid anchor for this strap and allows the air vessel to be securely clamped. A variety of types of clamp have been used and the one shown in the drawings section of this paper is probably the simplest.

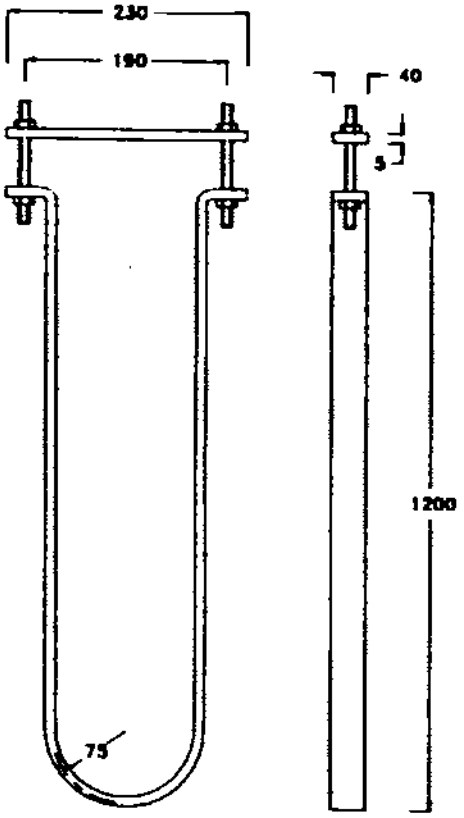

Pipe Fittings

Tee Piece

The original design of the DTU PVC ram pump had the drive pipe connected directly with the impulse valve. The impulse valve then pushed into an elbow that was incased in concrete and fixed to the concrete pump base. The delivery valve sat in the top of the elbow and the air vessel was pushed down on top of it. With an increased understanding of pump operation and after some laboratory testing it was decided to place the delivery valve and air vessel upstream of the impulse valve. On the DTU steel pumps this had given a number of operational advantages, particularly in reducing peak pressures and so it was also applied to the plastic pumps. This altered configuration overcame some installation problems but created others.

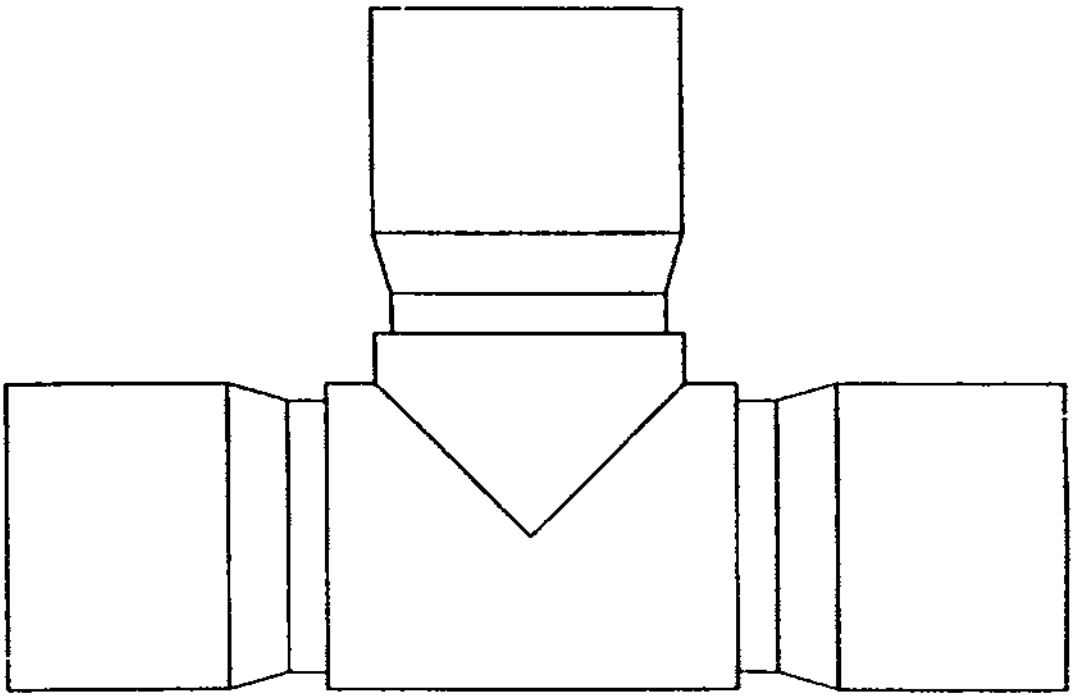

With the elbow solidly fixed downstream of the impulse valve the shocks during each pump cycle were transfered through the elbow into the concrete block. This provided good anchoring for the pump but led in some instances to cracking of the elbow. As the end of the drive pipe entering the drive tank is also fixed (and the pipe often buried) a removable section of pipe was required to allow fitting and removal of the impulse valve. This often proved to be a weak point as a good seal had to be made once the impulse valve was installed. With the revised arrangement the impulse valve is downstream of the concrete block and so provides no anchorage to prevent movement of the valve. So a further anchoring block has to be installed at the end of the impulse valve leaving enough room to allow the valve to be slid in and out of the tee piece. The gap between this second anchoring block and the valve is filled using a wedge once the valve is in place. The end of the valve also required an end cap for sealing (see below) which had to be capable of withstanding the constant shock loading. The elbow that previously experienced a substantial shock loading from the movement of the impulse valve was replaced by a tee piece that was free of this fatigue problem.

Tee fittings are commonly used in plastic pipework installations and are normally made by injection moulding. These fittings are often available in developing countries but in many cases, even where plastic pipe is manufactured, they have to be imported. They tend to be extremely expensive and are often of low quality. Experience of installations in Zimbabwe showed that the cost of a suitable tee piece was the equivalent to 3-4 meters of drive pipe - a significant cost. Such fittings were not only expensive but also in very short supply. In line with the goal of manufacturing pumps from standard pipe material a method for tee manufacture using small sections of pipe was developed. Sockets for the connection of pipes are formed by heating the ends of the pipe in an oven or oil bath and forcing them over a specially made, tapered former. Diagonal cuts are then made at 90 degress and the two sections glued together. (see drawing section). Fittings made in this way are much cheaper than those available commercially and overcome the problems of availability.

End Cap

The new pump configuration required that the end of the impulse valve be sealed with a cap. Commercially manufactured end caps are generally available and provide a good seal. However the constant movement of the impulse valve at each pump cycle crushes the end cap between the valve body and the solid end block.
It is not possible to significantly prevent this movement as the plastic material has a high degree of flexibility and so joints tend to move under the pulsing pressure experienced in the pump. Thin walled, injection moulded end caps were found to last a very short time before cracking due to the high fatigue loading experienced. On the first site installed in Zimbabwe with this configuration a number of end caps of increasing strength were fabricated. The final solution was to make a thick walled socket using the socket former, reinforced at the end with a number of extra rings of pipe. A 5mm metal disc was then shaped to fit into the end of the socket and sealed firmly in place using plumbers putty.

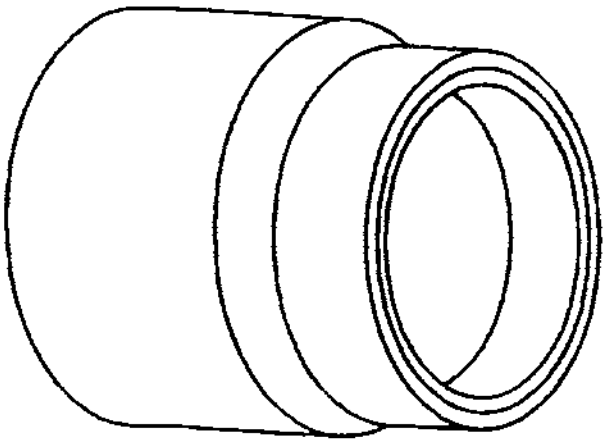

Drive Pipe

Drive Pipe Diameter

Throughout the DTU research into PVC ram pumps, the diameter of drive pipes used has been standard 4" 110mm O/D. Pumps have been designed specifically for this common size of pipe that has been found to be widely available in developing countries. The pump components themselves are now made almost entirely from this basic pipe material in order to reduce cost and simplify the raw material requirement.

The body of most ram pumps, and particularly the section housing the impulse valve, tend to be of a larger cross-sectional area than the recommended drive pipe. In the DTU steel designs for instance a 4" diameter body is used to match a 2" drive pipe diameter. This ensures that the frictional loss of water flowing through the impulse valve is low enough to allow sufficient flow in the drive pipe thus matching pump to drive pipe. A general rule that simplifies the initial sizing and design of an impulse valve is to ensure that, at all points through the pump body and impulse valve the area available for water flow is equal to, or greater than the area of the drive pipe. The design of the DTU PVC rams however is restricted to using the same 110mm pipe for the body of the impulse valve as is used for the drive pipe. The flow area through the holes of the valve is greater than the area of the drive pipe but at the leading edge of the tongue even at maximum stroke the flow area is reduced hy around 20%. This is illustrated in the diagram below.

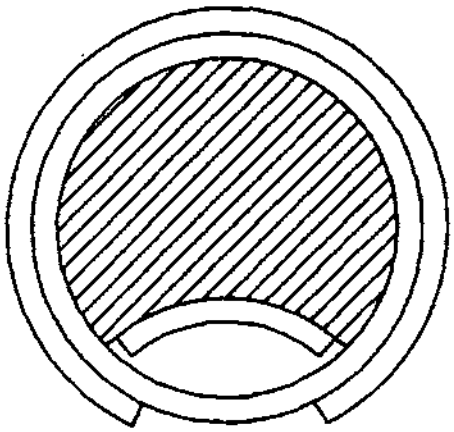

Cross-section of Impulse Valve showing restriction to flow.

Whilst it is possible to achieve drive flows in excess of 350 l/min with this arangement it became clear that particularly at low strokes the size and design of the impulse valve was not allowing full use of the diameter of the drive pipe. This situation is greatly exaggerated at lower strokes when the pump is tuned down in order to use less drive water. In effect the velocity of water in the drive pipe when the valve begins to shut is considerably lower than the maximum capacity of the pipe. As the kinetic energy available for pumping is proportional to the mass of the water and to its velocity squared, it makes sense to keep velocities high and lose a little mass by reducing pipe diameter.

Laboratory tests have been carried out in order to compare the 110mm drive pipe with the next common size down: 90mm. The results of these tests are summarised in Graph Nos X,X and show quite clearly that under most conditions both the efficiency and power output of the pump are improved by using the smaller drive pipe size.

Whilst the pump will work perfectly well with a 110mm drive pipe over the complete range of operating conditions it is now recommended that a 90mm pipe be used if available. This may also give a small saving in system cost and gives a greater potential range of pipe that can be used if one size is not available. In situations of particularly low drive flow the pump may not actually be able to operate with the larger sizes of drive pipe. The maximum head to which a pump can deliver is dependant upon the velocity of the water in the drive pipe. To reach a given delivery head there has to be a corresponding drop in velocity turning kinetic energy to potential energy. If the velocity drop required to reach a given pressure is larger than the maximum velocity of the water in the drive pipe then the pump will never reach the required delivery head although it can appear to be operating. Smaller diameter drive pipes will have a higher water velocity for a given flow and therefore will permit operation in situations where larger diameter pipes would not work. The graph below shows the typical lower boundary of the commonest pipes used for DTU M3.2 PVC pumps

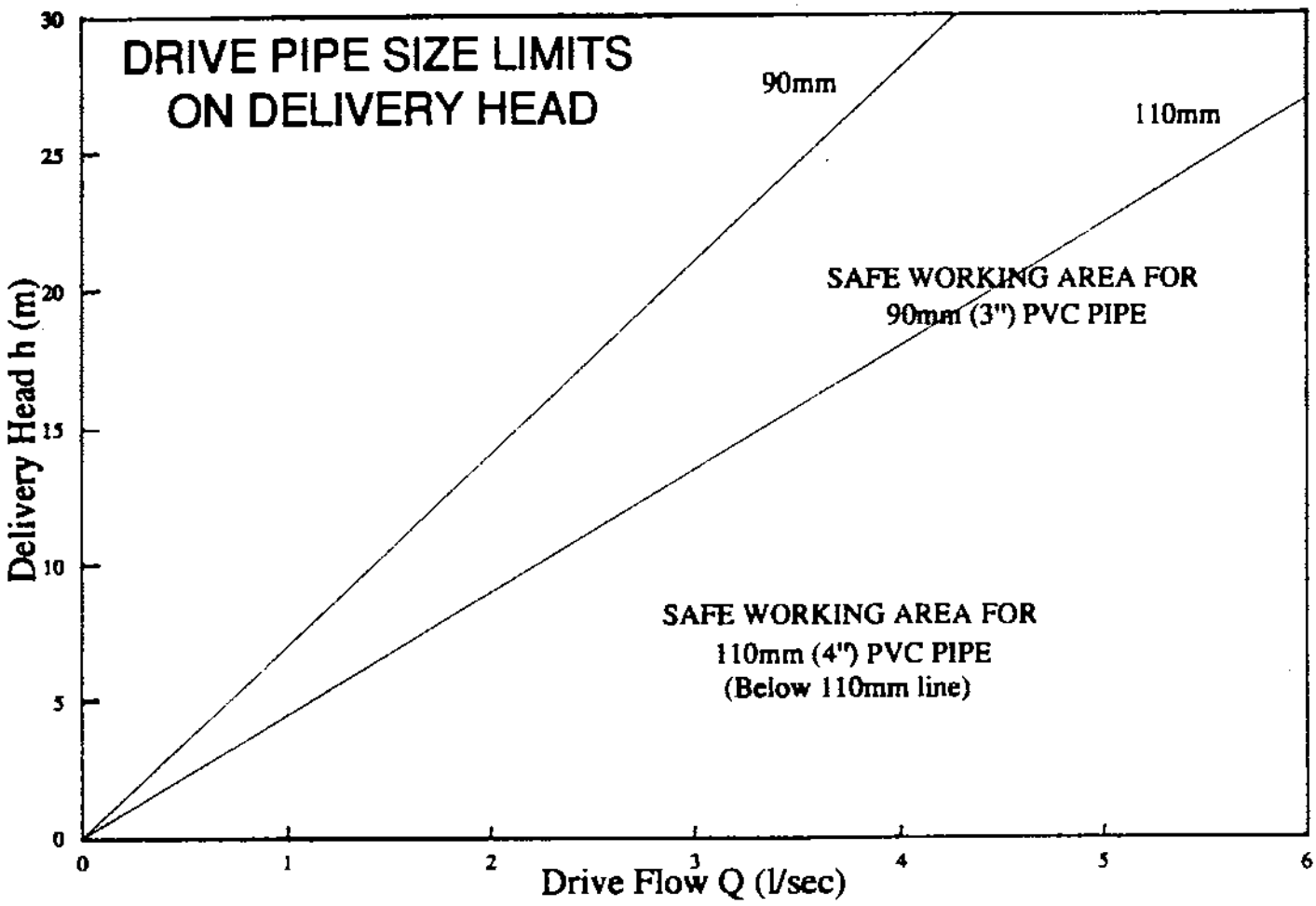

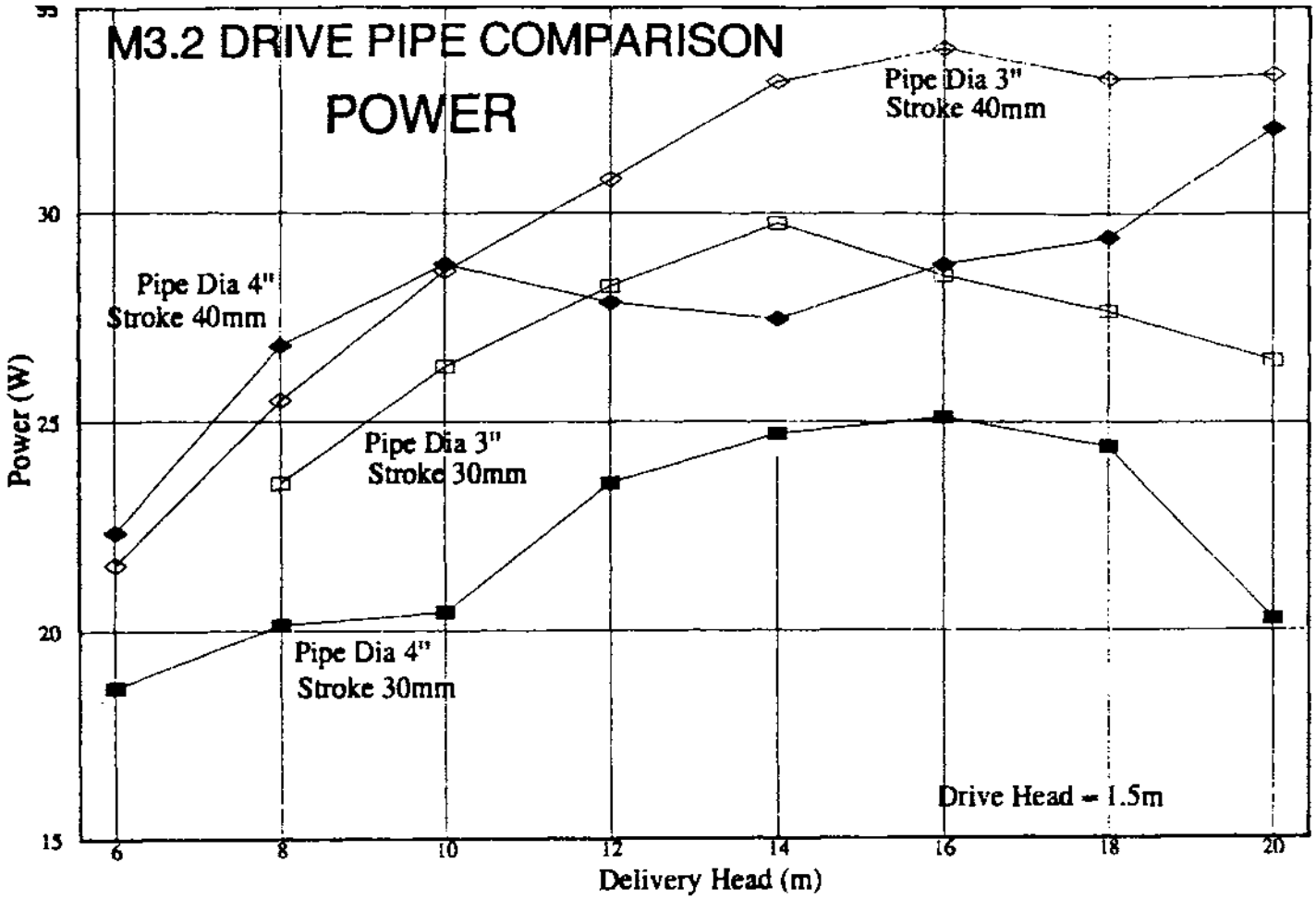
M3.2 DRIVE PIPE COMPARISON
POWER
Pipe Dia 3"
Stroke 40mm
Pipe Dia 4"
Stroke 40mm
Pipe Dia 3"
Stroke 30mm
Pipe Dia 4"
Stroke 30mm
Drive Head = 1.5m
Power (W)
Delivery Head (m)
15
20
25
30
6
8
10
12
14
16
18
20

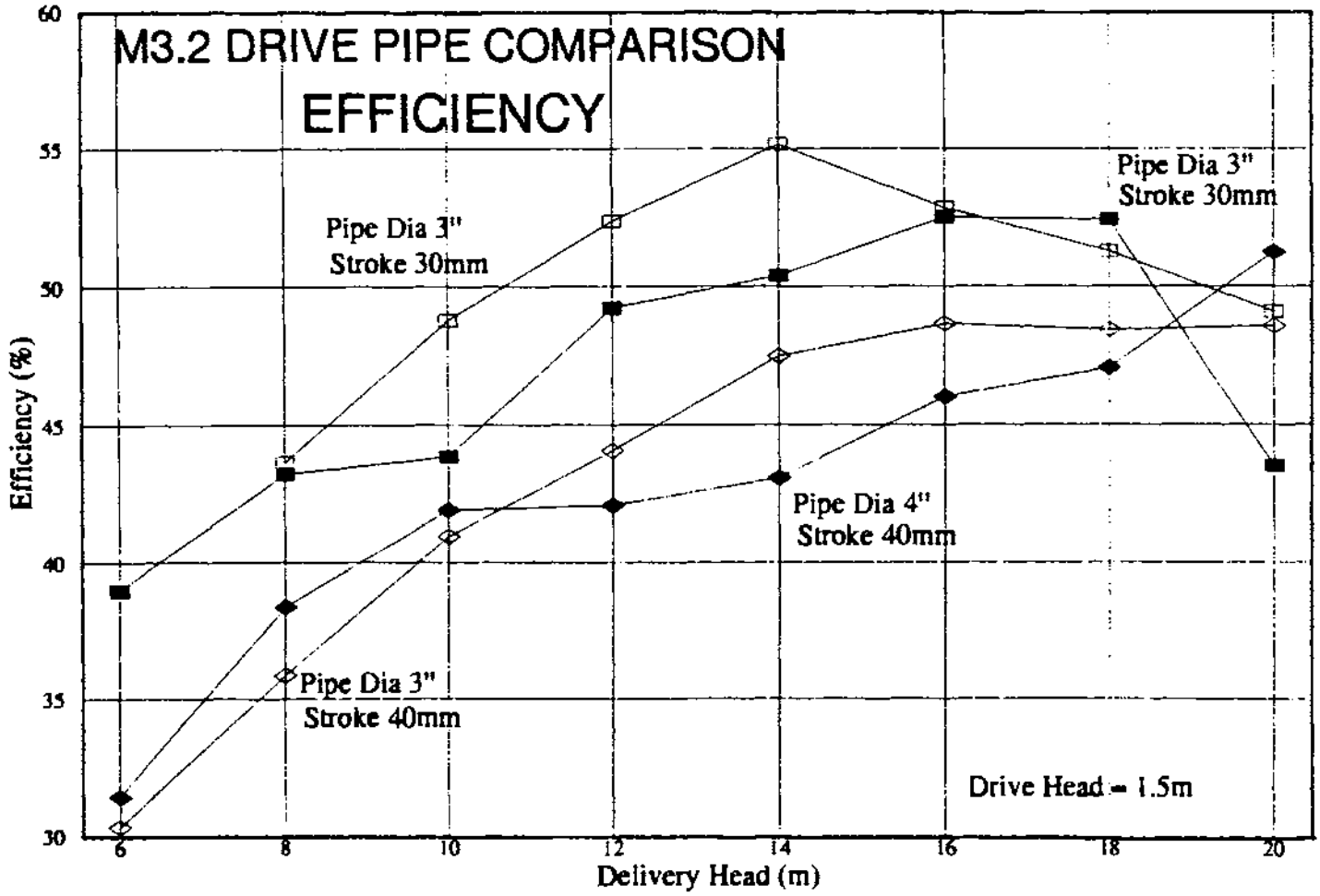
M3.2 DRIVE PIPE COMPARISON
EFFICIENCY
Pipe Dia 3"
Stroke 30mm
Pipe Dia 3"
Stroke 30mm
Pipe Dia 4"
Stroke 40mm
Pipe Dia 3"
Stroke 40mm
Drive Head = 1.5m
Efficiency (%)
Delivery Head (m)
30
35
40
45
50
55
60
6
8
10
12
14
16
18
20

Drive Pipe Length

One critical factor with PVC ram pumps for small irrigation schemes is cost. The pump and system constraints have been designed to give good performance, reliability, local manufacture, availability of spare parts, all for the smallest possible cost. One of the major cost components of any ram pump system is the drive pipe which can often equal or even exceed the cost of the pump unit itself! As drive heads are comparatively small for PVC pumps, the physical layout of the site can often allow drive pipe lengths to be very short. Systems have been installed and successfully run with drive pipe lengths of only 6m. Plastic pumps generally can utilise shorter drive pipes than their steel equivalents due to the much lower wave speeds of the transients moving in them. Longer drive pipes can increase the pumping energy available by increasing the mass of water moving in the drive pipe and increasing the length of the delivery cycle during operation. Longer drive pipes introduce greater friction into the system so that less of the drive head is available to the pump. This consideration of pipe friction imposes an upper limit on the length of drive pipe that can be used for a given drive head.

Bearing the all important cost factor in mind it is recommended that drive pipe length normally be kept in the range 6 to 30m with 12m being a rough guide to the optimum when balancing cost and performance. If a combination of a necessarily long drive pipe (greater than 20m), high drive flow (greater than 300l/min), and low delivery head (less than 8m) occurs it is recommended that a 110mm rather than the standard 90mm drive pipe be used as the friction in a 90mm pipe would be more significant in such a situation.

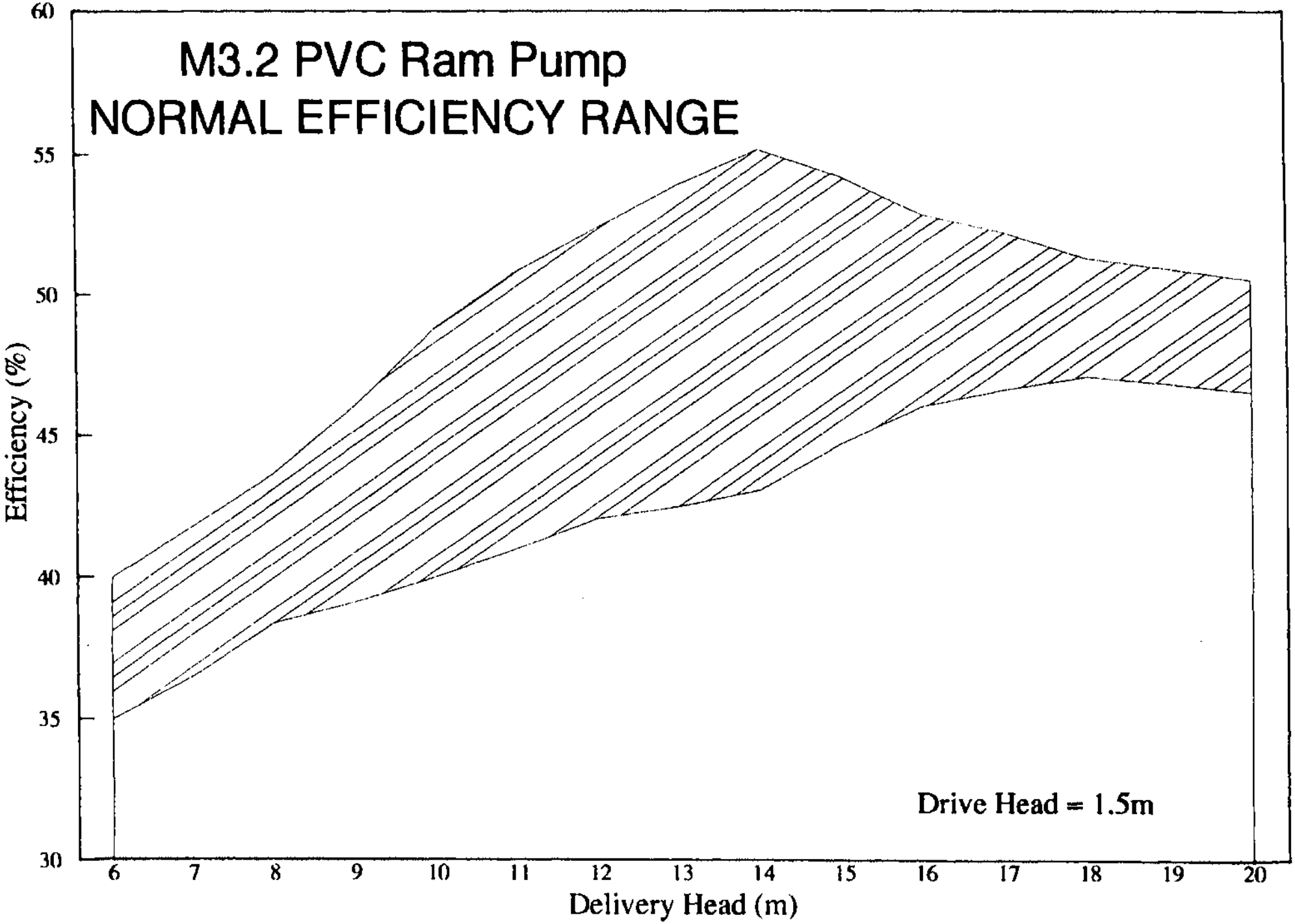
M3.2 PVC Ram Pump
NORMAL EFFICIENCY RANGE
Efficiency (%)
60
55
50
45
40
35
30
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Delivery Head (m)
Drive Head = 1.5m

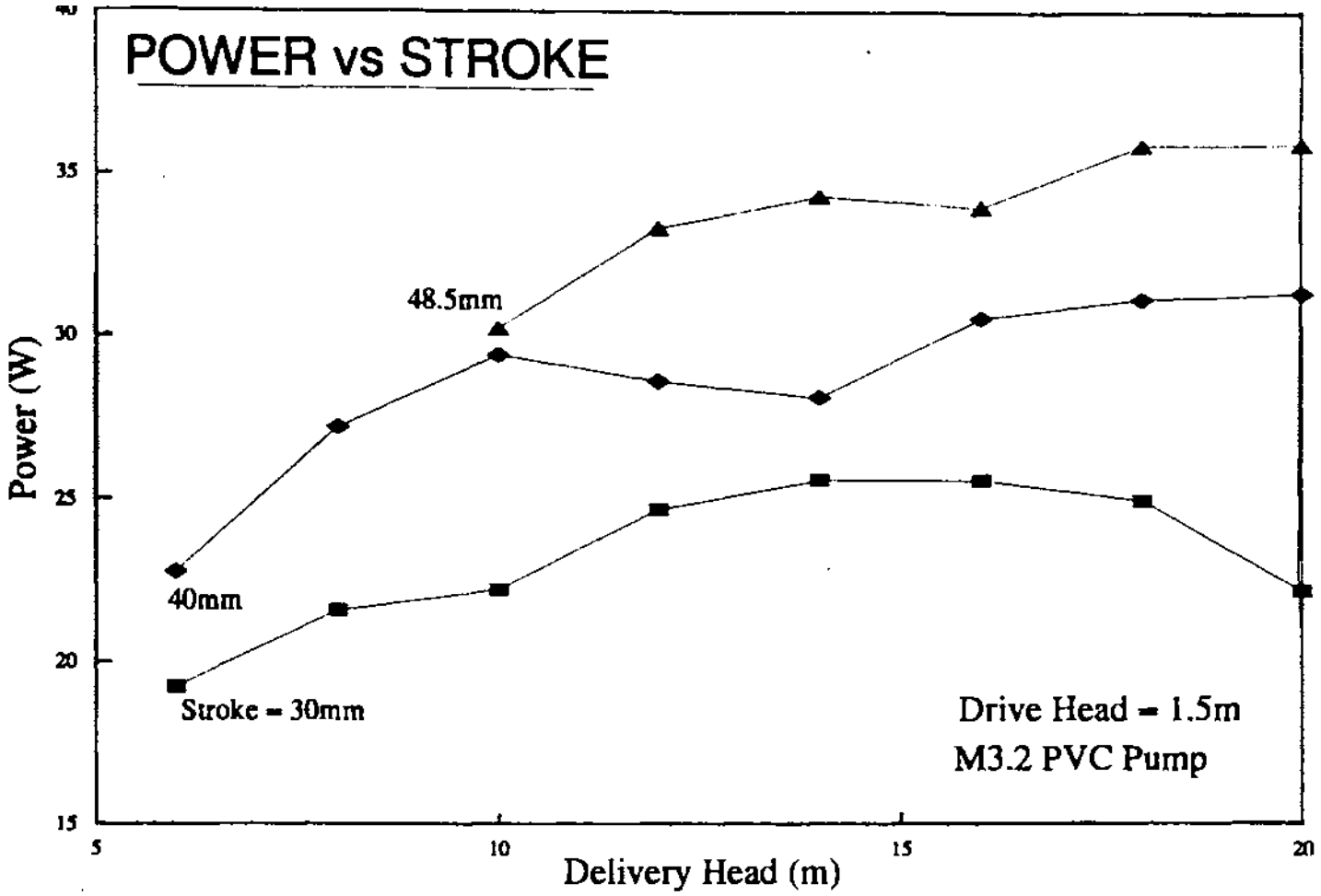
POWER vs STROKE
Power (W)
Delivery Head (m)
48.5mm
40mm
Stroke = 30mm
Drive Head = 1.5m
M3.2 PVC Pump
15
20
25
30
35
5
10
15
20

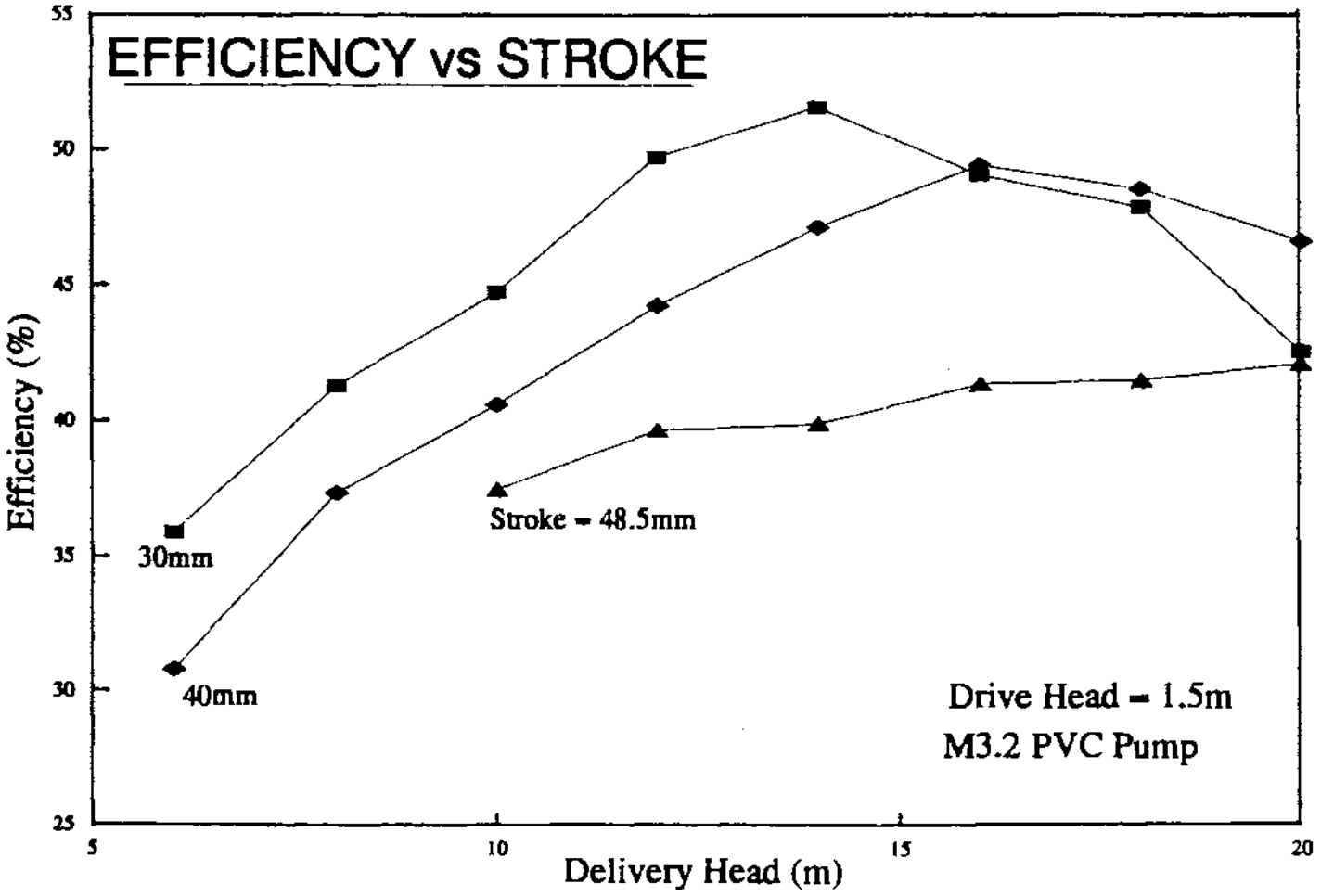
EFFICIENCY vs STROKE
Efficiency (%)
Delivery Head (m)
30mm
40mm
Stroke = 48.5mm
Drive Head = 1.5m
M3.2 PVC Pump
25
30
35
40
45
50
55
5
10
15
20

DEVELOPMENT TECHNOLOGY UNIT
University of Warwick, Coventry, UK

P90 ASSEMBLY

Drawing No. 1 of 12 NOT TO SCALE

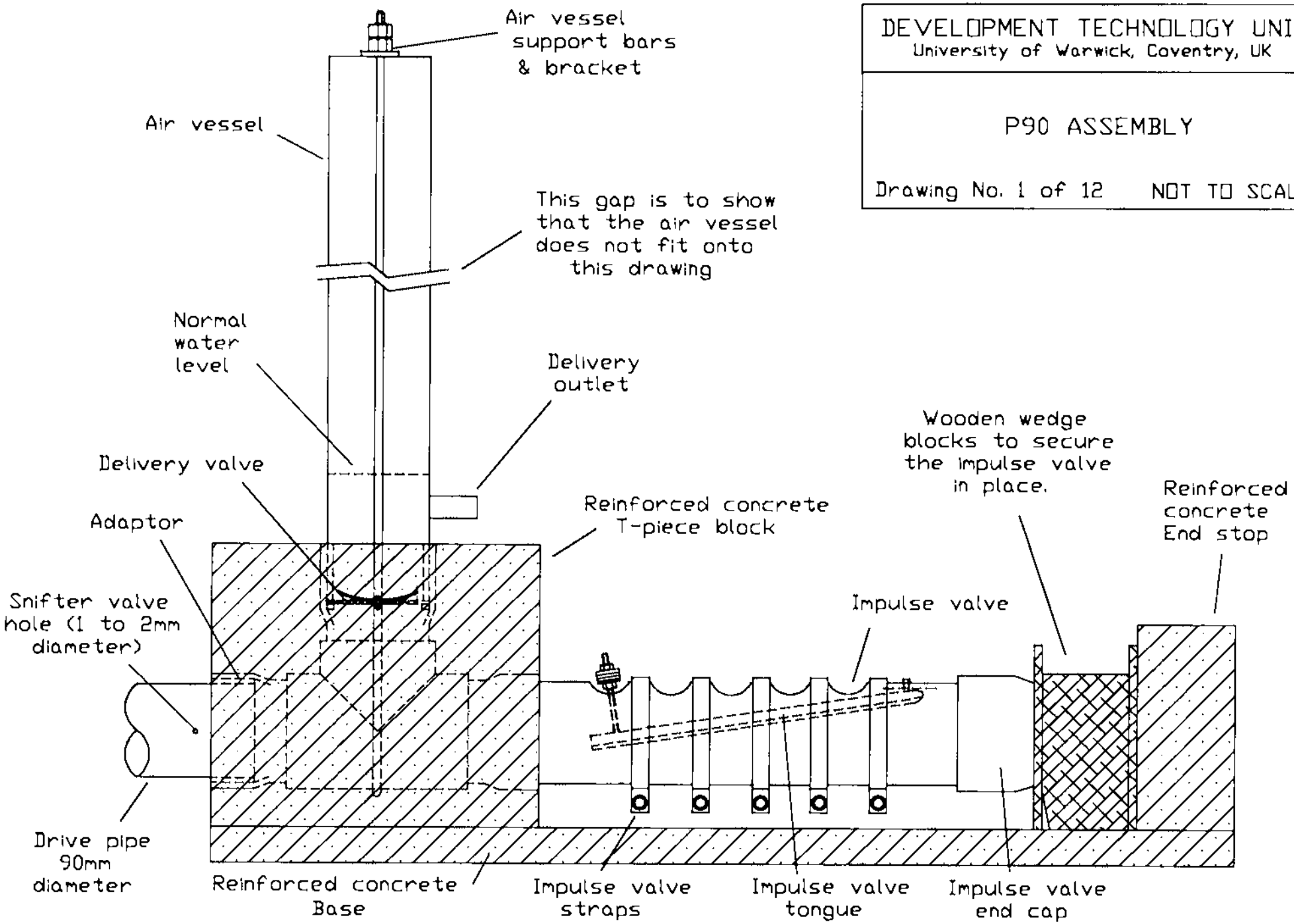

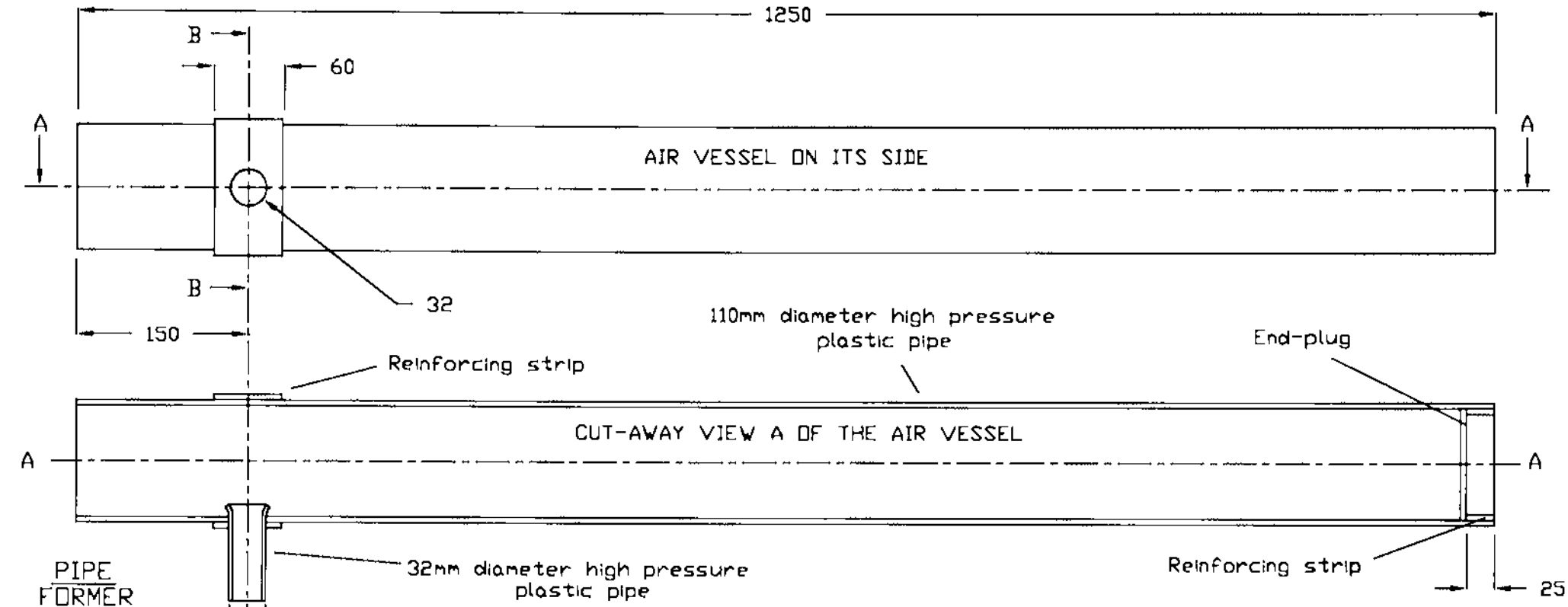

PIPE FORMER

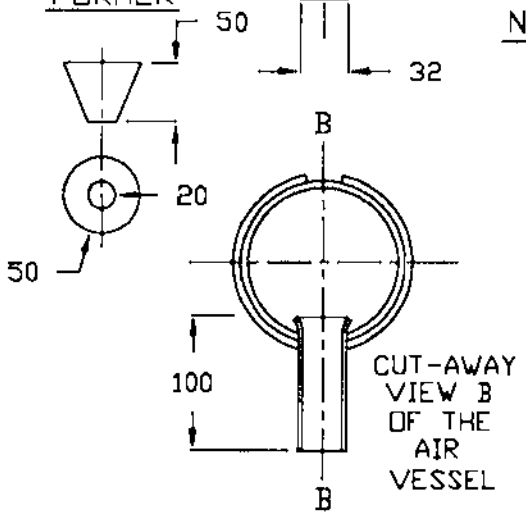

ALL DIMENSIONS IN mm

NOTES:

1 - The air vessel is made using 110mm diameter high pressure plastic pipe and 32mm diameter plastic pipe for the delivery pipe outlet.

2 - The reinforcing strip is also 110mm diameter high pressure plastic pipe. It is cut and glued into place using a good plastic adhesive

3 - To make the end-plug, a section of pipe is cut along its length, heated and flattened. Once cooled, a disc is cut out of this to form the correct shape.

4 - To secure the delivery outlet pipe to the air vessel, firstly, heat the end of the pipe until it starts to soften. Push the pipe through the hole in the air vessel and widen the pipe end. using a tapered wooden or steel former. (as shown).

5 - Use a good plastic adhesive to bond all the sections together.

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P90 AIR VESSEL

Drawing No. 2 of 12 NOT TO SCALE

AIR VESSEL ASSEMBLY

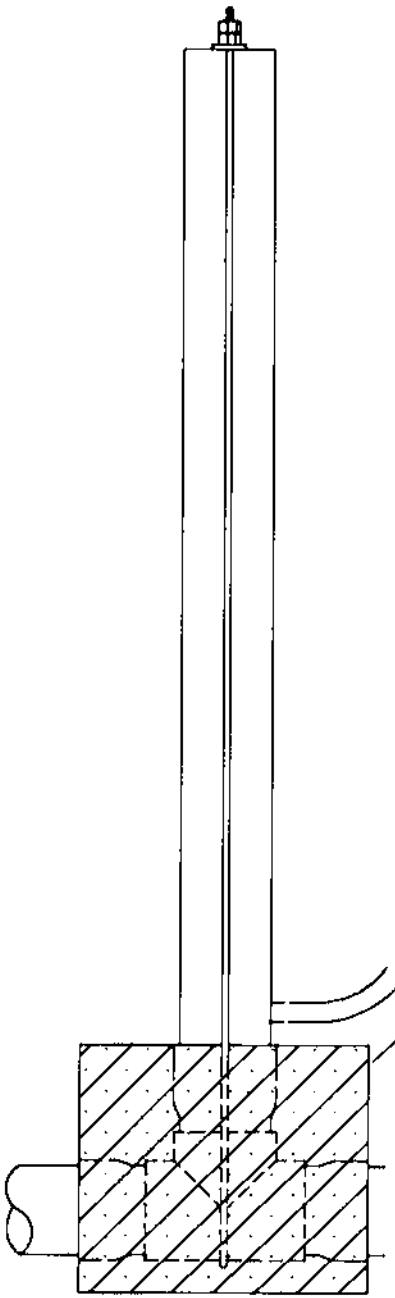

SUPPORT BAR

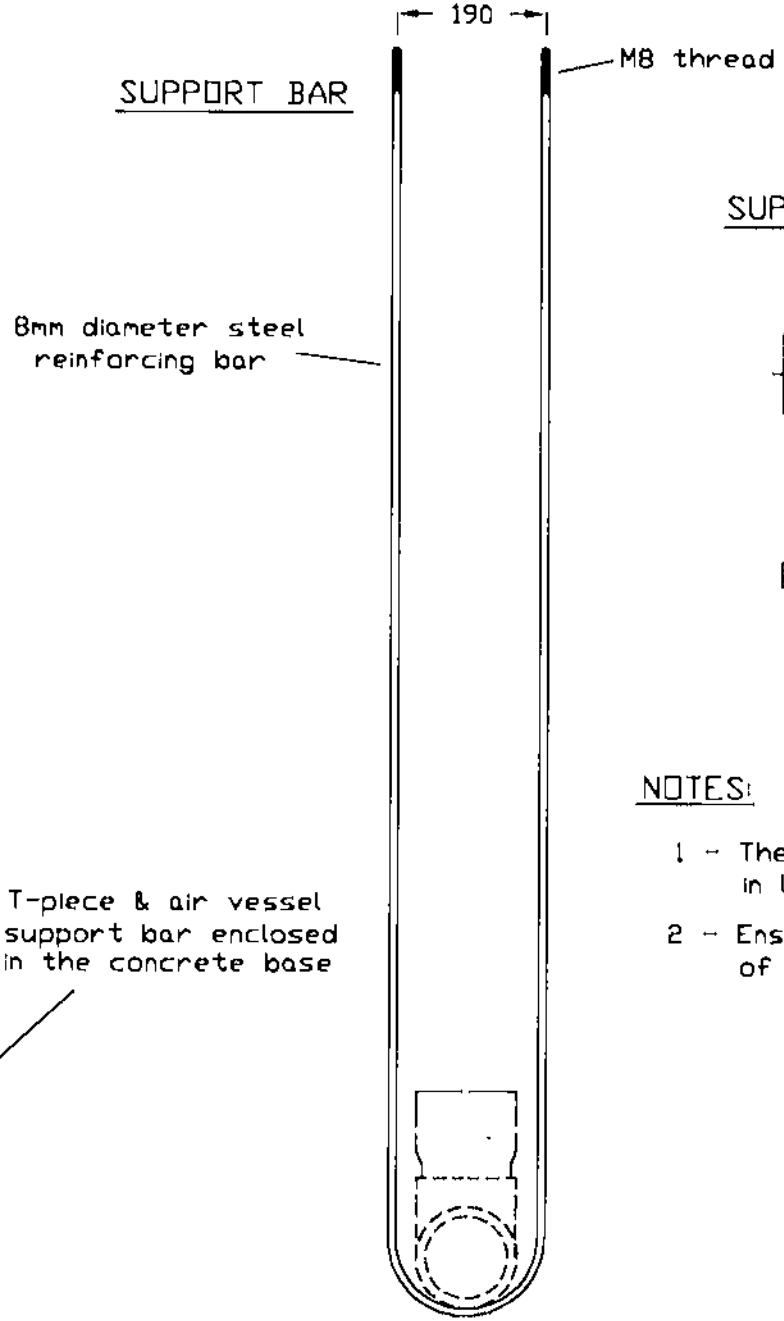

SUPPORT BRACKET

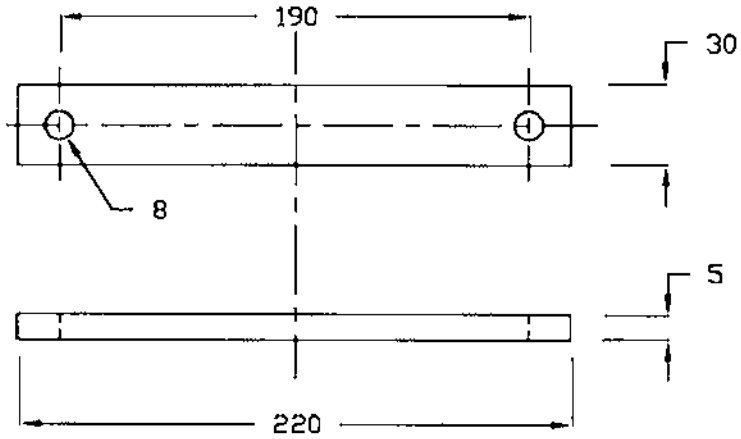

NOTES:

1 - The support bar is approximately 3.5 meters in length threaded at the ends (M8 thread)

2 - Ensure a secondary lock nut is used on each end of the support bar when assembling the pump

ALL DIMENSIONS IN mm

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P90 AIR VESSEL
SUPPORT BAR & BRACKET

Drawing No. 3 of 12 NOT TO SCALE

DELIVERY VALVE PLATE

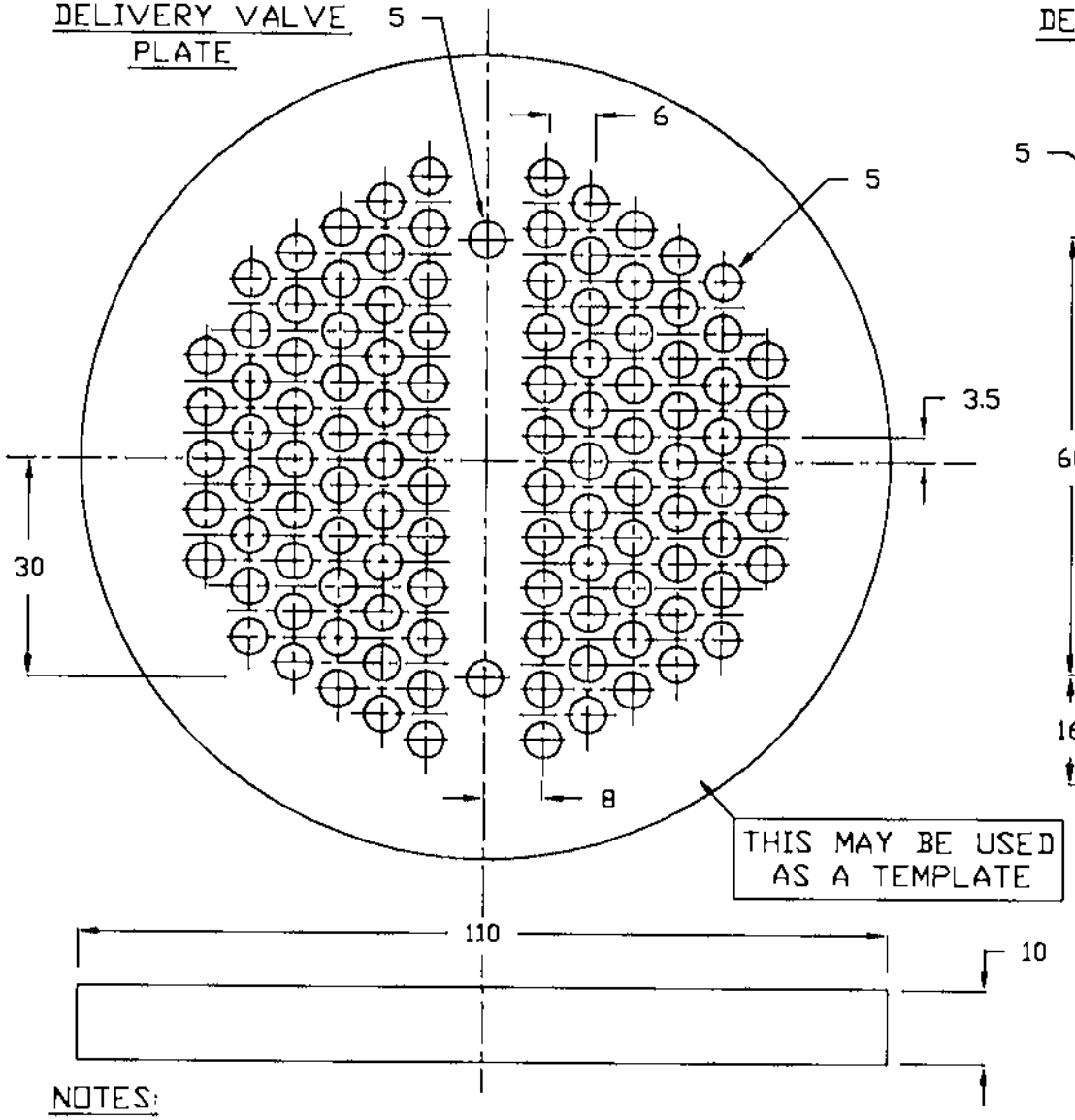

DELIVERY VALVE CROSS-BAR

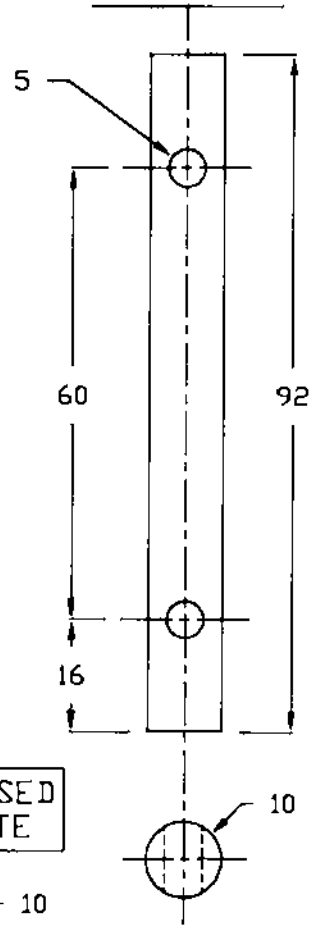

DELIVERY VALVE ASSEMBLY

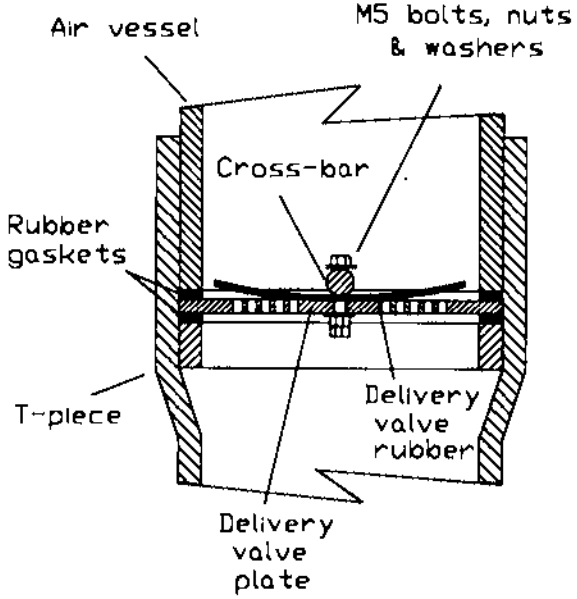

ASSEMBLY INSTRUCTIONS

1 - Place the valve rubber on the unchamfered side of the plate
2 - Push the bolts through the cross-bar, rubber and plate
3 - Add a nut onto each bolt and just finger tighten
4 - Add a second nut onto each bolt and tighten each pair of nuts securely together

NOTES:

1 - Delivery valve plate is 8 or 10mm mild steel plate
All holes should be chamfered on one side of the plate
2 - Delivery valve cross-bar is 10mm diameter steel reinforcing bar
3 - The delivery valve rubber has a diameter of 92mm and should be about 3mm thick

ALL DIMENSIONS IN mm

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University of Warwick, Coventry, UK

P90 DELIVERY VALVE

Drawing No. 4 of 12

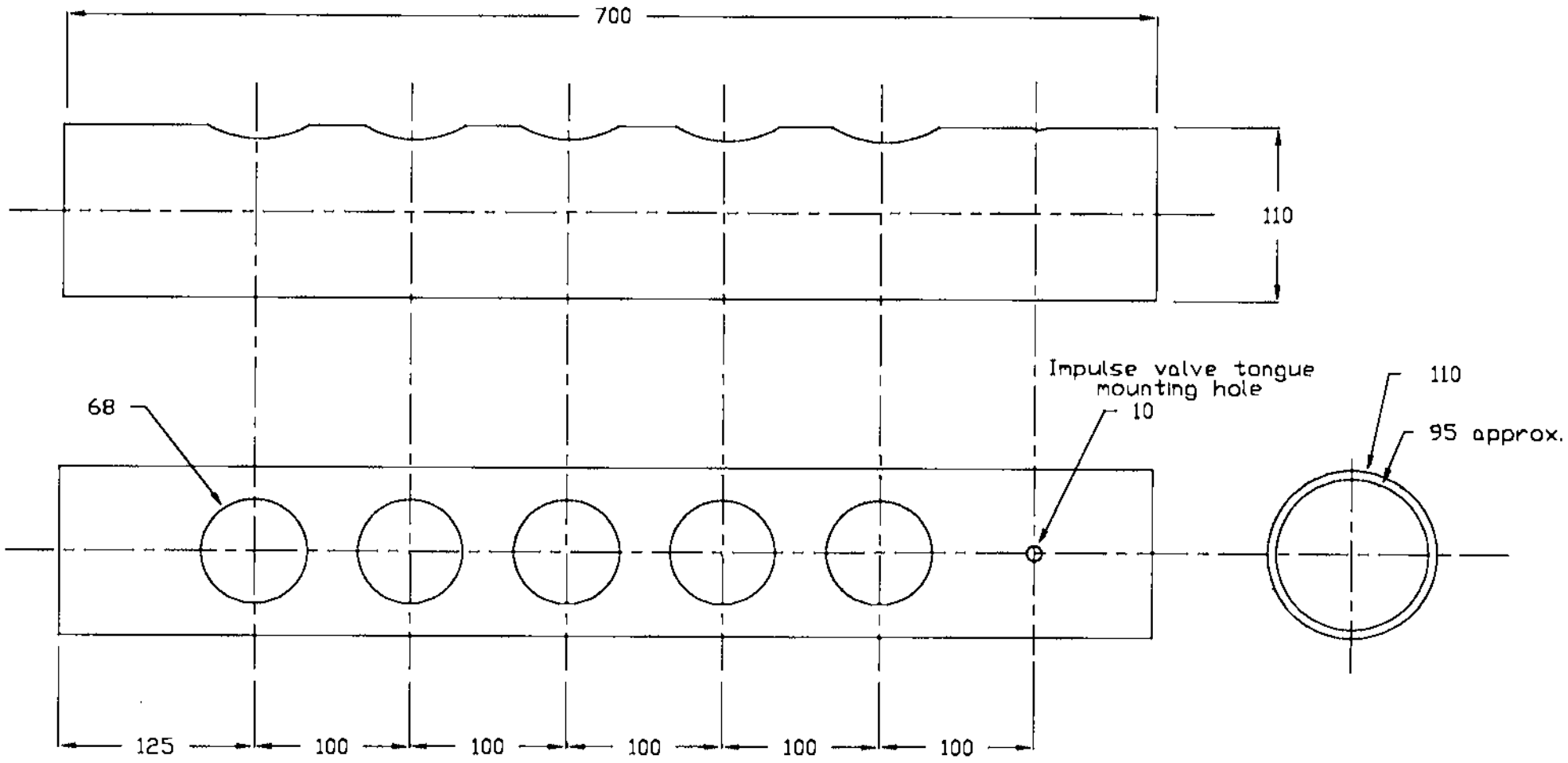

NOTES:

1 - The material used for the impulse valve is CLASS 16 high pressure PVC pipe. The wall thickness of the pipe is usually about 7mm.

2 - A tank cutter of between 66 and 70mm may be used to cut out the large impulse valve holes.

ALL DIMENSIONS IN mm

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P90 IMPULSE VALVE

Drawing No. 5 of 12 NOT TO SCALE

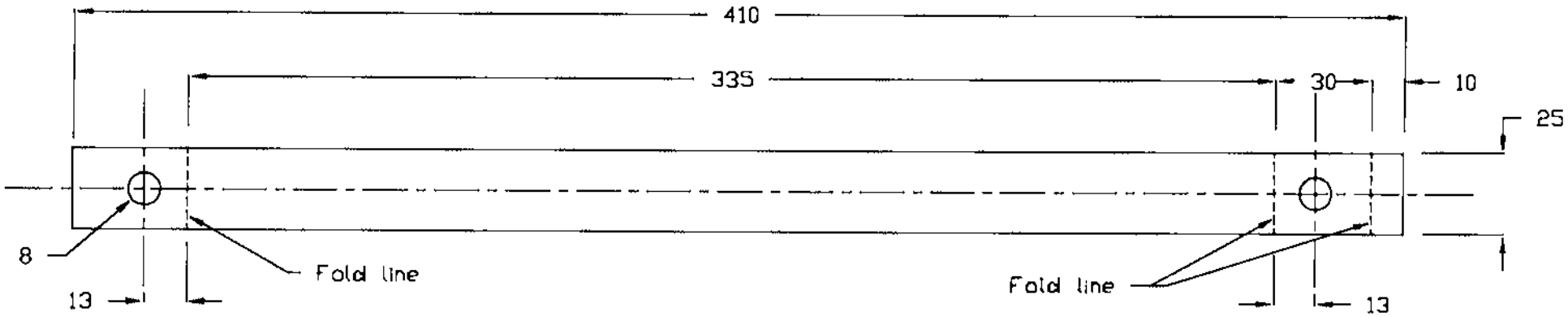

ASSEMBLED IMPULSE VALVE STRAP

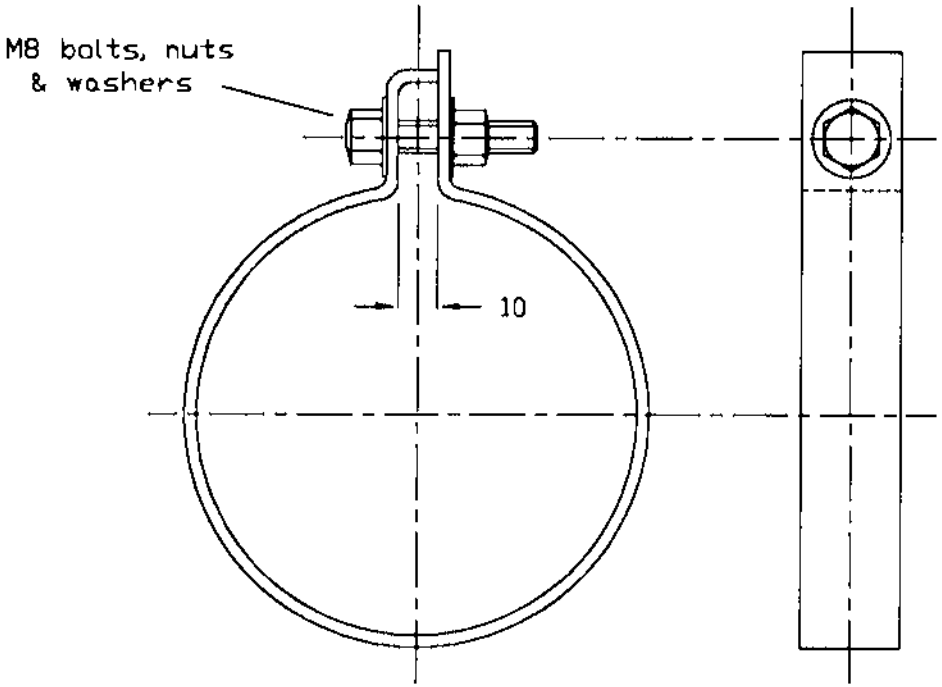

NOTES:

1 - The material used to make the strap is 25 x 3mm mild steel.

2 - 5 straps are needed for the impulse valve.

3 - Mark the measured fold lines on the cut lengths of steel. After folding the straps wrap them around the impulse valve and check that there is a minimum gap of about 10mm between the folded up-rights.

4 - When the straps are assembled, paint them before adding them to the impulse valve.

ALL DIMENSIONS IN mm

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P90 IMPULSE VALVE STRAP

Drawing No. 6 of 12 NOT TO SCALE

TONGUE

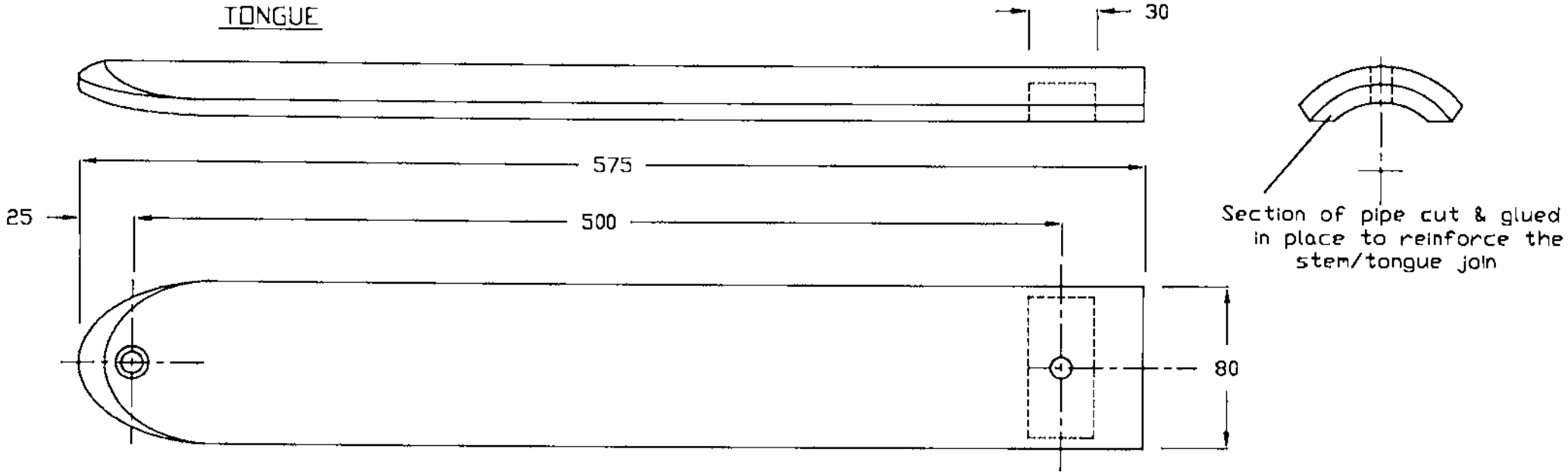

TONGUE MOUNTING

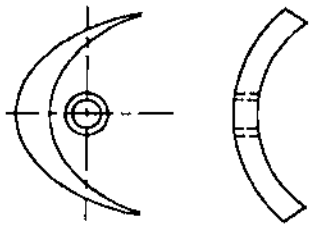

A steel ring with an internal diameter of approx. 10mm (3/8' pipe) is pushed into a hole in the tongue using an interference fit. Use a 50mm M8 bolt, 2 nuts and washers to fit the tongue to the impulse valve.

TONGUE STEM ASSEMBLY

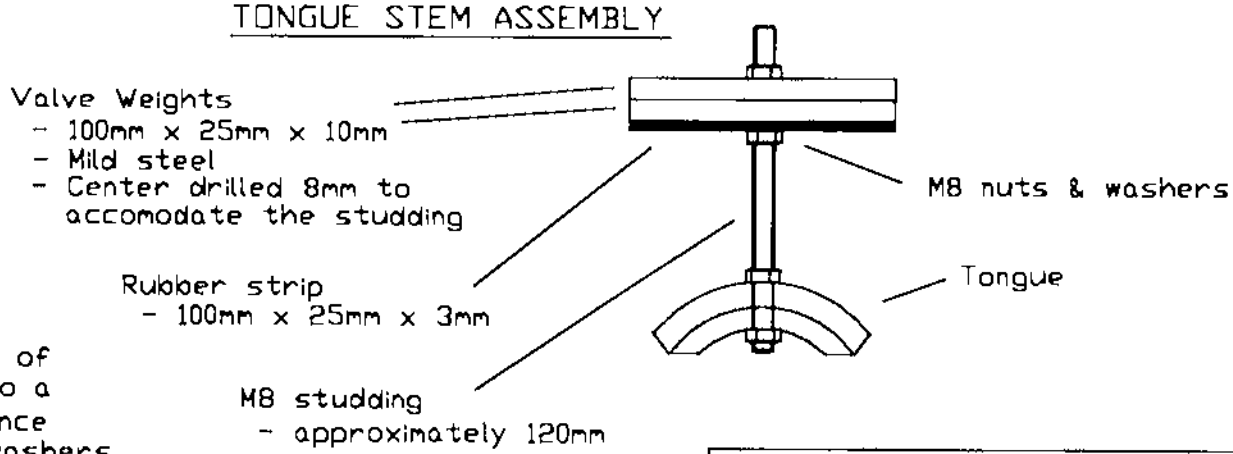

FITTING THE TONGUE

Hold the tongue in place inside the impulse valve. Feed the bolt through a washer and through the impulse valve and tongue mounting holes. Hold the tongue in the 'full-open' position, add another washer onto the bolt and screw on a nut until it just touches the tongue. Add a second nut and tighten the two nuts securely together.

ALL DIMENSIONS IN mm

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P90 IMPULSE VALVE TONGUE & ASSEMBLY

Drawing No. 7 of 12 NOT TO SCALE

STANDARD T-PIECE

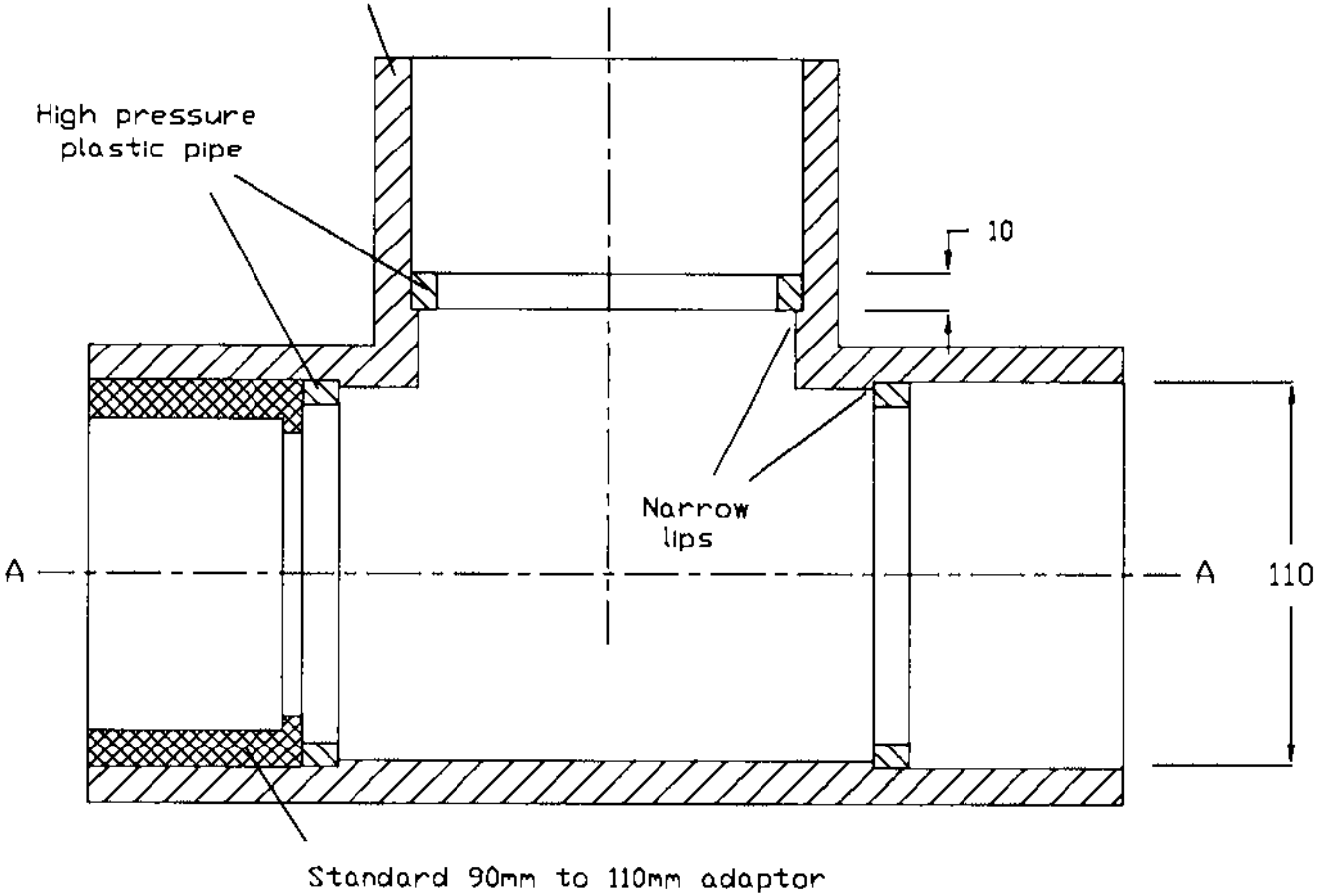

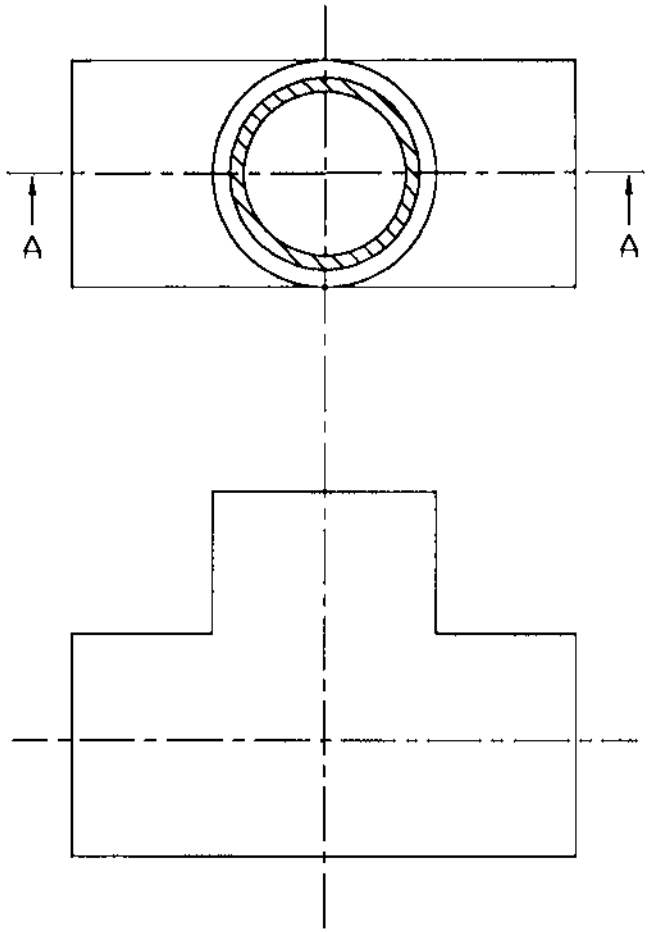

NOTES:

1 - The T-piece for the P90 may be bought commercially or made by hand. The drawing above shows an example of a commercial T-piece (high pressure plastic) that is suitable for 110mm diameter pipe.

2 - T-pieces available on the market tend to have narrow support lips as shown above. These need to be reinforced and this is done by gluing into place a 10mm length of high pressure plastic pipe as shown.

3 - When purchasing a 110mm high pressure plastic T-piece, also buy a 90mm to 110mm adaptor. This is because the drive pipe for the pump has a 90mm diameter and will have to be adapted to fit the T-piece.

ALL DIMENSIONS IN mm

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P90 - USING A STANDARD T-PIECE & ADAPTOR

Drawing No. 8 of 12 NOT TO SCALE

MAKING A T-PIECE

PART A

Cut 150 & 400mm lengths of pipe. Cut the shorter pipe down its length and heat it until workable. Open the heated shorter pipe and fit it over the center of the longer section using glue and clamp it in place.

Using the T-piece former, form sockets at each end of PART A. Next, cut out a 90 degree 'V-Notch as shown. Make sure the gap on the shorter outter pipe is opposite the @V-Notch'.

PART B

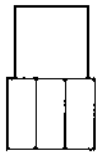

Cut 75 & 200mm lengths of pipe. Cut, heat & glue the shorter pipe flush with one end of the longer. Cut a piece of pipe to fit the gap left on the outer pipe. Heat & glue this into place.

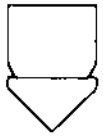

Form the socket on the end of PART B and cut the other end to fit the 'V-Notch' on PART A.

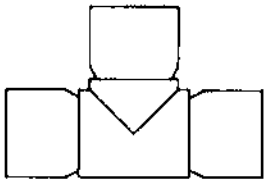

File both PARTS A & B until a reasonable fit is obtained. Glue together both parts using a mixture of PVC glue and pipe shavings to fill the gaps.

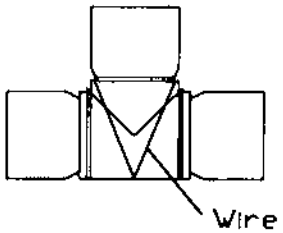

Wire may be wrapped around the glued parts to hold them more securely together. The T-piece is now ready to be set into a concrete base.

ALL DIMENSIONS IN mm

COMPLETED T-PIECE

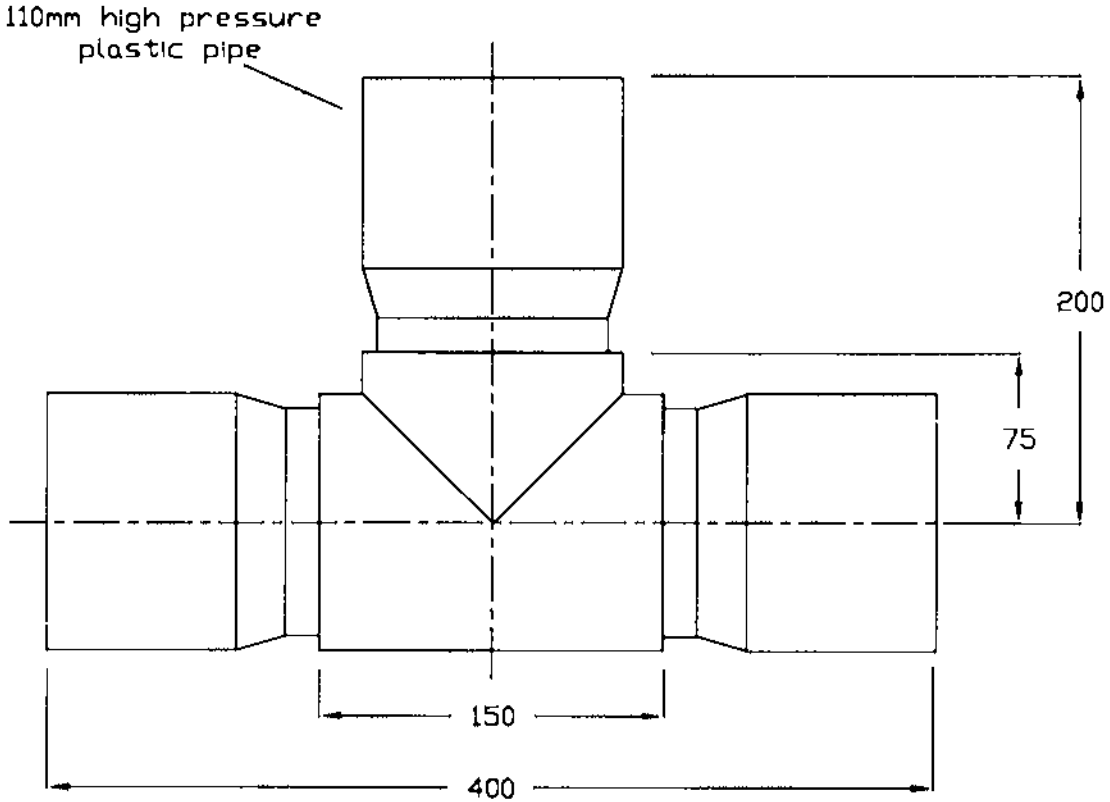

NOTE: The drive pipe for the P90 has a diameter of 90mm. Therefore, to fit the drive pipe into this T-piece, a 100mm to 90mm adaptor should be purchased or made up using available pipe.

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P90 T-PIECE
MANUFACTURE

Drawing No. 9 of 12 NOT TO SCALE

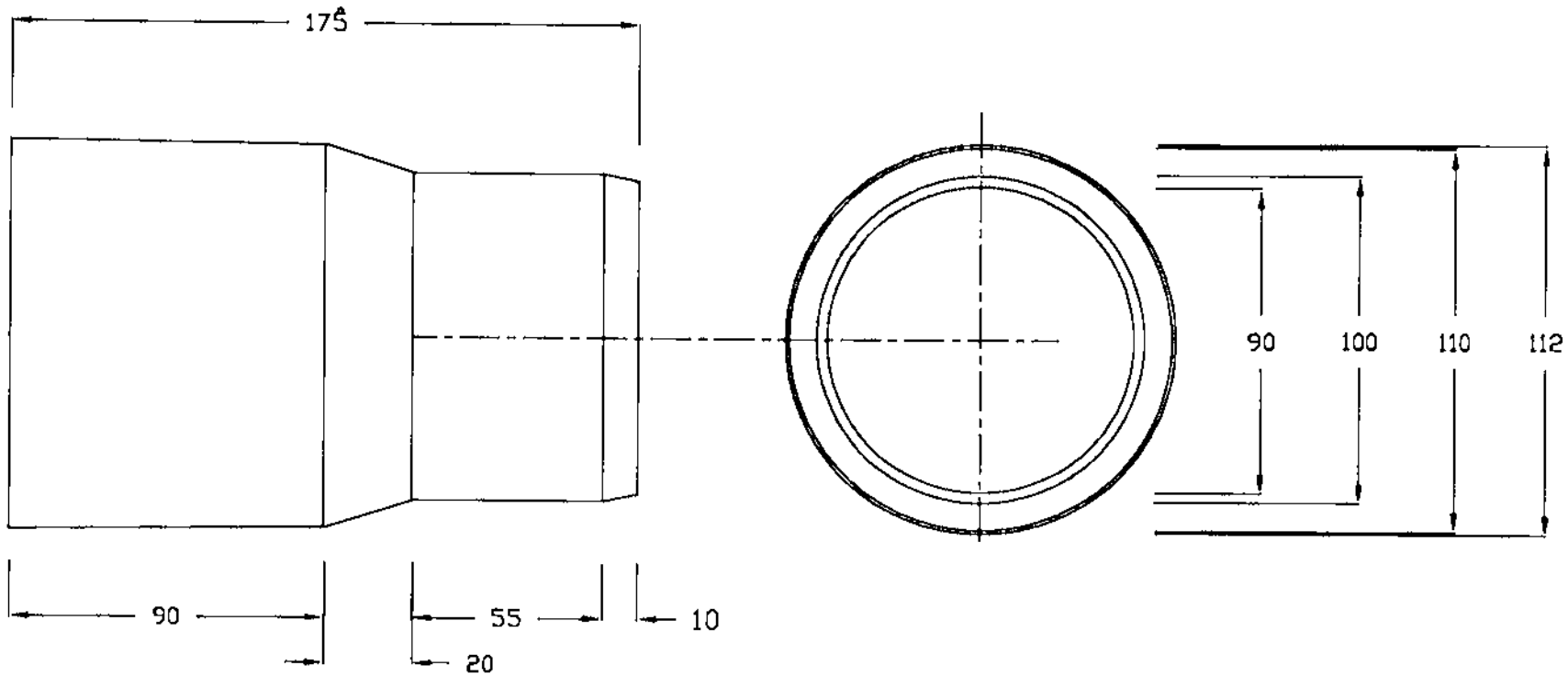

NOTES:

1 - This socket former is designed to be used with 110mm outside diameter plastic pipe.
2 - This former may be made from steel, aluminium or wood.
3 - The former is used to to make both the pump T-piece and End cap.

INSTRUCTIONS FOR USE

1 - The first step is to heat up the plastic pipe to make it soft and workable. This may be done by immersing the pipe in hot oil at about 130 C or by rotating the pipe slowly over a heat source.

2 - When the pipe is soft enough push it quickly and firmly over the former.

3 - Let the pipe cool and harden before removing it from the former.

ALL DIMENSIONS IN mm

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P90 SOCKET FORMER

Drawing No. 10 of 12 NOT TO SCALE

MAKING AN END CAP

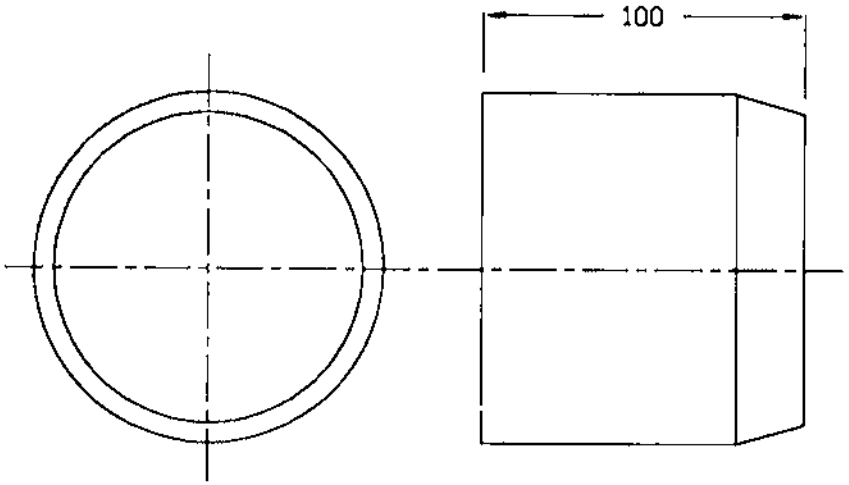

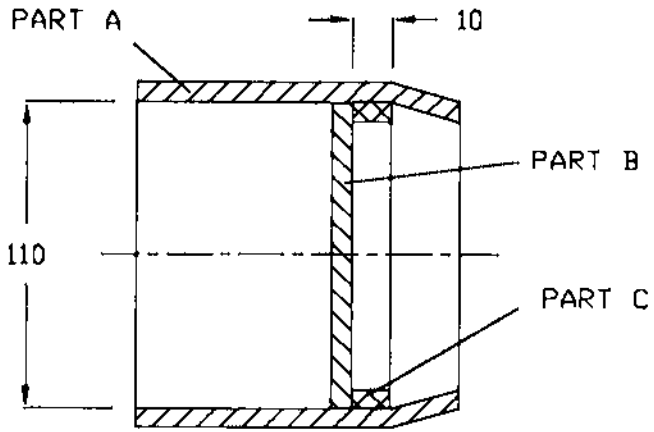

STANDARD END CAP

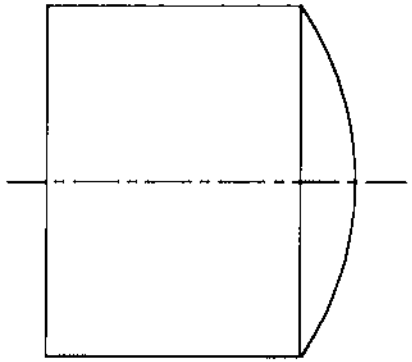

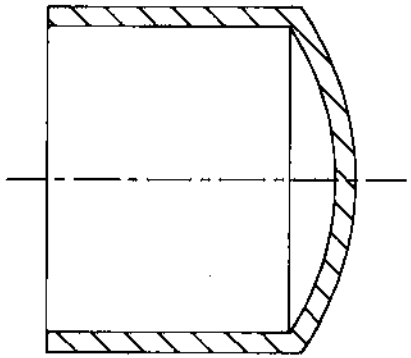

NOTE: The End cap may be purchased commercially or made as shown.

MANUFACTURE INSTRUCTIONS

1 - Cut a 100mm length of high pressure plastic pipe and heat it as per the socket former instructions.
2 - Push the softened pipe quickly and firmly over the socket former to shape PART A.
3 - PART B, the end cap plug, and PART C, the reinforcing strip are made by the same methods used to make the Air vessel.
4 - When PART A has cooled, use a good plastic adhesive to glue in the reinforcing strip followed by the end cap disc. When dry the end is ready for use.

ALL DIMENSIONS IN mm

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P90 IMPULSE VALVE
END CAP

Drawing No. 11 of 12 NOT TO SCALE

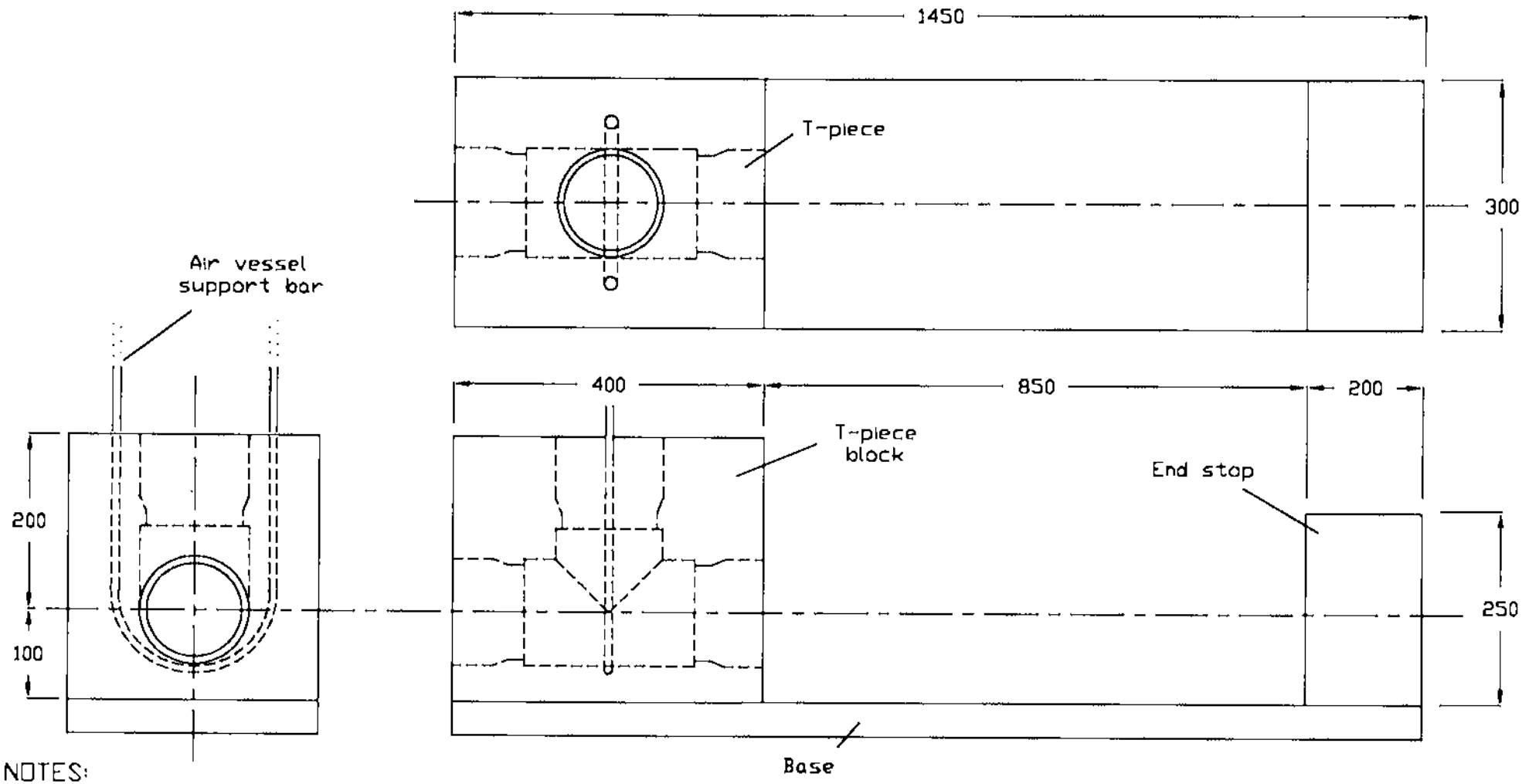

NOTES:

1 - The height and length of the T-piece block will be shorter when a standard T-piece is used. If a standard T-piece is used make sure the bottom of the T-piece is about 50mm above the top of the base.

2 - The depth of the base should be at least 75mm. The depth may be greater if a more solid foundation is needed.

3 - Use steel reinforcing in the base, T-piece block and end stop to join the three sections together and to reinforce each section. A local builder will know how to do this.

ALL DIMENSIONS IN mm

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P90 REINFORCED CONCRETE BASE, T-PIECE BLOCK & END STOP

Drawing No. 12 of 12 NOT TO SCALE

DTU

Ram Pump Programme

DTU S1 PUMP

TECHNICAL

11

RELEASE

DTU S1

hydraulic ram pump

The name "S1" stands for a Steel pump with a drive pipe up to 1" in diameter.

A ram pump is powered by falling water. Water from a stream or spring is diverted and dropped through a drive pipe into the pump. The power of the falling water is used to pump some of the water where it is wanted. The amount of power in the falling water limits how high you can pump, and how much water you can pump. Generally, the more water you drop and the further you let it fall, the more power there will be.

The DTU S1 hydraulic ram pump is a steel machine, using a ¾" or 1" diameter galvanised drive pipe, that can lift water up to a height of 80 meters. It was designed for water supply to small groups of houses from minor sources of water such as springs and small streams. It is being used successfully in many African countries.

The pump has been designed to be made in small workshops with welding equipment and a pillar drill. A lathe can be useful but is not essential.

In areas where the water source flow varies greatly during the year, more than one pump can be installed, all sharing the same delivery pipe as shown in the drawing below.

Distribution system, for domestic use. A tank is always recommended.

Delivery pipe, rising all the way along its length (no ups and downs). The pipe should be buried where possible and protected if it has to be above ground.

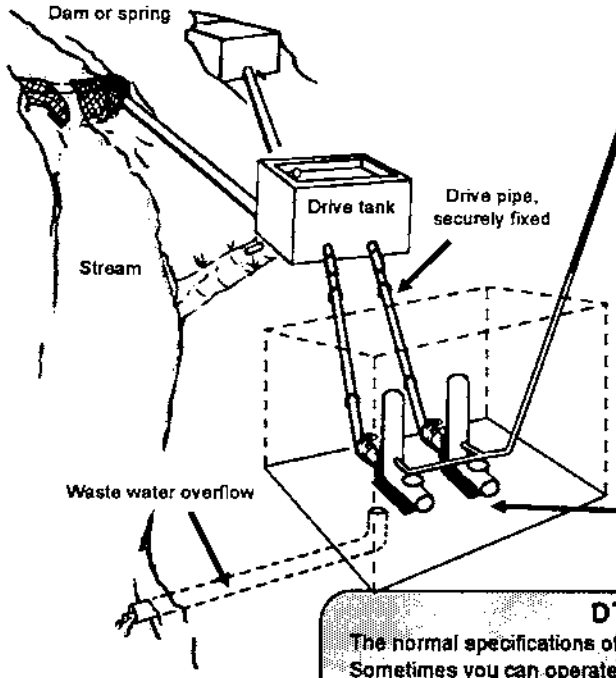

Use 20mm diameter plastic pressure pipe for the delivery pipe if there is one pump in the sytem, and one size larger if there are two.

The DTU S1 can be locally made is easy to maintain and cheap to run!

DTU S1 ram pump specifications

The normal specifications of the DTU S1 ram pump are given here. Sometimes you can operate pumps outside these limits, but they may not work well.

drive head range	—	2 to 15 meters
drive flow range	—	20 to 60 liters a minute
drive pipe material	—	Galvanised iron
drive pipe diameter	—	¾" for flows from 20 to 35 liters a minute
drive pipe diameter	—	1" for flows from 30 to 60 liters a minue
delivery head range	—	up to 80 meters
typical delivery range	—	0.5 to 10 liters a minute
delivery pipe diameter	—	20mm

TECHNICAL
11
RELEASE

DTU S1 PUMP: USER INSTRUCTIONS

AN EXPLODED VIEW OF THE DTU S1 PUMP

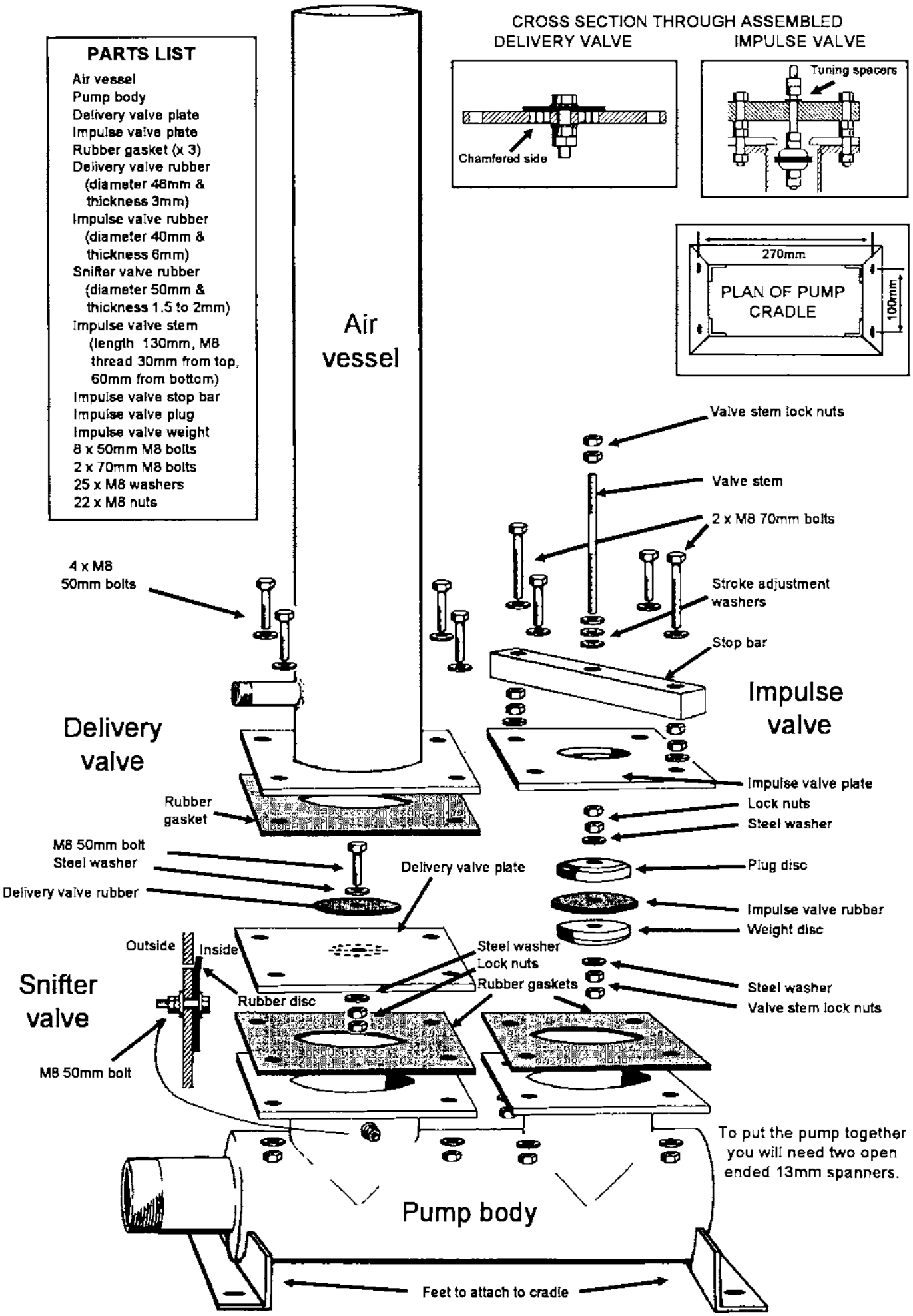

Pump repair

If the pump stops or starts delivering less water than usual, it may require adjustment or repair.

Look at the pump and if there is no obvious fault start it again if you can. Watch the pump and listen for irregular pumping or unusual noises. A worn impulse valve, for example, is usually obvious because water squirts through when the valve is closed. Some parts of your ram pump may need occasional replacement. the frequency of this will depend on how hard the pump is working and on the cleanliness of the drive water.

Tools you will need:

2 x 13mm ring/open end spanners to disassemble and assemble the pump
2 x Adjustable wrenches - to loosen a union joint on the delivery pipe (if fitted)

Taking the pump apart

Depending on the fault it may be necessary to disassemble the impulse valve and/or the air vessel. Before attempting to take apart the pump:

1. Make sure that the drive pipe valve is closed and the impulse valve is open. This will allow you to work on the impulse valve ONLY.
2. Depressurise the air vessel.

WARNING - Before attempting to remove the air vessel, always release the pressure in it slowly. An ideal system will have a gate valve or one-way valve and a union fitted between the air vessel and the bottom of the delivery pipe and the optional bleed screw fitted to the air vessel. With the pump stopped, close the gate valve in the delivery pipe to stop it draining back. If a one-way valve is fittad it will close automatically. Then loosen the bleed screw to release the pressure in the air vessel. If none of the above are fitted, the only other way to release the pressure in the air vessel is to loosen each of the air vessel flange bolts one turn at a time until the water and air escapes through the join at the flange. You will certainly get wat this way.

Checks

1. Check the delivery valve rubber for wear and blockage of the valve holes.
2. Check that the snifter valve is in good condition.
3. Remove the impulse valve and check the impulse valve rubber. Check the nuts on the valve stem and check for excessive wear of the stem. Replace things if necessary.
4. Check the pump body is firmly bolted down, then reassemble the pump, ensuring that all bolts are greased.

Putting the pump back together

Assembly of the pump is shown in the exploded view drawing, but the following important points need to be kept in mind:

1. Assembling the delivery valve
   Put together the delivery valve plate, the rubber and the bolt. Make sure the side of the plate with the chamfered holes is on the opposite side to the rubber, and that the rubber is on top.

   Screw on the first nut until it is finger tight and then undo it by one turn. Care must be taken not to overtighten the bolt and nuts as this will affect the performance of the valve. Next, screw on the other nut and tighten it up against the first. Use the spanners to tighten them firmly together. This will lock them together, and also allow a small up-and-down movement of the bolt and rubber.

2. Assembling the snifter valve
   Put the 'shaped' bolt and washer together, feed the bolt through the valve rubber, then push this through the pump body. Make sure that the shaped curve of the bolt head and washer align with the curvature of the body.

   Screw on the first nut until it is only finger tight. If the nut is on too tight the rubber will curl away from the pump body and will need to be slackened off slightly. Then screw on the second nut and tighten the two nuts firmly together using the spanners. Then check that the rubber has not distorted. If it has, slacken the nuts half a turn and tighten the outer one again.

3. Assembling the air vessel end delivery valve
   Align the delivery valve, air vessel, pump body and rubber gasket mounting holes and feed through the bolts. Make sure the delivery valve is the correct way up (the valve rubber facing upwards) and then tighten the nuts by hand. Use the spanners to tighten each nut and bolt a little at a time, working around the flange. This will draw the assembly together evenly.

4. Assembling the impulse valve
   The first parts to assemble are the valve stem, discs and rubber. Screw two nuts onto the longer threaded end of the stem up to the end of the thread. Push a steel washer on up to the nuts. Follow this with the valve plug disc, with the chamfered side towards the nut. Slide the valve rubber up against this, then the weight disk with the chamfered side facing away from the rubber. Follow this with another steel washer. Screw a nut up to them until it is finger tight. Thread on another nut and use the spanners to tighten the nuts together. This part of the assembly is sometimes known as the valve plug.

   Hold the impulse valve plate and the valve plug together, with the chamfered side of the plate opposite to the side against which the valve rubber presses. Slide the stop bar onto the top of the stem and thread a nut loosely on the stem.

   Push the two longer bolts through the ends of the stop bar and thread two nuts onto each. Use spanners to lock the nuts tightly. Align the valve assembly, pump body and rubber gasket and feed through the flange bolts.

   Thread on the four washers and nuts by hand, then use the spanners to tighten the two shorter bolts that hold down the valve plate. Again care must be taken to ensure that these nuts are tightened evenly. The next step is to make sure the closed valve plug is centred in the valve plate hole before tightening down the two remaining nuts that secure the stop ber. To check the alignment, open and close the valve manually turning the valve plug to make sure it does not catch on the hole in the valve plate.

Now you only need to set the stroke length of the valve for the pump to be ready for use.

Spare parts to keep on the site

- impulse, delivery and snifter valve rubbers
- an impulse valve stem
- a few spare M8 nuts, bolts and washers

The Development Technology Unit (DTU)
Department of Engineering
University of Warwick,
Coventry CV4 7AL UK
Tel: 44 (0)1203 523122
FAX: 44 (0)1203 418922

Installation notes

The DTU S1 pump should be installed in a properly designed system. To prevent vibration causing breakages, it should be firmly bolted to a steel frame (called a pump cradle) that is half buried in a concrete base. The cradle is usually made from 40 x 40mm angle iron and will vary in size depending on the number of pumps installed. Hole locations for just one pump are shown on the previous page.
All pipes in the system should be supported firmly, and buried where possible. The drive and delivery tanks should be constructed on good foundations by experienced tradesmen. Pipe joints to the drive tank should allow the pipes to move slightly without damaging the tank walls or leaking badly.

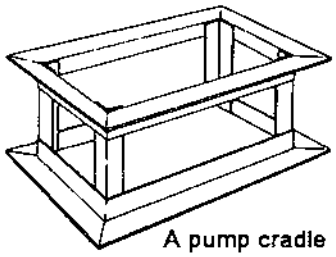
A pump cradle

Starting and stopping the ram pump

Although ram pumps often start very easily, they can be awkward the first time they are run.
To start the pump:

1. Make sure that any valve fitted on the delivery pipe is open and then open the drive pipe valve. Water will flow out of the open impulse valve until it suddenly shuts. If it reopens automatically, the pump should continue to run on its own. If it does not, you must prime the delivery system as described in Step 2 alongside.
2. Push down on the top of the impulse valve stem with your foot to reopen it (wear strong boots). Again, water will flow out of the open impulse valve until it suddenly shuts, then push down immediately to re-open the valve. Keep helping the valve to re-open until it will do so by itself.

To stop the pump, hold the impulse valve stem up to close it or shut the valve at the bottom of the drive pipe.

Tuning for best performance

The DTU S1 can be tuned to adjust performance. This is done by changing the up and down movement of the impulse valve, which is normally set to about 12mm. Tuning is usually done to achieve either the maximum delivery flow or the most efficient use of the drive water available.

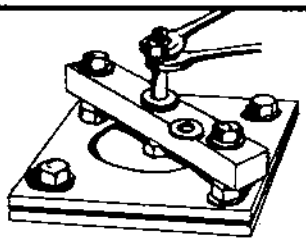

Maximum delivery
When there is plenty of drive water available, the pump can be tuned to deliver as much water as possible. To do this, remove all washers from the impulse valve stem so that the valve has as much up and down movement as possible.
WARNING: - this also puts the pump parts under greater stress and makes them wear more quickly.

Low drive flow
If the pump uses more drive flow than is available it will soon stop. If this happens it must be tuned to use less. The impulse valve should be tuned down to use 90-95% of the water available from the source. To tune the pump down, add washers onto the impulse valve stem so that the valve has less up and down movement. The shorter the stroke, the smaller the amount of drive flow needed, and the less water is delivered. The minimum stroke length is about 7mm.

Routine maintenance

While the pump is running normally, a visit should be made once a week to check that bolts are tight and that there are no leaks. Once a month an inspection of the whole system should be carried out. It is also recommended that a log book is kept to record the checks and repairs that have been made.

Monthly maintenance check list (without stopping the pump):

1. Inspect all the joints to check for leaks.
2. Check if there is sufficient air in the air vessel. This can be done by listening carefully to the pump. If there is insufficient air in the air vessel, the pump will be much louder than usual. This means that the snifter valve is probably blocked and will need to be cleared.
3. Clean any filters installed in the system.
4. Remove excess silt or debree from tanks or from behind the intake dam or weir if necessary.
5. Walk along all pipes looking for damage. Also, inspect the tanks for leaks, particularly at pipe joints.

The following Technical release contains more information about making the DTU S1 pump
TR 11b DTU S1 pump drawings
Similar information is available for the other DTU pumps.

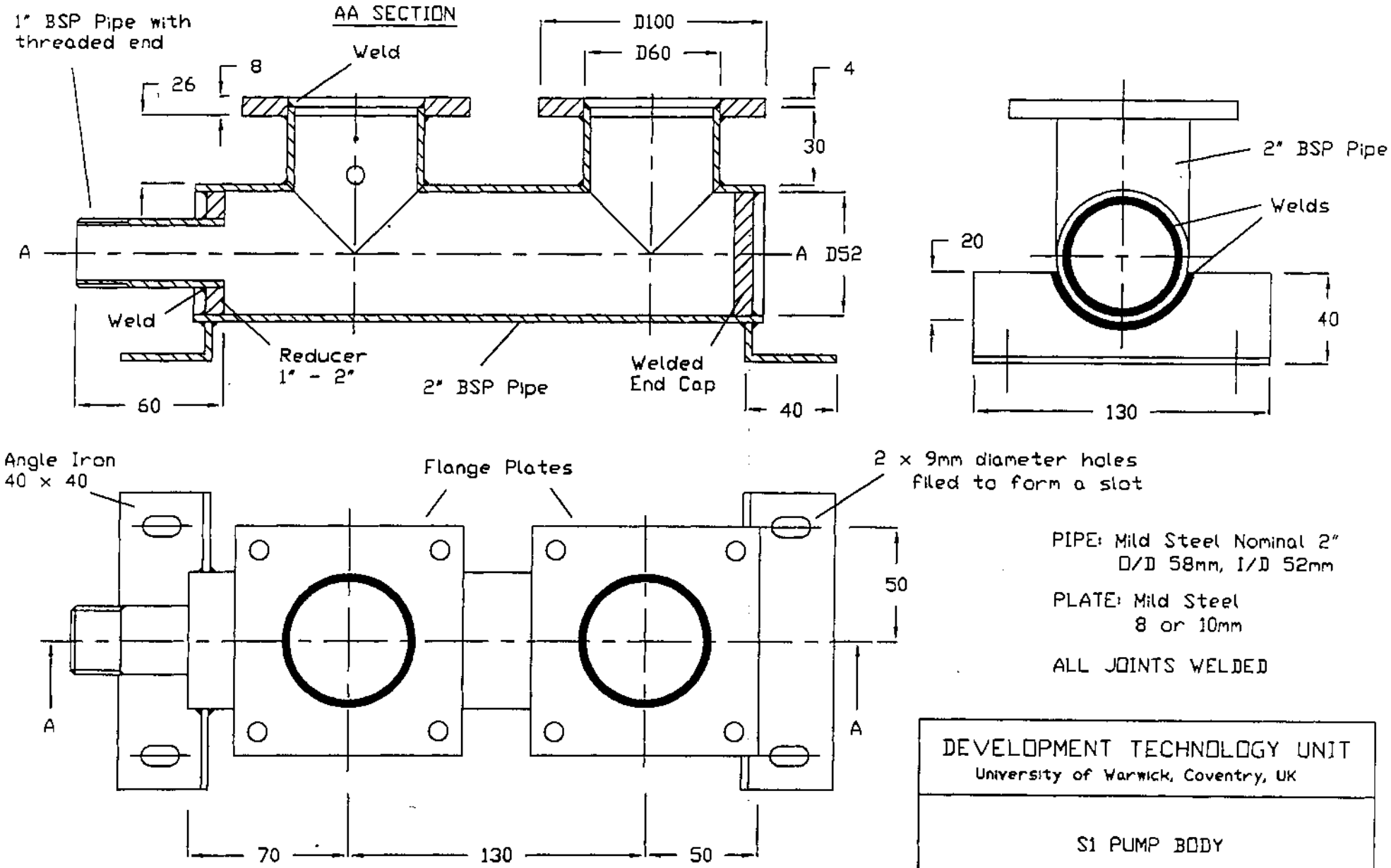

PIPE: Mild Steel Nominal 2"
O/D 58mm, I/D 52mm

PLATE: Mild Steel
8 or 10mm

ALL JOINTS WELDED

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S1 PUMP BODY

Drawing number 1 of 7 NOT TO SCALE

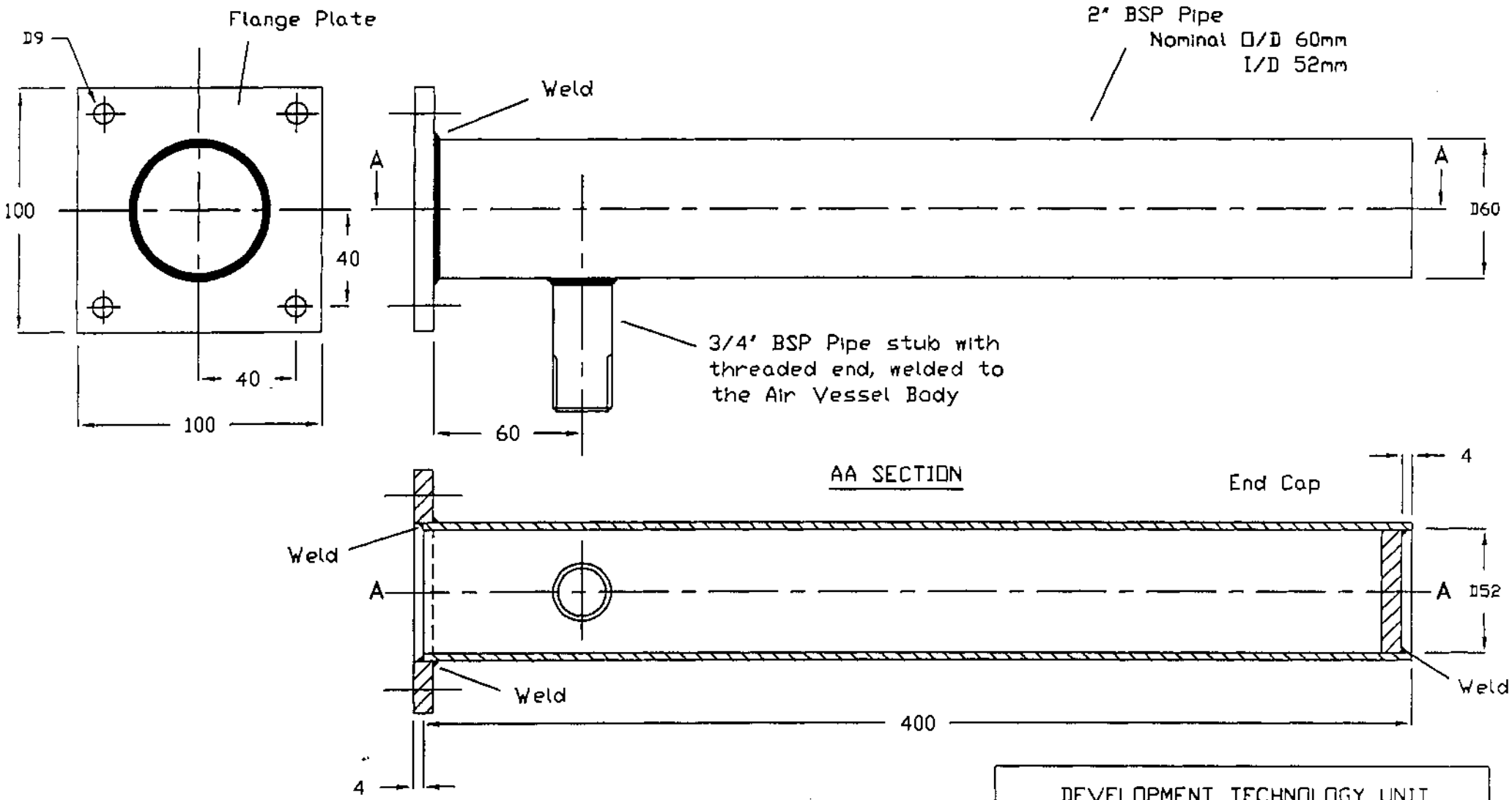

NOTE

The Flange Plate & End Cap are 8 to 10mm in thickness

To make the Flange Plate See the separate Drawing/Template

ALL DIMENSIONS IN mm

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S1 AIR VESSEL

Drawing number 2 of 7

NOT TO SCALE

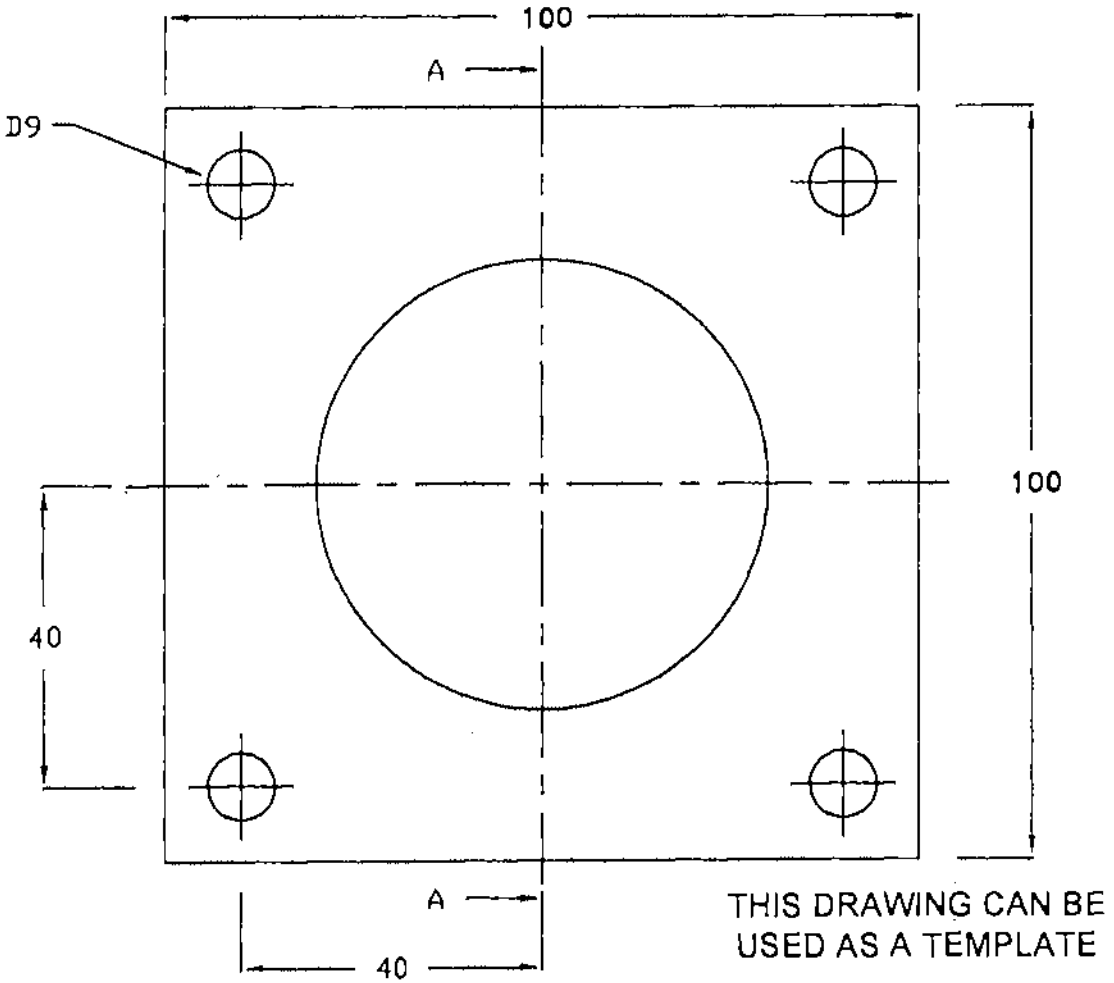

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AA SECTION

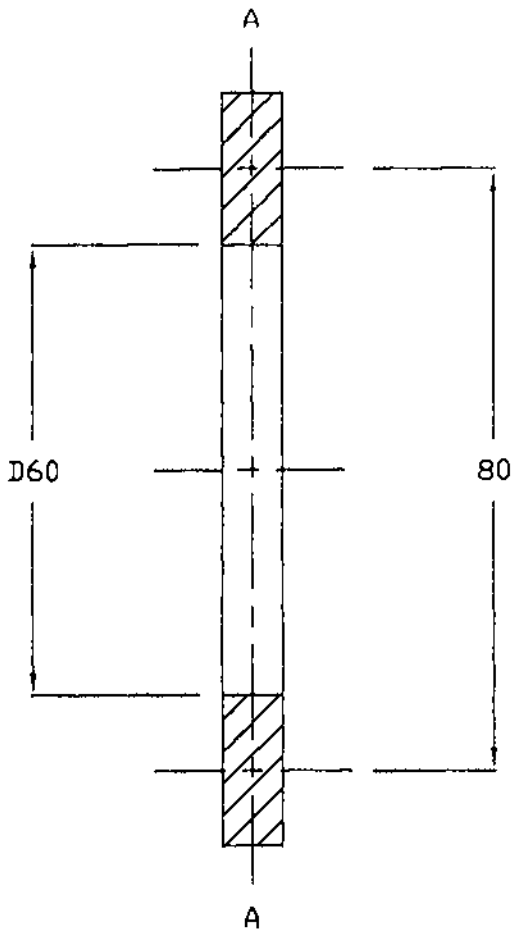

NOTE

Flange Plate thickness is 8 to 10mm

The internal diameter of the Flange Plate (60mm) may need to be different depending on the outside diameter of the steel pipe used for the pump body.

ALL DIMENSIONS IN mm

Measurement Check

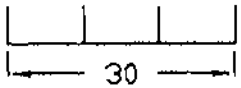

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S1 FLANGE PLATE

Drawing number 3 of 7

SCALE 1:1

AA SECTION

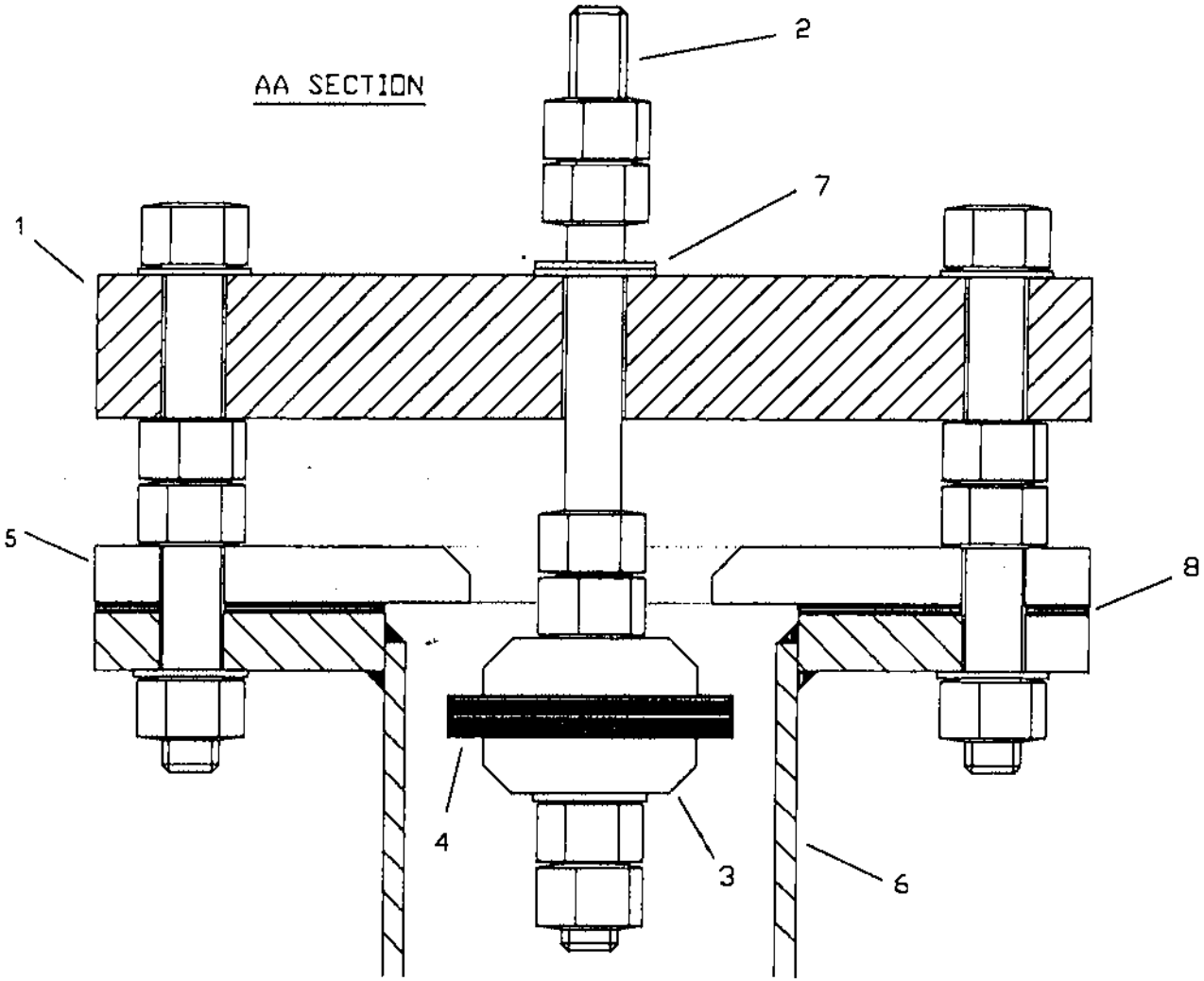

IMPULSE VALVE TOP VIEW

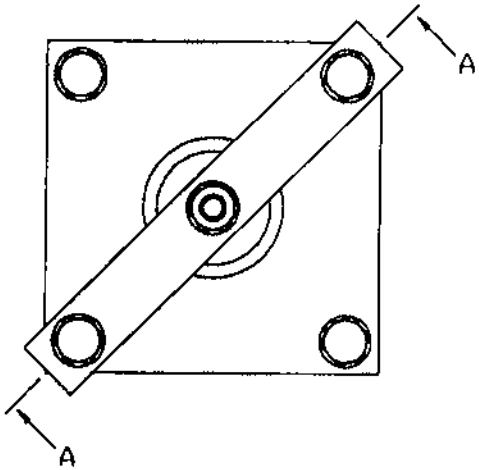

PARTS LIST

1 - Cross-bar
2 - Valve Stem
3 - Valve Disc (x2)
4 - Rubber Disc
5 - Valve Plate
6 - Pump Body
7 - Stroke Adjustment Washers
8 - Rubber Gasket
9 - M8 Bolts, Nuts and Washers
Bolts: M8 x 70mm (2 of)
M8 x 50mm (2 of)

NOTE

The Rubber Disc (4) is 40mm in diameter and 6mm thick DO NOT use a diameter larger than this as the flow through the valve will be restricted

The Rubber Gasket (8) can be 1.5 to 3mm thick and is cut to match the Pump Body Flange

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S1 IMPULSE VALVE ASSEMBLY
Drawing number 4 of 7
AA SECTION - SCALE 1:1

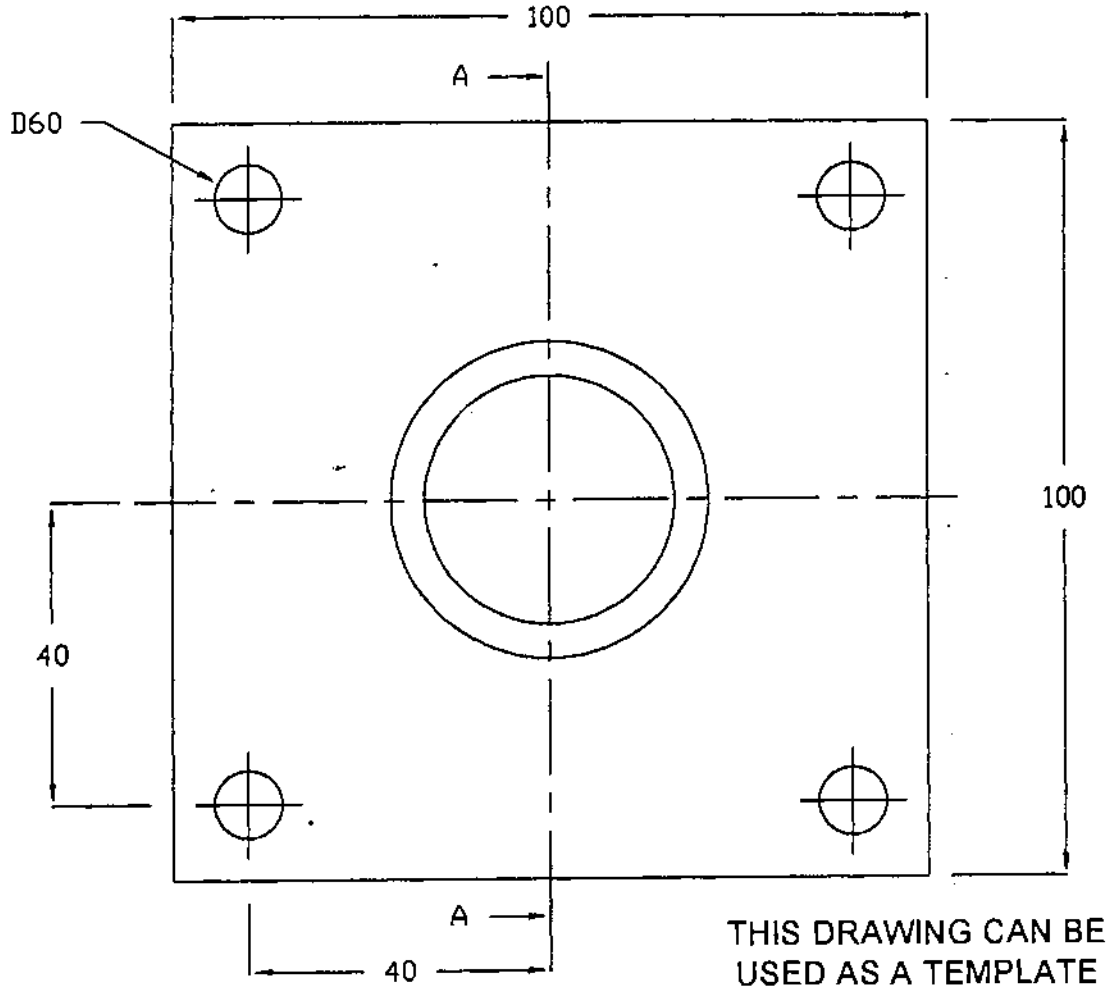

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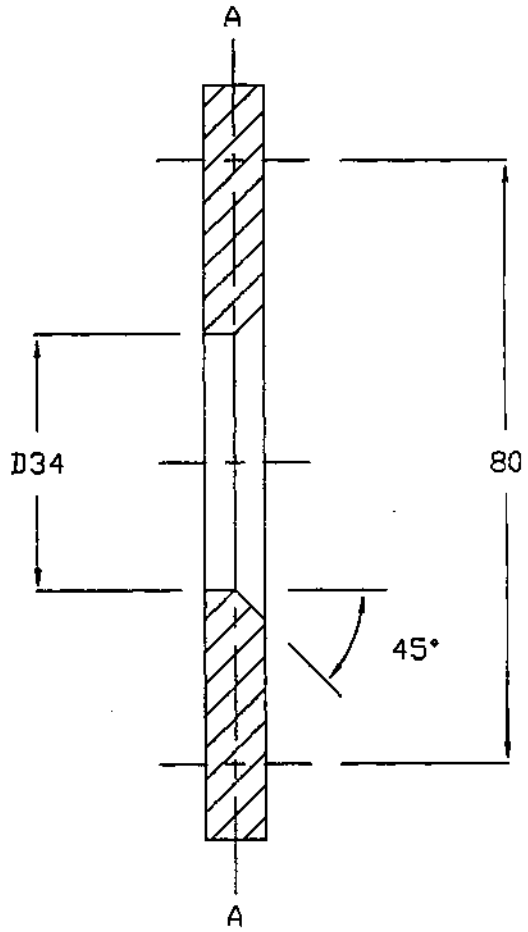

NOTE

The impulse valve plate thickness is 8 to 10mm.
It is important to ensure that the Impulse Valve Plate and the Impulse Valve Discs are of the same thickness.

ALL DIMENSIONS IN mm

Measurement Check

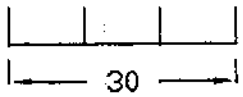

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S1 IMPULSE VALVE PLATE

Drawing number 5 of 7

SCALE 1:1

IMPULSE VALVE CROSS-BAR

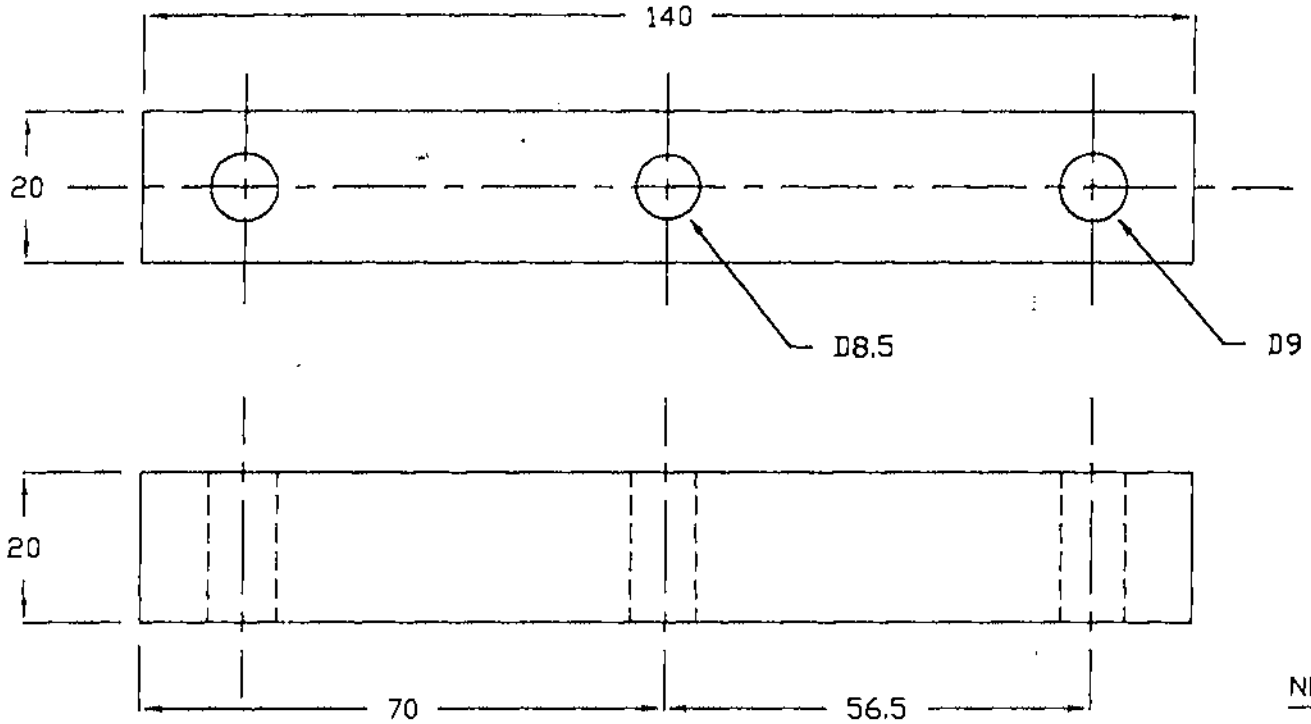

NOTE
Cross-bar is mild steel

IMPULSE VALVE DISCS

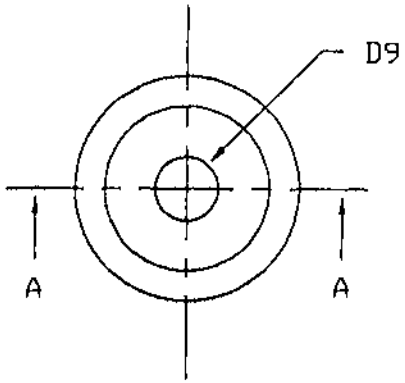

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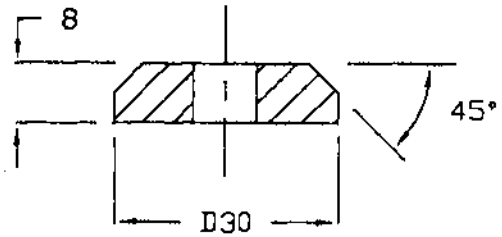

NOTE
2 Impulse Valve Discs are required.
Discs are of mild steel

IMPULSE VALVE STEM

THIS DRAWING CAN BE USED AS A TEMPLATE

Measurement Check

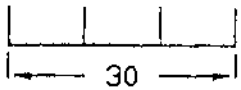

M8 Thread

NOTE
The Valve Stem is made from 8mm steel bar or reinforcing bar. Use Stainless steel if possible

ALL DIMENSIONS IN mm

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S1 IMPULSE VALVE COMPONENTS

Drawing number 6 of 7

SCALE 1:1

DELIVERY VALVE PLATE & ASSEMBLY

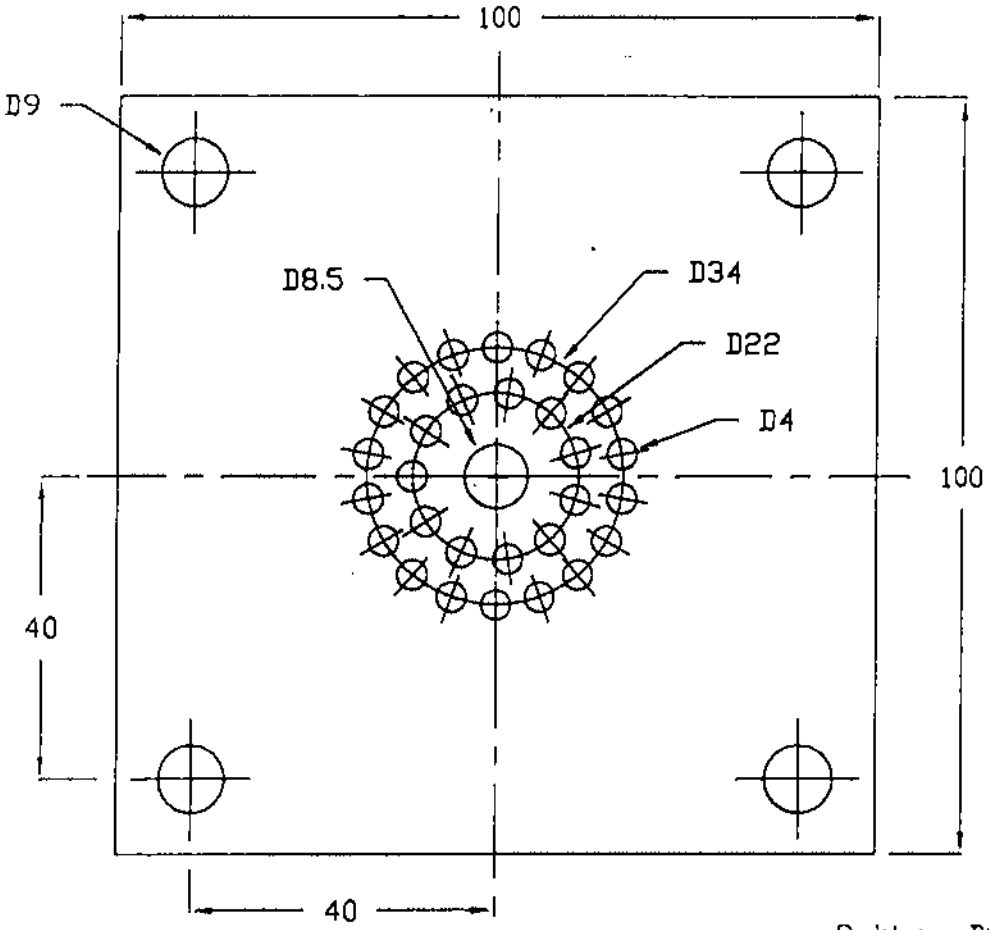

SNIFTER VALVE ASSEMBLY

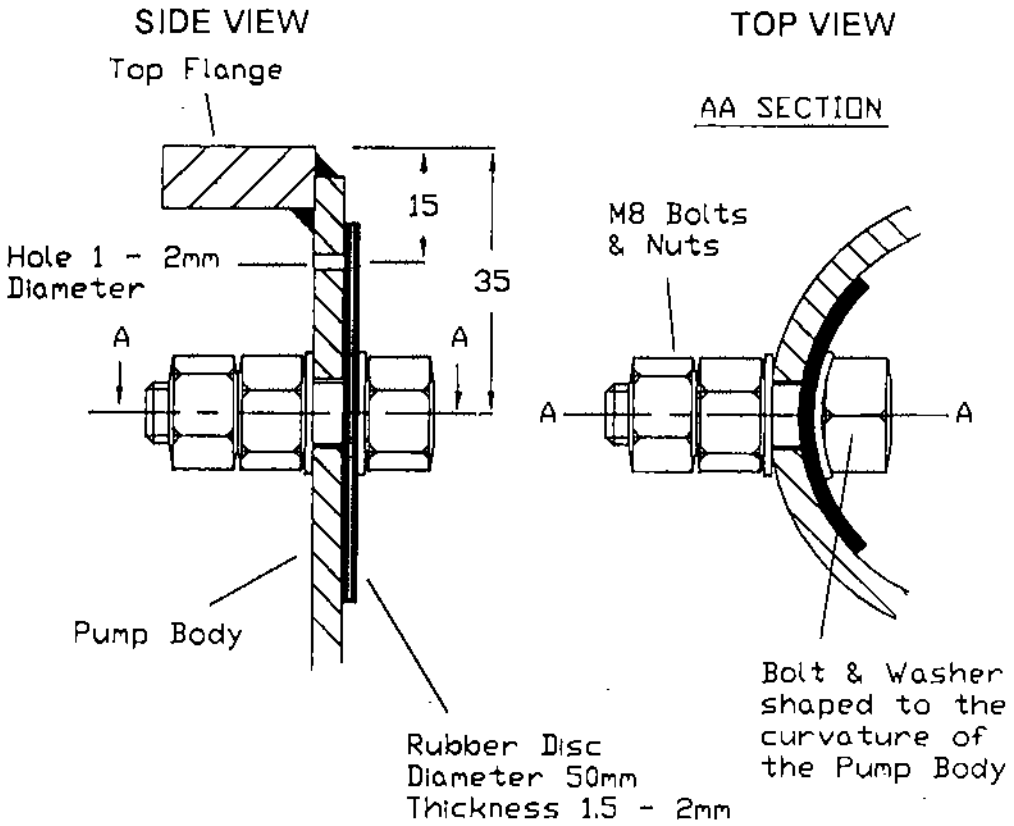

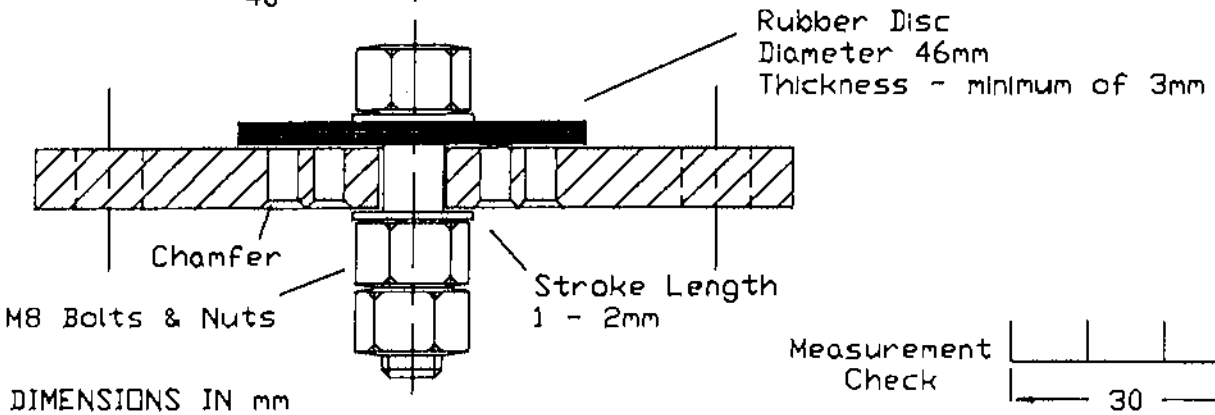

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Measurement Check

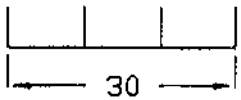

ALL DIMENSIONS IN mm

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University of Warwick, Coventry, UK

DELIVERY & SNIFTER VALVE ASSEMBLIES

Drawing number 7 of 7

SCALE 1:1

DTU

Ram Pump Programme

RAM PUMP SYSTEM CALCULATORS

TECHNICAL
10
RELEASE

Cardboard Calculators for Designing Ram Pump Systems

1 INTRODUCTION

In the Development Technology Unit we have for many years been designing water systems that use hydraulic ram pumps. We have also trained water specialists from over 10 countries how to make the pumps and design systems to put them in. To design a good system, you have to do some calculations. We have found that most people do not enjoy using formulas or doing maths, so we have developed special cardboard 'calculators' that can be used instead of formulas. They give the same answers as the formulas in books but are much easier and quicker to use.

When we design a water system using ram pumps, we like to be able to know *before* we build it how much water it will deliver. This is called the "delivery flow". The first DTU calculator is the *Ram Pump System Design Calculator* and is meant mainly for working out such delivery flows.

The second cardboard calculator is called the *Friction Headloss Calculator*. We use it to help select the right sizes for the different pipes in a ram pump system. It can also be used for choosing the pipe sizes in a gravity-feed water system.

In this Technical Release we describe how to make the two calculators and how to use them.

The last three pages of this Technical Release are single-sided master pages to be photo-copied each time you make a calculator. We suggest that the first photo-copy you make should be attached to this Release in case the copy masters get separated and lost.

Development Technology Unit
Department of Engineering
University of Warwick
Coventry CV4 7AL UK
Tel +44/0 1203 523523 ext 2339
(Director) 523122 Fax 418922
email dtu@eng.warwick.ac.uk

THE UNIVERSITY OF WARWICK

DTU

2 MAKING THE CALCULATORS

Start by photo-copying the calculator parts printed on the 3 pages at the end of this Release. The thicker the paper or card you can use for these copies, the better; card as thick as 180 gpm can be fed through some slow photo-copiers. The *Delivery Flow Calculator* has 2 parts, both on the same page. The *Friction Headloss Calculator* has 3 parts, spread over the two following pages.

Carefully cut out the parts of the *Delivery Flow Calculator.* You will be assembling them by pushing a rivet through the centre holes and turning the ends over, so the cut-out circles for these centre holes should be the same size as the rivet you will be using. It is important to make these holes round and put them in exactly the right place on the disc.

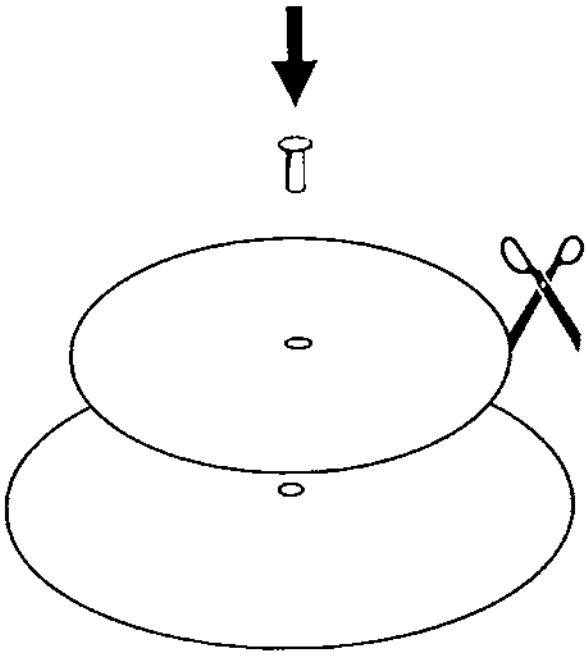

The rivet can be of plastic or soft metal. We have successfully made rivets from short strips cut from thick plastic piping, rolled on sandpaper to make them round and then turned over at the ends with a hot iron. You could also use a short plastic or steel bolt with washers and two nuts: the nuts have to be tightened against each other so that they hold the discs not quite tight.The holes can be reinforced with self adhesive "ring reinforcements" sold in some stationery shops to strengthen the holes on paper sheets held in ring-binders.

If the calculator is always to be used in one office, the 2 discs can be held by a drawing pin (through their exact centres) onto a notice board. The pin must be loose enough to allow the discs to rotate freely.

If the calculators are to be carried around or taken out of doors, they will soon get torn or dirty. If at all possible you should cover each one on both sides with transparent plastic. Clear adhesive plastic sheet is sometimes sold in stationery shops for use to protect schoolbooks. If you place any hole-strengthener under the plastic, this will help prevent it falling off. It also helps if you can make a waterproof pocket to carry the calculators in.

The *Friction Headloss Calculator* is made in the same way as the *Delivery Flow Calculator.* except that there are now 3 parts free to rotate on the same rivet or pin.

3 USING THE 'RAM PUMP SYSTEM DESIGN CALCULATOR'

The *Ram Pump System Design Calculator* has two discs and a swinging arm. It carries four scales

Feed head H	Range 1.5 to 30 meters
Delivery head h	Range 10 to 120 meters
Feed flow Q	Range 10 to 800 litres/minute
Delivery flow q	Range 0.5 to 80 litres/minute

Check that you can find each of these scales.

The last scale is in three parts called "efficiency = 50%", "efficiency = 60%" and "efficiency = 70%". If you do not know what your system efficiency might be, use the "60%" part. If you think it might be rather low, use the "50%" part and if it might be very good use the "70%" part.

The calculator is for calculating the flow from a complete *system*, not just from a single pump. If your system has several pumps working side by side, you should use as Q the feed flow to the whole system, not the drive flow to just one of the pumps. The calculator will then tell you the delivery flow from the whole system and not just the output of one pump. If your system does have only one pump in it, there is no problem; the feed flow you use will all go through that one pump.

To learn how to use the calculator we suggest you practice with the following example.

Suppose you have a system in which
feed head = 4 meters,
delivery head = 40 meters,
feed flow = 50 litres per minute,
efficiency is unknown so we use 60%,
then the calculator should show a delivery flow of 3 litres per minute.

Here are the two steps.

Step 1 Hold the outside disk and turn the inside disk until 50 litres per minute on scale Q is exactly in line with 4 meters on scale H.

Step 2 Pinch the two discs together with your fingers so that one cannot slip past the other and then turn both disks together until the q scale is at the top. Find 40 meters on scale h and read the flow above it on the "efficiency = 50%" part of scale q. You should get close to 3 litres per minute.

The calculator is not super-accurate. It will give you an answer that is "close enough". If you followed the example above and got an answer that was not close to 3 litres/min it might be that

- you let the disks slip past each other,
- you used the wrong scales,
- the holes in the middle of your disks have become badly worn and the disks are very loose.

4 USING THE 'FRICTION HEADLOSS CALCULATOR'

When water flows through a pipe there is some friction between the water and the pipe walls. This causes something called "friction headloss" which is measured in meters. A pipe with a small diameter has a bigger headloss than a larger pipe for the same flow of water. A big headloss usually means that the system delivers less water than it should.

The *Friction Headloss Calculator* has two disks and a swinging arm. It carries four scales which you might look for:

Length of pipe	Range 2 to 3000 meters
Flow through pipe	Range 1 to 500 litres per minute
Bore of pipe ("Bore" is the same as "Inside diameter")	Range 16mm to 200mm
Headloss	Range 10cm to 100 meters

and the two small arrows on the swinging arm called "steel" and "plastic". At the top of the swinging arm is a big arrow labelled "flow through pipe".

You can use this headloss calculator to help you choose the best size for the delivery pipe, the feed pipe and the drive pipes in a ram pump system. You can also use it for pipes in gravity feed systems. We will now describe each of these four uses.

Use 1: Delivery pipes

When you come to choose the size of a delivery pipe, you will usually already know how long it is, how high it rises and how much water is to flow through it.

Suppose for example you know that at a particular site:

pipe length = 500 meters,

flow through the pipe = 10 litres per minute and the pipe is plastic,

the delivery height h = 60 meters.

Standard pipe sizes (*outside* diameters) are 20 mm, 25 mm, 32 mm and 40 mm. For medium pressure pipes, their bores (their *inside* diameters) will be about 2 mm smaller - typically 18 mm, 23 mm, 30 mm and 37 mm. Your problem is to decide which size is right.

Suppose you think that the 30 mm bore pipe might be suitable. The calculator lets you find out if it is. The calculation goes as follows:

Step 1 Hold the outer disk and rotate the inner disk until 500 m on the Length scale is touching 30 mm on the Bore scale.

Step 2 Pinching the two disks together so that they do not slip, move the swinging arm until the big arrow at its top is touching 10 litres per minute on the Flow scale.

Step 3 Read the headloss scale underneath the "plastic" arrow. You should find about 1.6 m.

You now have to decide whether this headloss is OK. It should normally be between one fiftieth and one tenth of the delivery head h. If headloss is more than $h/10$ your system will be quite inefficient, so you should try a larger pipe. If it is less than $h/50$ you are using a delivery pipe that is too big: you could save money by trying a smaller pipe. In our example the headloss *is* between $h/50$ (1.2 m) and $h/10$ (6 m), so our pipe size of 30mm is OK.

Use 2: Feed pipes

Your ram pump system may have a feed pipe connecting a stream or spring to a drive tank from which drive pipes lead to each pump. The calculation for feed pipes is just like that for delivery pipes except that the flow is now the feed flow to the drive tank, and of course the length and diameter we use are those of the feed pipe. Feed pipes are usually plastic, so use the "plastic" arrow on the swinging arm. Common pipe sizes for feed pipes are 50 mm, 63mm, 75mm, 90 mm and 110mm outside diameter. The bores of these sizes for low-pressure pipe are about 47 mm, 59 mm, 72 mm, 86 mm and 105 mm. So first decide which bore you should try for the feedpipe, then use the calculator to work out its headloss.

When you have found the headloss, you should compare it with the *feed* head *H*). If it is over H/10, the feed pipe should be larger. If it less than *H*/50 the feed pipe could be smaller.

Use 3: Drive pipes

Each drive pipe carries the drive flow to a single pump: this is usually equal to the feed flow *Q* divided by the number of pumps running side by side. As the drive flow is not steady like the feed flow, but is constantly starting and stopping, the head loss in a drive pipe is higher than for other types of pipe. The *Friction Headloss Calculator* gives the right head loss for a steady flow. For a drive pipe with its unsteady flow we have to multiply the steady flow headloss by 2.

So choose a likely pipe size and for it calculate the steady flow headloss in the same way as for the delivery pipe, but using the length, bore, material and flow that belong to *one* drive pipe. Next multiply the calculator's answer by 2 to get the true headloss. Lastly check whether this true headloss lies between *H*/50 and *H*/10. If it lies outside this band, you should think of changing the drivepipe size. Notice that, as with the feed pipe headloss, we are comparing the drive pipe headloss with the *feed* head *H*.

Use 4: Pipes in gravity feed systems

In a gravity feed system, pipes are laid so that they slope downwards. The drop in height between where water enters a pipe and where it leaves it is what pulls the water through. For any one size of pipe, a bigger drop in height gives a bigger flow. We can use the *Friction Headloss Calculator* to work out what the flow will be. This is because in a gravity feed system, the friction headloss is exactly *equal* to the drop in height.

Let us take as an example a 1" galvanised iron pipe, whose length is 2 kilometres and which drops by 100 meters from one end to the other. We can now work out the flow through the pipe. The calculation goes as follows:

Step 1 Hold the outer disk still and turn the inner disk until 2 km on the length scale touches 26 mm on the bore scale. (A 1" GI pipe has a bore of about 26 mm)

Step 2 Keeping the two disks clamped together in your fingers, move the swinging arm until the "steel" arrow is touching 100 m on the Headloss scale.

Step 3 Read the flow opposite the big arrow on the Flow scale. You should get about litres/min.

If the flow is more than you wanted, try again with a smaller pipe. If the flow is too small, try a bigger pipe. Of course the flow through the pipe cannot be higher than the flow available at the entry to the pipe. So making the pipe bigger will only increase the flow if it is the pipe, and not the source, that is limiting it.

5 NOTE FOR ENGINEERS

The *Ram Pump System Design Calculator* is based on the simple formula:

delivery flow = efficiency x feed flow x feed head / delivery head ($q = Eff \times Q \times H/h$).

Most well-designed ram pump systems have an efficiency of between 0.5 and 0.7. Some pump manufacturers issue design tables based on the assumption that system efficiency is always 0.6. However you may meet systems that use undersize pipes or ram pumps operated at the very top of their drive-flow range or their delivery head range, where system efficiency is as low as 0.3.

The *Friction Headloss Calculator* is based on an approximate formula because a more exact formula would be too complex to convert into a slide rule (which is what these cardboard calculators are). The flow in pipes in practical water systems is always highly turbulent. In the range of flows of interest to system designers it is safe to use the approximate turbulent flow formula:

friction headloss = K x pipelength x flow $^{1.85}$ / internal diameter $^{4.9}$

If headloss and pipelength are measured in meters, diameter in mm and flow in litres per minute, then K = 650 for smooth plastic pipes and K = 800 for steel or GI pipes.

Headloss formulas are not very precise. The headloss may differ by +/-25% of the value predicted by the *Friction Headloss Calculator*. If you are using the calculator to predict flow in a pipe, you can expect to get within +/-10% of the actual value.

Delivery flow calculator
"outer dial"

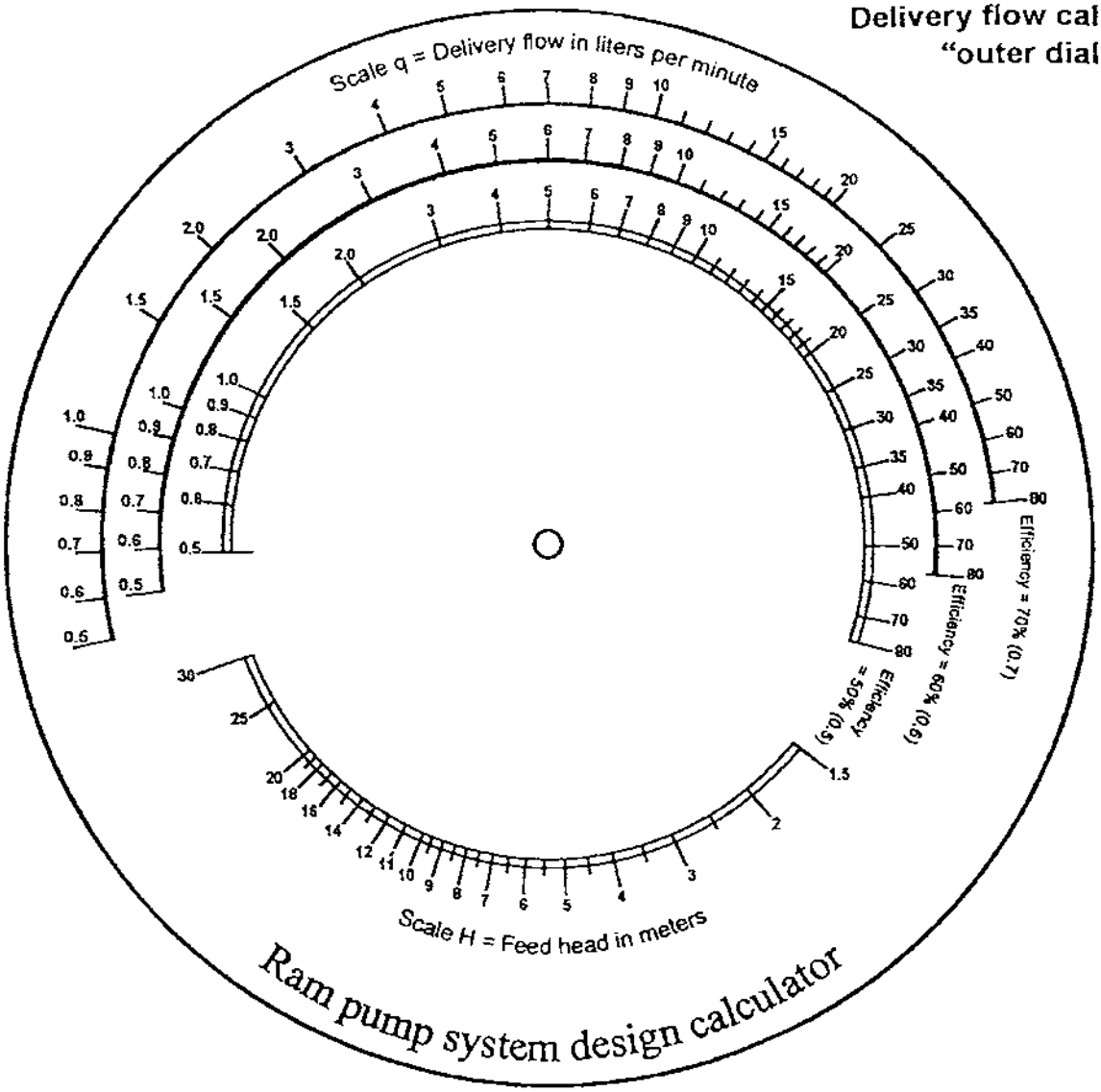

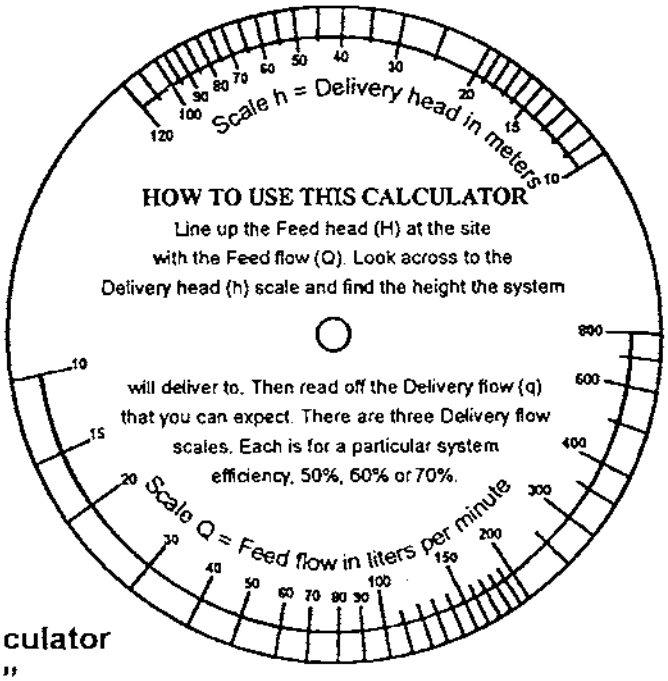

Delivery flow calculator
"inner dial"

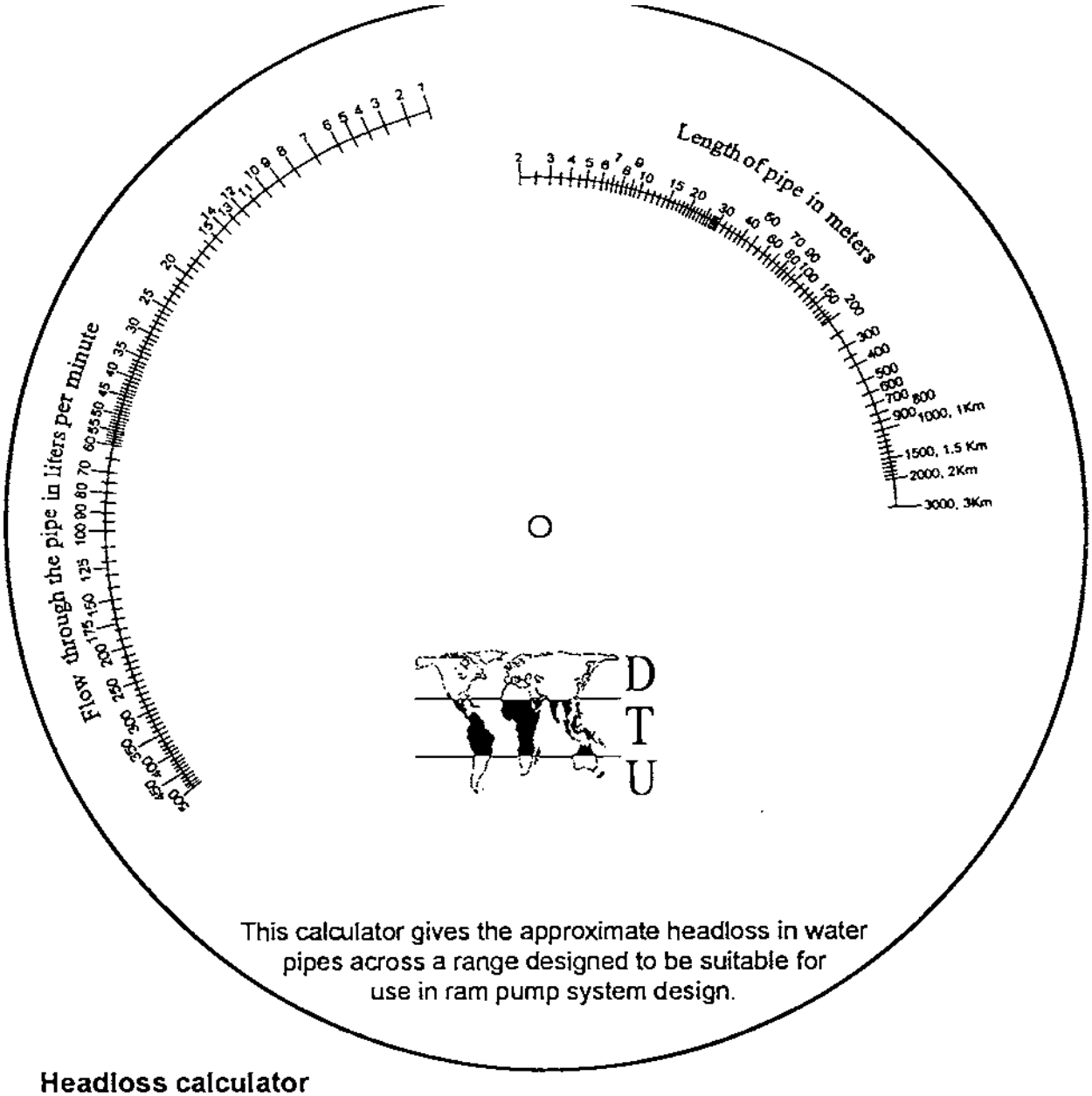

Headloss calculator
"outer dial"

Headloss calculator "inner dial"

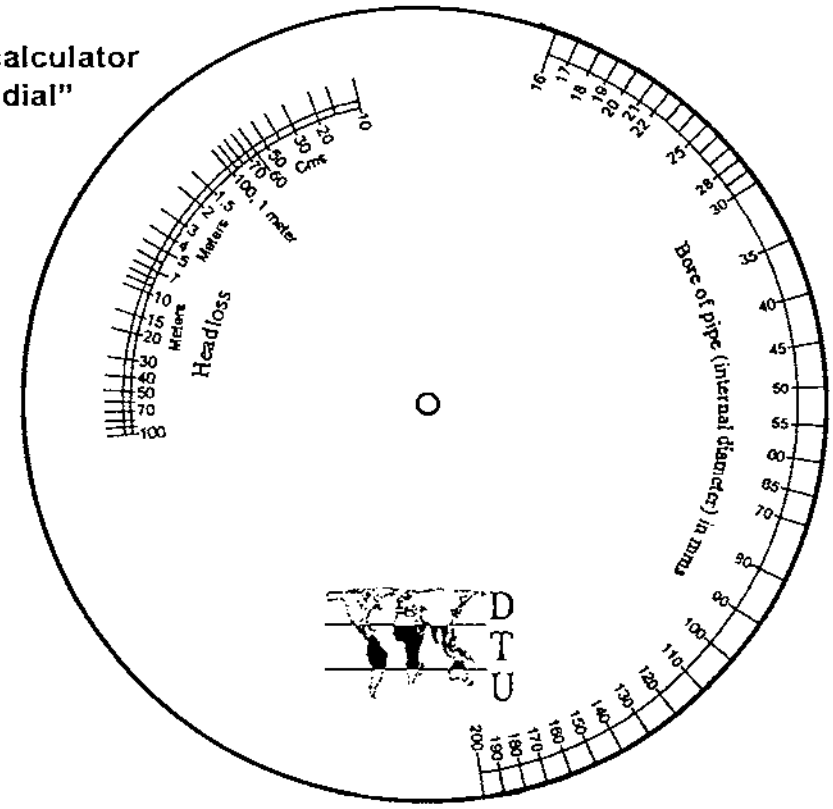

Headloss calculator "swinging arm"

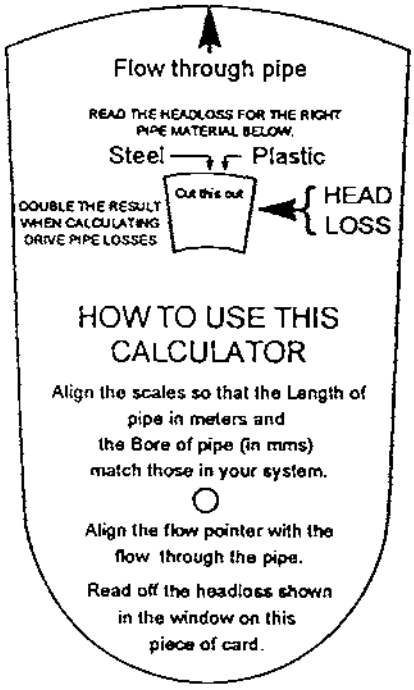

DTU

Ram Pump Programme

Ram pump system design notes

Suitable areas for a ram pump system

Although all watercourses slope downwards to some degree, the gradient of many is so shallow that many kilometres of feed pipe or canal would be needed to obtain a fall of water large enough to power a ram pump. Ram pumps can be made to run with drive heads of less than one metre but they are not normally considered viable unless heads of two metres or more are available. If it would take a long length of feed pipe or canal to achieve this head, a ram pump system would be prohibitively expensive. The best geographical area for ram pumps is one which is hilly, with rapidly dropping watercourses and, ideally, springs.

In some areas of the world good regional records of rainfall and flow from springs and in watercourses are kept in government offices and libraries. In others, another agency may have carried out recent relevant studies. If any hydrological studies are available for the region in which you plan to install ram pump systems, you can save time, effort and costly mistakes by consulting the records and using their findings in your site design.

After potential sites have been identified, they must be surveyed. The survey yields information about site dimensions and the materials required to construct the site as well as, when more than one site is surveyed, yielding a cost and performance comparison.

Designing a good drive and pump layout is crucial to achieving good system performance and limiting the amount of maintenance required. The aim is to be able to achieve a large head of water between the drive tank and pump, while using a short drive pipe to connect them. The best and cheapest sites are those where the land falls rapidly, allowing all pipework to be short.

What to look for

Before arriving at a community to survey for a ram pump system, consult any available large-scale contour maps of the area. Look for places near to the community where streams cross contour lines and measure the distance along the stream between two contours. The average stream gradient can be obtained by dividing the height change between contours by this distance. An average gradient of at least 0.02 (0.02 or 2% is the same as 1 in 50) is needed for a water supply ram pump system. The pump will often be installed alongside rapids or a waterfall. If stream flow data for the area is available, look for seasonal variations, particularly during the dry months, and also for any data on the increase of flow during floods.

The section of stream shown in the map alongside falls quite rapidly. Where the contours are closest together on the stream's course, there is a drop of 20m over a distance of 200m, giving an average slope on that section of 10%. This site would be worth looking at.

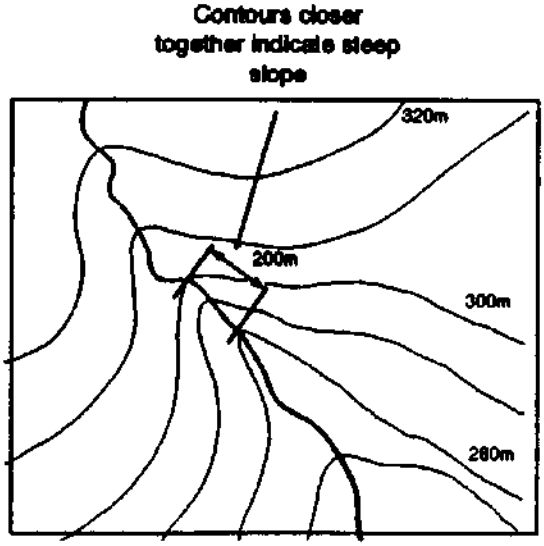

People living in a community are frequently the best source of reliable, up-to-date information about that particular area. The water in their area is vital to them, so ask them about local watercourses and sources, which ones they prefer to use, and which ones regularly dry up.

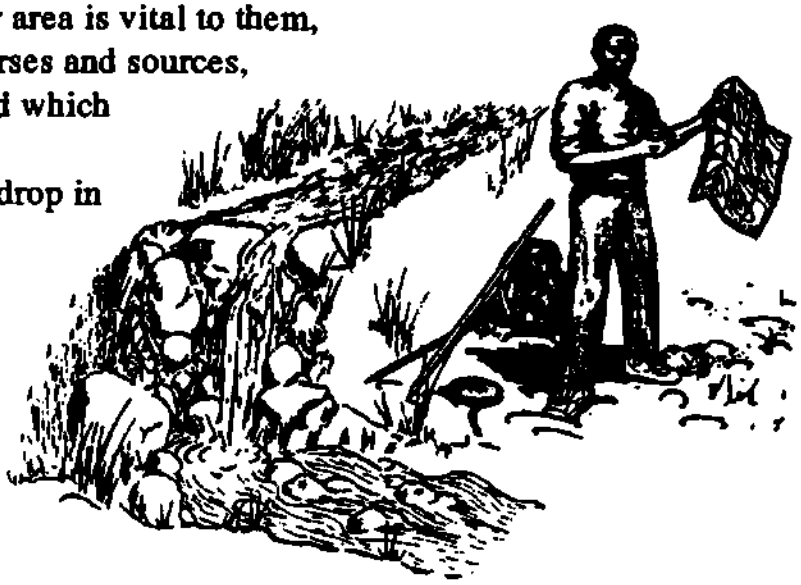

Sound is a good indicator of a drop in water. Where a watercourse is noisy and turbulent it will be dropping rapidly. It can save surveyors a lot of time to ask local people to show them places where the water is noisy, where it falls rapidly, and where there are rocks in the stream bed. Also ask to be shown any springs in the vicinity, particularly any with a source at the side of a valley along which a stream flows.

Allowing for floods

It is important to find out how the watercourse changes during a flood. Although spring-based systems are less susceptible to the extremes of flooding, it is still worth investigating and being aware of flooding as a potential problem when using a spring.

In very heavy rainfall, watercourses can swell to many times their normal flow within a short space of time. Design of a drive system must take account of these worst weather conditions, even if they only last a few hours each year. Ask local people how far the water rises during a big flood and look for evidence such as deposited rocks and stream erosion on the banks to help to confirm their reports. Keep the pumps and as much of the drive system as possible above the maximum flood water level to avoid unnecessary damage.

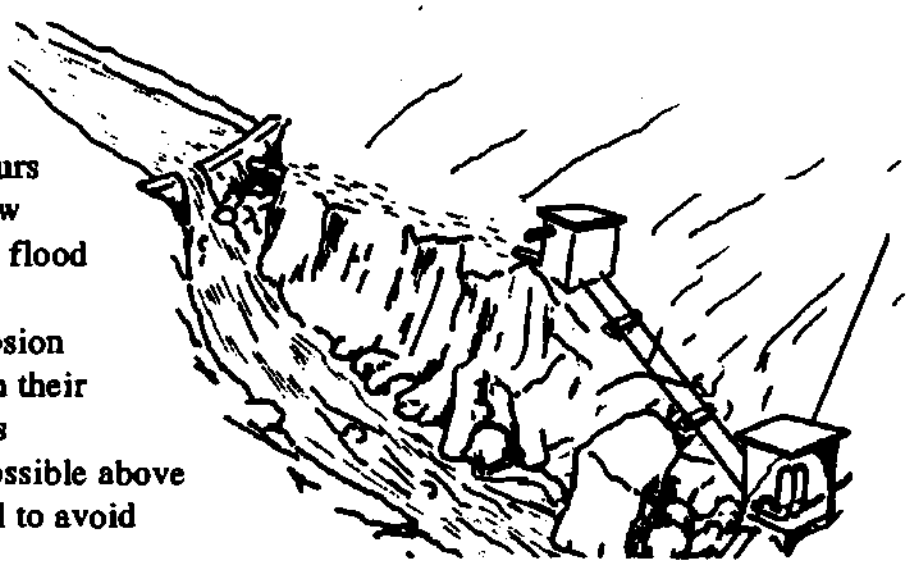

In the system sketched here, the main flow of flood water and debris is guided past the pumps by the large boulder or outcrop. Whilst the pumps may be submerged in a very high flood they will be protected from damage by most water-borne debris.

The one part of the system that will always be in the path of a flood is the dam or diversion structure. Bearing the expense in mind, this must either be built to withstand the worst flood conditions or built to be easily repairable. Some protection against the worst damage to a

dam should be included in the design, including a cage protection for the system intake, a floodwater overflow in the dam wall and boulders anchored into the stream bed above the dam to reduce the impetus of rolling stones.

Normally the pump(s) should be sited above floodwater level, but in some cases (particularly where the drive head available is marginal) this can be impractical. In these circumstances the pumps need to be sited so that they are protected from any debris in the flood, or so that they can be easily removed when a flood is expected.

Site surveying

Surveying should be in two stages, a preliminary assessment to locate potential sites, and a full survey to select the best option. In brief, the *preliminary survey* will involve the following:

- consulting any relevant maps and hydrology studies;
- travelling to potential sites to make a preliminary assessment and consult local people;
- selecting one or more sites with a high potential that will be surveyed fully.

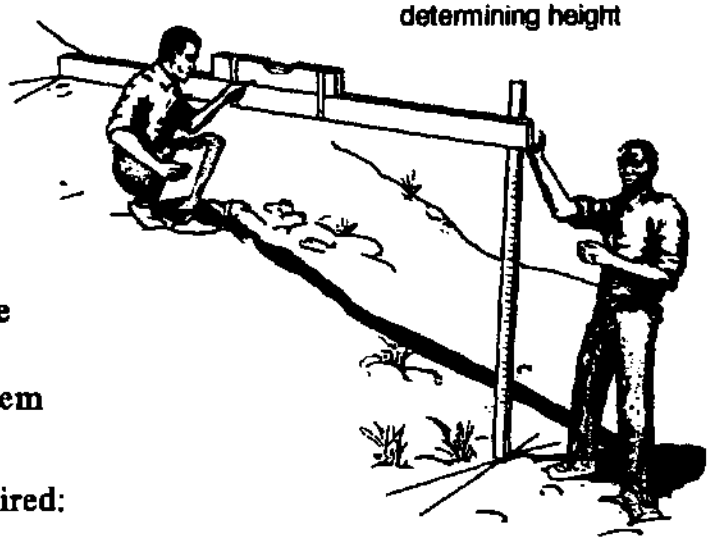

Simple method of determining height

The *full survey* of selected sites must be sufficiently detailed to provide all the information necessary for accurate system design.

The following information will be required:

Water source flow This figure must reflect the minimum flow of the water source in a normal year and so the measurements must be taken during the dry season. In order to ensure that the figure represents a typical minimum, local people should be consulted about the flow patterns over recent years. Some indication of maximum expected flows should also be obtained.

Drive head The maximum possible drive head of the site or the average angle of the slope below the water source should be measured.

Delivery head The height from the water source to the expected point of delivery should be measured. This will provide a rough estimate of delivery head but to be accurate the drive head should be added to this figure to give the actual delivery head.

Water requirement This should be estimated with reference to the population to be served (allowing for growth) or the area of land to be irrigated.

Pump selection

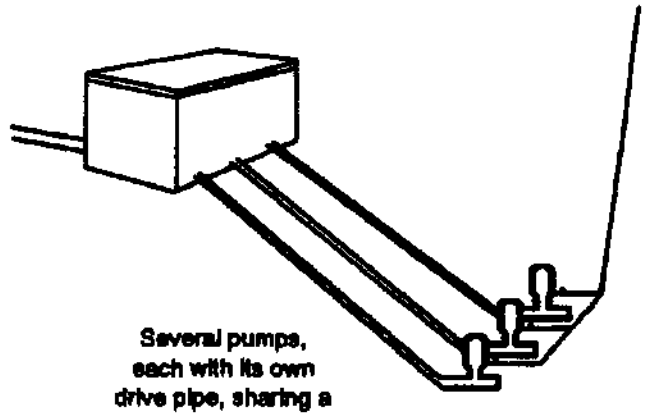

Several pumps, each with its own drive pipe, sharing a common drive tank

When selecting a ram pump there are often a number of decisions to be made concerning both its type and size. To make these decisions wisely, it is helpful to have some information about the site where the pump will be used. An estimation of the available drive flow and delivery head are needed, along with the anticipated delivery flow requirement. Knowing these will help to ensure that the correct pump is chosen. The main decisions to be made are:

- whether to buy an imported pump or to manufacture one locally;
- the size and number of pumps to be used.

Pumps with drive pipes of between ¾" and 4" are often commercially available or can be imported fairly quickly from manufacturers in Europe, N. America, etc. Larger models, with up to 12" drive pipes are also obtainable but usually have to be manufactured to order. Choosing between pumps from different manufacturers is not always straightforward. Comparisons of flow and efficiency can be made if the data is available. Cost, however, is normally very important, and varies considerably from pump to pump and manufacturer to manufacturer. The need to import spare parts and their cost should also be carefully considered. Where the source flow is large the choice is often between using one large pump or a number of smaller ones to meet the required delivery. Each model of ram pump with its recommended drive pipe will operate over a specified range of drive flows. In general, pumps are more efficient towards the lower limit of their drive flow, but produce a greater power output with large flows. A number of pumps can be used in parallel sharing a single drive tank and delivery pipe, but they must have separate drive pipes.

Using several small pumps rather than one large one can have the following advantages:

- each pump can be set for high efficiency;
- if the source flow falls below the required drive flow one pump can be stopped, allowing a reduced delivery flow to be maintained;
- a single pump can be stopped for maintenance work to be carried out without stopping all delivery flow;
- smaller sizes of pipe are often more readily available, whereas large steel pipe may have to be imported at high cost: it is also harder to work with large diameter pipe and to transport it;
- the maximum delivery head is generally higher on smaller pumps.

The cost of using a number of smaller pumps may be greater than using one large one but the benefits mentioned above need to be balanced against the extra cost.

Intake design

The drive water for ram pump systems is normally drawn from a spring or a stream and diverted into a feed pipe. An intake structure is required at the chosen water source to collect the water and keep the feed pipe properly supplied.

Spring intakes

When rain falls on high ground, some of the water soaks into the ground and seeps down through the permeable soil until it reaches an impermeable layer — usually clay or rock. The water collects on this layer, forming a water table of saturated material. The term water table refers to the upper level of the saturated material, and may rise and fall to reflect variations in rainfall throughout the year. As the level of the water table rises, the water spreads out until it reaches the side of the hill, then flows out as a spring.

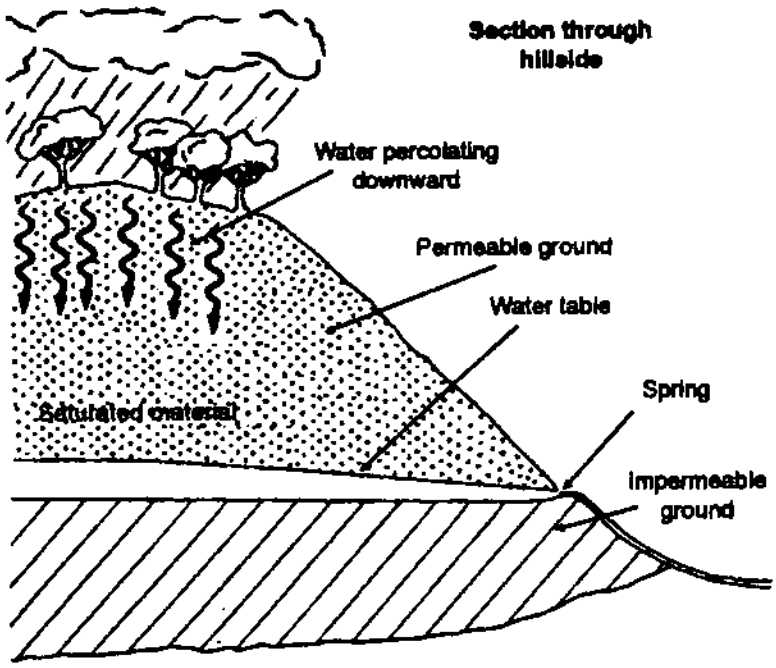

The nature of the permeable layer influences the kind of spring that occurs. If it is soft, sandy soil through which the water can travel easily, there may be many small springs as the water emerges all along the hillside. If the permeable layer is rock, with cracks through which the water sinks, there is usually one distinct spring.

Section through a capped spring intake

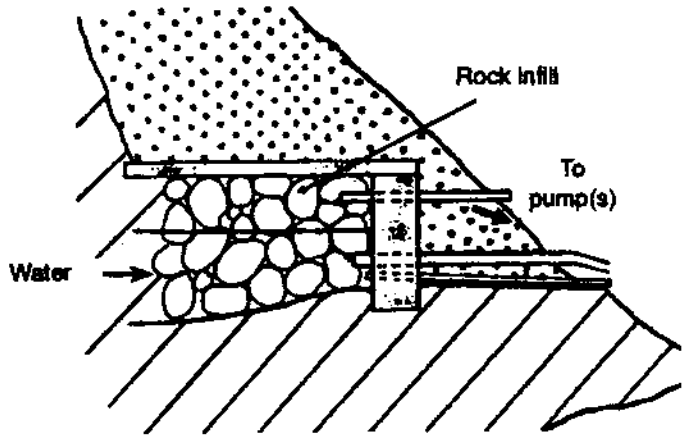

In most situations water emerging from springs is completely pure and safe for drinking, whereas by the time it flows into a stream or river it has often become contaminated. This is why it is preferable for a ram pump system supplying drinking water to be served directly by a spring.

Spring flows are often quite low and in many cases it is necessary to combine the flow from several springs to obtain enough drive flow for a ram pump system. When this is done, the drive head available to the pump(s) is the drop from the lowest of the springs to the pump(s).

Seasonal variations in spring flow must be allowed for. In most cases the users require the same amount of water at all times through the year, so the system must be designed to use the amount of flow available when the springs are at their lowest. If this is not done, there may be times during the year when there is not enough water delivered, or when there is too little water to run the pump(s) at all.

Stream intakes — dams and weirs

On streams and small rivers the feed pipe must draw water from a relatively deep pool to ensure that the end of the pipe remains below water level. To achieve this it is usual to build an obstruction across the stream to raise its level, and to run the feed pipe through it. The obstruction can either be a dam with a specific overflow point (a spillway), or a weir where the water flows over it across its whole length.

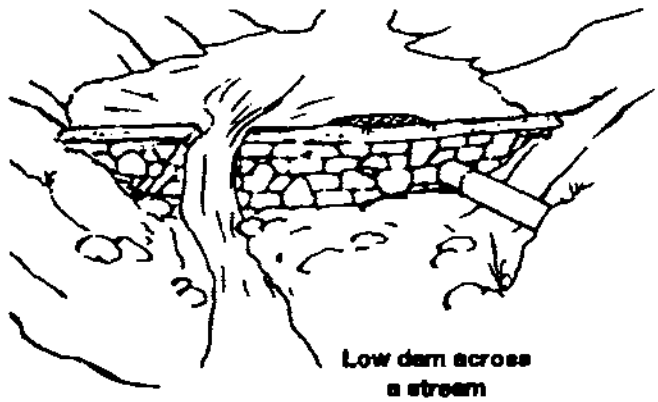
Low dam across a stream

The types of dam or weir normally constructed are relatively small and simple as the increase in level needs only to be around 300mm. In situations where the drive head must be increased significantly in order to make a system viable, larger dams may be necessary. In many parts of the world, simple, cheap designs of dam have been developed that suit the local conditions and use readily available materials.

Siting the intake The best site for a dam or weir is where the gradient of the stream is large, such as just above an area of rapids or a waterfall. This enables a high drive head to be obtained within a small distance and so helps to reduce the length of feed and drive pipes. In situations where the gradient of the stream is fairly constant, constraints on siting other components of the system may determine the location of the intake. On streams with a low gradient there are two ways of obtaining a suitable drive head. One is to build a small, cheap dam some distance upstream and run a long and therefore expensive feed pipe to the drive tank. The other is to build a much taller, more expensive and complex dam and run a short length of feed pipe to the drive tank. Siting the dam in a narrow section of stream can greatly reduce the amount of material required in construction, particularly where a taller dam is to be built.

When choosing a site, careful attention must be given to the foundation on which the dam structure will be built. Solid rock foundations ensure a firm base but require the use of cement or concrete to attach the structure securely. If building on loose material, such as soil or gravel, it is necessary to dig a trench across the stream bed to provide a firm anchor for the structure. The foundation should extend well into the banks on either side of the stream, especially where these are soft.

The size of expected floods and the type of debris carried by the floodwater also affects the type and site of the intake structure. A low, well-anchored dam or weir can be designed to allow floodwater to pass straight over it so that, apart from the additional build-up of silt and other debris behind it, the structure is little affected by floods. Larger dams should be built strongly enough to withstand flows much higher than the normal operating levels expected. A spillway will normally take excess water over the dam, but can rarely be large enough to cope with floodwater levels. In some cases a bypass can be built for floodwater but care should be taken to prevent the stream from establishing a new course along the bypass route after the flood.

Components of an intake A number of features should be built into any dam or weir intake:

- Feed pipe socket — a socket built into the structure to enable the end of the feed pipe to be disconnected in case repair or cleaning is required;
- Screen — a coarse wire mesh covering the inlet of the feed pipe to prevent larger debris such as leaves and sticks from entering the system with the drive water;
- De-silting pipe — a small bore steel pipe built into the base of the dam or weir to allow periodic or continuous removal of silt from behind the structure. Silt must be removed before it reaches the level of the feed pipe and starts to enter the system.

Run-of-river intakes

Where the flow of a watercourse is too great to allow construction of a suitable dam or weir, an intake can be built into one of the banks. Such a run-of-river intake diverts a portion of the water from the main flow of the watercourse and channels it into the feed pipe. The intake must be positioned at a site where there is fairly deep water near to the bank. It is also necessary to design and site it so as to prevent excessive silting.

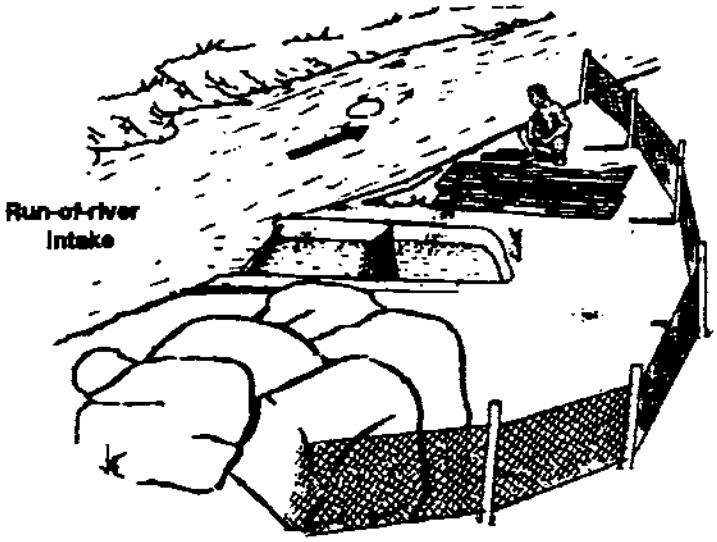

The spiralling flow of water on a bend tends to cause sedimentation on the inside of the curve, so intakes should never be sited in such a position. Siting an intake on the outside of a bend can be advantageous because the water tends to be deeper and silting reduced, but this position can leave it liable to damage by floating debris, especially during floods.

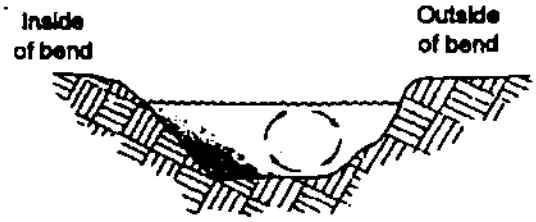

Section through river on a bend

Settling tank

Water, particularly in streams and rivers, can carry a large amount of small pieces of soil and sand — often referred to as silt. The amount of debris carried by water depends upon its velocity and the type of ground over which it has travelled. Silt can cause damage by eroding pipework and pumps as it is forced along by moving water, or by settling and building up to create blockages. When it is planned to use water that has a large silt content for a ram pump system, it is wise to include in the system a means of removing the worst of this debris.

When the velocity of flowing water is reduced, the particles of silt being carried tend to fall slowly and settle out. In some systems, the large pool of water behind a dam or in a spring box can slow down the water sufficiently to allow silt to settle out. A large drive tank will also reduce the velocity of the water sufficiently to allow some settling to occur.

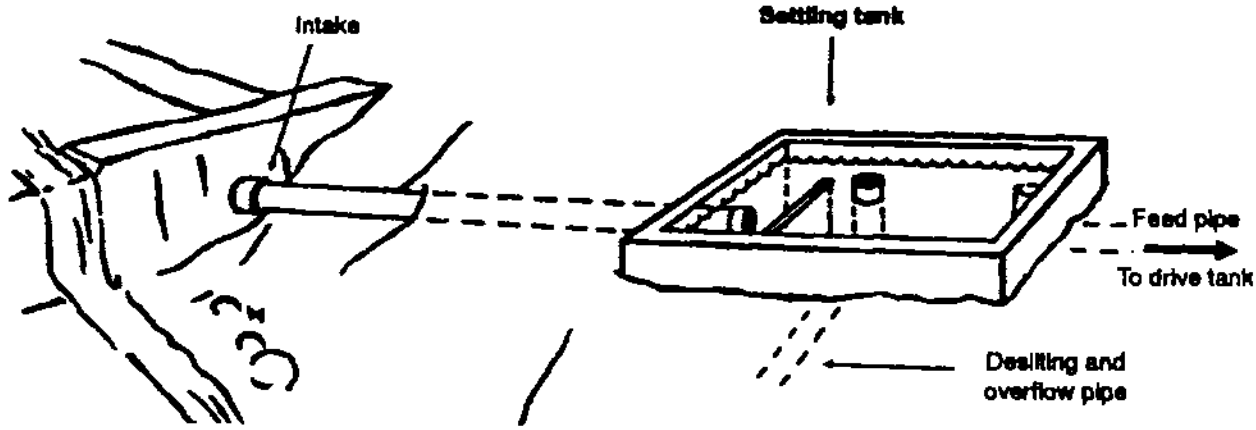

In situations where the source has a particularly high silt content and no large pool of water at the intake, a purpose-built settling tank should be included in the system. The settling tank should be designed to reduce the velocity of the water sufficiently to allow much of the silt to drop to the bottom of the tank rather than being carried with the water further into the feed pipe. The most convenient place to site a settling tank is near to the intake structure. If the system uses several springs, the settling tank can also be the most convenient place to combine the flows from each of the springs.

Settling tanks need regular maintenance. If they are well designed, a large amount of silt will collect very quickly and the tank will need cleaning. A removable overflow that serves as a silt pipe installed as shown can make cleaning fairly simple. Withdrawing the overflow pipe from the elbow in the base of the tank causes a large flow down the silt pipe, removing settled debris from the base of the tank.

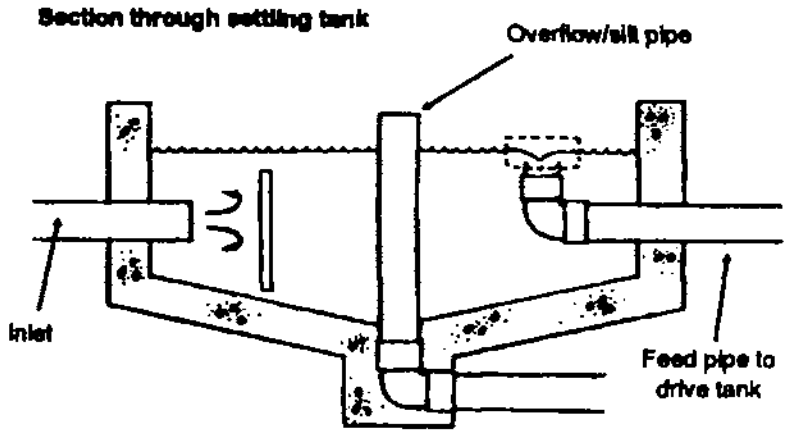

Drive system

The drive system is the part of a complete ram pump installation that receives water from the intake and feeds it to the pump(s). It normally comprises three main items:

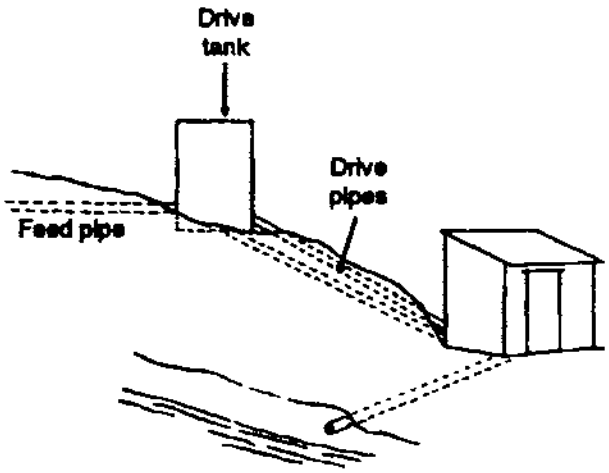

- a feed pipe that carries a constant flow of water from the intake to the drive tank;
- a drive tank that provides a store of water at the top of the drive pipe(s);
- the drive pipe(s) that supply water from the drive tank to the pump(s).

When first designing a drive system for a ram pump, all three items must be considered together because decisions involving any one of them will affect the design of the other two. In any particular situation there is a balance to be found between each of the items in the drive system. The balance involves the site layout and the relative costs of different types of pipe and of tank construction.

The system sketched below shows how the required drive head can be achieved in two different ways at the same site. Case A shows a small drive tank linked to the source by a short length of feed pipe. To reach the necessary drive head (H) a long drive pipe has to be installed to each pump.

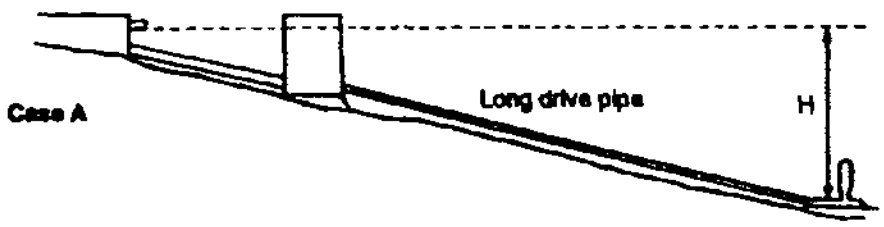

Case B uses a very tall drive tank being fed from the intake by a long feed pipe and supplying the pump through a much shorter drive pipe.

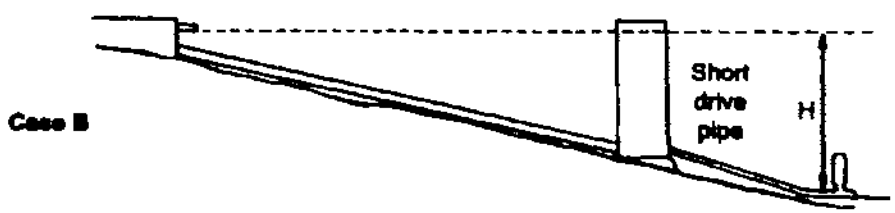

The final design choice in any situation will depend on the cost and the availability of materials and construction techniques.

Small drive tanks are generally cheap and simple to construct whereas tall ones require better foundations, reinforcing and more complicated construction techniques. On the other hand, galvanised steel drive pipe is usually far more expensive than low pressure plastic feed pipe and this cost constraint would often make Case B, using a long feed pipe with a short drive pipe, the more attractive option.

When designing a drive system it is best to look for an area below the proposed intake site which has a particularly steep slope. To obtain a certain drive head (H), the cheapest and most suitable site will be one that allows a small drive tank to be built at the top of a steep slope with a short drive pipe leading to the pump at the bottom as shown below. This will sometimes require a long feed pipe to carry water from the intake to the drive tank.

When using a spring or stream in a valley, the sides of the valley are often much steeper than the slope of the stream itself. Diverting the drive water in the feed pipe around the contour of the valley to a point where the side slopes more steeply (as shown below) can often enable the use of a small drive tank and relatively short drive pipe.

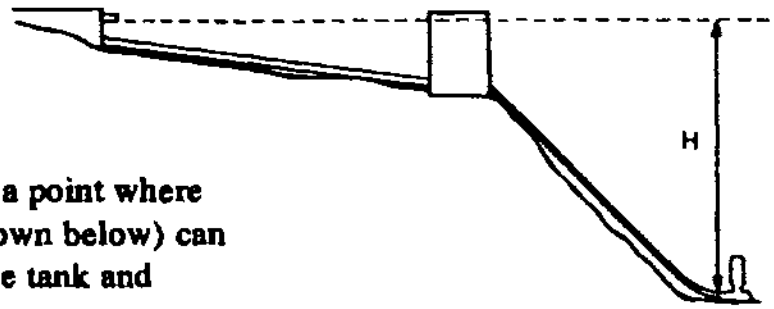

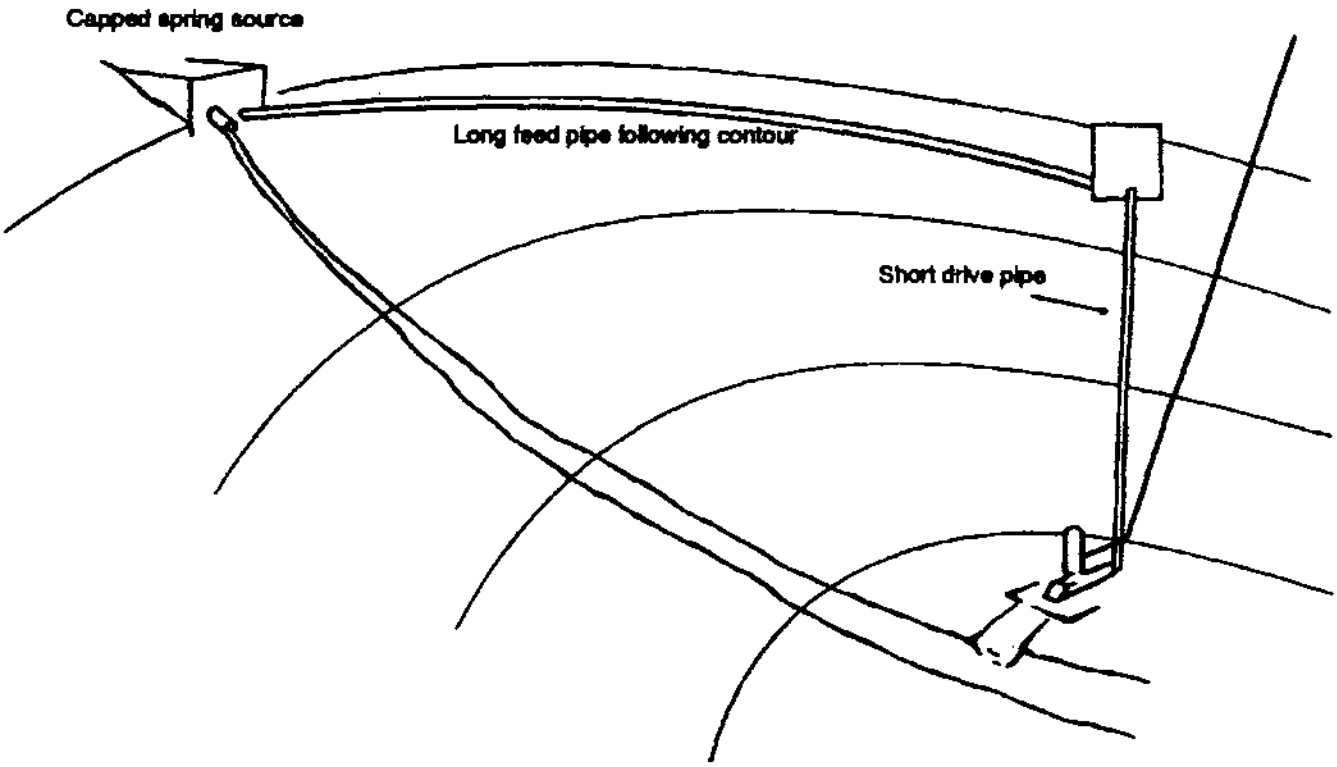

Feed pipe

The feed pipe carries a steady flow of water from the intake to the drive tank. It must supply sufficient water to feed all of the ram pumps running from the drive tank plus a small surplus that will overflow from the tank and ensure that a constant level is maintained inside. In small spring-based systems (or those using very small streams), all of the available source flow may be diverted into the feed pipe and the excess allowed to overflow from the drive tank. All feed pipes must be sized to carry enough water to supply all the pumps installed, plus an allowance for the overflow and any planned expansion of the system at a later date.

The pressure of the water in the feed pipe is generally very low, so cheap, low-pressure plastic pipe is usually adequate. If this type of pipe is used it should be buried or well covered in some way to protect it from damage by animals, farming, or strong sunlight.

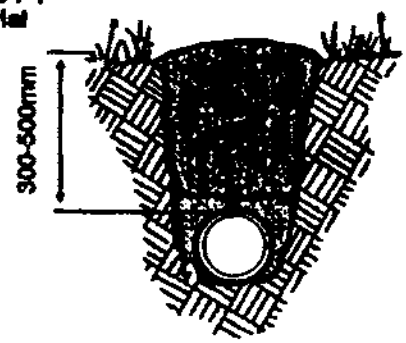

The water flowing through the feed pipe will experience some friction against the pipe walls. This friction takes up some of the energy of the water and means that the water level in the drive tank under normal operating conditions will be lower than the level at the intake. This head loss caused by the friction of the flowing water must be taken into account when choosing the diameter of the feed pipe. In situations where there is plenty of drive head available a smaller and cheaper pipe size can be used. To achieve the required drive flow, the water in a small pipe will have to flow faster, with more friction and therefore a higher head loss, but when there is plenty of drive head available this will not matter. In situations where the drive head available is very limited, very little head loss in the pipe can be allowed and a larger diameter pipe through which the water flows relatively slowly should be used: the low velocity of the water in a large diameter pipe reduces the friction and therefore reduces the head loss.

Drive tank

The drive tank is an important component in the operation of a ram pump system. It performs the following tasks:

- it keeps a steady water level, ensuring a regular supply to the pumps and a constant drive head;
- it provides a large body of water with an open surface that reflects the pressure waves travelling up the drive pipe when the pump is running;
- it also prevents air from being sucked into the drive pipe.

Very occasionally systems can be sited on a steep slope (more than 30 per cent) directly beneath the water source and can be designed without a drive tank. This can reduce the cost and complexity of the system but extra care must be taken in the design of the water catchment structure, which must then also perform the functions of a drive tank.

One common mistake when designing drive tanks is to have the entrance to the drive pipe too close to the surface of the water. In such cases air is drawn into the drive pipe

as the water accelerates down it. This can interrupt the operation of the pump and frequently leads to failure at the top of the drive pipe due to an effect called cavitation. It is recommended that the depth of water above the drive pipe inlet(s) be at least 500mm.

The volume of water in the drive tank, and in particular the cross-sectional area, must be large enough to maintain a steady level in the tank despite the intermittent outflow to the pump(s). As a rough guide, the cross-sectional area should be at least 20 times the total area of the drive pipes being supplied from it.

A number of types of drive tank can be considered. The choice between them depends both upon site conditions and the materials and skills available for their construction. From the authors' experience, three main types are useful, each with its own normal range of use.

A A square or rectangular tank made from cement block or fired brick and plastered inside and out. The height of these tanks is usually not greater than 2.0m.

B Large diameter PVC pipe set in a concrete base: restraining lines are recommended to ensure stability. These tanks are only appropriate for use in systems with small drive flows — particularly those systems that are spring- based. The height of these tanks is usually not greater than 6m.

C Circular tank made of cement blocks with re-bar (reinforcing bar) running vertically and horizontally within it. The height of these tanks is usually between 2 and 4m.

Care must be taken to site the drive tank conveniently for operational reasons and to ensure that it is stable. A large tank full of water is very heavy and the foundations must be strong enough to support this weight without movement. Where possible tanks should be built on a solid rock foundation.

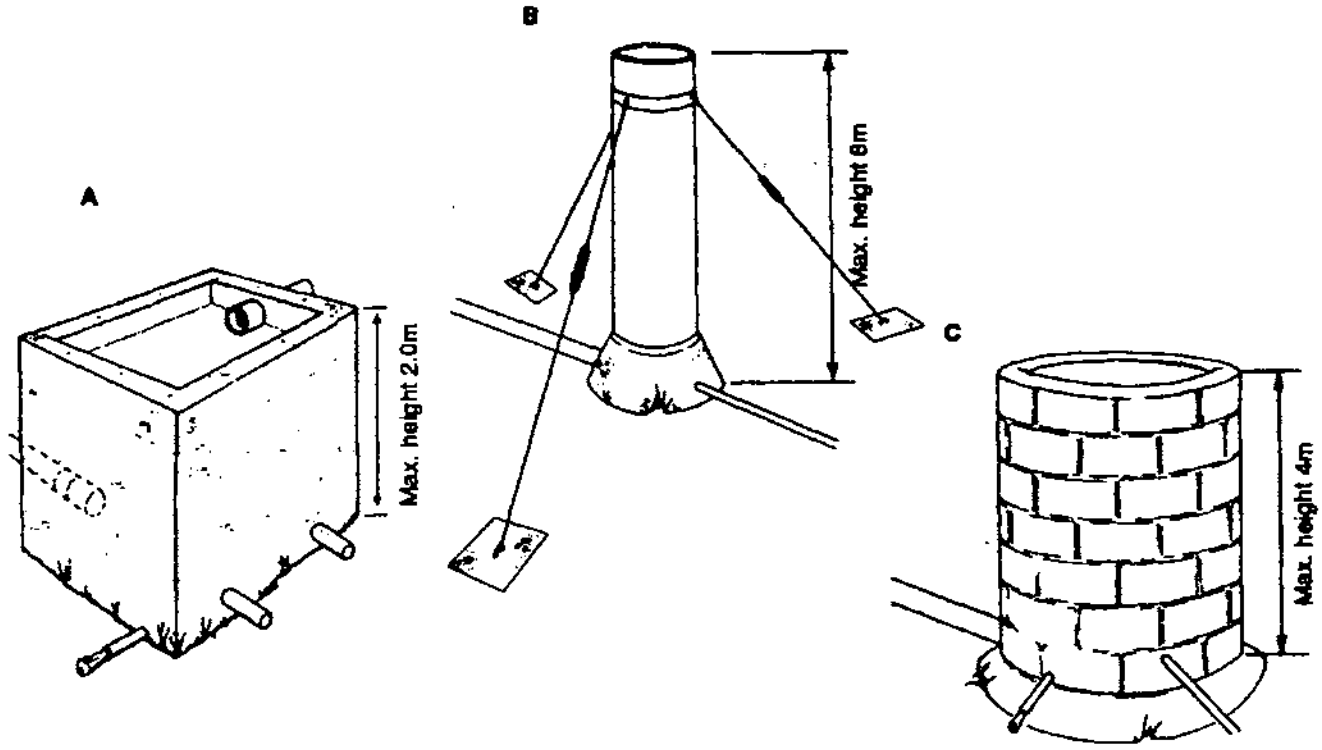

Drive pipes

Most pumps are designed for a particular diameter of drive pipe and this recommended size should be used under normal conditions, i.e. in the normal range of drive flows and pipe lengths. Selection of drive pipe diameter is a compromise between having a large diameter to reduce friction losses and a smaller diameter to give adequate water velocity. Never install a pump with a drive pipe diameter larger than the diameter of the drive pipe connection to the pump. Research has shown that many traditional pump designs actually underutilise their drive pipe capacity and so, where drive pipe lengths and drive flows are towards the lower limit of their range, the next standard size of drive pipe below that recommended can be installed. For example, the DTU M8 and M6 steel pumps are normally driven via a drive pipe in internal diameter 2" (50mm): for drive flows (not delivery flows) of less than 70-80 litres/minutes, a 1½" (38mm) drive pipe can be used instead. Despite its higher friction, the smaller diameter pipe will give better overall efficiency (and output) for the available drive flow because the velocity of the drive water through it is higher. This is especially so when the delivery head is towards the top of the pump's range. It is generally true of all ram pumps that at low flows and high heads reducing the drive pipe diameter leads to an increase in pump efficiency.

There are limits to the length of a drive pipe in a ram pump system. These limits can be calculated by reference to several theories that take account of such factors as the energy available to the pump, the friction in the system and the movement of pressure waves within the pipe. A complete explanation of the theory involved would be too complex to give here, so only some basic guidelines are described.

A short drive pipe, that is, one with a length less than about twice the drive head, will give a very high frequency of operation. This can reduce efficiency and will shorten the life of the pump. The advantage of keeping the drive pipe as short as possible is that its cost is reduced. As a general guide, it is recommended that the length of the drive pipe be kept to between two and four times the drive head, but should never be less than 6m. For example, a system with a drive head of 5m should be designed to keep the length of the drive pipe between 10 and 20m. Systems with drive pipes longer than about five times the drive head may not be able to operate at the optimum efficiency or peak output levels quoted by the manufacturer. Ram pumps with very long drive pipes will operate satisfactorily in many situations but are inefficient and unnecessarily expensive.

The angle of the drive pipe is not a critical factor and will normally be dictated by the particular site conditions. The manufacturer's recommendations for the correct angle for a drive pipe can be ignored provided that the guidelines for pipe length given above are followed. The drive pipe can have gentle bends along its length but it must be very firmly secured near to these points.

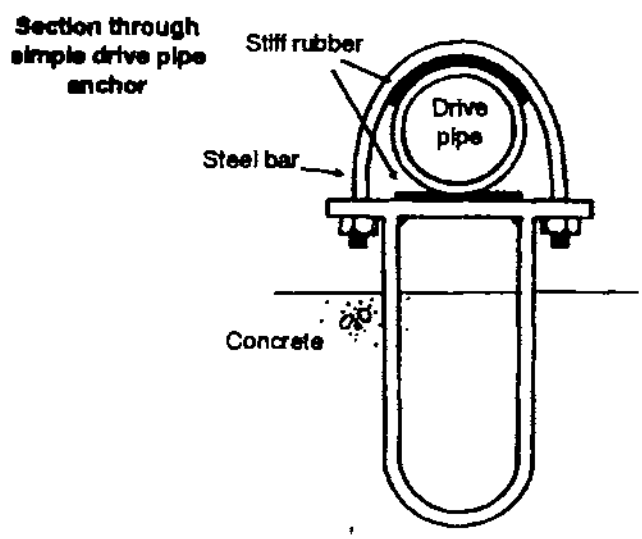

Drive pipes are normally made from galvanised steel pipe, which is the usually the cheapest and most readily available material with adequate strength and life. Well sealed, threaded joints can be used in most situations, provided that the pipe is properly anchored and cannot vibrate. In systems with very high delivery heads (over 100m), threaded drive pipe connections are sometimes inadequate. In these cases flanges should be welded to the ends of the lengths of drive pipe so that they can be bolted together. The same flanged connections should be used when the threads on the pipe are of poor quality, or when large diameter drive pipe is being used.

Pump

The pump itself should be considered as one component of the whole system. It needs to be carefully selected and sized in the same way as a tank or pipe, and its installation must be carried out carefully. The section on pump selection earlier in this pamphlet describes the process of choosing a ram pump or pumps to suit a particular set of conditions. After the particular requirements and constraints of an installation have been identified by the site survey, the pump(s) should be the first component to be selected. When the number and type of pump to be used is known, the sizing of tanks and pipes and the detailed design of the rest of the system can be carried out.

Pump base

It is essential that each pump be held rigidly to prevent it moving and vibrating with each pumping cycle. If a pump is not firmly secured, energy is lost as it moves and pipe joints will quickly break. The best way to secure a pump is to attach it firmly to a large concrete base. Some manufacturers recommend securing their pumps by setting bolts into the concrete but the difficulty of replacing these bolts when their threads rust or become damaged makes this unwise. A better method is to cast a steel frame, referred to as a pump cradle, into the concrete base.

There can be either a separate cradle for each pump or a single cradle to support them all. This can be made of angle-iron or other steel section welded together. The top of the cradle is left jutting out of the concrete and has holes pre-drilled through it so that the pump can be bolted down on it. If the securing bolts are damaged, they can be cut off and replaced without the need to recast the concrete base.

Section through pump base

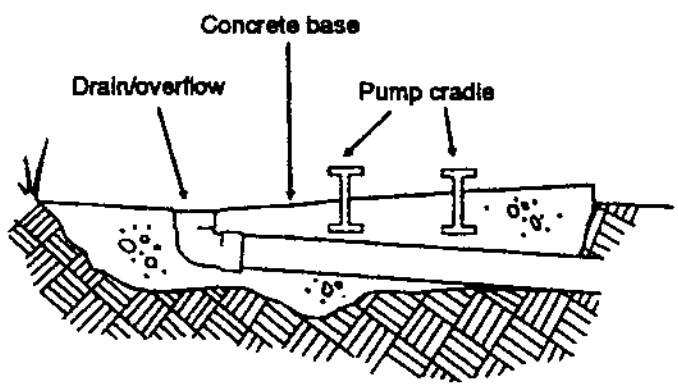

The shape of the cradle required will be different for each make of pump depending on the fixing methods incorporated by the manufacturer.

When designing a drive system, choose a suitable site for casting the pump base. The concrete base must be firmly anchored to prevent the continual vibration of the pump(s) damaging it, or separating the entire base from the material surrounding it. The site must also allow for drainage of the waste water from the pumps to prevent flooding around them.

Pump house

A structure built around the pumps is not essential to the operation of a ram pump system. However, a pump house is recommended to provide security and protection. Curious children can easily damage a ram pump left operating in the open and it also makes an easy target for thieves. The pump house must be made large enough to allow complete access to all parts of the pumps for installation and maintenance. As a general guideline, allow at least 500mm between any part of the pump and the walls of the pump house or another pump.

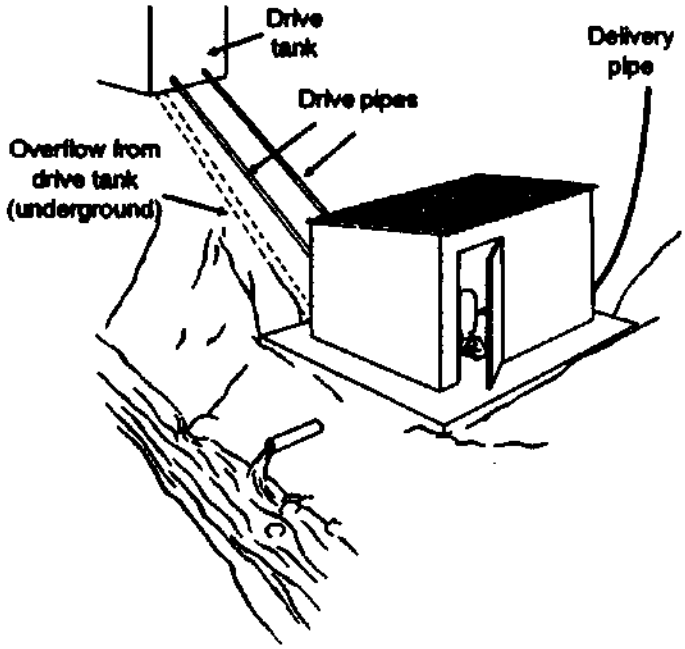

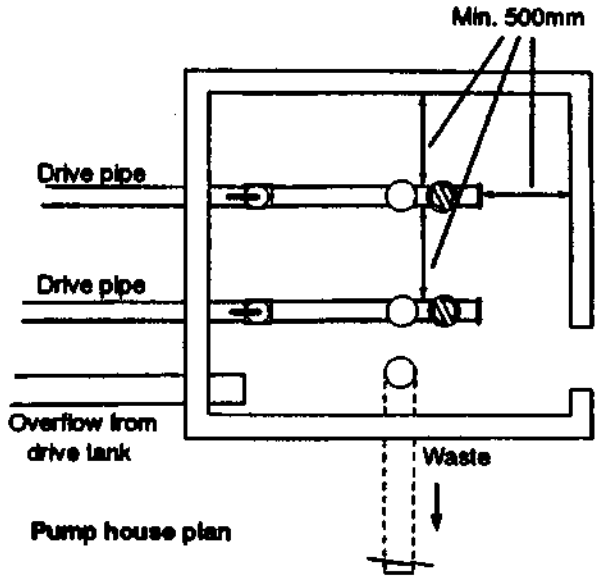

Delivery manifold

The delivery manifold connects the outlet from one or more ram pump's air vessels to the delivery pipe that carries the water to the point of use. It also traps air and collects silt.

Delivery pipe

The delivery pipe is an important part of any ram pump system and in many cases its length leads to it being the most expensive item. This is true despite the fact that, unlike drive pipes, many pumps can share the same delivery pipe. The delivery pipe must be sized to suit the expected delivery flow and the cost constraints. The larger the diameter of the delivery pipe, the more expensive it will be, but the lower the friction losses within it. Relatively cheap delivery pipe with a small diameter will impose high friction on the delivery flow, causing a high head loss. The pumps will have to overcome this head loss as well as lifting the water to the point of delivery. Choosing a diameter for the delivery pipe is therefore a balance between having a small diameter pipe to reduce costs or having a large diameter pipe to reduce head loss and maximise delivery flow.

As a rule of thumb, the calculated head loss in the pipe when it is carrying the predicted delivery flow should be between 5 per cent and 10 per cent of the delivery head.

Where there is plenty of delivery water available and low cost is important, a small

diameter delivery pipe can be used to reduce cost. If the expected delivery flow is only just sufficient for the users, a larger diameter pipe with a lower head loss should be chosen.

The route chosen for the delivery pipe should be as short as possible to reduce cost and head loss. However, the shortest route may not be technically feasible or necessarily the cheapest.

The sketch below shows a system with three possible delivery routes.

- Route A follows the lowest ground for much of its length: it is not recommended because a large section of the pipe is under high pressure and high pressure pipe tends to be more expensive;
- route B takes the most direct line but is not recommended because it has high points in which air would collect, causing air locks and reducing delivery flow;
- route C is the best route, rising quickly from the pump and then following a steady upward incline to the delivery tank. Only a short length of pipe is under high pressure and the line is fairly direct. A spur off the delivery pipe below the delivery tank should never be installed.

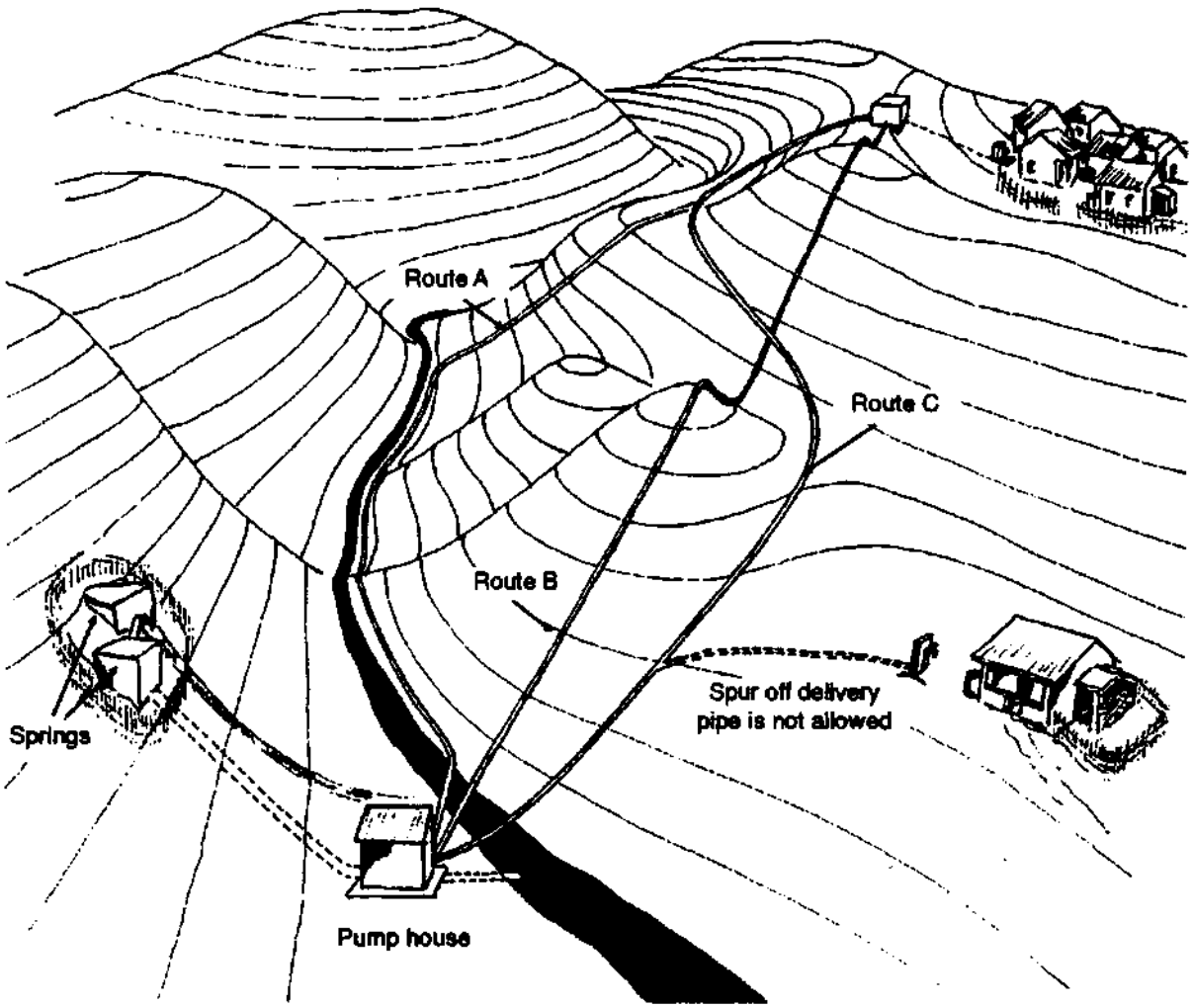

Distribution system

After installation and commissioning, most of the components of a ram pump system are forgotten by the users of the water supplied. The water is collected every day from stand pipes and it is the design of this distribution system that will be most relevant to them. It is particularly important to involve the whole community in the design of the distribution system and that the social organisation of water use is planned before construction.

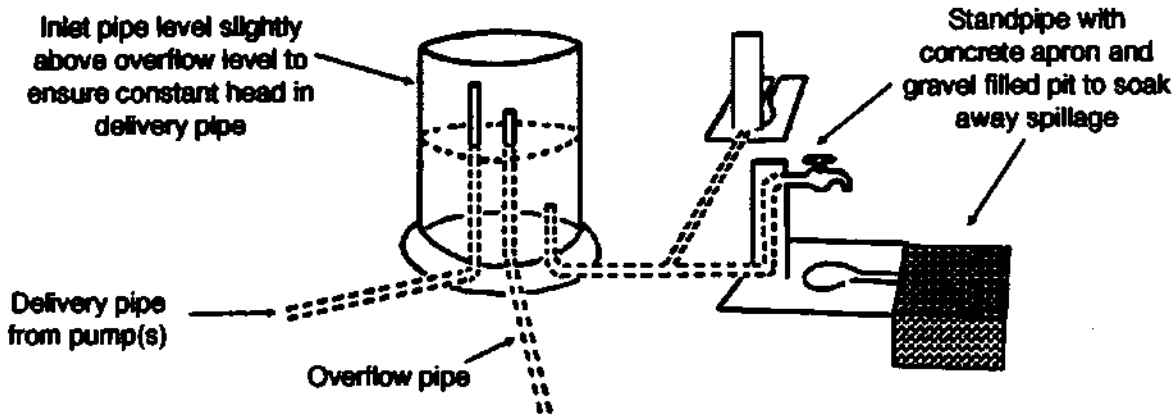

Most ram pump systems for domestic use will require a storage tank at the end of the delivery pipe. A ram pump operates for 24 hours each day, so the water pumped overnight must be stored for use during the times of peak demand. If there is to be more than one storage tank, the water should be pumped to the highest one and then fed by gravity down to the others. Alternatively, if valves are fitted on the inlets to each tank (except the highest one) the flows can be controlled so that all subsidiary tanks fill at the same rate. The total capacity of the delivery tank or tanks in the distribution system must be large enough to hold all of the water pumped overnight. They should therefore be sized to hold at least 12 hours supply and preferably 16 hours supply. The storage requirement can be calculated using the rule:

Storage required in litres = delivery flow in litres/minute x 60 minutes x 16 hours
= q x 960

Thus, for each litre per minute of delivery flow, provide about one cubic metre (= 1000 litres) of storage.

The delivery tank should either be conveniently situated for direct use or feed water into a distribution system. In many cases distribution can be directly through stand pipes connected to the delivery tank and fed by gravity. Larger systems serving bigger communities may require a number of distribution points each with a secondary storage tank and stand pipes. These tanks can either be assigned a priority — where the overflow from one tank feeds the next in a chain — or can be fed equally from the main delivery tank.

Single and multiple tank delivery systems

Single delivery tank | Priority chain delivery system | Equal priority multiple tank delivery system

Water drawn from springs and high mountain streams is often very clean and can be used without any form of treatment. Where the water to be used in a ram pump system is drawn from a dirty source, filtration of the water delivered may be necessary. Simple sand filters when carefully installed and maintained can be very effective in improving water quality. The details of filter design and construction can be found in many publications and are beyond the scope of this book. From a system design point of view, however, it is worth noting that the delivery tank can itself be a filter tank as shown below. The delivery/filter tank feeds clean water to a second storage tank from which water is drawn for use. The top of the link pipe in the distribution tank should be a few centimetres higher than the level of the sand in the filter tank: this ensures that the sand never dries out.

Simple method of filtering delivered water

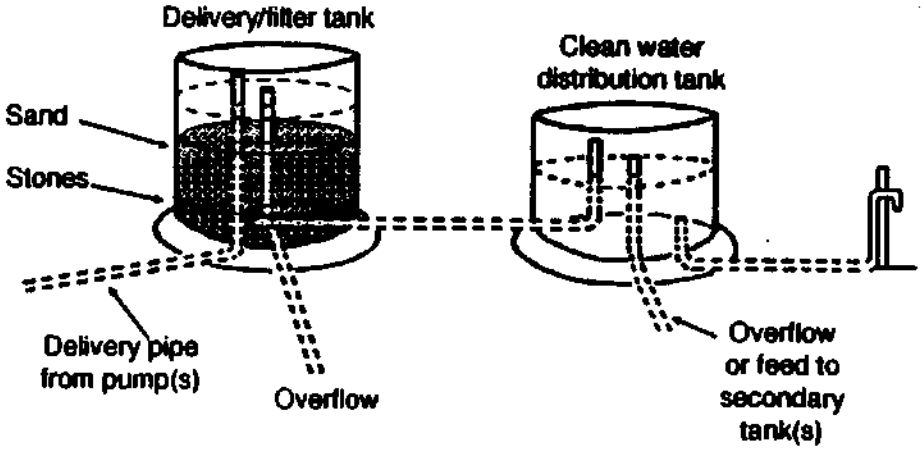

DTU

Ram Pump Programme

DTU P90 PUMP

TECHNICAL
12
RELEASE

DTU P90

The name "P90" stands for a Plastic pump with a drive pipe of 90mm in diameter.

hydraulic ram pump

The P90 is a plastic-bodied hydraulic ram pump designed mainly for the irrigation of vegetable gardens from streams running nearby. Each pump, used continuously day and night, can irrigate 0.2 to 0.6 hectares (½ to 1½ acres). If it is run only in daylight hours, it will only irrigate half the area. The P90 may be used for furrow irrigation, hose irrigation and watering by bucket from a storage pond at the top of a field. It does not give enough pressure for irrigation using water cannons or automatic sprinklers. The P90 can also be used for pumping drinking water, but only as high as twenty meters. For greater heights use steel-bodied pumps.

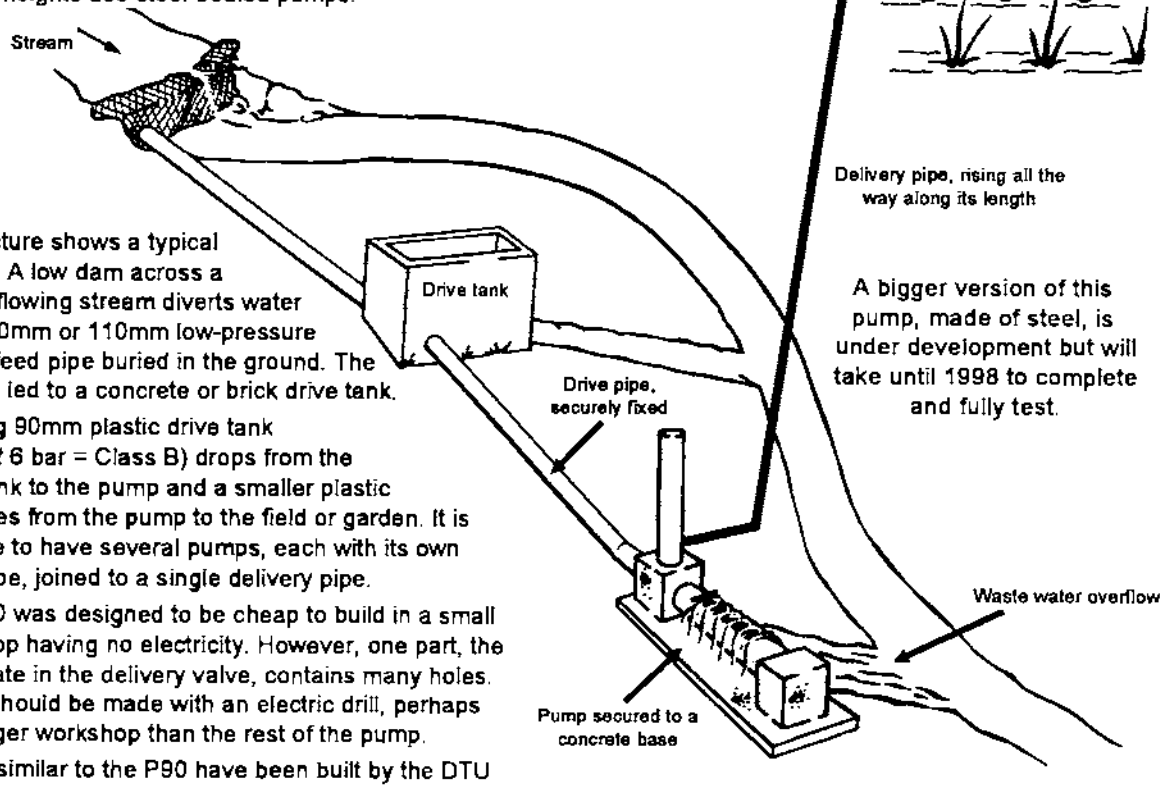

This picture shows a typical system. A low dam across a rapidly flowing stream diverts water into a 90mm or 110mm low-pressure plastic feed pipe buried in the ground. The water is led to a concrete or brick drive tank.

A strong 90mm plastic drive tank (*at least* 6 bar = Class B) drops from the drive tank to the pump and a smaller plastic pipe rises from the pump to the field or garden. It is possible to have several pumps, each with its own drive pipe, joined to a single delivery pipe.

The P90 was designed to be cheap to build in a small workshop having no electricity. However, one part, the steel plate in the delivery valve, contains many holes. These should be made with an electric drill, perhaps in a bigger workshop than the rest of the pump.

Pumps similar to the P90 have been built by the DTU in several countries. Although the DTU believes the P90 will operate for two years, only one pump trial (in Zimbabwe) has been run for that long.

A bigger version of this pump, made of steel, is under development but will take until 1998 to complete and fully test.

DTU P90 ram pump specifications

The normal specifications of the DTU P90 ram pump are given here. Sometimes you can operate pumps outside these limits, but they may not work well.

drive head range	—	up to 3 meters
drive flow range	—	100 to 360 liters a minute
drive pipe material	—	PVC or ABS (*at least* 6 bar or Class B)
drive pipe diameter	—	90mm
delivery head range	—	up to 20 meters
typical delivery range	—	3 to 40 liters a minute
delivery pipe diameter	—	25mm

The DTU plastic irrigation pump

Most ram pumps being manufactured are designed to supply water for domestic use because the low flows produced and the costs generally make ram pump systems unsuitable for small-scale crop irrigation. Sufficient water for 1000-1500 people, for example, would only irrigate a plot of around 1 hectare! Some very large bore (12") ram pumps have been built to supply water for irrigation but the capital costs of such schemes restricts their application. In many parts of the world there is a large potential for low-lift, low-cost irrigation of small garden plots to improve yields, allow alternative crops to be grown and increase crop security in unpredictable weather conditions.

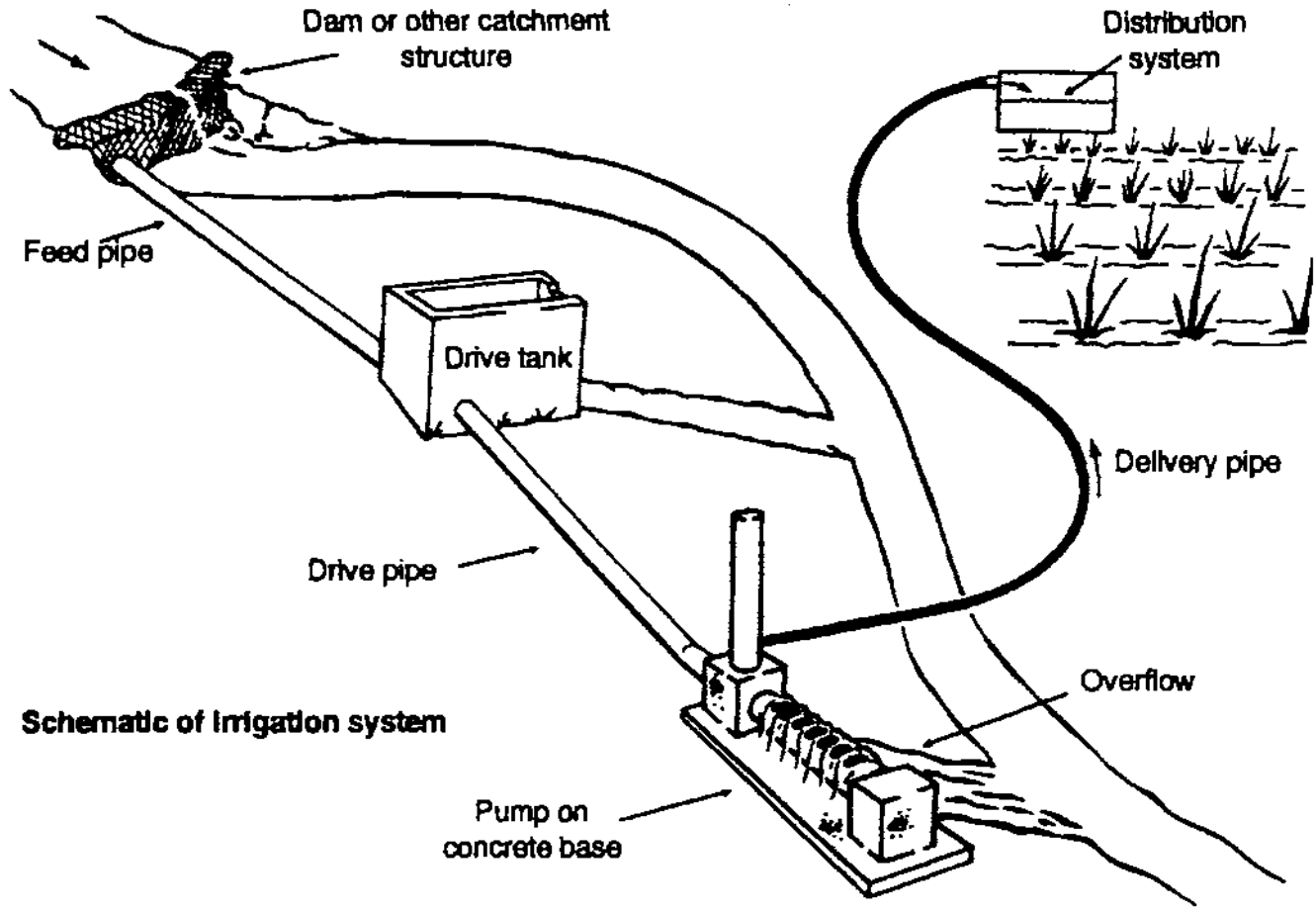

Schematic of irrigation system

The material the DTU selected as the only viable alternative to steel is plastic pipe. PVC 110mm (4") diameter pipe is now widely available in many developing countries and provides the scale of flow necessary for small-scale irrigation.

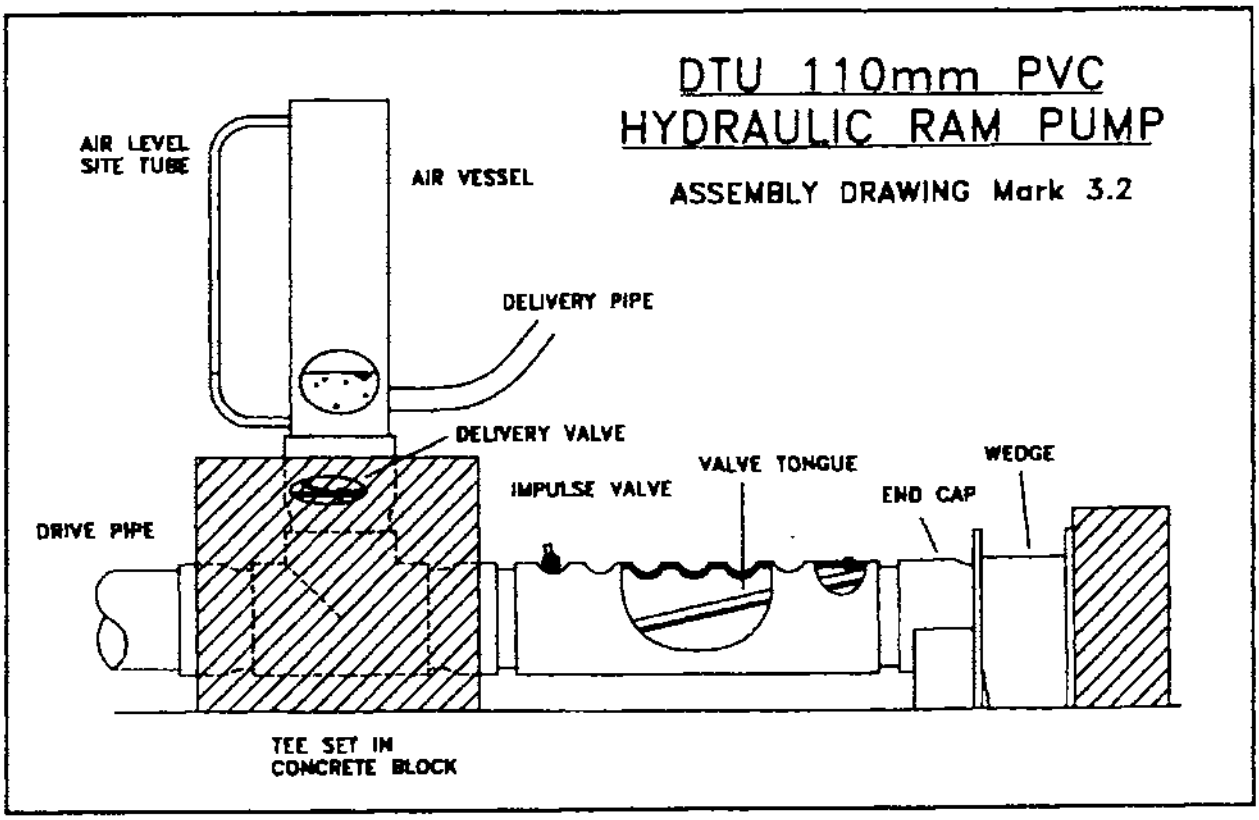

The DTU pump has the following specification:

- all major parts can be manufactured from 110mm pipe (with a minimum of other materials such as bolts, rubber, etc.);
- all parts can be manufactured using hand tools in small rural workshops;
- the system can be maintained by the user and all parts are capable of simple replacement in case of wear, damage or theft;
- designs have been extensively tested for performance and endurance (including extensive field tests);
- pumps should be easy to tune to suit a broad range of site conditions.

It meets the following performance specifications:

1. The drive head (fall of water) can be between 1 and 3 metres.
2. The drive flow available can be between 3 and 7 litres/second.
3. The maximum delivery head is 12m.
4. The energy efficiency exceeds 50%.

At 2 metres drive head, maximum delivery to 15 metres is 35,000 litres per day, adequate to irrigate ⅔ of a hectare.

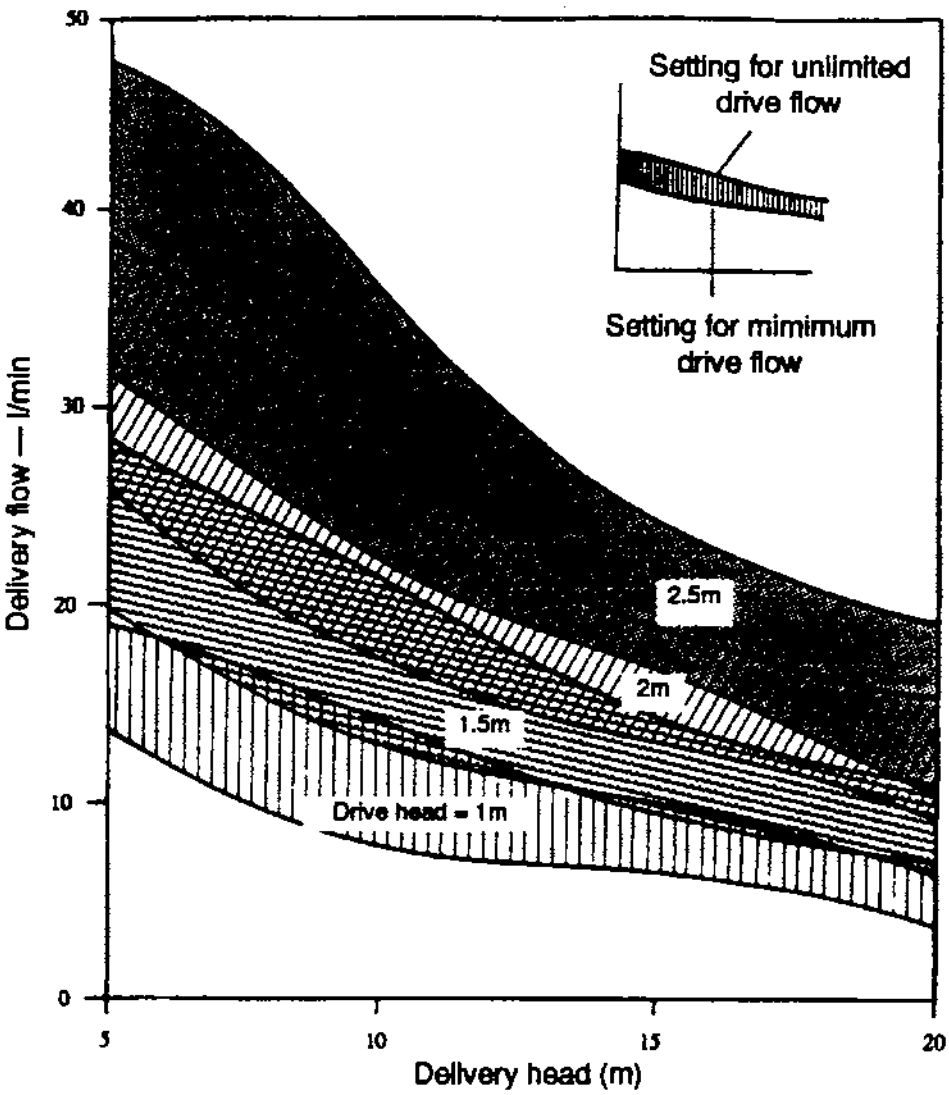

DTU PVC ram pump — Typical performance data

The shaded areas on the performance data chart above indicate the normal operating range for different values of drive head.

Pump designs have been developed over a number of years with increasing performance and component life. Plastic pipe is more prone to fatigue failure than steel, reducing the life of some components to two years. The current design has been extensively tested in Zimbabwe but is still (1993) at the proving stage of development.

Manufacturing notes

The first DTU ram pump to be built using plastic materials was tested in 1986 as part of an undergraduate project. It was constructed largely from standard PVC drain pipe fittings with a wooden impulse valve. The major interest in the use of plastic for ram pumps stemmed from the low cost of materials and the ease of manufacture using plastic components. There was some question initially whether the thin PVC material would withstand the continual fatigue loading and simply break under the first cycles. With the success of this first design, research was continued on its development and the horizontal axis impulse valve was introduced. Since then laboratory tests and field trials have significantly refined the design of the pump and produced data concerning its durability and pumping limitations.

Plastic ram pumps can provide a cheap and simple means of supplying water to elevations of less than 15m. The scale of flow produced and the limitations on their pumping head make them ideal for local manufacture and use for small scale irrigation in developing countries.

This Working Paper details the design of the M3.2 pump. It lists each component and describes any significant features and considerations. Drawings of all the components are also included along with some graphs showing the typical performance of the pump.

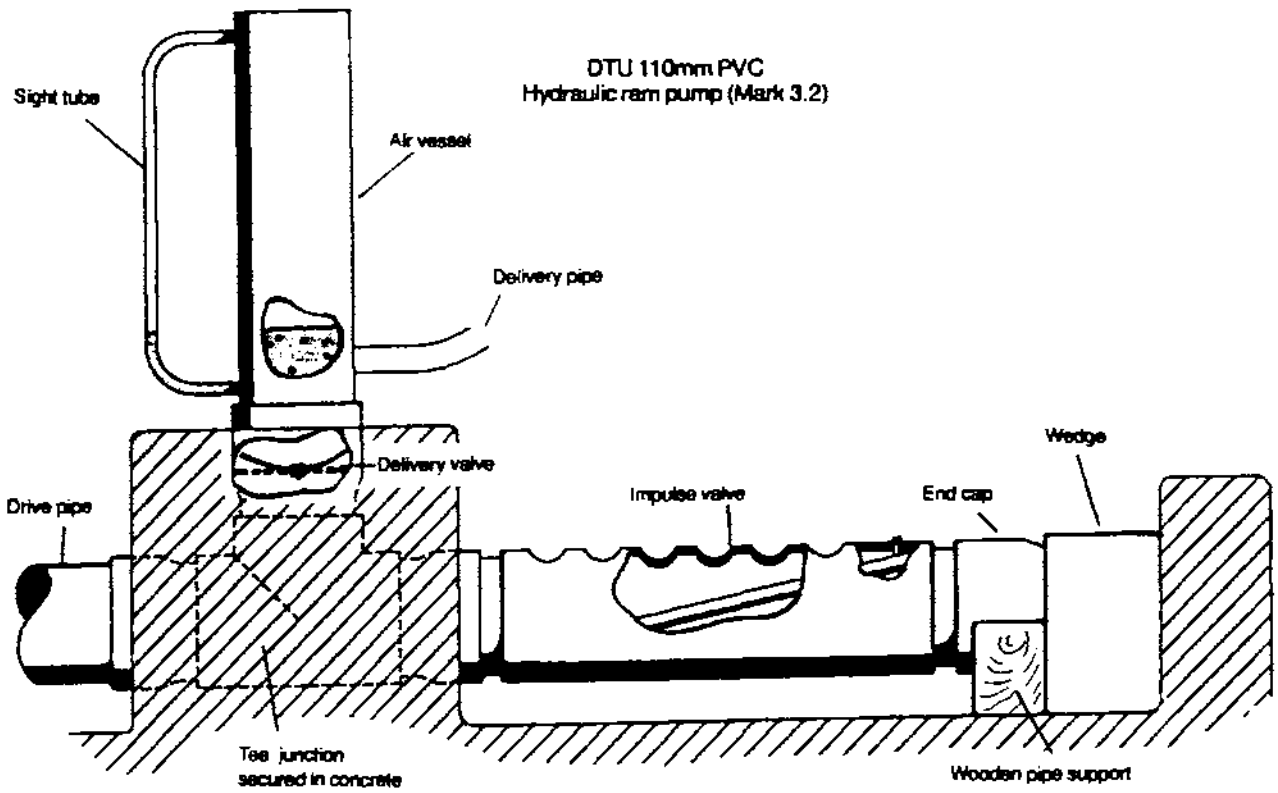

Impulse Valve

The design of impulse valve on the DTU M3.2 is unique amongst current ram pump designs. It aims to achieve a flow area through the valve equal to, or greater than, the area of the drive pipe whilst using the drive pipe material for its construction. This greatly simplifies the materials required for pump construction and reduces the need for steel components.

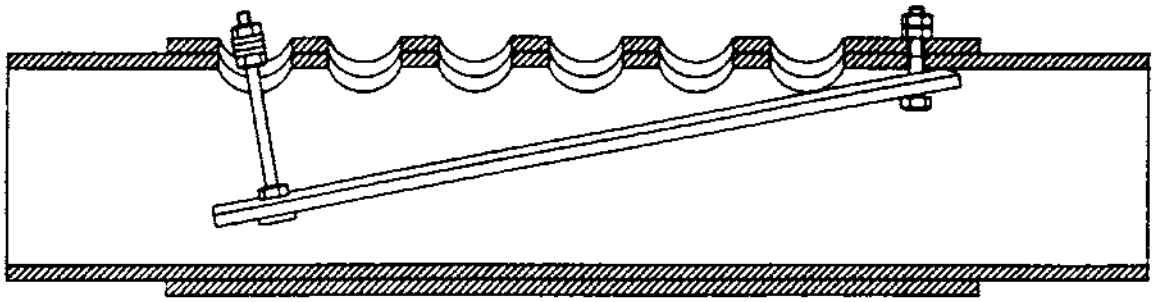

The M3.2 impulse valve

The valve operates under conditions similar to those that cause the aerodynamic lift of an aircraft wing. The velocity of the water flowing over the top of the tongue and out to waste, creates a slightly lower pressure on the top side than that underneath it. As the water accelerates, this pressure differential across the tongue increases until it is sufficient to begin to close the valve. As the tongue rises the velocity over it is increased, which in turn increases the pressure differential, causing the valve to close faster and further increasing the velocity. In this way the tongue accelerates and closes very rapidly producing the sudden deceleration of the water necessary to raise the pressure in the pump body to the delivery pressure.

The valve design works well using PVC materials due to its slight flexibility. When the valve closes the subsequent pressure rise actually flexes the tongue ensuring a good seal even though the tongue may not fit perfectly to the valve body. The same valve design has been tried using steel pipe material but was found not to work well as the tongue could not easily be contoured to the exact shape of the inside of the valve body and didn't have sufficient flexibility to deform under the normal working pressure. Provided that the tongue of a PVC pump fits sufficiently well to just operate it will deform over a number of days of operation until it seals properly.

The development of the this design from the basic concept has taken some time in using different configurations; hole sizes, spacing, valve length and in finding a design with sufficient strength to withstand the continual loading. PVC is not a material recommended for use in situations where a high fatigue loading is likely. Its use would therefore not normally be advisable in ram pumps where there is a highly fluctuating load from the pressure transients in the pump and drive pipe. Research has shown that provided the delivery pressure is kept within recommended limits, the pump and pipe material are sufficiently thick, and the pump well manufactured with no potential stress concentrators, that the normal fatigue loading experienced is well within the tolerance of the material. A Working Paper is available from the DTU detailing the research and findings of work undertaken on fatigue in PVC.

Impulse Valve Design and Manufacture Notes

1) Great care is needed in the manufacture of the holes in the valve body to ensure that there are no small cuts, indentations or cracks from the initial shaping of the holes. Once the holes have been roughly shaped they should be carefully filed until they are completely smooth to the touch and show no visual defects. This will help prevent the formation and propagation of cracks.

2) The tongue hinge is a potential source of rapid wear of the PVC material used both for the tongue and the valve body. The hinge is simply a bolt about which the tongue has some freedom to move. To prevent wear of the tongue, the hole that goes through it is lined with a piece of metal, either a small section of pipe with the correct I/D or a specially fabricated liner made from sheet steel.

3) On two occasions impulse valve cracks were found running down the valve parallel to the pipe axis at the upstream end that was pushed into the tee piece. These cracks were caused by the valve being wedged too hard into the tee piece socket. This created a significant additional hoop stress at that end of the valve and led to a crack propagating from some small imperfection in the first valve hole back to the end of the pipe. The main cause of this problem was the method of wedging the impulse valve into the tee piece against the concrete end block. It is possible to prevent this type of cracking by wedging the impulse valve more carefully. However this does not provide a fool proof solution and still allows the possibility of valve failure. The simplest method of preventing this problem is to shorten the length of the pipe that can fit into the tee socket so that the double skin of the impulse valve butts up against the tee before the valve is pushed in too tight.

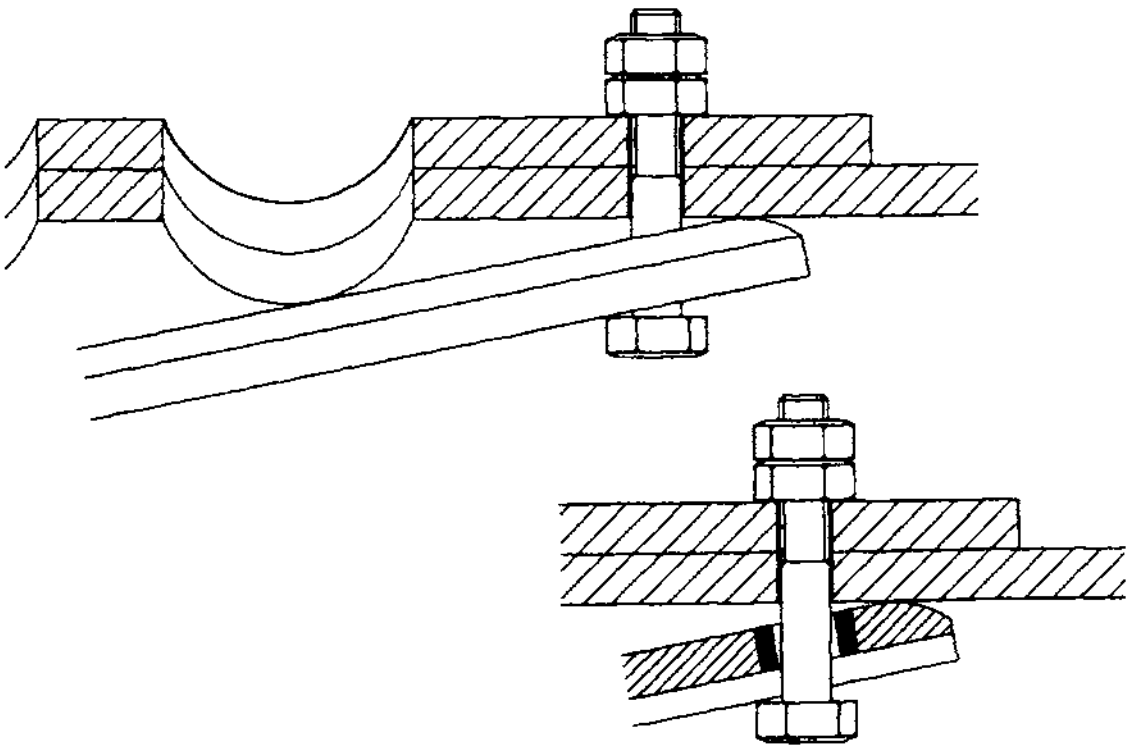

Diagram showing hinge arrangement of impulse valve tongue

Delivery Valve Design

The delivery valve for a low cost ram pump must satisfy all of the following requirements;

1) produce good performance by; opening quickly with a low pressure differential across it; have a low resistance to flow through it; allow little backflow by closing quickly with a small pressure differential.

2) have an acceptable working life with any disposable rubber parts lasting a minimum of 6 months.

3) be cheap and simple to manufacture.

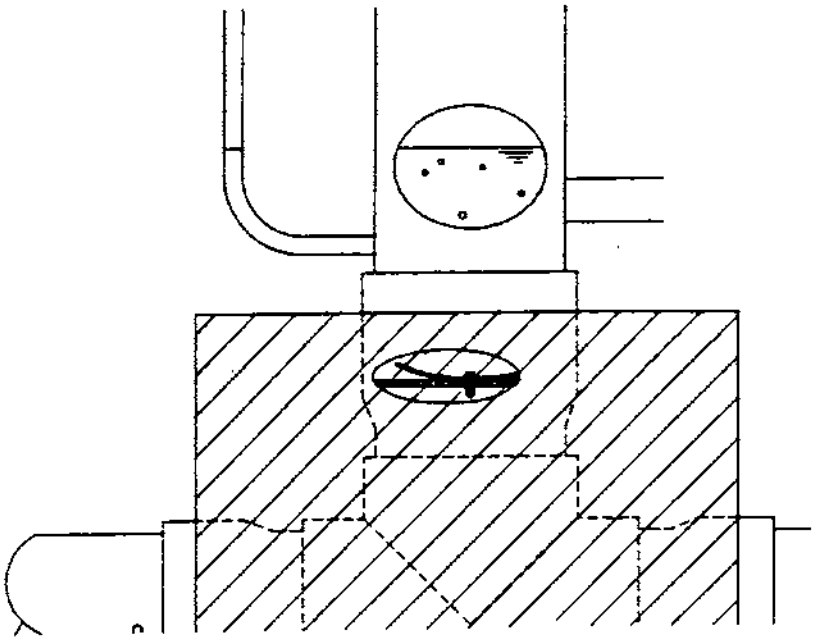

Position of the Delivery Valve

Laboratory tests have been carried out on a number of different types of delivery valve to assess their performance. These were simply designed to compare the throughput of the valve under a controlled set of conditions. Backflow of water through the valve from the air vessel during the period of recoil had been found to be significant on tests of steel ram pumps, reducing the delivery flow by up to 40% in the worst cases. With identical impulse valve settings, the delivery head and flows were measured for 5 different delivery valves. The results of the tests are shown in the following graphs.

The original flap type delivery valve proved to give the best performance over a wide range of conditions with two thicknesses of rubber to increase the rigidity of the valve. The rubber used in the tests was 3mm thick commercial sheet. One thickness of rubber gives lower performance due to its lower response to closure allowing more backflow to occur. Increasing the number of rubbers above 2 also reduces the delivery flow as the resistance of the valve to opening increases and the friction through the valve during delivery reduces the flow. Unfortuneately the quality and availability of rubber sheet varies enormously around the world and it is important to be able to make use of locally available materials to guarantee access to spare parts. Good quality inner tube from truck wheels is often the most available and reliable source of rubber. It is recommended that a number of thicknesses be used to make the total thickness of rubber between 4 and 6mm. Some experimentation with the materials available is advised. measuring performance with varying amounts of rubber to find an optimum and assess the rubbers' vulnerability to tearing and stretching.

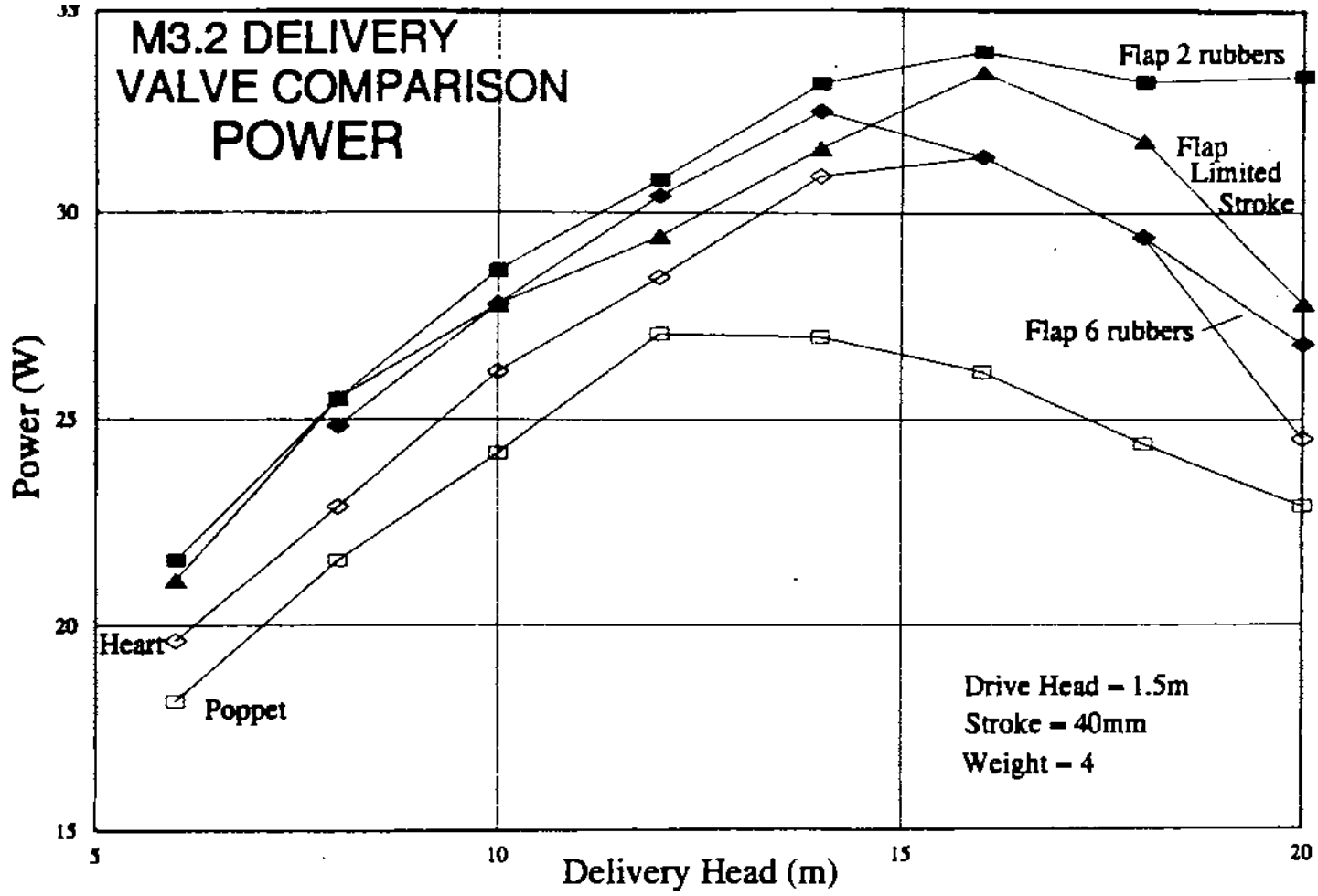
M3.2 DELIVERY
VALVE COMPARISON
POWER
Flap 2 rubbers
Flap
Limited
Stroke
Flap 6 rubbers
Heart
Poppet
Drive Head = 1.5m
Stroke = 40mm
Weight = 4
Power (W)
Delivery Head (m)
15
20
25
30
5
10
15
20

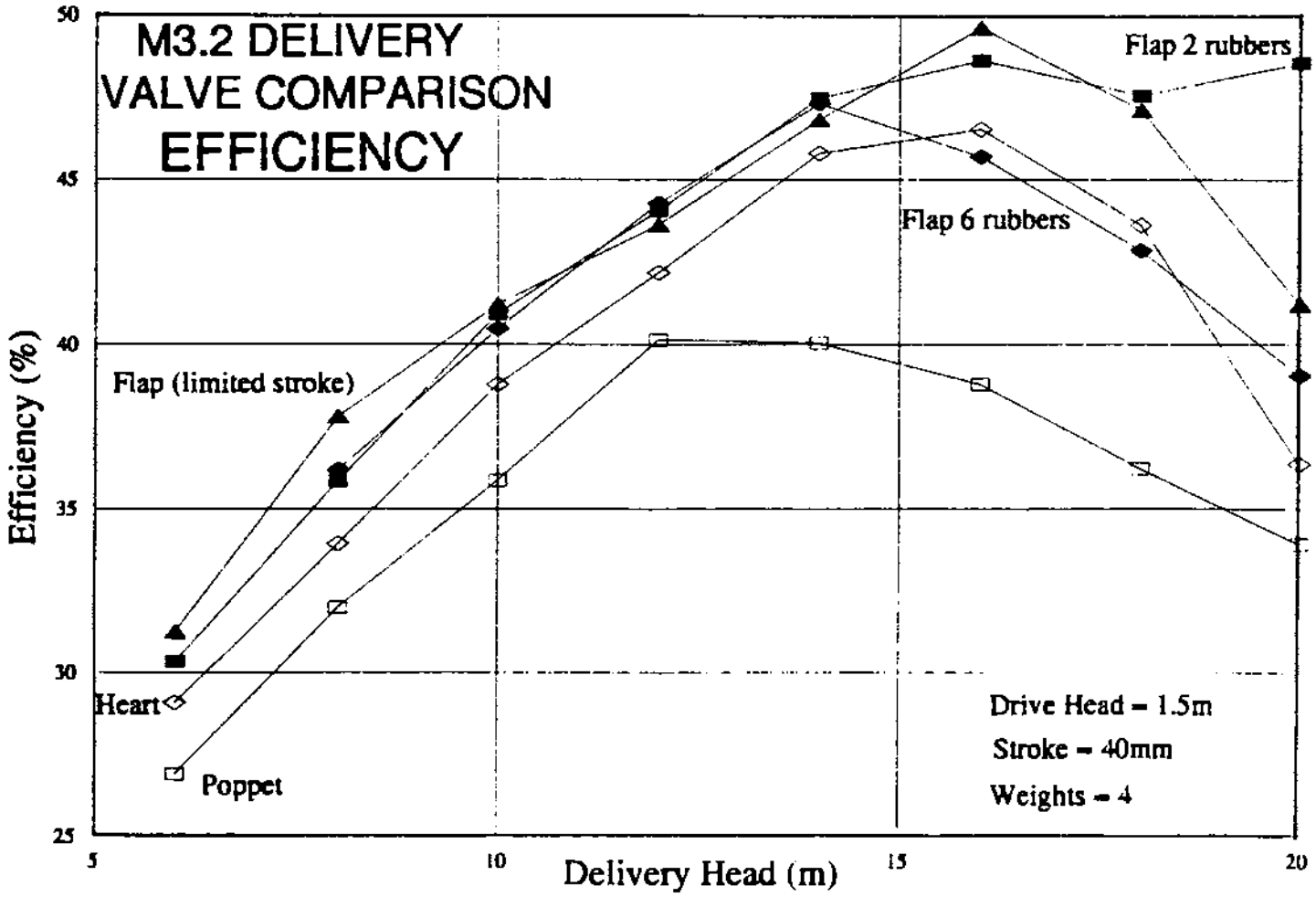
M3.2 DELIVERY
VALVE COMPARISON
EFFICIENCY
Flap 2 rubbers
Flap 6 rubbers
Flap (limited stroke)
Heart
Poppet
Drive Head = 1.5m
Stroke = 40mm
Weights = 4
Efficiency (%)
Delivery Head (m)
25
30
35
40
45
50
5
10
15
20

One problem experienced with the standard flap type valve, that has been extensively used, is splitting of the rubber at the point where it is clamped. The continual movement of the valve has often been found to lead to a stress related failure at the point about which the rubber trys to hinge. This occurs most frequently when the retaining bolt holding the valve rubber is over tightened, compressing the rubber. Using a curved washer reduces the problem by not having a sharp edge about which the rubber bends and eventually is cut. The rubber instead follows a more gentle curve along its length reducing the likelihood of stress concentration and splitting of the rubber.

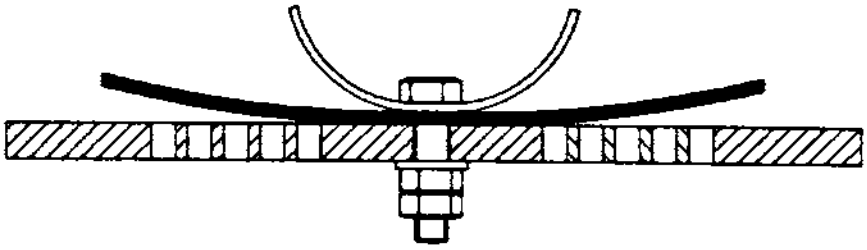

Diagram showing curved washer used in delivery valve.

Another important factor in manufacturing the rubber discs is the cutting of the central hole. This must be done cleanly with no ragged edges or flaws where cracks could start and then spread with the continual movement and stretching of the rubber. To do this it is recommended that a hole punch be bought or manufactured ensuring holes with clean edges can be accurately and repeatably made.

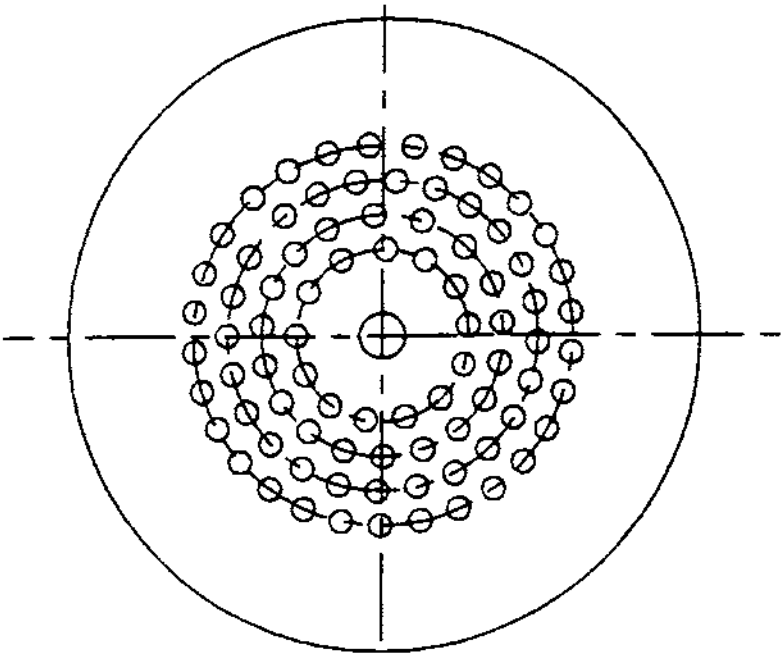

Diagram showing arrangement of delivery valve holes

The valve disc itself should be manufactured from steel plate with a minimum thickness of 3mm (10 swg) and preferably be up to 6mm. The arrangement and size of the holes in the plate is important for a number of reasons;

1) The hole size must be large enough to allow high flows with little resistance.

2) The hole size must be small enough to prevent the pressure of water in the air vessel from pushing the rubber into the holes thus deforming it and causing potential cracks.

3) The radius from the center in which the holes are confined needs to be as large as possible to maximise throughput but limited to allow sealing of the rubber around the outside of the valve plate.

4) The holes should not be too close together to prevent cracking of the valve disc between holes due to the continuous fatigue loading.

Valve plates using thick plastic material have been tested in an attempt to do without the need for a metal component. The life of such discs however was found to be too short under the loading experienced.

Marking out and accurately driling the arrangement of the large number of holes required in the valve plate can be an arduous and time consuming process. If a number of pumps are to be made it is well worth making a jig, both to cut down on the time taken and to ensure accuracy. Under the manufacturing aids section there is a drawing of one design of a valve plate jig. It ensures both the accuracy of the circumference of the plate and the accuracy of the spacing and number of holes.

Snifter Valve

During operation of the pump, air will be constantly taken into solution at the air/water interface in the air vessel. This slowly reduces the amount of air in the air vessel leading to inefficient operation and pressure spikes significantly higher than the static delivery head. Air therefore has to be constantly and reliably introduced into the air vessel to replenish that being lost in order to keep the air vessel full and the pump working at peak efficiency. This is done by the snifter valve allowing air to enter into the body of the pump each time the pressure recoil opens the impulse valve. The slight negative pressure during the recoil phase of the cycle draws air in through the snifter valve. It is placed to enable the air to travel to the under side of the delivery valve waiting to enter the air vessel at the next delivery cycle.

There are a number of types of snifter valve that have been used on ram pumps over the years. The main design considerations are that the valve is reliable and lets in the correct amount of air each cycle. On initial start-up of the pump the volume of air in the air vessel (at atmospheric pressure) is compressed as the delivery pressure builds up. The flow of air into the air vessel from the snifter valve needs to be sufficient to re-fill the air vessel over a period of time. If too much air is entering through the snifter, the air vessel will fill up quickly and then the excess air will simply be taken up the delivery pipe where it may create problems of air locks. The snifter therefore needs to be large enough to allow sufficient air to ensure replenishment of the air vessel but not so large that the delivery pipe has a large amount of air travelling in it.

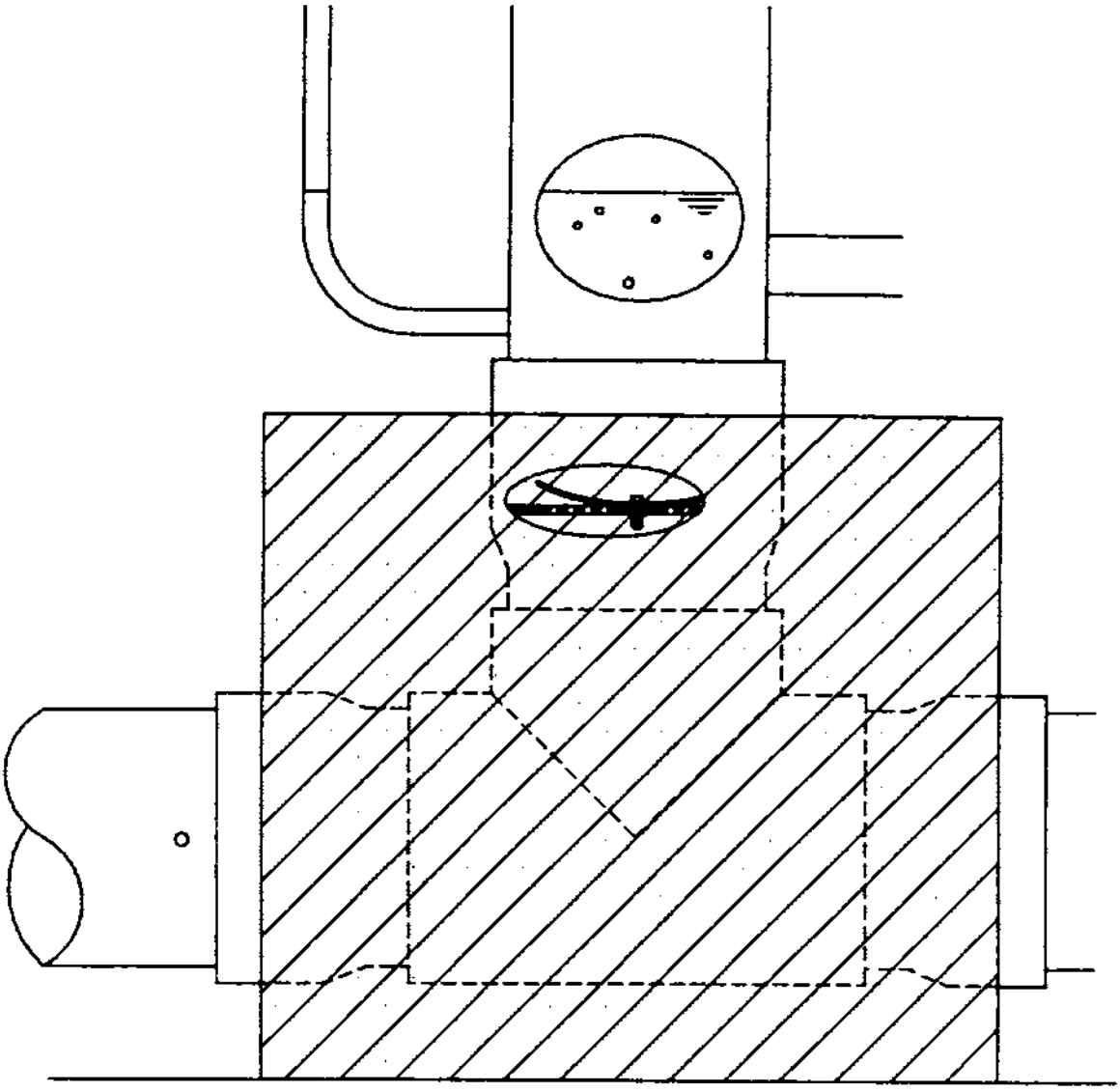

The simplest type of snifter is a hole drilled in the pump body close to the underside of the delivery valve. In the DTU M3.2 the best place for this is just upstream of the tee piece that connects the drive pipe to the pump. A small jet of water will squirt through the hole with the pressure inside the pipe until the recoil cycle occurs when air will be sucked through the hole into the pipe. As the water accelerates beginning the next cycle, some of the air rises up and sits under the delivery valve. This snifter hole should be drilled in the side of the pipe after the pump has been started for the first time.

Use the following procedure;

1) On initial start-up of the pump allow it to settle and stabalise at the system delivery pressure.

2) Make a note of the level of the air in the air vessel using the air sight tube.

3) Drill a 1.5mm dia hole in the tee/pipe as specified above.

4) Wait for 30 mins to 1 hour to see if the amount of air changes. If the air level continues to increase until it reaches the top of the delivery pipe connection, then the snifter valve is probably about the right size. If the amount of air remains constant or reduces then increase the hole diameter to 2mm. Repeat this process until the hole is big enough to allow the air level to drop down to the delivery pipe connection.

Air Vessel Size.

Over the years that ram pumps have been used there have been a number of different theories proposed and used to design air vessels. One purpose of the air vessel is to turn the intermittent flow through the delivery valve into a steady, continous flow up the delivery pipe. The air vessel provides the pump with a constant head to pump against, limits the size of the damaging pressure spikes, and removes the inefficiencies associated with intermittent flow in the delivery pipe. The size of the air vessel therefore should ensure that conditions (ie pressure) in the air vessel are little affected by the sudden inflow of water each cycle coming through the delivery valve. The volume of air in the air vessel therefore should be at least 20 and preferably nearer 50 times the expected delivery flow per cycle. An air vessel with a volume many times that of the water entering per cycle will experience little change in conditions at each delivery. Pumps running to low heads with large delivery flows therefore actually require air vessels larger than ones pumping smaller flows to high delivery heads.

For example; A pump delivering 30 l/min and operating at 60 cycles per minute has a flow per cycle of 0.5 litres. The minmum air vessel volume for this case should be 20 x 0.5 = 10 litres.

The design of the DTU M3.2 110mm PVC pump is attempting to use the fewest number of components possible. The air vessel has therefore been restricted to the same 110mm pipe used in the rest of the pump. This pipe typically has an internal cross sectional area of around 7500mm^2 and therefore a 130mm length of pipe is required per litre volume of air vessel. The maximum expected delivery flow under normal conditions is 0.5 litres per cycle requiring a 10 litre air vessel that is 1300mm long.

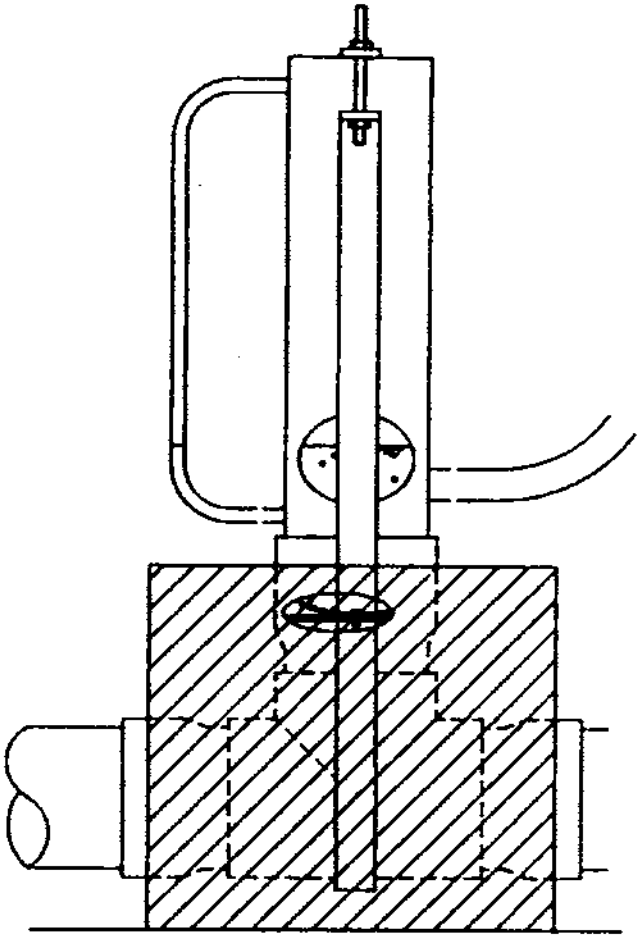

Sight tubes on an air vessel provide a very simple way of checking the level of air and therefore the effectiveness of the snifter valve. A number of problems have been encountered with the manufacture and use of air vessels that are worth mentioning:

1) Small bore, 'see-through' plastic tubing is not always easy to find.

2) Most tubing that is available deteriorates over a few months, becoming cloudy so that it is very difficult to distinguish the water level inside. Fitting a sight tube is still worthwhile under these circumstances as it is during commissioning of the pump and sizing the snifter valve that the sight tube is most useful.

3) Making connections onto the air vessel can be quite difficult. Reinforcing strips of pipe can be used over areas where the connections are to be made to increase the wall thickness of the pipe for glueing or threading.

Air Vessel Strap

The air vessel has to be held down to prevent the pressure inside it blowing out from the tee piece. The concrete block holding the tee piece makes a good solid anchor for this strap and allows the air vessel to be securely clamped. A variety of types of clamp have been used and the one shown in the drawings section of this paper is probably the simplest.

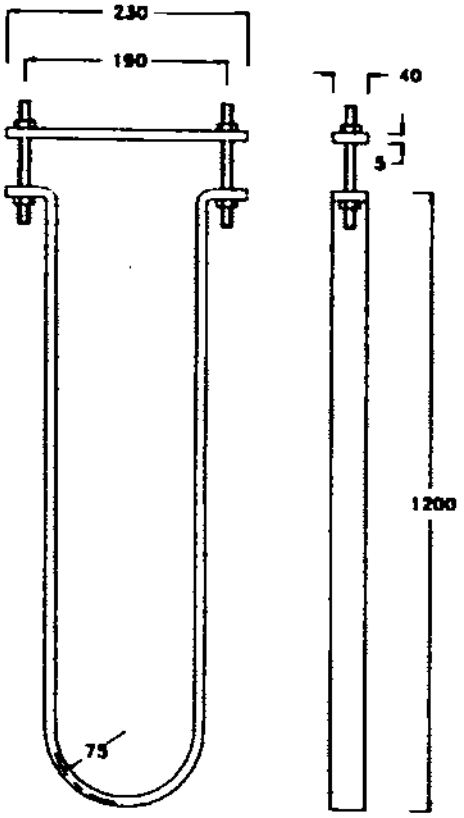

Pipe Fittings

Tee Piece

The original design of the DTU PVC ram pump had the drive pipe connected directly with the impulse valve. The impulse valve then pushed into an elbow that was incased in concrete and fixed to the concrete pump base. The delivery valve sat in the top of the elbow and the air vessel was pushed down on top of it. With an increased understanding of pump operation and after some laboratory testing it was decided to place the delivery valve and air vessel upstream of the impulse valve. On the DTU steel pumps this had given a number of operational advantages, particularly in reducing peak pressures and so it was also applied to the plastic pumps. This altered configuration overcame some installation problems but created others.

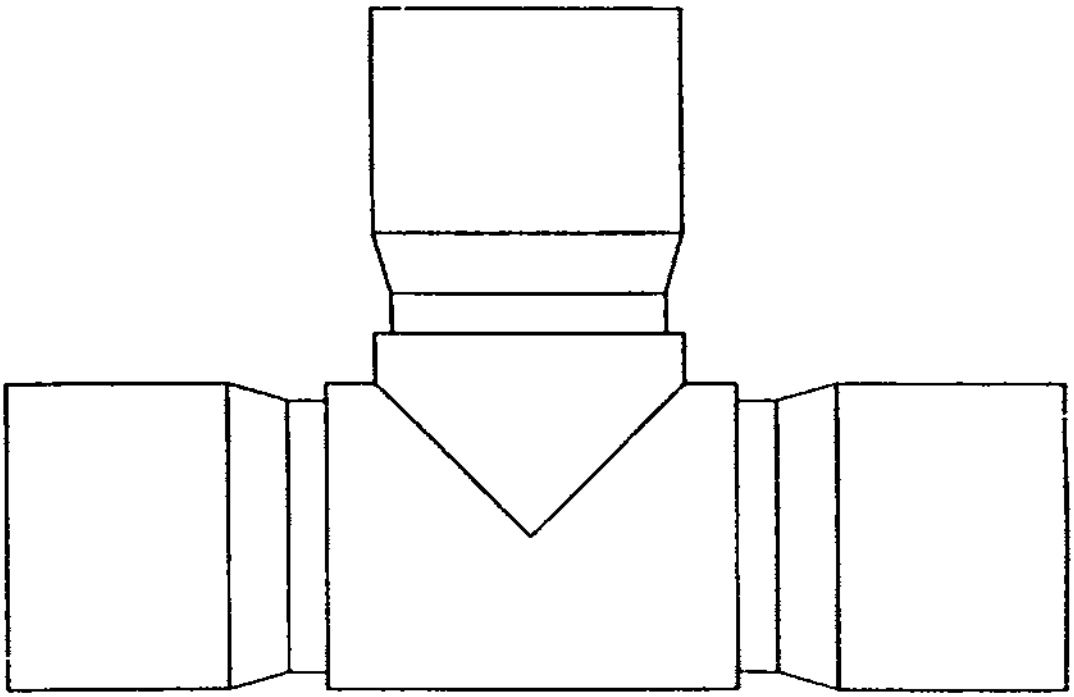

With the elbow solidly fixed downstream of the impulse valve the shocks during each pump cycle were transfered through the elbow into the concrete block. This provided good anchoring for the pump but led in some instances to cracking of the elbow. As the end of the drive pipe entering the drive tank is also fixed (and the pipe often buried) a removable section of pipe was required to allow fitting and removal of the impulse valve. This often proved to be a weak point as a good seal had to be made once the impulse valve was installed. With the revised arrangement the impulse valve is downstream of the concrete block and so provides no anchorage to prevent movement of the valve. So a further anchoring block has to be installed at the end of the impulse valve leaving enough room to allow the valve to be slid in and out of the tee piece. The gap between this second anchoring block and the valve is filled using a wedge once the valve is in place. The end of the valve also required an end cap for sealing (see below) which had to be capable of withstanding the constant shock loading. The elbow that previously experienced a substantial shock loading from the movement of the impulse valve was replaced by a tee piece that was free of this fatigue problem.

Tee fittings are commonly used in plastic pipework installations and are normally made by injection moulding. These fittings are often available in developing countries but in many cases, even where plastic pipe is manufactured, they have to be imported. They tend to be extremely expensive and are often of low quality. Experience of installations in Zimbabwe showed that the cost of a suitable tee piece was the equivalent to 3-4 meters of drive pipe - a significant cost. Such fittings were not only expensive but also in very short supply. In line with the goal of manufacturing pumps from standard pipe material a method for tee manufacture using small sections of pipe was developed. Sockets for the connection of pipes are formed by heating the ends of the pipe in an oven or oil bath and forcing them over a specially made, tapered former. Diagonal cuts are then made at 90 degress and the two sections glued together. (see drawing section). Fittings made in this way are much cheaper than those available commercially and overcome the problems of availability.

End Cap

The new pump configuration required that the end of the impulse valve be sealed with a cap. Commercially manufactured end caps are generally available and provide a good seal. However the constant movement of the impulse valve at each pump cycle crushes the end cap between the valve body and the solid end block.
It is not possible to significantly prevent this movement as the plastic material has a high degree of flexibility and so joints tend to move under the pulsing pressure experienced in the pump. Thin walled, injection moulded end caps were found to last a very short time before cracking due to the high fatigue loading experienced. On the first site installed in Zimbabwe with this configuration a number of end caps of increasing strength were fabricated. The final solution was to make a thick walled socket using the socket former, reinforced at the end with a number of extra rings of pipe. A 5mm metal disc was then shaped to fit into the end of the socket and sealed firmly in place using plumbers putty.

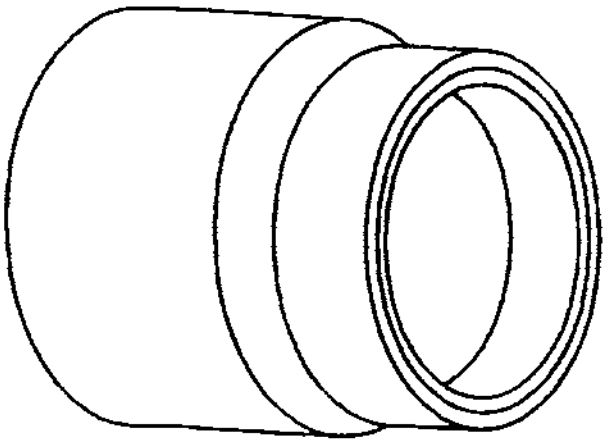

Drive Pipe

Drive Pipe Diameter

Throughout the DTU research into PVC ram pumps, the diameter of drive pipes used has been standard 4" 110mm O/D. Pumps have been designed specifically for this common size of pipe that has been found to be widely available in developing countries. The pump components themselves are now made almost entirely from this basic pipe material in order to reduce cost and simplify the raw material requirement.

The body of most ram pumps, and particularly the section housing the impulse valve, tend to be of a larger cross-sectional area than the recommended drive pipe. In the DTU steel designs for instance a 4" diameter body is used to match a 2" drive pipe diameter. This ensures that the frictional loss of water flowing through the impulse valve is low enough to allow sufficient flow in the drive pipe thus matching pump to drive pipe. A general rule that simplifies the initial sizing and design of an impulse valve is to ensure that, at all points through the pump body and impulse valve the area available for water flow is equal to, or greater than the area of the drive pipe. The design of the DTU PVC rams however is restricted to using the same 110mm pipe for the body of the impulse valve as is used for the drive pipe. The flow area through the holes of the valve is greater than the area of the drive pipe but at the leading edge of the tongue even at maximum stroke the flow area is reduced hy around 20%. This is illustrated in the diagram below.

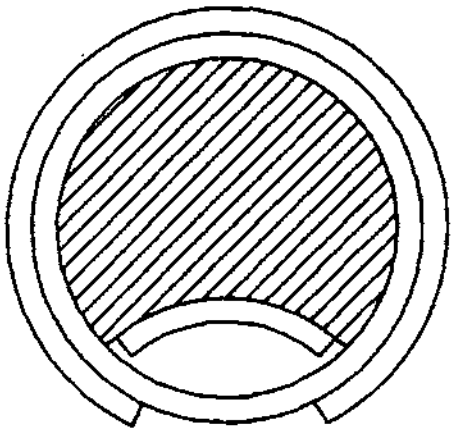

Cross-section of Impulse Valve showing restriction to flow.

Whilst it is possible to achieve drive flows in excess of 350 l/min with this arangement it became clear that particularly at low strokes the size and design of the impulse valve was not allowing full use of the diameter of the drive pipe. This situation is greatly exaggerated at lower strokes when the pump is tuned down in order to use less drive water. In effect the velocity of water in the drive pipe when the valve begins to shut is considerably lower than the maximum capacity of the pipe. As the kinetic energy available for pumping is proportional to the mass of the water and to its velocity squared, it makes sense to keep velocities high and lose a little mass by reducing pipe diameter.

Laboratory tests have been carried out in order to compare the 110mm drive pipe with the next common size down: 90mm. The results of these tests are summarised in Graph Nos X,X and show quite clearly that under most conditions both the efficiency and power output of the pump are improved by using the smaller drive pipe size.

Whilst the pump will work perfectly well with a 110mm drive pipe over the complete range of operating conditions it is now recommended that a 90mm pipe be used if available. This may also give a small saving in system cost and gives a greater potential range of pipe that can be used if one size is not available. In situations of particularly low drive flow the pump may not actually be able to operate with the larger sizes of drive pipe. The maximum head to which a pump can deliver is dependant upon the velocity of the water in the drive pipe. To reach a given delivery head there has to be a corresponding drop in velocity turning kinetic energy to potential energy. If the velocity drop required to reach a given pressure is larger than the maximum velocity of the water in the drive pipe then the pump will never reach the required delivery head although it can appear to be operating. Smaller diameter drive pipes will have a higher water velocity for a given flow and therefore will permit operation in situations where larger diameter pipes would not work. The graph below shows the typical lower boundary of the commonest pipes used for DTU M3.2 PVC pumps

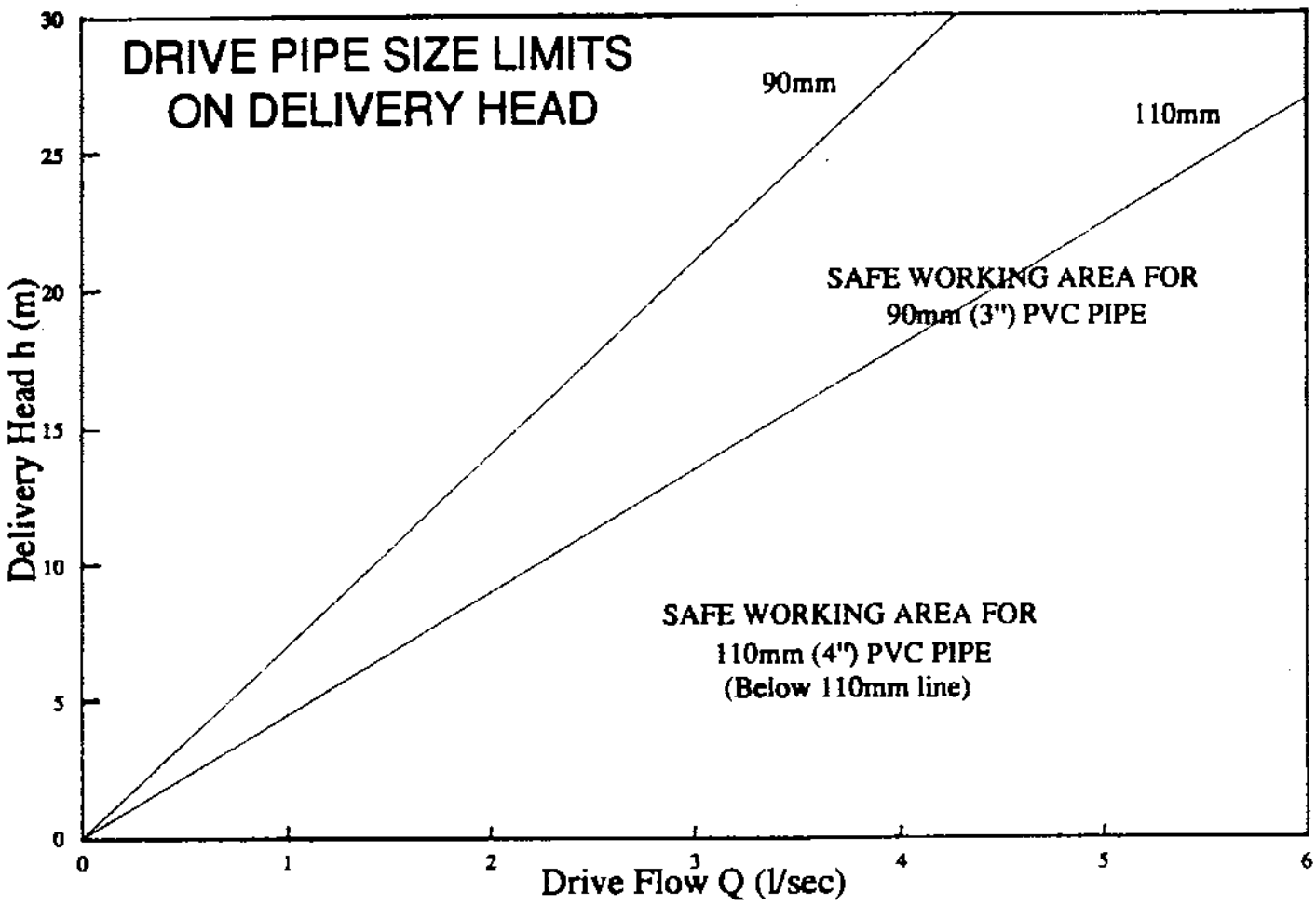

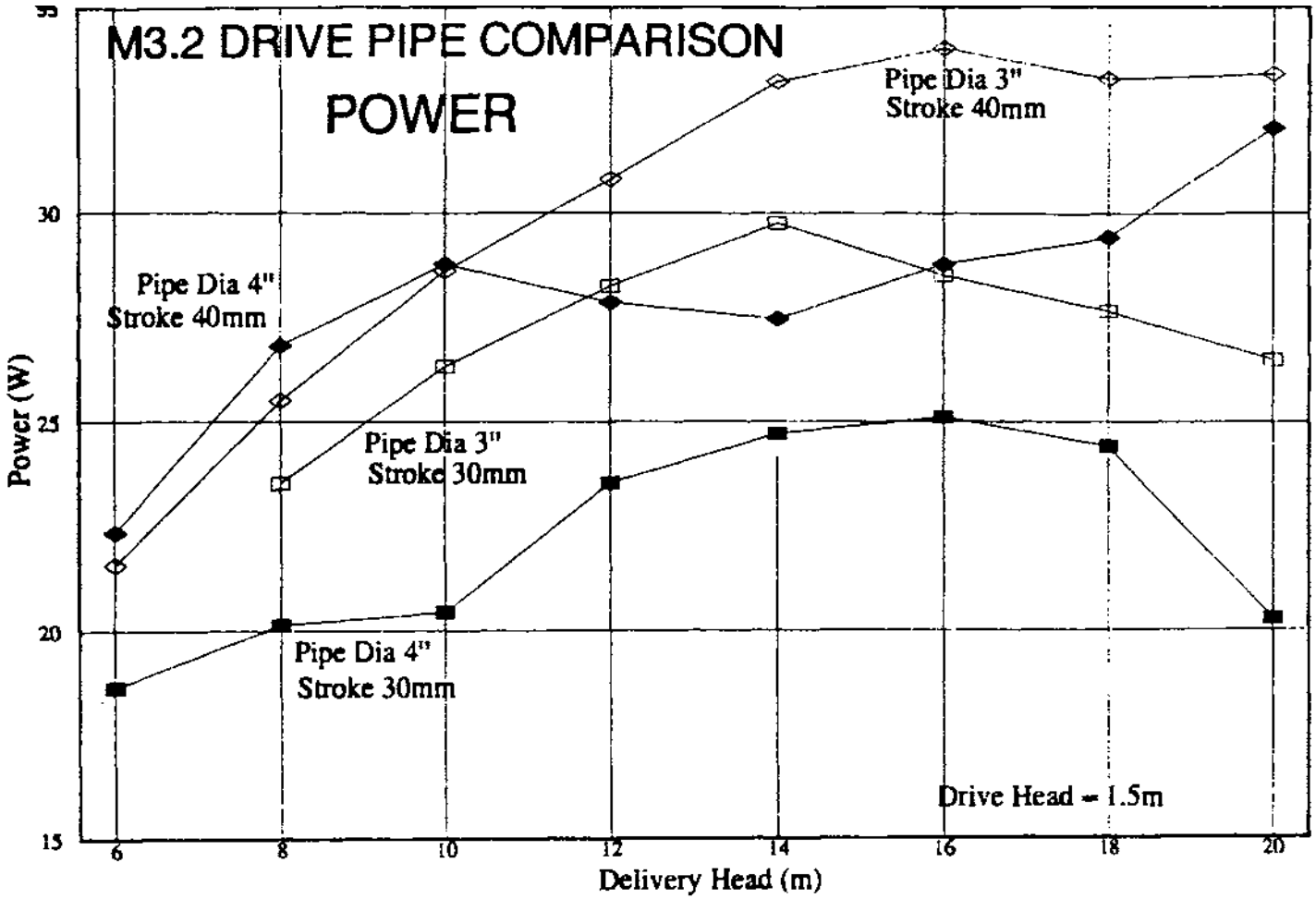
M3.2 DRIVE PIPE COMPARISON
POWER
Pipe Dia 3"
Stroke 40mm
Pipe Dia 4"
Stroke 40mm
Pipe Dia 3"
Stroke 30mm
Pipe Dia 4"
Stroke 30mm
Drive Head = 1.5m
Power (W)
Delivery Head (m)
15
20
25
30
6
8
10
12
14
16
18
20

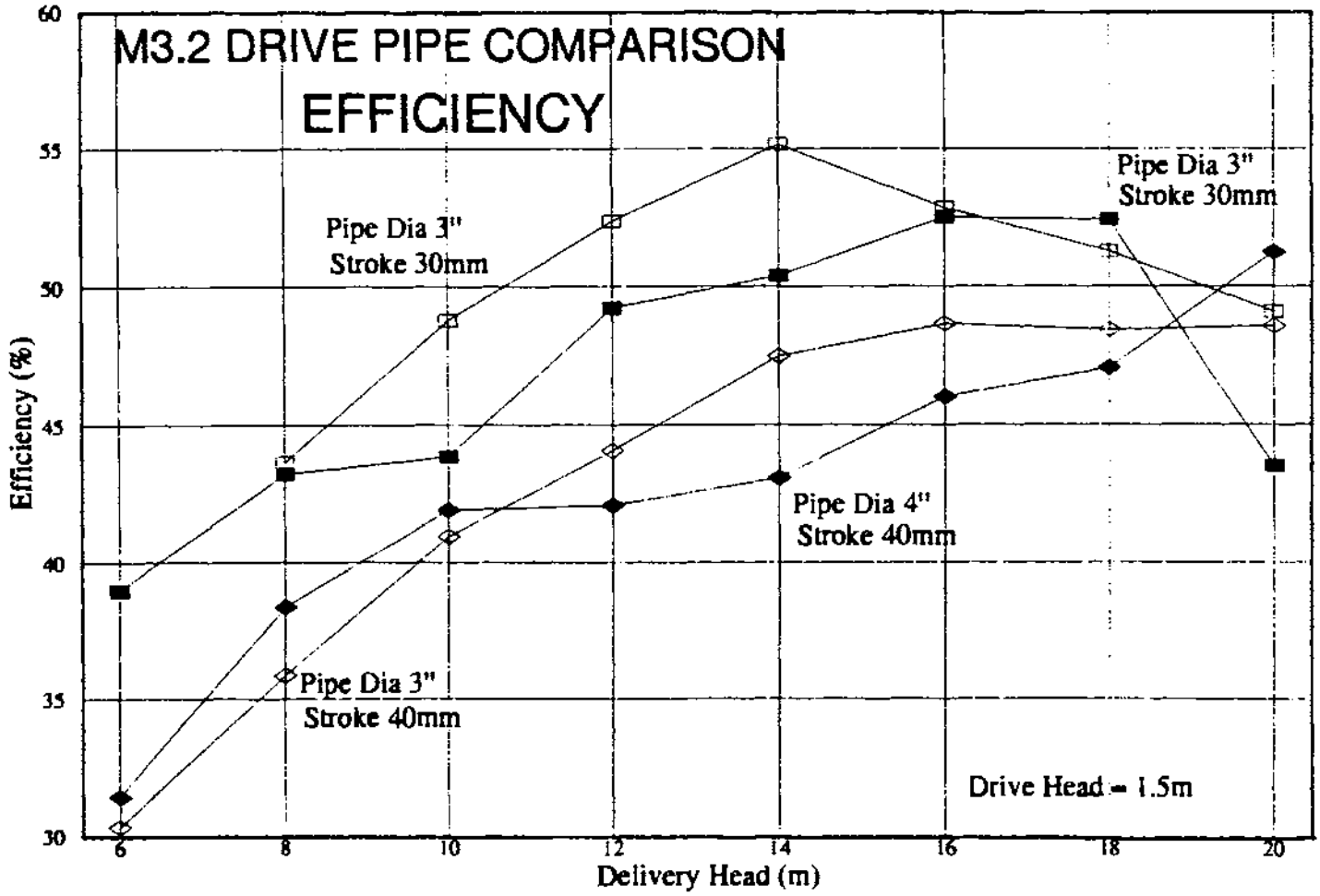
M3.2 DRIVE PIPE COMPARISON
EFFICIENCY
Pipe Dia 3"
Stroke 30mm
Pipe Dia 3"
Stroke 30mm
Pipe Dia 4"
Stroke 40mm
Pipe Dia 3"
Stroke 40mm
Drive Head = 1.5m
Efficiency (%)
Delivery Head (m)
30
35
40
45
50
55
60
6
8
10
12
14
16
18
20

Drive Pipe Length

One critical factor with PVC ram pumps for small irrigation schemes is cost. The pump and system constraints have been designed to give good performance, reliability, local manufacture, availability of spare parts, all for the smallest possible cost. One of the major cost components of any ram pump system is the drive pipe which can often equal or even exceed the cost of the pump unit itself! As drive heads are comparatively small for PVC pumps, the physical layout of the site can often allow drive pipe lengths to be very short. Systems have been installed and successfully run with drive pipe lengths of only 6m. Plastic pumps generally can utilise shorter drive pipes than their steel equivalents due to the much lower wave speeds of the transients moving in them. Longer drive pipes can increase the pumping energy available by increasing the mass of water moving in the drive pipe and increasing the length of the delivery cycle during operation. Longer drive pipes introduce greater friction into the system so that less of the drive head is available to the pump. This consideration of pipe friction imposes an upper limit on the length of drive pipe that can be used for a given drive head.

Bearing the all important cost factor in mind it is recommended that drive pipe length normally be kept in the range 6 to 30m with 12m being a rough guide to the optimum when balancing cost and performance. If a combination of a necessarily long drive pipe (greater than 20m), high drive flow (greater than 300l/min), and low delivery head (less than 8m) occurs it is recommended that a 110mm rather than the standard 90mm drive pipe be used as the friction in a 90mm pipe would be more significant in such a situation.

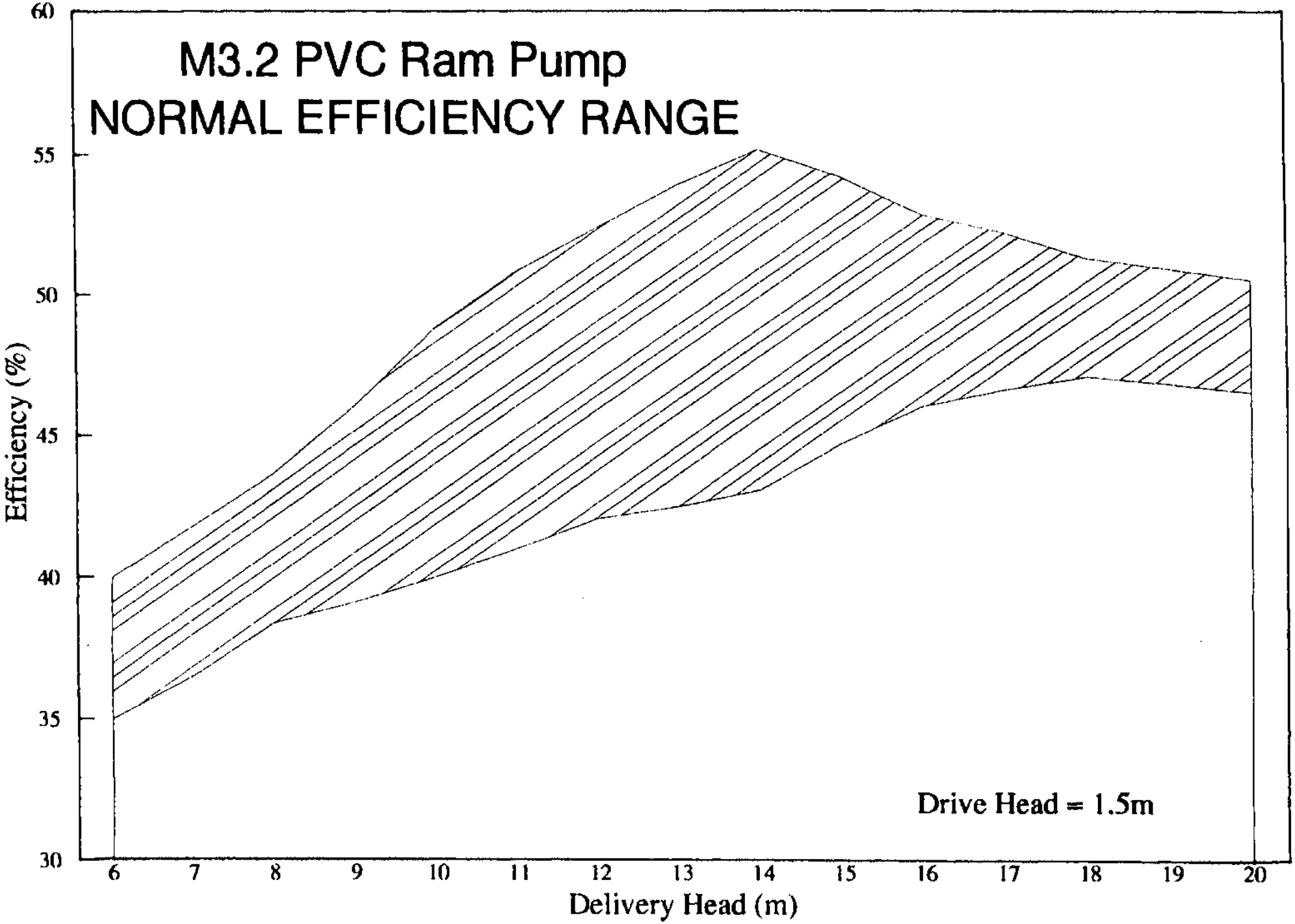
M3.2 PVC Ram Pump
NORMAL EFFICIENCY RANGE
Efficiency (%)
60
55
50
45
40
35
30
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Delivery Head (m)
Drive Head = 1.5m

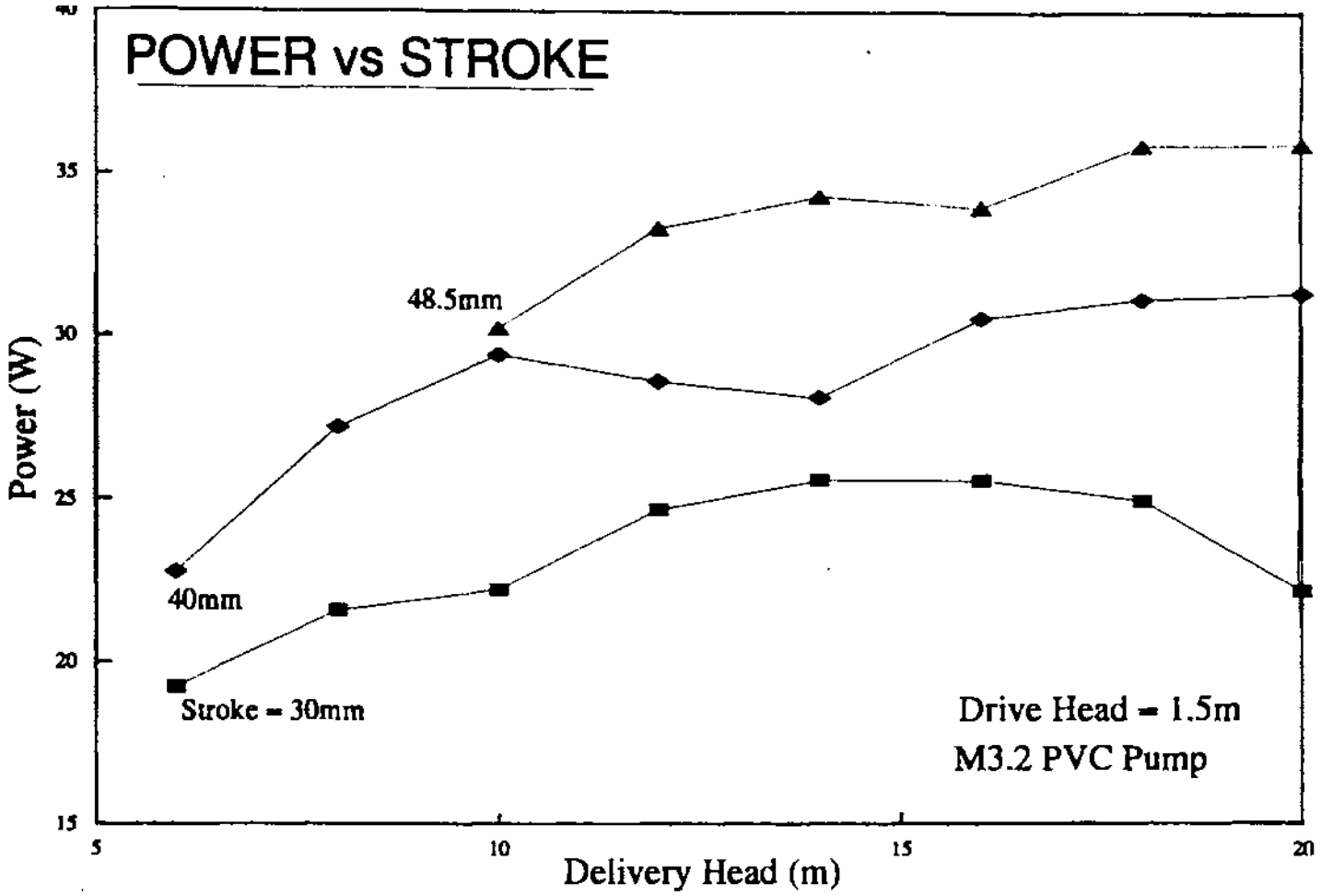
POWER vs STROKE
Power (W)
Delivery Head (m)
48.5mm
40mm
Stroke = 30mm
Drive Head = 1.5m
M3.2 PVC Pump
15
20
25
30
35
5
10
15
20

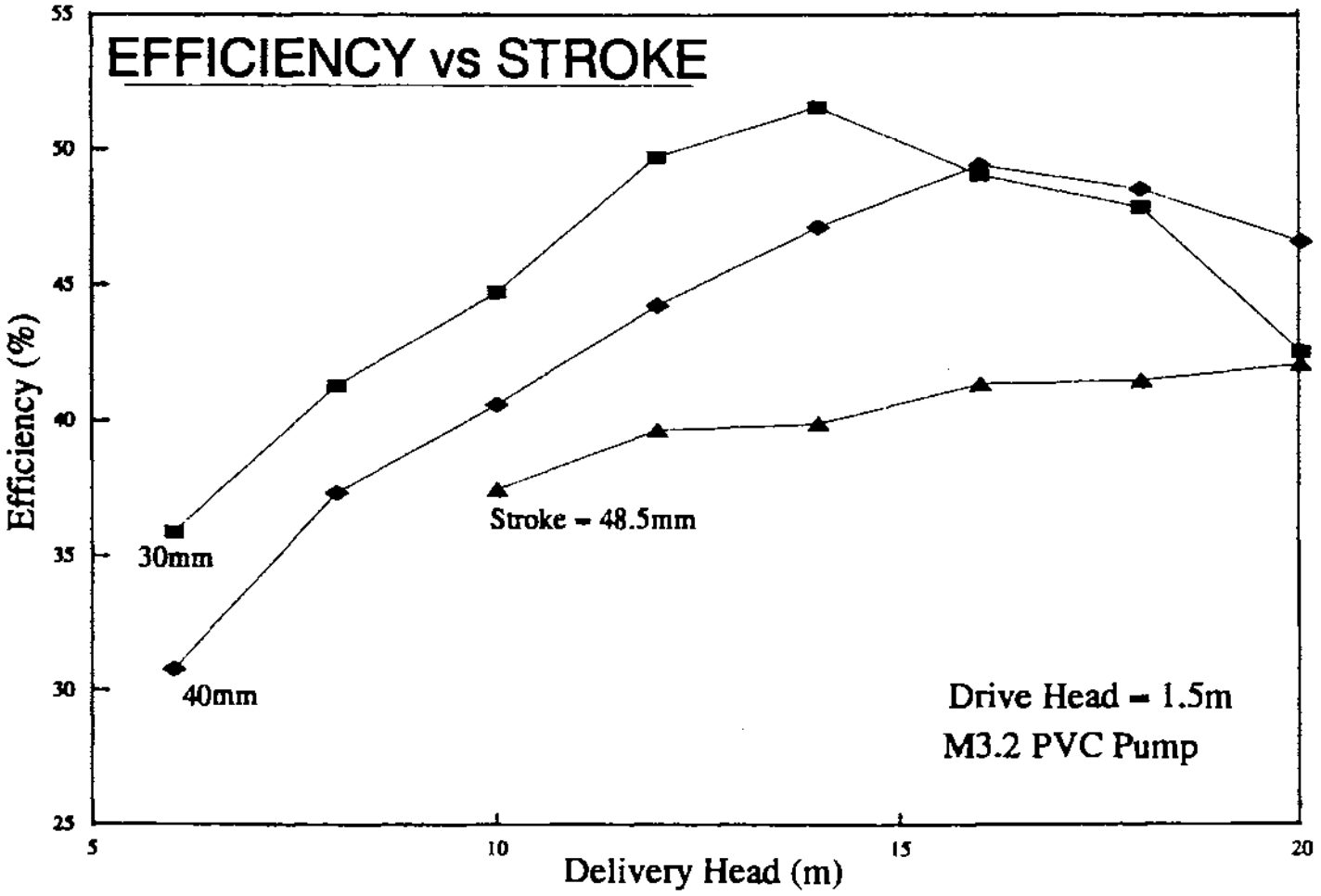
EFFICIENCY vs STROKE
Efficiency (%)
Delivery Head (m)
30mm
40mm
Stroke = 48.5mm
Drive Head = 1.5m
M3.2 PVC Pump
25
30
35
40
45
50
55
5
10
15
20

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P90 ASSEMBLY

Drawing No. 1 of 12 NOT TO SCALE

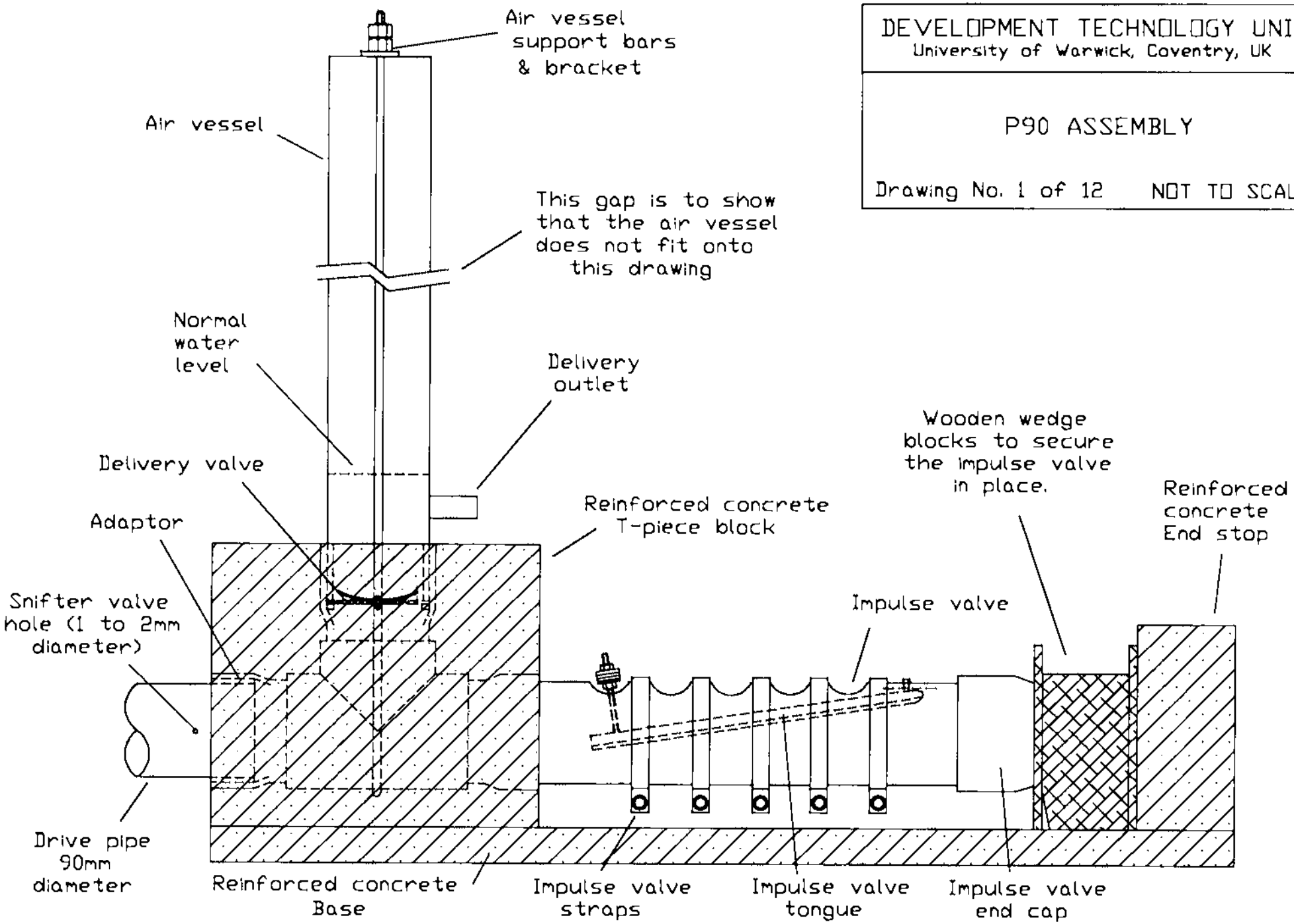

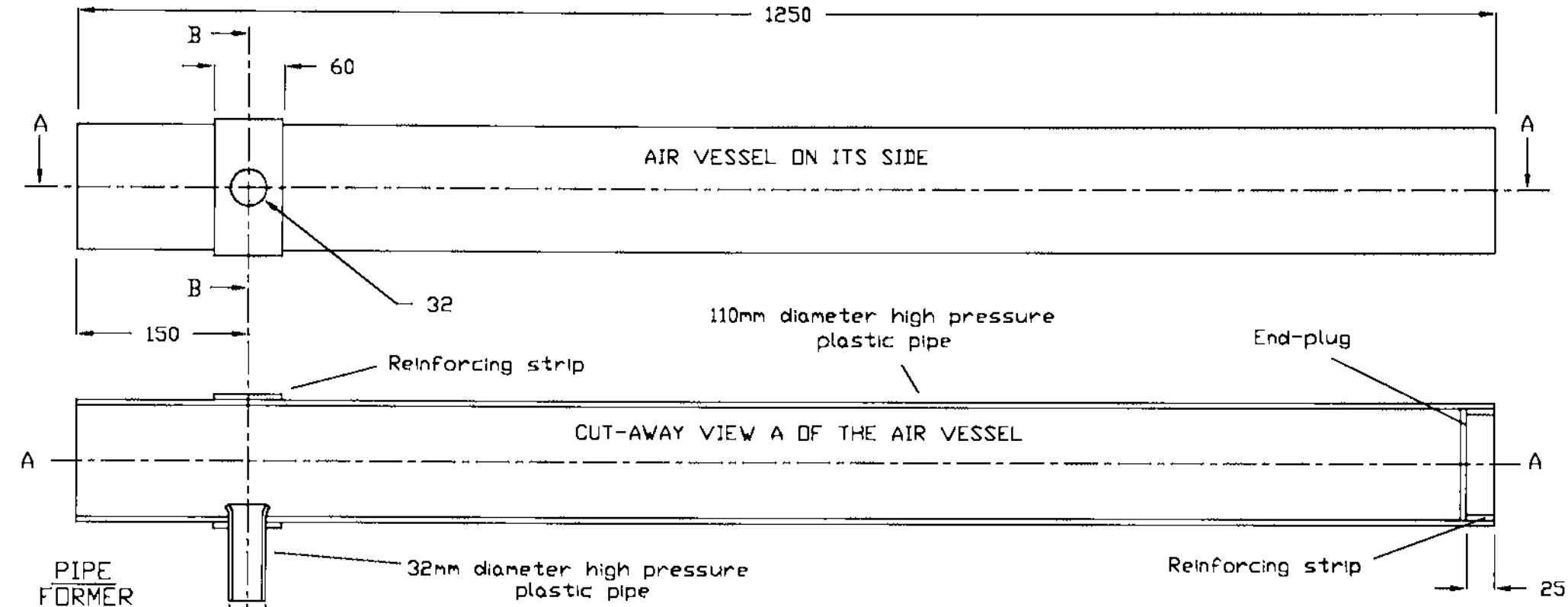

PIPE FORMER

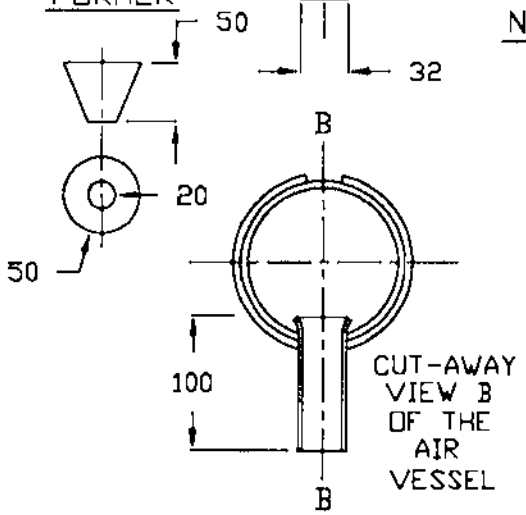

ALL DIMENSIONS IN mm

NOTES:

1 - The air vessel is made using 110mm diameter high pressure plastic pipe and 32mm diameter plastic pipe for the delivery pipe outlet.

2 - The reinforcing strip is also 110mm diameter high pressure plastic pipe. It is cut and glued into place using a good plastic adhesive

3 - To make the end-plug, a section of pipe is cut along its length, heated and flattened. Once cooled, a disc is cut out of this to form the correct shape.

4 - To secure the delivery outlet pipe to the air vessel, firstly, heat the end of the pipe until it starts to soften. Push the pipe through the hole in the air vessel and widen the pipe end. using a tapered wooden or steel former. (as shown).

5 - Use a good plastic adhesive to bond all the sections together.

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P90 AIR VESSEL

Drawing No. 2 of 12 NOT TO SCALE

AIR VESSEL ASSEMBLY

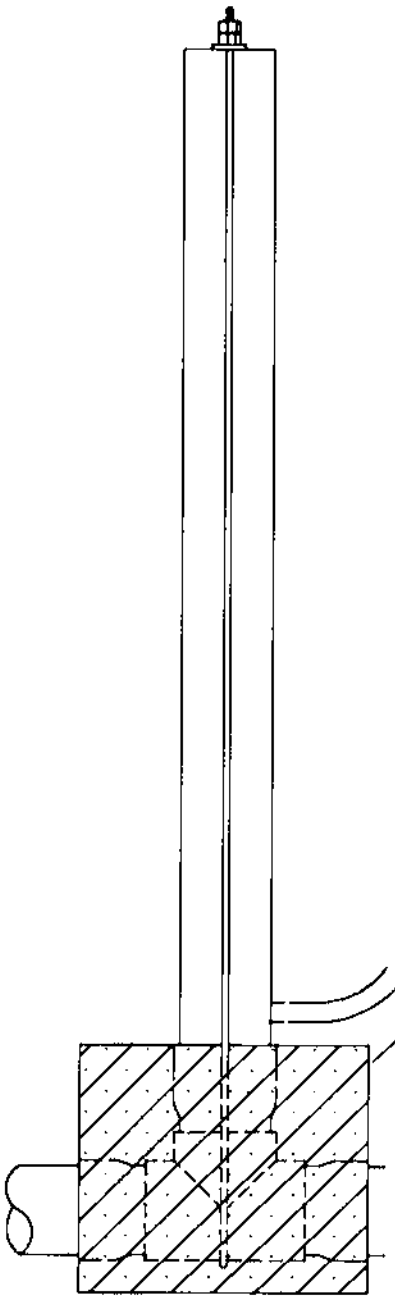

SUPPORT BAR

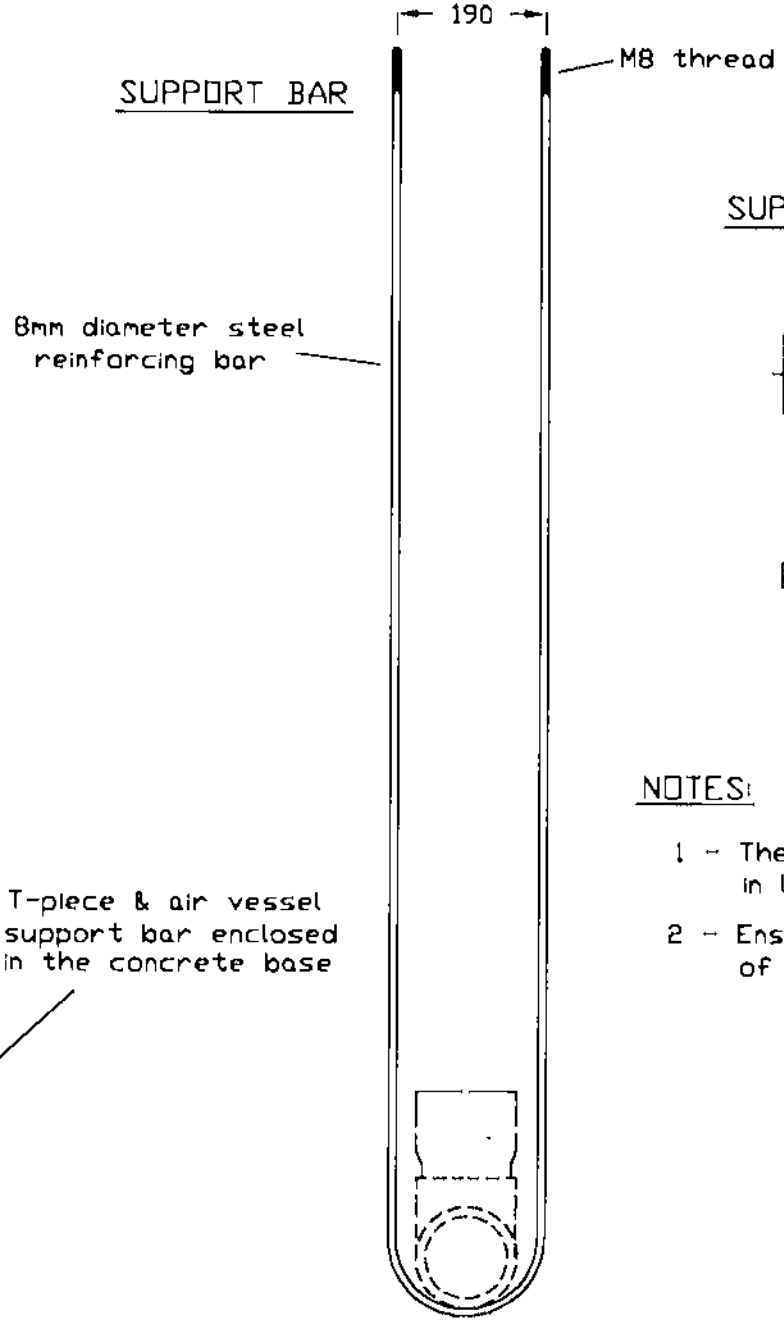

SUPPORT BRACKET

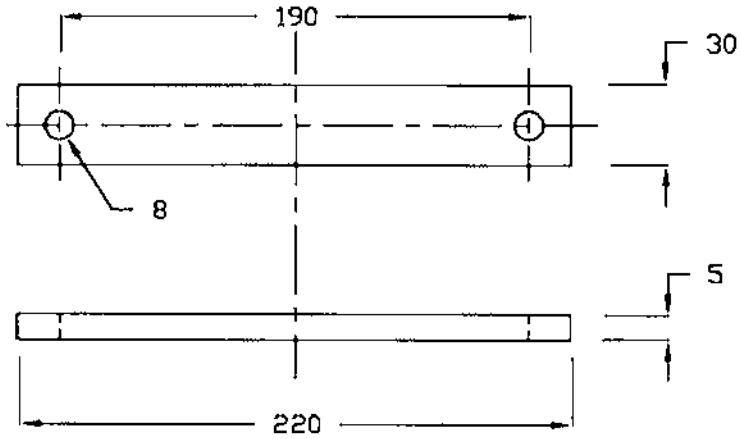

NOTES:

1 - The support bar is approximately 3.5 meters in length threaded at the ends (M8 thread)

2 - Ensure a secondary lock nut is used on each end of the support bar when assembling the pump

ALL DIMENSIONS IN mm

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P90 AIR VESSEL
SUPPORT BAR & BRACKET

Drawing No. 3 of 12 NOT TO SCALE

DELIVERY VALVE PLATE

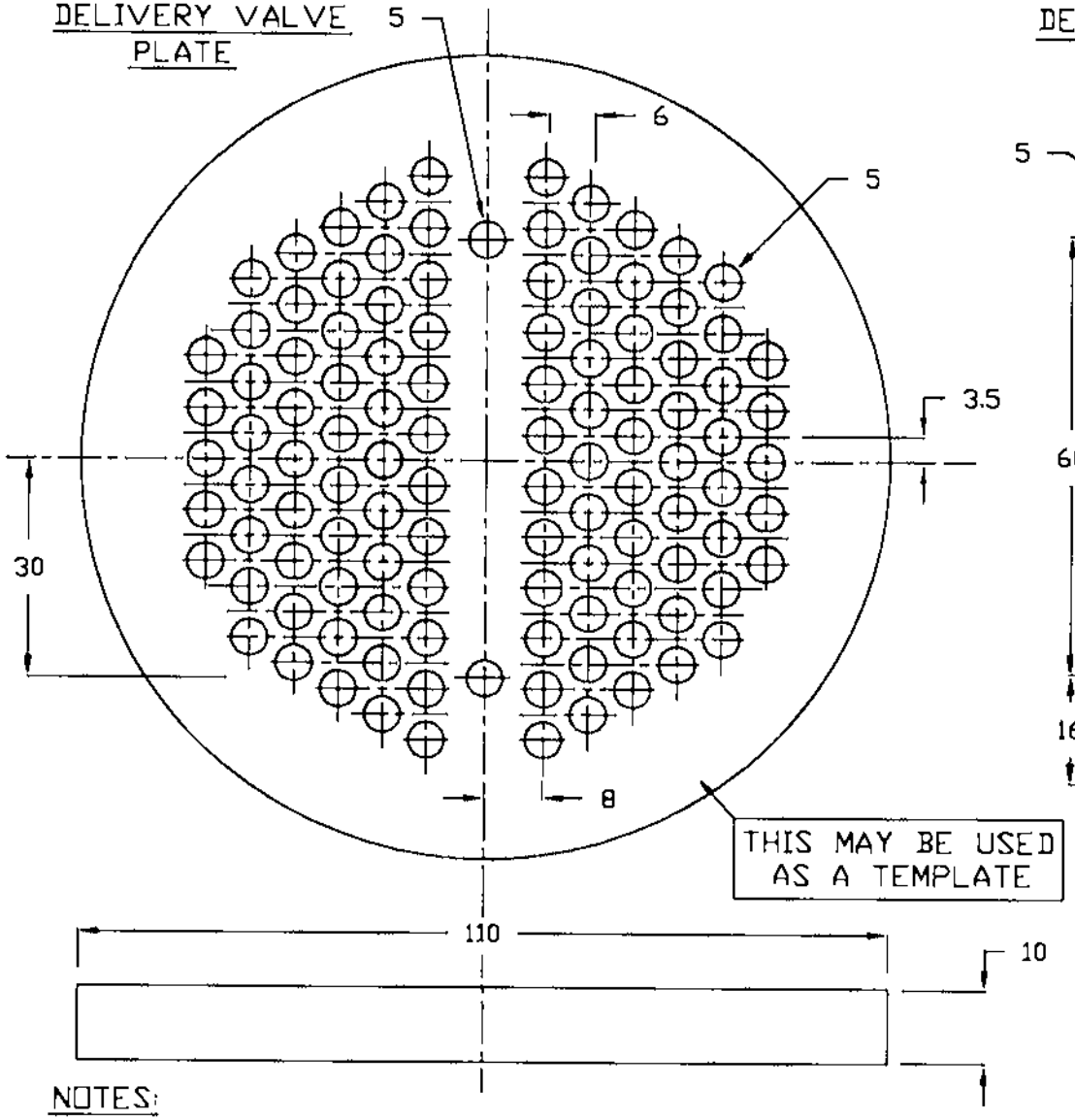

DELIVERY VALVE CROSS-BAR

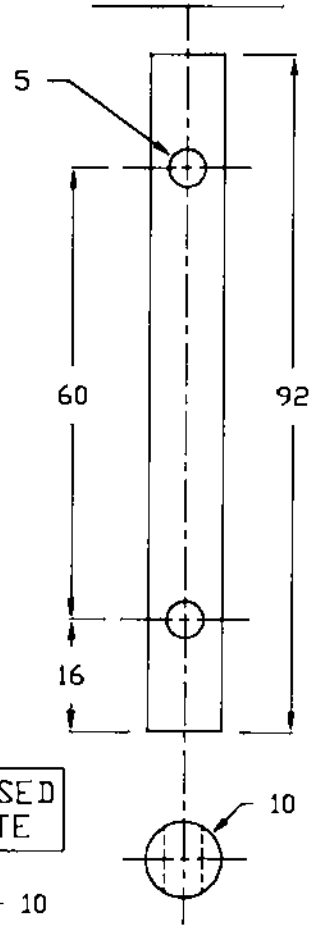

DELIVERY VALVE ASSEMBLY

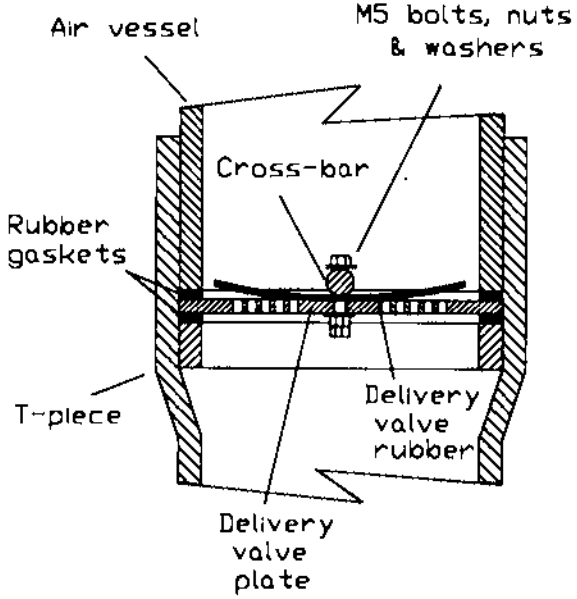

ASSEMBLY INSTRUCTIONS

1 - Place the valve rubber on the unchamfered side of the plate
2 - Push the bolts through the cross-bar, rubber and plate
3 - Add a nut onto each bolt and just finger tighten
4 - Add a second nut onto each bolt and tighten each pair of nuts securely together

NOTES:

1 - Delivery valve plate is 8 or 10mm mild steel plate
All holes should be chamfered on one side of the plate
2 - Delivery valve cross-bar is 10mm diameter steel reinforcing bar
3 - The delivery valve rubber has a diameter of 92mm and should be about 3mm thick

ALL DIMENSIONS IN mm

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P90 DELIVERY VALVE

Drawing No. 4 of 12

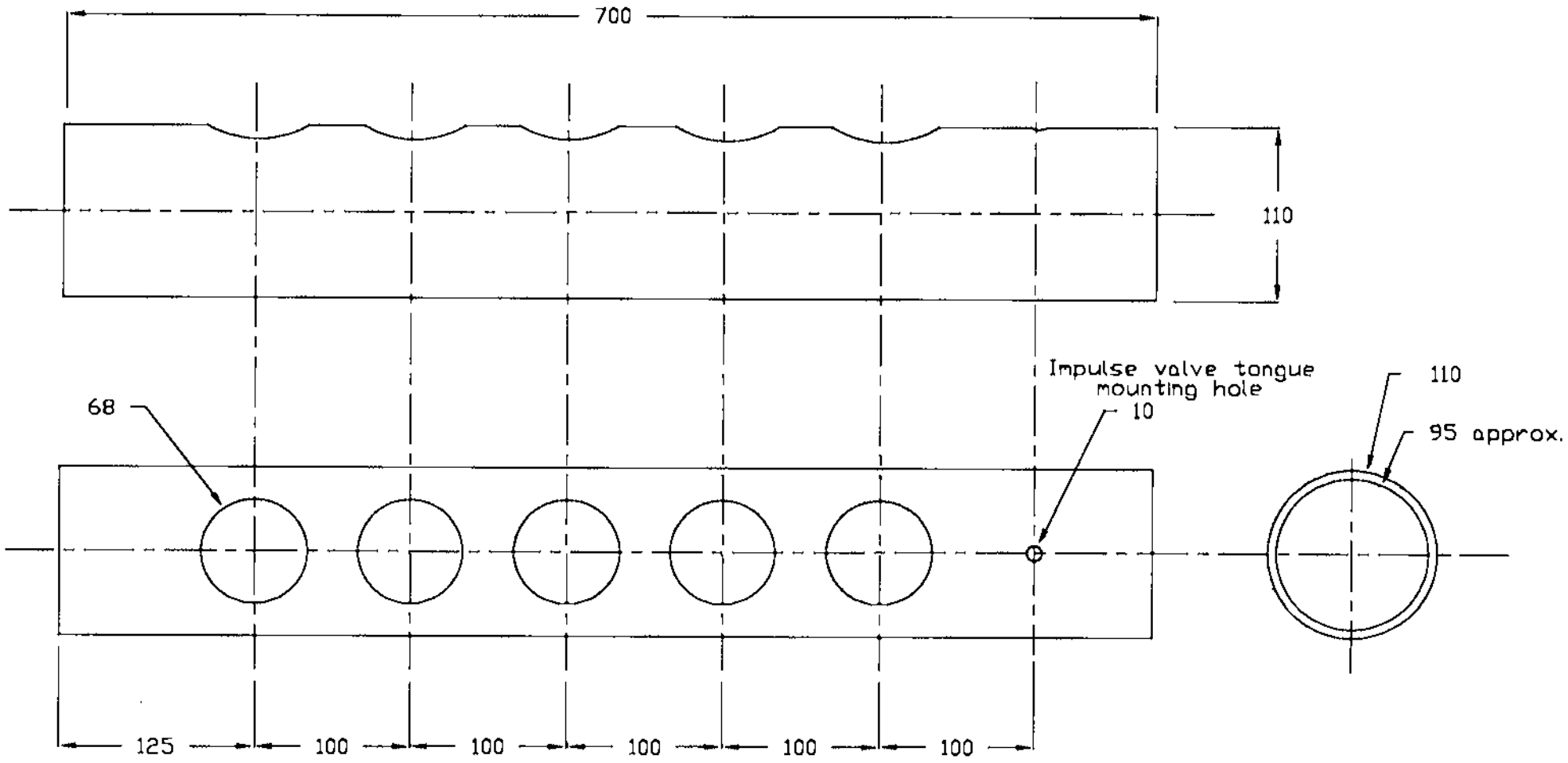

NOTES:

1 - The material used for the impulse valve is CLASS 16 high pressure PVC pipe. The wall thickness of the pipe is usually about 7mm.

2 - A tank cutter of between 66 and 70mm may be used to cut out the large impulse valve holes.

ALL DIMENSIONS IN mm

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P90 IMPULSE VALVE

Drawing No. 5 of 12 NOT TO SCALE

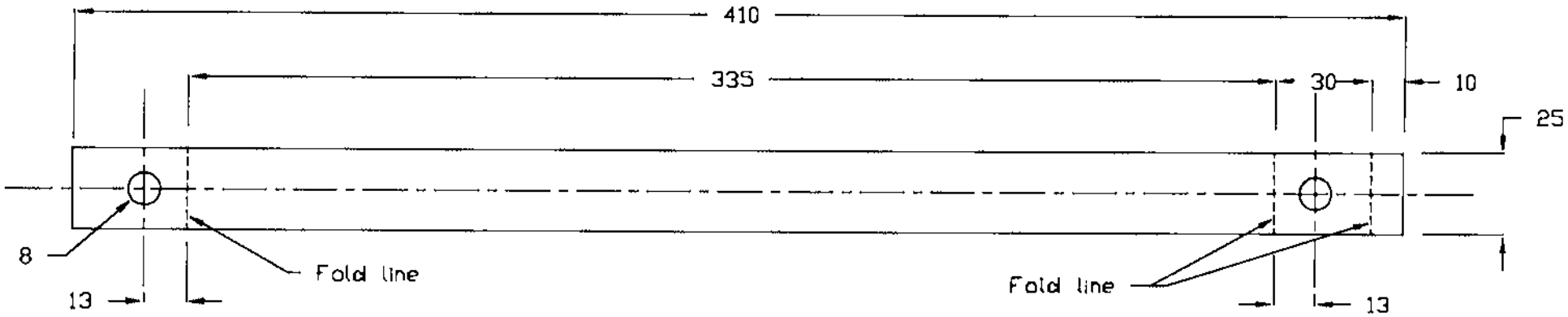

ASSEMBLED IMPULSE VALVE STRAP

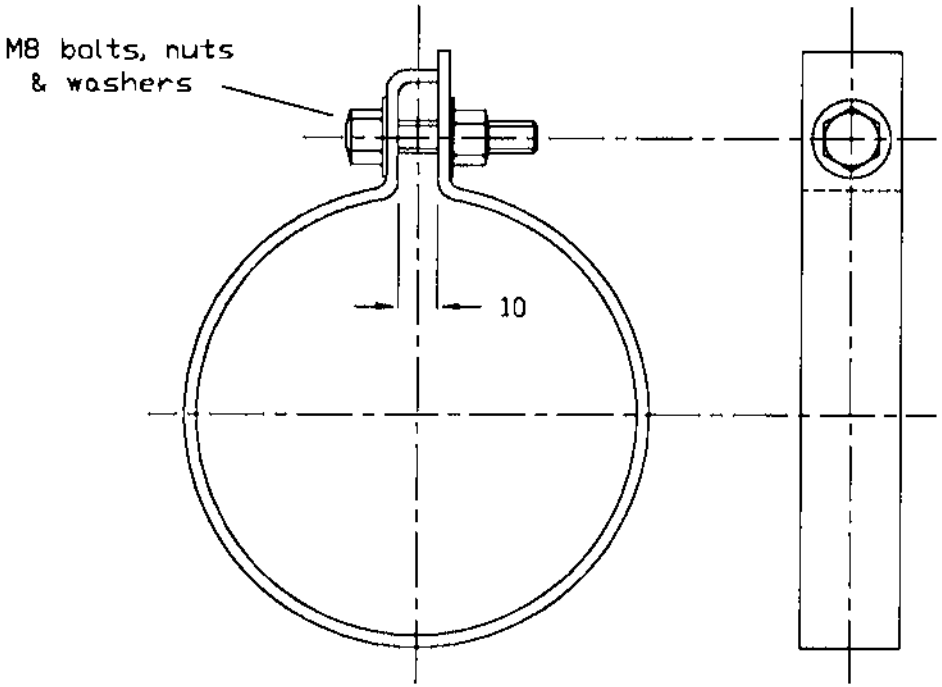

NOTES:

1 - The material used to make the strap is 25 x 3mm mild steel.

2 - 5 straps are needed for the impulse valve.

3 - Mark the measured fold lines on the cut lengths of steel. After folding the straps wrap them around the impulse valve and check that there is a minimum gap of about 10mm between the folded up-rights.

4 - When the straps are assembled, paint them before adding them to the impulse valve.

ALL DIMENSIONS IN mm

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P90 IMPULSE VALVE STRAP

Drawing No. 6 of 12 NOT TO SCALE

TONGUE

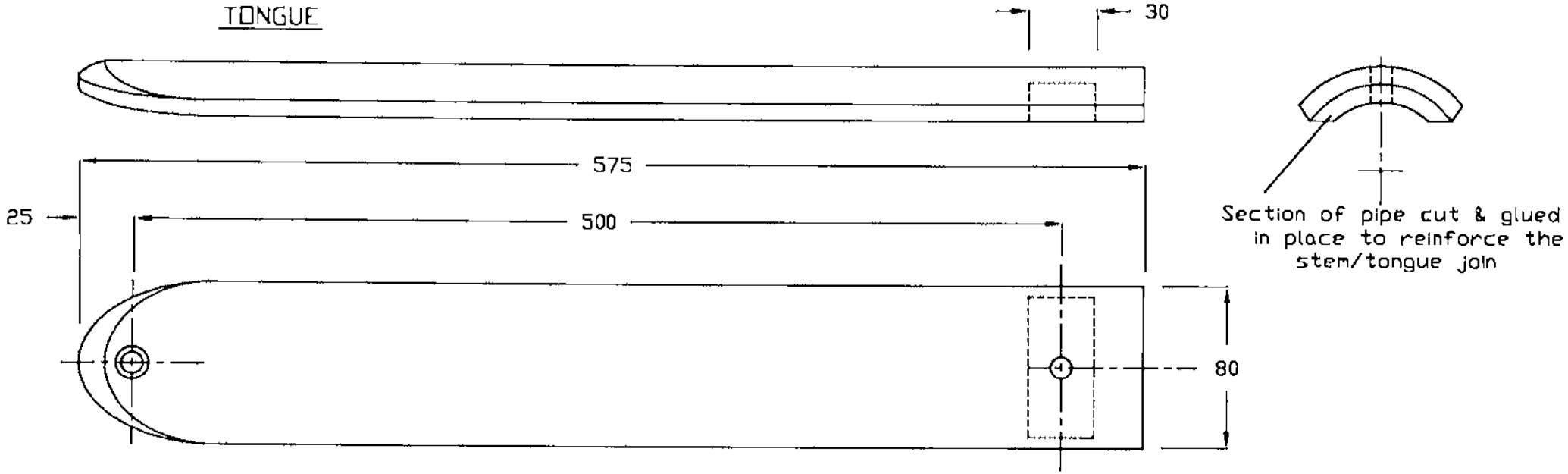

TONGUE MOUNTING

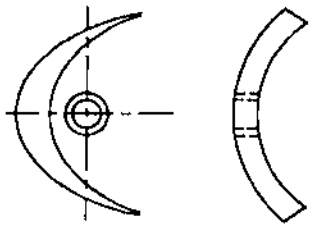

A steel ring with an internal diameter of approx. 10mm (3/8' pipe) is pushed into a hole in the tongue using an interference fit. Use a 50mm M8 bolt, 2 nuts and washers to fit the tongue to the impulse valve.

TONGUE STEM ASSEMBLY

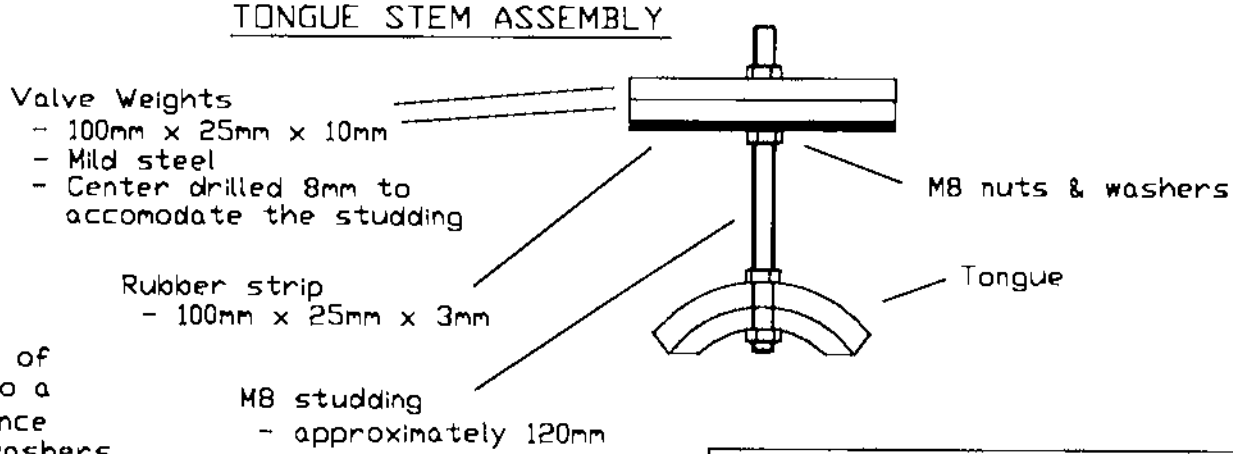

FITTING THE TONGUE

Hold the tongue in place inside the impulse valve. Feed the bolt through a washer and through the impulse valve and tongue mounting holes. Hold the tongue in the 'full-open' position, add another washer onto the bolt and screw on a nut until it just touches the tongue. Add a second nut and tighten the two nuts securely together.

ALL DIMENSIONS IN mm

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P90 IMPULSE VALVE TONGUE & ASSEMBLY

Drawing No. 7 of 12 NOT TO SCALE

STANDARD T-PIECE

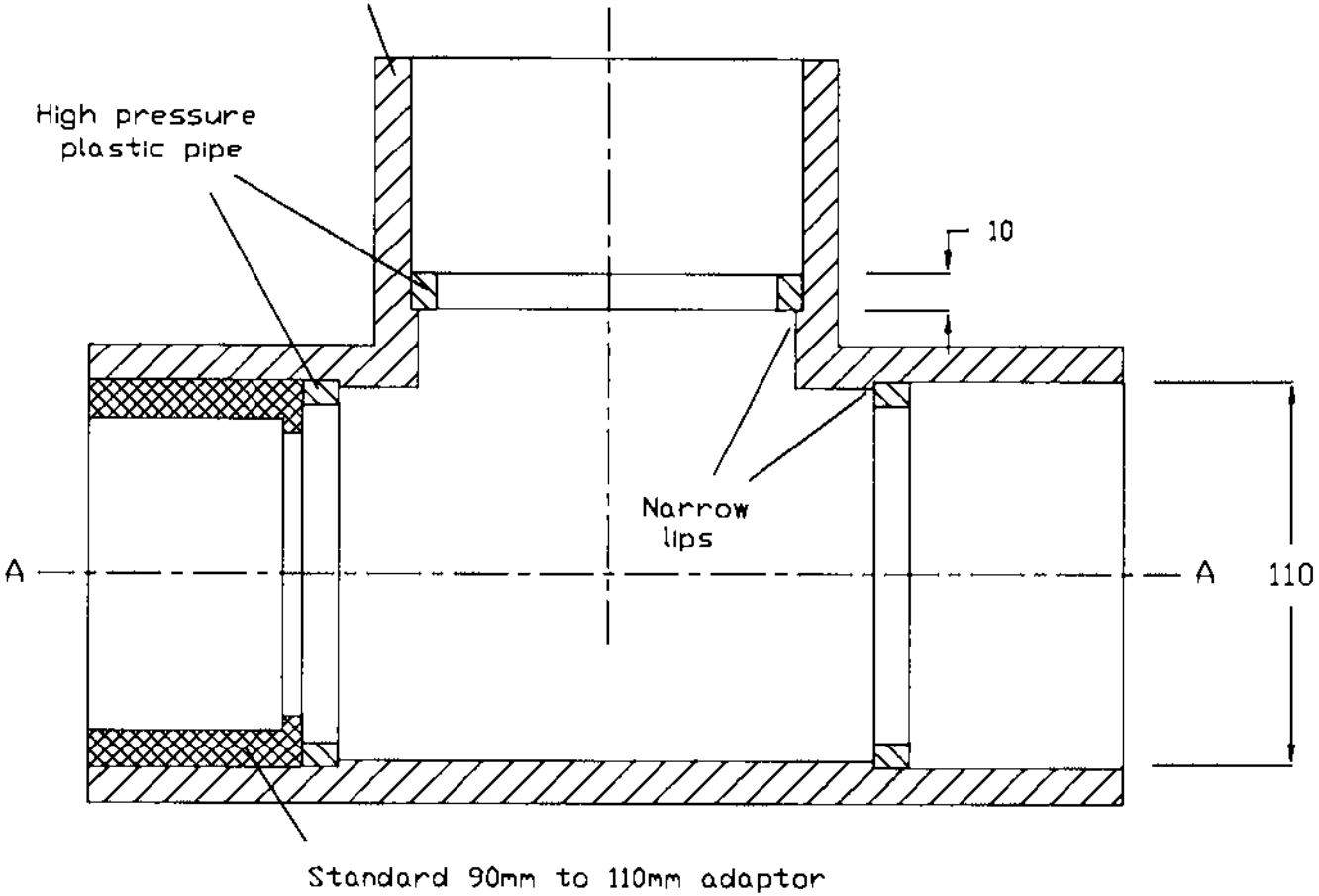

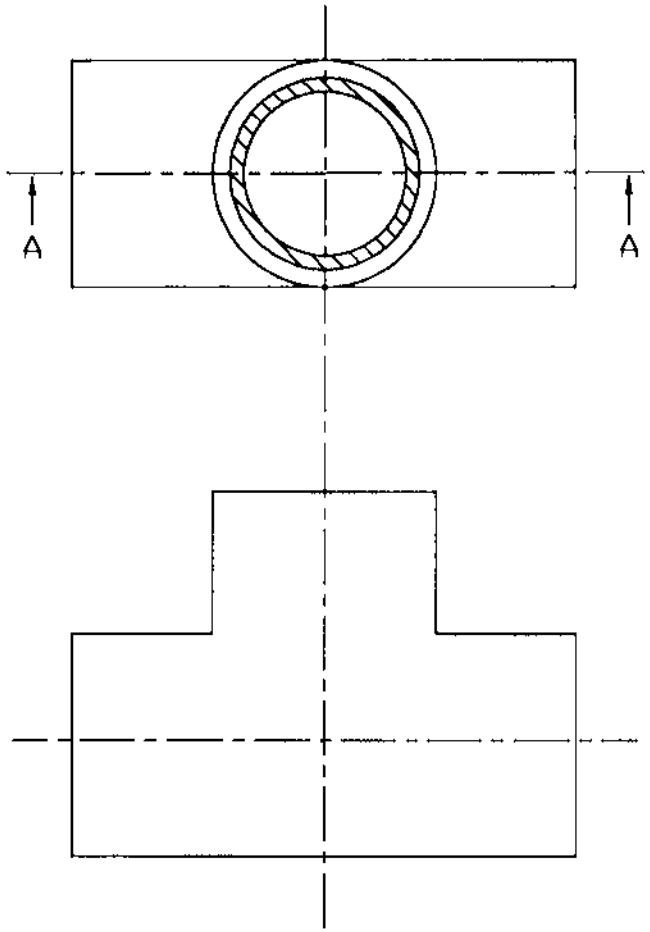

NOTES:

1 - The T-piece for the P90 may be bought commercially or made by hand. The drawing above shows an example of a commercial T-piece (high pressure plastic) that is suitable for 110mm diameter pipe.

2 - T-pieces available on the market tend to have narrow support lips as shown above. These need to be reinforced and this is done by gluing into place a 10mm length of high pressure plastic pipe as shown.

3 - When purchasing a 110mm high pressure plastic T-piece, also buy a 90mm to 110mm adaptor. This is because the drive pipe for the pump has a 90mm diameter and will have to be adapted to fit the T-piece.

ALL DIMENSIONS IN mm

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P90 - USING A STANDARD T-PIECE & ADAPTOR

Drawing No. 8 of 12 NOT TO SCALE

MAKING A T-PIECE

PART A

Cut 150 & 400mm lengths of pipe. Cut the shorter pipe down its length and heat it until workable. Open the heated shorter pipe and fit it over the center of the longer section using glue and clamp it in place.

Using the T-piece former, form sockets at each end of PART A. Next, cut out a 90 degree 'V-Notch as shown. Make sure the gap on the shorter outter pipe is opposite the @V-Notch'.

PART B

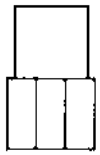

Cut 75 & 200mm lengths of pipe. Cut, heat & glue the shorter pipe flush with one end of the longer. Cut a piece of pipe to fit the gap left on the outer pipe. Heat & glue this into place.

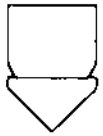

Form the socket on the end of PART B and cut the other end to fit the 'V-Notch' on PART A.

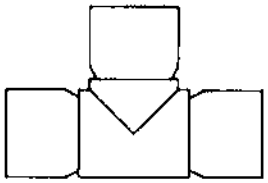

File both PARTS A & B until a reasonable fit is obtained. Glue together both parts using a mixture of PVC glue and pipe shavings to fill the gaps.

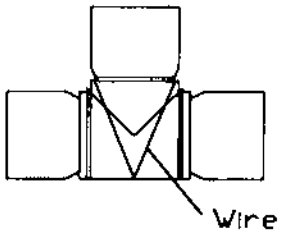

Wire may be wrapped around the glued parts to hold them more securely together. The T-piece is now ready to be set into a concrete base.

ALL DIMENSIONS IN mm

COMPLETED T-PIECE

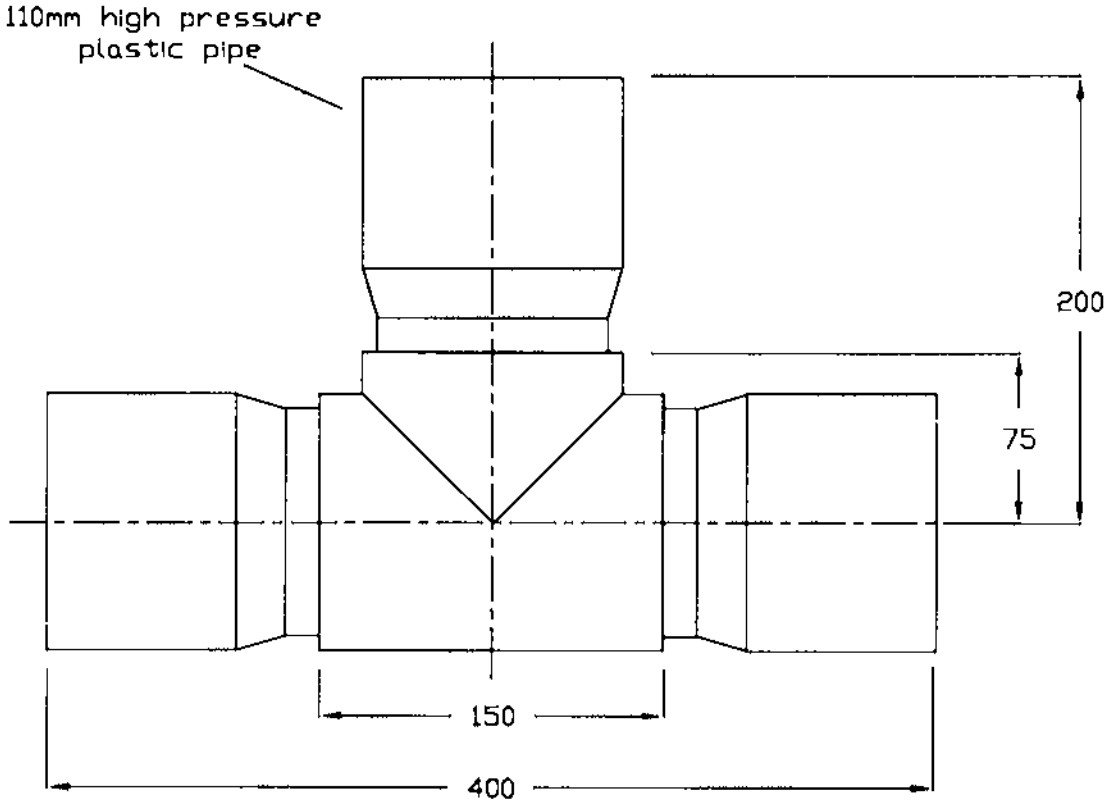

NOTE: The drive pipe for the P90 has a diameter of 90mm. Therefore, to fit the drive pipe into this T-piece, a 100mm to 90mm adaptor should be purchased or made up using available pipe.

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P90 T-PIECE
MANUFACTURE

Drawing No. 9 of 12 NOT TO SCALE

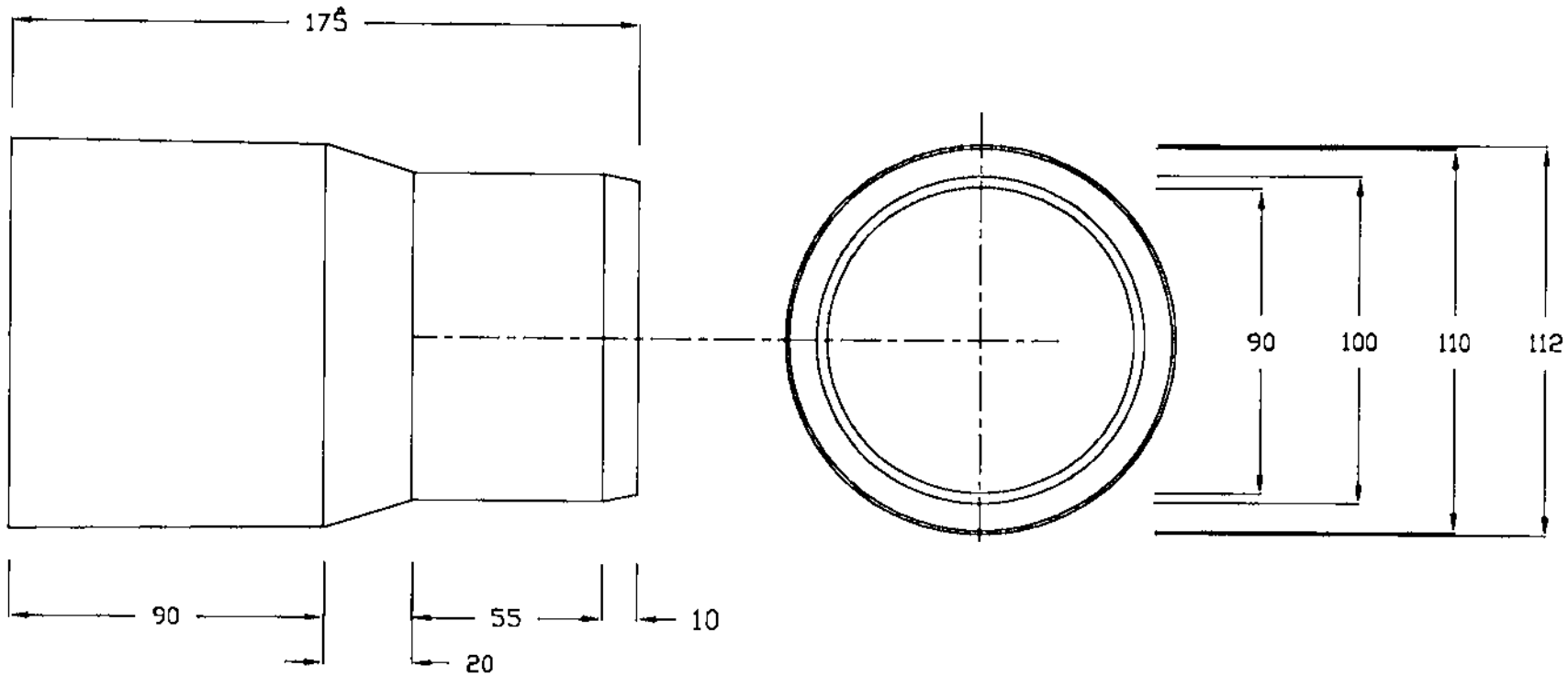

NOTES:

1 - This socket former is designed to be used with 110mm outside diameter plastic pipe.
2 - This former may be made from steel, aluminium or wood.
3 - The former is used to to make both the pump T-piece and End cap.

INSTRUCTIONS FOR USE

1 - The first step is to heat up the plastic pipe to make it soft and workable. This may be done by immersing the pipe in hot oil at about 130 C or by rotating the pipe slowly over a heat source.

2 - When the pipe is soft enough push it quickly and firmly over the former.

3 - Let the pipe cool and harden before removing it from the former.

ALL DIMENSIONS IN mm

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P90 SOCKET FORMER

Drawing No. 10 of 12 NOT TO SCALE

MAKING AN END CAP

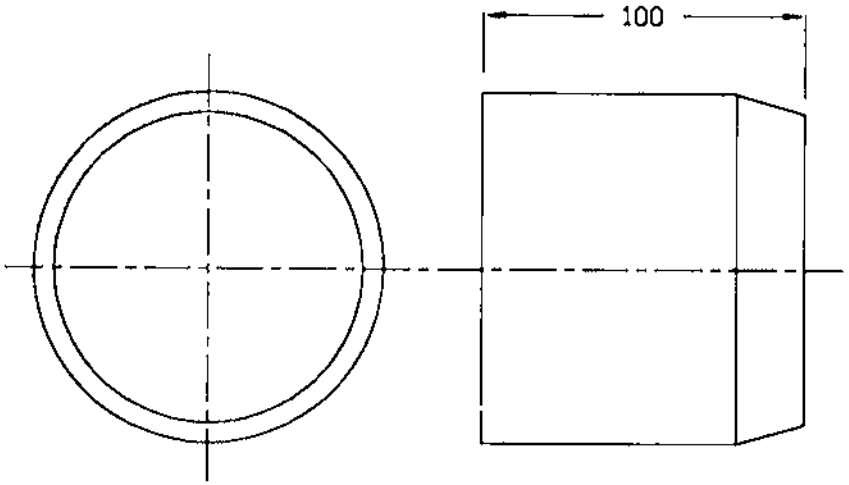

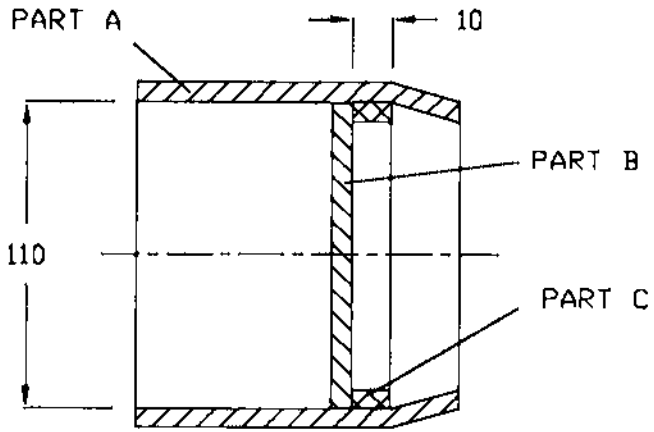

STANDARD END CAP

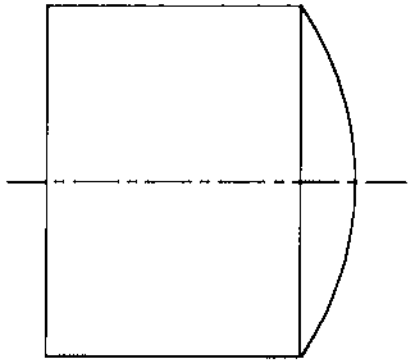

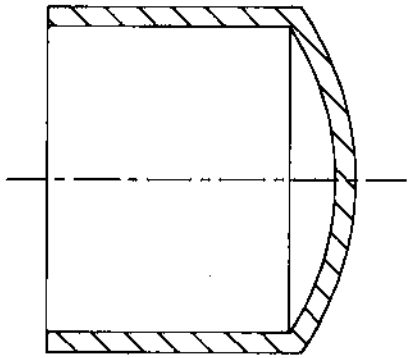

NOTE: The End cap may be purchased commercially or made as shown.

MANUFACTURE INSTRUCTIONS

1 - Cut a 100mm length of high pressure plastic pipe and heat it as per the socket former instructions.
2 - Push the softened pipe quickly and firmly over the socket former to shape PART A.
3 - PART B, the end cap plug, and PART C, the reinforcing strip are made by the same methods used to make the Air vessel.
4 - When PART A has cooled, use a good plastic adhesive to glue in the reinforcing strip followed by the end cap disc. When dry the end is ready for use.

ALL DIMENSIONS IN mm

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P90 IMPULSE VALVE
END CAP

Drawing No. 11 of 12 NOT TO SCALE

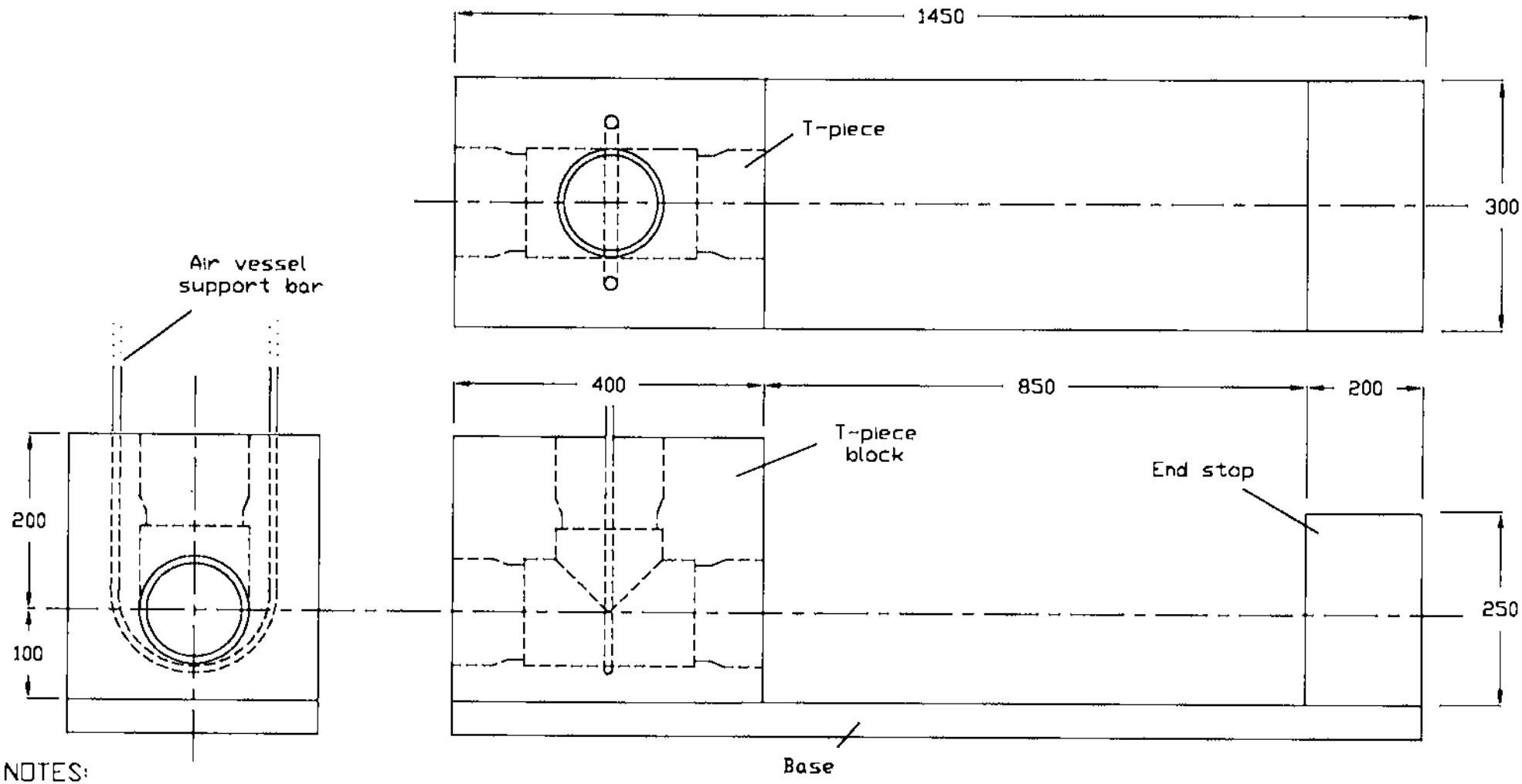

NOTES:

1 - The height and length of the T-piece block will be shorter when a standard T-piece is used. If a standard T-piece is used make sure the bottom of the T-piece is about 50mm above the top of the base.

2 - The depth of the base should be at least 75mm. The depth may be greater if a more solid foundation is needed.

3 - Use steel reinforcing in the base, T-piece block and end stop to join the three sections together and to reinforce each section. A local builder will know how to do this.

ALL DIMENSIONS IN mm

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P90 REINFORCED CONCRETE BASE, T-PIECE BLOCK & END STOP

Drawing No. 12 of 12 NOT TO SCALE

Things that Work!

Things that Work!
tested by *Home Power*

The Folk Ram Pump

Michael Welch

©1994 Michael Welch

Tested by Michael Welch, Cara Smith and classmates of Humboldt State University's International Development Program (Susan Brinton, Christopher Herbst, Christine Parra, David Potter, Jon Raybourn, Dav Camras, Daniel Oros, Mike Orr, and Wallapa Wongsuwan).

The Site

Cara Smith of Fieldbrook, California had a problem. Every year in August, her spring flow reduces to a mere trickle. As the Northern California drought got worse year after year, so did her spring's ability to supply her household needs. She needed a permanent solution to her problem.

Fortunately, a nice creek crosses Cara's property, and it flows year round. But, it is 360 feet in elevation below her water storage tank, which gravity feeds to her home. I had been looking for a site to adequately test the Folk ram pump, and this seemed like it would work. I had been attempting to test the pump on my own system at my home. While it worked well enough for me, my flow was too small to really put the pump through its paces.

So what is a ram pump anyway? Ram pumps use a downhill water pressure to pump a portion of that water even higher uphill to a holding tank. No other source of power is needed.

We enlisted the help of HSU's International Development Program to design, build and test the ram pump system. But that's a story in and of itself that we may tell in a future *HP* article. For now, suffice it to say that this academic program prepares students to help third world countries with their development requirements, and strongly emphasizes appropriate technology to meet these countries' needs.

The Pump Arrives

When I received the Folk ram, I was surprised to see that it was in pieces. Normally, Jim Folk ships his pumps completely assembled, ready to install. But, Jim knew that I was very interested in the workings of his pumps, so he sent it to me disassembled, with a labeling tag on each component explaining the why's and the how's of its design and use. I really appreciated that, but any other customer can expect the pump to arrive well-packed and already assembled.

His largest pump, however, is too heavy to ship by UPS, so it comes in two pieces easily bolted together.

This pump is heavy-duty. Its body is thickly cast and machined from high-grade aluminum alloy, and the inner components and the bolts make use of stainless steel. The internal "valves" are made of thick, bonded rubber seals.

A feature of the Folk ram not found in most ram pumps is a strong rubber diaphragm which separates the delivery water from the pressurized air chamber. This diaphragm keeps the air from mixing and exiting with the delivery water, thus eliminating the need for a "snifter valve" to replenish the air chamber.

Other features of the Folk ram pump include larger-than-usual impetus and check valves for faster reaction time and a large air dome to minimize delivery water pressure pulsations and thus decrease friction loss. The impetus valve stroke length is easily adjustable to change the frequency of pump cycles, which changes the amount of water the pump uses and delivers.

Installation

The Folk ram arrived with adequate instructions on how to install, maintain and run it, but there is some room for improvement. Jim Folk told me that he wanted to do a better and more detailed manual for the pump.

One great thing about Jim Folk is that it is as important to him that the pump works well as it is to sell the pump in the first place. If you have problems with your installation or operation, he will work with you in detail. It's just how he is, and most people can really appreciate it. For example, there was a problem with the bonded rubber the pumps used in their valves. When Jim discovered the defect, he automatically sent every pump owner a new set of valves, using improved materials, and he did it free of charge.

Long distance water pumping systems have so many variables that every installation is different. In our case, the terrain was very steep and somewhat rugged. In order to get adequate vertical drop to run the pump, we had to snake the supply pipe 420 horizontal feet from the source to a settling tank, and then go steeply down the hillside to the pump site with the drive pipe. The cost of having to run such a long horizontal distance was a reduced supply available to the pump. While Cara's creek flows at about 72,000 gallons per day, our 420 feet long, two inch diameter supply pipe with five feet of head between the creek inlet and the settling tank would make 5,400 gallons per day available to the pump.

Most installations will be more straightforward than ours, and less expensive as a result. The price of the

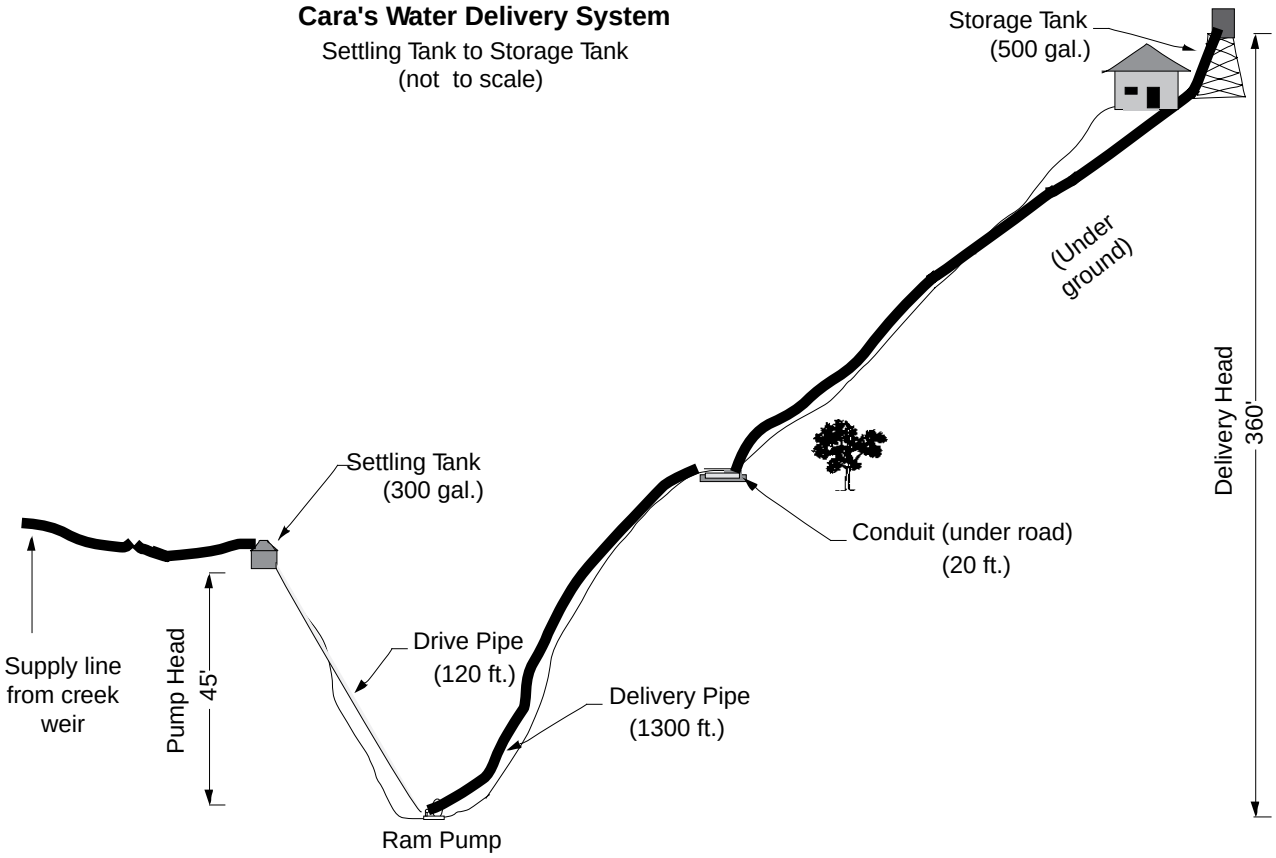

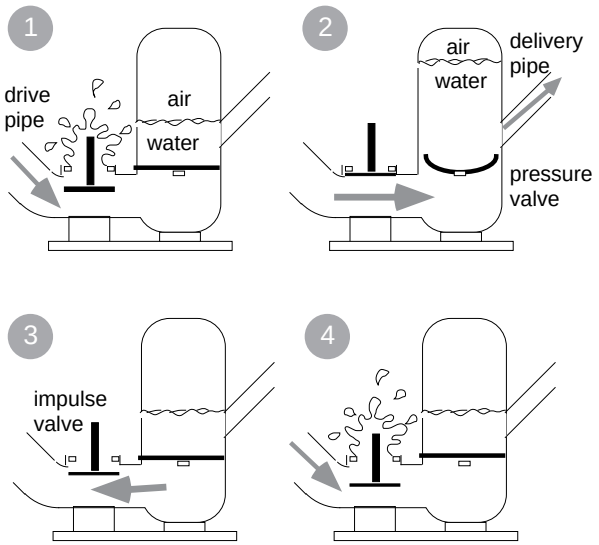

How a Ram Pump Works

All ram pumps work on the principle of momentum which is controlled by a cycle set up by the interaction of two valves in the pump.

When the impetus valve is opened (this must initially be done by hand to start the pump cycling), water begins to flow down the drive pipe and through the impetus valve as in Figure 1. When the drive water reaches a certain velocity, water friction slams shut the impetus valve as in Figure 2. The momentum of the water carries past the closed impetus valve, forcing open the flapper valve and pushing water past it to pressurize the air chamber above the water level. In Figure 3, the water pressure above the flapper valve overcomes the spent momentum below it, forcing the flapper closed again. The water that made it past the flapper in Figure 2 is then forced by the extra air pressure up the delivery pipe. Since the momentum of the water coming down the drive pipe was stopped, the impetus valve falls open, allowing the water to flow down the drive pipe again as in Figure 4 (just like Figure 1), starting the cycle over again.

This process occurs over and over again until something happens to stop the cycle. Ram pumps can cycle anywhere from 25 to 300 times per minute. The frequency of the cycle is adjustable by changing the length of the stroke of the impetus valve. A longer stroke produces a lower frequency. This means more of the supply flows to and through the pump and more is pumped up the delivery pipe.

The stroke is adjusted to restrict the amount of water used to the amount available, or if supply is unlimited, to regulate the amount delivered to match the amount needed.

pump remains a fixed cost for everyone, but the installation costs can vary widely. Because of the long supply line and the uncommonly high delivery elevation, Cara's installation costs were about double the average installation. I estimate the average to be about $1,000 for system components including the Folk ram pump which runs about $695. Labor is not included in these approximations.

A typical installation includes a 1.5 inch steel drive pipe from the source to the ram pump, a poured concrete foundation to secure the pump, a one inch poly delivery pipe to the household supply tank, and valves and unions to control flow and allow access to the various components of the system.

Pump Performance

Because the Folk ram's capabilities could easily outstrip our supply, we choked it back so it wouldn't run out of water. When a ram pump stops cycling, it needs to be restarted by hand. Once we had the pump properly set, it just kept running on and on for months without the need for further attention. This reminds me of a ram pump story I heard:

Friends were hiking near the New River in the Trinity Mountains of Northern California. This river is peppered with old gold mining claims. Far away from any other form of civilization, the hikers were surprised to come to an otherwise pristine spot where they heard a muffled "ka-chunk ka-chunk ka-chunk...." Taken by surprise, they were unable to discover the source of the mechanical noise until they dug down several inches through the forest humus finding a rotten board covering a hollow box. The box contained an old ram pump that had been operating on its own, unattended for as long as it took the box cover to become buried under many layers of duff.

Commercial ram pumps are known to provide years of trouble-free service. We expect that the Folk ram will furnish Cara with water for decades to come.

Even with the pump choked back for the decreased supply, we obtained delivery rates of 600 gallons per day. This is a far cry from the 2,400 gallons per day that this pump could achieve under the same drive and delivery heads with unlimited access to the creek's supply. However, it was more than adequate for Cara's needs which max out at 475 gallons per day. Jim Folk states that, under ideal supply, drive, and delivery conditions, this particular model of his pump will produce up to 5,000 gallons per day. He has a second model that will produce up to 25,000 gallons per day.

For you folks with super low flow situations, this pump may still work for you. For several months, I had this

pump installed on my own spring which was flowing at about 1,500 gallons per day, with 26 feet of drive head, and 158 feet of delivery height. This is really running the pump on the low end of its capabilities, yet it still was able to provide my home with about 190 gallons of water per day.

Conclusion

Folk ram pumps are well-made, dependable, and work as promised. While there are other ram pumps available, the Folk has features that are unique and proven. At $695 for a pump that will likely outlast its owner, it is an excellent buy. A larger model is available that lists for $995. These pumps are handmade in Conyers, Georgia.

Access

Author: Michael Welch, c/o Redwood Alliance, POB 293, Arcata, CA 95521 • voice 707-822-7884 • BBS 707-822-8640

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Building a Homemade Ram Pump

Scott Lee

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During the mid 1970s, I first encountered the hydraulic ram water pump. A friend of mine was interested in a water pump for irrigating a garden. I had also purchased some land with a stream and a nice garden spot, but no electrical service. The combination of a stream below my garden spot and no electrical power seemed to be a perfect situation for a hydraulic ram.

Three Tries

The manufactured rams back in the '70s were fairly expensive—US$250 and up. Some publications had home-built designs. One in particular was by an organization called VITA (Volunteers in Technical Assistance). Based on the cost of the manufactured rams, I set out to construct a home-built ram pump. The first two versions of my ram were based loosely on VITA's descriptions and plans. They weren't followed exactly, due to the difficulty in obtaining some of the parts that were mentioned.

Scott Lee's ram pump in operation.

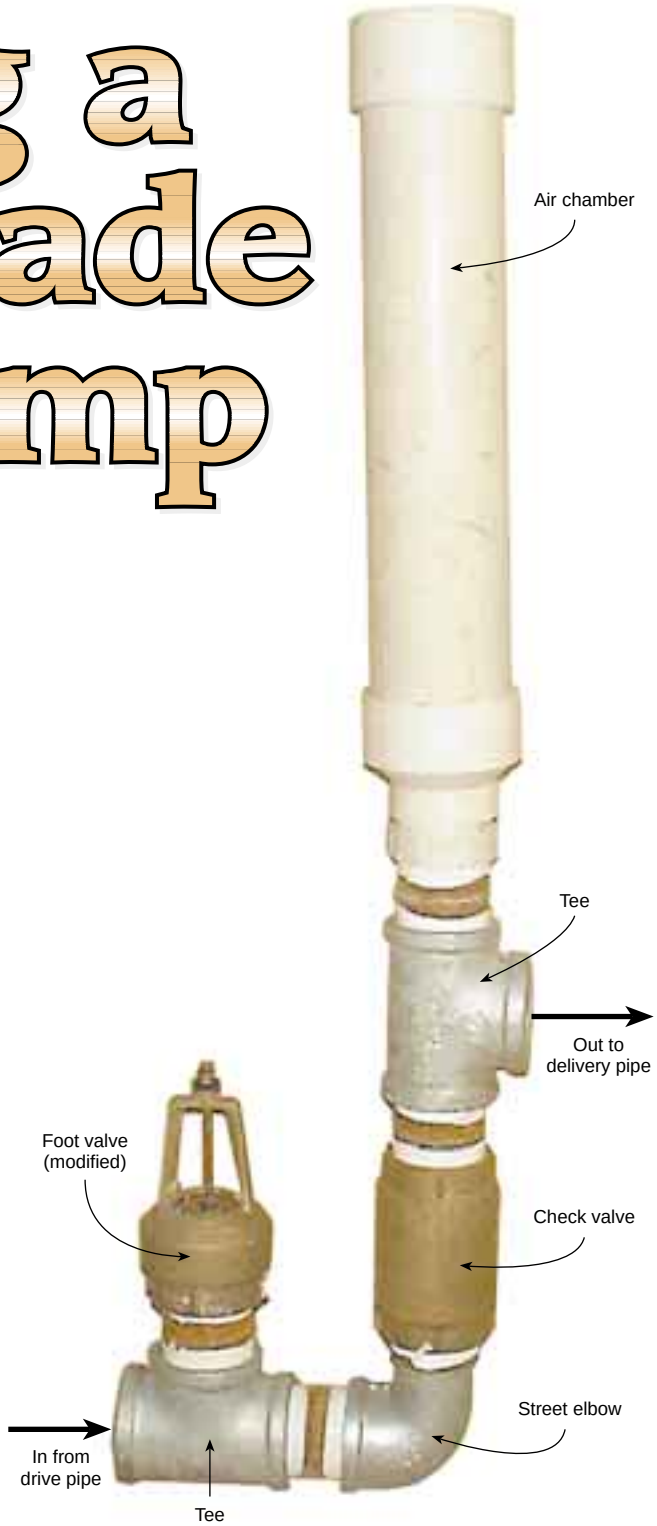

I recently went to the local hardware store to check out the cost of these parts. The 2 inch version of my homebrew ram will cost about US$130 (see parts list). A 1 inch ram will be cheaper, and might cost a little more than half that amount. The cost of the pipes needed to hook up the ram may exceed the cost of the ram itself.

Ram Pump Parts List

Qty	*Item*
1	2 inch foot valve (brass)
1	2 inch check valve (brass)
2	2 inch tees (galvanized)
6	2 inch close nipples (galvanized)
1	2 inch street elbow (galvanized)
1	2 by 1 inch bushing (galvanized)
1	1 inch close nipple (galvanized)
1	3 inch pipe cap (PVC)
1	3 inch pipe, 18 inches long (PVC)
1	3 by 2 inch reducer (PVC)
1	2 inch PVC to IPT adapter (PVC)
1	1/4 inch threaded rod (stainless)
6	1/4 inch nuts (stainless)
2	1/4 inch washers (stainless)
1	Faucet washer
1	14 gauge copper wire, 2 inches

The first version of my ram was built entirely out of galvanized steel pipe and fittings. The waste (or impetus) valve proved to be the hardest to construct. The first version's valve was constructed from a 1 1/2 by 1 inch bushing. While this valve worked after a fashion, it was very leaky. I figured that the ram would perform better if this valve would seal tightly. My second version had a valve that was constructed from a 1 1/2 inch pipe plug. The plug was bored with a 1 inch hole, and had the inside surface of the plug machined smooth. This resulted in better ram performance.

I never used the first two versions in working applications, though I did test them. Shortly after the second one was operational, an article appeared in *The Mother Earth News* (May/June 1979, #57, page 120) with instructions on how to build a ram mainly out of PVC pipe fittings. Using this design as a guide, I developed a third version. This version was also built from galvanized steel pipe fittings, with the exception of the air chamber, which was constructed from PVC pipe and fittings. This version still required machining of a sort—cutting threads on the outside of a 1 1/2 inch hose barb, so that it would thread into a 2 by 1 inch bushing.

Although this was a workable system for constructing the waste valve, it still was not as simple as I wanted. For a time, this ram was used to pump water to my garden. The water was also used to provide showers, with the use of 200 feet (60 m) of 3/4 inch black poly pipe for a solar water heater. This pump was installed with a 4 foot (1.2 m) fall (head) to the ram, developed over the distance of 100 feet (30 m). It had a delivery lift of 30 feet (9 m) to a 3 by 12 foot (0.9 x 3.7 m) pool used as a storage tank. The point of use was 15 feet (4.5 m) lower than this storage pool.

Standpipe

When the ram was first put into service, it operated very slowly—about 15 to 20 cycles per minute. Everything that I'd read stated that rams of this size should operate at about 45 to 60 cycles per minute. I fabricated a standpipe and inserted it in the drive line about 30 feet (9 m) from the ram. This is within the recommended 5–10 times ratio of head to drive pipe length. This allowed the ram to operate in the 45 to 60 cycles per minute range. The flow of water delivered to the tank increased from 0.25 to 0.75 gallons (0.9 to 2.8 l) per minute.

Ideally, the length of the drive pipe should be in the range of 5 to 10 times the head. So for a head of 3 feet (0.9 m), the length of the drive pipe should be in the range of 15 to 30 feet (4.5–9 m).

If the drive pipe is too long, the cycle frequency that the ram can operate at will be limited to some low value. The standpipe provides a closer location for the ram pump's supply. This means that there is less resistance in the drive pipe, and the flow can reach full velocity more

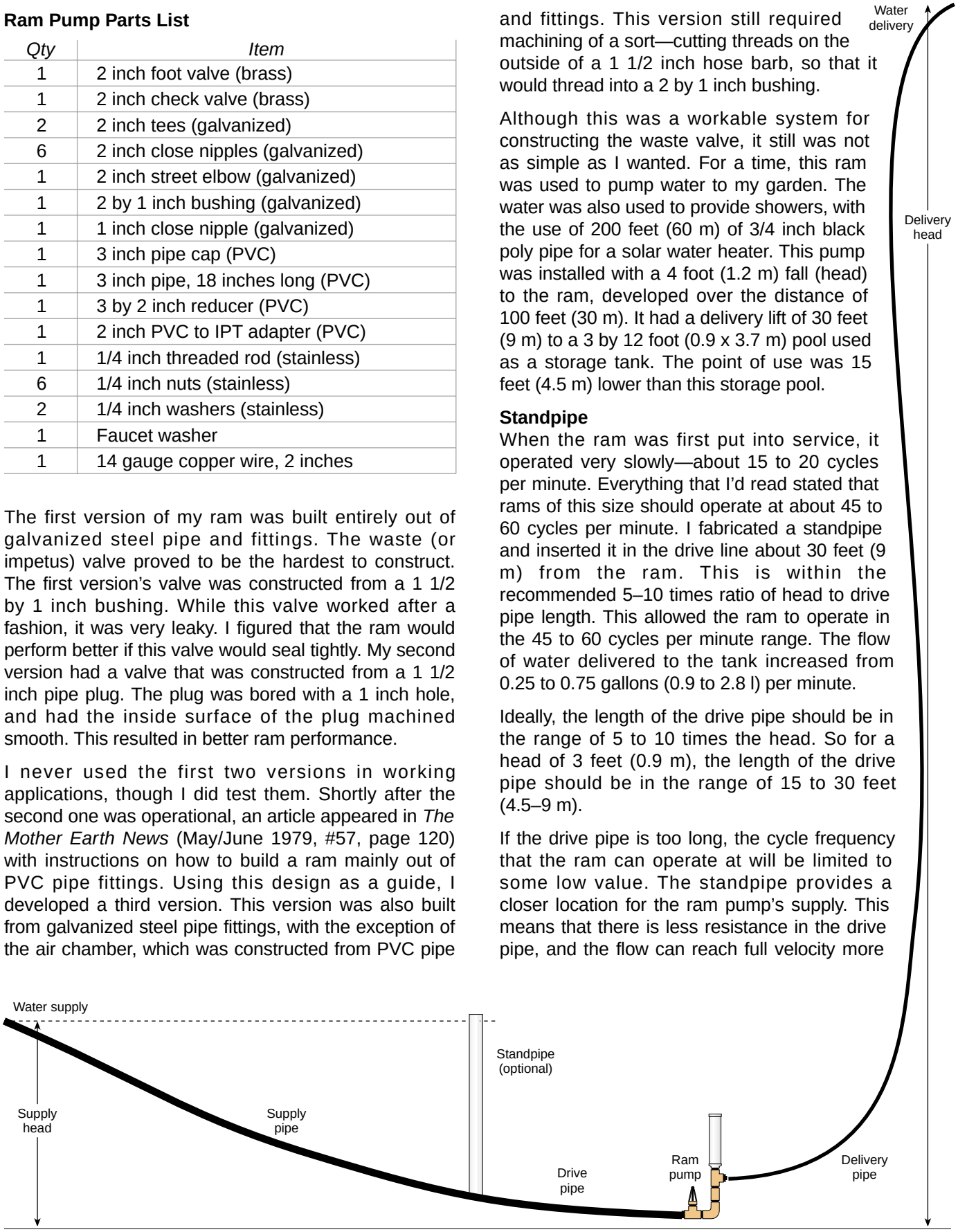

How a Ram Pump Works

The energy required to make a ram lift water to a higher elevation comes from water falling downhill due to gravity, as in all other water-powered devices. But unlike a water wheel or turbine, the ram uses the inertia of moving water rather than water pressure, and operates in a cycle.

1. When the waste valve is opened, water flows from the source, through the water inlet (drive) pipe, and out the waste valve.

2. After a short time, the velocity of the flow is high enough to force the waste valve closed. The water, due to its inertia, wants to continue moving past the valve. The pressure inside the ram will rapidly increase enough to force the check valve open. This forces some water into the air chamber, compressing the chamber's air bubble. The pressurized bubble forces that water through the delivery pipe to the point of use.

For a ram pumping one gallon (3.8 l) per minute, and cycling 60 times per minute, each cycle pumps one-sixtieth of a gallon—about two ounces (60 ml). The compressed air in the air chamber helps smooth out the flow on the delivery side of the ram, so the flow tends to be more continuous, rather than a small spurt during each cycle of the ram.

3. Soon after the check valve has opened, the pressure surge (generated by the waste valve closing) is spent. Flow will try to start backwards, but the check valve will close, preventing this from happening.

4. At about this time, the pressure in the drive pipe will be low enough so that the waste valve can open, allowing water to start flowing from the source to the ram, beginning a new cycle.

The cycle that the ram goes through can occur 30 to 120 times per minute, depending upon conditions such as head, flow, and the size of the ram.

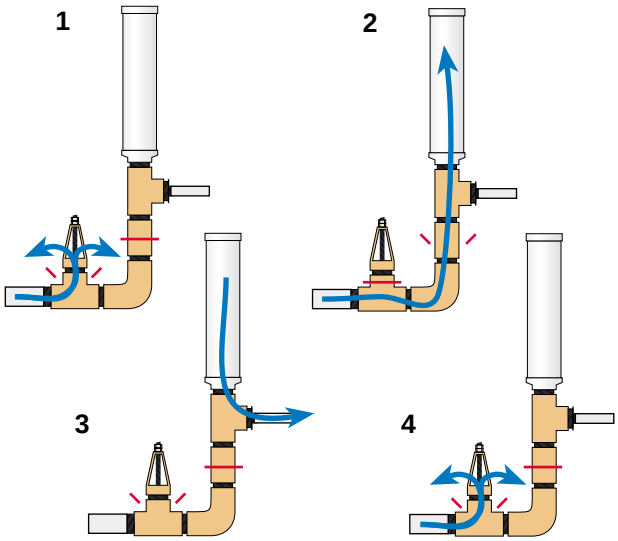

quickly than without the standpipe. Basically, a standpipe allows the ram to operate as if it had a shorter drive pipe.

The diagram on page 43 shows a standpipe inserted between the supply pipe and the drive pipe. The critical distance is now only the distance between the standpipe and the ram, not the total distance to the source of supply.

A standpipe can easily be constructed out of PVC pipe and fittings. The pipe needs to be long enough so that it is a few inches higher, in its installed location, than the elevation of the water source. Consider screening the top of the standpipe to keep out birds, insects, and detritus if you are pumping potable water.

The standpipe is usually inserted at a distance from the ram that is 5 to 10 times the supply head. This will vary from installation to installation. Since my installation had 3 feet (0.9 m) of supply head, I inserted the standpipe 30 feet (9 m) from the ram. This allows the ram to cycle properly, which results in more water pumped.

It's also important to consider the diameter of pipe on long drive runs, to minimize flow loss due to pipe friction. When in doubt, go up in size. It's recommended that the standpipe be at least two full pipe sizes larger than the drive pipe. I've used 4 inch standpipes with 2 inch rams, and 2 inch standpipes with 1 inch rams. It's also recommended that the pipe from the supply to the standpipe be one full pipe size larger than the drive pipe. This will insure that the flow to the standpipe will be able to keep up with the ram pump's usage.

Drive Pipe

This configuration operated for about six months, after which it was dismantled for the winter. It was later installed at a new location with 3 feet (0.9 m) of head and 12 feet (3.7 m) of lift. Most of the time it supplied garden soaker hoses, with an old 52 gallon (200 l) hot water tank being used for a small storage volume, operated as a pressure tank.

One day, we were operating the ram with the discharge valve shut, and we noticed that the 2 inch black poly drive pipe was actually expanding visibly with each closing of the waste valve. We concluded that a portion of the energy was being wasted expanding the drive pipe, rather than pumping water. We also noticed that the max discharge pressure was 21 psi.

So I replaced the 30 feet (9 m) of black poly pipe between the standpipe and the ram with schedule 40 PVC pipe. With this pipe in place, I noted that the maximum discharge pressure was now 57 psi. This meant an almost threefold increase in the amount of water delivered. With a 12 foot (3.7 m) lift, we

measured the flow at 2 gpm after the installation of the PVC drive pipe.

Based on these observations, I suggest that you don't use black poly pipe or other flexible pipe for the drive pipe. If you are using a standpipe, the pipe from the standpipe to the ram is the only section that needs to be rigid. The supply pipe from the source to the standpipe can be flexible. If your drive head is higher than a few feet, steel drive pipe is recommended, since high pressures can blow out plastic pipe joints.

The foot valve on its way to becoming the waste valve—the stem is cut off the valve disc and the lower crosspiece has been cut away from the casting.

Versions Four & Five

Although this ram was successful, it still was not completely satisfactory. The waste valve needed a lot of maintenance, and also required a pipe threading machine to make it. In light of these shortcomings, a fourth version was built using a standard plumbing check valve for the basis of the waste valve. This worked well, but required a lot of work to cut discharge ports into the check valve.

In a matter of days after version four was put in operation, it was discovered that a foot valve would serve the purpose as well as a check valve, with very little work required to convert. This valve was built and put into operation successfully and performed well. The fifth version is still in use. I think that it was first used in 1980 or '81. This ram continues to provide irrigation for a garden, and water for keeping a compost pile moist enough for proper decomposition.

It should be noted that this is not a year-round installation. Before winter weather starts, the ram and standpipe are removed from the stream to prevent freezing. They are reinstalled the following spring. This has worked well, since there is no demand for the water during the winter.

I built and installed another ram of this size for a neighbor, to supply water from a spring to two houses. This ram was a slightly improved version. The main differences were that I used a larger check valve and foot valve, which improved the performance slightly. This ram was supplied by 4 feet (1.2 m) of head and lifted the water 30 feet (9 m) to a 1,500 gallon (5,700 l) storage tank about 1,400 feet (425 m) away.

At the storage tank, separate centrifugal pumps and pressure tanks were used to supply water to both houses. The ram delivers almost 1 gpm to the storage tank, which has proved to be plenty of water for all normal household uses. This ram installation is freeze-proof, with the delivery line buried and the ram in an enclosure. The ram has proved to be superior to trekking to the spring and running a gasoline engine-driven pump every two to three days to fill the storage tank.

How to Build The Ram

All of the parts for the ram were obtained from a local hardware store's plumbing section. The foot and check valves were Simmons brand, but any other good quality valves should work as long as they are of the same general configuration.

Begin the fabrication of the waste valve by removing the screen that is supplied as part of the foot valve. Then use wrenches to remove the valve disc from the foot valve, and cut off the supplied stem from the valve.

Now take the disc and drill a 1/4 inch (6 mm) hole in the center of it.

Use extreme care in drilling this hole to make sure that it is straight and centered. Use a drill press if you can. It is possible to get this right by hand if you are careful.

Now cut a 6 inch (15 cm) piece of 1/4 inch (6 mm) threaded stainless steel rod for the new valve stem. Thread on one of the 1/4 inch nuts, far enough to allow the valve disc to be placed on the threaded rod with room for another 1/4 inch nut. Lock the disc to the threaded rod by tightening both nuts against the disc.

The valve disc is reassembled with a 6 inch long piece of 0.25 inch stainless steel threaded rod, and locked in place with nuts top and bottom.

Now take the valve body and enlarge the threaded hole in the top crosspiece to 1/4 inch with a drill. Again, use care to get this hole straight. Using a hacksaw, remove the lower crosspiece.

After these modifications have been made, take the modified valve disc and insert it up through the valve body. After you have inserted it, put on a 1/4 inch washer, a faucet washer with its hole enlarged to 1/4 inch, and another 1/4 inch washer. The faucet washer provides some cushion to help quiet the waste valve when it falls open. Then thread on two 1/4 inch nuts, adjusting them so that they allow about 1/2 inch (13 mm) of movement of the valve disc and stem within the body. This is a good starting point—further adjustments can be made later, after the ram is operating. Your assembled valve should look like the diagram at right.

Air Sniffer

The next step is to modify the 2 inch check valve by adding an air sniffer hole. This hole will allow a little air to be taken in on each stroke of the ram, replacing air in the air chamber that has dissolved in the water and gone up the delivery pipe. Loss of all the air in the air chamber can result in something breaking. I once saw the bonnet of a 2 inch PVC valve blow off. This valve was used to isolate the ram from the drive pipe. If you choose not to use an air sniffer, you must shut down the ram every few days and drain some water from the air chamber.

Begin the construction of the air sniffer by stripping the insulation from a piece of #14 (2 mm^2) copper wire. Select a drill bit that is just slightly larger than this wire. Use this bit to drill a hole in the check valve as shown in the next sketch.

Make sure that you drill this hole on the correct side of the valve seat, as shown on page 47. After you have drilled this hole, twist a small loop in one end of the wire you have stripped. Insert the straight end of this wire into the hole, and twist another small loop in the wire on the inside of the check valve. If you are building the ram for a low-head installation, you may want to remove the spring from the check valve at this time. Otherwise it can be left in place.

Air Chamber

The air chamber is the last piece you will need to assemble before the ram can be completely finished. A 4 inch diameter air chamber should be okay for up to 10 feet (3 m), while a 6 inch chamber should work for about 15 feet (4.5 m). When in doubt, it's probably better to err on the large side. The air chambers are usually about 18 inches (46 cm) plus the length of the fittings, but could be made longer if necessary.

Assembled Waste Valve Detail

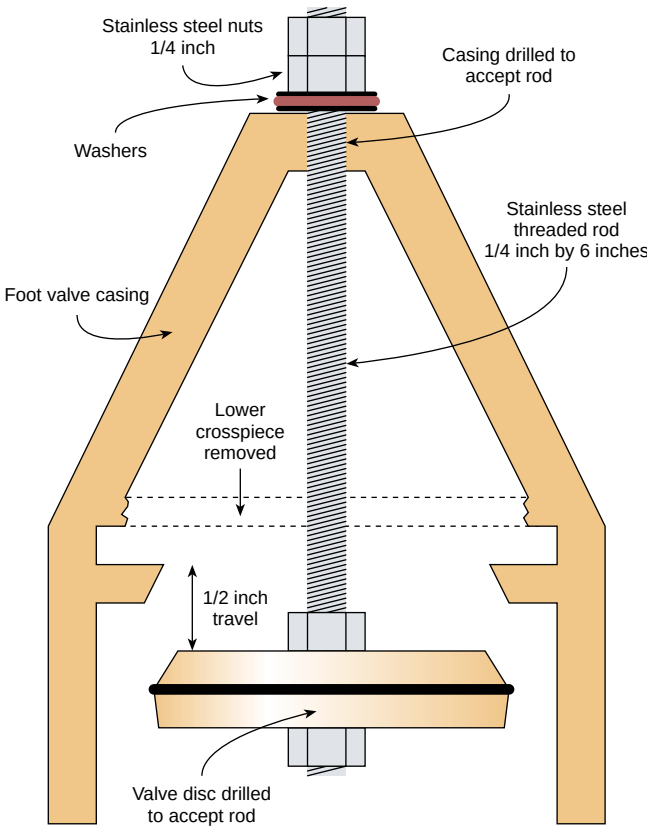

The modified foot valve ready to assemble onto the ram.

To assemble the air chamber, glue a cap to one end of the 3 inch PVC pipe. Then glue the 3 by 2 inch reducer to the other end of the pipe. After these are complete, glue in the PVC to IPT adapter. The air chamber should now be complete, and the final assembly of the ram can proceed.

Assembly

Screw a 2 inch close nipple into one of the end branches, and another into the side branch, of a 2 inch tee. Teflon tape should be used on all of the threaded connections. This will aid in any disassembly that may be required in the future. Screw your waste valve onto the nipple on the tee's side branch.

Screw the street bend onto the nipple on the end branch. Screw the check valve onto the end of the street bend. The flow directional arrow should point away from the street bend. Screw a 2 inch close nipple into the check valve. Screw an end branch of the other 2 inch tee onto the close nipple.

Screw another close nipple into the other end branch of the 2 inch tee. Screw your air chamber onto this nipple. Screw the 2 by 1 inch bushing into the side branch of the tee. Screw the 1 inch close nipple into this bushing. Go back to the first 2 inch tee and screw in the last 2 inch close nipple.

Your completed ram should look approximately like the photo on page 42. The 3 inch air chamber size on this ram should be adequate for supply heads of up to 5 feet (1.5 m). If the head is greater than this, the air chamber should be larger.

Installation

This completes the ram pump construction, but you may find that this is the easiest part of the job. As much or more depends on a good installation. I recommend that you use a union on either end of the ram. A gate valve on both the drive and discharge lines will also facilitate any maintenance that is required on the ram itself. The diagram on page 43 is a typical ram installation, showing head, lift, supply, delivery, and the length of the drive pipe.

To calculate how much a ram will deliver, divide the head by the lift, multiply by the flow, and finally multiply by 0.6. It takes at least 5 gpm to run this ram, with at least 2 feet (0.6 m) of head. In general it is easier to pump more water with more head, so run more drive pipe to get the head you need.

The check valve with the wire poking out of the air sniffer hole.

Check Valve Cutaway

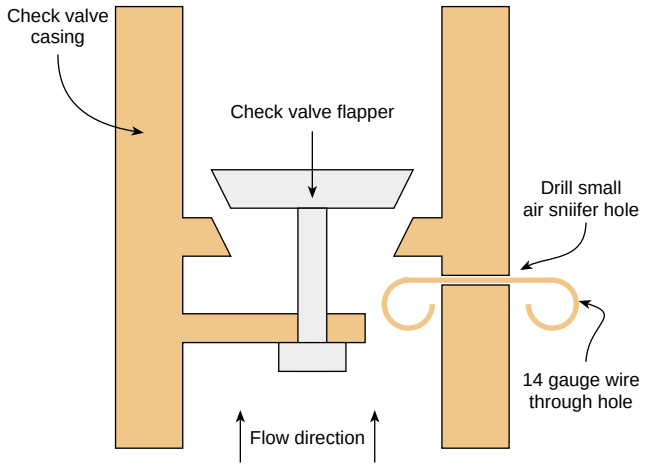

Using this equation, a site with 3 feet (0.9 m) of head, 20 feet (6 m) of lift, and a supply flow of 10 gpm would deliver 0.9 gpm. The same flow and lift, with 4 feet (1.2 m) of head, would result in 1.2 gpm delivered to the point of use. Or the same delivery could be accomplished with less supply flow. The delivered flow of 0.9 gpm could be achieved with 7.5 gpm of supply flow, using 4 feet (1.2 m) of head.

Maintenance on this ram is not very demanding. I've had to replace the faucet washer a couple of times per year. Otherwise the ram is noisy, and tends to wear the metal parts more. The O-rings on the valves will have to be replaced about every five years. The wire in the air sniffer will last two to four years.

Consider a Ram

Hydraulic rams can be very useful in providing a supply of water from a lower to a higher elevation. They can pump in a remote location, with no other energy required besides the falling water. Don't be discouraged about the small flow of water delivered by a ram, since they can pump 24 hours a day. Remember that one gallon per minute times 1,440 minutes per day will be 1,440 gallons per day delivered to wherever it is needed. It can also be used year-round if the ram and piping are protected from freezing.

The most important step in deciding if a ram is for you is a site survey. This will ensure that you have the flow and head required to operate a ram. Once this has been determined, build a ram to supply the water. Rams are inexpensive, easy to construct, and dependable, so there's no reason not to use one, if you have a location that meets the requirements.

Access

Scott Lee, 708 White Rock Gap Rd., Covington, VA 24426 • 540-862-4377 • slee529282@aol.com

Other *Home Power* articles on ram pumps:

Hydraulic Ram Pump, by Kurt Janke & Louise Finger, *HP41,* page 74.

Things that Work! on the Folk Ram Pump, by Michael Welch, *HP40,* page 44.

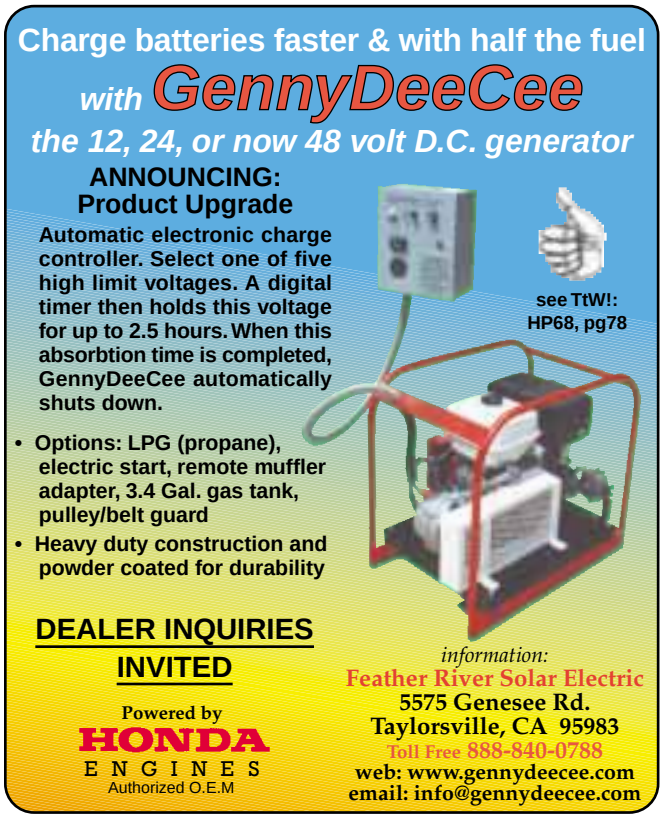

Hydraulic Ram Pump

adapted from *A Manual for Constructing and Operating a Hydraulic Ram Pump* by Kurt Janke & Louise Finger

©1994 Kurt Janke & Louise Finger

Here's a design for a hydraulic ram pump that requires readily available materials and few tools to construct. Ram pumps are commercially available that are potentially more efficient and durable, but are also more expensive. This pump can be built for under $75, and is capable of pushing 130 gallons per day 150 feet high, with a drive head of 20 feet.

A ram pump uses the potential energy of falling water to lift a fraction of that water to a higher elevation. (See Figure 1) Water accelerates through the drive pipe and open waste valve. Its velocity increases until the flow and upward force causes the waste valve to shut suddenly. The momentum of water produces a short-lived pressure, called the "ram", which is greater than that in the pressure tank. This causes a small amount of water to be released through the check valve into the tank. After the exerted energy is transferred into the pressure tank, the pressure below the check valve is less than that in the tank. The check valve shuts and the waste valve falls open, allowing the cycle to repeat continuously. The compressed air in the tank acts like a spring to drive the water that had passed through the check valve into the delivery pipe and on to a higher elevation.

The output volume of a ram pump is determined by the drive head, delivery head, amount of available water, and stroke length of the waste valve. The greater the drive head, the greater the acceleration in the drive pipe, and thus the potential energy at the pump. A longer stroke length also allows a greater velocity to reach the pump. Similarly, the greater the flow, the greater the mass of the moving water, and thus greater the potential energy. The greater the delivery head, the greater the energy required to pump a given volume of water.

Tools required for this homebrew ram pump are: two 24 inch pipe wrenches, two 7/16 inch wrenches, utility knife and/or circle cutter, drill and metal bits, #8 tap, and a screwdriver. For materials, see the list on right.

Waste Valve Assembly

Figure 2 illustrates the waste valve assembly. Use only half of the 1 1/4 inch union for the base/seat of the valve. It will be necessary to drill a 3/8 inch hole through the 1 1/4 inch male plug and a 5/16 inch hole in the shoe heel material. Attach the shoe heel disk to the bottom of the all-thread by securing the lock nuts and washers around it. The rubber washer at the top of the valve serves to reduce the stress induced on the adjustment nuts by the continuous pounding of the ram. The relatively soft all-thread used in the waste valve might stretch (or even break occasionally), so we recommend having replacements on site, or using a more durable material.

Be as accurate as possible with the tolerance between the all-thread and the plug. Cut the shoe material accurately round, and center the holes carefully. The success of the pump depends on the waste valve running up and down precisely as well as how it seats on the union.

Materials Required

Pump
10 liter fire extingisher (1" thread@)
1/2" gate valve
Two 2" tees
1" tee
2" 90° elbow
2" x 4" nipple
1" x 4" nipple
Two 1" close nipples
1/2" x 4" nipple
1/2" x 2" nipple
Two 2" x 1" reducer bushings
2" x 1/2" reducer bushing
1" x 1/2" reducer bushing
Teflon tape

Waste Valve
1/4" tee
1/4" close nipple
1/4" male plug
1/4" union
5/16" x 10" all-thread*
Two 5/16" nuts
Two 5/16" lock nuts
3/4" ID x 7/8" OD flat washer
5/16" ID x 3/4" OD flat washer
5/16" ID x 1" OD flat washer
rubber washer
7/8" diam. x 3/8" shoe heel material+

Check valve
Two 2" x 3/4" reducer bushings
3/4" close nipple
#8 x 1/4" machine
tractor tire rubber or leather+

@Other types of tanks or larger diameter pipes may work better, as fire extinguisher bodies are often made from soft aluminum with a potential for thread failure.

*A steel bolt with threads over its full length will also work and may be more durable.

+Available at shoe repair or leather-working shops.

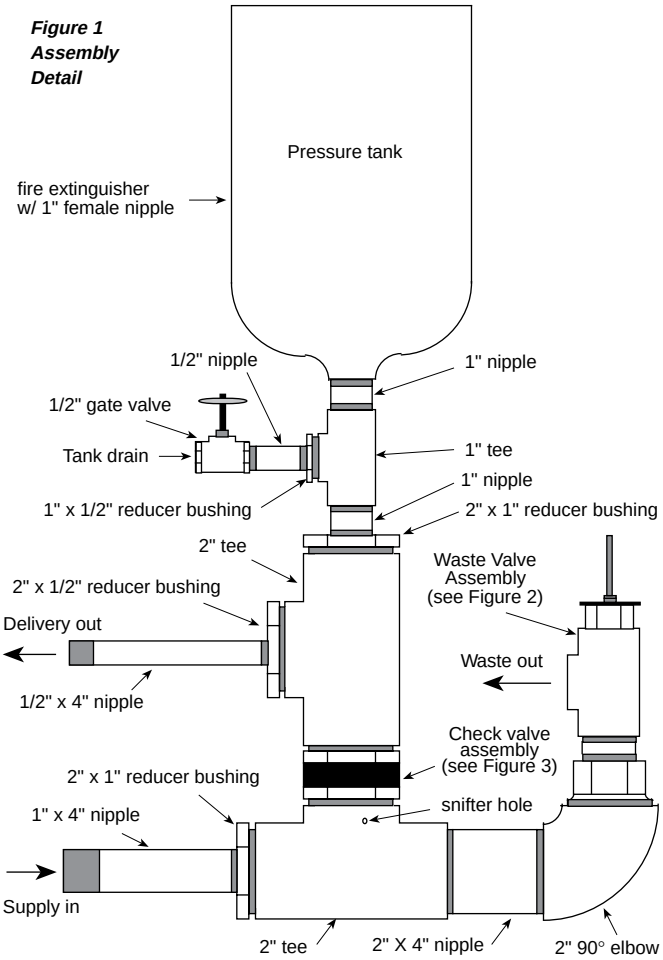

Figure 1 Assembly Detail

Check Valve Assembly

Figure 3 illustrates the check valve assembly. A reducer bushing is used as the valve seat. Drill a 1/16 inch hole in the bushing flange and thread the hole with a #8 tap. From tough rubber, such as a tire, cut a disk approximately 1/8 inch thick so that it fits loosely inside the bushing. Secure the disk with a screw. Cut additional disks to be used as spacers and support between the two bushings. Use Teflon tape on the nipple threads to prevent leakage.

Thick leather makes excellent check valve material, as well. Putting a heavy washer acting as a weight on top of the valve material may also increase the sealing ability of the valve. This washer should be centered over and cover the width of the seat, and can be secured with a short bolt and locknut, with a small washer on the underside.

Figure 3 Check valve detail

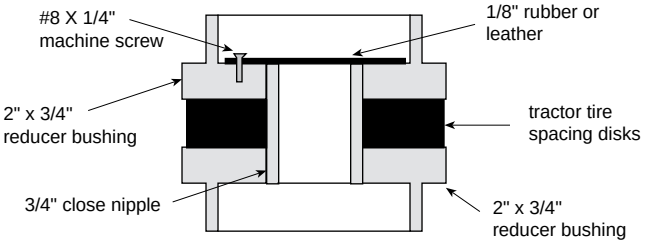

Pump Assembly

Valves, fittings, and pipes are assembled together as shown in Figure 1, using two pipe wrenches. In the same fashion as the check valve, all threaded pipe should be Teflon taped and tightly secured.

A very small snifter hole may be drilled in the tee below the check valve. This will allow air to be sucked into the pressure tank to replace the air that inadvertently mixes with water and exits through the delivery pipe. Many homemade pumps just leave this hole open, but efficiency can be lessened as water squirts out during the ram. Without a snifter, the pressure tank will eventually fill with water and need to be emptied regularly.

One marginal remedy is to put a nail through the hole with the head on the inside, bending the shank on the outside to prevent the nail from being sucked into the pump. Shoot for a loose back and forth fit so that air can be sucked in, yet the head of the nail can close off the inside of the hole during the ram.

Installation, Operation and Maintenance

Both the drive and delivery pipes should have a shut-off valve and union on the pump end of the pipe. The only mounting apparatus needed is a stable pad for the pump to rest (i.e., a board). The pump should be held upright and installed so that the waste valve unit is clear of water and obstruction.

Figure 2 Waste Valve Detail

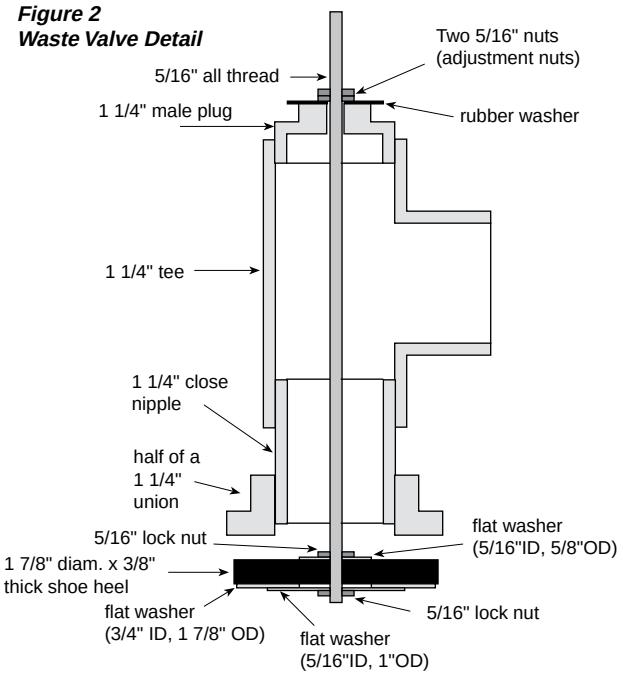

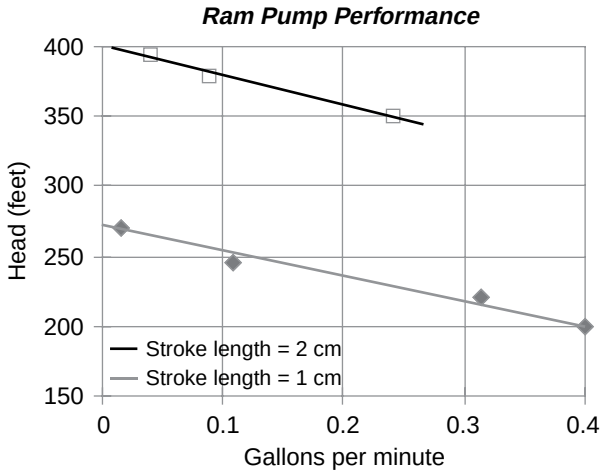

To start the pump, set the stroke length between one and two centimeters and open the inflow valve, keeping the outflow valve closed. Manually open and close the waste valve until it will operate on its own. Wait approximately one minute and then crack open the outflow valve a little at a time. If the pump fails to continue operating, repeat the process, lengthening the lag time prior to opening the outflow valve.

The stroke length can then be experimentally varied to optimize pump output. Shorter stroke lengths work better at lower flows and longer stroke lengths are better for higher flows. A longer stroke length provides a greater velocity in the drive pipe, thus increasing the potential energy in the falling water at the pump. However, more water is "wasted" which may result in possible source depletion.

If the pump is operated continuously without a snifter valve, it should be drained, via the tank drain, before the pressure tank becomes full of water. One should expect to drain the tank approximately once a month, unless you have a working snifter valve. The rubber used in the valves should withstand continuous use for several years. Periodic inspections will help determine when replacement is necessary.

This homemade ram pump is a "folk project", with improvements by each person who built it. If you find new solutions for keeping the waste valve in better alignment, or a good snifter design, please share them.

Access

Louise Finger & Kurt Janke developed this pump through Humboldt State University's International Development Program (see page 78). For information, call 707-826-3619.

Contact authors through Michael Welch, c/o Redwood Alliance, PO Box 293, Arcata, CA 95521 • 707-822-7884 (voice) • 707-822-8640 (Computer BBS)

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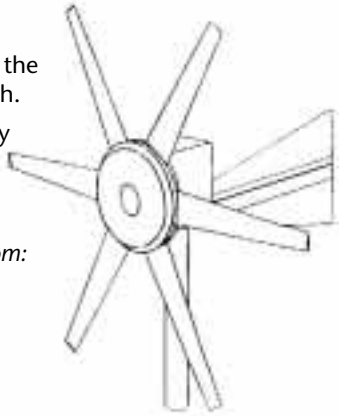

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Things that Work! Alternative Energy Engineering's High Lifter Pump

Things that Work!
tested by Home Power

Test Conducted by Michael Welch

Let me start by saying that I am completely sold on the High Lifter pump for my application. My High Lifter is pumping 240 gallons per day from a 6 gallons per minute spring that is 132 feet downhill from my water tank. The High Lifter is located 26 vertical feet below my spring.

Shipping Container and Documentation

The High Lifter comes well wrapped in a 6 in. x 6 in. x 28 in.cardboard box. Alternative Energy Engineering uses recycled materials for packaging their products. The shipping weight is 10 pounds. Included with the pump itself is an inlet filter, an inlet pressure gauge, a hose for between the filter and the pump, an output pressure gauge, and a ball valve with a check valve for the outlet.

The Owner's Manual that comes with the pump is one of the best written pieces of documentation that I've ever seen. It is 23 pages long and includes: an introduction, typical applications, how it works, how to install it for various situations, an in depth section on maintenance and troubleshooting, performance curves, a trouble shooting flow-chart, an exploded view showing all the pump parts, and a specifications table.

The Test Site

My water system is comprised of a spring which flows into a large 480 gallon settling tank. From there, the water flows at 6 gallons per minute through 3/4 inch Schedule 40 PVC pipe 26 vertical feet to my pump site. The pump then pushes the water up 158 vertical feet through 1" black rolled drinking water pipe (only 1/2 inch pipe is required). The 250 gallon tank at the top is suspended between two sturdy conifers about 20 feet above the taps in my home to obtain sufficient indoor water pressure.

Pumping water without electricity

This pump works great without electricity, without internal combustion, and without noise. This pump will take a steady but small flow of water, and, with a short drop, pump a significant part of the water way up hill to the place it is needed.

Oh, if only all our water supplies were located above the point of use. Alas, it is an imperfect world. Well, then, if only we could afford some of the fine solar water pumping systems that are available. By the time you purchase the pump, wiring and the fair number of PV panels needed, your cookie jar will look like a bottomless pit.

I know two ways to use a downhill flow of water to pump a portion of the water further uphill. One is with the time-tested ram pump. The ram pump lets a flow of water in a pipe build up momentum until the flow causes an impetus valve in the pump to slam shut. The water, still wanting to exert its moving energy, is channeled into a chamber containing air, which is compressed by the force of water. The compressed air bubble in the chamber then expands to push a small amount of water out a second pipe going up the hill to the point where water is needed. The pressures inside the pump are then equalized, allowing the impetus valve to

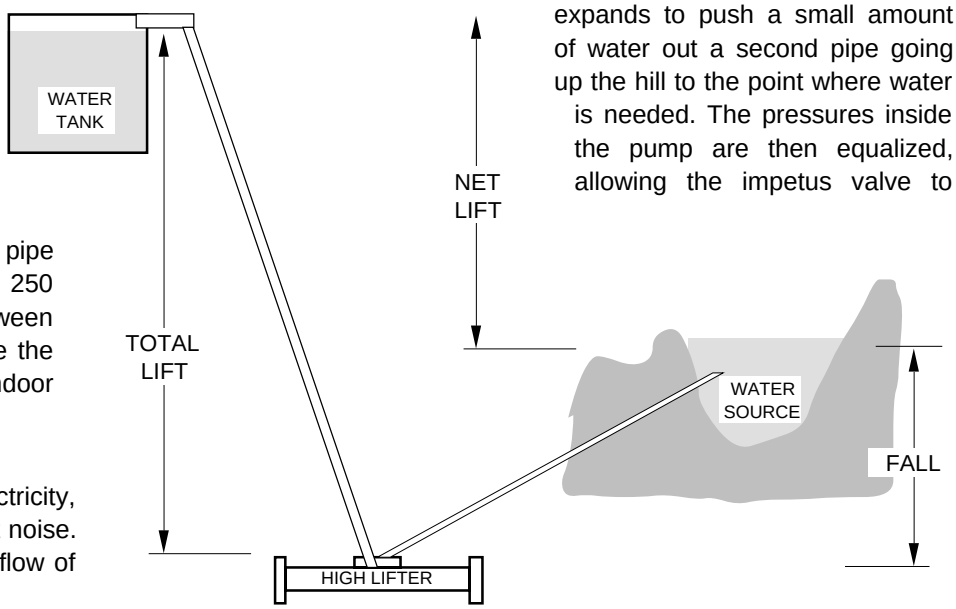

open again thus starting the downhill flow moving again, and the cycle repeats.

The second method is with the relatively new High Lifter. The High Lifter uses head pressure instead of momentum in a downhill pipe. It uses a larger volume of low-pressure water to pump a smaller volume of water at a higher pressure. A larger piston acts with a smaller one to gain mechanical advantage, a kind of "hydraulic lever." A collar inside the pump controls the inlet valve. As the pistons reach the end of their stroke, they contact this collar, pushing it until it directs a small amount of "pilot water" to the end of the spool in the pilot valve, thereby shifting it and changing the direction of the water flow in the pump. The flow moves the two-way pistons in the opposite direction until they again contact the collar, which shifts the pilot valve again, and the process repeats. Thus the pump's innards travel back and forth as it pushes water way up the hill.

High Lifter Specifications

The cylinders are made of stainless steel, the valve body and head materials are machined from acrylic, and the pistons are made of high quality nylon. The total width is about 4 inches, length 26 inches, and the pump itself weighs about 5.5 pounds. The High Lifter is obtainable in two volumetric pump ratio models, 4.5:1, and 9:1, and changeover kits are available to switch back and forth. The higher the volumetric ratio, the greater the pumping pressure and the lower the output flow.

FOR 4.5:1 VOLUMETRIC RATIO PUMPS

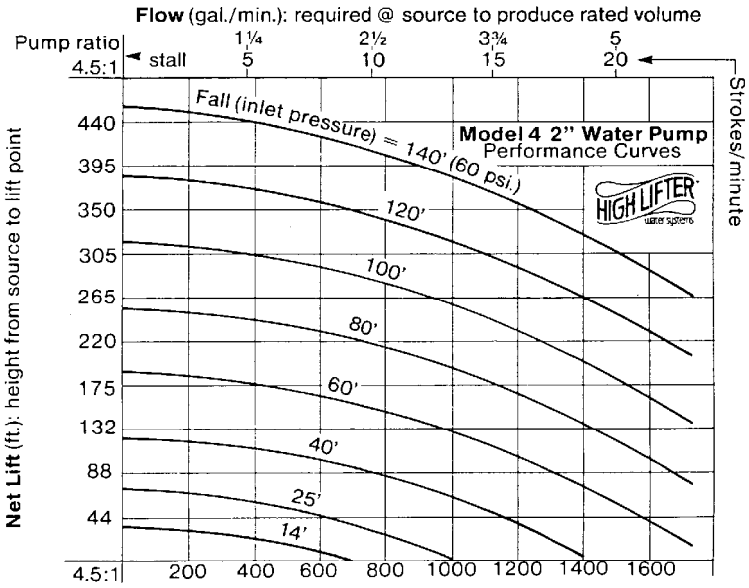

1 psi = 2.3' **Delivery** (gal./day): assuming adequate water @ source

FOR 9:1 VOLUMETRIC RATIO PUMPS

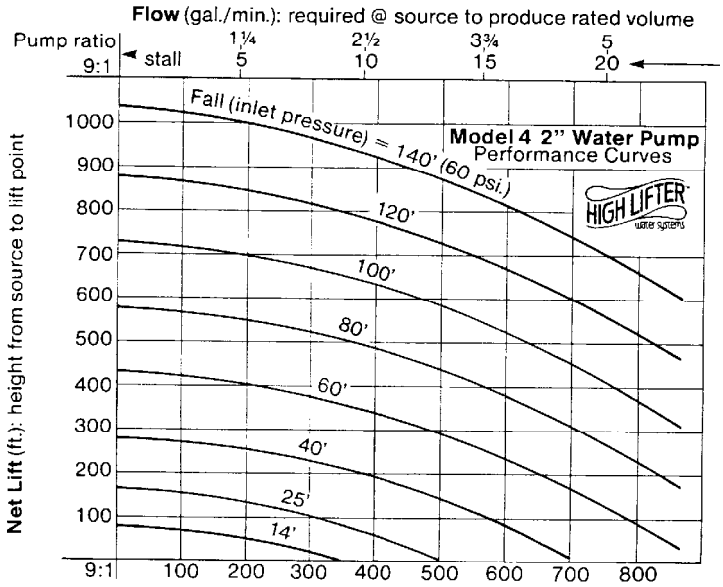

1 psi = 2.3' **Delivery** (gal./day): assuming adequate water @ source

Typical applications

According to the Owner's Manual, the High Lifter can deliver up to 750 or 1500 gallons per day, depending on the model. It can be used with flows as little as one quart per minute. It can achieve net lifts of up to 1,100 feet, depending upon the circumstances. In situations of low fall and high lift, two High Lifters can be used in series.

High Lifter Performance

When I took delivery of my High Lifter, I had nothing but problems. I thought I would be unable to recommend the pump in "Things that Work" because my test site seemed to put to much of a strain on the pump, causing it to stall out with regularity. After trying "everything in the book", and some things that weren't in the book, I took the pump back to Dave Katz's pump experts at Alternative Energy Engineering. (I like going there anyway because they have so much neat renewable energy stuff to look at.) There we discovered that some of the earlier pumps had been assembled with too much silicone glue between the barrel and the valve body. The excess silicone had slopped over to partially plug the pilot valve holes. They gave me a recently rebuilt pump since they didn't have a new one ready to give me.

I installed the newly rebuilt pump, and 30 hours later I checked my previously empty tank. I was totally amazed to discover that the 250 gallon tank was completely full! At that point I began keeping track of the flow: it was an remarkable 240 gallons per day. Two weeks later the

flow had decreased to 218 gallons per day so I cleaned the inlet filter. Now that the pump was broken in and the filter cleaned, my flow increased to 294 gallons per day! It seems to have settled in at between 220 and 300 gallons per day, depending on how clean the input filter is.

High Lifter Advantages

The advantages of the High Lifter over the ram pump are numerous. The pump is more efficient in that it uses less water to pump a given amount uphill. Additionally, it is a far piece quieter than the constant and very noisy KA-CHUNK of the ram, and it is quite a bit lighter and easier to move around than the ram. Last, but not least, the High Lifter will operate with relatively thin wall pipe in the input, whereas a ram, because of the intense and constant hydraulic hammering caused by the sudden closing of the impetus valve, requires solid mounting and steel pipe to keep from breaking apart joints.

The High Lifter is not without its disadvantages, though. It has a complex array of pilot valves and check valves, and relies heavily on close tolerance seals. Unlike the ram pump, water must be completely free of sand and grit lest the barrels and seals become scored allowing leakage. The High Lifter comes with a filter which takes out much of the harmful sized particles which may flow from your water supply. The filter must be cleaned regularly to avoid loss of inlet pressure. If a lot of foreign matter flows with your water, then the High Lifter may not be for you.

The Owner's Manual states that there is a danger that a hard knock to the valve body could cause a misalignment, but personal experience proved that it takes 2 large, strong people to successfully dislodge the glued and strapped valve body from the barrel.

Conclusions

The High Lifter has far exceeded my expectations, and definitely lives up to its promises. It is worth the $750. price tag, which includes access to the manufacturer who is willing to go the extra distance to help their customers.

Access

Author: Michael Welch, C/O Redwood Alliance, POB 293, Arcata, CA 95521 • 707-822-7884.
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No reason not to run your battery system at 120VDC, Ben. Just keep in mind that all your switches, fuses, etc., must be rated at 150 VDC or better. 120 VDC is just a nominal battery voltage. The actual voltage of a fully charged 120 V battery system will be pushing 140 VDC or more. Finding a 120 DC to 120 ac inverter is a little trickier. Try Chad Lampkin at Michigan Energy Works- (616) 897-5161. By "mechanical" I assume you mean a motor/generator type? They do work and have the added advantage of producing a true sine wave, but are pretty inefficient compared to today's FET based units.

Running a water pump "backwards" in a closed system as you describe can produce power, but unless we're talking about lots and lots of water, not very much. The push-pull that you describe only works if the water is flowing freely out the bottom end of the line at near zero pressure. That's fine if you are just using the water to fill a pond or something, but if you expect to use the water under pressure, you would be better off directing the tailwater after it freely exits your runner into a catchment and starting over from that point. - Bob-O

Solar Help

Dear HPM Staff, Thank you for this great magazine! Please renew our subscription for two more years.

We have been off the grid since 1974 and we have been using solar electric since 1982, and we love both. My husband is disabled with multiple sclerosis. He has been working on some solar electric devices to help other disabled people be more independent in the backwoods. As I am pressed for time I will not elaborate now, but if anyone is interested I will gladly write more. Sincerely, Lu Marie & Michael Strickland, Dearborn Solar Electric Co., Rt. 1 So., Box 2364, Cascade, MT 59421

We salute you, Michael & Lu Marie. Independence enriches any life, renewable energy enriches the earth. Keep us up to date on your projects - Kathleen

Ram Pump

Dear HP, I read with interest the article in HP #23 on the high lifter pump. I agree that in many applications this pump is the best way to go. However, in the list of advantages there are some not always true statements. While in some situations the high lifter would be more efficient than a hydraulic ram, this would not be the case if the ram were installed correctly. I operated a business here in Missouri building, servicing and installing hydraulic rams for 10 years and am known as the local ram expert. We have used hydraulic rams to pump our water since 1979 and still do. The hydraulic ram water pump was invented in the late 1600s and is still used, mostly in developing countries where power is not available. In 1979 I attended a workshop on hydraulic rams at New Life Farm in Drury, Missouri where we designed, built, and tested over 10 different hydraulic rams. The efficiency of most rams we built was over 80%, with one model having an efficiency of 95%! The efficiency was measured by measuring the amount of water used to operate the rams times the feet of fall used to operate the ram to give us the number of foot pounds of water used. We then measured the pounds of water delivered times the height the water was pumped to give us the foot pounds of water pumped. Dividing the foot pounds delivered by the foot pounds used actual efficiency was obtained.

For example, one test used 40 pounds of water per minute with a supply head of 6 feet for 40X6=240 foot pounds of water. The pump delivered 5 pounds of water to a height of 40 feet for 5X40=200 foot pounds of water. The efficiency was in this case 200/240=83% efficient. Most pumps scored 90% or better. The only one less than 80% was the plastic pump published many years ago in Mother Earth News which didn't work at all, probably due to poor construction or materials. I used the design we decided on as the best for 12 months here at home using 15 feet of head pumping 75 feet before the impetus valve required replacement.

Using the figures in the article to calculate the efficiency of the high lifter as follows. Six gallons per minute and 26 feet of head gives 6X26=156 gallon feet of water used. Delivered is 0.166 gallons per minute and 132 + 26 = 158 feet height gives 0.166X158=26 gallons feet of water delivered. The efficiency for this application is therefore 26/156 = 17% efficient.

I definitely do not want to imply that the high lifter is not a good pump. I can see that in many cases it would be a better pump than a hydraulic ram. It does have many other advantages as listed in the article. An efficiency of 17% is actually very good for this type of pump. The efficiency of hydraulic rams can be this low or lower if improperly installed or if there is something wrong with the ram. If anyone has trouble with their ram feel free to call me at 417-683-3570. Written responses please include a stamped self-addressed envelope and $10 per response. For plans to build a ram from metal pipe fittings send $5. Dave Luckenbach, Rt 1 Box 393, Ava, MO 65608

Solar Anthem

Dear Home Power Persons: Here is the new Official National Anthem of the Solar Power Movement. The song is intended for solo and group singing at all gatherings of

will have to wait and see how they are coordinating the subscriptions with you folks.

Sometime this next year I will be adding solar to heat our water but currently I'm just looking to see what's out there. One thing I have noticed is all the units use electricity as a backup. Why no gas fired units? Probably I will put in a system with no backup, just a 120-gallon storage tank, and installing some of the inline on-demand tankless water heaters to make it hotter if necessary.

Also inclosed is a copy of the reader survey from HP#27, my 1st issue to warrant a mailing label. To add an additional option I would be willing to pay $20-$30 for B&W reprint of the original masters of issues 1-10 if it were offered. In the survey you don't make it clear what dollar amounts by each format choice mean. Are they your costs or approximate costs to the purchaser. Assuming your costs I'd say $30-$50 is what I'd pay. If just estimates I'd drop to $20-$35.

Just got my copy of the 1990 Alternative Energy Source Book from the folks at Real Goods and recognize many articles as reprints from Home Power. I was especially pleased to find an article from Richard with Lead-Acid charge/discharge curves. Good luck to all and keep up the good work.

P.S. On page 28 of HP#27 the picture was printed upside down so left and right are reversed. Oops. Don't let it bother you too much most people will spot it and occasional slips like that remind us we're human and to watch out for Murphy. Michael Kline, 2932 Hyder SE, Albuquerque, NM 87106 • 505-277-8148-Work, Internet mail - mikep@triton.unm.edu, bitnet mail - mike@unm

An easy way to tell if you're getting burned on the "C cell in a D cell" package scam is by weight. Heft the 2 D cell package in one hand and a 2 C cell package in the other. The D cells should be noticeably heavier. If not, the fix is in. Bob-O

Hi, Michael. We too noticed that DHW heat exchanger tanks are only fitted with electric power for backup, not propane. Consider using the less efficient tube-in-tube heat exchanger to interface with the propane hot water heater/tank. Be sure to insulate the exchanger/pipes well, and use a circulating pump on the exchanger/propane heater loop. The Thermomax setup in Bob-O's home uses this technique to interface solar heated water with a propane fired backup. Richard

Hello, Michael– Thanks for returning your survey (there's still time for those of you who have not!!) The prices are guestimates of cost to you, the reader. The next issue of HP will have the findings from the survey. We noticed the reversed photo, too; the printer was a little rushed last issue. Ah well...Therese

High Lifter Pump Data

Dear HP: As the author of the "Things that Work" article on High Lifter pumps (HP#23), I'd like to respond to the letter from Dave Luckenbach as published in HP #26. Dave's letter put into question the efficiency of the High Lifter as opposed to ram pumps.

First of all, there was an error in the way I described my test site. I stated that 6 gpm flowed through my supply pipe to the High Lifter, and Dave's efficiency calculations were based on that amount being used by the pump. Actually, at that time, 6 gpm was flowing into my settling tank from my spring but only a small portion of that was needed to supply the High Lifter. Further development to improve the cleanliness of my spring water reduced the flow to under 2 gpm, still more than enough to feed the High Lifter.

I went back and did some more measurements to come up with an efficiency figure for the pump, which ended up being 78.6%. First I shut off the supply to the pump and carefully measured the total flow from my source tank, then I restarted the pump and measured the unused overflow from the tank. Subtracting, I deduced that the pump was using 1.19 gpm as its supply. Next, I measured the pump output at my storage tank above my house to be 0.154 gpm. I then calculated pump efficiency according to Dave's method: 1.19 gpm x 26 ft. head = 30.94 gallon feet of water per minute used; 0.154 gpm x 158 ft. delivery height = 24.33 gallon feet per minute of water pumped. Therefore, 24.33 / 30.94 = 78.6% efficient.

Second, based on my experience to date, the High Lifter pump appears more suitable than ram pumps in low flow situations. The pump I used previous to the High Lifter was a Davey ram. This pump needed the entire 6 gpm my spring originally put out, and still would pump less than 175 gallons per day or 0.122 gpm. Admittedly this pump's impetus valve was very worn from years of debris flowing through it, and not a fair representation of a new ram pump. In recent months I have been testing a new, commercially available ram pump installed according to manufacturer's instructions, and have not been able to make it run on less than 2 gpm. I have not, however, given up on its potential for applications similar to mine. As I continue to experiment with non-electric pumps, I'll keep you posted on positive results.

My conclusion is that a ram pump is likely to be as or more efficient in higher flow situations, but the High Lifter

appears to be more appropriate for those of us with low flow situations and debris-free water supplies. Michael Welch, c/o Redwood Alliance, PO Box 293, Arcata, CA 95521 • 707 - 822 - 7884

Hydromaniac

Dear friends; I haven't even finished reading your magazine and I'm already subscribing. I am enthused to read about different aspects of hydro usage as I am a hydromaniac. In the 5 years that I have been using our hydro, I have come from "So what is an amp?" to redesigning our entire system with my partner. I've had many challenges such as chipping ice out of a frozen hydro at minus 30°F every day for a week and yearly, climbing into and cleaning out a 4' deep, 3' wide well casings full of silt and debris. Being a conservationist, I decided to use an existing system which was anything but optimum. Thanks to my partner and Steve Willey (Backwoods Solar), my spirit endured and our power grew. Your magazine is inspiring as well as informative to a lay person as myself. For me, being self-reliant and respectful of Earth means using her resources efficiently and purposefully. I would like to see articles about the spirit that drives us to be inventive, visionary and enduring in our goals of living harmoniously with Nature. Abundantly, Noreen Wenborne, 9465 Rapid Lightning Rd., Sandpoint, ID 83864

I have admiration for you, Noreen. You have obviously grown in the last 5 years. In response to your comment about the spirit of RE users I think you will be interested in the following letter. - Kathleen

IEAN

Dear Home Power Editor: Please allow me to introduce myself. My name is Carolyn Erler. I am director of Independent Environmental Artists Network, a new organization dedicated to people who work with environmental elements as art, and who primarily do this on their own time, i.e., most are not actively seeking publication of their works, but are in need of correspondents for feedback. As for our members, a willingness to communicate, an enthusiasm for pooling ideas and sharing experience, is the only requirement for involvement. We are people – artists, though representing a rich diversity of professional backgrounds – who are not only exploring the boundaries of what constitutes an art form, but are also striving to assume a broader role in regards to the whole of nature.

Being that the term "environmental art" seems to mean so much to so many these days, it would no doubt be helpful to you if I specified the kind of creative worker IEAN is seeking – although, please, what is mentioned below should be taken merely as a set of focal points.

• Home-made passive energy installations: appliances, dwellings, related creative conceptualizations. • Creative stonemasonry. • Micro/macro organic and-or "found" architecture. • Original thoughtwork regarding that which may, in an enlarged sense, be seen as aspects of an overarching, autopoetic Geo-art. Some examples: rock metamorphism, the carbon cycle, petroleum formation, chemosynthesis, space lattices, symbiotic alliances, microbial mats, dissipative structures, bioluminous cells – the universe is the limit! We seek active, enthusiastic correspondence among workers in these general fields. The working goal of Independent Environmental Artists Network is for it to evolve into an art itself. This means an on-line art composed of creative workers communicating, resonating, breaking out of old patterns of competition and silence.

While searching for various avenues through which possible contacts might be found for IEAN, I was made aware, through the Planetary Association for Clean Energy, Inc., of Home Power magazine. As a service both to myself and to those associated with IEAN, I was wondering if you might be able to send us any material (resource/address lists, sample issues, etc.) which could prove beneficial to this community of creative workers. Also, if you happen to know of someone among your friends and associates who is working in one of the above-mentioned areas, please urge them to write me at the address below.

Thank you for your time, and for whatever you might be able to send our way. Sincerely, Carolyn Erler, Director, Independent Environmental Artists Network, POB 396, Rochester, New York 14603

Consider the word spread, Carolyn. - Kathleen

Working System

Having installed and maintained a stand alone system here for 3 years, I am glad for any opportunity to share what I have learned with others interested in home power. You can give my name, address and number to anyone in this area wanting to see home power. An electric vehicle has to come next!

You serve as a guide and mentor for me as for so many others. Each issue an inspiration - when HP comes in the mail becomes for me a moment of rededication to earthkeeping. Thanks, Rich Meyer, 13416 CR 44, Millersburg, IN 46543 • 219-642-3963

Thank you, Rich. Here is the name, address, and number for interested parties near you. - Kathleen

RANGE OF FUNCTIONS OF TRADITIONAL STOVES.

Rural: the open fire

Most common is the 3-stone fireplace, although sometimes the stones are ridged clay mounds. Some places have instead metal triangles with legs, or iron bars held by four clay mounds (Gill 1982) to support the post, or three legs on a cast iron pot. Sometimes the fire is sunken (Kapiyo 1982) and various other ways of shielding the fire and/or pot with mud have been developed in many traditions.

The open fire can:

burn wood, dung, agricultural waste;
provide light;
accommodate different pot sizes and types of pots.

Also such a fire can be:

portable;
of little or no cost;
used to dry wood stored overhead or alongside;
used to preserve grain stored overhead with its smoke.

Finally,

its heat output is easily variable and pots can be positioned around the fire to keep food warm;
its smoke keeps away mosquitoes;
most fires can cook many pots;
and it is often a social or ritual focus.

Urban: Metal Charcoal Stoves

Small portable combustion devices for cooking are often made from scrap metals. They contain a grate for fuels that require it and are often found in rural homes (that can afford it) as a supplementary cooker. It is known as the Jiko in East Africa and the Fourneau Malgache in West Africa.

Some of these stoves were introduced only this century, but are widespread and ingrained enough in the cooking practices to warrant the status of tradition.

Characteristics: urns charcoal, maize cobs, coconut shell, wood, dung, briquettes;
portable: can be lit outside and brought inside when smoke has subsided (often done by children);
can be placed in different parts of the kitchen for safety or convenience;
requires less attention re-fuelling and controlling temperature than woodstoves;
provides warmth;
easily repaired or replaced (both inexpensive and higher quality are available);
can roast food.

Other stoves have been developed to burn specific fuels, such as sawdust, and many adapted for special purposes such as brewing beer, which requires a large volume to simmer for long periods of time.

DESIGN FEATURES OF NEW STOVES

To assess the suitability of a new stove or the functions and performance of an existing stove, it is helpful that a classification system be devised and utilized during assessment.

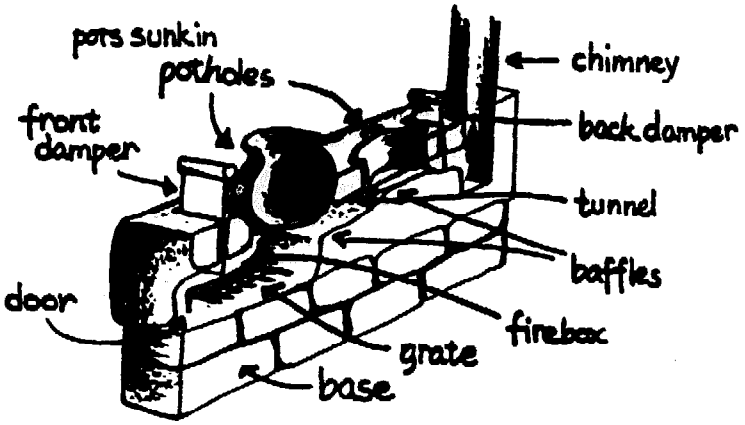

CUTAWAY VIEW INTO A COMPLEX 2-POT STOVE

Fig. 7.

Stoves and fireplaces come in many shapes and sizes. A range of materials and methods is used to make these stoves. Some stoves are purchased from artisans and some are made by members of the family. Some are fixed, some are portable. Stoves can have chimneys and grates in the fire box; others are little more than shields. Stoves and fireplaces can accommodate up to five pots of different sizes; some can only accommodate one pot. Some stoves have special devices (dampers) to control the flow of air - these can be placed at the entrance to the stove, between the pot-holes, or in the chimney. Some stoves have baffles to help increase heat transferred to the pot. Some stoves are specially designed to burn one fuel, others burn a range of fuels.

Two features that significantly affect the cost, acceptability, performance and method of dissemination of stoves are the number and type of pot seats used and whether or not a chimney is used. Key characteristics of stoves on the basis of these two variables are described below.

Single Pot Stoves

a) Single Pot Chimneyless Stoves are known as shielded fires (de Lepeliere 1981).

i) Burning woody fuels

Shielded fires can either accommodate one size of pot or a range of pot sizes. They can be portable or fixed. A shield is placed around the pot to both direct hot gases up the pot sides and prevent heat escaping from the pot. Fuel savings are greatest on stoves that take one size of pot that sits right into the stove. It has been found that the fuel savings are largest when a grate is used. To reduce smoke it is necessary to determine accurately the number and position of air holes in and above the grate. Using a

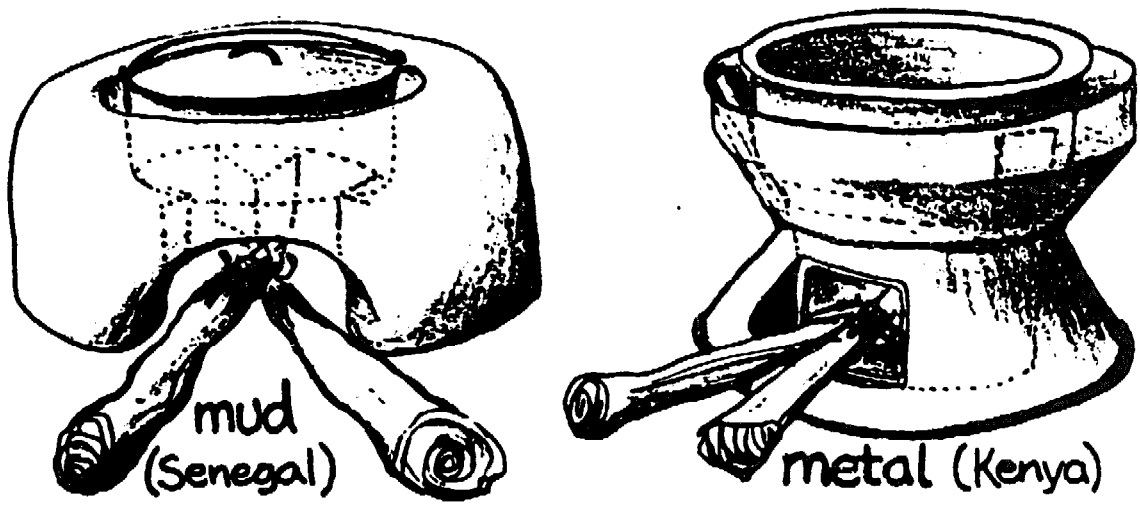

Fig. 8

grate reduces the amount of charcoal produced during cooking. It should be noted that the charcoal is often required for ironing and grilling or is used in the stove to simmer the food slowly. Thus stoves with grates may not be acceptable to some people. The performance of the stove does not seem to vary significantly if the distance between the pot and the shield and the grate and the pot is varied by 1 or 2 centi-

metres. These stoves can be used as ovens by placing an insulated lid on the top, and shutting the door. Stoves that accommodate a range of pot sizes can also fry as well as stew. The stoves can be constructed to provide light and allow the users to see the fire.

Simple mud or stone shielded fires can easily be made by the users, whereas metal or pottery must be made by artisans. Metal shields are made either by artisans or in small workshops. All these stoves are by far the cheapest to produce and appear to be more easily disseminated in large numbers in the African context (Madon, 1982; Thomas et al, 1983; Yameogo et al 1983). However, they are not smoke free (although often combustion is improved) and the portable stoves must be fixed if they are to be stable. Supporting pots that sit right into the stove is difficult, and it is necessary to have some type of fixture that wedges the pot in place for vigorous stirring. Single pot stoves are more appropriate when one dish is cooked at a time. If two or more dishes are to be cooked simultaneously it is necessary for the family to purchase two stoves. Metal stoves that are uninsulated can give considerable warmth to the room, where insulated stoves do not.

Shielded fires are most suitable when:

- people cook outside or in well ventilated kitchens
- more than one cooking area is used regularly;
- one dish is cooked;
- heating is required;
- mass dissemination/fuel conservation is the prime objective.

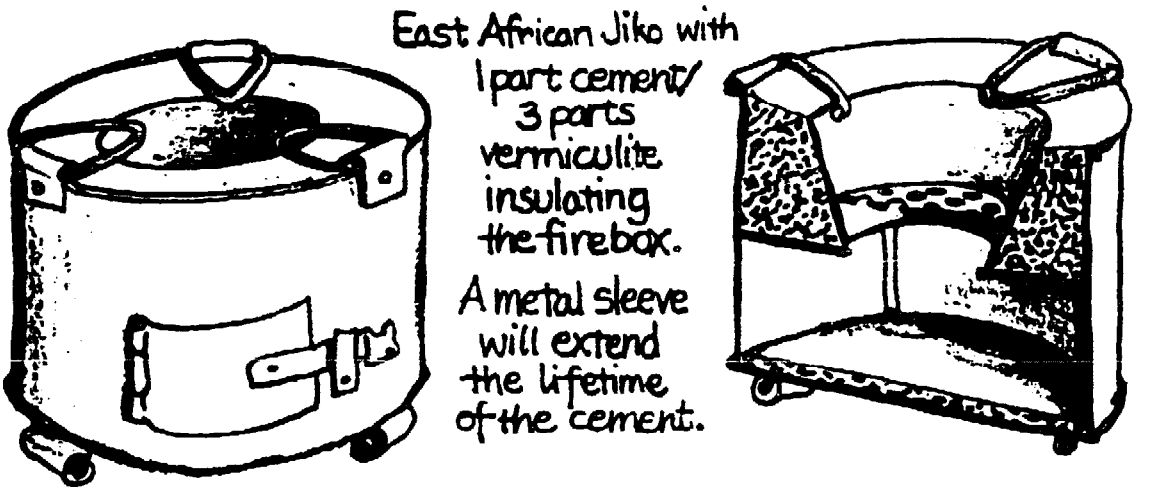

Fig. 9.

ii) Burning charcoal

Stoves that burn charcoal can be upgraded by placing either a metal, clay liner or cement and vermiculite liner inside. The pots can either be sunk inside the stove or sit on top of the stove. Sinking the pot inside the stove increases the fuel efficiency, but decreases the flexibility and ease of operation of the stove. Stoves that are insulated with clay, mud and cement and vermiculite do not radiate as much heat as those with only metal walls. However, a field survey of the Umeme stove carried out by the authors indicates that the heat retained by the stove with mud between the walls helps decrease fuel consumption for long periods of cooking. In Kenya, despite the fact that improvements on existing metal charcoal stoves double the cost, the payback period for a user (in terms of reduced expenditure) can be as little as two months.

b) Single Pot Chimney Stoves

These stoves usually accommodate one pot that is sunk into the stove. The pots usually have a diameter greater than 30 cm and thus are used by institutions and very large families (Micuta, 1983). If the pot is not sunk into the stove,

the fuel consumption and time to cook will be similar to a well tended open fire, that is shielded from the wind. The performance is similar to a shielded fire. However, they can accommodate much larger pots. These stoves can be portable or fixed depending on the material used and whether the chimney is fixed into the building. The stoves are very stable and if they are made with an insulating material are safe to use. The stoves must use a grate so that a range of fuels can be burnt. Careful control of the primary and secondary air can be achieved. These stoves can boil or fry (but only in the pot provided) and it is possible to bake inside the firebox.

Fig.10

These stoves must be made by skilled artisans, as it is important that the internal sizes and position of the baffles be accurate. They will be considerably more expensive to produce than a shielded fire. These stoves take at least twelve hours to build.

If a chimney is to be installed in a house it will be necessary to have a trained person provide this service (chimneys are covered in detail in Joseph 1983c and Micuta 1981). The maintenance requirements are higher than those for the shielded fire especially if a chimney is used. It is probable that the performance of this stove will be more susceptible to poor construction and maintenance than the shielded fire.

They provide little light and if insulated provide little warmth.

Single pot chimney stoves are appropriate when:

- only one pot cooking is performed and the pots used are large;
- it is a priority to remove smoke;
- enterprises can be established or artisans trained to produce the stoves;
- a regular maintenance service can be established or sufficient resources are available to train owners;
- light and heating are not requirements.

Two-Pot Stoves

These stoves can be made from all types of materials, but experience has indicated that metal should be used in conjunction with other materials and not used alone.

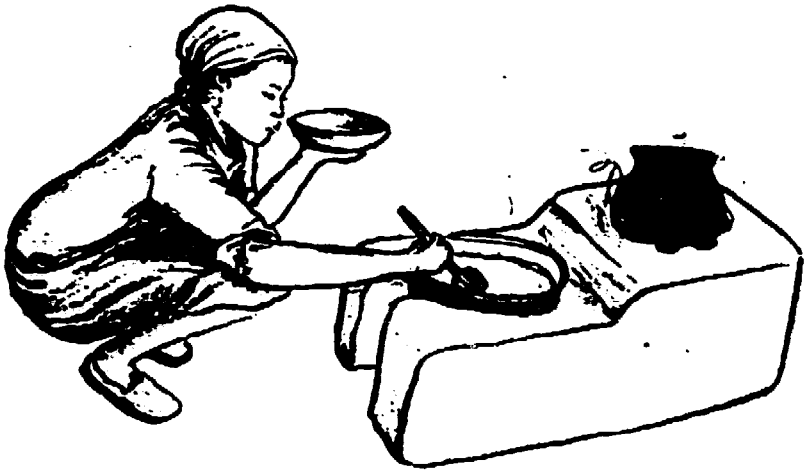

Fig. 11

a) Two pot chimneyless stoves

At present all stoves that have proven acceptable have pot seats that take a range of pot sizes. The two pots are usually sunk into the stove and the exhaust gas flows around them.

The stoves can be fixed. They are carved or moulded in situ (usually from mud) or pottery components are acquired, placed in the desired position, and surrounded by mud. Portable ceramic stoves of this design have proven popular in Indonesia (Kaufman 1983). These stoves do not need a grate but require a number of secondary air holes in the firebox. It is extremely important to construct these stoves accurately if optimum performance is required. The fuel consumption of these stoves is higher than the single pot stoves (where the pot sits inside the stove) (Yameogo 1983). If only one pot is used on a two-pot stove, then the performance of the stove is similar to or less than the well tended open fire. These stoves can provide light and heat by building the stove with an open front, which does not significantly lower the performance. Because of better combustion and the rear exit passage, the smoke is often reduced and released away from the user. It can also be used to dry wood and crops, keep out mosquitoes, and provide some indirect room heat.

These stoves can be made from mud or from fired clay inserts surrounded by mud. If made of mud these stoves can be manufactured both by skilled artisans or well trained groups drawn from the local community. A skilled potter can make 100 insert sets per month using a pottery wheel or about 200-300 using moulds. Alternatively a small ceramics industry can turn out the stoves using either moulds or simple presses.

The mud stoves need frequent cleaning and repairing, and the pottery stoves frequent cleaning, if the performance is to be maintained. Two-pot stoves can produce significant amounts of carbon monoxide and therefore should not be used in a closed room.

These stoves are usually more expensive and take longer to build than the single pot chimneyless stove because they are much more complex.

Two-pot chimneyless <u>mud</u> stoves are most suitable when:

- people want to cook two dishes at once;
- smoke reduction is of some importance but where its use is also of importance;
- users have a tradition of regular repair and cleaning of stoves;
- alternative more long lasting materials are not available;
- resources are available to:
  - train and support artisans to build and regularly service the stove (and where people are willing to pay for their service
  - train users to clean and make minor repairs.

Two-pot chimneyless <u>pottery</u> stoves are most suitable when:

- mass dissemination/time savings/fuelwood

savings are the principal objectives;

- pottery producers are highly skilled and available;
- people have the money to purchase (or subsidy is available);
- owners can be trained or encouraged to clean their stove.

Fig.12

Two Pot Chimney Stoves

There are a large number of stoves that have been designed using this basic configuration. Pots, of a fixed size, can be sunk into the stove. The stove can be designed to take a range of pot sizes that sit on top, but the performance of this stove is considerably lower than the stove where pots are sunk into the stove, and than that of the two-pot chimneyless stoves. The stove can be transportable if made of metal, mud and metal (see the Pogbi Stove illustrated at the end of this section), cement sections or ceramics and the chimney is less than two metres high (although a donkey cart is usually required to move the Pogbi stove). The largest segment, the stove body, weighs 200 lbs. Some of these stove models use a grate. It would appear that Pogbi

type stoves have a higher performance, but they are more expensive and more difficult to maintain (cleaning the chimney is not easy). The amount of air entering the stove is often controlled either by a door at the front or by using a damper placed between the chimney and second pot seat. These dampers are usually made of mild steel sheet and are often lost or corrode very quickly. They are rarely effective. Baffles are usually placed under the second pot to increase the amount of heat transferred to the second pot.

The size of the internal flues and the distance between the baffle and the second pot will depend on the height of the chimney and the type of fuel, its size and moisture content. If the stove is not made accurately to a predetermined size the performance will be significantly lowered.

The stoves can boil, fry, and possibly bake in the firebox. The models where the pot sits closer to the top of the stove can be opened at the front to provide light. If the stove is made of metal and not thickly insulated, it can provide heat.

Depending on the material, these stoves can be made by artisans or in small industries. The stoves can be made by groups involved in community development (if they are well trained). The time taken to build these stoves depends on the material used and the height of the chimney (and whether it is fixed into the house). A portable metal stove can be built in 2-4 hours; a pottery insert stove can be built and installed in 8 hours; and a mud stove in 8-20 hours.

Both pot holes must be covered while in use

difficult to make and use the chimneyless stove. Insulated stoves will provide little heat. These stoves must be well maintained and cleaned if they are to give significant savings in fuel.

Two-pot chimney stoves are suitable when:

- two dishes are to be cooked simultaneously;
- smoke must be removed from the room;
- skilled artisans or small enterprises can manufacture and possibly install the stove;
- resources are available to train users or establish an enterprise to repair and maintain the stove;
- light and heating are not required.

Other design features that can be incorporated into a stove include raising the stove off the ground, ovens, and special racks for drying.

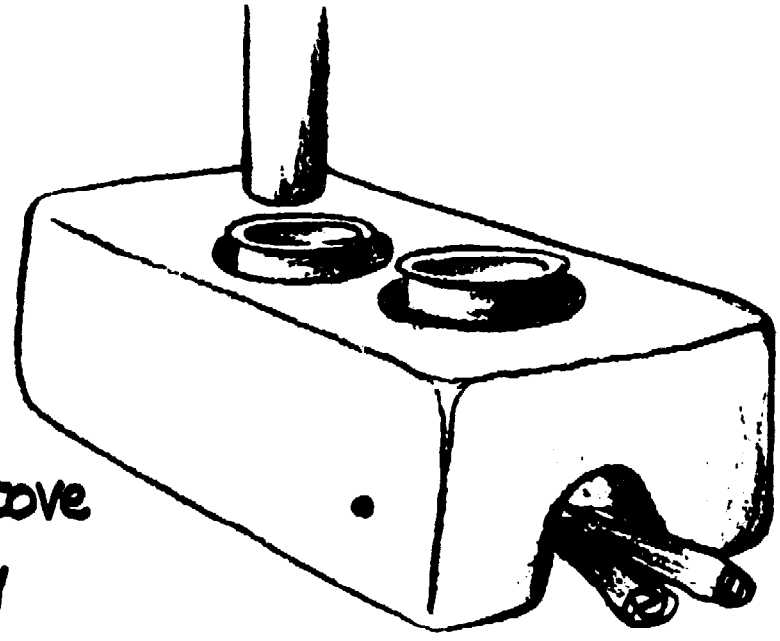

2-pot mud stove with chimney

Fig.13 .

MATERIALS

The overriding feature of a stove which affects

the cost, method of construction, the durability and, to some extent, the performance (and the change in performance as the stove ages), is the material or materials used to build the stove. The change in performance as the stove wears (and how this is affected by repair) is given in the first of the following charts. The effect of stove lifetime on the numbers of stoves distributed is given in the charts underneath (as calculated by K K Prasad, 1982).

The main materials that have been used in urban areas to manufacture stoves are steel, fired clay and cement. In rural areas the main materials have been stone, mud and fired clay.

THE MOST ACCEPTABLE STOVES HAVE COMBINED THE BEST QUALITIES OF TWO OR MORE MATERIALS IN THE DESIGN.

The important aspects of choosing and working with each material are presented below.

Metal

Many of the urban wood and charcoal burning stoves in Eastern Africa are made from metal. The main supply of metal is scrap, the thicker gauges (1.5mm thick) are obtained from oil drums and the thinner from 'tin' boxes. The lifetime of a thicker gauge stove (in constant use) is 18 to 24 months. The thinner gauges have a much shorter lifetime.

Grates are normally made from thicker material than the stove body, and have a lifetime of six to nine months. In Sudan strip steel from packing cases (a very strong steel) is woven to provide a much more long-lasting grate (see Fig. 16).

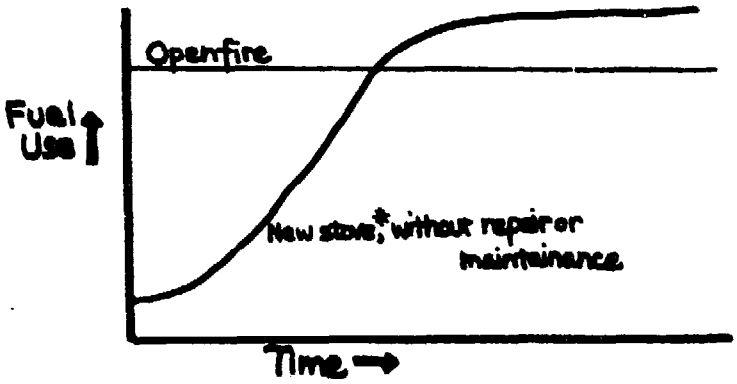

*Actual curve depends on type of stove. Repairs will also significantly alter the curve.
Based on information gained in Indonesia by ITDG.

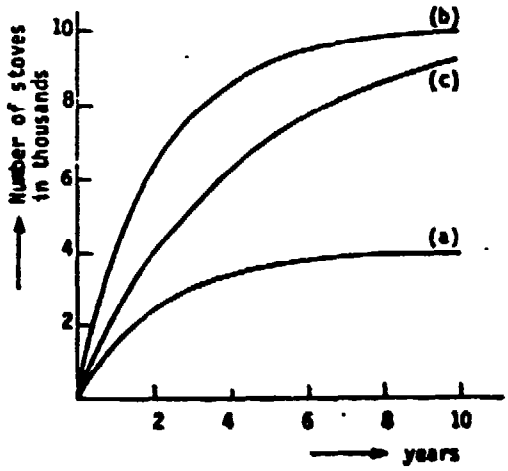

Fig.14 Operating stove population growth with time for a long-life stove design

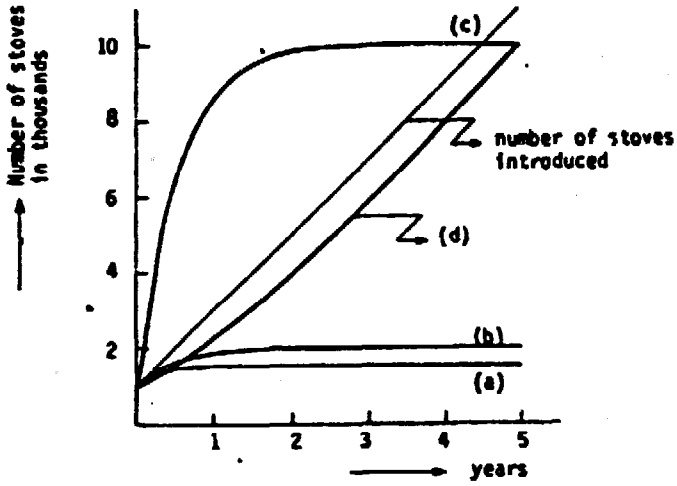

Fig.15 Operating stove population growth for a short-life stove design

Fig. 16

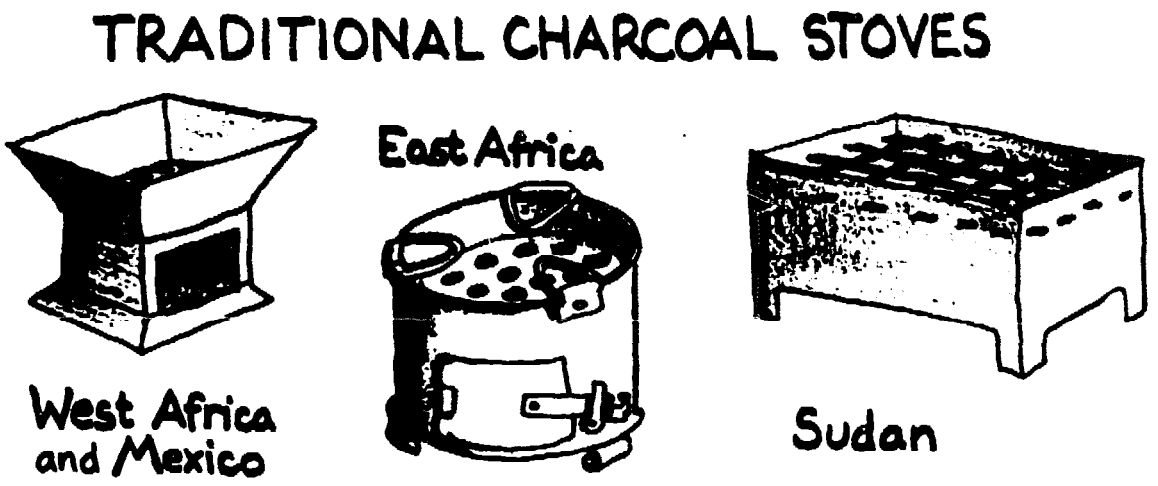

Stoves can be made from imported sheet steel at high prices (and probably with a shorter lifetime than those made from oil drum steel). The availability and cost of both imported and scrap steel depends on the level of manufacturing activity and government policy on importing materials. In Kenya, for example, the price of scrap and imported metal doubled in 1982-3.

Metal has the advantage of being easily shaped. Stoves can be produced in large numbers by the existing artisans working in the informal sector or by small or large engineering workshops. Experience in Kenya has indicated that stoves can be produced in the informal sector much more cheaply than in the formal sector. The investment required to produce a new stove is minimal and the time rquired to train skilled artisans to produce a new product can be less than one week. These people can make three to five stoves in a day. However, artisans will

often take short cuts and therefore not build the stove to the required degree of accuracy, thus tending to lower the performance of the stove.

Marketing a new product is a much more risky affair for the artisan than for a small industry, which has existing outlets. On the other hand, industry, small or large, may have to find considerable capital to retool or expand. The labour costs will often be greater and the actual market for the product may be smaller than for the artisans. The output from a small industry can be as high as fifteen stoves per day per person. Artisans operate in the rural sector whereas small engineering shops do not exist in many rural areas (and considerable effort is required to develop such industries). However, if small engineering enterprises are established, they may create employment and help produce other useful products.

Metal now has the advantage of providing area heat, though many children burn themselves on its hot surfaces. By adding an inner layer of fired clay (as in the Kenyan Ministry of Energy's stove), or by placing mud between two metal walls (as in UNICEF's Umeme stove), the same amount of heat will enter the room, but over a longer period of time, but will be much safer and more fuel-efficient. The techniques can be used for both charcoal and wood burning stoves, but may double or triple the cost. The addition of fired clay increases the complexity of the production process, but also extends considerably the lifetime of the metal cladding.

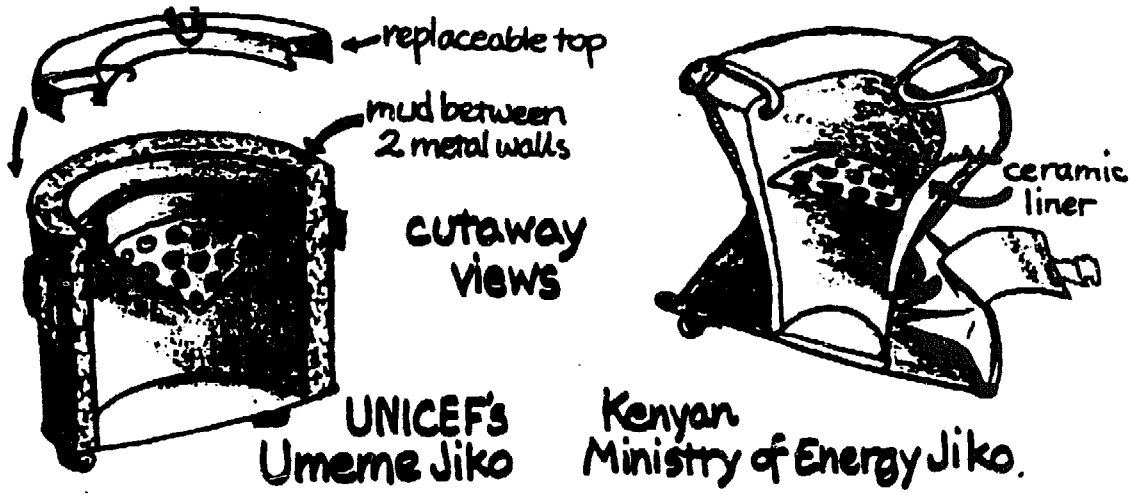

Fig. 17

Metal stoves can easily be lined with cement mixed with vermiculite or diatomite, or with soapstone or meerschaum (available in Somalia). This can be done by artisans or by semi-skilled workers who have received a short training course. The lining of charcoal stoves and wood burning single-pot shielded fires is relatively simple, but two-pot wood or charcoal stoves present greater problems. Repairs can be easily carried out by local artisans.

Pottery

Africa has a long tradition of producing fired clay ('pottery') pots, but there are few pottery stoves being produced. In most of Africa there are only a few areas where high quality clay is available for the manufacture of pottery stoves.

CLAY THAT IS SUITABLE FOR PRODUCING FIRED COOKING AND WATER POTS MAY NEED ADDITIONS TO PRODUCE LONG-LASTING POTTERY STOVES.

It is necessary to test the clay (see materials testing, Sec. 3.4). It may be necessary to mix clay from different deposits together, or to include additives such as sand, crushed fired clay, rice husk ash, soapstone, mica, dung or charcoal, in order to produce a satisfactory mixture. The mixture should be easy to form, should not shrink too quickly when wet, and should withstand repeated heating and cooling, and impact loads, when fired.

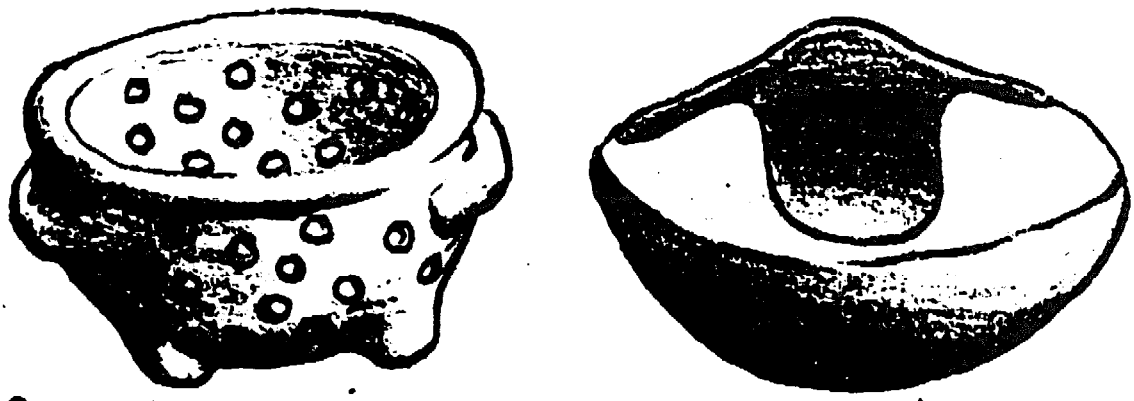

Senegal Kenya coast

Traditional Pottery Charcoal Stoves

Fig. 13

Pottery stoves are easily mass produced in moulds or on a wheel, and are usually less expensive than metal stoves. They can be portable or fixed. The length of life depends on the quality of the clay, its preparation, the firing temperature, and the stove design. Pottery can be made by artisans, working part time at their homes, or in small ceramic industries. The cost of production in rural areas is much lower than in urban, but transportation of the stoves over long distances is often expensive and difficult.

In Kenya the pottery liners for charcoal jikos are often made by a separate pottery company, and the assembly is done in the informal sector. Alternatively, a pottery company has sometimes hired and managed skilled artisans to do the work on site. Experience has shown that it is much more difficult to train itinerant or part-time potters to make high quality stoves than it is to train metal-working artisans. Often these potters cannot produce stoves all the year round because of lack of fuel or the need to be involved in agricultural activity.

The extension costs of a pottery stove project can be greater than that of a metal stove project. (This applies especially to wood stoves.)

Either potters or extension workers may be required to install the stove, especially if the stove has a chimney. There has only been limited experience of people working with small pottery industries in Upper Volta (Baldwin, 1982) and Kenya, but it would appear that these enterprises can expand to produce a quality product at a lower cost than metal stoves. Training required to upgrade skills is minimal, but frequent follow up is necessary. Investment is usually required to upgrade the artisan or small industry's facility to produce a cost-effective high quality product. This could include improved kilns, clay-working machinery, moulds, or extra drying and working space.

Pottery stoves must be carefully designed so that concentrations of stress do not build up, in order to give a long lifetime (for more information see Joseph, 1983). It is desirable not to rest pots on pottery stoves, and this can be done by encasing the stove in mud or in the case of shielded fires to place an iron frame inside the stove. The lifetime of a pottery stove encased

in mud can be from 18 months to 4 years depending on the quality of the clay and the care taken in preparing the mix.

Pottery stoves can easily be repaired with mud, or a mixture of mud, ash and cement, if they were originally encased in mud. A mixture of 2 parts clay : 1 part cement : 1 part rice or millet husk ash, or a mixture of 1 part cement : 3 parts vermiculite can be used to repair portable stoves. The lifetime of pottery charcoal stoves is probably increased if a mixture of cement and ash is used on the internal surface.

Mud

In Africa, most of the wood stoves that have been introduced into rural areas have been made from mud (a mixture of sand and clay). Although mud is widely available and very cheap, it often does not withstand constant heating and cooling for long periods of time. Unless the clay is of high quality, and the walls are very thick, the firebox will crumble when wood is continually struck against the sides, and cracks can occur adjoining pot-holes, and between wall and pot-hole, if heavy pots are continually dropped or placed heavily on the stove.

Mud stoves can be produced by artisans, extension workers, and by users. Quality tends to vary considerably with the skill and training of the builders. Stoves can be carved from a single block of mud (Fig. 19), made from ropes of clay/fibre (Fig. 20), or moulded (Fig. 21). A great deal of training and follow up is required if people are to carve mud stoves accurately. The stove can be produced in the home, or at a workshop, and then transported to the household. Small businesses making mud stoves have been established in Guatemala (Caceres, 1983), Senegal, and Kenya. The investment cost is low

and production can be intermittent.

'Methods of Manufacture of Mud Stoves'.

Fig. 19 Lorena (sand/clay) is compressed by layers into a solid block, and then carved with knives and spoons.

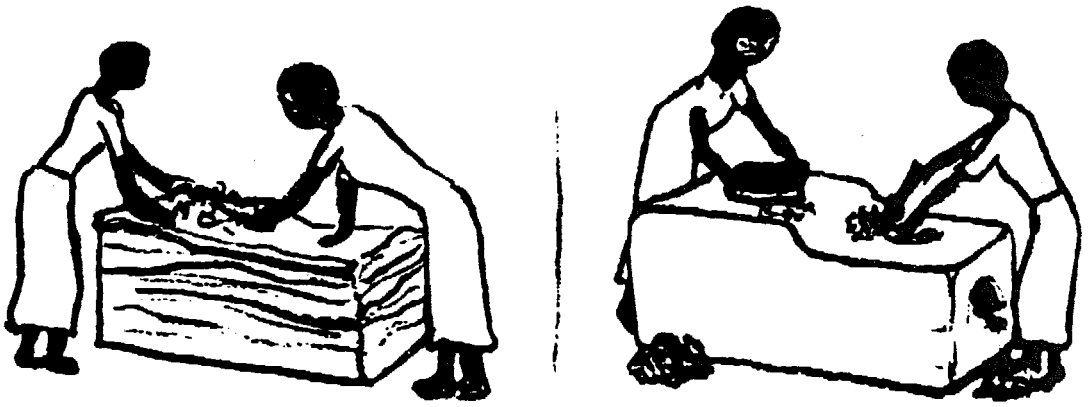

Fig. 20 'Ropes' of 50% clay/50% long fibres (either hay or raw sisal) are prepared, then interlocked and beaten into place around pots resting on three stones or bricks.

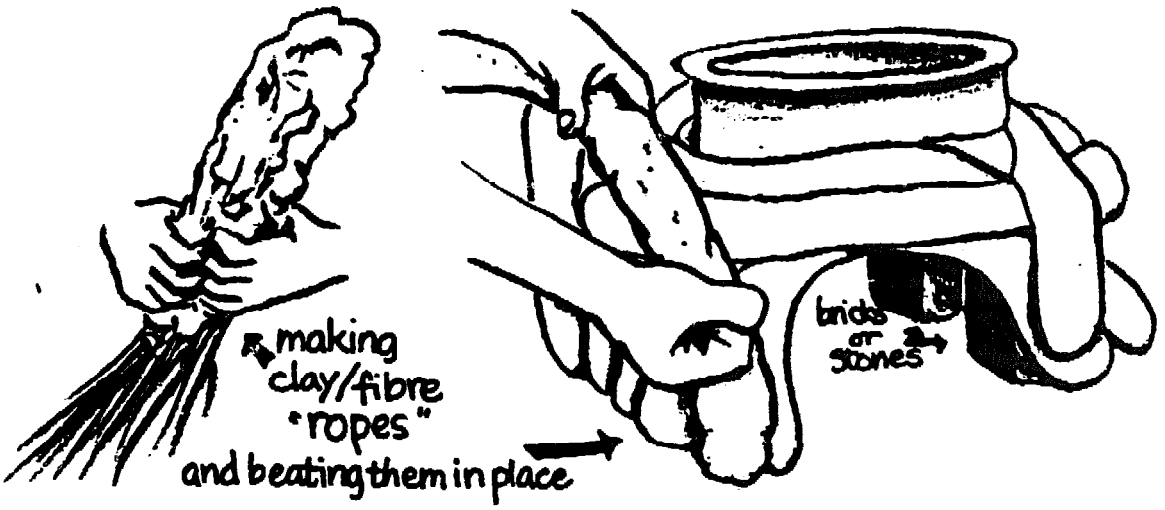

Fig. 21 Moulded stoves are (more often) accurately made, and can be transported if they have a significant fibre content.

Fig. 22 The Pogbi is made in a workshop by pounding clay/hay 'ropes' into wooden moulds. When dry, the body and chimney parts are transported and installed.

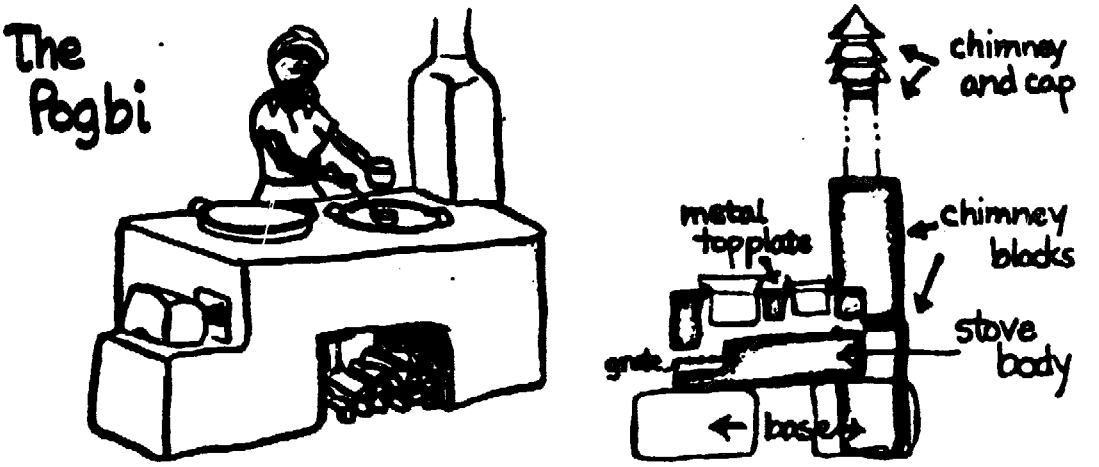

One person can produce a moulded stove in half a day, and a two pot-hole carved stove in one or two days. The total time taken depends on whether a chimney is installed and how much time

is spent collecting and preparing the material. A great deal of experimental work is often necessary to develop long-lasting mixes. Until recently mixes were developed by trial and error, but work at Kenyatta University College and at ITDG (UK) is starting to indicate how to speed up this process. Experience has indicated that termite mound is the best clay to make mud mixes. Clay should be crushed and sieved before use. It should be mixed with dung, ash and husks (the exact proportions must be found by experiment), mixed with water until damp, and allowed to stand before building. Some stove builders recommend mixing grass and crushed pottery with the clay although initial tests indicate that weak spots in the firebox are areas where grass has burnt away. The addition of fibres gives tensile strength to the block, reducing tendencies to crack. The properties of mud are possibly improved by the addition of 25% cement. A mixture of 2 parts mud : 1 part cement : 1 part rice husks, has been used to make bread ovens in Fiji (Petersham, 1982).

The lifetime of a mud stove can be as low as three months or as high as four years. Durability is considerably enhanced if the stove is constantly repaired. The extension cost of training and follow-up are considerably greater for a mud stove programme than for pottery or metal stoves.

Other Materials

Cement

West African cement stoves often have a lifetime of less than 18 months, are expensive, and difficult to repair. However, the lifetime of this stove could be increased by additions of vermiculite or diatomite to the cement that is being subjected to heat. Cement stoves can be moulded

in one piece or made in sections and can be made in the home by artisans or in a workshop. A man can make one to three woodburning stoves a day, depending on size, etc. The capital investment is relatively small.

Cement is quite good as a coating for mud stoves, making the surface impervious to water spills and strengthening against abrasion where pots are inserted into the stove.

Brick

Brick stoves have an extremely long lifetime - up to 20 years if good quality building bricks are used. The stove must be made in the household and usually takes at least one day to complete. To ensure proper construction these stove builders must be given extensive training and be provided with templates to fix the internal dimensions of a stove. The template can be made of metal, clay/fibre, banco or cement. Mortar between the bricks needs to be repaired occasionally.

Stone

Stoves can be formed from stone slabs or carved from soapstone, siltstone, or basalt. These are lifetime. Meerschaum stoves are made in Somalia and siltstone and basalt stoves are common in Indonesia and have now been developed in Lesotho (ARD 1982). Stones can be joined together with cement/clay/husk mixtures to make a stove.

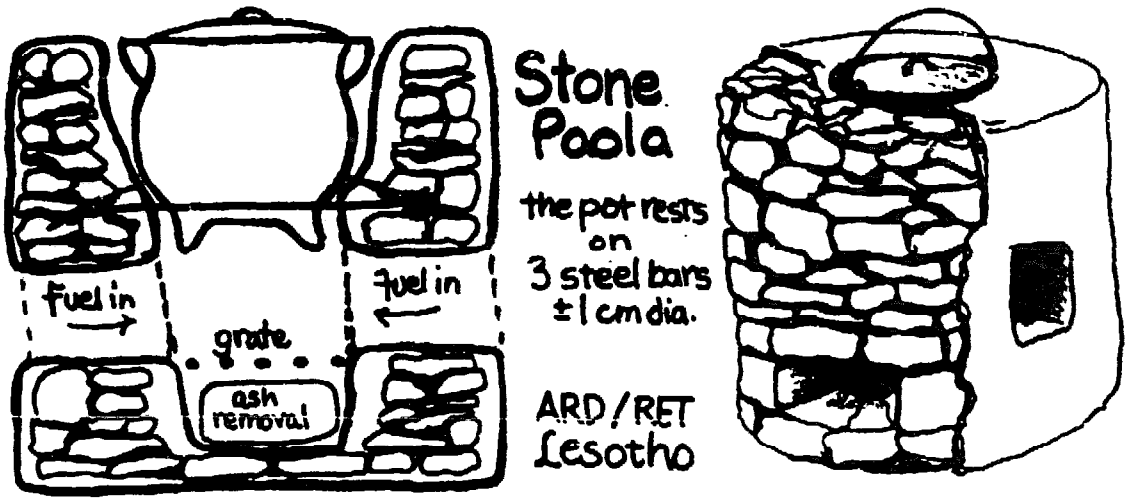

Fig.23

3.3 MATCHING TECHNOLOGY TO NEEDS AND RESOURCES

Having obtained the necessary information from the survey, and understanding the characteristics of different types of stoves, it is now essential to develop design criteria for stoves, and methods of promotion, manufacture, and distribution to meet the local needs and resources. This is presented here as a series of questions and possible answers.

1. What are user and implementing organization criteria for a stove?

NEEDS	POSSIBLE TECHNOLOGICAL
1. Smokeless kitchens	1. °Build a chimney stove °Build exhaust vent or fireplace chimney

	°Increase ventilation in house °Optimize firebox for efficient combustion
2. Use of smoke	2. °No chimney or short chimney °Build drying rack overhead
3. Safety	3. °Build stove too high off the ground for young children °Insert pots into the stove °Fully enclose firebox °Insulate stove °Use stable high-mass stove
4. Ease of maintenance	4. °Do not use chimney, or use a very short chimney that does not go through roof °Use pottery or cement and vermiculite inserts °Avoid more than two pot seats
5. Ease of operation a) in cooking	5.°Interchangeable pots °Easily reached pots for stirring °Build stove high or low, for sitting or standing, as desired
b) wood does not have to be chopped	°Build stove on ground (no base) or with ample support in front of door for long sticks of wood

c) fire needs little tending	°No grate
d) will ignite quickly	°Use grate
e) will ignite wet wood	°Use grate
f) able to raise and lower output of fire easily	°Use dampers or door °Use long sticks of wood
6.	
a) Cooks faster	6. °Cook two pots at one time °Pot inserted into the stove °Pot lids (thick wood or metal) °Increase fire output or heat transfer
b) First and second pot come to boil at the same time	°Alter baffle dimensions and position
7. Save fuel	7. °Sink pots into stove °Use single pot-shielded fire (multiple pot stoves have not been proven to save fuel in practice)
MOST IMPORTANT	°Well designed °Accurate construction °Proper maintenance
8. Occasional baking	8. °Build firebox large enough to accommodate pans
9. Low cost	9. °Use locally available skills and resources °Minimal cost of transport

	°Develop method of mass production of the stove, or mass dissemination of skills
10. Provides light	10. °Open up the front of the stove °Put many holes in the firebox (this will lower cooking efficiency) °Subsidize alternative liquid fuel for lamps
11. Charcoal for ironing or other use	11. °No grate
12. Provides space heat	12. °Use metal or thin-walled ceramics °Use high mass chimney stove with long tunnel °Lower draught into the kitchen
13. Similar lifetime as three stones	13. °Use high quality refractory cement °Use cement (1 part) and vermiculite (3 parts) °Use cast-iron steel plate °Use dressed stones °Keep design simple
14. Aesthetically pleasing	14. °Use high quality materials °designer or artist °Apply paint, diatomite, whitewash, varnish or tiles to final product

	°Apply patterns to outside
15. Can be made by local group	15. °Mud or rock must be used as main material °Some parts purchased and encased in mud °Cement can be used, especially if a trained mason is part of the group
16. Creates employment	16. °Establish a stove-building enterprise °Ceramic and/or metal stove made by artisans °Establish a repair and maintenance enterprise
17. Able to be produced in large numbers within a five year period (say 100,000 per year)	17. °Made from metal or pottery or a combination °Portable °If mud, requires a large extension service using moulds

It is possible that priority given to some criteria by users will be different to those of the implementing organizations (e.g. the implementers may want the stove to save wood primarily, whereas the users might want to save cooking time). Criteria may be conflicting (e.g. a stove that eliminates smoke will not be as easy to maintain). It is essential to resolve as many of these conflicts as possible before developing and testing stoves. Dialogue with users is the best method. Some of these conflicts will be resolved when other constraints on the designs are detailed. There is still scope for imaginative design

to meet conflicting criteria.

2. **How do you adapt the design to fit the physical space available?**

One way is to list the following:

- area occupied by existing stove (if it is to remain);
- area occupied by kitchen furniture;
- area required for preparation/consumption of food;
- area occupied/required for other items/activities.

Subtract the total of the above areas from the total floor area of the kitchen. This will then determine the maximum size of the stove, and possible position. Repeat this calculation for the range of kitchen sizes noted.

Another way is simply to place the pots on the floor where the stove is likely to be, taking account of where the air enters the room and arm movements in food preparation. Lines can then be drawn on the floor (for massive mud stoves).

Stoves are often tables in Guatemala, the large counter space being utilized for serving and sometimes eating (Aprovecho, 1980). Alternatively, the stove may need to be portable if the space is used for sleeping at night.

3. **How does the height of ceiling, type of roofing, degree of ventilation and prevailing wind affect design and position of the stove?**

1. 1.5 metre high chimneys can be placed inside if the roof or the ceiling is 3.5 metres above the floor and if the roofs are made of an inflammable material. If the height of the ceiling is less than 3.5 metres it is necessary to take the chimney directly through the wall or roof. If the roof is

flammable it is necessary to insulate the chimney when it passes through the roof. It is also necessary to have the chimney exit at least 1 metre away from the thatch. If a room is well ventilated it is possible not to use a chimney (a stove that operates properly does not produce smoke except when the fire is first lit).

It is possible to build a cowling to remove the smoke outside the room, in cases of portable or chimneyless stoves. A cowling may be built through the roof or into a window if the material surrounding it is non-flammable and if the cowling does not take away necessary light. Avoid placing the chimney close to an outside wall, especially if the wind hits this wall for a substantial proportion of the time.

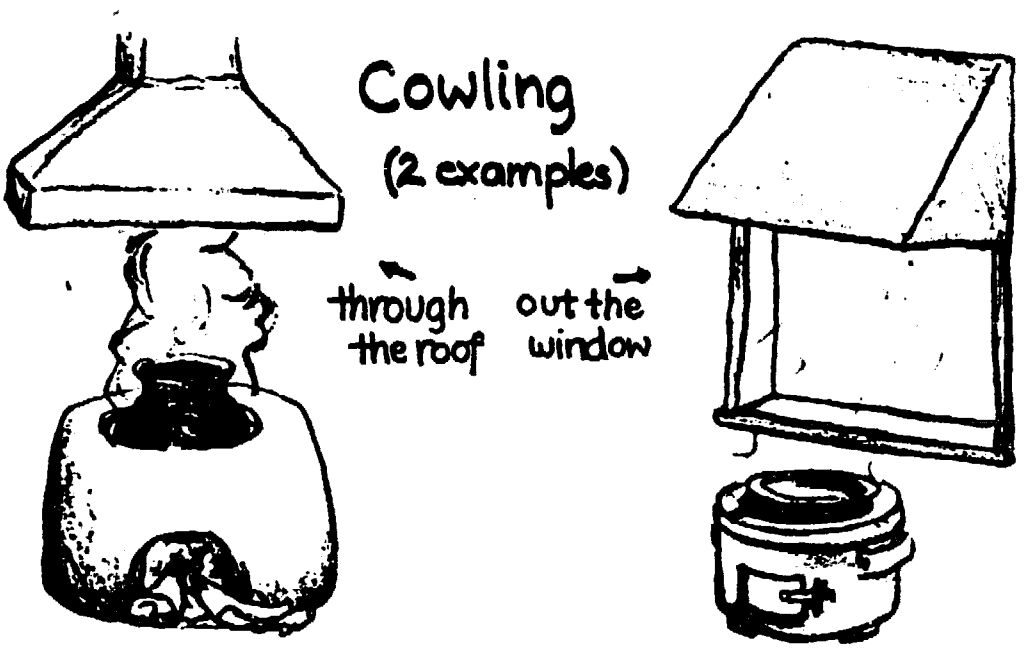

Fig. 24

4. **What are implications on the design and the impact of the stove if people have more than one cooking place? or more than one stove?**
- Design a portable stove
- Design stoves that fulfil the same functions as the existing stoves
- Be content, (if users are), that the stove can only fulfil some of their needs of fire and that the traditional stove will be used for some cooking and heating functions
- Considerable wood savings will not be seen if a single fixed stove is used.

5. **How does the type, number of, and size of pots reguarly used affect the design?**
- It is important that pot seats can accommodate all or at least the most frequently used pots.

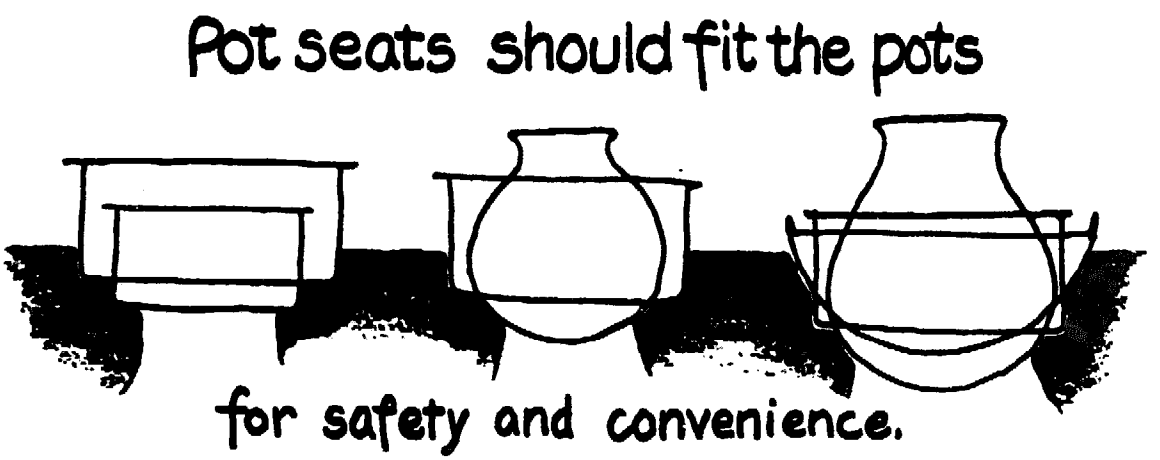

Fig.25

- It is preferable to mould the pot seat to the contours of the pot (Evans and Boutette 1981). This will provide extra stability when cooking. It is important that the bottom of the pot does not hit the baffle.

- If people only use one or two pot sizes it is possible to build a very simple shielded fire or a single chimney stove that has two fire-boxes. The pots would sit inside the stove.
- If people use small pots for brewing tea and large pots for cooking, it will be necessary either to make some type of ring or heavy wire screen on which to sit the small pot, or to provide a small stove for brewing teas. It is extremely important to determine whether people would restrict the range of pot sizes used if a stove with fixed pothole sizes were to be introduced (e.g. Pobgi Section 3.2). Pots of tea have to be modified or new pots purchased when 2-holed fixed pot size stoves are introduced.
- Suspend the pot (like a tea kettle) above a bed of charcoal.

6. What is the significance of different pot sizes for the installation of an insert stove or the construction of a mud stove?

- It is important for the builders and installers to get the women to bring out all their pots and identify the use (and frequency of use) of each one. The distance between the 2 pot holes should be large enough to accommodate the two largest pots placed side by side.
- It will then be necessary to determine the distance between pot seats and chimney, the inner and outer diameter of the pot seats, and the slope that will enable most of the pots to sit safely on the stove.
- If large pots are used frequently to prepare beer or cattle feed it may be necessary to design a special stove (that is cheap but fuel efficient).

7. **What are the implications of the diversity of existing stoves (and their different social and cultural significances) for the introduction of improved stoves?**

- It is essential for the promoters to spend considerable effort to get households to explain all the functions of the old stoves. It will then be necessary to understand what functions the new stove can perform (and what are its advantages). It may also be necessary to determine if the household will still use their old stove for ritual, light, or other cooking purposes.
- People who buy a stove may be more willing to purchase a new stove if the lifetime and cost are similar to the old stove. If people do not purchase their present stove they will have to be convinced that the benefits of the new stove outweigh the cost (in either money or labour).
- It is much harder to train people to repair and maintain new stoves if they have not had to do this before. Introducing mud stoves to people who have never used mud before is also extremely difficult.
- It will be necessary to monitor closely the response to the same stove by different ethnic groups living in the same village.
- Since women usually make and use the traditional stove/fireplaces it will be very beneficial to involve them in the choice and/ or installation of the stove.
- If the replacement stove has to be purchased (and the men make the decision on spending) they will need to be involved in the decision to adopt the stove and shown how it would benefit them (especially if they don't collect wood).

Rankine cycle

From Wikipedia, the free encyclopedia

The ***Rankine cycle*** is a model that is used to predict the performance of steam turbine systems. The Rankine cycle is an idealized thermodynamic cycle of a heat engine that converts heat into mechanical work. The heat is supplied externally to a closed loop, which usually uses water as the working fluid. It is named after William John Macquorn Rankine, a Scottish polymath and Glasgow University professor.

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- 1 Description
- 2 The four processes in the Rankine cycle
- 3 Variables
- 4 Equations
- 5 Real Rankine cycle (non-ideal)
- 6 Variations of the basic Rankine cycle
  - 6.1 Rankine cycle with reheat
  - 6.2 Regenerative Rankine cycle
- 7 Organic Rankine cycle
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Description

The Rankine cycle closely describes the process by which steam-operated heat engines commonly found in thermal power generation plants generate power. The heat sources used in these power plants are usually nuclear fission or the combustion of fossil fuels such as coal, natural gas, and oil.

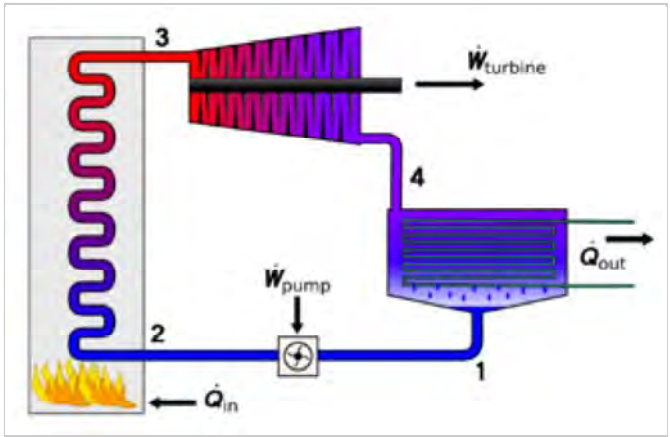

Physical layout of the four main devices used in the Rankine cycle

The efficiency of the Rankine cycle is limited by the high heat of vaporization of the working fluid. Also, unless the pressure and temperature reach super critical levels in the steam boiler, the temperature range the cycle can operate over is quite small: steam turbine entry temperatures are typically around 565 °C and steam condenser temperatures are around 30 °C. This gives a theoretical maximum Carnot efficiency for the steam turbine alone of about 63% compared with an actual overall thermal efficiency of up to 42% for a modern coal-fired power station.

This low steam turbine entry temperature (compared to a gas turbine) is why the Rankine (steam) cycle is often used as a bottoming cycle to recover otherwise rejected heat in combined-cycle gas turbine power stations.

The working fluid in a Rankine cycle follows a closed loop and is reused constantly. The water vapor with condensed droplets often seen billowing from power stations is created by the cooling systems (not directly from the closed-loop Rankine power cycle) and represents the means for (low temperature) waste heat to exit the system, allowing for the addition of (higher temperature) heat that can then be converted to useful work (power). This 'exhaust' heat is represented by the "Q_{out}" flowing out of the lower side of the cycle shown in the T/s diagram below. Cooling towers operate as large heat exchangers by absorbing the latent heat of vaporization of the working fluid and simultaneously evaporating cooling water to the atmosphere. While many substances could be used as the working fluid in the Rankine cycle, water is usually the fluid of choice due to its favorable properties, such as its non-toxic and unreactive chemistry, abundance, and low cost, as well as its thermodynamic properties. By condensing the working steam vapor to a liquid the pressure at the turbine outlet is lowered and the energy required by the feed pump consumes only 1% to 3% of the turbine output power and these factors contribute to a higher efficiency for the cycle. The benefit of this is offset by the low temperatures of steam admitted to the turbine(s). Gas turbines, for instance, have turbine entry temperatures approaching 1500°C. However, the thermal efficiency of actual large steam power stations and large modern gas turbine stations are similar.

The four processes in the Rankine cycle

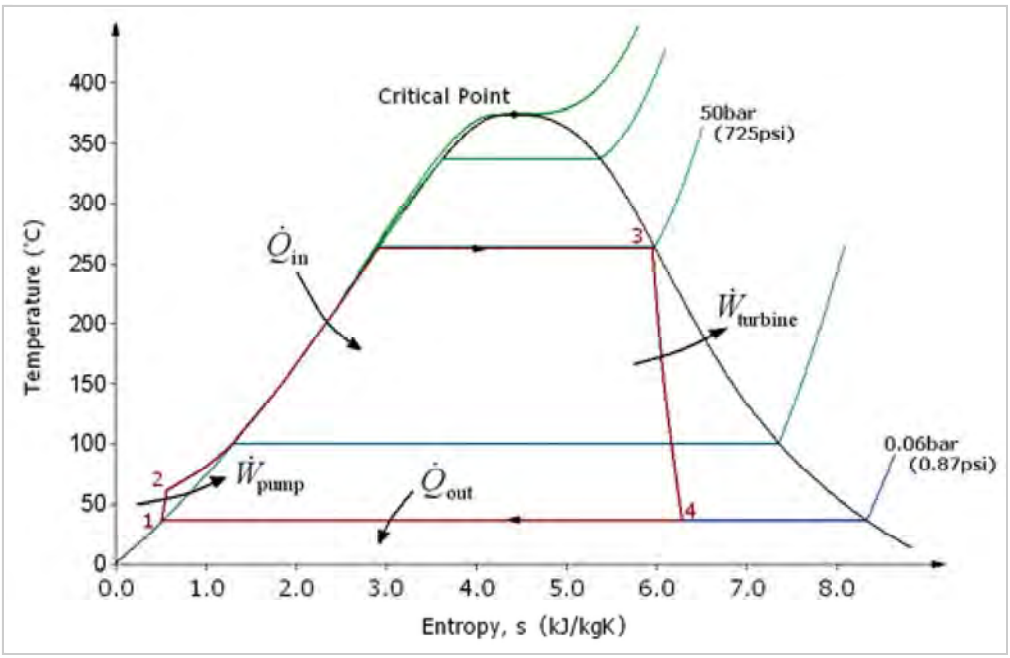

T-s diagram of a typical Rankine cycle operating between pressures of 0.06bar and 50bar

There are four processes in the Rankine cycle. These states are identified by numbers (in brown) in the above T-s diagram.

- **Process 1-2**: The working fluid is pumped from low to high pressure. As the fluid is a liquid at this stage, the pump requires little input energy.
- **Process 2-3**: The high pressure liquid enters a boiler where it is heated at constant pressure by an external heat source to become a dry saturated vapour. The input energy required can be easily calculated graphically, using an enthalpy-entropy chart (aka h-s chart or Mollier diagram), or numerically, using steam tables.
- **Process 3-4**: The dry saturated vapour expands through a turbine, generating power. This decreases the temperature and pressure of the vapour, and some condensation may occur. The output in this process can be easily calculated using the chart or tables noted above.
- **Process 4-1**: The wet vapour then enters a condenser where it is condensed at a constant pressure to become a saturated liquid.

In an ideal Rankine cycle the pump and turbine would be isentropic, i.e., the pump and turbine would generate no entropy and hence maximize the net work output. Processes 1-2 and 3-4 would be represented by vertical lines on the T-s diagram and more closely resemble that of the Carnot cycle. The Rankine cycle shown here prevents the vapor ending up in the superheat region after the expansion in the turbine, [1] which reduces the energy removed by the condensers.

The actual vapor power cycle differs from the ideal Rankine cycle because of irreversibilities in the inherent components caused by fluid friction and heat loss to the surroundings; fluid friction causes pressure drops in the boiler, the condenser, and the piping between the components, and as a result the steam leaves the boiler at a lower pressure; heat loss reduces the net work output, thus heat addition to the steam in the boiler is required to maintain the same level of net work output.

Variables

$\dot{Q}$	Heat flow rate to or from the system (energy per unit time)
$\dot{m}$	Mass flow rate (mass per unit time)
$\dot{W}$	Mechanical power consumed by or provided to the system (energy per unit time)
η_{therm}	Thermodynamic efficiency of the process (net power output per heat input, dimensionless)
η_{pump}, η_{turb}	Isentropic efficiency of the compression (feed pump) and expansion (turbine) processes, dimensionless
h_1, h_2, h_3, h_4	The "specific enthalpies" at indicated points on the T-S diagram
h_{4s}	The final "specific enthalpy" of the fluid if the turbine were isentropic
p_1, p_2	The pressures before and after the compression process

Equations

In general, the efficiency of a simple rankine cycle can be written as:

$$\eta_{therm} = \frac{\dot{W}_{thermal} - \dot{W}}{\dot{Q}_{in}} \approx \frac{\dot{W}_{turb}}{\dot{Q}_{in}}.$$

Each of the next four equations[1] is derived from the energy and mass balance for a control volume. η_{therm} defines the thermodynamic efficiency of the cycle as the ratio of net power output to heat input. As the work required by the pump is often around 1% of the turbine work output, it can be simplified.

$$\frac{\dot{Q}_{in}}{\dot{m}} = h_3 - h_2$$

$$\frac{\dot{Q}_{out}}{\dot{m}} = h_4 - h_1$$

$$\frac{\dot{W}_{pump}}{\dot{m}} = h_2 - h_1$$

$$\frac{\dot{W}_{turbine}}{\dot{m}} = h_3 - h_4$$

When dealing with the efficiencies of the turbines and pumps, an adjustment to the work terms must be made.

$$\frac{\dot{W}_{pump}}{\dot{m}} = h_2 - h_1 \approx \frac{v_1 \Delta p}{\eta_{pump}} = \frac{v_1 (p_2 - p_1)}{\eta_{pump}}$$

$$\frac{\dot{W}_{turbine}}{\dot{m}} = h_3 - h_4 \approx (h_3 - h_4)\eta_{turbine}$$

Real Rankine cycle (non-ideal)

In a real power plant cycle (the name 'Rankine' cycle is used only for the ideal cycle), the compression by the pump and the expansion in the turbine are not isentropic. In other words, these processes are non-reversible and entropy is increased during the two processes. This somewhat increases the power required by the pump and decreases the power generated by the turbine.

In particular the efficiency of the steam turbine will be limited by water droplet formation. As the water condenses, water droplets hit the turbine blades at high speed causing pitting and erosion, gradually decreasing the life of turbine blades and efficiency of the turbine. The easiest way to overcome this problem is by superheating the steam. On the Ts diagram above, state 3 is above a two phase region of steam and water so after expansion the steam will be very wet. By superheating, state 3 will move to the right of the diagram and hence produce a drier steam after expansion.

Variations of the basic Rankine cycle

The overall thermodynamic efficiency can be increased by raising the average heat input temperature $\left(\bar{T}_{in} = \frac{\int_2^3 T\,dQ}{Q_{in}}\right)$ of that cycle. Increasing the temperature of the steam into the superheat region is a simple way of doing this. There are also variations of the basic Rankine cycle which are designed to raise the thermal efficiency of the cycle in this way; two of these are described below.

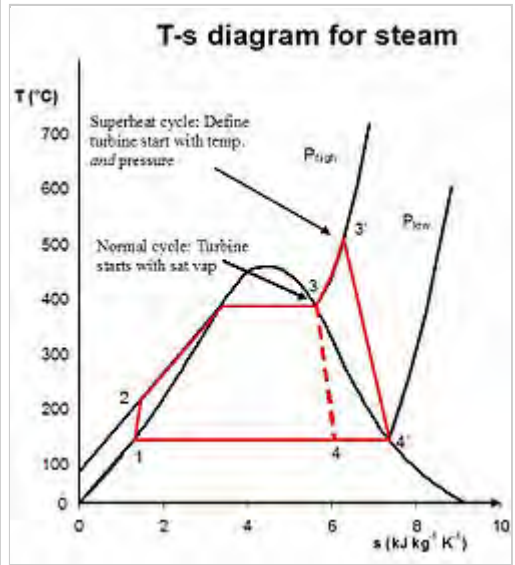

Rankine cycle with superheat

Rankine cycle with reheat

The purpose of a reheating cycle is to remove the moisture carried by the steam at the final stages of the expansion process. In this variation, two turbines work in series. The first accepts vapor from the boiler at high pressure. After the vapor has passed through the first turbine, it re-enters the boiler and is reheated before passing through a second, lower-pressure, turbine. The reheat temperatures are very close or equal to the inlet temperatures, whereas the optimum reheat pressure needed is only one fourth of the original boiler pressure. Among other advantages, this prevents the vapor from condensing during its expansion and thereby damaging the turbine blades, and improves the efficiency of the cycle, because more of the heat flow into the cycle occurs at higher temperature. The reheat cycle was first introduced in the 1920s, but was not operational for long due to technical difficulties. In the 1940s, it was reintroduced with the increasing manufacture of high-pressure boilers, and eventually double reheating was introduced in the 1950s. The idea behind double reheating is to increase the average temperature. It was observed that more than two stages of reheating are unnecessary, since the next stage increases the cycle efficiency only half as much as the preceding stage. Today, double reheating is commonly used in power plants that operate under supercritical pressure.

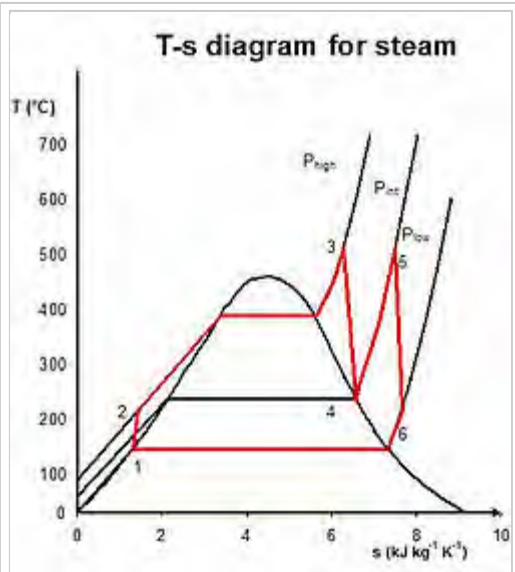

Rankine cycle with reheat

Regenerative Rankine cycle

The regenerative Rankine cycle is so named because after emerging from the condenser (possibly as a subcooled liquid) the working fluid is heated by steam tapped from the hot portion of the cycle. On the diagram shown, the fluid at 2 is mixed with the fluid at 4 (both at the same pressure) to end up with the saturated liquid at 7. This is called "direct contact heating". The Regenerative Rankine cycle (with minor variants) is commonly used in real power stations.

Another variation sends *bleed steam* from between turbine stages to feedwater heaters to preheat the water on its way from the condenser to the boiler. These heaters do not mix the input steam and condensate, function as an ordinary tubular heat exchanger, and are named "closed feedwater heaters".

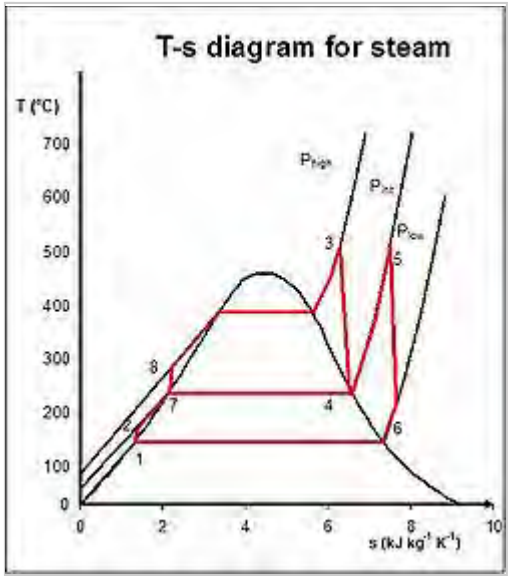

Regenerative Rankine cycle

Regeneration increases the cycle heat input temperature by eliminating the addition of heat from the boiler/fuel source at the relatively low feedwater temperatures that would exist without regenerative feedwater heating. This improves the efficiency of the cycle, as more of the heat flow into the cycle occurs at higher temperature.

Organic Rankine cycle

The organic Rankine cycle (ORC) uses an organic fluid such as n-pentane[1] or toluene[2] in place of water and steam. This allows use of lower-temperature heat sources, such as solar ponds, which typically operate at around 70–90 °C.[3] The efficiency of the cycle is much lower as a result of the lower temperature range, but this can be worthwhile because of the lower cost involved in gathering heat at this lower temperature. Alternatively, fluids can be used that have boiling points above water, and this may have thermodynamic benefits. See, for example, mercury vapour turbine.

The Rankine cycle does not restrict the working fluid in its definition, so the name “organic cycle” is simply a marketing concept and the cycle should not be regarded as a separate thermodynamic cycle.

Supercritical Rankine cycle

The Rankine cycle applied using a supercritical fluid[4] combines the concepts of heat regeneration and supercritical Rankine cycle into a unified process called the Regenerative Supercritical Cycle (RGSC) cycle. It is optimised for temperature sources 125 - 450°C.

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Categories: Thermodynamic cycles | Scottish inventions

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Rape

From Wikipedia, the free encyclopedia

Rape is a type of sexual assault usually involving sexual intercourse or other forms of sexual penetration perpetrated against a person without that person's consent. The act may be carried out by physical force, coercion, abuse of authority or against a person who is incapable of giving valid consent, such as one who is unconscious, incapacitated, has an intellectual disability or is below the legal age of consent.[1][2][3] The term *rape* is sometimes used interchangeably with the term *sexual assault*.[4]

The rate of reporting, prosecuting and convicting for rape varies between jurisdictions. Internationally, the incidence of rapes recorded by the police during 2008 ranged, per 100,000 people, from 0.2 in Azerbaijan to 92.9 in Botswana with 6.3 in Lithuania as the median.[5] Rape by strangers is usually less common than rape by persons the victim knows, and male-on-male and female-on-female prison rapes are common and may be the least reported forms of rape.[6][7][8]

Widespread and systematic rape and sexual slavery can occur during international conflict. These practices are crimes against humanity and war crimes. Rape is also recognized as an element of the crime of genocide when committed with the intent to destroy, in whole or in part, a targeted ethnic group.

People who have been raped can be traumatized and develop posttraumatic stress disorder.[9] Serious injuries can result along with the risk of pregnancy and sexually transmitted infections. A person may face violence or threats from the rapist, and, in some cultures, from the victim's family and relatives.[10][11][12]

Rape

The rape of noblewoman Lucretia was a starting point of events that led to the overthrow of the Roman Kingdom and establishment of the Roman Republic. As a direct result of rape, Lucretia committed suicide. Many artists and writers were inspired by the story, including Shakespeare, Botticelli, Rembrandt, Dürer, Artemisia Gentileschi, Geoffrey Chaucer, and Thomas Heywood.

Classification and external resources

Specialty	emergency medicine
ICD-10	T74.2 (http://apps.who.int/classifications/icd10/browse/2016/en#/T74.2)
ICD-9-CM	E960.1 (http://www.icd9data.com/getICD9Code.ashx?icd9=E960.1)
MedlinePlus	001955 (https://medlineplus.gov/ency/article/001955.htm)
eMedicine	article/806120 (http://emedicine.medscape.com/article/806120-overview)
MeSH	D011902 (https://www.nlm.nih.gov/cgi/mesh/2016/MB_cgi?field=uid&term=D011902)

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Etymology

The term *rape* originates in the Latin *rapere* (supine stem *raptum*), "to snatch, to grab, to carry off".[13][14] Since the 14th century, the term has come to mean "to seize and take away by force".[15] In Roman law the carrying off of a woman by force, with or without intercourse, constituted "raptus".[14] In Medieval English law the same term could refer to either kidnapping or rape in the modern sense of "sexual violation".[13] The original meaning of "carry off by force" is still found in some phrases, such as "rape and pillage" or in titles, such as the stories of the Rape of the Sabine Women and The Rape of Europa or the poem *The Rape of the Lock*, which is about the theft of a lock of hair.

Definitions

General

Rape is defined in most jurisdictions as sexual intercourse, or other forms of sexual penetration, initiated by a perpetrator against a victim without their consent.[16] The definition of rape is inconsistent between governmental health organizations, law enforcement, health providers and legal professions.[17] It has varied historically and culturally.[16][17] Originally, *rape* had no sexual connotation and is still used in other contexts in English. In Roman law, it or *raptus* was classified as a form of *crimen vis*, "crime of assault".[18][19] *Raptus* described the abduction of a woman against the will of the man under whose authority she lived, and sexual intercourse was not a necessary element. Other definitions of rape have changed over time. In 1940, a husband could not be charged with raping his wife. In the 1950s, in some states, a white woman having consensual sex with a black man was considered rape.[20]

Until 2012, the Federal Bureau of Investigation (FBI) still considered rape a crime solely committed by men against women. In 2012, they changed their definition from "The carnal knowledge of a female forcibly and against her will" to "The penetration, no matter how slight, of the vagina or anus with any body part or object, or oral penetration by a sex organ of another person, without the consent of the victim." The previous definition, which had remained unchanged since 1927, was considered outdated and narrow. The updated definition includes recognizing any gender of victim and perpetrator and that rape with an object can be as traumatic as penile/vaginal rape. The bureau further describes instances when the victim is unable to give consent because of mental or physical incapacity. It recognizes that a victim can be incapacitated by drugs and alcohol and unable to consent. The definition does not change federal or state criminal codes or impact charging and prosecution on the federal, state or local level; it rather means that rape will be more accurately reported nationwide.[21][22]

Health organizations and agencies have also expanded rape beyond traditional definitions. The World Health Organization (WHO) defines rape as a form of sexual assault,[23] while the Centers for Disease Control and Prevention (CDC) includes rape in their definition of sexual assault; they term rape a form of sexual violence. The CDC lists other acts of coercive, non-consensual sexual activity that may or may not include rape, including drug-facilitated sexual assault, acts in which a victim is made to penetrate a perpetrator or someone else, intoxication where the victim is unable to consent (due to incapacitation or being unconscious), non-physically forced penetration which occurs after a person is pressured verbally (by intimidation or misuse of authority to force to consent), or completed or attempted forced penetration of a victim via unwanted physical force (including using a weapon or threatening to use a weapon).[24]

Some countries or jurisdictions differentiate between rape and sexual assault by defining rape as involving penile penetration of the vagina, or solely penetration involving the penis, while other types of non-consensual sexual activity are called sexual assault.[25][26] Scotland, for example, emphasizes penile penetration, requiring that the sexual assault must have been committed by use of a penis to qualify as rape.

[27][28] In some instances, as in the case of Germany, penetration is not required for the act to be defined as rape.[16] The 1998 International Criminal Tribunal for Rwanda defines rape as "a physical invasion of a sexual nature committed on a person under circumstances which are coercive".[16] In other cases, the term *rape* has been phased out of legal use in favor of terms such as *sexual assault* or *criminal sexual conduct*.[29] Some laws have eliminated the term *rape* altogether.[30]

Scope

For research purposes, incidence of rapes are classified into a number of categories. These can be gender, age, ethnicity, geographical location, culture or historical periods. Other categories of rape describe the relationship of the perpetrator to the victim and the context of the sexual assault. Rape is categorized as date rape, gang rape, marital rape, incestual rape, child sexual abuse, prison rape, acquaintance rape, war rape and statutory rape.[31] Victims of rape or sexual assault come from a wide range of sexual orientations, genders, ages, and degrees of impairment or disability. Perpetrators sometimes use objects for penetration, force the victim to penetrate the perpetrator, force the victim to perform oral sex or assault the victim with anal penetration. Those experiencing non-consensual, forced sexual experiences and sexual assault include women, heterosexual men, homosexual men, boys, adolescent males, spouses, girlfriends, boyfriends, prepubescent girls and boys, adolescent girls, children, the elderly, and even infants. Forced sexual experiences can be committed over a long period of time accompanied with little to no physical injury.[32][33]

In an early study of U.S. 1,632 students from 79 different schools, boys and girls were surveyed and asked if they had, at some time, been asked to engage in unwelcome sexual behavior. 85% of the girls and 76% of the boys said that this had occurred. The boys and girls indicated that the behavior they experienced included pinching, grabbing, touching in a sexual manner. One fourth of the girls had been forced to kiss someone and 10% of both the girls and the boys reported having been forced against their wills to do something sexual other than kissing. Students reported that 80% of the unwelcome sexual behavior had come from other students with the remainder coming from teachers, coaches, or other adults.[33] Out of the total of child abuse rates, slightly more than 75% were neglected, 18% were assaulted and slightly more than nine percent were sexually abused.[34]

Consent

Lack of consent is key to the definition of rape.[3] Consent is not always expressed verbally. It may be implied from the context and from the relationship of the parties, but the absence of objection does not of itself constitute consent. Lack of consent may result from either forcible compulsion by the perpetrator or an incapacity to consent on the part of the victim (such as persons who are asleep, intoxicated or otherwise mentally compromised).[35] Sexual intercourse with a person below the age of consent, i.e., the age at which legal competence is established, is referred to as statutory rape.[3] In certain jurisdictions, consent may also be negated if an individual agrees to have sex only on certain terms. An example is the case of a man who deliberately ejaculated in a woman's vagina although she consented to sex only on the clear understanding that he would not do so.[36][37] Consent can be withdrawn at any time, so that any further sexual activity would constitute rape.

Duress is the situation when the person is threatened by overwhelming force or violence, and may result in the absence of an objection to intercourse. This can lead to the presumption of consent.[35] Duress may be actual or threatened force or violence against the victim or someone close to the victim. Even blackmail may constitute duress. Abuse of power may constitute duress. For instance, in the Philippines, a man commits rape if he engages in sexual intercourse with a woman *"By means of fraudulent machination or grave abuse of authority"*.[38] The International Criminal Tribunal for Rwanda in its landmark 1998 judgment used a definition of rape which did not use the word 'consent': "a physical invasion of a sexual nature committed on a person *under circumstances which are coercive*."[39]

Marital rape, or spousal rape, is non-consensual sex in which the perpetrator is the victim's spouse. It is a form of partner rape, of domestic violence, and of sexual abuse. Once widely accepted or ignored by law, spousal rape is now denounced by international conventions and is increasingly criminalized. Still, in many countries, spousal rape either remains legal, or is illegal but widely tolerated and accepted as a husband's prerogative. In 2006, the UN Secretary-General's *In-depth study on all forms of violence against women* stated that (pg 113): "Marital rape may be prosecuted in at least 104 States. Of these, 32 have made marital rape a specific criminal offence, while the remaining 74 do not exempt marital rape from general rape provisions. Marital rape is not a prosecutable offence in at least 53 States. Four States criminalize marital rape only when the spouses are judicially separated. Four States are considering legislation that would allow marital rape to be prosecuted."[40] Since 2006, several other states have outlawed marital rape (for example Thailand in 2007[41]). In the US, the criminalization of marital rape started in the mid-1970s and in 1993 North Carolina became the last state to make marital rape illegal.[42] In many countries, it is not clear if marital rape may or may not be prosecuted under ordinary rape laws. In the absence of a spousal rape law, it may be possible to bring prosecution for acts of forced sexual intercourse inside marriage by prosecuting, through the use of other criminal offenses (such as assault based offenses), the acts of violence or criminal threat that were used to obtain submission.[43]

The issues of consent in sexual situations can be complicated by language, context, culture and sexual orientation. Refusal or lack of consent is interpreted by cultural expectations of women. A common view is that a woman's refusal of sex cannot be 'heard' in strict patriarchal culture. If a culture depersonalizes and sexualizes women, the refusal and non-consensual, verbalized 'no' to sex can be distorted

and instead means 'keep trying', or even 'yes'. In this context, men are able to sincerely claim they did not understand the refusal. Women can then be blamed because they did not communicate their lack of consent clearly enough. When bruises or broken bones are not apparent, this is seen as proof that the woman consented.[44]

In other contexts, men never say 'no' when confronted with female pressure to engage in sex. In this same situation the lack of consent would be a threat and identify him as homosexual. If the man unwillingly engages in sex, this can create an unusual situation in which the man must defend his claim by highlighting the physical unattractiveness of the female. Interestingly, situations like this can progress to one where continued interaction can prolong the encounter in hopes of reversing non-consent to a 'yes'.[44]

Investigations into questions regarding the intentions behind non-consensual sex are sparse. One investigation in the early 1980s questioned 610 undergraduate women. They were asked if they had ever said no to sex, even though they fully intended to have sexual intercourse. The majority, 68.5% of these women answered 'no' when their intention was 'maybe'. The other 39.3% answered that when they have said 'no' really meant 'yes'. The explanations in support of their answers were that they were fearful of being considered promiscuous. Some claimed they were inhibited about sex. Others answered that they intended to manipulate the male because they were angry, wanted him to become more aroused or more aggressive.[44]

Context changes again when a man solicits sex from another man. Some stereotypes identify men who 'pursue' other men are the most virile of all. This type of interaction often becomes erotic in nature and now can be interpreted as an invitation. Conversely, unwanted sexual advances have created a legal precedent: Homosexual Panic Defense. This is invoked when a man who has murdered another man who they claim made sexual advances towards them. This is an argument in which a sexual advance itself is an act of aggression, and that the defendant was justified in using violence.[44]

Motives

The WHO states that the principal factors that lead to the perpetration of sexual violence against women, including rape, are:[45]

- beliefs in family honor and sexual purity;
- ideologies of male sexual entitlement;
- weak legal sanctions for sexual violence.

No single theory explains the motivation for rape; the motives of rapists can be multi-factorial. Several factors have been proposed: anger; power; sadism; sexual gratification in tandem with evolutionary proclivities.[46][47] American clinical psychologist David Lisak, co-author of a 2002 study of undetected rapists,[48] says that compared with non-rapists, both undetected and convicted rapists are measurably more angry at women and more motivated by a desire to dominate and control them, are more impulsive, disinhibited, anti-social, hyper-masculine, and less empathic.[49]

Sexual aggression is often perceived as masculine identity characteristic of manhood in some male groups and is significantly correlated to the desire to be held higher in esteem among male peers.[50] Sexually aggressive behavior among young men has been correlated with gang or group membership as well as having other delinquent peers.[51][52] Research also suggests that men with sexually aggressive peers have a higher chance of reporting coercive or forced sexual intercourse outside gang circles than men without such sexually aggressive peers.[53] Gang rape is often perceived by male perpetrators as a justified method to discourage or punish what they consider as immoral behavior among women for example wearing short skirts or visiting bars. In some areas in Papua New Guinea, women can actually be punished by public gang rape usually through permission by elders.[54]

Effects

One metric used by the WHO to determine the severity of global rates of coercive, forced sexual activity was the question "Have you ever been forced to have sexual intercourse against your will?" Asking this question produced higher positive response rates than being asked, whether they had ever been abused or raped.[55]

The WHO report describes the negative consequences of sexual abuse:

- Gynecological disorders
- Reproductive disorders
- Sexual disorders
- Infertility
- Pelvic inflammatory disease
- Pregnancy complications
- Miscarriage
- Sexual dysfunction
- Acquiring sexually transmitted infections, including HIV/AIDS
- Mortality from injuries
- Increased risk of suicide
- Depression
- Chronic pain

- Psychosomatic disorders
- Unsafe abortion
- Unwanted pregnancy (see Pregnancy from rape)[55]

Emotional and psychological

During the assault a person will generally act in one or more of five ways: fight, flight, freeze, friend, or flop; the way a person reacts is often not what he or she would have predicted, and after the rape is over, a rape survivor may be uncomfortable with and not understand how they reacted while it was occurring.[56] Most people respond passively to the assault, which afterwards can cause confusion for people (including the survivor) who assume that someone being raped would call for help or struggle, resulting in their clothes being torn or there being injuries resulting from the survivor being subdued after resisting.[56] People being raped often dissociate to some extent during the assault.[56] Partly due to that, the memory of the experience will often be fragmented, especially immediately afterwards; memory generally consolidates with time, and especially following REM sleep.[56] A man or boy who is raped may get an erection and may ejaculate during the experience, which may become a source of shame and confusion for him and people around him afterwards.[57]

Immediately following a rape, the survivor may react outwardly in a wide range of ways, from expressive to closed down; common emotions include distress, anxiety, shame, revulsion, helplessness, and guilt.[56] Denial is not uncommon.[56]

In the weeks following the rape, the survivor may develop symptoms of post traumatic stress syndrome and may develop wide array of psychosomatic complaints.[56][58]:310 PTSD symptoms include re-experiencing of the rape, avoiding things associated with the rape, numbness, and increased anxiety and startle response.[56] The likelihood of sustained severe symptoms is higher if the rapist confined or restrained the person, if the person being raped believed the rapist would kill him or her, the person who was raped was very young or very old, and if the rapist was someone he or she knew.[56] The likelihood of sustained severe symptoms is also higher if people around the survivor ignore (or are ignorant of) the rape or blame the rape survivor.[56]

Most people recover from rape in three to four months, but many have persistent PTSD that may manifest in anxiety, depression, substance abuse, irritability, anger, flashbacks, or nightmares.[56] In addition, rape survivors may have long term generalised anxiety disorder, may develop one or more specific phobias, major depressive disorder, and may experience difficulties with resuming their social life, and with sexual functioning.[56] People who have been raped are at higher risk of suicide.[57][59]

Men experience similar psychological effects of being raped, but they are less likely to seek counseling.[57]

Another effect of rape and sexual assault is the stress created in those who study rape or counsel the survivors. This is called vicarious traumatization.[60]

Physical

Rape and other sexual assault can result in physical trauma, tissue damage and infection, but most people will not suffer visible physical injury.[61] Since the central issue in many cases of rape or other sexual assault is whether or not both parties consented to the sexual activity or whether or not both parties had the capacity to do so, physical force resulting in visible physical injury is not always seen. This stereotype can be damaging because people who have experienced sexual assault but have no physical trauma may be less inclined to report to the authorities or to seek health care.[62]

While penetrative rape generally does not involve the use of a condom, in some cases a condom is used. This significantly reduces the likelihood of pregnancy and disease transmission, both to the victim and to the rapist. Rationales for condom use include: avoiding contracting infections or diseases (particularly HIV), especially in cases of rape of sex workers or in gang rape (to avoid contracting infections or diseases from fellow rapists); eliminating evidence, making prosecution more difficult (and giving a sense of invulnerability); giving the appearance of consent (in cases of acquaintance rape); and thrill from planning and the use of the condom as an added prop.Concern for the victim is generally not considered a factor.[63]

Sexually transmitted infections

Cuts and abrasions acquired during the rape or sexual assault can become infected. Sexually transmitted infections (STI) can be transmitted from the perpetrator to the victim. The presence of STIs in prepubescent children is an indicator of child sexual abuse. The risk of contracting an STI from being raped or sexually assaulted depends on a number of factors. The risk of infection is dependent upon the site of exposure, geographic region, the infection status of the perpetrator, and the type of assault. A pre-existing STI may be present in the patient.

Those who have been raped have relatively more reproductive tract infections than those who have not been raped.[64] Trichomoniasis, bacterial vaginosis (BV), gonorrhea, and chlamydial infection are the most frequently diagnosed infections among sexually assaulted women.[65] Hepatitis B is sometimes acquired.[66] The HIV virus can be transmitted through rape. Acquiring AIDS through rape puts people risk of suffering psychological problems. Acquiring HIV through rape may lead to the in behaviors that create risk of injecting drugs.[67] Acquiring sexually transmitted infections also makes someone more likely to acquire HIV.[64] In parts of Africa, there is a myth that sex with a virgin can cure HIV/AIDS; as such, girls and women are raped because of it.[68][69][70][71] It is not known how common the myth is and to what degree rapes happen because of the belief in it. The claim that the myth drives either HIV infection or child sexual abuse in South Africa is disputed by researchers Rachel Jewkes and Helen Epstein.[72]

A street sign in South Africa, appealing to men not to rape children in the belief that it will cure them of HIV/AIDS.

Victim blaming, bullying and other mistreatment

People who have been raped or sexually assaulted are sometimes blamed and considered responsible for the crime.[17] This concept refers to the just world fallacy and attitudes that certain victim behaviors (such as flirting or wearing sexually provocative clothing) may encourage rape.[73] In extreme cases, victims are said to have "asked for it" by not behaving demurely. In most Western countries, the defense of provocation is not accepted as a mitigation for rape.[74] A global survey of attitudes toward sexual violence by the Global Forum for Health Research shows that victim-blaming concepts are at least partially accepted in many countries. Women who have been raped are sometimes deemed to have behaved improperly. Often, these are countries where there is a significant social divide between the freedoms and status afforded to men and women.[75] Amy M. Buddie and Arthur G. Miller, in a review of studies of rape myths, state:

> Rape victims are blamed more when they resist the attack later in the rape encounter rather than earlier (Kopper, 1996), which seems to suggest the stereotype that these women are engaging in token resistance (Malamuth & Brown, 1994; Muehlenhard & Rogers, 1998) or leading the man on because they have gone along with the sexual experience thus far. Finally, rape victims are blamed more when they are raped by an acquaintance or a date rather than by a stranger (e.g., Bell, Kuriloff, & Lottes, 1994; Bridges, 1991; Bridges & McGr ail, 1989; Check & Malamuth, 1983; Kanekar, Shaherwalla, Franco, Kunju, & Pinto, 1991; L'Armand & Pepitone, 1982; Tetreault & Barnett, 1987), which seems to evoke the stereotype that victims really want to have sex because they know their attacker and perhaps even went out on a date with him. The underlying message of this research seems to be that when certain stereotypical elements of rape are in place, rape victims are prone to being blamed.

They also state that "individuals may endorse rape myths and at the same time recognize the negative effects of rape."[76] A number of gender role stereotypes can play a role in rationalization of rape. In the case of male-on-female rape, these include the idea that power is reserved to men whereas women are meant for sex and objectified, that women want forced sex and to be pushed around,[77] and that male sexual impulses and behaviors are uncontrollable and must be satisfied.[78]

Victim-blaming correlates with fear. Many rape victims blame themselves. Female jurors might look at the woman on the witness stand and believe she has done something to entice the defendant.[79] Victims may become the target of slut-shaming and cyberbullying. In addition, their credibility may be challenged.

Honor killings and forced marriages

In many cultures, those who are raped are at very high risk of suffering additional violence or threats of violence after the rape. These acts may be perpetrated by the rapist or by friends and relatives of the rapist, as a way of preventing the victims from reporting the rape, of punishing them for reporting it, or of forcing them to withdraw the complaint; or they may be perpetrated by the relatives of the victim as a punishment for "bringing shame" to the family. This is especially the case in cultures where female virginity is highly valued and considered mandatory before marriage; in extreme cases, rape victims are killed in honor killings.[10][11][12]

In some places, girls and women who are raped are often forced by their families to marry their rapist. Because being the victim of rape and losing virginity carry extreme social stigma, and the victims are deemed to have their "reputation" tarnished, a marriage with the rapist is arranged. This is claimed to be in the advantage of both the victim—who does not remain unmarried and doesn't lose social status—and of the rapist, who avoids punishment. In 2012, the suicide of a 16-year-old Moroccan girl—who, after having been forced by her family to marry her rapist at the suggestion of the prosecutor, and who subsequently endured abuse by the rapist after they married—sparked protests from activists against the law which allows the rapist to marry the victim in order to escape criminal sanctions, and against this social practice which is common in Morocco.[80]

Treatment

Non-genital injuries

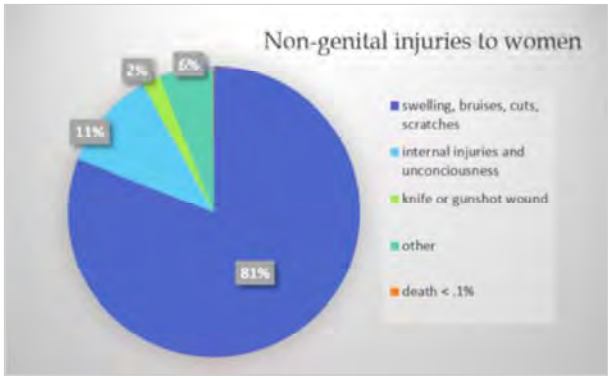

Non-genital injuries to women who are sexually assaulted

The first medical response to sexual assault is identifying serious or life-threatening injuries. An initial examination is performed by emergency room staff. The health care provider, often trained specifically to treat rape and sexual assault patients, examines the victim and looks for signs and symptoms of internal injuries and notes if the victim has experienced unconsciousness during or after the rape or sexual assault. The examiner notes the presence of broken bones,[81] pregnancy, bites,[82] swelling, bruising, lacerations and scratches. In more violent cases, the victim may need to have gunshot wounds or stab wounds treated. Staff that are trained to treat rape and sexual assault victims are careful to obtain full and explicit consent for every part of the physical examination acknowledging that the traumatic event needs to be handled sensitively and to allow the patient to regain a full sense of control over the procedures. It is during the physical examination that the treatment team begins to document the injuries and other information that can be used to identify and prosecute the perpetrator. Such evidence-gathering is only done with the complete consent of the patient or the caregivers of the patient. At this point in the treatment, experienced social support staff are made available to the patient and family.[83]

If the patient or the caregivers, (typically parents) agree, the medical team utilizes standardized sampling and testing usually referred to a "rape kit".[84] The patient is informed that submitting to the use of the rape kit does not obligate them to file criminal charges against the perpetrator. The patient is discouraged from bathing or showering for the purpose of obtaining samples from his or her hair. The sooner that samples are obtained after the assault, the more likely that evidence is present in the sample and will provide valid results. Once the injuries of the patient have been treated and she or he is stabilized, the sample gathering will begin. Staff will encourage the presence of a rape/sexual assault counselor to provide an advocate and reassurance.[83]

Some physical effects of the rape are not immediately apparent. Follow up examinations also assess the patient for tension headaches, fatigue, sleep pattern disturbances, gastrointestinal irritability, chronic pelvic pain, menstrual pain or irregularity, pelvic inflammatory disease, multiple yeast infections, sexual dysfunction, premenstrual distress, fibromyalgia, vaginal discharge, vaginal itching, burning during urination, and generalized vaginal pain.[81] Any victim with abrasions are immunized for tetanus if 5 years have elapsed since their last immunization.[85]

Women are typically offered contraceptive medications because about 5% of male-on-female rapes result in pregnancy.[85]

Genital injuries

A complete pelvic exam for rape (anal and/or vaginal) is conducted. An oral exam is done if there have been injuries to the mouth, teeth, gums or pharynx. Though the patient may have no complaints about genital pain signs of trauma can still be assessed. Prior to the complete bodily and genital exam, the patient is asked to undress, standing on a white sheet that collects any debris that may be in the clothing. The clothing and sheet are properly bagged and labeled along with other samples that can be removed from the body or clothing of the patient. Samples of fibers, mud, hair, leaves are gathered if present. Samples of fluids are collected to determine the presence of the perpetrator's saliva and semen that may be present in the patients mouth, vagina or rectum. A wood lamp is a device that can detect semen on the skin. Sometimes the victim has scratched the perpetrator in defense and fingernail scrapings can be collected.[83]

Injuries to the genital areas can be swelling, lacerations, and bruising. Common genital injuries are anal injury, labial abrasions, hymenal bruising, tears of the posterior fourchette and fossa. Genital injuries are more prevalent in post-menopausal women and prepubescent girls. Internal injuries to the cervix and vagina can be visualized using colposcopy. Using colposcopy has increased the detection of internal trauma from six percent to fifty-three percent. Genital injuries to children who have been raped or sexually assaulted differ in that the abuse may be on-going or it happened in the past after the injuries heal. Scarring is one sign of the sexual abuse of children.[83]

Infections

Sexually transmitted bacterial, viral and other infections, if diagnosed, are treated. This decision may be made by the clinician with prophylactic antibiotic treatment for vaginitis, gonorrhea, trichomoniasis and chlamydia. Chlamydial and gonococcal infections in women are of particular concern due to the possibility of ascending infection. Immunization against hepatitis B is often considered. After prophylactic treatment is initiated, further testing is done to determine what other treatments may be necessary for other infections transmitted during the assault.[85] These are:

- Serum hepatitis B surface antigen assay
- Microscopic evaluation of vaginal discharge (saline wash and staining)
- Cultures for Neisseria gonorrhoeae and Chlamydia trachomatis from each penetrated location
- Serum Venereal Disease Research Laboratory test
- CBC
- Liver function tests
- Serum creatinine level

Treatment may include the administration of Zidovudine/lamivudine, Tenofovir/emtricitabine, Ritonavir/lopinvir. Additional treatment options are available from the CDC.[83]

The transmission of HIV is frequently a major concern of the patient.[65] Prophylactic treatment for HIV is not necessarily administered. Routine treatment for HIV after rape or sexual assault is controversial due to the low risk of infection after one sexual assault. Transmission of HIV after one exposure to penetrative anal sex is estimated to be 0.5 to 3.2 percent. Transmission of HIV after one exposure to penetrative vaginal intercourse is 0.05 to 0.15 percent. HIV can also be contracted through the oral route but is considered rare.[83][86] Other recommendations are that the patient be treated prophylactically for HIV if the perpetrator is found to be infected.[82]

Testing at the time of the initial exam does not typically have forensic value if patients are sexually active and have an STI since it could have been acquired prior to the assault. Rape shield laws protect the person who was raped and who has positive test results. These laws prevent having such evidence used against someone who was raped. Someone who was raped may be concerned that a prior infection may suggest sexual promiscuity. There may, however, be situations in which testing has the legal purpose, as in cases where the threat of transmission or actual transmission of an STI was part of the crime. In nonsexually active patients, an initial, baseline negative test that is followed by a subsequent STI could be used as evidence, if the perpetrator also had an STI.[65]

Treatment failure is possible due to the emergence of antibiotic-resistant strains of pathogens.[87]

Emotional and psychiatric

Psychiatric and emotional consequences can be apparent immediately after rape and it may be necessary to treat these very early in the evaluation and treatment.[65]

Other treatable emotional and psychiatric disorders may not become evident after the rape. These can be eating disorders, anxiety, fear, intrusive thoughts, fear of crowds, avoidance, anger, depression, humiliation, post-traumatic stress disorder (PTSD) hyperarousal, sexual disorders,(including fear of engaging in sexual activity), mood disorders, suicidal ideation, borderline personality disorder, nightmares, fear of situations that remind the patient of the rape and fear of being alone,[81] agitation, numbness and emotional distance.[83] Victims are able to receive help by using a telephone hotline, counseling, or shelters.[32] Recovery from sexual assault is a complicated and controversial concept,[88] but support groups, usually accessed by organizations are available to help in recovery. Professional counseling and on-going treatment by trained health care providers is often sought by the victim.[89]

There are clinicians who are specially trained in the treatment of those who have experienced rape and sexual assault/abuse. Treatment can be lengthy and be challenging for both the counselor and the patient. Several treatment options exist and vary by accessibility, cost, or whether or not insurance coverage exists for the treatment. Treatment also varies dependent upon the expertise of the counselor—some have more experience and or have specialized in the treatment of sexual trauma and rape. To be the most effective, a treatment plan should developed based upon the struggles of the patient and not necessarily based upon the traumatic experience. An effective treatment plan will take the following into consideration: current stressors, coping skills, physical health, interpersonal conflicts, self-esteem, family issues, involvement of the guardian, and the presence of mental health symptoms. [89]

The degree of success for emotional and psychiatric treatments is often dependent upon the terminology used in the treatment, i.e. redefining the event and experience. Labels used like "rape victim" and "rape survivor" to describe the new identities of women who have been raped suggest that the event is the dominant and controlling influence on her life. These may have an effect on supportive personnel. The consequences of using these labels needs to be assessed.[81] Positive outcomes of emotional and psychiatric treatment for rape exist; these can be an improved self-concept, the recognition of growth, and implementing new coping styles.[81]

A perpetrator found guilty by the court is often required to receive treatment. There are many options for treatment, some more successful than others.[90] The psychological factors that motivated the convicted perpetrator are complex but treatment can still be effective. A counselor will typically evaluate disorders that are currently present in the offender. Investigating the developmental background of the offender can help explain the origins of the abusive behavior occurred in the first place. Emotional and psychological treatment has the purpose of identifying predictors of recidivism, or the potential that the offender will commit rape again. In some instances neurological

abnormalities have been identified in the perpetrators, and in some cases they have themselves experienced past trauma. Adolescents and other children can be the perpetrators of rape, although this is uncommon. In this instance, appropriate counseling and evaluation are usually conducted.[33]

Short-term treatment with a benzodiazepine may help with anxiety and antidepressants may be helpful for symptoms of post traumatic stress disorder, depression and panic attacks.[85]

Evidence collection

Though technically, medical staff are not part of the legal system, only trained medical personnel can obtain evidence that is admissible during a trial. The procedures have been standardized. Evidence is collected, signed, and locked in a secure place to guarantee that legal evidence procedures are maintained. This is known as the chain of evidence and is a legal term that describes a carefully monitored procedure of evidence collection and preservation. Maintaining the Chain of evidence from the medical examination, testing and tissue sampling from its origin of collection to court allows the results of the sampling to be admitted as evidence.[83] The use of photography is often used for documentation.[65]

The information derived from the analysis can often help determine whether sexual contact occurred, providing information regarding the circumstances of the incident, and be compared to reference samples collected from patients and suspects.

Prevention

As sexual violence affects all parts of society, the response to sexual violence is comprehensive. The responses can be categorized as: individual approaches, health care responses, community-based efforts and actions to prevent other forms of sexual violence.

Sexual assault may be prevented by secondary school,[91] college,[92][93] and workplace education programs.[94] At least one program for fraternity men produced "sustained behavioral change."[92][95]

Statistics and epidemiology

Worldwide

International Crime on Statistics and Justice by the United Nations Office on Drugs and Crime (UNODC) find that worldwide, most victims of rape are women and most perpetrators male.[96] The study also found that rapes against women are rarely reported to the police and that the number of female rape victims is significantly underestimated.[96] Southern Africa, Oceania and North America also report the highest records of rape rates.[96]

Most rape research and reports of rape are limited to male-female forms of rape. Research on male-on-male and female-on-male rape is rare. Fewer than one in ten male-male rapes are reported. As a group, males who have been raped by either gender often get little services and support, and legal systems are often ill equipped to deal with this type of crime.[97] Instances in which the perpetrator is female, are not clear and lead to the denial of women being sexual aggressors. This could obscure the true dimensions of the problem.[98] It is likely under-reported illustrating a double standard.[99] Forty-three percent of high school and young college men reported being coerced into sexual behavior and, of those, 95% reported that a female was the aggressor.[100]

The humanitarian news organization IRIN claims that an estimated "500,000 rapes are committed annually in South Africa",[101] once called 'the world's rape capital.'[102] The country has some of the highest incidences of child sexual abuse in the world with more than 67,000 cases of rape and sexual assaults against children reported in 2000, with welfare groups believing that unreported incidents could be up to 10 times higher.[68] Current data suggest that the incidence of rape has risen significantly in India.[103]

United States

FBI sex offense victims in 2012:[104]

- 67,354 female
- 12,000 male.

FBI convicted sex offenders in 2012:[105]

- 78,500 male
- 4394 female.

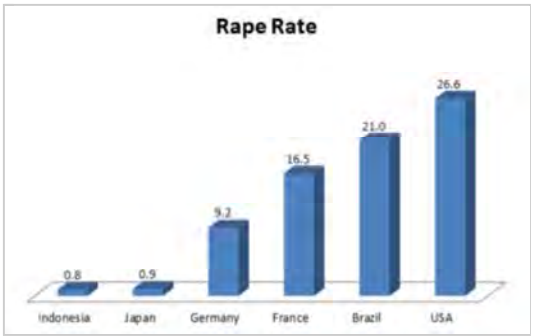

UNODC : Reported rape per 100,000 population (2011)

Statistics maintained by the CDC include:

- 27% of women and 12% of men have experienced sexual violence, including rape
- 50% of bisexual women have been raped at least once in their life.
- 12.5% of lesbians have been raped at least once in their life.
- 17% of heterosexual women have been raped at least once in their life.
- 50% of bisexual men have experienced sexual violence other than rape in their lifetime
- 50% of gay men have experienced sexual violence other than rape in their lifetime
- 20% of heterosexual men have experienced sexual violence other than rape in their lifetime
- 75% of female rape victims report that they were raped before age 25.
- 28% of male rape victims report that they were raped before age ten.[106]

Risk factors vary among different ethnicities. About one third of African American adolescent females report encountering some form of sexual assault including rape.[107] One in three Native American women will experience sexual assault, more than twice the national average for American women.[108]

More than 250,000 cases of rape or attempted rape were recorded by police annually in 65 countries in 2001 through 2002.[109] In 2007, 40% of the 90,427 forcible rapes reported were cleared by arrest or "exceptional means." Exceptional refers to situations where the person refuses to provide information or assistance necessary to obtain an arrest, the defendant dies before being arrested, or the defendant cannot be extradited from another state.[110]

Prosecution

Reporting

In 2005, sexual violence, and rape in particular, was considered the most under-reported violent crime in Great Britain.[111] The number of reported rapes in Great Britain is lower than both incidence and prevalence rates.[112] The legal requirements for reporting rape vary by jurisdiction — each U.S. state may have different requirements. while one country, New Zealand has less stringent limits.[113]

People in Bangalore, India demanding justice for young student who was gang-raped in Delhi in December 2012.

In Italy, a 2006 National Statistic Institute survey on sexual violence against women found that 91.6% of women who suffered this did not report it to the police.[114]

Conviction

In the United Kingdom, In 1970 there was a 33% rate of conviction, while by 1985 there was a 24 per cent conviction rate for rape trials in the UK, by 2004 the conviction rate reached 5%.[115] At that time the government report has expressed documented the year-on-year increase in attrition of reported rape cases, and pledged to address this "justice gap".[111] According to Amnesty International Ireland had the lowest rate of conviction for rape, (1%) among 21 European states, in 2003.[116] In America as of 2012, there exists a noticeable discrepancy in conviction rates among women of various ethnic identities; an arrest was made in just 13% of the sexual assaults reported by American Indian women, compared with 35% for black women and 32% for whites.[108]

False accusation

Eight percent of 2,643 sexual assault cases were classified as false reports by the police in one study. The researchers noted that some of these classifications were based on the personal judgments of the police investigators and were made in violation of official criteria for establishing a false allegation. Closer analysis of this category applying the Home Office counting rules for establishing a false allegation

and excluding cases where the application of the cases where confirmation of the designation was uncertain reduced the percentage of false reports to 3%. The researchers concluded that "one cannot take all police designations at face value" and that "[t]here is an over-estimation of the scale of false allegations by both police officers and prosecutors." Moreover, they added:

> The interviews with police officers and complainants' responses show that despite the focus on victim care, a culture of suspicion remains within the police, even amongst some of those who are specialists in rape investigations. There is also a tendency to conflate false allegations with retractions and withdrawals, as if in all such cases no sexual assault occurred. This reproduces an investigative culture in which elements that might permit a designation of a false complaint are emphasized (later sections reveal how this also feeds into withdrawals and designation of 'insufficient evidence'), at the expense of a careful investigation, in which the evidence collected is evaluated.[117][118]

Another large-scale study was conducted in Australia, with the 850 rapes reported to the Victoria police between 2000 and 2003 (Heenan & Murray, 2006). Using both quantitative and qualitative methods, the researchers examined 812 cases with sufficient information to make an appropriate determination, and found that 2.1% of these were classified by police as false reports. All of these complainants were then charged or threatened with charges for filing a false police report.[119]

FBI reports consistently put the number of "unfounded" rape accusations around 8%. The unfounded rate is higher for forcible rape than for any other Index crime. The average rate of unfounded reports for Index crimes is 2%.[120] "Unfounded" is not synonymous with false allegation[121] and as Bruce Gross of the Forensic Examiner explains,

> This statistic is almost meaningless, as many of the jurisdictions from which the FBI collects data on crime use different definitions of, or criteria for, "unfounded." That is, a report of rape might be classified as unfounded (rather than as forcible rape) if the alleged victim did not try to fight off the suspect, if the alleged perpetrator did not use physical force or a weapon of some sort, if the alleged victim did not sustain any physical injuries, or if the alleged victim and the accused had a prior sexual relationship. Similarly, a report might be deemed unfounded if there is no physical evidence or too many inconsistencies between the accuser's statement and what evidence does exist. As such, although some unfounded cases of rape may be false or fabricated, not all unfounded cases are false.[110]

Other studies have suggested that the rate of false allegations in America may be much higher. A nine-year study by Eugene J. Kanin of Purdue University in a small metropolitan area in the Midwestern United States found that 41% of rape accusations were false.[122] However David Lisak, an associate professor of psychology and director of the Men's Sexual Trauma Research Project at the University of Massachusetts Boston states that quote "Kanin's 1994 article on false allegations is a provocative opinion piece, but it is not a scientific study of the issue of false reporting of rape". He further states that Kanin's study has significantly poor systematic methodology and had no independent definition of a false report. Instead, Kanin classified reports that the police department classified as false also as false.[123] The criterion for falsehood was simply a denial of a polygraph test of the accuser.[122] A 1998 report by the National Institute of Justice found that DNA evidence excluded the primary suspect in 26% of rape cases and concluded that this "strongly suggests that postarrest and postconviction DNA exonerations are tied to some strong, underlying systemic problems that generate erroneous accusations and convictions."[124]

A 2010 study by David Lisak, Lori Gardinier and other researchers published in the journal of *Violence against Women* found that out of 136 cases reported in a ten-year period, only 5.9% were found false.[125]

History

Definitions and evolution of laws

Augustus Caesar enacted reforms for the crime of rape under the assault statute *Lex Iulia de vi publica*, which bears his family name, *Iulia*. It was under this statute rather than the adultery statute of *Lex Iulia de adulteriis* that Rome prosecuted this crime.[126]

Like theft or robbery, rape was originally considered a "private wrong" *iniuria privita*, a crime between the abductor and the legal guardian of the woman in question. It was made into a "public wrong" (*iniuria publica*) by the Roman Emperor Constantine.[127][128]

Emperor Justinian continued the use of the statute to prosecute rape during the sixth century in the Eastern Roman Empire.[129] By late antiquity, the general term *raptus* had referred to abduction, elopement, robbery, or rape in its modern meaning. Confusion over the term led ecclesiastical commentators on the law to differentiate it into *raptus seductionis* (elopement without parental consent) and *raptus violentiae* (ravishment). Both of these forms of *raptus* had a civil penalty and possible excommunication for the family and village receiving the abducted woman, although *raptus violentiae* also incurred punishments of mutilation or death.[130]

The Bulgarian martyresses, a painting depicting the rape of Bulgarian women by Ottoman troops during the April Uprising of 1876.

Virtually all societies have had a concept of the crime of rape. Although what constituted this crime has varied by historical period and culture, until quite recently, the definitions tended to focus around an act of forced vaginal intercourse perpetrated through physical violence or imminent threat of death or severe bodily injury, by a man, on a woman or a girl, not his wife. These definitions differ significantly from the modern definitions of rape in Western countries today. For example, the actus reus of the crime, was, in most societies, the insertion of the penis into the vagina, and, until the 19th century, many jurisdictions required ejaculation for the act to constitute the offense of rape.[131][132] Acts other than vaginal intercourse did not constitute rape in common law countries and in many other societies. In many cultures, such acts were illegal, even if they were consensual and performed between married couples (see sodomy laws). In England, for example, the Buggery Act 1533, which remained in force until 1828, provided for the death penalty for "buggery". Many countries criminalized "non-traditional" forms of sexual activity well into the modern era: notably, in the U.S. state of Idaho, sodomy between consensual partners was punishable by a term of five years to life in prison as late as 2003, and this law was only ruled to be inapplicable to married couples in 1995.[133] Today, in many countries, the definition of the actus reus has been extended to all forms of penetration of the vagina and anus (e.g. penetration with objects, fingers or other body parts) as well as insertion of the penis in the mouth. Throughout much of the history, rape was a crime that could only be perpetrated by a male on a female. The way sexuality was conceptualized in many societies rejected the very notion that a woman could force a man into sex — women were often seen as passive while men were deemed to be assertive and aggressive. Sexual penetration of a male by another male fell under the legal domain of "sodomy".

One of the most distinctive features of rape historically was the fact that not all incidents of forced intercourse constituted this crime. An incident could be excluded from the definition of rape due to the relation between the parties, such as marriage (until a few decades ago wives were nearly universally excluded, and in many countries they continue to be so) or due to the background of the victim (in many cultures forced sex on prostitute, slave, war enemy, member of a racial minority, etc., was not rape). For instance, in 17th century Scandinavia, Christian V's law of 1687 stipulated that rape could only be committed on three categories of women: somebody else's wife, a widow, or an honest virgin. Women who did not fit in any of these categories were not considered legal victims of the crime of rape.[134]

Social issues

In ancient history, rape was viewed less as a type of assault on the female, than a serious property crime against the man to whom she belonged, typically the father or husband. The loss of virginity was an especially serious matter. The damage due to loss of virginity was reflected in her reduced prospects in finding a husband and in her bride price. This was especially true in the case of betrothed virgins, as the loss of chastity was perceived as severely depreciating her value to a prospective husband. In such cases, the law would void the betrothal and demand financial compensation from the rapist, payable to the woman's household, whose "goods" were "damaged".[135] Under biblical law, the rapist might be compelled to marry the unmarried woman instead of receiving the civil penalty if her father agreed. This was especially prevalent in laws where the crime of rape did not include, as a necessary element, the violation of the woman's body, thus dividing the crime in the current meaning of rape and a means for a man and woman to force their families to permit marriage. (See Deuteronomy 22:28–29 (http://tools.wmflabs.org/bibleversefinder2/?book=Deuteronomy&verse=22:28–29&src=NIV).)

From the classical antiquity of Greece and Rome into the Colonial period, rape along with arson, treason and murder was a capital offense. "Those committing rape were subject to a wide range of capital punishments that were seemingly brutal, frequently bloody, and at times spectacular." In the 12th century, kinsmen of the victim were given the option of executing the punishment themselves. "In England in the early fourteenth century, a victim of rape might be expected to gouge out the eyes and/or sever the offender's testicles herself."[136] Despite the harshness of these laws, actual punishments were usually far less severe: in late Medieval Europe, cases concerning rapes of marriageable women, wives, widows, or members of the lower class were rarely brought forward, and usually ended with only a small monetary fine or a marriage between the victim and the rapist.[137] In the 15 and 16th centuries, rape in the Basque charters (Enkarterri, Durangaldea) was punished with death for the offender and the person who was helping him.[138]

Adult women were often extremely reluctant to bring up charges of rape: public admission of having been raped was severely damaging to one's social standing, courts tended to be skeptical of the charges, conviction rates were low, and, in the event that the accusation could not be proved, the victim could then be accused of committing adultery with the rapist (traditionally a serious offense that could have been punished by mutilation[139] or even death). Certain classes of women, such as prostitutes, were banned from raising accusations of rape altogether.[140]

The *ius primae noctis* ("law of the first night") is a term now popularly used to describe an alleged legal right allowing the lord of an estate to take the virginity of his serfs' maiden daughters. Little or no historical evidence has been unearthed from the Middle Ages to support the idea that such a right ever actually existed.[141][142]

The medieval theologian Thomas Aquinas argued that rape, though sinful, was much less sinful than masturbation or coitus interruptus, because it fulfilled the procreative function of sex, while the other acts violated the purpose of sex.[143][144][145][notes 1]

In Medieval Europe, a woman could be legally married by her parents to a stranger without her consent, and, once she was married, she could no longer refuse to consent to sex: the medieval concept of rape did not allow for the possibility of being raped by one's husband. In 1563, the Council of Trent expressly declared that legal Catholic marriages had to be done with consent of both parties, but did not require parental consent, essentially declaring forced marriages invalid.[146] This was not universally accepted: for example, in France, women were not granted the right to marry without parental consent until 1793.[147]

The criminal justice system of many countries was widely regarded as unfair to sexual assault victims. Both sexist stereotypes and common law combined to make rape a "criminal proceeding on which the victim and her behavior were tried rather than the defendant".[148] Additionally, gender neutral laws have combated the older perception that rape never occurs to men,[149]

Since the 1970s, many changes have occurred in the perception of sexual assault due in large part to the feminist movement and its public characterization of rape as a crime of power and control rather than purely of sex. In some countries the women's liberation movement of the 1970s created the first rape crisis centers. One of the first two rape crisis centers, the D.C. Rape Crisis Center, opened in 1972. It was created to promote sensitivity and understanding of rape and its effects on the victim. In 1960 law enforcement cited false reporting rates at 20%. By 1973 the statistics had dropped to 15%.

In war

La vuelta del malón (The return of the raiders) by Ángel Della Valle (1892).

In 1998, Judge Navanethem Pillay of the International Criminal Tribunal for Rwanda said: "From time immemorial, rape has been regarded as spoils of war. Now it will be considered a war crime. We want to send out a strong message that rape is no longer a trophy of war."[150] Rape, in the course of war, dates back to antiquity, ancient enough to have been mentioned in the Bible.[151] The Israelite, Persian, Greek and Roman armies reportedly engaged in war rape.[152] The Mongols, who established the Mongol Empire across much of Eurasia, caused much destruction during their invasions.[153] Contemporary documents say that after a conquest, the Mongol soldiers looted, pillaged and raped.[154] According to Rogerius of Apulia, a monk who survived the Mongol invasion of Hungary, the Mongol warriors "found pleasure" in humiliating local women.[155]

The systematic rape of as many as 80,000 women by the Japanese soldiers during the six weeks of the Nanking Massacre is an example of such atrocities.[156] During World War II an estimated 200,000 Korean and Chinese women were forced into prostitution in Japanese military brothels, as so-called "Comfort women".[157] French Moroccan troops known as Goumiers committed rapes and other war crimes after the Battle of Monte Cassino. *(See Marocchinate.)*[158] French women in Normandy complained about rapes during the liberation of Normandy.[159][160] Soldiers raping women and girls was common in many areas occupied by the Red Army. A female Soviet war correspondent described what she had witnessed: "The Russian soldiers were raping every German female from eight to eighty. It was an army of rapists."[161]

According to researcher and author Krisztián Ungváry, some 38,000 civilians were killed during the Siege of Budapest: about 13,000 from military action and 25,000 from starvation, disease and other causes. Included in the latter figure are about 15,000 Jews, largely victims of executions by Hungarian Arrow Cross Party militia. When the Soviets finally claimed victory, they initiated an orgy of violence, including the wholesale theft of anything they could lay their hands on, random executions and mass rape. An estimated 50,000 women and girls were raped,[162]:348–350[163][notes 2] although estimates vary from 5,000 to 200,000.[164]:129 Hungarian girls were kidnapped and taken to Red Army quarters, where they were imprisoned, repeatedly raped and sometimes murdered.[165]:70–71

See also

- Child grooming
- Courtship disorder
- Criminal transmission of HIV
- Emergency contraception (the morning after pill)
- Factors associated with being a victim of sexual violence
- Post-assault treatment of sexual assault victims
- Rape in fiction
- Sexual violence by intimate partners
- Special Victims Unit (also known as the Sex Crimes Unit)
- Serial rapist
- *Against Our Will*
- *A Natural History of Rape*

Notes

1. Thomas Aquinas, *Summa Theologica*, question 154. "...it follows that in this matter [the sin of unnatural vice] is gravest of all. After it comes incest... With regard to the other species of lust they imply a transgression merely of that which is determined by right reason, on the presupposition, however, of natural principles." Here, *unnatural vice* includes, in decreasing order of sinfulness, bestiality, homosexual intercourse, any unconventional form of heterosexual intercourse, and 'uncleanness' (masturbation). 'Other species of lust' include intercourse with a consecrated virgin or a nun, rape, adultery, seduction of a virgin, and 'simple fornication' (consensual intercourse between unmarried people.)
2. "The worst suffering of the Hungarian population is due to the rape of women. Rapes—affecting all age groups from ten to seventy are so common that very few women in Hungary have been spared." Swiss embassy report cited in Ungváry 2005, p.350. (Krisztian Ungvary *The Siege of Budapest* 2005)

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6. Human Rights WatchNo Escape: Male Rape In U.S. Prisons. Part VII. Anomaly or Epidemic: The Incidence of Prisoner-on-Prisoner Rape. (https://www.hrw.org/legacy/reports/2001/prison/report7.html#_1_48) estimates that 100,000–140,000 violent male-male rapes occur in U.S. prisons annually; compare with FBI statistics (https://www.fbi.gov/ucr/cius2007/offenses/violent_crime/forcible_rap that estimate 90,000 violent male-female rapes occur annually.
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External links

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- News related to rape at Wikinews

Wikiquote has quotations related to: ***Rape***

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TRANSESTERIFICATION PROCESS TO MANUFACTURE ETHYL ESTER OF RAPE OIL

Roger A. Korus, Dwight S. Hoffman, Narendra Bam,
Charles L. Peterson, and David C. Drown
Department of Chemical Engineering
University of Idaho
Moscow, ID 83843

ABSTRACT

A process for the production of the ethyl ester of winter rape [EEWR] for use as a biodiesel fuel has been studied. The essential part of the process is the transesterification of rape oil with ethanol, in the presence of a catalyst, to yield the ethyl ester of rape oil as a product and glycerin as a by-product. Experiments have been performed to determine the optimum conditions for the preparation of EEWR. The process variables were: 1) temperature, 2) catalyst, 3) rate of agitation, 4) water content of the alcohol used, and 5) the amount of excess alcohol used. The optimum conditions were: 1) room temperature, 2) 0.5% sodium methoxide or 1% potassium hydroxide catalyst by weight of rapeseed oil, 3) extremely vigorous agitation with some splashing during the initial phase of the reaction and agitation was not necessary after the reaction mixture became homogeneous, 4) absolute ethanol was necessary for high conversion, and 5) 50% excess ethanol with $NaOCH_3$ or 100% excess with KOH gave a maximum conversion. Viscosity, cloud point and pour point of the EEWR were measured. A preliminary break-even cost for the commercial production of EEWR was found to be $0.55/liter [$2.08/U.S. gallon].

INTRODUCTION

Background

Vegetable oils have attracted attention as a potential renewable resource for the production of an alternative for petroleum-based diesel fuel. Various products derived from vegetable oils have been proposed as an alternative fuel for diesel engines, including neat vegetable oil, mixtures of vegetable oil with petroleum diesel fuel, and alcohol esters of vegetable oils. Alcohol esters of vegetable oils appear to be the most promising alternative. Vegetable oils are triglycerides [glycerin esters] of fatty acids; alcohol esters of fatty acids have been prepared by the transesterification of the glycerides, wherein linear, monohydroxy alcohols react with vegetable oils in the presence of a catalyst to produce alcohol esters of vegetable oils [AEVO] and glycerin as a by-product (Fig. 1). AEVO when used as an alternative diesel fuel has been identified as a "biodiesel".

Detailed literature reviews concerning the production and use of AEVO have been given by Peterson et al. (1991) and Bam (1991). Previous publications reported the use of methyl, ethyl, and butyl alcohols for the transesterification of rape oil, sunflower oil, cottonseed oil, peanut oil, soybean oil, and palm oil to produce methyl, ethyl, and butyl esters. The transesterifications were enhanced by the use of potassium hydroxide, sodium hydroxide, sodium methoxide, or sodium ethoxide as a catalyst. Important reaction parameters for the transesterifications are: 1) ratio of alcohol to vegetable oil, 2) temperature, 3) rate of agitation, and 4) amount of water present in reaction mixture.

AEVO has a viscosity approximately twice that of diesel fuel. Viscosity is of prime concern because of its effects on spray patterns and deposit formation. AEVO performs similarly to diesel in both short- and long-term engine tests (Fig. 2) while the raw vegetable oil develops severe injector fouling after 200 hours of operation.

Alcohol esters of fatty acids have surprisingly good emission characteristics; the emissions of methyl esters of winter rape [MEWR] gave significantly lower total particulates and lower polynuclear aromatic hydrocarbons than #2 diesel fuel. However, combustion of MEWR gave higher levels of NO_X and aldehyde emissions than did #2 diesel fuel. Additional tests of emissions from biodiesel fuels are needed to enhance their commercialization.

The use of neat vegetable oil, mixtures of vegetable oil and other components, and alcohol esters of vegetable oils [AEVO] has been under study at the University of Idaho since 1979. Peterson et al. (1991) have given a complete description of the process for the production of the methyl ester of winter rape [MEWR]. MEWR has been manufactured in a 756-liter [200 - U.S. gallons] batch pilot plant scale (Fig. 3) using potassium hydroxide as a catalyst. The MEWR biodiesel product has been used as a replacement for diesel fuel in laboratory studies and in tractors using the ester under actual field conditions. A 20 KW (27 hp) Satoh tractor has been powered with 100% MEWR biodiesel since the spring of 1987. The tractor has been performing satisfactorily to date. A preliminary economic analysis of the commercial production of MEWR showed a break-even cost of $0.49/liter [$1.85/U.S. gallon). Costs are in 1991 U.S. dollars.

Research at the University of Idaho has been focused on alcohol esters of vegetable oils because vegetable oils are a renewable energy resource. Earlier work has concentrated on methyl esters. The next logical step is the use of ethanol rather than methanol and consequently produce the ethyl ester of vegetable oils. Ethanol can be produced from agricultural renewable resources, thereby attaining total independence from petroleum-based alcohols. Consequently, a process for the production of the ethyl ester of winter rape [EEWR] for use as a biodiesel fuel has been studied. The process system which has been studied is similar

to the process for production of MEWR as shown in Figs. 1 and 3 except ethanol was used instead of methanol and catalysts other than KOH as well as KOH were tested.

Objective

Optimum conditions for the transesterification of rape oil to produce EEWR were determined which yielded a maximum conversion of rape oil to the ethyl ester. The variables were: 1) Temperature of reaction; 2) Catalyst; 3) Rate of agitation of reaction mixture; 4) Water content of alcohol (ethanol); and 5) Amount of excess alcohol.

METHODS

Materials

The rapeseed oil used for the experiments was extracted from Bridger rapeseed; Bridger is a winter variety of rape. This oil has a high level of erucic acid (53.2%). Extraction of the oil from the rapeseed (Fig. 3) was done by the Department of Agricultural Engineering at the University of Idaho (Peterson et al. 1983). A Cecoco oil expeller press with an extraction efficiency of approximately 80% was an integral part of their process. The automated and instrumented system was equipped with a seed preheater-auger, seed bin, meal auger, and oil pump. Reagent grade absolute ethanol was used. Potassium hydroxide pellets with an assay of 85% were purchased from EM Science Company; Fisher Scientific Company provided the purified, dry sodium methoxide powder; sodium ethoxide was provided by Aldrich Chemical Company; and potassium methoxide was a product from Aldrich Chemical Company.

Fractional Factorial Experimental Design

A fractional, factorial experimental design was used to determine the optimum values of temperature, degree of agitation, type of catalyst, and water content of ethanol used. A 2^{4-1} fractional, factorial design was chosen for this purpose. Using a 2^{4-1} design, four variables were studied at two levels by performing eight experiments ($2^{4-1} = 8$). The fractional, factorial design contains three quantitative variables - temperature, agitation, and water content of ethanol - and one qualitative variable - catalyst. The response is degree of conversion of rape oil to ethyl ester. The design matrix (Table 1) shows the two levels of the variables and the response. Table 1 shows the recorded data with the levels coded so that a minus one (-1) represents the low level and a plus one (+1) represents the high level. The catalyst chosen for the lower level was sodium ethoxide and potassium hydroxide was chosen for the higher level.

The levels which were chosen for the various variables in this study were based on previous experiments and practical considerations. The low level of temperature was chosen as room temperature and the high level was chosen slightly higher below the boiling point of 190 proof ethanol. The lower level of ethanol chosen was 190 proof (five wt percent water); the higher level was 200 proof (zero wt percent water). The lower level of agitation was a gentle agitation and the higher level of agitation was an extremely vigorous agitation with some splashing.

Table I. Design Matrix for the Experimental Design

Parameters	Levels	
1 - Agitation	High (+1)	Low (-1)
2 - Temperature	75 C	30 C
3 - Catalyst	KOH	$NaOC_2H_5$
4 - Ethanol	200 proof	190 proof

Expt No.	Parameters 1 2 3 4	% Conversion
1	-1 -1 -1 -1	51
2	+1 -1 -1 +1	98
3	-1 +1 -1 +1	81.5
4	+1 +1 -1 -1	45
5	-1 -1 +1 +1	91.7
6	+1 -1 +1 -1	29
7	-1 +1 +1 -1	77.8
8	+1 +1 +1 +1	100

Experimental Setup and Procedure

Three operations were studied in the experimental work which was performed. These are shown in Figure 3; they are: 1) transesterification, 2) phase separation, and 3) washing. Figure 1 shows the tranesterification; in this study ethanol, in presence of a catalyst, instead of methanol was used and ethyl ester was produced. After the reaction was complete, the reaction products separated into two layers; the ester product formed the upper layer and the by-product glycerin formed the lower layer. The residual catalyst and unreacted excess alcohol were distributed between the two phases. After separation of the phases, the catalyst and alcohol were washed from the ester with water.

Transesterification

The transesterification experiments were performed in conical flasks using 250 g of rapeseed oil. Catalysts were 2.5 g (1% by weight of the oil) of potassium hydroxide or 1.25 g (0.5% by weight of oil) of sodium ethoxide The catalyst was first dissolved in 72 g of ethanol which represented a 100% excess of the stoichiometric amount required for the transesterification. It was necessary to heat the ethanol slightly with stirring to completely dissolve the catalyst The ethanol and dissolved catalyst were then added to the oil and stirring was begun. Samples of approximately 3-4 ml of the reaction mixture were pipetted out at 1, 30, 60, and 120 minutes respectively. The reaction was arrested in the samples by adding one or two drops of water. The samples were analyzed to determine the degree of completion of the reaction.

Additional experiments were conducted to study the effects of temperature and sodium methoxide and potassium methoxide catalysts on ester yields. Experiments were also performed to determine ester yields using the stoichiometric amount and amounts of alcohol equal to 50%, 75%, and 100% excess.

Phase separation

After 120 minutes of reaction time, the reaction was stopped and the reaction mixture was allowed to stand overnight while phase separations occurred. The ester phase was then decanted from the equilibrium mixture.

Washing

Excess alcohol and residual catalyst were washed from the ester with water. The ester phase was placed in a glass column 1.26 cm in diameter and 100 cm in length. Water was sprayed into the top of the column at a low velocity. The excess alcohol and catalyst were removed by the water as it percolated through the column. During the washing, some of the ester formed an emulsion with the water; a time of 24-48 hours was required for the water phase containing alcohol, catalyst, and emulsified ester to settle and the ester phase to become clear.

Analyses

The analyses have been described by Bam (1991). High Performance Liquid Chromatography (HPLC) was used to determine the composition of the reaction mixture and the ester conversion. The composition of the ester was determined by Gas Chromatography (GC). Viscosity measurements of the ester were made by following ASTM standards (ASTM D445 or IP 71). The ester was analyzed for cloud and pour points by following ASTM Standards D2500-81 and D97, respectively.

RESULTS AND DISCUSSION

Statistical Analysis of Experimental Design

The results obtained from the eight experiments performed according to the fractional factorial design (Table 1) were analyzed using Statistical Analysies System (SAS). The results of this analysis were used to develop an equation which shows the relationships between degrees of conversion, rate of agitation, temperature, water content of ethanol, and catalyst.

$$CONV = 71.75 - 3.75(A) + 4.325(T) + 21.05(ALC) + 9.95(T)(C) - 6.37(T)(ALC) \qquad (1)$$

where A = rate of agitation; T = temperature; ALC = water content of alcohol; C = catalyst; and CONV = percentage conversion of oil to ester.

In this equation, the values of A are either -1 (low agitation) or +1 (high agitation); values of T are either -1 (30C) or +1 (75C); values of ALC are either -1 (190 proof) or +1 (200 proof); values of C are either -1 ($NaOC_2H_5$) or +1 (KOH). For example, with high agitation, with temperature = 75C, using $NaOC_2H_5$ as catalyst, and 190 proof ethanol,

$$\begin{aligned} CONV &= 71.75 - 3.75(+1) + 4.325(+1) + 21.05(-1) + 9.95\,[(+1)(-1)] - 6.375[(+1)(-1)] \\ &= 47.7\% \end{aligned}$$

Inspection of Equation (1) shows that water content of alcohol is the most important independent factor affecting degree of conversion and that increasing water content (lowering proof) decreases degree of conversion. Further inspection shows that the interaction between temperature and catalyst and the

interaction between temperature and water constant of alcohol are significant.

A matrix was designed which contained sodium methoxide and potassium methoxide in place of potassium hydroxide and sodium ethoxide as shown in Table 1. The conversions obtained were approximately the same for all catalysts except potassium methoxide. The conversion obtained with potassium methoxide was significantly lower.

Phase separation was also treated as the dependent variable as a function of agitation, temperature, catalyst and water content of alcohol. The type of catalyst used was an important variable affecting the separation of the ester phase from the glycerin phase. Temperature, alcohol, and the interaction between temperature and alcohol also had significant effects on phase separation.

Optimum Conditions for Ethyl Ester Preparation

Transesterification

Temperature had no detectable effect on the ultimate conversion to ester. However, higher temperatures decrease the time required to reach maximum conversion. It is believed the cost of energy for heating would exceed the value of time saved by using higher temperatures. Therefore, room temperature is considered to be the optimum temperature for conversion.

A high degree of conversion could be obtained only if the oil and alcohol phases have been blended into one homogeneous phase. This requires extremely vigorous agitation with some splashing at the start of the reaction. When the reaction mixture is homogeneous, the conversion and time to reach maximum conversion are independent of agitation.

The presence of water in the reaction mixture markedly reduces the conversion of oil to ester (see Equation 1). 200 proof ethanol must be used in order to obtain a high degree of conversion. The experiments in which different amounts of excess alcohol were used in the reaction mixture showed that an amount in 50% excess of the stoichiometric ratio gave a high conversion when sodium methoxide was the catalyst. Potassium hydroxide catalyst required 100% excess alcohol to achieve similar conversion and phase separation from the glycerin.

Although SAS indicated sodium ethoxide, sodium methoxide, and potassium hydroxide all gave good conversions during transesterification, sodium methoxide was chosen as the most promising catalyst due to phase separation considerations described below. Experiments were performed in which the concentration of sodium methoxide varied from 0.3% to 0.5% by weight of rapeseed oil used. Conversion was maximum for 0 5% concentration of catalyst.

Phase Separation

The type of catalyst used during the transesterification has an important effect on the subsequent phase separation. Phase separation was erratic and dependent upon the amount of excess alcohol present in the case of potassium hydroxide. No phase separation occurred when potassium methoxide was used. When sodium methoxide or sodium ethoxide was used, separation was good; however, sodium methoxide was judged to give the better result.

The impact of variables other than catalyst and excess alcohol on phase separation was considered minor relative to their impact on transesterification.

Washing

During the washing of the ester phase care must be taken to add water slowly in a fine spray. Agitation of the ester with the flow of water caused a loss of as much as 18% of the ester due to the formation of an emulsion.

The importance of washing is the removal of residual catalyst from the ester. The effluent wash water was monitored for sodium content and washing continued until the sodium content of the effluent was the same as the sodium content of the entering wash water. Complete removal of catalyst from the ester was assured by determining the amount of sodium in the glycerin phase and the total sodium removal from the ester phase. The sum of these accounted for all of the sodium entering the reaction as a constituent of the catalyst.

Physical Properties of EEWR

The measured viscosity of the ethyl ester was 7.0 centistokes at 25C. The viscosity of the rapeseed methyl ester is 6 cs at 40C and 2.39 cs at 100C; the viscosity of #2 diesel is 3.2 cs at 40C and 1.26 cs at 100C. The cloud and pour points of the ethyl ester was found to be -7C and -16C, respectively.

Preliminary Economic Evaluation Between Methyl and Ethyl Esters

The economic viability of the rapeseed ethyl esters was compared to that of methyl esters. This was done by comparing the breakeven cost of methyl ester with that of ethyl ester. Breakeven costs were found by determining the sales value of product which would be required to operate a manufacturing facility at zero profit. At zero profit the total of all annual costs equals the sales value. In the comparison made in this study, annual costs were separated into raw material costs and all other costs which were identified as processing costs. Figure 4 shows the breakeven cost for four different situations. These are 1) methyl ester using KOH as catalyst and methyl alcohol, 2) ethyl ester using KOH as catalyst and denatured 200 proof-ethanol, 3) ethyl ester using sodium methoxide as catalyst and denatured 200 proof ethanol, and 4) ethyl ester using sodium methoxide as catalyst and 200 proof absolute alcohol. It can be noted that oil is the major cost in all cases. Raw material costs were based on a rapeseed oil cost of $0.44/kg [$0.20/lb]. The breakeven cost for methyl ester is $1.85/U.S. gallon and the maximum cost for ethyl ester is $2.39/U.S. gallon.

CONCLUSIONS

Rapeseed oil ethyl ester can be made successfully under the following conditions for transesterification: 1) Room temperature; 2) 0.5% sodium methoxide catalyst based on weight of rapeseed oil and 50% excess of the stoichiometric amount of required 200 proof alcohol; or 3) 1.0% potassium hydroxide catalyst and 100% excess of the stoiciometric amount of 200 proof alcohol; 4) Extremely vigorous agitation with a little splashing until the reaction mixture becomes homogeneous.

Since the ester has an extremely high tendency to form an emulsion on contact with water, care must be taken to maintain low levels of agitation during washing.

The economic viability can be significantly improved if lower valued oil feedstocks can be obtained. Waste animal fats from meat processing facilities, waste frying oils from French fried potatoes and other food frying operations, and low-grade residue oils from food grade oil crushing and refining plants could be

substituted for the rapeseed oil used in this study. The ethanol must be moisture free, but can be denatured with small amounts of gasoline

ACKNOWLEDGEMENTS

The authors thank the Department of Agricultural Engineering, University of Idaho for furnishing the rapeoil used in this study. The assistance given by members of the Agricultural Engineering Department is greatly appreciated. Dr. Rico Cruz assisted with the experimental setup and with the analyses performed during the research. This work was supported by a U.S. Department of Agriculture-ARS Cooperative Agreement #58-43YK-7-0045 Amendment #4.

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Correspondence should be addressed to: Dr. David C. Drown, Associate Professor, Department of Chemical Engineering, University of Idaho, Moscow, ID 83844-1021, Phone: (208)-885-7848.

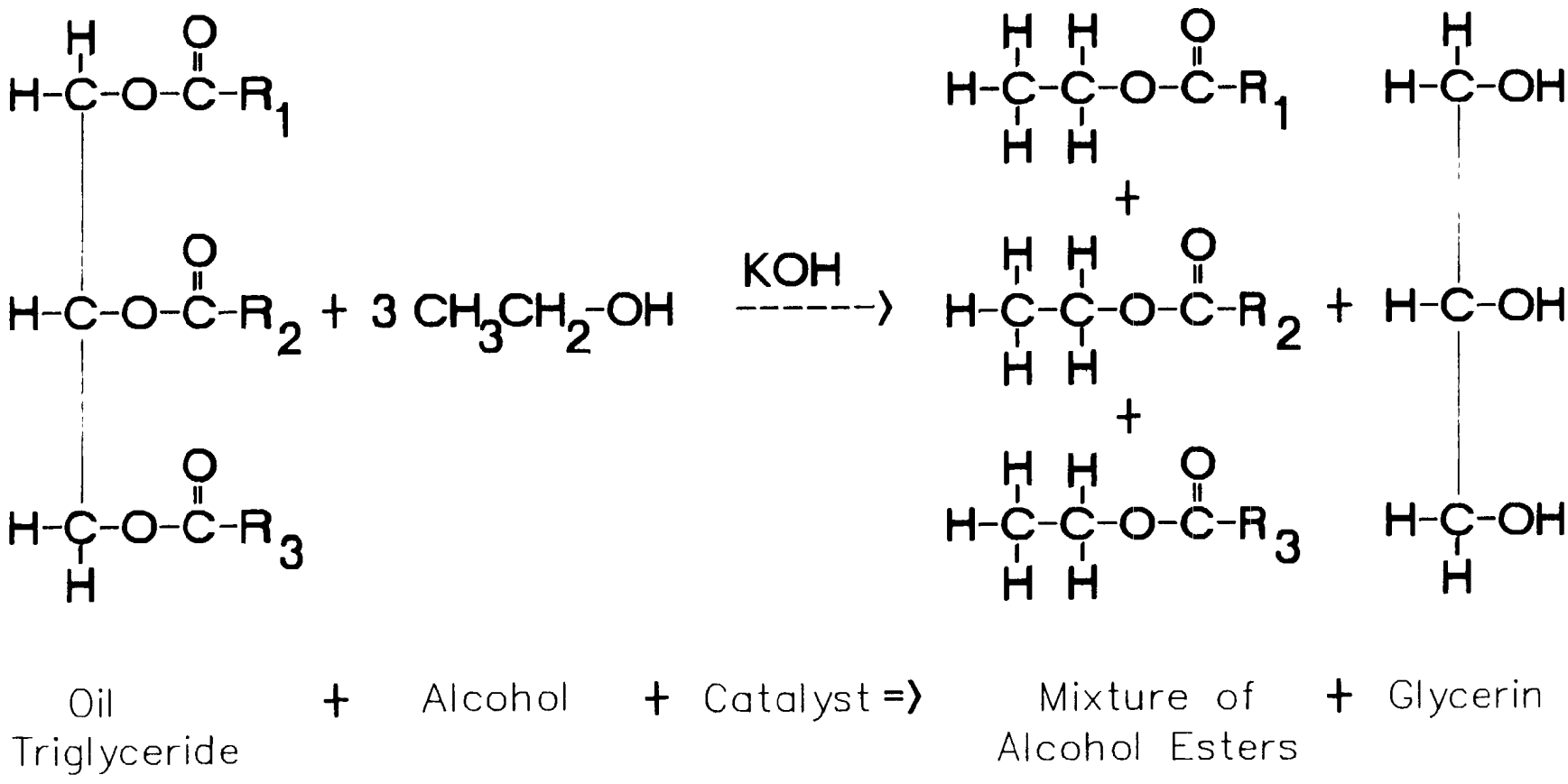

Figure 1. Transesterification Chemistry

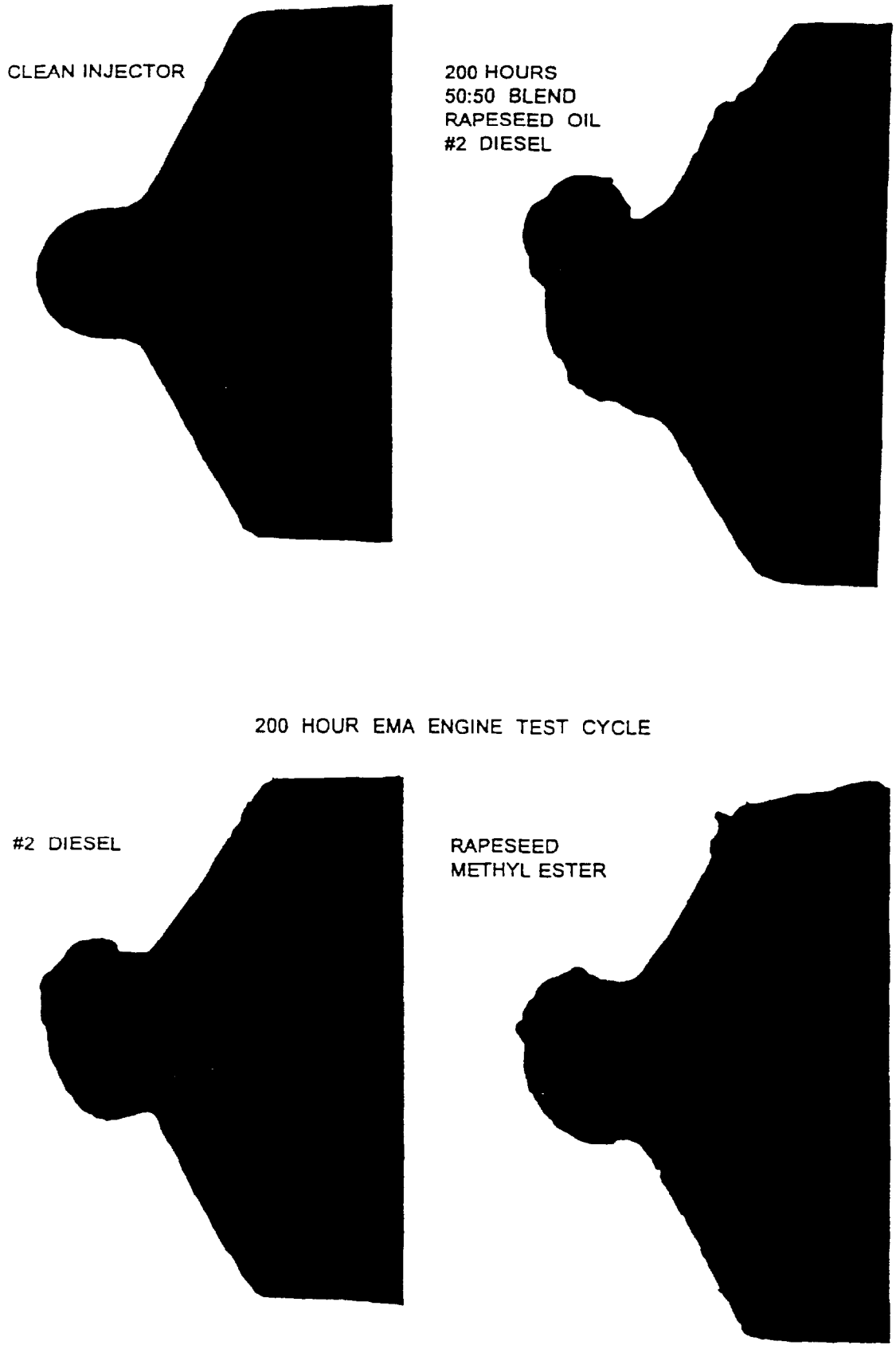

Figure 2. Injector nozzles: 200 hour EMA Engine Test Cycle

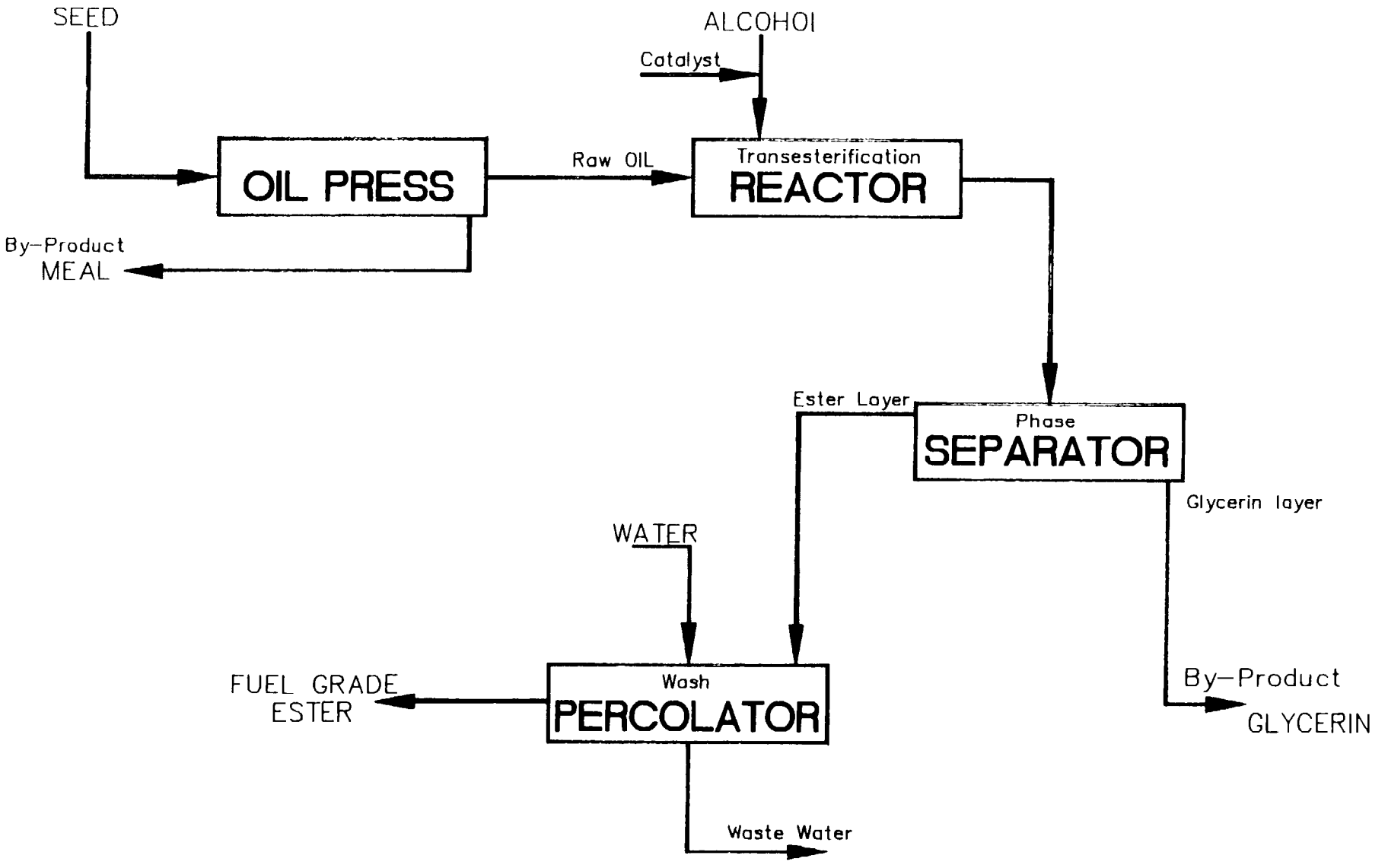

Figure 3. Biodesel Transesterification Process Flowsheet

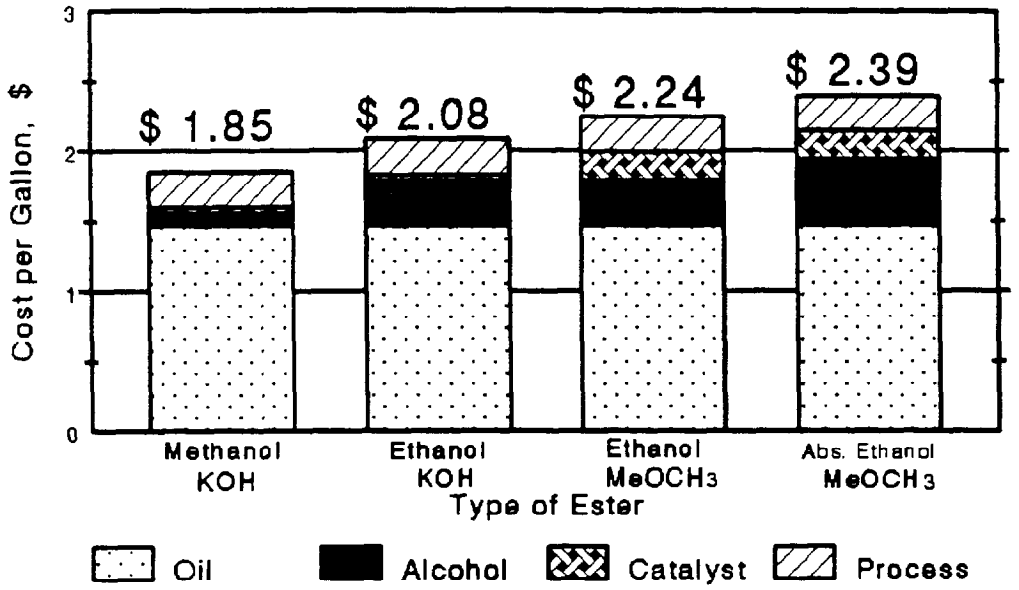

Figure 4. Cost of Ester Production

Abseiling

From Wikipedia, the free encyclopedia

An **abseil** (/ˈæbseɪl/ or /ˈɑːpzaɪl/; from German *abseilen*, meaning "to rope down"), also called a **rappel** after its French name, is a controlled descent of a vertical drop, such as a rock face, using a rope.

Abseiling using a belay device

Climbers use this technique when a cliff or slope is too steep and/or dangerous to descend without protection. Many climbers use this technique to protect established anchors from damage. Rope access technicians also use this as a method to access difficult-to-reach areas from above for various industrial applications like maintenance, construction, inspection and welding. Rescue teams are also known for using this method as a way to access injured or stranded victims.

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- 1 History
- 2 Equipment
- 3 Application
- 4 Styles/techniques
- 5 Safety and ecological issues
- 6 See also
- 7 References and footnotes
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History

The origin of the *abseil* is attributed[1] to Jean Charlet-Straton, a Chamonix guide who lived from 1840–1925. Charlet originally devised the technique of the *abseil* method of roping down during a failed solo attempt of Petit Dru in 1876. After many attempts, some of them solo, he managed to reach the summit of the Petit Dru in 1879 in the company of two other Chamonix guides, Prosper Payot and Frédéric Folliguet, whom he hired. During that ascent, Charlet perfected the abseil.

Equipment

- Ropes: Climbers often simply use their climbing ropes for abseiling. For many other applications, low-stretch rope (typically ~2% stretch when under the load of a typical bodyweight) called static rope is used to reduce bouncing and to allow easier ascending of the rope.
- Anchors for abseiling are sometimes made with trees or boulders, using webbing and cordellete, or also with rock climbing equipment, such as nuts, hexes and spring-loaded camming devices. Some climbing areas have fixed anchors such as bolts or pitons for rappelling off of without having to leave other (more valuable) gear behind.
- A descender or rappel device is a friction device or friction hitch that allows rope to be payed out in a

controlled fashion, under load, with a minimal effort by the person controlling it. The speed at which the abseiler descends is controlled by applying greater or lesser force on the rope below the device or altering the angle at which the rope exits the device. Descenders can be task-designed or improvised from other equipment. Mechanical descenders include braking bars, the figure eight, the abseil rack, the "bobbin" (and its self-locking variant the "stop"), the gold tail, and the "sky genie" used by some window-washers and wildfire firefighters. Some improvised descenders include the Munter hitch, a carabiner wrap, the basic crossed-carabiner brake and the piton bar brake (sometimes called the carabiner and piton). There is an older, more uncomfortable, method of wrapping the rope around one's body for friction instead of using a descender, as in the Dulfersitz or Geneva methods used by climbers in the 1960s.

- A climbing harness is often used around the waist to secure the descender. A comfortable climbing harness is important for descents that may take many hours.
- A prusik, Klemheist knot, or autoblock knot may be used as safety back-up, commonly referred to as an 'autoblock,' and is used as a back-up in the case of the abseiler losing control of the abseil. One of these friction hitches is wrapped around the rope below the rappel device, using a short loop of smaller diameter cord or webbing, often called a 'prusik loop'. The prusik loop is then attached to the belay loop or leg loop of the harness.
- Helmets may be worn to protect the head from bumps and falling rocks. A light source may be mounted on the helmet in order to keep the hands free in unlit areas.
- Gloves protect hands from the rope and from hits with the wall. They are mainly used by recreational abseilers, industrial access practitioners, adventure racers and military as opposed to climbers or mountaineers. In fact, they can increase the risk of accident by becoming caught in the descender in certain situations.[2]
- Boots or other sturdy footwear with good grips may be worn, especially climbing shoes
- Knee-pads (and sometimes elbow-pads) are popular in some applications for the protection of joints during crawls or hits.

A time-lapse panorama of a rock climber abseiling off a climb

Application

Abseiling is used in a number of applications, including:

- Climbing, for returning to the base of a climb or to a point where one can try a new route.
- Recreational abseiling.
- Canyoning, where jumping waterfalls or cliffs may be too dangerous.
- Caving and speleology, where underground pitches are accessed using this method (single rope technique).
- Adventure racing, where events often include abseiling and other rope work.

- Industrial/commercial applications, where abseiling techniques are used to access parts of structures or buildings so as to perform maintenance, cleaning or construction, e.g. steeplejacking, window cleaning, etc.
- Access to wildfires.
- Confined spaces access, such as investigating ballast tanks and other areas of ships.
- Rescue applications, such as accessing injured people or accident sites (vehicles or aircraft) and extracting casualties using abseiling techniques.
- (Military) Tactical heliborne insertion of troops, including special forces, into the battlefield close to the objective, when proper landing zones are not available. More commonly used in urban warfare scenarios and is increasingly replaced by fast-roping. Typical examples include: insertion into urban environments, boarding of sea-going vessels and insertion of forces to seize and secure a landing zone in enemy territory (air assault).

A United States Air Force Pararescueman rappels from a helicopter during a training exercise in Iraq, 2008

Styles/techniques

- Australian rappel — Involves descending facing down.
- Tandem or spider rappelling — Involves two climbers descending on the same belay device. This is done in some rescue situations when one of the climbers is incapacitated or the descent needs to be done quickly. The set-up is similar to a regular rappelling set-up with the first climber is girth hitched off a sling into the descender on the carabiner, and has an auto-block from belay loop of the harness to the rope as a backup. The second rappeller is also girth hitched into the belay device on the carabiner and also anchored into the main rappeller's harness as a back-up.
- *Simul-rappelling* or *simultaneously rappelling* — advanced technique where two climbers at the same time descend the same rope, or two ropes tied together, and one climber's weight counterbalances the other. Generally the technique is considered less safe than the regular repelling; however, it's useful in case of emergencies, or for rapping off opposite sides of a fin or spire where there are no anchor points, which is common in places like the Needles of South Dakota's Black Hills. [3]
- Counterbalance rappelling — Used typically by a leader to reach an injured second. Idea is to rappel off on one strand of rope, using the incapacitated second's weight on the other strand of the rope to counterbalance.
- Releasable abseil - Used by some guides with inexperienced abseilers. A rope is set up by anchoring it with a munter hitch and locking off the non-rappelling strand of the rope. The client descends on the non-locked strand of the rope. The guide unlocks the other strand and lowers the client or the rappeller if the client gets into trouble. Useful with an inexperienced rappeller or when the rappeller gets into trouble, for example, by getting a piece of clothing or hair entangled in the descender.

Australian rappel demonstrated at a dam in Norway

- Classical (non-mechanical methods), e.g. the Dülfersitz — Generally more dangerous and used only in emergencies when no other option is available. They involve descending without aid of mechanical devices, by wrapping the rope around the body, and were used before the advent of harnesses and hardware.
- South African classical abseil (double-roped)- This method is less dangerous as it provides better body support than the classical abseil.
- Fireman's Belay — A method to backup an abseil by a partner on the ground who is able to pull down on the rope from below to arrest the descent. This is a useful safety technique, particularly for inexperienced abseilers.

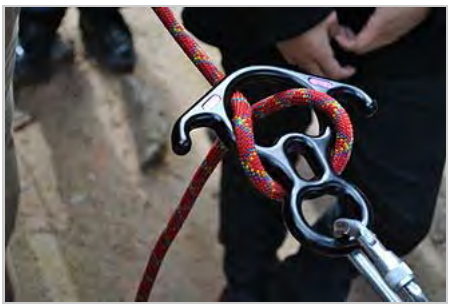

Rescue-style (eared) figure eight descender and rope

Safety and ecological issues

Abseiling can be dangerous, and presents risks, especially to unsupervised or inexperienced abseilers. According to German mountaineer Pit Schubert, about 25% of climbing deaths occur during abseiling, most commonly due to failing anchors. Another frequent cause of accidents is abseiling beyond the end of the rope.[4] Backing up the rope set-up with a friction knot (autoblock, Kleimheist, or prusik) such that the slipping of the rope is stopped even if the climber lets go of the control rope provides a measure of safety with regard to the control of the rate of descent.

Abseiling is prohibited or discouraged in some areas, due to the potential for environmental damage and/or conflict with climbers heading upwards, or the danger to people on the ground.

See also

- Abalakov thread
- List of climbing topics
- Mountaineering

References and footnotes

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4. Pit Schubert, *Sicherheit und Risiko in Fels und Eis* vol. I, München 2009, p.104

External links

- BMC: Abseiling: Not the quickest way to reach the ground (http://www.thebmc.co.uk/Feature.aspx?id=1396)
- Abseiling: Information and instruction for charities to fundraise (http://www.charityabseils.com/)

Wikimedia Commons has media related to ***Abseiling***.

Look up ***abseiling*** in Wiktionary, the free

dictionary.

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Categories: Types of climbing | Mountaineering techniques | Caving techniques | Climbing techniques

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KNOTS

Knots in general are only as good as the person who ties them. We recommend tying knots often and double checking them in every situation. Knots are designed to save lives, increase convenience, and solve problems....when used properly. Practice at home if you are unsure about how they are tied, before you go climbing, set anchors, or involve persons less experienced than yourself. Seeking professional assistance is always recommended. We designed our **Ground School** so you can be more aware, more patient, and safer in all outdoor activities.

Aware, patient, and safe climbers, canyoneers, and wilderness travelers live longer.

Doubled-Back Figure Eight

This knot is the industry standard for any situation where human body weight is attached to a rope: climbing, mountaineering, self rescue, rappelling... This knot tightens when weighted and should always be backed up with a **Fisherman's Knot**.

Eight on a Bight

This variation of the figure eight should only be used for body weight when backed up.

Bowline

A non-tensioning knot!!!! This knot is great for tying your tarp to a tree, your dog to a fence post, or towing heavy items. It is not recommended for any situations which require the knot to hold human body weight. Even when backed up, this knot has failed. Use at your own risk.

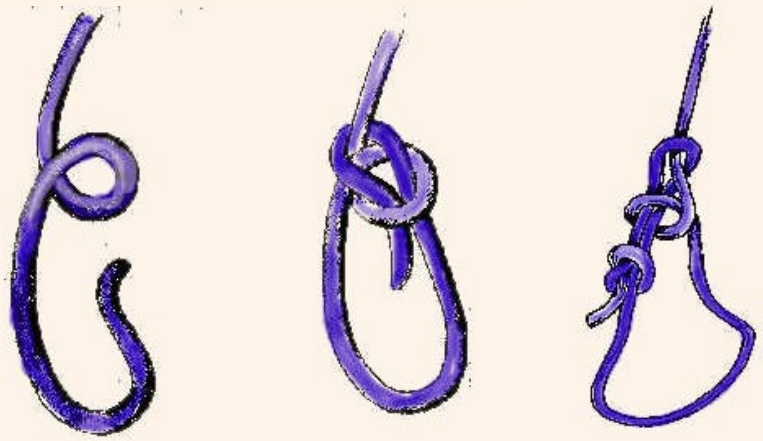

Grapevine

The only recommended way to join two ropes of varying thickness. E.G., an 11mm rope tied with a 10.2mm while descending or lowering. Play with the tension and number of times you rap the rope around its partner. The harder and heavier the rope is weighted, the tighter the knot becomes. Half a Grapevine, also known as a **Fisherman's Knot**, is a great back up knot.

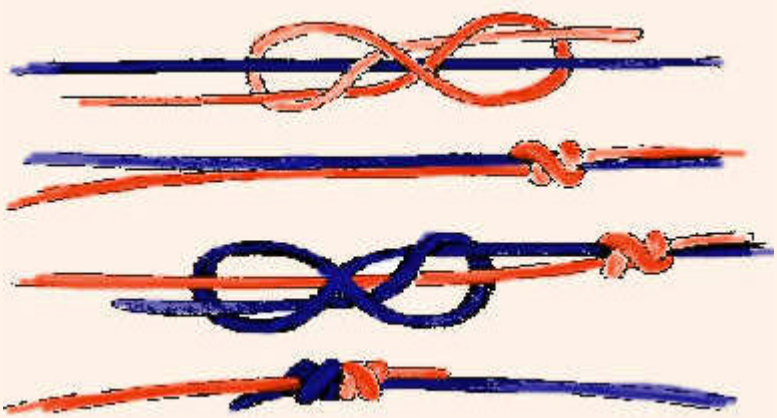

Prussik

A classic tension hitch. A minimum of three turns around the rope creates the necessary friction for ascending, for safety, for self rescue. Prussiks and the variations which follow (Hedden, Bachmann, Klemheist) are only recoomended to be tied with 5mm Spectra Cord or 7mm cord that has a minimum fall rating of 1600lbs.

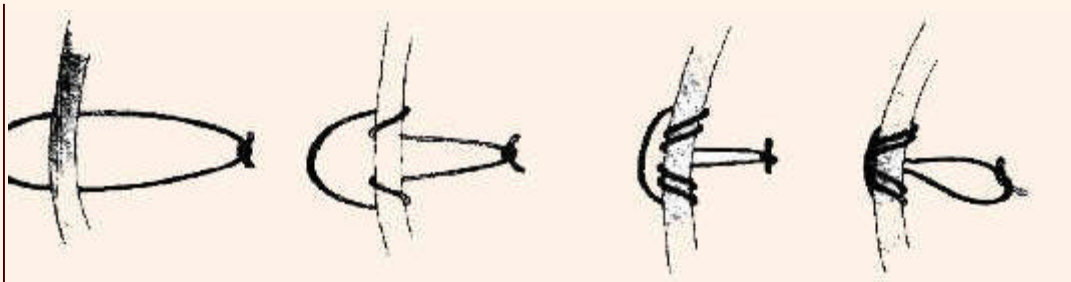

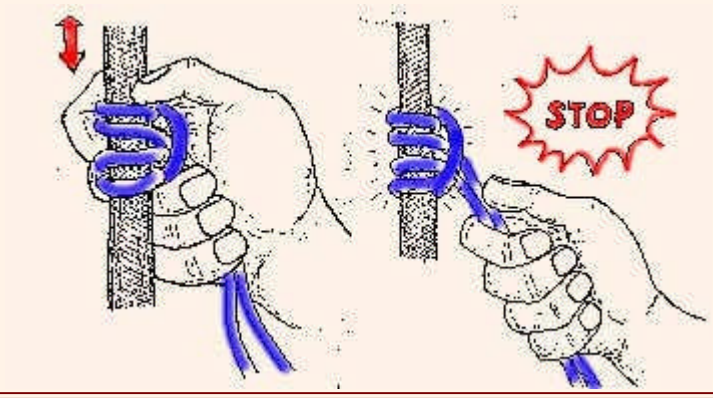

Bachmann

The Bachmann works well for ascending fixed ropes as well as pulling stubborn or twisted ropes from a descent. The carabiner acts as an ascender handle. When weighted, the biner and cord cinch against the rope. Best used as a pair. So simple. Why would anyone get technical without them?

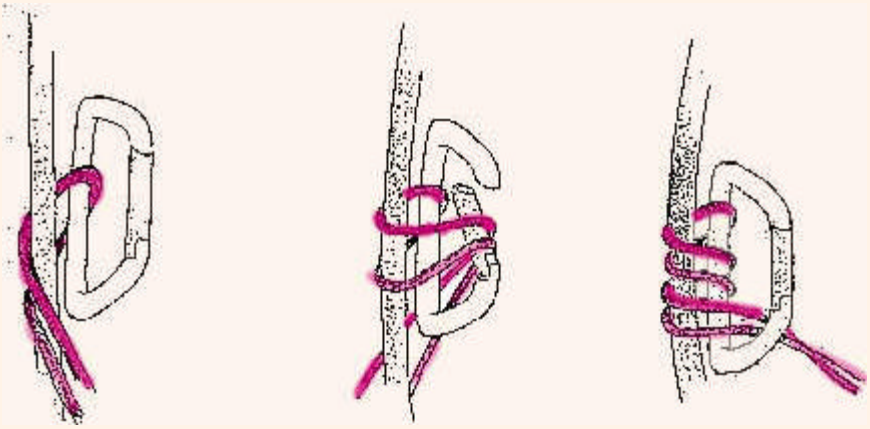

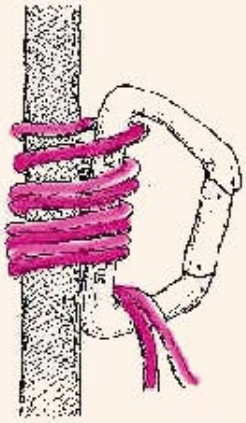

Klemheist

A European technique that is more straight forward to tie than the Prussik. A

minimum of three turns around the ascending rope is required for successful use.

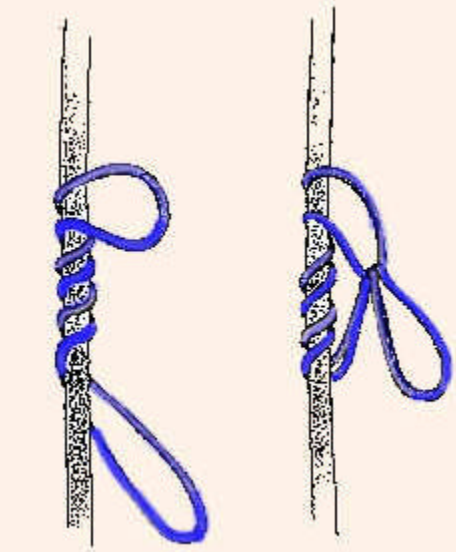

Water Knot

The only recommended knot for tying tubular webbing. Tales should be at least 3 inches long. The water knot is not recommended for tying Spectra or Kevlar beaded tape.

Hedden

- only works when the width of the webbing is no more than twice the width of the rope it is tied around, otherwise it will not tighten on the rope. (E.G. - 1 inch tied tubular will not work on a rope that is less than 11mm. A sewn 9/16 sling will work on ropes 5/16(8mm) or greater.)

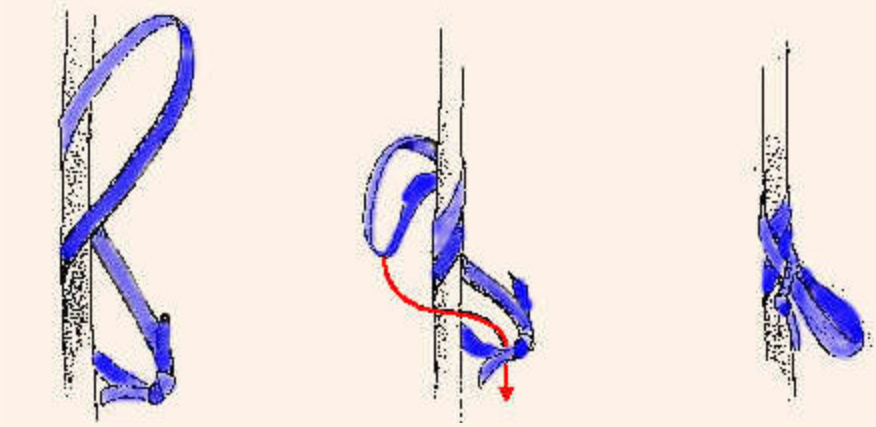

Home

Rare-earth magnet

From Wikipedia, the free encyclopedia

Ferrofluid on glass, with a rare-earth magnet underneath.

Rare-earth magnets are strong permanent magnets made from alloys of rare earth elements (elements in the lanthanide series, plus scandium and yttrium).[1] Developed in the 1970s and '80s, rare-earth magnets are the strongest type of permanent magnets made, producing significantly stronger magnetic fields than other types such as ferrite or alnico magnets. The magnetic field typically produced by rare-earth magnets can exceed 1.4 teslas, whereas ferrite or ceramic magnets typically exhibit fields of 0.5 to 1 tesla. There are two types: neodymium magnets and samarium-cobalt magnets. Magnetostrictive rare-earth magnets such as Terfenol-D also have applications—e.g. in loudspeakers. Rare earth magnets are extremely brittle and also vulnerable to corrosion, so they are usually plated or coated to protect them from breaking, chipping, or crumbling into powder.

The term "rare earth" can be misleading as these metals are not particularly rare or precious;[2][3] they are about as abundant as tin or lead.[4] The development of rare earth magnets began around 1966, when K. J. Strnat and G. Hoffer of the US Air Force Materials Laboratory discovered that an alloy of yttrium and cobalt, YCo_5, had by far the largest magnetic anisotropy constant of any material then known.[5][6]

Contents

- 1 Explanation of strength
- 2 Magnetic properties

- 3 Types
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  - 3.2 Neodymium
- 4 Hazards
- 5 Applications
  - 5.1 Common applications
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- 6 Rare-earth-free permanent magnets
- 7 References
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Neodymium magnets (small cylinders) lifting steel balls. As shown here, rare-earth magnets can easily lift thousands of times their own weight.

Explanation of strength

The rare earth (lanthanide) elements are metals that are ferromagnetic, meaning that like iron they can be permanently magnetized, but their Curie temperatures are below room temperature, so in pure form their magnetism only appears at low temperatures. However, they form compounds with the transition metals such as iron, nickel, and cobalt, and some of these have Curie temperatures well above room temperature. Rare earth magnets are made from these compounds.

The greater strength of rare earth magnets is mostly due to two factors. First, their crystalline structures have very high magnetic anisotropy. This means a crystal of the material preferentially magnetizes along a specific crystal axis but is very difficult to magnetize in other directions. Like other magnets, rare earth magnets are composed of microcrystalline grains which are aligned in a powerful magnetic field during manufacture so their magnetic axes all point in the same

direction. The resistance of the crystal lattice to turning its direction of magnetization gives these compounds a very high magnetic coercivity (resistance to being demagnetized).

Second, atoms of rare earth elements can have high magnetic moments because their orbital electron structure contains many unpaired electrons, in contrast to other elements in which almost all of the electrons exist in pairs with opposite spins, so their magnetic fields cancel out. This is a consequence of incomplete filling of the f-shell, which can contain up to 7 unpaired electrons. In a magnet it is the unpaired electrons, aligned so they spin in the same direction, which generate the magnetic field. This gives the materials high remanence (saturation magnetization J_s). The maximum energy density BH_{max} is proportional to J_s^2 so these materials have the potential for storing large amounts of magnetic energy. The magnetic energy product BH_{max} of neodymium magnets is about 18 times greater than "ordinary" magnets by volume. This allows rare earth magnets to be smaller than other magnets which produce the same field strength.

Magnetic properties

Some important properties used to compare permanent magnets are: remanence (B_r), which measures the strength of the magnetic field; coercivity (H_{ci}), the material's resistance to becoming demagnetized; energy product (BH_{max}), the density of magnetic energy; and Curie temperature (T_c), the temperature at which the material loses its magnetism. Rare earth magnets have higher remanence, much higher coercivity and energy product, but (for neodymium) lower Curie temperature than other types. The table below compares the magnetic performance of the two types of rare earth magnet, neodymium ($Nd_2Fe_{14}B$) and samarium-cobalt ($SmCo_5$), with other types of permanent magnets.

Magnet	B_r (T)	H_{ci} (kA/m)	$(BH)_{max}$ (kJ/m^3)	T_c (°C)
$Nd_2Fe_{14}B$ (sintered)	1.0–1.4	750–2000	200–440	310–400
$Nd_2Fe_{14}B$ (bonded)	0.6–0.7	600–1200	60–100	310–400
$SmCo_5$ (sintered)	0.8–1.1	600–2000	120–200	720
$Sm(Co,Fe,Cu,Zr)_7$ (sintered)	0.9–1.15	450–1300	150–240	800
Alnico (sintered)	0.6–1.4	275	10–88	700–860
Sr-ferrite (sintered)	0.2–0.4	100–300	10–40	450

Source:

Types

Samarium-cobalt

Samarium–cobalt magnets (chemical formula: $SmCo_5$), the first family of rare earth magnets invented, are less used than neodymium magnets because of their higher cost and weaker magnetic field strength. However, samarium–cobalt has a higher Curie temperature, creating a niche for these magnets in applications where high field strength is needed at high operating temperatures. They are highly resistant to oxidation, but sintered samarium-cobalt magnets are brittle and prone to chipping and cracking, and may fracture when subjected to thermal shock.

Neodymium

Neodymium magnet with nickel plate mostly removed

Neodymium magnets, invented in the 1980s, are the strongest and most affordable type of rare-earth magnet. They are made of an alloy of neodymium, iron, and boron ($Nd_2Fe_{14}B$), sometimes abbreviated as NIB. Neodymium magnets are used in numerous applications requiring strong, compact permanent magnets, such as electric motors for cordless tools, hard disk drives, magnetic holddowns, and jewelry clasps. They have the highest magnetic field strength and have a higher coercivity (which makes them magnetically stable), but they have a lower Curie temperature, m and are more vulnerable to oxidation than samarium–cobalt magnets. Corrosion can cause unprotected magnets to spall off a surface layer, or to crumble into a powder. Use of protective surface treatments such as gold, nickel, zinc, and tin plating and epoxy resin coating can provide corrosion protection.

Originally, the high cost of these magnets limited their use to applications requiring compactness together with high field strength. Both the raw materials and the patent licenses were expensive. However, since the 1990s, NIB magnets have become steadily less expensive, and the low cost has inspired new uses such as magnetic construction toys.

Hazards

The greater force exerted by rare earth magnets creates hazards that are not seen with other types of magnet. Magnets larger than a few centimeters are strong enough to cause injuries to body parts pinched between two magnets, or a magnet and a metal surface, even causing broken bones.[7] Magnets allowed to get too near each other can strike each other with enough force to chip and shatter the brittle material, and the flying chips can cause injuries. There have even been cases where young children who have swallowed

several magnets have had a fold of the digestive tract pinched between the magnets, causing injury and in one case intestinal perforations, sepsis and death.[8]

This finding by the CPSC of consumer risk and the associated rule restricting rare earth magnet size was vacated by a US Federal court in November, 2016. The court found the evidence of risk insufficient and currently available magnets as not inherently dangerous.[9]

Applications

Since their prices became competitive in the 1990s, neodymium magnets have been replacing Alnico and ferrite magnets in the many applications in modern technology requiring powerful magnets. Their greater strength allows smaller and lighter magnets to be used for a given application.

Common applications

Common applications of rare-earth magnets include:

- computer hard disk drives
- wind turbine generators
- audio speakers / headphones
- bicycle dynamos
- Magnetic resonance imaging devices
- fishing reel brakes
- permanent magnet motors in cordless tools
- high-performance AC servo motors
- traction motors and integrated starter-generators in hybrid and electric vehicles
- mechanically powered flashlights, employing rare earth magnets for generating electricity in a shaking motion or rotating (hand-crank-powered) motion

Neodymium magnet balls

- industrial uses such as maintaining product purity, equipment protection, and quality control
- capture of fine metallic particles in lubricating oils (crankcases of internal combustion engines, also gearboxes and differentials), so as to keep said particles out of circulation, thereby rendering them unable to cause abrasive wear of moving machine parts

Other applications

Other applications of rare-earth magnets include:

- Linear motors (used in mag-lev trains, etc.)
- Stop motion animation: as tie-downs when the use of traditional screw and nut tie-downs is impractical.
- Diamagnetic levitation experimentation, the study of magnetic field dynamics and superconductor levitation.
- Electrodynamic bearings
- Launched roller coaster technology found on roller coaster and other thrill rides.
- LED Throwies, small LEDs attached to a button cell battery and a small rare earth magnet, used as a form of non-destructive graffiti and temporary public art.
- Neodymium magnet toys
- Electric guitar pickups
- Miniature figures, for which rare-earth magnets have gained popularity in the miniatures gaming community for their small size and relative strength assisting in basing and swapping weapons between models.

Rare-earth-free permanent magnets

The United States Department of Energy has identified a need to find substitutes for rare earth metals in permanent magnet technology, and has begun funding such research. The Advanced Research Projects Agency-Energy (ARPA-E) has sponsored a Rare Earth Alternatives in Critical

Technologies (REACT) program, to develop alternative materials. In 2011, ARPA-E awarded 31.6 million dollars to fund Rare-Earth Substitute projects. [10]

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External links

- *Standard Specifications for Permanent Magnet Materials* (http://www.allianceorg.com/pdfs/MMPA_0100-00.pdf) (Magnetic Materials Producers Association)
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Categories: Magnetic levitation | Types of magnets | Ferromagnetic materials | Loudspeakers

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Rattan and Bamboo: Equipment for Physically Handicapped Children

by: J.K. Hutt

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West Sussex BN18 9NR
United Kingdom

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RATTAN AND BAMBOO

Ref: 2/79

Equipment for Physically Handicapped Children designed by J. K. Hutt, while physiotherapist for the Spastic Children's Association in Johore, West Malaysia.

DISABILITIES STUDY UNIT,
WILDHANGER,
AMBERLEY,
ARUNDEL,
W. SUSSEX, BN8 9NR.

PRICE: £2.00 including postage and packing

INTRODUCTION

In September 1976 the National Fund for Research into Crippling Diseases with generous assistance from the Commonwealth Foundation and with the support of the Ministry of Overseas Development, mounted a symposium on appropriate technology for the disabled in developing countries. This symposium was held at Oriel College, Oxford, and, as I said in an introduction to the proceedings: "That the meeting was successful is beyond doubt. Letters received from the participants after they had dispersed went far beyond the normal courtesies and made the value of the meeting extremely clear."

A peripheral contribution to the symposium was a display by Miss J. K. Hutt, as she then was, of rattan and bamboo aids for physically handicapped children. This equipment was made locally to Miss Hutt's designs when she was working as physiotherapist for the Spastic Children's Association in Johore, West Malaysia. Miss Hutt had been led to pioneer the local manufacture of such aids by the cost of imported equipment. The imported equipment was in any case usually unsuited to the build of local inhabitants and their way of life. For instance, the custom is to sit either on the floor or on much lower seats than those used in the West and to use squat toilets so that walking aids needed to be designed to enable the user to reach a standing position easily from a sitting position on the floor. Rattan is available locally and well-established rattan workshops exist in all large towns. Repairs can be carried out at any small village cane shop. Good quality cane also withstands the changes of a tropical climate, is cheaper than wood or metal, is more pliable and when heated can be moulded into almost any shape which it then retains. The woven network used for seats and backs of chairs etc. allows the air to circulate and thus reduces perspiration and subsequent heat rash.

DSU was fortunate in obtaining the working drawings for this equipment and in response to requests from as far away as Jamaica and Mexico has now been able to reproduce them for publication in a single volume. We believe that these designs will be of use in many countries, even if the materials available locally are not identical with those of Malaysia.

Our greatest debt of gratitude is of course to Miss Hutt herself, but we should also like to thank those who worked with her, those who were responsible for the excellent drawings and, may I add, those for whom the equipment was first made and who almost certainly did not realise that they were acting as guinea-pigs in appropriate technology. Finally we thank the National Fund for Research into Crippling Diseases for sponsoring the original meeting and for welcome co-operation thereafter.

Amberley,
West Sussex.

DUNCAN GUTHRIE
July, 1979

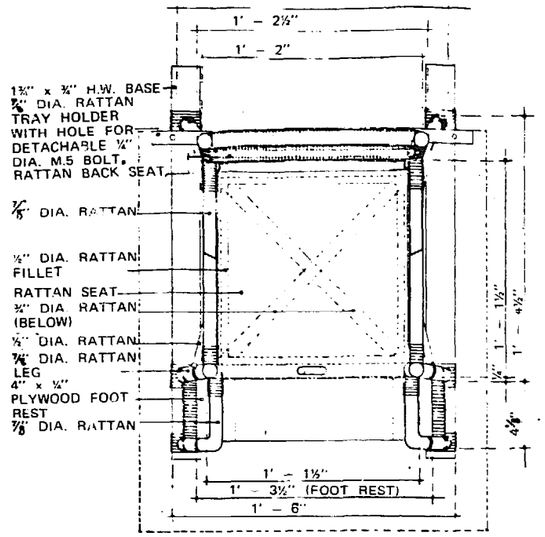
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⅞" DIA. RATTAN TRAY HOLDER WITH HOLE FOR DETACHABLE ¼" DIA. M.5 BOLT.
RATTAN BACK SEAT
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½" DIA. RATTAN FILLET
RATTAN SEAT
¾" DIA. RATTAN (BELOW)
½" DIA. RATTAN
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4" x ¼" PLYWOOD FOOT REST
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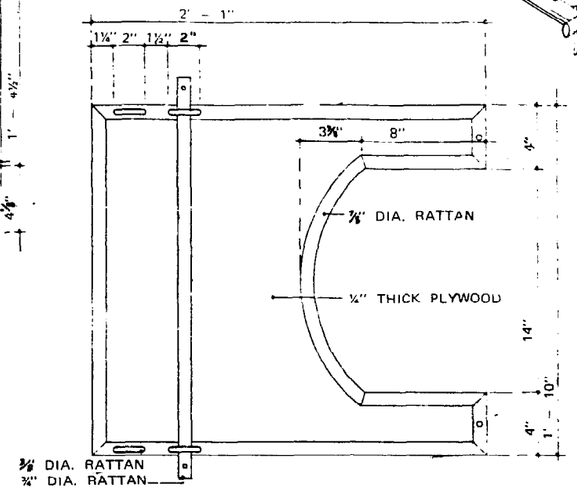
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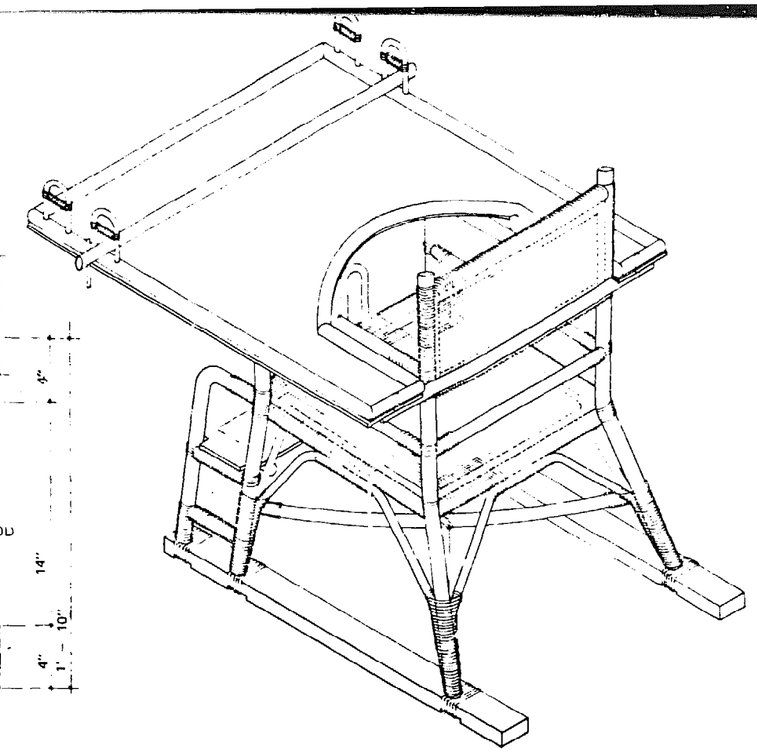

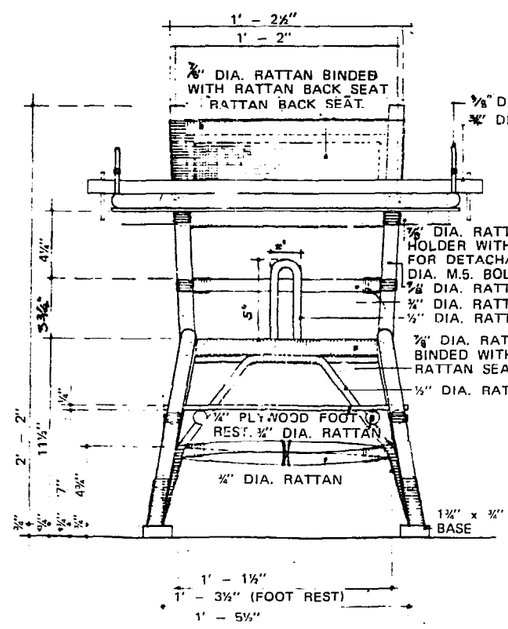
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⅞" DIA. RATTAN BINDED WITH RATTAN SEAT.
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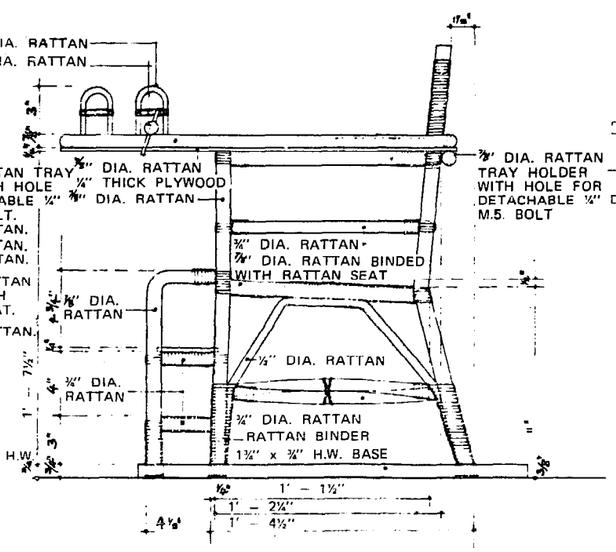
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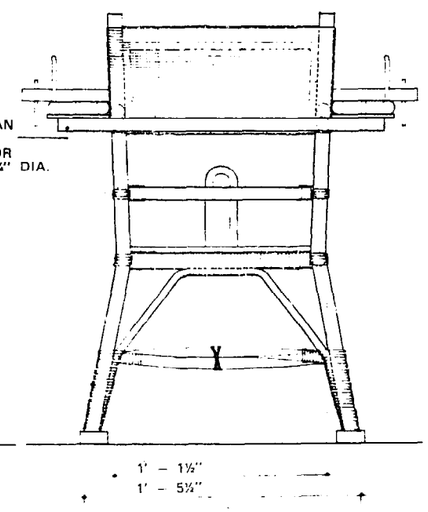
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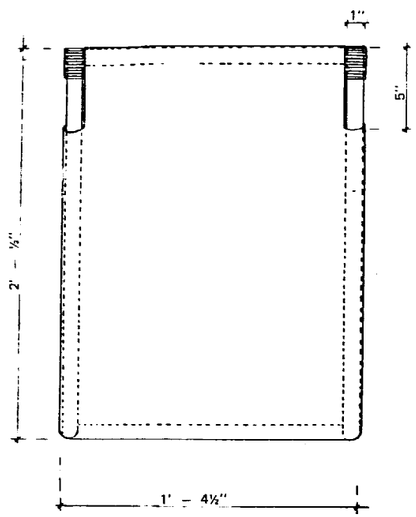
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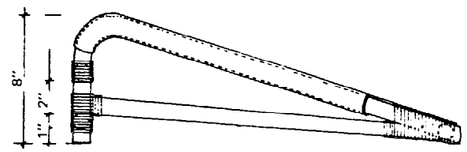
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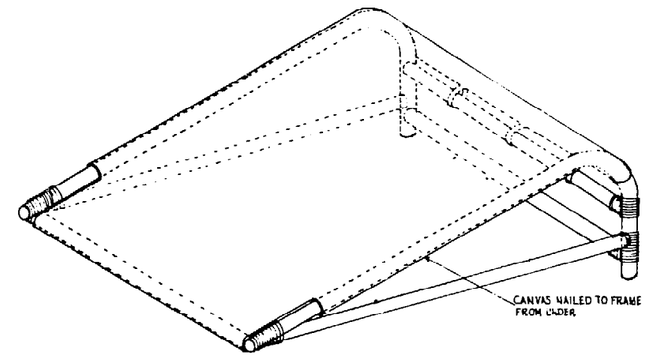
CANVAS NAILED TO FRAME
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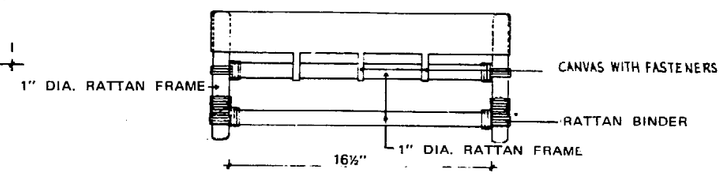
CANVAS WITH FASTENERS
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RATTAN BINDER
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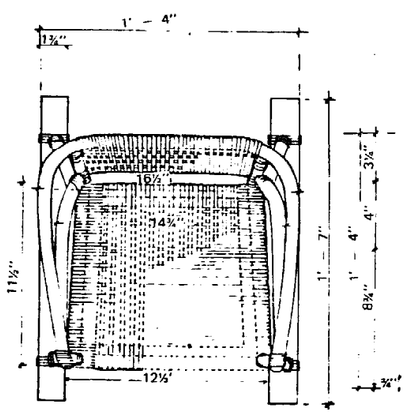
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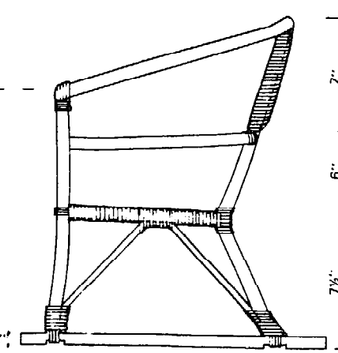

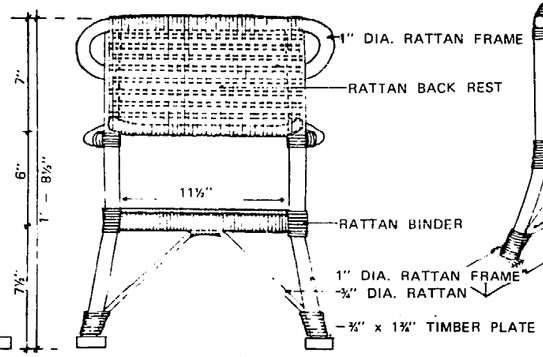
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¾" x 1¾" TIMBER PLATE

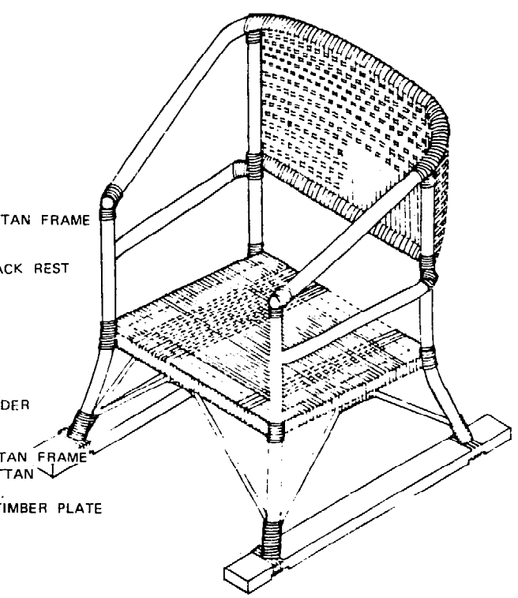

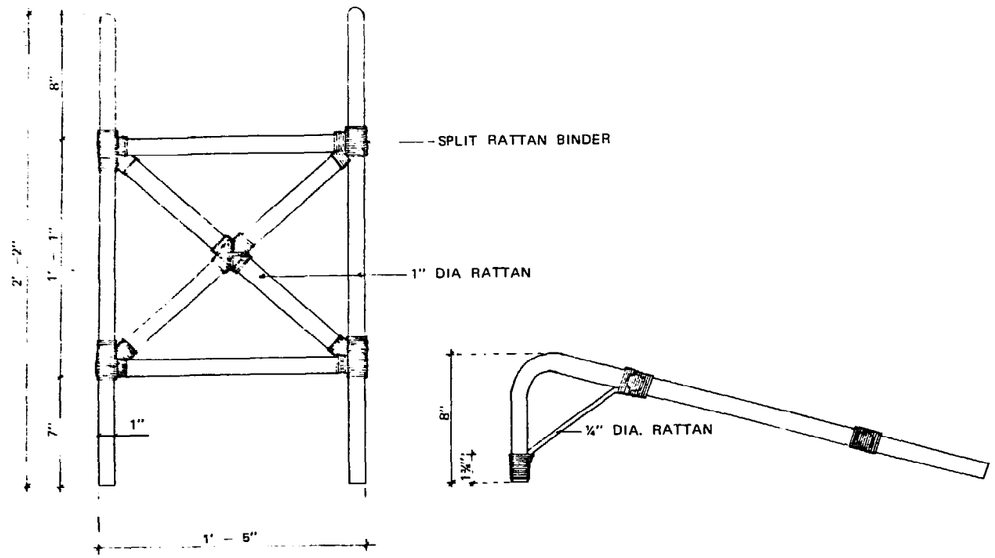
SPLIT RATTAN BINDER
1" DIA RATTAN
2' - 2"
1' - 1"
8"
7"
1"
1' - 5"
8"
1¾"
¼" DIA. RATTAN

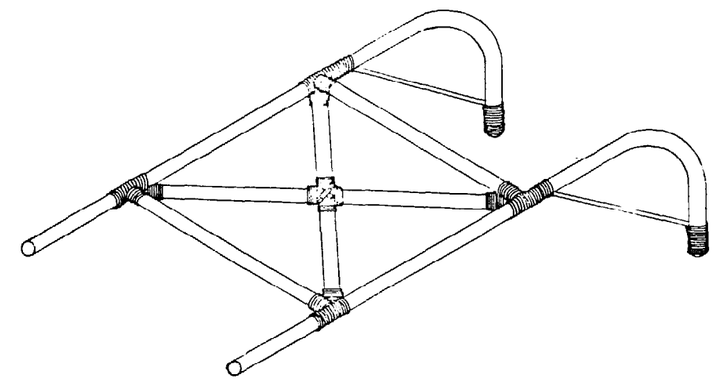

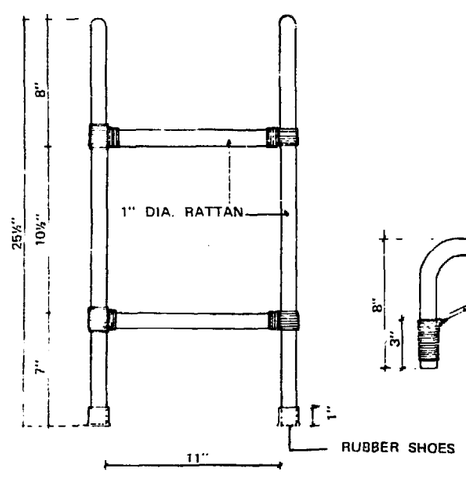
25½"
10½"
8"
7"
1" DIA. RATTAN
1"
11"
RUBBER SHOES

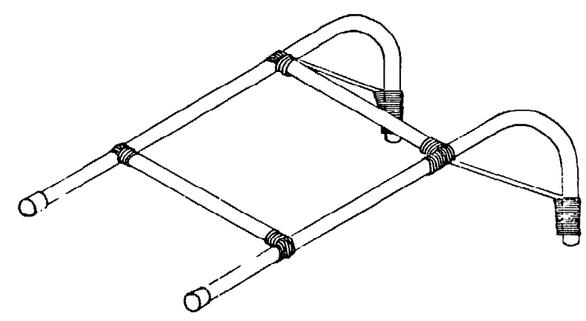

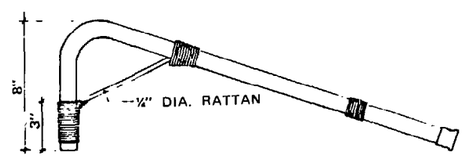
8"
3"
¼" DIA. RATTAN

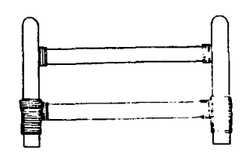

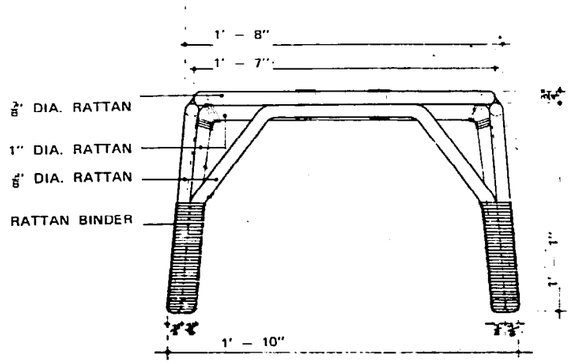
1' – 8"
1' – 7"
DIA. RATTAN
1" DIA. RATTAN
DIA. RATTAN
RATTAN BINDER
1' – 10"

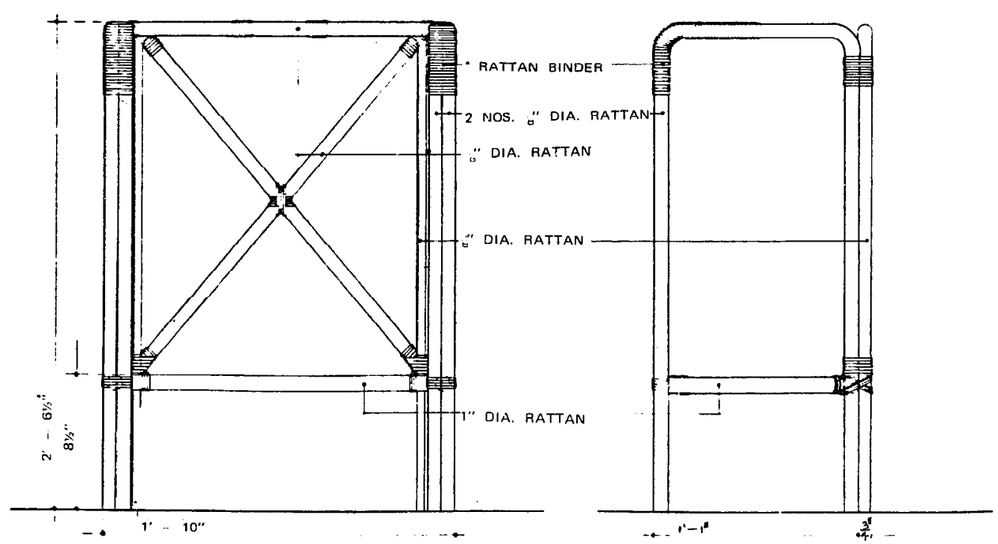
RATTAN BINDER
2 NOS. DIA. RATTAN
DIA. RATTAN
DIA. RATTAN
1" DIA. RATTAN
2' – 6½"
8½"
1' – 10"

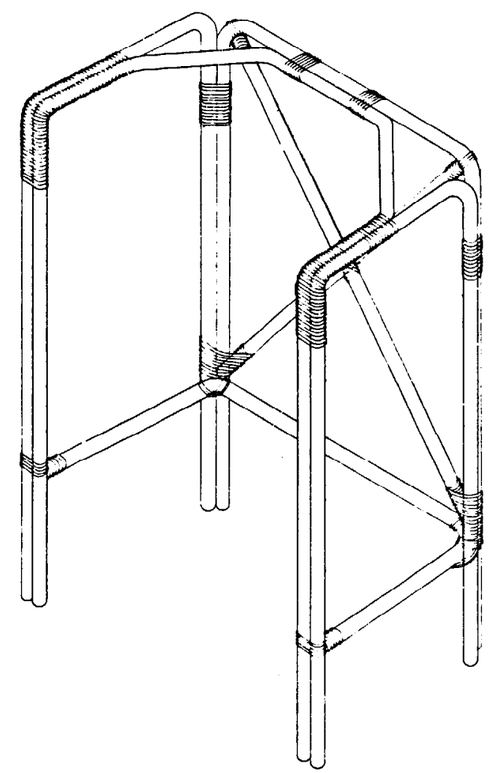

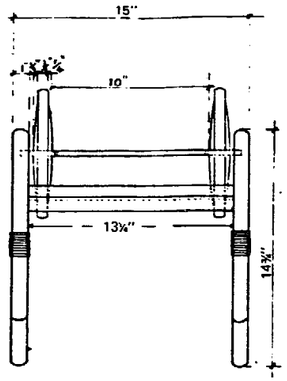
15"
10"
13¼"
14¾"

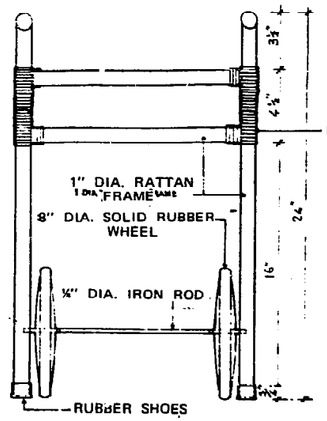
3½"
4½"
24"
16"
RATTAN BINDER
1" DIA. RATTAN FRAME
8" DIA. SOLID RUBBER WHEEL
¼" DIA. IRON ROD
RUBBER SHOES

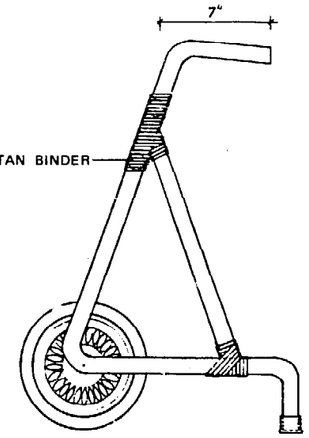
7"

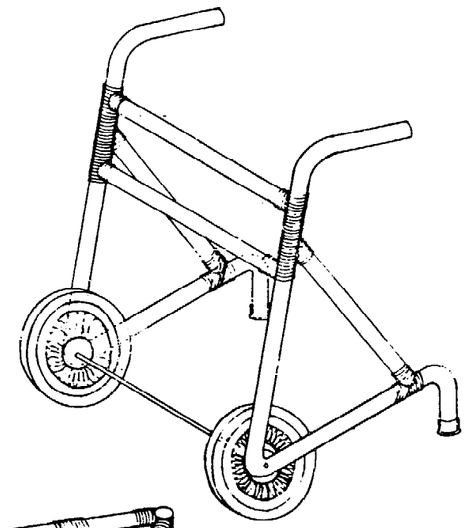

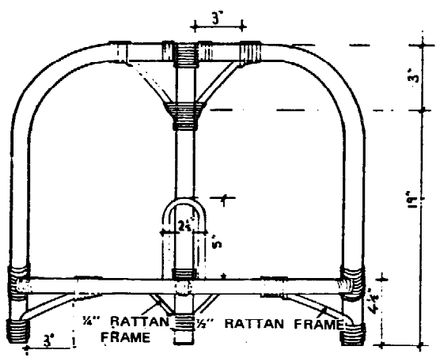
3"
3"
19"
2½"
5"
4½"
¼" RATTAN FRAME
½" RATTAN FRAME
3"

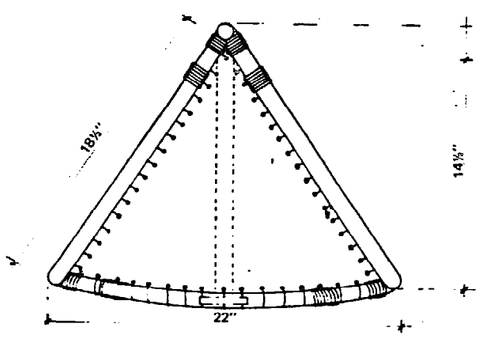
18½"
14½"
22"

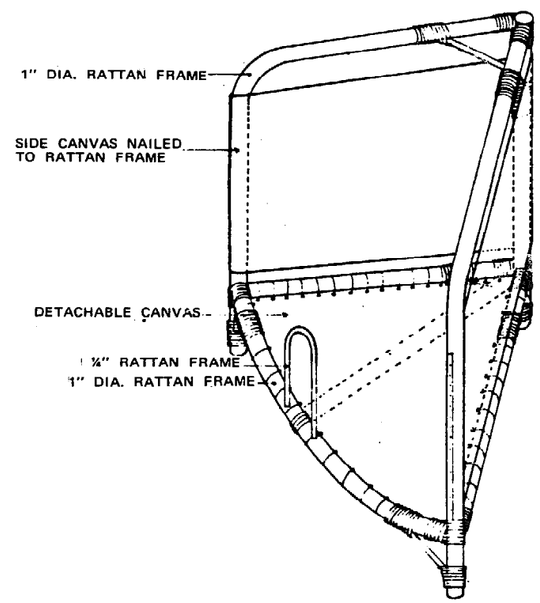
1" DIA. RATTAN FRAME
SIDE CANVAS NAILED TO RATTAN FRAME
DETACHABLE CANVAS
¼" RATTAN FRAME
1" DIA. RATTAN FRAME

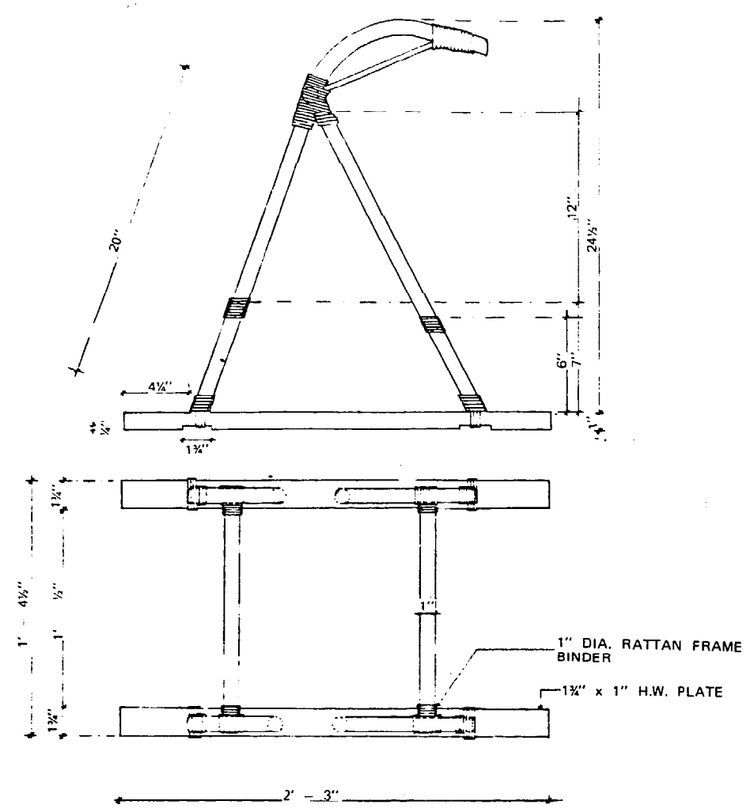
20"
12"
24½"
6"
7"
1"
4½"
¼"
1¾"
1¾"
½"
1' - 4½"
1'
1¾"
1"
1" DIA. RATTAN FRAME BINDER
1¾" x 1" H.W. PLATE
2' - 3"

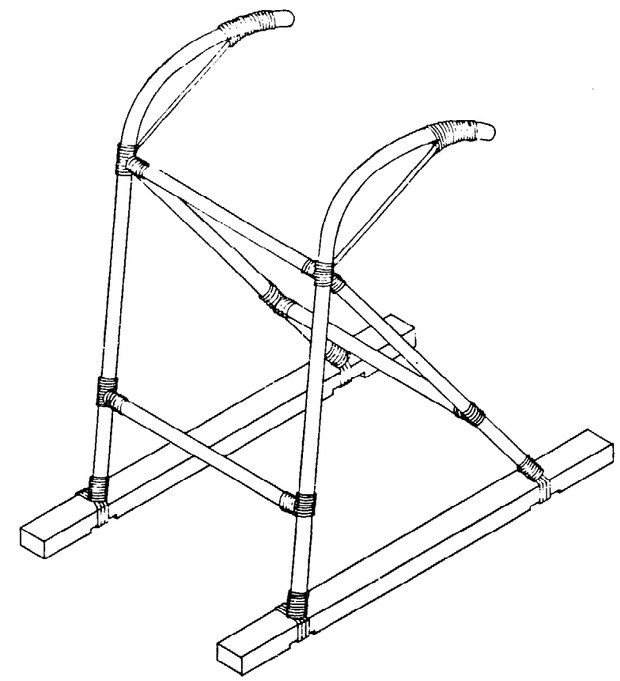

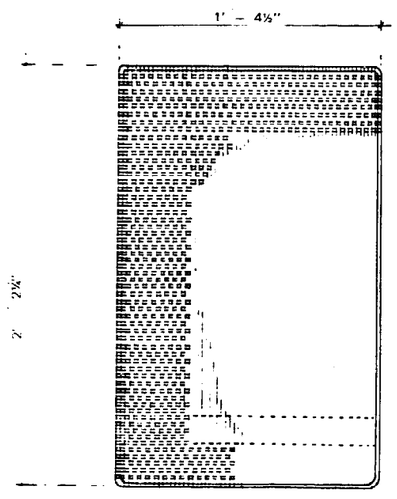
1' - 4½"
2' - 2¾"

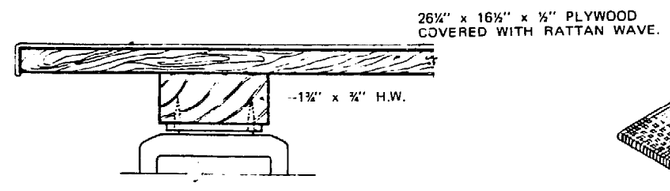
26¼" x 16½" x ½" PLYWOOD COVERED WITH RATTAN WAVE.
1¾" x ¾" H.W.

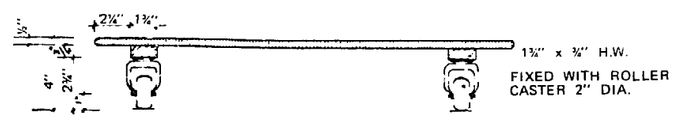
½"
2¼"
1¾"
4"
2¾"
1¾" x ¾" H.W.
FIXED WITH ROLLER CASTER 2" DIA.

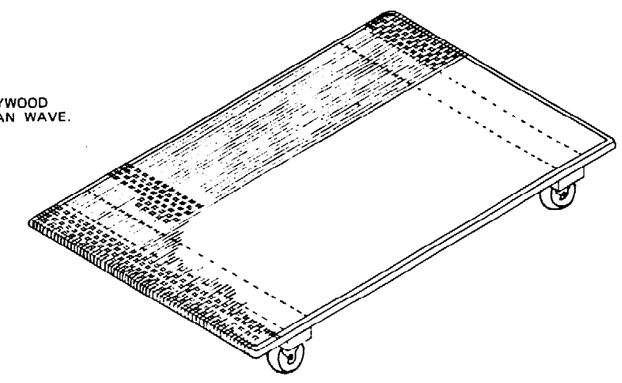

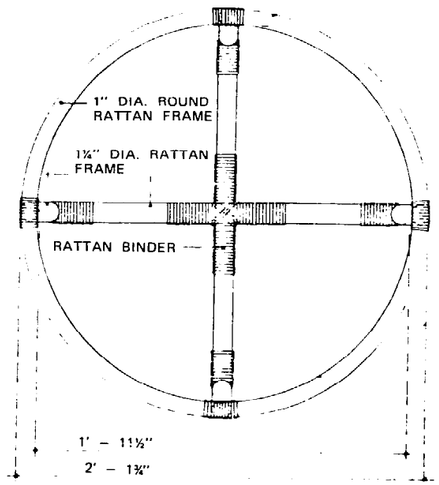
1" DIA. ROUND
RATTAN FRAME
1¼" DIA. RATTAN
FRAME
RATTAN BINDER
1' – 11½"
2' – 1¾"

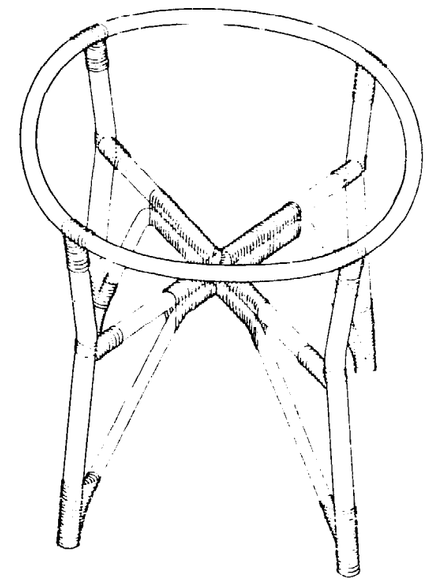

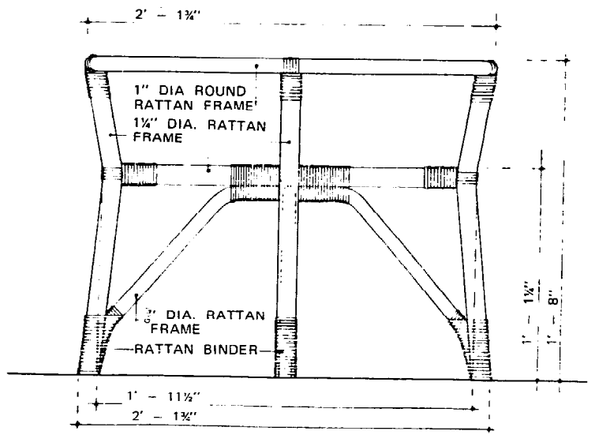
2' – 1¾"
1" DIA ROUND
RATTAN FRAME
1¼" DIA. RATTAN
FRAME
¾" DIA. RATTAN
FRAME
RATTAN BINDER
1' – 11½"
2' – 1¾"
1' – 1¾"
1' – 8"

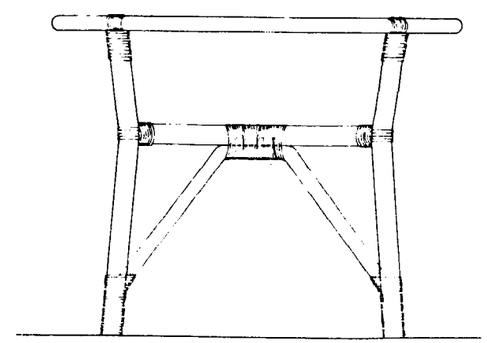

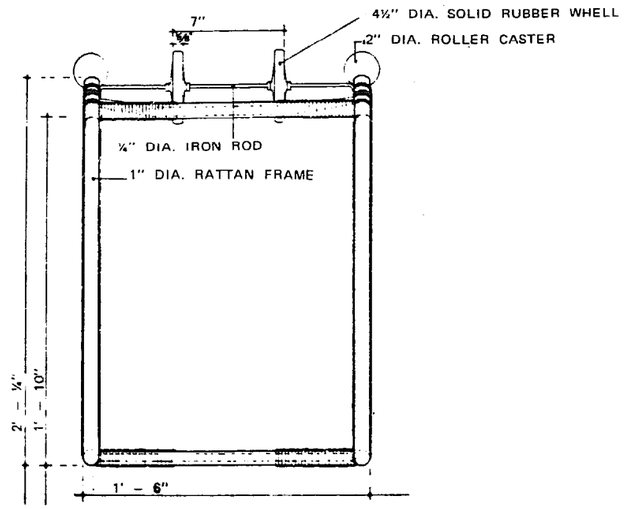
7"
½"
4½" DIA. SOLID RUBBER WHELL
2" DIA. ROLLER CASTER
¼" DIA. IRON ROD
1" DIA. RATTAN FRAME
2' – ¼"
1' – 10"
1' – 6"

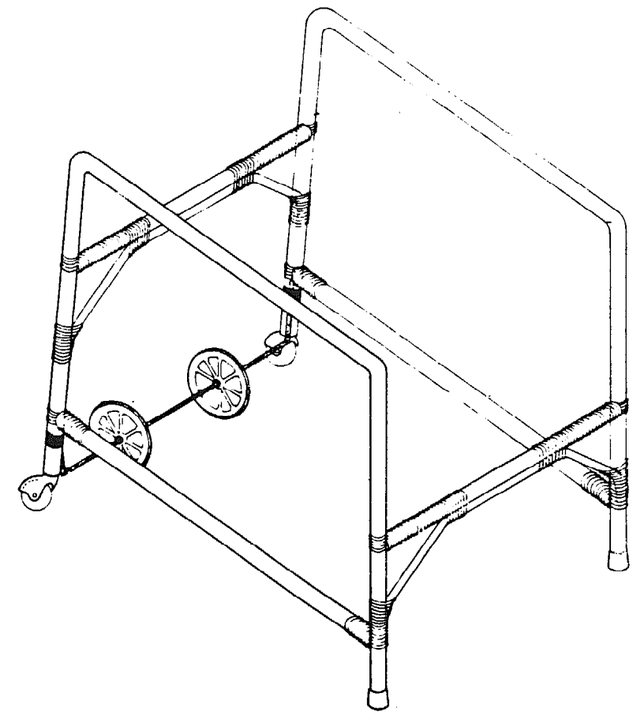

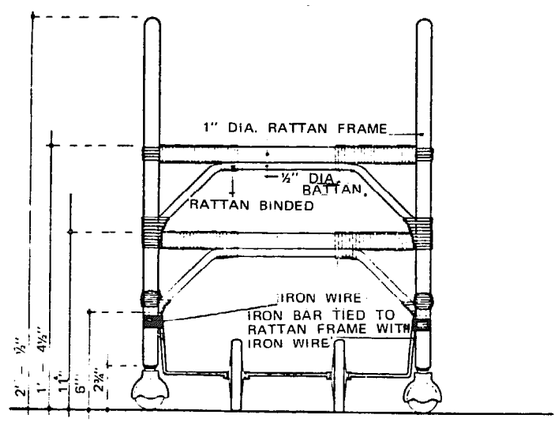
1" DIA. RATTAN FRAME
½" DIA. RATTAN
RATTAN BINDED
IRON WIRE
IRON BAR TIED TO RATTAN FRAME WITH IRON WIRE
2' – ½"
1' – 4½"
1'
6"
2¾"

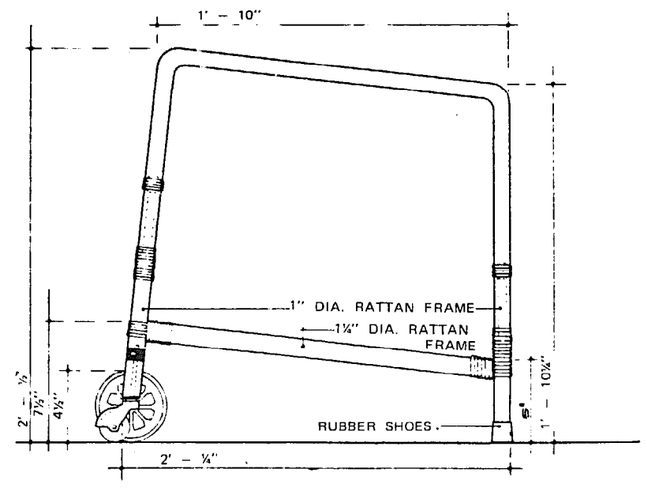
1' – 10"
1" DIA. RATTAN FRAME
1¼" DIA. RATTAN FRAME
RUBBER SHOES
2' – ½"
7½"
4½"
6"
1' – 10½"
2' – ¼"

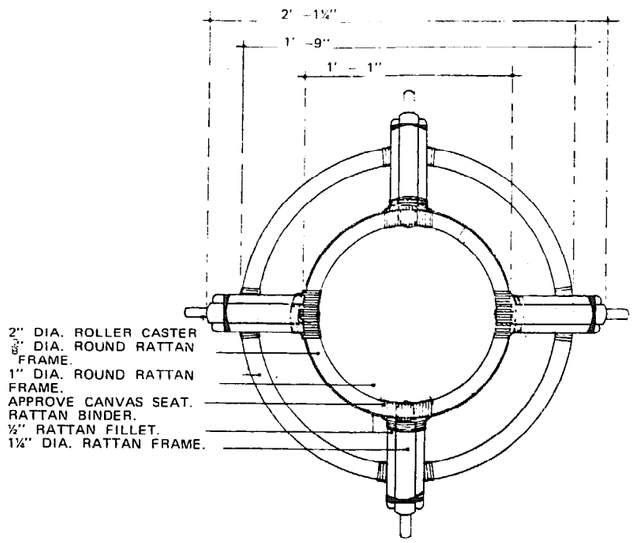
2' - 1¼"
1' - 9"
1' - 1"
2" DIA. ROLLER CASTER
⅜" DIA. ROUND RATTAN FRAME.
1" DIA. ROUND RATTAN FRAME.
APPROVE CANVAS SEAT.
RATTAN BINDER.
½" RATTAN FILLET.
1¼" DIA. RATTAN FRAME.

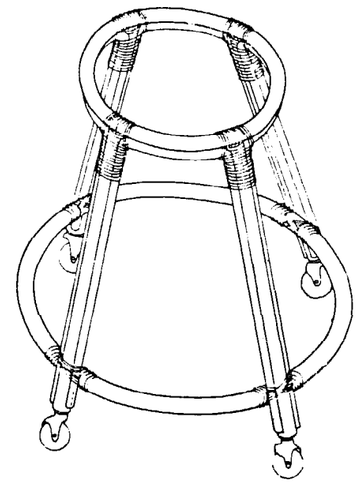

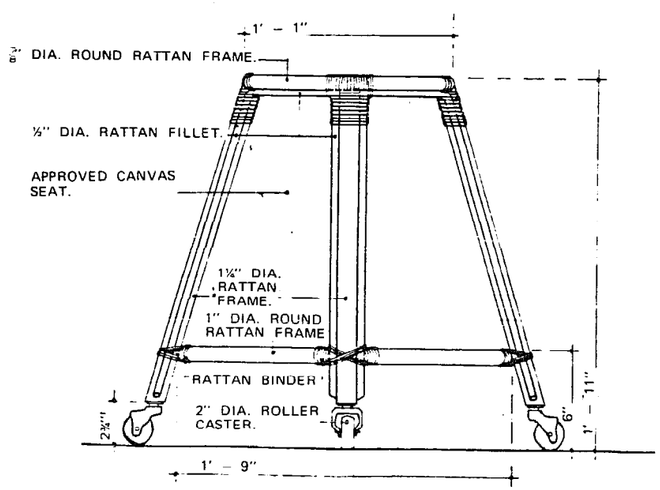
1' - 1"
⅜" DIA. ROUND RATTAN FRAME.
½" DIA. RATTAN FILLET.
APPROVED CANVAS SEAT.
1¼" DIA. RATTAN FRAME.
1" DIA. ROUND RATTAN FRAME
RATTAN BINDER
2" DIA. ROLLER CASTER.
2¾"
6"
1' - 11"
1' - 9"

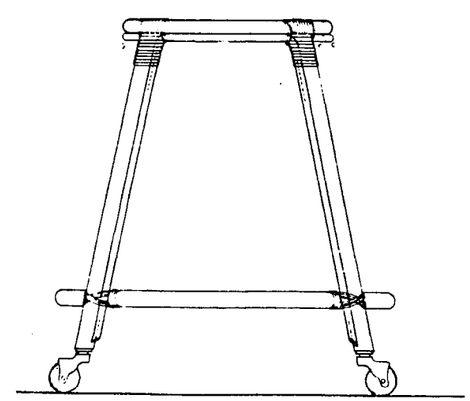

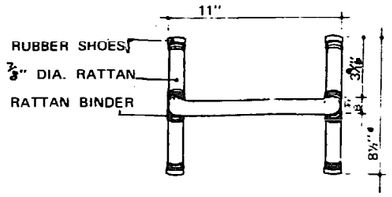
11"
RUBBER SHOES
⅞" DIA. RATTAN
RATTAN BINDER
3⅛"
8½"

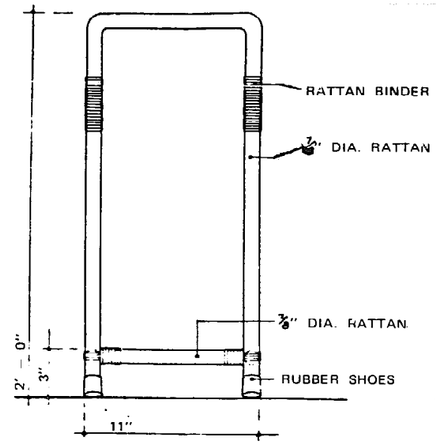
RATTAN BINDER
⅞" DIA. RATTAN
⅞" DIA. RATTAN
RUBBER SHOES
2' – 0"
3"
11"

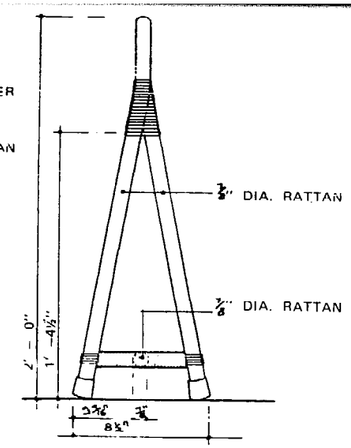
⅞" DIA. RATTAN
⅞" DIA. RATTAN
2' – 0"
1' – 4½"
8½"

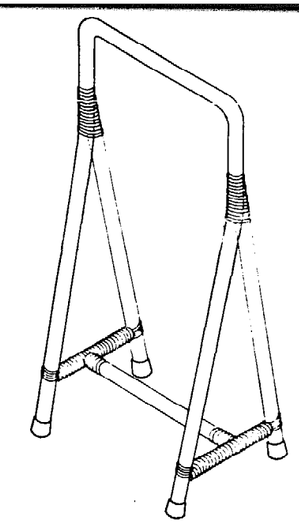

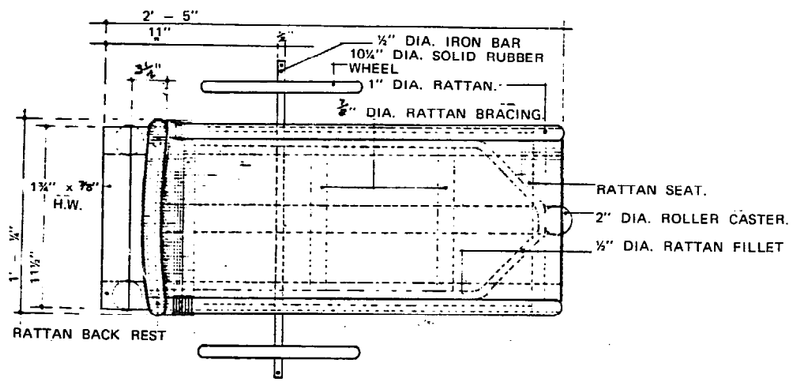
2' – 5"
11"
½" DIA. IRON BAR
10¼" DIA. SOLID RUBBER WHEEL
1" DIA. RATTAN.
⅞" DIA. RATTAN BRACING
1¾" x ⅞" H.W.
RATTAN SEAT.
2" DIA. ROLLER CASTER.
½" DIA. RATTAN FILLET
1' – 11½"
RATTAN BACK REST

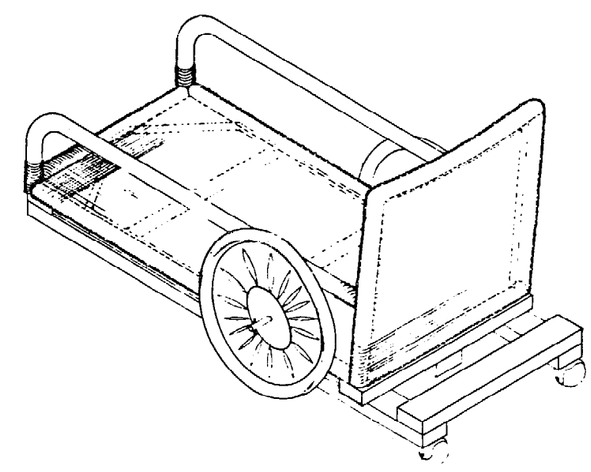

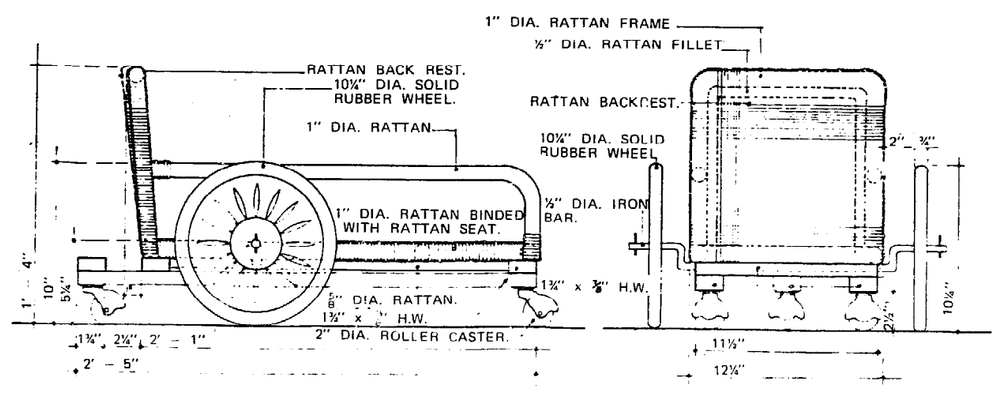
RATTAN BACK REST.
10¼" DIA. SOLID RUBBER WHEEL.
1" DIA. RATTAN
1" DIA. RATTAN BINDED WITH RATTAN SEAT.
⅞" DIA. RATTAN.
1¾" x ⅞" H.W.
2" DIA. ROLLER CASTER.
1' – 4"
10"
5¼"
1¾" 2¼" 2' – 1"
2' – 5"
1" DIA. RATTAN FRAME
½" DIA. RATTAN FILLET
RATTAN BACKREST.
10¼" DIA. SOLID RUBBER WHEEL
½" DIA. IRON BAR.
1¾" x ⅞" H.W.
2" – ¾"
10¼"
2½"
11½"
12¼"

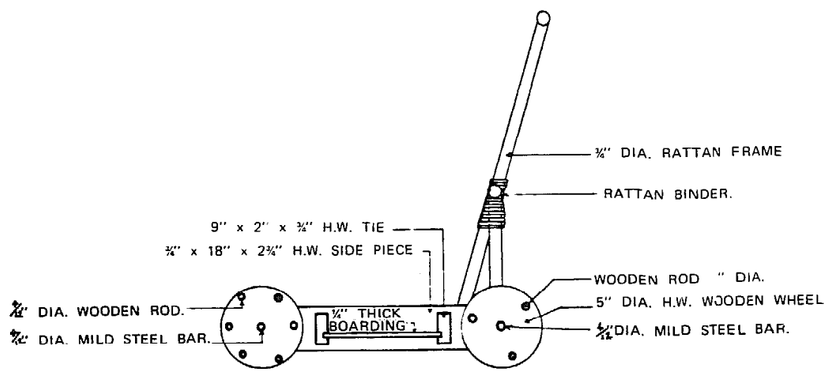
¾" DIA. RATTAN FRAME
RATTAN BINDER.
9" x 2" x ¾" H.W. TIE
¾" x 18" x 2¾" H.W. SIDE PIECE
WOODEN ROD " DIA.
5" DIA. H.W. WOODEN WHEEL
¾" DIA. WOODEN ROD.
¼" THICK BOARDING
¾" DIA. MILD STEEL BAR.
¾" DIA. MILD STEEL BAR.

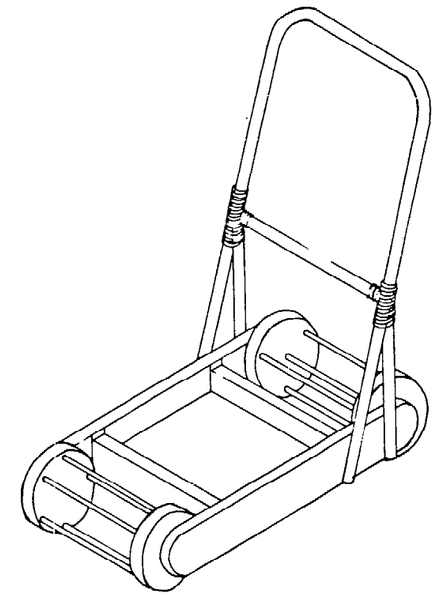

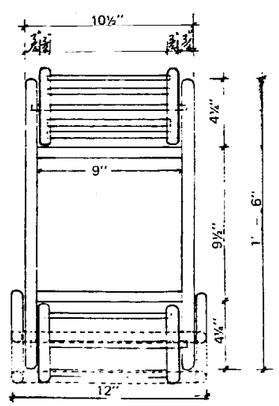
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4¼"
9"
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1' - 6"
4¼"
12"

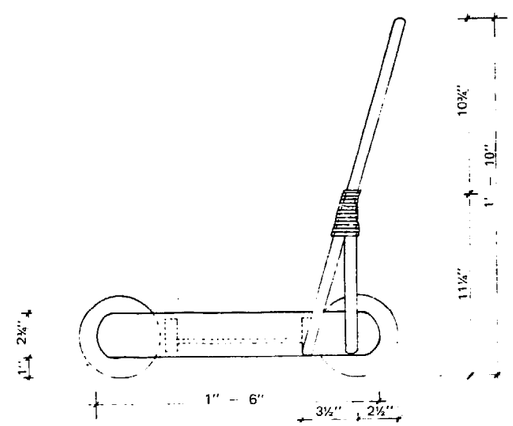
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1' - 10"
11¼"
2¾"
1' - 6"
3½"
2½"

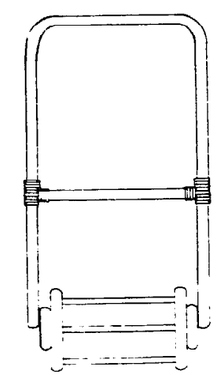

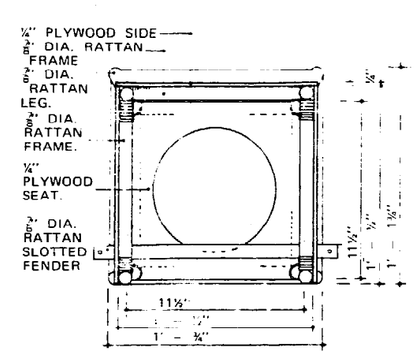
¼" PLYWOOD SIDE
⅜" DIA. RATTAN FRAME
⅜" DIA. RATTAN LEG.
⅜" DIA. RATTAN FRAME.
¼" PLYWOOD SEAT.
⅜" DIA. RATTAN SLOTTED FENDER
11½"
1' - ¾"

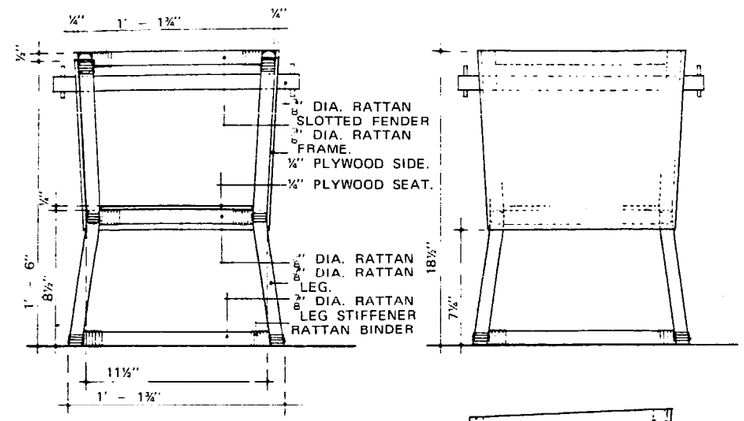
¼"
1' - 1¾"
⅜" DIA. RATTAN SLOTTED FENDER
⅜" DIA. RATTAN FRAME.
¼" PLYWOOD SIDE.
¼" PLYWOOD SEAT.
⅜" DIA. RATTAN
⅜" DIA. RATTAN LEG.
⅜" DIA. RATTAN LEG STIFFENER
RATTAN BINDER
1' - 6"
8½"
11½"
1' - 1¾"
18½"
7¼"

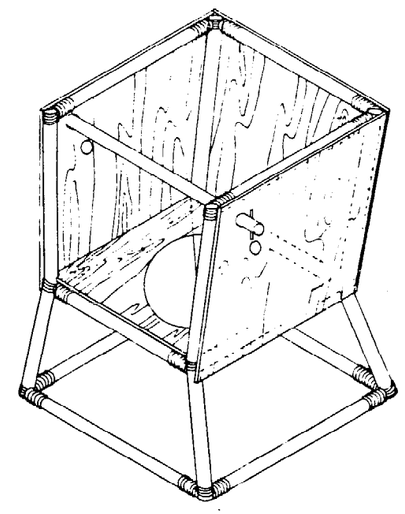

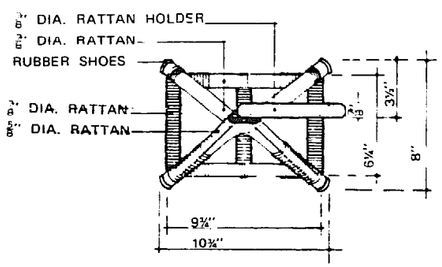
⅜" DIA. RATTAN HOLDER
⅜" DIA. RATTAN
RUBBER SHOES
⅜" DIA. RATTAN
⅜" DIA. RATTAN
3¼"
6¼"
8"
9¾"
10¾"

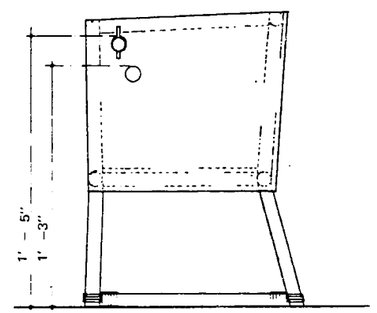
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1' - 3"

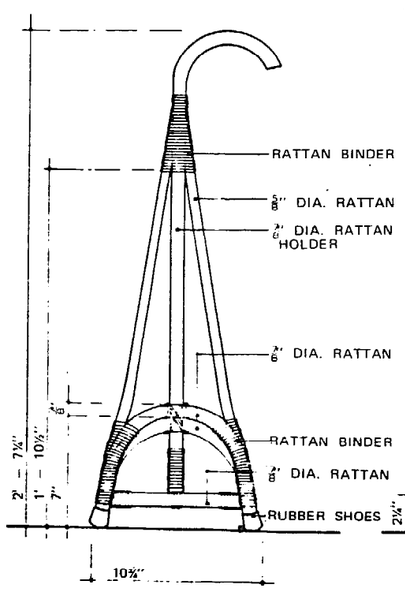
RATTAN BINDER
⅝" DIA. RATTAN
⅜" DIA. RATTAN HOLDER
⅜" DIA. RATTAN
RATTAN BINDER
⅜" DIA. RATTAN
RUBBER SHOES
2' - 7¼"
1' - 10½"
7"
10¾"

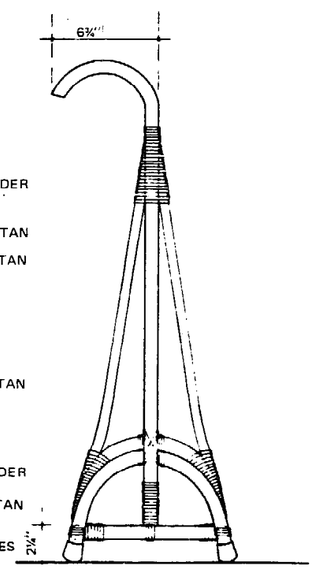
6¾"
2¼"

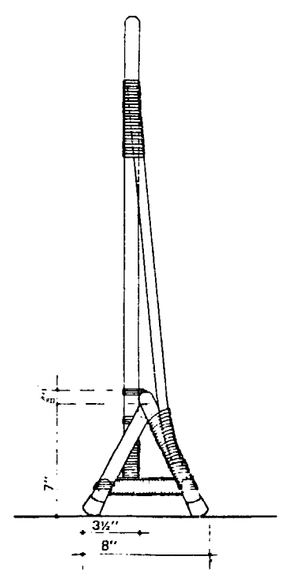
7"
3½"
8"

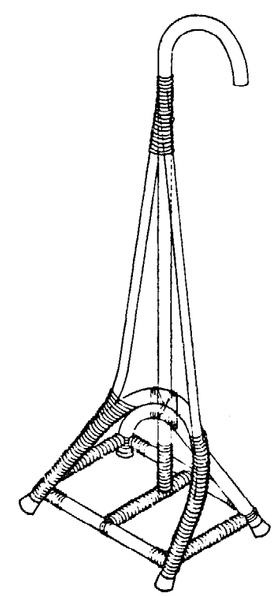

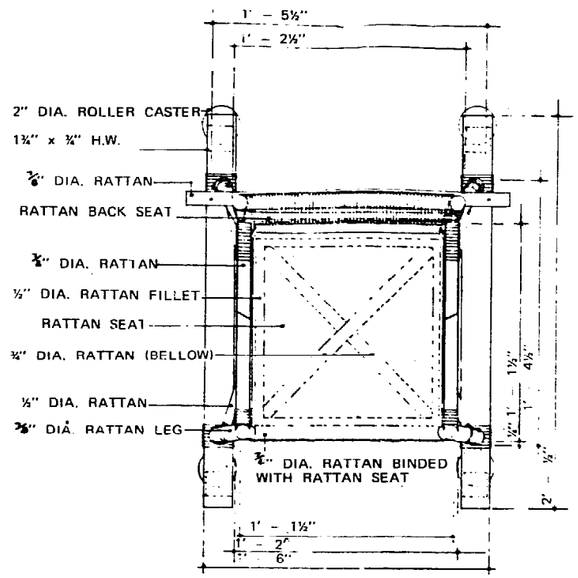
1' – 5½"
1' – 2½"
2" DIA. ROLLER CASTER
1¾" x ¾" H.W.
⅜" DIA. RATTAN
RATTAN BACK SEAT
⅜" DIA. RATTAN
½" DIA. RATTAN FILLET
RATTAN SEAT
¾" DIA. RATTAN (BELLOW)
½" DIA. RATTAN
⅜" DIA. RATTAN LEG
⅜" DIA. RATTAN BINDED WITH RATTAN SEAT
1' – 1½"
1' – 2"
1' – 6"

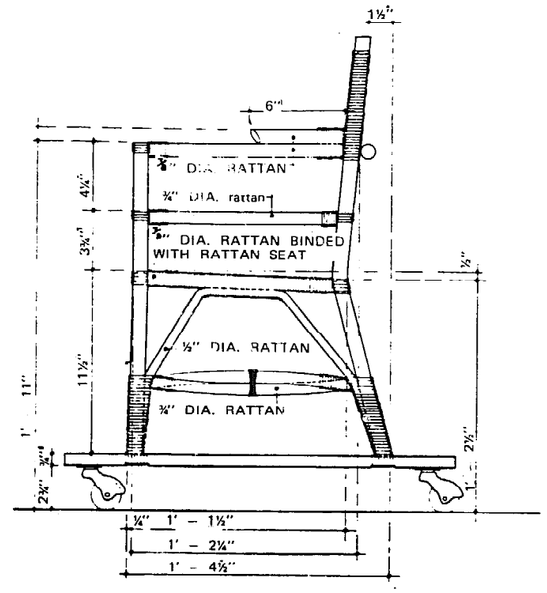
1½"
6"
⅜" DIA. RATTAN
¾" DIA. rattan
⅜" DIA. RATTAN BINDED WITH RATTAN SEAT
½" DIA. RATTAN
¾" DIA. RATTAN
¼" 1' – 1½"
1' – 2¼"
1' – 4½"

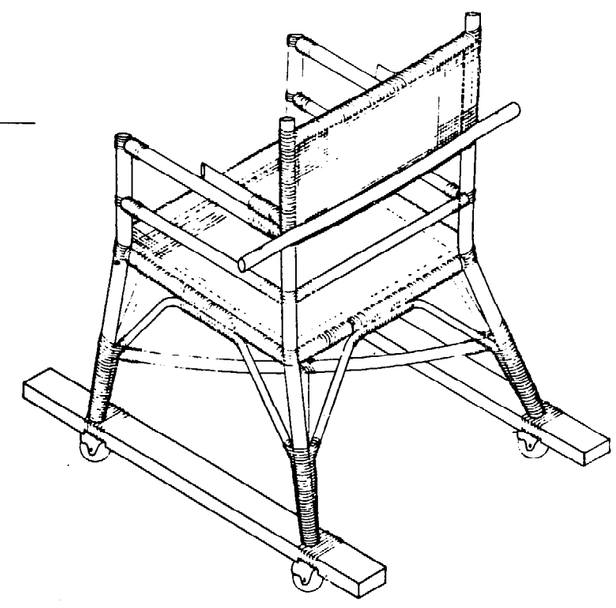

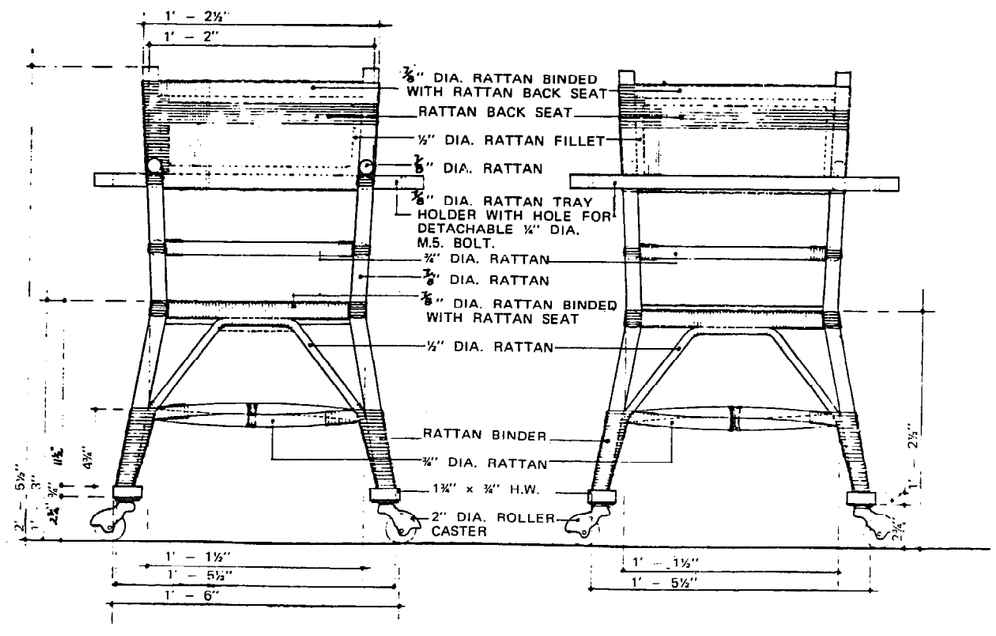
1' – 2½"
1' – 2"
⅜" DIA. RATTAN BINDED WITH RATTAN BACK SEAT
RATTAN BACK SEAT
½" DIA. RATTAN FILLET
⅜" DIA. RATTAN
⅜" DIA. RATTAN TRAY HOLDER WITH HOLE FOR DETACHABLE ¼" DIA. M.5. BOLT.
¾" DIA. RATTAN
⅜" DIA. RATTAN
⅜" DIA. RATTAN BINDED WITH RATTAN SEAT
½" DIA. RATTAN
RATTAN BINDER
¾" DIA. RATTAN
1¾" x ¾" H.W.
2" DIA. ROLLER CASTER
1' – 1½"
1' – 5½"
1' – 6"
1' – 1½"
1' – 5½"

Rattlesnake

From Wikipedia, the free encyclopedia

Rattlesnakes are a group of venomous snakes of the genera *Crotalus* and *Sistrurus*[1] of the subfamily Crotalinae (the pit vipers). The 36 known species of rattlesnakes have between 65 and 70 subspecies,[2] all native to the Americas, ranging from southern Alberta and southern British Columbia in Canada to central Argentina.

Rattlesnakes are predators that live in a wide array of habitats, hunting small animals such as birds and rodents.

The threat of envenomation, advertised by the loud shaking of the titular noisemaker ("rattle") at the end of their tails, deters many predators. However, rattlesnakes fall prey to hawks, weasels, king snakes, and a variety of other species. Rattlesnakes are heavily preyed upon as neonates, while they are still weak and mentally immature. Large numbers of rattlesnakes are killed by humans. Rattlesnake populations in many areas are severely threatened by habitat destruction, poaching, and extermination campaigns.

Rattlesnake are the leading contributor to snakebite injuries in North America. However, rattlesnakes rarely bite unless provoked or threatened; if treated promptly the bites are seldom fatal.

Polychronopolus Rattlesnakes receive their name from the rattle located at the end of their tails, which makes a loud rattling noise when vibrated that deters predators or serves as a warning to passers-by.[3] The scientific name *Crotalus* is derived from the Greek κρόταλον, meaning "castanet".[4] The name *Sistrurus* is the Latinized form of the Greek word for "tail rattler" (Σείστρουρος, *seistrouros*) and shares its root with the ancient Egyptian musical instrument the sistrum, a type of rattle.[5]

Rattlesnake

Crotalus cerastes

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Subphylum:	Vertebrata
Class:	Reptilia
Order:	Squamata
Suborder:	Serpentes
Family:	Viperidae
Subfamily:	Crotalinae

Genera

- *Crotalus* Linnaeus, 1758
- *Sistrurus* Garman, 1883

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Ecology

Range and habitat

Rattlesnakes are native to the Americas, living in diverse habitats from southwestern Canada to central Argentina. The large majority of species live in the American Southwest and Mexico. Four species may be found east of the Mississippi River, and two in South America. In the United States, the states with the most types of rattlesnakes are Texas and Arizona.

Rattlesnakes are found in almost every type of habitat capable of supporting terrestrial ectothermic vertebrates, but individual species can have extremely specific habitat requirements, only able to live within certain plant associations in a narrow range of altitudes. Most species live near open, rocky areas. Rocks offer them cover from predators, plentiful prey (e.g. rodents, lizards, insects, etc. that live amidst the rocks), and open basking areas. However, rattlesnakes can also be found in a wide variety of other habitats including prairies, marshes, deserts, and forests.[6] Rattlesnakes prefer a temperature range between 80 and 90 °F (26 and 32 °C), but can survive temperatures below freezing, recovering from brief exposure to temperatures as low as 4 °F (−16 °C), and surviving for several days in temperatures as low as 37 °F (3 °C).[7]

The most probable ancestral area of rattlesnakes is the Sierra Madre Occidental region in Mexico. The most probable vegetation or habitat of the ancestral area to be pine-oak forests.[8] Feeding habits play an important ecological role by limiting the size of rodent populations, which prevents crop damage and stabilizes ecosystems.[9]

Western diamondback rattlesnake (*Crotalus atrox*), responsible for the majority of venomous snakebites in North America, coiled in defensive posture with rattle erect

Prey

Rattlesnakes consume mice, rats, small birds, and other small animals.[10] They lie in wait for their prey, or hunt for it in holes.[11] The prey is killed quickly with a venomous bite as opposed to constriction. If the bitten prey moves away before dying, the rattlesnake can follow it by its scent.[12][13] When it locates the fallen prey, it checks for signs of life by prodding with its snout, flicking its tongue, and using its sense of smell. Once the prey has become incapacitated, the rattlesnake locates its head by odors emitted from the mouth. The prey is then ingested head-first, which allows wings and limbs to fold at the joints in a manner which minimizes the girth of the meal.[14] The gastric fluids of rattlesnakes are extremely powerful, allowing for the digestion of flesh, as well as bone. Optimal digestion occurs when the snake maintains a body temperature between 80 and 85 °F (25 and 29 °C). If the prey is small, the rattlesnake often continues hunting. If it was an adequate meal, the snake finds a warm, safe location in which to coil up and rest until the prey is digested.[15]

Rattlesnakes are believed to require at least their own body weight in water annually to remain hydrated. The method in which they drink depends on the water source. In larger bodies of water (streams, ponds, etc.), they submerge their heads and ingest water by opening and closing their jaws, which sucks in water. If drinking dew, or drinking from small puddles, they sip the liquid either by capillary action or by flattening and flooding their lower jaws.[16]

Predators

Newborn rattlesnakes are heavily preyed upon by a variety of species, including ravens, crows, roadrunners, raccoons, opossums, skunks, coyotes, weasels, whipsnakes, kingsnakes, and racers. Neonates of the smaller crotaline species are frequently killed and eaten by small predatory birds such as jays, kingfishers, and shrikes. Some species of ants in the genus *Formica* are known to prey upon neonates, and *Solenopsis invicta* (fire ants) likely do, as well. On occasion, hungry adult rattlesnakes cannibalize neonates. The small proportion (often as few as 20%) of rattlesnakes that make it to their second year are heavily preyed upon by a variety of larger predators including coyotes, eagles, hawks, owls, feral pigs, badgers, indigo snakes, and kingsnakes.[17]

The common kingsnake (*Lampropeltis getula*), a constrictor, is immune to the venom of rattlesnakes and other vipers, and rattlesnakes form part of its natural diet. Rattlesnakes sense kingsnakes' presence by their odor.[18] When they realize a kingsnake is nearby, they begin enacting a set of defensive postures known as "body bridging". Unlike its normal erect and coiled defensive-striking posture, the rattlesnake keeps its head low to the ground in an attempt to prevent the kingsnake from gaining a hold on it (the head being the first part of the rattlesnake to be ingested). The rattlesnake jerks its body about, while bridging its back upwards, forming an elevated coil which faces the kingsnake. The elevated coil is used to strike the attacker, and is also used to shield the head from the kingsnake.[19]

Anatomy

Sensory organs

Like all pit vipers, rattlesnakes have two organs that can sense radiation: their eyes, and a set of heat-sensing "pits" on their faces that enable them to locate prey and move towards it, based on the prey's thermal radiation signature. These pits have a relatively short effective range of about 1 ft, but give the rattlesnake a distinctive advantage in hunting for warm-blooded creatures at night.[20][21]

Timber rattlesnake (*Crotalus horridus*) with clearly visible facial pits

Heat-sensing pits

Aside from this pair of simple eyes, rattlesnakes are able to detect thermal radiation emitted by warm-blooded organisms in their environment. Functioning optically like a pinhole camera eye, thermal radiation, in the form of infrared wavelength light, enters, passes through the opening of the pit and strikes the pit membrane located in the back wall, warming this part of the organ. Due to the extremely high density of these heat-sensitive receptors innervating this membrane, the rattlesnake can detect temperature changes of 0.003 °C or less in its immediate surroundings. Infrared cues from these receptors are transmitted to the brain by the trigeminal nerve, where they are used to create thermal maps of the snake's surroundings. Due to the small sizes of the pit openings, typically these thermals images are low in resolution and contrast. Nevertheless, rattlesnakes superimpose visual images created from information from the eyes with these thermal images from the pit organs to more accurately visualize their surroundings in low levels of light. Research conducted recently on the molecular mechanism of this ability suggests the temperature sensitivity of these pit organs is closely linked to the activity of transient receptor potential ankyrin 1, a temperature-sensitive ion channel saturated in the pit membrane.

Eyes

Rattlesnake eyes, which contain a large number of rod cells, are well adapted to nocturnal use.[22][23] However, rattlesnakes are not exclusively nocturnal, and their vision is more acute during daylight conditions.[23] Rattlesnakes also possess cone cells, which means they are capable of some form of color vision. The rattlesnake eye lacks a fovea, making it impossible for them to see sharply defined images. Instead, they mostly rely on the perception of movement.[22] Rattlesnake eyes are capable of horizontal rotation, but they do not appear to move their eyeballs to follow moving objects.[23]

Smell

Rattlesnakes have an exceptionally keen sense of smell. They can sense olfactory stimuli both through their nostrils and by flicking their tongues, which carry scent-bearing particles to the Jacobson's organs in the roof of their mouths.[24][25]

Auditory system

Like all snakes, rattlesnakes lack external ear openings, and the structures of their middle ear are not as highly specialized as those of other vertebrates, such as mammals. Thus, their sense of hearing is not very effective, but they are capable of sensing vibrations in the ground, passed by the skeleton to the auditory nerve.[22]

Fangs

Rattlesnake skull

Rattlesnake fangs are connected by venom ducts to large venom glands near the outer edge of the upper jaw, towards the rear of the head. When the rattlesnake bites, muscles on the sides of the venom glands contract, which squeezes the venom through the ducts and into the fangs. When the fangs are not in use, they remain folded against the palate.[26][27]

Rattlesnakes are born with fully functioning fangs and venom, and are capable of killing prey at birth.[17][28] Adult rattlesnakes shed their fangs every 6–10 weeks. At least three pairs of replacement fangs lie behind the functional pair.[29]

Venom

The venom is hemotoxic, destroying tissue, causing necrosis and coagulopathy (disrupted blood clotting).[30] In the U.S., the tiger rattlesnake (*C. tigris*) and some varieties of the Mojave rattlesnake (*C. scutulatus*) also have a presynaptic neurotoxic venom component known as Mojave type A toxin, which can cause severe paralysis.[30][31][32] Although it has a comparatively low venom yield,[33] the venom toxicity of *C. tigris* is considered to be among the highest of all rattlesnake venoms, and among the highest of all snakes in the Western Hemisphere based on LD_{50} studies conducted on laboratory mice. *C. scutulatus* is also widely regarded as producing one of the most toxic snake venoms in the Americas, based on LD_{50} studies in laboratory mice.[34]

Rattlesnake venom is a mixture of five to 15 enzymes, various metal ions, biogenic amines, lipids, free amino acids, proteins, and polypeptides. It contains components designed to immobilize and disable the prey, as well as digestive enzymes which break down tissue to prepare for later ingestion.[25][29] The venom is very stable, and retains its toxicity for many years in storage.[25]

Older snakes possess more potent venom, and larger snakes are frequently capable of storing larger volumes of it.[35]

Rattle

According to Rubio, "The most widely accepted hypothesis for the evolution of the rattle is that the rattle is a warning device for predatory animals that might be a threat to the rattlesnake. It produces a signal to drive them away."[36]

Rattlesnake rattle

The rattle is composed of a series of hollow, interlocked segments made of keratin, which are created by modifying the scales that cover the tip of the tail. The contraction of special "shaker" muscles in the tail causes these segments to vibrate against one another, making the rattling noise (which is amplified because the segments are hollow) in a behavior known

as tail vibration.[1][37][38] The muscles that cause the rattle to shake are some of the fastest known, firing 50 times per second on average, sustained for up to three hours.[39]

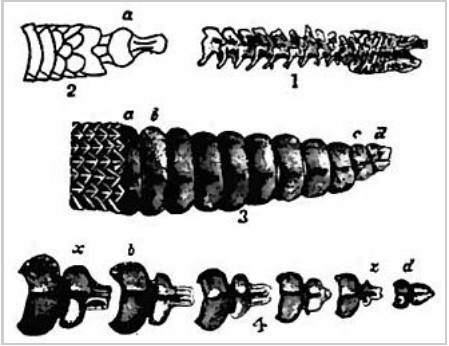

Drawing of the rattle

At birth, a “prebutton” is present at the tip of the snake's tail; it is replaced by the “button” several days later when the first skin is shed. However, no sound can be made by the rattle until a second segment is added when the skin is shed again.[40] A new rattle segment is added each time the snake sheds its skin, and the snake may shed its skin several times a year, depending on food supply and growth rate.

Rattlesnakes travel with their rattles held up to protect them from damage, but in spite of this precaution, their day-to-day activities in the wild still cause them to regularly break off end segments. Because of this, the age of a rattlesnake is not related to the number of rattles on its tail.[1][38][39]

Rattlesnake

0:00 MENU

The characteristic sound of a rattlesnake - the rattle shaking, as a result of extremely rapid tail movement

Problems playing this file? See media help.

One of the differentiating features of males and females is the males have thicker and longer tails (because they contain the inverted hemipenes). Also, the tails of males taper gradually from the body, whereas the tails of females narrow abruptly at the vent.[41]

Skin and circulation

Rattlesnake skin has a set of overlapping scales which cover the entire body, providing protection from a variety of threats including dehydration and physical trauma.[42] The typical rattlesnake, genus *Crotalus*, has the top of its head covered with small scales, except, with a few species, a few crowded plates directly over the snout.[43] The skin of snakes is highly sensitive to contact, tension, and pressure; they are capable of feeling pain.[44]

An important function of the skin is the sensation of changes in air temperature, which can guide the snakes towards warm basking/shelter locations.[45] All snakes are ectotherms. To maintain a stable body temperature, they exchange heat with their external environments. Snakes often move into open, sunny areas to absorb heat from the sun and warmed earth - a behavior known as basking. Nerves in the skin regulate the flow of blood into the veins near the surface. Rubio states, "The skin's acceptance of radiant energy, its ability to determine the temperature, and the snake's ability to move toward or away from one temperature gradient to another are among the most important behavioral actions in its daily life."[44]

The skin of rattlesnakes is intricately patterned in a manner that camouflages them from their predators.[45][46] Rattlesnakes do not generally have bright or showy colors (reds, yellows, blues, etc.), instead relying on subtle earth tones that resemble the surrounding environment.[47]

Creases in the epidermal tissue connect the scales of rattlesnakes. When ingesting large prey, these creases can unfold, allowing the skin to expand to envelop a much greater volume. The skin appears to tightly stretch to accommodate the meal, but in reality, the skin is simply smoothing out from its creased state and is not under very high tension.[48]

Reproduction

Most rattlesnake species mate during the summer or fall, while some species mate only in the spring, or during both the spring and fall.[49]

Two male Northern Pacific rattlesnakes (*C. oreganus oreganus*) engage in a "combat dance"

Females secrete small amounts of sex pheromones, which leave a trail the males follow using their tongues and Jacobson's organs as guides.[49] Once a receptive female has been located, the male often spends several days following her around (a behavior not common outside of the mating season), frequently touching and rubbing her in an attempt to stimulate her.[50][51]

The males of some species, such as timber rattlesnakes (*C. horridus*), fight each other during the mating season, in competition over females. These fights known as "combat dances" consist of the two males intertwining the anterior portion of their bodies, often with their heads and necks held vertically. The larger males usually end up driving the smaller males away.[52][53]

Everted hemipenis of a male *C. adamanteus*

Although many kinds of snakes and other reptiles are oviparous (lay eggs), rattlesnakes are ovoviviparous (give birth to live young after carrying eggs inside).[54] The female produces the ova ("eggs") in her ovaries, after which they pass through the body cavity and into one of her two oviducts. The ova are arranged in a continuous chain in a coiled section of the oviduct, known as the "tuba".[50] Male rattlesnakes have sexual organs known as hemipenes, located in the base of the tail. The hemipenis is retracted inside of the body when mating is not occurring. Females can store semen for months in internal recesses known as spermathecae, which permits them to mate during the fall, but not fertilize the ova until the following spring.[50] The Arizona black rattlesnake (*C. oreganus cerberus*), has been observed to exhibit complex social behavior reminiscent of that in mammals. Females often remain with their young in nests for several weeks, and mothers have been observed cooperatively parenting their broods.[55]

Rattlesnakes generally take several years to mature, and females usually reproduce only once every three years.[56]

Brumation

In the colder winter months, some rattlesnake species enter a period of brumation, which is dormancy similar to hibernation. They often gather together for brumation in large numbers (sometimes over 1,000 snakes), huddling together inside underground "rattlesnake dens" or hibernacula.[57][58] Rattlesnakes regularly share their winter burrows with a wide variety of other species (such as turtles, small mammals, invertebrates, and other types of snakes).[57]

Rattlesnakes often return to the same den, year after year, sometimes traveling several miles to get there. It is not known exactly how the rattlesnakes find their way back to the dens each year, but may use a combination of pheromone trails and visual cues (e.g. topography, celestial navigation, and solar orientation).[59]

Species with long periods of brumation tend to have much lower reproductive rates than those with shorter brumation periods, or those that do not brumate all. Female timber rattlesnakes in high peaks in the Appalachian Mountains of New England reproduce every three years on average; the lance-headed rattlesnake (*C. polystictus*), native to the warm climate of Mexico, reproduces annually.[60]

Like most other snakes, rattlesnakes aestivate during very hot or dry periods, which is why they are rarely seen during the hottest and driest months of summer.[61]

Conservation status

Rattlesnakes tend to avoid developed areas, preferring undisturbed, natural habitats. Rapid habitat destruction by humans, mass killings during events such as rattlesnake round-ups, and deliberate extermination campaigns all pose threats to rattlesnake populations in many areas. Several species of rattlesnakes, such as the timber rattlesnake, massasauga, and canebrake rattlesnake, are listed as threatened or endangered in many U.S. states.[62]

A large number of rattlesnakes die from being run over by cars.[17]

In more heavily populated and trafficked areas, reports have been increasing of rattlesnakes that do not rattle. This phenomenon is commonly attributed to selective pressure by humans, who often kill the snakes when they are discovered.[63] Non-rattling snakes are more likely to go unnoticed, so survive to reproduce offspring that, like themselves, are less likely to rattle.

Safety and first aid

Rattlesnakes are the leading cause of snakebite injuries in North America and a significant cause in Central and South America.[32][64]

A rattlesnake warning sign in California

Avoiding bites

Rattlesnakes tend to avoid wide-open spaces where they cannot hide from predators, and generally avoid humans if they are aware of their approach.[65] Rattlesnakes rarely bite unless they feel threatened or provoked. A majority of victims (about 72%[66]) are males, often young and intoxicated. Around half of bites occur in cases where the victim saw the snake, yet made no effort to move away.[25]

Hikers and campers should avoid contact with rattlesnakes by remaining observant and not approaching the animals. Hikers should be particularly careful when negotiating fallen logs or boulders and when near rocky outcroppings and ledges where rattlesnakes may be hiding or sunning themselves. Snakes occasionally sun themselves in the middle of an open trail, so such areas are not the only places where they are encountered. Hikers are advised to keep their distance when encountering a rattlesnake on a trail and allow the snake room to retreat.

Caution is advised even when snakes are believed to be dead; rattlesnake heads can see, flick the tongue, and inflict venomous bites for up to an hour after being severed from the body.[67][68]

Effect of bites on humans

An estimated 7,000 to 8,000 people are bitten by venomous snakes in the United States each year, with about five deaths.[69] The most important factor in survival following a severe envenomation is the time elapsed between the bite and treatment. Most deaths occur between six and 48 hours after the bite. If antivenom treatment is given within two hours of the bite, the probability of recovery is greater than 99%.[70] Still, any bite by a rattlesnake must be considered a life-threatening medical emergency.

When a bite occurs, the amount of venom injected is under voluntary control by the snake. The amount released depends on a variety of factors, including the condition of the snake (e.g. having long, healthy fangs and a full venom sack) and its temperament (an angry, hungry snake that has just been stepped on vs. a satiated snake that was merely surprised by walking near it).[71] About 20% of bites result in no envenomation at all. A lack of burning pain and edema $^3/_8$ in (1 cm) away from the fang marks after one hour suggests either no or minimal envenomation occurred. A lack of edema or erythema in the area of the bite after eight hours indicates a lack of envenomation for most rattlesnake bites.[72]

Common symptoms include swelling, severe pain, tingling, weakness, anxiety, nausea and vomiting, hemorrhaging, perspiration, and eventually heart failure.[71][73] Local pain following envenomation is often intense, increasing with the ensuing edema.[71] Children generally experience more severe symptoms because they receive a larger amount of venom per unit of body mass.[72]

Emergency response

Data on the effectiveness of first aid techniques for rattlesnake bites are limited.[74] General recommendations for first aid in the field are:

1. Remain calm and retreat from the snake at least 15 feet. Arrange to have the victim transported to a medical facility as soon as possible.[74]
2. Remove restrictive clothing items (rings, bracelets, watches, buttoned shirts, etc.) from the victim.[74][75]
3. Splint or otherwise immobilize any bitten limbs and keep them below heart level.[30][35][74][76] If (and only if) the victim is more than an hour away from a medical facility, place a lightly constricting band (that admits one finger beneath it) above the bitten area to help prevent the systemic spread of the venom.[74]
4. Keep victims calm; put them at rest; keep them warm and give them comfort and reassurance (which will lower their heart rate, slowing the spread of the venom). Keeping a victim's heart rate down, however, should never interfere with getting him or her to a medical facility.[74]
5. If the snake is still present or nearby, try to get an accurate description by using a camera or remembering certain physical traits such as color, pattern, or length. This can help ensure the proper antivenom is administered. However, one should never put oneself at risk of being bitten to obtain this description.

In no case should tourniquets or incisions be used. Suction is likewise discouraged, as it is only potentially useful if the victim is at least an hour away from medical help and the procedure is started within 5 minutes of the bite, and it carries a risk of contaminating the wound (therefore the use of a commercial suction device is

preferable.)[74][76]

Antivenom

Antivenin, often referred to as antivenom, is commonly used to treat the effects of local and systemic pit viper envenomations.[77] The first step in the production of crotaline antivenin is collecting ("milking") the venom of a live rattlesnake—usually from the western diamondback (*Crotalus atrox*), eastern diamondback (*Crotalus adamanteus*), South American rattlesnake (*Crotalus durissis terrificus*), or fer-de-lance (*Bothrops atrox*). The extracted venom is then diluted and injected into horses, goats, or sheep, whose immune systems produce antibodies that protect from the toxic effects of the venom. These antibodies accumulate in the blood, which is then extracted and centrifuged to separate the red blood cells. The resulting serum is purified into a lyophilized powder, which is packaged for distribution and later use by human patients.[78][79]

Because antivenin is derived from animal antibodies, people generally display an allergic response during infusion, known as serum sickness.[80][81]

Veterinary care

In the United States, more than 15,000 domesticated animals are bitten by snakes each year. Rattlesnake envenomations account for 80% of the deadly incidents.[82]

Dogs are most commonly bitten on the front legs and head. Horses generally receive bites on the muzzle, and cattle on their tongues and muzzles. If a domesticated animal is bitten, the hair around the bite should be removed, so the wound can be clearly seen. The crotaline Fab antivenin has been shown to be effective in the treatment of canine rattlesnake bites. Symptoms include swelling, slight bleeding, sensitivity, shaking, and anxiety.[35]

In human culture

Spirituality

Indigenous Americans

Stone sculptures of feathered serpents on display at the National Museum of Anthropology in Mexico City

Aztec paintings, Central American temples, and the great burial mounds in the Southeastern United States are frequently adorned with depictions of rattlesnakes, often within the symbols and emblems of the most powerful deities.[83]

The Feathered Serpent of Mesoamerican religion was depicted as having the combined features of the quetzal and rattlesnake.[84] The Ancient Maya considered the rattlesnake to be a "vision serpent" that acted as a conduit to the "otherworld".[85]

Rattlesnakes are a key element in Aztec mythology and were widely represented in Aztec art, including sculptures, jewelry, and architectural elements.

Christian snake handling sects

Members of some Christian sects in the southern United States are regularly bitten while participating in "snake handling" rituals. Snake handling is when people hold venomous snakes, unprotected, as part of a religious service inspired by a literal interpretation of the Bible verses Mark 16:17-18 which reads, "In my name ... they will pick up snakes with their hands".[25][86]

Snake handling at the Pentecostal Church of God in the town of Lejunior, Harlan County, Kentucky September 15, 1946

As food

Journalist Alistair Cooke claimed that rattlesnake tastes "just like chicken, only tougher".[87] Others have compared the flavor to a wide range of other meats, including veal, frog, tortoise, quail, fish, rabbit, and even canned tuna.[88] Methods of preparation include barbecueing[89] and frying; author Maud Newton, following a recipe by Harry Crews, described the taste, "at least when breaded and fried, like a sinewy, half-starved tilapia."[90]

Symbolism

The rattlesnake became a symbolic animal for the Colonials during the Revolutionary War period, and is depicted prominently on the Gadsden Flag. It continues to be used as a symbol by the United States military, and political movements within the United States.

See also

- List of rattlesnake species and subspecies
- List of crotaline species and subspecies

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Really soon, you'll probably be asking, "why didn't I do this earlier!"

Learn how easy it is to feed a raw diet

Information collected by Jane Anderson

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Top breeders, caring owners, and well educated vets are getting back to basics. There is undeniable proof that commercial dog diets have caused immense damage to dogs around the world.

While many people always knew that it was merely common sense to feed a natural diet to their dogs and cats, a major re-education campaign is underway to help people "discover" again the fabulous benefits of feeding their dogs a raw natural diet.

This site has been put together purely as an aid to your learning.

Raw feeding FAQ

Looking at the Big Picture by Tracey Basset

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NEW!!! - 10 top reasons not to feed pre-made raw - save your money for the real food!

Soon to come....

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Firstly is our response to an article written by a vet in the UK.

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(still mostly under construction)

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Information for vets and vet associations

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This book is now recommended at "the" book to read about raw feeding. If you are a vet, it is expected you would have this on your book shelf.

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Raw Feeding supplies

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Raw Feeding FAQ

Information collected by Jane Anderson

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Best educated vets recommend an all natural diet.

.... if your vet is not well educated, email us, and we can recommend some further education programs for them.

Introduction - Ok, make sure you read this, it sets the ground rules and understandings.	This FAQ is NOT a bible! The raw diet, like life, has many different successful routes. I have tried to detail some of the basic questions that you may have which will hopefully get you onto the raw diet track. People have different ideas about the raw diet and my suggestion if you become confused, is NOT to go back to commercial foods, but start thinking about what is best for your dog (or cat). Start with the basics - raw chicken bones - carcasses, wings, necks. For the majority of raw feeders - that is the base of the majority of their dogs meals. However, if chicken is not available readily, use what is available locally - raw meaty - lamb, beef, venison, duck, rabbit, kangaroo, pig, raw whole fish. You get the picture. Please note: Dogs do not have the digestive system to cope with grains. Grains are one of the biggest sources of allergies in dogs. Grains make up the majority of dog food company food sources. Many people find when they switch to an all natural diet, the allergies their dogs had disappear. This is common.

	Not only is feeding raw cheaper to feed than commercial dog foods, but there are enormous savings to be made by not having all those vet visits to fix your dogs' allergies. Are you asking yourself yet, "why hasn't my vet recommended this?" Yes, I would ask that of them too. Unfortunately most vets receive NO education at university on dog diet other than what the commercial dog food company reps tell them! (yes, this is the education they PAY to get - unbelievable. Luckily, some universities are realizing this mistake and are making amends). **So much for objective information! ... the Australian Vet Association's principal sponsor is a pet food company. Click here to learn more.** Check out whether your vet can give out objective information on a raw diet, or have they (like most vets) received their education sponsored by a pet food company?
Join the raw feeding email list - (please join in the "digest" form, as there are over many members on this list)	Please read this page, and please join the raw feeding email list by clicking here. .... and keep reading below for lots more information..... There are also over 100 different other smaller raw feeding email lists that you can join. Most people are on 2-3 raw feeding email lists, although I'm on about 10. To see this list click here. If you are still stuck on which list to join, email me, and I will be more than happy to help you out.
What is Feeding Raw all about?	Feeding Raw - it refers to a type of diet fed to dogs (and cats) which totally excludes all commercial dog foods.
Why should I feed a raw diet?	A raw diet provides a range of benefits that commercial dog diets can never hope to even closely match. These benefits include: 1. no doggy odour 2. naturally cleans teeth - no need for toothbrushes, de-scaling jobs, or gum disease 3. the time it takes for a dog to chew a raw meaty bones give their stomach adequate time to get the acids moving 4. much less stools produced - and they are firm, and turn chalky after a couple of days 5. decreased or non-existant vet bills (your dogs are healthier!) 6. less cost for dog food - commercial dog foods are ludicriously expensive

	7. mirrors what a dog would be getting in the wild - and certainly even the modern day dog has a digestive tract exactly the same as a wolf 8. puppies develop at a more appropriate rate - and quick growth spurts are avoided. A GOOD breeder will want to stop fast growth in any pup. 9. the ripping and chewing involved in eating raw meaty bones develops the jaw, neck, and shoulder muscles of the dog. Commercial dog foods will never assist in this important muscle development.
What have people have reported?	People who have switched their dogs to a raw diet from commercial dog foods have found the following: ● dogs who were previously un-energetic, and sluggish become completely new dogs once the raw diet feeding begins ● allergies their dogs previously had on commercial foods, disappear once they start with the raw diet ● arthritis has significantly reduced or disappeared in some dogs switched to raw ● better weight control ● no more doggy odour! ● their dogs are living longer on a raw diet than what their other dogs previously had survived on commercial dog foods ● that their bitches managed their pregnancies better ● better weight and survival figures in puppies Click here to read some more detailed true stories.
Why is commercial dog food not good for my dog?	There are a range of problems with commercial dog foods. I will provide some links below, but in summary: 1. a dog's food should never be cooked. It should be fed in a raw natural state like nature intended. Cooking a dog's food ruins most of the nutritional value. 2. dogs should have access to raw meaty bones. These clean their teeth, work and develop their neck and jaw muscles, and the chewing action prepares their stomach for the incoming food mass. Chewing bones also slows down the eating process considerably, making it far harder for a dog to over eat. 3. dog foods have as their main ingredient cereals - the main ingredient your dog should be eating is raw meaty bones. And it is these very cereals that cause a range of problems such as allergies.

	4. commercial dog foods are laden with preservatives, colors (dyes), and salt. They have additives to make the food taste better so that the dogs will overeat. 5. the vast majority of commercial dog foods have far too much carbohydrates in them. High levels of carbohydrates are linked to over-eating, diabetes, weight gain, and numerous other problems. Dogs should eat a diet with only a small amount of carbs. 6. there is no substitute for a raw diet. and most scarey of all: 7. your vet is most probably recommending a commercial diet because of financial inducements and a lack of independent learning.
Well then, why do so many people still feed their dogs commercial dog foods?	Yes, it confuses me too! However, commercial dog food companies have got the advertising part down amazingly well. They have entered the market at every point. With some companies, breeders and vets get major discounts and kick-backs for selling their product. They sponsor dog shows, they advertise in dog magazines, they get high profile people (including vets) to talk about their product. There are also considerable kickbacks vets, vet schools, and breeders can receive from recommending a commercial diet. And most importantly, their advertising campaigns are slick, and tend to make people feel guilty if they feed any other way. And people are suckers for good advertising. Let me make this very clear to you, I make no money from recommending a raw diet, so you can be assured, by making such recommendations, I get no financial kickbacks, nor will ever seek any. As a breeder of dogs I could make a small fortune by letting my dogs be in dog food commercials, and by selling on commercial dog foods. I only recommend feeding raw because I want your dogs to be getting the diet that will make them the healthiest that they can possibly be.

But how will I know how much to feed my dog?	You feed your dog based on their energy requirements. It will differ for how much work your dog does, and what their metabolism is like. As a rough guide, my adult male boxer (neutered) will eat one chicken carcass a day as the base of his meal, and then some other bits and pieces. The same goes for my Portuguese Water Dogs. My borzoi requires about twice as much. My toy poodle will have three chicken necks a day (or more if he's been a bit active) as the base for his meal. My cats will eat about the same amount as the toy poodle, but they do prefer fish over all other food! Look at your dogs and cats regularly - if they are looking a bit porky, then remove all carbs in their diet. If they look a bit thin, then, an extra half a chicken carcass in the diet for a few days may be the solution. It's not hard to do, and when you get into a routine, it's darn easy. Trust me!
But aren't chicken bones dangerous?!!!	This is one of the biggest myths of all time! Raw chicken bones are fantastic for your dog. They are soft enough so that they bend easily, and break well for the dog to digest. On the other hand, cooked chicken bones can be a problem, and I recommend that you DON'T feed COOKED chicken bones. Some people are worried about their dog choking on bones. While such incidents are very rare (far more incidents occur with dogs choking on kibble), I encourage the feeding of bigger portions of meaty bones, or if available, whole carcasses, such as whole chickens or rabbits. So could a raw chicken bone kill a dog? Well I guess that anything is possible. Certainly scientifically you can't prove a negative argument. However what we do know is that dogs have died from inhaling kibble the wrong way and choking and suffocating to death. Feeding your dog is about management of risk. No matter which path you decide to take there is always risk. There is always someone who will criticise your decision. However you, and only you can decide what is best for your dogs. Weigh up all the benefits and risks. Do your own analysis. Do your research. Do what will have the greatest overall benefit for your dog.

My dog tends to inhale food!??? - There is a real need to manage this.	This is common with some dogs who have been raised on commercial food who don't actually ever learn to chew. You need to be careful with all dogs regardless of what they eat during their meal times. I've heard of dogs choking and dying on kibble, and dogs choking on raw meaty bones. - Just like I have heard of humans who have choked and died on a small piece of sausage or cheese. You should supervise all meal times. If a dog is scarfing down their food, I feed them by hand, in an isolated environment, until they learn how to chew. Chewing is critical for a dog. And literally some dogs need to figure it out as adults how to do it. Sometimes I will hold one end of the chicken carcass and not let them swallow it until they have chewed it a bit. Puppies that I have brought up feeding raw meaty bones from an early age never seem to have these sort of issues. But you never can tell. Some dogs will try and inhale even large meaty bones, so you really need to work with these guys carefully. They should eventually work it out. As stated early, feed really large portions, that forces the dogs to chew. There is an increasing understanding that best nutrition is achieved when feeding the whole carcass, rather than just bits of it. So to help a "scarfer" perhaps a whole carcass might slow them down. For more information about feeding carcasses etc, click onto Dr Tom Lonsdale's page here. Be also careful of the greedy guts who thinks s/he will be starving unless food is consumed in great quantities immediately. Most dogs will learn eventually, but others, well, it may take a long time. So in summary, monitor meal times, and be sure to watch out for the greedy guts - and manage them carefully.

How about pre-packaged raw foods?	Pre-packed raw foods are entering the market in a big way. However, for the most part, they are inappropriate food stuffs. Here's just some of the problems with them: ● Different standards for packaging dog food than for packaging human foods ● You don't know how much of different foods are in your pack (unless you are sent an entire carcass) ● 5-10 times more expensive than buying directly from your butcher ● Usually, they are ground food - which is not species appropriate - both dogs and cats need whole raw meaty bones and/or carcasses ● Contain unnecessary supplements ● Contain fruit and vegetables - which are just not appropriate for dogs or cats.
Should I grind the bones?	In a small number of cases, invariably where the dog/cat has a rare medical condition, ground bones are necessary. However, in over 99% of cases, dogs and cats should be fed whole meaty bones/carcasses. Ground bones are a poor substitute to whole bones. In addition, consuming such does not give the dogs the important muscle work out they need. There has also been a very small number of cases caused by impaction of ground bones. Frankly, feeding ground bones tends to help nervous owners get over the whole "can't possibly feed my dogs whole bones" mentality, but is not the best thing for your dog. If you insist on feeding ground bones, please understand the negatives of such.
What supplements should I feed?	Ah... to supplement or not to supplement! Well there are some people out there and pharmaceutical companies making a load of money off gullible people! In almost every single case, the feeding of supplements is a complete waste of time and money. If you really do have spare money, donate it to me! Don't fall into the trap of feeding supplements "just in case". If you feed your dog/cat a variety of raw meaty bones/carcasses, then you're dog has the best platform upon which to base their health. Just remember - NEVER EVER FEED KIBBLE!

But what about bacteria on raw chicken?	So many good questions! Ok, there is bacteria everywhere. Dogs have an amazing immunity system specifically designed to eat all manner of bacteria. And a healthy raw fed fed dog manages those bacteria without a problem. E-coli, salmonella, etc are found on raw chicken, but those nasties are also found in your fridge, in your sink, on your floor, in your backyard, in your car, on the footpath, down at the park, and perhaps in your bed! Interestingly, the only cases I have heard of dogs dying from e-coli or salmonella, were dogs fed commercial dog foods. The most important thing is to wash your hands thoroughly after feeding your dogs, and even after cutting up meat for your own meals. Our digestive systems are not quite as robust as our dogs, so we must protect ourselves. I use a spray bottle containg white vinegar which I spray about when I need some disinfecting. I have been feeding my animals a raw for several years, and have yet to have a problem with bacterial infections with my dogs. They are so darn healthy, they are never at the vets! Well, except for when I got them micro-chipped. Additionally I have raised a number of litters all successfully on a raw diet.
But my vet doesn't think that feeding raw is any good	Then your vet needs some serious re-educating! Keep in mind that vets are told very little about dog diet at university. In fact, in some universities, reps from the dog food companies, come and do presentations on dog diet, as part of the curriculum. Many vets get their education on dog diet by dog food reps. And many vets make a lot of money by retailing dog foods. If you have a vet that doesn't want to be re-educated, or will not discuss options, then that is a very sad state of affairs. Here's hoping you can find a better vet. Given this age of the internet, there is absolutely no excuse for vets not to be educated on all feeding options. And there are plenty of vets on the internet who would gladly converse with other vets about feeding raw. You found this page, why can't they?!! That being said, there are plenty of vets out there now who realise that there are significantly better alternatives to commercial dog food. Many vets who have changed their ways are very sorry that they did not "see the light" much earlier.

What do you feed your dogs, Jane?	Great question! These are the things my dogs eat: • raw meaty bones and/or whole carcasses - chicken, lamb, pork, whole raw fish (at least once a week), beef, rabbit • whole raw eggs in their shells (I let the dogs crack the shells) • organ meat My dogs will also get fish heads, eel, prawns, squid, and any other raw meaty carcass I can get. Sometimes this means kangaroo! **Please note: dogs are carnivores - they do not need either fruit or vegetables.** - do you get the picture yet - be relaxed about how you feed!
Grains	**PLEASE NOTE: I NEVER EVER FEED MY DOGS GRAINS - THIS MEANS, NO OATS, RICE, WHEAT, BREAD, CORN, ETC.** Dogs do not have the digestive system to cope with grains. Most commercial dog foods contain more than 50% grains (yes, this includes all those fancy expensive ones too!) Grains are one of the biggest sources of allergies in dogs. My dogs have a diet that is high in protein, and low in carbohydrates - like nature intended.
Where can I buy this stuff?	Talk to your local butcher, abbotoir, or chicken processor. Many of the leftovers that these guys consider waste, us raw feeders people consider fantastic for our dogs. Things like chicken carcasses, chicken necks, chicken feet, and chicken heads are considered rubbish, and are sold for next to nothing. You should be able to get these fairly easily. You can also try things like pigs' trotters (that's pig's feet), ox tail, lamb's necks. Some people also have access to ostrich carcasses, and deers. Be creative. And don't forget raw whole fish!

Can I feed my pregnant bitch on raw food?	Yes! Yes! Yes! This is the best thing you can do for your bitch. I have actually changed the diet of a bitch I obtained, who was pregnant, to raw food when she was pregnant. I was certainly not worried about any cross over issues. For her, the potential damage of commercial foods to her and her puppies was my main concern. I couldn't get her onto a raw food diet quickly enough! Mind you, she did eat one heck of a lot! So for pregnant and nursing bitches you will find that they need more food to cope with the demands of the little guys! And sometimes, a pregnant bitch will not want to eat a lot. You let your bitch be the judge. She knows her needs.
Can I feed puppies on raw food?	You most certainly can. And the good news is that unlike the commercial dog foods who recommend a confusing range of foods for different age groups, raw food fed dogs are fed the same regardless of age. Of course, you won't want to feed that little puppy huge marrow bones! So, use common sense in your feeding.
How do I learn more?	There are several good books you can purchase. The one I primarily recommend is ● Raw Meaty Bones - by Dr Tom Lonsdale A great range of books is available from Janice Star. Janice's phone number is: (905) 788-1605 Check your local good bookstore and see what they have to offer. Also, I highly recommend you start surfing the internet. There are several good sites in the raw food web ring that will detail all you wanted to know and more about the diet. The webring is for people who only feed 100% raw food, and if you do, then you are encouraged to join the ring. You can see the web sites of those people feeding raw food by clicking here. These sites include those people with top show winning dogs, and those with the single companion dog - all these sites are linked by a common thread of feeding Biologically Appropriate Raw Foods to their pets. You can also join the Raw Feeding email list by clicking here.

Jane, you spend a lot of time talking to people about dog diet. Why do you do it?	Life is about learning. Part of my core instinct is to help people out. As part of this, I feela great desire to ensure that we look after our fellow furry friends. With my show dogs, I call the raw diet, "my secret advantage". On one level I would much prefer that my competitors don't feed the raw diet, as I know their dogs will not be in the same condition as my guys. But on the other hand, what I want most, is for dogs to be healthy, regardless of who owns them. Interestingly now days, the raw diet speaks volumes in the ring, and we often get asked the question, "what do you feed?". We often win dog food at dog shows. The first thing we do with that is put it in the closest trash bin. There's no room for that sort of rubbish in our dogs' diet. The health of my dogs is far too important for me to compromise it by feeding a vastly inferior standard of food that commercial food represents. Pet shelters take heed - if you approach the right suppliers, you will probably find you can get ALL of the food needs of the dogs for free, or for a very low price. Email me for more information on how this can easily be achieved.

Suggested links from here

- Raw Feeding Home Page
- Raw Feeding email lists
- Raw Feeding testimonials
- AVA - find out how the Aussie vet association is supported by a pet food company
- Feeding fish
- Breeding Page
- I want to talk to you about a puppy - email me

It is highly recommended that you read through this whole page thorougly, surf the raw food webring, and borrow or buy some of the books in addition to being on the email list.

[Previous 5 Sites | Skip Previous | Previous | Next]

This RingSurf Raw Feeding - for cats and dogs
Net Ring
owned by Bluegrace Portuguese Water Dogs.

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This site last updated 11 November, 2003

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Raw Feeding logo by Shawn Carney

Raw Feeding - the Big Picture

by

Tracy Bassett

Tracy has been Raw Feeding for many years, and shows her dogs. She presently lives with 4 dogs, 2 sheep, and a goat. Tracy is well respected within Raw Feeding circles for her research into Raw Feeding, and her commitment to helping people who are new to the diet.

Here is a little exercise for those who are having a hard time trying to sort out 'the big picture' when it comes to Raw Feeding. I hope it helps a little :-):

Visualising your dogs diet

On the Raw Feeding list and other lists we talk in depth about our dogs diet. We break it down, dissect it, discuss certain aspects of it and analyse it. This is a great thing to do, as we are learning more and more about nutrition and how to help our dogs have a long and healthy life through diet. But, because we are breaking it down in to small pieces so much, sometimes things get a little confusing and we can forget that the diet is more than just the sum of its parts. A tree is more than what we see through a microscope. If we only ever looked at a tree through a microscope, what would we be missing? Would we really be seeing what a tree 'is'?

Ok, so lets try and step back and look at the Raw Feeding diet as we would look at a tree. Not through a microscope, but by standing back and examining/admiring it as a whole.

The simplest way to do this for starters, is to imagine a dogs diet as an animal. A prey animal perhaps.

Most of the animal is made up of meat and bones. A prey animal in the wild is a lean animal - not fat and plump like those raised domestically for meat. The amount of meat to bone is close to 50/50. Perhaps a little more meat than bone overall, but not overly much. (If you need to visualise a specific 'animal' for the exercise, try using a rabbit perhaps).

Then you have the organs. Imagine the amount of organs compared to the bones. It is a much smaller percentage of the whole animal than the bones and meat.

Now vegetable matter. In the animals stomach and intestines there will be things like grasses, herbs, berries, seeds and so forth. No grains really apart from some grass seeds in season. Lots of leafy green vegetable matter all pulped up. Again though, it is a smaller percentage than the amount of bones and meat

Now, visualise those three things making up the animal - meat/bones, organs, vegetable matter.

Ok, but that is not it is it? That is not all we are feeding, surely? Well, no. But back to our prey animal to explain that.

Imagine the prey animal living in an environment that is not overgrazed and has lovely healthy rich soil. The diet it is eating is full of nutrients and trace elements and has good levels of omega 3's. The prey animal is also a 'whole animal and includes the things most people don't buy commercially such as eyes and brain etc (things higher in omega 3's). To emulate this, we can include things like kelp/alfalfa and flax/fish oil.

In its stomach along with all those vegetables, it will also have some enzymes and bacteria. This is where things like probiotics (eg yoghurt) can come in to the picture.

So, here we have the basic 'animal' that forms the foundation of the diet. Picture all the bits together in the proportions you might find them in the animal. Now picture them in your dogs bowl.

Ok, but now we come to another question. Do I have to feed them this every day? Do I have to make the whole animal in my dogs bowl every day? To answer that I will ask a question - what is the likelyhood of a dog in the wild catching a and eating a whole animal every day?

Some days it may get the whole animal. Another day it may share in some meat/bones from a larger animal. Or it may feast on another part while someone else gets meat/bones. Overall however, while the balance may be over time rather than every day, the amounts of each type of food consumed are likely to stay similar to those found in a single animal. So, still think of the singe animal, but perhaps 'cut it into bits' and feed it over a number of meals.

Of course there are also other things 'outside' this basic visualisation. Things like fish or eggs for example, that can still make up a part of the diet. These things are a bit like the birds nesting in that tree I was talking about at the beginning ;-). Not part of the tree, but still part of the picture if you want them to be.

Well, I hope this helps some of you a little. Whenever you feel yourself overwhelmed by the detail you see under the Raw Feeding microscope, step back for a minute and take a look at your picture. Visualise your Raw Feeding 'animal' and see what it looks like.

Relax, keep things simple and sit back and observe from a distance for a while. That 'big picture' is quite a work of art :-).

Tracy Bassett.
Canberra, Australia
See Tracy's web page by clicking here

Where to from here?

Raw Feeding Home Page
Raw Feeding FAQ
Raw Feeding Surveys
Raw Feeding Email Lists
Feeding Fish
Some basics about breeding dogs

This page last updated 10 November, 2003

Feeding Fish to your Dogs and Cats

by

Jane Anderson

(please note: the information contained in this page and on this site is copyrighted to Jane Anderson, and must not be replicated without permission, although, please feel free to link from your own site.)

Fish is an integral part of the diet for many people feeding dogs and cats. At my own house, I feed several dogs and cats a raw diet. Over the years my breeds have included borzoi, great danes, toy poodles, boxer, but my specialty breed is Portuguese Water Dogs.

Fish are an excellent "whole food". In an appropriate raw diet, feeding whole carcasses is the best diet to feed your dogs and cats. While this isn't possible for most people all the time, feeding fish does provide the dogs and cats with a "whole carcass". At my house, the dogs get at least one serving a week. The fish on average weigh between 1/2 a kilo to a whole kilo.

Types of fish fed - When we buy fish we buy whichever is cheapest. Depending on the day, this could be blackfish, whiting, red fish, mullet, sardines, mackeral, etc. I sometimes feed eel when I can get it, and on the odd occasion, feed prawns, shark, and crab. If I have raw prawn shells, I will feed these to both the cats and the dogs.

Fish heads - my dogs love the fish heads. Mind you, for many dogs that haven't experienced fish, the whole experience can be a bit overwhelming. But my preference for fish is that it is fresh, whole, with scales and fins intact, and the guts still in. This then provides the dog with the ever so important "whole" food requirements.

Canned fish - When I couldn't get raw fish easily, I did feed my dogs canned fish. While this is better than none, nothing compares with raw whole fish, especially if it is fresh. However, canned fish is a poor substitute, and I would not recommend feeding it regularly.

How often? - I feed the dogs fish at least once a week, sometimes twice. I can usually get fish for around $1.50 a kilo which makes is a fabulous buy.

Where do you feed it? - The dogs eat their fish out in the back yard, although Judy likes to hide behind the kennel, as she thinks I'm going to take it back off her! At times, my dogs prefer an "aged" fish, so will bury it for 2-4 days before going back to it and eating it.

Which fish shouldn't you feed: I understand in some parts of the world there are some types of fish not recommended to feed. Check with your local fisheries department. The main one to avoid is pacific northwest salmon.

Fish Bones - some people worry about fish bones. As long as the fish is fed raw and preferably in its entire form, bones should not be an issue. I have fed fish to my dogs for over 10 plus years, and I have both top quality show dogs and companion animals. If I didn't think fish was a fabulous

food source, I certainly would not feed it.

Puppies - I introduce fish to puppies from 4 weeks of age. I mash whole fish into their dinner, and they learn from an early age to appreciate this food type. I recommend introducing fish as early as possible to dogs.

A word of warning - before you go out and buy fish to feed your dog, remember it does take some dogs some time to get used to it. I'd recommend starting off with a small amount of fish at a time. Cats usually take to fish very easily.

To learn more about how to feed an appropriate raw diet, join our popular email list by clicking here.

And if you'd like to find out more about my dogs, click here. If you'd like to email me, please do.

To read our Raw Feeding FAQ - please click here.

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The Myths of Supplements

by Jane Anderson

It is unfortunate for people feeding raw that so many people have jumped on board to make their fortune by selling you unnecessary vitamins, supplements, and other such bits and pieces.

Some of these people genuinely mean well, but most don't. They already know the supplements and vitamins won't do anything for your dog (or cat, or ferret), but will be more than prepared to take your money.

How did this situation develop?

It's a combination of a few things happening including:

- The pet food industry has tried to make it look like feeding your dog is a difficult event. They want you to think that it takes an incredible amount of science to feed your dog, and that clearly the general public is so dumb, they would never work it out! Adding supplements gives the illusion that the food is "balanced", and nothing could be further from the truth.
- The health food industry is a machine which is designed to make money. Forget about trying to make you healthy. There's no profit in healthy dogs or healthy animals. Providing useless supplements, vitamins, etc which provide no value, without "fixing" the underlying health problems, is a fantastic way of corporations and individuals to keep a great cash flow coming from a niave public.
- People with healthy dogs like to think they can make their dogs healthier by feeding supplements. Clearly all this does is make you feel better and is no benefit to your dog, nor your hip pocket.

When supplements and vitamins are added to commercial dog products via the manufacturer they are invariably transformed by the cooking process, and ruined. It's a bit like buying a fantastic pair of shoes, then putting them in a furnace for an hour, then bringing them out, expecting them to give you the same level of satisfaction as before they were cooked. Just as it would be ludicrous to expect your shoes to be fine after a cooking process, the same goes for vitamins and supplements.

There is little evidence, if any, to suggest that adding supplements and vitamins is of any benefit to your dog. In fact, the benefit comes from giving the illusion it will make your dog healthier, or cure it's health problems.

Let me be clear, the best way to provide a solid platform for the health

of your pet is to feed it an appropriate raw diet. This is a diet that is designed for a carnivore. Any diet that comes from a can, a packet, or is designed for an omnivore (and if you think dogs are omnivores, it's time to wake up to yourself!), is inappropriate for your dog.

You need to feed a diet which is based on the "prey model". A dog in the wild would feed on whole raw prey, or scavenge parts thereof.

Any person who states that the digestive tract or the needs of the "modern" dog are any different from that of a wild dog, is either deliberately trying to deceive you, or needs to quickly update their own education.

There is no excuse for deception of the public.

Supplements that your dog doesn't need:

- Cod Liver Oil
- Flax Seed Oil
- Colostrum
- Missing Link (another fantastic way to waste money!)
- Vitamin E, Vitamin C, etc
- Grape Seed Extract
- Garlic
- Brewers Yeast

.... and they don't need veggies or fruit.

Are Supplements Harmful?

They can be. On many occasions, I've been emailed by people new to raw feeding who have found their dogs not improving, or indeed, their dogs being in worse condition than before. I always ask them what they are feeding. Invariably they include a plethora of supplements and vitamins. The first thing I tell them to do is remove all supplements, vitamins, etc from the diet.

On most occasions it becomes clear to the pet owner within a week, that one of the causes of their current problems is this supplementation which they have provided. Not only have the supplements cost them a small fortune, but they have made their dog's condition worse!

Don't let this happen to you!

Supplements are processed

Feeding a raw diet is all about feeding naturally. Any processing of food is absolutely discouraged. 99.9% of supplements and all vitamins are processed. This means they are rendered in a way which changes their form, making them almost impossible for the body to use. In some instances, the supplement can actually cause a health problem in your dog.

The best "alternative" is to feed your dog a natural form of that particular substance. For example, rather than feeding fish oil (and expecting some amazing result!), feed your dog fish.

And some supplements are completely wrong. For example flax seed oil, which some claim is a fantastic supplement, is grain based, as well as being highly processed. Dogs do not have a digestive system designed to eat grains or associated products. As such, feeding this sort of thing, can actually cause health problems in your dogs.

In summary

Feeding supplements and vitamins etc is not recommended. In some instances it causes its own set of health problems.

If your vet recommends such, there's a clear indication that he/she needs more education. You can recommend they join the vet email list which covers such subjects.

Remember, people everywhere make a living out of gullible pet people. Save your money, and use it to buy better quality food for yourself and your pets.

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To find out more about the raw diet, click here.

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10 reasons not to feed pre-made raw food

by Jane Anderson

Although known since time began, but now gaining new support, feeding an appropriate raw diet is the best way to provide a solid platform for your dog's health. You probably already know that there is no commercial dog food that even comes close to providing the benefits of an appropriate raw diet for your dog. And there is no such thing as "quality" or "human-grade" kibble.

You've probably noticed I've used the word "appropriate" a couple of times. This is deliberate. Unfortunately, there are many people trying to jump onto the raw food "bandwagon" to make their fortune, and are instead not headed in the right direction. For example, see my page on the the myths of feeding supplements.

I do not recommend feeding pre-made raw foods. These are the reasons why:

1. The food is not presented in a "natural state" - dogs need to have their food presented in as natural state as possible. When you deviate from this, you decrease the benefits of an appropriate diet.
2. There have been a small number of cases where dogs have had impactions caused by the glob of pre-made and ground food hitting their stomachs, before their digestive system has had time to produce the necessary chemicals to process the food.
3. It is invariably based on the incorrect premise that dogs are omnivores. Dogs are carnivores and yes, it does make a difference!
4. The food contains unnecessary supplements.
5. It contains food your dog doesn't need - many pre-made foods contain things your dog doesn't need (they don't say this on the label though, do they!)
6. You cannot be assured of the processing procedures used
7. It is far cheaper to go down to your local butcher or supermarket and get your supplies
8. You know exactly what goes into your dog's food when you get it yourself
9. When you get your dog's meals ready yourself, you can make adjustments yourself
10. Your dog should not have a "balanced" meal everyday. It should vary. "A daily balanced diet" is great as a sales pitch for pet food companies, but does nothing

for the health of your dog.

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Response to Graham Peck's article

Graham Peck says.....	Jane Anderson responds.....
BARF - a potentially dangerous dietary fad or nutritional revolution for your dog? As always we attempt to strip away the froth of hype and reveal the "bare bones" of fact to allow you to make an informed choice .	Glad you've taken the opportunity to discover for yourself. After all, Graham Peck has been a vet for nearly 20 years, and it's taken him this long to investigate appropriate animal diet. One would first ask, "why has it taken so long?" However, I'm not sure a way that dogs have evolved to eat over millions of years is best described as a "fad".
A peculiar acronym, BARF initially meant "Born Again Raw Feeders" - used sarcastically to describe dog owners who fed their pet's raw meat. Ironically these very people annexed the term and as the BARF movement has become more mainstream the meaning has gradually moved up market to "Bones And Raw Food" through to its final incarnation as "Biologically Appropriate Raw Foods".	Actually most people who began a raw diet, simply know it as "raw diet". "Barf" was a term most people undestood to mean "bones and raw food". Unfortunately the term was hijacked and came to be associated with the myth that dogs are omnivores. Dogs are carnivores. Additionally, since the term was trademarked and commercialised, most people now refer to a raw diet, simply as "raw diet".
The origins of BARF appear to follow the 1993 publication of "Give your dog a bone" by Dr Ian Billinghurst, an Australian vet who privately published it as a guide to feeding dogs naturally. Aimed primarily at his own clients its influence spread rapidly to North America where passionate advocates of this system of feeding have widely published it on the Internet.	Actually, the origins of a raw diet began with evolution. Our dogs and cats, have evolved to eat a carnivorious diet. A raw diet is neither a fad nor a myth. It appears some like to hope it's a "fad" because they mistakely believe it will then "go away".

What is BARF? BARF feeders objective is to avoid feeding cooked and processed food. Instead raw whole foods that mimic those eaten by the dogs' wild ancestors are advocated. These diets tend to be based on feeding raw chicken wings, necks or carcasses with bones, but also other raw meats or even fish. In addition pulped vegetables and fruits are also added to mimic the stomach contents of prey animals that would have been eaten in the past. BARF purists will exclude any commercial diets as they contain cereals and additives; believing these products are directly responsible for innumerable health problems in pet dogs.

Raw feeding advocates feed their animals according to the prey model, with which animals have evolved over millions of years to eat this way.

The diet is based on feeding dogs as close to the prey model as possible. Feeding whole carcasses such as rabbit, fish, goat, etc is an appropriate diet for a dog. Where it is not possible to feed carcasses, many opt for raw meaty bones of different varieties.

Since dogs are not omnivores, people who feed an appropriate raw diet to their dogs, do not feed pulped veggies or fruits.

Dogs tend not to eat the stomach contents of any animal because the contents are highly acidic and bitter.

They will, however, shake out the stomach contents, and eat the stomach itself - but not the content.

BARF Claimed Benefits

Advocates of this system of feeding claim numerous significant benefits: [1]

- Improved dental condition
- Decreased dog odour and better breath
- Decreased stool production
- Decreased or non-existent veterinary costs because the dogs are healthier!
- Improved stomach and bowel function
- Reduced allergy signs (itching and wheezing)
- Improved immune system
- Improved condition of jaw, neck and shoulder muscles

Actually, Mr Peck, since you have mis-quoted from my own writing, let me correct you on this, as you seem to have missed out some important benefits of a **raw diet**.

As such, let me quote directly from my website at: Raw Feeding FAQ:

People who have switched their dogs to a raw diet from commercial dog foods have found the following:

- dogs who were previously un-energetic, and sluggish become completely new dogs once the raw diet feeding begins
- allergies their dogs previously had on commercial foods, disappear once they start with the raw diet
- arthritis has significantly reduced or

• Better and more controlled development of puppies.	disappeared in some dogs switched to raw • better weight control • no more doggy odour! • their dogs are living longer on a raw diet than what their other dogs previously had survived on commercial dog foods • that their bitches managed their pregnancies better • better weight and survival figures in puppies It is not usual that Mr Peck would not have seen this in his own practice, since he encourages the feeding of commercial dog foods.
The above are merely anecdotal claims and at present remain unsupported by any credible scientific research.	Isn't it interesting how Mr Peck needs to have "credible scientific evidence" yet promotes feeding commercial dog food which is yet to scientifically prove it comes anywhere close to be as good as an appropriate raw diet? If Mr Peck would care to check the research done by the pet food companies, but hidden from the average consumer, he would find an incredible amount of research showing the damage caused by commercial pet foods. Indeed Mr Peck, although you seem to know of Dr Lonsdale, it seems you haven't read his book, then you would see more information about the damage of pet foods than you ever thought existed. Even more relevant, is this research has been done by the pet food companies themselves. eg: 95% of dogs fed a commercial diet will show signs of periodontal disease by the time they are 4 years old. Periodontal disease has a very low incidence in dogs fed an appropriate raw

	diet.
BARF Concerns A number of health issues have been raised about animals fed a BARF diet: 1. Stomach and bowel problems due to bones: * Choking - bones stuck in the throat * Obstruction - bones stuck in the gullet or small intestine * Perforation - sharp bone fragments that pierce the gut * Impaction - bony faecal material which accumulates in the large bowel The first three of these problems are life threatening and require urgent veterinary help to cure.	Indeed Mr Peck, all 4 of these problems are life threatening and require urgent attention. However, rather than scaremongering (and I notice you haven't noted any of the problems associated with feeding commercial dog food), you fail to include the facts. Namely that the incidence of these issues on an appropriate prey model raw diet is almost non-existent. However, feeding an inappropriate diet, whether it be on kibble (which has a considerable number of deaths each day caused by choking which you fail to mention), and or an inappropriate raw diet, will see incidents such as these. Additionally sticks, tennis balls, and rocks are main culprits for choking, obstruction, and perforations. Cooked bones can also lead to these problems.
2. Infection problems Potentially pathogenic bacteria commonly associated with raw meat such as Salmonella or E. coli can cause serious infections. Even if a case is made that dogs can tolerate bacteria-rich food there are equally important concerns for the owners and their family. Unless scrupulous hygiene measures are maintained for the storage and preparation of these raw meats there are real risks of infection.	The reason why there is such focus made on bacteria, is because it helps the dog food companies sell their product by scaring off consumers. In my vast experience with feeding a raw diet, and those of the many tens of thousands of contacts who are also feeding a raw diet, we are yet to see a case of e-coli or salmonella poisoining on an appropriate raw diet. However, if you have a dog who has a compromised immune system due to being fed a commercial diet for years, then your dog may have problems with rotten meat. However, advocates of an appropriate raw diet, recommend you feed your dog good quality carcasses/raw meaty bones.

	"Scrupulous hygiene measures" is another scare tactic, often used by those trying to sell anti-bacterial products, which are now being associated with the creation of "super-bacteria". While hygiene is important, the fanatical position of Mr Peck is purely trollop. The only cases I have heard of, of dogs suffering from salmonella and e-coli poisoning, have been in dogs on commercial diets.
3. Dietary Imbalance Owners who formulate their own BARF diet may fail to provide a balanced diet for their dog giving rise to significant health problems. Despite the fact the purists would argue a properly prepared BARF diet will be balanced, many BARF feeders do supplement the diet with either dog food or add a mineral and vitamin supplement.	The "balanced diet" position is another myth promoted by dog food companies and their puppet vets who use it to try and scare consumers that they couldn't possibly be smart enough to feed their dogs appropriately. Now consumers are becoming increasingly aware that feeding dogs is easy, and when based on the prey model is far simplier than vet puppets and pet food companies would like to have us believe. It's a shame that vets like Mr Peck seem to prefer their clients feed their dogs the poison that comes from commercial pet foods, than spend 20 minutes teaching clients appropriate ways to feed their dogs. Unfortunately, the myth of needing to feed vitamins and supplements continues, but increasingly, pet food owners are realising that it is large pharmaceutical companies that benefit most from the feeding of vitamins to our dogs, and our dogs receive no benefit.

Indeed a schism seems to be developing over this issue with vet Dr Lonsdale recommending the avoidance of supplements as they "create imbalance". However Dr Billinghurst advocates a growing number of supplements for use with his BARF preparations that not only balance the diet but "cleanse the digestive tract". Also advising that, "Vitamins and minerals at optimum levels promote growth, health, stamina, reproductive ability, disease resistance, detoxification and longevity".	There are indeed differences of opinion as to an appropriate raw diet. Dr Lonsdale's research comes from the position that correctly, dogs are carnivores. Mr Billinghurst's is based on the incorrect position that dogs are omnivores. This is the same position as the dog food companies, so it is natural to see such division.
Problems with Feeding BARF Diets Costs will probably be the same as the better quality commercial diets, possibly more if you are buying the commercially available BARF diets rather than preparing it yourself. BARF diet is inconvenient. It requires a significant amount of time to prepare the food. Each day handling large amounts of raw meat, pulverising vegetables and preparing meal sized portions.	As a matter of fact, almost everyone who feeds an appropriate raw diet, can do so at a considerably cheaper price than commercial dog foods. Additionally, because their dogs do not have the illnesses caused from feeding commercial dog foods, their owners are not wasting their money with unnecessary vet visits. Well we're sorry you believe an appropriate raw diet is inconvenient. Personally, I'd much rather spend the 5 mins a day feeding my dozen dogs and cats, than I would spending the 20 mins a day cleaning up the enormous smelly stools of dogs fed a commercial diet. Of course, I don't have to spend the time washing the horrible "doggy smell" from my dogs, because unlike the commercially fed dogs, my dogs don't have this smell. Additionally, there is not "large amounts" of raw meat to handle, and since dogs are carnivores, there is no need to pulverise vegetables (unless of course you use this as a calming mechanism after reading trollop written by vets). There is little, if any, preparation required for an appropriate raw diet for dogs. Clearly it seems, Mr Peck, you would

	prefer to continue to promulgate myths in the hope of scaring people off.
Whether buying commercially prepared BARF or preparing your own you'll need to buy a dedicated freezer to store the food. Obviously then, the food requires defrosting prior to use.	Why do you need a separate freezer? Many who feed just one or two pets easily store the food in their own freezer. Those who do have a separate freezer tend to do so because they have multiple pets and buy in bulk. And yes, defrosting is hard isn't it! But again, Mr Peck, why are you making this seem vastly more difficult, when it simply isn't?
Let me state my position up front, I'm not an advocate of BARF diets. Yes I acknowledge that some commercial pet foods use poor quality ingredients, contain large amounts of fillers such as cereals and significant amounts of preservatives to extend shelf-life. But anybody who really believes that a manufacturer can provide 50kg of dog food for £10.00 and isn't cutting corners has led a very sheltered life. As with most things you get what you pay for.	Well duh! As such, you are unable to write an objective report. Please tell me of one commercial pet food that doesn't use inappropriate ingredients! Name just one! You can't, because they all use inappropriate food for dogs. Oh, and where I live, it costs just as much for good vet advice, as it does for poor vet advice. And actually, most people who feed their dogs an appropriate raw diet, can get 50kg of great food for less than what you've mentioned for cheap and crappy commercial food.
At the end of the day most vets are happy to recommend the better quality diets to owners. Huge sums of money have gone into understanding the nutritional requirements of all ages and breeds of dogs. More importantly scientific research has also provided us with prescription diets specially formulated to help address various medical problems such as kidney failure. The contribution of these diets in managing many serious medical conditions cannot be overstated.	Yes, well as long as vets receive commissions and kickbacks from pet food companies, and in addition, receive the financial benefits of having to treat unnecessarily ill animals, their practices, using their standard way of operating, rely on commercial pet food to survive. After all, if you spend all your time in treatment of sick animals, rather than educating owners about how to stop their dogs from getting sick, then it's unsurprising that vet profits will fall when dogs are fed an appropriate raw diet.

	And yes, huge sums of money have gone into research for pet food companies. After all, they are taking poison and waste and trying to change it into something they can sell, while hiding the side effects. And as for your statement as to how they have "managed" health problems - unfortunately you and they receive no pat on the back for firstly causing those problems. In addition, there is an increasing amount of evidence that those so called "prescription" dog foods are not fixing the problem at all. Heck, why not stop our dogs from getting obese, and getting kidney disease first! Let's remove the cause, otherwise, all we will do is continue to try and eleviate symptoms. However, both you, Mr Peck, and I, as well as most consumers, recognise that both pet food companies and pharmacuetical companies make a lot of money out of making our pets sick firstly.
One would acknowledge that the presence of bones in the diet can help reduce dental problems. However there is nothing new here. Vets and dog food manufacturers have been long aware of this aspect of healthcare. For dogs that are prone to tartar build up and periodontal disease specially formulated foods to help minimise this are available. Vets have also been advocating dental hygiene measures with teeth brushing and the use of appropriate chews for years.	When dogs are fed an appropriate raw diet, dental problems are a rarity. Unfortunately, as stated earlier, when 95% of dogs on a commercial diet will suffer from periodontal disease caused by their diet, it's of no surprise that the pet food companies have seen an additional niche, accidently created by them, to yet again sell more products. Brushing dogs teeth is no replication for an appropriate raw diet, and can cause its own set of issues, and dog "chews" have never been found to reduce periodontal diseases in dogs. Wouldn't it just be simplier to recommend an appropriate raw diet? Or would this mean you'd lose a heck of a lot of

	business?
Would one advocate a BARF diet? Well no on balance. However I believe in informed choice. If the idea appeals to you, your dog enjoys it and you are prepared to tolerate the inconvenience and potential health risks of handling and freezing large amounts of raw meat then go for it.	Why would you recommend a raw diet when the outcomes of such would fundamentally change your practice and your approach, and more scarily, force you to admit you'd be recommending the very cause of many of your patients' health problems. Think of all those people who have trusted you for so long! Think of all those people who have turned to the internet to educate themselves, and finally figured out the reason for their pets' ailments was through a medium recommended by the very person they thought they could trust! Pet owners are now realising the scare tactics of vets like Mr Peck are to the detriment to their pets, and would rather the so called inconvenience of a raw diet, than having their pets be sick and die an early death on an inappropriate diet.
The dog owner who feels that feeding a BARF diet might provide health benefits beyond those currently achieved with quality commercial diets and modern day pet health care, will doubtless welcome the opportunity.	Yes, dog, cat, rabbit, ferret, chicken, and every other type of pet owner, is now finding out that the commercial pet foods are nowhere near as good as what a natural diet is.
As with so many areas of pet and indeed human health care the various camps appear to be polarising into the naturalistic / holistic and evidence based feeding cliques. Unfortunately the large body of testimonials and anecdotal evidence is not compelling from a scientific point of view. The mish-mash of dietary recommendations, suggested supplementation and woolly, if not miraculous, health claims give little confidence in the hyperbole of the more	Keep up your research Mr Peck, and one day, we look forward to you showing us the completely non-existant research detailing how commercial pet food comes within a bull's roar of being as good as an appropriate raw diet.

strident advocates.	
What the large body of testimonials may do is highlight areas worthy of further investigation using rigorous scientific trials. Until however significant scientific evidence is forthcoming from such trials then most veterinary surgeons will be unlikely to endorse the use of these diets.	Isn't it strange that Mr Peck still hasn't been able to see research indicating that his beloved commercial foods are as good as an appropriate raw diet, yet still can't see beyond them?
For the open-minded owner who wants the best for their pet I can only recommend that you make an informed choice, though achieving that can be a challenge. Entering "BARF diet" into one of the search engines produced over 3,000 links, the majority of which can only be described as a mixture of BARF fundamentalism and rampant misinformation.	I'm glad you are recommend people make their own choice, because as so clearly seen from your article, they are not going to get it from you. And yes, there is lots of mis-information on the internet, some of which is indeed written by vets.
Most owners I suspect and hope will be happy to continue to use the convenient quality diets that along with improved healthcare have given our pet dogs a quality and length of life that would have been undreamed of 50 years ago.	Actually, I'd suggest that if you told pet owners the side effects of feeding commercial pet foods, I'm sure they would not feed it. The healthcare has improved, however, it has been driven by the illnesses created by pet foods themselves. Frankly, I wish research money was spent in ways which led to overall improvement in dog health, rather than by artificially created disorders. And research has actually shown us, that since the introduction of pet foods, illnesses have dramatically increased, and dog life span is somewhat shorter! But heck, who wants the inconvience of healthy long living dogs!

To go to the raw learning website, click here.

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A Layperson's Guide to Learning about Raw Feeding

by Jane M. Anderson.

Some starting questions to identify our current position

- How did we get to this point? How did we get to a point in our society where we fundamentally change what an animal is supposed to eat, and replace it with a very poor substitute, charge more money, and even get our vets to sell it?
- How did we get to a point where we make our dogs and cats eat an offensive product, which then proceeds to make it sick, or fat, or worse, and then look at feeding it another source of offensive product to try and fix that problem.
- How did we get to a point where so called "prescription" pet foods, don't fix the problem their counterparts caused, and cost a bucket load of money?
- How did we get to a point where our universities are not providing their students with the best education, but rather information from a company selling a product, and then providing funding or kickbacks to the university?

Pet food was first created to provide an avenue to sell waste product from the human food chain. Straight from the start, the advertisers became involved, and without any evidence, claimed the products were wonderful for the animals.

The truth, however, is far from that.

There is not one single piece of evidence proving commercial pet foods have ever come close to meeting the nutritional needs of dogs, cats, or any other animal.

Yet within our society, we have allowed our vets, our universities, our legislators to allow a completely inappropriate product to be provided to our animals. Now, it is time for each and every one of us to become better educated to understand commercial pet foods are entirely inappropriate for our dogs and cats.

There is no such thing as a "natural" kibble. There is no such thing as a "holistic" kibble. There is no such thing as a "premium" or "quality" kibble. All are inappropriate for your dog. None come even close to being a worthy substitute for an appropriate raw diet for your animal.

If you are a current animal owner, or an intending animal owner and you want to learn more, please join the raw feeding email list.

Don't sit back any longer and let your vet try and sell you a product which is not good for your dog or cat. Do not allow a person with supposed "expert" knowledge who has not taken the time and energy to learn for themselves about appropriate canine nutrition, to sell you an offensive product like commercial pet foods.

For the most part, many vets don't mean to get it wrong. You don't have to be angry with them. Merely forgive them for their lack of knowledge, and go and find a better educated vet, or at least one who encourages you to follow your own learning path. My vet, while being a technical expert, doesn't recommend a raw diet to the majority of his patients, but 100% supports my choices.

Feel free to email me.

This site last updated 6th June, 2003

The Hidden Link between Vets, Universities, and Pet Food Companies

by Jane M. Anderson.

The medical profession is awash with sponsorships, kickbacks, and promotions provided by the drug companies. There is an increasing concern by a small number of doctors today regarding inappropriate behaviour by doctors receiving such. Click here to find out more about the moves underway to get independent medical advice being a priority of doctors.

Within the veterinarian profession, it is even worse. Many universities, and many vets receive a plethora of "advice" and funding, from both the drug companies, and the pet food companies.

Here's a sample:

- The American Veterinary Medical Association (AVMA) main two sponsors are Bayer (Drug company), and Hill's (pet food company). In fact, both sponsors contribute significantly to the annual junket, I mean, conference.
- The Australian Veterinary Association hides its main sponsor behind the name of "Masterfoods". This is of course, Uncle Bens, which is a dog food company.

As far as we know, there has been no research done to determine the exact correlation between influence by sales reps and what vets then recommend. However, this has been done in the medical profession.

In the website No Free Lunch set up by doctors to show the influence of drug companies on doctors, there is substantial evidence revealing the links. Let's quote from the site:

- In a study by Avorn, et al (1982), forty-six per-cent of physicians reported that drug reps are moderately to very important in influencing their prescribing habits
- In a study by Lurie, et al (1990), one-third of medical residents reported that they change their practice based on information provided by drug reps
- In a study by Steinman, et al (2000), 61% of medical residents stated that industry promotions did not influence their own prescribing, but only 16% believed other physicians to be similarly uninfluenced
- A study by Chew, et al (2000) , found that in the treatment of hypertension, over 90% of physicians would dispense a sample that differed from their preferred drug choice.

See even more disturbing information, and the links to the scientific journals in which these were published, by clicking here.

At this point, our contact with vets, who appear very upset by any questions regarding association between themselves and drug and pet food companies, deny any link whatsoever. A vet recently contacted me stating, "it's better to get free stuff than having to buy it ourselves. Why shouldn't we get it for free." The same vet went on to claim the pet food companies only gave them things to be nice, and not to influence any decision making.

Have a look around your local vet clinic. You will find all posters with a drug or food company stamp on them. All stationary will have been provided by a drug or pet food company. Even the software some vets use is provided by pet and drug companies.

There is little, if any, part of a vet's professional life, and their surgery set up, that is not influenced by a pet or drug food company.

If you have a vet surgery which does not have one poster, stationery, pamphlet, fridge magnet, etc, provided by a pet food or drug company, we'd like to be able to pass your details onto the general public. Please email us. We'd love to hear from you.

In a 4-5 year university degree, students receive, on average, less than 8 hours education on canine nutrition. Additionally, universities have been well known for using pet food company sales reps to present to their students the lectures on nutrition. The pet food companies influence in a variety of ways including:

- providing so called "nutritionists" to universities
- support the pre-vet groups financially
- provide scholarships and awards
- provide posters with sponsor logos
- put on additional "education" sessions
- hold fun events like bbq's and parties
- give free pet food to students
- free t-shirts

The whole idea is to make the product name in the forefront of the student's thinking.

There is hope!

With the onset of the internet, more and more people are becoming aware of the options available for feeding their pets. This is particularly an issue in the US, where pet food companies have been so influential. In other companies, where there is more independence of thought in the general community, the issue still remains large.

Our own research has shown it is now the vet school students who are starting to object to the influence of pet food companies in increasing numbers.

Unfortunately, their lecturers are still resisting the change. One university lecturer claimed to me that their university got in "trained nutritionists", not sales reps. It turns out, of course, the nutritionists were either niave to appropriate raw diets, and/or had been trained by the pet food companies themselves.

However, it is the young vets and students who are causing a wave of further investigation.

There are also an increasing number of vets who are seeking to further their knowledge. Vets are starting to realise, the very food they sell at their vet surgeries may be linked to a number of health problems in the very dogs they are treating!

There is no doubt, these findings are very difficult for many vets to come to terms with. In fact, there are vets who will go into denial, and will vehemently deny that the foods are anything but wonderful. This, of course, is their perogitive. It is therefore, not surprising, that there are lawsuits in the wings about to be launched against vets and pet food companies regarding the pet food they market.

For vets needing more information about appropriate raw diets, there has even been an email list established. Please click here, to join.

This email list is run by independent people, not associated in any means or form with any pet food company, or drug company, and run the list as a free service with absolutely no kick backs whatsoever, as a community service to aim for healthier pets.

There is no excuse for vets not getting themselves better educated.

Where to from here?

Click here to go back to the main page.

Feel free to email me.

This site last updated 9th June, 2003

Breeding Dogs and Cats, and Feeding a Raw Diet

by

Jane Anderson

of

Bluegrace Portuguese Water Dogs

(please note: the information contained in this page and on this site is copyrighted to Jane Anderson, and must not be replicated without permission, although, please feel free to link from your own site.)

I have raised several litters of dogs on a raw diet. In fact, it is the only way I have raised puppies.

There are some facts and myths about raising litters on a raw diet, and I will attempt to dispell some of these.

Myths	Facts
Modern dogs need to eat a commercial dog diet.	In order for pet food companies and most vets to stay in business, dogs need to eat a commercial dog diet. The truth is that dogs have evolved to eat a natural carnivorous diet.
It is not safe for bitches in whelp to eat raw meat.	Actually it is very safe to feed your dogs an appropriate raw diet. It is more dangerous to try and maintain the health of your bitch by feeding her an artifically created diet invariably resulting in obesity, malnutrition, allergies, and disease.

Bitches in whelp need to eat "puppy food" to prepare for their litter.	No, bitches in whelp need to eat an appropriate raw diet which contains all the nutrients they need to minimise birthing problems, maintain good puppy weight, and keep the bitch in good condition.
Bitches should be given calcium supplements.	Calcium supplements are akin to engaging trouble. Artificially provided calcium can bind with other minerals making both unusable. Sometimes the bitches will absorb too much calcium artificially, which interferes with their own ability to manage calcium naturally leading to all sorts of problems, sometimes resulting in death. Calcium is best provided naturally via raw meaty bones of different varieties, or whole raw carcasses (such as rabbit, fish, and chicken).
Most breeders raise their dogs on commercial pet diets.	Around the world, most people raise their dogs on a natural raw diet. Unfortunately artifical dog foods with their slick salesmen and puppet vets, particularly in north America and parts of Europe have led to a number of people using a commercial diet, to the detriment of the dogs and their puppies.
But the best breeders use commercial dog foods.	No, poorly educated breeders use commercial dog foods. With the advent of the internet and huge growth of such over the last 5 years, many breeders are discovering they have been considerably misled by both the pet food companies and their vets. An increasing number of breeders around the world are discovering considerable improvements in their breeding programs when moving to a raw diet.

Puppies shouldn't eat bones.	Bones are an essential part of the diet in puppies. The very physical act of chewing and ripping, develops a better digestive system, and muscular system, as well as providing the essential nutrients required by the puppy.
Salmonella and e-coli are on raw meat and are a huge risk to puppies.	Salmonella and e-coli as well as many other nasty bacteria can be found in commercial dog food, in addition to fungal growths. Additionally, a dog on a raw diet, has the best platform upon which to base their health, and to manage normal levels of bacteria. Attempts to provide a sterile environment for pups only serves to lead to an unchallenged immune system and leads to the proliferation of "super-bacteria".
My vet is very well educated in dog diet and he/she recommends a good kibble.	Unfortunately, vets, on average, receive less than 3 hours formal training in canine nutrition during their university degrees. They are wined and dined, and receive numerous monetary opportunities from pet food companies, from the moment they join the university, right through their career. At some universities, the "formal" lectures on canine nutrition are actually conducted by the pet food sales reps. The main reason vets are now reviewing raw foods as an option is because of the push from the owners of many of the very sick pets they see every day. Invariably, these pets' conditions are a direct result of feeding commercial dog foods.

Feeding puppies is very difficult, and impossible to get the balance right on a raw diet.	Feeding puppies a raw diet is very easy. Unfortunately many pet owners have succumbed to the belief that they are "too dumb" to feed their pets correctly. Whether you are feeding a puppy or an adult dog, they simply require plenty of raw meaty bones or raw carcasses, some meat and offal, and some eggs. The only allowances you will need to make is the younger pups will require their bones to be ground up or broken up, but by 7 weeks of age, they can manage some whole raw bones by themselves.

Unfortunately, many breeders have been misled and lied to by their vets and the pet food companies. They see increasing numbers of problems at birth, malnourished puppies, and small litters. Some breeders have seen this so often, they have strangely accepted it as "normal", not realising the cause of their heartbreak. Many breeders today, can't even recognise that many of their "rolly-polly" fat puppies are actually malnourished. They have never seen what a truly healthy puppy looks like. And of course, all their mis-information is then passed on to new puppy people.

And as for pet stores, I have not ever seen one single healthy looking puppy in a pet store window!

As a prime example, many puppies are leaving a breeders house with periodontal disease, amongst other problems, already establishing themselves. The breeder will vehemently deny it. The vet won't have a clue either. And the new puppy person won't know either.

However, things are a changing! There is a growing number of people who are demanding their next pup is raw raised, so we have even established an email list to link raw breeders with people who want a raw raised puppy.

Puppy Buyers Beware

Why would you buy a pup like this, when for exactly the same price, you can buy yourself a pup who has been raised on an appropriate raw diet?

If you are looking for a raw raised puppy, and can't find yourself a breeder in your area, email me, and at no cost to you, I will endeavour to help you locate a breeder who understands appropriate canine nutrition.

How I raise my puppies

All of my bitches and stud dogs are fed a raw diet. The diet is the same for both males and females. They get a selection each week of raw meaty bones - chicken, pork, beef, lamb, kangaroo; and raw whole fish. In addition, they get beef liver and eggs.

I allow a bitch in whelp to eat as much as she likes. She also must be kept physically in shape with appropriate levels of exercise each day. Naturally, the exercise gets less as she nears her whelping date. Her meals tend to get smaller, but more frequent during the last few days, and I tend to feed more raw liver and heart. As she whelps the puppies, I allow her to eat each placenta. This is essential step. If I've had to get a c-section done, I take the placentas home and give them to the bitch later to eat.

Average litter size is 10, and the bitches invariably manage to feed all 10 without supplementation, although I do keep a careful eye on the puppies. If I notice a problem, I will supplement the larger puppies with puppy formula, and keep them away from their mother, and allow the smaller puppies to feed well off their mothers. This system has worked very well for us, with no puppy losses.

Puppies are introduced to raw food from approximately 3.5 weeks of age, depending on how they are doing. I buy ground meaty bones from my butcher. Into that I mix a small amount of goat's milk, some water, eggs, and perhaps a small amount of fish and/or liver. I only feed a small amount of goat's milk, with no more provided after the age of 6 weeks. I will try and mix in 1 egg a day, which is then fed in the mix to all 10 puppies.

Pups are introduced to raw meaty bones from 4 weeks of age. They are invariably excited by the bones, and suck terrifically on them, but they don't eat the bones. I allow their mother to clean up what is left. By 7 weeks of age, the puppies are managing chicken necks fairly well. They are fed whole raw sardines 2-3 times weekly by this stage. I eliminate all ground food by 8 weeks of age.

If people pick up their puppy from me directly, I provide them with at least a week's supply of food, sometimes more, depending on their freezer space.

The puppies eat exactly the same as the adult dogs, but in smaller quantities, and in manageable sizes. Pups as they grow must have plenty of raw bones to eat. This is a critical part of their development.

And, with my dogs, puppies are only placed in homes which commit to feeding a raw diet.

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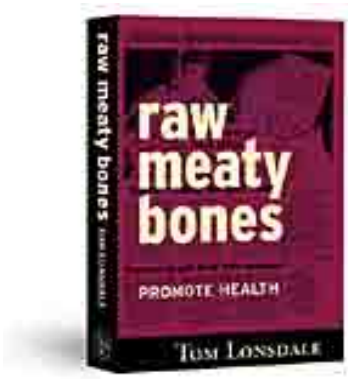

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Description

Category: Diet and Nutrition

Carnivore feed suppliers provides a list of what they have to offer people who feed their carnivores a natural raw diet. Pet owners list their needs.

This is a fully moderated list.

This is not a list designed to discuss raw diets. For more generalised information about the raw diet, please go to the general raw feeding email list.

Disclaimer: All messages posted to this list are solely the responsibility of the individuals who post them. This
list does not provide warranty of any kind on products offered by suppliers.

Group Info

Members: **1827**

Founded: **Jun 9, 2000**

Language: **English**

Group Settings

- Listed in directory
- Restricted membership
- All messages require approval
- All members may post
- Archives for members only
- Email attachments are not permitted

Most Recent Messages

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2004	254	237	367	263	214							
2003	141	183	177	133	216	213	316	187	186	211	282	214
2002	174	163	140	178	144	174	203	114	113	97	149	124
2001	171	88	72	44	82	125	173	107	96	58	163	122
2000						365	134	191	87	115	117	182

Group Email Addresses

Post message: CarnivoreFeed-Supplier@yahoogroups.com
Subscribe: CarnivoreFeed-Supplier-subscribe@yahoogroups.com
Unsubscribe: CarnivoreFeed-Supplier-unsubscribe@yahoogroups.com
List owner: CarnivoreFeed-Supplier-owner@yahoogroups.com

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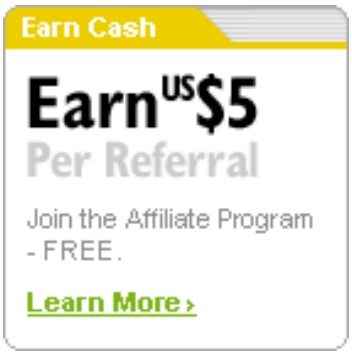

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Friendly, classy, sensitive, energetic at times, caring

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If you would like to talk to us about our puppies, now available, please email us.

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Our dogs - all our show dogs featured, with lots of pics (this is our most popular page!)

Puppy Temperament - finding the right puppy for you

Puppy Information Pack - specifically for people getting one of our pups

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We encourage further learning by browsing our other pages:

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- Our site map, or how to get lost quickly on our website!

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- Search our site
- Contact us.

Late News: Contact Sally at "Karlyermai Kennels for details of available puppies.

Bluegrace puppies are expected later this year. If you'd like to talk more about available puppies, please click click here.

Click here to email us. This site last updated 1 June, 2004

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Description

Category: Diet and Nutrition

image by Shawn Carney

Let's feed raw now!

There's an awesome amount of knowledge out there about how to successfully feed a raw diet. There are also some wonderful people who give up hour after hour of their time for free to assist people.

This list will give you access to an amazing amount of knowledge from people who own just one dog, to those who feed a raw diet to in excess of 30 dogs. There are people on this list with pet dogs (of all breeds), the tiniest dogs, to the largest! We also have a huge number of people with top show dogs, through to racing dog (professional greyhounds), lure coursing dogs, working dogs, and dogs who provide special assistance to people. Whatever your type of dog, there is sure to be someone here just like yourself.

The good news is you don't have to be a genius to work out how to feed a raw diet. You will need to do a bit of reading, and learn new ways of doing things, but in the general health of your dog or cat, it should well be worth it.

I hope you get as much fun out of being on the list as is possible. We will try to keep on topic though!

Please help us to maintain a friendly list environment, creating a free learning community of like minded people.

Most Recent Messages

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2004	3014	3155	3514	2629	1644							
2003	2824	1732	1647	1609	1693	1641	1603	2300	2671	4174	2514	2177
2002							636	2104	1081	1489	1311	1541

Group Email Addresses

For more information: http://www.rawlearning.com

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List owner: rawfeeding-owner@yahoogroups.com

Group Info

Members: **2756**
Founded: **Jul 16, 2002**
Language: **English**

Group Settings

- Listed in directory
- Restricted membership
- Posts from new members require approval
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- Archives for members only
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The South Beach Diet (Official Site): The healthy way to a carb-smart diet - lose weight while eating the right foods. Get started on your personalized plan today.
www.southbeachdiet.com

eDiets - Your Diet, Your Way: Let eDiets create a diet and fitness plan customized just for you. Get started today with a free profile and newsletter. Get nutrition information and more.
www.ediets.com

DietDivas Quick Weight Loss Program: Lose two to five pounds each week using real food. No pills or prepackaged meals. Personal counselors will help you reach your goal. Free newsletter. Join today - start today.
www.dietdivas.com

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Natural Diet

Join This Ring

RingMaster: jksales

Home > **Family & Home** > **Pets**

About this Ring

This webring is for breeders & pet owners feeding dogs and/or cats a raw, or homecooked natural diet. Sites should feature some information on the diet you use. No puppy/kitten mills or purely commercial sites allowed.

Ring Stats

- Created 02/28/1999
- 26 active site(s)
- 19 page views today
- 5017 total page views
- details

Sites in Ring - Navigation Rating: 100 what's this?, Uniqueness Rating: 32 what's this?

Sites 1 - 20 of 26

Next 6 > Search Ring

Sonia's Gang

2 Tenterfield Terriers, 2 Salukis, an Australian Kelpie and a JRT.

B.A.R.F.

Information about feeding the B.A.R.F. diet.

Esmond Rottweilers

Home to Mike Jackman and Ann Felske-Jackman, Esmond Rottweilers truly do it all! We are proud to have bred and/or owned American/Canadian Champions, Sieger/Siegerins, Best in Show and Best in Specialty Show Winners, Advanced Obedience, Tracking and Agility Dogs, High in Trial and Dog World Award Winners and Schutzhund competitors. Members ARC/RCC/MRC/USRC. OFA/CERF compliant.

Sleek Bull Terriers

Breeding and exhibiting Bull Terriers in New Zealand.

Conquerer Registered Golden Retrievers

Golden Retriever's of English Style. Active in the sports of conformation & obedience. Our website is a showcase of our dogs, and future plans!

Keldapark Kelpies & Pet Products - GC Animal Actors

Home of Max the Kelpie from Beastmaster. Promoting the Australian Kelpie in Obedience, Agility and the Australian Television and Film industry, and soon in the Three Sheep arena. Also promoting various other Animal Actors. Providing a range of Australian health products and accessories for your pet including all natural foods, supplements and herbal medications.

Chateau du Chien

Nutrition: The Truth About Cats and Dogs, and What They Should Really be

Eating! The basics of what goes into commercial pet foods, and an introduction to natural feeding.

Timberline Golden Retrievers

Timberline Golden Retrievers is located in the heart of Oregon. Our primary objectives are to produce healthy Golden Retrievers with sound temperament, working ability, and proper conformation. We have owned or have bred dogs with conformation, obedience, agility, and GRCA titles, and most importantly, some working service dogs and foundation stock for a service dog organization.

Lepus Reg'd Natural Reared Whippets & Borzoi

Sound, functional, home-raised and natural reared whippets (1976) & Borzoi (1988). Outstanding temperaments and body type. Multi-talented dogs! We test for genetic clearances.

Mega Nutrition

One of the largest nutritional supplements, diet and weight loss, body building, vitamins and sports nutrition sites on the Internet, with hundreds of deeply discounted products at savings of 30%-75% off of retail.

Newcastle Boxers: Mind, Body, Spirit - Naturally

Newcastle strives to produce quality dogs that possess good health, longevity & proper, stable temperaments. We take a holistic approach & endeavor to provide our dogs with every chance to achieve optimal health. This includes a raw diet, minimal toxins, clean water, fresh air, sunshine, & kindness. We believe that these influence our dogs' state of health fully as much as their genetics.

Red Brick...Bulldog Clothing, Gifts, and Collectib

Red Brick...Bulldog Clothing, Gifts, and Collectibles. Unique, original, and useful Bulldog merchandise. Secure shopping on-line, too.

Border Terriers & Cats

Meet my Border Terriers Spike, Kyra and Penny & the cats Smokey and Bandit. Information about Spike's Disease, a cramping condition a Border Terrier may suffer from.

Kimdale Persian & Devon Rex

Breeder of curly Devon Rex and fluffy Persian kittens.

Esme Pomeranians

I am a exhibitor of Pomeranians in conformation, obedience, and agility. I also use clicker training (or opperant conditioning) and feed an all natural raw diet. I am always willing to talk Poms!

Truman's Treats

"Truman's Treats" is an all-natural organic homemade doggie treat company providing healthy supplemetation for your pet. We also cater to the owner: doggie toys, doggie gifts, doggie accessories, etc. 25% of all profits benefit

our "own" local rescue efforts. Through your continued generosity and endless interest in our products - we can successfully "save" animals. Please help us help them ...

Diamond Paws

We are breeders of Staffordshire Bull Terriers.

Sandustin Manchesters

Describes the dogs I have bred or owned and their accomplishments. Discusses natural rearing and raw diets and provides links for more information.

K9 Pedigree Directory

A free webpage to enter your dogs Pedigree, Photo, Addresses, Wins, and more to be seen Worldwide.

TILCHA LOWCHENS K-9 CARE DOWNUNDER

Home of the first Lowchens in Australia! Canine care at a deeper level. Your opportunity to experience and understand more about your pet.

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Yahoo! Groups

There is no group called **rawfeeders**.

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The Reality of Breeding Dogs

by Jane Johnson

with the help of lots of other people.

This site is one of many on the web that people should visit prior to breeding their dogs.

Click on the links below to start your learning:

- Site objectives
- A checklist for breeding
- Questionnaire - don't even think about breeding before you can answer these questions
- Books you MUST read now
- Experiences - what you should learn, who you should learn from, and how long it should take - before you breed
- Virtual Breeding - Learn about some of the decisions needed to be made when breeding
- Costs - how much it costs to raise a litter
- True stories - some breeding experiences
- Breeding FAQ - frequently asked questions
- Email Lists - you should join now
- Breeding Realities - some of the things you won't want to read
- Hip Ratings
- Line Breeding
- A tongue in cheek account for those who think breeding dogs is akin to the miracle of life.
- Items recommended for whelping.
- Spaying your bitch
- Neutering your dog
- Click here to visit Jane's dogs

NEW!

Guestbook

Sign Guestbook View Guestbook

Out of Scope:

It is not the objective of this site to answer all your questions. This site should just be one resource you could use. I strongly recommend that you look at other resources, including other web sites, read books, read breed specific dog magazines, speak to your vet, and speak to experienced breeders.

What have you learned

If nothing else, after reading these pages, and you still decide that you want to take the breeding risks, at least you should be better prepared for some of the things that can go wrong.

If by reading this site, that a dog that may have died, doesn't, or one unwanted litter of pups was not produced, than something has been achieved.

Feel free to email me, especially if you find any errors on this page, or if you have any ideas for how it can be made better.

This site last updated 25 March, 2002.

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.... This many visitors since August 1998.

Visit a random site in the ring or the Raw Food for Dogs and Cats homepage!

The Previous 5 member sites of the Raw Food for Dogs and Cats NetRing:

- My Great Dane BARF page
  My site is about the Great Danes I share my life with. Please visit our BARF page and learn more about how you can feed your dog the NATURAL way!
- Cairnage Cairns
  A site about my dogs and their care.
- Sixstar Danes
  Come on by and meet our show & pet Great Danes. Marvel at the large number of movie & tv star Danes. See dog art & where you can commission a logo or web image and MORE!
- Von Bonehenge Great Danes
  Harlquin and Mantle Great Danes. Our danes participate show in the conformation ring, obedience ring. Our dogs are certified therapy assitance dogs and work in several nursing homes, hospitals and schools.{;}
- Seri's corner
  infomation on natural health care of dogs based on experience

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Mickey & Lupi - Our Sphynx HAIRLESS Cats!

SkinCats.com

Welcome to Mickey and Lupi's Site!

home
sphynx
mickey
lupi
gallery
care
allergic?
fvr
barf
resources
faq
links

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YOU SHAVE YOUR CATS?!?!?" Oh, heavens, no! We don't need to, nor are we advocates of such behavior! The relative hairlessness of the Sphnyx cat is the result of a spontaneous mutuation in the gene relating to the hair. While incidents of hairless cats have been documented for over 100 years, development of the breed is said to have begun by breeders in the US; unsuccessful attempts in the 1960s were followed by incidents in the mid- to late-1970s, when outcrossing attempts using domestic shorthair cats began producing hairless kittens in the US and Canada.

Here is a summary of the pages included in our site....

Sphynx - Tired of "Breed Standard" mumbo jumbo that makes sense to few folks other than breeders and those who show cats? Want to know what our Sphynx cats are really like?

Mickey - The story of his life and triumphant battle with Feline Viral Rhinotracheitis, and his countless nicknames.

Lupi - How she joined our family because she was diagnosed (and still struggles with) FVR, as well as her numerous aliases.

Gallery - Numerous photos, drawings and animations of Mickey and Lupi, including baby photos from Mickey's first year, featuring his beautiful brother, Bucky.

Care - Our honest commentary on what a commitment to one of these wonderful cats entails, as well as recommendations and helpful suggestions.

Allergic? - How we are able to live in harmony with this breed of cat, despite our severe cat allergies. These cats may offer an option for some people who are allergic to a variety of animal danders.

FVR - Feline Viral Rhinotracheitis, also known as Feline Herpesvirus, FRV or FVR, is an upper respiratory virus that both of the kids contracted early in life - Mickey, weeks after his birth; and Lupi, at around one year old. It's sometimes deadly, nearly always quite uncomfortable, and quite often, rather unpleasant. We also share some of the ways we've tried to help Mickey and Lupi fight its symptoms.

BARF - Mickey and Lupi enjoy Bio Active Raw Food, more commonly known as Bones And Raw Food! Many chemical additives, and even toxins, are found in even "premium" processed cat foods, and we're learning how fresh, home-made food can make a big difference in Mickey and Lupi's health and wellbeing. We offer many helpful resources on the subject, and a diary of our month-long ordeal of switching "Dry Kibble ADDICT" Mickey to a raw meat diet.

Become an ART.COM associate today and share your appreciation of art on your own website!

Resources - Books and online sources of information dealing with natural pet care and feeding and feline nutrition, to which we've referred numerous times as we learn all we can about caring for Mickey and Lupi in the best possible way.

FAQ - Because we've been so short of time since we moved into our new home in May, we thought it would be helpful to include a page of Frequently Asked Questions, as it is sometimes difficult for us to catch up on E-Mail immediately upon its receipt. We'll be adding more here as time permits.

Links - Web sites we've found to be interesting, informative, creative, entertaining, or otherwise worth checking out, as well as a brief comment on each site and why we've included it. You'll also find link banners to Mickey & Lupi's Page, in a variety of sizes.

Family - We've begun reconstruction of our own home page. Stay tuned.

Cat Art Gallery - Soon to be the world-renowned "**Mick's Picks**" - Although we love our cats, we respectfully refuse the description "Cat People." Other than drawings, paintings and, yes, Mom - cross stitch pictures - we've created ourselves or received from family or friends, our home is void of "Cat Pictures." However, due to his incessant nagging, and his pitiful denial of his obvious baldness, if we were to allow Mickey to hang posters in his room, these are the ones we'd have no problem hanging! You can buy them here, too!

Skincats.com last updated Tuesday, December 02, 2003

Visitors since September 24, 1999

This site is a member of WebRing. To browse visit
http://ss.webring.com/navbar?f=l&y=phaberman&u=10011551

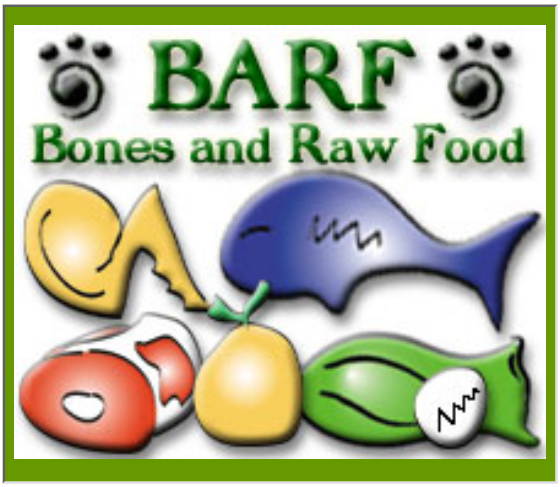

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[Skip Previous]
[Previous | Next]

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For Cats and Dogs Net Ring Site
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Jomari
German Shepherds

Located in Palmetto, Georgia

HAPPY 14TH BIRTHDAY LEX!!!!

DOB 5/12/90

Members of:

THE GSDC OF AMERICA

THE GSDC OF ATLANTA

THE GSDC OF WEST GEORGIA

***Click here** if you would like to read our old guestbook*

Welcome to Jomari Shepherds !! In the upcoming year we are looking forward to participating in the hobby of training, showing and competing with our beautiful shepherds!

Jomari Shepherds was formed in 1990 with the acquisition of our foundation bitch, *AMHERST'S CUSTOM MADE LEXUS TT OFA.* We found Lexus in 1990 and now fourteen years later we have been blessed with her kids, grandkids and her great grandkids. In 1999, we finished the championship titles on two of our dogs..... fulfilling a lifetime dream we had. We no longer actively breed but we still enjoy *dabbling* in our hobby. In 2004, we will be busy showing Lexus' great grandkids....Solo and Lady.

We thank you for visiting our website and hope that you enjoy your visit. Come back again soon as we try to update often!!

Click here to see the GSDC of Atlanta Show Proofs

Whats New? 4/10/04: "Lady" has some success at the Perry all breed shows!
Solo has his latest win photo up.

About Us | Lexus | Miata | Ch. Kid | Ch. Quila

We'd love to hear from you!!

Email Us

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This site was launched on August 30, 1997

This site is a member of WebRing.
To browse visit Here.

Show GSDs 4 Sale web ring

The Show German Shepherds For Sale SiteRing

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Our dogs are fed a 100% natural diet...consisting of raw meat and vegetables only!! We gave up commercial food over 2 years ago and have had nothing but positive results! For more information on this diet please surf the sites on the ring below!

BARF
Bones and Raw Food

[Previous 5 Sites | Skip Previous | Previous | Next]

This RingSurf Bones and Raw Food - for cats and dogs Net Ring
owned by Jomari Shepherds.

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[Next Page | Previous | Next 5 | Index | Random]

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Visit a random site in the ring or the Raw Food for Dogs and Cats homepage!

The Next 5 member sites of the Raw Food for Dogs and Cats NetRing:

- BARFing Boxers by Bree
  An abundance of BARF information, to include a BARF Message Board, Top 50 Most Frequently Asked BARF Questions Newcomers Ask, BARF Tips & Tricks, Purchase Your BARF Books, and loads of BARF links.
- J'Stone Cairns
  The site is about our Cairn Terriers.
- Kudos Akitas
  Kudos Akitas is a small kennel in SE Louisiana. We are constantly striving for a better Akita. We believe that an Akita must be sound in body as well in mind. Please drop by and look around. Thank you for visiting our site.
- Pur-Plesur Australian Shepherds
  Breeder of Raw fed Champion Australian Shepherds. Puppies, stud, and occasionally young adults available. (OFA'd & CERF'd)Located ouside Perry, GA.
- Chartwell Scottish Deerhounds and Whippets
  Chartwell is the home of top performance Scottish Deerhounds and Whippets who have been fed a totally raw diet since 1997.

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Free Newsletters: Pet Health Nutrition News, Tips & Tricks, Natural Pet Treat Recipes, Herbal Pet Care, New Holistic Product Announcements, and more!

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Transfer Factor for Canines & Felines

BARF FAQs

Whole Dog Journal Article on Immune Boosters and our Pets

Top 50 'BARF For Beginners - FAQs'

BARF Tips & Tricks

NEW Oma's Pride Raw Food - #1 raw food in North America

Dehydrated Holistic Dog Foods - Grain-FREE Formula Now Available!

Informational Articles

BARF Links

Community Forum

Purchase ALL Your BARF and Pet Nutrition Books at our Dog-Wise Approved Book Store

EFA Nutrition News in PDF Format

Nutrients in Various Food Sources in PDF Format

Join BARFing Boxers Mailing List

Join NJ-BARF Mailing List

Boxer Message Board

OMA'S PRIDE
OLD WORLD NATURAL CANINE AND FELINE RAW FOOD
OMA'S PRIDE

Available for shipping end of May, 2004 - Oma's Pride Raw Food Freeze-Dried Green Tripe, Chicken, Turkey, Beef and Lamb mixes, and Salmon! Oma's Pride is the #1 rated raw food by the Whole Cat Journal! These Freeze-Dried Packs are excellent for traveling, as well as storage!

More Info

The Top 50
Most Frequently Asked BARF Questions Newcomers Ask!

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BARF & Canine Bookstore
DogWise Affiliated!

IMPORTANT: The following information serves ONLY as a guide to those who are new to feeding their pets Bones & Raw Food. Yes, COMPLETELY RAW FOOD (nothing cooked), INCLUDING RAW BONES. **NEVER, EVER FEED COOKED BONES TO YOUR PET** because cooked bones WILL splinter and cause severe internal damage, possibly even death. Each animal's needs are unique; therefore, YOU will need to make the ultimate decision what is best for your pet -- healthwise and nutrition wise. The questions and answers that appear on this page are the most frequently asked questions newcomers to BARF have asked, along with the corresponding suggested answer. This information comes directly from experienced BARFers, as well as the books written by Billinghurst, Schultze and Pitcairn. Again, this is ONLY a guide, and NOT a bible. They are in no particular order and I will do my best to update this page frequently.

And also be sure to check out the BARF Tips & Tricks page, as well as **MORE** Most Frequently Asked BARF Questions Newcomers Ask, on this site, before you leave. Must-reading is also the main BARF FAQs. You'll find the links at the bottom of this page.

Purchase ALL your BARF & Pet Nutrition Books at our Book Store!

Photos of my Boxers

Contact Dr. B.

Most Common Internet Acronyms

Search this Site

This page is NOT a substitute for medical advice. If you feel (use your gut instinct) that something physically may truly be wrong with your pet, don't hesitate to drop off a stool/urine sample to your veterinarian or even get your pet to an animal hospital ASAP.

How do I get started?
I'm really scared to start, and I feel so overwhelmed...can someone send me some encouragement?
Is it possible to see some sample meal plans? I really think seeing what I may be feeding will help alot!
Should I switch cold-turkey or is gradual better?
I'm still researching BARF, and am not quite ready to make the change. Can you recommend an alternative food that is just as healthy, in the interim?
Can I feed kibble AND BARF?
How much do I feed daily?
I'm a Vegetarian and do not want to feed meat to my pet. Can I still feed a raw diet?
What exactly is the difference between Raw Meaty Bones & recreational bones? Which should I feed?
What is the best way to start my older dog on BARF?
I'm really concerned about salmonella. Am I over-reacting?
Is my dog experiencing detox?
Why is my dog drinking less water daily? Should I be concerned?
How does one measure the food when switching from kibble to BARF?
Why do I need to separate certain food items, like RMBs, veggies and grains, and why can't I feed them together?
Is it o.k. to feed grains?
Do I really need to use supplements?
How do I know what supplement is for what, should I decide to supplement?
What is ACV and what are some of it's benefits?
What is Ester C and bowel tolerance?
What are digestive enzymes and probiotics, and why is their use recommended?
What are other natural sources of calcium, other than egg shells and the bones themselves, to supplement?
Fish? You mean I can really toss my dog a whole fish?
When should I start introducing veggies?
What is the recipe for Dr. Billinghurst's veggie patties? Can I change this recipe?
Help, my dog won't eat his veggies!
Why can't I just chop up a veggie, or even give it whole?
Is it ok to mix the veggie mush with ground meat?
My supermarket frequently has chicken leg quarters on sale. Are these o.k. to use?
My dog literally inhales her food, and it scares me to near death. What can I do to get her to slow down?
I thought RMBs were supposed to be given whole...why are some people grinding them for their dogs?
I've heard so much about the Maverick Meat Grinder, where can I buy one?
How do I go about finding a Raw Meaty Bone supplier?
How much can I expect to pay for RMBs?
I've heard about trichinosis and pork. Is it safe to feed pork?
What is the bone to meat ratio?
Aside from natural calcium, what other nutrients do RMBs provide?
I've noticed my dog pooping less and it's white. Is this normal?
My dog is constipated. How can I help him?
Help!!! My dog has diarrhea!!!
Why is my dog's stool wrapped in mucous at times? Should I be concerned?
My dog is vomiting. What can I do?
I'm confused, do I have to fast my dog on occasion?
When thawing, is there a point where the food is considered dangerous and should be thrown out?
Can I use my microwave for thawing RMBs?
Is it possible that my dog is allergic to the Omega oils?
Can I still BARF my dog while traveling?
What are proper food safety techniques?
What are Satin Balls? Can they really put weight on my skinny dog?
How can a BARF diet reduce the chances of my dog bloating?
I think my dog is allergic to BARF...how can I be sure?
Will feeding raw meat make my dog vicious/mean and create a "blood lust?"

How do I get started?

The first thing you should do is some reading/research on the raw diet. There are a few books recommended and they can be purchase at this site's bookstore, through DogWise. The books are: "Give Your Dog A Bone" and "Grow Your Pup With Bones," by Ian Billinghurst, and "Natural Nutrition for Dogs and Cats: The Ultimate Diet" by Kymythy Schultze. Both of them go into great detail about the diet and how to get started.

You can also visit the BARF Webring site. Here you will find many people's stories about how they feed BARF and what led them to the transition from kibble. Take your time and do your research, and then you will be ready to begin. I lurked on the BARF list for about 6 months before I was ready to take the big plunge.

Most dogs do better on a cold turkey switch rather than half-kibble and half-BARF. Remember to keep things simple for the dog when you are starting. You might start with chicken or turkey and feed wings, necks or backs for the first couple of days. Let their body get used to the new foods before you start feeding them a huge variety of foods. Some dogs might not know what to do with the bones at first, but they will get the hang of it. If you have a small dog or a dog that doesn't get the hang of it, you can try crunching the bone into smaller pieces, or holding one edge of the bone for them.

For veggie meals, I would start with bland veggies with a bit of lean ground meat. Wait to add the richer foods, such as liver and eggs, for a few weeks. I would also wait to start adding any supplements until you are settled into a routine.

These are just some of the basics of the diet. Your research will provide you with more detailed information on how to get started. Good luck and happy barfing. Back to top of page

I'm really scared to start, and I feel so overwhelmed...can someone send me some encouragement?

Most of us felt the same way you do when we first started BARFing our pets. We thought it was very complicated (and maybe even more expensive), but have actually found it's much easier than kibble, or maybe that we all feel so good about what we're feeding them now--it just seems so simple now. Many of us believe the fact that BARF is less expensive than kibble too. Yes, it can feel very overwhelming at first, especially when thinking of supplements, how much to feed, meat-to-bone ratios, the veggies, and don't mix this with that, but once we finally relaxed and came to understand that it's a balanced diet OVER TIME, life got much easier. Back to top of page

Is it possible to see some sample meal plans? I really think seeing what I may be feeding will help alot!

Following are 4 sample meal plans (various size dogs) submitted by a BARFer who has been BARFing for 3 years. This is just a guide to help you get started as each dog is different and so is their activity level. What I suggest is to pick a weight closest to your dog's and feed a little more or less accordingly. As the days go on put your hand on your dog's rib cage and see if you press lightly you should feel ribs but not see them. If you can't feel ribs, your dog is too fat and if you can see ribs, your dog is too thin.

I feed 2x/day, so I split these amounts into 2 feedings but I am giving you a full day's worth for the RMB meal.

Golden Retriever - 55# - RMB meal - 1# chicken backs, or 12 chicken necks, or 8 chicken wings, or 2 beef ribs plus an egg or yogurt. You can feed lamb, but it is rich so I don't suggest it in the beginning. Even now after 3 years I will only feed lamb that I trim and only when I will be around to let them out more often. Lamb riblets (I think in Australia they are called lamb flaps) have soft very chewable bones and this is what I use if I can get it. Occasionally (like once every 2 weeks), I substitute fish - either canned mackerel or sardines as my dogs will only eat these. If yours eats other fishes then serve 'em up. I split one large can or 2 small cans among my four dogs

Offal - Offal (or organ meat, e.g. heart, kidney, liver, tripe, etc...) is usually mixed in with the veggie meal, because many dogs do not like the taste (some do). Just be careful not to feed too much, too quickly, as offal is very rich and too much will cause loose stools. Offal can be fed once or twice a week!

Veggie meal - This is for 1 meal not a full day's worth - 1/4 calves liver or an egg and I puree these veggies for about 3/4 cup worth. Mix and match veggies do not try to use all these at the same time - carrots, turnip, parsnip, green beans, yellow squash, zucchini, dark green lettuces, celery - I add a little - very little - of either spinach, kale, turnip greens, or broccoli. Now and then if I have a piece of cauliflower I toss that in too.

To most meals I add 1 teaspoon of oil (cold pressed flaxseed, or safflower or vegetable or olive but usually flaxseed for Omegas). To each meal I add 1 teaspoon nutritional yeast (Vitamin Bs), 1/4

teaspoon kelp, 1/4 teaspoon alfalfa powder. Also I add Vitamin C (about 2000mg) but you need to start off slow and increase a little at a time so as to not upset the tummy. My golden gets 200mg Vitamin E 1x/day

Poodle - 35# - gets exactly half of the above recipe - sometimes he is very active so I give a little more than 1/2 of the above. Halve the vitamins of yeast, kelp, alfalfa and remember Vitamin C 100mg Vitamin E/day

Cocker Spaniel 20# - gets 1/4 of above recipe - he tends to gain weight easily so I take a little away or add a little from his meals constantly - as I said, adjust to each dog's activity level and metabolism. 1/4 the vitamins of yeast, kelp, alfalfa and remember the Vitamin C, Vitamin. E - cocker gets "most" of a 100mg capsule but a few drops goes into the Chihuahua's meal

Chihuahua 8# - very active little guy - 1 1/2 chicken wings, or 4 chicken necks or about 2/3 of 1/2 a chicken back (I break it in half and then take a piece off). For the veggie meal, which is 1 out of 2 meals a day, he gets about 1/4 cup of veggie mix with a little liver (about a square inch) or some egg or a tablespoon plain yogurt. Meat - for 1 meal - a little less than 1/4 cup of beef heart or gizzards. Remember a few drops of the Vitamin E and a little Vitamin C

The easy way is to go by the Golden's meals - And don't be afraid to adjust as needed for YOUR dog. Halve it for a 35# dog, Quarter for 20# dog and about Eighth for 8# dog OR Double it for a large-breed dog.

TIP : Make a calendar - jot in on a ten day basis if feeding 1x/day 7 meals of RMBs, 2 veggie meals and 1 meat/offal meal I also throw in a fish meal now and then. As Dr. Billinghurst says - this is not etched in stone. If you have no RMBs one day - then take a few veggies and an egg or can of fish, puree and serve. Happy Crunching :)

Check out Sample Home-Feeding Diets for more great sample menus and feeding ideas OR EVEN view what some real BARF meals look like! Back to top of page

Should I switch cold-turkey or is gradual better?

Most dogs do very well being switched over to BARF cold-turkey, but the change over should be done 'easy.' It is recommended that when you are ready to begin, don't try and rush things. Take is slowly. Try to keep the diet bland and simple at first. This is particularly important for older/middle aged dogs. Don't overload your dog with the 'good stuff' - he may not be able to handle it yet - particularly after a lifetime on kibble. Start with just some lean chicken or turkey necks or backs only for the first couple of days, keeping meals small to begin with and don't let your dog overdo it. Once the dog has settled into this, add some bland veggies with a bit of lean mince (ground meat).

The veggies do need to be pulped up using something like a blender, juicer or food processor. You are aiming for something a bit like the vegetable matter found in the stomach of a prey animal. The reason for this is that dogs can not digest cellulose. Cell walls of plants are made of cellulose, so for our dogs to get the nutrients out of them, we need to crush the cell walls. Chopping them up only crushes the cell walls on the outside, leaving the bit in the middle pretty much unavailable to them nutritionally. Cooking them will also destroy the cell walls, but as this also destroys a lot of the nutrients and enzymes in the veggies, it kind of defeats the purpose.

You can start adding richer food like eggs and liver (and maybe leaving a little bit more fat on the chicken/turkey) after a week or two once your dog is used to the simple diet. And after you have got the hang of it for a few weeks, THEN start thinking about adding supplements, if you want to. Don't try to do it all at once. It is also suggested that with dogs new to the BARF diet that you stay away from the harder or fattier bones for at least a few months (and perhaps longer, particularly for older dogs). Give them time to develop some 'strength' in their digestive system first. Back to top of page

I'm still researching BARF, and am not quite ready to make the change. Can you recommend an alternative food that is just as healthy, in the interim?

Proper research can take several weeks or months, depending on your time and desire to feed a more natural & holistic diet. One should never embark on such a drastic diet change without doing the proper and necessary research. One alternative I'd like to recommend is HealthyPetNet's Life's Abundance, 100% all natural & holistic foods for dogs & cats, made of 100% all natural, human-grade ingredients. HealthyPetNet also carries a full line of all natural pet care products, canine supplements, feline supplements, pet-friendly cleaning products and even Dr. Barry Sear's (the Zone Diet) products, including Canine Zone!. Other excellent alternatives would be to go with a holistic pre-mix food like Dr. Harvey's, a prepared raw diet like Oma's Pride or even Verve, which is a dehydrated holistic dog food. You have a choice...

Can I feed kibble AND BARF?

Yes you can, but seriously, why? OK, I know change can be difficult, so please allow me to explain. Kibble and raw food are digested differently, and should NEVER be fed together, in the same meal. If you feed dry kibble at the same meal as the raw meat, you are increasing the amount of time the food is in the body, and increasing the possibility of illness from microbes. So, if you want to feed half & half, feed kibble one meal, raw the next. Your dog will probably be the one who will let you know, before you do, that BARF is IN and kibble is OUT! :>) But, if you really feel the need to feed kibble (alone or in addition to BARF) or just haven't made up your mind to switch completely to BARF, you may seriously consider a super premium dog and/or cat food, such as Life's Abundance, which contains all natural and human-grade ingredients....and NO Corn, No Wheat and No Dairy, formulated by Dr. Jane Bicks, world famous holistic veterinarian.

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How much do I feed daily?

Billinghurst recommends 60% RMBs and 40% veggies, etc... however; 60% to 75% CAN BE RMBs and the rest should be a combination of veggies, organs (also known as offal, to include liver, heart, kidney, green tripe, etc...), ground meat (e.g. lean beef, chicken or turkey), eggs and supplements. If you are just starting BARF, remember to start slow by adding new food items every few days or even weeks, until your dog gets used to the new food (especially the richer foods like liver). This is only a guide to help get you started. If your dog is on the skinnier side, up the food (RMBs) and reduce the veggies....if your dog is on the heavier side, reduce the RMBs and up the veggies. To know if your dog is 'just right,' rub the back of your hand.....his/her ribs should feel the same. If you can't feel his/her ribs, then reduce the daily food intake.

Multiply your dogs weight by 16 to get the number of ounces he weighs.
Multiply that by .02, which gives you 2 % of his body weight.
Multiply that by .6 to give you the weight of RMB you should feed. That is chicken necks, wings, backs etc.
Go back to the 2% of his body weight again and multiply that number by .4 to get the weight in ounces of vegetable patty mix you should feed.

For example: One of my Boxers weighs 70 Lbs. Here's the formula I used to calculate the daily food intake when I started:

70Lbs x 16 = 1120 ounces
1120 x .02 = 22.4 ounces of food per day
22.4 x .6 = 13.44 ounces of RMB -----60% RMB
22.4 x .4 = 8.96 ounces of Veg. Patty mix.-----40% Veg. Patty mix.

Remember this is only a place to start - adjust everything up or down, depending on your dogs condition.

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I'm a Vegetarian and do not want to feed meat to my pet. Can I still feed a raw diet?

Absolutely, you can feed your pet a vegetarian diet. But the most important thing you will need to remember, since your pet won't be getting any meat, is to feed high quality protein with the meals, just as you do. The amino acids in meat are essential nutrients, and if you're not feeding meat, your pet will get all the necessary amino acids from tofu, grains and beans. As you learn more about feeding a raw diet, you'll likely bump into many people who are totally against feeding grains. Feeding grains is a personal choice, and does work well for many. It is suggested that the protein be rotated because each and every protein source you choose has a different amino acid chain and concentration. It is also highly recommended to seek out organic grains and beans. Oils are also an essential ingredient in a vegetarian diet, so make sure these get alternated as well, once a week!

Putting together a proper and nutritionally complete vegetarian diet for your pet can be quite as complex as the traditional raw diet. You must do your research before plunging in! An absolutely EXCELLENT alternative, while you're researching and learning, is Dr. Harvey's. The foods come complete with organic grains, vegetables, herbs and some required supplements. All you need to do is add your protein source and essential oils...and you have a nutritionally complete meal for your dog or cat. The food is also an excellent choice for pet owners who want to feed a traditional raw diet with meat or who want the convenience of a home-cooked meal for their pets. Click here for more information.

What exactly is the difference between Raw Meaty Bones & recreational bones? Which should I feed?

RMBs are soft enough for the dog to chew up and eat - things like chicken

carcasses/backs/necks/wings, lamb necks, oxtails, turkey necks, etc..., which make up an RMB meal. Recreational bones, on the other hand, are larger bones that the dog will chew on but will not eat the whole bone - things like beef marrow bones, femurs, knuckle bones, etc... Weight-bearing bones can also be given (chicken legs/thighs), but they are a bit more difficult to chew (especially for a small animal). When giving chicken legs/thighs, remember to supplement with eggshell powder or bone dust, to even out the calcium/phosphorus ratio.

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What is the best way to start my older dog on BARF?

It is best with an old dog to keep the diet fairly bland and low fat when changing over. I would suggest adding some probiotics to the diet to help restore good bacteria into the system to fight the bad bacteria and help increase immunity. You can do this by adding yogurt with live cultures in it to the diet or by getting some kind of probiotic supplement. If you are feeding grains, you may wish to either reduce the amount or remove them altogether, until your dog has adjusted to his new way of eating.

Remember to start slow, adding a new food item every few days...build up the number of items slowly as you and your dog begin to get the hang of it. Back to top of page

I'm really concerned about salmonella. Am I over-reacting?

When first starting BARF, many people were actually overly compulsive and obsessive with regards to possible salmonella poisoning. In fact, I was one of them. I wore latex gloves when handling the chicken and I never allowed one tiny piece of chicken to touch ANYTHING in my kitchen. I was totally neurotic. After a couple of weeks of BARF, I began to relax a bit. I now use my bare hands when handling and practice proper food handling techniques. Knock on wood, none of my dogs or family members have gotten sick. To this day though, I won't allow ANYONE into my kitchen when I'm wrapping 80 pounds of chicken backs....NOT UNTIL I'M DONE and everything's been wiped down with Mr. Clean, Antibacterial full-strength (yes, it even kills salmonella). :>)

According to an FDA news release, "salmonella is not harmful to dogs". The message? Salmonella is everywhere - not just in raw meats. Employ basic hygiene practices, wash your hands and keep surfaces clean - just as you would when handling your own food. Simple, really! If you want to read more, then you'll find the article on The Question of Bacteria in Processed Pet Foods. Back to top of page

Is my dog experiencing detox?

When switching a dog over from commercial dog food to BARF, the dog's body may begin the process of ridding itself of toxins and impurities as it adjusts to the intake of proper nutrients. This process is called detox. Depending on the overall health of your dog, detox may last one week, one month or even several weeks...or not even at all. The most common symptoms of detox include vomiting, diarrhea, bad breath and itchy skin. It is normal for any of these detox symptoms to get worse before they get better...just don't give up and hang in there. Keep your dog as comfortable as possible during this process. Go slow on introducing new foods, to make sure there are no allergies. Pure pumpkin in the can (not pumpkin pie filling) works magic to firm stools quickly. Provide plenty of fresh water, but limit excessive water intake immediately after meals, as your dog may regurgitate. Give plenty of Vitamin E and C (the C to bowel tolerance) to help boost his/her immune system.
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Why is my dog drinking less water daily? Should I be concerned?

No, there is absolutely no reason to be concerned. Raw food is full of naturally occurring water! All the moisture needed to digest raw food is contained in raw food!

Although a lower sodium intake is part of the reason that our BARFing dogs drink less water, the real reason is that raw food has not had the water removed like kibble has. The different between kibble and canned dog food is the water content...they leave the water in the canned and dry out the kibble. It takes a lot of water to re-hydrate those little nuggets!

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How does one measure the food when switching from kibble to BARF?

I must admit I prefer the 'cold turkey' approach of switching rather than a slow switch. Try starting with around 2 to 3% of your dogs bodyweight (more for pups - up to about 10% for them) and adjusting from there. It is not an exact science and every dog is different so be prepared to adjust as you go along. Not getting it quite right is not really a problem as long as you accompany this with

observation of your dog so you can watch for changes (losing/gaining weight).

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Why do I need to separate certain food items, like RMBs, veggies and grains, and why can't I feed them together?

In Pat Lazarus book, "Keep Your Dog Healthy the Natural Way," under the topic of food combining he states:

"How you combine food groups can be crucial to your dog's health. Why? The digestive organs secret enzymes to break down food so it can be properly used by the body. When carbohydrates and proteins are eaten at the same time, the protein enzymes go to work first, and the digestion of carbohydrates must wait. While the carbohydrates are waiting around to be digested, they ferment and release toxins in the body.

Proper food combining might more aptly be called not combining foods: Give only meat (or other heavy proteins such as eggs or milk) at one meal; give carbohydrates (fruit & grains) for the other meal. Vegetables, though may be given with either grains or heavy proteins."

He goes on to mention this can also help in preventing pancreatitus.

Also, grains and meats should not be fed together but veggies can be feed with either, with no loss of nutrients. Fruits, except apples, should be feed alone and at least twenty minutes before or after anything else. Back to top of page

Is it o.k. to feed grains?

Grains are not a natural food for dogs. It is not something they would eat in the wild. Those grains they would have access to would be in small quantities eaten from the stomachs of prey animals who had (in the right season) eaten some grasses that had seeded. These grains would also not look like our modern grains - more like wild rice (check it out at the supermarket and compare to domestic types).

Grains are also full of carbohydrates which can be easily converted to sugars. Cancer cells feed on sugars and it is believed that by decreasing the amount of carbohydrate in the diet, we may greatly reduce the risk of cancer (which is a growing problem among modern dogs).

So, in answer to your question, yes, grains can be fed; however, please keep the following in mind (when feeding grains), taken directly from a Dr. Billinghurst seminar: grains are not a natural food for dogs; dogs do not, in fact, need carbohydrates; carbohydrates are easily converted into sugars which feed cancer. Remove the carbs and the cancer has less/nothing to feed on; and grains are one of the major causes of allergies in dogs, and can also cause flatulence (gas..PHEW!!!)!.

I would suggest you read more on grains at the Grain Free Pets website. The page now includes a basic description of yeast infections, why they occur, what are the diet recommendations, why didn't my vet diagnose this problem.... as well as links on candida. Back to top of page

Do I really need to use supplements?

I haven't cut supplements out totally, although IMO a lot of people tend to over-supplement. This was something Billinghurst suggested too at a recent seminar here, and he mentioned that he only supplements his own dogs every now and again.

I think if you are providing a good varied diet you will be providing pretty much what your dog needs - all in a highly bio-available form. My first preference when looking to a certain vitamin/mineral will always be to provide it in its natural form first. So if I feel I need to provide more Vitamin B for example, I would consider what foods contain that vitamin first (e.g. liver) rather than reaching for an artificial supplement.

That said, I certainly see a benefit in supplementing those things that our dogs may be missing in the translation from a 'wild' diet to its 'modern' equivalent (i.e. BARF). As we don't necessarily feed the whole animal for example (eyes, brains, stomach and intestines etc etc as well) the addition of things like EFA's (e.g. flaxseed oil) on occasion can be useful. I would include yogurt in this category too - it contains good bacteria which a dog may otherwise have got from eating stomach contents/intestines etc (but green tripe can help here too). An excellent fish oil recommendation is OmegaRx, a pharmaceutical-grade fish oil supplement...for us too! OmegaRx is 100% purified and 100 times stronger than the most popular brands of fish oil on the market! My Boxers receive it regularly, just as I do!

I like to add a bit of Kelp every now and again for its trace elements. Modern soils have been depleted by over-cropping etc and Australian soils in particular are low in iodine. Kelp adds back these

trace elements into the diet.

I add Vitamins C and E every now and then for their antioxidant properties and their value to optimize health - particularly in our modern polluted environment. Vitamin C is particularly good in times of stress and I am more likely to include it then than at other times.

Now realize that while I do include these supplements, I do not include them every day. I don't believe they are necessary every day except some in certain circumstances and perhaps only for short periods. Of course every dogs and every situation will be different (if I lived in a city I might give more C and E for example to combat higher pollution). But remember you are providing a much more nutritious product to begin with with raw natural foods. They are probably getting more nutritional value now out of a varied BARF diet without the supplements that they ever did on kibble.

If you do use herbs and vitamins on a regular basis (whether it be for you or your pet), may I suggest you checkout My Herbal Corner, where you'll find the highest quality herbal, vitamin, mineral and nutritional supplements worldwide! If you're only interested in herbs for pets, please click here.

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How do I know what supplement is for what, should I decide to supplement?

B and C vitamins are water soluable, which means whatever the body does not use are elminated in the urine. You basically cannot "overdo" the vitamins except too much can cause loose bowels (that's why you often see it recommended to supplement with Vitamin C "to bowel tolerance"). Vitamins A, D, E and K are fat soluable and it IS possible to cause problems by over-supplementing - sometimes the problems can be as bad if not worse than UNDER supplementation. According to Kymythy Schultze in her book, "The Ultimate Diet", she states:

"Alfalfa contains vitamins A, B1, B6, B12, C, D, E, K AND U, plus beta-carotene, niacin, pantothenic acid, biotin, folic acid, calcium, phosphorus, potassium, magnesium, iron, zinc, copper, protein, amino acids, trace elements and fiber. It reduces tissue damage from radiotherapy, helps bleeding disorders, has antibacterial action against salmonella and has a protein with known anti-tumor activity. It's used as a general tonic, to detoxify the body and to treat colon disorders, hemorrhages, diabetes, ulcers and arthritis. Use the alfalfa leaf and stem in powdered or liquid form. Do not use alfalfa seeds as they contain a natural toxin.

Kelp contains vitamins A, B1, B3, B5, B6, B9, B12, C and E, plus zinc, viotin, bromine, calcium, choline, copper, inositol, iodine, PABA, potassium, selenium, sodium and sulfur. Its iodine content is very good for glands and organs, especially the thyroid and liver. It can bind with chemical pollutants in the gastrointestinal tract and prevent their absorption by the body. It increases the contractile force of the heart, improves circulation and is often used for hair loss, goiter, ulcers, obesity and mineral deficiency. Equal parts of alfalfa and kelp in your dog's or cat's food provides a vast array of health-enhancing nutrients as a complete vitamin and mineral supplement.

Other green foods you may use include algae (chlorella, spirulina, blue-green), aloe vera, grasses and sea greens. Since these are plants, they should be fed to carnivores in fairly small amounts, proportionately"

Raw meat, fish and eggs provide an array of amino acids/protein, enzymes, antioxidants, Vitamins A, C, D, E, K, B1, B2, B3, B5, B6, B12, biotin, choline, folic acid, inositol, iodine, pantothenic acid, paba, fatty acids, caldium, phosphorus, magnesium, iron, potassium, chromium, copper, manganese, selenium, sodium, sulfur, vanadium, zinc and CoQ10 (see pg 26 of "The Ultimate Diet").

Raw veggies provide enzymes, antioxidants, betacarotene, carbohydrates, fiber, phytochemicals, Vitamins A, B1, B2, B3, B5, B6, C, D, E, K, boron, choline, folic acid, inositol, iodine, paba, pantothenic acid, calcium, chromium, copper, iron, iodine, magnesium, manganese, molybdenum, phosphorus, potassium, silicon, sodium, sulfur and selenium.

Many of us are of the opinion that our dogs, who are healthy, get the vitamins they need from the varied diet they are fed. Many BARFers supplement and many do not. Again, the choice is yours.
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What is ACV and what are some of it's benefits?

ACV stands for Apple Cider Vinegar. Of the 22 minerals essential for health, apple cider vinegar contains 19 in exactly the right amounts. *Some* of these minerals are potassium, phosphorus, sodium, magnesium, sulphur, iron, copper, silicon and pectin. ACV also contains natural malic and tartaric acids which are important in fighting body toxins and inhibiting unfriendly bacteria. There are claims that the additional acidity of ACV helps the digestion process. Many dogs like the taste of it, and it even makes the RMBs smell less raw meaty-like. Many people soak the RMBs in ACV prior to feeding, to aide with the digestion of bones. Remember in chemistry class, soaking a raw bone in vinegar? It turned rubbery! hummmm..some food for thought for those of you afraid of splintering bones. Again, the option to use ACV is purely another personal choice...some do and some don't. Oh, a teaspoon of

ACV (daily) in your dog's food also removes tear stains (for those with very light-colored dogs). Results are usually begun to be seen in 7 to 10 days. Back to top of page

What is Ester C and bowel tolerance?

Ester C is a buffered form of Vitamin C, which is easier on the stomach than other C's (ascorbic acid). If you decide to use Ester C or any of the other buffered form of C (calcium ascorbate or sodium ascorbate), you will be able to provide a much higher dosage than you would with ascorbic acid. If you are providing a buffered form of C, you might want to start out with 500 mg and increase the dosage (splitting the dosage to twice per day) until you determine the bowel tolerance. From that point, you can then determine how much C you want to offer per day.

As you are upping the daily dosage of C and you notice that your dog's stools are becoming a bit loose, then you have reached Bowel Tolerance. Any higher dosage will cause loose/watery stools, and even diarrhea.

Vitamin C is an immune booster and can be given daily. You can also UP the amount of Vitamin C during times of stress.

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What are digestive enzymes and probiotics, and why is their use recommended?

Digestive enzymes break down food so that it can be absorbed and utilized by the body. Raw food has enzymatic activity, and the body has a limited supply also. When our pets eat the raw food that their physiology is designed to thrive on, they receive plenty of food enzymes, which aid digestion and nutrient utilization. When they eat cooked food, which is devoid of enzymes, they can deplete the body's supply, and the enzyme-producing organs must work overtime to compensate. It doesn't matter what you put into the body if digestion is not equipped with enough enzymes to break it down and put it to good use within the body. Supplemental enzymes can be beneficial in cases of digestive disorders and degenerative diseases. They replenish the body with the tools needed to utilize nutrients.

Probiotics are beneficial bacteria. They are normally present in a healthy intestinal system. Beneficial bacteria keep unwanted bacteria, fungi, and other bad guys from disrupting homeostasis. For example, U.A.S. labs have conducted studies showing non-dairy probiotics to be extremely successful at destroying e.coli bacteria. Beneficial bacteria is killed by antibiotics. Supplemental use of non-dairy probiotics can help re-establish normal intestinal function (lots of yogurt).

Both enzymes and probiotics can be purchased from a variety of sources including health food stores, vitamin shops, catalog, etc. Look for products with a large amount of active ingredient and no fillers, binders, yeast, dairy, sugar, etc. Use according to directions. Enzymes are most often sprinkled on food right before feeding. Probiotics, which should be refrigerated, are most effective if given between meals. More information on digestive enzymes can be found here. Another excellent source for further information and to purchase is B-Naturals. Back to top of page

What are other natural sources of calcium, other than egg shells and the bones themselves, to supplement?

Personally I would stick with the eggshells, but I have heard people talking to their butcher/meat market and asking them to save bone "sawdust" from when they cut the meats down. This bone dust would be preferable to bonemeal because it would still be in its "raw" state. Eggshell powder can be made yourself, by saving the raw shells, drying and then running them through a coffee grinder. According to Pitcairn, there is 1,800 mgs. of calcium per teaspoon of eggshell powder. Bone Dust contains 8.74 % ash, (1/3 of which is calcium), 25.26 % fat, 13.42 % protein, and 52 % is water. Back to top of page

Fish? You mean I can really toss my dog a whole fish?

Absolutely...head, tail, body...the whole thing! Just be sure to check inside the fish for any hook that may have been forgotten to be removed. Fish is not a substitute for an RMB meal, but it can be fed a couple of times a week. One reason for this is the thiaminase enzyme in fish...it destroys thimaine (Vitamin B1). Fish especially rich in thiaminase are herring, capelin, suckers, smelts and various carp species, a total of some 50 species, most of which live in fresh water. Extra thiamin can be fed when feeding fish. Feeding whole fish is also an individual's personal choice. Many are afraid of the bones getting stuck...no problem, there are many varieties of nutritious canned fish on the market.

A special note with regards to those who live in the Pacific Northwest: salmon and trout can carry the rickettsia organism responsible for salmon poisoning. If your dog shows ANY signs of being ill within two weeks of feeding, get him/her to the vet, and tell them to look for salmon poisoning. This information is not meant to scare anyone, but it's extremely risky to feed raw salmon and trout from the Pacific Northwest..

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When should I start introducing veggies?

They are probably the second thing I would introduce after some Raw Meaty Bones such as chicken (Oh, I may add some yogurt or probiotics first though). When to add them usually depends on your dog. If he handles the chicken RMBs well for a few days, you can try adding some bland veggie mix (with perhaps some lean ground meat to tempt). You can add it sooner if the dog is getting a little constipated, or later if things are still a bit soft and runny ;-). Either way, try and keep the diet fairly bland and low fat for a while when starting out. Back to top of page

What is the recipe for Dr. Billinghurst's veggie patties? Can I change this recipe?

Yes, this recipe can be adjusted to suit your dog's needs or tastes, at the time. It is based on raw crushed vegetables - at least half e.g. one kilo vegetables such as carrots, celery, spinach, broccoli, etc. The other half consists of lean mince - beef, chicken, lamb {pork} e.g. one kilo. To which we add such things as: yogurt - low fat and plain - half a small tub eggs - raw preferably free range - about 3 flax seed oil - 2 or three dessertspoons liver - raw - say a quarter of a lamb's fry garlic - 2 or 3 cloves kelp powder - up to 4 teaspoons B vitamins - a teaspoon of Troy Vitamin B PLUS OTHER HEALTHY FOOD SCRAPS e.g. small amounts of cooked veggies, rice, cottage cheese etc. Any surplus - not fed on the day - should be formed into patties, frozen, thawed out as required. copyright IAN BILLINGHURST Back to top of page

Help, my dog won't eat his veggies!

I went through the same routine with my Dobe when I fed kibble and again when I fed Barf. Finally, what came about was our "Giant Veggie Battle". I finally decided that I had enough pampering, I knew he liked the veggies because at one point he used to gobble them up, but he was being stubborn. He would rather have RMBs.

So for 3 days he got veggie meals...for 3 days he refused to eat. He would eat a bite or two, sometimes 3 if I was lucky and walk away. Every meal, I would give him a fresh meal with maybe 2 tbsp. of veggie mix and the rest ground beef/mackerel/salmon, etc. I would leave it down for 10 minutes and then calmly pick it up. Well at 3 1/2 days, the boy finally ate his whole veggie meal. Apparently, he was hungry enough. Never again did we have the problem.

This might be worth looking into in your case. As long as you know the dog is healthy and has no reason other than "stubbornness" not to eat a particular meal, this is an option for you. Yes, it can be stressful and frustrating, however, in the long run you have very few "battles" after that and happier mealtimes.

Here are some suggestions that were given to me to try to tempt him in his veggie meals:

Mix veggies with canned fish (mackerel, tuna, sardines) or ground meat
Parmesan cheese on top
Grated Cheese in the mix
1 - 2 tsp. of molasses
Garlic powder or regular garlic
raw egg
baked beans
yogurt or cottage cheese
chopped raw liver or kidney
vegemite mixed with warm water (probably not relevant for the USA lol)

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Why can't I just chop up a veggie, or even give it whole?

The veggies need to be pulped up using something like a blender, juicer or food processor. You are aiming for something a bit like the vegetable matter found in the stomach of a prey animal. The reason for this is that dogs can not digest cellulose. Cell walls of plants are made of cellulose, so for our dogs to get the nutrients out of them, we need to crush the cell walls. Chopping them up only crushes the cell walls on the outside, leaving the bit in the middle pretty much unavailable to them nutritionally. Cooking them will also destroy the cell walls, but as this also destroys a lot of the nutrients and enzymes in the veggies (even canned veggies), it kind of defeats the purpose. Freezing the veggies and then thawing can also break down the cell walls. Back to top of page

Is it ok to mix the veggie mush with ground meat?

Yes, you can mix the ground meat in with the veggies :-). If this is purely muscle meat and not ground Raw Meaty Bones, it is best to limit the amount you are feeding though. Remember that 60 to 80% of the diet should be raw meaty bones. Of the remainder, less that 1/2 should usually be additional muscle meat without the bones. If you can try and make sure there is at least the same amount if not

more veggies and other stuff than the ground muscle meat in your veggie mix.

Of course if you are just introducing the veggies and that is the only way they will eat them, mixing a small amount of veggies in a larger amount of meat will sometimes help. You can gradually decrease the amount of meat and increase the veggies as they get used to it. Back to top of page

My supermarket frequently has chicken leg quarters on sale. Are these o.k. to use?

Yes - but they don't contain the proper calcium:meat ratio; plus they are load-bearing bones and are naturally harder (and harder on your dog's teeth over the long haul). If you DO decide to use them, you will need to supplement with additional calcium (in the form of eggshells or bonemeal). Back to top of page

My dog literally inhales her food, and it scares me to near death. What can I do to get her to slow down?

Many dogs have a tendency to gulp their food, without chewing, and this can be a very scary experience for an owner new to feeding raw bones. To teach the dog to chew before swallowing (yes, your dog needs to learn how to chew), try larger RMBs like chicken backs and turkey necks. Avoid all the smaller RMBs (chicken wings, chicken necks, etc...) until your dog learns to chew her food. Another option (submitted by a BARFer) is, "instead of giving her bigger things to chew on, I hand fed my dog, and made him pull the meat off the bone. I did this for about a week, and afterwards everything was fine. For people who have bigger dogs, and are afraid of getting their hand chopped off, they should teach their dog to respect their hand, and the meat that's in it." Back to top of page

I thought RMBs were supposed to be given whole...why are some people grinding them for their dogs?

Yes, RMBs should be given whole (not ground up or smashed), as chewing the entire RMB provides several benefits. Chewing RMBs provides superior jaw and upper body muscle exercise, as well as those pearly whites we've read so much about. Puppies who chew their RMBs satisfy their natural chewing desires, rather than chewing on your furniture or shoes. On the other hand, ground RMBs still provide all the nutritional requirements that are so crucial to your dog's health. There are people who choose to grind (or even smash up the RMB) for various reasons, examples are: feeding an older dog with few teeth left, the dog is a chronic 'gulper,' OR just for an owner's peace of mind that their dog won't choke on the bones (until they feel more comfortable feeding raw meaty bones). To grind or not to grind is purely an owner's personal choice. Unless there is an underlying medical condition, RMBs should be fed whole. An excellent alternative would be to go with a prepared raw diet like Oma's Pride. Back to top of page

I've heard so much about the Maverick Meat Grinder, where can I buy one?

You can purchase the Maverick Grinder directly at Pierce Food Service Equipment, Inc. This site does not endorse this grinder, but does endorse the grinder from Northern Tools (photo to the left). This comes from my personal research, comparison of many grinders and the actual use of this product. When you get to Northern Tools, simply type in the product # 168620 (numbers only) at the top of the page in the search box, and you'll be taken directly to the recommended grinder.

Again, it is purely a personal choice to grind or not to grind. Please use your utmost discretion before purchasing ANY grinder, or ANY product, for that matter. Back to top of page

How do I go about finding a Raw Meaty Bone supplier?

The best place to find a supplier for your raw meaty bones is in your phone book. Look up Butchers and Wholesale Poultry Distributors in the Yellow Pages. You can also search the International Purveyor Index using your zip code to find a supplier near you. Back to top of page

How much can I expect to pay for RMBs?

On the average, staple RMBs (chicken wings, chicken backs and turkey necks) can be purchased from a wholesale supplier in 40-pound cases for about .89 cents a pound, .29 cents a pound and .39 cents a pound, respectively (in US Dollars). Prices vary by state and supplier, and these are just average prices. These staples, and other RMBs, can also be purchased in your local supermarket(s), at a bit higher price per pound. If you are BARFing more than one dog, it will certainly 'pay' for you to shop around for the best prices and even invest in a chest or upright freezer. Back to top of page

I've heard about trichinosis and pork. Is it safe to feed pork?

As with many other food items, feeding pork is purely a personal choice. But yes, it CAN be fed, safely. Some dogs do very well on pork and others don't (loose stools). If you'd like to feed pork but are afraid of possible trichinosis, it is recommended that the pork be frozen, at Zero degrees F for 3 weeks, to kill the flukes. The incidence of trichinosis is actually fairly minimal in most places now (particularly in inspected meats). Many have fed fresh pork (pork necks, being a favorite) without any ill side-effects. Be aware of smoked pork necks, as they are slighly cooked from the smoking process. Pigs feet can also be fed, but are very high in fat...something you may want to avoid if your dog needs to lose a pound or two.

What is the bone to meat ratio?

Ideally, it is anywhere from 1:1 to 2:1 calcium:phosphorus (bone/eggshell:meat). The ratio for various food items can be researched using the Calcium/Phosphorus Calcium/Phosphorus Ratio Chart Ratio Chart. Back to top of page

Aside from natural calcium, what other nutrients do RMBs provide?

Raw meaty bones provide nutritious marrow, amino acids/protein, essential fatty acids, fiber, enzymes, antioxidants and a vast array of species-appropriate minerals and vitamins all in a usable form.
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I've noticed my dog pooping less and it's white. Is this normal?

Yes, this is completely normal for a BARFing dog. The reason your dog is pooping less is because most of the food he is now ingesting, is being digested and properly utilized by the body...thus, less waste. The RMBs account for it turning white. If you notice your dog straining while pooping, you can up the veggies a bit; however, straining a little bit can help express the anal glands, which would normally be done by your vet, at a price! Read more about Chalky White Poo.

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My dog is constipated. How can I help him?

Pure pumpkin in the can (not pumpkin pie filling) helps both loose stools and constipation. You can also reduce the RMBs and up the veggies a bit, or even add liver to the meal. Back to top of page

Help!!! My dog has diarrhea!!!

If you're just starting to BARF your dog, the diarrhea may be brought on because of the normal detox process (cleansing out the toxins and impurities) OR because you may have added one too many things too quickly. Pure pumpkin, in the can (not pumpkin pie filling), will immediately halt the diarrhea. If the diarrhea is because of the possibility of a reaction to a new food item, you'll need to start an elimination diet. Basically, go right back to feeding one thing only for a time (no supplements or anything else, including treats) and then gradually add things back one at a time and watch for a reaction. As every dog is different, this is the only way you will know for sure what your particular dog is reacting to. In the meantime, keep his food bland until he is feeling better (you too)! You can add applesauce, honey and even Slippery Elm Powder (an herb) to help settle his tummy.

If you feel detox or a new food item may not be the cause of the diarrhea, do not hesitate to drop off a stool sample to your veterinarian to check for parasites, worms and even unfriendly bacteria. If your dog is put on antibiotics for his/her gastrointestinal upset, make sure you give him plenty of yogurt, Vitamin C & E, during the recovery process.

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Why is my dog's stool wrapped in mucous at times? Should I be concerned?

Believe it or not, mucousy stools can appear any time, no matter how long one has been BARFing, and is generally no reason for concern. When first starting BARF, this may be a sign that the digestion track is ridding the junk out of it's system (normal part of detox). Mucousy stools can also be related to feeding dairy products. If you are feeding dairy, try cutting them out for a few days and see if this was the culprit. It can also mean an inflammation of the intestinal track. If you notice traces of blood, along with the mucousy stool, a trip to the vet is encouraged. Mucousy stools are also a sign of coccidia (a parasite commonly found in puppies), so you might want to drop off a fecal sample to your vet, and begin treatment. Again, use your judgment...if dog appears ill (gums may be white and not the normal pink/rose color) and is also having frequent bouts of diarrhea that last 24 to 48 hours, call your vet.

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My dog is vomiting. What can I do?

There are several reasons a dog may vomit, and it is up to you to determine why. If the vomit is yellow

bile, this means the dog's stomach is completely empty (and hungry!). Feed that poor baby. If the vomit is clear with white foam or mucusy globs, it is from drinking too much too fast (possibly on an empty stomach). I'd remove the water and, again, feed that baby!

Vomiting is also a symptom of the normal detox process. You can add applesauce, honey and even Slippery Elm Powder (an herb) to help settle his tummy, while he is getting accustomed to his new way of eating. The vomiting may also be the result of a new food item that does not agree with him. And yes, a dog new to BARF will occasionally regurgitate his food, and then begin to eat it again...probably more slowly this time, as he 'gulped' it the first time. This IS normal.

Sometimes pieces of bones stay undigested (may have been stuck in the stomach for a while) and cause a bit of blockage, which can cause quite a noxious odor on both ends. Increasing probiotics/digestive enzymes may be a good suggestion.

Dogs can also ingest various foreign objects (e.g. socks, toys, plants, etc...), so keep an eye on your pet if you suspect this type of ingestion, and your dog hasn't thrown up or passed out the foreign object within 24 to 48 hours.

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I'm confused, do I have to fast my dog on occasion?

No, you do not have to fast your dog. In nature, canines (wolves, feral dogs, etc.) don't eat everyday. The theory behind fasting our dogs is that it gives their digestive systems a chance to rest. Most people who fast their dogs do it once a week. Many people give recreational bones or liquid meals on fast days to help their dog get through the fast day. The choice to fast is a personal decision. Many, many BARFers fast usually on days that would be stressful like traveling, vet days, and so on. Many dogs will fast themselves and we must listen to them.

Now, if your dog pooped numerous times after fasting, this is good as he/she must have had some build up to get rid of and with the daily meals his/her system wasn't getting around to it. As long as they were not extremely loose from the start, then he/she sounds fine. Back to top of page

When thawing, is there a point where the food is considered dangerous and should be thrown out?

For my dogs here, it is when the smell of the meat is so bad I nearly throw up ;-). That usually takes a quite a number of days of being thawed out in the fridge. If it smells a little 'gamey' (a few days old) I will still feed it. With a dog new to BARF I would try and keep the meat fairly fresh for a while though. Easiest way is to thaw slowly in the fridge, or to thaw for a few hours or overnight in a container on the kitchen counter. Just thaw as much as you need for one day at a time.

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Can I use my microwave for thawing RMBs?

When using a microwave to thaw RMBs, you must be extremely careful, as the microwave can begin to cook the food from the inside (the bones) out. Thawing RMBs in the microwave is NOT the recommended method. NEVER, EVER give your dog a cooked bone, as it can splinter and cause severe internal complications. The safest method of thawing is room temperature or, if you're in a bit of a hurry, soak the RMBs in cold water in the kitchen sink. Back to top of page

Is it possible that my dog is allergic to the Omega oils?

Yes, it is possible. I think some dogs have been known to react to Flaxseed oil. If this is what you are using, you may want to try Fish Oil (not cod liver oil) as an alternative source. An excellent recommendation is OmegaRx, a pharmaceutical-grade fish oil supplement...for us too! OmegaRx is 100% purified and 100 times stronger than the most popular brands of fish oil on the market! Back to top of page

Can I still BARF my dog while traveling?

Yes, you can. When I travel if I have room for an extra cooler, I freeze RMB meals in separate portions so I can take one meal out at a time. I try to use a separate cooler for RMB so it isn't opened as much. I also freeze the RMBs a week or two in advance so they stay frozen longer.

If I don't have a lot of extra room for a cooler, some options are:

1. Shopping when you get to location (although this can be pricey and isn't always an option)
2. Canned mackerel/tuna/salmon

3. Cottage Cheese
4. Natural Applesauce
5. I've even fed canned green beans and other canned veggies

In terms of feeding the "correct balanced diet", remember that you are looking at the diet "over time" versus a daily diet. I don't try to bring any veggie mix with me when I travel. From what I've found, it doesn't work too well and gets messy.

There is also someone on the list who just feeds the dog, whatever they are eating at that time. While it might not be the exact ratios, it still is probably better than kibble. Back to top of page

What are proper food safety techniques?

Basic food safety techniques are really not much difference for handling dog food as they are for people food. Basically they involve washing your hands after handling meat etc, making sure cleaning cloths are clean and washed regularly (or use paper towels) and washing down benches with soap and hot water to curb bacteria growth (I use vinegar too). Some people do additional things, but these are the basics. Back to top of page

What are Satin Balls? Can they really put weight on my skinny dog?

The recipe and information on Satin Balls can be found here. Satin balls are not treats. They are a recipe that was developed to assist with putting weight on dogs. They were not developed as part of the BARF diet, but independently from it and are used by people who feed kibble as equally as those who feed home cooked or raw natural diets. The fact that they can be served either raw or cooked is the main factor that makes them 'acceptable' for all these. When it comes to the BARF diet though, there are some aspects about them that we may not like (the cereal for one). My suggestion is for those that want to feed something like a satin ball but do not like the recipe is to devise your own BARF friendly ones! Not that hard to do really :-). Back to top of page

How can a BARF diet reduce the chances of my dog bloating?

The chances of bloat are much less than on kibble. It is quite rare for a dog to bloat when they are eating a raw diet, for a couple of reasons.

The first is that raw food doesn't swell like kibble which can sometimes cause problems. The second thing is that most dogs eat more slowly when they are eating raw food compared to the familiar "inhale" style eating that dogs use when they are eating kibble. Because they aren't inhaling their food, less air is sucked into the stomach. Another reason is that chewing allows the dog's body to prepare for digestion. The necessary juices and acids are released slightly prior to the "deposit" of food into the stomach. Back to top of page

I think my dog is allergic to BARF...how can I be sure?

If you are truly concerned that something in the diet is causing a problem, the only true way to identify it and remove it is with an elimination diet. Basically, go right back to feeding one thing only for a time (no supplements or anything else, including treats) and then gradually add things back one at a time and watch for a reaction. As every dog is different, this is the only way you will know for sure what your particular dog is reacting to.

If it is not a food-related allergy, changing the diet around - for a dog already on BARF that is - is going to have minimal impact. Basically, if the cause of the allergy is still around, your dog is still likely to react to it no matter what you feed.

That said, BARF can have a positive (if not always total) effect in relation to non-food related allergies. This effect, however, is generally LONG TERM. Basically BARF helps to build the immune system which allows your dog to fight off the allergies when they occur. Over time, as the immune system strengthens, this can help to lessen their impact. While some effects may be immediate when switched to BARF, some dogs continue subtle improvements over a number of years. In simpler terms, allergies are an over reaction of the immune system usually brought about by a weakness or imbalance in the body (such as vaccinations, a chronic illness, virus, food, environmental, or thing(s) she/he comes in contact with). You can help boost your dog's immune system by increasing Vitamin C (to bowel tolerance) and adding Vitamin E. The herbs Echinacea and Goldenseal Root also help to boost the immune system.

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Will feeding raw meat make my dog vicious/mean and create a "blood lust?"

Basically, this IS a myth. There is NO causative relationship between eating raw meat and wanting to kill animals. It has nothing to do with what a dog is fed and has everything to do with natural prey drive, training and socialization. For example, some breeds like the husky can have a very high prey drive. If raised around animals and trained not to chase them, a lot of them will have no problem co-existing happily NO MATTER WHAT THEY ARE FED. With a lot of dogs, the instinct is a very ingrained primal one and the sight of an animal running can bring this out in them NO MATTER WHAT THEY ARE FED. Dogs can easily distinguish between what they are protecting and what they are eating.

Remember that kibble has not been around that long. For generations man has been feeding raw meat and bones to their dogs. I do not think in the hard reality of life dogs would have lasted too long as man's helpers in the field, on the farm or elsewhere if eating raw meat gave them a blood lust for the other animals around. Imagine an outback station owner for example. The dogs eat the foods the producer produces - the leftover cuts of the animals they slaughter for themselves or the old culls. The nearest town is a couple of hours by light plane or perhaps a 10 hour drive down the track. Before transport such as this, it may have taken a couple of days to get to the neighbours place. Now imagine if all the dogs they use to help them with the stock killed their stock because of the raw meat they were eating. Do you think they would still keep dogs? Would the Australian Cattle Dog or Kelpie have been developed as a breed? I doubt it - they would have all been shot a long long time ago. Yep, some dogs may turn out to be 'stock killers'. This happens. But as we have found, even kibble fed dogs can be stock killers. Back to top of page

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Raw Food for Dogs and Cats

About the Ring

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RING DESCRIPTION:
This is the raw food web ring.{;}{;}Feeding your dog and cat raw food, is the best way to raise them.{;}{;}This ring joins together those that do feed their dog and cats in an appropriate way for the health and benefit of their animals.

RING STATS:

- There are 146 active members in this Ring
- 23 prospective member is waiting for Approval in the Queue
- View the Stats for Raw Food for Dogs and Cats ring
- This ring was started

Ring Members

Member sites of the Raw Food for Dogs and Cats
Displaying from 1 to 50 of **146 :**

Hit counters started November 27, 2003.

1. **Frog Holler Fila Brasileiros Join Date: January 02, 2003**
   We at Frog Holler strive to produce the healthiest Fila Brasileiros by screening for hip and elbow disease through OFA and PennHIP, feeding ALL of our dogs and puppies on a BARF diet, and by administering no vaccines to our breeding stock, as well as minimal/no vaccines to our puppies.
2. **k9rawdiet Join Date: January 02, 2003**
   Site describes how I feed my Chows a raw diet and gives basic instructions to the novice. It provides resources so the person new to a raw diet can help him/herself.
3. **New Beginnings Mastiffs Join Date: January 02, 2003**
   Our Mastiffs are BARF raised and holistically raised. We have litters rarely and "girls" are house dogs who enjoy the couch more than we do!
4. **Wolfpaw Alaskan Malamutes Join Date: January 02, 2003**
   We are a small kennel located to the magnificent Alaskan Malamute. We are located in Saint John, New Brunswick, Canada. We have just recently started our dogs on the BARF diet. We are involved in Conformation showing, Obedience, Hiking and Backpacking and soon hope to add Recreational Sledding and Skijoring to our list of activities.
5. **Pur-Plesur Australian Shepherds Join Date: January 02, 2003**
   Breeder of Raw fed Champion Australian Shepherds. Puppies, stud, and occasionally young adults available. (OFA'd & CERF'd)Located ouside Perry, GA.
6. **Retrievers Etc Join Date: January 02, 2003**
   We raise Chesapeake Bay Retrievers, and offer obedience and gun dog training classes
7. **Tahali Dobermanns Join Date: January 02, 2003**
   Come and check out my girls. Genetically and Temperament Tested Breeding Stock. Feed on the Barf Diet
8. **Braelair Border Terriers Join Date: January 02, 2003**

The homepage of Braelair Border terriers In Sydney, Australia.{;}Breed and BARF info, great Links and pictures.{;}

9. **Scorpeo's Web Join Date: January 02, 2003**
   This site contains info about my dog, myself, and BARF, and also contains links about dog breeds, dog rescues, and misc. stuff.
10. **Avonti Standard Poodles Join Date: January 02, 2003**
    This site showcases my poodles and provides information about the poodle breed.
11. **Chadyline Cavaliers Join Date: January 02, 2003**
    Homepage of Chadyline Cavaliers, in Stockholm, Sweden. We feed all our dogs and puppies only a BARF diet.
12. **Seri's corner Join Date: November 11, 2000**
    infomation on natural health care of dogs based on experience
13. **Ferg n' Claud's page Join Date: January 02, 2003**
    Fergus and Claudia the weimaraners talk about their life and the food they eat.
14. **Angel's Page: Natural Pet Health Join Date: January 02, 2003**
    "Angel's Story" tells of our Border Collie Mix whose life was prolonged through Natural Pet care and the BARF diet. I have fed BARF to my pets for over 5 years and have links to many great resources and books.
15. **Ann-Christin's Yorkshire Terrier's Join Date: January 02, 2003**
    About my Yorkshire Terriers. Links on BARF
16. **Akira's Basenji Page Join Date: January 02, 2003**
    Dedicated to Basenjis. Includes photos, nutrition, breed info, vaccination info, parasite info, barf info, free graphics, free classifieds, awards and more!
17. **Von Himmel Rottweilers Join Date: January 02, 2003**
    We are active in AKC conformation & obedience. We are the only Totally Naturally Reared Rottie Breeders in Southern California. All of our dogs are raised in our home on Dr. Billinghurst's BARF (Bones & Raw Food) diet for optimum health & performance. We do not vaccinate and use Homeopathic and Holistic treatments whenever possible for the healthiest Rottweilers around.
18. **Perry's Place Join Date: January 02, 2003**
    an ex-racer's life of retirement
19. **Tenterfield Terriers Join Date: January 02, 2003**
    The Tenterfield Trio's site contain info about this breed, pictures and diet info.
20. **Spiritrun Alaskan Malamutes Join Date: January 02, 2003**
    Spiritrun Kennels, Ontario Canada,is home to beautiful

Alaskan Malamutes. Our BARF-fed dogs are active in conformation and sledding activities.{;}

21. **Joyvnture Papillons Join Date: January 02, 2003**
    We are devoted to feeding a total BARF diet to our lovely Papillons. Joyvnture is a joint venture in Australia and the USA.
22. **Sampson's Labrador Retrievers Join Date: November 11, 2000**
    We are a small kennel enjoying our family labradors. Particapating in conformation shows, obedience, hunting and Jessica is in AKC Junior showmanship.{;}All our dogs are fed BARF, we are so confident in our breeding program that all puppies are sold with a health guarentee.
23. **Odin and Merlin's Bearded Collie Web-site Join Date: January 02, 2003**
    Information about bearded collies, photo's of our beardies, info: on the barf diet for dogs, explanation of the UK show system, dog names
24. **wereldhonden Join Date: January 02, 2003**
    Honden uit het buitenland-ex zwerfers
25. **Jubilee Aires Airedale Terriers Join Date: November 11, 2000**
    Airedale Terrier show kennel. Puppies, adults and rescue information. Photos, pedigrees, articles, links and more. Puppies bred for show and companion.
26. **Adler Acres Australian Shepherds Join Date: January 02, 2003**
    AKC registered Australian Shepherds.
27. **Keldapark Kelpies & Pet Products - GC Animal Actors Join Date: January 02, 2003**
    Promoting All Natural Australian products - foods, supplements, training equipment, bedding, coat & skin care etc. As well as Australian Kelpies & other animal actors.
28. **Blairwick Dalmatians Join Date: January 02, 2003**
    Australian dalmatian lovers..breeding,exhibiting and obedience trialling our dalmatians..{;}Come see our dals on our web site!!!
29. **Canaltowne Labradors Join Date: January 02, 2003**
    My labradors and cats are all BARF fed. We compete with our labs in shows, obedience trials, hunt tests and soon agility. My labs are also registered Therapy Dogs.
30. **Mamosa Shelties Join Date: January 02, 2003**
    Just for fun is Mamosa Shelties mantra.No longer a breeding kennel our interests have turned to obedience, agility and "fun" times with our dogs. We advocate responsible breeding and natural diets - specifically "Barf"

31. **DreamCatcher Akita Join Date: January 02, 2003**
    German-Site about my Akita's, BARF-Diet, Akita-Info, Pictures and more.
32. **My Mal Join Date: January 02, 2003**
    A homepage dedicated to my Alaskan Malamute Takiah. Includes a large section on the benefits of feeding BARF.
33. **ARF4Westies Join Date: November 11, 2000**
    Website for ARF4Westies, an email list for Westie owners to exchange information about "how to practice" and "benefit from" a species-specific appropriate raw food (ARF) diet, including poultry and animal meat and bones. Practitioners believe that ARF provides optimum nutrition for their Westies in comparison to that provided by kibbles and other "processed" pet foods.
34. **The BARF Pictorial Join Date: November 11, 2000**
    A Pictorial description of a typical night of preparing a homemade "BARF" style diet. Photos include step by step meal preparation, and dogs enjoying their meals. Sample menu is given, as well as suggested further reading on the topic.
35. **The Schnauzer Chronicles Join Date: November 12, 2000**
    Catering to Miniature Schnauzer fanciers. Educational, instructional, funny. A MUST for all mini schnauzer owners and/or anyone considering to purchase/adopt one.
36. **Shadowpins Miniature Pinschers Join Date: January 02, 2003**
    We raise home bred Miniature Pinschers that are raw fed. Our dogs are AKC registered from Champion lines. We are also distributors for Oma's Pride All Natural Raw Pet Food.
37. **IndyWOO Malamutes Join Date: January 02, 2003**
    Indiana is home to IndyWOO Malamutes. We raise our dogs as pets, and are very active with them. Our site explains why we believe BARF is the only healthy way to feed, along with pictures and activities we enjoy. Welcome to IndyWOO.
38. **BARF Diet Log - Healthier Feeding for Our Canine Companions! Join Date: November 11, 2000**
    This site is a daily log of the switch and the observations, concerns and outcome, of my three varied dogs changes to the BARF feeding lifestyle. It's purpose is to help the new BARFER to see that we all go through similar feelings of nervousness and that the end result is so VERY well worth our going through some personal changes to learn the superiority iof this feeding protocol.{;}{;}Thanks for reading,{;}{;}Eric-DogStar

39. **Wayeh Malamutes & Siberians Join Date: May 02, 2004**
    Wayeh Alaskan Malamutes & Siberian Huskies, located in East Tennessee, where sleddogs work for their raw meaty bones.
40. **Grandview Goldens Join Date: January 02, 2003**
    The Adventures of {;}Ch. Sunrise's Wile E. Coyote{;}in the AKC Dog Show Circuit and some of the things we have learned to keep our dogs in Great Shape, especially the{;}Bones and Raw Fruit (BARF) based diets.{;}Our dogs and pups have been on BARF for over 4 years and doing GREAT!!!
41. **Selkatz Tonkinese Join Date: November 11, 2000**
    Naturally raised Tonkinese cats and kittens including raw food recipes, on-line book store and much more. Instructions on bathing, grooming and showing a Tonkinese cat.
42. **The Digital Dog Join Date: November 18, 2000**
    The Digital Dog is a site with information on choosing, naming, feeding, and training dogs.
43. **The K9 Kitchen Join Date: January 02, 2003**
    Fresh raw natural food for Pyrenean Mountain Dogs, also suitable other breeds
44. **Shakira Great Danes Join Date: January 02, 2003**
    Family hobby kennel raising fawn and brindle Great Danes & Pembroke Welsh Corgis. Started feeding BARF this summer,'01,and love it!
45. **Hillsdale Shiba Inu Join Date: January 02, 2003**
    An informational website focused the Shiba Inu dog and the importance of feeding the correct diet. We raise our dogs in the house with our family. Our dogs are raised on BARF diet (Bones and Raw Food).
46. **J'Stone Cairns Join Date: November 12, 2000**
    The site is about our Cairn Terriers.
47. **Paisley Dalmatians Join Date: January 02, 2003**
    The Internet home of the Paisley Dalmatians. Pictures and pedigrees of many of our 100+ champions and performance titled dogs, as well as information on upcoming litters. Our famous Color Pages, a new Barf page, rescue pages, and lots of useful articles and links.
48. **Wrangler Collies Join Date: January 02, 2003**
    We are a small hobby kennel located in Hunterdon County, NJ. We breed versatile Rough and Smooth Collies who excel in the breed and performance rings and also share our lives with retired racing Greyhounds. We feed a biologically appropriate raw diet and utilize holistic veterinary care when needed.
49. **BARF en español Join Date: January 02, 2003**
    Sitio con alimentación BARF. BARF feeding site for all dog lovers. In spanish.

50. **Raw Food email lists Join Date: November 11, 2000**
Hi there,{;}this page gives a comprehensive listing of all the raw food email lists that we can find. It is updated at least regularly. If you can't find a list you're looking for, we'll be highly surprised!{;}{;}Make sure you join at least one list!

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RawVet · Raw Vet

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Description

Category: Veterinary Medicine

This list is a place for vets and specifically related professionals to discuss raw diets.

There is an increasing awareness the information provided about dog nutrition generally is full of mis-information, and part of the role of this list is to expose those myths.

Importantly, this list is about educating and re-educating the vet peer group about appropriate raw diets for dogs and cats.

In terms of reading, try Dr. Lonsdales, "Raw Meaty Bones", an intellectual read worthy of your immediate attention.

For more generalised information about the raw diet, please go to the general raw feeding email list.

Please note: this list is not for the "pet owner" seeking vet advice or a well educated vet in their local area.

To join the list, you need to send an email to: rawvet-owner@yahoogroups.com detailing your reasons for wanting to join the list, your profession, your location, and vet association registration number (or the like).

Most Recent Messages

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2004	15	30	42	48	6							
2003	4	27	11	9	5	5	20	19	85	11	11	32
2002										28	6	5

Group Email Addresses

Group Info

Members: **80**

Founded: **Oct 8, 2002**

Language: **English**

Group Settings

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Post message: RawVet@yahoogroups.com
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Site design by Benita Marcus and Jason Stele

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Pharmaceutical Facts

- The "Research-based" pharmaceutical industry spends more on marketing and administration than it does on research and development. (Families USA)
- U.S. Drug spending increased 17.1% to $154.5 billion dollars in 2001. One-quarter of this increase was due to a shift to the use of more expensive drugs. (National Institute for Health Care Management)
- Pharmaceutical industry profits were 18.5% of revenue in 2001. For the remainder of Fortune 500 companies, median profits were 3.5% (FamiliesUSA).
- Since 1995, R&D staff of U.S. brand name drug companies have decreased by 2%, while marketing staff have increased by 59%. Currently, 22% of staff are employed in research and development, while 39% are in marketing. (PhRMA Industry Profile 2000; percentages calculated by Sager and Socolar)
- In a study by Avorn, et al, forty-six per-cent of physicians reported that drug reps are moderately to very important in influencing their prescribing habits (Am Journal of Med, 1982).
- In a study by Lurie, et al, one-third of medical residents reported that they change their practice based on information provided by drug reps (Journal of Gen Int Med, 1990).
- In a study by Steinman, et al, 61% of medical residents stated that industry promotions did not influence their own prescribing, but only 16% believed other physicians to be similarly uninfluenced.(Am Journal of Med, 2000)
- Two and one-half billion dollars were spent on advertising to consumers in 2000. Increases in the sales of the 50 drugs most heavily advertised to consumers were responsible for almost half (47.8%) of the $20.8 billion increase in spending in 2000.(NIHCM)
- In 2000, Merck spent $161 million on advertising for Vioxx. That is more than Pepsico spent advertising Pepsi. ($125 million), and more than Anheuser-Busch spent advertising Budweiser.($146 million). The increase in Vioxx sales in 2000 accounted for 5.7% of the 1 year increase in drug spending. (NIHCM)
- A study by Westfall, et al, found that 96% of physicians and staff had taken samples for personal or family use in the preceding year. (JAMA, 1997)
- According to industry estimates, drug companies spent $15.7 billion dollars on promotion in 2000. $7.2 billion dollars worth of free samples were distributed that year(IMS Health).
- A study by Chew, et al , found that in the treatment of hypertension, over 90% of physicians would dispense a sample that differed from their preferred drug choice. (JGIM, 2000)
- The AMA generates $20 million in annual income by selling detailed personal and professional information on all doctors practicing in the United States to the pharmaceutical industry (NY Times, November 16, 2000).

Submit your facts
(with references)

Fallacies in Pharmaceutical Promotion

(J Gen Int Med, 1994)

- **Argumentum ad Verecundiam (appeal to authority)**

  "Doctor, The Chairman of I.D. here says he's using Trovan™ for all his UTI patients; don't you think you should try it?"

- **Argumentum ad Populum (the bandwagon effect)**

  "Doctor, *everyone* over at University is using Trovan™; don't you think you should?"
  Oh and did I mention the FDA advisory . . .

- **Non Sequitur (the red herring)**

  "Yes it's true, doctor, that endoscopic ulcerations don't necessarily correlate with symptomatic ulcers, but nevertheless . . ."

- **Argumentum ad Misericordiam (appeal to pity)**

  "Doctor, Nexium just has not been doing well in my territory. Do you think you might try it?

and we add:

- **Post prandium ergo propter prandium**
  (After lunch, therefore, because of lunch)

  The tendency to prescribe a medication following a drug company lunch. In the case of a breakfast, referred to as "bagel bias."

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Description

Category: Puppies

This is a group of like minded dog (and sometimes cat) breeders who raise their dogs on an appropriate raw diet.

Many dog owners today want to find a breeder who raises their puppies on a raw diet. This list aims to connect these groups of people together.

This group is a sub-group of the main raw feeding email list.

This group provides the opportunity to locate breeders who may have puppies, older dogs, or rescue dogs available.

However, this group does not attest to the quality of either the puppies or the breeder. You need to do that research independently.

A note to breeders - this list clearly discourages poor breeding programs. This includes the plethora of excuses for not showing your dogs. If you have not shown your dogs to championships, this list is not for you. Not only are we encouraging raw feeding breeders, but we are here to encourage good breeding practices, and promoting quality puppies.

Puppy millers and deliberate cross breeders are not allowed on the list, and we encourage all people to raise their dogs correctly.

Most Recent Messages

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2004	5	10	4	4	4							
2003											25	3

Group Email Addresses

Post message: rawbreeders@yahoogroups.com
Subscribe: rawbreeders-subscribe@yahoogroups.com
Unsubscribe: rawbreeders-unsubscribe@yahoogroups.com
List owner: rawbreeders-owner@yahoogroups.com

Group Info

Members: **53**
Founded: **Nov 11, 2003**
Language: **English**

Group Settings

- Listed in directory
- Restricted membership
- Posts from new members require approval
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Train Your Puppy In 5 Minutes A Day: Live video lessons on DVD, VHS or CD-ROM. Potty and crate training, jumping, biting, chewing and obedience. Recommended by veterinary behaviorists and the Humane Society of the U.S.
www.puppysmarts.com

Save up to 60% off Vet Bills: Pet Care Direct saves you up to 60% off your vet's price on flea medicine for your pet dog and cat. Frontline, Advantage, Revolution, and Sentinel. Great range, come visit and save.
www.petcaredirect.com

Handcrafted Dog Jewelry: The finest silver, vermeil and gold pins and charms of dogs handcrafted in the USA. Also watches of all dog and cat breeds.
www.loveisarose.com

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Raw foodism

From Wikipedia, the free encyclopedia

Raw foodism (or following a **raw food diet**) is the dietary practice of eating only uncooked, unprocessed foods. Depending on the philosophy, or type of lifestyle and results desired, raw food diets may include a selection of fruits, vegetables, nuts, seeds, eggs, fish, meat and dairy products.[1]

It may also include simply processed foods such as various types of sprouted seeds, cheese, and fermented foods such as yogurts, kefir, kombucha or sauerkraut, but generally not foods that have been pasteurized, homogenized, or produced with the use of synthetic pesticides, chemical fertilizers, industrial solvents or chemical food additives.

Contents

- 1 Varieties
  - 1.1 Raw veganism
  - 1.2 Raw vegetarianism
  - 1.3 Raw animal food diets
- 2 History
- 3 Claims
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- 6 Role of cooking in human evolution
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Varieties

Raw food diets are diets composed entirely of food that is uncooked or which is cooked at low temperatures.[2]

Raw Vegan "Thanks-Giving Turkey"

Raw veganism

A raw vegan diet consists of unprocessed, raw plant foods, that have not been heated above 40–49 °C (104–120 °F). Raw vegans such as Brian Clement, Gabriel Cousens, Thierry Browers a.k.a. "Superlight", and Douglas Graham[3] believe that foods cooked above this temperature have lost much of their nutritional value and are less healthy or even harmful to the body. Advocates argue that raw or living foods have natural enzymes, which are critical in building proteins and rebuilding the body, and that heating these foods destroys the natural enzymes and can leave toxic materials behind. However, critics point out that

enzymes, as with other proteins consumed in the diet, are denatured and eventually lysed by the digestive process, rendering them non-functional. Typical foods included in raw food diets are fruits, vegetables, nuts, seeds, and sprouted grains and legumes.

Raw vegan "apple pie"

Among raw vegans there are some subgroups such as fruitarians, juicearians, or sproutarians. Fruitarians eat primarily or exclusively fruits, berries, seeds, and nuts. Juicearians process their raw plant foods into juice. Sproutarians adhere to a diet consisting mainly of sprouted seeds.

Raw vegetarianism

Vegetarianism is a diet that excludes meat (including game and byproducts like gelatin), fish (including shellfish and other sea animals) and poultry, but allows dairy and/or eggs. Common foods include fruit, vegetables, sprouts, nuts, seeds, grains, legumes, dairy, eggs and honey. There are several variants of this diet.[4]

Raw animal food diets

Included in raw animal food diets are any food that can be eaten raw, such as uncooked, unprocessed raw muscle-meats/organ-meats/eggs, raw dairy, and aged, raw animal foods such as century eggs, fermented meat/fish/shellfish/kefir, as well as vegetables/fruits/nuts/sprouts/honey, but in general *not* raw grains, raw beans, and raw soy. Raw foods included on such diets have not been heated above 40 °C (104 °F).[5] Raw animal foodists believe that foods cooked above this temperature have lost a lot of their nutritional value and are less bioavailable.

Steak tartare

Steak tartare with raw egg, capers and onions

Main ingredients	Raw beef
Variations	Tartare aller-retour

Cookbook: Steak tartare Media: Steak tartare

Examples of raw animal food diets include the Primal Diet,[6][7] Anopsology (otherwise known as "Instinctive Eating" or "Instincto"), and the Raw Paleolithic diet[8][9] (otherwise known as the "Raw Meat Diet").[10]

The Primal Diet consists of fatty meats, organ meats, dairy, honey, minimal fruit and vegetable juices, and coconut products, all raw.

The "Raw Meat Diet", otherwise known as the "Raw, Paleolithic Diet",[9][11] is a raw version of the (cooked) Paleolithic Diet, incorporating large amounts of raw animal foods such as meats/organ-meats, seafood, eggs, and some raw plant-foods, but usually avoiding non-Paleo foods such as raw dairy, grains, and legumes.[9][10]

A number of traditional aboriginal diets consisted of large quantities of raw meats, organ meats, and berries, including the traditional diet of the Nenets tribe of Siberia and the Inuit people.[12][13][14]

Kefir preparation

A sashimi dinner set

History

Raw food was first developed in Switzerland by Maximilian Bircher-Benner (1867 – 1939), who was influenced as a young man by the German *Lebensreform* movement, which saw civilization as corrupt and sought to go "back to nature"; it embraced holistic medicine, nudism, free love, exercise and other outdoors activity, and foods that it judged were more "natural".[15]:31–33 Bircher-Benner eventually adopted a vegetarian diet, but took that further and decided that raw food was what humans were really meant to eat; he was influenced by Charles Darwin's ideas that humans were just another kind of animal and Bircher-Benner noted that other animals do not cook their food.[15]:31–33 In 1904 he opened a sanatorium in the mountains outside of Zurich called "Lebendinge Kraft" or "Vital Force," a technical term in the Lebensreform movement that referred especially to sunlight; he and others believed that this energy was more "concentrated" in plants than in meat, and was diminished by cooking.[15]:31–33 Patients in the clinic were fed raw foods, including meusli which was created there.[15]:31–33 These ideas were dismissed by scientists and the medical profession of his day as quackery.[15]:31–33

Other proponents from the early part of this century include Ann Wigmore, Norman W. Walker (inventor of the Norwalk Juicing Press), and Herbert Shelton. Shelton was arrested, jailed, and fined numerous times for practicing medicine without a license during his career as an advocate of rawism and other alternative health and diet philosophies.[16] Shelton's legacy, as popularized by books like *Fit for Life* by Harvey and Marilyn Diamond, has been deemed "pseudonutrition" by the National Council Against Health Fraud.[17]

Leslie Kenton's book *Raw Energy - Eat Your Way to Radiant Health*, published in 1984, added popularity to foods such as sprouts, seeds, and fresh vegetable juices.[18] The book advocates a diet of 75% raw food which it claims will prevent degenerative diseases, slow the effects of aging, provide enhanced energy, and boost emotional balance; it cites examples such as the sprouted-seed-enriched diets of the long-lived Hunza people and Gerson therapy, an unhealthy, dangerous and potentially very harmful[19][20] raw juice-based diet and detoxification regime claimed to treat cancer.[19]

Claims

Claims held by raw food proponents include:

- That heating food above 104-118 °Fahrenheit (40-49 °C) starts to degrade and destroy the enzymes in raw food that aid digestion.[21][22] A few raw food proponents such as Douglas Graham dispute the importance of enzymes in foods.[23] However, enzymes in food are digested and play no role in human biology.[15]:34
- That raw foods have higher nutrient and antioxidants values than foods that have been cooked.[15]:34[24] In reality, whether cooking degrades nutrients or increases their availability, or both, depends on the food and how it is cooked.[15]:34[25]
- That cooked foods, and especially meat, contain harmful toxins, which can cause chronic disease and other problems, including trans fatty acids produced by heating oil, acrylamide produced by frying, advanced glycation end products (AGEs), and polycyclic aromatic hydrocarbons.[15]:34–5[26] While it is true that a healthy diet minimizes fried food and red meat, not all cooked food contains harmful chemicals (a serving of french fries has 200 times the AGEs of a bowl of cooked oatmeal), and a diet containing a normal mix of cooked and raw food does not shorten life.[15]:34–5[27][28]<[29] High rates of some of these compounds formed by cooking meat can cause cancer in other animals; whether such an exposure causes cancer in humans remains unclear.[27] According to the American Cancer Society it is not clear, as of 2013, whether acrylamide consumption affects people's risk of getting cancer.[30]

Health effects

A meta-analysis clinical trials and epidemiological studies published in 2004, and covering a broad range of cancers, found that it appears that there is an inverse relationship between the risk of developing certain types of cancer and eating both raw and cooked vegetables. Consumption of raw vegetables tended to be associated with decreased cancer risks somewhat more often than consumption of cooked vegetables.[31] On the other hand, a raw food diet is likely to impair the development of children and infants.[32]

Care is required in planning a raw vegan diet, especially for children.[33] Dr. Joel Fuhrman, author of *Disease-Proof Your Child*, says there may not be enough vitamin B_{12}, enough vitamin D, and enough calories for a growing child on a totally raw vegan diet. Fuhrman fed his own four children raw and cooked vegetables, fruits, nuts, grains, beans, and occasionally eggs.[34]

Food poisoning is a health risk for all people eating raw foods, and increased demand for raw foods is associated with greater incidence of foodborne illness,[35] especially for raw meat, fish, and shellfish.[36][37] Outbreaks of gastroenteritis among consumers of raw and undercooked animal products (including smoked, pickled or dried animal products[36]) are well-documented, and include raw meat,[36][38][39] raw organ meat,[38] raw fish (whether ocean-going or freshwater),[36][37][39] shellfish,[40] raw milk and products made from raw milk,[41][42][43] and raw eggs.[44]

In his book *Health or Hoax*, nutritionist Arnold E. Bender has written that "Many raw foods are toxic and only become safe after they have been cooked. Some raw foods contain substances that destroy vitamins, interfere with digestive enzymes or damage the walls of the intestine. Raw meat can be contaminated with bacteria which would be destroyed by cooking; raw fish can contain substances that interfere with vitamin B1 (anti-thiaminases)"[45]

Cooking and global warming

A close-up of a raw food dish

It has also been pointed out that cooking food, directly or indirectly, requires energy and may thus release gases associated with global warming.[46] Raw diets mitigate the use of non-renewable resources, which results in raw diets being less environmentally deleterious than cooked food diets in this respect.

Role of cooking in human evolution

Richard Wrangham, professor of biological anthropology at Harvard University,[47] proposes that cooked food played a pivotal role in human evolution. Evidence of a cooked diet, according to Wrangham, can be seen as far back as 1.8 million years ago in the anatomical adaptations of *Homo erectus*. Reduction in the size of teeth and jaw in *H. erectus* indicate a softer diet, requiring less chewing time. This combined with a smaller gut and larger brain indicate to Wrangham that *H. erectus* was eating a higher quality diet than its predecessors.[48] To explain a decreased gut providing the amount of energy required for an increased brain size, Wrangham links his research on the digestive effects of cooked versus raw foods with the lower reproductive abilities of female raw foodists, and BMI in both sexes, to support his hypothesis that cooked starches provided the energy necessary to fuel evolution from *H. erectus* to *H. sapiens*.[49]

Theories opposed to Wrangham's include that of Leslie Aiello, professor of biological anthropology at University College London, and physiologist Peter Wheeler. Aiello and Wheeler believe it was soft animal foods, including bone marrow and brains, which contributed to humans developing the characteristics Wrangham attributes to cooked foods.[50] Further, archaeological evidence suggests that cooking fires began in earnest only around 250 kya, when ancient hearths, earth ovens, burnt animal bones, and flint appear regularly across Europe and the Middle East. Two million years ago, the only sign of fire is burnt earth with human remains, which many anthropologists consider coincidence rather than evidence of intentional fire.[51] Many anthropologists believe the increases in human brain-size occurred well before the advent of cooking, due to a shift away from the consumption of nuts and berries to the consumption of raw meat.[52][53][54]

See also

- Amílcar de Sousa
- Anopsology
- Bernando LaPallo

Wikimedia Commons has media related to ***Raw food***.

- Béla Bicsérdy
- Cooking
- Fruitarianism
- Green smoothie
- Orthopathy
- Raw food diet for pets
- Raw foodists
- Rejuvelac
- Sattvic diet
- Taboo food and drink

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RC circuit

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A **resistor–capacitor circuit** (**RC circuit**), or **RC filter** or **RC network**, is an electric circuit composed of resistors and capacitors driven by a voltage or current source. A first order RC circuit is composed of one resistor and one capacitor and is the simplest type of RC circuit.

RC circuits can be used to filter a signal by blocking certain frequencies and passing others. The two most common RC filters are the high-pass filters and low-pass filters; band-pass filters and band-stop filters usually require RLC filters, though crude ones can be made with RC filters.

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Introduction

There are three basic, linear passive lumped analog circuit components: the resistor (R), the capacitor (C), and the inductor (L). These may be combined in the RC circuit, the RL circuit, the LC circuit, and the RLC circuit, with the acronyms indicating which components are used. These circuits, among them, exhibit a large number of important types of behaviour that are fundamental to much of analog electronics. In particular, they are able to act as passive filters. This article considers the RC circuit, in both series and parallel forms, as shown in the diagrams below.

Natural response

The simplest RC circuit is a capacitor and a resistor in parallel. When a circuit consists of only a charged capacitor and a resistor, the capacitor will discharge its stored energy through the resistor. The voltage across the capacitor, which is time dependent, can be found by using Kirchhoff's current law, where the current charging the capacitor must equal the current through the resistor. This results in the linear differential equation

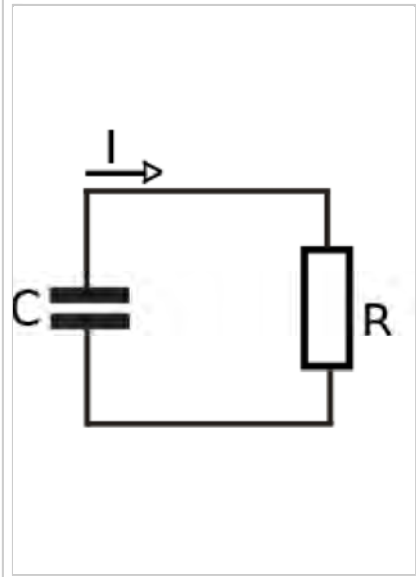

RC circuit

$$C\frac{dV}{dt} + \frac{V}{R} = 0\,,$$

where C is the capacitance of capacitor.

Solving this equation for V yields the formula for exponential decay:

$$V(t) = V_0 e^{-\frac{t}{RC}}\,,$$

where V_0 is the capacitor voltage at time $t = 0$.

The time required for the voltage to fall to $\frac{V_0}{e}$ is called the RC time constant and is given by[1]:1.13

$$\tau = RC\,.$$

Complex impedance

The complex impedance, Z_C (in ohms) of a capacitor with capacitance C (in farads) is

$$Z_C = \frac{1}{sC}$$

The complex frequency s is, in general, a complex number,

$$s = \sigma + j\omega\,,$$

where

- j represents the imaginary unit: $j^2 = -1$,
- σ is the exponential decay constant (in radians per second), and
- ω is the sinusoidal angular frequency (also in radians per second).

Sinusoidal steady state

Sinusoidal steady state is a special case in which the input voltage consists of a pure sinusoid (with no exponential decay). As a result,

$$\sigma = 0$$

and the evaluation of s becomes

$$s = j\omega\,.$$

Series circuit

By viewing the circuit as a voltage divider, the voltage across the capacitor is:

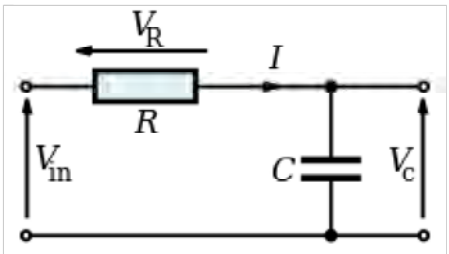

Series RC circuit

$$V_C(s) = \frac{\frac{1}{Cs}}{R + \frac{1}{Cs}} V_{\text{in}}(s) = \frac{1}{1 + RCs} V_{\text{in}}(s)$$

and the voltage across the resistor is:

$$V_R(s) = \frac{R}{R + \frac{1}{Cs}} V_{\text{in}}(s) = \frac{RCs}{1 + RCs} V_{\text{in}}(s)\,.$$

Transfer functions

The transfer function from the input voltage to the voltage across the capacitor is

$$H_C(s) = \frac{V_C(s)}{V_{\text{in}}(s)} = \frac{1}{1 + RCs}\,.$$

Similarly, the transfer function from the input to the voltage across the resistor is

$$H_R(s) = \frac{V_R(s)}{V_{\text{in}}(s)} = \frac{RCs}{1 + RCs}\,.$$

Poles and zeros

Both transfer functions have a single pole located at

$$s = -\frac{1}{RC}\,.$$

In addition, the transfer function for the resistor has a zero located at the origin.

Gain and phase

The magnitude of the gains across the two components are

$$G_C = |H_C(j\omega)| = \left|\frac{V_C(j\omega)}{V_{\text{in}}(j\omega)}\right| = \frac{1}{\sqrt{1 + (\omega RC)^2}}$$

and

$$G_R = \left|H_R(j\omega)\right| = \left|\frac{V_R(j\omega)}{V_{\text{in}}(j\omega)}\right| = \frac{\omega RC}{\sqrt{1+(\omega RC)^2}}\,,$$

and the phase angles are

$$\phi_C = \angle H_C(j\omega) = \tan^{-1}(-\omega RC)$$

and

$$\phi_R = \angle H_R(j\omega) = \tan^{-1}\left(\frac{1}{\omega RC}\right).$$

These expressions together may be substituted into the usual expression for the phasor representing the output:

$$\begin{aligned} V_C &= G_C V_{\text{in}} e^{j\phi_C} \\ V_R &= G_R V_{\text{in}} e^{j\phi_R}\,. \end{aligned}$$

Current

The current in the circuit is the same everywhere since the circuit is in series:

$$I(s) = \frac{V_{\text{in}}(s)}{R + \frac{1}{Cs}} = \frac{Cs}{1+RCs} V_{\text{in}}(s)\,.$$

Impulse response

The impulse response for each voltage is the inverse Laplace transform of the corresponding transfer function. It represents the response of the circuit to an input voltage consisting of an impulse or Dirac delta function.

The impulse response for the capacitor voltage is

$$h_C(t) = \frac{1}{RC} e^{-\frac{t}{RC}} u(t) = \frac{1}{\tau} e^{-\frac{t}{\tau}} u(t)\,,$$

where $u(t)$ is the Heaviside step function and $\tau = RC$ is the time constant.

Similarly, the impulse response for the resistor voltage is

$$h_R(t) = \delta(t) - \frac{1}{RC} e^{-\frac{t}{RC}} u(t) = \delta(t) - \frac{1}{\tau} e^{-\frac{t}{\tau}} u(t)\,,$$

where $\delta(t)$ is the Dirac delta function

Frequency-domain considerations

These are frequency domain expressions. Analysis of them will show which frequencies the circuits (or filters) pass and reject. This analysis rests on a consideration of what happens to these gains as the frequency becomes very large and very small.

As $\omega \to \infty$:

$$G_C \to 0 \quad \text{and} \quad G_R \to 1\,.$$

As $\omega \to 0$:

$$G_C \to 1 \quad \text{and} \quad G_R \to 0\,.$$

This shows that, if the output is taken across the capacitor, high frequencies are attenuated (shorted to ground) and low frequencies are passed. Thus, the circuit behaves as a *low-pass filter*. If, though, the output is taken across the resistor, high frequencies are passed and low frequencies are attenuated (since the capacitor blocks the signal as its frequency approaches 0). In this configuration, the circuit behaves as a *high-pass filter*.

The range of frequencies that the filter passes is called its bandwidth. The point at which the filter attenuates the signal to half its unfiltered power is termed its cutoff frequency. This requires that the gain of the circuit be reduced to

$$G_C = G_R = \frac{1}{\sqrt{2}}.$$

Solving the above equation yields

$$\omega_{\mathrm{c}} = \frac{1}{RC} \quad \text{or} \quad f_{\mathrm{c}} = \frac{1}{2\pi RC}$$

which is the frequency that the filter will attenuate to half its original power.

Clearly, the phases also depend on frequency, although this effect is less interesting generally than the gain variations.

As $\omega \to 0$:

$$\phi_C \to 0 \quad \text{and} \quad \phi_R \to 90^\circ = \frac{\pi}{2}\,\text{radians}\,.$$

As $\omega \to \infty$:

$$\phi_C \to -90^\circ = -\frac{\pi}{2}\,\text{radians} \quad \text{and} \quad \phi_R \to 0\,.$$

So at DC (0 Hz), the capacitor voltage is in phase with the signal voltage while the resistor voltage leads it by 90°. As frequency increases, the capacitor voltage comes to have a 90° lag relative to the signal and the resistor voltage comes to be in-phase with the signal.

Time-domain considerations

This section relies on knowledge of e, the natural logarithmic constant.

The most straightforward way to derive the time domain behaviour is to use the Laplace transforms of the expressions for V_C and V_R given above. This effectively transforms $j\omega \to s$. Assuming a step input (i.e. $V_{\text{in}} = 0$ before $t = 0$ and then $V_{\text{in}} = V$ afterwards):

$$V_{\text{in}}(s) = V \cdot \frac{1}{s}$$
$$V_C(s) = V \cdot \frac{1}{1 + sRC} \cdot \frac{1}{s}$$
$$V_R(s) = V \cdot \frac{sRC}{1 + sRC} \cdot \frac{1}{s}\,.$$

Partial fractions expansions and the inverse Laplace transform yield:

$$V_C(t) = V\left(1 - e^{-\frac{t}{RC}}\right)$$
$$V_R(t) = Ve^{-\frac{t}{RC}}\,.$$

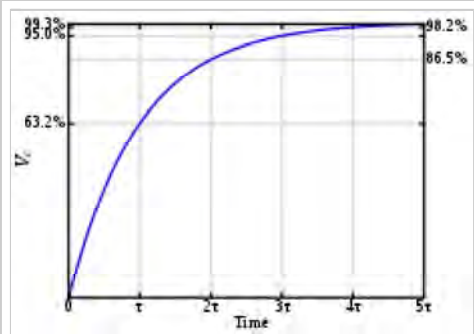

Capacitor voltage step-response.

These equations are for calculating the voltage across the capacitor and resistor respectively while the capacitor is charging; for discharging, the equations are vice versa. These equations can be rewritten in terms of charge and current using the relationships $C = \frac{Q}{V}$ and $V = IR$ (see Ohm's law).

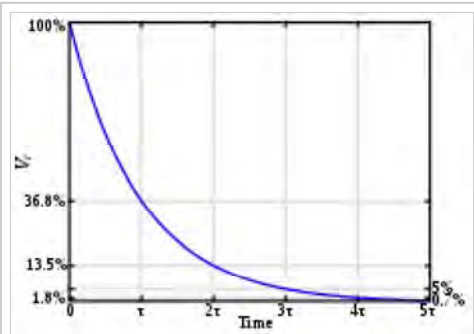

Resistor voltage step-response.

Thus, the voltage across the capacitor tends towards V as time passes, while the voltage across the resistor tends towards 0, as shown in the figures. This is in keeping with the intuitive point that the capacitor will be charging from the supply voltage as time passes, and will eventually be fully charged.

These equations show that a series RC circuit has a time constant, usually denoted $\tau = RC$ being the time it takes the voltage across the component to either rise (across the capacitor) or fall (across the resistor) to within $\frac{1}{e}$ of its final value. That is, τ is the time it takes V_C to reach $V(1 - \frac{1}{e})$ and V_R to reach $V(\frac{1}{e})$.

The rate of change is a *fractional* $1 - \frac{1}{e}$ per τ. Thus, in going from $t = N\tau$ to $t = (N + 1)\tau$, the voltage will have moved about 63.2% of the way from its level at $t = N\tau$ toward its final value. So the capacitor will be charged to about 63.2% after τ, and essentially fully charged (99.3%) after about 5τ. When the voltage source is replaced with a short-circuit, with the capacitor fully charged, the voltage across the

capacitor drops exponentially with t from V towards 0. The capacitor will be discharged to about 36.8% after τ, and essentially fully discharged (0.7%) after about 5τ. Note that the current, I, in the circuit behaves as the voltage across the resistor does, via Ohm's Law.

These results may also be derived by solving the differential equations describing the circuit:

$$\frac{V_{\text{in}} - V_C}{R} = C\frac{dV_C}{dt}$$
$$V_R = V_{\text{in}} - V_C\,.$$

The first equation is solved by using an integrating factor and the second follows easily; the solutions are exactly the same as those obtained via Laplace transforms.

Integrator

Consider the output across the capacitor at *high* frequency, i.e.

$$\omega \gg \frac{1}{RC}\,.$$

This means that the capacitor has insufficient time to charge up and so its voltage is very small. Thus the input voltage approximately equals the voltage across the resistor. To see this, consider the expression for I given above:

$$I = \frac{V_{\text{in}}}{R + \frac{1}{j\omega C}}\,,$$

but note that the frequency condition described means that

$$\omega C \gg \frac{1}{R}\,,$$

so

$$I \approx \frac{V_{\text{in}}}{R}$$

which is just Ohm's Law.

Now,

$$V_C = \frac{1}{C}\int_0^t I\,dt\,,$$

so

$$V_C \approx \frac{1}{RC}\int_0^t V_{\text{in}}\,dt\,,$$

which is an integrator *across the capacitor*.

Differentiator

Consider the output across the resistor at *low* frequency i.e.,

$$\omega \ll \frac{1}{RC}\,.$$

This means that the capacitor has time to charge up until its voltage is almost equal to the source's voltage. Considering the expression for I again, when

$$R \ll \frac{1}{\omega C}\,,$$

so

$$I \approx \frac{V_{\text{in}}}{\frac{1}{j\omega C}}$$
$$V_{\text{in}} \approx \frac{I}{j\omega C} = V_C\,.$$

Now,

$$V_R = IR = C\frac{dV_C}{dt}R$$
$$V_R \approx RC\frac{dV_{in}}{dt}\,,$$

which is a differentiator *across the resistor*.

More accurate integration and differentiation can be achieved by placing resistors and capacitors as appropriate on the input and feedback loop of operational amplifiers (see *operational amplifier integrator* and *operational amplifier differentiator*).

Parallel circuit

The parallel RC circuit is generally of less interest than the series circuit. This is largely because the output voltage V_{out} is equal to the input voltage V_{in} — as a result, this circuit does not act as a filter on the input signal unless fed by a current source.

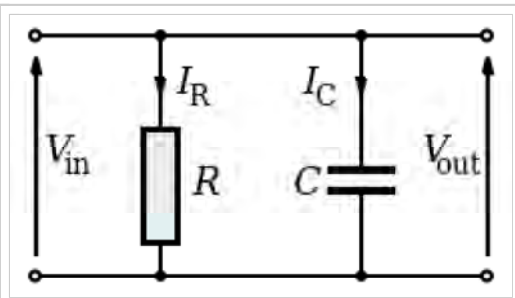

Parallel RC circuit

With complex impedances:

$$I_R = \frac{V_{\text{in}}}{R}$$
$$I_C = j\omega C V_{\text{in}} \ .$$

This shows that the capacitor current is 90° out of phase with the resistor (and source) current. Alternatively, the governing differential equations may be used:

$$I_R = \frac{V_{\text{in}}}{R}$$
$$I_C = C\frac{dV_{\text{in}}}{dt} \ .$$

When fed by a current source, the transfer function of a parallel RC circuit is:

$$\frac{V_{\text{out}}}{I_{\text{in}}} = \frac{R}{1 + sRC} \ .$$

See also

- RL circuit
- LC circuit
- RLC circuit
- Electrical network
- List of electronics topics
- Step response

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11.1 **Font Software.** Notwithstanding the Adobe Fonts service that is governed by Adobe Fonts Service Additional Terms), if the Software includes font software:

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You and Adobe will each have the right to terminate this Agreement for any reason upon providing at least 30 days' prior written notice. Effective upon termination, you will immediately cease your use of the Software and will destroy (at Adobe's request) your copy of the Software. All licenses granted to you by Adobe will immediately cease upon termination.

16. Survival.

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17. Export Rules: Trade Sanctions and Export Control.

The Software, and your use of the Software, is subject to laws, restrictions, and regulations of the United States and other jurisdictions that (A) govern the import, export, and use of the Software; and (B) may prohibit us from providing the Software to you without notice. By using the Software, you agree to comply with all such laws, restrictions, and regulations, and you warrant that you are not prohibited from receiving the Software by the laws of any jurisdiction.

18. Governing Law and Dispute Resolution.

18.1 If you reside in North America, your relationship is with Adobe Inc., a United States company, and this Agreement is governed by the laws of California, U.S.A. If you reside outside of North America, your relationship is with Adobe Systems Software Ireland Limited, and this Agreement is governed by the laws of Ireland. If you are in Australia, Adobe Systems Software Ireland Limited is acting as an authorized agent of Adobe Australia Trading Pty Ltd. and is entering into this contract in its capacity as agent for Adobe Australia Trading Pty Ltd. You may have additional rights under the law. We do not seek to limit those rights where it is prohibited by law. This Agreement will not be governed by the following, the application of which is hereby expressly excluded: (a) the conflict of law rules of any jurisdiction; (b) the United Nations Convention on Contracts for the International Sale of Goods; and (c) the Uniform Computer Information Transactions Act, as enacted in any jurisdiction. You may only resolve disputes with us on an individual basis and may not bring a claim as a plaintiff or a class member in a class, consolidated, or representative action. Notwithstanding the foregoing, in the event of your or others' unauthorized access to or use of the Software in violation of these terms you agree that we are entitled to apply for injunctive remedies (or an equivalent type of urgent legal relief) in any jurisdiction.

18.2 For any concern or dispute you may have, you agree to first try to resolve the dispute informally by contacting us. If a dispute is not resolved within 30 days of submission, you and Adobe must resolve any claims relating to these terms or the Software through final and binding arbitration, except that you may assert claims in small claims court if your claims qualify.

18.3 If you reside in the Americas, JAMS will administrate the arbitration in Santa Clara County, California, pursuant to its Comprehensive Arbitration Rules and Procedures. If you reside in Australia, New Zealand, Japan, mainland China, Hong Kong S.A.R., Macau S.A.R., Taiwan, South Korea, India, Sri Lanka, Bangladesh, Nepal, or a member state of the Association of Southeast Asian Nations (ASEAN), then the Singapore International Arbitration Centre (SIAC) will administer the arbitration in Singapore under its Rules of Arbitration, which rules are deemed to be incorporated by reference in this section. Otherwise, the London Court of International Arbitration (LCIA) will administer the arbitration in London under the LCIA Arbitration Rules. There will be one arbitrator that you and Adobe both select. The arbitration will be conducted in the English language, but any witness whose native language is not English may give testimony in the witness' native language, with simultaneous translation into English (at the expense of the party presenting the witness). Judgment upon the award rendered may be entered and will be enforceable in any court of competent jurisdiction having jurisdiction over the parties.

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19.2 If you are a U.S. Government entity, or if the Agreement becomes subject to the Federal Acquisition Regulations ("**FAR**"), then, the Software is a "Commercial Item(s)," as that term is defined at 48 C.F.R. Section 2.101, consisting of "Commercial Computer Software" and "Commercial Computer Software Documentation," and services related thereto, as such terms are used in 48 C.F.R. Section 12.212 or 48 C.F.R. Section 227.7202, as applicable. Consistent with 48 C.F.R. Section 12.212 or 48 C.F.R. Sections 227.7202-1 through 227.7202-4, as applicable, the Commercial Computer Software and Commercial Computer Software Documentation are being licensed to U.S. Federal Government End Users: (a) only as Commercial Items; and (b) with only those rights as are granted to all other end users pursuant to the terms and conditions herein. Unpublished rights are reserved under the laws of the United States- Adobe Inc., 345 Park Avenue, San Jose, CA 95110-2704, USA.

20. Compliance with Licenses.

20.1 If you are a business or organization, you agree that upon request from Adobe or Adobe's authorized representative, you will, within 30 days, fully document and certify that use of the Software at the time of the request is in conformity with the licenses granted herein.

20.2 **No Prejudice; European Economic Area Provisions.** Nothing in this Agreement will prejudice the statutory rights of any party, including those dealing as consumers. For example, for consumers in New Zealand who obtain the Software for personal business purposes, this Agreement is subject to the Consumer Guarantees Act. As another example, for consumers in Germany who obtain the Software, this Agreement is subject to the German Product Liability Act.

20.3 **Limitation of Liability**

20.3.1 Except for German or Austrian consumers, Section 14 (Limitation of Liability) still applies. You are advised to take all reasonable measures to avoid and reduce damages, in particular by making a backup copy of the Software and backup copies of your data.

20.3.2 If you obtained the Software in Germany or Austria, and you usually reside in that country, then Section 14 does not apply. Instead, subject to the provisions in Section 20.3.2, Adobe's statutory liability for damages shall be limited as follows: (a) Adobe shall be liable only up to the amount of damages as typically foreseeable at the time of entering into the license agreement, with respect to damages caused by a slightly negligent breach of a material contractual obligation; and (b) Adobe shall not be liable for damages caused by a slightly negligent breach of a non-material contractual obligation.

20.3.3 The aforesaid limitation of liability shall not apply to any mandatory statutory liability, in particular to liability under the German Product Liability Act, liability for assuming a specific guarantee, or liability for culpably caused personal injuries.

21. Updates and Availability.

21.1 **Updates to this Agreement**. We may modify this Agreement at any time, for example, to reflect changes to the law or changes to our Software. You should look at this Agreement regularly. We will post notice of modifications to this Agreement on this page. By continuing to use the Software after the revisions are in effect, you agree to be bound by the revised terms of the updated Agreement.

21.2 **Availability Limitation**. The Software and Adobe Online Services may not be available in all languages or to residents of all countries.

22. Miscellaneous.

22.1 **Entire Agreement.** This Agreement contains the entire understanding of you and Adobe relating to the subject matter and supersedes all earlier agreements, understandings, proposals, discussions, negotiations, representations and warranties, both written and oral, regarding the subject matter.

22.2 **English Version.** The English version of this Agreement will be the version used when interpreting or construing the terms of this Agreement.

22.3 **Headings**. Headings used in this Agreement are provided for convenience only and will not be used to construe meaning or intent.

22.4 **Severability.** If any provision of this Agreement is held invalid or unenforceable for any reason, this Agreement will continue in full force and effect.

22.5 **No Waiver.** Our failure to enforce or exercise any provision of this Agreement is not a waiver of that provision.

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Ready-mix concrete

From Wikipedia, the free encyclopedia

Ready-mix concrete is concrete that is manufactured in a factory or batching plant, according to a set recipe, and then delivered to a work site by truck mounted in–transit mixers. This results in a precise mixture, allowing specialty concrete mixtures to be developed and implemented on construction sites. The first ready-mix factory was built in the 1930s, but the industry did not begin to expand significantly until the 1960s, and it has continued to grow since then.

1.6 cuM. transit mixer

Ready-mix concrete is often preferred over on-site concrete mixing because of the precision of the mixture and reduced work site confusion.

Ready-mix concrete, or RMC as it is popularly called, refers to concrete that is specifically manufactured for delivery to the customer's construction site in a freshly mixed and plastic or unhardened state. Concrete itself is a mixture of Portland cement, water and aggregates comprising sand and gravel or crushed stone. Ready-mix concrete is bought and sold by volume - usually expressed in cubic meters (cubic yards in the US).

Small batching plant for local small deliveries

Ready-mix concrete is manufactured under controlled operations and transported and placed at site using sophisticated equipment and methods. In 2011, there were 2,223 companies employing 72,924 workers that produced RMC in the United States.[1]

Contents

- 1 Disadvantages of ready-mix concrete
- 2 Metered concrete
  - 2.1 Standard ready-mix concrete vs. site-mix concrete
- 3 See also
- 4 References
- 5 External links

Disadvantages of ready-mix concrete

- The materials are batched at a central plant, and the mixing begins at that plant, so the traveling time from the plant to the site is critical over longer distances. Some sites are just too far away, however the use of admixtures like retarder can be added.[2]
- Furthermore, access roads and site access have to be able to carry the greater weight of the ready-mix truck plus load. (Green concrete is approx. 2.5 tonne per m³.) This problem can be overcome by utilizing so-called 'mini mix' companies which use smaller 4m³ capacity mixers able to reach more-restricted sites.
- Concrete's limited time span between mixing and curing means that ready-mix should be placed within 210 minutes of batching at the plant.[3] Modern admixtures can modify that time span precisely, however, so the amount and type of admixture added to the mix is very important.

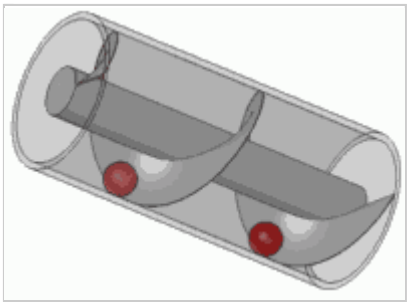

The inside of a transit mixer uses a simple Archimedes' screw to mix (clockwise) and to lift the concrete to the delivery chute (counter-clockwise).

Metered concrete

As an alternative to ready-mix concrete, volumetric mobile mixers may be used to provide metered concrete services. The volumetric mobile mixer is a truck that contains concrete ingredient materials and water to be mixed on the truck at the job site to make and deliver concrete according to the amount needed. The on-truck mixing at the job site eliminates the travel delays that can cause the pre-mixed concrete to become unusable, however not as precise as weighed batches. This is a hybrid approach between ready-mix concrete and traditional on-site mixing.[4]

Standard ready-mix concrete vs. site-mix concrete

- A centralized concrete batching plant can serve a wide area. Site-mix trucks can serve an even larger area including remote locations that standard trucks can not.
- The plants are located in areas zoned for industrial use, and yet the delivery trucks can service residential districts or inner cities. Site-mix trucks have the same capabilities.

Since site mixed concrete is volumetrically metered, the quality of the concrete is not on par with standard ready mixed concrete which is weighed.

See also

- Types of concrete

References

Notes

1. "Ready Mix Concrete Manufacturer". akonaindia.com.
2. "Chemical Admixtures".

3. ASTM C 94 and AASHTO M 157
4. Casey, Jon M. "Parmer Metered Concrete offers precision and quality". *Hard Hat News*. Retrieved 24 November 2014.

Bibliography

- Panarese, William C.; Kosmatka, Steven H.; Kerkhoff, Beatrix (2002). "10". *Design and Control of Concrete Mixtures*. Skokie, Illinois: Portland Cement Association. ISBN 0-89312-217-3.

External links

- National Ready Mixed Concrete Association (http://www.nrmca.org/)
- Ready Mixed Concrete Manufacturer's Association (http://www.rmcmaindia.org/)
- European Ready Mixed Concrete Organisation (http://www.ermco.eu/)
- Illinois Ready Mixed Concrete Association (http://www.irmca.org/)

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knot knots knotting tie tying rope yarn hitch hitches bend scout sail climb marlinespike.

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What are the recent changes of the Roper Site ??

990825 Breast plates. Some fancy knots. Because you want them so much. NEW! NEW!

The Web Knot index

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Instruction Pages

Stoppers Terminal Knots
Overhand-knot, (Flemish)eight and more

bends To bend two lines together.
Reef-Knot, Sheet-Bend, Carrick-Bend, True-Lover's, and more

Hitches To tie on an object.
Timber Hitch, Constrictor, The Eight, and more..

Single Loops
Bowline, Bowstring, and more...

The Noose
The running bowline, hangman, and more..

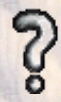

Frequently Asked Knots.
The monkey fist, Dolly (trucker-hitch).

Breast plates.
Some Fancy work

Links to other knot sites
.At the base of realknots

Books on Knots on the Web
Ashley, Klutz and more

Links to pages with links to Roper's pages
. For finding people with the same interests..

News in the knotting world

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If you like it you can subscribe to mail notification on major changes. (about once a fortnight.)
Ropers Knot Site is optimized for fast loading, even for non high performance connections. This to make it possible to enjoy the art of knotting all over the WEB.
Not all the knots are safe for children to play with. You can access Ropers knot pages also via bonus.com which blocks all unsafe links, also those to the nooses, but needs a high performance browser and connection. (Sorry).
For the next year (or two) there will be no fancy knotting in the instruction part of Ropers Knot Site.
Other knot sites on the web are listed in **Roper's Link Page.** If you found one or made one I missed, please let me know.

Subscribe

If you register your e-mail address you will get a mail each time I make an update in this site.

(You will be asked to retype it by the URL minder)
Your complete Internet e-mail address (user@domain):

Press Here to Register.

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Because I am proud of my awards I will show them.
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A review from YPN: Home & Family: Hobbies: Knotting

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Timber Hitch, Constrictor, The Eight, and more..

Single Loops
Bowline, Bowstring, and more...

The Noose
The running bowline, hangman, and more..

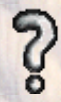

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Your complete Internet e-mail address (user@domain):

Press Here to Register.

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I can and will not allow junk mail nor spam. Therefor commercial, non-personal and bulk mail will be charged with handling costs of $100 per mail.

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Return to Ropers Knot Page

Touwslager's Knopen Pagina

(🇬🇧)

De knopen site met echte knopen.

Wat zijn de meest recente wijzigingen op deze site ??

De engelse knopen index

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Knopen aan een eind
Overhandsknoop, (Vlaamse)acht

Knopen om touwen aan elkaar te knopen
Platte Knoop, Schootsteek, Karaak steek, Zoeteliefjes en meer...

Knopen om touw aan iets anders vast te maken
Mastworp, Constrictor, De acht, en meer..

Enkele Lussen
Paalsteek, Boogpees knoop, en meer..

De Schuifknoop
De lopende paalsteek, beulsknoop, en meer..

Links naar andere knopen-sites
.

Books on Knots on the Web
Ashley, Klutz en meer

Links naar pagina's met links naar (Touwslager's) Roper's pagina's
.

Nieuws uit de knopen wereld

De nieuwsgroep **rec.crafts.knots** is on line.

Ik heb weer hulp van een corrector. De nederlandse versie van de site zal daarom weer groeien.

Over Touwslagers Knopen site.

Als je wilt kan je je abonneren op een mailbericht na wezenlijke wijzigingen in deze site. (ongeveer eens per veertien dagen.)
Touwslagers Knopen Site is geoptimaliseerd om snel te laden, ook op niet al te beste verbindingen. Dit maakt het voor iedereen mogelijk om van deze knopen te genieten.
Niet alle knopen zijn veilig voor kinderen om mee te spelen. Daarom heeft bonus.com deze site voor kinderen opgenomen. Alle "gevaarlijke" links zijn daarin geblokkeerd. Helaas heb je daar wel een krachtige processor en snelle verbinding voor nodig.
De komende paar jaar zullen er geen sierknopen worden opgenomen in het instructie deel van Touwslagers Knopen Site.
Andere knopen sites zijn te vinden via **Roper's Link Page.** Als je wat gevonden hebt wat daarin thuis hoort terwijl het er niet staat, laat het even weten.

Als je hier je e-mail adres registreert krijg je bericht per mail telkens als er een update van deze site geweest is.

(De URL minder vraagt nogmaals om je e-mail adres ter verificatie.)

Je complete Internet e-mail adres (user@domain):

Klik hier voor registratie

Commentaar, ideeen, sugesties mail me: ***qqqq at realknots.com*** *with subject "**question**"*

Alle mail zonder het juiste onderwerp worden automatisch, ongelezen weggemikt..

Het spijt me dat ik de mail link weg heb moeten halen. De Mailgrabbers hebben gewonnen.

Maar.... Ik heb een paar verborgen mail adresjes opgenomen zodat ze elkaar plat kunnen spammen nadat ze mijn "junk"gegrabbed hebben....

Omdat dit een niet commerciële site is kan en wil ik geen junk-mail of "spam" behandelen. Daarom behoud ik mij het recht voor om voor niet persoonlijke mail, bulk-mail en andere reclame uitingen f250,- afhandelings-kosten PER mail in rekening te brengen.

Deze Site wordt gesponsord door: even nog door niemand

(96/02/02)

Breast Plate Designs

(🇳🇱) 🎻

to make and wear .. ..

Brian E.Fields made a booklet : "Breast Plate designs." Because I liked it and because there was a great demand for fancy knots I aksed and got permission to publish a part of this work on the WEB.
If you like it and want the complete booklet you can find detailed information on how to buy it on The IGKT store
In the booklet you will find about 20 breast plates and about 5 mats. On this page you find a sample of 5 breastplates from his booklet.

These breastplates are small enough to be tied in the hand, but if you have ten thumbs, by all means use a board and pins.
A nine feet, three meter, fathom and a half lenght of two mm line is sufficient to make and double all these designs and form the neck loop. When tieng a knot start in the middle of the line and work with one end and then the other.

The Bell

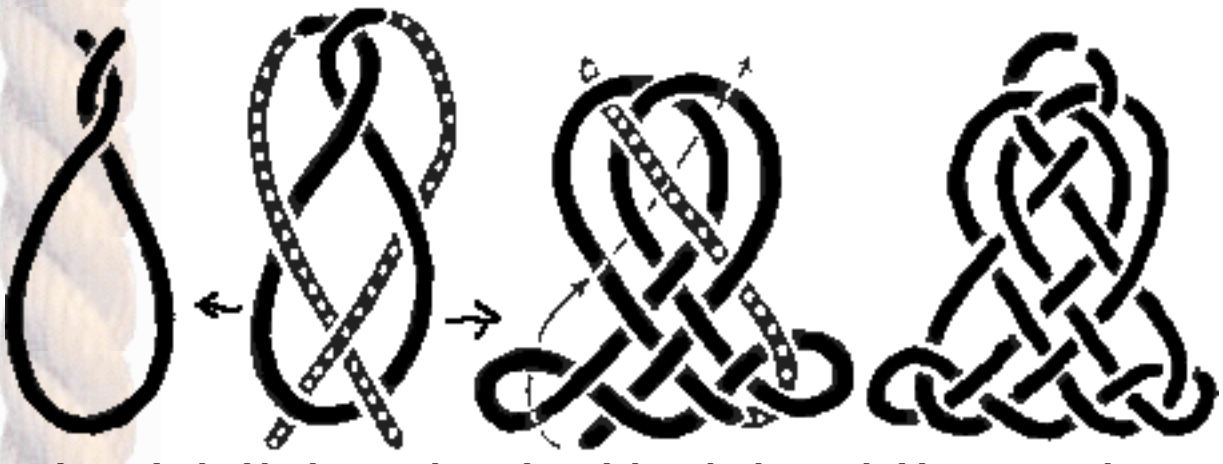

Start with a twist .. and lock it in position aby using the ends (see diagram right). Extend the bottom loop in the directions shown by the arrows.

The extended bottom loop is twisted to produce a locked bight on either side and these bights are held in position by passing the right side end as shown and then using the left end to lock and finish the knot.

Double Headed Carrick

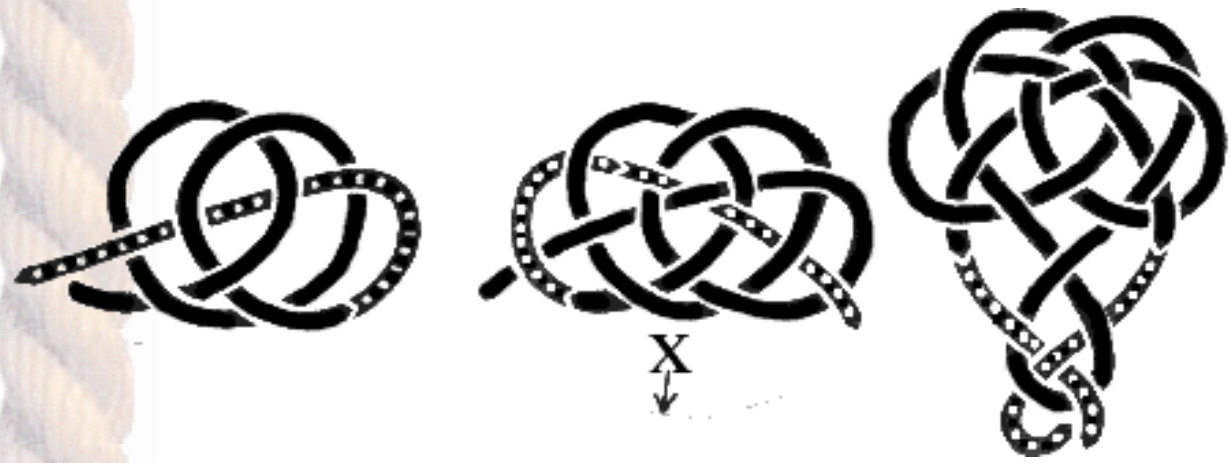

Start with two in terlinked half hitches and pass one end as shown.

The second end may now be passed in a regular over and under weave to complete the first part of the knot. Next work slack around the to extend bight x which is then twisted to lock.

The working ends are then used to lock the twisted bight in position and the knot is ready for doubling.

Handcuff Hitch Breasplate

Start with a half knot and lengthen the two bights. Twist the bights to lock them (this will produce a regular over and under weave). Lay one bight over the other (check that the sequence is correct by examining the rectangle r) Take one end and lock the bights as shown. Arrange the doubling so that both ends finish at x ~ this is the top loop of the knot.

The finished design is small but does form a basis for other patterns such as the design on the right. How to develop one from the other is your problem! (Solved on the next page in the booklet.)

Mors du Cheval (second Method)

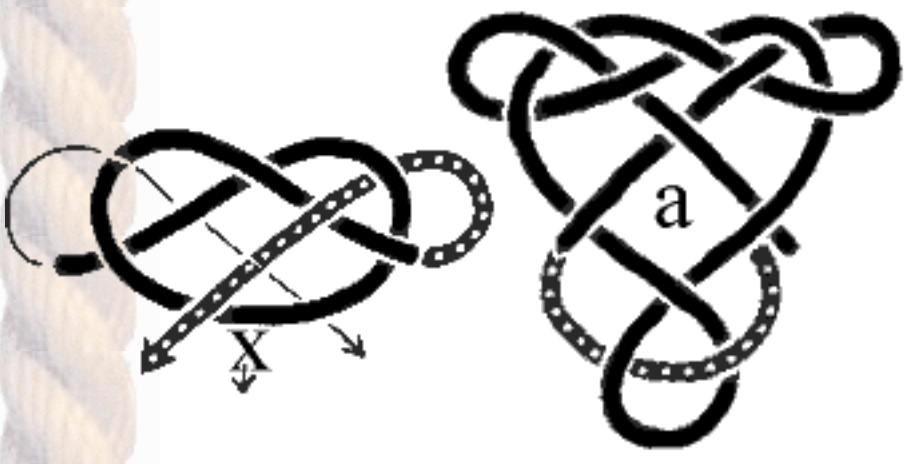

Start with two bights (unlocked half knot) and lock by passing the ends as shown. Extend bight x.
Twist the extended bight so as to lock it, (check the rectangle a. just to make sure the twist was correct), and pass the end as shown to complete the knot. Double (or preferably treble).

I believe this must have been the method used by the Viking who made the Bornhol pendant (dated 800ac-100 ac). He worked with three strands of wire rather than face the problems of trebling, and the work hardening that would inevitably affect the wire when bent as often as required by the tripling technique.

D-N

Start with Mors du Cheval (see previous knot) and extend the two center bottom bights.
Twist these extended bights to lock them and place one over the other, as shown.

The working ends are then pased as shown n a regular over and under weave to lock and complete the knot.
Its not quite a ´Tribulation´,but it was still a d--- n--- work out ~ hence the title.

Any comment, suggestions, anything mail me: ***qqqq at realknots.com*** *with subject "**question**"*
All mail without thr right subject is flussed unred. automaticly.
I am sorry I had to remove the mail link. The mailgrabbers and spammers won. But.... I have a few hidden mail address for them to mail to each other after they grabbed it.

Because this is an non-commercial site I can and will not allow junk mail nor spam. Therefore commercial, non personal and bulk mail will be charged with handling costs of $100 per mail.

Back To
<=Z

A

A B C D E F G H I J K L M N O
P Q R S T U V W X Y Z

Back To

Ropers Knot Page

- Adjusible bend
  - 22nd Farnworth Scout Group(Right part need correction.)
- The Adjusable Hitch Also called the Jamming Hitch.
  - 22nd Farnworth Scout Group
- Albright Knot A Fishermans knot, used for joining lines of different diameter to line or wire
  - On the Fishernet.
- Alpine Butterfly See Butterfly
- Anchor hitch or Anchor bend See Fishermans bend (The bend that is a hitch)
- Arbor Knot A Fishermans knot, used to tye a line to a reel
  - On the Fishernet.
- The Artillary loop. A usefull temporary loop for carrying things.

To=>B

A<=To

B

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

Ropers Knot Page

- Bachman climbing knot
  - On a Climbing Knot Dictionary (Among others in)
- Back Splice.
  - On The Scout Association Of Australia page.
- Barrel Knot. A Fishermans knot. Also called "the Blood knot" Used to join lines of different diameter, as in fly fishing.
  - On the Fishernet.
  - On another Fishernet.
  - The fishing knots.
  - BRMRG Knot Primer Good Picture But this is the fishermans bend..on mountain site
- Bao knot.
  - The Bao Knot. A fancy chineese knot
- Boatswain's Whistle Knot
  - Northnet Ropeworks Clear instruction.
  - Northnet Ropeworks Excelent Animation
- The Bimini-twist. a fixed loop in fishline.
  - Link lost
- Bindary Knot. How to tye a pakkage
  - Link Lost
- Blackwall Hitch.

Blackwall Hitch on Forty Boy Scout Knots

- Blood Knot. A stopper knot. Also called the dubble overhand
  - Blood Knot. (Fisherman) Also called "Barrel Knot".
  - Blood Bight Knot. A fixed loop for fishline.
  - The fishing knots.
- Bow Knot.
  - Bow Knot on Forty Boy Scout Knots
- Bög = Overhand knot.
  - Csomók.
- Bowline. A famous fixed loop.
  - How is the bowline called in other languages?
  - Bowline Game (for scouting 8-10 y)
  - Csomók.
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - On The Scout Association Of Australia page
  - In climbing. A climbing knot Among others in the Climbing Knot Dictionary
  - Animated Knots Requires plugin
  - Canoe Certificate Course Session 4 - Ropes & Lines
  - NautBob's Knots 4 well known copies of knots.
  - Animated Knots for Scouts No plugin needed
  - one of Forty Boy Scout Knots
- Bowline on the Bight.
  - Ropework Exelent instruction
  - one of Forty Boy Scout Knots
- The Bowstring knot. A permanent loop at the end of a rope.
  - Bowtie Knot.
    - A Tie Knot amongs a view others..
  - The Brubakker Loop knot. A fishermans loop
  - The Buntline Hitch.

- How is the buntline called in other languages?

- The Butterfly An Excellent loop in the middle of a rope.
  Link lost

To=>C

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C

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To
Ropers Knot Links

- Carrick Bend. The nearest thing er have to the perfect bend. Also called the Josephine Knot when used in macrame.
  - A poet on this famous knot.
- Cat's Paw.
  - one of Forty Boy Scout Knots
  - Website Gert Animated
- Cleath knot. Or How to belay a cleath
  - Northnet Ropeworks Clear instruction.
  - Northnet Ropeworks Excelent Animation
- Clinch Knot. A fishermans knot. Terminal to a tackle
  - On the Fishernet (Improved) ???.
- The Clove Hitch.
  - How is the clove hitch called in other languages?
  - On the Scout Association Of Australia page.
  - On the Yachtnet = Beautyfull but large page..
  - Website Gert Animated
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - Lehigh Samson (among other drawings with small description)
  - Quick Clove Hitch Good instruction for one way of tying.
  - Animated Knots Requires plugin
  - Canoe Certificate Course session 4 - ropes & lines
  - NautBob's Knots 4 well known copies of knots.
  - Animated Knots for Scouts No plugins needed

- one of Forty Boy Scout Knots
- Clovehitch Relay (game for youg scouts)

- The Constrictor Hitch.
  - Northnet Ropeworks Clear instruction.
  - Northnet Ropeworks Excelent Animation

- The Cow Hitch

- Csónak~ = Slip Knot

- Csomók.

To=>D

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<=C

D

A B C D E F G H I J K L M N O P Q R S T U V W X Y
Z

Back To

- Diagonal Lashing.
  - Northnet Ropeworks Clear instruction.

- Double Carrick Bend.
  on of Forty Boy Scout Knots

- Double Constrictor Hitch.
  Probably the strongest hitch. Best use for temporary whipping.

- Double Eight. Probably the strongest 'double-stopper' knot
  -

- Double Figure-of-eight loop.
  - one of Forty Boy Scout Knots

- Double Fisherman's Knot. A Fishermans knot. Used to join lines of different diameter, as in fly fishing.
  - On the Fisher net. Used to join lines of different diameter, as in fly fishing.
  -

- Double Marline Hitch.

- Double Overhand Knot. Stopper.
  - On the Climbing Knot Dictionary (Among others)

- one of Forty Boy Scout Knots

- Double Turle Knot. To Tye a hook with eye on a line
  - The fishing knots.

- Doubled Overhand.
  -

- Double sheetbend
  - Animated Knots for Scouts
  - Website GertAnimated
  - one of Forty Boy Scout Knots

- The Dropper Loop. A loop in fishline.
  - The fishing knots.

- The Dutch Marine Bowline.

To=>E

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E

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Eye Splice.
  - Ropework Exelent instruction
  - On the Scout Association Of Australia page.

To=>F

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F

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Farmers hitch.
  -

- Fiador.
  - Tie a First Class Rope Halter With Fiador Knot

- Figure eight knot. Stopper.
  - On the Scout Association Of Australia page.
  - On the Yachtnet. A beautifull but large page
  - Website GertAnimated
  - A short climbing page on this knot.
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - climbing knot Among others in the Climbing Knot Dictionary
  - Library of knots.(among other drawings)
  - Canoe Certificate Course Session 4 - Ropes & Lines
  - Knots, Bends and Hitches Between 4 other knots.
  - on Animated Knots for Scouts
  - on of Forty Boy Scout Knots
  - BRMRG Knot Primer Good Picture on mountain site
  - Northnet Ropeworks Clear instruction.
  - Northnet Ropeworks Excelent Animation

- Figure eight Lashing.
  - On the Scout Association Of Australia page.

- Figure eight Loop
  - Northnet Ropeworks Clear instruction. In the Bight

- Figure-of-nine knot.
  -

- Filipino Lashing.
  - On the Scout Association Of Australia page.

- Fisherman's Bend. The Hitch wich is called a bend and is (K)not.
  - Lehigh Samson (among other drawings with small description)
  - Knots,Bends and Hitches Between 4 other knots.

- Fisherman's knot= True Lovers Most common 'double-stopper' knot
  - How is the fisherman's knot called in other languages?
  - Website GertAnimated
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - On the Scout Association Of Australia page.
  - climbing knot Among others in the Climbing Knot Dictionary
  - on Animated knots for Scouts
  - on of Forty Boy Scout Knots

- Fisherman's Loop.
  - How is the fishermans loop called in other languages?

- Flamish Eight = Eight.

- Flower knot.
  - The flower Knot. A fancy chineese knot

- Four-In-Hand Knot
  - A way to tye your tie. A page with four knots

- On a fashion site. (Same drawings as previous link!)

- The Float Stop. A knot ON a fishline.
  - The fishing knots.

- Floor Lashinhg
  - Northnet Ropeworks Clear instruction.

- French knots
  -

- Frost knots
  - BRMRG Knot Primer Good Picture on mountain site

- French Prussic
  - climbing knot Among others in the Climbing Knot Dictionary

- Frendship Knot
  - Jazzman site!

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Gallow Knot.
  - Lehigh Samson among other drawings with small description
- Girth Hitch
  - BRMRG Knot Primer Good Picture on mountain site
- Granny. Do not forget to forget this knot
  - on of Forty Boy Scout Knots
- Gordian Knot
  -

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- The Half Hitch
- Halász = Fisherman's knot= True Lovers Most common 'double-stopper' knot
  - Csomók.
  - on of Forty Boy Scout Knots
- Halyard knot
  - on of Forty Boy Scout Knots
- Half-Windsor A Tie Knot.
  - A page with four Tie knots
  -
- Hangman.
  - Lehigh Samson among other drawings with small description
  - The fishing knots. Drawn as Scaffold...
- Harvester Hitch A truckers knot.
  - Canoe Certificate Course Session 4 - Ropes & Lines
- Hedden knot.
  - On a caving page.
- Highwayman's Hitch climbing knot
  - On Climbing Knot Dictionary Among others
  - Canoe Certificate Course Session 4 - Ropes & Lines

- Hunters Bend. = Zepplin Knot
  - On the Scout Association Of Australia page.

- Huffnagle knot.
  - Tying the Huffnagle for heavy shock leaders to class tippets.

To=>I

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Improved clinch knot A fishersknot.
  -
  -
  - NautBob's Fishin' Knots between 5 other knots.
- Italian/Munter Hitch.
  -

To=>J

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J

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- The Jamming Hitch Also called the Adjusible Hitch.

- The Jansik. For connecting a hook to a fishline.
  - The fishing knots.

- Japanese Square Lashing.
  - On the Scout Association Of Australia page.

- The Josophine Knot A Macrame knot same as the Caric Bend

- Jug Sling Hitch.
  - How is the Jug Sling Hitch called in other languages?
  - Northnet Ropeworks Clear instruction.

To=>K

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K

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- King Sling A fishermans knot. Allows you to make a nutaral presentation.
  - On the fisher net.
- Kleimheist climbing knot
  - On the Climbing Knot Dictionary (Among others)
- Kreuzklem climbing knot
  - On the Climbing Knot Dictionary (Among others)

To=>L

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<=K

L

A B C D E F G H I J K L M N O P Q R S T U V W X Y
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Back To

- The Lap-Knot. Excelent 'native' knot.
- Lark's head.
  - How is the Lark's head called in other languages?
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
- Lark's Food climbing knot
  - On the Climbing Knot Dictionary (Among others)
- The Lineman's Loop = The Butterfly An Excellent loop in the middle of a rope.
- The Lobster Buoy Hitch

To=>M

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M

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Manharness Knot.
  - On the Scout Association Of Australia page.
- Marline Hitch. Also called the marling hitch
  - Knots, Bends and Hitches Between 4 other knots.
- Masthead Knot
  - Northnet Ropeworks Clear instruction.
- Mauls
  - Northnet Ropeworks Clear instruction.
- Monkey Fist. The nice knot used as ropers logo.
  - Klabautermann Knotentafel Excelent
  - Northnet Ropeworks Excelent "alternative" way.
  - Knot of the month June 97 Animanted two steps.
- Mooring Hitch
  - Northnet Ropeworks Clear instruction.
  - Northnet Ropeworks Excelent Animation
- Multiple Overhand Knot. Stopper
- Munter/Italian Hitch.

To=>N

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- The Noose.
- Nyolcas = Figure eight knot.
  - Csomók.

To=>O

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O

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Overhand knot. Stopper
  - Ropework Exelent instruction
  - insigne District award of merit van BSA. a small gif picture.
  - Library of knots. (among other drawings)
  - BRMRG Knot Primer Good Picture on mountain site
- Overhand Loop climbing knot
  - On the Climbing Knot Dictionary (Among others)
- Orvis knot A fishersknot.
  - NautBob's Fishin' Knots between 5 other knots.

To=>P

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P

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Palomar knot A fishersknot.
  - On the fisher net.
  - The fishing knots.
  - Why KNot. Fisher knots
  - NautBob's Fishin' Knots between 5 other knots.
- The Pendant-Hitch. A Knot for breas-plates and necklace's
- Pile Hitch.
  - How is the pile hitch called in other languages?
- Pizen Knot A fishersknot.
  - On flyfishing sub-page.
  - On another flyfishing sub-page.
- Pratt Knot A Tie knot
- Prussic Knot. A very important climbing knot, also written as prussik prusik prusick
  - How is the Prussick called in other languages?
  - On the Scout Association Of Australia page.
  - On the Climbing Knot Dictionary (Among others)
  - Prusik Rappel "Safety" No picture,No drawing, but a plain tekst rappel for safety.

To=>Q

Back To
<=P

Q

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

I am still looking for a knot with a Q on the web...

To=>R

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<=Q

R

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Reefknot = Square Knot.
  - Ethicon Knot Tying Manual How Surgeons Tie the reefknot.
  - How is the Reefknot called in other languages?
  - On the Scout Association Of Australia page.
  - Website Gert Animated
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - On the yachtnet. A beautyfull but large page
  - insignes van BSA. a 32k gif immage with all BSA insignes.
  - Lehigh Samson (among other drawings with small description)
  - Library of knots. (among other drawings)
  - First Aid Book.
  - Animated KnotsRequires plugin
  - NautBob's Knots4 well known copies of knots.
  - Knots, Bends and HitchesBetween 4 other knots.
  - BRMRG Knot Primer Good Picture on mountain site
- Reverse Eight noose.
- Reversed Half Hitches
- Ringbold Hitching
  - Northnet Ropeworks Clear instruction.
- Rolling Hitch. Also called the Magnus Hitch
  - Best description on the WEB of the Rolling Hitch (probably gone...)
  - On the Scout Association Of Australia page.
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated

- Library of knots. (among other drawings)
- Canoe Certificate Course Session 4 - Ropes & Lines

- Round Lashing.
  - On the Scout Association Of Australia page.

- Round Turn.
  - How is the Round Turn called in other languages?

- Round Turn and two half Hitches
  - On the Scout Association Of Australia page.
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - On the yachtnet. Beautyfull but large page.
  - Animated Knots Requires plugin

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Scaffold Knot.A Noose.
  - The fishing knots.Drawn as double marline.
- Sheep Shank.
  - On the Scout Association Of Australia page.
  - Website GertAnimated
  - Picture from http://genius.tttk.bme.hu/MuszPed/Cserk/hir1.htmlA moving gif-picture from a hongarian page. Probaly gone..
- Sheetbend.
  -
  - On the Scout Association Of Australia page.
  - On the yachtnet = Beautyfull but large page
  - climbing knot Among others in the Climbing Knot Dictionary
  - Lehigh Samson (among other drawings with small description
  - Library of knots. (among other drawings)
  - Website GertAnimated
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - Animated Knots Requires plugin
  - Canoe Certificate Course Session 4 - Ropes & Lines
  - NautBob's Knots 4 well known copies of knots.
  - Northnet Ropeworks Clear instruction.
- (Tucked) Sheetbend.
  - The fishing knots.
- Single Hitch

- Simple Noose.
- Snelling Knot.
  - The fishing knots.Snelling a hook
  - Fisherman's Knots A page on 7 knots
- Spanish Windlass
  - Northnet Ropeworks Clear instruction.
- Spider hitch.A fishing knot
  - Why KNot. Fisher knots
- Square Lashing.
  - Ropework Exelent instruction
  - On the Scout Association Of Australia page.
- Square Knot = Reef Knot.
- Strangle Knot.
- Strangle-snare.
- Srugeon Knot.(Realy used by surgeons!)
  - USSC Sutures -- Knot Tying -- TOC Best site on the Surgeon Knot.(How can I improve this??)
  - Ethicon Knot Tying Manual How surgeons tie it..
  - Lehigh Samson (among other drawings with small description)
  - The fishing knots.
  - Why KNot. Fisher knots
- Srugeon End Loop.
  - The fishing knots.
- The Swivel Knot.For attatching a swivel to a fishline.
  - The fishing knots.

To=>T

Back To
<=S

T

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Takács~ = Reefknot = Square Knot.
  - Csomók.
- Tape KnotClimbing knot
  - On the Climbing Knot Dictionary (Among others)
- The Tautline Hitch Alse called the Midshipmans Hitch
  - Animated Knots Requires plugin
  - Northnet Ropeworks Clear instruction.
- The Thief knot
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
- Timber Hitch.
  - How is the Timber Hitch called in other languages?
  - Website Gert Animated
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - Lehigh Samson (among other drawings with small description)
  - Library of knots. (among other drawings)
  - Animated Knots Requires plugin
- Toldó1~ = Carrick Bend. The nearest thing er have to the perfect bend. Also called the Josephine Knot when used in macrame.
  - Csomók.
- The Transom knot A perfect cross knot for your kite.

- True Lovers = Fisherman's knot/bend
- Trilene KnotA fishersknot.
  - NautBob's Fishin' Knots between 5 other knots.
- Truckers Hitch
  - Canoe Certificate Course Session 4 - Ropes & Lines
- Thief Knot Sailors sequrity bend
- TRIPOD LASHING
  - Northnet Ropeworks Clear instruction.

- Two Half Hitches
  - Library of knots. (among other drawings)
  - Knotty Knots Outdoorsman Activity Badge

- The Turks Head Knot. Or Woggle
  - Northnet Ropeworks Plain
  - Northnet Ropeworks Animated

- The Turle.
  - The fishing knots.

To=>U

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<=T

U

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Uni-Knot An All purpose fishersknot.
  - On the Fisher net.
  - The fishing knots.
  - Why KNot. Fisher knots

To=>V

Back To
<=U

V

A B C D E F G H I J K L M N O P Q R S T U V W X Y
Z

Back To

I have not found a knot with a v on the web yet...

To=>W

Back To
<=V

W

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Water Knot.
  - How is the Water Knot called in other languages?
  - BRMRG Knot Primer Good Picture on mountain site
- What Knot A trick knot.
- The Weaver-EightThe waevers 'heavline knot'.
  The best weavers knot I know.
- The Weaver Knot The waevers 'sheetbend'.
  The most common weavers knot.
- Whipping.
  - How is the Whipping called in other languages?
  - On the Scout Association Of Australia page.
  - Northnet Ropeworks Clear instruction.
- Woggle.
  - 41 steps over 4 pages. Clear instructions on how te make a woggle.
- Windsor Knot
  - A way to tye your tie. A page with four Tie knots
  - Hoe knoop je je stropdas. Een Nederlandse Stropdas pagina.

To=>X

Back To
<=W

X

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

I have not found a knot with an X on the web yet...

To=>Y

Back To
<=X

Y

A B C D E F G H I J K L M N O P Q R S T U V W X Y
Z

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- Yosemite Bowline.
  - On a caving page. Link probaly lost...

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- Zászló~ = Sheetbend.
  - Csomók.
- Zeplin knot. by exident also called the Hunters bend
  - On the Scout Association Of Australia page.

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Ropers Knot Page

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Stoppers ( )

Knots on the end.

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Knots on the end of a rope or yarn. There are a lot of situations where you need a knot like this. Every application has its own special demands for knot properties. So you have to choose carefully. You can use a stopper to prevent a rope or yarn from unfolding, but please do that only in cheap rope/yarn. Use a proper whipping in all other cases.

The Overhand Knot

The Overhand Knot or Half Knot

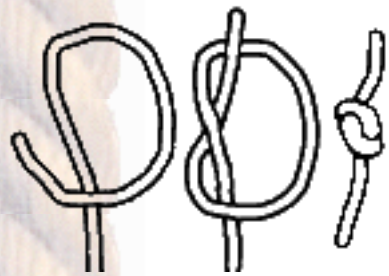

This is the simplest knot. Therefore probably the most used. The knot is very useful to support knots in yarns. The loose ends become a bit thicker. When this support makes the total bend too bulky you have to look for another bend. The overhand knot is not strong, so it is not used in situations where you might expect great force. It also reduces the strength of the rope or yarn by about 50%. But as an "anti-slip-knot" it does not have to withstand a lot.

This knot on the WEB.

The Double Overhandknot

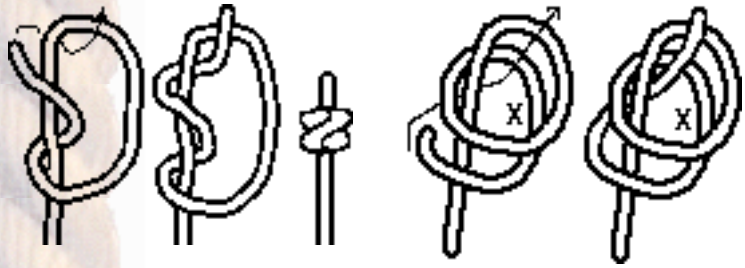

The double overhand knot is beautiful, thicker than the common overhand knot, but not any stronger. But use it with caution. The double overhand knot is also called the bloodknot when it is used at the end of a whip. This knot has several ways of tying and in principle two ways of working up. Both ways of tying shown here also show both results. The bloodknot shown in the middle is the preferred way of working up the second way of tying marked with the crosses. The bloodknot is very hard to untie after it has been under stress. If you put an object through the cross-marked hole the knot will work up as the strangleknot. It is usefull to practice this way.

This knot on the WEB.

the Multifold-Overhand-knot

If you make more than two turns in the overhand knot it wil be fatter. (But hardly stronger.) In twined rope it is important to work up the knot very carefully. (It will not only look neater, it wil prevent 'kinking' which will weaken the rope even more!)
This knot on the WEB.

The (Flemish) Eight

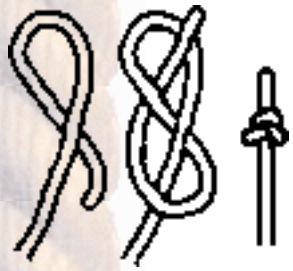

This knot is larger, stronger and more easy to untie than the overhand knot. It does not harm your rope as much as the overhand knot does. So therefore sailors use this knot in most cases. (! not for bend support, where the smaller overhand is used, or in rope, a permanent small stopper)
This knot on the WEB.

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Bends ( )

To 'unite' two ropes.

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The reef-knot

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The reef-knot is only useful in simple applications. Ashley says "it is a true Binder Knot, for which it is admirable, but under no circumstances should it be used as a bend." It is easy tied and will not jam, so it is always easy to untie. It is used to tie packages, and as a base for he shoe-bow. Sailors used it for binding rolled sails or better reefed sails. And that is where it got its english name from. Americans call it the square knot. Probably because it looks square, or because it was much used on square-rigged-ships, but that is a total guess of me.
Its relatives, the granny, the thief-knot and the what-knot all have their purposes, but not as a trustful knot.
For more information on the reef-knot-family you may visit the Reef-knot Family.

The Sheet Bend

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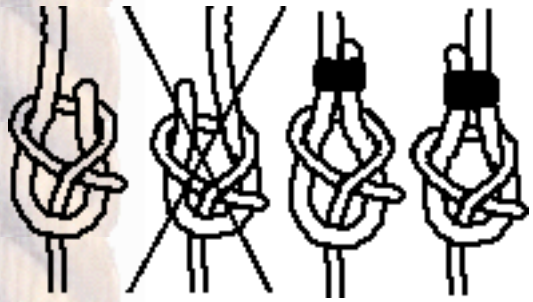

The sheet bend is my favorite bend. Be careful. With the loose end on the wrong side you have an other, weaker knot (Left-hand sheetbend). If the knot is well seized it does not matter if it is tied right or left handed
For more information on the reef-knot-family you may visit the Sheetbend Family.

The Carrick Bend / The Josephine Knot

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Also known as Full carrick Bend, Sailor's Knot and Anchor Bend. Beware! There are not many knots with so much wrong drawings as this bend. The ends have to be on opposite sites and the crossings always are alternating up/down/up/down... The Carrick Bend is one of the best knots. Ashley states it is possible the nearest thing we have to a perfect bend. It does not easily slip, not even if the rope is wet. And it is always easy to untie, also after a heavy load. If used as a Hawser bend in heavy material it is always seized and parceled to save wear.

The Josephine Knot

In the Macrame this knot is called the Josephine Knot. It is self evident the Josephine knot is not seized nor pulled tight.

The True Lovers or Fishermans's Knot

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The True Lovers, or Fisherman's Knot may be laid in two different ways. Which of both the is the stronger, I do not know.
With two equal overhandknots it is symmetrical. This is probably the most used variant.

With two different overhand knots you get the most beautiful version (always work it up neatly!)
Only ... The double eight is stronger, easier to untie after use and as decorative from all sides as the true lovers at best.

The Weavers-Eight

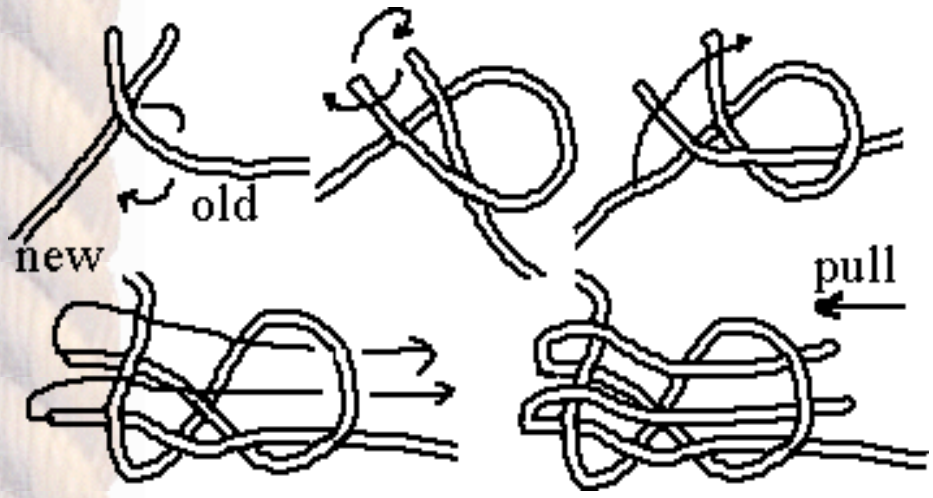

This is the best weaver knot I know. Although it looks difficult to tie, it is actually very easy. Fast to tie with small material, and reliable for wool, linen and most other weaver materials. Because both loose ends fall back over the standing part, it has an almost perfect lead.
Hold both threads together on the crossing between your thumb and finger. (first drawing)
Twist both threads together while you hold the cross in two simple movements. (first/Second drawing)
Now, you pull over the standing part of the line you tie on, (third drawing)
And put both loose ends over the line you tie on through the loop you just created.
Now let loose the cross and hold the loose ends fixed to the standing part of the line you tie with and pull the knot tight.
This knot is related with The (Flemish) Eight. You can observe this by removing the thread you tied the knot with, leaving the thread you tied the knot on unchanged. If you have difficulties in learning this knot, you can start by practicing the flemish eight in the thread you want to tie on, using an imaginary thread to tie with.

For the other direction

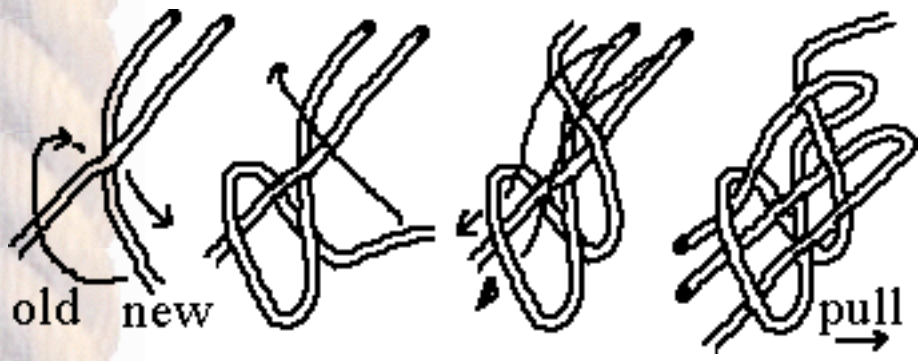

A weaver on a traditional weaving loom never knows in advance in what direction the next line has to be tied. Therefore he has to know two ways of tying the weaver knot. One for each direction. This is the same Weavers-Eight but tied different. Tied this way the knot points to the other direction.

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Knots to tie a rope on ... something.

'Elementery' Hitches

In this table you find the most elementary hitches. The hitches in each column are closely related. The top hitch is tied round a pole or other object. I will refer to them as primary-elementary Hitches. The hitches there under are 'the same' but tied round the standing part of the rope. I will refer to them as secondary-elementary Hitches. But beware, the application of the variants are very different. The primary-elementary Hitches will spill if the object is removed. The secondary-elementary hitches will not. Some of the secondary-elementary hitches are 'capsized' bindery knots. As for all knots working the knot well is for these knots extremely important. Work it wrong and you might end up with another (probably unwanted) knot. For example, capsizing the two half hitches might end up in a granny knot, one of the worst of all knots. On the other hand if you know what you are doing, you might tie the wrong knot on purpose and capsize it to the hitch you want. Take care!

Single Simple

Clove

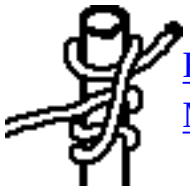
Rolling Magnus

Cow

Half

Two Half

Midshipmans Tautline

Reversed Half

Buntline

Adjustable Jamming

Lobster Buoy

The Single Hitch

(also called **The Simple Hitch**)

Although this is probably the simplest knot of all, you have to be a skilled knot-tyer to know how to tye and use it in a safe way. The loose end of the rope is nipped against the object and the standing part. The best nip is obtained against an edge or shoulder. If the load is released and the standing part shaken, the hitch is spilled instantly.

It is used to attatch rope to a belay-pin, a weaver needle or even to a tree branch, to start belaying, to start winding or as a temporary easy to spill made-fast.
The Single Hitch on the WEB.

The Half Hitch

This is the capsized overhand knot. It is very useful to carry light loads which have to be removed easily. Ashley recommends it to use it for hanging store to out of reach for mice. It should not be disturbed.
The Half Hitch on the WEB.

The Clove Hitch

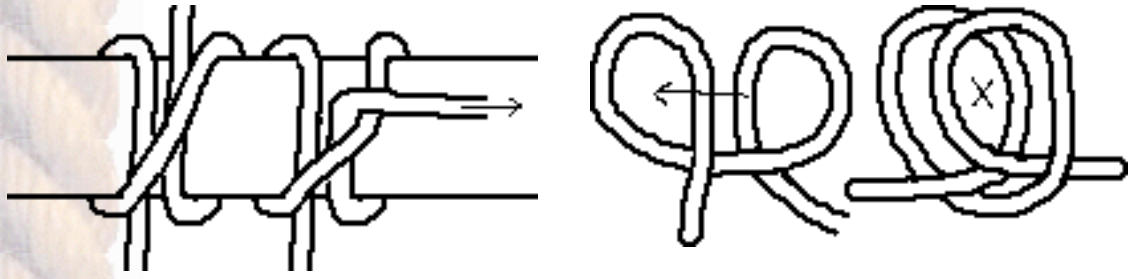

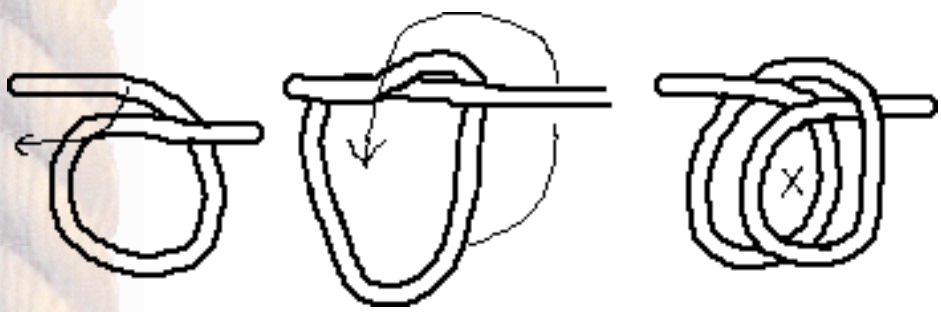

This is a very important knot of only theoretical value. Without extra support, it is untrustworthy in any situation, except as a crossing knot. You have to learn it for scouting and at sailing schools. If you have to use it, work it up properly; pull length-wise only at both ends before you load the working end. It is better to use The Rolling Hitch instead.

The Clove Hitch on the WEB.

Two Half Hitches

The two half hitches is used for tieing a rope with a right-angle pull to a pole or ring. It should be constant under load. (Not under constant load). It does not jam. If the object you tye it on has a small diameter it is better to use the "Round Turn with Two Half Hitches". This is the same knot but with an extra turn round the object.

The Two Half Hitches on the WEB.

Buntline Hitch

The Buntline Hitch is (was) used to tie a buntline to a square sail. It is a secure knot, but it tends to jam, so it is not easy to untie. Therefore, it is useful for work that will be left unattended for longer periods, since it will not untie suddenly.

The Buntline Hitch on the WEB.

The Rolling Hitch or Magnus and Magner's Hitch

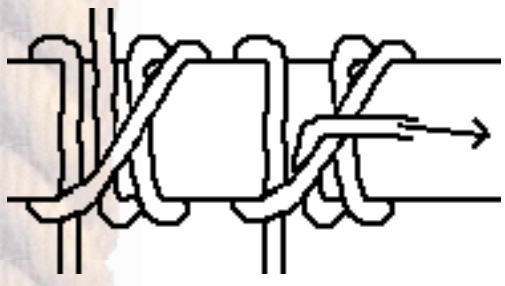

The best simple hitch for lengthwise pull. It needs to be laid very carefully and pulled firmly before loading. Never use it for right angle pull, for it will spill.
The Rolling Hitch on the WEB.

Midshipmans Hitch Or Tautline Hitch

This is a remarkably useful knot. It is adjustable AND trustworthy.
Each sailor should know how to tye this knot in any circumstance. Especially to tye himself to a rescue rope thrown to him in the water. On the lifeline he has to hold the loose end securely to the standing part. This gives a good grip and a useful goal in this critical situation (HOLD!)
Anyone who uses a tent should know this knot. It is the best way to adjust your lines to the tent-poles.
It is the most simple of the adjustable knot family.
The Tautline Hitch on the WEB.

Adjusible or Jamming Hitch

This brother of the midshipmans Hitch is just a bit less important. This is because it tends to jam. When jamming is desirable, this knot is o.k., as when work will be left unattended. Ashley states it was used by cotton brokers in New Bedford to tye their cotton samples they took from mill to mill. The packages could be opened and closed at will, and still be secure when left alone at travel.
The Adjusible or Jamming Hitch on the WEB.

The Cow Hitch

This hitch is really useful for tieing a cow to a pole so it can graze round it. I myself would add an overhand knot at the loose end as a stopper. But I am not a farmer. Sailors use it to secure a lanyard to a shroud.
The Cow Hitch on the WEB.

Reversed Half Hitches

This knot is used to tye guy-ropes to tent-poles. But is is inferior to the Tautline Hitch The only reason I have included it in the elementary hitches is because its topology places it there. I see no use for it. (Please let me know if you know an application where this knot is the best knot to use.) A keen eye will recognize a capsized Reefknot in it.
The Reversed Half Hitches on the WEB.

Lobster Buoy Hitch

The Lobster Buoy Hitch is almost as secure as the Buntline Hitch, but more easy to untie. It is used to tie timber.
The Reversed Half Hitches on the WEB.

Marline Hitch or Single Hitch

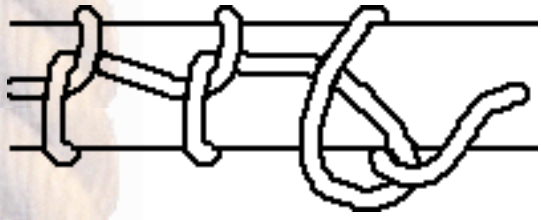

This hitch is very practical to lash long objects. The working end needs only one tug and will not slip easy. Before the 'tiewrap' (or how are they called) this hitch was used by electrical engineers to tye 'wiring-trees' A row marlshitches is best started en ended with a double marlshitch.

The Marline Hitch on the WEB.

The Strangle Knot or Double Marline Hitch

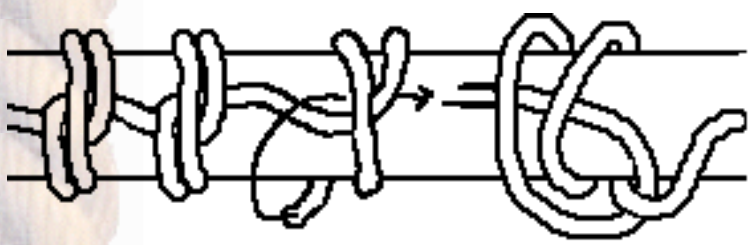

The strangle knot is important as temporary whiping and as permanent binding from which you need more in line. Laid well it is virtually impossible to untie without tools (needle or knife). So never use it if you need to untie. Used as marlhitch it is best used as first and last in a row. Or when a row becomes 'dangerously' long this hitch is used as ensurance between shorter rows.
Be careful!. Tied in this way the working end (or the bundle) needs only one tug, but it is not enoug to pull once, it needs to be worked up properly!
The Strangle Knot on the WEB.

The Constrictor Hitch

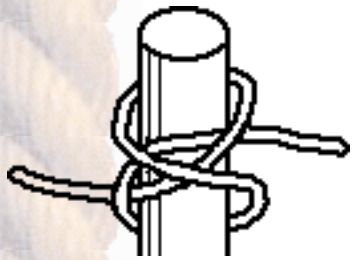

The constrictor knot is important as temporary whipping and as permanent binding from which you need more than one in a row, but not in line (when you should use the strangle knot). Laid well, it is virtually impossible to untie without tools (needle or knife). Never use it if you need to untie it. It is almost the strongest among the 'simple' hitches. Only the double constrictor is stronger. Because the constrictor may be tied in a bight, it is often preferred over the strangle knot.
For more information on the constrictor-knot-family you may visit the Constrictor-knot Family.

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The Bowline

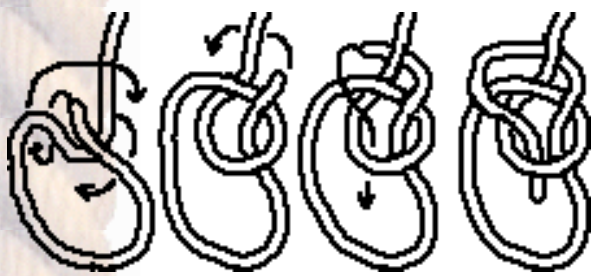

The Bowline Knot is one of the most used loop knots. This variant is most used in the world. Probably due to its simplicity, security, and its relationship with the Sheet bend. Keep the cross point in step A between a finger and thumb and make a clock-wise turn with your wrist. Without the loop in between, it is the same knot.
If the loop is expected to be heavily loaded, the bowline is, in fact, not secure enough. There is a rule of thumb which states that the loose end should be as long as 12 times the circumference for the sake of safety.

The Bowline
"Lay the bight to make a hole
Then under the back and around the pole
Over the top and thru the eye
Cinch it tight and let it lie"

The Dutch Marine Bowline / or The Cowboy Bowline

The Dutch Navy uses this variant of the bowline. And, of course, the Dutch sailor says this one is superior. The working end is not so easy pushed back by accident, they say. I think it is just a difference in culture.
There is a rule of thumb which states that the loose end should be as long as 12 times the circumference for the sake of safety.

Double Figure-of-eight loop.

The double eight is a knot used by climbers. It is easy to tie and safer as the bowline. There is a discussion whether there should be a stopper at the end of the loose end or not. Speed of (un)tying is a safety factor itself.
The first way of tying is equal to the way of tying the flamish eight, but now in a double rope. The 'loose-end' is the loop. This way is only applicable when the loop is 'empty' during tying.

If the loop is to be tied round something (round "your waist" for instance) you first tie an eight then lay the loop and double the eight. It is important to have enough rope for the loop. It requires experience, so start practicing.
The Double Figure-of-eight loop on the WEB.

The Bowstring Knot

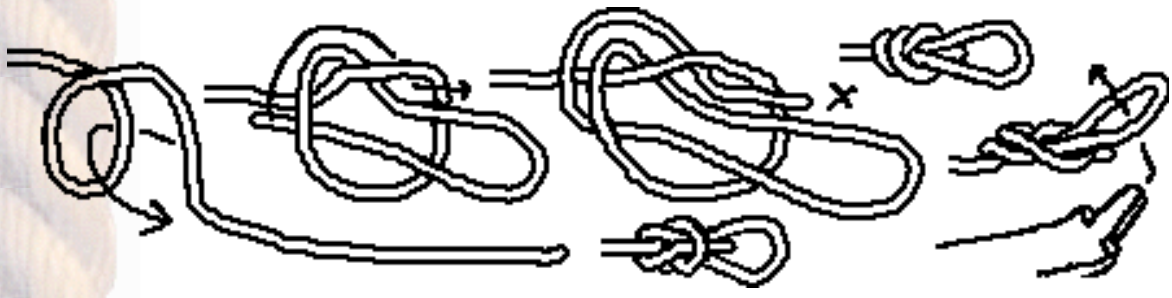

The Bowstring Knot is an ancient knot that is used as an eye for bowstrings. The knot is simple and strong. Once tied and pulled firmly, you do not want to untie it: you might call it a good 'tie-once' loop knot.
The bowstring knot is appreciated because it is small, strong, secure, and easy to tie. It's neat because it does not have loose ends.
Modern archers prefer fixed spliced loops.
If the loose (cross marked) end is not secured within the loop between the bow and loop, it is wise to add a small overhand knot as stopper.
The Bowstring Knot on the WEB.

The Tucked Double Overhand

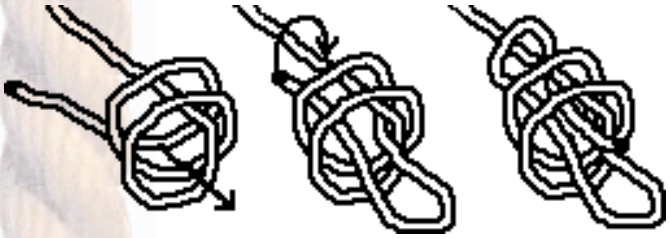

If you need a good looking and strong loop this is a good candidate. The Loose end must be at least two to three rope diameters long. But if you make the loose end inflexible with for instance glue, resch or by melting and you can hide it almost completely inside the two round turns. The "tucked double overhand" is a permanent loop. It jams badly, but that´s what it is made for.

The Butterfly or Lineman's Loop

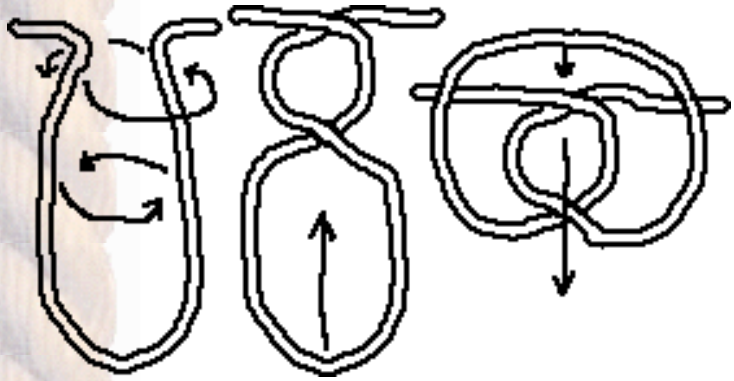

An excellent easy to tie loop for applications needing a loop in another place than the rope-end, but somewhere in the middle. It has an excellent lead, and is secure even if the forces on both ends are stronger than the load in the loop.
The Butterfly loop on the WEB.

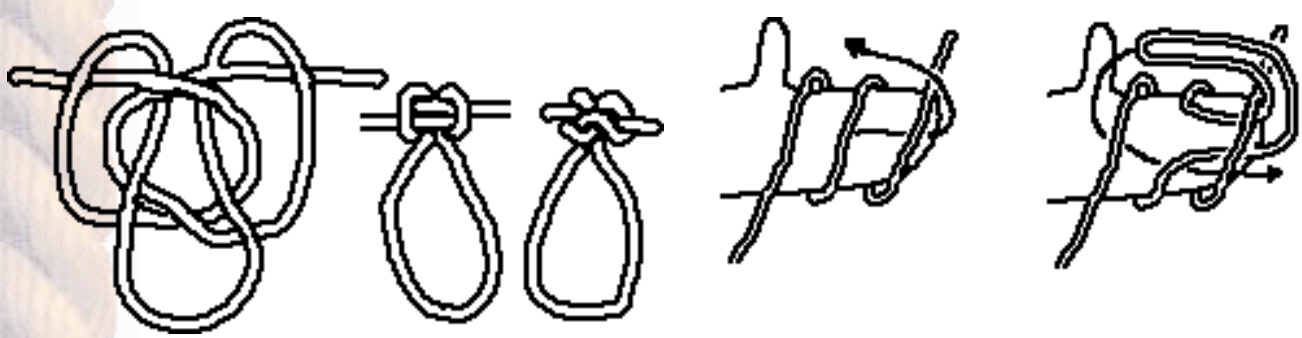

The Artillery Loop

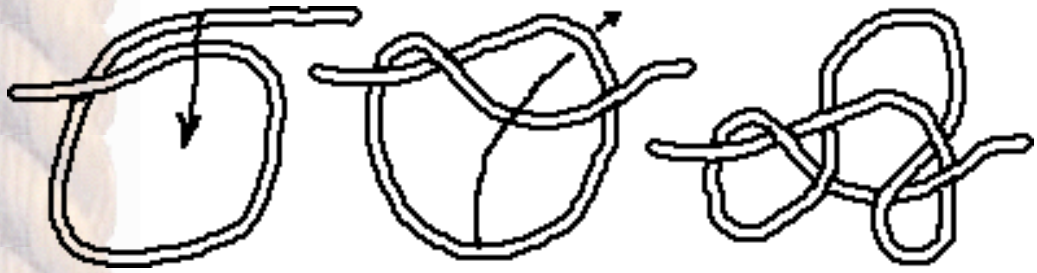

A practical and easy to tie loop for applications needing a loop in another place than the rope-end but somewhere in the middle. It is not as strong as the butterfly but is a bit faster to tie and untie. As the name already suggests it was used by the artillery (for carrying their guns over the shoulder.) Do not pull the rope too hard when the loop is not loaded. It is best used as temporary knot for carrying things. As always, work up the knot neatly!

The Artillery loop on the WEB.

The Pendant Hitch

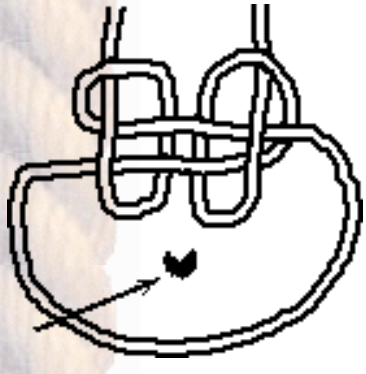

A hitch to tie a pebble or a breastplate to a necklace. You have to make sure the object is secured in the loop. If you use a loop (this loop) to tie a pebble or other nice stone to a neck loop without extra (visible) support it is wise to use a leather neck loop. Make a cut in the length of the inside of the loop. Not too deep; it is only to roughen the surface to improve the grip of the knot. And last but not least..... use a good shoemakers glue. The result is surprising.
The pendant hitch is closely related to the The True Lovers or Fisherman's Knot.

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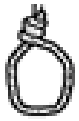

The Noose

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The Loops

The Noose ( )

Nooses, snares and lasso's.

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Ropers Knot Page

The Noose in General

WARNING!! The noose is not a knot to play hangman with. Too many accidents already killed children who thought they could release it in time. Even not strong pulled nooses can be dangerous round your neck.

There are three basic ways to make a noose. The first way is running the 'tail' of rope through a fixed loop on the end of that same rope. This may be a spliced-loop or a knotted-loop like the bowline. (In fact the bowline is used very often as the running loop by sailors.) The simple noose itself is used as a running knot for swift running loops.

The second way to make a noose is to tie a running knot (a simple knot or hitch) round the standing part of the rope in a way that pulling on the knot-side closes the loop. This is the most common way for making nooses. It makes the loop to close almost as easy as a noose using a fixed loop as a running knot.

The third way is to tie a running knot in a way that pulling the knot is opening the loop. I only know one practical application for this way of tieing this noose: for tying the rope to a yo yo, with the eight as running knot. But in packing bags and loads you will find it sometimes as an intermediate loop. It is also often the result of tying the running knot the wrong way.
The noose on the WEB.

The Simple Noose

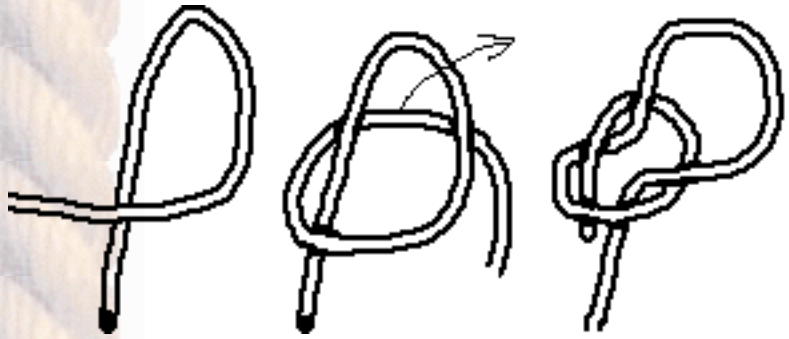

This is the simplest of the nooses. Its used mostly as a base for further work. It is a close relative of the overhand-knot and the Marline Hitch or Single Hitch If used as noose it is best to add an overhand-knot in the end. This noose is used as a poor snare for catching small birds.
The noose on the WEB.

The Strangle-Snare

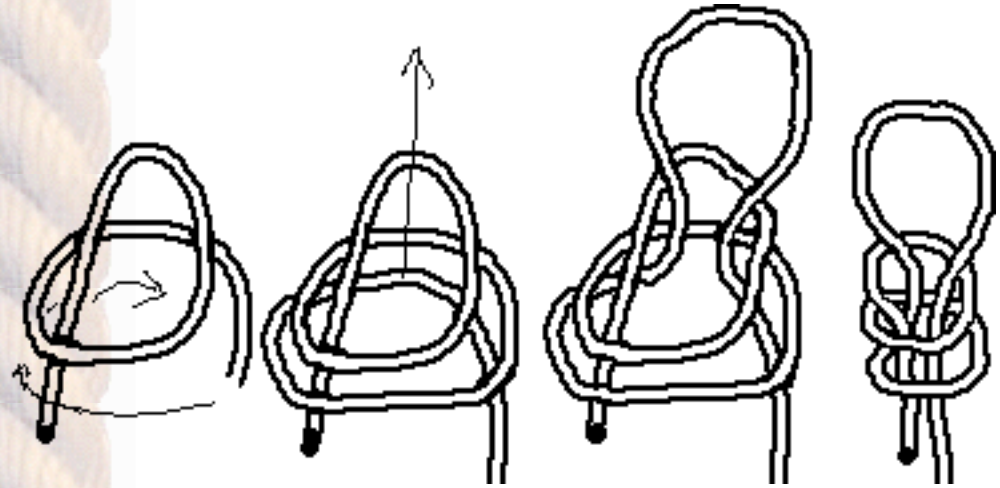

The strangle-knot is an excellent knot to be used a running knot for a snare. The pull is easy adjustable. The more force is applied from inside the loop the more firmly the running knot prevents opening of the loop.
The Strangle-Snare on the WEB.

The Scaffold knot or Gallows Knot.

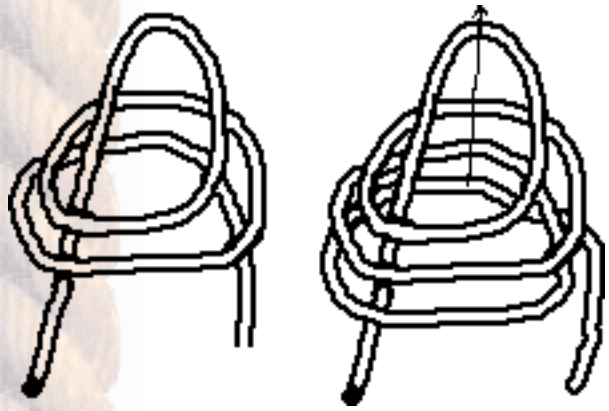

The third noose is based on the the Multifold-Overhand-knot.
As its second name already suggests it has a dark history.
It is also used as a knot to tie angling-rods to fishline.

Never play hangman. It can really kill.
The Scaffold knot or Gallows Knot the WEB.

The Hangman's Knot.

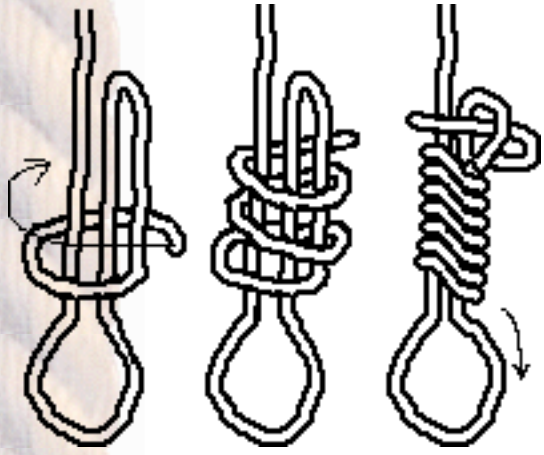

This knot is used for the gallows-tree as well. The force to close it is adjusted better than with the gallows knot. And because it is bigger in the neck it is believed to break the neck more easy. That would make it more mercy-full as the gallows-knot which kills by strangeling.
The Hangman is also used as a knot to tie angles to fishline.

Never play hangman. It can really kill.
The Hangman's Knot the WEB.

The Reverse Eight-noose.

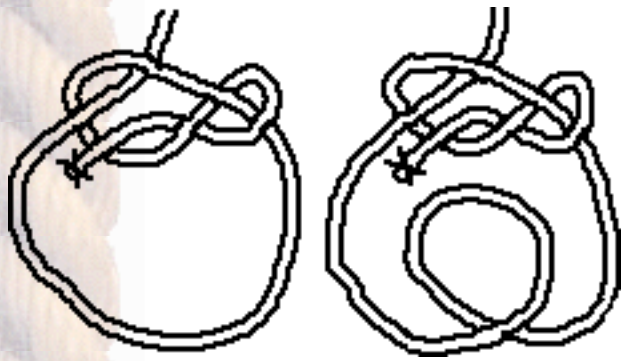

This is (so far) the only 'wrong' running noose I know applications for. It to tie a package and ... for tieing YoYo's. Experts use one loop to make it possible to let the yoyo spin on the end and to call it up with a little firm pull. The yoyo has to spin fast and the noose has to be trimmed carefully. Starters use two loops and tie it firmly.
Use eventually an overhand-knot on the cross-marked ends. (This is not the best way to fasten your YoYo. If you want to use the best thechnique you have to un-twine a line with two yarns and re-twine one of the yarns by doubling it with the YoYo in the middle. Free-spinning the YoYo my wear out the loop.) The Reverse Eight-noose the WEB.

Any comment, suggestions, anything mail me: ***qqqq at realknots.com*** *with subject "**question**"*
All mail without thr right subject is flussed unred. automaticly.
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The Noose

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FAK

frequently Asked Knots.

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Ropers Knot Page

Following knots were asked for very often last year. For frequently asked questions on knots also try: rec.crafts.knots FAQ
This page is more or less made to publish these "FAQ-knots" so I can add them in the knot index.

The Monkey Fist

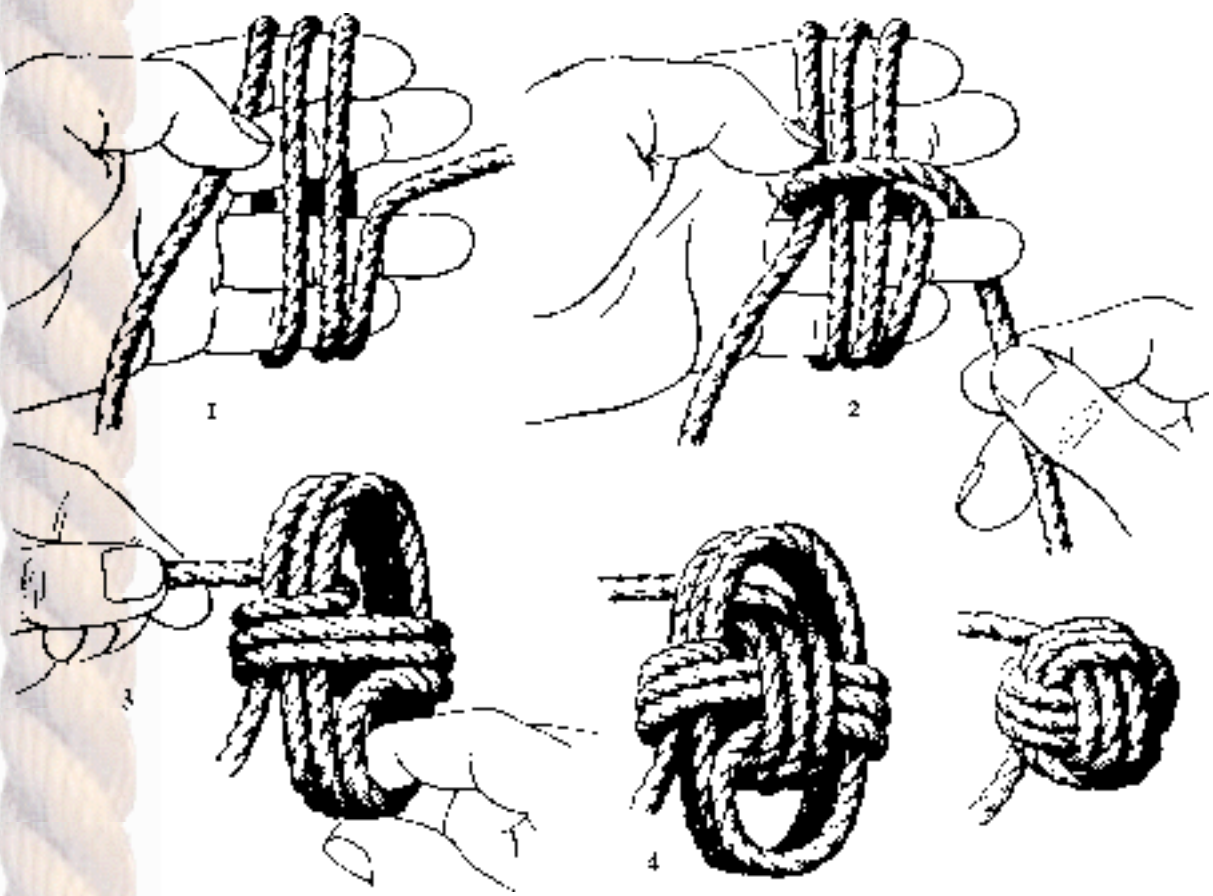

The Monkey Fist is used as an end knot for a heaving line. A heaving line is a line used for throwing from one location to another. This enables a larger line that could not be thrown over the distance to be pulled over. The most common use of a heaving line is at sea, to pull a cable to shore from a ship. A cable is not easily thrown over a distance of 10m [ft]or more, so instead one throws a heaving line. The line is tied to the cable and when it has been received the cable can then be pulled over. To make it easier to throw one needs to connect a weight on the end of the line - usually a stone, lead-ball or a small bag of sand is connected to the end. Better still a small rope ball is tied on the end. It is neat, it will endure many tosses

last long and it is easily thrown. That is what the monkey fist is was originally used for. Now it is also used as fancy knot for key-rings, necklaces and so on. The knot can be done with or without a central core (i.e. a round stone or ball bearing) to add extra weight but it is recommended to use extra loops depending on the size of the object.

The instruction drawing is made by Hervey Garrett Smith and copied from the dutch translation of his book **"The Marlinespike Sailor".** I got permission of "International Marine/Ragged Mountain Press" to use the instruction drawing on my site.
(I got 3 to 5 requests a week for this knot. That is why I am sure it is most wanted.)

The Dolly

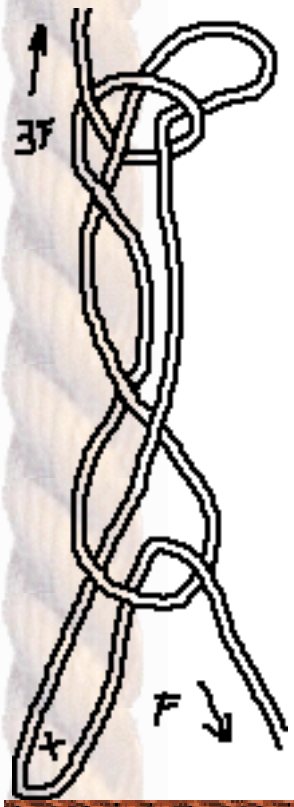

This is probably the most famous truckers knot. I never realized it was so wanted. I got 2 to 4 requests per month for it.

You need to hook in the cross marked place. The force F you apply at the loose end is multiplied by (almost) 3 on the standing part. You may say it is only a rope tackle. Beware, it wears out your precious rope fast, so if you use it often it is wise to use a form of protection in the bight where the loose end is pulled through. A folded paper will do, a smooth piece of leather is much better.

I do not have experience with this knot myself. But I have been told it will hold as long as the force is applied. And because that is also the case with its closest relative, the sheep shank, I think it will.

Any comment, suggestions, anything mail me: ***qqqq at realknots.com*** *with subject "**question**"*
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Ropers Knots Page

The knot site on real knots in rope.

What are the recent changes of the Roper Site ??

The Web Knot index

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

The Roper's Knot Pages

Ropers Knot Page The English 'root' of this knot-site.

Touwslagers knopen pagina De Nederlandse 'root' van deze site.

The WEB's Knot Index (All the knots I found on the web)

Books on Knots on the Web
Reverse Links Links To Pages with links to Roper's Page's

International Guild Of Knot Tyers

The International Guild of Knot Tyers
Texas Branch
North American Branch

Other Knot (link) pages.

Klabautermann Knotentafel
Frequently Asked Questions
Knot KnowledgePhoto-Illustrations
Knot Knotes Great site, Knots and links.
Knots on the Web (Peter Suber) An other (GOOD) site.
Differently orderd than this one.
The Art of Knot Tying
RopeCraft
The Argus Clearinghouse Knots (vanity) Peter and me.
Knot Tying Resources
FUN WITH KNOTS
Knopar på svenska och engelska

Knots in Rope

FM 5-125, Rigging Great site, but o so large, Not always "on line".
Get Knotted! Animated Knots for Scouts 42nd BRIGHTON (Saltdean)
Six Exploding Knots. Fast untieing slipknots.
Some useful knots mpeg! 4 'movies' three ok, the sheetbend wrong.
Lehigh Samson (among other drawings with small description)
S.A.Kids knots Requires netscape 3.0 with plugin.
Ropeworks Clear instructions, A sample taste of a book.
Marlinspike Knot of the Month A new knot each month
The BRMRG knot review

Josella's 2. HomePage A few great knot pictures.
Välkommen till Monicas Hemsida Knopar och Macrame. 4 great pictures.
Marlinspike Knot of the Month Animated. b u t s__l__o__w.
Programs Knots Examples of knot instruction programs.
Knot Some nice drawn interweaved knots.
Troop 480 knots Lots of Knots, indexed by name an use.

Sailing

Baidarka Instruction Manual Halfway the document a pipe lashing.
Nós de Marinheiro
Marine news: Knots 7 sailors knot
Boating knots 4 essential well known knots.

Scouting

Australian Scouts- Index of Knots
Index to Troop 24 Graphic Images
Canoe Certificate Course Redcliffe Scout District
Knots, Bends and Hitches Instruction on 4 knots.
Knots From a BSA group
Canoe Certificate Course session 4, Ropes and Lines

Fishing

Fishing Knots A great sample of important knots.
Useful Knots.
Dave Whitlock-- Knots: Putting it All Together
Fishing Knots Grant's Guide - by Ern Grant
Fishing In Early Medieval Times A bit of history.
Knots Good fish knots

Climbing And Caving

The Alpine Butterfly With an animated gif
The Prusik Knot
Caving Knots [More Like This]

Math.

The KnotPlot Site An entry to wonderfull pictures.
Tie me up, tie me down Great site.
Knots and Braids (and) Links a math index to other sites
The Knot Square
Knot--from Eric Weisstein's World of Mathematics
Pictures from knots and links
Math art gallery
A math page
Flaming Pear:Products:KnotAdvertizing page for a knotdrawing program
Design Any Knot from DNA A trefoil knot

Celtic Knots

Celtic Knot Construction#1
Computer Drawn Celtic Knotwork
Celtic Knot Puzzle This knot's not right, fix it!
Celtic Design Series A Home page on Celtic knots.
Celtic Knots A Celtic Knot Home Page.

Knot Art

Chineese Knotting Some Fancy knots
No Title Some Artistic knots
Not Knot A light sculpture by Scott Kim
Fair Winds design Woven Jewelry - Turksheads - Celtic Knots
Hand-crafted Knot Jewelry: Decorative Marlingspike Seamanship.
Art of Braiding Beautiful pictures of braiding work.

Poetry

Single Carrick Bend A poem on this famous knot.

The Tie

Marvin Minsky Rope Tie How to Tie A Tie
MBA Style magazine Realy a Tie of rope
The world headquarters for ties...X
Tie Yourself in Knots More than only tie knots.

Div.

Forensic Knot Analysis
The Sword Knot Collection
Gimp YES! a site on fancy knotting!!
Amaze Your Frends A 'magic' trick
Teach yourself knots and splices. A 60 minutes video.
Riggers Page
Splicing a Rope on a 30 hour Longcase Clock Splicing woven rope
How to Count Rug Knots.... Tapis/carpet knots
Types of Knots
The ins and outs of shoelace tying!
The Better Bow
Ian Fieggen's Site: How to tie an "Ian Knot"

About knots.(texts)

Knot So Fast. A proposal for regulating the world knot tying speed record.
Knots, Bends, and Hitches A great tekst on knots.

Knot Shops

MARLINESPIKE, LTD

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Knots&Splices I can not beat this excellent list!
Series on Knots and Everything is a book series polarized around the theory of knots.
Celtci Bibbliography

The Ashley Book of Knots

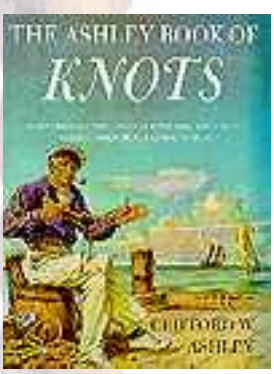

By: Clifford W. Ashley

Publisher: Faber and Faber, London & Boston.

ISBN: 0-385-04025-4

The book on knots. About 3800 different knots, 7000 drawings. It covers almost every practical knot and gives clear instructions on how to tie them. It gives some history from the knots and tells you where the author found them.

The Basic Essentials of KNOTS FOR THE OUTDOORS

By: Cliff Jacobson

Online Sports

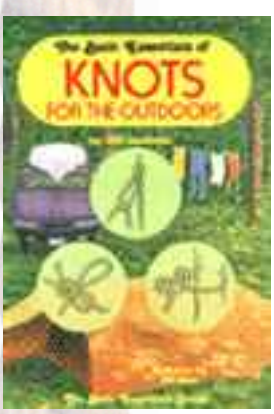

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Publisher: ICS Books

ISBN: 0-934802-57-2

Is unusual, if not unique, in having knot-tying instructions for lefthanders as well as righthanders. Table Of Contents

The Book of Outdoor Knots

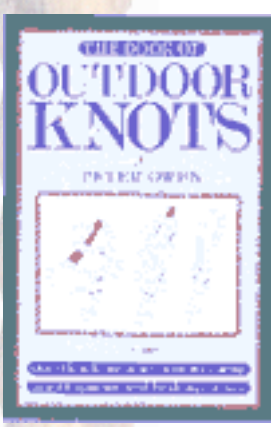

By: Owen, Peter

Publisher: Lyons & Burford

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The Adventurous Traveler Bookstore

ISBN: 1-55821-225-6

This book illustrates in a simple handbook format seventy of the most common knots for the outdoors.
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Celtic Ropework

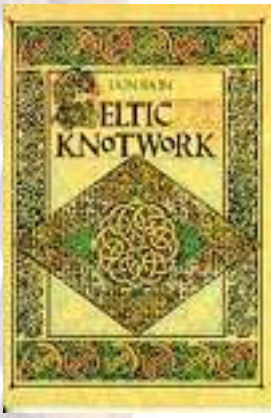

By: Iain Bain

Publisher: Sterling Publishing Co., Inc., New York

Danno's Celtic Site

ISBN: 0-8069-8638-7

The Essential Knot Book

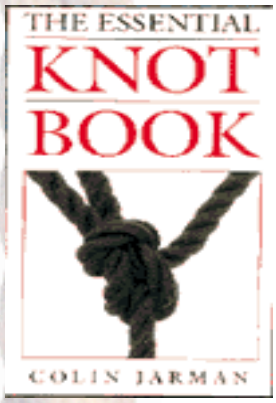

By: Colin Jarman

Publisher: International Marine/Ragged Mountain Press, A Division of the McGraw-Hill Companies

Red Sky at Night

ISBN: 0-87742-221-4

Here are the 43 most important knots and splices you need to use aboard your boat.

History and Science of Knots

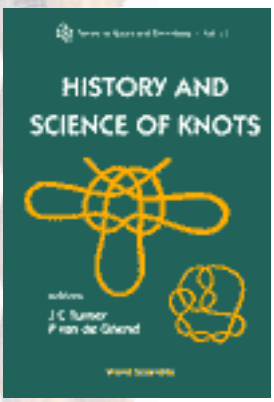

By: J C Turner & P van de Griend

Publisher: World Scientific

singnet
Series on Knots and Everything, Volume 11

ISBN: 981-02-2469-9

This book brings together twenty essays on various topics in the history and science of knots. It is divided into five parts, which deal respectively with knots in prehistory and antiquity, non-European traditions, working knots, the developing science of knots, and decorative and other aspects of knots.

How to Rock Climb, Knots for Climbers

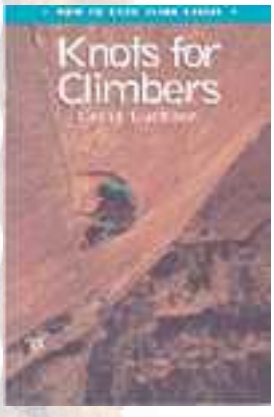

By: Luebben, Craig

Publisher: Chockstone Press

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Mountain Zone Bookstore

ISBN: 0-934641-58-7

This book is from the popular series on How to Rock Climb. In this book you will find detailed information with illustrations on the most popular knots used by rock climbers. A chapter in the book is also devoted to some of the equipment used by rock climbers. Table Of Contents

The Klutz Book of Knots

By: John Cassidy

Publisher: %%

ISBN: %%

Knots and Lines Illustrated

By: Paul Snyder

Publisher: %%

ISBN: %%

Knots and Splices

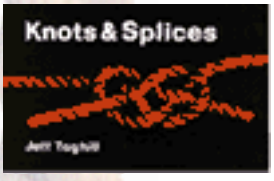

By: Jeff Toghill

Publisher: Fernhurst Books, Duke's Pat

ISBN: 0 906754 11 9

A booklet on all the common knots and splices with their uses and applications.
I got complaints having this book on my page. The first edition should contain too much errors.

The Marlinespike Sailor

By: Hervey Garret Smith

Publisher: International Marine, division of McGraw-Hill, Inc.

ISBN: 0-87742-412-8

Knots & Marlinspike Three books on knots

A reprinted/revised version of a popular book on knots. With sections on basic knot tieing, decorative rope-work, canvas-work and wood carvings.

The morrow guide to Knots

By: Mario Bigon, Guido Regazzoni

Publisher: William Morrow Company, New York

ISBN: 0-668-01225-4 (paper) 0-668-01225-6

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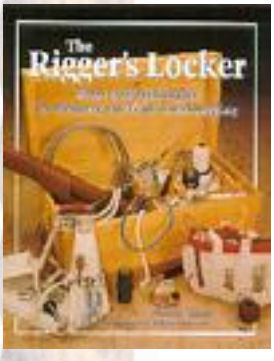

By: Brion Tos

Publisher: International Marine

ISBN: 0-87742-961-8

Rope Works

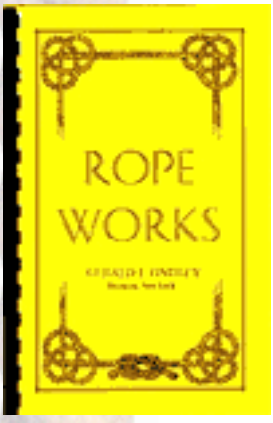

By: Gerald L. Findley

Publisher: Gerald L. Findley

Rope Works

ISBN: ????????

A book of knots, hitches, splicing, lashing and rope making. Whether for scouting or for outdoors recreation, you will learn to tie knots with confidence.

Symmetric Bends How to Join Two Lengths of Cord

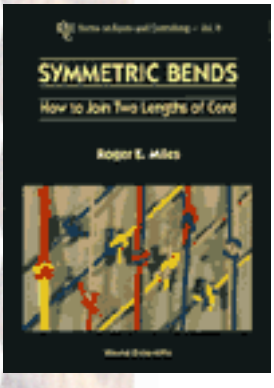

By: Roger E Miles

Publisher: World Scientific Publishing Co. Pte. Ltd.

Series on Knots and Everything, Volume 8

ISBN: 981-02-2194-0

Sufficiency: The Elementary Symmetric Bends; Necessity: Geometry and Planar Representations; Topological Considerations and a Theorem; Practical Considerations and Triple Symmetry; Sixty Symmetric Bends (Includes 16-page colour section); Miscellany; How to Invent Symmetric Bends.

World's Best Fishermans's KNOT BOOK

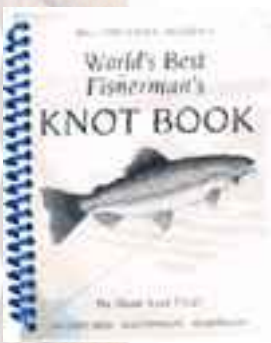

By: Bill Nelson

Publisher: ????

ISBN: ????

This is a pocket size, waterproof, tearproof book that shows the 11 knots and 5 loops every fly fisherman

needs to know.

No Junk Mial

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Here are the links to pages I found (or that are told to me) with a link to **Ropers Knot Page** -(The knots home page) or one of the other page's of the virtual knot site, and not concerning knots directly. (Otherwise you find them on my Roper's Link Page. Still these pages might be interesting because they all have at least one thing in common... They are interested in knotting (for whatever reason.)
If you have a link to one of the Roper's Knot Pages, and there is no reverse link to your page here you can always let me know. *question@realknots.com*

revlinks

All references without a flag are in english/american

General

Crafts,Skills and Hobbies Internet Sites

Scouting

The Scout Association of Hong Kong
ƒXƒJƒEƒeƒBƒ“ƒO•î•ñ
½ºÄ«¿ìÆ®¼¼°è·Î Ç×ÇØ¸¦..
Cub Scout Arrow of Light Board
Cub Scout Pack 46, Sam Houston Area Council
Cubitems's Home Page
Scouting Tips and Info Bits
Grupo Escoteiro Pingo D'Água - 126 / PR
Hawk Patrol Cool Web Sites

Internet Resources for Scouts, Golden Arrow District
Jim Speirs' Scouting Page
Joti 98 The Scout Association of Hong Kong
Junior Forest Wardens
Links naar andere scouting sites
Mõningaid linke nii huviks kui kasuks:
Mõningaid linke nii huviks kui kasuks: 2
Nerd World : SCOUTING
Open Directory - Recreation: Scouting: How_To's
Pacific Skyline Council
PHGSC - Inside our Cottage
PVGSC - Getting Connected! Just for Girls!
Royal Rangers ... A Ministry to Boys
Royal Ambassadors Campcraft
Scouting and Other Web Sites
Scouting by Nerd world media(TM)
Scouting Links to the Web
Scouting on the net
Scouting op het internet
Scouting skills and activities
Speider relaterte linker
Spy scout Alguns Links Interessantes.
en The NetCommish ©1997-2000 M.F. Bowman - Knots & Ropes
The Scouting JumpStation
TROOP 237's WEBPAGE
What's new on the InterNETional Scouting Pages
Troop 8 BSA Favorite Links
User Homepages
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Climbing

Climbing gyms

Free Climbing A climbing search engine

Jim Frankenfield - Climbing Page

RockList

TMRU Links

VER Sales Cable Rigging & Supply

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Sailing / Boating

Buzzards Bay Home Page Sailing

Chelmarsh Sailing Club

Das HochSeilNest

De Boot

Hot Marine Links

Jumbo

J30 "Awesome" Lake Michigan Sailboat Racing

Links

links

Links des DK-Yacht-Service

Links to other interesting web sites for sailors and rope users

NauticalNet -- Nautical Links

Open Directory - Recreation: Boating: Sailing: Education

Randy's Links - sailing;boating;marine;weather;knots - PART 2

Sailing-Links

Sailors Choice : Seamanship and Navigation

Seattle Times: Want to build a boat? Go sailing? Go online

Usefull Links for classic boating

VAART! F L I T S - wekelijks E-zine over Scheepvaart & Internet

Varazze Club Nautico

Ventura County Boating - Home Page - Sailing - Marine Weather - Directory - Race Results - Motoryachts

Yacht: Links - Tips

Outdoor sport

Ask the Chief Links
Camping/ Instruction and Training
Cadedian Outdoor Technologies
Homestead.org - Crafts, Skills and Hobbies Internet Sites
I.A.T.S.E. Local #21 Home Page
PE253
ReelOutdoor Adventure & Recreation--ROAR!!! !Under construction !
Wrolin Camping 'Round the World's Special Sites
Yahooligans Sports and Recreation

Fishing

Courtesy Web Links Resource
Living and working at sea
The Great Fly Fishing Page

Kiting

InfoJump : Web Directory/Recreation/Kites
Kite info on the Internet

Math

Pri..a o ..vorovima

Div

"A Pirate's Life for Me!!"
Æåëòûå ñòðàíèöû. ÄÅÒÑÊÀß ÏËÎÙÀÄÊÀ.
Curriculum Connections
Educational links
Harris Diving Links
IRM Zuerich - Forensische Internet-Ressourcen

IOWA CITY FIRE DEPARTMENT

Links from the Club

sailordaveQ&A School Project on ship wreks

Web Site of the Day - Archives North High School Library

Cool link sites

±âÅ¸

Cool Sites

FLATTY'S_HOT-SPOTS

FreeLinks - editie1.14

Harris (a.k.a. River Rat) dive links

The junkie.com -- eclectic junkie resources

Länkar - Linkkejä - Links

My Cool Site

munford.com's Best of the Web Hobbies

Online Infoage / Internet magazine

Uncle Al's Search Engines - 3.72

Private Bookmarks

Adrenalin T..rman.... ve Do..a Sporlar.. - Do..a sporlar.., da..c..l..k, seyahat ve kamp

Bob & Geri's home page

Brand's Links

Christina's Homepage!

Folie One -- Links

Henscon - Links, links, links

Heimdahl9's Home Page

Junioravd Odjuren

Kirres hemsida

Mark L. Hessenflow Vanity Page

Merenkulku ja veneily

Michel T. Talbot's Bookmarks

Oh no, not another Home Page!

Other Stites

Rickards hemsida

SchoonerMan Rope Locker

Stephen Jones's Bookmarks

Unols Rvtec Link-O-Rama

Just Fun

Engines

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Stoppers(🇬🇧)

Knopen aan een eind.

Terug naar:

Touwslagers Knopen Pagina

Knopen aan het uiteinde van een touw. Er zijn vele toepassingen waarin je zoiets gebruikt. Iedere toepassing stelt zijn eigen eisen en kent daarvoor een beperkt aantal knopen die het best geschikt zijn. Je kunt een stopper gebruiken om te voorkomen dat een touw of garen gaat rafelen. Doe dat echter alleen in goedkoop touw/garen. Gebruik anders een echte takeling.

De Overhandknoop

De Overhandknoop of de Halve Knoop

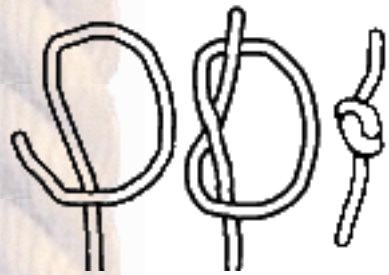

De eenvoudigste knoop die er bestaat, en daarom waarschijnlijk het meest gebruikt. De overhandknoop is goed bruikbaar om knopen in garens en snaren te ondersteunen. Losse tampen worden dan met een overhandknoop iets verdikt. Wanneer dat te rommelig wordt moet worden omgezien naar een betere verbindingsknoop. Er mag geen grote kracht op een overhandknoop worden uitgeoefend. De knoop halveert ongeveer de sterkte van het touw/garen ter plaatse. Als 'anti-slip-stopper' is dat niet erg want dan wordt hij nauwelijks belast.

De Dubbele Overhandknoop

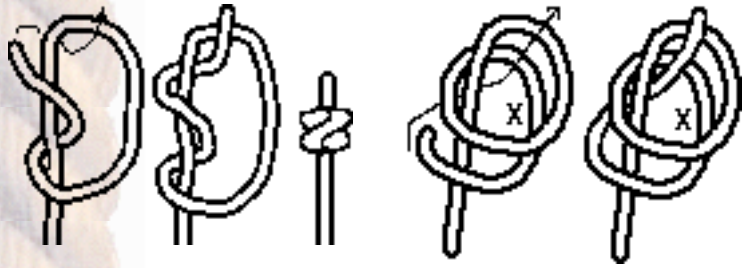

De dubbele overhandknoop is mooi, dikker dan de gewone overhandknoop, maar nauwelijks sterker. Dus hij kan alleen maar gebruikt worden als er maar weinig belasting te verwachten is. De dubbele overhandknoop wordt ook wel de bloedknoop genoemd als hij gebruikt is als zweeptop. De knoop kan op meerdere manieren worden gelegd en in principe op twee manieren worden afgewerkt. De twee manieren van leggen die hier getoond worden geven ook beide afwerkingen aan. De in het midden getoonde bloedknoop is de voorkeurs-afwerking van de tweede met kruisjes gemerkte knoopwijze. De bloedknoop is na belasting zeer moeilijk weer los te krijgen. Wanneer er een object door het met het kruisje gemerkte gat gestoken wordt trekt de knoop

samen tot de wurgknoop. Daarom is het de moeite waard deze manier te leren.

De Meervoudige Overhandknoop

Wanneer de overhandknoop meer dan twee interne rotorns heeft wordt hij dikker. (Echter nauwelijks sterker.) Bij geslagen touw is het van groot belang dat de knoop netjes wordt aangetrokken (opgewerkt) anders hebben de losse strengen sterk de neiging te kinken.

De Vlaamse Acht

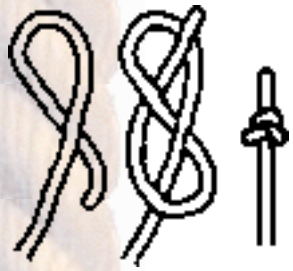

Dit is de stopper die volume, sterkte en eenvoud van leggen/losmaken in de optimale balans samen brengt.
Deze knoop op het WEB.

Commentaar, ideeen, sugesties mail me: ***qqqq at realknots.com*** *with subject "**question**"*
Alle mail zonder het juiste onderwerp worden automatisch, ongelezen weggemikt..
Het spijt me dat ik de mail link weg heb moeten halen. De Mailgrabbers hebben gewonnen.
Maar.... Ik heb een paar verborgen mail adresjes opgenomen zodat ze elkaar plat kunnen spammen nadat ze mijn "junk"gegrabbed hebben....

Terug naar:

Touwslagers knopen pagina

Door naar

De Verbindingsknopen

Terug naar:

De Stoppers

Verbindings Knopen(🇬🇧)

Knopen om twee touwen aan elkaar te binden.

Terug naar:

Touwslagers Knopen Pagina

De Platte knoop

De platte knoop is slechts bruikbaar voor het eenvoudige werk. Hij is eenvoudig te leggen en beklemt zich niet waardoor hij altijd makkelijk los te krijgen is. De toepassingen variëren van het vastzetten van opgerolde zeilen, het dichtbinden van pakjes, tot de basis van de schoenstrik. Zijn naaste verwanten, het ouwe-wijf, de dievenknoop en de what-knoop hebben zo hun eigen toepassingen, maar die hebben niets met een betrouwbare verbinding te maken.
Voor een uitgebreidere beschrijving van deze interessante knopen-familie kan je terecht bij de Platte-knopen Familie.

De Schootsteek

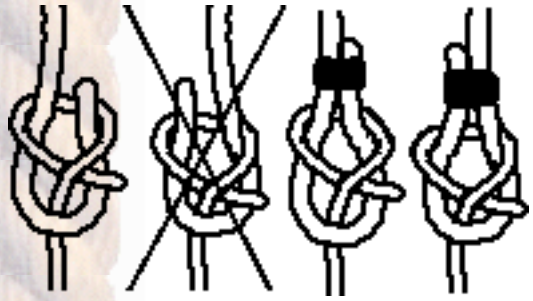

De Schootsteek is mijn favoriete verbindingsknoop. Pas op, wanneer het gekruiste tamp aan de verkeerde kant zit heb je een andere, zwakkere knoop. (In moderne materialen maakt het niet veel meer uit, maar in rechts geslagen touw is de foutieve schootsteek zwakker. Leer daarom de goede.)
Voor een uitgebreidere beschrijving van deze interessante knopen-familie kan je terecht bij De Schootsteek

De karaaksteek

Ook wel karaak hieling genoemd. Pas op! Er zijn maar weinig knopen die zo vaak verkeerd getekend worden als de karaaksteek. De einden moeten diagonaal tegenover elkaar uitkomen en de kruisingen moeten om en om onder- en bovenlangs uitkomen. De karaaksteek is een van de beste steken. Ashley stelt dat het mogelijk het dichtst bij de perfecte steek komt. Hij slipt niet, zelfs niet als het touw nat is, en bovendien is hij altijd los te krijgen, ook na zware belasting. Als hieling voor zwaar materiaal wordt hij altijd afgebonden om slijtage te minimaliseren.

De Zoeteliefjes

Eigenlijk leg je twee halve steken om de staande einden van beide touwen.
Je kunt de zoeteliefjes op twee manieren leggen. Welke van de twee varianten het sterkst is weet ik niet.

Met twee gelijke overhandknopen is hij symmetrisch. Dit is waarschijnlijk de meest gebruikte variant.

Met twee verschillende overhandsknopen krijg je de mooiste (Altijd netjes afwerken!)

Alleen ... de dubbele acht is zeker sterker, makkelijker los te krijgen na belasting en van alle kanten net zo decoratief als de zoeteliefjes op hun best.

De Dubbele Zoeteliefjes

Dit is de dubbel-stopper knoop met als basis de Dubbele Overhandknoop. Eigenlijk leg je twee wurgknopen om de staande einden van beide touwen. Het is het best om de knopen tegengesteld te leggen. Bij gelijke knopen is het lastiger ze goed tegen elkaar aan te sluiten.
Deze knoop wordt door klimmers veel gebruikt om twee touwen aan elkaar te knopen. Hij is sterk, betrouwbaar, maar is nogal lastig weer los te krijgen. Wanneer deze knoop in het midden van een klimtouw terecht komt is het verstandig om aan het hangend eind een vaste lus te maken om als zekering te gebruiken bij het passeren.

De Dubbele Acht

Dit is voor mij de universele dubbele-stopper-knoop. Hij is sterk, mooi, beknelt niet, dus wat wil je nog meer. Het is de verbindingsknoop variant van de Vlaamse Acht

De Wevers Acht

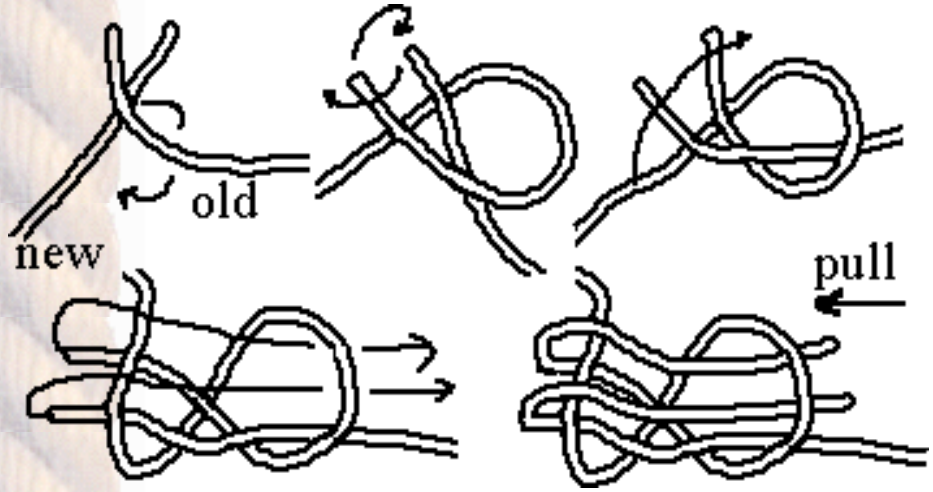

Dit is de beste wever knoop die ik ken. Hoewel het lijkt of hij moeilijk te leggen is blijkt hij juist erg makkelijk te leggen in klein materiaal en is betrouwbaar in wol, linnen en vele ander weef-materialen. Omdat beide losse einden terugvallen op het staande part heeft hij een bijna perfecte geleiding door het werk en over de machine-onderdelen.
Houd beide einden op de kruising tussen duim en wijsvinger. (eerste tekening)
Draai beide draden terwijl je het kruis vast blijft houden in twee eenvoudige bewegingen (tekening twee en drie)
Nu leg je het staande eind van de draad waar je wilt aanhechten over de nieuwe draad die je wilt aanhechten.
Ten slotte stop je over de lijn waar je aanhecht door de loep die je net gemaakt hebt.
Nu laat je het kruis los en hou de losse eindjes tegen het staande part van de nieuwe draad en trek de knoop aan.
Deze knoop is gerelateerd aan De (Vlaamse) Acht Dat kan je goed waarnemen als je deze knoop legt zonder nieuwe draad. (Je doet net alsof.) Je zult zien dat je de acht knoopt.

Voor de andere richting

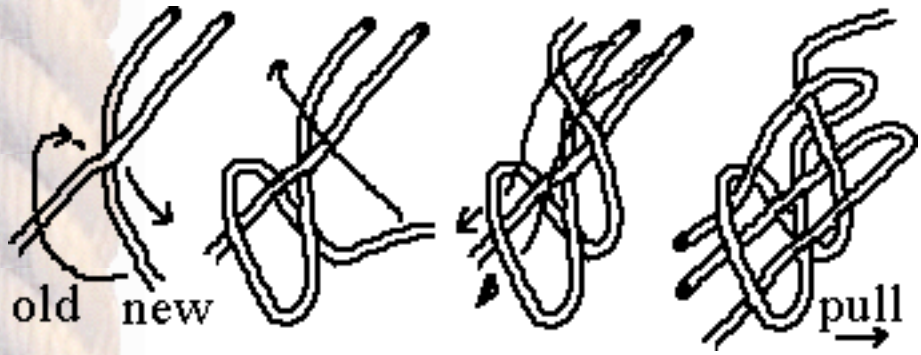

Een wever op een traditioneel weefgetouw weet niet van te voren in welke richting de volgende lijn aangehecht moet worden. Daarom moet hij de weverknoop in twee richtingen kunnen leggen. (Lang niet iedere wever/weefster kan dat en dat kost tijd of netheid.) Dit is de zelfde als de hierboven beschreven knoop, alleen dan

anders gelegd. Op deze manier gelegd kan de draad de andere kant op getrokken worden.

Commentaar, ideeen, sugesties mail me: ***qqqq at realknots.com*** *with subject "**question**"*
Alle mail zonder het juiste onderwerp worden automatisch, ongelezen weggemikt..
Het spijt me dat ik de mail link weg heb moeten halen. De Mailgrabbers hebben gewonnen.
Maar.... Ik heb een paar verborgen mail adresjes opgenomen zodat ze elkaar plat kunnen spammen nadat ze mijn "junk"gegrabbed hebben....

Omdat dit een niet commerciële site is kan en wil ik geen junk-mail of "spam" behandelen. Daarom behoud ik mij het recht voor om voor niet persoonlijke mail, bulk-mail en andere reclame uitingen f250,- afhandelings-kosten PER mail in rekening te brengen.

Terug naar:

Touwslagers knopen pagina

Door naar

De Steken

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Terug naar

De verbindingsknopen

Steken (🇬🇧)

Knopen om en touw aan ... iets te steken (verbinden)

Terug naar

Touwslagers Knopen Pagina

'Elementaire' Steken

In deze tabel staan de elementaire steken. De steken in iedere kolom zijn "familie" van elkaar. De bovenste steek wordt rond een paal of ander object geknoopt. Ik zal ze primaire elementaire steken noemen. De steken er onder zijn 'het zelfde' maar rond het eigen staande part gebonden. Ik zal ze verder de secundaire-elementaire steken noemen. Pas op! De toepassingen van de verschillende variaties zijn zeer verschillend. De primaire-elementaire steken "verdwijnen" als het object verwijderd wordt. De secundaire-elementaire steken doen dat niet. Sommige secundaire-elementaire steken zijn "gekapseisde" bindings knopen. Hoewel het eigenlijk voor alle knopen geldt is het goed afwerken van deze knopen extreem belangrijk. Verkeerd afwerken kan leiden tot een totaal andere en vaak zelfs gevaarlijke variant van de gewenste steek. Als je bijvoorbeeld de twee-halve-steken kapseist zit je met het "oud-wijf", een van de beroerdste knopen die je je maar kunt voorstellen. Aan de andere kant kan je als je weet wat je doet met opzet een "verkeerde" knoop leggen en die kapseizen tot de gewenste. Maar pas daar voor op en wees voorzichtig.
Helaas zijn de nederlandse namen die ik vond lang niet zo sprekend als de engelse.

Enkele Simpele

Mastworp

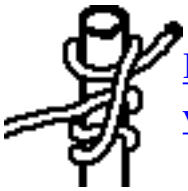

Mw met voorslag

Koe

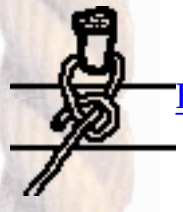

Halve

Twee Halve

Scheerlijn

Twee verkeerde halve

"Buntline"

Verschuifbare

"Lobster Buoy"

De enkele steek

(ook wel **De Simpele Steek.**)

Hoewel dit waarschijnlijk de meest eenvoudige knoop is die je kunt verzinnen moet je een vaardig knoper zijn om hem op een veilge manier te leggen en toe te passen. Het losse eind van het touw moet worden afgeknepen tegen een object of tegen het staande part. De beste kneep krijg je tegen een rand of riggel. (Daar zit hem de kneep! En daar komt ook deze zegswijze vandaan.) Als de steek wordt ontlast en het staande part geschud dan lost de steek direct.

Hij wordt gebruikt bij het beleggen om een kikker, een wevers-naald of zelfs aan een boomtak, als begin voor het beleggen, als start voor het opwinden of als tijdelijke, snel los te maken "steek".

De Halve Steek

Dit is de "gekapseisde" overhandknoop. Het is een bijzonder bruikbare steek om lichte lasten te dragen die snel los te maken moeten zijn. Ashley raadt hem aan voor het ophangen van voorraden buiten het bereik van muizen. Je moet hem echt met rust laten.

De Mastworp

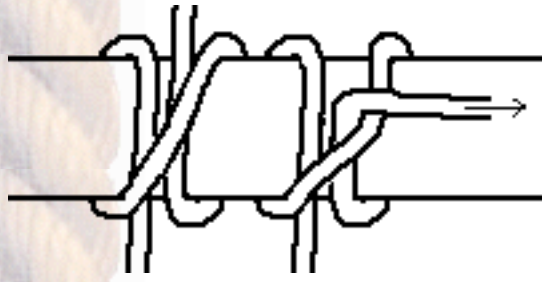

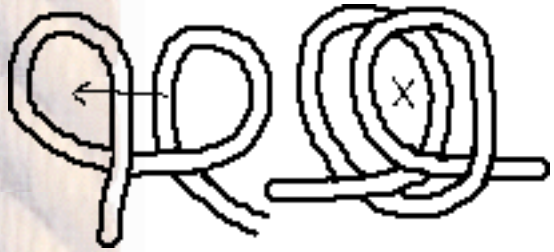

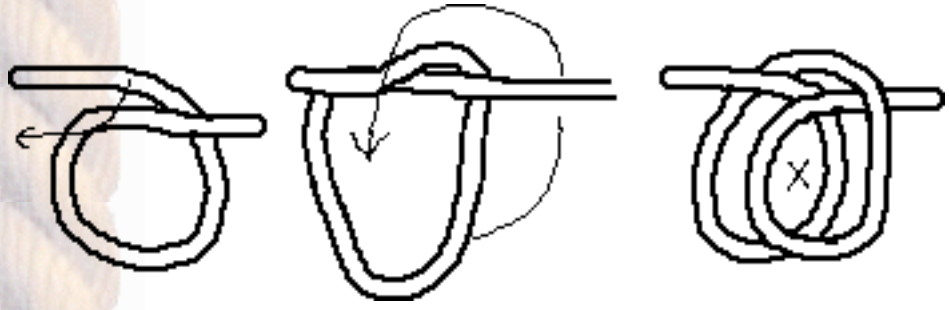

Deze belangrijke knoop heeft alleen theoretische waarde. Zonder extra ondersteuning is hij onbetrouwbaar in iedere situatie, behalve als kruisknoop. Je moet hem kennen voor de padvinderij en op zeilscholen. Als je hem toch moet toepassen werk hem dan netjes af. Trek beide einden stevig aan voor je hem belast, en dan nog alleen in de lengte-richting. Beter nog, gebruikde mastworp met voorslag als alternatief.

Twee Halve Steken

De twee halve steken worden gebruikt om een touw te knopen aan een ring of paal met een haakse belasting. Het moet constant belast blijven. (Hoeft niet onder een constante belasting.) Hij beknelt zich niet. Als het object een kleine diameter heeft is het verstandig om een extra rotorn te nemen.

De "Buntline" Steek.

De "Buntlijn" steek werd gebruikt om de "buntlijn" van een vierkant getuigd schip vast te zetten. Het is een veilige knoop, maar heeft nijging zich te beknellen. Hij is daarom niet eenvoudig los te krijgen. Daarom is hij geschikt voor werk dat langer zonder toezicht gelaten moet kunnen blijven.

Mastworp met voorslag

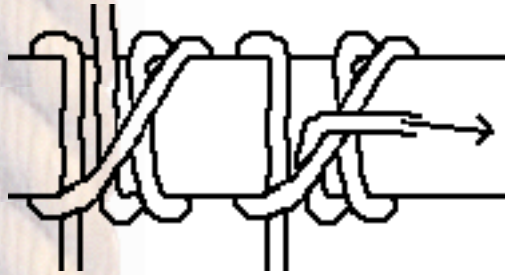

De beste knoop voor belasting in de lengterichting. Het is belangrijk hem goed af te werken en goed aan te halen voordat hij belast wordt. Gebruik hem nooit voor haakse belasting want dan schiet hij echt los.

Scheerlijn-steek

Dit is een bijzonder nuttige steek. Hij is verstelbaar EN betrouwbaar.
Iedere zeiler zou deze steek onder iedere omstandigheid moeten kunnen leggen. In het bijzonder om zichzelf te redden met het touw dat hem in het water is toegeworpen. Hij moet de lijn rond zich leggen, de scheerlijn-steek voor zich en zich tot doel stellen het losse eind tegen het staande part te houden. Dat geeft hem veiligheid en een doel in deze kritieke situatie: VASTHOUDEN!
Iedere kampeerder moet deze knoop ook kennen. Het is de beste knoop om je scheerlijn aan een haring te bevestigen.
Het is het eenvoudigste lid uit de verstelbare knopen familie.

Verstelbare steek.

Dit is de "broer" van de scheerlijn-steek en slechts een beetje minder belangrijk. Dat komt omdat hij zich eerder beknijpt. Als dat de bedoeling is, is dat natuurlijk prima zoals bijvoorbeeld voor werk dat lang zonder toezicht moet kunnen blijven. Ashley beschrijft een toepassing voor katoen-makelaars in New Bedford die hun monsterpakjes, die ze van molen tot molen namen, er mee sloten. De pakjes konden naar believen worden geopend en weer gesloten. Ze bleven veilig gesloten onderweg.

De Koe-steek.

Deze steek is zeer bruikbaar om een koe aan een paaltje vast te zetten. Zelf zou ik een overhand knoopje in het losse eind toevoegen, maar ik ben geen boer. Zeelui gebruiken hem om een koord aan een lijkwade te bevestigen bij een zeemans uitvaart.

"Verkeerde" halve steken

Deze steek wordt ook gebruikt om scheerlijnen vast te zetten, maar is daar veel minder goed voor als de Scheerlijn Steek. De enige reden dat ik hem hier noem is omdat zijn topologie hem hier plaatst. Ik zie er geen gebruiksmogelijkheden voor. (Laat me weten als je er een kent.) Een geoefend oog zal er de gekapseisde platte knoop in herkennen.

Lobster Buoy Steek

De Lobster Buoy Steek is ongeveer even veilig als de Buntline steek, maar veel makkelijker los te krijgen. Hij wordt gebruikt om houtbundels vast te zetten.

Marlsteek of Halvesteek

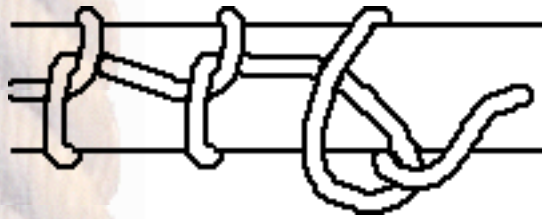

Deze steek is bijzonder praktisch als je een bos wil binden of een rol bij elkaar wil houden. Het werkend eind hoeft maar eenmaal doorgehaald te worden en toch schiet dit bindsel niet echt snel los. Voor de beroemde 'tie-wraps' (of hoe heten die plastic snelbinders) werd deze steek ook op technische scholen aan elektrotechnici geleerd voor het binden van draadbomen. De reeks steken wordt altijd begonnen en beëindigd met een dubbele marlsteek.

Dubbele Marlsteek of Wurgknoop

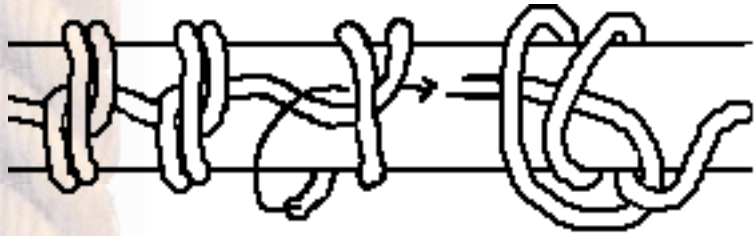

De wurgknoop is belangrijk als tijdelijke takeling, en als permanente binding waarvan er een aantal in elkaars verlengde moeten worden gelegd. Eenmaal goed gelegd is losmaken zonder hulpmiddelen (priem of mes) bijna onmogelijk. Gebruik hem dus nooit voor iets dat snel weer los moet. Als marlsteek wordt hij altijd als eerste en laatste in een rij gebruikt. Ook als een rij marlsteken 'gevaarlijk' lang wordt, pas je de dubbele marlsteek toe als 'tussenzekering', Let op! Op deze manier gelegd hoeft het werkend eind (of het 'klosje') maar één maal doorgehaald te worden. Je moet de knoop daarna wel even netjes afwerken. Gewoon aantrekken is daarbij niet voldoende!

De Constrictor

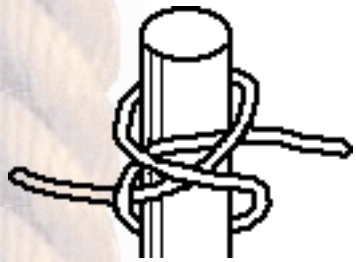

De constrictor is belangrijk als tijdelijke takeling. En ook als permanente binding waarvan je er meerdere naast elkaar nodig hebt. Eenmaal goed gelegd is losmaken zonder hulpmiddelen (priem of mes) bijna onmogelijk. Gebruik hem dus nooit voor iets dat snel weer los moet. Omdat de constrictor "in de bocht" gelegd kan worden wordt hij vaker gebruikt dan de wurgknoop. Voor meer informatie over de constrictor-knoop familie kun je terecht bij de Constrictor-knoop Familie.

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De Steken

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Enkele Lussen ( )

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De Paalsteek

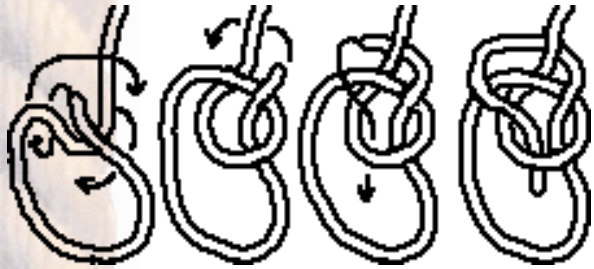

De Paalsteek is de meest gebruikte lus-knoop. Dat komt voornamelijk door de eenvoud, de betrouwbaarheid en waarschijnlijk ook de verwantschap aan de schootsteek. Houd in stap A het kruispunt tussen duim en wijsvinger van de rechterhand en draai vervolgens de pols met de klok mee. Wanneer je de lus weglaat heb je de schootsteek. Kan iemand me vertellen waarom ik in alle boeken deze paalsteek vind, behalve in de helft van mijn nederlandse boeken waarin de zwakkere linkse-paalsteek (met het losse eindje aan de verkeerde kant...) staat 'aangeprezen'???.

Gedubbelde Acht lus

De gedubbelde 8 is een door klimmers veel gebruikte knoop. De knoop is snel te leggen en is veiliger dan de paalsteek. Er is veel discussie of het losse eind nog een stopper behoeft of niet. Snelheid van leggen/losmaken is ook iets waar je voor veiligheid rekening mee moet houden. De eerste wijze van leggen is gelijk aan het leggen van de Vlaamse acht, maar dan met een dubbel touw. Het "losse-end" vormt de lus. Deze wijze van leggen is alleen toepasbaar als de lus pas na het leggen ergens om of in gelegd wordt.

Wanneer de lus ergens om gelegd moet worden, (om jezelf bijvoorbeeld) dan wordt eerst een enkele losse vlaamse acht gelegd die vervolgens gedubbeld wordt. Het is hierbij belangrijk dat er ruimte genoeg is voor de lus. Dat vraagt enige ervaring. Oefenen dus!

De boogpees knoop

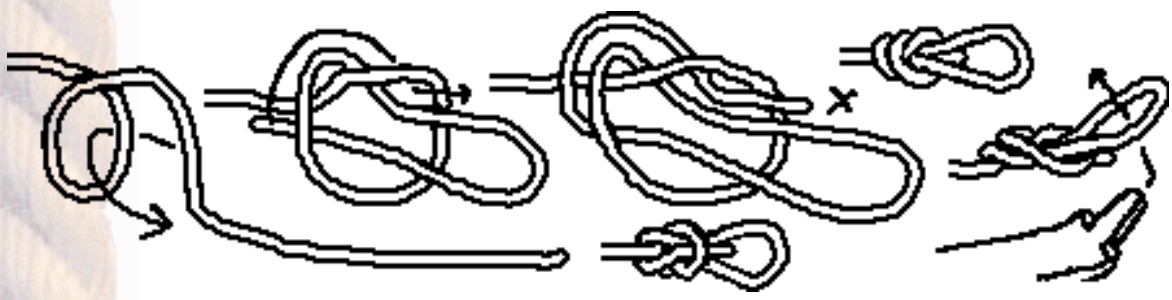

Dit is een zeer oude knoop die gebruikt werd als oog voor boogpezen. De knoop is eenvoudig en sterk. Eenmaal gelegd en stevig aangetrokken, wil je hem niet meer los knopen: je zou het een goede permanente lus kunnen noemen.
De boogpees knoop is geliefd omdat hij klein, sterk, veilig en eenvoudig te leggen is. Hij is netjes omdat er geen losse eindjes uitsteken.
Moderne boogschutters geven de voorkeur aan ingesplitste ogen.
Als het losse eind (gemerkt met een kruisje) niet tussen de boog en de loop gezekerd zit is het aan te bevelen om een extra overhand knoopje als stoppertje te leggen.

Het middenmannetje

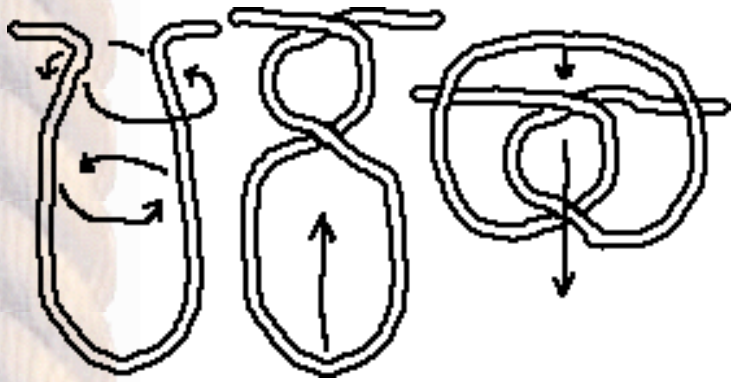

Een eenvoudig te leggen prima lus voor toepassingen waar de lus niet aan het uiteinde maar ergens in het werkend eind gelegd moet worden. Deze lus is in alle richtingen belastbaar. Dat is belangrijk voor toepassingen waarbij de spanning aan de einden groot is ten opzichte van die in de lus zelf.

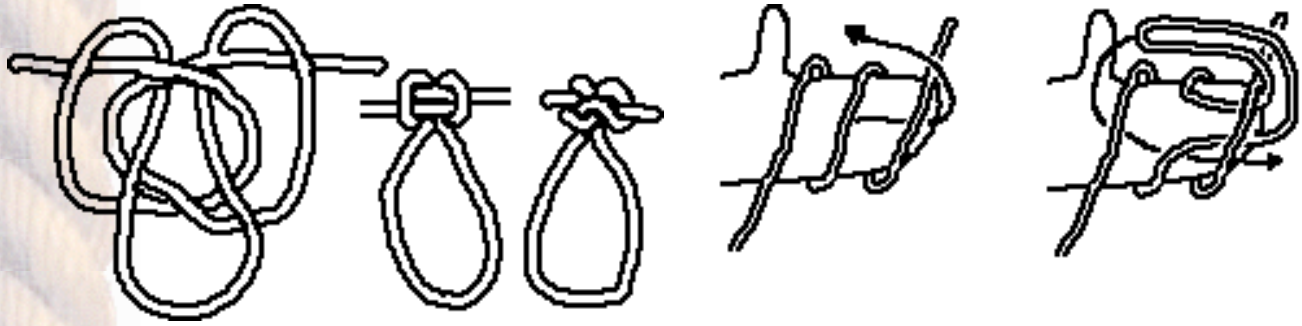

De Artillerie Lus

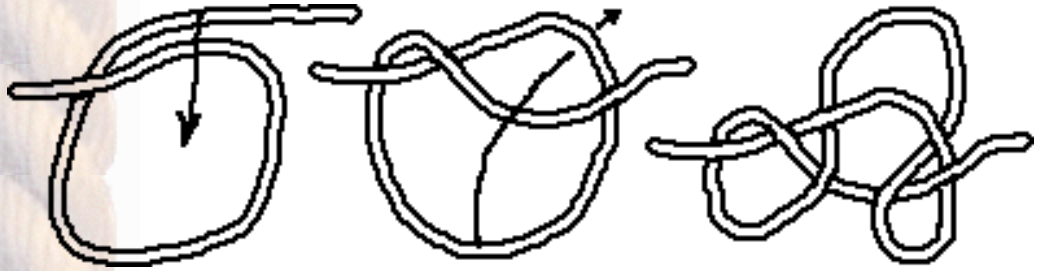

Een praktische en eenvoudig te leggen lus voor het midden van het touw. Hij is niet zo sterk als de middenman maar is iets sneller te leggen en weer los te maken. Zoals de naam al aangeeft werd hij door de artillerie gebruikt (voor het dragen van het geweer over de schouder). Belast het touw niet te zwaar zolang de lus niet belast wordt. Hij is het best toepasbaar als tijdelijke knoop om dingen te dragen of op te hangen. En zoals altijd, netjes afwerken!

De Pendant Steek

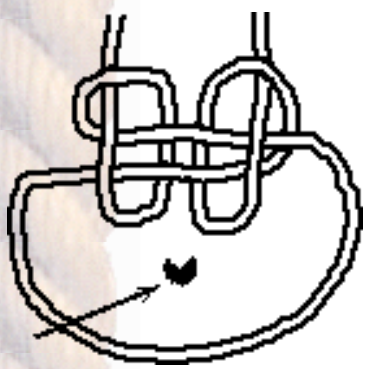

Een steek om een steentje in een amulet te binden. Zorg ervoor dat je het object goed in de lus zekert. Als je een lus (deze lus) gebruikt om een steentje of ander mooi object in een hanger te bevestigen is een leren veter de beste keuze. Maak een ondiep sneetje in de binnenkant van de lus. Precies diep genoeg om het oppervlak te vergroten zodat het beter grip heeft. En, zeker niet onbelangrijk, gebruik een goede schoenmakers-lijm (bijvoorbeeld bizon-kit.) Het resultaat is verrassend.
"De pendant steek is een naast familielid van de zoeteliefjes. Zoeteliefjes.

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De Schuifknoop

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De Lussen

Schuifknopen (🇬🇧)

Lopende-lussen, strikken en lasso's.

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De Schuifknooop algemeen

WAARSCHUWING!! De schuifknoop is geen speelknoop om galgje mee te spelen. Er zijn te veel kinderen per ongeluk gedood omdat ze dachten dat ze de knoop nog wel op tijd los zouden kunnen krijgen. Ook een niet strak aangehaalde schuifknoop is uiterst gevaarlijk rond je hals!

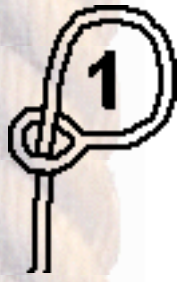

Er zijn drie basismethoden om een schuifknoop te maken. Bij de eerste wordt het staande part door een vast oog aan het einde van het touw genomen. Dit kan een ingesplitst oog zijn maar ook een geknoopte zoals de paalsteek. (De paalsteek wordt feitelijk veel door zeilers als lopend-oog gebruikt.) Ook de enkelvoudige schuifknoop zelf wordt wel gebruikt als soepel lopend-oog.

Bij de tweede manier knoop je een lopend oog rond het staande part, (een simpele knoop of steek) zodanig dat de lus sluit als aan het lopend eind getrokken wordt. Dit is de meest gebruikte manier om een schuifknoop te maken. Het zorgt ervoor dat de lus makkelijk sluit (maar vaak moeilijk opent.)

Bij de derde manier leg je een knoop andersom rond het staande part, zodat als je aan het lopend eind trekt de lus opent.
Ik ken maar één praktische toepassing van zo een schuifknoop: het aanbinden van een yoyo aan het touwtje. Met de achtknoop als lopende knoop.
Maar bij het opbinden van balen en pakketten worden ze regelmatig onbewust gelegd.
Ook tijdens het oefenen van het leggen van schuifknopen eindig je in het begin met dit soort lussen.

De enkelvoudige Schuifknoop

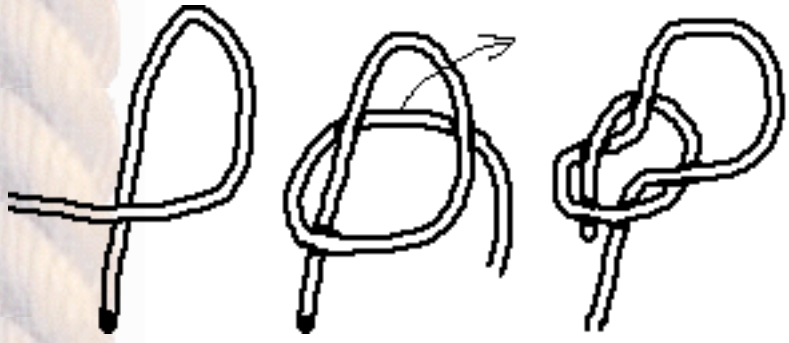

Dit is de eenvoudigste schuifknoop. Hij wordt meestal gebruikt als basis voor verder werk en is nauw verwant aan de overhandknoop en de Marlsteek Als hij als schuifknoop gebruikt wordt is het verstandig een stoppertje te leggen in het losse eindje (de overhandknoop). Hij wordt wel als stropers-strik voor kleine vogels gebruikt.

De Wurg Strik

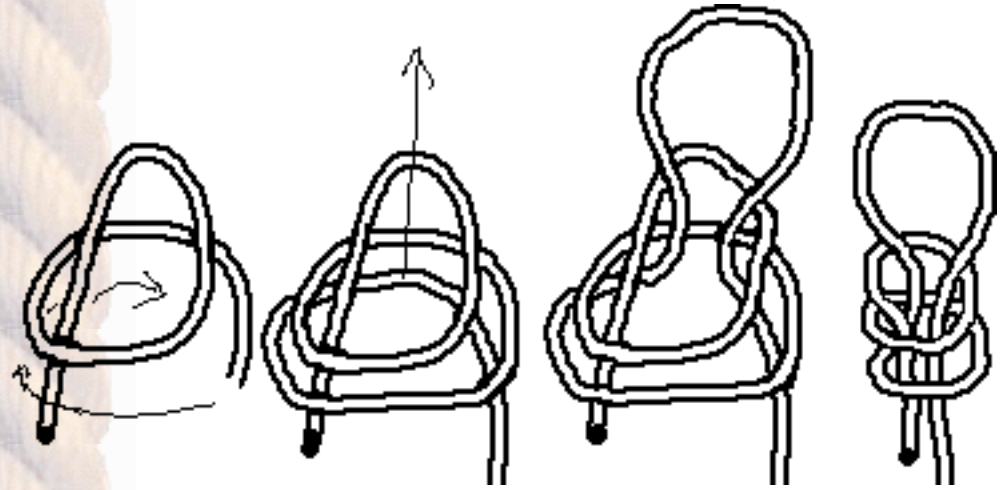

De wurgknoop is een uitstekende knoop om als lopende knoop voor een schuifknoop te gebruiken. Je kunt de kracht die nodig is voor het sluiten van de lus prima regelen. Hoe meer kracht er van binnen de lus wordt aangewend om los te komen, hoe sterker de wurgknoop zich hiertegen zal verzetten. Geen wonder dat deze knoop veel voor strikken gebruikt wordt.

De Galgen Knoop.

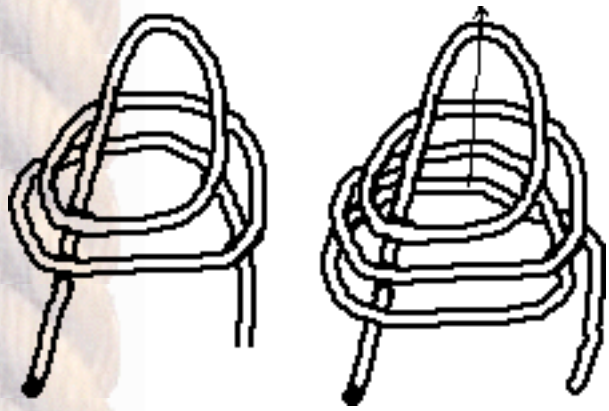

De meervoudige overhand knoop. Zoals de naam al aangeeft een knoop met een duister verleden.

Speel nooit 'Galgje'. Het is werkelijk dodelijk.

De Beulsknoop.

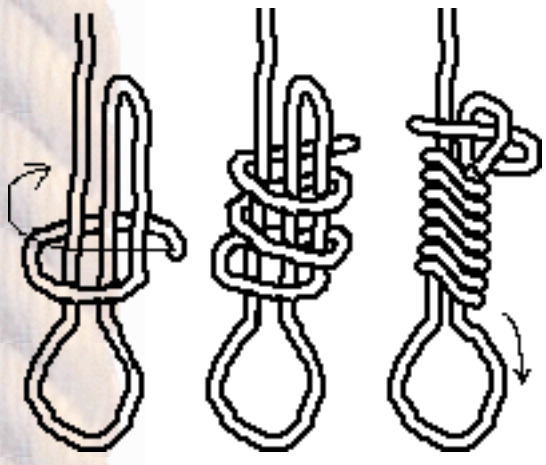

Deze knoop werd ook aan de galg gebruikt. De kracht om te sluiten is beter regelbaar dan bij de galgenknoop. En omdat hij groter is in de nek neemt men aan dat hij de nek eerder breekt. Dat zou 'menselijker' zijn dan het gebruik van de galgenknoop dit meer wurgde.

Speel nooit 'Galgje'. Het is werkelijk dodelijk.

De reverse acht schuifknoop.

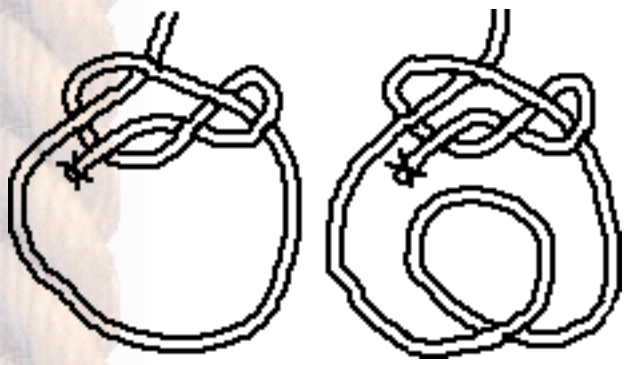

Dit is (tot nu toe) de enige 'verkeerd' lopende schuifknoop waarvoor ik toepassingen ken. Hij wordt gebruikt voor het binden voor pakjes en ... voor het vastmaken van het touwtje aan een YoYo. Gevorderde YoYo'ers doen de lus maar één maal om de yoyo. Zo kunnen ze de yoyo draaiend beneden houden (slippend) en met een klein rukje weer naar boven roepen. Hiervoor moet de yoyo zeer snel draaien en de lus goed getrimd zijn. Beginners willen de yoyo gewoon vast hebben. Zij slaan de lus er een keer extra om en trekken alles goed aan.
Leg eventueel een overhand knoopje in de tampjes. (gemarkeerd met kruisje).

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The Constrictor Hitch

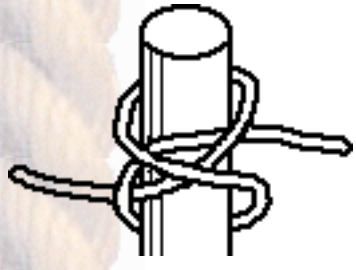

The constrictor knot is important as temporary whipping and as permanent binding from which you need more than one in a row, but not in line (when you should use the strangle knot). Laid well, it is virtually impossible to untie without tools (needle or knife). Never use it if you need to untie it. It is almost the strongest among the 'simple' hitches. Only the double constrictor is stronger. Because the constrictor may be tied in a bight, it is often preferred over the strangle knot.

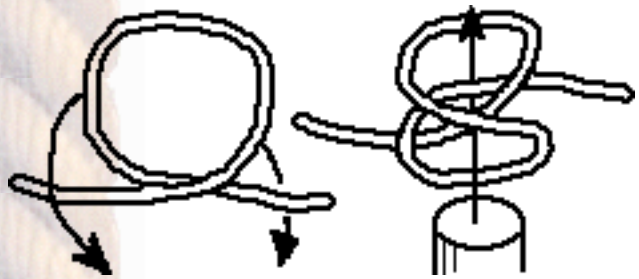

Lied in the bight, it is possible to use the constrictor virtually everywhere where a permanent hitch is needed. In fact, it is my favorite permanent hitch.

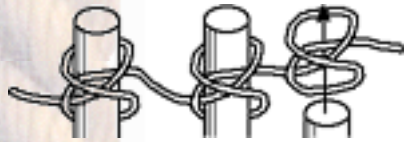

One of the best applications for this knot is the temporary whipping of ropestrands during marlinspiking. With one yarn, you can easily whip more than one strand at the time. Once tied, you pull them firmly all at once.

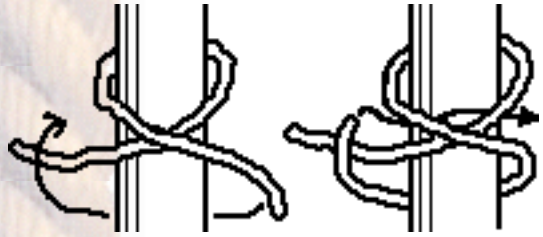

When you cannot place the knot around the object after the knot is formed, you have to tie it round the object. This may be difficult if you did not leave enough room to put the end through.

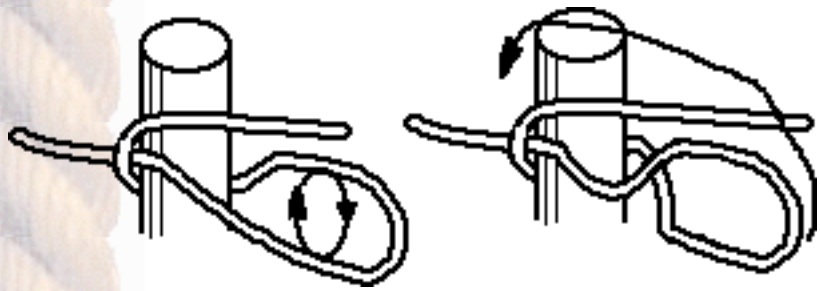

For tieing a fence rope, you can tie the constrictor in this interesting way. It allows working it up to one end while you maintain a limited force on the other end. So, you easily make a straight rope fence (As long as your posts stand firm)

The Constrictor Knot on the WEB.

The Transom Knot

The Transom Knot (Constrictor)

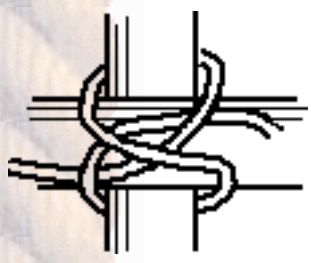

Tied this way the constrictor is an excellent cross knot, called the Transom Knot. (I used it for my kite when I was a kid). If you want to secure it, use two closely laid overhand knots in both ends, or simply use a good kit or glue. An extra knot above this knot does not have much effect. If more strength is required, tie another Transom Knot on the back.

The Transom Knot (Marlin)

Tied this way the Marline Hitch is an even better cross-knot as the previous version of the Transom. It is not possible for the half-knot to work itself between both rods where it is not held by the overlaying rope. Therefore, it is a better cross knot than the constrictor-version of the Transom. (Thanks for the comment! I wish I knew this as a kid. On the other hand I did not have any trouble with the constrictor version. But I argree this is better.)

The Transom Knot on the WEB.

The Double Constrictor

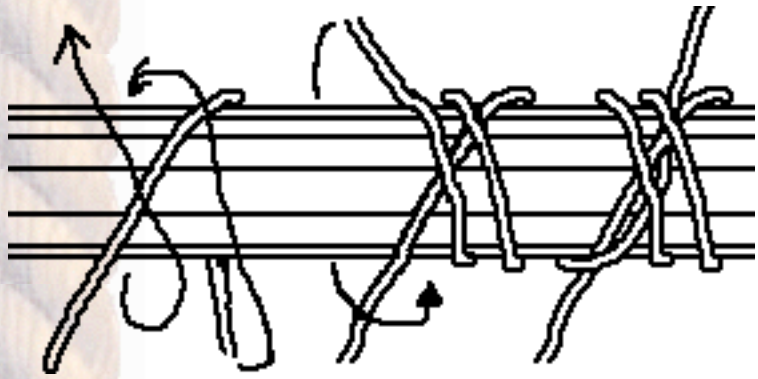

This is the strongest and most secure simple hitch. If the single constrictor does slip (on very slippery material) you can try this knot. If you make more turns round the enclosed half knot or if you twine the half knot one wrap extra it makes the total result weaker. That is probably because it makes it impossible to pull the knot as tight as this one. I always use the double constrictor to "strangle" tubes tight on a pipes. Tubes are often made from "slippery" materials.

The Double Constrictor tied in the bight.

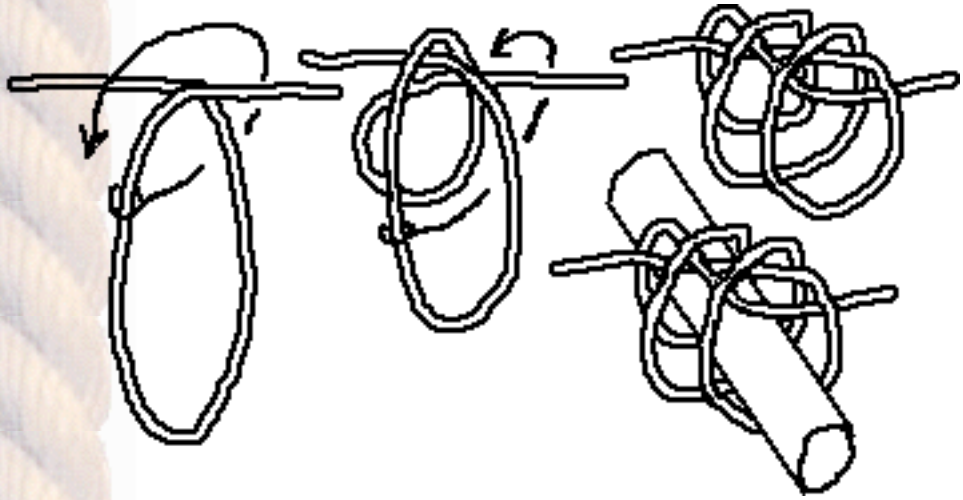

If the end of the object which you want to lay the double constrictor on is free, it is best to tie the knot in the bight. If you master this technique it is much faster. Practice and check yourself after the first turn. If that resulted in the single constrictor instead of the clove hitch you started the wrong way.

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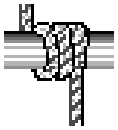

the Hitches

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The Bends

The Fishermans Bend Family

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The "Fishermans bend" is a bend. There is a page on bends.

The True Lovers or Fishermans's Knot

INDEX

The True Lovers, or Fisherman's Knot may be laid in two different ways. Which of both the is the stronger, I do not know.
With two equal overhandknots it is symmetrical. This is probably the most used variant.

With two different overhand knots you get the most beautiful version (always work it up neatly!)
Only ... The double eight is stronger, easier to untie after use and as decorative from all sides as the true lovers at best.

Related knots

Double Fisherman's Knot

INDEX

This is the double-stopper knot with the Double Overhandknot as a base. In fact you tie two strangle knots round the standing parts of both ropes. It is best to tie two counter-image strangle knots. With equal knots it is far more difficult to fit them close to eachother.

This knot is used by climbers to tie two ropes together. It is strong and releyable, but difficult to untie where this knot ends up in the middle of a climbing rope (and it will if you used it to tie two ropes together!) it is wise to tie a fixed loop in the loose end of the falling part as a security by passing the knot.

Double Fisherman's Knot

INDEX

This is for me the universal 'double-stopper-bend'. It is strong, beautiful, it does not jam, so what do you want more... It is the bend-variant of the flemish Eight

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The Reef Knot Family

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The reef-knot is a bend. There is a page on bends.

The Reef Knot or Square Knot General

The reef-knot is only useful in simple applications. Ashley says "it is a true Binder Knot, for which it is admirable, but under no circumstances should it be used as a bend." It is easy tied and will not jam, so it is always easy to untie. It is used to tie packages, and as a base for he shoe-bow. Sailors used it for binding rolled sails or better reefed sails. And that is where it got its english name from. Americans call it the square knot. Probably because it looks square, or because it was much used on square-rigged-ships, but that is a total guess of me.
Its relatives, the granny, the thief-knot and the what-knot all have their purposes, but not as a trustful knot.
The reef-knot on the WEB.

Related knots

The Granny.

This knot is dangerous, and untrustful. One moment is slips the other it jams. It is best to ban it out from your habits.
The granny on the WEB.

The Thief Knot.

The story goes sailors used this knot on their bags for they did not trust landsman. If a thief closed the bag after his theft, he would close it with a reef-knot, which is detectable by the sailor.
The thief-knot on the WEB.

The What Knot.

It is said to be used in a magic trick. Don't ask me how.
The what-knot on the WEB.

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The Sheetbend Family
( )

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The sheetbend is a bend. There is a page on bends **The Sheet Bend, general.**

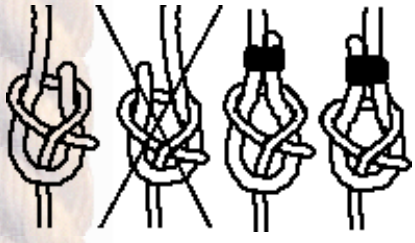

The sheet bend is my favorite bend. Be carefull. With the loose end on the wrong side you have an other, weaker knot (Left-hand sheetbend). If the knot is well seized it does not matter if it is tied right or left handed
The sheetbend on the WEB.

The Sheet Bend

This way of tieing is for connecting equally sized ropes to each other. When the ends are connected you have the Bowline Knot. You have to try to take the first 'steps' as one simple clockwise turn of your wrist. So practice...

The wever_sheetbend

If you want to tie two thin yarns to each other you use a wever-knot. The one shown here is the same as the Sheet Bend. If the yarn is slippery use an Overhandknot on the ends before tying this knot. If this ends up into a to bulky knot you need an other wever_knot.

Sheet Bend for a (to) short end.

With the simplest noose you can catch an end and capsize the knot to a sheed bend. Be careful. without practicing you have a 50% change of catching it wrong. Also, (as always) working up the knot properly is important.

The Lap-Knot

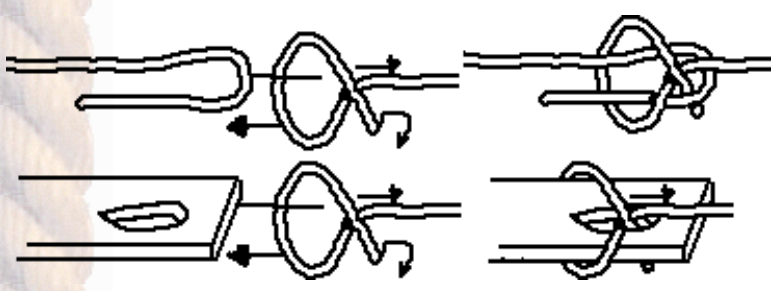

The Lap Knot sometimes is called the false sheetbend. But false knots do not exist. The Lap knot has been in use for ages by many civilisations. I use the name Lap knot because that is the name Robert Pont used in his description of this knot. He found it was used in Lapland in a lot of applications. Especially in lether, it is very suitable, just as secure as the sheetbend, but even more easy to untie. That is important, especially when your fingers are cold.

The Lap Knot is the knot to tie a rope to a strap. If the strap is hard to bend and the rope is slippery, it is advisable to add an overhand knot at the end. Robert Pont thinks it is the best solution for this special situation. He tested it with a many heavy loads under hard conditions. Every time with the same strap, and the same rope. It did not slip a bit, in rain,sun, and snow during several months.

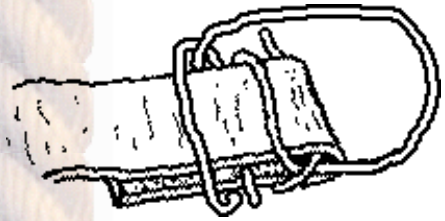

If the Lap Knot is the knot for tieing a rope to a strap it is certainly the knot to make a rope loop at the end of a strap. With a bit of practice, you can enjoy its usefulness.

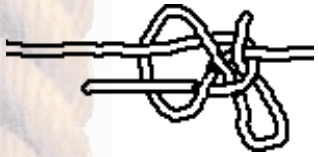

Ever needed a slipped knot which holds secure and releases instantly when pulled? tie the slipped version of the Lap-knot. You will be surprised. I saw this knot for the first time observing a man who hung sausages on a line. He knitted the line into a small noose and shifted the slipped loop over it making a slipped Lap knot. When he needed a sausage he simply grabbed an end and pulled. No scissors, no tools.

The sheetbend is a bend. There is a page on bends

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The Bends

De Platte-knoop Familie ( )

De platte knoop is een verbindingsknoop. Er is een pagina over verbindingsknopen.

De Platte knoop Algemeen

De platte knoop is slechts bruikbaar voor het eenvoudige werk. Hij is eenvoudig te leggen en beklemt zich niet waardoor hij altijd makkelijk los te krijgen is. De toepassingen variëren van het vastzetten van opgerolde zeilen, het dichtbinden van pakjes, tot de basis van de schoenstrik. De platte knoop heeft zeer veel toepassingen, maar is geen verbindingsknoop. Zijn naaste verwanten, het ouwe-wijf, de dievenknoop en de whatknot hebben zo hun eigen toepassingen, maar die hebben niets met een betrouwbare verbinding te maken.

Gerelateerde knopen

Het Ouwe-wijf, of de boeren-knoop

Deze knoop is bijzonder onbetrouwbaar. Het ene moment slipt hij, het andere moment beklemt hij zich tot een bijzonder lastig los te peuteren knoop. Het is de moeite waard deze knoop actief uit je gewoonte te bannen.

De dievenknoop

Het verhaal gaat dat zeelui die de landrotten niet vertrouwden deze knoop op hun plunjezak legden. Een dief die de zak opende zou hem dan met een platte knoop weer sluiten en dat zou de zeeman dan opmerken.

De What-Knoop

Deze knoop schijnt gebruikt te worden in een goocheltruc. Maar hoe die gaat??

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Maar.... Ik heb een paar verborgen mail adresjes opgenomen zodat ze elkaar plat kunnen spammen nadat ze mijn "junk"gegrabbed hebben....

Touwslager's Home Page

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Terug Naar
De Verbindings-knopen

De Schootsteek Familie

(🇬🇧)

Terug naar
Touwslagers Knopen Pagina

De schootsteek is een verbindingsknoop. Er is een pagina over verbindingsknopen

De schootsteek

De hier getoonde manier om de schootsteek te maken is geschikt voor het verbinden van twee touwen van gelijke dikte. Wanneer de tampen aan elkaar zouden zitten en dus een lus zouden vormen dan hadden we de paalsteek. Het is de bedoeling de eerste 'lastige stapjes' met een simpele draai van de pols te realiseren. Even oefenen dus.

De wevers_schootsteek

Wanneer er twee dunne touwtjes/garens aan elkaar geknoopt moeten worden gebruiken we wever knopen. De hier getoonde is gelijk aan de schootsteek. In glad garen is het aan te raden een overhandknoop in de eindjes te leggen. Als dat de knoop te dik maakt moet een andere weversknoop worden toegepast.

Schootsteek aan een (te) kort eindje

Met de eenvoudigste schuiflus kan je aan een eindje een schootssteek leggen. Dit vereist wel enige oefening, de kans dat je het fout insteekt is 50%. Wat bij iedere knoop geldt, geldt hier in het bijzonder: **goed afwerken!**.

De Lap-Knoop

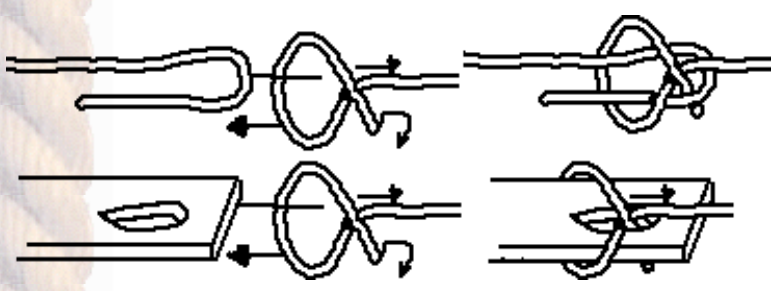

De Lap-Knoop wordt wel ten onrechte de valse schootsteek genoemd. Maar valse knopen bestaan niet. De Lap knoop wordt al eeuwen door vele volken in de wereld gebruikt. Ik gebruik de naam Lap-Knoop omdat Robert Pont deze naam gebruikte bij zijn beschrijving van deze knoop. Hij vond hem in Lapland waar hij veel gebruikt wordt. Met name in leer is hij zeer bruikbaar, net zo betrouwbaar als de schootsteek, maar eenvoudiger en makkelijker weer los te maken. Dat laatste is belangrijk, vooral als je koude vingers hebt.

De Lap knoop is de knoop om een touw aan een band te zetten. Als de band erg stug is of het touw erg glad, leg dan een overhandknoopje in het eind om slip te voorkomen. Robert stelt dat het de beste oplossing voor deze situatie is die hij is tegen gekomen. Hij heeft de Lap knoop getest onder de zwaarste omstandigheden. Gedurende het trekken van verschillende zware lasten, telkens met de zelfde tape en het zelfde touw. In regen, zon, sneeuw, gedurende vele maanden. De knoop gaf geen krimp.

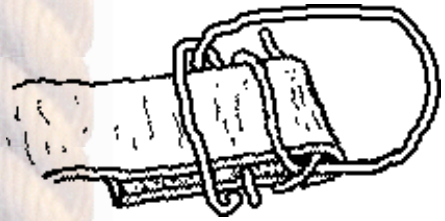

Als de Lap Knoop al de knoop is om aan een touw aan een band te leggen dan is hij zeker ook de knoop om met een touw een lus aan een band te zetten. Even oefenen en je hebt er echt plezier van.

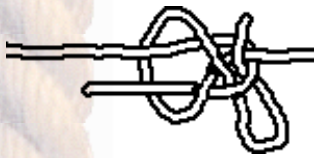

Wel eens een slip-knoop nodig gehad die stevig houdt en toch direct los schiet als je de lus lostrekt? De slip-Lap Knoop is je knoop. Probeer het eens. Je zult verbaasd zijn over het effect. Zelf kwam ik deze knoop tegen bij iemand die worstjes aan een lijn hing. Hij kneep een lusje in de lijn en schoof het touwtje van de worst erover tot een slip-Lap-Knoop. Als hij een worstje eraf wilde halen trok hij aan het eindje. Geen knijpers, geen andere hulpmiddelen.

De Schootsteek is een verbindingsknoop. Er is een pagina over Verbindingsknopen

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De Constrictor Knoop Familie (🇬🇧)

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De Constrictor

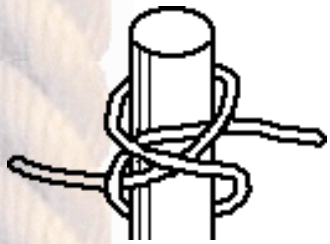

De constrictor is belangrijk als tijdelijke takeling, en als permanente binding waarvan je er meerdere naast elkaar nodig hebt. Eenmaal goed gelegd is losmaken zonder hulpmiddelen (priem of mes) bijna onmogelijk. Gebruik hem dus nooit voor iets dat snel weer los moet. Omdat de constrictor "in de bocht" gelegd kan worden wordt hij vaker gebruikt dan de wurgknoop.

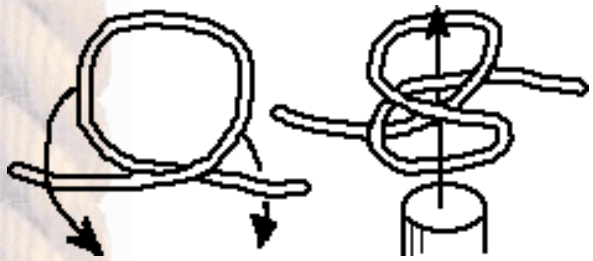

In de bocht gelegd kan je de constrictor bijna overal waar je een permanente binding nodig hebt toepassen. Feitelijk is het mijn favoriete permanente binding. Alleen de dubbele constrictor is sterker.

Waarschijnlijk de beste toepassing voor deze knoop is die van tijdelijke takeling. Met een garen leg je met gemak meerdere constrictors naast elkaar en je trekt ze in één keer allemaal tegelijk aan. Zo takel ik ook de tampen voor het splitsen. Ook als ik daarna moet dunnen.

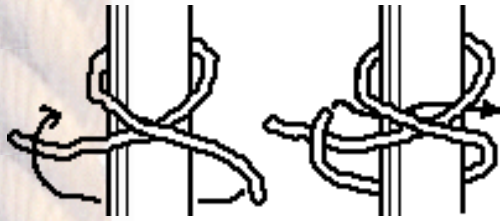

Als je de knoop niet over het object kunt schuiven nadat je de knoop hebt gevormd dan kan je hem ook om het object heen leggen. Dit kan lastig zijn als je te weinig ruimte vrij laat om het losse eind door te steken.

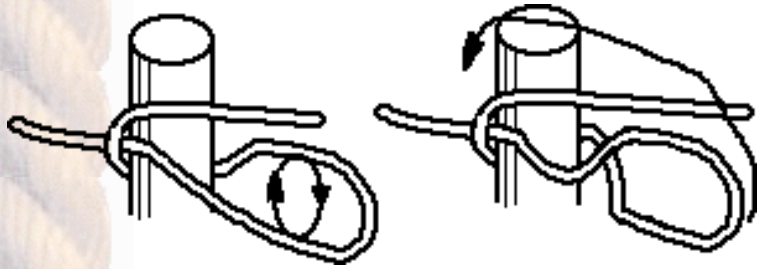

Als je een afscheiding van touw moet maken kan je de constrictor op deze interessante manier leggen. Zo kan je hem aantrekken terwijl je een constante (kleine) kracht aan één kant handhaaft. Zo krijg je een strakke afscheiding (als de paaltjes tenminste stevig staan.)

De Transom knoop

De Transom knoop (Constrictor)

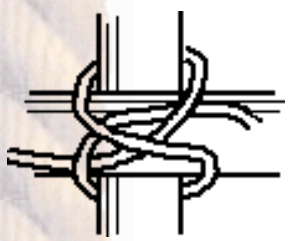

Op deze manier gelegd is de constrictor een prima kruisbinding voor klein materiaal. In het engels de ***Transom knot***. (Ik gebruikte hem vroeger voor mijn vlieger.) Als je hem wilt zekeren doe dat dan met twee overhand knoopjes aan de einden (strak aangelegd). Of gebruik een druppel lijm. Een extra knoop er boven op doet weinig. Als je een grotere sterkte nodig hebt leg je een zelfde knoop aan de andere kant.

De Transom knoop (Wurg)

Op deze manier gelegd is de Marlsteek en nog betere variant van de ***Transom knoop***. Het is hier niet mogelijk dat de halve knoop onder de overliggende bocht uit komt en zich tussen de twee te verbinden rondhouten los werkt. (Bedankt voor de tip! Ik had dit als kind moeten weten. Aan de andere kant heb ik met de constrictor versie nooit problemen gehad. Maar ik geef toe, deze variant is beter.)

De Dubbele Constrictor

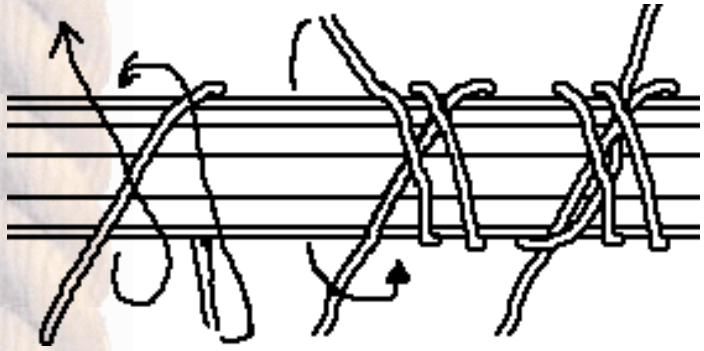

Dit is de sterkste en zekerste van alle simpele steken. Als de (enkele) constrictor slipt (op glad materiaal) dan kan je deze steek proberen. Als je meer rotorns maakt of als je een meervoudige halve-steek onder de beknijpende bochten legt wordt de steek slechts slechter. Dat komt omdat je hem dan niet meer zondermeer zo strak kunt trekken als deze. (Natuurlijk kun je varianten met marlpriemen strakker aanhalen dan deze, maar dan is het echt geen simpele steek meer.) Ik gebruik deze steek altijd als ik slangen op pijpen moet zetten en ik even geen slangklem heb.

De Dubbele Constrictor in de bocht gelegd.

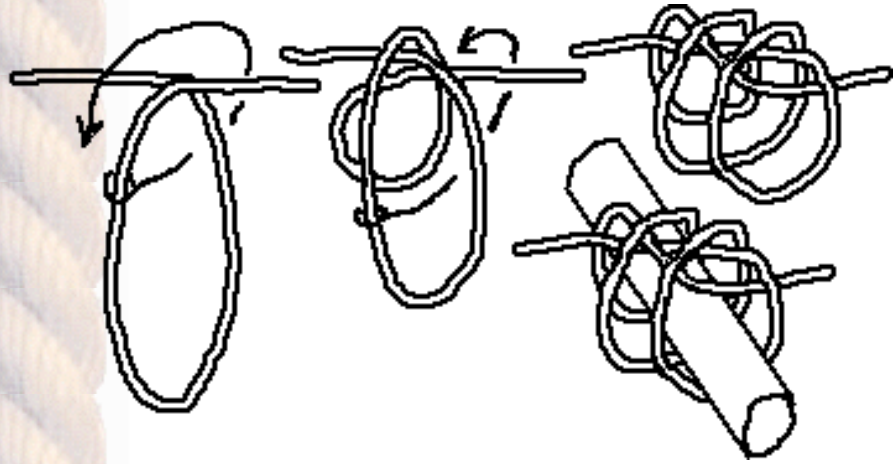

Als het eind van het touw niet beschikbaar is en/of als het eind van het object waarover je de constrictor wilt leggen juist wel vrij is dan is deze wijze van leggen verreweg het snelst. Wel even oefenen en goed kijken nadat je de eerste slag gemaakt hebt. Als je dan al de (enkele)constrictor hebt in plaats van de mastworp dan ben je verkeerd begonnen.

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Campcraft Badge - Adventurer Level - Knots and Lashings

Fishermans Knot
Manharness Knot
Hunters Bend
Back Splice
Eye Splice
Japanese Square Lashing
Filipino Lashing
Prussic Knot

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1. Fishermans Knot

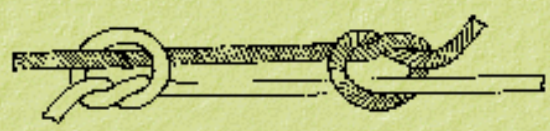

For stiff ropes and cords use the Fisherman's Knot. Easy to make, difficult to untie, so don't use it on a good rope, especially if there is a lot of strain on it.

2. Manharness Knot

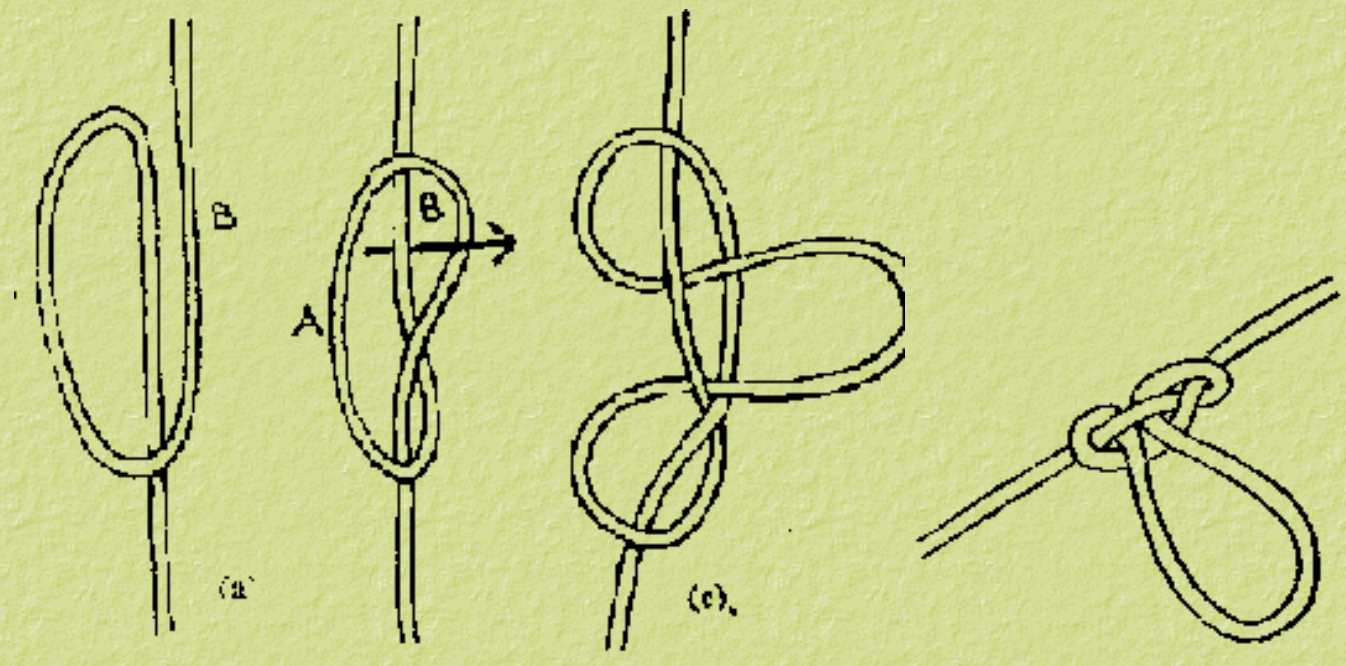

Also called the Artillery Knot and Diagonal Figure of Eight. A loop knot tied in the bight through which an arm can be put up to the shoulder to assist in hauling, while leaving the hands free. Formerly used on gun carriages, one end of the rope being fastened to a ring on the end of the axle. Good for tying a 2nd boat/raft into the painter of a boat already tied to the only decent point on shore.

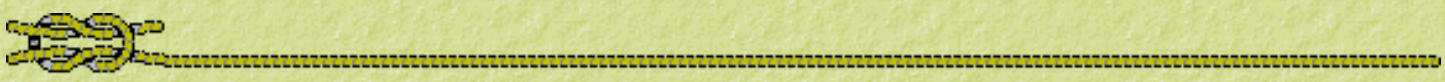

3. Hunters Bend

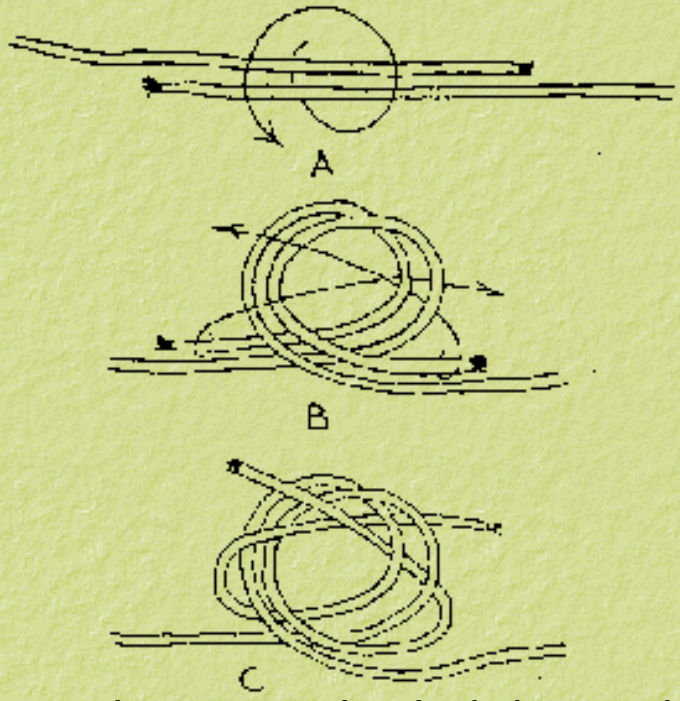

History: The Hunter's Bend used to be known as the Rigger's Knot. When it appeared on the front page of the The London Times in 1978 it was credited to Dr Edward Hunter. This led to much publicity for a knot and also to the foundation of the International Guild of Knot Tyers

4. Back Splice

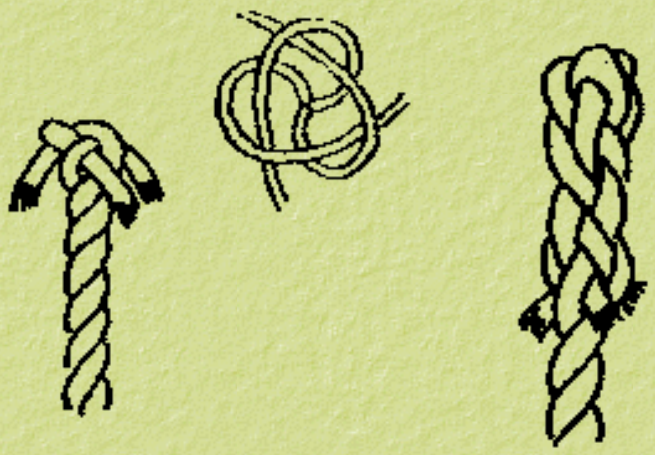

A simple and effective method of finishing the end of a rope in which a crown knot is made with the strands at the end which are then spliced back into the rope.

5. Eye Splice

A method of putting a permanent eye in the end of a rope. The strands are unlaid, a loop of suitable size formed and the three strands are spliced or worked in and out of the rope, usually under and over. Three "tucks" are normally taken.

6. Japanese Square Lashing

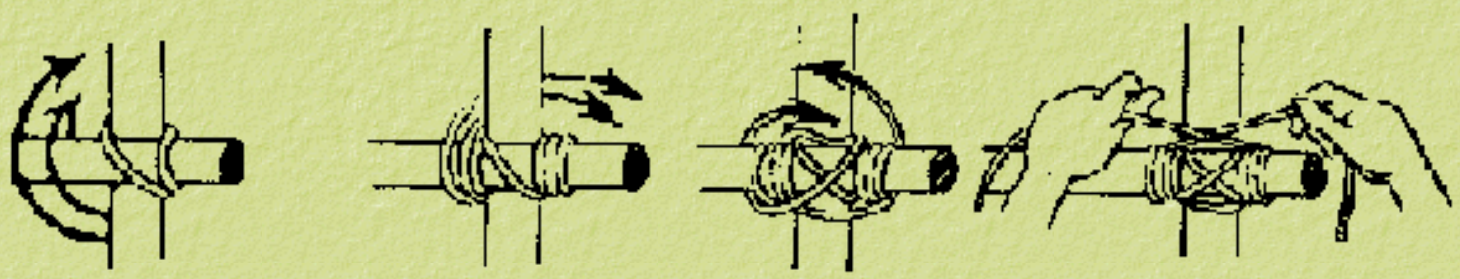

A lashing used in lightweight construction work.

6. Filipino Diagonal Lashing

A lashing used in lightweight construction work.

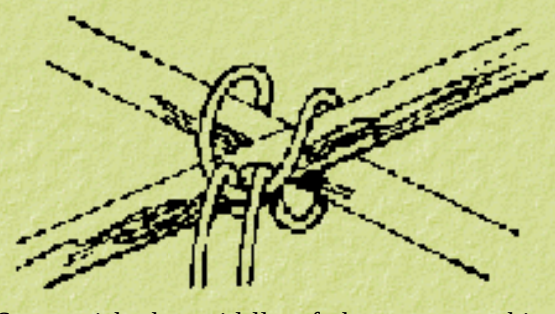

1. Start with the middle of the rope, tucking the running ends through the middle "loop" after going round both spars. Use the "loop" to pull the spars together.

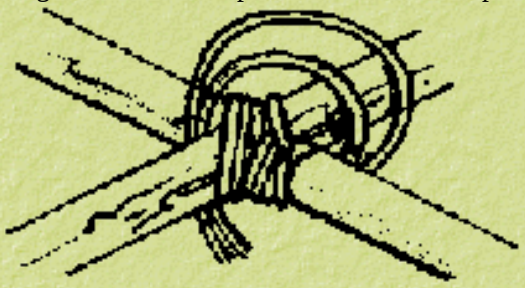

2. Now proceed as for a diagonal lashing taking the running end round both spars, keeping both ends together.

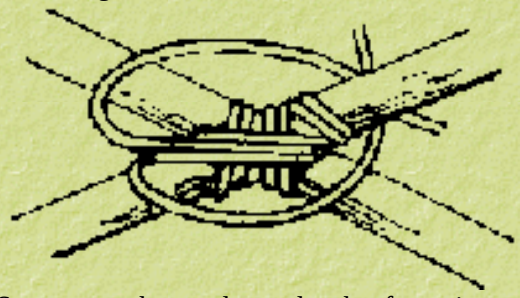

3. Separate the ends and take frapping turns between the spars, pulling the rope tight as you do so.

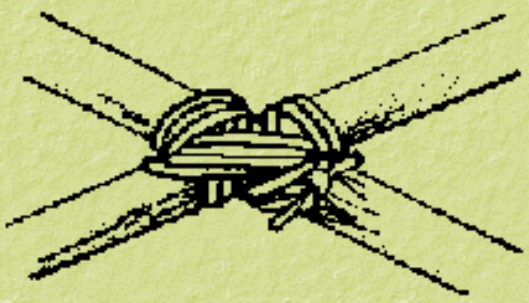

4. Complete the frapping turns and finish off with a square knot.

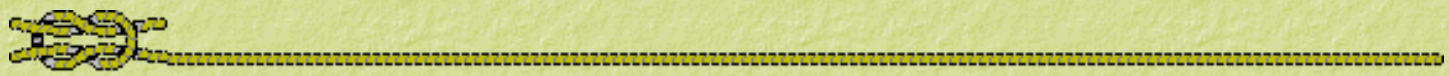

7. Prussic Knot

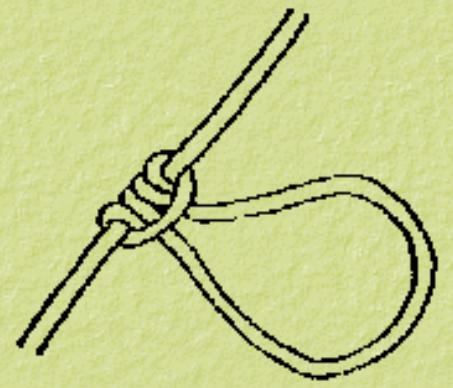

A knot used by climbers. It is made with a strop (endless loop, either spliced or tied) round the main climbing rope. It can be loosened and slid along the rope to vary its position on the rope.

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Rebar Tips

by Greg Casorso

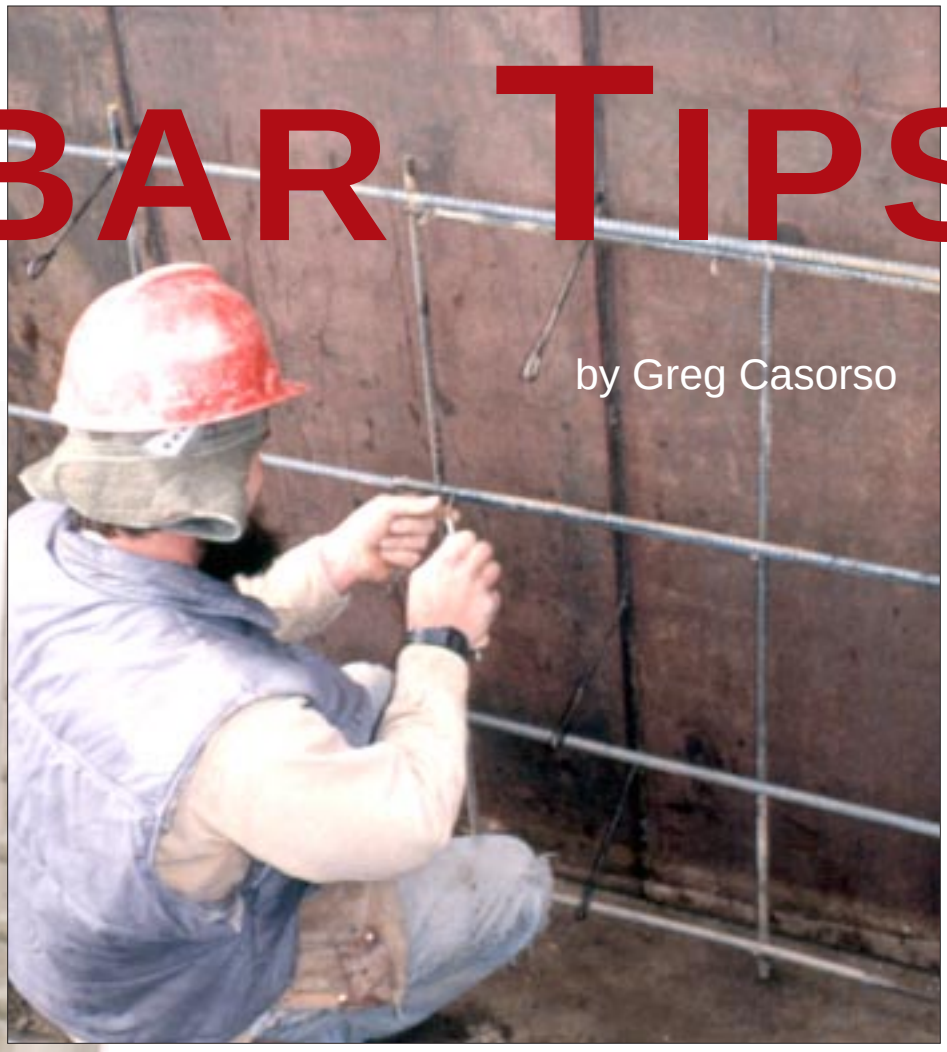

Reinforcing steel enables concrete to resist bending forces — but you have to place it and tie it correctly

The steel reinforcing that we all know as "rebar" is a critical component of quality concrete construction. By enabling concrete to resist bending forces, rebar allows concrete to be used for overhead spans like freeway overpasses or multilevel parking garages. In residential use, rebar enables slender concrete foundation walls to resist horizontal soil pressures, and gives piers, grade beams, and slabs the strength to support the weight of a home.

Anyone who's had to break out a concrete structure knows that a slab or wall poured without steel is much easier to demolish than one with even a few pieces of rebar. It's no coincidence that bomb shelters and missile silos are made of steel-reinforced concrete. It is steel reinforcing that makes concrete such a valuable and versatile building material.

Rebar Specs

Engineers design strength into a concrete structure by specifying a certain size and grade of rebar, placed in specific ways. Rebar specs are usually detailed on the blueprints.

Sizes. Rebar comes in a range of diameters, numbered 3 through 11. The numbers denote the diameter of the bar in 1/8-inch increments. Thus, #3 bar is 3/8 inch in diameter, #4 bar is 4/8 (or 1/2) inch, #5 bar is 5/8 inch, and so on. The size most commonly used in residential construction is #4, though #5 and #6 bar are used often in hillside construction (see "Hillside Foundations," 3/93). Rebar larger than #6 will sometimes be found in large retaining walls or in large-diameter deep piers, but in residential work these larger bars are rare. Patio slabs, garage floors, walkways, pool decks, steps, and simple landings are often made with #3 bar. The 3/8-inch size is also used in stirrups or cage ties, which also contain an assembly of larger bars (see Figure 1, next page).

Grades. Besides a variety of bar diameters, rebar is graded in two

Figure 1. *For deep concrete piers, the author uses steel cages made from #3 rebar spirals with #5 rebar in the middle. The cage shown here will help support the brick chimney in a foundation underpinning job.*

Figure 2. *The author uses an oxyacetylene torch to cut large-diameter rebar (left), while #3 and #4 can be cut and bent with a combination cutting and bending tool (right).*

primary grade classifications, commonly known as grade 40 and grade 60. Grade 40 is more malleable and easier to bend. Grade 60 is stiffer and does not bend as easily. Generally, grade 40 is found in #3 and #4 bar, and grade 60 in #5 and larger.

Lengths. When you're ordering rebar, you should be aware that it's manufactured in standard lengths. Depending on the mill, it's usually available in 20-foot, 30-foot, and 60-foot lengths, with 20-foot the most common. So if you order prebent rebar in an odd length, the supplier has to cut some off. The remnants get collected and recycled, but you pay for them anyway. To cut your own costs, try to work in lengths that divide evenly into 20, 30, or 60 feet.

Proper Use of Reinforcing Bar

To get the full benefit of steel in a concrete structure, the rebar must be handled and installed properly. As with any other material, the correct techniques become a habit with experience.

Handling. Specs usually call for rebar to be clean and free from rust. In practice, the thin film of rust you often see on rebar isn't a problem. If the material sits on the job site for four to six weeks or so, it will still be fine. We don't even cover it on the site. Occasionally, however, sandblasting is required to clean the rust off rebar that has been exposed for too long. Rebar that is old and has rusted extensively should not be used.

Keeping the rebar clean is a more common problem. Mud and dirt on the steel will prevent the concrete from bonding to it and reduce its effectiveness. Rebar can easily get muddy as it's dragged around a job site. We take care to keep the mud off it.

Cutting. To cut #5 or larger rebar, you really need an oxygen acetylene cutting torch (Figure 2), which you can buy at welding supply stores (a torch also makes cutting smaller sizes easier). The torch costs about $350, and then you have to rent bottles of oxygen and acetylene. Oxyacetylene torches are dangerous — anyone who's handling one should be trained to use it properly.

Rebar sizes #4 and smaller can be both cut and bent with a cutter/bender

How Rebar Works in a Retaining Wall

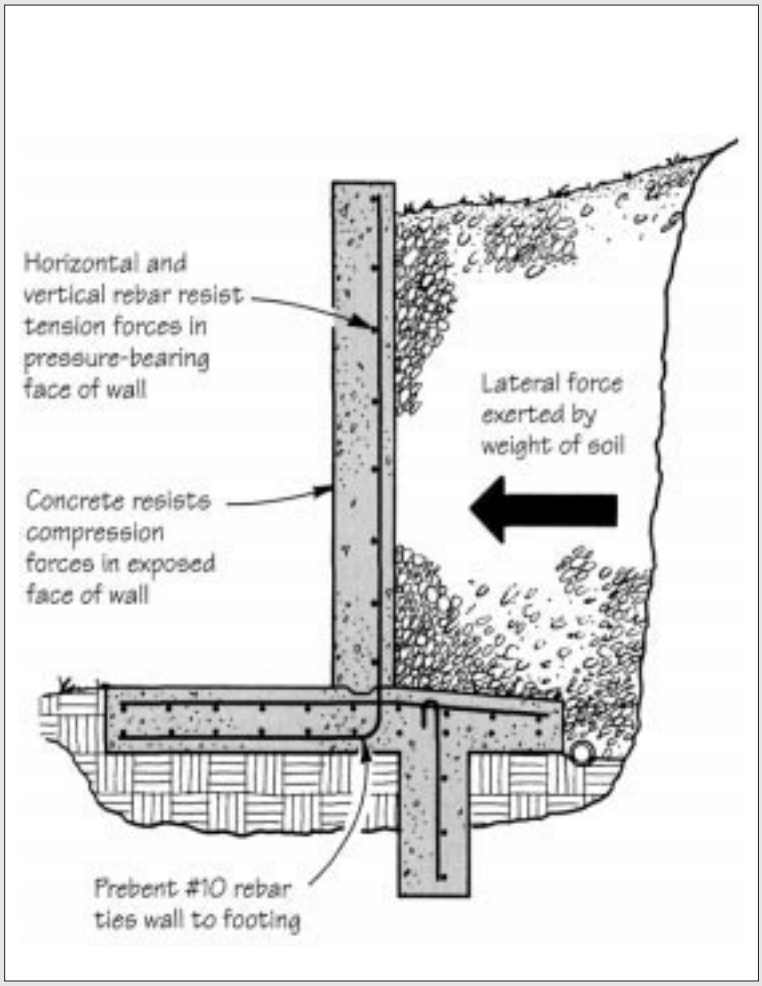

The compressive strength of concrete and the tensile strength of steel work together to resist lateral soil pressures in this retaining wall.

Concrete has tremendous compressive strength — anywhere from 3,500 psi to 6,000 psi. But it has almost no tensile strength — tension forces can easily pull it apart. Steel rebar, on the other hand, is very strong in tension.

When a sideways load is applied to a concrete retaining wall, tension develops on the pressure-bearing side and compression on the side away from the load. Concrete readily resists the compression, while the steel carries the tension and prevents the structure from breaking and toppling.

The retaining wall drawn here is from a job my company did recently. The engineer called for #6 bar to be placed vertically on 6-inch centers, 3 inches from the pressure-bearing face of the wall, tied to horizontal courses of #5 rebar every 16 inches on-center to the top of the wall. Prebent #10 bar provided the crucial link between the wall and the spread footing below.

In this case, steel rebar not only provides the necessary tensile strength for the pressure-bearing vertical face of the wall, but it also provides vital tensile strength at the joint between the wall and the spread footing. Without the continuous steel running from footing to wall, that joint would fail, causing failure of the entire structure.

Retaining walls should be designed by experienced design professionals. Each case is different, and there is no "cookbook solution" that works for all walls. Also, different engineers will find different ways to solve the same problem. The concrete contractor must place the steel where the engineer says to (industry standards allow a 1/4-inch tolerance for error). If you put the steel in the wrong place, you've entered lawsuit country.

— G.C.

tool. The tool is readily available at most concrete supply stores, also for about $350.

Bending. We bend #3 and #4 bar on site with the bending tool, but the larger sizes are practically impossible to work on site. I always order the larger sizes bent by the supplier and delivered to the site ready for installation. Never bend rebar by heating it with a torch — this makes the steel brittle and easy to break, defeating its structural purpose of resisting flex.

Placing. Rebar has to be buried at least 3 inches deep in the concrete unless otherwise specified. Good concrete cover is essential — otherwise water will get to the rebar, rust the steel, and eventually cause failure. To hold rebar off the ground or away from the forms, we use concrete spacer blocks called "dobies" (Figure 3). Dobies come in many sizes: 1 inch, 2 inch, 3 inch, and larger. Three-inch dobies are the most common, because 3-inch concrete coverage is the industry standard.

Tying. Rebar should be tied together with tie wire at every intersection (Figure 4, next page). The wire is wrapped around the bars and twisted just like the tie wrap on a loaf of bread. The rebar should be held in place firmly and securely by the tie wire — on larger walls we tie the rebar so securely that we can actually climb up the bars.

Tie wire comes in rolls, or in bundles of precut lengths. We like to

Figure 3. *Concrete "dobies" are used to hold rebar off the ground or away from forms, ensuring adequate concrete coverage and preventing rust.*

Figure 4. *The author ties the rebar at every intersection. Precut wire can be bought in bundles and twisted with a special swiveling tool (top right), but the author's crew prefers to use a pair of spring-loaded linesman's pliers and a roll of wire on a spool (right).*

use the roll-type that comes on a special spool that can be worn on a work belt. The spool conveniently dispenses the tie wire as needed without tangles. We tie the wire with special spring-loaded linesman's pliers that gently open by themselves, making it easy to grasp, wrap, twist, and cut.

Installers who work with precut bundles of looped wire use a special tool that twists the wire up with a few snaps of the wrist. I've found that this is an efficient method if you have acres of slab to tie, where there are a lot of intersections that are easy to get at. But the reel-and-pliers method is more versatile for smaller jobs because it's good for working in tight spaces.

Splicing. Be sure to splice the rebar as specified by the engineer. For example, if you are using #4 bar and the engineer calls for splices of 28 bar diameters, then you know that you need at least a 14-inch overlap when two bars are spliced together. The overlap should be tied with wire in at least two places.

The pour. When you place the concrete, make sure that it fills in completely around the rebar and bonds to the steel tightly. You should spray release agents on the forms before placing the rebar, but don't get any release agent on the rebar, or the concrete won't bond to the steel as well.

Use a mechanical vibrator to work the concrete in and around the rebar. Pay special attention to corners, where there is often lots of rebar. The vibrator works air out of the concrete and allows a better concrete-to-rebar bond. But don't rest the vibrator head on the rebar. That causes the rebar to pulsate and reduces the bond between the concrete and the rebar.

Figure 5. *The exposed ends of rebar can cause fatal accidents. OSHA regulations call for rebar ends to be covered with high-visibility protective caps.*

Safety. Exposed rebar ends are very dangerous. There is a very real risk of falling on the sharp steel. A man was killed recently in my area when he tripped and fell from a grade beam form. He didn't fall from a height — he just tripped and fell down, and a piece of rebar punctured his heart.

OSHA now requires that all rebar ends be covered with high-visibility plastic safety caps (Figure 5). This is one rule that I strongly support. It is worth making the effort to train people to put those caps on, and to be aware of the risk. We take the caps off when the concrete gets poured, and caps come off by accident, too. At any given time, there are probably some exposed ends around. I just try to stay continuously vigilant, and make sure my workers remember to put the caps on and keep them on. ■

Greg Casorso is the owner of Casorso Construction, in Lafayette, Calif., specializing in foundation construction, repair, and drainage.

THE AUTOMOBILE STORAGE BATTERY ITS CARE AND REPAIR

1922

0. A. WITTE

(Formatted for 800x600 viewing with Internet Explorer. For more viewing area collapse your browser's tool bar! In Explorer, this is under View:Collapse Toolbars and use keyboard shortcuts for back/forward buttons instead.)

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RADIO BATTERIES, FARM LIGHTING BATTERIES

A practical book for the repairman. Gives in nontechnical language, the theory, construction, operation, manufacture, maintenance, and repair of

the lead-acid battery used on the automobile. Describes at length all subjects which help the repairman build up a successful battery repair business. Also contains sections on radio and farm lighting batteries.

BY

0. A. WITTE

Chief Engineer, American Bureau of Engineering, Inc.

Third Edition Completely Revised and Enlarged Fourth Impression

Published 1922 by

THE AMERICAN BUREAU OF ENGINEERING, INC. CHICAGO, ILLINOIS, U. S. A.

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Differences from the original were graphics trimmed and juggled around to cut down on white space and bandwidth. Some graphics were blown up or reduced depending on usefulness of detail of a picture, nearly all where whitened up and touched up. The chapter on business methods was omitted completely. A few charts were omitted because they were completely outdated, of little value and labor intensive to include. Advertisements and the Buyers Index at the end of this book were omitted because they were completely outdated and of little use compared to the bandwidth. I probably should have cut out a bunch more. Omissions are noted in this color text.

I make no guarantee as to the accuracy or completeness of this manual. As with optical character recognition, **ERRORS** certainly occur and some may not necessarily show up in a spell checker, especially numbers. Typical errors might be "B" switched with "l3", an "h" with "li", "8" with an "S", "on" with "oil", etc. Also the degree symbol gets switched with 0, for instance "10° F" might get switched with "100 F". I corrected as many as I found. I did pay more attention to fractions and especially chemical formulas, but this is a big book, things get missed, so rely on your own judgment.

Furthermore, this book was written at a time when people were far less safety conscious and knowledgeable than they are today. Lead poisoning is a real danger. Before attempting the work in this book, you are urged to not only learn the safety habits in this book and read the lead safety section I've added from information gleaned from the web, but also seek additional expert safety information on working with lead. We've all heard about the dangers of lead poisoning especially in babies and children which can cause lifelong brain damage; The lead worker can easily bring contamination home on his work clothing to contaminate his family. I am not an expert and only reproducing information, so be warned and be careful.

My main motivation behind converting this book was to help those going "off grid" a way to substantially reduce the high cost of replacing a big battery bank every few years; And also a way to make energy independence obtainable to many more people. Rebuilding only a few batteries for reasons other than research would not be practical or worth the health risk, but for those intending to maintain dozens or hundreds of batteries this information could be very useful. Richard Allain, who supplied the original scans of this book for this project, admitted he has been off grid for 15 years, said his motivation was in event that we "come into real bad times there may be a way to rework old dead batteries to function again." Thank you, Richard Allain!

Mark Posey

September 2003

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Preface

Many books have been written on Storage Batteries used in stationary work, as in electric power stations. The storage battery, as used on the modern gasoline car, however, is subjected to service which is radically different from that of the battery in stationary work. It is true that the chemical actions are the same in all lead-acid storage batteries, but the design, construction, and operation of the starting and lighting battery, the radio battery, and the farm lighting battery are unique, and require a special description.

This book therefore refers only to the lead-acid type of starting and lighting battery used on the modern gasoline Automobile, the batteries used with Radio sets, and the batteries used with Farm Lighting Plants. It is divided into two sections. The first section covers the theory, design, operating conditions, and care of the battery.

The second section will be especially valuable to the battery repairman. All the instructions given have been in actual use for years, and represent the accumulated experiences of the most up-to-date battery repair shops in the United States.

The first edition of this book met with a most pleasing reception from both repairmen and battery manufacturers. It was written to fill the need for a complete treatise on the Automobile Storage Battery for the use of battery repairmen. The rapid sale of the book, and the letters of appreciation from those who read it, proved that such a need existed.

The automobile battery business is a growing one, and one in which new designs and processes are continually developed, and in preparing the second and third editions, this has been kept in mind. Some of the chapters have been entirely rewritten, and new chapters have been added to bring the text up-to-date. Old methods have been discarded, and new ones described. A section on Farm lighting Batteries has been added, as the automobile battery man should familiarize himself with such batteries, and be able to repair them. A section on Radio batteries has also been added.

Special thanks are due those who offered their cooperation in the preparation and revision of the book. Mr. George M. Howard of the Electric Storage Battery Co., and Mr. C. L. Merrill of the U. S. Light & Heat Corporation very kindly gave many helpful suggestions. They also prepared special articles which have been incorporated in the book. Mr. Henry E. Peers consulted with the author and gave much valuable assistance. Mr. Lawrence Pearson of the Philadelphia Battery Co., Mr. F. S. Armstrong of the Vesta Accumulator Co., Messrs. P. L. Rittenhouse, E. C. Hicks and W. C. Brooks of the Prest-O-Lite Co., Mr. D. M. Simpson of the General Lead Batteries Co., Mr. R. D. Mowray and Mr. C. R. Story of the Universal Battery Co., Mr. H. A. Harvey of the U. S. Light and Heat Corporation, Mr. E. B. Welsh of the Westinghouse Union Battery Co., Mr. S. E. Baldwin of the Willard Storage Battery Co., Mr. H. H. Ketcham of the United Y. M. C. A. Schools, and Messrs. Guttenberger and Steger of the American Eveready Works also rendered much valuable assistance.

The Chapter on Business Methods was prepared by Mr. G. W. Hafner.

0. A. WITTE

Chief Engineer, American Bureau of Engineering, Inc.

September, 1922

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ADVERTISEMENTS (Omitted)

LEAD POISONING AND SAFETY (Added)

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1. INTRODUCTORY (3 pages)

Gasoline and electricity have made possible the modern automobile. Steps in development of electrical system of automobile. Sources of electricity on the automobile.

2. BATTERIES IN GENERAL (5 pages)

The Simple Battery, or Voltaic Cell. Chemical Actions which Cause a Cell

to Produce Electricity. Difference between Primary and Secondary, or Storage Cells. A Storage Battery Does Not "Store" Electricity. Parts Required to Make a Storage Battery.

3. MANUFACTURE OF STORAGE BATTERIES (18 pages)

Principal Parts of a "Starting and Lighting" Battery. Types of Plates Used. Molding the Plate Grids. Trimming the Grids. Mixing Pastes. Applying Pastes to the Plate Grids. Hardening the Paste. Forming the Plates. Types of Separators. Manufacture of Separators. Manufacture of Electrolyte. Composition and Manufacture of Jars. Types of Cell Covers. Single and Double Covers. Covers Using Sealing Compound Around the Cell Posts. Covers Using Lead Bushings Around the Cell Posts. The Prest-O-Lite Peened Post Seal. Batteries Using Sealing Nuts Around Cell Posts. Construction of Vent Tubes. Exide and U. S. L. Vent Tube Design. Vent Plugs, or Caps. Manufacture of the Battery Case. Assembling and Sealing,the Battery. Terminal Connections. Preparing the Completed - Battery for "Wet" Shipment. Preparing the Completed Battery for "Dry" Shipment. "Home-Made" Batteries.

4. CHEMICAL CHANGES IN THE BATTERY (5 pages)

Chemical Changes in the Battery. Plante's Work on the Storage Battery. Faure, or Pasted Plates. How Battery Produces Electricity. Chemical Actions of Charge and Discharge. Relations Between Chemical Actions and Electricity.

5. WHAT TAKES PLACE DURING DISCHARGE (6 pages)

What a "Discharge" Consists of. Voltage Changes During Discharge. Why the Discharge Is Stopped When the Cell Voltage Has Dropped to 1.7 on Continuous Discharge. Why a Battery May Safely be Discharged to a Lower Voltage Than 1.7 Volts per Cell at High Rates of Discharge. Why Battery Voltage, Measured on "Open Circuit" is of Little Value. Changes in the Density of the Electrolyte. Why Specific Gravity Readings of the Electrolyte Show the State of Charge of a Cell. Conditions Which Make Specific Gravity Readings Unreliable. Why the Specific Gravity of the Electrolyte Falls During Discharge. Why the Discharge of a Battery Is Stopped When the Specific Gravity Has Dropped to 1.150. Chemical Changes at the Negative Plates During Discharge. Chemical Changes at the Positive Plates During Discharge.

6. WHAT TAKES PLACE DURING CHARGE (3 pages)

Voltage Changes During Charge. Voltage of a Fully Charged Cell. Changes in the Density of the Electrolyte During Charge. Changes at the Negative Plates During Charge. Changes at the Positive Plates During Charge.

7. CAPACITY OF STORAGE BATTERIES (7 pages)

Definition of Capacity. Factors Upon Which the Capacity of a Battery Depend. How the Area of the Plate Surfaces Affects the Capacity. How the Quantity, Arrangement, and Porosity of the Active Materials Affect the Capacity. How the Quantity and Strength of the Electrolyte Affect the Capacity. Why Too Much Electrolyte Injures a Battery. Why the Proportions of Acid and Water in the Electrolyte Must Be Correct if Specific Gravity Readings Are to Be Reliable.

8. INTERNAL RESISTANCE (3 pages)

Effect of Internal Resistance. Resistance of Grids. Resistance of Electrolyte. Resistance of Active Materials.

9. CARE OF BATTERY ON THE CAR (18 pages)

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Shedding, or Loss of Active Material.-Normal Shedding. How Excessive Charging Rate, or Overcharging Causes Shedding. How Charging Sulphated Plates at Too High a Rate Causes Shedding. How Charging Only a Portion of the Plate Causes Shedding. How Freezing Causes Shedding. How Overdischarge Causes Loose Active Material. How Buckling Causes Loose Active Material.

Impurities.-Impurities Which Cause Only Self -Discharge. Impurities Which Attack the Plates. How to Remove Impurities. Corroded Grids.-How Impurities Cause Corroded Grids. How Sulphation Causes Corroded Grids. How High Temperatures Cause Corroded Grids. How High Specific Gravity Causes Corroded Grids. How Age Causes Corroded Grids.

Negatives.-How Age and Heat Cause Granulated Negatives. Heating of Charged Negatives When Exposed to the Air. Negatives with Very Hard Active Material. Bulged Negatives. Negatives with Soft, Mushy, Active Material. Negatives with Rough Surfaces. Blistered Negatives.

Positives.-Frozen Positives. Rotten, Disintegrated Positives. Buckled Positives. Positives Which Have Lost Considerable Active Material. Positives with Soft Active Material. Positives with Hard, Shiny Active Material. Plates Which Have Been Charged in the Wrong Direction.

Separator Troubles.-Separators Not Properly Expanded Before Installation. Improperly Treated Separators. Rotten and Carbonized Separators.

Separators with Clogged Pores. Separators with Edges Chiseled Off.

Jar Troubles.-Jars Damaged by Rough Handling. Jars Damaged by Battery Being Loose. Jars Damaged by Weights Placed on Top of Battery. Jars Damaged by Freezing of Electrolyte. Jars Damaged by Improperly Trimmed Plate Groups. Improperly Made Jars. Jars Damaged by Explosions in Cell.

Battery Case Troubles.-Ends of Case Bulged Out. Rotted Case.

Troubles with Connectors and Terminals.-Corroded and Loose Connectors and Terminals.

Electrolyte Troubles.-Low Gravity. High Gravity. Low Level. High Level. Specific Gravity Does Not Rise During Charge. "Milky" Electrolyte. Foaming of Electrolyte.

General Battery Troubles.-Open Circuits. Battery Discharged. Dead Cells. Battery Will Not Charge. Loss of Capacity. Loss of Charge in an Idle Battery.

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11. SHOP EQUIPMENT (103 pages)

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Mechanical Rectifiers. The Stahl Rectifier. Other Charging Equipment. The Charging Bench. Illustrations and Working Drawings of Charging Benches. Illustrations and Working Drawings of Work Benches. Illustrations and Working Drawings of Sink and Wash Tanks. Lead Burning Outfits. Equipment for Handling Sealing Compound. Shelving and Racks. Working Drawings of Receiving Racks, Racks for Repaired Batteries, Racks for New Batteries, Racks for Rental Batteries, Racks for Batteries in Dry Storage, Racks for Batteries in "Wet" Storage. Working Drawings of Stock Bins. Working Drawings for Battery Steamer Bench. Description of Battery Steamer. Plate Burning Rack. Battery Terminal Tongs. Lead Burning Collars. Post Builders. Moulds for Casting Lead Parts. Link Combination Mould. Cell Connector Mould. Production Type Strap Mould. Screw Mould. Battery Turntable. Separator Cutter. Plate Press. Battery Carrier. Battery Truck. Cadmium Test Set and How to Make the Test. Paraffine Dip Pot. Wooden Boxes for Battery Parts. Acid Car boys. Drawing Acid from Carboys. Shop Layouts. Floor Grating. Seven Architects' Drawings of Shop Layouts. The Shop Floor. Shop Light.

12. GENERAL SHOP INSTRUCTIONS (101 pages)

Complete instructions for giving a bench charge. Instructions for Burning Cell Connectors and Terminals. Burning Plates to- Strap and Posts. Post Building. Extending Plate Lugs. Moulding Lead Parts. Handling and Mixing Acid. Putting New Batteries Into Service (Exide, Vesta, Philadelphia, Willard, Westinghouse, Prest-O-Lite). Installing Battery on Car. Wet and Dry Storage of Batteries. Age Codes (Exide, Philadelphia, Prest-O-Lite, Titan, U.S.L., Vesta, Westinghouse, Willard). Rental Batteries. Terminals for Rental Batteries. Marking Chapter Page Rental Batteries. Keeping a Record of Rental Batteries. General Rental Policy. Radio Batteries. Principles of Audion Bulb for Radio. Vesta Radio Batteries. Westinghouse Radio Batteries. Willard Radio Batteries. Universal Radio Batteries. Exide Radio Batteries. Philadelphia Radio Batteries. U.S.L. Radio Batteries. Prest-O-Lite Radio Batteries. "Dry" Storage Batteries. Discharge Tests. 15 Seconds High Rate Discharge Test. 20 Minutes Starting Ability Discharge Test. "Cycling" Discharge Tests. Discharge Apparatus. Packing Batteries for Shipping. Safety Precautions for the Repairman. Testing the Electrical System of a Car. Complete Rules and Instructions for Quickly Testing, Starting and Lighting System to Protect Battery. Adjusting Generator Outputs. How and When to Adjust Charging Rate. Re-insulating the Battery. Testing and Filling Service. Service Records. Illustrations of Repair Service Record Card. Rental Battery Stock Card.

13. BUSINESS METHODS (Omitted 14 pages)

Purchasing Methods. Stock Records. The Use and Abuse of Credit. Proper Bookkeeping Records. Daily Exhibit Record. Statistical and Comparative Record.

14. WHAT'S WRONG WITH THE BATTERY? (15 pages)

"Service." Calling and Delivering Repaired Batteries. How to Diagnose Batteries That Come In. Tests on Incoming Batteries. General Inspection of Incoming Batteries. Operation Tests for Incoming Batteries. Battery Trouble Charts. Causes of Low Gravity or Low Voltage. Causes of Unequal Gravity Readings. Causes of High Gravity. Causes of Low Electrolyte. How to Determine When Battery May Be Left on Car. How to Determine When Battery Must Be Removed from Car. How to Determine When It Is Unnecessary to Open a Battery. How to Determine When Battery Must Be Opened.

15. REBUILDING THE BATTERY (47 pages)

How to Open a Battery.-Cleaning Outside of Battery Before Opening. Drilling and Removing Connectors and Terminals. Removing the Sealing Compound by Steam, Hot Water, Hot Putty Knife, Lead Burning Flame, and Gasoline Torch. Lifting Plates Out of Jars. Draining Plates. Removing Covers. Scraping Sealing Compound from the Covers. Scraping Sealing Compound from Inside of Jars.

What Must Be Done with the Opened Battery?-Making a Preliminary Examination of Plates. When to Put in New Plates. When Old Plates May Be Used Again. What to Do with the Separators. Find the Cause of Every Trouble. Eliminating "Shorts." Preliminary Charge After Eliminating Shorts. Washing and Pressing Negatives. Washing Positives. Burning on New Plates. Testing Jars for Cracks and Holes. Removing Defective Jars. Repairing the Case.

Reassembling the Elements.-Putting in Now Separators. Putting Elements Into Jars. Filling Jars with Electrolyte. Putting Chapter Page on the Covers. Sealing the Covers. Burning on the Connectors and Terminals. Marking the Repaired Battery. Cleaning and Painting the Case. Charging the Rebuilt Battery. Testing.

16. SPECIAL INSTRUCTIONS (60 pages)

Exide Batteries.-Types. Type Numbers. Methods of Holding Jars in Case. Opening Exide Batteries. Work on Plates, Separators, Jars, and Case. Putting Plates in Jars. Filling Jars with EIectrolyte. Sealing Covers. Putting Cells in Case. Burning on the Cell Connectors. Charging After Repairing. Tables of Exide Batteries.

U.S.L. Batteries.-Old and New. U.S.L. Covers. Special Repair Instructions. Tables of U.S.L. Batteries.

Prest-O-Lite Batteries.-Old and New Prest-O-Lite Cover Constructions. The "Peened" Post Seal. Special Tools for Work on Prest-O-Lite Batteries. The Peening Press. Removing Covers. Rebuilding Posts. Locking, or "Peening" the Posts. Precautions in Post Locking Operations. Tables of Prest-0-Lite Batteries.

Philadelphia Diamond Grid Batteries.-Old and New Types. The Philadelphia "Rubber-Lockt" Cover Seal. Philadelphia Rubber Case Batteries. The Philadelphia Separator. Special Repair Instructions.

Eveready Batteries.-Why the Eveready Batteries Are Called "Non-Sulphating" Batteries. Description of Parts of Eveready Battery. Special Repair Instructions.

Vesta Batteries.-Old and New Vesta Isolators. The Vesta Type I'D" Battery. The Vesta Type "DJ" Battery. Vesta Separators. The Vesta Post Seal. Special Repair Instructions for Old and New Isolators and Post Seal.

Westinghouse Batteries.-The Westinghouse Post Seal. Westinghouse Plates. Types of Westinghouse Batteries. Type "A" Batteries. Type "B" Batteries. Type "C" Batteries. Type "E" Batteries. Type "H" Batteries. Type "J" Batteries. Type "0" Batteries. Type 'F" Batteries.

Willard Batteries.-Double and Single Cover Batteries. Batteries with Sealing Compound Post Seal. Batteries with Lead Inserts in Cover Post Holes. Batteries with Rubber Casket Post Seal. Special Repair Instructions for Work on the Different Types of Post Seal Constructions. Willard Threaded Rubber Separators.

Universal Batteries.-Types. Construction Features. Putting New Universal Batteries Into Service.

Titan Batteries.-The Titan Grid. The Titan Post Seal.

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17. FARM LIGHTING BATTERIES (75 pages)

Comparison of Operating Conditions of Farm Lighting Batteries with Automobile Batteries. Jars for Farm Lighting Batteries. Separators. Electrolyte. Charging Equipment. Relation of the Automobile Battery Man to the Farm Lighting Plant. Rules Governing the Selection of a Farm Lighting Plant. Location and Wiring of Farm Lighting Plant. Installation. Care of Plant in Service. Care of Battery. Charging Farm Lighting Batteries. Rules Governing Discharging of Farm Lighting Batteries. Troubles Found in Farm Lighting Batteries. Inspection and Tests on Farm Lighting Batteries. Description of Prest-O-Lite Farm Lighting Battery. Rebuilding Prest-O-Lite Farm Lighting Batteries. Description of Exide Farm Lighting Batteries. The Delco-Light Battery. Rebuilding and Repairing Exide Farm Lighting Batteries. Westinghouse Farm Lighting Batteries. Willard Farm Lighting Batteries.

DEFINITIONS

Condensed Dictionary of Words and Terms Used in Battery Work.

GENERAL INDEX

A VISIT TO THE FACTORY

Photographs showing factory processes.

BUYERS' INDEX. (Omitted. Obviously outdated after 80 years)

For the Convenience of Our Readers We Have Prepared a List of Companies

from Whom Battery Shop Equipment May Be Obtained.

ADVERTISEMENTS (Omitted. Outdated and high bandwidth)

LEAD POISONING AND SAFETY (Added)

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CHAPTER 12

GENERAL SHOP INSTRUCTIONS

CHARGING BATTERIES

The equipment for charging batteries, instructions for building and wiring charging benches have already been given. What we shall now discuss is the actual charging. The charge a battery receives on the charging bench is called a "**bench charge**."

Battery charging in the service station may be divided into two general classes:

1. Charging batteries which have run down, but which are otherwise in good condition, and which do not require repairs.

2. Charging batteries during or after the repair process.

The second class of charging is really a part of the repair process and will-be described in the chapter on "Rebuilding the Battery." Charging a battery always consists of sending a direct current through it, the current entering the battery at the positive terminal and leaving it at the negative terminal, the charging current, of course, passing through the battery in the opposite direction to the current which the battery produces when discharging. When a battery discharges chemical changes take place by means of which electrical energy is produced. When a battery is on charge, the charging current causes chemical changes which are the reverse of those which take place on discharge and which put the active materials and electrolyte in such a condition that the battery serves as a source of electricity when replaced in the car.

Batteries are charged not only in a repair shop but also in garages which board automobiles, and in car dealers' shops. No matter where a battery is charged, however, the same steps must be taken and the same precautions observed.

When a Bench Charge is Necessary:

(a) When a battery runs down on account of the generator on the car not having a sufficient output, or on account of considerable night driving being done, or on account of frequent use of the starting motor, or on account of neglect on the part of the car owner.

(b) Batteries used on cars or trucks without a generator, or batteries used for Radio work should, of course, be given a bench charge at regular intervals.

(c) When the specific gravity readings of all cells are below 1.200, and these readings are within 50 points of each other.

Should the gravity reading of any cell be 50 points lower or higher than that of the other cells, it is best to make a 15-seconds high rate discharge test (see page 266) to determine whether the cell is defective or whether electrolyte has been lost due to flooding caused by over-filling and has been replaced by water or higher gravity electrolyte. If any defect shows up during the high rate test, the battery should be opened for inspection. If no defect shows up, put the battery on charge.

(d) When the lamps burn dimly while the engine is running.

(e) When the lamps become very dim when the starting switch is closed.

If a battery is tested by turning on the lights and then closing the starting switch, make sure that there is no short-circuit or ground in the starting motor circuits. Such trouble will cause a very heavy current to be drawn from the battery, resulting in a drop in the voltage of the battery.

(f) When the voltage of the battery has fallen below 1.7 volts per cell, measured while all the lights are turned on.

(g) When the owner has neglected to add water to the cells regularly, and the electrolyte has fallen below the tops of the plates.

(h) When a battery has been doped by the addition of electrolyte or acid instead of water, or when one of the "dope" electrolytes which are advertised to make old, worn out batteries charge up in a ridiculously short time and show as much life and power as a new battery. **Use nothing but a mixture of distilled water and sulphuric acid for electrolyte.** The "dope" solutions are not only worthless, but they damage a battery considerably and shorten its life. Such a "doped" battery may give high gravity *readings and yet the lamps will become very dim when the starting motor cranks the car, the voltage per cell will be low when the lights are burning, or low voltage readings (1.50 per cell) will be obtained if a high rate discharge test is made.

Every battery which comes in for any reason whatsoever, or any battery which is given a bench charge whenever necessary should also be examined for other defects, such as poorly burned on connectors and terminals, rotted case, handles pulled off, sealing compound cracked, or a poor sealing job between the covers and jars, or covers and posts. A slight leakage of electrolyte through cracks or imperfect joints between the covers and jars or covers and posts is very often present without causing any considerable trouble. If any of the other troubles are found, however, the battery needs repairing.

Arrangement of Batteries on Charging Bench. If a battery comes in covered with dirt, set it on the wash rack or in the sink and clean it thoroughly before putting it on charge. In setting the batteries on the charging bench, place all of them so that the positive terminal is toward the right as you face the bench. The positive terminal may be found to be painted red, or may be stamped "+", "P", or "POS". If the markings on one of the terminals has been scratched or worn off, examine the other terminal. The negative terminal may be found to be painted black, or be stamped "-", "N" or "NEG".

If neither terminal is marked, the polarity may be determined with a voltmeter, or by a cadmium test. To make the voltmeter test, hold the meter wires on the battery terminals, or the terminals of either end cell. When the voltmeter pointer moves to the right of the "0" line on the scale, the wire attached to the "+" terminal of the meter is touching the positive battery terminal, and the wire attached to the "-" terminal of the meter is touching the negative battery terminal. If this test is made with a meter having the "0" line at the center of the scale, be sure that you know whether the pointer should move to the left or right of the "0" line when the wire attached to the "+" meter terminal is touching the positive battery terminal.

Another method of determining which is the positive terminal of the battery is to use the cadmium test. When a reading of about two volts is obtained, the prod held on one of the cell terminals is touching the positive terminal. When a reading of almost zero is obtained, that is, when the needle of the meter just barely moves from the "0" line, or when it does not move at all, the prod held on one of the cell terminals is touching the negative terminal. This test, made while the battery is on open-circuit, is not a regular cadmium test, but is made merely to determine the polarity of the battery.

The polarity of the charging line will always be known if the bench is wired permanently. The positive charging wire should always be to the right. If a separate switch is used for each battery (Figures 43 and 65), the wire attached to the right side of the switch is positive. If the batteries are connected together by means of jumpers (Figures 44 and 47), the positive charging wire should be at the right hand end of the bench as seen when facing the bench. If a constant-potential charging circuit is used as shown in Figure 48, the positive bus-bar should be at the top and the neutral in the center, and

the negative at the bottom.

If the polarity of the charging line wires is not known, it may be determined by a voltmeter, in the same way as the batter-, polarity is determined. If this is done, care should be taken to use a meter having a range sufficient to measure the line voltage. If no such voltmeter is available, a simple test is to fill a tumbler with weak electrolyte or salt water and insert two wires attached to the line. The ends of these wires should, of course, be bare for an inch or more. Hold these wires about an inch apart, with the line alive. Numerous fine bubbles of gas will collect around the negative wire.

With the polarities of all the batteries known, arrange them so that all the positive terminals are at the right. Then connect them to the individual switches (see Figure 43), or connect them together with jumpers (see Figure 44), being sure to connect the negative of one battery to the positive of the next. Connect the positive charging line wire to the positive terminal of the first battery, and the negative line wire to the negative terminal of the last battery. See page 105.

With all connections made, and before starting to charge, go over all the batteries again very carefully. You cannot be too careful in checking the connections, for if one or more batteries are connected reversed, they will be charged in the wrong direction, and will most likely be severely damaged.

As a final check on the connections of the batteries on the line, measure the total voltage of these batteries and see if the reading is equal to two times the total number of cells on the line.

Now inspect the electrolyte in each cell. If it is low, add distilled water to bring the electrolyte one-half inch above the plates. Do not wait until a battery is charged before adding water. Do it now. Do not add so much water that the electrolyte comes above the lower end of the vent tube. This will cause flooding.

Charging, Rate. If you connect batteries of various sizes together on one circuit, charge at the rate which is normal for the smallest battery. If the rate used is the normal one for the larger batteries, the smaller batteries will be overheated and "boiled" to death, or they may gas so violently as to blow a considerable portion of the active material from the plates.

It is quite possible to charge 6 and 12 volt batteries in series. The important point is not to have the total number of cells too high. For instance, if the 10 battery Tungar is used, ten 6-volt batteries (30 cells), or any combination which gives 30 cells or less may be used. For instance, five 12-volt batteries (30 cells), or six 6-volt batteries (18 cells) and two 12-volt batteries (12 cells), or any other combination totaling 30 cells may be used. The same holds true for motor-generators.

The charging rate is generally determined by the size of the charging outfit. The ten battery Tungar should never have its output raised above 6 amperes. A charging rate of 6 amperes is suitable for all but the very smallest batteries. In any case, whether you are certain just what charging rate to use, or not, there are two things which will guide you, temperature and gassing.

1. Temperature. Have a battery thermometer (Figure 37) on hand, and measure the temperature of the electrolyte of each cell on the line. If you note that some particular cell is running hotter than the others, keep the thermometer in that cell and watch the temperature. Do not let the temperature rise above 110 degrees Fahrenheit, except for a very short time. Should the highest of the temperature of the cells rise above 110 degrees, reduce the charging rate.

2. Gassing. Near the end of a charge and when the specific gravity has stopped rising, or is rising very slowly, bubbles of gas will rise from the electrolyte, this being due to the charging current decomposing the water of the electrolyte into hydrogen and oxygen. If this gassing is too violent, a considerable amount of active material will be blown from the plates. Therefore, when this gassing begins, the charging rate should be reduced, unless the entire charging has been done at a low rate, say about five amperes.

If gassing begins in any cell soon after the charge is started, or before the specific gravity has reached its highest point, reduce the charging rate to eliminate the gassing.

If one battery or one cell shows a high temperature and the others do not, or begins gassing long before the others do, remove that battery from the charging line for further investigation and replace it with another so as not to slow up the

charge of the other batteries which are acting normally.

As long as excessive temperatures and too-early gassing are avoided, practically any charging rate may be used, especially at the start. With a constant potential charging set, as shown in Figure 48, the charge may start at as high a rate as 50 amperes. If this system of charging is used, the temperature must be watched very carefully and gassing must be looked for. With the usual series method of charging, a charge may, in an emergency, be started at 20 amperes or more. As a general rule do not use a higher rate than 10 amperes. A five ampere rate is even better, but more time will be required for the charge.

Time Required for a Charge. The time required is not determined by the clock, but by the battery. Continue the charge until each cell is gassing freely (not violently) and for five hours after the specific gravity has stopped rising. The average condition of batteries brought in for charge permits them to be fully charged in about 48 hours, the time being determined as stated above. Some batteries may charge fully in less time, and some may require from four days to a week, depending entirely upon the condition of the batteries. Do not give any promise as to when a recharge battery will be ready. No one can tell how long it will take to charge.

Specific Gravity at the End of the Charge. The specific gravity of the electrolyte in a fully charged cell should be from 1.280 to 1.300. If it varies more than 10 points above or below these values, adjust it by drawing off some of the electrolyte with a hydrometer and adding water to lower the gravity, or 1.400 acid to raise the gravity. After adjusting the gravity charge for one hour more.

Battery Voltage at End of Charge. The voltage of a fully charged cell is from 2.5 to 2.7 when the temperature of the electrolyte is 80 degrees Fahrenheit; 2.4 to 2.6 when the temperature of the electrolyte is 100 degrees Fahrenheit, and 2.35 to 2.55 volts when the temperature of the electrolyte is 120 degrees Fahrenheit, and this. voltage, together with hydrometer readings of 1.280-1.300 indicate that the battery is fully charged.

Just before putting a battery which has been charged into service, give it a 15 seconds high rate discharge test, see page 266.

Painting. Before returning a battery to the owner wipe it perfectly clean and dry. Then wipe the covers, terminals, connectors and handles with a rag wet with ammonia. Next give the case a light coat of black paint which may be made by mixing lamp black and shellac. This paint dries in about five minutes and gives a good gloss. The customer may not believe that you are returning the battery which he brought in but he will most certainly be pleased with your service and will feel that if you take such pains with the outside of his battery you will certainly treat the inside with the same care when repairs are necessary. The light coat of paint costs very little for one battery, but may bring you many dollars worth of work.

Level of Electrolyte. During charge the electrolyte will expand, and will generally flow out on the covers. This need not be wiped off until the end of the charge. When the electrolyte has cooled after the battery is taken off charge, it must be about 1/2 inch above the plates. While the electrolyte is still warm it will stand higher than this, but it should not be lowered by drawing off some of it, as this will probably cause it to be below the tops of the plates and separators when it cools.

TROUBLES

If all goes well, the charging process -will take place as described in the preceding paragraphs. It frequently happens, however, that all does not go well, and troubles arise. Such troubles generally consist of the following:

Specific gravity will not rise to 1.280. This may be due to the plates not taking a full charge, or to water having been used to replace electrolyte which has been spilled. To determine which of these conditions exist, make cadmium test (see page 174) on the positives and negatives, also measure the voltage of each cell. If these tests indicate that the plates are fully charged (cell voltage 2.5 to 2.7, Positive-Cadmium 2.4 volts, Negative-Cadmium minus 0.15 to 0.20 volts), you will know that there is not enough acid in the electrolyte. The thing to do then is to dump out the old electrolyte, refill with 1.300 electrolyte and continue the charge until the specific gravity becomes constant. Some adjustment may then have to

be made by drawing off some of the electrolyte with a hydrometer and adding water to lower the gravity, or 1.400 acid to bring it up. **Remember that specific gravity readings tell you nothing about the plates, unless it is known that the electrolyte contains the correct proportions of water and acid.** The cadmium test is the test which tells you directly whether or not the plates are charged and **in charging a battery the aim is to charge the plates, and not merely to bring the specific gravity to 1.280.**

If the specific gravity will not rise to 1.280 and cadmium tests show that the plates will not take a full charge, then the battery is, of course, defective in some way. If the battery is an old one, the negatives are probably somewhat granulated, the positives have probably lost much of their active material, resulting in a considerable amount of sediment in the jars, and the separators are worn out, carbonized, or clogged with sediment. Such a battery should not be expected to give as good service as a new one, and the best thing to do if the tests show the battery to be more than half charged, is to put it back on the car, taking care to explain to the owner why his battery will not "come up" and telling him that he will soon need a new battery. Remember that improperly treated separators, or defective separators will cause poor Negative-Cadmium readings to be obtained.

If a fairly new battery will not take a full charge, as indicated by hydrometer readings and cadmium tests, some trouble has developed due to neglect, abuse, or defect in manufacture. If all cells of a fairly new battery fail to take a full charge within 48 hours, the battery has probably been abused by failing to add water regularly, or by allowing battery to remain in an undercharged condition. Such a battery should be kept on the line for several days more, and if it then still will not take a full charge the owner should be told what the condition of the battery is, and advised to have it opened for inspection.

If one cell of a battery fails to take a charge, but the other cells charge satisfactorily, and cadmium tests show that the plates of this cell are not taking a charge, the cell should be opened for inspection. If one cell of a battery charges slowly, cut the other cells out of the line, and charge the low cell in series with the other batteries on the charging line.

If all cells of a battery, whether new or old, will not take even half a charge, as indicated by hydrometer readings (1.200), the battery should be opened for inspection.

If the gravity. of a battery on charge begins to rise long before the voltage rises, and if the gravity rises above 1.300, there is too great a proportion of acid in the electrolyte. The remedy is to dump out the electrolyte, refill with pure water and continue the charge at a lower rate than before, until the specific gravity stops rising. Then charge for ten hours longer, dump out the water (which has now become electrolyte by the acid formed by the charging current), refill with about 1.350 electrolyte and continue the charge, balancing the gravity if necessary at the end of the charge.

If a battery becomes very hot while on charge at a rate which is not normally too high for the battery, it indicates that the battery is badly sulphated, or has a partial short-circuit. Gassing generally goes with the high temperature.

If you can detect a vinegar-like odor rising from the vent holes, you may be absolutely sure that the separators used in that battery have developed acetic acid due to not having received the proper treatment necessary to prepare them for use in the battery. The electrolyte should be dumped from such a battery immediately and the battery should be filled and rinsed with water several times. Then the battery should be opened without loss of time, to see whether, by removing the separators and washing the plates thoroughly, the plates may be saved. If the acetic acid has been present for any length of time, however, the plates will have been ruined beyond repair, the lead parts being dissolved by the acid.

If the electrolyte of a battery on charge has a white, milky look, there may be impurities which cause numerous minute bubbles to form, such bubbles giving the electrolyte its milky appearance. The milky appearance may be due to the use of "hard" water in refilling, this water containing lime.

The electrolyte as seen with the acid of an electric lamp or flashlight should be perfectly clear and colorless. Any scum, particles of dirt, any color whatsoever shows that the electrolyte is impure. This calls for dumping out the electrolyte, filling and rinsing with pure water, refilling with new electrolyte and putting the battery back on the charging line. Of course, this may not cause the battery to charge satisfactorily, which may be due to the troubles already described.

Should it ever happen that it is impossible to send a current through a charging circuit go over all the connections to make sure that you have good contact at each battery terminal, and that there are no loose inter-cell connectors. If all connections to the batteries are -good, and there are no loose inter-cell connectors, cut out one battery at a time until you start the current flowing, when you cut out some particular battery. This battery should then be opened without further tests, as it is without a doubt in a bad condition.

The conditions which may exist when a battery will not charge, as shown especially by cadmium tests, are as follows:

(a) The battery may have been allowed to remain in a discharged condition, or the owner may have neglected to add water, with the result that the electrolyte did not cover the plates. In either case a considerable amount of crystallized sulphate will have formed in the plates. Plates in such a condition will require a charge of about a week at a low rate and will then have to be discharged and recharged again. Several such cycles of charge and discharge may be necessary. It may even be impossible to charge such a battery, no matter how many cycles of charge and discharge are given. If the owner admits that his battery has been neglected and allowed to stand idle for a considerable time, get his permission to open the battery.

(b) The battery may have been overheated by an excessive charging rate, or by putting it on a car in a sulphated condition. The normal charging rate of the generator on the car will over heat a sulphated battery. Overheated plates buckle their lower edges cut through the separators, causing a short-circuit between plates.

(c) The pockets in the bottoms of the jars may have become filled with sediment, and the sediment may be short-circuiting the plates.

(d) Impurities may have attacked the plates and changed the active materials to other substances which do not form a battery. Such plates may be so badly damaged that they are brittle and crumbled. Acetic acid from improperly treated separators will dissolve lead very quickly, and may even cause an open circuit in the cell.

(e) The conditions described in (a), (b), and (c) will permit a charging current to pass through the battery, but the plates will not become charged. It is possible, of course, but not probable, that a condition may exist in which all the plates of one or both groups of a cell may be broken from the connecting straps, or inter-cell connectors may be making no contact with the posts. In such a case, it would be impossible to send a charging current through the battery. Acetic acid from improperly treated separators, and organic matter introduced by the use of impure water in refilling will attack the lead of the plates, especially at the upper surface of the electrolyte, and may dissolve all the plate lugs from the connecting straps and cause an open-circuit.

(f) The separators may be soggy and somewhat charred and blackened, or they may be clogged up with sulphate, and the battery may need new separators.

(g) The spongy lead may be bulged, or the positives may be buckled. The active material is then not making good contact with the grids, and the charging current cannot get at all the sulphate and change it to active material. The remedy in such a case is to press the negatives so as to force the active material back into the grids, and to put in new positives if they are considerably buckled.

(h) One of the numerous "dope" electrolytes which are offered to the trustful car owner may have been put in the battery. Such "dopes" might cause very severe damage to the plates. Tell your customers to avoid using such "dope."

The conditions which may exist when the plates of a battery take a charge, as indicated by cadmium tests, but the gravity will not come up to 1.280 are as follows:

(a) There may be considerable sediment in the jars but not enough to short circuit the plates. If the battery has at some time been in a sulphated condition and has been charged At too high a rate, the gassing that resulted will have caused chips of the sulphate to drop to the bottom of the jars. When this sulphate was formed, some of the acid was taken from the electrolyte, and if the sulphate drops from the plates, this amount of acid cannot be recovered no matter how long the

charge is continued. If the owner tells you that his battery has stood idle for several months at some time, this is a condition which may exist. The remedy is to wash and press the negatives, wash the positives, put in new separators, pour out the old electrolyte and wash out the jars, fill with 1.400 acid, and charge the battery.

(b) Impurities may have used up some of the acid which cannot be recovered by charging. If the plates are not much damaged the remedy is the same as for (a). Damaged plates may require renewal.

(c) Electrolyte may have been spilled accidentally and replaced by water.

(d) Too much water may have been added, with the result that the expansion of the electrolyte due to a rise in temperature on charge caused it to overflow. This, of course, resulted in a loss of some of the acid

The causes given in (c) and (d) may have resulted in the top of the battery case being acid-eaten or rotted. The remedy in these two instances is to draw off some of the electrolyte, add some 1.400 acid and continue the charge. If plates and separators look good and there is but little sediment, this is the thing to do.

If Battery will not hold a Charge. If a battery charges properly but loses its charge in a week or less, as indicated by specific gravity readings, the following troubles may exist:

(a) Impurities in the cells, due to the use of impure water in the electrolyte, or in the separators. Some impurities (see page 76) do not attack the plates, but merely cause self-discharge. The remedy is to dump out the old electrolyte, rinse the jars with pure water, fill with new electrolyte of the same gravity as the old and recharge. If this does not remove impurities, the battery should be opened, the plates washed, jars cleaned out, new separators put in, and battery reassembled and charged.

(b) There may be a slow short-circuit, due to defective separators or excessive amount of sediment. If preliminary treatment in (a) does not cause battery to hold charge, the opening of battery and subsequent treatment will remove the cause of the slow short-circuit.

Suggestions

1. Make sure every battery is properly tagged before going on line.

2. Determine as quickly as possible from day to day, those batteries that will not charge. Call owner and get permission to open up any such battery and do whatever is necessary to put it in good shape.

3. As soon as a battery charges to 1.280-1.300, the voltage is 2.5-2.7 per cell and the cadmium readings are 2.4 or more for the positives and -0.15 to -0.20 for the negatives and the gravity voltage and cadmium readings do not change for five hours, remove it from the line as finished and replace it with another if possible. Go over your line at least three times a day and make gravity, temperature, and cadmium tests.

4. Make a notation, with chalk, of the gravity of each cell each morning. Do not trust to memory.

5. Remove from the line as soon as possible any battery that has a leaky cell and neutralize with soda the acid that has leaked out.

6. Batteries that are sloppers, with rotten cases, and without handles are sick and need a doctor. Go after the owner and get permission to repair.

7. Keep the bench orderly and clean.

8. Remember that if you have a line only partly full and have other batteries waiting to be charged you are losing money by not keeping a full line.

9. Leave the Vent Plugs in When Charging. The atmosphere in many service stations, where the ventilation is poor, is so filled with acid fumes that customers object to doing business there.

The owners of these places may not notice these conditions, being used to it, or rather glory in being able to breathe such air without coughing or choking, but it certainly does not invite a customer to linger and spend his money.

The remedy for such a condition is to leave the vent plugs in place on the batteries that are charging so that the acid spray in the gas from the battery condenses out as it strikes these plugs and drips back into the cells, while the gas passes out through the small openings in the plug.

The plugs need only be screwed into the openings by one turn, or only set on top of the vent openings to accomplish the result.

This takes no additional time and more than repays for itself in the saving of rusted tools and improved conditions in the battery room and surroundings. In charging old Exide batteries, be sure to replace the vent plugs and turn them to open the air passages which permit the escape of gases which form under the covers. If you wish to keep these air passages open without replacing the plugs, which may be done for convenience, give the valve (see page 21) a quarter turn with a screwdriver or some other tool.

10. If the electrolyte from a battery rises until it floods over the top of the jar, it shows that too much water was added when the battery was put on charge, the water rising to the bottom of the vent tube, thereby preventing gases formed (except those directly below the vent hole) from escaping. This gas collects under the covers, and its pressure forces the electrolyte up into the vent hole and over the top of the battery. In charging old U.S.L. batteries it is especially necessary to keep the air vent (see page 20) open to prevent flooding, since the lower end of the vent tube is normally a little below the surface of the electrolyte.

Remember, do not have the electrolyte come up to the lower end of the vent tube.

NOTE: To obtain satisfactory negative cadmium readings, the charging rate should be high enough to give a cell voltage of 2.5-2.7.

Improperly treated separators, or separators which have been allowed to become partly dry at any time will make it impossible to obtain satisfactory negative cadmium readings.

LEAD BURNING (WELDING)

Lead cannot be "burned" in the sense that it bursts into flame as a piece of paper does when a match is applied to it. If sufficient heat is applied, the lead will oxidize and feather away into a yellow looking dust, but it does not burn. The experienced battery man knows that by "lead burning" is meant the heating of lead to its melting point, so that two lead surfaces will weld together. This is a welding and not a "burning" process, and much confusion would be avoided if the term "lead welding" were used in place of the term "lead burning."

The purpose of welding lead surfaces together is to obtain a joint which offers very little resistance to the flow of current, it being absolutely necessary to have as low a resistance as possible in the starting circuit. Welding also makes joints which are strong mechanically and which cannot corrode or become loose as bolted connections do. Some earlier types of starting and lighting batteries had inter-cell connectors which were bolted to the posts, but these are no longer used.

The different kinds of lead-burning outfits are listed on page 143 The oxygen-acetylene and the oxygen-hydrogen flames give extremely high temperatures and enable you to work fast. Where city gas is available, the oxygen illuminating gas combination will give a very good flame which is softer than the oxygen acetylene, oxygen-hydrogen outfits. Acetylene and compressed air is another good combination.

There are two general **classes of lead-welding**:

(a) Welding connecting bars, called "cell" connectors, top connectors, or simply "connectors," to the posts which project up through the cell covers, and welding terminals to the end posts of a battery.

(b) Welding plates to "straps" to form groups. The straps, of course, have joined to them the posts which project through the cell covers and by means of which cells are connected together, and connections made to the electrical system of the car.

In addition to the above, there are other processes in which a burning (welding) flame is used:

(c) Post-building, or building posts, which have been drilled or cut short, up to their original size.

(d) Extending plate lug. If the lug which connects a plate to the plate strap is too short, due to being broken, or cut too short, the lug may be extended by melting lead into a suitable iron form placed around the lug.

(e) Making temporary charging connections between cells by lightly -welding lead strips to the posts so as to connect the cells together.

(f) A lead-burning (welding) flame is also used to dry out the channel in cell covers before pouring in the sealing compound, in re-melting sealing compound which has already been poured, so as to assure a perfect joint between the compound cover and jar, and to give the compound a smooth glossy finish. These processes are not welding processes and -will not be described here.

General Lead Burning Instructions

Flame. With all the lead burning outfits, it is possible to adjust the pressures of the gases so as to get extremely hot, medium, and soft flames. With the oxygen-acetylene, or oxygen-hydrogen flame, each gas should have a pressure of about two pounds. With the oxygen-illuminating gas flame, the oxygen should have ,a pressure of 8 to 10 pounds. The city gas then does not need to have its pressure increased by means of a pump, the normal pressure (6 to 8 ounces) being satisfactory.

Various makes of lead-burning outfits are on the market, and the repairman should choose the one which he likes best; since they all give good results. All such outfits have means of regulating the pressures of the gases used. With some the gases are run close to the burning tip before being mixed, and have an adjusting screw where the gases mix. Others have a Y shaped mixing valve at some distance from the burning tip, as shown in Figure 78. Still others have separate regulating valves for each gas line.

With these adjustments for varying the gas pressure, extremely hot, hissing flames, or soft flames may be obtained. For the different welding jobs, the following flames are suitable:

1. A sharp, hissing flame, having a very high temperature is the one most suitable for the first stage in welding terminals and connectors to the posts.

2. A medium flame with less of a hiss is suitable for welding plates to strips and lengthening plate lugs.

3. A soft flame which is just beginning to hiss is best for the finishing of the weld between the posts and terminals or connectors. This sort of a flame is also used for finishing a sealing job, drying out the cover channels before sealing, and so on.

In adjusting the burning- flame, 4 the oxygen is turned off entirely, a smoky yellow flame is obtained. Such a flame gives but little heat. As the oxygen is gradually turned on the flame becomes less smoky and begins to assume a blue tinge. It will also be noticed that a sort of a greenish cone forms in the center portion of the flame, with the base of the cone at the torch and the tip pointed away from the torch. At first this inner-cone is long and of almost the same color as the outer portion of the flame. As the oxygen pressure is increased, this center cone becomes shorter and of a more vivid color, and its tip begins to whip about. When the flame is at its highest temperature it will produce a hissing sound and the inner

cone will be short and bright. With a softer flame, which has a temperature suitable for welding plates to a strap, the inner cone will be longer and less vivid, and the hissing will be greatly diminished.

The temperature of the different parts of the flame varies considerably, the hottest part being just beyond the end of the inner cone. Experience with the particular welding outfit used will soon show how far the tip of the torch should be held from the lead to be melted.

Cleanliness. Lead surfaces which are to be welded together must be absolutely free from dirt. Lead and dirt will not mix, and the dirt will float on top of the lead. Therefore, before trying to do any lead welding, clean the surfaces which are to be joined. -The upper ends of plate lugs may be cleaned with a flat file, knife., or wire brush. The posts and inter-cell connectors should be cleaned with a knife, steel wire brush, or triangular scraper. Do not clean the surfaces and then wait a long time before doing the lead burning. The lead may begin to oxidize if this is done and make it difficult to do a good job.

The surfaces which are to be welded together should also be dry. If there is a small hole in the top of a post which is to be welded to a connector or terminal, and this hole contains acid, a shower of hot lead may be thrown up by the acid, with possible injury to the operator.

Do not try to save time by attempting to weld dirty or wet lead surfaces, because time cannot be saved by doing so, and you run the risk of being injured if hot lead is thrown into your face. Remove absolutely every speck of dirt, --you will soon learn that it is the only way to do a good job.

Safety Precautions. Remove the vent plugs and blow down through the vent holes to remove any gases which may have collected above the surface of the electrolyte. An explosion may result if this is not done. To protect the rubber covers, you may cover the whole top of the battery except the part at which the welding is to be done, with a large piece of burlap or a towel which has been soaked in water. The parts covered by the cloth must be dried thoroughly if any welding on them. Instead of using a wet cloth, a strip of asbestos may be laid over the vent holes, or a small square of asbestos may be laid over each vent hole.

Burning on the Cell Connectors and Terminals

Have the posts perfectly clean and free from acid. Clean the tops, bottoms and sides of the connectors with a wire brush, Figure 143. Finish the top surfaces with a coarse file, Figure 144. With a pocket knife clean the inside surfaces of the connector holes.

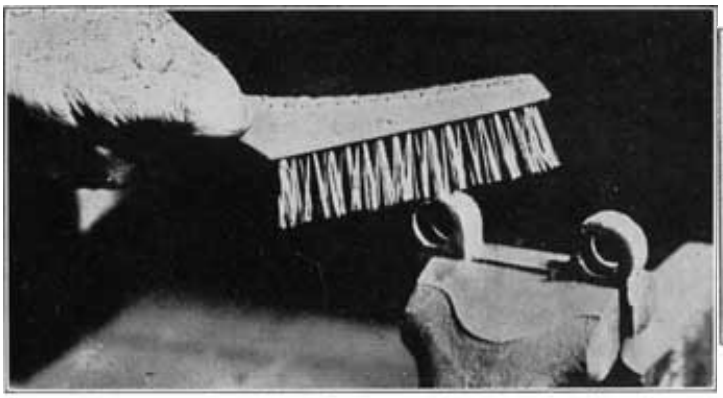

Fig. 143. Brushing Connector Before Burning In

Fig. 144. Rasping Connector Before Burning In

Place the connectors and terminals in their proper positions on the posts, and with a short length of a two by two, two by one, or two by four wood pound them snugly in position, Figure 145. Be sure that the connectors are perfectly level and that the connectors are in the correct position as required on the car on which the battery is to be used. The top of the post should not come flush with the top of the connector. Note, from Figure 146, that the connector has a double taper, and that the lower tapered surface is not welded to the post. If the post has been built up too high it should be cut down with a pair of end cutting nippers so that the entire length of the upper taper in the connector is in plain sight when the connector

is put in position on the post. This is shown in Figure 146. With the connectors in place, and before welding them to the posts, measure the voltage of the whole battery to be sure that the cells are properly connected, as shown by the voltage reading being equal to two times the number of cells. If one cell has been reversed, as shown by a lower voltage reading now is the time to correct the mistake.

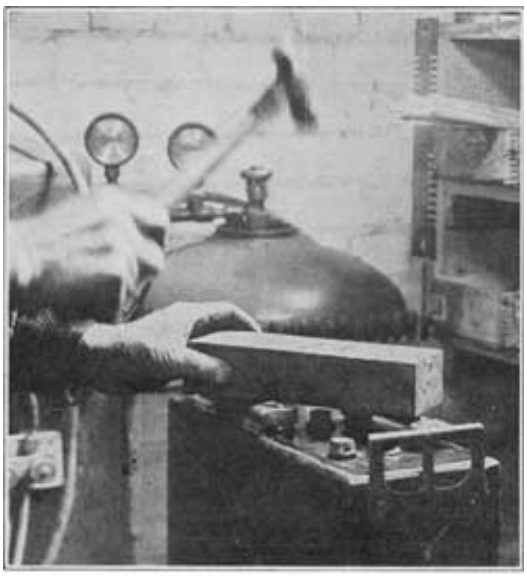

Fig. 145. Leveling Top Connectors Before Burning In

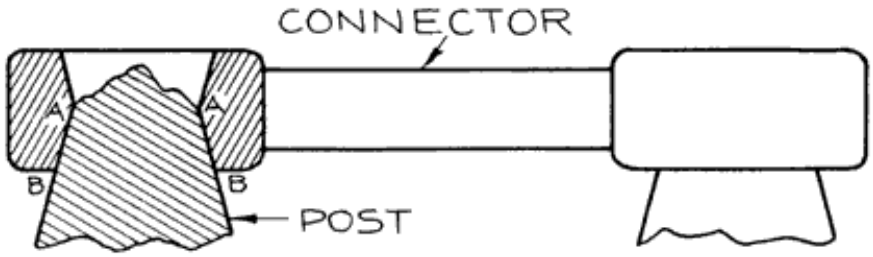

Fig. 146. Connector in Position on Post for Welding to Post. Surfaces A-B Are Not Welded Together 146

The connectors and terminals are now ready to be welded to the posts. **Before bringing any flame near the battery be sure that you have blown out any gas which may have collected under the covers.** Then cover the vents with asbestos or a wet cloth. as, already described. You will need strips of burning lead, such as those made in the burning lead mould described on page 164.

Use a hot, hissing flame for the first stage. With the flame properly adjusted, hold it straight above the post, and do not run it across the top of the battery. Now bring the flame straight down over the center of the post, holding it so that the end of the inner cone of the flame is a short distance above the post. When the center of the post begins to melt, move the flame outward with a circular motion to gradually melt the whole top of the post, and to melt the inner surface of the hole in the connector. Then bring the lower end of your burning lead strip close to and over the center of the hole, and melt in the lead, being sure to keep the top of the post and the inner surface of the hole in the connector melted so that the lead you are melting in will flow together and unite. Melt in lead until it comes up flush with the upper surface of the connector. Then remove the flame. This completes the first stage of the welding process. Now repeat the above operation for each post and terminal.

It is essential that the top of the post and the inner surface of the hole in the connector be kept melted as long as you are running in lead from the strip of burning lead. This is necessary to have all parts fuse together thoroughly. If you allow the top of the post, or the inner surface of the hole in the connector to chill slightly while you are feeding in the lead, the parts will not fuse, and the resuilt will be a poor Joint, which will heat up and possibly reduce the current obtained from the battery when the starting switch is closed. This reduction may prevent the starting motor from developing sufficient torque to crank the engine.

When the joint cools, the lead will shrink slightly over the center of the posts. To finish the welding, this lead is to be built up flush or slightly higher than the connector. Brush the tops of the post and connector thoroughly with a wire brush to remove any dirt which may have been floating in the lead. (Dirt always floats on top of the lead.) Soften the burning flame so that it is just barely beginning to hiss. Bring the flame down over the center of the post. When this begins to melt, move the flame outward with a circular motion until the whole top of post and connector begins to melt and fuse. If necessary run in some lead from the burning lead strip. When the post and connector are fused, clear to the outer edge of the connector, raise the flame straight up from the work.

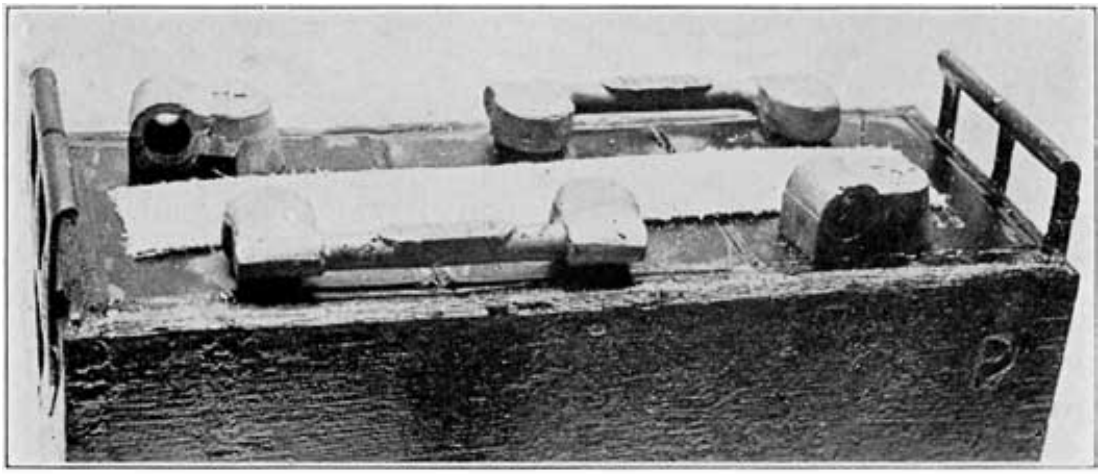

Fig. 147. Connectors "Burned" to Posts

You will save time by doing the first stage of the burning on all posts first, and then finish all of them. This is quicker than trying to complete both stages of burning on each post before going to the next post. The object in the finishing stage is to melt a thin layer of the top of post and connector, not melting deep enough to have the outer edge of the connector melt and allow the lead to run off. All this must be done carefully and dexterously to do a first-class job, and you must keep the flame moving around over the top and not hold it in any one place for ally length of time, so as not to melt too deep, or to melt the outer edge and allow the lead to run off and spoil the job. Sometimes the whole mass becomes too hot and the top cannot be made smooth with the flame. If this occurs wait until the connector cools, soften the flame, and try again. Figure 147 shows the welding completed.

Burning Plates to Strap and Post

First clean all the surfaces which are to be welded together. Take your time in doing this because you cannot weld dirty surfaces together.

Plates which compose a group are welded to a "strap" to which a post is attached, as shown in Figure 5. The straps shown in Figure 5 are new ones, as made in the factory. Plate lugs are set in the notches in the straps and each one burned in separately. In using old straps from a defective group, it is best to cut the strap close to the post, thus separating all the plates from the post in one operation, as was done with tile post shown in Figure 96. If only one or two plates are to be burned on, they are broken or cut off and slots cut in the strap to receive the lugs of tile new plates, as shown in Figures 148 and 149.

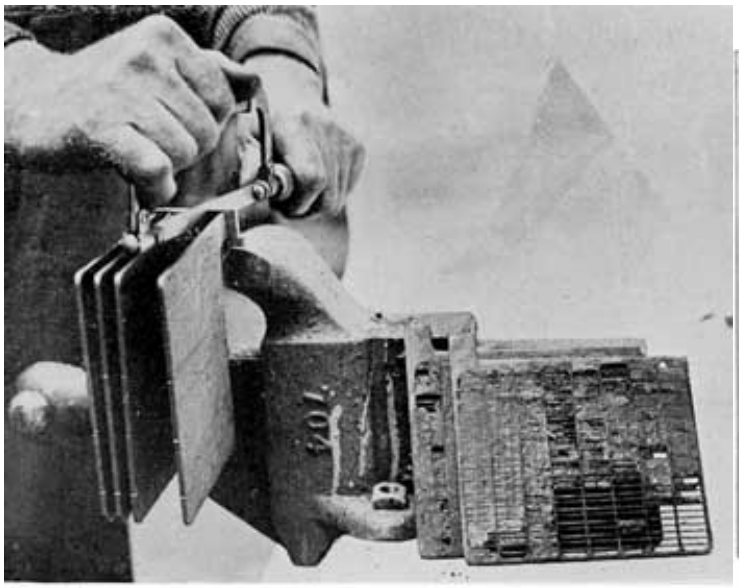

Fig. 148. Sawing Slot in Plate Strap

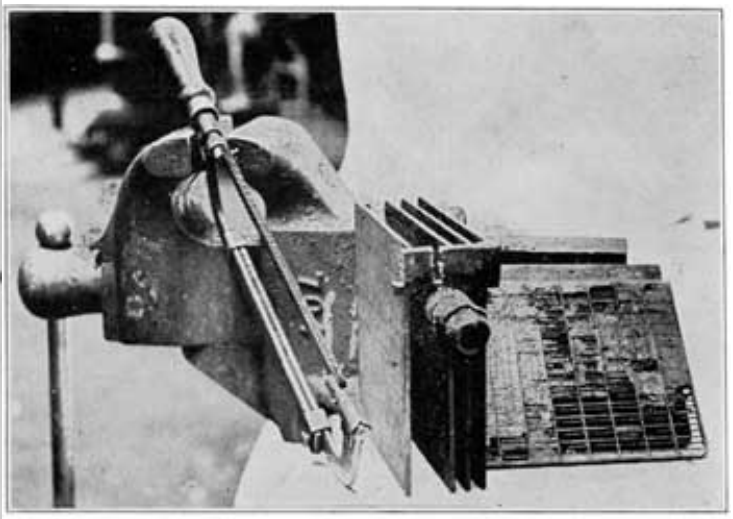

Fig. 149. Slotting Saw, a Group with Two Plates Cut Off, and Slots in Strap for New Plates

Set the plates in a plate burning rack, as shown in Figure 96, placing the adjustable form around the lugs and strap as shown in this figure. Be sure to set the post straight, so that the covers will fit. A good thing is to try a cover over the post to see that the post is set up properly. The post must, of course, be perpendicular to the tops of the plates. If the slotted plate strap shown in Figure 5 is used, or if one or two plates have been cut off, melt the top of the lug of one of the plates which are to be burned oil, and the surfaces of the strap to which the plate is to be welded. Melt in lead from a burning-lead strip to bring the metal up flush with the surface of the strap. Proceed with each plate which is to be burned on.

If all the plates have been sawed from the strap, leaving the post with a short section of the strap attached, as shown in Figure 96, melt the edge of the strap, and the top of one or two of the end plate lugs and run in lead from the burning strip to make a good joint. Proceed in this way until all the lugs are joined to the strap and then run the flame over the top of the entire strap to make a smooth uniform weld. Be sure to have the lower edge of the strap fuse with the plate lugs and then run in lead to build the strap up to the proper thickness. Raise the flame occasionally to see that all parts are fusing thoroughly and to prevent too rapid heating.

When enough lead has been run in to build the strap tip to the correct thickness and the plate lugs are thoroughly fused with the strap, raise the flame straight up from the work. Allow the lead to "set" and then remove the adjustable form and lift the group from the burning rack. Turn the group up-side-down and examine the bottom of the strap for lead which ran down the lugs during the welding process. Cut off any such lead with a saw, as it may cause a short-circuit when the plates are meshed with the other group.

Post Building

In drilling down through the inter-cell connectors to separate them from the posts in opening a battery, the posts may be drilled too short. In reassembling the battery it is then necessary to build the posts up to their original height. This is done with the aid of post-builders, shown in Figure 100.

Clean the stub of the post thoroughly and also clean the inside of the post builder. Then set the post builder carefully over the stub post, so that the upper surface of the post builder is parallel to the upper surface of the plate strap. The built up post will then be perpendicular to the surface of the strap, which is necessary, in order to have the covers and connectors fit properly.

With the post builder set properly adjust the burning torch to get a sharp, hissing flame. Bring the flame straight down on the center of the post stub. When the center of the post stub begins to melt, move the flame outward with a circular motion until the whole top of the stub begins to melt. Then run in lead from a burning lead strip, Figure 101, at the same time keeping the flame moving around on the top of the post to insure a good weld. In this way build up the post until. the lead comes up to the top of the post builder. Then lift the flame straight up from the post. Allow the lead to set, and then

remove the post builder, grasping it with a pair of gas or combination pliers and turn the post builder around to loosen it.

Extending Plate Lugs

It sometimes happens that a good plate is broken from a strap, thus shortening the lug. Before the plate may be used again, the lug must be extended to its original length. To do this, clean the surfaces of the lug carefully, lay the plate on a sheet of asbestos, and place an iron form having a slot of the correct width, length, and thickness, as shown in Figure 150. Use a medium hissing flame, and melt the upper edge of the lug, and then run in lead from the lead burning strip to fill the slot in the iron form. The plate may then be used again.

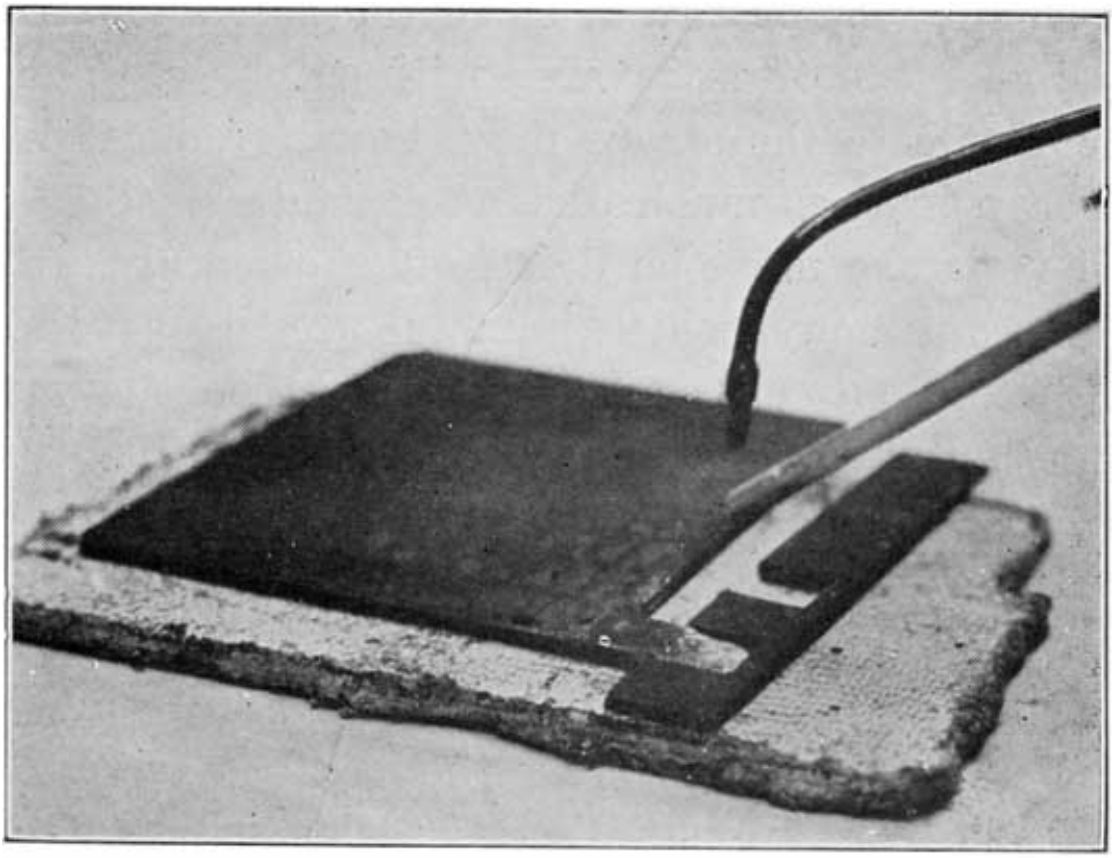

Fig. 150. Extending Lug on Plate

Making Temporary Charging Connections

After a battery has been opened it is often desired to charge a battery without burning on the intercell connectors. Temporary connections may be made between cells by placing a short length of a burning lead strip from post to post and applying a flame for an instant to spot-weld the strip to the top of the post.

MOULDING LEAD PARTS

In using special moulds for casting inter-cell connectors, plate straps with posts, terminals, etc., follow the special instructions furnished by the manufacturers as to the manipulation of the special moulds made by them.

Aside from the special instructions for the use of moulds, there are general rules for the melting of lead and handling it after it is melted, which must be observed if good castings are to be made.

Raw Materials. In every battery repair shop a supply of old terminals, cell connectors, posts, and straps, will gradually accumulate. These should not be thrown away or sold as junk, but should be kept in a box or jar provided for that purpose. Old plates should not be saved, since the amount of lead in the grid is small and it is often covered with

sulphate. The lugs connecting the plates to the straps may, however, be used. Before using the scrap lead as much dirt as possible should be brushed off, and all moisture must be dried off thoroughly. Scrap lead contains some antimony, which is metal used to give stiffness to tile parts. Using miscellaneous scrap sometimes gives castings which do not contain the proper percentage of antimony. If there is too much antimony present, cracked castings will be the result. To remedy this condition, bars of pure lead should be purchased from some lead manufacturing company. Adding pure lead will reduce the percentage of antimony. Bars of pure antimony should also be kept oil hand in case the castings are too soft.

Lead Melting Pots are standard articles which may be purchased from jobbers. A pot having a 25 pound capacity is suitable for small shops and for larger shops a 125-pound size is best. Before melting any lead in such pots, have them thoroughly free from dirt, grease, or moisture, not merely in order to get clean castings, but also to avoid melted lead being thrown out of the pot on account of the presence of moisture. Severe burns may be the result of carelessness in this respect.

In starting with an empty melting pot, turn oil the heat before putting in any lead, and let the pot become thoroughly heated in order to drive off any moisture. With the pot thoroughly hot, drop in the lead, which must also be dry. When the metal has become soft enough to stir with a clean pine stick, skim off the dirt and dross which collects on top and continue heating the lead until it is slightly yellow oil top. Dirt and lead do not mix, and the dirt rises to the top of the metal where it may readily be skimmed off.

With a paddle or ladle, drop in a cleaning compound of equal parts of powdered rosin, borax, and flower of sulphur. Use a teaspoonful of this compound for each ten pounds of metal, and be sure that the compound is absolutely dry. Stir the metal a little, and if it is at the proper temperature, there will be a flare, flash, or a little burning. A sort of tinfoil popcorn effect will be noticed oil top of the lead. Stir until this melts down.

Have the ladle with which you dip up the melted lead quite dry. When dipping up some of the lead, skim back the dark skin which forms oil top of the lead and dip up the clean bright lead for pouring.

In throwing additional lead into a pot which is partly filled with melted lead, be sure that the lead which is thrown in the pot is dry, or else hot lead may be spattered in your face.

Have the moulds clean and dry. The parts with which the lead comes into contact should be dusted with a mould compound which fills in the rough spots in the metal so that the flow of lead will not be obstructed, and the lead will fill the mould quickly. Dip tip enough lead to fill the part of the mould you use. When you once start pouring do not, under any circumstance, stop pouring until the lead has completely filled the mould. Lead cools very quickly after it is poured into the mould, and if you stop pouring even for all instant, you will have a worthless casting.

In a shop having an ordinary room temperature, it is generally unnecessary to heat the moulds before making up a number of castings. If it is found, however, that the first castings are defective due to the cold mould chilling the lead, the mould should be heated with a soft flame. After a few castings have been made, the mould will become hot enough so that there will be no danger of the castings becoming chilled.

When the castings have cooled sufficiently to be removed, strike the mould a few blows with a wooden mallet or a rawhide hammer to loosen, the castings before opening the mould. The castings may then be removed with a screwdriver.

Cracked castings indicate that the mould was opened before the castings had cooled sufficiently, or that there is too much antimony in the castings. The remedy is to let the castings cool for a longer time, or to add pure lead to the melting pot.

HANDLING AND MIXING ACID

The electrolyte used in the battery is made by mixing chemically pure concentrated Sulphuric Acid with chemically pure water. The concentrated acid, or "full strength" acid cannot be -used, not only because it would destroy the plates, but also because water is needed for the chemical actions which take place as a cell charges and discharges. The water therefore serves, not only to dilute the acid, but also to make possible the chemical reactions of charge and discharge.

The full strength acid has a specific gravity of 1.835, and is mixed with the water to obtain the lower specific gravity which is necessary in the battery. The simplest scheme is to use only 1.400 specific gravity acid. This acid is used in adjusting the specific gravity of a battery on charge in case the specific gravity fails to rise to a high enough value. It is also used in filling batteries that have been repaired.

Acid is received from the manufacturer in ten gallon glass bottles enclosed in wooden boxes, these being called "carboys." Distilled water comes in similar bottles. When distilled in the shop, the water should be collected in bottles also, although smaller ones may be used.

Neither the acid nor the water should ever be placed in any vessels but those made of lead, glass, porcelain, rubber, or glazed earthenware. Lead cups, tanks, and funnels may be used in handling electrolyte, but the electrolyte must not be put in containers made of any metal except lead. Lead is rather expensive for making such containers, and the glass bottles, porcelain, rubber, or glazed earthenware may be used.

In mixing acid with water, pour the water in the bottle, pitcher. or jar, and then **add the acid to the water very slowly.** Do not pour the acid in quickly, as the mixture will become very hot, and may throw spray in your face and eyes and cause severe burns. **Never add the water to the acid**, as this might cause an explosion and burn your face and eyes seriously. Stir the mixture thoroughly with a wooden paddle while adding the acid. A graduate, such as is used in photography, is very useful in measuring out the quantities of acid and water. The graduate may be obtained in any size up to 64 ounces, or two quarts. In using the graduate for measuring both acid and water, **be sure to use the following table giving the parts of water by volume.** Although the graduate is marked in ounces, it is for ounces of water only. If, for instance, the graduate were filled to the 8 ounce mark with acid, there would be more than eight ounces of acid in the graduate because the acid is heavier than the water. But if the proportions of acid and water are taken by volume, the graduate may be used.

A convenient method in making up electrolyte, is to have a16 ounce graduate for the acid, and a 32 or 64 ounce graduate for the water. In the larger graduate pour the water up to the correct mark. In the 16 ounce graduate, pour 1.400 acid up to the 10 ounce mark. Then add the acid directly to the water in the graduate, or else pour the water into a bottle or pitcher, and add the acid to that. For instance, if we have a 32 ounce graduate, and wish to make up some 1.280 acid, we fill this graduate with water up to the 5-1/2 ounce mark. We then fill the 16 ounce graduate with 1.400 acid up to the 10 ounce mark. Then we slowly pour the 1.400 acid into the graduate containing the water, giving us 1.280 acid. In a similar manner other specific gravities are obtained, using the same amount of 1.400 acid in each case, but varying the amount of water according to the figures given in the last column of the next to the last table.

The following table shows the number of parts of distilled water to one part of 1.400 specific gravity electrolyte to prepare electrolyte of various specific gravities. The specific gravity of the mixture must be taken when the temperature of the mixture is 70° F. If its temperature varies more than 5 degrees above or below 70°F, make the corrections described on page 65 to find what the specific gravity would be if the temperature were 70° F.

BY WEIGHT

For 1.300 specific gravity use 5 ounces of distilled water for each pound of 1.400 electrolyte.

For 1.280 specific gravity use 6-1/2 ounces of distilled water for each pound of 1.400 electrolyte.

For 1.275 specific gravity use 6-3/4 ounces distilled water for each pound of 1.400 electrolyte.

For 1.260 specific gravity use 7-1/2 ounces distilled water for each pound of 1.400 electrolyte.

BY VOLUME

For 1.300 specific gravity use 3-1/2 pints distilled water for each gallon of 1.400 electrolyte.

For 1.280 specific gravity use 4-1/2 pints distilled water for each gallon of 1.400 electrolyte.

For 1.275 specific gravity use 5 pints distilled water for each gallon of 1.400 electrolyte.

For 1.260 specific gravity use 5-1/4 pints distilled water for each gallon of 1.400 electrolyte.

In case you wish to use other measuring- units than those given in the above table, this table may be written as follows, giving the number of parts distilled water to **10 parts** of 1.400 specific gravity electrolyte:

Specific Gravity Desired	Parts by Weight	Parts by Volume
1.300	3	4-1/4
1.280	4	5-1/4
1.275	4-1/6	6
1.260	4-7/10	6-1/2

The next table gives the number of parts of distilled water to 10 parts of concentrated sulphuric acid (which has a specific gravity of 1.835) to prepare electrolyte of various specific gravities:

Specific Gravity Desired	Parts by Weight	Parts by Volume
1.400	8-1/2	15-8/10
1.300	13-1/2	25
1.280	15	27
1.270	16	28
1.260	17	30

PUTTING NEW BATTERIES INTO SERVICE

New batteries are received (a) fully charged and ready for service, (b) fully assembled with moistened plates and separators, but without electrolyte, (c) in a "knockdown" condition, with dry plates and without separators, (d) fully assembled with "bone dry" plates and rubber separators, and without electrolyte.

Those received fully charged should be put on a car as soon as possible. Otherwise they will grow old on the shelf. Every month on the shelf is a month less of life. If the battery cannot be sold, put it into dry-storage. Batteries received in condition (b) should not be kept in stock for more than six months. Batteries received with dry plates and without separators or with rubber separators may be stored indefinitely without deteriorating.

Batteries Shipped Fully Charged, or "Wet." All Makes

Unpack the battery, keeping the packing case right side up to avoid spilling electrolyte.

Brush off all excelsior and dirt, and examine the battery carefully to see if it has been damaged during shipment. If any damage has been done, claim should be made against the express or railroad company.

1. Remove the vent caps from the cells and determine the height of the electrolyte. It should stand from three-eighths to one-half inch above the tops of the plates. The level may be determined with a glass tube, as shown in Fig. 30. If the electrolyte is below the tops of the plates, it has either been spilled, or else there is a leaky jar. If all cells have a low level of electrolyte, it is probable that the electrolyte has been spilled.

2. Next measure the specific gravity of the electrolyte of each cell with the hydrometer, and then add water to bring the electrolyte up to the correct level, if this is necessary. Should the temperature of the air be below freezing, charge the battery for an hour if water is added no matter what the specific gravity readings are. This will cause the water to mix thoroughly with the electrolyte. If the battery were not charged after water is added, the water, being lighter than the electrolyte, would remain on top and freeze. For this one hour charge, use the "starting" rate, as stamped on the nameplate.

3. If the specific gravity of the electrolyte reads below 1.250, charge the battery until the specific gravity reads between 1.280 and 1.300. For this charge use the normal bench charging rates.

4. After this charge place the battery on a clean, dry spot for twenty-four hours as an extra test for a leaky jar. If there is any dampness under the battery, or on the lower part of the battery case, a leaky jar is indicated. An inspection of the level of the electrolyte, which even though no dampness shows, will show the leaky jar.

5. Just before putting the battery on the car, make the high rate discharge test on it. See page 266.

BATTERIES SHIPPED "DRY"

Exide Batteries

Storing. 1. Keep the battery in a dry, clean place, and keep the room temperature above 32 degrees, and below 110 degrees Fahrenheit.

2. Put the battery into service before the expiration of the time limit given on the tag attached to the battery. The process of putting the battery into service will require about five days.

3. If the battery has been allowed to stand beyond the time limit, open up one of the cells just before beginning the process necessary to put the battery into service. If the separators are found to be cracked, split, or warped, throw away all the separators from all the cells and put in new ones. If the separators are in good condition, reassemble the cell and put the battery into service.

Putting Battery into Service. 1. Fill the cells with electrolyte of the correct specific gravity. To do this, remove the vent plugs and pour in the electrolyte until it rises to the bottom of the vent tubes. The correct specific gravities of the electrolyte to be used are as follows:

(a) For Types DX, XC, XE, XX and XXV, use 1.360 electrolyte. In tropical countries use 1.260 electrolyte.

(b) For Types LX, LXR, LXRE, LXRV, use 1.340 electrolyte. In tropical countries use 1.260 electrolyte.

(c) For Types MHA and PHC, use 1.320 electrolyte. In tropical countries use 1.260 electrolyte.

(d) For Types KXD and KZ, use 1.300 electrolyte. In tropical countries use 1.240 electrolyte.

2. After filling with the electrolyte, allow the battery to stand ten to fifteen hours before starting the initial charge. This gives the electrolyte time to cool.

3. No sooner than ten to fifteen hours after filling the battery with electrolyte, add water to bring the electrolyte up to the bottom of the vent tubes, if the level has fallen. Replace the vent caps and turn them to the right.

Start charging at the rates shown in the following table. Continue charging at this rate for at least 96 hours (4 days).

Table of Initial and Repair Charging Rates

TYPE AND SIZE OF CELL	Charging Rate- Amperes	Minimum Ampere Hours
KZ-3	1/2	50
LX-5, LXR-5, LXRE-5	1-1/2	145
KXD-5	2	190
XC-9, XX-9	2-1/2	240
DX-11, KXD-7, LXR-9, LXRE-9, XC-11, XE-11	3	290
DX-13, KXD-9, LXR-11, XC-13, XE-13, XX-13	4	385
LXR-13, LXRE-13, XC-15, XE-15, XX-15	4-1/2	430
KXD-11, XC-17, XE-17	5	480
LXRV-15, LXR-15, LXRE-15	5-1/2	525
LX-17, LXR-17, LXRE-17, XC-19, XE-19, XXV-19	6	575
MHA-11, PHC-13	6	575
XC-21, XE-21	6-1/2	625
XC-23	7	675
XC-25	7-1/2	720

4. Occasionally measure the temperature of the electrolyte. Do not allow the temperature to rise above 110° Fahrenheit (120° Fahrenheit in tropical countries). Should the temperature reach 110°, stop the charge long enough to allow the temperature to drop below 100°.

5. At the end of the charge, the specific gravity of the electrolyte should be between 1.280 and 1.300 (1.210 and 1.230 in tropical countries). If it is not between these limits adjust it by drawing off some of the electrolyte with the hydrometer and replacing with water if the specific gravity is too high, or with electrolyte of the same specific gravity used in filling the battery, if the specific gravity is too low.

6. Wipe off the top and sides of the battery case with a rag dampened with ammonia to neutralize any electrolyte which may have been spilled.

7. Just before putting the battery into service, give it a high rate discharge test. See page 266.

Vesta Batteries

1. Remove vent caps from each cell and fill with electrolyte of 1.300 specific gravity. This electrolyte should not have a temperature greater than 75° Fahrenheit when added to the cells.

2. After the addition of this acid, the battery will begin to heat and it should be left standing from 12 to 24 hours or until it has cooled off.

3. Battery should then be put on charge at the finish charging rate stamped on the name plate. Continue charging at this rate for approximately 48 to 72 hours or until the gravity and voltage readings of each cell stop rising.

4. Care should be taken to see that the temperature of battery does not rise above 110° Fahrenheit. If this occurs., the charging rate should be cut down.

5. The acid in each cell will undoubtedly have to be equalized.

6. At the finish of this developing charge the gravity should read 1.280 in each cell. If below this, equalize by putting in 1.400 specific gravity acid, or if the contrary is the case and the acid is above 1.280 add sufficient distilled water until the gravity reads 1.280.

7. After the acid has been equalized and it has stopped rising in density the voltage of each cell while still on charge at the finishing rate should read at least 2.5 volts per cell or better.

8. The battery is then ready for service. Just before putting battery into service, make a high rate discharge test on it. See page 266.

Philadelphia Diamond Grid Batteries

1. Remove the vent plugs and immediately fill the cells With electrolyte until the level is even with the bottom of the vent tube in the cover. Do not fill with electrolyte whose temperature is above 90° Fahrenheit. The specific gravity of the electrolyte to be used in starting batteries varies with the number of plates in each cell, the correct values being as follows:

Charging Rates

Fill batteries listed in Table No. 1 with 1. 270 sp. gr. acid.

TABLE -NO. 1

No. of Plates	LL-LLR and LH	LM LMR	LT LTR	LS LSR	LG	ST	LSF
9	2.0	2.5	2.0	2.5	3.0		
11	2.5	3.0	2.5	3.5	4.0		
13	3.0	3.5	3.0	4.0			2.5
15	3.5	4.0	3.5	4.5	5.5		
17	4.0	5.0	4.0	5.5		6.0	
19	4.5	5.5	4.5	6.0			

Special Battery: 136 USA.....6. 0 amps.

TABLE N0.2

No. of Plates	LL-LLR and LLH	LM LMR	LT LTR	LS LSR	S SH	ST	LSF
5	1.0	1.0			2.0	1.5	
7	1.5	1.5	1.5	2.0	3.0	2.0	1.5
9					4.0		
11					5.0		

Special Batteries: 330 AA..... 1. 0 amps.

524 STD-H2 ..... 1. 0 amps.

7 6 SPN ..... 1. 5 amps.

The number of plates per cell is; indicated in the first numeral of the type name. For instance, 712 LLA-1 is a 7 plate LL. For all lighting batteries, types S and ST. use 1.210 electrolyte.

2. Allow the battery to stand for one or two hours.

3. Remove the seal from the top of the vent caps, and open by blowing through the cap.

4. Insert vent plugs in the vent tubes.

5. Put the battery on charge at the rate given in the table on page 228. To determine the rate to use, see type name given on the battery nameplate and find correct rate in the table. Keep the battery charging at this rate throughout the charge.

6. Continue the charge until the battery voltage and the specific gravity of the electrolyte stop rising, as shown by readings taken every four hours. From three and one-half to four days of continuous charging will be required to fully charge the battery.

7. Watch the temperature of the electrolyte, and do not allow it to rise above 110° Fahrenheit. If the temperature rises to 110° F., stop the charge and allow battery to cool. Extend the time of charging by the length of time required for the battery to cool.

8. After the specific gravity of the electrolyte stops rising, adjust the electrolyte to a specific gravity of 1.280 at a temperature of 70° Fahrenheit. If the temperature is not 70°, make temperature corrections as described on page 65.

9. The battery is now ready to be installed on the car. Just before installing the battery, make a high rate discharge test on it.

Willard Bone-Dry Batteries

A Willard Threaded Rubber insulated battery is shipped and carried in stock "bone-dry." It is filled with electrolyte and charged for the first time when being made ready for delivery.

Threaded Rubber Insulated Batteries received bone-dry must be prepared for service, as follows:

1. Mix electrolyte to a density of 1.275.

2. Remove the vent plugs and fill to the top of the vent hole with 1.275 electrolyte. Be sure that the electrolyte is thoroughly mixed by stirring and that its temperature is not above 90 degrees Fahrenheit.

3. A portion of the solution will be absorbed by the plates and insulation because they have been standing dry without In-\ liquid in the cells. The volume is thus decreased, necessitating the addition of electrolyte after first filling.

Wait five minutes and then again fill to the top of the vent hole with 1.275 electrolyte.

4. The battery must now stand at least twelve hours and not more than twenty-four hours before charging,. After it has been filled an increase in temperature of the battery solution will take place. This is caused by the action of the acid in the solution penetrating the plates mid reacting with the active material, but does no injury. Since the acid in the solution joins the active material in the plates the density of the solution becomes proportionately lower. This is to be expected and should cause no concern.

In order that the entire plate volume of active material may be in chemical action during charge, the battery should stand before being placed on charge -until the solution has bad time to penetrate the entire thickness of the plates. This requires at least twelve hours, but not more than twenty-four hours.

5. Just before charging the battery, again fill with 1.275 electrolyte to 3/8 inch over the top of the separators. After this, do not add anything but distilled water to the battery solution.

6. The battery should then be put on charge at the finish rate until the gravity stops rising. At the end of this period the specific gravity should be between 1.280 and 1.300. It may take from 36 to 72 hours before this density is reached.

Care should be taken not to prolong the charging unduly, for that may cause active material to fall out of the grids, thus

injuring the plates beyond repair.

7. Because of the evaporation of water in the solution during the charging process, it is necessary to add distilled water from time to time in order to keep the solution above the tops of the separators.

The temperature of the battery while on charge should never exceed 110 degrees Fahrenheit. If the temperature rises above this point the charging must be discontinued for a time or the rate decreased.

If at any time during the initial charging the density rises above 1.300 some of the solution should immediately be drawn off with a syringe and distilled water added. This must be done as often as is necessary to keep the density below 1.300.

If the specific gravity does not change after two successive readings and does not then read within the limits of 1.280 to 1.300 it should be adjusted to read correctly. If the reading is less than 1.280 it should be adjusted by drawing off as much solution as can be taken out with a syringe and electrolyte of 1.400 specific gravity added. The battery must then be placed on charge for at least four hours and another reading taken. If it is again found to be less than 1.280 this operation should be repeated as many times as necessary to bring the density up to 1.280.

9. The height of solution when taking the battery off charge should be 5/8 of an inch above the top of the separators. After the battery has been off charge long enough to permit the solution to cool to normal temperature, draw off the excess to a final height of 3/8 inch above separators. Replace the vent plugs and battery is ready for service.

Unfilled Willard Wood Insulated Batteries

Unfilled, wood-insulated batteries have not had an initial charge and require a treatment similar to batteries with threaded rubber insulation. When shipment is made in this manner, such batteries should be placed in service before the date indicated on the tag attached to the battery.

To prepare such a battery for service:

1. Remove the vent plugs and fill each cell with 1.335 specific gravity electrolyte (one part of concentrated sulphuric acid by volume to two parts of distilled water by volume) to 3/8 inch above the tops of the separators.

2. Wait 5 minutes and then fill each cell again with 1.335 specific gravity electrolyte to 3/8 inch above the tops of the separators.

3. The battery must then stand from 10 to 15 hours before placing on charge.

4. After standing for this length of time, fill each cell again, if necessary, with 1.335 specific gravity electrolyte to bring the level of the electrolyte 3/8 inch above the tops of the separators before charging.

5. Place the battery on charge at the finish rate marked on the name plate until the gravity and cell voltage stop rising. This charging will require at least 48 hours.

6. If, after a charge of 48 hours or longer the specific gravity does not rise for two consecutive hours, the gravity should be between 1.280 and 1.300. If it is not between these limits, the specific gravity should be adjusted to these values at the end of the charge.

7. If, during the charge, the temperature exceeds 110 degrees Fahrenheit, the charge rate should be reduced so as to keep the temperature below 110 degrees Fahrenheit and the time of charging lengthened proportionately.

Preparing Westinghouse Batteries for Service

(These batteries are prepared for shipment in what is known as export condition.)

1. Remove vent plugs and discard soft rubber caps.

2. Fill all cells with 1.300 specific gravity sulphuric acid until top of connecting straps, as seen through vent holes are completely covered. Temperature of filling acid should never be above 90 degrees Fahrenheit.

Note: The aim is to fill the cells with acid of such a Specific gravity that the electrolyte, at the end of charge, will need very little adjusting- to bring it to the proper specific gravity.

1.300 specific gravity acid has been found to be approximately correct for this purpose. However, if after several batteries have been prepared for service -using 1.300 specific gravity acid, considerable adjusting at the end of charge is necessary, it is permissible to use a slightly different specific gravity of filling acid, but the use of acid above 1.325 specific gravity or below 1,250 specific gravity is not recommended.

3. Allow batteries to stand after filling for from two to three hours before putting on charge.

4. Put on charge at finish charge rate shown on name plate of battery.

Note: If temperature of electrolyte in battery reaches 100 degrees Fahrenheit (determined by inserting special thermometer through vent hole in cover), the charging rate should be immediately reduced, as continued charging at a temperature above 100 degrees Fahrenheit is injurious to both separators and plates.

5. Continue charging until all cells are gassing freely and individual cell voltage. and specific gravity of electrolyte have shown no decided rise for a period of five hours.

Note: The length of time required to completely charge a new battery depends largely upon the time the battery has been in stock, varying from twelve to twenty-four hours for a comparatively fresh battery to four or five days for a battery six months or more old.

6. Keep level of electrolyte above tops of separators at all times, while charging by adding distilled water to replace that lost by evaporation.

7. After battery is completely charged the specific gravity of electrolyte in all cells should be adjusted to 1.285 at 70 degrees Fahrenheit, and the level of electrolyte adjusted so that after battery is taken off charge the height of electrolyte stands 1/8 inch above tops of connecting straps.

Note: Corrections for temperature if temperature of electrolyte is above or below 70 degrees Fahrenheit the correction is one point of gravity for each three degrees of temperature. See page 65.

If specific gravity of electrolyte is above 1.285, a portion of the electrolyte should be removed and replaced with distilled water.

If the specific gravity is below 1.285, a portion of electrolyte should be removed and replaced with 1.400 specific gravity sulphuric acid. Acid of higher gravity than 1.400 should never be put in batteries.

Batteries should always be charged for several hours after adjusting gravity to insure proper mixing of the electrolyte and to see that the correct specific gravity of 1.285 has been obtained.

8. After first seven sections have been followed examine vent plugs to see that gas passage is Dot obstructed and screw back in place. Battery is now ready for service.

The Prest-O-Lite Assembled Green Seal Battery

This type of battery is made up of the same sort of plates as the old partly assembled green seal battery. The elements are,

however, completely assembled will wood separators and sealed in the jars and box in the same manner as a wet battery to be put into immediate service; the cell connectors are burned in place.

How to Store It. A room of ordinary humidity, one in which the air is never dryer for any reason than the average, should be used to store these batteries. They should be shielded from direct sunlight.

Examine the vents-they should be securely inserted and remain so during the entire storage period.

If these precautions are observed, this type battery may be stored for at least a year.

To Prepare Battery for Use. 1. Prepare sufficient pure electrolyte of 1.300 specific gravity. If during the mixing considerable heat is evolved, allow electrolyte to cool down to 90 degrees Fahrenheit. Never pour electrolyte, that is warmer than 90 degrees Fahrenheit, into cells.

2. Remove the vents and lay them aside until the final charging operation has been completed.

Within 15 minutes from the time the vents are removed fill all cells to the bottom of vent openings with the electrolyte prepared, as stated above.

3. Allow the electrolyte to remain in the cells, not less than one hour. At the end of this time, should the electrolyte level fall below the tops of the separators, add enough electrolyte to bring level at least one-half inch above separators. If the temperature in the cells does not rise above 100 degrees Fahrenheit, proceed immediately (before two hours have elapsed) with the initial charging operation. If the temperature remains above 100 degrees Fahrenheit, allow the battery to stand until the electrolyte cools down to 100 degrees Fahrenheit. Then proceed immediately with the charge. It is important that the acid does not stand in the cells for more than two hours, unless it is necessary to allow the acid to cool.

4. Initial Charging Operation. Place the battery on charge at the ampere rate given in the following table. The total initial charge must be for fifty-two hours, but at no time permit the electrolyte temperature to rise above 115 degrees Fahrenheit. If the temperature should reach 115 degrees Fahrenheit, take the battery off the line and allow the electrolyte to cool, but be sure that the total of fifty-two hours actual charging at the ampere rate specified is completed.

Initial Charge---52 Hours

Type of Plate

Plates per Cell	AHS	WHN	RHN	SHC	BHN	JFN	GM	CLN	KPN
3							1.5		
5	2	2	2.5	3					
7	3	3	3.5	4		3			5
9	4	4	5	5					7
11	5	5	6	7	7.5	5			9

13	6	6	7	8	9	6		10.5	10.5
15	7	7	9	9.5	10.5	7			12
17			10	12		9			
19	9	9	11	12		9			

The nominal battery voltage and the number of plates per cell is indicated by the Prest-O-Lite type designations, i. e.: 613 RHN denotes 6 volts, 13 plates per cell or 127 SHC denotes 12 volts, 7 plates per cell.

5. The electrolyte density at the end of fifty-two hours charge should be near 1.290 specific gravity. A variation between 1.285 and 1.300 is permissible. If, after fifty hours of the initial charge, the electrolyte density of any of the cells is outside these limits, adjustment should be begun while still charging. For those cells in which the density is higher than 1.300 specific gravity replace some of the electrolyte with distilled water. In those cells where the density is lighter than 1.285 specific gravity replace some -of the electrolyte with previously prepared electrolyte of 1.400 specific gravity. Wait until the cells have charged one hour before taking readings to determine the effect of adjustment, which, if not accomplished, should be attempted again as before. Practice Will enable the attendant to estimate the amount of electrolyte necessary to replace in order to accomplish the proper density desired-at the end of initial charge.

6. Following the completion of the fifty-two hour charge, if there is time to do so, it is good practice to put the battery through a development cycle, i. e., to discharge it at about the four-hour rate and then put it on the charging line again at the normal rate until a condition of full charge is again reached. The objects gained by this discharge are:

(a) Further development of the plates.

(b) Adjustment or stabilization of the electrolyte.

(c) Checking the assembly by noting the failure of any cell or cells to act uniformly and satisfactorily during discharge.

The four-hour discharge rate is, of course, like the normal rate of Initial Charge, dependent upon the size and number of plates per cell in any particular battery; the number of cells determines the voltage only and has nothing to do with the battery's charge or discharging rating. These four-hour discharge rates are as follows:

Type of Plate

Plates per Cell	AHS	WHN	RHN	SHC	BHN	JFN	GM	CLN	KPN
3							3		
5	5	5	5.5	6.5					
7	7.5	7.5	8	10		7.5			13.5

9	10	10	11	13				18
11	12.5	12.5	14	16	19	12.5		22.5
13	15	15	16.5	19.5	22.5	15	27	27
15	17.5	17.5	19	23	26	17.5		31.5
17			22	26				
19	22.5	22.5	25	29		22.5		

(7?) Immediately at the end of the four-hour discharge, put the battery on the line and charge it at the normal rate prescribed in the Initial Charge rate table until a state of complete charge, as noted by cell voltage and gravity is reached. This charging time should be about sixteen hours.

Any adjustments of electrolyte found necessary at the end of this charging period in the same manner prescribed in paragraph No. 5, for such adjustments made just before the completion of the initial fifty-two hour charge.

8. At the end of the fifty-two hour charge, or, if the Development discharge has been given, at the end of the Development Cycle Charge, replace the vent plugs, wash all exterior surfaces with clean water and dry quickly. The battery is then ready for service.

INSTALLING A BATTERY ON A CAR

A battery must be installed carefully on the car if it is to have any chance to give good service. Careless installation of a battery which is in good working order will invariably lead to trouble in a very short time. On the other hand, a properly installed battery is, nine times out of ten, a good working and long lived battery.

After you have removed the old battery, scrape all rust and corrosion from the inside of the battery box or compartment in which the battery is placed. This can best be done with a putty knife and wire brush. If you find that electrolyte has been spilled in the box, pour a saturated solution of baking soda on the parts affected so as to neutralize the acid. Then wipe the inside of the box dry and paint it with a good acid proof paint.

Next take out the hold down bolts. Clean them with a wire brush, and oil the threads on the bolt and in the nut to make them work easily. It is very important that this oiling be done, as the oil protects the bolts from corrosion, and to remove the nuts from a corroded bolt is an extremely difficult and aggravating piece of work, often resulting in the bolts being broken. Should such bolts become loose while the car is in use, it is hard to tighten them.

Wooden strips found in the battery box should be thoroughly cleaned and scraped, and then painted with acid proof paint. When you lower the battery into its box, lower it all the way **gently**. Do not lower it within an inch or so of the bottom of the case and then drop it. This will result in broken jars and plate lugs. Turn the hold downs tight, but not so tight as to break the sealing compound at the ends of the battery, thereby causing electrolyte to leak out, and battery to become a "slopper".

Cables and connectors should be scraped bright with a knife and brushed thoroughly with the wire brush to remove all corrosion. Old tape which has become acid soaked should be removed and the cable or wire underneath cleaned. Before applying new tape, take a small round bristle brush and paint Vaseline liberally over the exposed cable immediately back of the taper terminal. Then cover the Vaseline with tape, which Should be run well back from the terminal. The Vaseline

prevents the corrosion of the cable and the tape holds the Vaseline in place. After the tape has been applied, paint it with acid proof paint. Cover the terminals of the battery with Vaseline. Cables must have enough slack to prevent strains from being put on the battery terminals.

By following these directions, you will not only have a properly installed battery, which will have a good chance to give good service, but will have a neat looking job which is most pleasing to the eye of the car owner.

Remove all dirt from the battery and cable terminals and thoroughly clean the surfaces which are to connect together, but do not scrape off the lead coating. Apply a heavy coating of pure Vaseline to these surfaces and tighten the connection perfectly, squeezing out the Vaseline. Then give the whole connection a heavy coating of Vaseline. This is very important in order to prevent connection trouble.

If battery is installed in an enclosing box, be sure that none of the ventilating holes are clogged.

STORING BATTERIES

When a battery is not in active use on a car it should be put into storage. Storage is necessary:

1. When a car is to stand idle for a considerable period, such as is the case when it is held for future delivery.

2. When a car is laid up for the winter.

3. When batteries are kept in stock.

Batteries may be stored "wet," i.e., completely assembled and filled with electrolyte, or "dry," i.e., in a dry disassembled condition, without electrolyte. In deciding whether a battery should be stored "wet" or "dry," two things are to be considered, i.e. the length of time the battery is to be in storage, and the condition of the battery. If a battery is to be out of commission for a year or more, it should be put into "dry" storage. If it is to be in storage for less than one year, it may be put into "wet" storage if it is in a good condition. If the condition of the battery is such that it will need to be dismantled soon for repairs, it should be put into "dry" storage, even though it is to be out of service for less than one year.

Batteries in "dry" storage require no attention while they are in storage, but they must be dismantled before being put into storage and reassembled when put back into service.

When a battery is brought in to be stored, note its general condition carefully.

(a) Its General Appearance-condition of case, handles, terminals, sealing compound, and so on.

(b) Height and specific gravity of the electrolyte in each cell.

(c) Age of Battery. Question owner as to length of time he has had battery. Read date marks on battery if there are any, or determine age by the age code. See page 243. If a battery is less than a year old, is in good condition, and is to be stored for less than one year, it may be put into "wet" storage. If it is more than a year old, put it into dry storage, unless it is in first class shape and is to be stored for only several months.

After making your general observations, clean the battery, add distilled water to bring the electrolyte up to the proper level, put the battery on charge and keep it on the line until it is fully charged. Watch for any abnormal condition during the charge, such as excessive temperature rise, failure of voltage to come up, failure of specific gravity to come up, and gassing before gravity becomes constant.

If no abnormal conditions develop during the charge, put the battery on discharge at a rate which will cause the voltage to drop to 1.7 volts per cell in about four hours. Measure the cell voltages at regular intervals during the discharge test. If the voltage of any cell drops much more rapidly than that of the other cells, that cell is defective in some way, and should be opened for inspection. If the voltage of all cells drops to 1.7 in three hours or less, the battery should be put into dry

storage.

After completing the discharge test, recharge it fully, no matter whether it is to be put into wet or dry storage.

If no trouble developed during the charge or discharge, the battery may be put into "wet" storage. If trouble did develop, the battery should be put into "dry" storage.

If dry storage is found to be necessary the owner should be informed that the condition of his battery would cause it to deteriorate in wet storage and necessitate much more expensive repairs when put into use again than will be necessary in the thorough overhauling and rejuvenation of dry storage. He should be advised that dry storage involves dismantling, drying out elements and reassembling with the needed repairs and new separators in the Spring. **Be sure** that the customer understands this. **If it is evident that repairs or new parts, involving costs additional to storage charges, will be necessary, tell him so. Do not leave room for a complaint about costs in the Spring.**

To avoid any misunderstanding, it is highly advisable to have the customer put his signature on a STORAGE AGREEMENT which states fully the terms under which the battery is accepted for storage. The storage cost may be figured on a monthly basis, or a price for the entire storage period may be agreed upon. The monthly rate should be the same as the regular price for a single battery recharge. If a flat rate is paid for the entire storage period, $2.00 to $3.00 is a fair price.

"Wet" Storage

1. Store the batteries on a bench or shelf in a convenient location and large enough to allow a little air space around each battery.

2. Place each battery upon wooden strips in order to keep the bottom of the battery clear of the bench or shelf,

3. Apply Vaseline freely to the battery terminals, and to exposed copper -wires in the battery cables if the cables are burned directly to the battery terminals. If the cables are not burned on, remove them from the battery.

4. If convenient, install the necessary wiring, switches, etc., so that batteries may be connected up and charged where they stand. Otherwise the batteries must be charged occasionally oil the charging bench.

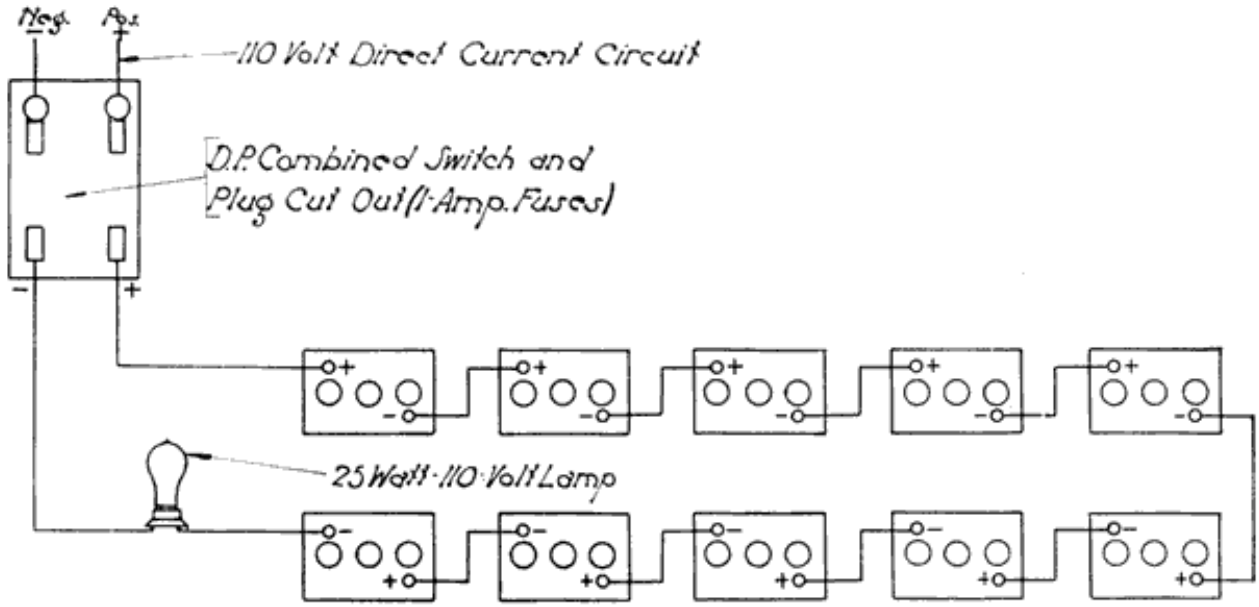

Fig. 151. Batteries Connected Up For "Trickle" Charge

5. Batteries in wet storage may be charged by the Exide "Trickle" charge method, or may be given a bench charge at regular intervals.

6. Bench Charge Method.- Once every month, add distilled water to replace evaporation. Then give battery a bench charge. See page 198. Before putting battery into service repeat this process and just before putting the battery into service, make the high rate discharge test on it. See page 266.

7. Trickle Charge Method.- This consists of charging the batteries in storage continuously at a very low rate, which is so low that no gassing occurs, and still gives enough charge to maintain the batteries in good condition. In many cases the "Trickle" Charge method will be found more convenient than the bench charge method, and it has the advantage of keeping the batteries in condition for putting into service on short notice. It should, however, be used only where direct current lighting circuits are available.

In the "Trickle" method, the batteries are first given a complete bench charge, and are then connected in series across a charging circuit with one or several incandescent. lamps in series -with the batteries to limit the current. In Fig. 151, an example of connections for a "Trickle" charge is given. The charging current for different sized batteries varies from 0.05 to 0.15 ampere. The following table gives the lamps required to give the desired current on 110 volt circuit.

In each case, the lamps are connected in series with the batteries. The "2-25 watt, (lamps), in parallel" listed in the table are to be connected in parallel with each other and then in series with the batteries. The same is true of the "3-25 watt (lamps), in series" listed in the table.

Amp. Hours. Capacity 5 Amp. Rate	Amperes Approximate	No. of Cells in Series on Line 115-Volt	No. 115 Volt Lamps Required 115-Volt	
50 or less	0.05	3	5-15 watt, in series	
50 or less	0.05	30	2-15 watt, in series	
50 or less	0.05	45	1-15 watt, in series	
50 - 100	0.10	3	3-25 watt, in series	
50 - 100	0.10	30	1-25 watt, in series	
50 - 100	0.10	45	2-25 watt, in parallel	
100 or over	0.15	3	2-25 watt, in series	
100 or over	0.15	30	1-25 watt, in series	
100 or over	0.15	45	3-25 watt, in parallel	

Every two months interrupt the trickle charge long enough to add water to bring the electrolyte up to the proper level. When this has been done, continue the trickle charge.

Before putting the batteries into service, see that the electrolyte is up to the correct level, and that the specific gravity of the electrolyte is 1.280-1.300. If necessary, give a short charge on the charging bench to bring the specific gravity up to the correct value.

Dry Storage

1. Give the battery a complete charge. Pour out the electrolyte, and separate the groups. If the negatives have bulged active material, press them in the plate press. In batteries such as the Prest-OLite in which it is difficult to remove the plates from the cover, the groups need not be separated unless the negatives have badly bulged active material. It may not be necessary to separate the groups even then, provided that the positives are not buckled to any noticeable extent. If only a very slight amount of buckling exists, the entire element may be pressed by putting thin boards between the plates in. place of the separators.

2. Immerse the negatives in distilled water for ten to twelve hours. If positives and negatives cannot be separated, wash each complete element in a gentle stream of water.

3. Remove plates from water and allow them to drain thoroughly and dry. The negatives will heat up when exposed to the air, and when they do so they should be immersed in the water again to cool them. Repeat this as long as they tend to heat up. Then allow them to dry thoroughly.

4. Throw away the old separators. Rubber separators may be saved if in good condition. Clean the covers and terminals., wash out the jars, and turn the case up side down to drain out the water. Examine the box carefully. It is advisable to wash with a solution of baking soda, rinsing the water in order to neutralize as far as possible the action of acid remaining on the box. If this is not done, the acid may start decomposition of the box while in storage, in which. case the owner of the battery may insist on its renewal before acceptance at the end of the storage period.

5. When, the plates are perfectly dry, nest the positives and negatives together, using dry cardboard instead of separators, and replace them in the jars in their proper positions.

6. Replace the covers and vent plugs, but, of course, do not use any sealing compound on them.

7. Tie the terminals and top connectors to the handle on the case with a wire.

8. Tag the battery with the owner's name and address, using the tag on which you made the sketch of the arrangement of the terminals and top connections.

9. Store the battery in a dry place, free from dust, until called for.

10. When the battery is to be put into service again, put in new separators, put the elements in the jars, seal the covers, and burn on the top connectors and terminals (if these are of the burned-on type). Fill the cells with electrolyte of about 1.310 specific gravity and allow the battery to stand for ten to twelve hours in order to cool. Then put the battery on charge at one-half the normal charging rate and charge until the specific gravity of the electrolyte stops rising and remains stationary for five hours. The total time required for this development charge will be about four days. Watch the temperature of the electrolyte carefully, and if it should rise to 110° Fahrenheit, stop the charge until it cools.

11. The specific gravity will fall during the first part of the charge, due to the new separators; at the end of the charge, the specific gravity should be 1.280-1.300. If it is not within these limits, adjust it by withdrawing some electrolyte with the hydrometer and adding water if the gravity is high, or 1.400 electrolyte if the gravity is low.

12. Clean the case thoroughly and give it a coat of asphaltum paint.

13. Just before putting the battery into service, give it a high rate discharge test. See page 266.

DETERMINING AGE OF BATTERY

Battery manufacturers use codes to indicate the age of their batteries. These codes consist of letters, figures, or combinations of letters and figures, which are stamped on the inter-cell connectors or on the nameplate. The codes may also be burned on the case.

The codes of the leading makes of batteries follow. In addition to determining the age of a battery by means of the code, the owner should be questioned as to the time the battery was installed on his car. If the battery is the original one which came with the car, the dealer's or car manufacturer's records will help determine the battery's age. If a new battery has been installed to replace the one that came with the car, the battery distributor's records will help determine the age of the battery.

Familiarity with the different makes and types of battery will also help in determining a battery's age. Manufacturers make improvements in the construction of. their batteries from time to time, and by keeping up-to-date on battery constructions, it is often possible to approximate the age of a battery by such changes.

If a battery was kept "dry" while in stock, its age should be figured from the time it was prepared for service and placed on the car, since batteries in dry storage do not deteriorate. Some batteries are shipped from the factory "wet," i.e., filled with electrolyte and fully charged and the age of such batteries should be figured from the time they were shipped from the factory, because deterioration begins as soon as a battery is filled with electrolyte. When batteries are "dry" no chemical action can take place, and the battery does not deteriorate, while in a "wet" battery, chemical action takes place which gradually causes a battery to deteriorate.

(Omitted were **nine** charts and their short descriptions which contained the number/letter date code information ranging from 1918 to 1923 for nine brands of batteries.)

RENTAL BATTERIES

Rental batteries are those which are put on a customer's car while his own is being repaired or recharged. They are usually rebuilt batteries turned in when a new battery is bought. They may also be made of the good parts of batteries which are junked. By carefully saving good parts, such as plates, jars, covers, and cases, a stock of parts will gradually be acquired from which rental batteries may be made. Rental batteries may also be bought from the battery manufacturers.

A supply of rental batteries should, of course, be kept ready to go out at any time. The number of such batteries depends upon the size of the business. 25 batteries for each 1000 cars in the territory served is a good average. Do not have too many rental batteries of the same type. Many of them will be idle most of the time and thus will not bring in any money. Rentals should be made to fit those makes of cars of which there are the greatest number in the territory served by the repair shop. Sufficient parts should be kept on hand to make up other rentals on short notice.

Terminals for Rental Batteries

There are several combination terminals on the market which allow rental batteries equipped with them to be easily connected to several of the various types of cable terminals that are in use. Yet it is a universal experience for the average service station always to have calls for rental batteries with just the type of terminals which are not on hand. When the station has many batteries with the clamp type straight posts the call always seems to be for the taper plug type and vice versa.

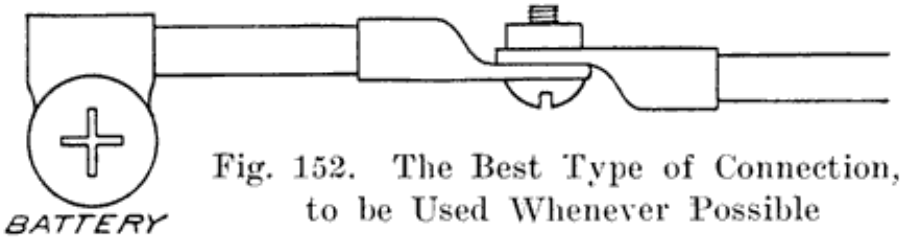

Fig. 152. The Best Type of Connection, to be Used Whenever Possible

Most of us will agree that the clamp type post terminal is the cause of much trouble. It is almost impossible to prevent corrosion at the positive post and many a car owner has found that this has been his trouble when his lights burn all right but the battery seemingly does not have power enough to turn over the engine and yet every cell tests 1.280. Service Station men should not scrape and clean up a corroded clamp type terminal and put it back on again, but should cut it off and put on either a taper plug or, preferably, a lead-plated copper terminal lug. Of course either of these terminal connections necessitates changing the battery terminals to correspond.

For rental batteries it will be found that short cable terminals with lead-plated copper lugs at the end will enable a battery man to connect most any type of cable terminal on any car. It is true that such connections must be taped up, but the prompt service rendered more than offsets a little tape. Figures 152 to 158 illustrate how these connections can be made to the taper plug and clamp types which are used on most cars.

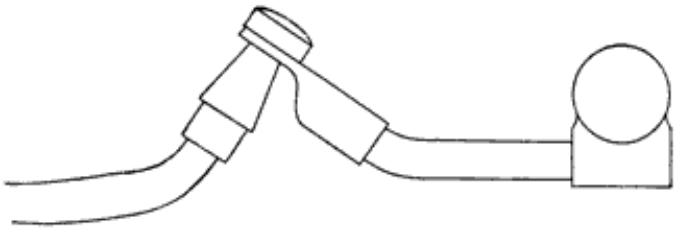

Fig. 153. Showing Method of Connecting Rental Battery with Cable Terminals to Car with Taper Plug

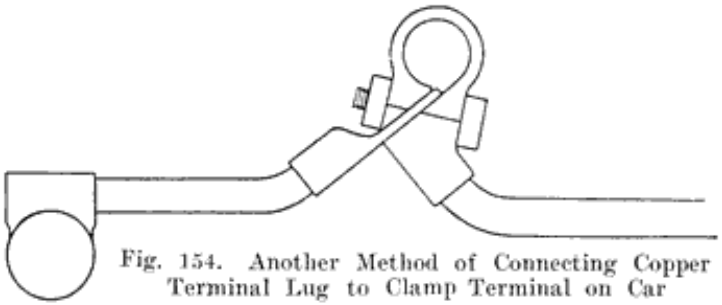

Fig. 154. Another Method of Connecting Copper Terminal Lug to Clamp Terminal on Car

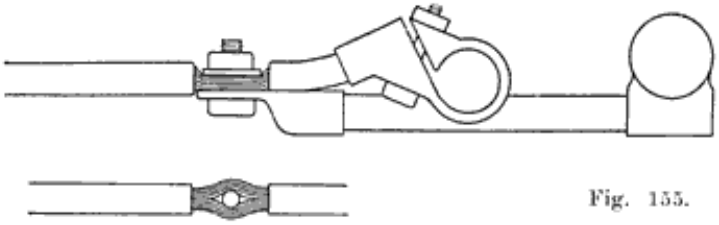

Fig. 155.

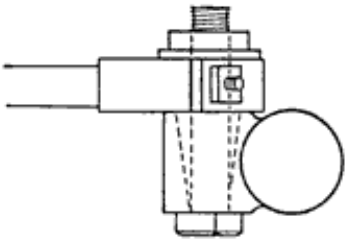

Fig. 156

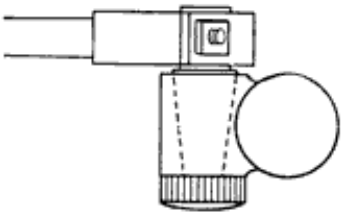

Fig. 157

Fig. 155. Showing method of connecting rental batteries with cable terminals, to cars with clamp type terminals. In Fig. 155 the cable insulation is stripped for a space of an inch and the strands are equally divided with an awl. A bolt is passed through the opening and a washer and nut complete the connection.

Two methods of connecting a clamp type terminal to taper plug terminals. In Fig. 156 a taper plug is inserted and screwed tight. The projecting part of the plug has been turned down to fit the clamp type terminal which is clamped to it. In Fig. 157 a bolt is passed through and the clamp type terminal tightened to the plug type terminal with a washer and nut.

Fig. 158

Fig. 158 shows a simple means of putting on a lead-plated copper terminal lug without solder. These lugs should be soldered on whenever possible, but it is often a difficult job to put one on in the confined space of some battery compartments. In such places, a quick and lasting job can be made with a band vise and a short piece of round iron. This latter is laid across the lug and the vise screwed up, making a crimp across the lug which firmly grips down upon the bared cable strands that have been inserted into the lug.

New batteries sold to replace other batteries should be installed with cable connections, as illustrated in Figure 152. This method of connecting a battery is superior to any other method and will never cause trouble. It will usually be found that the old taper plugs or clamp terminals that have been in use have started to corrode and that a new battery works increasingly at a disadvantage from the day it is installed until the corrosion becomes so great that the car cannot be started and then the customer kicks about his new battery. The best connection possible will pay handsome dividends to all concerned, in the end.

Marking Rental Batteries. Rental batteries should be marked in a mariner which enables them to be recognized quickly. Painting the cases a red color is a good way. The service station's name should appear somewhere on the battery. A good plan is to have a lead tag, which is attached to the handle at the negative end of the battery, or is tacked to the case. The name may also be painted on the case. Each battery should be given a number which should preferably be painted in large white figures on the end or side of each case. The number may also be stamped on a lead tag tied to the handle at the negative end.

A service station which sells a certain make of battery should not use cases of some other make if the name of the other make appears on the case. Such names may give a wrong impression to the customer, which will not be fair either to the service station or to the manufacturer whose name appears on the case. If the service station sells, another make of battery, the customer may get the impression that the service station man does not have enough confidence in the make which he sells, and must use some other make for his rentals. If the rental battery does not give good service, the customer will get the impression that the manufacturer whose name appears on the case does not turn out good batteries, when as a matter of fact, the plates, covers, jars, and other parts used in the rental battery may not have been made by this manufacturer. Some battery men would, perhaps, consider the failure of a rental battery as an opportunity to "knock" the manufacturer whose name appears on the case. Such an action may have the desired effect on a very few customers, but the great majority of men have no use for any one who "knocks" a competitor's products.

Keeping a Record of Rental Batteries. A careful record should be kept of all rental batteries. The more carefully such a record is kept, the less confusion there will be in knowing just where every rental battery is. A special rack for rental batteries, such as those shown in Figures 88 and 89 should be provided, and all rental batteries which are in the shop should be kept there, except when they are on charge or are being overhauled. Have them fully charged and ready to go out immediately, without keeping a customer waiting around, when he is in a hurry to go somewhere else.

General Rental Policy. No service station should make a practice of installing rental batteries on any car unless the owner leaves his own battery to be repaired or recharged. The purpose of having a stock of rental batteries is to enable customers to have the use of their cars while their own batteries are being repaired by the battery man who furnishes the rental battery and not to furnish batteries to car owners who may be taking their batteries to some other station to be repaired. It is, of course, a good thing to be generous and accommodating, but every battery repairman should think of his own business first, before he helps build up the business of a competitor.

The customer must have some inducement to bring in your rental battery and get his own. A rental charge of 25 cents- per day serves as a reminder to most customers. However, some customers are forgetful and the battery man must telephone or write to any owner who fails to call for his battery. If, due to failure to keep after the owner, a rental battery is out for several weeks, there is likely to be an argument when the rental bill is presented to the owner. If the delay in calling in a

rental battery is due to failure to repair the customer's battery, the rental charge should be reduced.

A rental battery should not be put in place of a battery which is almost ready for the junk pile. The thing to do is to sell the customer a new battery. Repairs on an almost worn out battery are expensive and the results may not be satisfactory.

RADIO BATTERIES

The wide-awake battery man will not overlook the new and rapidly growing field which has been opened for him by the installation of hundreds of thousands of radio-phone receiving sets in all parts of the country. The so-called radio "craze" has affected every state, and every battery repairman can increase his income to a considerable extent by selling, charging, and repairing radio storage batteries.

The remarkable growth of the radio-phone has, of course, been due to the radio broadcasting stations which have been established in all parts of the country, and from which concerts, speeches, market reports, baseball reports, news reports, children's stories and religious services are sent out. These broadcasting stations have sending ranges as high as 1,000 miles. The fact that a service station is not located near a broadcasting station is therefore no reason why it should not have its share of the radio battery business, because the broadcasting stations are scattered all over the United States, and receiving sets may be made powerful enough to "pick up" the waves from at least one of the broadcasting stations.

Radio receiving sets may be divided into two general classes, the "Crystal" sets and the "Bulb" sets. "Crystal" sets use crystals of galena (lead sulphide), silicon (a crystalline form of silicon, one of the chemical elements), or carborundum (carbide of silicon) to "detect" or, in other words, to rectify the incoming radio waves so that they may be translated into sound by the telephone receivers. Receiving sets using these crystals do not use a battery, but these sets are not very sensitive, and cannot "pick up" weak waves. This means that crystal receiving sets must be used near the broadcasting stations, before the waves have been weakened by traveling any considerable distance.

As a general rule, the radio-listener's first receiving set uses a crystal detector. Very often it is difficult to obtain good results with such a set, and a more elaborate set is obtained. Moreover, even if a crystal set does give good results, the owner of such a set soon hears of friends who are able to hear concerts sent out from distance stations. This gives him the desire to be able to hear such stations also and he then buys a receiving set which uses the "audion-bulb" for detecting, or rectifying the incoming waves.

The audion-bulb resembles an ordinary incandescent lamp. It contains three elements:

1. In the center of the bulb is a short tungsten filament, the ends of which are brought out to two terminals in the base of the bulb. This filament must be heated to incandescence, and a storage battery is required for this purpose, because it is necessary to have a very steady current in order to obtain clear sounds in the receiver. Lately plans have been suggested for using a direct current lighting line, and even an alternating current lighting line for heating the filament, but at present such plans have not been perfected, and the battery will undoubtedly continue to be used with the majority of sets.

2. Surrounding the filament but not touching it is a helix of wire, only one end of which is brought out to a terminal in the base of the bulb. This helix is called the "grid." In some bulbs the grid is not made in the form of a helix, but is made of two flat gridlike structures, one on each side of the filament.

3. Surrounding the "grid" is the "plate" which is sometimes in the shape of a hollow metallic cylinder. Some plates are not round, but may be oval, or they may be two flat plates joined together at some point, and one placed on either side of the grid. The plate has one terminal in the base of the bulb.

The action of an audion-bulb is quite complex, but a simpler explanation, though one which may not be exactly correct from a purely technical point of view, is as follows, referring to Figure 159:

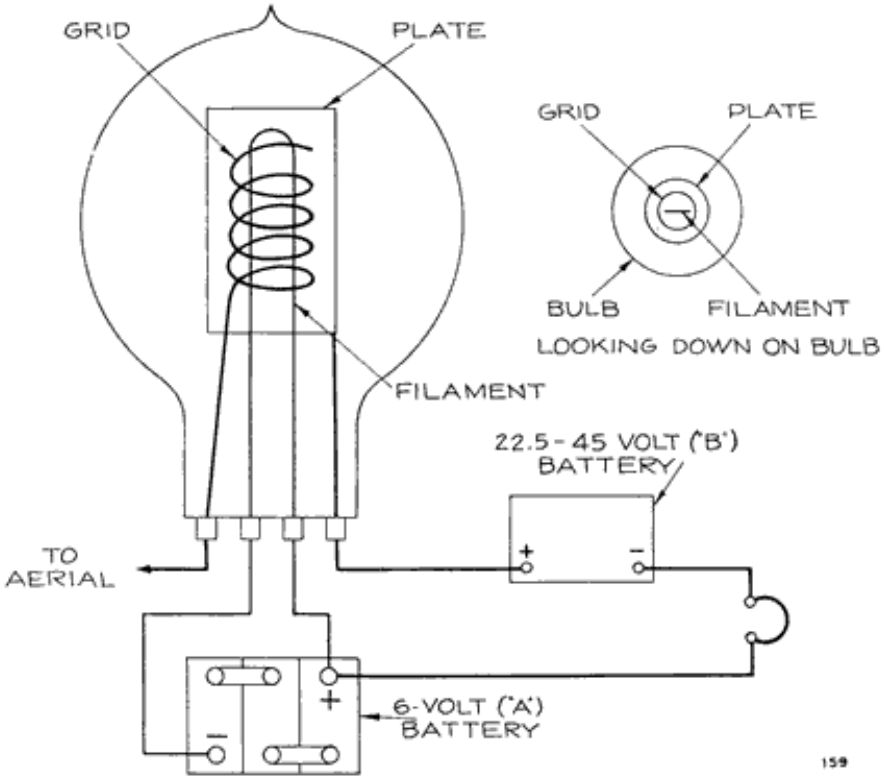

Fig. 159. Illustrating Principle of the Audion Radio Bulb

The "A" battery heats the filament, causing a stream of electrically charged particles to flow out from the filament in all directions. These electrons act as a conductor, and close the circuit which consists of the plate, the "B" battery, and the telephone receivers, one end of this circuit being connected to one side of the filament circuit. Current then flows from the positive terminal of the "B" battery to the plate, then to the filament by means of the stream of electrons emitted by the filament, along one side of the filament, through the wire connected to the positive terminal of the "A" battery to the telephone receivers, through the receivers to the negative terminal of the "B" battery,

As long as the filament remains lighted a steady current flows through the above circuit. The "grid" is connected to the aerial wire to intercept the radio waves. These waves produce varying electrical charges on the grid. Since the stream of charged particles emitted by the filament must pass through the grid to reach the plate, the charges which the radio waves produce on the grid strengthen or weaken the stream of electrons emitted by the filament, and thus vary the current flowing in the telephone receiver circuit. The changes in this current cause the receiver diaphragm to vibrate, the vibrations causing sounds to be heard. Since the variation in the telephone receiver circuit is caused by electrical charges produced by the radio waves, and since the radio waves change according to the sounds made at the transmitting station, the variations in the telephone receiver current produces the same sounds that are sent out at the transmitting station. In this way concerts, speeches, etc., are reproduced in the receivers.

The modern radio receiving set includes various devices, such as variable condensers, variocouplers, loose-couplers, variometers, the purpose of which is to "tune" or adjust the receiving set to be capable of receiving the radio waves. An explanation of such devices is not within the scope of this book, but there are numerous reasonably priced books and pamphlets on the market which describes in a simple manner all the component parts of a radioreceiving set.

From the foregoing remarks it is seen that a six-volt storage battery is required with each receiving set which uses the audionbulb type detector. The filament current of an audion-bulb averages about one ampere. If additional bulbs are used to obtain louder sounds, each such bulb also draws one ampere from the storage battery. The standard audion-bulb receiving set does not use more than three bulbs, and hence the maximum current drawn from the battery does not exceed three amperes.

The automobile battery manufacturers have built special radio batteries which have thick plates and thick separators to give longer life. The thick plates are much stronger and more durable than the thin plates used in starting and lighting work, but do not have the heavy current capacity that the starting and lighting battery plates have. A high current capacity is, of course, not necessary for radio work, and hence thick plates are used.

Batteries used for radio work do not operate under the severe conditions which exist on automobiles, and trouble is much less likely to develop. However, the owner of the radio set rarely has any means of keeping his battery charged, and his

battery gradually discharges and must then be recharged. It is in the sale of batteries for radio work and in the recharging of them that the battery man can "cash-in" on the radio phone "craze."

This business rightfully belongs to the automobile battery man and he should go after it as hard as he can. A little advertising by the service station man, stating that he sells radio batteries, and also recharges them should bring in: very profitable business. The battery man who calls for and delivers the radio batteries which need recharging and leaves rental batteries in their place so that there is no interruption in the reception of the evening concerts is the one who will get the business.

As already stated, radio storage batteries have thick plates and thick separators. Perforated rubber sheets are also used in addition to the separators. Large sediment spaces are also generally provided to allow a considerable amount of sediment to accumulate without causing short-circuits. The cases are made of wood or hard rubber. Since radio batteries are used in homes and are, therefore, used with handsomely finished cabinets containing the radio apparatus, the manufacturers give the cases of some of their radio batteries a pleasing varnished or mahogany finish. Before returning radio batteries which have been recharged, the entire batteries should be cleaned and the cases polished. Returning radio batteries in a dirty condition, when they were received clean, and polished, will drive the radio recharging business to some other service station.

VESTA RADIO BATTERIES

The Vesta Battery Corporation manufacturers three special types of "A" batteries for radio work, as follows:

1. The 6EA battery, made in capacities of 60, 80, and 100 ampere hours. Fig. 160.

2. The V6EA7 battery, having a capacity of 80 ampere hours. Fig. 161.

3. The R6EA battery, having a capacity of 100 ampere hours. Fig. 162.

Fig. 160

Fig. 161

Fig. 162

Fig. 163

Vesta Radio Batteries. Fig. 160 shows the 6EA Series, "A" Battery. Fig. 161 shows the V6EA Series, "A" Battery. Fig. 162 shows the R6EA (Rubber Case) Series, "A" Battery. Fig. 163 shows the "B" Battery.

These batteries have 5, 7, 9 plates per cell, respectively. The plates are each 5 inches high, 5 7/8 inches wide, and 5/32 inches thick. The cases for these batteries are furnished in three designs - plain black boxes (all sizes), finished maple boxes (7 plate size only), and hard rubber boxes (9 plate size only). These Vesta batteries are the "A" batteries used for heating the filaments of the audion bulbs. The Vesta Radio "B" battery, Fig. 163, is a 12 cell, 24 volt battery, with a 22 and a 20 volt tap.

EXIDE RADIO BATTERIES

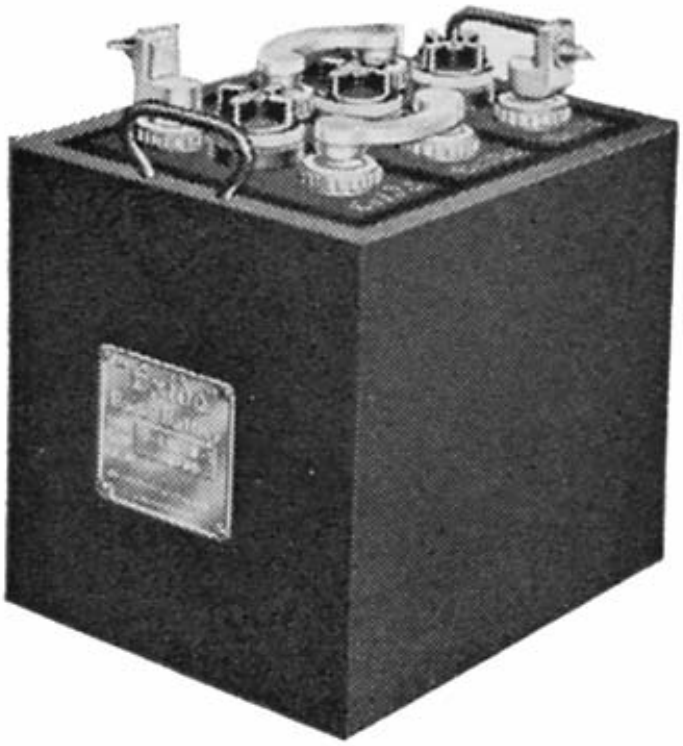

Fig. 164. Exide Radio "A" Battery

The Exide Radio "A" battery, Fig. 164, is made in four sizes, the capacities ranging from 20 to 120 ampere-hours. The design and construction of these batteries are similar to the Exide starting batteries. The over-all height of these batteries is approximately 95/8 inches, the width 7-5/16 inches, while the length varies with the number of the plates.

Type	Cat. No.	Length	Weight	Capacity
3-LXL-3	13735	4-9/16	15-1/2 lbs.	20 amp. hrs.
3-LXL-5	13736	5-11/16	24-1/2 lbs.	40 amp. hrs.
3-LXL-9	13737	9-1/16	42-1/2 lbs.	80 amp. hrs.
3-LXL-13	13750	12-7/16	59-1/2 lbs.	120 amp. hrs.

WILLARD RADIO BATTERIES

The Willard Storage Battery Co. manufactures both "A" and "B" storage batteries. The Willard "A" battery, Fig. 165, is an all-rubber battery. The case is a rubber "Monobloc" construction, that is, the entire case is pressed into shape at one time. There are no separate jars for the cells, there being rubber partitions which form integral parts of the case. The case is, therefore, really a solid, one piece, three compartment jar. The ribs at the bottoms of the compartments are parts of the one-piece block, and are higher than those found in the usual starting and lighting battery. Embedded in each side wall of the case is a bronze button which holds the handle in place. Soft rubber gaskets of pure gum rubber surround the post to make an acid proof seal to prevent electrolyte from seeping from the cells. The separators are the standard Willard "Threaded Rubber" separators.

Fig. 165

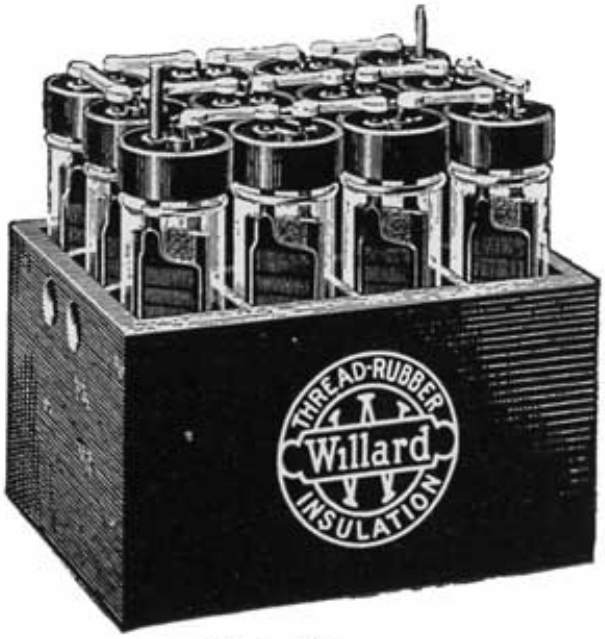

Fig. 166

Fig. 167

Willard Radio Batteries. Fig. 165 shows the All-Rubber "A" Battery. Fig. 166 shows the complete "B" Battery. Fig. 167 shows one cell of the "B" Battery.

The Willard "A" battery comes in five sizes, type WRR97 (20 ampere hours capacity), type WRRO (50 ampere hours capacity), type WRR1 (89 ampere hours capacity), type WRR2 (100 ampere hours capacity), and type WRR3 (125 ampere hours capacity).

The Willard "B" storage battery, type CBR124, Figs. 166 and 167, is a twelve cell battery, each cell consisting of a round glass container having one negative and one positive plate insulated from each other by a small "Threaded Rubber" separator. The plates and separators rest on a hard rubber "bottom rest" which consists of a short length of hard rubber tube, so formed as to support the plates and separators and at the same time hold them together. The cells are assembled in a case which has a separate compartment for each cell. As seen from Fig, 166, the upper parts of the cells project above the top of the case, which simplifies inspection.

WESTINGHOUSE RADIO BATTERIES

Fig. 168. Westinghouse Radio "A" Battery, Type HR

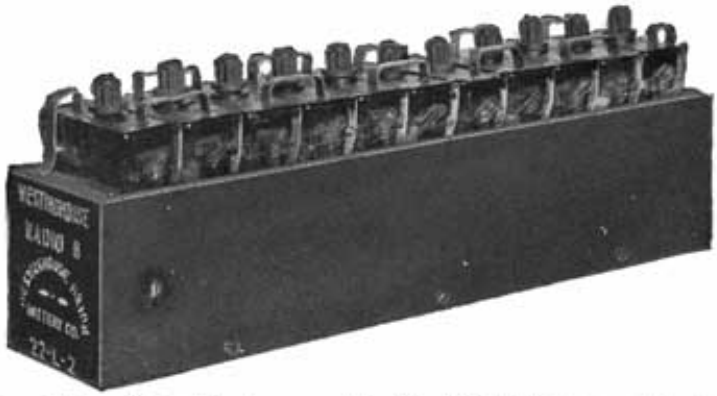

Fig. 169. Westinghouse Radio "B" Battery, Type L

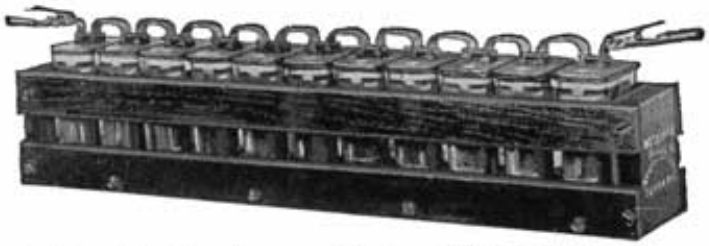

Fig. 170. Westinghouse Radio "B" Battery, Type M

The Westinghouse Union Battery Co. manufactures both "A" and "B" storage batteries. Their "ER" type, Fig. 168, is the "A" battery, and their "L" and "M" types, Figs. 169 and 170, are the "B" batteries. The HR battery has 3/16 inch thick plates, high rests to provide ample mud and acid space, and thick separators. Rubber sheets are placed on both sides of the positive plates. Rubber covered cables are moulded into the terminals to minimize corrosion at the positive terminal. The "HR" batteries are made in six and eight volt sizes, with 3 plates per cell, 5 plates per cell, 9 plates per cell, and 13 plates per cell.

The Westinghouse Radio "B" batteries are made in two sizes. Type 22-M-2, Fig. 170, has a capacity of 1.2 ampere hours at 0.04 ampere. It is designed to operate a receiving set having one detector and two amplifier bulbs for three to five weeks between charges. The type 22-L-2 battery, Fig. 169, has a capacity of 4.5 ampere hours at 0.25 ampere.

Part No.	Type	Volts	Amp. Hours. at 3 Amps. Intermittent rate.	Weight
100110	6-HR-5	6	54 A.H.	30 Lbs.
100111	6-HR-9	6	108 A.H.	46 Lbs.
100112	6-HR-13	6	162 A.H.	65 Lbs.
100135	8-HR-5	8	54 A.H.	40 Lbs.
100136	8-HR-9	8	108 A.H.	60 Lbs.

100137	8-HR-13	8	162 A.H.	87 Lbs.
100145	6-HR-3	6	27 A.H.	20 Lbs.

Part No.	Type	Volts	Capacity	Weight
100148	22-M-2	22	1.2 A.H. at .04 Amps.	6-1/4 Lbs.
100140	22-L-2	22	4.5 A.H at .25 Amps	19-3/4 Lbs.

PHILADELHIA RADIO BATTERIES

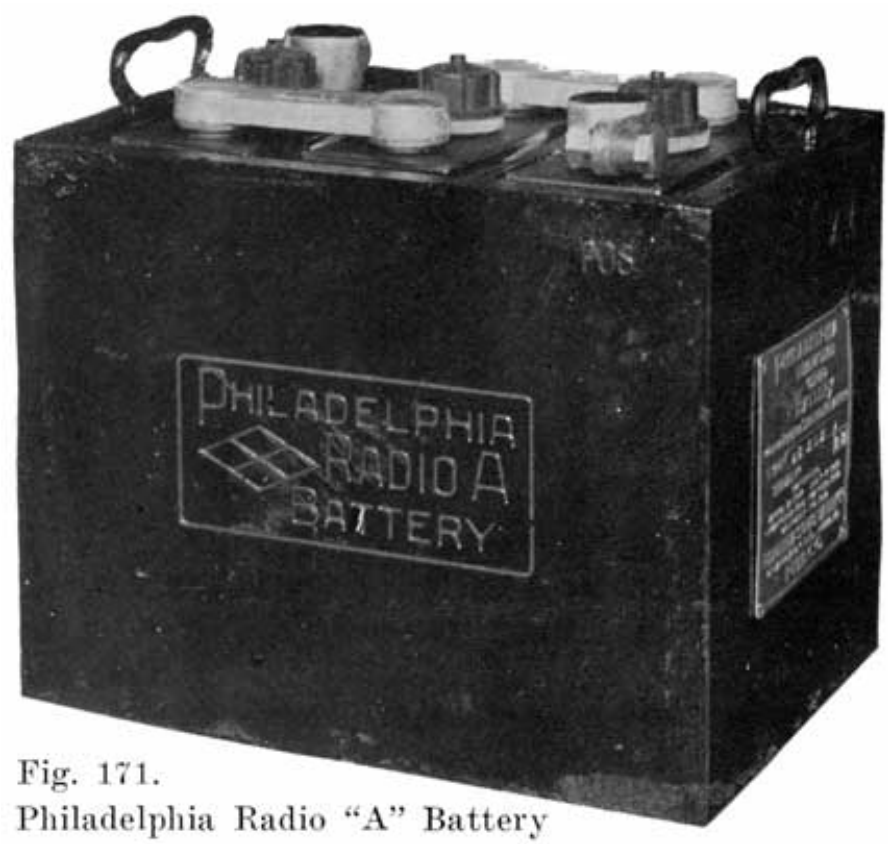

Fig. 171.
Philadelphia Radio "A" Battery

The Philadelphia Storage Battery Co. makes both "A" and "B" Radio batteries. The "A" battery, Fig. 171, uses the standard diamond-grid plates, and the "Philco Slotted Retainer" used in Philadelphia starting batteries. The cases of the "A" batteries are made of hardwood, finished in an ebonite black. Soft rubber insulating feet on the bottom of the case prevent scratching any table or varnished floor on which the battery may be set. The instructions for preparing the Philadelphia "A" battery for service are similar to those given for the. starting and lighting batteries, given on page 228. For the initial filling, 1.220 electolyte is used, and the battery charged at the following rates:

Initial and Recharge Charging Rate

Type	Initial Rate	Recharge Rate

56LAR	1.0	2
56RAR	2.0	3
76RAR	3.0	4.5
96RAR	4.0	6
116RAR	5.6	7.5
136RAR	6.0	9

The final gravity of the electrolyte should be 1.250. However, if the owner insists on getting maximum capacity, the battery may be filled with 1.250 electrolyte and balanced to 1.290 at the end of the charge.

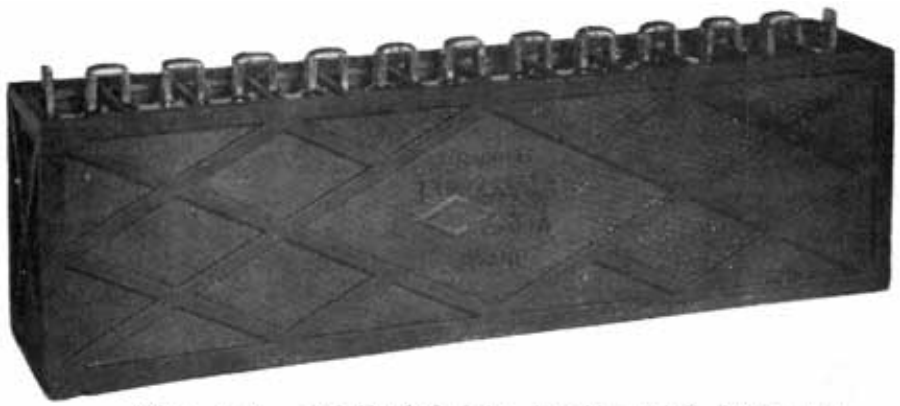

Fig. 172. Philadelphia Radio "B" Battery

The Philadelphia Radio "B" battery, type 224-RB, Fig. 172, has 12 cells contained in a one-piece rubber case. It is shipped dry, and requires no initial charge. To prepare it for service, the soft rubber vent caps are removed and 25 c. c. of 1.250 electrolyte poured into each cell.

U. S. L. RADIO BATTERY

Fig. 173. U. S. L. Radio "A" Battery

The U. S. L. Radio "A" battery, Fig. 173, uses 1/4 inch positives, with 3/16 inch intermediate and 1/8 inch outside negatives. Port Orford cedar separators are used which are four times as thick as the usual starting battery separator. The case is made of hardwood, and is varnished to match cabinet work. The electrolyte has a specific gravity of 1.220. The heavy plates and separators and the low gravity of the electrolyte are designed to give long life.

Type	Plates per Cell	Ampere Hour Capacity @ 3 Amperes	Ampere Hour Capacity @ 1 Amperes (or intermintet use)	Dimensions	Weights
DXA-303-X	3	12	20	5-3/16 x 7-1/4 x 9-1/4	18
DXA-305-X	5	40	60	9-1/8 x 7-1/4 x 9-1/4	39
DXA-307-X	7	70	85	11-3/4 x 7-7/16 x 9-1/4	48
DXA-309-X	9	98	115	14-3/8 x 7-7/16 x 9-1/4	59

PREST-O-LITE RADIO BATTERIES

The Prest-O-Lite Co. makes two lines of Radio "A" Batteries. First, an inexpensive battery, Fig. 174, and a deluxe battery, Fig. 175, which has a better finish and appearance. Both types have a mahogany finished case with rubber feet to

prevent damaging furniture. A bail handle simplifies the carrying of the battery. Capacities range from 47 ampere-hours to 127 ampere-hours at a one ampere discharge rate.

Fig. 174. Prest-o-Lite Radio "A" Battery

Fig. 175. Prest-o-Lite Radio "A" Battery

Table of Prest-O-Lite Radio Batteries

Hours Discharge at Rate of:

Type	1 Amp	2 Amps.	3 Amps.	5 Amps	10 Amps.
67 WHNR	47.5	21.7	13.6	7.5	3.0
69 WHNR	66	30	18.9	10.5	4.5
611 WHNR	82.8	38.5	24.3	13.5	6.0
67 KPNR	95	44.2	27.8	15.0	6.5
69 KPNR	127	61.5	38.5	21.5	9.5

UNIVERSAL RADIO BATTERIES

The Universal Battery Co. manufacture three types of Radio "A" storage batteries. Type WR, Fig. 176, has three sealed hard rubber jars assembled in a hardwood case which is stained and finished in mahogany. The separators are made of Port Orford cedar and are 1/8 inch thick, about twice the thickness of the separator used in starting and lighting batteries. The plates also are much thicker than the standard starting and lighting battery plate. The type WR battery comes in three sizes. Types WR-5, WR-7, and WR-9, having capacities of 60, 85, and 105 ampere hours, respectively, at a 3 ampere rate.

Fig. 176. Universal Type WR, Radio "A" Battery

The Universal type RR radio "A" battery, Fig. 177, is assembled in a hard rubber combination case, which is a solid piece of rubber divided into three compartments. This gives a compact, acid proof case. This battery also comes in three sizes, types RR-5, RR-7, and RR-9, having capacities of 60, 85 and 105 ampere hours, respectively, at a three ampere discharge rate.

Fig. 177. Universal Type RR, Radio "A" Battery

Fig. 178. Universal Type GR, Radio "A" Battery

The Universal type GR radio "A" battery, Fig. 178, is assembled in three sealed glass jars which are placed in a mahogany finished wooden crate. This construction makes the cell interiors visible, enabling the owner to detect troubles and to watch the action of the cells on charge and discharge. The GR battery comes in two sizes, GR-5 and GR-Jr., having respective capacities of 60 and 16 ampere hours at a 3 ampere discharge rate.

"DRY" STORAGE BATTERIES

During the past year or two, so-called "dry" starting and lighting storage batteries have appeared on the market. This class includes batteries having "dry," "semi-dry," and "jelly" electrolytes. The claims made for these batteries are that there is nothing to evaporate and that the periodical addition of water is therefore unnecessary, that spilling and slopping of electrolyte is impossible, and that injurious sulphation does not take place.

The "dry" storage battery is not a new idea, for as much as thirty-five years ago, the Oerlikon Company of Switzerland manufactured "dry" electrolyte storage batteries in commercial quantities. These batteries were for a long time a distinct success for work requiring only low rates of discharge. For high rates of discharge the lack of diffusion, due to the absence of a liquid electrolyte, reduces the capacity. The lack of diffusion will cause a rapid drop in voltage when cranking the engine! and a slow recovery after the engine begins to run under its own power.

The manufacturers of the "dry" storage batteries, of course, claim that their batteries are more efficient and satisfactory than the standard "wet" battery, but it has been impossible to get sufficient data from the manufacturers to go into detail on the subject.

Several of the largest of "wet" battery manufacturers formerly made "dry" storage batteries for lighting and ignition service, but when starting motors came into use, discarded the "dry" batteries in favor of the present "wet" storage batteries.

DISCHARGE TESTS

Discharge tests may be divided into four general classes:

(a) Brief High Rate Discharge Tests to determine condition of battery. These tests are made for 15 seconds at a high rate.

(b) Lighting Ability Discharge Tests.

(c) Starting Ability Discharge Tests.

(d) "Cycling" Discharge Tests.

The 15 Seconds High Rate Discharge Test

The 1.5 seconds high rate discharge test is a valuable aid in determining the condition of a battery, particularly where the hydrometer readings give false indications, such as is the case when electrolyte or acid is added to a cell instead of water to replace evaporation. Only two or three percent of the battery capacity is consumed by the test, and it is not usually necessary to recharge the battery after making the test. The test must be made in conjunction with hydrometer readings, as otherwise it might give false indications itself. Both incoming and outgoing batteries may be tested, and the method of testing depends upon whether the battery is coming in for repairs, or is going out after having been charged, repaired, or worked on in any way. In either case, the test consists of discharging the battery at a high rate for a short time, and taking voltage readings and making observations while the battery is discharging.

Rates of Discharge. It is not necessary to have any definitely fixed discharge rate. The rate should merely be high enough to reveal any improperly burned joints, short-circuited cells, or cells low in capacity for any reason. The discharge tester is suitable for all batteries used on cars and trucks.

For an Incoming Battery. Take a hydrometer reading of each cell. If the readings are all below 1.200 and are within 50 points of each other, most likely all the battery needs is a bench charge, with a possible adjustment of the gravity of the electrolyte at the end of the charge. The discharge test should in this case be made after the battery has been fully charged.

If the gravity readings are all above 1.200, or if the reading of one cell differs from the others by 50 points or more, make the discharge test, as shown in Fig. 179.

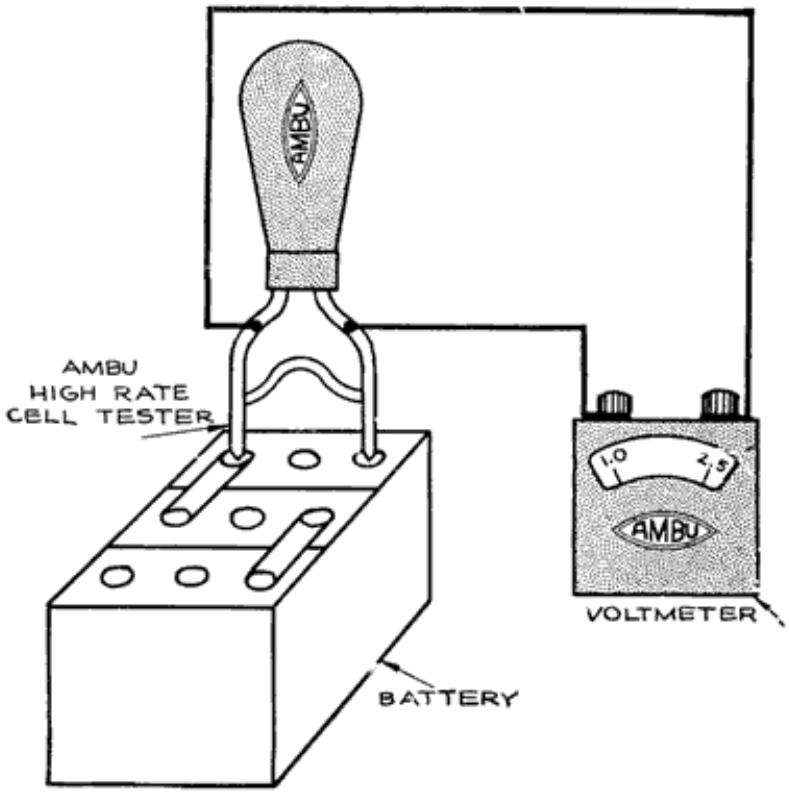

Fig. 179. Making a 20 Seconds High Rate Discharge Test

After fifteen seconds, read the voltage of each cell. If the cells are uniformly low in voltage; that is, below 1.5 volts per cell, the battery needs recharging. If the voltage readings of the cells differ by 0.1.0 volt or more and the battery is fairly well charged, there is something wrong in the cell having the low reading, and the battery should be -opened and examined. With a discharged battery the difference in cell voltage will be greater, depending on the extent of the

discharge, and only experience can guide in drawing correct conclusions. A short-circuited cell will give a very low voltage reading. Remember that the actual voltage reading is not as important in indicating a defective cell as the difference between the voltage readings of the cells. A cell which gives a voltage which is 0.1 volt or more less than the others is generally defective.

For Outgoing New, Charged, or Repaired Batteries. Just before putting the battery into service, make the test as a check on the internal condition of the battery, particularly if the battery has been repaired or has stood for sometime since being charged. (It is assumed that the battery has been charged and the gravity of the electrolyte properly adjusted when the test is made.)

The battery should not show more than 0.10 volt difference between any two cells at the end of 15 seconds, and no cell should show a voltage less than 1.75 volts, and the voltage should remain fairly constant during the test. If every cell reads below 1.75 volts, the battery has not been completely charged. If one cell is more than 0.10 volt lower than the others, or if its voltage falls off rapidly, that cell still needs repairs, or is insufficiently charged, or else the top connectors are not burned on properly. Top connectors which heat up during the test are not burned on properly.

Lighting Ability Discharge Tests

These are tests continuing for 5 hours to a final voltage of 1.7 per cell. These tests are not of as great an interest as the Starting Ability Tests, description of which follows:

Starting Ability Discharge Tests

The Society of Automotive Engineers recommends two ratings for starting and lighting batteries:

"Batteries for combined lighting and starting service shall have two ratings. The first shall indicate the lighting ability and be the capacity in ampere-hours of the battery when discharged continuously at the 5 hour rate to a final voltage of not less than 1.7 per cell, the temperature of the battery beginning such a discharge being 80 deg. Fahr. The second rating shall indicate the starting ability and shall be the capacity in ampere-hours when the battery is discharged continuously at the 20 minute rate to a final voltage of not less than 1.50 per cell, the temperature of the battery beginning such discharge being 80 deg. Fahr."

The capacity in ampere-hours given by manufacturers is for a continuous discharge for 5 hours. In the battery shop, however, the "starting-ability" discharge test is the test which should be made, though the conditions of the test are changed somewhat. To make this test, the battery should be fully charged. Connect a rheostat to the battery terminals and adjust the rheostat to draw about 100 amperes from an 11 plate battery, 120 amperes from a 13 plate battery, 135 amperes from a 15 plate battery, 155 amperes from a 17 plate battery, 170 amperes from a 19 plate battery and so on. Continue the discharge for 20 minutes, keeping the discharge current constant, and taking voltage readings of each cell at the start, and at the end of 5, 10, 15, and 20 minutes. At the end of 20 minutes, if the battery is in good condition, the voltage of each cell should not be less than 1.5, and the temperature of the electrolyte in any cell should not exceed 95 degrees Fahrenheit, provided that the temperature at the start was about 80 degrees.

The cell voltages should drop slowly during the test. If the voltage begins to drop rapidly during the test, as shown by the current falling off so rapidly that it is difficult to keep it at 100 amperes, measure the cell voltages quickly to see which cells are dropping rapidly. An example of a 100 ampere test on a good rebuilt cell with eleven plates is as follows:

Voltage immediately after start of discharge, 1.88. After 5 minutes, 1.86 volts. After 10 minutes, 1.80 volts. After 15 minutes, 1.72 volts. After 20 minutes, 1.5 volts.

If the voltage of a cell begins to fall off rapidly before the twenty minutes are up, but not before 15 minutes, the cell needs "cycling" (charging and discharging) to bring it up to capacity.

If the voltage drops rapidly before the end of 15 minutes, the plates are low in capacity, due to age, or some defect. It is not safe to expect very good service from a cell which will not stand up for 20 minutes before de voltage begins to drop

rapidly.

If the rapid voltage drop begins very much before 20 minutes, it is very doubtful whether the battery will give good service. Comparisons of the results of tests with the service which the battery gives after installed on the car will soon enable the repairman to tell from the results of the tests just what to expect from any battery.

The "starting-ability" test should be made on all batteries which have been rebuilt whenever there is time to do so and on all batteries about which there is any doubt as to what service they will give. After the test, the batteries should be put on the line again and charged before sending them out.

The rates of discharge given here for the "starting-ability" tests may be varied if experience with a particular make of battery shows some other rate to be better. The important thing is to use the same rate of discharge for the same make and type of battery at all times. In this way the repairman will soon be able to distinguish between good and bad batteries of a particular make and type.

Cadmium Tests may be made during the Starting Ability Discharge Tests. See page 174.

"Cycling" Discharge Tests

New batteries, or rebuilt batteries which have had new plates installed, or sulphated batteries which will not "come up" on charge, should be discharged when they have "come-up," as far as they will go. In some cases it is necessary to charge and discharge them several times before they will be ready for service. This charging and discharging is often called "cycling" the battery.

New batteries are generally "cycled" at the factory before sending them out. The forming charge generally does not convert all the pastes into active material and the battery using plates which have been treated in the forming room is put through several discharges and charges after the battery is fully assembled. In service on a car, the battery is being "cycled" constantly and there is generally an increase in capacity after a battery is put on a car. Positive plates naturally increase in capacity, sometimes up to the very clay when they fall to pieces, while negatives tend to lose capacity with age.

Batteries which are assembled in the service station, using new plates, generally require several cycles of charge and discharge before the specific gravity will rise to 1.280 before the positives will give 2.4-2.5 volts on a Cadmium test, before the negatives will give a reversed voltage reading of 0.175 to 0.20 volt on a Cadmium test, and before a satisfactory "starting-ability" or "breakdown" test can be made.

A battery which has been abused by failing to add water to replace evaporation, by allowing to remain in a partially or completely discharged condition for sometime, or which has been allowed to become sulphated in any other way, will generally require "cycling" before it will "come-up" to a serviceable condition.

The rates for a "cycling" discharge should be such that the battery will be discharged during the daytime, the discharge being started in the morning, and the battery being put back oil the charging line in the evening in order that it may be charging during the night. The rate of discharge should be somewhat higher than the rate used when the plates are formed. Two or three amperes per positive plate in each cell will generally be satisfactory.

Discharge Apparatus

A simple discharge rheostat is shown in Fig. 180. The terminal on the end of the cable attached to the right hand terminal of the battery shown in the illustration is movable, and it may be clamped at any point along the coils of wire so as to give various currents. The wire should be greased lightly to prevent rusting.

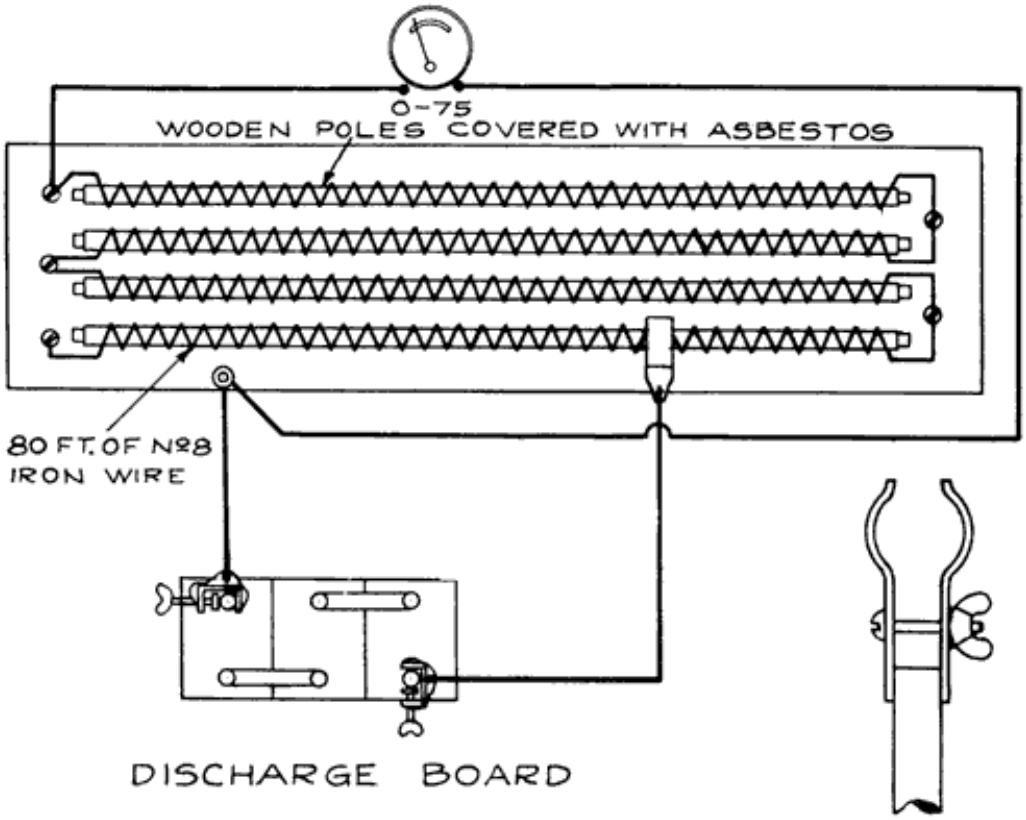

Fig. 180. Simple High Rate Discharge Rheostat

Another simple apparatus consists of a board on which are mounted six double contact automobile lamp sockets which are all connected in parallel. A pair of leads having test clips attached is brought out from the sockets for fastening to the battery terminals. Lamps of various candlepower may be turned into the sockets to obtain different currents.

Discharge tests are helpful in the case of a battery that has lost capacity. The battery is first fully charged, and is then discharged at the 5 hour rate. When the voltage of the battery has fallen to 1.7 volts per cell (measured while the battery is discharging) a Cadmium test is made to determine whether the positives or negatives are causing the lack of capacity. For further descriptions of the Cadmium Test see Page 174.

In reviving sulphated batteries, it is sometimes necessary to charge and discharge the battery several times to put the active material in a healthy condition.

Discharge tests at a high rate are very valuable in diagnosing the condition of a battery. A description of such tests will be found on Page 267. For making the heavy discharge tests a rheostat of the carbon plate type is suitable. With such a rheostat currents from 25 to more than 200 may be drawn from a six volt battery, and a smooth, even variation of a current may be obtained from the minimum to the maximum values. Such a rheostat is on the market and may be purchased complete with ammeter and leads for attaching to the battery.

PACKING BATTERIES FOR SHIPPING

Batteries which are shipped without electrolyte need merely have plenty of excelsior placed around them in a strong crate for protection from mechanical injury.

Batteries which are shipped filled with electrolyte must be protected from mechanical injury and must also be packed so that it is difficult to turn the crate upside down and thus allow the electrolyte to run out. A very popular crate has been the so-called "dog-house," with a gable roof such as is actually used on dog-houses. The idea of such a roof is that it is impossible to place the crate with the roof down, since it will tip over if this is done. However, if these crates are placed side by side, it is a very simple matter to put a second row of crates on top of them, turning the second row up-side-down, as shown in Fig. 181, and allowing the electrolyte to run out. The men who load freight or express-cars have often shown

great skill and cunning in packing "dog-house" crates in other ways so as to damage the batteries. Many have attained a high degree of perfection in breaking the crates.

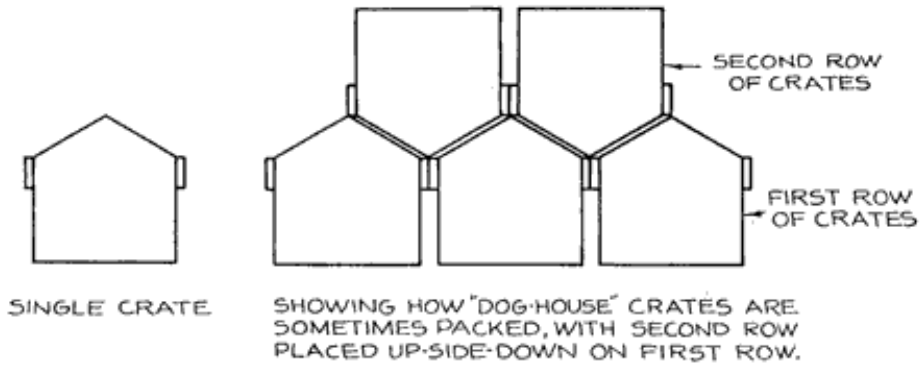

Fig. 181. "Dog-House" Crates for Shipping Batteries

Some sort of a roof on a battery crate is required by law, the idea being to make it difficult to turn the crate up-side-down. Perhaps the best crate would be one with a flat top marked "This Side Up," but such a crate would not comply with the law.

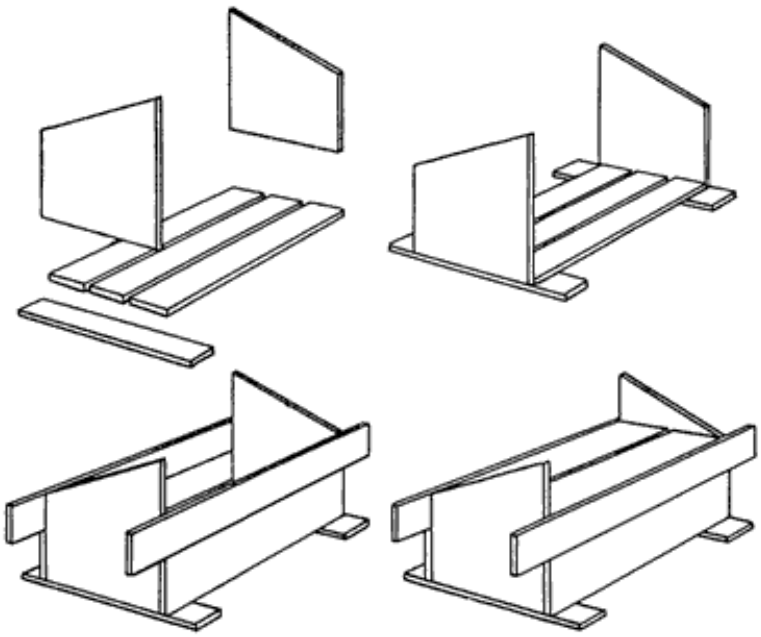

Fig. 182. Steps in the Construction of a Crate for Shipping Battery

A better form of crate than the "dog-house" and one which complies with the law, is shown in Fig. 182. The top of each end piece is cut at an angle, the peak on one end being placed opposite the low point of the opposite end piece. Fig. 182 shows the steps in the construction of the crate.

1. The case should be built of strong lumber (11/2 inch preferably), and of ample size to allow packing with excelsior top, bottom, sides and ends to a thickness of two or three inches. Nail strongly.

2. When the case is complete (except cover) place a thick, even layer of excelsior (or packing straw) in the bottom and set in *he battery right side up. Lay paper (preferably paraffined) over top of battery to keep it clean, then pack tightly with excelsior sides and ends.

3. Now lay sufficient packing material on top of the battery so that cover will compress it tightly, stuffing it under cover boards as they are put on.

The extended boards at bottom, and the gable roof are provided to prevent the battery from being tipped over; extensions of sides for carrying. Box should be plainly labeled: **"HANDLE WITH CARE. DAMAGES CLAIMED IF TIPPED ON SIDE."** In addition to the address of destination, as given in shipping instructions be sure to mark with name of shipper for identification upon arrival. When shipping by freight, the proper freight classification in the United States is "Electric Storage Batteries, Assembled." When shipping by express in the United States, "Acid" caution labels must be attached to each package.

STORING SEPARATORS

Separators which have been given the chemical treatment necessary to remove the substances which would cause trouble in the battery, and to make the wood porous, must be kept wet and never be allowed to become dry. A lead lined box, or large earthenware jars may be used as containers. Put the separators in the container and then pour in enough very weak electrolyte to cover the separators. This electrolyte may be made of I part of 1.220 electrolyte to 10 parts of distilled water, by volume. Be very careful to have the container absolutely clean and to use chemically pure acid and distilled water in making the weak electrolyte. Remember- that impurities which are picked up by the separators will go into the battery in which the separators are placed. Therefore, keep the separator tank in a clean place and keep a cover on it. Have your hands clean when you take separators out of the tank to place in a battery, and do not put the separators on a dirty bench before inserting them between plates. The best thing to do is to hold the separators in one hand and insert them with the other, and not lay them on any bench at all.

REINSULATION

Separators are the weakest part of a battery and wear out while the other parts of a battery are still in good condition. Good plates are often ruined by weakened separators causing short-circuits. Many batteries which have to be junked after being in service about a year would have given considerable service if they had been reinsulated.

Generally the separators of one cell wear out before those of the other cells. Do not, however, reinsulate that cell alone. The separators in the other cells are as old as those which have worn out, and are very near the breaking down point. If you reinsulate only one cell, the owner will naturally assume that the other cells are in good condition. What happens? A month or so later one of the other cells "goes dead." This does not have a very soothing effect on the owner, who will begin to lose confidence in you and begin to look around for another service station.

If you explain frankly that it is useless to reinsulate only one cell of a battery and that the other cells will break down in a short time, the customer will want you to reinsulate all the cells. A somewhat higher bill for reinsulating all the cells at once will be more agreeable than having the cells break down one at a time within a month or two.

In the case of the customers who come in regularly for testing and filling service, you will be able to tell when the separators are wearing out. When you find that a battery which has been in service about a year begins to run down frequently, and suceessive tests made in connection with testing and filling service show that the generator is not able to keep the battery charged, advise the owner to have the battery reinsulated. Do not wait for the battery to have a dead cell. Sell the owner on the idea that reinsulation will prevent the possibility of his battery breaking down when he may be out on a tour, and when it may be necessary to have his car towed in to a service station. If you allow the battery to remain on the car when it begins to lose its charge, the owner will not, of course, suspect that anything is wrong, and if his battery one day breaks down suddenly, lie will very likely lose confidence both in you and the battery, since he has been bringing in his car regularly in order to have his battery kept in good shape. The sudden failure of his battery will, therefore, make him believe that you do not know your business, or that the battery is a poor one.

New separators will give every battery which is a year old a new lease on life. If you explain to a customer that he will get a much longer period of service from his battery if he has it reinsulated when the battery is a year old, you should have no trouble in getting the job, and the subsequent performance of the battery will show that you knew what you were talking about.

SAFETY FIRST FOR THE BATTERY REPAIRMAN

1. Do not work on an empty stomach-you can then absorb lead easily.

2. Keep your fingers out of your mouth when at work.

3. Keep your finger nails short and clean.

4. Do not chew tobacco while at work. In handling tobacco, the lead oxides are carried to your mouth. Chewing tobacco does not prevent you from swallowing lead.

5. When you leave the shop at night, and before eating, wash your face, hands, and arms with soap, and clean your nose, mouth, and finger nails.

6. Do not eat in the repair shop.

7. Drink plenty of good milk. It prevents lead poisoning.

8. Use Epsom Salts when constipated. This is very important.

9. Bathe frequently to prevent lead poisoning.

10. Leave your working clothes in the shop.

11. It is better not to wear a beard or mustache. Keep your hair covered with a cap.

12. Before sweeping the shop dampen the floor to keep down the dust.

13. Do not drink beer or whisky, or any other alcoholic liquors. These weaken your system and make you more susceptible to lead poisoning.

14. In handling lead, wear gloves as much as possible, and -wash and dry the gloves every day that you wear them.

15. Wear goggles to keep lead and acid out of your eyes.

16. When melting lead in a hydrogen flame, as in burning on the top connectors, the fumes given off may be blown away by a stream of air. The air supply to the flame may be tapped for this purpose.

17. The symptoms of lead poisoning are: gums darken or become blue, indigestion, colic, constipation, loss of appetite, muscular pain. In the later stages there is muscular weakness and paralysis. The hands become limp and useless.

18. Wear rubber shoes or boots. Leather shoes should be painted with a hot mixture of equal parts of paraffine and beeswax.

19. Wear woolen clothes if possible. Cotton clothing should be dipped in a strong solution of baking soda and dried. Wear a flannel apron covered with sacking.

20. Keep a bottle of strong ammonia handy. If you should spill acid on your clothes, apply some of the ammonia immediately to neutralize the acid, which will otherwise burn a hole in your clothes.

21. Keep a stone, earthenware, or porcelain jar filled with a solution of washing soda or baking soda (bicarbonate of soda). Rinse your hands in this solution occasionally to prevent the acid from irritating them.

22. If you should splash acid in your eye, wash it out immediately with warm water, and drop olive oil on the eye. If you have no olive oil at hand, do not wait to get some, but use any, lubricating oil, or vaseline.

TESTING THE ELECTRICAL SYSTEM

"Out of sight, out of mind," is a familiar saying. But when does it hold true?

What about the battery repairman? Are the batteries he repairs "out of sight, out of mind?" Does his responsibility end when he has installed a battery on a car? Suppose he put-, a battery in first class shape, installs it on a car, and, after a week or two the battery comes back, absolutely dead? Is the battery' at fault, or is the repairman to blame for neglecting to make sure that the battery would be given a reasonably good chance to give good service and receive fair treatment from the other part of the electrical system?

The actual work on the battery is finished when the battery cables are fastened to the battery terminals. **But real battery SERVICE does not end there.** The battery is the most important part of the, electrical system of a car, but it is only one part, and a good battery cannot be expected to give satisfactory service when it is connected to the other parts of the electrical system without making sure that these parts are working properly, any more than a man wearing new, shoes can step into a mud puddle and not have his shoes covered with dirt.

The battery functions by means of the current which flows through it by way of the cables which are connected to its terminals. A battery is human in many respects. It must have both food and exercise and there must be a proper balance between the food and the exercise. Too much food for the amount of exercise, or too much exercise for the amount of food consumed will both lead to a lowering of efficiency, and disease frequently results. A battery exercises when it turns over the starting motor, furnishes energy to the lamps, or operates the a ignition system. It receives food when it is charged. Proper attention to the electrical system will result in a correct balance between food and exercise, or in other words, charge and discharge.

The electrical equipment of a car consists of five principal parts:

1. The Battery.

2. The Ignition System.

3. The Starting Motor.

4. The Generator.

5. The Lighting System.

The normal course of operation of this system is as follows:

Starting. The ignition switch is closed, and connects the ignition system to the battery. The starting switch is then closed, connecting the starting motor to the battery. The battery sends a heavy current through the starting motor, causing the motor to turn over, or "crank" the engine. The motion of the engine pistons draws a mixture of air and gasoline vapor into the cylinders. At the proper instant sparks are made to jump between the points of the spark plugs, igniting the air and gasoline vapor mixture, forming a large amount of gas. This gas expands, and in doing so puts the engine into motion. The engine begins to run under its own power and the starting switch is opened, since the starting motor has performed the work required of it, and has nothing further to do as long as the engine runs.

The engine now operates the generator. The generator begins to build up a voltage as the engine speed increases. When the voltage of the generator has risen to about 7-7.5, the generator is automatically connected to the battery by the cutout (also known as reverse- current relay, cut-out relay, or relay). The voltage of the generator being higher than that of the battery, the generator sends a current through the battery, which "charges" the battery. As long As the engine continues to run above the speed at which the generator develops a voltage higher than that of the battery, a charging current will normally flow through. the battery. When the ignition switch is opened the engine can no longer develop any power and consequently stops running. When the decreasing engine speed causes the generator speed to drop to a point at which the

generator voltage is less than that of battery, the battery sends a reverse, or discharge current through the cutout and generator, thereby causing the cutout to open and disconnect the generator from the battery.

Lights. When the engine is not running, the battery furnishes current to the lights. This is a discharge current. When the engine runs at a speed which is greater than that at which the the cutout closes, the generator furnishes current for the lights, and also for the ignition system, in addition to sending a charging current through the battery.

From the foregoing description. we see that the battery is at rest, is discharging, or charging under the following conditions:

Engine Not Running, Lamps Off, Ignition Off. Under these conditions all switches are open, and hence no current should be passing through the battery. If a current is found to be passing through the battery under these conditions, it is a discharge current which is not doing any work and is caused by a defective cutout, defective switches, or grounds and short-circuits in the wires, cables, or apparatus connected to the battery.

Starting the Engine. A heavy discharge current is drawn from the battery. This current should not flow more than 10 seconds. If the starting motor does not crank the engine or cranks it too slowly, the motor or the cables and switch connecting the motor to the battery are defective, assuming that the battery is large enough and is in a good condition. If the starting motor cranks the engine, but the engine does not begin to run under its own power within ten seconds, the starting system is not at fault, and the starting switch should be opened.

Engine Not Running, All Lamps On. A discharge current flows from the battery which is equal to the sum of the currents drawn by lamps when connected to the battery separately. If the current is greater than this sum, trouble is present.

Engine Running, Lamps Off. The generator sends a charging current into the battery and also supplies current to the ignition system (except when a magneto is used). If the generator does not send a charging current through the battery there is trouble in the generator, or in the parts connecting the generator to the battery (assuming the battery to be in a good condition). If the generator sends a current through the battery, it may be of the correct value, it may be insufficient, or it may be excessive. A normal current is one which keeps the battery fully charged, but does not overheat it or cause excessive gassing. An insufficient current is one which fails to keep the battery charged. An excessive charging current is one which keeps the battery charged, but which at the same time overheats the battery and causes excessive gassing. The excessive current may also overheat the generator, while a normal or insufficient charging current will not injure the generator.

It is possible, but not probable, that the generator may be sending &-current through the battery in the wrong direction, so as to discharge it instead of charging it. This will happen if a very badly discharged battery is installed with the connections reversed. If a fully or even partly charged battery is installed with its connections reversed, the battery will generally reverse the polarity of the generator automatically, and the battery will be charged in the proper direction, although the current flow in the charging circuit is actually reversed.

Engine Running, Lamps On. Under these conditions, the generator should supply the current for the lights, and still send a charging current of 3 to 5 amperes through the battery. This means that the current drawn from the battery when the engine is not running and the lights are all turned on should be at least several amperes less than the charging current which the generator sends into the battery when the engine is running and the lamps are turned off.

Tests to Be Made by the Repairman

The battery repairman can, and always should, make a few simple tests which will tell him whether the various conditions of operation are normal. This should be done as follows:

1. Install the battery carefully (see page 236), and connect the negative battery cable to the negative battery terminal. Now tap the positive battery cable on the positive battery terminal. If a snappy spark is obtained when this is done, some of the switches are open or are defective, the cutout is stuck in the closed position, or there are grounds or short-circuits in

the parts which are permanently connected to the battery.

Even though no spark is obtained when you tap the positive battery cable on the positive battery terminal, there may be some trouble which draws enough current from the battery to cause it to run down in a short time. To detect such trouble, connect a voltmeter (which has sufficient range to indicate the battery voltage) between the positive battery cable and the positive battery terminal. (Cable is disconnected from the terminal.) If the voltmeter now gives a reading equal to the voltage of the battery, there is some condition causing a current leakage from the battery, such as a cutout stuck in the closed position, defective switches which do not break the circuits when in the open position, or grounds or short-circuits in the cables and wires connected to the battery.

If the voltmeter pointer does not move from the "0" line on the scale, complete the battery connections by fastening the positive battery cable to the positive battery terminal, and make the test described in Section 2. If the voltmeter pointer moves from the "0" line, and gives a reading equal to the battery voltage, connect the voltmeter permanently between the positive battery cable and the positive battery terminal and make a general inspection of the wiring, looking for cut or torn insulation which allows a wire or cable to come in contact with the frame of the car, or with some other wire or cable, thereby causing a ground or short-circuit. Old, oil-soaked insulation on wires and cables will often cause such trouble. If a general inspection does not reveal the cause of the current leakage, proceed as follows:

Closed Cutout, or Defective Cutout Windings. (a) If the cutout is mounted outside the generator, remove the cover from it and see if the points are stuck together. If they are, separate them and see if the voltmeter pointer returns to the "0" line. If it does, you have found the trouble. The points should be made smooth with 00 sandpaper. See that the moving arm of the cutout moves freely and that the spring which tends to hold the arm in the open position is not weak or broken.

If the voltmeter pointer does not return to the "0" line when the cutout points are separated, or if the points were not found to be stuck together, disconnect from the cutout the wire which goes to the ammeter or battery. If this causes the voltmeter pointer to return to the "0" line, the cutout is defective and a new one should be installed, unless the trouble can be found by inspection and repaired.

If the voltmeter pointer does not return to the "0" line when the battery or ammeter wire is disconnected from the cutout, see paragraph (d)

(b) If the cutout is mounted inside the generator, disconnect from the generator the wire which goes to the ammeter or indicator. If this causes the voltmeter pointer to return to the "0" line, the cutout points are stuck together or the cutout is defective, and the generator should be taken apart for inspection. If this does not cause the voltmeter pointer to return to the "0" line, replace the wire and see paragraph (d).

(c) If no cutout is used and connections between the generator (or motor-generator) and the battery are made by closing the ignition or starting switch, such as is the case on Delco and Dyneto motor-generators, and some Delco generators, disconnect from the generator or motorgenerator the wire that goes to the ammeter or indicator. If this causes the voltmeter pointer to return to the "0" line, the switch which connects tile generator or motor-generator to the ammeter or indicator is defective. If the voltmeter pointer does not return to the "0" line, replace the wire and consult paragraph (d).

(d) Defective Starting Switch. Disconnect from the starting switch the cable that goes to the battery. If one or more smaller wires are connected to the same terminal as the heavy cable, disconnect them also and hold their bare ends on the bare end of the heavy cable. If this causes the voltmeter pointer to return to the "0" line, the starting switch is defective. If the voltmeter pointer does not return to tile "0" line, replace the cable and wires on the starting switch terminal and proceed as follows:

Defective Switches. See that the ignition and lighting switches are in their "OFF" positions. If they are not, open them and see if the voltmeter pointer returns to the "0" line. If it does, you have found the trouble. If it does not, disconnect from the switch (or switches, if there are separate lighting and ignition switches), the feed wire which supplies current to the switch from the battery. If this causes the voltmeter pointer to return to the "0" line, the switches are defective. If the pointer does not return to the "0" line, replace the wires on the switch and consult the next paragraph.

If there are other switches which control a spot light, or special circuits, such as tonneau lamps, or accessories, such as gasoline vaporizers, electric primers, etc., make the same tests on these switches. If no trouble has been found, see paragraph (e).

(e) Grounds or Short-Circuits in Wiring. Disconnect from each terminal point in the wiring system the wires which are connected together at that point. Also remove fuses from the fuse blocks. If the voltmeter pointer returns to the "0" line when a certain wire or fuse is removed, there is a ground or short-circuit in the wire or in the circuit to which the fuse is connected.

(f) Turn on the Lights. Remove the voltmeter and complete the battery connection-,. -Note how much current is indicated on the ammeter mounted on the instrument panel of the car as the different lamps are turned on. In each case the ammeter should indicate "discharge." Should the ammeter indicate "charge" the battery connections have been reversed, or the ammeter connections are reversed. The driver will tell you whether the ammeter has been reading "charge" or "discharge" when the lamps were turned on. This is a good way to check your battery connections.

If the car has no ammeter, or has an indicator which is marked "ON" or "OFF," or "Charge" or "Discharge," an ammeter may be connected in series with the battery by disconnecting the cable from the positive battery terminal and connecting the ammeter to the cable and to the terminal, and the readings obtained from this meter.

The amperes indicated on the ammeter should be the greatest when the main headlamps are burning bright. By comparing the readings obtained when the different lighting combinations are turned on, it is sometimes possible to detect trouble in some of the lighting lines.

3. Start the Engine. Before you do this, be sure that the cables are connected directly to the battery terminals, and that no ammeter or voltmeter is connected in series with the battery, as the heavy current drawn by the starting motor would ruin the instruments very quickly. An ammeter may be left connected in series with the battery, providing that a switch is used to short-circuit the meter while starting the engine. A meter having a 500 ampere scale may be left connected in series with the battery while the engine is being started, but for the tests which are to be made a 25 ampere scale should be used.

The engine should start within ten seconds after the starting switch is closed. If more time than this is required, carburetor adjustments, position of the choke lever, etc., should be looked after. Continued cranking of the engine will run the battery down very quickly, and the chances are that the car will not be run long enough to allow the generator to recharge the battery. Make whatever adjustments are necessary to reduce the cranking time to ten seconds, or advise the owner to have them made, warning him that otherwise you will not be responsible if the battery runs down very quickly.

4. When the engine has started, set the throttle lever so that the engine runs As slowly as possible. The ammeter (either that on the instrument panel, or a special test ammeter connected in* series with the battery) will indicate several amperes discharge, this being the current taken by the ignition system.

Now speed up the engine gradually. At an engine speed corresponding to a car speed of 7 to 10 miles per hour in "highly (if there is any difficulty in estimating this speed, drive the car around the block while making this and the following tests) the ammeter pointer should move back to, or slightly past, the "0" line, showing that the cutout has closed. If the ammeter needle jumps back and forth and the cutout opens and closes rapidly, the polarity of the battery and that of the generator are not the same. This condition may be remedied by holding the cutout points closed for several seconds, or by short-circuiting the "Battery" terminal on the cutout with the "Generator" terminal on the cutout.

After a slight movement of the ammeter pointer indicates that the cutout has closed, speed up the engine gradually. When the engine speed corresponds to a car speed of 18-25 miles per hour in "high," the current indicated on the ammeter should reach its maximum value and the pointer should then stop moving, or should begin to drop back toward the "0" line as the speed is increased.

For average driving conditions, the maximum charging current should not exceed 12 to 14 amperes for a 6 volt, 11 to 13 plate battery, and 6 to 7 amperes for a 12 volt battery. (These currents should be obtained if "constant-current" generators, such as the "third brush ... .. reversed-series," or vibrating current regulators are used. The "third brush" type of generator

is used on more than 99 per cent of the modern cars. Some cars use a "constant-voltage" regulated generator, such as the Bijur generator, having a voltage regulator carried in a box mounted on the generator. On all cars using a "constant-voltage" generator, the charging rate when the battery is fully charged should not exceed five amperes for a six volt generator). If the generator has a thermostat, such as is used on the Remy generators, the charging rate will be as high as 20 amperes until the generator warms up, and then the charging rate will drop to 10-12 amperes, due to the opening of the thermostat points, which inserts a resistance coil in series with the shunt field.

If the charging current reaches its maximum value at 18-25 miles per hour, and shows no increase at higher speeds, decrease the engine speed. When the engine is running at a speed corresponding to a car speed of about 7 miles per hour, or less, the cutout should open, indicated by the ammeter indicating several amperes discharge, in addition to the ignition current, for an instant, and then dropping back to the amount taken by the ignition system.

Now turn on the headlights (and whatever lamps are turned on at the same time) and speed the engine up again. The ammeter should indicate some charging current at engine speeds corresponding to the usual speed at which the car is driven. If it does not, the charging current should be increased or smaller lamps must be installed.

Troubles

The operation of the electrical system when the engine is running may not be as described in the foregoing paragraphs. **Troubles may be found as follows:**

1. Cutout does not close until engine reaches a speed in excess of 10 miles per hour. This trouble may be due to the cutout or to the generator. If the ammeter shows a charging current of three amperes or more as soon as it closes, the cutout is at fault. The thing to do in such a case is to adjust the cutout. First see that the movable armature of the cutout moves freely and does not bind at the pivot. If no trouble is found here, the thing to do is to decrease the air gap which exists between the stationary and movable cutout points when the cutout is open., or to decrease the tension of the spring which tends to keep the points open. On most cutouts there is a stop which the cutout armature strikes when the cutout opens. By bending this stop the air-gap between the points may be decreased. This is the adjustment which should be made to have the cutout close earlier, rather than to decrease the spring tension. Some cutouts have a spiral spring attached to the cutout armature. Others have a flat spring. On still others, the spring forms the connection between the armature and the cutout frame. In the first two types, the spring tension may be decreased, but wherever possible the air-gap adjustment should be made as described.

If the cutout closes late, and only about an ampere of charging current is indicated on the ammeter, and the cutout points are fairly clean and smooth, the trouble -is generally in the generator.

The generator troubles which are most likely to exist are:

a. Dirty commutator.

b. Dirty brush contact surface.

c. Loose brushes.

d. Brushes bearing on wrong point of commutator (to set brushes properly, remove all outside connections from generator, open the shunt field circuit, and apply a battery across the main brushes. Shift the brushes until the armature does not tend to rotate in either direction. This is, of course, a test which must be made with the generator on the test bench).

e. Loose connections in the shunt field circuit.

The foregoing conditions are the one-, which will generally be found. More serious troubles will generally prevent the generator from building up at all.

2. Cutout does hot open when engine stops. This condition is shown by a discharge current of about 5 amperes when the engine has stopped. (In Delco systems which have no cutout, an even greater discharge will be noted as long as the ignition switch remains closed.) This trouble is generally due to cutout points stuck together, a broken cutout spring, or a bent or binding cutout armature.

3. Cutout does not open until ammeter indicates a discharge of three or more amperes (in addition to the ignition discharge). This may be remedied by increasing the spring tension of the cutout, or removing any trouble which causes the cutout armature to bind. On many cutouts the armature does not actually touch the core of the cutout winding when the points are closed, there being a small piece of copper or other non-magnetic metal on the armature which touches the end of the cutout and maintains a small air gap between the core and armature, even when the points are closed. The opening action of the cutout may be changed by filing this piece of non-magnetic material so as to decrease the air gap, or pinching it with heavy pliers so as to make it stand farther out from the cutout armature and thus increase the air gap between the armature and core when the points are closed.

Decreasing this air gap will cause the cutout to open late, and increasing it will cause the cutout to open early.

4. Cutout will not close at any engine speed. If cutout does not close the first time the engine speed is increased, stop the engine. This condition may be due to a defective cutout, an 'open-circuit in the charging line, a ground or short-circuit between the cutout and the generator, or a defective generator. To determine whether the cutout is defective, remove the wires from it and hold together the ends of the wires coming from the generator, and the one going to the ammeter. Start the engine. If no other trouble exists, the ammeter will indicate a charging current at speeds above 8-10 miles per hour. If no current is obtained, stop the engine. If the cutout trouble consisted of an open circuit in one of its windings, or in the points not closing, due to dirt or a binding armature, or if there is an open-circuit in the charging line, the generator will, of course, have been running on open-circuit. This will cause the fuse in the shunt field circuit to blow if there is such a fuse, and if there is no such fuse, the shunt field coils may be burned open, or the insulation on the field coil wires may have become overheated to a point at which it burns and carbonizes, and causes a short-circuit between wires. Such troubles will, of course, prevent a generator from building up when the cutout wires are disconnected and their ends held together.

If there is a ground in the cutout, or between the cutout and the generator, the generator will very likely be unable to generate (if a "one-wire" system is used on the car). If there is some defect in the generator-such as dirty commutator, high mica, brushes not touching, commutator dirty, or loose brushes, brushes too far from neutral, grounded brushes, brushes not well ground in, wrong type of brushes, grounded commutator or armature windings, short-circuited commutator or armature windings, open-circuited armature windings, grounded field windings, short-circuited field windings, open-circuit or poor connections in field circuit, one or more field coil connections reversed, wrong type of armature or field coils used in repairing generator, generator drive mechanism broken-then the generator will not build up.

If no charging current is, therefore, obtained when the generator and ammeter wires are disconnected from the cutout and their ends held together, there may be a ground or short-circuit in the cutout windings or in the circuit between the generator and the cutout, or the generator may be defective, due to having been operated on open-circuit, or due to troubles as described in the foregoing paragraph. The presence of a ground or short in the circuit between the generator and cutout or in the cutout may be determined by disconnected the wire from the generator, disconnecting the battery (or ammeter) wire from the cutout, and running a separate extra wire from the generator to the wire removed from the cutout. Then start the engine again. If a charging current is obtained, there is a ground or short either in the cutout or in the circuit between the cutout and the generator. (It is also possible that the failure of the generator to build up was due to poor brush contact in the generator. The use of the extra wire connected the generator directly to the battery, thus magnetizing the generator fields and causing generator to build up. If poor brush contact prevented the generator from building up, closing the cutout by hand will often cause the generator to start charging. If you can therefore cause the generator to build up by holding the cutout points closed by hand, or by shorting across from the generator terminal to the battery terminal of the cutout, it is probable that the generator brushes are not making good contact). The cutout may be tested by stopping the engine, replacing the battery (or ammeter) wire on the cutout, and holding the end of the extra wire on the generator terminal of the cutout. If a charging current is then obtained, the cutout is 0. K. and the trouble is between the cutout and the generator.

5. An excessive current is obtained. If a third brush generator is used, look for loose or dirty connections in the charging line, dirty cutout points, dirty commutator, dirty brushes (especially the brush, or brushes, which is Dot connected to one end of the field winding), brushes loose, brushes not well ground in, and any other conditions which will cause a high resistance in the charging line. It is characteristic of third brush generators that their current output increases if there is an increase in resistance in the charging circuit. If no troubles such as those enumerated above are found, the third brush may need adjusting.

Generators using vibrating current or voltage regulators will give an excessive output if the points need adjusting or if the regulating resistance is short-circuited.

Generators using reversed series regulation will give an excessive output if there is a short-circuit in the series field coils.

6. Low charging current is obtained. This may be due to adjustment of the regulating device, to high resistance in the shunt field circuit in case of a third brush generator. In case of generators using other kinds of regulation, loose connections, dirty commutator and brushes, etc., will cause low charging current.

7. Generator charges up to a certain speed and then stops charging. The trouble is caused by some condition which causes the brushes to break contact with the commutator, especially in the case of a "third" brush. High mica, loose brush spring, or a commutator which has been turned down off-center may cause the trouble. This trouble most frequently occurs on cars using third brush motor-generators having a 3 to 1 or more speed ratio between them and the engine. These motor-generators operate at such high speeds that high mica and a commutator which is even slightly off center have a much greater effect than the same conditions would cause in separate generators which operate at much lower speeds. The remedy for this trouble is to keep the mica under-cut, and to be very careful to center the armature in the lathe when taking a cut from the armature. In turning down the commutators of high speed motor-generators, special fittings should be made by means of which the armature may be mounted in its own ball-bearings while the commutator is turned down.

ADJUSTING GENERATOR OUTPUTS

The repairman should be very slow in adjusting generator outputs. Most cases of insufficient or excessive charging current are due to the troubles enumerated in the foregoing paragraphs, and not due to incorrect adjustment of the regulating device. Before changing the adjustment of any generator, therefore, be sure that everything is in good condition. The third brush generator, for instance, will have an excessive output if the brushes are dirty, loose, or not well seated on the commutator. The use of a third brush which is too wide, for instance, will change the output considerably. A high resistance third brush will decrease the output, while a low resistance brush will increase the output. On the other hand, an increase in the resistance of the charging circuit will cause an increase in the output of a third brush generator, which is just the opposite to what is ordinarily expected. Such an increase in resistance may be due to loose or dirty connections, dirty cutout contact points, corroded battery terminals and so on. Remember also that the third brush' generator sends a higher current into a fully charged battery than it sends into a discharged battery. It is, therefore, essential that a fully charged battery be on the car when the output of a third brush generator is adjusted.

There are two things which determine whether any change should be made in the charging rate on the car, viz: Driving, Conditions and the Season of the Year.

Driving Conditions. A car which makes short runs, with numerous stops, requires that the starting motor be used frequently. This tends to run the battery down very quickly. Moreover, such a car usually does not have its engine running long enough to give the generator an opportunity to keep the battery charged, and to accomplish this, the charging rate should be increased.

A car which is used mostly at night may need a higher charging rate, especially if short runs are made, and if the car stands at the curb with its lights burning. Long night runs will generally call for only a normal charging rate, since the long charging periods are offset by the continuous use of the lamps.

A car used on long daylight runs should generally have the charging rate reduced, because the battery is charged

throughout such runs with no discharge into lamps or starting of motor to offset the continued charge. If the lamps are kept lighted during such runs, the normal charge rate will be satisfactory, because the lamp current will automatically reduce the current sent into the battery.

In the winter time, engines must be cranked for a longer time before they will start, the battery is less efficient than in warm weather, and lights are burning for a greater length of time than in summer. Such conditions require an increase in the charging rate, especially if the car is used on short runs. Oil long runs in the winter time, the normal charging rate will generally be satisfactory because the long charging period will offset the longer cranking period.

In the summer time, engines start more easily than in winter, and hence require less cranking. The lamps are used for only short periods and the battery is more efficient than in winter. A lower charging rate will, therefore, keep the battery charged. Long tours in the summer time are especially likely to result in overcharged, overheated batteries, and a reduced charging rate is called for.

How and When to Adjust Charging Rates

A correct charging rate is one which keeps a battery fully charged, but does not overcharge it, and which does not cause either the generator or the battery to become overheated. The only way to determine whether a certain charging rate is correct on any particular car is to make an arrangement with the car owner to bring in his car every two weeks. On such occasions hydrometer readings should be taken and water added, if necessary, to bring the surface of the electrolyte up to the proper level. The hydrometer readings will show whether the generator is keeping the battery charged, and if a change in the charging rate is necessary, the necessary adjustments may be made. If a customer does not bring in his car every two weeks, call him up on the phone or write to him. The interest which you show in his battery by doing this will generally result in the customer giving you all his repair business, and he will also tell his acquaintances about your good service. This will give you considerable "word of mouth" advertising, which is by far the best form of advertising and which cannot be bought. It must be earned by good battery service.

Adjusting a third brush generator. The best rule to remember for changing the output of a third brush machine is that to increase the output, move the third brush in the direction in which the commutator rotates, and to decrease the output, move the third brush in the opposite direction. Move the third brush only 1/16 inch and then sandpaper the brush seat with 00 sandpaper. Allow the generator to run for about twenty minutes to "run-in" the brush. Then vary the speed to see what the maximum charging rate is. If the change in the charging rate is not sufficient, move the third brush another 1/16 inch and proceed as before until the desired charging rate is obtained.

Adjusting Vibrating Regulators. The output of generators which use a vibrating regulator is adjusted by changing the tension of the spring fastened to the regulator arm. In many cases this adjustment is made by means of a screw which is turned up or down to change the spring tension. In other cases a hook or prong is bent to change the spring tension. Where a coil spring is used, lengthening the spring will decrease the tension and lower the output, while shortening the spring will increase the tension and raise the output.

Vibrating regulators are of the "constant" current or the "constant-voltage" types. The constant current regulator has a winding of heavy wire which carries the charging current. When the charging current reaches the value for which the regulator is set, the electromagnet formed by the coil and the core on which it is wound draws the regulator armature toward it and thereby separates the regulator points, which are in series with the shunt field. A resistance coil, which is connected across the regulator points and which is short-circuited when the points are closed, is put in series with the shunt field when the points separate. This reduces the shunt field current, causing a decrease in generator voltage and hence current output. As the current decreases, the pull of the electromagnet on the regulator armature weakens and the spring overcomes the pull of the electromagnet and closes the regulator points. This short-circuits the resistance coil connected across the regulator points and allows the shunt field current to increase again, thereby increasing the generator output. This 'cycle is repeated at a high rate of speed, causing the regulator points to vibrate rapidly.

The action of a vibrating "constant-voltage" regulator is exactly the same as that of the "constant current" regulator, except that the coil is connected across the generator brushes. The action of this coil therefore depends on the generator voltage, the regulator points vibrating when the generator voltage rises to the value for which the regulator is set.

Adjusting Reverse-Series Generators. The regulation of the output of this type of generator is accomplished by means of a field winding which is in series with the armature, and which therefore carries the charging current. These series field coils are magnetically opposed to the shunt field coils, and an increase in charging current results in a weakening of the field flux. A balanced condition is reached at which no increase of flux takes place as the generator speed increases, the tendency of the increased shunt field current to increase the total flux being counterbalanced by the weakening action of the flux produced by the series field current.

To increase the output of a reverse series generator, it is necessary to weaken the opposing series field flux. The only way of doing this is to short-circuit the series field coils, or connect a resistance across them. To decrease the output of a reverse series generator, a resistance coil may be connected in series with the shunt field winding. Neither of these schemes is practicable, and hence the reverse series generator may be considered as a "non-adjustable" machine. Under-charging may be prevented by using the starting motor and lights as little as possible, or by giving the battery a bench charge occasionally. Over-charging may be prevented by burning the lights whenever the engine is running, or leaving the lights turned on over night.

Other forms of regulation have been used on the older cars, but the majority of the cars now in use use one of the four forms of regulation described in the foregoing paragraphs. If adjustments need to be made on some car having a system of-regulation with which the battery man is not familiar, the work should be done in a service station doing generator work.

If generator outputs are changed because of some special operating condition, such as summer tours, the rate should be changed to normal as soon as the usual driving conditions are resumed.

TESTING AND FILLING SERVICE

Every man expects to be paid for his work, since his purpose in working is to get money. Yet there are numerous instances in every line of work requiring work to be done for which no money is received. The term "Free Service" is familiar to every repairman, and it has been the cause of considerable discussion and dispute, since it is often very difficult to know where to draw the Tine between Free Service and Paid Service.

The term "Free Service" might be abolished with benefit to all concerned. In the battery business "Free Inspection" service is a familiar term. It is intended to apply to the regular addition of distilled water by the repairman and to tests made at the time the water is added. Since the term "Inspection" might be Misinterpreted and taken to apply to the opening of batteries for examination, the term "Testing and Filling Service" should be used instead of "Free Inspection Service."

Battery makers furnish cards for distribution to car owners. These cards entitle the holder to bring in his battery every two weeks to have distilled water added if necessary, and to have his battery tested without paying for it. This service requires very little time, and should be given cheerfully by every service man.

"Testing and Filling Service" is an excellent means of becoming acquainted with car owners. Be as pleasant and courteous to the "Testing and Filling" customer as you are to the man who brings in a battery that needs repairs. For this customer will certainly give you his repair business if you have been pleasant in giving the Testing and Filling Service.

A thoroughly competent battery man should be put in charge of the Testing and Filling Service, since this man must meet the car owners, upon whom the service station depends for its income. Customers are impressed, not by an imposing array of repair shop equipment, but by the manner of the men who meet them. These men will increase the number of your customers, or will drive trade to competitors, depending on the impression they leave in the minds of the car owners.

Every service station owner should persuade all the car owners in the vicinity of the station to come in regularly for the free testing and filling service, and when they do come in they should be given cheerful, courteous service. Each "testing" and "filling" customer is a prospective paying customer, for it is entirely natural that a car owner will give his repair work to the battery man who has been taking care of the testing and filling work Oil his battery. When a new battery is needed, the "testing" and "filling" customer will certainly buy it from the man who has been relieving him of the work of keeping

his batter.), in good shape.

Car owners who depend on your competitor for their "testing and filling" service will not come to you when their battery needs repairing, or when they need a new battery. You may be convinced that you handle a better make of battery than your competitor does, but your competitor's word will carry far more weight than yours with the man who has been coming to him for testing and filling. Good testing and filling service is, therefore, the best method of advertising and building up your business. The cost of this service to you is more than offset by the paying business it certainly brings, and by the saving in money spent for advertising. Remember that a boost by a satisfied customer is of considerably greater value to your business than newspaper advertising.

A careful record should be kept of every battery which is brought in regularly for testing and filling service. If a test shows that one or more cells are low in gravity, say about 1.220, this fact should be recorded. If the gravity is still low - when the battery comes in again for test, remove the battery and give it a bench charge. The customer should, of course, pay for the bench charge and for the rental battery which is put on the car in the meantime.

Battery manufacturers generally furnish cards to be used in connection with the testing and filling service, such cards being issued to the customers. A punch mark is made every time the battery is brought in, If the owner neglects to come in, this is indicated by the absence of a punch mark, and puts the blame for any trouble caused by this neglect on the owner. if any cell shows low gravity, a notation of that fact may be made opposite the punch mark for the date on which the low gravity was observed. If the low gravity is again found the next time the battery is brought in, the battery should be removed and given a bench charge. If the bench charge puts the battery in good shape, and the subsequent gravity readings are high, no trouble is present. If, however, the low gravity readings begin to drop off again, it is probable that new separators are required, especially if the battery is about a year old.

The logical course of events in the testing and filling service is to keep the battery properly filled (at no cost to the customer), give the battery an occasional bench charge (for which the customer pays), reinsulate the battery when it is about a year old (for which the customer pays), and sell the customer a new battery when the old one is worn out. If some trouble develops during the lifetime of the battery which is not due to lack of proper attention, the customer should pay to have the repairs made. From this the battery man will see how the Testing and Filling Service pays. The way to get business is to have people come to your shop. Become acquainted with them, treat them right, and you need not wonder where the money is to come from.

SERVICE RECORDS

In order to run a repair shop in an orderly, business-like manner, it is necessary to have an efficient system of Service Records. Such a system will protect both the repairman and the customer, and simplify the repairman's bookkeeping. For a small service station a very simple system should be adopted. As the business grows, the service record system must necessarily become more complicated, since each battery will pass through several persons' hands. Battery manufacturers generally furnish service record sheets and cards to their service stations, and the repairman who has a contract with a manufacturer generally adopts them. The manufacturers' service record systems are often somewhat complicated, and require considerable bookkeeping

For the smaller service station a single sheet or card is most suitable, there being only one for each job, and carbon sheets and copies being unnecessary. Such a service record has three essential parts: (a) The customer's claim check. (b) The battery tag. (c) The record card. Fig. 183 shows a service record card which is suitable for the average repair shop. Part No. I is the customer's claim check, Part No. 2 the battery tag, and part No. 3 the record card, and is 5 inches by 8 inches in size. The overall size of the entire card is 5 inches by 12 inches. Parts I and 2 are torn off along the perforated lines marked (A).

When a battery comes in the three parts are given the same number to identify them when they have been torn apart. The number may be written in the "No." space shown on each part, or the numbers may be stamped on the card. The record should not be made out as soon as a customer comes in, but after the battery has been examined and tested and the necessary work determined. Put the customer's name on parts 2 and 3. Record the address, telephone, etc., in the proper spaces on part 3. Having determined by test and inspection what is to be done, fill out the "WORKCOSTS" table on part 3, putting a check mark in the first column to indicate the work to be done and the material needed. Figure up the cost

while the customer waits, if this is possible. Explain the costs to the customer, and have him sign Contract No. 1. If you do this there can never be any argument about the bill you hand the customer later If the customer cannot wait, or if he is well known to you and you know lie will not question your bill, have him sign Contract No. 2. In either case, the terms printed on the back of the card authorize the repairman to make whatever repairs he finds to be necessary, and bind the customer to pay for them. Find out whether the customer will call, whether you are to deliver the battery, or whether you are to ship it, and put a check mark in the proper space at the right of the "WORK-COSTS" table. Mark the battery with the chalk whose color is indicated, and you will know how to dispose of the battery when the repairs are completed.

Fill out the claim check and give it to the customer, tearing it off along the perforated lines. Fill out the battery tag, indicating after "Instructions" just what is to be done. Make a sketch of the top of the battery in the space provided, dip the tag in the paraffine dip pot (see page 182) and tack the card on the battery. File part 3 in a standard 5 by 8 card index file. To the right of the "WORK-COSTS" table are spaces for entering the date on which the work is completed, the date the customer is notified and the date the battery goes out. These dates are useful in keeping a record of the job. When the job is finished and the rental comes in, enter the costs in the "COSTS" table, and note the date the bill was paid, in the space marked "PAID."

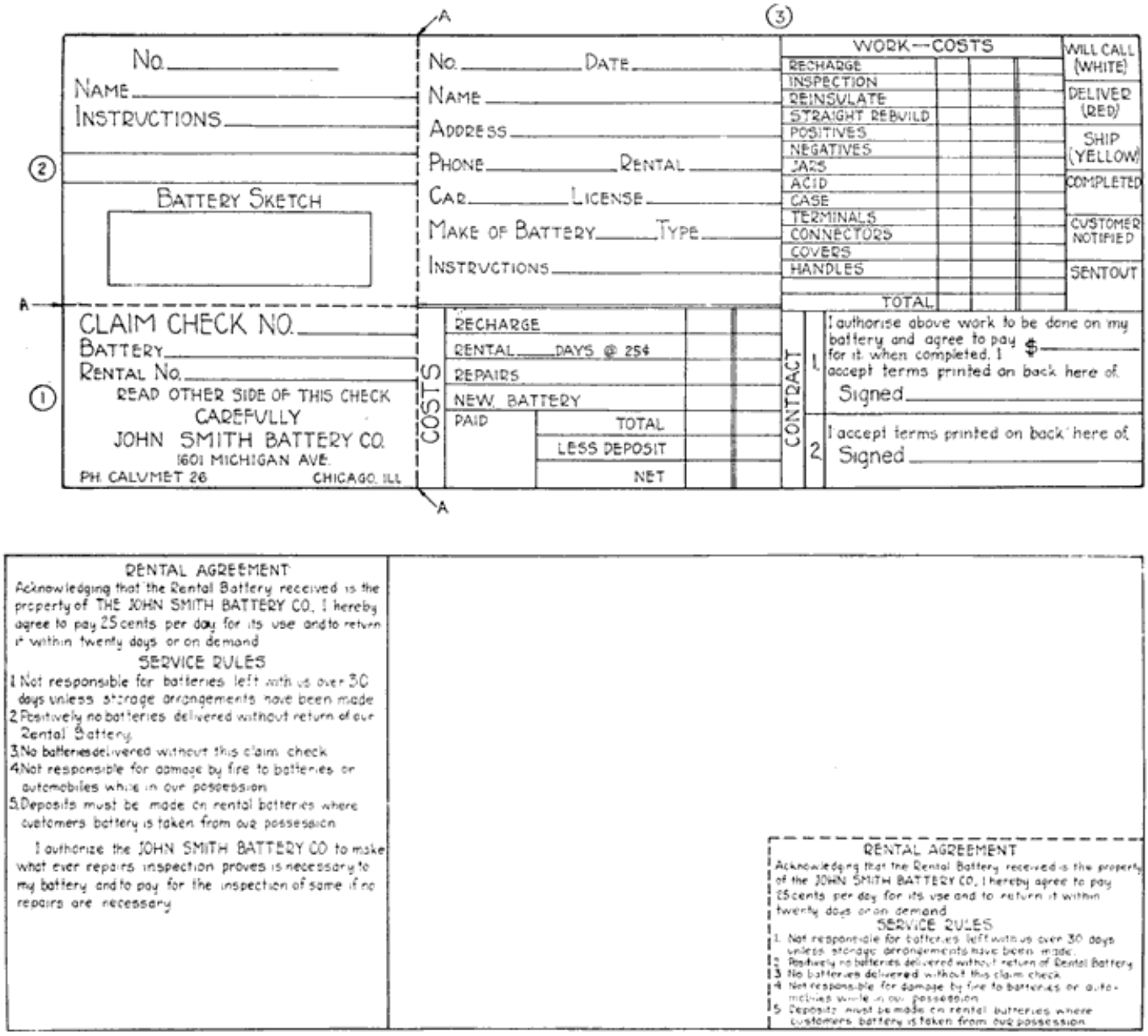

Fig. 183. Front and Back of Repair Service Record Card

File all the 5 by 8 cards (Part 3) in alphabetical order in a "dead" ticket file, in either alphabetical or numerical order. With this file you can build up an excellent mailing list of your customers. You can note how many new customers you are securing and how many customers are not coming back. The latter information is very valuable, as it enables you to find out what customers have quit, and you can go after them to get their repair business again.

When a rental is put on a card, the card shown in Fig. 184 may be tied to the car where it is easily seen. This will serve as a reminder to the customer and will help advertise your shop to those who ride in the car.

Each rental battery should have a number painted on it in large white letters, or should have attached to it at all times a lead tag on which is stamped a number to identify the battery. To keep a record of the rental batteries, a card or sheet similar to that shown in- Fig. 185 may be used. Each time the rental is put on a car, a record is made of this fact on the card. Each rental battery has its own card, and reference to this card will show at once where the battery is. Each card thus gives a record of the battery. The number of the rental is also written on the Stock Card shown in Fig. 183, but the purpose of putting the number on these cards is merely to make sure that the battery is returned when the customer's battery is replaced on the car and to be able to figure out the rental cost quickly and add it to the time and material costs in repairing the customer's battery.

Fig. 184. Card to be Tied on Car of Customer Using a Rental Battery

The Record Card shown in Fig. 183 does not help you locate any particular rental battery. For instance, suppose that rental battery No. 896 is out and you wish to know who is using it. You may, of course, look over the "Battery Tags" which are tied to the batteries which are being repaired in the shop, or you may examine the file containing the record cards, but this would take too much time. But if you refer to the rental file you can determine immediately where rental battery No. 896 is, since the cards in this' file should be arranged numerically.

The rack on which rental batteries are placed should have a tag bearing the same number as the rental battery tacked to the shelf below the place provided for the battery. Each rental battery should always be placed in the same place on the shelf. You can then tell at a glance which batteries are out.

A good plan, and one which will save space, is to write the number of the rental battery on the customer's claim check, and when repairs on his own battery are completed, to set his battery in the place provided on the rental rack for the rental which he is using. When he comes in for his battery, you can tell at a glance whether his battery is ready by looking at the place where the rental he is using is normally placed on the rental rack. If a battery is there you will know that it is his battery, and that it is ready for him.

(Omitted Fig. 185 showing "Rental Battery Stock Card" which simply showed date out, date in, days out and customer's name, address and phone. The following Chapter 13 - Business Methods which contained Figs. 186, 187 and 188 was omitted.).

You could, of course, look through the batteries on the "Ready Rack," but this would take more time, since the numbers of the batteries on this rack will always be different, and you would have to look through all the batteries on the "Ready Rack" before you would be able to tell whether any particular battery were ready. By putting a customer's battery in place of the rental he is using, you will have only one place to look at in order to know whether his battery is ready.

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Section II

Shop Equipment

Shop Methods

CHAPTER 11

SHOP EQUIPMENT

Any man who goes into the battery repair business will gradually learn by experience what equipment he finds necessary for his work. Some men will be able to do good work with comparatively little equipment, while others will require a somewhat elaborate layout.

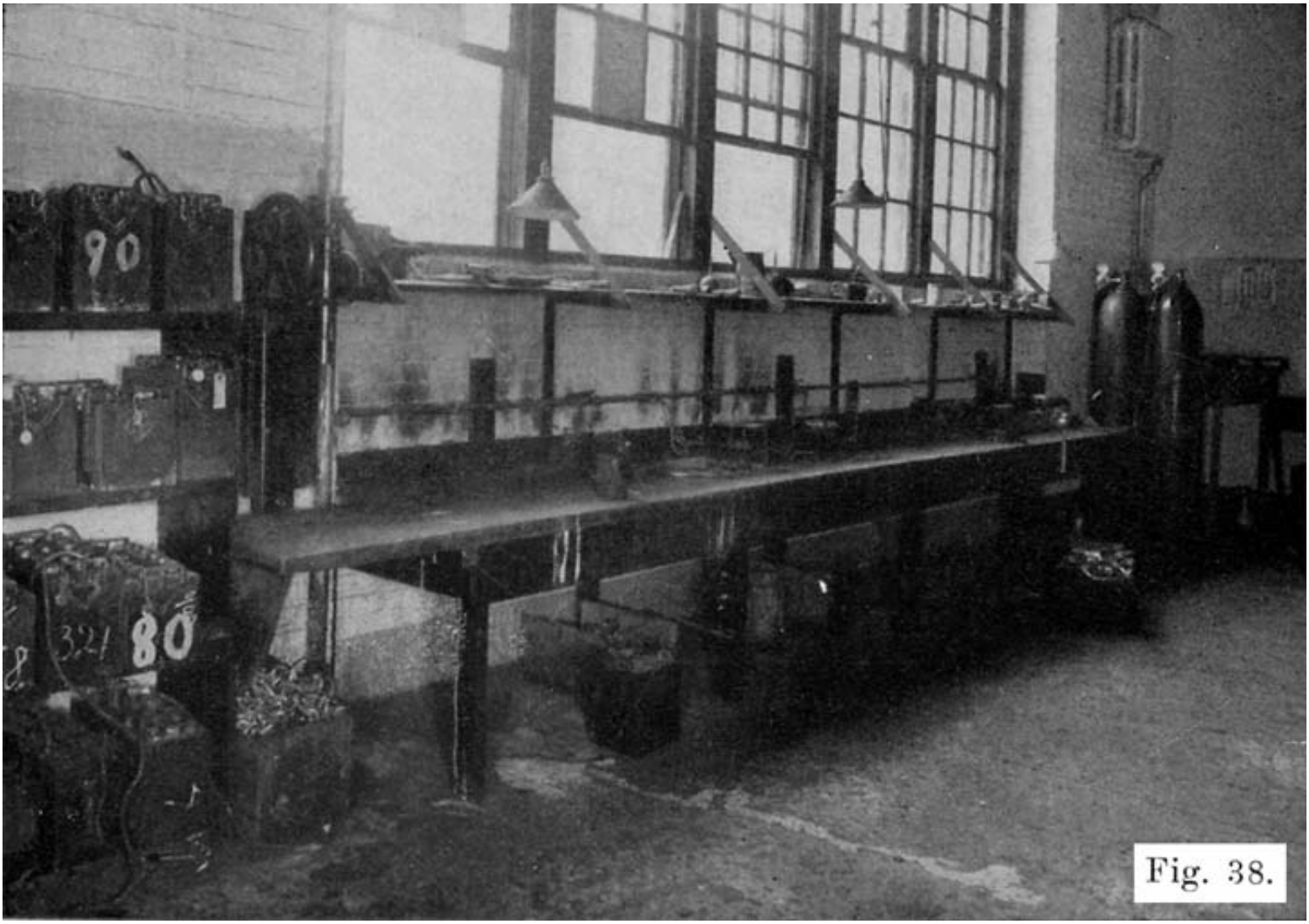

Fig. 38. Typical Work Room Showing Bench About 34 Inches High, Lead Burning Outfit, Hot Plates for Melting Sealing Compound and Hand Drill-Press for Drilling off Inter-Cell Connectors.

There are some things, however, which are necessary, and the following lists are given to help the repairman select his equipment. The man with limited capital will be unable to buy a complete equipment at the start, but he should add to his equipment as fast as his earnings will permit. The repairman may be able to "get-by" with crude equipment when his business is very small, but to make his business grow he must absolutely have good equipment.

The following list gives the various articles in the order of their importance. The first seven are absolutely necessary, even for the poorest beginner. The others are also essential, but may be bought as soon, as the money begins to come in. Some of the tools must also be bought before opening doors for business, such as the putty knife, screwdrivers, pliers, and so on. Each article, which requires explanation, is described in detail, beginning on page 100.

Equipment Which is Absolutely Necessary

1. Charging Outfit, such as a motor-generator set, rectifier, or charging resistance where direct current is available.

2. Charging Bench and Accessories. With the charging bench must go the following:

A. A syringe-hydrometer for measuring specific gravity of electrolyte, for drawing off electrolyte and for adding water to cells.
2. A special battery thermometer for measuring temperature of electrolyte.
3. A voltmeter to measure cell, battery, and cadmium voltages.
4. An ammeter to measure charging current.
5. A glass bottle for distilled water. Also one for electrolyte.
6. A number of eighteen inch lengths of No. 12 flexible wire fitted with lead coated test clips, for connecting batteries in series while on charge.

3. Work bench with vise.

4. Sink or wash tank and water supply.

5. Lead-burning outfit. (This should properly be called a lead welding outfit, since it is used to melt lead parts so that they will be welded together.)

6. For handling sealing compound, the following are necessary.

A. Stove.
2. Pot in which compound is melted.
3. An iron ladle for dipping up the melted compound.
4. One or two old coffee pots for pouring compound.

7. Shelving or racks for batteries waiting to be repaired, batteries which have been repaired, rental batteries, new batteries, battery boxes, battery jars, battery plates, etc.

8. Bins for battery parts, such as covers, inter-cell connectors, plate straps, terminals, handles, vent plugs, hold down bolts, separator hold-downs, and so on.

Equipment Needed In Opening Batteries

9. A battery steamer for softening sealing- compound and making covers limp, for softening compound around defective jars which are to be removed, for softening jars which are to be set in a battery box, and so on.

10. Putty knife to remove softened scaling compound.

11. One ratchet brace with set of wood bits or square shank drills of the following sizes: 3/8, 5/8, 3/4, 13/16, and 7/8 inch, for drilling off terminals and inter-cell connectors. A power drill press, or a portable electric drill will save time and labor in drilling off the terminals and connectors.

12. Center punch for marking terminals and connectors before drilling.

13. Ten inch screwdriver for prying off connectors and terminals which have been drilled. The screwdriver may, of course, be used on various other kinds of work also.

14. A ten-inch length of 3/4 inch angle iron to protect upper edge of case when prying off the connectors and terminals which have been drilled.

15. Two pair-, of standard combination pliers for lifting elements out of jars. A pair of six or eight inch gas pliers will also do for this work.

16. Machinist hammer. This is, of course, also used for other purposes.

17. Terminal tongs for removing taper lugs from terminals

18. Pair of long, fiat nosed pliers for pulling out separators and jars.

19. Open-end wrench for use in removing taper lugs from terminals.

Equipment for Lead Burning (Welding)

In addition to the lead burning- outfit, the following tools are needed:

20. A plate burning rack for setting up plates which are to be burned to a plate strap.

21. A plumber's or tinner's triangular scraper for cleaning surfaces which are to be welded together. A pocketknife will do in a pinch.

22. Steel wire brush for cleaning surfaces which are to be -welded together. This may also be used for general cleaning of lead parts.

23. Coarse files, vixen, round, and flat, for filing lead parts.

24. Set of burning, collars to be used in burning inter-cell connectors to posts.

25. Moulds for casting sticks of burning lead. A pot for melting lead is needed with the mould, and mould compound is also needed.

26. Set of post builders-moulds used for building up posts which have been drilled short in removing terminals and intercell connectors.

27. Pair of blue or smoked glasses to be worn when using lead burning outfit.

Equipment for General Work on Cell Connectors and Terminals

28. Set of moulds for casting inter-cell connectors, terminals, terminal screws, taper lugs, plate straps and posts, etc.

29. Set of reamers to ream holes in terminals and connectors.

30. Set of hollow reamers for reducing posts.

Equipment for Work on Cases

31. Cans of asphaltum paint for painting cases. May also be used for acid-proofing work benches, floor, shelves, charging bench, and so on.

32. Paint brushes, one wide and several narrow.

33. Battery turntable.

34. Several wood chisels of different sizes.

35. Small wood-plane for smoothing up top edges of case.

36. Large glazed earthenware jars of washing or baking soda solution for soaking cases to neutralize acid.

Tools and Equipment for General Work

37. One pair of large end cutting nippers for cutting connectors, posts, plate lugs, and so on.

38. One pair of 8 inch side cutting pliers.

39. One pair of 8 inch diagonal cutting pliers.

40. Several screwdrivers.

41. Adjustable hacksaw frame with set of coarse blades.

42. Gasoline torch.

43. Soldering iron, solder and flux.

44. Separator cutter.

45. Plate press for pressing bulged, spongy lead of negative plates flush with surface of grids.

46. Battery carrier.

47. Battery truck.

48. Lead lined box for storing separators. A large glazed earthenware jar may be used for this purpose, and is much cheaper, although it will not hold as many separators, on account of its round shape, as the lead lined box.

49. Several old stew pans for boiling acid soaked terminals, connectors, covers, etc., in a solution of washing soda.

50. Set of metal lettering stamps, for stamping POS and NEG on battery terminals, repairman's initials, date battery was repaired, and nature of repairs, on inter-cell connectors.

51. Cadmium test set.

52. High rate discharge testers.

53. Pair of rubber gloves to protect hands when handling acid.

54. Rubber apron to protect clothing from acid.

55. Pair of rubber sleeve protectors.

56. Rubbers to protect shoes, or pair of low rubber boots.

57. Tags for tagging repair and rental batteries, batteries in storage, etc.

58. Pot of paraffine which may be heated, and paper tags dipped after date has been written on tag in pencil. A 60-watt lamp hung in the can may be used for heating the compound. In this way the tag is protected from the action of acid, and the writing on the tag cannot be rubbed off or made illegible.

59. A number of wooden boxes, about 12 inches long, 8 inches wide, and 4 inches deep, in which are placed terminals, inter-cell connectors, covers, vent plugs, etc., of batteries being repaired.

60. Several large glazed earthenware jars are convenient for waste acid, old separators, and general junk, which would otherwise litter up the shop.

Stock

61. A supply of spare parts, such as cases, jars, covers, plate straps, inter-cell connectors, plates, vent plugs, etc., should be kept.

62. A supply of sealing compound is necessary.

63. A carboy of. pure acid, and carboys of 1.400 electrolyte ready for use should be on hand. A 16 oz. and a 32 or 64 oz. graduate are very useful in measuring out acid and water.

64. A ten gallon bottle of distilled water is necessary for use in making up electrolyte, for addition to cell electrolyte to bring electrolyte up to proper level, and so on. If you wish to distill water yourself, buy a water still.

65. A supply of pure vaseline is necessary for coating terminals to prevent corrosion.

Special Tools

Owing to special constructions used oil sonic of the standard makes of batteries, special tools are required, and such tools should be obtained if work is done oil these batteries. Some of these tools are as follows:

66. Special wrenches for turning sealing nuts on Exide batteries.

67. Two hollow reamers (post-freeing tools) for cutting lead seal around posts of Prest-O-Lite batteries. There are two sizes, large and small, see page 389.

68. Style "B" peening press for sealing posts of Prest-O-Lite batteries to covers, see page 390.

69. Pressure tongs for forcing lead collar oil posts of Vesta batteries, see page 415.

70. Special wrench for tightening sealing nut oil Titan batteries.

71. Special reamer for cutting sealing ring oil Universal batteries.

The list of special tools is not intended to be complete, and the repairman will probably find other special tools necessary from time to time. In any case, it is best to buy from the battery manufacturer such special tools as are necessary for the batteries that come in for repairs. It is sometimes possible to get along without the special tools, but time and labor will be saved by using them.

DESCRIPTIONS OF TOOLS AND EQUIPMENT NAMED IN FOREGOING LIST

Charging Equipment

A battery is charged by sending a direct current through it, this "charging" current entering the battery at, the positive terminal and passing out at the negative terminal. To send this current through the battery, a voltage of about 7.5 volts is applied to each battery.

Two things are therefore necessary in charging a battery:,

1. We must have a source of direct current.

2. The voltage impressed across each battery must be, about 2.5 per cell. The charging voltage across each six volt battery must therefore be 7.5, and for each twelve volt battery the charging voltage must be about 15 volts.

With the battery on the car, there are two general methods of charging, i. e., constant potential (voltage) and constant current. Generators having a constant voltage regulator have a constant voltage of about 7.5, the charging current depending upon the condition of the battery. A discharged battery thus receives a high charging current, this current gradually decreasing, or "tapering" as the battery becomes more fully charged. This system has the desirable characteristic that a discharged battery receives a heavy charging current, and a fully charged battery receives a small charging current. The time of charging is thereby decreased.

With a constant-current charging system, the generator current output is maintained at a certain value, regardless of the state of charge of the battery. The disadvantage of this system is that a fully charged battery is charged at as high a rate and in most cases at a higher rate than a discharged battery.

In the shop, either the constant-potential, or the constant-current system of charging may be used. Up to the present time, the constant current system has been used in the majority of shops. The equipment for constant current charging uses a lamp bank or rheostat to regulate the charging current where direct current is available, and a rectifier or motor-generator set where only alternating current is available. Recently, the Hobart Brothers Company of Troy, Ohio, has put on the market a constant potential motor-generator set which gives the same desirable "tapering" charge as does the constant voltage generator on the car. This set will be described later.

Where a 110-volt direct current supply is available, fifteen 6-volt batteries may be connected in series across the line without the use of any rheostat or lamp bank, only an ammeter being required in the circuit to indicate the charging current. The charging rate may be varied by cutting out some of the batteries, or connecting more batteries in the circuit. This method is feasible only where many batteries are charged, since not less than fifteen 6-volt batteries may be charged at one time.

Constant Current Charging

Using Lamp Banks, or Rheostats

Figures 39 and 40 show the wiring for a "bank" of twenty 100-watt lamps for battery charging from a 110 volt line. Figure 39 shows the wiring to be used when the positive side of the line is grounded, while Figure 40 shows the wiring to be used when the negative side of the line is grounded. In either case, the "live" wire connects to the lamp bank. The purpose of this is to eliminate the possibility of a short-circuit if any part of the charging line beyond the lamp bank is accidentally grounded.

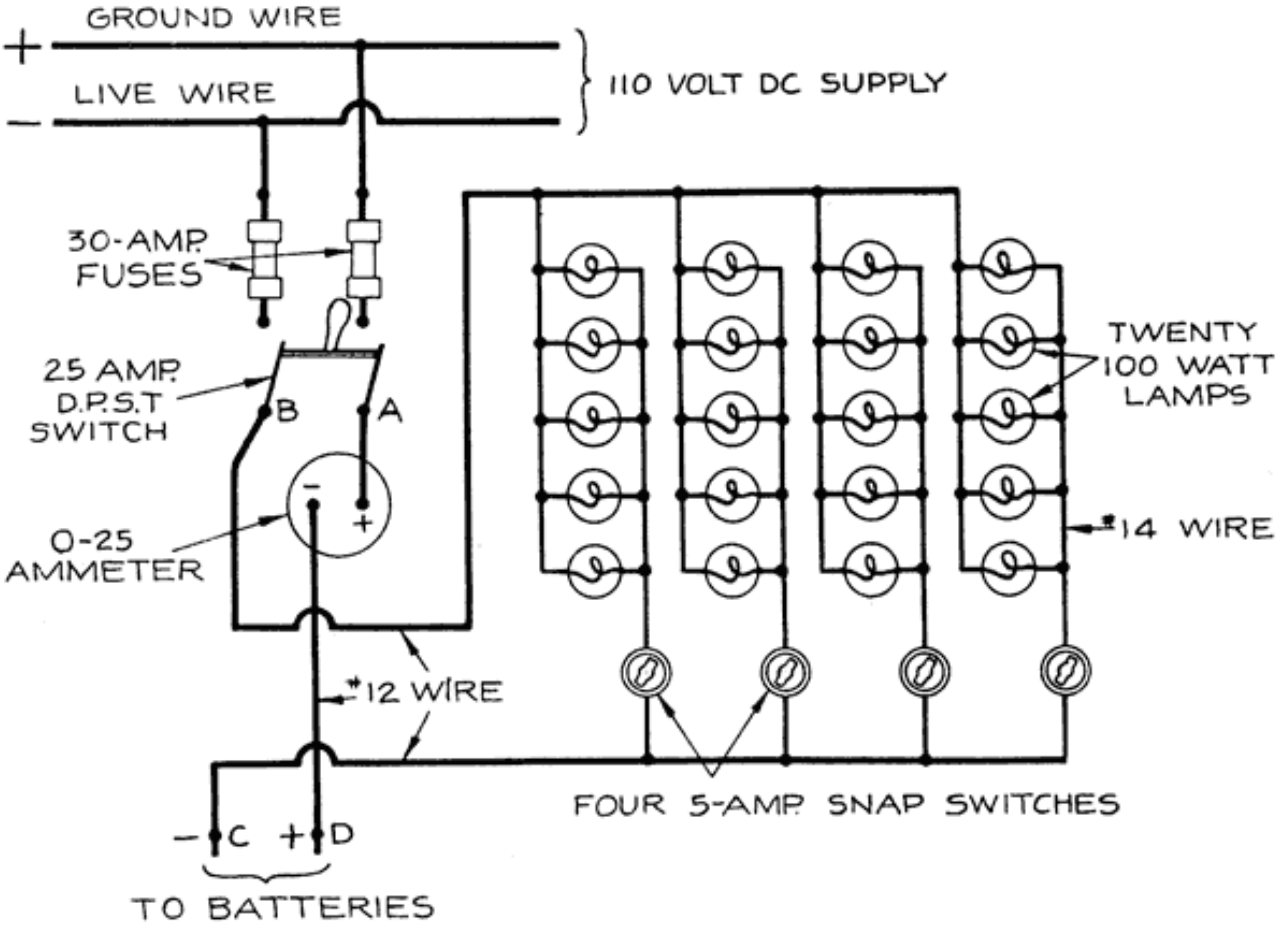

Fig. 39. Lamp Bank for Charging from a 110 Volts, D. C. Line (Positive Grounded)

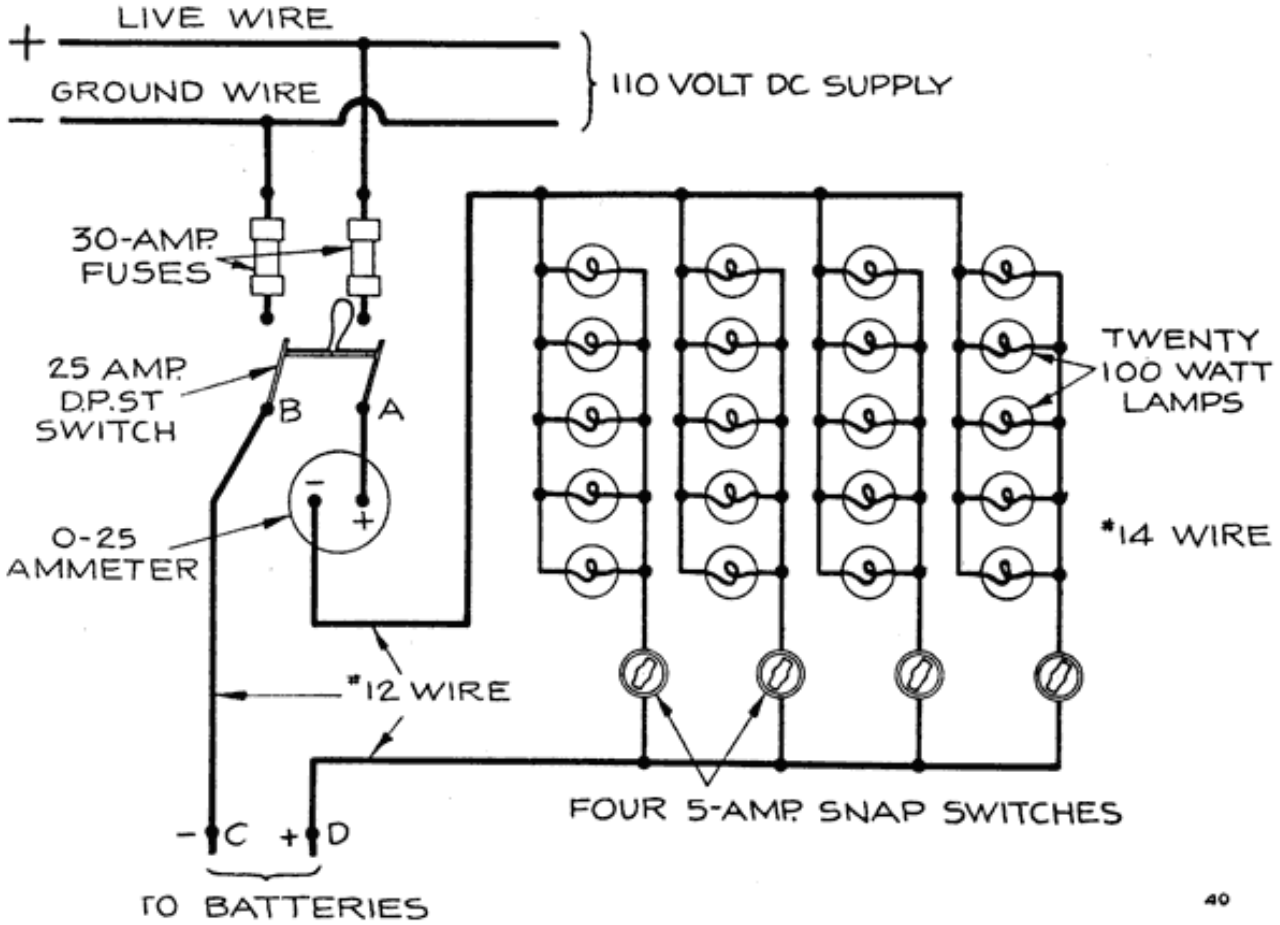

Fig. 40. Lamp Bank for Charging from a 110 Volts, D. C. Line (Negative Grounded)

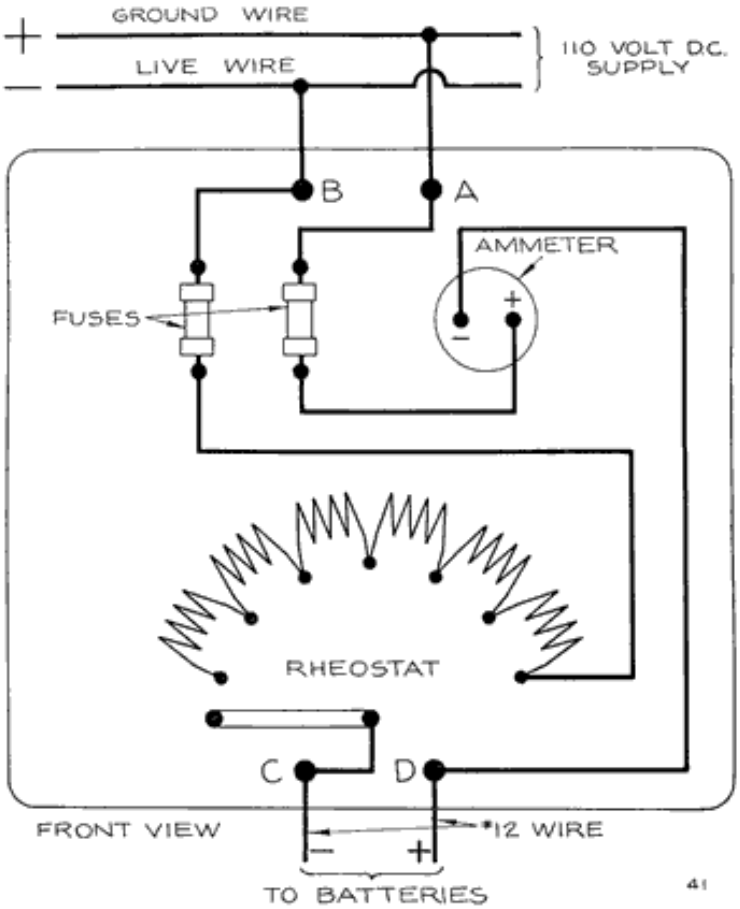

Fig. 41. Rheostat for Charging from a 110 Volts, D. C. Line (Positive Grounded)

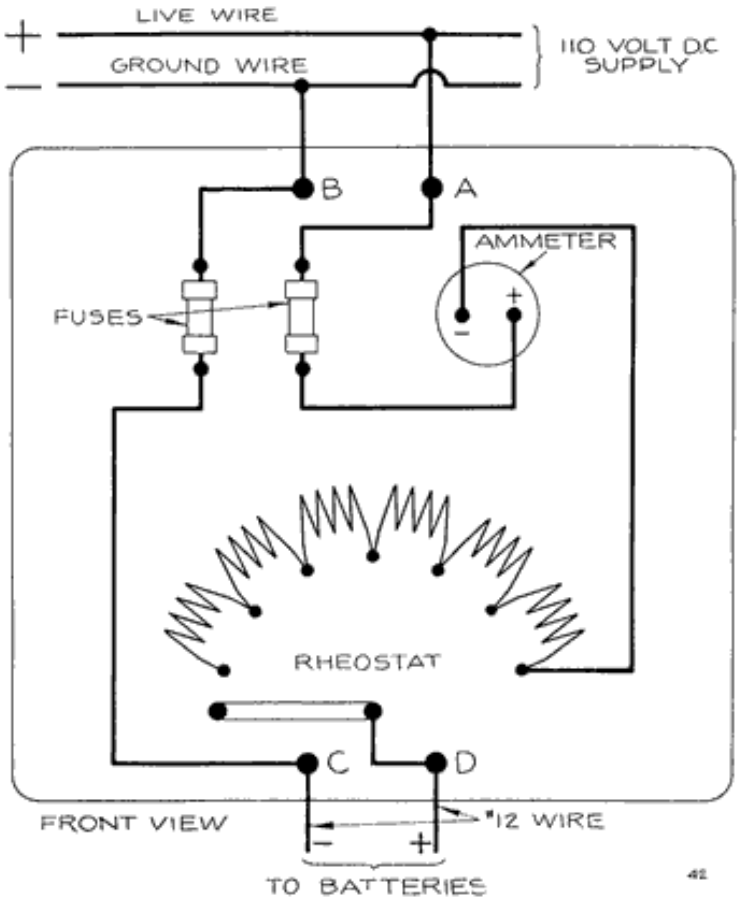

Fig. 42. Rheostat for Charging from a 110 Volts, D. C. Line (Negative Grounded)

Figures 41 and 42 show the wiring of two charging rheostats which may be used instead of the lamp banks shown in Figures 39 and 40. In these two rheostats the live wire is connected to the rheostat resistances in order to prevent short-circuits by grounding any part of the circuit beyond the rheostats. These rheostats may be bought ready for use, and should not be "homemade." The wiring as shown in Figures 41 and 42 is probably not the same as will be found on a rheostat which may be bought, but when installing a rheostat, the wiring should be examined to make sure that the "live" wire is connected to the rheostat resistance and does not connect directly to the charging circuit. If necessary, change the wiring to agree with Figures 41 and 42.

Figures 43 and 44 show the wiring of the charging circuits. In Figure 43 each battery has a double pole, double throw knife switch. This is probably the better layout, since any battery may be connected in the circuit by throwing down the knife switch, and any battery may be cut out by throwing the switch up. With this wiring layout, any number of batteries from one to ten may be cut-in by means of the switches. Thus, to charge five batteries, switches 1 to 5 are thrown down, and switches 5 to 10 are thrown up, thereby short-circuiting them.

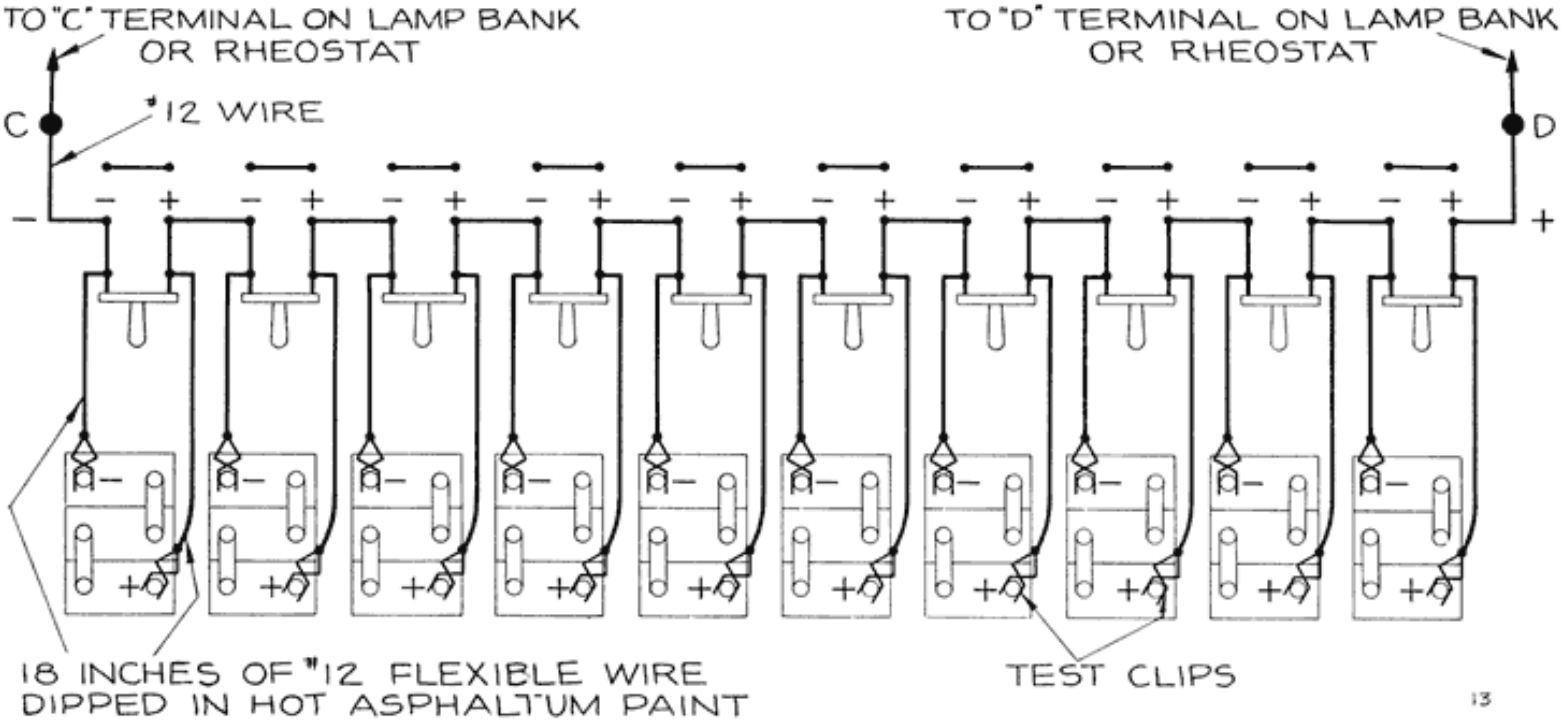

Fig. 43. Wiring for a Charging Circuit, Using a D. P. D. T. Switch for Each Battery

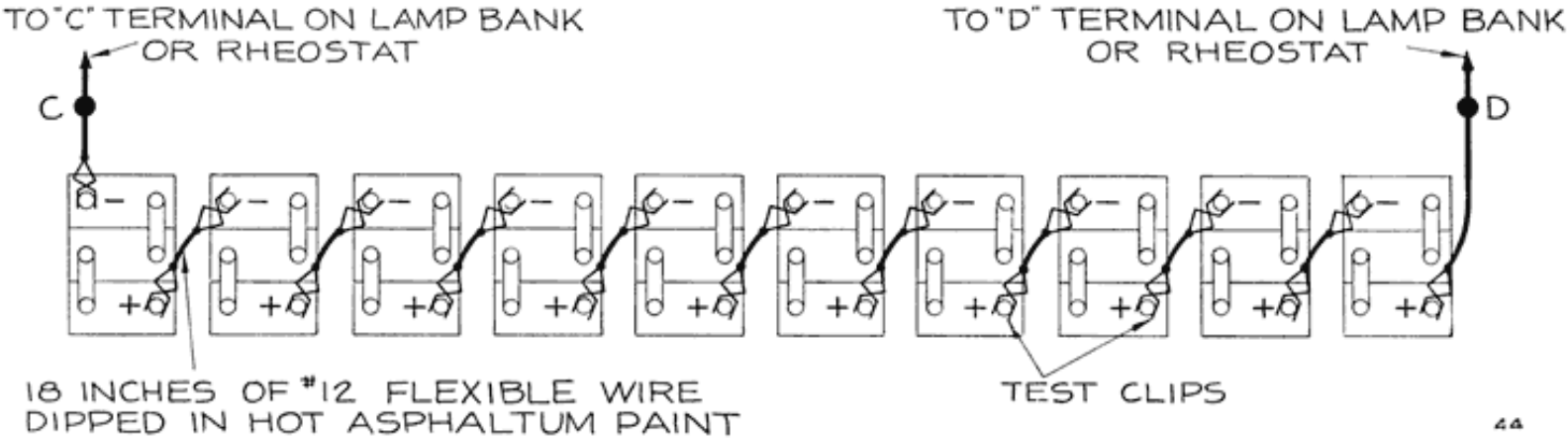

Fig. 44. Wiring for a Charging Circuit, Using Jumpers to Connect Batteries in Series

Figure 44 shows a ten-battery charging circuit. on which the batteries are connected in series by means of jumpers fitted with lead coated test clips, as shown. This layout is not as convenient as that shown in Figure 43, but is less expensive.

Using Motor-Generator Sets

Where no direct current supply is available, a motor-generator or a rectifier must be installed. The motor-generator is more expensive than a rectifier, but is preferred by some service stations because it is extremely flexible as to voltage and current, is easily operated, is free from complications, and has no delicate parts to cause trouble.

Motor-Generator sets are made by a number of manufacturers. Accompanying these sets are complete instructions for installation and operation, and we will not attempt to duplicate such instructions in this book. Rules to assist in selecting the equipment will, however, be given.

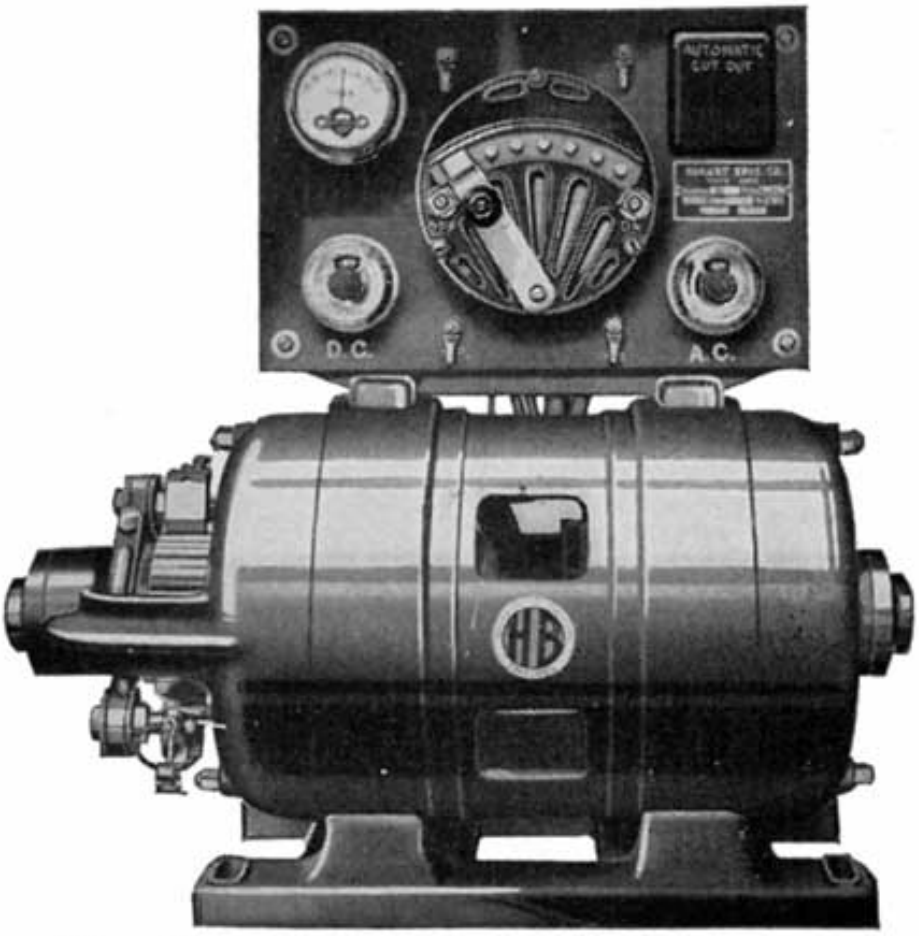

Fig. 45. Ten Battery Motor-Generator Charging Set

Except in very large service stations, a 40 volt generator is preferable. It requires approximately 2.5 volts per cell to overcome the voltage of a battery in order to charge it, and hence the 40 volt generator has a voltage sufficient to charge 15 cells in series on one charging line. Five 6 volt batteries may therefore be charged at one time on each line. With a charging rate of 10 amperes, each charging line will require 10 times 40, or 400 watts. The size of the generator will depend on the number of charging lines desired. With 10 amperes charging current per line, the capacity of the generator required will be equal to 400 watts multiplied by the number of charging lines. One charging line will need a 400 watt outfit. For two charging lines 800 watts are required. Each charging line is generally provided with a separate rheostat so that its charging rate may be adjusted to any desired value. This is an important feature, as it is wrong to charge all batteries at the same rate, and with separate rheostats the current on each line may be adjusted to the correct value for the batteries connected to that line. Any number of batteries up to the maximum may be charged on each line.

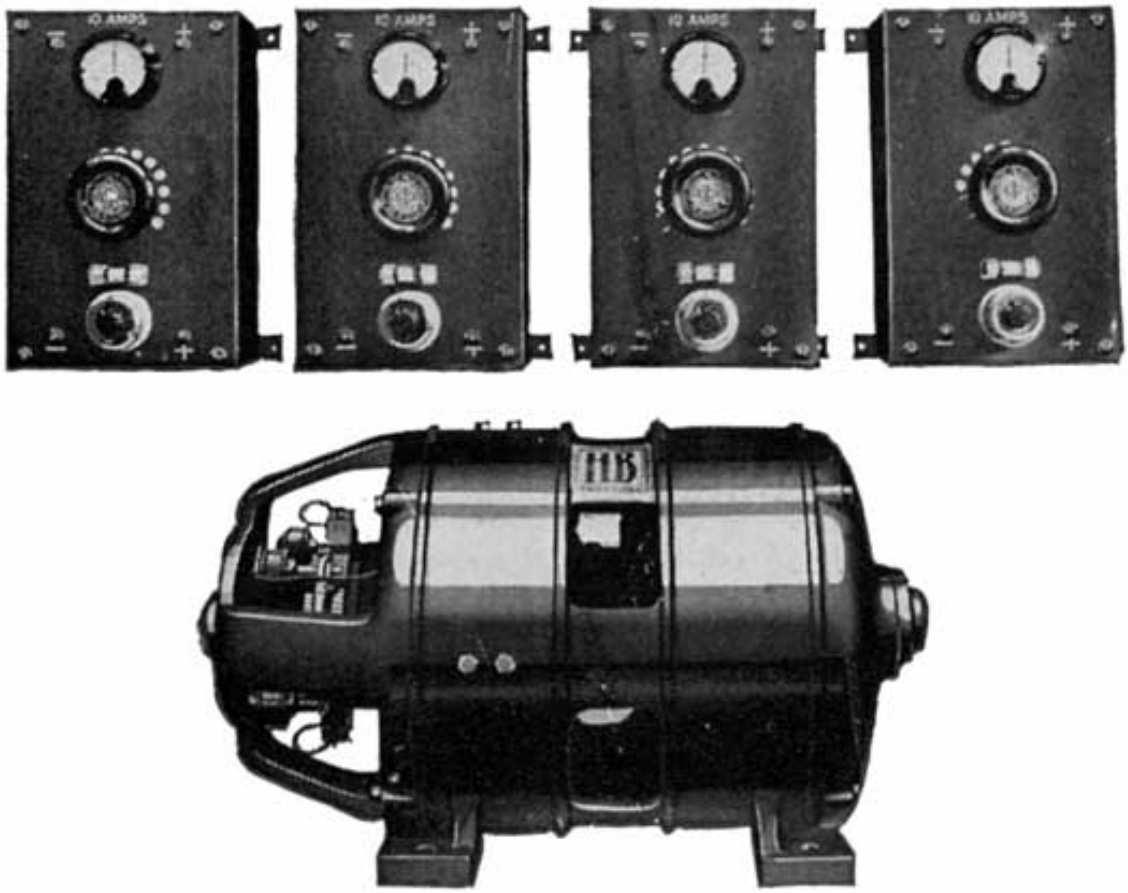

Fig. 46. Thirty-two Battery Motor-Generator Charging Set

In choosing a charging outfit, it is important not to get one which is too large, as the outfit will operate at a loss when running under a minimum load. It is equally important not to get one which is too small, as it will not be able to take care of the batteries fast enough, and there will be a "waiting list" of batteries which cannot be charged until others are taken off charge. This will prevent the giving of good service. Buy an outfit that will care for your needs in the future, and also operate economically at the present time. Most men going into the battery business make the mistake of underestimating their needs, and getting equipment which must soon be discarded because of lack of capacity.

The manufacturers each make a number of sizes, and the one which will best fill the requirements should be chosen. In selecting an outfit the manufacturer's distributor or dealer should be consulted in deciding what size outfit to obtain. The particular outfit will depend on the voltage and frequency of the alternating current power circuits, the maximum charging current desired (10 amperes per line is ample), and the greatest number of batteries to be charged at one time.

For the beginner, a 500 watt ten battery outfit, as shown in Fig. 45, is suitable. For the medium sized garage that specializes in battery charging, or for the small battery service station, a one kilowatt outfit is most satisfactory. Two charging panels are generally furnished with this outfit, and two charging lines may thus be used. This is an important feature, as one line may be used in starting a charge at 10 amperes, and the other for charging the batteries, that have begun to gas, at a reduced rate. Fig. 46 shows a 2 K. W. four-circuit, 32 battery motor-generator set. Each circuit is provided with a separate rheostat and ammeter. The two terminals near the top of each rheostat are connected to one charging circuit. The two terminals near the lower end of each rheostat are connected to the generator.

The 2 kilowatt set is suitable for a city garage, or a battery service station in a medium sized town. A beginner should not purchase this large set, unless the set can be operated at at least one-fourth capacity continuously. As a service

station grows, a 5 kilowatt set may be needed. The 1, 2 and 5 kilowatt sets should not be used on anything but city power lines. Single phase, or lighting lines are not satisfactory for handling these sets.

A few suggestions on Motor-Generator Sets

1. Installation. Set the motor-generator on as firm a foundation as possible. A good plan is to bolt it to a heavy bench, in which position it is easily inspected and adjusted, and is also less likely to be hit by acid spray, water, etc.

Set the motor-generator at some distance from the batteries so that acid spray and fumes will not reach it. Sulphuric acid will attack any metal and if you are not careful, your motor-generator may be damaged seriously. The best plan is to have the motor generator set outside of the charging room, so as to have a wall or partition between the motor-generator and the batteries. The charging panels may be placed as near the batteries as necessary for convenience, but should not be mounted above the batteries. Figure 47 shows a convenient layout of motor-generator, charging panels, and charging benches. Note that the junipers used in connecting the batteries together are run through the upper holes of the wire porcelain insulating cleats, the lower hole of each insulator supporting the wire from the charging panel which runs to the end of the bench.

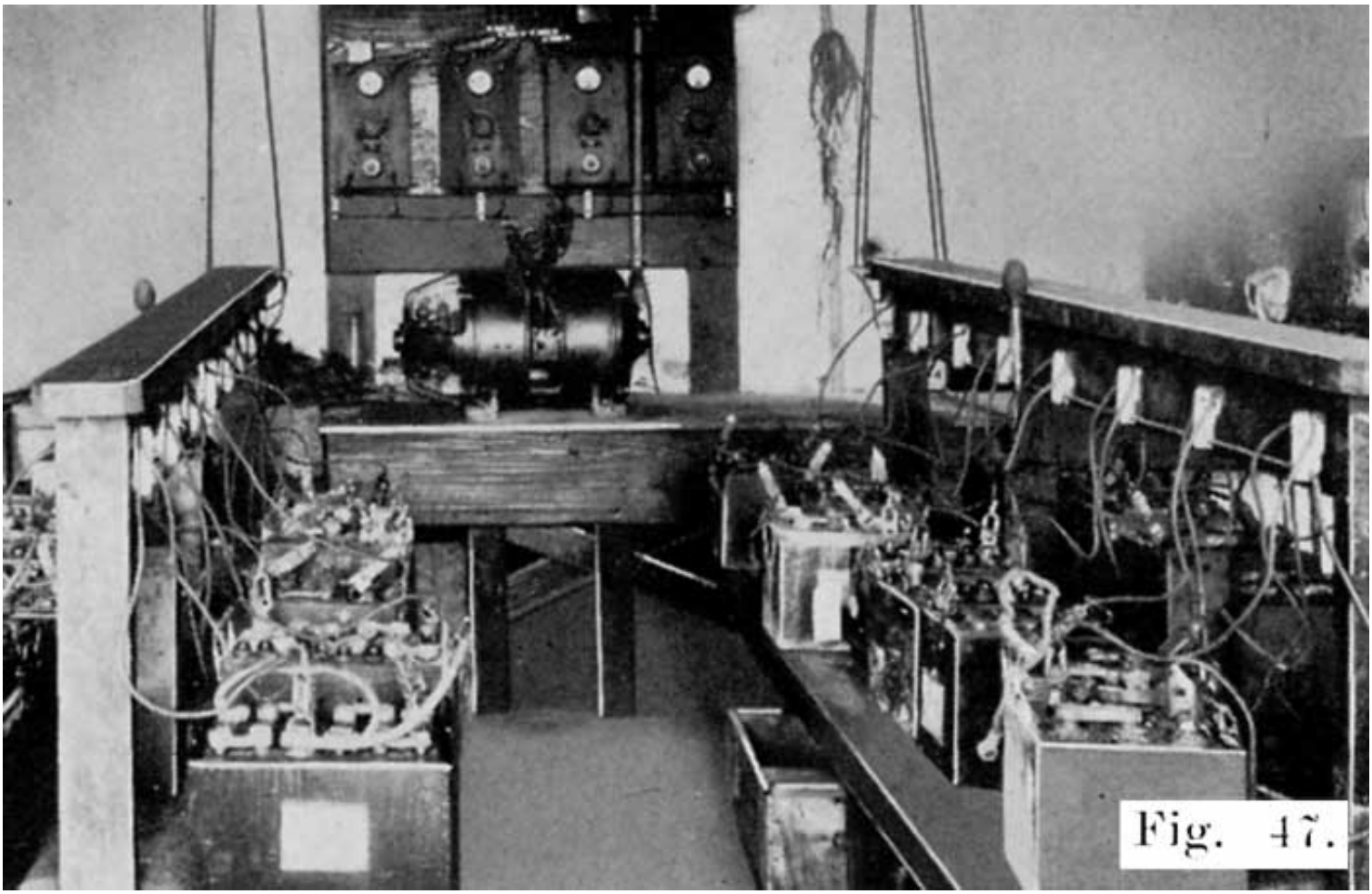

Fig. 47. Convenient Arrangement of Motor-Generator, Charging Panels, and Charging Benches

Instructions for the wiring connections to the power lines generally come with each outfit, and they should be followed carefully. Fuses in both the motor and generator circuits are especially important, as they protect the machines from damage due to overloads, grounds, or short-circuits. The generator must be driven in the proper direction or the generator will not build up. The rotation of a three-phase motor may be reversed by reversing, and Charging Benches any two of the cables. To reverse a two-phase motor, reverse the cables of either phase. Before putting a motor-generator set into operation, be sure to check all connections to make sure that everything checks

with the instructions furnished by the manufacturer.

Operating the Charging Circuits

A generator operates most efficiently when delivering its rated output. Therefore, keep the generator as fully loaded as possible at all times. When you do not have enough batteries to run the generator at full load, run each charging circuit at full load, and use as few circuits as possible. This will reduce your power bill, since there is a loss of power in the rheostat of each charging circuit, this loss being the greatest when only one battery is on the circuit, and a minimum when the circuit is fully loaded.

With several charging circuits, it is also possible to put batteries which are in the same condition on one circuit and adjust the charging rate to the most suitable value. Thus, badly sulphated batteries, which must be charged at a low rate, may be put on the same circuit, while batteries which have had only a normal discharge may be put oil another circuit and charged at a higher rate. As each battery becomes almost fully charged, it may be removed from the circuit and put on another circuit and the charge completed at the finishing rate. This is a good practice, since some batteries will begin to gas sooner than others, and if the charging rate is not reduced, the batteries which have begun to gas will have active material blown out by the continued gassing. A careful study of such points will lead to a considerable saving in power costs.

Care of Motor-Generator Set

A. Machine will not build up or generate. This may be due to:

1. Machine rotating in wrong direction.
2. Brushes not making good contact. Clean commutator with fine sandpaper"
3. Wrong connections of field rheostat-check connections with diagram.
4. Open circuit in field rheostat. See if machine will build up with field rheostat cut out.

B. Excessive heating of the commutator. This may be due to:

1. Overload-Check your load and compare it with nameplate reading. Add the total amperes on all the panels and see that it does not exceed the ampere reading on the nameplate.
2. Wrong setting of the brush rocker arm. This causes sparking, which soon will cause excessive heating.
3. Rough commutator. This will cause the brushes to chatter, be noisy and spark. Caused many times by allowing copper to accumulate on the bottom of the brushes.
4. Insufficient pressure on brushes, resulting in sparking. This may be due to brushes wearing down to the point where the brush lead screw rests on the brush holder.
5. Dirt and grease accumulating between the brush and brush holder causing brush to stick;brush must always move freely in the holder.
6. Brush holder may have come loose, causing it to slip back, relieving brush press-Lire.
7. Brush spring may have become loosened, releasing the tension.
8. Watch commutator carefully and keep it in the best of condition. There will not be excessive heating without sparking. Excessive sparking may raise the temperature so high as to cause throwing of solder. You can avoid all this by taking proper care of the commutator.

C. Ammeters on Panels Read Reverse: This is caused by improperly connecting up batteries, which has reversed the polarity of the generator. This generally does no harm, since in most cases the batteries will automatically reverse the polarity of the generator. Generally the condition may be remedied by stopping the machine, reversing the batteries and starting the machine again. If this is unsuccessful raise the brushes on the machine. Connect five or six batteries in series in the correct way to one panel, while the machine is not in operation. Turn on the panel switch. When the machine is started, it will then build up in the right direction. If it does not do so, repeat the above, using a larger number of batteries.

D. Machine Refuses to Start. If there is a humming noise when you try to start the motor, and the outfit does not start, one of the fuses needs replacing. The outfit will hum only on two or three phase current. Never leave the power turned on with any of the fuses out.

Constant-Potential Charging

In the Constant-Potential system of battery charging, the charging voltage is adjusted to about 7.5, and is held constant throughout the charge. With this system a discharged battery receives a heavy current when it is put on charge. This current gradually decreases as the battery charges, due to the increasing battery voltage, which opposes, or "bucks" the charging voltage, and reduces the voltage which is effective in sending current through the batteries. Such a charge is called "tapering" charge because the charging current gradually decreases, or "tapers" off.

The principle of a "tapering" charge is, of course, that a discharged battery may safely be charged at a higher rate than one which is only partly discharged, because there is more lead sulphate in the discharged battery which the action of the current changes back to active material. As the battery charges, the amount of lead sulphate decreases and since there is less sulphate for the current to act upon, the charging rate should be reduced gradually. If this is not done, excessive gassing will occur, resulting in active material being blown from the grids.

A battery which has been badly sulphated, is of course, in a discharged condition, but is not, of course, able to absorb a heavy charging rate, and in handling such batteries on a constant potential system, care must be taken that the charging rate is low. Another precaution to be observed in all constant potential charging is to watch the temperature of batteries while they are drawing a heavy charging current. A battery which gasses soon after it is put oil charge, and while still in a discharged condition, should be taken off the line, or the charging line voltage reduced. With constant potential charging, as with constant current charging, the two things to watch are temperature and gassing. **Any charging rate which does not cause an excessive temperature or early gassing is safe**, and conversely any charging rate which causes an excessive battery temperature, or causes gassing while the battery is still less than three-fourths charged, is too high.

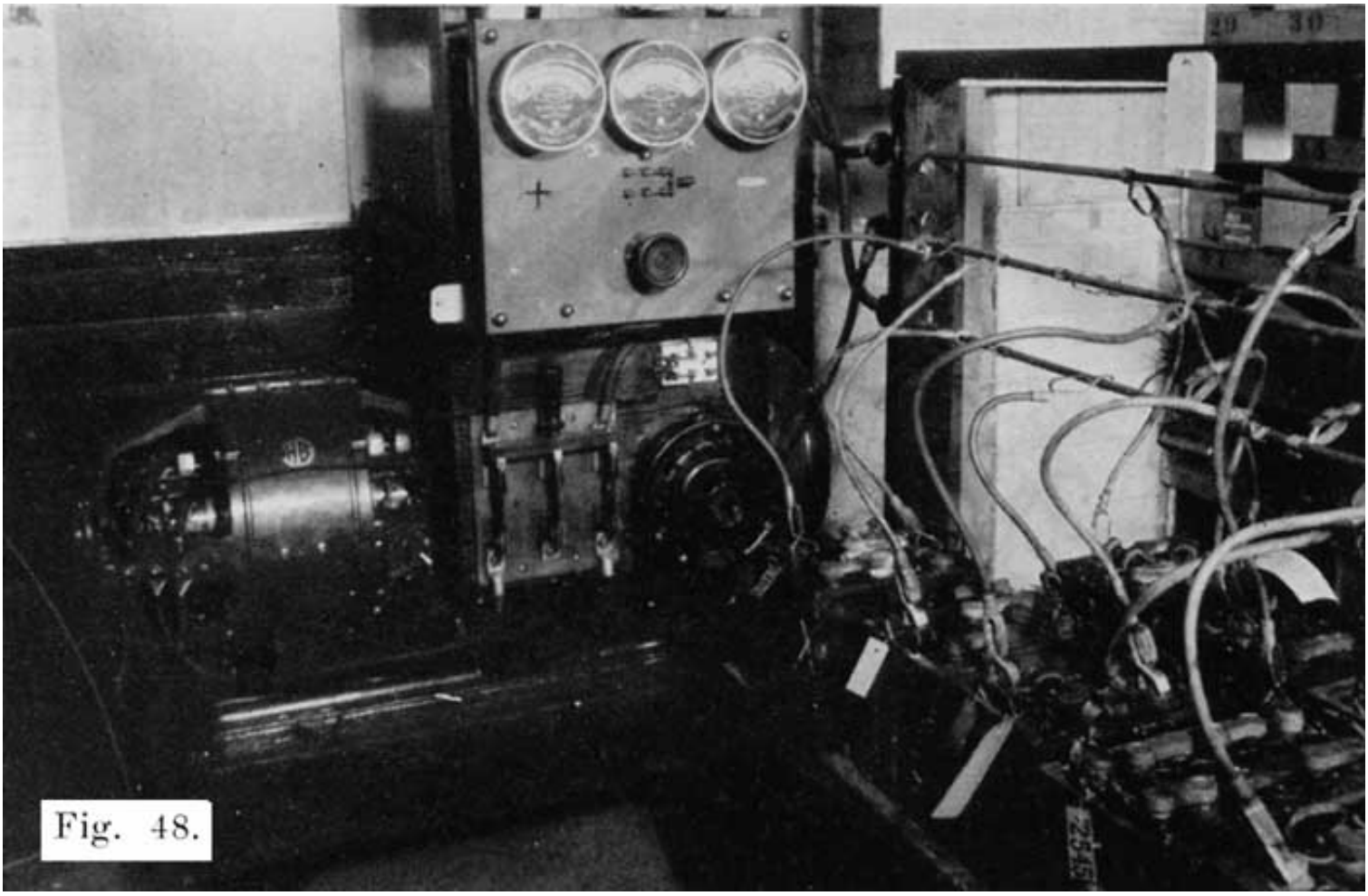

Fig. 48. Hobart Bros. Co. 3 K. W. Constant Potential Motor-Generator Charging Set

The Constant-Potential Charging Set manufactured by the Hobart Bros. Co., consists of a 3 K.W. generator rated at 7.5 volts, and 400 amperes. This generator is direct connected to a 5 H.P. motor, both machines being mounted oil the same base plate. Figure 48 shows this outfit. Note that for the charging line there are three bus-bars to which the batteries are connected. Twelve volt batteries are connected across the two outside bus-bars, while six volt batteries are connected between the center bus-bar and one of the outer ones.

The Tungar Rectifier

All rectifiers using ail are operate oil the principle that current call pass through them in one direction only, due to the great resistance offered to the flow of current in the opposite direction. It is, of course, not necessary to use mercury vapor for the are. Some rectifiers operate on another principle. Examples of such rectifiers are the Tungar made by the General Electric Co., and the Reetigon, made by the Westinghouse Electric and Manufacturing Co. The Tungar Rectifier is used extensively and will therefore be described in detail.

The essential parts of a Tungar Rectifier are: A bulb, transformer, reactance, and the enclosing case and equipment.

The bulb is the most important of these parts, since it does the rectifying. It is a sort of check valve that permits current to flow through the charging circuit in one direction only. In appearance the bulb, see Figure 49, resembles somewhat an ordinary incandescent bulb. In the bulb is a short tungsten filament wound in the form of a tight spiral, and supported between two lead-in wires. Close to the filament is a graphite disk which serves as one of the electrodes. Figure 50 shows the operating principle of the Tungar. "B" is the bulb, containing the filament "F" and the graphite electrode "A." To serve as a rectifier the bulb filament "F" must be heated, this being done by the transformer "T." The battery is connected as shown, the positive terminal directly to one side- of the alternating current supply, and the negative terminal to the graphite electrode "A."

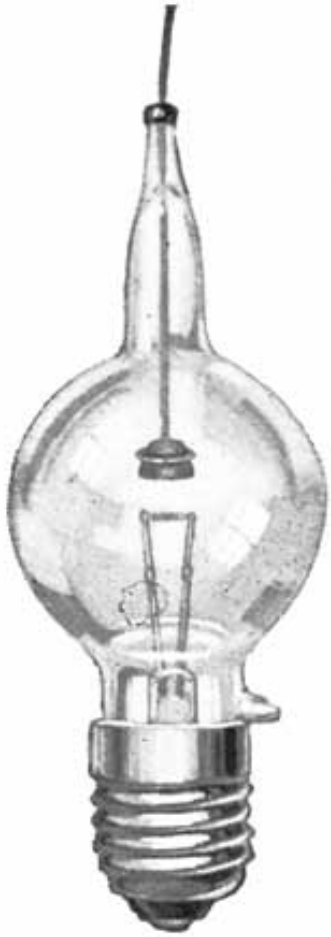

Fig. 49. Tungar Rectifier Bulb

To understand the action which takes place, assume an instant when line wire C is positive. The current then flows through the battery, through the rheostat and to the graphite electrode. The current then flows through the are to the filament and to the negative side of the line, as indicated by the arrows.

During the next half cycle -when line wire D is positive, and C is negative, current tends to flow through the bulb from the filament to the graphite, but as the resistance offered to the flow of current in this direction is very high, no current will flow through the bulb and consequently none through the battery.

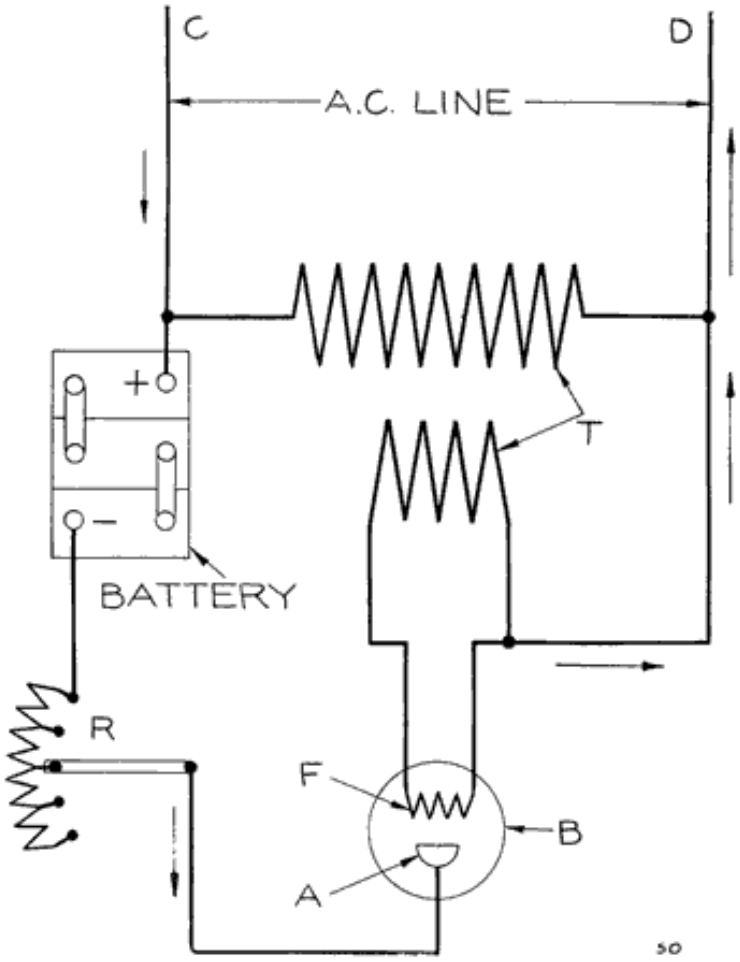

Fig. 50. Illustrating the Principle of the Tungar "Half-Wave" Rectifier

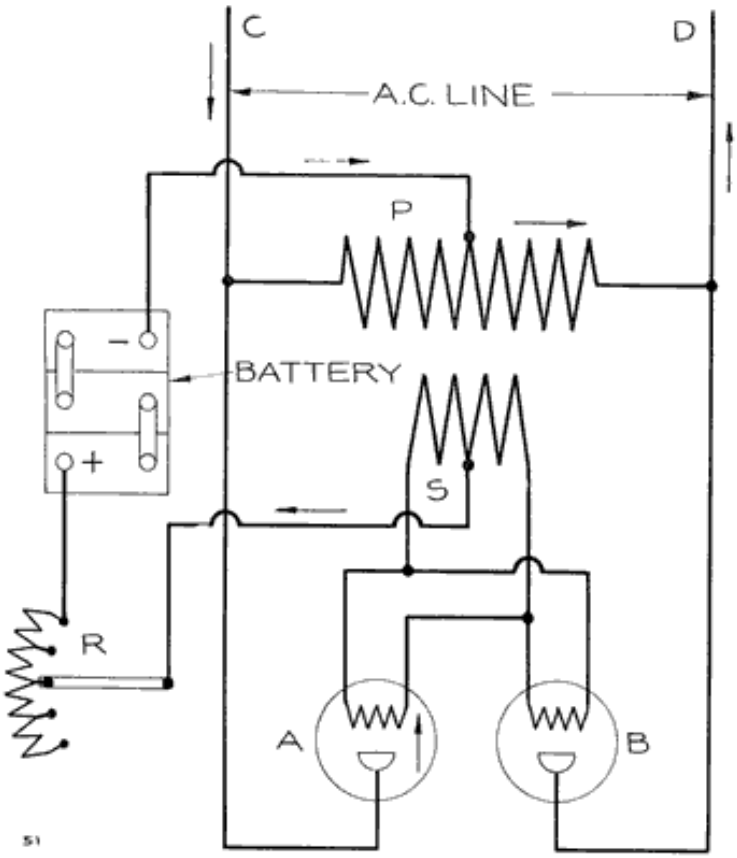

Fig. 51. Illustrating Principle of Tungar "Full-Wave" Rectifier

The rectifier shown in Figure 50 is a "half-wave" rectifier. That is, only one-half of each alternating current wave passes through it to the battery. If two bulbs are used, as shown ill Figure 51, each half of the alternating current wave is used in charging the battery. To trace the current through this rectifier assume an instant when line wire C is positive. Current will then flow to the graphite electrode of tube A, through the secondary winding of the transformer S to the center tap, through the rheostat, to the positive battery terminal, through the battery to the center of the primary transformer winding P, and through part of the primary winding to D. When D is positive, current will flow through tube B from the graphite electrode to the filament, to the center of transformer winding S, through the rheostat and battery to the center of transformer winding P, and through part of this winding to line wire C. In the actual rectifiers the rheostat shown in Figures 50 and 51 are not used, regulation being obtained entirely by means of other windings.

From the foregoing description it will be seen that if the alternating current supply should fail, the batteries cannot discharge into the line, because in order to do so, they would have to heat up the filament and send current through the bulb from the filament to the graphite electrode. This the batteries cannot do, because the connections are such that the battery cannot send a current through the complete filament circuit and because, even if the batteries could heat the filament they could not send a current from the filament to the graphite, since current cannot flow in this direction.

As soon as the alternating line is made alive again, the batteries will automatically start charging again. For these reasons night charging with the Tungar is entirely feasible, and no attendant is required to watch the batteries during the night. The Tungar Rectifier is made in the following sizes:

A. Two Ampere Rectifier

Catalogue No. 195529

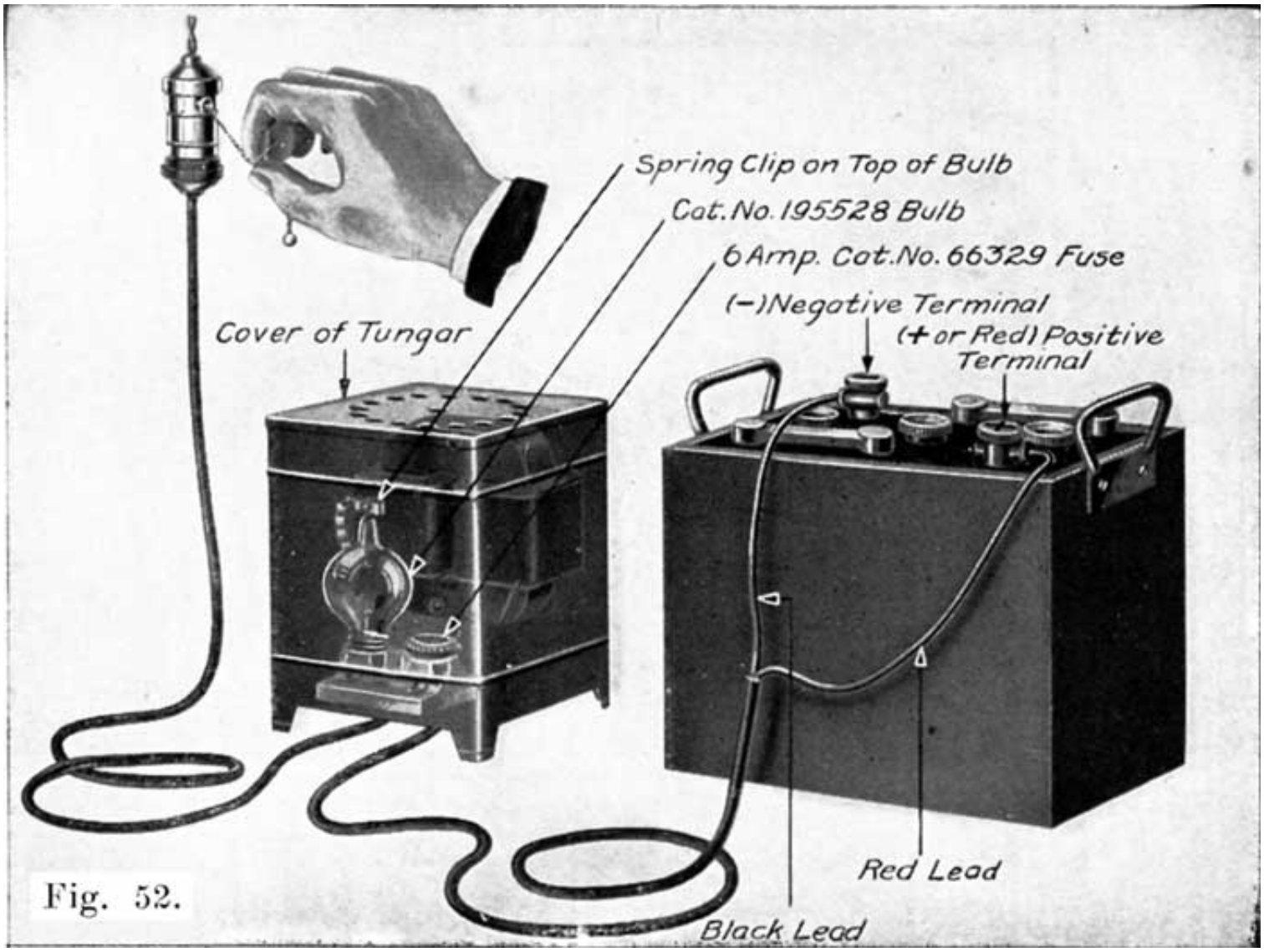

Fig. 52. The Two Ampere Tungar Rectifier

This is the smallest Tungar made. Figure 52 shows the complete rectifier. Figure 53 shows the internal wiring. This Tungar will charge a 6 volt battery at two amperes, a 12 volt battery at one ampere and eight cells at 0.75 ampere. It is suitable for charging a lighting battery, or for a quick charge of a motorcycle or ignition battery. It will also give a fairly good charge over night to a starting battery. Another use for this rectifier is to connect it to a run-down starting battery to prevent it from freezing over night. Of course, a battery should not be allowed to run down during cold weather, but if by chance a battery does run down, this Tungar will prevent it from freezing

during the night.

The two ampere Tungar is, of course, more suitable for the car owner than for a garage or service station. It is also very suitable for charging one Radio "A" battery. The two ampere Tungar is normally made for operation on a sixty cycle circuit, at 115 volts. It may also be obtained for operation on 25-30, 40-50, and 125-133 cycles alternating supply line. See table on Page 130.

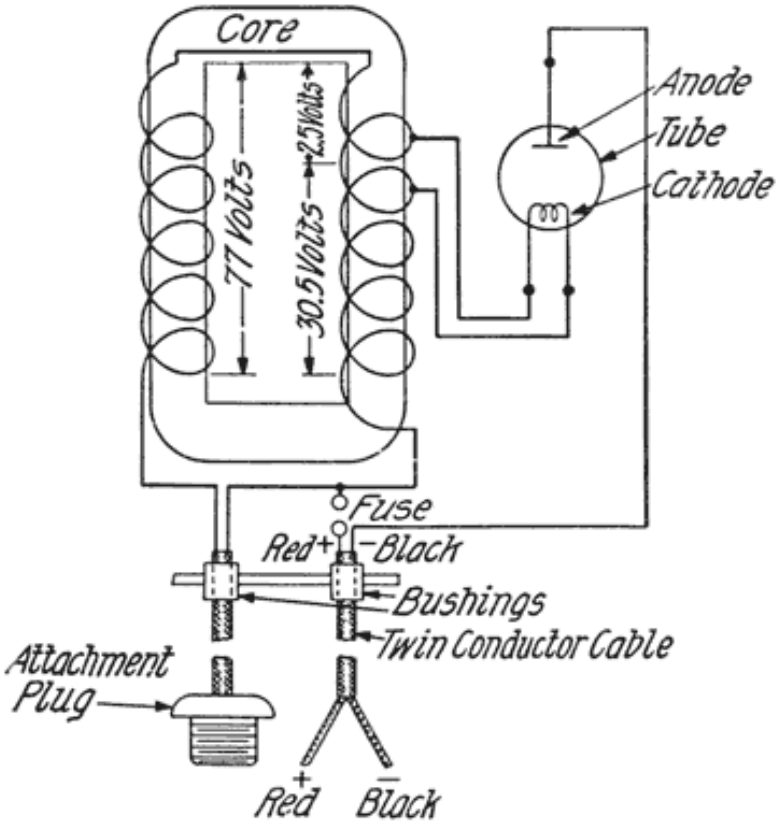

Fig. 53. Internal Wiring of the Two Ampere Tungar Rectifier

B. The One Battery Rectifier

Catalogue No. 219865

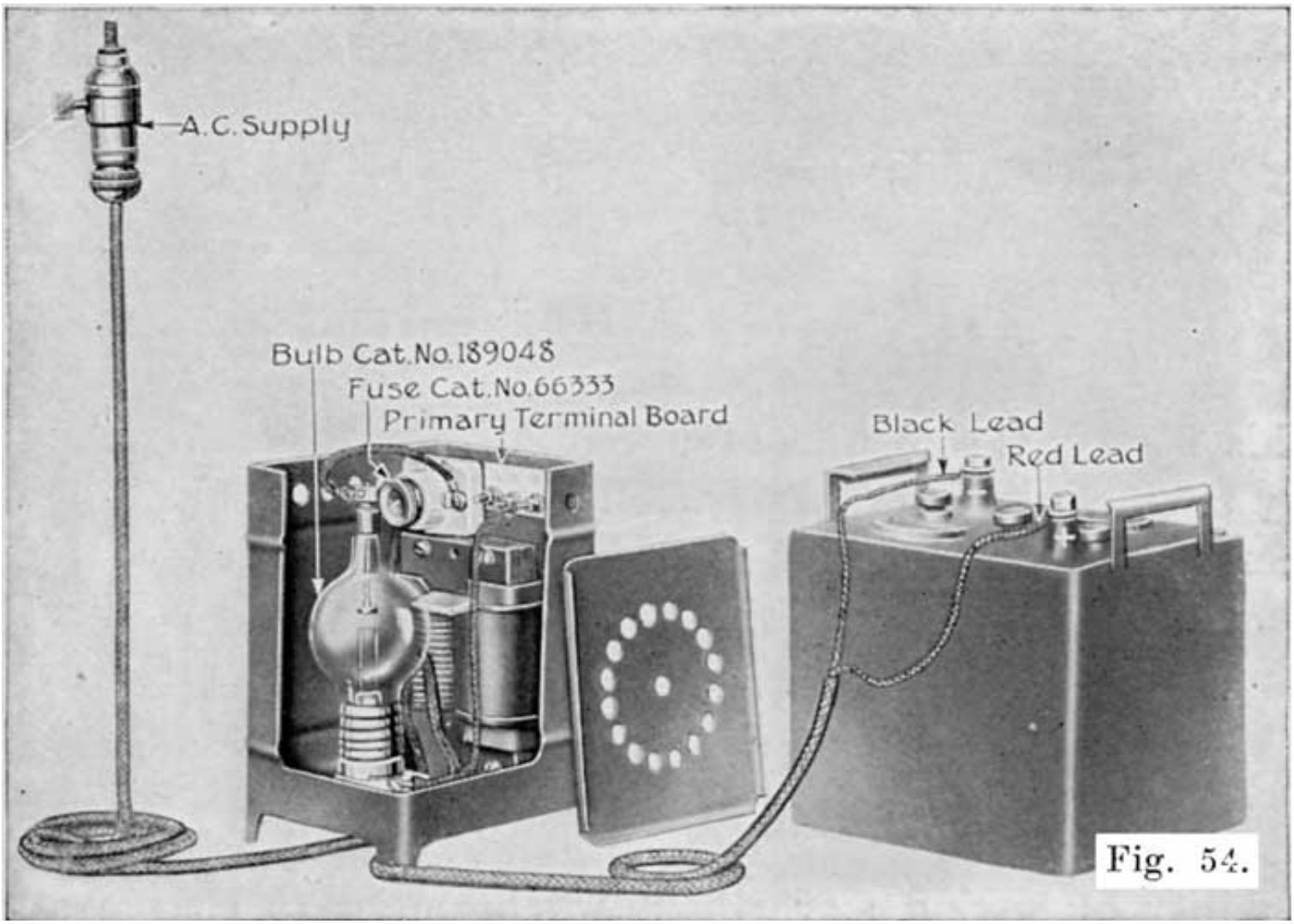

Fig. 54. The One Battery Tungar Rectifier

This Tungar will charge a 6 volt battery at five amperes, or a 12 volt battery at three amperes. Figure 54 shows this Tungar, with part of the casing cut away to show the internal parts.

To take care of variations in' the voltage of the alternating current supply from 100 to 130, a set of connections is provided which are numbered 105, 115, and 125. For most supply voltages, the 115 volt tap is used, for lower voltage the 105 volt tap is used, and for higher voltage the 125 volt tap is used. This Tungar is designed for 60 cycle circuits, but on special order it may be obtained for operation on other frequencies.

This Tungar is most suitable for a car owner, is satisfactory for charging a radio "A" battery, and a six volt starting and lighting battery at one time.

C. The Two Battery Rectifier

Catalogue No. 195530

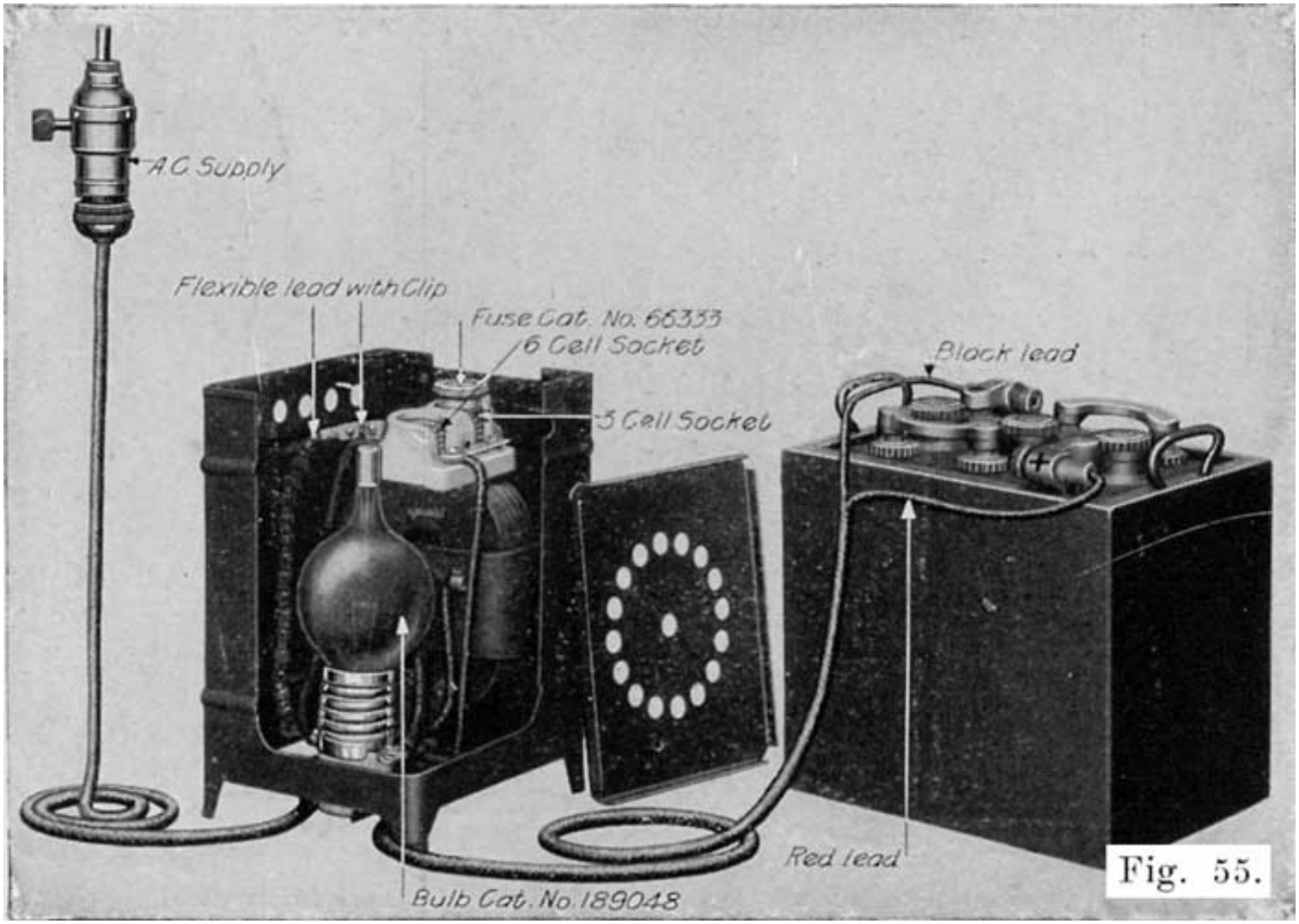

Fig. 55. The Two Battery Tungar Rectifier

This Tungar is shown in Figure 55, with part of the casing cut away to show the internal parts. It was formerly sold to the car owner, but the one battery Tungar is now recommended for the use of the car owner. The two-battery Tungar is therefore recommended for the very small service station, or for department stores for taking care of one or two batteries. The four battery Tungar, which is the next one described, is recommended in preference to the two-battery outfit where there is the slightest possibility of having more than two batteries to charge at one time.

The two-battery rectifier will charge two 6-volt batteries, or one 12-volt battery at six amperes, or one 18-volt battery at three amperes. It has a double-pole fuse block mounted on the auto transformer core, which has one fuse plug only. Figure 55 shows the fuse plug in the position for charging a 6-volt battery. When it is desired to charge a 12-volt battery or an 18-volt battery, the fuse is removed from the first receptacle and is screwed into the second receptacle.

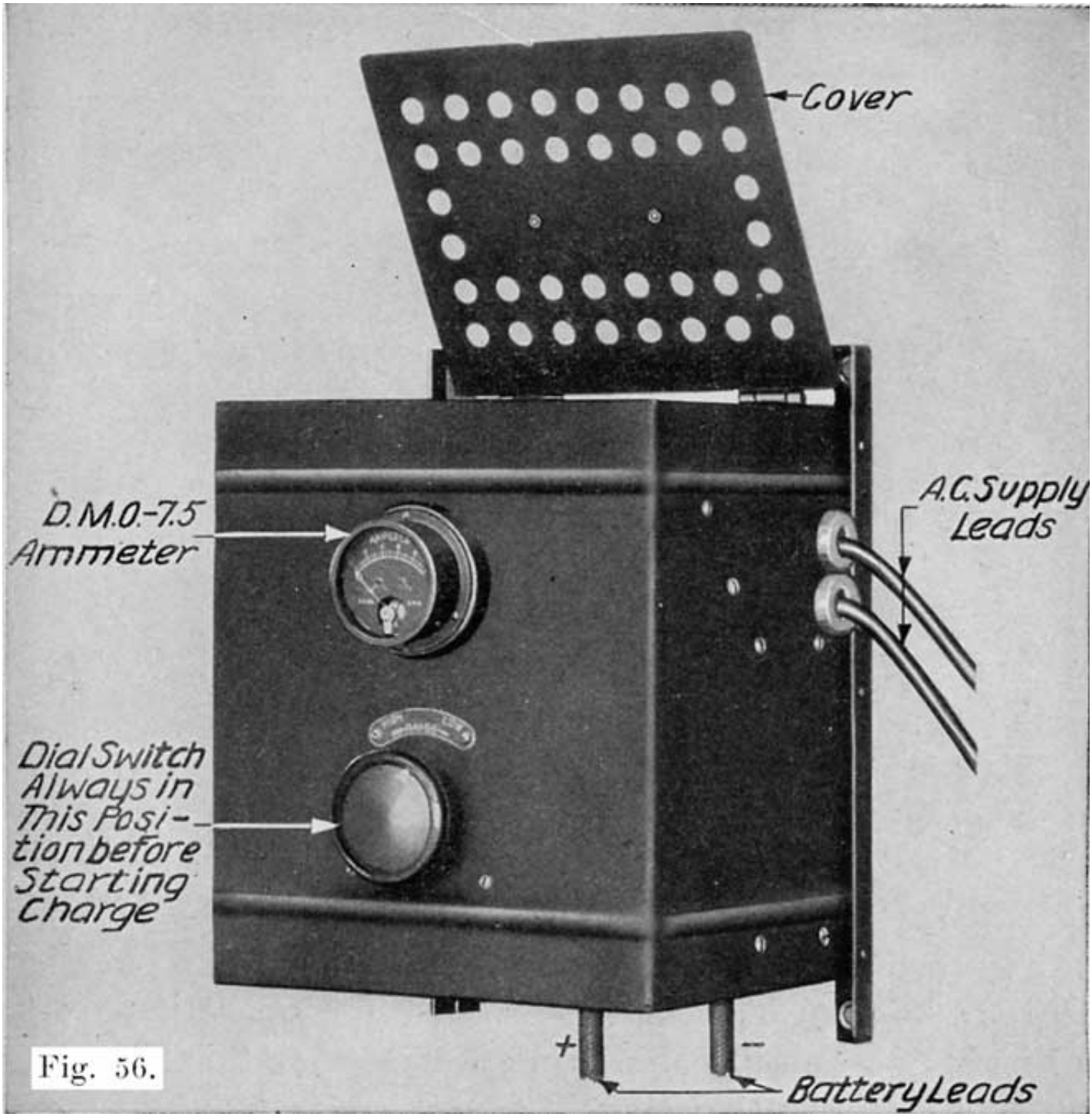

Fig. 56. The Four Battery Tungar Rectifier Complete

The two-battery rectifier is designed to operate on a 115-volt, 60-cycle line, but oil special order may be obtained for operation on 25-30, 40-50, and 125-133 cycle lines.

D. The Four Battery Tungar

Catalogue No. 193191

This Tungar is shown complete in Figure 56. In Figure 57 the top has been raised to show the internal parts. Figure 58 gives the internal wiring connections for a four battery Tungar designed for operation on a 115 volt line.

The four battery Tungar will charge from one to four 6 volt batteries at 5 amperes or less. It is designed especially for garages having very few batteries to charge. These garages generally charge their boarders batteries rather than send them to a service station, and seldom have more than four batteries to charge at one time. The four battery Tungar is also suitable for the use of car dealers who wish to keep the batteries on their cars in good shape, and is convenient for preparing for service batteries as they come from the car manufacturer.

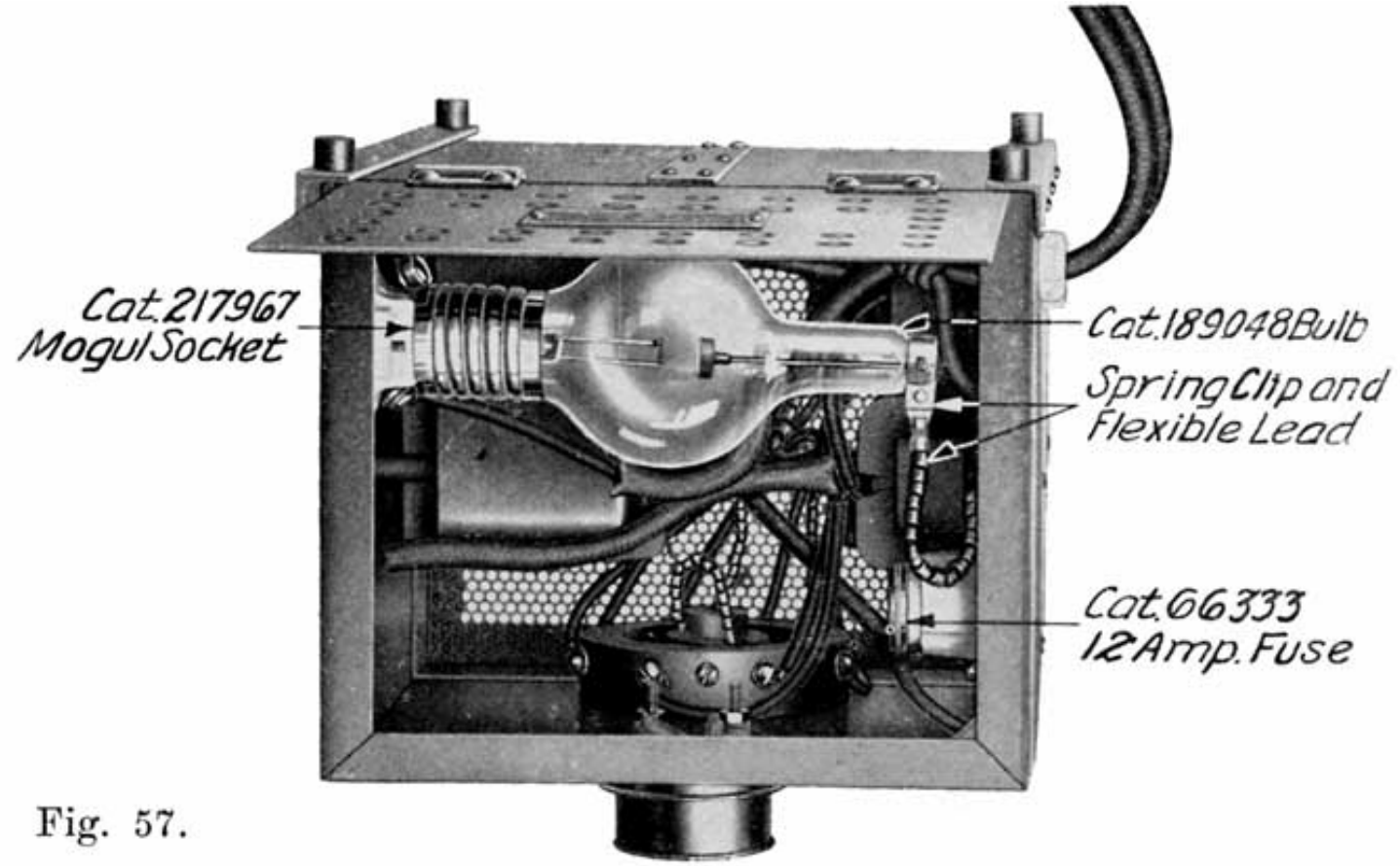

Fig. 57. The Four Battery Tungar Rectifier, with Top Raised to Show Internal Parts.

The four battery Tungar is designed for operation. on a 60-cycle line at 115 or 230 volts. On special order this Tungar may be obtained for operation on other frequencies.

E. The Ten Battery Rectifier

Catalogue No. 179492

This is the Tungar which is most popular in the service stations, since it meets the charging requirements of the average shop better than the smaller Tungars. It will charge from one to ten 6 volt batteries, or the equivalent at six amperes or less. Where more than ten batteries are generally to be charged at one time, two or more of the ten battery Tungars should be used. Large service stations use as many as ten of these Tungars.

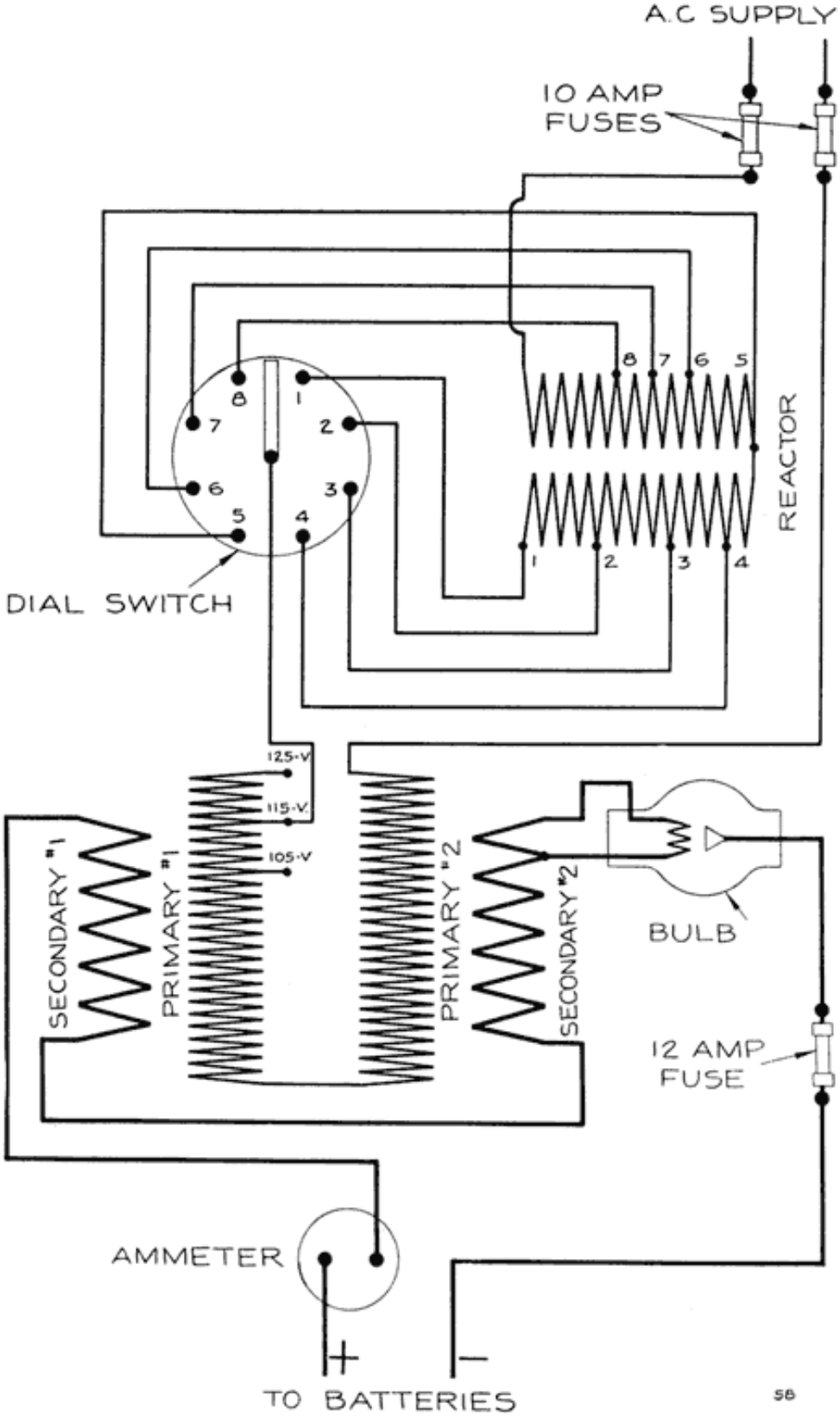

Fig. 58. Internal Wiring of the Four Battery Tungar Rectifier

The efficiency of the ten battery Tungar at full load is approximately 75 per cent, which compares favorably with that of a mercury-are rectifier, or motor-generator of the same size. This makes the ten battery Tungar a very desirable piece of apparatus for the service station.

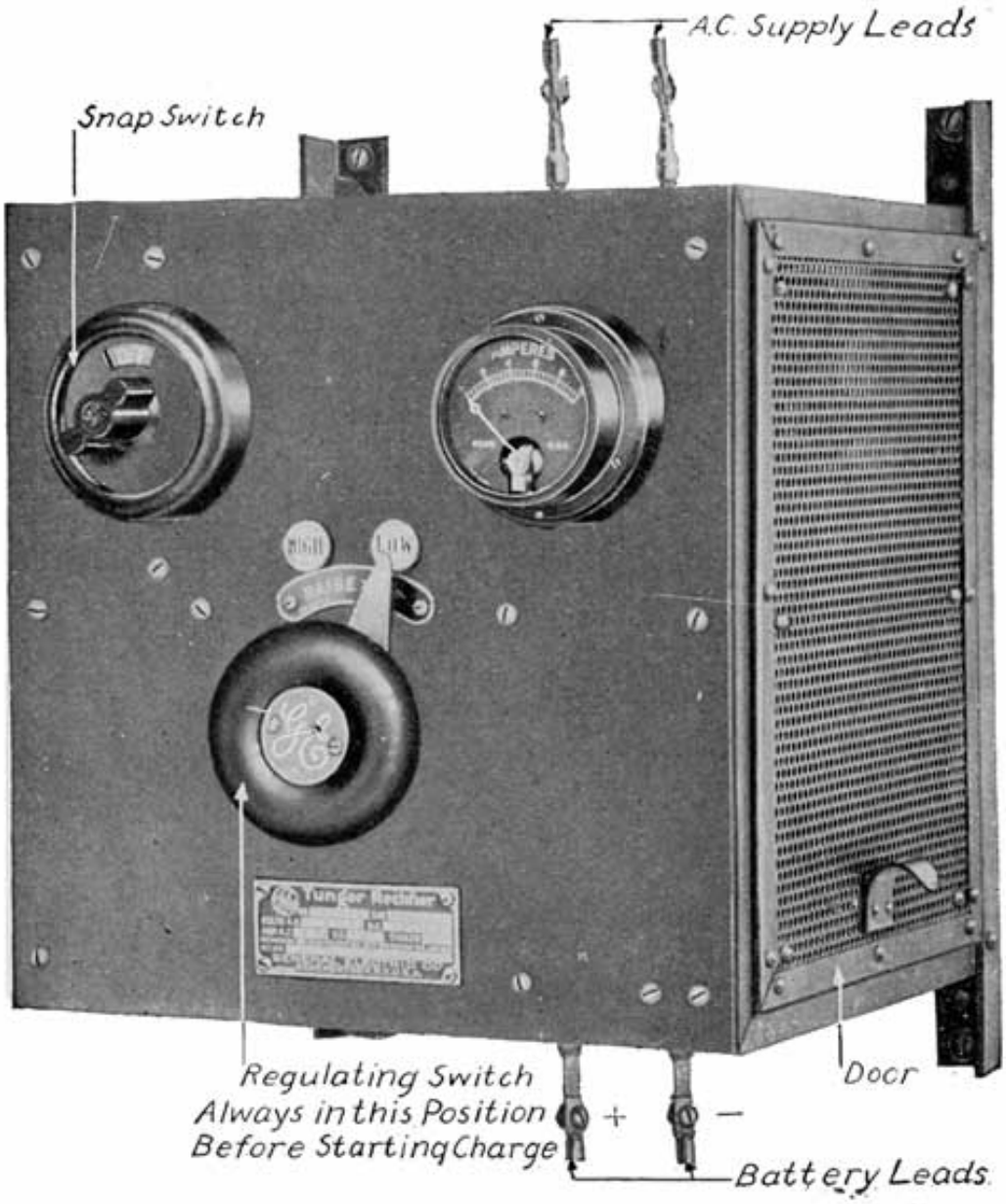

Fig. 59. The Ten Battery Tungar Rectifier, Complete

Figure 59 shows the complete ten battery Tungar, Figure 60 gives a side view without the door to show the internal parts.

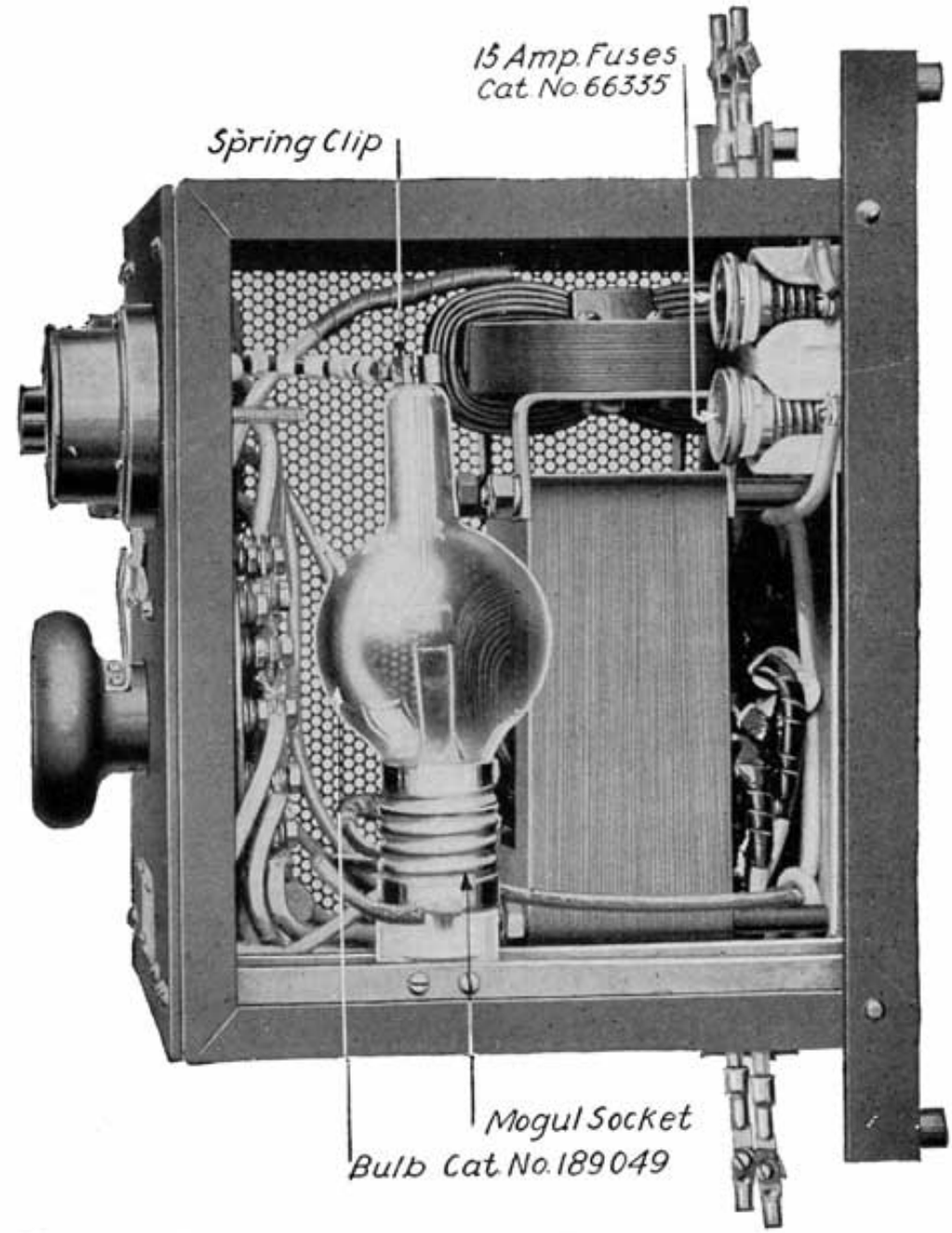

Fig. 60. Side View of the Ten Battery Tungar Rectifier Without the Door, to Show Internal Parts

Figure 61 shows the internal connections for use on a 115-volt A.C. line and Figure 62 the internal connections for use on a 230-volt line. This Tungar is made for a 60-cycle circuit, 25-30, 40-50, and 125-133 cycle circuits.

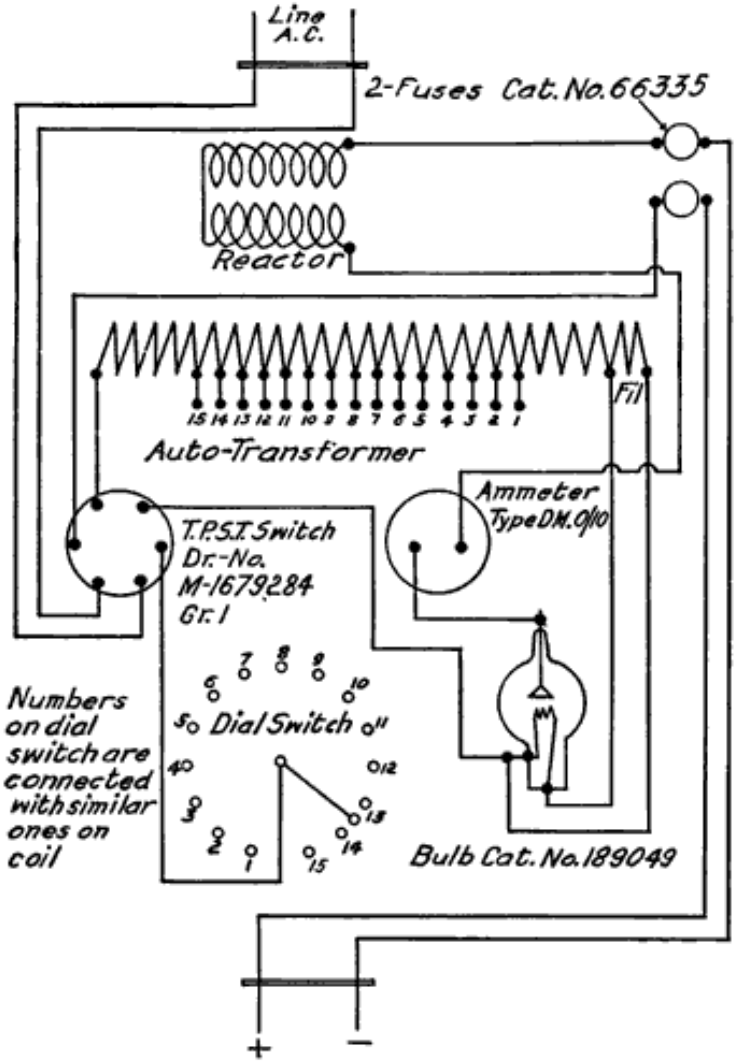

Fig. 61. Internal Wiring for the Ten Battery Tungar Rectifier for Operation on a 115 Volts, A. C. Line

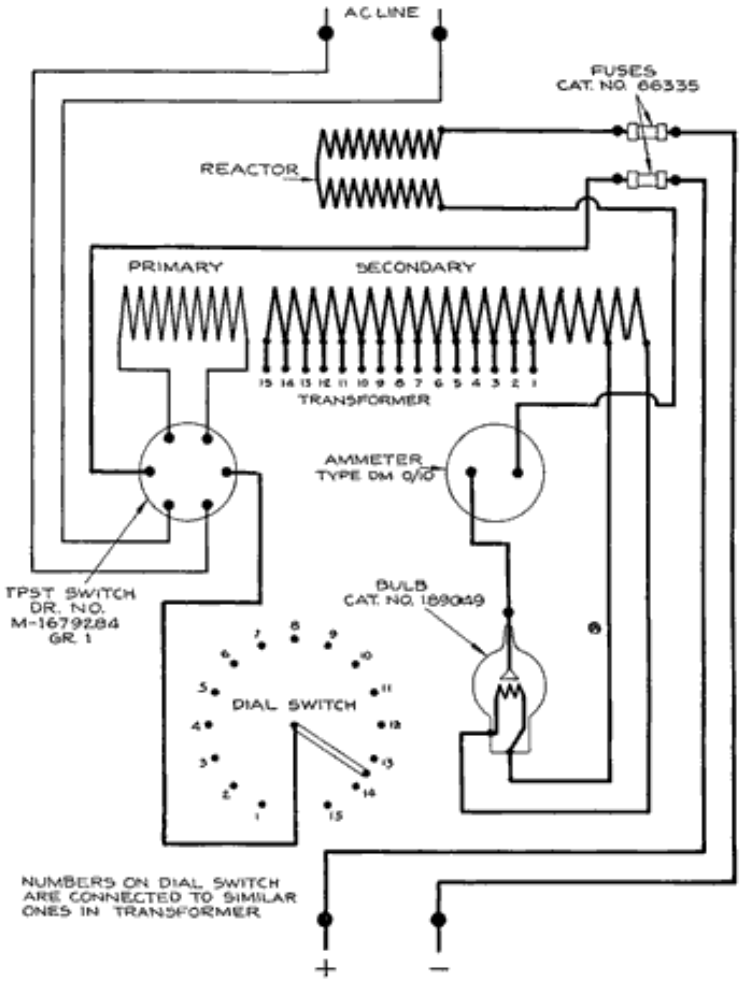

Fig. 62. Internal Wiring for the Ten Battery Tungar Rectifier for Operation on a 230 Volts, A. C. Line

F. The Twenty Battery Tungar

Catalogue No. 221514

This Tungar will charge ten 6-volt batteries at 12 amperes, or twenty 6-volt batteries at six amperes. Figure 63 shows the complete rectifier, and Figure 64 shows the rectifier with the side door open to show the internal parts. This rectifier will do the work of two of the ten battery Tungars. It is designed for operation on 60 cycles, 230-volts. On special order it may be obtained for operation on 115 volts and also for other frequencies.

The twenty battery Tungar uses two bulbs, each of which is the same as that used in the ten battery Tungar, and has two charging circuits, having an ammeter and regulating switch for each circuit. One snap switch connects both circuits to the supply circuit. The two charging circuits are regulated independently. For example, one circuit may be regulated to three amperes while the other circuit is delivering six amperes. It is also possible, by a system of connections to charge the equivalent of three circuits. For instance, five batteries could be charged at six amperes, five batteries at four amperes, and five batteries at ten amperes. Other corresponding combinations are possible also.

General Instructions and Information on Tungars

Life of Tungar Bulbs. The life of the Tungar Bulb is rated at 600 to 800 hours, but actually a bulb will give service for 1,200 to 3,000 hours if the user is careful not to overload the bulb by operating it at more than the rated current.

Fig. 63

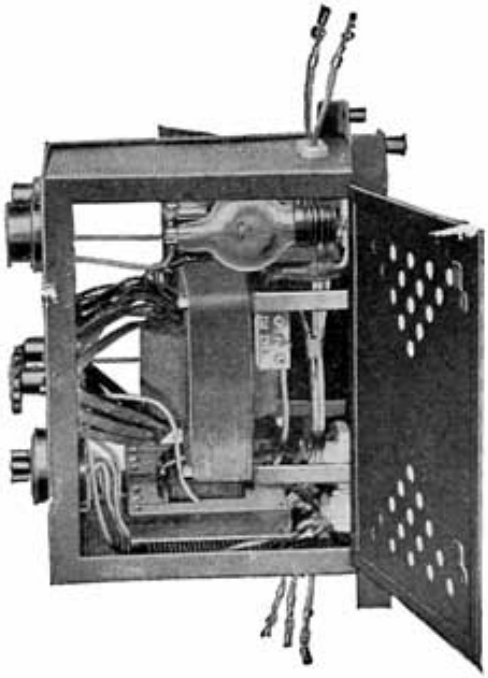

Fig. 64

The Twenty Battery Tungar Rectifier

Instructions. Complete instructions are furnished with each Tungar outfit, the following being those for the ten battery Tungar.

Installation

A Tungar should., be installed in a clean, dry place -in order to keep the apparatus free from dirt and moisture. To avoid acid fumes, do not place the Tungar directly over the batteries. These precautions will prevent corrosion of the metal parts and liability of poor contacts.

Fasten the Tungar to a wall by four screws, if the wall is of wood, or by four expansion bolts if it is made of brick or concrete.

Though the electrical connections of the outfit are very simple, it is advisable (when installing the apparatus) to employ an experienced wireman familiar -with local requirements regarding wiring.

Line Connections

The two wires extending from the top of the Tungar should be connected to the alternating current supply of the same voltage and frequency, as stamped on the name plate attached to the front panel. These connections should be not less than No. 12 B. & S. gauge wire and should be firmly soldered to the copper lugs.

External fuses are recommended for the alternating-current circuit, as follows:

With 115-volt line use 15-ampere capacity fuses.

With 230-volt line use 10 ampere capacity fuses.

One of the bulbs (Cat. No. 189049) should now be firmly screwed into its socket. Squeeze the spring clip attached to

the beaded cable and slip this clip over the wire protruding from the top of the bulb. Do not bend the wire.

Battery Connections

In making battery connections have the snap-switch in the "Off" position.

The two wires extending from the bottom of the Tungar should be connected to the batteries. The wire on the left, facing the front panel, is marked + (positive) and the other wire - (negative). The positive wire should be connected to the positive terminal of the battery and the negative wire to the negative terminal.

The two flexible battery cables are sometimes connected directly to the two wires projecting from the bottom of the Tungar. These cables should be securely cleated to the wall about six inches below the outfit. This arrangement will relieve the strain on the Tungar wires when cables are changed to different batteries.

When two or more batteries are to be charged, they should be connected in series. The positive wire of the Tungar should be connected to the positive terminal of battery No. 1, the negative terminal of this battery of the positive terminal of battery No. 2, the negative terminal of battery No. 2 to the positive terminal of battery No. 3, and so on, according to the number of batteries in circuit. Finally the negative terminal of the last battery should be connected to the negative wire from the Tungar.

Reverse connections on one battery is likely to damage the plates; and reverse connections oil all the batteries will blow one or more fuses.

Operation

A Tungar is operated by means of a snap-switch in the upper left-hand corner and a regulating switch in the center. Before starting the apparatus, the regulating switch should be in the "low" position.

The Tungar is now ready to operate. Turn the snap-switch to the right to the "On" position, and the bulb will light. Then turn the regulating switch slowly to the right, and, as soon as the batteries commence to charge, the needle on the ammeter will indicate the charging current. This current may be adjusted to whatever value is desired within the limits of the Tungar. The normal charging rate is six amperes, but a current of as high as seven amperes may be obtained without greatly reducing the life of the bulb. Higher charging rates reduce its life to a considerable extent. Lower rates than normal (six amperes) will increase the life of the bulb.

Turn the snap-switch to the "Off" position when the charging of one battery or of all the batteries is completed; or when it is desired to add more batteries to the line.

The Tungar should be operated only by the snap-switch and not by any other external switch in either line or battery circuits.

When the snap-switch is turned, the batteries will be disconnected from the supply line, and then they may be handled without danger of shock.

Immediately after turning the snap-switch, move the regulating handle back to the "Low" position. This prevents any damage to the bulb from the dial switch being in an improper position for the number of batteries next charged.

Troubles

If on turning on the alternating-current switch the bulb does not glow:

1. See whether the alternating-current supply is on.

2. Examine the supply line fuses. If these are blown, or are defective, replace them with 15 ampere fuses for a 115-volt line or with 10-ampere fuses for a 220-volt line.
3. Make sure that the bulb is screwed well into the socket.
4. Examine the contacts inside the socket. If they are tarnished or dirty, clean them with sandpaper.
5. Try a new bulb, Cat. No. 189049. The old bulb may be defective.

If the bulb lights but no current shows on the ammeter:

1. Examine the connections to the batteries, and also the connections between them. Most troubles are caused by imperfect battery connections.
2. Examine the fuses inside the case. If these are blown or are defective, replace them with 15 ampere fuses, Cat. No. 6335.
3. See that the clip is on the wire of the bulb.
4. The bulb may have a slow leak and not rectify. Try a new bulb, Cat. No. 189049.
5. Have the switch arm make good contact on the regulating switch.

If the current on the ammeter is high and cannot be reduced:

1. The ammeter pointer may be sticking; tap it lightly with the hand. The ammeter will not indicate the current correctly if the pointer is not on the zero line when the Tungar is not operating. The pointer may be easily reset by turning slightly the screw on the lower part of the instrument.
2. Be sure that the batteries are not connected with reversed polarity.
3. The. alternating-current supply may be abnormally high. If only one three-cell battery is being charged, and the alternating-current supply is slightly high, then the current on the ammeter may be high. The simplest remedy is to connect in another battery or a small amount of resistance.

A spare bulb should always be kept on hand and should be tested for at least one complete charge before being placed in reserve. All Tungar bulbs are made as nearly perfect as possible, but occasionally one is damaged in shipment. It may look perfect and yet not operate. For this reason all bulbs should be tried out on receipt. If any bulb is found defective, the tag which accompanies it should be filled out, and bulb and tag should be returned to your dealer or to the nearest office of the General Electric Company, transportation prepaid.

Tungar Rectifiers

(The following columns omitted: Catalog Numbers, Dimensions, Net Weight and Shipping Weight).

Name	No. 6V Bats.	No. 12V Bats.	D.C Amps	D.C. Volts	A.C. Volts	Freq.
2 Amp. Tungar	1 (2 amps.)	1 (1 amps.)	1-2	7.5-15	115	60
2 Amp. Tungar	1 (2 amps.)	1 (1 amps.)	1-2	7.5-15	115	40-50
2 Amp. Tungar	1 (2 amps.)	1 (1 amps.)	1-2	7.5-15	115	25-30
2 Amp. Tungar	1 (2 amps.)	1 (1 amps.)	1-2	7.5-15	115	125-133

1 Battery Tungar	1 (5 amps.)	1 (3 amps.)	1-5	7.5-15	115	60
2 Battery Tungar	2 (6 amps.)	1 (6 amps.)	1-6	7.5-15	115	60
2 Battery Tungar	2 (6 amps.)	1 (6 amps.)	1-6	7.5-15	115	40-50
2 Battery Tungar	2 (6 amps.)	1 (6 amps.)	1-6	7.5-15	115	25-30
2 Battery Tungar	2 (6 amps.)	1 (6 amps.)	1-6	7.5-15	115	125-130
4 Battery Tungar	4 (5 amps.)	2 (5 amps.)	1-5	7.5-30	115	60
4 Battery Tungar	4 (5 amps.)	2 (5 amps.)	1-5	7.5-30	115	40-50
4 Battery Tungar	4 (5 amps.)	2 (5 amps.)	1-5	7.5-30	115	25-30
4 Battery Tungar	4 (5 amps.)	2 (5 amps.)	1-5	7.5-30	115	125-133
4 Battery Tungar	4 (5 amps.)	2 (5 amps.)	1-5	7.5-30	230	60
4 Battery Tungar	4 (5 amps.)	2 (5 amps.)	1-5	7.5-30	230	40-50
10 Battery Tungar	10	5	1-6	7.5-75	115	60
10 Battery Tungar	10	5	1-6	7.5-75	115	40-50
10 Battery Tungar	10	5	1-6	7.5-75	115	25-30
10 Battery Tungar	10	5	1-6	7.5-75	115	125-133
10 Battery Tungar	10	5	1-6	7.5-75	230	60
10 Battery Tungar	10	5	1-6	7.5-75	230	40-50
20 Battery Tungar	10 (12A.) 20 (6A.)	10 (6A.)	1-12	7.5-75	230	60
20 Battery Tungar	10 (12A.) 20 (6A.)	10 (6A.)	1-12	7.5-75	230	40-50

20 Battery Tungar	10 (12A.) 20 (6A.)	10 (6A.)	1-12	7.5-75	230	25-30
Bulb (all 4 Amp. Tung.)	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,
Bulb (all 10 and 12 Amp. Tung.)	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,
Bulb (all 2 Amp. Tung.)	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,
Bulb (all 1-2 Bat. Tung.)	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,	,,,,,,,,

Mercury Arc Rectifier

The operation of the mercury are rectifier depends upon the fact that a tube containing mercury vapor under a low pressure and provided with two electrodes, one of mercury and the other of some other conductor, offers a very high resistance to a current tending to pass through the tube from the mercury electrode to the other electrode, but offers a very low resistance to a current tending to pass through the tube in the opposite direction. Current passes from the metallic electrode to the mercury electrode through an are of mercury vapor which is established in the tube by tilting it so the mercury bridges the gap between the mercury and an auxiliary electrode just for an instant.

The absence of moving parts to got out of order is an advantage possessed by this rectifier over the motor-generator. The charging current from the rectifier cannot, however, be reduced to as low a value as with the motor-generator, and this is a disadvantage. This rectifier is therefore more suitable for larger shops, especially where electric truck and pleasure cars are charged.

Mechanical Rectifiers

Mechanical rectifiers have a vibrating armature which opens and closes the charging circuit. The circuit is closed during one half of each alternating current cycle, and open during the next half cycle. The circuit is thus closed as long as the alternating current is flowing in the proper direction to charge the battery, and is open as long as the alternating current is flowing in the reverse direction. These rectifiers therefore charge the battery during half the time the battery is on charge, this also being the case in some of the are rectifiers.

The desired action is secured by a combination of a permanent magnet and an electromagnet which is connected to the alternating current supply. During half of the alternating current cycle, the alternating current flowing through the winding of the electromagnet magnetizes the electromagnet so that it strengthens the magnetism of the permanent magnet, thus causing the vibrator arm to be drawn against the magnet. The vibrator arm carries a contact which touches a stationary contact point when the arm is drawn against the magnet, thus closing the charging circuit.

During the next half of the alternating current cycle, or wave, the current through the electromagnet coil is reversed, and the magnetism of the electromagnet then weakens the magnetism of the permanent magnet, and the vibrator arm is drawn away from the magnet and the charging circuit is thus opened. During the next half of the alternating current cycle the vibrator arm is again drawn against the magnet, and so on, the contact points being closed and opened during half of each alternating current cycle.

Mechanical rectifiers are operated from the secondary windings of transformers which reduce the voltage of the alternating current line to the voltage desired for charging. Each rectifier unit may have its own complete

transformer, or one large transformer may operate a number of rectifier units by having its secondary, or low tension winding divided into a number of sections, each of which operates one rectifier.

The advantages of the mechanical rectifier are its simplicity, cheapness and portability. This rectifier also has the advantage of opening the charging circuit when the alternating current supply fails, and starting again automatically when the line is made alive again. Any desired number of independent units, each having its own charging line, may be used. The charging current generally has a maximum value of 6 amperes. Each rectifier unit is generally designed to charge only one or two six volt batteries at one time.

Stahl Rectifier

This is a unique rectifier, in which the alternating current is rectified by being sent through a commutator which is rotated by a small alternating current motor, similar to the way the alternating current generated in the armature of a direct current generator is rectified in the commutator of the machine. The Stahl rectifier supplies the alternating current from a transformer instead of generating it as is done in a direct current generator. Brushes which bear on the commutator lead to the charging circuit.

The Stahl rectifier is suitable for the larger service stations. It gives an interrupted direct current. It is simple' in construction and operation, and is free of delicate parts.

Other Charging Equipment

If there is no electric lighting in the shop, it will be necessary to install a generator and a gas, gasoline, or steam engine, or a waterwheel to drive it. A 10 battery belt driven generator may be used in such a shop, and may also, of course, be used with a separate motor. The generator should, of course, be a direct current machine. The size of the generator will depend upon the average number of batteries to be charged, and the amount of money available. Any of the large electrical manufacturers or supply houses will give any information -necessary for the selection of the type and size of the outfit required.

If an old automobile engine, and radiator, gas tank, etc., are on hand, they can be suitably mounted so as to drive the generator.

CHARGING BENCH

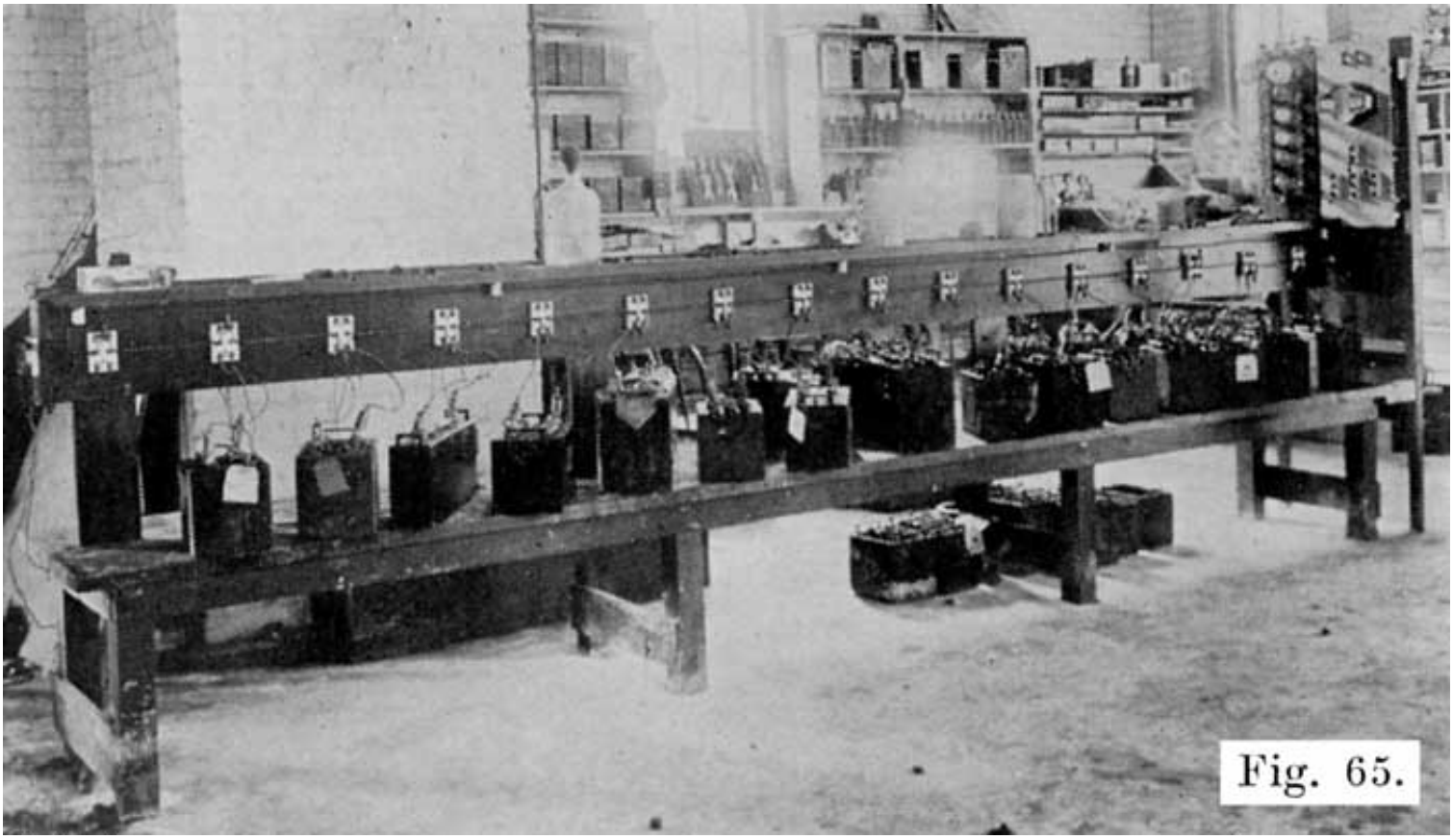

Fig. 65. Charging Bench with D.P.D.T. Switch for Each Battery

Figures 47 and 65 show charging benches in operation. Note that they are made of heavy stock, which is of course necessary on account of the weight of the batteries. The top of the charging bench should be low, to eliminate as much lifting of batteries as possible. Figure 66 is a working drawing of the bench illustrated in Figure 65. Note the elevated shelf extending down the center. This is convenient for holding water bottle, acid pitcher, hydrometer. Note also the strip "D" on this shelf, with the voltmeter hung from an iron bracket. With this arrangement the meter may be moved to any battery for voltage, cadmium, and high rate discharge readings. It also has the advantage of keeping the volt meter in a convenient and safe place, where it is not liable to have acid spilled on it, or to be damaged by rough handling. In building the bench shown in Figure 66, give each part a coat of asphaltum paint before assembling. After assembling the bench give it two more coats of asphaltum paint.

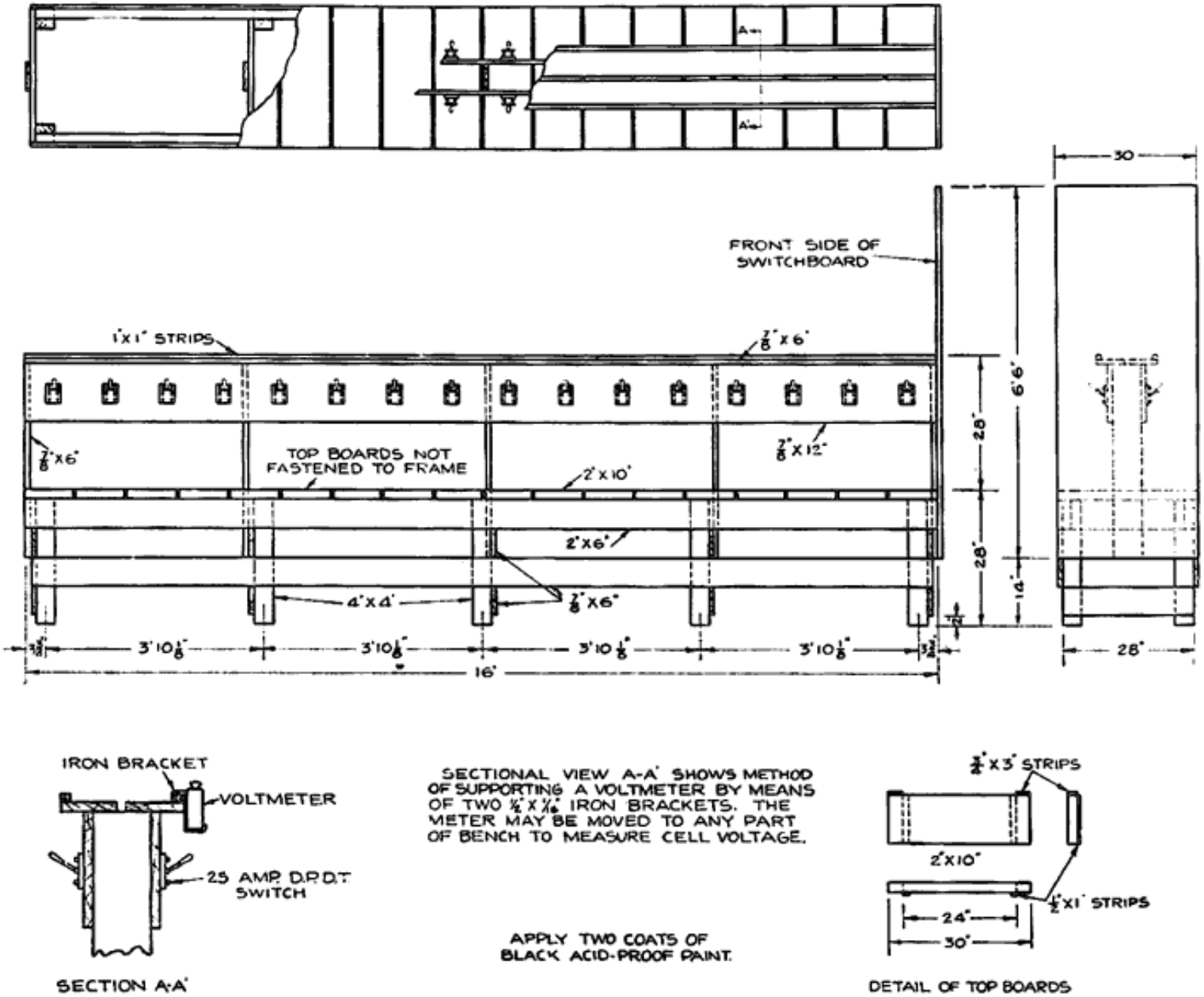

Fig. 66. Working Drawing of Charging Bench Shown in Fig. 65

Figures 67, 68, 69 and 70 show the working plans for other charging benches or tables. The repairman should choose the one which he considers most suitable for his shop. In wiring these benches, the elevated shelf shown in Figure 66 may be added and the double pole, double throw switches used. Instead of these switches, the jumpers shown on the benches illustrated in Figure 47 may be used. If this is done, the elevated shelf should also be installed, as it is a great convenience for the hydrometer, voltmeter, and so on, as already described.

As for the hydrometer, thermometer. etc., which were listed on page 96 as essential accessories of a charging bench, the Exide vehicle type hydrometer is a most excellent one for general use. This hydrometer has a round bulb and a straight barrel which has projections on the float to keep the hydrometer in an upright position when taking gravity readings. The special thermometer is shown in Figure 37. A good voltmeter is shown in Figure 121. This voltmeter has a 2.5 and a 25 volt scale, which makes it convenient for battery work. It also gives readings of a .2 and 2.0 to the left of the zero, and special scale markings to facilitate the making of Cadmium tests as described on page 174. As for the ammeter, if a motor-generator set, Tungar Rectifier or a charging-rheostat is used, the ammeter is always furnished with the set. If a lamp bank is used, a switchboard type meter reading to about 25 amperes is suitable. With

the constant potential system of charging, the ammeters are furnished with the motor-generator set. They read up to 300 amperes.

The bottles for the distilled water and electrolyte are not of special design and may be obtained in local stores, There are several special water bottles sold by jobbers, and they are convenient, but not necessary. Figure 133 shows a very handy arrangement for a water or acid bottle.

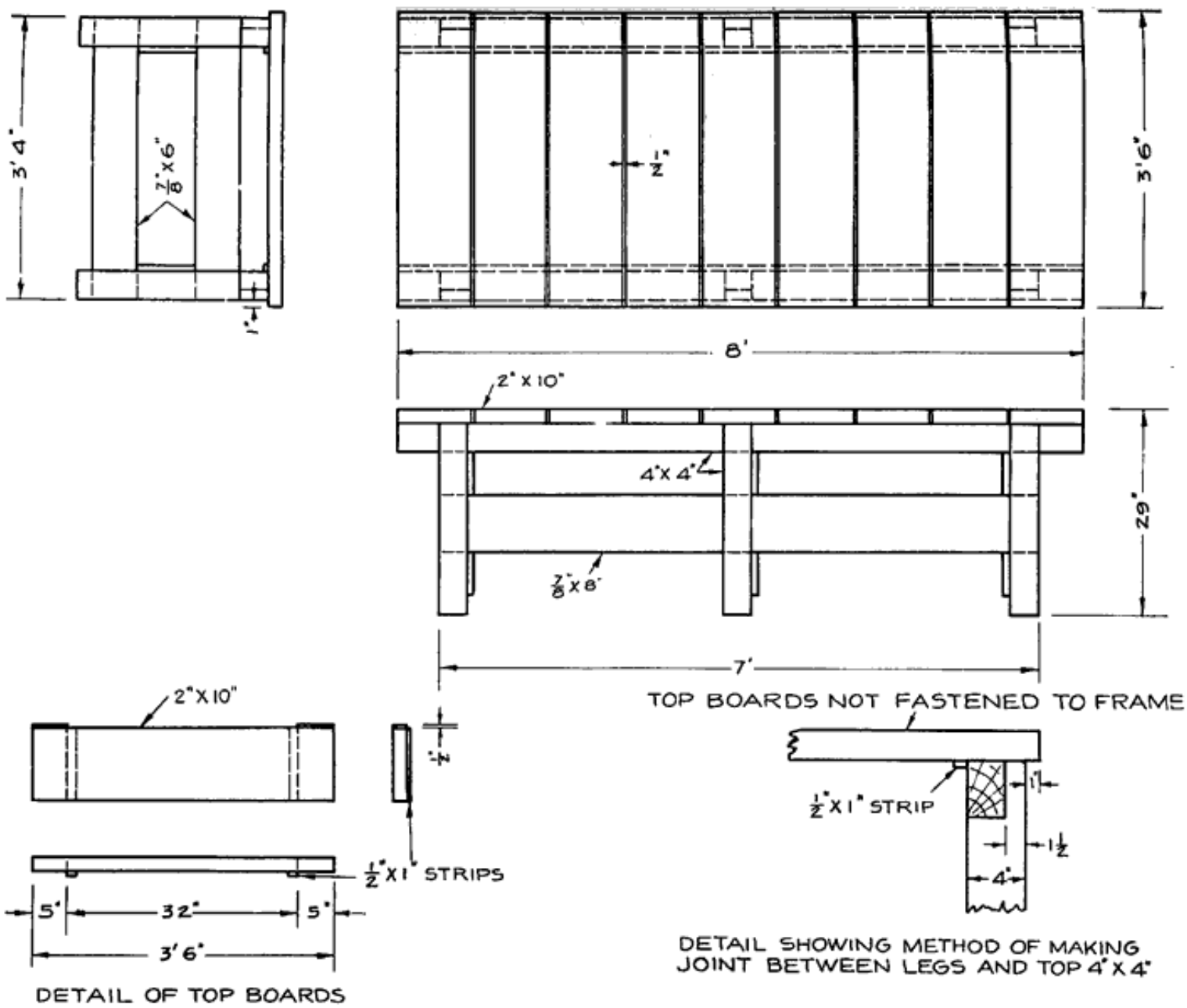

NOTE:- APPLY TWO COATS OF BLACK ACID-PROOF PAINT 67

Fig. 67. Working Drawing of Eight Foot Charging Bench

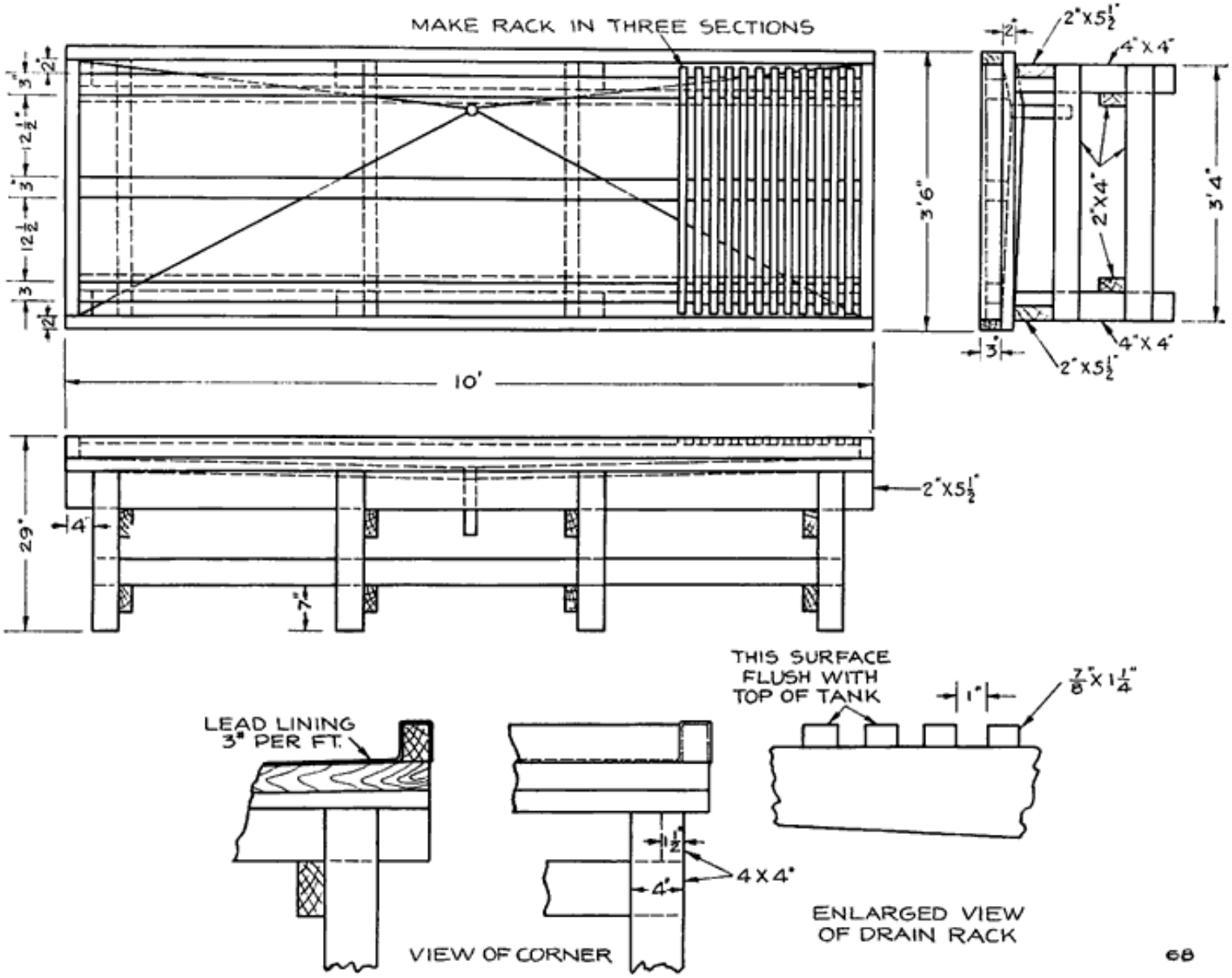

Fig. 68. Working Drawing of a Ten Foot Charging Bench

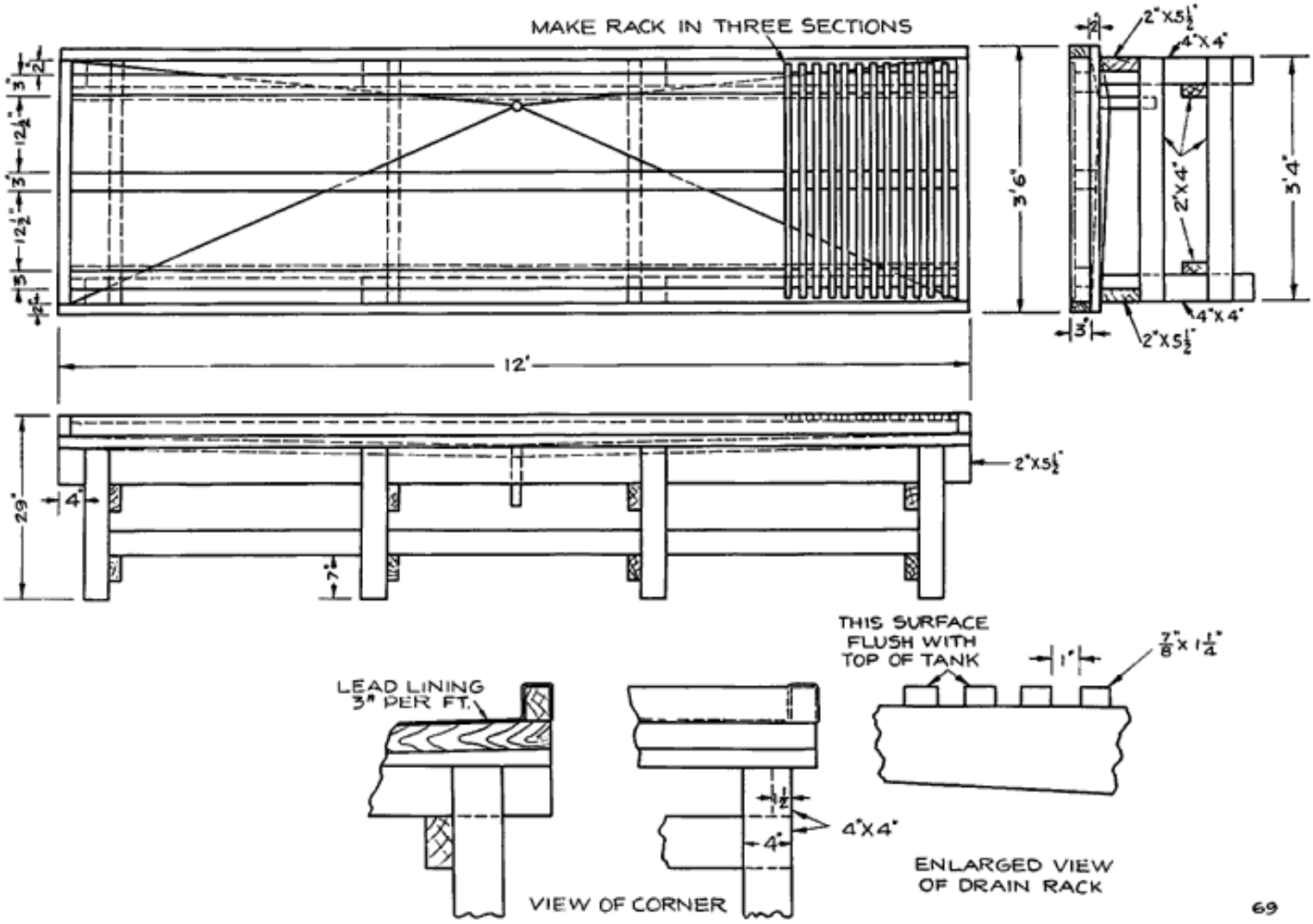

Fig. 69. Working Drawing of a Twelve Foot Charging Bench

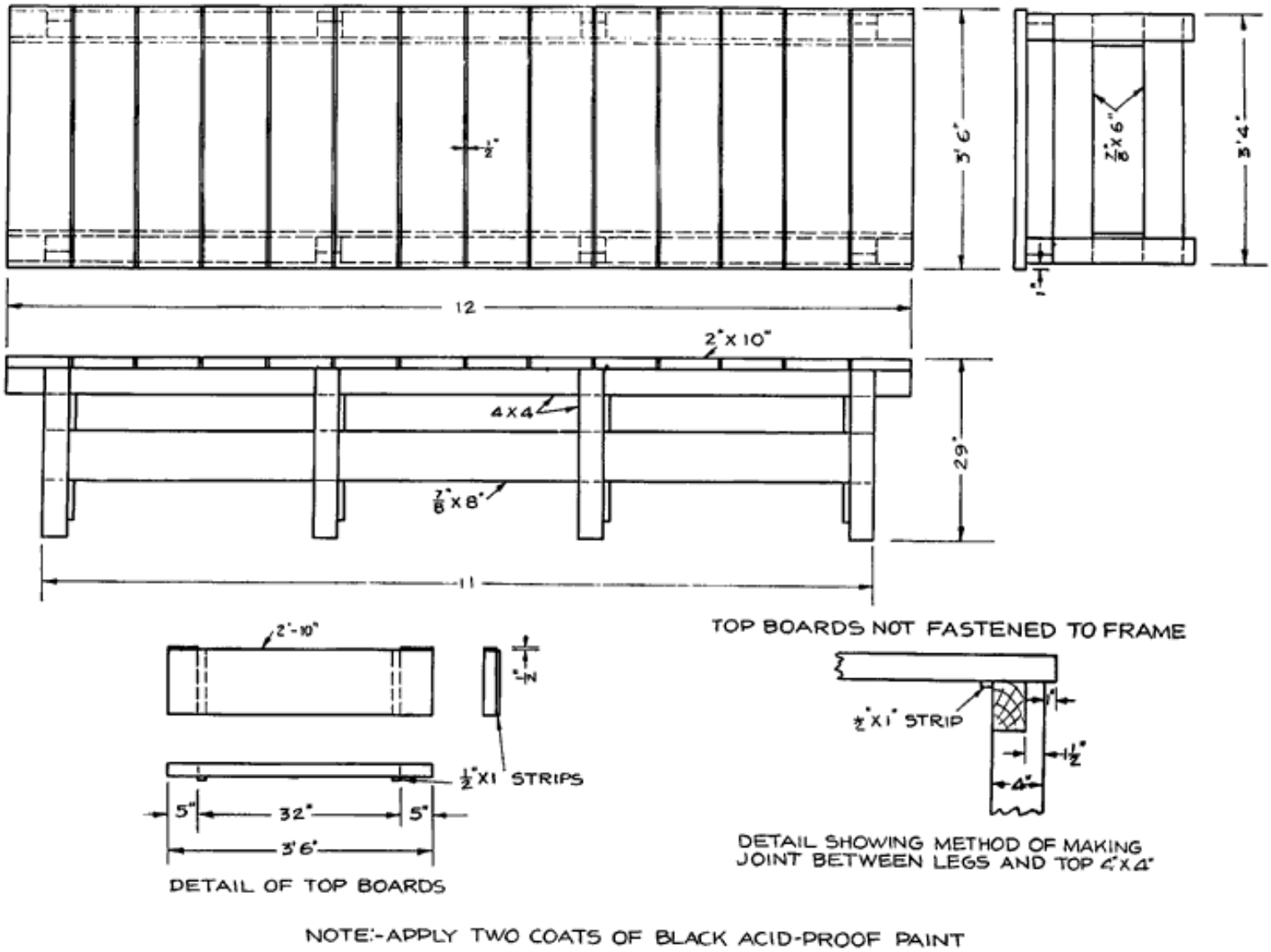

Fig. 70. Working Drawing of a Twelve Foot Charging Bench (Without Drain Rack)

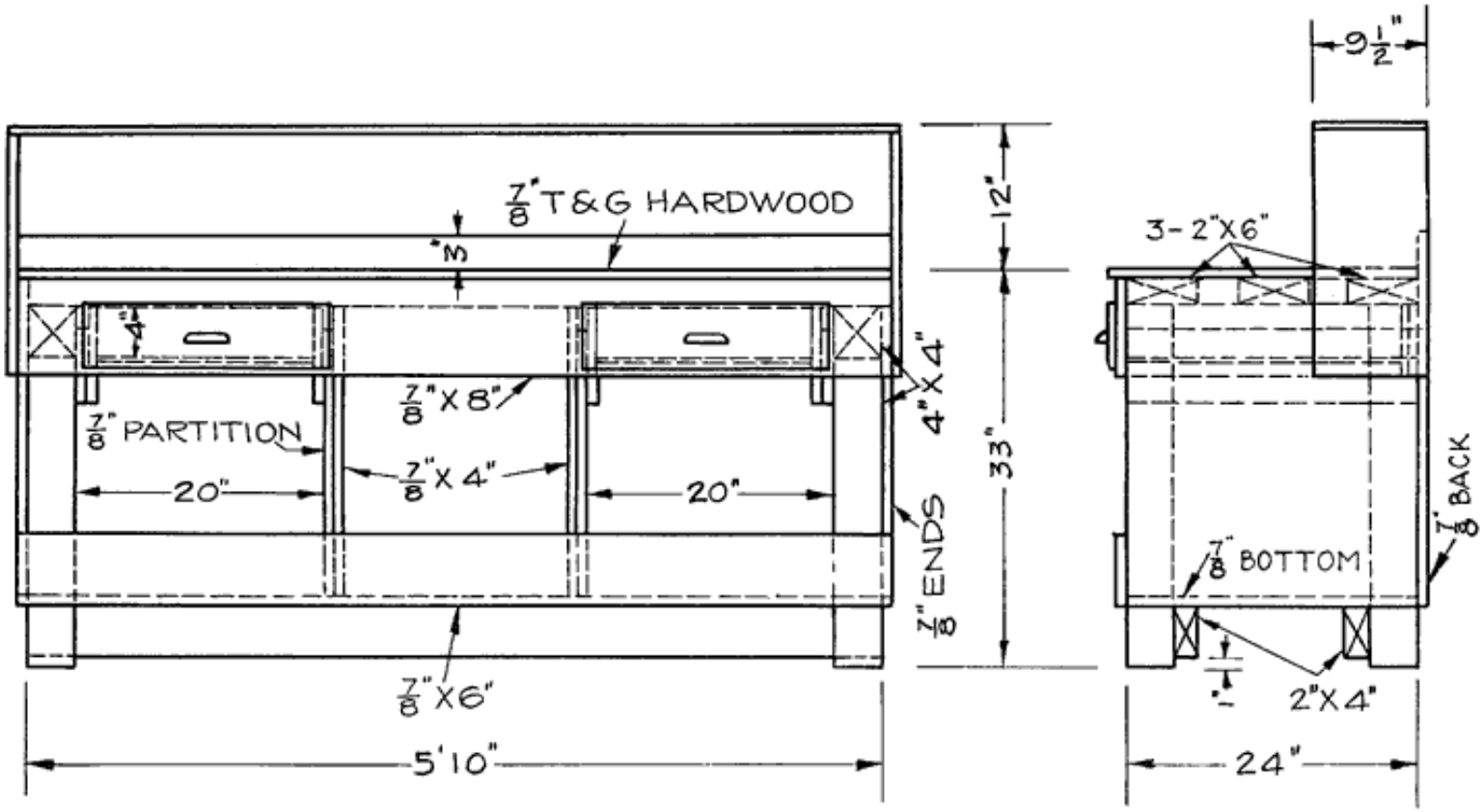

Fig. 71. Working Drawing of a Two Man Work Bench to be Placed Against a Wall

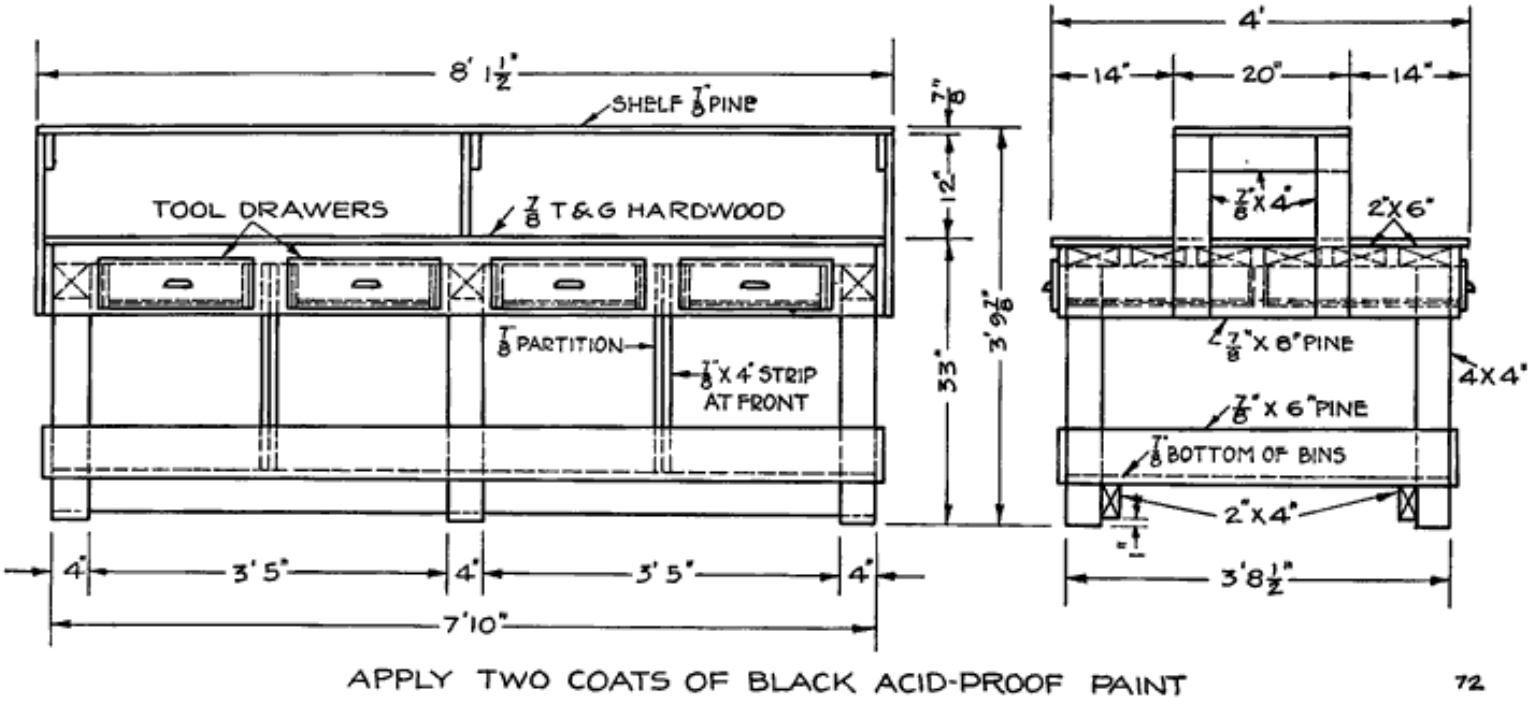

Fig. 72. Working Drawing of a Double, Four Man Work Bench, with Two Tool Drawers for Each Man

WORK BENCH

A work bench is more of a standard article than the charging bench, and there should be no trouble in building one. Figure 38 illustrates a good bench in actual use. A vise is, of course, necessary, and the bench should be of solid construction, and should be given several coats of asphaltum paint.

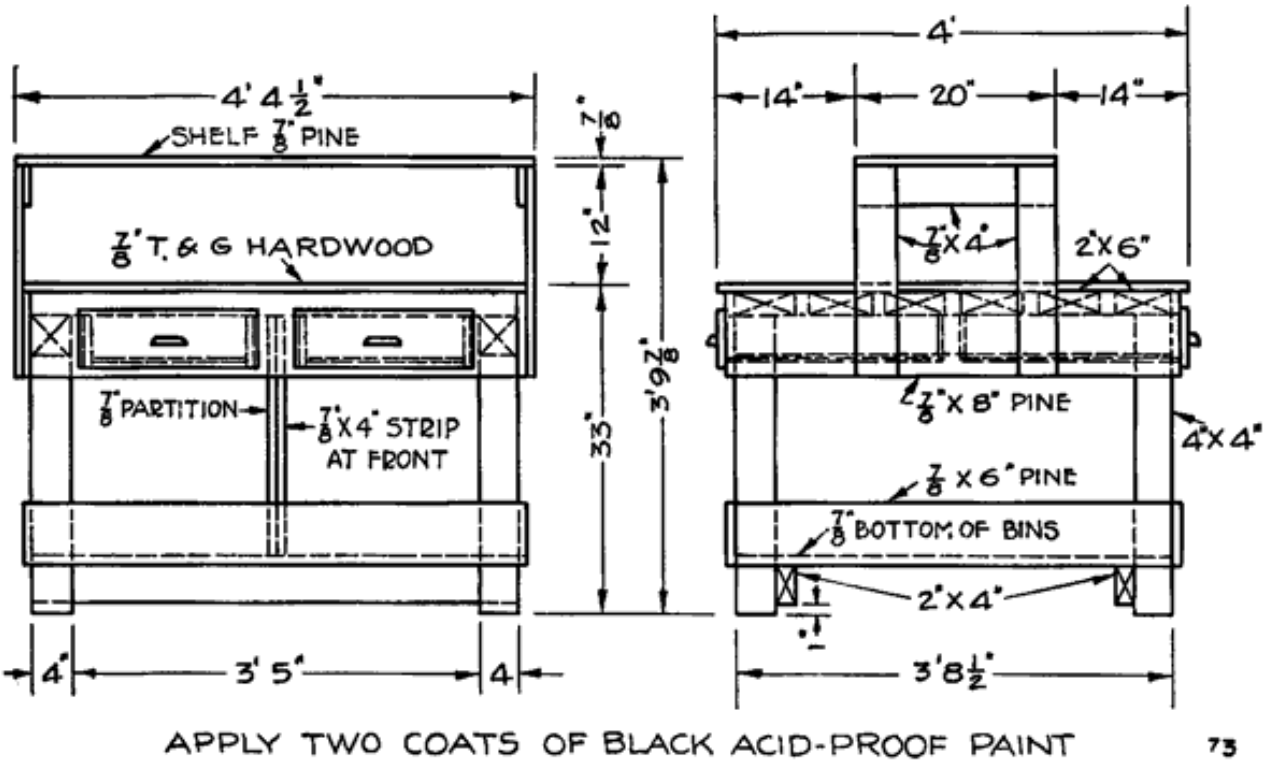

Fig. 73. Working Drawing of a Two Man, Double Work Bench

Figure 71 shows a single work bench which may be placed against a wall. Figures 72 and 73 show double work benches. Note that each bench has the elevated shelf, which should not, under any consideration be omitted, as it is absolutely necessary for good work. The tool drawers are also very convenient.

It is best to have a separate "tear down" bench where batteries are opened, as such a bench will be a wet, sloppy place and would not be suitable for anything else. It should be placed near the sink or wash tank, as shown in the shop layouts illustrated in Figures 136 to 142.

SINK OR WASH TANK

An ordinary sink may be used, as shown in Figure 74. This figure also shows a convenient arrangement for washing out jars. This consists of a three-fourths inch pipe having a perforated cap screwed over its upper end. Near the-floor is a valve which is normally held closed by a spring, and which has attached to it a foot operated lever. In washing sediment out of jars, the case is inverted over the pipe, and the water

turned on by means of the foot lever. A number of fine, sharp jets of water are thrown up into the jar, thereby washing out the sediment thoroughly.

If an ordinary sink is used, a settling tank should be placed under it, as shown in Figure 75. Otherwise, the drain pipe may become stopped up with sediment washed out of the jars. Pipe B is removable, which is convenient in cleaning out the tank. When the tank is to be cleaned, lift pipe B up very carefully and let the water drain out slowly. Then scoop out the sediment, rinse the tank with water, and replace pipe B. In some places junk men will buy the sediment, or "mud," as it is called.

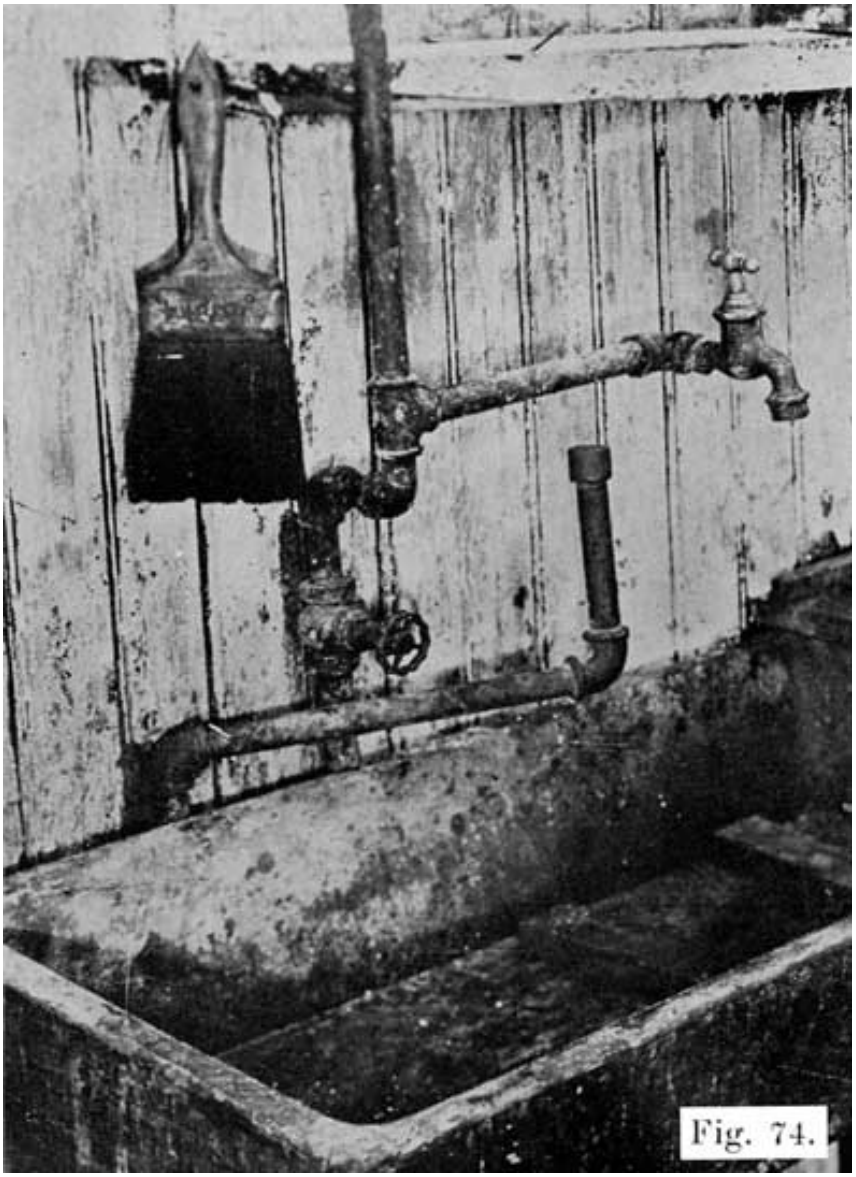

Fig. 74. Sink with Faucet, and Extra Swinging Arm Pipe for Washing Out Jars. Four Inch Paint Brush for Washing Battery Cases

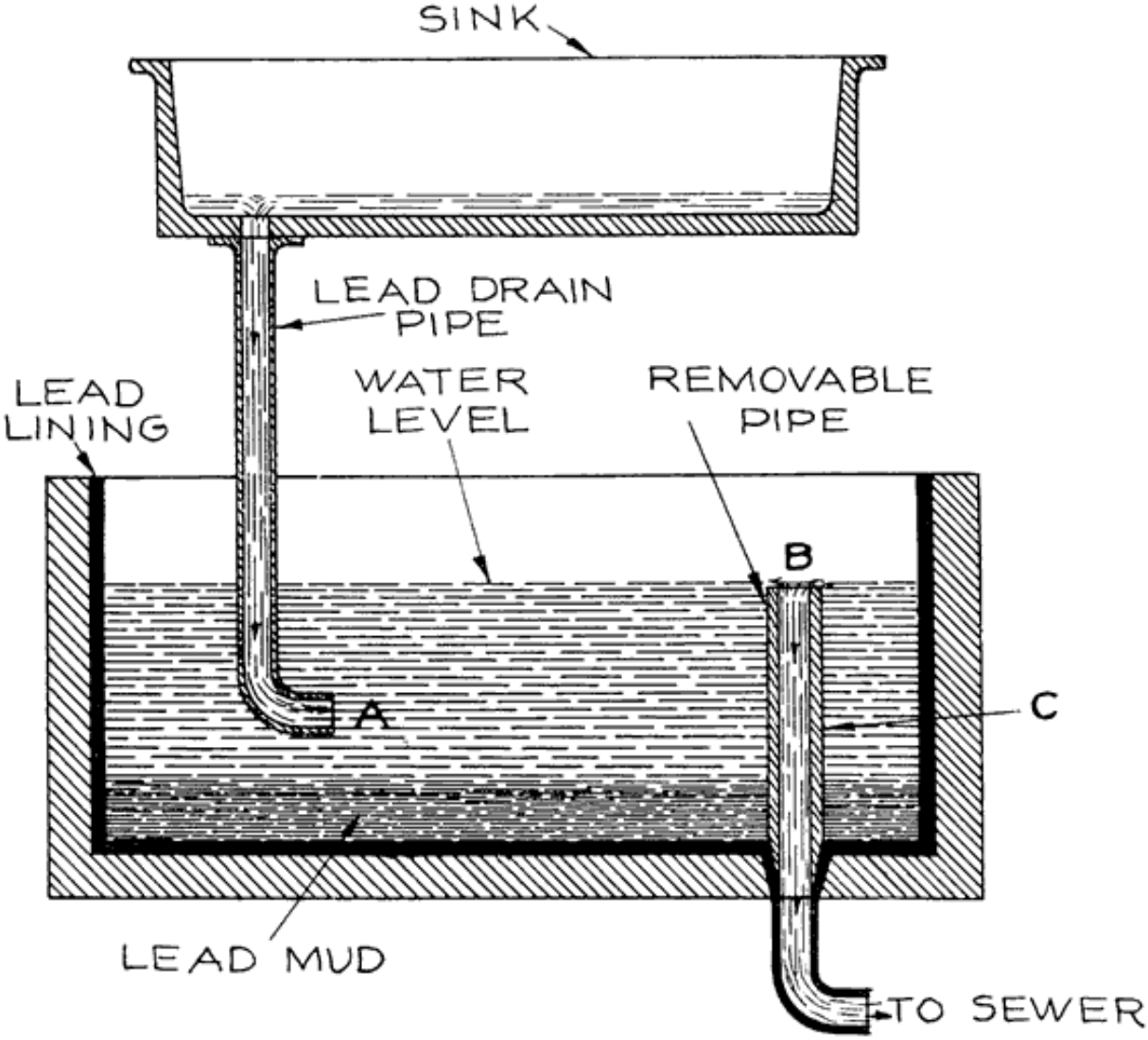

Fig. 75. Settling Tank to be Used with Sink Shown in Fig. 74

Figures 76 and 77 give the working drawings for more elaborate wash tanks. The -water supply shown in Figure 74 may be used here, and the drain pipe arrangement shown in Figure 75 may be used if desired.

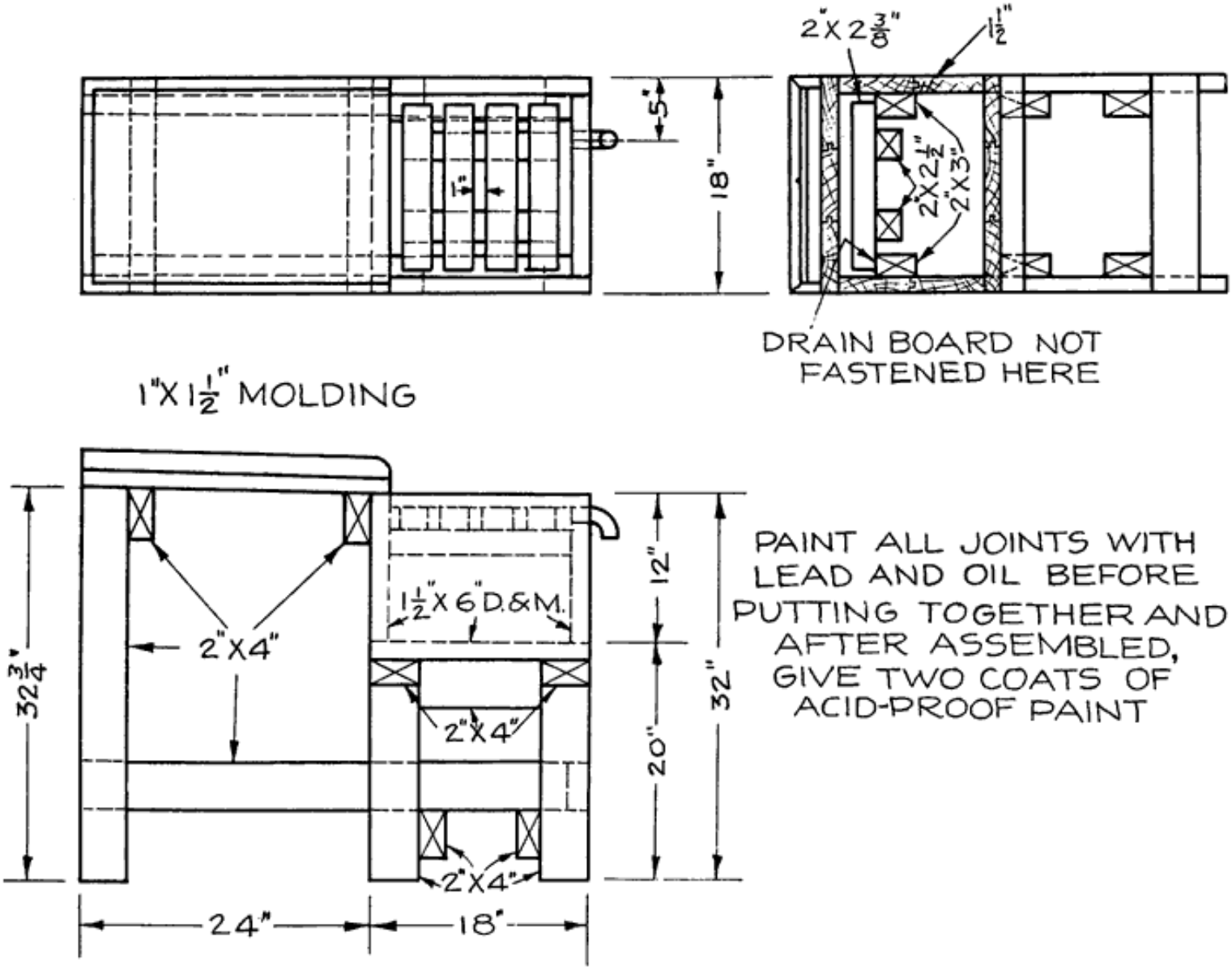

Fig. 76. Working Drawing of Wash Tank

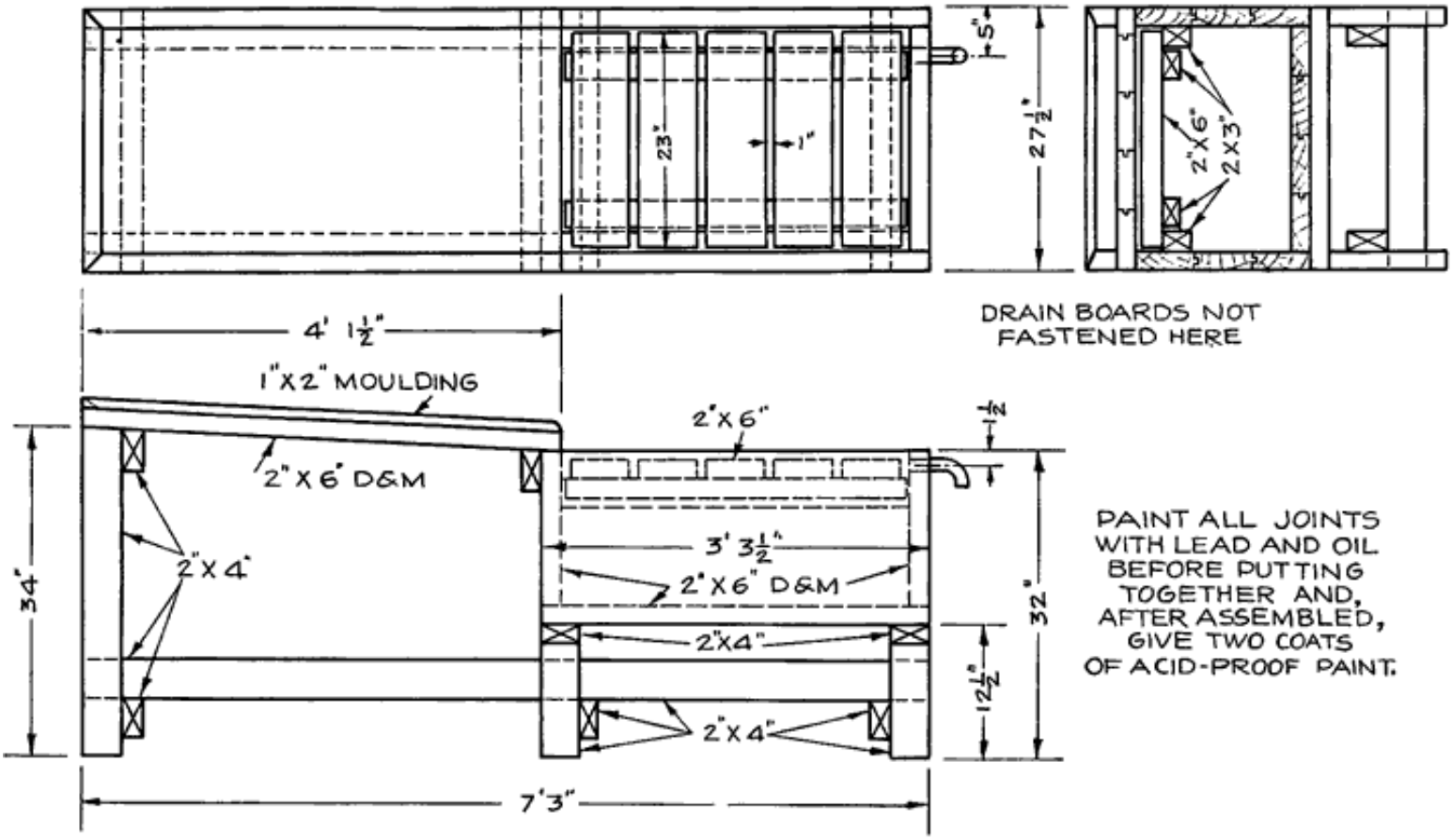

Fig. 77. Working Drawing of a Wash Tank

LEAD BURNING (WELDING) OUTFIT

In joining the connectors and terminals to the positive and negative posts, and in joining plate straps to form a "group," the parts are joined or welded together, melting the surfaces to be joined, and then melting in lead from sticks called "burning lead." The process of joining these parts in this manner is known as "lead burning." Directions for "lead burning" are given on page 210.

There are various devices by means of which the lead is melted during the "lead burning" process. The most satisfactory of these use a hot, pointed flame. Where such a flame is not obtainable, a hot carbon rod is used.

The methods are given in the following list in the order of their efficiency:

1. Oxygen and Acetylene Under Pressure in Separate Tanks. The gases are sent through a mixing valve to the burning tip. These gases give the hottest flame.

2. Oxygen and Hydrogen Under Pressure in Separate Tanks, Fig. 78. The flame is a very hot one and is very nearly as satisfactory as the oxygen and acetylene.

Fig. 78. Hydrogen-Oxygen Lead Burning Outfit. A and B are Regulating Valves. C is the Safety Flash Back Tank. D is the Mixing Valve. E is the Burning Tip.

3. Oxygen and Illuminating Gas. This is a very satisfactory method, and one that has become very popular. In this method it is absolutely necessary to have a flash back tank (Fig. 79) in the gas line to prevent the oxygen from backing up into the gas line and making a highly explosive mixture which will cause a violent explosion that may wreck the entire shop.

To make such a trap, any strong walled vessel may be used, as shown in Figure 79. A six to eight inch length of four inch pipe with caps screwed over the ends will make a good trap. One of the caps should have a 1/2 inch hole drilled and tapped with a pipe thread at the center. This cap should also have two holes drilled and tapped to take a 1/4 inch pipe, these holes being near the inner wall of the large pipe, and diametrically opposite one another.

Into one of these holes screw a short length of 1/4 inch pipe so Fig. 79. Flash-Back Tank for Lead Burning Outfit that it comes flush with the inner face of the cap. This pipe should lead to the burning outfit.

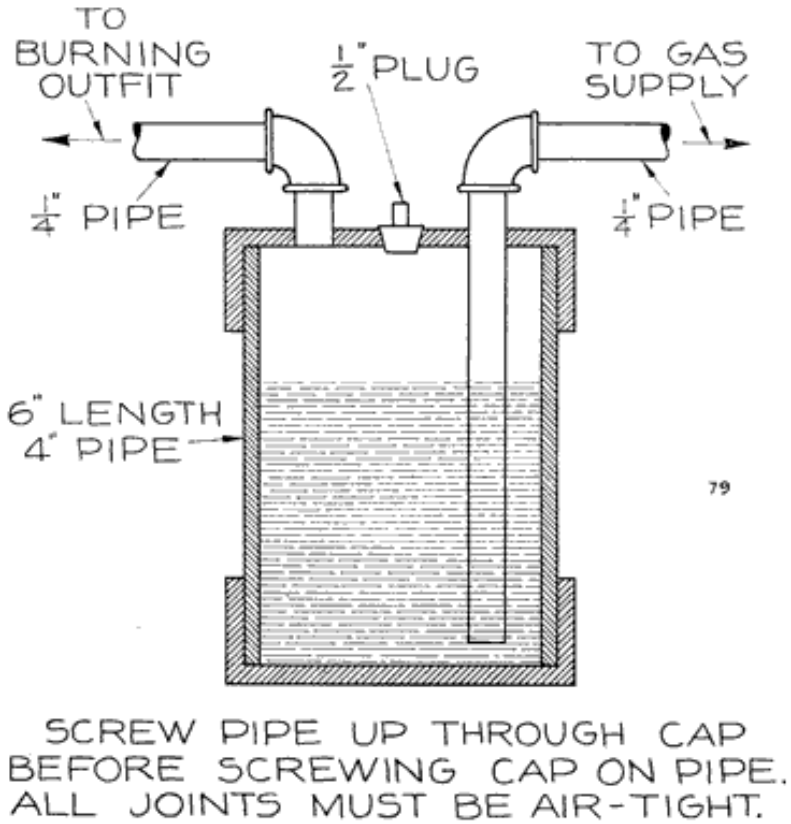

Fig. 79. Flash-Back Tank for Lead Burning Outfit

Into the other small hole screw a length of 1/4 inch pipe so that its lower end comes within 1/2 inch of the bottom of the trap. This pipe is to be connected to the illuminating gas supply.

To use the trap, fill within one inch of top with water, and screw a 1/2 inch plug into the center hole. All connections should be airtight.

4. Acetylene and Compressed Air. The acetylene is bought in tanks, and the air compressed by a pump.

5. Hydrogen and Compressed Air. This is the method that was very popular several years ago, but is not used to any extent at present because of the development of the first three methods. A special torch and low pressure air supply give a very satisfactory flame.

6. Wood Alcohol Torch. A hand torch with a double jet burner gives a very clean, nonoxidizing flame. The flame is not as sharp as the oxygen flame, and the torch is not easily handled without the use of burning collars and moulds. The torch has the advantage of being small, light and portable. A joint may be burned without removing the battery from the car.

7. Gasoline Torch. A double jet gasoline torch may be used, provided collars or moulds are used to prevent the lead from running off. The torch gives a broad flame which heats the parts very slowly, and the work cannot be controlled as easily as in the preceding methods.

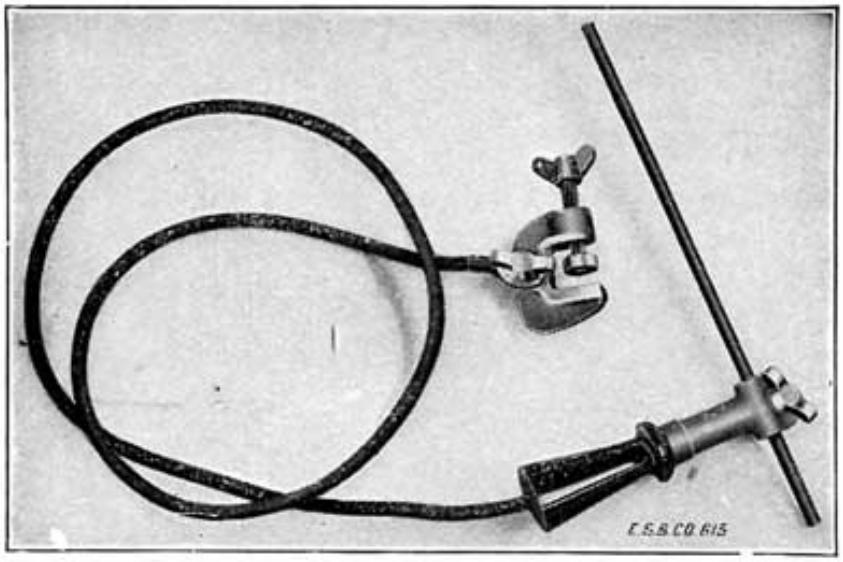

Fig. 80. Carbon Lead Burning Outfit

8. Carbon Arc. This is a very simple method, and requires only a spare 6 volt battery, a 1/4 inch carbon rod, carbon holder, cable, and clamp for attaching to battery. This outfit is shown in Fig. 80. It may be bought from the American Bureau of Engineering, Inc., Chicago, Ill. This outfit is intended to be used only when gas is not available, and not where considerable burning is to be done.

In using this outfit, one terminal of an extra 6 volt battery is connected by a piece of cable -with the connectors to be burned. The contact between cable and connector should be clean and tight. The cable which is attached to the carbon rod is then connected to the other terminal of the extra battery, if the battery is not fully charged, or to the connector on the next cell if the battery is fully charged. The number of cells used should be such that the carbon is heated to at least a bright cherry red color when it is touching the joint which is to be burned together.

Sharpen the carbon to a pencil point, and adjust its position so that it projects from the holder about one inch. Occasionally plunge the holder and hot carbon in a pail of water to prevent carbon from overheating. After a short time, a scale will form on the surface of the carbon, and this should be scraped off with a knife or file.

In burning in a connector, first melt the lead of the post and connector before adding the burning lead. Keep the carbon point moving over all parts to be joined, in order to insure a perfectly welded joint.

9. Illuminating Gas and Compressed Air. This is the slowest method of any. Pump equipment is required, and this method should not be used unless none of the other methods is available.

The selection of the burning apparatus will depend upon individual conditions as well as prices, and the apparatus selected should be one as near the beginning of the foregoing list as possible. Directions for the manipulation of the apparatus are given by the manufacturers.

The most convenient arrangement for the lead burning outfit is to run pipes from one end of the work bench to the other, just below the center shelf. Then set the gas tanks at one end of the bench and connect them to the pipes. At convenient intervals have outlets for attaching the hoses leading to the torch.

EQUIPMENT FOR HANDLING SEALING COMPOUND

(a) Stove. Where city gas is available, a two or three burner gas stove or hot-plate should be used. Where there is no gas supply, the most satisfactory is perhaps an oil stove. It is now possible to get an odorless oil stove which gives a hot smokeless flame which is very satisfactory. In the winter, if a coal stove is used to heat the shop, the stove may also be used for heating the sealing compound, but it will be more difficult to keep the temperature low enough to

prevent burning the compound.

(b) Pot or Kettle. An iron kettle is suitable for use in heating compound. Special kettles, some of which are non-metallic, are on the market, and may be obtained from the jobbers.

(c) An iron ladle should be obtained for dipping up compound, and for pouring compound when sealing a battery. Figure 81 shows a convenient form of ladle which has a pouring hole in the bottom. A taper pin, which is raised by the extra handle allows a very fine stream of compound to be poured.

The exact size of the ladle is not important, but one which is too heavy to be held in one hand should not be used.

(d) Several old coffee pots are convenient, and save much time in sealing batteries.

Sealing compound is a combination of heavy residues produced by the fractional distillation of petroleum. It is not all alike-that accepted for factory use and distribution to Service Stations must usually conform to rigid specifications laid down by the testing laboratories governing exact degrees of brittleness, elongation, strength and melting point. For these qualities it is dependent upon certain volatile oils which may be driven off from the compound if the temperature of the molten mass is raised above the comparatively low points where some of these oils begin to volatilize off as gaseous vapor or smoke.

Compound from which certain of these valuable constituent oils have been driven off or "burned out" through overheating is recognized through too great BRITTLENESS and SHRINKAGE on cooling, causing "CRACKED COMPOUND" with all of its attending difficulties.

Fig. 81. Pouring Ladle

Do not put too much cold compound in the kettle to begin with. It is not advisable to carry much more molten compound in the kettle at any time than can easily be dipped out-cold compound may be added during the day as needed. When there is considerable cold compound in the kettle and the,, heating flame is applied, the lower bottom part of the mass next to the surface of the iron is brought to a melting point first-heat must be conveyed from this already hot part of the compound upward throughout the whole mass-so that before the top part of it is brought to a molten condition the lower inside layers are very hot indeed. If there is too much in the kettle these lower layers are necessarily raised in temperature beyond the point where they lose some of their volatile oils-they are "burned" before the whole mass of compound can be brought to a molten state.

Do not use too large a heating flame under the kettle. for the same reasons. A flame turned on "full blast" will certainly "burn" the bottom layers before the succeeding layers above are brought to the fusion point. USE A SLOW FLAME and TAKE TIME IN MELTING UP THE COMPOUND. It PAYS in the resulting jobs.

The more compound is heated, the thinner it becomes-it should never be allowed to become so hot that it flows too freely -it should never exceed the viscosity of medium molasses. It should flow freely enough to run in all narrow spaces but NOT freely enough to flow THROUGH them before it cools.

Stir the kettle frequently during the day. It is advisable about once a week to work as much compound out of the kettle as possible, empty that still remaining, clean the kettle out, and start with fresh compound.

NEVER USE OLD COMPOUND OVER AGAIN-that is, do not throw compound that has been dug out of used batteries into the kettle with the new compound. The old compound is no doubt acid soaked, and this acid will work through the whole molten mass, making a satisfactory job a very doubtful matter indeed.

Cold weather hardens sealing compound, of course, and renders it somewhat brittle and liable to crack. This tendency could be overcome by using a softer compound, but, on the other hand, compound so soft that it would have no tendency to crack in cold weather would be so soft in warm weather that it would fail to hold the assembly with the necessary firmness and security. It is far better policy to run the risk of developing a few cracks in the winter than a loose assembly in summer. Surface cracks developed in cold weather may be easily remedied by stripping off the compound around the crack with a heated tool, flashing with the torch and quickly re-sealing according to the above directions.

It is not practical to work any oil agent, such as paraffin or castor oil, into the compound in an effort to soften it for use in cold weather.

SHELVING AND RACKS

The essential things about shelving in a battery shop are, that it must be covered with acid-proof paint, and must be made of heavy lumber if it is to carry complete batteries. Figure 82 shows the heavy shelving required in a stock-room, while Figure 83 shows the lighter shelving which may be used for parts, such as jars, cases, extra plates, and so on.

Fig. 82.

Fig 82. Typical Stockroom, Showing Heavy Shelving Necessary for Storing Batteries.

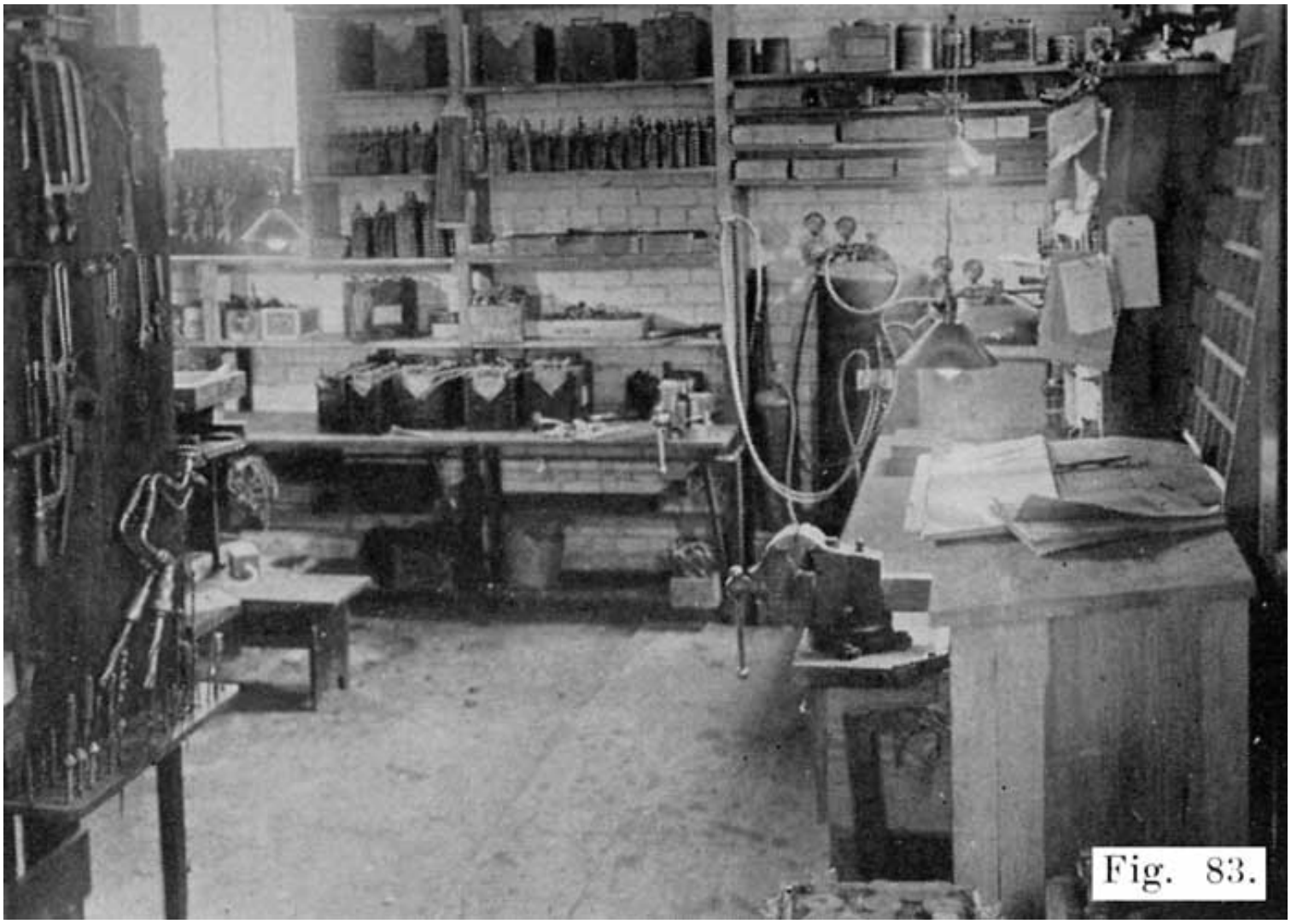

Fig. 83. Corner of Workshop, Showing Lead Burning Outfit, Workbench and Vises.

Figures 84 and 85 show two receiving racks for batteries which come in for repairs. In many shops batteries are set on the floor while waiting for repairs. If there is plenty of floor space, this practice is not objectionable. In any case, however, it improves the looks of the shop, and makes a better impression on the customer to have racks to receive such batteries. Note that the shelves are arranged so as to permit acid to drain off. Batteries often come in with wet, leaky cases, and this shelf construction is suitable for such batteries.

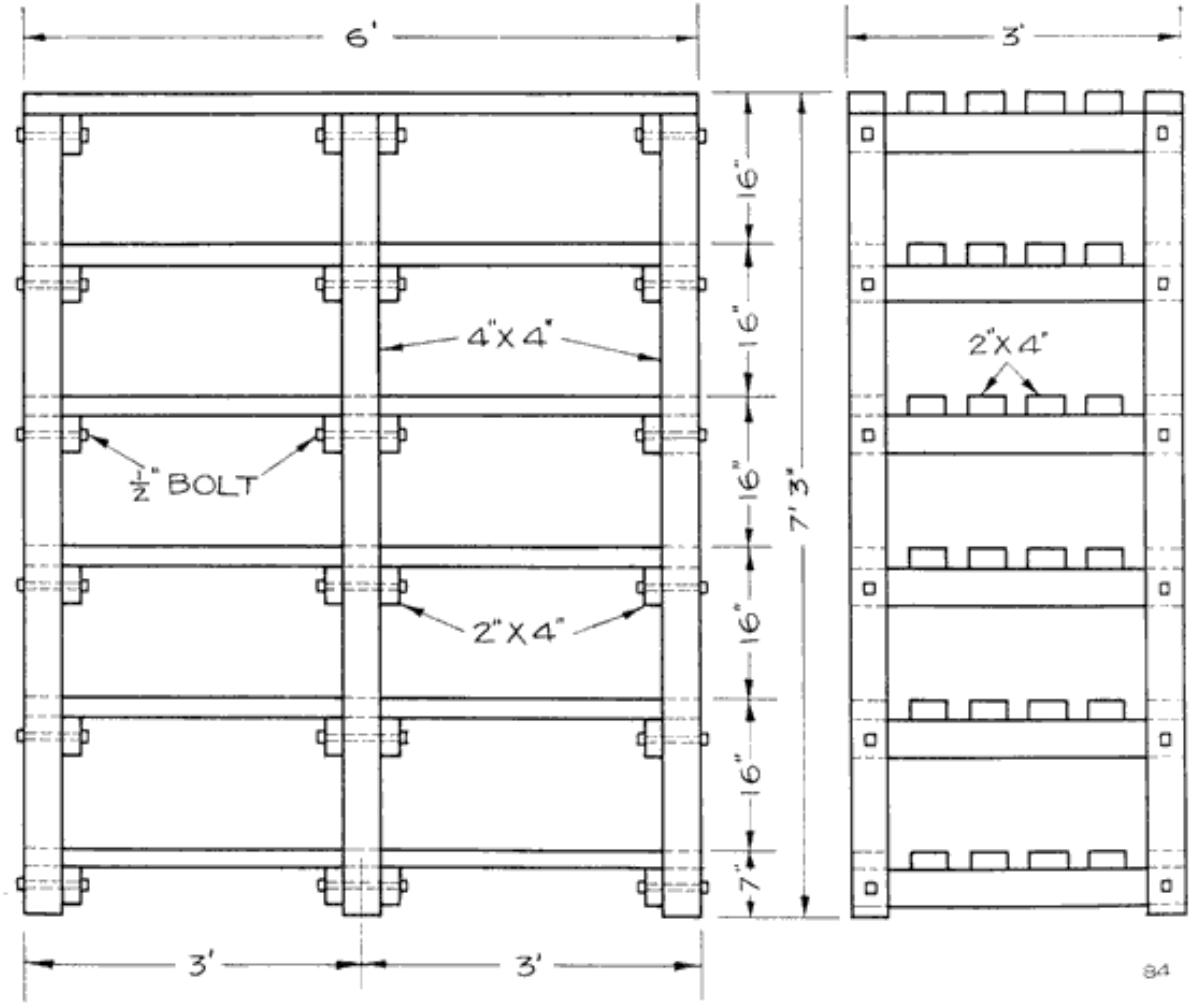

APPLY TWO COATS OF BLACK ACID-PROOF PAINT

Fig. 84. Working Drawing of Receiving Rack

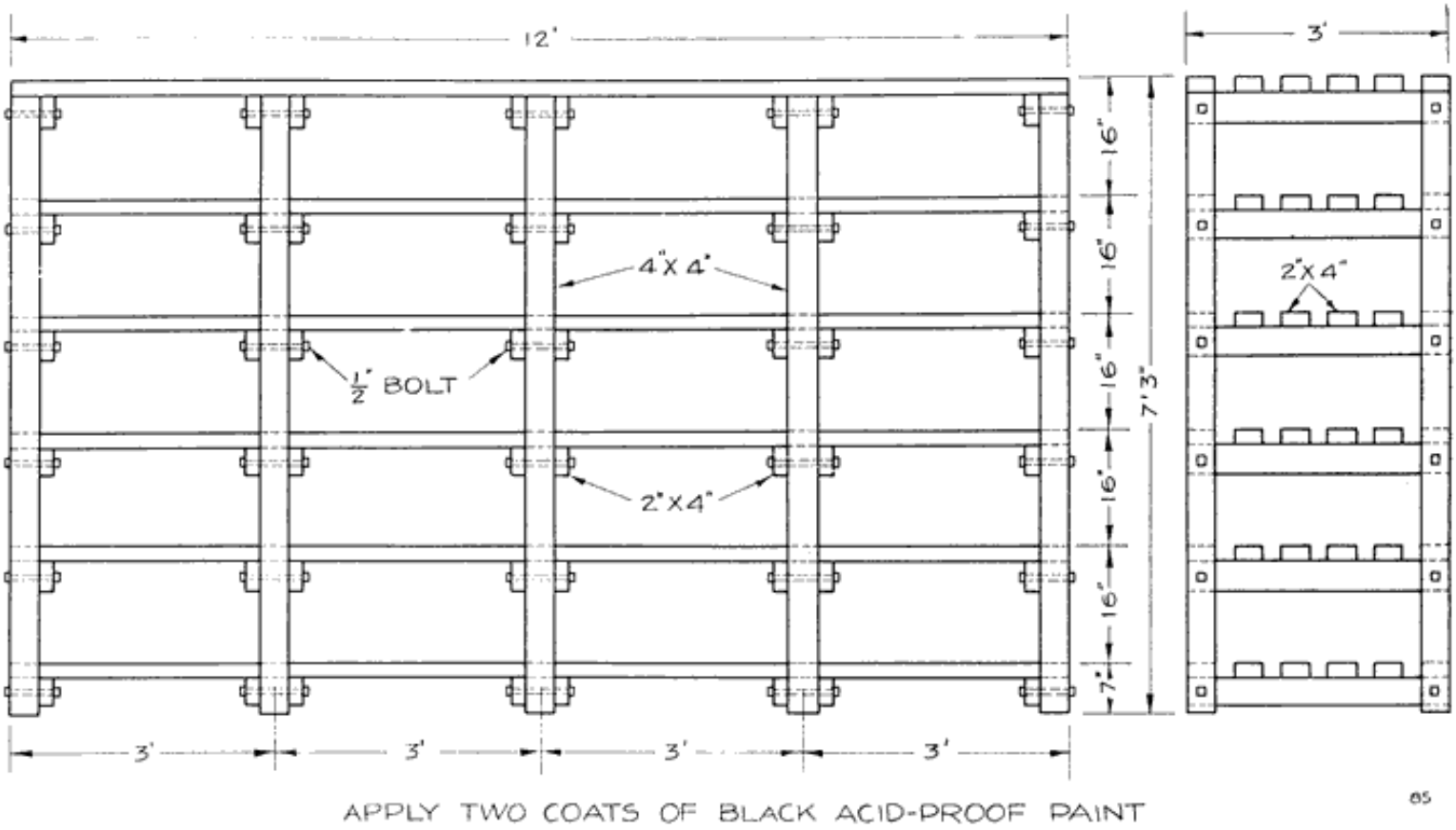

Fig. 85. Working Drawing of Receiving Rack

The racks shown in Figures 86 and 87 are for repaired batteries, new batteries, rental batteries, batteries in dry storage, and for any batteries which do not have wet leaky cases.

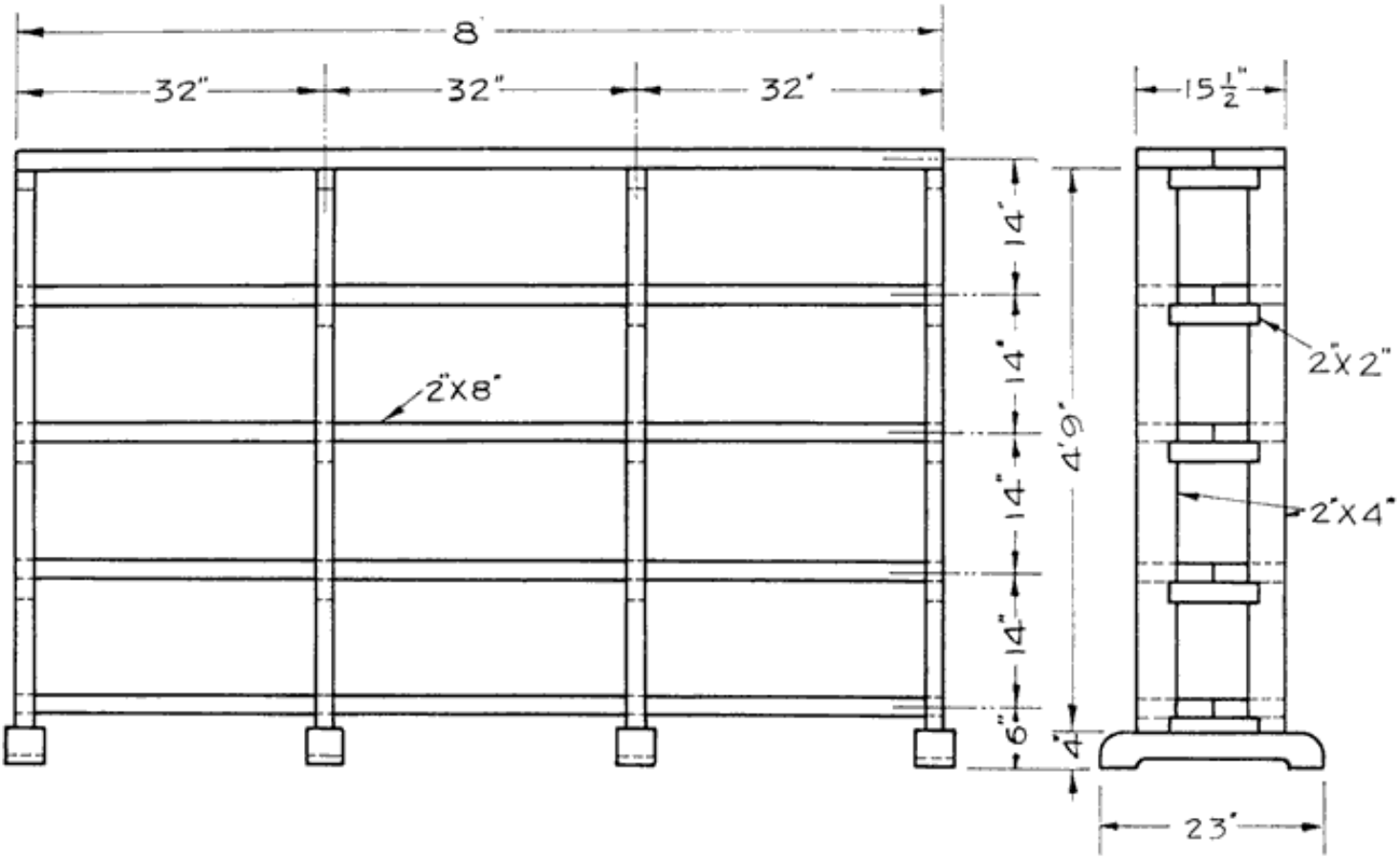

APPLY TWO COATS OF ACID-PROOF PAINT

86

Fig. 86. Working Drawing of Rack for Repaired Batteries, New Batteries. Rental Batteries, Batteries in Dry Storage, Etc.

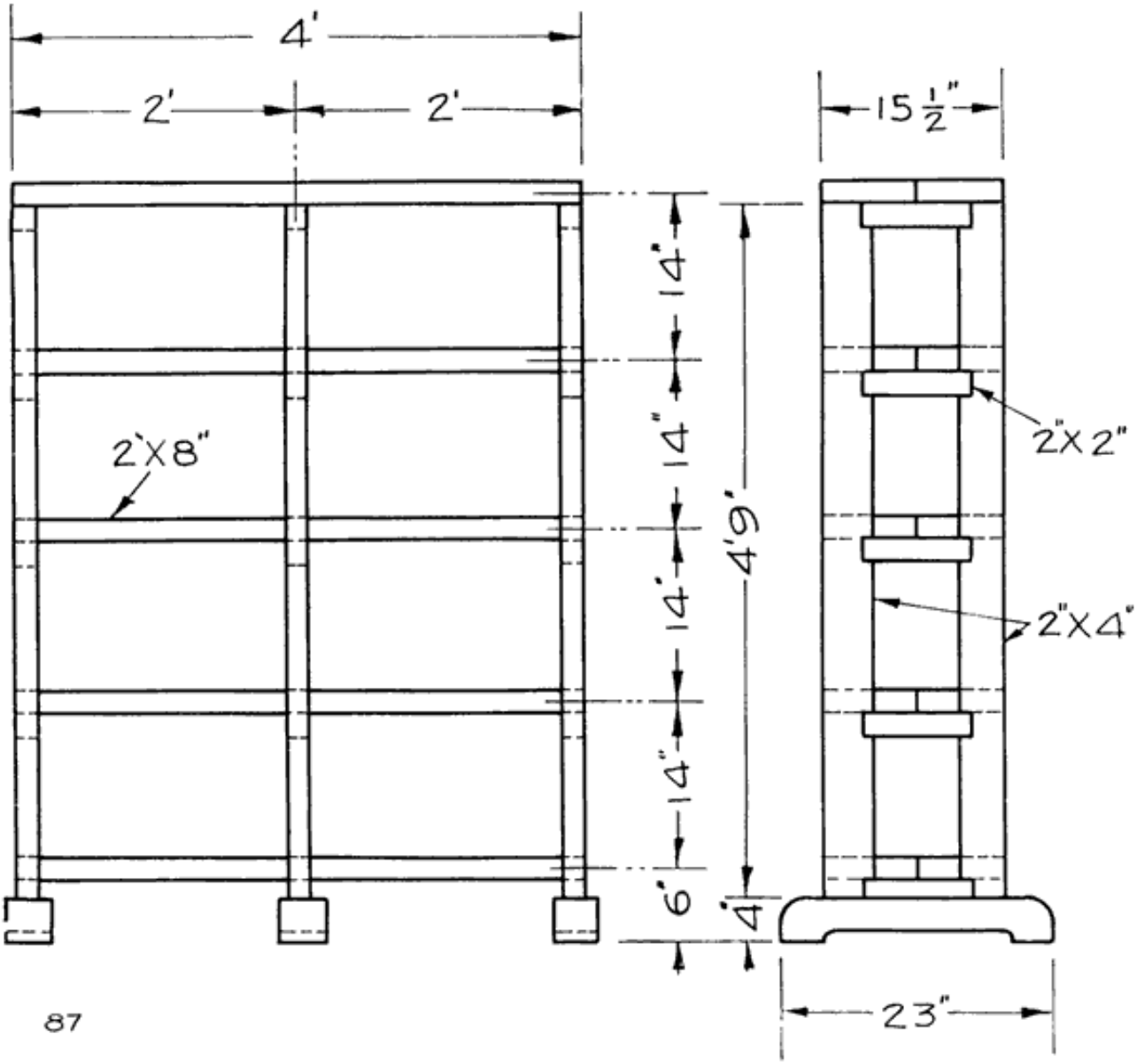

Fig. 87. Working Drawing of Rack for Repaired Batteries, New Batteries, Rental Batteries, Batteries in Dry Storage, Etc.

Figures 88 and 89 show racks suitable for new batteries which have been shipped filled with electrolyte, batteries in "wet" or "live" storage, rental batteries, and so on. Note that these racks are provided with charging circuits so that the batteries may be given a low charge without removing- them from the racks. Note. also that the shelves are spaced two feet apart so as to be able to take hydrometer readings, voltage readings, add water, and so on, without removing the batteries from the racks.

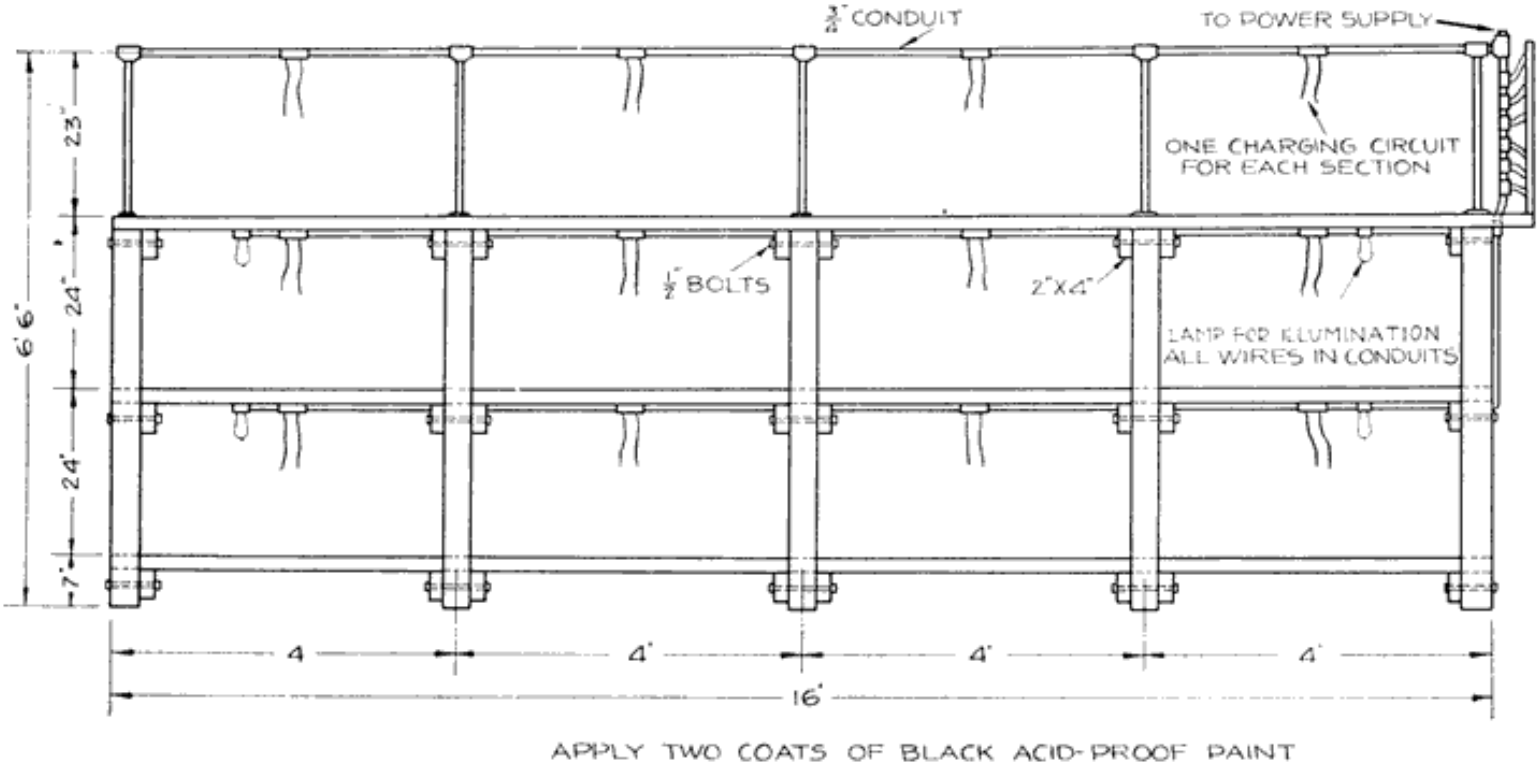

Fig. 88. Working Drawing of Rack Suitable for New Batteries (Shipped Filled and Fully Charged), Batteries in "Wet" Storage, Rental Batteries, Etc.

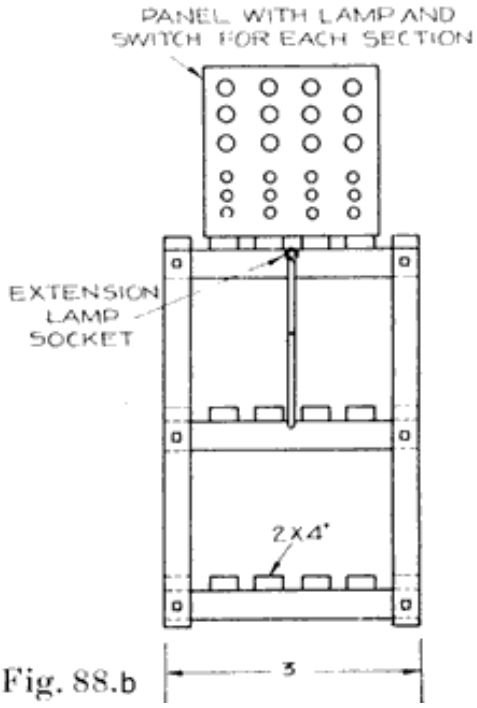

Fig. 88.b

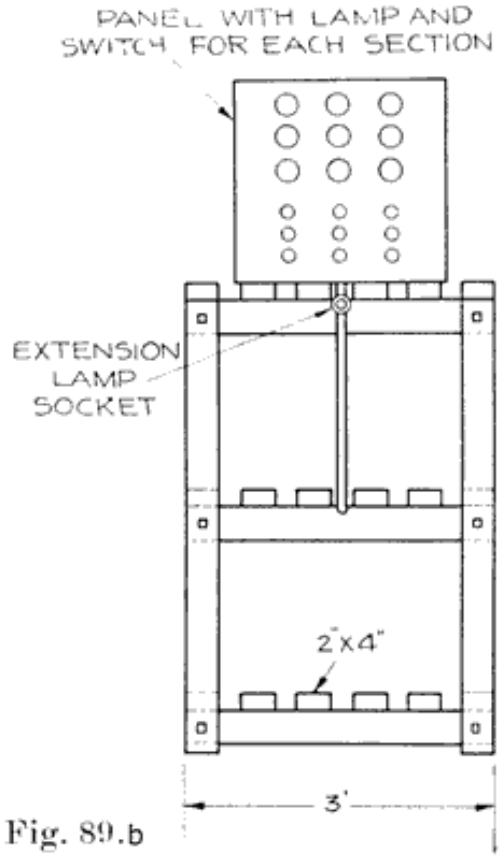

Fig. 89.b

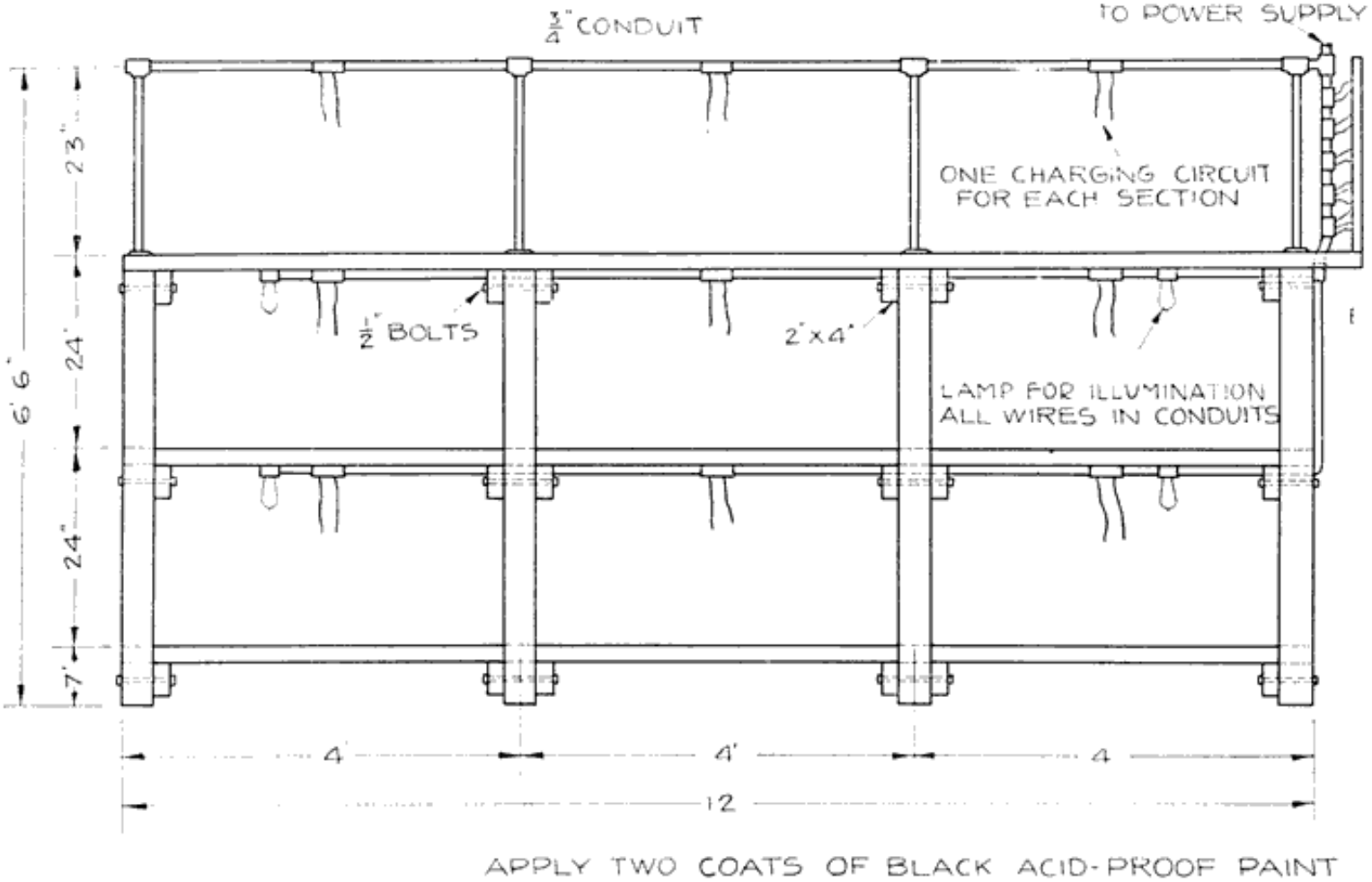

Fig. 89. Working Drawing of Rack Suitable for New Batteries (Shipped Filled and Fully Charged).Batteries in "Wet" Storage, Rental Batteries, Etc.

BINS

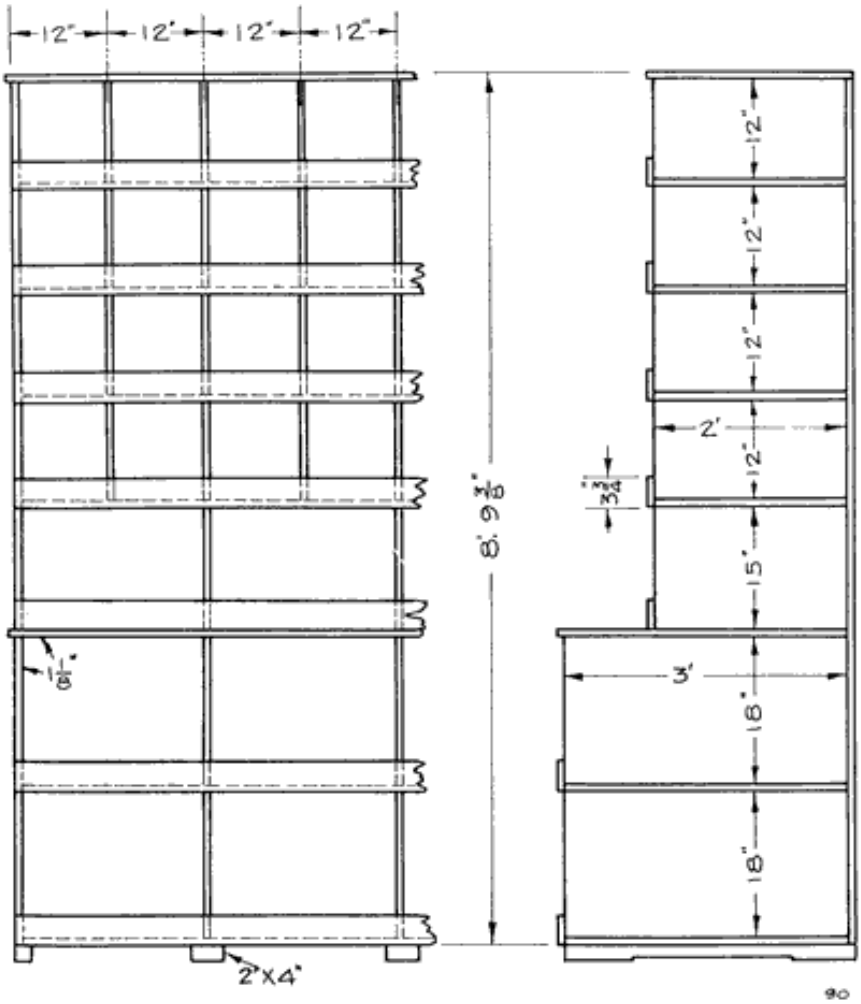

ALL MATERIAL 7/8" YELLOW PINE EXCEPT AS NOTED

Fig. 90. Working Drawing of Bins Suitable for Battery Parts

Figure 90 gives the dimensions for equipment bins suitable for covers, terminals, inter-cell connectors, jars, cases, and various other parts. These bins can be made with any desired number of sections, and additional sections built as they are needed.

BATTERY STEAMER

Steaming is the most satisfactory method of softening sealing compound, making covers and jars limp and pliable. An open flame should never be used for this work, as the temperature of the flame is too high and there is danger of burning jars and covers and making them worthless. With steam, it is impossible to damage sealing compound or rubber parts.

A soft flame from a lead burning torch is used to dry out the channels in the covers before sealing, and is run over the compound quickly to make the compound flow evenly and unite with the jars and covers. But in such work the flame is used for only a few seconds and is not applied long enough to do any damage.

With a steaming outfit, it is also possible to distill water for use in mixing electrolyte and replacing evaporation in the cells. The only additional equipment needed is a condenser to condense the steam into water.

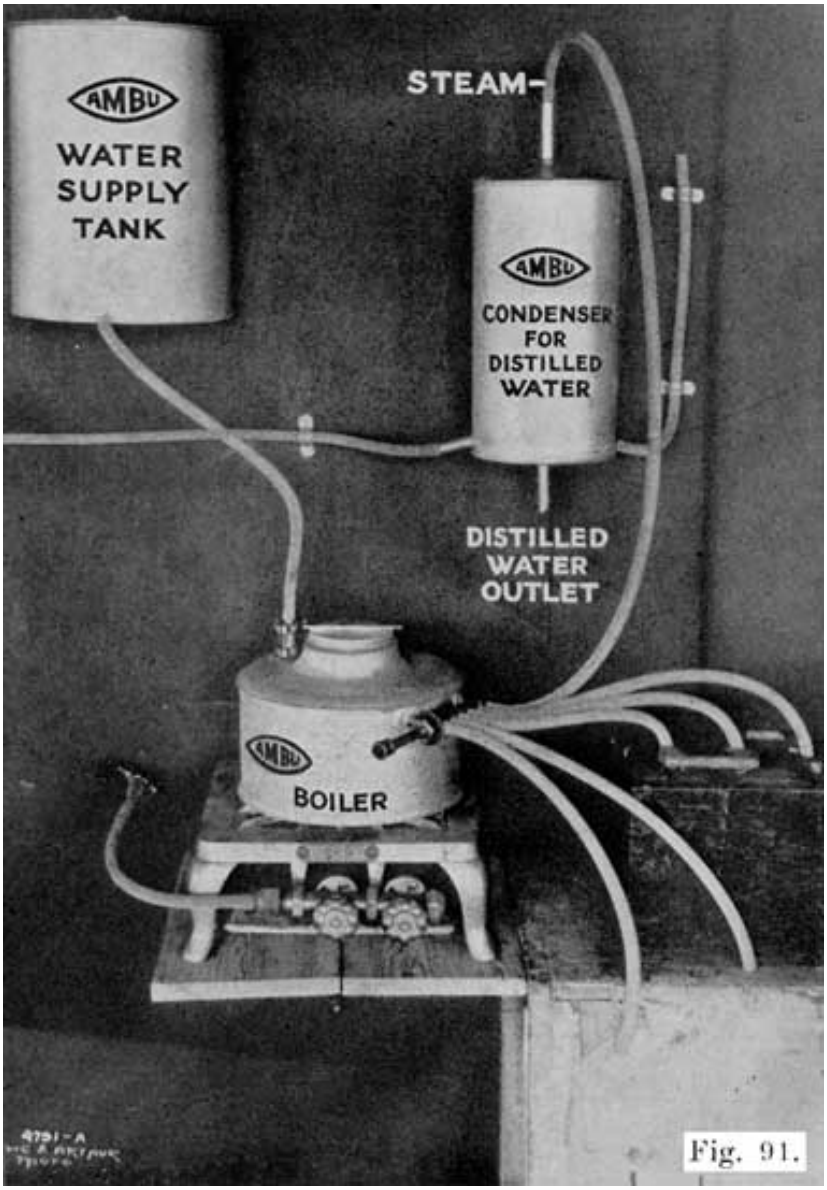

Fig. 91. Battery Steamer, with Steam Hose for Each Cell

Fig. 92. Condenser for Use with Battery Steamer.

Figure 91 shows a steaming outfit mounted on a wall, and shows the rubber tube connections between the several parts. The boiler is set on the stove, water being supplied from the water supply tank which is hung above the boiler to obtain gravity feed. The water supply tank is open at the top, and is filled every morning with faucet water. This tank is suitable for any shop, even though a city water supply is available. A water pipe. from the city lines may be run to a point immediately above the tank and a faucet or valve attached. Where there is no city water supply, the tank may, of course, be filled with a pail or pitcher.

The boiler is equipped with a float operated valve which maintains a one to one and one-half inch depth of water. As the water boils away, the float lowers slightly and allows water to enter the boiler. In this way, the water is maintained at the proper level at all times. A manifold is fitted to the boiler and has six openings to which lengths of rubber tubing are attached. These tubes are inserted in the vent holes of the battery which is to be steamed. Any number of the steam outlets may be opened by drawing out the manifold plunger valve to the proper point. When distilling water, a tube is attached to one of the steam outlets as shown, and connected to the condenser as shown. A bottle is placed under the distilled water outlet to collect the distilled water.

Cooling water enters the condenser through the tubing shown attached to the condenser at the lower right-hand edge.

The other end of this tube is attached to the water faucet, or other cooling water supply. The cooling water outlet is shown at the lower left hand edge of the condenser. The cooling water inlet and outlet are shown in Figure 92.

If there is no city water supply, a ten or twenty gallon tank may be mounted above the condenser and attached by means of a rubber tube to the cooling water inlet shown at the lower right hand edge of the condenser in Figure 92. A similar tank is placed under the cooling water outlet. The upper tank is then filled with water. When the water has run out of the upper tank through the condenser and into the lower tank, it is poured back into the upper tank. In this way a steady supply of cooling water is obtained.

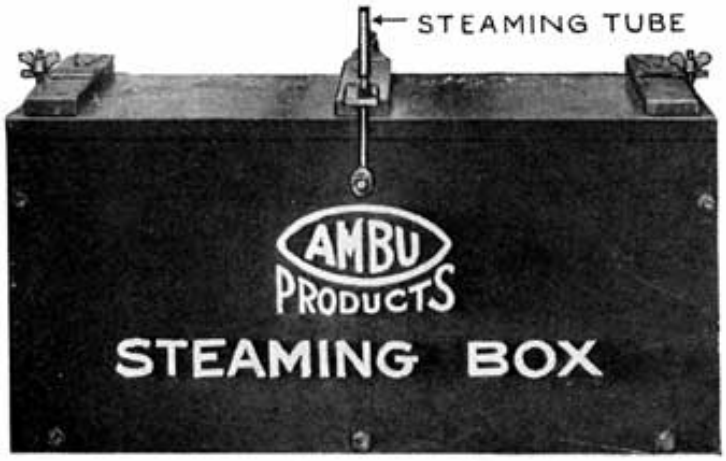

Fig. 93. Steaming Box in Which Entire Battery is Set

Another type of steamer uses a steaming box, Figure 93. The battery is placed in the box and steam is sent in through the cover. The boiler has only one steam outlet, and this is connected to the box by means of a hose.

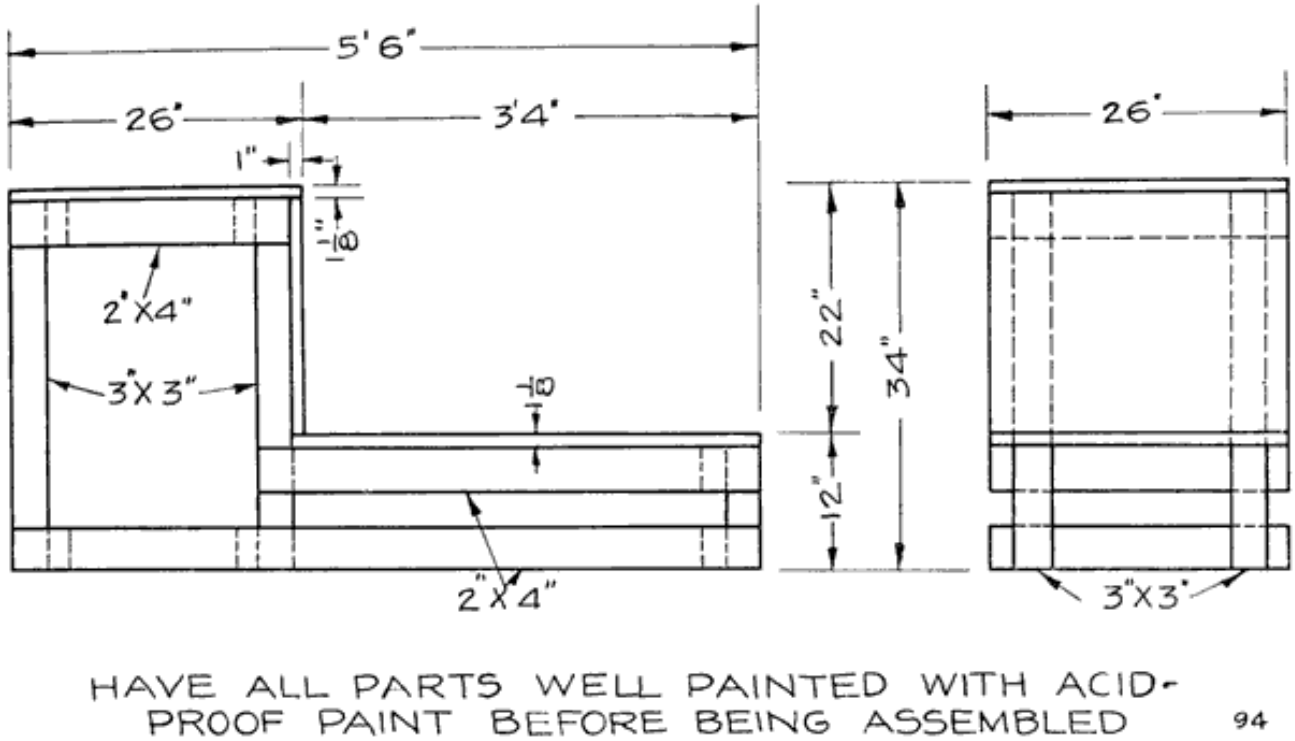

Fig. 94. Special Bench for Battery Steamer

If desired, a special bench may be made for the steaming outfit, as shown in Figure 94.

The other tools needed for opening batteries, as given in the list on page 97 are standard articles, and may be obtained at any hardware store, except the terminal tongs, which should be purchased from a battery supply house.

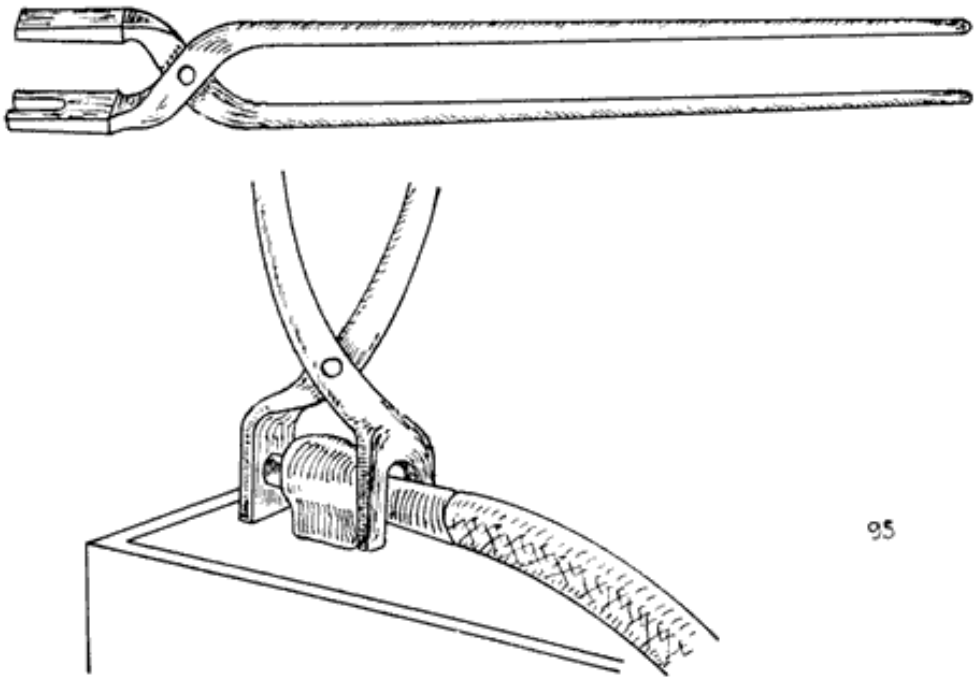

Fig. 95. Battery Terminal Tongs

Figure 95 illustrates the use of terminal tongs. Battery terminals usually stick so tight that they must be forced out with pliers or other tools. Here is shown a pair of tongs that makes easy work of the job. One end has a fork and the other is shaped to come between the fork. It is placed on the battery terminal, as shown, and when the handles are brought together the terminal attached to the battery lead is forced out without marring any of the parts.

EQUIPMENT FOR LEAD BURNING (WELDING)

Plate Burning Rack

The plates which compose a "group" are joined to the plate connecting strap to which the post is attached. The plates are "burned" to the strap, and this must be done in such a manner that the plates are absolutely parallel, that the distance between plates is correct, and that the top surface of the strap is at right angles to the surface of the plates. These conditions are necessary in order that the positive and negative groups may mesh properly, that the complete element, consisting of the plates and separators may fit in the jar properly, and that the cell covers may fit over the posts easily.

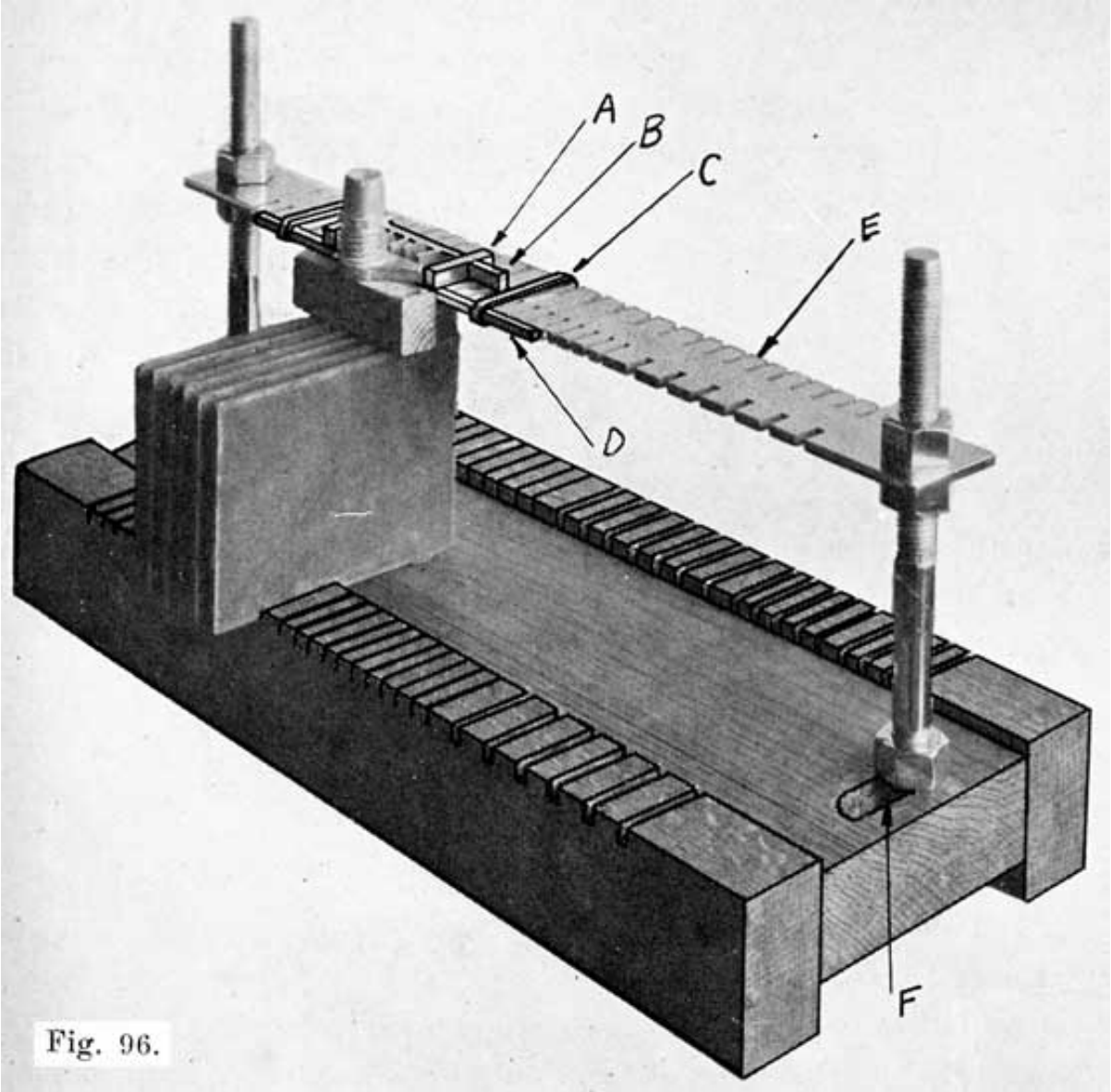

Fig. 96. Universal Plate Burning Rack. Will Hold Three Groups of Plates at One Time. Designed for Standard and Special Plates

In order to secure these conditions, plates that are to be burned to the strap are set in a "burning rack," shown in Figs. 96 and 97, which consists mainly of a base upon which the plate rest, and a slotted bar into which the lugs on the plates fit. The distance between successive slots is equal to the correct distance between the plates of the group. An improved form of burning rack has a wooden base which has slots along the side. The plates are set into these slots and are thus held in the correct position at both top and bottom.

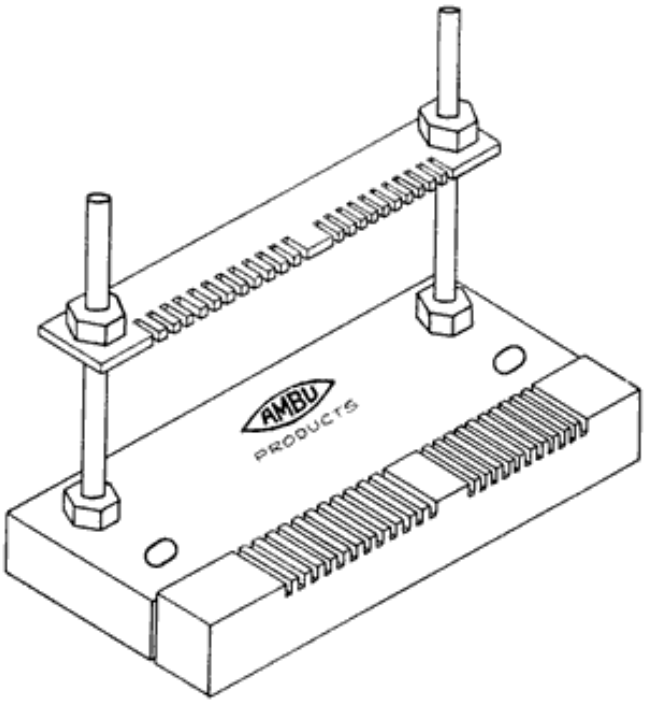

Fig. 97. Plate Burning Rack for Standard ⅛ Inch, and Thin Plates

Fig. 97 shows a rack for use with 1/8 inch and 7-64 inch plates. Fig. 96 shows a "Universal" rack which may be used with both the 1/8 and 7-64 inch plates, and also many special plates.

The guide-bar, or "comb," E, has slots along two sides, the base having corresponding slots, as shown. To accommodate different sized plates, the comb may be raised or lowered, and the uprights may be moved back and forth in two slots, one of which is shown at F. In using this rack, the plates are set in position, with their lower edges in the slots of the base, and their lugs in the slots in the comb. The plates are in this way held at opposite corners, and are absolutely straight and parallel.

Special fittings are provided to simplify the work of burning. A bar, D, fits along the edge of the comb, and holds the lugs of the plates firmly in the slots. This bar is movable to any part of the comb, being held by two spring clips, C. Two bars, A and B, which are adjustable, make a form around the plate lugs which will prevent the hot lead from running off while burning in the plates.

Instructions for burning on plates are given on page 217.

The triangular scraper, steel wire brush, coarse files and smoked or blue glasses are all standard articles and may be obtained from any supply house. The burning collars are made of iron, and are set over the end of inter-cell connectors when burning these to the posts, see Figure 98. Experienced repairmen generally do not use them, but those who have trouble with the whole end of the connector melting -and the lead running off should use collars to hold in the lead.

Fig. 98. Burning Collars

The Burning Lead Mould

In every shop there is an accumulation of scrap lead from post drillings, old connecting straps, old plate straps, etc. These should be kept in a special box provided for that purpose, and when a sufficient amount has accumulated, the lead should be melted and run off into moulds for making burning- lead.

The Burning Lead Mould is designed to be used for this purpose. As shown in Fig. 99, the mould consists of a sheet iron form which has been pressed into six troughs or grooves into which the melted lead is poured. This sheet iron form is conveniently mounted on a block of wood which has a handle at one end, making it possible to hold the mould while hot without danger of being burned. A sheet of asbestos separates the iron form from the wood, thus protecting the wood from the heat of the melted lead. A hole is drilled in the end of the handle to permit the mould being hung on a nail when not in use. The grooves in the iron form will produce bars of burning lead 15 inches long, 5-16 inch thick, 3/8 inch wide at the top, and 1/4 inch wide at the bottom.

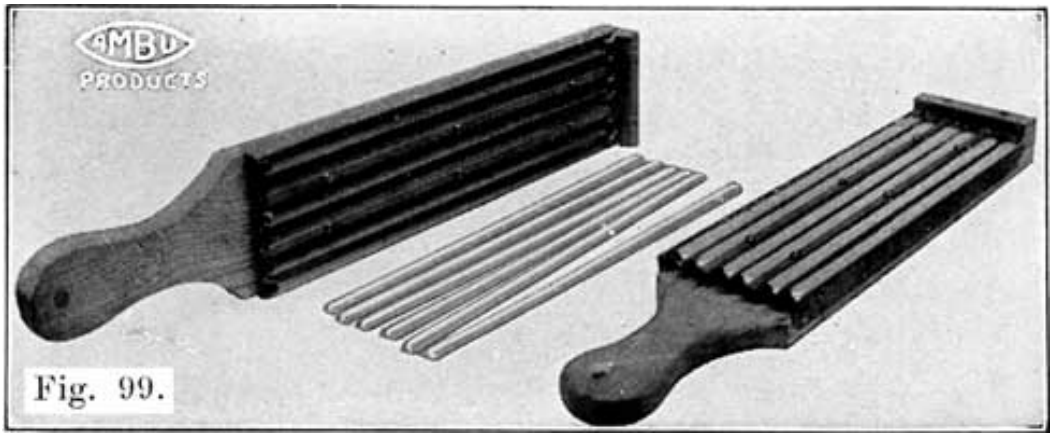

Fig. 99. Burning-Lead Moulds, and Burning Sticks Cast in Them

The advantage of this type of Burning Lead Mould over a cast iron mould is obvious. The form, being made of sheet iron, heats up very quickly, and absorbs only a very small amount of heat from the melted lead. The cast-iron mould, on the other hand, takes so much heat from the melted lead that the latter cools very quickly, and is hard to handle.

An iron pot that will hold at least ten pounds of molten lead should be used in melting up lead scraps for burning sticks.

When the metal has become soft enough to stir with a clean pine stick skim off the dross. Continue heating metal until slightly yellow on top.

With a paddle or ladle drop in a cleaning compound of equal parts of powdered rosin, borax and flower of sulphur. Use a teaspoonful for a ten-pound melting and make sure the compound is perfectly dry.

Stir a little and if metal is at proper heat there will be a flare, flash or a little burning. A sort of tinfoil popcorn effect will be noticed floating on top of the metal. Stir until this melts down. Have your ladle hot and skim off soft particles. Dust the mould with mould compound, a powder which makes the lead fill the entire grooves, and not become cool before it does.

When everything is ready, fill the ladle and pour the lead into one of the grooves. Hold the ladle above one end of the groove while pouring, and do not move it along the groove. Fill the other grooves in a similar manner.

Post Builders. These are moulds which are set over the stumps of -posts which have been drilled short in removing the inter-cell connectors. Lead is then melted in with a burning flame to build the post up to the proper height. Figure 100 shows a set of post-builders, and Figure 101 illustrates their use.

Fig. 100. Set of Post Builders

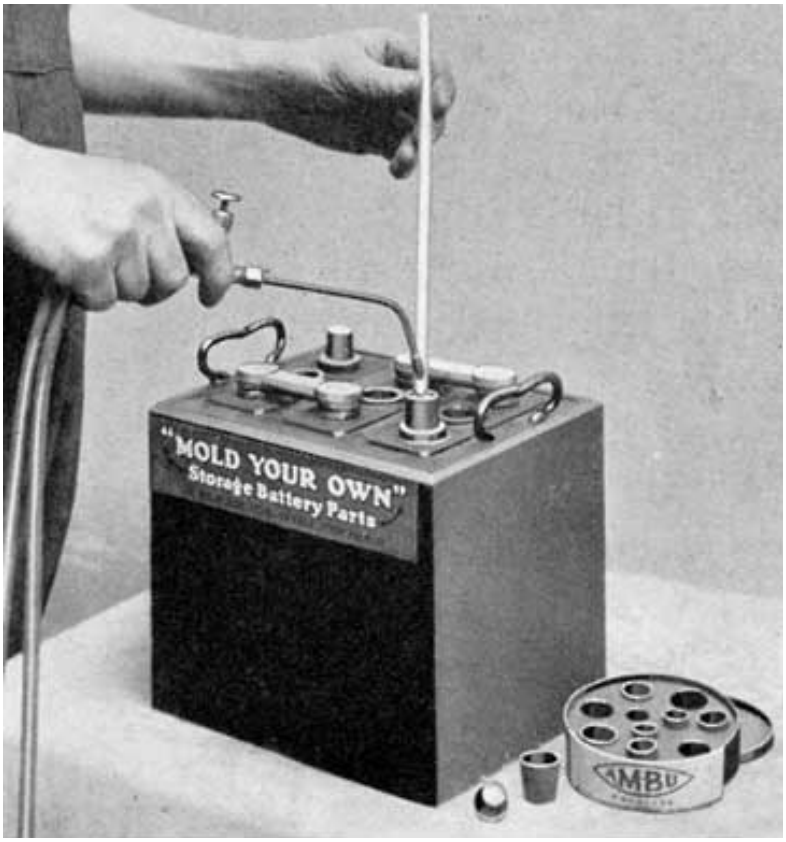

Fig. 101. Illustrating Use of Post Builders

Fig. 102. Plate Strap Mould

EQUIPMENT FOR GENERAL WORK ON

CONNECTORS AND TERMINALS

Moulds for Casting Inter-Cell Connectors, Terminals, Terminal

Screws, Taper Lugs, Plate Straps, Etc.

Figure 102 shows a plate strap mould with which three straps and posts may be cast in one minute. It has a sliding movable tooth rack for casting an odd or even number of teeth on the strap.

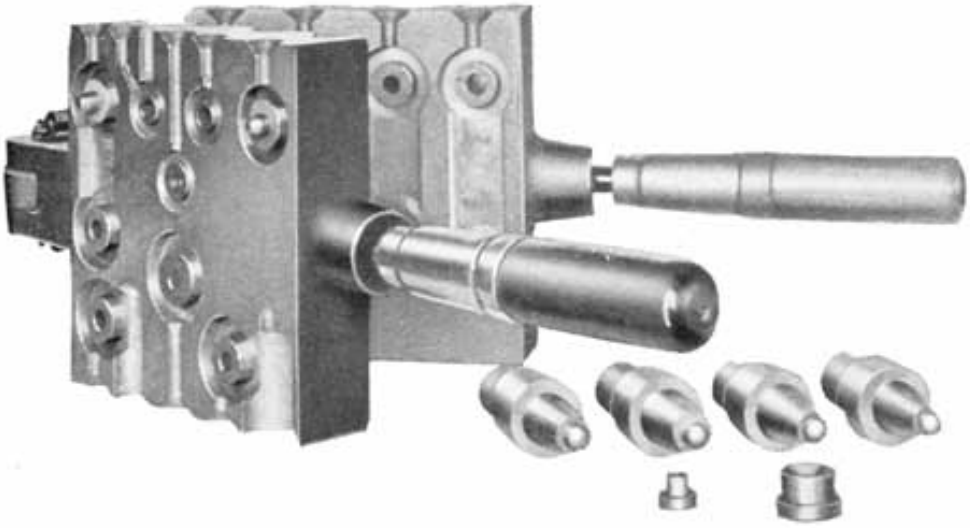

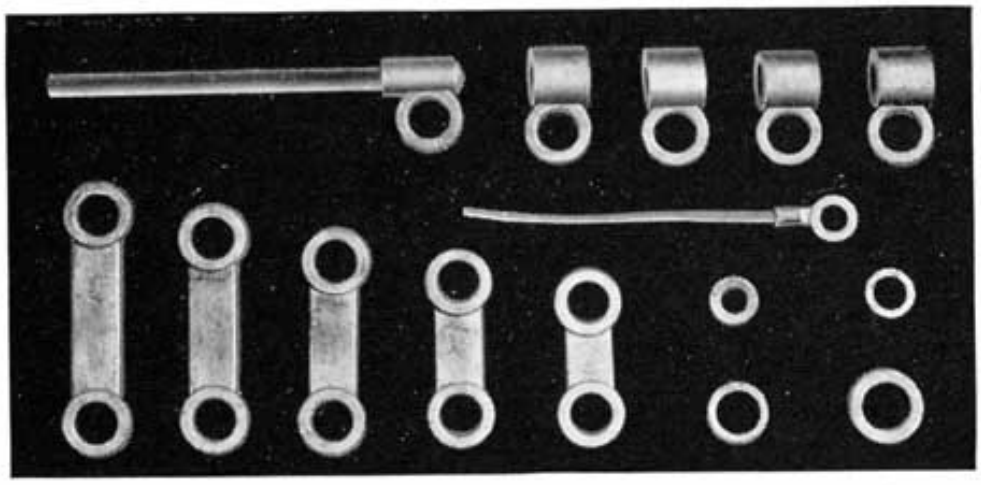

Figs. 103 and 104. Link Combination Mould, and Castings Made in It

Figure 103 shows a Link Combination Mould which casts five inter-cell connectors for use on standard 7, 9, 11, 13 and 15 plate batteries, four end connectors (two Dodge tapers, and standard tapers, negative and positive), one end connector with 3/8 inch cable used on 12 volt Maxwell battery and on all other cars a wire cable, and- one small wire

to connect with end post on batteries requiring direct connection. It also casts two post support rings to fit standard size rubber covers and to fit posts cast with plate strap mould, and two washers which are often needed when installing new or rental batteries.

Figure 104 shows the parts which may be made with this mould.

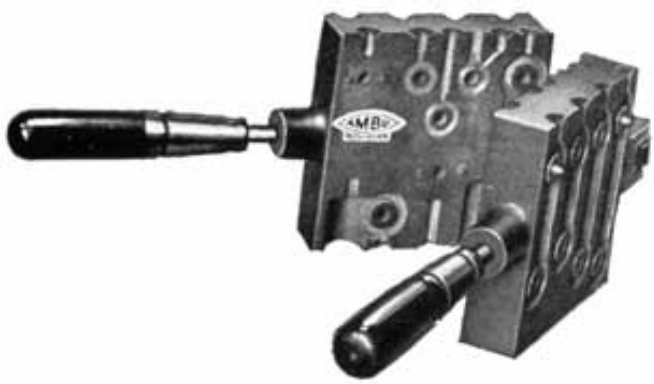

Fig. 105. Cell Connector Mould

Fig. 106

Figure 105 shows a cell connector mould which casts practically all the cell connectors used on standard 7, 9, 11, 13 and 15 plate batteries. This mould is similar to the Link Combination Mould shown in Figure 103.

Fig. 107

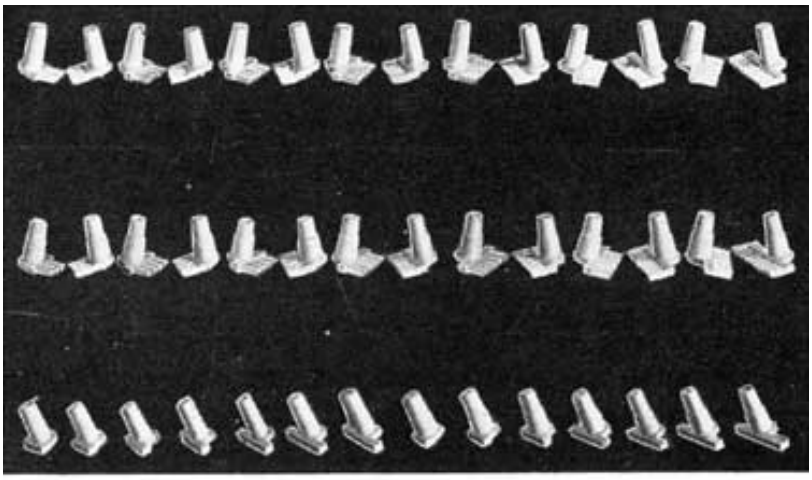

Fig. 108

Figure 106 shows a production type strap mould which is designed to be used by large battery shops. Forty-two styles of straps are, cast by this mould. This mould has an indexing device as shown in Figure 107, which is adjusted by means of a screw for moulding the straps for any number of plates from seven to nineteen. Figure 109 shows some of tile castings which are made with this mould.

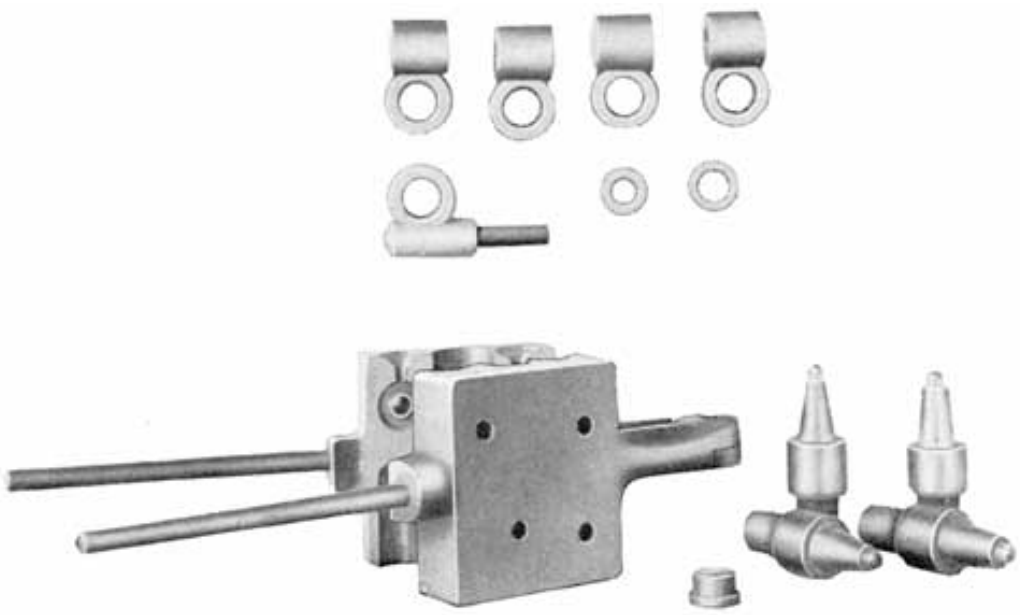

Fig. 109. Terminal Mould and Castings Made in It

Figure 109 shows a Terminal Mould which casts five reversible end terminal connectors, a cable connector, such. as is used on the Maxwell battery, and two washers often needed in making a tight connection.

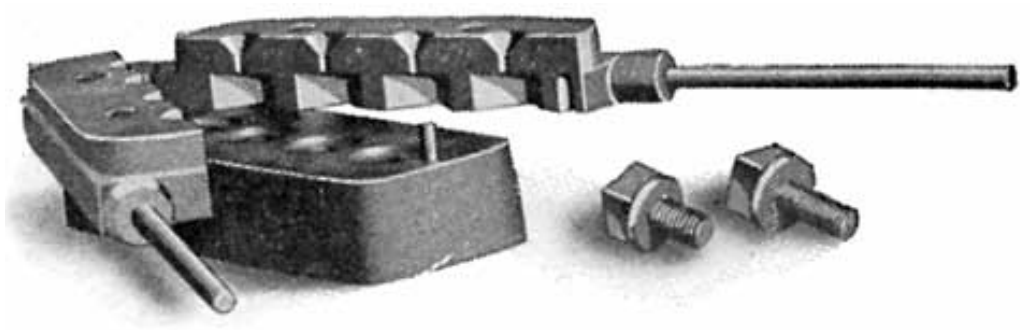

Fig. 110. Screw Mould

Figure 110 shows a Screw Mould which casts standard square lead leads on four screws in one operation, two 5/8 inch and two 3/8 inch. This mould has a screw adjustment in the base which makes each cavity adaptable to any length screw.

EQUIPMENT FOR WORK ON CASES

The acid proof asphaltum paint, paint brushes, wood chisels, wood plane, and earthenware jars are all standard articles.

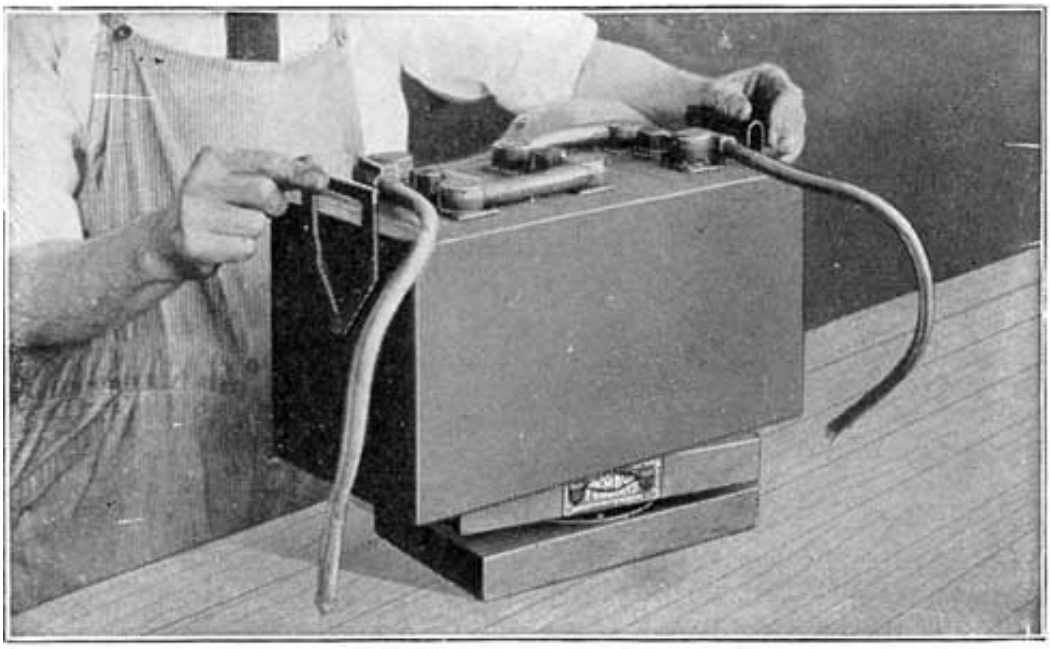

Fig. 111. Battery Turntable

Figure 111 shows a battery turntable which is very convenient when painting cases, lead burning, etc.

TOOLS FOR GENERAL WORK

Most of the articles in this list require no explanation. Some of them, however, are of special construction.

Separator Cutter. Some battery supply houses sell special separator cutters, but a large size photograph trimmer is entirely satisfactory.

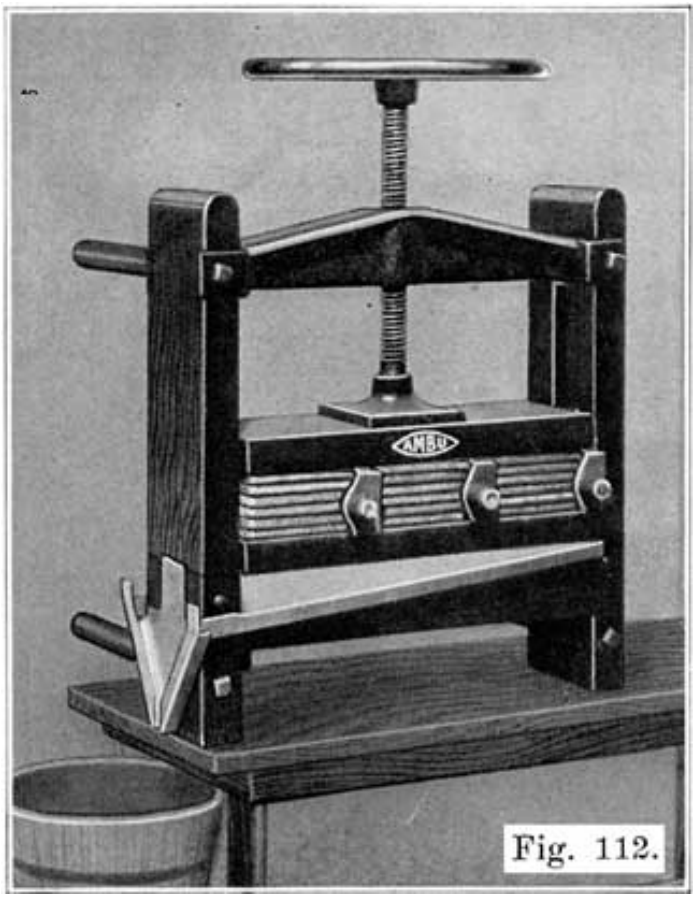

Fig. 112. Plate Press for Pressing Swollen, Bulged Negatives (After Plates Have Been Fully Charged)

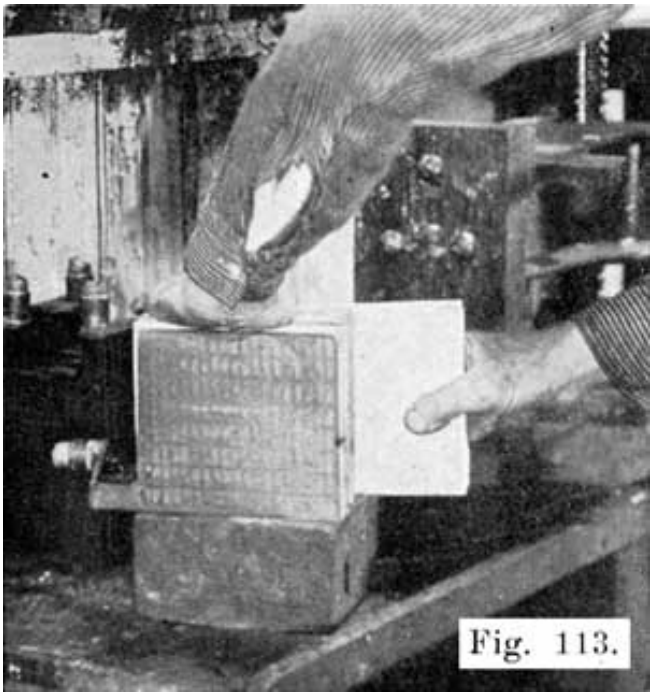

Fig. 113. Inserting Plate Press Boards Between Negatives Preparatory to Pressing

Plate Press. Figure 112 shows a special plate press in which the plates are pressed between wooden jaws. No iron can come into contact with the plates. This is a very important feature, since iron in solution causes a battery to lose its charge very quickly. This press is made of heavy hardwood timbers, and may be set on a bench or mounted on the - wall. A set of lead coated troughs carry away the acid which is squeezed from the plates.

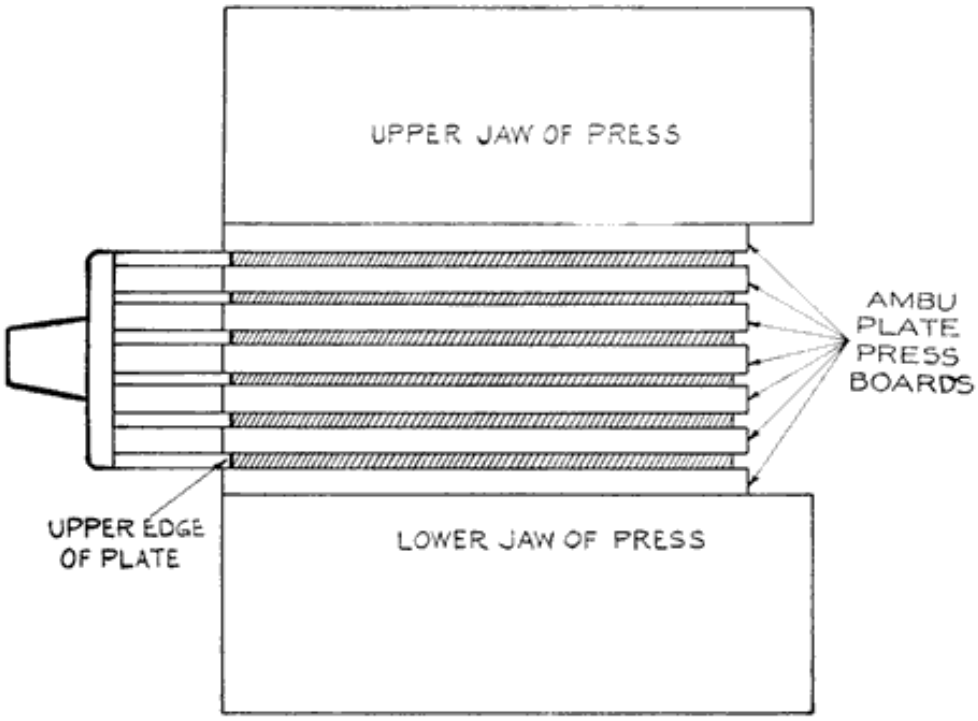

Fig. 114. Showing How Negatives Should be Placed in the Plate Press

This press- is designed for pressing negative plates, the active material of which has become bulged or swollen. A plate in this condition has a low capacity and cannot give good service. Swollen negatives often make it impossible to replace the plates in a jar. When negatives are found to be bulged or swollen, the battery must be fully charged, and the negatives then pressed. To do this, plate press boards, which are of acid proof material, and of the proper thickness are inserted between the negatives, as shown in Figure 113, and the plates are then set in the press is shown in Figure 114.

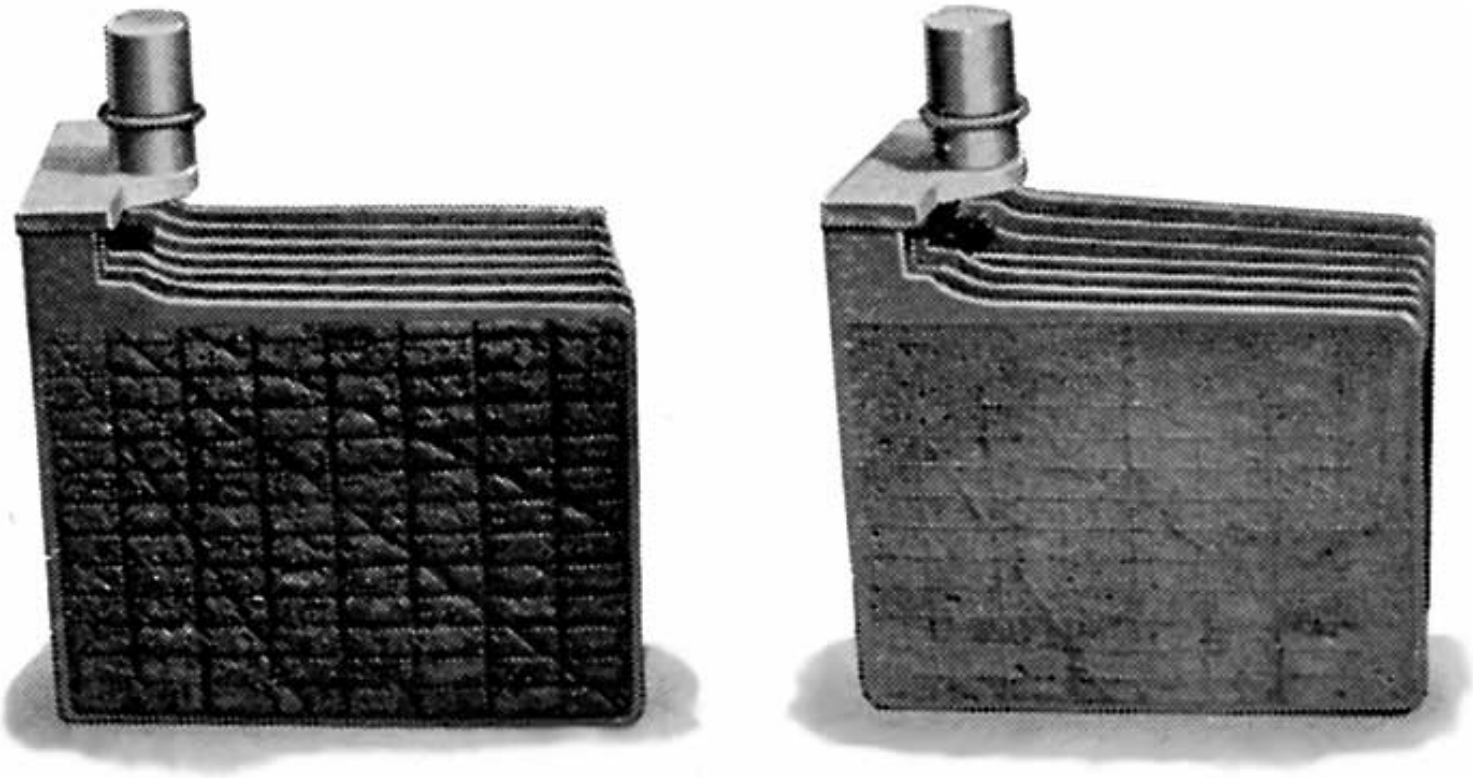

Fig. 115. Negative Group Before and After Pressing

Figure 115 shows a group before and after pressing. Note that pressing has forced the active material back into the grid where it must be if the plates are to give good service. **Never send out a battery with swollen or bulged negatives.**

Slightly buckled negatives may also be straightened out in the Plate Press. Positives do not swell or bulge as they discharge, but shed the active material. They are therefore not pressed Positives buckle, of course, but should never be pressed to straighten them. The lead peroxide of the positive plates is not elastic like the spongy the negatives, and if positives are pressed to straighten them the paste will crack and break from the grid. Slightly buckled positives may be used, but if they are so badly buckled that it is impossible to reassemble the element or put the element back into the jars, they should be discarded.

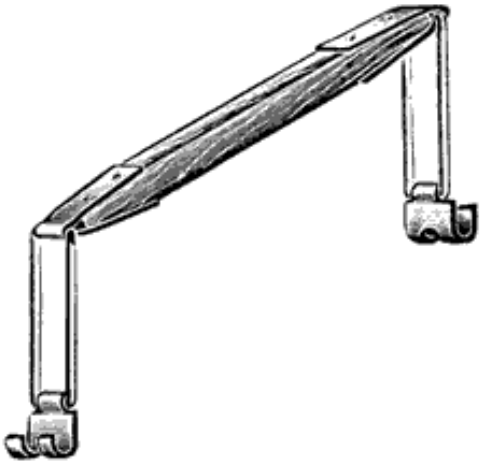

Fig. 116. Battery Carrier

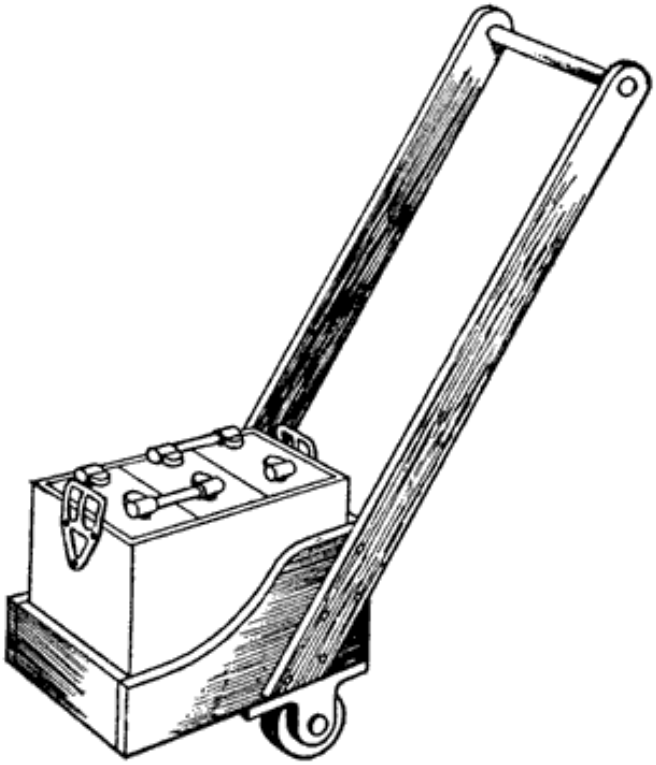

Fig. 117. Battery Truck

Battery Carrier. Figure 116 shows a very convenient battery carrier, having a wooden handle with two swinging steel hooks for attaching to the battery to be carried. With this type of carrier no strain is put on the handle, as is the case if a strap is -used.

Battery Truck. When a battery must be moved any considerable distance, a truck, such as that shown in Figure 117 should be used. This truck may easily be made in the shop, or may be made at a reasonable cost in a carpenter shop. The rollers should be four inches or more in diameter and should preferably be of the ball-bearing type. Rubber tires on the rollers are a great advantage, since the rubber protects the rollers from acid and also eliminates the very disagreeable noise which iron wheels make, especially in going over a concrete floor or sidewalk. The repairman need not make his truck exactly like that shown in Figure 117, which is merely shown to give a general idea of how such a truck should be constructed.

The truck shown in Figure 117 was made from a heavy wooden box. With this construction lifting batteries is largely eliminated, which is most desirable, since a battery is not the lightest thing in the world. The battery is carried in a horizontal position and the truck is small enough to be wheeled between cars in the shop.

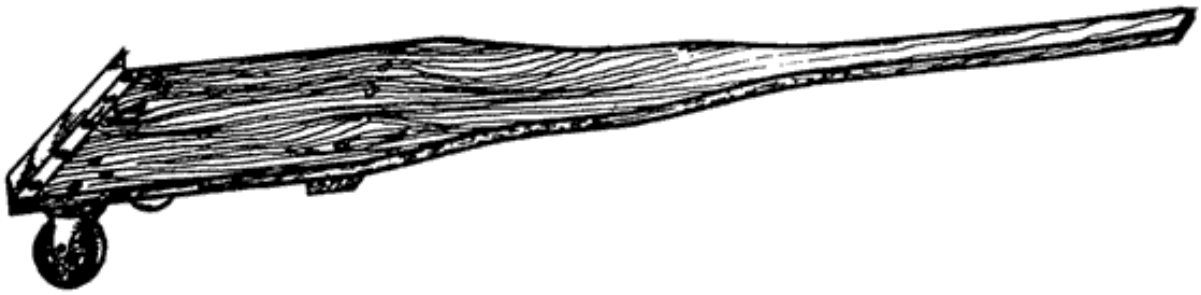

Fig. 118. Battery Truck

Another form of battery truck is shown in Figure 118, although this, is not as good as that shown in Figure 117.

CADMIUM TEST SET AND HOW TO MAKE THE TEST

As the cell voltage falls while the battery is on discharge, the voltage of the positive plates, and also the voltage of the negative plates falls. -When the battery is charged again the voltages of both positive and negative plates rise. If a battery gives its rated ampere-hour capacity on discharge, we do not care particularly how the voltages of the individual positive and negative groups change. If, however, the battery fails to give its rated capacity, the fault may be due to defective positives or defective negatives.

If the voltage of a battery fails to come up when the battery is put on charge, the trouble may be due to either the positives or negatives. Positives and negatives may not charge at the same rate, and one group may become fully charged before the other group. This may be the case in a cell which has had a new positive group put in with the old negatives. Cadmium tests made while the battery is on charge will tell how fully the individual groups are charged.

Since the voltages of the positives and negatives both fall as a battery is discharged, and rise as the battery is charged, if we measure the voltages of the positives and negatives separately, we can tell how far each group is charged or discharged. If the voltage of each cell of a battery drops to 1.7 before the battery has given its rated capacity, we can tell which set of plates has become discharged by measuring the voltages of positives and negatives separately. If the voltage of the positives show that they are discharged, then the Positives are not up to capacity. Similarly, negatives are not up to capacity if their voltage indicates that they are discharged before the battery has given its rated capacity.

Cadmium readings alone do not give any indication of the capacity of a battery, and the repairman must be careful in drawing conclusions from Cadmium tests.

In general it is not always safe to depend upon Cadmium tests on a battery which has not been opened, unless the battery is almost new. Plates having very little active material, due to shedding, or due to the active material being loosened from the grid, will often give good Cadmium readings, and yet a battery with such plates will have very little capacity. Such a condition would be disclosed by an actual examination of the plates, or by a capacity discharge test.

How Cadmium Tests Are Made

To measure the voltages of the positives and negatives separately, Cadmium is used. The Cadmium is dipped in the electrolyte, and a voltage reading is taken between the Cadmium and the plates which are to be tested. Thus, if we wish to test the negatives, we take a voltage reading between the Cadmium and the negatives, as shown in Fig. 119. Similarly, if we wish to test the positives, we take a voltage reading between the Cadmium and the positives, as shown in Fig. 120.

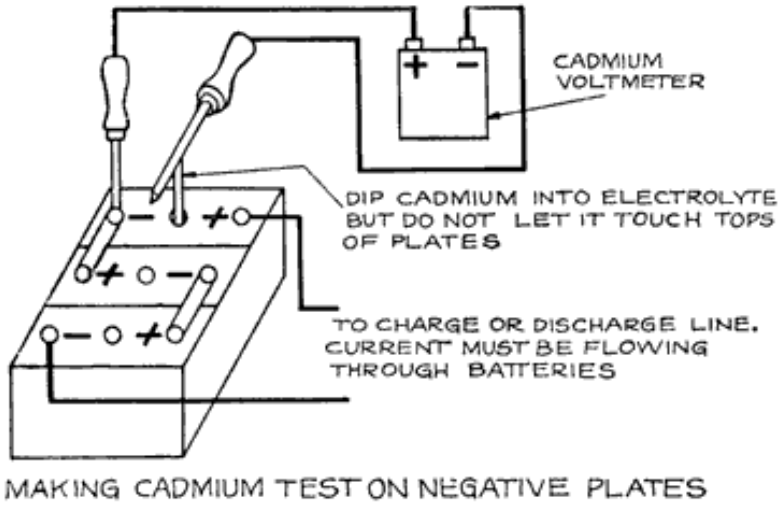

MAKING CADMIUM TEST ON NEGATIVE PLATES

Fig. 119

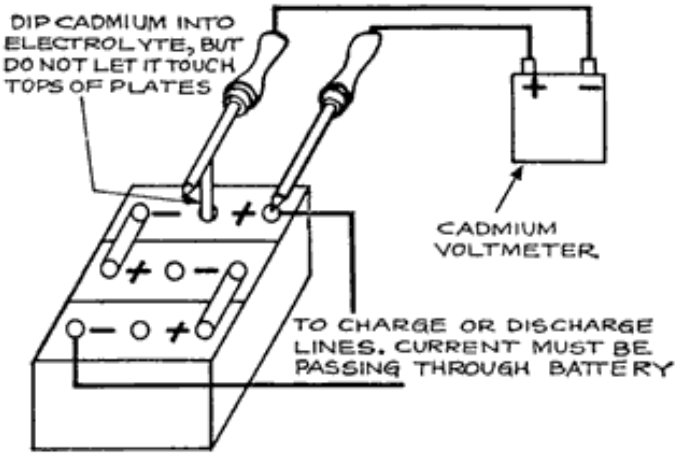

Fig. 120 MAKING CADMIUM TEST ON POSITIVE PLATES

In dipping the Cadmium into the electrolyte, we make two cells out of the battery cell. One of these consists of the Cadmium and the positives, while the other consists of the Cadmium and the negatives. If the battery is charged, the Cadmium forms the negative element in the Cadmium-Positives cell, and is the positive element in the Cadmium-Negatives cell. The voltage of the Cadmium does not change, and variations in the voltage readings obtained in making Cadmium tests are due to changes in the state of charge of the negative and positive plates which are being tested.

What Cadmium Is: Cadmium is a metal, just like iron, copper, or lead. It is one of the chemical elements; that is, it is a separate and distinct substance. It is not made by mixing two or more substances, as for instance, solder is made by mixing tin and lead, but is obtained by separating the cadmium from the compounds in which it is found in nature, just as iron is obtained by treatment of iron ore in the steel mill.

When Cadmium Readings Should Be Made

1. When the battery voltage drops to 1.7 per cell on discharge before the battery has delivered its rated ampere-hour capacity, at the 5-hour rate when a discharge test is made.

2. When a battery on charge will not "come up," that is, if its voltage will not come up to 2.5-2.7 per cell on charge, and its specific gravity will not come up to 1.280-1.300.

3. Whenever you charge a battery, at the end of the charge, when the voltage and specific gravity no longer rise, make Cadmium tests to be sure that both positives and negatives are fully charged.

4. When you put in a new group, charge the battery fully and make Cadmium tests to be sure that both the new and old groups are fully charged.

5. When a 20-minute high rate discharge test is made. See page 267.

That Cadmium Readings should be taken only while a battery is in action; that is, while it is on discharge, or while it is on charge.

Cadmium Readings taken on a battery which is on open circuit are not reliable.

When you are not using the Cadmium, it should be put in a vessel of water and kept there. Never let the Cadmium become dry, as it will then give unreliable readings.

Open Circuit Voltage Readings Worthless

Voltage readings of a battery taken while the battery is on open circuit; that is, when no current is passing through the battery, are not reliable. The voltage of a normal, fully charged cell on open circuit is slightly over 2 volts. If this cell is given a full normal discharge, so that the specific gravity of its electrolyte drops to 1.150, and is allowed to stand for several hours after the end of the discharge, the open circuit voltage will still be 2 volts. Open circuit voltage readings are therefore of little or no value, except when a cell is "dead," as a dead cell will give an open circuit voltage very much less than 2, and it may even give no voltage at all.

What the Cadmium Test Set Consists of

The Cadmium Tester consists of a voltmeter, Fig. 121, and two pointed brass prods which are fastened in wooden handles, as shown in Fig. 122. A length of flexible wire having a terminal at one end is soldered to each prod for attachment to the voltmeter. Fastened at right angles to one of the brass prods is a rod of pure cadmium.

Fig. 121. Special Cadmium Test Voltmeter

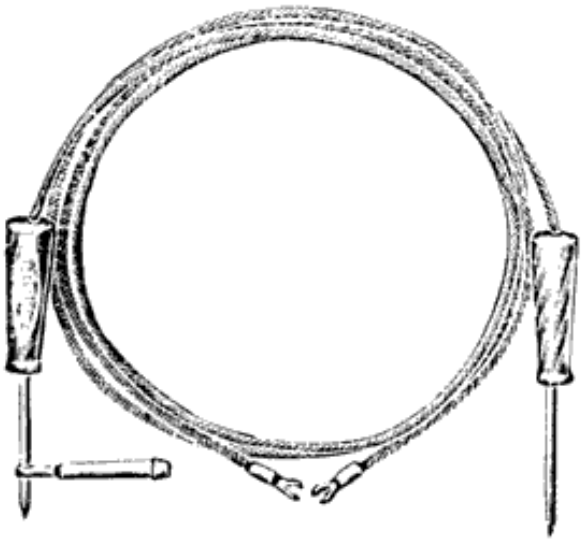

Fig. 122. Cadmium Test Leads

Cadmium tests may be made with any accurate voltmeter which gives readings up to 2.5 volts in divisions of .05 volt.

The instructions given below apply especially to the special AMBU voltmeter but these instructions may also be used in making cadmium tests with any voltmeter that will give the correct reading.

The AMBU Cadmium Voltmeter

Fig. 121 is a view of the special AMBU Voltmeter, which is designed to be used specially in making Cadmium tests. Fig. 122 shows the Cadmium leads. The four red lines marked "Neg. Charged ... .. Neg. Discharged," "Pos. Charged,." and "Pos. Discharged," indicate the readings that should be obtained. Thus, in testing the positives of a battery on charge, the pointer will move to the line which is marked "Pos. Charged," if the positive plates are fully charged. In testing the negatives, the pointer will move to the line marked "Neg. Charged," which is to the left of the "0" line, if the negatives are fully charged, and so on. Figs. 123, 124, 125 and 126 show the pointer in the four positions on the scale which it takes when testing fully charged or discharged plates. In each figure the pointer is over one of the red lines on the scale. These figures also show the readings, in volts, obtained in making the cadmium tests on fully charged or completely discharged plates.

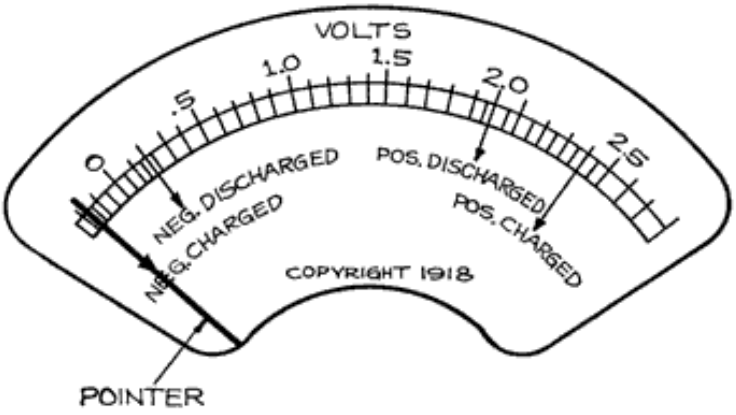

Fig. 123

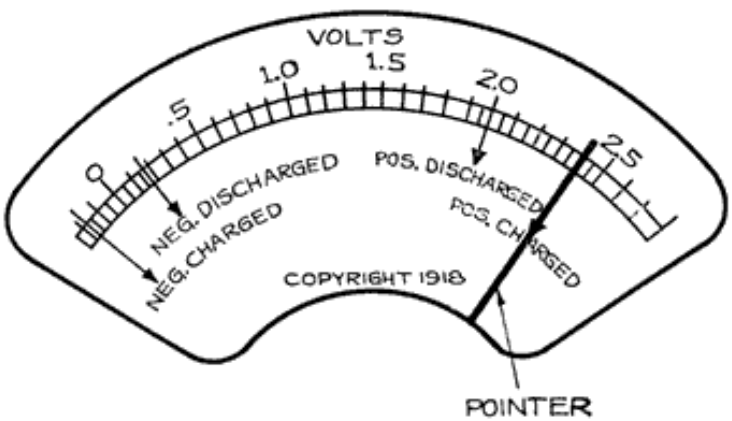

Fig. 125

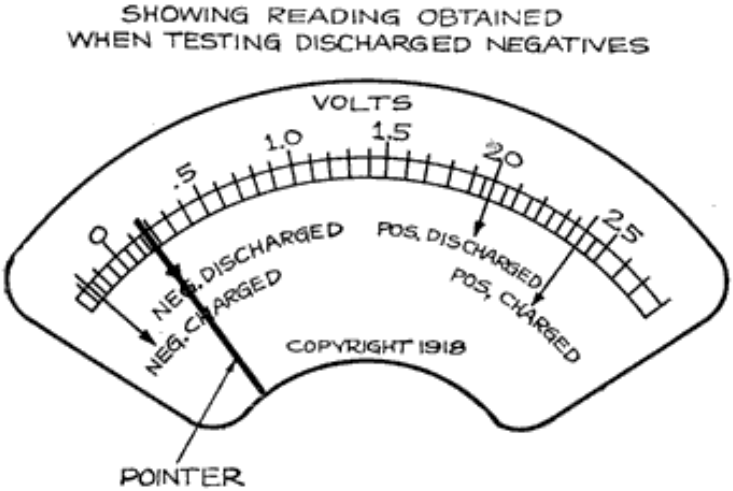

Fig. 124

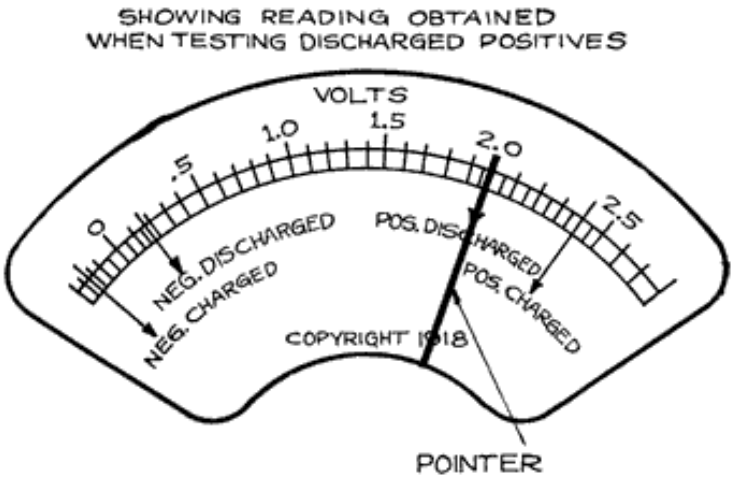

Fig. 126

If Pointer Is Not Over the "0" Line: It sometimes happens, in shipping the instrument, and also in the use of it, that the pointer does not stand over the "0" line, but is a short distance away. Should you find this to be the case, take a small screwdriver and turn the screw which projects through the case, and which is marked "Correct Zero," so as to bring the pointer exactly over the "0" line on the scale while the meter has no wires connected to its binding posts.

Connections of Cadmium Leads: In making Cadmium Tests, connect the prod which has the cadmium fastened to it to the negative voltmeter binding post. Connect the plain brass prod to the positive voltmeter binding post. The connections to the AMBU Cadmium Voltmeter are shown in Fig. 127.

Testing a Battery on Discharge

The battery should be discharging continuously, at a constant, fixed rate, see page 265.

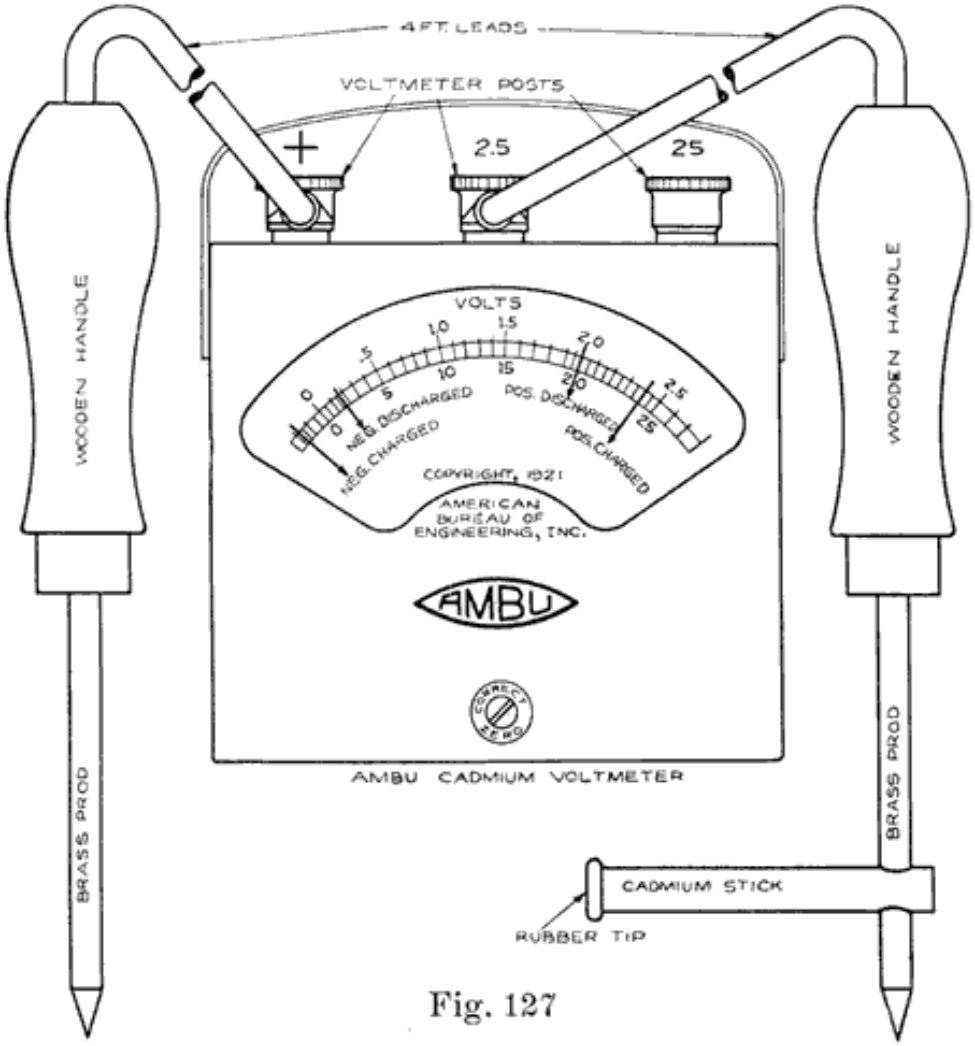

Fig. 127

Generally, on a starting ability test (see page 267), the positive Cadmium readings will start at about 2.05 volts for a hard or very new set of positives, and at 2.12 volts or even higher for a set of soft or somewhat developed positives, and will drop during the test, ending at 1.95 volts or less. The negative Cadmium readings will start at 0.23 volt or higher, up to 0.30, and will rise gradually, more suddenly toward the end if the plates are old, ending anywhere above 0.35 and up to 0.6 to 0.7 for poor negatives.

Short Circuited Cells: In cases of short circuited cells, the voltage of the cell will be almost down to zero. The Cadmium readings would therefore be nearly zero also for both positives and negatives. Such a battery should be opened for inspection and repairs.

Testing a Battery on Charge

The Battery should be charging at the finishing rate. (This i's usually stamped on the battery box.) Dip the cadmium in the electrolyte as before, and test the negatives by holding the plain prod on the negative post of the cell. See Fig. 119. Test the positives in a similar manner. See Fig. 120. The cell voltage should also be measured. If the positives are fully charged, the positive cadmium reading will be such that the pointer will move to the red line marked "Pos. Charged." See Fig. 125. If you are using an ordinary voltmeter, the meter will give a reading of from 2.35 to 2.42 volts. The negatives are then tested in a similar manner. The negative-cadmium reading on an ordinary voltmeter will be from .175 to .2 to the left of the "0" line; that is, the reading is a reversed one. If you are using the special ABM voltmeter, the pointer will move to the red line marked "Neg. Charged." See Fig. 123. **The cell voltage should be the sum of the positive-cadmium and the negative cadmium readings.**

If the voltage of each cell will not come up to 2.5 to 2.7 volts on charge, or if the specific gravity will not rise to

1.280 or over, make the cadmium tests to determine whether both sets of plates, or one of them, give readings indicating that they are fully charged. If the positives will not give a reading of at least 2.35 volts, or if the negatives will not give a reversed reading of at least 0.1 volt, these plates lack capacity.

In case of a battery on charge, if the negatives do not give a minus Cadmium reading, they may be lacking in capacity, but, on the other hand, a minus negative Cadmium reading does not prove that the negatives are up to hill capacity. A starting ability discharge test (page 267) is the only means of telling whether a battery is up to capacity.

Improperly treated separators will cause poor negative-Cadmium readings to be obtained. The charging rate should be high enough to give cell voltages of 2.5-2.7 when testing negatives. Otherwise it may not be possible to get satisfactory negative-Cadmium reading. Separators which have been allowed to become partly dry at any time will also make it difficult to obtain satisfactory negative-Cadmium readings.

HIGH RATE DISCHARGE TESTERS

(See page 265 for directions for making tests.)

Figure 128 shows a high rate discharge cell tester. It consists of a handle carrying two heavy prongs which are bridged by a length of heavy nichrome wire. When the ends of the prongs are pressed down on the terminals of a cell, a current of 150 to 200 amperes is drawn from the cell. A voltage reading of the cell, taken while this discharge current is flowing is a means of determining the condition of the cell, since the heavy discharge current duplicates the heavy current drawn by the starting motor. Each prong carries a binding post, a low reading voltmeter being connected to these posts while the test is made. This form of discharge tester is riot suitable for making starting ability discharge tests, which are described on page 267.

Other forms of high rate discharge testers are made, but for the shop the type shown in Figure 128 is most convenient, since it is light and portable and has no moving parts, and because the test is made very quickly without making any connections to the battery. Furthermore, each cell is tested separately and thus six or twelve volt batteries may be tested without making any change in the tester.

For making starting ability discharge tests at high rates, a carbon plate or similar rheostat is most suitable, and such rheostats are on the market.

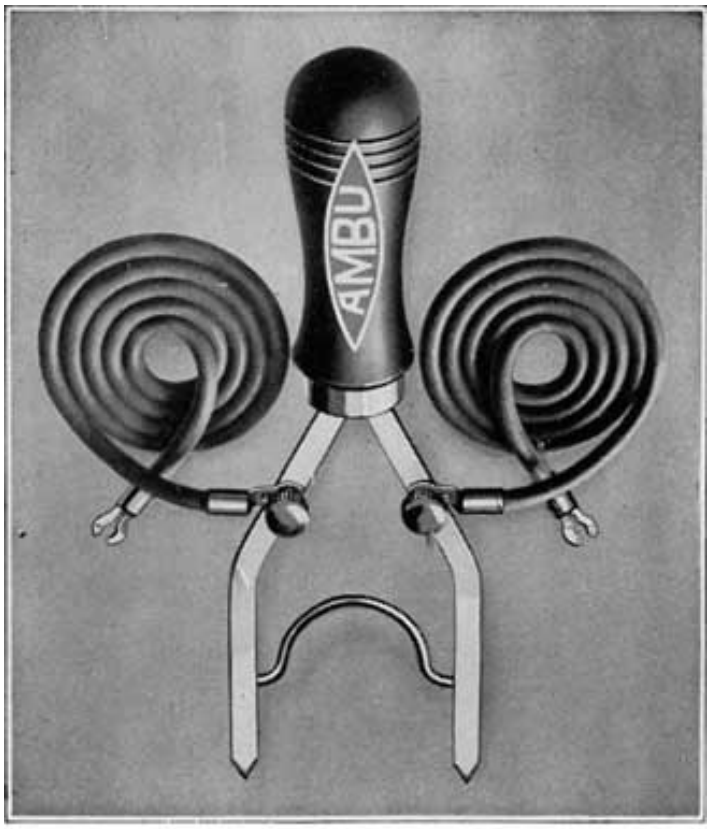

Fig. 128. High Rate Discharge Tester

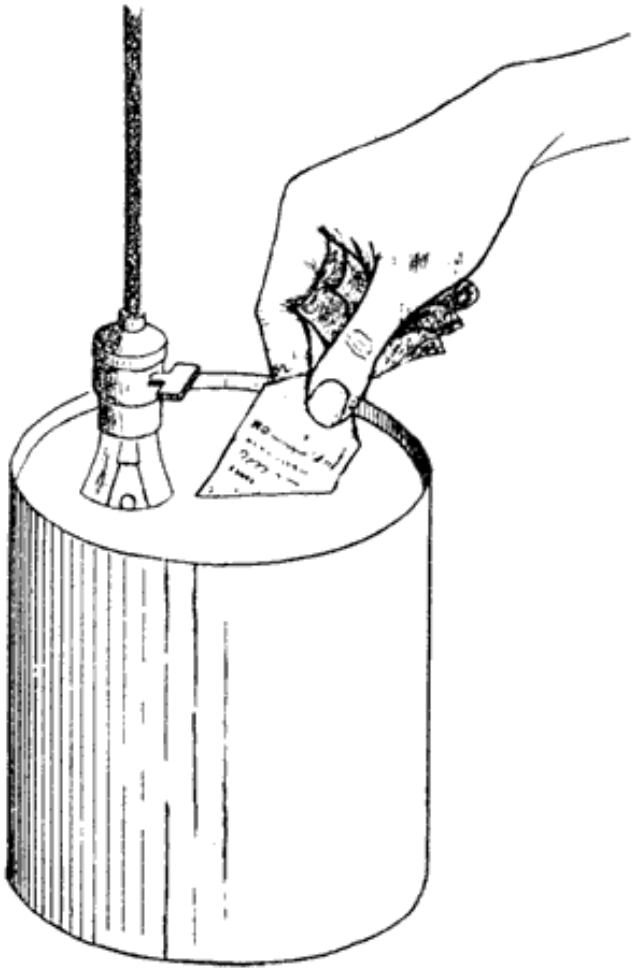

Fig. 129. Paraffine Dip Pot

PARAFFINE DIP POT

Paper tags are not acid proof, and if acid is spilled on tags tied to batteries which are being repaired, the writing on the tags is often obliterated so that it is practically impossible to identify the batteries. An excellent plan to overcome this trouble is to dip the tags in hot paraffine after they have been properly filled out. The writing on the tags can be read easily and since paraffine is acid proof, any acid which may be spilled on the paraffine coated tags will not damage the tags in any way.

Figure 129 shows a paraffine dip pot. A small earthenware jar is best for this purpose. Melt the paraffine slowly on a stove, pour it into the pot, and partly immerse a 60-watt carbon lamp in the paraffine as shown. The lamp will give enough heat to keep the paraffine melted, without causing it to smoke to any extent. After filling out a Battery Card, dip it into the Paraffine, and hold the card above the pot to let the excess paraffine run off. Let the paraffine dry before attaching the tag to the battery, otherwise the paraffine may be scratched off.

WOODEN BOXES FOR BATTERY PARTS

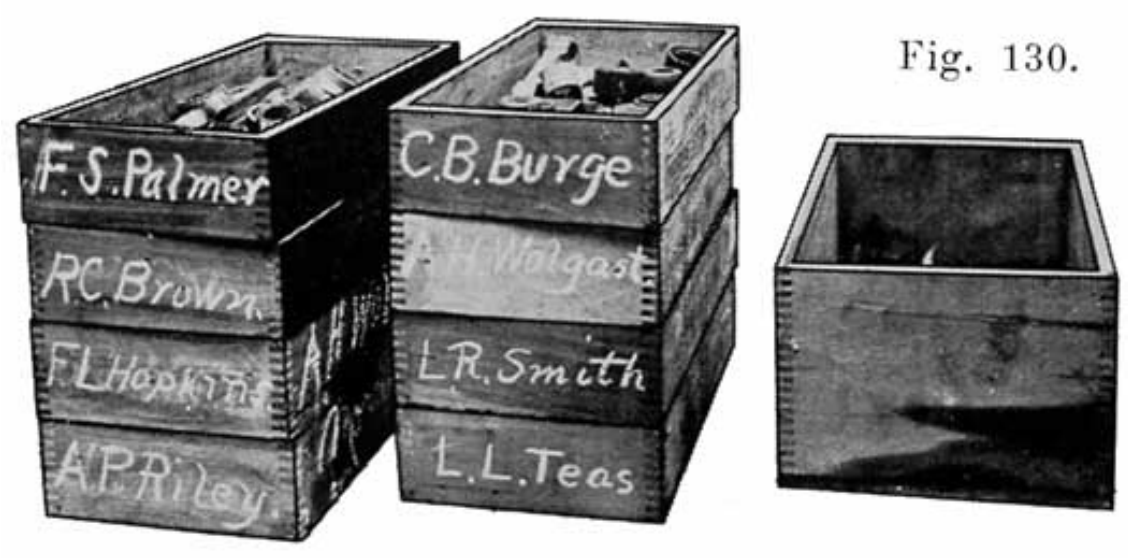

Fig. 130. Boxes for Holding Parts of Batteries Being Prepaired

Figure 130 shows a number of wooden boxes, about 12 inches long, 8 inches wide, and 4 inches deep. These boxes are very useful for holding the terminals inter-cell connectors, covers, plugs, etc., of batteries which are dismantled for repairs. Write the name of the owner with chalk on the end of the box, and rub the name off after the battery has been put together again. The boxes shown in Figure 130 had been used for plug tobacco, and served the purpose very well. The larger box shown in Figure 130 may be used for collecting old terminals, inter-cell connectors, lead drillings, etc.

EARTHENWARE JARS

The twenty gallon size is very convenient for waste acid, old separators, and any junk parts which are wet with acid. The jars are acid proof and will help keep the shop floor dry and anything which will help in this is most desirable.

ACID CARBOYS

Acid is shipped in large glass bottles around each of which a wooden box is built to prevent breakage, the combination being called a "carboy." Since the acid is heavy, some means of drawing it out of the bottle is necessary. One method is illustrated in Figure 131, wooden rockers being screwed to the box in which the bottle is placed.

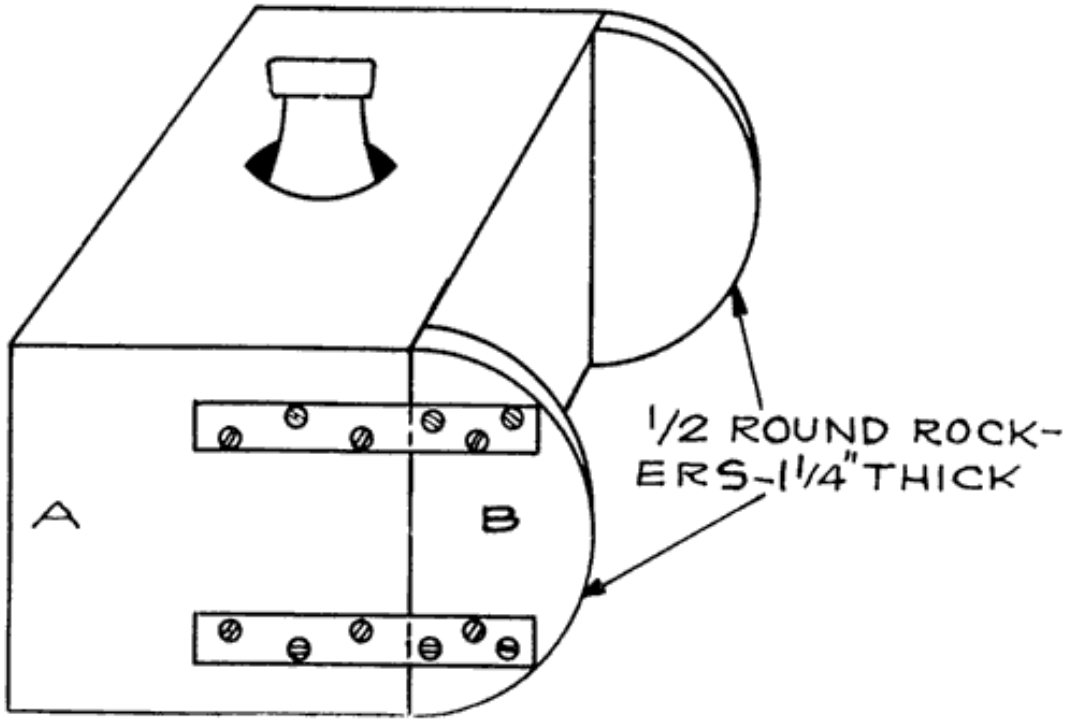

Fig. 131. A Simple Method of Drawing Acid from Carboy

A very good addition to the rockers shown in Figure 131 is the inner tube shown in Figure 132. In this illustration the rockers are not shown, but should be used. The combination of the rockers with the inner tube gives a very convenient method of pouring acid from a carboy, since the heavy bottle need not be lifted, and since it helps keep the floor and the top of the box dry.

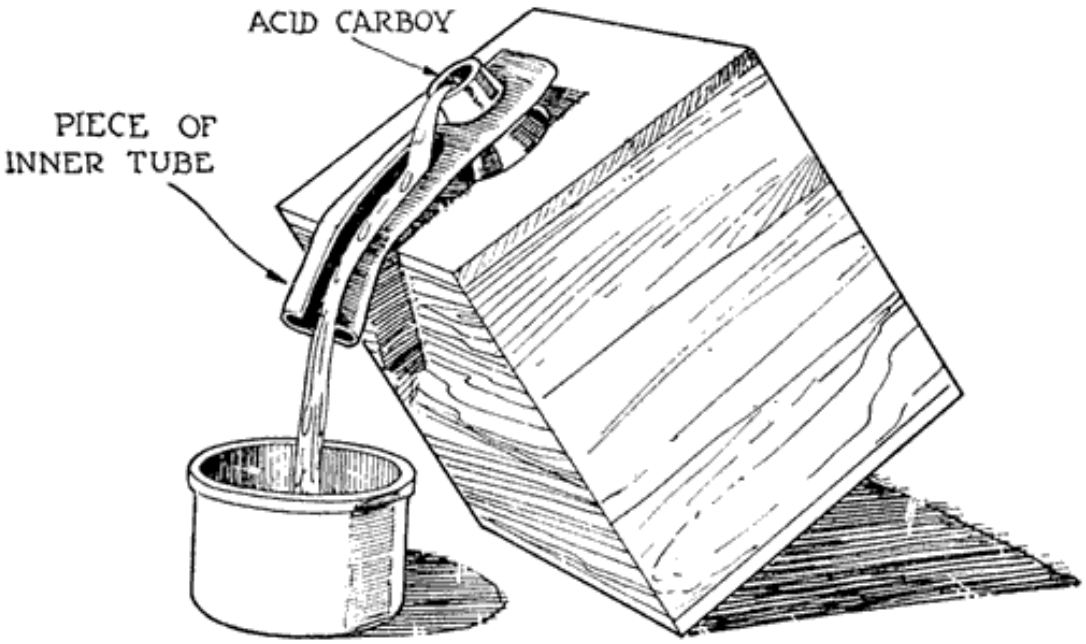

Fig. 132. Use of Inner Tube to Protect Box When Pouring Acid

The rubber tube shown in Figure 132 is a piece of 4 inch inner tube which is slit down one side to make it lie flat. Near one end is cut a hole large enough to fit tightly over the neck of the acid bottle. Slip this rubber over the neck of the bottle and allow the long end to hang a few inches over the side of the carboy bottle or box. This is for pouring acid from a carboy when it is too full to allow the contents to be removed without spilling. This device will allow the

contents of the carboy to be poured into a crock or other receptacle placed on the floor without spilling, and also prevents dirt that may be laying on top of the carboy from falling into the crock.

Figure 133 shows a siphon method for drawing acid from a bottle, although this method is more suitable for distilled water than for acid. "A" is the bottle, "B" a rubber stopper, "C" and "D" are 3/8 inch glass or hard rubber tubes, "E" is a length of rubber tubing having a pinch clamp at its lower end. To use this device, the stopper and tubes are inserted in the bottle, and air blown or pumped in at "C," while the pinch clamp is open, until acid or water begins to run out of the lower end of tubing ""E." The pinch clamp is then released. Whenever acid or water is to be drawn from the bottle the pinch clamp is squeezed so as to release the pressure on the tube. The water or acid will flow down the tube automatically as long as the pinch clamp is held open. The clamp may be made of flat or round spring brass or bronze. This is bent round at (a). At (c) an opening is made, through which the part (b) is bent. The clamp is operated by pressing at (d) and (e). The rubber tubing is passed through the opening between (b) and (c).

This method is a very good one for the small bottle of distilled water placed on the charging bench to bring the electrolyte up to the proper height. The lower end of tube (e) is held over the vent hole of the cell. The pinch clamp is then squeezed and water will flow. Releasing the clamp stops the flow of water instantly. If tube (e) is made long enough, the water bottle may be set on the elevated shelf extending down the center of the charging bench.

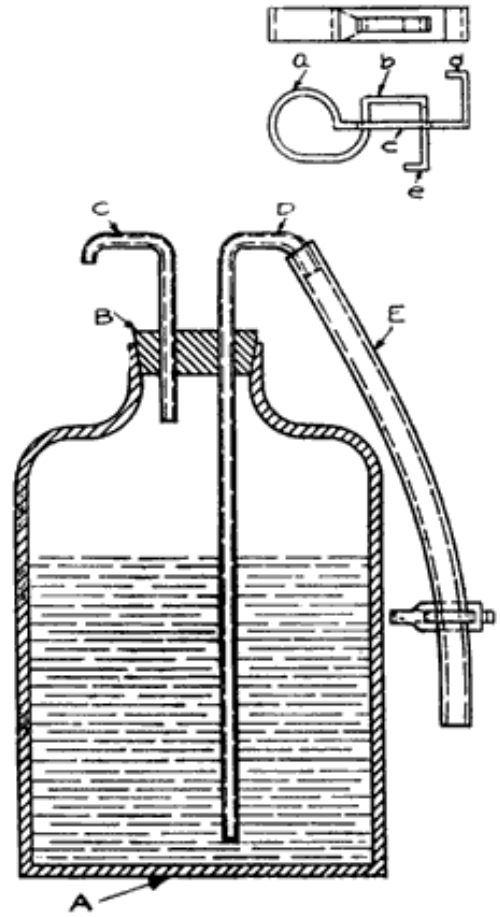

Fig. 133. Siphon for Drawing Acid from Carboy

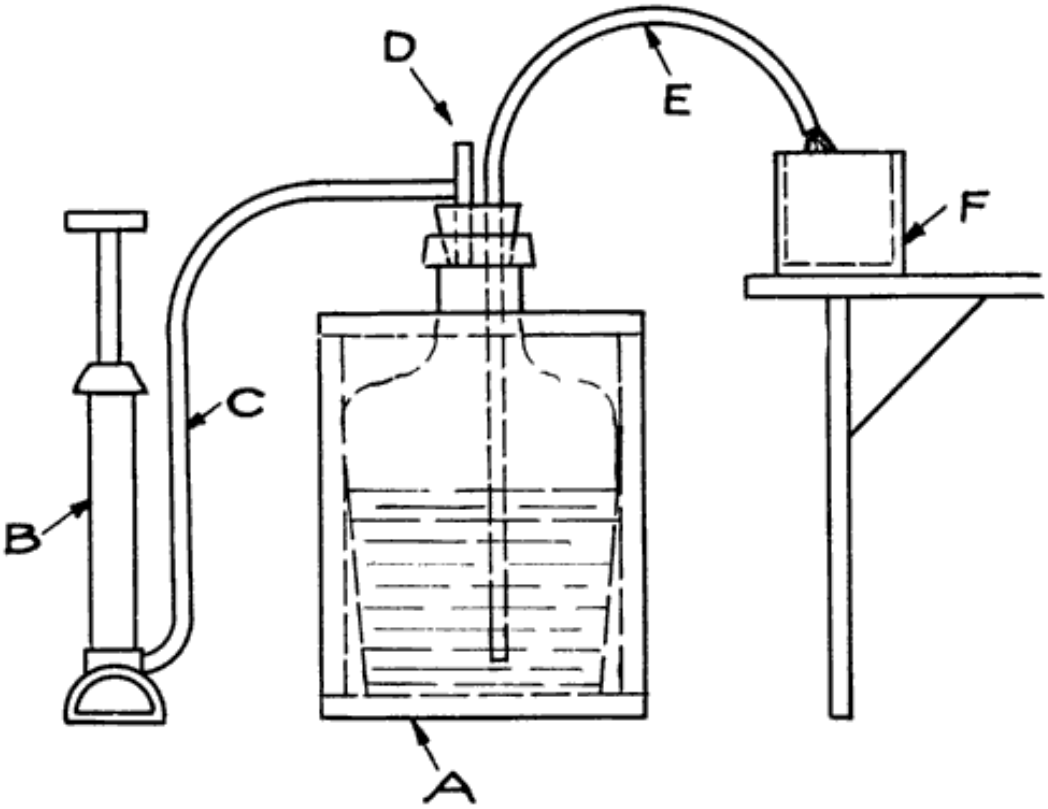

Fig. 134. Foot Pump for Drawing Acid from Carboy

Figure 134 shows another arrangement, using a tire pump. D and E are 3/8 inch hard rubber tubes. D is open at both ends and has a "T" branch to which the pump tubing is attached. To operate, a finger is held over the upper end of D, and air is pumped into the acid bottle, forcing the acid into the vessel F. To stop the flow of acid, the finger is removed from D. This stops the flow instantly. This method is the most satisfactory one when fairly large quantities of acid or water are to be drawn off.

SHOP LAYOUTS

The degree of success which the battery repairman attains depends to a considerable extent upon the workshop in which the batteries are handled. It is, of course, desirable to be able to build your shop, and thus be able to have everything arranged as you wish. If you must work in a rented shop, select a place which has plenty of light and ventilation. The ventilation is especially important on account of the acid fumes from the batteries. A shop which receives most of its light from the north is the best, as the light is then more uniform during the day, and the direct rays of the sun are avoided. Fig. 38 shows a light, well ventilated workroom.

The floor should be in good condition, since acid rots the wood and if the floor is already in a poor condition, the acid will soon eat through it. A tile floor, as described below, is best. A wooden floor should be thoroughly scrubbed, using water to which baking soda has been added. Then give the floor a coat of asphaltum paint, -which should be applied hot so as to flow into all cracks in the wood. When the first coat is dry, several more coats should be given. Whenever you make a solution of soda for any purpose, do not throw it away when you are through with it. Instead, pour it on the floor where the acid is most likely to be spilled. This will neutralize the acid and prevent it from rotting the wood.

If you can afford to build a shop, make it of brick, with a floor of vitrified brick, or of tile which is not less than two inches thick, and is preferably eight inches square. The seams should not be less than one-eighth inch wide, and not wider than one fourth. They should be grouted with asphaltum, melted as hot and as thin as possible (not less than 350° F.). This should be poured in the seams. The brick or tile should be heated near the seams before pouring in the

asphaltum. When all the seams have been filled, heat them again. After the second heating, the asphaltum may shrink, and it may be necessary to pour in more asphaltum.

If possible, the floor should slope evenly from one end of the room to the other. A lead drainage trough and pipe at the lower end of the shop will carry off the acid and electrolyte.

It is a good plan to give all work benches and storage racks and shelves. at least two coatings of asphaltum paint. This will prevent rotting by the acid.

The floor of a battery repair shop is, at best, a wet, sloppy affair, and if a lead drainage trough is too expensive, there should be a drain in the center of the floor if the shop is small, and several if the shop is a large one. The floor should slope toward the drains, and the drain-pipes should be made of glazed tile.

To keep the feet as dry as possible, rubbers, or even low rubber boots should be worn. Sulphuric acid ruins leather shoes, although leather shoes can be protected to a certain extent by dipping them in hot paraffine.

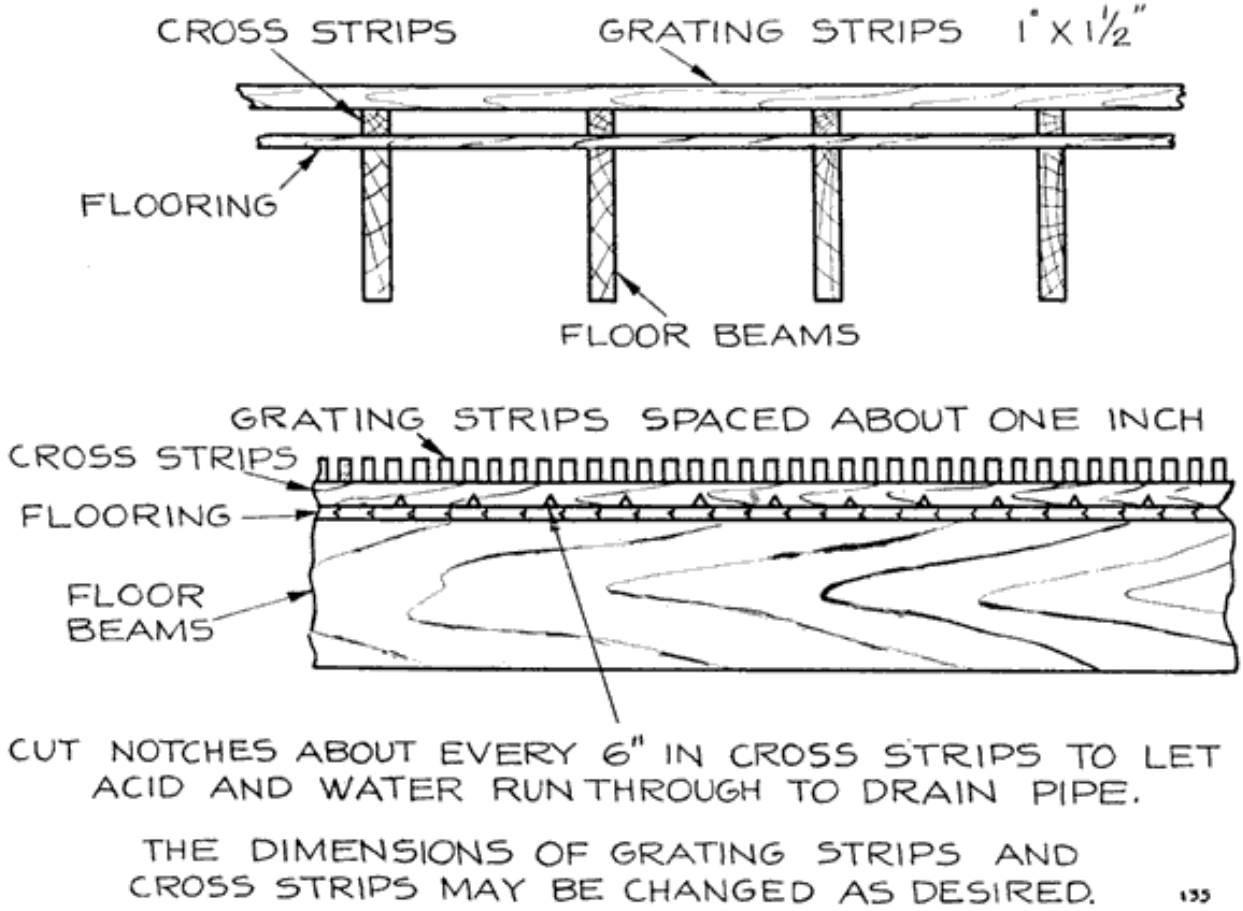

Fig. 135. Wooden Grating on Shop Floor to Give Dry Walking Surface for the Repairman

A good plan is to lay a wooden grating over the floor as shown in Figure 135. Water and acid will run down between the wooden strips, leaving the walking surface fairly dry. If such a grating is made, it should be built in sections which may be lifted easily to be washed, and to permit washing the floor. Keep both the grating and the floor beneath covered with asphaltum paint to prevent rotting by acid. Once a week, or oftener, if necessary, sweep up all loose dirt and then turn the hose on the floor and grating to wash off as much acid as possible. When the wood has dried, a good thing to do is to pour on the floor and grating several pails of water in which washing soda or ammonia has been dissolved.

Watch your floor. It will pay-in better work by yourself and by the men working for you. Have large earthenware jars set wherever necessary in which lead drillings, old plates, old connectors, old separators, etc., may be thrown. Do not let junk cases, jars, separators, etc., accumulate. Throw them away immediately and keep your shop clean. A clean shop pleases Your customers, --and **satisfied customers mean success.**

On the following pages a number of shop layouts are given for both large and small shops. The beginner, of course, may not be able to rent even a small shop, but he may rent part of an established repair shop, and later rent an entire shop. A man working in a corner of an established service must arrange his equipment according to the space available. Later on, when he branches out for himself, he should plan his shop to got the best working arrangement. Figure 136 shows a suggested layout for a small shop. Such a layout may have to be altered because of the size and shape of the shop, and the location of the windows.

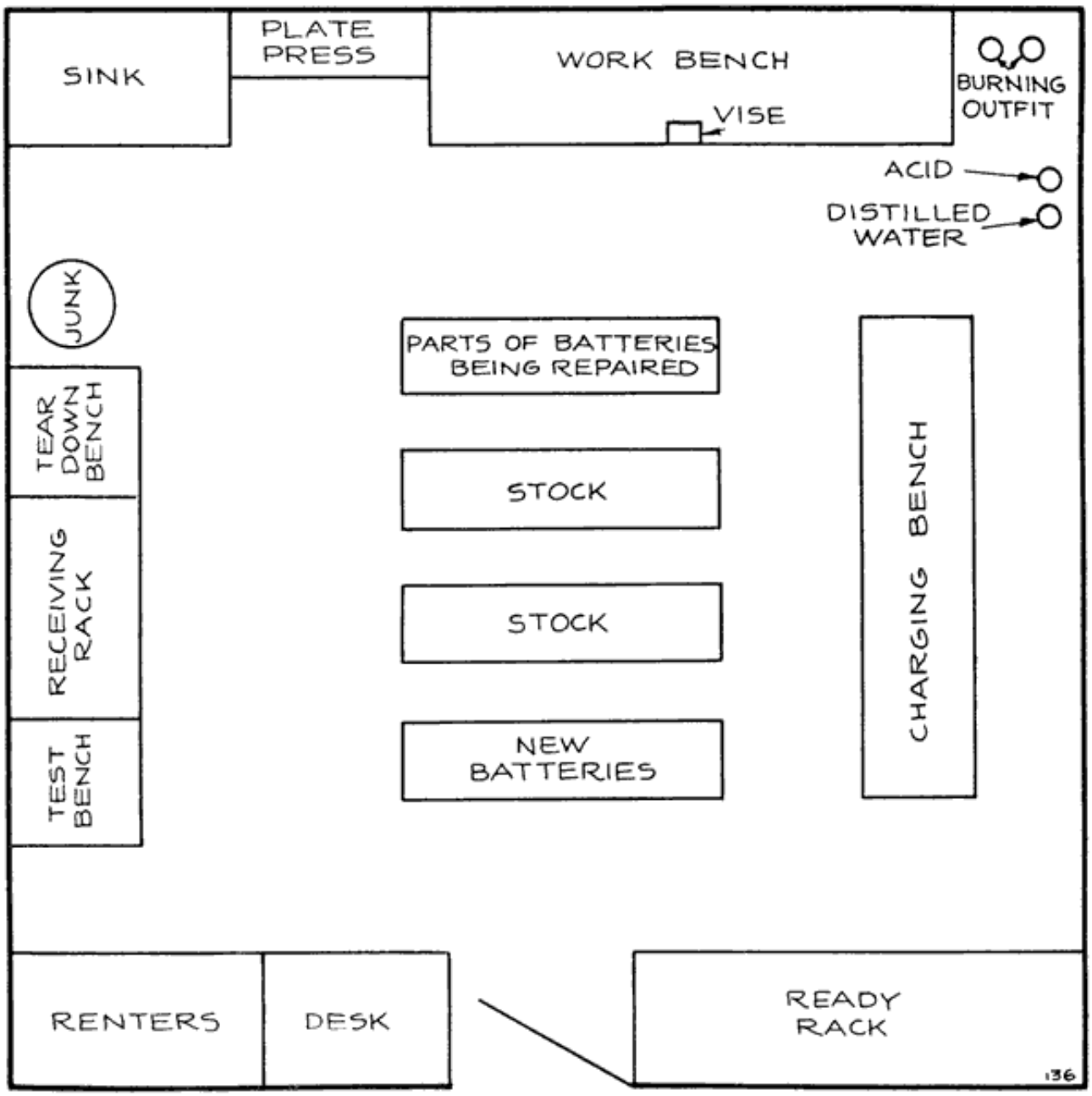

Fig. 136. Layout for a Small Shop

As soon as growth of business permits, a shop should have a drive-in, so that the customer may bring his car off the street. Without a drive-in all testing to determine what work is -necessary will have to be done at the curb, which is

too public for many car owners. A drive-in is also convenient if a customer leaves his car while his battery is being repaired. To a certain extent, the advantages of a drive-in may be secured by having a vacant lot next to the shop, with a covering of cinders. As soon as possible, however, a shop which is large enough to have a drive-in should be rented or built.

Figure 137 shows a 24 x 60 shop with space for three cars. The shop equipment is explained in the table.

Figure 138 shows a 40 x 75 shop with room for six cars and a drive-in and drive-out. This facilitates the handling of the cars.

Figure 139 shows a 30 x 100 shop in a long and somewhat narrow building. It also has a drive-in and drive-out.

Another arrangement for the same sized shop as shown in the preceding illustration is shown in Figure 140. Here the drive-out is at the side and this layout is, therefore, suitable for a building located on a corner, or next to an alley.

Figure 141 shows a larger shop, which may be used after the business has grown considerably.

Figure 142 shows a layout suitable for the largest station.

Somewhere between Figures 136 and 142 is a layout for any service station. The thing to do is to select the one most suitable for the size of the business, and to fit local conditions, If a special building is put up, local conditions are not so important,

If a shop is rented, it may not be possible to follow any of the layouts shown in Figs. 136 to 142. However, the layout which is best adapted for the actual shop should be selected as a guide, and the equipment shown obtained. This should then be arranged as nearly like the pattern layout as the shop arrangement will permit.

Concerning Light

Light is essential to good work, so you must have plenty of good light and at the right place. For a light that is needed from one end of a bench to the other, to look into each individual battery, or to take the reading of each individual battery, there is nothing better than a 60 Watt tungsten lamp under a good metal shade, dark on outside and white on inside.

A unique way to hang a light and have it movable from one end of the bench to the other, is to stretch a wire from one end of the bench to the other. Steel or copper about 10 or 12 B & S gauge may be used. Stretch it about four or five feet above top of bench directly above where the light is most needed. If You have a double charging bench, stretch the wire directly above middle of bench. Before fastening wire to support, slip an old fashioned porcelain knob (or an ordinary thread spool) on the wire. The drop cord is to be tied to this knob or spool at whatever height you wish the light to hang (a few inches lower than your head is the right height).

Put the ceiling rosette above center of bench; cut your drop cord long enough so that you can slide the light from one end of bench to the other after being attached to rosette. Put vaseline on the wire so the fumes of gas will not corrode it. This will also make the spool slide easily. This gives you a movable, flexible light, with which you will reach any battery on bench for inspection. The work bench light can be rigged up the same way and a 75 or 100 Watt nitrogen lamp used.

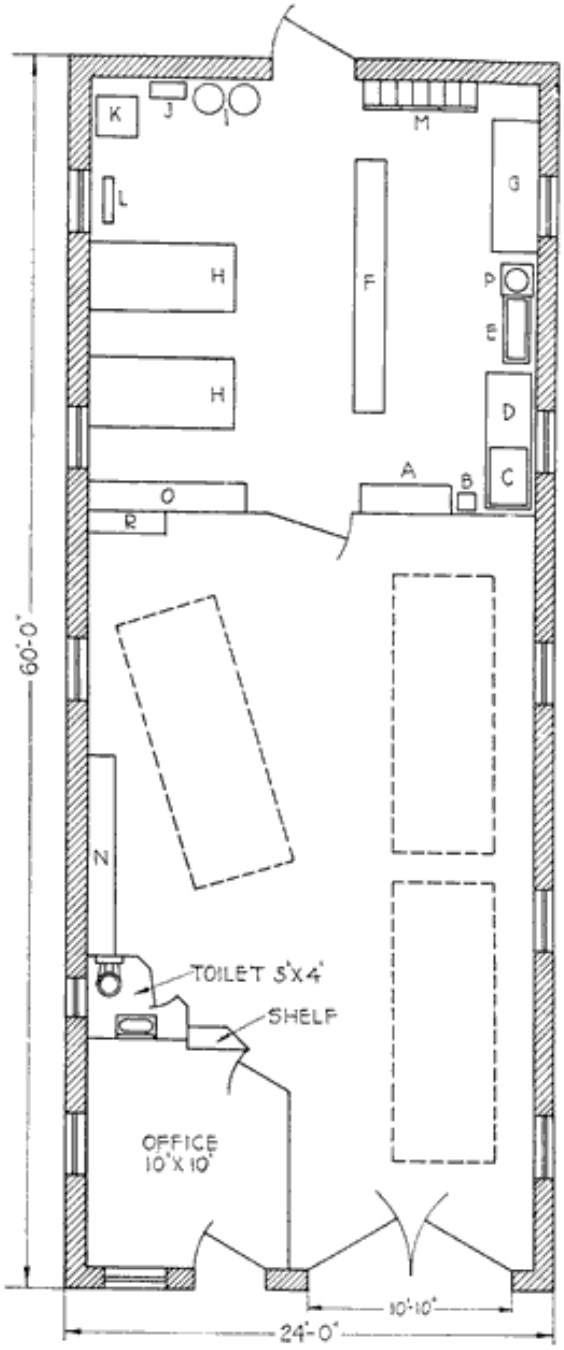

Fig. 137. Shop Layout

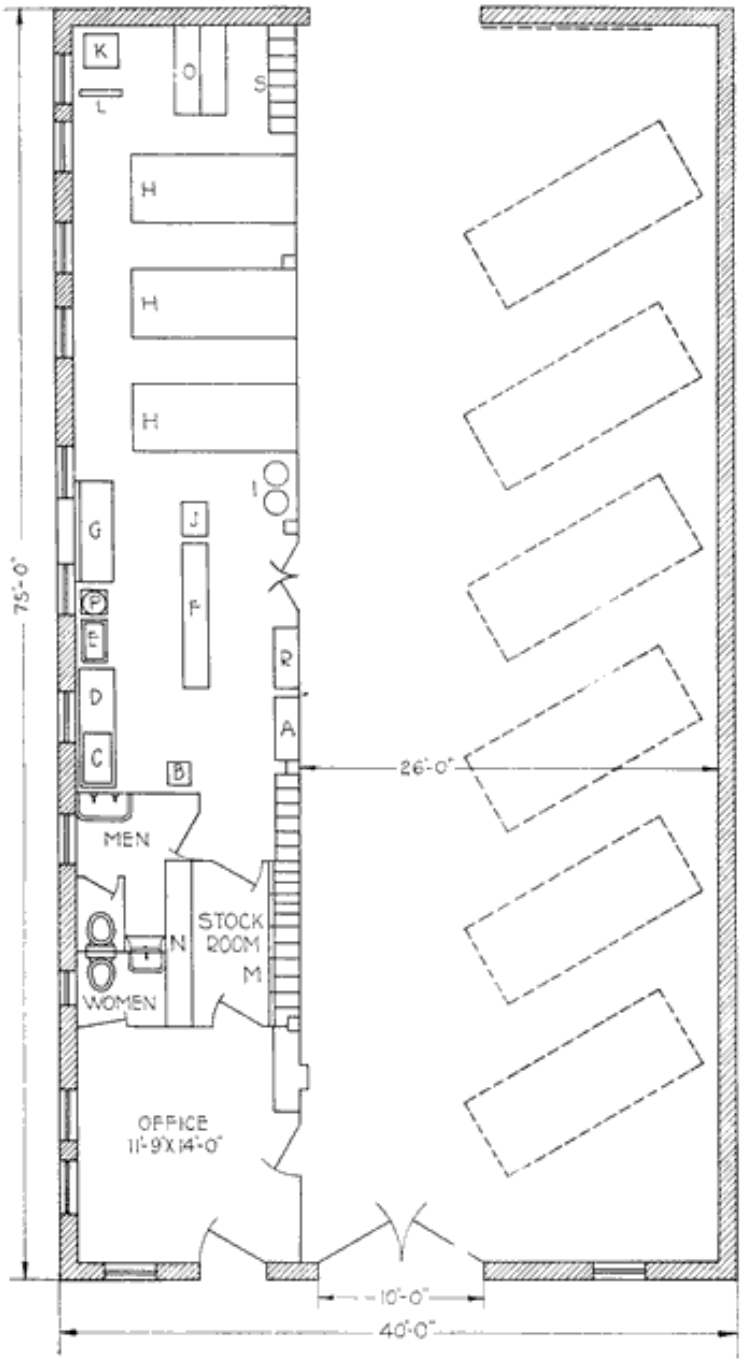

Fig. 138. Shop Layout

Fig. 137 and 138: A- Receiving Rack. B-Portable Electric Drill, or Hand Drill. C-Wash Tank, D-Tear Down Bench. E-Hot Water Pan. F-Waiting Rack (5 Shelves). G-Repair Bench (6 ft. by 2 ft. 3 in.). H-Charging Table (3 Circuits). I-Electrolyte(10 Gal. Crocks). J-Separator Rack. K-Generator. L-Switchboard. M-Stock Bins, N-New Batteries, O-Live storage. P-Sealing Compound. R-Ready Rack (5-Shelves). S-Dry Storage. (S is not in Fig. 137.)

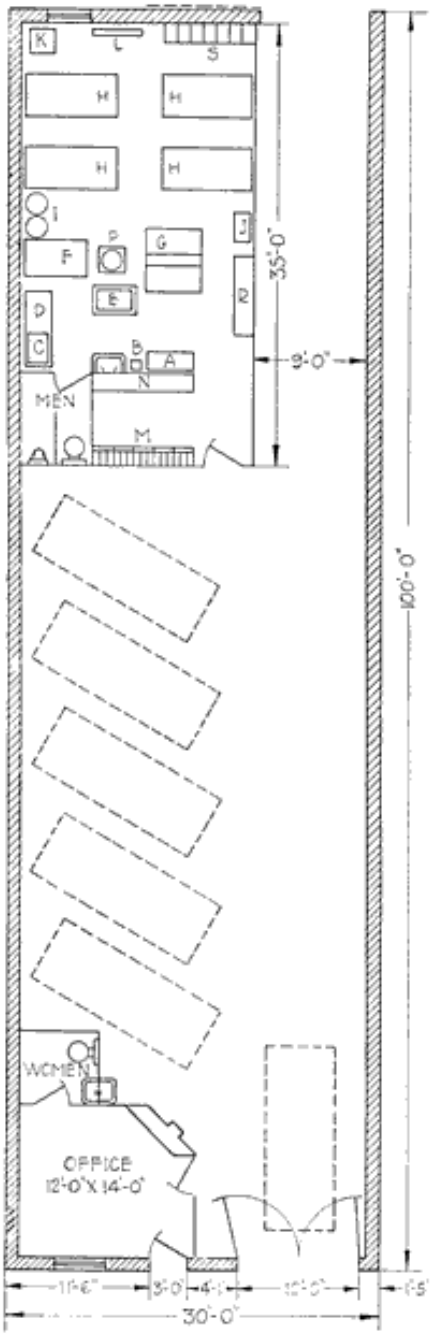

Fig. 139. Shop Layout

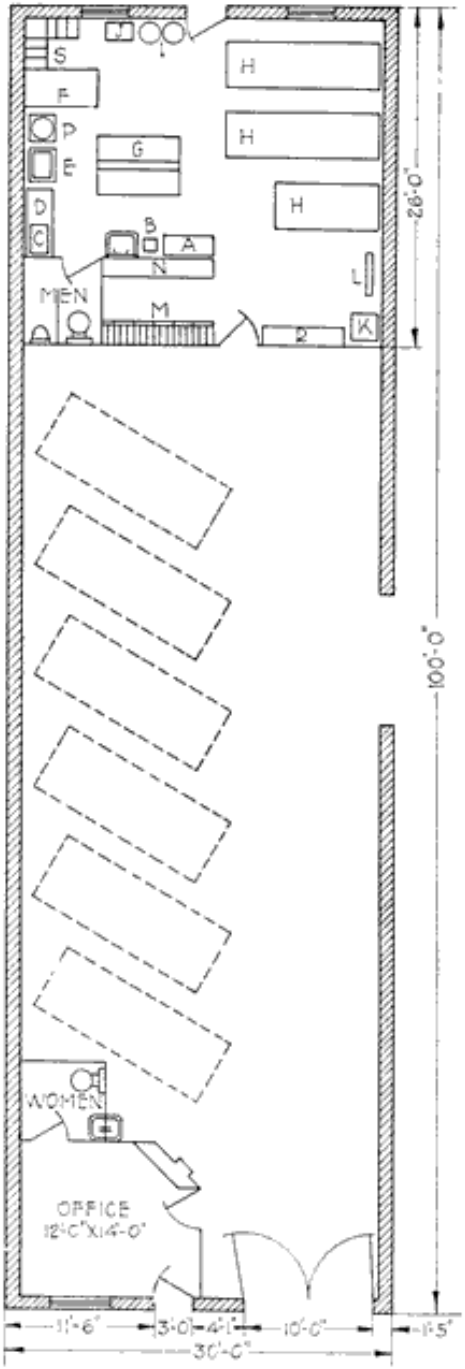

Fig. 140. Shop Layout

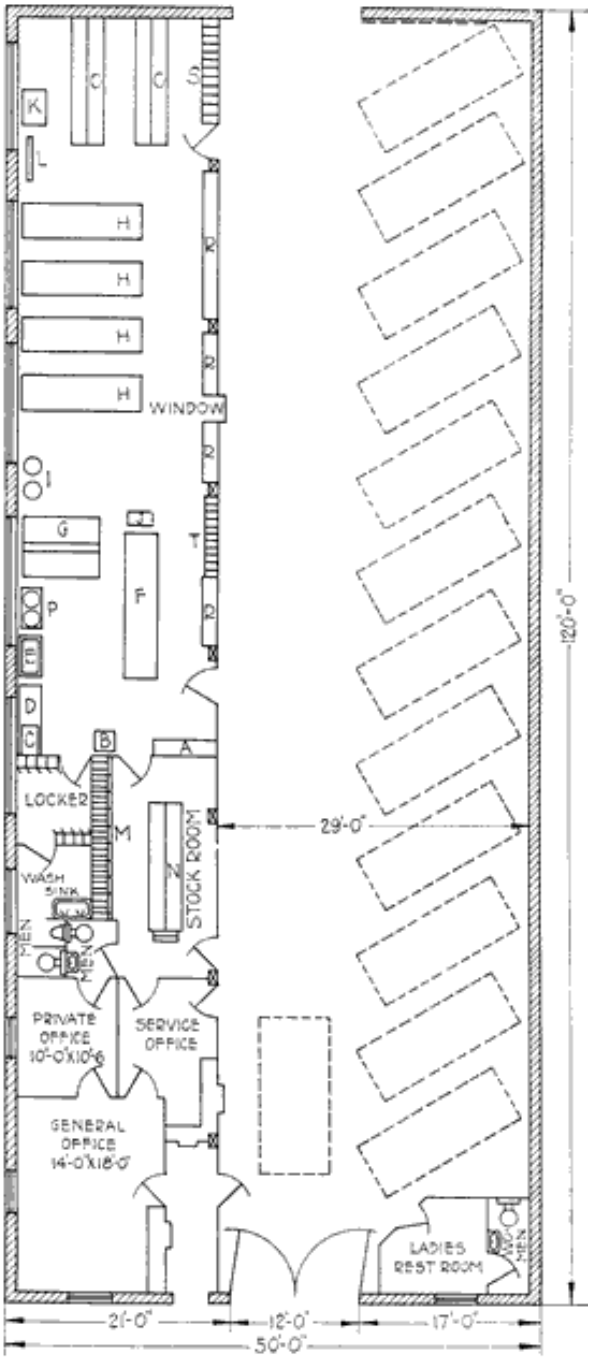

Fig. 141. Shop Layout

Fig. 139, 140 and 141: A- Receiving Rack. B-Power Drill. C-Wash Tank. D-Tear Down Bench. E-Hot Water Pan. F-Waiting Rack (6 Shelves). G-Repair Bench. H-Charging Table (3 Circuits). I-Electrolyte (10 Gal. Crocks). J-Separator Rack. K-Generator. L-Switchboard. M-Stock Bins. N-New Batteries. O-Live storage. P-Sealing Compound. R-Ready Rack (5-Shelves). S-Dry Storage. T-Torn Down Parts. (O and T in 141, not in 139 and 140.)

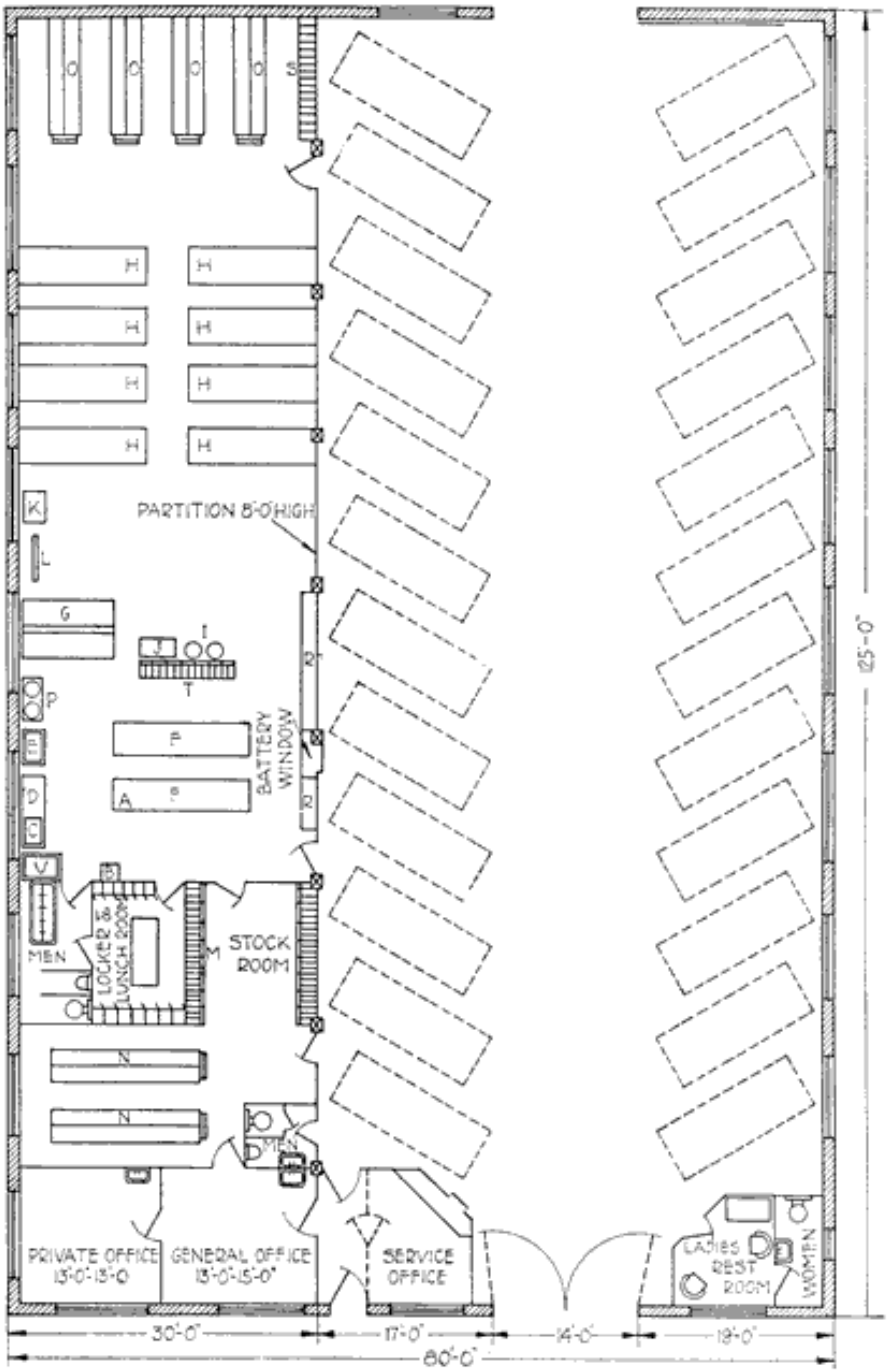

Fig. 142. Shop Layout

Fig. 142: A- Receiving Rack. B-Power Drill. C-Wash Tank. D-Tear Down Bench. E-Hot Water Pan. F-Waiting Rack (6 Shelves). G-Repair Bench. H-Charging Table. I-Electrolyte (10 Gal. Crocks). J-Separator Rack. K-Generator. L-Switchboard. M-Stock Bins. N-New Batteries. O-Live storage. P-Sealing Compound. R-Ready Rack. S-Dry Storage. T-Torn Down Parts.

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CHAPTER 10

STORAGE BATTERY TROUBLES

The Storage Battery is a most faithful servant, and if given even a fighting chance, will respond instantly to the demands made upon it. Given reasonable care and consideration, it performs its duties faithfully for many months. When such care is lacking, however, it is soon discovered that the battery is subject to a number of diseases, most of which are "preventable," and all of which, if they do not kill the battery, at least, greatly impair its efficiency.

In discussing these diseases, we may consider the various parts of which a battery is composed, and describe the troubles to which they are subject. Every battery used on an automobile is composed of :

1. **Plates**
2. **Separators**
3. **Jars in which Plates, Separators, and Electrolyte are placed**
4. **Wooden case**
5. **Cell Connectors, and Terminals**
6. **Electrolyte**

Most battery diseases are contagious, and if one part fails, some of the other parts are Affected. These diseases may best be considered in the order in which the parts are given in the foregoing list.

PLATE TROUBLES

Plates are the "vitals" of a battery, and their troubles affect -the life of the battery more seriously than those of the other parts. It is often difficult to diagnose their troubles, and the following descriptions are given to aid in the diagnosis.

Sulphation

1. Over discharge. Some battery men say that a battery is suflphated whenever anything is wrong with it. Sulphation is the formation of lead sulphate on the plates. **As a battery of the lead acid type discharges, lead sulphate must form.** There can be no discharge of such a battery without the formation of lead sulphate, which is the natural product of the chemical reactions by virtue of which current may be drawn from the battery. This sulphate gradually replaces the lead peroxide of the positive plate, and the spongy lead of the negative plate. When a battery has been discharged until the voltage per cell has fallen to the voltage limits, considerable portions of the lead peroxide and spongy lead remain on the plates. The sulphate which is then present is in a finely divided, porous condition, and can readily be changed back to lead peroxide and spongy lead by charging the battery.

If the discharge is continued after the voltage has fallen to the voltage limits, an excessive amount of sulphate forms. It fills up the pores in the active materials, and covers up much of the active material which remains, so that it is difficult to change the sulphate back to active material. Moreover, the expansion of active material which takes place as the sulphate forms is then so great that it causes the active material to break off from the plate and drop to the bottom of the jar.

2. Allowing a Battery to Stand Idle. When lead sulphate is first formed, it is in a finely divided, porous condition, and the electrolyte soaks through it readily. If a battery which has been discharged is allowed to stand idle without being charged, the lead sulphate crystals grow by the combination of the crystals to form larger crystals. The sulphate, instead of having a very large surface area, upon which the electrolyte may act in changing the sulphate to active material, as it does when it is first formed, now presents only a very small surface to the electrolyte, and it is therefore only with great difficulty that the large crystals of sulphate are changed to active material. The sulphate is a poor conductor, and furthermore, it covers up much of the remaining active material so that the electrolyte cannot reach it.

A charged battery will also become sulphated if allowed to stand idle, because it gradually becomes discharged, even though no wires of any kind are attached to the battery terminals. How this takes place is explained later. The discharge and formation of sulphate continue until the battery is completely discharged. The sulphate then gradually forms larger crystals as explained in the preceding paragraph, until all of the active material is either changed to sulphate, or is covered over by the sulphate so that the electrolyte cannot reach it. The sulphate thus forms a high resistance coating which hinders the passage of charging current through the battery and causes heating on charge. **It is for this reason that sulphated plates should be charged at a low rate.** The chemical actions which are necessary to change the sulphate to active material can take place but very slowly, and thus only a small current can be absorbed. Forcing a large current through a sulphated battery causes heating since the sulphate does not form uniformly throughout the plate, and the parts which are the least sulphated will carry the charging current, causing them to become heated. The heating damages the plates and separators, and causes buckling, as explained

later.

If batteries which have been discharged to the voltage limits are allowed to stand idle without being charged, they will, of course, continue to discharge themselves just as fully charged batteries do when allowed to stand idle.

3. Starvation. If a battery is charged and discharged intermittently, and the discharge is greater than the charge, the battery will never be fully charged, and lead sulphate will always be present. Gradually this sulphate forms the large tough crystals that cover the active material and remove it from action. This action continues until all parts of the plate are covered with the crystalline sulphate and we have the same condition that results when a battery is allowed to stand idle without any charge.

4. Allowing Electrolyte to Fall Below Tops of Plates. If the electrolyte is allowed to fall below the tops of the plates, so that the active materials are exposed to the air, the parts thus exposed will gradually become sulphated. The spongy lead of the negative plate, being in a very finely divided state, offers a very large surface to the oxygen of the air, and is rapidly oxidized, the chemical action causing the active material to become hot. The charging current, in passing through the parts of the plates not covered by the electrolyte also heats the active materials. The electrolyte which occasionally splashes over the exposed parts of the plates and which rises in the pores of the separators, is heated also, and since hot acid attacks the active materials readily, sulphation takes place quickly. The parts above the electrolyte, of course, cannot be charged and sulphate continues to form. Soon the whole exposed parts are sulphated as shown in Fig. 209.

As the level of the electrolyte drops, the electrolyte becomes stronger, because it is only the water which evaporates, the acid remaining and becoming more and more concentrated. The remaining electrolyte and the parts of the plates covered by it become heated by the current, because there is a smaller plate area to carry the current, and because the resistance of the electrolyte increases as it grows more concentrated. Since hot acid attacks the active materials, sulphation also takes place in the parts of the plates still covered by the electrolyte.

The separators in a battery having the electrolyte below the tops of the plates suffer also, as will be explained later. See page 346.

5. Impurities. These are explained later. See page 76.

6. Adding Acid Instead of Water. The sulphuric acid in the electrolyte is a heavy, oily liquid that does not evaporate. It is only the water in the electrolyte which evaporates. Therefore, when the level of the electrolyte falls, only water should be added to bring the electrolyte to the correct height. There are, however, many car owners who still believe

that a battery may be charged by adding acid when the level of the electrolyte falls. Batteries in which this is done then contain too much acid. This leads to two troubles. The first is that the readings taken with a hydrometer will then be misleading. A specific gravity of 1.150 is always taken to indicate that a battery is discharged, and a specific gravity of 1.280 that a battery is charged. These two values of specific gravity indicate a discharged and charged condition of the battery **ONLY WHEN THE PROPORTION OF ACID IN THE ELECTROLYTE IS CORRECT.** It is the condition of the plates, and not the specific gravity of the electrolyte which determines when a battery is either charged or discharged. With the correct proportion of acid in the electrolyte, the specific gravity of the electrolyte is 1.150 when the plates are discharged and 1.280 when the plates are charged, and that is why specific gravity readings are generally used as an' indication of the condition of the battery.

If there is too much acid in the electrolyte, the plates will be in a discharged condition before the specific gravity of the electrolyte drops to 1.150, and will not be in a charged condition until after the specific gravity has risen beyond the usual value. As a result of these facts a battery may be over-discharged, and never fully charged, this resulting in the formation of sulphate.

The second trouble caused by adding acid to the electrolyte is that the acid will then be too concentrated and attacks both plates and separators. This will cause the plates to become sulphated, and the separators rotted.

7. Overheating. This was explained in Chapter 9. See page 66.

Buckling

Buckling is the bending or twisting of plates due to unequal expansion of the different parts of the plate, Figs. 207 and 208. It is natural and unavoidable for plates to expand. As a battery discharges, lead sulphate forms. This sulphate occupies more space than the lead peroxide and spongy lead, and the active materials expand. Heat expands both active materials and grids. As long as all parts of a plate expand equally, no buckling will occur. Unequal expansion, however, causes buckling.

1. Over discharge. If discharge is carried too far, the expansion of the active material on account of the formation of lead sulphate will bend the grids out of shape, and may even break them.

2. Continued Operation with Battery in a Discharged Condition. When a considerable amount of lead sulphate has, formed, and current is still drawn from the battery, those portions of the plate which have the least amount of sulphate will carry most of the current, and will therefore become heated and expand. The parts covered with sulphate will not

expand, and the result is that the parts that do expand will twist the plate out of shape. A normal rate of discharge may be sufficient to cause buckling in a sulphated plate.

3. Charging at High Rates. If the charging rate is excessive, the temperature will rise so high that excessive expansion will take place. This is usually unequal in the different parts of the plate, and buckling results. With a battery that has been over discharged, the charging current will be carried by those parts of the plates which are the least sulphated. These parts will therefore expand while others will not, and buckling results.

4. Non-Uniform Distribution of Current Over the Plates. Buckling may occur in a battery which has not been over-discharged, if the current carried by the various parts of the plate is not uniform on account of faulty design, or careless application of the paste. This is a fault of the manufacturers, and not the operating conditions.

5. Defective Grid Alloy. If the metals of which the grids are composed are not uniformly mixed throughout the plate, areas of pure lead may be left here and there, with air holes at various points. The electrolyte enters the air holes, attacks the lead and converts the grid partly into active material. This causes expansion and consequent distortion and buckling.

Buckling will not necessarily cause trouble, and batteries with buckled plates may operate satisfactorily for a long time. If, however, the expansion and twisting has caused much of the active material to break away from the grid, or has loosened the active material from the grids, much of the battery capacity is lost. Another danger is that the lower edges of a plate may press against the separator with sufficient force to cut through it, touch the next plate, and cause a short-circuit.

Shedding, or Loss of Active Material

The result of shedding, provided no other troubles occur, is simply to reduce the capacity of the plates. The positives, of course, suffer more from shedding than the negatives do, shedding being one of the chief weaknesses of the positives. There is no remedy for this condition. When the shedding has taken place to such an extent that the capacity of the battery has fallen very low, new plates should be installed. After a time, the sediment space in the bottom of the jar becomes filled with sediment, which touches the plates. This short-circuits the cell, of course, and new plates must be installed, and the jars washed out thoroughly.

1. Normal Shedding. It is natural and unavoidable for the positives to shed. Lead Peroxide is a powder-like substance, the particles of which do not hold together. A small amount of sulphate will cement the particles together to a considerable extent. At the surface of the plate, however, this sulphate is soon changed to active material, and the peroxide loses its coherence. Particles of peroxide drop from the plates and fall, into the space in the bottom

of the jar provided for this purpose.

Bubbles of gas which occur at the end of a charge blow some of the peroxide particles from the plate. The electrolyte moving about as the battery is jolted by the motion of the car washes particles of peroxide from the positive plates. Any slight motion between positive plates and separators rubs some peroxide from the plates. It is therefore entirely natural for shedding to occur, especially at the positives. The spongy lead of the negatives is much more elastic than the peroxide, and hence very little shed. ding occurs at the negative plates. **The shedding at the positives explains why the grooved side of the separator is always placed against the positive plate.** The grooves, being vertical, allow the peroxide to fall to the bottom of the jar, where it accumulates as sediment, or "mud."

2. Excessive Charging Rate, or Overcharging. If a battery is charged at too high a rate, only part of the current is used to produce the chemical actions by which the battery is charged. The balance of the current decomposes the water of the electrolyte into hydrogen and oxygen, causing gassing. As the bubbles of gas force their way out of the plates, they blow off particles of the active material.

When a battery is overcharged, the long continued gassing has the same effect as described in the preceding paragraph.

3. Charging Sulphated Plates at too High a Rate. In sulphated plates, the chemical actions which take place as a battery is charged can proceed but very slowly, because the sulphate, besides being a poor conductor, has formed larger crystals which present only a small surface for the electrolyte to act upon, and has also covered up much of the remaining active material. Since the chemical actions take place slowly, the charging current must be kept at a low value. If too heavy a charging current is used, the battery will be overheated, and some of the current will simply cause gassing as explained in No. 2 above. The gas bubbles will break off pieces of the sulphate, which then fall to the bottom of the jars as "mud."

4. Charging Only a Part of the Plate. If the electrolyte falls below the tops of the plates, and the usual charging current is sent into the battery, the current will be too great for the plate area through which it passes, and hence gassing and shedding will result as already explained.

The same condition exists in a battery in which one or more plates have been broken from the strap, either because of mechanical vibration or because of impurities such as acetic acid in improperly treated separators. The remaining plates are called upon to do more work, and carry the entire charging current. Gassing and shedding will result.

5. Freezing. If a battery is given any care whatever, there is little danger of freezing. The

electrolyte of a fully charged battery with a specific gravity of 1.280 freezes at about 92° below zero. With a specific gravity of 1.150, the electrolyte freezes at about 5° above zero. A frozen battery therefore indicates gross neglect.

As the electrolyte freezes, the water of the electrolyte expands. Since there is electrolyte in all the inner parts of the plate, the expansion as the water in the paste freezes forces the pastes out of the grids. The expansion also cracks the rubber jars, and sometimes bulges out the ends of the battery case

Loose Active Material

This refers to a condition in which the active materials are no longer in contact with the grid. Corrosion, or sulphation, of the grids themselves is generally present at the same time, since the chemical actions are shifted from the active material to the grids themselves.

1. Over discharge. As a battery discharges, the lead sulphate which forms causes an expansion of the active material. If a battery is repeatedly over-discharged, this results in the positives shedding. In the negatives, the spongy lead is puffed out, resulting in the condition known as "bulged negatives" as illustrated in Fig 122.

2. Buckling. As a plate grid is bent out of shape, the active material, especially the peroxide, breaks loose from the grid, since the peroxide cannot bend as much as the grids. This occurs in the negatives also, though not to such an extent as in the positives.

If the plates are buckled to such an extent that the element will not go back into the jar, the positives should be discarded. If the positives are buckled, the negatives will be also, but not to the extent that the positives are.

In the case of the positives, there is no remedy, and the plates should be discarded. The negatives, however, may be fully charged, and then straightened, and the active material forced back flush with the grids by pressings, as described in Chapter 15.

Impurities

Impurities may be divided into two general classes. The first class includes those which do not attack the separators or grids, but merely cause internal self-discharge. The second class includes those which attack the grids or separators.

1. Impurities Which Merely Cause Self-discharge. This includes metals other than lead. If these metals are in solution in the electrolyte, they deposit on the negative plate, during charge, in their ordinary metallic state, and form small cells with the spongy lead. These

small cells discharge as soon as the charging circuit is opened, and some of the lead is changed to lead sulphate. This, of course, causes a loss in capacity. Free hydrogen is given off by this local discharge, and so much of it is at times given off that the **hydrogen bubbles give the electrolyte a milky appearance.**

Silver, gold, and platinum are the most active in forming small local cells. These metals form local cells which have comparatively high voltages, and which take away a considerable portion of the energy of a cell. Platinum is especially active, and a small amount of platinum will prevent a negative plate from taking a charge. Gradually, however, the spongy lead covers up the foreign metal and prevents it from forming local cells.

Iron also forms local cells which rob the cell of a considerable portion of its capacity. This may be brought into the cell by impure acid or water. Iron remains in solution in the electrolyte, and is not precipitated as metallic iron. The iron in solution travels from the positive to the negative plate, and back again, causing a local discharge at each plate. It is, moreover, very difficult to remove the iron, except by pouring out all of the electrolyte. Manganese acts the same as the iron.

2. Impurities Which Attack the Plates. In general, this class includes acids other than sulphuric acid, compounds formed from such acids, or substances which will readily form acids by chemical action in the cell. Nitric acid, hydrochloric or muriatic acid, and acetic acid belong in this class of impurities. Organic matter in a state of decomposition attacks the lead grids readily.

Impurities in the second class dissolve the lead grids, and the plate disintegrates and falls to pieces, since its backbone is destroyed. When a battery which contains these impurities is opened, it will be found that the plates crumble and fall apart at the slightest touch. See Fig. 210.

Separators which have not been treated properly introduce acetic acid into a cell. The acetic acid attacks and rots the lead, especially the lugs projecting above the electrolyte, and the plate connecting straps. The plates will generally be found broken from the connecting strap, with the plate lugs broken and crumbled.

As for remedies, there is not much to be done. Impurities in the first class merely decrease the capacity of the battery. If the battery is fully charged, and the negatives then washed thoroughly, some of the impurities may be removed. Impurities of the second class have generally damaged the plates beyond repairs by the time their presence is suspected.

The best thing to do is to keep impurities out of the battery. This means that only distilled water, which is known to be absolutely free from impurities should be used.

Impurities which exist in the separators or acid cannot be detected readily, but in repairing a battery, separators furnished by one of the reliable battery makers should be used. Pure acid should also be used. This means that only chemically pure, or "C. P." acid, also known as battery acid should be used. In handling the acid in the shop, it should always be kept in its glass bottle, and should be poured only into a glass, porcelain, earthenware, lead, or rubber vessel. Never use a vessel made of any other material.

Corroded Grids

When the grids of a plate are attacked chemically, they become thin and weak, and may be spoken of as being corroded.

1. Impurities. Those impurities which attack the lead grids, such as acids other than sulphuric acid, compounds formed from these acids, or substances which will readily form acids dissolve some of the lead which composes the grids. The grids gradually become weakened. The decrease in the amount of metal in the grids increases the internal resistance of the cell and give a tendency for temperatures to be higher in the cell. The contact between grids and active material is in time made poor. If the action of the impurities continues for any length of time, the plate becomes very weak, and breaks at the slightest touch.

2. High Temperatures. Anything that raises the temperature of the electrolyte, such as too high a charging rate, causes the acid to attack the grids and form a layer of sulphate on them. The sulphate is changed to active material on charge, and the grids are thereby weakened.

3. Age. Grids gradually become weak and brittle as a battery remains in service. The acid in the electrolyte, even though the electrolyte has the correct gravity and temperature, has some effect upon the grids, and in time this weakens them. During the life of a battery it is at times subjected to high temperatures, impurities, sulphation, etc., the combined effects of which result in a gradual weakening of the grids.

Granulated Negatives

1. Age. The spongy lead of the negative plate gradually assumes a "grainy" or "granulated" appearance. The lead then seems to be made up of small grains, like grains of sand, instead of being a smooth paste. This action is a natural one, and is due to the gradual increase in the size of the particles of the lead. The plate loses its porosity, the particles cementing together and closing the pores in the lead. The increase in the size of the particles of the spongy lead decreases the amount of surface exposed to the action of the electrolyte, and the plate loses capacity. Such plates should be thrown away, as charging and discharging will not bring the paste back to its original state.

2. Heat will also cause the paste to become granulated, and its surface to become rough or even blistered.

Heating of Negatives Exposed to the Air

When charged negatives are exposed to the air, there is a decided increase in their temperature. Spongy lead is in an extremely finely divided state, the particles of lead being very minute, and forming a very porous mass. When the plate is exposed to the air, rapid oxidation takes place because the oxygen of the air has a very large surface to act upon. The oxidation causes the lead to become heated. The heating, of course, raises the temperature of the electrolyte, and the hot acid attacks both grids and lead.

Fully charged negatives should therefore be watched carefully when removed from a battery. When they become heated and begin to steam, they should be dipped in water until they have cooled. They may then be removed from the water, but should be dipped whenever they begin to steam. After they no longer heat, they may be left exposed to the air.

This method of dipping the negatives to prevent overheating has always been followed. However, the Electric Storage Battery Company, which makes the Exide batteries, does not take any steps to prevent the heating of the negatives when exposed to the air, stating that their plates are not injured by the heating which takes place.

Negatives With Very Hard Active Material

This is the characteristic condition of badly sulphated negatives. The active material may be as hard as a stone. The best method of treating such negatives is to charge them in distilled water. See Chapter 15.

Bulged Negatives

This is a characteristic of a repeatedly over-discharged negative. The lead sulphate which forms as a battery discharges is bulkier than the spongy lead, and the lead expands and bulges out between the ribs of the grid.

Negative With Soft, Mushy Active Material

1. High Gravity. Gravity above 1.300 causes the acid to act upon the spongy lead and soften it.

2. Heat will soften the spongy lead also. The softened spongy lead is loosened and falls from the grids, as shown in Fig. 211. Little can be done for such 'negatives.

Negatives With Roughened Surface

This is caused by slight overheating, and is not a serious condition.

Frozen Positives

A battery which is allowed to stand in a cold place while completely discharged will freeze. The water in the electrolyte expands as it freezes, cracking the rubber jars and bulging out the end of the wooden case. As the electrolyte which fills the pores of the positive plates freezes and expands, it breaks the active material loose from the grids. When the battery thaws, the active material does not go back into the grids. When such a battery is opened, and the groups separated, the positive active material sticks to the separators in large pieces, Fig. 112, and that remaining in the grids falls out very easily. The active material has a pinkish color and is badly shrunken.

Rotted, Disintegrated Positives

1. Impurities. This has already been discussed. See page 76.

2. Overheating. The hot electrolyte dissolves the lead of the grids and that which is dissolved is never converted back to lead. Continued overheating wears out the grids, and the active material also, and the plate falls to pieces at the slightest pressure.

3. Age. Positives gradually disintegrate due to the prolonged action of the electrolyte on the grids, an occasional overheating, occasional use of impure water, etc.

Positives which are rotted and disintegrated are, of course, hopeless, and must be junked.

Buckled Positives

As previously described, buckling is caused by unequal expansion. If the buckling is only slight, the plates may be used as they are. If the plates are badly buckled, the active material will be found to be loose, and the plates cannot be straightened. Such positives should be discarded.

Positives That Have Lost Considerable Active Material

This is the result of continued shedding, the causes of which have already been given. If

the shedding is only slight, and the plate is good otherwise, it may be used again. If such active material has been lost, the plates must be discarded.

Positives With Soft Active Material

Continued operation at high temperatures, will soften the peroxide, and make the plates unfit for further use. Old positives are soft, clue to the natural deterioration of the paste with age.

Positives With Hard, Shiny Active Material

This condition is found in batteries that have been charged with the acid below the tops of the plates. The part of the plate above the acid is continually being heated by the charging current. It becomes hard and shiny, and has cracks running through it. The peroxide becomes orange or brick colored, and the grid deteriorates. The part of the plate below the electrolyte suffers also, as explained more fully on page 71. Such plates should be discarded if any considerable portion of the plates is affected. Plates in which 1/2 to 1 inch of the upper parts are affected may be used again if otherwise in good condition.

Plates Which Have Been Charged in Wrong Direction

Such plates have been partly reversed, so that there is lead peroxide and spongy lead on both positive and negative plates, and such plates are generally worthless. If the active materials have not become loosened from the grids, and the grids have not been disintegrated and broken, the plates may sometimes be reversed by a long charge at a low rate in the right direction. If this does not restore the plates, discard them.

SEPARATOR TROUBLES

Separators form the weakest part of a battery, but at the same time perform a very important duty. New separators should therefore be installed whenever a battery is opened for repairs. Repairs should never be attempted on separators.

1. Not Properly Expanded Before Installation. Separators in stock must be kept moist. This not only prevents them from becoming dry and brittle, but keeps them fully expanded. If separators which have been kept dry in stock are installed in a battery, they do their expanding inside the battery. This causes them to project beyond the edges of the plates. The crowding to which they are subjected causes them to crack. Cracked separators permit "treeing" between plates, with a consequent short circuit.

2. Not Properly Treated. Separators which have not been given the proper chemical treatment are likely to develop Acetic acid after they are in the battery. Acetic acid

dissolves the lead grids, the plate lugs, and the plate connecting straps rapidly. If the plate lugs are found broken, and crumble easily, acetic acid is very likely present, especially if an odor like that of vinegar is noticeable. Improperly treated separators will cause a battery to show low voltage at high rates of discharge, particularly in cold weather, and will also cause the negatives to give poor cadmium readings, which may lead the repairman to conclude that tile negatives are defective. The separators of batteries which have been shipped completely assembled without electrolyte and with moistened plates and separators will sometimes have the same effect.

3. Cracked. Separators should be carefully "candled" -- placed in front of a light and looked through. Cracks, resinous streaks, etc., mean that the separator should not be used, as it will breed trouble.

4. Rotted and Carbonized. This may be the result of old age, overheating, or high gravity electrolyte.

5. Pores Clogged. Impurities, dirt from impure water, and lead sulphate fill the pores of a separator and prevent the proper circulation of the electrolyte. The active material of frozen positives also fills up the pores of a separator.

6. Edges Chiseled Off. A buckling plate will cut through the lower edge of a separator and short circuit the cell. Holes will be cut through any part of a separator by a buckling plate, or a negative with bulged active material.

JAR TROUBLES

Battery jars are made of hard rubber, and are easily broken. They are not acted upon by the electrolyte, or any of the impurities which may be found in the jar. Their troubles are all mechanical, and consist of being cracked, or having small holes through the walls. Jars are softened by high temperatures, but this does no particular harm unless they are actually burned by an open flame or red hot metal. The causes of jar troubles are as follows:

1. Rough Handling. By far the most common cause of jar breakage is rough handling by careless or inexperienced persons. If one end of a battery rests on the floor, and the other is allowed to drop several inches, broken jars will probably result from the severe impact of the heavy lead plates. Storage batteries should be handled as if made of glass. When installed on a car, the springs protect the battery from shock to a considerable extent, but rough roads or exceptionally severe jolts may break jars.

2. Battery Not Properly Fastened. In this case a battery is bumped around inside the battery compartment, and damage is very likely to result.

3. Any Weight Placed on Top of the Battery is transmitted from the links to the plates, and by them to the bottom of the jars. Batteries should always be stored in racks, and not one on top of another. The practice of putting any weight whatever on top of a battery should be promptly discouraged.

4. Freezing. This condition has already been explained. It causes a great many broken jars every winter.

5. Groups Not Properly Trimmed. The outside negative plates in a cell come just inside the jar, and the strap ends must be carefully trimmed off flush with the plates, to prevent them from breaking the top of the jars. Jars have slightly rounded corners, and are somewhat narrower at the extreme ends than nearer the center. A group may therefore go into a jar quite readily when moved toward the other end of the jar to that into which the post strap must go when in proper position for the cover. When the group is forced back into its proper position the strap may break the jar. It is a good plan not only to trim the ends of the negative straps perfectly flush, but to round the strap corners where they go into the jar corners.

6. Defective Jars. (a) A jar not properly vulcanized may come apart at the scam. (b) A small impurity in the rubber may dissolve in the acid and leave a minute pinhole. All jars are carefully tested at the factory and the likelihood of trouble from defective jars is extremely small.

7. Explosion in Cell. (a) Hydrogen and oxygen gases evolved during charging make a very explosive mixture. An open flame brought near a battery on charge or freshly charged, will probably produce an explosion resulting in broken jars and jar covers. (b) An open circuit produced inside a cell on charge in the manner described on page 86 under the heading "Open Circuits," will cause a spark at the instant the circuit is broken, with the same result as bringing a flame near the battery. (c) The small holes in the vents must be kept free for the escape of the gases. These holes are usually sealed in batteries shipped with moistened plates and separators, to keep air out of the cells. The seals must be removed when the battery is prepared for service. If the vents remain plugged, the pressure of the gases formed during charge will finally burst the covers of jars.

BATTERY CASE TROUBLE

1. Ends Bulged Out. This may be due to a battery having been frozen or to hold-downs being screwed down too tight, or some similar cause. Whether the case can be repaired depends on the extent of the bulging. This can best be determined by the repairman.

2. Rotted. If the case is rotted around the top, it is evidence that: (a) Too much water was added, with subsequent overflowing when electrolyte warmed up during charge. (b) The

tops were poorly sealed, resulting in leaks between the covers and the, jars. (c) Battery has not been fastened down properly, and acid has been thrown out of the jars by the jolting of the car on the road. (d) The vent plugs have not been turned down tightly. (e) Electrolyte has been spilled in measuring specific gravity.

If the case is rotted around the lower part it indicates that the jars are cracked or contain holes. Instructions for making repairs on battery cases are given on page 360.

TROUBLE WITH CONNECTORS AND TERMINALS

1. Corroded. This is a very common trouble, and one which should be guarded against very carefully. Corrosion is indicated by the presence of a grayish or greenish substance on the battery terminals, especially the positive. It is due to several causes:

(a) Too much water added to cells. The electrolyte expands on charge and flows out on the top of the battery.

(b) Battery not fastened firmly. The jolting caused by the motion of the car on the road will cause electrolyte to be thrown out of the vent caps.

(c) Battery poorly sealed. The electrolyte will be thrown out on the cover by the motion of the car through the leaks which result from poor sealing.

(d) Vent caps loose. This also allows electrolyte to be thrown out on the battery top.

(e) Electrolyte spilled on top of battery in measuring specific gravity.

(f) Battery cables damaged, or loose. The cables attached to the battery terminals are connected to lugs which are heavily coated with lead. The cables are insulated with rubber, upon which sulphuric acid has no effect. Care should be taken that the lead coating is not worn off, and that the rubber insulation is not broken or cut so as to allow electrolyte, which is spilled on the battery top as explained in (a), (b), (c), (d) and (e), to reach the bare copper conductors of the cable. The terminal parts are always so made that when the connections are kept tight no acid can come into contact with anything but lead and rubber, neither of which is attacked by sulphuric acid.

(g) Attaching wires directly to battery terminals. There should be no exposed metal except lead at the battery terminals. No wires of any other metal should be attached to the battery terminals. Such wires should be connected to the rubber covered cables which are attached to battery, and the connections should be made far enough away from the battery to prevent electrolyte from coming in contact with the wire. Car manufacturers generally observe this rule, but the car owner may, through ignorance, attach copper wires directly to

the battery terminals. The positive terminal is especially subject to corrosion, and should be watched carefully. To avoid corrosion it is necessary simply to keep the top of the battery dry, keep the terminal connections tight, and coat the terminals with vaseline. The rule about connecting wires directly to the battery terminals must of course be observed also.

2. Loose. Loose terminal connections cause a loss of energy due to their resistance, and all such connections must be well made. If the inter-cell connectors are loose, it is due to a poor job of lead burning. This is also true of burned on terminals, and in either case, the connections should be drilled off, cleaned and re-burned.

Terminals sometimes become so badly corroded that it is impossible to disconnect the cables front the battery. Stitch terminals should be drilled off and soaked in boiling soda water.

ELECTROLYTE TROUBLES

(1) Low Gravity. See page 321.

(2) High Gravity. See page 323.

(3) Low Level. See page 323.

(4) High Level. This condition is due to the addition of too much water. It leads to corrosion as already explained. It also causes a loss of acid. The Electrolyte which overflows is lost, this of course, causing a loss of acid. The condition of Low Gravity then arises, as described on page 321.

(5) Specific gravity will not rise during charge. See page 204.

(6) Milky Electrolyte:

> **(a) Lead Sulphate in Battery Acid.** It sometimes happens that sulphuric acid contains some lead sulphate in solution. This sulphate is precipitated when water is added to the acid in mixing electrolyte, and gives the electrolyte a milky appearance. This sulphate settles if the electrolyte is allowed to stand.
>
> **(b) Gassing.** The most common cause of the **milky** appearance, however, is the presence of minute gas bubbles in large quantities. These may be the result of local action caused by the presence of metallic impurities in the battery. The local action will stop when the battery is put on charge, but will

begin as soon as the battery is taken off charge. The impurities are gradually covered by lead or lead sulphate, and the local action is thus stopped.

Excessive gassing in a cell which contains no impurities may also cause the electrolyte to have a milky appearance. The gas bubbles are very numerous and make the electrolyte look milky white.

(c) Impurities in the electrolyte will also give it a milky appearance.

GENERAL TROUBLES

Open Circuits

1. Poor Burning of Connectors to Posts. Unless a good burned connection is made between each connector and post, the joint may melt under high discharge rates, or it may offer so much resistance to the passage of current that the starting motor cannot operate. Sometimes the post is not burned to the connector at all, although the latter is well finished off on top. Under such conditions the battery may operate for a time, due to frictional contact between the post and connector, but the parts may become oxidized or sulphated, or vibration may break the connection, preventing the flow of current. Frequently, however, the circuit is not completely open, and the poor connection acts simply as a high resistance. Under such a condition the constant current generator automatically increases its voltage, and forces charging current through the battery, although the latter, having only a low fixed voltage, cannot force out the heavy current required for starting the engine.

2. Terminals Broken Off. Inexperienced workmen frequently pound on the terminals to loosen the cable lugs, or pry on them sufficiently to break off the battery terminals. If the terminals and lugs are kept properly greased, they will come apart easily. A pair of terminal tongs is a very convenient tool. These exert a pressure between the terminal and the head of the terminal screw, which is first unscrewed a few turns.

3. Acid on Soldered Joints. Amateurs sometimes attempt to make connections by the use of a soldering iron and solder. Solder is readily dissolved by acid, not only spoiling the joint, but endangering the plates if any gets into the cells. Solder must never be used on a battery except for sweating the cables into the cable lugs, and the joint even here must be well protected by rubber tape.

4. Defective Posts. Posts withdrawn from the post mould before they are cool enough may develop cracks. Bubbles sometimes occur in the posts. Either trouble may reduce the current carrying capacity or mechanical strength of the post and result in a broken or burned-out spot.

5. Plates Improperly Burned. As previously explained, this is not likely to cause immediate trouble, but by imposing extra work on the balance of the plates, causes them to wear out quickly.

Battery Discharged

1. Due to excessive use of starting motor and lamps.

2. Failure of generator.

3. Defective switches, which by being grounded, or failing to open allow battery to discharge.

4. Defective cutout, allowing battery to discharge into generator.

5. Addition of accessories, or use of too large lamps.

6. Defective wiring, causing grounds or short-circuits.

7. Insufficient charging rate.

8. Battery allowed to remain idle.

Dead Cells

1. Worn out Separators. The duties of separators are to prevent the plates from touching each other, and to prevent "treeing," or growth of active material from the negative to the positive plates. If they fail to perform these duties, the battery will become short-circuited internally. The separator troubles described on page 81 eventually lead to short-circuited cells.

2. Foreign Material. If a piece of lead falls between plates so as to later punch a hole through a separator, a short circuit will result. Great care should be taken in burning plates on the straps to prevent lead from running down between plates, as this lead will cause a short circuit by punching through the separator.

3. Accumulation of Sediment. The active material which drops from the plates accumulates in the "mud" space in the bottom of the jar. If this rises until it touches the bottom of the plates, a short-circuit results. Usually it is advisable to renew the positives in a battery which has become short-circuited by sediment, since the sediment comes largely from the positives, and if they have lost enough active material to completely fill the

sediment space, they are no longer fit for use.

4. Badly sulphated plates and separators, impurities which attack the plates.

Loss of Capacity

A battery loses capacity due to a number of causes. Some of them have already been considered.

1. Impurities in the Electrolyte. These have already been discussed.

2. Sulphation. This also has been described.

3. Loose Active Material, as already described. The active materials which are not in contact with the grids cannot do their work.

4. Incorrect Proportions of Acid and Water in the Electrolyte. In order that all the active material in the plates may be utilized, there must be enough acid in the electrolyte, and also enough water. If there is not enough acid, the battery will lack capacity. If there is too much acid, the acid when the battery is fully charged will be strong enough to attack and seriously damage the plates and separators. Insufficient amount of acid may be due to replacing, with water, electrolyte which has been spilled or which has leaked out. Too much acid results from an incorrect proportion of acid and water in the electrolyte, or from adding acid instead of water to bring the electrolyte above the plate tops, and causes sulphation, corroded plates, and carbonized separators.

The remedy for incorrect proportions of acid and water in the electrolyte is to give the battery a full charge and adjust the gravity by drawing off some of the electrolyte and replacing it with water, or 1.400 specific gravity electrolyte, as the case may require.

5. Separators Clogged. The pores of the separators may become filled with sulphate or impurities, and thus prevent the proper circulation of the electrolyte. New separators must be put in.

6. Shedding. The capacity of a battery naturally decreases as the active material falls from the plates, since the amount of active material which can take part in the chemical actions that enable us to draw current from the battery decreases.

7. Low Level of Electrolyte. Aside from the loss of capacity which results from the sulphation caused by low electrolyte, there is a loss of capacity caused by the decrease in the useful plate area when the electrolyte is below the tops of the plates. Only that part of the plate surface which is below the electrolyte does any work, and the area of this part

gradually decreases as the electrolyte falls.

8. Reversal of Plates. If one cell of a battery has an internal short circuit, or some other defect which causes it to lose its charge, the cell will be discharged before the others which are in series with it, and when this cell is completely discharged, the other cells will send a current through it in a discharge direction, and the negative plates will have a coating of lead peroxide formed on them, and will assume the characteristics of positive plates. The positives will be reversed also.

This reversal may also be the result of charging a battery in the wrong direction, on account of reversed charging connections. The remedy for reversed plates, provided they have not become disintegrated, is to give them a long charge in the right direction at a low rate.

9. Effect of Age. A battery gradually loses capacity due to its age. This effect is independent of the loss of capacity due to the other causes. In the negatives, the size of the grain increases its size, giving the plates a granulated appearance. Stitch plates are called "granulated" negatives. The spongy lead cements together and loses porosity.

Loss of Charge in An Idle Battery

It has been found that if a charged battery is allowed to stand idle, and is not charged, and no current is drawn from it, the battery will gradually become completely discharged and must be given an occasional "freshening" charge.

Now, as we have learned, when a battery discharges lead sulphate forms on each plate, and acid is taken from the electrolyte as the sulphate forms. In our idle battery, therefore, such actions must be taking place. The only difference in this case is that the sulphate forms without any current passing through the battery.

At the lead peroxide plate we have lead peroxide paste, lead grid, and sulphuric acid. These are all the element-, needed to produce a storage battery, and as the lead peroxide and the lead are touching each other, each lead peroxide plate really forms a short circuited cell. Why does this plate not discharge itself completely? A certain. amount of discharge does take place, and results in a layer of lead sulphate forming between the lead peroxide and the grid. The sulphate, having high resistance then protects the lead grid and prevents any further action. This discharge action therefore does not continue, but causes a loss of a certain part of the charge.

At the negative plate, we have pure spongy lead, and the grid. This grid is not composed entirely of lead, but contains a percentage of antimony, a metal which makes the grid harder and stronger. There is but very little difference of potential between the spongy lead

and the grid. A small amount of lead sulphate does form, however, on the surface of the negative plate. This is due to the action between the spongy lead and the electrolyte.

Some of the lead combines with the acid to form lead sulphate, but after a small amount has been formed the action is stopped because a balanced chemical condition is soon obtained.

Thus only a small amount of lead sulphate is formed at each plate, and the cell thereby loses only a small part of its charge. In a perfectly constructed battery the discharge would then stop. The only further action which would take place would be the slow evaporation of the water of the electrolyte. The loss of charge which actually occurs in an idle charged battery is greater than that due to the formation of the small amounts of sulphate on the plates, and the evaporation of the water from the electrolyte.

Does an idle cell discharge itself by decomposing its electrolyte? We have a difference of potential of about two volts between the lead and lead peroxide plate. Why is the electrolyte not decomposed by this difference? At first it might seem that the water and acid should be separated into its parts, and hydrogen liberated at the negative plate. As a matter of fact, very little hydrogen gas is set free in an idle charged cell because to do so would require a voltage of about 2.5. At two volts, so little gas is formed that the loss of charge due to it may be neglected entirely.

The greatest loss of charge in an idle battery results from conditions arising from the processes of manufacture, internal troubles, and leakage between terminals. The grids of a cell are an alloy of lead and antimony. These are mixed while in a molten condition, and are then allowed to cool. If the cooling is not done properly, or if a poor grade of antimony is used, the resulting grid is not a uniform mixture of antimony and lead. There will be areas of pure lead, with an air hole here and there. The lack of uniformity in the grid material results in a local discharge in the grid. This causes some loss of charge.

If the active material completely fills the spaces between- the grids, the acid formed as the cell is charged may not be able to diffuse into the main body of the electrolyte, but forms a small pocket of acid in the plate. This acid will cause a discharge between paste and grid and a coating of lead sulphate forms on the arid, resulting in a certain loss of charge.

In general any metallic impurity in a cell will cause a loss at the lead plate. When a cell is charged, the current causes the metals to deposit on the lead plate. Local cells are formed by the metallic impurity, the lead plate, and the acid, and these tiny cells will discharge completely, causing a loss of charge. This has already been described on page 76.

Another cause of loss of charge in an idle cell is leakage of current between the

terminals on the outside of the battery. During charge, the bubbles of gas which escape from the electrolyte carry with them minute quantities of acid which may deposit on the top of the battery and gradually form a thin conducting layer of electrolyte through which a current will flow from the positive to the negative terminals. This danger may be avoided by carefully wiping any moisture from the battery. Condensation of moisture from the air, on the top or sides and bottom of a battery will cause the same condition. This will be especially noticeable if a battery is kept in a damp place.

The tendency for crystals of lead to "tree" over from the negative to the positive plates is well known. An idle battery is one in which this action tends to take place. Treeing will occur through the pores of the separators and as there is no flow of electrolyte in or out of the plates, the lead "trees" are not disturbed in their growth. A freshening charge causes this flow to take place, and break up the "trees" which would otherwise gradually short circuit the cells.

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CHAPTER 14

WHAT'S WRONG WITH THE BATTERY?

When a man does not feel well, he visits a doctor. When he has trouble on his car, he takes the car to a service station. What connection is there between these two cases? None whatever, you may say. And yet in each instance the man is seeking service. The term "Service Station" generally suggests a place where automobile troubles are taken care of. That does not mean, however, that the term may not be used in other lines of business. The doctor's office is just as much a "Service Station" as the automobile repair shop. The one is a "Health Service Station" and the other is an "Automobile Service Station." The business of each is to eliminate trouble.

The battery repairman may think that he cannot learn anything from a doctor which will be of any use to his battery business, but, as a matter of fact, the battery man can learn much that is valuable from the doctor's methods of handling trouble. The doctor greets a patient courteously and always waits for him to tell what his symptoms are. He then examines the patient, asking questions based on what the patient tells him, to bring out certain points which will help in making an accurate diagnosis. Very often such questioning will enable the doctor to determine just what the nature of the illness is. But he does not then proceed to write out a prescription without making an examination. If he did, the whole case might just as well have been handled over the telephone. No competent physician will treat patients from a distance. Neither will he write out a prescription without making a physical examination of the patient. The questioning of the patient and the physical examination always go together, some questions being asked before an examination is made to give an approximate idea of what is wrong and some during the examination to aid the doctor in making an accurate diagnosis.

The patient expects a doctor to listen to his description of the symptoms and to be guided by them in the subsequent examination, but not to arrive at a conclusion entirely by the description of the symptoms. A patient very often misinterprets his pains and aches, and tells the doctor that he has a certain ailment. Yet the doctor makes his examination and determines what the trouble is, and frequently find a condition which is entirely different from what the patient suspected. He then prescribes a treatment based on his own conclusions and not on what the patient believes to be wrong.

Calling for Batteries. A doctor treats many patients in his office, but also makes his daily calls on others. Similarly, the battery repairman should have a service truck for use in calling for customers' batteries, especially where competition is keen. Some car owners cannot bring their cars to the repair shop during working hours, and yet if they knew that they could have their battery called for and have a rental battery installed, they would undoubtedly have their battery tested and repaired more frequently. In some instances a battery will be so badly run down that the car cannot be started, and the car is allowed to stand idle because the owner does not care to remove his battery, carry it to a service station and carry a rental battery with him. Batteries are heavy and generally dirty and wet with acid, and few people wish to run the risk of ruining their clothes by carrying the battery to a shop. The wise battery mail will not overlook the business possibilities offered by the call for and deliver service, especially when business is slow. A Ford roadster with a short express body will furnish this service, or an.),- old chassis may be fitted up for it at a moderate cost. Of course, you must advertise this service. Do not wait for car owners to ask whether you will call for their batteries. Many of them may not think of telephoning for such service, and even if they do, they might call up some other service station.

When Batteries Come In

What does a man expect when he brings his battery to the battery service-station? Obviously lie expects to be greeted courteously and to be permitted to tell the symptoms of trouble which he has observed. He furthermore expects the repairman to examine and test the battery carefully before deciding what repairs are necessary and not to tell him that he needs new positives, new separators, or an entirely new battery without even looking at the battery.

When a car is brought to your shop, you are the doctor. Sonic part of the mechanism is in trouble, and it is your duty to put yourself in charge of the situation. Listen to what the customer hp to say. He has certainly noticed that something is wrong, or he would not have come to you. Ask him what he has observed.

He has been driving the car, starting the engine, and turning on the lights, and certainly has noticed whether everything. has been operating as it should. The things lie has noticed were caused by the trouble -which exists. He may not know what sort of trouble they indicate, but you, as the battery doctor can generally make a fairly accurate estimate of what the trouble is. You should, of course, do more than merely listen to -what the customer says. You can question him as to how the car has been used, just as the doctor, after listening- to what a patient has to say, asks questions to give him a clue to what has caused such symptoms.

The purpose of the preliminary questioning and examination is not merely to make an accurate diagnosis of the troubles, but to establish a feeling of confidence on the part of the

customer. A man who owns a car generally possesses an average amount of intelligence and likes to have it recognized and respected. Your questioning- and examination will either show the customer that you know your business and know what should be done, or it will convince him that you are merely putting up a bluff to hide your ignorance.

What the customer wants to know is how much the, repairs will cost, and how soon lie may have his battery again. Estimate carefully what the work, will cost, and tell him. If a considerable amount of work is required and you cannot estimate how much time and material will be needed, tell the customer that you will let him know the approximate cost later, when you have gone far enough with the work to be able to make an estimate. If you find that the battery should be taken off, take it off without any loss of time and put on a rental battery. If there is something wrong outside of the battery, however, it will be necessary to eliminate the trouble before the car leaves the shop.otherwise the same battery trouble will occur again. If there is no actual trouble outside the battery, and if the driving conditions have been such that the battery is not charged sufficiently while on the car, no actual repairs are necessary on the electrical system. The customer should be advised to drive in about every two weeks to have his battery tested, and occasionally taken off and given a bench charge. It is better to do this than to increase the charging rate to a value - which might damage the generator or battery.

Adopt a standard method of procedure in meeting, a customer and in determining what is wrong and what should be done. If the customer is one who brings his car in regularly to have the battery filled. and tested, you will: be able to detect any trouble as soon as it occurs, and will be able to eliminate it before the battery is seriously damaged. A change in the charging rate, cleaning of the generator commutator or cutout contact points, if done in time, will often keep everything in good shape.

With a new customer who has had his battery for sometime, you must, however, ask questions and make tests to determine what is wrong. Before sending the customer away with a new, rental, or repaired battery, test the electrical system as described on page 276.

The most important transaction and one which will save you considerable argument and trouble is to get everything down in black and white. Always try to have the customer wait while you test the battery. If you find it necessary to open the battery do this in his presence. When he leaves there should be no question as to what he shall have to pay for. If more time is required to determine the necessary work, do not actually do the work without getting in touch with the owner and making a written agreement as to what is to be done and how much the cost will be. The Service Record shown in Fig. 183 may be used- for this purpose.

The following method of procedure is suggested as a standard. Follow it closely if possible, though in some cases, where the nature of the trouble is plainly evident, this will

not be necessary any more than a doctor who sees blood streaming from a severe cut needs to question the patient to find out what is wrong.

It may not always be necessary to ask all the questions which follow, or to ask them in the order given, but they cover points which the repairman should know in order to work intelligently. Some of the information called for in the questions may often be obtained without questioning the customer. Do not, however, hesitate to ask any and all questions covering points which you wish to know.

1. Greet the customer with a smile.

Your manner and appearance are of great importance. Be polite and pleasant. Do not lose your temper, no matter how much cause the customer gives you to do so. A calm, courteous manner will generally cool the anger of an irate customer and make it possible to gain his confidence and good will. Do not argue with your customers, Your business is to get the job and do it in an agreeable manner. If you make mistakes admit it and your customer will come again. Keep your clothes neat and clean and have your face and hands clean. Remember that the first glimpse the customer has of the man who approaches him will influence him to a very considerable extent in giving you his business or going elsewhere. Do not have a customer wait around a long time before he receives any attention. If he grows impatient because nobody notices him when he comes in, it will be hard to gain his confidence, no matter how well you may afterwards do the work.

2. What's the Trouble?

Let the customer tell you his story. While listening, try to get an idea of what may be wrong. When he has given you all the information he can, question him so that you will be able to get a better idea of what is wrong.

(a) How long have you had the battery? See page 242.

(b) Was it a new battery when you bought it?

(c) How often has water been added?

(d) Has distilled water been used exclusively, or has faucet, well, or river water ever been used? Impure water may introduce substances which will damage or even ruin a battery.

(e) Has too much water been added? If this is done, the electrolyte will flood the tops of the jars and may rot the upper parts of the wooden case.

(f) How fast is car generally driven? The speed should average 15 M. P. H. or more to keep battery charged.

(g) How long must engine be cranked before it starts? This should not require more than about 10 seconds. If customer is in doubt, start the engine to find out. If starting motor cranks engine at a fair speed, engine should start within 10 seconds. If starting motor cranks engine at a low speed, a longer cranking time may be required. The low cranking speed may be due to a run-down or defective battery, to trouble in the starting motor or starting circuit, or to a stiff engine. To determine if battery is at fault, see **"Battery Tests,"** below.

(h) Has the car been used regularly, or has it been standing idle for any length of time? An idle battery discharges itself and often becomes damaged. If car has been standing idle in cold weather, the battery has probably been frozen.

(i) Has it been necessary to remove the battery occasionally for a bench charge?

(j) Has battery ever been repaired? See page 322.

Battery Tests

1. Remove the vent plugs and inspect electrolyte. If the electrolyte covers the plates and separators to a sufficient depth, measure the specific gravity of the electrolyte. If the electrolyte is below the tops of the plates and separators, see following section No. 2.

If all cells read 1.150 or less, remove the battery and give it a bench charge.

If the specific gravity readings of all cells are between 1.150 and 1.200, and if no serious troubles have been found up to this point, advise the owner to use his lights and starting motor as little as possible until the gravity rises to 1.280-1.300. If this is not satisfactory to him, remove the battery and give it a bench charge.

If the specific gravity readings are all above 1.200, or if -the gravity reading of one cell is 50 points (such as the difference between 1.200 and 1.250, which is 50 "points") lower or higher than the others (no matter what the actual gravity readings may be), make the 15 seconds high rate discharge test on the battery. See page 266. If this test indicates that the internal condition of the battery is bad, the battery should be removed from the car and opened for inspection. If the test indicates that the internal condition of the battery is good, the specific gravity of the electrolyte needs adjusting. The difference in specific

gravity readings in the cells is due to one of the following, causes:

(a) Water added to the cell or cells which have low gravity to replace electrolyte which had been spilled or lost in some other manner.

(b) Electrolyte added to the cell or cells which have high gravity to replace the water which naturally evaporates from the electrolyte.

(c) Trouble inside the cell or cells which have low gravity. The high rate discharge test will show whether there is any internal trouble.

If any cell shows a gravity above 1.300, remove the battery, dump out all the electrolyte, fill battery with distilled water and put the battery on charge.

If the gravity of one or more cells is 50 points less than the others, water has been used to replace electrolyte which has been spilled or lost in some other manner, or else one or more jars are cracked. A battery with one or more cracked jars usually has the bottom parts of its wooden case rotted by the electrolyte which leaks from the jar. If you are not certain whether the battery has one or more cracked jars, see that the electrolyte covers the plates in all the cells one-half inch or so, and then let the battery stand. If the electrolyte sinks below tile tops of the plates in one or more cells within twenty-four hours, those cells have leaky jars and the battery must be opened, and new jars put in.

If the low gravity is not caused by leaky jars, give the battery a bench. charge and adjust the level of the electrolyte.

2. If you found electrolyte to be below tops of plates in all the cells, the battery has been neglected, or there mail be leaky jars. Add distilled water 'until the electrolyte covers the plates to a depth of about one-half inch.

(a) If it requires only a small amount of water to bring up the level of the electrolyte, remove the battery and give it a bench charge. See page 198. Only a brief charge may be necessary. Ask the driver when water was added last. If more than (I month has passed since the last filling, the upper parts of the plates may be sulphated, and the battery should be charged at a low rate.

(b) If it requires a considerable amount of water to bring up the level of the electrolyte, and the bottom of the wooden battery case shows no signs of being rotted, the battery has been neglected and has been dry for a long time, and the plates are mostly likely badly damaged. Open the battery for inspection.

(c) If only one cell requires a considerable amount of water to bring up the level of its

electrolyte, and the bottom of the wooden battery ease shows no sign of being rotted, that cell is probably "dead," due to in internal short-circuit. To test for "dead" cells, turn on the lamps and measure the voltage of each cell. A dead cell will not give any voltage on test, may give a reversed voltage reading, or at the most will give a very low voltage. A battery with a dead cell should be opened for inspection.

(d) If the bottom part of the wooden battery case is rotted, and a considerable amount of water had to be added to any or all cells to bring up the level of the electrolyte, the battery has leaky jars and must be opened to have the leaky jars replaced by good ones.

If there is any doubt in your mind as to whether any or all jars are leaking, fill the cells with distilled water and let the battery stand for twelve to twenty-four hours. If at or before the end of that time the electrolyte has, fallen below the tops of the plates in any or all cells, these cells have leaky Jars and the battery must be opened and the leaky jars replaced with good ones. The electrolyte which leaks out will -wet the bench or on which the battery is placed and this is another indication of a leaky jar.

General Inspection

In addition to the tests which have been described, a general inspection as outlined below will often be a great help in deciding what must. be done.

1. Is battery loose? A battery which is not held down firmly may have broken jars, cracked sealing compound around posts or between posts and separators, and active material shaken out of the grids. There may also be corrosion at the terminals.

2. Are cables loose? This will cause battery to be in a run down condition and cause failure to crank engine.

3. Is there corrosion at the terminals? This will cause battery to be in a run-down condition and cause failure to start engine. Corrosion is caused by electrolyte attacking terminals. A coating of vaseline on the terminals prevents corrosion.

4. Is top of battery wet? This may be due to addition of too much water, overheating of battery, cracks around posts and between posts and cover, electrolyte thrown out of vents because of battery being loose, or electrolyte or water spilled on battery. Such a condition causes battery to run down.

5. Is top of case acid soaked? This is caused by leaks around posts or between covers and jars, flooding of electrolyte due to overheating or due to addition of too much water, or by electrolyte spilled on covers.

6. Is lower part of case acid soaked? This is caused by leaky jars.

7. Are ends of case bulged out? This may be due to battery having been frozen.

This general inspection of the battery can be made in a few seconds, and often shows what the condition of the battery is.

Operation Tests

Two simple tests may be made which will help considerably in the diagnosis.

Turn on the lights. If they burn dim, battery is run down (and may be defective) and battery needs bench charge or repairs. If they burn bright battery is probably in a good condition.

With the lights burning, have the customer or a helper step on the starting switch. If the lights now become very dim, the battery is run down (and may also be defective), or else the starting motor is drawing too much current from the battery.

Trouble Charts

For the convenience of the repairman, the battery troubles which may be found when a car is brought in, are summarized in the following tables:

All Cells Show Low Gravity or Low Voltage

A. Look for the following conditions:

1. Loose or dirty terminals or cell connectors. This may reduce charging rate, or open charging circuit entirely. Remedy: Tighten and clean connections.

2. Corrosion on terminals or cell connectors caused by acid on top of battery due to over-filling, flooding, defective sealing, lead scraped from lead-coated terminals, and copper wires attached directly to battery. A badly corroded battery terminal may cause the generator, ignition coil, and lamps to burn out because of the high resistance which the corroded terminal causes in the charging line. It may reduce charging rate, or open charging circuit entirely. Remedy: Remove cause of corrosion. Clean corroded parts and give coating of vaseline.

3. Broken terminals or cell connectors. These may reduce charging rate or open charging circuit entirely. Remedy: Install new parts.

4. Generator not charging. Remedy: Find and remove cause of generator not charging (see page 284).

5. Charging rate too low. Remedy: If due to generator trouble, repair generator. If due to incorrect generator setting change setting. If due to driving conditions increase charging rate

6. Acid or moisture on top of battery due to defective sealing, flooding, spilling electrolyte in taking gravity readings, loose vent plugs. This causes corrosion and current leakage. Remedy: Find and remove cause.

7. Tools or wires on battery causing short-circuits. Remedy: Tell customer to keep such things off the battery.

8. Short-circuits or grounds in wiring. Remedy: Repair wiring.

9. Cutout relay closing late, resulting in battery not being charged at ordinary driving speeds. Remedy: Check action of cutout. See page 282.

10. Excessive lighting current, due to too many or too large lamps. Remedy: Check by turning on all lamps while engine is running. Ammeter should show three to five amperes charge with lamps burning. In winter the charging rate may have to be increased.

B. Question Driver as to following causes of low gravity and low voltage:

1. Has water been added regularly?

2. Has impure water, such as faucet, well, or river water ever been added to battery?

3. Has too much water been added?

4. Has electrolyte been spilled and replaced by water?

5. Has battery been idle, or stored without regular charging?

6. Is car used more at night than in daytime? Considerable night driving may

prevent battery from being fully charged.

7. Is starter used frequently?

8. What is average driving speed? Should be over 15 M. P. 11.

9. How long is engine usually cranked before starting-? Cranking period should not exceed 10 seconds.

C. If battery has been repaired. The trouble may be due to:

1. Improperly treated separators used.

2. Grooved side of separators put against negatives instead of positives.

3. Separator left out.

4. Cracked separator.

5. Positives used -which should have been discarded.

6. Bulged, swollen negatives used.

7. Poor joints due to improper lead-burning.

D. Battery Troubles which may exist:

1. Sulfated plates.

2. Buckled Plates.

3. Internal Short-circuits.

4. Cracked Jars.

5. Clogged Separators.

Gravity Readings Unequal

1. Acid or moisture on top of battery, due to defective sealing, flooding, spilling electrolyte, loose vent plugs. This causes current leakage. Remedy: Find and remove

cause.

2. Tools or wires on battery, causing short-circuits. Remedy: Tell driver' to keep such things off the battery.

3. Electrolyte or acid added to cells giving the high gravity readings.

4. Electrolyte spilled and replaced by water in cells giving low readings.

5. Grooved side of separators placed against negatives in cells giving the low readings.

6. Separator left out, cracked separator used, hole worn through separator by buckle([plate or swollen negatives, or separators in some cells and new ones in others.

7. Old plates used in some cells and new ones in others.

8. Impurities in cells showing low gravity.

9. Shorted cell, due to plates cutting through separators.

10. Cracked jar.

11. Oil some of the, older cars a three wire lighting system was used. If the lights are arranged so that more are connected between one of the outside wires and the center, than between the other outside wire and the center, the cells carrying the heavier lighting load will show low gravity.

12. On some of the older cars, the battery is made of two or more sections which are connected in series for starting and in parallel for charging. Oil such cars the cells in one of the sections may show lower gravity than other cells due to longer connecting cables, poor connections, corroded terminals, and so on. Such a condition AN-ill often be found in the old two section Maxwell batteries used previous to 1918.

High Gravity

This is a condition in which the hydrometer readings would indicate that a battery is almost or fully- charged, but the battery may fail to operate the starting motor. If the lights are burning while the starting switch is closed, they -will become very dim. The gravity readings may be found to be above 1.300.

The probable causes of this condition are:

1. Electrolyte or concentrated acid added instead of water.

2. One of the numerous "dope" solutions which have been advertised extensively within the past two years. Never use them. If customer admits having used such a "dope" warn him not to do so again.

Low Electrolyte

Probable Causes:

1. Water not added.

2. Electrolyte replaced in wrong cell after taking gravity readings.

3. Cracked jars.

4. Battery overcharged, causing loss of water by overheating and excessive gassing.

Probable Results:

1. Sulfated Plates.

2. Carbonized, dry, cracked separators.

3. Considerable shedding.

Battery Overheats

Probable Causes:

1. Water not added regularly.

2. Impure water used.

3. Impure acid -used.

4. Battery on hot place on car.

5. Alcohol or other anti-freeze preparation added.

6. Excessive charging rate.

7. Improperly treated separators.

8. Battery over-charged by long daylight runs.

Probable Results:

1. Sulfated Plates.

2. Burned, Carbonized Separators.

3. Buckled Plates.

4. Excessive Shedding.

Electrolyte Leaking Out at Top

Probable Causes:

1. Too much water added.

2. Battery loose in box.

3. Cracks in sealing compound due to poor sealing, or cables pulling on terminals, or due to poor quality of sealing compound, or good quality compound which has been burned.

4. Vent plugs loose.

Probable Results:

1. Upper portion of case rotted by acid.

2. Electrolyte low.

3. Plates sulphated.

4. Upper parts of separators dry.

Summary

1. When May a Battery Be Left on the Car?

(a) When you find that the specific gravity of all cells is more than 1.150, the voltage of each cell is at least 2, the voltage doe's not drop when the lights are turned on, or the lights do not become very dim -when the engine is cranked with the starting motor, there are no loose terminals or connectors, the sealing compound is not broken or cracked so as to cause a "slopper," the electrolyte covers the plates, the box is not rotted by acid, and there are no broken jars.

These conditions will exist only if battery has been well taken care of, and some trouble has suddenly and recently arisen, such as caused by a break in one of the battery cables, loosening of a cable connection at the battery or in the line to the starting motor.

2. When Should a Battery Be Removed From Car?

(a) When you find broken sealing compound, causing the battery to be a "slopper."

(b) When you find inter-cell connectors and terminals loose, corroded, or poorly burned on.

(c) When you find box badly rotted by acid, or otherwise defective.

(d) When you find a cracked jar, indicated by lower part of case being acid soaked, or by low electrolyte, or find that electrolyte level falls below the tops of the plates soon after adding water.

(e) When you find a dead cell, indicated by very low or no voltage, even on open circuit.

(f) When specific gravity of electrolyte is less than 1.150, or gravity readings of cells vary considerably.

(g) When battery voltage drops to about 1.7 or less per cell when lamps are turned on, or lamps become very dim when the starting motor is cranking the engine, or the high rate discharge test shows that there is trouble in the cells.

(h) When you find that electrolyte is below tops of plates, and it requires considerable water to bring it up to the correct height.

(i) When battery overheats on charge, or discharge, although battery is not located in hot

place, charging rate is not too high and lamps and accessories load is normal.

(j) When battery is more than a year old and action is not satisfactory.

(k) When a blacksmith, tinsmith or plumber has tried his hand at rebuilding the battery. Such a battery is shown in Fig. 189.

(1) When ends of care are bulged out.

3. When Is It Unnecessary to Open a Battery?

(a) When the only trouble is broken sealing compound. The battery should be resealed.

(b) When loose, corroded, or poorly burned on terminals and connectors have merely resulted in keeping battery only partly charged and no internal troubles exist. The remedy is to drill off the connectors, or terminals, and re-burn them.

(c) When the external condition of battery is good, and a bench charge, see page 198 (with several charge and discharge cycles if necessary) puts battery in a good condition, as indicated by voltage, cadmium, and 20 minute high rate discharge test.

4. When Must a Battery Be Opened?

(a) When prolonged charging (72 hours or more) will not cause gravity or voltage to rise. Such trouble is due to defective plates and separators.

(b) When battery case is badly acid soaked. A slightly acid soaked case need not be discarded, but if the damage caused by the acid has been excessive, a new case is needed. Plates may also be damaged.

(c) When one or more jars are cracked. New jars -are needed. The plates may also be damaged.

(d) When one or more cells are "dead," as indicated by little or no voltage, even on open circuit. New plates (positives at least) may be required.

(e) When battery is more than a year old and action is unsatisfactory. (Battery will not hold its charge.) Battery may have to be junked, or new separators may be required. Every battery should be reinsulated at least once during its lifetime.

(f) When a blacksmith, tinsmith, or plumber have tried to repair a case, Fig. 189.

Fig. 189. A Blacksmith and Tinsmith Tried Their Hands on This Case, Lower Part Enclosed in Tin, Strap Iron, Covered with Friction Tape, Around The Top.

(g) When the ends of case are bulged. A new case is needed. If the battery has been frozen it should generally be junked. There are some cases on record of a frozen battery having been thawed out and put in serviceable condition by a long charge at a low rate followed by several cycles of discharge and recharge. Generally, at least, a new case, jars, and positives are required.

NOTE: New separators should always be installed, whenever a battery is opened for repairs, unless the separators already in the battery are new, and the trouble for which the battery was opened consists of a leaky jar, a separator left out, or some other trouble which does not require pulling the plates out of mesh.

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CHAPTER 15

REBUILDING THE BATTERY

How to Open a Battery

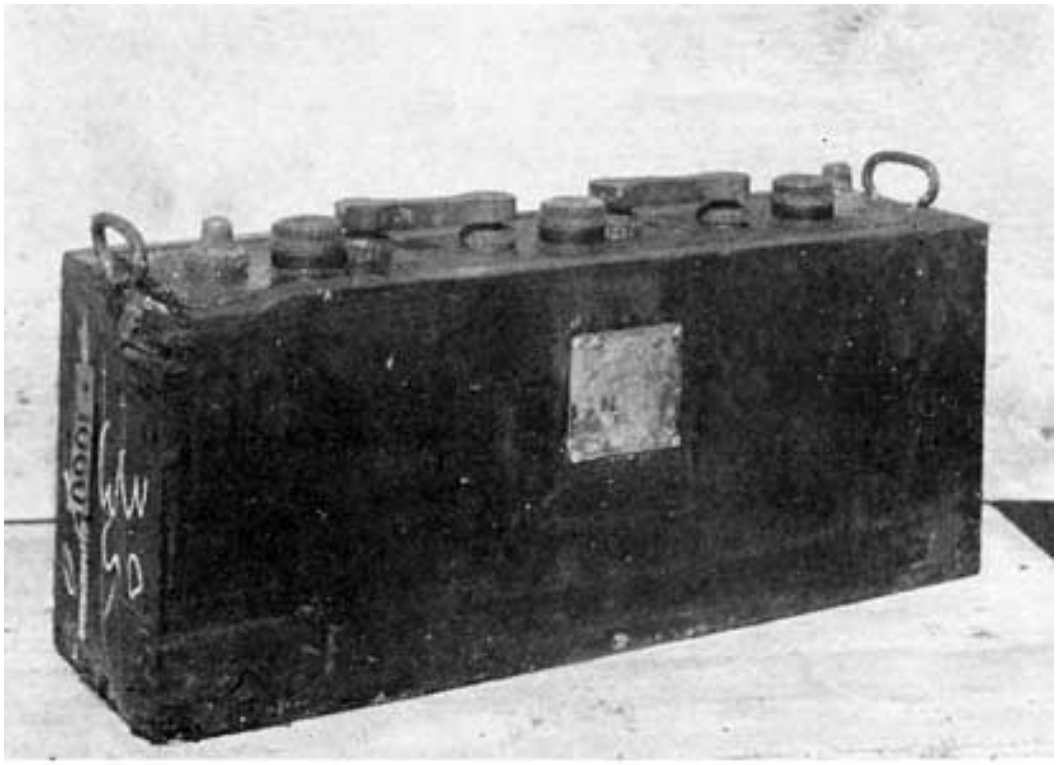

Fig. 190. Battery Which is to be Opened

A battery is open when its plates have been drawn out of the hard rubber jars. All parts are then exposed, and accessible for inspection and repairs. In an assembled battery, the top of each cell is closed by a hard rubber cover. Leakproof joints are made between these covers and the rubber jars and the wooden case by means of sealing compound which is poured in place while in a molten condition, and joins the covers to the jars and which hardens as it cools. The joints between the covers and the posts which project through the covers are in many batteries made with sealing compound. The cells are then connected to each other by means of the cell connectors, also called "top-connectors," or simply "connectors." These connectors are joined to the lead posts, to which are connected the plate groups by fusing with a flame, and melting in additional lead to make a joint.

In opening a battery, we must first disconnect the cells from each other, and then open the joint made by the sealing compound between the covers and the jars and case. The plates may then be lifted out of the jars, and the battery is open. The steps necessary to open a battery follow, in the order in which they must be taken.

1. Clean the Battery. Set the battery on the tear down rack. See that the vent plugs are all tight in place. Then clean the outside of the battery. Remove the greater part of the dirt with a brush, old whisk-broom, or a putty knife. Then put the battery in the water, using a stiff bristled brush to remove whatever dirt was not removed in the first place. A four-inch paint brush is satisfactory for this work, and will last a year or more if taken care of. If water will not remove all the dirt, try a rag wet with gasoline.

2. Drilling Off the Connectors and Terminals. When you have cleaned the outside of the battery as thoroughly as possible, set the battery on the floor near your work bench. Make a sketch of the top of the battery, showing the exact arrangement of the terminals and connectors. This sketch should be made on the tag -which is tied to the battery. Tic this tag on the handle near the negative terminal of the battery or tack it to the ease. Then drill down over the Center of the posts. For this you will need a large brace with a heavy chuck, a drill the same size as the post (the part that goes down into the battery), a large screw driver, a center punch, and a hammer.

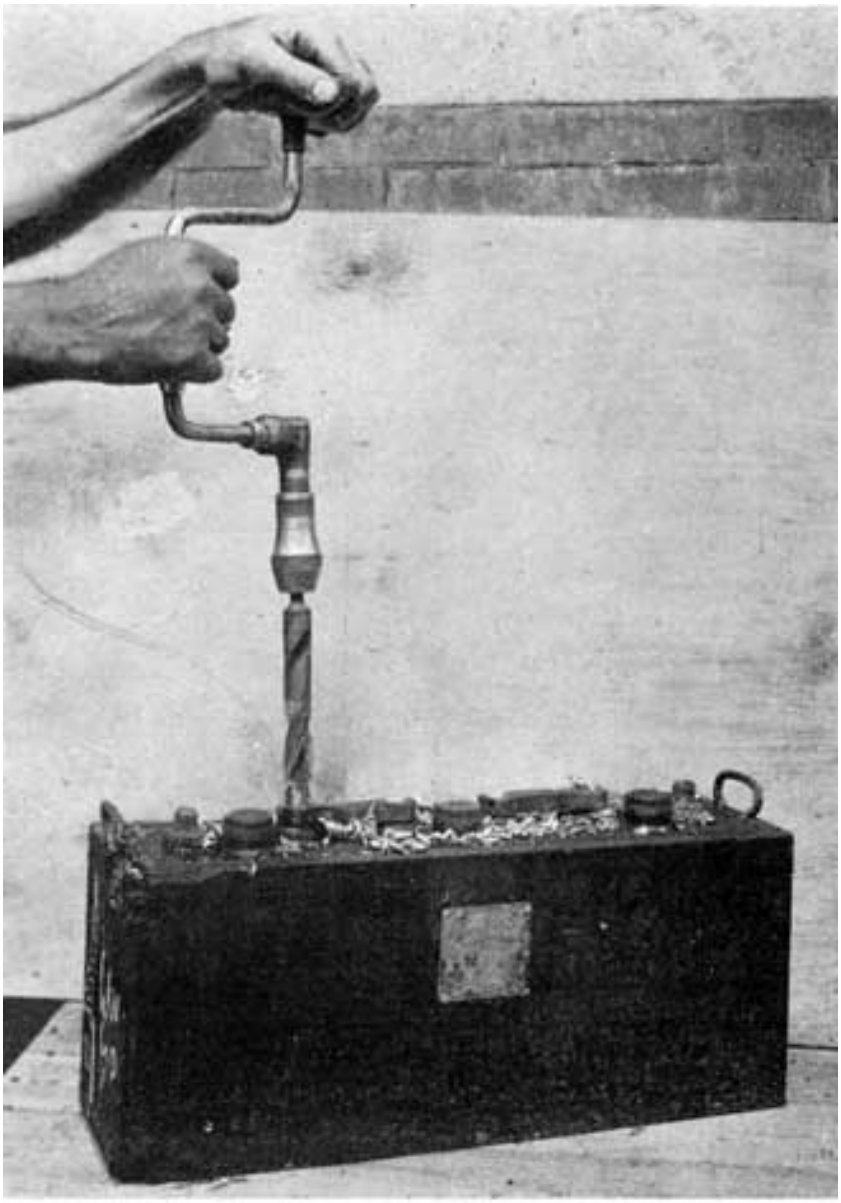

Fig. 191. Drilling Post and Cell Connector

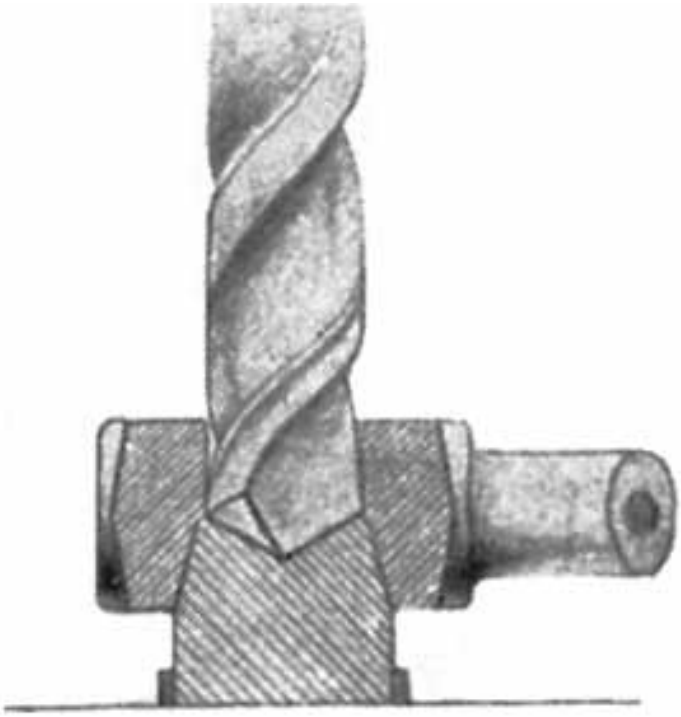

Fig. 192. Connector Drilled to Correct Depth

With the center punch, mark the exact centers of the tops of the posts and connectors. Then drill down about half way through the connectors and terminals until you cut through the part of the connector which is welded to the post. When you can see a seam between the post and connector you have drilled through the welded part. See Figs. 191 and 192.

Now pry off the connectors with the screw driver, as shown in Fig. 193. Lay a flat tool such as a chisel or file on the top edge of the ease to avoid damaging the ease when prying off the connectors.

If any connector is still tight, and you cannot pry it off with a reasonable effort, drill down a little deeper, and it -will come off easily, provided that the hole which you are drilling is exactly over the center of the post and as large as the post. There are five things to remember in drilling the connectors and posts:

(a) Be sure that the hole is exactly over the center of the post.

(b) Do not drill too deep. Make each hole just deep enough so that the connector will come off easily. Fig. 192 shows a cross section of a post and connector drilled to the proper depth. Notice that you need not drill down the whole depth of

the connector, because the bottom part is not burned to the post.

(c) Be sure that the drill makes the right sized hole to permit the connectors and terminals to be removed easily when drilled half way through. An electric drill will do the work much faster than a hand brace.

(d) Protect the edge of the battery box when you pry up the connectors with a screw driver.

(e) Remove your drill after the hole is well started and see whether the hole is in the center of the post. Should you find that it is off center, tilt the drill, and with the end of the drill pointing the center of the post as you drill, gradually straighten the drill. This will bring the hole over the center of the post.

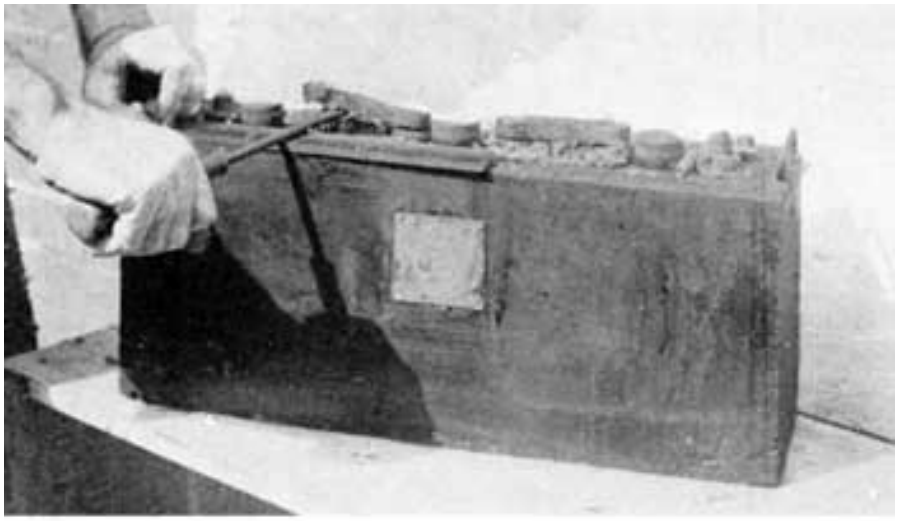

Fig. 193. Prying Off Cell Connector

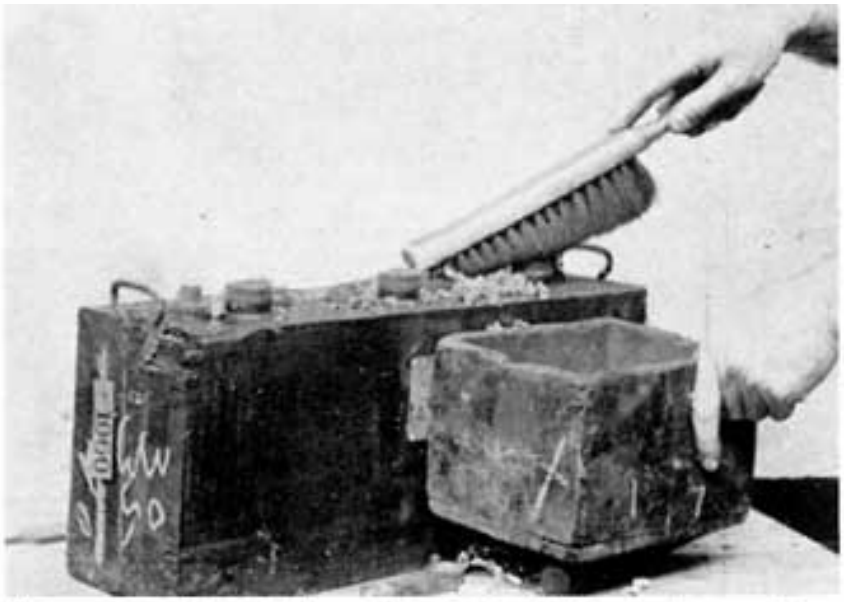

Fig. 194. Brushing Lead Drillings Into Box

Having removed the connectors, sweep all the lead drillings front the top of the battery into a box kept for lead drillings only. Fig. 194. When this box is full, melt the drillings and pour off in the burning lead mould.

Post Seal. If the post seal consists of a lead sealing nut, this may be removed now. With some types of batteries (Willard and U. S. L.), drilling the connectors also breaks the post seal. With other batteries, such as the Vesta, Westinghouse, Prest-0-Lite, Universal, it is more difficult to break the post seal. On these batteries, therefore, do not break this seal before drawing out the plates. You may find that it will not be necessary to separate the groups, and the post seal will not have to be broken at all, thereby saving yourself considerable time on the overhauling job.

3. Heating Up the Sealing Compound. Having disconnected the cells from each other by removing the cell connectors, the next step is to open the joint made by the sealing compound between the covers and jars. Fig. 195 shows the battery ready for this step. When cold, the compound is a tough substance that sticks to the cover and jar, and hence it must be heated until it is so soft that it is easily removed. There are several methods by means of which compound may be heated. These are as follows:

Fig. 195. Battery Ready for Steaming

Steam. This is the most popular, and undoubtedly the best means of heating the compound, and in the following instructions it will be assumed that steam has been used. The battery is either placed in a special box in which steam is sent, or else steam is sent directly into each cell through the vent tube. In the first method the compound is heated from the outside, and in the second it is heated from the inside of the cell.

If the battery is placed in the steaming box, about ten minutes will be required for the steam to heat up the sealing compound. For batteries which use but very little compound, less time is required. if steam is sent directly into the cells through the vent tubes, five to seven minutes will generally be enough. The covers must be limp and the 1 compound must be soft before turning off the steam.

Hot Water. The electrolyte is poured out of the battery, which is then inverted in a vessel of hot water. This method is slower than the others, and is more expensive because it requires a larger volume of water to be heated.

Hot Putty Knife and Screwdriver. The compound may be dug out with a hot putty knife. This is a slow, unsatisfactory method in most instances, especially in those batteries which use a considerable amount of sealing compound. With some batteries using only a small quantity of compound, a heated putty knife may be run around the inside of the jar between the jar and the cover. This will break the joint between the cover and the jar, and allow the plates to be lifted out. The compound is then scraped from covers and inside of jars, heating the knife or screwdriver whenever it cools off.

Lead Burning Flame. Any soft lead burning flame may be used. Such a flame may be adjusted to any desired size. Where steam is available, a flame should, however, never be used. The temperature of the flame is very high, and the covers, jars, case, posts, and vent plugs may be burned and made worthless. Even for the expert repairman, a flame is not as satisfactory as steam.

The Gasoline Torch. This is the most unsatisfactory method, and should not be used if possible. The torch gives a hot, spreading flame and it is difficult to prevent the covers, jars, case, etc., from being burned. Do not use a gasoline torch if you can possibly avoid doing so. Alcohol torches are open to the same objections, and are not satisfactory, even in the hands of a highly skilled workman.

If a flame is used for heating the compound, be sure to blow out with a hand bellows or compressed air any gas that may have gathered above the plates, before you bring the flame near the battery.

Electric Heat. Special electric ovens for softening sealing compound are on the market. The heating element is brought close to the top of the battery. Where electric power is cheap, this method may be used. Otherwise it is rather expensive.

When the sealing compound has been softened, place the battery on the floor between your feet. Grasp the two posts of one cell with pliers, and pull straight up with an even, steady pull. If the battery has been steamed long enough, the plates will come up easily, carrying with them the cover (or covers, if the batter has upper and lower covers) to which the compound is sticking, as shown in Fig. 196. Do not remove the plates of the other cells until later.

Fig. 196. Drawing up an Element

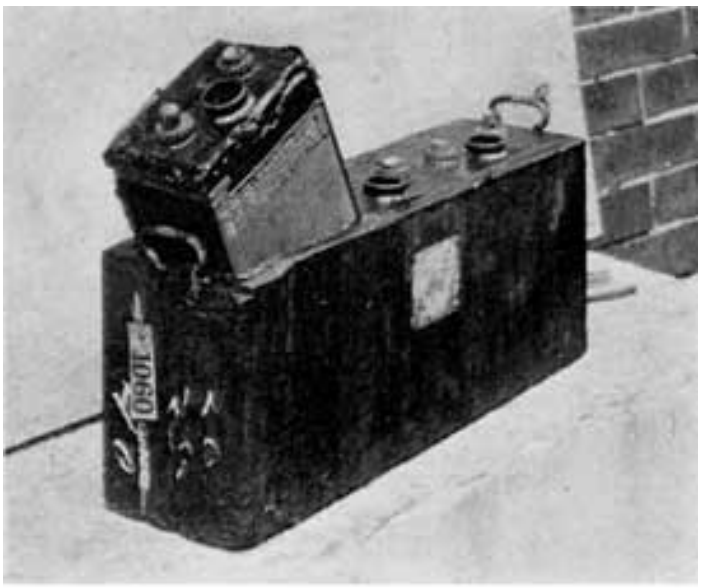

Fig. 197. Resting Element on Jar to Drain

Rest the plates on the top of the jar just long enough to allow most of the acid to drain from them, Fig. 197. If you have removed the post seal, or if the seal consists of compound (old Philadelphia batteries), pry off the covers now with a screw driver. Otherwise, leave the covers in place while cleaning off the compound.

While the plates are resting on the jars to drain, scrape the compound from the covers with a warm screw driver or putty knife, Fig. 198. Work quickly -while the compound is still hot and soft, and comes off easily. As the compound cools it hardens and sticks to the covers and is removed with difficulty. If the battery has sealing compound around the posts, this should also be removed thoroughly, both from the cover and from the post.

Fig. 198. Removing Compound from Cover

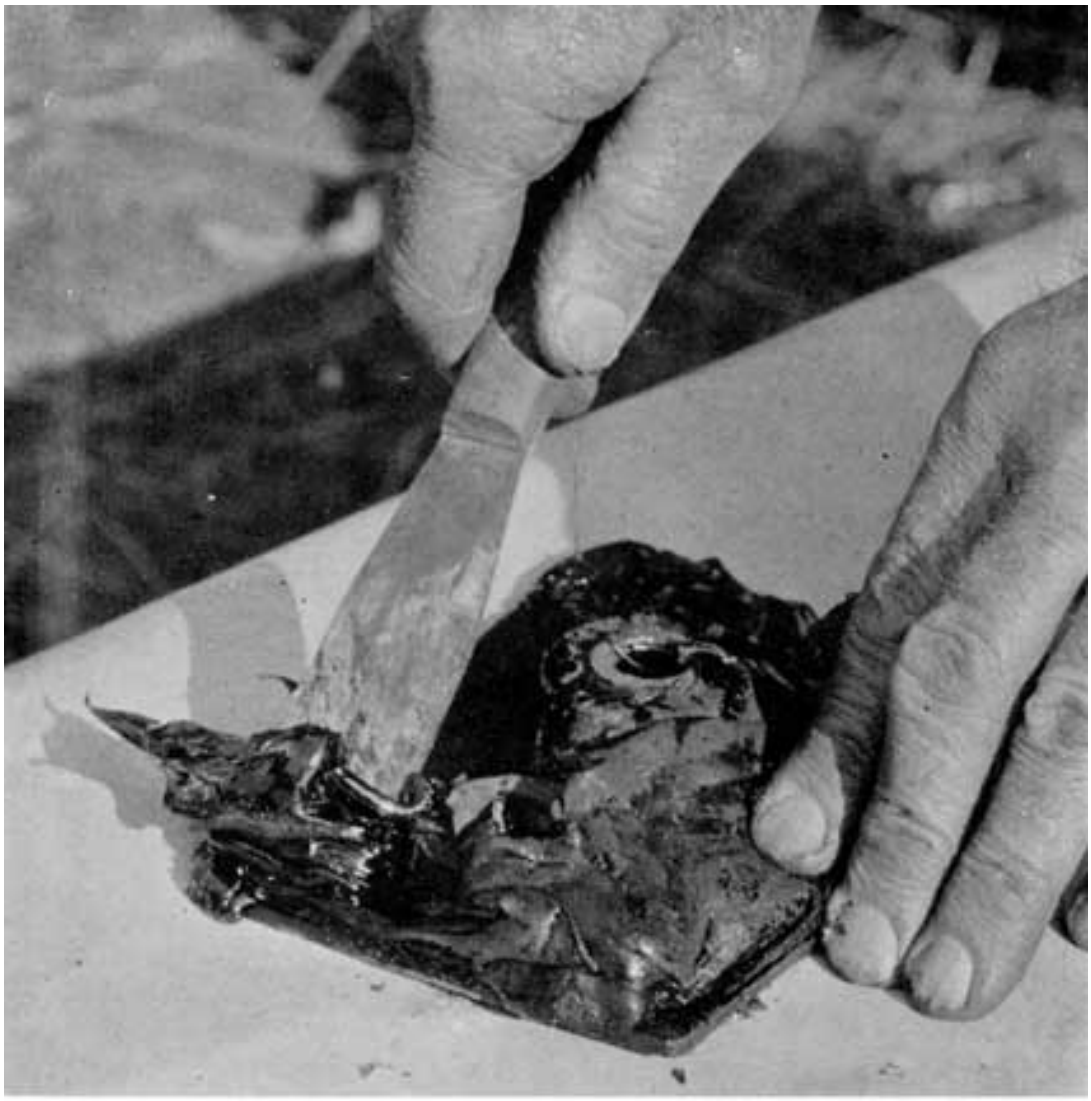

Fig. 199. Removing Sealing Compound from Double Cover

When you scrape the compound from the covers, do a good job. Do not scrape off most of it, and then leave pieces of it here and there. Remove every bit of compound, on the tops, edges, sides, and bottoms of the covers. If you need different sized putty knives or screw drivers to do this, use them. The time to remove all the compound is -while it is still hot, and not after it has become hard and cold. If the battery has single covers, the compound can be removed very quickly. If the battery is of the old double-cover type, the job will take more time, since all the compound should be scraped from both top and bottom covers, Fig. 199.

As soon as you have removed the compound from the covers of the first cell, serape away the compound which may be sticking to the top and inside walls of the jar, Fig. 200. Here again you must do a good job, and remove all of this compound. If you do not do it now, you will have to do it when you try to put the plates back into the jar later on, as compound sticking to the inside walls of the jar will make it difficult, and even impossible to lower the plates into the jar.

Now draw up the plates of the next cell. Rest the plates on the top of the jar just long enough to drain, and then lift off the covers, and remove all of the compound, from cover, posts, and jar,

just as you did in the first cell. The third cell, (and the others, if there are more than three cells) are handled just as you did the first one.

Remember that you should lose no time after you have steamed the battery. Hot compound is soft. and does not stick to the covers, jars, and posts and may therefore be removed quickly and easily. Cold compound is hard, and sticks to the covers. Draw out the plates of only one cell at a time, and clean the compound from the cover, posts and jar of that one cell before you draw out the plates of the other cells. In this way, the compound on the covers of the other cells will remain hotter than if all the plates of the battery were drawn out of the jars before any of the compound was removed from the covers. You should have all the plates drawn out, and all the compound removed within five minutes after you draw up the plates,

Throw away the old compound. If is very likely acid-soaked and not fit for further use.

What Must Be Done with the Battery?

The battery is now open, and in a condition to be examined and judgment pronounced upon it. The question now arises, "What must be done with it!" In deciding upon this, be honest with your customer, put yourself in his place, and do just what you would like to have him do if he were the repairman and you the car owner. The best battery men occasionally make mistakes in their diagnosis of the battery's condition, and the repairs necessary. Experience is the best teacher in this respect, and you will in time learn to analyze the condition of a battery quickly.

Handle every cell of a battery that comes in for repairs in the same way, even though only one dead cell is found, and the others are apparently in good condition. Each cell must be overhauled, for all cells are of the same age, and the active materials are in about the same condition in all the cells, and one cell just happened to give out before the others. If you overhaul only the dead cell, the others cells are quite likely to give out soon after the battery is put into service again.

It is absolutely necessary for you to have a standard method in working on battery plates. You must divide your work into a number of definite steps, and always perform these steps, and in the same order each time. If you have a different method of procedure for every battery, you will never be successful. Without a definite, tangible method of

Fig. 200. Removing Compound from Top of Jar

procedure for your work you will be working in the dark, and groping around like a blind man, never becoming a battery expert, never knowing why you did a certain thing, never gaining confidence in yourself.

It is impossible to overemphasize the importance of having a **standard method of procedure** and to stick to that method. Careless, slip-shod methods will please your competitor and give him the business which belongs to you.

1. Examine plates to determine whether they can be used again Rules for determining when to discard or use old plates follow.

2. If all plates of both positive and negative groups are to be discarded, use new groups.

The question as to whether the old negatives should be used with new positives has caused considerable discussion. If the negatives are old and granulated, they should of course be discarded. Remember that the capacity of negatives decreases steadily after they are put into service, while the capacity of positives increases. Putting new positives against negatives which are rapidly losing capacity is not advisable. However, trouble often arises in a battery whose negatives still have considerable capacity, and such negatives may safely be used with new positives.

If you feel that a battery will not give at least six months' more service after rebuilding with the old negatives, put in all new plates, or sell the owner a new battery, allowing him some money on the old battery. But if you really believe that the negatives still have considerable capacity, put in new positives if required. If all new plates are used, proceed as directed in this chapter, beginning at page 348.

3. If you find that only some of the plates are to be discarded, or if you are not certain as to the condition of the plates, eliminate any short circuits which may exist, and give the battery a preliminary charge, as described later, before you do any work on the plates. Plates that are fully charged are in the best possible condition for handling, and you should make it an ironclad rule that **if some of the plates can be used again always to charge a battery before you work on**

the plates, no matter what is to be done to them. If both positives and negatives are to be discarded, the preliminary charge should not, of course, be given, but if only the negatives, or the negatives and some or all of the positives are to be used again, give this preliminary charge. Very few batteries will come to your shop in a charged condition, and an exhausted battery is not in a good condition to be worked on. Charge the whole battery even though only one cell is in a very bad condition. **This is a method that has been tried out thoroughly in practice, not in one or two cases, but in thousands.** Batteries in all sorts of conditions have been rebuilt by this method, and have always given first class service, a service which was frequently as good, if not better than that given by new batteries.

Examining the Plates

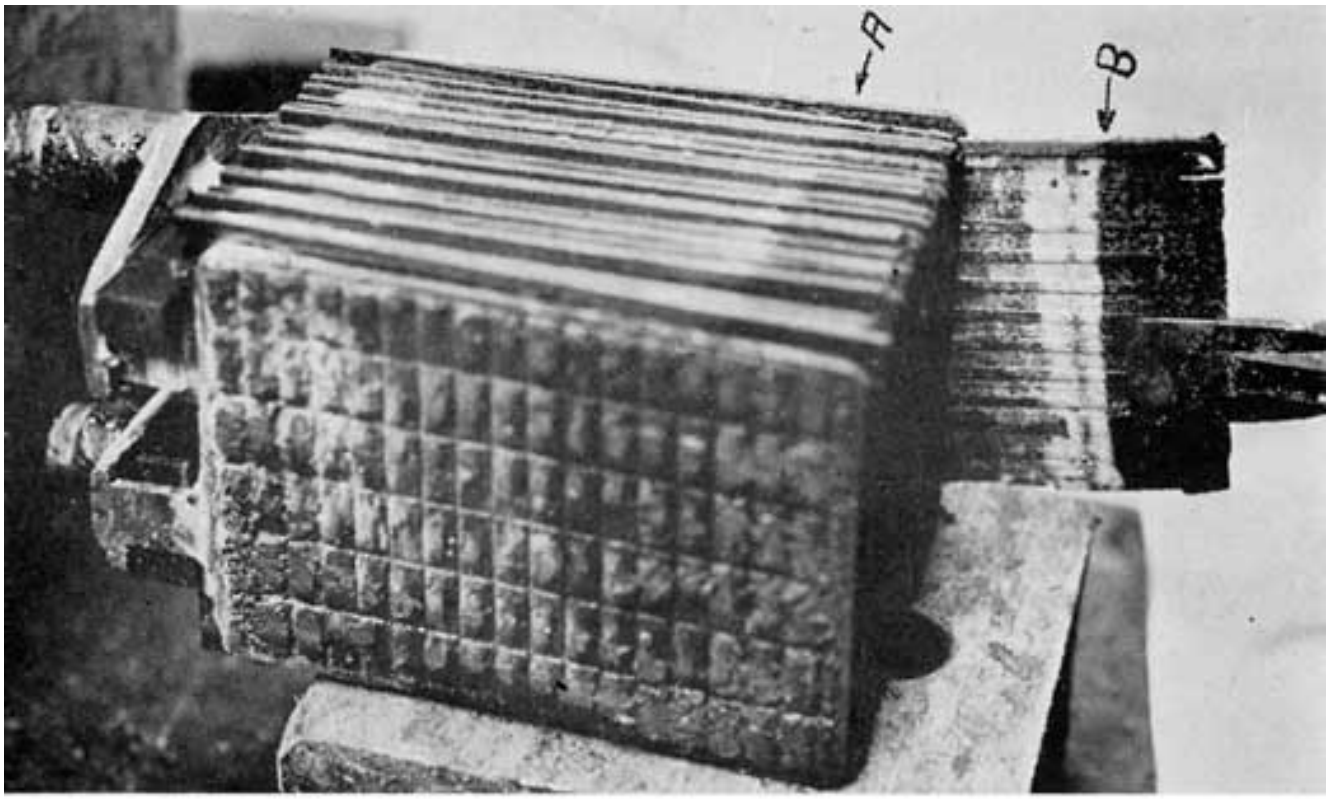

Fig. 201. Element on Block for Examination

Place an element on a block of wood as shown in Fig. 201. Carefully pry the plates apart so that you can look down between them and make a fair preliminary examination. Whenever possible, make your examination of the plates without separating the groups or removing the old separators. This should be done because:

(a) Very often the active material is bulged or swollen, and if you pull out the old separators and put in new ones before charging, the element spreads out so at the bottom that it cannot be put back into the jars without first pressing in a plate press. **Pressing a complete element with the separators in place should never be done** if it can possibly be avoided. If it is done the separators should be thrown. away after you have charged the battery, washed and pressed the negatives, and washed the positive.

(b) If you put in new separators before giving the battery the preliminary charge, the new separators may pick up any impurities which may be on the plates, and will probably be cracked by forcing them- between the bulged and sulphated plates. If, however, the old separators are covered with sulphate, it is best to throw them away and put in new separators before giving the battery its preliminary charge, because such separators will greatly hinder the flow of the charging current. In batteries using rubber sheets in addition to the wooden separators, remove all the wooden separators and leave the rubber sheets in place between the plates. Where only wooden separators are used in a battery, these may be thrown away and perforated rubber separators used for the preliminary charge. Rubber separators may be used again. See (a) above about precautions against pressing a complete element.

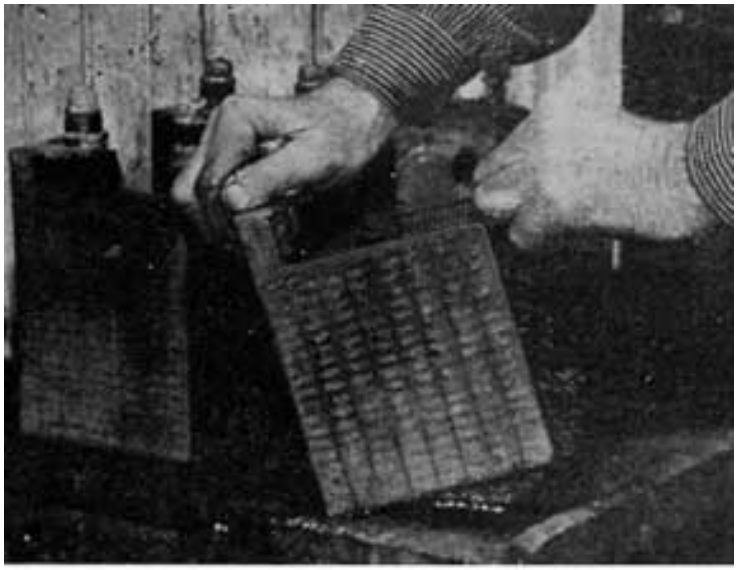

Fig. 202. Separating the Groups

If you are not absolutely certain as to the condition of the plates, draw out a few separators. If separators stick to the plates, loosen them by inserting a putty knife blade between them and the plates. Removing a few separators will permit you to separate the groups before removing the rest of the separators. To separate the groups, grasp a post in each hand, as, in Fig. 202, and work them back and forth, being careful not to injure the posts, or break off any plates. With the groups separated, the remaining separators will either fall out or may be easily pushed out with a putty knife. Ordinarily, the groups may be separated in this way if the elements have thirteen plates or less.

The natural thing to do at this point is to decide what must be done to the plates, and we therefore give a number of rules to help you determine which are to be junked, and which are to be used again. Study these rules carefully, and have them fixed firmly in your mind so that you can tell instantly what must be done with the plates.

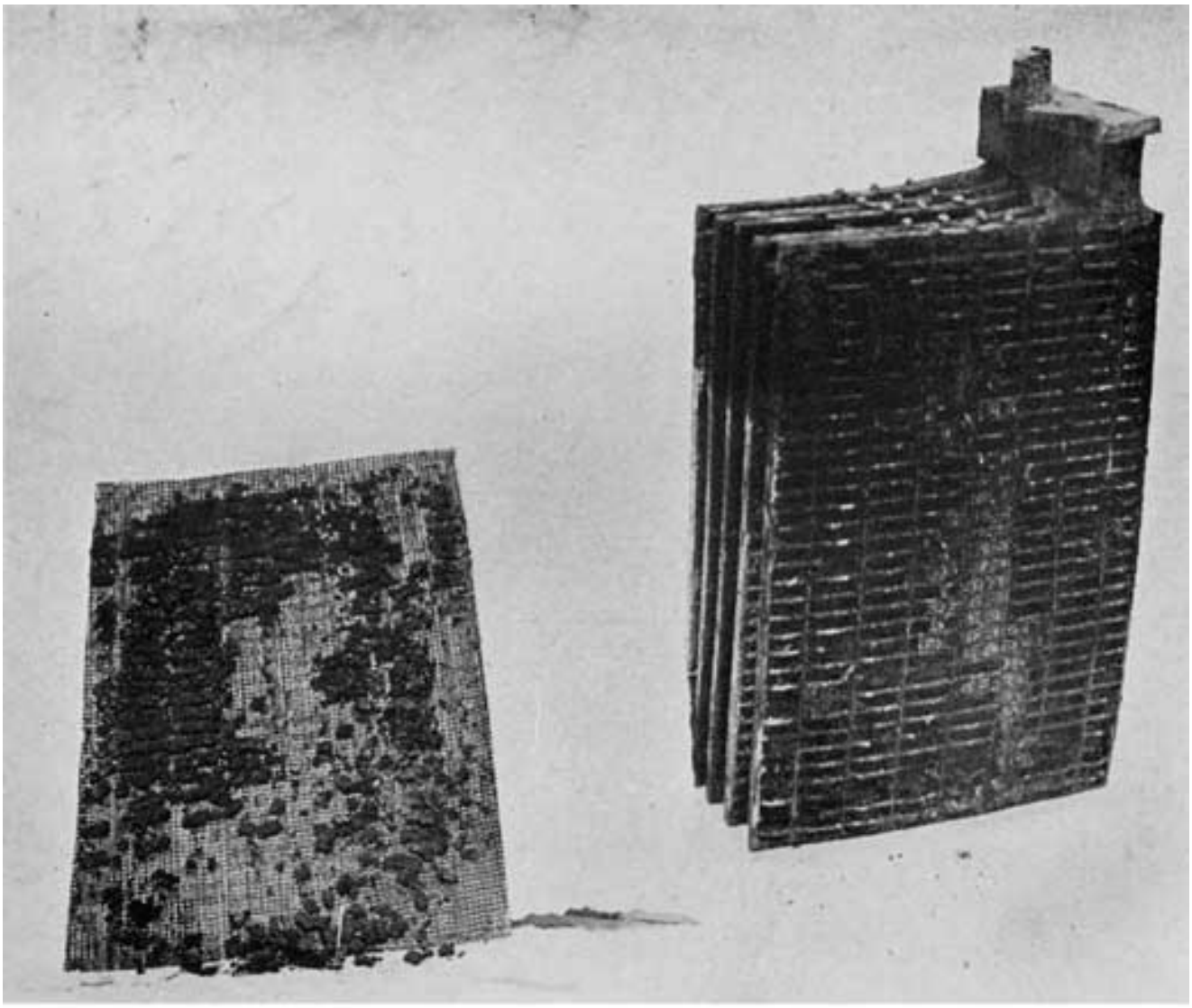

Fig. 203. Positives from Frozen Vehicle Cell. Note Active Material Sticking to Separator

When to Put In New Plates

1. If one or more jars are cracked and leak, and positive plates have been ruined by freezing, as shown in Fig. 203, and if upon drawing out the separators, and separating the positive and negative groups the active material drops out of the grids, the only way to put the battery in a good condition is to put in 'new positives, and new jars and case if necessary.

Make a careful estimate of

(a) Cost of new jars.

(b) Cost of new plates.

(c) Cost of new case if needed.

(d) Cost of labor required.

Try to have the owner present while you are opening his battery. If, however, he could not wait, and has left, call him up and tell him what the total cost will be, and if he has no objections, go ahead with the job. If he is not entirely satisfied with your price, try to get him to come to your shop. Show him the battery, explain its condition, tell him just what must be done with it, and explain how you made your estimate of the cost of the whole job. If you do this. there will never be any misunderstanding as to cost. Tell him the cost of a new battery, and let him decide if lie wants one. If the cost of repairing is almost as much as the price of a new battery. advise him to buy a new one, but allow him to make the decision himself. He will then have no cause for complaint.

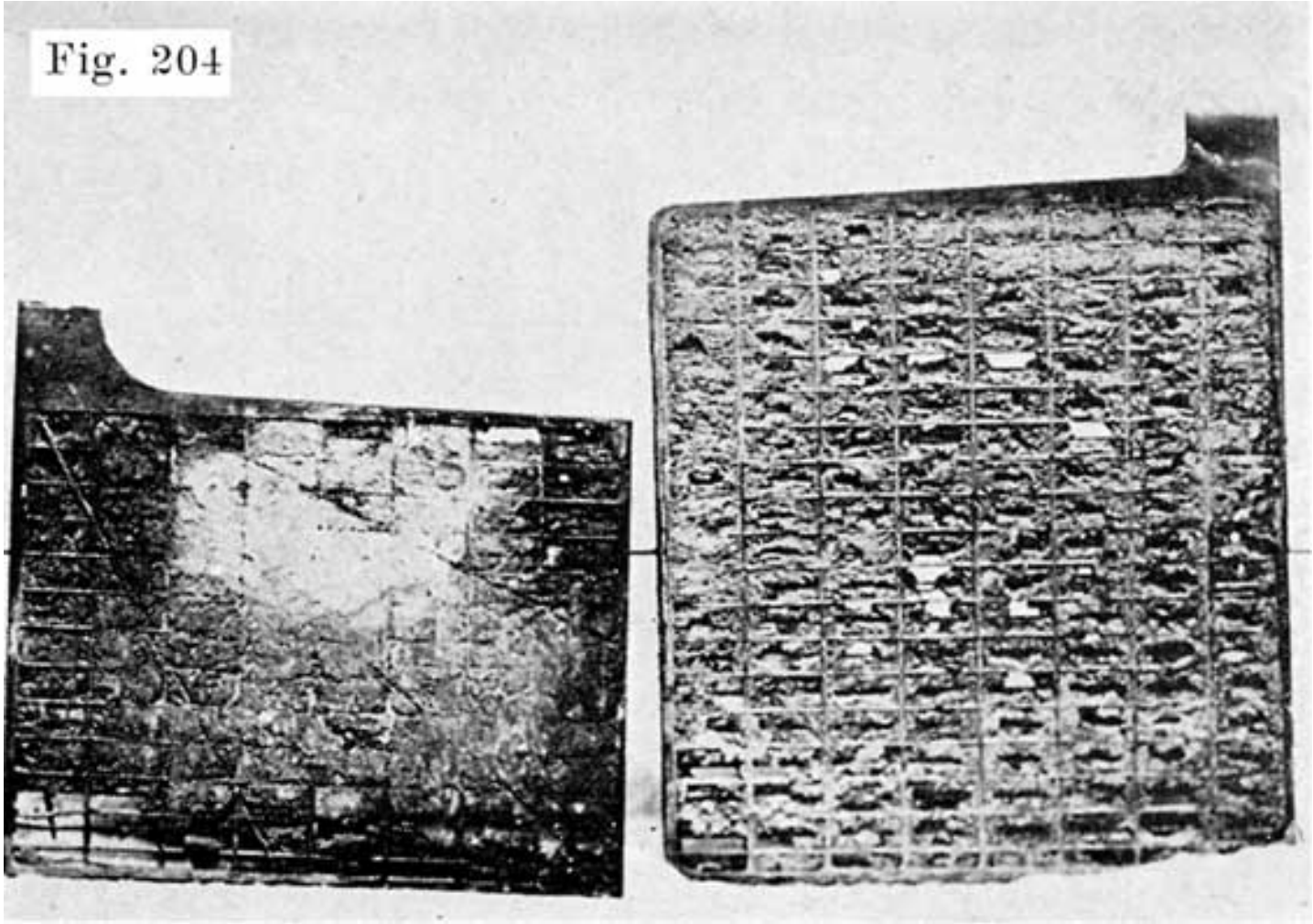

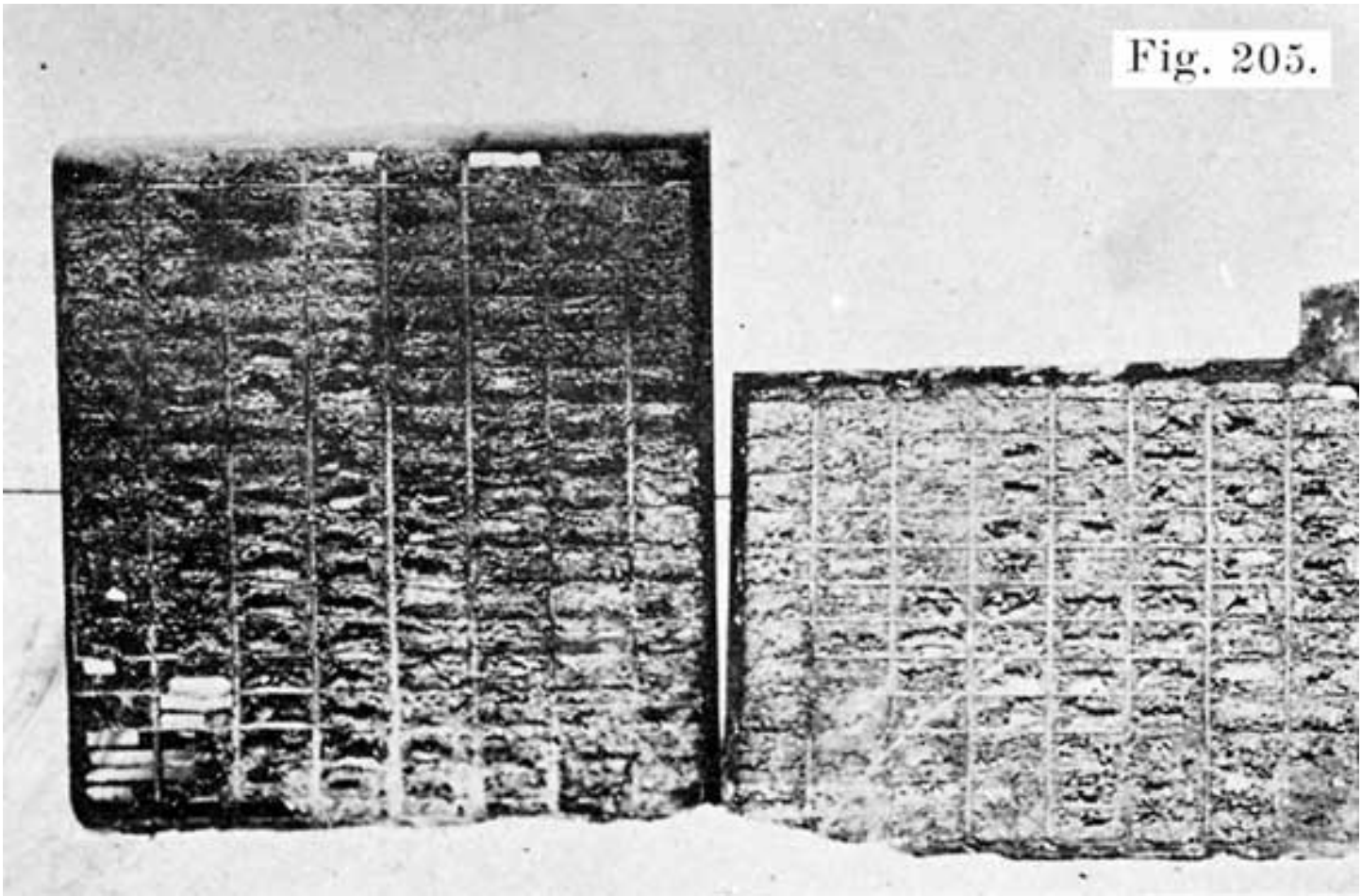

Fig. 204 and 205, Show Diseased Negatives. The Large Ones Only Eight Months Old. Active Material, Granulated and Blistered.

2. If the battery is more than two years old, and the active material on the negative plates is granulated (grainy appearance), Figs. 204 and 205, and somewhat disintegrated; if the plates are weak and brittle around the edges, and several grids are cracked, Fig. 206, and the plates have lost a considerable amount of active material; and if the case has been rotted by the acid, the battery should be junked.

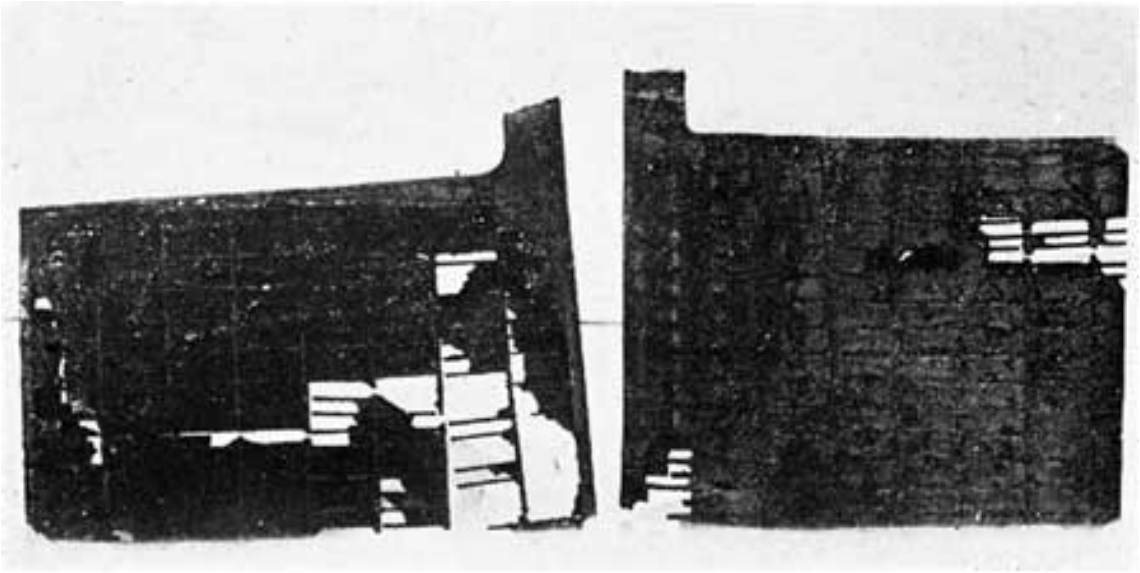

Fig. 206. Weak and Cracked Positives

Call up the owner, and tell him he needs a new battery. If he does not seem pleased, ask him to come to your shop. Then show him his battery, and explain its condition. If you are courteous and patient, you will sell him a new battery. Otherwise he will never return.

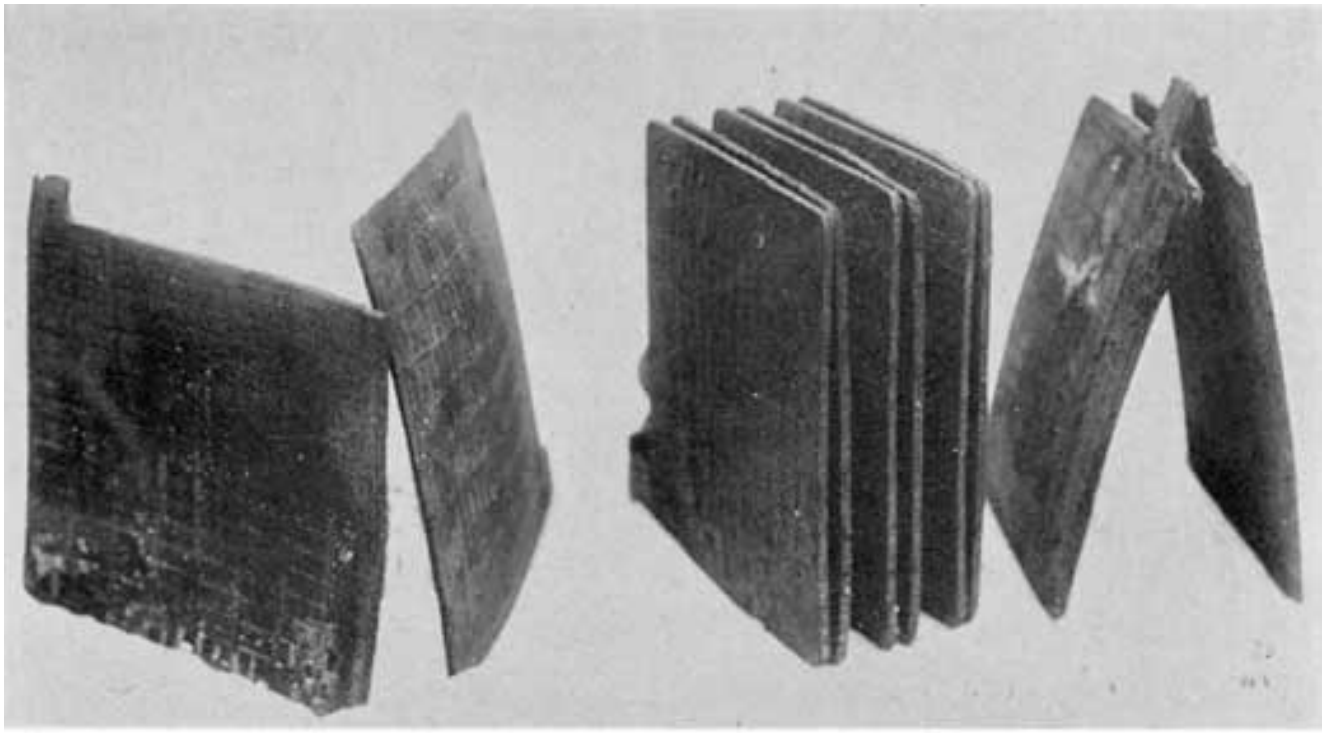

Fig. 207. Buckled Plates

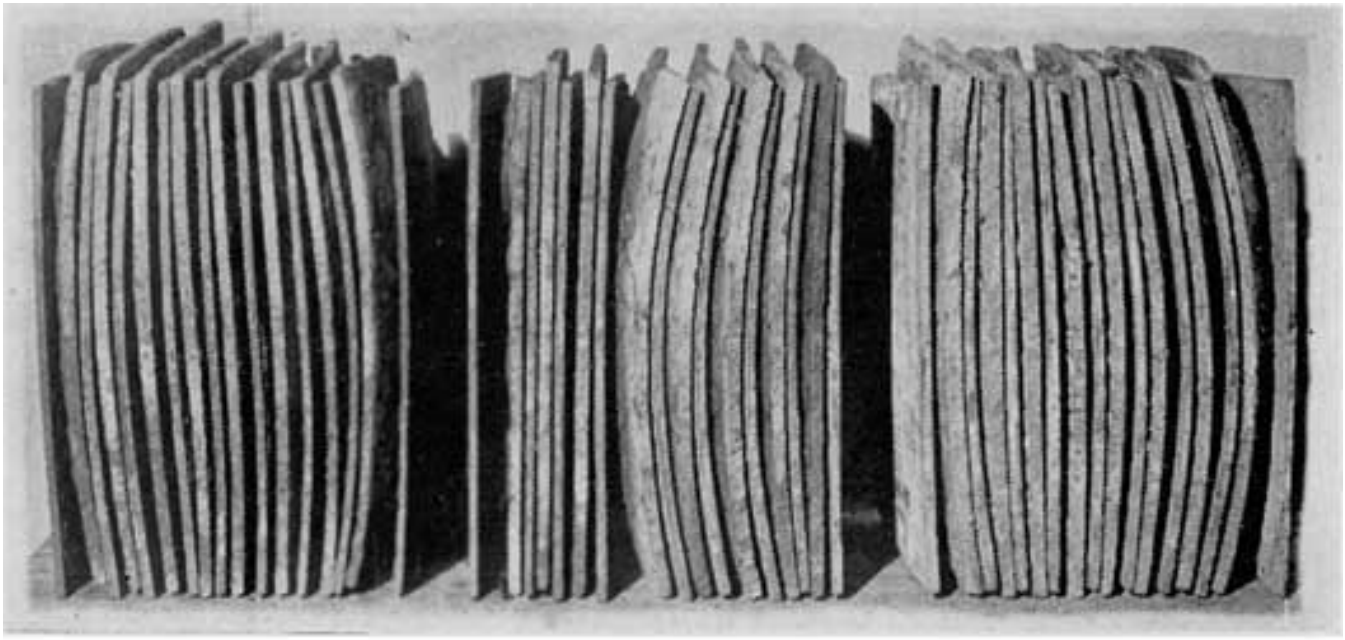

Fig. 208. An Unusually Bad Case of Buckling

3. If the positive plates are badly distorted from buckling, as in Figs. 207 and 208 discard them, for they will cut through new separators, if put into commission again, ill from two to six months.

4. A battery which has has been dry and badly sulphated at some past period of its life will have tile dry portion.", covered with a white sulphate, tile acid line being clearly distinguishable by this white color, as shown at A and B in Fig. 201. If the plates are otherwise ill good shape and you wish to use them, give them the "water cure" described on page 349.

Fig. 209. Corroded, Bulged, and Sulphated Negatives. Disintegrated, Rotten Positives

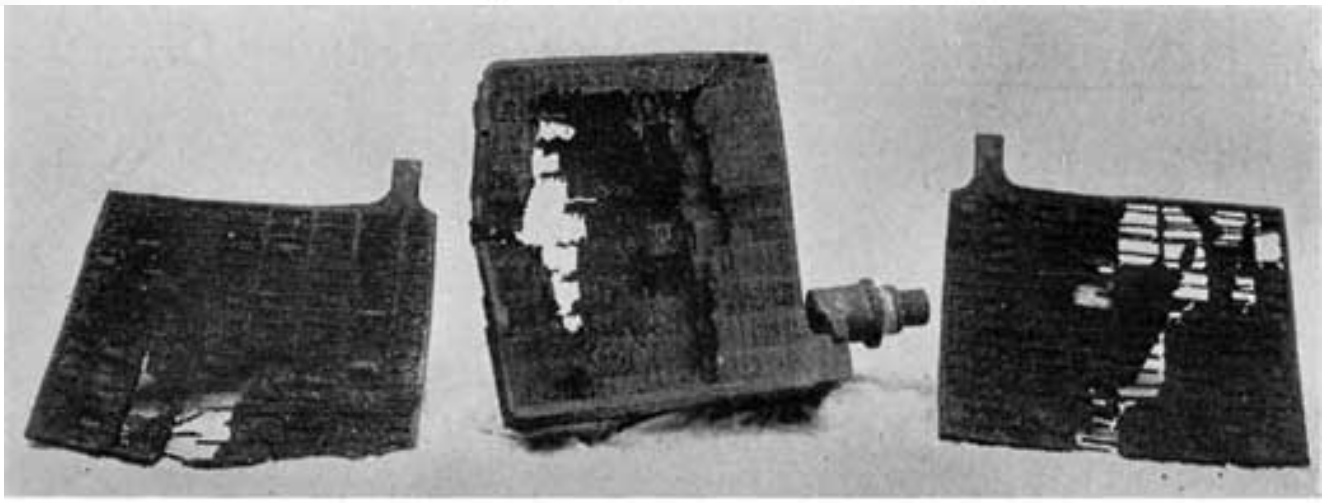

Fig. 210. Disintegrated Positives

5. Rotten and disintegrated positive plates, Figs. 209 and 210, must be replaced with new plates. The plates have fallen to pieces or break at the slightest pressure. Disintegrated plates are an indication of impurities or overcharging, providing the battery is not old enough to cause disintegration normally,--say about two years. The lead grid is converted into peroxide of lead

and becomes soft. As a result, there is nothing to support the paste, and it falls out. Better put in new negatives also.

6. Batteries with high gravity or hot electrolyte have burned and carbonized separators, turning them black and rotting them, the negative paste becomes granulated and is kept in a soft condition, and gradually drops from the grids on account of the jolting of the car on the road. Fig. 211 shows such a battery.

7. Dry, hard, and white, long discharged, and badly sulphated plates, Figs. 201 and 209, are practically ruined, though if the trouble is not of long standing, the plates may be revived somewhat by a long charge at a very low rate, using distilled water in place of the electrolyte, and then discharging at a current equal to about one-eight to one-tenth of the ampere hour capacity of the battery at the discharge board. Charge and discharge a battery a number or times, and you may be able to put a little "pep" into it. In charging sulphated plates, use a low charging rate, and do not allow gassing before the end of the charge, or a temperature of the electrolyte above 110°F.

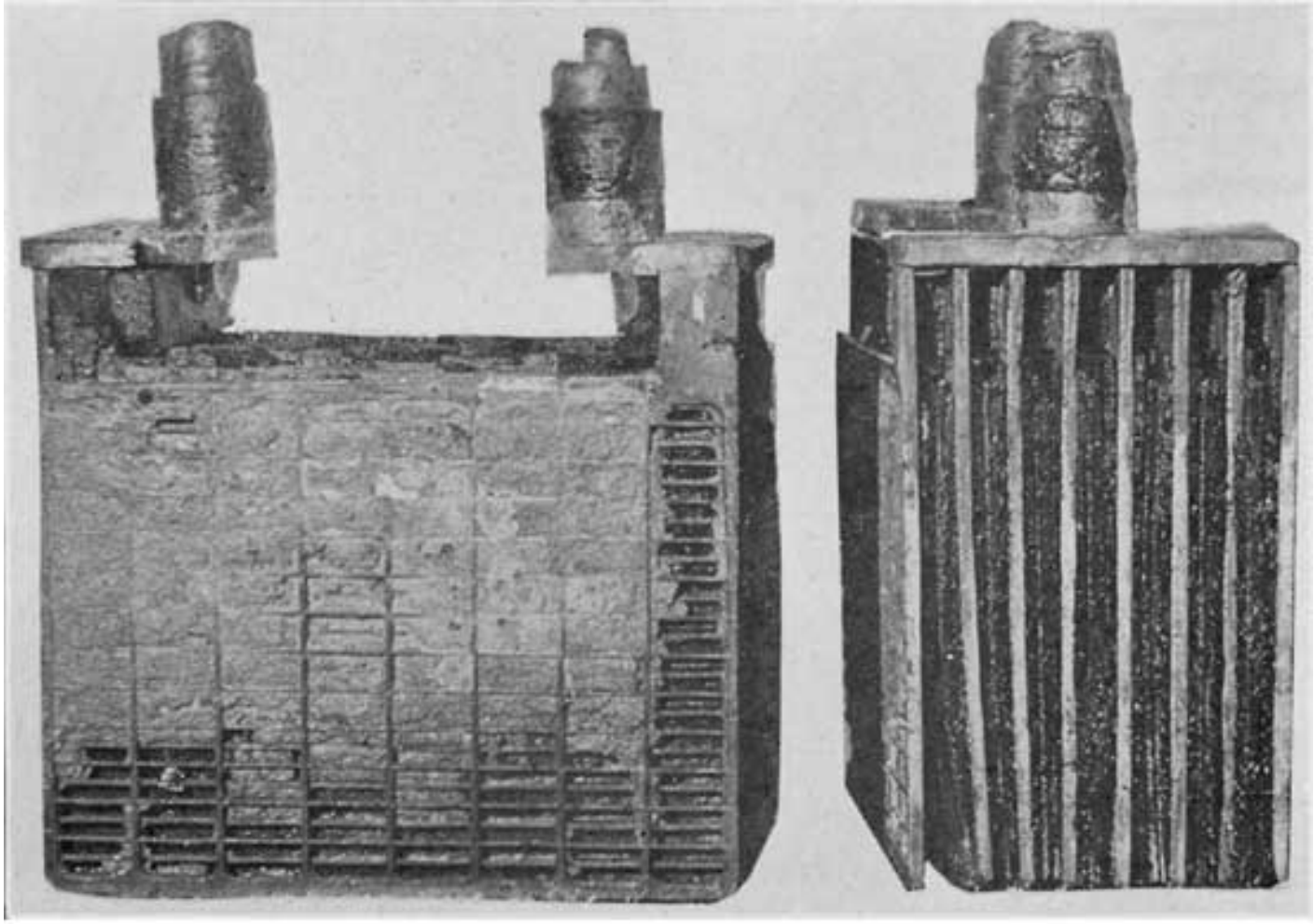

Fig. 211. Side and End View of Element from Traveling Salesman's Battery

8. If a battery case is not held down firmly, or if the elements are loose in the jars, the plates

will jump around when the car is in motion. This will break the sealing compound on top of the battery, and cause the battery to be a slopper. The active materials will be shaken out of the grids, as shown in Fig. 212, and the plates will wear through the separators. New plates are required.

9. If Battery Has Been Reversed. Often the plates of such 'a battery disintegrate and crumble under the slightest pressure. If the reversal is not too far advanced, the plates may be restored (See page 81), but otherwise they should be discarded. This condition is recognized by the original negatives being brown, and the original positives gray.

From. the foregoing explanations, you see that most of the trouble is with the positives:

(a) Because the positive active material does not stick together well, but drops off, or sheds easily.

(b) Because the positives warp or buckle, this causing most of the battery troubles.

(c) Because the positive plate is weaker and is ruined by freezing.

When the Old Plates May be Used Again

1. If one or more plates are broken from the plate connecting straps, or the joint between any strap and the plate is poorly made. If plates are in good condition, reburn the plate lugs to the straps.

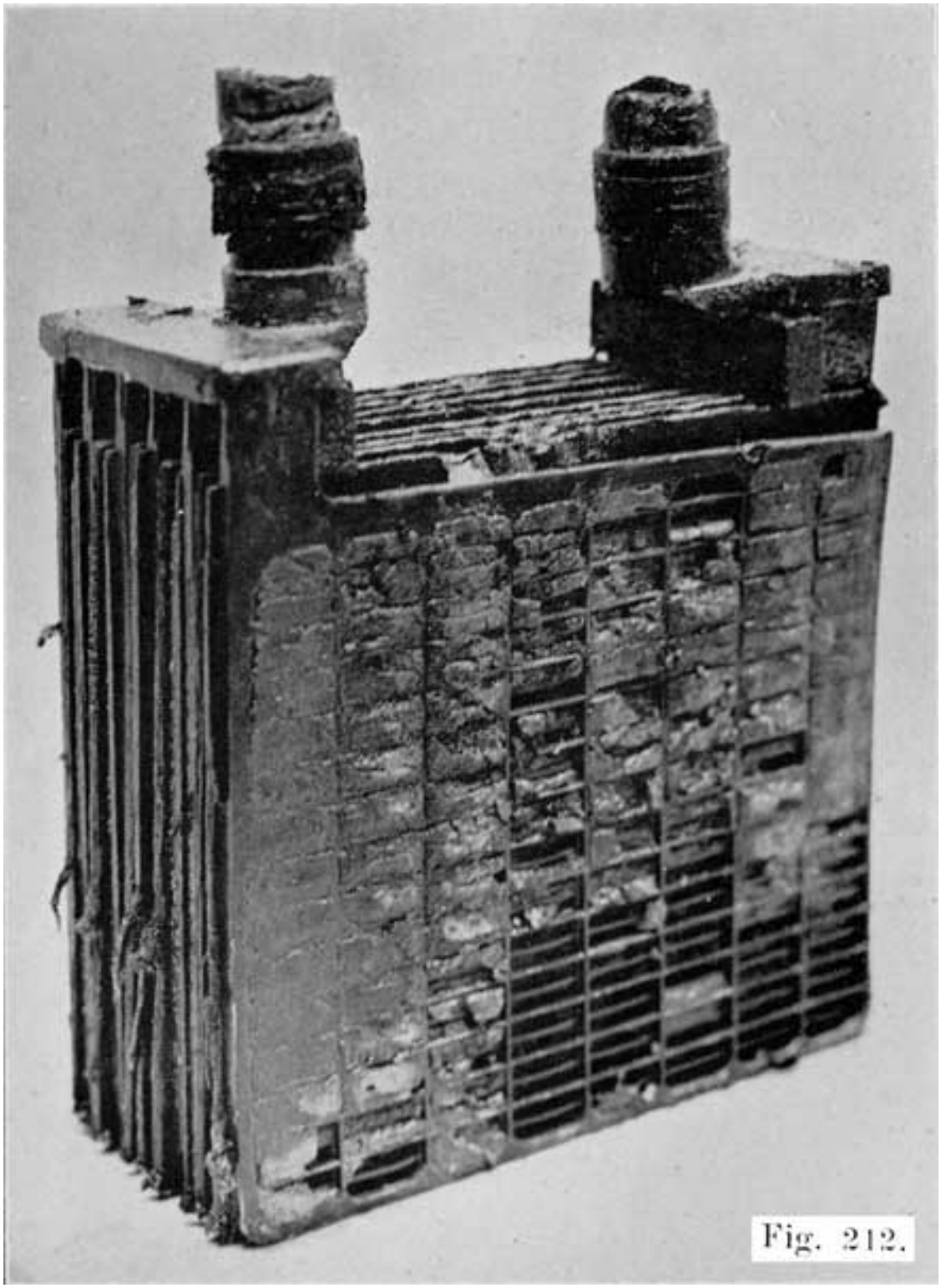

Fig. 212. Element from a "Slopper." Element was Loose in Jar. and Jolting of Car Caused Paste to Fall Out

2. Straight Rebuild. If the general condition of the battery is good, i.e., the plates straight or only slightly buckled. only a slight amount of shedding of active material, no white sulphate oil either plate, the grids not brittle. active material adhering to and firmly touching the grids. the

positive active material of a dark chocolate brown color and fairly hard (as determined by scratching with blade of a pocket knife), tile negative active Material dark gray in color and not blistered or granulated, and tile plates not too thin, make a straight rebuild. To do this, charge the battery. remove any sediment from the bottom of the jar, wash and press the negatives, wash the positives, clean the parts, insert new separators, and reassemble as directed later. The only trouble may be cracked sealing compound, or a broken jar. Broken jars should, of course, be replaced.

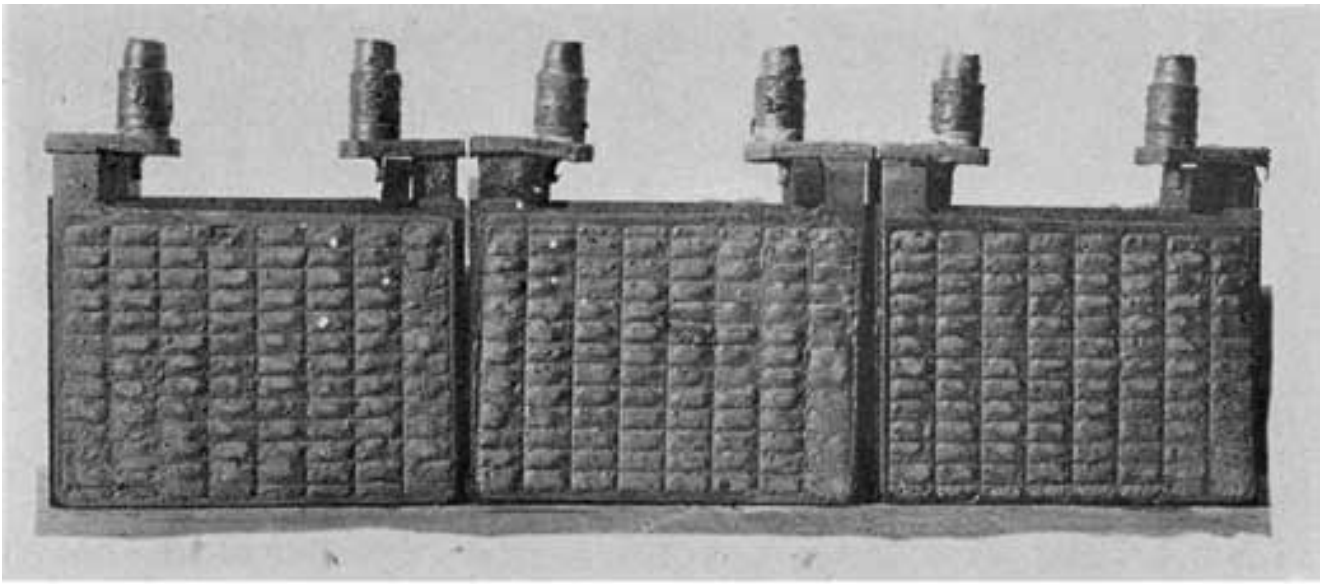

Fig. 213. Badly Bulged Negatives.
Such Plates Must Be Pressed

3. "Badly bulged negative plates, Fig. 213, cause lack of capacity because the active material is loose, and does not make good contact with the grids. If the active material is not badly granulated (having a grainy appearance) the plates call be used again. Sulphated negatives have very hard active material, and will feel as bard as stone when scratched with a knife. Hard negatives from Which active material has been falling ill lumps Oil account of being overdischarged after having been in in undercharged condition may be nursed back to life, if too much of the active material has not been lost.

4. The formation of an excessive amount of sulphate may result in cracking the grids, and the active materials falls out in lumps. Such plates may be put in a serviceable condition by a long charge and several cycles of charge and discharge if there is not too much cracking or too much loss of active material.

5. Positives which are only slightly warped or buckled may be used again.

6. When the only trouble found is a slight amount of shedding. Positive active material must be of a dark chocolate brown color and fairly hard. Negatives must be a dark gray.

7. When the plates are in a good condition, but one or more separators have been worn or out through, or a jar is cracked.

If the battery is one which will not hold its charge, and plates seem to be in a good condition, the trouble is very likely caused by the separators approaching the breaking down point, and the repair job consists of putting in new separators or "reinsulating" the battery.

What To Do With the Separators

It is the safest plan to put in new separators whenever a battery is opened, and the groups separated. Separators are the weakest part of the battery, and it is absolutely essential that all their pores be fully opened so as to allow free passing of electrolyte through them. Some of the conditions requiring new separators are:

1. Whenever the pores are closed by any foreign matter whatsoever. Put in new separators whether you can figure out the cause of the trouble or not. The separator shown in Fig. 201 is sulphated clear through above the line B, and is worthless. The separator shown in Fig. 203 should not be used again.

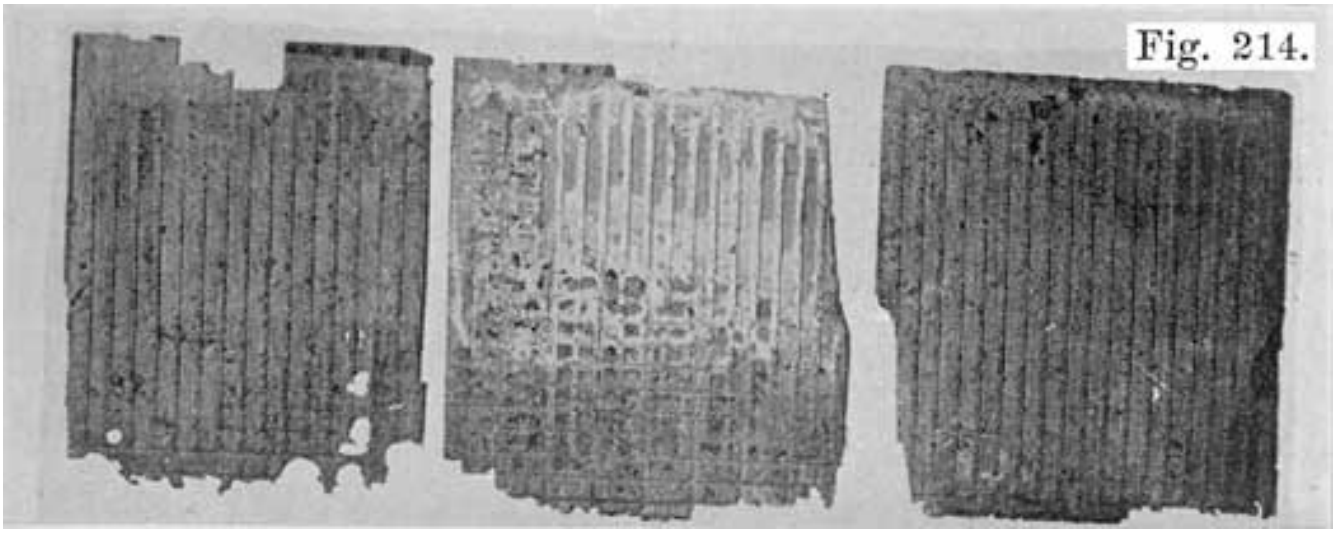

Fig. 214. Separators Worn Thin and Cut Through on Edges by Buckled Plates. Holes Worn Trhough by Bulged Active Material, Center One Shows Cell Was Dry Two Thirds of the Way Down.

2. When the separators have been cut or "chiseled off" by the edge of a buckled plate, Fig. 214.

3. When a buckling plate or plate with bulged active material breaks through the separator, Fig. 214.

4. When a battery has been used while the level of the Fig. 214. Separators Worn Thin and Cut Through on Edges by Buckled Plates. Holes Worn Through by Bulged Active Material. Center

One Shows Cell Was Dry Two Thirds of the Way Down electrolyte has been below the tops of the plates, or the battery has been used in a discharged condition, and lead sulphate has deposited on the separators, Fig. 201.

5. When a battery has been over-heated by overcharging or other causes, and the hot acid has rotted, burned and carbonized the separators, Fig. 215.

6. When a battery has been damaged by the addition of acid and the separators have been rotted, Fig. 215.

7. Separators which are more than a year old should be replaced by new ones, whether plates are defective or not.

When you have put in new separators, and put the battery on charge, the specific gravity of the electrolyte may go down at first, instead of rising. This is because the separators may absorb some of the acid. If the battery was discharged when you put in the new separators, the lowering of the specific gravity might not take place, but in most cases the specific gravity will go down, or not change at all.

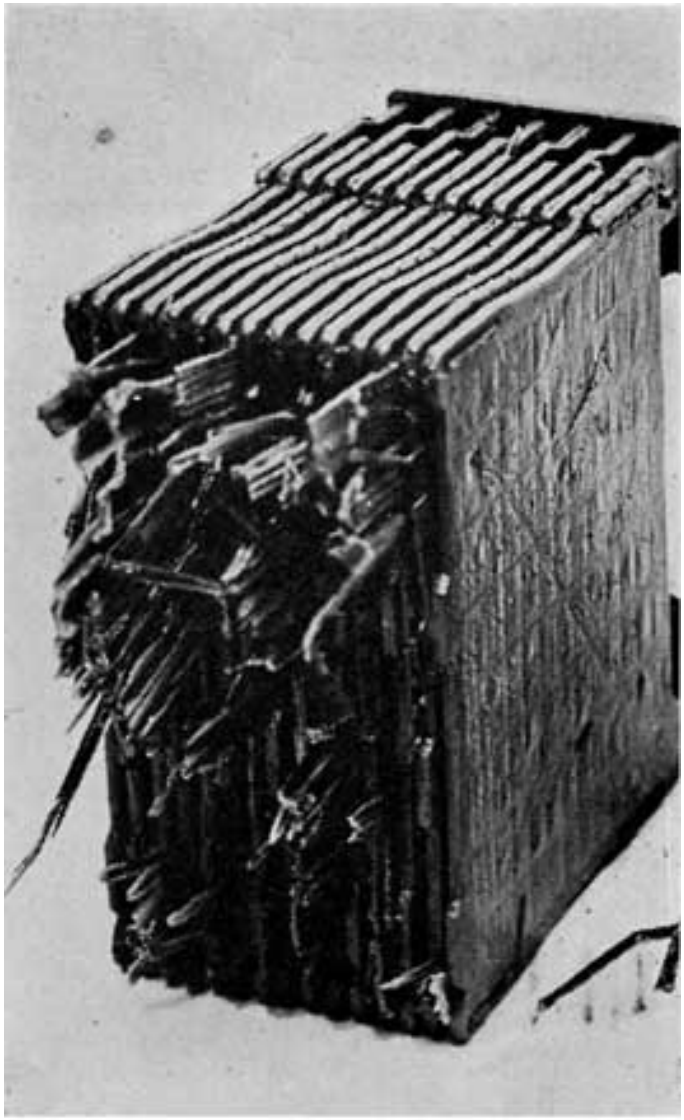

Fig. 215. Rotted Separators

Find the Cause of Every Trouble

The foregoing rules **must** be studied carefully and be clearly tabulated in your mind to be able to tell what to put into commission again and what to discard as junk. It will take time to learn how to discriminate, but keep at it persistently and persevere, and as you pass judgment on this battery and that battery, ask yourself such questions as: What put this battery in this condition? Why are the negative plates granulated? Why are the positive plates buckled? What caused the positive plates to disintegrate? Why are the separators black? Why is the case rotten when less than a year old? Why did the sealing compound crack on top and cause the electrolyte to slop? Why did one of the terminal connectors get loose and make a slopper? Who is to blame for it, the car manufacturer, the manufacturer of the battery, or the owner of the car? Why did this

battery have to be taken off the car, opened up and rebuilt at 5 months old, when the battery taken off a car just the day before had been on for 30 months and never had been charged off the car but once? There is a reason; **find** it. Locate the **cause** of the **trouble** if possible, **remove** the **cause**; your customer will appreciate it and tell his friends about it, and this will mean more business for you.

Eliminating "Shorts"

If you have decided that some or all of the plates may be used again, the next thing to do is to separate any plates that are touching, and put the battery on charge. It may be necessary to put in new separators in place of the defective ones. Examine the separators carefully. Whenever you find the pores of the separators stopped up from any cause whatsoever, put in new separators before charging.

1. Sometimes the negative plates are bulged or blistered badly and have worn clear through the separators, Fig. 214, and touch the positives. In cases of this kind, to save time and trouble, separate the groups, press the negatives lightly, as described later, assemble the element with new separators, and it is ready for charging.

2. There is another case where the groups must be separated and new separators inserted before they will take charge, and that is where the battery has suffered from lack of water and has sulphated clear through the separators, Fig. 201. The separators will be covered with white sulphate. Chemical action is very sluggish in such cases.

If you find. that the separator pores are still open, leave the separators in place and proceed to separate the plates that are touching. How? That depends on what insulating material you have available that is thin enough. If nothing else is available, take a piece of new dry separator about 3/8 inch to 1/2 inch square, or a piece of pasteboard the same size. Use a screw driver or putty knife to separate the plates far enough to insert the little piece of insulation as in Fig. 216. Free all the shorts in this way, unless you have some old rubber insulators. In this case, break off some narrow strips 3/4 inch wide or less, put two together and repeat the operation as above, using the rubber strips instead of the pieces of separator. Insert down 1/2 inch or so and bend over and break off. Occasionally the Lipper edges of the plates are shorted, in which case they must be treated the same way.

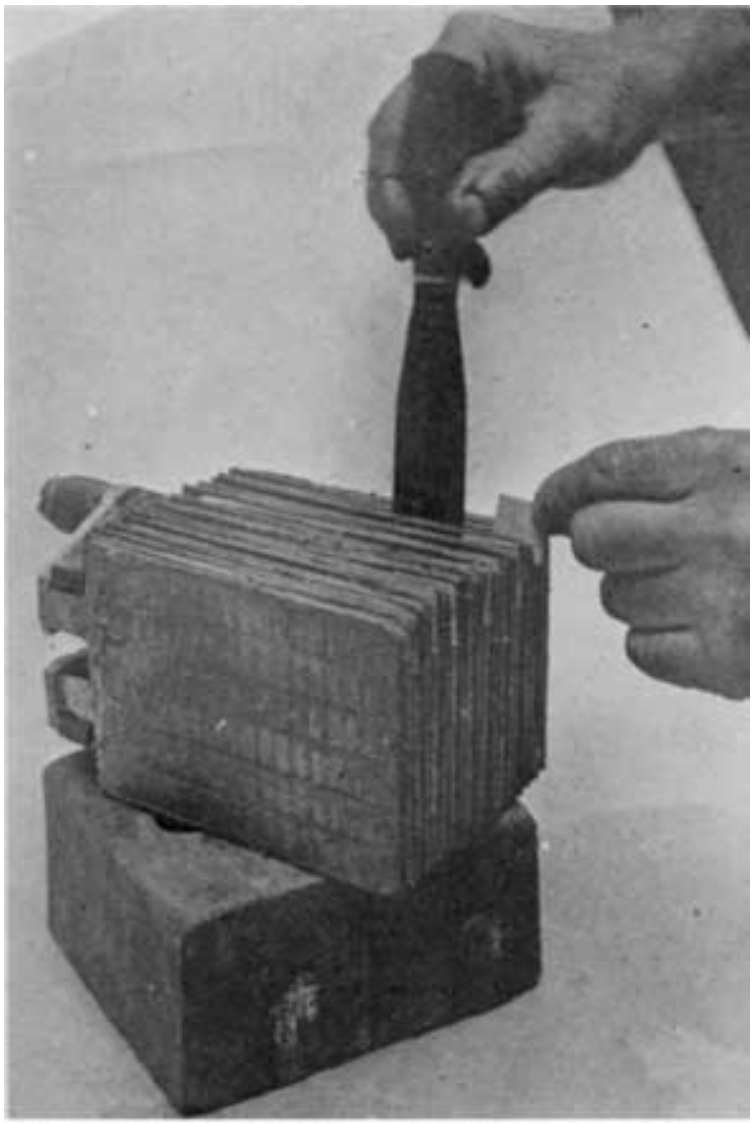

Fig. 216. Clearing Short Circuits

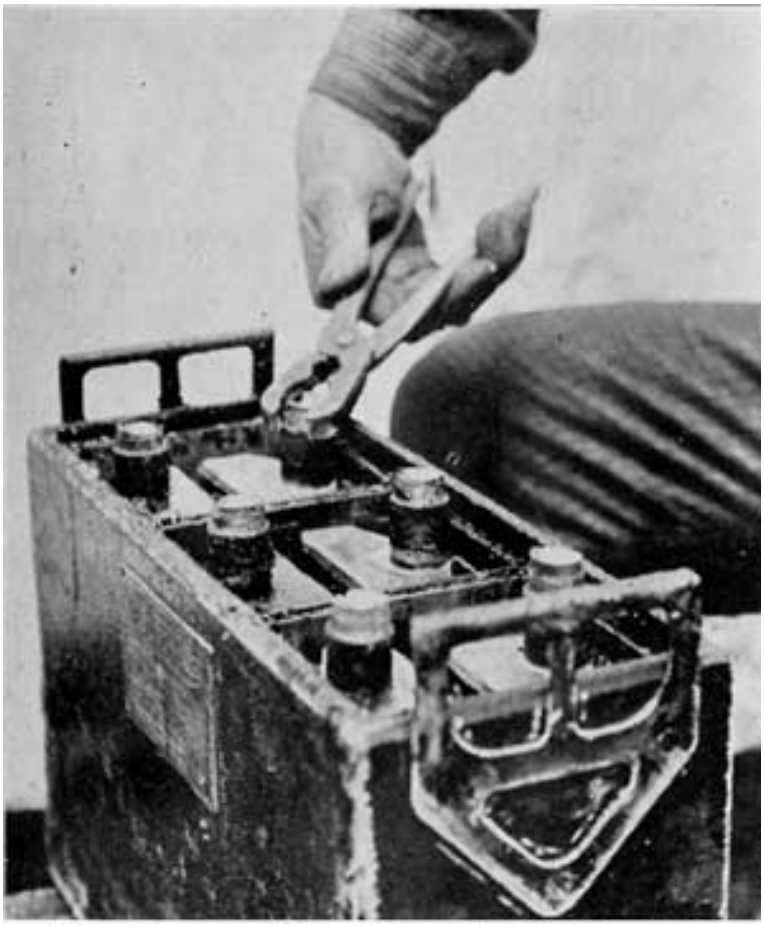

Fig. 217. Cleaning Scale From Posts Before Replacing Connectors Temporarily for Charge

Charging

When you have in this way cleared all the "shorts" in the elements place the elements back in the jars in the same position as they were when you opened the battery, and add enough distilled water to the electrolyte to cover the plates to a depth of one-half inch.

If the negatives are badly sulphated (active material very hard), they will charge more quickly if all the old electrolyte is dumped out and the cells filled with distilled water before putting the battery on charge. This "water cure" is the best for sulphated negatives and will save many plates that could otherwise not be used again. Make it a rule to replace the old electrolyte with distilled water if negatives are sulphated.

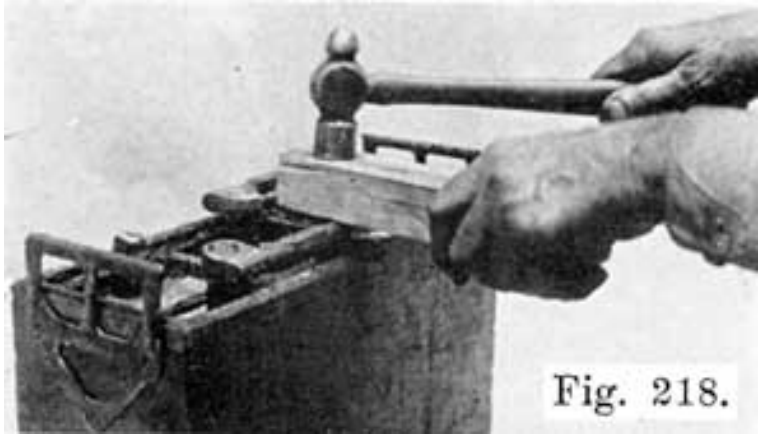

Fig. 218. Tapping Connectors in Place. Preparatory to Charging After Battery Has Been Opened and Shorts Removed

The next operation is to put the battery on charge. Grasp each post in the jaws of a pair of gas pliers and work the pliers back and forth, Fig. 217, so as to remove the scale and allow the connecting straps to make good contact. Now take a knife and cut off the rough edges left in the connecting straps by the drill. Taper the edge, if necessary to go on post. Turn the connectors upside down and pound gently in position, Fig. 218, to make a good connection. Temporary charging connections may also be made by burning lead strips on the posts. This being properly done, the battery is ready for charging. Check up the connections to be sure they are correct.

Now put the battery on charge, and charge at a low rate. Do not allow the temperature of any cell to rise above 110°F. Continue the charge until the electrolyte clears up, and its specific gravity stops rising and the plates have a normal color' over their entire surface. Fully charged positive plates have a chocolate brown color, and fully charged negative plates have a dark gray color. By holding an electric light directly over a cell, and looking down, the color of both negatives and positives may be determined. Do not take the battery off charge until you have obtained these results, although it may be necessary to continue the charge for two, three, four, or five days. In this preliminary charge it is not necessary to bring the gravity up to 1.280, because the electrolyte is not to be used again, and the plates will become charged completely, regardless of what the gravity is. The essential thing is to charge until the electrolyte becomes perfectly clear, the gravity stops rising, and the plates have the right color. The Cadmium test may be used here to determine when the plates are charged. If the gravity rises above 1.280 during the preliminary charge, adjust it to 1.280 by drawing out some of the electrolyte and adding distilled water. **The battery must stay on charge** until you have the desired conditions. If one cell does not charge,--that is, if its specific gravity does not rise,--you have probably not freed all the shorts, and must take the element out of the jar again and carefully inspect it for more shorts.

Right here is where one of the most important questions may be asked about rebuilding batteries. Why must you free the shorts and put the battery on charge? Why not save time by putting in all new separators, sealing the battery, burning on the cell connectors, and then putting it on charge? If you have ever treated a battery in this way, what results did you get? Why did you have a badly unbalanced gravity of electrolyte? How could you know what specific gravity electrolyte to put in each cell? Perhaps one was charged, one only half charged,

and the other dead. Suppose the dead cell had impurities in it. How could you get rid of them? Suppose the battery showed poor capacity on test, what would you do?

Washing and Pressing the Negatives

To continue the actual work on the battery. The battery being fully charged,--the electrolyte clear, the plates of normal color, the specific gravity no longer rising,--remove it from the charging bench and put it on the work bench. Draw each element and let drain as in Fig. 197.

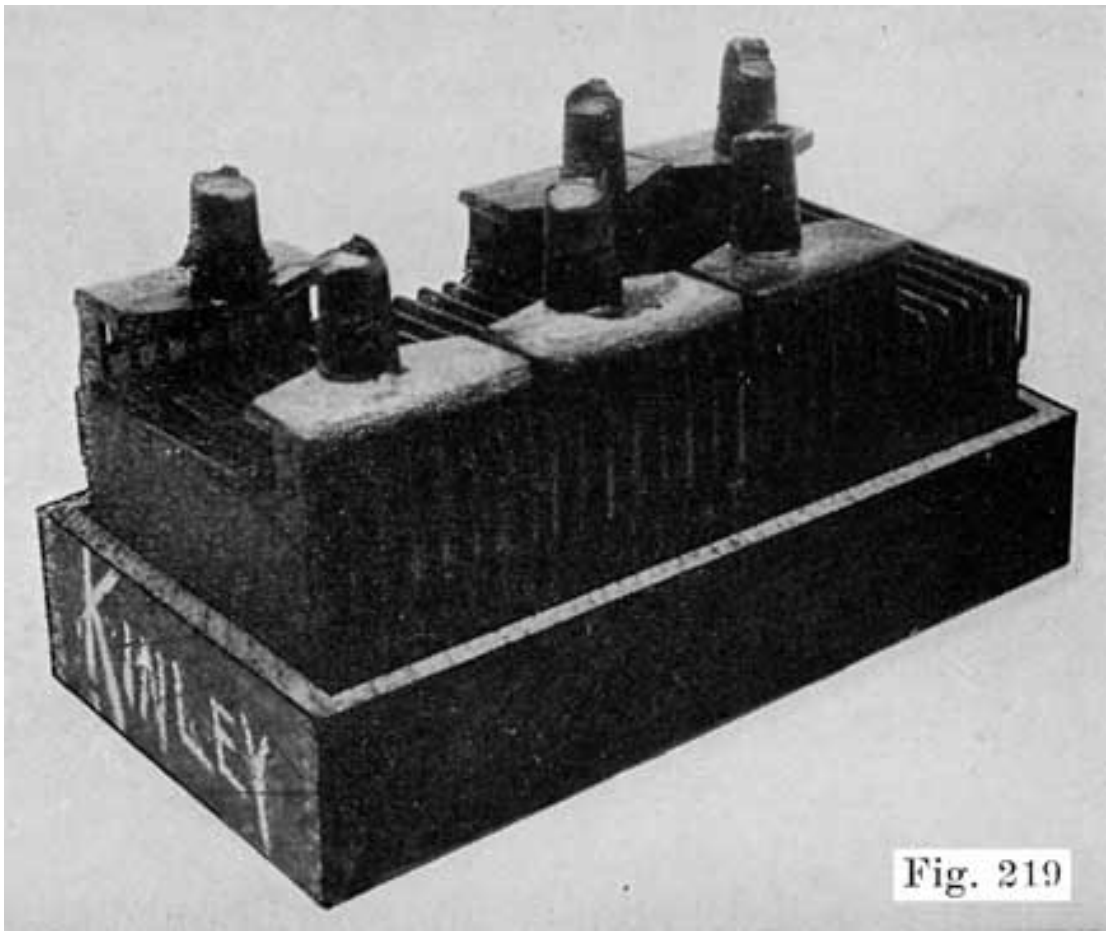

Fig. 219

Here again the labeled boxes described on page 183 come in handy. Separate one group, remove the separators, and put one group in each end of box to keep clean. Separate another group, And nest the plates, Fig. 219, the negative with the negative, and positive with positive. Separate the third element and put groups in the boxes. Pour the old electrolyte out of the jars, and wash out the jars as described on page 360. You now have the plates in the best possible shape for handling. 'Fake the boxes containing the plates to the sink. Have the plate press and the plate press boards ready for use.

If, for any reason, you are called away from your work at this point to be gone for five minutes, do not leave the fully charged negatives exposed to the air, as they will become very hot. Cover them with water. A one-gallon stone or earthenware jar will hold the negative plates of a 100 ampere hour battery if you nest two of the groups. You may also put negatives back in jars from which they were taken, and fill with water.

Now hold a negative group under the faucet, and let a strong stream of water run down over each plate so as to wash it thoroughly, and to remove any foreign matter from the plate surfaces. All negative groups must be handled in exactly the same way so as to get the same results in each case.

After you have washed the first group, place it on edge on a clean board with the post down and pointing away from you, and the bottom of the group toward you. Now insert plate press boards which are slightly larger than the plates, and of the exact thickness required to fill the spaces between plates, Fig. 113. For the standard 1/8 inch plates, a 5-16 inch board, or two 1/8 inch boards should be placed between plates.

The 1/8 inch boards are actually more than 1/8 inch thick, and will give the proper spacing. For thin plates, use 1/4 inch boards. Do not push the plate press boards more than 1/8 inch above the tops of the plates, and be sure that the boards cover the entire plates. Put a board on the outside of each end plate of the group. In this way insert the plate press boards in each of the three negative groups.

Then place each negative group on the lower jaw of the plate press with the post of each group pointing toward you. Three groups may be pressed at one time. Bring the top edges of the transite boards flush with the front edge of the lower jaw of the press, so that no pressure will be applied to the plate lugs. See Fig. 114. Pressure applied to the plate lugs will break them off.

Now screw down the upper jaw of the press as tightly as you can with the handwheel, so as to put as much pressure on the plates as possible. Leave the plates in the press for about five minutes. Then remove them from the press, take out the boards, and replace the plates in the battery jar from which they were removed, and cover with water. They may also be placed in a stone or earthernware jar and covered with water, especially if there is any work to be done on the jars or case of the battery. If the spongy lead of the negatives is firm, they may be reassembled in the battery as soon as they have been pressed. If, however, the spongy lead is soft and mushy, keep the negatives covered with water for 12 to 24 hours. This will make them hard and firm. Then remove them from the water and dry them in the air. In drying, the plates will become heated and will steam. As soon as you notice any steaming, dip the plates in water until they are cool. Then remove them from the water and continue the drying process. Each time the negatives begin to steam as they dry in the air, dip them in the water until they are cool.

When the negatives are dry, they are ready to be reassembled in the battery and prepared for service. Negatives treated in this way will give good service for a much longer time than they would if not treated in this way. The spongy lead has been made firm and elastic. If you have other negatives in your shop which are not in use, treat them in the same way and put them away for future use, to use as rental batteries. Always put them through the same process:

1. Charge them fully.

2. Press them in the plate press to force the spongy lead back into the grids.

3. Soak them in water, if the spongy lead is soft and mushy, for 12 to 24 hours, or even longer until the spongy lead is firm. Dry them in the air, dipping them in water whenever they begin to steam and become heated. This -will give you negatives that will give excellent service and have a long life. Many negatives treated in this way will be good for fifteen months to two years of additional service. The rental batteries should be assembled in the same way as those you are rebuilding for the owners.

The importance of pressing negatives cannot be exaggerated. Always press the negatives of the batteries which you rebuild. Do not do it to half, or three-fourths of the negatives, but to all of them. The work takes but a few minutes, and the time could not be put to better advantage. The spongy lead of the negatives swells and bulges out and makes very poor contact with the grids as a battery become,, discharged. This results in a loss of capacity, gradual sulphation of the loose active material, corrosion of the grids, failure of the gravity to rise high enough on charge, overheating of the battery on charge, gassing before the sulphate is reduced to active material with breaking off and roughening of the active material, and makes the battery lazy and sluggish in action. The spongy lead must make good contact with the grids if the battery is to have a long life and give good service.

No amount of charging will cure a negative with bulged, swollen active material. Once this material becomes bulged nothing but pressing will put it back where it belongs, and until it is pressed back into the grids the plates are in a poor condition for service. Even if the bulging is but very slight, the plates must be pressed.

Washing Positives

If you intend to use some of the positives, they should now be washed. If you intend to use all new positives, throw away the old ones, of course. The positives should not be held under the faucet as the negatives were, because the stream of water will wash out much of the positive active material. Rinse the positives a number of times in a jar of clean water by moving them up and down in the water. This will remove impurities from the surfaces of the plates and wash off any foreign or loose materials. After rinsing each positive group, replace it in the box.

Never attempt to straighten badly buckled positives, as the bending cannot be done successfully, and the active material will not have good contact with the grids. Positives cannot be pressed as negatives can, because the positive active material lacks the elasticity and toughness of the negative spongy lead. Slightly buckled positives may sometimes be straightened by bending them lightly all around the edges with a pair of thin, wide nosed pliers. This should be (lone very carefully, however, and the straightening done. gradually. If the plates cannot be straightened in this way and the separators do not lie perfectly flat against them without pinching at the corners, the plates should be discarded, and new ones used in their place.

This is all the work to be done on the old plates, and those which are to be used again are ready to be reassembled in the battery. The process of treating the plates should be followed in every

battery that you rebuild, and the same steps should always be taken, and in the same order. With one Standard method of rebuilding batteries you will do 'uniformly good work and satisfy all your customers. The essential thing for the success of your battery business is to learn the Standard method and use it. Do not rush a battery through your shop, and leave out some of the steps of the process, even though the owner may be in a hurry. If you have a good stock of rental batteries you can put one on his car and keep it there until you have done as good a job of rebuilding on his battery as you possibly can. Remember that the Standard method which has been described has not simply been figured out as being a good method. This method has been worked out in the actual rebuilding of thousands and thousands of batteries of all makes and in all conditions, and has produced batteries full of life and power, ready to give one to two years more of good, reliable service.

Burning on Plates

When you put new plates into a battery, or find some of the plates broken from the connecting strap, it will be necessary to burn the plates to the strap. Frequently you will find plates which are otherwise in a good condition broken from the connecting straps. This is most likely to happen when the plates have been cast on to the connecting strap instead of being burned on. These plates must be burned on.

New plates are frequently necessary. From pages 339 to 346 you see that new plates are required under the following conditions:

(a) Positives. Ruined by freezing; weak and brittle from age, large part of active material shed; badly buckled; rotten and disintegrated by impurities; reversed. Positives in a reasonably good mechanical condition can be restored to a good electrical condition by charging.

(b) Negatives. Active material granulated, bulged and disintegrated; charged while dry; positives disintegrated by impurities; ruined by overcharging; badly sulphated because allowed to stand idle, or used while discharged; much active material lost, and that which is left soft and mushy; negatives reversed by charging battery backwards.

When making plate renewals, never install plates of different design in the same group. Always use plates of the type intended for the battery. The battery should first be fully charged, as already explained. If all the plates in a group are to be discarded, clamp the post in a vise, being careful not to crack the hard rubber shell if one is on it, or to damage the threads on Posts such as the Exide or to draw up the vise so tightly as to crush the post. Then saw off all the old plates with a new coarse toothed hacksaw, a sharp key hole saw, or any good saw which has a wide set, close to the post. This separates the entire group of plates from the post in one short operation. This method is much better than the one of sawing the plates off below the connecting strap, and sawing or punching the old plate ends out of the strap. See page 217 for instructions for welding plates to the straps.

Work on the Jars

The work on the jars consists of removing any sediment which may have collected, washing out all dirt, and replacing leaky jars. The removal of sediment and washing should be done after the preliminary charge has been given and the old electrolyte poured out unless the preliminary charge was given with distilled water in the jars. The old electrolyte need not be poured down the sewer, but may be kept in stone or earthenware jars and used later in making electrical tests to locate leaky jars.

Testing Jars

Remove all sealing compound from the jar by means of a hot putty knife, finishing by wiping with a gasoline soaked rag. Inspect each jar carefully under a strong light for cracks and leaks. If you know which jar is leaky by having filled each cell with water up to the correct level, when you made the first examination of the battery, and then having it allowed to stand over night to see if the electrolyte in any cell has dropped below the tops of the plates, no tests are necessary, but if you are in doubt as to which jar, if any, is leaky, you must make tests to determine which jar is leaky. If you know that there is no leaky jar, because of the bottom of the case not being acid eaten and rotted, it is, of course, not necessary to test the jars.

One test consists in filling the jar within about an inch of the top with old or weak electrolyte, partly immersing the jar in a tank which also contains electrolyte, and applying a voltage of 110 or 220 between the electrolyte in the jar and the electrolyte in the tank in which the jar is partly immersed. If current Vows, this indicates that the jar is leaky.

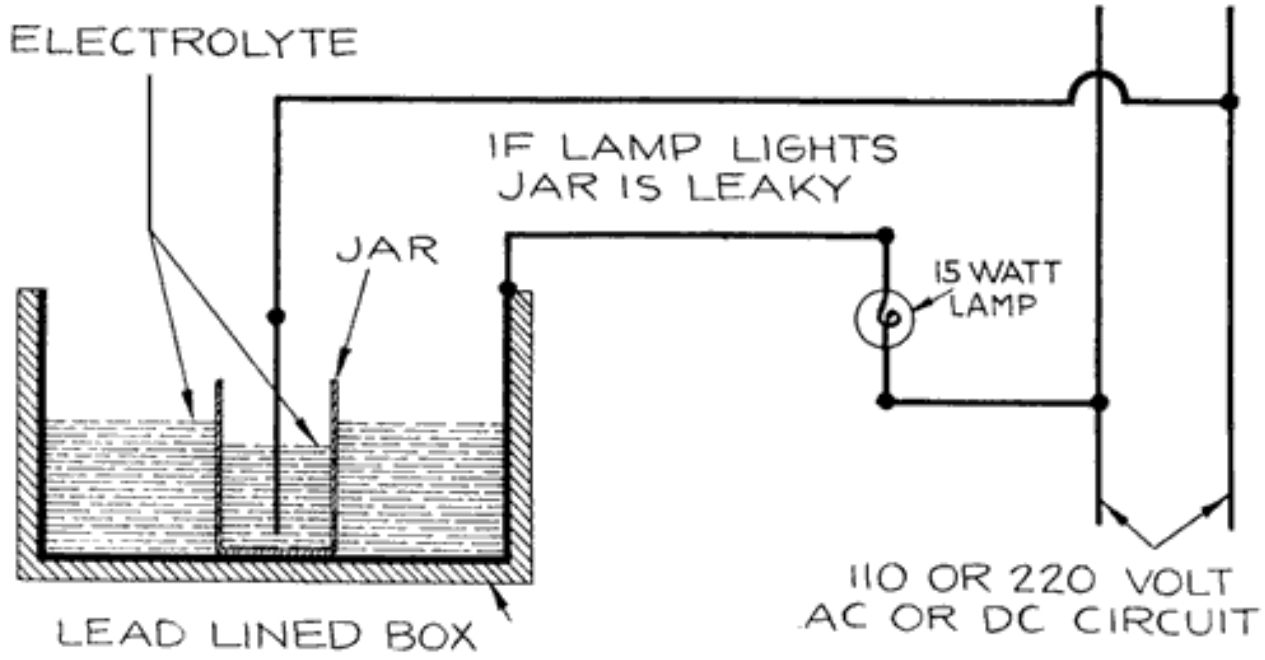

Fig. 220. Testing Jar for Leaks, Using a 15-Watt Lamp in Series with Test Circuit

Fig. 220 shows the principle of the test. A suitable box, -an old battery case will do, - is lined with sheet lead, and the lead lining is connected to either side of the 110 or 220 volt line. The

box is then partly filled with weak electrolyte. The jar to be tested is filled to within about one inch of the top with weak electrolyte. The jar is immersed to within about an inch of its top in the box. The top part of the jar must be perfectly dry when the test is made, or else the current will go through any electrolyte which may be wetting the walls of the jar. A lead strip or rod, which is connected to the other side of the 110 or 220 volt line, through a lamp as shown, is inserted in the jar. If there is, a leak in the jar, the lamp will burn, and the jar must be discarded. If the lamp does not light, the jar does not leak.

Instead of using a lead lined box, a stone or earthenware jar may be used. A sheet of lead should be placed in this jar, being bent into a circular shape to fit the inside of the jar, and connected to one side -of the line. The lead rod or sheet which is inserted in the jar may be mounted on a handle for convenience in making the test. The details of the testing outfit may, of course, be varied according to what material is available for use. The lamps should be suitably mounted on the wall above the tester.

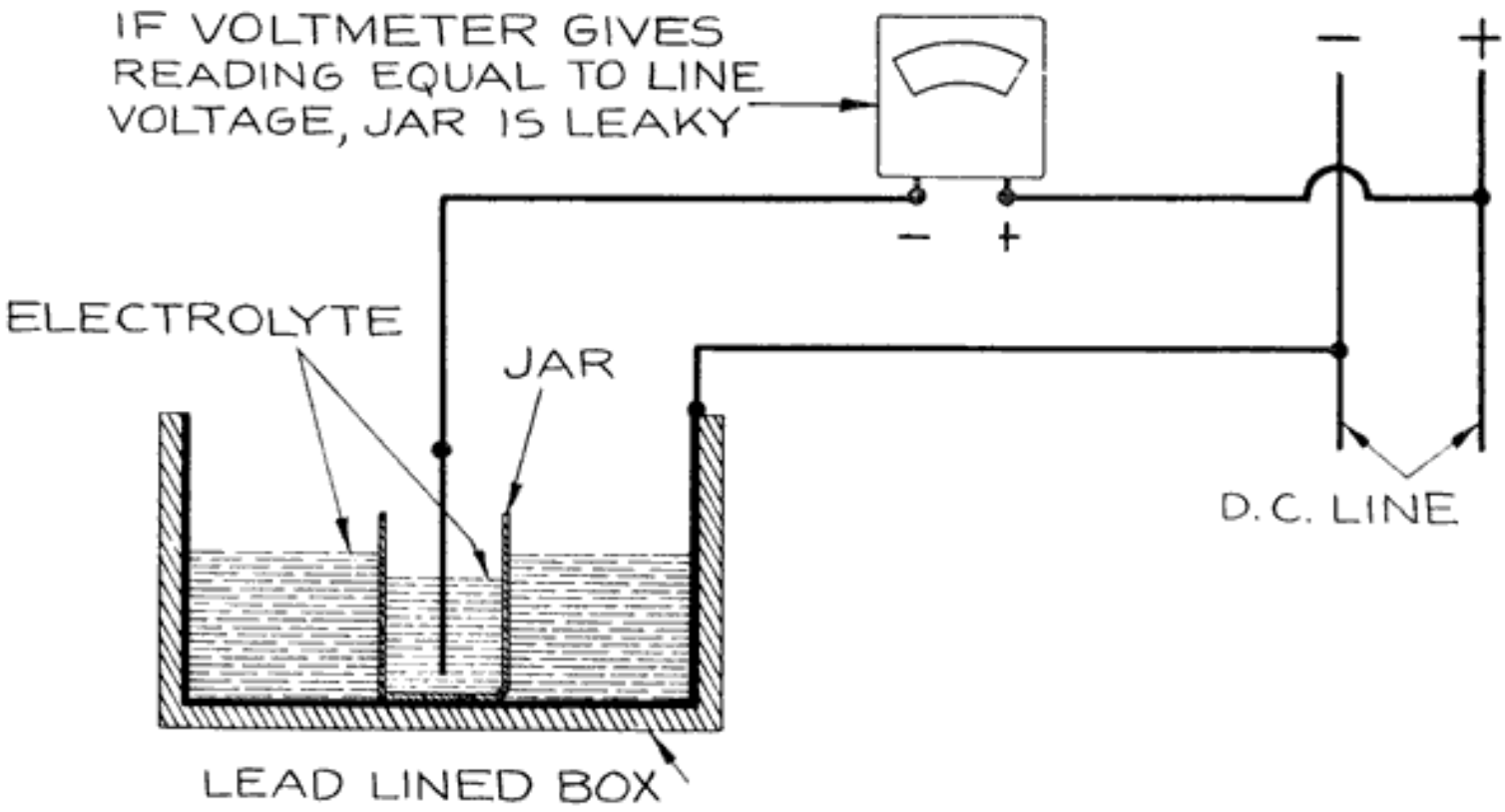

Fig. 221. Testing Jar for Leaks, Using a Voltmeter in Series with Test Circuit

This test may be made by using a voltmeter instead of lamps, as shown in Fig. 221. If a voltmeter is used, be especially careful to have the part projecting above the liquid perfectly dry. A leaky cell will be indicated by a reading on the meter equal to the line voltage.

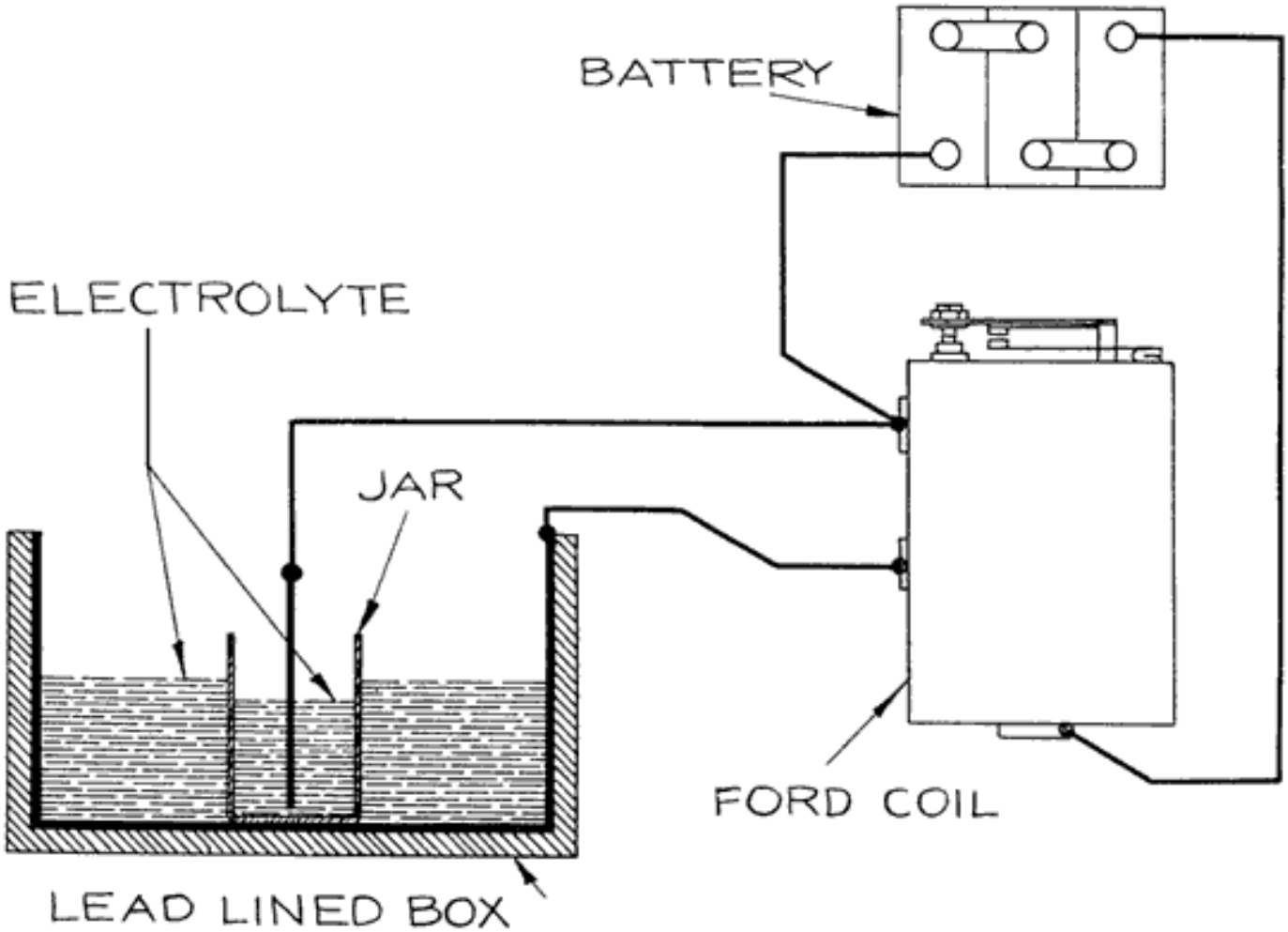

Fig. 222. Testing Jar for Leaks, Using Secondary of Ford Ignition Coil, or Any Other Vibrator Ignition Coil

A third method uses a Ford ignition coil, as shown in Fig. 222. A leak will be indicated by a spark, or by the vibrator making more noise than it ordinarily does. Instead of using the Ford coil, as shown in Fig. 222, the test may be made as shown in Fig. 223. Fill the jar to within an inch of the top with electrolyte and immerse one of the high tension wires in the electrolyte. Attach the other high tension wire to a wire brush, comb, or rod having a wooden handle and rub it over the outside of the jar. A leak is shown by a spark jumping to the jar.

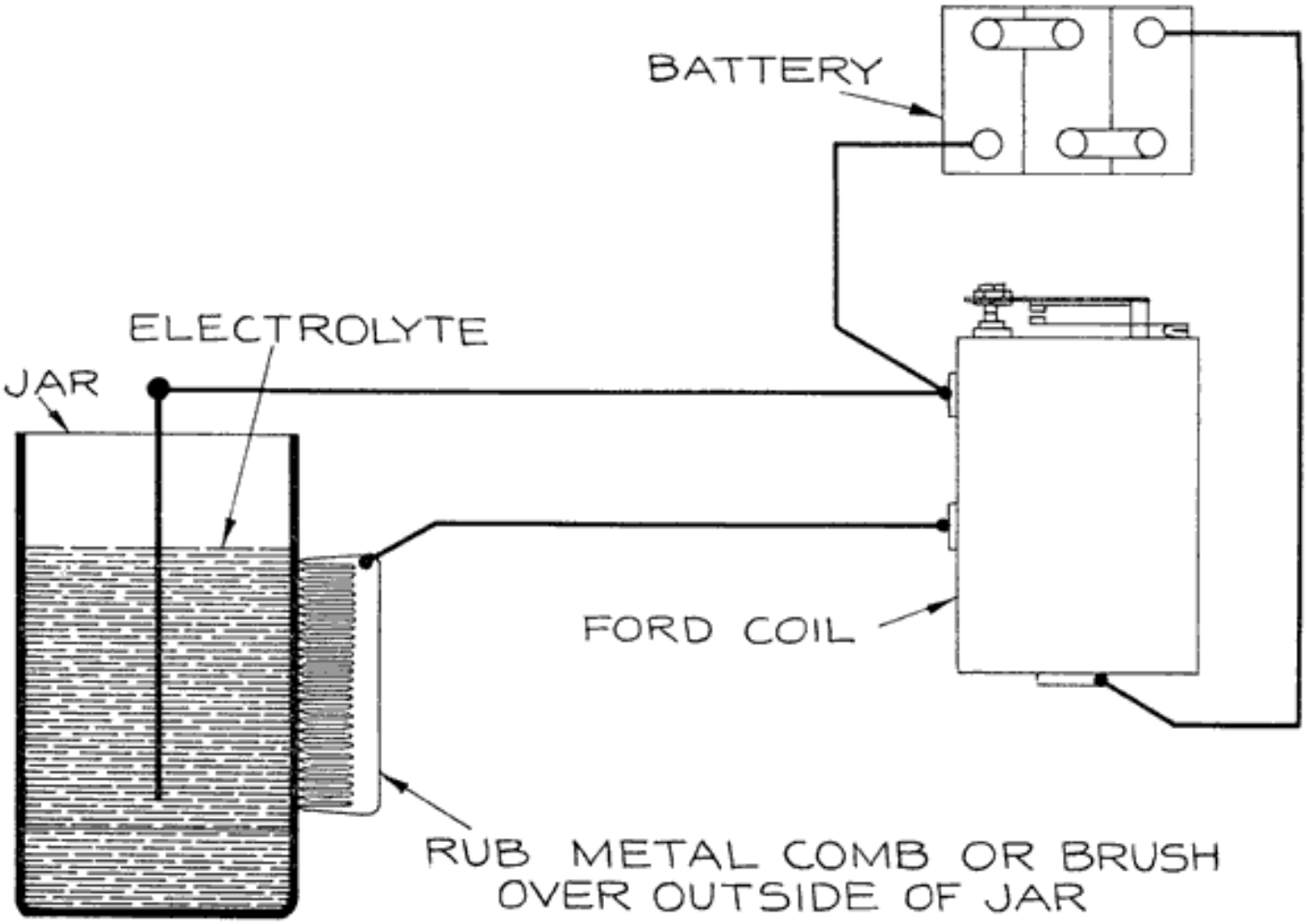

Fig. 223. Testing Jar for Leaks, Using Secondary of Ford Ignition Coil, or Any Other Vibrator Ignition Coil

The test may also be made without removing the jar. If the lead lined box be made two feet long, the entire battery may be set in the box so that the electrolyte in the box comes within an inch of the top of the battery case. Fill each jar with weak electrolyte and make the test as before. If this is done, however, remove the battery immediately after making the test and wipe the case dry with a cloth. To make the test in this way. the case must be considerably acid eaten in order to have a circuit through it to the jar.

Removing Defective Jars

The method of removing the jars from the case depends on the battery. In some batteries the jars are set in sealing compound. To remove a jar from such a battery, put the steam hose from your steamer outfit into the jar, cover up the top of the jar with rags, and steam the jar for about five minutes. Another way is to fill the jar with boiling hot water and let it stand for fully five minutes. Either of these methods will soften the sealing compound around the jar so that the jar may be pulled out. To remove the jar, grasp two sides of the jar with two pairs of long, flat nosed pliers and pull straight up with an even, steady pull. Have the new jar at hand and push it

into the place of the old one as soon as the latter is removed. The new jar should first be steamed to soften it somewhat. Press down steadily on the new jar until its top is flush with the tops of the other jars.

Some batteries do not use sealing compound around the jars, but simply use thin wooden wedges to hold the jars in place, or have bolts running through opposite faces of the case by means of which the sides are pressed against the jars to hold them in place. The jars of such batteries may be removed without heating, by removing the wedges or loosening the bolts, as the case may be, and lifting out the jars with pliers, as before. New jars should be steamed for several minutes before being put in the case. When you put jars into such batteries, do not apply too much pressure to them, as they may be cracked by the pressure, or the jar may be squeezed out of shape, and the assembling process made difficult.

Repairing the Case

Fig. 224. Washing Sediment from Jars. Water Supply Controlled by Foot Valve

The case may be repaired with all the jars in place, or it may be necessary to remove the jars. If the case is to be junked and the jars used again, the case may simply be broken off, especially if there is much sealing compound around the jars.

Empty the old acid from the jars, take the case to the sink and wash out all the sediment, Fig. 224. With the pipe shown in Fig. '14, you have both hands free to hold the case, as the water is controlled by' a foot operated spring cock.

If the case is rotten at top, patch it with good wood. If the top and bottom are so rotten that considerable time will be required to repair it, advise the owner to buy a new case. Sometimes the top of the case can be greatly improved by straightening the side edges with a small smoothing plane, and' sometimes a 1/2 inch strip or more fitted all along the edge is necessary for a good job. Handles that have been pulled, rotted, or corroded off make disagreeable repair

jobs, but a satisfactory job can be done unless the end of the case has been pulled off' or rotted. Sometimes the handle will hold in place until the battery is worn out by old age if three or four extra holes are bored and countersunk in the handle where the wood is solid, and common wood screws, size 12, 1/2 or 5/8 inch long used to fasten the handle in place. Sometimes it will be necessary to put in one half of a new end, the handle being fastened to the new piece with brass bolts and nuts before it is put into place. Sometimes you can do a good job by using a plate of sheet iron 1-16 inch thick, and 4 inches wide, and as long as the end of the case is wide. Rivet the handle to this plate with stovepipe, or copper rivets, and then fasten the plate to the case with No. 12 wood screws, 1/2 inch long.

If the old case is good enough to use again, soak it for several hours in a solution of baking soda in water to neutralize any acid which may have been spilled on it, or which may be spilled on it later. After soaking the case, rinse it in water, and allow it to dry thoroughly. Then paint the case carefully with asphaltum paint.

REASSEMBLING THE BATTERY

Reassembling the Elements

Take a negative group and put it on edge on a board, with post away from you, and lower edge toward you. Mesh a positive in the negative group. The groups are now ready for the separators. Take six moist separators from your stock. Slip one into position from the bottom in the middle of the group, with the grooved side toward the positive plate, spreading the plates slightly if necessary. Take another separator, slip it into position on the opposite side of the positive against which your first separator was placed. In this way, put in the six separators, with the grooved side toward the positives, working outward in both directions from the center, Fig. 225. The grooves must, of course, extend from the top to the bottom of the plate. Now grasp the element in both hands, and set it right side up on the block, giving it a slight jar to bring the bottoms of the plates and separators on a level.

Fig. 225. Inserting Separators

Fig. 226. Trying on a Cover

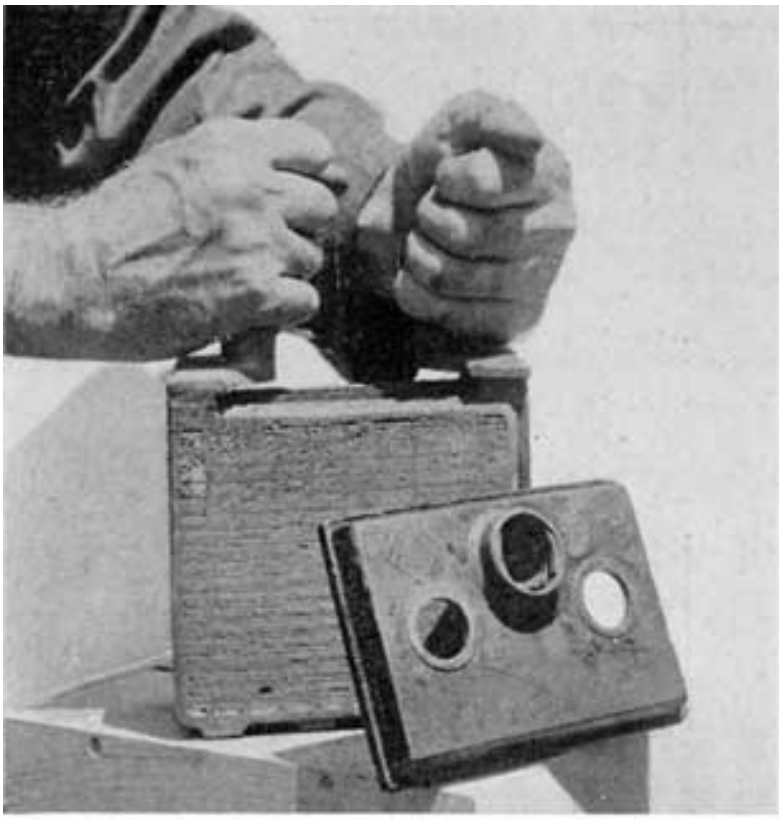

Fig. 227. Shifting Groups to Make Cover Fit

Now grasp the element in both hands, and set it right side up on the block, giving it a slight jar to bring the bottoms of the plates and separators on a level.

Next take a cover, and try it on the posts, Fig. 226. Pull the groups apart slightly, if necessary, before inserting any more separators, so that the cover fits exactly over the posts, Fig. 227. See that the separators extend the same distance beyond each side of the plates. You may take a stick, about 10 inches long, 1 1/2 inches wide, and 7/8 inch thick, and tap the separators gently to even them up. A small wood plane may be used to even up the side edges of wood separators. If you put in too many separators before trying on the cover, the plates may become so tight that you may not be able to shift them to make the cover fit the posts or you may not be able to shift the separators to their proper positions. It is therefore best to Put in only enough separators to hold the groups together and so they can be handled and yet remain in their proper position when set up on the block. Without separators, the posts will not remain in position.

With the element reassembled, and the remaining separators in their proper positions, see that all the plates are level on bottom, and no foreign matter sticking to them. Place the element in box shown in Fig. 219 to keep clean. Reassemble the other elements in exactly the same way, and put them in the box. The elements are now ready to be put in the jars.

Putting Elements in Jars

Steam the jars in the steamer for about five minutes to soften them somewhat, so that there will

be no danger of breaking a jar when you put in the elements.

With the case ready, look for the "+", "P" or "POS" mark on it. (Cases which are not marked in this way at the factory should be marked by the repairman before the battery is opened.) Place the case so that this mark is toward you. Grip an element near the bottom in order to prevent the plates from spreading, and put it in the jar nearest the mark, with the positive post toward you, next to the mark. Put an element in the next jar so that the negative post is toward you. Put an element in the third jar so that the positive post is toward you, and so on. The elements are correctly placed when each connecting strap connects a positive to a negative post. If the case has no mark on it, reassemble exactly according to the diagram you made on the tag before you opened the battery. Set the jars so that the posts are exactly in line so that the cell connectors will fit.

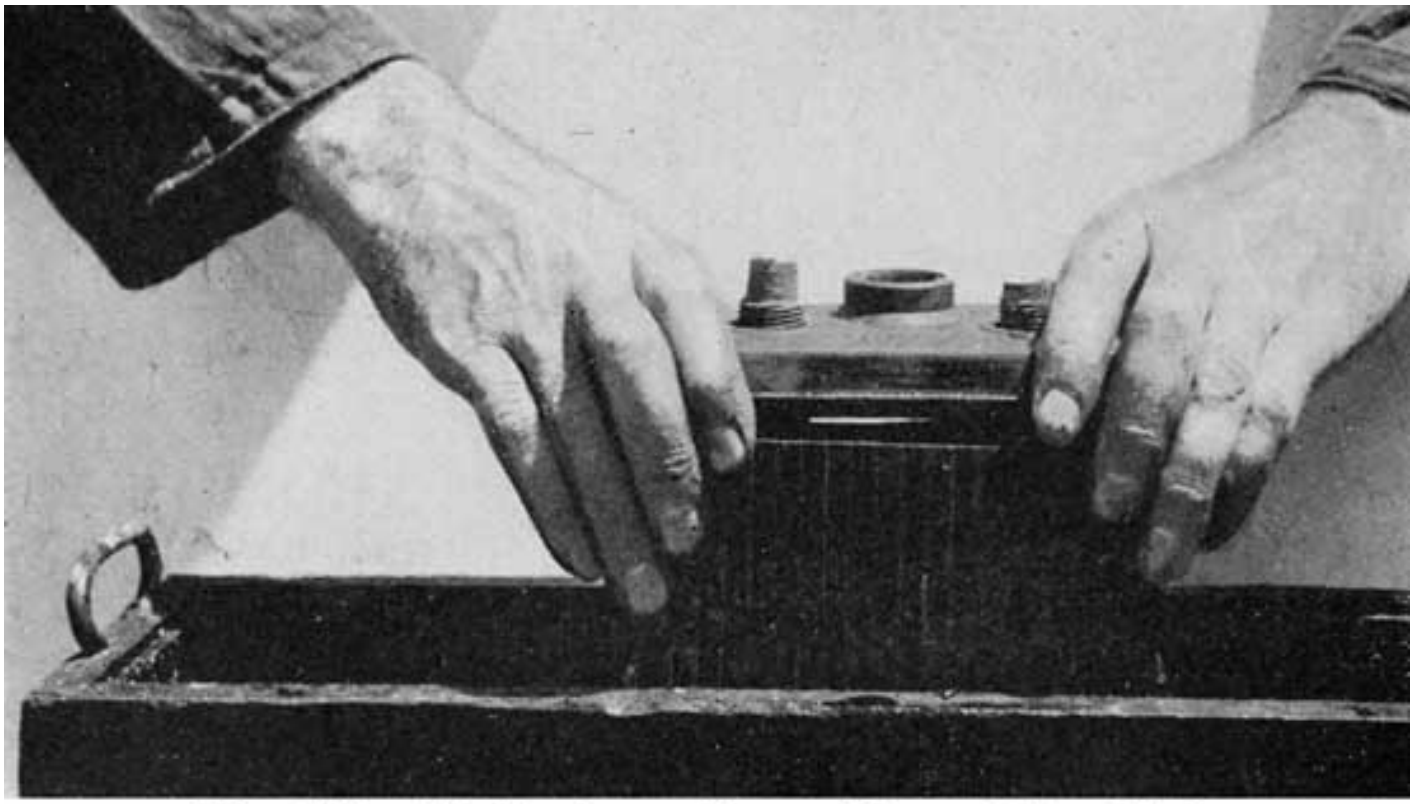

Fig. 228. Tightening a Loose Element by Placing a Separator Against Outside Negative

If an element fits loosely in the jar, it must be tightened. The best way to do this is to put one or more separators on one or both sides of the elements before putting it in the jar, Fig. 228. If you leave the elements loose in the jars, the jolting of the car will soon crack the sealing compound, and you will have a "slopper" on- your hands.

If element fits very tight, be sure that the corners of the plate straps have been rounded off and trimmed flush with outside negatives. Be sure also that there is no compound sticking to the inside of jars. Take care not to break the jar by forcing in a tight fitting element when the jar is cold and stiff.

Filling Jars with Electrolyte or Putting on the Covers

With all the elements in place in the jars, one of two things may be. done. First, the jars may be filled with electrolyte and the covers then sealed on, or the covers may first be sealed on and the jars then filled with electrolyte. Each method has its advantages and disadvantages. If the jars are first filled with electrolyte, acid may be splashed on the tipper parts of the jars and sealing made very difficult.

On the other hand, if the electrolyte is first poured in, the charged negatives will not become hot, and sealing compound which runs into the jar will be chilled as soon as it strikes the electrolyte and will float on top and do no harm. If the covers are sealed before any electrolyte is added, it will be easier to do a good sealing job, but the negatives will heat up. Furthermore, any sealing compound which runs into the jar will run down between the plates and reduce the plate area.

If care is taken to thoroughly dry the upper parts of the jars, add the electrolyte before sealing on the covers.

Use 1.400 Acid

If you have followed the directions carefully, and have therefore freed all the shorts, have thoroughly charged the plates, have washed and pressed the negative groups, have washed the positives, have then added any new plates which were needed, and have put in new separators, use 1.400 specific gravity electrolyte. This is necessary because washing the plates removed some of the acid, and the new separators will absorb enough acid so that the specific gravity after charging will be about 1.280.

The final specific gravity must be between 1.280 and 1.300. In measuring the specific gravity the temperature must be about 70°F., or else corrections must be made. For every three degrees above 70°, add one point (.001) to the reading you obtain on the hydrometer. For every three degrees under 70°, subtract one point (.001) from the reading you obtain on the hydrometer. For instance, if you read a specific gravity of 1.275 and find that the temperature of the electrolyte is 82°F., add ((82-70)/3 = 4)

four points (1.275 + .004), which gives 1.279, which is what the specific gravity of the electrolyte would be if its temperature were lowered to 70°. The reason this is done is that when Ave speak of an electrolyte of a certain specific gravity, say 1.280, we mean that this is its specific gravity when its temperature is 70°F. We must therefore make the temperature correction if the temperature of the electrolyte is much higher or lower than 70°F.

Putting on The Covers

This operation is a particular one, and must be done properly, or you will come to grief. Get the box containing the covers and connectors for the battery you are working on; take the covers, and clean them thoroughly. There are several ways to clean them. If you have gasoline at hand, dip a brush in it and scrub off the compound. The covers may also be cleaned off with boiling water, but even after you have used the hot water, it will be necessary to wipe off the covers with gasoline. Another way to soften any compound which may be sticking to them, is to put the covers in the Battery Steamer and steam them for about ten minutes. This will also heat 'the covers and make them limp so that they may be handled without breaking.

If the covers fit snugly all around the inside- of the jars so that there is no crack which will allow the compound to run down on the elements, all is well and good. If, however, there are cracks large enough to put a small, thin putty knife in, you must close them. If the cracks are due to the tops of the jars being bent out of shape, heat the tops with a soft flame until they are limp, (be careful riot to burn them). Now, with short, thin wedges of wood, (new dry separators generally answer the purpose), crowd down on the outside edges of the jar, until you have the upper edge of jars straight and even all around. If the jars are set in compound, take a hot screwdriver and remove the compound from between the jar. and case near the top. If the cracks between cover and jar still remain, calk them with asbestos packing, tow, or ordinary wrapping string. Do not use too much packing;--just enough to close the cracks is sufficient. When this is done, see that the top of the case is perfectly level, so that when the compound is poured in, it will settle level all around the upper edge of the case.

Sealing Compounds

There are many grades of compounds (see page 149), and the kind to use must be determined by the type of battery to be sealed. There is no question but that a poor grade used as carefully as possible will soon crack and produce a slopper. A battery carelessly sealed with the best compound is no better.

The three imperative conditions for a permanent lasting job are:

1. Use the best quality of the proper kind of compound for sealing the battery on hand.

2. All surfaces that the compound comes in contact with must be free from acid and absolutely clean and dry.

3. The sealing must be done conscientiously and all details properly attended to step by step, and all work done in a workmanlike manner.

With respect to sealing, batteries may be divided into two general classes. First, the old type battery with a considerable amount of sealing compound. This type of battery generally has a lower and an upper cover, the vent tube being attached or removable, depending on the design.

The compound is poured on top of the lower cover and around the vent tube, and the top covers are then put on. Most of the batteries of this type have a thin hard rubber sleeve shrunk on the post where the compound comes in contact with it; this hard rubber sleeve usually has several shallow grooves around it which increase its holding power. This is good construction, provided everything else is normal and the work properly done with a good stick-, compound. There are a few single cover batteries with connecting straps close to top of covers, and the compound is poured over the top of the straps. See Fig. 262.

The second general type consists of single one-piece cover batteries that have small channels or spaces around the covers next to the jars into which the sealing compound is poured. This type of battery is the most common type.

Compound in bulk or in thin iron barrels can be cut into small pieces with a hatchet or hand ax. To cut off a piece in hot weather, strike it a quick hard blow in the same place once or twice, and a piece will crack off. Directions for properly beating sealing compound will be found on page 150.

Sealing Double Cover Batteries

The following instructions apply to batteries having double covers. These are more difficult to seal than the single cover batteries. If you can seal the double cover batteries well, the single cover batteries will give you no trouble.

Always start the fire under the compound before you are ready to use it, and turn the fire lower after it has melted, so as not to have it too hot at the time of pouring. If you have a special long nosed pouring ladle, fill it with compound by dipping in the pot, or by pouring compound from a closed vessel. If you heat the compound in an iron kettle, pour it directly into pouring ladle, using just about enough for the first pouring. The compound should not be too hot, as a poor sealing job battery will result

Fig. 229. Pouring Compound on Lower Covers

from its use. See page 150.

Before sealing, always wipe the surfaces to be sealed with a rag wet with ammonia or soda solution, rinsed with water, and wiped dry with a rag or waste. If you fail to do this the compound will not stick well, and a top leak may develop. Then run a soft lead burning flame over the surfaces to be sealed, in order to have perfectly dry surfaces. Remember that sealing compound will not stick to a wet surface.

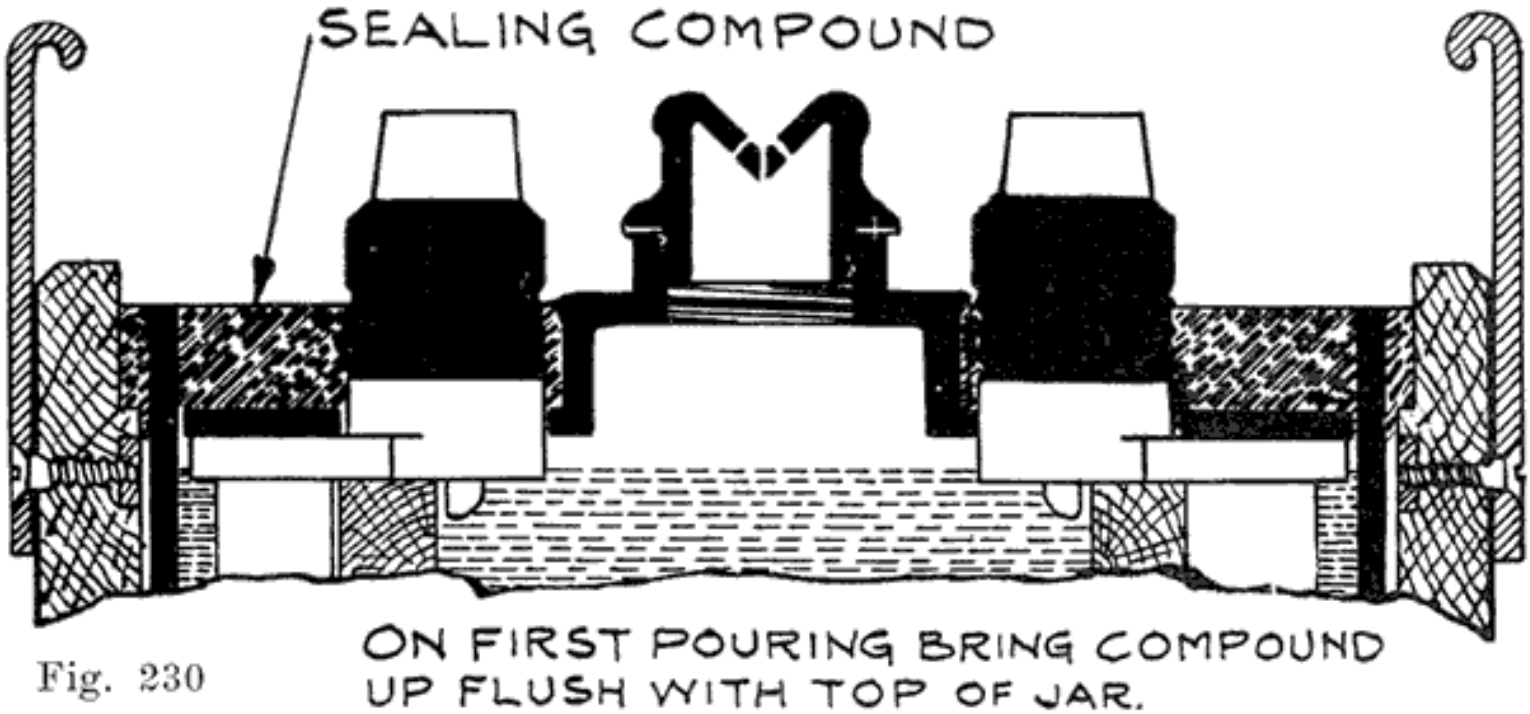

Fig. 230

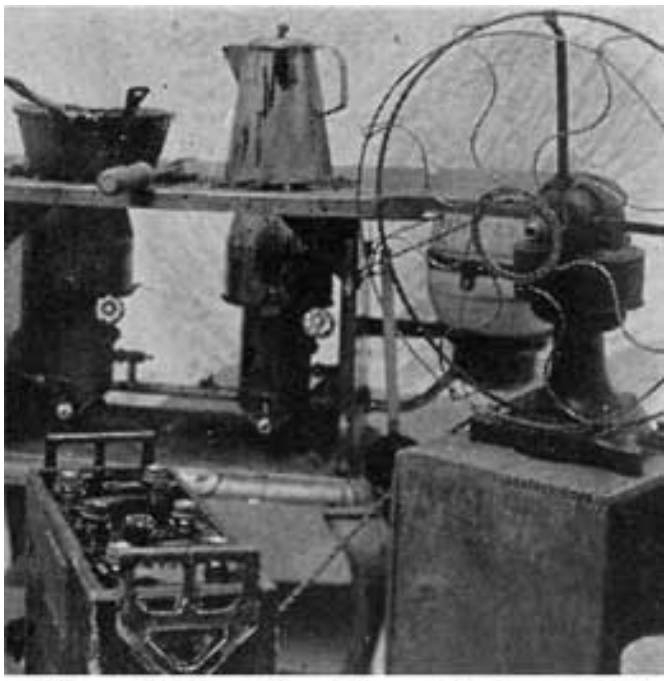

Fig. 231. Cooling Compound with Electric Fan

Pour compound on the lower covers, as in Fig. 229. Use enough to fill the case just over the tops of the jars, Fig. 230. Then pour the rest of the compound back in compound vessel or kettle. To complete the job, and make as good a job as possible, take a small hot lead burning flame and run it around the edges of case, tops of jars, and around the posts until the compound runs and makes a good contact all around. If you have an electric fan, let it blow on the compound a few minutes to cool it, as in Fig. 231. Then the compound used for the second pouring may be hotter and thinner than the first.

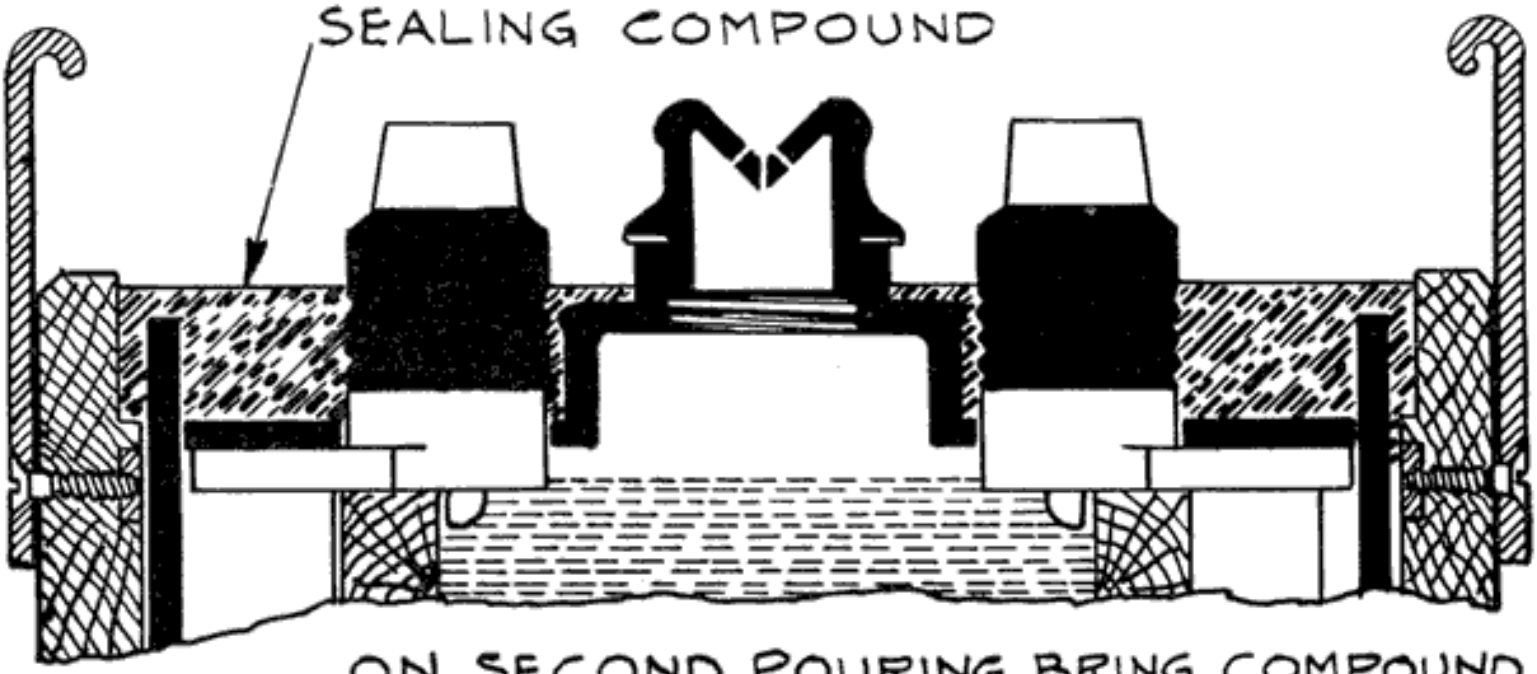

Fig. 232

ON SECOND POURING BRING COMPOUND WITH 1/16 INCH OF TOP OF CASE.

Fill the pouring ladle with compound, which is thinner than that used in the first pouring, and pour within 1/16 inch of the top of the case, being careful to get in just enough, so that-after it has cooled, the covers will press down exactly even with the top of the case, Fig. 232. It will require some experience to do this, but you will soon learn just how much to use.

As soon as you have finished pouring, run the flame all around the edges of the case and around the post, being very careful not to injure any of the vent tubes. A small, hot-pointed flame should be used. Now turn on the fan again to cool the compound.

While the compound is cooling, get the cell connectors and terminal connectors, put them in a two-quart granite stew pan, just barely cover with water, and sprinkle a tablespoon of baking soda over them. Set the stew pan over the fire and bring water to boiling point. Then pour the water on some spot on a bench or floor where the acid has been spilled. This helps to neutralize the acid and keep it from injuring the wood or cement. Rinse off the connectors and wipe them dry with a cloth, or heat them to dry them.

Now take the top covers, which must be absolutely clean and dry, and spread a thin coat of vaseline over the top only, wiping off any vaseline from the beveled edges. Place these covers right side up on a clean board and heat perfectly limp with a large, spreading blow torch flame. Never apply this flame to the under side of the top covers. The purpose is to get the covers on top of the battery absolutely level, and exactly even with the top of the case all around it, and to have them sticking firmly to the compound. There is not an operation in repairing and rebuilding batteries that requires greater care than this one, that will show as clearly just what kind of a workman you are, or will count as much in appearance for a finished job. If you are careless with any of the detail, if just one bump appears on top, if one top is warped, if one cover sticks above top of case, try as you may, you never can cover it up, and show you are a first-class workman. See that you have these four conditions, and you should not have any difficulty after a little experience:

1. You must have just enough compound on top to allow the top covers to be pressed down exactly even with upper edge of case.

2. The top covers must be absolutely clean and have a thin coat of vaseline over their top, but none on the bevel edge.

3. A good sized spreading flame to heat quickly and evenly the tops to a perfectly limp condition without burning or scorching them.

4. Procure a piece of 7/8-inch board 1-1/2 inches wide and just long enough to go between handles of battery you are working on. Spread a thin film of oil or vaseline all over it.

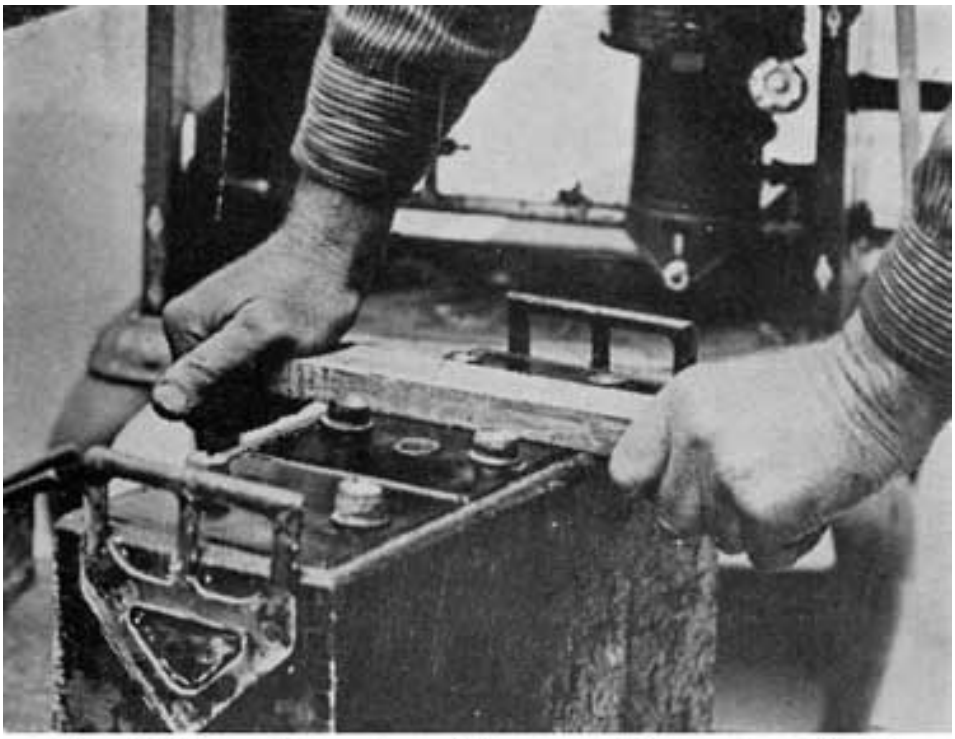

Fig. 233. Pressing Covers Down to Make Them Level with Top of Case

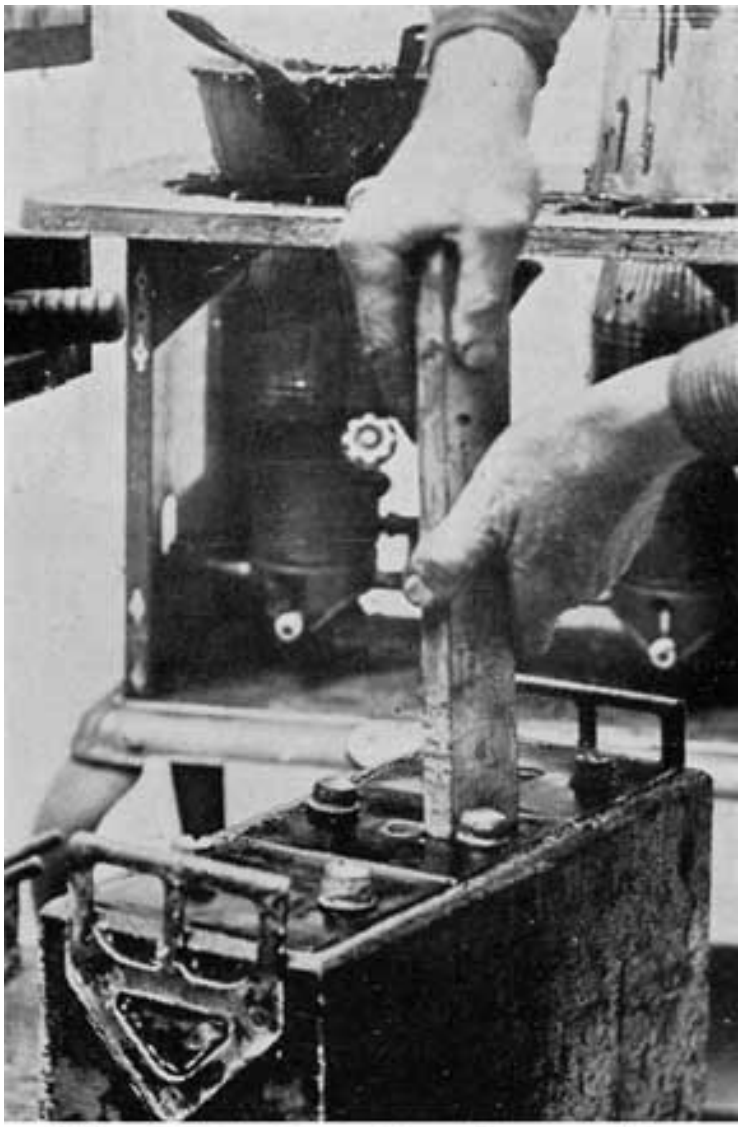

Fig. 234. Pressing Covers Down Around Posts to Make Them Flush With Top of Case

Having heated the covers and also the top surface of the compound until it is sticky so that the covers may be put down far enough and adhere firmly to it, place the covers in position. Then press the covers down firmly with a piece of oiled wood, as in Fig. 233, applying the wood sidewise and lengthwise of case until the top of cover is exactly even with the top of the case. It may be necessary to use the wood on end around the vent tubes and posts as in Fig. 234, to get that part of the cover level. If the compound comes up between covers and around the edges of the case, and interferes with the use of the wood, clean it out with a screwdriver. You can then finish without smearing any compound on the covers.

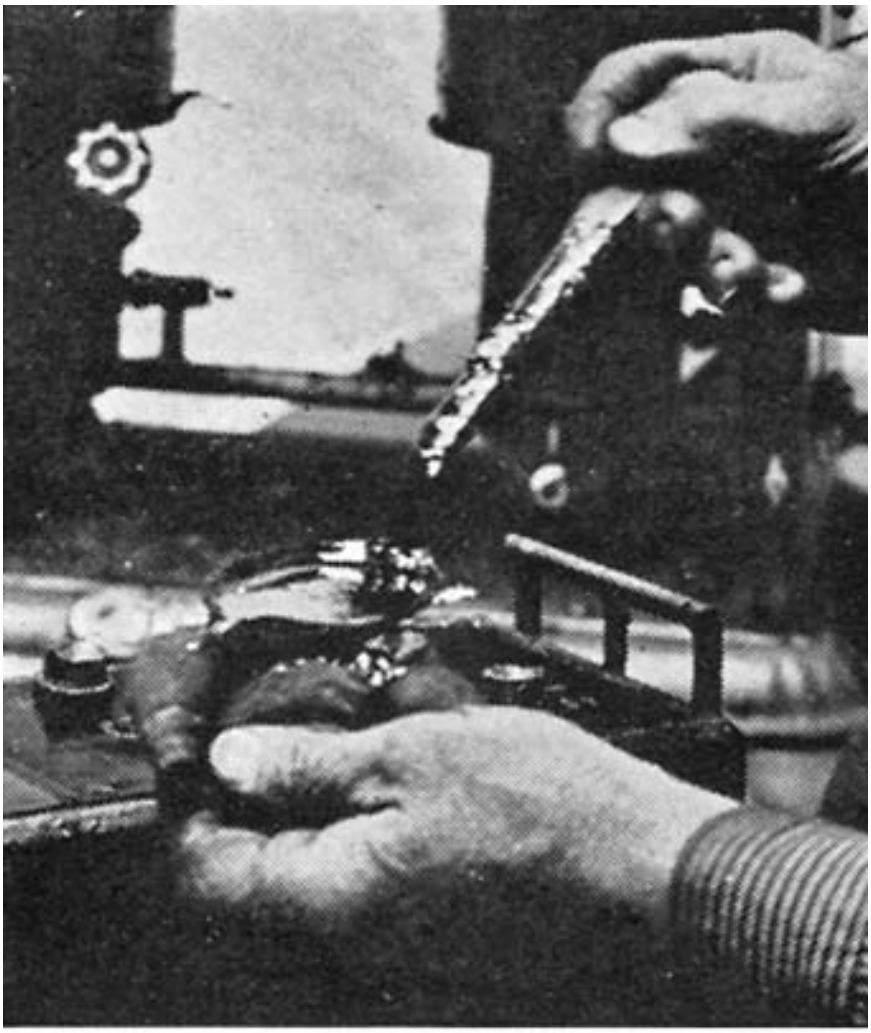

Fig. 235. Wiping Bottom of Spoon Filled with Sealing Compound

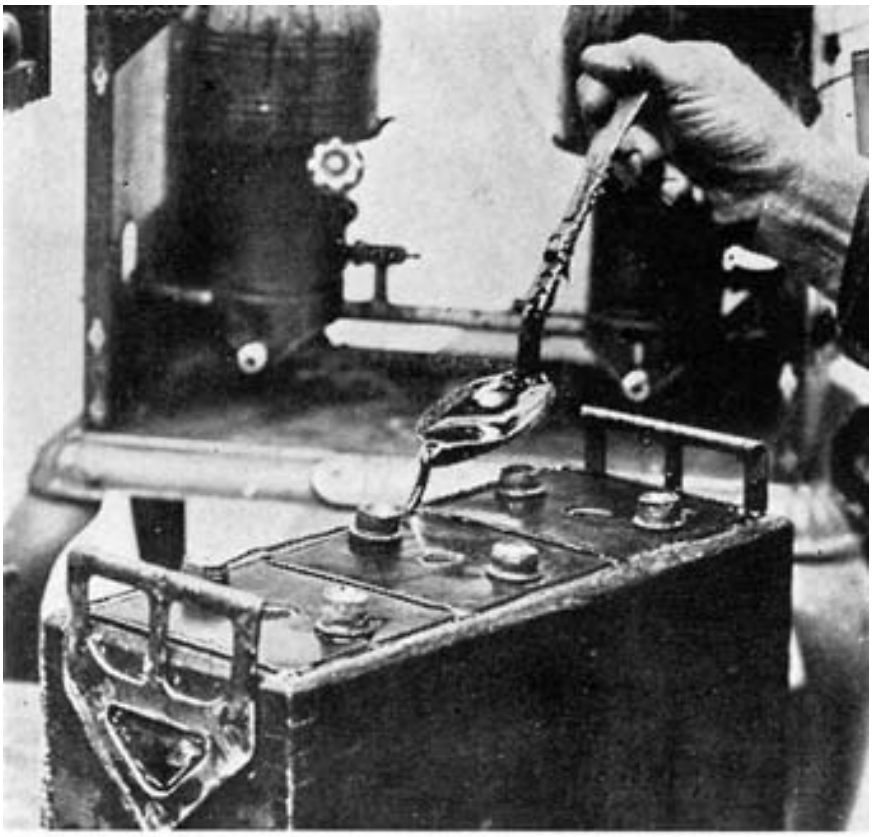

Fig. 236. Filling Cracks Around Covers With Sealing Compound

When you have removed the excess compound from the cracks around the edges of the covers with the screwdriver, take a large iron spoon which has the end bent into a pouring lip, and dip up from 1/2 to 2/3 of a spoonful of melted compound (not too hot). Wipe off the bottom of the spoon, Fig. 235, and pour a small stream of compound evenly in all the cracks around the edges of the covers until they are full, as in Fig. 236. Do not hold the spoon too high, and do not smear or drop any compound on top of battery or on the posts. No harm is done if a little runs over the outside of the case, except that it requires a little time to clean it off. A small teapot may be used instead of the spoon. If you have the compound at the right temperature, and do not put in too much at a time, you will obtain good results, but you should take care not to spill the compound over covers or case.

After the last compound has cooled, --this requires only a few minutes, --take a putty knife, and scrape off all the surplus compound, making it even with the top of the covers and case, Fig. .237. Be careful not to dig into a soft place in the compound with the putty knife. If you have done your work right, and have followed directions explicitly, you have scraped off the compound with one sweep of the putty knife over each crack, leaving the compound smooth and level. You will be surprised to see how finished the battery looks.

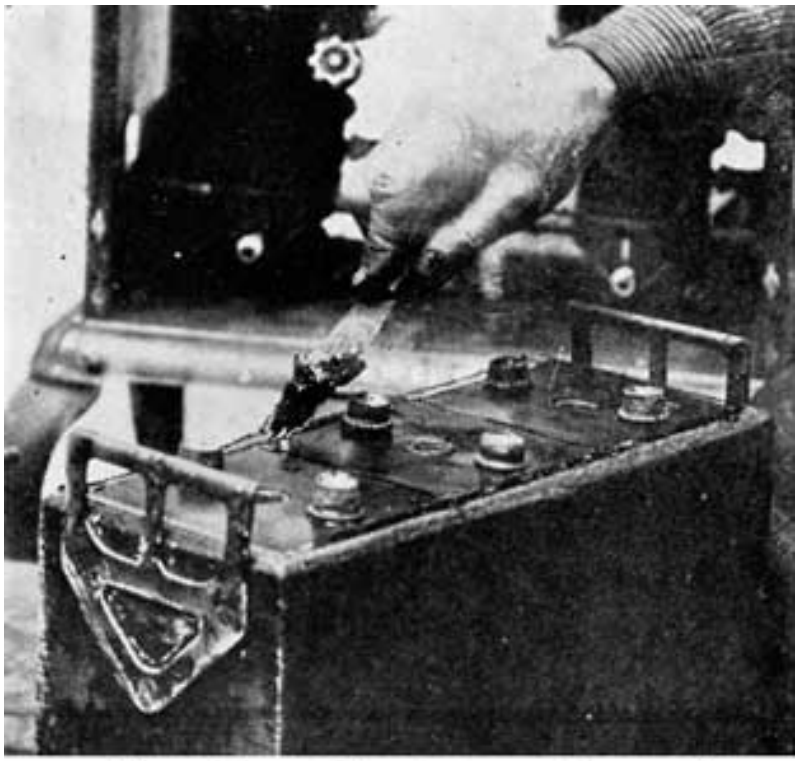

Fig. 237. Final Operation of Cleaning Off Excess Compound

Some workmen pour hot compound clear to the top of the case and then hurry to put on a cold, dirty top. What happens? The underside of the cover, coming in contact with the hot compound, expands and lengthens out, curling the top surface beyond redemption. As you push down one corner, another goes up, and it is impossible to make the covers level.

Sealing Single Cover Batteries

Single cover batteries are scaled in a similar manner. The covers are put in place before any compound is poured in. Covers should first be steamed to make them soft and pliable. The surfaces which come in contact with the sealing compound must be perfectly dry and free from acid. Before pouring in any compound, run a soft flame over the surfaces which are to be sealed , so as to dry them and warm them. Close up all cracks between Jars and covers as already directed. Then pour the cover channels half full of sealing compound, which must not be too thin. Now run a soft flame over the compound until it flows freely and' unites with the covers and jars. Allow the compound to cool.

For the second pouring, somewhat hotter compound may be used. Fill the cover channels flush with the top of the case, and again run a soft flame over the compound to make it flow freely and unite with the covers, and to give it a glossy finish. If any compound has run over on the covers or case, remove it with a hot putty knife.

Burning-on the Cell Connectors

With the covers in place, the next operation is to burn in the cell connectors. Directions for doing this are given on page 213. If you did not fill the jars with electrolyte before sealing the covers, do so. now. See page 364.

Marking the Battery

You should have a set of stencil letters and mark every battery you rebuild or repair. Stamp "POS," "P," or "+" on positive terminal and "NEG," "N," or on negative terminal. Then stamp your initials, the date that you finished rebuilding the battery, and the date that battery left the factory, on the top of the connectors. Record the factory date, and type of battery in a book, also your date mark and what was done to the battery. By doing this, you will always be able to settle disputes that may arise, as you will know when you repaired the battery, and what was done.

To go one step farther, keep a record of condition of plates, and number of new plates, if you have used any. Grade the plates in three divisions, good, medium and doubtful. The "doubtful" division will grow smaller as you become experienced and learn by their appearance the ones to be discarded and not used in a rebuilt battery. There is no question that even the most experienced man will occasionally make a mistake in judgment, as there is no way of knowing what a battery has been subjected to during its life before it is brought to you.

Cleaning and Painting the Case

The next operation is to thoroughly clean the case; scrape off all compound that has been spilled on it, and also any grease or dirt. If any grease is on the case, wipe off with rag soaked in gasoline. Unless the case is clean, the paint will not dry. Brush the sides and end with a wire brush; also brighten the name plate. Then coat the case with good asphaltum paint. Any good turpentine asphaltum is excellent for this purpose. If it is too thick, thin it with turpentine, but be sure to mix well before using, as it does not mix readily. Use a rather narrow brush, but of good quality. Paint all around the upper edge, first drawing the brush straight along the edges, just to the outer edges of rubber tops. Now paint the sides, ends and handles, but be careful not to cover the nameplate. To finish, put a second, and **thick** coat all around top edge to protect edge of case. Paint will soak in around the edge on top of an old case more easily than on the body of the case as it is more porous.

Charging the Rebuilt Battery

With the battery completely assembled, the next step is to charge it at about one-third of the starting or normal charge rate. For batteries having a capacity of 80 ampere hours or more, use a current of 5 amperes. Do not start the charge until at least 12 hours after filling with electrolyte. This allows the electrolyte to cool. Then add water to bring electrolyte up to correct level if necessary. The specific gravity will probably at first drop to 1.220-1.240, and will then begin to rise.

Continue the charge until the specific gravity and voltage do not rise during the last 5 hours of the charge. The cell voltage at the end of the charge should be 2.5 to 2.7, measured while the battery is still on charge. Make Cadmium tests on both positive and negatives. The positives should give a Cadmium reading of 2.4 or more. The negatives should give a reversed reading of 0.175. The tests should be made near the end of the charge, with the cell voltages at about 2.7. The Cadmium readings will tell the condition of the plates better than specific gravity readings. The Cadmium readings are especially valuable when new plates have been installed, to determine whether the new plates are, fully charged. When Cadmium readings indicate that the plates are fully charged, and specific gravity readings have not changed for five hours, the battery is fully charged. If you have put in new plates, charge for at least 96 hours.

Measure the temperature of the electrolyte occasionally, and if it should go above 110°F., either cut down the charging current, or take the battery off charge long enough to allow the electrolyte to cool below 90°F.

Adjusting the Electrolyte

If the specific gravity of the electrolyte is 1.280 to 1.300 at the end of the charge, the battery is ready for testing. If the specific gravity is below or above these figures, draw off as much electrolyte as you can with the hydrometer. If the specific gravity is below 1.280, add enough 1.400 specific gravity electrolyte with the hydrometer to bring the level up to the correct height (about 1/2 inch above tops of plates). If the specific gravity is above 1.300, add a-similar amount of distilled water instead of electrolyte. If the specific gravity is not more than 15 points (.015) too low or too high, adjust as directed above. If the variation is greater than this, pour out all the electrolyte and add fresh 1.280 specific gravity electrolyte.

After adjusting the electrolyte, continue the charge until the gravity of all cells is 1.280-1.300, and there is no further change in gravity for at least two hours. Then take the battery off charge and make a final measurement of the specific gravity. Measure the temperature at the same time, and if it varies more than 10° above or below 70°, correct the hydrometer readings by adding one point (.001 sp. gr.) for each 3 degrees above 70°, and subtracting one point (.001 sp. gr.) for each 3 degrees below 70°. Be sure to wipe off any electrolyte which you spilled on the battery in adjusting the electrolyte or measuring the specific gravity. Use a rag dipped in ammonia, or baking soda solution.

High Rate Discharge Test

Whenever you have time to do so, make a 20-minute high rate discharge test on the rebuilt battery, as described on page 266. This test will show up any defect in the battery, such as a poorly burned joint, or a missing separator, and will show if battery is low in capacity. If the test gives satisfactory results, the battery is in good condition, and ready to be put into service, after being charged again to replace the energy used by the test.

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Section I

Working Principles, Manufacture, Maintenance, Diseases and Remedies

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CHAPTER 1

The Automobile Storage Battery

INTRODUCTORY

Gasoline and electricity have made possible the modern automobile. Each has its work to do in the operation of the car, and if either fails to perform its duties, the car cannot move. The action of the gasoline, and the mechanisms that control it are comparatively simple, and easily understood, because gasoline is something definite which we can see and feel, and which can be weighed, or measured in gallons. Electricity, on the other hand, is invisible, cannot be poured into cans or tanks, has no odor, and, therefore, nobody knows just what it is. We can only study the **effects** of electricity, and the wires, coils, and similar apparatus in which it is present. It is for this reason that an air of mystery surrounds electrical things, especially to the man who has not made a special study of the subject.

Without electricity, there would be no gasoline engine, because gasoline itself cannot cause the engine to operate. It is only when the electrical spark explodes or "ignites" the mixture of gasoline and air which has been drawn into the engine. cylinders that the engine

develops power. Thus an electrical ignition system has always been an essential part of every gasoline automobile.

The first step in the use of electricity on the automobile, in addition to the ignition system, consisted in the installation of an electric lighting system to replace the inconvenient oil or gas lamps which were satisfactory as far as the light they gave was concerned, but which had the disadvantage of requiring the driver to leave his seat, and light each lamp separately, often in a strong wind or rain which consumed many matches, time, and frequently spoiled his temper for the remainder of the evening. Electric lamps have none of these disadvantages. They can be controlled from the driver's seat, can be turned on or off by merely turning or pushing a switch-button, are not affected by wind or rain, do not smoke up the lenses, and do not send a stream of unpleasant odors back to the passengers.

The apparatus used to supply the electricity for the lamps consisted of a generator, or a "storage" battery, or both. The generator alone had the disadvantage that the lamps could be used only while the engine was running. The battery, on the other hand, furnished light at all times, but had to be removed from the car frequently, and "charged." With both the generator and battery, the lights could be turned on whether the engine was running or not, and, furthermore, it was no longer necessary to remove the battery to "charge," or put new life into it. With a generator and storage battery, moreover, a reliable source of electricity for ignition was provided, and so we find dry batteries and magnetos being discarded in a great many automobiles and "battery ignition" systems substituted.

The development of electric lighting systems increased the popularity of the automobile, but the motor car still had a great drawback-cranking. Owing to the peculiar features of a gasoline engine, it must first be put in motion by some external power before it will begin to operate under its own power. This made it necessary for the driver to "crank" the engine, or start it moving, by means of a handle attached to the engine shaft. Cranking a large engine is difficult, especially if it is cold, and often results in tired muscles, and soiled clothes and tempers. It also made it impossible for the average woman to drive a car because she did not have the strength necessary to "crank" an engine.

The next step in the perfection of the automobile was naturally the development of an automatic device to crank the engine, and thus make the driving of a car a pleasure rather than a task. We find, therefore, that in 1912, "self-starters" began to be used. These were not all electrical, some used tanks of compressed air, others acetylene, and various mechanical devices, such as the spring starters. The electrical starters, however, proved their superiority immediately, and filled such a long felt want that all the various makes of automobiles now have electric starters. The present day motor car, therefore, uses gasoline for the engine only, but uses electricity for ignition, starting, lighting, for the horn, cigar lighters, hand warmers on the steering wheel, gasoline vaporizers, and even for shifting speed changing gears, and for the brakes.

On any car that uses an electric lighting and starting system, there are two sources of electricity, the generator and the battery, These must furnish the power for the starting, or "cranking" motor, the ignition, the lights, the horn, and the other devices. The demands made upon the generator are comparatively light and simple, and no severe work is done by it. The battery, on the other hand is called upon to give a much more severe service, that of furnishing the power to crank the engine. it must also perform all the duties of the generator when the engine is not running, since a generator must be in motion in order to produce electricity.

A generator is made of iron, copper, carbon, and insulation. These are all solid substances which can easily be built in any size or shape, and which undergo very little change as parts of the generator. The battery is made mainly of lead, lead compounds, water and sulphuric acid. Here we have liquids as well as solids, which produce electricity by changes in their composition, resulting in complicated chemical as well as electrical actions.

Fig. 1. The Battery

The battery is, because of its construction and performance, a much abused, neglected piece of apparatus which is but partly understood, even by many electrical experts, for to understand it thoroughly requires a study of chemistry as well as of electricity. Knowledge of the construction and action of a storage battery is not enough to make anyone an expert battery man. He must also know how to regulate the operating conditions so as to obtain the best service from the battery, and he must be able to make complete repairs on any battery no matter what its condition may be.

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CHAPTER 2

BATTERIES IN GENERAL

There are two ways of "generating" electricity on the car: 1. Magnetically, 2. Chemically. The first method is that used in a generator, in which wires are rotated in a "field" in which magnetic forces act. The second method. is that of the battery, and the one in which we are now interested.

If two unlike metals or conducting substances are placed in a liquid which causes a greater chemical change in one of the substances than in the other, **an electrical pressure**, or **"electromotive" force** is caused to exist between the two metals or conducting substances. The greater the difference in the chemical action on the substances, the greater will be the electrical pressure, and if the substances are connected together outside of the liquid by a wire or other conductor of electricity, an electric current will flow through the path or **"circuit"** consisting of the liquid, the two substances which are immersed in the liquid, and the external wire or conductor.

As the current flows through the combination of the liquid, and the substances immersed in it, which is called a **voltaic "cell,"** one or both of the substances undergo chemical changes which continue until one of the substances is entirely changed. These chemical changes produce the electrical pressure which causes the current to flow, and the flow will continue until one or both of the substances are changed entirely. This change due to the chemical action may result in the formation of gases, or of solid compounds. If gases are formed they escape and are lost. If solids are formed, no material is actually lost.

Assuming that one of the conducting substances, or **"electrodes,"** which are immersed in the liquid has been acted upon by the liquid, or **"electrolyte,"** until no further chemical action can take place, our voltaic cell will no longer be capable of causing a flow of electricity. If none of the substances resulting from the original chemical action have been lost as gases, it may be possible to reverse the entire set of operations which have taken place. That is, suppose we now send a current through the cell from an outside source of electricity, in a direction opposite to that in which the current produced by the chemical action between the electrodes and electrolyte flowed. If this current now produces chemical actions between electrodes and electrolyte which are the reverse of those which occurred originally, so that finally we have the electrodes and electrolyte brought back to their original composition and condition, we have the

cell just as it was before we used it for the production of an electrical pressure. The cell can now again be used as a source of electricity as long as the electrolyte acts upon the electrodes, or until it is **"discharged"** and incapable of any further production of electrical pressure. Sending a current through a discharged cell, so as to reverse the chemical actions which brought about the discharged conditions, is called **"charging" the cell.**

Fig. 2

A Complete Cell Negative Group Positive Group

Cells in which an electrical pressure is produced as soon as the electrodes are immersed in the electrolyte are called it **"primary"** Cells. In these cells it is often impossible, and always unsatisfactory to reverse the chemical action as explained above. Cells whose chemical actions are reversible are called **"storage"** or "**secondary"** cells. In the "storage" cells used today, a current must first be sent through the cell in order to cause the chemical changes which result in putting the electrodes and electrolyte, in such a condition that they -will be capable of producing an electrical pressure when the chemical changes caused by the current are complete. The cell now possesses all the characteristics of a primary cell, and may be used as a source of electricity until "discharged." It may then be "charged" again, and so on, the chemical action in one case causing a flow of current, and a reversed flow of current causing reversed chemical actions.

We see from the above that the "storage" battery does not "store" electricity at all, but changes chemical into electrical energy when "discharging," and changes electrical into

chemical energy when "charging," the two actions being entirely reversible. The idea of "storing" electricity comes from the fact that if we send a current of electricity through the cell for a certain length of time, we can at a later time draw a current from the cell for almost the same length of time.

Fig. 3. A complete element, consisting of a positive and negative group of plates and seperators ready for placing in the har rubber jars.

Three things are therefore required in a, storage cell, the liquid or "electrolyte" and two unlike substances or electrodes, through which a current of electricity can pass and which are acted upon by the electrolyte with a chemical action that is greater for one substance than the other. In the storage cell used on the automobile today for starting and lighting, the

electrodes are lead and peroxide of lead, and the electrolyte is a mixture of sulphuric acid and water. The peroxide of lead electrode is the one upon which the electrolyte has the greater chemical effect, and it is called the positive or "+" electrode, because when the battery is sending a. current through an external circuit, the current flows from this electrode through the external circuit, and back to the lead electrode, which is called the negative, or electrode.

When starting and lighting systems were adopted in 1912, storage batteries had been used for many years in electric power stations. These were, however, large and heavy, and many difficult problems of design had to be solved in order to produce a battery capable of performing the work of cranking the engine, and yet be portable, light, and small enough to occupy only a very limited space on the automobile. As a result of these conditions governing the design, the starting and lighting battery of today is in reality "the giant that lives in a box." The Electric Storage Battery Company estimates that one of its types of batteries, which measures only 12-5/8 inches long, 7-3/8 wide, and 9-1/8 high, and weighs only 63-1/2 pounds, can deliver enough energy to raise itself to a height of 6 miles straight up in the air. It must be able to do its work quickly at all times, and in all sorts of weather, with temperatures ranging from below 0° to 100° Fahrenheit, or even higher.

The starting and lighting battery has therefore been designed to withstand severe operating conditions. Looking at such a battery on a car we see a small wooden box in which are placed three or more "**cells**," see Fig. 1. Each "cell" has a hard, black rubber top through which two posts of lead project. Bars of lead connect the posts of one cell to those of the next. To one of the posts of each end cell is connected a cable which leads into the car, and through which the current leaves or enters the battery. At the center of each cell is a removable rubber plug covering an opening through which communication is established with the inside of the cell for the purpose of pouring in water, removing some of the electrolyte to determine the condition of the battery, or to allow gases formed within the cell to escape. Looking down through this opening we can see the things needed to form a storage battery: the electrolyte, and the electrodes or "**plates**" as they are called. If we should remove the lead bars connecting one cell to another, and take off the black cover, we should find that the posts which project out of the cells are attached to the plates which are broad and flat, and separated by thin pieces of wood or rubber., If we lift out the plates we find that they are connected alternately to the two lead posts, and that the two outside ones have a gray color. If we pull the plates out from each Other, we find that the plates next to the two outside ones, and all other plates connected to the same lead post as these have a chocolate-brown color. If we remove the jar of the cell, we find that it is made of hard rubber. Pouring out the electrolyte we find several ridges which hold the plates off the bottom of the jar. The pockets formed by these ridges may contain some soft, muddy substance. Thus we have exposed all the elements of a cell,--**posts, plates, "separators," and electrolyte.** The gray colored plates are attached to the "**negative**" battery post, while the chocolate-brown colored ones are connected to the "**positive**" battery post. Examination will show that each of the plates consists of a skeleton metallic framework which is filled with the brown or gray substances. This construction is used to decrease the weight of the battery. The gray filler material is pure lead in a condition called "**spongy lead.**" The chocolate-brown filler substance is **peroxide of lead.**

We have found nothing but two sets of plates,-one of pure lead, the other of peroxide of lead, and the electrolyte of sulphuric acid and water. These produce the heavy current necessary to crank the engine. How this is done, and what the chemical actions within the cell are, are described in Chapter 4.

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CHAPTER 3.

MANUFACTURE OF STORAGE BATTERIES.

To supply the great number of batteries needed for gasoline automobiles, large companies have been formed. Each company has its special and secret processes which it will not reveal to the public. Only a few companies, however, supply batteries in any considerable quantities, the great majority of cars being supplied with batteries made by not more than five or six manufacturers. This greatly reduces the number of possible different designs in general use today.

The design and dimensions of batteries vary considerably, but the general constructions are similar. The special processes of the manufacturers are of no special interest to the repairman, and only a general description will be given here.

A starting and lighting battery consists of the following principal parts:

1. **Plates**
2. **Separators**
3. **Electrolyte**
4. **Jars**
5. **Covers**
6. **Cell Connectors and Terminals**
7. **Case**

Plates

Of the two general types of battery plates, Faure and Plante, the Faure, or pasted type, is universally used on automobiles. In the manufacture of pasted plates there are several steps which we shall describe in the order in which they are carried out.

Casting the Grid. The grid is the skeleton of the plate. It performs the double function of

supporting the mechanically weak active material and of conducting the current. It is made of a lead antimony alloy which is melted and poured into a mould. Pure lead is too soft and too easily attacked by the electrolyte, and antimony is added to give stiffness, and resistance to the action of the electrolyte in the cell. The amount of antimony used varies in different makes but probably averages 8 to 10%.

The casting process requires considerable skill, the proper composition of the metal and the temperature of both metal and moulds being of great importance in securing perfect grids, which are free from blowholes, and which have a uniform structure and composition. Some manufacturers cast two grids simultaneously in each mould, the two plates being joined to each other along the bottom edge.

Trimming the Grids. When the castings have cooled, they are removed from the moulds and passed to a press or trimming machine which trims off the casting gate and the rough edges. The grids are given a rigid inspection, those having shrunken or missing ribs or other defects being rejected. The grids are now ready for pasting.

Fig. 4. Grid, Trimmed, and Ready for Pasting

Fig. 4 shows a grid ready for pasting. The heavy lug at one upper corner is the conducting lug, for carrying the current to the strap, Fig. 5, into which the lugs are burned when the battery is assembled. The straps are provided with posts, to which the intercell connectors and terminal connectors are attached. The vertical ribs of the grids extend through the plate, providing mechanical strength and conductivity, while the small horizontal ribs are at the surface and in staggered relation on opposite faces. Both the outside frames and the vertical ribs are reinforced near the lug, where the greatest amount of current must be carried.

The rectangular arrangement of ribs, as shown in Fig. 4, is most generally used, although, there are other arrangements such as the Philadelphia "Diamond" grid in which the ribs form acute angles, giving diamond shaped openings, as shown in Fig. 6.

Pastes. There are many formulas for the pastes, which are later converted into active material, and each is considered a trade secret by the manufacturer using it. The basis of all, however, is oxide of lead, either Red Lead (Pb_30_4), Litharge (PbO), or a mixture of the two, made into a paste with a liquid, such as dilute sulphuric acid. The object of mixing the oxides with the liquid is to form a paste of the proper consistency for application to the grids, and at the same time introduce the proper amount of binding, or setting agent which will give porosity, and which will bind together the active material, especially in the positive plate. Red lead usually predominates in the positive paste, and litharge in the negative, as this combination requires the least energy in forming the oxides to active material.

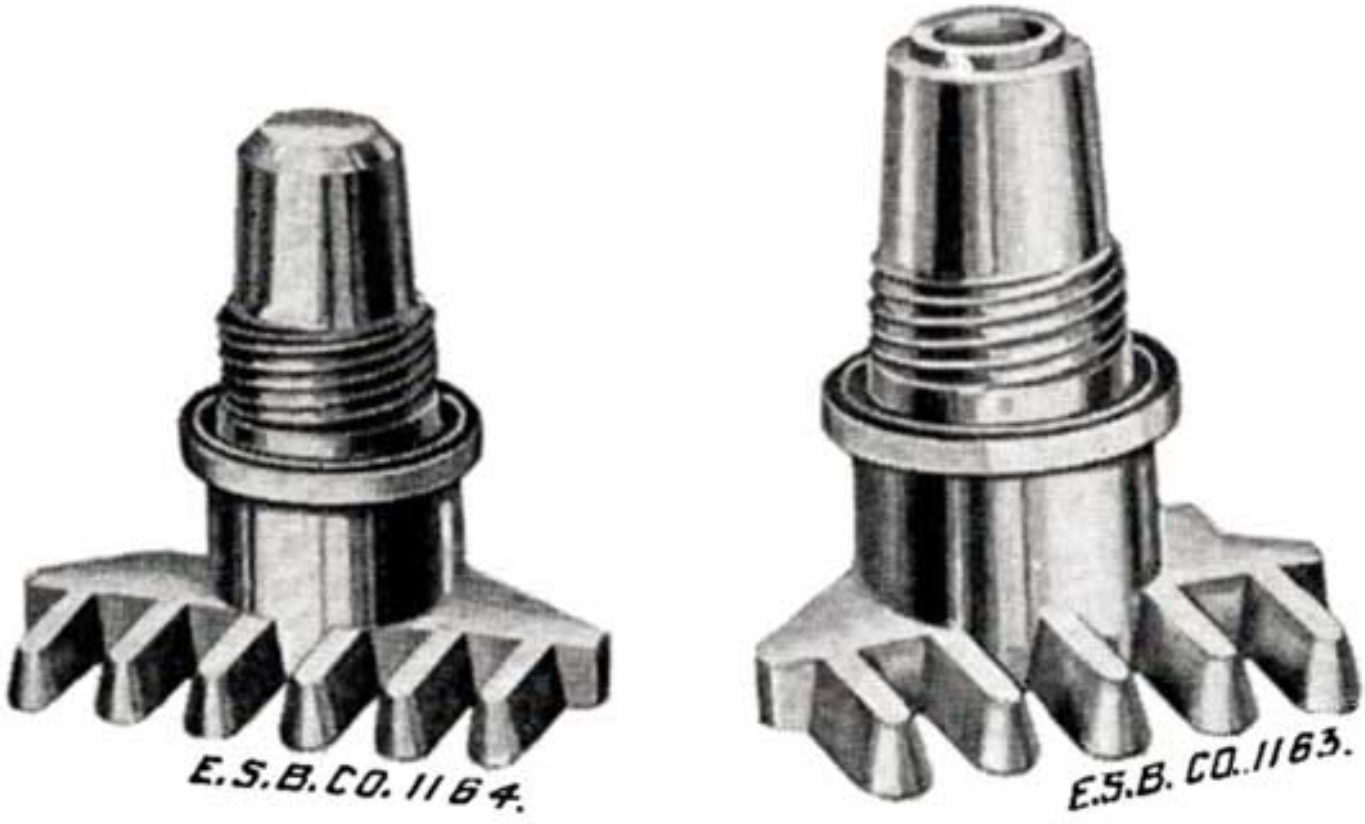

Negative Strap Positive Strap

Fig. 5. Plate Straps and Posts

The oxides of lead used in preparing the pastes which are applied to the grids are powders, and in their dry condition could not be applied to the grids, as they would fall out. Mixing them with a liquid to make a paste gives them greater coherence and enables them to be applied to the grids. Sulphuric acid puts the oxides in the desired pasty condition, but has the disadvantage of causing a chemical action to take place which changes a considerable portion of the oxides to lead sulphate, the presence of which makes the paste stiff and impossible to apply to the grids. When acid is used, it is therefore necessary to work fast after the oxides are mixed with sulphuric acid to form the paste.

In addition to the lead oxides, the pastes may contain some binding material such as ammonium or magnesium sulphate, which tends to bind the particles of the active material together. The paste used for the negatives may contain lamp black to give porosity.

Applying the Paste. After the oxides are mixed to a paste they are applied to the grids. This is done either by hand, or by machine In the hand pasting process, the pastes are applied from each face of the grid by means of a wooden paddle or trowel, and are smoothed off flush with the surface of the ribs of the grid. This work is done quickly in order that the pastes may not stiffen before they are applied.

U. S. L. plates are pasted in a machine which applies the paste to the grid, subjecting it at the same time to a pressure which forces it thoroughly into the grid, and packs it in a dense mass.

Drying the Paste. The freshly pasted plates are now allowed to dry in the air, or are dried by blowing air over them. In any case, the pastes set to a hard mass, in which condition the pastes adhere firmly to the grids. The plates may then be handled without a loss of paste from the grids.

Fig. 6. Philadelphia Diamond Grid

Forming. The next step is to change the paste of oxides into the active materials which make a cell operative. This is called "forming" and is really nothing but a prolonged charge, requiring several days. In some factories the plates are mounted in tanks, positive and negative plates alternating as in a cell. The positives are all connected together in one group and the negatives in another, and current passed through just as in charging a battery. In other factories the positives and negatives are formed in separate tanks against "dummy" electrodes.

The passing of the current slowly changes the mixtures of lead oxide and lead sulphate, forming brown peroxide of lead (PbO_2), on the positive plate and gray spongy metallic lead on the negative. The formation by the current of lead peroxide and spongy lead on the positive and negative plates respectively would take place if the composition of the two pastes were identical. The difference in the composition of the paste for positive and negative plates is for the purpose of securing the properties of porosity and physical condition best suited to each.

Fig. 7. Formed Plate, Ready to Be Burned to Plate Connecting Strap

When the forming process is complete, the plates are washed and dried, and are then ready for use in the battery. If the grids of two plates have been cast together, as is done by some manufacturers, these are now cut apart, and the lugs cut to the proper height. The next step is to roll, or press the negatives after they are removed from the forming bath so as to bring the negative paste, which has become roughened by gassing that occurred during the forming

process, flush with the surface of the ribs of the grid. A sufficient amount of sulphate is left in the plates to bind together the active material. Without this sulphate the positive paste would simply be a powder and when dry would fall out of the grids like dry dust. Fig. 7 shows a formed plate ready to be burned to the strap.

Separators

In batteries used both for starting and for lighting, separators made of specially treated wood are largely used. See Fig. 8. The Willard Company has adopted an insulator made of a rubber fabric pierced by thousands of cotton threads, each thread being as long as the separator is thick. The electrolyte is carried through these threads from one side of the separator to the other by capillary action, the great number of these threads insuring the rapid diffusion of electrolyte which is necessary in batteries which are subjected to the heavy discharge current required in starting.

In batteries used for lighting or ignition, sheets of rubber in which numerous holes have been drilled are also used, these holes permitting diffusion to take place rapidly enough to perform the required service satisfactorily, since the currents involved are much smaller than in starting motor service.

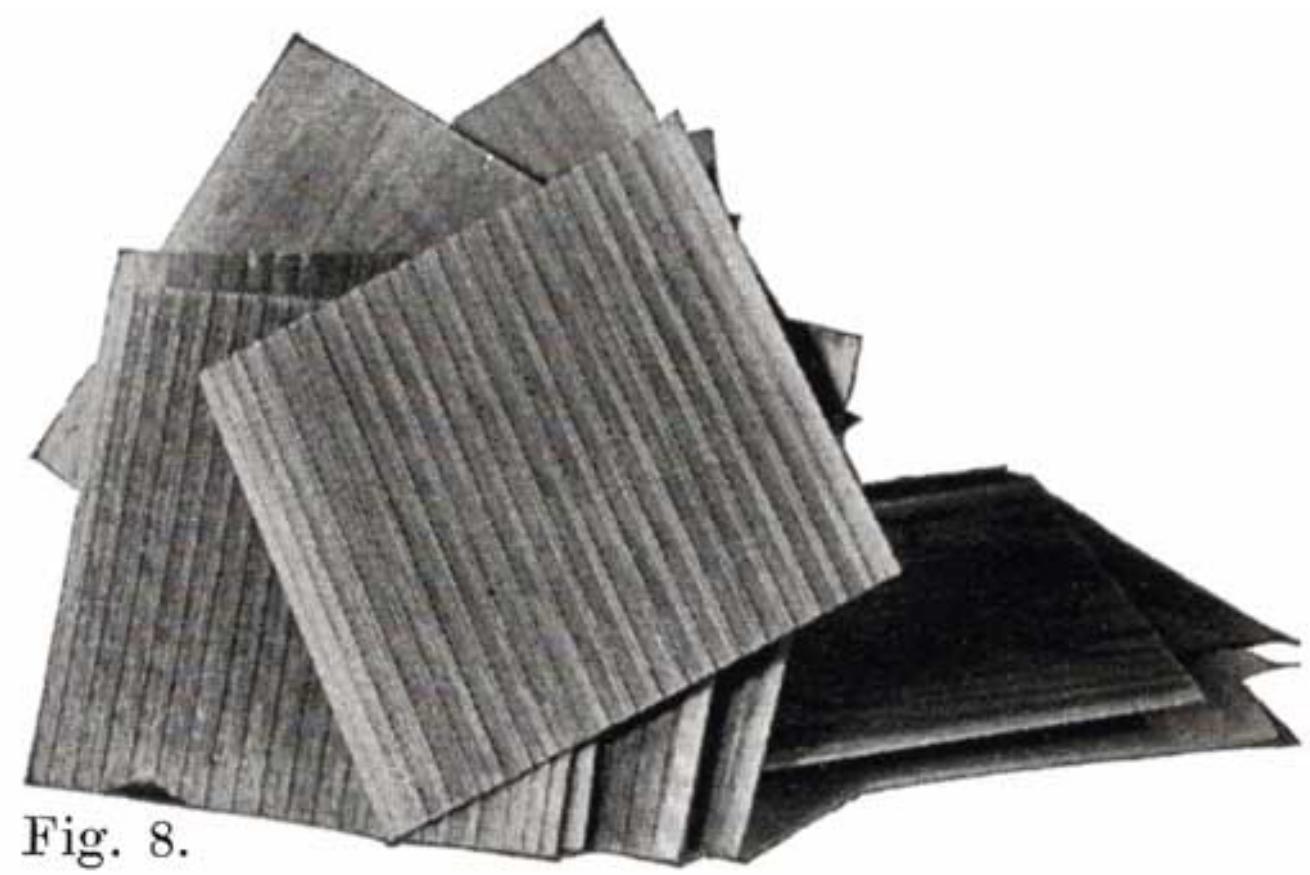

Fig. 8.

Fig. 8. A Pile of Prepared Wooden Seperators Ready to be Put Between the Positive and Negative Plates to Form the Complete Element.

For the wooden separators, porous wood, such as Port Orford cedar, basswood, cypress, or cedar is used. Other woods such as redwood and cherry are also used. The question is often asked "which wood makes the best separators?" This is difficult to answer because the method of treating the wood is just as important as is the kind of wood. The wood for the separators is cut into strips of the correct thickness. These strips are passed through a grooving machine which cuts the grooves in one side, leaving the other side smooth. The strips are next sawed to the correct size, and are then boiled in a warm alkaline solution for about 24 hours to neutralize any organic acid, such as acetic acid, which the wood naturally contains. Such acids would cause unsatisfactory battery action and damage to the battery.

The Vesta separator, or "impregnated mat," is treated in a bath of Barium salts which form compounds with the wood and which are said to make the separators strong and acid-resisting.

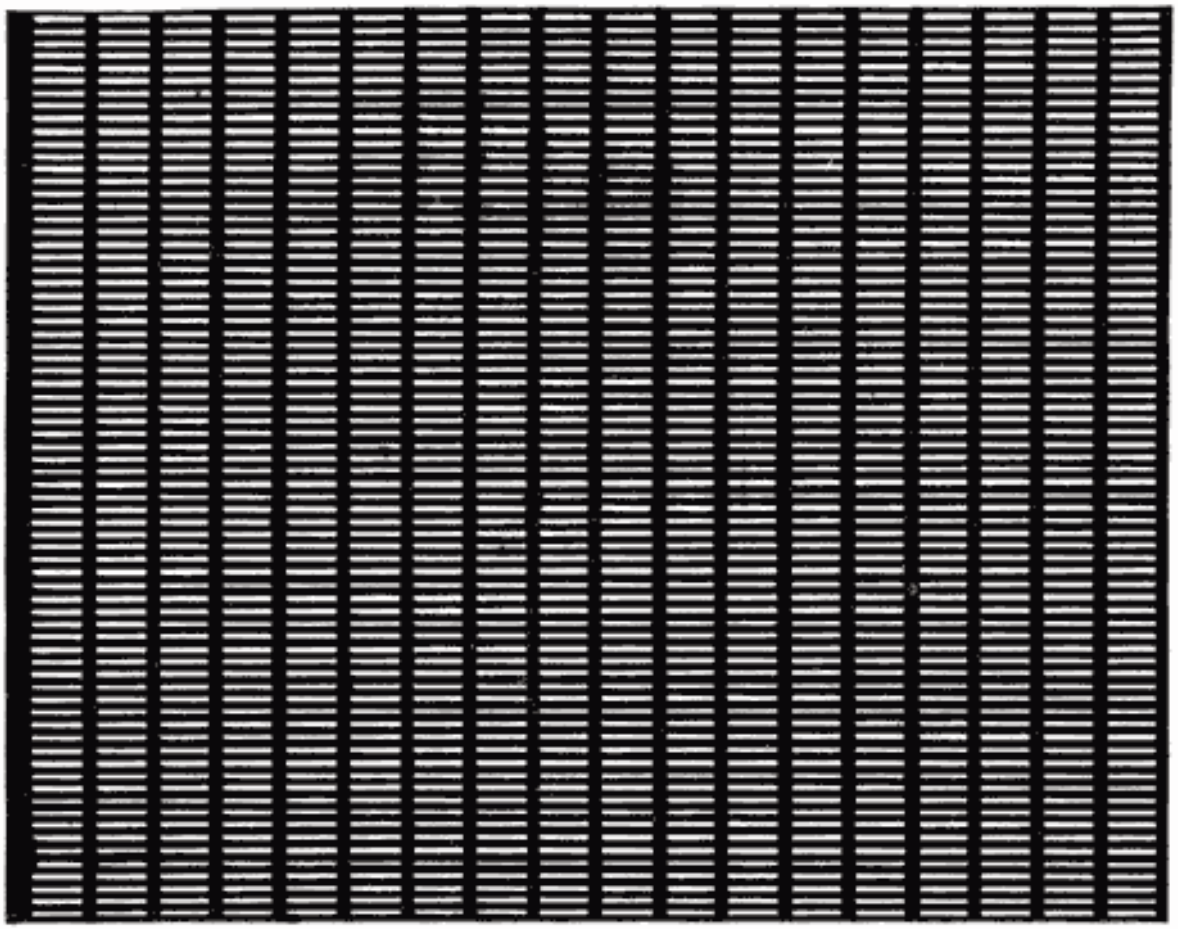

Fig. 9. Philco Slotted Retainer

Some batteries use a double separator, one of which is the wooden separator, while the other consists of a thin sheet of hard rubber containing many fine perforations. This rubber sheet is

placed between the positive plate and the wooden separator. A recent development in the use of an auxiliary rubber separator is the Philco slotted retainer which is placed between the separators and the positives in Philadelphia Diamond Grid Batteries. Some Exide batteries also use slotted rubber separators. The Philco slotted retainer consists of a thin sheet of slotted hard rubber as shown in Fig. 9. The purpose of the retainer is to hold the positive active material in place and prevent the shedding which usually occurs. The slots in the retainer are so numerous that they allow the free passage of electrolyte, but each slot is made very narrow so as to hold the active material in the plates.

Electrolyte

Little need be said here about the electrolyte, since a full description is given elsewhere. See page 222. Acid is received by the battery manufacturer in concentrated form. Its specific gravity is then 1.835. The acid commonly used is made by the "contact" process, in which sulphur dioxide is oxidized to sulphur trioxide, and then, with the addition of water, changed to sulphuric acid. The concentrated acid is diluted with distilled water to the proper specific gravity.

Jars

The jars which contain the plates, separators, and electrolyte are made of a tough, hard rubber compound. They are made either by the moulding process, or by -wrapping sheets of rubber compound around metal mandrels. In either case the jar is subsequently vulcanized by careful heating at the correct temperature.

The battery manufacturers do not, as a rule, make their own jars, but have them made by the rubber companies who give the jars a high voltage test to detect any flaws, holes, or cracks which would subsequently cause a leak. The jars as received at the battery maker's factory are ready for use.

Across the bottom of the jar are several stiff ribs which extend up into the jar so as to provide a substantial support for the plates, and at the same time form several pockets below the plates in which the sediment resulting from shedding of active material from the plates accumulates.

Covers

No part of a battery is of greater importance than the hard rubber cell covers, from the viewpoint of the repairman as well as the manufacturer. The repairman is concerned chiefly with the methods of sealing the battery, and no part of his work requires greater skill than the work on the covers. The manufacturers have developed special constructions, their aims being to design the cover so as to facilitate the escape of gas which accumulates in the upper part of a cell during charge, to provide space for expansion of the electrolyte as it becomes heated, to

simplify inspection and filling with pure water, to make leak proof joints between the cover and the jar and between the cover and the lead posts which project through it, and to simplify the work of making repairs.

Single and Double Covers. Modern types of batteries have a single piece cover, the edges of which are made so as to form a slot or channel with the inside of the jar, into which is poured sealing compound to form a leak proof joint. This construction is illustrated. in Exide, Fig. 1.5; Vesta, Fig. 264; Philadelphia Diamond Grid, Fig. 256; U. S. L., Figs. 11 and 244; and Prest-0-Lite, Fig. 247, batteries. Exide batteries are also made with a double flange cover, in which the top of the jar fits between the two flanges. In single covers, a comparatively small amount of sealing compound is used, and repair work is greatly simplified.

In the Eveready battery, Fig. 262, compound is poured over the entire cover instead of around the edges. This method requires a considerable amount of sealing compound.

The use of double covers is not as common as it was some years ago. This construction makes use of two flat pieces of hard rubber. In such batteries a considerable amount of sealing compound is used. This compound is poured on top of the lower cover to seal the battery, the top cover serving to cover up the compound and brace the posts. Fig. 10 illustrates this construction.

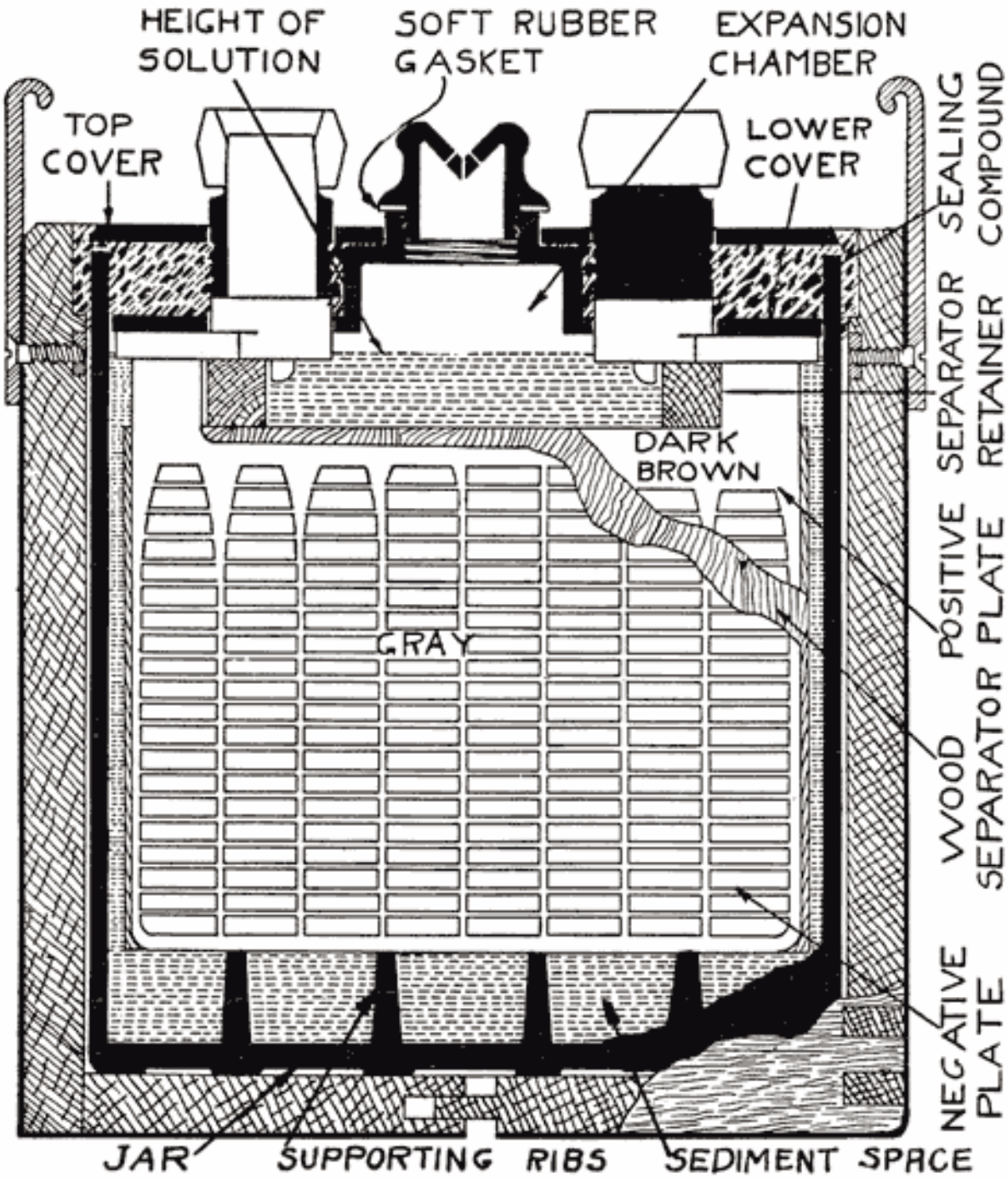

Fig. 10. Cross-Section of Gould Double Cover Battery

Sealing Around the Posts. Much variety is shown in the methods used to secure a leak proof joint between the posts and the cover. Several methods are used. One of these uses the sealing compound to make a tight joint. Another has lead bushings which are screwed up into the cover or moulded in the cover, the bushings being burned together with the post and cell connector. Another method has a threaded post, and uses a lead alloy nut with a rubber washer to make a tight joint. Still another method forces a lead collar down over the post, and presses the cover down on a soft rubber gasket.

Using Sealing Compound. Some of the batteries which use sealing compound to make a tight

joint between the cover and the post have a hard rubber bushing shrunk over the post. This construction is used in Gould batteries, as shown in Fig. 10, and -in the old Willard double cover batteries. The rubber bushing is grooved horizontally to increase the length of the sealing surface.

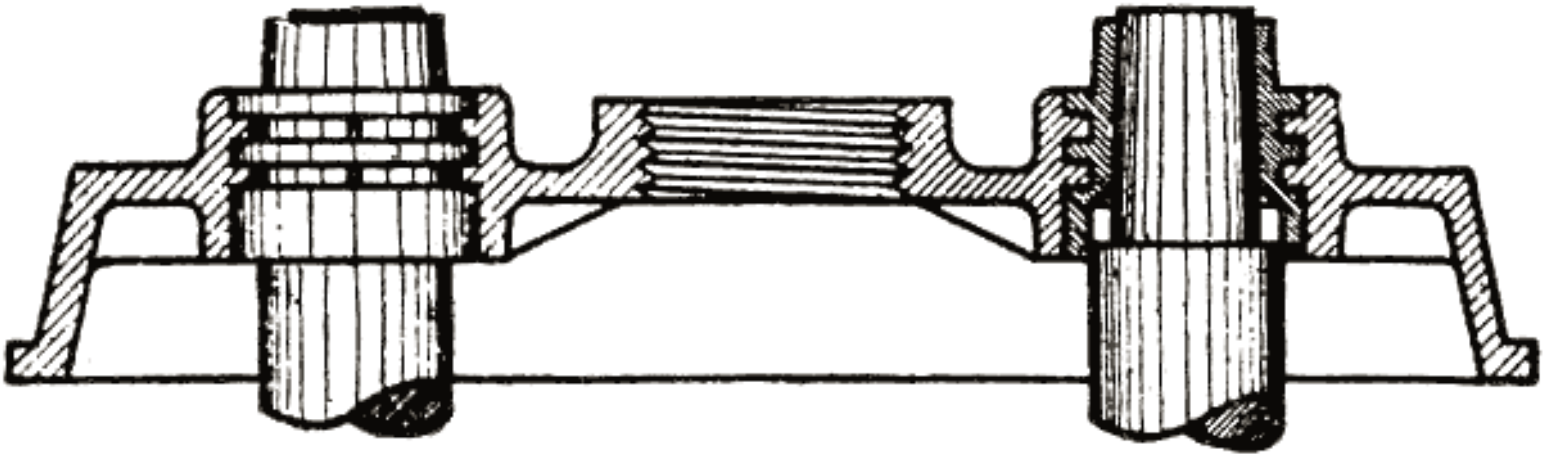

Fig. 11. U. S. L. Cover

Other batteries that use sealing compound around the posts have grooves or "petticoats" cut directly in the post and have a well around the post into which the sealing compound is poured. This is the construction used in the old Philadelphia Diamond Grid battery, as shown in Fig. 254.

Using Lead Bushings. U. S. L. batteries have a flanged lead bushing which is moulded directly into the cover, as shown in Fig. 11. In assembling the battery, the cover is placed over the post, and the cell connector is burned to both post and bushing.

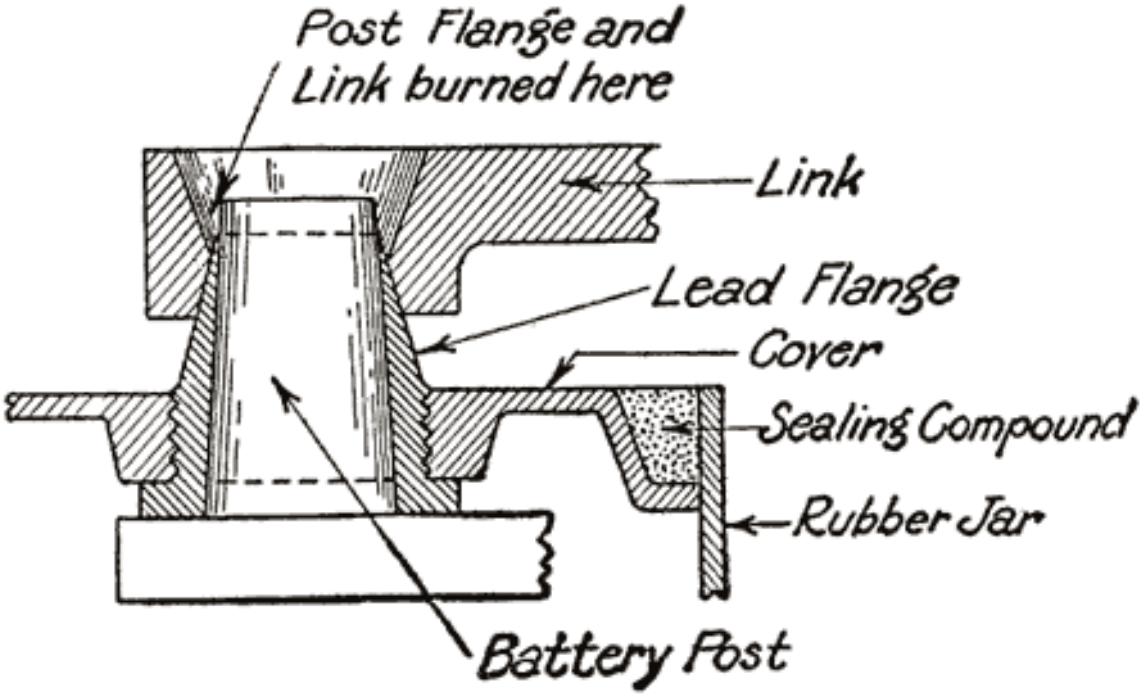

Fig. 12. Lead Bushing Screwed into Cover

In older type U. S. L. batteries a bushing was screwed up through the cover, and then burned to the post and cell connector.

An old type Prest-O-Lite battery used a lead bushing which screwed up through the cover similarly to the U. S. L. batteries. Fig. 12 illustrates this construction. The SJWN and SJRN Willard Batteries used a lead insert. See page 424.

The modern Vesta batteries use a soft rubber gasket under the cover, and force a lead collar over the post, which pushes the cover down on the gasket. The lead collar and post "freeze" together and. make an acid proof joint. See page 413. The Westinghouse battery uses a three part seal consisting of a lead washer which is placed around the post, a U shaped, soft gum washer which is placed between the post and cover, and a tapered lead sleeve, which presses the washer against the post and the cover. See page 417.

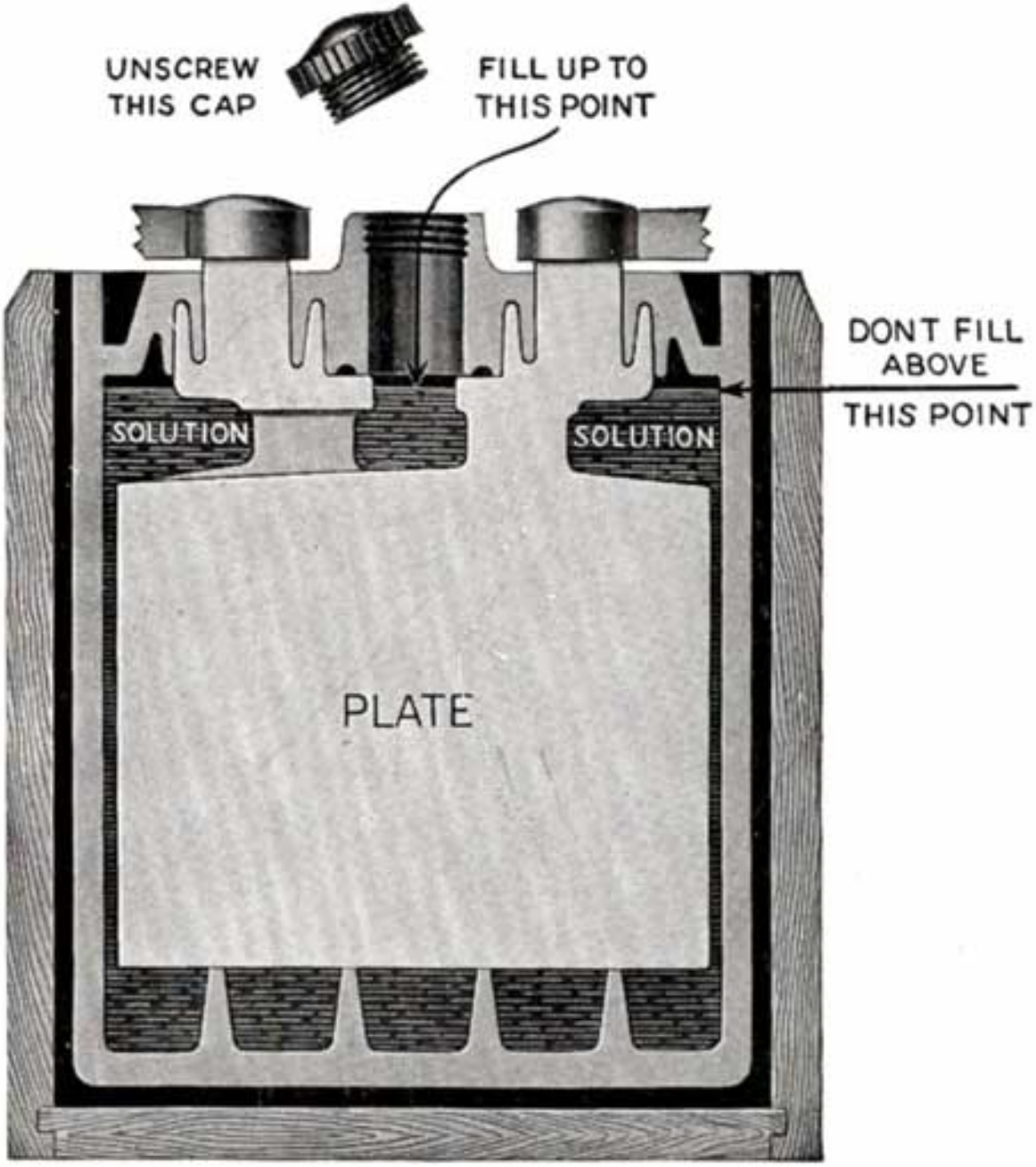

Fig. 13. Cross Section of Old Type Willard Battery

The Prest-O-Lite Peened Post Seal. All Prest-O-Lite batteries designated as types WHN, RHN, BHN and JFN, have a single moulded cover which is locked directly on to the posts. This is done by forcing a solid ring of lead from a portion of the post down into a chamfer in the top of the cover. This construction is illustrated in Fig. 247.

Batteries Using Sealing Nuts. The Exide batteries have threaded posts. A rubber gasket is placed under the cover on a shoulder on the post. The nut is then turned down on the post to force the cover on the gasket. This construction is illustrated in Fig. 239. The Titan battery uses a somewhat similar seal, as shown in Fig. 293.

Some of the older Willard batteries have a chamfer or groove in the under, side of the cover.

The posts have a ring of lead in the base which fits up into the. groove in the cover to make a tight joint. This is illustrated in Fig. 13. The later Willard constructions, using a rubber gasket seal and a lead cover insert, are illustrated in Figs. 278 and 287.

Filling Tube or Vent Tube Construction. Quite a number of designs have been developed in the construction of the filling or vent tube. In double covers, the tube is sometimes a separate part which is screwed into the lower cover. In other batteries using double covers, the tube is an integral part of the cover, as shown in Fig. 10. In all single covers, the tube is moulded integral with the cover.

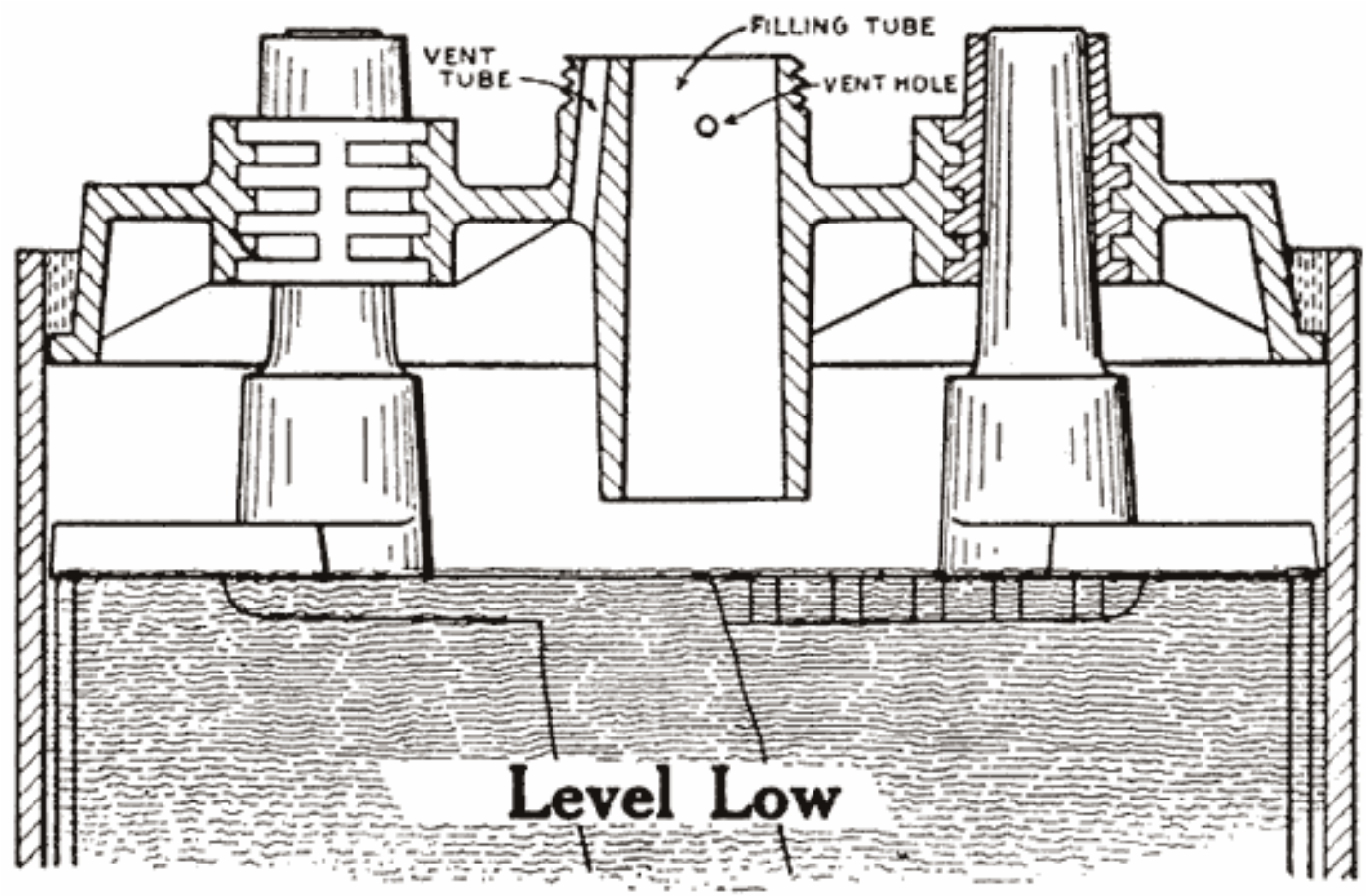

Fig. 14. a

Several devices have been developed to make it impossible to overfill batteries. This has been done by the U. S. L. and Exide companies on older types of batteries, their constructions being described as follows:

In old U. S. L. batteries, a small auxiliary vent tube is drilled, as shown in Fig. 14. When filling to replace evaporation, this vent tube prevents overfilling.

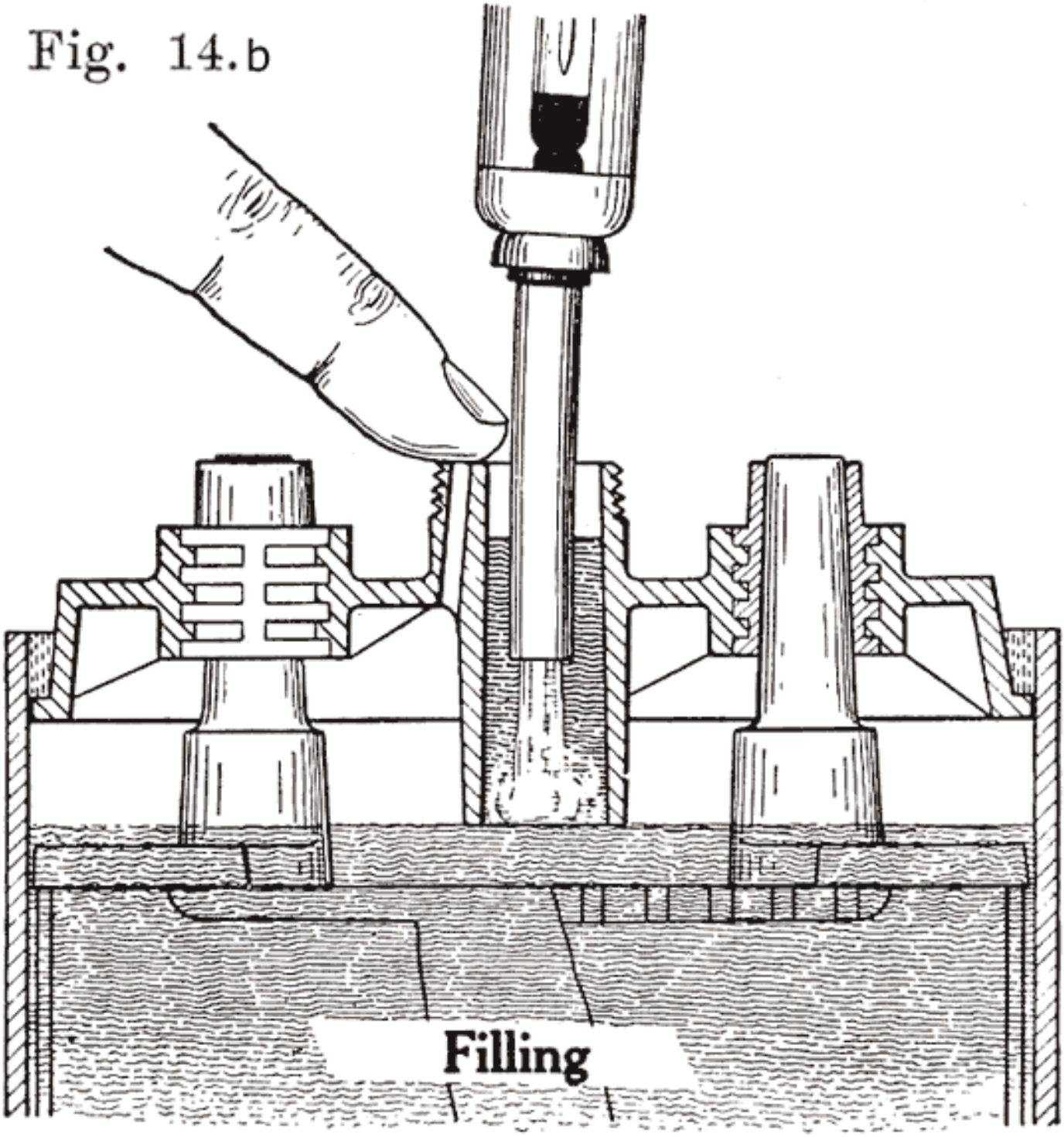

A finger is placed over the auxiliary vent tube shown in Fig. 14. The water is then poured in through the filling or vent tube. When the water reaches the bottom of the tube, the air imprisoned in the expansion chamber can no longer escape. Consequently the water can rise no higher in this chamber, but simply fills up the tube. Water is added till it reaches the top of the tube. The finger is then removed from the vent tube. This allows the air to escape from the expansion chamber. The water will therefore fall in the filling or vent tube, and rise slightly in the expansion chamber. The construction makes it impossible to overfill the battery, provided that the finger is held on the vent hole as directed.

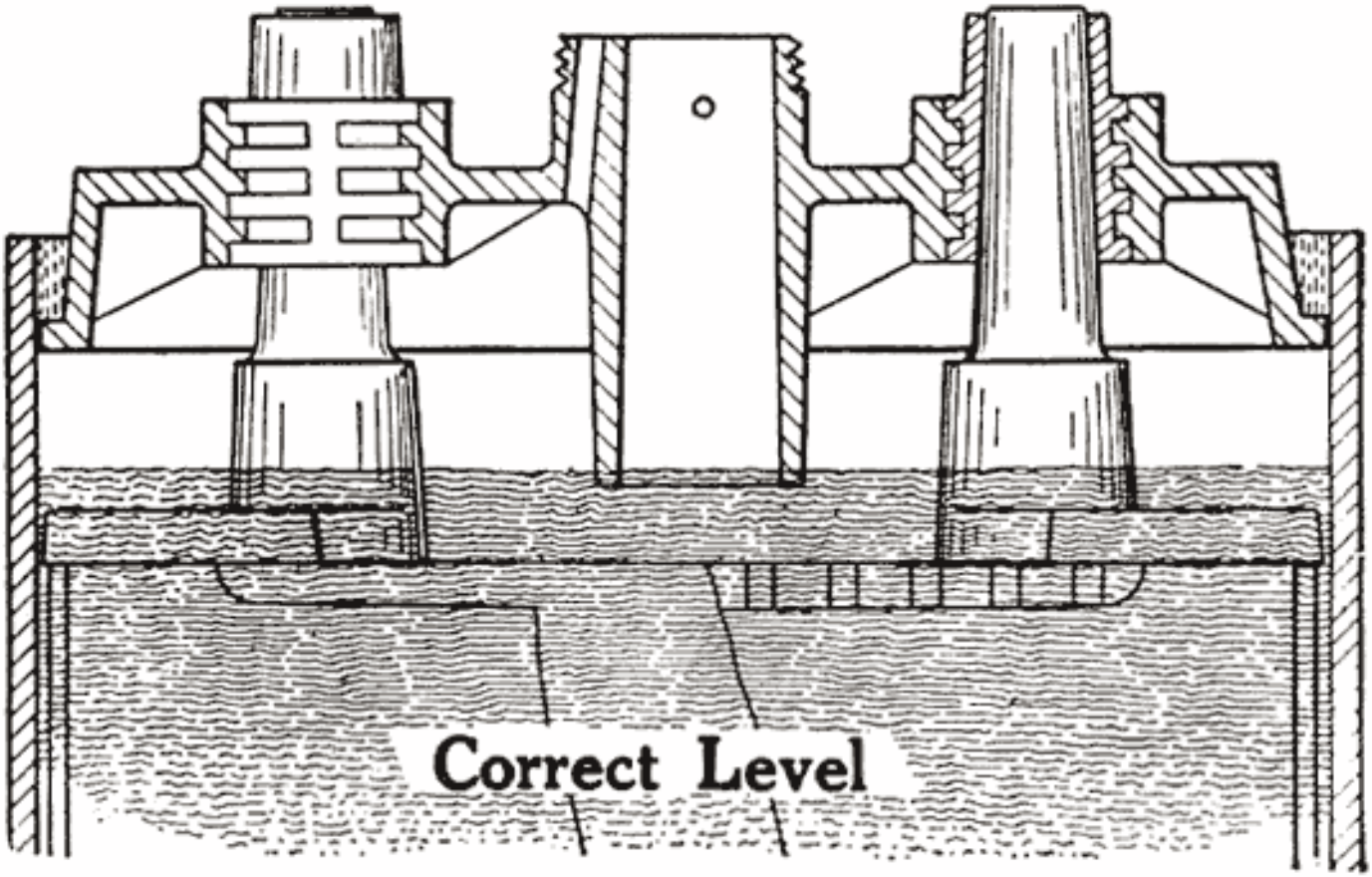

Fig. 14.c Filling U. S. L. Battery (Old Types)

Figure 15 shows the Non-Flooding Vent and Filling Plug used in the older type Exide battery, and in the present type LXRV. The new Exide cover, which does not use the non-flooding feature, is also shown. The old construction is described as follows:

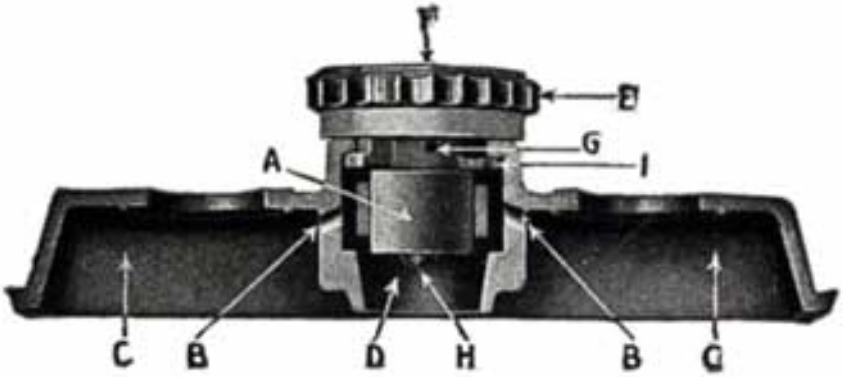

Sectional View of Cover, Plug in Place. Air Lock (A) in Position to Allow Free Escape of Gas Through Passages (BB)

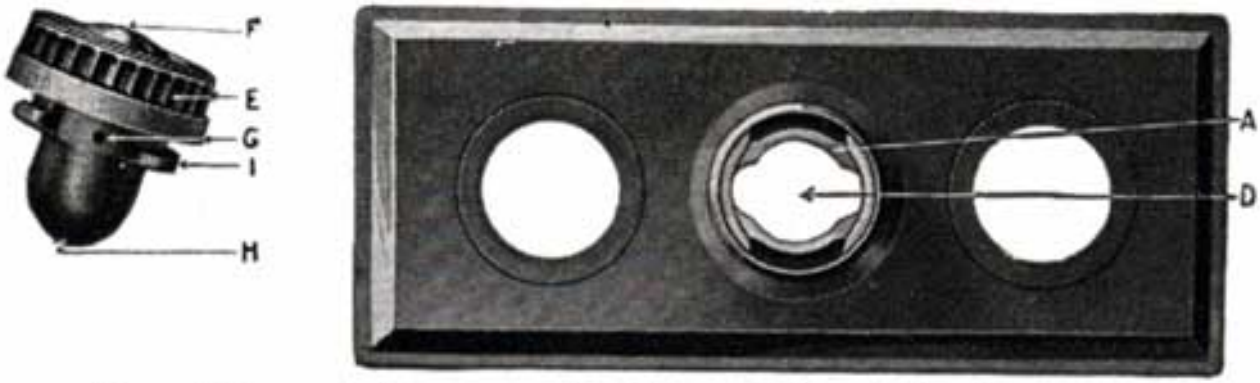

Top View of Cover and Filling Plug, Plug Removed

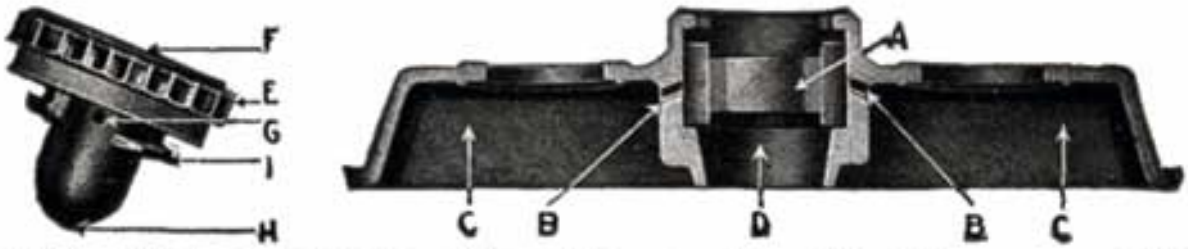

Sectional View of Cover, Plug Removed. Air Passages (BB) Closed and Air Lock (A) in Position to Prevent Overfilling

Old Exide Cover

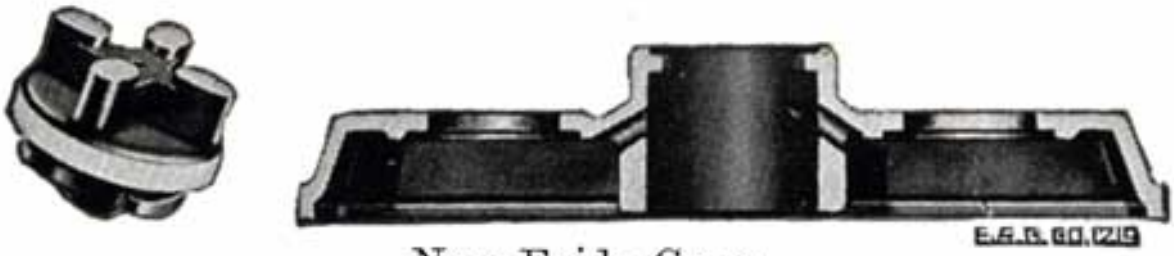

New Exide Cover

Fig. 15. Old and New Exide Covers

From the illustrations of the vent and filling plug, it will be seen that they provide both a vented stopper (vents F, G, H), and an automatic device for the preventing of overfilling and flooding. The amount of water that can be put into the cell is limited to the exact amount needed to replace that lost by evaporation. This is accomplished by means of the hard rubber valve (A) within the cell cover and with which the top of the vent plug (E) engages, as shown in the illustrations. The action of removing the plug (E) turns this valve- (A), closing the air passage (BB), and forming an air tight chamber (C) in the top of the cell. When water is poured in, it cannot rise in this air space (C) so as to completely fill the cell. As soon as the proper level is reached, the water rises in the filling tube (D) and gives a positive indication that sufficient water has been added. Should, however, the filling be continued, the excess will be pure water only, not acid. On replacing the plug (E), valve (A) is automatically turned, opening the air passages (BB), leaving the air chamber (C) available for the expansion of the solution, which occurs when the battery is working.

Generally the filling or vent tube is so made that its lower end indicates the correct level of electrolyte above the plates, In adding water, the level of the electrolyte is brought up to the bottom of the filling tube. By looking down into the tube, it can be seen when the electrolyte reaches the bottom of the tube.

Vent Plugs, or Caps. Vent plugs, or caps, close up the filling or vent tubes in the covers. They are made of hard rubber, and either screw into or over the tubes, or are tightened by a full or partial turn, as is done in Exide batteries. In the caps are small holes which are so arranged that gases generated within the battery may escape, but acid spray cannot pass through these holes. It is of the utmost importance that the holes in the vent caps be kept open to allow the gases to escape.

Case

The wooden case in which the cells are placed is usually made of kiln dried white oak or hard maple. The wood is inspected carefully, and all pieces are rejected that are weather- checked, or contain worm-holes or knots. The wood is sawed into -various thicknesses, and then cut to the proper lengths and widths. The wood is passed through other machines that cut in the dovetails, put the tongue on the bottom for the joints, stamp on the part number, drill the holes for the screws or bolts holding the handles, cut the grooves for the sealing compound, etc. The several pieces are then assembled and glued together. The finishing touches are then put on, these consisting of cutting the cases to the proper heights, sandpapering the boxes, etc. The cases are then inspected and are ready to be painted.

A more recent development in case construction is a one-piece hard rubber case, in which the jars and case are made in one piece, the cell compartments being formed by rubber partitions which form an integral part of the case. This construction is used in several makes of Radio "A" batteries, and to some extent in starting batteries.

Fig. 16. Battery Case

Asphaltum paint is generally used for wooden cases, the bottoms and tops being given three, coats, and the sides, two. The number of coats of paint varies, of course, in the different factories. The handles are then put on by machinery, and the case, Fig. 16, is complete, and ready for assembling.

Assembling and Sealing

The first step in assembling a battery is to burn the positive and negative plates to their respective straps, Fig. 5, forming the positive and negative "**groups**," Fig. 2. This is done by arranging a set of plates and a strap in a suitable rack which holds them securely in proper position, and then melting together the top of the plate lugs and the portion of the strap into which they fit with a hot flame.

A positive and a negative group are now slipped together and the separators inserted. The grooved side of the wood separator is placed toward the positive plate and when perforated rubber sheets are used these go between the positive and the wood separator. The positive and negative "groups" assembled with the separators constitute the "**element**," Fig. 3.

Before the elements are placed in the jars they are carefully inspected to make sure that no separator has been left out. For this purpose the "Exide" elements are subjected to an electrical test which rings a bell if a separator is missing, this having been found more infallible than trusting to a man's eyes.

In some batteries, such as the Exide, Vesta, and Prest-O-Lite batteries, the cover is placed on the element and made fast before the elements are placed in the jars. In other batteries, such as the U. S. L. and Philadelphia batteries, the covers are put on after the elements are placed in the jars.

After the element is in the jar and the cover in position, sealing compound is applied hot so as to make a leak proof joint between jar and cover.

Fig. 17. Inter-Cell Connector

The completed cells are now assembled in the case and the cell connectors, Fig. 17, burned to the strap posts. After filling with electrolyte the battery is ready to receive its "initial charge," which may require from one day to a week. A low charging rate is used, since the plates are generally in a sulphated condition when assembled. The specific gravity is brought up to about 1.280 during this charge. Some makers now give the battery a short high rate discharge test (see page 266), to disclose any defects, and just before sending them out give a final charge. The batteries are often "**cycled**" after being assembled, this consisting in discharging and recharging the batteries several times to put the active material in the best working condition. If the batteries are to be shipped "wet," they are ready for shipping after the final charge and inspection. Batteries which are shipped "dry" need to have more work done upon them.

Preparing Batteries for Dry Shipment

There are three general methods of "dry" shipment. **The first method** consists of sending cases, plates, covers, separators, etc., separately, and assembling them in the service stations. Sometimes these parts are all placed together, as in a finished battery, but without the separators, the covers not being sealed, or the connectors and terminals welded to the posts. This is a sort of "**knock-down**" condition. The plates used are first fully charged and dried.

The second method consists of assembling a battery complete with plates, separators, and electrolyte, charging the battery, pouring out the electrolyte, rinsing with distilled water, pouring out the water and screwing the vent plugs down tight. The vent holes in these plugs are sealed to exclude air. The moisture left in the battery when the rinsing water was poured out cannot evaporate, and the separators are thus kept in a moistened condition.

The third method is the Willard "Bone Dry" method, and consists of assembling the battery complete with dry threaded rubber separators and dry plates, but without electrolyte. The holes

in the vent plugs are not sealed, since there is no moisture in the battery. Batteries using wooden separators cannot be shipped "bone-dry," since wooden separators must be kept moist.

Terminal Connections

When the battery is on the car it is necessary to have some form of detachable connection to the car circuit and this is accomplished by means of "terminal connectors," Fig. 18, of which there are many types.

Fig. 18. Battery Terminal

Many types of terminals are in two parts, one being permanently attached to the car circuit and the other mounted permanently on the battery by welding it to the terminal post, the two parts being detachably joined by means of a bolted connection.

In another type of terminal, the cable is soldered directly to the terminal which is lead burned to the cell post. In this construction there is very much less chance of corrosion taking place, and it is therefore a good design.

HOMEMADE BATTERIES

The wisest thing for the battery shop owner to do is to get a contract as official service station for one of. the well known makes of batteries. The manufacturers of this battery will stand behind the service station, giving it the benefits of its engineering, production, and advertising departments, and boost the service station's business, helping to make it a success.

Within the past year or so, however, some battery repairmen have conceived the idea that they do not need the backing of a well organized factory, and have decided to build up their own batteries. Some of them merely assemble batteries from parts bought from one or more manufacturers. If all the parts are made by the same company, they will fit together, and may make a serviceable battery. Often, however, parts made by several manufacturers are

assembled in the same battery. Here is where trouble is apt to develop, because it is more than likely that jars may not fit well in the case; plates may not completely fill the jars, allowing too much acid space, with the results that specific gravity readings will not be reliable, and the plates may be overworked; plate posts may not fit the cover holes, and so on. If such a "fabricated" battery goes dead because of defective material, there is no factory back of the repairman to stand the loss.

If the repairman wishes to assemble batteries, he should be very careful to buy the parts from a reliable manufacturer, and he should be especially careful in buying separators, as improperly treated separators often develop acetic acid, which dissolves the lead of the plates very quickly and ruins the battery. Batteries made in this way are good for rental batteries, or "loaners." These batteries are assembled and charged just as are batteries which have been in dry storage, see page 241.

If the repairman who "fabricates" batteries takes chances, the man who attempts to actually make his own battery plates is certainly risking his business and reputation. There are several companies which sell moulds for making plate grids. One even sells cans of lead oxides to enable the repairman to make his own plate paste. Even more foolhardy than the man who wishes to mould plate grids is the man who wishes to mix the lead oxides himself. Many letters asking for paste formulas have been received by the author. Such formulas can never be given, for the author does not have them. Paste making is a far more difficult process than many men realize. The lead oxides which are used must be tested and analyzed carefully in a chemical laboratory and the paste formulas varied according to the results of these tests. The oxides must be carefully weighed, carefully handled, and carefully analyzed. The battery service station does not have the equipment necessary to do these things, and no repairman should ever attempt to make plate paste, as trouble is bound to follow such attempts. A car owner may buy a worthless battery once, but the next time he will go to some other service station and buy a good battery

No doubt many repairmen are as skillful and competent as the workers in battery factories, but the equipment required to make grids and paste is much too elaborate and expensive for the service station, and without such equipment it is impossible to make a good battery.

The only battery parts which may safely be made in the service station are plate straps and posts, intercell connectors, and cell terminals. Moulds for making such parts are on the market, and it is really worth while to invest in a set. The posts made in such moulds are of the plain tapered type, and posts which have special sealing and locking devices, such as the Exide, Philadelphia, and Titan cannot be made in them.

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CHAPTER 4

CHEMICAL CHANGES IN THE BATTERY

Before explaining what happens within one storage cell, let us look into the early history of the storage battery, and see what a modest beginning the modern heavy duty battery had. Between 1850 and 1860 a man named Plante began his work on the storage battery. His original cell consisted of two plates of metallic lead immersed in dilute sulphuric acid. The acid formed a thin layer of lead sulphate on each plate which soon stopped further action on the lead. If a current was passed through the cell, the lead sulphate on the "**anode**" or lead plate at which the current entered the cell was changed into peroxide of lead, while the sulphate on the other lead plate or "**cathode**" was changed into pure lead in a spongy form. This cell was allowed to stand for several days and was then "discharged," lead sulphate being again formed on each plate. Each time this cell was charged, more "spongy" lead and peroxide of lead were formed. These are called the "active" materials, because it is by the chemical action between them and the sulphuric acid that the electricity is produced. Evidently, the more active materials the plates contained, the longer the chemical action between the acid and active materials could take place, and hence the greater the "capacity," or amount of electricity furnished by the cell. The process of charging and discharging the battery so as to increase the amount of active material, is called "**forming**" the plates.

Plante's method of forming plates was very slow, tedious, and expensive. If the spongy lead, and peroxide of lead could be made quickly from materials which could be spread over the plates, much time and expense could be saved. It was Faure who first suggested such a plan, and gave us the "**pasted**" plate of today, which consists of a skeleton framework of lead, with the sponge lead and peroxide of lead filling the spaces between the "ribs" of the framework. Such plates are known as "pasted" plates, and are much lighter and more satisfactory, for automobile work than the heavy solid lead plates of Plante's. Chapter 3 describes more fully the processes of manufacturing and pasting the plates.

We know now what constitutes a storage battery, and what the parts are that "generate" the electricity. How is the electricity produced? Theoretically, if we take a battery which has been entirely discharged, so that it is no longer able to cause a flow of current, and examine and test the electrolyte and the materials on the plates, we shall find that the electrolyte is pure water, and both sets of plates composed of white lead sulphate. On the other hand, if we make a similar test and examination of the plates and electrolyte of a battery through which a current has been sent from some outside source, such as a generator, until the current can no longer cause chemical reactions between the plates and electrolyte, we will find that the electrolyte is now composed of water and Sulphuric acid, the acid comprising about 30%, and the water 70% of the electrolyte. The negative set of plates will be composed of pure lead in a spongy form, while the positive will consist of peroxide of lead.

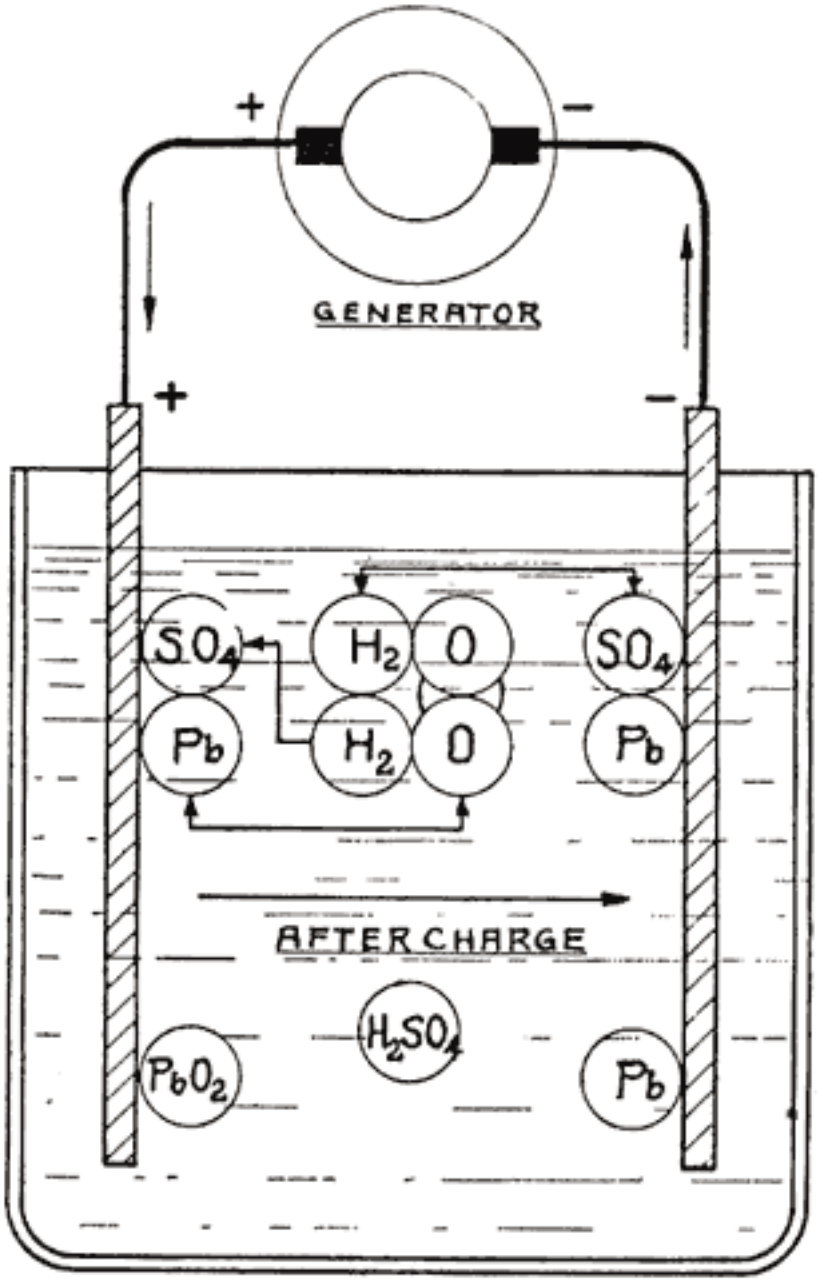

Chemical Action in a Storage Cell During Charge
Fig. 19

The foregoing description gives the final products of the chemical changes that take place in the storage battery. To understand the changes themselves requires a more detailed investigation. The substances to be considered in the chemical actions are sulphuric acid,

water, pure lead, lead sulphate, and lead peroxide. With the exception of pure lead, each of these substances is a chemical compound, or composed of several elements. Thus sulphuric acid is made up of two parts of hydrogen, which is a gas; one part of sulphur, a solid, and four parts of oxygen, which is also a gas; these combine to form the acid, which is liquid, and which is for convenience written as H_2SO_4, H_2 representing two parts of hydrogen, S one part of sulphur, and 0_4, four parts oxygen. Similarly, water a liquid, is made up of two parts of hydrogen and one part of oxygen, represented by the symbol H_2O. Lead is not a compound, but an element whose chemical symbol is Pb, taken from the Latin name for lead. Lead sulphate is a solid, and consists of one part of lead, a solid substance, one part of sulphur, another solid substance, and four parts of oxygen, a gas. It is represented chemically by Pb SO_4. Lead peroxide is also a solid, and is made up of one part of lead, and two parts of oxygen. In the chemical changes that take place, the compounds just described are to a certain extent split up into the substances of which they are composed. We thus have lead (Pb), hydrogen (H), oxygen (0), and sulphur (S), four elementary substances, two of which are solids, and two gases. The sulphur does not separate itself entirely from the substances with which it forms the compounds H_2SO_4 and Pb SO_4. These compounds are split into H_2 and SO_4 and Pb and SO_4 respectively. That is, the sulphur always remains combined with four parts of oxygen.

Let us now consider a single storage cell made up of electrolyte, one positive plate, and one negative plate. When this cell is fully charged, or in a condition to produce a current of electricity, the positive plate is made up of peroxide of lead (PbO_2), the negative plate of pure lead (Pb), and the electrolyte of dilute sulphuric acid (H_2SO_4). This is shown diagrammatically in Fig. 19. **The chemical changes that take place when the cell is discharging and the final result of the changes are as follows:**

(a). At the Positive Plate: Lead peroxide and sulphuric acid produce lead sulphate, water, and oxygen, or**:**

$$\text{(a).} \quad PbO_2 + H_2SO_4 = PbSO_4 + H_2O + O$$

(b). At the Negative Plate: Lead and sulphuric acid produce lead sulphate and Hydrogen, or:

$$\text{(b).} \quad Pb + H_2SO_4 = PbSO_4 + H_2$$

The oxygen of equation **(a)** and the hydrogen of equation **(b)** combine to form water, as may be shown by adding these two equations, giving one equation for the entire discharge

action:

$$\text{(c).}\quad PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O$$

In this equation we start with the active materials and electrolyte in their original condition, and finish with the lead sulphate and water, -which are the final products of a discharge. Examining this equation, we see that the sulphuric acid of the electrolyte is used up in forming lead sulphate on both positive and negative plates, and is therefore removed from the electrolyte. This gives us the easily remembered rule for remembering discharge actions, which, though open to question from a strictly scientific viewpoint, is nevertheless convenient:

During discharge the acid goes into the plates.

The chemical changes described in **(a)**, **(b)**, and **(c)** are not instantaneous. That is, the lead, lead peroxide, and sulphuric acid of the fully charged cell are not changed into lead sulphate and water as soon as a current begins to pass through the cell. This action is a gradual one, small portions of these substances being changed at a time. The greater the current

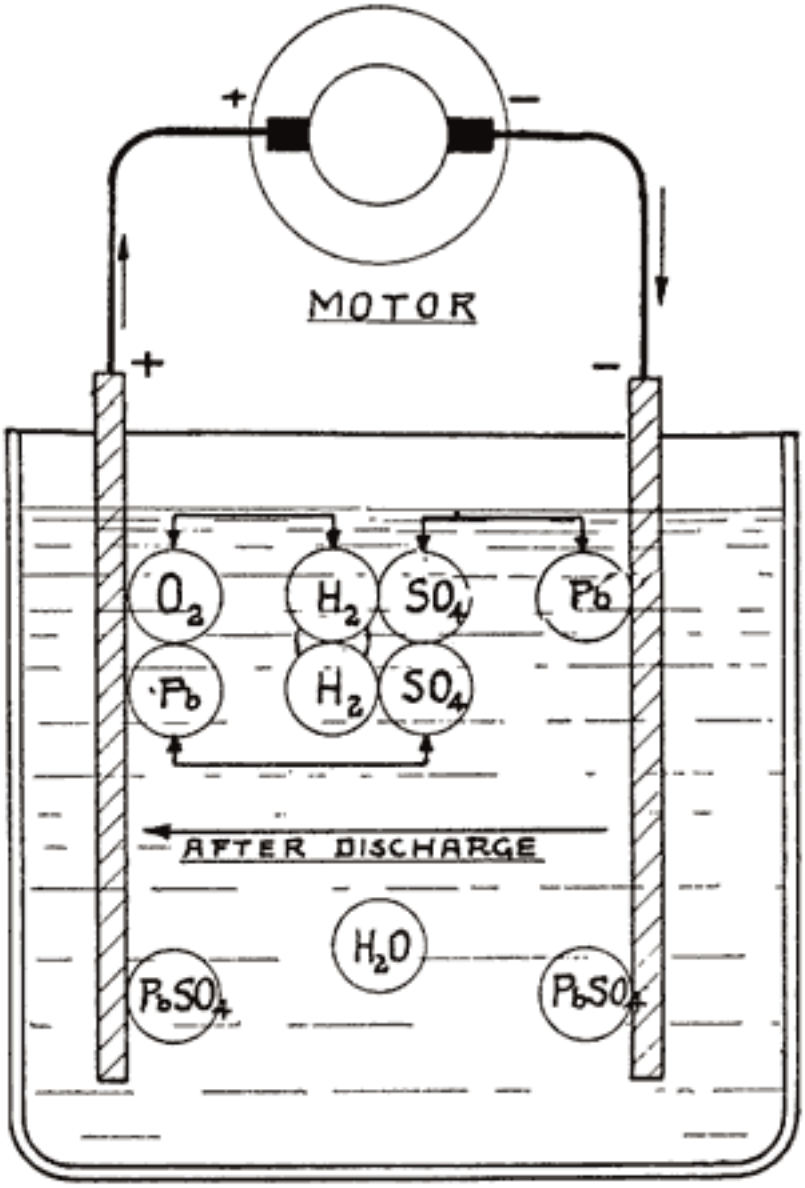

Chemical Action in a Storage Cell During

that flows through the cell, the faster will the changes occur. Theoretically, the changes will continue to take place as long as any lead,,. lead peroxide, and sulphuric acid remain. The faster these are changed into lead sulphate and water, the shorter will be the time that the storage cell can furnish a current, or the sooner it will be discharged.

Chemical Action in a Storage Cell During Discharge
Fig. 20

Taking the cell in its discharged condition, let us now connect the cell to a generator and send current through the cell from the positive to the negative plates. This is called "charging" the cell. The lead sulphate and water will now gradually be changed back into lead, lead peroxide, and sulphuric acid. The lead sulphate which is on the negative plate is changed to pure lead; the lead sulphate on the positive plate is changed to lead peroxide, and sulphuric acid will be added to the water. **The changes at the positive plate may be represented as follows:**

Lead sulphate and water produce. sulphuric acid, hydrogen and lead peroxide, or**:**

$$\text{(d).}\quad PbSO_4 + 2H_2O = PbO_2 + H_2SO_4 + H_2$$

The changes at the negative plate may be expressed as follows: Lead sulphate and water produced sulphuric acid, oxygen, and lead, or:

$$\text{(e).}\quad PbSO_4 + H_2O = Pb + H_2SO_4 + O$$

The hydrogen (H_2) produced at the positive plate, and the oxygen (0) produced at the negative plate unite to form water, as may be shown by the equation:

$$\text{(f).}\quad 2PbSO_4 + 2H_2O = PbO_2 + Pb + 2H_2SO_4$$

Equation **(f)** starts with lead sulphate and water, which, as shown in equation **(c)**, are produced when a battery is discharged. It will be observed that we start with lead sulphate

and water. Discharged plates may therefore be charged in water. In fact, badly discharged negatives may be charged better in water than in electrolyte. The electrolyte is poured out of the battery and distilled water poured in. The acid remaining on the separators and plates is sufficient to make the water conduct the charging current.

In equation **(f)**, the sulphate on the plates combines with water to form sulphuric acid. This gives us the rule:

During charge, acid is. driven out of the plates.

This rule is a convenient one, but, of course, is not a strictly correct statement.

The changes produced by sending a current through the cell are also gradual, and will take place faster as the current is made greater. When all the lead sulphate has been 'used up by the chemical changes caused by the current, no further charging can take place. If we continue to send a current through the cell after it is fully charged, the water will continue to be split up into hydrogen and oxygen. Since, however, there is no more lead sulphate left with which the hydrogen and oxygen can combine to form lead, lead peroxide, and sulphuric acid, the hydrogen and oxygen rise to the surface of the electrolyte and escape from the cell. This is known as "**gassing**," and is an indication that the cell is fully charged.

Relations Between Chemical Actions and Electricity.

We know now that chemical actions in the battery produce electricity and that, on the other hand, an electric current, sent through the battery from an outside source, such as a generator, produces chemical changes in the battery. How are chemical changes and electricity related? The various chemical elements which we have in a battery are supposed to carry small charges of electricity, which, however, ordinarily neutralize one another. When a cell is discharging, however, the electrolyte, water, and active materials are separated into parts carrying negative and positive charges, and these "charges" cause what we call an electric current to flow in the apparatus attached to the battery.

Similarly, when. a battery is charged, the charging current produces electrical "charges" which cause the substances in the battery to unite, due to the attraction of position and negative charges for one another. This is a brief, rough statement of the relations between chemical reactions and electricity in a battery. A more thorough study of the subject would be out of place in this book. It is sufficient for the repairman to remember that the substances in a battery carry charges of electricity which become available as an electric current when a battery discharges, and that a charging current causes electric charges to form, thereby "charging" the battery.

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CHAPTER 5

WHAT TAKES PLACE DURING DISCHARGE

Considered chemically, the discharge of a storage battery consists of the changing of the spongy lead and lead peroxide into lead sulphate, and the abstraction of the acid from the electrolyte. Considered electrically, the changes are more complex, and require further investigation. The voltage, internal resistance, rate of discharge, capacity, and other features must be considered, and the effects of changes in one upon the others must be studied. This proceeding is simplified considerably if we consider each point separately. The abstraction. of the acid from the electrolyte gives us a method of determining the condition of charge or discharge in the battery, and must also be studied.

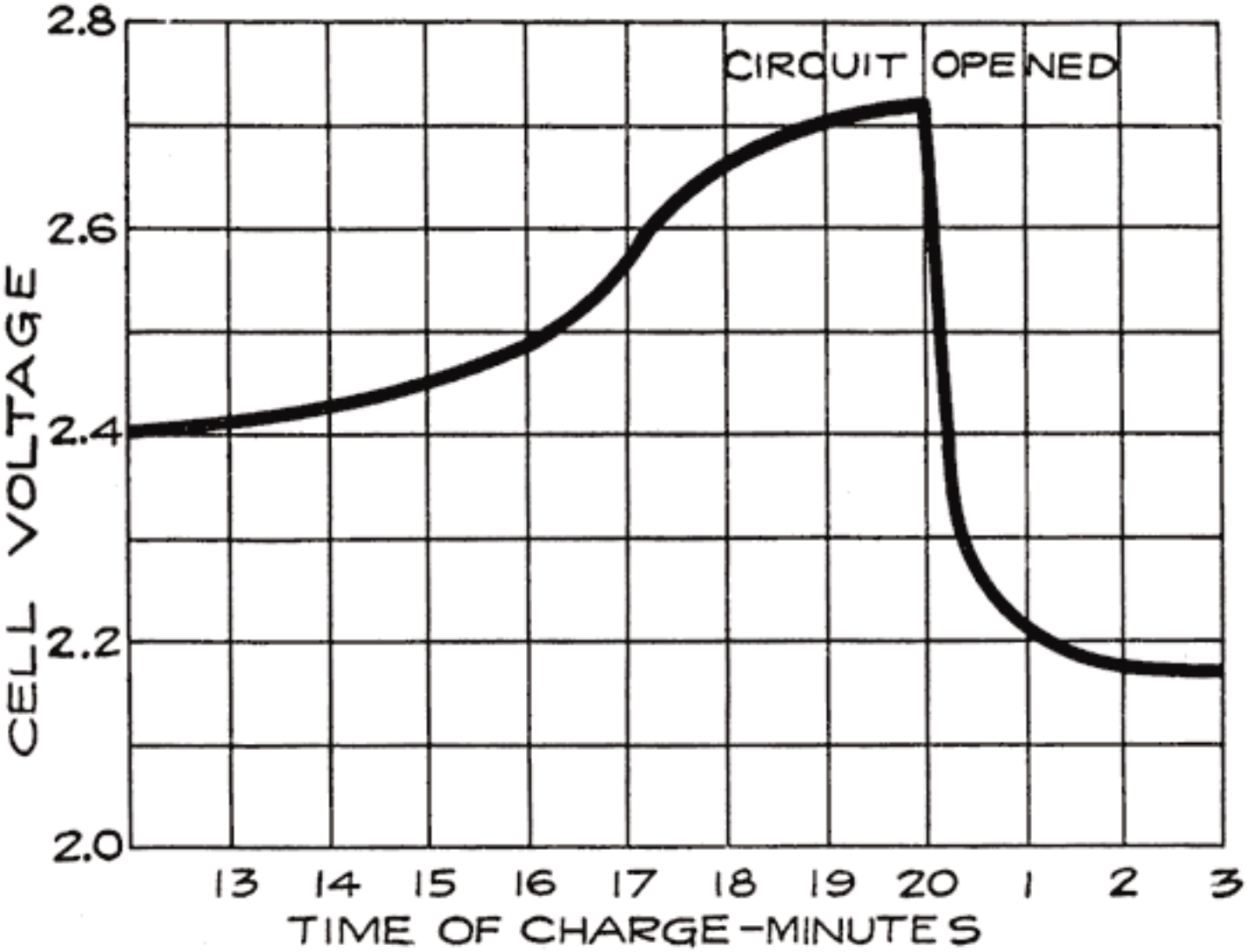

Fig. 21. Voltage Changes During Last Eight Minutes of Charge and First Three Minutes After End of Charge

Voltage Changes During Discharge. At the end of a charge, and before opening the charging circuit, the voltage of each cell is about 2.5 to 2.7 volts. As soon as the charging circuit is opened, the cell voltage drops rapidly to about 2.1 volts, within three or four minutes. This is due to the formation of a thin layer of lead sulphate on the surface of the negative plate and between the lead peroxide and the metal of the positive plate. Fig. 21 shows how the voltage changes during the last eight minutes of charge, and how it drops rapidly as soon as the charging circuit is opened. The final value of the voltage after the charging circuit is opened is about 2.15-2.18 volts. This is more fully explained in Chapter 6. If a current is drawn from the battery at the instant the charge is stopped, this drop is more rapid. At the beginning of the discharge the voltage has already had a rapid drop from the final voltage on charge, due to the formation of sulphate as explained above. When a current is being drawn from the battery, the sudden drop is due to the internal resistance of the cell, the formation of more sulphate, and the abstracting of the acid from the electrolyte which fills the pores of the plate. The density of this acid is high just before

the discharge is begun. It is diluted rapidly at first, but a balanced condition is reached between the density of the acid in the plates and in the main body of the electrolyte, the acid supply in the plates being maintained at a lowered density by fresh acid flowing into them from the main body of electrolyte. After the initial drop, the voltage decreases more slowly, the rate of decrease depending on the amount of current drawn from the battery. The entire process is shown in Fig. 22.

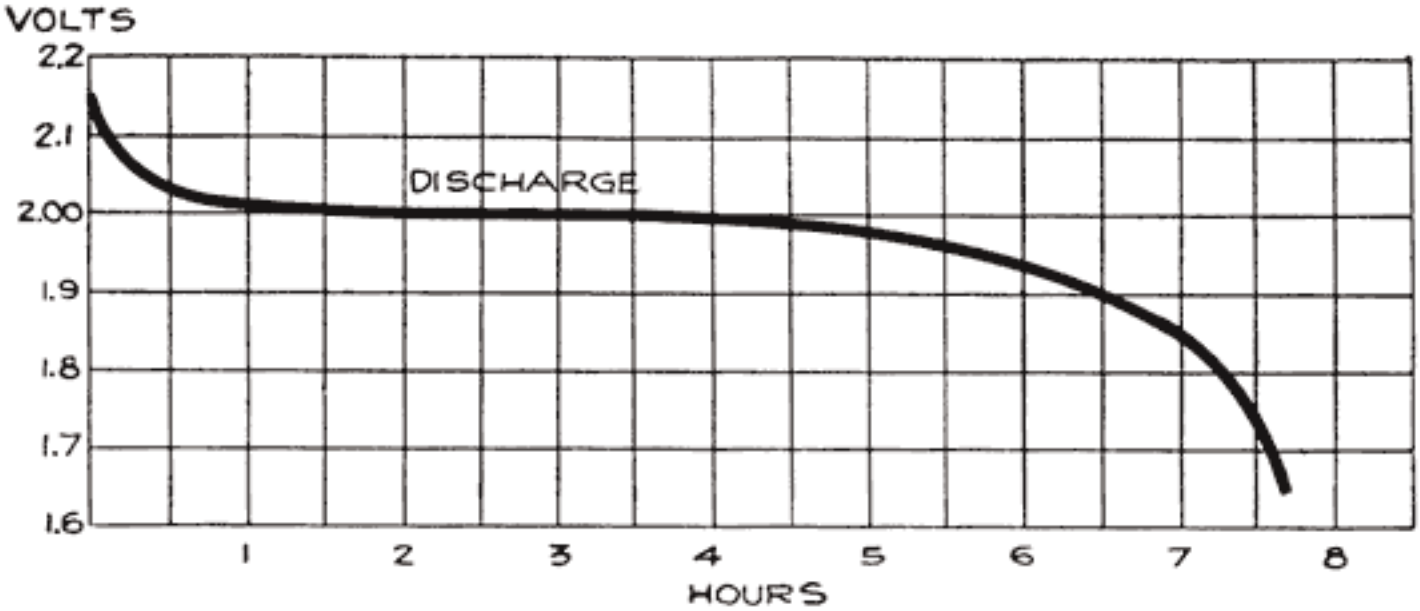

Fig. 22. Voltage Changes During Discharge

Lead sulphate is being formed on the surfaces, and in the body of the plates. This sulphate has a higher resistance than the lead or lead peroxide, and the internal resistance of the cell rises, and contributes to the drop in voltage. As this sulphate forms in the body of the plates, the acid is used up. At first this acid is easily replaced from the main body of the electrolyte by diffusion. The acid in the main body of the electrolyte is at first comparatively strong, or concentrated, causing a fresh supply of acid to flow into the plates as fast as it is used up in the plates. This results in the acid in the electrolyte growing weaker, and this, in turn, leads to a constant decrease in the rate at which the fresh acid flows, or diffuses into the plates. Furthermore, the sulphate, which is more bulky than the lead or lead peroxide fills the pores in the plate, making it more and more difficult for acid to reach the interior of the plate. This increases the rate at which the voltage drops.

The sulphate has another effect. It forms a cover over the active material which has not been acted upon, and makes it practically useless, since the acid is almost unable to penetrate the coating of sulphate. We thus have quantities of active material which are entirely enclosed in sulphate, thereby cutting down the amount of energy which can be taken from the battery. Thus the formation of sulphate throughout each plate and the abstraction of acid from the electrolyte cause the voltage to drop at a constantly increasing

rate.

Theoretically, the discharge may be continued until the voltage drops to zero, but practically, the discharge should be stopped when the voltage of each cell has dropped to 1.7 (on low discharge rates). If the discharge is carried on beyond this point much of the spongy lead and lead peroxide have either been changed into lead sulphate, or have been covered up by the sulphate so effectively that they are almost useless. Plates in this condition require a very long charge in order to remove all the sulphate.

The limiting value of 1.7 volts per cell applies to a continuous discharge at a moderate rate. At a very high current flowing for only a very short time, it is not only' safe, but advisable to allow a battery to discharge to a lower voltage, the increased drop being due to the rapid dilution of the acid in the plates.

The cell voltage will rise somewhat every time the discharge is stopped. This is due to the diffusion of the acid from the main body of electrolyte into the plates, resulting in an increased concentration in the plates. If the discharge has been continuous, especially if at a high rate, this rise in voltage will bring the cell up to its normal voltage very quickly on account of the more rapid diffusion of acid which will then take place.

The voltage does not depend upon the area of the plate surface but upon the nature of the active materials and the electrolyte. Hence, although the plates of a cell are gradually being covered with sulphate, the voltage, measured when no current is flowing, will fall slowly and not in proportion to the amount of energy taken out of the cell. It is not until the plates are pretty thoroughly covered with sulphate, thus making it difficult for the acid to reach the active material, that the voltage begins to drop rapidly. This is shown clearly in Fig. 22, which shows that the cell voltage has dropped only a very small amount when the cell is 50% discharged. With current flowing through the cell, however, the increased internal resistance causes a marked drop in the voltage. Open circuit voltage is not useful, therefore to determine how much energy has been taken from the battery.

Acid Density. The electrolyte of a lead storage battery is a mixture of chemically pure sulphuric acid, and chemically pure water, the acid forming about 30 per cent of the volume of electrolyte when the battery is fully charged. The pure acid has a "specific gravity" of 1.835, that is, it is 1.835 times as heavy as an equal volume of water. The mixture of acid and water has a specific gravity of about 1.300. As the cell discharges, acid is abstracted from the electrolyte, and the weight of the latter must therefore grow less, since there will be less acid in it. The change in the weight, or specific gravity of the electrolyte is the best means of determining the state of discharge of a cell, provided that the cell has been used properly. In order that the value of the specific gravity may be used as an indication of the amount of energy in a battery, the history of the battery must be known. Suppose, for instance, that in refilling the battery to replace the water lost by the

natural evaporation which occurs in the use of a battery, acid, or a mixture of acid and water has 'been used. This will result in the specific gravity being too high, and the amount of energy in the battery will be less than that indicated by the specific gravity. Again, if pure water is used to replace electrolyte which has been spilled, the specific gravity will be lower than it should be. In a battery which has been discharged to such an extent that much of the active material has been covered by a layer of tough sulphate, or if a considerable amount of sulphate and active material has been loosened from the plates and has dropped to the bottom of the cells, it will be impossible to bring the specific gravity of the electrolyte up to 1.300, even though a long charge is given. There. must, therefore, be a reasonable degree of certainty that a battery has been properly handled if the specific gravity readings are to be taken as a true indication of the condition of a battery. Where a battery does not give satisfactory service even though the specific gravity readings are satisfactory, the latter are not reliable as indicating the amount of charge in the battery.

As long as a discharge current is flowing from the battery, the acid within the plates is used up and becomes very much diluted. Diffusion between the surrounding electrolyte and the acid in the plates keeps up the supply needed in the plates in order to, carry on the chemical changes. When the discharge is first begun, the diffusion of acid into the plates takes place rapidly because there is little sulphate clogging the pores in the active material, and because there is a greater difference between the concentration of acid in the electrolyte and in the plates than will exist as the discharge progresses. As the sulphate begins to form and fill up the pores of the plates, and as more and more acid is abstracted from the electrolyte, diffusion takes place more slowly.

If a battery is allowed to stand idle for a short time after a partial discharge, the specific gravity of the electrolyte will decrease because some, of the acid in the electrolyte will gradually flow into the pores of the plates to replace the acid used up while the battery was discharging. Theoretically the discharge can be continued -until all the acid has been used up, and the electrolyte is composed of pure water. Experience has shown, however, that the discharge of the battery should not be continued after the specific gravity of the electrolyte has fallen to 1.150. As far as the electrolyte is concerned, the discharge may be carried farther with 'safety. The plates determine the point at which the discharge should be stopped. When the specific gravity has dropped from 1.300 to 1.150, so much sulphate has been formed that it fills the pores in the active material on the plates. Fig. 23 shows the change in the density of the acid during discharge.

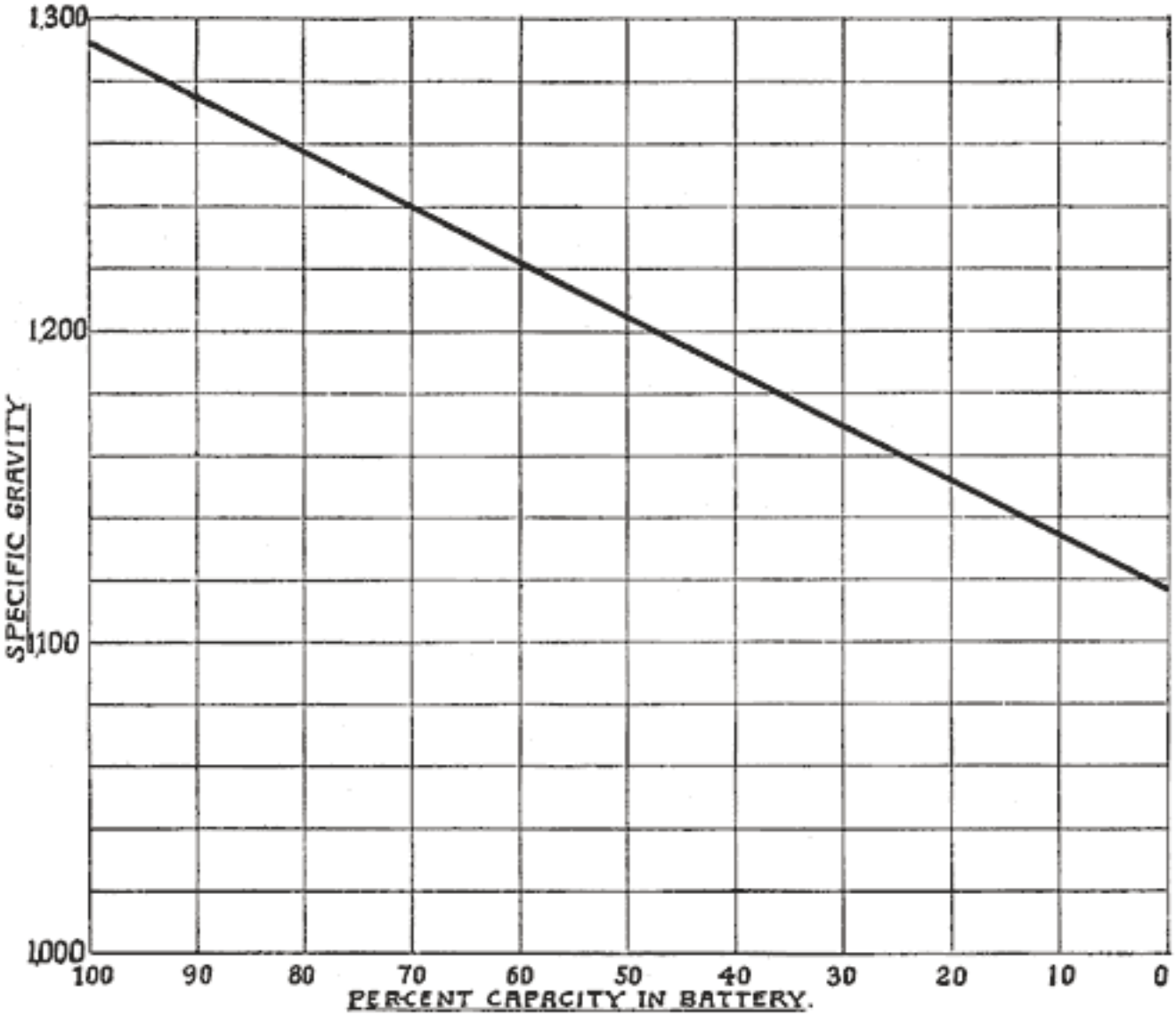

Fig. 23. Variation of Capacity with Specific Gravity

Changes at the Negative Plate. Chemically, the action at the negative plate consists only of the formation of lead sulphate from the spongy lead. The lead sulphate is only slightly soluble in the electrolyte and is precipitated as soon as it is formed, leaving hydrogen ions, which then go to the lead peroxide plate to form water with oxygen ions released at the peroxide plate. The sulphate forms more quickly on the surface of the plate than in the inner portions because there is a constant supply of acid available at the surface, whereas the formation of sulphate in the interior of the plate requires that acid diffuse into the pores of the active materials to replace that already used up in the formation of sulphate. In the negative plate, however, the sulphate tends to form more uniformly throughout the mass of the lead, because the spongy lead is more porous than the lead peroxide, and because the acid is not diluted by the formation of water as in the positive plate.

Changes at the, Positive Plate. In a fully charged positive plate we have lead peroxide as the active material. This is composed of lead and oxygen. From this fact it is plainly

evident that during discharge there is a greater chemical activity at this plate than at the negative plate, since we must find something to combine with the oxygen in order that the lead may form. lead sulphate with the acid. In an ideal cell, therefore, the material which undergoes the greater change should be more porous than the material which does not involve as great a chemical reaction. In reality, however, the peroxide is not as porous as the spongy lead, and does not hold together as well.

The final products of the discharge of a positive plate are lead sulphate and water. The lead peroxide must first be reduced to lead, which then combines with the sulphate from the acid to form lead sulphate, while the oxygen from the peroxide combines with the hydrogen of the acid to form water. There is, therefore, a greater activity at this plate than at the lead plate, and the formation of the water dilutes the acid in and around the plate so that the tendency is for the chemical actions to be retarded.

The sulphate which forms on discharge causes the active material to bulge out because it occupies more space than the peroxide. This causes the lead peroxide at the surface to begin falling, to the bottom of the jar in fine dust-like particles, since the peroxide here holds together very poorly.

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CHAPTER 6

WHAT TAKES PLACE DURING CHARGE

Voltage. Starting with a battery which has been discharged until its voltage has decreased to 1.7 per cell, we pass a current through it and cause the voltage to rise steadily. Fig. 24 shows the changes in voltage during charge. Ordinarily the voltage begins to rise immediately and uniformly. If, however, the battery has been left in a discharged condition for some time, or has been "over discharged," the voltage rises very rapidly for a fraction of the first minute of charge and then drops rapidly to the normal value and thereafter begins to rise steadily to the end of the charge. This rise at the beginning of the charge is due to the fact that the density of the acid in the pores of the plates rises rapidly at first, the acid thus formed being prevented from diffusing into the surrounding electrolyte by the coating of sulphate. As soon as this sulphate is broken through, diffusion takes place and the voltage drops.

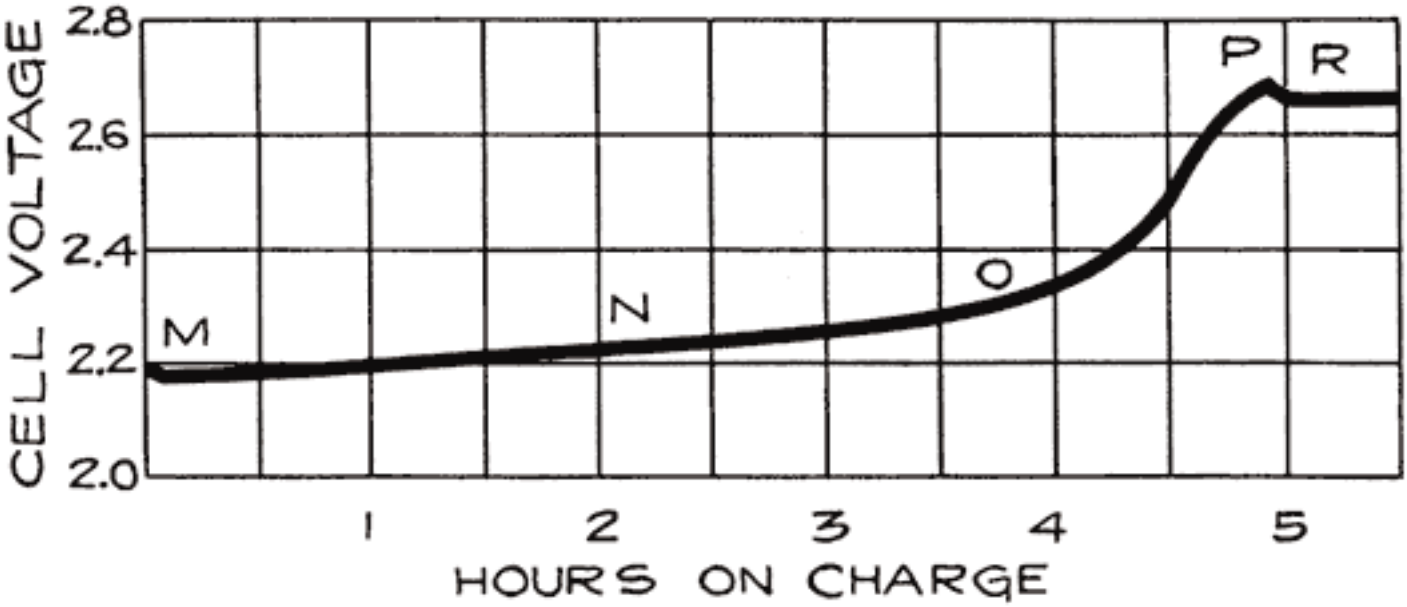

Fig. 24. Voltage Changes During Charge

As shown in Fig. 24, the voltage remains almost constant between the points M and N. At N the voltage begins to rise because the charging chemical reactions are taking place farther and farther in the inside parts of the plate, and the concentrated acid formed by the chemical actions in the plates is diffusing into the main electrolyte. This increases the

battery voltage and requires a higher charging voltage.

At the point marked 0, the voltage begins to rise very rapidly. This is due to the fact that the amount of lead sulphate in the plates is decreasing very rapidly, allowing the battery voltage to rise and thus increasing the charging voltage. Bubbles of gas are now rising through the electrolyte.

At P, the last portions of lead sulphate are removed, acid is no longer being formed, and hydrogen and oxygen gas are formed rapidly. The gas forces the last of the concentrated acid out of the plates and in fact, equalizes the acid concentration throughout the whole cell. Thus no further changes can take place, and the voltage becomes constant at R at a voltage of 2.5 to 2.7.

Density of Electrolyte. Discharge should be stopped when the density of the electrolyte, as measured with a hydrometer, is 1.150. When we pass a charging current through the battery, acid is produced by the chemical actions which take place in the plates. This gradually diffuses with the main electrolyte and causes the hydrometer to show a higher density than before. This increase in density continues steadily until the battery begins to "gas" freely.

The progress of the charge is generally determined by the density of the electrolyte. For this purpose in automobile batteries, a hydrometer is placed in a glass syringe having a short length of rubber tubing at one end, and a large rubber bulb at the other. The rubber tube is inserted in the cell and enough electrolyte drawn up into the syringe to float the hydrometer so as to be able to obtain a reading. This subject will be treated more fully in a later chapter.

Changes at Negative Plate. The charging current changes lead sulphate into spongy lead, and acid is formed. The acid is mixed :with the diluted electrolyte outside of the plates. As the charging proceeds the active material shrinks or contracts, and the weight of the plate actually decreases on account of the difference between the weight and volume of the lead sulphate and spongy lead. If the cell has had only a normal discharge and the charge is begun soon after the discharge ended, the charge will proceed quickly and without an excessive rise in temperature. If, however, the cell has been discharged too far, or has been in a discharged- condition for some time, the lead sulphate will not be in a finely divided state as it should be, but will be hard and tough and will have formed an insulating coating over the active material, causing the charging voltage to be high, and the charge will proceed slowly. When most of the lead sulphate has been reduced to spongy lead, the charging current will be greater than is needed to carry on the chemical actions, and will simply decompose the water into hydrogen and oxygen, and the cell "gasses. " Spongy lead is rather tough and coherent, it, and the 'bubbles of gas which form in the pores of the negative plate near the end of the charge force their way to the surface without dislodging

any of the active material.

Changes at the Positive Plate. When a cell has been discharged, a portion of the lead peroxide has been changed to lead sulphate, which has lodged in the pores of the active material and on its surface. During charge, the lead combines with oxygen from the water to form lead peroxide, and acid is formed. This acid diffuses into the electrolyte as fast as the amount of sulphate will permit. If the discharge has been carried so far that a considerable amount of sulphate has formed in the pores and on the surface of the plate, the action proceeds very slowly, and unless a moderate charging current is used, gassing begins before the charge is complete, simply because the sulphate cannot absorb the current. The gas bubbles which originate in the interior of the plate force their way to the surface, and in so doing cause numerous fine particles of active material to break off and fall to the bottom of the jar. This happens because the lead peroxide is a granular, non-coherent substance, with the particles held together very loosely, and the gas breaks off a considerable amount of active material.

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CHAPTER 7

CAPACITY OF STORAGE BATTERIES

The capacity of a storage battery is the product of the current drawn from a battery, multiplied by the number of hours this current flows. The unit in which capacity is measured is the ampere-hour. Theoretically, a battery has a capacity of 40 ampere hours if it furnishes ten amperes for four hours, and if it is unable, at the end of that time, to furnish any more current. If we drew only five amperes from this battery, it should be able to furnish this current for eight hours. Thus, theoretically, the capacity of a battery should be the same, no matter what current is taken from it. That is, the current in amperes, multiplied by the number of hours the battery, furnished this current should be constant.

In practice, however, we do not discharge a battery to a lower voltage than 1.7 per cell, except when the rate of discharge is high, such as is the case when using the starting motor, on account of the increasing amount of sulphate and the difficulty with which this is subsequently removed and changed into lead and lead peroxide. The capacity of a storage battery is therefore measured by the number of ampere hours it can furnish before its voltage drops below 1.7 per cell. This definition assumes that the discharge is a continuous one, that we start with a fully charged battery and discharge it continuously until its voltage drops to 1.7 per cell.

The factors upon which the capacity of storage batteries depend may be grouped in two main classifications:

1. Design and Construction of Battery.
2. Conditions of Operation.

Design and Construction.

Each classification may be subdivided. Under the Design and Construction we have:

a. Area of plate surface.
2. Quantity, arrangement, and porosity of active materials.
3. Quantity and strength of electrolyte.

4. Circulation of electrolyte.

These sub -classifications require further explanation. Taking them in order:

(a) Area of Plate Surface. It is evident that the chemical and electrical activity of a battery are greatest at the surface of the plates since the acid and active material are in intimate contact here, and a supply of fresh acid is more readily available to replace that which is depleted as the battery is discharged. This is especially true with high rates of discharge, such as are caused in starting automobile engines. Therefore, the capacity of a battery will be greater if the surface area of its plates is increased. With large plate areas a greater amount of acid and active materials is available, and an increase in capacity results.

(b) Quantity, Arrangement, and Porosity of Active, Materials. Since the lead and lead peroxide are changed to lead sulphate on discharge, it is evident that the greater the amount of these materials, the longer can the discharge continue, and hence the greater the capacity.

The arrangement of the active materials is also important, since the acid and active materials must be in contact in order to produce electricity. Consequently the capacity will be greater in a battery, all of whose active materials are in contact with the acid, than in one in which the acid reaches only a portion of the active materials. It is also important that all parts of the plates carry the same amount of current, in order that the active materials may be used evenly. As a result of these considerations, we find that the active materials are supported on grids of lead, that the plates are made thin, and that they have large surface areas. For heavy discharge currents, such as starting motor currents, it is essential that there be large surface areas. Thick plates with smaller surface areas are more suitable for low discharge rates.

Since the inner portions of the active materials must have a plentiful and an easily renewable supply of acid, the active materials must be porous in order that diffusion may be easy and rapid.

(c) Quantity and Strength of Electrolyte. It is important that there be enough electrolyte in order that the acid may not become exhausted while there is still considerable active material left. An insufficient supply of electrolyte makes it impossible to obtain the full capacity from a battery. On the other hand, too much electrolyte, due either to filling the battery too full, or to having the plates in a jar that holds too much electrolyte, results in an increase in capacity up to the limit of the plate capacity. There is a danger present, however, because with an excess of electrolyte the plates will be discharged before the specific gravity of the electrolyte falls to 1.150. This results in over discharge of the battery with its attendant troubles as will be described more fully in a later chapter.

It is a universal custom to consider a battery discharged when the specific gravity of the electrolyte has dropped to 1.150, and that it is fully charged when the specific gravity of the electrolyte has risen to 1.280-1.300. This is true in temperate climates. In tropical countries, which may for this purpose be defined as those countries in which the temperature never falls below the freezing point, the gravity of a fully charged cell is 1.200 to 1.230. The condition of the plates is, however, the true indicator of charged or discharged condition. With the correct amount of electrolyte, its specific gravity is 1.150 when the plates have been discharged as far as it is considered safe, and is 1.280-1.300 when the plates are fully charged. When electrolyte is therefore poured into a battery, it is essential that it contains the proper proportion of acid and water in order that its specific gravity readings be a true indicator of the condition of the plates as to charge or discharge, and hence show accurately how much energy remains in the cell at any time.

A question which may be considered at this point is why in automobile, work a specific gravity of 1.280-1.300 is adopted for the electrolyte of a fully charged cell. There are several reasons. The voltage of a battery increases as the specific gravity goes up. Hence, with a higher density, a higher voltage can be obtained. If the density were increased beyond this point, the acid would attack the lead grids and the separators, and considerable corrosion would result. Another danger of high density is that of sulphation, as explained in a later chapter. Another factor which enters is the resistance of the electrolyte. It is desirable that this be as low as possible. If we should make resistance measurements on various mixtures of acid and water, we should find that with a small percentage of acid, the resistance is high. As the amount of acid is increased, the resistance will grow less up to a certain point. Beyond this point, the resistance will increase again as more acid is added to the mixture. The resistance is lowest when the acid forms 30% of the electrolyte. Thus, if the electrolyte is made too strong, the plates and also the separators will be attacked by the acid, and the resistance of the electrolyte will also increase. The voltage increases as the proportion of acid is increased, but the other factors limit the concentration. If the electrolyte is diluted, its resistance rises, and the amount of acid is insufficient to give much capacity. The density of 1.280-1.300 is therefore a compromise between the various factors mentioned above.

(d) Circulation of Electrolyte. This refers to the passing of electrolyte from one plate to another, and depends upon the ease with which the acid can pass through the pores of the separators. A porous separator allows more energy to be drawn from the battery than a nonporous one.

Operating Conditions.

Considering now the operating conditions, we find several items to be taken into account. The most important are

(e) Rate of discharge.

(f) Temperature.

(e) Rate of Discharge. As mentioned above, the ampere hour rating of a battery is based upon a continuous discharge, starting with a specific gravity of 1.280-1.300, and finishing with 1.150. The end of the discharge is also considered to be reached when the voltage per cell has dropped to 1.7. With moderate rates of discharge the acid is abstracted slowly enough to permit the acid from outside the plates to diffuse into the pores of the plates and keep up the supply needed for the chemical actions. With increased rates of discharge the supply of acid is used up so rapidly. that the diffusion is not fast enough to hold up the voltage. This fact is shown clearly by tests made to determine the time required to discharge a 100 Amp. Hr., 6 volt battery to 4.5 volts. With a discharge rate of 25 amperes, it required 160 minutes. With a discharge rate of 75 amperes, it required 34 minutes. From this we see that making the discharge rate three times as great caused the battery to be discharged in one fifth the time. These discharges were continuous, however, and if the battery were allowed to rest, the voltage would soon rise sufficiently, to burn the lamps for a number of hours.

The conditions of operation in automobile work are usually considered severe. In starting the engine, a heavy current is drawn from the battery for a few seconds. The generator starts charging the battery immediately afterward, and the starting energy is soon replaced. As long as the engine runs, there is no load on the battery, as the generator will furnish the current for the lamps, and also send a charge into the battery. If the lamps are not used, the entire generator output is utilized to charge the battery, unless some current is furnished to the ignition system. Overcharge is quite possible.

When the engine is not running, the lamps are the only load on the battery, and there is no charging current. Various drivers have various driving conditions. Some use their starters frequently, and make only short runs. Their batteries run down. Other men use the starter very seldom, and take long tours. Their batteries will be. overcharged. The best thing that can be done is to set the generator for an output that will keep the battery charged under average conditions,

From the results of actual tests, it may be said that modem lead-acid batteries are not injured in any way by the high discharge rate used when a starting motor cranks the engine. It is the rapidity with which fresh acid takes the place of that used in the pores of the active materials that affects the capacity of a battery at high rates, and not only limitation in the plates themselves. Low rates of discharge should, in fact, be avoided more than the high rates. Battery capacity is affected by discharge rates, only when the discharge is continuous, and the reduction in capacity caused by the high rates of continuous discharge does not occur if the discharge is an intermittent one, such as is actually the case

in automobile work. The tendency now is to design batteries to give their rated capacity in very short discharge periods. If conditions should demand it, these batteries would be sold to give their rated capacity while operating intermittently at a rate which would completely discharge them in three or four minutes. The only change necessary for such high rates of discharge is to provide extra heavy terminals to carry the, heavy current.

The present standard method of rating starting and lighting batteries, as recommended by the Society of Automotive Engineers, is as follows:

"Batteries for combined lighting and starting service shall have two ratings. The first shall indicate the lighting ability, and shall be the capacity in ampere hours of the battery when discharged continuously at the 5 hour rate to a final voltage of not less than 1.7 per cell, the temperature of the battery beginning such discharge being 80°F. The second rating shall indicate the starting ability and shall be the capacity in ampere-hours when the battery is discharged continuously at the 20-minute rate to a final voltage of not less than 1.5 per cell, the temperature of the battery beginning such discharge being 80°F."

The discharge rate required under the average starting conditions is higher than that specified above, and would cause the required drop in voltage in about fifteen minutes. "In winter, when an engine is cold and stiff, the work required from the battery is even more severe, the discharge rate being equivalent in amperes to probably four or five times the ampere-rating of the battery. On account of the rapid recovery of a battery after a discharge at a very high rate, it seems advisable to allow a battery to discharge to a voltage of 1.0 per cell when cranking an engine which is extremely cold and stiff.

(f) Temperature. Chemical reactions take place much more readily at high temperatures than at low. Furthermore, the active materials are more porous, the electrolyte lighter, and the internal resistance less at higher temperatures. Opposed to this is the fact that at high temperatures, the acid attacks the grids and active materials, and lead sulphate is formed, even though no current is taken from the battery. Other injurious effects are the destructive actions of hot acid on the wooden separators used in most starting and lighting batteries. Greater expansion of active material will also occur, and this expansion is not, in general, uniform over the surface of the plates. This results in unequal strains and the plates are bent out of shape, or "buckled." The expansion of the active material will also cause much of it to fall from the plates, and we then have "shedding."

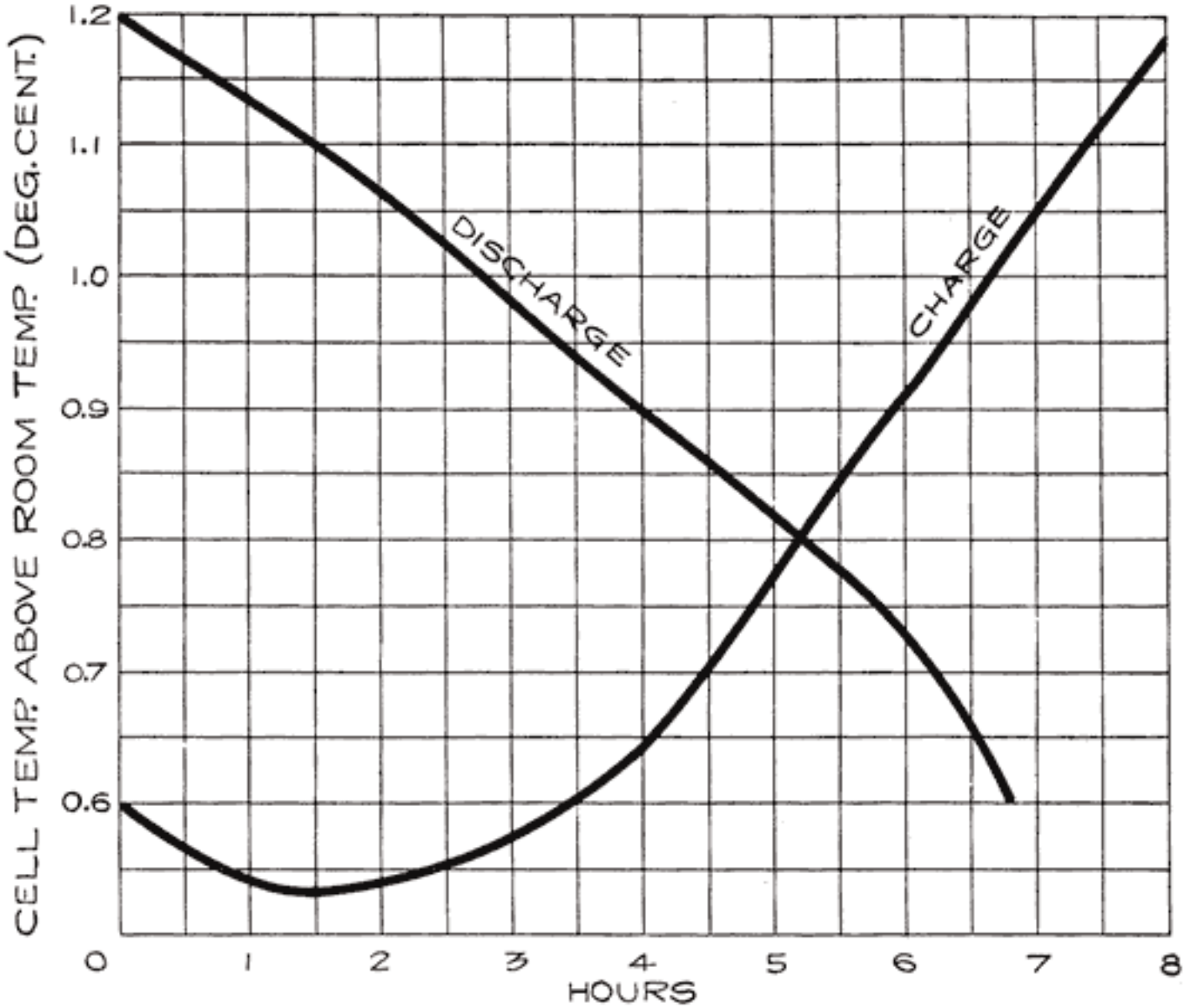

Fig. 25. Theoretical Temperature Changes During Charge and Discharge

When sulphuric acid is poured into water, a marked temperature rise takes place. When a battery is charged, acid is formed, and when this mixes with the diluted electrolyte, a temperature rise occurs. In discharging, acid is taken from the electrolyte, and the temperature has a tendency to drop. On charging, therefore, there is danger of overheating, while on discharge, excessive temperatures are not likely. Fig. 25 shows the theoretical temperature changes on charge and discharge. The decrease in temperature given-in the curve is not actually obtained in practice, because the tendency of the temperature to decrease is balanced by the heat caused by the current passing through the battery.

Age of Battery.

Another factor which should be considered in connection with capacity is the age of the battery. New batteries often do not give their rated capacity when received from the manufacturer. This is due to the methods of making the plates. The "paste" plates, such as are used in automobiles, are made by applying oxides of lead, mixed with a liquid, which generally is dilute sulphuric acid, to the grids. These oxides must be subjected to a charging current in order to produce the spongy lead and lead peroxide. After the charge, they must be discharged, and then again charged. This is necessary because not all of the oxides are changed to active material on one charge, and repeated charges and discharges are required to produce the maximum. amount of active materials. Some manufacturers do not charge and discharge a battery a sufficient number of times before sending it out, and after a battery is put into use, its capacity will increase for some time, because more active material is produced during each charge.

Another factor which increases the capacity of a battery after it is put into use is the tendency of the positive active material to become more porous after the battery is put through the cycles of charge and discharge. This results in an increase in capacity for a considerable time after the battery is put into use.

When, a battery has been in use for some time, a considerable portion of the active material will have fallen from the positive plates, and, a decrease in capacity will result. Such a battery will charge faster than a new one because the amount of sulphate which has formed when the battery is discharged is less than in a newer battery. Hence, the time required to reduce this sulphate will be less, and the battery will "come up" faster on charge, although the specific gravity of the electrolyte may not rise to 1.280.

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CHAPTER 8

INTERNAL RESISTANCE

The resistance offered by a storage battery to the flow of a current through it results in a loss of voltage, and in heating. Its value should be as low as possible, and, in fact, it is almost negligible even I in small batteries, seldom rising above 0.05 ohm. On charge, it causes the charging voltage to be higher and 'on discharge causes a loss of voltage. Fig. 26 shows the variation in resistance.

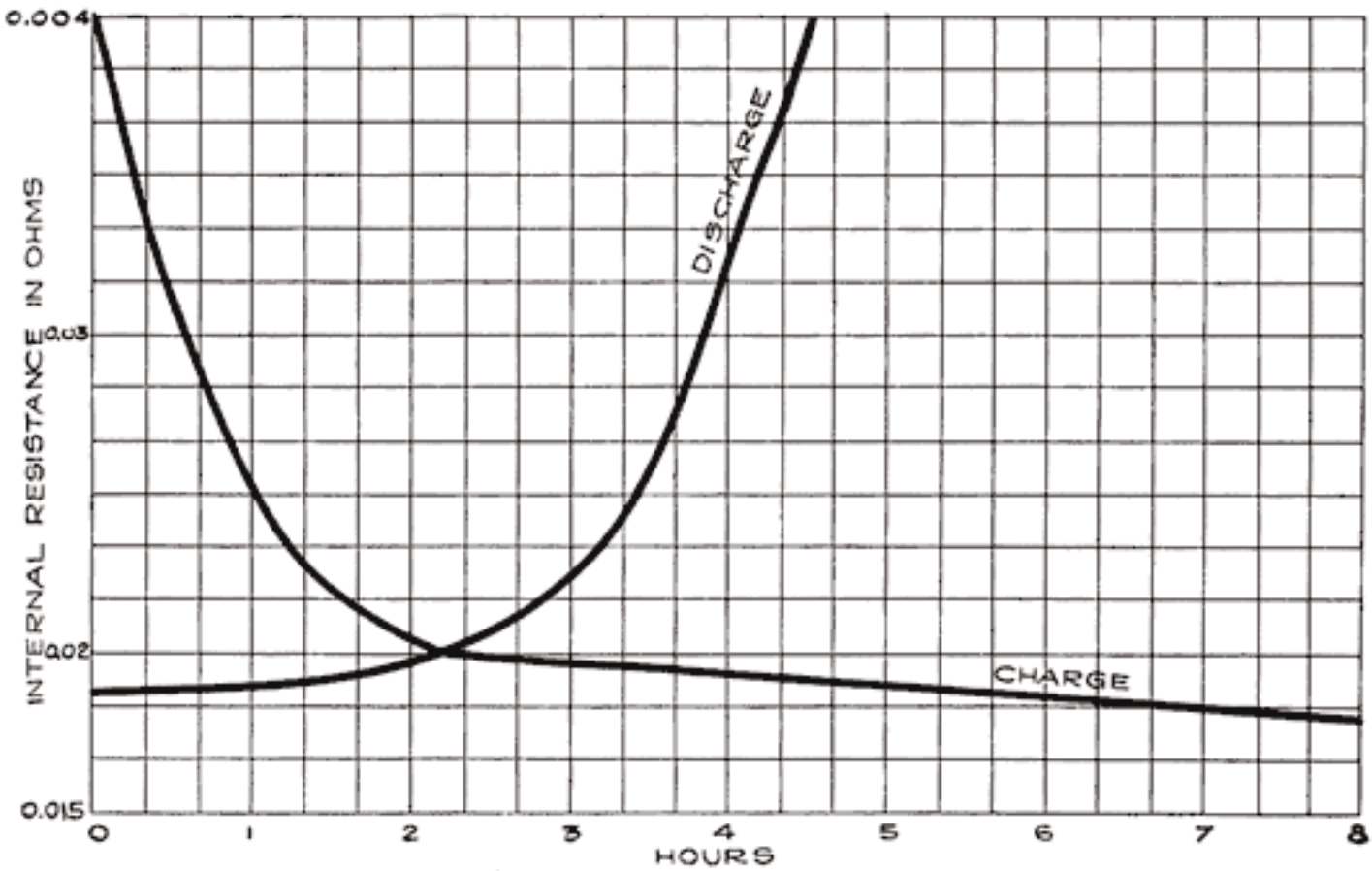

Fig. 26. Changes in Internal Resistance During Charge and Discharge

The resistance as measured between the terminals of a cell is made up of several factors as follows:

1. Grids. This includes the resistance of the terminals, connecting links, -and the framework upon which the active materials are pasted. 'This is but a small part of the total resistance, and does not undergo any considerable change during charge -and discharge. It increases slightly as the temperature of the grids rises.

2. Electrolyte. This refers to the electrolyte between the plates, and varies with the amount of acid and with temperature. As mentioned in the preceding chapter, a mixture of acid and water in which the acid composes thirty per cent of the electrolyte has the minimum resistance. Diluting or increasing the concentration of the electrolyte will both cause an increase in resistance from the minimum I value. The explanation probably lies in the degree to which the acid is split up into "ions" of hydrogen (H), and sulphate (SO_4). These "ions" carry the current through t he electrolyte. Starting with a certain amount of acid, let us see how the ionization progresses. With very concentrated acid, ionization does not take place, and hence, there are no ions to carry current. As we mix the acid with water, ionization occurs. The more water used, the more ions, and hence, the less the resistance, because the number of ions available to carry the current increases. The ionization in creases to a certain maximum degree, beyond which no more ions are formed. It is probable that an electrolyte containing thirty per cent of acid is at its maximum degree of ionization and hence its lowest resistance. If more water is now added, no more ions are formed. Furthermore, the number of ions per unit volume of electrolyte will now decrease on account of the increased amount of water. There Will therefore be fewer ions per unit volume to carry the current, and the resistance of the electrolyte increases.

With an electrolyte of a given concentration, an increase of temperature will cause a decrease in resistance. A decrease in temperature will, of' course, cause an increase in resistance. It is true, in general, that the resistance of the electrolyte is about half of the total resistance of the cell. The losses due to this resistance generally form only one per cent of the total losses, and area practically negligible factor.

3. Active Material. This includes the resistance of the active materials and the electrolyte in the pores of the active materials. This varies considerably during charge and discharge. It has been found that the resistance of the peroxide plate changes much more than that of the lead plate. The change in resistance of the positive plate is especially marked near the end of a discharge. The composition of the active material, and the contact between it and the grid affect the resistance considerably.

During charge, the current is sent into the cell from an external source. The girds therefore carry most of the current. The active material which first reacts with the acid is that near the surface of the plate, and the acid formed by the charging current mixes readily with the main body of electrolyte. Gradually, the charging action takes place in the inner portions of the plate, and concentrated acid is formed in the pores of the plate. As the sulphate is

removed, however, the acid has little difficulty in mixing with the main body of electrolyte. The change in resistance on the charge is therefore not considerable.

During discharge, the chemical action also begins at the surface of the plates and gradually moves inward. In this case, however, sulphate is formed on the surface first, and it becomes increasingly difficult for the fresh acid from the electrolyte to diffuse into the plates so as to replace the acid which has been greatly diluted there by the discharge actions. There is therefore an increase in resistance because of the dilution of the acid at the point of activity. Unless a cell is discharged too far, however, the increase in resistance is small.

If a battery is allowed to stand idle for a long time it gradually discharges itself, as explained in Chapter 10. This is due to the formation of a tough coating of crystallized lead sulphate, which is practically an insulator. These crystals gradually cover and enclose the active material. The percentage change is not high, and generally amounts to a few per cent only. The chief damage caused by the excessive sulphation is therefore not an increase in resistance, but consists chiefly of making a poor contact between active material and grid, and of removing much of the active material from action by covering it.

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CHAPTER 9

CARE OF THE BATTERY ON THE CAR

The manufacturers of Starting and Lighting Equipment have designed their, generators, cutouts, and current controlling devices so as to relieve the car owner of as much work as possible in taking care of batteries. The generators on most cars are automatically connected to the battery at the proper time, and also disconnected from it as the engine slows down. The amount of current which the generator delivers to the battery is automatically prevented from exceeding a certain maximum value. Under the average conditions of driving, a battery is kept in a good condition. It is impossible, however, to eliminate entirely the need of attention on the part of the car owner, and battery repairman.

The storage battery requires but little attention, and this is the very reason why many batteries are neglected. Motorists often have the impression that because their work in caring for a battery is quite simple, no harm will result if they give the battery no attention whatever. If the battery fails to turn over the engine when the starting switch is closed, then instruction books are studied. Thereafter more attention is paid to the battery. The rules to be observed in taking care of the battery which is in service on the car are not difficult to observe. It is while on the car that a battery is damaged, and the damage may be prevented by intelligent consideration of the battery's. housing and living conditions, just as these conditions are made as good as possible for human beings.

1. Keep the Interior of the Battery Box Clean and Dry. On many. cars the battery is contained in an iron box, or under the seat or floorboards. This box must be kept dry, and frequent inspection is necessary to accomplish this. Moisture condenses easily in a metal box, and if not removed will cause the box to become rusty. Pieces of rust may fall on top of the battery and cause corrosion and leakage of current between terminals.

Occasionally, wash the inside of the box with a rag dipped in ammonia, or a solution of baking soda, and then wipe it dry. A good plan is to paint the inside of the box with asphaltum paint. This will prevent rusting, and at the same time will prevent the iron from being attacked by electrolyte which may be spilled, or may leak from the battery.

Some batteries are suspended from the car frame under the floor boards or seat. The iron parts near such batteries should be kept dry and free from rust. If the battery has a roof of sheet iron placed above it, this roof should also be kept clean, dry and coated with asphaltum paint.

Fig. 27. Do not drop tools on top of Battery

2. Put Nothing But the Battery in the Battery Box. If the battery is contained in an iron box, do not put rags, tools, or anything else of a similar nature in the battery box. Do not lay pliers across the top of the battery, as shown in Fig. 27. Such things belong elsewhere. The battery should have a free air space all around it, Fig. 28. Objects made of metal will short-circuit the battery and lead to a repair bill.

3. Keep the battery clean and dry. The top of the battery should be kept free of dirt, dust, and moisture. Dirt may find its way into the cells and damage the battery. A dirty looking battery is an unsightly object, and cleanliness should be maintained for the sake of the appearance of the battery if for no other reason.

Moisture on top of the battery causes a leakage of current between the terminals of the cells and tends to discharge the battery. Wipe off all moisture and occasionally go over the tops of the cell connectors, and terminals with a rag wet with ammonia or a solution of baking soda. This will neutralize any acid which may be present in the moisture.

The terminals should be dried and covered with vaseline. This protects them from being

attacked by acid which may be spilled on top of the battery. If a deposit of a grayish or greenish substance is found on the battery terminals, handles or cell connectors, the excess should be scraped off and the parts should then be washed with a hot solution of baking soda (bicarbonate of soda) until all traces of the substance have been removed. In scraping off the deposit, care should be taken not to scrape off any lead from terminals or connectors. After washing the parts, dry them and cover them with vaseline. The grayish or greenish substance found on the terminals, connectors, or handles is the result of "corrosion," or, in other words, the result of the action of the, sulphuric acid in the electrolyte upon some metallic substance.

Fig. 28. Battery installed so as to have air space on all sides

The acid which causes the, corrosion may be spilled on the battery when hydrometer readings are taken. It may also be the result of filling the cells too full, with subsequent expansion and overflowing as the temperature of the electrolyte increases during charge. Loose vent caps may allow electrolyte to be thrown out of the cell by the motion of the car on the road. A poorly sealed battery allows electrolyte to be thrown out through the cracks left between the sealing compound and the jars or posts. The leaks may be caused by the battery cables not having sufficient slack, and pulling on the terminals.

The cap which fits over the vent tube at the center of the top of each cell is pierced by one or more holes through which gases formed within the cell may escape. These holes must be kept open; otherwise the pressure of the gases may blow off the top of the cell. If these holes are found to be clogged with dirt they should be cleaned out thoroughly.

The wooden battery case should also be kept clean and dry. If the battery is suspended from the frame of the car, dirt and mud from the road will gradually cover the case, and this mud should be scraped off frequently. Occasionally wash the case with a rag wet with ammonia, or hot baking soda solution. Keep the case, especially along the top edges, coated with asphaltum or some other acid proof paint.

Fig. 29. Battery held in place by "hold-down" bolts

4. The battery must be held down firmly. If the battery is contained in an iron box mounted on the running-board, or in a compartment in the body of the car having a door at the side of the

running-board, it is usually fastened in place by long bolts which hook on the handles or the battery case. These bolts, which are known as "hold-downs," generally pass through the running board or compartment, Fig. 29, and are generally fastened in place by nuts. These nuts should be turned up so that the battery is held down tight.

Other methods are also used to hold the battery in place, but whatever the method, it is vital to the battery that it be held down firmly so that the jolting of the car cannot cause it to move. The battery has rubber jars which are brittle, and which are easily broken. Even if a battery is held down firmly, it is jolted about to a considerable extent, and with a loosely fastened battery, the jars are bound to be cracked and broken.

5. The cables connected to the battery must have sufficient slack so that they will not pull on the battery terminals, as this will result in leaks, and possibly a broken cover.

The terminals on a battery should be in such a position that the cables may be connected to them easily, and without bending and twisting them. These cables are heavy and stiff, and once they are bent or twisted they are put under a strain, and exert a great force to straighten themselves. This action causes the cables to pull on the terminals, which become loosened, and cause a leak, or break the cover.

6. Inspect the Battery twice every month in Winter, and once a week in Summer, to make sure that the Electrolyte covers the plates. To do this, remove the vent caps and look down through the vent tube. If a light is necessary to determine the level of the electrolyte,, use an electric lamp. Never bring an open flame, such as a match or candle near the vent tubes of a battery. Explosive gases are formed when a battery "gasses," and the flame may ignite them, with painful injury to the face and eyes of the observer as a result. Such an explosion may also ruin the battery.

During the normal course of operation of the battery, water from the electrolyte will evaporate. **The acid never evaporates. The surface of the electrolyte should be not less than one-half inch above the tops of the plate.** A convenient method of measuring the height of the electrolyte is shown in Fig. 30. Insert one end of a short piece of a glass tube, having an opening not less than one-eighth inch diameter, through the filling hole, and allow it to rest on the upper edge of the plates. Then place your finger over the upper end, and withdraw the tube. A column of liquid will remain in the lower end of the tube, as shown in the figure, and the height of this

column is the same as the height of the electrolyte above the top of the plates in the cell. If this is less than one-half inch, add enough distilled water to bring the electrolyte up to the proper level. Fig. 31 shows the correct height of electrolyte in an Exide cell.

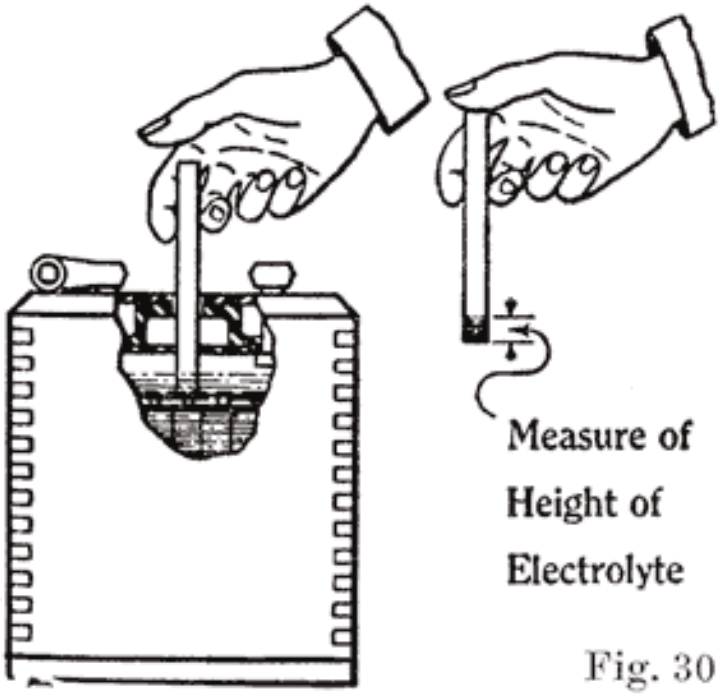

Fig. 30

Never add well water, spring water, water from a stream, or ordinary faucet water. These contain impurities which will damage the battery, if used. It is essential that distilled water be used for this purpose, and it must be handled carefully so as to keep impurities of any kind out of the water. Never use a metal can for handling water or electrolyte for a battery, but always use a glass or porcelain vessel. The water should be stored in glass bottles, and poured into a porcelain or glass pitcher when it is to be used.

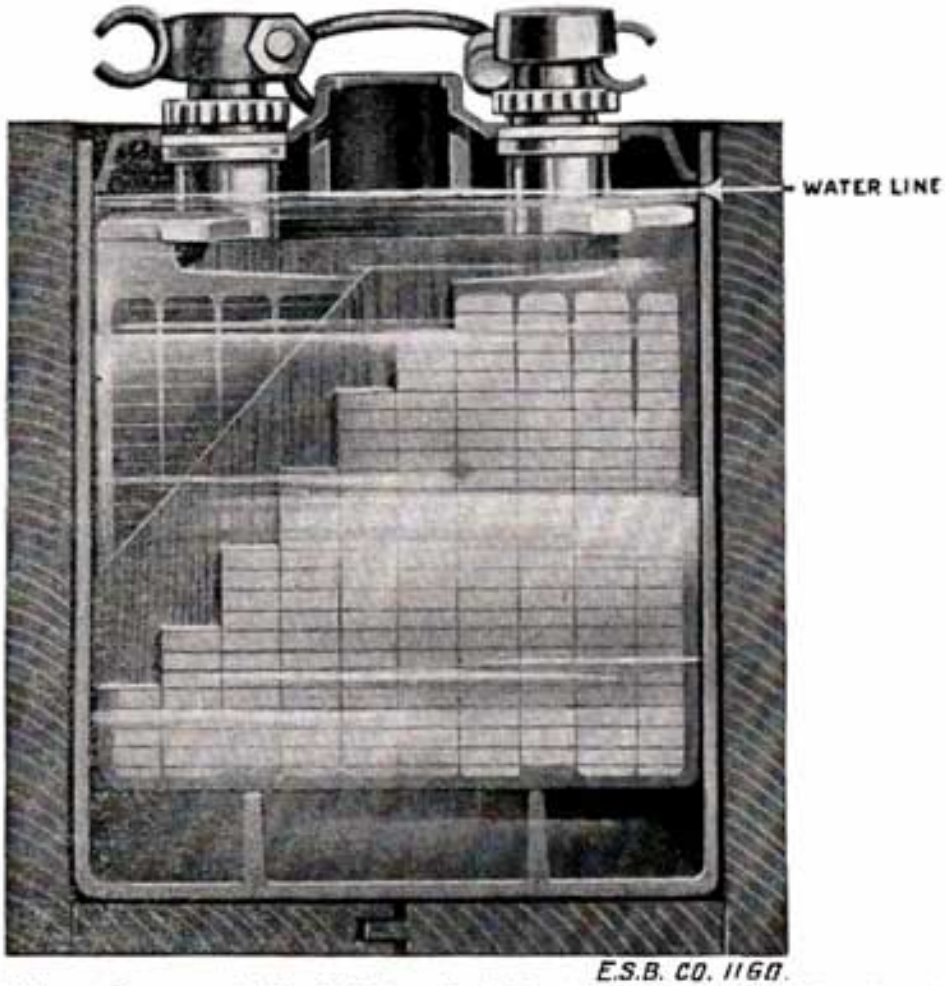

Fig. 31. Correct height of Electrolyte in Exide Cell

A convenient method of adding the water to the battery is to draw some up in a hydrometer syringe and add the necessary amount to the cell by inserting the rubber tube which is at the lower end into the vent hole and then squeezing the bulb until the required amount has been put into the cell.

In the summer time it makes no difference when water is added. **In the winter time**, if the air temperature is below freezing (32° F), start the engine before adding water, and keep it running for about one hour after the battery begins to "gas." A good time to add the water is just before starting on a trip, as the engine will then usually be run long enough to charge the battery, and cause the water to mix thoroughly with the electrolyte. Otherwise, the water, being lighter than the electrolyte, will remain at the top and freeze. Be sure to wipe off water from the battery top after filling. If battery has been wet for sometime, wipe it with a rag dampened with ammonia or baking soda solution to neutralize the acid.

Never add acid to a battery while the battery is on the car. By "acid" is meant a mixture of sulphuric acid and water. The concentrated acid, is of course, never used. The level of the electrolyte falls because of the evaporation of the water which is mixed with the acid in the electrolyte. The acid does not evaporate. It is therefore evident that acid should not be added to a cell to replace the water which has evaporated. Some men believe that a - battery may be

charged by adding acid. This is not true, however, because a battery can be charged only by passing a current through the battery from an outside source. On the car the generator charges the battery.

It is true that acid is lost, but this is not due to evaporation, but to the loss of some of the electrolyte from the cell, the lost electrolyte, of course, carrying some acid with it. Electrolyte is lost when a cell gasses; electrolyte may be spilled; a cracked jar will allow electrolyte to leak out; if too much water is added, the expansion of the electrolyte when the battery is charging may cause it to run over and be lost, or the jolting of the car may cause some of it to be spilled; if a battery is allowed to become badly sulphated, some of the sulphate is never reduced, or drops to the bottom of the cell, and the acid lost in the formation of the sulphate is not regained.

If acid or electrolyte is added instead of water, when no acid is needed, the electrolyte will become too strong, and sulphated plates will be the result. If a battery under average driving conditions never becomes fully charged, it should be removed from the car and charged from an outside source as explained later. If, after the specific gravity of the electrolyte stops rising, it is not of the correct value, some of the electrolyte should be drawn off and stronger electrolyte added in its place. This should be done only in the repair shop or charging station.

Care must be taken not to add too much water to a cell, Fig. 32. This will subsequently cause the electrolyte to overflow and run over the top of the battery, due to the expansion of the electrolyte as the charging current raises its temperature. The electrolyte which overflows is, of course, lost, taking with it acid which will later be replaced by water as evaporation takes place. The electrolyte will then be too weak. The electrolyte which overflows will rot the wooden battery case, and also tend to cause corrosion at the terminals.

If it is necessary to add water very frequently, the battery is operating at too high a temperature, or else there is a cracked jar. The high temperature may be due to the battery being charged at too high a rate, or to the battery being placed near some hot part of the engine or exhaust pipe. The car manufacturer generally is careful not to place the battery too near any such hot part. The charging rate may be measured by connecting an ammeter in series with the battery and increasing the engine speed until the maximum current is obtained. For a six volt battery this should rarely exceed 14 amperes. If the charging, current does not reach a maximum value and then remain constant, or decrease, but continues to rise as the speed of the engine, is increased, the regulating device is out of order. An excessive charging rate will cause continuous gassing if it is much above normal, and the temperature of the electrolyte will be above 100° F. In this way an excessive charging current may be detected.

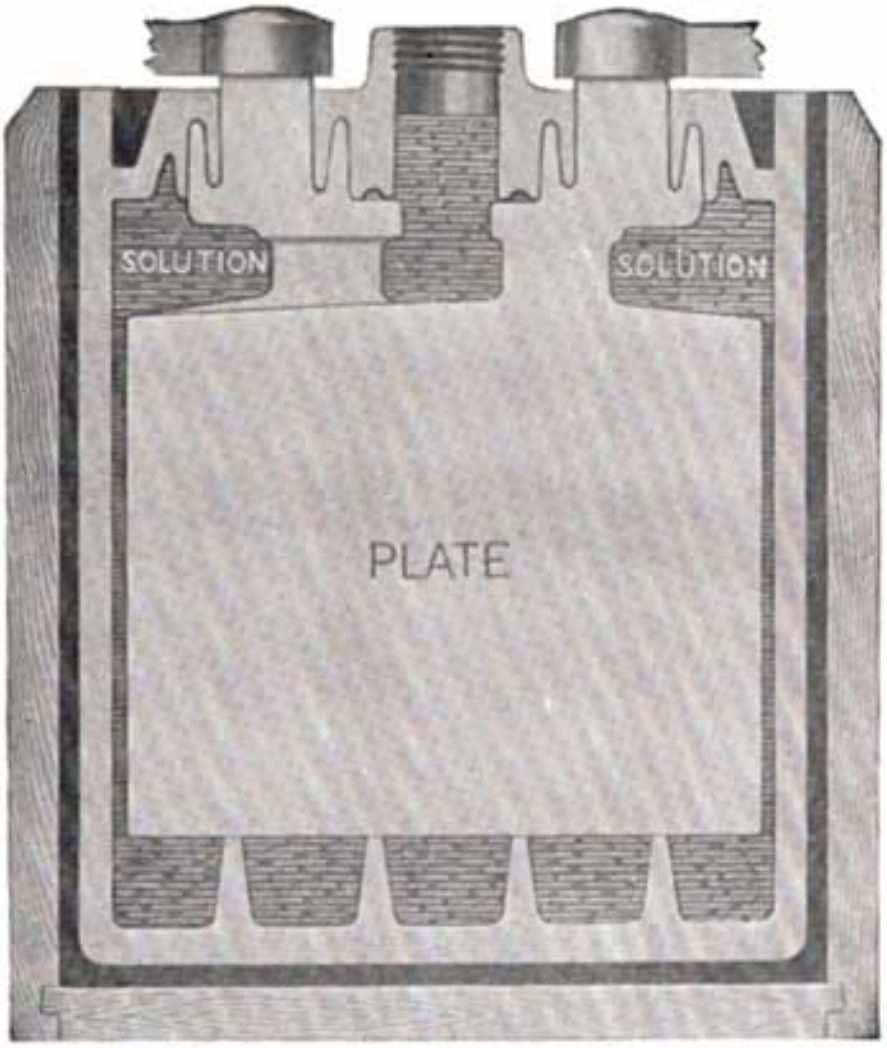

Fig. 32. Cell with level of Electrolyte too high

In hot countries or states, the atmosphere may have such a high temperature that evaporation will be more rapid than in temperate climates, and this may necessitate more frequent addition of water.

If one cell requires a more frequent addition of water than the others, it is probable that the jar of that cell is cracked. Such a cell will also show a low specific gravity, since electrolyte leaks out and is replaced by water. A battery which has a leaky jar will also have a case which is rotted at the bottom and sides. A battery with a leaky jar must, of course, be removed from the car for repairs.

"Dope" Electrolytes

From time to time within the past two years, various solutions which are supposed to give a rundown battery a complete charge within five or ten minutes have been offered to the public. The men selling such "dope" sometimes give a demonstration which at first sight seems to prove their claims. This demonstration consists of holding the starting switch down (with the

ignition off) until the battery can no longer turn over' the engine. They then pour the electrolyte out of the battery, fill it with their "dope," crank the engine by hand, run it for five minutes, and then get gravity readings of 1.280 or over. The battery will also crank the engine. Such a charge is merely a drug-store charge, and the "dope" is generally composed mainly of high gravity acid, which seemingly puts life into a battery, but in reality causes great damage, and shortens the life of a battery. The starting motor test means nothing. The same demonstration could be given with any battery. The high current drawn by the motor does not discharge the battery, but merely dilutes the electrolyte which is in the plates to such an extent that the voltage drops to a point at which the battery can no longer turn over the starting motor. If any battery were given a five minutes' charge after such a test, the diluted electrolyte in the plates would be replaced by fresh acid from the electrolyte and the battery would then easily crank the engine again. The five minutes of running the engine does not put much charge- into the battery but gives time for the electrolyte to diffuse into the plates.

Chemical analysis of a number of dope electrolytes has shown that they consist mainly of high gravity acid, and that this acid is not even chemically pure, but contains impurities which would ruin a battery even if the gravity were not too high. The results of some of the analyses are as follows:

No. 1. 1.260 specific gravity sulphuric acid, 25 parts iron, 13.5 parts chlorine, 12.5, per cent sodium sulphate, 1 per cent nitric acid.

No. 2. 1.335 specific gravity sulphuric acid, large amounts of organic matter, part of which consisted of acids which attack lead.

No. 3. 1.340 specific gravity sulphuric acid, 15.5 per cent sodium sulphate.

No. 4. 1.290 specific gravity sulphuric acid, 1.5 per cent sodium sulphate.

No. 5. 1.300 specific gravity sulphuric acid.

If such "dope" electrolytes are added to a discharged battery, the subsequent charging of the battery will add more acid to the electrolyte, the specific gravity of which will then rise much higher than it should, and the plates and separators are soon ruined.

Do not put faith in any "magic" solution which is supposed to work wonders. There is only **one** way to charge a battery, and that is to send a current through it, and there is only one electrolyte to use, and that is the standard mixture of distilled water and chemically pure sulphuric acid.

7. The specific gravity of the electrolyte should be measured every two weeks and a permanent record of the readings made for future reference.

The specific gravity of the electrolyte is the ratio of its weight to the weight of an equal volume of water. Acid is heavier than water, and hence the heavier the electrolyte, the more acid it,

contains, and the more nearly it is fully charged. In automobile batteries, a specific gravity of 1.300-1.280 indicates a fully charged battery. Generally, a gravity of 1.280 is taken to indicate a fully, charged cell, and in this book this will be done. Complete readings are as follows:

1.300-1.280--Fully charged.

1.280-1.200--More than half charged.

1.200-1.150--Less than half charged.

1.150 and less--Completely discharged.

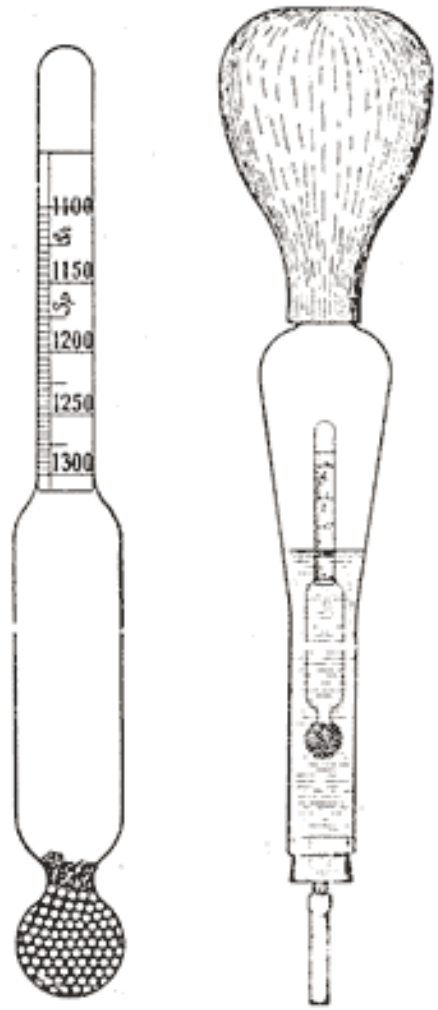

Fig. 33 Fig. 34

For determining the specific gravity, a hydrometer is used. This consists of a small sealed glass tube with an air bulb and a quantity of shot at one end, and a graduated scale on the upper end. This scale is marked from 1.100 to 1.300, with various intermediate markings as shown in Fig. 33. If this hydrometer is placed in a liquid, it will sink to a certain depth. In so doing, it will displace a certain volume of the electrolyte, and when it comes to rest, the volume displaced will just be equal to the weight of the hydrometer. It will therefore sink farther in a light liquid than in a heavy one, since it will require a greater volume of the light liquid to equal the weight of the hydrometer. The top mark on the hydrometer scale is therefore 1.100 and the bottom one 1.300. Some hydrometers are not marked with figures that indicate the specific gravity, but are marked with the words "Charged," "Half Charged," "Discharged," or "Full," "Half Full," "Empty," in place of the figures.

For convenience in automobile work, the hydrometer is enclosed in a large tube of glass or other transparent, acid proof material, having- a short length of rubber tubing at its lower end, and a large rubber bulb at the upper end. The combination is called a hydrometer-syringe, or simply hydrometer. See Figure 34. In measuring the specific gravity of the electrolyte, the vent cap is removed, the bulb is

squeezed (so as to expel the air from it), and the rubber tubing inserted in the hole from which the cap was removed. The pressure on the bulb is now released, and electrolyte is drawn up into the glass tube. The rubber tubing on the hydrometer should not be withdrawn from the cell. When a sufficient amount of electrolyte has entered the tube, the hydrometer will float. In taking a reading, there should be no pressure on the bulb, and the hydrometer should be floating freely and not touching the walls of the tube. The tube must not be so full of electrolyte that the upper end of the hydrometer strikes any part of the bulb,

Fig. 35. Taking a Specific Gravity Reading

The tube must be held in a vertical position, Fig. 35, and the stem of the hydrometer must be vertical. The reading will be the number on the stem at the surface of the electrolyte in the tube, Fig. 36. Thus if the hydrometer sinks in the electrolyte until the electrolyte comes up to the 1.150 mark on the stem, the specific gravity is 1.150.

If the battery is located in such a position that it is impossible to hold the hydrometer straight up, the rubber tube may be Pinched shut with the

fingers, after a sufficient quantity of electrolyte has been drawn from the cell and the hydrometer then removed and held in a vertical position.

Specific gravity readings should never be taken soon after distilled water has been added to the battery. The water and electrolyte do not mix immediately, and such readings will give misleading results. The battery should be charged several hours before the readings are taken. It is a good plan to take

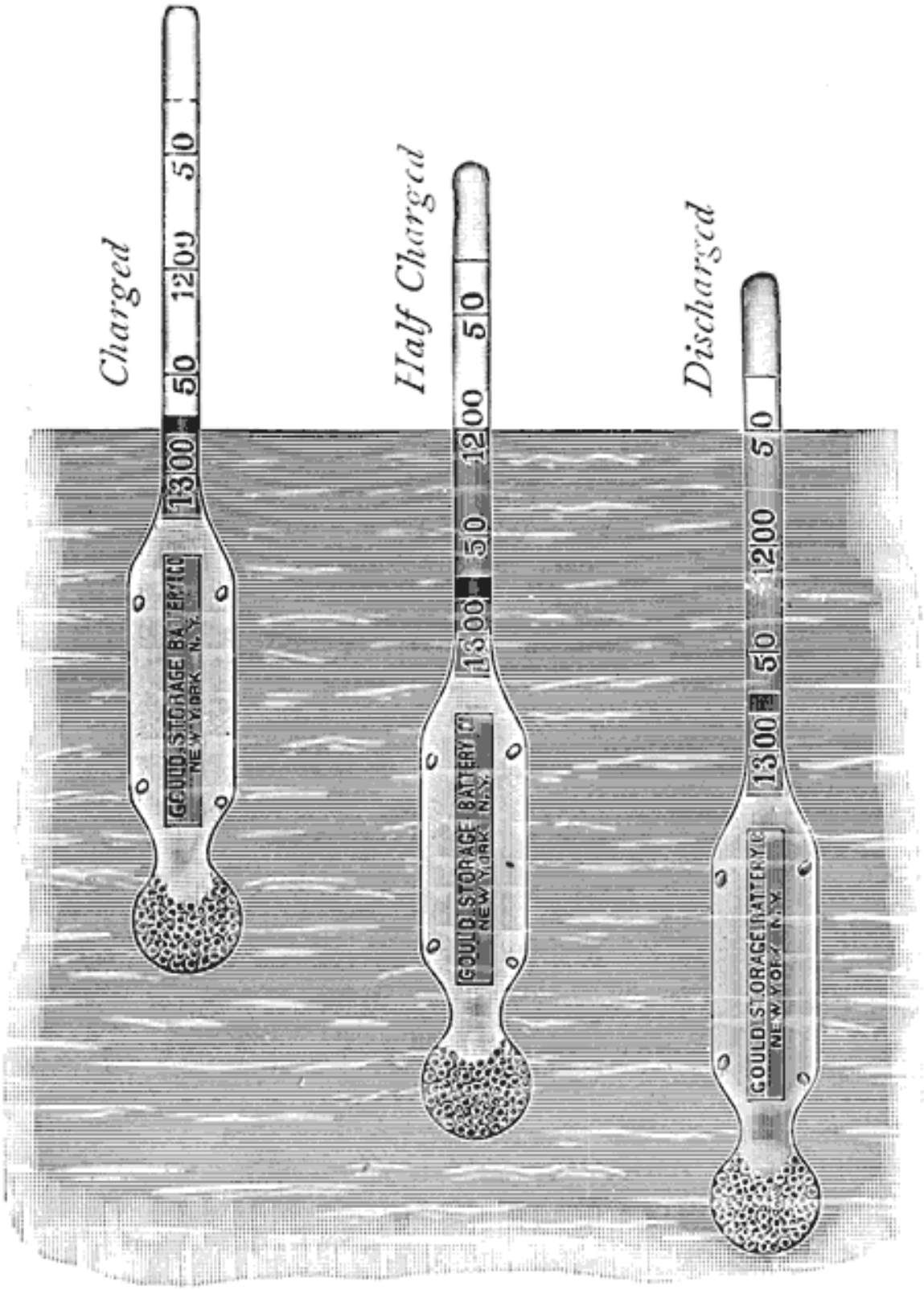

Fig. 36. Hydrometer reading showing cell Charged, Half Charged, and Discharged

Fig. 36. Hydrometer reading showing cell Charged, Half Charged, and Discharged

a specific gravity reading before adding any water, since accurate results can also be obtained in this way.

Having taken a reading, the bulb is squeezed so as to return the electrolyte to the cell.

Care should be taken not to spill the electrolyte from the hydrometer syringe when testing the gravity. Such moisture on top of the cells tends to cause a short circuit between the terminals and to discharge the battery.

In making tests with the hydrometer, the electrolyte should always be returned to the same cell from which it was drawn.

Failure to do this will finally result in an increased proportion of acid in one cell and a deficiency of acid in others.

The specific gravity of all cells of a battery should rise and fall together, as the cells are usually connected in series so that the same current passes through each cell both on charge and discharge.

If one cell of a battery shows a specific gravity which is decidedly lower than that of the other cells in series with it, and if this difference gradually increases, the cell showing the lower gravity has internal trouble. This probably consists of a short circuit, and the battery should be opened for inspection. If the electrolyte in this cell falls faster than that of the other cells, a leaky jar is indicated. The various cells should have specific gravities within fifteen points of each other, such as 1.260 and 1.275.

If the entire battery shows a specific gravity below 1.200, it is not receiving enough charge to replace the energy used in starting the engine and supplying current to the lights, or else there is trouble in the battery. Use starter and lights sparingly until the specific gravity comes up to 1.280-1.300. If the specific gravity is less than 1.150 remove the battery from the car and charge it on the charging bench, as explained later. The troubles which cause low gravity are given on pages 321 and 322.

It is often difficult to determine what charging current should be delivered by the generator. Some generators operate at a constant voltage slightly higher than that of the fully charged battery, and the charging current will change, being higher for a discharged battery than for one that is almost or fully charged. Other generators deliver a constant current which is the same regardless of the battery's condition.

In the constant voltage type of generator, the charging current automatically adjusts itself to the condition of the battery. In the constant current type, the generator current remains constant, and the voltage changes somewhat to keep the current constant. Individual cases often require that another current value be used. In this case, the output of the generator must be changed. With most generators, a current regulating device is used which may be adjusted so as to give a fairly wide range of current, the exact value chosen being the result of a study of driving conditions and of several trials. The charging current -should never be made so high that the temperature of the electrolyte in the battery remains above 90° F. A special thermometer is very useful in determining the temperature. See Fig. 37. The thermometer bulb is immersed in the electrolyte above the plates through the filler hole in the tops of the cells.

Batteries used on some of the older cars are divided into two or more sections which are connected in parallel while the engine is running, and in such cases the cables leading to the different sections should all be of exactly the same length, and the contacts in the switch which connect these sections in parallel should all be clean and tight. If cables of unequal length are used, or if some of the switch contacts are loose and dirty, the sections will not receive equal charging currents, because the resistances of the charging circuits will not be equal. The section having the greatest resistance in its circuit will receive the least amount of charge, and will show lower specific gravity readings than for other sections. In a multiple section battery, there is therefore a tendency for the various sections to receive unequal charges, and for one or more sections to run down continually. An ammeter should be attached with the engine running and the battery charging, first to one section and then to each of the others in turn. The ammeter should be inserted and removed from the circuit while the engine remains running and all conditions must be exactly the same; otherwise the comparative results will not give reliable indications. It would be better still to use two ammeters at the same time, one on each section of the battery. In case the amperage of charge should differ by more than 10% between any two sections, the section receiving the low charge rate should be examined for proper height of electrolyte, for the condition of its terminals and its connections at the starting switch, as described. Should a section have suffered considerably from such lack of charge, its voltage will probably have been lowered. With all connections made tight and clean and with the liquid at the proper height in each cell, this section may automatically receive a higher charge until it is brought back to normal. This high charge results from the comparatively low voltage of the

section affected.

In case the car is equipped with such a battery, each section must carry its proper fraction of the load and with lamps turned on or other electrical devices in operation the flow from the several sections must be the same for each one. An examination should be made to see that no additional lamps, such as trouble lamps or body lamps, have been attached on one side of the battery, also that the horn and other accessories are so connected that they draw from all sections at once.

Some starting systems have in the past not been designed carefully in this respect, one section of the battery having longer cables attached to it than the others. In such systems it is impossible for these sections to receive as much charging current as others, even though all connections and switches are in good condition. In other systems, all the cells of the battery are in series, and therefore must receive the same charging current, but have lighting wires attached to it at intermediate points, thus dividing the battery into sections for the lighting circuits. If the currents taken by these circuits are -not equal, the battery section supplying the heavier current will run down faster than others. Fortunately, multiple section batteries are not being used to any great extent at present, and troubles due to this cause are disappearing.

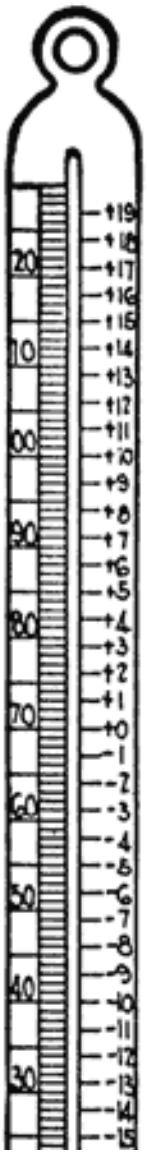

The temperature of the electrolyte affects the specific gravity, since heat causes the electrolyte to expand. If we take any battery or cell and heat it, the electrolyte will expand and its specific gravity will decrease, although the actual amount of acid is the same. The change in specific gravity amounts to one point, approximately, for every three degrees Fahrenheit. If the electrolyte has a gravity of 1.250 at 70°F, and the temperature is raised to 73°F, the specific gravity of the battery will be 1.249. If the temperature is decreased to 67°F, the specific gravity will be 1.251. Since the change of temperature does not change the actual amount of acid in the electrolyte, the gravity readings as obtained with the hydrometer syringe should be corrected -one point for every three degrees change in temperature. Thus **70°F is considered the normal temperature**, and one point is added to the electrolyte reading for every three degrees above 70°F. Similarly, one point is subtracted for every three degrees below 70°F. For convenience of the hydrometer user, a special thermometer has been developed by battery makers. This is shown in Fig. 37. It has a special scale mounted beside the regular scale. This scale shows the corrections which must be made when the temperature is not 70°F. Opposite the 70° point on the thermometer is a "0" point on the special scale. This indicates that no correction is to be made. Opposite the 67° point on the regular scale is a -1, indicating that 1 must be subtracted from the hydrometer reading to find what the specific gravity would be if the temperature were 70°F. Opposite the 73° point on the regular

scale is a +1, indicating that 1 point must be added to reading on the hydrometer, in order to reduce the reading of specific gravity to a temperature of 70°F.

8. Storage batteries are strongly affected by changes in temperature. Both extremely high and very low temperatures are to be avoided. At low temperatures the electrolyte grows denser, the porosity of plates and separators decreases, circulation and diffusion of electrolyte are made difficult, chemical actions between plates and acid take place very slowly, and the whole battery becomes sluggish, and acts as if it were numbed with cold. The voltage and capacity of the battery are lowered.

As the battery temperature increases, the density of the electrolyte decreases, the plates and separators become more porous, the internal resistance decreases, circulation and diffusion of electrolyte take place much more quickly, the chemical actions between plates and electrolyte proceed more rapidly, and the battery voltage and capacity increase. A battery therefore works better at high temperatures.

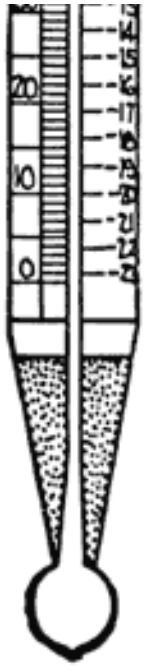

Fig. 37

Special Thermometer

Excessive temperatures, say over 110° F, are, however, more harmful than low temperatures. Evaporation of the water takes place very rapidly, the separators are attacked by the hot acid and are ruined, the active materials and plates expand to such an extent that the active materials break away from the grids and the grids warp and buckle. The active materials themselves are burned and made practically useless. The hot acid also attacks the grids and the sponge lead and forms dense layers of sulphate. Such temperatures are therefore extremely dangerous.

A battery that persistently runs hot, requiring frequent addition of water, is either receiving too much charging current, or has internal trouble. The remedy for excessive charge is to decrease the output of the generator, or to burn the lamps during the day time. Motorists who make long touring trips in which considerable day driving is done, with little use of the starter, experience the most trouble from high temperature. The remedy is either to decrease the charging rate or burn the lamps, even in the day time.

Internal short-circuits cause excessive temperature rise, both on charge and discharge. Such short circuits usually result from buckled plates which break through the separators, or from an excessive amount of sediment. This sediment consists of active material or lead sulphate which has dropped from the positive plate and fallen to the bottom of the battery jar. All battery jars are provided with ridges which keep the plates raised an inch or more from the bottom of the jar, and which form pockets into which the materials drop. See Fig. 10. If these

pockets become filled, and the sediment reaches the bottom of the plates, internal short circuits result which cause the battery to run down and cause excessive temperatures.

If the electrolyte is allowed to fall below the tops of the plates, the parts of the plates above the acid become dry, and when the battery is charged grow hot. The parts still covered by the acid also become hot because all the charging current is carried by these parts, and the plate surface is less than before. The water will also become hot and boil away. A battery which is thus "charged while dry" deteriorates rapidly, its life being very short.

If a battery is placed in a hot place on the car, this heat in addition to that caused by charging will soften the plates and jars, and shorten their life considerably.

In the winter, it is especially important not to allow the battery to become discharged, as there is danger of the electrolyte freezing. A fully charged battery will not freeze except at an extremely low temperature. The water expands as it freezes, loosening the active materials, and cracking the grids. As soon as a charging current thaws the battery, the active material is loosened, and drops to the bottom of the jars, with the result that the whole battery may disintegrate. Jars may also be cracked by the expansion of the -water when a battery freezes.

To avoid freezing, a battery should therefore be kept charged, The temperatures at which electrolyte of various specific gravities freezes are as follows:

Specific Gravity	Freezing Pt.
1.000	32°F
1.050	26°F
1.100	18°F
1.150	5°F
1.200	-16°F
1.250	-58°F
1.280	-92°F

1.300	-96°F

9. Care of Storage Battery When Not in Service. A storage battery may be out of service for a considerable period at certain times of the year, for example, when the automobile is put away during the winter months, and during this time it should not be allowed to stand without attention. When the battery is to be out of service for only three or four weeks, it should be kept well filled with distilled water and given as complete a charge as possible the last few days, the car is in service by using the lamps and starting motor very sparingly. The specific gravity of the electrolyte in each cell should be tested, and it should be somewhere between 1.280 and 1.300. All connections to the battery should be removed, as any slight discharge current will in time completely discharge it, and the possibilities of such an occurrence are to be avoided. If the battery is to be put out of service for several months, it should be given a complete charge by operating the generator on the car or by connecting it to an outside charging circuit. During the out-of-service period, water should be added to the cells every six or eight weeks and the battery given what is called a freshening charge; that is, the engine should be run until the cells have been gassing for perhaps one hour, and the battery may then be allowed to stand for another similar period without further attention. Water should be added and the battery fully charged before it is put back into service. It is desirable to have the temperature of the room where the battery is stored fairly constant and as near 70 degrees Fahrenheit as possible.

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CHAPTER 16

SPECIAL INSTRUCTIONS

EXIDE BATTERIES

Exide batteries may be classified according to their cover constructions as follows:

1. Batteries with single flange covers, as shown in Figs. 15 and 238. This class includes types DX, LX, LXR, LXRV, PHC, XC, XX, and XXV.

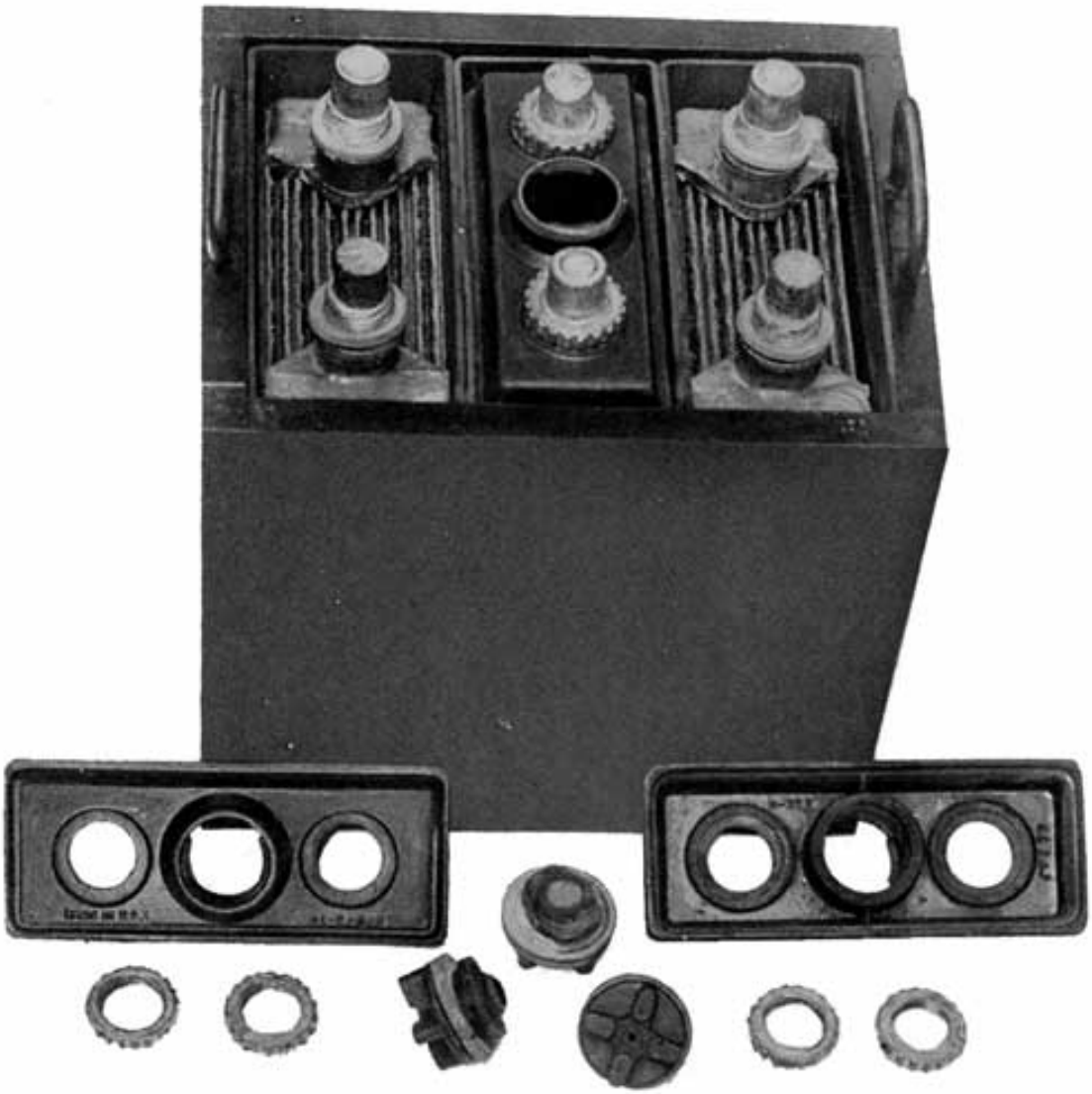

Fig. 238. Exide Battery, Partly Disassembled

2. Batteries with double flange covers, as shown in Fig. 242. This class includes types MHA, KZ, KXD, LXRE, and XE. The cover constructions are-described in Chapter 3.

All Exide batteries, except types KXD, LXRE, and XE, have burned-in lead top connectors. All types have a removable sealing nut around each post to make a tight joint between the post and cell cover, as described on page 19. Formerly some Exide batteries had cell connectors -which were bolted to the cell posts, but this construction is now obsolete. Types KXD, LXRE, and XE have cell connectors made of flexible, lead coated copper strips.

Types DX, LX, LXR, LXRV, MHA, PHC, XC, XX, and XXV have been designed and built to meet the requirements of starting, lighting and ignition service* for passenger automobiles and power boats.

Types KXD, LXRE, and XE have been especially developed to meet the requirements of the starting, lighting and ignition service on motor trucks and tractors.

Type KZ has been produced particularly for motorcycle lighting and ignition service.

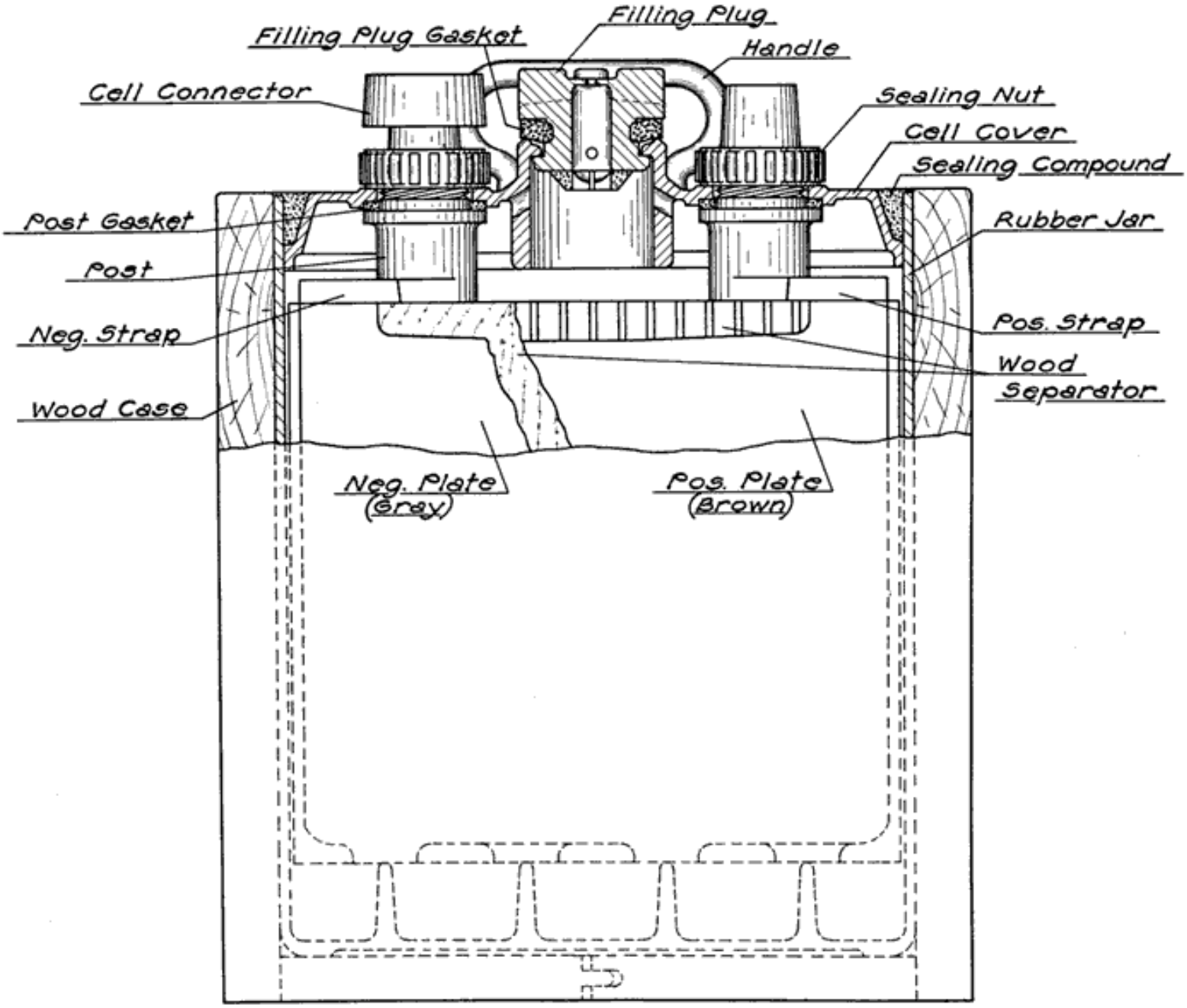

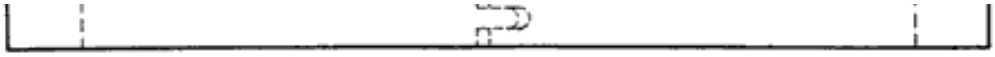

Fig. 239. Exide Battery with Single Flange Cover

Type Numbers

The type of an Exide battery is stamped on the battery name plate. Thus, on one of the most popular Exide batteries is marked Type 3-XC-13-1. Other Exide batteries have different numerals and letters in their type numbers, but the numerals., and letters are always arranged in the same order as given above. The first numeral gives the number of cells. The letters give the type of cell. The numerals following the letters give the number of plates per cell. The last numeral indicates the manner of arranging the cells in the battery case. Thus, in the example given above, 3-XC-13-1 indicates that there are three cells in the battery, that the type of cell is XC, that each cell has 13 plates, and that the cells are arranged according to method No. 1, this being a side to side assembly.

Methods of Holding Jars in Case

Two methods of holding Exide jars in the battery case are used:

1. Types MHA, KXD, LXRE, and XE have the jars separated by horizontal wooden spacers, there being two spacers between adjoining jars. Running horizontally between these two spacers are tie bolts which pass through the case. These bolts are tightened after the jars are placed in the case, thus pressing the sides of the case against the jars and holding them in, place.

Types KXD, LXRE, and XE, in addition to the tie bolts, are secured in the case by sealing compound beneath and around the jars. Each cell is provided with two soft rubber buffers which are V shaped, and are placed over the ridges in the bottom of the jars, thereby minimizing the effect of shocks on the plates and separators which rest on the buffers.

2. In types DX, LX, LXR, LXRV, PHC, XC, XX, and XXV, there are no spacers between adjoining jars, and the jars simply fit tight in the case. Should they not fit tight enough to hold them in place securely, thin boards are inserted between the jars and the case to pack them in.

Type KZ has the three sets of plates in one jar, having three compartments, with a three compartment cover.

Opening Exide Batteries

1. Drilling Off the Top Connectors. Do this as described on page 329. For type KZ batteries use a 3/8 inch drill. For all other types use a 5/8 inch drill.

2. Removing Plates from Jars. Follow the general instructions on page 333.

Types DX, LX, LXR, LXRV, PHC, XC, XX, and XXV. In opening these batteries, all of which have the single flange cover, you may remove each cell complete from the case, and then draw out the plates; or you may draw out the plates without taking out the jars. To remove the complete cell, heat a thin bladed putty knife and work it down all around the outside of the jar. Then lift out the complete cell by pulling steadily on the cell posts with two pairs of gas pliers. The battery should be placed on the floor when you do this, and you should stand with one foot pressed against the side of the case.

If you do not wish to remove the complete cells, or should the jars fit too tight in the case, unseal the covers and

remove the plates according to the instructions given on page 333.

Types KZ and MHA. These batteries have the double flanged cover. Several methods may be used in removing the plates from the jars. In each case, the top of the cell is cleaned, gas blown out of the vent holes, and the sealing nuts removed before opening the cells.

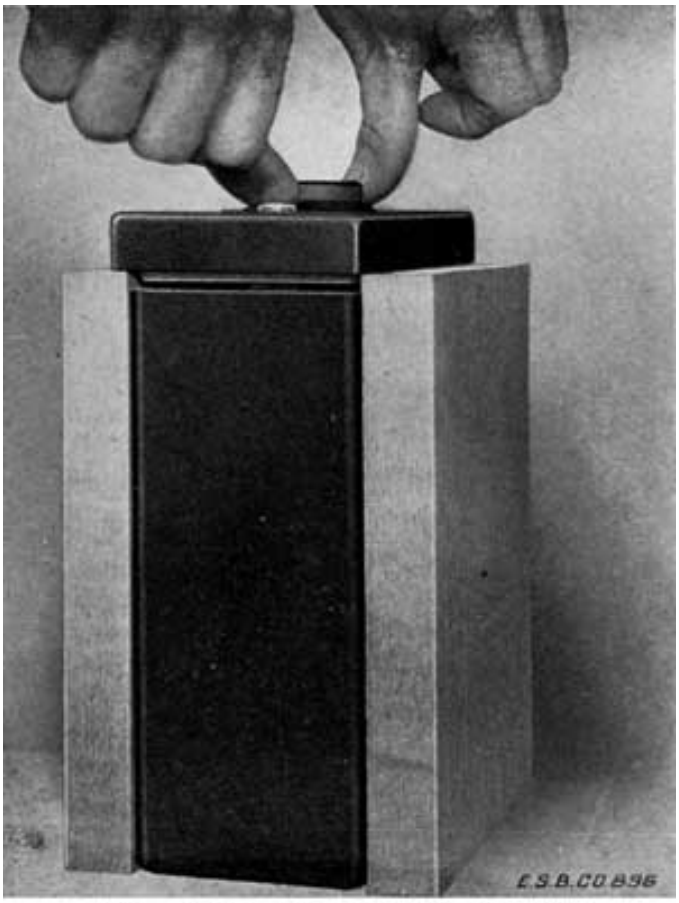

Fig. 240. Removing Double Flange Exide Cover

First, a flame may be used to soften the sealing compound which is placed in the slot formed by the two flanges of the cover. If you wish to use a flame, first remove each complete cell from the case, loosening the tie bolts that pass through the case to release the jars. Then hit out each complete cell. Now get two strong boards which are about one fourth inch longer than the height of the jar. See Fig. 240. Support the jar on these boards by resting the lower edge of the sides of the cover on the top edge of the boards. Then run a moderate flame around the outside of the flange until the cover is soft, and the compound melting. Then press down on the cell posts with your thumbs, and the jar. and plates will drop free of the cover. The plates are then drawn out and rested on the top of the jars to drain, as usual.

Another method is to remove the cells from the case and put them in the battery steamer for ten minutes as described on page 332. Instead of first taking the complete cells out of the case and then steaming them separately, you may steam the entire battery for about ten minutes, and then draw out the plates and cover of each cell with gas pliers without removing the jars. This method must be used in opening types KXD, LXRE, and XE, which have sealing compound 'under the jars.

Work on Plates, Separators, Jars, and Case

Having opened the battery, follow the instructions given on pages 335 to 361 for examination of plates and separators, and all work on plates, jars, separators, and case.

Reassembling Plates

Fig. 241. Upsetting Threads to Prevent Nut from Turning

First slip the positive and negative groups together without separators. Then wipe the posts with a rag moistened with ammonia, rinse them with water, and dry thoroughly with a clean rag. Next slip the soft rubber washers over the posts and place the cover in position. Lubricate the lead sealing nuts with graphite that has been mixed to a paste with water. Do not use grease or vaseline to lubricate these nuts. Then put on the sealing nuts and tighten them partly with your fingers.

You are now ready to insert the separators as directed on page 361. Types MHA, PHC, KXD, KZ, LXR, LXRE, LXRV, XX, and XXV have, in addition to the usual wooden separators, perforated rubber sheets, which should be placed against the grooved side of each wooden separator before inserting, and insert with rubber sheet against the positives.

Make a careful examination to see that you have not left out any separators.

When the separators are all in place, even them up on each side. Then tighten the sealing nuts with the special Exide wrench. When you have turned the nuts down tight, lock them in place by driving a center punch on the threads on the post just above the nut, Fig. 241. This will damage the thread and prevent the nut from turning loose.

Putting Plates In Jars

The next step is to lower the plates into the jars, as described on page 362. In types KXD, LXRE, and XE be sure to first replace the two soft rubber buffers in the bottom of the jar, one over each ridge.

Filling Jars With Electrolyte

As soon as you have an element in place in the jar, fill the jar with electrolyte of the proper strength, as described on page 364, to prevent the separators and plates from drying. The negatives, especially, must be covered with electrolyte to prevent them from heating and drying.

Sealing Exide Battery Covers

For Types DX, LX, LXR, LXRV, PHC, XC, XX, and XXV, which have the single flange type of cover, slowly heat the sealing compound until it runs, but do not get it so thin that it will run down into the cell between the cover and jar. Then pour it into the channel between cover and jar walls. Allow it to cool and finish it off -flush with a hot knife. When pouring, be sure the compound is liquid and not lumpy, as in such a case a poor seal will result. A glossy, finished appearance may be given to the compound by passing a flame over it

after the job is finished.

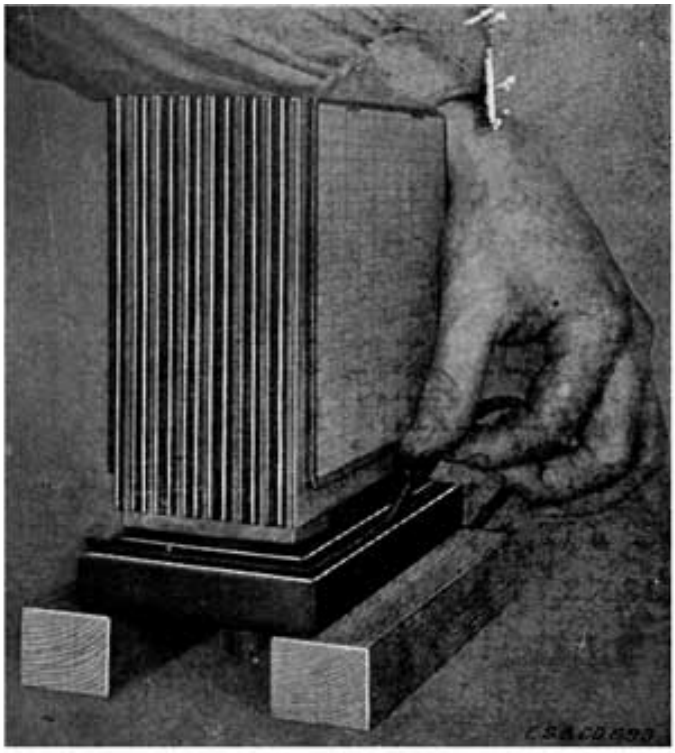

Fig. 242. Laying "Worm" of Sealing Compound in Exide Double Flange Cover

For Types KXD, KZ, LXRE, MHA, and XE, which have the double flange type of cover, have ready a string or worm of sealing compound about 3-16 inch in diameter, made by rolling between boards some of the special compound furnished for the purpose. The cover may or may not have been attached to the element, depending on how repairs have been made. In either case the procedure is the same as far as sealing is concerned. Assuming the element is attached, stand it upside down, with the cover resting upon two strips, Fig. 242. Lay the string of compound all around the cover channel. Now turn right side up and insert in the jar, taking care that the jar walls enter the cover channels at all points. Apply heat carefully to the edges of the cover and gently force cover clown. If too much compound has been used, so that it squeezes out around the cover, scrape off the excess with a hot knife while forcing cover down.

(Chart "Capacity of Exide Batteries" Omitted. Information not really useful.)

Putting Cells In Case

When the covers have all been sealed, put the cells in the case, taking care to put the negative and positive posts in their proper positions, so that each cell connector will connect a positive to a negative post.

In Types MHA, KXD, LXRE, and XE, which have wooden spacers between the cells, take care that the spacers- are in position and then, after cells are in place, tighten the tie bolts with a screw driver to clamp the jars.

In Types DX, LX, LXR, LXRV, SX, XC, XX, and XXV the cells should fit tight in the case; pack them in with thin boards if necessary.

Burning on the Cell Connectors

See instructions on pages 213 to 216.

Charging After Repairing

See also instructions on page 373.

Not sooner than ten to fifteen hours after filling battery with electrolyte, add electrolyte to restore level if it has fallen.

U. S. L. BATTERIES

The instructions for rebuilding batteries which have already been given, pages 328 to 374, apply also to all U. S. L. batteries. In working on the old U. S. L. batteries, illustrated in Fig. 243, draw out the electrolyte down to the tops of the plates so that the electrolyte is below the lower end of the vent tube. Then blow out any gas which may have collected under the cover with compressed air or bellows. Never fail to do this, as there is only a small vent hole in the cover through which the gas can escape, the vent tubes extending down into the electrolyte when the cells are properly filled.

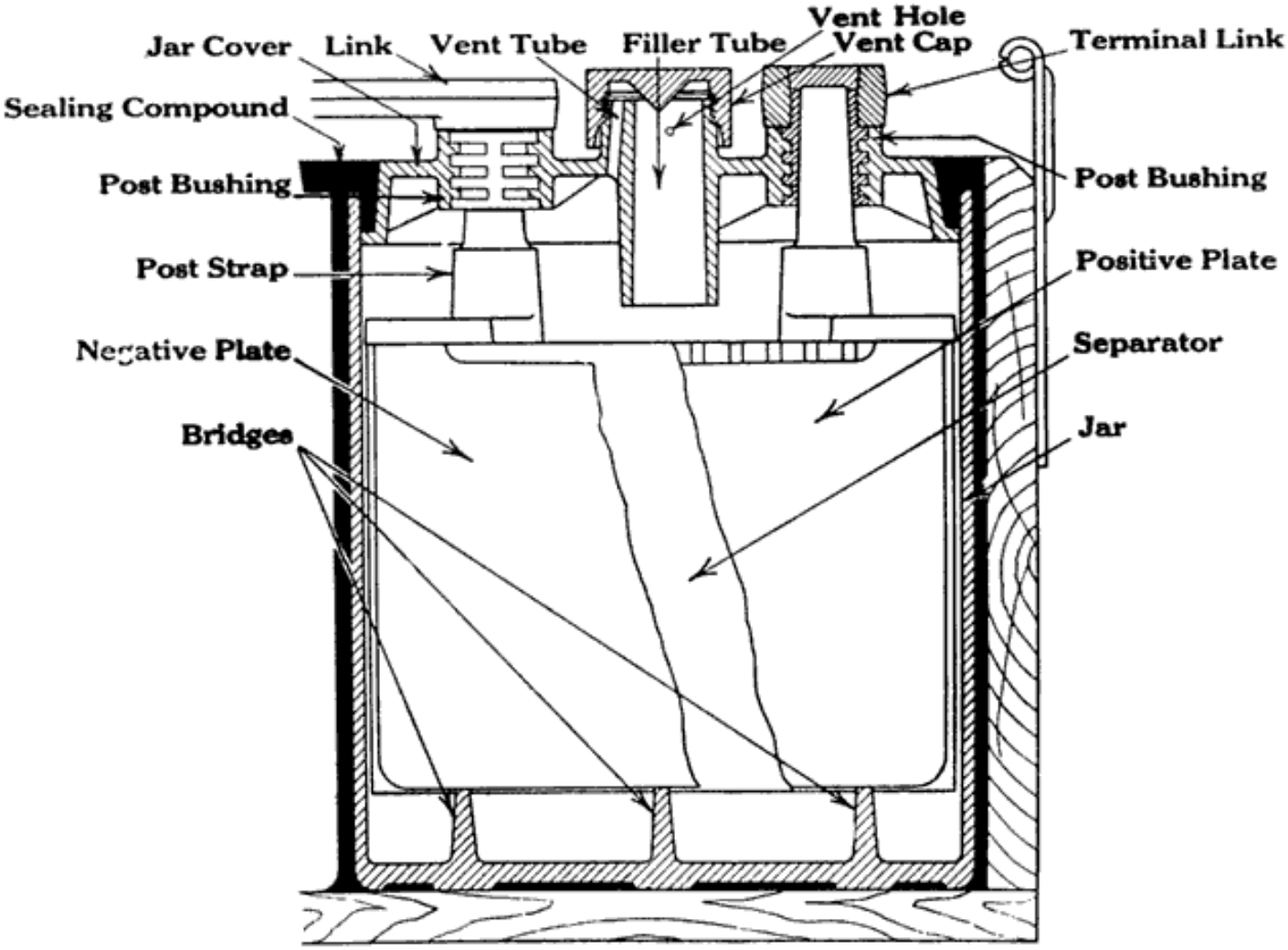

Fig. 243. Cross Section of Old Type U. S. L. Battery

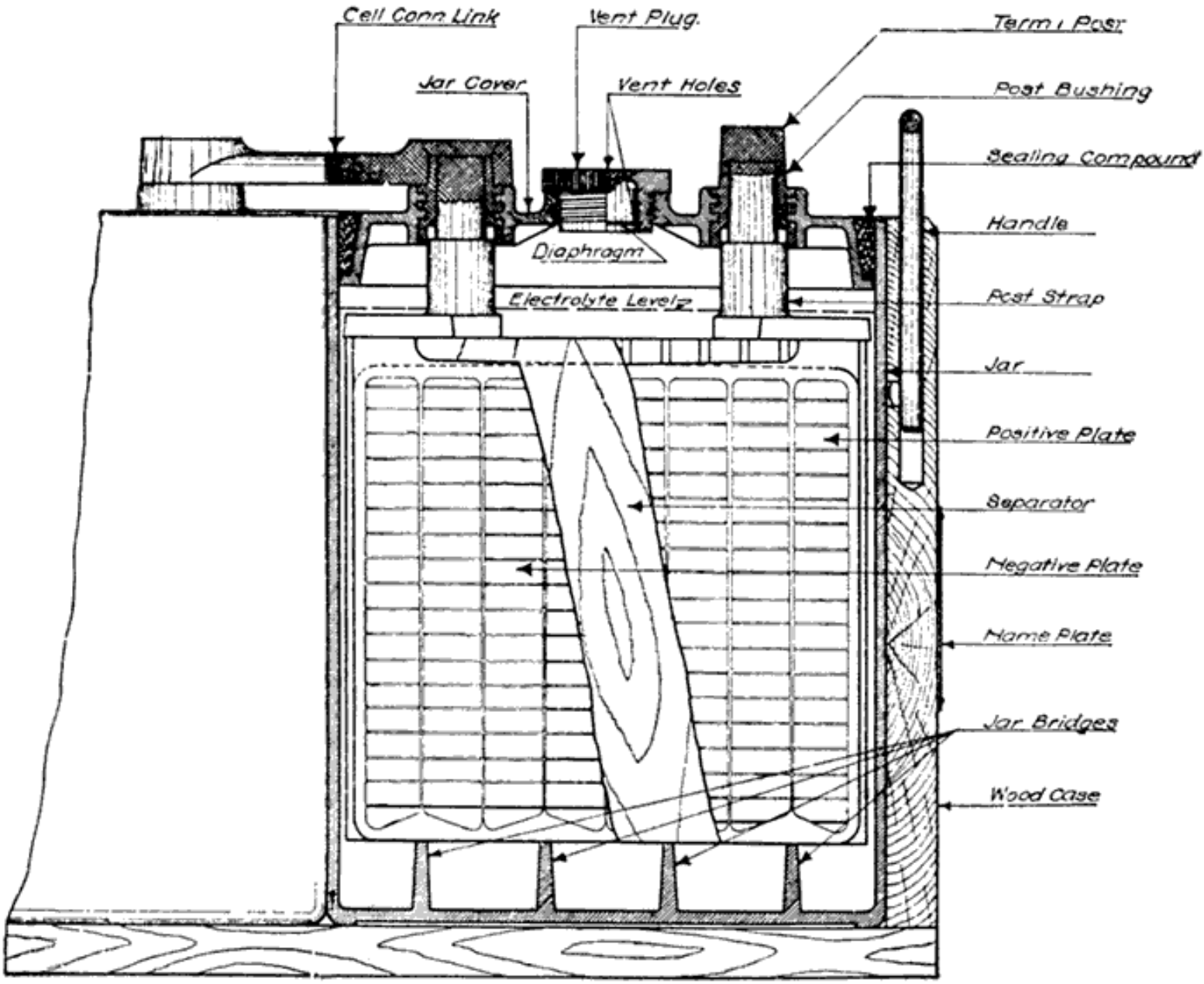

Fig. 244. Cross Section of New Type U. S. L. Battery

Fig. 244 shows the new U. S. L. cover construction. Note that the special cell filling device is no longer used. U. S. L. batteries have lead bushings moulded into the cover. These bushings fit around the posts, and are burned to the posts and top connectors, Figs. 243 and 244, thus giving leak proof joints between the cover and the posts. In burning on the connectors, melt bottom edge of hole first, then top of post and cover bushing, and melt in your burning lead slowly.

(Two charts - "Capacity of U.S.L. Batteries" omitted. Information not really useful.)

PREST-O-LITE BATTERIES

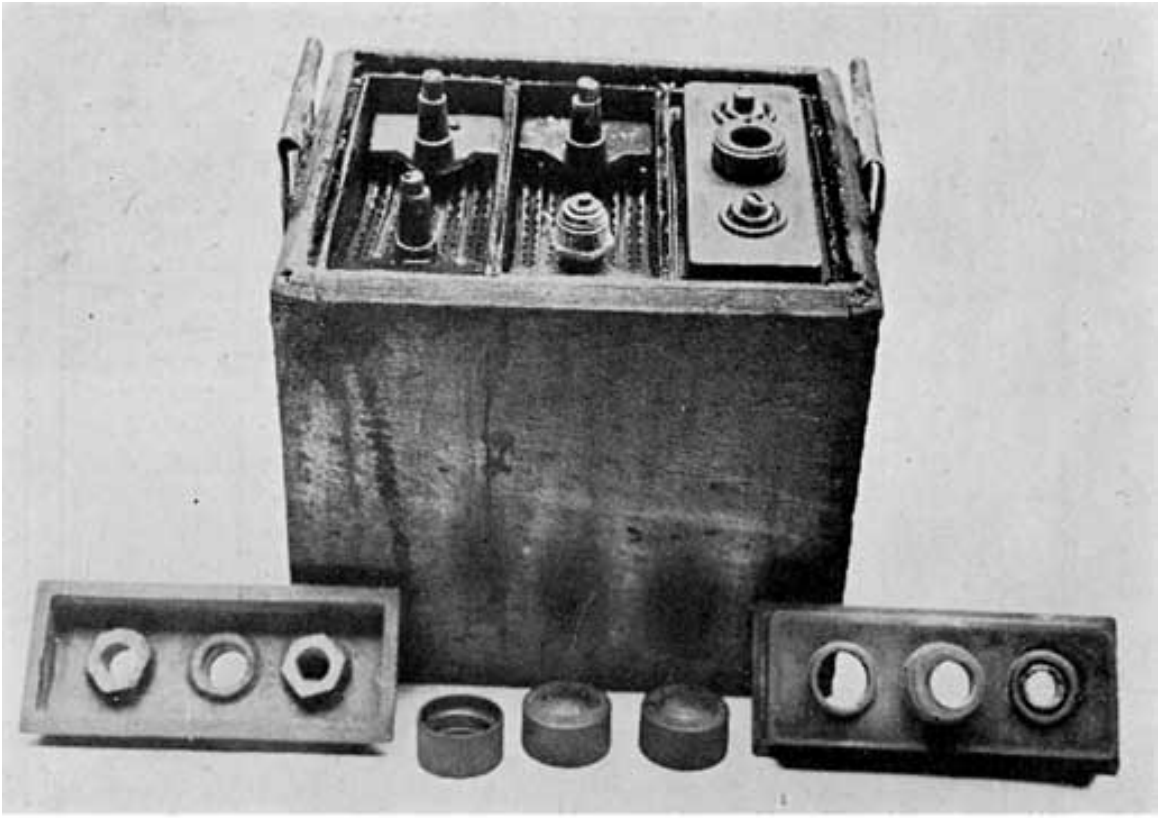

Fig. 245. Old Type Prest-O-Lite Battery with Lead Bushings That Screw Up Into Cover

Some of the old Prest-O-Lite batteries have a lead bushing around the post, Fig. 245, similar to the U. S. L. batteries. This will make a perfectly tight seal, provided that you screw the. bushing up tight. The new types of Prest-O-Lite batteries have a "Peened" post seal, special instructions for which follow.

The general instructions for rebuilding batteries given on pages 328 to 374 apply to Prest-O-Lite batteries in every respect. The "Peened" post seal is, however, a special construction, and directions for working on this seal are as follows:

All Prest-O-Lite batteries designated as Types WHN, RIJN, BHN, JFN, KPN, and SHC, have a single moulded. cover which is locked directly on to the posts of the element. This feature is the result of forcing a solid ring of lead from a portion of the post, projecting above the cover, down into a deep chamfer in the top of the cover. Figs. 246 and 247 show this construction.

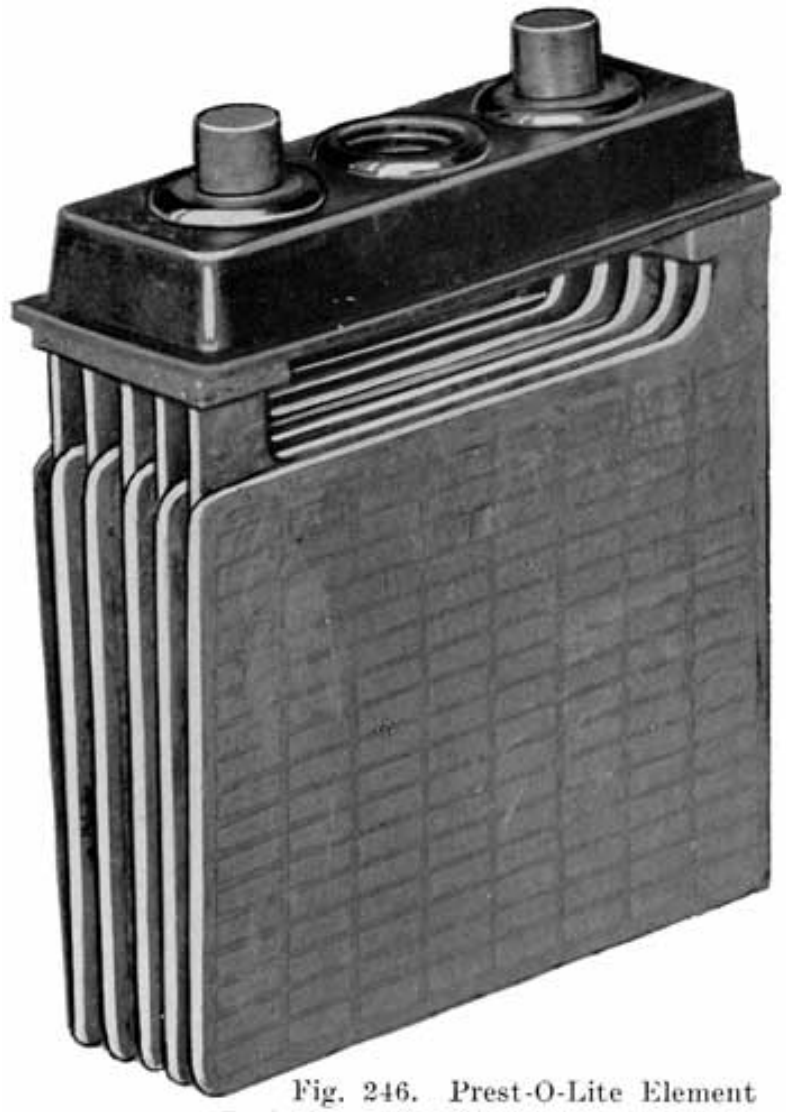

Fig. 246. Prest-O-Lite Element Locked to Cover by Peening Process

This construction makes a solid unit of the cover and element, which does away with the sealing compound, washers, nuts, etc., for making the acid tight seal around the posts.

The locking operation requires some special instructions and shop equipment for assembly and all repairs which involve removal from and replacement of the cover on the element.

The majority of battery repairs such as renewal of jars, separators, straightening of plates, and removal of sediment, can be made without separating the cover and element. In such cases the connectors are drilled off, compound is softened and removed from around the covers and the complete unit is removed from the cell. It may be handled throughout the repair as a unit, and the cover serves as a bridge to hold the plates of both groups in line just as they remain in the jar.

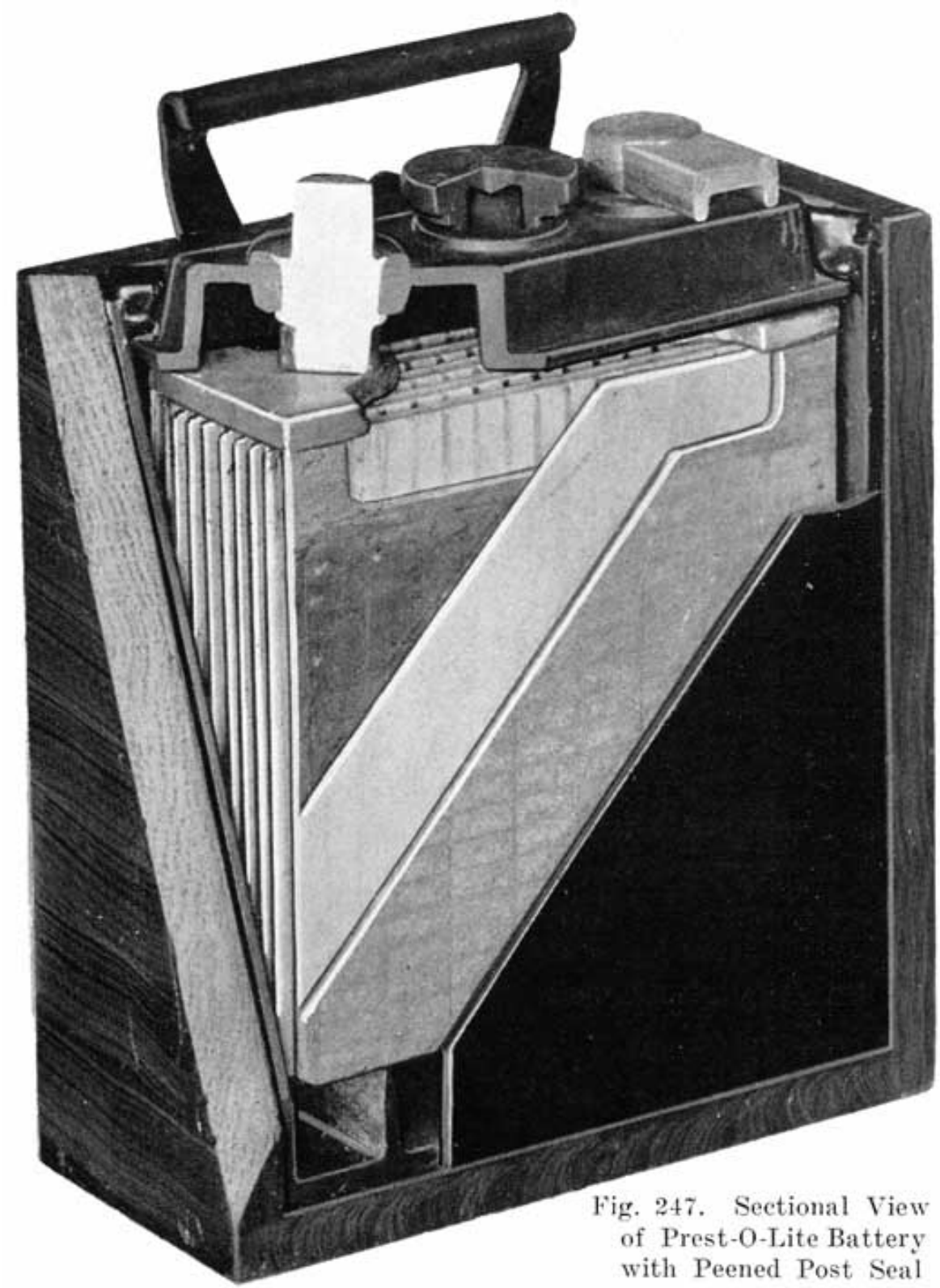

Fig. 247. Sectional View of Prest-O-Lite Battery with Peened Post Seal

However, where the cover is broken or must be replaced for other reasons, when plates have to be renewed, or the posts have been broken off below the cover, the element and cover must be separated.

All the apparatus and special tools which are used in connection with the locking, as well as the building-up, unlocking (freeing), and rebuilding, of the posts in all Prest-O-Lite battery types are grouped together and collectively termed the type "N" Post Locking Outfit.

This outfit, complete, is carried in stock at all Prest-O-Lite warehouses under the part number 27116. Each of

the individual parts or tools also has a separate part number and may be bought separately.

Prest-O-Lite Type "N" Post Locking Outfit

Arbor Press (complete with following 12 parts)	27115
Main Casting	27114
Latch	27107
Bed Plate	27113
Lever	27108
Rack	`27211
Washer	27112
Pinion Shaft	27110
Pinion	27109
Latch Pin	27111
*Special CLN & KPN Spacer	27233
*Special CLN & KPN Latch	27232
*Special CLN & KPN Bed Plate	27234
Large Peening Tool (9-21 RHN, WHN, BHN, SHC, KPN, CLN; 11-17 JFN)	27101
Small Peening Tool (7-WHN, RHN, SHC; 9-JFN)	27100
Peening Tool for small terminal posts in which are east threaded brass inserts (Columbia)	27105
Large Post Freeing Tool	27103

Small Post Freeing Tool	27102
No. 8 Post Freeing Tool (13/16" diameter straight post)	27123
[1] Large Post Re-Builder (9-21 RHN, WHN, BHN, SHC, KPN, CLN; 11-17 JFN)	27005
[1] Small Post Re-Builder (7-WHN, RHN, SHC; 9-JFN)	27004
[2] Ford Positive Post Builder	27006
[2] Ford Negative Post Builder	27224
2 No. 8 Post Builder (13/16" diameter straight post)	27225
Style "B" Prest-O-Lite Torch, with six feet of red gum tubing	A-3116
Automatic Reducing Valve	A-427
COMPLETE TYPE "N" OUTFIT including all parts above	27116

* The CLN and KPN Spacer block, bent Latch and Bed Plate are special parts used only in the Arbor Press when it is especially assembled to lock CLN or KPN posts.

[1] The Re-Builder is used to build up posts before attempting to lock on the cover. The replacing of the metal cut away from the original diameter of the post when the jar cover was removed is necessary to the correct operation of the Peening Tool.

[2] The Builder is used to build up posts, after they have been locked and shaped by the Peening Tool, to a size large enough to take some special terminal. For example, the Ford Positive Post Builder is used in building up posts, locked by the Large Peening Tool, to the proper size to take the Ford positive terminal.

The Automatic Reducing Valve delivers the gas from the P-O-L tank at a uniform pressure of 3 pounds per square inch, whether the tank is full, half empty, or nearly empty, and regardless of the volume of gas used. The volume or flow of gas is regulated by the key.

The style "B" torch mixes the pure acetylene from the gas tank with the proper amount of air necessary to an efficient heating flame.

The heating flame is conducted or delivered to the Peening Tool by the short length of brass tubing known as the Torch-Holder, over which the "B" Torch is pressed by hand in completing the assembly.

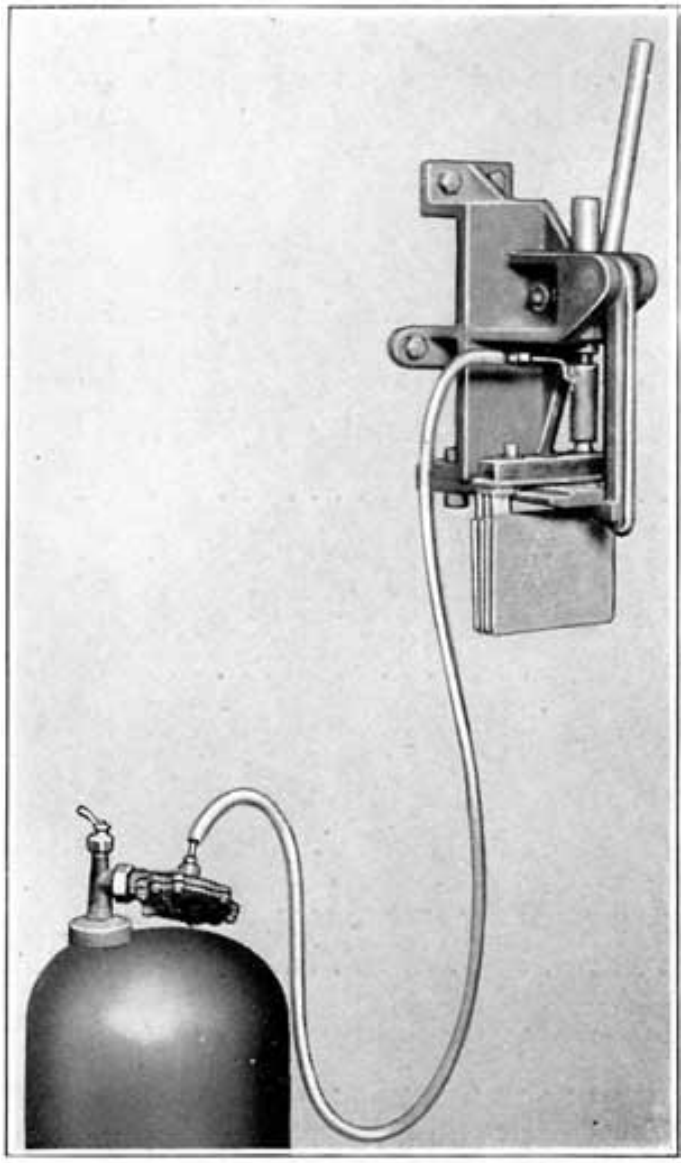

Fig. 248. Special Prest-O-Lite Peening Press

Both the "B" Torch and the Automatic Reducing Valve are absolutely essential to the use of the Prest-O-Lite gas tank for heating the Peening Tool.

Prest-O-Lite gas tanks, style A, B, C, or E, may be used in connection with the Automatic Reducing Valve, as shown in Fig. 248. To use a welding size gas tank it is necessary to insert a "W to A" Adapter between the tank and Reducing Valve. This- Adapter can be purchased from the Prest-O-Lite Co., Inc.

The Arbor Press when received by the Service Station is fully assembled, ready for mounting and operation with all P-O-L locked post types except CLN and KPN.

Mount the Press in a vertical position (Fig. 248) in a convenient place and at an accessible height on a wall or post. Holes are provided in the Press for mounting by lag screws or bolts. The position of the Peening Tool should be well below the level of the eyes, to prevent serious injury from a possible spattering of overheated lead.

Screw the proper size Peening Tool into the bottom of the Press rack, as shown in Fig. 248. The Torch-Holder must be removed from the Peening Tool to do this; it should be immediately replaced.

In using the Press to lock CLN or KPN posts it is necessary to remove the Bed Plate and the Latch, and replace these parts with the Special Bed Plate and Special Latch provided for this purpose, using the spacing block or Spacer (also provided) between the Special Bed Plate and the bottom of the Press.

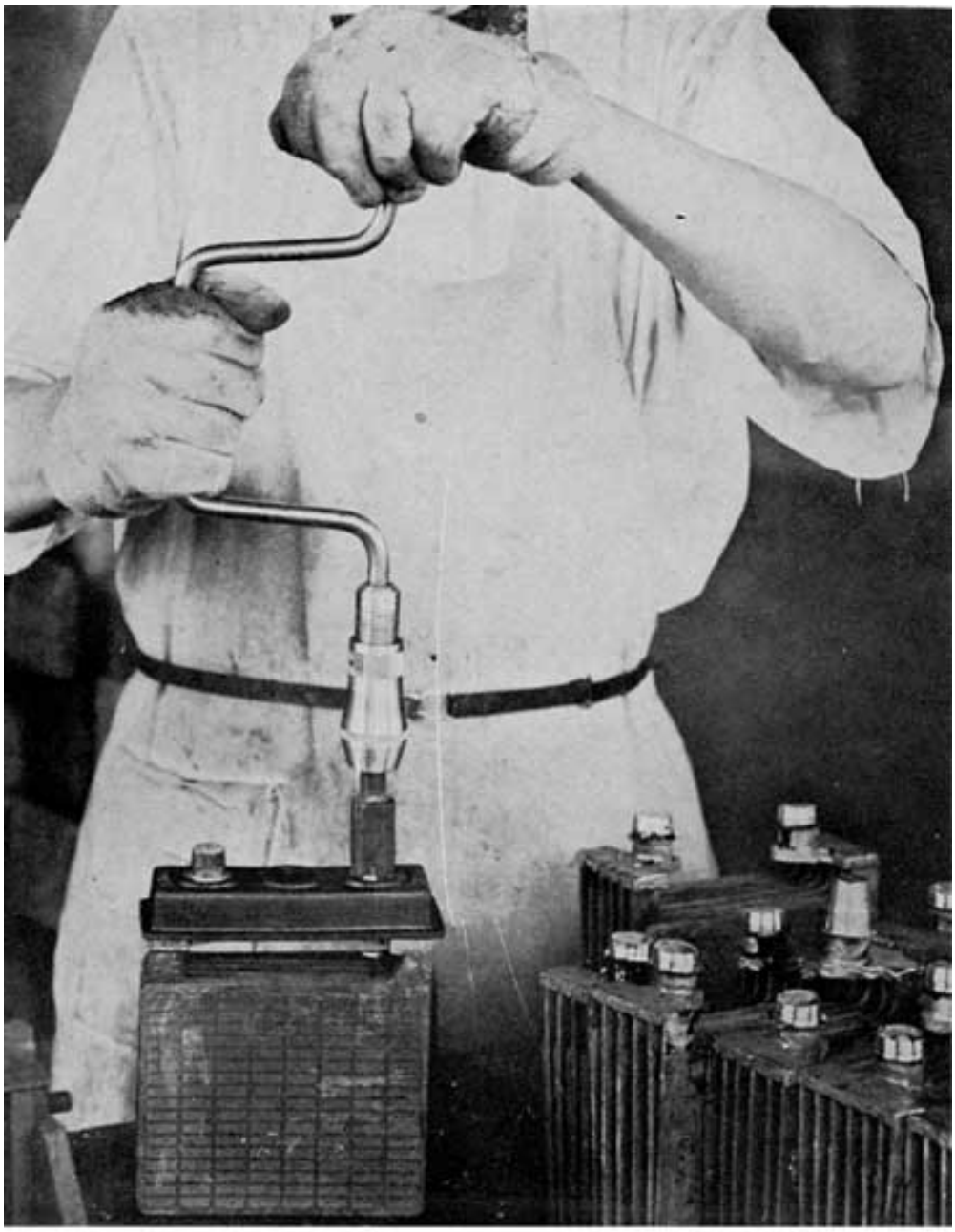

Fig. 249. Reaming Prest-O-Lite Peened Post to Remove Cover

Connect the "B" Torch to the Peening Tool. The Torch is merely pressed by the hand over the Torch-Holder.

Connect the Torch with the Automatic Reducing Valve on the gas tank by the rubber tubing, and turn on the gas and light. The flame should be blue and hot.

Allow the Peening Tool to become just hot enough to melt the end of a piece of 50-50 solder. **Do not allow it to get any hotter than this.** The tool is then ready for use. The flame may be left on while the Tool is in use. In case the Tool becomes too hot turn the flame off and allow it to cool to the proper temperature before using.

To Remove Cell Covers from Elements

Drill off cell connectors and terminals as usual. Insert the proper size Freeing Tool (or reamer), furnished with the outfit, in an ordinary hand-power drill press or bit-and-brace. With this reamer remove the ring of metal or flange on the post, thereby releasing the cell cover. Fig. 249. The Freeing Tool should not be used in a power-driven press, as slow speed is essential to prevent breaking cell covers. To get the best results, center the Freeing Tool over the post, gradually forcing it down, at the same time keep it turning slowly until the ring of metal which locks the post in the cover has been removed. A little machine oil should be put on the metal directly under the tool for this operation. After the metal ring has been removed, the cover can be easily lifted off the posts, Fig. 250.

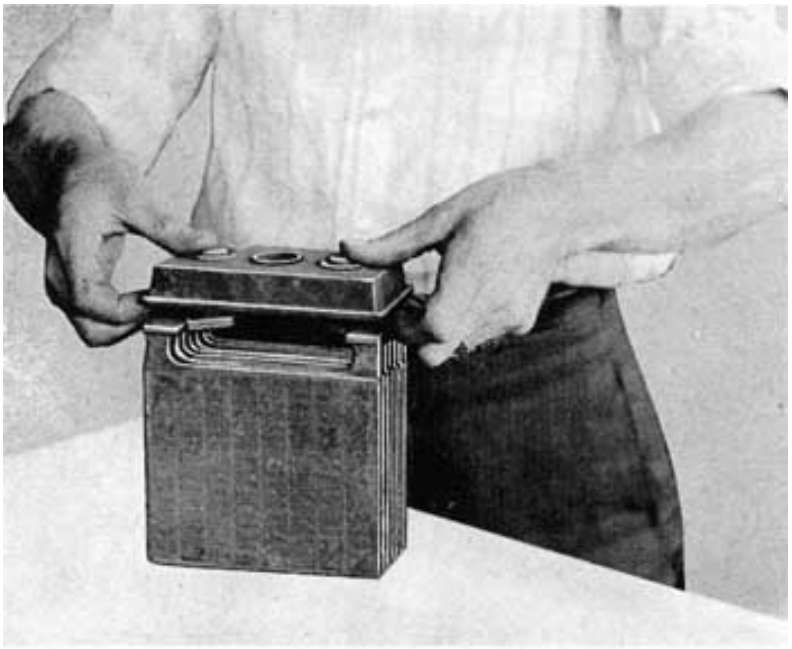

Fig. 250. Removing Prest-O-Lite Cover

Fig. 251. Building up Posts on Prest-O-Lite Element

The use of the Freeing Tool in removing the cell cover cuts away a certain amount of metal from the diameter of the posts. Before these posts can be relocked by the Peening Tool in replacing the cell cover they must be built up in size or diameter again so that there will be enough lead to insure a tight joint.

To Rebuild Posts

Thoroughly clean the post. Place the proper Post Re-Builder so that it rests on the shoulder of the post, and run in enough new lead to fill the Re-Builder. Fig. 251. Be sure and bring the lead surface of the post into fusion before the new lead is run in, to insure a strong post.

To build a smooth, solid post, be sure that the post is thoroughly clean; then use a hot flame.

To Lock or Peen Posts

(1) Assemble positive and negative groups without separators, and paint the posts (just above the shoulder) with hot sealing compound.

(2) Prepare the cell covers by immersing them in hot water until they are flexible.

(3) Place a warmed cover over the posts of the two assembled groups (the elements). Fig. 252.

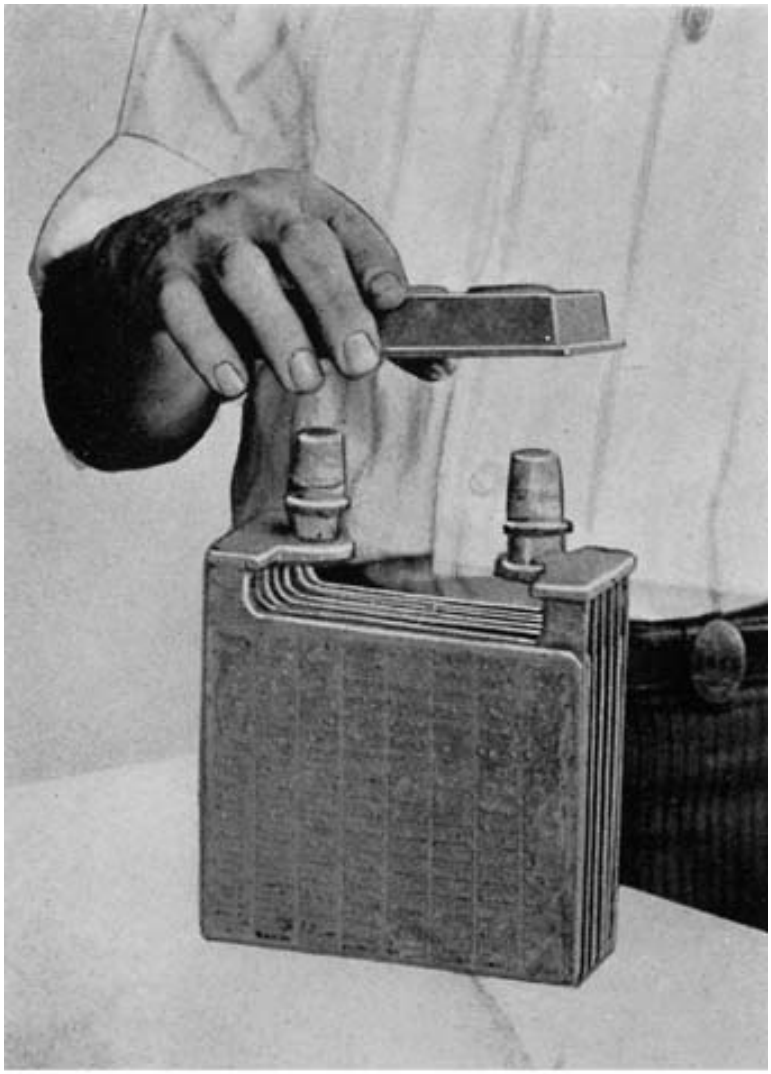

Fig. 252. Replacing Prest-O-Lite Cover on Built Up Posts

(4) Slide the element over the Bed Plate directly under Peening Tool, with the bottom of the plate connectors resting on the Bed Plate. (See Fig. 253).

(5) Pull down the Latch to hold the Bed Plate in alignment.

(6) Center the post with Peening Tool. Then force the Peening Tool down slowly until it has covered about two-thirds of the distance to the cover. Pause in this operation to allow the metal of the post to become heated; then force tool the rest of the distance. Raise the Peening Tool slightly and force down again.

(7) Release the Latch, withdraw and reverse the element, and repeat operations 4, 5 and 6 on the other post.

(8) The assembled groups are now ready to receive separators.

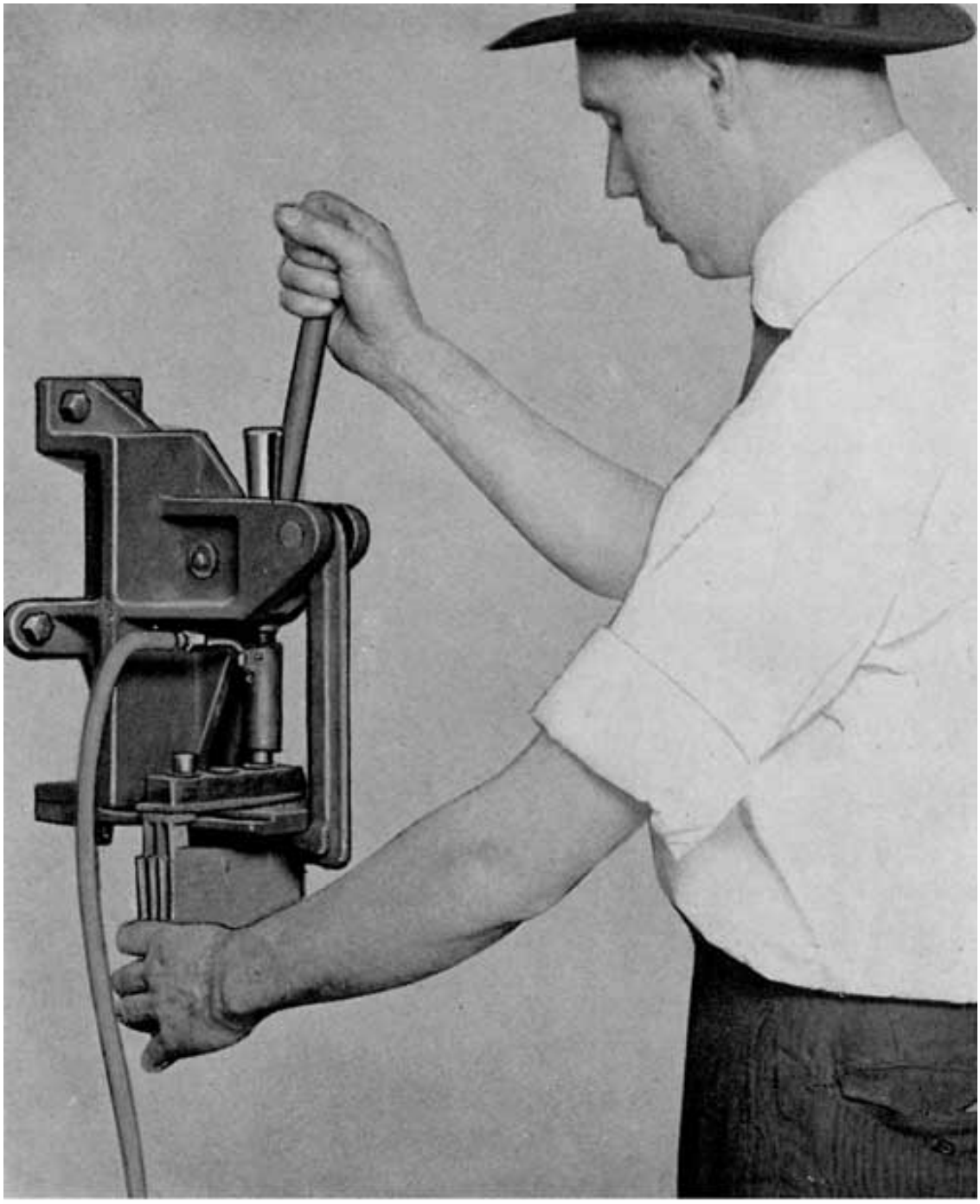

Fig. 253. Peening Prest-O-Lite Post with Special Peening Press

Precautions in Post Locking Operations

1-Be sure all covers are warmed until they are flexible before attempting to assemble.

2-Be sure that the Peening Tool is not too hot. If it is, the post will melt away and be ruined. A very hot tool sometimes causes dangerous spattering of hot lead.

3-Be sure that the post is centered with the Peening Tool before forcing the Tool down on the post.

4-Be sure the cover has been forced down, so that it rests on the shoulder of the post, before releasing.

General Instructions

In breaking in a new Peening Tool it is advisable to squirt several drops of machine oil inside the Tool, as well as putting some oil on the top of the post, before forcing the hot Tool down over the post. This will prevent the Tool from sticking to the post.

If the Peening Tool should stick to the post, force the Tool down again, being certain that the cover is slightly compressed. Sticking of the Peening Tool indicates either that the Tool has not yet been broken in, or that there is not sufficient compression in the cover to free the Tool on releasing the pressure on the lever of the Press.

To. repair the 13/16" diameter straight terminal post, the Ford positive terminal post, the Ford negative terminal post, it is good practice to remove the cover in the usual manner, then cut the upper portion of the posts off and rebuild them with the large Post Re-Builder. Reassemble the element and cover in the recommended manner and then use the proper Post Builder to burn the post to its original size.

(Charts omitted: "STANDARD TYPES OF PREST-O-LITE STARTING, LIGHTING AND IGNITION BATTERIES - Starting Types. 6 volt.", "12 -Volt", "16-18-24 and 30-Volt.", "Special Heavy Duty Truck Batteries for Starting and Lighting", and "6-Volt Lighting and Ignition Types." These only showed battery type numbers, charge and discharge rates, dimensions and weights. Would have been very tedious and time consuming to add this mundane information which isn't very useful. I'm not getting paid for this, btw.)

THE PHILADELPHIA DIAMOND GRID BATTERY

Old Type

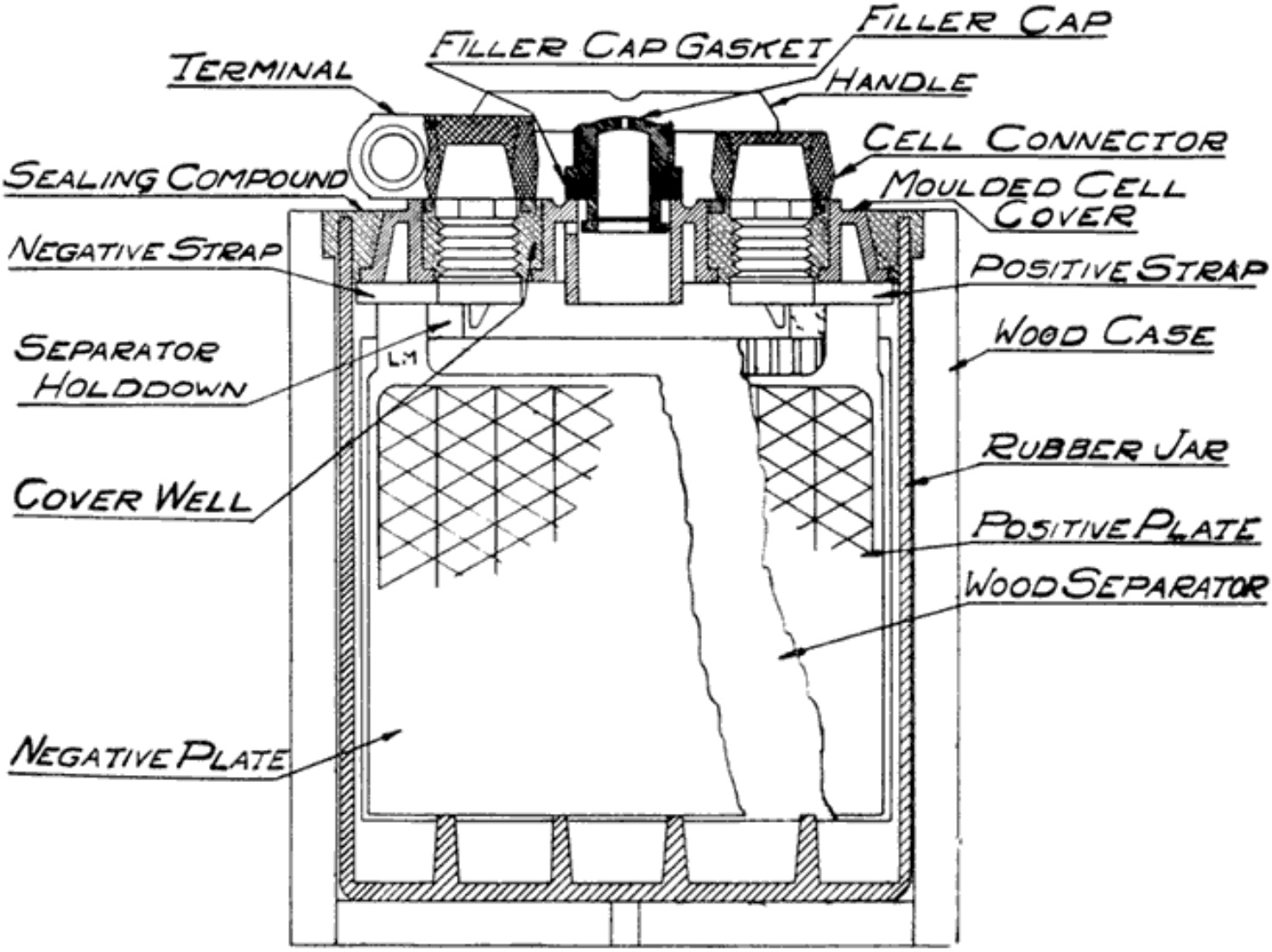

Fig. 254. Cross Section of Old Type Philadelphia Diamond Grid Battery

Figs. 254 and 255 show the construction of the old type Philadelphia Diamond Grid. Battery. Figs. 254 and 256 show the diamond shaped grid from which the battery derives its name. It is claimed that this construction gives a very strong grid, holding the active materials firmly in place, and giving a large amount of contact surface between the grid and the active material.

Figs. 254 and 255 show the old type battery, and give the details of the cover, terminal posts, vent plug, and so on. The post seal is made tight by pouring the compound into the cover well so that it flows in around all of the petticoats on the post.

Fig. 255. Old Type Philadelphia Diamond Grid Battery

This construction increases the distance that the acid must travel along the post, in order to cause a leak, about two and one-half times the vertical distance on a smooth post. The hard rubber washer which fits around the post acts as a lock to prevent the post from turning. This applies especially to the two terminal posts to which the cables are attached. The washer is intended to prevent any strain in the cable from turning the post and breaking the seal between the post and the compound.

New Development in the Philadelphia Battery

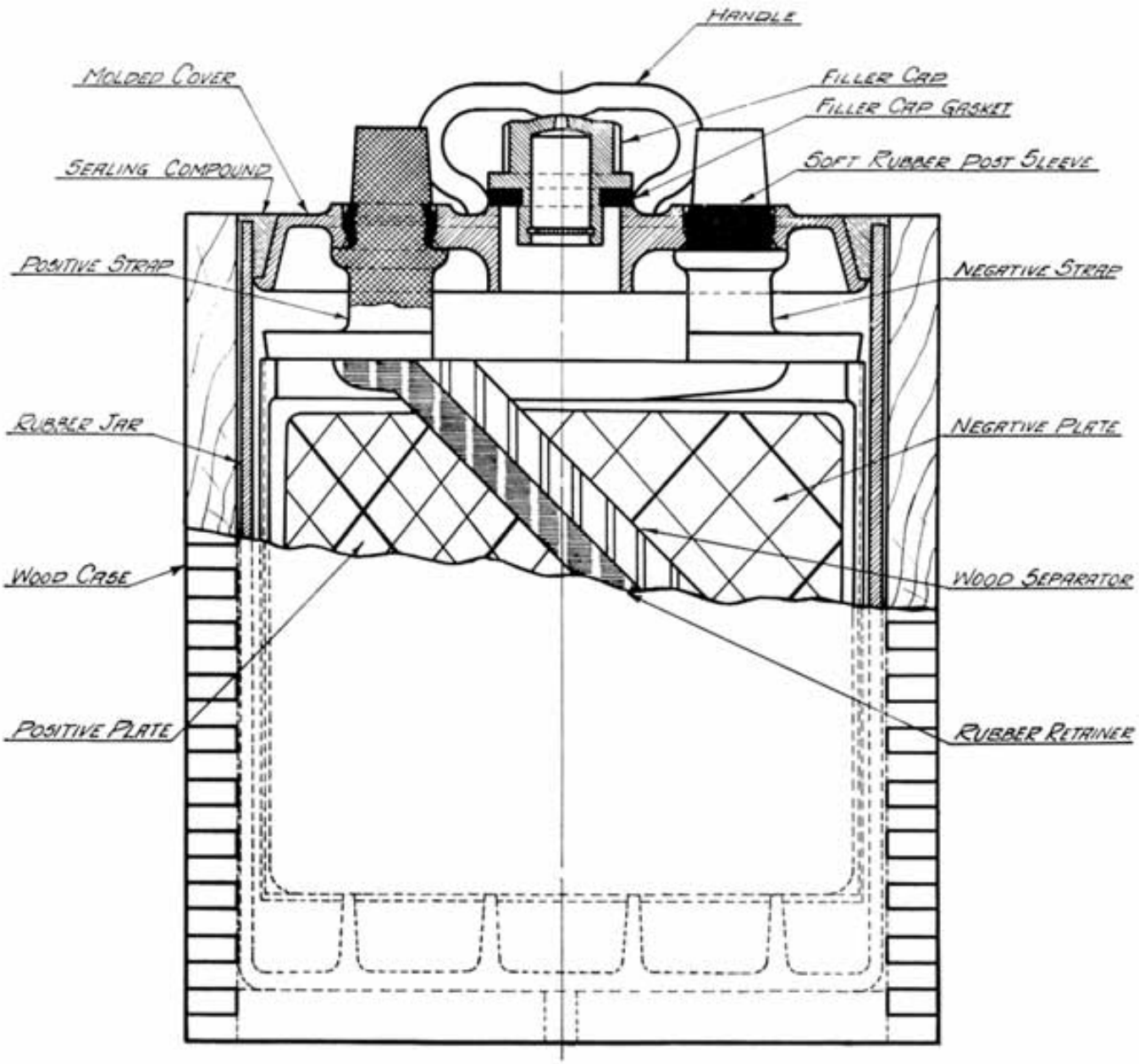

Fig. 256. Cross Section of New Type Philadelphia Diamond Grid Battery

Fig. 257. New Type Philadelphia Diamond Grid Battery

Rubber Lockt Seal Covers. During the last few years there has been a marked tendency in the battery industry to do away with the use of sealing compound for making a joint between the cell cover and the terminal posts and to substitute a mechanical seal of some kind at this joint. The Philadelphia Storage Battery Co. has developed the "Rubber Lockt". cover seal, the construction of which is shown in detail in Figs. 256 and 257. On the cell posts there is a. flange which supports the cover, and above this there is a recessed portion into which is slipped a soft rubber sleeve or bushing. This portion of the post is made with a ridge extending around the post and with the rubber sleeve forming a high point over which a corresponding locking edge in the terminal hole of the cover is snapped. This construction makes a joint which is flexible and at the same time acid tight. Vibration tends to push the cover down on the supporting flanges, as the post diameter is smaller below the locking edge. The design is simple, both from the assembly and the repair standpoint, as no tools are required for either operation. In the assembly operation the groups are lined up so that the post centers are correct and, after wetting the soft rubber sleeves, the cover is snapped in place with a quick downward push. See Fig. 258. In removing the covers, catch under each end with the fingers and pull upward, at the same time pressing with the thumbs on the top of the posts. See Fig. 259.

Fig. 258. Replacing Cover of Philadelphia Diamond Grid Battery

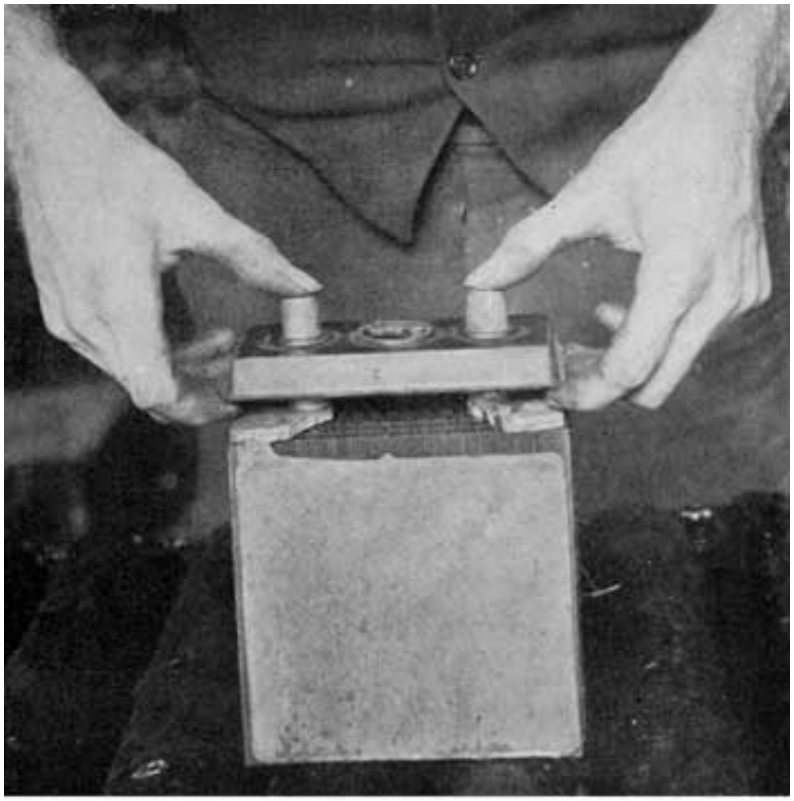

Fig. 259. Removing Cover from Philadelphia Diamond Grid Battery

Rubber Case Batteries. Another development of recent years consists of the replacing of the wood case and rubber jars by a one-piece container of hard rubber with compartments for the elements The Philadelphia Storage Battery Co. has developed the Diamond Rubber case, which combines strength and lightness with an attractive appearance. See Fig. 260. One of the troubles experienced with the earlier designs of the rubber case

was the bulging of the end, due to the pull of the battery hold down rod on a small handle attached to the center of the end. In the Philadelphia battery this has been overcome by the use of a wide handle which snaps into openings in the end of the case. in such a way that the pull on the handle is transferred to the sides. Another feature of this type handle is that it is a separate piece snapped into the case without the use of any metal insert in the rubber case, and if the handle should break, it can be replaced at small expense without the use of any tools.

Fig. 260. Philadelphia Diamond Grid Battery with Rubber Case

The Philadelphia vent plug is of the bayonet type, and is tightened by a quarter turn. The plug simply has a small vent hole in the top, and may either be taken out or left on while battery is charging.

The Philadelphia Separator

The Philadelphia separator is made of quarter sawed hardwood. It has a hard resinous wood in which the hard and soft portions occur in regular alternating vertical layers. The soft layers are porous, and permit the diffusion of the acid from plate to plate. The hard layers give the separator stiffness and long life. The alternating hard and soft layers are at right angles to the surface of the separator, so that the electrolyte has a direct path between plates.

The methods of repairing Philadelphia Diamond Grid batteries are no different from those already given, on pages 328 to 374.

When the elements of the old type batteries have been assembled and returned to the jars, put the covers in place, and pour the compound around the edges of the cover, and in the post wells. The old compound must be removed from the petticoats on the posts before new compound is poured in. The compound must be warm and thin enough to flow around and fill up the petticoat spaces on the posts in order to get a good seal. When the

post wells are full of compound, and while compound is still warm, put on the square sealing washers and press them down so that the holes in the washers fit closely around the octagonal part of the posts.

THE EVEREADY STORAGE BATTERY

It is claimed by the manufacturers that the sulphate which forms in the Eveready battery during discharge always remains in the porous, convertible form, and never crystallizes and becomes injurious, even though the battery is allowed to stand idle on open circuit for a considerable length of time. Due to this fact, the Eveready battery is called a "Non-Sulphating Battery."

The manufacturers state that Eveready batteries which have stood idle or in a discharged condition for months do not suffer the damages which usually result from such treatment, namely: buckling, and injurious sulphation. The plates do become sulphated, but the sulphate remains in the porous, non-crystalline state in which it forms. Charging such a battery at its normal rate is all that is necessary to bring it back to its normal, healthy condition. Due to the excessive amount of sulphate which forms when the battery stands idle or discharged for a long time, it is necessary to give the battery 50 percent overcharge to remove all the sulphate and bring the battery back to a healthy working condition. The colors of the plates are good guides as to their condition at the end of the charge. The positives should be free from blotches of white sulphate, and should have a dark brown or chocolate color. The negatives should have a bright gray or slate color.

Description of Parts

Eveready plates are of two general types. Plates of the R type are each provided with two feet on lower ends, the positive set and the negative set resting on two separate pairs of bridges in the jars, thereby preventing the sediment which accumulates on top of bridges from short circuiting a cell.

Plates of the M type, instead of having feet, are cut away where they pass over the bridges of the opposite group. See Fig. 261. This construction secures a greater capacity for a given space, and gives the same protection against short circuit from sediment as the foot construction does, since the same amount of sediment must accumulate with either type of plate to cause a short circuit.

Fig. 261. Type "M" Eveready Grid

The separators used in Eveready batteries are made of cherry wood because it is a hard wood which will resist wear, is of uniform texture, even porosity, and has a long life in a given degree and condition of acid.

Eveready cherry wood separators go to the repair man in a dry condition, as they do not require chemical treatment. Separators when received should be soaked in 1.250 specific gravity acid for four days or longer in

order to expand them to proper size and remove natural impurities from the wood. After being fully expanded they should be stored moist as previously described. Stock separators may be kept indefinitely in this solution and can be used as required. Fig. 262 shows the top construction in the Eveready battery.

Fig. 262. Eveready Battery. Cell Connectors Are Covered by Compound

Cell connectors are heavily constructed and are sealed over solidly with a flexible sealing compound, Fig. 262. Two types of cell connectors are used-the crescent and the heavy or "three way" type.

Repairing Eveready Batteries

To properly open and re-assemble an Eveready battery, proceed as follows:

1. Take a hot putty knife and cut the compound from the top of each of the inter-cell connectors until the entire top of the connector is exposed.

2. Center punch tops of cell connectors and terminal posts.

3. Drill off cell connectors. In drilling off crescent cell connector use 1/2 inch drill, and for heavy type connector use 5/8 inch drill.

Drill deep enough, usually 3/8 to 1/2 inch, until a seam between connector and post is visible around lower edge of hole. Having drilled holes in both ends of connector, heat connector with soft flame until compound adhering to it becomes soft. Then take a 1/2 inch or 5/8 inch round iron or bolt, depending on connector to be removed, insert in one of the holes, and pry connector off with a side to side motion, being careful not to carry this motion so far as to jam connector into top of jar.

4. After connectors have been removed, steam and open the battery, as described on pages 332 to 335.

5. Examine plates, and handle them as described on pages 335 to 355. Remember, however, that Eveready plates which show the presence of large amounts of sulphate, even to the extent of being entirely covered with white sulphate, should not be discarded. A battery with such plates should be charged at the normal rate, and given a 50 percent overcharge.

6. Before re-assembling plate groups preparatory to assembling the battery, take negative and positive plate groups and build up the posts with the aid of a post builder to their original height.

Assemble groups in usual manner, taking care that posts on straps are in proper position relative to group in adjoining cell, so that cell connectors will span properly. Eveready batteries use a right and left hand strap for both positive and negatives, making it necessary to use only one length of cell connector.

7. After inserting assembled plate groups into battery in their proper relation as to polarity, heat rubber covers to make them fairly pliable and fit them over posts and into top of jar, pressing them down until they rest firmly on top of plate straps. See that covers are perfectly level and that vent tubes are perpendicular and all at same height above the plates.

8. Heat compound just hot enough so that it will flow. Pour first layer about one quarter inch thick, being careful to cover entire jar cover. Take a soft flame and seal compound around edges of jar and onto posts.

9. Now proceed to burn on top connectors. Cell connectors need only be cleaned in hole left by post, and top of each end.

10. While burning in cell connectors the first layer of compound will have cooled sufficiently to permit the second layer to be applied. This should be done immediately after burning on connectors and while they are still hot. Also heat the terminal posts, as compound will adhere to hot lead more readily than to cold.

Start second layer of compound by pouring it over cell connectors and terminal posts, first filling in with sufficient compound to bring level just above the tops of jars. Apply flame, sealing around edges of wood case, being particularly careful to properly seal terminal posts. Let this layer cool thoroughly before applying third layer.

11. The third layer of compound should be applied in the same way as second layer, pouring on connectors and terminal posts first, and filling in to the level of top of wood ease. The spaces between bars of cell connectors will fill and flow over properly if second layer has been allowed to cool and if cell connectors have not been burned up too high. In sealing last layer with flame, care should be taken not to play flame on compound too long as this hardens and burns the compound. Burned compound has no flexibility and will crack readily in service, thus causing the battery to become a "slopper." In pouring compound be sure to have battery setting level so that compound will come up even on all edges of case. Do not move battery after pouring last layer until thoroughly cool.

Before installing battery on car be sure that no compound, etc., has been allowed to get onto taper of terminal post, as this will make a poor connection. If this has happened, clean with medium grade sandpaper.

VESTA BATTERIES

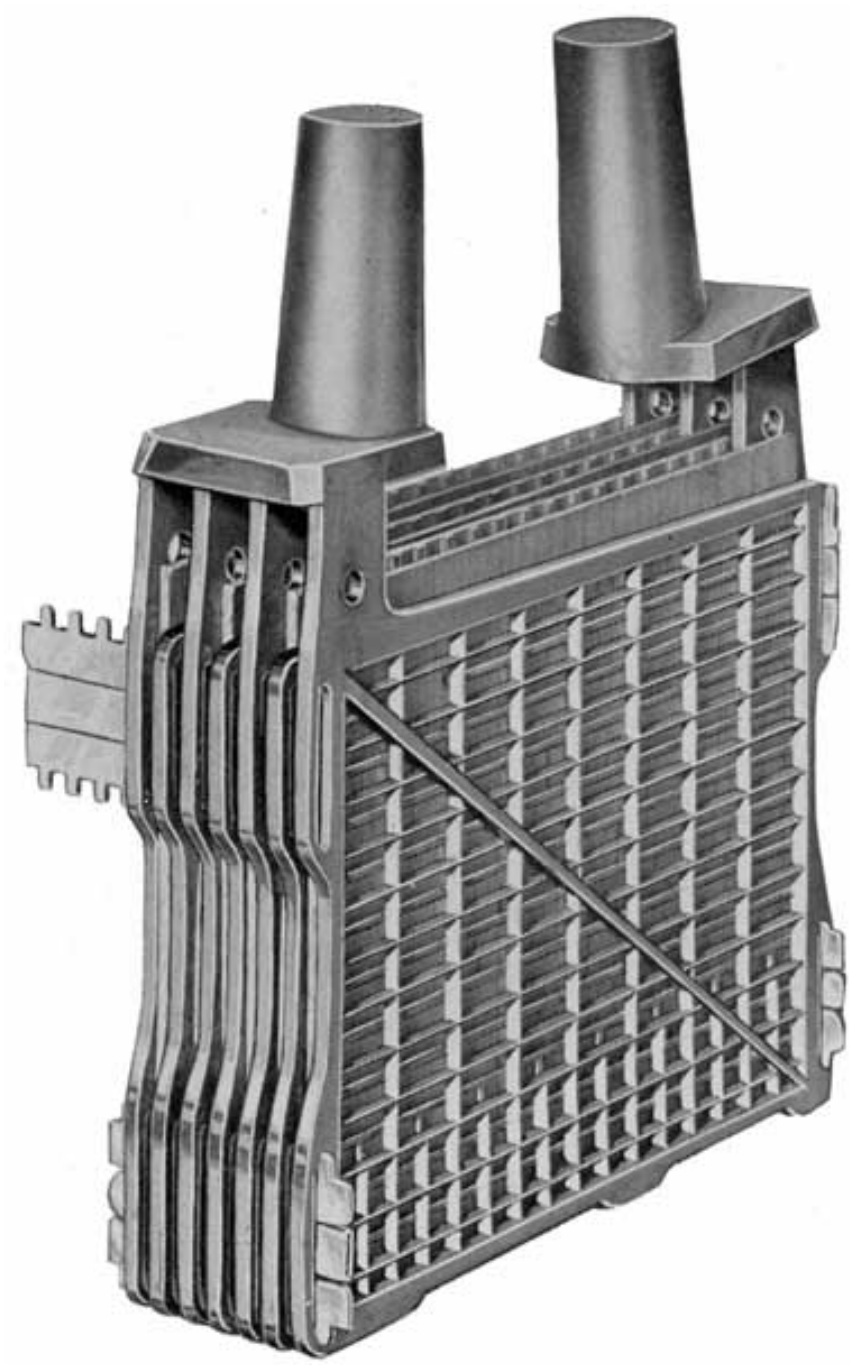

Vesta Isolators. The Vesta plate embodies in its design devices which are intended to hold the plates straight and thus eliminate the buckling and short-circuiting which form a large percentage of battery trouble. Fig. 263 shows clearly the construction of the old type of plate. Each isolator used in the old type of plate consists of two notched strips of celluloid, with a plain celluloid strip between them. The notches are as wide as the plates are thick, the teeth between the notches fitting into the spaces between plates, thus holding the plates at the correct distances apart. The plain celluloid strip holds the notched strips in place. At each corner of the Vesta plate is a slot into which the isolator fits, as shown in Fig. 263. Since the teeth on the two notched pieces of each. isolator hold the plates apart, they 'cannot "cut-out" or "short-out" by pinching through the wooden separators, or "impregnated mats" as they are called by the Vesta Company.

The celluloid of which the isolators are made are not attacked by the electrolyte at ordinary temperatures. At higher temperatures, however, the electrolyte slowly dissolves the

Fig. 263. Vesta Grid with Three Piece Isolator

isolators. The condition of the isolator, therefore, may be used to determine whether the temperature of the electrolyte has been allowed to rise above 100° Fahrenheit.

The Vesta Type "D" Battery

The appearance of a group of the new Type "D" construction is shown in Fig. 265, where Type "C" and Type "D" groups are illustrated side by side for purposes of comparison. It will be seen that the "D" isolator is of one piece only (shown separately in Fig. 266). The material is a heavy hard rubber stock which will be no more affected by acid or by electrical conditions in the cell than the hard rubber battery jar itself. The indentations on the two edges of isolator engage in hook shaped lugs on plate edges (Fig. 267 shows these clearly) and lock the plates apart fully as efficiently as the three-piece construction.

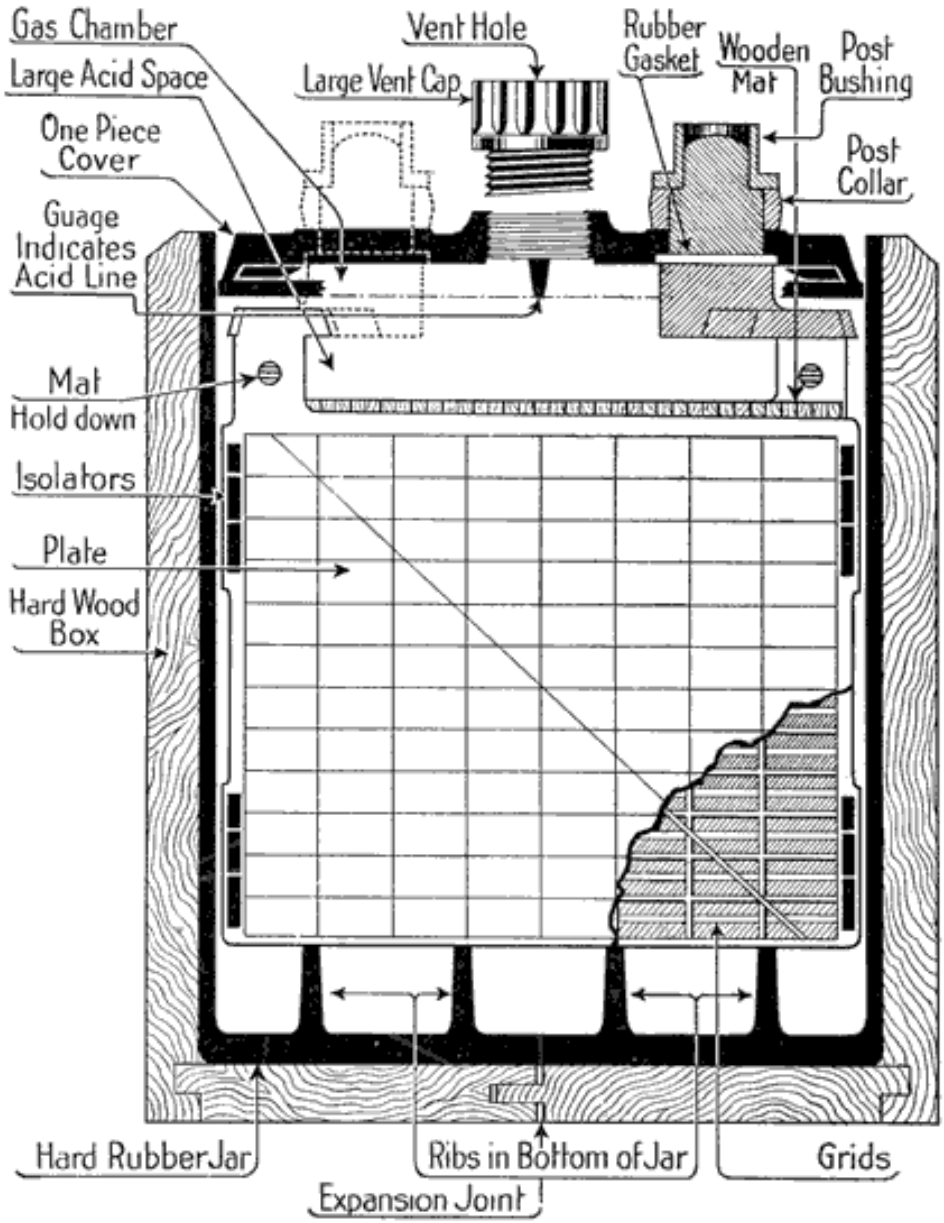

Fig. 264. Cross Section of the Vesta Isolator Battery, Type C.

There are a number of important advantages which have been gained by the new method of isolation. The illustration (Fig. 265) shows how the "D" isolator permits the separators to completely cover and project slightly beyond the edges of the plates, whereas in the old construction there is an edge just above the isolators where the plates are not covered. This improvement means protection against shorts due to flaking, always so likely to occur during the summer "overcharging" season. Overcharging is, of course, a form of abuse, and Type "D" batteries are designed to meet this sort of service. Another great advantage gained is in the arrangement of lugs, It will be noted that the positive isolator hooks are in alignment, as are the negative hooks, but that these two rows, of opposite polarity, are separated from each other by the full width of the isolator; whereas in the Type "C" construction the outer edges of the plates, of opposite polarity, were separated only by the usual distance between plates.

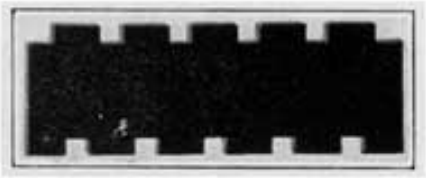

Fig. 266. Vesta One-Piece Hard Rubber Isolator

Fig. 265. Vesta Elements. Showing Old Three-Piece Celluloid Isolator and New One-Piece Hard Rubber Isolator

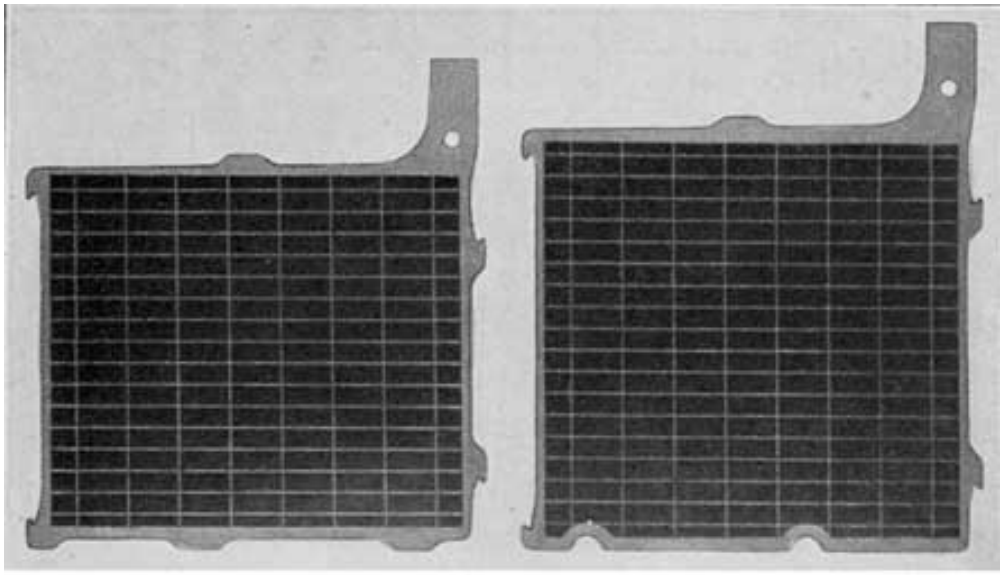

Fig. 267. Vesta Plates, Types U and DJ

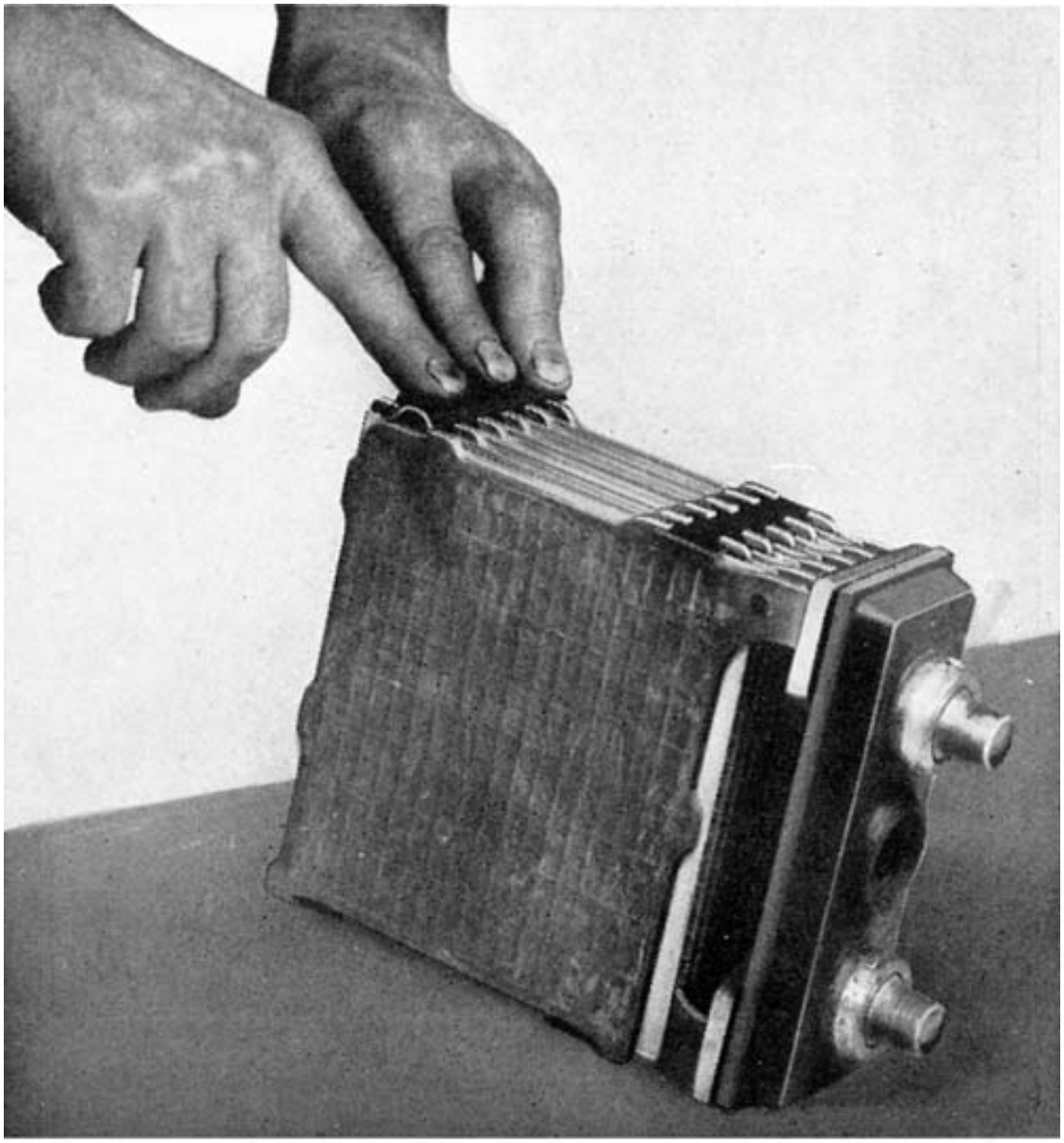

Fig. 268. Inserting Vesta Hard Rubber Isolator

The new isolator is simple to insert and remove. Being made of hard rubber, it will soften and become pliable if a sufficient degree of heat is applied. The heat required is approximately 150° to 160°F., a temperature far above that reached by any battery cell, even under the most extravagant condition of abuse, but readily attained in the shop by means of a small flame of any kind-even a match will do in an emergency. The flame (which should be of the, yellow or luminous variety, as the blue flame tends to scorch the rubber) is played lightly over the isolator a few seconds. The rubber becomes soft and is then removed by inserting under the end of the isolator any narrow tool, such as a small screw driver, a wedge point, chisel, etc., and prying gently. In replacing isolators, a small hot plate is convenient but not at all necessary. The isolators are placed on the hot plate, or held in a luminous flame, until soft enough to bend. They are then bent into an arched shape, as shown in Fig. 268, and quickly fitted into place under the proper lugs. The regular isolator spacing tool is convenient and helpful in maintaining the plates at uniform intervals while this operation is carried out. The job is completed by pressing down the. still warm isolator with any handy piece of metal having a flat edge that will fit the distance between the lugs (Fig. 269). The shank of. a screw driver does splendidly for this work. . The pressure causes the isolator to straighten out, and the indentations fit snugly under the respective hooks on the plates. At the same time the contact with the cold metal chills the rubber to its normal hard condition. It is especially to be noted that the entire operation of isolator removal and replacement can be carried out with none but the commonest of shop tools.

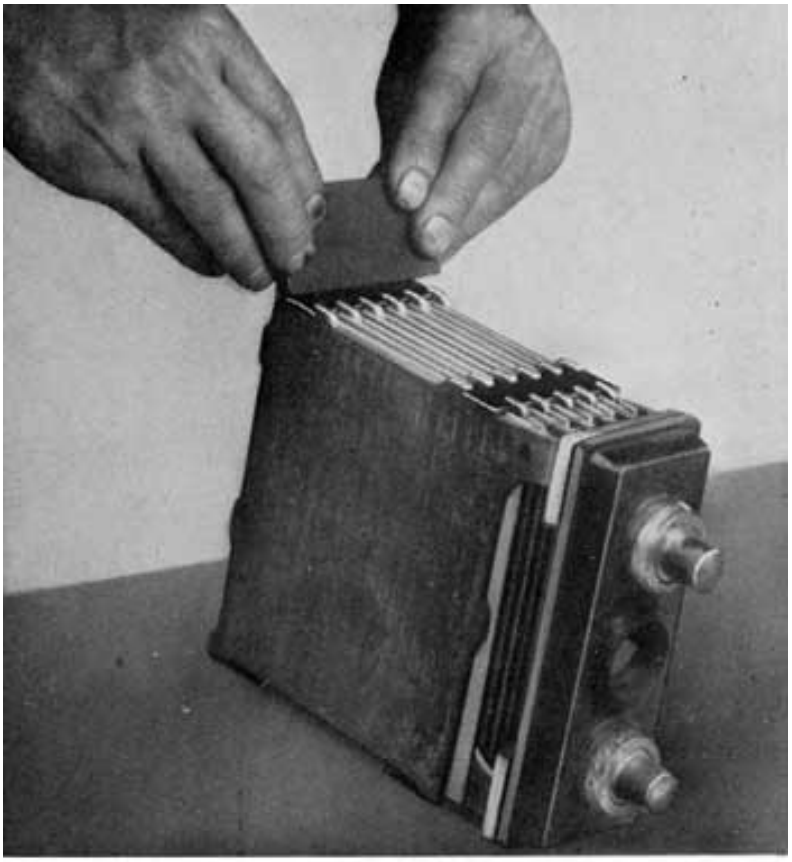

Fig. 269. Pressing Down Vesta Hard Rubber Isolator

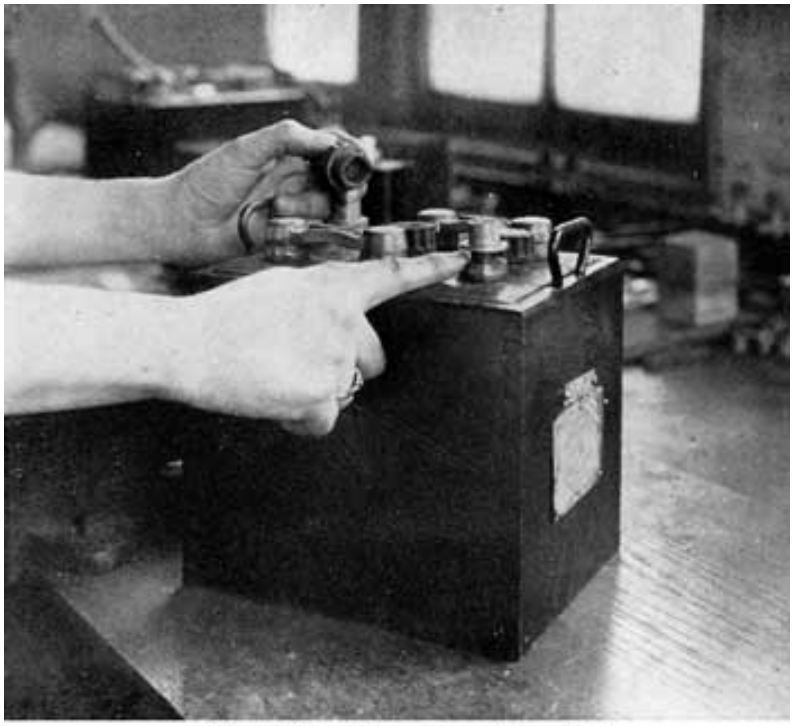

Fig. 270. Showing Complete Vesta Battery. Note Lead Collars

All of the "U" size batteries have been changed to Type "D," so that all "CU" types are superseded by corresponding "DU's." Type "D" will not be used on cells of sizes "L," "H," or A, all of which remain of the "C" or three-piece isolator construction. Type "S" remains old style as before.

Type "DJ"

The Vesta Company has added a new plate size, produced in the "D" style (one-piece) isolator only, and known as "DJ."

This plate is one-half inch higher than the "U," as shown in Fig. 267. It has 10 per cent more capacity. "DJ" batteries are available in all forms corresponding with "CU" types, and can be obtained by merely changing the type form name in ordering, as for example, to replace form 150, 6-DJ11-Y-150. The overall height of the completed battery is, of course, one-half inch more, and the "DJ" should therefore be ordered only when this additional height space is available in the battery compartment of the car.

Vesta Separators

The Vesta separators, or "mats," are treated by a special process. The Vesta Company considers its "mats" a very important feature of the battery. See page 15.

Vesta Post Seal

A lead collar fits over each post to hold the cover tight against the soft rubber gasket underneath. This collar is not screwed or burned on the post, but is simply pressed down over the post, depending. for its holding power upon the fact that two lead surfaces rubbing against each other tend to "freeze," and unite so as to become a unit. The connector rests upon the upper race of the collar, and also helps to hold it down in its proper position. Fig. 270 shows the complete battery with the lead collar, and the large vent plug.

In rebuilding Vesta batteries having the lead collars, the cover should be left in place when working on the plates, if possible. If, however, it is necessary to separate groups, and the lead collars must be removed, this is done as shown in Fig. 271. A few blows on the side of the collar with a light, two ounce hammer expands the lead collar several thousands of an inch so that the collar may be removed.

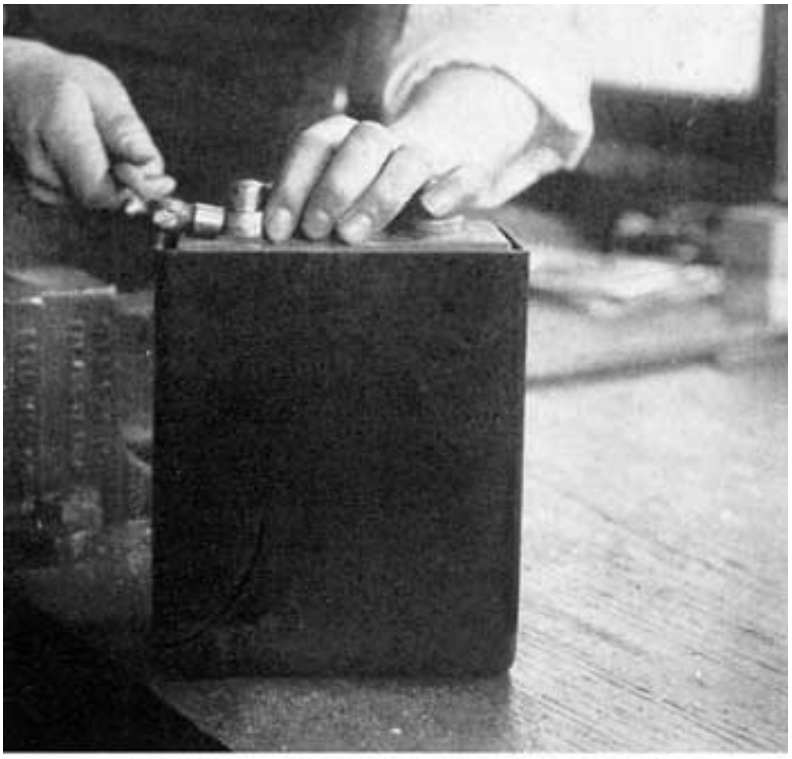

Fig. 271. Expanding Lead Collar of Vesta Battery with Light Hammer

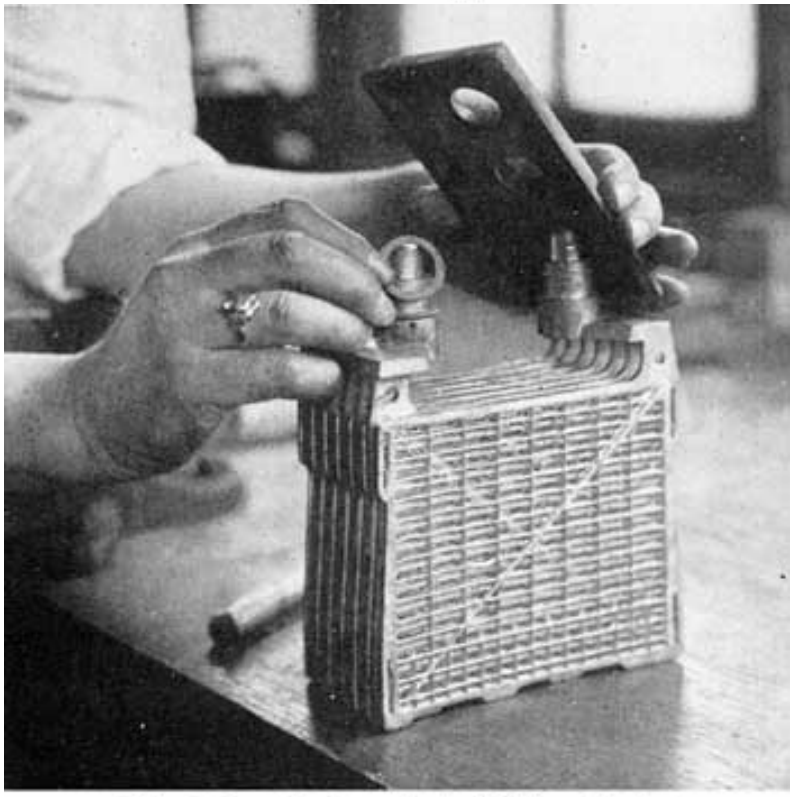

Fig. 272. Placing Soft Rubber Gasket over Post of Vesta Battery

In replacing the covers, the lead collar must be forced down over the post, and special pressure tongs are required for this purpose. Before driving on the old collar, the post should be expanded slightly by driving the point-of a center-punch into the shoulder on the post. Instead of expanding the shoulder a new collar may be used.

Fig. 272 shows the soft rubber gasket. being placed over the post, and shows the construction of the cover with its recess to fit the gasket.

Fig. 273 shows the lead collar being placed over the post after the cover is in place.

Fig. 274 shows the special long lipped tongs required to force the collar down on the post shoulder. One lip of the tongs has a hole into which the post fits. The necessary driving force may be obtained by applying pressure to the ends of the lips of the tongs With an ordinary vise. This forces the cover down on the rubber gasket to make the acid-tight seal.

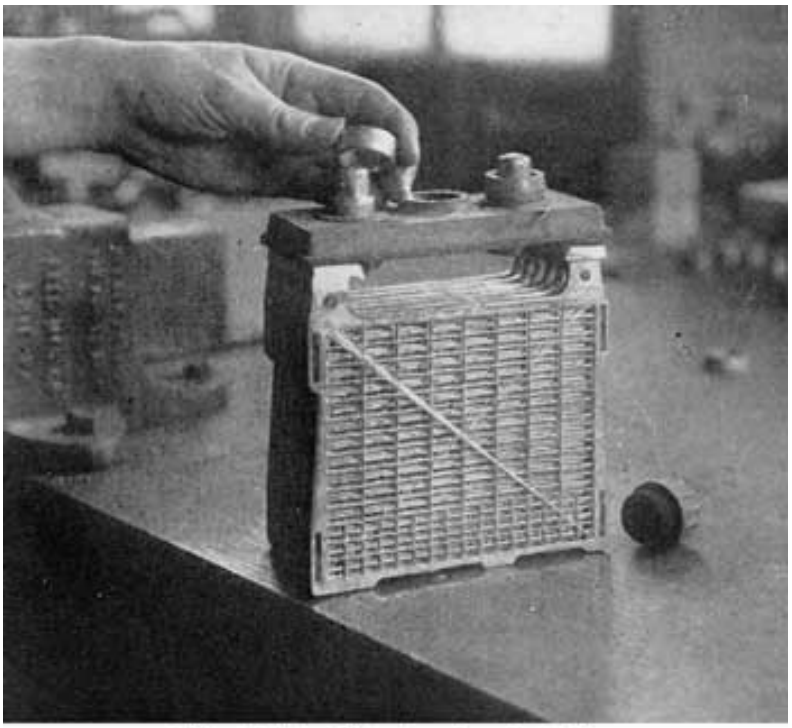

Fig. 273. Placing Lead Collar over Post of Vesta Battery

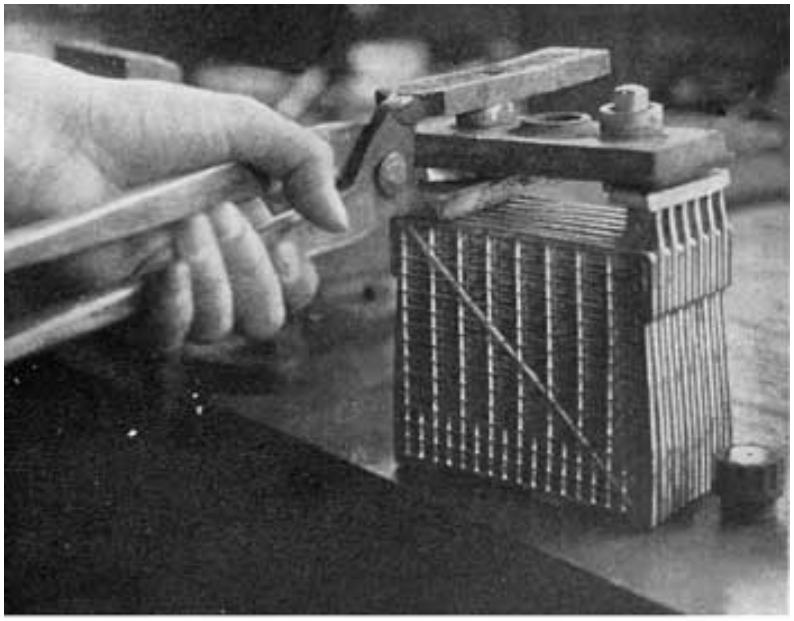

Fig. 274. Pressing Lead Collar over Post of Vesta Battery

WESTINGHOUSE BATTERIES

Westinghouse batteries have a special seal between covers and posts, as' shown in Fig. 275. A lead foundation washer (J) is set around the post. A "U" shaped rubber gasket, (K) is then forced between the cover and post, with the open end up. The lips of this gasket are tapered, with the narrow edge up. A tapered lead sleeve (L) is then forced between the lips of gasket (K), thereby pressing the inner lip against the post and the outer lip against the cover.

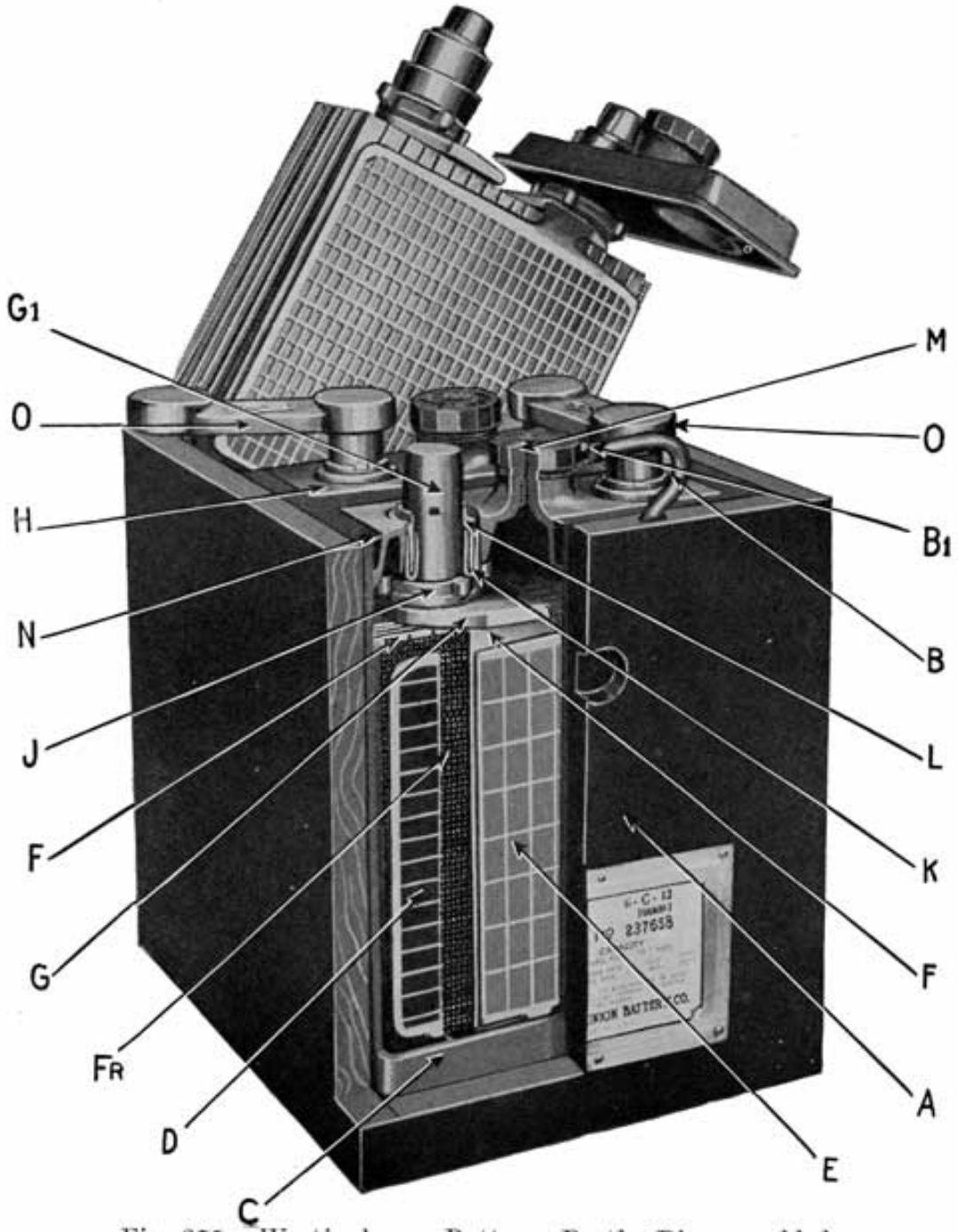

Fig. 275. Westinghouse Battery, Partly Dis-assembled

The lead sleeve is held in place by broaching or indenting the collar on taper lead sleeve into the posts.

To break the seal, a hollow reamer or facing tool, fitted into a drill press or breast drill, is slipped over the post. A few turns will remove that part of the sleeve which has been forced into the post. Remove sealing compound around cover, remove group from cell. The cover can then be lifted off and if any difficulty is experienced, it can easily be removed by prying up cover with screwdriver. After removing the cover, the tapered lead sleeve and "U" shaped gasket can be removed. If these instructions are followed, the "U" shaped gasket and taper lead sleeves can be used when battery is reassembled.

With the addition of the foregoing instructions on the post seal, the standard directions for rebuilding batteries given on pages 328 to 374 apply to Westinghouse batteries.

Westinghouse Plates

In any given size, the Westinghouse battery has two more plates per cell than the usual 1/8 inch plate battery. It has the same number of plates as the 3/32 inch thin plate battery, but the thickness of the plates is about half-way between the 1/8 inch and 3/32 inch plates.

The Westinghouse negative grids, Fig. 276, have very few and small bars, just enough to hold the active material. It is slightly thinner than the positive but has the same amount of active material, due to the design of the grids. The condition of Westinghouse negatives should not be determined by cadmium readings as these plates may be fully charged and yet not give reversed cadmium readings.

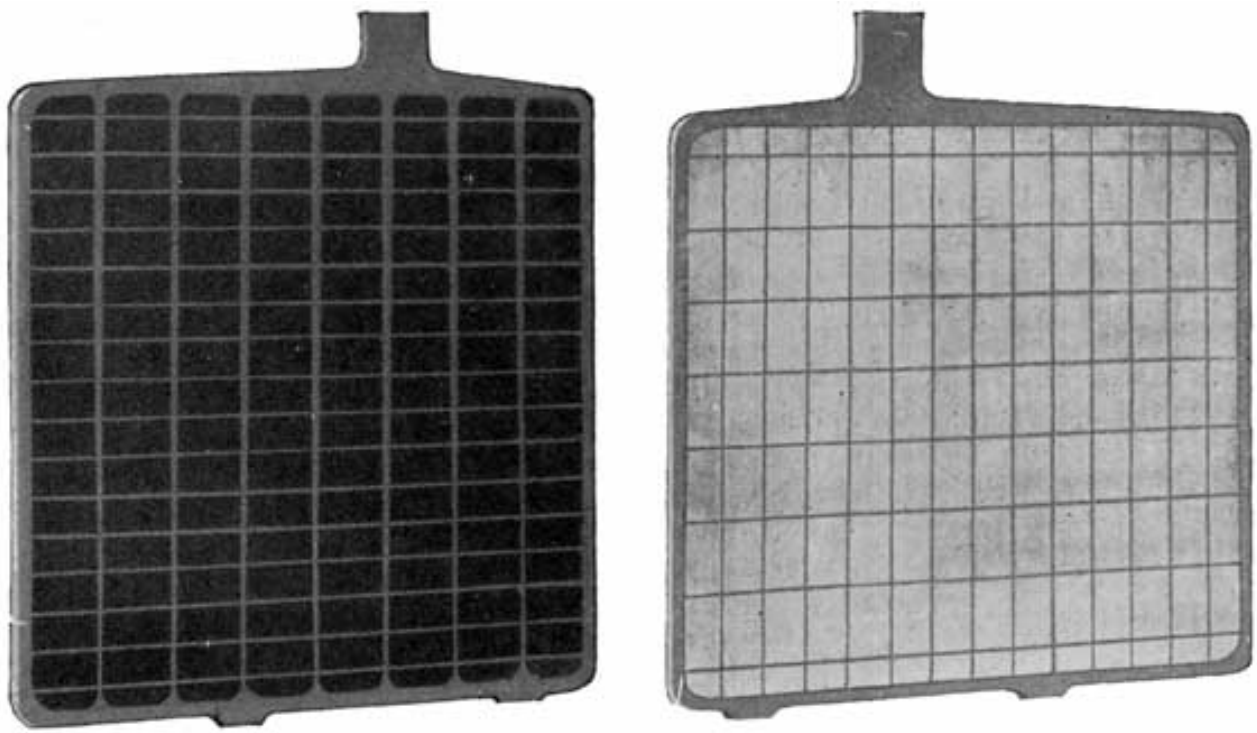

Fig. 276. Westinghouse Positive and Negative Plates

Aside from the special instructions given for the Westinghouse Post Seal, the Standard Instructions for Rebuilding Batteries, given. on pages 328 to 374 may be used in rebuilding Westinghouse batteries.

TYPES OF WESTINGHOUSE BATTERIES

Type "A" Batteries

The type "A" series was designed to fit the battery compartment in certain rather old models of cars. Owing to a lack of space this series is not of as efficient design as the "C " and "B" series. It does have the Westinghouse Post Seal, however.

Type "A" batteries are not recommended for use when "B" or "C" batteries can be used.

Type	Part No.	Ampere Hours at Usual Lighting Rate	Ampere Rate for 20 Minutes	Ampere Rate for 5 Hours	Length in Inches L	Weight in Pounds
6-A-11	100071	64	68	9.1	8	38
6-A-13	100072	79	82	11.0	9-1/8	42
6-A-15	100073	94	96	12.8	10-1/4	46
6-A-17	100074	109	109	14.6	11-9/16	52
6-A-21	100075	139	136	18.2	14-3/16	63
6-A-25	100076	169	164	22.0	17	75
12-A-7	100077	34	41	5.5	10-7/16	48
12-A-11	100078	64	68	9.1	14-15/16	70
12-A-17	100079	109	109	14.6	22-1/16	102

(The above is typical of the of previous charts that were omitted, very typical of following omitted charts.)

Plates

Width	Height	Thickness
5-5/8	4-1/8	.098

Type "B" Batteries

The type "B" series of batteries has been designed for use on a number of cars now in service that do not have a sufficient headroom in the battery compartment for type "C." Type "B" batteries carry all of the features of the type "C." Due to the fact that the plates of necessity must be somewhat shorter than in the type "C" batteries their efficiency from the point of ampere hours per pound of weight is slightly less than the type "C" series.

(Chart omitted.)

Plates

Width	Height	Thickness
5-5/8	4-3/4	0.1

Type "C" Batteries

The type "C" series of batteries is the Westinghouse standard. The outside dimensions and capacity are such that some one of this design may be used in a majority of cars now in service. The Westinghouse design was built around this type and it should be used for replacement or new equipment.

Type "C" batteries are provided with the Westinghouse Post Seal wherever possible.

(Chart omitted.)

Plates

Width	Height	Thickness
5-5/8	4-1/4	0.1 inch

Type "E" Batteries

The type "E" series was designed for replacement work on a few old model cars now in service where a narrow, high battery was necessary. The design is not as efficient as the "B" and "C" lines, due to a lack of space and further, it has been necessary to omit the Westinghouse Post Seal for the same reason.

(Chart omitted.)

Plates

Width	Height	Thickness
4-1/8	5-5/8	.098

Type "H" Batteries

The type "H" battery is built with heavier plates than the type "C" and "B" batteries for use in cars where the necessary increased space is available and where the weight per ampere output is not a consideration. Under the

same -use the battery will give a greater life than the type "C" or "B" battery having the same positive area.

This battery has a greater space between the plates than the "C" or "B" battery and will therefore have less internal discharge when standing on open circuit, and is more desirable for miscellaneous use where open circuit discharge is of consideration.

(Chart omitted.)

Plates

Width	Height	Thickness
5-5/8	5	.19

Type "J" Batteries

The type "J" battery is an extremely heavy construction battery with thick plates, and it was designed primarily for use on trucks and other vehicles of this type where there is excessive vibration and other possibility of mechanical abuse. This battery will give a greater life than either the "H", "C" or "B" battery with the same plate -area. It is provided with wood separators and rubber sheets.

This battery has a greater space between the plates than the "C" or "B" battery and will therefore have less internal discharge when standing on open circuit, and is more desirable for miscellaneous use where open circuit discharge is of consideration.

(Chart omitted.)

Plates

Width	Height	Thickness
5-5/8	5	.19

Type "0" Batteries

The "0" type battery sacrifices some capacity in obtaining a rugged strength. It is a special battery made only with nineteen plates per cell where the percentage of sacrificed capacity is not great as compared with the twenty-one plate "C" type. It fills the same space as does a 6-C-21. It has greater life and strength. It has less capacity but it is built for conditions requiring less capacity than a twenty-one plate cell.

(Chart omitted.)

Plates

Width	Height	Thickness
5-5/8	5-1/4	.123

Type "F" Batteries

There is only one type "F" battery. It is of big heavy construction exactly the same dimensions as the battery used for a number of years on the Cadillac and certain other cars. This battery is heavier than type "C" of the same capacity and it has a greater life.

(Chart omitted.)

Plates

Width	Height	Thickness
4-3/4	5-1/4	.17

WILLARD BATTERIES

Since 1912, when the Willard Storage Battery Co. began to manufacture storage batteries for starting and lighting work, various types of Willard batteries have been developed. The original Willard starting and lighting batteries used two-piece, or "double" covers. These are shown in the cuts used to illustrate the sealing of double-cover covers in the preceding chapter, and no further description will be given here. The doublecover batteries are no longer made, but the repairman will probably be called upon to repair some of them. The instructions given in the preceding chapter should be used in making such repairs.

Following the double cover batteries came the single cover battery, of which a number of types have been made. One type used a rectangular post, and was very difficult to repair. Fortunately, this type was not used extensively, and the battery is obsolete.

Willard Batteries With Compound Sealed Posts

The oldest type single-cover Willard battery which the repairman will be called upon to handle is the compound sealed post type, illustrated in-Fig. 277. This battery includes types SEW, SER, SJW, SL, SLR, SM, SMR, STR, SXW, SXR, SP, SK, SQ, EM, and EMR. As shown in Fig. 277, there is a well around each post which is filled with: sealing compound. On the under side of the cover is a corresponding well which fits into the post well, the sealing compound serving to make the seal between the cover and the post.

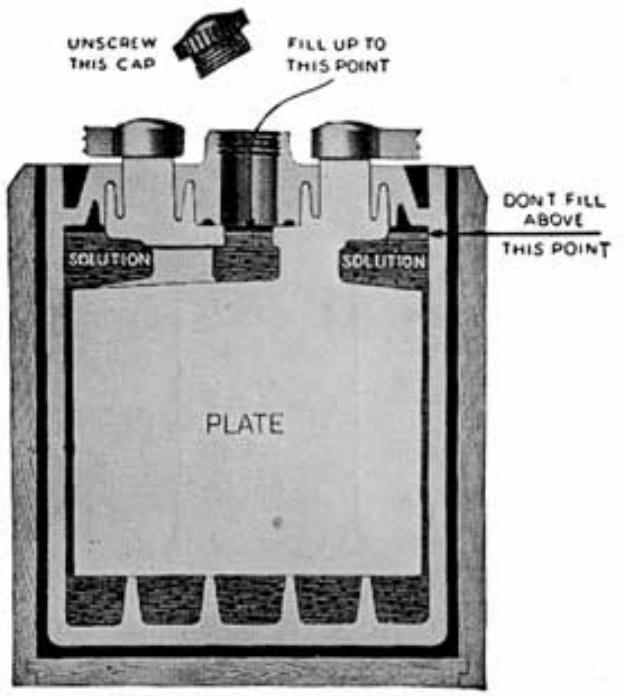

Fig. 277. Willard Battery Using Sealing Compound Around Posts

Aside from this post seal, no special instructions are required in rebuilding this type of Willard battery. A 3/4 inch drill is needed for drilling off the connectors. When the plates have been lifted out of the jars, and are resting on the jar to drain, and while- the compound and cover are still hot, remove the cover by placing your fingers under it and pressing down on the posts with your thumbs.

With a narrow screw driver or a knife, clean out all of the old compound from the wells around the posts, and also remove the compound from the under side of the cover which fits into the post wells.

In reassembling the battery first try on the covers to see that they will fit in the post wells. Then remove the covers again and heat them with a soft flame. Then heat the post wells perfectly dry with a soft flame. Pour the post wells nearly full of compound, and quickly press the cover into position.

Willard Batteries With Lead Inserts In Covers

The types SJWN and SJRN Willard batteries have lead inserts in the cover post holes, as shown in Mg. 278, the inserts being welded to the posts. For removing the connectors and for separating the post from the cover insert, the Willard Company furnishes special jigs and forms. The work may also be done without these jigs and forms, as will be described later.

When the special jigs and forms are used, the work is done, as follows:

1. Place Willard drill jig Z-72 (Fig. 279) over the connector, and with a 13/16 inch drill, bore down far enough to release the connector from the post (Fig. 279).

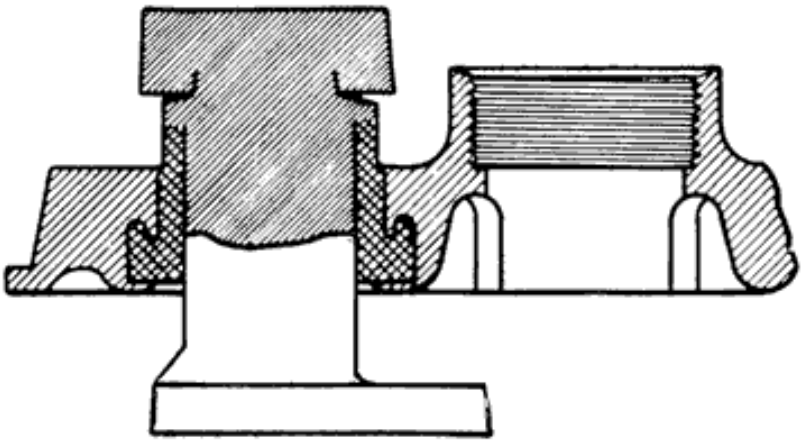

Fig. 278. Lead Insert Used on Willard Batteries, Types SJWN and SJRN

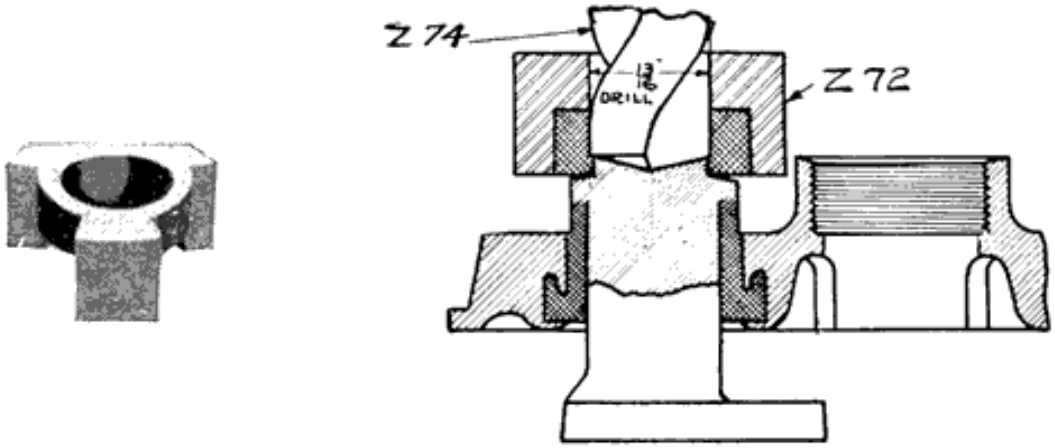

Fig. 279. Willard Drill Jig Z-72 and How it Is Used

2. File off the post stub left by drilling. This will give a flat surface on top of the cover insert and will make it easier to center the drill for the next operation.

3. With a 57/64 inch drill, and Willard jig Z-94 (Fig. 280), drill down to release the post from the cover insert.

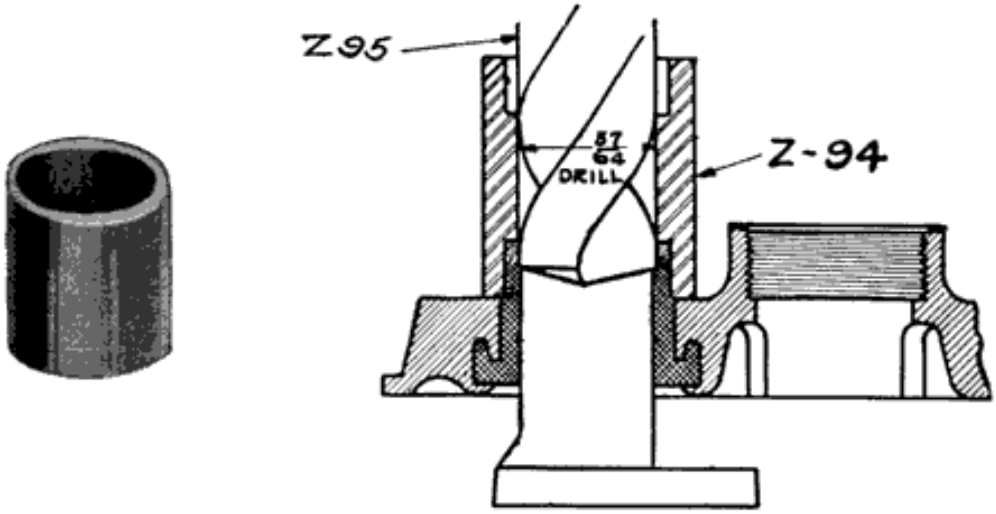

Fig. 280. Willard Jig Z-94, and How it Is Used

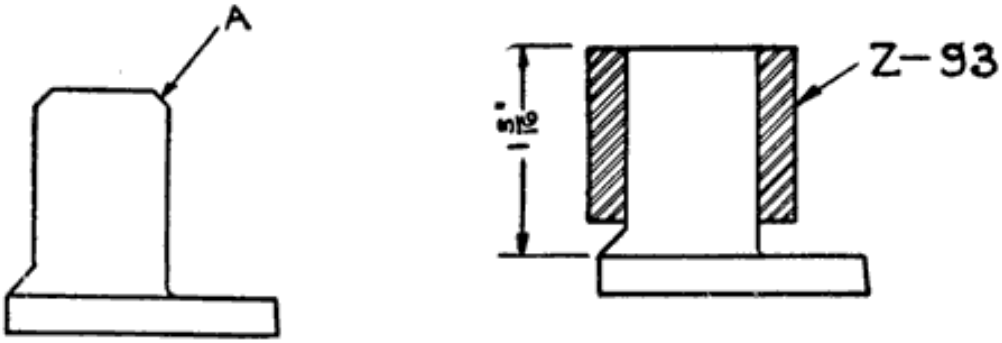

Fig. 281. Willard Post-Builder Z-93, and Built-Up Post

4. In reassembling, build the post up to a height of 1-5/16 inches above the top of the plate strap, using Willard post builder Z-93 (Fig. 281).

5. After removing the post builder, bevel the top edge of the post with a file, as indicated at "A" (Fig. 281). Then replace plates in the jars.

6. File off tops of cover inserts at "A" (Fig. 282), to a height of 3/16 inch above the cover. Also remove any roughness on surface "B" caused by pliers when cover was removed.

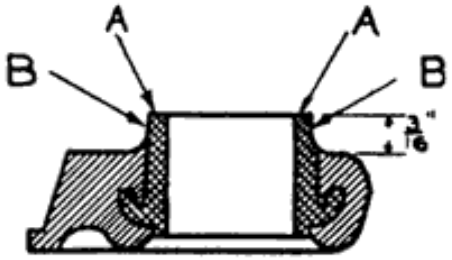

Fig. 282

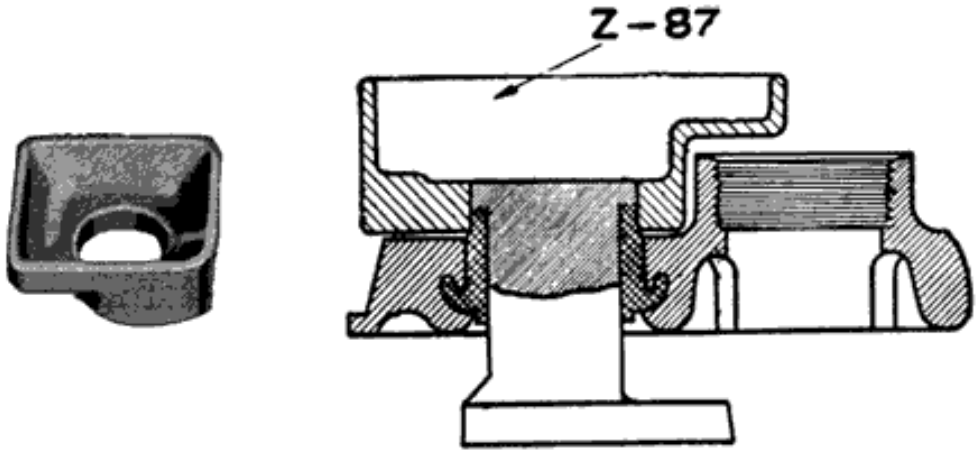

Fig. 283. Willard Burning Form Z-87, and How it Is Used

7. Put on the covers so that their tops will be 1/32 inch above the top edge of the jars, tapping them lightly with a small hammer.

8. Place Willard burning form Z-87 (Fig. 283) over the post and cover insert and burn the post to the insert.

9. Remove form Z-87 and thoroughly brush off the top of the post stub. Then build up the stub post, using Willard burning form Z-88 on the positive posts and form Z-89 on the negative posts (Fig. 284).

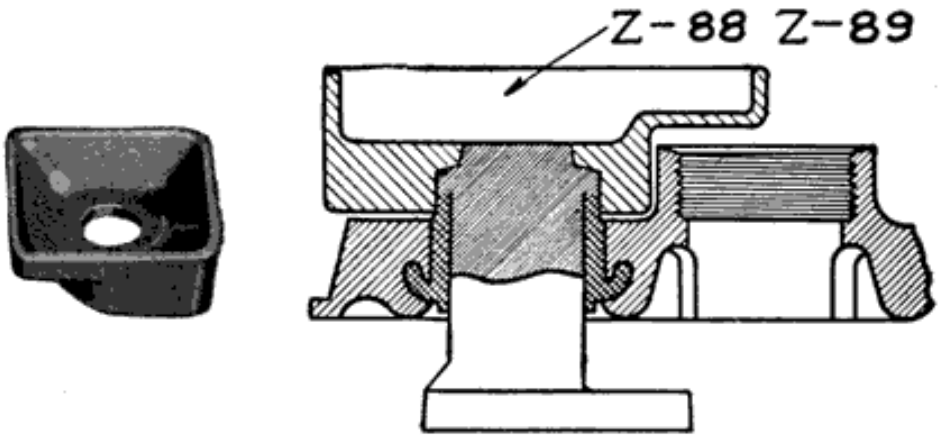

Fig. 284. Willard Burning Form Z-88 and Z-89, and How it Is Used

10. Now seal the covers with sealing compound as usual, and burn on the connectors.

11. If the terminal posts are made for clamp terminals, build up the posts by using Willard burning form Z-90, for the positive posts and Z-91 for the negative posts (Fig. 285).

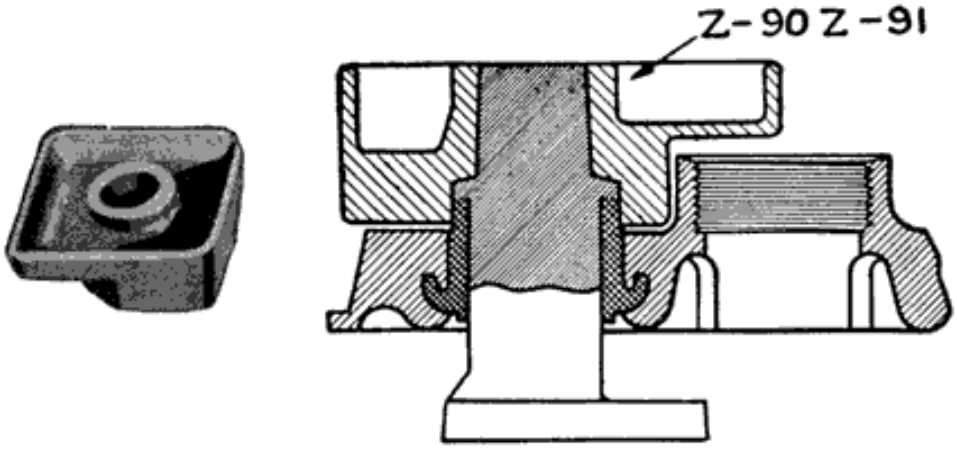

Fig. 285. Willard Burning Form Z-90, Z-91, and How it Is Used

To work on the post seals of Willard types SJWN and SJRN without the special Willard jigs and forms:

1. Remove the connectors and terminals as usual.

2. Saw off the posts close to the covers, taking care not to injure the covers; This will separate the posts from the cover inserts, and the covers may be removed.

3. In reassembling, Ale off the top of the cover insert at "A" (Fig. 292).

4. Put covers on so that their tops will be 1/32 inch above the top edge of the jars, tapping the covers lightly with a small hammer.

5. Brush the top of post and cover insert perfectly clean. Now make a burning form consisting of a ring 1-1/8 inside diameter and 1-5/8 inch outside diameter and 3/16 to 1/4 inch high. Set this over the stub post and cover. With a hot lead burning flame melt the top of the post and cover insert together. Then melt in lead up to the top of the special burning form (Fig. 286). Then remove the form.

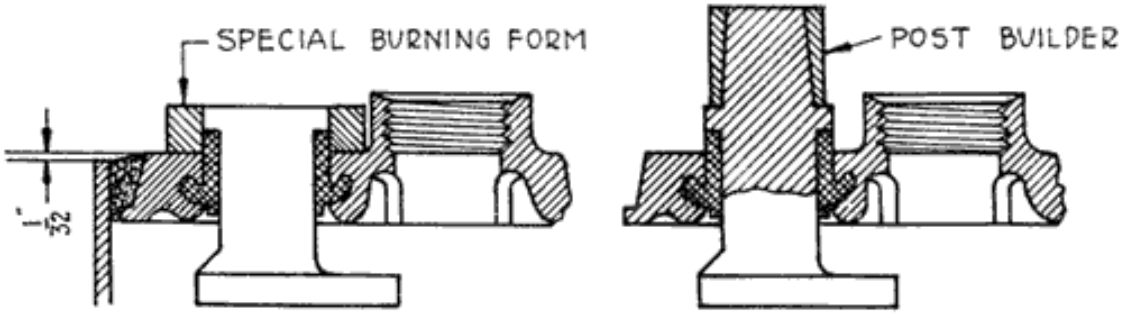

Fig. 286. Building up Posts of Willard Types SJWN and SJRN Without Using Special Willard Forms

6. Set post builders on the part of the posts which has been built up and build up the posts as usual, Fig. 286. Then burn on the connectors and terminals.

Willard Gasket Type Batteries

Fig. 287 shows this type of construction, used on types SJRG and SLWG. Fig. 288 shows the seal in detail. A soft rubber gasket is slipped over the post, and the cover is pushed down over the gasket. For removing the covers, have a cover removal frame made as shown in Fig. 289. Fasten the frame to a solid wall or bench so that it will withstand a strong pull. In rebuilding this type of battery proceed as follows:

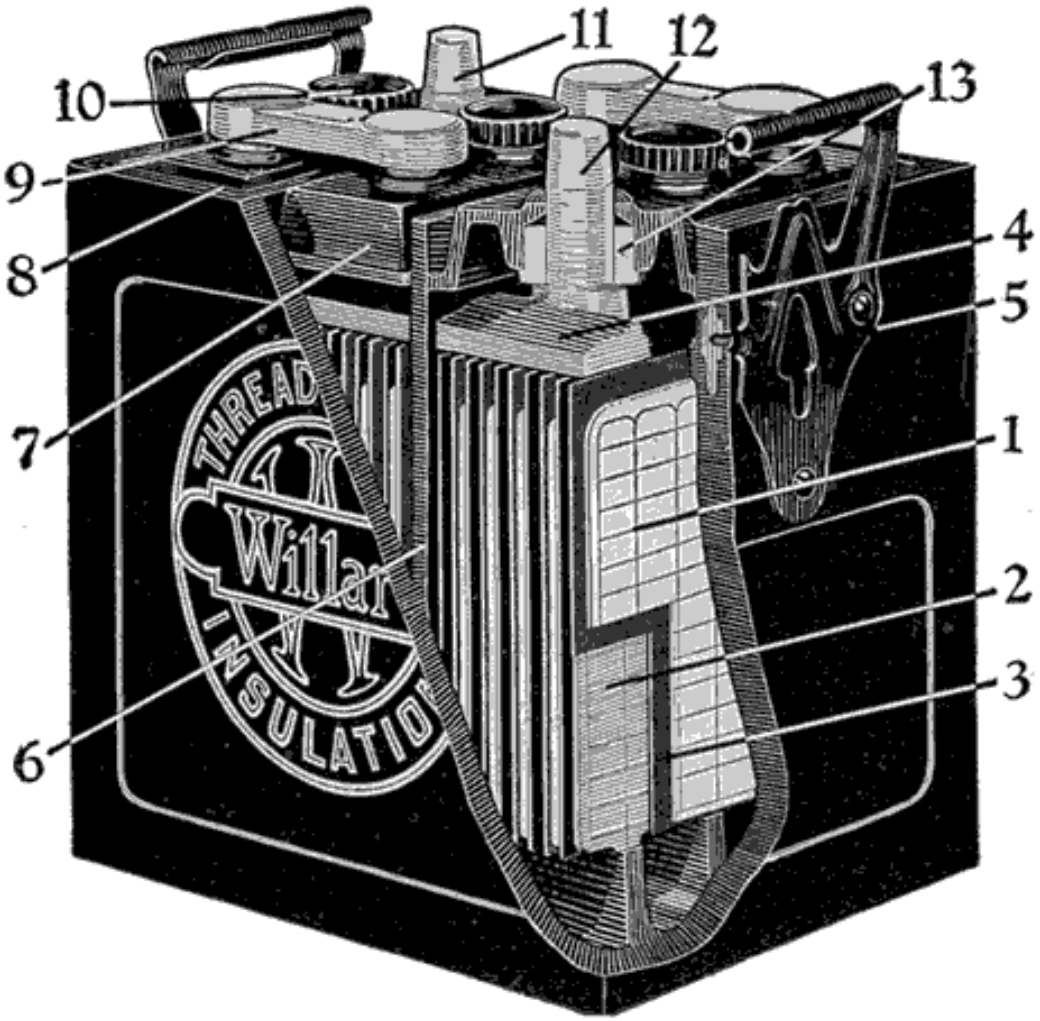

Fig. 287. Willard Gasket Seal Battery

1. Drill off the connectors and terminals, leaving the post stubs, as high as possible, since the only way of removing the plates is by grasping the post stubs with pliers.

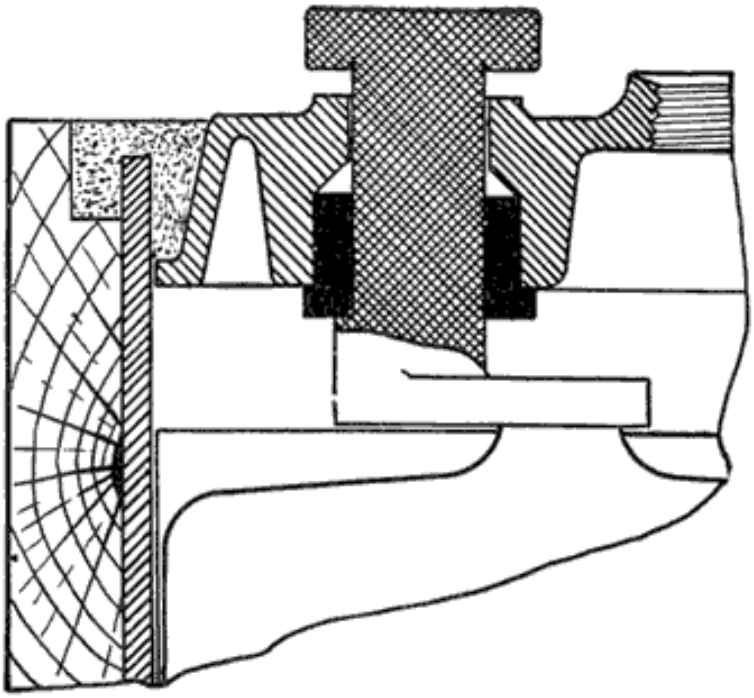

Fig. 288. Details of Willard Gasket Seal

2. Steam the battery to soften the sealing compound and lift out the plates as usual.

3. To remove covers. Saw the post stubs off flush with the covers. Place the element in the cover removal frame (Fig. 289) and pull steadily on the element. A little swaying motion from side to side may help in loosening the covers. If any of the gaskets remain on the posts when the covers are removed, replace them in the cover and thoroughly dry the inside with a rag.

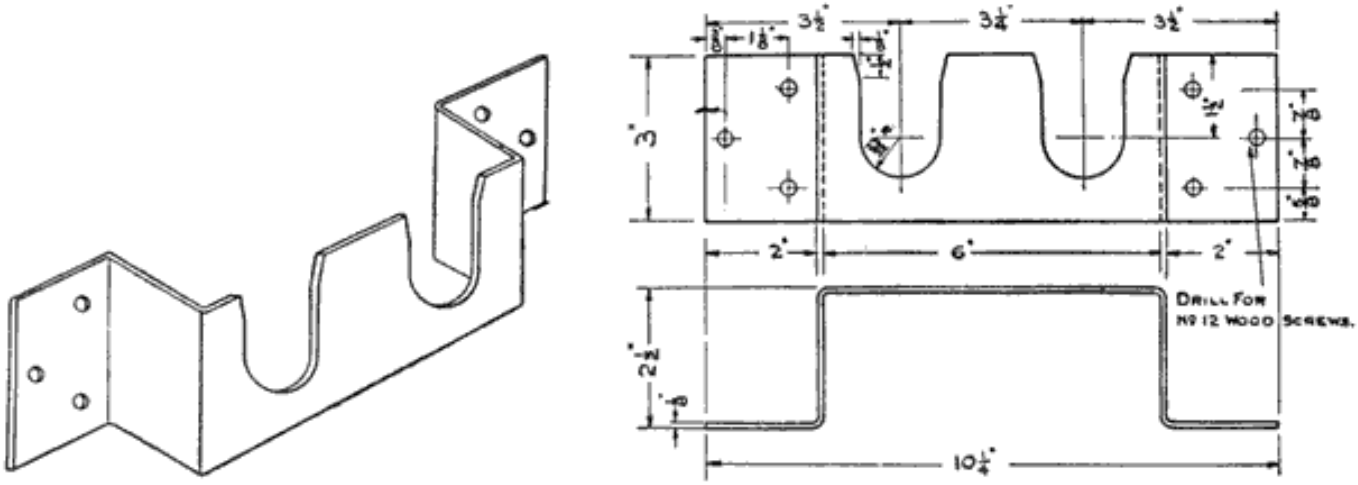

Fig. 289. Cover Removal Frame for Willard Gasket Seal Battery

4. To replace covers. With a rag or tissue paper wipe off the posts and then dry them thoroughly with a soft flame.

With a 3/4 inch bristle bottle brush apply a thin coating of rubber cement to the inside surfaces of the gaskets. Do this to one cover at a time and apply the cover quickly before the cement dries. The cement acts as a lubricant, and without it, it will be impossible to replace the covers.

Willard Separators

Fig. 290 shows the Willard Threaded Rubber Separator which is made of a rubber sheet pierced by thousands of threads which are designed to make the separator porous. This separator is not injured by allowing it to become dry, and makes it possible for the Willard Company to ship its batteries fully assembled without electrolyte or moisture, the parts being "bone-dry."

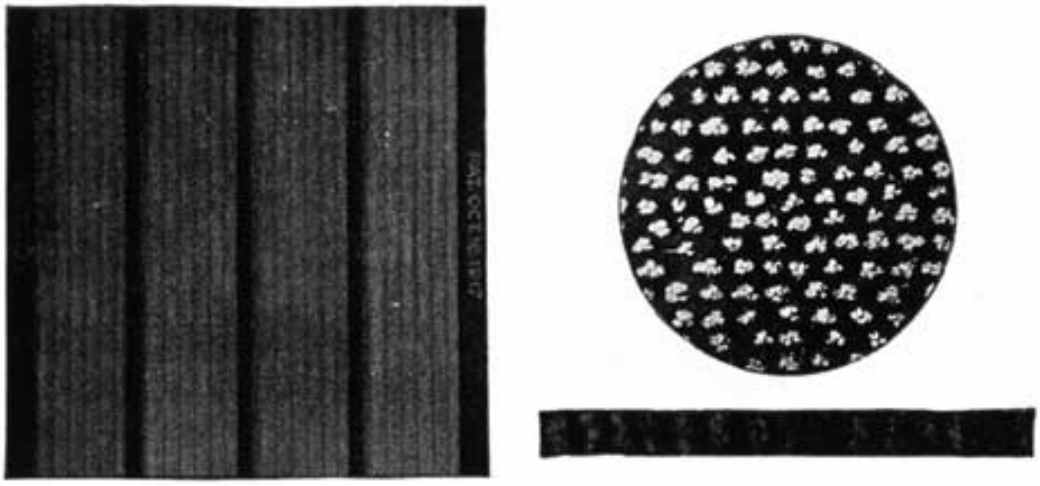

Fig. 290. Complete Willard Threaded Rubber Separator, and Magnified Cross Section to Show Threads

UNIVERSAL BATTERIES

Types. The Universal Battery Co. manufactures batteries for (a) Starting and Lighting, (b) Lighting, (c) Ignition, (d) Radio, (e) Electric Cars and Trucks, (f) Isolated, or Farm Lighting Plants, and (g) General Stationary Work.

Construction Features. The Universal Starting and Lighting Batteries embody no special or unique constructions. The boxes are made of hard maple, lock cornered and glued. The jars have single rubber covers. The separators are made of Port Orford white cedar wood, this wood being the same as that used in some of the other standard makes of batteries. The space between the covers and connectors is- sufficient to permit lifting the battery by grasping the connectors.

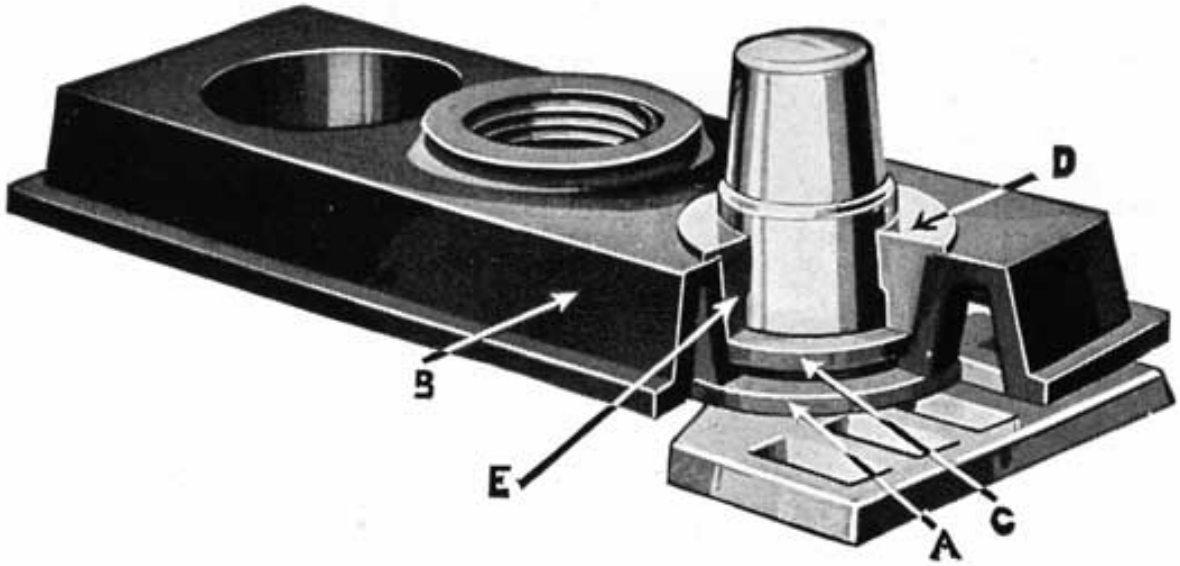

Fig. 291. Universal Battery Cover Construction

Fig. 291 shows the Universal Co. Post Seal construction. A soft rubber washer (A) is first slipped over the post. The cover (B) is then put in place, and rests on the washer (A) as shown. A second washer (C) is then slipped over the post, resting on the upper surface of the shoulder of the cover. The lead sleeve washer (D) is then forced down over the post, pressing washer (C) down on the cover, and pressing the cover down on washer (A). The two rubber washers serve to make a leak proof joint between post and cover. The lead sleeve-washer (D) "freezes" to the post, and holds cover and washers in position.

In rebuilding Universal batteries the cover need not be removed unless it is desired to replace plate groups. To remove the cover, after the cell connectors have been drilled off, drill down through the post-stub until the drill has penetrated to the shoulder (E). This releases the seal and the cover may be lifted off. To save time, the post-stub may be cut off flush with the top of the cover with a hack saw after the cell connectors have been drilled off. The drill is then used as before to release the grip of the washer. Using a drill to release the grip of the washer makes it necessary to build up the posts when the battery is reassembled. Instead of using an ordinary twist drill, a special hollow drill may be obtained from the Universal Battery Co. This drill cuts away the lead sleeve gasket without injuring the post. If an ordinary drill is used, a 3/4 inch drill is required for the seven plate battery and a 13/16 inch drill for all other sizes.

ONE-PIECE BATTERY CONTAINERS

The standard practice in battery assembly has always been to place the plates of each cell in a separate, hard rubber jar, the jars being set in a wooden box or case. Each six-volt battery thus has four containers. When a wooden case is used, jars made of rubber, or some other nonporous, acid-resisting material are necessary.

Fig. 292. One-Piece Battery Container.

Wooden cases have been fairly well standardized as to the kinds of wood used, dimensions, constructional features, and to a certain extent, the handles. The disadvantage of both the wooden case and the iron handles is that they are not acid proof. Acid-proof paint protects them from the action of the acid to a certain extent, but paint is easily scraped off, exposing the wood and iron to the action of the acid. It is practically impossible to prevent acid from reaching the case and handles, and corroded handles and rotted cases are quite common.

A recent development is a one-piece container which takes the place of the jars and wooden case. Such a container is made of hard rubber or a composition of impregnated fibre which uses a small amount of rubber as a binder. These cases are, of course, entirely acid proof, and eliminate the possibility of having acid soaked and acid rotted cases. Painting of cases is also eliminated. The handles are often integral parts of the case, as shown in Fig. 292, being made of the same material as the case.

The repairman should not overlook the possibilities of the one-piece containers. In making up rental batteries, or in replacing old cases, the one-piece containers may be used to advantage. These containers are suitable for Radio batteries, since they have a neater appearance than the wooden cases, and are not as likely to damage floors or furnishings because the acid cannot seep through them.

THE TITAN BATTERY

The Titan Battery is built along standard lines, as far as cases, plates, separators, and jars are concerned. The ribs of the grids not arranged at right angles but are arranged as shown in Fig. 293. Each pellet of active material is supported by a diagonal rib on the opposite face of the grid.

Fig. 293. a

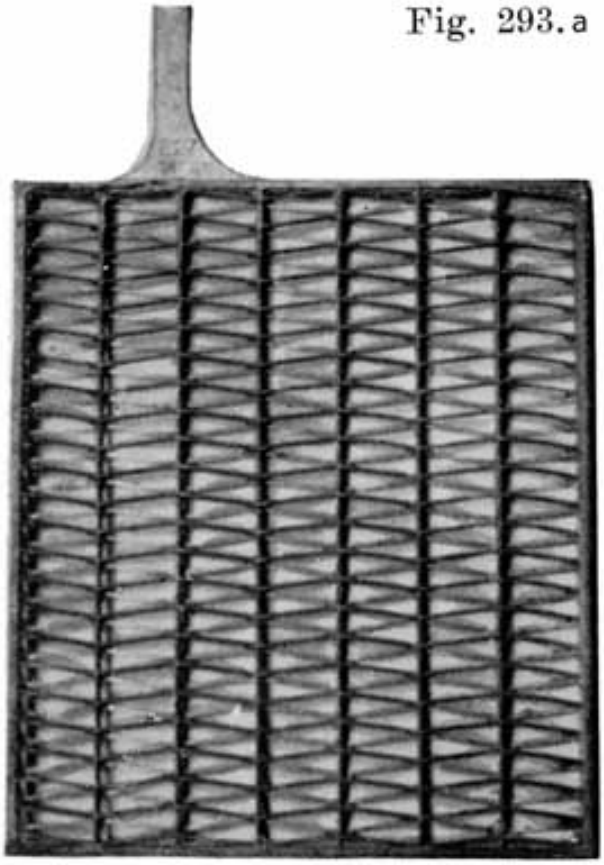

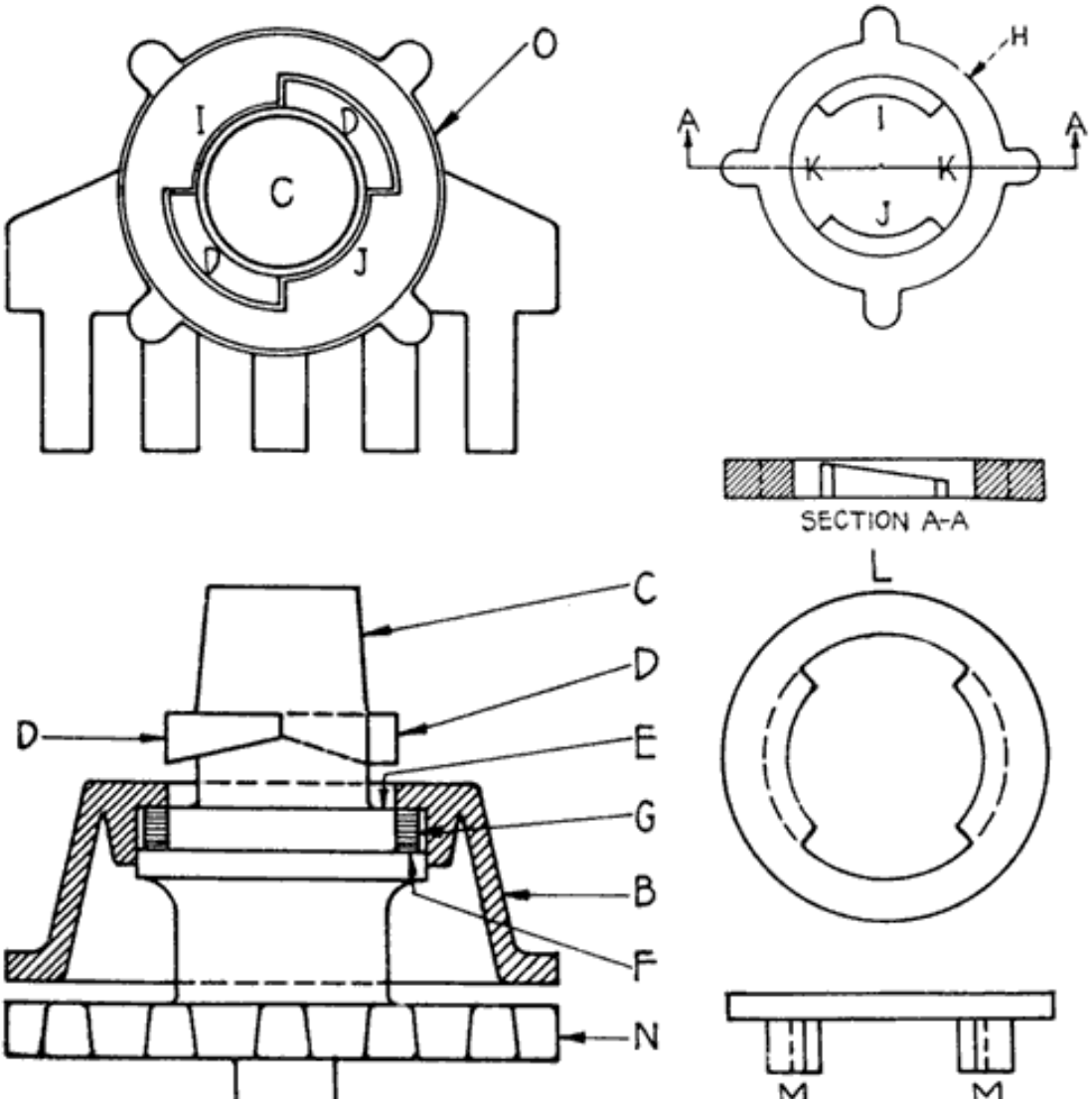

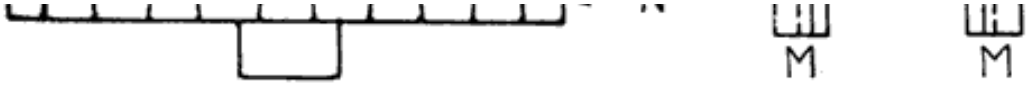

Fig. 293.b Titan Grid, and Post Seal Construction

The Titan Post Seal is shown in Fig. 293. A soft rubber gasket (G) is slipped over the post, and rests on a shoulder (F) on the post. The cover has a channel which fits over the gasket and prevents the gasket from being squeezed out of place when the cover is forced down on the gasket. The post has two projections (DD), as shown, the lower surface of each of which is inclined at an angle to the horizontal. A lock nut (H), which has corresponding projections (IJ) is slipped over the post as shown at (0), and is given a quarter turn. The top surfaces of the projections on the lock-nut are inclined and as the locknut is turned, the projections on the post and nut engage, and the cover is forced down on the gasket (G). To lock the nut in place, a lock washer (L) is then slipped over the post, the projections (MM) fitting into spaces (KK) between the projections on the post and nut, thus preventing the nut from turning. A special wrench is furnished for turning the lock-nut. The cell connectors rest on the tops of the lock washers and keep them in place.

The overhauling of Titan batteries should be done as described on pages 328 to 374.

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SECTION III

CHAPTER 17

FARM LIGHTING BATTERIES

Although the large Central Station Companies are continually extending their power lines, and are enlarging the territory served by them, yet there are many places where such service is not available. To meet the demand for electrical power in these places, small but complete generating plants have been produced by a number of manufacturers. These plants consist of an electrical generator, an engine, to drive the generator, and a storage battery to supply power when the generator is not running. The complete plants are called "House Lighting," "Farm Lighting," or "Isolated" plants.

The batteries used in these plants differ considerably from the starting batteries used on automobiles. The starting battery is called upon to deliver very heavy currents for short intervals. On the car the battery is always being charged when the car is running at a moderate speed or over. The battery must fit in the limited space provided for it on the car, and must not lose any electrolyte as the car jolts along over the road. It is subjected to both high and low temperatures; and is generally on a car whose owner often does not know that his car has such a thing as a battery until his starting motor some day fails to turn over the engine. All starting batteries have wooden cases (some now use rubber cases), hard rubber jars, and sealed on covers. The case contains all the cells of the battery. Automobile batteries have, therefore, become highly standardized, and to the uninformed, one make looks just like any other.

Farm lighting batteries, on the other hand, are not limited as to space they occupy, are not subjected to irregular charging and discharging, do not need leak proof covers, and are not called upon to delivery very heavy currents for -short periods. These facts are taken advantage of by the manufacturers, who have designed their farm lighting batteries to give a much longer life than is possible in the automobile battery. As a result the farm lighting battery differs from the automobile battery in a number of respects.

Jars. Both glass and rubber are used for farm lighting battery jars, and they may or may not have sealed-in covers. Fig. 294 shows a glass jar of an Exide battery having a hard rubber cover, and Fig. 295 shows a Prest-O-Lite glass jar cell having a cover made of lead and antimony. Unsealed glass jars, such as the Exide type shown in Fig. 324, generally have a plate of glass placed across the top to catch acid spray when the cell is gassing. Each jar with its plates and electrolyte forms a complete and separate unit which may easily be disconnected from the other cells of the battery by removing the bolts which join them. In working on a farm lighting battery, the repairman, therefore, works with individual cells instead of the battery as a whole, as is done with automobile batteries.

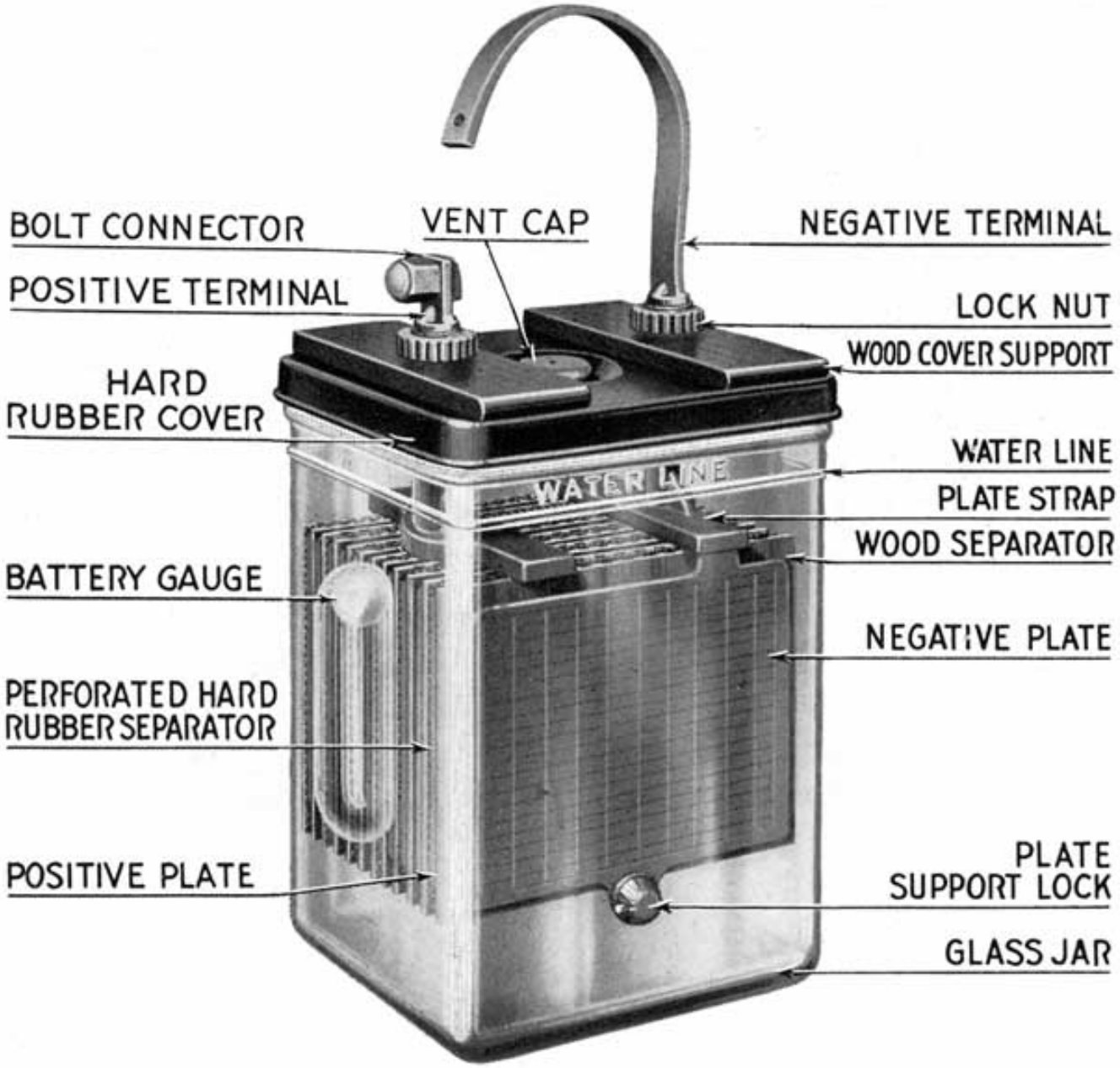

Fig. 294. Exide "Delco Light" Farm Lighting Cell with Hard Rubber Cover

Batteries with sealed jars are generally shipped completely assembled and filled with electrolyte, and need only a freshening charge before being put into service, just as automobile batteries which are shipped "wet" are in a fully charged condition when they leave the factory and need only a charge before being installed on the car.

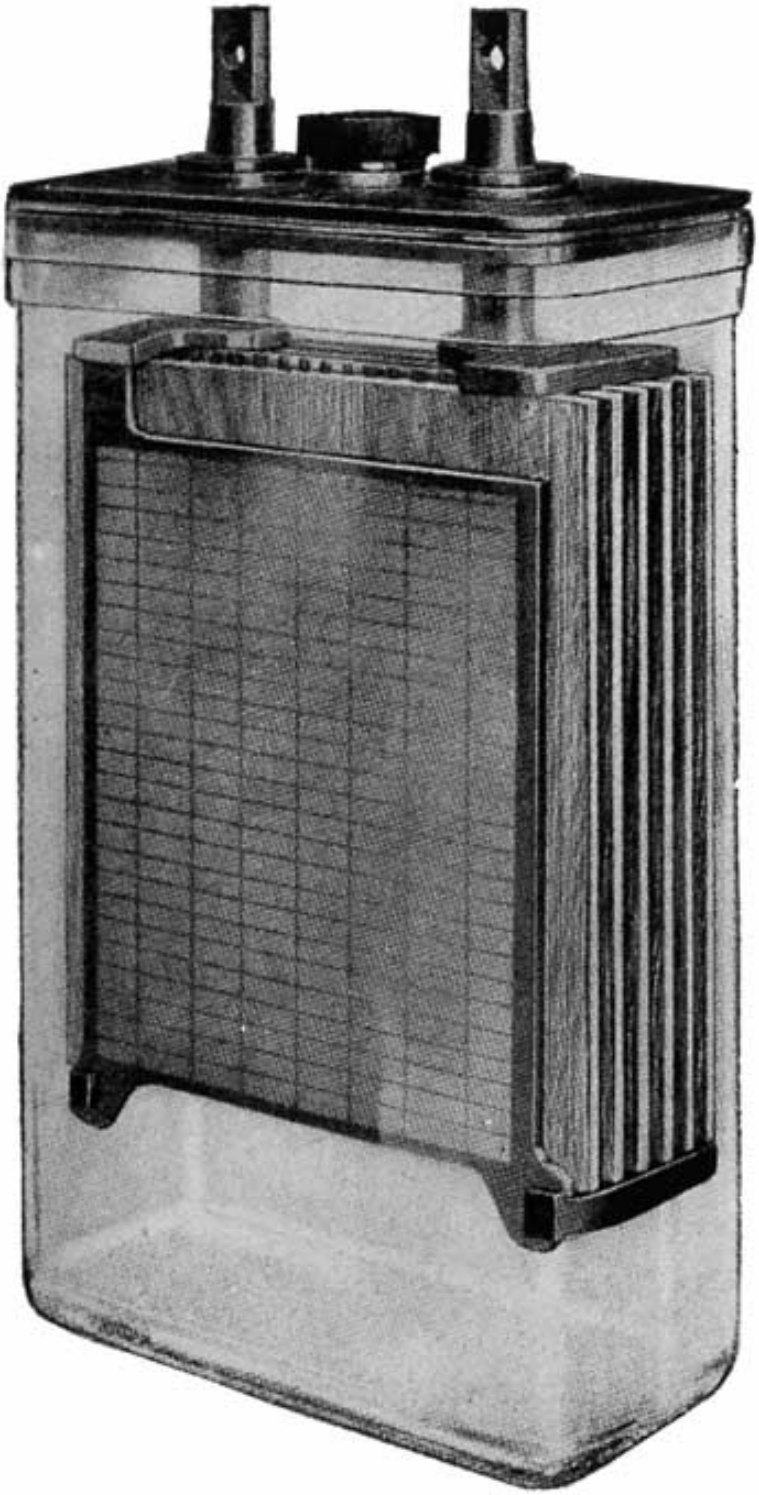

Fig. 295. Prest-O-Lite Farm Lighting Cell, with Lead-Antimony Cover

Jars that are not sealed are set in separate glass trays filled with sand, or sometimes the entire battery is set in a shallow wooden box or tray filled with sand. This is necessary because the absence of a sealed cover allows acid spray to run down the outside of the jar and this acid would, of course, attack the wooden shelf and make a dirty, sloppy battery. Batteries using jars without sealed covers cannot be shipped assembled and charged, and hence they require a considerable amount of work and along initial charge to put them in a serviceable condition.

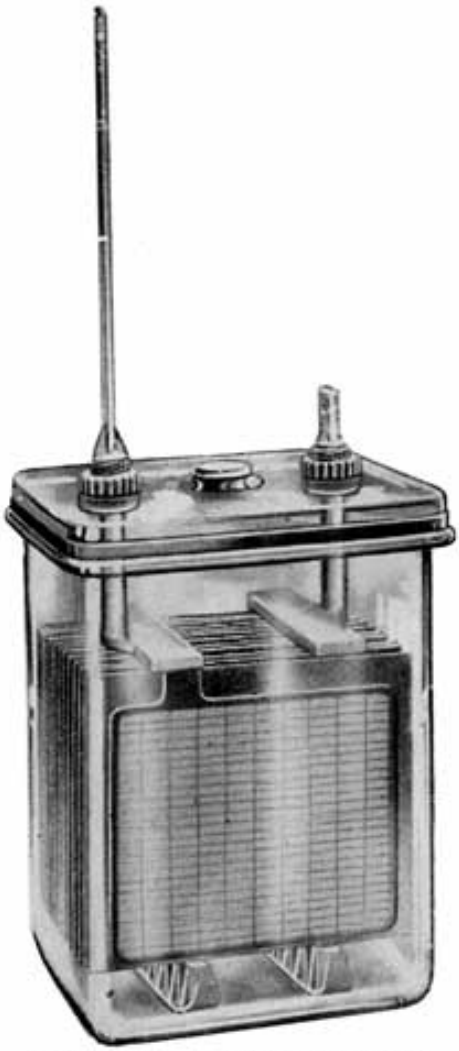

Fig. 296. Exide Farm Lighting Cell with Sealed Glass Jar

Farm lighting battery jars are less liable to become cracked than those of automobile batteries because they are set in one place and remain there, and are not jolted about as automobile batteries are. Cracked jars in farm lighting batteries are more easily detected as the jar will be wet on the outside and the acid will wet the shelf or sand tray on which the jar rests.

Batteries with sealed rubber jars are normally assembled four cells in a case or tray, with a nameplate on each tray which gives the type and size of cell. The cells are connected together with lead links which are bolted to the cell posts by means of lead covered bolt connectors.

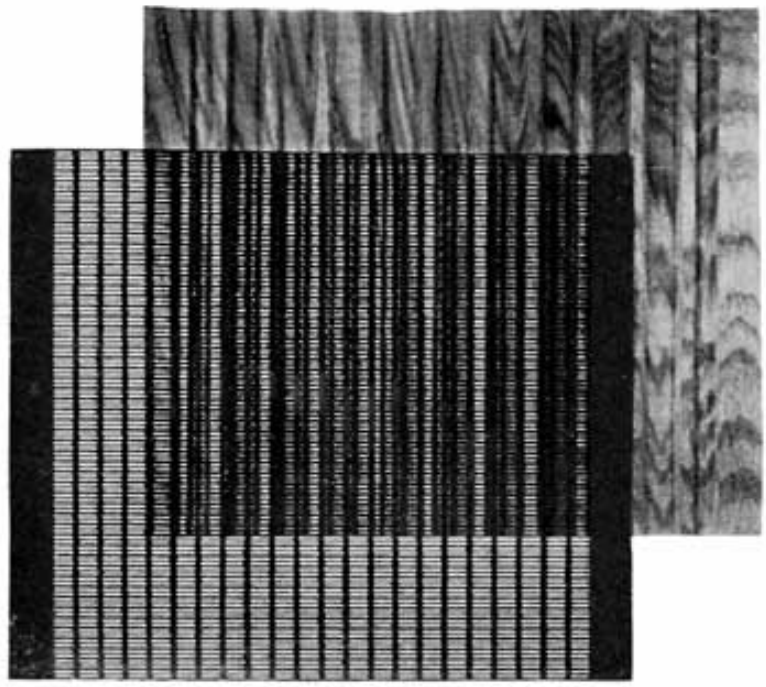

Fig. 297. Combination Wood and Rubber Separator Used in Delco-Light and Exide Farm Lighting Cell

Plates. Since farm lighting batteries are not required to deliver very heavy currents at any time, the plates are made thicker than in starting batteries. this giving a stronger plate which has a longer life. than the starting battery plate.

All makes of starting batteries use the Fauré, or pasted plate. This type of plate is also used ill many farm lighting batteries, but the Plante plate (see page 27) may also be used. The Exide "Chloride Accumulator" cell, Fig. 323 uses a type of positive plate called the "Manchester" positive' as described Oil page 497.

Separators. Grooved wooden separators are used in some farm lighting batteries, while others use rubber separators, or both rubber and wooden separators. Some use wooden separators which are smooth on both sides, but have dowels pinned to them.

Electrolyte. In a starting battery the specific gravity of the electrolyte of a fully charged cell is 1.280-1.300, no matter what the make of the battery may be. In farm lighting batteries, the different types have different values of specific gravity when fully charged. The usual values are as follows:

(a) Batteries with sealed glass jars 1.210 to 1.250

(b) Batteries with open glass jars 1.200 to 1.250

(c) Batteries with sealed rubber jars 1.260 to 1.280

A brief discussion of specific gravity might be helpful at this point. In any lead acid battery current is produced by a chemical action between the active material in the plates and the water and sulphuric acid in the electrolyte. The amount of energy which can be delivered by the battery depends on the amount of active material, sulphuric acid, and water which enter into the chemical actions of the cell. As these chemical actions take place, sulphuric acid is used up, and hence there must be enough acid contained in the electrolyte to enter into the chemical actions. The amount of water and acid in the electrolyte may be varied, as long as there is enough of each present to combine with the active material of the plates so as to enable the cell. to deliver its full capacity. Increasing the amount of acid will result in the plates and separators being attacked and injured by the acid. Increasing the amount of water dilutes the acid, giving a lower gravity, and preventing the Acid from injuring plates and separators. This results

in a longer life for the battery, and is a desirable condition. In starter batteries, there is not enough space in the jars for the increased amount of water. In farm lighting batteries, where the space occupied by the battery is not so important, the jars are made large enough to hold a greater amount of water, thus giving an electrolyte which has a lower specific gravity than in starting batteries.

Take a fully charged. cell of any starting battery. It contains a set of plates and the electrolyte which is composed of a certain necessary amount of acid and a certain amount of water. If we put the plates of this cell in a larger jar, add the same amount of acid as before, but add a greater amount of water than was contained in the smaller jar, we will still have a fully charged cell of the same capacity as before, but the specific gravity of the electrolyte will be lower.

Charging Equipment. Automobile batteries are being charged whenever the car is running at more than about 10 miles per hour, regardless of what their condition may be.

In farm lighting outfits, the charging is under the control of the operator, and the battery is charged when a charge is necessary. There is, therefore, very much less danger of starving or overcharging the battery. The operator must, however, watch his battery carefully, and charge it as often as may be necessary, and not allow it to go without its regular charge.

The generator of a farm lighting outfit is usually driven by an internal combustion engine furnished with the outfit. The engine may be connected to the generator by a belt, or its shaft may be connected directly to the generator shaft. A switchboard carrying the necessary instruments and switches also goes with the outfit. The charging of farm lighting batteries is very much like the charging of automobile batteries on the charging bench, except that the batteries are at all times connected to switches, by means of which they may be put on the charging line.

Some plants are so arranged that the battery and generator do not provide current for the lights at the same time, lights being out while the battery is charging. In others the generator and battery, in emergency, may both provide current. In others the lights may burn while the battery is being charged; in this case the battery is sometimes provided with counter-electromotive force cells which permit high enough voltage across the battery to charge it and yet limit the voltage across the lamps to* prevent burning them out or shortening their life. In some cases the battery is divided into two sets which are charged in parallel and discharged in series.

Relation of the Automobile Storage Battery Man to the Farm Lighting Plant. Owners and prospective owners of farm lighting plants generally know but little about the care or repair of electrical apparatus, especially batteries, which are not as easily understood as lamps, motors or generators. Prospective owners may quite likely call upon the automobile battery repair man for advice as to the installation, operation, maintenance, and repair of his battery and the automobile battery repairman should have little trouble in learning how to take care of farm lighting batteries. The details in which these batteries differ from starting batteries should be studied and mastered, and a new source of business will be opened.

Farm lighting plants in the vicinity should be studied and observed while they are in good working order, the details of construction and operation studied, the layout of the various circuits to lamps, motors, heaters, etc., examined so as to become familiar with the plants. Then When anything goes wrong with the battery, or even the other parts of the plant, there will be no difficulty in putting things back in running order.

Selection of Plant

"Farm Lighting Plant" is the name applied to the small electric plant to be used where a central station supply is not available. Such a plant, of course, may be used for driving motors and heating devices, as well as operating electric lights, and the plant is really a "Farm Lighting and Power Plant."

Make. There are several very good lighting plants on the market and the selection of the make of the plant must be left to the discretion of the owner, or whomever the owner may ask for advice. The selection will depend on cost, whether the plant will fill the particular requirements, what makes can be obtained nearby, on the delivery that can be made, and the service policy of the manufacturer.

Type. Plants are made which come complete with battery, generator, engine, and switchboard mounted on one base. All such a plant requires is a suitable floor space for its installation. Other plants have all parts separate, and require more work to install. With some plants, the generator and engine may be mounted as a unit on one base, with battery and switchboard separate.

The type of jar used in the battery may influence the choice. Jars are made of glass or rubber. The glass jars have sealed covers, or have no covers. The rubber jars generally have a sealed cover. The glass jar has the advantage that the interior may be seen at all times, and the height of the electrolyte and sediment may be seen and the condition of the plates, etc., determined by a simple inspection. This is an important feature and one that will be appreciated by the one who takes care of the battery. Jars with sealed covers, or covers which although not sealed, close up the top of the jar completely have the advantage of keeping in acid spray, and keeping out dirt and impurities. Open jars are generally set in trays of sand to catch electrolyte which runs down the outside walls of the jars. The open jars have the advantage that the plates are very easily removed, but have the disadvantage that acid spray is not kept in effectually, although a plate of glass is generally laid over part of the top of the jar, and that dirt and dust may fall into the jar.

Size. The capacity of storage battery cells is rated in ampere hours, while power consumed by lights, motors, etc., is measured in watt hours, or kilowatt hours. However, the ampere hour capacity of a battery can be changed to watt hours since watt hours is equal to

Watt hours = ampere hours multiplied by the volts

If we have a 16 cell battery, each cell of which is an 80 ampere hour cell, the ampere hour capacity of the entire battery will be 80, the same as that of one of its cells, since the cells are all in series and the same current passes through all cells. The watt hour capacity of the battery will be 32 times 80, or 2560. The ampere hour capacity is computed for the 8 hour rate, that is, the current is drawn from the battery continuously for 8 hours, and at the end of that time the battery is discharged. If the current is not drawn from the battery continuously for 8 hours, but is used for shorter intervals intermittently, the ampere hour capacity of the battery will be somewhat greater. It seldom occurs that in any installation the battery is used continuously for eight hours at a rate which will discharge it in that time, and hence a greater capacity is obtained from the battery. Some manufacturers do not rate their batteries at the 8 hour continuous discharge rate but use the intermittent rate, thus rating a battery 30 to 40 percent higher. Rated in this way, a battery of 16 cells rated at 80 ampere hours at the 8 hour rate would be rated at 112 ampere hours, or 3584 watt hours.

In determining the size of the battery required, estimate as nearly as possible how many lamps, motors, and heaters, etc., will be used. Compute the watts (volts X amperes), required by each, Estimate how long each appliance will be used each day, and thus obtain the total watt hours used per day. Multiply this by 7 to get the watt hours per week. The total watt hours required in one week should not be equal to more than twice the watt hour capacity of the battery (ampere hours multiplied by the total battery voltage) at the eight hour. rate. This means that the battery should not require a charge oftener than two times a week.

The capacity of a battery is often measured in the number of lamps it will burn brightly for eight hours. The watts consumed by motors, heaters, etc., may be expressed in a certain number of lamps. The following table will be of assistance in determining the size of the battery required:

No.	Type of Appliance	Watts Consumed	Equivalent Number of 20 Watt Lamps
1	16 candle power, Mazda lamp	20	1
2	12 candle power, Mazda lamp	115	3/4
3	Electric Fan, small size	75	4
4	Small Sewing machine motor	100	5
5	Vacuum cleaner	160	8
6	Washing machine	200	10
7	Churn, 1/6 h.p.	200	10
8	Cream Separator 1/6 h.p.	200	10
9	Water pump 1/6 h.p,	200	10
10	Electric water heater, small	350	18
11	Electric toaster	525	26
12	Electric stove, small	600	30
13	Electric iron	600	30
14	Pump, 1/2 h.p.	600	30

From the foregoing table we can determine the current consumption of the various appliances:

No.	Watts	Amps. at 32 Volts	Amps. at 110 Volts

1	20	0.625	0.18
2	15	0.47	0.14
3	75	2.34	6.80
4	100	3.125	0.90
5	160	5.00	1.44
6	200	6.25	1.80
7	200	6.25	1.80
8	200	6.25	1.80
9	200	6.25	1.80
10	350	11.00	3.20
11	525	16.4	4.77
12	600	18.75	5.40
13	600	18.75	5.40
14	600	18.75	5.40

(Omitted, two simple charts that show how long "32-Volt Battery" and "110-Volt Battery" will carry various currents continuously.)

Location of Plant

The various appliances should be placed as near to each other as possible. The lights, of course, must be placed so as to illuminate the different rooms, barns, etc., but the power devices should be placed as close as possible to each other and. to the plant. The purpose of this is to use as little wire as possible between the plant and the various appliances so as to prevent excessive voltage drop in the lines.

Wiring

The wires leading to the various appliances should be large enough so that not more than one or two volts are lost in the wires. To obtain the resistance of the wire leading to any appliance, use the following equation:

$$\text{Resistance} = \frac{\text{Volts lost in line (from 1 to 2)}}{\text{Current flowing in line}}$$

Knowing the resistance of the wire, and the total length of the two wires leading from the plant to the appliance, the size of the wire may be obtained from a wiring table.

Rubber insulated copper wire covered with a double braid should preferably be used, and the duplex wire is often more convenient than the single wire, especially in running from one building to another. Wiring on the inside of buildings should be done neatly, running the wires on porcelain insulators, and as directly to the appliance as possible. The standard rules for -interior wiring as to fuses, soldering joints, etc., should be followed.

Installation

(See also special instructions for the different makes, beginning page 460.)

The room in which the plant is installed should be clean, dry, and well ventilated. It should be one which is not very cold in winter, as a cold battery is very sluggish and seems to lack capacity. If possible, have the plant in a separate room in order to keep out dirt and dust. If no separate room is available, it is a good plan to build a small room in a corner of a large room. Keep the room clean and free of miscellaneous tools and rubbish.

If the entire plant comes complete on one base, all that is necessary is to bolt the base securely to the floor, which should be as nearly level as possible. If the battery is to be installed separately, build a rack. Give the rack several coats of asphaltum paint to make it acid proof. The location of the battery rack should be such that the rack will be:

(a) Free from vibration.

(b) At least 3 feet from the exhaust pipe of engine.

(c) Far enough away from the wall to prevent dirt or loose mortar from dropping on the cells.

Figs. 298 and 299 illustrate two types of battery racks recommended for use with farm light batteries. The stair-step rack is most desirable where there is sufficient room for its installation. Where the space is insufficient to make this installation, use the two-tier shelf rack. The racks should be made from 1-1/2 or 2 inch boards.

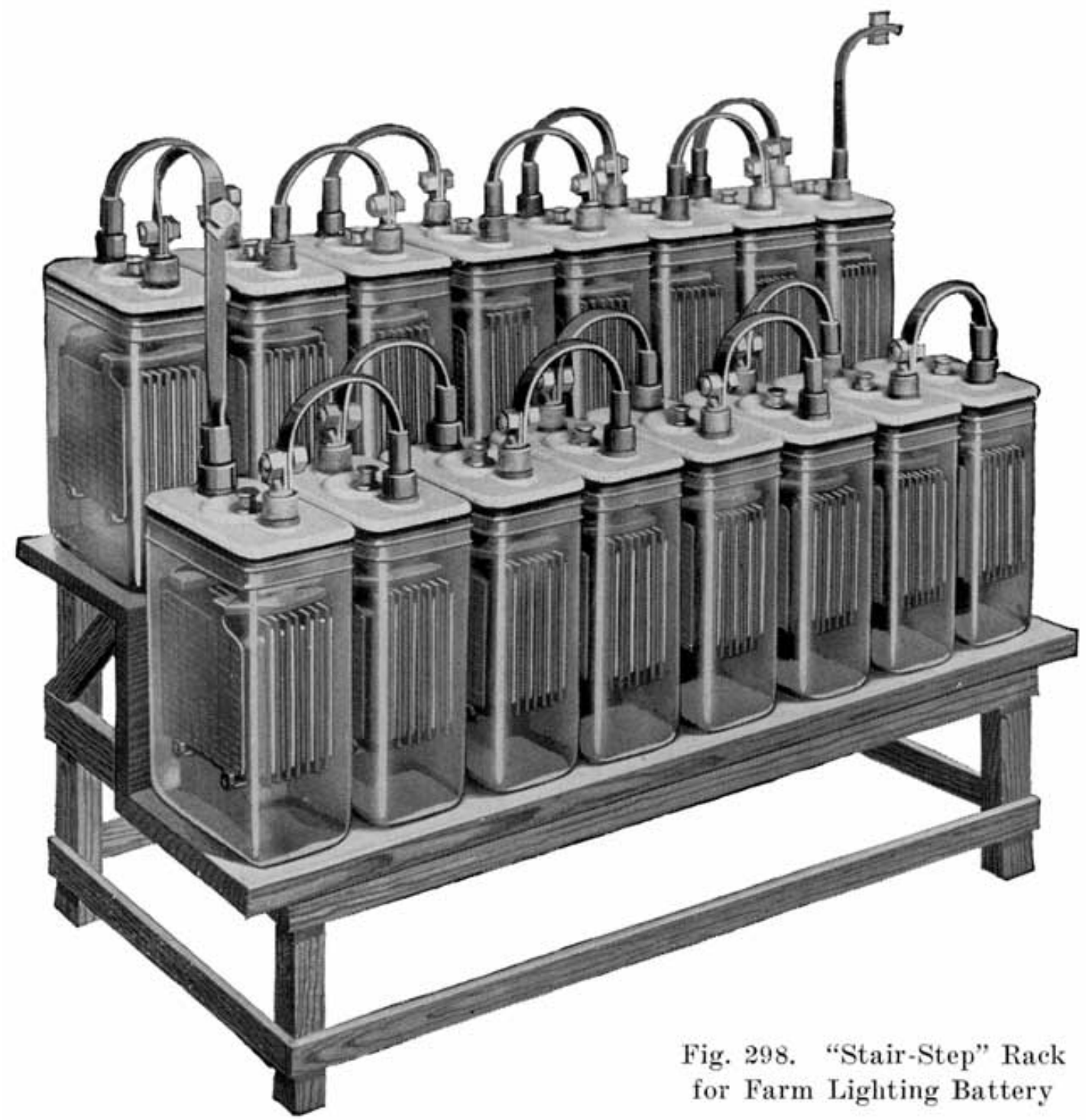

Fig. 298. "Stair-Step" Rack for Farm Lighting Battery

The cells may be placed on the battery rack with either the face or the edges of the plates facing out. The latter method requires a shorter battery rack and is very desirable from the standpoint of future inspections. In very dark places, it is more desirable to have the surface of the plates turned out to enable the user-to see when the cells are bubbling during the monthly equalizing charge. Either method is satisfactory.

All metal parts such as pipes, bolt heads, etc., which are near the battery should be given at least three coats of asphaltum paint. Care must be taken not to have an open flame of any kind in the battery room, as the hydrogen and oxygen gases, given off as a battery charges may explode and cause injury to the person and possible severe damage to the battery. When making an installation, it is always a good plan to carry' the following material for taking care of spillage and broken jars:

1 Thermometer
2 Series Cells
6 Battery Bolts and Nuts
1 Hydrometer Syringe
2 Gallons distilled water
1 Jar Vaseline
1 Gallon 1.220 specific gravity electrolyte

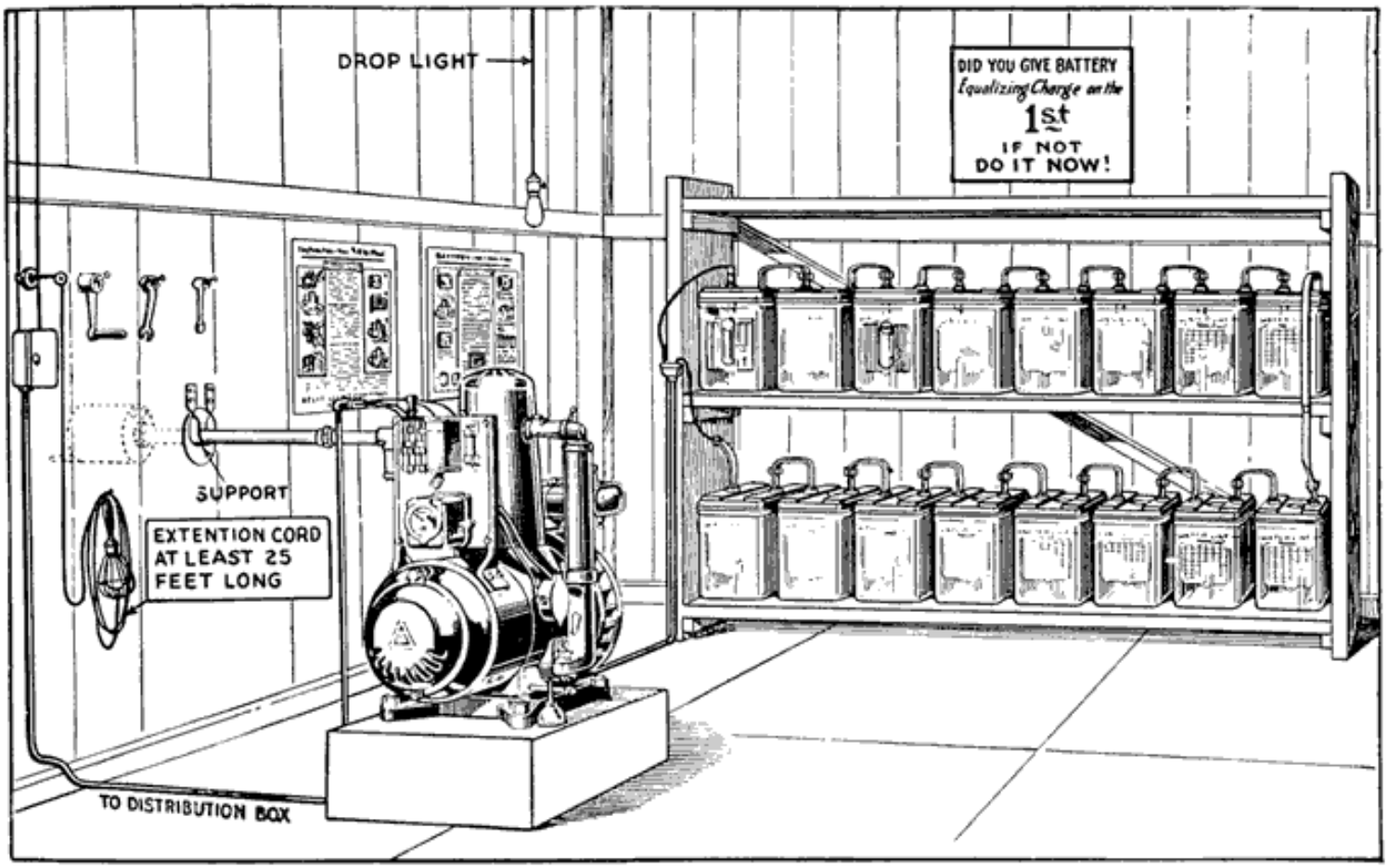

Fig. 299. Installation of a Delco-Light Plant, Showing Two-Tier Shelf Rack for Battery

When a battery arrives at the shipping destination, the person lifting this shipment should remove the slats from the top Of each crate and inspect each cell for. concealed damage, such as breakage: Should any damage be discovered, it is important that a notation covering this damage be made and signed by the freight agent on the freight bill. This will enable the customer or dealer to make a claim against the railroad for the amount of damage. If a notation of this kind is not made before the battery 'is lifted, the dealer will be forced to stand the expense of repairing or replacing the damaged cells.

When removing cells from a crate, avoid lifting them by the terminal posts as much as possible. This causes the weight of the electrolyte and jar to pull on the sealing compound between the jar and cover, and if the sealing is not absolutely tight, the jar and electrolyte may fall from the cover. A cell should never be carried using the terminal posts as handles. The hand should be put underneath the jar.

Sometimes a battery will arrive with electrolyte spilled from some of the cells. If spillage is only about one-half to one inch down on the plates of three or four cells, this spillage may be replaced by drawing a little electrolyte out of each cell of the other full cells in the set. Oftentimes several cells will have electrolyte extending above the

water line, which will aid greatly in making up any loss in other cells. After all cells have been drawn on to fill up the ones that are spilled, the entire set may then have its electrolyte brought up to the water line by adding distilled water.

Very carefully adjust spillage of pilot cells (Delco), as it is very important that the specific gravity 'of the pilot cells be left as near 1.220 as possible.

In case the spillage is more than one inch below the top of plates or glass broken, remove cell and install a new cell in its place. The spilled or broken cell must not be used until given special treatment.

Connecting Cells

Before connecting up the cells the terminals should be scraped clean for about 11/2 inches on both sides. An old knife or rough file is suitable for doing this work. After the terminals are thoroughly brightened, they should be covered with vaseline. The bolts and nuts used in making the connections on the battery should also be coated with vaseline. The vaseline prevents and retards corrosion, which is harmful to efficient operation.

If a new battery is to be installed in parallel with one already in service, connections should be made so that each series will consist of half new and half old cells. The pilot cells for the new battery should be placed in one series and that for the old battery in the other, unless local conditions may make some other arrangement desirable.

A drop light must always be provided to enable the user to inspect his battery, particularly when giving the monthly equalizing charge.

Initial Charge

When a battery is connected to the plant, it should be given a proper INITIAL CHARGE before any power or lights are used.

Batteries shipped filled with electrolyte are fully charged before leaving the factory. As soon as a storage battery cell of any type or make is taken off charge and stands idle for a considerable length of time, some of the acid in the electrolyte is absorbed by the plates, thereby lowering the gravity and forming sulphate on the plates. This process is very gradual, but it is continuous, and unless the acid is completely driven out of the plates by charging before the battery is used, the battery will not give as good service as the user has a right to expect. Due to the time required in shipment, the above action has a chance to take place, which makes it necessary to give the initial charge.

The initial charge consists of charging the battery, with the power and light switch open, until each cell is bubbling freely from the top to bottom on the surface of the outside negative plates and both pilot balls are up (Delco-Light), and then CONTINUING THE CHARGE FOR FIVE HOURS MORE. If the battery has no pilot cells, measure the specific gravity of the electrolyte of each cell, and continue the charge until six consecutive readings show no increase in gravity.

As an -accurate check on giving the initial charge properly (Delco-Light), we strongly recommend that hourly hydrometer readings of both pilot cells be taken after both balls are -up, the charge to be continued until six consecutive hourly readings show no RISE in gravity.

Due to the fact that it is impossible to hold each cell in a battery to a definite maximum gravity when fully charged, there is likely to be a variation of from ten to fifteen points in the specific gravity readings of the various cells. It should be understood, however, that the maximum gravity is the gravity when the cells are fully charged and with the level of the solution at the water line. For example, with each cell in a battery fully charged and

therefore at maximum gravity and with the level at the proper height, some cells may read 1.230, one or two 1.235, several 1.215 and 1.210. All of these cells will operate efficiently, and there should be no cause for alarm. An exception to this is the pilot cell of the Delco-Light Battery.

If this check on the initial charge is properly made, it assures the service man and dealer that the battery is in proper operating condition to be turned over to the user. Negligence in giving the initial charge properly may result in trouble to both user, service man and dealer.

The initial charge may require considerable running of the plant, depending upon the state of charge of the cells when installed.

Instructing Users

During the time the initial charge is being given, the service man should instruct the user on the care and operation of the plant and battery.

The best way to give instructions to the user is to tack the instruction cards on the wall near the plant in a place where the user can read them easily.

Proceed to read over the plant operating card with the user. Read the first item, go to the plant, explain this feature to the user and allow him to perform the operation, if the instruction calls for actual performance.

Remember, the user is not familiar with the plant and battery, and the actual performance of each operation aids him to retain the instructions.

After the first item has been covered thoroughly, proceed to the second, etc. During the course of instruction, the user will often interrupt with questions not dealing directly with the point being explained. The service man should keep the user's attention on the points he is explaining. When the service man has finished explaining both plant and battery instruction cards, he should answer any points in question which the user wants explained.

When the monthly equalizing charge is explained to the user, the service man should always take the user. to the battery and show him a cell bubbling freely. This is necessary in order that the user may recognize when the cells are bubbling freely at the time he gives the monthly equalizing charge.

Impress upon the user the importance of inspecting each cell when giving the monthly equalizing charge to see that every cell bubbles freely. If a cell fails to bubble freely at the end of the equalizing charge, the user should inform the service man of this condition immediately.

Caution the user against the use of an open flame near the plant or battery at any time. The gas which accumulates in a cell will explode sufficiently to break the glass jar if this gas is ignited by a spark or open flame.

Care of the Plant in Operation

(See also special instructions for the different makes, beginning page 460.)

The battery repairman should be able not only to repair the batteries, but should also be able to keep the entire plant in working order, and suggestions will be given as to what must be done, although no detailed instructions for work on the generator, engine, and switchboard will be given as this is beyond the scope of this book.

Battery Room. The essential things about the battery room are that it must be clean, dry, and well ventilated. This means, of course, that the battery and battery rack must also be kept clean and dry. A good time to clean up is

when the battery is being charged. Clean out the room first, sweeping out dirt and rubbish, dusting the- walls, and so on. Both high and low temperatures should be avoided. If the battery room is kept too hot, the battery will become heated and the hot electrolyte will attack the plates and separators. Low temperatures do no actual harm to a charged battery except to make the battery sluggish, and seem to lack capacity. A discharged battery will, however. freeze above 0° Fahrenheit. The battery will give the best service if the battery room temperature is kept between 60° and 80° Fahrenheit.

Do not bring any open flame such as a lantern, candle or match near a battery and do not go near the battery with a lighted cigar, cigarette or pipe, especially while the battery is charging. Hydrogen and oxygen gases form a highly explosive mixture. An explosion will not only injure the battery, but will probably disfigure the one carrying the light, or even destroy his eyes.

It is a good plan to keep the windows of the battery room open as much as possible.

Engine. The engine which drives the generator requires attention occasionally. Wipe off all dirt, oil or grease. Keep the engine well lubricated with a good oil. If grease cups are used, give these several turns whenever the engine is run to charge the battery. Use clean fuel, straining it, if necessary, through a clean cloth or chamois, if there is any dirt in it. The cooling water should also be clean, and in winter a non-freezing preparation should be added to it. Do not change the carburetor setting whenever the engine does not act properly. First look over the ignition system and spark plug for trouble, and also make sure that the carburetor is receiving fuel. If possible, overhaul the engine -once a year to clean out the carbon, tighten bearings and flywheel, remove leaky gaskets, and so on.

Generator. Keep the outside of the generator clean by wiping it occasionally with an' oiled rag. See that there is enough lubricating oil in the bearings, but that there is not too much oil, especially in the bearing at the commutator end of the generator. Keep the commutator clean. If it is dirty, wipe it with a rag moistened slightly with kerosene. The brushes should be lifted from the commutator while this is being done. Finish with a dry cloth. If the commutator is rough it may be made smooth with fine sandpaper held against it while the generator is running, and the brushes are lifted.

The surfaces of the brushes that bear on the commutator should be inspected to see that they are clean, and that the entire surfaces make contact with the commutator. The parts that are making contact will look smooth and polished, while other parts will have a dull, rough appearance. If the brush contact surfaces are dirty or all parts do not touch the commutator, draw a piece of fine sandpaper back and forth. under the brushes, one at a time, with the sanded side of the paper against the brush. This will clean the brushes and shape the contact surfaces to fit the curve of the commutator. Brushes should be discarded when they be come so short that they do not make good contact with the commutator. See that the brush holders and brush wires are all tight and clean. Watch for loose connections of wires, as these will cause voltage loss when the generator is charging the battery. Watch for "high mica," which means a condition in which the insulation between the segments projects above the surface of the commutator, due to the commutator wearing down faster than the insulation. If this condition arises, the mica should be cut down until it is slightly below the surface of the commutator. An old hack saw blade makes a good tool for this purpose. A commutator may have grooves cut in by the brushes. These grooves do no harm as long as the brushes have become worn to the exact shape of the grooves. When the brushes are "dressed" with sandpaper, however, they will not fit the. grooves, and the commutator should be turned down in a lathe until the grooves are removed.

A steady low hum will be heard when the generator is in operation. Loud or unusual noises should be investigated, however, as a bearing may need oil, the armature may be rubbing on the field pole faces, and so on.

Watch for overheating of the generator. If you can hold your hand on the various parts of the generator, the temperature is safe. If the temperature is so high that parts may be barely touched with the hand, or if an odor of burned rubber is noticeable, the generator is being overheated, and the load on the generator should be reduced.

Switchboard. Clean off dirt and grease occasionally. Keep switch contacts clean and smooth. If a "cutout" is on the board, keep its contacts smooth and clean. If the knife switch blades are hard to move, look for cutting at the pivots. Something may be cutting into the blades. If this is found to be the case, use a file to remove all roughness from the parts of the pivot. See that no switches are bent or burned.

Keep the back of the board clean and dry as well as the front. See that all connections are tight. Keep all wires, rheostats, etc., perfectly clean. A coat of shellac on the wires, switch studs, etc., will be helpful in keeping these parts clean.

Care of Battery

Cleanliness. Keep the battery and battery rack clean. After a charge is completed, wipe off any electrolyte that may be running down the outsides of the jars. Wipe all electrolyte and other moisture from the battery rack. Occasionally go over the rack with a rag wet with ammonia or washing soda solution. Then finish with a dry cloth. Paint the rack with asphaltum paint once a year, or oftener if the paint is rubbed or scratched.

If sand trays are used, renew the sand whenever it becomes. very wet with electrolyte. Keep the terminals and connectors clean. Near the end of a charge, feel each joint between cells for a poor connection. Watch also for corrosion on the connections. Corrosion is caused by the electrolyte attacking any exposed metals other than lead, near the battery, resulting in a grayish deposit on the connectors or bolts at the joints. Such joints will become hotter than other joints, and may thus be located by feeling the joints after the battery has been charged for some time. Corrosion may be removed by washing the part in a solution of baking soda.

Be very careful to keep out of the cells anything that does not belong there. Impurities injure a cell and may even ruin it. Do not let anything, especially metals, fall into a cell. If this is done accidentally, pour out the electrolyte immediately, put in new separators, wash the plates in water, fill with electrolyte having a gravity about 30 points higher than that which was poured out, and charge. The cell may be connected in its proper place and the entire battery charged. Vent plugs should be kept in place at all times, except when water is added to the electrolyte.

Keep the Electrolyte Above the Tops of the Plates. If the battery has glass jars, the height of the electrolyte can be seen easily. If the battery has sealed rubber jars, the height of the electrolyte may be determined with a glass tube, as described on page 55. In most batteries the electrolyte should stand from three-fourths of an inch' to an inch above the plates. Some jars have a line or mark showing the proper height of the electrolyte. A good time to inspect the height of the electrolyte is just before putting the battery on charge. If the electrolyte is low, distilled water should be added to bring it up to the proper level. Water should never be added at any other time, as the charging current is required to mix the water thoroughly with the electrolyte.

Determining the Condition of the Cells. The specific gravity of the electrolyte is the best indicator of the condition of the battery as to charge, just as is the case in automobile batteries, and hence should be watched closely. It is not convenient or necessary to take gravity readings on every cell in the battery on every charge or discharge. Therefore, one cell called the "Pilot" cell should be selected near the center of the battery and its specific gravity readings taken to indicate the state of charge or discharge of the entire battery. Delco-Light batteries each have two pilot cells with special jars. Each of these has a pocket in one of its walls in which a ball operates as a hydrometer or battery gauge. One pilot cell contains the pilot ball for determining the end of the charge, and other pilot cell containing the ball for determining the end of the discharge. See Fig. 294.

Hydrometer readings should be taken frequently, and a record of consecutive readings kept. When the gravity drops to the lowest value allowable (1.150 to 1.180, depending on the make of battery) the battery should be charged.

Once every month voltage and gravity readings of every cell in the battery should be taken and recorded for future guidance. These readings should be taken after the monthly "overcharge" or "equalizing charge" which is explained later. If the monthly readings of any cell are always lower than that of other cells, it needs attention. The low readings may be due to electrolyte having been spilled and replaced with water, but in a farm lighting battery this is not very likely to happen. More probably the cell has too much sediment, or bad separators, and needs cleaning. See special instructions on Exide and Prest-O-Lite batteries which are given later.

There are several precautions that must be observed in taking gravity readings in order to obtain dependable results. Do not take gravity readings if:

(a) The cell is gassing violently.

(b) The hydrometer float does not ride freely. If a syringe hydrometer is used, the float must not be touching the walls of the tube, and the tube must not be so full that the top of the float projects into the rubber bulb at the upper end of the tube.

(c) Water has been added less than four hours before taking the readings. A good time to take readings is just before water is added.

The hydrometer which is used should have the specific gravity readings marked on it in figures, such as 1.180, 1.200, 1.220 and so on. Automobile battery hydrometers which are marked "Full," "Empty," "Charged," "Discharged," must not be used, since the specific gravities corresponding to these words are not the same in farm lighting batteries as in automobile batteries and the readings would be incorrect and misleading. If the manufacturer-of the battery furnishes a special hydrometer which is marked "Full," "Half-Full," "Empty," or in some similar manner, this hydrometer may, of course, be used.

Temperature corrections should be made in taking hydrometer readings, as described on page 65. For Prest-O-Lite batteries, 80" is the standard temperature, and gravity readings on these batteries should be corrected to 80' as described on page 461.

Gravity readings should, of course, be taken during charge as well as during discharge. The readings taken during charge are described in the following sections on charging.

Charging

(See also special instructions for the different makes of batteries, beginning page 460.)

Two kinds of charges should be given the battery, the "Regular" charge, and the "Overcharge" or "Equalizing Charge." These will be spoken of as the "Regular" charge and the "Overcharge." The Regular charge must be given whenever it is necessary in order to enable the battery to meet the lighting or other load demands made upon it. The overcharge, which is merely a continuation of a regular charge, should be given once every month. The overcharge is given to keep the battery in good condition, and to prevent the development of inequalities in condition of cells.

When to Charge. Experience will soon show how often you must give a regular charge in order to keep the lights from becoming dim. When the voltage reading, taken while all the lamps are on has dropped to 1.8 volts per cell a Regular charge is necessary. When the specific gravity of the pilot cell indicates that the battery is discharged, a Regular charge is necessary. It is better to use the specific gravity readings as a guide, as described later.

A good plan, and the best one, is to give a battery a Regular charge once every week, whether the battery becomes discharged in one week's time or not. A regular charge may be required oftener than once a week. Every fourth

week give the Overcharge instead of the Regular charge.

If a battery is to be out of service, arrangements should be made to add the necessary water and give an overcharge every month, the Regular charges not being necessary when the battery stands absolutely idle.

Overcharge. Charge the battery as near as practicable at the rate prescribed by the manufacturer. If the manufacturer's rate is not known, then charge at a rate which will not allow the temperature of the electrolyte to rise above 110° Fahrenheit, and which will not cause gassing while the specific gravity is still considerably below its maximum value. One ampere per plate in each cell is a safe value of current to use. A battery having eleven plates in each- cell should, for example, be charged at about 11 to 12 amperes.

Watch the temperature of the pilot cell carefully. This cell should have an accurate Fahrenheit thermometer suspended above it so that the bulb is immersed in the electrolyte. If this thermometer should show a temperature of 110°, stop the charge immediately, and do not start it again until the temperature has dropped to at least 90'. Feel the other cells with your hand occasionally, and if any cell is so hot that you cannot hold your hand on it measure its temperature with the thermometer to see whether it is near 110'. A good plan is to measure the temperature of the electrolyte in every cell during the charge. If any cell shows a higher temperature than that of the pilot cell, place the thermometer in the cell giving the higher reading, and be guided by the temperature of that cell. You will then know that the thermometer indicates the highest temperature in the entire battery, and that no other cell is dangerously hot when the thermometer does not read 100' or over. Another point in the selection of a pilot cell is to determine if any particular cell shows a gravity which is slightly less than that of the other cells. If any such cell is found, use that cell as the pilot cell in taking gravity readings while the battery is on discharge and also on charge. No cell will then be discharged too far.

When all cells are gassing freely, continue the charge at the same current until there is no rise in the specific gravity of the pilot cell for one to two hours, and all cells are gassing freely throughout the hour. Then stop the charge.

After the overcharge is completed, take gravity readings of all the cells. A variation of about eight to ten points either above or below the fully charged gravity after correction for temperature does not mean that a cell requires any attention. If, however, one cell continually reads more than 10 points lower then the others, the whole battery may be given an overcharge until the gravity of the low cell comes up. If the cell then does not show any tendency to charge up properly, disconnect it from the battery while the battery is discharging and then connect it in again on the next charge. If this fails to bring the gravity of the cell up to normal, the cells should be examined for short circuits. Short circuits may be caused by broken separators permitting the active material to bridge between the plates; the sediment in the bottoms of the jars may have reached the plates, or conducting substances may have fallen in the cells.

Broken separators should be replaced without loss of time, and the cells cleaned if the sediment in the jars is high.

Regular Charge. A Regular Charge is made exactly like an Overcharge, except that a Regular Charge is stopped when cells are gassing freely, when the voltage per cell is about 2.6, and when the specific gravity of the pilot cell rises to within 5 points of what it was on the previous Overcharge. That is, if the gravity reading on the Overcharge rose to 1.210, the Regular Charge should be stopped when the gravity reaches 1.205.

Partial or Rapid Charge. If there is not enough time to give the battery a full Regular Charge, double the normal charging rate and charge until all the cells are gassing, and then reduce to the normal rate. Any current which does not cause excessive temperature or premature gassing is permissible, as previously mentioned. If a complete charge cannot be given, charge the battery as long as the available time allows, and complete the charge at the earliest possible opportunity.

Discharge

Do not allow the battery to discharge until the lights burn dim, or the voltage drops below 1.8 per cell. The specific gravity is a better guide than the lamps or voltage. The gravity falls as the battery discharges, and is therefore a good indicator of the condition of the battery. Voltage readings are good guides, but they must be taken while the battery is discharging at its normal rate. If the load on the battery is heavy, the voltage per cell might fall below 1.8 before the battery was discharaged. Lamps will be dim if the load on the battery is heavy, especially if they are located far away from the battery. The specific gravity readings are therefore the best means of indicating when a battery is discharged.

Overdischarge. Be very careful not to discharge the battery beyond the safe limits. Batteries discharging at low rates are liable to be overdischarged before the voltage gives any indication of the discharged condition. This is another reason why hydrometer readings should be used as a guide.

A battery must be -charged as soon as it becomes discharged. It is, in fact, a good plan, and one which will lengthen the life of the battery, to charge a battery when it is only about three fourths discharged, as indicated by the hydrometer. Suppose, for instance, that the specific gravity of the fully charged battery is 1.250, and the specific gravity when the battery is discharged is 1.180. This battery has a range of 1.250 minus 1.180, or 70 points between charge and discharge. This battery will give a longer life if its discharge is stopped and the battery is put on charge when the gravity falls to 1.200, a drop of 50 points instead of the allowable 70.

Allowing discharged battery to stand without charge. A battery should never be allowed to stand more than one day in a discharged condition. The battery will continue to discharge although no current is drawn from it, just as an automobile battery will. See page 89. The battery plates and separators will gradually become badly sulphated and it will be a difficult matter to charge the battery up to full capacity.

Battery Troubles

Farm lighting batteries are subject to the same general troubles that automobile batteries are, although they are not as likely to occur because the operating conditions are not as severe as is the case on the automobile. Being in plain view at all times, and not being charged and discharged irregularly, the farm lighting battery is not likely to give as much trouble as an automobile battery. Neglect, such as failure to keep the electrolyte up to the proper height, failure to charge as soon as the battery becomes discharged, overdischarging, allowing battery to become too hot or too cold, allowing impurities to get into the cells, will lead to the same troubles that the same treatment will cause in an automobile battery, and the descriptions of, and instructions for troubles in automobile batteries will apply in general to farm lighting batteries also.

When a battery has been giving trouble, and you are called: upon to diagnose and remedy that trouble, you should:

1. Get all the details as to the length of time the battery has been in service.

2. Find out what regular attention has been paid to its upkeep; whether it has been charged regularly and given an overcharge once a month; whether distilled water has been 'used in replacing evaporation of water from the electrolyte; whether impurities such as small nails, pieces of wire, etc., have ever fallen into any cell; whether battery has ever been allowed to stand in a discharged condition for one day or more; whether temperature has been allowed to rise above 110° F. at any time; whether electrolyte has ever been frozen due to battery standing discharged in very cold weather.

3. Talk to the owner long enough to judge with what intelligence he has taken care of the battery. Doing this may, save you both time and subsequent embarrassment from a wrong diagnosis resulting from incomplete data.

4. After getting all the details that the owner can supply, you will probably know just about what the trouble is. Look over the cells carefully to determine their condition. If the jars are made of glass note the following:

(a) Height of sediment in each jar.

(b) Color of electrolyte. This should be clear and colorless. A decided color of any kind usually means that dirty or impure water has been added, or impurities have fallen into the cell. For discussion of impurities see page 76.

(c) Condition of plates. The same troubles should be looked for as in automobile batteries. See pages 339 to 346. An examination of the outside negatives is usually sufficient. The condition of the positives may also be determined if a flash light or other strong light is directed on the edges of the plates. Look for growths or "treeing" between plates,

(d) Condition of separators. See page 346.

If cells have sealed rubber jars, proceed as follows:

(a) Measure height of electrolyte above plates with glass tube, as in Fig. 30. If in any cell electrolyte is below tops of plates that cell is very likely the defective one, and should be filled with distilled water. If a considerable amount of water is required to fill the jar it is best to open the cell, as the plates have probably become damaged. If the jar is wet or the rack is acid eaten under the jar, the jar is cracked and must be replaced.

If you have not found the trouble, make the following tests, no matter whether glass or rubber jars are used:

(a) Measure specific gravity of each cell. If any cell is badly discharged it is probably short-circuited, or contains impurities and had better be opened for inspection.

(b) Turn on all the lamps and measure the voltage of each cell. If any cell shows a voltage much less than 1.8 it is short-circuited or contains impurities, and should be opened for inspection.

(c) Examine the connections between cells for looseness or corrosion; and examine the connections between the battery and the generator, going over cables, switches, rheostats, etc. Make sure that you have a complete and closed charging circuit between the generator and the battery.

(d) If cutout is used on the switchboard, see that its contact points are smooth and clean, and that they work freely.

(e) Run the generator to see if it builds up a voltage which is sufficient to charge the battery,about 42 volts for a 16 cell battery. If the generator is not working properly, examine it according to directions on page 451. Check up the field circuit of the generator to be sure that it is closed. A circuit-tester made of a buzzer and several dry cells, or a low voltage lamp and dry cells, or a hand magneto is convenient for use in testing circuits. Test armature windings and field coils for grounds.

By the foregoing methods you should be able to determine what is to be done. The following rules should also help:

Cleaning and renewal of electrolyte is necessary when:

(a) Sediment has risen to within one-half inch of the bottom of the plates.

(b) Much foreign material is floating in the electrolyte, or electrolyte is of a deep brown color.

Replacement of parts is necessary when

(a) Separators are cracked or warped. See page 346 for Separator troubles.

(b) Plates are defective. See rules on pages 339 to 346.

PREST-O-LITE FARM LIGHTING BATTERIES

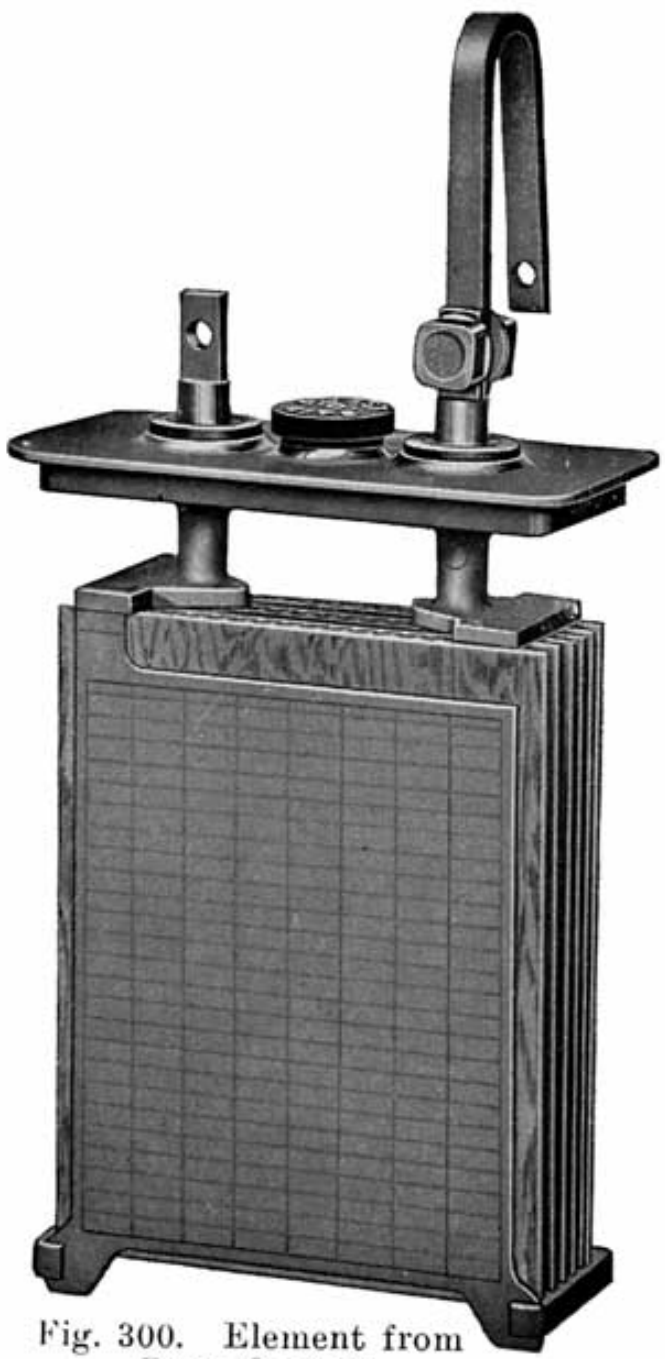

Fig. 300. Element from Prest-O-Light Farm Lighting Cell

The Prest-O-Lite battery which is designed for use in connection with farm lighting plants is known as the FPL type. Cells of 7, 9, 11, 13 and 15 plates are made, the -number of plates being indicated by putting the figure in front of the type letters. A seven plate cell is thus designated as a 7 FPL cell, which has an 80 ampere hour capacity at the 8 hour continuous discharge rate.

The FPL cell, the construction of which is shown in Figs. 295, 300, 301, 302 and 303, has a sealed glass jar -with a lead antimony cover. The cover construction is shown in detail in Figs. 301 and 302. Insulation between the posts and cover is provided by a hard rubber bushing, a hard rubber washer, and a soft rubber washer. The bushing is shaped like a "T" with a hole drilled in the stem. The stem of the bushing fits down into the post hole in the cover, the flange at the top testing on the raised portion of the cover around the post hole. The post has a shoulder a little less than halfway up from its lower end. Upon this shoulder is placed the hard rubber washer, and upon the hard rubber washer is placed the soft rubber washer. This assembly is fastened to the cover by the "peening" process used in Prest-O-Lite automobile batteries as described on page 386. This forces the soft rubber washer tightly against the cover so as to make a leak proof joint-between the bushing and cover. The ring of lead formed around the posts by the peening process supports the posts, plates, and separators, which therefore are suspended from the cell cover. The plate straps extend horizontally across the tops of the plates, and thus also act as "hold-downs" for the separators. The separators are held up by two rectangular rubber bridges which fit Mito slotted extension lugs cast into the lower corners of the outside negative plates. An outside negative having these extension lugs is shown in Fig. 303.

Fig. 301. Cover of Prest-O-Lite Farm Lighting Cell

Fig. 302. Parts of Prest-O-Lite Farm Lighting Cell

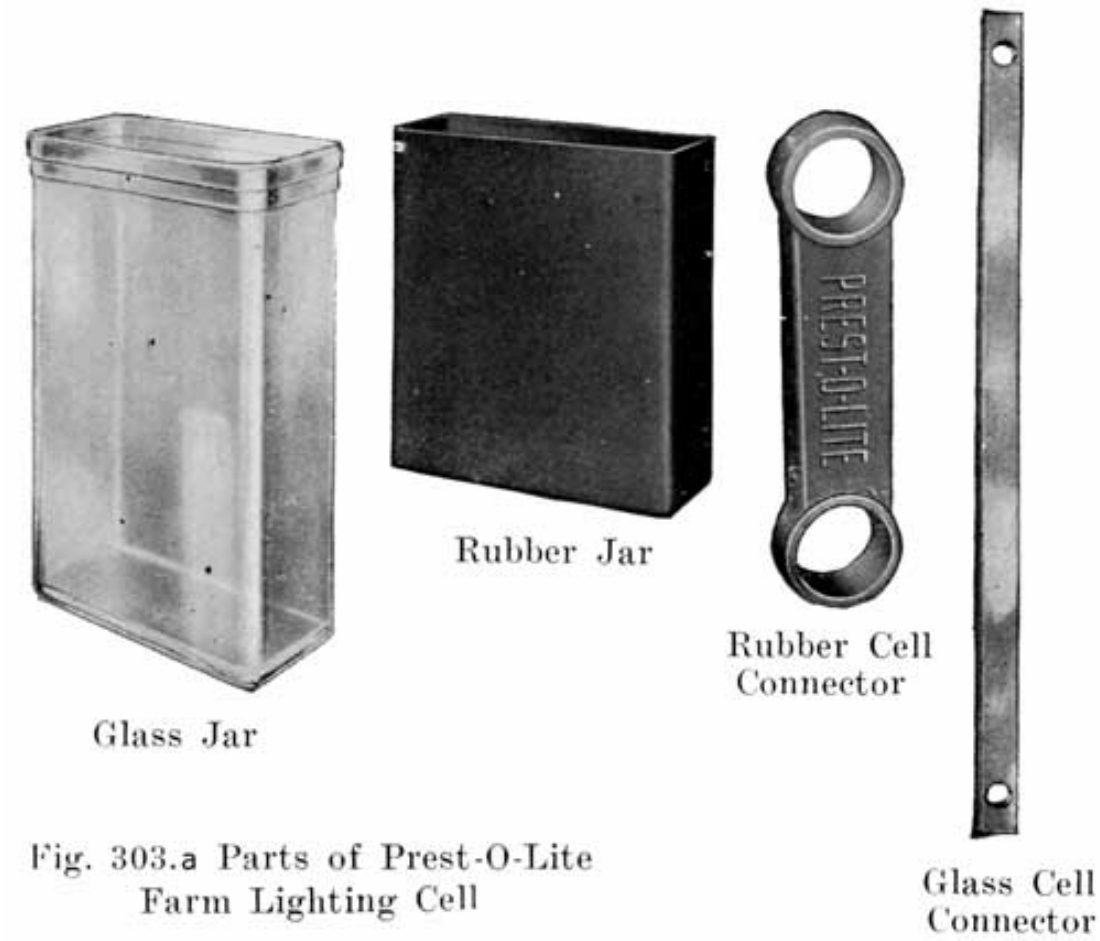

Fig. 303.a Parts of Prest-O-Lite Farm Lighting Cell

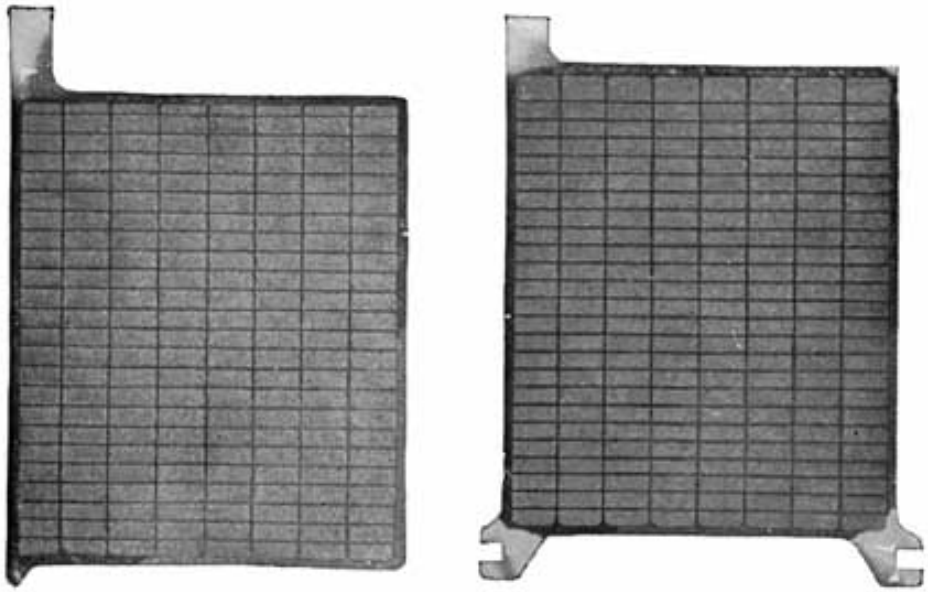

Positive Plate Outside Negative Plate

Fig. 303.b Parts of Prest-O-Lite Farm Lighting Cell

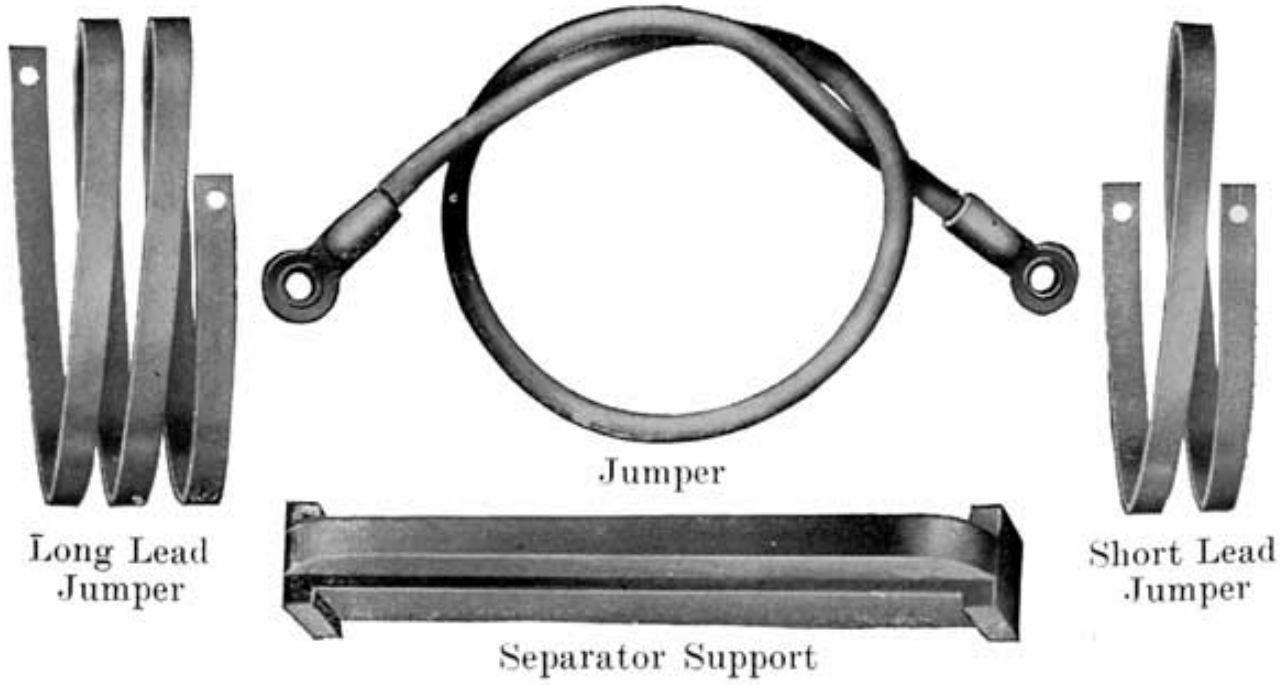

Fig. 303.c Parts of Prest-O-Lite Farm Lighting Cell

Specific Gravity of Electrolyte. The values of the specific gravity of Prest-O-Lite farm lighting batteries are as follows:

Battery fully charged reads 1.250
Battery three-fourths charged reads 1.230
Battery one-half charged reads 1.215
Battery one-fourth charged reads 1.200
Battery discharged completely reads 1.180

These readings are to be taken with the electrolyte at a temperature of 80° Fahrenheit. Readings taken at other

temperatures should be converted to 80°. To convert readings at a lower temperature to the values they would have at 80°, subtract one point for every two and one-half degrees temperature difference. For example, suppose a cell reads 1.225 gravity at 60°. To find what the gravity would be if the temperature of the electrolyte were 80° divide the difference between 80° and 60° by 2-1/2, or 80° minus 60° divided by 21/2 equals 8. The gravity at 80° would therefore be 1.225 **minus .008**, or 1.217, which is the value of specific gravity to use. If the specific gravity is read at a higher temperature than 80°, divide the difference between 80° and the temperature at which the gravity reading was taken by 21/2, and add the result to the actual gravity reading obtained. If, for example, the gravity were 1.225 at 100°, the gravity at 80° would be 1.225 **plus .008**, or 1.233.

This apparently works out to:

(gravity at temp) + (temp — 80°)/2500 = (gravity at 80°)

or

(gravity at Temp-A) + (Temp-A — Temp-B)/2500 = (gravity at Temp-B)

Charging Rates. The normal charging rate to be used in giving Prest-O-Lite batteries a regular charge or overcharge are as follows:

Battery	Charging Rate
5 F.P.L.	5.0 amps.
7 F.P.L.	7.5 amps.
9 F.P.L.	10.0 amps.
11 F.P.L	12.5 amps.
13 F.P.L.	15.0 amps.
15 F.P.L.	17.5 amps,

Rebuilding Prest-O-Lite Farm Lighting Batteries

Opening the Cell.

1. Make sure that the cell is as fully charged as possible. Since it is not very convenient to charge a single cell, a good time to open a cell for cleaning and repairing is immediately after the battery has been given an overcharge. See page 455.

2. Disconnect the cell from the adjoining ones.

3. Heat a thin bladed putty knife and insert it 'under the edge of the lead-antimony cover to melt the sealing compound. Run the knife all round the cover, heating it again if it should become too cool to cut the compound readily.

4. Grasp the lead posts above the cover and lift up gradually. This will bring up the cover, plates, and separators.

5. Place the plates on a clean board for examination. Use the instructions given on pages 339 to 346. Do not keep the plates out of the electrolyte long enough to let them dry, and the negatives heat up. If you cannot examine the plates as soon as you have removed them immerse them in 1.250 acid contained in a lead or non-metallic vessel until you can examine them.

6. In renewing the electrolyte, pour in as much new 1.250 acid as there was old electrolyte in the jar. (It is assumed that the electrolyte was up to the lower ridge of the glass jar before the cell was opened.) The new electrolyte must not have a temperature above 100' when it is poured into the jar.

7. The separators can be pulled out easily when the plates are laid on their sides. All that is necessary is to remove the small rubber bridge at the bottom corners of the plates. The separators can then be pulled out. If the old separators are to be used again brush off any material that may be adhering to them, and keep them wet with 1.250 acid until they are replaced between the plates. Any separators that show cracks or holes, or that split while being replaced between the plates should be thrown away and new ones used.

8. It is not- necessary to remove the sediment from the bottom of the jar unless it is within one half inch of the bottom of the plates. If the sediment is to be removed, carefully pour off the clear electrolyte into a lead, hard rubber, or earthenware jar, if the electrolyte is to be used again.

9. If one or two of the plates in either positive or negative groups need to be replaced it is best to burn a new plate to the strap without removing the peened cover. This is done by blocking under the row of -plate lugs with metal blocks after cutting off old plate and cleaning the surface of strap. Insert new plate, the lug of which has been cut about 1/4 inch short, to allow for new metal. Choosing small oblong iron blocks of suitable size, build a form about the plate lug which fits same well. Now with a torch and burning lead fuse the new plate onto the old strap. When cool remove and test joint by pulling and slightly twisting the plate at the same time.

Sometimes one group of a starting and lighting battery may be in sufficiently good condition to pay to combine it with a new group, but this condition will very rarely, if. ever, be met in farm lighting cell service. We advise the replacement of the complete cell element if either group is worn out, for the cost of repairs and of new group will probably not be warranted by the short additional life which the remaining old group will give.

10. Putting Repaired Cell Back into Service. After having finished all necessary cleaning, replacement, or repairs, remove all old sealing material, return the element with attached lead cover to the cell jar. It is not necessary to reseal the cover to the jars this sealing is essential only for insurance against breakage or leakage in shipment.

Add through the vent plug opening sufficient cool acid of 1.250 Sp. Gr. to reestablish the proper electrolyte level, which means that the electrolyte is brought up to the lower moulded glass ridge near the top of jar.

Connect the cell with any other repaired cells and charge at normal rate already indicated under "charging rates" until dell voltage reads 2.5 or above, at 80°. The positive to cadmium voltage should be at least 0.10 volts less than cell voltage itself. When this condition is obtained cell may be replaced in operating circuit with others and should give satisfactory service.

EXIDE FARM LIGHTING BATTERIES.

Exide Farm lighting Batteries are made with sealed glass jars, open glass jars, and sealed rubber jars, each of which will be described.

Batteries with Sealed Glass Jars.

Two types with sealed glass jars are made, these being the Delco Light Type, and the Exide type.

1. Delco-Light Type. This type is shown in Fig. 294. The cell shown is a pilot cell, there being two of these in each battery as explained below.

These cells are made in two sizes, the KXG-7, 7 plate, 80 ampere hour cell, and the KXG-13, a 13 plate, 160 ampere hour cell. These cells are assembled into a 32 volt, 16 cell battery, or a 110 volt, 56 cell battery.

The plate groups are supported from the cover, the weight being carried by the wooden cover supports as shown in Fig. 294. The strap posts are threaded, and are clamped to the cover and supports by means of alloy nuts, just as is the case in Exide automobile batteries.

A hard rubber supporting rod or lock pin extending across the bottoms of the plates holds the separators in position and prevents the plates from flaring out at the bottom. A soft rubber bumper fastened on each end of the rod acts as a cushion to prevent jar breakage in shipping.

The hard rubber cover overlaps the flanged top of the jar, to which it is sealed with special compound.

Battery Gauges and Instruments for Testing.

Every set of Delco-Light batteries has either one or two cells equipped with a pilot ball. Such a cell is known as a PILOT CELL. Fig. 294.

Pilot Cells are used to indicate to the USER the approximate state of charge or discharge of the battery.

The pilot ball is a battery gauge which is UP or DOWN, depending upon the state of charge of the battery.

Very high temperature affects the operation of the pilot ball. This accounts for-the fact that occasionally a battery will be charged and the pilot ball will be at the bottom of the pocket. A few hours later, after the electrolyte has cooled, the pilot ball will rise to the top.

We urge that the user be made to feel that the pilot ball is an excellent gauge and a good signal to watch in connection with the care and operation of his Delco-Light plant and battery. (Further mention will be made of the pilot ball in connection with the subject of proper operation.)

It is necessary that the maximum specific gravity of pilot cells be as near 1.220 as possible. Any great variation higher or lower will affect the operation of the pilot balls. Therefore, every effort should be made to adjust the maximum specific gravity of pilot cells to 1.220 when placed in service.

Batteries equipped with one pilot cell contain a white pilot ball which will be up when the specific gravity of the electrolyte is approximately 1.185. This ball will drop DOWN when the specific gravity falls a little below 1.185.

In other words, the pilot ball will float at a specific gravity of 1:185 or higher, and will sink at a specific gravity lower than 1.185.

Therefore, when the pilot ball is UP, the battery is more than half charged. When the pilot ball is DOWN, the battery is more than half discharged.

Batteries equipped with two pilot cells have one cell which contains a white ball and the other cell a white ball with a blue band.

The plain white ball will be UP when the specific gravity is approximately 1.175. The blue band ball will be UP when the specific gravity is approximately 1.205.

When both balls are UP, the battery is charged. When DOWN, the battery is discharged. The blue band ball will drop soon after the battery starts on discharge, or, in other words, when the specific gravity falls below 1.205. The white ball will remain UP until the specific gravity falls below 1.175.

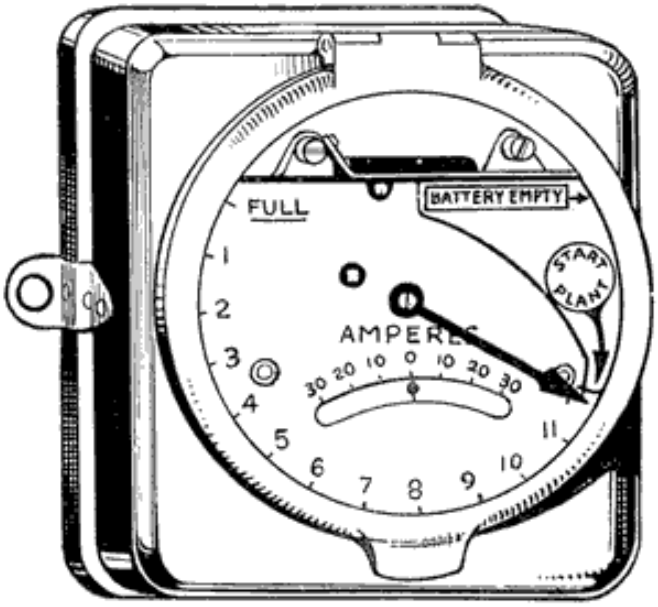

Fig. 304. Delco-Light Ampere-Hour Meter

The Ampere-Hour Meter

The ampere-hour meter, Fig. 304, is an instrument for indicating to the user the state of charge of the battery at all times and serves to-stop the plant automatically so equipped, when the battery is charged. (Further mention will be made of the ampere hour meter on page 471.)

In order to check the speed of the ampere-hour meter, use the following rule: On charge, the armature disc should give 16 revolutions in 30 seconds, with a charging rate of 15 amperes; on discharge, the armature disc should give 20 revolutions in 30 seconds, with a discharging rate of 15 amperes.

Hydrometers

The standard hydrometer for service men is known as the Type V-2B.

A special type hydrometer showing three colored bands in' place of numbers has been designed for users.

The bands are red, green and black. When the hydrometer test shows the bottom of the red band in the electrolyte, the battery, whether in glass or rubber jar, is discharged. When the top of the green band is out of the electrolyte, the glass jar battery is charged. The top of the black band out of the electrolyte indicates the rubber jar battery is charged.

When and How to Charge Battery

Plants with Average Loads

Loads of legs than ten (10) amperes can be taken directly from the battery, until:

1. The large hand on the ampere-hour meter reaches 12, or

2. Both pilot balls are down, or

3. Hydrometer test shows bottom of red band in the electrolyte.

If any or all of the three gauges listed above show the battery discharged, the plant should be started and operated continuously until the battery is charged, as indicated by:

1. Ampere-hour meter hand at FULL, or

2. Both pilot balls UP, or

3. Hydrometer test shows top of FULL band out of electrolyte.

(NOTE: Any one or all of the above three items may indicate battery charged. Meter hand at FULL would necessitate. both balls UP. If both balls are not up, set hand back and charge to bring them up; then set hand at FULL.)

Should the user be operating for two or three hours with a seven or eight-ampere load, it would be more efficient to run the plant to carry this load. This only applies for those cases where the battery is partly discharged.

Carry Heavy Loads Greater Than 10 Amperes.

If there is a constant load of 10 amperes or more, the plant should be started up when the heavy load comes on. When the heavy load is off, the plant may be stopped, but it would be entirely satisfactory to allow the plant to continue to run until "Charged," as indicated by:

1. Ampere-hour meter hand reaches FULL, or

2. Both pilot balls are UP, or

3. Hydrometer test shows top of FULL band out of electrolyte.

In any case, plant should be run until battery is "Charged" at least once a week.

Always Start Charging When Battery Gauges Indicate Battery Discharged.

On ampere-hour meter plants, when the hand is at FULL, the plant cannot be operated on account of the ignition circuit being broken.

In such cases allow load to be taken from the battery until the hand travels back sufficiently to allow the plant to run.

Occasionally the plant and battery are used to carry continuous loads of from 10 to 15 amperes each night, with practically no day load. This condition necessitates running the plant to carry the load, but at the same time the battery is continually receiving from 1O to 15 amperes charge, with the result that the battery may receive too much charging. This would be indicated by the battery bubbling freely every time the plant is operated. To

prevent this condition, the user should be instructed to carry the load off the battery frequently enough to prevent continual bubbling.

Where Small Load Is Used.

There are many installations where the battery capacity is sufficient to last several weeks. On installations of this kind it is advisable to charge the battery to FULL at least once a week.

The dealer or service man should use his own judgment on the preceding instructions as to which is best suited for the different conditions encountered.

Regularly on the first of each month, regardless of whether or not the battery has been used, a special charge, called the **Equalizing Charge,** should be given. This charge should be given as follows: The battery should be charged until EACH cell is bubbling freely from top to bottom on surface of the outside negative plates and then the charge should be continued for TWO MORE HOURS.

The monthly equalizing charge is a NECESSARY precautionary measure to insure that the user will bring each cell in the battery up to maximum gravity at least once a month. It also provides a means on the ampere-hour meter plants to set the ampere-hour meter hand at FULL when the battery is FULL.

The users should be cautioned to inform the service man or dealer immediately if any cell fails to bubble at the end of an equalizing charge, when all others are bubbling freely. This will enable the service man to inspect such cells for trouble and remedy same before the trouble becomes serious. (See further information under inspection and repairs.)

INSPECTION TRIPS

Undercharging or injurious sulphation is the most common trouble encountered. Undercharging causes the plates to blister and bulge, and in place of good gray edges on the negative plates and good brown color edges on the positive plates, the edges will show a faded color, with very little brown color showing on the edges of the positive plates.

Overcharging is not so evident on inspection, except that in such cases the active material from the positive plates, which is brown in color, will be thrown to the bottom as sediment more rapidly than the sediment would accumulate due to normal wear.

Heavy usage -on a battery will also cause considerable sediment in the bottom of the cells, so that it is necessary to investigate carefully whether it is overcharging or overwork. A few questions as to method of operation and load requirements will aid in deciding the cause of excessive sediment. (See When and How to Charge, page 468.)

Sediment Space Filled.

When the space below the plates is filled up with sediment and touching the plates, the cell becomes short-circuited and will deteriorate very rapidly. It will be noticed, however, that the sediment is heaped in the middle of the cell. If the cells are unbolted and unshaken, it will level the sediment and leave a space between the sediment and plates. It is very important that the sediment be shaken down before the cell becomes short-circuited. This will very often prolong the life of the battery a number of months. When the sediment space is completely filled, approximately all the active material will be out of the positive plates.

A thorough study should be made as to the general condition of the battery and method of operation before forming an opinion or suggesting any change in method of operation.

Check Ampere-Hour Meters

On plants which have ampere-hour meters, the meter should be checked as to its speed on discharge, and also check position of the meter hand at the time of inspection, to see if it checks with the specific gravity and the pilot balls. (See Ampere Hour Meter, page 467.)

It will generally be found that when a battery is sulphated, it is operating in very low specific gravity, or, in other words, the charges have not been carried far enough to drive all the acid out of the plates.

A battery that is not receiving quite enough charge may not as a whole become "sulphated," but several cells might become considerably weaker than the others and become "sulphated," causing trouble in these particular cells. Such cells will not bubble freely, or possibly not at all, when the other cells are bubbling freely. Therefore, a few questions to the user will generally help in locating the low cells.

Cells that are in trouble, or which soon will be, can very easily be picked out by making a few tests on the battery. Therefore, on all inspections, regardless of the age of a battery, it is suggested that the following tests be made: Take a specific gravity reading of all cells and note if there are any cells much lower than the others. Amy cells having a specific gravity of 30 points lower than the average will generally be found to be in trouble, unless these cells happen to be low from having had spillage in shipment, replaced with water. (This condition, however, should not exist in future installations if the spillage is properly taken care of, as has been explained on page 482.)

Voltage Readings

After taking a specific gravity reading, a voltage reading of each cell should be taken. Voltage readings taken on open circuit are of no value, so while taking these readings the battery should be on discharge, having at least a discharge of 15 amperes. A good way to get this discharge is to hold the starting switch in and set mixing valve lever at lean point or wide open.

A low or defective cell will show a voltage reading .10 to .20 volts lower than the other cells on discharge, while a reversed cell will show a reading in the reversed direction when on discharge, especially on heavy discharge.

The voltage readings are a sure check if taken in connection with the specific gravity. When you have low specific gravity and low voltage on the same cells, it is a sure indication of low cells. These cells should be inspected for the probable cause of their being low. Shorting of the lugs at bottom of plates and moss bridging across at bottom of the elements, or possibly a split separator, will generally be the main trouble.

When any of these conditions exist, it is best to take the low" cells back to your shop for repairs.

When there is absolutely no indication why the cells are low, they can be cut out of the battery on discharge and put in on charge, until they come up.

The following is a good example of readings taken on a battery with a 10-ampere discharge and having four low cells, 4, 8, 11 and 16. The battery had been giving poor service, due to insufficient charging:

Cell No.	Specific Gravity	Volts
1	1.200	1.98

2	1.180	1.95
3	1.205	1.98
4	1.150	1.75
5	1.190	1.95
6	1.195	1.98
7	1.200	1.98
8	1.130	1.70
9	1.200	1.95
10	1.205	1.98
11	1.100	1.40
12	1.190	1.95
13	1.180	1.95
14	1.195	1.98
15	1.190	1.95
16	0.000	zero or reversal

The main thing to consider in checking voltage readings is the variation from the average. The average voltage readings will vary, depending on the state of charge of the battery when the readings are taken.

REPAIRS

To repair, the following equipment is necessary:

1. Portable lead burning outfit.
2. A suitable blow torch.
3. Standard sealing nut wrench.
4. File (shoemaker's rasp).

5. Pair of pliers.
6. Putty knife.
7. Pair of tin snips.
8. Wooden blocks to support elements while being worked upon.
9. Good supply of battery parts consisting of:

KXG-13 Glass jars
KXG-13 Pilot jars
KXG-13 Positive groups
KXG-13 Negative groups
KXG-13 Round rods
KXG-13 Vent plugs
Sealing nuts
Rubber gaskets
Wood separators
KXG-13 Rubber covers
KXG-7 Round rods
Lead pins
Carboy electrolyte (including retainer).
KXG-7 Pilot jars
KXG-7 Glass jars
KXG-7 Positive groups
KXG-7 Negative groups
Outside negative plates
KXG-7 Rubber covers
Emergency repair straps

Disassembling a Cell

The glass jar battery covers are sealed to the jars by sealing compound, which may be softened very easily with a blow-torch.

When a blow-torch or an open flame is used for softening the sealing compound, the vent plug MUST be removed before applying a flame. It is also important to blow into the vent after the plug has been removed in order to expel any gas that may have collected in the space above the electrolyte in the cell.

If the gas is held in place by leaving the vent plug in, it is apt to explode when an open flame or intense heat is applied to the cover.,

Removing covers may be greatly facilitated by suspending the cell by the terminals, as shown in Fig. 305. Care should be taken to make this suspension so that the bottom of the jar will not be more than two inches above the table. A pad of excelsior should be placed- under it to avoid breaking the glass jar when it drops.

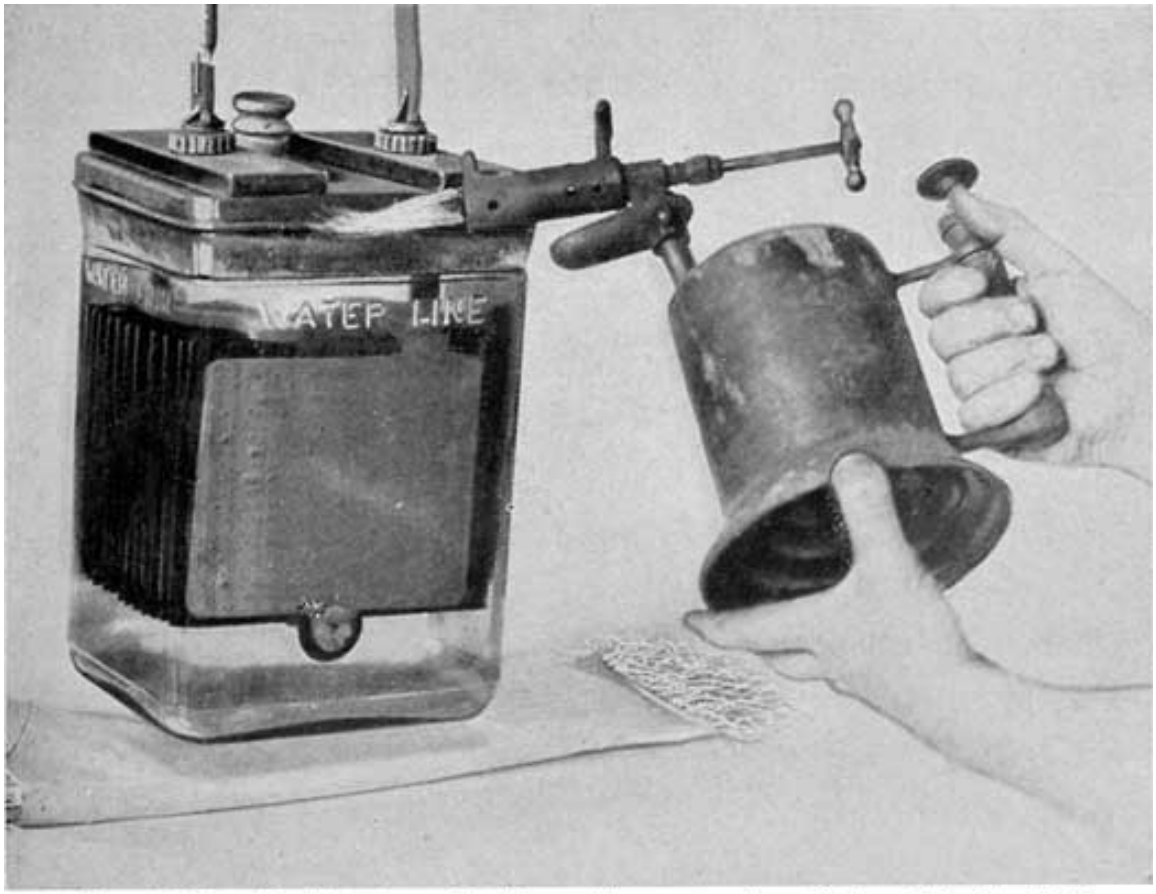

Fig. 305. Softening Sealing Compound. Delco-Light Cell

After the sealing compound has been sufficiently softened, the cover may be loosened by inserting a hot putty knife, as shown in Fig. 306, There is no danger of breaking the cover by this operation if the cover has been sufficiently warmed. After the jar of electrolyte has dropped, the element should be removed from the jar and carefully placed across the top of it, so that the solution upon the plates will drain back into the jar. (See Fig. 307.)

Fig. 306. Removing Delco-Light Cell Cover

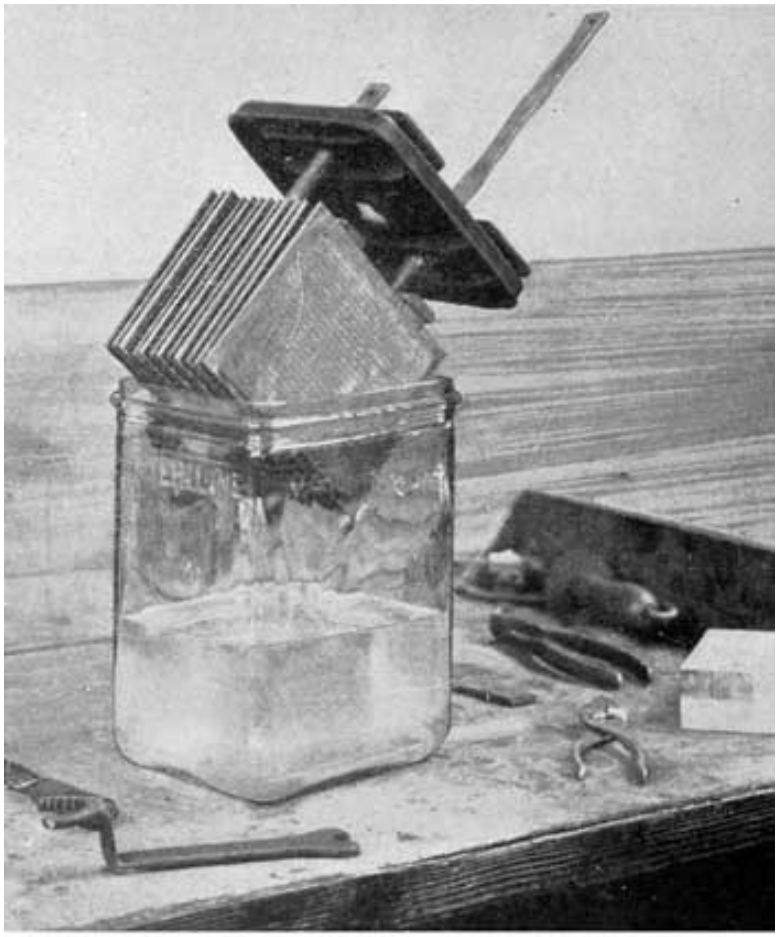

Fig. 307. Draining Element. Delco-Light Cell

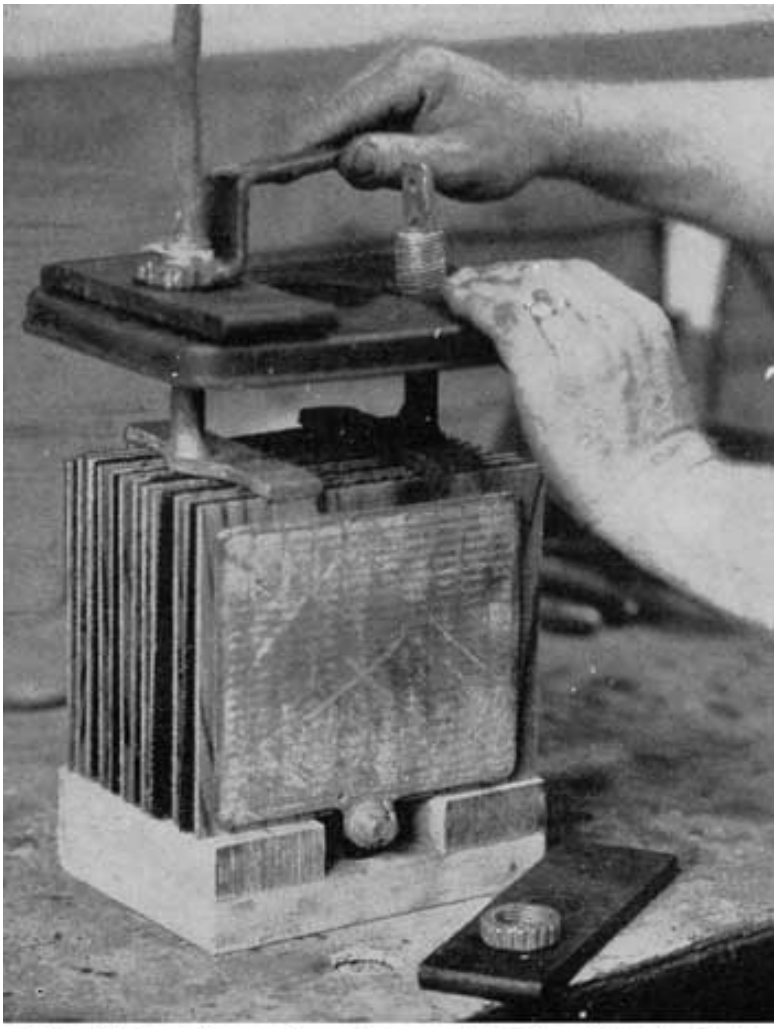

Fig. 308. Removing Cover of Delco-Light Cell

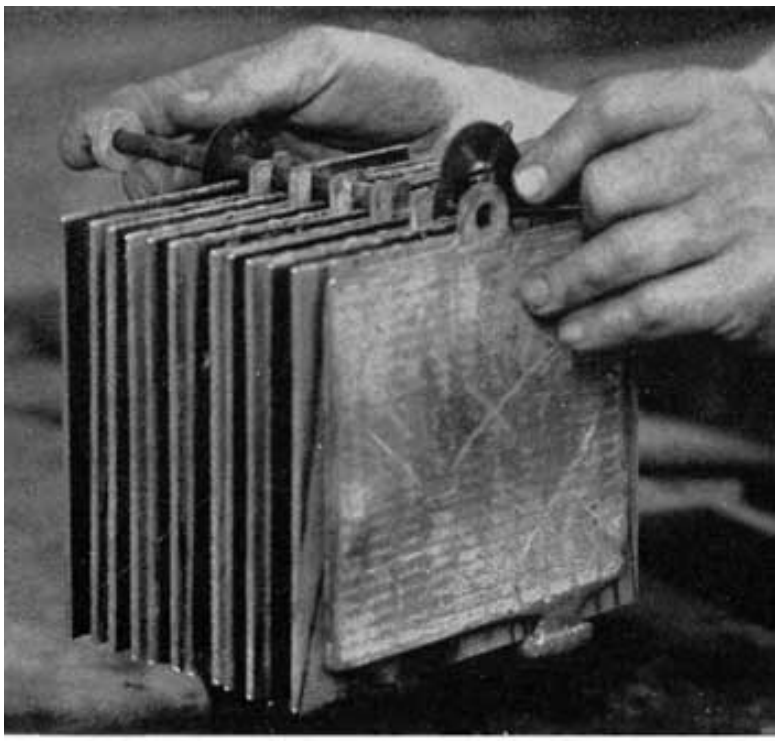

Fig. 309. Removing Lock Pin. Delco-Light Cell

After element has drained, place on wooden blocks, as shown in Fig. 308, and remove cover. Clean the sealing compound. from the cover and jar immediately with a putty knife. Turn element upside down with posts through holes in bench and remove lead pin and rubber bumper and withdraw, lock pin. (Fig. 309.) The separators may then be withdrawn from the group. (Fig. 310.)

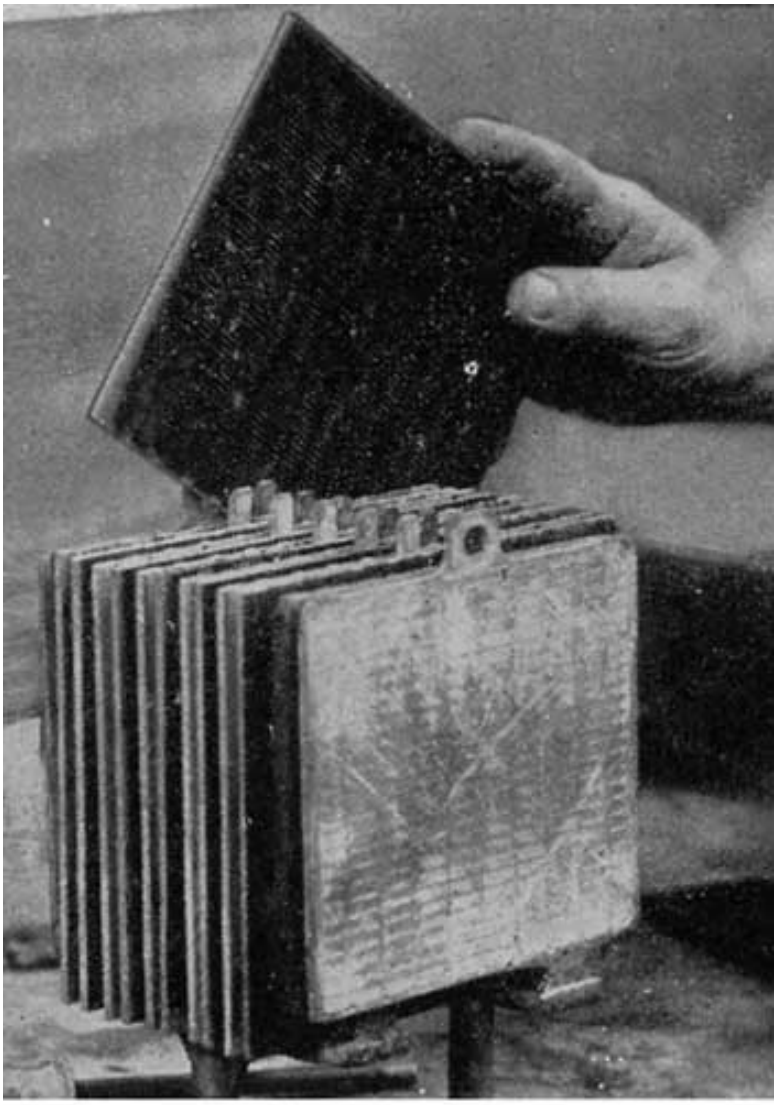

Fig. 310. Removing Separators. Delco-Light Cell

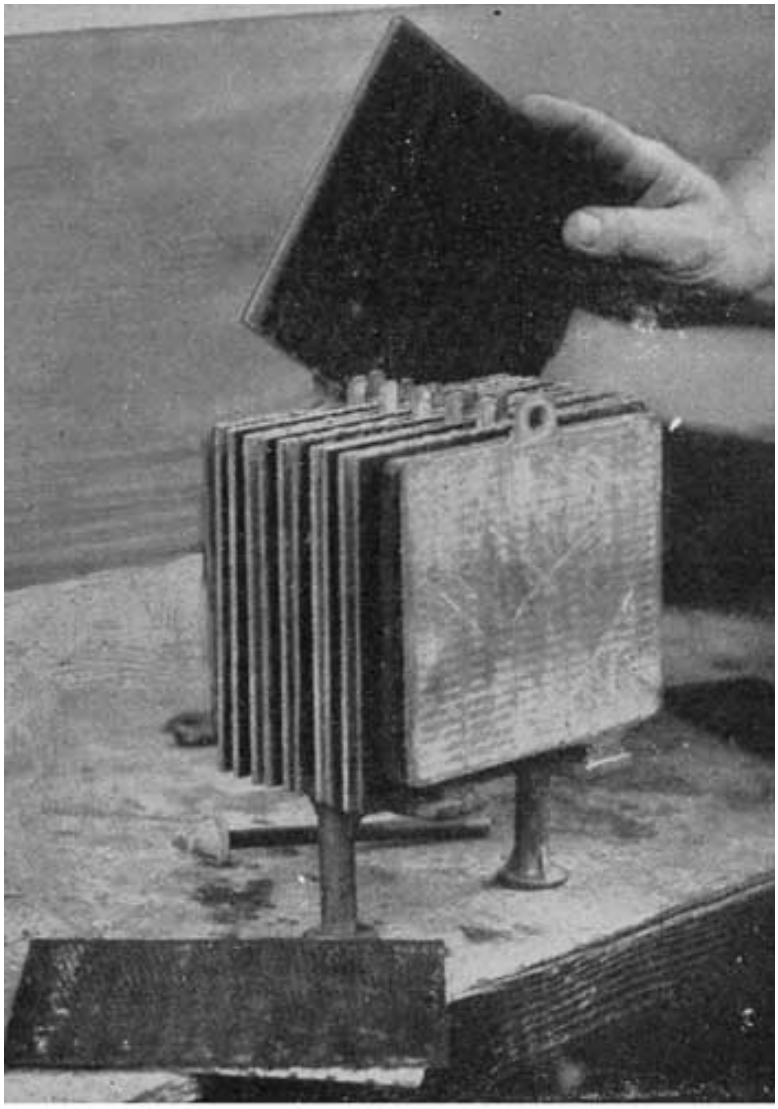

Fig. 311. Assembling Separators. Delco-Light Cell

Assembling

Place the positive and negative groups upside down with posts through holes in bench and slide in separators. The wood and rubber separators are inserted as follows: The rubber separator is placed against the grooved side of the wood separator. and the two are then slipped between the negative and positive plates with the rubber separator next to the positive plate. (See Fig. 311.)

Inserting Locking Pin

A rubber bumper is pinned on one -end of the lock pin by means of a lead pin, and the lock pin is then slipped into place with the lock pin insulating washer placed between the outside negative plates and the wood separators. (See Fig. 312.)

A rubber bumper is then slipped over the other end of the lock pin and secured by a lead pin.

Place element on wooden blocks and fasten cover, as shown in Fig. 313.

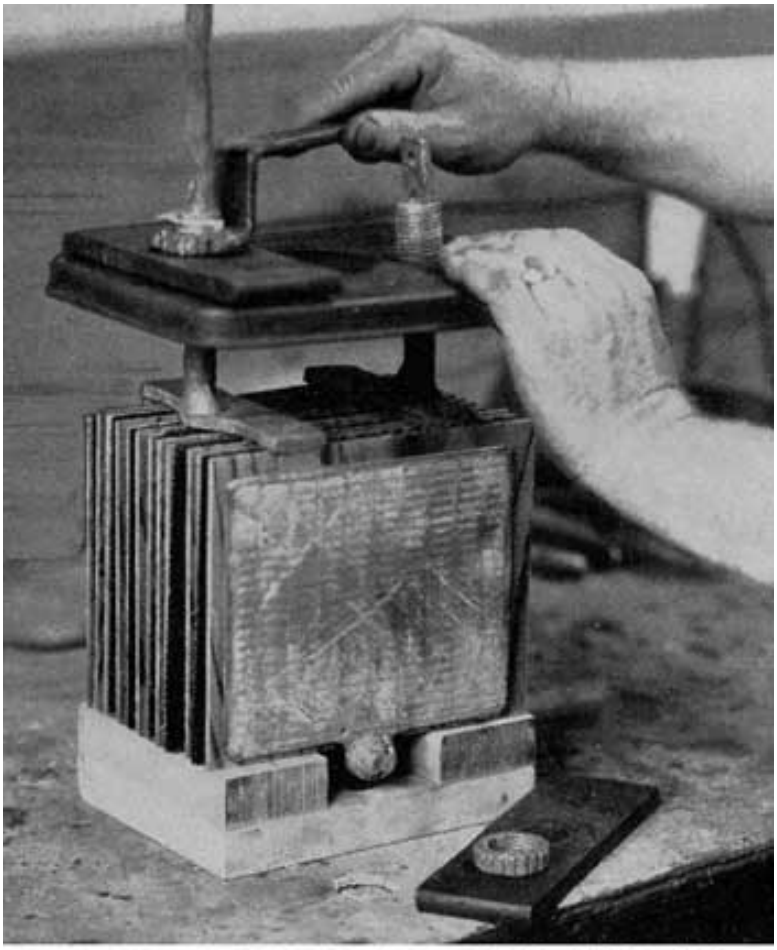

Fig. 313. Fastening Cover. Delco-Light Cell

Fig. 314. Preparing Cover for Sealing. Delco-Light Cell

Sealing Covers

Be sure all old sealing compound and traces of electrolyte are removed from the cover. Heat sealing compound until it can be handled like putty, roll out into a strip about 1/2 inch in diameter, place strip of compound around inside edge of cover (Fig. 314) and heat to melting point with blow-torch. The top of jar should also be heated to insure a tight seal. Compound can be melted in a suitable vessel and a 1/2 inch strip poured around cover.

When sealing compound and jar have been heated sufficiently, turn jar upside down (Fig. 315) and carefully place jar over element and press gently into compound. (Do not press hard.) Immediately place jar and element upright, and press cover firmly into place. (Press hard.) Finally, tighten sealing nuts. The cell is now ready for the electrolyte.

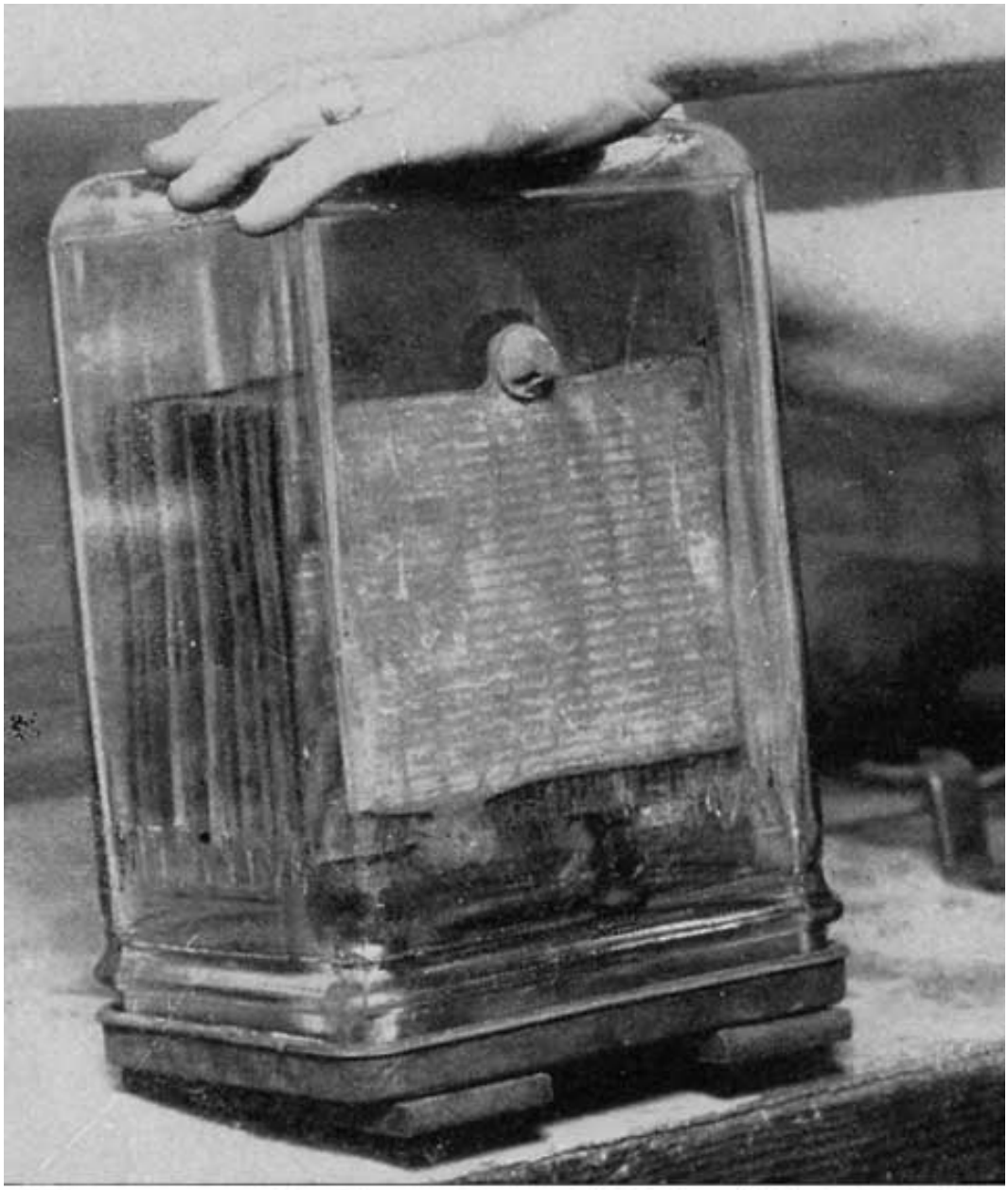

Fig. 315. Sealing Jar of Delco-Light Cell

Filling Cell with Electrolyte

Repaired cells should be filled with electrolyte of 1.200 specific gravity, or with water, as the case may require.

Standard Delco-Light electrolyte of 1.220 specific gravity may be purchased from the Delco Light distributor. The 1.220 electrolyte- should be reduced to 1.200 by adding a very small amount of distilled water. This should be thoroughly mixed by pouring the solution from one battery jar into another. The 1.200 specific gravity electrolyte may then be added to the newly assembled cell until flush with the water line.

Charging

The completed KXG-13 cell should be placed on a 12-ampere charge and kept on charge until maximum gravity has been reached. A KXG-7 cell should be charged at a 6-ampere rate.

Adjusting Gravity of Electrolyte

If the maximum gravity is above 1.220, draw off some of the electrolyte and refill to water line with distilled water. The charge should then be continued for at least one hour to thoroughly mix the electrolyte before taking another hydrometer reading. It may be necessary to repeat this operation.

If the maximum gravity is below 1.220, pour off the electrolyte into a glass jar or a suitable receptacle, and then refill the cell with 1.220 electrolyte. Charge for one hour to thoroughly mix the solution before checking readings.

NOTE: Gravity readings in adjusting the electrolyte should always be taken in connection with thermometer readings, making necessary temperature corrections. This is particularly important in adjusting electrolyte in pilot cells.

HOW TO REPAIR DELCO-LIGHT CELLS

Treating Broken Cells

Whenever a shipment of batteries is received in which any of the jars have been broken, the first thing to do is to carefully remove the elements from the broken jars to prevent damage to the plates or separators. These elements should be placed in distilled water to prevent further drying. The plates will not be damaged in any way and can be restored to a healthy condition by charging in 1.200 specific gravity at a 12-ampere rate for the 13-plate cell or, 6-ampere rate for the 7-plate cell, until maximum gravity is reached. (See Charging and Adjustment of Electrolyte, explained on page 481.)

Treating Spilled Cells

If the spillage is more than one inch below the water level, it should be replaced by electrolyte of 1.200 specific gravity and charged to maximum gravity.

Treating Badly Sulphated Cells That Have Been in Service

When cells are removed from an installation to make repairs, they are usually badly sulphated, which means that considerable acid is in the plates.

In charging such cells, use distilled water in place of electrolyte, as this will allow the acid to come out of the plates more readily. The KXG-13 cells should be charged at about 12 amperes and the KXG-7 cells at 6 amperes. Cells badly sulphated when charged at the low rate will require from 50 to 100 hours to reach maximum gravity. Extreme cases will require even longer charging.

In case it is impossible to read the gravity after the cells have been on charge a sufficient length of time, pour out the solution and use 1.220 specific gravity.

The charge should then be continued further to insure that maximum gravity has been reached.

CAUTION: Should the temperature of the electrolyte approach 110° F., the charging rate should be reduced or the charge stopped until the cell has cooled.

Treating Reversed Cells

A complete battery may be reversed if the battery is completely discharged and its voltage is not sufficient to overcome any residual magnetism the generator might have. Under such conditions the negative plates will begin to discolor brown and the positive turn gray. Such a case would be extremely rare.

The remedy is to first completely discharge the cells to get rid of the charge in the wrong direction. Then short-circuit them. (Connect a wire across the terminals.) Then charge them in the right direction at a low rate. (12 amperes for a KXG-13 cell, or 6 amperes for a KXG-7 cell.) Charge until the specific gravity reaches a maximum. If the battery is operated reversed for any length of time, the negatives will throw off their active material and become useless.

A single cell may become reversed by gradually slipping behind the rest of the cells in a set, due to insufficient charging, until it becomes so low that it will reverse on each discharge. This condition cannot be corrected by giving the regular charge, but it will be necessary to give an equalizing charge, continuing the charge until the cell is in normal condition. (Be sure to make temperature corrections when taking hydrometer readings.) If the cell appears to require an excessive amount of charge to restore it to condition, it should be removed and taken to the repair shop for a separate charge.

If the cell has been allowed to operate in a reversed condition to such an extent that the entire material of the negative plates has turned brown, both positive and negative groups should be discarded.

Removing Impurities

Impurities, such as iron, salt (chlorine) or oil, may accidentally get into a cell, due to careless handling of distilled water.

Iron is dissolved by sulphuric acid and the positive plates become affected, change color (dirty yellow) and wear rapidly. The cell becomes different from the rest in gravity, voltage and bubbling. The remedy is to discard the electrolyte as soon as possible, flush the plates and separators in several changes of water, thoroughly wash the jar, use new electrolyte and then proceed in same manner as explained for the treatment of badly sulphated cells, page 482.

Chlorine has an effect about as described for iron, and is evident by the odor of chlorine gas. The remedy is the same as for iron.

Oil in the electrolyte, if allowed to get into the pores of the plates, will fill them and lower the capacity very much. It affects negative plates much more than positives. Probably the only remedy in this case is new plates.

Impurities of any nature should be removed as quickly as possible.

Clearing High Resistance Short Circuits

A high resistance short is caused by the sediment falling from the plates and lodging between the positive and negative lugs. As a rule this condition will occur only when severe sulphation is present in the plates.

A cell in this condition can be repaired by removing the element and clearing the short circuit. The wood separators should then be withdrawn and replaced by new ones. Lock pin insulating washers. should be installed land the element reassembled in the jar and charged to maximum gravity.

Clearing Lug Shorts

Short-circuited lugs are caused by excessive sulphation. The outside negative bulges and the bottom lug bends over and touches the adjacent positive lug. This can be remedied by removing both outside negative plates and burning on new plates which have already been charged and inserting lock pin insulating washers.

Putting Repaired Cells Back in Service

When placing a new or repaired cell in a battery which is in service, connect in the cell at the beginning of a charge. This will insure that the new or repaired cell is started off in good condition, because this charge is of the nature of an initial charge to these cells.

Charging Outside Negative Plates

Individual negative plates are always received dry, which makes it necessary to charge them before using. The best way to charge such plates is as follows: Set up 7 loose negative plates in a KXG-13 jar together with a good positive group, using KXG separators to prevent the plates touching. Then stretch a piece of wire solder across the lugs at the top of the negative plates and solder the wire to the plates. Fig. 316. The jar may then be filled with 1200 specific gravity and the plates charged at a 12-ampere rate until maximum gravity is obtained. Never use negative plates unless they have been treated as described above. After the charge is completed, the negative plates may be placed in distilled water and kept until ready for use. Always be sure to give a charge to maximum gravity after burning on new negative plates to an element.

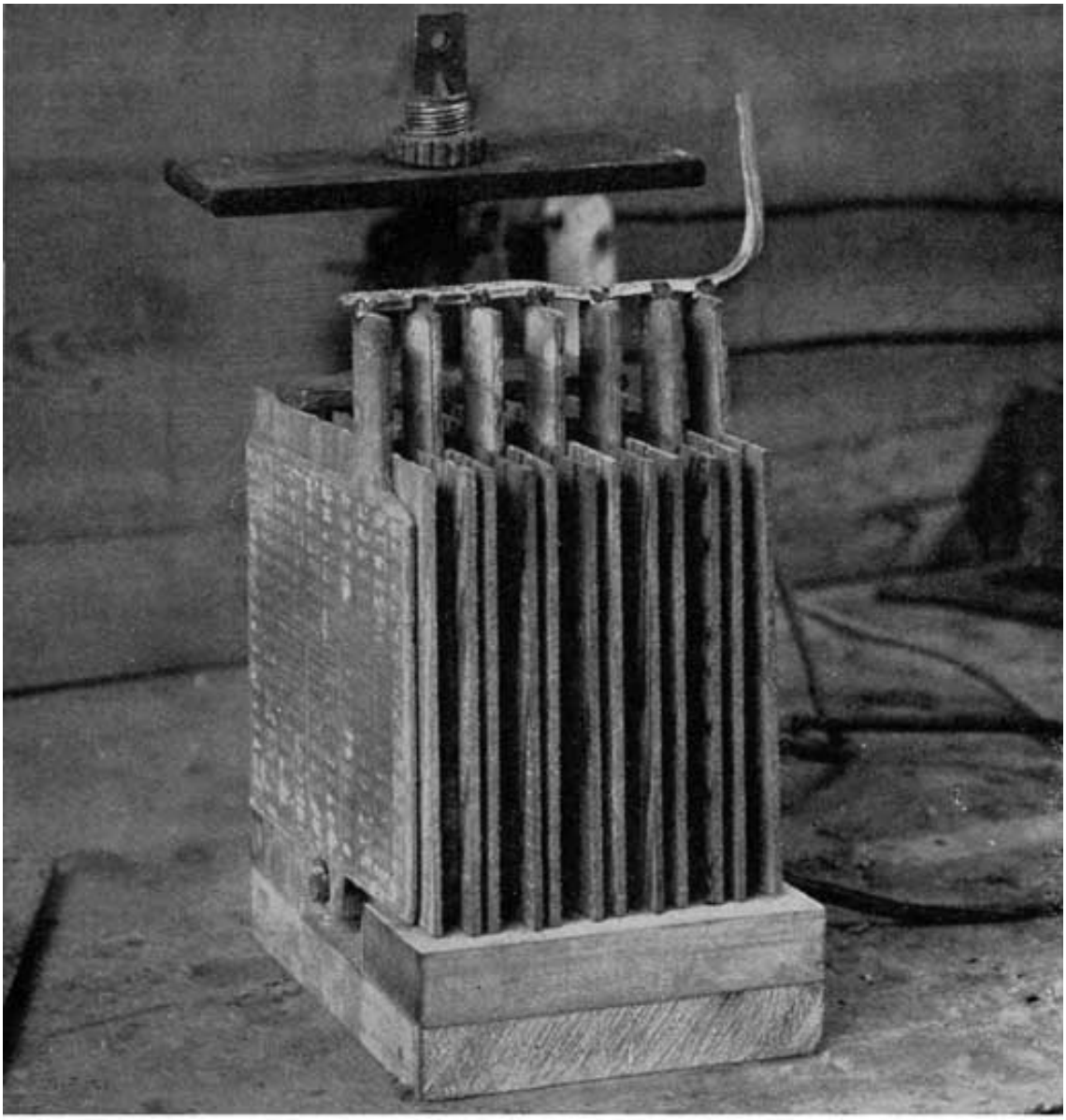

Fig. 316. Preparing Outside Negatives for Charging

Pressing Negative Plates

After badly sulphated cells are recharged, it is sometimes advisable to remove the elements and, press the negative plates, as explained on page 351. Care should be taken to prevent the negative plates from drying out while making repairs, in order to avoid the long charge necessary for dried negative plates.

The battery should be charged to maximum gravity before attempting to press the plates.

It is not necessary and will do no good to press the positive plates.

In some cases the active material may be nearly all out of the outside negative plates and the inside negatives may be in good condition, in which case new charged plates should be burned on. (Fig. 322.)

Salvaging Replaced Cells

When it has been necessary to replace cells which have been in service, the elements can very often be saved and assembled again and used as replacement cells in batteries which are several years old. In no case should the cells be used as new cells.

The positive plates may be allowed to dry out, but the negatives should be kept in distilled water and not allowed to dry out in the least. They should not be kept this way indefinitely, but should be assembled and charged as soon as possible.

Do not attempt to repair groups or plates which have lost as much as half of the active material in wear, or which have the active material disintegrated and falling out. Such plates should not be used. This does not apply to small bits of active material knocked out mechanically and amounting to an extremely small percentage of the whole. Abnormal color indicates possible impurity, and such plates should be washed and used with caution. Badly cracked or broken plates should be replaced with new plates or plates from other groups.

Before new negative plates are used they should be fully charged. (See Charging Negative Plates, page 484.)

Always use new wood separators when assembling repaired cells.

When cells have been operated reversed in polarity to such an extent that the active material of the negative plates has turned brown, both positive and negative groups may have to be replaced.

Repairing Lead Parts

The portable carbon burning outfit used for battery repairs is operated from the battery itself, making it possible to make repairs at the user's residence without using a gas flame.

This outfit can be secured from the Delco-Light Company, Dayton, Ohio, and consists of a carbon holder with cable, clamp, and one-fourth inch carbon rods. Six cells are usually required to properly heat the carbon. If it is completely discharged an outside source must be used. For this purpose a six-volt automobile battery is suitable, or a tray of demonstrating batteries, one terminal being connected to the connection to be burned, the other to the cable of the burning tool. A little experience will. soon demonstrate the number of cells necessary to give a satisfactory heat. The cable is connected by means of the clamp to a cell in the battery, the required number of cells away from the joint to be burned. Care should be taken that contact is made by the clamp, the lead being scraped clean before the connection is made. The carbon should be sharpened to a long point like a lead pencil and should project not more than 2 inches from the holder. (Fig. 317.)

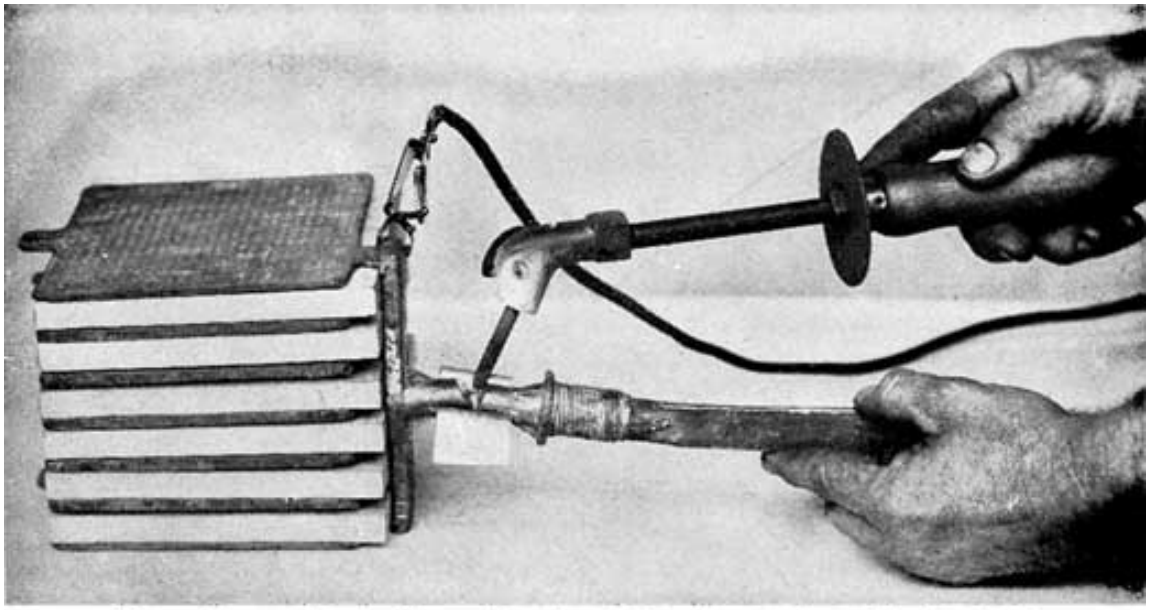

Fig. 317. Repairing Broken Post. Delco-Light Cell

After being used a short time, the carbon will not heat properly, due to a film of scale formed on the surface. This should be cleaned off with a file.

In case of lead burning, additional lead to make a flush joint should not be added until the metal of the pieces to be joined has melted. The carbon should be moved around to insure a solid joint at all points.

In case a post is broken off under the cover, proceed as follows: To make repairs take an old group and cut off the post about one-half way down. Saw off the post to be repaired to such a length that when the new post is burned on the length of the post will be approximately the same length as the original post.

Repairing Broken Posts.

Make a half circle mould out of a piece of tin or galvanized iron, as shown in Fig. 317. Burn solid the side of the post facing up, file it around and then turn the group over, place the form on the burned side and proceed to complete the burning operation.

Caution:

1. Always use clean lead.

2. Do not clean the lead and let it stand for any length of time before starting to burn. If it is allowed to stand it will oxidize and prevent a good burning operation.

3. Burn with an are and not with a red hot carbon.

Burning on Straps

Fig. 318. Splitting End of Strap. Delco-Light Cell

Place the strap to be burned in a vise and split the end through the center and then bend the two halves over to form a foot, as shown in Fig. 318. Make a mould out of a piece of tin or galvanized iron and place this mould around the post to which this strap is to be burned. (Fig. 319.) Then proceed to burn the post and strap together.

When a union is made between the strap and the post a small amount of new clean lead should be burned on the top of the foot to reinforce this point. Care should be taken not to get the mould too high, as this will cause trouble in getting the carbon down to the foot and the post.

Fig. 319. Burning on Negative Strap. Delco-Light Cell

Fig. 320. Auxiliary Strap. Delco-Light Cell

How to Eliminate Burning on Straps by Use of an Auxiliary Strap

A very good way to repair broken straps without the burning operation is to use the auxiliary strap shown in Fig. 320. This strap is slipped over the post of the terminal or strap which is broken and the sealing nut is then clamped down on the strap, as shown in Fig. 321. These straps may be obtained from the Delco-Light Distributors or from the Delco-Light factory at Dayton, Ohio.

Fig. 321. Fastening Auxiliary Strap. Delco-Light Cell

Fig. 322. Burning on Outside Negative Plate. Delco-Light Cell

Burning on New Plates

When it is necessary to burn on new plates, carefully clean with a file the lead on both the plate and the common strap to which all plates of the group are attached. Block up the plate with thin boards or wood separators until it is spaced the proper distance from the adjacent plate. Care should be taken to see that the side and bottom edge of the plate to be burned on is in line with the other plates of the group. Proceed to burn on the plate by drawing a small blaze or are and do not attempt to burn with just a glowing carbon. (Fig. 322.)

If only a glowing carbon is used the result will be a smeary mass and in the majority of cases will not hold, due to the fact that it is not welded but simply attached in one or two points.

The principle of lead burning is to weld or burn two parts into one solid mass and not merely attach one to the other.

Keeping Wood Separators In Stock

No wood separators should be used except those furnished by the Delco-Light Company. These should be kept in distilled water, to which has been added 1.220 electrolyte in the proportion of one part to ten parts of water. It is advisable whenever possible to use new separators when making repairs on a cell. Separators which have been in service are liable to be damaged by handling.

Freezing Temperature of Electrolyte

The freezing temperatures of electrolyte in the Delco-Light batteries depends upon the specific gravity of the battery. The Delco-Light battery fully charged, with a specific gravity of 1.220, should not freeze above a temperature of 30 degrees below zero. Since, however, the freezing point rises very rapidly with a decrease in specific gravity, special care should be taken to keep batteries charged when temperatures below zero are encountered. The following table shows freezing temperatures of several different gravities of electrolyte.

Specific Gravity	Freezing Point
1.100	19° F. above zero.
1.150	5° F. above zero.
1.175	6° F. below zero.
1.200	16° F. below zero.
1.220	31° F. below zero.

At the temperature given, the electrolyte does not freeze solid, but forms a slushy mass of crystals, which does not always result in jar breakage.

Care of Cells in Stock

Frequently a Dealer or Distributor will have' several sets of new batteries in stock for five or six months. In this case, the cells should be given a freshening charge before putting into service. This charge should consist of charging the cells to maximum gravity.

Cells received broken in transit or cells sent in for repairs should be repaired and charged as soon as possible and put into service immediately. This eliminates the possibility of the cells standing idle over a long period in which they would need a freshening charge before they could be used.

However, if such cells must be kept in stock, they can be maintained in a healthy condition by keeping on charge at a one fifth ampere rate for 13-plate cells and one-tenth ampere rate for 7-plate cells.

Taking Batteries Out of Commission

If a battery is not to be used at all for a period not longer than about 9 months, it can be left idle if it is first treated as follows: Add sufficient water to bring the electrolyte up to the water line in all cells and then give an equalizing charge, continuing the charge until the specific gravity of each cell is at a maximum, five consecutive hourly readings showing no rise in gravity. As soon as this charge is completed, take out the battery fuse and open up one or two of the connections between cells so that no current can be taken from the battery. Have vent plugs in place to minimize evaporation.

If the battery is to be taken out of commission for a longer time than 9 months, the battery should be fully charged

as above and the electrolyte poured off into suitable glass or porcelain receptacles. The plates should immediately be covered with water for a few hours to prevent the negatives heating, after which the separators should be removed, the water poured out of the jars, and the positive and negative groups placed back in the jar for storage. Examine the separators. If they are cracked or split they should be thrown away. If in good condition they should be stored for further use in a non-metallic receptacle and covered with water, to which has been added electrolyte of 1.220 specific gravity, in the proportion of one part electrolyte to ten of water by volume.

Putting Batteries Into Commission After Being Out of Service

When putting batteries into commission again, if the electrolyte has not been withdrawn, all that is necessary is to add water to the cells if needed, replace connections, and give an equalizing charge.

If the electrolyte has been withdrawn and battery disassembled, it should be reassembled, taking care not to use cracked, split or dried-out separators, and then the cells should be filled with the old electrolyte. which' has been saved, provided no impurity has entered the electrolyte. After filling, allow the battery to stand for 12 hours and then charge, using 6 amperes for KXG-7 size and 12 amperes for the KXG-13 size. Charge at this rate until all cells start gassing freely or temperature rises to 110° F. Then reduce the charging rate one-half, and continue at this rate until the specific gravity is at a maximum, five consecutive hourly readings showing no rise in gravity. At least 40 hours will be required for this charge. To obtain these low rates with the Delco-Light plant, lights or other current-consuming devices must be turned on while charging.

General Complaints from Users and How to Handle Them.

1. Pilot balls do not come up.

This condition may be caused by

(a) Battery discharged.
(b) Weak electrolyte caused by spillage in shipment.
(c) Defective ball.

Question the user to determine whether the ball will not come up if the pilot cell is bubbling freely. Weak electrolyte or a defective ball will require a service trip to determine the one which is responsible for the ball not rising. (See page 470.)

2. Lights dim-must charge daily.

This condition may be caused by

(a) Discharged battery.
(b) Loose dirty connections in battery or line.
(c) Low cells in battery.

The user should be questioned to determine whether the battery is being charged sufficiently. In case the user is positive the battery is charged, the next probable trouble would be that there were some loose or dirty connections in either plant or battery. Have the user check for loose connections. Should it be necessary to make an inspection trip, instruct the user to give battery an equalizing charge so the battery will be fully charged when the inspection is made.

Low cells can be checked by asking the user if all of the cells bubble freely when equalizing charge is given. In case user claims several cells fail to bubble, an inspection trip would be necessary to determine the trouble. (See

page 470.)

3. Cells bubbling when on discharge.

This complaint would indicate a reversed cell. (See page 483.)

4. Cells overflowing on charge.

This would mean that the cells were filled too high above water lines.

5. Engine cranks slowly but does not fire.

This would indicate over-discharged battery. Explain to user how to start plant under this condition.

6. Plant will not crank.

This might be caused by

(a) Blown battery fuse.
(b) Battery over-discharged.
(c) Loose or broken connection on battery or switchboard.

OTHER EXIDE FARM LIGHTING BATTERIES

The Exide type is shown in Figure 296. The plates are held in position both by the cover and by soft rubber support pieces in the bottom of the jar. The support pieces are provided with holes in which projections on the bottom of the plates are inserted. The cover is of heavy moulded glass. The separators are of grooved wood in combination with a slotted rubber sheet (Fig. 297). The strap posts are threaded and are clamped to the cover by means of alloy nuts. The cover overlaps the top of the jar to which it is sealed with sealing compound. The method of sealing and unsealing is practically the same as in the Exide Delco-Light Type."

Batteries with Open Glass Jars

Batteries with open glass jars, in addition to the conducting lug, have two hanging lugs for each plate. The plates are hung from the jar walls by these hanging lugs, as shown in Figs. 323 and 324. The plate straps, instead of being horizontal are vertical and provided with a tail so that adjacent cells may be bolted together by bolt connectors through the end of the tail.

1. The Exide Cell is shown in Fig. 324. It has a grooved wood separator between each positive and negative plate. The separators are kept from floating up by a glass "hold-down" laid across the top. The separators are provided at the top with a pin which rests on the adjoining plates. The pins together with the plate glass hold-downs keep the separators in Position.

To remove an element it is simply necessary to unbolt the connectors, remove the glass cover and hold-down and lift wit the element.

2. The Chloride Accumulator cell is shown in Fig. 323. It differs from the Exide only in type of plates and separators. The positive plates are known as Manchester positives and have the active material in the form of corrugated buttons which are held in a thick grid, as shown in Fig. 325. The buttons are brown in color, the same as all positive active material.

The separators, instead of being grooved wood, am each a sheet of wood with six dowels pinned to it.

The element is removed the same as in the Exide type.

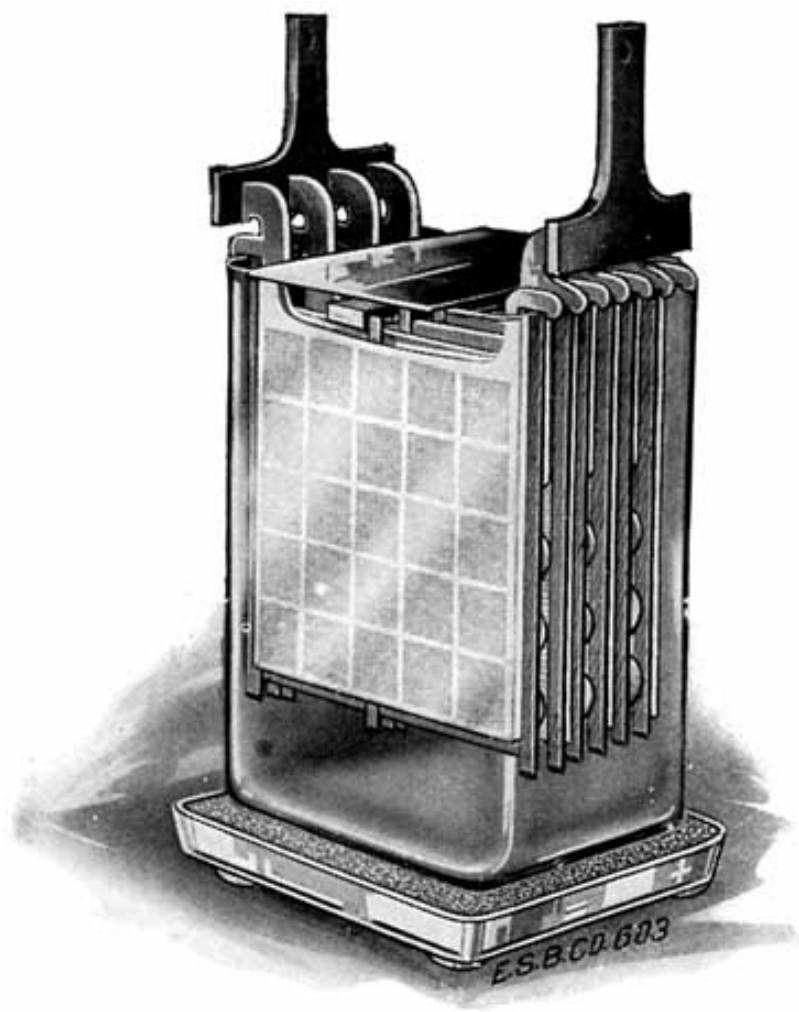

Fig. 323. Exide Chloride Accumulator Cell with Open Glass Jar

Fig. 324. Exide Cell with Open Glass Jar

Batteries with Sealed Rubber Jars

1. The Exide cell is shown in Fig. 326. It is assembled similar to Exide starting and lighting batteries, except that the plates are considerably thicker, wood and rubber separators are used, and the terminal posts are shaped to provide for bolted instead of burned-on connection. The method of sealing and unsealing the cells is the same as in Exide starting and lighting batteries.

All instructions already given for glass for cells apply to rubber jar cells except for a few differences in assembling and disassembling.

Care should be taken to keep the water level at least 1/2 inch above plates at all times as the evaporation is very rapid in rubber jar cells.

The temperature should be watched on charging to prevent overheating. Never allow temperature to go above 110° F.

Unlike the glass jar cells the sediment space in the rubber jar is not sufficient to take care of all the active material in the positive plates. On repairs, therefore, always clean out the sediment and prevent premature short circuits.

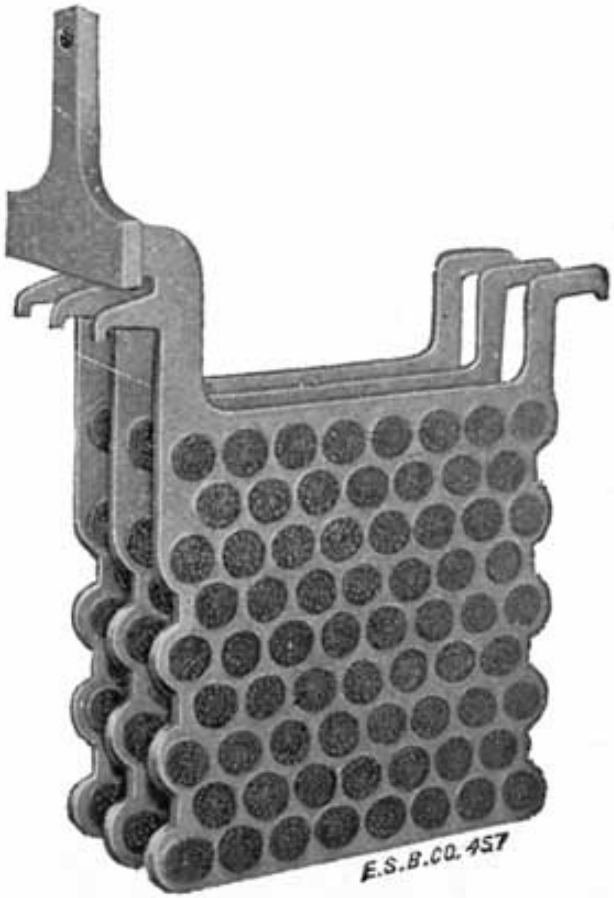

Fig. 325. Manchester Positive Plates

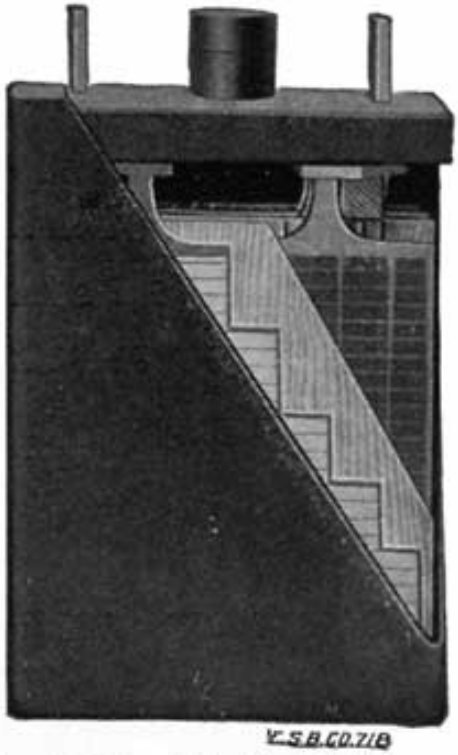

Fig. 326. Exide Cell with Sealed Rubber Jar

WESTINGHOUSE FARM LIGHTING BATTERIES

Jars. Westinghouse Farm Lighting Battery jars are made of glass, with a 5/16 inch wall. The jars are pressed with the supporting ribs for the elements an integral part from a mass of molten glass. A heavy flange is pressed around the upper edge to strengthen the jar.

Top Construction. A sealed-in cover is used similar to that used in starting and lighting batteries. The opening around the post hole is sealed with compound.

Plates. Pasted plates are used. The positives are 1/4 inch thick, and the negatives 3/16 inch. Posts are 13/16 inch in diameter.

Separators. A combination of wood and perforated rubber sheets is used.

Opening and Setting-Up Westinghouse Farm Lighting Batteries

Fig. 327. Westinghouse Farm Lighting Cell

It is preferable that the temperature never exceed 100 deg. Fahrenheit nor fall below 10 deg. in the place where the battery is set up. If the temperature is liable to drop below 10 degrees the battery should be kept in a fully charged condition.

1. Remove all excelsior and the other packing material from the top of the cells. Take cells out carefully and set on the floor. Do not drop or handle roughly. Be sure to remove the lead top connectors from each compartment.

2. Cells should be placed 1/4 inch apart. Also, cells should be placed alternately so that positive post of one cell is adjacent to negative post of the next cell. Positive post has "V" shape shoulder and the negative post has a square shoulder.

3. Grease all posts, straps and nuts with vaseline.

4. Connect positive posts of each cell to negative post of adjacent cell, using top connectors furnished. Top connectors are made so as to fit when connection is made between positive post of one cell and negative post of next cell. Use long connector between end cells of upper and lower shelves.

5. With all connections between cells in position, join the remaining positive post with a connection marked

"Positive" leading from the electric generator. Do likewise with the remaining negative post.

6. If liquid level in any cell is 1 inch or more below the "Liquid Line" on side of glass jar, some liquid has been spilled and must be replaced. This should be done by an experienced person.

7. Immediately after installation operate electric generator and charge battery until gas bubbles rise freely through the liquid in all cells. A reading with the hydrometer syringe which is furnished with the battery should be taken, When the hydrometer float reads between 1.240 and 1.250, the battery is fully charged.

8. The time required to complete the charging operation mentioned above may vary from one to several hours, depending upon the length of time the battery has been in transit. During the charge the temperature of the cells should not be permitted to rise above 110 deg. Fahrenheit. If this condition occurs discontinue the charge or decrease the charge rate until cells have cooled off.

9. When charge is complete replace vent plugs.

The Relation Between Various Sizes of Westinghouse Farm Light Batteries and Work to be Done

The size of the battery furnished with complete farm lighting units vary greatly. Sometimes the battery size is varied with the size of the engine and generator, while again the same size of battery may be used for several sizes of engines and generators. In making replacements, while it is always necessary to retain the same number of cells, it is not necessary to retain the same size of cells.

Usually increasing the cell size increases the convenience to the owner and prolongs the life of the battery to an amount which warrants the higher cost.

With a larger battery, danger of injury through overcharging is lessened, the load on the battery is more easily carried and the engine and generator operate less frequently.

In order to give an idea of various battery capacities, below is a table showing the number of 32 volt, 25-watt lamps which may be lighted for various lengths of time from sixteen cells. The number of hours shows the length of time that the lamps will operate.

Table A

Type	3 Hours	5 Hours	8 Hours
G-7	22 Lamps	14 Lamps	10 Lamps
G-9	28 Lamps	19 Lamps	13 Lamps
G-11	32 Lamps	24 Lamps	15 Lamps
G-13	41 Lamps	28 Lamps	19 Lamps
G-15	47 Lamps	33 Lamps	22 Lamps

G-17	54 Lamps	38 Lamps	25 Lamps

Note:--Based on 32-Volt 25-Watt Lamps.

For example- The table shows opposite G-7 that, with the battery fully charged, twenty-two lamps may be lighted for three hours, fourteen lamps for five hours and ten lamps for eight hours, by a sixteen cell G-7 battery, without operating the engine and generator.

Motors for operating various household and farm appliances are usually rated either in horsepower or watts. The following table will give a comparison between horse-power and watts as well as the number of 25-watt lamps to which these different sizes of motors and appliances correspond.

Table B

H. P. of Motor	No. of Watts	Corresponding Corresponding No. of 25-Watt Lamps
1/8	93	4
1/4	185	7
1/2	373	15
3/4	559	22
1 H.P.	746	30

From table B it will be seen, for example, that a one horsepower motor draws from the battery 373 watts or the same power as do fifteen 25-watt lamps. Then referring to table A, it will be found that a G-11 battery could operate 15 lamps or this motor alone for 8 hours.

Due to the fact that a motor or electric appliance may become overloaded and therefore actually use many more watts than the name plate indicates, it is not advisable to operate any motor of over 1/4 H. P. or even an appliance of over 186 watts on the G-13 or smaller sizes unless the engine and generator are running.

It is safe, however, to operate motors or other appliances up to 375 watts on the G-15 or G-17 batteries without operating the engine and generator.

WILLARD FARM LIGHTING BATTERIES

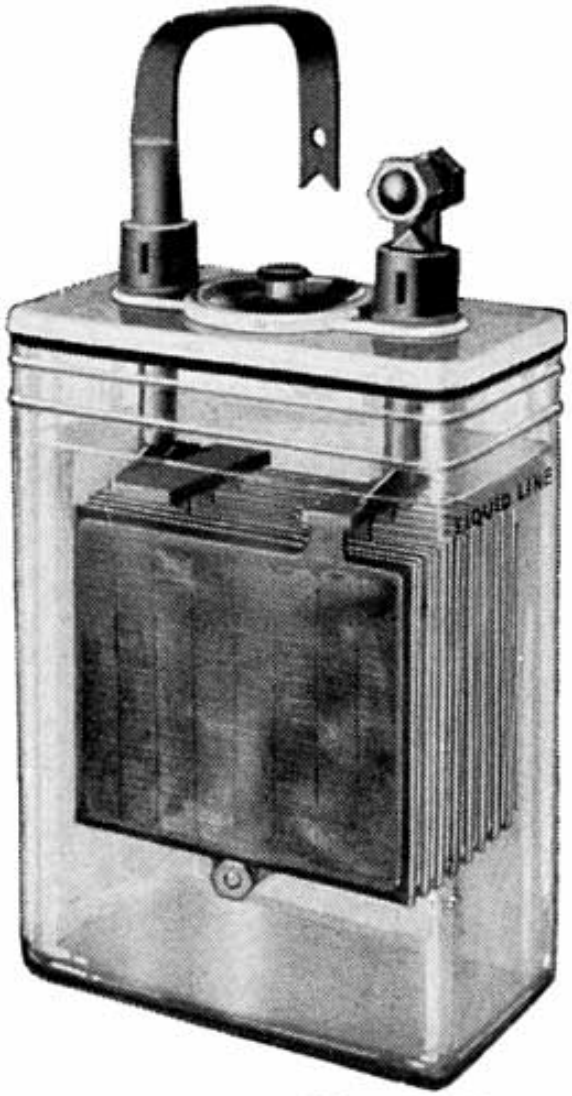

Fig 328. Willard Farm Lighting Cell

The Willard Storage Battery Co. manufactures farm lighting batteries which use sealed glass jars, or sealed rubber jars. Those using the sealed glass jars include types PH and PA. The sealed rubber jar batteries include types EM, EEW, IPR, SMW, and SEW. Both types of batteries are shipped fully charged and filled with electrolyte, and also dry, without electrolyte. The following instructions cover the installation and preparation for service of these batteries.

Glass Jar Batteries. Fully Charged and Filled With Electrolyte

Each sixteen cell set of batteries is packed in two shipping crates.

One crate, which is stenciled "No. 1" contains:

8 Cells.
18 Bolt Connectors.
1 Hydrometer Syringe.
1 Instruction Book.
The other crate which is stenciled "No. 2" contains:
8 Cells.

(NOTE:--If the batteries are re-shipped by the manufacturer or distributor, care must be exercised to see that they are sent out in sets.)

Unpacking

Remove the boards from the tops of the shipping crates and the excelsior which is above the cells.

To straighten the long top connector, grasp the strap firmly with the left hand close to the pillar post and raise the outer end of the strap until it is in an upright position. Do not make a short bend near the pillar post. Lift the cells from the case by grasping the glass jars. Do not attempt to lift them by means of the top connectors.

Clean the outside of the cells by wiping with a damp cloth.

Inspection of Cells.

Inspect each cell to see if the level of the electrolyte is at the proper height. This is indicated on the jar by a line marked LIQUID LINE.

If the electrolyte is simply a little low and there is no evidence of any having been spilled (examine packing

material for discoloration) add distilled or clean rain water to bring the level to the proper height.

If the liquid does not cover the plates and the packing material is discolored, it indicates that some or all of the electrolyte has been lost from the cell either on account of a cracked jar or overturning of the battery.

If only a small quantity of electrolyte is lost through spilling, the cell should be filled to the proper height with electrolyte of the same specific gravity as in the other cells. This cell should then be charged until the gravity has ceased rising. If all the electrolyte is lost write to the Willard Storage Battery Co., Cleveland, Ohio, for instructions.

Connecting the Cells

Each cell of the type PH battery is a complete unit, sealed in a glass jar. The cells are to be placed side by side on the battery rack so that the positive terminal of one cell (long connecting strap) can be connected to the negative terminal (short strap) of the adjacent cell.

Join the positive terminal of one cell to the negative terminal of the adjacent cell and continue this procedure until all the cells are connected together. This will leave one positive and one negative terminal of the battery to be connected respectively to the positive and negative wires from the switchboard. The bend in the top connector should be made about one inch above the pillar post to eliminate the danger of breakage at the post.

In tightening the bolts do not use excessive force, as there is liability of stripping the threads.

Give the battery a freshening charge before it is put in service. Type PH cells have a gravity of 1.250 when fully charged, and 1.185 when discharged.

Willard Glass Jar Batteries Shipped "Knock-Down."

Each sixteen cell set of Batteries consists of:

16 Glass Jars.
16 Positive Groups.
16 Negative Groups.
16 Covers.
16 Vent Plugs.
32 Lead Collars.
32 Lead Keys.
32 Soft Rubber Washers.
32 Hard Rubber Rods.
64 Hard Rubber Nuts.
18 Bolt Connectors.
Wood Insulators (the quantity depends upon the size of the cells).
Sealing Compound.
Hydrometer.
Instruction Books.
Electrolyte is not supplied with batteries shipped in a knockdown condition.
Examine all packing material carefully and check the parts with the above list.

Cleaning the Glass Jars

Wash the glass jars and wipe them dry.

Preparing the Covers

Wash the covers and scrub around the under edge to remove all dust. After they are thoroughly dry place them upside down on a bench.

Melt the sealing compound and pour it around the outer edge to make a fillet in the groove.

Assembling the Element and Separators

Place the plates of a positive group between the plates of a negative group and lay the element thus formed on its edge, as shown in Fig. 329.

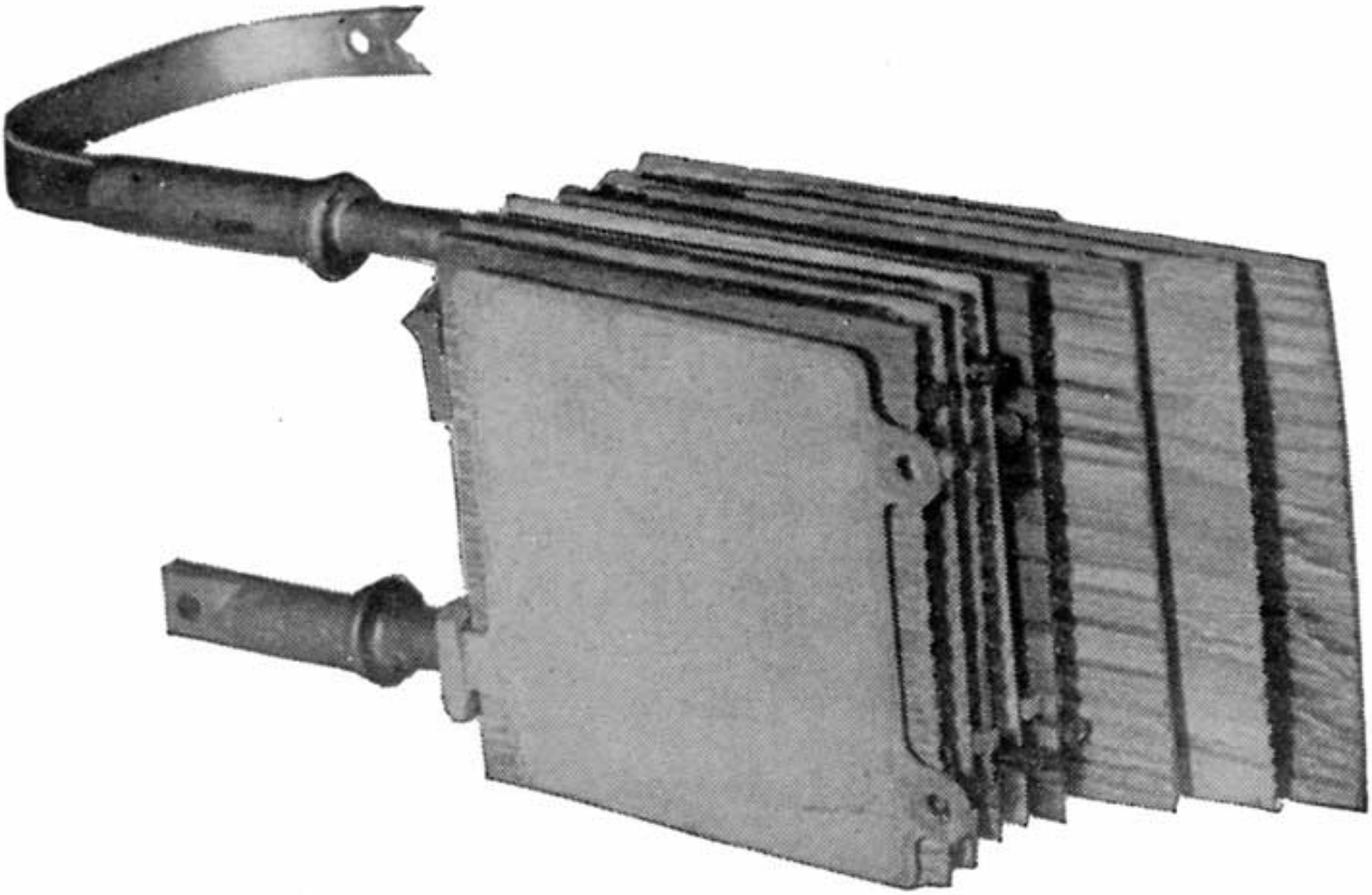

Fig. 329. Inserting Separators.
Willard Farm Lighting Cell

Next insert a wood separator between each of the positive and negative plates.

Next insert the hard rubber rods through the holes in the lugs of the end negative plates, and screw on the nuts. Do not screw the nuts so tight as to make the plates bulge out at the center. The rod should project the same amount on each side of the element.

Place the element in a vertical position.

The cover can now be placed over the posts. Slip a rubber washer and a lead collar over each post. The two key holes in the lead 'collar are unequal in size. The collar must be placed over the post so that the end which measures 3/16 inch from the bottom of the holes to the end of the collar will be next to the rubber washer. Dip the lead key in water and then put it through the holes, having the straight edge of the key on the bottom side. This operation can easily be done by using a pair of tongs (see Figs. 330 and 331) to compress the washer. After the keys are driven tight they can be cut off with a pair of end cutters and then smoothed with a file.

Sealing Element Assembly in Jar

Turn the element upside down and place over a block of wood so that the

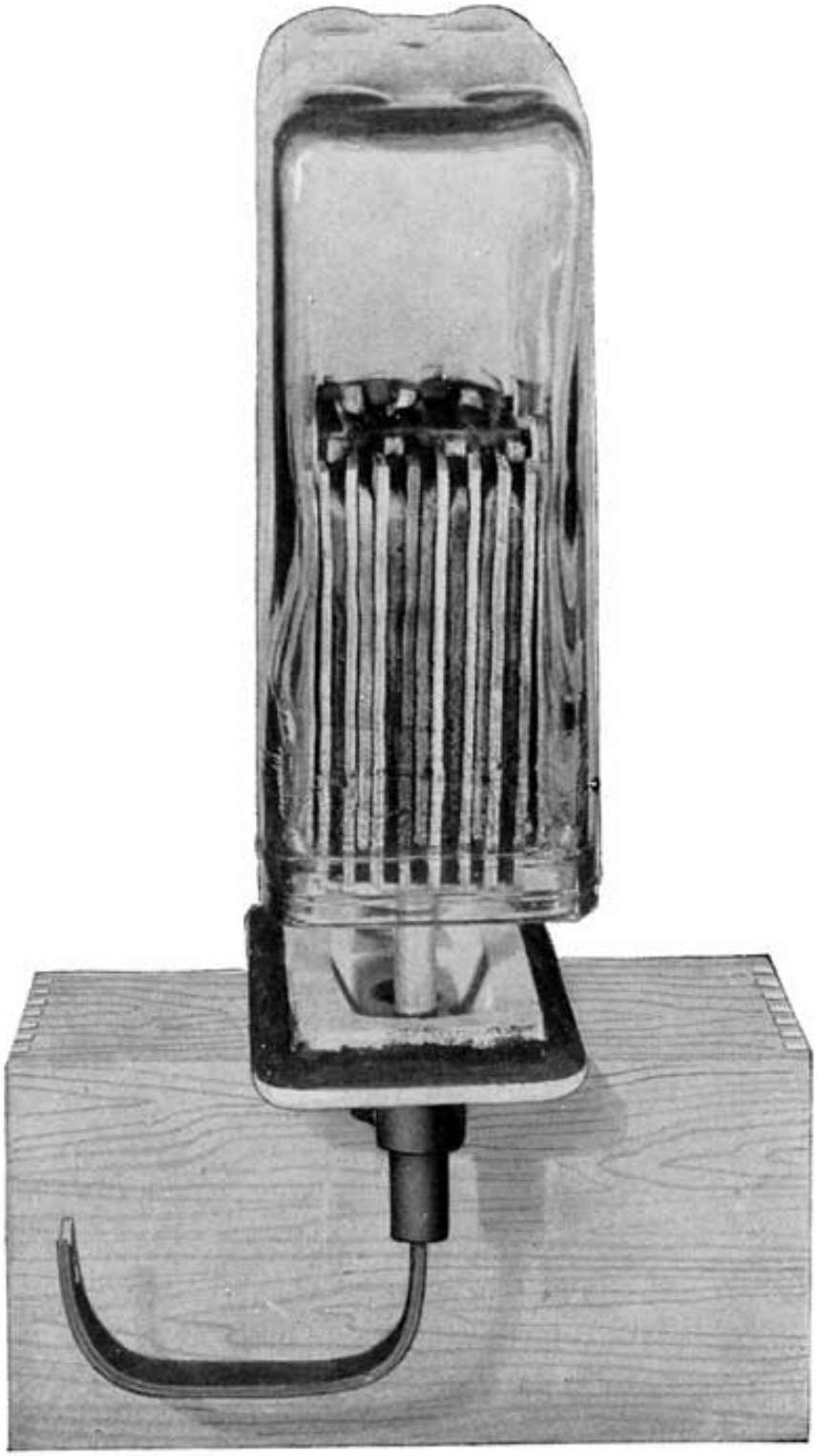

Fig. 332. Sealing Element Assembly, Willard Farm Lighting Cell

weight is supported by the cover. (See Fig. 332.)

Heat the sealing compound by means of a flame (a blow torch will answer the purpose), and place the jar over the element, as shown in Fig. 331. The jar should be firmly pressed down into the compound. With a hot putty knife, clean off any compound which has oozed out of the joint. The assembled cell can now be turned to an upright position.

In case it is necessary to remove a cover, heat a wide putty knife and run it around the edge between the cover and the glass jar. This will soften the compound so that the cover can be pried off.

If it is necessary to remove the cover from the posts, the keys must be driven out by pounding on the small end, as the keys are tapered-and the holes in the lead collars are unequal in size.

Filling with Electrolyte

Fill the cells with 1.260 specific gravity electrolyte at 70° F. to the LIQUID LINE marked on the glass jars. (About I inch above the top edge of separators.) Allow the cells to stand 12 hours, and if the level of the electrolyte has lowered, add sufficient electrolyte to bring it to the proper height.

Initial Charge

Connect the positive terminal (long strap) of one cell to the negative terminal (short strap) of the adjacent cell and continue this procedure until all the cells are connected together. This will leave one positive and one negative terminal to be connected respectively to the positive and negative wires from the charging source.

The bends in the top terminal connectors should be made about one inch above the pillar posts to eliminate the danger of breakage at the post.

In tightening the bolts, do not use excessive force, as there is liability of stripping the threads.

After the cells have stood for 12 hours with electrolyte in the jars, they should be put on charge at the following rates:

Type	Amperes
PH-7	4
PH-9	5
PH-11	6-1/4
PH-13	7-1/2
PH-15	9
PH-17	10

They should be left on charge continuously until the specific gravity of the electrolyte reaches a maximum and remains constant for six hours. At this point, each cell should be gassing freely and the voltage should read about 2.45 volts per cell, with the above current flowing.

Under normal conditions it will require approximately 80 hours to complete the initial charge. The final gravity will be approximately 1.250. If the gravity is- above this value, remove a little electrolyte and add the same amount of distilled water.

If the gravity is too low, remove a little of the electrolyte and add the same amount of 1.400 specific gravity acid and leave on charge as before.

After either water or acid has been added, charge the cells three hours longer in order to thoroughly mix the solution, and if at the end of that time the gravity is between 1.245 and 1.255, the cells are ready for service.

It is very important that the initial charge be continued until the specific gravity reaches a maximum value, regardless of the length of time required. The battery must not be discharged until the initial charge has been

completed.

If it is impossible to charge the battery continuously, the charge can be stopped over night, but must be resumed the next day.

It is preferable to charge the battery at the ampere rate given above, but if this cannot be done, the temperature must be carefully watched so that it does not exceed 110° F.

Wilard Rubber Jar Batteries Shipped Completely Charged and Filled with Electrolyte

Immediately upon receipt of battery, remove the soft rubber nipples and unscrew the vent plugs.

The soft rubber nipples are to be discarded, as they are used only for protection during shipment. Inspect each cell to see whether the electrolyte is at the proper height.

If the electrolyte is simply a little low and there is no evidence of any having been spilled (examine packing material for discoloration), add distilled water to bring the level to the proper height.

If electrolyte does not cover the plates and the packing material is discolored, it indicates that some or all of the electrolyte has been lost from the cell, either on account of cracked jar or overturning of the battery.

If only a small quantity of electrolyte is lost through spilling, the cell should be filled to the proper height with electrolyte of the same specific gravity as in the other cells. This cell should then be charged until the gravity has ceased rising, If all the electrolyte is lost, write to the Willard Storage Battery Co., Cleveland, Ohio, for instructions.

Place batteries on rack and connect the positive terminal of one crate to the negative terminal of the next crate, using the jumpers furnished.

The main battery wires from the switch board should be soldered to the pigtail terminals, which can *then be bolted to the battery terminals. Be sure to have the positive and negative battery terminals -connected respectively to the positive and negative generator terminals of switchboard.

Before using the battery, it should be given a freshening charge at the -rate given on page 510.

The specific gravity of the rubber jar batteries is 1.285-1.300 when fully charged, and 1.160 when discharged.

Willard Rubber Jar Batteries Shipped Dry (Export Batteries)

Batteries which have been prepared for export must be given the following treatment:

Upon receipt of battery by customer, the special soft rubber nipples, used on the batteries for shipping purposes only, should be removed and discarded.

Types SMW and SEW batteries should at once be filled to bottom of vent hole with 1.285 specific gravity electrolyte at 70° F.

In mixing electrolyte, the acid should be poured into the water and allowed to cool below 90° F. before being put into the cells. If electrolyte is shipped with the battery, it is of the proper gravity to put into the cells.

Immediately after the batteries are filled with electrolyte, they must be placed on charge at one half the normal charging rate given on page 510, and should be left on charge continuously until the specific gravity of the electrolyte stops rising. At this point, each cell should be gassing freely and the voltage should read at least 2.40 volts per cell with one-half the normal charging current flowing.

If during the charge the temperature of the electrolyte in any one cell exceeds 105° F., the current must be reduced until the temperature is below 90° F. This will necessitate a longer time to complete the charge, but must be strictly adhered to.

Under normal conditions it will require approximately 80 hours to complete the initial charge. The final gravity of the types SMW and SEW will be approximately 1.285. If the gravity is above this value, remove a little electrolyte and add same amount of distilled water while the battery is left charging (in order to thoroughly mix the solution), and after three hours, if the electrolyte is within the limits, the cell is ready for service. If the specific gravity is below these values, remove a little electrolyte and add same amount of 1.400 specific gravity electrolyte. Leave on charge as before. The acid should be poured into the water and allowed to cool below 90° P. before being used. The batteries are then ready for service.

Installing Counter Electromotive Force Cells

Counter EMF cells, if used with a battery, are installed in the same manner as regular cells. They are connected positive to negative, the same as regular cells, but the negative terminal of the CEMF group is to be connected to the negative terminal of the regular cell group. The positive terminal of the counter CEMF group is then to be connected to the switchboard.

Table of Willard Farm Lighting Batteries

(Omitted 4 charts showing charge and discharge rates for different types of batteries, and "Lineal Feet Rack Space Required for...")

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Definitions and Descriptions of Terms and Parts

Acid. As used in this book refers to sulphuric acid (H_2SO_4), the active component of the electrolyte, or a mixture of sulphuric acid and water.

Active Material. The active portion of the battery plates; peroxide of lead on the positives and spongy metallic lead on the negatives.

Alloy. As used in battery practice, a homogeneous combination of lead and antimony.

Alternating Current. Electric current which does not flow in one direction only, like direct current, but rapidly reverses its direction or "alternates" in polarity so that it will not charge a battery.

Ampere. The unit of measure of the rate of flow of electric current.

Ampere Hour. The product resulting from multiplication of amperes flowing by time of flow in hours, e.g., a battery supplying 10 amperes for 8 hours gives 80 ampere hours. See note under "Volt?' for more complete explanation of current flow.

Battery. Two or more electrical cells, electrically connected so that combination furnishes current as a unit.

Battery Terminals. Devices attached to the positive post of one end cell and the negative of the other, by means of which the battery is connected to the car circuit.

Bridge (or Rib). Wedge-shaped vertical projection from bottom of rubber jar on which plates rest and by which they are supported.

Buckling. Warping or bending of the battery plates.

Burning. A term used to describe the operation of joining two pieces of lead by melting

them at practically the same instant so they may run together as one continuous piece. Usually done with mixture of oxygen and hydrogen or acetylene gases, hydrogen and compressed air, or oxygen and illuminating gas.

Burning Strip. A convenient form of lead, in strips, for filling up the joint in making burned connections.

Cadmium. A metal used in about the shape of a pencil for obtaining voltage of positive or negative plates. It is dipped in the electrolyte but not allowed to come in contact with plates.

Capacity. The number of ampere hours a battery can supply at a given rate of current flow after being fully charged, e.g., a battery may be capable of supplying 10 amperes of current for 8 hours before it is exhausted. Its capacity is 80 ampere hours at the 8 hours rate of current flow. It is necessary to state the. rate of flow, since same battery if discharged at 20 amperes would not last for 4 hours but for a shorter period, say 3 hours. Hence, its capacity at the 3 hour rate would be 3x2O=60 ampere hours.

Case. The containing box which holds the battery cells.

Cell. The battery unit, consisting of an element complete with electrolyte, in its jar with cover.

Charge. Passing direct current through a battery in the direction opposite to that of discharge, in order to put back the energy used on discharge.

Charge Rate. The proper rate of current to use in charging a battery from an outside source. It is expressed in amperes and varies for different sized cells.

Corrosion. The attack of metal parts by acid from the electrolyte; it is the result of lack of cleanliness.

Cover. The rubber cover which closes each individual cell; it is flanged for I sealing compound to insure an effective sea].

Cycle. One charge and discharge.

Density. Specific gravity.

Developing. The first cycle or cycles of a new or rebuilt battery to bring about proper electrochemical conditions to give rated capacity.

Diffusion. Pertaining to movement of acid within the pores of plates. (See Equalization.)

Discharge. The flow of current from a battery through a circuit, opposite of "charge."

Dry. Term frequently applied to cell containing insufficient electrolyte. Also applied to certain conditions of shipment of batteries.

Electrolyte. The conducting fluid of electro-chemical devices; for lead-acid storage batteries it consists of about two parts of water to one of chemically pure sulphuric acid, by weight.

Element. Positive group, negative group and separators.

Equalization. The result of circulation and diffusion within the cell which accompanies charge and discharge. Difference in capacity at various rates is caused by the time required for this feature.

Equalizing. Term used to describe the making uniform of varying specific gravities in different cells of the same battery, by adding or removing water or electrolyte.

Evaporation. Loss of water from electrolyte from heat or charging.

Filling Plug. The plug which fits in and closes the orifice of the filling tube in the cell cover.

Finishing Rate. The current in amperes at which a battery may be charged for twenty-four hours or more. Also the charging rate used near the end of a charge when cells begin to gas.

Flooding. Overflowing through the filling tube.

Forming. Electro-chemical process of making pasted grid or other plate, types into storage battery plates. (Often confused with Developing.)

Foreign Material. Objectionable substances.

Freshening Charge. A charge given to a battery which has been standing idle, to keep it fully charged.

Gassing. The giving off of oxygen gas at positive plates and hydrogen at negatives, which begins when charge is something more than half completed-depending on the rate.

Generator System. An equipment including a generator for automatically recharging the battery, in contradistinction to a straight storage system where the battery has to be removed to be recharged.

Gravity. A contraction of the term "specific gravity," which means the density compared to water as a standard.

Grid. The metal framework of a plate, supporting the active material and provided with a lug for conducting the current and for attachment to the strap.

Group. A set of plates, either positive or negative, joined to a strap. Groups do not include separators.

Hold-Down. Device for keeping separators from floating or working up.

Hold-Down Clips. Brackets for the attachment of bolts for holding the battery securely in position on the car.

Hydrogen Flame. A very hot and clean flame of hydrogen gas and oxygen, acetylene, or compressed air used for making burned connections.

Hydrogen Generator. An apparatus for generating hydrogen gas for lead burning.

Hydrometer. An instrument for measuring the specific gravity of the electrolyte.

Hydrometer Syringe. A glass barrel enclosing a hydrometer and provided with a rubber bulb for drawing up electrolyte.

Jar. The hard rubber container holding the element and electrolyte.

Lead Burning. Making a joint by melting together the metal of the parts to be joined.

Lug. The extension from the top frame of each plate, connecting the plate to the strap.

Maximum Gravity. The highest specific gravity which the electrolyte will reach by continued charging, indicating that no acid remains in the plates.

Mud. (See Sediment.)

Negative. The terminal of a source of electrical energy as a cell, battery or generator

through which current returns to complete circuit. Generally marked "Neg." or

Ohm. The unit of electrical resistance. The smaller the wire conductor the greater is the resistance. Six hundred and sixty-five feet of No. 14 wire (size used in house lighting circuit) offers I ohm resistance to current flow.

Oil of Vitriol. Commercial name for concentrated sulphuric acid (1.835 specific gravity). This is never used in a battery and would quickly ruin it.

Over-Discharge. The carrying of discharge beyond proper cell voltage; shortens life if carried far enough and done frequently.

Paste. The mixture of lead oxide or spongy lead and other substances which is put into grids.

Plate. The combination of grid and paste properly "formed." Positive$ are reddish brown and negatives slate gray.

Polarity. An electrical condition. The positive terminal (or pole) of a cell or battery or electrical circuit is said to have positive polarity; the negative, negative polarity.

Positive. The terminal of a source of electrical energy as a cell, battery or generator from which the current flows. Generally marked "Pos." or It+."

Post. The portion of the strap extending through the cell cover, by means of which connection is made to the adjoining cell or to the car circuit.

Potential Difference. Abbreviated P. D. Found on test curves. Synonymous with voltage.

Rate. Number of amperes for charge or discharge. Also used to express time for either.

Rectifier. Apparatus for converting alternating current into direct current.

Resistance. Material (usually lamps or wire) of low conductivity inserted in a circuit to retard the flow of current. By varying the resistance, the amount of current can be regulated. Also the property of an electrical circuit whereby the flow of current is impeded. Resistance is measured in ohms. Analogous to the impediment offered by wall of a pipe to flow of water therein.

Rheostat. An electrical appliance used to raise or lower the resistance of a circuit and correspondingly to decrease or increase the current flowing.

Rib. (See Bridge.)

Ribbed. (See Separator.)

Reversal. Reversal of polarity of cell or battery, due to excessive discharge, or charging in the wrong direction.

Rubber Sheets. Thin, perforated hard rubber sheets used in combination with the wood separators in some types of batteries. They are placed between the grooved side of the wood separators and the positive plate.

Sealing. Making tight joints between jar and cover; usually with a black, thick, acid-proof compound.

Sediment. Loosened or worn out particles of active material fallen to the bottom of cells; frequently called' "mud."

Sediment Space. That part of jar between bottom and top of bridge.

Separator. An insulator between plates of opposite polarity; usually of wood, rubber or combination of both. Separators are generally corrugated or ribbed to insure proper distance between plates and to avoid too great displacement of electrolyte.

Short Circuit. A metallic connection between the positive and negative plates within a cell. The plates may be in actual contact or material may lodge and bridge across. If the separators are in good condition, a short circuit is unlikely to occur.

Spacers. Wood strips used in some types to separate the cells in the case, and divided to provide a space for the tie bolts.

Specific Gravity. The density of the electrolyte compared to water as a standard. It indicates the strength and is measured by the hydrometer.

Spray. Fine particles of electrolyte carried up from the surface by gas bubbles. (See Gassing.)

Starting Rate. A specified current in amperes at which a discharged battery may be charged at the beginning of a charge. The starting rate is reduced to the finishing rate when the cells begin to gas. It is also reduced at any time during the charge if the temperature of the electrolyte rises to or above 110' Fahrenheit.

Starvation. The result of giving insufficient charge in relation to the amount of discharge, resulting in poor service and injury to the battery.

Strap. The leaden casting to which the plates of a group are joined.

Sulphate. Common term for lead sulphate. ($PbSO_4$.)

Sulphated. Term used to describe cells in an under-charged condition, from either over-discharging without corresponding long charges or from standing idle some time and being self discharged.

Sulphate Reading. A peculiarity of cell voltage when plates are considerably sulphated, where charging voltage shows abnormally high figures before dropping gradually to normal charging voltage.

Terminal. Part to which outside wires are connected.

Vent, Vent Plug or Vent-Cap. Hard or soft rubber part inserted in cover to retain atmospheric pressure within the cell, while preventing loss of electrolyte from spray. It allows gases formed in the cell to escape, prevents electrolyte from spilling, and keeps dirt out of the cell.

Volt. The commercial unit of pressure in an electric circuit. Voltage is measured by a voltmeter. Analogous to pressure or head of water flow through pipes. NOTE. - Just as increase of pressure causes more volume of water to flow through a given pipe so increase of voltage (by putting more cells in circuit) will cause more amperes of current to flow in same circuit. Decreasing size of pipes is increasing resistance and decreases flow of water, so also introduction of resistance in an electrical circuit decreases current flow with a given voltage or pressure.

Wall. Jar sides and ends.

Washing. Removal of sediment from cells after taking out elements; usually accompanied by rinsing of groups, replacement of wood separators and renewal of electrolyte.

Watt. The commercial unit of electrical power, and is the product of voltage of circuit by amperes flowing. One ampere flowing under pressure of one volt represents one watt of power.

Watt Hour. The unit of electrical work. It is the product of power expended by time of expenditure, e.g., 10 amperes flowing under 32 volts pressure for 8 hours gives 2560 watt hours.

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A VISIT TO THE FACTORY

THE following pages show how Batteries are made at the Factory. The illustrations will be especially interesting to Battery Service Station Owners who have conceived the idea that they would like to manufacture their own batteries.

A completed battery is a simple looking piece of apparatus, yet the equipment needed to make it is elaborate and expensive, as the following illustrations will show. Quantity production is necessary in order to build a good battery at a moderate cost to the car owner, and quantity production means a large factory, elaborate and expensive equipment, and a large working force. Furthermore, before any batteries are put on the market, extensive research and experimentation is necessary to develop a battery which will prove a success in the field. This in itself requires considerable time and money. No manufacturer who has developed formulas and designs at a considerable expense will disclose them to others who desire to enter the manufacturing field as competitors, nor can anyone expect them to do so.

If the man who contemplates entering the battery manufacturing business can afford to develop his own formulas and designs, build a factory, and organize a working force, it is, of course, perfectly. proper for him to become a manufacturer; but unless he can do so, he should not attempt to make a battery.

The following illustrations, will of course, be of interest to the man who repairs batteries. A knowledge of the manufacturing processes will give him a better understanding of the batteries which he repairs. The less mystery there is about the battery, the more efficiently can the repairman do his work.

Casting Exide Grids

Pasting Exide Plates

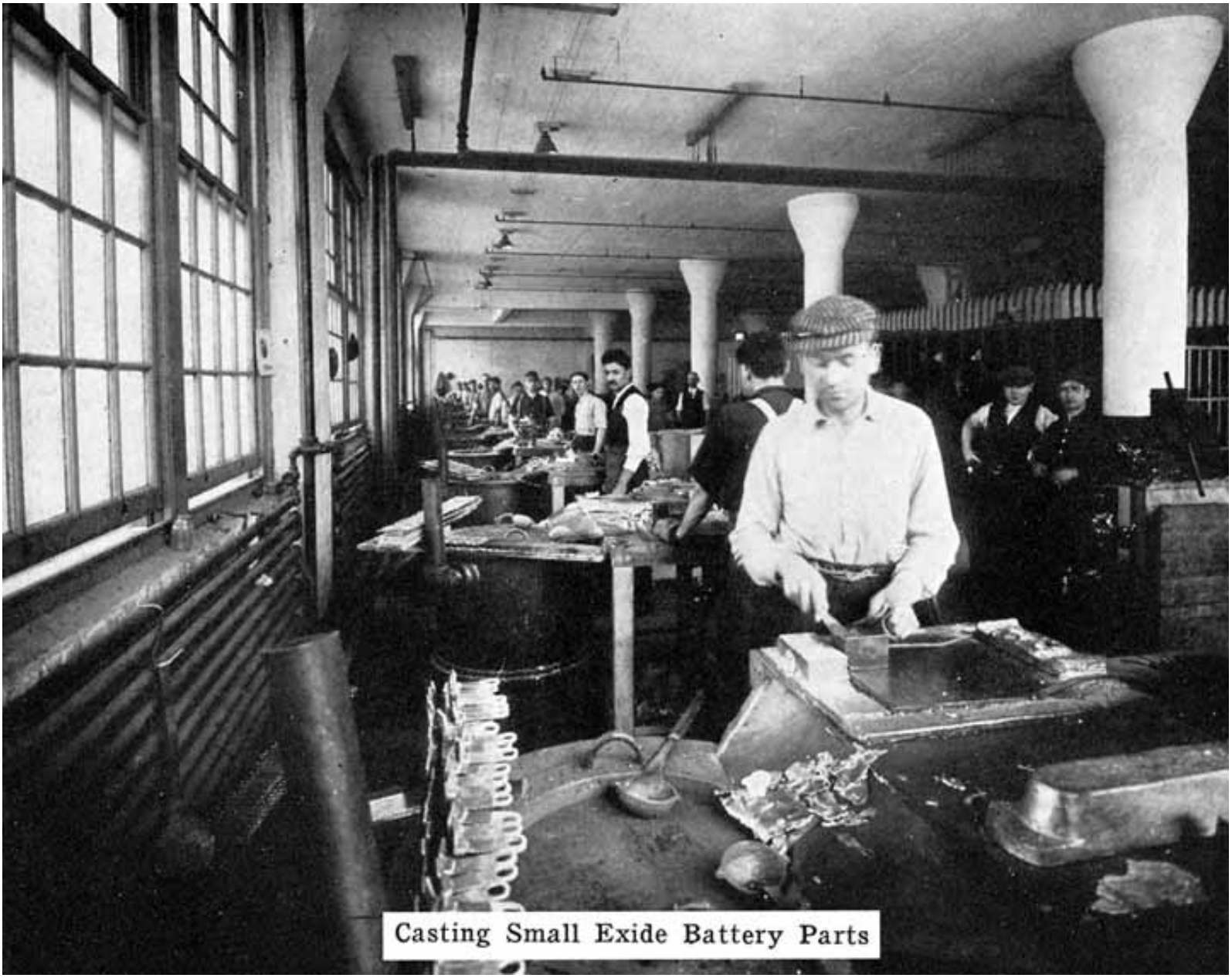
Casting Small Exide Battery Parts

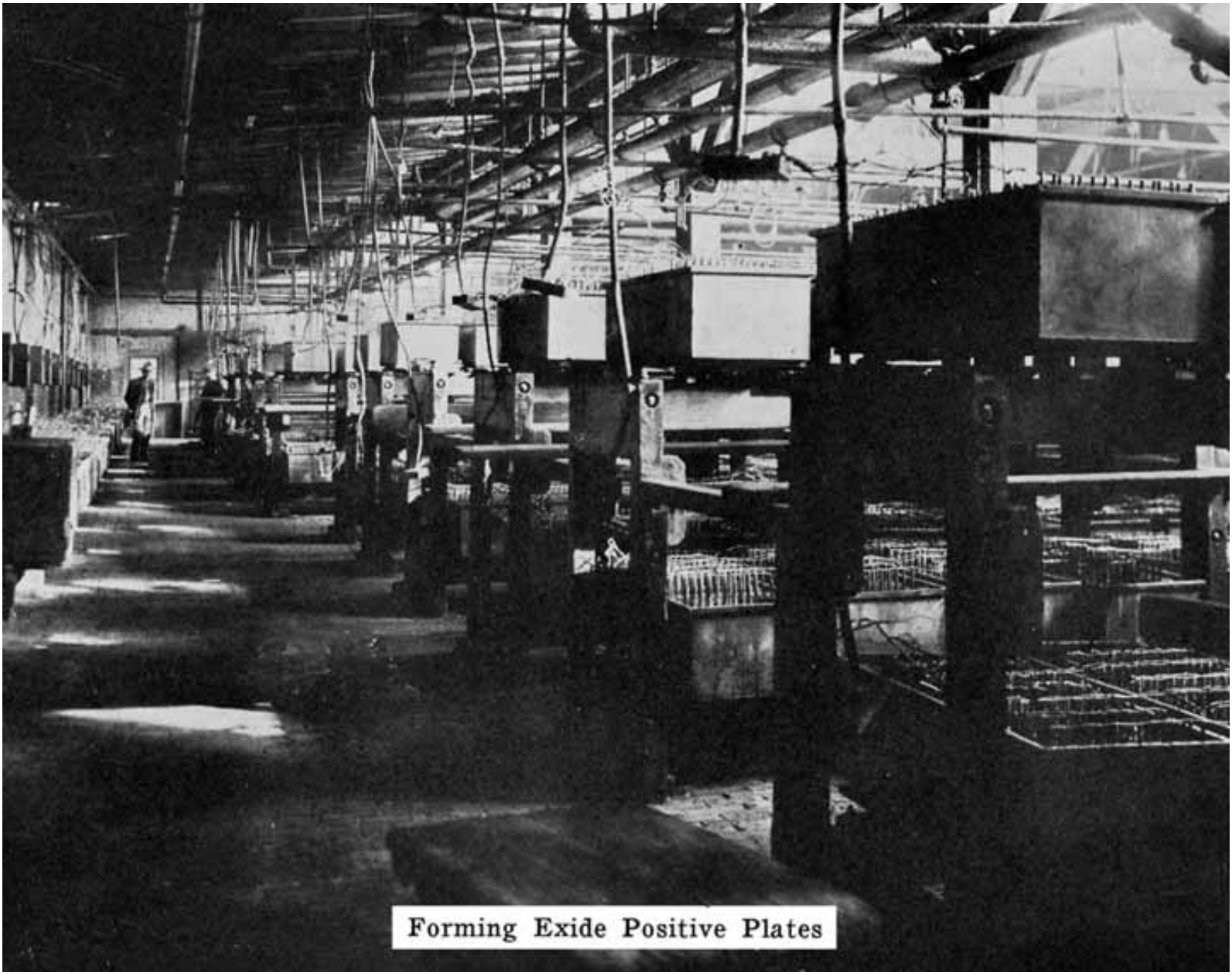

Forming Exide Positive Plates

Burning Exide Plates Into Groups

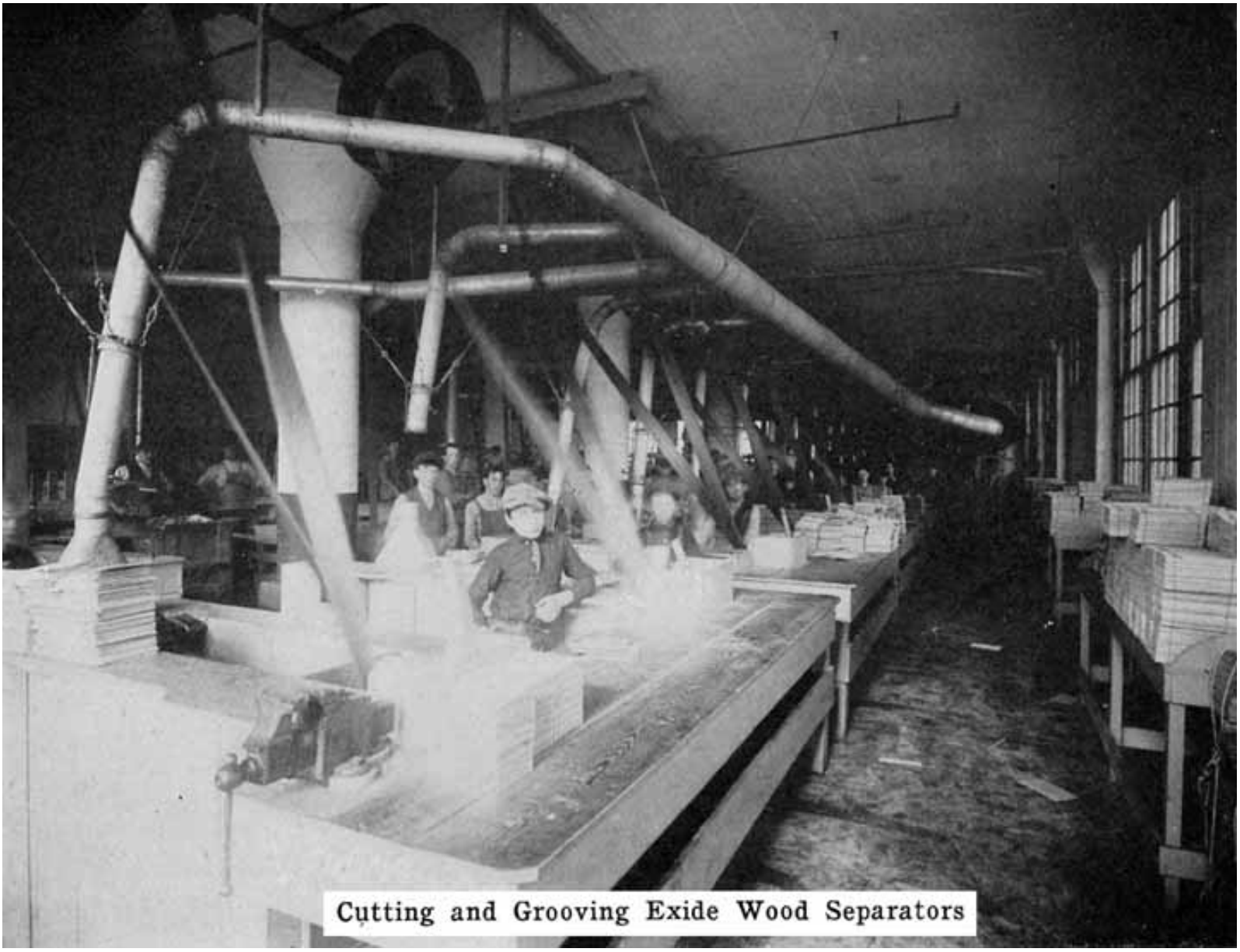
Cutting and Grooving Exide Wood Separators

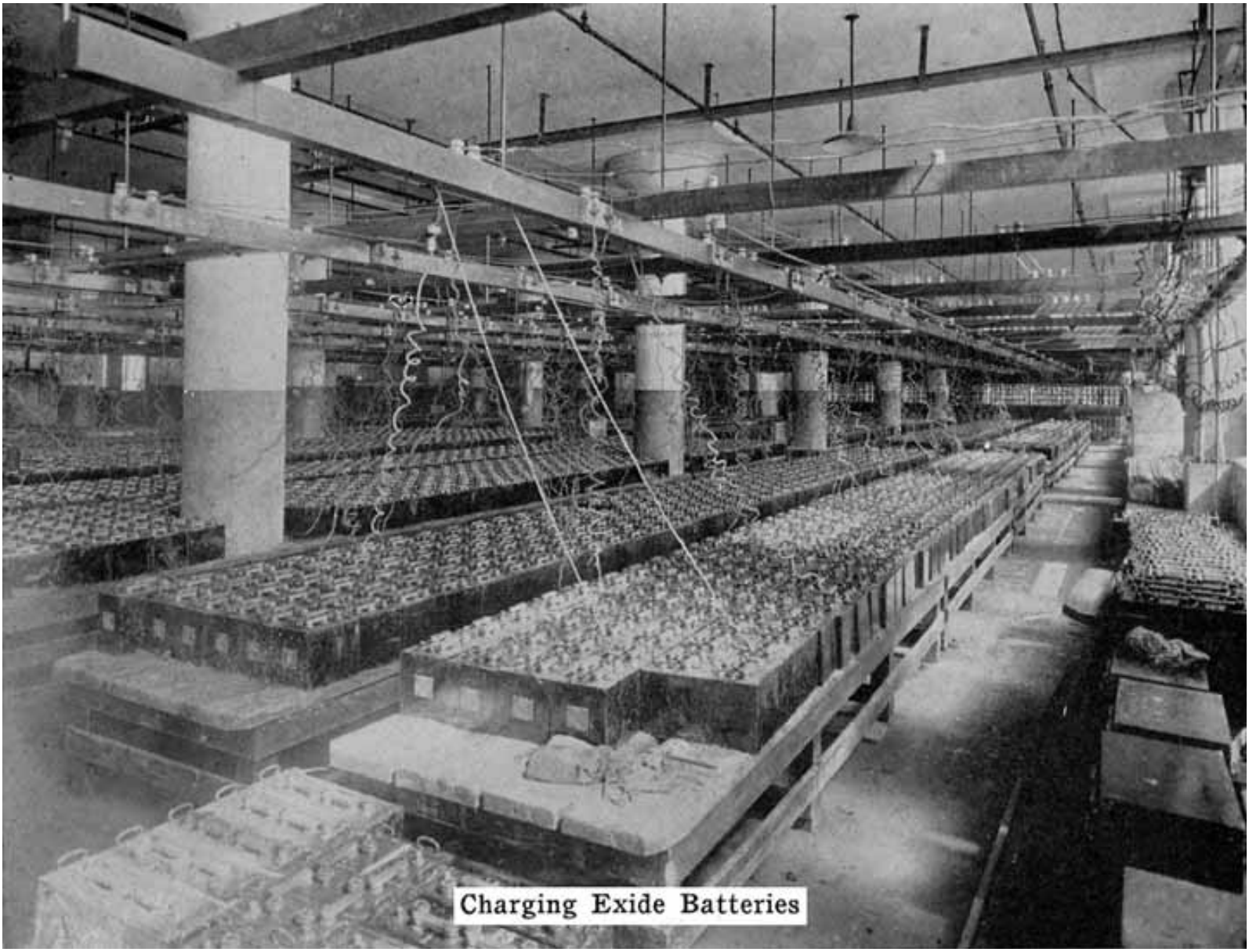
Charging Exide Batteries

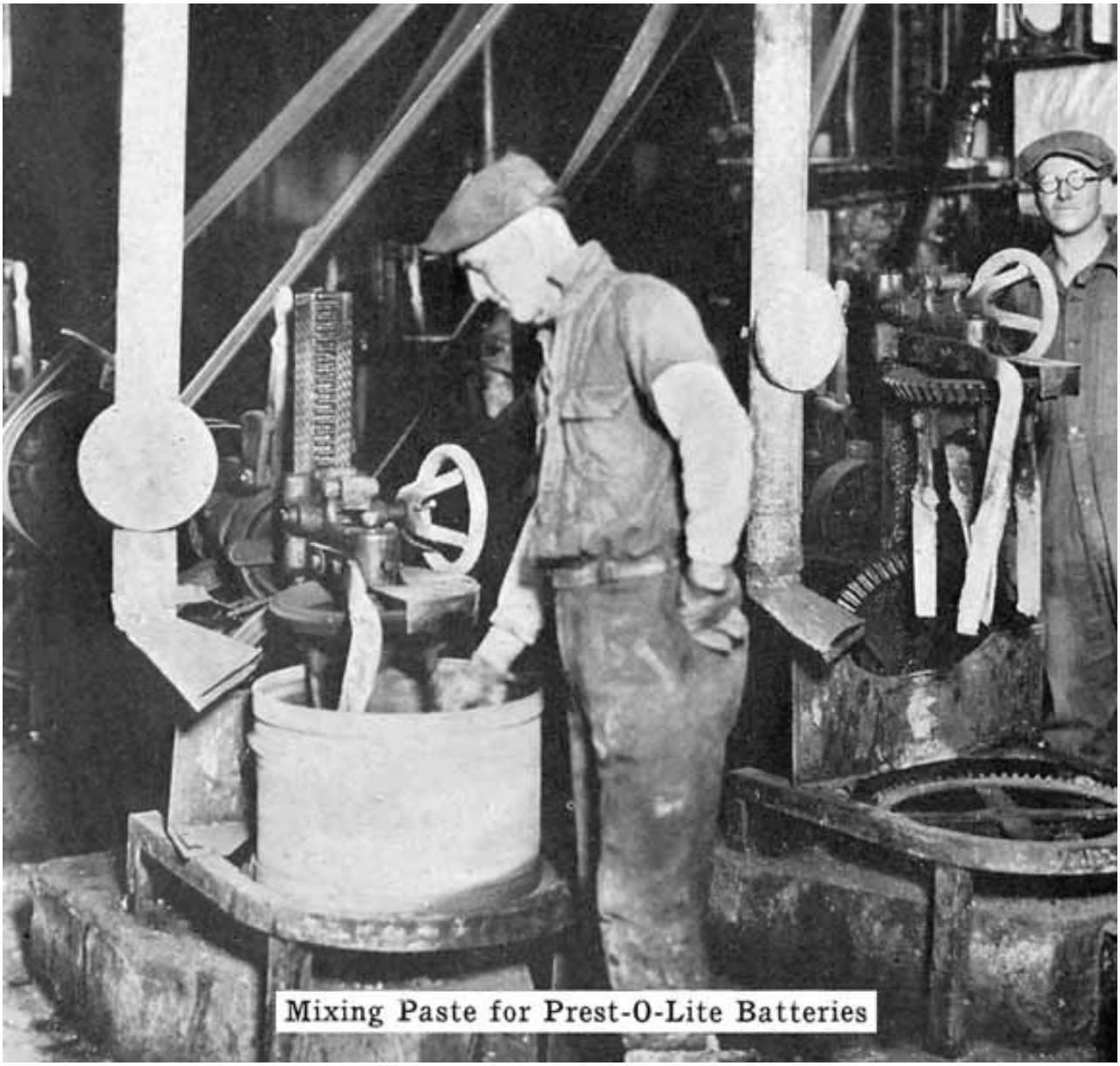

Mixing Paste for Prest-O-Lite Batteries

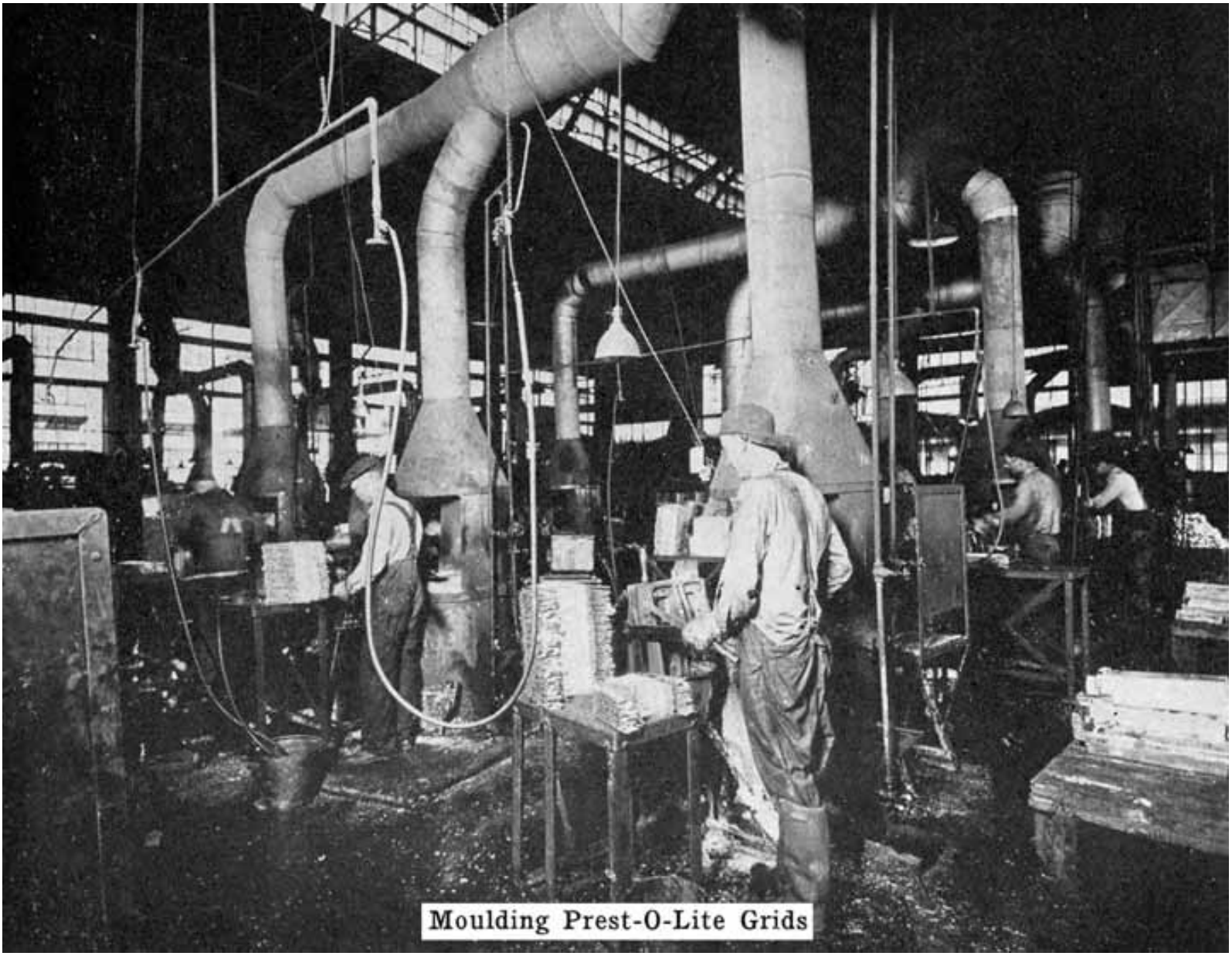

Moulding Prest-O-Lite Grids

Inspecting Prest-O-Lite Grids for Defects

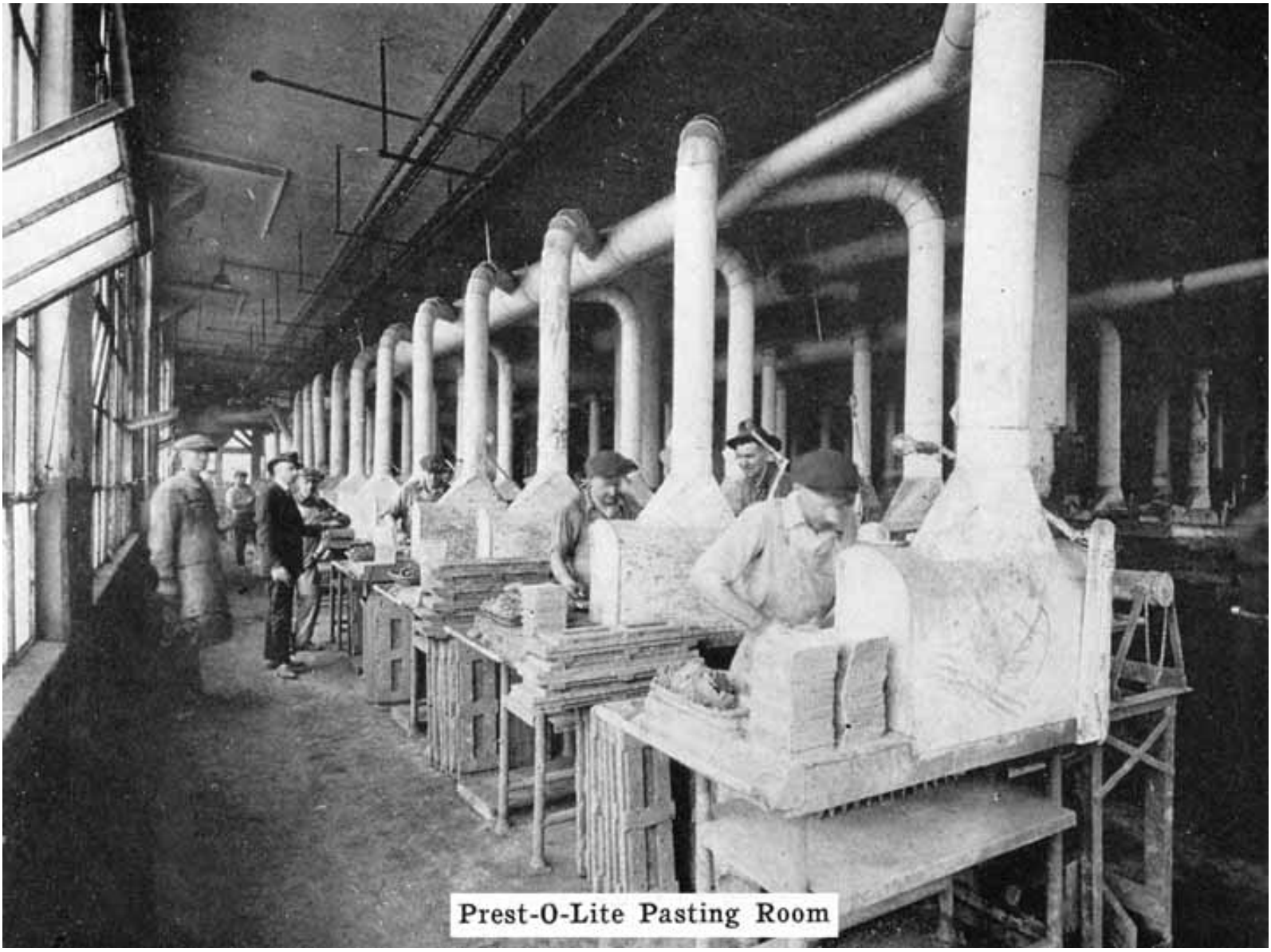
Prest-O-Lite Pasting Room

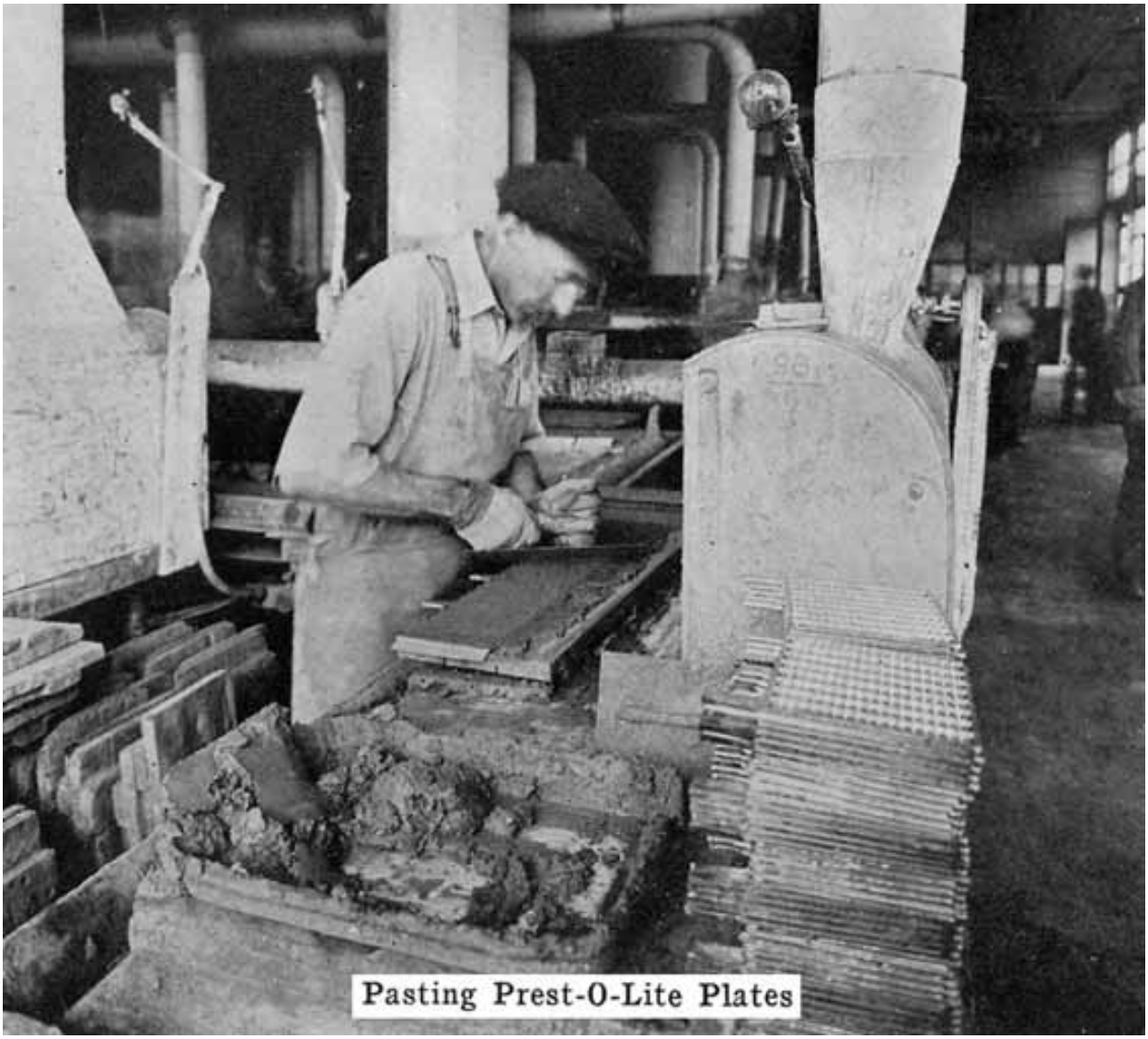
Pasting Prest-O-Lite Plates

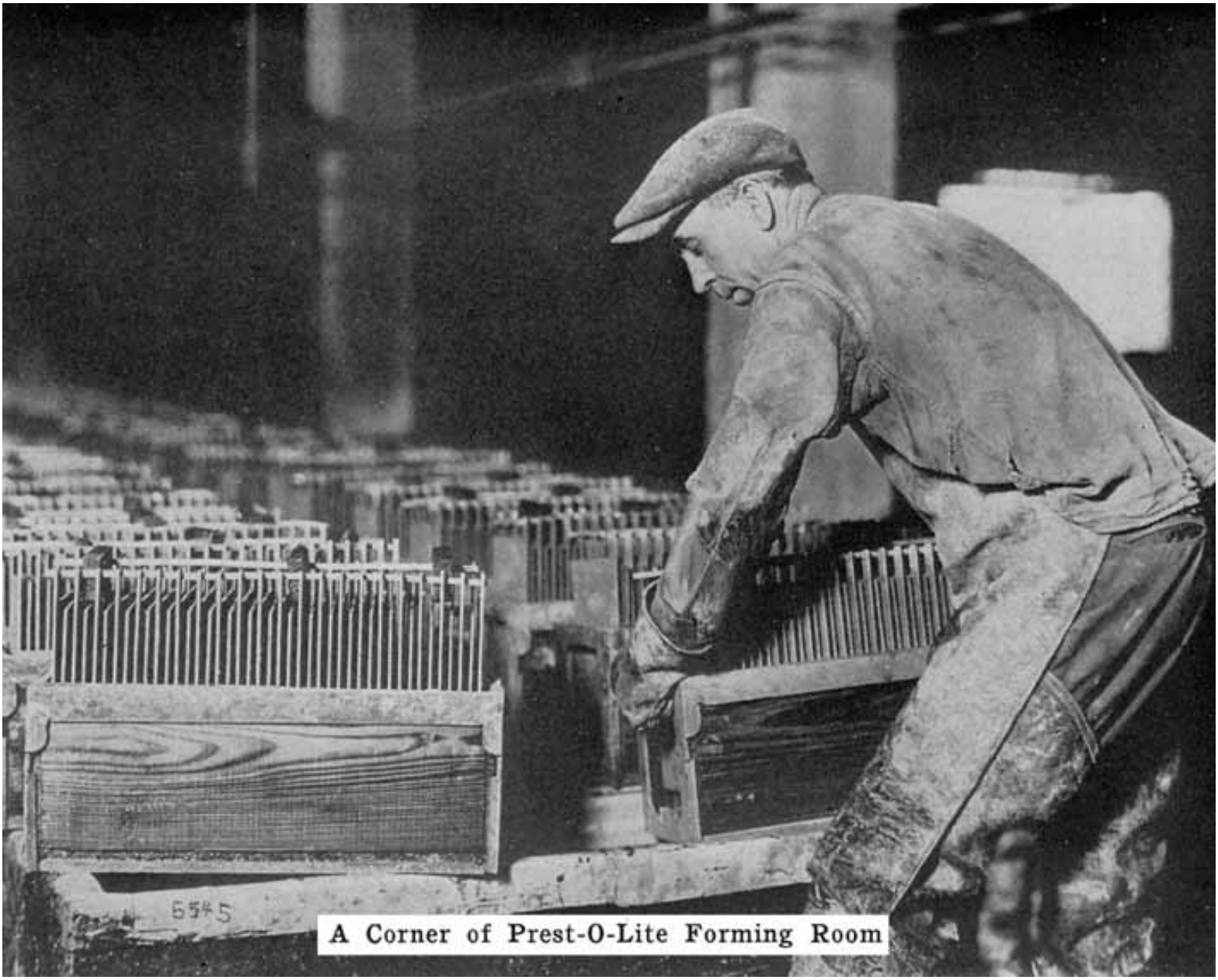

A Corner of Prest-O-Lite Forming Room

General View of Prest-O-Lite Assembly Room

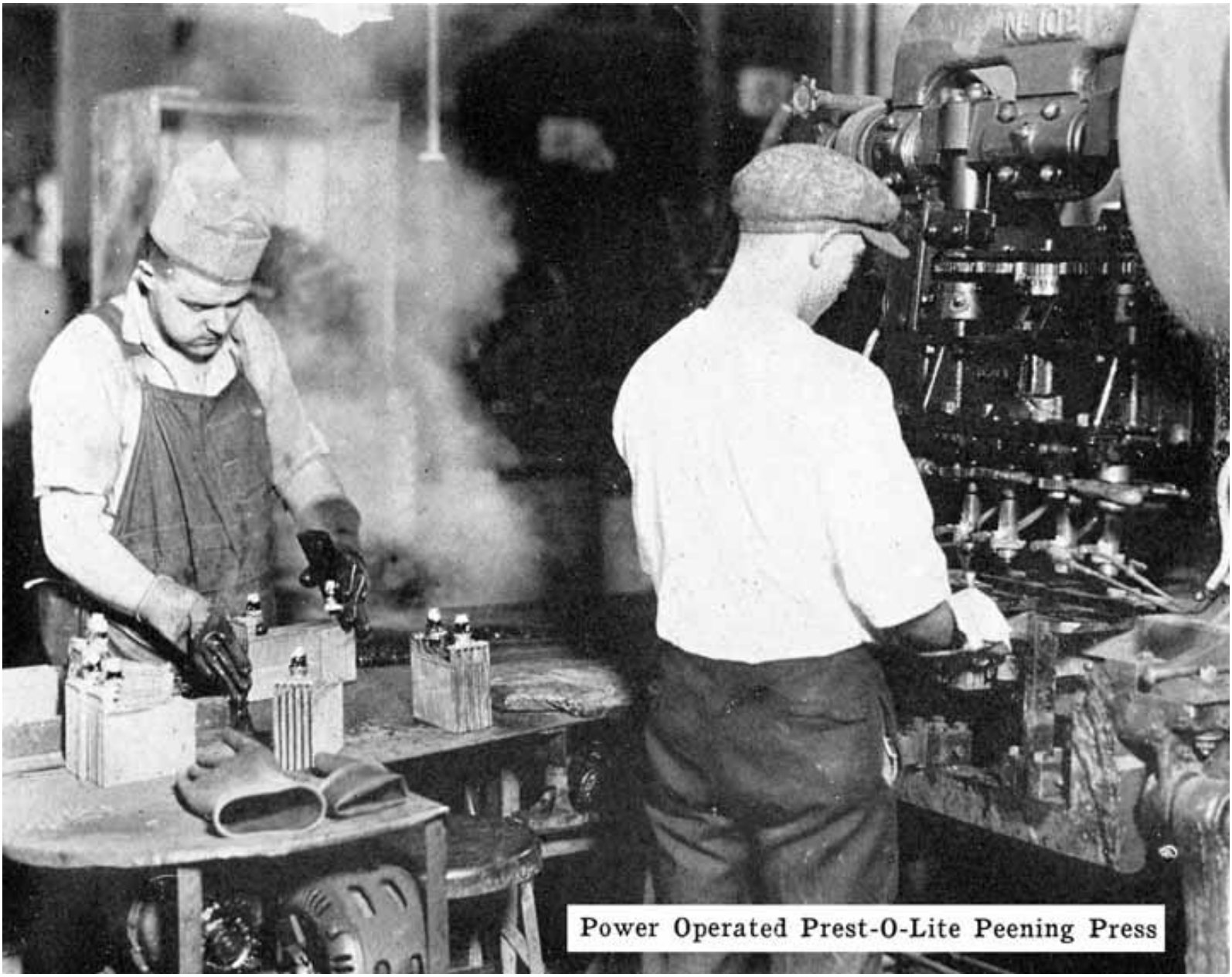

Power Operated Prest-O-Lite Peening Press

Inspecting Prest-O-Lite Separators

Inserting Separators in Prest-O-Lite Plate Elements

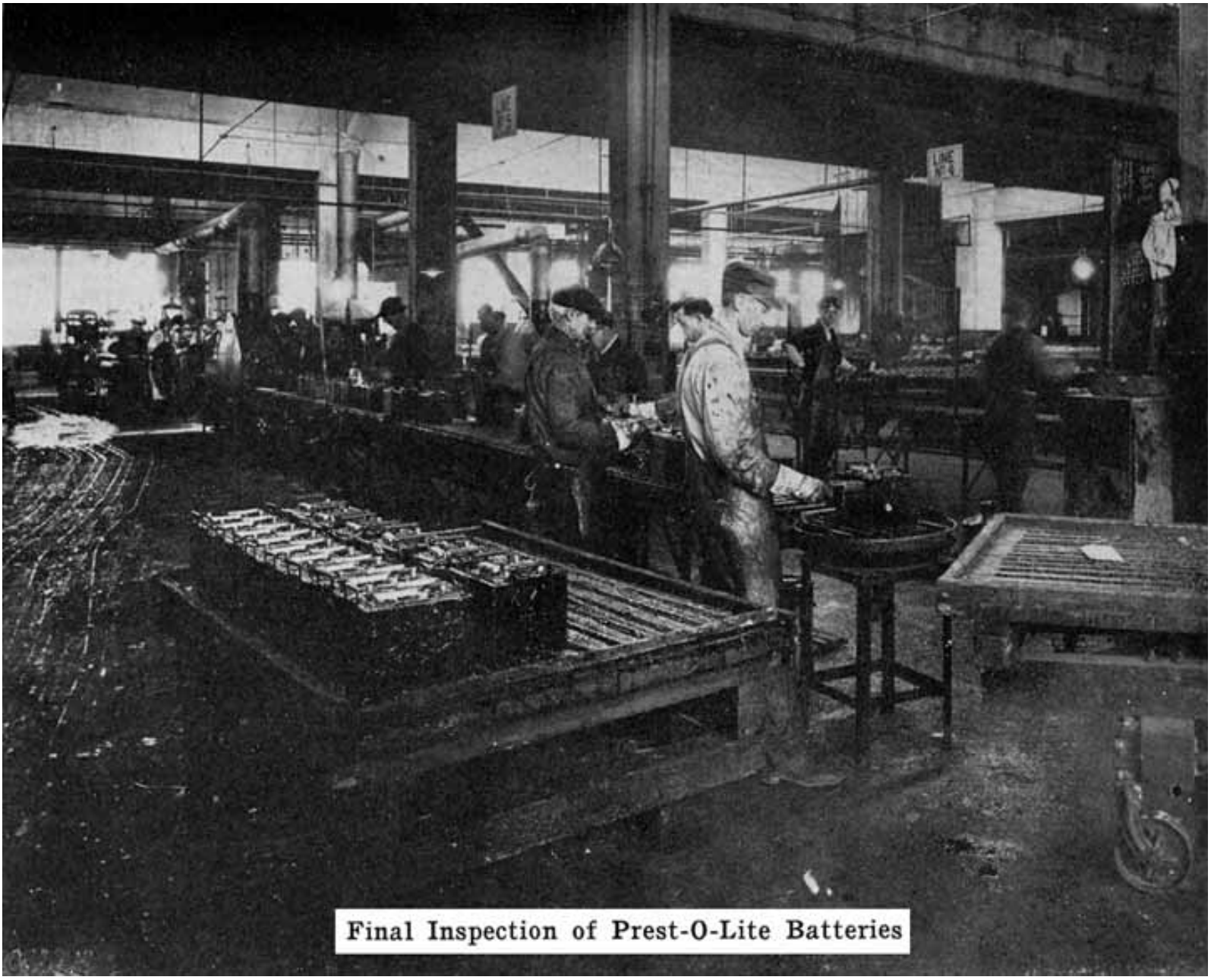

Final Inspection of Prest-O-Lite Batteries

Prest-O-Lite Experimental Laboratory

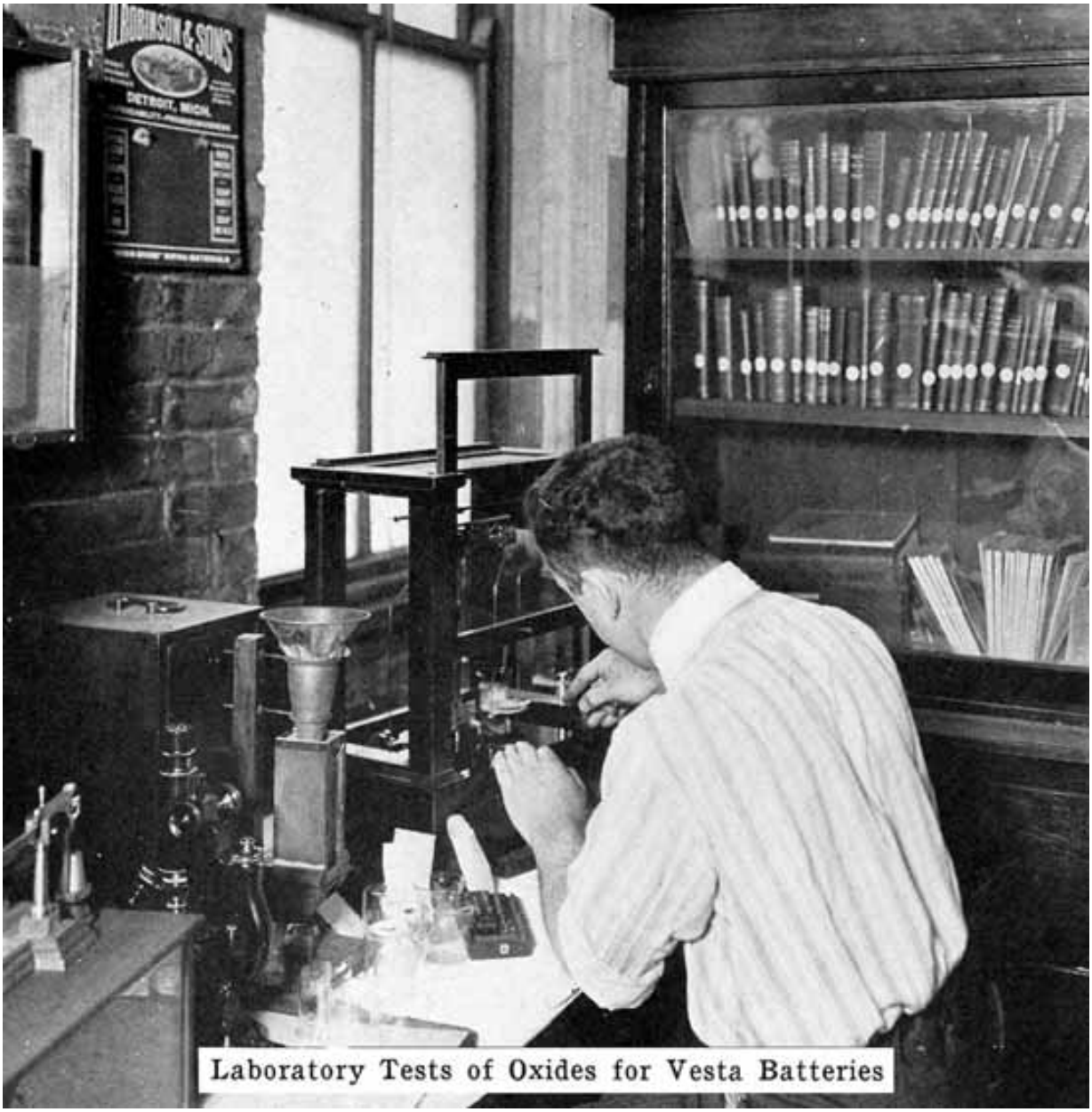

Laboratory Tests of Oxides for Vesta Batteries

Moulding Vesta Grids

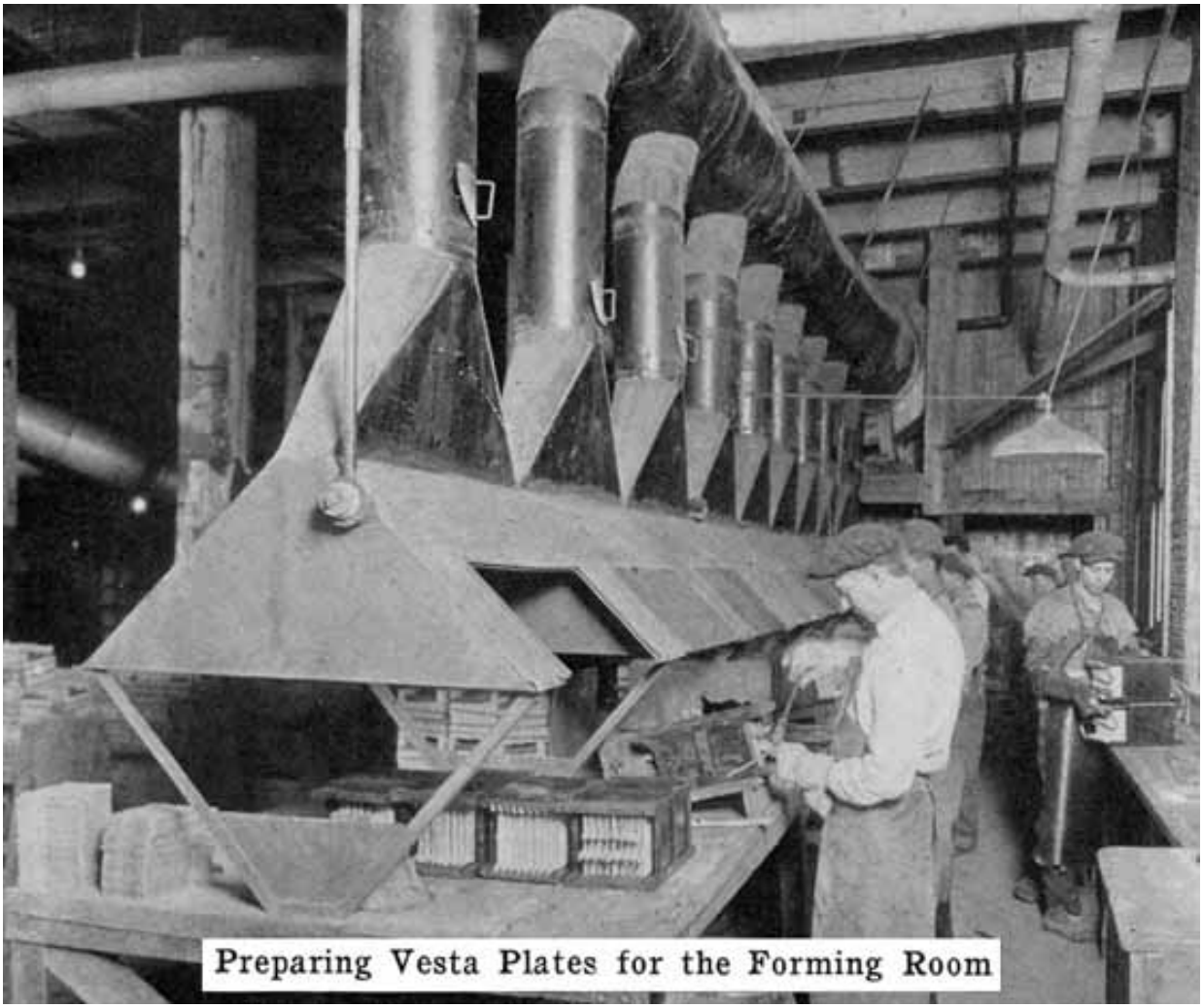

Preparing Vesta Plates for the Forming Room

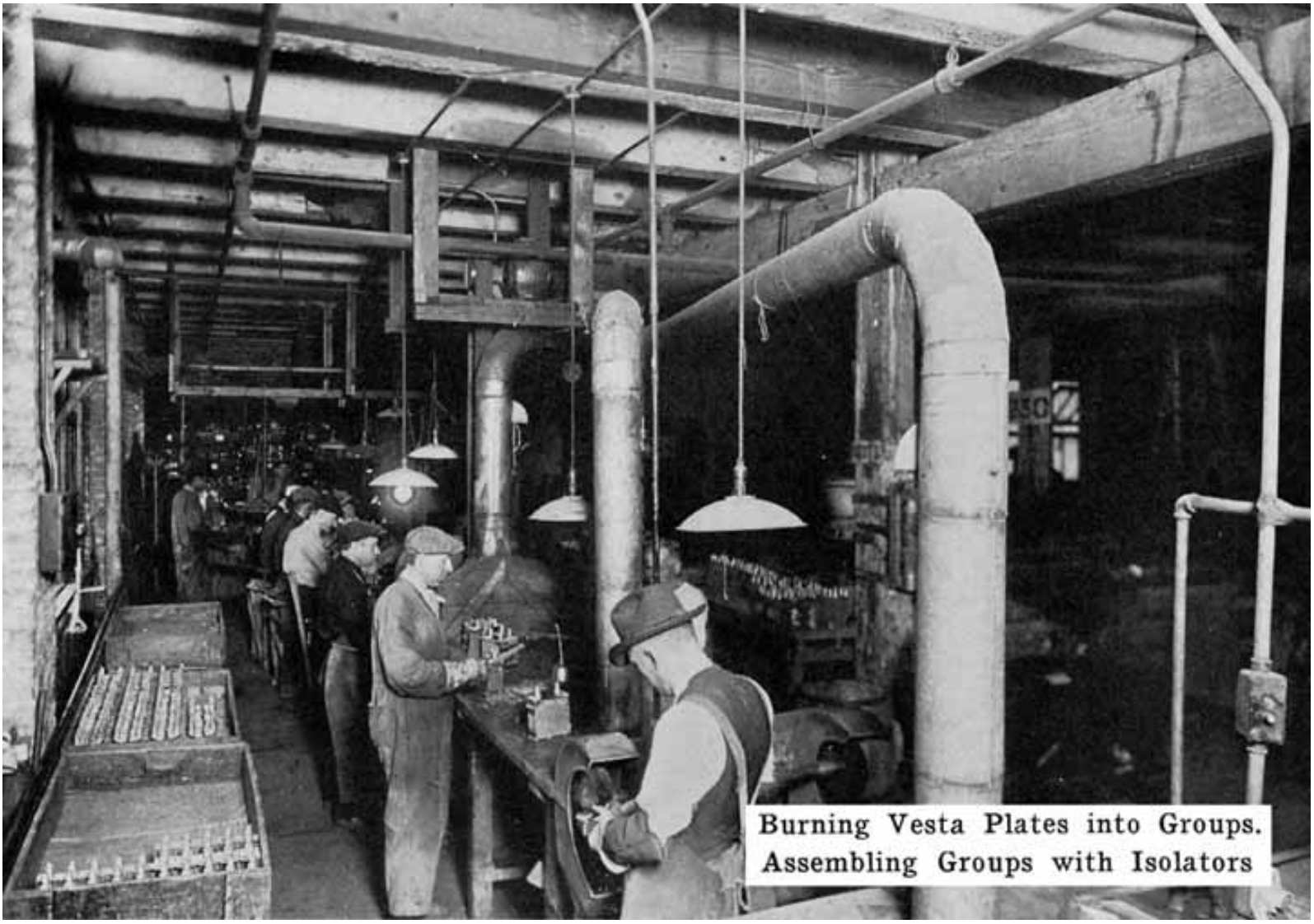

Burning Vesta Plates into Groups.
Assembling Groups with Isolators

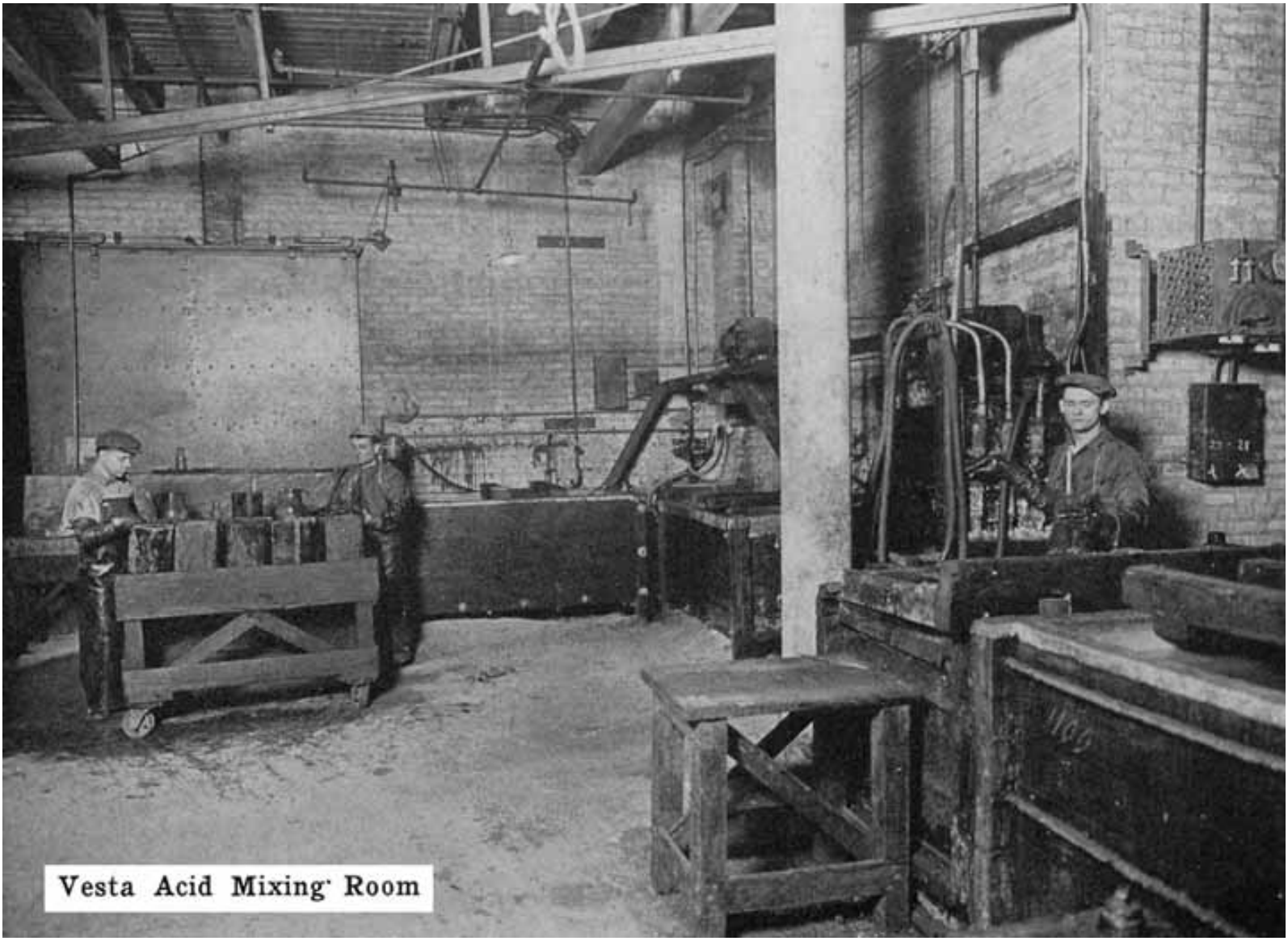
Vesta Acid Mixing Room

Checking and Adjusting Cell Readings of Vesta Batteries on Development Charge

Final Assembly Inspection of Vesta Batteries

Trimming Westinghouse Grids

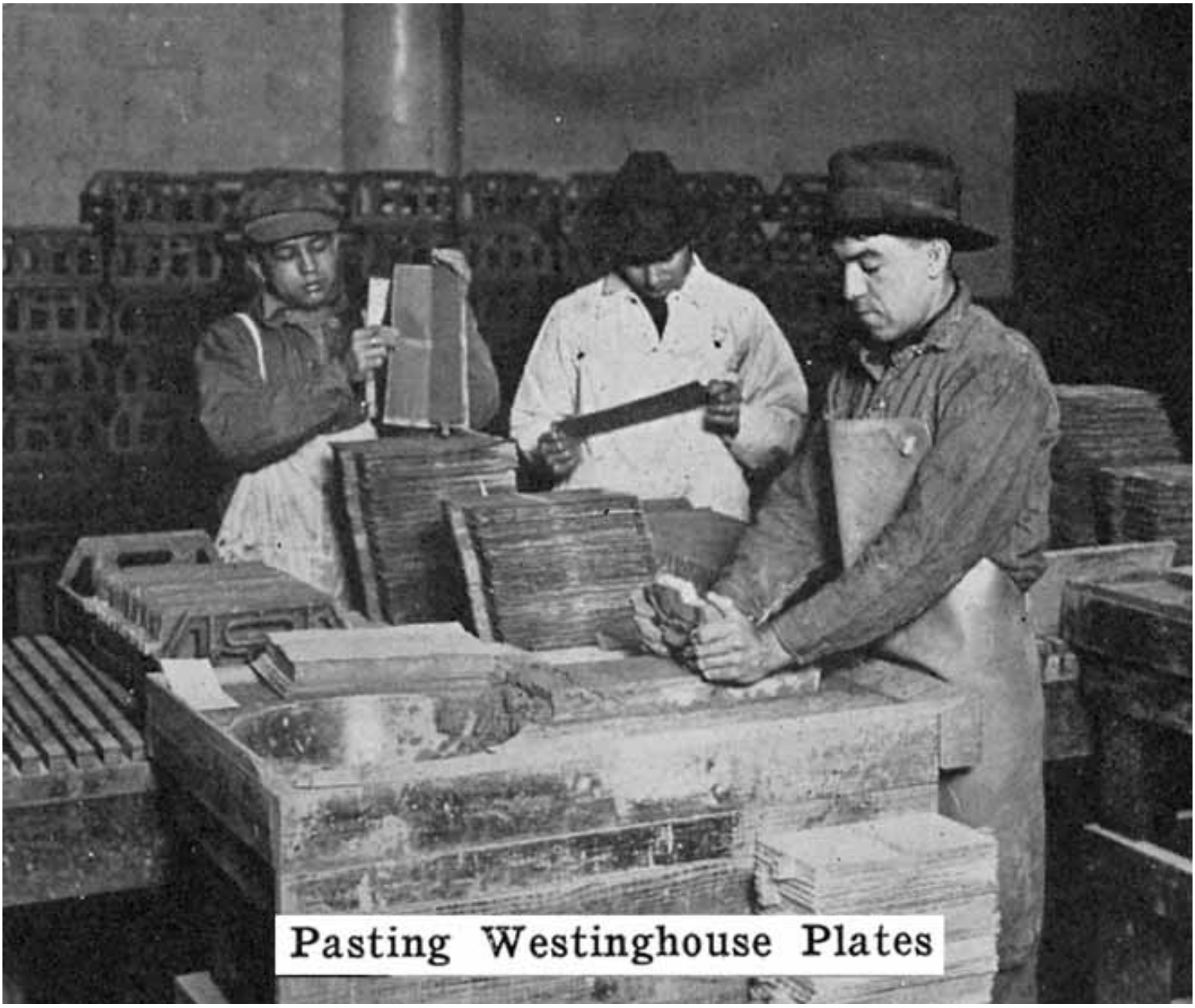
Pasting Westinghouse Plates

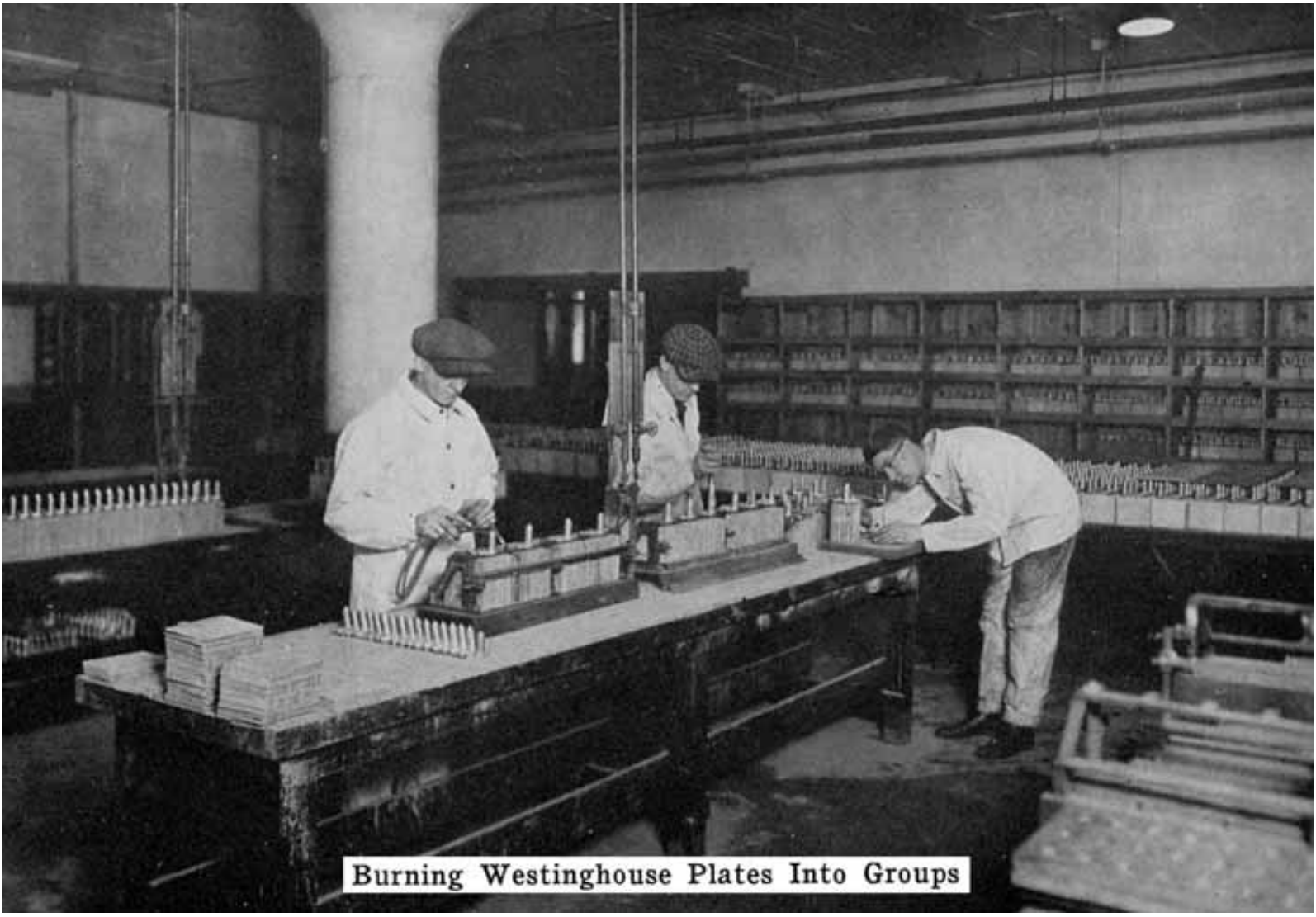

Burning Westinghouse Plates Into Groups

Packing Westinghouse Batteries for Shipment

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Lead Poisoning and Safety

See also the safety habits in this book

(This section was added by me [Mark Posey]. It is a summery of information gathered from various sources on the web. I am not an expert. Seek information written by lead safety experts before attempting the work in this book.)

LEAD POISONING is commonly caused by **breathing in lead dust** or **lead fumes**. It is also commonly caused by **ingesting lead dust** by swallowing contaminated food or by touching one's mouth with lead contaminated fingers, typically by **smoking with lead contaminated fingers.**

A developing unborn child is at particular risk from exposure to lead, especially in the early weeks before a pregnancy becomes known. Children are also especially susceptible to lead poisoning not only because they tend to absorb toxins more easily than adults, but also children tend to put things in their mouths. Children may appear healthy despite high levels of lead in their bodies. So it is especially important that the **lead worker avoid carrying contamination home to his family**. The symptoms of **chronic lead poisoning** can take a **long time** to show up and include:

Learning disabilities
Nerve disorders
Memory loss
Mental retardation
Hyperactivity
Slowed growth
Headaches
Hearing loss
High blood pressure
Digestive problems
Tiredness
Irritability

Constipation
Stomach pain
Joint pain
Cell wall damage
Anaemia
Loss of weight

Acute lead poisoning shows up more quickly and can be fatal, with these possible symptoms:

Severe abdominal pain
Diarrhea
Nausea and vomiting
Kidney Damage
Weakness of the limbs
Seizures
Blindness
Coma
Death

Methods to avoid lead poisoning include:

- **Ventilation** systems used where lead dust or fumes are present.
- **Cleanliness** of workers and workspace to keep surfaces as free of lead dust as possible. **DO NOT** use a dry broom or compressed air for cleaning!! This raises dust into the air. Use wet mop or vacuum.
- **Use respirators** approved for protection against lead and other toxic dusts.
- **Do not eat, drink or smoke in the work area** to avoid swallowing lead particles.
- **Work clothes** should be coveralls, a washable or disposable cap, and work boots. When leaving work area, leave work clothes in work area. Storage of work clothes must be in different place than change clothes. Even shower when changing. This is especially important before returning home to young children or pregnant women in early pregnancy. Work clothes sent to the laundry must be placed in a plastic bag and washed separately from other clothes.
- **Wearing Heavy Plastic Gloves** can both remind you that you are working with a toxic substance and discourage you from touching your face or mouth with contaminated hands.
- Before eating, **wash hands, face and scrub nails** with warm, soapy water. Even **rinse out your mouth** and **blow/clean your nose**.

Washing and eating areas must be separate from work area. Keep your nails short and shave off beard or mustache if you work with lead often.

- **Smoking is prohibited** when working with lead or lead products because that act will carry lead particles from contaminated fingers to the mouth.
- **Control fumes** while melting dross **-** When dross ("waste product or impurities formed on the surface of molten metal") is melted, make sure that the melting pot has a thermostat that keeps the temperature around 327°C, the melting point of lead. The temperature must be kept below 500°C or it will produce lead fumes.
- **Medical monitoring** through medical examinations are used to detect poisoning so that corrective measures will be used.
- **Lead particles dissolve in alcohol** which can easily cause acute lead poisoning, so extreme care should be taken to prevent lead particles from contaminating any alcoholic beverage.

This brief information is not meant to replace information on lead safety written by qualified experts. Seek additional information lead safety before attempting to work with lead.

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http://www.healthatoz.com/healthatoz/Atoz/hl/sp/home/homeon.html

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Rechargeable alkaline battery

From Wikipedia, the free encyclopedia

Rechargeable Alkaline AA battery

A **rechargeable alkaline battery** (also known as alkaline rechargeable or rechargeable alkaline manganese (RAM)) is a type of alkaline battery that is capable of recharging for repeated use. The first-generation rechargeable alkaline technology was developed by Battery Technologies Inc in Canada and licensed to Pure Energy, EnviroCell, Rayovac, and Grandcell. Subsequent patent and advancements in technology have been introduced. The formats include AAA, AA, C, D, and snap-on 9-volt batteries. Rechargeable alkaline batteries are manufactured fully charged and have the ability to hold their charge for years, longer than NiCd and NiMH batteries, which self-discharge.[1] Rechargeable alkaline batteries can have a high recharging efficiency and have less environmental impact than disposable cells.

Contents

- 1 Proper use and durability
- 2 Comparison to other rechargeable batteries
- 3 Environmental issues
  - 3.1 Chemical composition
- 4 See also
- 5 References
- 6 External links

Proper use and durability

Although these batteries can be used in any device that supports a standard size (AA, AAA, C, D, etc.), they are formulated to last longest in periodical use items. This type of battery is better suited for use in low-drain devices such as remote controls or for devices that are used periodically such as flashlights, television remote control handsets, portable radios, etc. If they are discharged by less than 25%, they can be recharged for hundreds of cycles to about 1.42 V. If they are discharged by less than 50%, they can be almost fully recharged for a few dozen cycles, to about 1.32 V. After a deep discharge, they can be brought to their original high-capacity charge only after a few charge-discharge cycles.

Comparison to other rechargeable batteries

The rechargeable alkaline battery is cheaper than other rechargeable types. Cells can be manufactured in the fully charged state and retain capacity well. Their capacity is about 2/3 that of primary cells. They are of dry-cell construction, completely sealed and not requiring maintenance. Cells have a limited cycle

life, which is affected by deep discharge; the first cycle gives the greatest capacity, and if deeply discharged a cell may only provide 20 cycles. The available energy on each cycle decreases. Like primary alkaline cells, they have a relatively high internal resistance, making them unsuitable for high discharge current (for example, discharging their full capacity in one hour).[1]

Environmental issues

Chemical composition

Rechargeable alkaline batteries are developed from primary alkaline batteries, designed to resist leakage that a recharge could cause, so they can be safely recharged many times.

Some other types of rechargeable cells contain mercury or cadmium and thus can be an environmental hazard unless disposed of properly. As of August 2007, a number of companies make batteries that are free from these heavy metals. According to the websites of EnviroCell[2] and PureEnergy and according to old Rayovac packaging, these manufacturers' rechargeable alkaline batteries have no mercury or cadmium.

See also

- List of battery types
- List of battery sizes
- Comparison of battery types
- Battery recycling
- Recharging alkaline batteries (of types not designed to be recharged)

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1. David Linden, Thomas Reddy (ed.), "Handbook of Batteries Third Edition", McGraw Hill, 2002 ISBN 0-07-135978-8 chapter 36 *Rechargeable zinc/alkaline/manganese dioxide batteries*
2. "EnviroCell Alkaline Rechargeable Batteries". Envirocell.com. Retrieved 2010-10-15.

External links

- Alkaline battery charging (http://www.allaboutbatteries.com/Alkaline-charging.html)

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Categories: Rechargeable batteries

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Rechargeable Alkaline Manganese Dioxide (RAM™) Cell Chemistry

Dr. Josef Daniel-Ivad
Battery Technologies Inc.
30 Pollard St., Richmond Hill, Ontario, Canada L4B 1C3
Phone: (905) 881-5100; Fax: (905) 881-6043; e-mail: josef@bti.ca

ABSTRACT

The continuous growth of portable applications in the consumer market demands more and more battery power. Battery chemistries such as nickel-cadmium, nickel-metal hydride, lithium-ion and alkaline manganese are available to serve the various market needs. This paper discusses the low-cost RAM battery system that is a potential power source for a variety of consumer applications. RAM's performance characteristics are compared to competing rechargeable battery systems as well as primary alkaline cells. Advantages of improved charge retention at higher operating temperatures and in intermittent use are discussed and possible solutions for OEM (Original Equipment Manufacturing) applications are offered.

INTRODUCTION

BTI's proprietary RAM technology is available through BTI's licensees. Rayovac Corporation manufactures under their trademark *RENEWAL™* in the United States (1993), Pure Energy Battery Corporation (*PURE ENERGY™*) in Canada (1994), Young Poong Corporation (*ALCAVA™*) in South Korea (1996) and Grand Batteries Technologies *GRANDCELL™*) in Malaysia (1998).

CONSTRUCTION OF RAM CELLS

Figure 1 shows a cross sectional view of a RAM AA cell, which is in principle not different from the construction of a single-use primary alkaline cell. The positive electrode consists of multiple cathode rings (pellets) formulated from electrolytic manganese dioxide, graphite and additives.[1] Gelled zinc anodes for RAM are prepared from atomized zinc powders using a BTI proprietary method that involves deposition of indium on the zinc particle surfaces.[2] Special separators with a microporous layer are required to prevent internal shorting from zinc dendrites (a needle like buildup) formation on recharge. A brass nail functions as negative current collector. The active materials are chosen so that the zinc electrode is limiting the capacity of the cell to the one-electron discharge of manganese dioxide.

This basic construction allows applying the same low-cost manufacturing principles than single-use primary alkaline batteries do. The production cost of RAM cells is by far the lowest amongst all other rechargeable small format cells. A relative manufacturing cost comparison will result in the following approx. multiples:

- NiCad.....3 times RAM
- NiMH.....5 times RAM
- Li-Ion.....10-12 times RAM

0-7803-5075-8/98/$10.00 ©1998 IEEE.

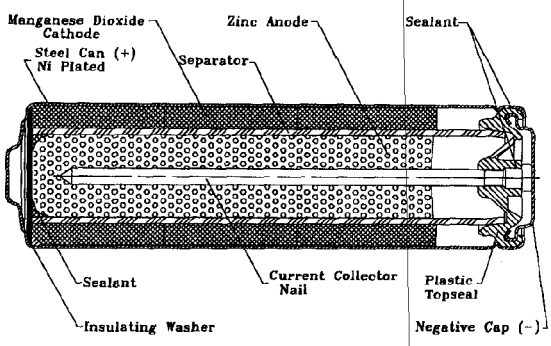

Figure 1: Cross sectional view of a RAM AA cell.

DISCUSSION

RAM cells are available in the 4 major cylindrical cell sizes AAA, AA, C and D. However, AA and AAA are the predominant cell sizes with a market share of approx. 85% and the rest is shared by C and D cells.

RAM Cell Performance

RAM cells can be basically applied in all applications where presently single-use primary cells, zinc-carbon and alkaline, are being used. They can also replace NiCad and NiMH rechargeables, provided they fall within a practical drain rate range as described below. Figure 2 shows that the ampere-hour (Ah) capacity of RAM cells increases with decreasing current rate and in intermittent use. RAM cells have a sloping discharge curve at all current rates as shown in figure 3. This provides a warning that cells need charging, e.g., by distorted sound, slower motor speed, dimmer light, etc. It also permits the use of simple low-battery warning circuitry. From figure 3, one can determine the approximate percentage useable capacity for AA RAM cells based on the cut-off (end point) voltage of the device. This parameter is important for battery applications with more cells in series. In order to maximize capacity utilization one should use this parameter to decide on the number of cells in the series configuration. For optimum performance, it is better to allow a 0.9V to 0.8V cut-off level on a per cell basis.

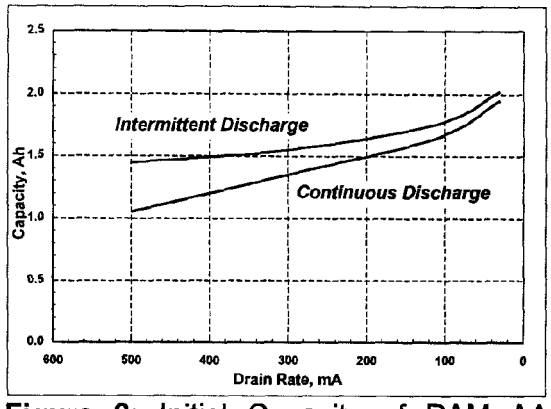

Figure 2: Initial Capacity of RAM AA Cells as Function of Discharge Rate.

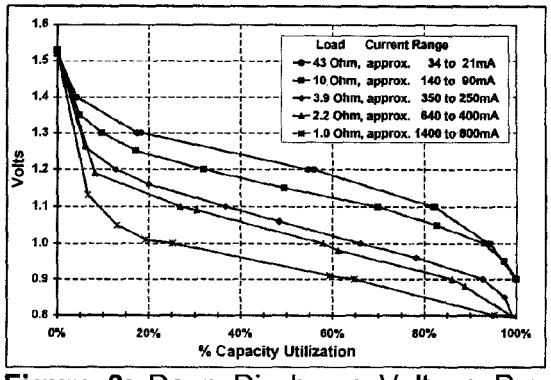

Figure 3: Deep Discharge Voltage Profiles for Various Test Loads at Room Temperature.

Figure 4 illustrates a comparison of discharge voltage profiles of different battery chemistries. As one can see, RAM cells perform at a slightly lower operating voltage as primary cells and quite comparable to NiCad and MiMH cells in the middle discharge region with a much improved capacity over NiCad and NiMH in the voltage range of 1.1 to 0.9V. Figure 5

demonstrates that RAM cells can be cycled many hundred times when not all of the capacity is removed in each and every cycle. This mode of cycling is the most efficient mode, providing the greatest cumulative capacity or cell life. In shallow discharge cycling cumulative performance of RAM over 200 cycles can reach 50 times the performance of Single-Use Alkaline cells!

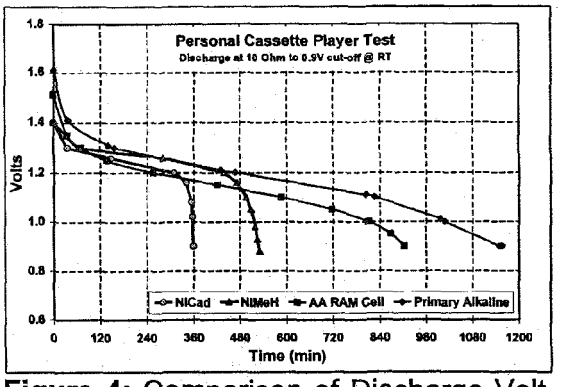

Figure 4: Comparison of Discharge Voltage Profiles for NiCad, NiMH, RAM and Primary Alkaline chemistry.

The discharge time and capacity of RAM cells decreases or fades with increasing number of discharge/charge cycles under deep discharge conditions, that is when all of the capacity is removed in each and every cycle. Under such, not recommended, operating conditions the capacity of a RAM cells reduces to approx. 40% of its initial value in cycle 25, to approx. 30% in cycle 50 and 25% in cycle 100.

As shown in Table 4, RAM cells exhibit very low self-discharge compared to Nickel-Cadmium, Nickel-Metal Hydride and Lithium-Ion systems. At higher temperatures the benefit of RAM cells is even more pronounced.[3] For example, RAM cells lose only approximately 5% capacity per month at 45C, whereas NiCad lose 60%, NiMH 80% and Li-Ion 30-50%. Therefore, RAM cells are the ideal choice for intermittent or periodic use without the need to recharge before using, even in hot climatic conditions.

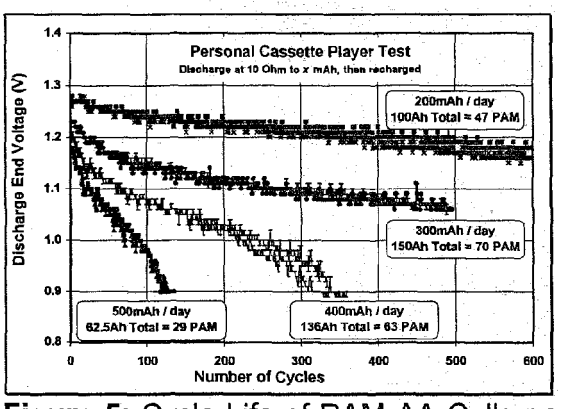

Figure 5: Cycle Life of RAM AA Cells on Various Endurance Tests

Table 4: Self-Discharge Comparison of Various Battery Chemistries.

Characteristic	NiCd	NiMH	Li-Ion	RAM
Specific Energy, [Wh/kg]	50	70	125	79*)
Energy Density, [Wh/liter]	150	250	300	222*)
Self-Discharge@ 20°C, [%/month]	15-20	20-30	8-15	1
Self-Discharge@ 45°C, [%/month]	60	80	30-50	5
Self-Discharge@ 65°C, [%/month]	100	100	Note1	20

*) Initial capacity of AA-size cells calculated from averaging results of 43, 10, 3.9 and 2.2 ohm tests.

Note1.: Li-Ion cells experience irreversible capacity losses of approx. 10%/week at temperatures of 60°C and higher. In addition, there is no "generic" Li-Ion chemistry available and results between different manufacturers will vary.

All tests measuring self-discharge typically involve storage at high temperature and capacity measurements at room temperature. High temperature performance of RAM has been studied at elevated temperatures of 45 and 65°C, whereby discharge and charge were performed at the elevated temperatures.

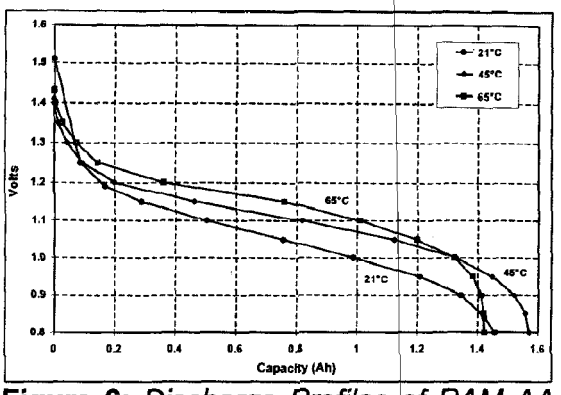

Figure 6: *Discharge Profiles of RAM AA Cells at Different Temperatures for a 3.9 Ohm Load.*

Figure 6 shows the discharge voltage profiles for RAM cells tested at 21, 45 and 65°C. As one can see, the operating voltage at higher temperatures actually increases, due to the lower resistance at higher temperatures, resulting in a reliable operation of any equipment. Figure 8 illustrates the capacity evolution of RAM AA cells when cycled at 45°C in comparison to room temperature performance. Unlike NiCd and NiMeH cells, which rapidly loose capacity at higher temperatures, a performance gain of up to 30% is achieved at high temperature for RAM cells, making the system an ideal choice where reliability at higher temperatures, e.g. dessert conditions, is of essence.

RAM Cell Charging

RAM cells are charged by means of voltage-controlled charging to avoid overcharging. Typically, the discharged cells are removed from the battery-operated device and placed in an approved RAM charger where the cell terminals make proper contact for charging.

The cells are usually charged in parallel. Constant voltage chargers perform such that the charging current tapers off to a trickle as the 1.65 ± 0.05 volt maximum is reached, but not exceeded. Charging times are up to overnight, depending on cell size and the depth of the preceding discharge. Pulse chargers with microchip charge control charge at a higher rate but stop when cells are fully charged. Charging times range from 2 to 8 hours, depending on cell size and the depth of the preceding discharge. Figure 8 shows a typical average voltage and current response of RAM cells for pulse charging.

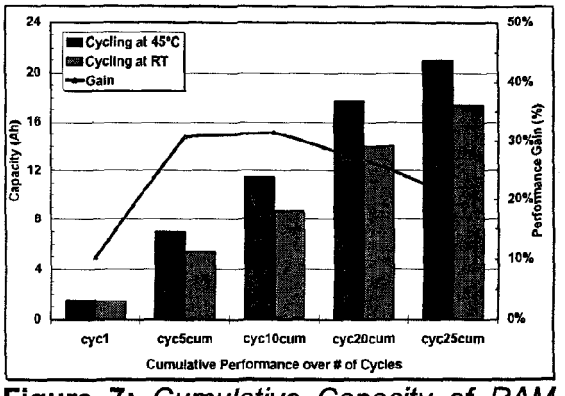

Figure 7: *Cumulative Capacity of RAM AA Cells during Cycling at 21 and 45°C for a 3.9 Ohm Load.*

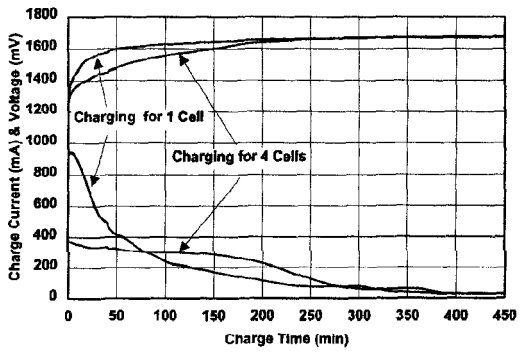

Figure 8: Typical Pulse Charge Curves of RAM AA Cells in a 4-Up Pulse Charger.

OEM applications require built-in chargers to enable recharging of the battery pack in the battery-operated device, usually in series. For series arrangements of 3 or more cells, in order to avoid overcharging and facilitate equalization, spe-

cial circuits are required to provide overflow of charging current to individual cells. Also recommended for these series arrangements is the use of diodes to protect individual cells against deep voltage reversal. A large breakthrough in application possibilities was achieved by using various very low-cost semiconductor devices (diodes, LED's and transistors) as charge overflow control, charge equalization and over-discharge preventing means in series connected cell arrangements. Also, damaging cell reversal in multi-cell strings (e.g. if for-gotten on load) is greatly alleviated that way. Now RAM cells can be used in many OEM applications and do not have to be removed for charging, as was practiced before. Simply described, a battery package containing these devices behaves like a NiCad battery and can be charged with a limited constant current from a transformer plus rectifier, without sophisticated voltage controls.[4,5]

Many portable applications/devices such as portable radios, cassette players, CD players, cordless phones, to name a few, may require only two or three cells in series to operate. Applications of this type can be easily adapted to allow for in-application charging of RAM cells in a battery pack arrangement by means of one Zener diode. Figure 9 shows the circuit for replacing 3 N-270 AA Ni-Cd battery in cordless phones with a RAM battery pack consisting of 3 AAA RAM cells in series (e.g. SANYO Companders II). If a requirement exist for individual cell removal capability, a somewhat different low-cost circuit approach can be applied, utilizing a Darlington transistor for switching off the diode circuits to prevent self-discharge on stand-by.[6] A diode and a Darlington transistor in series determine the overflow voltage. The diode and the transistor act like 2 diodes in series (1.65V drop) and allow a high current flow. The circuit is switched off by the transistor as soon as the charger is off, preventing self discharge. Figure 10 presents such a circuit for a 3-in-series application. The diodes can be high current diodes and used as charge equalizing devices for any number of RAM cells in series ranging from 6 to 30 V and up to 5 Ampere charge current. Utilizing these simple design principles for in-application charging of RAM batteries will ensure that the RAM system becomes a major player for many OEM applications in the future.

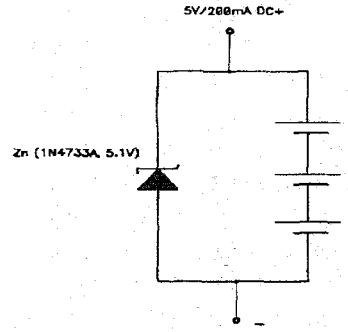

Figure 9: The 3-cell cordless phone circuit with Zener diode overcharge protection.

In addition to the low cost approaches described above, BENCHMARQ Microelectronics Inc. has developed chips for in-system charging of RAM cells. Presently, a two cell in-series (bq2902) and a three or four cell in-series (bq2903) RAM control chip is available that controls the charge and also the depth of discharge.

The excellent high temperature charge retention and charge acceptance of RAM cells allows an effective use of solar energy for recharge. The solar charging of NiCad and NiMeH cells is not very successful due to the poor high temperature charge retention of these battery chemistries.

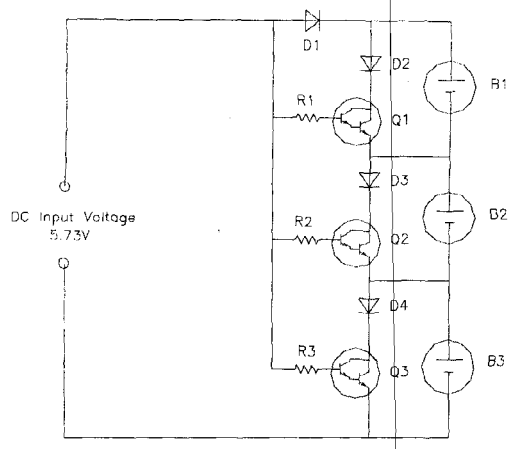

Figure 10: 3-cell Circuit for In-Application Charging of RAM with Individual Cell Equalization. D1:1N4001, D2-D4:1N4448, Q1-Q4:BC517, R1: 68K, 0.5W, R2:180K, 0.5W, R3: 300K, 0.5W, B1-B3: RAM Cells

RAM in High-Drain Devices

A trend in the electronic device market over the last two years resulted in the development and implementation of high rate primary alkaline cells by various battery manufacturers. New, high-tech devices introduced to the market place require more and more power to operate. In other words, these devices "eat up" batteries like crazy due to the short life of regular alkaline cells. High-tech devices are defined as complex, multi-functional devices often requiring higher operating voltages and higher drain rates. This category includes such devices as: cellular telephones; digital and flash cameras; camcorders; MiniDisc players; handheld televisions; radio control toys; halogen flashlights; palmtop computers; and personal digital assistants (PDAs).

In an effort to stay abreast with the new requirements of the market, BTI launched their own R&D program to develop a special high-rate (HR) RAM cell, that would work satisfactorily in this high drain device market. Initial results of this work are very promising and resulted in a HR RAM prototype cell which can already compete with regular alkaline cells on high rate tests. Figure 11 illustrates the present capability of HR-RAM cell prototypes in comparison to regular RAM cells and regular primary alkaline cells on a very severe continuous high-rate current drain of 1500 mA. As one can see, HR RAM cells provide equivalent capacity to regular alkaline cell at a somewhat lower operating voltage.

Manufacturer's of high-rate primary alkalines claim up to 50% improvement under certain high drain test conditions compared to regular primaries. Results on HR RAM would show in the excess of 50% improvement compared to regular RAM cells on the same test. The high-rate RAM project will be continued at BTI and further improvements are anticipated. We have already identified a number of additional improvement categories in the lab that all will lower the internal resistance of RAM and thereby increase high-rate performance.

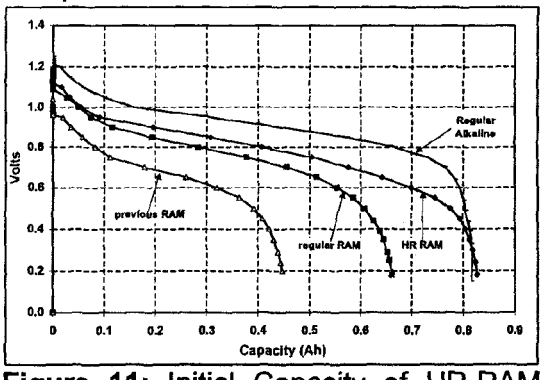

Figure 11: Initial Capacity of HR-RAM cell prototypes in comparison to regular RAM cells and regular primary alkaline cells at a high-rate current of 1500 mA.

CONCLUSION

The RAM Technology offers an environmentally responsible, low cost rechargeable battery system that can be utilized for practically all applications where Single-Use cells (alkaline manganese, zinc-carbon) are currently being used. In addition, it can replace Nickel-Cadmium and Nickel-Metal Hydride cells in low to medium power applications with much improved charge retention even at higher operating temperatures and in intermittent. Unlike NiCad and NiMeH batteries, which show a high self-discharge especially in warm climates, RAM cells work well with solar charging.

Simple, low-cost methods of charge overflow and equalization have also opened the way for OEM applications where in-application charging is of essence.

New high tech, high-drain devices requiring more power to operate can be effectively run by improved high-rate RAM cells.

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Keywords: Li-Ion, Li-Polymer, NiCd, NiMH, rechargeable battery, charger

Mar 21, 2005

APPLICATION NOTE 3501

Rechargeable Batteries: Basics, Pitfalls, and Safe Recharging Practices

This overview of charging methods and current battery technologies gives you a better understanding of the batteries used in portable devices. Nickel-cadmium (NiCd), nickel-metal-hydride (NiMH), and lithium-ion (Li+) battery chemistries are discussed. The article also describes a product that protects single-cell lithium-ion and lithium-polymer batteries.

Introduction

The use of batteries has never been greater. Batteries are becoming smaller and lighter, even as they package more energy per unit volume. The main driving force for battery development has been the enormous growth in portable equipment such as mobile phones, laptops, camcorders, and MP3 players. This application note about charging methods and current battery technologies will give you a better understanding of the batteries used in these portable devices.

Definition of a Battery

Defining a battery merely as an energy storage system requires inclusion of such elements as flywheels and clock springs. In the context of modern technology, however, a more accurate definition says that batteries are usually portable, self-contained chemical systems that produce electrical energy.

One-way batteries, called nonrechargeable or primary cells, create electricity from a chemical reaction that permanently transforms the cell. Discharge of the primary cell leads to a permanent and irreversible change in the cell chemicals. Rechargeable batteries, called secondary cells, however, can be charged by a charger as well as discharged by the application. Thus, secondary cells store, rather than generate energy.

Charge or discharge current is usually expressed (in amperes) as a multiple of the rated capacity, called the C-rate. For example, a C/10 discharge current for a battery rated at one ampere-hour (1Ah) is 1Ah/10 = 100mA. The rated capacity of a cell or battery (in Ah or mAh) is the amount of electricity that it can store (produce) when fully charged under specified conditions. Thus, the total energy of a battery is its capacity, multiplied by its voltage, resulting in a measurement of watt-hours.

Measuring Battery Performance

The chemistry and the design of a battery cell together limit the current it can source. Excluding the practical factors that limit performance, a battery could produce an infinite current, if only briefly. The main impediments to infinite current are the chemicals' basic reaction rates , the cell design, and the area over which the reaction takes place. Some cells inherently produce high currents. Shorting a nickel-cadmium cell, for instance, produces currents high enough to melt metals and start fires. Other batteries can produce only weak currents.The net effect of all chemical and mechanical factors in a battery can be expressed as a single mathematical factor, called the equivalent internal resistance. Lowering the internal resistance enables higher currents.

No battery stores energy forever. It is inevitable that the cell chemicals react and slowly degrade, causing degradation in the charge stored by the battery. The ratio of battery capacity to weight (or size) is called the battery's storage density. High storage density enables the storage of more energy in a cell of given size or weight.

The following tables list nominal voltage and storage density (expressed in watt-hours per kilogram of weight,Wh/kg)

of the major chemistries used in storage batteries for personal computers and cell phones.

Table 1. Storage Density for Major Storage-Battery Chemistries

CELL TYPE	NOMINAL VOLTAGE (V)	STORAGE DENSITY (Wh/kg)
Lead acid	2.1	30
Nickel cadmium (NiCd)	1.2	40 to 60
Nickel metal hydride (NiMH)	1.2	60 to 80
Circular lithium ion (Li+)	3.6	90 to 100
Prismatic lithium ion	3.6	100 to 110
Polymer lithium ion	3.6	130 to 150

Table 2. Characteristics of Major Storage-Battery Chemistries

Attribute	Nickel Cadmium	Nickel Metal Hydride	Lithium Ion
Energy density	Low	Medium	High
Energy storage	Low	Medium	Medium
Cycle life	High	High	High
Cost	Low	Medium	High
Safety	High	High	Medium
Environment	Low	Medium	Medium

One could ask why not always choose secondary cells, if primary and secondary cells fulfil the same purpose? The answer is, because secondary cells have drawbacks:

- All practical secondary cells lose their electrical charge relatively quickly, through self-discharge.
- Secondary cells must be charged before use.

Charging Batteries

A new rechargeable battery or battery pack (several batteries in one package) is not guaranteed to be fully charged. It is, in fact, probably nearly discharged. The first thing to do, therefore, is to charge the battery/pack in accordance with the manufacturer's chemistry-dependent guidelines.

Every charging operation applies voltage and current in a sequence that depends on the battery chemistry. Thus, battery-cell chemistries have different requirements that must be met by the charger and the charging algorithm. The terms most commonly found in battery charging are constant current (CC), used for NiCd and NiMH cells, and constant current/constant voltage (CC/CV), applied to Li+ and lithium-polymer cells (**Figures 1-6**).

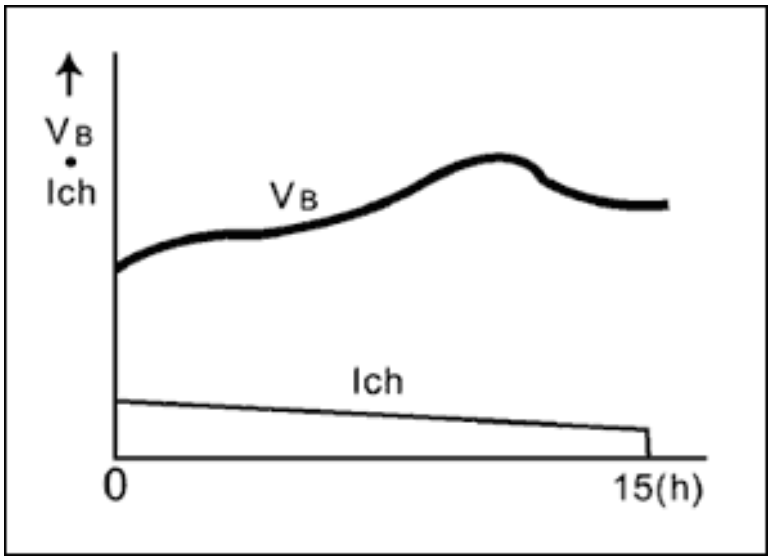

Figure 1. Semi-constant current charging, chiefly used in applications like shavers, digital cordless phones, and toys.

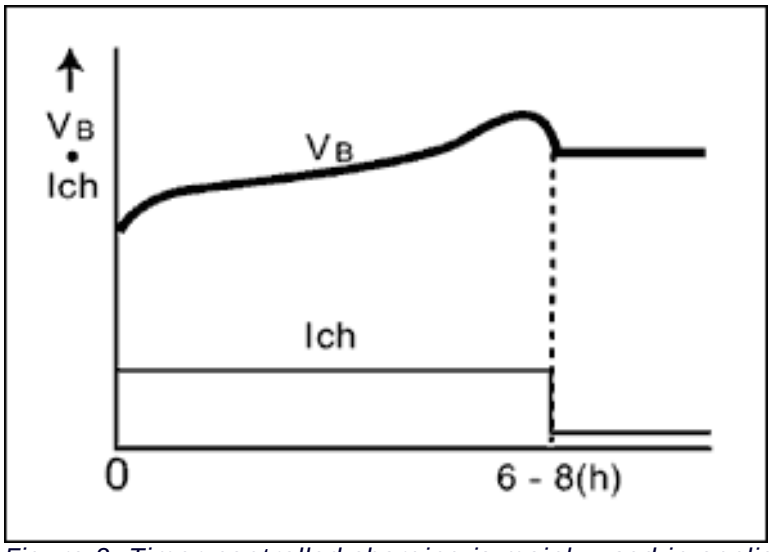

Figure 2. Timer-controlled charging is mainly used in applications like notebooks, data terminals, wireless equipment, and cellular phones.

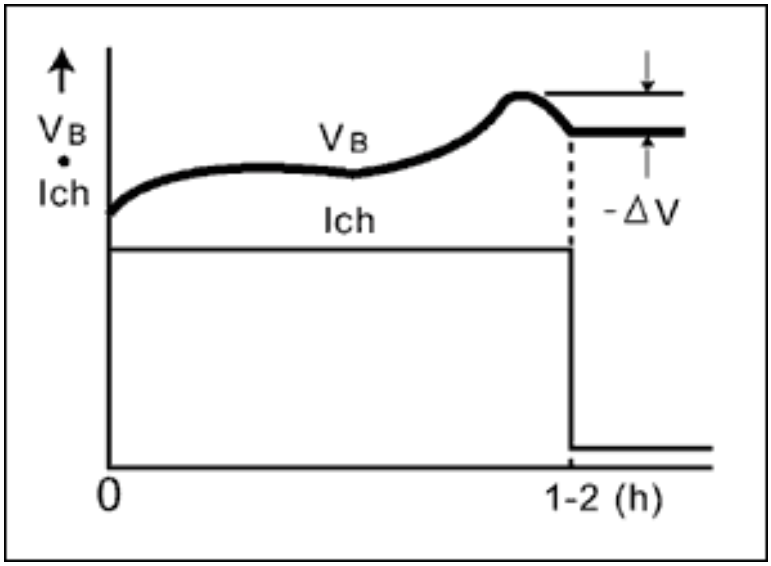

Figure 3. Charging is terminated through -DV cutoff in applications like notebooks, data terminals, camcorders, wireless equipment, and cellular phones.

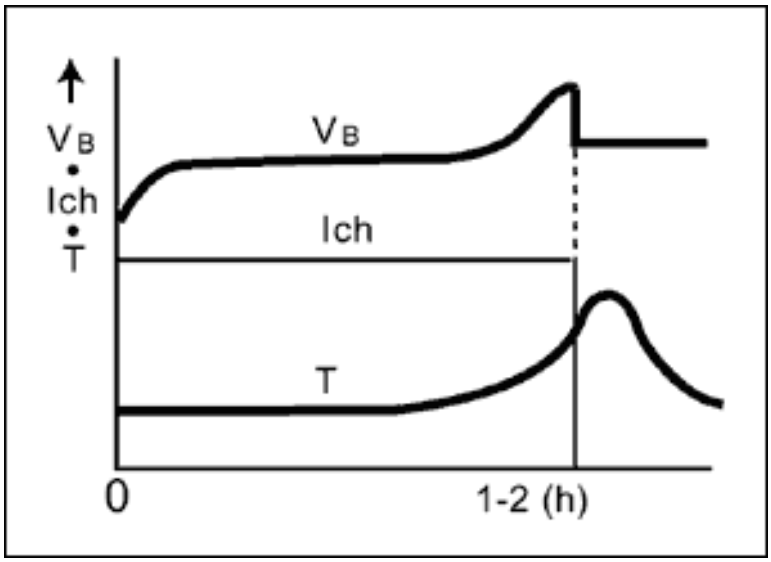

Figure 4. Charging is terminated through -dT/dt cutoff in applications like power tools and electric tools.

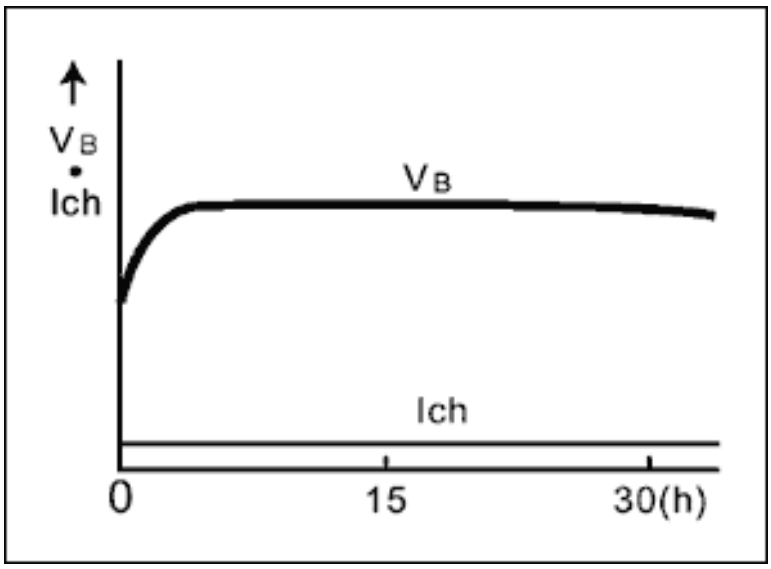

Figure 5. Trickle-charging is mainly used in applications like emergency lights, guide lights, and memory backup.

Table 3.Charging Methods

Chemistry	Charging Method	Feature	No. of Terminals	Charge Time (hours)	Charge Current (CmA)	Trickle Current (CmA)	Charge Level at End of Charge (%)	Figure Reference
	Semi-constant current charging	Most typical system; simple and low cost	2	15	0,1	----	----	1
	Timer-controlled charging	More reliable than semiconstant current system; relatively simple and low cost	2	6 to 8	0,2	1/20-1/30	Approx. 120	2

Nickel Based (NiCl and NiMH)	-ΔV cut-off charging	Most popular; more complex	2	1 to 2	0,5-1	1/20-1/30	Approx. 110 to 120	3
	ΔT/Δt cut-off charging	More costly, but overcharge can be avoided enabling longer life cycle that the others	3 or 4	1 to 2	>1	1/20-1/30	Approx. 100 to 110	4
	Trickle-charging	Simple and low cost; applicable for continuous long charging	2	15	0,1	----	----	5
Lithium Based	Constant current-constant voltage (CC-CV)	Not recommended for the main charge-control system for Ni-Cd /NiMH batteries. Prevailing charge method for Li + and Li-Polymer batteries. Relatively complex charger design.	2	1 to 3	1	----	Approx 100	6

Table 4. Determining a Full Charge for Different Cell Chemistries

Chemistry	NiCl	NiMH	Li+
Charging	Constant current	Constant current	Constant current/constant voltage
Full charge detect	-ΔV/dt and/or ΔT/dt	ΔV/dt = 0 and/or ΔT/dt	Icharge = eg 0.03C and/or time

As shown above, the end-of-charge determination differs according to chemistry and charging technique.

Charging Nickel-Cadmium Cells

NiCd cells are charged by applying a constant current in the range 0.05C to more than 1C. Some low-cost chargers terminate the charge by means of absolute temperature. Though simple and inexpensive, that charge-termination method is not accurate. A better method terminates a charge when a drop in voltage indicates a full-charge condition. The -ΔV phenomenon is most useful for charging NiCd cells at 0.5C or greater. The -ΔV end-of-charge detection should be combined with battery-temperature measurement as well, because aging cells and mismatched cells can reduce the voltage delta.

You can achieve more precise full-charge detection by sensing the rate of temperature increase (dT/dt). This charge-detection method is less harsh for the battery than is a fixed-temperature cutoff. By avoiding overcharge, a charge termination method based on a combination of ΔT/dt and -ΔV cut-off enables a longer life-cycle.

Fast charging improves charge efficiency. At 1C, the efficiency is close to 1.1 (91%), and the charge time for an

empty pack will be slightly more than one hour. When applying a 0.1C charge, the efficiency drops to 1.4 (71%) with a charge time of about 14 hours.

Because the charge acceptance of a NiCd battery is close to 100%, almost all energy is absorbed during the initial 70% of charging, and the battery remains cool. Ultra-fast chargers use this phenomenon to charge a battery to the 70 percent level within minutes, applying currents equal to several times the C-rating without heat buildup. Above 70% charge capacity, the charging continues at a lower rate until the battery is fully charged. Eventually, you top off the battery by applying a trickle charge in the range 0.02C to 0.1C.

Charging Nickel-Metal-Hydride Cells

Though similar to NiCd chargers, a NiMH charger employs the $\Delta T/dt$ method, by far the best method for charging NiMH cells. The end-of-charge voltage depression for NiMH batteries is smaller, and for small charge rates (below 0.5C, depending on temperature) there may be no voltage depression at all.

New NiMH batteries can show false peaks early in the charge cycle, causing the charger to terminate prematurely. Moreover, an end-of-charge termination solely by $-\Delta V$ detection almost certainly ensures an overcharge, which, in turn, limits the number of charge/discharge cycles possible before the battery fails.

It seems that there is no -dV/dt algorithm that works well for charging NiMH batteries under all conditions: new or old, hot or cold, and fully or partly discharged. For that reason, do not charge a NiMH battery with a NiCad charger unless it utilizes the dT/dt method for end-of-charge termination. Furthermore, because NiMH cells do not absorb overcharge well, the trickle charge must be lower (about 0.05C) than that recommended for NiCd cells.

Slow-charging a NiMH battery is difficult, if not impossible, because the voltage and temperature profiles associated with a C-rate of 0.1C to 0.3C do not provide a sufficiently accurate and unambiguous indication of the full-charge state. The slow charger must therefore rely on a timer to indicate when the charge cycle should be terminated. Thus, to fully charge a NiMH battery you should apply a rapid charge of approximately 1C (or a rate specified by the battery manufacturer), while monitoring both voltage ($\Delta V=0$) and temperature (dT/dt) to determine when the charge should be terminated.

Charging Lithium-Ion and Lithium-Polymer Cells

While chargers for nickel-based batteries are current-limiting devices, chargers for Li+ batteries limit both voltage and current. The initial Li+ cells called for a charge-voltage limit of 4.10V/cell. Higher voltage means greater capacity, and cell voltages as high as 4.2V have been achieved by adding chemical additives. Modern Li+ cells are typically charged to 4.20V with a tolerance of ±0.05V/cell.

Full charge is attained after the terminal voltage reaches the voltage threshold and the charging current drops below 0.03C, which is approximately 3% of Icharge (**Figure 6**). The time required for most chargers to achieve a full charge is about three hours, although some linear chargers claim to charge a Li+ battery in about one hour. Such chargers usually terminate the charge when the battery's terminal voltage reaches 4.2V. That method of charge determination, however, charges the battery only to 70% of its capacity.

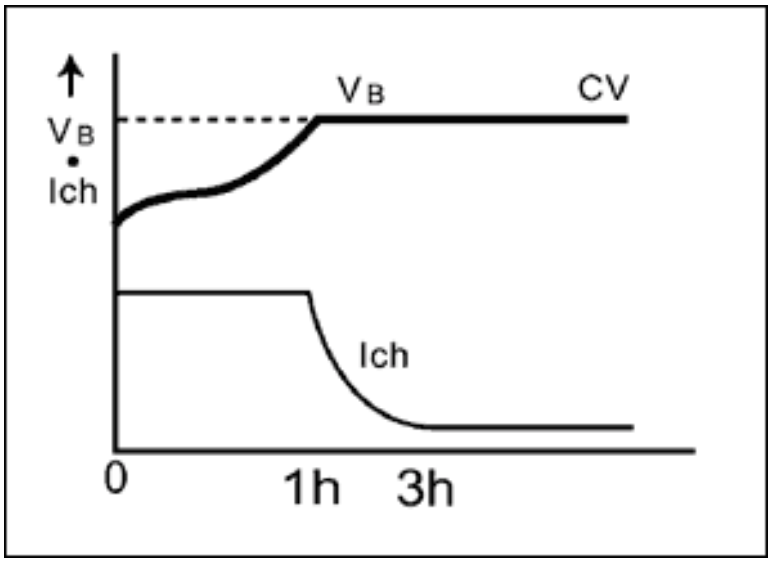

Figure 6. Constant-current, constant-voltage charging is used in applications like cellular phones, wireless equipment, and notebook PCs.

A higher charging current does not shorten the charge time by much. Higher current lets you reach the voltage peak earlier, but then the topping charge takes longer. As a rule, the topping charge will take twice as long as the initial charge.

Lithium-Ion Safety

Because overcharging or overdischarging a Li+ cell can cause it to explode and injure people, safety is a major concern when handling this type of storage cell. As a result, commercial Li+ battery packs contain a protection circuit, such as the DS2720 (**Figure 7**). The DS2720 provides all the electronic safety functions required for applications that involve rechargeable Li+ batteries: protection for the battery during charge, protection for the circuit against excess current flow, and maximizing battery life by limiting the level of cell depletion.

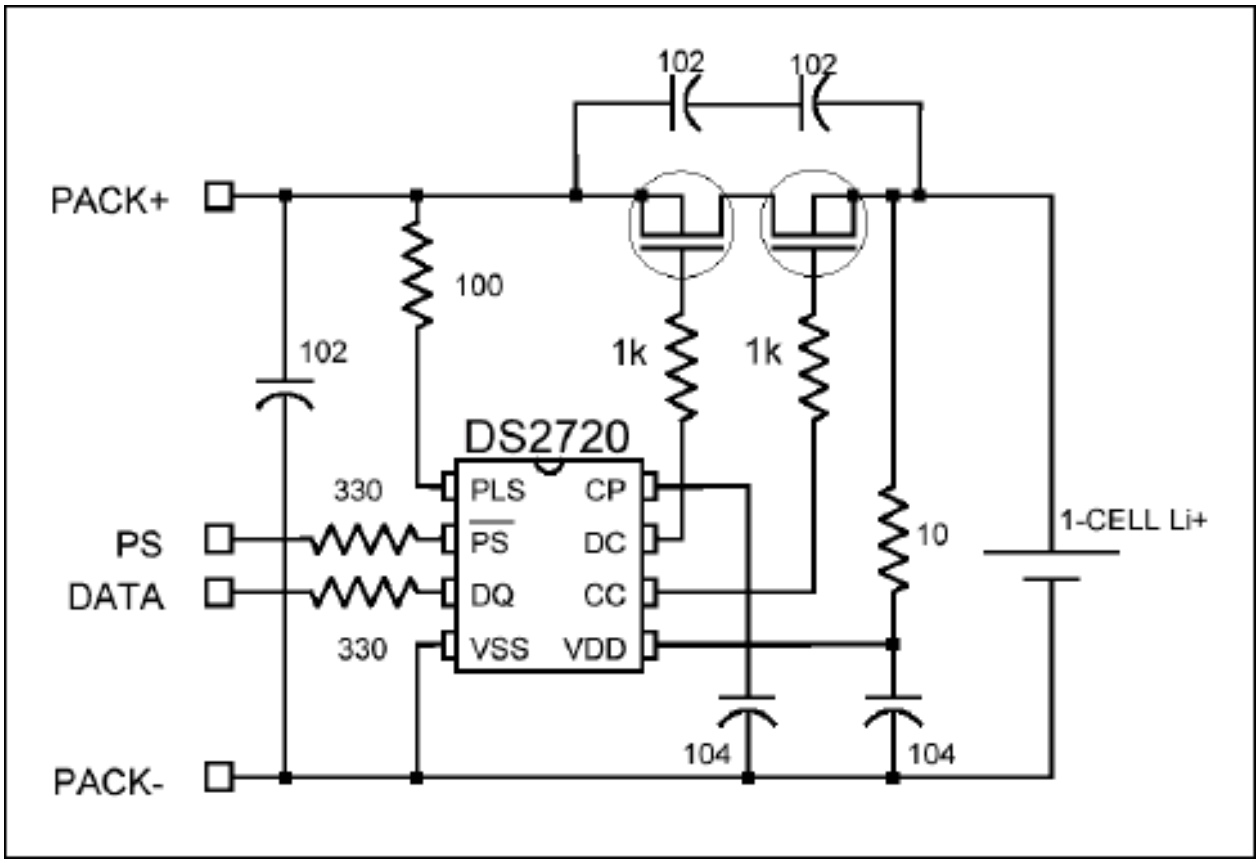

Figure 7. Typical application diagram for the DS2720 lithium-cell protection IC.

DS2720 ICs control the conduction paths for charge and discharge currents with external switching devices such as low-cost n-channel power MOSFETs. The circuit's internal 9V charge pump provides high-side drive to the external n-channel MOSFETs, yielding lower on-resistances than do the same FETs operating in a more common low-side protection circuit. FET on-resistance actually decreases as the battery discharges (**Figure 8**).

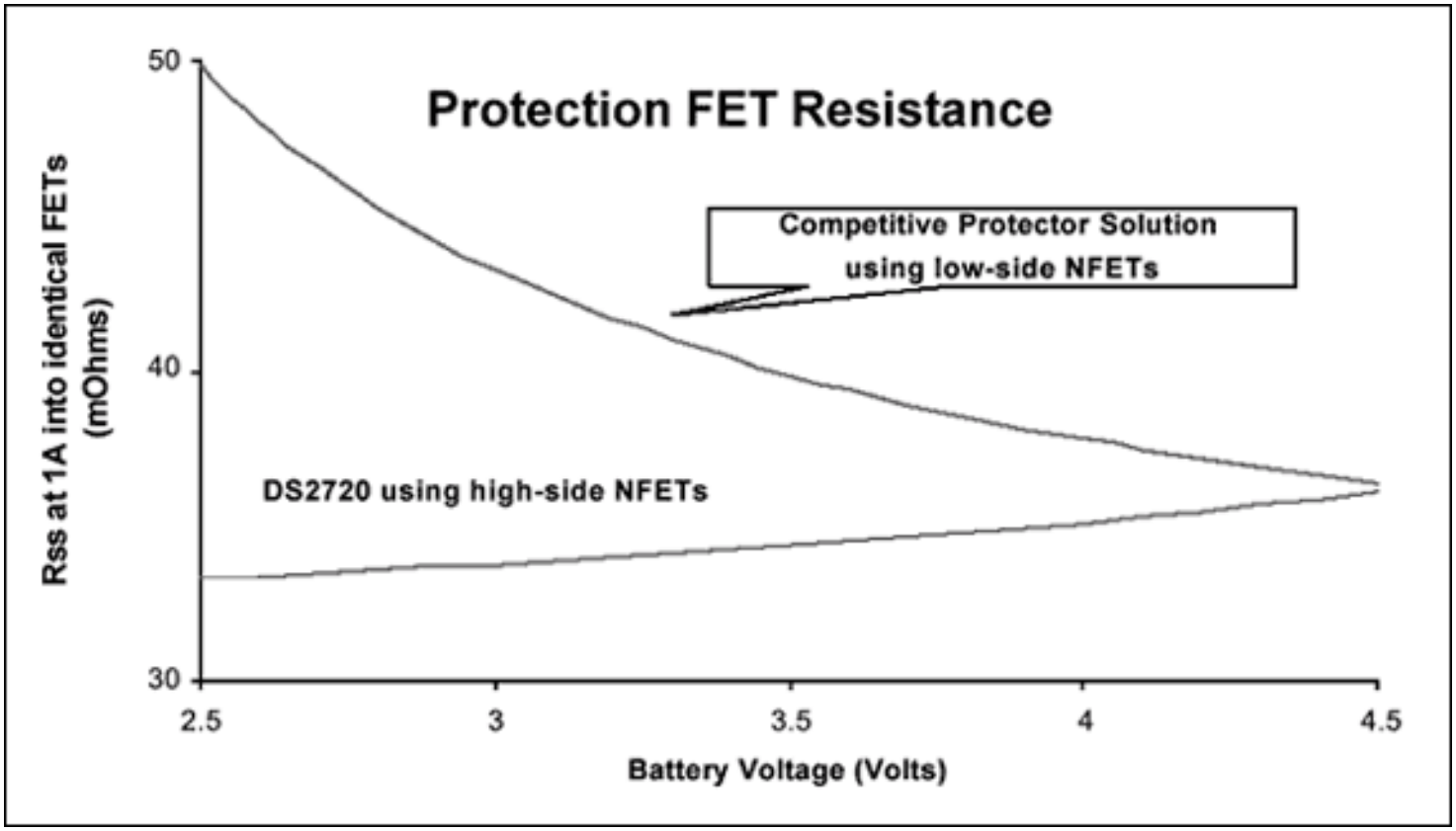

Figure 8. The resistance of protection FETs controlled by the DS2720 in high-side mode is lower than FETs operating in the traditional low-side mode. FET resistance controlled by the DS2720 actually drops with battery voltage.

DS2720's regulated high-side n-FET drive results in lower switch resistance, even at end of discharge. The result is longer runtime for your portable needs.

- Monitors Cell for Over-/Under-Voltage, Overcurrent, and *Overtemperature*
- Regulated Charge Pump Supports High-Side n-Channel MOSFETs
- Integrated Multiple Battery Selector
- 8 Bytes of Lockable User-EEPROM
- 64-Bit Unique Electronic Serial Number
- Low Power: 15µA Active, 1µA Standby
- Available in Tiny 8-Pin MSPO Package
- 1-Wire Data Communication Interface

The DS2720 lets you control the external FETs from the data interface or from a dedicated input, thereby eliminating the redundant power-switch controls otherwise required in a rechargeable Li+ battery system. Through its 1-Wire interface, a DS2720 provides the host system with read/write access to the status and control registers, instrumentation registers, and general-purpose data storage. A factory-programmed 64-bit net address allows each device to be individually addressed by the host system (**Figure 9**).

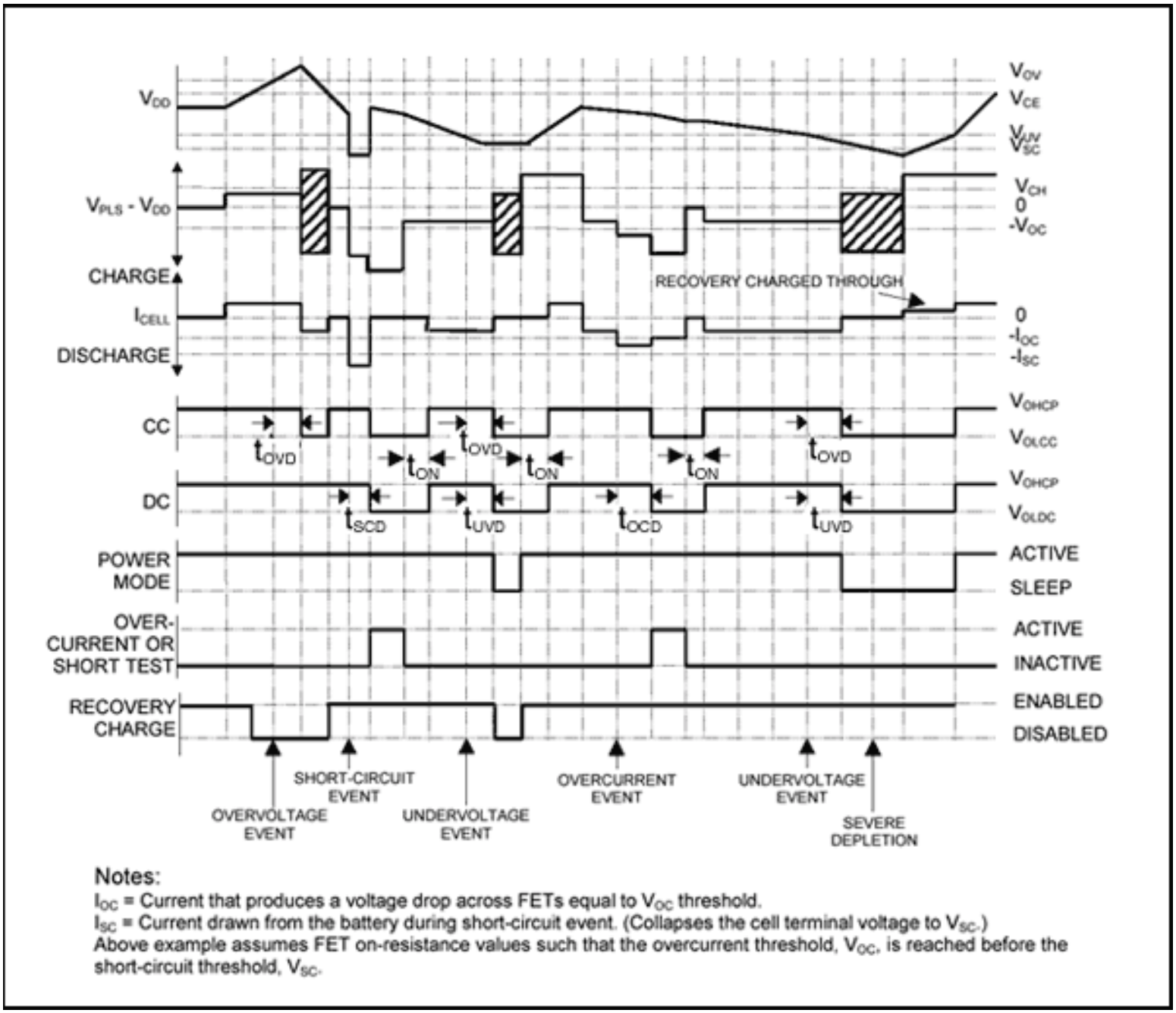

Figure 9. Example waveforms showing Li+ protection by the DS2720.

The DS2720 provides two types of user memory for battery-information storage, EEPROM and lockable EEPROM. EEPROM is a true nonvolatile (NV) memory whose contents (important battery data) remain unaffected by severe battery depletion, accidental shorts, or ESD events. When locked, a lockable EEPROM becomes a read-only memory (ROM) that provides additional security for unchanging battery data.

Protection Modes

Overvoltage

If the cell voltage sensed at V_{DD} exceeds the overvoltage threshold, V_{OV}, for a period longer than the overvoltage delay, t_{OVD}, the DS2720 shuts off the external charge FET and sets the OV flag in the protection register. The discharge path remains open during overvoltage. Unless blocked by another protection condition, the charge FET is reenabled when the cell voltage falls below the charge-enable threshold, V_{CE}, or discharging causes $V_{DD} - V_{PLS} > V_{OC}$.

Undervoltage

If the cell voltage sensed at V_{DD} drops below the undervoltage threshold, V_{UV}, for a period longer than the undervoltage delay, t_{UVD}, the DS2720 shuts off the charge and discharge FETs, sets the UV flag in the protection register, and enters sleep mode. After the cell voltage rises above V_{UV} and a charger is present, the IC turns on the charge and discharge FETs.

Short Circuit

If the cell voltage sensed at V_{DD} drops below the depletion threshold, V_{SC}, for a period of t_{SCD}, the DS2720 shuts off the charge and discharge FETs and sets the DOC flag in the protection register. The current path through the charge and discharge FETs is not reestablished until the voltage on PLS rises above V_{DD} - V_{OC}. The DS2720 provides a test current through internal resistor R_{TST} (from V_{DD} to PLS) to pull up PLS when V_{DD} rises above V_{SC}. This test current allows the DS2720 to detect the removal of the offending low-impedance load. In addition, the test current enables a recovery charge path through R_{TST} from PLS to V_{DD}.

Overcurrent

If voltage across the protection FETs (V_{DD} - V_{PLS}) is greater than V_{OC} for a period longer than t_{OCD}, the DS2720 shuts off the external charge and discharge FETs and sets the D_{OC} flag in the protection register. The current path is not reestablished until the voltage on PLS rises above V_{DD} - V_{OC}. The DS2720 provides a test current through internal resistor R_{TST} (from V_{DD} to PLS) to detect removal of the offending low-impedance load.

Overtemperature

If the DS2720 temperature exceeds T_{MAX}, the device immediately shuts off the external charge and discharge FETs. The FETs are not turned back on until two conditions are met: cell temperature drops below T_{MAX}, and the host resets the OT bit.

Charging at High and Low Temperatures

Efforts should be made to charge at room temperature. Nickel-based batteries should only be fast-charged between 10°C to 30°C (50°F to 86°F). Below 5°C (41°F) and above 45°C (113°F), the charge acceptance of nickel-based batteries is drastically reduced. Li+ batteries offer reasonably good charge performance throughout the temperature range, but below 5°C (41°F) the charge rate should be less than 1C.

Summary

NiMH chargers can accommodate NiCd batteries, but not vice versa. Chargers dedicated to NiCd batteries will overcharge a NiMH battery. The cycle life and performance of nickel-based batteries are enhanced by fast charging because fast charging reduces the memory effect from formation of internal crystals. Nickel- and lithium-based batteries call for different charge algorithms. Li+ batteries need protection circuitry to monitor and protect against overcurrent, short circuits, over- and under-voltage, and excessive temperature. Remember to remove a battery from its charger when the battery is not used regularly, and apply a topping-charge before use.

Application Note 3501: http://www.maxim-ic.com/an3501

More Information

For technical questions and support: http://www.maxim-ic.com/support
For samples: http://www.maxim-ic.com/samples
Other questions and comments: http://www.maxim-ic.com/contact

Related Parts

DS2720: QuickView -- Full (PDF) Data Sheet -- Free Samples

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Waste Prevention World

Rechargeable Battery and Charger Sources

Note—There is a new type of rechargeable battery technology now being introduced to the market that will most likely alter some of your decisions about which type of rechargeable AAA and AA batteries to buy. The new technology is Low Self Discharge (LSD) Nickel-Metal Hydride (NiMH) batteries. They are only available in AAA and AA sizes. They are different than other rechargeable AAA and AA batteries because they lose significantly less charge when not in use. According to manufactures, they lose only 15% per **year**, compared to 4% per **day** for ordinary NiMH. See AAA and AA Rechargeable Batteries Compared. LSD batteries can be charged with ordinary NiMH chargers.

This page contains a list of distributors of Nickel-Cadmium (NiCd) batteries, Nickel-Metal Hydride (NiMH) batteries, Low Self Discharge Nickel-Metal Hydride (LSD) batteries, and the chargers needed to maintain these batteries. This table only lists distributors of rechargeable batteries and chargers designed to be used as substitutes for disposable batteries of the sizes AAA, AA, C, D, and 9 Volt. Not all distributors listed carry all sizes of batteries. Not all distributors listed carry chargers for all sizes of batteries.

The number of vendors that carry LSD batteries seems to be rapidly increasing. So, do not assume that if a vendor is not identified on this list as a supplier of LSD batteries, that they do not sell them. Most of the vendors below and others may carry LSD batteries by the time you read this.

Brands of LSD batteries include the following. Please let us know if you learn of others:

- Accupower Acculoop—Not available yet in the United States.
- Greenbatteries.com—Available in 2,000 mAh capacity AA size, and 800 mAh AAA size. Bulk discounts are available.
- Nexcell energyON—Available in 2,000 mAh capacity AA size, and 750 mAh capacity AAA size.
- Rayovac Hybrid—Available in 2,000 mAh capacity AA size, and 800 mAh AAA size.
- Sayno Eneloop (Canadian Site)—Available in 2,000 mAh capacity AA size, and 800 mAh AAA size.
- Uniross Hybrio—Available in 2,000 mAh capacity AA size, and 800 mAh AAA size.

For more information about selecting and using NiCd, NiMH, and LSD batteries and chargers, see Rechargeable Batteries.

Please recycle your rechargeable batteries when they are worn out. For information on the recycling and disposal of batteries in California, see the Waste Prevention Information Exchange's battery page.

To add to the following list, or to make modifications, contact the Waste Prevention Information Exchange.

NiCd = Nickel-Cadmium NiMH = Nickel-Metal Hydride LSD = Low Self Discharge Nickel-Metal Hydride
LSD batteries can be charged with ordinary NiMH chargers.

Distributor Name	Battery Types	Battery Charger Types	Battery Chargers with the Ability to Discharge (Recondition) Batteries
Amazon.com	NiCd, NiMH, LSD	NiCd & NiMH	NiCd & NiMH AAA, AA, C, and D
Batteries.com	NiMH	NiCd & NiMH	
Battery Mart.com	NiCd & NiMH	NiCd & NiMH	
BatteryPrice	NiCD & NiMH	NiCd & NiMH	NiCd & NiMH AAA, AA, C, and D
Batteryweb.com	NiCd & NiMH		
CompUSA	NiMH	NiMH	
GoodHumans	NiMH	NiCd & NiMH	
Green Batteries	NiMH & LSD	NiCd, NiMH, & LSD	NiCd & NiMH AAA, AA, C, and D
Only Batteries	NiCd & NiMH	NiCd & NiMH	NiCd & NiMH AAA, AA, C, and D
Radio Shack	NiCd & NiMH	NiCd & NiMH	NiCd & NiMH AAA, AA, C, and D
Real Goods	NiMH	Solar Powered	
Sundance Solar	NiCd & NiMH	NiCd & NiMH Solar Powered	
Sun Star		Solar Powered	
Thomas Distributing	NiMH, LSD	NiCd, NiMH, & LSD	NiCd & NiMH AAA, AA, C, and D. Also carries reconditioning travel chargers for AA and AAA.
Walmart	NiMH	NiMH	

The inclusion of a company on this list does not constitute an endorsement of that company's product.

This list is only intended to give an extremely brief description of these companies products, and might not accurately represent the companies or their products. Other disclaimers apply. To add other companies, which manufacture recycling containers, to this list, or to request removal from this list, contact the staff listed at the bottom of this page. Additions are subject to the discretion of the California Integrated Waste Management Board.

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Waste Prevention World http://www.ciwmb.ca.gov/WPW/
Don Van Dyke: dvandyke@ciwmb.ca.gov, (916) 341-6615
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Rechargeable Batteries and Chargers: A Personal Perspective

This page is a personal perspective of a CIWMB staff person who is an avid user of rechargeable batteries.

The following insight addresses rechargeable replacements for single-use batteries of the sizes AAA, AA, C, D, and 9 Volt. For a brief description of other types of rechargeable batteries, see Electrical Storage, Present, Past and Future. To learn where to buy rechargeable batteries and chargers, see Rechargeable Battery and Charger Sources.

There are three types of rechargeable batteries, as described below. They are Nickel-Cadmium (NiCd), which are the oldest type; Nickel-Metal Hydride (NiMH), which where developed around the same time that low-cost digital cameras were invented; and a new type of NiMH battery, called Low Self Discharge (LSD). The characteristics of the three types of rechargeable batteries are described below. Battery chargers come with a variety of characteristics, as well. This page will help you and your entire household almost completely avoid single use batteries.

If you are in a hurry to just buy some rechargeable batteries and a charger, and you don't want to make a formal study of the subject as I do, skip the following introduction and just read the section entitled, What to Do, in Brief.

- Introduction
- What to Do, in Brief
- Examples of NiMH Battery Capacity
- AAA and AA Rechargeable Batteries Compared
- AAA and AA Single-Use Batteries Compared
- Additional Quirks
- Consider This
- An Example of What Not to Do
- Other Types of Rechargeable Batteries
- Battery Capacity
- What's a mAh?
- Notes and Tips
- Alternatives to Batteries
- More Information

Introduction

I hate throwing batteries away when they die. Single use (ordinary) batteries, sometimes called primary batteries by the manufacturers, have gotten so expensive that I feel am throwing away cash when I buy them. I also hate not knowing when my batteries are going to conk out. There is an ease and a freedom that come with rechargeable batteries. I pay for them once every five or more years, and if for any reason I want fresh batteries in an electrical device, I just pop out the batteries and charge them, or swap them for some others that I have already charged. I have not had a battery go dead on me in the middle of an important task since I made the switch to rechargeables. Furthermore, I don't need to concern myself with completely using up batteries to avoid wasting money or natural resources, not to mention the energy needed to manufacture and ship both the batteries and the materials to make the batteries.

I made the switch to rechargeable batteries over three years ago. I now use rechargeable batteries for almost everything in my home that uses batteries of the sizes, AAA, AA, C, D, and 9 Volt. I am pleased with the change, but I had a rough start. My first foray into the world of rechargeables was neither happy nor cost effective. The purpose of this page is to help you avoid the mistakes I made, and to achieve the dramatic long-term reductions in both cost and waste generation that rechargeable batteries can provide.

Rechargeable batteries are much better than they used to be. The higher capacity rechargeable batteries today have nearly three times the capacity of what was readily available a few years ago. Their capacity equals or exceeds ordinary single use Alkaline batteries, and the new Low Self Discharge (LSD) rechargeable batteries, explained in the following paragraph, provide a charged shelf life that is as practical as the shelf life of ordinary single use batteries. If you take care of your rechargeable batteries, as described in What to Do, in Brief, they will, according to the manufactures, last for between 500 and 1,000 charge/discharge cycles. Once in a while I find a battery that stops holding a complete charge and goes out much sooner. In my experience, this happens more frequently with some of the cheapest brands, but by no means with all of the cheapest brands. However, most of my rechargeable batteries are going strong after three years, with no sign of weakening. I recharge about half of my non-LSD batteries every couple of months. Most of the rest are recharged every three to five months. The new LSD batteries will probably alter this picture considerably.

The new Low Self Discharge (LSD) batteries have entered the market in sizes AAA and AA. If the manufacturers' claims are true, they will outlast alkaline batteries, but not the new extra long lived single-use lithium batteries. Yet the greatest advantage of LSD batteries is not the capacity, but the shelf-life. LSD batteries are a new version of the Nickel-Metal Hydride (NiMH) batteries, which became popular a few years ago with the advent of digital cameras. The problem with rechargeable batteries, especially traditional NiMH batteries, has been that they loose a significant amount of charge with time, even when not in use. According to the manufacturers, the new LSD NiMH batteries loose much less. (See AAA and AA Rechargeable Batteries Compared, below.)

So far, there are only three instances where I have not let go of single use batteries. My smoke detectors is one. I am not confident that 9 Volt NiMH or

NiCD batteries will last a full year or more in a smoke detector as single-use batteries will. Another instance is in my headlamp and flashlight that I take backpacking. There prefer the new lithium single use batteries because they last the longer than anything in AAA size, and because warm temperatures do not cause them to loose a significant amount of charge. The last instance where I still use throw-away batteries is, somewhat ironically, in my digital multi meter that I use to test battery strength, because it is hard to replace the battery in this particular device. If LSD 9 Volt batteries are ever made, I might use them in the smoke detectors and multi-meter.

What to Do, in Brief

If you want to cut to the chase and keep it simple, then do these three things:

1. Buy a battery charger that has these five features (In order of importance.):

(a) Charges Nickel-Metal Hydride (NiMH) batteries, or better still, charges both Nickel-Metal Hydride batteries and Nickel-Cadmium (NiCd) batteries. Almost all chargers sold today charge NiMH batteries, but check to make sure, especially if you are buying a used charger. All chargers designed to charge NiMH batteries are perfectly compatible with the new Low Self Discharge (LSD) NiMH batteries, described in the introduction.

(b) Has an optional discharge cycle, more commonly called a reconditioning cycle. For reasons why, see #3 below.

(c) Switches to a trickle charge or shuts off or automatically after the batteries are charged. This prevents you from over cooking your batteries and dramatically shortening their life.

(d) Charges each battery individually. Many chargers only charge batteries in pairs. That works OK if you use batteries only in pairs. But wall clocks and some remote controls use only one battery, and some flashlights use one, three, or five. Additionally, you will find in time that supposedly identical rechargeable batteries differ slightly in their capacity. Allowing each battery to recondition and recharge individually assures that each battery will last as long as it can. More importantly, if a rechargeable battery goes bad, and if your charger charges each battery individually, it can tell you precisely which battery is the bad one.

(e) Automatically switches from recondition mode to recharge mode, without requiring you to go to the charger to flip a switch half-way through the process. This is a tremendous convenience. Without this feature you will find yourself either repeatedly going to the charger to see when you can start the charging process, or you will forget to switch to the charging process and not have charged batteries when you want them. Worse still, you may get frustrated by the reconditioning cycle, stop reconditioning your batteries, and thus shorten the life of your batteries.

Your best bet might be to make your first charger one that charges/discharges (typically four) AAA, AA, C and D batteries. Some of these also charge 9 Volt batteries. Alternately, if you don't think that C and D rechargeable batteries will be in your future soon, get a charger that charges about 10 AAA and AA batteries. You may think you will never want to charge that many, but if you start to replace all the AAA and AA batteries in your home with rechargeables, you will most likely find smaller capacity chargers to be limiting. If you buy two or more smaller capacity chargers, then you may spend more on all your small chargers than if you had just bought the big in the first place. You might also have trouble finding a place to plug in all of them. Another benefit of the larger chargers is that they tend to be more sophisticated, and thus usually possess all the characteristics listed above, although a few of the smaller chargers have all the characteristics too.

To find vendors that sell such chargers, see Rechargeable Battery and Charger Sources.

Note—It is recommended by some who regularly use rechargeable batteries to plug your chargers into a surge protector to not only protect the charger, but to reduce the chances of a an electrical surge acting to confuse your charger during a charge cycle, and thus not properly charge your battery. Any ordinary surge protector will suffice, including strip surge protectors commonly sold in computer stores, or wall-outlet surge protectors sold in hardware and electronic stores.

Note—It is recommended by some who regularly use rechargeable batteries to place your charger on a noncombustible surface to insulate the charger from the table or counter on which is rests. This is because in a few instances chargers have been reported to have become quite hot as a result of some sort of malfunction. Such instances are reportedly rare. This measure is only precautionary. Examples of a noncombustible insulators include a kitchen trivet or an inverted pie plate. I use left-over ceramic bathroom tile. Of course, this precaution does not apply if your charger is of a type where the entire charging unit plugs into

the wall socket, and does not draw power through a wire connected to a transformer (power brick).

2. Buy Nickel-Metal Hydride (NiMH) batteries, or Low Self Discharge (LSD) Nickel-Metal Hydride batteries of the highest or nearly the highest capacity (mAh) that you can find.

(a) When buying AAA and AA sizes, buy Low Self Discharge (LSD) Nickel-Metal Hydride batteries (NiMH). The only exception would be for electronic devices that you or your children use so intensively that you recharge the batteries more than every three weeks or so when you use them. Such might be the case with digital cameras and motorized toys. If you generally run your batteries down in about three weeks, consider buying ordinary **high capacity** Nickel-Metal Hydride batteries (NiMH) batteries, because they hold a little more charge than the LSD batteries. Check the mAh rating on the batteries before you buy. See AAA and AA Rechargeable Batteries Compared, below.

(b) When buying C, D and 9 Volt batteries, buy ordinary high capacity Nickel-Metal Hydride batteries (NiMH). LSD batteries are not yet available in these sizes. (Let us know if you ever find them.) The only exceptions might be with devices that you use only lightly **and** in which you need the battery to stay charged a long time in very warm temperatures. In these cases, the old Nickel-Cadmium (NiCd) batteries might be a little better. I say "might" because it depends on whom you want to believe. It has been traditionally stated that the advantage of NiCd batteries is that they self discharge (lose their charge when not in use) at a rate of only about 1% per day, compared to the 4% per day of NiMH batteries, and that these rates of self discharge are greater in warm temperatures. This has been my personal experience. Others would argue. However, makers of ordinary NiMH batteries have apparently been trying to reduce the NiMH self discharge rate. See Technical Information About Rechargeable Batteries, below.

Ordinary NiMH batteries and NiCd batteries are available in drastically different capacities. Check the mAh rating on the batteries before you buy. Also, be aware that the best NiCd batteries have half or less of the capacity of the best NiMH

batteries.

Note—Single use lithium batteries outlast all rechargeable batteries.

Test the water. I have found that batteries of some manufactures seem to provide electricity for longer durations than others. For example, I have some 2,600 mAh AA NiMH batteries that last only about as long as some 1,600 mAh AA NiMH batteries of another brand. In this case the 2,600 mAh batteries are underperforming, not the 1,600 mAh batteries over performing. I have also found instances where some samples of a particular brand of AA NiMH batteries were too wide to fit in some samples of one popular brand of AA flashlight, and also were too long to fit in one of my two wall clocks. I do not know if the battery manufacturer, the flashlight manufacturer, the clock manufacturer, or all the manufacturers had built some of their products outside some sort of standard specifications of diameter and length.

3. Send your Nickel-Metal Hydride batteries (NiMH) and your Low Self Discharge (LSD) Nickel-Metal Hydride batteries through a reconditioning (discharge) cycle about every fourth time you charge them. Send your Nickel-Cadmium batteries (NiCd) through more frequent reconditioning cycles). You may have heard that NiCd batteries develop discharge memory and that NiMH batteries do not. This is not quite true. Both NiCd and NiMH develop discharge memory, the NiCd just do it more readily. Discharge memory refers to the behavior of batteries whereby if a battery is discharged, for example, only half way every time it is used; eventually the battery can only be discharged half way before it dies. So, for example, a 1,000 mAh battery begins to behave something like a 500 mAh battery.

I recondition my batteries every time I charge them unless I am in a hurry. With over 75 rechargeable NiCd and NiMH batteries at my home, it is hard to remember which ones were reconditioned when. (You could easily have over 75 batteries in your home too.) It is far simpler to just recondition them almost every time, and if your charger automatically switches from recondition mode to recharge mode without requiring you to go to the charger to flip a switch half way though the process, then it is not an inconvenience to recondition them most times.

Examples of NiMH Battery Capacity:

- **AAA**—High capacity AAA batteries would have 1,000 or 950 mAh capacity. They can come with as little as 400 mAh capacity or with no capacity listed. As of the date of this writing, Low Self Discharge AAA batteries have a capacity of 750 or 800 mAh.

- **AA**—High capacity AA batteries would have 2,700 or 2,650 mAh capacity. They can come with as little as 600 mAh capacity or with no capacity listed. As of the date of this writing, Low Self Discharge AA batteries have a capacities around 2,000 mAh.

- **C**—High capacity C batteries would have 5,500 or 5,000 mAh capacity. They can come with as little as 1,000 mAh capacity or with no capacity listed. As of the date of this writing, there are no Low Self Discharge C size batteries. Let us know if you ever find them.

- **D**—High capacity D batteries would have 12,000 or 10,000 mAh capacity. They can come with as little as 1,000 mAh capacity or with no capacity listed. As of the date of this writing, there are no Low Self Discharge D size batteries. Let us know if you ever find them.

- **9 Volt**—High capacity 9 Volt batteries would have 275 or 250 mAh capacity. They can come with as little as 120 mAh capacity or with no capacity listed. As of the date of this writing, there are no Low Self Discharge 9 Volt batteries. Let us know if you ever find them.

  Note: If you cannot find the higher capacity batteries, or the Low Self Discharge batteries near where you live, check vendors listed in Rechargeable Battery and Charger Sources. For my own purposes, I find better batteries on the Web than I do in stores where I live.

AAA and AA Rechargeable Batteries Compared

Battery Type	Total Capacity	Self-Discharge Rate	Use Characteristics
Nickel-Metal Hydride (NiMH)	Up to 1,000, AAA. Up to 2,700 mAh, AA. Available capacities vary widely. Check the mAh rating before you buy.	Does not hold charge well over long periods. Loses 4% per **day**[1], much more in warm temperatures.	Works well in devices that require sudden high amperage discharge, such as digital cameras. Also works well in most other devices.

Low Self Discharge Nickel-Metal Hydride (LSD NiMH)	Up to 800, AAA. Up to 2,000, AA Almost all LSD batteries sold have close to these capacities.	Holds charge well over long periods. Loses 15 % per **year**[2], very slightly more in warm temperatures.	Works well in devices that require sudden high amperage discharge, such as digital cameras. Also works well in most other devices.
Nickel-Cadmium (NiCd)	Up to 350 mAh, AAA. Up to 1,000 mAh, AA. Available capacities vary widely. Check the mAh rating before you buy.	Loses 1% per **day**[3], slightly more in warm temperatures.	Does not work well in devices that require sudden high amperage discharges. Does not work well in digital cameras, but does work well in most other devices.

Footnotes

1. NiMH lose 4% of their charge per day, according to Sundance Solar, a battery distributor. According to Green Batteries, another distributor, NiMH batteries can lose up to 40 percent of their charge in a month when stored at 70 degrees F.
2. LSD NiMH lose 15% per **year**, according to Sanyo, which makes Enloop.
3. NiCd lose 1 percent per day, according to Sundance Solar.

See Technical Information About Rechargeable Batteries, below.

AAA and AA Single-Use Batteries Compared

Battery Type	Total Capacity	Self-Discharge Rate	Discharge Characteristics

Lithium (Very High Capacity Single-Use Batteries)	Up to 1,250 mAh, AAA. Up to 3,000 mAh, AA.	Holds charge very well over long periods and in warm temperatures. Other data not available.	Works well in devices that require sudden high amperage discharge, such as digital cameras. Also works well in most other devices.
Alkaline (High Capacity Single-Use Batteries)	Data not available.	Holds charge very well over long periods and in warm temperatures. Other data not available.	Works well in devices that require sudden high amperage discharge, such as digital cameras. Also works well in most other devices.

Additional Quirks

The battery strength of NiCd batteries starts out strong, and then tapers off gradually during the discharge cycle. NiMH batteries start out strong and stay strong until the batteries conk out. They quit with little on no warning. I have not yet heard anything that would lead me to think that LSD NiMH batteries would behave any differently in this regard than ordinary NiMH batteries.

The duration of future discharge cycles and battery life can easily be shortened if NiCd batteries are not fully discharged between charges. By contrast, the duration of future discharge cycles and battery life of NiMH batteries are not shortened as easily as NiCd batteries if the battery is not fully discharged between charges. However, NiMH batteries do benefit from being fully discharged once in a while. (See Notes and Tips, below.)

NiCd batteries seem to work a little bit better than NiMH as temperatures dip below 40 degrees Fahrenheit, but low temperature NiMH batteries are available.

It is sometimes said that NiCd batteries are not environmentally friendly, and that NiMH batteries are. This is usually said in reference to federal standards, which in many other states allow NiMH batteries to be disposed in the trash, but which require NiCd batteries to be disposed or recycled as hazardous waste. However **in California, all batteries, including NiMH, LSD, NiCd and ordinary single use batteries, must be disposed or recycled as hazardous waste**. It is illegal to place them in the trash. So, if you dispose of batteries as you should in California, there is little difference in the environmental risks of disposing the various types of batteries.

Consider This

If you keep your charger or chargers handy and at the ready, it will be much more convenient to charge batteries in a hurry, than if the chargers are stashed in a drawer. Consider installing a simple shelf especially for the chargers, perhaps in your kitchen, laundry room, or garage. Perhaps buy a surge protecting power strip as used on computers so that you can more easily plug in two or three chargers. I built a simple plywood cabinet in my garage with four electrical outlets on the back wall of the cabinet. Power to the outlets runs through a lighted switch on the outside of the cabinet, so that when the cabinet door is closed I am reminded that there are batteries charging inside the cabinet. The closed cabinet keeps out dust and debris from my occasional woodworking and other garage projects. The cabinet has vents at the top an bottom to allow enough air circulation to keep the chargers and transformers (power bricks) cool on hot summer days. Batteries get warm when they are charged, especially D size.

Note—It is recommended by some who regularly use rechargeable batteries to plug your chargers into a surge protector to not only protect the charger, but to reduce the chances of a an electrical surge acting to confuse your charger during a charge cycle, and thus not properly charge your battery. Any ordinary surge protector will suffice, including strip surge protectors commonly sold in computer stores, or wall-outlet surge protectors sold in hardware and electronic stores.

Note—It is recommended by some who regularly use rechargeable batteries to place your charger on a noncombustible surface to insulate the charger from the table or counter on which is rests. This is because in a few instances chargers have been reported to have become quite hot as a result of some sort of malfunction. Such instances are reportedly rare. This measure is only precautionary. Examples of a noncombustible insulators include a kitchen trivet or an inverted pie plate. I use left-over ceramic bathroom tile. Of course, this precaution does not apply if your charger is of a type where the entire charging unit plugs into the wall socket, and does not draw power through a wire connected to a transformer (power brick).

An Example of What Not to Do

My first attempt using rechargeable batteries involved Nickel-Metal Hydride (NiMH) batteries for the head light and tail light on my bicycle. At first I thought I had the perfect solution. I bought two sets of batteries, one set to keep at the ready in the quick chargers, and one set to keep inside the lights on the bicycle. I just swapped the batteries every few days to assure they would not go dead during commutes, and all seemed well with the world. But after a few months I noticed the batteries weren't holding a charge. My quick chargers were a type that neither turned off nor switched to trickle charge when the batteries were fully charged. Thus, I had overcharged my batteries by not removing them as soon as they were charged. I may have also created some battery memory. Because I did not want the batteries conking out during my commute, I did not let the batteries fully discharge. However, these batteries had only experienced about 50 charging cycles. So, over-charging was most likely the problem. If I had used chargers that either shut themselves off or switched to trickle charge when the batteries were fully recharged, then I would have been much better

off.

It may seem like not overcharging batteries would be simple, just go unplug the charger. However, if the charger does not shut off or switch to trickle charge, you have no way of knowing when they are fully charged. Timing the charging, and remembering to remove the batteries promptly and continually for batteries that you are recharging once every week or two, time after time, gets to be annoying. Even if you only need to charge batteries once a month, if you are dealing with a household, let alone a business or grammar school, with lots of rechargeable batteries, such diligence can be daunting to impossible. That is why I suggest using the type of chargers described above. Pay a little more and buy battery chargers that do all the work for you. To find such chargers, see Rechargeable Battery and Charger Sources.

Other Types of Rechargeable Batteries

There is another type of rechargeable replacement for batteries in sizes AAA, AA, C, D, and 9 volt, reusable alkaline. This page does not address reusable alkaline batteries because they are capable of only about a half dozen charge/ discharge cycles, and thus do not provide anywhere near as much potential for waste prevention as NiCd, NiMH, or LSD batteries.

Of course, some electrical gadgets come with their own custom made rechargeable batteries. Cell phones, cordless phones, cordless power tools, some types of cordless shavers and digital cameras, and other gadgets use batteries made in special shapes and sizes. These batteries might be NiCd, NiMH, or Lithium. This article does not address these batteries except to say two things:

1. To make these batteries last as long as they can, remember to run them through full discharge cycles before every third or forth time you charge the battery. (More frequent full discharge cycles are better.) This is most important with Nickel-Cadmium batteries, but even Nickel Metal Hydride and rechargeable Lithium batteries benefit from this according to anecdotal reports from users, and according to some instructions supplied with both some of these devices and with some of their replacement batteries.
2. None of these batteries, or any other batteries, are allowed in the trash in California. See the Waste Prevention Information Exchange's battery page, for more information on battery recycling and disposal.

Battery Capacity

When comparing two different NiCd batteries or two different NiMH batteries, look for the mAh rating. (Explained in the following section.) The higher numbers generally correlate to more hours or minutes of use between charges.

When buying rechargeable batteries, it pays to pay attention to the mAh rating. These ratings vary drastically in ordinary NiMH and NiCd batteries. At the

time of this writing, all LSD batteries seem to be manufactured with nearly the same mAh rating. Ordinary NiMH batteries are manufactured with capacities both above and below LSD batteries. Don't expect to find NiCd batteries with as much capacity as NiMH batteries. Typically, the highest capacity NiCd batteries hold half or less than half the capacity of best NiMH batteries. However this does not automatically mean that NiCd batteries are not as good. When factoring cost, the type of use, and sometimes temperature, NiCd can be the better choice if the new Low Self Discharge batteries are not available. At the time of this writing, LSD batteries were only available in AAA and AA sizes.

Manufacturers sometimes sell batteries of the same brand name and in the same packaging, but with different mAh ratings, in some cases very different. Batteries that look nearly identical can have very different capacities. This is not an intentionally deceptive practice. These manufactures are just giving you a choice in how much you spend. It is up to you to read the mAh rating that manufacturers usually print for you both on the packaging and on the battery. Of course, if the mAh capacity is not listed on a rechargeable battery, then beware. Unfortunately, for some reason the capacity is not usually printed on single-use batteries.

What's a mAh?

The capacity of NiCd and NiMH batteries is rated in milliampere hours. One milliampere hour (mAh) is one thousandth of an ampere delivered for a duration of one hour. In the case of AAA, AA, C, and D batteries, this energy is delivered at somewhere around 1.5 Volts.

If a one of these 1.5 Volt batteries had the potential to provide one thousandth of an amp for one hour we would say that it has a capacity, of 1 mAh. If it could provide 2,000 milliamps for one hour, or 1 milliamp for 2,000 hours, it would be called a 2,000 mAh battery.

Amperes (often called Amps) can be thought of as the amount of electricity in motion, or an amount being delivered at any instant. Voltage, or Volts can be thought of as force." The Voltage coming from the battery is roughly constant. It stays in the neighborhood of 1.5 Volts. However, the amperage utilized or drawn by any particular electrical device can vary from device to device. For example, wall clocks and remote controls use just a tiny amount, digital cameras use a comparatively large amount, although in both cases only tiny fractions of an ampere are used, hence the measurement of thousandths of Amps.

Strictly speaking, mAh is not a measurement of an amount of electrical energy. It is only a measurement of milliampers over time. To make it a measurement of an amount of electrical energy, we would need to factor the Voltage. This is impractical because:

1. The actual Voltage of AAA, AA, C, and D (and 9 Volt) batteries weakens as the batteries are drained of charge.
2. Different types of batteries start out with different maximum Voltages. NiMH batteries, in the sizes AAA, AA, C, and D, provide a maximum

Voltage of about 1.40 to 1.45 Volts. A single use battery will actually generate a maximum voltage a little over 1.5 Volts when it is new, I have measured them as high as 1.7 Volts.

Battery powered devices are designed to handle the range of Voltage that their batteries generate.

Notes and Tips

Battery manufactures have warned that discharging rechargeable batteries so thoroughly that they hold no charge at all can damage or destroy batteries. On this page, the term "fully discharge" refers to the practices of using batteries until the device that they power does not operate normally, or using the batteries until the device that they power tells the user to replace the batteries, or discharging batteries to their lowest safe level in a "reconditioning" battery charger. Many modern devices with sophisticated electronic circuitry turn themselves off when batteries are low. However, a simple device, such as a flashlight, might, if left on, discharge batteries so thoroughly that they become damaged.

NiCd and NiMH batteries can also be damaged by over charging. Once a battery has been recharged, it is recommended that users do not try to add additional charge to the battery by sending it through another recharge cycle before using the battery. This is especially true when using chargers that charge for a specific period of time every time that the charger is turned on. If you use a charger that either stops charging or switches to trickle charge when a battery is fully charged, you greatly reduce the risk of overcharging, although the conventional wisdom is that batteries should not be left in trickle charge mode indefinitely.

You might find it useful to write the purchase date on each battery with permanent ink as you collect them. This will help you keep track of which ones are old, and thus perhaps getting ready to fail. It could also help you determine if you are using and charging your batteries in a manner that allows them to last as long as you think they should.

You may eventually find it most convenient to have more than one charger. I have three, and I sometimes use all three simultaneously. One of my chargers individually reconditions and charges up to ten batteries, but only of sizes AAA and AA, and at a fairly slow rate of charge. The other two individually recondition and charge up to four batteries of sizes AAA, AA, C, and D, and at a fairly high rate. These two chargers also each charge two 9 Volt batteries, but they do not recondition the 9 Volt batteries. I have not found a charger that reconditions 9 Volt batteries. However, the lack of a recondition cycle for 9 Volt batteries has not been a problem for me, because I usually discharge my 9 Volt batteries completely in the electrical devices that use them. All three chargers automatically and individually switch each battery from discharge to charge at the appropriate time, and all three of my chargers individually switch each battery to trickle charge when they are charged.

To find both batteries and chargers, see Rechargeable Battery and Charger Sources.

Alternatives to Batteries

Let's go back to square one for a moment. Do you need batteries? Interestingly enough, in two cases the answer is sometimes no. To learn more about the possibilities, see Alternative Power Products.

Don't forget to recycle your rechargeable batteries, or dispose of them as hazardous waste, when they are worn out.

More Information

- **Batteries Digest**—Batteries, fuel cells, and photovoltaics.
- **Batteries in a Portable World. A handbook on rechargeable batteries for non-engineers**—By Isidor Buchmann.
    - Frequently Asked Questions about Rechargeable Batteries
- **Batteryweb.com**—Frequently Asked Questions
- **Conscious Consumer - Buy Better Batteries**—From the Conscious Consumer Project of Center for a New American Dream
- **Electrical Storage, Present, Past and Future**—From Waste Prevention World.
- **Rechargeable Battery Information**—From Steve's Digicams
- **Battery and Cell Phone Drop-Off Locator**—Find where to recycle used rechargeable batteries from the Rechargeable Battery Recycling Corporation (RBRC) Web site.
- **Waste Prevention Information Exchange, Batteries**
- ***Waste Source Reduction Hospital Case Study***—This study from the Minnesota Office of Environmental Assistance addresses several common hospital waste streams, one of which is batteries. This study documents significant cost and waste reductions achieved by switching from single use to rechargeable batteries for flashlights. Portable Document Format (PDF), 136 KB.
- **Technical Information about Rechargeable Batteries**—Some of this information supports, and some if this information contradicts, the statements made on this page about self discharge rates. It is posted so that you can come to your own conclusions:
    - Candle Power Forums, Enloop Self Discharge Study
    - *Duracell, Ni-MH Rechargeable Batteries* (Adobe PDF, 504 KB)
    - *Panasonic, Nickel Metal Hydride Batteries* (Adobe PDF, 76 KB)
    - *PG Batteries, NiMH Rechargeable Batteries* (Adobe PDF, 648 KB)
    - *Quest Batteries, Nickel Metal Hydride* (Adobe PDF, 152 KB)
    - *Sanyo Twicell Batteries* (Adobe PDF, 448 KB)

For information about how to recycle or reuse other electronic equipment, see the CIWMB Electronic Product Directory.

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Waste Prevention World http://www.ciwmb.ca.gov/WPW/
Don Van Dyke: dvandyke@ciwmb.ca.gov, (916) 341-6615
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This Ultra Low Self Discharge battery comes ready to use and is ideal for devices that you do not use all the time. The charge retention is higher than the standard high capacity 2400mAh greenbatteries brand NiMH batteries that we prefer for heavy use.

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Rechargeable battery

From Wikipedia, the free encyclopedia

A **rechargeable battery**, **storage battery**, **secondary cell**, or **accumulator** is a type of electrical battery which can be charged, discharged into a load, and recharged many times, while a non-rechargeable or primary battery is supplied fully charged, and discarded once discharged. It is composed of one or more electrochemical cells. The term "accumulator" is used as it accumulates and stores energy through a reversible electrochemical reaction. Rechargeable batteries are produced in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of electrode materials and electrolytes are used, including lead–acid, nickel cadmium (NiCd), nickel metal hydride (NiMH), lithium ion (Li-ion), and lithium ion polymer (Li-ion polymer).

A battery bank used for an uninterruptible power supply in a data center

Rechargeable batteries typically initially cost more than disposable batteries, but have a much lower total cost of ownership and environmental impact, as they can be recharged inexpensively many times before they need replacing. Some rechargeable battery types are available in the same sizes and voltages as disposable types, and can be used interchangeably with them.

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A rechargeable lithium polymer mobile phone battery

A common consumer battery charger for rechargeable AA and AAA batteries

Usage and applications

Devices which use rechargeable batteries include automobile starters, portable consumer devices, light vehicles (such as motorized wheelchairs, golf carts, electric bicycles, and electric forklifts), tools, uninterruptible power supplies, and battery storage power stations. Emerging applications in hybrid internal combustion-battery and electric vehicles drive the technology to reduce cost, weight, and size, and increase lifetime.[1]

Older rechargeable batteries self-discharge relatively rapidly, and require charging before first use; some newer low self-discharge NiMH batteries hold their charge for many months, and are typically sold factory-charged to about 70% of their rated capacity.

Battery storage power stations use rechargeable batteries for load-leveling (storing electric energy at times of low demand for use during peak periods) and for renewable energy uses (such as storing power generated from photovoltaic arrays during the day to be used at night). Load-leveling reduces the maximum power which a plant must be able to generate, reducing capital cost and the need for peaking power plants.

The US National Electrical Manufacturers Association estimated in 2006 that US demand for rechargeable batteries was growing twice as fast as demand for disposables.[2]

Small rechargeable batteries can power portable electronic devices, power tools, appliances, and so on. Heavy-duty batteries power electric vehicles, ranging from scooters to locomotives and ships. They are used in distributed electricity generation and in stand-alone power systems.

Cylindrical cell (18650) prior to assembly. Several thousand of them (lithium ion) form the Tesla Model S battery (see Gigafactory).

Charging and discharging

During charging, the positive active material is oxidized, producing electrons, and the negative material is reduced, consuming electrons. These electrons constitute the current flow in the external circuit. The electrolyte may serve as a simple buffer for internal ion flow between the electrodes, as in lithium-ion and nickel-cadmium cells, or it may be an active participant in the electrochemical reaction, as in lead–acid cells.

The energy used to charge rechargeable batteries usually comes from a battery charger using AC mains electricity, although some are equipped to use a vehicle's 12-volt DC power outlet. Regardless, to store energy in a secondary cell, it has to be connected to a DC voltage source. The negative terminal of the cell has to be connected to the negative terminal of the voltage source and the positive terminal of the voltage source with the positive terminal of the battery. Further, the voltage output of the source must be higher than that of the battery, but not *much* higher: the greater the difference between the power source and the battery's voltage capacity, the faster the charging process, but also the greater the risk of overcharging and damaging the battery.

Lithium ion battery monitoring electronics (over- and discharge protection)

Chargers take from a few minutes to several hours to charge a battery. Slow "dumb" chargers without voltage or temperature-sensing capabilities will charge at a low rate, typically taking 14 hours or more to reach a full charge. Rapid chargers can typically charge cells in two to five hours, depending on the model, with the fastest taking as little as fifteen minutes. Fast chargers must have multiple ways of detecting when a cell reaches full charge (change in terminal voltage, temperature, etc.) to stop charging before harmful overcharging or overheating occurs. The fastest chargers often incorporate cooling fans to keep the cells from overheating.

Battery charging and discharging rates are often discussed by referencing a "C" rate of current. The C rate is that which would theoretically fully charge or discharge the battery in one hour. For example, trickle charging might be performed at C/20 (or a "20 hour" rate), while typical charging and discharging may occur at C/2 (two hours for full capacity). The available capacity of electrochemical cells varies depending on the discharge rate. Some energy is lost in the internal resistance of cell components (plates, electrolyte, interconnections), and the rate of discharge is limited by the speed at which chemicals in the cell can move about. For lead-acid cells, the relationship between time and discharge rate is described by Peukert's law; a lead-acid cell that can no longer sustain a usable terminal voltage at a high current may still have usable capacity, if discharged at a much lower rate. Data sheets for rechargeable cells often list the discharge capacity on 8-hour or 20-hour or other stated time; cells for uninterruptible power supply systems may be rated at 15 minute discharge.

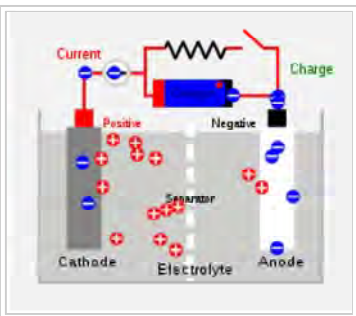

Diagram of the charging of a secondary cell or battery.

A solar-powered charger for rechargeable AA batteries

Battery manufacturers' technical notes often refer to voltage per cell (VPC) for the individual cells that make up the battery. For example, to charge a 12 V lead-acid battery (containing 6 cells of 2 V each) at 2.3 VPC requires a voltage of 13.8 V across the battery's terminals.

Non-rechargeable alkaline and zinc–carbon cells output 1.5V when new, but this voltage drops with use. Most NiMH AA and AAA cells are rated at 1.2 V, but have a flatter discharge curve than alkalines and can usually be used in equipment designed to use alkaline batteries.

Damage from cell reversal

Subjecting a discharged cell to a current in the direction which tends to discharge it further to the point the positive and negative terminals switch polarity causes a condition called cell reversal. Generally, pushing current through a discharged cell in this way causes undesirable and irreversible chemical reactions to occur, resulting in permanent damage to the cell. Cell reversal can occur under a number of circumstances, the two most common being:

- When a battery or cell is connected to a charging circuit the wrong way around.
- When a battery made of several cells connected in series is deeply discharged.

In the latter case, the problem occurs due to the different cells in a battery having slightly different capacities. When one cell reaches discharge level ahead of the rest, the remaining cells will force the current through the discharged cell.

Many battery-operated devices have a low-voltage cutoff that prevents deep discharges from occurring that might cause cell reversal.

Cell reversal can occur to a weakly charged cell even before it is fully discharged. If the battery drain current is high enough, the cell's internal resistance can create a resistive voltage drop that is greater than the cell's forward emf. This results in the reversal of the cell's polarity while the current is flowing.[3][4] The higher the required discharge rate of a battery, the better matched the cells should be, both in the type of cell and state of charge, in order to reduce the chances of cell reversal.

In some situations, such as when correcting Ni-Cad batteries that have been previously overcharged,[5] it may be desirable to fully discharge a battery. To avoid damage from the cell reversal effect, it is necessary to access each cell separately: each cell is individually discharged by connecting a load clip across the terminals of each cell, thereby avoiding cell reversal.

Damage during storage in fully discharged state

If a multi-cell battery is fully discharged, it will often be damaged due to the cell reversal effect mentioned above. It is possible however to fully discharge a battery without causing cell reversal—either by discharging each cell separately, or by allowing each cell's internal leakage to dissipate its charge over time.

Even if a cell is brought to a fully discharged state without reversal, however, damage may occur over time simply due to remaining in the discharged state. An example of this is the sulfation that occurs in lead-acid batteries that are left sitting on a shelf for long periods. For this reason it is often recommended to charge a battery that is intended to remain in storage, and to maintain its charge level by periodically recharging it. Since damage may also occur if the battery is overcharged, the optimal level of charge during storage is typically around 30% to 70%.

Depth of discharge

Depth of discharge (DOD) is normally stated as a percentage of the nominal ampere-hour capacity; 0% DOD means no discharge. As the usable capacity of a battery system depends on the rate of discharge and the allowable voltage at the end of discharge, the depth of discharge must be qualified to show the way it is to be measured. Due to variations during manufacture and aging, the DOD for complete discharge can change over time or number of charge cycles. Generally a rechargeable battery system will tolerate more charge/discharge cycles if the DOD is lower on each cycle.[6]

Lifespan and cycle stability

If batteries are used repeatedly even without mistreatment, they lose capacity as the number of charge cycles increases, until they are eventually considered to have reached the end of their useful life.

Lithium iron phosphate batteries reach according to the manufacturer more than 5000 cycles at respective depth of discharge of 70%.[7] After 7500 cycles with discharge of 85% this still have a spare capacity of at least 80% at a rate of 1 C; which corresponds with a full cycle per day to a lifetime of min. 20.5 years.

The lithium iron phosphate battery Sony Fortelion has after 10,000 cycles at 100% discharge level still a residual capacity of 71%. This battery has been on the market since 2009.[8]

Used in solar batteries Lithium-ion batteries have partly a very high cycle resistance of more than 10,000 charge and discharge cycles and a long service life of up to 20 years.[9][10]

Plug in America has among drivers of the Tesla Roadster, a survey carried out with respect to the service life of the installed battery. It was found that after 100,000 miles = 160,000 km, the battery still had a remaining capacity of 80 to 85 percent. This was regardless of in which climate zone the car is moved.[11][12] The Tesla Roadster was built and sold between 2008 and 2012. For its 85-kWh batteries in the Tesla Model S Tesla are 8-year warranty with unlimited mileage.[13]

Varta Storage guarantees its engion battery systems for 14,000 full cycles and a service life of 10 years.[14][15]

The best-selling electric car is the Nissan Leaf, which is produced since of 2010. Nissan stated in 2015 that until then only 0.01 percent of batteries had to be replaced because of failures or problems and then only because of externally inflicted damage. There are few vehicles that have already covered more than 200,000 km away. These have no problems with the battery.[16]

Recharging time

BYD e6 taxi. Recharging in 15 Minutes to 80 percent

Electric cars like Tesla Model S, Renault Zoe, BMW i3, etc. can recharge their batteries at quick charging stations within 30 minutes to 80 percent.[17][18][19][20]

In laboratories the company StoreDot from Israel reportedly demonstrated the first lab samples of unspecified batteries that can, as of April 2014, be charged in 30 seconds in mobile phones.[21][22]

Researchers from Singapore in 2014 developed a battery that can be recharged in 2 minutes to 70 percent. The batteries rely on lithium-ion technology. However, the anode and the negative pole in the battery is no longer made of graphite, but a titanium dioxide gel. The gel accelerates the chemical reaction significantly, thus ensuring a faster charging. In particular, these batteries are to be used in electric cars.[23][24][25] Already in 2012 researchers at the Ludwig-Maximilian-University in Munich have discovered the basic principle.[26]

Scientists at Stanford University in California have developed a battery that can be charged within one minute. The anode is made of aluminum and the cathode made of graphite (see Aluminium-ion battery).[27][28]

The electric car Volar-e of the company Applus + IDIADA, based on the Rimac Concept One, contains lithium iron phosphate batteries that can be recharged in 15 minutes.[29]

According to the manufacturer BYD the lithium iron phosphate battery of the electric car e6 is charged at a fast charging station within 15 minutes to 80%, after 40 minutes at 100%.[30]

In 2005, handheld device battery designs by Toshiba were claimed to be able to accept an 80% charge in as little as 60 seconds.[31]

Scientists of university of Oslo from Norway have developed a battery which can be recharged less than one second. According to the scientists this battery would be interesting for example for city buses, which could be loaded at each bus stop, and thus would require only a relatively small battery. A disadvantage is, according to the researchers that the bigger the battery, the greater must be the charging current. Thus, the battery can not be very big. According to the researchers of the new battery could also be used as a buffer in sports car to provide power in the short term. For now, however, the researchers think of applications in small and micro devices.[32][33]

According to the manufacturer battery of the smartphone OnePlus 3 can be charged from 0 to 60 percent within 30 minutes.[34]

Price history

Lead-acid batteries typically cost €100 / kWh. Li-Ion batteries cost in January 2014, however, typically around €110 / kWh (150 USD / kWh). The prices for Li-Ion batteries have, since 2011, dropped significantly (2011: €500 / kWh, 2012: €350 / kWh, 2013: €200 / kWh) [35][36][37][38][39] At a conference for electric mobility October 2013 mentioned the trend researcher Lars Thomsen, that Tesla has built its battery at the time 200 USD / kWh (equivalent to €148 / kWh).[40] for the planned for autumn 2016 e-mobile Bolt expects General Motors 145 USD / kWh, and a reduction to 100 USD / kWh by 2022.[41] Reasons for the price decline is the increasing mass production, which has reduced costs through better technologies and economies of scale.

In the German retail LiFePO4 battery cells (as of January 2015) are available from about 420 € / kWh (1.35 € / Ah).[42]

The Powerpack of Tesla costs in spring 2016 250 USD per kWh [43] (see Tesla Powerwall).

Active components

The active components in a secondary cell are the chemicals that make up the positive and negative active materials, and the electrolyte. The positive and negative are made up of different materials, with the positive exhibiting a reduction potential and the negative having an oxidation potential. The sum of these potentials is the standard cell potential or voltage.

In primary cells the positive and negative electrodes are known as the cathode and anode, respectively. Although this convention is sometimes carried through to rechargeable systems—especially with lithium-ion cells, because of their origins in primary lithium cells—this practice can lead to confusion. In rechargeable cells the positive electrode is the cathode on discharge and the anode on charge, and vice versa for the negative electrode.

Types

The lead–acid battery, invented in 1859 by French physicist Gaston Planté, is the oldest type of rechargeable battery. Despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, its ability to supply high surge currents means that the cells have a relatively large power-to-weight ratio. These features, along with the low cost, makes it attractive for use in motor vehicles to provide the high current required by automobile starter motors.

The nickel–cadmium battery (NiCd) was invented by Waldemar Jungner of Sweden in 1899. It uses nickel oxide hydroxide and metallic cadmium as electrodes. Cadmium is a toxic element, and was banned for most uses by the European Union in 2004. Nickel–cadmium batteries have been almost completely superseded by nickel–metal hydride (NiMH) batteries.

The nickel–metal hydride battery (NiMH) became available in 1989.[44] These are now a common consumer and industrial type. The battery has a hydrogen-absorbing alloy for the negative electrode instead of cadmium.

The lithium-ion battery was introduced in the market in 1991, and it is the choice in most consumer electronics and has the best energy density and a very slow loss of charge when not in use.

Lithium-ion polymer batteries are light in weight, offer slightly higher energy density than Li-ion at slightly higher cost, and can be made in any shape. They are available[45] but have not displaced Li-ion in the market.

Experimental types

Type	Voltage[a]	Energy density[b]			Power[c]	E/$[e]	Self-disch.[f]	Charge Efficiency	Cycles[g]	Life[h]
	(V)	(MJ/kg)	(Wh/kg)	(Wh/L)	(W/kg)	(Wh/$)	(%/month)	(%)	(#)	(years)
Lithium sulfur [46]	2.0	0.94-1.44 [47]	400[48]	350					~1400[49]	
Sodium-ion[50]	3.6			30		3.3			5000+	Testing
Thin film lithium	?		300[51]	959[51]	6000[51]	?[p][51]			40000[51]	
Zinc-bromide		0.27-0.31	75-85							
Zinc-cerium	2.5[52]									Under testing
Vanadium redox	1.15-1.55	0.09-0.13	25-35[53]				20%[54]		14,000[55]	10 (stationary) [54]
Sodium-sulfur		0.54	150					89–92%	2500—4500	
Molten salt	2.58	0.25-1.04	70-290[56]	160[57]	150-220	4.54[58]			3000+	<=20
Silver-zinc	1.86	0.47	130	240						
Quantum Battery (oxide semiconductor) [59][60]	1.5-3			500	8000 (W/L)				100,000	

‡ citations are needed for these parameters

Notes

- [a] Nominal cell voltage in V.
- [b] Energy density = energy/weight or energy/size, given in three different units
- [c] Specific power = power/weight in W/kg
- [e] Energy/consumer price in W·h/US$ (approximately)
- [f] Self-discharge rate in %/month
- [g] Cycle durability in number of cycles
- [h] Time durability in years
- [i] VRLA or recombinant includes gel batteries and absorbed glass mats
- [p] Pilot production

The lithium–sulfur battery was developed by Sion Power in 1994.[61] The company claims superior energy density to other lithium technologies.[62]

The thin film battery (TFB) is a refinement of lithium ion technology by Excellatron.[63] The developers claim a large increase in recharge cycles to around 40,000 and higher charge and discharge rates, at least 5 *C* charge rate. Sustained 60 *C* discharge and 1000*C* peak discharge rate and a significant increase in specific energy, and energy density.[64]

A smart battery has voltage monitoring circuit built inside. Carbon foam-based lead acid battery: Firefly Energy developed a carbon foam-based lead acid battery with a reported energy density of 30-40% more than their original 38 Wh/kg,[65] with long life and very high power density.

UltraBattery, a hybrid lead-acid battery and ultracapacitor invented by Australia's national science organisation CSIRO, exhibits tens of thousands of partial state of charge cycles and has outperformed traditional lead-acid, lithium and NiMH-based cells when compared in testing in this mode against variability management power profiles.[66] UltraBattery has kW and MW-scale installations in place in Australia, Japan and the U.S.A. It has also been subjected to extensive testing in hybrid electric vehicles and has been shown to last more than 100,000 vehicle miles in on-road commercial testing in a courier vehicle. The technology is claimed to have a lifetime of 7 to 10 times that of conventional lead-acid batteries in high rate partial state-of-charge use, with safety and environmental benefits claimed over competitors like lithium-ion. Its manufacturer suggests an almost 100% recycling rate is already in place for the product.

The potassium-ion battery delivers around a million cycles, due to the extraordinary electrochemical stability of potassium insertion/extraction materials such as Prussian blue.

The sodium-ion battery is meant for stationary storage and competes with lead–acid batteries. It aims at a low total cost of ownership per kWh of storage. This is achieved by a long and stable lifetime. The effective number of cycles is above 5000 and the battery is not damaged by deep discharge. The energy density is rather low, somewhat lower than lead–acid.

The quantum battery (oxide semiconductor) was developed by MJC. It is a small, lightweight cell with a multi-layer film structure and high energy and high power density. It is incombustible, has no electrolyte and generates a low amount of heat during charge. Its unique feature is its ability to capture electrons physically rather than chemically.[67]

In 2007, Yi Cui and colleagues at Stanford University's Department of Materials Science and Engineering discovered that using silicon nanowires as the anode of a lithium-ion battery increases the anode's volumetric charge density by up to a factor of 10, leading to the development of the nanowire battery.[68]

Another development is the paper-thin flexible self-rechargeable battery combining a thin-film organic solar cell with an extremely thin and highly flexible lithium-polymer battery, which recharges itself when exposed to light.[69]

Ceramatec, a research and development unit of CoorsTek, as of 2009 was testing a battery comprising a chunk of solid sodium metal mated to a sulfur compound by a paper-thin ceramic membrane which conducts ions back and forth to generate a current. The company claimed that it could fit about 40 kilowatt hours of energy into a package about the size of a refrigerator, and operate below 90 °C; and that their battery would allow about 3,650 discharge/recharge cycles (or roughly 1 per day for one decade).[70]

Battery electrodes can be microscopically viewed while bathed in wet electrolytes, resembling conditions inside operating batteries.[71]

In 2014, an Israeli company, StoreDot, claimed to be able to charge batteries in 30 seconds.[72][73][74]

Secondary magnesium battery types are an active (2015) topic of research, as a replacement for lithium ion cells.

Aluminium-ion battery types had big success in 2015 in research.

Alternatives

A rechargeable battery is only one of several types of rechargeable energy storage systems.[75] Several alternatives to rechargeable batteries exist or are under development. For uses such as portable radios, rechargeable batteries may be replaced by clockwork mechanisms which are wound up by hand, driving dynamos, although this system may be used to charge a battery rather than to operate the radio directly. Flashlights may be driven by a dynamo directly. For transportation, uninterruptible power supply systems and laboratories, flywheel energy storage systems store energy in a spinning rotor for conversion to electric power when needed; such systems may be used to provide large pulses of power that would otherwise be objectionable on a common electrical grid.

Ultracapacitors—capacitors of extremely high value— are also used; an electric screwdriver which charges in 90 seconds and will drive about half as many screws as a device using a rechargeable battery was introduced in 2007,[76] and similar flashlights have been produced. In keeping with the concept of ultracapacitors, betavoltaic batteries may be utilized as a method of providing a trickle-charge to a secondary battery, greatly extending the life and energy capacity of the battery system being employed; this type of arrangement is often referred to as a "hybrid betavoltaic power source" by those in the industry.[77]

Ultracapacitors are being developed for transportation, using a large capacitor to store energy instead of the rechargeable battery banks used in hybrid vehicles. One drawback of capacitors compared to batteries is that the terminal voltage drops rapidly; a capacitor that has 25% of its initial energy left in it will have one-half of its initial voltage. By contrast, battery systems tend to have a terminal voltage that does not decline rapidly until nearly exhausted. The undesirable characteristic complicates the design of power electronics for use with ultracapacitors. However, there are potential benefits in cycle efficiency, lifetime, and weight compared with rechargeable systems. China started using ultracapacitors on two commercial bus routes in 2006; one of them is route 11 in Shanghai.[78]

Flow batteries, used for specialized applications, are recharged by replacing the electrolyte liquid. A flow battery can be considered to be a type of rechargeable fuel cell.

Research

Lithium Ion batteries normally have an anode made of graphite. Using an anode made of silicon (Si) can increase the capacity up to 6 times, because the Si-anode can accept much more Lithium-ion than a graphite-anode. A problem was, that the Si-anode expands 300–400% when charged. The Si-anode had only a small lifespan. Researchers of the university of Stuttgart (institute of photovoltaic (IPV), Prof. Dr. Jürgen H. Werner and his team) found a way making the Si-anode porous, so that accepting so many Lithium-ion will not longer increase the volume of the Si-anode, so that the lifespan of the battery with Si-anode is now four times higher than batteries with graphite-anode. The battery is ready for production.[79][80]

See also

- Battery pack
- Comparison of battery types
- Energy storage
- List of battery types
- List of energy densities
- Metal–air electrochemical cell

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Categories: Rechargeable batteries | Flexible electronics

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Recipe

From Wikipedia, the free encyclopedia

A **recipe** is a set of instructions that describes how to prepare or make something, especially a culinary dish. It is also used in medicine or in information technology (user acceptance). A doctor will usually begin a prescription with *recipe*, Latin for *take*, usually abbreviated to Rx or an equivalent symbol.

Recipe in a cookbook for pancakes with the prepared ingredients

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  - 1.2 Modern recipes and cooking advice
- 2 Components
- 3 Internet and television recipes
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History

Early examples

The earliest known recipes date from approximately 1600 BC and come from an Akkadian tablet from southern Babylonia.[1] There are also ancient Egyptian hieroglyphics depicting the preparation of food.[2]

Many ancient Greek recipes are known. Mithaecus's cookbook was an early one, but most of it has been lost; Athenaeus quotes one short recipe in his Deipnosophistae. Athenaeus mentions many other cookbooks, all of them lost.[3]

Roman recipes are known starting in the 2nd century BCE with Cato the Elder's De Agri Cultura. Many other authors of this period described eastern Mediterranean cooking in Greek and in Latin.[3] Some Punic recipes are known in Greek and Latin translation.[3]

The large collection of recipes *De re coquinaria*, conventionally entitled 'Apicius', appeared in the 4th or 5th century and is the only more or less complete surviving cookbook from the classical world.[3] It lists the courses served in a meal as 'Gustatio' (appetizer), 'Primae Mensae' (main course) and 'Secundae Mensae' (dessert).[4] It begins each recipe with the Latin command "Take...", *Recipe*....[5]

Arabic recipes are documented starting in the 10th century; see al-Warraq and al-Baghdadi.

King Richard II of England commissioned a recipe book called *Forme of Cury* in 1390,[6] and around the same

time another book was published entitled *Curye on Inglish*, "cury" meaning cooking.[7] Both books give an impression of how food for the noble classes was prepared and served in England at that time. The luxurious taste of the aristocracy in the Early Modern Period brought with it the start of what can be called the modern recipe book. By the 15th century, numerous manuscripts were appearing detailing the recipes of the day. Many of these manuscripts give very good information and record the re-discovery of many herbs and spices including coriander, parsley, basil and rosemary, many of which had been brought back from the Crusades.[8]

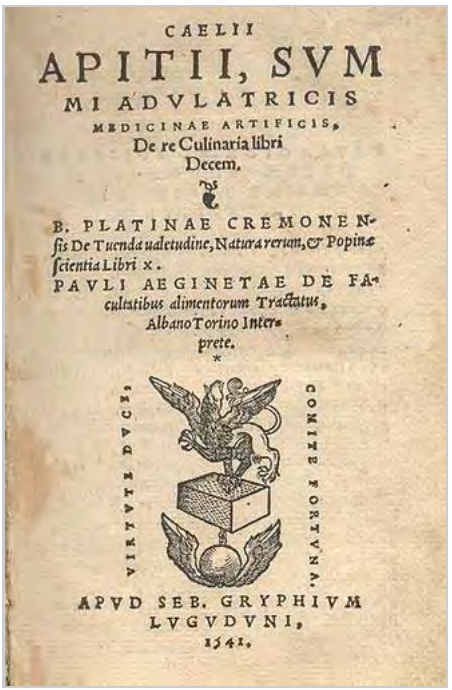
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PAVLI AEGINETAE DE FAcultatibus alimentorum Tractatus,
Albano Torino Interprete.
VIRTVTE DVCE, COMITE FORTVNA.
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1541.

Apicius, *De re culinaria*, an early collection of recipes.

Modern recipes and cooking advice

With the advent of the printing press in the 16th and 17th centuries, numerous books were written on how to manage households and prepare food. In Holland[9] and England[10] competition grew between the noble families as to who could prepare the most lavish banquet. By the 1660s, cookery had progressed to an art form and good cooks were in demand. Many of them published their own books detailing their recipes in competition with their rivals.[11] Many of these books have now been translated and are available online.[12]

By the 19th century, the Victorian preoccupation for domestic respectability brought about the emergence of cookery writing in its modern form. Although eclipsed in fame and regard by Isabella Beeton, the first modern cookery writer and compiler of recipes for the home was Eliza Acton. Her pioneering cookbook, *Modern Cookery for Private Families* published in 1845, was aimed at the domestic reader rather than the professional cook or chef. This was immensely influential, establishing the format for modern writing about cookery. It introduced the now-universal practice of listing the ingredients and suggested cooking times with each recipe. It included the first recipe for Brussels sprouts.[13] Contemporary chef Delia Smith called Acton "the best writer of recipes in the English language."[14] *Modern Cookery* long survived Acton, remaining in print until 1914 and available more recently in facsimile.

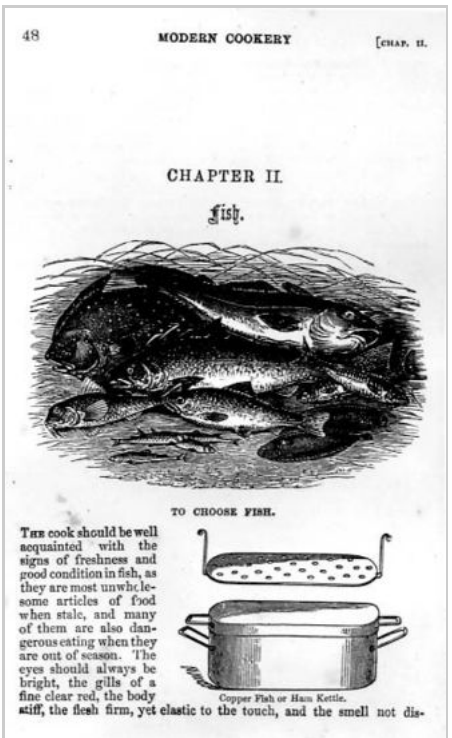
48 MODERN COOKERY [CHAP. II.

CHAPTER II.

Fish.

TO CHOOSE FISH.

The cook should be well acquainted with the signs of freshness and good condition in fish, as they are most unwholesome articles of food when stale, and many of them are also dangerous eating when they are out of season. The eyes should always be bright, the gills of a fine clear red, the body stiff, the flesh firm, yet elastic to the touch, and the smell not dis-

Copper Fish or Ham Kettle.

from *Modern Cookery for Private Families* by Eliza Acton (London: Longmans, Green, Reader, and Dyer, 1871. p.48.)

Acton's work was an important influence on Isabella Beeton,[15] who published *Mrs Beeton's Book of Household Management* in 24 monthly parts between 1857 and 1861. This was a guide to running a Victorian household, with advice on fashion, child care, animal husbandry, poisons, the management of servants, science, religion, and industrialism.[16][17] Of the 1,112 pages, over 900 contained recipes. Most were illustrated with coloured engravings. It is said that many of the recipes were plagiarised from earlier writers such as Acton, but the Beetons never claimed that the book's contents were original. It was intended as a reliable guide for the aspirant middle classes.

Titlepage of *Beeton's Book of Household Management*

The American cook Fannie Farmer (1857–1915) published in 1896 her famous work *The Boston Cooking School Cookbook* which contained some 1,849 recipes.[18]

Components

Modern culinary recipes normally consist of several components

- The name (and often the locale or provenance) of the dish
- How much time it will take to prepare the dish
- The required ingredients along with their quantities or proportions
- Necessary equipment and environment needed to prepare the dish
- An ordered list of preparation steps and techniques
- The number of servings that the recipe will provide (the "yield")
- The texture and flavor
- A photograph of the finished dish

An example recipe, printed from the Wikibooks Cookbook.

Some recipes will note how long the dish will keep and its suitability for freezing. Nutritional information, such as calories per serving and grams of protein, fat, and carbohydrates per serving, may also be given.

Earlier recipes often included much less information, serving more as a reminder of ingredients and proportions for someone who already knew how to prepare the dish.

Recipe writers sometimes also list variations of a traditional dish, to give different tastes of the same recipes.

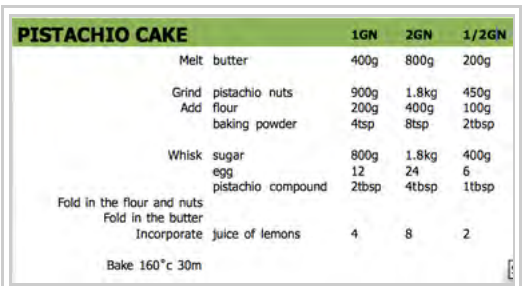

PISTACHIO CAKE		1GN	2GN	1/2GN
Melt	butter	400g	800g	200g
Grind	pistachio nuts	900g	1.8kg	450g
Add	flour	200g	400g	100g
	baking powder	4tsp	8tsp	2tbsp
Whisk	sugar	800g	1.8kg	400g
	egg	12	24	6
	pistachio compound	2tbsp	4tbsp	1tbsp
Fold in the flour and nuts				
Fold in the butter				
Incorporate	juice of lemons	4	8	2
Bake 160°c 30m				

Recipe with ingredients integrated into the method.

Internet and television recipes

By the mid 20th century, there were thousands of cookery and recipe books available. The next revolution came with the introduction of the TV cooks. The first TV cook in England was Fanny Cradock with a show on the BBC. TV cookery programs brought recipes to a new audience. In the early days, recipes were available by post from the BBC; later with the introduction of CEEFAX text on screen, they became available on television.

In the early 21st century, there has been a renewed focus on cooking at home due to the late-2000s recession.[19] Television networks such as the Food Network and magazines are still a major source of recipe information, with international cooks and chefs such as Jamie Oliver, Gordon Ramsay, Nigella Lawson and Rachael Ray having prime-time shows and backing them up with Internet websites giving the details of all their recipes. These were joined by reality TV shows such as Top Chef or Iron Chef, and many Internet sites

offering free recipes, but cookery books remain as popular as ever.[20]

Recipe design tools

Molecular gastronomy provides chefs with cooking techniques and ingredients, but this discipline also provides new theories and methods which aid recipe design. These methods are used by chefs, foodies, home cooks and even mixologists worldwide to improve or design recipes.

See also

- Cookbook
- Course (food)
- Culinary art
- hRecipe - a microformat for marking-up recipes in web pages
- List of desserts
- List of foods
- Rhyming recipe
- Desi Appetite

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Reclaimed water

From Wikipedia, the free encyclopedia

Reclaimed water or **recycled water**, is former wastewater (sewage) that is treated to remove solids and impurities, and used in sustainable landscaping irrigation, to recharge groundwater aquifers, to meet commercial and industrial water needs, and for drinking. The purpose of these processes is water conservation and sustainability, rather than discharging the treated water to surface waters such as rivers and oceans. In some cases, recycled water can be used for streamflow augmentation to benefit ecosystems and improve aesthetics.[1] One example of this is along Calera Creek in the City of Pacifica, CA.[2]

Samples of different types of (waste)water, starting with raw sewage then plant effluent and finally reclaimed water (after several treatment steps)

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Definition

Reclaimed waste can be defined as

> "The end product of wastewater reclamation that meets water quality requirements for biodegradable materials, suspended matter and pathogens."

[3] Simply stated, reclaimed water is water that is used more than one time before it passes back into the natural water cycle. Scientifically-proven advances in water technology allow communities to reuse water for many different purposes, including industrial, irrigation, and drinking. The water is treated differently depending upon the source and use of the water and how it gets delivered.

Cycled repeatedly through the planetary hydrosphere, all water on Earth is recycled water (http://athirstyplanet.com/your_h20/downstream), but the terms "recycled water" or "reclaimed water" typically mean wastewater sent from a home or business through a pipeline system to a treatment facility, where it is treated to a level consistent with its intended use. The water is then routed directly to a recycled water system for uses such as irrigation or industrial cooling.

Usage

There are examples of communities that have safely used recycled water for many years. Los Angeles County's sanitation districts have provided treated wastewater for landscape irrigation in parks and golf courses since 1929. The first reclaimed water facility in California was built at San Francisco's Golden Gate Park in 1932. The Water Replenishment District of Southern California was the first groundwater agency to obtain permitted use of recycled water for groundwater recharge in 1962. The Irvine Ranch Water District (IRWD) was the first water district in California to receive an unrestricted use permit from the state for its recycled water; such a permit means that water can be used for any purpose except drinking. IRWD maintains one of the largest recycled water systems in the nation with more than 400 miles serving more than 4,500 metered connections. The Irvine Ranch Water District and Orange County Water District in Southern California are established leaders in recycled water. Further, the Orange County Water District, located in Orange County, and in other locations throughout the world such as Singapore, water is given more advanced treatments and is used indirectly for drinking.[4]

In spite of quite simple methods that incorporate the principles of water-sensitive urban design (WSUD)[5] for easy recovery of stormwater runoff, there remains a common perception that reclaimed water must involve sophisticated and technically complex treatment systems, attempting to recover the most complex and degraded types of sewage. As this effort is driven by sustainability factors, this type of implementation should inherently be associated with point source solutions, where it is most economical to achieve the expected outcomes. Harvesting of stormwater or rainwater can be an extremely simple to comparatively complex, as well as energy and chemical intensive, recovery of more contaminated sewage.

Terminology

There is no one-size-fits-all solution to water reuse, but there are many safe and scientifically-proven options that allow communities to sustain their local water supplies. Below are terms scientists and water experts use to describe some of these reclaimed water options:

Reused water is water used more than once or recycled.

Potable water is drinking water.

Potable reuse refers to reused water you can drink.

Nonpotable reuse refers to reused water that is not used for drinking, but is safe to use for irrigation or industrial purposes.

De facto, unacknowledged or unplanned potable reuse occurs when water intakes draw raw water supplies downstream from discharges of treated effluent from wastewater treatment plants/water reclamation facilities or resource recovery facilities. For example, if you are downstream of a community, that community's used water (run-off and treated wastewater) gets put back into river or stream and is delivered downstream to your community and becomes part of your drinking water supply.

Effluent storage tank from where treated effluent (after constructed wetland) is pumped away for irrigation, Haran-Al-Awamied, Syria

Planned potable reuse is publicly acknowledged as an intentional project to recycle water for drinking water. It can be either direct or indirect. It commonly involves a more formal public process and public consultation program than is observed with de facto or unacknowledged reuse.

How potable reused water is delivered determines if it is called Indirect Potable Reuse or Direct Potable Reuse.

- **Indirect potable reuse** means the water is delivered to you indirectly. After it is purified, the reused water blends with other supplies and/or sits a while in some sort of storage, man-made or natural, before it gets delivered to a pipeline that leads to a water treatment plant or distribution system. That storage could be a groundwater basin or a surface water reservoir.
- **Direct potable reuse** means the reused water is put directly into pipelines that go to a water treatment plant or distribution system. Direct potable reuse may occur with or without "engineered storage" such as underground or above ground tanks.

Greywater uses the same waste as water reclamation with the exception of toilet water. Greywater can be used for irrigation, toilet flushing or other domestic uses.

Desalination is an energy-intensive process where salt and other minerals are removed from sea water to produce potable water for drinking and irrigation, typically through membrane filtration (reverse-osmosis), and steam-distillation.

Maximum water recovery - To determine maximum water recovery there are various techniques that have been developed by researchers; for maximum water reuse/reclamation/recovery strategies such as water pinch analysis. The techniques help a user to target the minimum freshwater consumption and wastewater target. It also helps in designing the network that achieves the target. This provides a benchmark to be used by users in improving their water systems.

Applications

Most of the uses of water reclamation are non potable uses such as: washing cars, flushing toilets, cooling water for power plants, concrete mixing, artificial lakes, irrigation for golf courses and public parks, and for hydraulic fracturing. Where applicable, systems run a dual piping system to keep the recycled water separate from the potable water.

New technologies for recycling allow the water to be used for fracking purposes and can save an estimated 4 - 7 million or more gallons per well.[6]

Cover for reclaimed water valve, San Francisco Water District

Potable uses

Some water agencies reuse highly treated effluent from municipal wastewater or resource recovery plants as a reliable, drought proof source of drinking water. By using advanced purification processes (https://www.watereuse.org/foundation/ways-of-water), they produce water that meets all applicable drinking water standards. System reliability and frequent monitoring and testing are imperative to them meeting stringent controls.

The water needs of a community, water sources, public health regulations, costs, and the types of water infrastructure in place, such as distribution systems, man-made reservoirs, or natural groundwater basins, determine if and how reclaimed water can be part of the drinking water supply. Communities in El Paso, Texas and Orange County, California, for example, reuse water to replenish groundwater basins. Others, such as the Upper Occoquan Service Authority in Virginia, put it into surface water reservoirs. In these instances the reclaimed water is blended with other water supplies and/or sits in storage for a certain amount of time before it is drawn out and gets treated again at a water treatment or distribution system. In some Texas communities, the reused water is put directly into pipelines that go to a water treatment plant or distribution system. In Singapore reclaimed water is called NEWater and is bottled directly from an advanced water purification facility for educational and celebratory purposes. Though most of the reused water is used for high-tech industry in Singapore, a small amount is returned to reservoirs for drinking water.

A 2012 study conducted by the National Research Council in the United States of America found that the risk of exposure to certain microbial and chemical contaminants from drinking reclaimed water does not appear to be any higher than the risk experienced in at least some current drinking water treatment systems, and may be orders of magnitude lower.[7] This report recommends adjustments to the federal regulatory framework that could enhance public health protection for both planned and unplanned (or de facto) reuse and increase public confidence in water reuse.

Modern technologies such as reverse osmosis and ultraviolet disinfection are commonly used when reclaimed water will be mixed with the drinking water supply. An experiment by the University of New South Wales reportedly showed a reverse osmosis system removed ethinylestradiol and paracetamol from the wastewater, even at 1000 times the expected concentration.[8]

Indirect potable reuse

Some municipalities are using and others are investigating Indirect Potable Reuse (IPR) of reclaimed water. For example, reclaimed water may be pumped into (subsurface recharge) or percolated down to (surface recharge) groundwater aquifers, pumped out, treated again, and finally used as drinking water. This technique may also be referred to as *groundwater recharging*. This includes slow processes of further multiple purification steps via the layers of earth/sand (absorption) and microflora in the soil (biodegradation).

Direct potable reuse

In a Direct Potable Reuse (DPR) scheme, water is put directly into pipelines that go to a water treatment plant or distribution system. Direct potable reuse may occur with or without “engineered storage” such as underground or above ground tanks. Communities in Texas have implemented DPR projects, and the state of California is studying the feasibility of developing DPR regulations.

Unplanned potable reuse

Water reuse occurs in various ways throughout the world. It happens daily on rivers and other water bodies everywhere. If you live in a community downstream of another, chances are you are reusing its water and likewise communities downstream of you are most likely reusing your water. Unplanned Indirect Potable Use[9] has existed even before the introduction of reclaimed water. Many cities already use water from rivers that contain effluent discharged from upstream sewage treatment plants. There are many large towns on the River Thames upstream of London (Oxford, Reading, Swindon, Bracknell) that discharge their treated sewage ("non-potable water") into the river, which is used to supply London with water downstream.

This phenomenon is also observed in the United States, where the Mississippi River serves as both the destination of sewage treatment plant effluent and the source of potable water. Research conducted in the 1960s by the London Metropolitan Water Board demonstrated that the maximum extent of recycling water is about 11 times before the taste of water induces nausea in sensitive individuals. This is caused by the buildup of inorganic ions such as Cl^-, $SO4^{2-}$, K^+ and Na^+, which are not removed by conventional sewage treatment.

Space travel

Wastewater reclamation can be especially important in relation to human spaceflight. In 1998, NASA announced it had built a human waste reclamation bioreactor designed for use in the International Space Station and a manned Mars mission. Human urine and feces are input into one end of the reactor and pure oxygen, pure water, and compost (humanure) are output from the other end. The soil could be used for growing vegetables, and the bioreactor also produces electricity.[10][11]

Aboard the International Space Station, astronauts have been able to drink recycled urine due to the introduction of the ECLSS system. The system costs $250 million and has been working since May 2009. The system recycles wastewater and urine back into potable water used for drinking, food preparation, and oxygen generation. This cuts back on the need for resupplying the space station so often.[12]

Design considerations

Distribution

Nonpotable reclaimed water is often distributed with a dual piping network that keeps reclaimed water pipes completely separate from potable water pipes. In the United States and some other countries, nonpotable reclaimed water is distributed in lavender (light purple) pipes to distinguish it from potable water.[13][14] The use of the color purple for pipes carrying recycled water was pioneered by the Irvine Ranch Water District in Irvine, California.

In many cities using reclaimed water, it is now in such demand that consumers are only allowed to use it on assigned days. Some cities that previously offered unlimited reclaimed water at a flat rate are now beginning to charge citizens by the amount they use.

Reclamation processes

A lavender-colored pipeline carrying nonpotable water.

Wastewater must pass through numerous systems before being returned to the environment. Here is a partial listing from one particular plant system:

- **Barscreens** - Barscreens remove large solids that are sent into a grinder. All solids are then dumped into a sewer pipe at a Treatment Plant.
- **Primary Settling Tanks** - Readily settable and floatable solids are removed from the wastewater. These solids are skimmed from the top and bottom of the tanks and sent to the Treatment Plant where it'll be turned into fertilizer.
- **Biological Treatment** - The wastewater is cleaned through a biological treatment method that uses microorganisms, bacteria which digest the sludge and reduce the nutrient content. Air bubbles up to keep the organisms suspended and to supply oxygen to the aerobic bacteria so they can metabolize the food, convert it to energy, CO_2, and water, and reproduce more microorganisms. This helps to remove ammonia also through nitrification.
- **Secondary Settling Tanks** - The force of the flow slows down as sewage enters these tanks, allowing the microorganisms to settle to the bottom. As they settle, other small particles suspended in the water are picked up, leaving behind clear wastewater. Some of the microorganisms that settle to the bottom are returned to the system to be used again.
- **Tertiary Treatment** - Deep-bed, single-media, gravity sand filters receive water from the secondary basins and filter out the remaining solids. As this is the final process to remove solids, the water in these filters is almost completely clear.
- **Chlorine Contact Tanks** - Three chlorine contact tanks disinfect the water to decrease the risks associated with discharging wastewater containing human pathogens. This step protects the quality of the waters that receive the wastewater discharge.

One of two procedures are then followed according to the future disposal site:

1. **Reclaimed Water Pump Station** - The pump station distributes reclaimed water to users around the City. This may include golf courses, agricultural uses, cooling towers, or in land fills.
2. Water is passed through high level purification to be returned to the environment. Currently this means a reverse osmosis system.

Treatment improvements

As world populations require both more clean water and better ways to dispose of wastewater, the demand for water reclamation will increase. Future success in water reuse will depend on whether this can be done without adverse effects on human health and the environment.

In the United States, reclaimed waste water is generally treated to secondary level when used for irrigation, but there are questions about the adequacy of that treatment. Some leading scientists in the main water society, AWWA, have long believed that secondary treatment is insufficient to protect people against pathogens, and recommend adding at least membrane filtration, reverse osmosis, ozonation, or other advanced treatments for

irrigation water.[15]

There have been recent advances in reverse osmosis in different countries, but have consistently produced very high quality water all the same. In Singapore, reclaimed water, also known as NEWater has become cleaner than the government issue tap water.[16] Also, according to Bartels, the Bedok Demonstration Plant, which uses RO membranes, has successfully run for the past 3 years, producing high quality wastewater all the while.[17]

Seepage of nitrogen and phosphorus into ground and surface water is also becoming a serious problem, and will probably lead to at least tertiary treatment of reclaimed water to remove nutrients in the future.[18] Even using secondary treatment, water quality can be improved. Water quality can also be improved as it passes through the subsurface mixing zone where surface water and groundwater combine.[19] Testing for pathogens using Polymerase Chain Reaction (PCR) instead of older culturing techniques, and changing the discredited fecal coloform "indicator organism" standard would be improvements.

In a large study[20] treatment plants showed that they could significantly reduce the numbers of parasites in effluent, just by making adjustments to the currently used process. But, even using the best of current technology, risk of spreading drug resistance in the environment through wastewater effluent, would remain.

Some scientists have suggested that there need to be basic changes in treatment, such as using bacteria to degrade waste based on nitrogen (urine) and not just carbonaceous (fecal) waste, saying that this would greatly improve effectiveness of treatment.[21] Currently designed plants do not deal well with contaminants in solution (e.g. pharmaceuticals). "Dewatering" solids is a major problem. Some wastes could be disposed of without mixing them with water to begin with. In an interesting innovation, solids (sludge) could be removed before entering digesters and burned into a gas that could be used to run engines.[22]

Emerging disinfection technologies include ultrasound, pulse arc electrohydraulic discharge, and bank filtration.[23] Another issue is concern about weakened mandates for pretreatment of industrial wastes before they are made part of the municipal waste stream.[24] Some also believe that hospitals should treat their own wastes. The safety of drinking reclaimed water which has been given advanced treatment and blended with other waters, remains controversial.

In recent years, as hydraulic fracturing of oil and gas formations has become more and more common place, new technologies for water recycling have emerged. One such technology uses a combination of ozone and electrocoagulation. This process removes organics, hydrocarbons, spent polymers, chemical additives used in the fracturing process, and heavy metals such as barium, iron, boron and more.[6]

Alternatives

Seawater desalination

In urban areas where climate change has threatened long-term water security and reduced rainfall over catchment areas, using reclaimed water for indirect potable use may be superior to other water supply augmentation methods. One other commonly used option is seawater desalination. Recycling wastewater and desalinating seawater may have many of the same disadvantages, including high costs of water treatment, infrastructure construction, transportation, and waste disposal problems. Although the best option varies from region to region, desalination is often superior economically, as reclaimed water usually requires a dual piping network, often with additional storage tanks, when used for nonpotable use.

Greywater systems

A less elaborate alternative to reclaimed water is a greywater system. Greywater is wastewater that has been used in sinks, baths, showers, or washing machines, but does not contain sewage (see blackwater) and has not been treated at the same levels as recycled water. In a home system, treated or untreated greywater may be used to flush toilets or for irrigation.[25] Some systems now exist which directly use greywater from a sink to flush a toilet.[26][27]

Rainwater harvesting

Perhaps the simplest option is a rainwater harvesting system. Although there are concerns about the quality of rainwater in urban areas, due to air pollution and acid rain, many systems exist now to use untreated rainwater for nonpotable uses or treated rainwater for direct potable use. Urban design systems which incorporate rainwater harvesting and reduce runoff are known as Water Sensitive Urban Design (WSUD) in Australia, Low Impact Development (LID) in the United States and Sustainable urban drainage systems (SUDS) in the United Kingdom. There are also concerns about rainwater harvesting systems reducing the amount of run-off entering natural bodies of water.

Health aspects

Reclaimed water is highly engineered for safety and reliability so that the quality of reclaimed water is more predictable than many existing surface and groundwater sources. Reclaimed water is considered safe when appropriately used. Reclaimed water planned for use in recharging aquifers or augmenting surface water receives adequate and reliable treatment before mixing with naturally occurring water and undergoing natural restoration processes. Some of this water eventually becomes part of drinking water supplies.

A water quality study published in 2009 compared the water quality differences of reclaimed/recycled water, surface water, and groundwater.[28] Results indicate that reclaimed water, surface water, and groundwater are more similar than dissimilar with regard to constituents. The researchers tested for 244 representative constituents typically found in water. When detected, most constituents were in the parts per billion and parts per trillion range. DEET (a bug repellant), and Caffeine were found in all water types and virtually in all samples. Triclosan (in anti-bacterial soap & toothpaste) was found in all water types, but detected in higher levels (parts per trillion) in reclaimed water than in surface or groundwater. Very few hormones/steroids were detected in samples, and when detected were at very low levels. Haloacetic acids (a disinfection by-product) were found in all types of samples, even groundwater. The largest difference between reclaimed water and the other waters appears to be that reclaimed water has been disinfected and thus has disinfection by-products (due to chlorine use).

A 2005 study titled "Irrigation of Parks, Playgrounds, and Schoolyards with Reclaimed Water" found that there had been no incidences of illness or disease from either microbial pathogens or chemicals, and the risks of using reclaimed water for irrigation are not measurably different from irrigation using potable water.[29] Studies by the National Academies of Science,[30] the Monterey Regional Water Pollution Control Agency,[31] and others[32] have found reclaimed water to be safe for agricultural use.

Testing standards

Reclaimed water is not regulated by the Environmental Protection Agency (EPA), but the EPA has developed water reuse guidelines that were most recently updated in 2012.[33] The EPA Guidelines for Water Reuse

represents the international standard for best practices in water reuse. The document was developed under a Cooperative Research and Development Agreement between the U.S. Environmental Protection Agency (EPA), the U.S. Agency for International Development (USAID), and the global consultancy CDM Smith. The Guidelines provide a framework for states to develop regulations that incorporate the best practices and address local requirements.

Ongoing wastewater research sometimes raise concerns about pathogens in the water.[34] Many pathogens cannot be detected by currently used tests.[35]

Recent literature also questions the validity of testing for "indicator organisms" instead of pathogens.[36] Nor do present standards consider interactions of heavy metals and pharmaceuticals which may foster the development of drug resistant pathogens in waters derived from sewage.[37]

To address these concerns about the source water, reclaimed water providers use multi-barrier treatment processes and constant monitoring to ensure that reclaimed water is safe and treated properly for the intended end use.

Potable use

Many humans associate a feeling of disgust with reclaimed water and 13% of a survey group said they would not even sip it.[38] Nonetheless, the main health risk for potable use of reclaimed water is the potential for pharmaceutical and other household chemicals or their derivatives (Environmental persistent pharmaceutical pollutants) to persist in this water.[39] This would be of much less concern if the population were to keep their excrement out of the wastewater[39] e.g. via the use of the Urine-diverting dry toilet or systems that treat blackwater separately from greywater.

Environmental aspects

There is debate about possible health and environmental effects. To address these concerns, A Risk Assessment Study (http://athirstyplanet.com/real_life/valuable_research/reuse_safe) of potential health risks of recycled water and comparisons to conventional Pharmaceuticals and Personal Care Product (PPCP) exposures was conducted by the WateReuse Research Foundation. For each of four scenarios in which people come into contact with recycled water used for irrigation - children on the playground, golfers, and landscape, and agricultural workers - the findings from the study indicate that it could take anywhere from a few years to millions of years of exposure to nonpotable recycled water to reach the same exposure to PPCPs that we get in a single day through routine activities.

Using reclaimed water for non-potable uses saves potable water for drinking, since less potable water will be used for non-potable uses.[40]

It sometimes contains higher levels of nutrients such as nitrogen, phosphorus and oxygen which may somewhat help fertilize garden and agricultural plants when used for irrigation.

The usage of water reclamation decreases the pollution sent to sensitive environments. It can also enhance wetlands, which benefits the wildlife depending on that eco-system. It also helps to stop the chances of drought as recycling of water reduces the use of fresh water supply from underground sources. For instance, The San Jose/Santa Clara Water Pollution Control Plant instituted a water recycling program to protect the San Francisco Bay area's natural salt water marshes.[40]

Costs and evaluation

Estimates indicate that just 3% of the Earth's water is freshwater, and that 1/8 of the Earth's human population do not have access to freshwater resources.[38] The cost of reclaimed water exceeds that of potable water in many regions of the world, where a fresh water supply is plentiful. However, reclaimed water is usually sold to citizens at a cheaper rate to encourage its use. As fresh water supplies become limited from distribution costs, increased population demands, or climate change reducing sources, the cost ratios will evolve also. The evaluation of reclaimed water needs to consider the entire water supply system, as it may bring important value of flexibility into the overall system [41]

History

Storm and sanitary sewers were necessarily developed along with the growth of cities. By the 1840s the luxury of indoor plumbing, which mixes human waste with water and flushes it away, eliminated the need for cesspools. Odor was considered the big problem in waste disposal and to address it, sewage could be drained to a lagoon, or "settled" and the solids removed, to be disposed of separately. This process is now called "primary treatment" and the settled solids are called "sludge."

At the end of the 19th century, since primary treatment still left odor problems, it was discovered that bad odors could be prevented by introducing oxygen into the decomposing sewage. This was the beginning of the biological aerobic and anaerobic treatments which are fundamental to waste water processes.

By the 1920s, it became necessary to further control the pollution caused by the large quantities of human and industrial liquid wastes which were being piped into rivers and oceans, and modern treatment plants were being built in the US and other industrialized nations by the 1930s.[42]

Designed to make water safe for fishing and recreation, the Clean Water Act of 1972 mandated elimination of the discharge of untreated waste from municipal and industrial sources, and the US federal government provided billions of dollars in grants for building sewage treatment plants around the country. Modern treatment plants, usually using oxidation and/or chlorination in addition to primary and secondary treatment, were required to meet certain standards.[43]

Current treatment improves the quality of separated wastewater solids or sludge. The separated water is given further treatment considered adequate for non potable use by local agencies, and discharged into bodies of water, or reused as reclaimed water. In places like Florida, where it is necessary to avoid nutrient overload of sensitive receiving water, reuse of treated or reclaimed water can be more economically feasible than meeting the higher standards for surface water disposal mandated by the Clean Water Act[24]

Examples

Non-potable reuse (NPR)

- Austin, Texas[44]
- Caboolture and Maroochy (South East Queensland, Australia) LGA's currently provide reclaimed water for industrial use (primarily capital works). Users must apply for a key to be able to access the compounds in which the outlets are located.[45]
- Clark County, Nevada[46]

- Clearwater, Florida[47]
- Contra Costa County, California[48]
- Melbourne, Australia[49]
- Mount Buller Ski resort uses recycled water for snow making.
- San Antonio[50] operates the largest recycled water system in the United States.
- Sydney, Australia[51]
- Tucson, Arizona[52]
- San Diego, California (San Diego County)[53]
- St. Petersburg, Florida[54]

Indirect potable reuse (IPR)

- Big Spring, Texas indirect potable reuse program[55]
- Orange County, California[56][57]
- Pasadena, California[58]
- Singapore[38] (where it is branded as *NEWater*)
- Payson, Arizona[59]
- The Torreele project in the Veurne coastal region of Belgium, which began operating in 2002[60]
- Virginia Occoquan Reservoir - The Upper Occoquan Sewage Authority plant discharges its highly treated output to supply roughly 20% of the inflow into the Occoquan Reservoir, which provides drinking water used by the Fairfax County Water Authority - one of the three major water providers in the Washington, D.C. metropolitan area.
- Windhoek, Namibia[61][38]
- Wichita Falls, Texas (toilet-to-tap reuse as a temporary measure during drought conditions, 2014-2015;[55] Indirect potable use 2015)[62]

Proposed

In some places, reclaimed water has been proposed for either potable or non-potable use:

- South East Queensland, Australia (planned for potable use as of late 2010)[63][64]
- Newcastle, New South Wales, Australia (proposed for non-potable use as of 2006).[65]
- Canberra, Australian Capital Territory, Australia (proposed in January 2007 as a backup source of potable water)[66]
- Los Angeles, California - By 2019, the Los Angeles Department of Water and Power will build a plant to replenish their groundwater aquifer with purified water[67] in order to deal with the shortage of rain and snow fall, restricted water imports and local groundwater contamination.[68]
- San Diego, California (San Diego County)[38]

Israel

As of 2010, Israel leads the world in the proportion of water it recycles.[69] Israel treats 80% of its sewage (400 billion liters a year), and 100% of the sewage from the Tel Aviv metropolitan area is treated and reused as irrigation water for agriculture and public works. The remaining sludge is currently pumped into the Mediterranean, however a new bill has passed stating a conversion to treating the sludge to be used as manure.

Only 20% of the treated water is lost (due to evaporation, leaks, overflows and seeping). The recycled water allows farmers to plan ahead and not be limited by water shortages. There are many levels of treatment, and many different ways of treating the water—which leads to a big difference in the quality of the end product. The best quality of reclaimed sewage water comes from adding a gravitational filtering step, after the chemical and biological cleansing. This method uses small ponds in which the water seeps through the sand into the aquifer in about 400 days, then is pumped out as clear purified water. This is nearly the same process used in the space station water recycling system, which turns urine and feces into purified drinking water, oxygen and manure.

To add to the efficiency of the Israeli system - the reclaimed sewage water may be mixed with reclaimed sea water (Plans are in action to increase the desalinization program up to 50% of the countries usage by 2013 - 600 billion liters of drinkable sea water a year), along with aquifer water and fresh sweet lake water - monitored by computer to account for the nationwide needs and input. This action reduced the outdated risk of salt and mineral percentages in the water. Plans to implement this overall usage of reclaimed water for drinking are discouraged by the psychological preconception of the public for the quality of reclaimed water, and the fear of its origin. As of today, all the reclaimed sewage water in Israel is used for agricultural and land improvement purposes.

U.S.

The leaders in use of reclaimed water in the U.S. are Florida and California,[70] with Irvine Ranch Water District (http://www.irwd.com/Reclamation/index.php) as one of the leading developers. They were the first district to approve the use of reclaimed water for in-building piping and use in flushing toilets.

In a January 2012 U.S. National Research Council report,[71] a committee of independent experts found that expanding the reuse of municipal wastewater for irrigation, industrial uses, and drinking water augmentation could significantly increase the United States' total available water resources.[72] The committee noted that a portfolio of treatment options is available to mitigate water quality issues in reclaimed water. The report also includes a risk analysis that suggests the risk of exposure to certain microbial and chemical contaminants from drinking reclaimed water is not any higher than the risk from drinking water from current water treatment systems—and in some cases, may be orders of magnitude lower. The report concludes that adjustments to the federal regulatory framework could enhance public health protection and increase public confidence in water reuse.

Australia

As Australia continues to battle the 7–10-year drought, nationwide, reclaimed effluent is becoming a popular option. Two major capital cities in Australia, Adelaide and Brisbane, have already committed to adding reclaimed effluent to their dwindling dams. The former has also built a desalination plant to help battle any future water shortages. Brisbane has been seen as a leader in this trend, and other cities and towns will review the Western Corridor Recycled Water Project once completed. Goulbourn, Canberra, Newcastle, and Regional Victoria, Australia are already considering building a reclaimed effluent process.

European Union

The second largest waste reclamation program in the world is in Spain, where 12% of the nation's waste is treated. [73]

According to an EU-funded study, "Europe and the Mediterranean countries are lagging behind" California,

Japan, and Australia "in the extent to which reuse is being taken up." According to the study "the concept (of reuse) is difficult for the regulators and wider public to understand and accept."[60]

See also

- Atmospheric water generator
- Desalination
- Dual piping
- Greywater
- Irrigation
- Living machines
- Water conservation
- NEWater
- Sewage treatment
- Water Pinch
- WateReuse

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External links

- World Health Organization
  - *Guidelines for the safe use of wastewater, excreta and greywater* Volume 1: Policy and regulatory aspects (http://apps.who.int/iris/bitstream/10665/78265/1/9241546824_eng.pdf)
  - *Guidelines for the safe use of wastewater, excreta and greywater* Volume 2: Wastewater use in agriculture (http://www.who.int/water_sanitation_health/publications/gsuweg2/en/)
  - *Guidelines for the safe use of wastewater, excreta and greywater* Volume 3: Wastewater and excreta use in aquaculture (http://www.who.int/water_sanitation_health/publications/gsuweg3/en/)
  - *Guidelines for the safe use of wastewater, excreta and greywater* Volume 4: Excreta and greywater use in agriculture (http://www.who.int/water_sanitation_health/publications/gsuweg4/en/)
- Waterwise (http://waterwise.org.uk) A nonprofit non-governmental Organization dedicated to promoting the wise use of water.
- WateReuse (http://www.watereuse.org/?assoc&wra) A nonprofit Organization whose mission is to advance the beneficial and efficient use of water resources using reclamation, recycling, reuse, and

desalination.

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Categories: Water conservation | Water supply | Irrigation | Water and politics | Water and the environment | Water treatment | Sewerage | Sustainable technologies | Sustainable gardening | Sustainable agriculture | Organic farming | Organic gardening | Landscape architecture | Recycling by material | Reuse | Hydrology and urban planning

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Light Meter Recommendations

(2/11/2017)

Light meters capable of down to 0.01 Lux can be found for around $20 and up.

Examples of 0.01 Lux light meters are:
HYELEC MS6612 Digital Lux Meter 3%
MASTECH MS6612 Digital Lux Meter 3%
TES1330A Digital Lux Meter
TES1334A Digital Lux Meter

Or you can make a useable very sensitive light meter from digital volt meter that will measure to at least 2 or 20 meg-ohms and a good photo resistor. Like the GL5528 LDR Light Dependent Resistor at 5mm in size. Harbor freight sells digital volt meter (Cen-Tech 61593) for under $30 or the Cen-Tech 92020 that sells for under $10. This approach will measure relative intensive and will not be calibrated unless one has a calibrated Lux meter to compare to.

Now if one adds a 270nm Short Pass 12.5 mm uv filter (found on eBay) then one can measure the range of UVC or ultraviolet light that is normally used for germicidal and water purification lamps. It is as close to the 297 nm needed for the body to make Vitamin-D that was able to be found at a reasonable (price around $30). The Idea is this might be useful for testing light sources to make sure that they can produce D and for determining when the sun comes back enough to use for this purpose.

This UVC light sensor (shown on the right above) was made using (front to back) a fender washer with a ¼” hole in it, then the UV pass ban filter then the photo resistor. This was embedded in black foam rubber. Enough black tape was used on the outside to keep light from coming in form the side. Sun light being very high intensity parallel waves from one direction was used to test for leakage by slowing turning the sensor to different direction and watching the ohm meter.

See the following curves for typical values for full sunlight pre-pole sift day and the resistance found when testing for UVC using the same photo resistor light sensor and a 270 nm pass ban filter.

It was found that during days just after a rain where the sun was brightest that the UVC band of light frequency gave a maximum light intensity of about 87,000 ohms and at time would range to a lower intensity of about 110,000 ohms. So 90 to 100 k-ohms was about

average for a average maximum intensity of UVC light from the sun. The following shows the resulting calibration curve for the GL5528 and GL5506 LDR Light Dependent Resistors and ohm meter when compared to several off the shelf Lux meters. One measured the full spectrum maximum light of the sun at 156000 Lux and the other showed 126000 Lux.

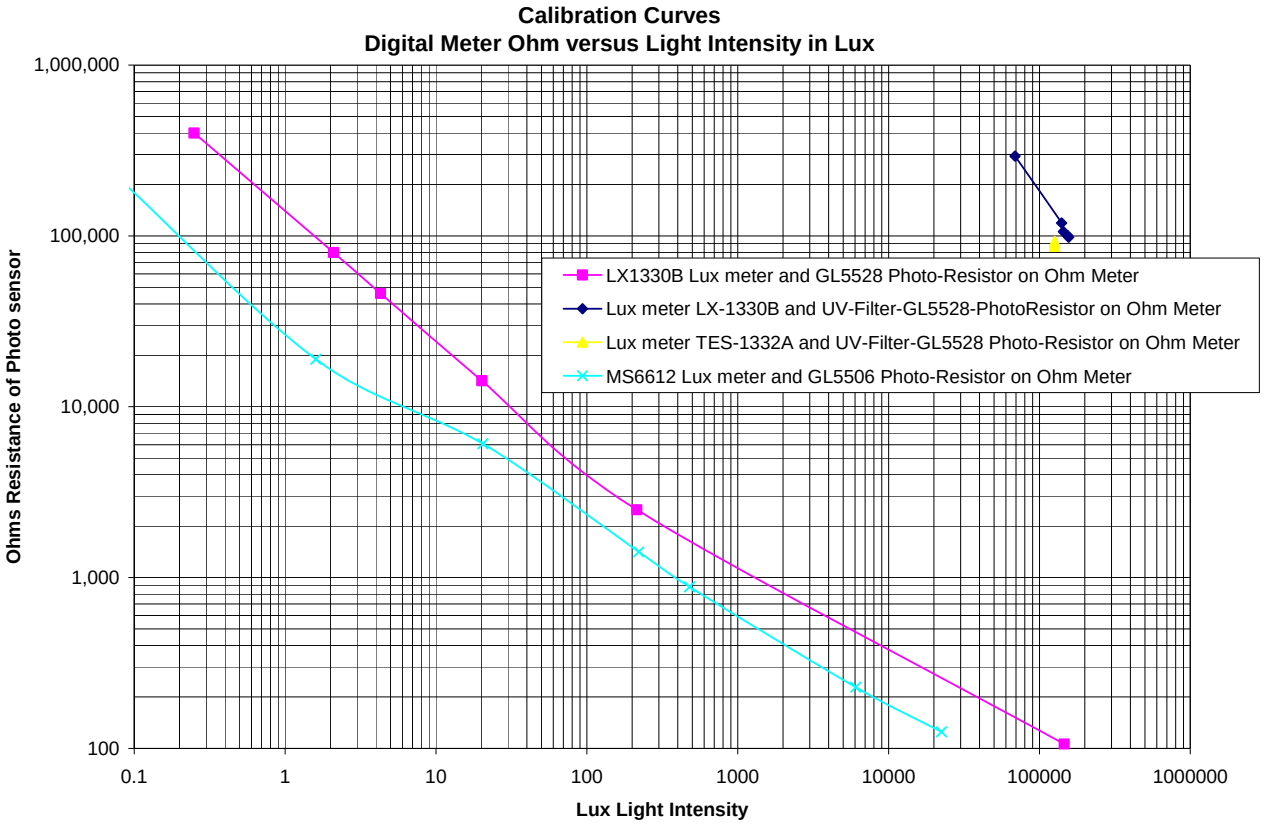

Photo resistor GL5506 works better for measuring low light intensities. For accuracy one needs to do ones own testing. For there is a wide range of different ohm values for the same model photo resistors, with each individual having a different calibration results.

See the following file for details on how to produce vitamin-D.

"UV_Light_Needed_for_Vitamin-D_Production_to_Keep_Bones_Healthy-2017.pdf"

Plant
pH Preference Range
Lists by Category

Why pH Is Important To Plant Growth

Soils are known as "sweet" if they are alkaline and "sour" if they are acid. Values of pH 7.0 indicate a neutral soil; above pH 7.0 is alkaline and below pH 7.0 is an acid soil. Most soils are within a range of highly acidic pH 4 to alkaline at pH 7.5 to 8.

If you wish to grow plants not suited to the pH of your soil, you can change the pH. You can make an acid soil more alkaline by adding lime. Slightly acid soils can be made more acidic by adding peat, iron sulphate or flowers of sulfur. It is, however, more difficult to lower pH in an alkaline, lime-rich soil than it is to raise pH.

pH is important in plant growth because it affects the availability of plant foods and prevents the spread of soil borne diseases. Check it regularly, at least twice a year, as nature tends towards the acid side.

Working with your soil, not against it, will help you achieve more successful results. Any changes you make in pH should be small in scale, 1/2 to 1 point in either direction at the maximum. Don't try to go straight from a 4.0 soil to a 7.0 soil in one season.

Raising and lowering pH is not an exact science and most plants have a reasonably wide tolerance, certainly to within 1 full pH point. Check the lists of plant pH preferences below and you will see that the majority can manage well on a pH around 6.5... and many have a wide tolerance for different pH levels. But there are also many plants that only thrive in a very narrow pH range, so if your plants aren't as healthy as you think they should be, check the pH range below, then test your soil.

Vegetables & Herbs	Preferred pH Range
Artichoke	6.5 - 7.5
Asparagus	**6.0 - 8.0**
Basil	5.5 - 6.5
Bean	**6.0 - 7.5**
Beetroot	6.0 - 7.5
Broccoli	**6.0 - 7.0**
Brussels	6.0 - 7.5
Cabbage	**6.0 - 7.5**
Calabrese	6.5 - 7.5
Carrot	**5.5 - 7.0**
Cauliflower	5.5 - 7.5

Fruit Variety	Preferred pH Range
Apple	5.0 - 6.5
Apricot	**6.0 - 7.0**
Avocado	6.0 - 7.5
Banana	**5.0 - 7.0**
Blackberry	5.0 - 6.0
Cherry	**6.0 - 7.5**
Cranberry	5.5 - 6.5
Currant, Black	**6.0 - 8.0**
Currant, Red	5.5 - 7.0
Currant, White	**6.0 - 8.0**
Damson	6.0 - 7.5

Flowers, Ornamental Trees, & Shrubs	Preferred pH Range
Abelia	6.0 - 8.0
Acacia	**6.0 - 8.0**
Acanthus	6.0 - 7.0
Aconitum	**5.0 - 6.0**
Adonis	6.0 - 8.0
Ageratum	**6.0 - 7.5**
Ailanthus	6.0 - 7.5
Ajuga	**4.0 - 6.0**
Althea	6.0 - 7.5
Alyssum	**6.0 - 7.5**

Celery	**6.0 - 7.0**
Chicory	5.0 - 6.5
Chinese Cabbage	**6.0 - 7.5**
Chives	6.0 - 7.0
Corn, Sweet	**5.5 - 7.5**
Cress	6.0 - 7.0
Courgettes	**5.5 - 7.0**
Cucumber	5.5 - 7.5
Fennel	**5.0 - 6.0**
Garlic	5.5 - 7.5
Ginger	**6.0 - 8.0**
Horseradish	6.0 - 7.0
Kale	**6.0 - 7.5**
Kohlrabi	6.0 - 7.5
Leek	**6.0 - 8.0**
Lentil	5.5 - 7.0
Lettuce	**6.0 - 7.0**
Marjoram	6.0 - 8.0
Marrow	**6.0 - 7.5**
Millet	6.0 - 6.5
Mint	**7.0 - 8.0**
Mushroom	6.5 - 7.5
Mustard	**6.0 - 7.5**
Olive	5.5 - 6.5
Onion	**6.0 - 7.0**
Paprika	7.0 - 8.5
Parsley	**5.0 - 7.0**
Parsnip	5.5 - 7.5
Pea	**6.0 - 7.5**
Peanut	5.0 - 6.5
Pepper	**5.5 - 7.0**
Peppermint	6.0 - 7.5
Pistacio	**5.0 - 6.0**
Potato, Sweet	4.5 - 6.0
Potato	**5.5 - 6.0**

Gooseberry	**5.0 - 6.5**
Grapevine	6.0 - 7.0
Grapefruit	**6.0 - 7.5**
Hazelnut	6.0 - 7.0
Hop	**6.0 - 7.5**
Lemon	6.0 - 7.0
Lychee	**6.0 - 7.0**
Mango	5.0 - 6.0
Melon	**5.5 - 6.5**
Mulberry	6.0 - 7.5
Nectarine	**6.0 - 7.5**
Papaw	6.0 - 7.5
Peach	**6.0 - 7.5**
Pear	6.0 - 7.5
Pineapple	**5.0 - 6.0**
Plum	6.0 - 7.5
Pomegranate	**5.5 - 6.5**
Quince	6.0 - 7.5
Raspberry	**5.0 - 6.5**
Rhubarb	5.5 - 7.0
Strawberry	**5.0 - 7.5**
Watermelon	5.5 - 6.5

Houseplants & Greenhouse Plants	**Preferred pH Range**
Abutilon	5.5 - 6.5
Acorus	**5.0 - 6.5**
Aechmea	5.0 - 5.5
African Violet	**6.0 - 7.0**
Aglaonema	5.0 - 6.0
Amaryllis	**5.5 - 6.5**
Anthurium	5.0 - 6.0
Aphelandra	**5.0 - 6.0**
Araucaria	5.0 - 6.0

Amaranthus	6.0 - 6.5
Anchusa	**6.0 - 7.5**
Androsace	5.0 - 6.0
Anemone	**6.0 - 7.5**
Anthyllis	5.0 - 6.0
Arbutus	**4.0 - 6.0**
Arenaria	6.0 - 8.0
Aristea	**6.0 - 7.5**
Armeria	6.0 - 7.5
Arnica	**5.0 - 6.5**
Asperula	6.0 - 8.0
Asphodoline	**6.0 - 8.0**
Aster	5.5 - 7.5
Aubrieta	**6.0 - 7.5**
Avena	6.0 - 7.5
Azalea	**4.5 - 6.0**
Beauty Bush	6.0 - 7.5
Bergenia	**6.0 - 7.5**
Bluebell	6.0 - 7.5
Broom	**5.0 - 6.0**
Buddleia	6.0 - 7.0
Buphthalum	**6.0 - 8.0**
Calendula	5.5 - 7.0
Camassis	**6.0 - 8.0**
Candytuft	6.0 - 7.5
Canna	**6.0 - 8.0**
Canterbury Bells	6.0 - 7.5
Carnation	**6.0 - 7.5**
Catalpa	6.0 - 8.0
Celosia	**6.0 - 7.0**
Centaurea	5.0 - 6.5
Cerastium	**6.0 - 7.0**
Chrysanthemum	6.0 - 7.0
Cissus	**6.0 - 7.5**
Cistus	6.0 - 7.5

Pumpkin	5.5 - 7.5
Radish	**6.0 - 7.0**
Rice	5.0 - 6.5
Rosemary	**5.0 - 6.0**
Sage	5.5 - 6.5
Shallot	**5.5 - 7.0**
Sorghum	5.5 - 7.5
Soybean	**5.5 - 6.5**
Spearmint	5.5 - 7.5
Spinach	**6.0 - 7.5**
Swede	5.5 - 7.0
Thyme	**5.5 - 7.0**
Tomato	5.5 - 7.5
Turnip	**5.5 - 7.0**
Watercress	6.0 - 8.0

Asparagus Fern	**6.0 - 8.0**
Aspidistra	4.0 - 5.5
Azalea	**4.5 - 6.0**
Begonia	5.5 - 7.0
Bird Of Paradise	**6.0 - 6.5**
Bishop's Cap	5.0 - 6.0
Black-eyed Susan	**5.5 - 7.5**
Blood Leaf	5.5 - 6.5
Bottlebrush	**6.0 - 7.5**
Bougainvillea	5.5 - 7.5
Bromeliads	**5.0 - 7.5**
Butterfly Flower	6.0 - 7.5
Cacti	**4.5 - 6.0**
Calceolaria	6.0 - 7.0
Caladium	**6.0 - 7.5**
Calla Lily	6.0 - 7.0
Camellia	**4.5 - 5.5**
Campanula	5.5 - 6.5
Capsicum	**5.0 - 6.5**
Cardinal Flower	5.0 - 6.0
Castor Oil Plant	**5.5 - 6.5**
Century Plant	5.0 - 6.5
Chinese Primrose	**6.0 - 7.5**
Christmas Cactus	5.0 - 6.5
Cineraria	**5.5 - 7.0**
Clerodendrum	5.0 - 6.0
Clivia	**5.5 - 6.5**
Cockscomb	6.0 - 7.0
Coffee Plant	**5.0 - 6.0**
Coleus	6.0 - 7.0
Columnea	**4.5 - 5.5**
Coral Berry	5.5 - 7.5
Crassula	**5.0 - 6.0**
Creeping Fig	5.0 - 6.0
Croton	**5.0 - 6.0**
Crown Of Thorns	6.0 - 7.5

Clarkia	**6.0 - 6.5**
Clianthus	6.0 - 7.5
Clematis	**5.5 - 7.0**
Colchicum	5.5 - 6.5
Columbine	**6.0 - 7.0**
Convolvulus	6.0 - 8.0
Coreopsis	**5.0 - 6.0**
Coronilla	6.5 - 7.5
Corydalis	**6.0 - 8.0**
Cosmos	5.0 - 8.0
Cotoneaster	**6.0 - 8.0**
Crab Apple	6.0 - 7.5
Crocus	**6.0 - 8.0**
Cynoglossum	6.0 - 7.5
Daffodil	**6.0 - 6.5**
Dahlia	6.0 - 7.5
Day Lily	**6.0 - 8.0**
Delphinium	6.0 - 7.5
Deutzia	**6.0 - 7.5**
Dianthus	6.0 - 7.5
Dogwood	**5.0 - 7.0**
Edelweiss	6.5 - 7.5
Elaeagnus	**5.0 - 7.5**
Enkianthus	5.0 - 6.0
Erica	**4.5 - 6.0**
Euphorbia	6.0 - 7.0
Everlasting Flower	**5.0 - 6.0**
Firethorn	6.0 - 8.0
Forget-me-not	**6.0 - 8.0**
Forsythia	6.0 - 8.0
Foxglove	**6.0 - 7.5**
Fritillaria	6.0 - 7.5
Fuchsia	**5.5 - 6.5**
Gaillardia	6.0 - 7.5
Gazania	**5.5 - 7.0**
Gentiana	5.0 - 7.5

Cuphea	**6.0 - 7.5**	**Geum**	**6.0 - 7.5**
Cyclamen	6.0 - 7.0	Gladiolus	6.0 - 7.0
Cyperus	**5.0 - 7.5**	**Globularia**	**5.5 - 7.0**
Dieffenbachia	5.0 - 6.0	Godetia	6.0 - 7.5
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For more info see:
http://homeharvest.com/plantphpreference.htm

Recommended Items to have on hand for after PS use

Meters:
Digital multi-meter
Soil ph tester digital or analog
Ph meter digital hand held
Light meter
Wood moisture meter for measuring fire wood
Water TDS (total dissolved solids) Meter to measure water hardness.
Non-contact and contact type RPM meter for wind and water power
RF output or power meter

Recommended to use only NiMH Low Self-Discharge Batteries

For AA and AAA sizes: purchase only emb Low Self-Discharge from HobbyPartz.com
http://www.hobbypartz.com/77p-recharge-aa-2200-8pcs.html
http://www.hobbypartz.com/77p-recharge-aaa-800-8pcs.html

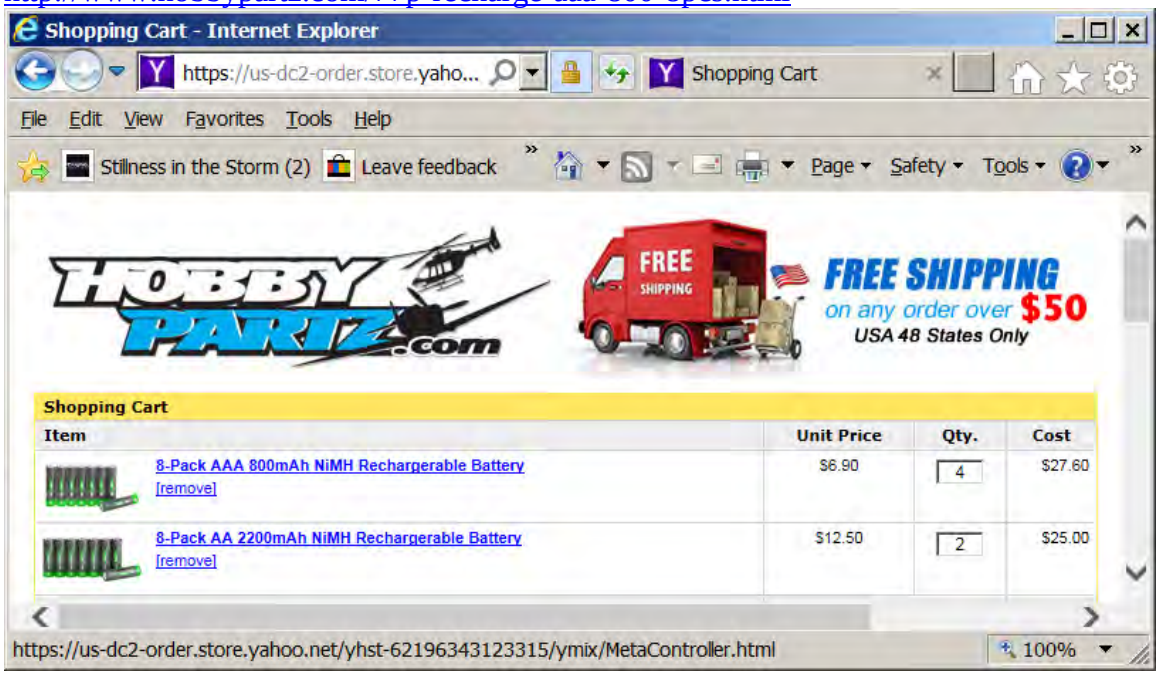

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Purchase as you can afford and use these 3 sizes as your standards for portable devices such as meters, flashlights, and etc.

Small farms

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Reconstruction by Way of the Soil

by

G.T. Wrench

Faber and Faber Ltd
24 Russell Square
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This book by Dr. Wrench enters a field very different from that of his *Wheel of Life* and challenges judgment and criticism of a different kind. It is nothing less than an outline history of the relation between civilization and the soil: which means that it is not only a brief universal history of agriculture but much more besides. No work of scholarship could be devoted to a purpose more useful to mankind at any time, and at the present time none could fill a more urgent need. There is, we believe, nothing of the kind in existence;

and if there were it would be out of date, since so vast a quantity of new and important knowledge on the subject has lately become available.

Dr. Wrench has the advantage of many years' experience of agrobiological affairs in this country and in India. He gives us here a series of brief histories and striking examples of the effects of civilizations upon their primary biological resources. He first states the essential principles of sound agronomy; then he gives examples of their fulfilment or violation in China, Mesopotamia, the Roman Empire and in Islamic Spain; in England through the centuries, in Africa since the coming of the Europeans, in Egypt and India and the Dutch Empire, in the British Dominions and colonies, in the U.S.S.R. and in the U.S. A. to-day. Dr. Wrench's plea for the recognition of natural laws in the symbiosis of soil and civilization is supported by impressive evidence; and his thesis is of the first importance, not only to agronomists, but to students of politics and to all who are concerned with the future of our damaged civilization.

To
Lord Northbourne

My friend is that one whom I can associate with my choicest thought. -- Thoreau

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Acknowledgements

In the construction of this book, I am indebted to many living authors, whose words I have quoted in my text. Amongst them, I feel I owe an especial tribute and apology to Mrs. Elspeth Huxley for the use I have made of her book *The Red Strangers*, a tribute in my immeasurable admiration for her exquisite story, an apology in that, being in India, I have not been able personally to visit her to explain my enforced encroachment.

In my faith in primary value of the soil I have been greatly strengthened by the books of two honoured friends, the Earl of Portsmouth's *Alternative to Death* and Lord Northbourne's *Look to the Land*.

The Earl's book, published in 1943, has only recently reached me. With a general outlook closely similar to my own, the author has something which I do not possess, namely, an intimate, personal knowledge of all that pertains to the soil of Britain. His book constitutes the comprehensive guide for which all workers, determined to give a sane, terrene basis to our national life, have been looking.

Lord Northbourne's book was published in 1940, and it has been my frequent companion

in the three years which I have taken in the actual writing of this book. Lord Northbourne has also helped me in ways surpassing the usual kindness of friendship. He has taken full charge of the typescript of the book in England, and, by a careful study of the text, has assisted me with most acceptable criticisms.

Lastly, I desire to thank my friend, Dr. Haji Kassim, for his great help in the compilation of the twenty-first and twenty-second chapters.

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Chapter 1

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Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 1

Introductory

It will be clear to a reader, who, like a prospector sampling a face of rock, runs his eye down the page of Contents of this book, that its subject is a general one. It is, indeed, widespread both in space and time, yet in spite of its generality it cannot be said to be widely recognized; so little so, in fact, that to not a few it will appear a new subject. Men, under the advanced differentiation of the present, are apt to think of themselves as finished products, as soldiers, merchants, sailors, engineers, lawyers and so on; to speculate on what they, one and all, actually are, seldom occupies many of them for more than a few casual brevities of time.

Nevertheless, now that they are involved in a supreme crisis, now that, however complete victory may be, the future cannot be the replica of the past, it is inconceivable that men will not be forced to face fundamental questions, such as, in previous times of habit and routine, they were able to avoid.

They have already come to learn that this age, so distinguished for its scientific progress and its widespread knowledge has, in spite of these advantages, completely failed in its promise of peace and prosperity. Even in such vital social problems as feeding and employment, it has failed and failed signally. Men, who have now been forced to experience in their own persons, and therefore to reflect upon these two problems, are astounded that their settlement has been so definitely brought about by war. Where peace failed, war succeeded. The will of the people and the skill of organization have assured all of their share in the national food, and those who do hard manual labour can reckon on sufficient energy being given to them by their allowance to accomplish their work without the weariness that results from a partial starvation in essential foods. Why, then, is war so much juster in these respects than peace? What is lacking in times of peace, that comes

into being in times of war? Is it that under the supreme strain of war against a powerful and ruthless enemy there arises in the homeland a peace, goodwill, and indeed a veritable brotherhood of man, which displaces the greedy competition, the covert hostility and the social barriers of peace that destroy the best qualities of country, blood and language? Does our civilization need war to make a decency of human conduct prevail?

Many answers have been given to these and kindred questions, but in order to look at them afresh, it is proposed in this book to review conditions, both historical and immediate, with a vision untarnished by the pride of the present, the pride attached to that in which one's ego has its being. This is a hard saying, for all are tarred with the same brush, and none can claim impartiality exempting him from his heritage and the prejudice of circumstance.

Yet, if we are to enjoy a better communal and individual life after the war than before it, the attempt has to be made with the probity it demands.

To introduce the attempt is the object of this opening chapter, and to make this beginning we will try to look at men, not as final products, not as labourers, merchants, shopmen and the rest, not as rich and poor, sick and healthy, wise and foolish, but as they are, all and each, inseparably linked together in a common likeness, which will pervade the chapters of this book. This likeness is that they are all feeding animals, getting, mostly and daily, their life from the products of the soil. Like other forms of life, vegetable and animal, men are dependent for their existence upon the crust of the globular earth on which they live.

Men, however, possess a marked peculiarity which distinguishes them from other forms of earthly life. It is this -- that they alone have been able to make themselves partners in the creative power of the soil. They alone are agriculturists or farmers, whereby they assure themselves the constancy of their food, clothing and other primal necessities in place of having to trust to the gifts of chance. They alone, amidst terrene life, have acquired a quota of mastery in creation.

In this ability to take a part in the creation of their necessities, men have gained something more than a repetitive increase of their food. They have gained an understanding, dim though it may be, of a relation between themselves and the powers which rule the universe and that minute part of it on which they live. They realize that to be partners in creation, they have to submit themselves to the unavoidable autocracy of these powers; they have to be, in their own language, creatures of the Creator, and as such, however headstrong and dominant they may be over weaker forms of life than theirs, they are, nevertheless, like them limited by the laws of their existence. Upon the basis of limitation, they are inevitably compelled to shape their individual and social lives. Should they transgress, they or their descendants are inevitably punished.

These rules and restrictions, under which mankind lives, are those of the nature of life and death. Life and death are the two essential conditions of terrene existence; they are the two

different phases of this existence. The living ceases to be what is called living, but it is not lost to the cycle of existence but remains within it as a necessary part of it. In the condition which is called dead, matter is commonly in the soil or will eventually reach it. That which, by its life, has often had the power to lift itself from the crust of the earth, now returns to that crust. There it plays an essential part in promoting further life. In a word, there is no actual death as a permanent thing. There is a suspension of life. Death itself is but a phase of life, in which the dead matter returns to the soil, where it is reformed into living matter again. *There is nothing that has once taken life from the soil, that will not, by reaching the soil, again become living.* The dead leaf, that we see lying on the path at our feet, is not dead in the sense of being finished. Let it lie, and, through the creative agency of the soil, its substance will again enter into a blade of grass, a flower, an insect, bird or animal and so return to the kingdom of the living.

Life and death are, therefore, not separate entities, but phases of each other. The living has to respect the dead as a part of itself, not finally dead but living, and this respect has been expressed in the religious mind of man by various forms of reverence in which the innate eternity of life in its most highly developed form, that of the human soul, is recognized.

When man does not interfere and the soil is left to itself, it does not fail. Through it everything that has passed from a state of life is restored again to a state of life; nothing fails or is lost. In the philosophy of modern science, however, the seeds that lie scattered upon the ground and do not fructify are stigmatized as failures, but those that grow into plants are dubbed the fittest, because they survive and expand into plants. Yet the other seeds survive no less; they re-enter cycles of life by other paths. Some even enter the very plants to which their fellow-seeds have given rise. So, for example, every one of the countless seeds of the elm that bestrew the ground in early summer, as well as the fittest surviving as elm plants, are not failures in the symphony of nature. In a musical symphony, each note, even the lowest and lowliest, *fits*. It is not a question of the fittest excluding or making superfluous the remainder. That is a wholly false outlook upon the processes of terrene life. Each has its place without which the whole is incomplete. Each has its place in a creative cycle, each passes from soil to plant and then, in many cases, to animal, and, after an interlude of death, returns to the creative realm of soil.

This is the symphony of nature and creation to which men as terrene animals are inevitably bound and yet not wholly bound. Though they themselves are products of the soil, yet through the possession of their intellect, they have become co-creators and, in their limited human sphere, fashioned in the image of the Creator. They can produce life other than their own. To do this in accord with the processes of creation, they must themselves be continuous and limited in production; they must act in harmony with the process as it exists on earth apart from them. Here they have to *fit*. They have to act within a process of balance. In it the living as a whole is balanced by the dead as a whole. In the living itself, its chief forms, vegetable and animal, balance each other. They are interdependent, and are incomplete without each other. In the exchange of vegetable and animal life with the enveloping atmosphere, a similar balance is effected. It has to be

regarded as a whole of balanced parts and therefore partakes, in human phraseology, of the character of art. Nothing in it is isolated, everything belongs to the pattern. From this art of fitting within the whole, certain consequences necessarily follow. Wholeness or health -- two words of a like origin and meaning -- is one consequence.

This wholeness as a consequence has to be proved. Though it seems logical enough, yet little has been done to prove it in an age of unprecedented speed and discovery, of immense progress at a constantly expanding periphery, which by distance has almost shut men's ultimate terrenity from their vision.

We are to-day no longer whole or healthy physically or mentally. In the careful work of the Peckham investigators it has been established that the vast majority of us are subnormal. We seem to have broken away from the great primary fact of our existence, namely, that we are first and foremost *terrene animals*, and, until we regain that fact and put it into practice, we cannot expect our social and individual lives to be whole. Our civilization, threatened with destruction as we know it to be, has to be *healed* -- another word meaning whole -- and to be healed it has to be overhauled and *reconstructed in its relation to the soil that provides it with the means of existence*.

This was the task that in dim outline presented itself to the author when, as a medical student, he was appalled by the crowded gatherings of the out-patient department of a large London hospital. 'Why disease? What then is health?' were the questions that often vexed him. To answer them he had not the opportunity, nor the tenacity which truly great men have in pursuing an object that is to them a consuming passion and for which they will forgo the pleasures of life, and end -- God knows how often -- in destitution and despair. For that heroic life he had not courage, but the questions did not entirely leave him, and it was when he had leisure in which to retire for a space of years, brought to an end by the war, that he was able to gather material for the answer to this *first question of correct terrene being*: 'Is there a relation of man to the soil which assures his health?'

The answer came as a decided yes, and in the instances he was able to gather, he found that a group of men could acquire health if they gave to the soil, from which they lived, all the food and water it required, and if they did not weaken it by exceeding the limits of the creative powers which nature had allotted to it.

His chief lesson he gained from a little, shut-away people called the Hunza, to whom he was attracted by what Sir Robert McCarrison, who knew them well, wrote of them: 'They are long lived, vigorous in youth and age, capable of great endurance and enjoy a remarkable freedom from disease in general.'

His further inquiries opened out a prospect of intense interest and even beauty such as their own mountain valley, amidst the vast mountains of the Karakoram in North-west India, possessed. He found that they pursued a close attention to the soil, which strangely enough, seemingly related them to a time of the golden age of agriculture. As a

strengthening of this supposition, he found that their present farming recalled to that most cultured of mountaineers, the late Lord Conway, the unsurpassed farming of pre-Spanish Peru, the remnants of which he had seen and which caused another well-cultured explorer of these gigantic relics, Mr. O. F. Cook of the Bureau of Plant Industry of the U.S.A. Department of Agriculture, to exclaim: 'Agriculture is not a lost art, but must be reckoned as one of those which reached a remarkable development in the remote past and afterwards declined.' The glowing pages of Prescott's second chapter in the *Conquest of Peru* seem to shine again amidst this little people, huddled between the highest congress of great mountains that uprises from our globe.

The author found that this people meticulously preserved the rule of return; they were, indeed, the source of the understanding of the ultimate nature of the soil and man and of the warp and woof of life and death, to which he has referred a few pages back. Nothing that once got life from the Hunzas' soil was ever wasted but all, from the least fleck of wool, the fallen leaf, the broken nutshell, to human refuse itself, was gathered and, after suitable preparation, returned to the soil for its food. He found that the Hunzas paid the same heed to water, which, by means of their principal aqueduct, the Berber -- itself famous far beyond the limit of their own small country -- they brought with its silt from a glacier snout to their terraced fields. Of the Berber, Lord Conway wrote: 'The Alps contain no *Wasserleitung* which for volume and boldness of position can be compared to the Hunza canal. It is a wonderful work for such a toolless people as the Hunzakats to have accomplished, and it must have been done many centuries ago and maintained ever since, for it is the life-blood of the valley.' Here, too, they were like the people of Peru, of whose water-ways, stretching for hundreds of miles athwart the slopes and precipices of mountains, Prescott wrote: 'That they should have accomplished these difficult works with such tools as they possessed is truly wonderful.'

The words 'many centuries ago' led the author to further inquiries. He found that Professor N. I. Vavilov, of the Institute of Applied Botany, Leningrad, had discovered that the area of which the Hunza Valley forms a part 'is one of the most important primary world agricultural centres, where the diversity of a whole series of plants have originated'. The people of ancient Peru, according to Mr. Cook, also produced a wonderful series of plants in the secluded valleys of the Andes and so made them the most important originating agricultural centre in America.

Here, then, within the precincts of British-supervised India, was a people who brought quite a marvellous message from the remote past, a past that justifies the tradition of the Golden Age, a past of perfect relations between men and the soil. The Hunzas had created a symphony of nature. As each note, however humble, has its proper place in a symphony of Beethoven, so even the humblest fallen leaf, each drop of water have their place in the symphony of Hunza. The author learnt from its example that the work of the Hunza, too, was an art in its original sense from *aro*, to 'fit'. *He learnt that farming is an art and something infinitely wider than scientific agriculture. It is a way of life itself.*

So much for health, such health and the constant cheerfulness of wholeness, which the Hunza now enjoy. There are many other examples of this health still extant on the globe, all of them in places remote from our Western civilization. To those who are attracted by this, at present, novel meaning of genuine health, the author unblushingly commends his little book of a hundred and forty-odd pages, *The Wheel of Health*, in which these examples are also recorded. It is an essential subject to understand for any who feel the need of a reconstruction by way of the soil.

Nevertheless, it cannot be gainsaid that such small and remote examples are scarcely likely to have much effect on those upon whom this reconstruction by way of the soil is now urged. It seems that one is doomed to stir one's readers by the negative proof of the devastation and sickness that the modern era has brought to the soil and the feeders of its products, rather than by isolated proofs of wholeness, health, cheerfulness and well-being.

Before, however, entering upon the long path of negative proof, there presents itself a second positive element of construction, which is complementary to the meticulous care of the soil. This is the form in which the men of that meticulous care served the soil. The form was that of family farming.

The family as a group is but a human complement of the soil itself, both family and soil recreating life. The family is human continuity and the soil is vital continuity. Continuity of the family necessitates marriage as the mode of the bond of the woman to the soil; marriage bringing sons and daughters to the service of the land. It is the land that gave its particular meaning to the farming family; it is its creative power that united itself with the creation of the farmers' children. Marriage, the bearing of children, the apprenticeship of children, the respect of children for their parents and their ancestors, the care that is bestowed by the elders on the present generation because it is to repeat itself in future generations, all this wholeness of life finds its true significance in continuous family ownership or inherited right to the land. It is, then, the land as family property, or in lesser and more dependent degree, the craft as family property, requiring the work of the family for their continuity, which primarily gives stability to men and women making a people.

This right the people of ancient Peru possessed. Their self-governing communities or *ayullus*, settled in ownership of limited areas of land, existed from remote antiquity. They were the basis of the autocratic state, and they themselves constituted an agrarian communism collectively holding the land. The uniting of the *ayullus* was effected by the rulership of the principal *ayullu* or royal family community. By far the majority, too, of the Hunza families -- and the Hunza are also an ancient people -- are freeholders, subject in their unity to the rulership of the Mir. The greatest of these peoples of family farming are our allies, the Chinese. Their empire is by far the most stable and continuous in the world's history and it was originally founded in the long distant past upon family property or right to the land.

It was to their revered sages that the Chinese have always attributed their Tsing Tien

system, the system of the nine fields. A square of land was divided by drawing two lines across it from side to side and two up and down, as in the nursery game of noughts and crosses. Nine squares were thereby formed, eight outer and one central square. The eight outer squares of land were allotted to eight families, the centre square was worked co-operatively and its produce given to the government officials as a tax in kind.

This division into nine squares was symbolic of the principles of the sages. Where it could be, it was, no doubt, carried out. But it was not rigid. The soil is not so similar in character that it can be divided with such exactness. One square might be less readily cultivated than another; one family might be larger than another. So adjustments were made; for example, if one family had several and another no sons, one or more sons of the first might be adopted by the second family. Adaptations were made, but the principal and standard measurements remained. It was considered by the sages as the principle of choice for the reasons that it promoted co-operation, close social relations, mutual production, easy exchange of commodities, unified customs, saving of individual expenses, and it related the work and life of the families to the officials of the nation by the work which the combined families undertook on the central field. This central field could also be adjusted within limits; it could be enlarged or diminished according to the general fortune of the province or nation.

The nine squares within a square symbolized a simple planning and basis of life, which, without doubt, as opposed to change, progress and instability, produced a stability now inconceivable to our Western minds trained in its opposites. We have been accustomed to regard it as stagnation. Since we have become confused and disillusioned with progress and the disasters which it has brought and with which it further threatens almost all mankind including the Chinese people themselves, we have come to think of them historically with more interest and approval, but nevertheless as something so distant and foreign to us that their methods and history cannot really affect us.

Yet, if nature is limited, if man cannot pass certain boundaries or exceed certain controls without entering upon generations of disaster and even human extinction, then some such stable system as that of the Chinese takes upon itself a very different aspect in the measure of human wisdom. It may be that it will then appear as a natural human system, in scale and endurance the greatest achievement in the partnership of intelligent man and nature upon the earth. It was one that long ago attained a certain finality, a completion such as a great art work, a great cathedral or temple reaches. The building needs care, love and daily attendance and sometimes renovation, but it cannot be made more beautiful. It reaches its excellence and, though time may make it more revered and loved, its very excellence shows that it had, from the very beginning, a power of duration within it. A great art has this duration. It is not subject to frequent change as is science. Changes fail to improve it. Recasting a symphony of Beethoven would not make it more but less beautiful, but the devotion with which it is played supports its beauty as human generations pass.

It is in this sense that we should, I believe, try to estimate and understand the Tsing Tien

system. It is a national thing on a great scale *that has kept within the limits imposed by nature*. Through this system the Chinese sages produced and continued a productivity from the soil unexcelled elsewhere, and, from humanity, a community of peasant-family farmers, the largest in numbers, the most skilful, the most contented and the most peaceful amongst the peoples of mankind. The Chinese have, of course, had their misfortunes and occasional catastrophes. They have been beset by people without any settled system such as they enjoyed. Large landowners have from within sometimes destroyed the rights of the peasants, but the Tsing Tien system has been the thread upon which has been threaded period after period of their long history. 'The whole history of government administration of agriculture in China', writes Dr. Ping-Hua Lee, in Volume 99 of the *Studies in History* of the Columbia University, 'coincides with the history of the Tsing Tien system, for it started with this system of land tenure. Its vicissitudes, its crises and epochs were timed by the abolition or re-establishment of the system ... It is fortunate for the economic historian that the history of the Tsing Tien system is coincident with China's political history.'

Thus in the small body of the Hunza and in the large body of the Chinese, much broken by the near past and present havoc, we have rare survivals, instances of skilled and continuous life within the limits that are set by nature and the land; a fitting of skilled mankind into the life-cycle.

The Chinese had not the stupendous secluding mountain wall of the Hunza, but as far as men's power could reach, they made such a wall, the Great Wall fortress, stretching for 1,500 miles to shut out the Tartar. They had not the control of their water supplies from their sources as had the Peruvians and the Hunza; the floods of their great rivers have their origins in huge ranges of stripped hills mostly outside their control. Yet in spite of these foes of secured stability, their system endured until it was finally worn down by the constant attrition of contact with the West. Although it has been the West and its ways that have broken up this system of stability, nevertheless sufficient of it is known, owing to the Chinese historical habit, to see in it the supreme example of the Wisdom of the East in contrast to the Science of the West. The Tsing Tien has been the chief historical system of a human partnership with the soil. In it was secured for century after century the comprehensive range of both the minuteness and grandeur of this partnership, which has by no Western writer been better expressed than by the well-known words of Hasbach in his unique *History of the English Agricultural Labourer*, 1920. 'Trifles', he wrote, 'are the very objects of the small cultivator; he has everything near him and under his eye, makes use of every small advantage, cultivates every corner, has the help of his wife, and brings up his children to be the most useful the country produces. Such men serve the land as it should be served, never stinting themselves, and as absorbed in their service as any priest in his religion.' Upon this basis stable civilizations of conservation have been and can be built.

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Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 2

Rome

Rome and its civilization constitute the progenitors of the civilized Western world; consequently, without a knowledge of Rome's relation to the soil, it would not be possible for us to extract from history the principles of reconstruction from the soil.

We have to study history, because in no other way can we tell what the Roman land was like and how it looked. History reveals that if, by some magic, we could transport ourselves back to the days of the early Latin farmers, we should see a picture of a well-populated countryside with the land divided up into a number of small farms, often not exceeding five acres in extent. As each small farm had to support a family, the farming, we should see, was intensive; in other words, each particle of soil would be in use, so that the fields appeared quite crowded with a variety of crops. The whole food of the family would come from the farm, and not only the food of the family, but that of some of its domestic animals. By day we should see the various members of the family hard at work upon the farm, the males -- and sometimes females -- busy upon the land itself, and the womenfolk in the home and dairy. We should see also a large number of villages with a pleasant light of prosperity shining upon them. Other things would also be there of great importance, soon to be described, some of which could be seen, and some found under the earth.

Then let us be allowed to look at the same land some five centuries later. The picture is now quite different. We should see but few villages and few small farms, and upon the farms we should see what farmers call foul fields and even land that was derelict. In place of the small farms we should see mainly orchards, vineyards and dairy farms. It would, indeed, be quite clear to us that the main object of this different form of farming was to supply fruit, grapes, olives, milk and cheese to people who did not work upon the farms or

in the villages at all, but who lived in the proud, neighbouring city that had now become the chief city of all Italy and was soon to become the capital of the Mediterranean world. We should also see that these estates were no longer worked by Latin farmers, but by quite a different sort of men, clearly not Italians, and men lacking the buoyancy and freedom of the older farmers. We should, indeed, have reason to rub our eyes, for some of these men, incredible though it might seem to us, would be shackled with iron and some even chained to each other while they worked. These were the slaves, some of whom were strong, fierce men and some weak and depressed. These two pictures we should see; the first would be that of family farming, the second that of capitalistic farming.

Transporting ourselves to a yet later date, we should see a third picture. The land is now swampy and derelict, and its most significant product swarms of mosquitoes, which caused the fevers that permitted only a few wretched men and cattle to scrape together some sort of livelihood and that visited, with lethal effect, the inhabitants of the great but waning city itself. This would be the picture of debased soil fertility.

Now let us see how history explains these three pictures.

Of the farming of their ancestors in Latium the later Romans had no history. Nevertheless, a strong tradition existed, and that tradition placed both farming and farmers very high. In the words of the elder Cato, to call a man a good farmer was in the past the best commendation, the highest praise.

Now this praise in the pages of *De Agricultura* must have been read a host of times without more than a general significance or regretful sentiment being attached to it. But modern discovery has shown that it had a very sound, practical significance. The high esteem of the men of ancient Latium for good farming and the facts concomitant with it were not sentimental; they have been summed up under these words: 'It is impossible, after surveying such elaborate undertakings, to avoid the conclusion that Latium in the sixth century (B.C.) was cultivated with an intensity that has seldom been equalled anywhere.' This is the statement of a modern authority. In short, *the tradition of the later Romans about the wonderful farming of their ancestors was not founded upon sentiment, but upon fact*. By the time of Cato and later writers, a good deal of sentiment had entered and a good deal of fact had slipped away. These later Romans knew that their ancestors had been great farmers, but they do not seem to have known the greatest part of their work. That has been revealed by modern investigators and particularly by the excavations of Monsieur M. R. L. la Blanchère, published in 1893 in *Mémoires présentes par divers savants à l'Académie des Inscriptions et Belles Lettres*. Professor Tenny Frank, the above-quoted authority in *An Economic History of Rome*, 1927, summarizes this remarkable paper, which can be itself read in the library of the British Museum. The excavations reveal that Latium was the home of a farming which it might well be said, has seldom been equalled anywhere. It was a farming related to the great farming of ancient Peru, the farming of Asia Minor in its prolific days, the farming in which Professor Vavilov researches, the farming of the Hunza, the farming indeed of many or even all great

countries of the world in a time when farming reached a height from which almost all of them later fell so steeply as to have become oblivious to it.

Professor Tenny Frank begins his book on the economic story of Rome where it should begin, namely, in the soil of Latium. On the one hand, that soil was singularly rich, rich as the loess soil of the Chinese and the alluvial soil of the Egyptians were rich. It had not their depth, but it had the exceptional contribution of the ash of some fifty craters, which are within twenty miles of Rome. On the other hand, it was placed in a perilous situation if men were to neglect it. It was a wide band or plain, the Campagna, situated between the sea and the steep Alban and Apennine mountains. Upon these mountains rain at certain seasons fell heavily. When there were trees on the slopes, then the rain in its fall was broken by leaf, twig and branch into a spray before reaching the soil. Where the trees were cut down freely or where the slopes were too steep for them to grow, the storm-rain reached the earth to beat upon it and send muddy freshets sweeping down to the plain. The short rivers between the mountains and the sea became torrents loaded with silt. Sometimes their mouths and the direct discharge of the water to the sea were blocked and swamps took the place of well-drained land.

Farming in this country, therefore, depended above all on one great feature of farming, proper drainage. Against heavy rain falling upon precipitous hills, men had to protect the soil if they were to be great farmers of it. The men of the Latium were great farmers and they accomplished astonishing things.

Monsieur la Blanchère, excavator in Latium, revealed in part what the farmers did. He found an extensive engineering system of water-control and drainage, numerous relics of drains, tunnels and dams. 'By diverting the rain waters from the eroding mountain gullies into underground channels', writes Professor Frank, 'the farmers not only checked a large part of the ordinary erosion of the hillside farms, but also saved the space usually sacrificed to the torrent-bed. It would be difficult to find another place where labour had been so lavishly expended to preserve the arable soil from erosion.' Noting the finely trimmed polygonal masonry of the dams, largely made of blocks weighing half a ton each, the professor adds: 'It, is impossible, after surveying such elaborate undertakings, to avoid the conclusion that Latium in the sixth century B.C. was cultivated with an intensity that has seldom been equalled anywhere.'

The men of Latium, later to be known after their capital city as Romans, began their unequalled story with a *tremendous, vital force*, that of an exceptional and well-treasured soil. One can immediately realize the vigorous and profound respect for farmers and farming which characterized the Roman poets, prose writers and statesmen of much later ages, and their looking backward to their ancestors as men of exceptional fibre and character derived from their farming. They looked back to something exceptional in seeking for the origin of the firm strength of Rome.

These great farmers, who protected their land from the torrential invasions of the climate,

had also to protect it against the invasions of human beings, not neighbours merely, but those who had come over the Alps and Apennines in search of land. The farmers then proved themselves great warriors. Farmer and warrior contended within them, but as successes in war grew, so the warrior factor transcended that of the farmer, and the type of farming changed. The number of small farmers, able to keep themselves and their families well on less than five acres of intensive farming, decreased. From the point of view of the soil, indeed, the story of Latium, Rome and its empire, was largely a race between warriors gaining land by conquest and exploitation, and farmers losing it by enforced, inferior ways of farming and by erosion. But amongst the splendour of Rome's achievements, this basic quality of her story has hardly been perceived. The rebelling soil was there all the time, and, in the end, it was the rebellious soil that broke the strength of the warrior.

It is very understandable that, if farmers were liable to be called up for national service as warriors, intensive, personal farming suffered. The farms could not be kept in good condition when many of the men, who worked upon them, were away at the wars.

This drain began with the wars the Romans fought in or about Latium, but it only became critical at the time of the terrific struggle of Rome against Carthage and particularly as the result of the fifteen years of Hannibal's warfare within Italy itself. That led to an immense destruction, not only of the farmer-warriors themselves, but of water-channels, drainage, farm buildings, roads, bridges, trees and other props of intensive farming.

When the war was over, the government of the victorious but exhausted Romans was faced with the question of the reconstruction of the land.

Now at the same time that this question became paramount in Roman Italy, it also became paramount in China. The Chinese Empire of that time was situated in the middle part of the Huang Ho (known to us as the Yellow River) basin and the great territories on either side of it. To protect his empire against the warriors of the Tartars, the famous Chinese Emperor, Chin Chi Huangti, resolved to build a huge, fortified wall. To build it, he had to procure vast numbers of labourers and these he had to take from the land. So he abolished the Tsing Tien system and the inalienability of the land, which was the essential part of it, turned the peasants from their holdings and sold the land to all able and willing to buy. In both the Roman dominion and that of Chin Chi Huangti the land was the chief source of wealth. The rich men, therefore, readily bought the land of the dispossessed peasant families. So, after the second Punic War in Italy and the building of the Great Wall in China, the rulers of Italy and the rulers of China were faced with the same question, a question *the most momentous perhaps of all questions in the final story of mankind upon the earth*: Shall the *common* form of farming be by owners of small holdings or shall it be that of large estates owned by a small class of wealthy men?

The Chinese chose the former method. The great Chin Chi Huangti lived out his day, but immediately after his strong hand had been removed by death, revolt broke out, his son

was slain and the Han Dynasty (202 B.C.-A.D. 220) brought with it the long struggle between the imperial ministers, who aimed at the restoration of the Tsing Tien system of small family holders, and the new aristocracy of large landowners of Chin Chi Huangti. The struggle was long and bitter, but in the end, save for some large estates which the land itself dictated as needful, the Tsing Tien system was restored.

This restored also the Wisdom of the East, for the direct relation of the great majority of Chinese subjects to the creative soil was the ultimate basis of the Wisdom of the East.

In Italy the same struggle occurred. It was also prolonged and bitter, but always, if slowly, success turned away from small family ownership.

In the peace that followed the conflict with Hannibal, the Roman statesmen strove to turn the current back to the traditional ways of their forefathers, but Rome's conquests and the great influx of foreign slaves to work the land in the place of the dispossessed peasants, in addition to the injury to the soil wrought by the war, weighed heavily in favour of the wealthy classes. To all the land was the chief source of wealth. There were, at that time, no large manufacturing towns, and little commerce, for, in the words of Professor Tenny Frank, 'the ancient world has no record of any state of importance so unconcerned about its commerce as was the Roman Republic'. On the other hand, in favour of the small landowners, was the firmly rooted belief that those who worked upon the land were also the finest warriors and the chief strength of Rome's military power.

The great Roman writers were fully aware of this. Cato the Censor (234-149 B.C.) staunchly maintained that it was the farmers and tillers of the soil who made the best citizens and bravest soldiers. Varro (116-27 B.C.) voiced the same conviction that country life in its form of peasant-farming was the chief strength of the State. Cicero eulogized the farmer-citizens, who left the plough to save the State, and used his unequalled art to protect working farmers, whose extinction was threatened by the growth of wealthy proprietors. Virgil used the persuasion of poetry to exalt the culture of the land by the hands which possessed it. Horace, like the greater poet, proclaimed the older type of farming as the best. Columella, at the time of the Emperors Claudius and Nero (A.D. 41-68), declaimed against the poverty of the land, which resulted from handing its cultivation over 'to the unreasoning management of ignorant and unskilful slaves'. Pliny, the Elder, who wrote about the same time as Columella, championed those who worked their own land against the owners of the *latifundia* or great estates, who abandoned the work upon the land to slaves and for their own part only lived in their country houses when they could entertain house parties of their friends. How was it, he asked, there was so great a fertility of the soil in the past that seven *jugera* (a little over four acres) were held to be sufficient for a farmer and his family? His answer was that in those days the lands were tilled by the hands of generals and soldiers. 'Whether', he questioned, 'it was that they tended the seed with the same care that they had displayed in the conduct of wars and manifested the same diligent attention to their fields that they had done in the arrangement of their camp, or whether it is that under the hand of honest men everything prospers the

better by being attended to with scrupulous exactness?' The conception lasted up to the time of Vegetius, in the fourth century, who bitterly regretted the abandonment of the ancestral ways, when he saw the poor quality of the military recruits.

The great Roman writers of the latter part of the Republic and the early part of the Empire, then, had a passion and a hope for the reconstruction of the family ownership of the land not only because the farmers were the healthiest, most honest, and most diligent members of the State, as well as its best farmers, but because in times of danger they made the best soldiers.

The military leaders of the late republic were equally convinced of the value in character and physique of the farming class. When the supply of farmer-warriors failed, there seemed to be only one alternative and that was to start with warriors and, as a reward for their services, to give them land to farm. Marius was the first to give the twist from farmer-warriors to warrior-farmers. He overthrew the tradition that only the propertied classes were worthy to fight for their country, enlisted the proletariat, especially those who were living on the land, and rewarded their services with a gift of land. Slaves were never enlisted. Their grievances were too great and their numbers too many for any Roman to dare or even dream of such a dangerous experiment.

When the change to empire brought its long years of peace, its good government, its roads, its reliable civil servants, its self-governing city states served by an unequalled zeal on the part of public-minded citizens, its greater humanity towards slaves, and such prosperity that, of the best part of these first two centuries (from the death of Domitian in A.D. 96 to the ascension of Commodus in A.D. 180), Gibbon could write, 'If a man were called to fix the period in the history of the world during which the condition of the human race was most happy and prosperous, he could without hesitation name' that between these two dates, even then, the emperors, almost without exception, strove to revive the small family holdings. Augustus and his successors planted colonists on the land; Nerva spent millions in purchasing land for small farmers; generous laws dealt with the food of the agricultural classes; veterans were given free allotments; and Pertinax allowed squatters to occupy uncultivated fields even upon imperial estates, and to possess full ownership if they brought them into cultivation.

Nevertheless, in spite of these desperate endeavours to reconstruct personal farming, the power of money prevailed. The small farming class continuously and literally lost ground and the wealthy class as continuously gained it. In the place of the generous laws of the first two centuries of the empire, there came the restrictive laws of the last two centuries. Agricultural slaves were bound to the land. Heavy impositions and innumerable duties or liturgies were loaded upon the large class of *curiales*, or members of the senates of the city-states and large villages. This class of *curiales* included the landowners. As the demands of revenue became more exacting, membership of the *curiae* was made hereditary. The *curiales*, harassed by innumerable officials, duties that could not be fulfilled, poverty which withheld money from the land and forced them more and more to

exploit their deteriorating soils, sought by every means to escape from their ruinous property and its duties. 'Many of them', wrote Abbott and Johnson in *Municipal Administration in the Roman Empire*, 1926, 'abandoned their property and fled. Others sought to enter some vocation which would give them exemption from municipal charges. The emperors strove to check this movement by binding the *curiales* to their place of origin, and by forbidding them to enter any of the privileged professions.'

These measures failing, laws were then passed under which all the property of the *curiae*, whose members managed to escape, was made liable for the accustomed dues, the burden then falling on the less fortunate owners. Failure in payment led to the confiscation of property and its transference to the imperial estates which rapidly increased in all parts of the empire, and the tenants of which were exempted from municipal liabilities. Some also fell to the owners of the great *latifundia*, who were strong enough to resist the demands of the tax-gatherer or to hand on the burden of taxation to their tenants, who had originally sought their patronage as the only way of escape. The *coloni* or voluntary tenants were also bound to the soil and in the fourth century were reduced almost 'to the level of agricultural slaves'. 'The only class in the municipalities not affected by imperial legislation was the proletariat. The practice of Rome in maintaining this parasitic element by private charity was unfortunately widely copied, and imposed a serious charge on the civic budget. Not only that but the glamour of ancient urban life attracted labour from the farms and other industries where a bare living was gained by arduous toil. In the city one could be fed at the expense of the State, and when the *capitatio plebeia*' (a tax imposed by Diocletian on the working power of a man in good health) 'was removed from the residents of the towns, we cannot wonder that the urban movement went on apace' (Abbott and Johnson).

All this downward career was both accompanied and caused by the continuous depletion of soil-fertility. To this Italy, the imperial mother-country, was the most exposed, and upon her soil the story of its effect was most mournfully unfolded. In the early days of Rome seven *jugera* (4-1/4 acres) were found sufficient for a family, and this was the original assignment given to the *coloni* as tenants of the state. Gracchus found it advisable to increase the assignments to thirty *jugera*. The fall in fertility due to the war against Hannibal forced upon much Italian land the necessity of large ranches devoted to the raising and feeding of domestic animals or to orchards, and this necessity justified economically the brutality of the 'Enclosures' of that time, under which land that had previously grown good crops of grain was taken from evicted small farmers by the wealthy classes and cultivated as ranches. This, in its turn, confirmed the dependence of the masses upon imported corn. Caesar, as an evidence of the soil's further depletion, raised the assignments to sixty *jugera*, and Columella, writing about A.D. 60, asserted that a fourfold return of grain was unknown on Italian farms. Finally, in the third and fourth centuries the debasement of the soil completed itself. Much of Latium, once the parent of the sturdy strength of the Latin fathers, became a pestilential swamp. Provinces, which had once been the native land of formidable legions, were almost bereft of the human

species. Flourishing towns dwindled to villages and disappeared. The proletariat of Rome ceased to exist.

The capitalists of the western capital did not await the complete degradation of Italy. They transferred their capital at the call of Constantine the Great (A.D. 288-337) to a new capital city on the shores of the Bosphorus, a city situated midway between the rich wheat lands that ringed the Black Sea and the inexhaustible fertility brought annually in the Nile flood. Abandoned Italy fell to Odoacer in A.D. 476.

Now this story will be found to be fraught with meaning to those conversant with or, by a perusal of these pages, about to become conversant with the past story of agriculture in England and the present state of agriculture throughout the British Empire and other countries of Western civilization. Amongst other things, they will also see the perilous significance of the attempt of the Nazis to conquer the world and bind subject peoples to slavery upon the land. This subjection of the land, against which so many of the great Romans vainly strove, advanced steadily and irresistibly as an inevitability of a civilization which valued the soil as a commodity producing money, not as the very creator of the life and health of man.

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Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 3

The Roman Foods

In the previous chapter, we have not proved the point that it was the intensive personal agriculture in a favourable soil and climate, which gave to the early Romans their physiological vigour and virile character. We have not proved it for it is not susceptible of proof as a separate entity. It can only be brought forward as an example of the reasonable supposition that the quality of the food and the animal that eats it must be interwoven. All, therefore, that we have been able to do has been to bring forward certain facts bearing upon early Latium which to some readers will at least link up with the tradition of the exceptional character of its inhabitants.

Let us now review, as far as we are able, the foods themselves from which this physiology derived.

At the beginning we are forced to realize that in history generally it is difficult to find out about the quality and character of the food of a people, and to this the early Romans afford no exception. Dr. K. Hintze, however, has in his invaluable *Geographie und Geschichte der Ernährung* collected such knowledge as persistent scholarship can reveal.

What Hintze is able to tell us about the foods of the early Romans is not copious, but nevertheless it is fully in accordance with that of some of the most virile people at present upon the earth. It has already been shown what care was given to its cultivation. That is of primary importance. One may presume that with such skilled and laborious cultivation, the soil, itself of excellent natural gifts, rendered healthy and well-growing vegetable and animal food.

There is no contemporary information, says Hintze, about the foods of early Latium; there are only the traditions, supported by the influences of modern research, of what it had

been.

Of grains, there was barley, wheat (emmer) and millet. There were no mills, but the grains were crushed in a mortar and the husk removed. The grain was then made into a porridge and eaten with salt. The grains were often lightly roasted so as to make the removal of the husk easier. Later came the hand mill and the grain was crushed between two millstones.

The student of nutrition and dietetics will at once note that only the husk was removed. The porridge was thus wholemeal porridge and, if flat cakes of bread were made, they too were wholemeal.

This traditional porridge, Hintze surmises, was the staple food of the early Romans, who ate alike as there was little or no food distinction of the classes at that time.

Then came vegetables and fruit. There were cattle, but flesh was seldom eaten, except on the days of religious festivals. The animals were kept for work upon the farm, for the provision of manure, and for milk and cheese. Milk and cheese were an important part of the food.

The grape was cultivated in Italy in pre-Roman times, but in ancient Latium it seems to have been unknown. Its culture, however, reached Latium at some early date and the inhabitants then drank wine. Whether they drank wine made from other juices, as was the later habit of the Romans, is not known. Barley beer, the drink of northern peoples, never found favour in the land of the grape.

The food of the early Latin farmers was, therefore, the lacto-vegetarian, which has won such high praise from Sir Robert McCarrison and other distinguished modern nutritionists, as the food of many of the healthiest and strongest peoples of the present day. If a healthy soil can be granted to these people, then they had in their food all the necessary elements of physiological excellence.

The lacto-vegetarian diet is not the only healthy whole diet. There are other such diets, that of the Polar Eskimos for example in which whole carcass feeding plays almost but not quite as prominent a part as it does in that of the beasts of prey. But the lacto-vegetarian diet of wholemeal grains, fruits, vegetables, milk and its products, as McCarrison has shown, is the basis of the excellent health and physique of the Hunza, the Pathans and the Sikhs of North-western India and, with a more precarious supply of grain and vegetables, of the Arabs and Baggaras.

What proportion milk and its products added to the vegetables and fruit foods of the early Romans is not of course known. Their value was, one would think, firmly established in the tradition of people, some of whose ancestors came from central and eastern central Europe. It was certainly a tradition handed down to and maintained from the early days of the republic. The *latifundia* or large estates of the later republic largely specialized in milk

and milk products, as well as wines and olives, and left the growing of corn in large degree to the provinces. They raised cows, sheep, goats, horses and asses, and the milk and cheeses of the milks of all these animals were consumed with the inner knowledge, which Cossinius, in Varro's work, displays. Cossinius discusses the qualities and differences of these products as connoisseurs discuss those of wine. Nothing perhaps shows more vividly the immense gap that exists between the sophisticated town diets of to-day and that of early and middle republican Rome than this serious devotion to milk and its products.

It is in this lacto-vegetarian character that the early Roman diet allies itself, as has been said, to that of many of the finest people of the present day. It is in their intensive cultivation of the land as individual farmer-families that they resembled the Chinese, Koreans and pre-modern Japanese. It is in their traditional reverence for the nutritional qualities of milk and its products, however, that they differ from these far-eastern peoples, whose land supports so numerous a population that there is not sufficient for the support of a large number of domesticated animals as well. It is in the combination of the two, intensive cultivation and the culture of dairy products, that the Roman diet most resembled that of the Hunza people of the western Himalayas who are probably unsurpassed in physique and health by any other people of the present times. Moreover, whether by tradition or not cannot be said, but certainly in mid- and later republican times, and therefore possibly in the early Roman period, a great quantity of different fruits were cultivated in Italy, so that Hintze, at one passage, yielding perhaps to hyperbole, declares, that 'at Varro's time all Italy resembled a fruit garden'. In this generous provision of fruit, the diet resembled that of the present-day Hunza, who eat great quantities of fresh and sun-dried fruits. It also has allied to it the great quantities of dates, which those other people of superb physique, the Arabs of Arabia, eat.

As regards early Roman agriculture, the intensity of which has already been indicated, Frank praises its practical efficiency. Professor Whitney, in his great work *Soil and Civilization* (1926), writes of the Roman knowledge of certain principles and practices, such as their recognition of the different types of soil and the crops suitable for them; their recognition of the need of local knowledge of the soil and its preservation by successive generations of families cultivating the soil, where they themselves were born and bred; their use of legumes which allied them to the prolonged agricultural history of the Chinese, as also in their avoidance of any waste upon the farm, all animal and vegetable refuse being returned to the soil as manure, and other technical features of agricultural practice upon which a competent student of practical agriculture like Whitney is qualified to write and to whose book I refer the interested reader.

There is therefore, I think, quite sufficient evidence to presume that the Romans and their neighbours belonged to those people who by long adaptation to a repetitive, well-cultivated, sound diet, seem to have acquired an absolute harmony with their food, and, as a sequential necessity, were themselves a people of exceptional physique and health. The foundations of their western world dominion included their foods and agriculture.

The change in both came with the spread of that dominion.

The change amongst the agricultural Italians was much slower in its ingress than it was amongst the rapidly increasing urban populations. The rural people were necessarily affected by the changes recorded in the previous chapter, but their foods were still locally produced, milk and its products, grains, vegetables, fruit, oil, wine and occasional meat.

It was upon the metropolis and other major urban centres that the chief effect of the change fell. The bread or porridge of the lower classes was now prepared, not from local grains, but from grain imported across the seas from Egypt and northern Africa. 'The sustenance of the Roman people is day by day being tossed about at the caprice of wave and storm', were the words of the Emperor Tiberius to the Senate. But that is almost all that can be said with accuracy about the urban lower classes and their food. Hintze laments that 'unfortunately as concerns the life of the smaller folk, comprising the mass of the population, we can learn practically nothing from the writers of the time'.

It is a very different story as regards the wealthier classes of the later republican and early imperial Rome. Their breakaway from the simplicity of their great ancestors to luxury were frequent themes of the writers of the time. The wealthy Romans were indulgent of their appetites. Taste and the temptations of delicate dishes replaced the satisfaction of robust appetites. Dinner (cena), beginning about 3 p.m., became a cult. Individually and socially it occupied by its time alone, which was three or more hours, a considerable part of the day.

Hintze gives a list of the foods in their variety which reached the table at the time of the empire: milk, cheese, honey, wine, wheat, barley, millet, beans, lentils, peas, cabbage and other leafy vegetables, tubers, beets, turnips, radish, salad, onion, cucumber, celery, mushrooms, truffles, dill, mint, garlic, coriander, mustard, pepper, cardamon, olives, grapes, apples, oranges, lemons, dates, pears, plums, cherries, figs, quinces, apricots, peaches, almonds, walnuts, hazelnuts, fruit-wines of apple, pear, pomegranate, mulberry and other juices, mutton, goat, pig, deer, boar, chamois, antelope, hare, spiced meats, smoked meats, hams, goose, chicken, ortolan, bunting, starling, thrush, dove, peacock, flamingo, guineafowl, fish, mussels, crabs, lobsters and oysters. Beef was not much eaten, the bullock being kept for labour and the cow for milk.

There was, therefore, a complete change from the ancestral lacto-vegetarian diet to one drawn from all parts of the available world by the fame and wealth of Rome.

The new diet had what has been termed the virtue of variety. Whether the incentive of variety or the adaptation of familiarity is better for individual men cannot be answered. As far as I know, the question is one of those which has had little attention paid to it.

One can only repeat facts. This very varied diet is essentially one of wealthy urban or

urbanized classes, and it entails gradations downwards to the masses of the urban population. Immediately below the upper class which gets the pick of the food, there is a grade which gets the foods that are in excess of those required by the rich or those slightly spoilt for the fastidious palates of the wealthy. So the diet passes downwards, contracts, and changes to that of the lower classes, who, in the case of Rome, depended for their staple food on distant countries.

It is most important, however, here to realize that the defects due to poor food are acquired defects and therefore they are not, in the commonly accepted view of modern science, inheritable or inherited defects. Any poor Roman, who by wisdom or fortune, received a good diet from conception onwards, would show the better physique and health which that diet ensured. As to the rich, their varied diet judiciously used clearly gave opportunity for health and fine bodily quality, for the rich mostly had estates and other means of access to good milk, cheese, oil, fruit, vegetables and corn.

The rural population, like the wealthy, had access to fresh food. The growing of wheat in Italy did not come to an end. 'In Nero's day,' writes Frank, 'Egypt sent about five million bushels of wheat to Rome annually while Africa sent about twice as much. That would suffice for the capital alone, and reveals why cereal-culture could be neglected in the vicinity of the city. But the rest of Italy had a population of about fifteen millions and they would require more than 150 million bushels a year ... We must conclude therefore that wheat was very extensively and successfully raised during the first century.'

The foods of Rome of the period of dominion may then be summed up broadly as four.

Firstly, there were the small farm home-produced foods to the Italian countrymen. These approached most closely of the four groups to the traditional foods of their ancestry. To what degree they did so it is impossible to relate, for as Mr. H. Stuart Jones says in *Companion to Roman History*, 1912, though 'there is good evidence in the literature and inscriptions of the early Empire that the small holding was far from extinct in A.D. 100 and later, we know so little of its working that we can only describe the *fundus* of the capitalistic landowner as Cato and Varro picture it.'

Secondly, there were the home-produced foods of the slave-worked *latifundia*. Under the late republic the condition of the slaves was wretched in the extreme. Under the empire their lot was gradually ameliorated. Their foods were presumably not the equal of the first group. Moreover, the specialization of the estate limited the number of foods compared to that produced on the general farm.

Thirdly, there was the varied diet of the wealthy classes comprised of fresh foods from their own or neighbouring farms and estates, fish from the seas and rivers, and luxury foods imported from abroad.

Lastly, there was the food of the lower urban classes. Of this Mr. F. H. Marshall, in Sir

John Sandys' *A Companion to Latin Studies*, 1921, writes: a kind of porridge of wheat, like that eaten in early republican times 'even in imperial times continued to be eaten by the classes ... with green vegetables, seldom meat'. The grain was still consumed as a wholemeal grain. As to its quality, there is no means of comparing it with the wheat or emmer and other grains of early Latium. But its wholemeal character was certainly preserved.

This is about the only fact of importance one can gather from what is known of the food of the urban lower classes. One knows little or nothing about their access to dairy foods. As already quoted, Hintze states that 'unfortunately as concerns the life of the smaller folk, comprising the mass of the population, we can learn practically nothing from the writers of the time'.

Summing up one may assert that compared to the foods produced by the farmers of early Latium, that of the first group approached, but owing to the increasing difficulties of the farmers, cannot have reached that of the early period.

The food of the second class of the agricultural slaves was certainly inferior.

The food of the third class, the wealthy, is less comparable. It is not possible to state, but it is possible to imagine that it produced a greater variety of human qualities. That it also brought with it the deterioration of over-luxurious and over-gross feeding is certain. Nevertheless, the daily life of its eaters, their gymnastics, games, and bathing proves the persistence of the ideal of bodily health and physique.

The food of the fourth class, the poorer urban class, was certainly inferior.

With the degeneration of Italian agriculture, there came a degeneration of foods and their quality, and a degeneration of the eaters of these foods. To whatever other causes the decline and fall of the Western Empire was due, this of its foods was assuredly amongst the primary ones. It suggests that no empire can endure with its centre in the motherland, if the agriculture of the motherland deteriorates. The process is naturally a slow one and as such was not mentally impressed upon the Romans as a people, though realized by many of its thoughtful and prominent men.

Chapter 4

The Roman Family

The human group, by which the farming of early Latium was carried out, was the family. A slave of that time was one of the family and took his part in the general work and domestic life without degradation.

The human family and the cultivated soil were indissolubly connected; the family was pledged and wedded to the soil. The very type of marriage, that of monogamy, was dictated by the soil.

The farm provided the family group with food, clothing, shelter, fuel and an overflow of produce for exchange for goods produced by others. It gave security to the children and old people, and the security was continuous so long as the soil was well-husbanded. The peculiar knowledge of the family and of their ancestry was that of their farm and all that affected it.

To the family its land with its particularities was as living and particular as were their own particularities. The creation of children to continue the family was, as it were, an aspect or relation of the creative quality of the soil. The blended intimacy was an intimacy formed within the mystery of the recurrent creation of both. The farming family was inevitably religious; it was so near in its life to the abundant life in which it was itself the agent of creation; in death it was so near to the inevitability of the resurrection of that which is apparently dead but which, mixed with the soil, again joins the regions of life.

Every schoolboy, recalling his Roman history, carries in his mind the grim figure of the *pater familias*, the head of a Roman family, who preserved the form of the family and punished any member of it who endangered its corporative existence, and did not in extreme cases hesitate to inflict death upon his own flesh and blood.

Ordinarily, one may presume, as member of a family he was not grim, but the fact that he had those traditional powers showed that the family was cultivated with as great an intensity as the land; and his summoning of the family at the awakening of day to the worship of the household gods showed that that, which man ultimately does not reach but which by intimacy he can approach, was a deeper interpretation of the common life upon the farm.

The family was the large or joint family, which is the form of family particularly correlated with the intensive hereditary cultivation of small farms. It was the large or joint family consisting of the father and mother, their sons and grandsons with their wives and children, and their unmarried daughters. The men worked upon the land and for the State, the women worked for the family. Outside the family woman had no recognized place. She inherited her portion of the family land, but that was for her security and not to give her individual scope for agricultural skill or toil.

She was the mother and the housewife. But in the relation of her children to the State and family, she was subordinate to the *pater familias*. It was he who had an absolute legal right to decide whether a child born to him or in his family should be reared or not. It was he who ordained the death of a defective child or one threatening the family unit by over-population. 'The maxim was not suggested by indifference to the possession of a family,' is Mommsen's comment. 'On the contrary, the conviction that the founding of a house and

the begetting of children were a moral necessity and a public duty had a deep and earnest hold of the Roman mind.'

But the family had to be strong in its individual units and in itself as a unit of the State. It had to be strong because the proper service of the soil demanded physiological strength, and the strong State, the State that could successfully defend itself against invaders and aggressive neighbours, had to be compounded of strong family units. The family was, indeed, the very essence of the State. 'Of all Roman institutions marriage was the most sacred,' wrote Mr. Romaine Patterson in *The Nemesis of Nations*, 1907. 'The family altar, transmitted from one generation to another and holding a fire which had been lit by ancestors who had been dead for centuries, was the central and most impressive fact in the life of a Roman burgess.'

The economy which was attached to this sanctity of the family has been called a 'natural economy'. After the Punic Wars, there arose as its rival and supplementer a 'money economy'. The new rich, in the main, were new men, the Equites. The older landed aristocracy, as was to be seen later in other nations, were not a match for the new men. It was the Equites who made and controlled the money economy in its various forms. *They* farmed rents, taxes, customs, excise and other duties. They controlled the import of food, the slave trade, and the creation and circulation of money. The most certain path to wealth was the profession of banking. Only exceptional cleverness or luck in speculation built up wealth more rapidly than did banking, and this very speculation was supported by the bankers. Almost all, who laid claim to credit, fell into the bankers' debt. The successful politicians depended upon the backing given to them by the bankers. Capital, labour and competition, under the money economy, became commonplaces, though unknown under natural economy. In the growing ascendancy of money economy, the bankers necessarily became indispensable, and eventually the whole State became an exhibition of their indispensability. Everything hung from them as the staples of the State. Property concentrated. The tribune, Philippas, quoted by Cicero, stated that there were only 2,000 property and landowners in the whole Commonwealth.

The effect upon the family and marriage was profound; they both began to lose their meaning, and indeed did lose the greater part of their meaning. As the sacredness of marriage and the family fell, it is in the women of the upper class -- the class which, as in the case of food, practically monopolized the pens of the great Roman writers from which we get our information -- that the change of values is most vividly illustrated.

The Roman matrons now became figures of tradition. The object of the fashionable ladies was the *reverse* of that of the displaced *domina* or mistress of the home and family. Their desire was to avoid by all possible means the appearance of being matronly. To conceal all appearances of advancing years, to look young, attractive and ripe for adventure, that was, in particular the object of the society women. Their culture was beauty culture, their scarcely concealed convention was to occupy themselves with love affairs without fruition. As, perhaps, a form of revenge for the secret desolation of their wifehood and

motherhood, they wasted the imperial resources with lavish prodigality. Fashion and beauty cost so much that thousands of slaves throughout the empire were necessary to support them. The passion for personal freedom, in the sense of untrammelled desire, divided them from the few children which they had. The younger folk, on their part, freed themselves from the shackles of parental authority. The *pater familias* vanished into the past with the *domina*. The family elders, once honoured as the store-house of experience and wisdom and links with the past, were unreverenced and made to feel the uselessness of old age.

I cannot better substantiate the accuracy of the picture of the upper class Roman women than quote Theodor Mommsen's account in his *History of Rome*. He is describing the time when society had first erected itself to a great height of luxury upon the wealth that accrued from the exploitation of Rome's widespread provinces and the great number of slaves, which filled the place in the Roman world that machines were to fill in the Industrial Era. Amongst society, he wrote: 'Morality and family life were treated as antiquated things amongst the ranks of society. To be poor was not merely the saddest disgrace and the worst crime, but the only disgrace and the only crime.' The effect upon society women, he described in these words: 'Liaisons in the first houses had become so frequent, that only a scandal altogether exceptional could make them the subject of special talk; a judicial interference seemed now almost ridiculous. An unparalleled scandal, such as Publius Clodius produced in 61 B.C. at the women's festival in the house of the Pontifex Maximus, although a thousand times worse than the occurrences which fifty years before had led to a series of capital sentences, passed almost without investigation and wholly without punishment. The watering-place season -- in April, when business was suspended and the world of quality congregated in Baiae and Puteoli -- derived its chief charm from the relations licit and illicit which, along with music and song and elegant breakfasts on board or on shore, enlivened the gondola voyages. There the ladies held absolute sway; but they were by no means content with this domain which rightfully belonged to them; but also acted as politicians, appeared in party conferences and took part with their money and their intrigues in the wild coterie-proceedings of the time.' 'Celibacy and childlessness became common, especially amongst the upper classes,' and it was held to be the duty of 'a citizen to keep great wealth together and therefore not to beget too many children'.

Childlessness, indeed, had further advantages. Men and women who had children were debarred from the joys of society and were omitted from invitations to social gatherings. Hence Seneca (5 B.C. - A.D. 65), himself a man of great wealth, whose strange attachment to Stoic philosophy led him, with his colleague Burrus, to the wise and humane government of the first five years of Nero's reign, did not think it ill, in a manner that would have outraged the farmer-Romans, to console a mother who had lost her only son by pointing out that she would now be free to enjoy the pleasures and prestige of society.

Nothing could better than this convey the gulf that formed between the position of the

women of 'natural economy' and the dominant women of 'money economy'. But it is juster to regard this great change as an example of relativity than to condemn it on the grounds of morality. The conduct of the first women was relative to the pre-eminence of the soil, that of the second to the pre-eminence of money. The first economy was preservative of life and the soil, the second was destructive. How destructive it was will be seen in the next chapter.

Chapter 5

Roman Soil Erosion

The best summary of this aspect of Roman history which I have read is that of Professor Simkhovitch, in an essay published in the *Political Science Quarterly* of the Columbia University, 1916, under the title of 'Rome's Fall Reconsidered'.

Simkhovitch began with quotations from Roman writers, Pliny, Horace, Varro, Columella and others, who were fully aware of Rome's progressive degradation at the roots. The process was a slow, progressive exhaustion of soil fertility. It was not due to lack of knowledge of good farming, for, 'nothing could be more startling than the Roman knowledge of rational and intensive agriculture'. Nor, I think, could it be said to be due to debt, for debt did not begin its devastating career until the fertility of the soil became impoverished. Debt was not necessary as long as the farming families were able to give their time to intensive cultivation.

The spread of the degradation of the soil was centrifugal from Latium itself outwards. Varro noted abandoned fields in Latium, and two centuries later Columella, about A.D. 60, referred to all Latium as a country where the people would have died of starvation, but for their share of Rome's imported corn. The Roman armies moved outwards from Latium demanding land; victory gave more land to the farmers; excessive demands again brought exhaustion of fertility; again the armies moved outwards.

'Province after province was turned by Rome into a desert,' wrote Simkhovitch, 'for Rome's exactions naturally compelled greater exploitation of the conquered soil and its more rapid exhaustion. Province after province was conquered by Rome to feed the growing proletariat with its corn and to enrich the prosperous with its loot. The devastation of war abroad and at home helped the process along. The only exception to the rule of spoliation and exhaustion was Egypt, because of the overflow of the Nile. For this reason Egypt played a unique role in the empire. It was the emperor's personal possession, and neither senators nor knights could visit it without special permission, for even a small force, as Tacitus stated, might "block up the plentiful corn country and reduce all Italy to submission".'

Latium, Campania, Sardinia, Sicily, Spain, Northern Africa, as Roman granaries, were

successively reduced to exhaustion. Abandoned land in Latium and Campania turned into swamps, in Northern Africa into desert. The forest-clad hills were denuded. 'The decline of the Roman Empire is a story of deforestation, soil exhaustion and erosion,' wrote Mr. G. V. Jacks in *The Rape of the Earth*. 'From Spain to Palestine there are no forests left on the Mediterranean littoral, the region is pronouncedly arid instead of having the mild humid character of forest-clad land, and most of its former bounteously rich top-soil is lying at the bottom of the sea.'

The same fate at a later date fell upon Asia Minor, the decline of the Eastern repeating that of the Western Empire in its soil-aspects. Sir William Ramsay, in *The National Geographical Magazine* of November, 1922, wrote one of those articles which almost stagger one with the super-eminence of the treatment of the soil in the story of mankind. The Province of Asia 'in Roman times was highly populated and therefore highly cultivated ... It is difficult to give by statistics any conception of the great wealth and the numerous population of Asia Minor in the Roman period. In the single province of "Asia", to use the Roman name for the western part of the peninsula, which was the richest and most highly educated of the whole country, there were 230 cities which each struck its own special coinage, under its own name and its own magistrates, each proud of its individuality and character as a self-governing unit in the great Empire.'

Sir William carried out a careful exploration of some of the areas of high cultivation, which he regarded as the necessary basis of this wealthy province. What he found was what is found elsewhere, namely, hills denuded of forest and swept by heavy seasonal rains, and what he further found was the relics of the extensive terraced engineering by which the nourishing water had once been conserved and distributed: 'In older time', he wrote, 'the numerous terraces would have detained the water from point to point up the mountain side, preventing it from ever acquiring a sufficient volume to sweep down in a destroying flood.' Against this fertile land came invaders. First came the least destructive, the Arabs, least destructive because they observed in war the sanctity of trees. The Arabs could under the rules of war destroy the crops and produce of the enemy, but only exceptionally the tree, which conserved the soil. 'It was left to the Crusaders under the command of German, Norman and Frankish nobles and bishops, to inaugurate the era of total destruction of a country by cutting down the trees ... These broke the strength of an organized society by reducing a great part of the country from the agricultural to the nomadic stage. The supply of food diminished accordingly, and with the waning of the food-supply the population necessarily decreased.

'A decreasing population', continued this masterly account, 'in its turn was unable to supply the labour necessary to maintain the old standard of water engineering, on which prosperity rested. Gradually industries languished and died in the towns as well as the agriculture in the country. The Sultans did what they could. Neither the Seljuk Turks nor the Ottoman Turks were actuated by fanaticism. They wished to preserve the old social system so far as it was consistent with the dominance of a conquering caste; but they could not maintain the education which was necessary in the old Roman system ... Thus

the whole basis of prosperity was wrecked, not by intention, but by steady decay. A number of causes co-operated and each cause intensified the others. Can the prosperity of this derelict land be restored?'

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Chapter 6

Farmers and Nomads

I. The Land

Physical maps, showing the different elevations of land, have always had an irresistible attraction for me, and none is more attractive than that of the vast continent of Asia with its European appendage, pushed out like a tongue between the Mediterranean and Northern Seas. What a huge playground of history this map presents! There has been nothing like it in the other continents of the world, Africa Australia and the Americas. They are, excepting Egypt, almost without history, compared to the Eurasiatic Continent.

The map which I possess has five colours to denote different heights, dark green to show land below sea-level, light green from sea-level to 500 feet, yellow 500 to 2,000 feet, light brown 2,000 to 5,000 feet, and dark brown over 5,000 feet.

Asia begins with the beaches of the Arctic Ocean. Then comes a vast light green band or belt with a few yellow areas within it. It stretches right across Asia and Europe. In Asia it is the Siberian Plain; in Europe the Great Lowland Plain.

Except for an extreme northern band of Arctic vegetation, called *tundra*, this light green belt is forest land with great rivers passing through it to the Arctic Ocean. It is Belt No. 1. It has played very little part in Asiatic history.

Yellow-tinted is the land between this green belt and the mountains to the south of it. It has less rainfall than the green land north of it, and is subject to seasons of aridity. It is grass land, the land of the Steppes. This is Belt No. 2. It has played a great part in Asiatic history.

Belonging to Belt No. 2 as Steppe land, there is a patch of light green near the Caspian Sea. It is a part of the Kirghiz Steppes and it passes directly to the Steppes of south-eastern European Russia; when north of the Caspian, it is actually tinted dark green or below sea-level. This is the Caspian Tract, through which so many hordes of Asiatics passed into Europe in prehistoric and historic times.

The third belt begins with light brown almost from the northeastern tip of Asia. It then shows a dark brown series of mountain ranges. From east to west these are, the long thin line of the Yablonoi Mountains, the much greater mass of the Sayan and Altai Mountains, and the lofty Tianshan, which ends at the seventieth longitude in the Pamir or Roof of the World.

Belt No. 4 is a light brown belt between Belts 3 and 5. It includes Mongolia, the Gobi Desert and Turkestan. It comes to an end at the Pamir. Mongolia is Steppe country and its inhabitants have played a large part in history, not only of Asia but also of eastern Europe. The name Mongol, or Tartar of the Chinese historians, however, has become attached to other peoples of the Steppes as well as to the people of Mongolia.

The filth belt constitutes the largest mass of elevated land in the world. In the east it rises almost abruptly above the light green of the lowland of China, and then forms the most extensive elevation, that of Tibet, 11,000 feet and over, which is inhabited by man. Tibet's southern border is formed by the highest mountains of the world, the range of the Himalaya. The Himalaya pass on westwards, forming the northern barrier of India and join the lofty Tianshan of the third belt in the Pamir.

From the Pamir the conjoint Tianshan and Himalaya continue westwards as the Hindu Kush Range; thence reaching across northern Afghanistan and Persia to arrive at Ararat in the east of Asia Minor. Ranges of lesser height pass from the Hindu Kush southwards to form the eastern border of Afghanistan and then pass west and north-west to the east of the Persian Gulf as the mountains of west Persia and so reach Ararat. They, and the northern ranges, enclose a smaller and much lower plateau than that of Tibet, the Iranian Plateau. Finally from Ararat, mountains continue westwards in Asia Minor, and appear in Europe as the Balkans, the Alps and the Pyrenees.

Belt No. 6 is the land of the Farmers. For our purpose it is the light green land about the great rivers, the Huang Ho or Yellow River and Yangtse Kiang of China, the Brahmaputra, Ganges, and Indus of India, the Euphrates and Tigris of Irak.

Such, in brief, is the physical map of Asia. Its fascination lies in the fact that one can read from it some of the vast progeny of history upon the huge stage of the continent of Asia.

II. The Nomads

The Nomads are the inhabitants of Belt 2, the Steppe country. They are defined in *Annandale's Concise English Dictionary* as 'those people whose chief occupation consists of feeding their flocks, and who shift their residence according to the state of the pasture'.

The Nomads, according to this definition, present a picture to the mind's eye of wandering shepherds and peaceful pastoralists passing from pasture to pasture to the sound of tinkling cow bells. They would erect their tents of oxhide at new pastures and enjoy the comfort of a home and resting place, until their experienced eyes told them that the pasture was insufficient for their cattle and it was time to move on.

Probably in the earliest historical times, the Nomads had horses. The horse is an Asiatic animal and the only wild horse now known is found in Western Mongolia, as a natural denizen of its dry, open steppes. Certainly the Nomads had horses before 2000 B.C., for horses appeared in Babylonia at that time and two centuries or so later the Hyksos, who conquered Egypt, introduced horses into that country. So we can add the horse to a company of Nomads. But the horse was to them a noble animal and was ridden only. It was not used as a beast of burden as it is to-day; it was the oxen who drew the heavy wagons of the Nomads when they trekked. The horse was loved for its speed. It was the swiftest animal of the steppes and it was this which made it loved by the Nomads.

The picture of the Nomads is a pleasant one and their life was peaceful and pleasant as long as the pasture was good. But, when the rain was scanty and the pasture poor, they were in trouble, Then they had to move frequently and, sometimes, faced by the loss of their cattle by starvation and themselves feeling the pinch of hunger, they would move quickly and their warriors, mounted on their loved steeds and armed with bows and arrows, would fling themselves upon peaceful people, either more fortunate pastoralists like themselves or farmers, slay many and take possession of their land. With their incredible swiftness on the march and an unprecedented speed of encircling attack, with their deadly accuracy of arrows shot from the saddle, with their horrific cries to terrorize their slow-moving victims, they must have seemed like a horde of winged insects, whose sting was death, and whose capture and destruction were impossible.

The cause of this disturbing loss of food was at one time believed to be an increasing dryness of the climate in historical times. This hypothesis was propounded by Prince Kropotkin in an article in the *Royal Geographical Journal* of 1904 in which he stated that it was quite certain that Belt No. 4 was more populated than it is now; it was quite certain, for example, that within historical times Eastern Turkestan and the adjacent part of Mongolia 'were not deserts as they are now. They had a numerous population, advanced in civilization, which stood in lively intercourse with different parts of Asia'. Many of them were successful farmers dependent on irrigation from rivers flowing from their enclosing mountains. This, Sir Aurel Stein, in his monumental work *The Desert Cities of Cathay*, 1912, has convincingly proved beyond further discussion. Kropotkin continued: 'All this is now gone, and it must have been the rapid desiccation of this region which compelled its inhabitants to rush down to the Jungarian Gate' (Jungaria was a name of Western

Mongolia) 'to the lowlands of Balkash and the Obi.' Mr. Huntingdon Ellsworth skilfully developed this hypothesis in *The Pulse of Asia*.

The hypothesis gave rise to very widespread investigation, with the result that, though fluctuations of climate undoubtedly occurred, as shown, for example, by the rise and fall of the level of the Caspian Sea, nevertheless a continuous decline in humidity in historical times could not be accepted. Drives through the Jungarian Gate were, however, accepted.

Another reason had to be found. *It was found in the particular character of the treatment of the soil by the Nomads*.

The first statement of this other reason, which I have been able to find, is that by Monsieur Rorit in the Royal Geographical Journal of 1870. Rorit wrote: 'The nakedness of Arabia and the vast tracts of Asia in the north and west, the sterility, which extends over Persia, cannot be traced to any other cause than the pastoral habits of the inhabitants. The people inhabiting them are locusts; they destroy all woodland and vegetation, modifying even the climate -- whence the necessity of migrations. Had the invasions of the barbarians any other cause? A study of the question in this sense would perhaps give us the key to the great migrations of mankind.'

Monsieur Rorit's reason is pungently expressed, but it is now accepted. It could not well be otherwise, for, to confirm it, the same process is going on in many parts of the world under our eyes today.

In the countries in which Nomads fed their flocks and herds and grew temporary crops of grain, there was, as is usual in uninterfered with nature, a balance between animal and vegetable life. Animals feed upon the land and manure it, but they do not ravage it. When human pastoralists entered these countries, there entered with them an altogether new danger, namely a form of terrene animals so advantaged by their upright position, their hands and their large brains, that they have the capacity to *override the natural law of balance*. They could breed more animals than the land could permanently support; they could break up the natural life-cycle of a district by using all that the soil produced, and then, when exhaustion of the soil came, move on to another district. With weapons forged from the iron of the Altai Mountains, these Nomads could cut down trees and shrubs and, with their ability to create fire from flint or friction, they could burn as well as cut down. The ash of the burnt trees and shrubs gave the manure of their substance to the land and enabled the Nomads to grow good temporary crops for a number of seasons. They, in short, as men, had power; *and power in this sense may be defined as the ability to exceed the limitations set by nature*.

Nature followed the rule of return, and the Nomads, unlike the true farmers, failed to follow the, rule of return. Indirectly, by cutting down trees and shrubs for fuel and for ash, they made the soil drier. Rain fell and was by nature broken into a fine spray by trees, shrubs and thick grass and was thus evenly and widely spread in the topsoil. The topsoil,

sheltered from sun and rain, stored the water. By slow evaporation from the vegetation, the water was returned to the air. But where excess of cattle fed upon the land and where trees and shrubs were widely burnt, the soil was exposed, dried and powdered, and then blown away by the winds or washed away by the rain. So a district of desert was formed, which forced the Nomads to move on. Nature then returned and in many cases restored the ravage. But if the destruction of fertility had been too great or if the half-recovered soil was again used for crops and grazing, permanent deterioration was the result.

The Nomads, then, lived a life of ill-balance by not following the rule of return, which is *the only stable rule of living*. They were, therefore, forced to live a life of *chance*. They depended on the seasons and, as the seasons varied, they themselves were necessarily *speculative*. In this character, indeed, they were like to other kinds of speculators, many prominent at the present time. Speculators disregard the rule of return. They strive to gain without giving; they disregard future generations; they are indifferent to the sufferings of others, provided they themselves can escape suffering. Yet eventually there is no escape from the effects of these actions, because ultimately their values are destructive and not conservative.

As long as the Nomads failed to use settled agriculture and limit their cattle-breeding, life was sometimes generous to them, sometimes even-handed, sometimes, at seasons of drought, harsh. At times of harshness, mounted on their horses they organized wide-sweeping hunts of wild animals for their food. If further pressed, they were forced to move on and this sometimes entailed making raids into the lands of their neighbours, who, in their turn might raid or join with them in raiding. Then, with increasing numbers, they might successfully, make themselves masters of the land of settled farmers and the food and wealth, which they had not the wit to get by their own skill and toil. Hence they praised war, not as a means of defence in the way in which a sturdy peasantry has so often successfully defended itself and its soil, but as a means to mastery and wealth. To them life was not only a struggle for existence, but a will to power over their enemies, an assertion of the right of the better-armed and of the more savage nature over what they regarded as possible, and if possible legitimate, prey. They terrorized when they attacked, and, when they conquered, they were successful owing to the speed of their attack, the terror they aroused, and the human slaughter they effected. All these characters of theirs ultimately, therefore, arose from their attitude to the soil. *The soil was something to be exploited and even plundered for their gain*. This attitude was in the sharpest possible contrast to the tenet of the Babylonians, that the soil belonged to their god, or to the sanctity with which the soil was endowed by the followers of Zoroaster. *These faiths of the holiness or wholeness of the soil were, as we shall see, faiths of the farmers*; the very word cultivate is derived from the Latin verb *colere*, of the two-fold meaning of tilling and worship.

Yet the Nomads were not by any means always wild horsemen, as when they presented themselves to their enemies, the farmers. They had within them the gentler character of humanity. Professor Keane, in *Man, Past and Present*, said of the Tartars or Mongols of

Mongolia: 'They are all brave, warlike, even fierce, and capable of great atrocities, though not normally cruel.' The invention of the gun has now robbed them of their power and, in consequence, they have 'almost everywhere undergone a marked change from a rude and ferocious to a milder and more humane disposition.'

The Nomads have been *the great human desert-makers*, and the deserts of the Gobi, the Lop Nor, the Taklamakan, the Registan, the Great Salt Desert, the Syrian Desert, and even the Arabian Desert and the Sahara of Africa are due to their treatment of the soil. Nor is this desert-making by men at an end. It is going on at the present, as future chapters will show, in North and South America, in Russia, in Asia, in North and South Africa, in Australia, and even in the islands of New Zealand and the West Indies, with a speed that outstrips that of the Asiatic Nomads, so much so that it may even be said that man, in this proud scientific era, has paid for his all-too-swift advance by the loss of terrene capital, of the fertility of the soil. He has become the great transferrer of this capital to other fields than those of the soil, and, by his destruction of the soil, has foredoomed himself to God knows what impending calamities, exceeding those brought about by the Asiatic Nomads, unless he calls a halt.

It is this fact which gives this dissertation on the Nomadic character its present significance.

III. The Farmers

Belt No. 6 of Asia is the belt of the Farmers. From the mountains of Belt No. 5 great rivers run southwards into the Persian Gulf, the Indian Ocean and the Pacific Ocean, and along these rivers the Farmers built up their civilizations. The first civilization we shall take will be the one that is believed to be the oldest of them with the doubtful exception of that of China. It is that of Iraq.

This civilization was, *par excellence*, the civilization of irrigated farming. The rivers upon which it built itself were three, the Euphrates, the Tigris and the Karun. All three rivers, throughout its duration, discharged their waters separately into the head of the Persian Gulf. To-day the Karun joins the Tigris, and the Euphrates and Tigris have one joint mouth 140 miles to the south of where the three mouths then met the sea.

The first river of the three to form a basis of civilization was the shortest and the most eastern, the Karun, with its important tributary, the Ab-i-Diz. These two rivers ran through flat alluvial country before they reached the sea. Their courses in the flat land were brief compared to those of the Euphrates and the Tigris, their major lengths being amidst the mountains, through which they dashed down. Elam, as was the name of this country, therefore, resembled Latium, having a plain near the sea, and a great capital, Susa, situated on the plain within thirty miles of the hills. The civilization of the farmers and hillsmen of Elam preceded that of the Latins by some three thousand years. Elam showed much of the

tenacity of Rome, for mostly it kept its independence and played a considerable part in the riverine civilization of Iraq for a period of some 2,000 years.

The riverine civilization was further developed by Sumer, Akkad, and Babylonia, with their City-States watered by the sluggish Euphrates. The Tigris was swifter and more steeply banked and, therefore, less used. The Akkadians and Babylonians were men of the Semitic Race. The Sumerians were of doubtful origin. They were believed to have preceded the Semites, and to have been the inventors, about 3500 B.C., of the cuneiform writing later adopted by the Semites and found upon the baked clay tablets, the excavation and deciphering of which have enabled scholars to extract from the sites of the City-States the history of this artistic, flourishing, powerful and very ancient civilization of irrigated farming.

The City-States consisted of the cities and the pastures of the cattle, together surrounded by walls, and of the farmed land outside the walls. The life of the land depended solely on irrigation and it was the ambition of good rulers of the City-States to cut out a new canal and clean out the old ones. The early history of the tablets records such work, the building of temples and the wars carried out by the cities against each other, wars to establish suzerainty, but not in any way to injure the farming of the soil, upon which all depended for their existence. Eventually Babylon became paramount. Babylon's first dynasty is given as beginning about 2400 B.C. Babylon was conquered by the Persians under Cyrus in 538 B.C.

Lastly in the accumulated centuries of this riverine civilization came the Assyrians, also a Semitic people, appearing in the thirteenth century. They inhabited the land of the middle reaches of the Tigris.

From the level of Hit on the Euphrates, a little to the north of the modern Bagdad on the Tigris, the land for 550 miles to the Persian Gulf is purely alluvial, with all the advantages of alluvial soil, such as lower Egypt enjoys from the Nile, Bengal from the Ganges and the Brahmaputra, and the Chinese in the lower reaches of the Huang Ho and Yangtse Kiang. Above Hit there is a reef of hard rock from which to the north the land continues to be rocky. For this reason the Assyrians, with their capital at Kalaat Shirgat on the Tigris about 200 miles to the north of Babylon, were not so favoured as the southern alluvial peoples, and therefore exhibited what Sir Percy Sykes, in his *History of Persia*, calls a predatory character. Their initial strength, says Sykes, lay in the formidable fighting quality of a free agricultural class. When this class became exhausted, the Assyrian rulers moved their capital to Nineveh on the opposite bank to the modern Mosul, near where the Tigris enters Iraq from the mountains of the south-eastern corner of Asia Minor. This gave them the control and use of sturdy hillsmen as mercenaries. The Assyrians, as northerners, became masters of the southerners of Babylonia in 745 B.C. and remained so until 606 B. C., the brief period of about a century and a half which is so constant in the case of inferior conquerors. In 606 B.C. the Medes, with the assistance of the revolting Babylonians, sacked Nineveh. So great had been the cruelty and barbarity of the

northerners compared to the southerners of Babylon, that Sykes declares: Assyria 'shone only as a great predatory power, and when she fell, passed away into utter and well-merited oblivion'.

Assyria's predatory character introduces us to the Aryans, for the Medes were Aryans, living in the valleys of the Zagros Mountains, and the adjacent Iranian plateau in the north-west of Persia.

The Aryans entered the north of Persia about 2400 B.C. and the Medes about 2000 B.C. They were steppe dwellers, as their language, in its omission to speak of forests and mountains, discloses. They came as Nomads with flocks and herds, moving their habitation from place to place with the help of large wagons.

The Medes, at the time of Assyria's ascendancy, were subject to predatory raids by the armed Assyrian forces; and the results of these raids show the Medes as a more settled people than were their nomadic ancestors. 'From the frequency with which these expeditions raided the Iranian plateau', writes Sykes -- the plateau that is to-day so desolate -- 'and from the number of towns they destroyed, it was then a distinctly fertile and well-populated country. The inference is confirmed by the number of prisoners and the thousands of horses, cattle and sheep that were captured.' Thus in one raid in 744 B.C. 'the success of the campaign may be estimated from the fact that 60,500 prisoners and enormous herds of oxen, sheep, mules and dromedaries were led back in triumph to Calah', near Nineveh.

These afflictions brought about a desire for vengeance in the Medes. They were sturdy hillsmen and unexcelled horsemen. Under Cyaxares, their great leader, they circled round the Assyrian soldiers just beyond the range of their weapons, and poured a ceaseless shower of arrows into their midst. With the help of the Babylonians, they destroyed the Assyrian Empire in 0o6 B.C.

The Persians entered eastern Persia from the steppes to the north of Khorasan in what is now Russian Turkestan and, traversing the south-eastern Persian province of Kerman, reached Fars, with the Persian Gulf as its western limit and Elam and the Medes to the north. At this time a notable event happened, which illustrates the soil character of the Medes and Persians. They both adopted the religion of Zoroaster, who was born 'about 660 B.C. or perhaps a few generations earlier' (Sykes), and therefore some half a century or more before the destruction of the Assyrians. Zoroaster raised the use of the soil to the first place in the three chief tenets of his religion. His first tenet was: '*That agriculture and cattle-breeding are the noble callings*.' 'He who sows the ground with care and diligence', he announced, 'acquires a greater stock of religious merit than he would gain by the repetition of ten thousand prayers.'

A further illustration of the character of these farming and pastoral peoples in the highland of Western Persia is shown by the remarkable fact that Cyaxares and his Medes did not

take possession of the wonderful riverine civilizations of Iraq after the sack of Nineveh. They were content to hand it over to their allies, the Babylonians, who then erected the brief but brilliant Tenth Dynasty. Cyaxares, however, did not cease from his conquests, but confined them to the uplands of Persia, Armenia, the upper reaches of the Tigris and western Cappadocia.

One of the greatest of Aryan leaders, the Persian, Cyrus, defeated the son of Cyaxares by taking Ecbatana, the modern Hamadan, and the capital of the Medes, in 550 B.C. Cyrus became the first king of all Persia and proceeded to make himself master of the most extensive empire the world had then seen. From 500 B.C. to A.D. 600 Persia must have denoted an area more than half the size of Europe. The Medes were not made the subjects of Cyrus, but his brethren in religion and status. He overthrew Croesus in 546 B.C. and became master of the Greek colonies in Asia Minor. He took Babylon in 538 B.C. So the early Persian conquests, it seems, were not based on the strength in food of Iraq. By becoming the master of Iraq, Cyrus brought the independence of its riverine civilizations to an end.

Now, this long story of the riverine civilizations, enduring as it did for thirty centuries and only surpassed by the forty centuries of China, illustrates the *extraordinary stability of a civilization founded upon the soil as its first principle*. The City-States of Babylonia regarded,the land as sacred. Each state had its god and, writes Mr. C. H. W. Johns, in *Ancient Babylonia*, 1913, 'the god was the owner of all the city land, its *belu*, or "Lord".' The priests acted as his agents. Sykes terms it 'a feudal, ecclesiastical system', but the fact remains that *the soil was regarded as sacred*. This sanctity was revived by the followers of Mohammed, when they became masters of Iraq.

A second notable fact of the thirty centuries of the civilization founded on farming was *its freedom from destruction by the Nomads*. Only once, in Sykes's record, did Nomads threaten its independence. That was the invasion of Iraq by the Semitic Aramaean hordes from Arabia. They apparently took the whole of Assyria, and brought the Eighth Dynasty of Babylonia to its end. They were eventually subdued by the Assyrians. With this exception and a brief raid by Scythians, sent against the Medes by the failing Assyrians, *the factor of the invasions and conquests of Farmers by Nomads*, which played so large a part in history, did not greatly affect the strength of the organized societies of the Farmers. It is to its vast effects on history that we must now turn.

IV. Nomadic Migrations and Farmers

The first great migrations of the Nomads occurred between 2500 and 2000 B.C. During that time Aryans, as we have seen, reached the Iranian Plateau. It was the time of the First and Second Dynasties of Babylon, and apparently had no effect upon the highly organized riverine civilizations.

The second migratory period was about 1500 B.C. It was the time of the overthrow of the early Minoan civilization of Crete by the Dorians, the conquest of Egypt by the Hyksos and the disturbances of the first dynasty of China, the Shang, 1750-1122 B.C., by the Mongolian, Hiung-wu.

The third migratory period was about 1200 B C. It was the time of the invasion of Greece by the Dorians and their destruction of the later Minoan civilization, and the end of the Shang Dynasty of China brought about by the Hiung-wu.

Neither of these two periods of nomadic migration affected the riverine civilization of Babylonia. The Kassites, who formed the Third Dynasty of Babylonia (1700-1170 B.C.) and came from the Zagros Mountains though originally, perhaps, nomadic Aryans, were not at this time nomadic, but a settled people like those of Elam, their southern neighbour amidst the hills.

The fourth migratory period witnessed the virtual fall of the Chow Dynasty in China in 659 B.C. The same movement brought the Sesunaga to India in 620 B.C. They established the Magadha Kingdom in the central and eastern Gangetic Plain. Possibly contemporaneous movements in Europe were those of the Celts into the middle valley of the Danube, and from there at a later date into France, Spain and Northern Italy.

The remarkable fact, then, about these four great migratory periods of the Nomads is that they had little or no effect upon the first and perhaps greatest Asiatic farming civilization, though they were so destructive to other lands and peoples. The Persians who succeeded the Babylonians, in 538 B.C., were no less strong. They were Zoroastrians and Zoroaster taught the high significance of farming. From the time of Cyrus and for a long period later, Persia offered an almost invincible obstacle to these movements of the Nomads of Asia, diverting them to India to the south and northwards to Central Turkestan and Europe. Persia fell to Alexander of Macedon and after his death the Seleucids reigned. They were replaced by their pupils the Parthians of Khorasan, like the Persians an Iranian people, the words of Arya and Iran having the same derivation. The Parthians, in their turn, gave way to the Persian Sassanian Dynasty, and the Sassanians to a people who rapidly became great farmers, the Arabs of Islam. The, significance of this barrier-power of Farmers against Nomads is very great indeed. It began with Babylon's first dynasty, nearly 2400 B.C., and it endured until the overthrow of the Arabs by the nomadic Mongols in A.D. 1258, a total of some four thousand years.

The next great farming people of Asia were the Chinese, and they can also claim a history of four thousand years. Professor F. H. King, who quite recently wrote his famous book on their agriculture, called it truly *Farmers of Forty Centuries*. The first location of the Chinese was along the Huang Ho or Yellow River, which arises in the highlands of Tibet, as does their second great river, the Yangtse Kiang. They settled upon the lands along the Huang Ho after it makes its right-angled bend from east to south in the fortieth latitude. The Nomads, who so frequently threatened this otherwise peaceful people were called by

them the Tartars, and by us the Mongols and their country Mongolia. The Chinese are historically-minded. They begin their history with the Emperor Fuhi (2852-2738 B.C.), who is said to have founded the large or patriarchal family system. In the reign of the Emperor Huang-ti (2704 or 2491 B.C.), the northern Mongols receive their first mention under the name of Hun-yu. The date of the first definite dynasty, the Shang, is given as 1766-1122 B.C. In their time, Chinese history was mainly one of peace, but towards the end of their period, the Mongols, known now as Hiung-wu, appeared, and it is said that it was with their help that the Shang Dynasty was overthrown by its successor, the Chow (1122-659 B.C.). The Chow and the Shang Dynasties together reigned for a thousand years. In this length of time, they resembled the Babylonians.

When the Chow Dynasty came to an end, a general unity ended with it. Various states, especially the border states, asserted their independence and fought together for suzerainty. It was in the period of Contending States, as the Chinese historians call it that, from 551 to 479 B.C., the most famous of the Chinese, Confucius, lived.

Another very famous Chinaman changed the complexion of the Contending States. He was the Emperor Chin Chi Huang-ti, who ruled from 249-210 B.C. This Emperor united the Chinese, and to shut off the invasions of their troublesome neighbours, the Mongols, he built perhaps the most prodigious Maginot Line mankind has ever witnessed. This immense fortified Great Wall stretched from the sea to the north of Pekin for 1,500 miles. Nor did the Emperor's energy exhaust itself in this brobdingnagian undertaking. He drove the Mongols out of Inner Mongolia, on the borders of China, into Outer Mongolia, and the Early Han Dynasty (206 B.C. to A.D. 23) continued the aggression. Then occurred one of those remarkable shunting-train movements which the Chinese in an aggressive imperial mood originated. The driven Mongols and Turki-Mongols retreated westwards, forcing other peoples before them. Some of these peoples, continuing westwards, conquered the Greek Kingdom of Bactria-Sogdiana between the Hindu Kush and the Sea of Aral; others turned south and eventually passed through the Bolan Pass and invaded the land of Five Rivers, the Punjab. The Early Hans annexed Mongolia and Eastern Turkestan, and Bactria and Sogdiana were compelled to acknowledge their supremacy. Any further conquest was then stopped by the barrier of organized Persia.

The Hans, early and late (A.D. 23-230), bring us to the Mongol or Nomadic movements of our own era. A great Mongol movement brought about the downfall of the Western Tsin Dynasty in China in A.D. 419. The Gupta Dynasty in India was overcome by the White Huns in A.D. 450. These White Huns also for many years harassed the Persians, but were eventually destroyed by the power of the Sassanian Dynasty. The date of the movement under Attila the Hun, who reached Rome, is given as A.D. 445-453, and caused the Slavs to push the Teutons into Britain, France, Austria and Lombardy.

The Chinese, under the short Suy Dynasty (A.D. 590-618), and the Tang Dynasty (A.D. 618-907), in its early period, launched an imperial recoil movement and by A.D. 640 had again conquered Eastern Turkestan and extended their influence as far as Persia and the

Caspian. The Arabs in Persia checked their threat to Persia about A.D. 650.

A further Mongol movement brought the Tang Dynasty to an end in A.D. 907 and sent the Turki-Mongol Ghazni Dynasty into North-western India. The Magyars entered Europe and divided the Slavs into northern and southern Slavs.

The vast Mongol and Turki-Mongol movements under Genghiz Khan and his successors occupied the thirteenth century. China was conquered. Northern India was conquered. The Arab power was broken in A.D. 1258. Assaults were made on the Byzantine Empire, and southern Russia was conquered and occupied.

The latter half of the fourteenth century witnessed the peculiarly personal achievements of the greatest of Asiatic conquerors, Tamerlane (A.D. 1335-1405), the Turk. No ruler of the time was able to oppose his supreme genius with success. He was not destructive and murderous as were Genghiz Khan and his successors, but supplanted the established rulers by conquest. He was, wrote Sykes, 'profoundly sagacious, generous, experienced and persevering ... In *The Institutes* it is laid down that every soldier surrendering should be treated with honour and regard, a rule which, in striking contrast with the customs prevailing at the period, is remarkable for its humane spirit.' As a consequence no marked change occurred in the habitation of peoples.

The last two Mongol movements were conquests and changes of dynasty without any general effect. The first was the Moghul conquest of most of India (Akbar, A.D. 1556-1605); the second that of the Manchu conquest of China in A.D. 1644.

Such, in outline, was the historical effect of the Nomads of Asia. A full account of these movements, the history caused by them, and the numerous dynasties founded by them in Asia and in Europe, mostly to endure only about a century and a half, will be found in my *Causes of Peace and War* (Heinemann, 1926).

Here let us close the physical atlas, and this long chapter, which it is hoped will convince readers of a dependence of much war and history upon men's attitude to the soil. At present it is a subject mostly ignored by the historians, but I hope that soon some great modern scholar will deal with the subject more adequately than I have been able to do. Perhaps it will give rise to a greater knowledge of the causes of devastating wars and their prevention. Perhaps it will show that home-farming establishes in each nation a class strong in its desire for peace, and that, as in the past the Nomads were the chief enemies of peace, so the nomadic type is still prevalent and powerful, and still sees in war the means of its advantage. The social elimination of these advantages and a true valuation of the soil may then prove powerful factors in the maintenance of peace.

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by G.T. Wrench

Chapter 7

Contrasting Pictures

In order to get a clear idea of the modern valuation of the soil and its effects, it is well to begin with the opposite of the unavoidable sketchiness of a trans-continental survey, such as that of the last chapter, and to concentrate upon self-contained examples on a small scale. Small islands offer themselves at once as the opposite to great continents. By nature they are self-contained. Their inhabitants get food from the sea, a source with which they are unable to interfere as they can with the soil. Sea-food, therefore, has the natural quality of wholeness. Health, therefore, should be found in such islands.

It is never vain to ask health from nature, and small islands still preserve to a large extent this gift, or certainly did until trade intervened. The health of the few inhabitants of that most isolated island, Tristan da Cunha, was described by a medical visitor in the *British Medical Journal*, March 1938, as 'vastly superior to that of the civilized world'. Similar health distinguished the inhabitants of the once isolated Iceland and the Faroe Islands. The health of uninterfered-with South Sea islanders affords further examples.

This whole health is shared by all forms of life and is preserved whilst the island is a self-contained life-cycle and the rule of return is followed automatically. But, when trade enters and breaks the rule of return, then a deterioration of life sets in. This has happened in the Falkland Islands in the South Atlantic. There are many islands, but only two of any size. They run parallel to each other and are some 100 miles long. These islands came into the hands of the British over a century ago. Bleak and almost treeless, they nevertheless possessed vegetation upon which sheep and cattle could feed. So these animals were imported and bred for the British market. The venture was a success, but in course of time there came evidence that the way in which the trade was conducted was inimical to the life-creating soil of the islands. Sir John Orr, in *Minerals in Pasture*, described what this

was: 'Munro reports that in the Falkland Islands sheep have been reared and exported for forty years without any return to the soil to replace the minerals removed. During the last twenty years it has become increasingly difficult to rear lambs. The other animals are also deteriorating.'

The sequence or story is a very simple one.. There are these two islands, which have their own life-cycle. They became British and Britons imported sheep and other domestic animals to the islands. These animals were not predatory. They belonged to the grazing animals, which all over the world feed on grass and other herbage and do the soil no harm. Presumably, then, they could have been added to and supported in the Falkland life-cycle without doing it any harm, if, as just part of that cycle, they grazed and at the same time returned to the soil again what they took from it in life and finally after death. The story does not, however, run this good and happy way; it, like so many primitive stories of life, has its demon. In this case the demon quite probably lives in Liverpool, and he shows his demoniac quality in buying the Falkland sheep, having them shipped to Britain for the Britons to eat their flesh and spin their wool. He is not a demon of commission but of omission. This is what he and his like effect in the words of Sir John Orr: 'The process of depletion and the resulting deterioration which shows itself in decreased rate of growth and production, and in extreme cases by the appearance of disease, is proceeding on all pastures from which the milk, carcasses and other animal products are taken off without a corresponding replacement being made.' In Britain itself domestic animals are reared and then sent off to industrial areas without replacement. 'In our own country this process of depletion has been going on for many years, especially in hill pastures, and it is probable that the recognized decrease in the value of hill pastures in certain areas, owing to the increase in the diseases and mortality of sheep, is associated with the gradual process of the impoverishment of the pasture and its soil.'

The sheep want to get their full share in the life-cycle, but they cannot. The minerals are not there, for they left the life-cycle when the sheep's ancestors were deported to industrial areas. Precisely the same has happened in the Falkland Islands in the distant South Atlantic; and in both places it happens for the same reason, that the men, who own both, put money before life.

This is known with the half-conviction and half-knowledge, which are part of the famous facility for compromise of the trading race which owns them. In certain grazing areas, a form of return is given, which again forms a trade. The pastoralists or their employers buy the chief minerals, which the soil loses, from other men who mine and excavate them, and these imported minerals are put into the depleted soil. It is something to the gain of the soil for the time being and maybe this is being done to the Falklands. I have no information on the subject, but it is possible that phosphates from the South Sea island of Nauru eventually reach the soil of the Falklands.

Such a return would occur, and does occur in a great number of places, *not as a following out of the rule of return, but from an almost absolute necessity because the rule has not*

been followed. Were it followed, there would be no need of any reconstruction of the treatment of the Falkland Islands, nor to state how it would have to be carried out as a reconstruction based on the soil.

The herds kept by the British in the Falkland Islands constitute the biggest animal feeders upon the herbage. The herbage draws its minerals from the soil, and these minerals pass into the bodies of the cattle. When those bodies, either alive or as carcasses, are taken out of the islands, then so much of the minerals of the soil as they contain are taken out of the islands. They arrive in Britain and there these minerals enter into the bodies of the British, who eat the meat of the animals. The British are, in brief, eating up the soil of the Falkland Islands. To fulfil the rule of return, when ships take the animals to Liverpool or London, ships should take back their equivalent in food for the Falkland Islands to Port Stanley. This is no more impossible than it is for iron to float upon the water and form the ships in which the food travels. It is only a question of values. If the *condition of the soil were the valuer*, this would be done. If health were the valuer it would be done. If the *economy* of health and quality were the valuer, it would be done. It is not done, because under present values, a number of people actually profit from the ill health of a far greater number, their methods of business being inseparably involved in the breaking of life-cycles and consequent ill health and its social complications. The buyer buys the products of the small islands, but he gives back only something abstract, namely money; he has no duty to give back anything more than his money. Further, the owners of the Falkland products exchange them for money and they also have no duty to life in the form of the rule of return. They may be forced to buy some sort of manure for the land, but they do this under pressure of the land's depreciation. But as long as they can sell the minerals or stored fertility of the Falklands to Britain for money, they do so without any pricks of conscience as regards the effect of their deeds upon the quality of life. It is, in short, an astonishing anomaly that they who ship this life to Britain, in doing so, each time actually commit murder on a certain quality of life in the Falklands. They become ultimately as dangerous to the pastureland as the pastoralists of the last chapter, and, indeed, being more powerful in means than they, correspondingly more dangerous.

What could be ensured if the rule of return were followed? This can be answered by a consideration of a contrasting picture to the Falklands, a yet smaller microcosm than the islands, actually a dairy farm. The one I propose to review suits my purpose well because it was a deliberate reconstruction based largely on the rule of return.

The farm of 165 acres only is situated within a hundred miles of the southern shore of the Baltic Sea, in a land of heath and pinewoods and an unfavourable climate of heavy wind and low rainfall. Its story starts with failure. In spite of importing sound cattle and feeding stuffs from outside at considerable expense, the farm fell, where sick farms and industries do fall, namely, into the hands of a bank. But the bank failed to make it flourish and eventually it came into the hands of a farmer who believed that to get a sound and healthy farm it must be a self-contained unit within the countryside itself. The beasts had to get their health from the soil on which they lived and not from outside, and they had to give

back what they took from it. He proposed, as it were, to put a circle round it and that circle was to be a magic circle. Its magic was to be the aboriginal strength of the soil. A self-contained world of plants, animals and insects was to be brought into being and the balance that nature produces allowed to give its wholeness or health. The faith of the farmer was that only when the cattle bind their whole nature with the soil that nourishes them can they and the soil unitedly reach their full strength.

Everything was planned as a whole, but for the purposes of description the parts will be taken separately. Firstly comes the soil, Its chief needs were water, protection against wind, and food. Water depended upon the annual rainfall and this was some thirteen to seventeen inches yearly. More rain could not be got, but shelter helped to prevent evaporation, as shown in the woods and heaths, which were the uninterfered-with vegetative cover of the land. So the growing of trees and hedges with their double use of protecting soil by their above-ground growth and connecting soil and subsoil by their below-ground growth. Trees also gave a homeland to birds, and hedges to flowers, hedgehogs, lizards, hens, hares and a varied world of insects, all of which were neither encouraged nor suppressed, but allowed by the knowledge that in free instinct each form of life seeks its sustenance from and gives its quota to the whole, which in natural balance is health.

Then came the cultivated plants and these were chosen for the food of the animals, a smaller part for the humans and a larger part for the domestic animals. The plants for the animals were so chosen that food from the soil was available all the year round. Where special protection for finer foodstuffs was necessary, a terraced garden was devised for their growth. When use had been made of the edible part of these plants, the rest was rotted into manure by a process of composting with the dung of the animals and so returned to the soil. Nothing went off the farm except the milk and the occasional sale of a young animal in later years, when their vigour became celebrated.

We can now form a picture of what this farm became. It became, in its having as far as possible a setting in the original nature of the land, an aboriginal farm. But added to this was the skill and knowledge of specially trained men. It was a farm which deliberately reintroduced the methods of nature in uncultivated lands so as to regain nature's health and strength. It was a declaration that *it is never vain to ask nature to give health to the work of those who know what health is*.

The results were termed miraculous. The healing brought about certainly makes one think that the miracle is not in nature being able to create health, but that so few westerners know it. Here are the conditions before and after the miracle. When the dairy farm was started on the new lines, the herd of cattle suffered from contagious abortion, and were strongly tuberculous. A number of the animals had to be destroyed owing to tuberculosis, and it was even debated whether it would not be better to destroy the whole herd to get rid of tuberculosis, contagious abortion and other diseases once and for all, and buy a new herd. But the faith that works miracles was present. Out of the sandy floor came a fount of

animal health. The one-time sick herd acquired a new health. The new methods required understanding, hard and sacrificing work. But the result was that on this new shut-off and self-contained farm the soil revealed its surprising gifts.

The young plants took upon themselves a new being. They now were healthy and reproduced abundantly. The seeds that they bore were seeds which the sandy soil welcomed; they were just the right seeds being in the same cycle as the soil itself. The plants looked well and the fodder straw preserved its beautiful golden colour. The plants grown for human use yielded foods notably rich in taste. The animals in their qualities accompanied the plants. They became healthy and fertile instead of sick and infertile. The cows gave more abundant milk and the young cows born on the farm doubled the output of the past milkers. The milk itself was rich in taste and acquired a special market amongst invalids, who enjoyed its taste and experienced its nourishment. Particularly noticeable, because of the eternal charm that belongs to healthy youth, were the generation that were born into this life-cycle on the farm. At birth the calves at once sprang up and showed a lively temperament. They grew strong limbs and glossy coats. Rather surprisingly they contradicted the dictum that soils poor in chalk produce poor bones. These calves built notably strong bones upon their chalk-poor soil. That other weird fact, which in itself seems to partake of the miraculous, that rays from the sun upon the skin of beasts assist powerfully in the use of chalk, came into its full operation so that such chalk as the soil had was economically excellent chalk. Every particle of it fell into its right place in the cycle, and, as an outward and visible sign of it, owners of neighbouring farms came to inspect the calves, felt their strong limbs, admired their vivacity and delight in life and readily bought them when for sale to increase the strength of their own herds according to the accustomed manner, which the farm itself had been able to abandon.

So we have these two contrasting pictures, the picture of the Falkland Islands, where the cattle showed such marked deterioration and where they were difficult to rear, and that of the sick farm which became a fount of animal health. The similarity of health and wholeness of the farm is unmistakable. Health is a positive quality and I do not know how else it can be obtained or maintained except by wholeness in the cycle of life. Nutrition diets, vitamins, protective foods are not wholes. They are only selections of one factor of a cycle, the factor of human food. If they are given the claim to produce health, which is a whole, it is a claim which will lead men, or mislead men, to further disappointment. Health is now being particularly pursued by a nutritional avenue as well as by the anti-microbic sanitation avenue. But when the whole is the aim, the fragmentations which are sought by these avenues, the specific microbes, the antiseptics, the sera, the vaccines, the great chemical remedies which now compel the admiration of all, the vitamins, the minerals of food, the protective foods, the hormones -- all become unessentials, being absorbed by the positive whole, in which even the microbic world loses its negative and dangerous character and becomes positive and beneficial. Negatives vanish and positives take their place. The world, as fashioned by men, undergoes an enormous simplification. The scores of diseases of men and the animals and vegetables they farm constitute an

immense mass of negatives, the elimination of which would alter the very aspect of life. At present we are pushed to a host of discoveries, inventions, and health, and even life-destroying creations, because the simple contrasting pictures, which figure in this chapter, have not been seen at all by the vast majority and not seen with lively vision by the few. We shall now review further happenings in the wide world brought about by the alienation of men's minds from the creative power of the soil.

Chapter 8

Banks for the Soil

The traders of England take living matter in the form of cattle from the soil of the Falkland Islands, pay money for it to the Falkland farmers, but pay nothing at all to the living soil itself. The reason for this is that there are no banks in Britain for the soil of the Empire, though there are plenty of them for the farmers of the Empire.

What the soil needs as payment for its share in the production and feeding of the cattle is not, of course, money. It does not want *symbols of reality; it needs reality itself*. Unless it has this reality, it becomes less and less able to carry out its part of the partnership between it and the Falkland farmers. So it must have a payment in its own currency, that of soil-food-substances, and not in the currency of men.

It is true that the currency in which the farmers are paid could be turned into one factor of soil-food by means of a further trading transaction. The farmers, for example, could with the help of their banks buy phosphates from the island of Nauru in the Pacific Ocean and give it to the Falkland soil to make up for the phosphates that were taken out of it in the bodies of the exported cattle. But this transaction, being carried out by traders' money-banks, would not prevent the final loss of the phosphates of the Falkland' soil. These phosphates would, in the absence of banks for the soil in Britain, just go down the drain; in other words, they would first be eaten as a part of beef or mutton by some people in Britain, made use of by them, be passed by them as excreta into the drainage system and, through it, eventually reach some part of Britain's Atlantic girdle. So, from the world of terrene men, these phosphates would be dispersed into the vast, dark world of the waters of the sea.

With banks for the soil in Britain, however, the story would be very different. Not only the phosphates, but all the life substances of the Falkland soil would be collected by the banks for the soil and paid back to it, just as the farmers' banks collect the money due to the farmers and pay it back to them. The banks for the soil would, in brief, follow the rule of return. They would do for the Falklands, what they would also do for all exporting countries, the products of whose living soils were imported into Britain. They would collect all forms of imported soil substances after use, make them into soil-food and return

them to the exporting countries. Thus the balance of life, which is far more important ultimately than is the balance of trade, would be preserved. As it is, in this age of commercial values, nothing at all is done; the benefits of trade are split off from life itself as a whole, and, quite unconsciously, the traders become the enemies of that life. They actually destroy that upon which their own very wealth depends. They impoverish the soils and in the end will so degrade them that trade will come to an end. Even the soil of the huge cattle estates of the Argentine, which send far more animal food than the little Falklands to Britain, is known to be deteriorating.

It is, then, where traders and other business men are most concentrated that the need of banks for the soil is most urgent; it is there that the wastage of the currency of life substances is most colossal; it is there that the knowledge of this wastage is so meagre as almost to be entirely absent. Britain, as an importing country in particular, takes large quantities of raw material for food, clothing and manufacture from foreign soils. The towns of many other countries do likewise. The result is that export trade in terms of the life-cycles, entails a great transfer of the elements of life from one country to another without return, or, in other words, a slow bleeding of the exporting countries. The importing countries are seen as leeches or other blood-sucking parasites harboured, all too willingly, by the exporting countries. With vast territories the exporting countries will enjoy a long spell of prosperity founded upon a primal high fertility of the soil, but the end is inevitable, a loss of the wholeness of its life-cycles, partial or complete spoiling of the land, erosion, flood, swamp, even barren hills and desert, degenerate plant and animal life, human depopulation and poverty, disease, and other sequels of the loss of soil fertility.

In reconstruction, this loss of the fertility of the soil, due to the wrongful values of commercial dominance, can only be met by banks for the soil. It is not a question only of whether life can be healthily carried on without them, but of *whether it can be carried on at all*. In 1896 Professor Shaler of Harvard gave a very clear and ominous reply to this question of questions:, 'If mankind', he said, 'cannot design and enforce ways of dealing with the earth which will preserve the sources of life, we must look forward to a time -- remote it may be, but clearly discernible -- when our kind, having wasted its great inheritance, will fade from the earth because of the ruin it has accomplished.' That is the startling fact, with which the neglect of banks for the soil faces the peoples of the era of progress.

The Falkland Islands are very small and very distant. Their loss to the modern world would make little difference. They do but present an infinitesimal part of a wastage that is going on on a truly enormous scale. Of this wastage, let us now take one of its chief examples, that of the wastage of human sewage.

Everyone knows that manure can be turned into food by the soil, and in nature is returned to the soil. Yet the waste of potential manure is prodigious. The dictionary definition of waste is 'resembling a desert'. Yet what is called waste does not resemble, but is the opposite of the desert. The desert is *out* of life. It is modern water-carriage sanitation that

takes the elements essential to human life and puts them *out* of life, and then calls them waste.

A vast picture of this waste is given by Professor F. H. King in his classic, *Farmers of Forty Centuries*: 'On the basis of the data of Wolff, Kellner and Carpenter, or of Hall, the people of the United States and Europe are pouring into the sea, lakes or rivers, and into the underground waters, from 5,794,300 to 12,000,000 pounds of nitrogen, 1,881,900 to 4,151,000 pounds of potassium, and 777,200 to 3,057,600 pounds of phosphorus per million of adult population annually, and this waste we esteem one of the greatest achievements of our civilization.'

The loss of such quantities of the three elements is but a partial measure of the total loss, into the sea and other waters, of elements of the human life-cycle, a loss which could be avoided by the banking of these elements and returning them to the soil. To supply, by contrast, a picture of banking, Mr. King quotes Dr. Arthur Stanley, when Health Officer of the city of Shanghai, in his annual report of 1899: 'Regarding the bearing on the sanitation of Shanghai of the relationship between Eastern and Western hygiene, it may be said, that if prolonged national life is indicative of sound sanitation, the Chinese are a race worthy of study by all who concern themselves with Public Health. While the ultra-civilized Western elaborates destructors for burning garbage at a financial loss and turns sewage into the sea, the Chinaman uses both for manure. He wastes nothing while the sacred duty of agriculture is uppermost in his mind.' Banking for the soil, therefore, captures Dr. Stanley's decision. He was no advocate of sanitary progress for Shanghai in the form of destructors for garbage and the water-carriage system.

There are in Europe, however, towns which, like those of the Far East, bank in the interests of the soil. There are towns which have actually gone back to this banking after trying out the water-carriage system. The beautiful capital of Sweden is one, and its transfer back to use in place of wastage must have been just completed when the war broke out. In German towns banking was ordered by the Government in 1937, not as a part of the soil basis of civilization, but as a war measure amongst other war measures, an application of knowledge about life-creation to assist at life destruction.

In Britain, the Ministry of Agriculture in 1923 published a leaflet, No. 398, advocating this banking, but again not for the obvious reasons of the rule of return. Motor-cars, buses and lorries had greatly reduced the number of horses and the amount of stable manure. Among the various substitutes for this loss, one which had thereby gained a financial farming value, declared the department, was ashpit refuse. There was plenty of it, but it was unfortunately very little used. 'Incineration of this refuse is costly and is sheer waste. More up-to-date town authorities are now making an effort to dispose of their refuse in a better and more useful way, and some are adding other wastes and crushing the whole for use as a fertilizer.'

There follows an account of what some of these towns were doing: London, Glasgow,

Dundee, Perth, Aberdeen, Rochdale, Warrington, Halifax and in particular Gateshead, where 80 per cent of the houses had 'mixed pail' or ash closets, and hence the 'home refuse contains a considerable proportion of human excreta'. This was crushed with ordinary town and slaughter-house refuse, and made into a manure at the low price of two shillings and sixpence per ton, at which price it was eagerly bought by local farmers. Tested in the field, it showed itself a valuable substitute for farmyard manure. Night-soil in dried form was prepared and sold by the Rochdale, Warrington and other corporations, a method, which if generally adopted, said the leaflet, would solve the problem of the wastage of sewage and 'the shortage of organic manures on the farm would be greatly relieved; but we must expect these methods of conservancy to be superseded'. Fifty years ago even London was a town from which farmers could take night-soil for their fields. But the excessive convenience and niceness of the water-carriage system have given it the approval, not only of the urban peoples, but of many of the country folk also, so that now something surreptitious has become attached to any other method of disposal. One must expect these other forms of conservancy to supersede any form which recognizes sewage and garbage as merely latent forms of life. That, however, is unquestionably what they are; and a hygiene which destroys them and drives them out of the human life-cycle, has no real title to its name. In this it is the opposite of the name it bears.

The waste substances themselves show their avidity for life when put together. In the. making of manure from the various town wastes, the materials, when mixed together, cook themselves by fermentation. A heap of compost, for example, gets so hot that, if an iron rod is thrust into it, when withdrawn it is too hot to grip and hold. The final result of this cooking is like the leaf-mould that forms on the floor of a forest. The rotting of vegetable and animal matter in a forest is a cleanly process and that done in a town with town wastes can be as clean, and as free from flies and smell. It can, indeed, and should be the replica of the method of the forest, except that the pace of the urban method is rapid and makes good, sweet humus in three months, whereas the making of humus in the forest is a slower process. But in both cases there is evidence of active life. The heat is one evidence, and the growth of fungus is so active that it can be seen like smears of whitewash both on the floor of the forest and in the urban heap.

This waste then announces, in a really emphatic manner for something supposed to be dead and done for, that it is very much alive and that it is just as much a part of the life-cycle as a whole as it is when it pulses in the hot blood of a Derby winner. It is also hot life, indeed, for during the greater part of its activity it is considerably hotter than is an animal's blood. Then, when its heat and activity die down, it has become the pleasant-smelling and crumbling humus, which is a starting point of the rich green growth of healthy vegetation.

Such is one result of banks for the soil. The shamefully misnamed waste becomes the beautiful, soft, crumbling humus, which is the very substance of healthy life. It needs, perhaps, a poet to realize what beauty it contains. A poet can see in it the great, positive Yea, which is the unchangeable token of healthy life and of all that gives strength, grace,

swiftness, endurance, cheerfulness, agility, elegance and beauty to mankind. It is the universal parent of the excellencies of life.

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Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 9

Economics of the Soil

The link which connects towns and country in such a matter as the use of town waste is a money link, or cash nexus. Under present values one would be unable to find a municipality that turned its wastes into humus *for* the good of the soil, but only because, *as* good for the soil, the farmers bought it. By selling that which once had been waste, it is converted into cash, and this, in present values, is, the *good* result from the municipal point of view.

Leaflet No. 398, of course, had to accept the dominance of this way of valuing. It wished to persuade the farmers to make use of prepared waste, because thereby the great loss to the land of organic manure, which had resulted from the diminution of stable manure, would be mitigated, if not compensated. It was true that money, in the form of railway costs in particular, prevented farms distant from towns being able to get the manure, but those in their vicinity were urged to its use. As things were, the leaflet found that some 10,000,000 tons of ashpit refuse was produced annually in England and Wales, and that towns were spending £6,000,000 a year on collection and disposal. This was unquestionably waste.

The cash nexus, therefore, overrode more vital reasons. Twelve years after the issue of the leaflet of 1923, Sir George Stapledon gave out the ominous information that sixteen and a half million acres of England and Wales, or 43 per cent of the total of cultivable lands, had fallen into 'a more or less neglected condition'. They were, however, 'capable of radical improvement'. The Earl of Portsmouth, about the same time, summed up another aspect of the same question in these words: 'It is a staggering commentary on our present attitude to health and agriculture that, excluding all accident, all patent medicines and private medical cases, the bill for sickness in this country amounts to £276,000,000 a year, while

the farmer receives for his gross output barely £250,000,00O.,

Putting the two together, there was a great deal of wastage of wastes and of land itself. The wastage of land was very great indeed and the more surprising in that it occurred in a country threatened by war on a greater scale than that recently experienced in 1914-18, in which it was nearly brought to its knees by the lack of well-cultivated homeland, a war in which also the blockade of its enemies and their consequent shortage of food was a large factor in their collapse. The need of good soil had been emphasized by world events in such high tones that it would be almost incredible that it was not regarded as a paramount national and popular need, were it not that, for a prolonged period, a thought-barrier had practically and intellectually shut out the people from the soil.

So one of the strangest things happened. In spite of the great danger of the neglect of soil being written large in letters of blood, the people were blind. They were also deaf, for they did not hearken to the warnings of such authorities as Sir George Stapledon, the Earl of Portsmouth, and many other leaders of the countryside. 'It takes two to speak the truth,' said Thoreau. 'One to speak and one to hear.' They were unable to hear.

The barrier was the paramountcy of money, of the cash nexus. As long as that was paramount, the creative power of life and all that pertained to it was inextricably fettered.

Only the rare man could himself escape from the entanglement and see things in their proper proportion. Such a rare man was the late Oswald Spengler, author of *The Decline of the West*, and his account is so clear that it must here be given in his own words. Spengler's German is very difficult. My quotations are from the two-volumed English translation of his work.

He begins his analysis at the time when civilization was purely agrarian. The life of the population is purely that of the peasant on the open land. The experience of the town has not yet come. All that elevates itself from amongst the villages, castles, palaces, monasteries, temple-closes, is not a city, but a *market*, a mere meeting place of yeomen's interests, which also acquired, and at once, a certain religious and political meaning, but certainly cannot be said to have any special life of its own. The inhabitants, even though they might be artisans or traders, would still *feel* as peasants, and even in one way or another work as such.

'That which separates out from a life in which everyone is alike producer and consumer is *goods*, and traffic in goods is the mark of all early intercourse, whether the object be brought from the far distance or merely shifted about within the limits of the village or even the farm. A piece of goods is that which adheres by some quiet threads of its essence to the life that has produced it or the life that uses it. A peasant drives "his" cow to market, a woman puts away "her" finery in the cupboard. We say a man is endowed with this world's "goods"; the word "*possession*" takes us back right into the plant-like origin of property, into which this particular being -- no other -- has grown, from the roots up.

Exchange in these periods is a process whereby goods pass from one circle of life into another. They are valued with reference to life, according to a sliding-scale of *felt* relation at the moment. There is neither a conception of value nor a kind or amount of goods that constitutes a general measure -- for gold and coins are goods too, whose rarity and indestructibility cause them to be highly prized.

'Into the rhythm and course of this barter the dealer comes only as an intervener. In the market the acquisitive and creative economics encounter one another, but even at places where fleets and caravans unload, trade only appears as an *organ* of countryside traffic. It is the "eternal" form of economy, and it is even to-day seen in the immemorially ancient figure of the pedlar of the country districts remote from towns, and in the out-of-the-way suburban lanes where small barter-circles form naturally, and in the private economy of savants, officials, and in general everyone not actively part of the daily economic life of the great city.

'With the soul of the town a quite other kind of life awakens. As soon as the market has become the town, it is no longer a question of mere centres for goods-streams traversing a purely peasant landscape, but of a second world within walls, for which the merely producing life "out there" is nothing but object and means, and out of which another stream begins to circle. The decisive point is this -- the true urban is not a producer in the prime terrene sense. He has not the inward linkage with the soil or with the goods that pass through his hands. He does not live with these, but looks at them from outside and appraises them in relation to his own life-upkeep.

'With this goods become wares, exchange turnover, *and in place of thinking in goods we have thinking in money*.

'With this a purely extensional something, a form of limit-defining, is abstracted from the visible objects of economics, just as mathematical thought abstracts something from the mechanistically conceived environment. Abstract money corresponds exactly to abstract number. Both are entirely inorganic. The economic picture is reduced exclusively to quantities, whereas the important point about "goods" had been their quality. For the early-period peasant "his" cow is, first of all, just what it is, a unit being, and only secondarily an object of exchange; but for the economic outlook of the true townsman the only thing that exists is an abstract money-value which at the moment happens to be in the shape of a cow that can always be transferred into that of, say, a bank-note. Even so the genuine engineer sees in a famous waterfall not a unique natural spectacle, but just a calculable quantum of unexploited energy.

'It is an error of all modern money-theories that they start from the value token or even the material of the payment-token, instead of from the form of economic thought. In reality money, like number or law, *is a category of thought*.'

Here is clarity joined with profundity, a feat only to be executed by genius. The initial

picture of the agrarian world, in which production primarily from the soil, gives the products a reality because of the quality or life that is within them. They become man's possessions, something near him, placed or sitting by him, and valued with reference to life. But with the soul of the town a quite other kind of life arises, one in which something intervenes between 'goods' and man. The result, in its essence, is contained in the change from creative goods-thinking to abstracted money-thinking, expressed in phrases italicized by Spengler himself: 'With this goods become wares' (things of the warehouse not of the personal home), 'exchange turnover' (not as a mere inter-change of goods for other goods), '*and in place of thinking in goods we have thinking in money*', and 'in reality money, like number and law, *is a category of thought*'.

Let us look closely at this differentiation, particularly in its relation to those 'goods', which are most nearly related to life and without which life could not be, the food-products of the soil. The vegetable food-products are seeds, roots, leaves and fruits, and early men made the observation that when seeds were put in the ground, a plant grew up which produced a greater number of seeds than were put into the ground. These men did not worry about whether or not the production of a great number of seeds from a few revealed a rather gloomy and even brutal design on the part of nature to make the few seeds successful in becoming plants and so proving their superiority to the rest as the fittest to survive in a struggle for existence. They did not regard the few and the many as being due to a rather snobbish, if divine, order of precedence, serving as the explanation of the exuberance of the creative power. They were more simply bound to the facts that these extra seeds, tubers, fruits and foliage provided them with food, and they saw themselves dependent upon the manifold character of re-creation. All they understood was what they saw, namely, the generous outpouring of abundance, in response to their efforts, by a mystical power, which in its working was beyond them, but in its revelation to them aroused their awe, their reverence, their gratitude. So they served nature to the best of their ability, drew their share from the cornucopia of abundance and humbly thanked a God in this revelation of paternal love and superhuman magnanimity.

The abundance, as the result of their labours, enabled the work of a group of families to supply food not only for themselves, but for others. A certain part of their produce was, therefore, set aside for the non-working members of the families, for craftsmen who gave them possessions in return for food, and for the men of government in the form of taxes. So much of their produce had to go to government. They did not pay government for its services in money, but in produce.

Now the great significance of the tax in kind is that it is, of course, completely related to the basis of human life, the soil. The soil yields so much grain. The grain is mixed, spread out and a portion, say a fourth, is taken by an official for government. Taxation, therefore, receives the stability of the soil, and nothing really is so stable in human life as the well-cultivated soil. There is, when products are many in character, a fairly steady average return in response to a traditional agriculture, if that agriculture is not wasteful. There *must* be some such steady relation of the soil to men, for human life to continue without

violent fluctuations. There are, of course, good seasons and bad seasons. There are times of drought, there are times of flood, but a settled and capable form of agriculture does produce prolonged national life.

Payment of taxes in kind is a payment in terms of that which is primary to national life. It is factual and real in a whole national sense. It is terrenely genuine and sufficient, and has no foreign, extraneous and unlimited character, such as life dependent on conquests, on the wreck of weaker nations or, through the agency of money, on the well- or over-fed condition of the few and the underfed condition, or malnutrition, of the many. It, in fact, liberates the soil and keeps it free from money, the one real and essential freedom for a whole national life.

In the old conception the peasants paid the king for national protection. That was the service he rendered to them and for which they returned reciprocal service. That is the doctrine to be found in the classics of the past, such as the Smriti or law-books of ancient India. The land of the country was not the king's property, but *the common property of all who work on that land, and enjoy therefrom the fruits of their labour*, as Professor Dvijadas Datta insists in *Peasant-Proprietorship in India*, 1924. Taxes were to protect the living land and the land of the living, and not as they have now become, under the priority of money, for things so anomalous as, for example, the payment of interest on money lent by the privileged class for wars that were fought and decided over a century ago. The peasants did not pay the king to protect the land against enemies, whose dead bodies had for long been dissolved into soil-fertility. They paid for the protection of the land on which they were living and by which their nation was living.

No one can juggle with the soil as acquisitive men have learnt to juggle with money. The soil is reality; it has its own dominant character: it is more powerful than man, for it has that infinite mystery of power to turn death into life, and so not to remain as death. But money is purely man's invention and he can fashion it of what he likes, from the ponderous blocks of iron of the honest Lycurgus to the book-entries of modern bankers or manufacturers of credit. It can take every form of transubstantiation that dominant men choose to put upon it. It permeates everything that they dominate. It is only upon the land that men will ever be able to get free of it. It is only there that they will be able to see clearly what life really is.

And life is something that starts from the health of the soil in a way that, if it is to be successful, the principle of life must direct. Soil, in conservative and whole life, directs and rules money, not money the soil. Soil is the first primary thing and in reconstruction its needs must be provided for apart from the assumption of priority by money.

Money acts rather as a balance, as a subservant to the soil. So it acted at least amongst Indian and other peasantries. That is why it was denoted by metal and why it was recognized as a possession because, being metal, *it had durability* as the land had durability. It could act as a substitute of the land. When there was scarcity in local soil-

products, coins came into existence to make stored food and second-class food available by assisting poor land to be cultivated. When famine threatened or existed, then the silver bangles of Indian women were taken and handed to the *sowcar* and weighed by him and turned into an equivalent weight of silver coins. So coin became more plentiful at times of distress.

This is the *exact opposite* of urban banking. When distress threatens, bankers call in their loans. As distress increases, money in circulation becomes less, not more -- more distress less local money, not more distress more local money. In very great distress, according to the sages, it was right for the king not only to forgo the taxes in kind, but to give money, not loan it, in order to lighten the distress by enabling the suffering people to buy food and assistance from outside their locality.

The right economics of the soil do not exist under thinking in terms of money. If the soil is lined up with other productive agents of saleable goods, then its intrinsic character vanishes. It is essentially different to goods manufactured for sale, for it is as much property of life as is the air. Neither soil nor air have market value because they are necessary means of life. There is no market value yet for air, there should not be one for soil. City air, burdened with petrol, is not bad economics but bad life. The soil, that is burdened with money, is not bad economics, but bad life. That is why the right human partnership with the soil is an essential of human life, if it is to endure.

With the right conservation and service, the soil responds with something that is as certainly stable as the human virtue which, through the continuity of family service, provides this protection. It responds with its repetitive, but limited, gifts with a regularity, which is entirely different to the violent fluctuations in national and personal life which have occurred from the output of the precious metals, and owing to which the most profound effects in modern civilization have followed upon the discovery of Potosi silver, Californian gold and improved chemical processes for extracting gold. Nothing, one feels, could be more fantastic than to try to stabilize human life -- and it must be stabilized if catastrophe (or change in the crust of the earth which is one of its dictionary definitions) is to be avoided -- while measures of such inconstancy are permitted to dominate.

Let us now, then, in the midst of our inconstancies and the great catastrophes in which we have our present being, in this our reconstruction review this great virtue of *constancy* in terms of the creative power of the soil. Here we have for our enlightenment Professor F. H. King's book, *Farmers of Forty Centuries*.

His introduction of ten pages is one of contrast pictures of the thorough and profound relation of men to the soil in China and its pupillary countries, of the conditions of social constancy that result therefrom, and of the undeveloped relation to the soil of men in the West. He took as a striking example the meticulous care with which water is preserved and used for the land in China. 'To anyone who studies the agricultural methods of the Far East in the field', he wrote, 'it is evident that these people, centuries ago, came to

appreciate the value of water in crop production as no other nations have. They have adapted conditions to crops and crops to conditions to such a pitch that in rice they have produced a cereal which permits the most intense fertilization and at the same time ensures the maximum yields against both drought and flood. With the practice of Western nations in all humid climates, no matter how completely and highly we fertilize, in more years than not, yields are reduced by a deficiency or an excess of water.'

He went on to summarize the magnitude of the systems of canalization in China, a conservative estimate of which would place the miles of canals at 200,000. China has as many acres in rice each year as the United States has in wheat, yet the rice does not bear rice alone, but 'produces at least one and sometimes two other crops each year'.

When and where water is not available for irrigation, the people cultivate 'quick-maturing, drought-resisting millets as the great staple food crops', and for them the water is preserved by 'almost universal planting in hills or drills, and so making possible the utilization of earth mulches in conserving soil moisture'. Thus 'these people have with rare wisdom combined both irrigation and dry farming methods to an extent and with an intensity far beyond anything our people have ever dreamed of, in order that they might maintain these dense populations'.

The canals, moreover, render not only water, but a refreshment of soil itself comparable to that of the overflow of the Nile or of the warping of the Isle of Axholme. 'In China enormous quantities of canal mud are applied to the fields, sometimes at the rate of even seventy or more tons per acre.' And where this mud is not available, they yet refresh the soil in a manner again rivalling the autochthonous renewal of Egypt. 'So, too, where there are no canals, both soil and subsoil are carried into villages and there they are, at the expense of great labour, composted with organic refuse, then dried and pulverized, and finally carried back to the fields to be used as home-made fertilizers.'

Finally, on page 241, he asserted that 'China, Korea and Japan long ago struck the keynote of permanent agriculture ... In selecting rice as their staple crop; in developing and maintaining their systems of combined irrigation and drainage, notwithstanding that they have a large summer rainfall; in their systems of multiple cropping; in their extensive and persistent use of legumes; in their rotations for green manure to maintain the humus of their soils and for composting; and in the almost religious fidelity with which they have returned to their fields. every form of waste which can replace plant food removed by the crops, these nations have demonstrated a grasp of essentials and of fundamental principles which may well cause Western nations to pause and reflect.'

Without much reflection, it must be quite clear that in these works and actions of the Chinese, all the factors which promote the fertility of the soil are brought together so as to ensure and preserve its highest creative power. This is done 'at the expense of great labour' as the true character of the economics of the soil. By such great labour a fair constancy of return from the soil can be assured, a constancy which has no parallel in the dominant

money system of our time, a constancy which depends upon the fact that if all the factors of fertility in a locality are brought into the action of cultivation, the results will reach a certain degree which they cannot surpass.

The whole conception of dominant money is, on the other hand, foreign to the soil. When money is lent, it expects to get not itself but more than itself in return. Omitting the speculative hopes of capital improvement, money lent expects an addition of itself called interest.

But in good agriculture, fertility is fully used in producing a crop. It is not and cannot be called upon to create an extra quantity of itself so as to produce an extra crop or interest. Only something parasitical could add itself as an *extra growth on decadent vitality* and that does not occur in whole farming. In farming dominated by money, however, parasitism is as abundant as debt, like breeding like. If one reads a book on modern farming one cannot help being struck by the number of parasites that take their share in it. There are warble flies, scabs, lice, fleas, maggot flies, bollworms, eelworms, wireworms, fruit flies, fungi, leaf roll, blackscab, blight, mosaic, rust, bunt, smut, leaf stripe, black leg and so on. The more complex scientific farming becomes says Mr. D. H. Robinson, the greater 'the spread of complaints which formerly were unknown or of little importance'.

There is clearly quite a definite difference between a farm carried on for the preservation of a high fertility and one for the immediate production of money-crops, enforced to this by the dominance of money and credit-debt. Once a farm is involved in the credit-debt dominance, once this credit-debt is looked upon as a first need or chief claimant, then agriculture becomes inextricably involved in a huge system, with its owners and managers, and its local, national and international debts. These debts affect everyone within the system. Modern men, therefore, in facing the problem of life, find themselves loaded and hampered by the dead weight of debt. The size and pace of enhancement of these debts are so extreme that there is no hope of their being balanced by the creative power of life. The only reply to them is to use up without replacement the stored fertility of the past. Even this fails. It does not abolish, but extends debts and debtors on the land. The whole position is so utterly beyond any balance that only men with minds split from the reality of creative life could possibly acquiesce in the hypotheses and creeds which have arisen to fortify it and to make it appear rational and sane, hypotheses which were eventually forced to raise the sleek speculator and the barrel-bellied millionaire to the status of darlings of nature; her selections in the survival of the fittest!

The stark fact that appears now, and which wrote itself across the Roman Empire, is that debt and taxation increase as the soil declines. The one is a counterpart of the other. The huge, unpayable debts are the measures of the death of reality; step by step they are matched by the loss of soil-fertility. In coming chapters we shall see how remarkably the greater money dominance of the present era is matched by the greater ill of the soil. The money dominance and its vast debts, personal, local, national and international, are on the side of death and against the creative power of life.

Nature, it must be remembered, has no interest in maintaining a more highly organized form of life such as man is. If he takes a harmonious place in a life-cycle, he will continue; if not, he will be replaced by some other form of organic life, as bracken replaces grass. Survival is not a matter of struggling to be fittest, it is not a matter of the modern boast of the conquest and exploitation of nature. *It is a matter of reverence*.

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Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 10

The English Peasant and Agricultural Labourer

The English peasant first appears in Engleland as an individual with a strong bent for independence. Engleland was the southern part of the thumb of land that projects itself between the North and the Baltic Seas, the northern part being the land of the Jutes or Jutland.

The dwellers in Engleland, writes Mr. John Richard Green, in his Short History of the English People, 'seem to have been merely an out-lying fragment of what was the Engle or English folk, the bulk of whom lay probably along the middle Elbe and on the Weser', and he adds that they were allied to peoples occupying a wide tract reaching to the Rhine and collectively known as Saxons.

Mr. Green does not, however, speak of the fascinating theory of Henri de Tourville, who gives the name of 'particularist' to these Nordic peoples, because they were people of the small or particularist families of husband, wife, and children as opposed to the large joint families of fathers, their sons and grandsons and their wives and children. Henri de Tourville, in his *Histoire de la Formation Particulariste*, believes this small family came into being in the following way: some Teutonic or Nordic people reached the plains of Sweden and in their search for undisturbed homes, passed on over the mountains and settled along the fiords of Norway.

Anyone who has voyaged up these fiords must have been struck by the patches of bright green cultivation that are set between the precipitous mountains and the sea water of the fiords. They are like unequally spaced gems of emerald. He will also have been struck by the smallness of the greater number of them. Nevertheless, what is grown on them and the fish of the fiords still form the food of isolated families.

These families were small or particularist owing to the sheer limitation of vegetable food. When the families of a fiord grew too large, the younger members gathered together, stocked a few ships and voyaged southwards, seeking land for themselves in fiords farther south, in the projecting thumb of Denmark, in the northwestern river-lands of Germany, and finally in the island of Britain. In the new settlements, the love of independence led to the persistence of the small family system.

However this system actually arose, it has been of great significance in the world's history. It is the oddity as opposed to the customary large or joint family; it is independent individuality as opposed to dependence on joint opinion; and a very strong oddity it has proved to be. However rude and rough these early Engles may have been, there are few Englishmen now who will not be thrilled, when they read how Tacitus, coming from the great city-world of Rome, was struck by the jealous independence of each farmer and his family in their settlements. 'They live apart,' he wrote, 'each by himself, as woodside, plain or fresh spring attracts him.'

They could not, however, be quite independent. Dangers from other peoples sometimes threatened them and they then joined together, chose a chief and took to arms. They were fierce fighters and, when they arrived in Britain under their captains, they drove the Britons westwards or slew them, and took their land, until once more they were independent farmers at peace. They were the forerunners of similar settlers in America, Australia and New Zealand.

But, before the coming of the Norman Conqueror, these farmers, says Green, lost most of their peace and much of their independence. They had so many wars that warrior-kings and their military subordinates had become a standing feature of their society. For greater protection against invaders, like themselves in race, they had to submit to larger associations, and eventually one kingdom. They lost their spontaneity of action and had, as a condition of existence, to attach themselves to a lord or thegn of the King's party. 'The ravages of the long insecurity of the Danish wars aided to drive the free farmer to seek protection from the thegn,' wrote Green. 'His freehold was surrendered to be received back as a fief, laden with service to its lord. Gradually the "lordless man" became a sort of outlaw in the realm. The free churl sank into the villein, and changed from the freeholder who knew no superior but God and the law, to the tenant bound to do service to his lord, to follow him in the field, to look to his court for justice and render days of service in his demesne.'

The coming of the Conqueror, William of Normandy, increased and confirmed the subordinate position of the English farmers, by giving them foreign conquerors as their lords. The tendency to the establishment of the authority of the aristocrat 'was quickened by the conquest', wrote Green; 'the desperate and universal resistance of his English subjects forced William to hold by the sword what the sword had won, and an army strong enough to crush at any moment a national revolt was necessary for the preservation of his throne. Such an army could only be maintained by a vast confiscation of the soil. The

failure of the English risings cleared the way for its establishment; the greater part of the higher nobility fell in battle or fled into exile, while the lower thegnhood either forfeited the whole of their lands or redeemed a portion of them by the surrender of the rest.' Land became the property of the King, who rewarded his followers and bound them in their interests to his, by gifts of land as private property. The Norman aristocracy received many estates, scattered so that they could not constitute a dangerously strong local power, but even 'the meanest Norman rose to wealth and power in the new dominion of his lord'.

So William initiated land as the private property of an aristocratic caste of landowners, and the peasants became bound to the land as serfs.

England was, humanly speaking, a very small country at that time. The population was some two million at the time of the Conqueror and two and a half million at the time of Edward III. The total area of cultivated soil was small, the greater part of the land being forest and therefore possessing undisturbed its primal vegetative cover. The farming was backward as the slow growth of the population reveals, and, compared to that of more enterprising countries on the Continent, it remained backward for many centuries. Nevertheless, it produced a life-cycle which, though of low grade, preserved within itself a certain stability and was free from pronounced waste.

When a balance between the English and their Norman conquerors was brought about by time, the features of an association based upon the soil, with which readers are now largely acquainted, came into being. The farming was carried out by a method of large estates. These estates were called manors and the heads of the estates were the lords of the manor. Under them the people worked, with various grades of right to the land, by which one and all got their food and home directly from the land. The country as a whole was in a condition of 'Natural Economy', not 'Money Economy', and such commonplaces of the country of to-day as are capital, labour, competition, employee, had no meaning. The family or associative method was everywhere. A man might employ labour, but he worked himself with those he employed and he ate the same foods as they did. The manor was, indeed, like a large family. It was a self-contained community and the land itself was the father and mother of the community. The lord of the manor represented a personal government, but he was not able then to do with the land what he wished. His position was that of chief functionary, and not that of slave-owner as in post-Punic Italy.

The land was worked on a common plan. There were no separate fields, but one large open space marked off into strips by balks. The lord of the manor would often have his strips amongst those of the villagers. In such cases the community was a true community, in which the land was alike to all. But in other cases the personal land of the lord of the manor was not amongst but separated from that of the villagers. The community was then almost, but not quite, a true community based upon the soil.

In addition to farming by the manor system, the most or only educated section of the people, the monks of the Church, contributed to the national farming the benefits of their

devotion, learning and art.

William Cobbett has given an account of the special character and quality of the monasteries and their meaning in an agricultural civilization, in *The History of the Protestant Reformation*, written over a hundred years ago. He said: 'Nor must we by any means overlook the effects of these institutions on the mere face of the country. That man must be low and mean of soul who is insensible to all feeling of pride in the noble edifices of his country. The monastics built as well as wrote for posterity. The never-dying nature of their institutions set aside in all their undertakings every calculation as to time and age. Whether they built or planted, they set the generous example of providing for the pleasure, the honour, the wealth and the greatness of generations upon generations unborn. They executed everything in the very best manner: their gardens, fishponds, farms, were as near perfection as they could make them; in the whole of their economy they set an example tending to make the country beautiful, to make it an object of pride with the people, and to make the nation truly and permanently great. Go into any county and survey, even at this day, the ruins of its, perhaps, twenty abbeys and priories and then ask yourself, "What have we in exchange for these?"'

To their practical farming, the monks brought the help of the classic writers of Rome, of Cato, Varro, Columella and others, whose works in Latin they were able to read. They were *cultured* farmers, to whom the spiritual side of creation appealed with especial significance. It was they who instituted improvements and preserved a standard in medieval farming. It was they who harboured that endeavour to do well, without which the work of the mass of men tends to decline. It was they who built roads and bridges, and maintained traffic by opening their monasteries as places of temporary rest and hospitality to all travellers, rich or poor; they who drained marshes, reclaimed wastes, and improved livestock. It was they who filled in what one might call the full composition of a soil-based civilization by giving it the vision of religion, the art of the temple, and the culture of studentship. They also defended, as far as they could, the independence of the peasants, and supported them in their efforts to rise out of serfdom.

The lords of the manor were the worldly heads of the people. They supervised and directed the division of the land, saw to the upkeep of cottages and buildings, presided over schooling and apprenticeship, arranged marriages, punished slovenly work, dealt with quarrels and crimes, checked short weights and the adulteration of grain and beer, arranged for the exchange of goods, and directed the relations of the villagers with the outer world which began on the farther side of the forest that bounded the manor.

We now come to the introduction of 'Money Economy' to the land.

At the time when the manor system flourished best, the lords of the manor were the paternal chiefs of the villagers. But they also had a number of rights which belonged to a conquest and were, in fact, derived from the Norman Conquest. It was these rights that made their precedence in the village something different from that of the village assembly,

which is the common form of village rule and which constitutes the true freedom and independence of the partners of the soil. The lords of the manor had the right to exact a varying amount of enforced work from the villagers; they exacted fees for the services of the manorial court; they had the right to sell timber from the estate, to permit strangers to take up land, to mill and even bake the people's bread; and, their class being the lawmakers of the country, they were able to pass such laws as the Statute of Merton in A. D. 1236, which gave them a right to enclose certain lands of the villagers for their own use. In brief, they were indisputable masters; they prolonged the Conquest indefinitely and thereby prevented the villagers of England from getting complete freedom of property in the land they cultivated.

There was one other privilege of the lords of the manor which was a direct contradiction of the freedom of the soil to terrene man. It was this. They had the right to fold, not only their own cattle, but also those of the villagers, on their land. They became the manurial, as well as the manorial lords of the estates, and everyone in the village, of course, knew that their lords robbed them of food, when they took the manure.

The lords of the manor, judged from the basis of the soil, became thereby *life-robbers in the midst of the village*. They were manurial robbers long before they became open robbers and pillagers under Henry VIII. By their theft or privilege, whichever it be called, their land received a greater and the villagers a less fertility and, *in accordance with this change in the soil, there came into being a change in the human beings*. A difference in quality entered. The rich, fed by a more fertile soil, were better in physical quality. The level of the people generally was degraded. Rich and poor became not only a thing of measurement by money, but a visible physical condition.

There is nothing perhaps that has to be made more clear than this: that the first separation leading to the divided classes of employers and employed, of rich and poor, with the poor dependent not on the soil but on the rich, was a separation of farm dung. It was a personal sequestration of life-elements. It was not a crime in English law, but in terms of the soil, a lethal type of crime eventually to lead to disasters for the robbed. Immediately, owing to it, the life-cycle of the lord's demesne was improved, that of the peasants' land was diminished. 'On land which was inadequately manured,' wrote the late Lord Ernle, in *English Farming, Past and Present*, 1922, 'and on which neither field-turnips nor clovers were known till centuries later, there was no middle course between the exhaustion of continuous cropping and the rest-cure of barrenness.' Much of the land had to lie fallow, unused and uncultivated until it recovered its strength, a natural part of which the lords of the manor had taken from it. The aristocracy needed the extra wealth which this sequestration of life-elements brought them. The crime was forced upon them by their luxury and expenses as courtiers and as warriors in the Crusades and French wars. They became, consequently, exactors, not protectors, of the soil, and they displaced the old Natural Economy of the manor for the new Money Economy.

The more enterprising and frugal villeins of the manor, supported by the Church, saw in

this need of their lords the opportunity to satisfy their cravings for independence. With the surplus they achieved by their ability, they won their freedom from service to their lords and they became tenants by the payment of rent. They took over land, too, from the least efficient of the manor's farmers and worked it with the previous owners as labourers, thereby becoming in the manor the *Kulaks in the Mir*, to speak in Russian terms.

Thus, during the slow break-up of the manor system owing to the introduction of the new Money Economy, the people of the manor came to be divided into four classes; the first was the lords and their families and personal dependants; the second the tenant farmers; the third the villeins, who did not become tenants; and the fourth those who failed to support themselves upon the land that had been allotted to them, and who now worked for their more successful brethren for a wage paid in kind or in money. This fourth class are often spoken of as the class of *free labourers*, because they were to some extent free to sell their labour. Their freedom was very limited, being due to their poverty, which compelled them to use it, as labour uses its freedom to-day, in binding itself to this or that master. They lost their right to the land and to the stock which had been their capital. Their value was relative to their abundance or their shortage. Only when there was a great shortage of labour, such as that which followed for many scores of years the destructive Black Death of the middle of the fourteenth century, did their wages exceed the cost of their necessities. Thorold Rogers called the fifteenth century the golden age of the English labourers or farm-workers measured by the relation of their wages to the prices of their necessities.

The freedom that these relatively high wages brought was defeated by the continuous decline of the soil of the land in the early Tudor period. Lord Ernle wrote: 'Land had depreciated in value; rents had declined; farming had deteriorated; useful practices had discontinued; cattle were dwindling in size and weight; the common pastures had become infected with "murrain"; the arable area of open fields had grown less productive, and without manure its fertility could not be restored.'

Desperate measures were required to save the land and the measures undertaken were those dictated by the ascendant Money Economy. In Roman Italy, after the Punic Wars, the deterioration in fertility of the soil led to the substitution of family-owned farming by large estates, the *latifundia*, and large landowners. In Tudor England the same substitution of *latifundia* for small family farming also took place. In post-Punic Italy, acquisitive men seized the lands of weakened farmers with complete disregard of the law. 'The whole system', Mommsen tells us, 'was pervaded by the utterly unscrupulous spirit characteristic of the power of capital. ... Roman capital was gradually absorbing the intermediate and small landed estates in Italy as well as in the provinces, as the sun absorbs drops of rain.' In Italy, the large number of slaves acquired by Rome's conquests, hastened the process, for it was easy for large landowners to break right away from their own fellow-countrymen, and, leaving them to their fate, to engage foreign slaves for the service of the Italian soil. In England the process of the eviction of peasant family farming was not completed until the industrial era itself.

In both cases, as on similar occasions elsewhere in history, the social change was in the nature of a conquest. A group of acquisitive men, who had got money by other ways than those of direct agriculture, acted as conquerors. They overthrew the peasants' customary rights in the soil as the basis of the State and made land a commodity to be purchased by the richest bidder. In Italy these acquisitive men were the Equites or Knights, who had acquired great wealth by acting as middlemen in the newly acquired realm of Rome, and who were to form the chief part of the aristocracy of the eventual empire. In England the acquisitive men, who overthrew the agricultural basis of the State and with it the Church and the monks, became the new aristocracy of Tudor England. In both cases also there were statesmen and other leading men, who set themselves against the 'terrible measures' under which the independence and rights of the farmers and of the free labourers were to succumb. Such were Wolsey, More, Latimer, and Queen Elizabeth and her Ministers amongst the English. Nevertheless, in spite of all such efforts the great living fact about a soil remained and that fact was expressed by Ernle in the words: 'Without manure its fertility could not be restored.' Dung had to save the soil, and the quickest way to dung the land was to enclose it with hedges and breed and put upon the fields sheep and cattle. Fortunately, the acquisitive men were attracted to this method by the price that British wool fetched upon the Continent. It was this opportunity for more wealth that made them seize the land of the small men and of the monasteries and with the expenditure of their capital turn it into sheep farms. It was unquestionably good for the soil, but it entailed a brutal punishment to the small farmers, and farm labourers, whose only sin had been that they had submitted originally to the enclosing of the lord's demesne upon the manor and the robbery of the dung of their animals for the land of the manor's lord. So, a new aristocracy arose upon the human relics of a system that had failed and the brilliant later Tudor period of English history followed.

From that time the proletariat and pauperism became the familiars of social England. No appreciation of the value of the small holdings appeared. There was no Prince Kropotkin at that time to make what would have seemed an insanely preposterous statement that, with the intensive farming of small holders, the British soil might support a hundred million inhabitants. Nothing was known of the rich results of the Chinese peasants, who were so skilled in the use of water and who followed the rule of return with such meticulous care. Nothing was known of the agriculture of the fallen Arabic Empire. The Tudor world was deeply stirred by what Green calls the New Learning, but the New Learning did not bend down to the humble giver of life, the soil.

For the further story of the English agricultural labourer, the -only authoritative history in English that I have been able to find is *A History of the English Agricultural Labourer*, by Dr. W. Hasbach of the University of Kiel. It was first published in 1894, translated into English in 1908 and reprinted in 1920.

Where enclosure occurred, Hasbach says, a proletarian class appeared. English agriculture from the fifteenth century, when rich commercial men began to buy out owners living on

their land, was 'sacrificed to the interests of industry'.

He gives a full account of the second great period of enclosures, that of the eighteenth century. It was in the latter part of this century that the genius of the English and Scotch brought in a new epoch, that of the machine. The power of the machines effected a revolution. Manufacturing towns grew up and multiplied, and the demand for food put a premium on the land. The Tudor enclosures had only affected a limited area, but now there was a far greater cry for new and undeveloped land and for the deteriorated land, on which the poor crops and poorer cattle revealed the need for capital and manure. In the pre-machine part of the eighteenth century, Enclosure Acts were few; in Anne's reign two, in George I sixteen, in George II two hundred and twenty, but in the latter part of the century, when George III reigned, there were three thousand five hundred and fifty-four. In the fifty years before George III 337,876 acres were enclosed; at the end of his reign 5,686,000 acres had been enclosed.

As in the times of the Tudor, there was a great improvement of the soil enclosed. Robert Bakewell (1725-95) transformed raw-boned cattle and lean sheep into animals twice the size; from 1776 on, Thomas Coke of Norfolk proved the capacity of capitalistic mixed farming to carry treble the livestock and to produce rich crops of wheat in place of scanty rye. Turnips were grown for winter feed of the cattle and clover for the improved feeding of the soil. Earnest farmers followed these great examples. Nevertheless, the main impulse to the enforcement of enclosures was the opportunity of acquisitive men to rise quickly to great wealth. It was this that gave the movement its brutality and the character of a civil war between one section of the people and another. Though the swords of the fortune hunters were sheathed in legality, they were none the less keen when unsheathed and so, says Hasbach, enclosures were 'not seldom changed into a national curse'. It was the better class of inhabitants of rural areas who appreciated local opportunities of seizure, and it was therefore 'squires, parsons and lawyers who were the chief owners and benefiters'.

Though peasant-ownership-farming survived in some few parts of England, in general 'yeomen farmers and peasant proprietors ceased to exist; they drifted to the towns and sank into workers at a daily wage. Not only small holdings but the lesser tenancies gradually vanished in a universal system of large estates and farms.' This quotation is from Richard Green.

The agricultural labourers in this period reached the nadir of their fate. They had no protection from the Church and the monasteries, as they had when Catholicism was the religion of England; their cottage industries had been supplanted by the new machines of the towns; the days of an agricultural labourer trades union were yet to come. They were utterly helpless and hopeless. They were not even slaves, ensured by their masters as regards board and bed. The landowners ceased to pay wages in kind, in other words in food, because food fetched higher prices in the towns and the yeomen who had once filled the village markets, were no more. Their food was almost confined to wheaten bread, which, being wholemeal, supported life. Their wages were miserably small, so small that

the parishes often had to add to its pittance an allowance from the rates. Because of this the parish authorities hired out the labourers, and sometimes, says Ernle, 'the paupers were paraded by the overseers on a Monday morning, and the week's labour of each individual was offered at auction to the highest bidder'.

The labourers presented heart-rending pictures to their bravest champion, William Cobbett. Here is one taken from his *Rural Rides* in 1821. 'The labourers are miserably poor. Their dwellings are little better than pig-beds, and their looks indicate that their food is not nearly equal to that of a pig ... The land all along here is good. Fine fields and pastures all around; and yet the cultivators of these fields are so miserable ... When I see their poor faces present as nothing but skin and bone, while they are toiling to get the wheat and the meat ready to be carried away to be devoured by the tax-eaters; I am ashamed to look at these poor souls and to reflect that they are my countrymen, and particularly to reflect that we are descended from those amongst whom beef, mutton, pork and veal were the food of the poorer sort of people.'

This degradation of labourers on the land was essentially English. It did not happen in England's neighbour, the Netherlands. Nathaniel Kent travelled in the Netherlands, and, in his *Hints to Gentlemen of Landed Property*, A.D. 1775, tried to awaken the said gentlemen to this fact. In the Netherlands, he wrote, there was an astonishing quantity of provisions, and as one of his broad hints to the Gentlemen of Property, he recorded that *the holdings were all small and the cultivators on equality*. This degradation, therefore, only happened in England. And even then, strangely enough, it was not inevitable everywhere in England itself. That indefatigable traveller on behalf of agriculture, Arthur Young, at one time the zealous champion of Enclosures, but later of the opposite opinion, discovered 'with great delight the life of the small proprietors of Axholme' (*Report on the Agriculture of Lincoln*, A.D. 1799)

Now the singular fact about these small proprietors of the Isle of Axholme was that they were *not English but Dutch*. *They were a bit of the Netherlands transplanted to England*. Their ancestors had been transplanted in the Isle of Axholme more than a century before Young visited them. The Isle was a swampy property of 46,000 acres between three rivers in Lincolnshire, and had the good fortune of belonging to one of the most cultured and educated men of his time in England, Charles I. Charles had knowledge of the small holders of the Netherlands, and he called some of their families over to England to drain the Isle of Axholme and cultivate it. They were true intensive peasant-family farmers, who, as Hasbach wrote, took every small advantage, cultivated every corner, had the help of their wives, brought up their sons in their footsteps, and 'serve the land in the way it should be served, never stinting themselves and as absorbed in their service as any priest in his religion'. So these peasant-families caused Axholme to flourish, and it was flourishing when it delighted the eyes of Arthur Young at the time of the degradation of the small English proprietors and their expulsion by the Enclosures.

Axholme is still flourishing. Sir Rider Haggard in his *Rural England*, 1906, welcomed its

'almost inexhaustible richness ... it will produce magnificent crops of wheat, potatoes, celery, or whatever it may be desired to grow'. Mr. Gilbert Slater, yet later, in the *Making of Modern England*, 1934, seeing heavier crops in the Isle than he ever saw elsewhere, drew the conclusion that the men of the Isle of Axholme had abundantly justified their stout refusal to submit to enclosure in the eighteenth century. 'Not only are the open fields of the Isle of Axholme exceptionally well cultivated at the present time, but the island serves as a training ground in practical and effective farming, and men who begin as labourers there frequently become large farmers elsewhere.'

These skilled, independent men met with strong resistance from the English farmers who tried to expel them, but they inherited a tradition of soil-protection and feeding, which gave them great faith in their own work. They knew its superiority and they have not changed. Their ancestry 'affects the physical appearance and accent of the inhabitants of the present day' (*Encyclopaedia Britannica*, 14th edition).

The English labourers, in the early part of the nineteenth century, on the other hand, had lost all courage. They were an unprotected proletariat. In the times of their prosperity and independence, says Hasbach, 'they had avoided early marriages and abstained from multiplying as a mere proletariat does; whereas now all such evils appeared'. This, he goes on to say, with great significance to all narrow-visioned reformers who wish to increase a population, this is the answer to Malthus, who failed to recognize the psychological elements (despair of the future and of freedom) in the rapid increase of population. 'The error was immense.'

Hasbach places the beginning of the slight recovery of the English agricultural labourer at 1834, in which year a Poor Law stopped the parish allowance to advantage the farmers and made them, the farmers, pay the whole of the labourer's wage. Actual paupers were put in the workhouse. But the real betterment, he found, was in two things, allotments and trade unions.

About this time certain kindly farmers gave allotments of land to their labourers for their own use and were glad to find that, instead of making them work worse on the farmers' lands, they worked better. The eternal truth that everyone likes to be able to pride himself on his own work glimmered into being again and, from being proud of the crops they raised on their own land, these humble men and their wives and children took pride in the crops they raised on their masters' land. They did so well on their private land that when a Government Report in 1843 pressed for the extension of allotments by law, the farmers complained that they had difficulty in getting enough cheap manure as the labourers wanted it for themselves. The labourers in a very small way were, in fact, turning the scales against the old lords of the manor who had started their troubles by stealing their soil-food.

In 1872 the labourers, under Joseph Arch, started a trade union, and 'considering the character of the labourers and their natural isolation they were at first very successful'. But

their efforts to get better wages were defeated by the farmers, who summoned unemployed workers from the towns and impoverished Irishmen for harvesting, hop-picking and other unskilled work in the busy seasons.

'After a long period of depression the unions sprang into life again in the year 1890.' We find them going to the root of the matter in their attempts to free land from the dominance of money. They supported the Land Restoration League, which wished to put a tax upon rent and increase it progressively until it absorbed and eventually abolished rent, and thus achieve the aim of Henry George. Agricultural and urban unions began to work together to prevent town labourers frustrating rural strikes and vice versa. Though poverty, ignorance and isolation of their members kept the rural unions back, they always 'gave expression to the labourers' desire for land'.

Allotments remained the most recognized form of relief. In 1889 a Parliamentary Committee on Small Holdings, with Joe Chamberlain as Chairman, reported, with 'farsightedness and objectivity', that a well-to-do peasantry was beneficial to any country, nationally, socially, and economically, and this was supported by the Central Chamber of Agriculture maintaining that, whereas large farming was suitable to sheep and corn, small holders were suitable to other types of farming.

'The theory that the agricultural population in general was unconquerably attracted by the towns cannot be seriously maintained.' 'The labourers did not depart where allotments could be obtained, where good houses could be had at a fair price,' and where some independence thereby was theirs. They preferred to live in villages to having cottages on farms. Yet, with the village life, the younger generation began to show themselves discontented. 'The old semi-feudal relationships of the English village were no longer quite pleasing to the younger generation,' who were more willing to migrate to towns, chiefly, or even solely, because on the land there was so little chance to raise themselves socially.

Hasbach ends with a review of the labourer from 1894-1906, and in these last pages the light of hope is dulled. The prospects of betterment did not mature. The generation that was content with allotments, good wages and decent cottages almost died out. The new generation 'altogether despises the position of an agricultural labourer'. 'He is at the bottom of the social scale,' and knows it; whereas in a town a man can lose identity among the masses of the inhabitants'.

As a result of his study, Hasbach came to the belief that little or no permanent betterment in the lot of the labourer had been attained. He could not avoid the impression 'that, in spite of the talk of better wages, the lot of the agricultural labourer in many parts of the midlands, south, south-east and south-west, where often the houses are wretched and both allotments and small holdings are wanting, is such that he is strongly induced to turn his back on the land, even though his sense of self-respect is comparatively undeveloped'. While the labourer strives for a humble independence, it is definitely the end of many

people 'to place a proletarian class at the disposal of the farmer, believing such a step was in the interest of the employers'. No statesman had arisen capable of viewing the picture as a whole or of 'estimating the total probable result of any measure'. 'Hitherto failure has attended all attempts to apply to the problems of agricultural labour the principles which have been effective in the realm of industrial labour.' The consequence has been the demoralization and depopulation of the countryside. Facts show that the system of the large farm cannot meet the crisis. Hasbach's final advice is the greatest possible extension of small and middling holdings.

So ends this most instructive and unique book.

Between 1906, when Hasbach ended his story, and the present day, England has fought in two Great Wars; in both her people have been aroused to the perilous state of their food supply; in both they might and almost certainly would have been starved into submission, had it not been for supplies sent to them by the people of the U.S.A. In the first war there was a wise increase of allotments to increase food. Powers were given to local authorities to acquire land by compulsion for allotments, and their number leaped from 130,536 acres to 1,330,000 acres. In the interval of peace that followed, much land went out of cultivation. The great efforts to increase the production of food before and during the second Great War are too well known to be recounted here. How far we are from the knowledge of how to feed our soil, and how it can best be cultivated, these two great crises have revealed. In no country is a reconstruction by way of the soil more needed than in our island. We have a large population; we need a large fertility of the soil to render our population safe and healthy. We need to free ourselves from robbery of the soil.

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Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 11

Primitive Farmers

The word primitive is defined by *Annandale's Concise Dictionary* as 'characterized by the simplicity of the old times'. The lexicographer, with this definition, hits off with happy ease an exact description of the primitive peoples of this chapter and of the two that follow it. 'The simplicity of old times' just fits, for the lexicographer informs us under the word 'simple' that it derives 'from a root meaning one or unity'. We can now paraphrase our heading of Primitive Farmers, as Farmers characterized by unity. We must do this quickly before going on to read other definitions of 'simple', for we shall find that one of them is 'easily intelligible', and farmers characterized by unity are not a bit easily understood by modern peoples. It is because they have so rarely been understood that so many troubles have come to them from the moderns.

The primitive people here to be considered are the Kikuyu of East Africa, for about these same Kikuyu a very rare kind of book has been written. Its authoress, in the beautiful phrase of Robert Louis Stevenson, eavesdrops at the door of the hearts of the people she describes. She is Mrs. Elspeth Huxley; her book, *The Red Strangers*. She tells her story from the mind and heart of the Kikuyu, to whom the British were the Red Strangers.

Before the coming of the British, the Kikuyu were a family of people, who cultivated the land by family ownership. The land was cleared from forest and cultivated. When its fertility was exhausted, a new clearing was made, and the old one allowed a long rest and return to jungly conditions for its recovery. This farming is known as that of shifting cultivation.

The Kikuyu grew fruits, beans, peas, millets, sweet potatoes and other food crops. They kept goats and cattle. The fields were worked by the women; the men protected the fields against the inroads of wild animals, tended and protected their domestic animals, acted as

warriors when young and as councillors when old. They fitted their life-cycle into conditions, which they modified to their own advantage, but to which they did no permanent destructive harm.

An important feature of the tribe in regard to its eventual meeting with Western civilization, was that it had no metal money. Nor did it have any other form of durable money. Its currency was formed by domestic animals; the smaller currency being provided by goats, the larger by cows. In this matter of currency, therefore, they reached back to that of the early ancestors of Western civilization, whose word for money, pecunia, was derived from pecu, cattle. This character is very useful to our contrast picture. In looking at the rather hearty and cheerful Kikuyu, as they first showed themselves, Westerners saw a people who still possessed characteristics of the original Latins, from whom their own civilization itself had derived. They thus looked over a Great Rift Valley of time.

Goats, then, were the pecuniary units of the Kikuyu. A poor man had a few goats, a little land and one wife; a rich man many goats and fields, together with more than one wife to work the larger possession and more sons to tend the more numerous animals. Cows also were symbols of wealth. A cow was valued at about a dozen goats. If a man procured the consent of a maid to marriage, he had to pay some such sum as thirty-five goats, or two cows and ten goats to her father, and sometimes rams and brews of beer made a part of the payment. A field was valued at so many goats. A crime was expiated in a payment of goats to the injured party, or, in the case of murder, a fine of over one hundred goats paid by the clan of the slayer to the clan of the slain.

Goats possessed a second quality of money, over and above their general distribution; they helped a family at times of hardship. Goats are distinguished amongst domestic animals as those most able to feed themselves under adverse circumstances. In a drought, when other animals perish, goats manage to survive. They tend, it is true, to survive at the expense of the reduced herbage. They are, amongst animals, those most calculated to strip the vegetative cover and promote erosion and desert-making, for not only do they bite close, but they are nimble climbers; they can denude a hillside and find sustenance in its coarse, weedy vegetation. So they increase and perpetuate the disaster of drought, as does money when, as debt, it adds to and perpetuates seasonal disasters of Western farmers.

In, 1898 the Kikuyu of Mrs. Huxley's story were first visited by the Red Strangers, as they called the Britons, and in 1902, their elders or councillors at Nyeri surrendered their freedom to the Red Strangers. They were forced to this by magic. The magic of the strangers was beyond all that they had imagined. Under it a mere noise could kill a man many fields away. The Kikuyu magicians strove to oppose it, but they were as feeble against it as were the prophets of Baal against Elijah. The story itself is, indeed, not a little magical, in that an established wisdom, that which had fitted the people so well into a cycle of life, should be at once dispersed because of a mixture of saltpetre, sulphur and charcoal. Neither Kikuyu nor Britain can answer the question why wisdom gets no

immediate support from nature, so that these magics at times do struggle for the survival of the most powerful. What is sure is that *nature in her own time does write her verdict* and she writes it upon the soil. Then she makes herself the measure of wisdom and gives her verdict in its favour.

The Kikuyu cultivated the southern slopes of Mount Kenya at an elevation of 4,000 feet, with a climate in which the northern peoples could make their homes. So, with scarcely any preliminaries beyond the display of magic, the Red Strangers announced that the land which the Kikuyu regarded as theirs, really belonged to a distant king.

The Kikuyu, upon the ridges of the hills, had their enemies, the Masai of the plains. They and the Masai had fought mainly so that the victors could seize the cattle of the defeated. The first thing that the strangers brought about was peace between the Kikuyu and Masai. But it was not a peace that was the counterpart of war, that is to say, a peace between plumed warriors. Like most that was happening, it was so odd as to be inexplicable. The men of Kikuyu were commanded by the strangers to go amongst the Masai peacefully and to carry the possessions of the Masai, while the Masai themselves, men, women, children and beasts were ejected from the land of their fathers and sent to a new land. Under the aegis of the peace, the two peoples met and mingled in humiliation.

As the younger men were deprived of the pride and privilege as warriors, so also their elders found their dignity stripped from them. It was their right as councillors to dispense justice and compel the guilty to pay fines to the injured. But now it was a Red Stranger who took over the dispensation of justice and imposed fines. These fines now had to be paid not in goats, but in round metal coins and when paid by the guilty to the Red Stranger, he did not give them to the injured, but kept them himself. This clearly was not justice but theft. There was no effecting of a balance by means of compensation. The Red Stranger alone benefited, not only by keeping the coins, but by forcing the guilty to do paid work, which the Red Stranger required, so that they might get the coins for paying the fine.

Later came new and terrible demands. The men of Kikuyu were taken from their homes and brought down to the sea, which they saw for the first time. They were put into a wagon that rested on the sea and locked into a room with iron walls, the floor of which, when the wagon moved, rocked under their feet. They were overwhelmed with fear; it was like being in the belly of an animal. They were brought to a strange land, where again they carried loads as porters and served the Red Strangers, whose king was engaged in a very big war. They endured hardships so severe, that those who eventually returned to their home could not speak of them for many years. Such grim memories were the ghosts of great fear.

On their return, some of them did not go back to their original homes, but went to take up new land at some distance from the old, where the Red Strangers were installed. Now they were free and happy to be free upon farms of their own making. But, after a while, quite

unexpectedly, a Red Stranger arrived and told them he had given coins to the Serkali or Government, and because of this all the land and even their farms were his. But he did not, he said, intend to take away their farms or their animals. These they could continue to cultivate, but the men must also work for him. They would work one month for him and get six coins or rupees for the work, and then one month for themselves, and so on, through the year. By this arrangement large fields of maize were grown and many beasts were pastured for the stranger, and the Kikuyu kept their farms in cultivation and received coins.

The early result was surprisingly good. They got their silver coins every second month and what was more, the Red Stranger knew of markets where they could, for more coins, sell the surplus products which the virgin land produced abundantly. So coins began to accumulate. One odd thing, however, happened. It was the Serkali who gave out the coins. Nevertheless, the Serkali would not let them keep all the coins they got, but asked for some of them back. As the Serkali themselves made the coins, this was another insoluble puzzle. But, though some were given back, there was still a goodly number left, either to be buried in the floor of the hut, or to be put in the post office to be spent, when opportunity occurred, on taking up more land and a second wife to work upon it, and more goats for pasture. So, under the leadership of the Red Stranger, who now became in some sort a friend, riches, that is to say land, wives, and goat,s became more plentiful and the future held out hands of promise as never before.

Then something happened that neither the old nor the new magic with its new coins could avert. There were two years of drought, terminating with locusts and famine. The Serkali sent food from outside to the people, whereby they were saved from actual starvation. There followed a season which seemed to concentrate its own rain with that which should have fallen in the two previous years. The crops were now not burnt up but drowned. Further, in spite of the great shortage brought about by the drought, when any surplus product was now taken to the market, instead of many coins being given for it, for some reason inexplicable, so few were given that they did not balance the cost of cultivation.

The Red Stranger, who had taken their freedom from them, nevertheless had helped them and become their friend. He was now filled with sorrow, and in sorrow he dismissed some of those who worked upon his big fields and paid fewer coins to those that remained. There followed a further season of drought, when the unclouded sun beat day after day upon the land. The lake in the valley shrank to a lowness unrecorded in living memory. The pastures, stripped by locusts, turned to powdered earth, and dust-devils whirled across the valley like wild dancers. Erosion had begun. It was as if the new treatment of the old earth made the soil become something ghoulish and caused it to tear itself from its home and flee in towering columns with the wind. So it escaped from the Red Strangers, which the Kikuyu could not do.

As has been said, something had gone wrong with the coins of the new currency and it was now found necessary to contract or cut down the currency of the Kikuyu. The Red

Stranger, whom the Kikuyu had had to obey and had come to trust, issued an order to them to limit the goats, first to ten goats for each married woman, and then five. But this too failed, and the stranger, having no coins left, gathered his family together, bid a sad farewell to his sorrowing Kikuyu friends and was no more there.

In his place came another and with him an officer of the Serkali. Then fell the final blow. All the goats, which in their hunger were eating down to the very roots, were expelled from the stranger's pastures. The Kikuyu, who worked on the large fields, were allowed to continue their work, but they must have no goats. If they wished to keep goats, they and their animals must go elsewhere.

In this way the traditional currency of the Kikuyu peasants, that which had been to them what the coins had been to the kindly Red Stranger, was as effectively destroyed, as was that of the peasants of India by Act No. 8 of 1893. It was replaced by a currency which had no relation to the local returns of the soil, as had the goats, but was something quite outside the humble fortune or misfortune, which work and the seasons brought to the Kikuyu. The new currency, it is true, brought with it certain advantages. In times of actual famine, it was able to relate the Kikuyu to better conditions far distant from their locality. With it came trade, education and the creation and improvement of towns as means of livelihood. But it took away something that was an essential part of the life-cycle, an automatic animal factor upon the farms, which rose and fell according to the creative capacity of the soil. When severe adversity came, the animal life was diminished; it was only extreme and rare disaster that had a like effect upon human life. Being a part of the life-cycle itself, the currency moved up and down with the favourable or unfavourable condition of the soil. The new coins, on the other hand, had no relation whatever to the soil, local or otherwise. They were completely dissevered from it. They had, indeed, the agricultural impossibility of having nothing at all local about them and of having an existence entirely apart from the life-cycle. They were related not to the soil, but to world finance, the first modern attempt by a group of men to be masters of the world.

Without their goats the Kikuyu were like the friendly stranger without his coins, and they, too, in their despair, followed his example. They packed up and left the land of their adventure to return to the land of their forefathers.

In the further narration of the fortunes of this family, Mrs. Huxley skilfully contrives to give an epitome of the Kikuyu people, as a whole, in their transition from a subsistence to a capitalistic farming basis, which with its ancillaries occupied in years as many decades, as it took centuries in England, so swift was the tempo. Nevertheless, all the main features reappear in the Kikuyu story. The large estate and the extrinsic money system have already been described.

The family returned back to their homeland, confident that, according to tribal custom, they would have a right to the land, which the father, when young, had cleared at the side of a forest glade. But, on their arrival, they found changes even more varied than those

they had experienced in the land of their adventure. A cousin had taken over both the land and the glade. The glade had been turned into a pasture, and it had something unknown in the past, in a fence which enclosed it. Previously all pasture had been open and the common ground of the villagers. Fields in the past had had temporary fences to protect crops from wild pigs and other animals, but the fencing they now saw was substantially made and not the temporary fence of custom. The cultivation of the fenced-in fields was also different to that which they had expected. The native method of hoeing by hand had been supplanted by a plough with oxen to draw it, and they soon discovered that there were other new ways of cultivation, such as a rotation of crops. Still more surprising was a square house built of stone, with windows, a veranda and a shining iron roof, and about the house was a garden with flowers and with fruit trees planted in rows.

The family looked about for goats, but saw none at all. That animal, once the currency and also the victim of religious sacrifice and so in two aspects closely interwoven with men, they later found had, under British advice, been entirely discarded. There were some other measures of wealth, and then they realized that what they had seen of the home of the Red Stranger in the land they had left, was here repeated. They were looking, not at communal or tribal land any longer, but at something more like to the estate of the Red Stranger. So they saw and, asking many questions, they learnt that the cousin himself had become as the Red Stranger, one who, by the right of the Serkali, claimed that the land was his. They were looking on *private property*.

Certainly this cousin had benefited greatly by means of the Serkali and by listening obediently and intelligently to its agricultural officers. As a progressive man, the Serkali had made him something new to the Kikuyu, though not, had they known it, strange to the English Red Strangers, something derived from the lord of the manor. They had made him the local land-chief and he had become so rich that he had no less than twenty-two wives to serve him. Even the form of the wives' service was strange, for it was they and not the cousin's men who tended the cattle. There were sons enough for the work, but they had all of them been to the schools of the Serkali and this placed them above tending cattle. Education was something which turned the young men from the land to the town, where they became clerks or teachers or policemen or took other forms of subordinate service to the Serkali. In these services there lay a greater safety, a prior claim it seemed upon the Serkali, for in Nairobi, the capital town, during the long drought and famine, these younger people had still had enough to eat, still travelled comfortably in omnibuses to their work, still dressed in European clothes and danced in European fashion. The great affliction of the countryside was fended from the town.

The returning family saw and heard all this. Particularly, of course, did they note what concerned them most, the stone house, the rows of fruit trees, the cattle, the fencing and other changes upon the land that according to custom was theirs. On the one hand, then, was their traditional right, on the other the robust facts of private ownership. The father, now an old man nearing his end, wished to bow before the power of the new, the son was unwilling and prevailed. And so a claim for the land was lodged by the family.

The case aroused the keen interest of the whole locality. It staged the conflict that was everywhere diffused between the old and the new. The elders stood firmly for the tribal laws of inheritance and the safe living upon the land which they gave to each family, and opposed the new rights, which made men dependent upon the will or whim of so-called owners of the land. The younger generation stood as firmly for the cousin, because of the improvements he had made under the guidance of the Serkali's experts. This, they said, made the land his. As to the family, if dispossessed, there were other ways of getting a living open to them, such as by becoming labourers upon the roads or railway or in house-building, or porterage, or even in Nairobi, by acquiring dignity as taxi or bus drivers. They could even stay on the land in the humble form of hired labourers, receiving wages from the new owners.

As the claimants could not afford to pay compensation for the improvements, the land was finally awarded to the cousin. But the claim of the family was also acknowledged and land, belonging to the clan, was awarded of equal size and excellence to the original clearing by the forest glade.

So, after many experiences of sudden and quite unpredictable changes of fortune, the family attained once more to the traditional security of the homeland. But even here they had to submit to the fringes of what was to become by far the most dangerous change of all.

The old father died and he left behind him one legacy. It was a prophetic pronouncement of his not long deceased friend, Irumu, who had been the seer of the tribe: 'When women walk all day to seek firewood and when cultivation lies naked under the sun, then shall evil come. On the days when trees again darken the ridges and bring shelter to the weary, then shall good fortune return.'

From the deep, inward oneness with the local life-cycle,, which such tribal wise men have, had arisen a vision of the coming of the Great Erosion. Where the new greed for land as property caused too many trees to be felled along the ridges of the hills upon which the Kikuyu had their homes, there the torrential rains would be unchecked by these umbrageous ramparts. The watery bullets would pound some of the top-soil into mud, which escaped in turbid runnels down the slopes of the hills. This was the beginning of water-erosion, which as it spreads causes women to walk all day in search of firewood. And when the fields were broken open by the plough in place of being lightly stirred by the native digging-knives, and when they were made to grow one crop in place of several plants of different heights, foliage and roots, then the cultivation lay naked under the sun. A dry season made the surface of the soil dusty and some was blown away by strong winds. This was the beginning of wind erosion.

These two erosions form the last phase of the present story of the entry of the Kikuyu peasantry into modern civilization. Due to this civilization, there was a greater call upon

the fertility of the soil and in some strange way a similar call on the fertility of its partners, for a native proletarian population increases under the early rule of the Westerners. Many new ways of earning the new coins were opened up. The colonial governments called for more coffee, more sugar, more cotton, more hides, more maize, more sisal and so on for export. More land was exposed for cultivation, its fertility taken up by the crops and the rule of return neglected.

Here is an account of the last phase of this process as it is affecting the Kikuyu, written by Messrs. Jacks and Whyte in *The Rape of the Earth*, 1939. This account completes the story so brilliantly told by Mrs. Huxley.

Erosion, they write in their world review, has attacked the lands of the Kikuyu, and it is due to agriculture being forced to too speedy a pace in 'the increased desire to obtain cash through the sale of crops' and in the need for more food crops by the increasing population, much of which migrated to the growing towns.

The original mixed farming for sustenance succumbs to the new commercial farming, *it does not everywhere form the basis for the new*. One farmer will concentrate on the growing of maize, another will stock or overstock the land as pasture; both practise thereby a rape of the earth. They farm for cash, and, not heeding the rule of return, they take more fertility than the soil can recurrently yield. They treat the soil as conquerors and not as partners.

In the general demand for more crops, the peasants cultivate not only the ridges upon which they had their homes, but also the easier slopes of the hills. There comes a loss in the quality of the soil, a loss of that wonderful air-containing, loose adhesiveness of the soil due to good humus, and with this degeneration the great natural elements of rain, wind and sun, once friends and partners, now, at the times of their especial strength, become enemies. The Serkali has taken no proper measures to prevent this. There is a 'lack of conservation measures in general', say Messrs. Jacks and Whyte.

The European owners mostly exhaust their estates by the same disregard of the precepts of nature. They override nature before the fall. 'In the European areas erosion is caused by exhaustion of the soil through long continuous cropping without the adoption of methods to prevent erosion and maintain the humus content of the soil. The results of land misuse are only now becoming apparent in a grave form, as much of the land in the settled areas has only been cultivated for fifteen to twenty-five years. Some areas of Kenya have already reached such a state of devastation that nothing short of the expenditure of enormous and quite impossible sums of money could restore the land for human use above a bare and precarious subsistence standard ... Generally speaking, erosion has become serious only during the past five years. In addition to the causes enumerated above, the invasions of locusts of 1929-31 and the drought of 1931-5 greatly accelerated the process and were largely responsible for making it so apparent in the space of a few years.'

The Red Strangers came to the land of the Kikuyu in Kenya, because, though situated upon the Equator, it is highland and has a climate in which they can live and farm. They make their homes there, but to maintain their accustomed standard of living and to save money, they concentrate on farming for profit and in this they do but follow the common lines of modern farming. The facts that the fertility of soil is exhaustible and that methods, under which in the cool, wet climate of Britain the soil is slowly depleted will, in Kenya, deplete it with rapid momentum; that sun, wind, rain, goats and cattle, all fitting into the old life-cycle, will thereby be turned from partners into enemies -- these are foreign to their experience and knowledge. In their own land the rule of return and the conservation of humus are not axiomatic.

So they farm and so, wishing the Kikuyu to share in the wealth from the new methods, they induce them to adopt the new values.

The intention is good. Both white men and black shall profit by progress and science. Though the Red Strangers, with their greater magic, claim the land as belonging to the distant king, any further exploitation of the Kikuyu is not the king's wish. In July 1923, His Majesty's Government itself decreed that the interest of the natives must be paramount over those of all immigrants, including the British, and that on no account were the black men to be sacrificed to the white. The Red Stranger, who announced to our Kikuyu family that the land had become his by the payment of coins, nevertheless, as befitted this good intent, soon became their beneficial friend. 'They understood then that they, the black, were not to be sacrificed to the white.' But both black and white depended upon the soil and it was the soil that was sacrificed. It was stripped of its sheltering cover with eager haste and a tragic lack of understanding. The final result is not yet known, but what is known is sufficient. In some parts, in very truth, the words of Irumu are no longer words but facts: the women walk all day to seek firewood and the cultivation lies naked under the sun. Can the days, of which he spoke, cease to be words and too become facts: 'On the days when trees again darken the ridges and bring shelter to the weary, then shall good fortune return.'

Money, that has been the root of this evil, is *unable to save*. The authorities quoted say that only enormous and quite impossible sums of money could restore the land. And before money, representing effort, there must be again the change of values, a change of outlook and a change of faith.

Nature is very careful, but men are careless. In some of the species of acacia trees in Australia, the leaves are suppressed, and the leaf-stalks or petioles are vertically flattened to take upon themselves the function of leaves. It seems that the vertical. position of these petioles prevent injury from excessive sunlight, as, with their edges to the sky and earth, the petioles are not so exposed to the light as are the horizontal leaves. Scientific theorists explain how this comes about, but to the thinker, it is an exquisite example of nature's care, and should impress farmers, telling them: 'Do likewise. Exquisite care is necessary in

the preservation and adjustment of the details of life-cycles, and that is what farming should be.'

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by G.T. Wrench

Chapter 12

Nyasa

Here is the story of another primitive farming people of East Africa, about 1,000 miles south of the Kikuyu and occupying highlands of lesser elevation at about the same distance from the sea.

In 1935 the Government of Nyasaland became perturbed by the increasing exodus of able-bodied peasants from the homeland. The Governor appointed a committee of inquiry. How alarming the exodus and its far-reaching consequences were was revealed to the members of this committee. As they travelled and saw and questioned, vista after vista of the tragedy of native life was disclosed.

This is what they reported: 'We must confess that, six months ago, there was not one of us who realized the seriousness of the situation; as our investigations proceeded we became more and more aware that this uncontrolled and growing emigration brought misery and poverty to hundreds and thousands of families, and that the waste of life, happiness, health and wealth was colossal.'

Now this statement of a well-intentioned committee is worthy of the closest attention. At the outset it should be noted that there was not a rural native upon the committee. It was assumed that wisdom lay outside the land. The committee men were not terrene men, measured by the axioms of the soil, but super-terrene men with very little knowledge of the terrene men of the land of Nyasa. Consequently, within six months, they found themselves astonished, even overwhelmed, by the disruption of a terrene life-cycle, involving many humble people, for whom they and their kind were responsible. The wealth, of which they wrote, was the wealth of the land, and they laid down their belief about it in these words: 'We consider it essential that the whole Protectorate should be surveyed by local agriculturists with the idea of discovering the best uses to which the

land can be put, regarding the land not as something to be exploited piecemeal, but as the sole capital of the Protectorate.'

The language, one will note, is that of money-minded men; the land is called the *capital* of the Protectorate; as capital it must not be exploited for industrial profit, but put to the best uses as the only means of livelihood for the people of the Protectorate. How this was to be done was to be decided by local agriculturists. This term did not include native farmers, because they would not be capable of surveys with an accumulation of facts and figures from which to draw conclusions. The committee men did not seek a renovation of the indigenous social and farming life, from which improvements could eventually develop, but advised the consideration of the question from the up-to-date Western agriculturists' outlook. In that way it could be decided how to put this particular *capital* to its best uses.

The indigenous methods by which the natives of Nyasaland farmed had general resemblances to those of the Kikuyu. They cleared a part of the forest and cultivated it as long as it gave good results. Then they abandoned it for a number of years, in which, by encroachments from the neighbouring forests, it reverted to the natural plants and conditions of the country. This is called shifting cultivation.

'Shifting cultivation,' write Messrs. Jacks and Whyte, 'although it kept men as unimportant servants of wild nature, maintained soil fertility indefinitely, since the forest drove the cultivator out and re-assumed its beneficent control as soon as any sign of soil exhaustion occurred.' The indigenous method, therefore, included as a practice, if not as an intellectual precept, the indefinite maintenance of soil-fertility. The Western agricultural, money-making land-owners only awoke to the devastating effects of the loss of soil-fertility after it had markedly occurred, and then devised methods of preservation.

This is because dominant money falsifies conservative farming. The whole conception of money plus interest is foreign to the soil. When money is lent, it is in the expectation of getting not itself, but more than itself in return, an additional creation called interest. But a crop does not reproduce more than the substances it gets from the soil and the air. *The creative power never creates anything extra*. It changes forms. In nature there is only transition, not addition. The conception, then, that money can produce extra money, something over and above itself, is not one derived from the creative power of the soil or the character of nature, and that no doubt is the ultimate reason why interest has been so strongly condemned by religions and philosophies. Peasants feel it to be wrong and the poets, who in Dante's definition are 'those who know the secrets of nature', the 'makers' of the Greeks, know it to be against nature and unreal and therefore inimical to the intellect and morally wrong.

For these reasons money-directed farming, however scientific, cannot create the honest constancy of equivalent return. It strives to get more than it gives, and thereby brings about a difficulty in actual survival. It is this which constitutes the story of Nyasa. Money-directed farming was expected from a primitive people by a government belonging to the

money system. The primitive people belonged to a completed life-cycle, in which surplus crops were exchanged for other human needs. There was no space in their work or habits for anything over and above this completed life-cycle, nothing, that is to say, which could be stored away as dead capital or discarded as not wanted. It would be turned immediately into wealth, which meant cattle or other such visible 'goods' of the native. It certainly could not be symbolized and banked. Consequently when the Nyasa Government demanded a hut-tax to be paid in money, it drew the peasants into the money system without any preparation or aptitude for it and without defence.

They could have paid the tax in goods or kind according to their custom. But they had not the coins which the Government demanded, and their own elder men, in their own urgent need for the coin commanded by government, ordered the younger men to pay the bride-price in coin, not the conventional cattle.

The cash asked for by Government through taxation, wrote the committee in their Report, was considerable. It was more than a farming district, after providing for subsistence, earned. The committee gave, as examples, five districts, which had to pay taxes of £18,000, though earning but £14,000, made up of market earnings £1,000 and wages £13,000. In response to these urban infiltrations amongst primitive farmers, therefore, none of them proved to be 'the fittest to survive' upon the land of their fathers. There was only one thing to be done, as was done in England by many of the harassed Tudor and Georgian peasantry; they had to evict themselves and seek employment in the modern, Westerners' mining, towns of Tanganyika, Rhodesia and the Transvaal, all of which could be reached on foot. Hence, out of a total population of 1,600,000, there were 120,000 farmers continuously out of the country, 50 to 60 per cent of the able-bodied population. Basutoland and Swaziland, farther south, had almost the same percentage of young workers absent from the land. The workers, partners of the soil, were disintegrated and blown, as it were, like eroded soil, to regions where they were made to take from the earth, not crops, but the gold that was then the god of the money system. 50 to 6o per cent left their farms; yet the Government of the Belgian Congo had been advised by one of their committees that even the absence of 5 per cent of young able-bodied men from an African village upsets the whole economic and social balance of the community.

There is scarcely need to give a picture of the state of the peasant families who remained; of the women, the old men and the elder children, who strove to carry on the cultivation of the land; the fields overgrown with weeds and jungle invasion; the huts falling to pieces; abandoned fields and crumbling villages, as if the Tudor period flung a long reflection of itself upon Nyasa and the neighbouring lands.

A partial remedy came through the unchastity of the married women. Wearied by the unequal battle and the increasing illnesses of themselves and their families which accompanied it, they gave up the attempt to remain chaste for their husbands' return from the mining towns with the cash and the venereal disease they had there acquired. So, when natives of Portuguese East Africa discovered that there were women and land across the

border, they seized their opportunity. At the present time, it is said, there are as many, or even more, such male cuckoos resident in Nyasaland as there are Nyasa men.

The story of Nyasaland tells that 'waste of life, happiness, health and wealth was colossal'. It is a tale of the misery of a shattered life-cycle. It is not a tale for the heart only, but for the brain. It is an expected tale. History does repeat itself over and over again. Post-Punic history and Tudor history, with their evictions and brilliancy, are repeated in the story of Nyasaland and its neighbours. Distances are greater and the brilliance was to be found distantly amidst the wealthy of London and other cities, and those who derived something from them.

But the modern story was debased by its being one caused by naked gold itself, to mine which the peasants went from their farms to earn cash, for the taxation by coin that was put upon them. It is a tale of the immediate contact of the raw material of the money-system itself with primitive farmers. The foes were face to face.

Some readers may sometimes have wondered why primitive peoples seem to die out with the 'advance of civilization'. Here is one way. It shows directly how the money-system acts. It is the system, which elsewhere is represented by high explosives, bombs, tanks and the rest. But against the soil its weapons are not known as weapons. Nevertheless, through them, the money-system is far more widely and more permanently lethal than it is by the destructive efficiency of its machines. It kills at the source. It kills the partnership of the soil and the peasants. Wherever it is in action, it produces an eventual desolation of death; peasants and soil vanish and with their loss, what was a source of healthy creative power is given over to death.

Chapter 13

Tanganyika

Between Kenya and Nyasaland lies the great, sparsely-inhabited territory of Tanganyika. In this territory, there is a life-cycle of a very remarkable character, which contains within it, as a part of its ecology, an insect, the tsetse fly. This fly has come to play the part which the lions of Judah once played as defenders of the natural forest against the intrusions of man. Palestine no longer has its lions and the consequence is that, when one flies over it in an aeroplane, one looks down upon the watershed to see barren rock where there should be forest.

The tsetse's method of defending its forested life-cycle is more subtle than the terror by which the lion once kept men from his home. There is nothing regal about the tsetse, but its part in its life-cycle forms one of the most remarkable in nature. It feeds like the mosquito, upon blood, biting both animal and human. Tsetse is also a host of the microscopic trypanosome; consequently when it bites it may inject the trypanosome into

the blood of the bitten animal. When it injects animals in its own life-cycle, the animals live. The trypanosomes do not harm them more than a number of microbes, which live in men, harm their hosts.

But if man's domestic animals and man himself invade the tsetse area, it is a very different story. On the expedition to Tanganyika, to which the Kikuyu peasants were taken as porters and endured such miseries, none of the animals imported into Tanganyika in the service of the British Forces survived. Practically all that were not killed accidentally succumbed to the fly. It is destructive too, to men. The first trypanosomes were brought by cattle driven across the watershed between West and East Africa. In parts of Uganda the tsetse lived. They became the hosts of the trypanosomes, and 200,000 out of 300,000 people died in six years.

Men, therefore, have a very great fear of the localities of this insect, a great fear like that of past Palestinians for the lions of their forests. The tsetse evicted them and their cattle from its forest areas. It is said that in the full 365,000 square miles of Tanganyika, two-thirds of the five million inhabitants have to confine themselves to one-tenth of the total territory. Then came scientific white men determined not to be evicted by, but to evict the insect. So they cut down the trees and bushes near the streams, lakes and pools, in the shade of which the tsetse lives. The result has been an erosion, not so threatening and extensive as in Kenya, because the area that is cultivated is so limited, but so serious as to call a halt. It was clear that trees must be left to protect the soil against the heavy rain of tropical East Africa; otherwise the forest became savanna, then coarse grassland and, eventually, if this poor pasture was over-stocked with cattle, barren waste.

The hydrological or water-cycle, in which vegetative cover plays an absolute part, had to be preserved, and consequently the wholesale destruction of the haunts of the tsetse along river and around pools and lakes had to be abandoned. In its place very cautious ablation of bushes and trees favoured by the fly, is being tried. Indeed, in no part of Africa probably has the value of distribution and conservation of the water supply been more thoroughly grasped than in present Tanganyika. In the Kilimanjaro Native Co-operative Union, which claims 24,000 members out of the 36,000 farmers on the slopes of Kilimanjaro, there are 26 societies, and the reason of this number is that it corresponds to 26 streams, which take their origin in the great mountain and water its slopes. Under the guidance of Sir Donald Cameron, geologists, plant ecologists and water surveyors have been linked together to fit farmers in an understanding manner to the local character of the water supply as a whole. They have marked out the catchment areas of the 26 streams. Each catchment area with the river to which it gives rise has been made into a separate entity and is presided over by a native chief, and the 26 entities united in the Co-operative Union; 26 catchment areas, 26 rivers, 26 cultivated areas, 26 chiefs, 26 communes, and one Union. It is a real association of communes and the assembly of the Union a real House of Communes or Commons, people of a common source of life and not the mixed mockery which the Assemblies of Communes have elsewhere become.

So in the strange way in which nature replies to human acts, man has been shown that the tsetse, which has been such a prolific killer of him and his animals, has nevertheless proved a great saviour of the source of terrene life, the soil. Had it not been for the tsetse, the rich soil fed by the greatest mountains of Africa under an Equatorial sun, would have been greedily seized upon and its stored fertility turned into cash, until an irrevocable erosion stayed further ravages. But, owing to the tsetse, this swift onslaught could not be made. The tsetse has prevented it; in the words of Mr. R. 0. Whyte 'the presence of the tsetse in many parts may be a blessing in disguise, as it can be regarded as the trustee of the land for future generations'.

The tsetse is a pest to man, but man, greedily eager to make his fortune from stored soil fertility, is a pest to life itself. So the strange story of Tanganyika ends with the little tsetses still defending their waterways against the lords of the earth, so giving time for nature in her own ways to tell these lords that, masterful though they may be, if they claim to be *masters of nature*, they are doomed. They themselves must re-learn with humility that they are the *creatures* of nature, and, this time, a little insect shall teach them.

Chapter 14

'Earth Thou Art'

Before continuing the story of the present misfortunes of the, soil, it is well to recall again how earthly we ourselves are. This may be done by a meditation, in which one concentrates the mind on some one thing of those so common to us that normally we never trouble ourselves about them. We concentrate and allow our minds constantly to widen the circle of thought that arises from this concentration. We are accustomed to give a good deal of time thinking out our problems, but we rarely meditate, we rarely make ourselves strange to the familiar. We accept the air as air, the sun as sun, the earth as earth without at any time making ourselves strange to them until we comprehend both them and ourselves in relation to them.

'Earth we are and to earth we return' is a sage and familiar saying upon which we may well widen our reflection. It seems that this earth now under our feet is in some way us. To it and its darkness we and so much else in the world of light belong. The interchange from the visible to the invisible and from the invisible back into the light, is continuous. We ourselves, as part of the visible, are largely concerned with the invisible. The great majority of men trouble little about it, but since man is, it seems, the sole creature of the soil that is endowed with meditative thought, he has gathered a good deal of knowledge of the crust of his planet. Deeper than the crust of the earth he can scarcely reach, but in it he searches from a wide generality of instinct, which tells him that, though he has spirituality, he is nevertheless essentially terrene, and when he searches into the earth, he searches for a further understanding of his own being.

Living in the visible world, he is destined to return to the earth. As electricity can be separated by him from the earth and made to run trains, drive ships, bathe night cities in radiance, and draw great clouds together over thirsty lands, yet like man it has its earthy phase and to the earth it must return.

Similarly man, in his farming, separates land from its natural state of forest and prairie. There he grows products for his use, but in the end they too are destined to return to the earth.

So also it is with water. Water rises invisibly from the ocean and ascends to the skies there to take visible form as clouds. Thence it descends again to the earth and takes visible form upon it as brooks, rivers, lakes, ponds and dew. Man, too, separates some of it for his purposes. By irrigation he waters his fields, by conduits he waters his cities, by tanks and reservoirs he waters himself. But eventually these waters return to the invisible, they sink into the earth or the depths of the ocean, from which once again they come back to the visible world.

We human beings, whose substance plays its part in these transitions, are conceived by the sparks that set our being in motion and spring from the mystery of creation. But from the very moment after the two sparks, male and female, unite, we are in growth of the earth earthy. Heredity, in all its variety, comes from two cells so small that they need the microscope to make them visible. In these two cells for us and other beings of the earth, there is the magic of predestination. It is they that determine the launching of man or animal or plant. In man, they determine sex, colour, character. Though only two specks, they have within them a multiplicity of destiny that is quite beyond our understanding. We know there are so many *genes* in each cell, but to know such mathematical details, though most acceptable, is not to understand its mysteries.

In this early stage, as in later ones, we receive the means of growth from the earth and from those things which also have their earthy phase, the air and water. These means of growth are made up of substances, many of which have been separated as entities, by the knowledge of man and called by him elements. There are only ninety known elements, but they occur in so many combinations, that we should be entirely lost if we had to manage them ourselves. It is nature that manages them and their interchange. This we know, that otherwise there would be no life. Nevertheless, we boldly again isolate elements and certain combinations, identify them by tests, weigh them and give our names to them and try, as it were, to come to some stable and positive relation towards them, calling a halt, for the time of our own being, to their constant transitions.

These are the elements that have been found to be a part of human bodies: nitrogen, oxygen, carbon, hydrogen, sodium, potassium, sulphur, iodine, fluorine, manganese, silicon, cobalt, copper, iron, zinc, lead, arsenic, lithium, magnesium, aluminium, boron, chromium, strontium, cadmium, barium, tin, vanadium, titanium. Some of these twenty-

eight elements may not be essential to human life. But they are part of it, for all have been found in sewage sludge. They may, one hazards, be essential, if not to life, to certain qualities of life.

The four great elements of our body, our brain, our thought and our affections, nitrogen, oxygen, carbon and hydrogen, are all aerial, as if they have to pass to the heavens for their purification before they turn with pristine vitality to the earth again. Perhaps there, bathed in the rays of the celestial bodies, they gather that marvellous power of combination, which makes them the supreme elements of life. In their endowment of life they show a singular affinity for each other, an affinity so dazzling that it blinds our very thought in conceiving it. They associate together in innumerable patterns, as if in the great spaces from which they come they had become like Wordsworth's birds displaying

Hundreds of curves and circlets, to and fro,
Upward and downward, progress intricate
Yet unperplexed, as if one spirit swayed
Their indefatigable flight.

It is the four of them that, joining together in almost uncountable varieties, form the proteins of living substance. Some of their steps in the protein dance have been separated out by the cold skill of the masters of organic chemistry. These steps are called amino-acids. Here is one and this is how it is written: six atoms of carbon, thirteen of hydrogen, one of nitrogen and two of oxygen, or (CH3)2:CH. CH2. CH(NH2). COOH. Or they may be spaced like this:

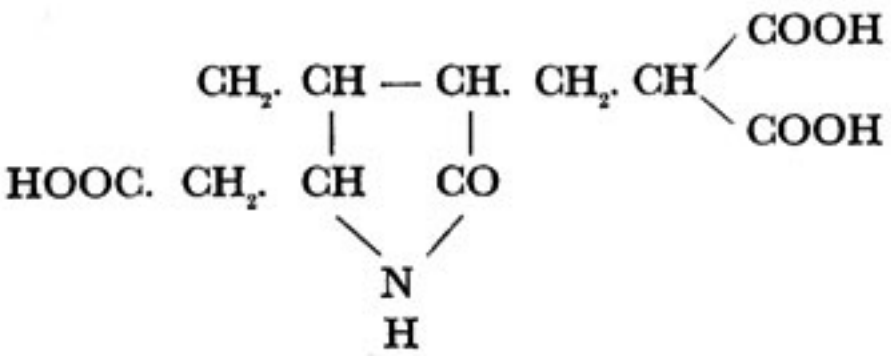

The number of possible proteins is quite beyond men's imagination -- Berg gives them as 6,708,373,705,728,100 -- and the transition of associating elements from one temporary form to other forms gives one a glimpse of the constant and amazing variety of living nature, before which man can only, with such glimpses as he has gained, regard his own creative and manufacturing power as something, excellent though it may be for him, yet very lowly and humble before this whirling, form-making artistry.

When nitrogen steps aside from this quadruple partnership and leaves carbon, oxygen and hydrogen, the three again meet and re-meet in the less dazzling combinations of the carbohydrates or starchy and sugary substances of living matter. They too are illustrated

by the chemists in formations more regular, but nevertheless as wondrous as when nitrogen takes so vital a share. Here is a common sugar, dextrose, CH2OH. CHOH. CHOH. CHOH. CHOH. CHO. Were this form placed amidst a number of surrounding mirrors, there would be an equivalent number of reflections. There are actually sixteen of those reflections to the above sugar, dextrose, four of which are found in nature, twelve prepared synthetically by Emil Fischer and others, but not yet found in nature.

There is something sober and shapely about the carbohydrates; for the majority of them are so many atoms of carbon in combination with so much hydrogen and oxygen, combined as they are in water or H20. This cannot be said of these three elements, when nature with her marvellous jugglery uses them to make the fats. Here for example is an arrangement which makes a fat: C3H5 (O.CO.C15H31) (O.CO.C17H33) (O.CO.C17. H35). Even with this jugglery with the three elements in the making of food substance known as carbohydrates and fats, nature is not content, but from them she fashions certain hormones, which have a governing power within the body, such as the hormones of the testes and ovaries and also one of the adrenal glands which in excess can give a beard to a woman with other qualities of masculinity. Some of the popular vitamins are so made. By adding nitrogen there result one or two other hormones and vitamins, and yet again with the addition of iodine and nitrogen the hormone of that very dominant gland, the thyroid, and, with nitrogen, sulphur and chlorine, the well-known vitamin B.

When one reverently meditates upon these four marvellous aerial elements, is it strange that man, who derives so much of his vitality and the fabric of his spirituality from them, should not almost from the beginning have felt his intimate unity with the pellucid heavens above him? Truly it seems that he has a heavenly, as well as an earthly body. Yet, in his murky worship of money, in his manufacturing cities, he shuts himself off no less from the clean air than he does from the clean earth. We know that in consequence he is less whole and healthy. We know that he has to go to the sea side or the country to recover some of his aerial factors. We know that authorities have to plan camps for children and adolescents to go under the open sky. We know that we have to install plants of artificial sunlight in the cities as a treatment for the most obvious cases of deprivation of natural sunlight. We do not know how wide, subtle or deep is the total extent of deprivation, because our wholeness within the life-cycle is unknown to us and, at the most, only the subject of fragmentary research. How then dare we to proclaim ourselves the masters of nature and the lords of creation, we who have broken our own life-cycle, divided ourselves from its earthly and heavenly elements and look to mortal men of mediocre health and physique, sitting in their laboratories, for guidance in these immortal truths that are clearly evident in our inward feelings and written upon the open face of the great sphere where we live?

There are other aerial elements, argon, crypton, neon, xenon and helium, of the relation of which to life we know little or nothing. We will return then to the terrene elements. How many of the twenty-eight already named in this chapter are essential has not been determined, but it has been discovered that mere traces of some of them are essential.

Thus, in the case of the black rot of sugar beet, it has been found that this disease occurs if there is lacking a necessary trace of boron in the soil. Similarly, a trace of manganese protects oats from black speck. A fatal disease of sheep in parts of Australia and New Zealand is made curable if a little cobalt is added to the soil. In Florida cattle were found to die until a trace of copper was put in the fields, in which they pastured. It is probable, then, that all these twenty-eight elements are workers and that none are drones in the cycle of life.

There is, then, a procession of the elements and, though there is no pause in it, it may be said to start in the microbic and fungoid stage in the soil. In man's cycle, the procession starts in man himself, for the breaking down of waste substances by microbes begins in the lower bowel. Microbes in health are friendly microbes. Their hostility only appears when living matter seems to lack what we call quality. Then they set about hastening the return of the living matter which lacks quality to the soil. By far the greater part of the microbic world is, then, not only friendly, but it is merely ourselves in a different form. Our elements are their elements. They make us and we make them. Therefore, when we concern ourselves about them, we concern ourselves with what we ourselves are. This is a secret of healthy food. If we take elements out of the cycle and disperse them in the sea, we are robbing ourselves. The microbes then take measures, as it were, to save themselves. Unfriendly microbes multiply. One witnesses, in fact, a break in the *mores*, the morality, of the microbic world. The microbes start exploiting the weak for their own benefit, they become aggressive, bring the weak to the ground and become emboldened to attack the strong. But it is the *original weakness that brings about this break in morality and turns one phase of the procession of the elements to become the enemy of another phase*. The microbic theory and money-dominance are certainly no strangers to each other.

It can all be so different. These marvellous elements are like the notes of the piano, which under skilled and reverent treatment produce an infinite number of melodies and harmonies. In the rhythm and the completeness of the forms they make in the natural world, one can indeed see a wider picture of that music to which the ancient Greeks gave the highest place in human culture. Misplaced they make cacophony, the hideous cacophony that now roars throughout the inhabited globe.

Man must revere and respect these elements. He must lose none, he must spoil none. He must consider them wherever and however he meets them as a part of a great being and becoming in which he has his share. Whether as non-farmer or farmer, *it should be his wisdom to understand his life-cycle and keep to it*. He should know that, as man, he tends to be so anthropomorphic, so self-centred, that he interprets food from his own point of view only. He thinks of it as things of the day, the market and the shop, as bread, vegetables, meat, eggs, fruits and milk, or as things of the factory, processed, preserved, tinned, bottled, dried or dehydrated, or as things of the field, as growing grains and vegetables and fruits upon the tree. He thinks of them as things in themselves, as indeed he must do in the daily traffic of life. But to preserve quality in them and to maintain quality, he must also think of them as transitionary parts of a whole. This he has failed to

do. *It is a failure in thought and observation*. With that failure he has become, in the words of the great seer, F. H. King: 'the most extravagant accelerator of waste the world has ever endured. His withering blight has fallen upon every living thing within his reach, himself not excepted.' He pursues the path of race-suicide, while he chants the hymn of progress.

He is terrene and everything that is terrene is of importance to him. He is of and for the earth. As the sugar-beet gets black rot without its trace of boron, oats get black speck without their trace of manganese, and sheep, 'pine-sickness' without their trace of cobalt, so he also requires such final sculptural touches for the perfection of his physical and mental health. If he depletes his life-cycle, he is himself depleted. In the intelligent United States, the depletion of the soil has awakened alarm, and scientists now make statements which seem extreme but may well be true. Such statements are that 99 per cent of the American people show some lack of minerals. Dr. Sherman, of California, has said of his people, what Sir John Orr has said of his, that above half the people suffer from calcium deficiency. Dr. Northen, of Alabama, added a number of minerals to the soil and found that, though vegetables and milk produced by it had the accustomed appearance, they had a very different mineral content. Quite new standards are, therefore, needed.

Textbook analyses, once made, stand. But often they are standards set by a soil that has been injured by faulty practices. So they are faulty value standards. We need the standards of the perfectly healthy soil.

Man's bodily substance, when not lost to the sea, returns to the earth many times in the course of his life. The grim saying, 'Earth thou art and to earth thou shalt return', said of his dead, is no less true of his living body. He is a terrene animal, of the earth earthy. That he cannot escape, and so he lives as a product of the soil to conserve it or deplete it. At present he depletes it. The story of this depletion is in its way mystical and inexplicable. It is one of retributive justice. The old doctrine that sickness and wars were the punishments of God appears again as truth. It seems that, in non-recognition of it, man acts with a perversity little short of insanity, for the insane are those who irrationally endanger both others and themselves.

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Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 15

Sind and Egypt

According to a famous saying, the greatest benefactor of mankind is he who makes two blades grow where formerly one grew. This is an especial motto of perennial irrigation.

This chapter is written mainly about a land where the largest or one of the largest schemes of perennial irrigation is in action, the province of Sind, India. The Lloyd or Sukkur Barrage, which controls this scheme, was opened in 1932.

The making of soils from the weathering of rock is a process which takes a very long time. The geologist, Mr. T. C. Chamberlin, in an address given at a Conference of the State Governors of the United States of America, held in 1908, wishing to impress upon his authoritative hearers the tremendous importance of the conservation of the soil, did so in the following words: 'We have no accurate measure of the rate of soil production. We know it is very slow. It varies with the kind of rock ... Without any pretensions to a close estimate, I should be unwilling to name a mean rate of soil formation greater than one foot in 10,000 years on the basis of observation since the glacial period. I suspect that if we could positively determine the time taken in the formation of the four feet of soil over our average domain, where such depth obtains, it would be found to be above rather than below 40,000 years. Under such an estimate, to preserve a good working depth, surface wastage should not exceed such a rate as one inch in a thousand years. If one chose to indulge in a more liberal estimate of the soil-forming rate, it will still appear, under any intelligent estimate, that surface wastage is a serious menace to the retention of our soils under our present management. Historical evidence enforces this danger. In the Orient there are large tracts almost absolutely bare of soil, on which stand ruins implying former flourishing populations. Other long-tilled land bears similar testimony. It must be noted that more than the loss of fertility is here menaced. It is the loss of the soil body itself, a

loss almost beyond repair. When our soils are gone, we too must go, unless we shall find some way to feed on raw rock, or its equivalent.'

This is a very succinct description of the final danger of unwise cultivation of stationary weathered soils. But the soil of the Indus Valley in the alluvial plain of Sind has not been formed from the rock beneath it. It is soil which has been formed at varying, and, mostly at great, distances. The greater part of the preliminary weathering has been done in the Himalaya, the Karakoram and the Hindu Kush Mountains. These mountains have crumbled under the action of frost, heat, ice, snow and rain, and the crumbled stuff has been carried by innumerable streams and rivers, uniting near the border of Sind into one great river some three hundred miles from the sea. The alluvial plain of Sind is the result of this river's annual floods.

Sind, therefore, has *not* to fear the dangers of surface wastage, of which Mr. Chamberlin spoke. Contributions to her soil have been made on a far more generous scale. To her the highest mountains of the world have paid their annual tribute for countless years, in the thin layer of silt, which is spread out by the flooding Indus. The soil of Sind is, therefore, very deep compared to weathered soils; in place of the four feet of weathered soil, of which Mr. Chamberlin spoke, there is as much as forty feet formed by waferlike sheets of mud.

Further, in contrast to stationary soils, there is not any sharp distinction between soil and subsoil. An alluvial soil, seen in the cutting of an embankment, is featureless, but it also lacks uniformity, for it is the result of a series of irregular floods carrying their silt hither and thither in no regimented way. The two soils, stationary and alluvial, are quite distinct. Here, then, there is ample opportunity for the objectivity of man -- different soils, different treatment. Or if subjective, here lies a trap -- different soils, similar treatment. Has man avoided the trap or has he let himself be caught in it? Let us see.

Let us here again quote Mr. T. C. Chamberlin, with his neat, succinct way of saying things: 'Some of the soluble substances ... formed at the base of soils are necessary plant foods, while some are harmful; but what is more to the point, all are harmful if too concentrated. There is need therefore that enough water pass through the forming soil, and on down to the ground-water and out through the under-drainage, to carry away the excess of these products. An essential part of the best adjustment is thus seen to lie in *a proper apportionment of the amount of water which goes through the soils*. If this be not enough, the plants will suffer from saline excess.'

I have myself been able to examine alluvial soil in Sind, not as an expert but as an humble observer. I have been able to observe it in a cutting ten feet deep, above which the surface was soaked by irrigation. After the surface-irrigation, the water sank through the whole ten feet and disappeared into the earth at the foot of the cutting.

Just at the edge of my cutting there grew a border of stunted grass and a low ericaceous

plant. Farther from the edge was the irrigated crop. When the irrigation ceased, the upper layers of soil, wetted by a transverse spreading of water, began to dry owing to sun and wind. Eventually the upper two or three feet became quite dry and when I scraped it powdered off as fine, pale sand. But below this dry surface the layers down to the foot of the cutting remained moist for months after a good soaking, as I discovered when I scooped out small tunnels into its interior. The lower layers, then, have a notable capacity of storing water and, with it, soluble plant foods.

The humble desert plants, the stunted grass and ericaceous shrub, knew this, for they sent slender roots straight through the upper dry layers down to the moist layers. Some of the roots traversed the whole ten feet of the cutting and disappeared into the earth at its foot. These astonishingly long, fine roots, in places where they are numerous, look like combed hair. They show quite clearly that they only rely for a short time upon the upper layers of the alluvial soil for their food and water. *It is upon the lower layers that they rely for their continued sustenance*.

The character of an upper dry, and lower moist, area after a soaking with water appears to be similar in all deep, river-made soils in arid climates, such as those of Sind, Egypt, Irak and the like. This character was described in 1906 by Professor Hilgard, as found by him in the San Joaquin Valley in California. He found also a third, dry, airy area, below the moist area, due to the soaking water pushing the air in the soil in front of it through smaller and smaller channels, until it could no longer bubble up. The compressed air in this third area prevents the further fall of water, except in cracks through which it finds its way to the ground water.

This third area not only holds up the water in the middle area and prevents further loss downwards, but it also supplies that area with oxygen, which helps the microbes in it to prepare soil-foods for the plants. The arrangement, in short, is a strikingly perfect one, as one might expect, for how else could vegetative life be possible in these climates? It is possible because of the storage of water and foods and air in the voluminous middle layers, which are themselves protected against evaporation by the upper dry layers. It is, indeed, just another example of the usual, that where there is life under unusual and difficult conditions, there will be found so appropriate and delicate an arrangement that men used to declare they saw in it the revelation of a higher intelligence.

And they might well in all reverence take that view now. Certainly when they separated out the acres of Sind for themselves under the Sukkur Barrage and Canals System, they placed their own intelligence in immediate relation to this higher intelligence. That the Sukkur System can be acclaimed great, there is no question. It is great. The making of it is indisputable testimony to great technical intelligence. But is the planning and execution also testimony to higher intelligence? Here one may hazard that, from the point of view of the soil itself, the lack of higher intelligence so characterizes the industrial age, that its existence in this planning would be exceptional. The Sukkur Barrage in its aims has not been exceptional. It has been sponsored by modern, practical, money-making men, who

have made such tragic blunders in the agricultural world elsewhere.

Nature's way of *soaking* these soils in arid countries is precisely the same as that by which she *forms* them, namely, by an *annual* overflow of the river. When men originally brought in irrigation to direct the overflow to their own advantage, they did so by putting embankments to enclose large areas or basins of flat land and then sending the water into them by water-channels. During the period of the flood, water passed on from higher basins to lower basins on the way to the sea, and in each basin silt was deposited. This form of irrigation is known as basin-irrigation. Its chief exponents have been the Egyptians. The waters of the Nile were enclosed in the embanked basins for fifty days or so, some movement occurring all the time as water passed from the higher to the lower basins, eventually to be drained back to the river. In that fifty days the soil of each basin got a continuous soaking and upon it a certain amount of rich silt settled. The soil of each basin was cropped each year and, after the harvest, was left uncropped until the next season of flood.

Now, if this method of irrigation is carefully considered it will be seen that it is an adaptation of the natural cycle of events to the Egyptians' use. The water lay upon the land for the same fifty days or so of the natural flood of the Nile and received the same deposit of mud. Throughout their long history, the Egyptians did not alter the natural cycle. It was only in the last half-century that perennial began substantially to replace basin irrigation, and the reason was that perennial irrigation permitted two crops in place of one. It earned, therefore, the blessing given to *those who make two blades grow in place of one.*

This advantage of perennial irrigation is brought about by a *permanent* high level of the river above a dam or barrage placed in its course. Main canals lead off the heightened water from above the dam and minor canals distribute it. It makes constant use of the artificial high level of the river, and, using the water that flows in the river all the year round, it is obviously not wasteful but conservative. But there is one daring thing about perennial irrigation; *it alters the age-long habit of river-made soils in arid countries*. What it is made to do is, in fact, to treat these arid soils as if they were soils dependent upon frequent rain, for by means of locks and gates there is a giving of water every ten to twenty days.

The system increases the products of the soil not only by putting more land more frequently into use, but also through more frequent crops it makes greater demands on the stored plant-foods; at the same time it does not cater for an annual settlement of silt as does the basin method. It gets its results by an exploitation of the alluvial plain and not by an application of its natural habit; thereby issuing as it were a challenge to nature. It might, therefore, call forth a retaliation from nature. Actually it does do so and the retaliation takes the form of an accumulation of salines in the soil. These alkaline salts lead to a deterioration of the soil and, when advanced, prevent the growth of crops altogether.

'The Egyptians, writes Mr. G. V. Jacks in *The Rape of the Earth*, during the long period in which they used basin irrigation, 'lived on the soil's income and won lasting security against natural hazards at the expense of progress. With the introduction of a more efficient technique into Egyptian agriculture, the soils have steadily deteriorated. "Soil alkali" has become a serious and growing menace, cotton yields are falling. The deterioration has been due in the main to the substitution of perennial for basin irrigation.' Basin irrigation suits the soil and is akin to it. Perennial irrigation, on the other hand, is not akin to it. But, at a time of the unchallenged dominance of money, the perennial form was unavoidable as 'a substitution indispensable for the cotton growing, by which Egypt has advanced and enriched itself' (Jacks). Nevertheless, in its very success, it has staged once more the drama of money versus the soil, with money in the role of victor. But nature will not be gainsaid. The very source of Egypt's life suffers, and though the present generations gain the future ones will lose. 'Egypt's advance to modern civilization is being bought with soil fertility,' is the conclusion of Mr. Jacks.

That great agricultural genius, the late Professor F. H. King, who became Chief of the Division of Soil Management, United States Department of Agriculture, in his book, *Irrigation and Drainage*, 1898, reflecting upon 'the fields of the Nile kept free from alkalis for thousands of years', and upon the present increase of salts 'to so serious an extent that many acres have been abandoned', was struck by the thought, which like a flash in the dark illumines the brain of genius, that these great irrigators must have *tried out* so obvious a modification of basin irrigation as is the perennial. 'The probabilities', he wrote, 'are that long long ago the more rational methods (?) now being practised had been tried and found inadequate or inapplicable, on account of the accumulation of alkalis which they permitted, and the old irrigators learnt to be content with a system which, although more wasteful in some ways, still kept the dread alkalis under control ... It is a noteworthy fact that the excessive development of alkalis in India, as well as in Egypt and California, are the results of irrigation practices, modern in their origin and modes, and instituted by people lacking in the traditions of the ancient irrigators, who had worked these lands for thousands of years before. The alkali lands of to-day, in their intense form, are of modern origin, due to practices which are evidently inadmissible, and which, in all probability, were known to be so by the peoples whom our modern civilization has supplanted.'

In India the adjacent provinces of the Punjab and Sind have both been widely developed by perennial irrigation, and both have reacted, even in a brief span of years, by increasing alkali. In *The Summary of Results*, published in 1940 by the Agricultural Department of the Punjab States, one reads: 'In the Punjab vast areas of alkali soils have come into existence.' In Sind there have been but a few years of perennial irrigation, for the Barrage was only opened in 1932. Nevertheless, in the 1937-8 Report of the Department of Agriculture, it is stated: 'This constant application of irrigation water, for raising crops in such intensity, has brought in complex soil problems, the solution of which is necessary to the success of the projected agricultural progress of the Province ... Though precise

information is not available, it is known that there are thousands of acres of *kalai* (the local name for alkali) land where no crops would grow. Besides these large stretches, there are scattered all over the Province, almost in every holding, small pieces of *kalai* land where crop either does not grow or grows very poorly.' Since the opening of the Barrage, as is above stated, precise information is not available. A few researches made, where it was possible to contrast pre-Barrage with post-Barrage conditions, show that the warning of Mr. T. F. Main, Director of Agriculture in 1929, that 'under perennial irrigation one must look forward to vast areas more or less infected with salt' is a prophecy likely to be fulfilled. Alkali is already the most urgent problem in Sind, and the most effective remedy that has been found, is, says the Report, to put large quantities of irrigation water, 16-32 inches, depending upon the salinity,' to soak the soil. In other words, *the most effective remedy is a temporary return to basin irrigation*.

When the soil is capricious and tends to deteriorate, more is involved than a diminution of crops. The whole life-cycle deteriorates too. In reading the Report one is impressed by the great amount of disease, not only of the soil, that there is in the Barrage area. It is true that at present no immediate linkage between disease and alkali has been investigated, but then nowhere is the relation of the soil to the disease of the life-cycle it supports properly recognized. It is not put in the foreground of official agricultural reports anywhere and only appears more or less by chance.

Cotton is the crop to which the Barrage System is particularly suited, yet in Sind this fluffy beauty is as delicate as a Brighton invalid. Here are some of its enemies and diseases: jassids, white ants, pink and spotted boll worm, black-headed cricket, dusky cotton bug, lucerne caterpillar, red pumpkin beetle, root rot, boll rot, red leaf. So it is officially stated: 'There is no doubt that the losses suffered annually by the cotton growers of Sind, on account of damage to their crops by insect pests or fungoid and bacterial diseases, are immense, and scientific research work on these pests and diseases is most urgently required.'

Re the animal phase of the cycle, the system was not designed for Sind's famous red cattle, as is evidenced by the fact that 'since the commencement of perennial irrigation, the yield and quality of the *jowar* crop in Sind have deteriorated in many tracts'. *Jowar* is a common food of cattle and with its deterioration 'there is a general deterioration in the breed'. A 'heavy toll' in animals is taken by such diseases as liver fluke, rinderpest, parasitic gastritis, haemorrhagic septicaemia, and so on.

Lastly comes the human phase. The chief disease, which affects the countrymen of Sind is malaria, and, *re* malaria, the Public Health Report of 1938 states: 'Its incidence has increased with the inauguration of the Lloyd Barrage and Canal Construction Scheme.' It is not possible to compile accurate statistics in rural Sind, but the prevalence of malaria is brought home to landowners, because its weakening effect on the labourers is produced when there is the greatest call for their labour. Some harvesting actually has been abandoned because of the shortage malaria produces.

The increase of malaria is connected up with the System in the following way: the System brings more water; more water brings more pools; more pools bring more mosquitoes, and the bite of mosquitoes leads to the infection of malaria. But this quite possibly is not the whole story. The Sind soils tend to be alkaline, with, in the language of science, a pH of over 7. Low degrees of alkalinity can be neutralized by the carbonic acid which the roots secrete, but, if alkalinity increases, the water of the soil cannot hold iron and manganese to the same degree as it can when it is neutral, and these two are the chief metals of the red matter of the blood.

Under the Barrage System only a small investigation of pH values has been made, when it was found that the pH had risen from an average between 7 to 8.5 in pre-Barrage days to an average between 8 and 9.5 in post-Barrage. If this were generally true, then the plants in the post-Barrage period as eaten by the Sindhis would have less of the metals that form the strength of human blood. Malaria in particular, is due to parasites in the blood itself. The weaker blood favours the parasites of malaria and so malaria is increased for subtle reasons of the life-cycle and not merely from more pools and more mosquitoes.

Whether this sequence will be found or recognized to be a further example of how we humans must be thought of as part of a life-cycle or whether it is rejected, there can be no question that the growing of two blades where one grew in Sind has ushered in a cycle of sicker soil, sicker plants, sicker animals and sicker humans. Were there a definite measure of character and morals, it is possible that even now these would be found to have deteriorated. In the general opinion of those with knowledge of Sind, there has been a notable deterioration, but this is not attributed by them to a slackening of efficiency and authority under provincial self-government.

Mr. Jacks proclaims that alkali is not as dangerous as erosion, because it can be remedied. The most effective remedy in Sind and elsewhere is the soaking of the soil. Rice growing is also effective, for in the growing of rice, the soil is covered with water and thoroughly soaked. Both processes are of the nature of the basin irrigation, which in Egypt for so many centuries completely protected that wonderful land against alkali.

What will be the end in Sind? Will the stubbornness of nature and her dominion over all terrene life once again either force men to comprehend, or will it make their habitations barren? Is an old, old story in the East again to be repeated? Sind, like Egypt, is buying her way into a money-ruled civilization with her soil-fertility. Will the agricultural scientists, obedient not to the soil but to their urban masters, enable this money-dominance to hold its position against the affronted land? Will they, by their fragmented methods, be able to go further and establish a stable, healthy life-cycle in Sind? Will they fail?

For myself, I look for an answer to the man, who of all men seems to me to have had the widest and wisest vision in these great matters, the late Professor F. H. King, and return to his words: 'The alkali lands of to-day, in their intense form, are of modern origin, due to

practices which are evidently inadmissible, and which, in all probability, were known to be so by the people whom our modern civilization has supplanted.'

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Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 16

Fragmentation

When, in the first half of the industrial era, the call upon the soil for food and raw material became urgent, certain scientists set themselves to study the means by which the soil was enabled to create more life. They did not do this by a wide observation of nature in the forest, prairie or elsewhere, nor by a study of successful farming, past and present, but they did what is typical of scientists, they selected one aspect of the question and concentrated on it. They selected plant-food, not in its entirety, but in the fragmentary aspect of a particular character of it, its chemical character. They acted as simplicists, split off a part of a whole problem, and attempted by an intense study to make the part solve the whole. Thereby they eventually made the part greater than the whole. However, the story tells itself.

The men who set out to solve this problem, or, in other words, to put a scientific theory and practice of plant-feeding in the place of the traditional, observational knowledge and practice, were not farmers. They were chemists, allied, therefore, to the chemists who then were making factories so successful.

The three leading men in this venture of the human mind were Theodore de Saussure, Justus von Liebig and J. B. Lawes. Liebig (1803-73), with whose name the venture became chiefly connected, had already won a wide recognition as one of the greatest chemists of his time. In 1832 he, with Wöhler, published a memoir called *Researches on the Radical in Benzoic Acid*, in which he showed that the radical benzoyl might be regarded as forming an unchanging constituent of a long series of compounds. By this great work, he opened out a new era of organic chemistry, and made possible the elucidation of the numberless combinations of a few elements, such as those which figured in Chapter 14.

It was, therefore, with a great prestige and unavoidable recognition on his part of his own pre-eminence as a chemist, that in 1838 he turned his powers to a subject that was urgent and immediate, the subject of the production of more food. It was a time known in England as the 'Hungry Forties' and in Germany one of grave social unrest amongst the growing industrial population. Liebig became drawn to the nature of food, vegetable and animal, and such was his forceful intelligence that he was sure to make out a very strong case for the chemist with regard to it. He did so. In this vital matter, he made out the claim that the chemist should be the supreme arbiter.

He rejected the farmers' knowledge that the plants derived their chief nourishment from humus, formed by the decay of dead animal and vegetable matter. He taught that plants took their nitrogen and carbon from the air and eventually returned them to the air by the agencies of putrefaction and fermentation. There was no loss of either carbon or nitrogen in this cycle. But it was a different matter with the minerals that plants required, such as phosphorus, potash, soda, sulphur and lime. These came from the superficial earth, in which they were limited and could become exhausted. What the farmers had to do was to make good the loss by giving back the required amount to the soil. To affect this, they had to put themselves in the hands of the chemists. The chemists would take some of the crops to the laboratory and there burn away the organic matter and analyse the minerals of the ash that was left. They would, then, discover whether phosphates, potash, sulphates, lime, and also nitrates since nitrogen was not supplied speedily enough by the air, were defective in quantity. By mining the deficient salts or by manufacturing them in factories, they would supply those that were required. The ones particularly required were grouped under nitrogen, phosphorus and potash, with lime which had long been given to fields in the form of marl or chalk. These chemicals became known by the term of 'artificial' manures in contrast to natural, farmyard manures.

At no time could circumstances have been more favourable to artificials than at the time of their introduction. The overthrow of the conception of men's partnership with the soil, which is embodied in a free peasantry, had been completed as has already been told. The old feeling for the land as something living and creative had disappeared with the peasantry. The land had become something to be owned and worked for money. Large, new populations were awaiting food and also other raw materials of plant growth. Fortunes were won through ownership of land as quickly as through that of factories. The land of England had, therefore, been seized by wealthy and ambitious men, and the peasants had been turned off their holdings and their commons. The peasants were subjugated by the rich, as if they were a conquered people and not fellow-countrymen.

Urban areas, too, were rapidly ceasing to have the character of country-towns and were differentiating themselves as almost purely industrial. The leading industrialists, on their part, had also defeated the countryside. They had destroyed the rural cottage industries and thereby had forced the young and able-bodied country folk to serve their factories. Whether on the land or in factories and mines, the new order was rich men and,

completely subservient to them, the proletarians. This was the rural condition which constituted the parentage of 'artificials', and, from the point of view of life-cycles, it was bad.

On the other hand, it may be claimed that these chemical fertilizers made a big contribution to the difficulty of feeding the new, urban populations. Apart from exceptional farmers, the soil had for long been indifferently manured. The elements which artificials supplied were needed, and larger crops followed their use. Healthier and better results could have been effected by the systematized collection of great quantities of urban and rural waste and the manufacture of it into manure. But there were difficulties. Firstly, the roads were bad. Even the best of roads were such that royalty sometimes could not get from Kensington Palace to Richmond owing to the mud. If this were so where royalty passed, collection and distribution of stuff needed by farms and villages were not likely to be systematized, a word that did not apply to the farming of that day. Secondly, the making of manure from wastes requires planning and labour, and there was a lack of both in the English countryside.

Artificials had many advantages over natural manure. They were either mined or manufactured. They were much less bulky to transport, and they were very easy to spread upon the fields. They were, indeed, almost too practical and convenient; they offered the allurement of ease, and, as they gave quick results, landowners and large farmers were satisfied. Science thus came to the rescue and scored a triumph. Artificials did great service in a period when the altogether unprecedented increase of population and new towns enforced an exploitation of the soil in a country of backward agriculture. They provided a partial and artificial fulfilment of the rule of return. They singled out the most important elements of plant food and replaced them, even if distant islands had to be sought to get the required substance. This feeding to the land was certainly superior in its results to no feeding at all. It was planned and conducted under skilled guidance. It increased yields, strengthened weakling crops in their growth, filled in gaps when the introduction of motors and tractors led to losses of organic manure by displacing horses and oxen. In consequence, artificials came to be used in large quantities in many parts of the world.

Nevertheless, they were and they remain fragmentary; they are not a full return of all that is taken from the soil. Is there evidence that in results they have not had a whole effect, such as their partial character would indicate? At the very outset there is something which, in a sense, is so fantastic and yet so in keeping with the spirit of that exuberant time, when the first burst of wonder was aroused by the many triumphs of the scientific method, that it seems almost logical. It is this: *the life-cycle was not used as a test of artificials*.

There is the justly famous small plot of ground of Broadbalk, Rothamsted, the experimental station founded by Mr. J. B. Lawes, where for a century wheat has been grown yearly on soil with a full complement of artificials next to a similar plot, where farmyard manure has been used. The wheat on both plots looks well and yields well. But

all tests of this century of experiment have stopped with the crop itself and its quantity. The crop has been watched as a thing in itself by the close, careful, fragmentary , watch of science. It has just been a market test, the quantity of wheat yielded by a plot of such a size. No animal phase of the wheat as a food has been tested, nor has its vegetable factor been complete, *for the seed of the plots has been imported from outside*, bringing in qualities of life-cycles not belonging to the plot. So the whole century-old experiment has been without any life-cycle tests, *has indeed belonged to no life-cycle. It has been individualized, separated, specialized. But in nature nothing is like that.*

This fragmentary method in agriculture, as elsewhere, became the standardized method of test. It has not, even now, reached the stage of the life-cycle, in which observant peasants and the health of themselves and their products enter as a part of it. Scientists, it is true, do test out crops and foods on animals, but in a fragmentary and apparently inexhaustible manner, and, except the estate planned by Lady Eve Balfour in Suffolk before the outbreak of war, there was in Britain no experimental farm, in which the life-cycle was the standard of test.

There seems to be, then, only one way to get an answer to the life-cycle results of artificials and that is to take a general view of the results of agriculture in the period, in which artificials have played a prominent part.

Firstly, we will take quality as denoted by taste. That great farmer, Mr. F. A. Secrett, at the Royal Society of Arts in 1935, spoke of taste and quality in this practical manner: 'I notice that in Covent Garden and the larger provincial markets, those stands are favoured where the produce has come from farms which have received organic manure. Although higher prices are charged for this produce, it is sold out first.'

Taste and choice are, of course, natural measures of food, but they are not scientific ones. People are so subject to the statements 'proved scientifically', 'measured scientifically', that they fail to realize that the excellencies are not measurable and therefore have to be disregarded by science. The customer, who likes the look of a basket of gooseberries and takes one to taste, is a sound measurer, but he is not a scientist. A scientist, as scientist, cannot measure appearance and taste. (A very great and honest scientist, Charles Darwin, said that his work had spoiled his appreciation of music.) But people can still judge by taste, and it has been noted by those who grow vegetables and fruits upon land where full return is practised, that customers give a sudden expression of surprised delight when they first bite into these products. They have come to expect almost a savourlessness in market-garden produce. Anyone who has tried out foods grown from full return and those from artificials, immediately recognizes the distinction. One is inviting, the other insipid. Market-gardeners themselves know it, but now that motor-cars and vans have driven out the huge horse population which once belonged to the towns the gardeners served, they have been left mostly helpless. Animals, too, know that taste is a safe guide to good food. Mice have been tried out by giving them two troughs, the one filled with grain grown by the bio-dynamic methods, which is a 'whole' method, and one with grain grown by

artificials. The mice invariably chose the first trough and finished its grain before they went to the second. Similarly cattle, let into a field equally divided into 'artificials' and 'whole return' areas, collect and graze upon the whole return.

Nevertheless, in searching around it is surprising how few are the examples of choice. The curious fact emerges that *the taste of fresh foods is no longer regarded as a guide*. The great majority of modern foods are scarcely expected to taste of themselves by the mass of their consumers. Tastes, as condiments, sauces, curries,, and so on, have to be added to them.

The next test of quality is health. Can it be said that the products are healthy under modern farming, in which artificials have come to play a dominant part?

To answer this question by personal observation, one would have to go on a tour like those of Arthur Young, William Cobbett and Rider Haggard, and see for oneself. We have to find a less laborious journey, and this is readily achieved by going through a textbook on modern farming, which gives one, as it were, a guidebook to a country one does not know. As the majority of people do not know the farming world, such a book will form a guide to what is to the reader virtually a foreign country. I have such a book before me, written with the excellent technical skill which one expects in such instructive books. I have read through it several times, with the spirit of a traveller seeking to know what this new farming world is like, and each time I have wondered the more at what I read.

There is first the soil. In this new country one soon comes to realize that the soil is not a bit like the soil in nature, a part of a general life-cycle. It is *a thing in itself*, the composition of which is understood by scientists as something that they can manipulate, compound into its several parts and dispense to farmers as compounders dispense medicines. What the soil did in the past and still does where left to nature, what it did under the cultivation of past farmers, these are things of the Dark Ages before the light of modern science came to the world. As principles or assistants to knowledge, they are not even mentioned. Previous knowledge and tradition of the land are treated as the previous knowledge of, say, radiology and wireless, as not worth mentioning. But the soil is something very different to new scientific subjects or discoveries in technique such as that of Marconi. The scientists, however, seem to see no difference between technique and vitality.

The manipulated soil gets a number of diseases, so the wise modern farmer will get his soil overhauled by a soil-scientist, as the townsman gets himself overhauled by his local doctor. But with these numerous complaints and their treatments we will not deal. The spontaneity of the soil, by which it has done its job of life-supporting for endless vistas of time, is lost in this new country. So, even though one knows the language, one has also to know the exact meaning the scientist gives to his words. One wonders what exactly he thinks of the soil. Is it a vigorous re-creator of life or a cantankerous invalid? Is it the peasant's partner or the scientist's patient? It is really confusing, but let us go on with our

journey.

We now enter another province, that at which the scientist is at his happiest technically, manipulating the breeding of plants and animals in ways so quietly discovered by the monk, Mendel. In this province, wonderful varieties of life have been fashioned. Here, for example, are pigs so fat that to their progenitors they would appear nightmares rather than pigs. They have been conjured into masses of streaky bacon such as a public has been taught especially to value. Sometimes the public taste in bacon is changed, and with it the pigs are changed, the scientists being able to switch their fat and lean about so as to make a change practical. These pigs are bred, fed in special ways, stalled and slaughtered, and often never go under the open sky, until they are taken to the market. They are, of course, delicate, but they are bulky. They are tasty, too, when they reach the table, so that here public taste itself seems faulty as a guide, and this would be so, were it not that the taste is directed not so much by the consumers as by the retailers.

Still they are tasty, especially to those who have not or care not for the powerful crunch of orthodontic teeth.

Here, too, are cows specially bred for milk. They also see very little of the open sky during their useful life. They become mothers and their udders fill with milk. Their calves are almost at once taken from them and the mothers are transferred for service to long and very clean buildings near large towns, where each one has her stall. Antiseptic chemicals are requisitioned to cleanse the teats of microbes and then a machine is attached to the teats, which sucks out the milk into sterile receptacles. Extreme watchfulness and care is taken. Above all the scientists have to test and examine for tuberculosis, for there is probably no group of living animals so prone to a grave infection as are these unnatural cows to tuberculosis. I have not with me nor can I recall the percentage of cows in Britain that have tuberculosis, but it is surprisingly large. Our guide to this new farming country, however, comes to our assistance. The best way of preventing the spread of tuberculosis in dairy herds, it says, is to test the cows by the tuberculin test and to destroy those with a positive reaction. The objection to this practical man's treatment of an invited disease is that it means a capital loss to farmers, which they cannot afford. The scheme, though declared to be *scientifically sound*, is not carried out in practice. It is a good example of the language of this new country being so topsy turvy as to distort the meaning of words. *Sound may be so allied with science, but it certainly cannot be so allied with nature. To be sound in nature is to be healthy*.

We have now had a sight of some of the animals in the new country. We will direct ourselves to some of its crops. It does not really matter which crops we choose. We will, therefore, select two of the commonest forms of human food, wheat and potatoes.

What is wanted is a wheat of the best quality. There we all agree, but the word quality in the new country has a different meaning to that which it had in the old one, when it meant a wheat that gave a health-giving and tasty loaf. Quality is now milling quality, the

capacity to make large loaves. Imported wheat is better quality in this respect than British wheat, for a two-pound British loaf is only two-thirds as big as a two-pound loaf of imported flour. For this reason the British flour is called weak and the imported strong.

The science of plant-breeding is recent; it belongs to the present century, and one of its early triumphs was in the making of British wheat strong. This was accomplished by breeding on Mendel's principles. 'Yeoman' and other wheats show that strong wheat could be grown in Britain. But, though these wheats were strong in the baker's sense of the word, they were not strong in health. They were, like the so-called soft wheats, subject to many diseases, of which certain 'rusts' are particularly destructive. A wheat, called 'Ghurka', was fetched from Russia because it resists rust and it was bred with British wheats, and finally there emerged 'Little Joss', which was immune to Yellow Rust. Its baker-quality was not so good as that of 'Yeoman', but its health was better; so by better health it lost one quality in gaining another.

There are many other diseases of wheat; there is, for instance, one with the unpleasant name of stinking smut. To avoid stinking smut the seeds of wheat before sowing are soaked or dusted with chemical antiseptics, so strong that those who handle the seed have to guard themselves against being poisoned. Some of the poisons were too dangerous for common use, so the scientists set to work to find safer poisons. Coated with these poisons, wheats of good quality can emerge into life.

Now those who can remember the cottage loaf, as made by hand in the countryside before these changes were begun, will recall the delicious flavour of the bread. But a delicious flavour is not a measure in this new country. See, for example, what has been done with our second choice, the potato. The potato is an American plant with its original home in Peru, when that country was itself the home of a very great agricultural civilization. Our guide to the new country, however, tells us what a poor-quality thing the potato was before being taken in hand by the scientists. Potatoes of the present day, the guide-book, declares, are much superior to the small 'highly flavoured' potato of the last century. Nowadays a hygienic public, trained to associate the colour white with cleanliness, demand what in the new country is a quality-potato. It must be of medium size, thin-skinned, with few eyes, and above all, it must be white. It must have a 'good' appearance, it must be a 'shop-window' potato, though its flavour is poor compared to its yellow-fleshed, highly-flavoured and more nutritious ancestor. But this yellow colour is not 'quality'; it is, a 'discoloration'; merchants will not buy such potatoes and the public will not eat them. How is it that the public rejected flavour and nutritiousness in favour of bulk and appearance? Is the answer not clear to my readers? Bulk, if it means ultimately less to the consumer, means more gain to the seller. Money scores. And appearance, is that not a second falsity of money, the eye displacing the tongue, where the tongue should serve the whole in the supreme matter of vitality? Or, to discard the serious for the humorous, how many times have I not read and laughed at Alice in the Looking-Glass, until, following my guide-book, I realized that I too was living in such a wrong-way-round country.

Of course the potato has a number of diseases. We read of them, in the guide-book. It is really delicate, so delicate in fact that in many countries, including Britain, certificates are issued by special inspectors that seed-potatoes are free of virus, and, in consequence, that their offspring will not be killed out to an extent of more than 50 per cent by virus diseases. There are, of course, fungus diseases as well. There is, for example, wart disease, which is so dangerous that in 1923, Government made its occurrence notifiable to the police.

So one travels in the new country, to hear the same tale again and again repeated. Finally the traveller comes to the opinion that *the modern scientific farm, and especially the experimental farm, is a mixture of forcing house and hospital*. It fragments the life-cycle. It is the offspring of a defect of thought, the splitting or departmentalizing of the mind, which disables it from seeing wholeness and that men, animals, plants and soil are inseparably united.

Under this fragmentation, insects and other pests have assumed a dominion, which assuredly they have not got in nature, frit flies, aphides, moths, cut worms, wireworms, leather-jackets, warble flies, maggot flies and the rest. But, through these misfortunes of the new farming, the balance of nature is once again emerging under the term ecology. How different is the tale of ecologists to that of scientific money-farms. Here is the evidence of one of them, taken from the Bio-dynamic Agricultural News Sheet of April 1938:

'We have found it possible to prevent the plants from suffering damage from insects simply by means of suitable biological measures, and without taking steps to kill them. In vegetable culture proper we have mostly to do with plants whose flowering impulse is held back, as, for example, all kinds of cabbage, carrots, radish, chicory, leek, celery, beetroot, turnip, etc. Or we have to do with plants whose flowers are not very prominent, such as beans, tomatoes and similar plants. From this repressed impulse to bloom there results a certain one-sidedness. True flowering plants are not amongst them. A close study of the relationships in nature makes it clear that the insect and plant worlds are complementary to and dependent upon one another, and moreover that certain insects and certain plants are sympathetic to each other. Vegetables enable insects to develop their larvae and flowers offer food to countless fully-developed insects. And there are many small creatures which prey on each other, such as the spiders, ichneumon-fly, ladybirds, etc. If we provide as large a variety of insects as possible with the means of living, most of them will in time live harmoniously together, and the harm done by this or that one will be practically negligible. That is why it is so important to have flowering plants near vegetables. The aromatic herbs are especially valuable for this purpose, e.g. borage, lavender, hyssop, sage, thyme, marjoram, dill and fennel ...

'At first the grubs of the cabbage-fly were very destructive. Now we do not mind them at all. If on, warm days, at the end of April or May, the fly lays her eggs on the cabbage plant, the red mites find them and suck the eggs before the larvae emerge. There are many

such compensatory adjustments. The sand-fly drags many caterpillars away to bury them for its larvae. In springtime ants seek among grass and plants for the larvae of the daddy-long-legs and kill them. Even the wireworm made itself useful by preferring pre-digested plant-stuff and destroying the larvae of a cabbage-fly.

'Not only do insects balance amongst themselves, but toads, frogs, moles, shrew-mice and lizards take part in this adjustment.'

Men, animals, plants and the soil are balanced and united. That is the clear meaning of the above close observer and follower of nature. It is the answer to all that strange, new country, through which we have travelled. It is also the answer to that particular part of it called 'artificials'. Men separate and fragment. They separate a science from nature as chemistry. Then the common thing, which bad thought permits, happens. The new specialists, the chemists, look at the vital processes chemically and lay claim to be its guides and masters. Being scientists they get the support of other scientists, and that of the scientific method, the method of experiments, which can be repeated by any properly trained individuals. Thereby they fragment, isolate and simplify questions, and make them readily 'comprehensible' and 'controlled'. By 'artificials' not only do they reduce the feeding of the soil to a purely chemical process, not only do they omit the secrecy, delicacy and variety of nature's own methods, but they limit the very chemistry itself. They fragment and simplify it to three or four minerals, those of nitrogen, phosphorus, potassium and calcium. But there are more minerals in the soil than are dreamt of in their philosophy; for example, those that accompany the growth of sugar-beet by the sea constitute, as Dr. Pfeiffer calls it in *Bio-dynamic Farming*, 1938, a 'small pharmacy of sodium, lithium, manganese, titanium, vanadium, strontium, caesium, copper, rubidium', some of which elements are as rare as their names are beautiful.

As to these rare and common metals, do we know what tone and quality we miss, if we lack our share of them? We already know from Chapter 14 of grave defects from small omissions, but the mind need not get confused contemplating their possibilities. We have just read of the wonderful balance of nature's adjustment between insects, flowers and other small forms of life. Will not nature effect the same balance within us, if she is allowed her way, and we follow and do not fragment her method of life-cycles? Will not each element harmonize with the others and so express health? How then can we expect health, when that harmony is broken in the soil itself? That is the answer to 'artificials'.

I could give other answers and show how, when the whole is followed, health must necessarily accompany it, but I will not do so, as I have already made this the subject of my book, *The Wheel of Health* (1938). But I prefer to end this chapter not with minerals but men. The intelligence department of our agriculture is wrongly based; it is an intelligence largely directed to cure the evils which it itself brings into being. It is the countrymen's wisdom we need now, that of the countrymen who have built up long-lasting agriculture and whose wisdom lies in tradition. They have fashioned it by muscular and bodily work and by a close and immediate observation, by a personal intimacy with

nature, which we have come to associate with the poet. And, in fact, peasantries are poetical and are so because of this intimacy. The music, dances and songs of the peasantries are *characteristic* of their countries; they are the creative expression of their own lives. Nothing collective or characteristic, as their life is, originates from people separated from the soil as are townfolk. The poems and essays that played a notable part in the country life of the Chinese, the Tibetan art which finds its way into every home, the sylvan setting of the modern Japanese villages, of the Balinese and Burmese, the vocal harmony of Swiss peasants returning from their fields, the reproduction of floral beauty and colour in festive dress of so many countries, these betoken the unvoiced poet that lies in every peasant's heart. It is this intimacy that becomes creative in the poet, as the great Greek people recognized in their use of their word poet, namely, a 'maker' or creator, and which Dante voiced in the *Divine Comedy*, when he declared that the poet was not the disciple of the imagination, but he who knows the secrets of nature.

It is this intimacy which reveals to the cultureless or self-cultured countrymen the complete, inter-dependent character of all the varying forms of life, and the health, goodness and beauty which come from it. Its all-pervading quality is something known by being seen, felt, lived with and realized, and not told to the ear. It constitutes that mystical unity, about which all the most meditative religious thought and all the most sublime art have gathered. The most famous temples of the world, the noblest poems, the loveliest pictures, the most transcendent music, have acclaimed it. They are all works of balance and beauty, created by the unity of realization on the part of artists, who know the secrets of nature. It is to their company that the knowledge and arts of the peasantries belong. They are, both great and humble, of like origin. But modern, urban civilization, split off from the creative power of the soil, has forsworn this great heritage. In its place there has spread a nihilism that year by year has been destroying art, truth and beauty, and, at the same time, in an immeasurable degree, the soil itself, to be consummated in a holocaust of men and nations.

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Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 17

East and West Indies

The Dutch began their career as empire-makers in the East almost at the same time as the British, the British actually having the small start of ten years. Both peoples came to the East to trade and both became imperialists almost as an accident of their being traders. But there was a notable difference between the two peoples, close neighbours though they were in Europe. It lay in their attitude to their own soils, and this difference they carried with them to their eastern possessions.

The consequence was that the Dutch, in their island government, left the cultivation of the acquired lands to the native cultivators, without interference other than that of the payment of taxes in kind, by which they got the tropical products they needed for sale in the markets of Europe. All that was concerned with the native agriculture, subsistence farming, the village system, and native rule, were left undisturbed. It was a method of rule, like to that which the British now follow in some of their West African Colonies and which that great colonial statesman, Lord Lugard, described as *The Dual Mandate*.

In the latter part of the last century, the Dutch Government of the islands gave up acting itself as trader. But it had become so firmly convinced of the value of the Javanese and other peasantries, that it protected them by the absolute prohibition of the sale and purchase of land.

Mr. Boys, of the Bengal Civil Service, visited Java in 1892, and he summed up the preservation of the Javanese peasantry in this remarkable passage: 'The Javans have escaped the fatal gift of proprietary right, which has been the ruin of so many tens of thousands of our peasantry in India, and with which, while striving to bless, we have so effectually cursed the soil of India. It is not too much to say that the many benefits which would have been conferred on Java by the substitution of the English for the Dutch rule,

were not too high a price to escape from the many evils of the unrestrained power to alienate private property. Under their present Government, the Javans according to our English ideas ought to be the most miserable people. That they are not so, but that, on the contrary, they are the most prosperous of Oriental peasantry, is mainly due to one cause -- the inability of the Javan to raise a single florin on the security of his fields, and the protection thus gained against the moneylender and himself. Nature is bountiful in Java, and undoubtedly the abundant fertility of the soil enables the Javan to stand up against many ills to which he is subject; but were her fecundity doubled, were she able to pour her gifts as from a cornucopia into his lap, nothing would ultimately save him from the moneylender and from the consequent eviction from his fields and his home, if he were able to pledge the one or the other as a security for an advance.'

The Javans carry out a very skilled peasant-agriculture and 'have got erosion under as complete control as has been achieved anywhere in the world,' writes Mr. G. V. Jacks, and continues: 'The Dutch Government in Java has carefully preserved and encouraged native anti-erosion agriculture, and the same principles are applied to European-controlled estates. There are no social barriers between European and natives in Java. The primary object of agriculture is to feed the people; the food supply of the community as a whole must be maintained on a permanent and secure basis before rubber, tobacco, coffee, etc., can be produced for export.'

Here, in this island picture, everything has been favourable to the soil. The traditional cultivation and anti-erosion measures of the Javanese are excellent; the early Dutch Government, as trader, was able to get what it required through taxes in kind without other interference; with knowledge, the Government came to value the peasants' skill so highly that it did everything to support it. And, in order to support it, the Dutch encouraged a rightly ordered agriculture, *the primary object of which was to feed the people*. By the absence of social barriers, both peoples, Dutch and Javans, were able to base themselves on the soil. By both the soil is, one can say, *vitally* valued. In Java, writes Mr. Jacks, they 'give every acre of land a national value that may be out of all proportion to its money-making power'.

This high valuation of the soil was indigenous. But one can well understand how highly it itself was appreciated by such a people as the Dutch. When they came to Java, the Dutch were themselves the best cultivators in Europe. But they were something in addition. Of all peoples in Europe, they had waged the greatest and most unceasing fight for the preservation of the soil; they, above all people had given land a national value. They had for centuries won land from the sea and flood and guarded it by dykes, which were their perpetual care. In knowledge of the use of water and drainage, in the rotation of crops, in the use of clover, in the full art of cultivation, the Dutch invaders in the Indies were greatly the superiors of their British contemporaries. The very improvements in agriculture in England, which were first adumbrated at the time of Elizabeth, were due to Dutch and Flemish influence and infiltration. It was Charles the First who brought Dutch

experts in dyke and drainage to make his estate of the Isle of Axholme the best worked in England. Of all Western peoples, therefore, appreciatively to take over Java and its sister-islands -- if such were destined to occur -- none could have been better chosen than these skilled and soil-revering farmers of north-western Europe.

So, in this respect, the Dutch East Indian islands had the advantage over the British West Indian Islands. Of the quality of the Eastern cultivators themselves, there is no better account than that of Mr. C. R. Wallace in his famous book *The Malay Archipelago*, firstly, because he was a great observer, and secondly, because he visited the islands seventy years ago and, in the island to be described, saw its agriculture as something entirely its own. It was a most felicitous combination of observer and observed. The resulting almost paradisical picture is one of enthusiasm, but at the same time of unexaggerated verity. The island is that of Lombock, separated from Java by the island of Bali. It has at present some 600,000 inhabitants. Its capital is Mataram.

'Soon after passing Mataram', wrote Mr. Wallace, 'the country began gradually to rise in gentle undulations, swelling occasionally into low hills towards the two mountainous tracts in the northern and southern parts of the island. It was now that I first obtained an adequate idea of one of the most wonderful systems of cultivation in the world, equalling all that is related of Chinese industry, and as far as I know surpassing in the labour bestowed upon it any tract of equal extent in the most civilized countries of Europe. I rode through this strange garden utterly amazed, and hardly able to realize the fact, that in this remote and little-known island, from which all Europeans except a few traders are jealously excluded, many hundreds of square miles of irregularly undulating country has been so skilfully terraced and levelled, and so permeated by artificial channels, that every portion of it can be irrigated and dried at pleasure. According as the slope of the ground is more or less rapid, each terraced plot consists in some places of many acres, in others of a few square yards. We saw them in every state of cultivation; some in stubble, some being ploughed, some with rice crops in various stages of growth. Here were luxuriant patches of tobacco; there, cucumbers, sweet potatoes, yams, beans or Indian corn, varied the scene. In some places the ditches were dry, in others little streams crossed our road and were distributed over lands about to be sown or planted. The banks which bordered every terrace rose regularly in horizontal lines above each other, sometimes rounding an abrupt knoll and looking like a fortification, or sweeping round some deep hollow and forming on a gigantic scale the seats of an amphitheatre. Every brook and rivulet had been diverted from its bed, and instead of flowing along the lowest ground were to be found crossing our road half-way up an ascent, yet bordered by ancient trees and moss-grown stones so as to have all the appearance of a natural channel, and bearing testimony to the remote period at which the work has been done. As we advanced farther into the country, the scene was diversified by abrupt rocky hills, by steep ravines, and by clumps of bamboos and palm trees near houses and villages; while in the distance the fine range of mountains of which Lombock peak, eight thousand feet high, is the culminating point, formed a fit background to a view scarcely to be surpassed in human interest or picturesque beauty.'

This great naturalist and observer, it will be noted, is struck by 'one of the most wonderful systems of cultivation in the world'; 'in a remote and little-known island, from which all Europeans except a few traders are jealously excluded'; a cultivation due to assiduous labour; a skilled and complete use of water including every rivulet and brook; the roads themselves are made subject to the water channels; the levelling of every plot of land, large and small, so that the water could be equally distributed; and he is able to end his description with a true and happy association of 'picturesque beauty' and 'human interest'.

The British in the West Indies met with no great indigenous cultivators like those of Java, Bali and Lombock. The British pioneer invaders of the West Indian Islands were themselves men of adventure. They were buccaneers, the bold buccaneers, who at their own personal risk and for their own personal gain set out upon the high seas to dispute the Pope's fiat that the New World, known and unknown, belonged to the Spanish King. They and the French took many of the islands from the Spaniards, and made them their own.

The early history of Jamaica is typical of these happenings. The island was discovered by Columbus in 1494, and taken over by the Spaniards. With a criminality towards indigenous peoples, which seems to have been peculiarly their own, the Spaniards annihilated its gentle and peaceful inhabitants. When the British took the island from them, the total of Spanish masters and their slaves did not exceed three thousand. So the British, who had left their homeland for love of adventure, and others who had left for fear of the law, now found fortune before them. In 1672 the Royal African Company was formed and Jamaica became one of the busiest slave marts of the New World. The cultivation of sugar was then introduced. Pepper, coffee, cocoa, ginger and indigo, products sent from Java to Holland by the Dutch, were now sent from Jamaica to Britain. When slavery was abolished in 1838, the prosperity ofJamaica was at its zenith.

In Java, as we have seen, the management of trade was undertaken by the Government itself, and the work was carried out by the people on their traditional lines. In Jamaica, the work was carried out by Negro slaves owned by planters, whose object was to enrich themselves, with or without the enrichment of partners in Britain. Though buccaneers no longer, the personal motive of the buccaneer remained with them, namely, that of using their property primarily for their own personal advantage. Soil and labour were both their slaves.

But slavery, while it endured, carried with it the obligation of the planter to feed and house his slaves upon the estate. So, the first function of the soil, to feed the people who work upon it, was fulfilled. There was a direct relationship between the workers and the soil upon which they worked. The planters, as slave-owners, had also a direct relation with their workers, a position that in the case of many of them, possessing the innate moderation and humanity of the British, amounted to a guardian, paternal chieftainship. They stood in a parental relationship, such as is so movingly described in a recent best-seller, the novel *Gone with the Wind*, a relationship which, indeed, in its wide dimensions,

has constituted the main human binding power of the British Empire, and which acted as a drag-anchor to the endangering selfishness of the increasing money-power.

'Slavery', writes Mr. W. M. Macmillan, in his *Warning from the West Indies*, 1936, 'was not, as some maintain, wholly evil in its effect on the slave-owner's character. It not only fostered a proprietary sense of responsibility; slaves made possible a spacious leisure ... Many fine planters in the West Indies and the Southern States, like some Cape farmers, have a delicacy of culture associated only with the choicest traditions of old Europe.' Such culture made good masters. The prosperity of the planters overflowed in a generosity to their dependants. One may say that, in terms of happiness, the West Indies were well off in the eighteenth century.

Anomalous as it may seem, the change was brought about by the emancipation of the slaves in 1838. This emancipation was an act of liberalism. But there is something greater than liberalism, and that is soil-wisdom. And in the light of soil-wisdom, this emancipation was superficial and unreal ... It was an apparent release of the slaves from compulsion; it was no less a release of the planter from certain responsibilities. The overruling factor in an agricultural island is not slavery or freedom, but direct subsistence-farming and craftsmanship for the peasants, their families and their kinsfolk.

And it is because of this that there are only two human relations of agricultural workers to the soil. The first is that of slaves, when they are assured of their subsistence from the soil and are valued by their owners and kept in health and happiness, because the estates are then well-worked and conserved and the human feelings of the family-owners give to the estates the quality of a home. A certain easy and ready acceptance of life, with the rich flavour of a landed aristocracy, comes into being, and places the whole art of life on a plane which stands above that of land as a mere agency for the market and for profit. The buccaneer becomes a gentleman and the slave a devotee.

Nevertheless, the money-purpose will become paramount, when the freedom and wealth of the landed gentry becomes shackled by the middlemen of the town. Money takes command. Moreover, the highly skilled, soil-conserving agriculture is not acquired by slaves, because they have not the sense of property. The meticulous care of the soil, which is required for it, seems to be the possession only of the second form of a human relationship of agriculture, that of the peasant-family ownership. The self-dependence of free peasants produces qualities of a grade necessarily superior to those of slaves.

The emancipation of slaves converts them into supposedly and so-called free, individual labourers. This change presented itself upon the West Indian arena in 1838. It has existed now a hundred years and recently celebrated its centenary. This it did, logically enough as we shall see, by riots and revolts.

Mr. Harold Stannard, in *The Times* in 1938, described the dwellings of the humble agrarians in Jamaica: 'The first time I saw one of these hovels, I could hardly believe that

it was intended for human habitation. Strands of dried bamboo are woven round a framework of stakes and the "room" thus formed is covered with palm thatch. There is no furniture except sacking on the earth and some sort of table for the oil-stove ... Urban conditions are, if anything, worse.' Royal Commissioners declared the slums of Port of Spain, Trinidad, to be 'indescribable in their lack of elementary needs of decency'. Conditions of labour sometimes find the Commissioners equally wordless: 'It would be hardly possible to find terms strong enough' to express their disapproval. The expression is but a part of the general chorus, which accompanies the imperial achievements of the time and which finds its full harmony in Royal Commission reports on labour in India, Basutoland and elsewhere.

Here is Mr. Stannard's statement with regard to nutrition and subsistence, the primary test of a right of property in the soil: 'Under the stimulus of a circular dispatch from the Colonial Office, inquiries have been conducted in the islands and have yielded disquieting results. Even to a non-medical eye the frequency of bad teeth among a population whose diet could and should contain a large proportion of fresh fruit and vegetables, gives cause for misgiving. Indeed, it is not necessary to look into the islanders' mouths. It is enough to glance inside the shops where they buy their food. Every Chinese-kept store exhibits, from floor to ceiling, shelf after shelf of tinned goods. These superbly productive islands, living mostly by the export of food, cannot feed themselves. It is estimated that Trinidad imports four-fifths of what it eats.'

This, then, is the condition of the islands, which Britain cherishes as the oldest of her colonies. Throughout their career of 'freedom', *she has never adopted, as an unalterable principle, the right of the people to support from their soil*. She brought Africans as slaves to the islands. In the ascendancy of the money power, even the subsistence of the slaves from the soil has been taken from them, and under the cover of apparent freedom, she has made their condition more subtly oppressive than it was in the past. The words of that great pope, Leo XIII: 'For every man has by nature the right to possess property as his own. Hence man should possess the fruits of the earth, but also the very soil', do not apply. They apply neither as to the soil nor as to the fruits of this very fertile island earth. The money power once again emerges as the enemy of the people's source of life.

We will continue with Mr. Stannard's words: 'Only by a reversal of the policy which prefers money crops to food crops can the native labourer be assured of the conditions which make a civilized life possible. Apparently the evil has increased in recent years. The Barbadian report is definite on this point. "In the old days plantation-proprietors planted a fairly large acreage in food crops, some of which were sold to labourers at preferential rates. But in recent years the cultivation of food crops has been so curtailed that the price of locally grown vegetables is so high as to be beyond the modest means of the labourer ... The absence of fresh vegetables and proteins in the diet of the labourer is, we gather, having a deleterious effect on his health and physique. In short, the modern methods, which have tended to divorce the field from the sugar factory and make of them distinct and separate entities of plantation economy, have worked to the detriment of the

field labourer".' The quoted Barbadian report, it will be noted, uses emollient phraseology, such as 'we gather', 'in short', 'have tended', 'the detriment', to blur the stark reality. Mr. Stannard, however, is in no doubt about the reversal of the policy, *re* money and food crops. 'In the Dutch East Indies', he writes, 'land sufficient to meet the needs of the whole population is earmarked for food crops before any money crops are allowed to be grown.' Therein is the difference between the British West Indies and the Dutch East Indies.

Our fertile islands now exhibit the stigmata, which, under urban conditions in Britain, have come to be known under the slogan of Scarcity amidst Plenty. Here are plentiful soils in a plenteous climate, and the stigmata which the British have incurred by their values are those of extreme poverty in the homes and malnutrition of the mass of the people. From cold, of course, the people cannot suffer and so their hovels have not to take upon themselves the protective character of northern homes. But, with this sole advantage over the northern island to which they belong, the people seem to be as far from plenty and as near destitution as a people can be. Mr. Macmillan, from his personal investigations, states that the spending power of the average citizen is so low that it is scarcely above that of the people of one of our more recent colonies, Nyasaland. But in many ways the islanders are what is considered advanced. The Barbadians, so many of whom cannot afford fresh vegetables, apparently take pride in calling their island 'Little England', since, though it is smaller than the Isle of Man, it supports, if not available vegetables, an Established Church, two Chambers, a Court of Grand Sessions, eleven Parish Vestries for local government, and probably the best educational system in the West Indies.

Agriculturally, the Barbadians are careful and skilled cultivators of cane. Their fields are clean and well tilled, and 'a respectable tradition demands a serious effort to find and make work for as many hands as possible ... for an abnormally dense population of more than 1,000 to the square mile by intensive island-wide cultivation of the sugar-cane'. Out of 176,000 inhabitants, some 18,000 are said to be small holders of a total of 14,000 acres, so 77 per cent of the small holders have less than an acre. Moreover, the land which the peasants do get for themselves is 'only the poorest soil. Quite often it is the land of some estate ruined by its European owner's bad and indifferent cultivation; but European critics are quick to point a finger and judge peasant possibilities by failure in such conditions ... Barbados, however, in face of a most serious population problem is in fact dead set against the peasant solution. Peasants, it is held, have failed to maintain the output, which has so far kept the island going, and so long as cane is the only industry nothing but the highest possible output will suffice. The peasants, however, have had their chance only on poorer soil, without organization or even sympathetic direction. The Barbadians, moreover, have no experience as peasants, little tradition but of supervised plantation labour. Though intelligent workers under direction they would not be at their best as individual cultivators. In the long run the only alternatives for Barbados would seem to be great industries absorbing much labour and making the island more like one town -- or a steady flow of emigration' (Macmillan).

Barbados and Antigua lack the range of mountains of most other islands in the West Indies. They have, therefore, been given over to mono-culture, that of sugar and, as Macmillan states, have no experience as peasants and little tradition but of supervised plantation work. They are, therefore, the most widely separated of all agricultural labourers from the families of the East Indian island of Lombock.

The other islands, in this, have great advantages over them. Let us take Jamaica, the largest island of the British West Indies with its 4,550 square miles and nearly a million inhabitants, as the chief example of an island with a central range of mountains.

Mr. Macmillan writes: 'The Jamaica peasant tradition is due not to any special aptitude of the slaves imported, but rather to the fortunate juxtaposition of ample valleys and less accessible but still fertile and attractively habitable hill country; this accident gradually led the estate owners, as seldom elsewhere, to leave some of the slaves to grow their own food supplies. Thus a strong agricultural tradition was established and has persisted. After Emancipation many freedmen became independent cultivators and the Jamaicans, though they may be less disciplined, to some extent escaped the routine work characteristic of the sugar islands.'

It has been said that there are no less than 150,000 smallholders. Mr. Macmillan, however, doubts this and declares that 'peasant lots are now obviously too few and too small to provide an adequate living for any sufficient number of Jamaica's million inhabitants'.

Some few are successful and have saved money from their farming. But they do not use their money to improve their land, but to buy up more land. They buy up the land of their weaker brethren, who then become their tenants. They are no careful partners of the soil. The values under which they live are those of private property and individuals, the survival of the fittest, and not of the controlled, recurrent creation of the well-farmed soil. So the successful peasants imitate the white landowners. Frequently they overreach themselves by taking too much land, while the white landowners, on their part, continue to hold only partially used estates in the hope that fortune will change and bring a better market. The final human stigma of an ill-founded agriculture then appears: 'Control if not ownership passing into the hands of banks or business firms ... the almost unseen change of control from private landlords to outside mortgagors.'

So peasant ownership as a policy languishes in the mountainous islands of the West Indies, as it does in England. 'In enlightened circles of widely different views', writes Mr. Macmillan, 'the approved policy, so far as there is a policy, is to offer opportunities of rising to peasant-status to as many as possible of this heterogeneous mass of small tenants -- a few of whom originally set the fashion without help. Official encouragement has been strongly pressed by individuals -- especially by Sir Henry Norman, ex-Governor, head of the West Indian Commission of 1897, and following him, by Sir Sydney (Lord) Olivier in his Governorship of Jamaica; but it is still only an aim, not an achievement. Even the aim

has usually been hesitant. It is not quite clear whether peasants are to be relied on for the main agricultural production of the country, or whether peasant-ownership is only a means of relieving unemployment.'

The final terminus of ill-founded agriculture also now shows itself in these naturally luxuriant islands. Erosion of the soil is at work ... 'Different factors are concerned with the erosion which is occurring in many of the islands of the West Indies,' writes Mr. R. 0. Whyte. 'In Jamaica, small tenant farmers have practised shifting cultivation, paying rent for, say, one acre but burning and destroying forest over a very much larger area. In addition, accessible areas of forest have been heavily over-exploited, and there are insufficient Forest Reserves. In the plantation districts all land fit for this type of cropping has been cleared, but in addition, excessively steep slopes have been disposed of to petty settlers, for the production of foodstuffs ... Deforestation has also been excessive on some of the Windward and Leeward Islands. For example, a critical stage has been reached on the island of St. Vincent ... In Trinidad, felling of protection forests and shifting cultivation have caused serious denudation, erosion and severe flooding in the Maracas Valley and the Caroni plain.' Particularly valuable is the result of a reconnaissance survey of the United States island of Puerto Rico. It was found that 'there is slight erosion on 19 per cent of the island, mostly on cultivated parts of the coastal plains and alluvial valleys or on gently rolling pasture lands; moderate erosion was found on 29 per cent and severe erosion of about 39 per cent on the area. Most of the severe erosion occurs in the rough mountainous interior. Sheet erosion is the most common type, with gullies occurring on a little less than 22 per cent of the area.'

The same author elsewhere in his book writes of two British islands, scarcely less fertile than Puerto Rico and Jamaica, where a similar wanton disregard of the soil 'threatens to leave the country like an emaciated skeleton'. It seems that this haunting vision of the South Pacific now reaches the lovely-bodied islands of the Caribbean Sea.

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Chapter 18

German Colonies: The Mandates

The Germans were the last Europeans to colonize. They were also the people most imbued with the faith of modern science, and this taught them, with a clear conscience, to pursue the rights of the fittest to its extreme, logical conclusion. Armed with this faith, they conquered three areas in Africa: South-west Africa, the Cameroons, Tanganyika.

The Germans date their colonial empire from 1884, when Lüderitz hoisted the German flag at Angra Pequena, a port of South-west Africa, Nachtigal did the same at Duala, a port of the Cameroons, and Karl Peters and his companions landed at Zanzibar. So began their part in the exploitation of the Dark Continent.

Many countries had preceded them, Portugal, Britain, France and Belgium and, in their exploitation of their new territories, had not always refrained from cruelty. One of them, Belgium, under the influence of its king, was in the nineties to give an example of cruelty on such a large scale and so pitiless that, when knowledge of it became public, it projected a widening wave of horror through the United States, Britain, France, and Belgium itself. The period of harsh treatment of natives had come to an end as far as the great publics of Western Europe and America were concerned.

With this equal start in the three colonies in the year 1884, the German version of the policy of exploitation began.

As regards South-west Africa, a dry land and chiefly of agricultural value because of its pasture land, Paul von Rohrbach defined the policy in the *Deutsche Kolonialwirtschaft*, in these words, as quoted by Mr. G. L. Steer in his book of convincing thoroughness, *Judgment on German Africa*, 1939: 'The decision to colonize South-west Africa could after all mean nothing less than this: that the native tribes would have to give up their

lands on which they had previously grazed their stock in order that the white men should have the land for foraging their own.'

The Hereros and Hottentots were the chief peoples concerned in this appropriation. It was begun with a harsh oppression of both peoples, particularly of the prouder and more warlike of the two, the Hereros.

One of their chieftains described the German methods in words, again quoted from Mr. Steer's book, which is my guide in this chapter: 'Our people were being robbed and deceived right and left by German traders. Their cattle were taken by force. They were flogged and ill-treated and got no redress. In fact, the German police assisted the traders instead of protecting us. Very often one man's cattle were taken to pay other people's debts. If we objected and tried to resist, the police would be sent for and, what with floggings and threats of shooting, it was useless for our poor people to resist. If the traders had been fair and reasonable, like the old English traders, we would never have complained. But this was not trading at all. It was only theft and robbery.'

The Hereros rebelled in 1904, and fought according to their savage code, calculated to call for reprisals. They were defeated and, to finish the work, General von Trotha issued an order of total extermination, the Vernichtungs-Befehl. This is how it ran:

'I, the great general of the German soldiers, send this letter to the Herero nation. The Hereros are no longer German subjects. They have murdered and robbed, they have cut off the ears and noses and privy parts of wounded soldiers, and they are now too cowardly to fight ... The Herero nation must now leave the country. If they do it not I will compel them with the big tube. Within the German frontier every Herero, with or without a rifle, with or without cattle, will be shot. I will not take over any more women and children, but I will either drive them back to your people or have them fired on. These are my words to the nation of the Hereros. The great General of the Mighty Emperor, von Trotha.' By the end of 1905 official extermination had reduced the Herero people from 90,000 to 15,000.

In October 1904 the Hottentots also rebelled and were partly exterminated. As to the *human* result upon the Protectorate of the policy, Leutwein, the German historian of the south-west, declared: 'At the cost of several hundreds of millions of marks and several thousand German soldiers we have, of the three business assets of the Protectorate, mining, farming and native labour, destroyed the second entirely, and the last as to two-thirds.'

Before the Germans were themselves conquered in the Great War, the condition of the natives is thus summed up by Mr. Steer: 'Officially still, the native was a State serf, guilty of serf-like offences. Out of 4,356 convictions against natives, in the Protectorate between 1 January 1913 and 31 March 1914, 3,167 were for desertion, negligence, vagrancy, disobedience, insolence, laziness and contravention of the Pass laws; crimes not of man against man, but of the slave against his boss.' This did not include the punishments of

'Väterliche Züchtigung', or paternal punishment, allowed to the German master over their serfs, which led Governor Seitz, in order to avoid a further native revolt, to threaten in 1912 'to withdraw labour supplies from those "who rage in mad brutality against the native, and consider their white skin a charter of indemnity from punishment for the most brutal crimes".'

After the Great War, South-west Africa was allotted as a Mandated Territory to the Union Government of South Africa.

In the Cameroons the Germans adopted the same policy, but it did not lead to any rebellion and annihilation such as that of the Hereros. The policy was to hand over the land and the natives, as and when required, to great German commercial companies. Governor Jasko von Puttkamer was the chief support of these companies and he carried out the government with German efficiency in their interests. 'Administrative recruitment' was the name under which the natives were used precisely and only as the planters and traders needed them. At first rubber was the chief source of wealth, but when the energetic Puttkamer in 1895 saw the coffee, cocoa and banana plantations on the neighbouring Spanish island of Fernando Po, he initiated estates for these products upon the lower lands of the lofty peak of Kamerun. Concessions were given by Puttkamer to German companies, and plantations were opened out on land taken from the Africans in possession, who were induced to work for the planters by being left sufficient plots on which to grow their own food.

The demand for porterage now increased to carry the products of the new plantations, as well as the rubber, to the coastal ports. Men were taken from their farms and families by 'administrative recruitment', to carry loads on ceaseless journeys, the police acting, as in South-west Africa, on behalf of the planters and in no way protecting the natives. For the sake of the planters, 10 per cent of the population were forced to be their serfs.

Puttkamer's exactions, financial machinations and private life were rooted out by the Social Democrats in Germany. He was disgraced and dismissed in 1907, but so wealthy and influential had the planters become that his policy continued to dominate in order to keep the labour market full, which the disease and hardship due to porterage in particular depleted. A better spirit prevailed or was enforced upon the German Colonial Ministry. A German medical service was organized to check the loss of labour due to diseases, the most feared of which was sleeping sickness. Some little official attention was also paid to education. One thousand children were to be found in government schools in 1914 and there were 40,000 in German and American missionary schools. There were reforms but minor reforms. As far as they went, they were for the good of the natives, but 'administrative recruitment' remained. The natives were still the serfs of their masters and discipline was enforced by severe paternal punishments. Planters were accused of the 'physical and moral annihilation' of the native, and it was not until the fatal year of 1914 that the Colonial Minister, Dr. Solf, was able to announce a doctrine new to the Germans: 'The colonies will prosper with the natives and for the natives, not in spite of them and

against them.'

After the Great War the Mandate for the government of the German Cameroons was divided into two. The greater share was given to the French, the lesser to the British. The French now ruled a population of 2,400,000; the British one of 800,000.

The conquest of the third colony, Tanganyika, was due to Dr. Karl Peters. Of Dr. Peters, Mr. Steer writes: 'Of all the German pioneers Hangman Peters was the most unprincipled and bloody. I have not written of his cruelties, because I do not regard him as typical of the old German colonists; none but Trotha was as foul as the merciless doctor. But evidently the Nazis of 1934 held him to be typical; nay more, a prototype. Their propaganda has pursued him with praise in the five years since they gummed a memorial to him on their envelopes,' for his portrait figures on a stamp, which celebrated Germany's Colonial jubilee in 1934, and is placed as the frontispiece of Mr. Steer's book.

In 1888 Dr. Peters acquired Tanganyika by what Mr. Steer calls 'a novel piece of international theft, to which all civilized powers were parties'.

For ten years Peters conquered and enjoyed his power sadistically. Then his hangings and shootings of natives and the flogging of his concubines became known to the Social Democrats of the Reichstag. In 1897 he was brought to trial before the German Colonial Disciplinary Court. He was dismissed from the governorship and took refuge in England. Nevertheless, the hatred which he had aroused amongst the natives did not subside. Too many German bullies remained behind; too many native chiefs had been robbed. One called Mkwawa rebelled; and was defeated. His German conquerors cut off his head and actually sent it as a trophy to Berlin. A special clause was inserted in the Treaty of Versailles which ordered its return to his tribe.

A more serious rebellion, that of the Maji-Maji, of the combined tribes of the south, raged for two years. The Germans, failing to overcome the Africans in the field, destroyed their villages and crops by fire. Thousands of Africans died of starvation and the entire south of Tanganyika was devastated. Money became frightened and so, in 1907, Dr. Dernburg, an able business man and banker, who had been given the new appointment of first Secretary of the Colonies, left for East Africa to institute reforms and to endeavour to turn the hatred of the Africans into their natural tolerance, if not affection. Very shortly after his arrival, he announced publicly: 'I saw too many whips in the hands and on the tables of the planters and colonizers.' He attempted to permit the natives to be free producers, as well as to free those who were in German employment, limiting forced labour to public works and paying it for its work. The planters were rendered bitterly hostile by these humanities, and succeeded in enforcing Dernburg's resignation. In practice, therefore, the seizure of land, forced labour, floggings and imprisonment continued until the Great War.

After the Great War, the Mandate for Tanganyika was allotted to Britain.

The Permanent Mandates Commission of the League of Nations brought a redemptive spirit into governance. Under the first clause of their charter, they were to be *the trustees of the material and moral well-being of the natives*. Each Mandatory Power had to present an annual report for acceptance and suggestions by the Commission. Reports and comments were made public. The old-time secrecy which was able to screen offences was made impossible. Mr. Steer, in his chapter on 'Mandates' Work', gives a most moving account of the improvement of the lot of the sons of the soil, which had once formed the territories of the German northerners.

Of South-west Africa, he states: 'It has multiplied by ten, the amount of land in the hands of the native in German days, and it has enabled him to keep herds of cattle and sheep again, a tribal necessity of which Germany cruelly deprived him.' The mandated natives are even better off in the south-west than are the natives in the Union; the former, for example, have to pay no poll-tax which often forces the Africans into industry where their wages never rise; their tribal institutions have been restored and the chiefs in the far north actually share in the responsibility of government. The white men, who now direct the country, are men of the Union and, therefore, versed by experience in the type of land of the south-west as also in the native character. No gross cruelties now occur, and, did they do so, they would be reported in the annual reports to the Permanent Mandates Commission. The general result has been a notable increase in prosperity.

In the Cameroons under the French Mandate there has been a similar new spirit of humanity, carried out in the way that is especial to the French. Everything local, social services, State services, the construction of the wonderful French roads, education, public health, co-operative agriculture, emanate from the top. The French have no faith in ancient systems and traditions; that they have destroyed in their great French Revolution of 1789. They have not therefore set about strengthening the tribal chiefs and restoring tribal institutions. 'Governors sack chiefs on any pretext,' says Mr. Steer. 'Tradition to them is a thing that clogs.' With the network of roads which the French build, they introduce speed of communication, enabling them to establish centralization in place of the old local administration. Within these limits, they give the Africans freedom, public service, instruction and medical aid.

Under the Mandate, French authorities have to publish, for all who wish to read, their annual report to the Mandate Commission, and it is due to this, says Mr. Steer, that the French Cameroons have the advantage of their neighbour, the non-Mandated French Equatorial Africa, whose reports are seldom read outside the Colonial Ministry. The officials of the former are spurred by the knowledge of the coming publicity. The consequence is that, whereas the Cameroons grow in strength and population, Equatorial Africa wanes in both. Under eager but careful officials, the freed natives are themselves infused with energy and zeal, and take a growing part in production. 'Production', writes Mr. Steer, 'is balanced nicely between white and black ... Some crops, such as cocoa, which were exclusively European, are now exclusively African ... Production has become so popular a pastime that the sources of white labour have dried up.' This energetic spirit

has advanced hand in hand with prosperity, with the result that 'the French Cameroons balance their own budget; they have only in the 'thirties borrowed money from France, and their total debt is infinitesimal. Neighbour Equatorial is one of the territories which promotes most gloom in the French Colonial Ministry. There is always a colossal deficit. Sometimes it amounts to 30 per cent of the total receipts. There is always a crushing debt.'

The British in Tanganyika have worked in the opposite way to the French. Sir Donald Cameron, who knew, as no one else, where, how and to what degree self-government could be developed, gave this succinct account of his British methods: 'We built from the bottom, from the common people upwards on a purely democratic basis, in distinction from other countries, where the tendency has been to invert the pyramid and build from the top.' The spirit of the Mandates was most acceptable to his humane and understanding heart. Mr. Steer's words on this are so nobly eloquent that they will be quoted in full: 'The Mandate for Tanganyika, as for the Cameroons, destroyed the system of forced labour set up by Germany; it has assured the native primary rights in the land of his fathers, and a paramountcy of his interests where they conflict with those of European settlers -- where the German policy was diametrically opposite; it has constructed a peaceful native peasantry where none existed before; it has given peace for armed repression; impartial for rough justice.

'Above all it has established the natural foundations of native society where these had been hammered out of sight by the German machine. It found an oppressive and foreign rule in Tanganyika twenty years ago; in that brief time-period it has not only restored the native system, but given it responsibilities of which it never dreamed before. The native authorities, suitably democratized, spend their own money, hold their own courts, carry out their own measures of education, hygiene, and all other forms of local government.

'There is no need to compare Tanganyika with Kenya or Nyasaland on her northern and south-western frontiers. Through the breadth of Africa south of the Sahara you will not find a territory where the native African has such freedom of self-expression as in Tanganyika; or such grand responsibility; or responsibility so faithfully borne. When one lifts the veil of wishful thinking and asks, in a clearer atmosphere, what is the purpose of colonial government, clarity demands no stupid answer such as raw materials for the mother country (seeing that all the colonies of the world produce only 3 per cent of the world's raw materials), or pockets for European investment (seeing that the beneficiaries can only be the few), or strategic power (seeing that if war is permanent life is not worth living). No; the light shines too hard to-day to admit evasion. If we are to remain in tropical Africa we are there for the benefit of the people whom we rule; and their benefit is not only to learn and be healthy, have peace and produce; the greatest gift we can offer them is the opportunity to manage their affairs. That is why Cameron justly said, "We have given back their soul to the people".'

The Mandates in the three countries have been carried out in three varying ways by the Union of South Africa, the French and the British, but each method has been inspired by

the new spirit. It is this that has led to their success and prosperity, for Tanganyika too is prosperous, 'the richest of the former German Colonies'. The, Mandates, indeed, have worked like a *miracle of social benefit* and civilization in these three countries, especially in Tanganyika. It is very impressive and will become yet more so to the reader of Chapters 21 and 22 in which similar miracles on a grander scale of civilization will be described.

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by G.T. Wrench

Chapter 19

Russia, South Africa, Australia

Russia

The land of European Russia is not complicated. It is the direct extension of Belt No. 1 of Asia, described in Chapter 6. Its sea-coasts are too limited and removed from the open ocean to alter its essential character, which, with its situation between Asia and Europe, directed the history of the Russians.

Its physical map is, therefore, mostly tinted green, indicating an elevation up to five hundred feet. It has two irregular areas of yellow, of elevation up to two thousand feet running north and south; one to the west, the second to the east. The eastern is intersected by a thin strip of light brown, of elevation up to five thousand feet, the Ural Mountains. These west and east areas are in latitude 60 degrees joined by a transverse yellow band. The three areas form the watersheds of Russia's rivers. Two considerable rivers, the Dwina and the Petchora, open into the Arctic Ocean, but the largest Russian rivers, unlike those of Siberia, run south. The Volga rises from all three watersheds, west, east and transverse, and runs into the Caspian, its last section in the Caspian Tract being actually below sea level. The Don rises from the eastern side of the west yellow area, and the Dnieper from its western side, and also by its big tributary, the Pripet, from the northern Carpathian Mountains outside Russia. Both flow into the Black Sea. The Dniester, also entering the Black Sea, forms the south-western boundary of Russia.

Russia is thus an extension of the Siberian Plain, made European by the Ural Mountains. South-east Russia, with the Caspian Tract, is the European extension of the Asiatic Kirghiz Steppes. Through the Steppe country many Nomads of Asia passed into Europe and, at a later time, Russians passed into Asia.

At the time of the last Glacial Age, nearly all European Russia was covered with ice. As the ice receded, Russia emerged in a sodden condition of boggy lands and lakes, the abundant waters of which were drained away by the great rivers.

In the drying up of the Post-Glacial epoch, Russia slowly attained to the condition of being habitable to men. European Russia is now divided into three belts.

Firstly there is the northern belt, with its Arctic tundra cap, with a long winter, a brief summer and a saturated, boggy soil. It offers only the most limited opportunities for farming.

The central belt has a more equable climate than the other two. Its soil is capable of receiving and storing water to a considerable depth, and it gets an abundance of water in the spring from the melting of the snows. Its surface then becomes a sea of mud, but five or six months of open season follows; the surface dries, and so becomes cultivable by men. This central belt, which contains the capital and other manufacturing towns, constitutes the farmed, but food-deficient area of Russia.

For these two deficient belts, Russia is compensated by the third or southern belt, the food-surplus area. Here the season of freedom from snow lasts up to nine months. Here also the extremes of heat and cold are greater than are those of the central belt. So dry is it at times, from the heat and the hot winds which sweep into it from Central Asia, that it is subject to drought. But its soil is rich, and that of the Black Earth Zone, immediately south of the middle belt, is the granary of Russia.

Russian agriculture began in the middle belt, the belt of forests. It was not until the reign of Ivan IV (A.D. 1533-84) that the grain land was reached. Sir Bernard Pares in his most instructive *A History of Russia*, 1944, states that the Russian peasants were peaceful men, seeking to cultivate land without interference. They would clean a piece of land along the bank of a river, burning down the trees and digging out the stumps. They would erect a colony of a few houses, keeping close to the river for fishing and transport. In the north they met the Finns, then entirely unorganized, and they established friendly relations, with them. 'The Russian peasant', says Pares, 'was a man of peace and he did not come to start new conflicts, but to avoid them.'

But they were not left at peace by their rulers at Kiev and Moscow for the reason that they were the source of the greater part of the wealth of a poor country and, secondly, because the army was recruited from them.

The chief enemies of the Russian people from about A.D. 1130 to the reign of Ivan IV were the Nomadic Mongols from Asia, who passed into Russia through the Caspian Tract. To preserve themselves and their peoples from the Mongols, the Russian rulers relied on the strength of the land and its peasants. When Kiev was the capital, the near land was in

the hands of a landed aristocracy, the far in the hands of pioneer peasants themselves. When Moscow became the centre of the eventual Emperor, land was given to a second class of superior landowners, who were allotted it for their lifetime on condition of rendering military and other service to the State. 'The conditions of tenure', writes Pares, 'stated precisely the number of recruits who had to be placed in line. The allotment of land corresponded to this number and was graded carefully according to class, which was practically synonymous with military rank'; and he adds that military service was also demanded from the hereditary landowners: 'the patrimonies themselves were put under the same obligation of military service, and, in fact, all land in Russia came to be held only by the title of service to the Tsar'.

'As a system of agriculture', continues Pares, 'nothing could be more unsound. The squire was firstly a fighter, only secondly a squire. His absences were frequent. His efficiency was rated only by his military service;' and, as regards the landowners of the second class, they could be moved at will, which prevented them from acquiring any permanent interest in their peasants.

The peasants were bound to the soil, for the aggression of the Mongols was 'such as to convince the dullest of peasants of the necessity of national defence and of national sacrifices'. Nevertheless, some peasants were bold enough to seek freedom from the oppression of their rulers and moved eastwards and to the south and south-east. 'Flitters', Sir John Maynard calls them in his fascinating *The Russian Peasant*, 1943, and it was the flitters who came to constitute the Cossacks, or border peasantry, who were so powerful a factor in the eventual repulsion and conquest of the Mongols. The Cossacks came to possess, writes Pares, 'wonderful military resource and were masters at taking cover. They practically never parted with their horses and were trained riders from childhood. Their scouting tactics were those of the Russian army of to-day. Tall lonely trees were used as observation posts; different points at some distance from each other were garrisoned, and between them relays of individual Cossacks patrolled, never dismounting'. Such men, therefore, enjoyed a freedom not given to the more central peasants.

Even when the Mongols were subdued by Ivan IV, the heavy burdens of the Russian peasants were not lifted. The danger to the Russian kingdom then shifted from the south and east to the west, as Europe advanced in civilization and military strength. The virtual serfdom of the peasants, severe according to their relative proximity to Moscow, was continued, and, in 1649, a code of laws was issued which 'finally confirms the establishment of serfdom, which henceforth becomes a state institution'.

Not even Peter the Great (A.D. 1682-1721), who in physical strength, will, genius and energy was perhaps the greatest of all European rulers, could relax the oppression of the peasants. It was he, above all, who realized that Russia was lost in the struggle against European aggression, unless her backward people were Europeanized. So, though 'Peter was far closer to the Russian peasant than any Tsar before him or since', his vast expenses forced him to increase the weight of the peasants' chains. Flitters to the freer south and

south-east increased greatly in numbers, and some passed over the Urals into the land, familiar in character, of the Siberian Plain. As time passed, the freeing of the peasants from serfdom in order to promote the advancement of by far the largest number of the Russians became more and more urgent, and eventually an Act of Emancipation was passed in 1861. It was in many ways ineffective, and the final stage of release came with the Soviet Revolution and the Collective Farms of Lenin and Stalin. Under the Collective Farms the medieval tempo of farming was transformed into modern farming of an advanced kind. Sir John Maynard, in his sixteenth chapter, gives a full account of these collective farms, with their advantages and difficulties, their tractor machines, their economics, their lack of sufficient manure, their associated work on the large farms, their personal work on their private farms.

From this account of the soils and their ownership it will be seen that two forms of erosion could have been witnessed in European Russia. The first would occur from the destruction, without afforestation, of the forests upon the slopes and watersheds of the higher land, if the land itself was owned by men who were anxious to get the most wealth from the soil without adequate return. When the forest had been destroyed on the slopes and watersheds, sheet and gully erosion would occur owing to heavy rain or melting snow. The rivers would, in the wet periods, then be in flood and bear top-soil to the sea; later on, in the summer season, their profitable streams would dwindle.

Such a dominance of money did, indeed, occur in historical Russia, particularly in the seventeenth, eighteenth and nineteenth centuries. Mr. Jacks' pronouncement, in *The Rape of the Earth*, on this cause of erosion is one with which we are already familiar. The peasants of Russia were serfs; all the profits of farming went to enrich a landed aristocracy. We are told: 'The landowners' aim was to get the maximum out of the soil in the shortest time with the least expenditure of labour and improvements. Sheet erosion was extreme, though generally unnoticed and not associated with the new gullies that continued to break up the land.'

Fortunately for Russia, the primitive farming of the serfs was very slow in extension. Though marshes and lakes dried up and the streams of great rivers flooded and dwindled, there was a tempo very much less than that of the United States under the era of the machine. Consequently, loss of the Russian soil was far from reaching the disastrous magnitude of that of the American soil.

When the serfs of Russia were emancipated in 1861 and became possessors of much of its soil, there was no halt in this form of erosion. The peasants were given the poorest eroded land and they, therefore, set to work to extend the cultivation of the slopes. Their method of ploughing was in long strips up and down the slopes to the tops of the watersheds; the hollows between the ridges became first water courses and then gullies and so erosion was increased. Even under the Soviets, no halt was called to the destruction of forests owing to the need of timber in exchange for the machines from foreign countries which the new manufacturing towns of the U.S.S.R. required.

So much for the first form of erosion, namely, sheet and gully erosion. The second form of erosion is wind erosion. This would affect the third or southern belt of Russia, both the rich Black Soil Zone and the land of the Steppes. Here is what Major Law, Commercial Attache in St. Petersburg in 1892, reported upon this belt, once protected by belts of forests: 'It is certain that those forests do not now exist , and that the black soil country is often scourged by devastating blasts from the Steppes, and not infrequently baked by prolonged droughts.' Wind erosion and floods work their havoc and 'smite the soil with perpetual barrenness'.

This erosion at length aroused alarm in the Russian aristocracy and, in the eighteen-nineties, many shelter belts of trees were planted to break the force of the hot winds upon the top-soil 'on such a spectacular scale and with such excellent results that a special government commission was appointed to study afforestation' (Whyte, in *The Rape of the Earth*).

The sudden stride of the U.S.S.R. into the modern era, with its reliance upon machines, made the tractor-plough in particular a symbol of modernization. It became the visible image of the inner belief in the machine as a saviour, and wherever the tractor went it was heralded as a propagandist. Nevertheless, it had its intrinsic dangers. Messrs Jacks and Whyte, in the *Technical Communication No. 36 of the Imperial Bureau of Soil Science*, 1938, discussed this danger and quoted the Russian Professor Kornev as saying, with regard to both forms of erosion: 'At the present day there are huge areas in the U.S.S.R. where, owing to the excessive breaking up of the topography, whole territories, formerly under profitable agriculture, are now occupied by immense ravines and infertile wastes.' To this the two authors added: 'The tractor-plough is the enemy of the grass land in dry areas, but is indispensable to the propagandist of Russian agriculture. Though forewarned by the experience of other countries, it is difficult to ascertain if the authorities are aware of the danger of mechanization.'

Certainly, by the year 1938, the Soviet authorities had put tractors upon the land on a very vast scale. Whereas, according to Appendix III of the Trade Unions of the U.S.S.R. (quoted in the Fabian Essay on *Our Soviet Ally*, 1943), in 1913 no tractors were in use in the Russias; in 1938 there were used, upon the scientific, mechanized, collective farms, no less than four hundred and eighty-three thousand tractors. The potential threat of erosion in such numbers is enormous, as the consideration of the other three of the four great examples of modern erosion, South Africa, Australia and the United States, will show. The war and its demands have concealed the threat and even made it one that had to be concealed. No account of the degree of new erosion can, therefore, be given.

South Africa

South Africa is described by Mr. Whyte, in *The Rape of the Earth*, under the italicized sub-

heading of *The Transformation of South Africa into Semi-desert in the Twentieth Century*. The agricultural wealth of South Africa is chiefly pastoral. The natural veld and the Karroo provide animal fodder, though in favoured localities special grasses and foreign crops are grown. But this natural vegetative cover has deteriorated and 'erosion has already transformed parts of the richest pastoral areas in the country into semi-desert. Considering that the luxuriance and excessive wetness of the veld in the Orange Free State were previously an obstacle to pastoral farming, the rapid appearance of the disastrous consequences of erosion is very remarkable. It occurs in all parts of the Union, either as an actual or probable menace, and is predominantly a pastoral problem.'

He then continued with this important paragraph: 'The great uncertainties of the South African climate, and the suddenness with which the country was opened up after the discovery of gold, have contributed largely to the rapid acceleration of erosion. Towards the end of the nineteenth century it was realized that serious overstocking was taking place, but public attention was not focused on the danger until the Drought Investigation Committee issued its final report in 1923. Until then the opinion had been gaining ground that the climate was becoming drier and the rains more torrential. The report pointed out that there was no proof of a definite and recent climatic change, but that erosion would account for the drying up of rivers and waterholes, the falling watertable and the increasingly disastrous effects of droughts and heavy rains. The Commission concluded that the erosion was caused chiefly by deterioration of the vegetative cover brought about by incorrect veld management, and that all efforts to improve the latter would have a beneficial effect on the former.'

South Africa was taken from the Dutch by the British in 1812.

Australia

In the speed with which fertility of the soil is being lost, Australia is believed to surpass even the United States. This is the opinion of Mr. E. S. Clayton of the Department of Agriculture, New South Wales, who was sent to study erosion and anti-erosion measures in the United States for the better defence of his own country. In *Investigations Overseas*, 1937, he writes: 'There is no doubt that we Australians are in a process of transforming the semi-arid areas into desert at a more rapid rate than in the U.S.A.'

Australia is, in short, being threatened with becoming to the British Empire what Libya became to the Romans. The loss of soil from rapid deforestation and burning of vegetative cover and from overgrazing is severe. 'Approximately two-thirds of the area covered by the Alpine woody shrub type has been completely cleared by the action of fire,' writes Mr. R. V. Byles of the catchment area of Australia's greatest river, the Murray, in *Bulletin 13 of the Commonwealth Bureau of Forestry*. He continues: 'The organic layer, with no cover to protect it and no live roots to hold it, dries up and is blown away; the loose sandy soil is in its turn blown away, leaving the final product, bare granite rocks and stones with no

vegetative cover.' The once constant river has become inconstant and its water is intermittently turbid in place of the original constant clarity. 'In thirty years the land about it has become desert, according to the testimony of men who have nurtured cattle there all their lives.'

The eagerness for wealth in a country that does not nestle to the heart as does the homeland destroys the permanence of its gifts to men. There is no real ecological link between the white man and its nature, nor habit and tradition which expresses it. They do not feel that when they burn or tear its verdure they are tearing at their own home fields, at something which is an eternal associate of their own, and their ancestors' and their descendants' lives. It is land and land can give wealth, but it is not *motherland*, and, until that human term and what it implies in the fullest sense becomes bred in the bone, it will not be real, and *the land will not be properly treated*. It is the heart, faith, sentiment that ultimately prompt action.

So in the drier parts of Australia there are thousands of acres of lightly stocked pastoral country, which are suffering from erosion and where men, like fifth columnists, have helped the central desert to advance. Not only is the fertility of these undulating lands being depleted at an alarming rate, but the wetter, riverine districts near the sea are also in many parts gravely affected by erosion, due to the same eager speed to clear the land, as has already done so much harm to the riverine area of the great Murray River.

Finally, there are the rabbits, introduced from Britain to this, to the white man and rabbits, new world. In *Pamphlet No. 64 of the Commonwealth of Australia* there is an incomparably vivid picture of these pests given by Mr. F. N. Ratcliffe. In a way, the four-legged immigrants from Britain behave like the two-legged from the same country. When the going is good and there is abundant pasture, the rabbits do not act as if they were part of a country in balanced equilibrium, but as pitiless ravagers of its soil fertility. They revel in the rich harvest and they multiply out of all counting, as if the future must be a repetition of the past. In numbers they eat up the pasture and drive the hungry sheep to devour saltbush. They overreach their good fortune. Then come the hard times of a drier season. They are hungry, so hungry that they eventually eat all and any food within reach and even beyond the ordinary reach of their kind. They eat the surface plants. They climb. They burrow into the earth and get at the roots of the hardy acacia scrub. They take all that is above and below the soil and give it no chance of regeneration. Then comes a drought, and the rabbits die in heaps under the very eaves of the settlers' houses or wherever man-made shade can shelter them from the pitiless sun. So the rabbits, too, fail to fit into the balanced life which nature had long established in Australia, before they were brought out with the intention of providing food, not destroying it, for the white settlers.

The British first settled in Australia a century and a half ago.

The British annexed New Zealand, the islands of the 'emaciated skeleton' threat mentioned at the end of Chapter 17, in 1840, just over a century ago.

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Chapter 20

The United States of America

0f all countries in the world, that which is most typical of modern progress; that which, at its initiation, announced the gift of liberty to every man to pursue wealth within the limit of the law and has permitted the greatest liberty of thought and action on the part of its inhabitants of all ranks; that which has encouraged genius or avidity to develop themselves most freely in the belief that the accretions of knowledge and wealth, which would accrue, would be of ultimate benefit to the community and to humanity as a whole; that which has produced the greatest business achievements and made itself the nation with the widest scientific equipment and the most skilful practical technique; that which rushed forward into the new with such speed and eagerness that the old has been forgotten; that upon which nature has now written most broadly and definitely her grim judgment in terms of erosion of the soil; that which, with its accustomed, heroic practicality, is now surpassing all nations similarly stricken in the vigour and thoroughness of its measures to oppose this life-destroying menace; is the United States of America.

In April 1928, the Agricultural Department of the U.S.A. published Circular No. 33, by Messrs. H. H. Bennett and W. R. Chapline. The circular bore the title of *Soil Erosion: A National Menace*. It is divided into two parts, a general consideration of the loss of soil due to erosion by the first author, and of the erosion of grazing lands by the second. It consists of thirty-five pages and contains thirty-five photographs, and he who looks and reads, especially if it is his first intimate meeting with the question, finds a graphic revelation of the greatest rebellion of our time, the rebellion of the earth itself. The figures of destruction given are colossal, and when one looks at the photographs and sees these figures embodied in visual reality, the effect is so impressive that one understands how it is that this short pamphlet in particular assembled the voices crying in the wilderness and

made them startle into attention the governments of the world.

Mr. Bennett, after a few preliminary remarks, gives an exposition of the *Figures on Soil Wastage*: 'The amount of plant food in this minimum estimate of soil wastage by erosion (1,500,000,000 tons of solid matter annually) amounts to 126,000,000,000 pounds, on the basis of the average compositions of the soils of the country as computed from chemical analyses of 389 samples of surface soil collected by the Bureau of Soils. This is more than twenty-one times the annual net loss due to crops removed. The amount of phosphoric acid, nitrogen and potash alone in this annually removed soil material equals 54,000,000,000 pounds. Not all of this wasted plant food is immediately available, of course; but it comes principally from the soil layer, the main feeding reservoir of plants, and for this and for other reasons it is justifiable, doubtless, to consider the bulk of it as essentially representing lost plant food, without any quibbling about part of it having potential value only.'

It is impossible to get a succinct method of thinking out the meaning of figures so colossal. One can put them before oneself in some such way as this: There are 120,000,000,000 pounds of plant food lost by 120,000,000 people. The permanent loss of plant food, therefore, is at the rate of 1,000 pounds per person in the U.S.A. As each person eats about 1,000 pounds of food a year as plant substance or as animal substance derived from plant substances, one can get some sort of equivalent conception as to what this means. Nor is this all. The destruction is proceeding at an 'ever-increasing rate' as we shall see in the next quotation from Mr. Bennett. Clearly such a system of treatment of land cannot indefinitely continue. One recalls again here the prophetic words of Professor Shaler of Harvard uttered thirty years before the publication of this pamphlet: 'If mankind cannot design and enforce ways of dealing with the earth which will preserve the sources of life, we must look forward to a time -- remote it may be, but clearly discernible -- when our kind, having wasted its great inheritance, will fade from the earth because of the ruin it has accomplished.'

There is something, too, paradoxical about these millions and thousands of millions of figures, attached to something so general to man as the soil, that allies them to those of the money system of the same period. Farmers create what men eat, but in doing so create life-strangling erosion and deserts. In the money system, financiers create money for men's livelihoods, but in doing so they also create life-strangling debts and financial deserts. The vast accumulation of negative money, as national and municipal debts, runs into figures comparable to those concerned with negative soil. The two seem to have a definite kinship. Yet urban peoples still view both their food methods and their money methods with a scarcely shaken trust. Again the split mind gives evidence of itself.

There are further figures. The loss of phosphorus, potash and nitrogen alone, without reckoning other soil foods, is estimated at 2,000,000,000 dollars a year, which is the better portion of the British national revenue before the war of 1914-18. Mr. Bennett, writing in 1928, which he denotes as a time of meagreness of fundamental data of 'what is going on

at an ever-increasing rate', states: 'That some 15,000,000 acres or more of formerly tilled land has been utterly destroyed by erosion in this country is but an insignificant part of the story, for it is the less violent form of erosional wastage, sheet erosion, that is doing the bulk of the damage to the land. Land depreciation by this slow process of planing off the surface is of almost incalculable extent and seriousness, and since the denudation does not cease when the subsoil is reached, there must be in the near future, unless methods of land usage are very radically changed, an enormous increase in the abandonment of farm lands.' Nine years later Mr. E. S. Clayton of the Agricultural Department of New South Wales, after his study of erosion in the U.S.A., came back with the momentous figures: 50,000,000 acres of cultivated land destroyed, 50,000,000 acres seriously eroded and about to be abandoned, 100,000,000 acres with loss of much of the topsoil, out of 987,000,000 acres, the total of agricultural land in the States. Finally the United States Department of Soil Conservation Service published a map with various shading to show the areas of slight and severe wind erosion, and slight and severe sheet erosion due to widespread movement of thin sheets of water. The unshaded non-eroded areas contrast with a widespread prevalence of shade. The above figures of Mr. Clayton are certainly not belied by the map.

The figures of loss in the U.S.A. are, indeed, incredible, in that the mind cannot grasp that a country of incalculable national wealth and fertility, almost within a century can be thrust into such danger. This is but a paraphrase of Mr. Bennett's own summary: 'To visualize the full enormity of land impairment and devastation brought about by this ruthless agent is beyond the possibility of the mind ... Any American of live imagination knows that the people of the United States would willingly spend 20,000,000,000 dollars to redress the wrong', had it been due to a foreign foe. But because it is an inner fault of American thought, because the sun, the wind and the rain, the natural conditions of earthly life, are concerned, the people scarcely heed it. So Mr. Bennett ends his part of Circular 33 with the words: 'A little is being done here and there to check the loss -- an infinitesimal part of what should be done.'

Then comes the visual evidence, the photographs from many of the States. In the first photograph one sees a sloping cotton field showing shallow channels caused by rain between the rows of plants. When heavy rains came and the extensive field had only a light cover of young plants, then more water ran along these channels between the plants than where the soil was held by the roots of the plants. This is sheet erosion; some water sinks into the soil, but some runs away without sinking in. The runnels collect together and form a gully. The next photograph shows the result of gullies, which have collected together to one channel in the Greenville fine sandy loam. The channel is a chasm 100 feet deep, with precipitous sides, fringed by forest trees. Where it now is, there stood a school-house forty years ago.

There follow further pictures of erosion due to rain and melting snow. There is one of a wide, laterally extending gorge in the Mississippi Valley; one of cornfields covered with a blanket of coarse sand deposited on it by the erosional waters of heavy rain; arable land in

Kansas so cut up by gullies that it could no longer be ploughed and was given over to pasture; bald patches on the rich, black soil of Iowa, washed away by sheet erosion and showing the clay beneath; smooth fields in Texas split by gullies as a flat glacier is split by crevasses; rolling, hilly country of Northern California, once forested but now complete desert, with no topsoil and what is left of subsoil slashed by gullies; a spacious hilly area in California left desolate of growth by fire and water; in Virginia erosion following a few drops on slopes which should never have been cleared; in Colorado, farm buildings caught and undermined by a wide stream, the natural obstructions to the free flow of which the owners of the buildings had themselves removed; wagon tracks starting eroding streams, which will eventually lead to the loss of a valley full of rich soil; driftwood and other debris from hills made barren by fire and deposited by flood upon a young orchard; wind erosion due to trampling of an excess of cattle in dry New Mexico; vegetation destroyed by smelter fumes over thousands of acres in Arizona. The last picture of all is one that cheers the heart after so much witness of destruction. It is one of 'abundant and excellent feed and a maximum of watershed protection', in Montana. It shows a well-watered, hilly country bearing tall fir trees, bordering upon spaces of rich grass, and in the foreground, a flock of feeding sheep. The land and its cover are good and man himself joins in its life-cycle with his good flock.

Nevertheless, Montana takes its share of the famous grazing grounds of the North-West, where it is said that 58,000,000 acres are now only able to feed one-fifth of the number of animals they were once able to support. But it is in Montana's neighbour, the Pacific North-West, that something very positive has arisen, an action of new values in keeping with the awakening of Americans to the primal value of a sheltered soil, protected by a continuous ownership of those who will care for it on small-sized farms. Once again the land is to be the centre of homes, a homeland.

In the Pacific North-West flows the great Columbia River, across which have been placed two dams, the Bonneville and the Grand Coulee. These two huge dams will produce more electric power than the 14,082,282,000 kilowatt-hours turned out by the two hundred and sixty electric plants in the State of New York.

What to do with this enormous amount of energy? There enters into this question something strange and new to accustomed industrialists. They wanted a vast factory community near the Bonneville Dam itself. But there were eyes of a great leader looking upon this mighty dam before him and looking also beyond it with the vision that extends what is seen into the realms of the future. In September 1937, it was this leader, President Roosevelt, who delivered a speech of dedication beneath the dark crags of the Columbia Gorge, the river of which in its change now foretold a change for the mighty stream of the American people.

The North-West, consisting of the States of Washington, Oregon, Idaho and the section of Montana west of the crest of the Rockies, offers an opportunity, said the President, 'to avoid some of the mistakes and wasteful exploitation of resources that have caused such

serious problems in other parts of the country'. The North-West should not be a land of new 'Pittsburgs'. The President continued: 'It is because I am thinking of the nation and the region fifty years from now that I venture the further prophecy that as the time passes we will do everything to encourage the building up of smaller communities of the United States. To-day many people are beginning to realize that there is an inherent weakness in cities which become too large, and inherent strength in a wider geographical distribution of the population.'

The Grand Coulee, now nearing completion, in addition to providing power, will irrigate 1,200,000 acres. These acres are to be given to families and small cultivators. They are being protected against combines and other large-scale operations. These types of land-ownership are forbidden. Land, held in defiance of this limitation, will get no water from government canals. Families, who have been driven by erosion from the western grazing lands and migrated from the now famous Desert Bowl, will here find land. Some are doing so now. The amount of land allowed to be held is limited to eighty acres for a family and forty acres for a single man. The purpose of the Grand Coulee is to take care of as many families as possible. The partnership of family and soil is to be revived. But there is to be something more on this irrigated land. There are to be small industries served by electric power. Men and women, who work at these industries, will also be able to have kitchen gardens, and thereby will carry out what Mr. Stuart Chase proposed several years ago for the North-West, small farms which will act as 'anchors to windward', if at any time industry fails.

Everyone in this area will have the opportunity to gain soil-sense. The land as food producer will be the basis of society and will be its associate. Many small industries dotted about the North-West will serve the countryside as once did village crafts. Other industries will develop for industrial purposes the raw materials of the local farms. Industry will be truly distributed; it will administer to the comfort and happiness of the people on the land as its primary object, and act as the means of external trade as its secondary object. The dicta, indeed, of the North-West, will be those so concisely expressed by Napoleon at St. Helena: 'Agriculture is the soul, the foundation of the Kingdom; industry ministers to the comfort and happiness of the population; foreign trade is the superabundance; it allows the due exchange of the surplus of agriculture and industry ... Foreign trade, which in its results is infinitely inferior to agriculture, was an object of secondary importance to my mind. Foreign trade ought to be the servant of agriculture and home industry; these last ought never to be subordinated to foreign trade.'

The cost of the electric power of the Bonneville Dam is governed by 'postage-stamp rates' all along its transmission line of 275 miles; the industry farthest from the dam pays for its power at the same rate as the industry that is nearest. This mandate was not directed against industries and factories as such, but against industries and factories compounded into places like Pittsburg, Chicago and Detroit. The fear of the great metropolitan city is so ingrained in the thought of the people, writes Mr. Richard Neuberger in *Free America*, August 1940, in a quite triumphant article from which I have taken my information, that

during the struggle over the Bonneville power rates, the words of President Jefferson (1743-1820) appeared in many local papers: 'I view great cities as pestilential to the health, the morals and the liberty of mankind.' That saying was directed against financial and industrial magnates, ambitious politicians and demagogues, who arise in cities and only by cities are made possible. The logical end of metropolitan civilization,and its most complete, one-piece form, is totalitarianism which is confessedly and in action 'pestilential to the liberties of mankind'. In this scheme in the Pacific North-West, men and women have now the opportunity to combine manufacture with a home partnership with the soil. The soil, once again now, and yet more in the future, will be their associate and instructor. There is a grandeur about the scheme, which belongs to a great country that can still revive its epic character.

There is another illustration of the redemptive spirit in the U.S.A. which stirs hope and admiration no less than the story of the Grand Coulee. It is the story of a complete education of the children and people in the local soil.

It was called forth in an area of the United States by the great catastrophes of the Dust Bowl and the floods in the basin of the Mississippi River and eventually united all classes of the inhabitants. It is described in a pamphlet issued by the U.S. Department of Agriculture in October 1940. Pupils and teachers used their own local land as text-book. They walked over the land and with their eyes learned to recognize the symptoms of misuse, to discover the causes, and to work out the principles of good use. A miniature whirl of dust led to the study of wind erosion and the Dust Bowl. The results of a flood and the loss of valuable cotton land led to the study of the watershed, its inter-relationships and the delivery of water from a forested area to the irrigated land below.

Owing to the war I have not as yet been able to procure the pamphlet itself, but I have read a review in *Indian Farming*, January 1942, which quotes verbatim from the pamphlet. It is so important and encouraging that I am reproducing the quotation in full.

'Basic concepts and bodies of subject matter were needed -- an understanding of the water cycle, the behaviour of the soil and water, the growth of vegetation. These were observed and understood and related to the daily life of human beings. Children gained some understanding of the hydrologic cycle in the simple story of the raindrop. Grass as a necessary food for livestock was known to even the smallest child in the south-west. How grass grew, how it reproduced, how over-grazing and trampling destroyed it, led quite logically to such statements as: "The cowboys should not let the cattle eat in one place too long." Sustained use of timber on forest land was expressed as the necessity for large trees, middle-sized trees, and little trees. Human use, human needs, human plans and solutions, were the core of each study.

'Children have a way of talking about matters that really interest them. Visits by pupils to demonstration areas have led to visits by parents. Parents have written letters to schools expressing their interest and pleasure upon learning that the children are studying land

use. In sections where this type of education was going on, the technical men reported an added interest in the districts and a great facility in obtaining agreements' (presumably for the better use of land and water by farmers and local authorities).

'The educational superintendents, supervisors, departments of education lent every facility, advised, took over where possible. The technical staff of the Soil Conservation Service conducted tours, learned to adapt their language to children's understanding, frequently wrote for us expositions in lucid, simple language. The material on human surveys, from our section of conservation economics, supplied information about the population, its use of land, its economic and social problems. Teachers, recognizing that soil conservation was of great interest to their community, that it helped in the vitalizing and socializing of the whole school programme, threw themselves into the programme with originality and eagerness.

'Our brief experiment has shown that land planning and use has an immediate interest for every school, and that teachers, pupils, parents, and State officials are eager to have a part in it. It is one of the great problems before us to-day. It has to do with subsistence, with food, clothing, shelter, taxes, and with many other problems which are a daily part of the home, community and the nation.'

Everyone concerned, it must be noted, becomes interested. It is a call to all from their very origin itself, and each man, woman and child, all creatures of the earth, eagerly respond to it. *It is a construction of the children's minds and a reconstruction of their elders' minds in terms of the soil*.

Mr. Bennett sums up his survey of the soil of the United States with these fateful words:

'After 4,000 years of building dykes and digging great systems of canals, the Yellow River broke over its banks and brought death to a million human beings during a single great flood. During one flood that great river, known in China as "the scourge of the sons of Han", changed its channel to enter the sea 400 miles from its former mouth.

'No one, of course, wants anything remotely like this to take place in this country, but "coming events cast their shadows before". That the greatest flood of which we have reliable records came down the Mississippi in 1927 was a prophetic event. G. E. Martin's statement about erosion as an enemy to agriculture -- "It is very unlikely that any other industry could suffer such losses and survive" -- is prophetic. That bare land, at the Missouri Agricultural Experiment Station, was found to be wasting 137 times faster than land covered with blue grass on a slope less than 4 per cent gradient is prophetic. That many millions of acres of cut-over land lie bare and desolate and exposed to the ravages of fire and erosion, with but pitifully little done towards reforestation, is prophetic. That minimum estimates show that the rate of plant-food wastage by erosion is twenty-one times faster than the rate at which it is being lost in crops removed, is prophetic.

'These shadows are portents of evil conditions that will be acutely felt by posterity. Shall we not proceed immediately to help the present generation of farmers and to conserve the heritage of posterity?

'The writer, after twenty-four years spent in studying the soils of the United States, is of the opinion that soil erosion is the biggest problem confronting the farmers of the nation over a tremendous part of its agricultural lands. It seems scarcely necessary to state the perfectly obvious fact that a very large part of this impoverishment and wastage has taken place since the clearing of forests, the breaking of the prairie sod, and the over-grazing of pasture lands. A little is being done here and there to check the loss -- an infinitesimal part of what should be done.'

These words did not fall on deaf ears. The President and Congress were deeply stirred and five years after the publication of Circular No. 33, the Tennessee Valley Authority took control of the valley of the Tennessee River and its tributaries, an area belonging to seven different States and of no less size than that of England and Scotland. This was the first answer of the Government of the United States to the question of the Circular: 'Shall we not proceed immediately to help the present generation of farmers and to conserve the heritage of posterity?' It was the first radical attack on the 'little that is being done here and there to check the loss -- an infinitesimal part of what should be done'.

To help the understanding of this great project, it is advisable to recall how in Tanganyika, under the guidance of Sir Donald Cameron, in order to avoid the erosion following upon the wholesale destruction of forests harbouring the tsetse fly, geologists, plant ecologists and water surveyors were called together to fit farmers in a manner understood by them to *the local character of the water supply as a whole*. Each river with its catchment area was made into a native-governed entity, and twenty-six such entities combined in one Union.

What the tsetse fly forced upon the discerning mind of Sir Donald Cameron, the devastation and poverty of the Tennessee River area forced upon the mind of the great President of the U.S.A., Mr. Roosevelt, and a strong following of members of Congress. The story has been told with a comprehensiveness worthy of the theme by the Chairman of the T.V.A., Mr. David Lilienthal, in his book, *The Tennessee Valley Authority*, 1944.

The story begins with the natural unity of the Tennessee Valley area, with its forested catchment areas of mountains and valleys, and the varied and interlocking animal and vegetable life they maintained. The forest-covering protected the soil against heavy rainfall, let the rain-water filter through the soil and return by the clear Tennessee River to the Mississippi and the sea.

Then came the White Men, lords of creation and of the negroes, who accompanied them. They surveyed the land and found it suitable for two good money crops, cotton and tobacco. There were also many fine, saleable timber trees upon the mountainous ridges and slopes; there were minerals worth smelting; there were swift, clear rivers, which, if

harnessed by dams, would yield electric power for the machines of the manufacturies. These primeval mountains and valleys were full of promise in a land of promise. Men set to work, each individual or group for their several purposes, and so the primal unity of the valley was destroyed.

At first, the land lived up to the title, land of promise, but little by little, the land was abused and rebelled. The time came when the hill-farmers found their land scored with gullies, the farmers on the plains their fields coated with silt from floods. The exploiters of timber, neglecting afforestation, saw their stock depleted and barrenness take its place. Hard-wood fuel no longer was enough to serve the furnaces of the smelters of ore, and the fumes of their ovens killed even the thin vegetation which attempted to cover the deforested land. Finally, the owners of dams found their pipes blocked by the silt of murky floods, and electricity no longer leaping from the dynamos which the piped water drove. The river itself was thick with silt, local navigation upon it was destroyed and, in flood, farmland washed away. Each was an enemy to the other, and, before the Tennessee Valley Authority took over the whole valley, the inhabitants were the most poverty-stricken and backward of any people in the U.S.A. They were in the front rank of the eroders and devastators, to whom Mr. Bennett attributed the results of his twenty-four years' study of the soils of the U.S.A. The outlook was as ominous as it could well be. The sole hope was to alter the very principles and methods of the usage of the valley as a whole and reintroduce those of the unity of nature, which had been ignored and fragmented. This was the work which Congress allotted to the Tennessee Valley Authority on that momentous date, 18 May 1933.

In the brief space of ten years, the T.V.A. have erected sixteen dams, some of them amongst the biggest in the world, and taken over and modified the five existing dams, and made them into one system of regulation of the rivers under their central control. They have now become masters of the rivers and their floods, and in 1942, when torrents came raging down a large part of the catchment area of the mountains, they conducted them safely into controlled channels. They protected the Tennessee Valley as a whole and its 4,500,000 inhabitants. They have planted a million trees grown in their nurseries and locally suitable to the soil. They have introduced contour ploughing, terraced cultivation, farmers' woodland and a balanced economy of legumes, clover, rotations, pigs, poultry and cattle upon 20,000 demonstration farms, in the midst of the 225,000 farms with 1,350,000 people living upon them in family farms averaging 75 acres. They manufacture phosphates, discovered by their experts as the present-needed artificial manure, and Mr. Lilienthal calls it in results 'the almost magic phosphate'. They have, with their mighty dams, created cheap electric power which gives each person 2,400 kilowatt hours compared to the average of the U.S.A. of 1,530 kilowatt hours, or 120,000,000,000 man hours for a single region. This has increased heavy and light industries, and, as a war consequence, it was largely because of this power that, in 1943, the U.S.A. was able to build its huge fleet of bombers for use in Europe and the South Pacific. They have made a stretch of 464 miles of the river navigable with a depth of six feet and they will soon have

a stretch of 650 miles with a depth of nine feet. Lastly, the number of fish in the river and its reserves has been increased fifteen times.

To effect these great harmonizing practices, the T.V.A. had to possess new harmonizing principles. They had to regard the inter-relation and independence of the different factors of nature in place of seeing nature as a battle in which each living type is set in open and secret enmity to other types in the bitter struggle for survival and priority.

Mr. Lilienthal illustrates and discusses, in a variety of aspects, the change which was necessary, not only in Congress itself, but in every sentient inhabitant of the Tennessee Valley. Here are some few of his words:

'Congress in creating the T.V.A. broke with the past. No single agency had in this way ever been assigned the unitary task of developing a river so as to release the total benefit from its waters for the people ... The T.V.A. Act was nothing inadvertent or impromptu. It was rather the deliberate and well-considered creation of a new national policy. For the first time in the history of the nation, the resources of a river were only to be "envisioned in their entirety"; they were to be developed *in that unity with which nature herself regards her resources* -- the waters, the land, the forests together, a "seamless web" -- just as Maitland saw "the unity of all history", of which one strand cannot be touched without affecting every other strand for good or ill.

'Under this new policy, the opportunity of creating wealth for the people from the resources of this valley was to be faced as a single problem. To integrate the many parts of that problem into a unified whole was to be the responsibility of one agency. The Tennessee Valley's resources were not to be dissected into separate bits that would fit into the jurisdictional pigeon-holes into which the instrumentalities of government had by custom become divided. It was not conceded that at the hour of creation the Lord had divided and classified natural resources to conform to the organization chart of the federal government. The particular and limited concerns of private individuals or agencies in the development of this or that resource were disregarded and rejected in favour of the principle of unity. What God had made one, man was to develop as one.'

The T.V.A. controls and bears the responsibility of the dams, the electric power, advice to the farmers, the fitting of industry to the whole, and general supervision and planning. Otherwise the greatest possible share has been given to the people of the valley by decentralization. 'A man wants to feel that he is important' is the maxim that directs this. 'The very essence of the T.V.A.'s method in the undertaking was at every hand to use directly, and to encourage and stimulate, the broadest possible *coalition* of all forces. Private funds and private efforts, on farms and in factories; state funds and state activities; local communities, clubs, schools, associations, co-operatives -- all have had major roles. Moreover, scores of federal agencies have co-operated' -- here a list of twenty is given -- 'the list, if complete, would include most national agencies.' The farmers themselves decide as to which farms shall be demonstration farms. The distribution of electric power

is directed by the farmers, the industries, the municipalities, the States. The experts live amongst the people and are one with them. Labour is take primarily from the people of the valley; others chosen by merit are directed to expert work. No inducements are allowed to industries located in other regions to move to the Tennessee Valley.

Responsibility is distributed. The T.V.A. management is responsible to Congress, yet it is a separate authority, and its separation underlined in that neither its management nor its staff are permitted any share in politics except that of voting. The same separation is aimed at between the management and the staff; its members are encouraged to act and take responsibilities and not worry about mistakes. A like relation exists between T.V.A. and local bodies and associations, who are given and readily accept action and responsibility for their localities. Mr. Lilienthal himself terms it *Democracy on the March*.

The results have awakened the keenest interest, not only in the United States itself, but in other countries of the world, An impoverished and fear-stricken people in ten years have become prosperous, confident, well fed, well clothed. They are happier and better citizens.

One principle of service to the soil is missing from Mr. Lilienthal's book, the rule of the return of what is taken from the soil, after use, to the soil, by which, in particular, the Chinese have maintained their soil for so many centuries. There is one oblique reference to it in the statement that, if cotton-seed oil-mills made money, Tennessee cattle could be fed with the cotton-meal cakes they now export for sale. If they did this, 'as much as 80 per cent of the fertilizing value of the meal would be returned to the soil rather than continuously drained by export'.

Otherwise, the T.V.A. is a wonderful re-discovery of almost forgotten laws. How great this re-discovery may become, we shall now see in the story of a kingdom in Europe, which was, one might say, except for electric power, all Tennessee Valley and more.

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Small farms

Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 21

A Kingdom of Agricultural Art in Europe

It is refreshing -- and an essential restoration of the mind -- to turn from the dismal tale of farming under modern civilization and to review in its place a kingdom of agricultural art in western Europe. Such a kingdom can be found, but one has to go back a thousand years to find it. Further, apart from this long interval of time, there are other distances between this great agricultural society and the society of modern Europe. The race which directed this society is no longer to be found in Europe. Moreover, the religious faith which directed it is now only to be found in a few mountainous areas of eastern Europe. In its racial and religious characteristics, then, this society was strange to Europe, yet, in spite of this strangeness, perhaps because of it, it did for a period *attain to a fullness of civilization not reached by any other European people*.

This kingdom was that of the Arabs in Spain, which began with their invasion under Tarick in A.D. 711 and came to an end with the fall of Granada in 1472. Its period of harmony by no means extended for the whole of this term of seven and a half centuries.

The story of its achievements has been related by Mr. S. P. Scott in the three large volumes of his *History of the Moorish Empire in Spain*, published in Philadelphia in 1904, with a wealth of detail collected during a period of 'more than twenty years' in which 'this work engaged the attention of the author'. Particularly notable is the account in the thirtieth chapter of the agriculture on which this flourishing empire was based, and by which it supported a population believed greatly to exceed that of the united populations of England, France, Germany and Italy of that time. The figures given are some 15,000,000 to 20,000,000 for the four countries compared to some 30,000,000 in Arabic Spain.

The account of this wonderful agriculture existing in the Dark Ages of the rest of Europe

will be so strange to many readers, that they may feel that it is beyond the range of their credibility. The reason of this is that in English education the influence of Arabic culture is entirely left out. We are taught a lot about the Greeks and Romans, but nothing about the Arabs, as intellectual leaders of Europe.

Mr. Scott himself is well aware of the special educational default with which we are now concerned. He begins his thirtieth chapter with some bitter words, to show that he anticipated the incredulity with which his account would be met. 'In all the vast domain of historical inquiry', he wrote, 'there is probably no subject which has been treated with such studied neglect, with such flagrant injustice, as the civilization of the Arabs in the Spanish Peninsula. Its story has been written in the majority of instances by the implacable enemies of those who founded and promoted it. Theological hatred has lent its potent aid to the prejudice of race and the envy arising from conscious inferiority to deny or belittle its achievements.' Of how bitter this theological hatred could be a single example must suffice. Eulogius, a learned Spanish priest, discovered by his studies or invented the knowledge that Mohammed announced to his followers that three days after his death he would be raised by the angels to heaven; 'instead of this, dogs devoured his rotting corpse'. This example is taken from the well-known book of S. Khuda Baksh on *Islamic Culture*, 1905. When one thinks of the reverence with which Mohammed spoke of Jesus in the Koran and the same reverence which he transmitted to his followers, one can see on which side the bitter religious hatred lay.

Consequently, in view of this neglect and prejudice, Mr. Scott, in a list of 'Authorities consulted in the Preparation of this Work', gives no less than seven hundred and three, covering fourteen different languages.

Some of these numerous books are concerned with the Arabic culture and history as a whole. In the sphere of science and thought for example, William Lecky, in his *History of Rationalism*, 1865, paid this tribute to the Arabs: 'Not till the education of Europe passed from the monasteries to the universities, not till Mohammedan Science broke the sceptre of the Church did the intellectual revival of Europe begin.' Mr. John William Draper, in *A History of the Intellectual Development of Europe*, 1875, wrote in the same strain. A more recent writer than Mr. Scott, Mr. Robert Briffault, in *The Making of Humanity*, 1919, finally summed up the relation of the Arabic Sciences to those of Europe in the following words: 'The debt of our science to that of the Arabs does not exist in startling discoveries or revolutionary theories ... Science owes a good deal more to Arab culture, it owes its existence ... What we call science arose in Europe as a spirit of inquiry, of new methods of investigation, of the method of experiment, observation, measurement, of the development of mathematics in a form unknown to the Greeks. That spirit and these methods were introduced into the European world by the Arabs.'

One need not, therefore, be surprised that these same Arabs produced in the homeland of Irak, in Spain and elsewhere a great system of farming on which to support their brilliant civilization. Many of the books quoted in Mr. Scott's list bear testimony to their farming

art. I will confine myself, however, to coupling the quotations from two well-known French authors in his list. One is from Monsieur Gustav le Bon's *La Civilisation des Arabes*, 1884, 'The Arabs had even a greater aptitude for agriculture than for letters and arts. What means of irrigation are now found in Andalusia were made by them'; the other from Monsieur Sédillot's *Histoire Générale des Arabes*, 1877: 'In short they had irrigated and cultivated the land so excellently that it was befitting to call Andalusia a garden.' Mr. Martin Hume, writing three years before Mr. Scott and not quoted by him, summarized the farming art of the Spanish Arabs in these words: 'Agriculture and horticulture were developed to an extent never heard of before.'

Mr. Scott also gives in his list original works on Spanish farming. One of these works that escaped the attempted total destruction of the literature of the Arabs by their fanatical conquerors is *The Book of Farming*, by Ibn-Al-Awam, or to give him his full Arab name, Abu Zackaria Yahya Bin Mohammed Bin Ahmed Ibn Awam, who lived in Seville in the sixth century of the Mohammedan era. Mr. Scott quotes him in his list under the French translation of his work, *Le Livre de l'Agriculture*, 2 vols., Paris, 1866. This book was also translated into Spanish in 1802, and into Urdu in 1927, in two volumes in each case. It was not translated into English at the time of Mr. Scott, nor, as far as I know, has this grave omission in English scholarship yet been corrected. The Arabic MSS., however, repose in the British Museum Library, as well as in the libraries of Leyden, Paris and the Escorial.

Ibn-Al-Awam also has his list of one hundred and seven authorities upon the varied aspects of farming, and, since the Arabs were great translators, he quotes freely not only from Arabic writers, but from Greek, Latin, Persian, Nabathean and other agricultural experts, as well as experts on the allied subjects, botany, zoology, chemistry, mechanics and meteorology, etc. His translator into Urdu, moreover, emphasizes that he was a very cautious student, a true scientist, in short. This is what his translator writes: 'The peculiar quality of this book is that, whenever the author quotes the statement of an expert, he first tests it by personal experiment. Where he had not the opportunity to verify a statement by experimentation, he tells his readers that, though he has been unable to do so, he has such faith in the veracity of his informant, that he has copied his statements into his book. This precaution which is absent in other books, has greatly increased the value of the work of Ibn-Al-Awam.' A very reliable man, then, is this Spanish-Arabic scholar.

Mr. Scott himself gives the following epitome of *The Book of Farming*: 'The great work of Ibn-Al-Awam, of Seville, a vast monument of industry and erudition embracing every conceivable branch of the subject, shows to what extraordinary perfection the science of agriculture had been carried in the twelfth century by the Spanish Mohammedans. It treats, in a comprehensive and exhaustive manner, not only of the methods found by the experience of centuries to be the best adapted to the sowing and harvesting of grain, to the planting and cultivation of orchards, to the propagation of edible and aromatic plants; but it also, with infinite minuteness of detail, describes the breeding and care of every species of domestic animals, their qualities, their relative excellence, their defects, their habits,

their diseases. It discourses at length upon the different breeds of horses and upon the rearing of that useful animal so prized by the Arab. It explains the details of artificial incubation, a process borrowed from Egypt. It directs how to produce in geese the abnormal hepatic conditions which induce the *foie gras*, that artificial delicacy so dear to the epicure, and a thousand years ago, as to-day, an invaluable adjunct to fashionable gluttony. It teaches the different methods of cooking and the preparation of various confections, jellies, syrups and sweetmeats of every description. The manufacture of wine, so rigidly forbidden to the Moslem, and whose immense consumption had already, in the time of the Khalifate, scandalized the pious, is detailed in all its stages in this remarkable book. In it are given recipes for cordials of many kinds, cooling beverages and hydromel. It also prescribes the rules by which the household of the farmer should be governed, and defines the reciprocal duties of employer and employee. In every operation of rural life and domestic economy, it enforces by repeated admonition the necessity for cleanliness, system and order.'

I have dealt at some length with the credibility of Mr. Scott's account of the Arabic agricultural system in Spain, because, though in the Industrial Era, which began some hundred and seventy years ago, we have made vast strides in the sciences and have far outstripped their initiators the Arabs, we have, at the same time, not advanced but dangerously receded in the recognition that our complicated civilization must for our safety and prosperity be founded upon the soil and its preservation. Where the Arabs accomplished a success and brilliancy in all the factors of social life, we have changed our agriculture into a Rape of the Earth. It has lost its national meaning and the love and reverence of the people it supports. To convert readers in this contention, I saw no better way than to acquaint them with A Kingdom of Agricultural Art in Europe and An Historical Reconstruction, and convince them of their reality.

The agricultural system of the Moors in Spain was, writes Mr. Scott: 'the most complex, the most scientific, the most perfect, ever devised by the ingenuity of man. Its principles were derived from the extreme Orient, from the plains of Mesopotamia, and from the valley of the Nile -- those gardens of the ancient world where, centuries before the dawn of authentic history, the cultivation of the earth had been carried to a state of extraordinary excellence. To the knowledge thus appropriated were added the results obtained from investigation and experiment, from the introduction of foreign plants; from the adoption of fertilizing substances; from the close and intelligent observation of the geographical distribution and climatic influence.'

No cultivators had a more profound knowledge than this people of the value of water. They, like the great riverine peoples, from whom they derived so much knowledge, realized that *the proper use of water was civilization. Without its just and conservative distribution, the true justice and magnanimity of civilization do not really exist*. By the art of distributing water 'a considerable portion of the country which had never been subjected to tillage because of its aridity became suddenly metamorphosed, as if by the wand of an enchanter. Barren valleys were transformed into flourishing orchards of olives,

oranges, figs and pomegranates. Rocky slopes were covered with verdant terraces. In districts where, according to ancient tradition, no water had even been seen, now flowed noisy rivulets and broad canals. Where marshes existed, the rich lands they concealed were drained, reclaimed and placed under thorough cultivation. On all sides were visible the works of the hydraulic engineer -- which supplied the necessary moisture to the fields by every device then known to human skill -- the reservoir, the well, the sluice, the tunnel, the siphon, the aqueduct.'

Water was lifted to higher levels by Persian wheels, of which in a few square leagues there might be five hundred, some with diameters of seventy feet. Grades were ascertained by the use of the astrolabe. 'The public works constructed for irrigating purposes were on a gigantic scale. The artificial basin near Alicante, elliptical in shape, is three miles in circumference and fifty feet deep; the dam at Elche is two hundred and sixty-four feet long, fifty-two feet high, and a hundred and fifty feet wide at the bottom; that over the Segura, near Murcia, is seven hundred and sixty feet long and thirty-six feet in height. The aqueduct at Manesis, in Valencia, is seven hundred and twenty feet long, and is supported by twenty-eight arches. The principle of the siphon, familiar to the Arabs eight hundred years before it was known in France, was utilized to a remarkable degree in the Moorish hydraulic system. The length of the curve in the great siphon at Almonora is five hundred and seventy feet; the diameter of the latter is six feet, and it passes ninety feet under the bed of a mountain stream. The subterranean aqueduct at Maravilla, which waters the plain of Urgel, is a mile long and thirty feet in diameter; that of Crevillenta, north of Orkuela, is fifty-five hundred and sixty-five feet long and thirty-six feet in diameter. All of these underground conduits are cut through the solid rock. The masonry of the reservoirs is of the finest description, and the cement made use of has become harder than stone itself. Contingencies are provided for with some skill and foresight that no overflow occurs, and no damage ever results, even in the time of the greatest inundations. The excellence of construction of these massive works of Arab engineering is demonstrated by the fact that they have needed practically no repairs in a thousand years.'

The distribution of the water was governed by a peculiar code of laws, perfect familiarity with which was only to be obtained by those working for their livelihood under its direction. With a wise trust in local government, the execution of these laws was presided over by a Tribunal of the Waters, the members of which were chosen by the farmers themselves. This Tribunal saw that there was no waste; theft was heavily punished; disputes and violations of the regulations came under its jurisdiction. 'Judgment was rendered after consultation, and from it there was no appeal. The most exalted rank, the greatest wealth, the most distinguished public service, did not confer exemption from the jurisdiction of the court or affect the impartiality of its decrees. The noble was summoned to its bar with little more ceremony than the slave ... The wisdom of these regulations is demonstrated by their longevity.

'In the distribution of water the measurement was by volume, a certain quantity being

allotted to a stated area during a given period of the day or night at intervals of ten to fifteen days. The sides of the canals were provided with flood gates, kept under lock and key, by which the adjoining fields could be submerged at the proper time. Drains carried the surplus back into the original channels, so that there was the least possible loss.'

Such was the way in which water was used so as to make a great society of people possible and durable. It is of profound significance, but it is seldom known by modern men of even wide education. Yet there is no knowledge more entirely needed by modern Europe. What is the use of a glutted treasury of knowledge, while it is, at the same time, *defective in the vital knowledge* which the Arabs possessed.

In the second great precept of the art of agriculture, the rule of return, the Arabs were as effective as they were in the knowledge of water. The same care and economy were observed in fertilizing the soil, which the requirements of a dense population never permitted to rest, writes Mr. Scott, and continues: 'Manure and dust were collected from the highways. The contents of sewers and vaults were preserved, desiccated, and, mingled with less powerful substances, were used to supply the impairment consequent upon incessant cultivation. Ashes, the burned and pulverized seeds of fruits, the blood and bones of slaughtered animals, all played an important part in the intelligent and systematic treatment of the rich and productive valleys of the south, whose surface, resting on an impenetrable subsoil of clay, required continued renovation. The curious and minute investigations of the skilled agriculturist had determined the best composts, the most advantageous modes of applying them, the kind of vegetation to which they were especially adapted.

'Manures were deposited in stone reservoirs contrived to prevent evaporation or leakage. Nothing was wasted; every substance available for the fertilization of crops was carefully preserved, the different varieties being separated and applied to such soils as experience had taught were most productive under their use.'

The third great precept of the art of agriculture was followed by the Arabs in the preference for independent small holdings. 'Unlike the policy adopted under the Roman and Gothic dominations, there were few large estates. The land was divided into small tracts, and for that reason was much more thoroughly tilled ... Every indulgence and encouragement was afforded by the laws to the Moorish cultivator. The independence so necessary to the successful prosecution of agricultural pursuits, he enjoyed to the utmost degree compatible with the social order. For the most part, he himself instituted the regulations of husbandry, which were enforced by magistrates taken from his class and of his own selection. His taxes were not oppressive. The productiveness of the soil, the equability of the climate, never permitted his labours to go unrewarded.'

A fourth was the use of terraced cultivation. 'In localities unfavourable to cultivation the deficiencies of the soil were supplied by untiring industry. Walls of ponderous masonry supported terraces where the very cliffs were made productive, and where only a bush or

vine could be planted the narrow space was utilized. Not only water, but loam and fertilizing materials were brought from great distances.'

The cultivators were also encouraged to adventure upon new paths. 'The unrivalled excellence of the agricultural methods employed by the Spanish Mohammedans was, in large measure, due to their profound botanical knowledge.' Botanists were dispatched to Egypt, Mesopotamia, India, the East and every quarter of the globe, to collect seeds of useful plants and fruits for experimental cultivation. 'Gardens for the propagation of both native plants and exotics were established in the environs of all the great cities, and the results of intelligent observers were regularly tabulated for the public benefit ... In all the multifarious duties of his occupation the Moorish horticulturist possessed expert knowledge.' Owing to this scientific knowledge and the keen adventure of the naturalists, the Arabs introduced into Europe the strawberry, lemon, date, quince, fig, mulberry, banana, pistachio, almond, rice, sesame, buckwheat, spinach, asparagus, mace, nutmeg, pepper, caper, saffron, coffee, cotton, sugar-cane, though according to Dr. H. Hintze, in his book, *Geographie und Geschichte der Ernährung*, some few, such as lemons, quince, almonds and mulberries, appeared on the tables, if not on the fields, of the Romans at the time of the Empire.

Botanical knowledge and widespread education, shortly to be described, therefore combined to promote these excellent results. The treatises on agriculture and horticulture dealt with every aspect of cultivation. The cultivators were, thereby, made familiar with the movement of the sap, the difference of sex in plants, and the process of artificial fecundation. They invested plants with the conditions of activity and repose, of motion and sleep. They followed no less than eight methods of grafting and protected the grafts by ingenious devices from the injurious effects of the sun. They knew how to preserve fruits and grains in subterranean chambers hewn out of the rock. In all agricultural matters, in brief, knowledge was strengthened and widened by skilled agricultural literature.

There was the same skill and knowledge in the rearing of cattle and horses, in the breeding of sheep and the culture of bees, which attained to the highest degree of proficiency. The Arab horse lost none of its speed and endurance for being bred and reared in Spain. The abundant, silky fleece of the merino sheep was due to a peculiar method by which flocks were tended. Immense flocks were driven twice a year between the slopes of the Pyrenees and the plains of Estremadura, by which means they secured both fresh and continual pasturage and freedom from the droughts of summer and the storms of winter.

Lastly the love of flowers was a passion among the Spanish Muslims. Mr. Scott writes: 'As they were the greatest botanists in the world, so no other nation approached them in the perfection of their floriculture and the ardour with which they pursued it.' Whether they were cultivated solely for their beauty and perfume or whether they also cultivated them, because, as has been seen in Chapter 16, they help in their especial way to preserve the cultivation of the soil, Mr. Scott does not say.

By this fine farming, the food of the people was provided, but, owing to varieties of climate and in spite of the great system of irrigation, bad years would occur. To secure the people against hunger at such times, the export of grain was forbidden -- as laid down in the Koran -- and the surplus of good harvests was deposited in granaries hewn in the rock. Forests of oak were also carefully preserved for the sake of their acorns, which furnished a coarse but nutritious diet at time of extremity, when famine otherwise threatened.

Such a wide and complete agricultural factor of a human life-cycle, as the Arabs of Spain created, must necessarily give a wholeness and health to the other factors of civilization. Consequently, in every other art, there occurred the same prosperity and excellence as those which distinguished the art of the soil.

Of their other arts, Mr. Scott writes with a fervour no less inspired by their adequacy than it is by the adequacy of the cultivation of the soil. He describes the organization of the traffic of commerce by land and by sea; the markets and fairs; the principles of equitable dealing in business transactions and in dealing with other nations, as laid down by Islamic law; the ports and the great centres of manufacturing and mercantile activity situated on the Mediterranean Sea; the silk factories and the factories of iron and copper utensils of Almeria; the potteries of Andalusia; the leather work of Cordova, the capital; the silks of Seville; the paper of Xativa; the steel of Toledo; the textile fabrics of Lusitania and Andalusia; the glass-work at Almeria, which was the teacher of later glass-work in Venice; the jewellers of Granada; the mats and basket work of Alicante; the mills of Murcia and Saragossa; the linens of Salamanca; the musical instruments of Seville; and the wines, the use of which scandalized the orthodox Moslem, to whom intoxicants of any kind were forbidden.

Above all these accomplishments of labour was the passion for literature and knowledge. The great monarchs of the great period, from A.D. 755, when Abd-al-Rahman I founded the Ommeyade Dynasty in Spain, to the death of Al-Hakem II in A.D. 976, were not only patrons of literature, but were themselves personally distinguished as authors. Abd-al-Rahman I himself, amidst a life of inexhaustible adventure, from prince to beggared outcast and from outcast eventually to king, was a real lover of literature and art, and a poet of unusual ability. He cultivated the public taste by periodical literary contests, and attracted the most accomplished scholars and poets to his side, not only by material rewards, but by his friendship and the engaging versatility of his comprehensive genius. Had Leonardo da Vinci lived in his time, he would have found the royal friend, worthy of his consummate genius, whom he sought for in vain in Italy and France.

The successors of this great man were worthy successors, indeed, one can hardly believe how there came into being a series of monarchs, not of education only, but of that high degree of culture which alone can be promoted and nourished by an inward passion for it. Such men have filled thrones in many lands with great benefit to their peoples. But the Ommeyade Dynasty in Europe certainly was unique in the number of its monarchs of high

culture. It reached its peak in the reign of the monarch regarded as the greatest of the Arab kings of Spain, Abd-al-Rahman III, and his son Al-Hakem II, the monarch who in himself represented the highest personal culture possibly reached by a monarch. 'The prominent features of the character of Al-Hakem', writes Mr. Scott, 'were his love of learning, his profuse but always judicious liberality, and his profound reverence for the doctrines of the Koran and the laws of the Empire. The few military operations he was called upon to direct showed no want of vigour, and suggested that in a less peaceful age he might have obtained the laurels of a successful general. His devotion to literature amounted to a passion. No monarch of whom history makes mention has equalled him in the extent of his knowledge or the number and diversity of his literary accomplishments.' He gathered together an unequalled library, which required forty-four volumes for the catalogue alone. 'With the contents of most of these works Al-Hakem is said to have been familiar, and, indeed, many of them were enriched by notes and comments written by his own hand. The title-page of each volume bore not only the name of the author, but also his genealogy, as well as the date of his birth and his death, all collected and preserved by the indefatigable industry of the royal scholar.' His prodigious memory; his powers of acquisition; his critical acumen; his talent for composition; and the capacity which could abstract from the administration of public affairs of a great monarchy sufficient time for literary undertakings -- that, under ordinary circumstances, could only be accomplished in a lifetime of constant study, are marvellous and incredible. For Al-Hakem was an historian of approved merit, as well as an impartial critic and a voluminous commentator. He wrote a history of Spain, now unhappily lost, which was considered a high authority in its time, and whose reputation was universally admitted to be independent of the prestige which it would naturally derive from the name and rank of its author. Such was his erudition that in knowledge on obscure points of genealogy and biography he was without rival, even in the learned court of Cordova; and his fund of historical information was so profound, and his judgment so accurate, that his opinions were respected and unquestioned by the most accomplished scholars of the Mohammedan world. As may be conjectured, a prodigious impulse was imparted to education by this extraordinary patronage of letters. The accumulated wisdom of Africa, Asia and Europe was to be found at Cordova ... Education was reduced to a system, whose regulations were enforced with military precision.' Linguists exhausted every source of knowledge. Not only did they translate the masterpieces of Greek and Roman literature, but they familiarized themselves with Persian, Chaldaic, Hebrew, Chinese, Hindu and Sanscrit works. This education and 'the absolute intellectual liberty which there existed was, indeed, considered a reproach by ignorant Moslems of less enlightened lands, who could not understand the association with heretics and the toleration of infidels; but in Spain, where a system of universal education had been established, and was enforced as well by law as by the influence of public opinion, this inestimable privilege was thoroughly appreciated'. Encouraged by the patronage of royalty 'the mental development of the masses advanced with gigantic strides'. 'In Cordova alone there were 800 public schools frequented alike by Moslems, Christians and Jews ... There was not a village within the limits of the Empire where the blessing of education could not be enjoyed by the most indigent peasant.' Women joined

in this advance. 'The exalted position occupied by women under the Arab domination in Spain gave them an influence and invested them with an importance, elsewhere unknown in the Mohammedan world.' Chemists, botanists, biologists, astronomers, mathematicians, physicians and surgeons lifted science to a level it had never previously reached in Europe. Engineers covered the land with roads, canals and public works; lastly architects brought into being the exquisite buildings, the palaces, colleges and mosques, which the religious fanaticism of the Christian conquerors later destroyed together with the libraries and their books.

In the education of this great period, the farmers had their full share. In all the principal towns there were schools of agriculture. From them the cultivators learnt to preserve fruits and to protect their fields against noxious insects. They learnt meteorology and could foresee atmospheric changes with effective accuracy. In all the multifarious duties of farming they possessed an expert knowledge. It was in this period and supporting it that 'agriculture was brought to such excellence as seemed to make any further improvement impossible'.

The best indications of Arabic Spain as a pro-life civilization are those of population. 'It has been estimated by competent authorities that the subjects of Abd-al-Rahman III numbered at least thirty millions. Great as was the extent of the metropolis, incredible as was her wealth, superb as were her environs, many of the other cities of the Empire, while they could not rival her power and grandeur, shared the enormously profitable benefits of a civilization in which Cordova enjoyed a well-deserved pre-eminence. The dominions of the Khalif included eighty municipalities of the first rank and three hundred of the second; the smaller towns were innumerable. Along the banks of the Guadalquivir alone stood twelve thousand villages. So thickly was the country settled that the traveller usually passed, in the space of a single day's journey, no less than three large cities in the midst of an unbroken succession of towns and hamlets. Nothing comparable with the opulence and splendour of the great provincial capitals was to be seen outside the Peninsula. Seville contained five hundred thousand inhabitants; Almeria an equal number; Granada four hundred and twenty-five thousand; Malaga three hundred thousand; Valencia two hundred and fifty thousand; Toledo two hundred thousand.'

The effect of the final expulsion in 1609 of the Moriscoes, Muslims who remained in Spain after the Christian conquest and were compelled to become converts to Christianity, is described by Buckle in his classic *History of Civilization in England*, 1861, in these words: 'The effects upon the material prosperity of Spain may be stated in a few words. From nearly every part of the country, large bodies of industrious agriculturists and expert artificers were suddenly withdrawn. The best systems of husbandry then known were practised by the Moriscoes, who tilled with indefatigable labour. The cultivation of rice, cotton and sugar, and the manufacture of silk and paper were almost confined to them. By their expulsion all this was destroyed at a blow, and most of it was destroyed for ever. For the Spanish Christians considered such pursuits beneath their dignity. In their judgment, war and religion were the only two avocations worthy of being followed. When, therefore,

the Moriscoes were thrust out of Spain, there was no one to fill their place; arts and manufactures either degenerated, or were entirely lost, and immense areas of arable land were left uncultivated. Some of the richest parts of Valencia and Granada were so neglected, that means were wanting to feed even the scanty population which remained there. Whole districts were suddenly deserted, and down to the present day have never been re-peopled.'

The population of Madrid, continues Buckle, fell from some 400,000 to 200,000; Seville's population decreased by three-quarters and her 16,000 looms dwindled to under 300; Toledo witnessed the disappearance of her silk manufactory, which employed 40,000 people, and upwards of 50 woollen manufactories shrank to 13; Burgos became deserted and lost everything but its name. In Buckle's grim words, 'Spain, numbed into a death-like torpor, spell-bound and entranced by the accursed superstitions which preyed on her strength, presented to Europe a solitary example of constant decay'.

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Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 22

An Historical Reconstruction

The Islamic civilization in Spain, of which an account was given in the previous chapter, formed a significant part of what was, perhaps, the most remarkable reconstruction of mankind in history. An outline of it can best be given, if it is divided into three periods, that of its initiation, that of its institution, and that of its achievement.

The Initiation

The period of initiation was that of the life of its founder, the prophet Mohammed.

Mohammed was born in Mecca in A.D. 570 as a member of the leading tribe of Mecca, the Koraish. His father dying before he was born and his mother when he was six, he came under the tutelage of his grandfather, Abd-al-Muttalib. His grandfather died when he was thirteen, and he was then confided to the family of a poor but affectionate uncle, Abu Talib.

Mohammed grew up to be a quiet, meditative man, taking little or no part in public affairs, but by his humanity and justness earning for himself the name of The Trusty. Then, when over forty, upon a night of meditation, he heard a Voice commanding him: 'Cry: in the name of the Lord.' He obeyed and henceforth became a Messenger crying in the name of the Lord. In Mecca his message was to denounce the idolatry which constituted the religion of the people, and in its place to teach the worship of Allah, the one and only God. This aroused the fury of the Koraish against him and his disciples. The latter escaped to Yathreb, or Medina, the City of the Prophet, as it became named. Mohammed remained behind amongst his enemies. Discovering a joint plan to murder him, he also fled from Mecca to Medina. This Hegira or Flight took place in A.D. 622 and from it dates the

Mohammedan calendar.

In Medina the religion he taught was simple. He preached that there was but one God, the unity of living things, the brotherhood of man, kindness to women and children, gentleness to animals, alms for the poor, and the value of prayer.

His preaching and person won the hearts of the people of Medina. He was made the Chief Magistrate, with power to carry into practice what he taught. At that time, writes Ameer Ali Syed, in *A Short History of the Saracens*, 1900, 'there was no law or order in any city of Arabia'. Medina itself was torn by a feud between two principal tribes. Mohammed reconciled the two tribes, abolished all tribal distinctions, and grouped the inhabitants of Medina under one generic name, Ansar or Helpers. He issued a Charter, by which all blood-feud was abolished and lawlessness repressed. Equal rights were granted to the Jews, of whom there were many in and about Medina, and who, on their part, bound themselves to help the Moslems in defending the city if attacked.

The next step in his mission was to unite the peoples of Arabia, but in this he was hindered by the bitter enmity of his own tribe, the Koraish of Mecca. The Meccans, in the first year of the Hegira, attacked the Moslems and were defeated. In the third year, the Meccans, under the command of Abu Sufian, the son of Ommeya, whose descendants were to become the Ommeyade Caliphs of the early Arabic Empire, were successful, but their losses were so great that they did not venture to attack Medina itself. In the fifth year of the Hegira the Meccans with an army of 10,000 besieged Medina, but, in spite of the treachery of the Jews, who took the side of the Meccans in the siege, the Moslems, owing to the defensive skill of Mohammed, were victorious. This victory freed Mohammed for his work; its fame and the prestige, which Mohammed gained, both as teacher and as general, led to his acknowledgement by tribe after tribe throughout Arabia. In the seventh year of the Hegira, the Meccans attacked one of these tribes. Mohammed gathered together an army of 10,000 men and entered Mecca as a conqueror. Nevertheless, at the sight of the city and of familiar but hostile faces, he treated the Meccans as brothers. Excepting four criminals, all were forgiven and accepted Islam. Mohammed himself shattered the idols of Mecca with the cry: 'Truth is come, darkness departeth'.

The ninth year of the Hegira, known as the Year of Deputations, witnessed the general acceptance of Islam by the tribes of Arabia. Mohammed dealt with them in the same liberal spirit as he had shown to the Meccans. 'A written treaty guaranteeing the privileges of the tribe was often granted,' writes Ameer Ali, but in order to promote the change of heart that was Mohammed's especial mission, 'a teacher invariably accompanied the departing guests to instruct the newly converted people in the duties of Islam, and to see that every evil practice was obliterated in their midst'.

Mohammed had now fulfilled his mission by uniting all Arabia. He died on 8 June A.D. 632, at the age of sixty-two.

The actions, character and teaching of Mohammed made so profound an impression upon his contemporaries that the total effect of his personality formed the basis of the Islamic law and civilization. The chief source of that law was the Koran, but the Koran did not cover all the growing needs of the Arabic Empire that so swiftly followed upon the death of Mohammed. Hence, in addition to the Koran, every detail that could be recalled by contemporaries and especially by those most near and dear to him and with whom it was his habit to consult in questions not actually revealed to him was carefully recorded. In Medina, he had been the final judge, the spiritual leader of religion, and the temporal leader, with the duties and powers of an essential sovereign, given to him, in complete trust in The Trusty, by the people. Hence, in the formation of the Islamic law, his inspired utterances in the Koran, his discourses, his decisions after consultations, his expressed approvals, his tacit agreements by gesture, his judgments, his actions, were all brought into service as guides of conduct for pious Moslems by the Islamic legalists and religious Caliphs. From them were derived the fundamental or fixed laws, fundamental and fixed because they were derived from the Prophet of God.

Islamic law controlled every aspect of the life of a Moslem, but for simplification of this vast subject it was divided into categories, ranging from the few obligatory or prohibited things as determined by the Koran and the *Hadith* or the traditions of the Prophet, to the limited number of the approved or disliked, and the unlimited number, which were left to everybody's common sense. By-laws were made by the legalists to adjust changes and circumstances, which time brought about, but they were kept within the orbit of the fundamental laws. Only in cases of extreme emergency could a fundamental law be abrogated, and then only for the duration of the emergency.

Never, therefore, in history has any man been so intimately identified with a civilization as was Mohammed with that of Islam, which endured as an empire until the sacking of Baghdad by the Tartars six and a quarter centuries after the death of Mohammed. As this civilization produced a truly remarkable reconstruction of mankind in agriculture, manufacture, trade, knowledge, art and other departments of human society, the *spirit* of Mohammed's precepts become peculiarly important at a time such as the present, when a further reconstruction is so urgently needed.

This spirit has been admirably told for readers of English by Ameer Ali Syed, in *The Spirit of Islam*, 1922. Its chief character, to my mind, can be put in homely language: Mohammed was the first statesman to introduce *decency of human conduct in every department of society*. He left no class of human beings out of his thought. He was, I feel, unquestionably the greatest humane, constructive statesman in history.

Ameer Ali, however, does not give a very explicit account of Mohammed's attitude to war, which is of such vital concern to men in these days. So, before taking up his review, it will be well first briefly to consider Mohammed's attitude to war. It has been admirably told by Mr. Marmaduke Pickthall in an article entitled 'War and Religion' in the *Islamic Review Book Series*.

Firstly, Mohammed recognized the necessity of war in the collective life of mankind, for the reason that: 'If it had not been for Allah's repelling some men by others, the world would have gone to badness; but Allah is a lord of kindness in creation' (Koran). To repel bad men was, therefore, the reason for going to war and it was for this reason that every capable Moslem must be prepared to go to war, if called upon to do so. It was not conscription, but a sacred duty, provided that the war was a holy war or *Jihad*. Then 'fighting is enjoined upon you, and it is a thing hateful to you. But it may be that you hate a thing which is good for you, and it may be that you love a thing which is bad for you; God knows best and you do not know,' said the Koran.

War was enjoined against grave injustice, 'to defend the weak man, and for women and for children, those who say: "Our Lord, take us out of this city whose people are oppressors. Oh, send us from Thy presence a befriender; oh, send us one who can help us!"' (Koran). Retaliation against aggressors was commanded. 'Kill them wherever you find them and drive them out of the places from which they drove you out. Persecution is more cruel than killing. And do not fight them round the sacred mosque, unless they attack you there. And if they do attack you, kill them. Such is the reward of graceless people' are the words of the Koran. But on no account were the Moslems to be the aggressors. 'Fight in the way of Allah against those who fight against you, but do not originate hostility. Truly Allah loves not the aggressor.' By the spread of Islam, therefore, Mohammed hoped to abolish the brutality or even existence of war.

Throughout the Koran, writes Mr. Pickthall, 'the word "treaty" means a sacred compact, a solemn covenant, which to break is impious,' and he adds, from a wide knowledge of Islam not possessed by any other Englishman: 'With Islamic nations, treaties have always had this sacred character. I cannot recall a single instance of a Muslim power ever consciously breaking a treaty, though they have the right to throw the treaty back if they fear treachery.' Actual treachery was to be treated with the severest punishment, such as was inflicted upon the Jewish traitors of Medina.

Lastly, Moslem soldiers were forced to observe correct or decent conduct. The sanctity of the soil was to be respected. Moslems, invading a country, were forbidden to destroy fields of corn, or palms, or any fruit trees, or to slaughter cattle except in case of urgent need. 'Destroy not the means of subsistence,' was Mohammed's command. Similarly 'the quiet people', as the old Moslem jurists called the unarmed inhabitants, were to be respected. They were not to be killed; they were not even to be molested; neither they nor their houses were to be plundered. 'Plunder is no better than carrion,' said the Prophet. That, however, which was left on the field of battle, was lawful booty. Finally, enemy combatants were to be respected. 'If they desist (from fighting), then (there should be) no hostility except to evil-doers' (Koran). For the evil-doers, there was the law of retaliation. As they had done, so should it be done to them.

Now, under the guidance of Ameer Ali, we will review Mohammed's relation to conquest.

In this no statesman ever used the quality of clemency to those forced to acknowledge his authority with more effectiveness. To those who accepted Islam, he ordained all the privileges and freedom associated with that sacred name, meaning as it does Surrender to Allah or God. To those who submitted, but wished to keep their own faith other than that of idolatry, he presented the utmost tolerance. They were allowed to pursue their own customs and their religious faith, provided they paid the not onerous taxes and obeyed the other civic duties imposed upon them by their Arabic rulers. They were exempted from military service, paying an especial tax in lieu of it. Their lands were not taken from them. The precedent of this tolerance was set by the Charter, which the Prophet granted to all Christians in the sixth year of the Hegira. The spirit of it was Christian in its best sense, since Mohammed always regarded Jesus as the Teacher most akin to him in time and teaching. 'In this Charter', writes Ameer Ali in his *History of the Saracens*, 1900, 'the Prophet undertook himself, and enjoined on his followers, to protect the Christians, to guard them from all injuries, and to defend their churches, and the residences of their priests. They were not to be unfairly taxed; no bishop was to be driven out of his bishopric; no Christian was to be forced to reject his religion; no monk was to be expelled from his monastery; no pilgrim was to be detained from his pilgrimage; nor were the Christian churches to be pulled down for the sake of building mosques or houses for the Moslems. Christian women married to Moslems were to enjoy their own religion and not be subjected to compulsion or annoyance of any kind on that account. If the Christians should stand in need of assistance for the repair of their churches or monasteries, or any other matter pertaining to their religion, the Moslems were to assist them.'

In pre-Mohammedan Arabia, the women were the chattels of the men. 'In both the Empires, the Persian and the Byzantine', writes Ameer Ali in *The Spirit of Islam*, 'women occupied a very low position in the social scale. Fanatical enthusiasts, whom Christendom in later time canonized as saints, preached against them and denounced their enormities.' Then, when the family, and with it the whole social fabric, was falling to pieces on all sides, Mohammed introduced his reforms and 'enforced, as one of the essential teachings of his creed, "respect for women".'

Mohammed raised women to a legal and economic equality with the stronger sex. His precepts and the eventual fixed laws on divorce were strikingly just to women, though he himself expressed his strong disapproval of divorce, in that it brought evil and hardships upon the children. So also, as regards property, the rights which he gave to woman, in spite of the later deterioration of their status under Persian and Byzantine influence, were and are such as even now have not been fully attained in most Western countries. Mohammed's aim was to enable women to become individuals in the State, and this independence he gave them by allowing them to own property, to possess that which they earned by their own efforts, to have their share in the widely spread inheritances left by their fathers, husbands and other near kinsfolk, to be given marriage settlements from their prospective husbands in their favour, and to possess the right to act in any legal matters concerned with these rights without any intervention on the part of their fathers or their

husbands. To the best of his power -- and his power was great in spite of the opposition of the times -- he was the emancipator of women.

Following his precept of the brotherhood of men, Mohammed strove for the betterment of the slaves. Slaves formed a large part of every society of the time. 'The, Church itself held slaves', writes Ameer Ali of the Christian attitude to slavery, 'and recognized in explicit terms the lawfulness of this baneful institution.' Though Mohammed himself abhorred slavery and taught that no action was more acceptable to Allah than the freeing of a slave, he did not attempt the total abolition of a custom so deeply rooted in the economic life of society. What he did do was to infuse the whole question with the spirit of brotherhood and thereby he entirely altered the character of slavery. He provided funds out of the public treasury to enable slaves to purchase their freedom without interference from their masters; he ordered that they could purchase their liberty by the wages of their service; in many ways he opened up the path of liberty. He ordained decency of conduct to slaves, who were to be treated by their owners with the same kindness that they showed to kindred and neighbours. The slave mother was not to be separated from her child, nor the father from the son, the husband from the wife, the relative from the relative. There was to be *equality of food* between slaves and their owners, and equality of dress. They were only to be addressed in terms of affection and not with words implying a.degraded position. 'The whole tenor of Mohammed's teaching', says Ameer Ali, 'made "permanent chattelhood" or caste impossible; and it is simply "an abuse of words" to apply the word slavery, in the English sense, to any status known to the legislation of Islam.' By abolishing all distinctions of race and colour, black and white, citizens and soldiers, subjects and rulers, Mohammed gave an equal humanity to slaves. 'In the field or in the guest-chamber, in the tent or in the palace, in the mosque or in the market, they mingled without reserve and without contempt.' In so far then as slavery continued, Mohammed made it a *social condition within the brotherhood of man*. Moslem slaves could rise to high positions in a state. Many were to become kings; others became governors of provinces, generals, famous men of learning and religion.

Dealing with the chief of economic difficulties, that of the distribution of wealth so as to avoid the extremes of the very rich and the degraded poor, Mohammed displayed the rarest wisdom of statesmanship. This was evidenced in the *Zakat*, the rules of inheritance, and the abolition of usury. The story of that great economic work has recently been retold by Mr. M. Hamidullah, in the second number for 1926 of the quarterly, *Islamic Culture*, in an article entitled 'Islam's Solution of the Basic Economic Problems.'

Mohammed, in the Koran, frequently declared that it is for God to provide a livelihood to every creature: 'We have given you power in the earth and appointed you therein a livelihood.' It was the duty of the State, by means of the Zakat, or Growth-tax, to ensure this livelihood. Zakat was a tax on all property owned beyond a certain maximum and was meant, as Mohammed said: 'To be taken from the rich among them in order to be given to the poor.' And if the treasury was not sufficient to supply the needs of the poor, the ruler could compel the rich to do so. The poor man he defined as one 'who finds not the

wherewithal to make himself independent'.

Zakat was of two kinds, Sadaqah, or the tax on the growth of capital goods and the Tithe or tax on the surplus produce of the soil. 'The Zakat is only for the poor and needy' was the command of the Koran, 'for those whose hearts are to be reconciled' (men who had become impoverished by accepting Islam) 'and to free the captives and debtors, and for the cause of God, and for the wayfarer; a duty imposed by God.'

Mr. M. Hamidullah points out some of the particular virtues of this tax and the balance it effected between rich and poor. It gave the workers a certain security and thereby increased their productive efficiency, and it justified the prohibition of begging, stealing, and indolence by the Koran. As all superfluous wealth was regarded as productive and was, therefore, taxed, whether it was put to use or left unused, it prevented employers taking unfair advantage of labourers, for, if the latter went on strike, the idle money and property of the employers continued to be taxed. It prevented deliberate or careless hoarding, for the hoard was taxed. 'Let not those who hoard up that which God has bestowed upon them of His bounty think that it is better for them. Nay, it is worse for them,' were the words of the Koran. Hoarding for the sake of the family was likewise forbidden, for the Koran declared: 'Among your wives and your children are enemies for you, therefore beware of them. Let not your wealth nor your children distract you from the remembrance of God.' 'Establish worship and pay the Zakat,' are the constantly repeated dicta of the Koran. No rich man could be a Moslem without paying the Zakat. Finally the Prophet believed that so great would be the prosperity resulting from a greater equalization of wealth that a time would come when people offer Sadaqah and there will be none to take it'.

The second of Mohammed's measures to prevent the large accumulation of wealth in a few hands lay in the principles of inheritance. Private property could be accumulated in a man's lifetime within due restrictions, but at his death it was widely distributed amongst his offspring and kindred, and thus large individual fortunes were dispersed amongst many individuals.

The third measure was the forbiddance of usury or 'interest on money', as the dictionary defines it. So the money of Islam did not come into existence with interest attached to it, which would load the sacred duties of farming and trade with debt at the outset. Only the original sum of a money loan was to be repaid, otherwise the interest on a loan would make it destructive. In one of his most searching and prophetic sayings, Mohammed seized upon this truth: 'Although interest brings increase, yet its end tends to scarcity.'

Money was to assist trade by the method of partnership. It was not to be hoarded nor lent out at interest. It must be used for trade or spent in alms, said the Koran, 'so that the Zakat due on it do not swallow it up'. By means of partnership the ender or partner took his share of the success or failure of the enterprise. 'They say trade is just like interest-taking, whereas God permitteth trading and forbiddeth interest.' Genuine partnerships were

encouraged to further trade, manufacture and farming, but debenture-holders and commercial loans were ruled out as destructive. The imposition of the Zakat and the prohibition of interest forced money into use and into the promotion of a general prosperity which resulted from its use.

Economic ranks and occupations did not affect the general freedom of the individual. Islam destroyed money as a standard of social distinction. A man was wealthy according to the good he did to others. Money-wealth had only a limited value, whereas virtue could not be measured but by the good to mankind that followed from it.

Three taxes were attached to the products of the crust of the earth, the tithe, the *rikaz*, which assigned one-fifth of the products of mines exclusively, like the tithe, to the poor, and the *kharaj*, a levy for the general welfare of about 2-1/2 per cent on the output of the land due irrespective of whether the owner cultivated the land or not. According to Islam, land is a gift to all men, and all men are united by the bond of their terrenity in their dependence for sustenance upon the soil. Yet all could not own land. So the land was not socialized, but its products were socialized by these taxes. Through them the poor were given their measure of independence, and the general welfare was given an economic basis in the land. As the soil depended upon the use of everything that nourished it, so the soil, in its turn, was made to give nourishment to all, and to produce the social balance that belonged to it as an integral factor of the life-cycles of man.

Based on the limitation of the soil's products, the economics of Islam dictated a limitation to the acquisitiveness of individual men. As an outgrowth of this, Mohammed's instructions on leisure were also directed so that people's attention was diverted to other things than the making of individual fortunes. Through learning, service, and the call to prayer five times in the day, people's leisure was directed to self-cultivation, whereas their working hours were directed to the cultivation and distribution of material goods. This was possible, sums up Mr. Hamidullah, because Islam was a religion and not an economic organization.

With this independence that Islam gave to the individual, labour was elevated as a general duty and both commerce and farming were announced to be meritorious in the eyes of the Lord. The pursuit of the cultivation of the soil was regarded by labourers and rulers alike as a sacred duty; Mohammed himself ploughed his own land. The contemptuous sneer, which turned the Latin *paganus* or villager into *pagan*, and the man of the heath or field (Anglo-Saxon *haeth* or heath, Gothic *haithi* or field) into *heathen*, was utterly foreign to the *sanctity*, with which Mohammed and Islam endowed the duties of both.

Having freed women from their traditional subordination to the stronger sex, slaves from their ignominy, the poor from their destitution, and farming and labour from their subordination, Mohammed turned to the liberation of men's minds from ignorance.

He made education incumbent upon every Moslem, male and female, and sought thereby

to influence the minds of all men by the passionate emphasis he laid upon the value of knowledge to humanity. Ameer Ali describes this passion in these noble sayings of the Prophet: 'Acquire knowledge, because he who acquires it in the way of the Lord performs an act of piety; who speaks of it, praises God; who seeks it, adores God; who dispenses instruction in it, bestows alms; and who imparts it to its fitting objects, performs an act of devotion to God. Knowledge enables its possessor to distinguish what is forbidden from what is not; it lights the way to Heaven; it is our friend in the desert, our guide to happiness; it sustains us in misery; it is our ornament in the company of friends; it serves us as an armour against our enemies. With knowledge, the servant of God rises to the heights of goodness and to a noble position, associates with sovereigns in this world, and attains to the perfection of happiness in the next.' He would often say, 'The ink of the scholar is more holy than the blood of the martyr', and he repeatedly impressed on his disciples the necessity of seeking for knowledge 'even unto China'. 'He who leaves his home in search of knowledge walks in the path of God. He who travels in search of knowledge to him God shows the way to paradise.'

Our scholar, Ameer Ali Syed, finally gives this summary of the teaching of Mohammed in Medina: 'Islam gave to the people a code which however archaic in its simplicity, was capable of the greatest development in accordance with the progress of material civilization. It conferred on the State a flexible constitution, based on a just appreciation of human rights and human duty. It limited taxation, it made men equal in the eye of the law, it consecrated the principles of self-government. It established a control over the sovereign power by rendering the executive authority subordinate to the law -- a law based upon religious sanctions and moral obligations. "The excellence and effectiveness of each of these principles", says Urquhart, "(each capable of immortalizing its founder) gave value to the rest; and all combined, endowed the system which they formed with a force and energy exceeding those of any other political system. Within the lifetime of a man, though in the hands of a population wild, ignorant and insignificant, it spread over a greater extent than the dominions of Rome. While it retained its primitive character, it was irresistible!'"

With their personal experience of these and other Islamic precepts in action in the microcosm of Medina, the Arab leaders went forth upon their great reconstruction of many millions of oppressed men.

The Institution

Before telling the story of the institution of this reconstruction, it is, however, essential to give a brief description of the conditions of the masses, in what Ameer Ali, whose words I choose as better than my own, names the West and the East. His East does not include the great farming country of China, which, since it seems mankind tends to be similarly affected at any one period, was also engaged in a reconstruction of the Tsing Tien system under the Tang Dynasty (A.D. 618-905) after a long period of divided States and Tartar

conquests.

'In the West as in the East', writes Ameer Ali, 'the condition of the masses was so miserable as to defy description. They possessed no civil rights or political privileges. They were the monopoly of the rich and the powerful, or of the sacerdotal classes. The law was not the same for the weak and the strong, the rich and the poor, the great and the lowly. In Sassanide Persia, the priests and the landed proprietors, the Dehkans, enjoyed all the power and influence, and the wealth of the country was centred in these hands. The peasantry and the poorer classes generally were ground to the earth under a lawless despotism. In the Byzantine Empire, the clergy and great magnates, courtesans and other nameless ministrants to the vices of Caesar and proconsul, were the happy possessors of wealth, influence and power. The people grovelled in the most abject misery. In the barbaric kingdoms -- in fact, wherever feudalism had established itself -- by far the largest proportion were either serfs or slaves. Villeinage or serfdom was the ordinary status of the peasantry.'

The first thirty years of the story from A.H. 11 to A.H. 40 of the Mohammedan calendar, were occupied with the settlement of Persia, Iraq, Syria, Palestine and Egypt. Under Omar, the second Caliph, in A.H. 21, occurred the *Victory of Victories* at Nehawand, in which the Persians, who outnumbered the Arabs by six to one, were totally defeated. Egypt, too, was conquered. Owing to these victories, the precepts of Mohammed affected the fate of many millions of people. By the fire which Mohammed lighted, masses of lowly and oppressed men, as well as men of power and wealth, were warmed and enlightened to a new life.

Convinced that the stability of the Empire and its material development depended upon the prosperity of the agricultural classes, writes Ameer Ali in *A Short History of the Saracens*, Omar 'took immediate steps to settle the peasantry securely in their possessions. "They were released from the galling oppression of the large land-owners; their assessments were revised and placed on a stable basis; the broken aqueducts were restored and new ones built ... Egypt, Syria, Irak, and Southern Persia were measured field by field, and the assessment fixed on a uniform basis. The record of this magnificent cadastral survey forms a veritable "catalogue", which, beside giving the area of the lands, describes in detail the quality of the soil, the nature of the produce, the character of the holdings.' The Zakat gave independence to the poor, but the rich were not oppressed, though shorn of their excesses to promote a greater equalization of wealth. There was no communistic division of their lands nor were they taken by the Arabs. The land-holders kept their estates, subject to a fixed tax. 'Liberty of conscience was allowed to everyone, and the Moslems were ordered not to interfere with the religion of the people. Those who adhered to the old faith received the designation of *Zimmis* (the protected people or liege men). The sole inducement to proselytism, if inducement it could be called, consisted in the fact that whereas the Moslems,, who were liable to be called at any time to serve in the army, contributed only a tithe to the State, the *Zimmis* paid a higher tax in consideration of being exempted from military service.' Nevertheless this *Jazia*, or poll-tax, was in no way

onerous.

When Omar died in A.H. 23, after a reign of ten years, Othman was elected Caliph. Othman was a member of the Ommeyade family of Mecca, of the clan of the Koraish that had shown itself most active in its hatred of Mohammed. The aged Othman was elected to the Caliphate by the intrigues of the Ommeyades. They then got themselves appointed as governors of the provinces; seized the land; subverted the precepts and actions of Mohammed and the first two Caliphs of the Republic, Abu Bakr (A.H. 11-13) and Omar (A.H. 13-23), both the early converts and devoted companions of Mohammed, treated the conquered peoples as satellites and slaves, and enriched themselves by oppression. This aroused the intense hatred of the true Moslems and led to an insurrection in which Othman, at the age of eighty-two, was slain in A.H. 34.

Ali, the beloved adopted son and later son-in-law of Mohammed, was elected as the fourth and last Caliph of the Republic. No man was more revered or trusted by the Moslems than he, not only because of his intimate association with the Prophet, but because he was 'the truest-hearted and best Moslem of whom Mohammedan history has preserved the remembrance' (Major Osborn), and, because both before and during his Caliphate he so stoutly upheld the doctrines of Mohammed and, in Othman's reign, upheld and extended the practical improvements of Omar through his energy and prestige. Then, wrote the French historian Sédillot: 'One would have thought that all would have bowed before this glory so pure and grand; but it was not to be.'

The Ommeyades were the chief cause of the failure of Ali and it was through their intrigues that he was assassinated after a brief reign (A.H. 34-40). They, the Ommeyades, were supported by tribal chiefs, who had been largely weakened in authority by Mohammed's reliance on the assured and faithful Moslems of Medina.

The all-too-human hatred of these reactionaries may seem to have its justification in their deposition from free and arbitrary authority. But their fury and tenacity, of which the modern reader can scarcely form a conception, all students are agreed, had their origin in the very roots of the pre-Mohammed conditions of the Arabian people. From the very earliest times blood-feud had been bitterly active amongst the tribes and consummated in the hatred that existed between the nomadic Arabs of the desert and the farming people of the more fertile south of Arabia bordered by the Arabian Gulf and known as Yemen. 'This blood-feud', wrote the Dutchman, Reinhart Dozy, in his *Histoire des Mussulmans d'Espagne*, translated into English by Mr. F. G. Stokes, 1913, 'has endured for twenty-five centuries; it can be traced back to the earliest historical times, and is far from extinct to-day.'

To the question why it preserved its bitterness with such extraordinary tenacity for so many centuries, Dozy wrote: 'Handed down from generation to generation in spite of community of language, laws, customs, modes of thought, religion, and, to some extent, of, origin -- since both races were Semitic -- we can only say that its causes are

inexplicable, but that it is "in the blood".' Nevertheless, it may be, as we have seen in Chapter 6, that the hostility lay in the ultimate relation of the two peoples to the soil, farming and trade on the one hand and nomadism on the other, and in the tenacity that characterizes the Semitic peoples. Whatever the true explanation is, this passion for feud and tribal independence runs, as a rebellious and anarchical spirit, through the pages of Arab history. It brought about the failure of Ali's courageous attempt in Othman's and in his own short reign to uphold and re-establish the precepts of Mohammed; it led to his assassination by Ommeyade intrigue; it brought the Ommeyades to the headship of the Moslem world, the cruel persecution of the family of Mohammed and the sack of the sacred city of Medina; it foiled the Period of Conquest of the Ommeyades and brought about the defeat of the Moslems by the Christians at Tours on the bank of the River Loire; it took its part in the disintegration of the Kingdom of Spain; it promoted the disintegration of the Saracenic Empire of the Abbasides and caused it to fall to pieces before the assault of the nomadic Mongols. 'It led', says Ameer Ali, 'not only to the end of the Republic, but also to the downfall of the Saracenic Empire.' To-day, it seems to the Europeans, that the Arabs are prevalently nomadic.

The Ommeyade Dynasty, which followed the assassination of Ali, with its capital at Damascus, endured for ninety years. Only one Caliph of the dynasty, Omar II, strove to re-enact the precepts of Mohammed. He, like Ali, was assassinated. The Ommeyades were themselves destroyed by the Abbasides, the descendants of Abbas, the uncle of the Prophet. One, Abd-al-Rahman, escaped to Spain and there founded the great Spanish Dynasty of the Ommeyades.

The Achievement

The Abbasides ruled from A.D. 750 to A.D. 1258, when their capital, Baghdad, was seized by the nomadic Mongols under Hulagn, the Caliph, and 800,000 inhabitants butchered within a week, and the great system of irrigation destroyed.

It was under the Abbasides that the great task of reconstruction was accomplished. Mansur, their second Caliph, was the first of a series of brilliant Caliphs, equal to that of the contemporaneous dynasty of the Ommeyades of Spain. The story of the development of the civilization of the Moors has many resemblances to that of the Abbasides, for both carried out the statesmanship of the fixed Islamic laws.

The Abbasides brought the era of conquests to an end. They renounced further warlike enterprises, and devoted themselves to the development of the land, the prosperity of the peasants, the promotion of commerce, the construction of roads and caravanserai, the establishment of charitable institutions, the spread of education, and the stimulation of literature and the arts.

The system of irrigation, which the Abbasides extended and amplified, was one of the

most wonderful in the world. Only time-honoured China and Islamic Spain had anything to compare with it; in actual fact, the Abbaside irrigation was superior to that of the Chinese, for it had control of the whole of the two great rivers, the Tigris and Euphrates, whereas the Chinese had no control over the sources of their great rivers.

The spirit and practice of the great riverine civilization of Babylon were revived. Throughout the whole Abbaside Empire the work of promoting agriculture was regarded as a religious duty, and the art of cultivation was developed and maintained with religious zeal. Mansur first abolished the payment of the Ommeyade money-tax upon grains and replaced it by a payment in kind. He extended this principle to other crops, and, in the case of the most fertile of lands, the produce-rates were fixed at two-fifths of the whole. Remission of taxes were frequent at times of stress even in the reigns of his most severe successors. By thus following the true economics of the soil, the prosperity of the peasants was at once implanted and the soil itself conserved as the basis of the State.

The method of land taxation was, however, not uniform throughout the Empire. 'In Babylonia, Chaldea, Irak, Mesopotamia and Persia there were numerous landowners and peasant free holders', writes Ameer Ali in his *History*, 'whose rents were permanently fixed upon the basis of agreements entered into at the time of the Conquest. No variation could be made in the tax leviable from them, and they were thus protected from all harassment. The same boon was enjoyed by the village communities of Northern Persia and Khorasan.' In a brief time, under this just care, the countryside of Irak and Southern Persia had the appearance of a veritable garden. Between Baghdad and Kufa especially, it made a setting of verdure for a number of prosperous towns, flourishing villages and fine villas. There was a teeming population. According to the writer of the article 'Irak-Arabi', in the 11th Edition of the *Encyclopaedia Britannica*, quoted by Mohammed Fadhel Jamali, Director of Education, Ministry of Education, Baghdad, in his book, *The New Iraq*, 1934, it was perhaps five hundred times as great as what 'it usually contains', in its present decadence.

A further feature of the greatest value to farming, with its *essential character of locality*, was the principle of self-government, that freedom for local customs and traditions on which Mohammed laid such stress. The Abbasides spread this precept throughout their dominions. 'The government carried its policy of non-interference with the separate communities sometimes to the extremest verge, to the detriment of its own interests. Each village, each town administered its own affairs, and the government only interfered when disturbances arose, or the taxes were not paid.' But so vital was the land, and so stupendous the system of irrigation which nourished it, that the construction of new canals and the cleansing and repair of old ones were entirely in governmental hands, as also was the maintenance of an efficient river police. The cost of the new canals was borne by the State, that of cleansing and repair was shared by the State and the recipients of the water. The workers on the land opened up by the new canals, consequently started their work without the shackles of a debt that had to be paid off. The benefit to the new farmers was primary, and, from their produce, they paid the usual taxes for the maintenance of the

State, which itself repaid them with so many benefits. In this way the soil was dominant and money the adjuvant.

With the same magnanimity as they bestowed on the soil, the Abbasides developed the precepts of Mohammed on knowledge. Academies, colleges and schools were everywhere established; education was opened to all, urban and rural; the education of the women proceeded on parallel lines with that of the men. This zeal for knowledge was developed to the highest pitch, as Ameer Ali, in *The Spirit of Islam*, writes: 'Under the Abbasides we find them (the Moslems) the repositories of the knowledge of the world. Every part of the globe is ransacked by the agents of the Caliphs for the hoarded wealth of antiquity; these were brought to the capital, and laid before an admiring and appreciating public. Schools and academies spring up in every direction; public libraries are established in every city for every comer; the great philosophers of the world are studied side by side with the Koran. Galen, Dioscorides, Themistius, Aristotle, Plato, Euclid, Ptolemy and Apollonius receive their due meed of appreciation. The sovereigns assist at literary meetings and philosophical disquisitions. For the first time in the history of humanity a religious and autocratic government is observed to ally itself with philosophy, preparing and participating in its triumphs.' What this zeal for knowledge meant for farming, we have already seen in Chapter 21.

This great reconstruction was to be witnessed in every country, where Islamic culture was implanted. It was the same story in Persia, Syria, Iraq, Egypt, Mauritania, Sicily and Spain. It seemed as if there was something magical, something beyond all previous conceptions of man, in the arrival of Islam. Spain, Mauritania, Sicily and other countries, previously stagnant or in decay, blossomed into active life. Idris of Medina, for example, escaped from a false charge of drunkenness. He won the adhesion of the Berbers of Mauritania and founded the Idriside dynasty. He built Fez and made it his capital. Under the new spirit Fez became a famous seat of learning, and the country, of which it was the capital, leapt into wealth and prosperity. Musa, Abd-al-Rahman and their successors in Spain, Majorca, Minorca, Sardinia, Corsica and a part of Sicily, in a very short time established a new culture and prosperity. There is nothing exactly like this in all history. The early Roman Empire and the Scientific Era are no parallels, because they both progressed, as we have seen, at the expense of humble peasantries and the exploitation of the soil. On the other hand, growth in prosperity in these Islamic countries *occurred in all branches of social life*. Farming, manufacture, trade, art, education, knowledge, all attained a very high level. *They increased in power and capacity equally*; they attained a balance amongst themselves, because they based themselves on a highly developed and conserved life-cycle, of which the Spirit of Islam was the creator.

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Small farms

Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 23

Recapitulation

In a chapter on Recapitulation designed to sum up the principles of reconstruction by way of the soil, I could have taken other civilizations than those of the period of Islamic success as a measure of our present needs. Mr. 0. F. Cook of the U.S. Agricultural Department, for example, tempts me with words I have already quoted and will here repeat: 'Agriculture is not a lost art, but must be reckoned as one of those which reached a remarkable development in the remote past and afterwards declined.' This is his conclusion after his examination of the farming system of Ancient Peru.

William Prescott, in his *History of the Conquest of Peru*, 1847, gave a brief account of that remote farming. The land, he wrote, was divided into three parts, one for the support of the national religion and the sick and infirm, one for the maintenance of the Royal Family and Government, and one 'divided, per capita, in equal shares for the people'. By law each man had to marry at a certain age, and the land was re-allotted each year and 'increased or diminished according to the number of the members of his family'. None were allowed to be idle 'from the child of five years old to the aged matron not too infirm to hold a distaff'. Prescott then discussed this agrarian law, and, of European countries that resembled it, he selected that in Judaea as 'the nearest approach to the Peruvian constitution'.

Nevertheless, our information, or mine at least, of this system of irrigated fields 'cultivated wholly by the people', is so scanty and remote that thorough and practical to the highest degree as it was, it would have been quixotic for me to have made it a measure of choice.

The same applies to the riverine civilizations of Iraq; knowledge of essential details is lacking. These civilizations collectively offer a stability of the soil of some four thousand years, but so far off is this period that again it would be quixotic to choose ancient Iraq for

modern guidance.

It is a very different matter with a far more numerous people of a like duration of four thousand years, the Chinese, a people whose farming, right up to the years preceding the Great War of 1914-18, earned the unstinted praise of that genius of agriculture, Professor King. The introductory chapter of his *Farmers of Forty Centuries* is a well-deserved paean to the Chinese farming, carried out in spite of the floods of their great rivers, which, rising in the vast area of Tibet, have been beyond their control. Moreover, they have in their history records of several reconstructions by way of the soil one of which, that of the Tangs, was contemporary with the Islamic reconstruction. When their society was disintegrated by the incursions and conquests of the Tartars and when their land was devastated, the first task of a Chinese dynasty after overcoming the Nomads was the reconstruction of their peasant-farming system.

In the West, there has been abundant studentship given to the arts of China, and especially to its pictures and ceramics, but it has ignored the greater art, the art of agriculture and its reconstruction. One student, however, of the Columbia University, New York, Dr. Ping-Hua Lee, has been a fortunate exception, and this gifted author has given accounts of the Han and other dynastic reconstructions of the system of land tenure of the Chinese sages, of which I made use in the third chapter of my *Restoration of the Peasantries*, under the heading of 'The First Agricultural Path'. The history and character of these reconstructions, and of Chinese historic farming generally, to my mind and to that of the late Professor King, offer a wide field of invaluable research to future western students, but that time has not yet come. When it does come it will, doubtless, reveal a number of principles of reconstruction by way of the soil at present not available.

For these reasons, therefore, I have chosen the Arabic reconstruction, and for the further reason that they were, according to many scholars, the initiators of the modern sciences. It is true that we have surpassed their sciences to an immeasurable degree, but the same cannot be said of their arts, and particularly of their farming as a national art. Here we have by no means surpassed them; on the contrary, we are far below their level. So, although by their violent jealousies and extravagances, such as the Chinese were never guilty of, the Arabs exposed themselves to their enemies, who destroyed their empire, and though, with a fatality that seems as inexorable as it is inexplicable, they have almost reverted to their original desert status and to-day nowhere exhibit any art of agriculture for our enlightenment, I have chosen their historical reconstruction as the measure of what should be possible to us in our present urgent need. Consequently, to give coherence to my subject before my final chapter, I propose in this reconstruction to review the first twenty chapters of my book in the light of chapters 21 and 22.

Chapter 1 discloses the general theme and purport of the book as a need to accept the priority of the soil in a sane and sound civilization. It describes the intimacy and oneness of Man with the soil, which forms the initial factor of life-cycles, in which men have their being. It reveals the wholeness or health, which arises from a complete adherence to the

life-cycle by a brief account of possibly the healthiest people on the earth. It goes on to show how the human family conjoined with property in the soil, through which the life of the soil and of humanity become vitally interwoven. It ends with an account of the most enduring association of soil and family in history, that of the Tsing-Tien System of the Chinese.

The duration of the Chinese family system and the degree of positive health of the Hunza both surpass what the Arabs attained. Nevertheless, Islam attached great significance to both family and health. Mohammed asseverated the sanctity of agricultural work and coupled with it the declaration that the land or other property, was inviolable as long as it was rightly used. Islam, founded upon the Prophet's dicta, embodied them in its fixed laws upon the freedom and security of the peasantry and the inviolability of property rightly used.

As regards health, we know that, at the time of the rise of Islam and after, Europe was frequently devastated by epidemics. The condition of the towns and the homes of the people was one of extreme filth, and this condition has lasted amongst the poor urban classes almost to the present day. In many of the most populous capitals of Europe not a single public bath was to be found, and religion itself made personal dirtiness almost synonymous with holiness. The practice of Islam was the very opposite of this. Mohammed himself taught the paramount importance of hygiene. He also placed right feeding as the first source of health and decreed that lack of restraint in food and drink was 'the source of all physical ills'. Islamic civilization was marked by its insistence on bodily cleanliness, and public baths were provided on a liberal scale. Drainage in towns was efficient without being wasteful. Nevertheless, though vastly superior to anything in Europe, Islam needed the assistance of the medical art, which it developed to a high degree as shown by the fame of its Schools of Medicine and its hospitals, and the knowledge of botany, pharmacy, chemistry and other branches of medicine, from which much of the modern healing art is derived.

The next four chapters, Chapters 2 to 5, tell the story of Rome and the evil effect of its capitalistic civilization upon the peasantries and family, upon the food of the poor, and upon the soil resulting in its extensive loss through erosion and the formation of marshes. Islam supported the peasantries, honoured the family, dictated that even the slaves should have the same food as their masters, and took every care to conserve the soil.

Chapter 6 is concerned with Nomads and Farmers, and the effect which scarcity of the food of the Nomads had upon the civilizations of the Farmers and the history resulting therefrom.

Chapter 7 brings forward two contrasting examples, the first of the deprivation of the soil of the Falkland Islands under the dominance of modern commerce, and the second of the renovation of the soil of a Baltic dairy farm by correct farming and ecology. Both form examples on a small scale of vital issues. The local self-government in things of the soil

would have avoided the first; the second is in accord with the final unity of all living things of Mohammed's teaching.

Chapter 8 gives an account of the proper and the wrongful uses of urban and rural wastes. Islamic agriculture was, amongst other things, based on the proper use of wastes. Chapter 9 continues this theme and shows the reason why the cash-nexus leads to the wrongful use of wastes. Under the guidance of Oswald Spengler, it develops the difference in thought and values of the countrymen and townsmen, which are illustrated by the different character of their taxations, the natural character of that of the farmers being payment in kind or farm products, that of urbans payment in money. This difference was recognized and acted upon by Islamic civilization. The chapter continues with further illustrations of the economics of the soil, including an account of the Chinese economics of the use of water for the soil, as given by Professor King. It concludes with a brief description of the disastrous effect of the dominant money values upon the fertility and health of the soil.

Chapter 10 contains the story of the peasantry of England and the robbing of the food of the soil by the lords of the manor, culminating in the ruin of the peasantry in the Industrial Era by acquisitive men. Only the peasants of the Isle of Axholme escaped this fate.

The story shows especially the entire lack of decent conduct towards rural labour at the introduction of modern capitalism and is the precise opposite of the sacredness that was bestowed on all labour by the introduction of Islamic civilization.

Chapter 11 is the first tale of primitive agriculturists, those of Kenya, under the aegis of commercial farming, so poignantly told by Mrs. Huxley. It is a story without redemption, but not without the retribution of an extraordinarily rapid and devastating spread of erosion of the soil. Chapter 12 is a second story of a primitive people in Nyasa lured or forced from their land to serve in the adjacent gold and diamond mines. It has an all-too-near resemblance to the fate of the English peasantry as told in Chapter 10. The conditions of the miners in the gold and diamond mines was never as terrible as those of English miners under which children of six years, harnessed to small carts by chains, drew coal along the passages of the mines, but it was one with a large share of bondage, drunkenness and disease, under the stress of which many great and successful social and medical improvements have now been effected.

Chapter 13 tells the story of the salvation of Tanganyika, effected by the little tsetse fly, from the rapid erosion that has visited Kenya. It also contains a most promising story of redemption in the proper use of rivers, in which, instead of forming boundaries of human hostility with the ill-effect that such a river as the Rhine in particular has had, they are made beneficial by being used primarily for people on either bank.

The last tale of the due effect of dominance of money over a primitive peasantry is that of our oldest colonies, the West Indies, in Chapter 17. The hardships and erosion it has caused is made the more graphic by an account of an uninterfered with, and flourishing

island -- that of Lombock in the East Indies.

Under the Islamic principles of the treatment of peasants, none of the disasters of Chapters 11, 12 and 17 could have been brought about; on the contrary, the Lombocks would have been multiplied, as the results in the Mediterranean Moslem islands show.

Chapter 14 is a philosophic interlude on the extraordinarily delicate and infinitely varied nature of our food substances built up from only a few elements, the most common of which are not only earthly but also aerial, and the need for a wider conception of them and their nature, if positive mental and physical health are to be attained.

Chapter 15 is another tale of the effect of the dominance of money. It concerns itself with Sind and Egypt, and shows the danger to the alluvial soil, of trying to force it out of its primal character in order to make two blades grow where one or none grew before. The perennial irrigation, which has been introduced into Egypt and Sind, has been first financed by money at interest, and thereby has followed another path than that of Islam, in which the cost of new canals was borne by the government and that of cleansing and repair alone shared between the State and the recipients of water. There was no interest; there were no bankers who brought the huge sums into existence out of nothing and issued them as loans to be repaid with interest. The first thing the bankers sow upon the new land is debt, as one might sow tares amidst the wheat. They enforce greater productive effort upon the land than it will bear. 'Although interest brings increase', said Mohammed, 'yet its end tends to scarcity.' This great saying again proves itself true in this modern example. Both in Egypt and Sind, the forcing of the land out of its natural capacity to make it 'pay', has already produced scarcity, through alkalinity. Writing only from the purely agricultural side, Professor King says that in all probability the people whom our modern civilization has supplanted knew of this error and had tried and abandoned perennial irrigation. Islam went further in the interests of soil. *From the very start it shut out the men of greed*.

Chapter 16 is a second interlude chapter. It is a review of what are known as artificial manures. The introduction of artificial manures was a fragmentation, an incursion of one particular section of scientists into the realm of farming. These scientists took a partial view of the character of the soil. They took a few of the most important chemical elements of the soil, and tried to make them into a whole. They sought to displace natural manure with measured doses of these chemicals; they first diagnosed the land, and then prescribed for it. They began to be important when the quantity of natural manure itself began to decrease owing to railways taking away horse traffic and sanitation abolishing the disposal of refuse upon the soil. With motors displacing horses, and tractors displacing horses and oxen on the farm itself, artificials became yet more strongly advocated. They have their occasional place in increasing the amount of produce of underfed land, and they have been of great service during the period of war. But they have distracted thought from natural manures; they have helped to hide away the disastrous misuse of wastes. They are a fragmentation, a default in philosophic thought upon the wholeness of the association of

the dead and the living in farming. They have, therefore, been accompanied by a farming so beset by disease that the scientific farm has become a blend of factory and hospital, producing products inferior in health, quality and taste, and deterioration of the soil.

Artificials, of course, played no part in the farming of the Islamic civilization; nor, indeed, of that of ancient Peru, nor of any of the great farmings that men erected in the past.

Chapter 18 is the tale of the German Colonies, in which the creed of the rights of the fittest received almost its final consummation. The latter part of the chapter tells the happy stories of these same colonies under the guardianship of the Permanent Mandates Commission of the League of Nations. Differing in manner, the three governments, those of the Union of South Africa, of France and of Britain, effected a miraculous change by means of principles approaching, and in the case of Tanganyika nearly identical with, those of Islam, when dealing with oppressed peoples of the soil.

In Chapters 19 and 20, the huge countries of Russia, South Africa, Australia and the United States illustrate the climax of the destruction and death of the soil which our modern values make inevitable. In spite of their great scientists, all these countries have been placed in grave danger owing to erosion.

In Russia erosion, particularly that due to deforestation, is of longer duration than in the other three countries of later development. But, with Russia's modernization and especially its almost fanatical faith in the tractor or machine farming, Professor Kornev has had to utter the warning: 'At the present day there are huge areas in the U.S.S.R. where, owing to the excessive breaking up of topography, whole territories formerly under profitable agriculture are now occupied by immense ravines and infertile wastes.'

South Africa has been described by Mr. R. 0. Whyte under the italicized sub-heading of *The Transformation of South Africa into Semi-desert in the Twentieth Century*. Mr. E. S. Clayton, in *Overseas Investigation*, 1937, declares: 'There is no doubt that we Australians are in a process of transforming the semi-arid areas into desert at a more rapid rate than in the U.S.A.'; and.in the wetter, riverine districts many parts are gravely affected by erosion.

Finally we arrive at that great country, which has become the leading modern country in the production of food for itself and other countries, as well as of other essential crops for the benefit of all men and its own prosperity. Yet in doing so, it is fulfilling the prophecy of its own Professor Shaler that unless some radical change is adopted, we must anticipate a time 'when our kind, having wasted its great inheritance, will fade from the earth because of the ruin it has accomplished'. The chapter closes with an example of a great awakening, a powerful effort towards redemption in the U.S.A., the Tennessee Valley Authority, which follows the values of Islam in the priority given to local, agricultural knowledge, and the balance and mutuality of all labour, whether it be in the factory or on the land.

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Reconstruction by Way of the Soil

by G.T. Wrench

Chapter 24

Action

It may seem boastful on the part of a writer to say that his subject is world-wide, but the world, at one time so very large, has shrunk a good deal in these latter days and a number of questions, once national or local, have consequently become world-wide. Certainly, if any question has a world-wide significance it is that of the treatment of the world's crust. Action, therefore, at this present time, in the reconstruction via the soil must have a certain world-wide character attached to it.

What, then, of a world-wide character can form a means of action in reconstructions via the soil? The present has shown convincingly what, indeed, scarcely needed another demonstration, namely, that at a time of war every nation engaged, whatever its form of society and government, is not hindered by money. Nor is it hindered by unemployment. At such times there is work for one, and all, and work takes precedence of money; money does not call forth work, but work money. The impulse to action is so great that it takes complete mastery of men and matter. Hence, for a reconstruction of the soil, a very wide impulse will have to be called into being. It is not to be expected, of course, that the impulse will have the cohesive fury of a people called to war, but it should certainly seek for means that are world-wide in their character.

What means of this wide character are, then, favourable to a big-scale movement?

First and foremost there is the unique positive achievement of the war. The war has achieved, as never before, *the technical unity of the world*. The spirit of unity is quite a different matter. The riven spirit of the pre-war times remains, and as yet there has been nothing in the plans for the post-war period to prove positively that it has been radically diminished. This is as one might expect. The characteristic of the last few decades has been the improvement of technique, to which one great war, one great revolution,

expectation of war, and a second great war have jointly given an impulse that has been terrific. This technical achievement cannot possibly be overlooked as means to reconstruction. With its wireless reaching so many homes and papers, its multiple air routes and air bases, its great roads, even amidst the supposedly eternal defiance of the mountains of Central Asia, its innumerable mass-made ships, its thousand inventions in means of communication, it has developed a capacity to weld the world together, such as itself foretells a new era. The world has been technically transformed into one borderless whole, for neither the air nor the ether has frontiers. Unless, then, mankind is to be overtaken by physical degeneration, unless a decay of character brings with it one of those periods of disintegration of civilization, with which historians are familiar and of which the decline and fall of the Roman Empire has been the classic example in the West, there is no possibility of the future technical disseverance of the world. Its technical unity is a fact; all depends upon the uses to which it is put. It may, for example, be made subservient to a revived pre-war money power through a continuance of the officialism necessitated by the war. It may be limited by a variety of fragmentations, if the divided nationalities continue to indulge their political appetites and make the primary needs of their peoples means to national aggrandisement. Its use and misuse may, indeed, lead to further wars, famines and increasing social chaos. All this will be possible, if men continue to ignore the crust of the earth, until the uncontrollable increase of the soil's devastation sinks men into despair or forces them, before it is too late, to use this tremendous technical power for what its wide-world capacity seems to be designed, namely, the world's terrene salvation and not its destruction.

Those, then, who are convinced of the need of reconstruction via the soil, should not now allow themselves any laments for the past or indulge in vain dreams of a world other than it is at this very present. They should look upon the technical unity of the world as a giant of assistance to the awakening of the brotherhood of man through the common parent of all, the soil. They have a message and a means of communication commensurate with its vastness. Their message has undoubted prior claims because, physically, mentally and morally, it affects all men who tread the earth. If they can enforce themselves upon the world's wireless; if, by travel, they can reach once distant lands by air-speed, which now makes east and west and north and south neighbours; if in the world's press they can publish to innumerable readers at one and the same time the more striking news of their movement; if men of each country can communicate to men of other countries what they are doing, what developments have been accomplished or are expected, then they will fill the world with the creed of the soil. There is much to communicate at this day, as soon as the din of war has become silent. This will be far more when the thoughts of men are no longer directed to the slaughter of life, but to the means of its conservation.

Each country will need its band of men and women to take a part in this new unity of the world. The type of men required to form the initial bonds is of the greatest significance. It is at once clear that they must be of a kind that was almost voiceless in the period, between the two great wars, when their contraries, by converting soil-fertility freely into

money, were 'drawing the whole world headlong to starvation', in the words of Mr. Jacks. Upon their ignorant greed, there was, says Mr. Jacks, at that time only one check, the threat of war. Then came the actuality of war, and the governments of the Great Powers engaged in it, realizing at last the paramount and primary character of soil-fertility, allowed it no longer to be turned freely into money, but treated it as a national armament no less precious than were the metals and the chemicals. This dominance of soil over money must not be allowed to relapse with the cessation of the war. *The lesson then learnt must this time be unforgettable*.

A new social, non-military war, indeed, opens out, the war on behalf of the soil and of the healthy life and physical freedom of men. In this war, the soil will have, in the beginning, many opponents. Firstly, except for men of genius and the capacity it gives them to change an outlook and break with the personal trammels of the past, those men who rose to high authority before the war may be expected to be opponents, *from the very fact that they rose to authority under the ruinous values of the earth's devastation*. These values will still be treasured, because the use of them brought them their public power. To purge themselves of the gross defect of mind that the values entailed, will be beyond their capacity; whether they wish it or not, the familiar spirits will not cease to haunt their thoughts and actions.

Then, there are aliens and men without any country of their own, without, in the first case, any inborn, native love for the land in which they have their refuge; in the second, without any actual kinship of mind, occupation, and tradition with the soil. With both money is, of necessity, the paramount object, because the only world-wide rival to money is the soil. Such men are dangerous.

Urban people are likely to be opponents at the beginning, for urbans become perforce not individuals so much as mass. In small matters they hold the opinions of their set; in larger they are subject to mass-emotion. Their interests and faiths wax and wane, are hot and cold. Fed by selected news and spurred by propaganda, they are the objects of unfixed laws, each of which, like a wave on a sandy shore, wipes out the impress of its predecessor. Severed as they are by modern town life from the soil and its creative powers, they are alien to fixed laws, by which alone its dominance can be maintained.

Modern education itself is an opponent and a powerful detractor of the land, because the soil is only regarded in it as something that can be ignored. All education for the young, one can say, in all advanced countries seems to have this profound defect. Personally I am best acquainted with my own education, that of a public school in England. The school was situated amongst cultivated fields and riverside pastures. Yet never once was the local character of the land of sufficient significance to be mentioned by the teachers. I realized vaguely even then that our education *did not start at the beginning*, not from the soil and the river from which our life began, *but from somewhere else*, as if the roots of being did not matter in education and could be left invisible or unknown almost for ever to the instructed mind. It taught us to be gentlemen, something superior to the soil. It cut us

away at the start from the Islamic sanctity of the soil. And this stigma most of us had to carry throughout our lives, only the rare sceptic might escape from its trammels. Even when the Empire's needs called some of my colleagues to the charge of primitive agricultural peoples, the stigma remained. 'Unfortunately most of the Europeans who come out to this country (Nigeria)', stated Mr. G. N. Herrington, at a West African Agricultural Conference in 1938, 'have received an education which is divorced from rural life and few have any knowledge of its interest and variety, or the intelligent skill that rural life entails. This type of education has created a traditional attitude that is very difficult to overcome.' It has only very rarely been overcome, only in great sceptics and men with rare sympathy for their rural subjects, such as were pre-eminent in British India before the Mutiny, the four M's, Sir Thomas Munro, Sir John Malcolm, Sir Mountstuart Elphinstone and Sir Charles Metcalfe. Because of this almost invincible, traditional attitude, our empire over rural lands has been one mostly divorced from rural life and antagonistic to the soil.

In addition, to the famous British public schools, education in our state schools, in the United States and other countries, has had the same tendency. In the German University, where I spent eighteen months in post-graduate education, it seemed to me, then more awakened to the fault, to be the same; men with so-called brains were considered to be suited for something better and more *lucrative* than for work upon the land. This profound fault in the education of the Industrial Era has worked untold mischief in health, sanity, food and the conservation of the soil. It makes education undoubtedly an opponent, not an adjuvant to reconstruction via the soil.

The new men and women -- for the war has brought many women in direct contact with the land -- will be those who have been shaped and fashioned by the soil to a serenity, a sense of the spaciousness of time, and a capacity of individual judgment. The soil itself has been their textbook and printed books only subsidiary. Books widen the understanding and give to their students knowledge of many chemical and physical properties of the earth's crust, but they have not the magic in revelation of the soil itself. They are very valuable supports and helpers, but they are not initiators of the sense of kinship. Initiation belongs only to the parent of life.

The new men and women know the soil and its creative powers personally, learning chiefly through their eyes and muscle-sense, and not through their ears. Their knowledge and feeling for the soil are the same as they are for other living things, a matter of touch, smell and sight, a physical response to contact with it. It is made up of a variety of factors; the feel and sight of rain, snow, dew, sun and wind; the characters and purposes of hedges, woods, fields, hills, valleys and plains, of insects, plants, flowers, weeds, all subject to the seasons in their progress through the years. It is, then, something very real, something very vital, something that proclaims an ordered multitude of being, far transcending the ephemeral life of individuals. 'It is to the fresh air of the open field that we belong by right,' said Goethe. 'It is as if the Spirit of God there breathes immediately upon men and thereby a godlike strength exercises its influence.'

The new men and women possess or gain a health that transcends what the practitioners of scientific medicine have taught the public to regard as health, namely, something that can be acquired by a process of severally discovering and putting into practice means of escape or recovery from diseases in their severalty. What will be required is not this, but the positive, whole health, which exists in itself quite apart from disease. It will be required, because it is a necessary prerequisite of the comprehensive simplification which the times require. Cleverness there is at the present day in abundance, for when the simplification of positive health is mostly absent, cleverness finds opportunity in a thousand hydra-headed problems. It is for this reason that, in spite of the numbers of educated, clever men and women and in spite of their signal ability in dealing with fragmentary social and political difficulties, in their lack of the central understanding of what was really happening in the world they failed entirely to avoid the emergence of a series of catastrophes. Health, therefore, there must be. Its simplification -- such as healthy fields bring healthy men -- of hydra-headed difficulties is essential.

Health is, as Goethe said of truth, like a diamond, it emits its rays in all directions. Being whole itself, it brings with it a lively valuation of the things of health and wholesomeness, and a ready acceptance of them with rejection of the fragmentary. Its convictions are not mere matters of mental persuasion. They are matters of bodily response, sober in action and hard to oust, for they are creatively positive. By right choosing, they prevent the complication of many particulate solutions burdening a problem with much argument, for they are attracted to the right intuitively. The correct terrene life is in reality not nearly so difficult as the wrong, because it is *simple* in the root meaning of the word, which is unity.

It is to men and women so equipped that the initial guidance of reconstruction should be entrusted. Power comes later, when conviction of the need has become widespread. Then power will be given, as it was willingly and freely given by the people to its leaders during the war. Of this power, the great urgency of war has provided many valuable precedents, the memory of which, it is hoped, will not be permitted to die out with the rapidity that affects the day to day memory, which the swift transition of events and the concentration on those of the present inculcate in the public. Of these precedents there are few which surpass that established by Lord Woolton, Minister of Food in Britain. His is, to my mind, a classic example of an inspiration to workers in many, if not all, countries concerned in these primary matters. One only wishes that reconstruction via the soil could be almost a continuance of the work done by the Departments of Food and Agriculture, without the long lapse that seems inevitable for the initiation of the public to the need for reconstruction.

As to the nature of the work of initiation, it will come under some such headings as the following:

1. The restoration of the peasantries and peasant families as the cardinal cultivators of the soil; the use of large estates, where suitable to particular soils, forms of

cultivation, or social conditions.
2. The freedom of the soil from money-power.
3. The first claim of the soil upon a country's water; the local control of its distribution.
4. A rural education, which is, locally and generally, a true soil-education.
5. An education of all urban populations, which begins at the beginning in the soil and in the life which it provides to all men.
6. The adoption by both town and country of the rule of return.
7. The unity of the healths of the soil, the plant, the animal and man.
8. The right of all men to their share of essential foods and work.
9. The use of modern technique in promoting and maintaining the brotherhood of man throughout the world by the common bond of the soil and its conservation.

The gateways of change have been thrown open by the war, and when I venture near them to descry a vista of the future, I must confess that I am possessed by a dazzling vision of which this cruel war seems to be the immediate, creative cause.

The war has brought together, as allies, the four Powers that have control over the four greatest areas of land upon the surface of the globe. These four Powers divide themselves by neighbourhood into two pairs, namely, China and Russia, with a basic similarity soon to be propounded, the other pair, connected by the mediate country of Canada, the United States and the British Empire, the two leading capitalistic powers of the world.

These four allies form a strange conjunction of many differences. There is first the aged China, with an unequalled history of stability and conservatism, now torn asunder by the inroads of modernity. Secondly, there is Russia, also an ancient, historical autocracy, which has recently overthrown capitalism and with so fierce an energy has created a Collective State. Thirdly, there is the United States, so compact in the spacious unity of their land, in which they endeavoured to shut themselves from the troubles of the world, but suddenly aroused to the futility of this isolation by the catastrophe of Pearl Harbour. Lastly, there is the British Empire of dominions so wide and varied as to make it the leading power of the world, but aghast at the discovery of its inability to protect its far-flung possessions and almost its homeland, in the early years of the war.

There are, then, apparent infusible differences of need and necessity in the character and circumstance of the four allies, and especially do they reveal themselves if attempts to effect a fusion are made by the agency of politics and politicians.

One general need, however, indissolubly binds the four. It is to prevent the repetition of the present in the future by precluding the possibility, now and for ever, of further irruptions of the Teutonic Northerners or their pupils of the Pacific Sea.

Apart from this need it must seem, to those not instructed in the present terrene state of mankind, that genuine unity will find no bond in the manifest differences of character and

circumstance of the four allies. Yet there is such a bond, the bond that ultimately unites all terrene men in an ultimate similarity, and that bond is the soil. *It is the soil, and the soil alone, which can bind the four Powers together in a reconstruction of life. All four Powers, and with them the rest of the wide earth, are bound together as to their future state by the perilous condition of the world's soil. None can escape its dangers in the new technical unity of the world. That is the one imperative and vital bond in their conjunction for reconstruction.*

Let us take the four allies severally and see what contributions they can make to this fundamental question of life itself and to their own particular needs with regard to it.

The Chinese are by far the oldest people of the allies. Their contribution is that of the accumulated wisdom of four thousand years.

None have better described this gift of the historic Chinese and their pupils the Koreans and pre-modern Japanese, than Professor King in a partially written *Message of China and Japan to the World*, which he proposed to add to his great book on the *Farmers of Forty Centuries*, but which purpose was frustrated by his death.

In the part of this message that has survived his death, he wrote: 'It could not be other than a matter of the highest industrial, educational and social importance to any nation, if it could be furnished with a full and accurate account of all those conditions which have made it possible for such dense populations to be maintained upon the products of the Chinese, Korean and Japanese soils. Many of the steps, phases and practices through which this evolution has passed are irrecoverably buried in the past, but such remarkable maintenance attained centuries ago and projected into the present with little apparent decadence merits the most profound study. Living as we do in the morning of a century of transition from isolated to cosmopolitan national life, when profound readjustments, industrial, educative and social, must result, such an investigation cannot be made too soon.'

The practices and the methods, by which these meticulously careful farmers conserved the fertility of their soils are nowhere better described than in the pages of King's book. But he makes no specific mention of the Tsing Tien System of which Dr. Ping-Hua Lee, in Volume 99 of the Columbia University of New York's *Studies in History*, wrote: 'The whole history of the government administration of agriculture in China coincides with the Tsing Tien System. Its vicissitudes, its crises and its epochs were timed by the abolition or re-establishment of the System ... It is fortunate for the economic historian that the Tsing Tien System is coincident with China's political history.'

Yet, not the Chinese farmers' devotion to the rule of return; not their incomparable and tireless spreading of the mud of their numerous canals to the extent of seventy tons per acre; not their careful preservation of the humble earth-worm, who, said Darwin, spreads ten tons per acre of an even finer soil than silt upon the fields he studied, in addition to the

other services he so eloquently eulogizes; not the irrigation of their carefully levelled fields; not the mixed crops, will form a bond more firmly riveting peasants to peasants than this Tsing Tien System. What else, indeed, is the *Kolkhoz* System of the present Russians than the Tsing Tien System modified to suit their imperative duty to provide food and other soil-products for the hundred and more new manufacturing towns which were built to give them their place amongst the modern Powers, and to equip them for the Power-war, for which their rulers prepared with such marvellous speed? The Russian farming families have the same private fields handed over to them for continuous ownership and their partial subsistence. The central plot, immensely larger though it is than the ninth field of the Chinese sages, is like that ninth field in that it is the State's plot, worked co-operatively by the Russian farming families.

Moreover, the very dangers of the Kolkhoz System, in the pressure that perforce was put upon it for large and speedy returns by the threat of war, will find their solution nowhere better than in a study of Chinese methods. There can be no stronger bond between two huge, neighbouring terrene peoples, the Chinese and the Russians, than this bond of their peasantries.

The Chinese themselves are also in great need of effective bonds with their allies. Anyone who has talked to the Chinese leaders, knows how eagerly they look to the great water engineers of the British Empire and the United States, for instruction to curb the devastating floods of their great rivers, especially the Yellow River; to re-forest their barren catchment areas; to refructify the fertile loess soil, which was the teeming home of their first ancestors, but is now so miserably given over to waste; and in a hundred other ways to assist in the reconstruction of a distraught farming people. No one of the allies, then, has so much to give and so much to receive in the bonds of the soil as the Chinese.

The Russians are the next oldest people of wide dominions to the Chinese. Ivan IV (A.D. 1533-84), Ivan the Terrible, is now heralded as one of the greatest fathers of the Russian people. With ruthless determination, he consolidated the Russian lands, drove out the Mongols, made the Volga into a Russian river, annexed Siberia and made its lands so attractive to the Russian peasants that his successor to power, Boris Godounov, issued an order stopping further migrations of peasant families.

In Chapter 19 we have seen how the Russians had eroded vast areas of their land more or less from the time of Ivan onwards and mainly by the destruction of forests in order to open up new land. They did not even spare the watersheds and their slopes. But the tempo of those days was far slower than that of the modern Russians. Their need of cash for foreign machinery led to the wholesale destruction of Russian and Siberian forests, the timber of which was sold. The Steppe and other and lands did not offer the same inducement, so, while they were developed and arid lands were reclaimed with singular skill, the forested lands were gravely depleted. To the warning of Professor Kornev, quoted by Messrs. Jacks and Whyte, the two authors added this comment: 'The tractor plough is the enemy of grassland in dry areas, but is indispensable to the propagandist in

the modernization of Russian agriculture. Though fore-warned by the experience of other countries, it is difficult to ascertain if the authorities are aware of the danger of mechanization.'

To what degree the Russians have degraded their farmed soil owing to the pressure of the war cannot yet be known, but it must be considerable; it may be, indeed, the greatest loss which they as victors in the war have suffered. That they have much to give and much to receive from their allies in terms of the soil is clear. They can give their experience particularly in the reclamation of arid land; they can give the picture of land developed under an economic system by which the land is developed and farmed without the burden of financial debt, but with the help of their share of the State's revenues; they were about to give in their fourth Five-Year Plan a control of water of a stupendous character, linking together the waters of the north-flowing and south-flowing rivers, as well as individual rivers, and the same with the rivers flowing east and west, perhaps, to use Professor Kornev's words, an act 'of the excessive breaking-up of the topography', the results of which can only be estimated by experience. Yet, on a small scale, Mesopotamia once gave an example of unparalleled success in a linking of rivers.

So the Russians have much to give in terms of the soil. They have also much to receive; especially from the great work of the Americans of the United States in the reclamation and conservation of arid lands, and the re-growth of forests upon watersheds. They have, then, many bonds to forge in terms of the soil.

The last two allies give pictures of the development of farming of land under the dominion of money. The picture that they present has already been sufficiently illustrated in previous chapters as one of progressive destruction of life for temporarily successful financial farming and ranching. They have both pursued the path of Rome with a tempo far exceeding that of Rome. One writer, indeed, has stated that North America would, at the pace set, be turned into a Sahara within a century.

The rude fact is that neither the Americans nor the British are yet civilized in terms of the soil; neither has yet learnt the meaning of the Wisdom of the East. Their use of their dominant money is too often nomadic. They invest it in land or other ventures for *personal profit* and, when profit fails to appear, the pressed and overworked land is abandoned, and finance transfers itself to other ventures, even such as the help of other countries to arm themselves in a preparation to fight the very countries and peoples of the lending financiers themselves. Between the financiers and the nomads, between them and the practitioners of shifting cultivation, there is, indeed, very little difference in principle and in values in terms of the soil. Only the nomads of the past consciously risked much more; they risked their lives, those of their wives and children, their very existence. The financial nomads, on the other hand, consciously risked very little. They risked much *unconsciously*; their own lives by enemy bombing, those of their wives and children, their homes and the very safety and freedom of the countries in which they lived.

The Americans of North America, and especially the farmers of the United States, have recently become woefully aware and alarmed at the results of nomadism on the soil, of the free cutting down of forests, of over-grazing of the deforested land, of the deep ploughing and mechanical farming of their prairies, of the one-year tenures of farms which enable men to turn fertility into cash and, when this land is degraded, to purchase new land in the great territories of fertile soil which are still theirs. They can ponder over special maps, as we pondered, in Chapter 6, over the map of Asia, and read their fate in its distinctions. Such a special map of the United States is to be found on page 51 of Messrs. Jacks and Whyte's now famous warning to the world. The land of little or no erosion is white, the lands of erosion are graded in shades to indicate its character and degree. One may well shudder at the supreme peril of this great people, if one ponders on the human meaning of this map. The white areas are so few; they seem to cover but a tenth of the map. The rest is eroded lands, according to their kind and their degree, together with mountains, mesas, canyons, and bad-lands. This visual evidence is enhanced by a number of photographs, which terrify the mind, eased though it is by the knowledge that what is happening points to a dread future, to which our own span of life will not extend. 'Not in our time, 0 Lord,' but surely enough, in our time, and to many farmers who have witnessed their farms blown away in storms of dust, 'in our time' with a poignant reality.

Against this tale of home-destruction, with the haunting fear it brings to farmers of the richest country in the world in money, can now be set the supreme achievement of the Tennessee Valley Authority, which has brought about in the valley's inhabitants a veritable resurrection of the human spirit. Mr. Lilienthal does not fail to lay stress on this human change-about and quotes these words from an editorial of a newspaper of Alabama, one of the seven states: 'We can write of the great dam ... of the building of home-grown industry and of electricity at last coming to the farms of thousands of farm people in the Valley. *Yet the significant advance has been made in the thinking of a people*. They are no longer afraid. *They have caught the vision of their own powers*.'

This gift of confidence, one thinks, will be the outstanding contribution of the U.S.A. It has already attracted the keen interest of many governments of South America, Europe, the East and South Africa. But, if the men of the United States have much to give, they have also much to learn from their Allies. From the Russians, they can learn the value of saving the soil from the dominance of money; from the Chinese, the meticulous conservation of the soil, the full rule of return, and agriculture as a national art; and since they now have colonies; from the British, the right and wrong ways of the treatment of tropical colonies, and much else.

The gift of the British to their allies is, indeed, unique in that they, with their extensive empire, have been brought into relationship with all kinds and varieties of terrene conditions. The British have the greatest world-knowledge; ranging from the many millions of India and their imperilment due to their relation of the soil, which I have described elsewhere in my *Restoration of the Peasantries*, 1939; from the vast plains of Canada, which share so fully the most dramatic dangers of the Dust Bowl of the United

States; from the disasters that are afflicting her Australasian colonies; from the erosion and degradation of the fertile West Indian Islands, to the little twin islands of the Falklands in the cold waters of the South Atlantic. They are, indeed, fortunate, in comparison to their allies, in that their homeland, set in a temperate sea and served by a humid climate, is almost free from the dangers of erosion. The problems of the reconstruction of its misused soil have not the gigantic proportions of the homelands of the other three.

They, therefore, with the vast varieties of their experience, can act as bonds not only between the Allies, but between them and the whole wide world. Their knowledge of cold, temperate and tropical soils and their peoples is not yet understanding enough for them to be the bond that is needful, but at least they possess the links, through which that knowledge, when recognized and formulated, can be diffused. With their contact with their allies and their contact with many lands and their peoples, with their empire-made neighbours, they, like their great technical achievements, are making the world one.

The meeting of the Four Powers, then, has potentially a far greater meaning than the somewhat hackneyed phrase of a Conference of Powers customarily conveys. It is a meeting, not of tongues and diplomats of the countries they represent, but of the soil of the world and of mankind. It is a meeting, not of four great Powers only, but of four great masses of men all witnessing the rebellion of the soil to its human treatment. They are severally not China, but the Chinese with their forty centuries of farming; not Russia, but the Russians, who first conjoined great tracts of two continents in one whole and who are now testing ways of treating their soils so as to form the basis of a civilization of stability; not the United States, but Americans, people of yet another continent, who are gathering their forces together to stem the terror of an insulted virgin soil; not Britain, but the British, who have been marching upon the path of soil destruction so clearly marked out by Rome, but who, with a like courage and enterprise to that great people, link together most parts of the habitable world. What a conjunction of opportunity! The heart almost stops at the thought that, had the war ended as at one time it seemed it might end, the future of the world would have belonged to the Germans, who, shut in their history between their southern and eastern neighbours and two cold northern seas, have none of the treasures of experience which the Four Allies can bring to reconstruction.

But to the Four Allies are opened the gateways of an opportunity to bless the whole world as never before. Beyond the murk and rubble of the war; beyond the last, bleak resting places of millions of heroic men; beyond the razed homes and shattered towns of 'the quiet people'; beyond the scorched acres and barren fields; beyond the famines and their reign of death; beyond all this horrible orgy of life-destruction, is seen the vista of the living earth. as the source of the reconstruction of terrene mankind. At the gateways stand sentinels awaiting the password -- THE SOIL.

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Recycling from Municipal Refuse: A State-of-the-Art Review and Annotated Bibliography

By: Sandra Johnson Cointreau, Charles G. Gunnerson, John M. Huls, Neil N. Seldman

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Integrated Resource Recovery

UNDP Project Management Report Number 1

INTEGRATED RESOURCE RECOVERY SERIES

GLO/80/004

Number 1

This is the first in a series of reports being prepared by the Resource Recovery Project as part of a global effort to realize the goal of the United Nations International Drinking Water Supply and Sanitation Decade, which is to extend domestic and community water supply and sanitation services throughout the developing world during 1981 to 1990. The project objective is to encourage resource recovery as a means of offsetting some of the costs of community sanitation.

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Effluent Irrigation
Remanufacturing
Transferable Technologies
Ultimate (marine) Disposal

and a series of case studies of various projects throughout the world.

Series cover design (clockwise from top): Aquaculture using wastewater yields about 8 tons of fish per hectare per year in India. Biogas is produced from organic wastes in India. Sullage from a shower is used to irrigate a garden in the Sudan. The original value added to aluminum is captured by using waste oil to melt scrap and then pouring new ingots in Egypt. A "state-of-the-art" plant, built to demonstrate the pyrolysis of garbage to make fuel oil, has been shut down temporarily because of excessive operation and maintenance costs in the United States. Paper is recycled in a factory of the Shanghai Resource Recovery and Utilization Company in China.

This report is printed on recycled paper.

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Recycling from Municipal Refuse

A State-of-the-Art Review and Annotated Bibliography

Sandra Johnson Cointreau, Charles Gunnerson, John M. Huls,
and Neil N. Seldman
with the assistance of
Phillip Mitchell, Lee Jackson Long, and Elissa Courtney Bellassai

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Sandra Johnson Cointreau is president of Solid Waste Management Consulting Services, Ltd; Charles G. Gunnerson is senior project officer in the Water Supply and Urban Development Department of the World Bank; John M. Huls is an associate with Harding, Lawson, and Associates; and Neil N. Seldman is president of the Institute for Local Self-Reliance. Phillip Mitchell is an information research assistant with, and Lee Jackson Long and Elissa Bellassai are consultants to, the World Bank.

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ABSTRACT

This report is in two parts: a concise state-of-the-art overview of recycling from municipal refuse, focusing on techniques and conditions germane to developing countries; and an annotated bibliography with abstracts of more than 200 published references on recycling. It was prepared as part of a global research, development and demonstration effort of the United Nations Development Programme and the World Bank.

Recycling is used in its broadest sense, encompassing the full range of resource recovery and reuse techniques, including repair, remanufacture, materials recovery and energy conversion of refuse materials, broken machine parts, and discarded consumer products. The philosophy behind the report is that some of the value added from production activities, such as agriculture, mining and manufacture, is retained when a "waste" is recycled. Thus, through recycling, more sustainable economies, for countries and cities, are achievable.

The state-of-the-art overview contains numerous case examples of recycling efforts throughout the world. It provides insight into the informal network of relationships and incentives that affect recycling. Techniques of recycling are arrayed, focusing on those of limited mechanization that better meet the needs for job development and constraints on foreign exchange in developing countries. Strategies which several countries have used to encourage recycling are highlighted, showing the needs for public education and government support in linking macroeconomic benefits and microeconomic costs.

The annotated bibliography, with selections from a world wide search in which several thousand documents were collected and reviewed, covers a wide spectrum of published references providing technical, economic, institutional, environmental and cultural information about recycling.

CONDENSE

Le présent rapport comprend deux parties : un examen concis de la situation actuelle du recyclage des déchets urbains, principalement les techniques et la situation dans les pays en développement, et une bibliographie annotée portant sur plus de 200 ouvrages de référence sur le recyclage qui ont été publiés. Il a été préparé dans le cadre d'un effort global de recherche, de développement et de démonstration auquel ont participé le Programme des Nations Unies pour le développement et la Banque mondiale.

Le terme recyclage est ici utilisé dans son sens le plus large, et recouvre toute la gamme des techniques de recouvrement et de réutilisation des ressources, notamment réparation, réfection, recouvrement de matériaux et conversion pour produire de l'énergie, portant sur les déchets, pièces d'outillage cassées et produits de consommation jetés. L'idée directrice du rapport est qu'une partie de la valeur ajoutée par les activités de production telles que l'agriculture, l'extraction minière et la fabrication, est conservée lorsqu'il y a recyclage d'un "déchet". En conséquence, le recyclage des déchets devrait permettre aux pays et aux agglomérations urbaines de mieux soutenir le niveau de développement économique atteint.

L'analyse de la situation actuelle contient de nombreux cas de recyclage pris dans le monde entier et examine le réseau informel de relations et de motivations affectant le recyclage. Les différentes techniques de recyclage sont présentées, particulièrement celles qui s'appuient sur une mécanisation réduite et qui par conséquent favorisent particulièrement la création d'emplois et ne font pas beaucoup appel aux ressources en devises limitées des pays en développement. Le document présente les stratégies utilisées par plusieurs pays pour encourager le recyclage en mettant l'accent sur le soutien indispensable du Gouvernement et sur l'éducation de la population dans les efforts déployés pour lier les avantages macroéconomiques et les coûts microéconomiques.

La bibliographie annotée, choisie parmi plusieurs milliers de documents rassemblés dans le monde entier, couvre une gamme étendue d'ouvrages de référence publiés et fournissant des renseignements techniques, économiques, institutionnels, écologiques et culturels sur le recyclage.

EXTRACTO

Este informe consta de dos partes: una reseña concisa de la tecnología actual del reciclaje de los desechos municipales, que se concentra en las técnicas y condiciones propias de los países en desarrollo, y una bibliografía comentada, con extractos de más de 200 publicaciones sobre reciclaje. Fue preparado como parte de un trabajo global de investigación, desarrollo y demostración del Programa de las Naciones Unidas para el Desarrollo y el Banco Mundial.

El término reciclaje se emplea en su sentido más amplio, que comprende toda la gama de las técnicas de recuperación y reuso de recursos, incluso la reparación, remanufactura, recuperación de materiales y conversión de energía de materiales de desecho, piezas de máquina rotas y productos de consumo desechados. La idea que hay detrás de este informe es que parte del valor agregado en actividades como la agricultura, minería y manufactura se retiene cuando se recicla un "desecho". Por lo tanto, mediante el reciclaje los países y ciudades pueden lograr economías más sostenibles.

La reseña contiene numerosos ejemplos de reciclaje en todo el mundo. Permite discernir la red informal de relaciones e incentivos que afectan al reciclaje. Las técnicas de reciclaje se presentan en cierto orden, poniendo de relieve las de mecanización limitada que mejor se adaptan a las necesidades de los países en desarrollo en lo que respecta a la generación de empleos y las limitaciones de las divisas. Se destacan las estrategias que varios países ya han usado para fomentar el reciclaje y se demuestra que para vincular los beneficios macroeconómicos con los costos microeconómicos se necesitan la educación pública y el apoyo del gobierno.

La bibliografía comentada --que contiene selecciones efectuadas después de haber reunido y examinado varios miles de documentos que se buscaron en el munto entero-- comprende una amplia gama de referencias publicadas que ofrecen información técnica, económica, institucional, ambiental y cultural sobre el reciclaje.

Recycling from Municipal Refuse: A State-of-the-Art Review and Annotated Bibliography

Sandra Johnson Cointreau, Charles G. Gunnerson, John M. Huls, and Neil N. Seldman

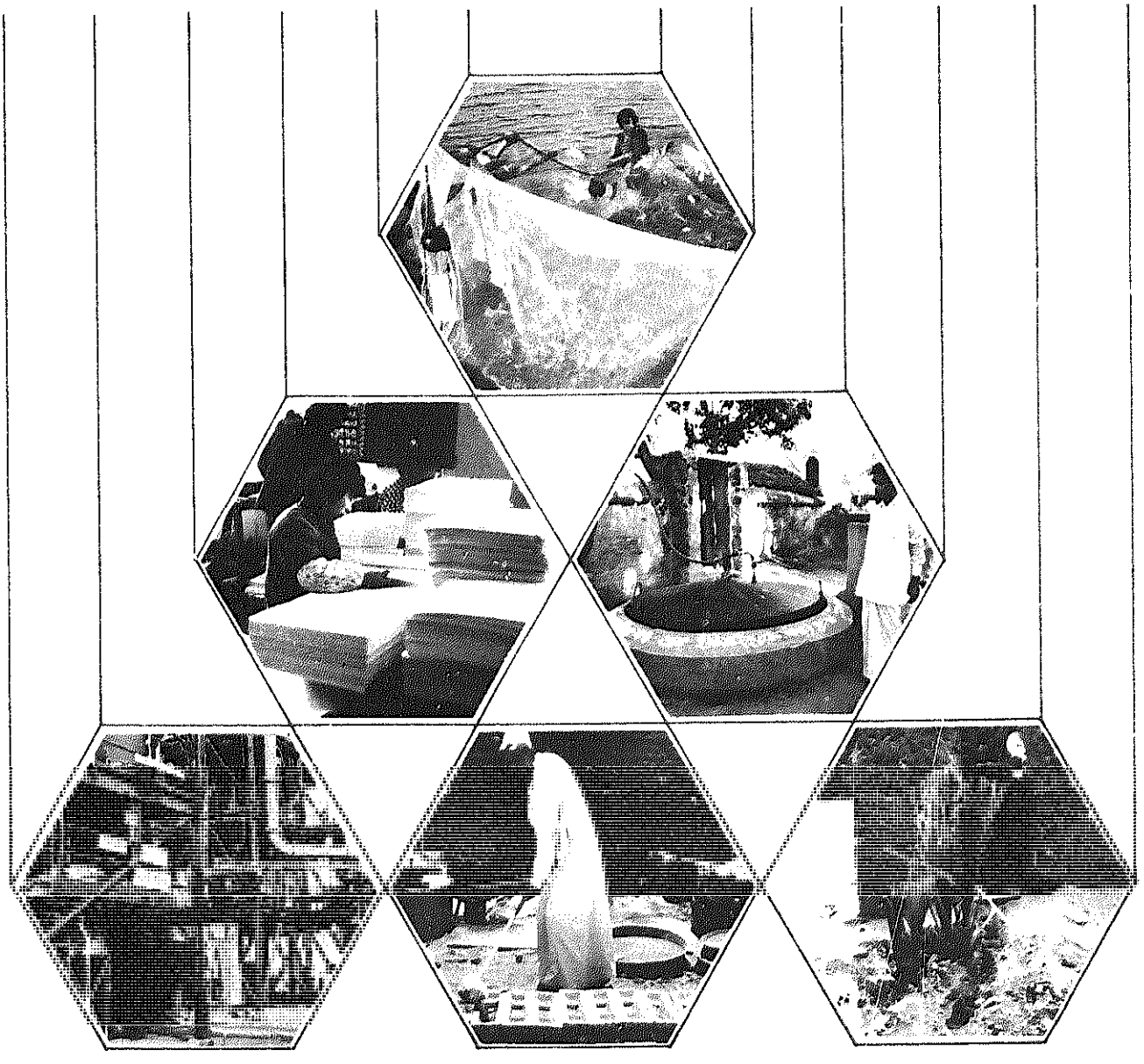

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FOREWORD

There is increasing recognition in both developing and industrial countries of the need for technical and economic efficiency in allocation and utilization of resources. A World Bank Report has been directed to this end, within a study on Appropriate Technology for Water Supply and Waste Disposal. As part of the United Nations International Drinking Water Supply and Sanitation Decade, it was concluded that research and development in integrated systems for recovery and utilization of household and community wastes should be conducted.

In 1981, a three year global research and development project on integrated resource recovery (GLO/80/004) was undertaken by the World Bank as executing agency for the UNDP-United Nations Development Programme (DGIP). Project goals are to achieve economic and environmental benefits through sustainable resource recovery and utilization projects and programs in developing countries. Liquid and solid wastes from municipal, commercial and agricultural sources and their recycling are within the scope of the project.

Sustainability in waste management systems depends upon a number of important policy, technical and economic interrelationships. These interrelationships are particularly important in integrated resource recovery. The project was conceived and initiated by John M. Kalbermatten, Senior Adviser, Water and Wastes. The objective of the series is to provide governments, development agencies, consultants and others with information necessary for waste management policy development and implementation. This document summarizes the state-of-the-art of resource recovery applicable to cities in developing countries as reported in the literature, mostly in English, up to the early 1980's.

We would like to express our sincere thanks to Charles G. Gunnerson whose efforts led to this report and the others that will be published. Your comments on this report would be especially welcomed.

PREFACE

This is the first in a series of reports being prepared by the Resource Recovery Project. It is part of a global effort to realize the goal of the United Nations International Drinking Water and Sanitation Supply Decade, which is to extend domestic and community water supply and sanitation services throughout the developing world during 1981 to 1990.

The Resource Recovery Project was conceived and initiated by John M. Kalbermatten, Senior Advisor, Water and Wastes, and received executive and administrative support from Christopher R. Willoughby, Director, Transportation and Water Department, World Bank; and financial support from the United Nations Development Programme, Global and Interregional Projects Division, William R. Mashler, Senior Director.

The project objective is to encourage resource recovery as a means of offsetting some of the costs of community sanitation. This report and the annotated bibliography which follows focus on municipal refuse and its recycling potential. The bibliography includes documentation published mostly in English through 1981. Readers are referred to the publications and regularly scheduled specialty conferences listed in Annex I for more recent bibliographic documentation.

CONTRIBUTORS

The text of the state-of-the-art report on recycling was written by Sandra Johnson Cointreau, Solid Waste Management Consulting Services, Ltd. John M. Huls, Harding, Lawson & Associates, and Neil N. Seldman, Institute for Local Self-Reliance, reviewed and compiled the literature and contributed to both the report and the annotated bibliography.

Charles G. Gunnerson, Senior Project Officer, World Bank, contributed to, and was responsible for, scientific and technological editing of the state-of-the-art report and annotated bibliography. Lee Jackson Long and Elissa Courtney Bellassai, consultants, edited both the report and the bibliography.

Phillip Mitchell, World Bank, performed the computerized literature search. Grace Whittome, World Bank, retrieved documents through interlibrary loan; and David Bardaglio and Belinda Watts, Institute for Local Self-Reliance, also retrieved documents and provided report production support.

PART I. STATE-OF-THE-ART REVIEW

RECYCLING FROM MUNICIPAL REFUSE

Introduction

Municipal refuse contains inherent values. Recycling provides an opportunity to recover some of these values in municipal refuse, particularly in the form of long-term energy and resource savings. For the purposes of this report, the term recycling is used in its broadest sense, encompassing the full range of resource recovery and reuse techniques, which include repair, remanufacture, and conversion of materials, parts and products.

The essential reason for recycling is that some of the value added through production activities such as agriculture, mining and manufacture is retained. And thus, through recycling, more sustainable economies, for countries and cities, are achievable.

A key to increasing the extent of recycling is to acknowledge and assess long-term savings. Costs ordinarily accrue to different sectors than those receiving benefits, and over different time spans. Therefore, economic strategies are needed to translate the more macroeconomic benefits into short-term direct profits for communities, entrepeneurs, residents and workers who actually perform the work of recovering and reusing wastes.

In this report, potential benefits from recycling wastes are summarized. Furthermore, prominent reasons why recycling is not practiced to its fullest potential are discussed. The report outlines methods of recycling which are being used, concentrating on those which are readily applicable in developing countries.

Further details on recycling techniques are provided in the references and the accompanying bibliography. Perhaps more importantly, strategies which have been implemented in several developing countries to overcome cultural, economic and institutional barriers to recycling are discussed.

The focus of this report is municipal refuse, and the formal and informal institutions involved in recycling. Included in municipal refuse are solid wastes from households, commercial establishments, markets, industries, institutions, and streets. Refuse composition is a function of levels of consumption, which are related to overall economic levels. Table 1 indicates how paper, metal, organic matter, etc.,

Table 1

PATTERNS OF MUNICIPAL REFUSE QUANTITIES AND CHARACTERISTICS FOR LOW, MIDDLE AND UPPER INCOME COUNTRIES

	Low-Income Countries[a]	Middle-Income Countries[b]	Industrialized Countries
Waste Generation (kg/cap/day)	0.4 to 0.6	0.5 to 0.9	0.7 to 1.8
Waste Densities (wet weight basis-kg/cubic meter)	250 to 500	170 to 330	100 to 200
Moisture Content (% wet weight at point of generation)	40 to 80	40 to 60	20 to 40
Composition (% by wet weight)			
Paper	1 to 10	15 to 40	15 to 50
Glass, Ceramics	1 to 10	1 to 10	4 to 12
Metals	1 to 5	1 to 5	3 to 13
Plastics	1 to 5	2 to 6	2 to 10
Leather, Rubber	1 to 5	-	-
Wood, Bones, Straw	1 to 5	-	-
Textiles	1 to 5	2 to 10	2 to 10
Vegetable/Putrescible	40 to 85	20 to 65	20 to 50c
Miscellaneous inerts	1 to 40	1 to 30	1 to 20
Particle Size, % greater than 50 mm	5 to 35	-	10 to 85

a Includes countries having an annual per capita income of less than US$360 in 1978.

b Includes countries having an annual per capita income of more than US$360 and less than US$3,500 in 1978.

c This may be reduced in areas with household or commercial garbage grinders which discharge to sewers.

contents vary in cities of low-income, middle-income, and industrial countries.

A material becomes a waste when the owner or generator of a material discards it without expecting to be compensated for its inherent value. Most municipalities consider wastes to be their responsibility (and within their domain of "ownership") only after they have been placed on the curb or street for municipal collection and disposal.

Municipal solid waste recycling activities contend with mixtures of materials. The more a waste is mixed with others from various sources of generation, the more difficult it is to recover for reuse. There are a number of points in the waste management system, between initial waste discharge and ultimate waste disposal, where recycling can occur. Generally, the nearer to the origin of the waste that recovery occurs, the less sorting and processing will be needed before the material can be recycled.

Incentives for Recycling

Recycling both conserves and uses energy, materials and products. If it conserves more than it uses, it may save material, money, and enviromental degradation. In the process, it may also reduce dependence on foreign imports, create employment and small scale enterprises, and build up skills of industrialization through repair and remanufacturing.

Energy savings occur from the recycling of metals. For example, producing copper from already segregated scrap metal requires only about one-tenth the energy required for production from virgin cooper ore.(70) Recycling magnesium results in a 97 percent energy savings, and recycling aluminum results in a 96 percent energy savings.(32) Using scrap instead of iron ore to make new steel means a 74 percent energy savings.(33) This is equivalent to estimated energy savings of about 350 x 10^{6} BTU per ton (95 x 10^{6} kcal/tonne) of recycled magnesium, 250 x 10^{6} BTU per ton (60 x 10^{6} kcal/tonne) of recycled aluminum, and 200 x 10^{6} BTU per ton (55 x 10^{6} kcal/tonne) of recycled steel.

Similarly, energy is saved when paper, glass and rubber are recycled. Recycling of office-grade paper, for example, has been shown to result in an energy savings of 26 x 10^{6} BTU per ton (7 x 10^{6} kcal/-tonne), over production from virgin wood materials.(32) The U.S. Glass Packaging Institute notes that roughly a 1/2 percent savings in energy

accrues from every 1 percent of cullet (broken glass) above 15 percent.(5) To produce a pound of virgin rubber, 31.4 x 10^6 BTU per ton (8 x 10^6 kcal/tonne) are required; while that expended to produce recycled rubber is only 9.2 x 10^6 BTU per ton (2.5 x 10^6 kcal/tonne), an energy savings potential of over 70%. Furthermore, much less energy is required to manufacture a product from recycled versus virgin rubber, sometimes as little as 60% of the energy required for virgin rubber.(33)

Grandjean estimated energy savings from the existing recycling of municipal refuse of two main Colombian cities--Medellin and Bogota.(36) Extrapolating from his estimates, and assuming comparable waste generation and waste recovery rates for all of Colombia's urban population, an estimated 2.4 x 10^9 kilowatt hours of energy probably was saved in 1980. This total was equivalent to about 1.4 x 10^6 barrels of oil, or 19 percent of Colombia's petroleum imports.(30, 31)

These examples indicate that the energy equivalent of recyclable materials could be far greater than potential energy generated from the conversion of solid wastes by incineration, refuse derived fuel, pyrolysis or anaerobic digestion technologies. It has been estimated that converting refuse to energy in Germany, France, Great Britain and Italy could offset only 1 to 2 percent of their national electricity demands.

Product recycling yields the highest potential energy savings. Overby (56) reports from a number of sources on the potential for saving energy through reconditioning and remanufacturing goods (which involves centralized disassembly, inspection, restoration or replacement of worn components, reassembly, testing and distribution of durable products). For example, original manufacture of a new automobile engine requires about 13 x 10^6 BTU (4 x 10^6 kcal), of which 35% can be retained by remanufacturing. Similarly, he estimates that 65 x 10^{12} BTU (16 x 10^{12} kcal) could have been saved in the United States in 1973 if all tires had been recapped once, which is roughly equivalent to 160 x 10^6 barrels of petroleum.

Recycling also conserves water resources. For example, nationwide implementation of reuseable beverage containers in the United States could reduce use of process-water for glass manufacture by 44 percent. (14) Use of steel scrap instead of virgin iron ore can reduce water use in steel-making by 40%, as well as reduce resulting water pollutants discharged by 76%.(33)

Some recycling is stimulated by environmental concerns, as well as market demand for recoverable resources. For example, a plant converting solid waste to energy in Nancy, France, is removing polyvinylchloride from plastic bottles prior to combustion, in order to limit chlorine emission from the stack as well as recover plastics.

Dependence on chemical fertilizers, which are petroleum-derived and commonly imported by developing countries, could be reduced through recycling and reuse of organic wastes as organic fertilizers. Solid wastes containing appreciable portions of organic matter are converted to organic fertilizers through techniques such as composting and anaerobic digestion. The latter technique also produces a useable, medium BTU gas (biogas).

Compost does not approach the nutrient value of chemical fertilizer by weight. However, unlike chemical fertilizers, which ordinarily dissolve readily and are easily leached away from plant root zones, organic fertilizers hold their nutrients in colloidal forms which slowly release as the organics decompose in the soil.(65, 24, 39) Furthermore, there are traces of minerals in compost which provide micro-nutrients to crops. Researchers in China report that as compost is increasingly applied, enzymes such as urease and proteinase become more active. This results in a higher rate of mineralization of nitrogenous compounds and an increase in the overall supply of nitrogen to the crop.(13)

Studies on refuse-derived compost indicate other potential resource conservation benefits: erosion control, soil moisture retention, soil density improvements, increased ion-exchange capacity, and trace mineral availability.(79,81) These are in addition to the primary fertilizer effect of nitrogen and phosphorus in compost. Field experiments throughout China demonstrate that application of 500 kg/ha of refuse-derived compost increases rice grain production by 25 to 50 kg/ha. The Chinese typically apply 60 to 70 tons of compost per hectare of rice paddy during land preparation before planting, and usually there are two crops and related planting periods per year.(13)

Shredded paper wastes have been used successfully as soil mulch.(65) Soil mulching, whereby organic matter is spread on top of the soil around plants, limits soil erosion, suppresses weed growth, buffers against temperature fluctuations, and limits evaporation of soil moisture.

In Rome, since 1964, recycling has been a daily city-wide endeavor. Depending upon market demands, various amounts of paper, ferrous metal, plastic, organic matter as animal feed, organic matter as compost, and energy through incineration are recovered from refuse. The estimated annual benefits include: saving over 400,000 trees, amending 60,000 acres of agricultural land, and saving over 30,000 tons of fuel.(12)

Recycling results in fewer solid wastes requiring ultimate disposal. In China, the Shanghai Donghai Oil and Chemical Recycling Works has diverted over 2 million tons of liquid and solid industrial (and sometimes hazardous) wastes from landfill since 1958. Much of this has been accomplished through an active waste exchange program; i.e., spent acids from one industry are recoverd and used as feedstock in another industry.(51) Furthermore, the Shanghai Materials Recovery and Utilization Company has, since 1957, retrieved more than 20 million tons of waste metal, paper, cloth, plastics, rubber, etc.(50)

Constraints to Recycling

With such worthy benefits as those noted above, it is appropriate to ask why recycling is not more widely practiced.

As discussed below, whether recycling is practiced at the source depends on whether the original owner feels it is convenient and/or economically worthwhile. Thereafter, people performing the various steps of retrieval, sorting, recovery and reuse must receive enough tangible benefit to compensate them for their time and effort.

When the owner of a material discards it as a waste, he ordinarily has little incentive to prepare it so that others can recycle its contents. Unless the owner derives comensation or is otherwise induced for the time and effort involved in keeping recyclable materials segregated, some or all of these materials may be contaminated or damaged beyond recovery.

Another point is that the value of waste tends to increase as the income level of the population does. In Cairo in 1982, for example, the total resource value of household waste ranged from a high of LE 5.23/ton ($7.47/ton) for upper income residents and a low of LE 1.86/ton ($2.66/ton) for low income residents.(54) At the same time, as income level increases a higher value usually is placed on leisure time. Thus, more compensation is required to help convince people that it is worth their time and effort to continue to recycle as their incomes rise.

Julius (44) postulates that one way to increase recycling by higher-income populations is through public education programs that stress the benefits of recycling and by enhancing the access to scavengers of materials discarded by these populations.

Money is not the only means of motivating people to recycle. Sometimes, good will towards one's neighbor is enough of an incentive. In Sri Lanka, for example, wealthier residents actively separate coconut shells from their other wastes in order to donate these shells to their launderers who use them as char in the irons.(15) In the United States, the recycling activities of Goodwill Industries, St. Vincent de Paul, the Salvation Army and others rely on good will to motivate people to donate their used goods for others to reuse.

In much the same manner that recycling is encouraged when people are compensated for cooperating with the process, recycling is discouraged by perceived costs of inconvenience to the waste generator or owner. If, for example, collection of recyclables occurs at irregular and infrequent intervals, the owner may choose disposal over storage. Furthermore, owners may not wish to be bothered with visits by various buyers or their agents.

Traditional attitudes toward scavengers influence whether there is an antagonistic environment for recycling. In large part, these stem from the social stigma typically applied towards those who handle wastes.(61) This can be exacerbated when the scavenging population is composed largely of religious or ethnic minorities, low castes, or rural immigrants.

When citizens perceive wastes as recyclable materials, attitudes toward scavengers could change. In Manila, Philippines, a pilot recycling program was established and supported by a wide-spread public information campaign. The program trained workers (called ECO-AIDES) and provided them with clean attractive uniforms emblazoned with the message: "pera sa basura" (money from refuse). To some extent, the social stigma toward house-to-house scavengers appears to have lessened.(17)

Another factor contributing to lack of recycling is poor documentation of the full costs of safe, environmentally acceptable solid waste disposal -- particularly in developing countries where unregulated open dumping prevails as the means of disposal at what appears to be little or no cost, because there is no accounting for the adverse social,

environmental and health effects that occur. Furthermore, in industrialized countries, there is seldom a full cost accounting of landfill disposal costs, particularly life-cycle economics that take into account landfill closure and monitoring expenses.

Retrieval Systems

There are several points within a solid waste management system where wastes can be retrieved for purposes of recycling. The first of these is at the source, the place of waste generation and initial ownership. A second is at the designated place of waste pickup, such as along the curb. A third is within the refuse collection and transport vehicle. A fourth is at an interim transfer station or waste processing facility. And the fifth is at the ultimate disposal site.

At the source, the owner of the waste has three options: (a) to deliver it to a redemption or purchasing center or sell it directly to a buyer, (b) to allow others to retrieve the waste and be responsible for recycling it, or (c) to have it be collected for disposal.

In Colombo, Sri Lanka, the National Paper Corporation publishes a price list for waste paper.(15) The list tells residents how much compensation they will receive if they bring their waste paper directly to the Corporation's redemption centers, and indicates fair buying prices they can expect to receive from neighborhood agents collecting door-to-door.

To encourage retrieval at the source, a number of industrialized countries rely on mini-redemption centers strategically placed for convenience. Commonly, this involves a portable metal container placed in a shopping area. The site is generally not manned, and the residents are not compensated for bringing materials to be recycled. Cooperation relies on public awareness of the resource conservation derived from recycling and the savings based on diminishing landfill requirements. In Germany, there is approximately one container provided to every 5,000 residents for glass recycling. Highest returns of used glass are obtained where the containers are located at central supermarkets.(67)

When the owner of a waste allows others to collect and recycle it, the service may be informal or formal. The informal system operates when individual scavengers walk through neighborhooda and pick through discarded wastes awaiting formal collection. In most cities within developing countries, this occurs to some extent; and is usually

evident in the early morning in high-income residential neighborhoods. While not encouraged, it generally is tolerated if the scavengers leave the piles and containers of discarded wastes in the same general condition as when they found them.

Commonly, the informal system is based on a network of buyers and their appointed neighborhood agents. Typically, the buyers and agents specialize in only one or just a few categories of materials (e.g., paper, bottles, cans) and have an established rapport with residents to service their neighborhooda on a fairly regular basis, using carts and bicycles for transportation.

In some cases, the informal system has even more tiers than this. In Istanbul, Turkey, there are scavengers who collect from door-to-door using handcarts; they sell to collectors who then transport it to merchants who operate sorting yards; if the merchants have transport, they sell direct to the user factories; otherwise, other merchants with transport buy it and sell it to the user factories.(57)

Cairo, Egypt, has a private sector system for collecting refuse for purposes of recovery and reuse. There, through indirect negotiation and contracts with original owners of individual buildings, organized communities of Zabbaleen, most of which are Coptic Christians, have the sole rights to collect and reuse wastes from these establishments.(53) A major portion of the city's refuse is collected by the Zabbaleen, with service provided primarily to high-income and middle-income establishments.(35) Each day, Zabbaleen heads-of-household, usually with their eldest sons, go to their service areas to collect wastes. The full carts are brought home, emptied into their small court-yard, and the wastes sorted by the women and younger children of the family. Edible wastes are fed to pigs raised by the family, and materials are sold to dealers. Zabbaleen families are strongly tied to their dealers, as the dealers often provide advance cash when needed.(45)

Sweepers in Kathmandu, Nepal, are privately engaged by residents to clean courtyards, etc., within and between homes. The edible portion of the wastes collected is fed to pigs, and the pig manure is sold to farmers. Scavengers work door-to-door in the wealthier neighborhoods of Kathmandu, returning home with a full cart for the women and children to sort into piles of materials and edibles. There is a close relationship between scavengers and ealers (kabaris), since scavengers are usually provided free housing by the dealers.(59) The recycling systems of most cities in developing countries are characterized by strong informal

networks.(17) Lomnitz (48) has written a comprehensive and engaging book on the informal networks of the Mexico City recycling system, which has its roots in certain shanty-town communities.

Driven by the increasing amount of refuse and the decreasing availability of land for waste disposal, some communities in industrialized countries are returning to separate collection systems for wastes which can be recycled, as part of their refuse collection system. In Islip, New York, USA, one day a week is set aside for the collection of recyclables such as paper, cans and bottles. Residents are required to sort and clean these materials and place them outside for collection.(55) Prison labor (non-violent offenders) is used to perform the final sorting and grading at the Islip redemption center.(20) The use of prison labor in recycling is not new. In 1915, the Chicago Salvage System used prisoners to sort and repair goods collected from public buildings.(64)

Simultaneous collection of refuse and presorted recyclable materials is being implemented using a number of techniques, including compartmentalized vehicles, racks built onto vehicles, trailers, and bags.(70) Open trailers hitched to refuse collection trucks incur little additional cost, but do reduce truck maneuverability.(5) Bags and baskets are most often used in developing countries, as noted in Colombo, Sri Lanka; Manila, Philippines; and Bangkok, Thailand.(15, 16, 72) Bags can even be used in conjunction with compaction-type refuse collection vehicles. Tests in Modesto, California, USA, showed that 70% of the color-coded bags containing dense recyclable material, when placed on one side of the hopper of a rear-loading compaction truck during refuse collection, were later retrieved unbroken.(19) Note, however, that compaction vehicles are generally inappropriate in developing countries; because the uncompacted density of the refuse in developing countries is usually as much or greater than the compacted density of refuse in industrialized countries where the vehicles are designed and manufactured.(16)

Specially designed vehicles are being built and tested for simultaneous collection of refuse and presorted recyclables.(21, 37) A USA version, known as the Separate Discards Carrier, has compartmentalized containers for glass, cans, newspapers, and refuse The glass and cans are contained in bins, the newspapers on shelves, and the refuse in a compaction chamber.

Wastes may be retrieved for recycling by collection crews.(15, 16, 17, 72) Collection crews of municipalities in developing countries often supplement their income by recovering materials from refuse and selling it to agents buying for various end-users.(17) For example, in Bangkok, Thailand, collection crews spend up to 40% of the time while on their service routes recovering and sorting paper, bottles, cans, and plastics. Reportedly, they earn an income from recycling which is comparable to their official salary.(7)

On the other hand, in Manila, Philippines, collection crews spend no more than 6% of their time enroute recovering materials for reuse.(72) This is attributed to the fact that many crews in Manila allow an extra man to ride the truck (one that is not an employee of the city) solely for the purpose of sorting.(17)

Collection crews can become involved in the recycling process in other ways, as well. For example, they may sell their load to the highest bidder at the dump. At one unofficial dump site in Lima, crews receive a fee for dumping within pig corrals on-site rather than on the open disposal area accessible to scavengers.(17) At the main dump site for Mexico City, agents for various groups of scavengers bid against each other to have collection crews dump in their picking area.(29)

Local government officials often complain that these recycling activities by refuse collection crews tend to take away some of their available working time.(17) However, there have been no measurements on the relative speed and efficiency of such crews who, provided with the added incentive of increasing income through increasing the quantities of materials recovered for recycling, may be correspondingly increasing the quantity of wastes collected.

At the very end of the retrieval system are the scavengers who work at the dump sites and typically live on its perimeter in shanty-towns. There are scavengers at dump sites in most major cities of developing countries. Estimated numbers of scavengers at dump sites are as high as 5,000 in Metro Manila, a metropolis of about 8 million; 10,000 for Mexico City's 10 million people; 1,000 for Lima Metropolitana's 4 million people; and 400 for Cali, Colombia, with its 1-1/2 million population. (10, 28, 29, 72)

The impacts described above of collection equipment and practices upon scavenging are amply demonstrated. They are highlighted by responses to proposals for replacing entrepreneurial small-scale waste

collection in carts by municipal-scale collection in compaction trucks. In addition to increased municipal costs, such replacement would largely eliminate employment of the scavengers and the small-scale enterprises dependent upon them for materials.(37)

The reverse is also true. Scavenging practices can determine the success of innovation in collection and disposal. In Jakarta, hand-operated baling equipment was introduced to increase the capacities of the open-top collection vehicles and of the dump. The scheme was sabotaged when scavengers went for the bales with cutters to remove and salvage the baling wire. This response to technical intervention was not predicted, and indicates the need for carefully designed demonstration projects as precursors to full-scale implementation.(17)

Strong informal networks of agents and buyers typically control these sites. For example, only certain scavengers are allowed access to the main dump site in Manila. All materials retreived at this site reportedly must be sold to one of the approved agents. Any scavenger discovered removing found materials from the site, is likely to have his access privileges revoked.(17)

Birbeck (10) provides an in-depth view of the working conditions and informal networks which exist at dumping grounds in Cali, Colombia. He describes the factory-like atmosphere of the dumps, where a large force of workers is controlled by a few bosses. There is limited chance for upward mobility of the scavengers, since becoming an agent or buyer requires capital and the payments scavengers receive for materials they have retrieved do not provide very much for private savings.

Generally scavengers at dumps work independently and are paid by the piece. The direct link between work efforts and daily wages is a key motivator to scavengers. However, this system can also lead to fierce competition among them. Birbeck (10) notes that conflicts in Cali dumps over certain choice materials have resulted in arguments and have led to killings. In Manila, several years ago, such conflicts reportedly led to a large fight at the dump, which resulted in 28 scavengers killed.(17)

In a few instances in developing countries, scavengers are noticeably absent from dump sites. Recent efforts to implement sanitary landfill operations in, for example, Buenos Aires and Cordoba, Argentina, have been enforced by guards being posted to keep out scavengers.(6, 80) One area of research of the UNDP Resource Recovery Project is to study

the effects of eliminating dump-site scavenging on the overall recovery and reuse of waste materials, and the relative costs and benefits to different sectors of the population.

Intermediate Handling

Once wastes are retrieved for reuse, they either may be sent directly to the recovery or reuse site, or to a station for intermediate handling. At a station for intermediate handling, wastes are sorted and accumulated. Small lots obtained from various sources are aggregated and graded to meet the needs of individual buyers. To the extent that there is available space and cash flow, materials are stored. This allows the intermediate handler to have supply better match demand, and thereby obtain a better price.

Intermediate handling is done by community redemption centers, salvage dealers, secondary materials processors, and special interest groups. Each of these is briefly discussed below.

There are municipal redemption/purchasing centers in Shanghai, China. Individual scavengers and residents bring their recyclables to these centers and are paid according to posted prices. Materials are sorted and graded to meet the users' needs. These post-consumer wastes are sent, along with induatrial scrap, to central factories for payment and processing. These factories are under municipal management, which is also responsible for street cleaning, sewerage, and refuse and night soil collection.(50)

Salvage dealers do essentially the same things as municipal redemption centers. Both are likely to handle a variety of recyclables, including metal, paper, textile, and plastic. The key difference is that these dealers' centers are run by private entrepreneurs. Their position in the system depends on their network with scavengers and agents retrieving recyclables and with buyers. Cities such as Bangkok, Thailand, and Colombo, Sri Lanka, appear to have a well-run system of salvage dealers who interact largely with municipal collection crews as their source of recyclables.(17)

Secondary materials processors are apt to specialize in one type of recyclable material, such as paper or ferrous metal. Generally, they have strong connections with end-users, such as paper or steel mills. They are likely to process the incoming waste to meet their buyers' specifications. Mechanized equipment to reduce the volume of waste is

often used. In Lima, Peru, a government-owned paper corporation includes about 10 percent waste paper in its feedstock. The corporation has a fixed number of secondary materials processors who buy waste paper from sorters and transport it to the corporation's storage area where it is baled.(26)

In industrial countries, special interest groups providing intermediate handling tend to rely on voluntary support. Charitable groups, including church groups, commonly receive and distribute used clothing, furniture, and household appliances. Service organizations such as the Salvation Army, Goodwill Industries, and Volunteers of America do the same.(40) Generally, goods are cleaned and repaired before they are distributed.

In communities throughout the United States, various organizations provide drop-off stations for paper, cans, and bottles. These efforts stem from concern over resource conservation and desire to limit the amount of land required for ultimate disposal. Some sorting usually is done by such organizations; but for the most part they rely on residents to sort their materials before leaving them at the drop-off station.

Recovery and Reuse

Solid wastes can be recycled in many ways. For purposes of this report, we categorize these into three levels of recovery and reuse:

Level 1--after sorting and cleaning, discarded items are reused, repaired or remanufactured;
Level 2--the waste is sorted, cleaned, processed, and recycled as a new material or product; and
Level 3--the waste is converted into a different material or into energy.

To illustrate, tires can be reused at all three levels. Tire retreading, whereby the worn treads are removed and replaced with new uncured rubber, is an example of Level 1 recycling.(78) A Level 2 example is when tires are split into strips and woven into doormates.(18) And at Level 3, used tires may be pyrolized into fuel oil.

Recovery and reuse activities grouped in the lower levels tend to use less mechanical energy for sorting, processing, transporting, etc., than those grouped in the higher level. Also, Level 1 and 2 activities often involve wastes before they are mixed with other wastes, and

potentially degraded; and Level 3 activities often involve mixed wastes. Each level is discussed below, and examples of recycling within each level are noted from the literature.

Level 1. This level involves direct reuse of a product or material without changing its basic form and/or function. A common example is reusing (after sorting and cleaning) a packaging container, such as a can, bottle or box.(58) Standardization of bottles in the Federal Republic of Germany has facilitated this level of reuse.(11) Another common example is when discarded clothing, donated to charitable groups and service organizations, is cleaned and mended for reuse.

Through physical labor, and with simple tools, products often can be repaired and returned to a functioning state. For example, textiles can be sewn, patched, rewoven, and dyed to restore them to usefulness. Furniture can be rebuilt and re-upholstered. Garden tools are commonly restored by replacement of their wooden handles.

Remanufacturing involves disassembling similar products at a central facility, with the parts subsequently cleaned, inspected, replaced or refurbished, reassembled, tested and distributed.(56) Examples of remanufactured products are: automotive engines, transmissions, water pumps, clutches, and brakes; refrigeration and air conditioning compressors; white goods such as stoves and dishwashers; and telephone sets. Generally, products contain most of their original parts. In the United States, the Xerox Corporation operates remanufacturing plants for its equipment.

According to the Association of Petroleum Re-refiners in the U.S.A., "Oil never wears out -- it just gets dirty." Re-refined lubricating oil has been proven to be equal in quality and performance to that made from virgin oils. And yet, in 1982, less than 10% of recovered used lubricating oil was recycled in the U.S.A.(33)

Discarded products can be reused in the same basic shape as the original, but for a different function, for example as building components. A WOBO (World Bottle) was conceived by Habraken for reuse as a building block.(58) Old tires are used to form breakwaters and artificial reefs in the United States. Building materials are retreived from cardboard cartons, wooden crates, and demolition debris to build shelters and workplaces all over the world.

Level 2. Recycling of glass cullet is a common example of Level 2 recovery and reuse, whereby the waste is reprocessed into a new product of comparable composition. In the United States, a number of states have passed legislation requiring citizens to return beverage containers to stores selling beverages.(49) For example, in the U.S.A. in 1981, 24.8 billion aluminum cans and 3 billion glass bottles and jars were processed into new containers.(33)

Materials for conventional glass-making include sand, soda ash, limestone, and broken glass (cullet).(25) The cullet replaces soda ash.(5) Glass manufacturing using 100 percent cullet is found in plants from Bangkok, Thailand, to Dayville, Connecticut, USA, where carbonated beverage bottles are produced.(34, 77) More commonly, glass cullet makes up 20 to 30 percent of the total mix.(25)

In Manila, a pilot project implemented by the Technology Resource Center involved forming a cooperative of low-income women to collect high-grade paper from office buildings and (using a simple labor-intensive process) wash, bleach, and pulp it into a high-quality stationery.(17) In Colombia, an estimated 46 percent of the total material requirements of the paper mills is waste paper.(10) Waste papers should, where possible, be separated at the source, before it is contaminated and degraded. There is no equally cost-effective mechanical substitute for manual separation and sorting. The mechanized fiber-sorting techniques that do exist (9, 83) tend to produce a low-grade fiber.

The extent to which steel mills can utilize scrap as an input depends on type of furnace.(41, 43, 75) The Basic Oxygen Furnace is the most limiting, using no more than 40 percent ferrous scrap in the charge. On the other hand, the Electric Arc Furnace can use up to 100 percent scrap. Because of this, and the fact that the Electric Arc Furnace can be economically implemented in a smaller unit size than other furnace types, it may be particularly appropriate for developing countries.

Steel foundries can melt steel scrap to produce steel castings; and iron foundries can combine pig iron with iron scrap to produce iron castings.(25, 43) Other foundries use nonferrous metal scrap, such as aluminum and copper scrap.(69)

Recycling may involve changing both the shape and function of a product. Tires are cut into soles for shoes, as in India and Peru.(17,

68, 78) Bottles are cut into glasses, ashtrays and funnels in Cuzco, Peru.(77) Textiles are reused in rag dusters, as stuffing for pillows and dolls, sewn into patchwork cloth, or woven into rag rugs.(78) Waste paper is shredded into animal bedding.(78) Steel drums from oil are cut up and made into charcoal-burning jika cooking stoves.(68)

Vogler (78) focuses on labor-intensive technologies appropriate to developing countries. He explains how to start-up a number of Level 2 recycling operations, including: asphalted roofing sheets made from waste paper; tools, horseshoes, and machine parts forged from ferrous scrap; iron manhole covers cast from ferrous metal scrap with some tinplate cans in the mix; saucepans and kitchen utensils cast from scrap aluminum; and roofing felt made from textile wastes.

Level 3. Waste is processed into a different material or a form of energy at this level of recovery and reuse. For example, the new material may be recovered element, or some relatively homogeneous substance. The new energy may be heat, char, a combustible gas, or incineration steam. A number of Level 3 processes (e.g., composting, anaerobic digestion [biogas], fermentation [ethanol production] and incineration) are described from an engineering standpoint by Diaz, Savage and Golueke.(28) There is increasing interest in extraction of methane generated within refuse dumps and landfills.

Tin can be recovered from tin-plate scrap through several detinning processes readily applicable for implementation in developing countries.(78) Because the resulting tin is more pure than primary tin, it is commonly used in pharmaceuticals (particularly stannous fluoride toothpaste). Furthermore, detinning renders the original tin-plate scrap more saleable. According to Vogler (78), detinned scrap with less than 0.05 percent tin normally fetches a price double that of scrap tinplate.

Glass can be reprocessed into a number of new materials. For example, it can be substituted for quartz or feldspar in the manufacturing of high-strength porcelain.(60) Up to 50 percent waste glass can be used in the manufacture of mineral wool insulation.(82) Composites of waste glass and polymers can be used to make durable construction products, such as sewer pipe.(82)

Composting and anaerobic digestion are biochemical processes that decompose organic wastes. In composting, aerobic bacteria decompose organics in the waste to carbon dioxide, nitrogen compounds and water

vapor, leaving behind a relatively dry humus-like material composed of cellulosic (humic) organics, nitrogen compounds and inert substances. In anaerobic digestion, successions of anaerobic bacteria decompose organics in the waste to methane and to carbon dioxide with traces of hydrogen sulfide and nitrogen, leaving behind an organic slurry carrying humus and fertilizer constituents.

High temperatures of over 50°C and as much as 80°C are achieved in aerobic composting and may be provided in thermophilic digestion by using say 30 percent of the methane for heating. These temperatues are sufficient to destroy human pathogens and fly larvae within one day. Both compost and the slurry from digestion are used for soil amendment, because of their organic and trace mineral contents, as well as their nitrogen-phosphorus-potassium contents. The slurry product of anaerobic digestion would tend to be richer in nitrogen than compost, because nitrogen would not be converted to a gas and released as it is during composting.

It is common in cities of China for domestic garbage to be composted. Garbage from Shanghai, for example, is trucked and barged to farms surrounding the city. Typically, the garbage is mixed with night soil, piled into a heap about 4 meters wide, 4 meters long and 1.5 meters high, set with subsequently withdrawn bamboo poles to provide aeration, then sealed with a thin layer of mud. Temperatures within the pile rise to over 50°C and are maintained at this level for more than 10 days, effectively destroying disease-causing micro-organisms and parasite eggs. It takes 3 to 4 months before the compost is ready for application to crop land.(13)

Vermicomposting uses common earthworms to decompose organic wastes, and has been demonstrated in small-scale projects. For example, in Manila, vermicomposting is being promoted as a means of recycling-at-the-source and thereby reducing the overall costs of Municipal garbage collection.(17, 27) Garbage segregation is done at the household in separate containers provided at cost by the Metro Manila Municipal Government to project participants. The earthworms, Eisenia foetida, reduce the waste volume by up to 50 percent, and their castings consolidate the nutrients originally found in the waste.(22) The earthworms are harvested every 40 to 45 days and recycled to new pots of garbage. The castings can be either marketed as soil enhancers or used in the soil pots to raise selected vegetables and herbs.(1, 2, 3)

Anaerobic biochemical processes that result in methane gas generation become dominant in moat refuse landfill cells, usually after about 2 years wherein all the entrapped oxygen is consumed. Methane is produced and collected from refuse in landfills in West Germany, the United Kingdom, the United States, and Brazil. To maintain oxygen-free conditions, the refuse should be well compacted under a soil cover. To maintain moisture content at levels optimum for bacterial growth and gas production (about 60 to 75 percent moisture), it may be necessary to recirculate leachate or add water. Recirculating leachate can have the added benefit of also providing nutrients, buffer and assimulated bacteria; but must be approached with great care to insure that groundwater quality is protected. Active gas removal aystems are recommended, and consist of a site perimeter trench or series of wells fitted with mechanical pumping systems. After processing for removal of condensate and particulates, the gas has an energy value ranging from 450 to 600 BTU/ft^3 (4,000 to 5,300 kcal/m^3), which is suitable for use in boilers. For pipeline quality transport, the carbon dioxide is removed to provide about 1,000 BTU/ft^3 (8,900 kcal/m^3).(8)

Energy recovery from refuse incinerators is not ordinarily applicable to developing countries, where kitchen wastes make up a much higher portion of refuse. Therefore, moisture contents are markedly higher. The moisture content of refuse in developing countries tends to range between 40 and 70 percent, compared to the 20 to 40 percent moisture content of refuse in industrialized countries.(16) As a result, incineration would require supplementary fuel and result in a net energy deficit. Even Japan, which has more incineration plants than any other country, is reported as recovering little useful energy for sale because of the high moisture content of its refuse.(62) Nevertheless, recent developments in separation technology, if proven in practice, may eventually offer an economic way to separate the dryer combustible portions from the rest of the waste.

Strategies for the Future

Sustainable resource recovery and utilization are essential elements of living within finite resources. Economically justified recycling practices are objectives of a number of individuals, groups, and governments. Examples of both efficient and inefficient recycling systems abound. Improvements always involve building on existing activities. This requires that three strategic objectives be addressed:

1) Identify and acknowledge existing strengths in both the formal and informal systems.

2) Improve productivity of existing systems by removing technical, financial and institutional constraints to recycling.

3) Link macro-economic and micro-economic factors.

Examples of how various cities and countries have addressed some or all of these objectives are discussed briefly below. Common threads which wind through most of these examples are improved public education and cooperation, as well as government encouragement of, if not participation in, the recycling endeavor.

Recognizing the contributions that informal sector scavengers make to recover materials for recycling, reduce dependence on foreign imports, and lessen the volume of wastes requiring land disposal, the Ministry of Environment in Indonesia is developing strategies aimed at supporting scavenging.(17, 76) For example, some communities are being encouraged to provide scavengers with water supply and sanitation facilities at the main refuse handling and disposal sites, and to provide them with access to health care services.(17)

In Indonesia, scavengers belong to the low income group. Many families earn from scavenging only enough money for one meal a day. For their day-to-day survival, income is also needed from other informal business activities. Profits accrue mostly to the higher circuits of the recycling system: dealers and middlemen.(76) The Ministry of Environment, together with the Informal Sector Project, is planning a pilot effort to form a local cooperative of scavengers at one municipal landfill.(17) The cooperative is viewed as one means of strengthening the individual scavenger's bargaining position in obtaining fair market value for recovered materials, easing access to credit, and providing

education on basic rights and resources available for greater self-reliance.(17, 76)

Recycling is a community employment activity of the Zabbaleen in Cairo, Egypt. Few of their inhabitants work in other trades.(45) In an effort to extend the activities of the Zabbaleen to low income neighborhoods which have a lower fraction of recyclables in their refuse, the city is pilot testing contracting with the Zabbaleen for collection from these neighborhoods. Because the Zabbaleen are limited in number, studies are underway to improve their efficiencies through better cart designs and sorting/handling facilities.(54) Credit has been built into a World Bank urban project loan to support this effort.(4)

During a recent solid waste master planning effort for Manila, Philippines, integrated materials recovery and sanitary landfill facilities were recommended.(72) To take advantage of the pool of talent available at the present open dumps, and to minimize loss of income to the many hundreds of scavengers working at these dumps, scavengers are proposed to be hired as sorters along the conveyor lines of the materials recovery facilities.

In Shanghai, China, there are separate collection systems for residential and commercial/industrial wastes. This minimizes the content of potentially hazardous substances within wastes targeted for composting and application to cropland. And the purity of commercial/industrial wastes entering the materials processing and exchange network is maintained.

A waste materials exchange program was established in the United Kingdom in 1974, with funding provided by the government as a free service to industry. A small secretariat was established with staff seconded from the Warren Spring Laboratory, which already had significant involvement and expertise in waste utilization. Quarterly bulletins announced the wastes available from various manufacturers, as well as those wanted. Information was coded and stored by computer to facilitate matching industries with specific wastes to discard and industries needing those same wastes as feedstock. Eventually, more than 5,000 organizations participated in the program.(74) After 5 years, participants were invited to subscribe to the costs of operating the Exchange, but response was insufficient to maintain a self-funding operation and the Exchange was closed down.

One difficulty in materials recycling is balancing of supply, storage and demand. Since 1957, the Shanghai Materials Recovery and Utilization Company has set up 502 centers to purchase, store and balance the flow of materials. Over 1,000 agencies in the surrounding rural areas work on a commission basis with the Company. Twenty-six agencies (each with about 300 workers) are set up to separately retrieve materials from industrial wastes. To complete the system, there are an additional 15 processing factories, 59 specialized business centers and 121 waste materials sales departments.(50)

Not all efforts to address perceived obstacles are successful; however, they may provide valuable lessons for others. Despite a series of projects begun in 1978 in Manila, Philippines, to develop a municipal recycling system based on neighborhood redemption/purchasing centers, recycling continues to be characterized by informal private sector individuals.(17) Thirty community redemption centers employing over 300 workers were eventually equipped and put into operation. The redemption centers were temporarily closed in 1979, so that their efforts could be fully assessed. Among the problems perceived were: insufficient participation by residents, inadequate communication with local neighborhood leaders to gain their support, too few collectors (called ECO-AIDES) to cover the redemption routes, competition from private "junk dealers," and faulty arithmetic and poor record-keeping. Lack of adequate financing was manifested by the inability of the responsible private organization to procure vehicles to transport the recyclable materials. This in turn led to an unsightly accumulation of recyclables at the centers, and complaints by neighbors. It further led to an inability to market the materials, and an aggravated shortage of cash.(27)

Within a year, six centers were temporarily reopened under public management. Once again financial problems were encountered, and the municipality recognized that specialized knowledge and experience was needed to operate the centers and business of recycling. Arrangements were then made with private entrepreneurs interested in and knowledgeable of recycling, who would use their own capital and personnel. Eventually 31 municipal redemption centers were operating under the new system.(27)

However, there then was a proliferation of competing privately owned "junk shops," and the market became saturated. The redemption centers accumulated more materials than they could sell, became unsightly, and were forced closed by residents. Presently, there are no redemption centers operating under the municipal program.(27)

The number of biogas digesters in China has increased from only 1,300 in 1972 to approximately 7 million in 1982. This impressive development is attributed to strong government support and advocacy. The government focused its efforts on areas of firewood shortages and severe schistosomiasis--emphasizing the gas use for family cooking and lighting and the slurry use for organic fertilizer. Government programs included financial support to install new biogas units, training, extension offices to provide technical and administrative assistance, publicity, and research and development to improve biogas techniques.(71)

Over the past 8 years, India has made a major commitment to its All-India Co-ordinated Biogas Program. About 62,000 biogas units have been installed since the program started in 1975. Eight research institutes and a number of universities have been actively involved in research and development of biogas technology. However, it appears that implementation has not been as wide-spread as in China. Research and development have not been as closely linked to implementation, resulting in less feedback from users to enable technology to be improved. Also, there has apparently been less effective dissemination of information to the target population. Some of these program deficiencies are presently being amended.(71)

From the case examples described above it is clear that government strategies to promote recycling should be dynamic processes. Research coupled with applied engineering to develop appropriate technology for local users is a necessary component. Continued training and technical assistance need to be coupled with a network of extension offices which also obtain feedback to ways of improving technology. Quite often, financial support for capital investments is essential, as well as start-up operational monies.

Seemingly unrelated government actions can influence the incentives people have to recover and reuse wastes. In Lahore, Pakistan, 40 percent of the refuse generated by residents is collected by farmers. However, with increasingly available, government-subsidized chemical fertilizers, farmers are losing interest in the refuse as soil amendment and collecting it only when it suits their convenience.(84) Similarly. government action to open Colombo, Sri Lanka, as a duty-free port resulted in paper products from other countries being dumped on the domestic market at prices with which local paper products could not compete, leading to a marked decrease in paper recycling.(15)

In many contries, taxes often favor virgin materials. A study in 1971 by the Joint Economic Committee of the USA government found that federal tax subsidies (depletion allowances) for natural resources smounted to 1.45 billion dollars. The study noted, "The subsidies to timber, oil, and other minerals appear to provide incentives to use these (virgin) resources in greater amounts and instead of other alternatives."(42) Shipping rates set by national governments often favor natural resources over scrap materials.

Government procurement specifications commonly discriminate against refurbished and remanufactured products. On the other hand, in the U.S.A. there are some procurement regulations for securing paper supplies with a minimum content of secondary fiber. Clearly, a national commitment to recycling requires examination of existing and proposed actions in light of the government itself.

Recycling can be an opportunity to reduce dependence on foreign imports, create domestic employment, and conserve limited resources, including space that would be required for burial of waste. In the annotated bibliography which follows, references covering the wide spectrum of recycling techniques are reviewed. The bibliography, and the references abstracted, provide information useful to assess the opportunity of recycling. The references also describe a variety of worldwide examples of recycling endeavors. These examples may be adapted to meet the needs of other cities, as part of the continued dynamic process of implementing a recycling program.

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PART II. ANNOTATED BIBLIOGRAPHY

INTRODUCTION TO THE ANNOTATED BIBLIOGRAPHY

This annotated bibliography is based on a one year literature search and review. The objectives of this search were to identify, assemble and review for annotation relevant literature useful to developing countries in selecting appropriate technologies in resource recovery, especially those considered to be alternatives to conventional means of solid waste management.

Many urban and regional governments, national and international agencies, and private industries are aware of the need for approaches to solid waste management that will maintain or enhance established recycling programs. However, information on many of the current recycling practices is not readily available.

As a result, many countries have experienced numerous failures in attempting to set up recovery systems. It is not because there are inherent problems in recycling but that often the intricacies of developing recovery programs are ignored, thereby building failure into the project from the start. Equally important, much of the available literature is written in an isolated context or in limited theoretical terms, and focuses on traditional or energy recycling rather than remanufacturing or reuse technologies. Therefore, the aim of this bibliography is to identify many of the data gaps and promote research by enterprising individuals and agencies. We hope the abstracts are useful in describing the techniques, issues, and other factors present in the expanding field of resource recovery.

Literature Search

A two-fold search was initiated. A computer search of several internationally available data bases was conducted early on in the project and a manual search of selected private and public information centers continued throughout the project. Constraints on travel required the project team to rely on information centers, verbal, written or telephoned requests for information.

The computer search was carried out under the auspices and direction of the World Bank's Information Center Section, Records Management Division located in Washington, D.C., U.S.A. Sixteen data bases were searched using the key word list shown in Table 2. Over 90,000 potential documents were identified.

Table 2. KEY WORDS

Agriculture

Alchemy

Animal feed supplement

Appropriate technology, low technology

Asia, Africa, Oceania, North America, South America, Central America, Europe, Middle East, India

Collection, separate truck, integrated collection

Composting, vermicomposting

Construction materials, urban debris

Enterprise(s)

Equipment files

Fiber, paper, newspaper, cellulose, insulation, high grade paper

Financing, economic developing, economy of scale, job and employment creation

Glass, bottles, bottle washing, color sorting, intermediate processing, bottle and glass crushers, screens, container deposits

Health and safety, environmental protection

Humus, fertilizer, soil amendment

Landfill, landfill high grading

Less Developed nations, developing nations

Metals, tin cans, steel cans, aluminum, ferrous, non-ferrous, bimetal

Oil, energy recovery

Organic, putrescibles, food wastes, aerobic and anaerobic fermentation, methane

Policies

Polymers, plastics, rubber, cryogenics, crumb rubber, tires

Processing, mechanical separation, hand picking, labor intensive separation

Protein

Recycling, salvage, scavenging, resource recovery, materials recovery

Regulations

Research

Resource conservation, materials conservation

Reuse, reduction, remanufacturing

Secondary materials, industries

Segregation, separation, source separation, collection centers, buy back

Shredding and grinding

Solid waste, refuse, garbage, waste, residuals, municipal solid waste

Thermal processes

Transfer stations

Transportation, horse-drawn wagons, rail

Urban, urban fringe, rural

Waste composition and quantity, waste surveys

Waste utilization, close loop systems

The use of computerized bibliographic data bases was complicated by three factors.

(1) No one data base specializes in waste recycling;

(2) Different data bases do not define subjects in the same way, and there is no standardization of indexing among data bases;

(3) Data bases do not emphasize developing countries, and there is no consistency in indexing geographic locations; e.g., a document dealing with Brazil may or may not be cross referenced to Latin America.

Many data bases do, however, cover waste recycling to the extent that it overlaps with their subject specialty. For example, CAB, which is an agricultural data base, includes waste recycling in agriculture. Thus, by searching a wide variety of data basas, we achieved a comprehensive perspective.

The problem of inconsistent subject indexing was more difficult to overcome. We developed two approaches. The first involved very general key words in all relevant data bases; e.g., solid waste, and waste recycling. This allowed us to cast a broad net and capture most records on our subject. However, it also resulted in many irrelevant items and necessitated searching through long lists to obtain the relevant records. The second involved developing individual key words for specific data bases; e.g., in searching CAB we used key words such as "composting," and when searching Compendex--an engineering data base--we used key words such as "glass crushers." This resulted in many additional items.

To overcome the problem of inconsistent country indexing, a geographic region list and a country liat were developed. Also, by using key words such as "appropriate technology," records from the perspective of the developing countries were included.

The best 658 documents from the computer data bases were ranked based on a five-point system for selection using the actual documents or abstracts. The criteria were: (1) the document had to be technical in nature and contain data that would be useful either for evaluating or implementing a technology; (2) the document should deal with resource recovery primarily of low technology origin; (3) the document should contain information on the study wastes (glass, plastics, organics, paper, metals, demolition debris, oil, etc.); (4) the document should cover historical data of developed countries; (5) the document should cover developing countries. Where abstracts showed potential of three or above, the document was retrieved. One hundred and fifty of the computer references received a three or better and eventually, 50 were used in the bibliography. The results of the computer search are presented in Table 3, below.

The manual search was carried on throughout the project. Initially, the World Bank sent a letter under the Project Officer's signature, which solicited data from information centers around the world. This was done very early in the project, as it was expected to provide little information, especially from distant information centers. In fact, it became a most significant source and picked up momentum as the project progressed. Also, fifteen information centers within convenient travel distance were visited. (See Table 4 for information centers visited and contacted.)

Table 3. DATA BASES

Data Base	PreSelection	Selected For Final Review
Agricola	4,562	0
Biosis	109	5
CAB	7,355	50
CAS	4,647	0
CIS	5,587	101
Comp Dissert	4,138	35
Compendex	4,982	8
Control Data	150	0
CPI	4,486	77
Economic Abstracts International	515	90
Enviroline	17,484	40
GPO Monthly	5,396	66
NTIS	24,829	46
Pollution Abstracts	12,638	41
Scisearch	4,486	34
SSIE	1,754	65
TOTAL	93,236	658

Table 4. LISTING OF ORGANIZATIONS AND AGENCIES CONTACTED

American Electroplating Society, Winter Park, FL, USA

American Iron and Steel Institute, Washington, DC, USA

American Paper Institute, New York, NY, USA

American Public Works Association Library, Chicago, IL, USA

American Society for Testing and Materials Committee E-38 on Resource Recovery, Philadelphia, PA, USA

Applications de Recherches sur l'Energie et la Societe, Toulouse, France

Appropriate Health Resources and Technologies Action Group, Ltd., London, UK

Archives of the United States of America, Washington, DC, USA

Asian Institute of Technology, Bangkok, Thailand

Asian Recycling Association, Makati, Philippines

British Plastics Federation, London, UK

Bureau of Industrial Economics, United States Department of Commerce, Washington, DC, USA

Can Manufacturers Institute, Washington, DC, USA

Center for Policy Alternatives, Massachusetts Institute of Technology, Cambridge, MA, USA

Center for the Study of Materials, University of Toronto, Toronto, Canada

Centro Panamericano de Ingenierio Sanitania Ciencias del Ambiente, Lima, Peru

Council for International Urban Liaison, Washington, DC, USA

Department of Industrial Urban Liaison, Washington, DC, USA

Department of Industry, Warren Springs Laboratory, Stevenhaege, Heats, England

Earth Resources, Ltd., London, UK

Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland

Economic Commission on Europe, Geneva, Switzerland

Elmia, Jonkoping, Sweden

Environmental Protection Service, Environment Canada, Ottawa, Canada

Fachzeitschrift des Bundes Deutscher Champignon Züchter e.V., Bonn, Germany (FR)

Glass Packaging Institute, Washington, DC, USA

Governmental Refuse Collection and Disposal Association, Washington, DC, USA

Indian Ministry of Works and Housing, New Delhi, India

Institut für Bodenbiologie der Bundesforschungsanstalt für Landwirtschaft, Braunschweig, Germany (FR)

Institute for Local Self-Reliance, Washington, DC, USA

Institute for Scientific and Technical Information for Agriculture, Prague, Czechoslovakia

Institute for Soil Science, Swedish University for Agricultural Sciences, Uppsala, Sweden

Instituto Centro-Americana de Investigacion y Tecnologia Industrial, Guatemala City, Guatemala

Instituto de Investigaciones Agropecurias, Santiago, Chile

Instituto de Investigaciones en Matematicas Aplicadas y en Sistemas, Universidad Nacional Autonoma de Mexico, Mexico City, Mexico

Instituto Nacional para Programas Especiales de Salud, Bogota, Colombia

Instituto National De Edafologia y Agrobiologia "Jose M. Albareda" del Consejo Superior de Investigaciones Cientificas, Madrid, Spain

Intermediate Technology Development Group, Ltd., London, UK

International Atomic Energy Authority, Vienna, Austria

International City Management Association, Washington, DC, USA

International Development Research Center, Ottawa, Canada

International Institute of Biological Husbandry, Suffolk, UK

International Solid Wastes and Public Cleansing Association, Zürich, Switzerland

Internationale Fachzeitschrift für Verarbeitung, Gestaltung und Anwendug von Kunststaffen, Speyer am Rhein, Germany (FR)

Israel Institute for Technology, Samuel Neaman Institute for Advanced Studies in Science and Technology, Haifa, Israel

Keep America Beautiful, Inc., New York, NY, USA

Merlewood Research Station, Grange-over-Sands, Cumbria, UK

Minimum Cost Housing Group, School of Architecture, McGill University, Montreal, Canada

Ministerio de Industria y Energia, Madrid, Spain

National Academy of Sciences, Washington, DC, USA

National Association of Recycling Industries, New York, NY, USA

National Center for Resource Recovery, Washington, DC, USA

National Conference of State Legislature, Washington, DC, USA

National Environmental Engineering Research Institute, Inside Chandrauel Water Works No. 2, New Delhi, India

National Science Council of Sri Lanka, Colombo, Sri Lanka

National Solid Waste Management Association, Waste Equipment Manufacturers Institute, Washington, DC, USA

National Technical Information Service, United States Department of Commerce, Washington, DC, USA

Office of Energy Conservation, Department of Energy, Mines and Resources, Ottawa, Canada

Pan American Health Organization, Washington, DC, USA

Ross Institute , London School of Hygiene and Tropical Medicine, London, UK

Royal Netherlands Society of Agricultural Science, The Hague, Netherlands

Royal Swedish Academy of Agriculture and Forestry, Stockholm, Sweden

Secondary Resources Development, Inc., Alexandria, VA, USA

Secretariat des Missions d'Urbanisme et d'Habitat, Paris, France

Society for Plastic Engineers, Brookfield Center, CT, USA

Soil and Crop Science Society of Florida, University of Florida, Gainesville, FL, USA

Soil Conservation Society of America, Ankeny, Iowa, USA

Technical Association of Pulp and Paper Industries, Chamblee, Georgia, USA

United Kingdom Overseas Development Agency, London, UK

United Nations Environmental Program—Environmental Management Service, Nairobi, Kenya

United Nations Food and Agriculture Organization, Rome, Italy

United Nations Industrial Development Organization, Vienna, Austria

United States Agency for International Development Library, Washington, DC, USA

United States Conference of Mayors, Washington, DC, USA

United States Coordination for NATO Committee on Challenges to Modern Society, Washington, DC, USA

United States Environmental Protection Agency, International Activities Office, Washington, DC, USA

United States Library of Congress, Washington, DC, USA

United States National Archives, Washington, DC, USA

University of Nebraska Agriculture and Engineering Libraries, Lincoln, NE, USA

Urban Development Institute, Bombay, India

Waste Management Advisory Group, Toronto, Canada

Waste Management Group, Organization for Economic Cooperation and Development Paris, France

World Health Organization, Environmental Health Division, Copenhagen, Denmark

Several thousand documents were reviewed using the same criteria as the computer search. In Table 5, sources of all documents selected are presented.

Table 5. SOURCE OF DOCUMENT RETRIEVAL, BOTH PUBLISHED AND UNPUBLISHED

Source	Unpublished	Published	Total
Computer Search	-	50*	50
Consultants' Holdings	8	49	57
World Bank Reports	5	-	5
United Nations Reports	-	15	15
Additional Literature**	3	107	87
	16	221	214

*23 documents already identified were also found in computer search.
**Derived from library search and correspondence with information centers.

Scope of the Bibliography

The final bibliography is not considered complete by any means. It consists of annotated documents useful in evaluating or implementing waste recovery and utilization technologies. Documents provide technical, economic, institutional, environment, and cultural information. They are categorized into areas of waste characterization, collection, processing, waste utilization, environment, cultural aspects, and economics. Twenty two percent of the references originated in developing countries, 70 percent in industrial nations (36 percent are U.S. documents), and 8 percent with international agencies.

The differences in site specific conditions, which include social and economic factors, and the magnitude of the solid waste problem make it difficult to apply technical and institutional data from one country to another. This holds true for applications from an industrial country to a developing country and from one developing country to another. The literature confirms that all too often developing countries are attracted by industrial research and technology, even though local traditions and practices may be better alternatives. The failure to document local accomplishments and development needs of small scale approaches is one reason for the lack of emphasis on indigenous solutions. Furthermore, verification of information is required. Too often, incorrect information within the small literature base is replicated and becomes "fact." This is obviously an inadequate foundation upon which to conduct planning and implementation.

We have focused on low cost, labor intensive technologies which are appropriate to the economic, environmental and social needs and resources of developing countries.

Key words are provided to guide the reader to other relevant documents. The documents are numbered for ease of reference. The numbers are used in the index section. Annexes I and II, providing an Additional Bibliography and a Glossary, the Key Word Index, Geographic Index and Authors' Index follow the Annotated Bibliography.

ANNOTATED BIBLIOGRAPHY

Resource Recovery Technology

101 Bevis, M. J.
Brawley, J. W.

Plastic Waste Resources from Textile and Related Industries. British Plastics Federation. London, U.K. #277/1. October, 1980. 35 pages. References.

This document reports on an investigation of quantities and types of wastes arising from the manufacture of textiles and acrylic fabrics. Detailed information provides a useful data base in identifying business opportunities in the recovery and reuse of plastic wastes in the textile industry. A summary of proven and commercially available techniques is included and the techniques are comparatively evaluated.

The report provides a model for business and municipalities interested in the development of plastics recycling.

plastics, textiles, resource recovery, economics, surveys, United Kingdom

102 Bevis, M. J.
Ham, A. J.

Plastic Waste Resources on the Agricultural, Horticultural and Produce Distribution Industries. British Plastics Federation. London, U.K. #276/1. October, 1980. 37 pages. References.

This report discusses processes suitable for converting waste plastics into products which can be used in horticultural and agricultural industries. It reviews the sources and amounts of plastics available for conversion. Specific uses of plastics are individuslly addressed.

Although collecting used plastics from farms and nurseries is financially unfeasible because of the widespread area over which the low-density polyethylene sheet plastics are used, farmers supported the idea of reclaiming plastic in the United Kingdom.

plastics, agriculture, recycling, United Kingdom

103 Bhide, A. D.
Arcfivala, S. J.

Solid Waste Management in Indian Cities. U.S. Environmental Protection Agency. Foreign Research Agreement No. 01-504-1. National Environmental Engineering Research Institute. Nehru Marg, Nagrur, India. 1974. 70 pages. References.

This is a study of the refuse practices in 33 Indian cities, which contain nearly 20 percent of the urban population of India. Questionnaires and solid waste samples collected on a seasonal basis

(including chemical analysis of samples) were used to determine existing solid waste practices and characteristics. Conclusions drawn from the study were that: 1) collection of refuse in India is labor intensive, employing 1,000-3,000 workers per million inhabitants; 2) solid wastes are collected daily; 3) glass and paper represented less than 1 and 2 percent of the refuse, respectively; 4) from 32 to 43 percent of the refuse could be composted; 5) chemical analysis showed poor refuse combustibility; 6) solid waste density was 330-560 kg/m^3 (505-943 pounds per cubic yard); and 7) per capita waste generation ranged from 0.15-0.25 kg/capita/day.

In the majority of cities the administrator of the solid waste program was a health officer. Community waste is manually collected and transported in open-body trucks. The average age of the vehicles was seven years.

Twenty two of the 33 cities composted part of their refuse with nightsoil using the Bangalore method. All but a few cities were able to sell the compost they produced. Over 62 percent of these composting facilities were small scale, using less than 4 hectares (10 acres). NPK values ranged from 0.4 to 0.8 percent.

In most of the refuse samples fine earth, ash and compostable matter were the major components. Calorific values were quite low and were always less than 6283.17 BTU/kg (2,850 BTU/lb).

Workers at composting yards did not wear gloves or use protective devices.

Two intestinal parasites were found: A. lumbricoides and T. trichiura. The former predominated in the samples examined.

composting, solid waste, organics, energy, paper, waste composition, collection, recycling, glass, India

104

Grandjean, O.
Rehi, R.
Gomes, I.C.

Composition and Treatment of Domestic Refuse of the City of Blida, Algeria. International Solid Wastes Association Journal. Number 30. pages 7-9. International Solid Waste and Public Cleansing Association. January, 1980. Zurich, Switzerland. References.

A study of the composition and physiochemical analyses of municipal wastes in Algeria was done to determine the most appropriate disposal practices. The major share of the refuse was organic and included vegetable waste (66.9 percent) and paper (15.7 percent). The refuse had a high moisture content, significant salt content and a high potassium content. Composting was the recommended disposal method. The possibility of secondary markets for metals recovered from the refuse was suggested. Further investigation is needed to determine the feasibility of

mixing the refuse with sewage sludge for composting. Extensive local and national benefits in agricultural production and land reclamation could be realized by composting.

Algeria, waste disposal/treatment, composting, sorting, sludge, waste composition, agriculture

105 Grandjean, O.
Gestion des Dechets Solides de la Region de Medellin. Ecole Polytechnique Federal de Lausanne, Lausanne, Switzerland. December, 1980. 75 pages. References.

This document provides an in-depth view of solid waste management in Medellin, Colombia and the surrounding area. It details a proposal to: 1) enhance informal sector activities in reclamation; 2) implement a workable compost system; 3) reduce the use of the landfill and long distance transportation for solid waste disposal. The review of waste management practices finds the current system expensive and a drain on municipal revenues. The environmental impact is negative for the current landfill which suggests either expensive cleanup or moving new landfills to distant locations.

A sampling methodology for wastes is described which deals not only with mixed wastes, but with individual components (glass, wood, paper, etc.) in order to determine their value. Seasonal samples of wastes were collected from several areas of the city. There was little variation noted. Sixty percent of the materials are organics.

Physiochemical analysis of the refuse showed that the energy value was very low--about 30 percent volatiles with energy contents of 1,060 kcal/kg (unprocessed raw), 2,610 kcal/kg (wet, processed) and 3280 kcal/kg (dry, processed).

Analyses for heavy metals revealed 3,000 ppm of chromium, 2,300 ppm of zinc, 1,200 ppm of manganese, 825 ppm of lead, and 1.3 percent iron.

An economic/energy analysis for source separation and composting versus incineration is presented which shows that incineration would be more expensive, less energy efficient and would add a high incremental cost to the current solid waste system. The separation-composting system would show a net energy gain.

Waste Component	Estimated Value		Verified Value
	Pesos/Ton	Pesos/Kg	Pesos/Kg
Average value	250	-	1.91-2.89
Commercial	210	2.39	-
Residential	350	2.54	-
Downtown	450	2.62	-

Further recommendations include: integrating sorting and recycling with end users, and further investigation of markets, transportation and institutional change.

Colombia, sorting, informal sector, economics, composting, organics, paper, waste composition, economic analysis

106 Lohani, B. N.
Thanh, N. C.

Problems and Practices of Solid Waste Management in Asia. Prepared for the Asian Institute of Technology. Bangkok, Thailand. Adapted for publication in Journal of Environmental Sciences. May/June, 1980. pages 29-33. References.

This paper discusses variables which affect solid waste generation and management activities in urban areas of Asia. The nature of waste is changing with rising standards of living. Homes and businesses are increasingly highrise buildings. Population densities have greatly increased. Religious practices and social attitudes towards cleanliness must be taken into consideration and can compound problems. Comparative data on solid waste generation are presented. In developing countries the density is greater due to the amount of moisture and organic materials which are present.

Wastes are collected at varying frequencies. A large quantity of waste is not collected and accumulates, which causes problems of diseases and rodent infestation. Urban congestion tends to limit collection services.

Use of landfills is not high as land availability is poor and there are not enough vehicles. Ninety percent of landfill is crude dumping. Composting is extensively practiced in India, but is rare elsewhere. Mechanized plants in Southeast Asia are unable to sell the compost which they produce.

Information is presented on pollution and health problems. Constraints to using European and U.S. methods of waste management are detailed.

waste composition, solid waste, Asia, India

107 Munoz, M.
Analysis y Necesidades del Servicio de Aseo Urbano de Lima Metropolitana. Municipality of Lima. Lima, Peru, December 1981. 21 pages.

This document analyzes data on waste composition and institutional arrangements and makes recommendations for new approaches to solid waste management in Lima, Peru.

Per capita generation of solid waste is 0.84 kg/day or 4,000 metric tons per day for the city. Household and commercial wastes are collected daily. The city has 233 compactor trucks, 19 non-compactor trucks and 78 other vehicles. About 50 percent of these are operative. The labor force numbers 3,300. Three transfer stations and one landfill are used. Unofficial landfills are operated by syndicates which cause social and environmental problems. Although feeding organic waste to pigs is illegal, the practice is ongoing and contributes to the risks of infectious disease.

Materials recovered from a landfill in one day's time include 50 tons of corrugated paper, 20 tons of plain waste paper, 10 tons of glass, 40 tons of metal, 10 tons of plastic, 10 tons of textiles, 20 tons of bone, and 10 tons of aluminum.

The report details financial and environmental problems associated with solid waste management in Lima, which has grown in population from 1.8 million in 1961 to 5 million in 1981. Comprehensive planning efforts for 1982-1985 and 1985-1990 are recommended.

waste composition, scavengers, landfills, Peru, solid waste management

108 Rathje, W. L.
The Milwaukee Garbage Project. Solid Waste Council of the Paper Industry. Milwaukee, Wisconsin, U.S.A. 1981. 115 pages. References.

This study compared household income with waste generation. Five neighborhoods, differentiated largely by income, in Milwaukee, Wisconsin were analyzed in detail. The methods used were developed based on seven years of experience analyzing household solid wastes in Tucson, Arizona. The purpose of the project was to investigate how households disposed of their wastes and if waste disposal could be correlated to family income and/or size.

Refuse from five selected and stratified sample areas was recorded during fall 1978, spring 1979 and fall 1979, using standard "Garbage Project" methodology. This work produced three data bases: Total Pickup Weights, consisting of the total weights of individual household refuse pickups (598 samples); Weight Sorts, consisting of refuse samples whose contents were sorted into fifteen material composition categories and weighed (224 samples); and Regular Sorts, composed of refuse samples whose contents, including food debris and packaging, were recorded item by item (179 samples).

It was found that: (1) The solid waste discarded by Milwaukee sample households in 1978 and 1979 were well below projections based on national per capita discard weights calculated by the U.S. EPA for 1971. This is a good indication of what the U.S. EPA has emphasized, that the realities of local solid waste streams are better measured in the field than estimated from product-flow models. (2) The average weight of solid waste discarded weekly by sample households was a little over 25 pounds. Sample households in the two low income, and one middle income area discarded more refuse overall than households in the other two areas. (3) As percentages of total weight, the material composition of refuse from sample Milwaukee households seems within the normal range for other American cities. (4) The material composition breakdown of household solid wastes indicates that sample households in the two low income areas discarded more packaging by weight than sample households in other areas. (5) Differences in discarded packaging are due to home consumption of some prepared foods and beverages and to large numbers of products packaged in small containers. (6) Judging from their higher discard of food and beverage packaging, sample households in the low income areas would probably pay more than households in the other areas--in both real dollars and in percentage of income--if product disposal charges were levied.

municipal wastes, testing methods, United States, waste composition

109 Woodyard, J.
Municipal Solid Waste Survey Protocol. U.S. Environmental Protection Agency. Municipal Environmental Research Laboratory. Cincinnati, Ohio. U.S.A. 1978. Prepared by SCS Engineers. Contract #68-03-2486. 400 pages. References.

This study was conducted for the U.S. EPA and is a comprehensive report on different methods to estimate, characterize and sample wastes. Survey costs, objectives and methods are discussed in detail. Statistical analyses of waste samples were developed and used in computer models to assess economic sensitivity of resource recovery operations.

solid wastes, municipal solid wastes, waste sampling, United States

COLLECTION AND TRANSPORTATION

201
Analysis of Source Separate Collection of Recyclable Solid Waste: Collection Centers. Prepared for Resource Recovery Division, U.S. Environmental Protection Agency, Washington, D.C., U.S.A. Prepared by SCS Engineers. August, 1974. 49 pages. References.

This report presents the results of 13 case studies of collection centers. Information was obtained on performance and operating costs, as well as the time needed for households to separate, prepare and deliver recyclable waste materials to the centers. There are an estimated several thousand recycling centers in the U.S. Recycling/collection centers are of three types: citizen, commercial or municipal. All types require labor, land and equipment. Citizen centers rely on voluntary labor, while commercial and public municipal centers have paid labor.

Expensive and extensive equipment was used at municipal centers, while citizen and commercial centers used donated or salvaged equipment.

United States, solid wastes, recycling center, costs

202
Analysis of Source Separate Collection of Recyclable Solid Waste: Separate Collection. Prepared for Resource Recovery Division, U.S. Environmental Protection Agency. Washington, D.C., U.S.A. Prepared by SCS Engineers. 1974. 103 pages. References.

This report presents results of 22 case studies on separate collection programs throughout the United States. Sample households conducted a two-month study which required separating items suitable for recycling. The amount of time the households needed to prepare the items is detailed, as are complete cost data. An analysis was done to determine optimal approaches to home recycling. Separate versus integrated collection is considered. The data indicate a negative attitude is usually displayed toward the scavenger sector. Recommendations are made to forcibly exclude scavengers from participating in community efforts, rather than integrating their efforts.

resource recovery, scavengers, solid wastes, source separation, costs

203
Case Study: Separate Collection in Hoje Tastrup, Denmark. Organization for Economic Cooperation and Development. Environment Directorate. ENV/WMP/79.5. Paris, France. July 1979. 38 pages. References.

A separate collection program for recyclables was developed in Hoje Tastrup, Denmark. Paper, glass and metals are separated for pick-up at 4 week intervals from homes, using trucks with compartments and adjustable partitions. Apartment buildings use a central container, also

with compartments. Collection is done as necessary. Free collection of recyclables is offered to businesses who separate material.

Collected materials are sorted at the municipal recycling station. Reusable bottles are salvaged. White goods are dismantled for metals recovery using simple hand tools. Goods are sold directly from the station to end users or secondary materials dealers.

Collection from single-family households had contaminants of 15 percent, while apartments had 70 percent. By weight, the recyclables were 58 percent paper, 19 percent metal and 23 percent glass. Energy savings of recyclables versus virgin materials were computed as 162 kg of oil equivalent per ton recycled. The incremental cost of recycling was estimated at 38-57 kroner per household per year. Social benefits include increased employment, and reduction in disposal requirements.

source separation, paper, glass, tin cans, intermediate processing, Denmark

204
Households Contributing to Resource Recovery. Swedish Institute for Resource Recovery. Malmo, Sweden, 1975. 42 pages. References.

This document was prepared by the Swedish Institute for Resource Recovery. It provides municipalities and companies with information on resource recovery. Tests were done to determine how much household waste could be recycled through source separation, on a nationwide basis.

Source separation recycling can be introduced with a net decrease in costs. For example, three to seven percent of the costs of waste disposal can be eliminated in a town of 50,000 people. Further reductions might be possible if treatment facilities and transportation costs were reduced, based on reduced amounts of waste collected. Municipalities should view source separation as an activity at least as important as waste disposal. In addition, professional attention must be given to selling the recycled goods. Recommendations included making long term arrangements with Swedish paper mills to utilize waste paper and establishing other secondary materials markets. Tests were done in 176,000 households and indicated that residents have a favorable attitude and will initiate source separation. Participation averaged 70 percent.

source separation, Sweden, resource recovery, marketing, costs

205
Source Separation Collection and Processing Equipment: A User's Guide. Report (SW-842). Prepared for the Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C., U.S.A. Prepared by Resource Planning Associates. 1980. 55 pages. References.

This document provides an overview of source separate collection processing procedures and equipment. It is well illustrated and helps instruct municipalities in the selection of equipment and systems. In

designing source separate collection systems, the following points need to be considered: 1) estimating citizen support; 2) surveying and negotiating with markets; 3) informing the public; 4) selecting equipment; 5) assessing labor needs; and 6) consideration of local ordinances.

Collection systems are varied. Specific equipment for collection and processing is described, with advantages and disadvantages listed for each.

Manufacturers and suppliers are listed. A number of systems in the United States are identified and described in terms of size, operation and equipment.

recycling, equipment, source separation, appropriate technology, United States

206 Archer, T.
Huls, J.

Resource Recovery from Plastic and Glass Wastes. U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, Office of Solid and Hazardous Waste Research. Cincinnati, Ohio, U.S.A. Prepared by Pacific Environmental Services. July, 1981. 139 pages. References.

This document reports on state of the art for recovering glass and plastics from municipal solid wastes. It is based on a review of the literature.

Questionnaires were distributed to firms involved with plastic and glass recovery. The data were evaluated for technical, economic and environmental content.

Both industries were characterized by processes, material flows, economic dynamics, and waste generated. Methods for recovery and recycling are identified. Economic and environmental parameters are provided. Currently, labor intensive source separation of glass and plastic predominant, although mechanical recovery will achieve greater importance in the future.

Also covered are world wide state of the art reports on materials recovery including estimates of the composition and per capita generation of waste in several countries.

glass, plastic, recycling, equipment, state of the art, markets, economics, processing, environmental management

207 Brown, M. D.
Vence, T. D.
Reilly, T. C.

Solid Waste Transfer Fundamentals. Ann Arbor Science, Ann Arbor, MI, U.S.A. 1981. 69 pages. References.

This manual covers the consolidation of refuse collected by small vehicles and then transferred to large volume trailers for efficient

transportation to a disposal site or a resource recovery facility. Truck transport of refuse is a well established technology which has initiated the development of equipment designed specifically for this purpose.

The manual presents a simple technique to evaluate whether refuse transfer will benefit a specific solid waste disposal situation. It also discusses the basic data required to analyze, design and implement a transfer system. Data include waste quantity and composition, traffic patterns, site characteristics, and opportunities for materials recovery.

There are two basic types of transfer systems: 1) direct dump and 2) hydraulic compaction. Direct dump systems can be subdivided into container, open top trailer, and storage pit systems. Hydraulic compaction systems use a stationary compactor and either enclosed trailers or enclosed containers. A variety of methods are used to feed the compactor: direct dumping, a front-end loader on the tipping floor, a conveyor, or a hydraulic push-pit.

Factors contributing to a successful operation, regardless of size, include a daily operating procedure, proper equipment and facility maintenance, adequate safety provisions, and an effective record keeping system. Transfer stations also offer opportunities for recovery of recyclable materials and energy from the solid waste being handled. Often a drop-off recycling center is provided at the site. Station users are encouraged (sometimes with financial incentives) to separate reusable items and recyclable materials. Additionally, certain materials can be recovered directly from the station floor. It is quite common to see cardboard picked from commercial loads and baled for resale. The transfer station may also serve as the first step in the development of a mechanized resource and energy recovery facility. As the cost of energy rises, systems utilizing the energy value of refuse become more and more attractive. Transfer stations should be designed to allow for a possible future resource recovery project.

The manual presents a case study based on the authors' experience in transfer station design. A city of 110,000 reaponded to the impending closure of its municipal landfill by developing a plan for a three part solid waste management center. It will include a recycling center with storage capacity for curbside collection of source separated materials, a transfer station, and a materials and energy recovery facility.

salvaging, solid wastes, intermediate processing, economics, collection

208 Bukreyev, Y.
Waste Systems in the U.S.S.R. Waste Age. National Solid Wastes Management Association. Washington, D.C., U.S.A. Volume 13, Number 2. February, 1982. Pages 68-70.

Collection practices in the U.S.S.R. share characteristics with operations in the U.S., but there are notable differences. For example, most housing in large Soviet cities consists of apartment buildings which require centralized collection. Containers are loaded from garbage chutes in the buildings and then hauled to a central depot.

Another example is a vacuum system for removing household wastes through special sewers that have been established in Moscow.

Currently, collected wastes in Moscow are incinerated. Metal is extracted from the residues with an electro-magnetic separator. Emissions have been acceptable. Other cities use landfill disposal, with increasing costs due to longer hauling requirements.

Composting of mixed waste is practiced with contaminants mechanically removed after processing. Compost is applied primarily on agricultural lands, but can also be used in greenhouses to raise temperature levels, and as a fertilizer supplement.

A waste to energy (steam) plant will soon be operating in the city of Vladimir. Its three chambers will burn 180 tons per day of solid waste, generating 53,000 hectocalories annually to be used by the city's utilities. Up to 30 percent of the residues (slag and ashes) will be used for making tiles. Metal will be recovered from the slag. The Vladimir plant will test equipment produced in the U.S.S.R. There is a high demand for installation of similar plants elsewhere.

solid waste management, Union of Soviet Socialist Republics, incineration, energy recovery, composting

209 Bunk, B.
Refuse Separation and Utilization on the North Sea Island of Juist, Federal Republic of Germany. Proceedings of the International Recycling Congress (Recycling Berlin '79). Berlin, Federal Republic of Germany. Pages 204-210. References.

This paper discusses source separation on the island of Juist. Two experiments were conducted in 1977 and 1978 which resulted in an ongoing program of separation and recycling, using horsedrawn carts. Recycling begins with on-site separation at commercial and residential locations. Three categories of waste are collected: paper, glass and metal/plastics. Organic wastes are composted and used in agriculture. Metals and plastics are currently disposed of, due to no end use markets.

recycling, source separation, Juist (Island of), Germany (Fed. Rep. of)

210 Flintoff, F.
Management of Solid Wastes in Developing Countries. World Health Organization. WHO Regional Publications, South-east Asia Series #1. 1976. Green Park, New Delhi, India. 276 pages. References.

This manual was initially developed to guide Indian officials who are responsible for solid waste collection and disposal. It is an important work useful for solid waste management in all developing countries. Topics covered are: sampling methods to characterize wastes, refuse storage and collection, collection vehicles, sources of waste, transfer facilities, and treatment and disposal.

The data is based on experiences in over 20 countries in Southeast Asia, the Western Pacific, and the Eastern Mediterranean. Well illustrated, the document present technical, economic and sociological data.

The author suggests that Western technical literature is not directly applicable to developing countries. Cultural differences, the lack of capital and the type of wastes all must be considered when planning a solid waste management system. It is important to create a system that is labor intensive, using indigenous tools and equipment. Costs should be in keeping with local budgets.

Composting is discussed in substantial detail. Wide variations are noted between countries in what is composted and how best to utilize the product.

waste composition, testing methods, composting, economics, solid waste management, India, recycling, developing country

211 Gotah, S.
Tamara, E.
Yukhi, Y.

Source Separation for Resource Recovery--State of the Art. National Institute for Environmental Studies. Tsukuba, Japan. November, 1978. 58 pages. References.

This report describes resource recovery in two medium sized Japanese cities. Resource recovery is extensively practiced in cities where the population is less than 300,000. Incineration is a major form of waste disposal and the resulting environmental problems helped influence a move towards resource recovery and source separation. It is recognized that resource recovery at the source reduces waste and, at the same time, collection costs and requirements. Citizens separate three to five categories of recyclables and non-recyclables.

The document details a community conflict of recycling versus incineration which was resolved to allow for both recycling and incineration--an example of an integrated approach to resource recovery where high and low technology co-exist. The costs and design of the system are presented.

resource recovery, state of the art, processing, collection, costs, economics, incineration, source separation, Japan

212 Hoy, S. M.
Robinson, M. C.

Recovering the Past: A Handbook of Community Recycling Programs, 1890-1945. Public Works Historical Society. Chicago, U.S.A. 1979. 24 pages. References.

This document traces the roots of conservation and recycling in the United States. Basic strategies for implementing recycling programs include marketing, labor, materials handling and promotion.

In the early 20th century industrialization and the resulting waste and pollution created new citizen awareness of the need to clean up the cities. New York City, under the direction of George Waring, created a comprehensive program of resource recovery and promoted cleaner streets and better public health, which reduced costs of solid waste management. This program, begun in the early 1890s, was successful and widely copied.

World War I gave further impetus to resource recovery and materials reclamation. Some cities used prisoners as a labor source for these programs and set aside some of the revenues for the prisoners' families. For example, in 1916, the city of Chicago gave US$40,000 to the families. Additional revenues were used for landfill reclamation projects.

During World War II, the War Production Board coordinated renewed recycling efforts. However, after the war, with the coming of prosperity, Americans abandoned most recycling, until the early 1970s.

United States, recycling, prison employment, historical

213 Stearns, R. P.
Anthony, R. V.
Howard, S. E.

Office Paper Recovery: An Implementation Manual. Prepared for U.S. Environmental Protection Agency. Washington, D.C., U.S.A. Prepared by SCS Engineers. 1977. 53 pages. References.

This document was prepared by the U.S. Environmental Protection Agency in accordance with the Resource Conservation and Recovery Act of 1976. The recovery and utilization of paper from office buildings can save valuable fiber resources, lower environmental emissions and reduce waste management expenses. This implementation manual was prepared for distribution to the public and private sectors.

Information is provided on the quantity of paper which could be recovered, its market value, the various kinds and grades of paper, separation methods, collection and storage equipment, and model contracts.

Recovery of high grades of paper from office buildings is one of the fastest growing forms of resource recovery in the U.S. Costs of waste disposal from office buildings can be significantly reduced through revenue from sales.

office building recycling, waste paper recovery, waste management, costs

214 Von Heidenstam, O.

Swedish Experience in Separation at Source Solid Wastes. Institute of Solid Waste Management. London, U.K. Volume LXVII, Number 7. July, 1977. pages 284-95. References.

This document reports on the increasing need for source separation of waste in Sweden. The government view is that refuse is raw

material to be recovered. In May 1975, a national bill was approved on the collecting and recycling of wastes. It required the collection of waste paper exclusively by the municipal refuse disposal authority. In homes, compulsory sorting applies only to newspaper and magazines. The legislation was preceded by pilot studies indicating household cooperation was essential.

State grants are available for 50 percent financing for recovery plants and 25 percent grants for material benefication. Regional solutions are preferred.

Municipal wastes are characterized. Also the amounts of recovered material are noted in the report.

Collection is done by separate vehicles or by bagging recyclables separately which are picked up with the regular refuse collection. In apartments, the landlord pays for extra sacks or dustbins and benefits from lower refuse removal costs. For private homes, a 2 1/2 to 3 ton truck with a two person crew is used while a 3 1/2 to 4 ton truck with a one person crew is used for apartment house pickups.

Contracts between municipal authorities and paper companies vary in regard to price and responsibility for collection. Problems in paper recovery by municipalities are price and storage.

paper, source separation, separate collection, municipal waste, vehicles, waste composition, solid wastes, Sweden

215 Werth, P.
Vehicles and Containers for Separate Collection--Technical and Economic Criteria. Proceedings of the International Recycling Congress (Recycling Berlin '79). Berlin, Federal Republic of Germany. Pages 853-858. E. Freitag--Verlag für Umwelttechnik. 1979. References.

This paper examines several types of vehicles and containers which collect and separate recyclables.

Recycling is enhanced by cleaning and keeping the various materials separate. Once mixed, they are usually reduced to their lowest economic value unless additional sorting takes place. Separate collection of recyclables requires large scale citizen information and motivation, a highly developed organization, and special attention to proper integration of collection systems and equipment with end use markets.

Separate collection in trade industries for recycling is feasible due to high and concentrated volumes of scrap. Drop-off boxes and roll-off containers are convenient to use. For selected light materials it seems advantageous to use a compaction mechanism. The author compares compaction vehicles and roll-off containers for plastics and paper. The results suggest greater payload opportunity for compaction vehicles but larger volumes are needed to justify the vehicles. Problems can also be created if more than one material is collected and separation is required at a

later date. Separate collection was found to be more efficient than collection centers for household wastes.

separate collection, economics, source separation, vehicles

216 Willerup, O. H.
Recycling of Glass. Conservation and Recycling. Pergamon Press. U.K. Volume 1, Number 1, 1976. Pages 149-159. References.

Recovery of glass from European households is discussed in this article. The arguments for and against nonreturnable beverage containers are discussed. The results of a Swedish study are reported where the energy consumption is compared for a returnable bottle, a nonreturnable PVC bottle, a nonreturnable steel can and a nonreturnable glass bottle. Results are reported of British, Danish and Swedish test collection of paper, glass and metal. Reuse procedures are described for collected glass.

Household refuse in Europe generally contains five to ten percent glass. Per capita production of refuse in Denmark is about 300 kg per annum. An unusually low percentage is comprised of beer and soft drink bottles because government legislation permits brewers to sell only four percent of their total consumption in non-renewable bottles.

Glass scrap is not simply competitive with virgin materials; it complements the manufacturing process. This both aids and complicates the possibilities of recycling glass. Glass usually contains a specified addition of cullet which, because of its lower viscosity, speeds up the mixing and reaction of raw materials and also reduces the energy consumption. For this reason, glass manufacturers usually produce a supply of their own cullet, whose quality is known and preferred to purchased glass scrap of unknown quality and composition.

glass recycling, Denmark, Sweden, United Kingdom, returnable containers

217 Diaz, L. F.
Savage, G. M.
Golueke, C. G.
Resource Recovery from Municipal Solid Wastes, Volume 1 Primary Processing and Volume 2 Final Processing. CRC Press. Boca Raton, Florida. 1982.

The authors summarize and evaluate municipal solid waste management and recycling practices in the United States as of 1980. Cost data presented for a few of the unit processes reflect the greater emphasis in the United States on technological and operational aspects of capital intensive resource recovery from mixed refuse. Engineering observations or principles are given for selecting equipment for conveyance, size reduction (horizontal and vertical hammermills), separation (air classificators, trommel screens, magnets), incineration with heat recovery from mixed refuse or from refuse derived fuel (pelletized or loose), anaerobic digestion, single cell protein and ethanol production, composting, and

residual disposal (landfill) systems. Glass, paper, and other recyclable components are identified.

anaerobic digestion, appropriate technology, composting, costs, equipment, fuel, glass, incineration, landfill, municipal solid wastes, paper, processing, recycling, solid waste management, United States

218 Vogler, J.
Work from Wastes. Intermediate Technology Publications, Ltd., and Oxfam. London, United Kingdom. 1981.

The author provides comprehensive technological information and marketing strategies for recycling paper, ferrous and nonferrous metals, glass, plastics, rubber, nonferrous and precious minerals, chemicals, oil, and human and animal wastes. Details of designs or names of manufacturers are provided for such products as egg cartons, roofing paper, sorted and processed metal scrap or billets, metal fabrication, shoe soles, simple and advanced glassmaking, molded and extruded rubber and plastics, and construction materials. Initial costs are provided for selected systems.

Case studies of small scale enterprises based on waste plastics or vegetable matter are presented. Emphasis is on collection, sorting, quality control, health aspects, and pricing.

agricultural wastes, appropriate technology, building materials, chemicals, collection, costs, equipment, ferrous/nonferrous recovery, glass manufacturing, glass recycling, health and safety, marketing, molded products, oil, paper, plastics, plastics recycling, processing, recycling, rubber, small scale industry

219 Abert, J. G.
Resource Recovery Guide. Van Nostrand Reinhold Company, Inc. New York, New York, U.S.A. 1983. 593 pages.

This publication is a selection of articles, some condensed, mostly published in the United States from 1976 to 1979. One section considers planning, procurement, marketing, economic and financial aspects of industrial systems for resource recovery, and for some systems aggregated costs. Information is provided on glass, paper, steel, plastics, rubber and aluminum recycling, energy recovery through direct combustion of unprocessed and processed waste, pyrolysis, and other recycling techniques.

Some of the changes in attitute and technology regarding municipal waste recycling during the 1970s are documented. Also included are details on U.S. Department of Energy planning approches and risk analysis.

costs, economic analysis, energy recovery, ferrous/nonferrous recovery, glass, marketing, paper, plastic, pyrolysis, recycling, rubber scrap, technology

PROCESSING

301 Ambrose, J. A.
Composting. In Proceedings of International Symposium, "The Practical Implications of the Reuse of Solid Waste." 11-12 November, 1981. London, U.K. Pages 63-111. Institution of Civil Engineers. 1981. References.

This paper reviews several large composting plants. The mechanical methods by which batch production has been modernized into continuous plant operations are discussed.

Italy: The large Dano plant feeds refuse to stabilizers without pretreatment. Compost is produced and stored in covered shipment from the site. A large percentage of plastics is removed. This includes the bags used for collection, which are then burned in incineratora. Metals are left in the refuse and extracted from the product after discharge from the stabilizers. The presence of metals in the stabilizer was reported to help in the breakdown of the refuse.

Hong Kong: The plant was commissioned in 1979 and has a through-put of 240 tons per eight hour shift. It is a combination of several methods of producing compost. Refuse is fed through a primary and secondary crusher before it is fed into a horizontal slow speed drum. From this drum it is lifted to vertical composting towers. Each tower has three floors. After a 72-hour retention period, it is passed to a covered windrow for final maturing. The main purpose of this plant is to produce suitable material for covering landfills, which is not readily available in Hong Kong.

Libya: Three plants have been built in Benghazi, Tripoli and Beida. Benghazi produces 400 tons per day; Tripoli 500 tons per day and Beida 60 tons per day of compost. The refuse at all plants is pulverized in both primary and secondary mills before being screened. The fine product is then passed to the digester. Metals are extracted before screening. The system includes a compost grading plant, an incinerator for materials not composted, a metals "roaster" and a baling system for recovered ferrous metal.

India: The Bangalore system of composting has been used in India for many years. Originally this was an anaerobic system used on a small scale which provided a low-cost solution for the combined disposal of solid wastes and nightsoil. These materials are placed in alternate layers in small trenches which are sealed and left undisturbed for many months. The contents are then dug out and used as compost.

This system is now being abandoned in favor of aerobic methods, which are faster and need less land than anaerobic methods. The character of solid waste components has to be anslyzed to determine how suitable it is for composting. Although similarities exist in solid waste throughout the world, there are extremely wide variations in the proportions of the components. This can vary not only between countries but even between regions within the same country. Middle Eastern wastes are compared with those of India and Europe in the table below. It illustrates the importance of adopting composting systems to match available wastes.

CONSTITUENTS

	% By Weight		
	India	Middle East	British
Essential to compost			
Vegetable, putrescible	75	50	28
Acceptable for compost			
Mixed paper	2	20	37
Inert below 10 mm	12	14	9
Compostable total	89	84	74
Salvageable Constituents			
Paper (also included above)	2	20	37
Metals	0	9	9
Glass	0	4	9
Textiles	3	4	3
Plastics	1	3	3
TOTAL of potential salvage	6	40	61

composting, technology, solid waste, India, Italy, Hong Kong, Libya, organics

302
Advances in Small Scale Refuse Incinerators. Seminar Proceedings. Newfoundland, Canada. Solid Waste Management Branch. Environmental Conservation Directorate. EPS-3-76-10. 103 pages. 1978. References.

This document is based on two seminars held in Newfoundland to consider the use of small-scale refuse incinerators as a solution for provincial solid waste problems. Topics included design, costs and benefits, air quality standards and a detailed description of state of the art. Detailed illustrations explain how the design of the incinerator relates to the combustion process. The costs for all basic types of units are presented and compared to typical landfill costs. Case studies of three sites in Canada are reviewed. The data focus on how the incinerators were selected, how their sites were selected, and how to meet environmental standards economically. Federal regulations pertaining to incinerators are evaluated.

Based on practical experience, the authors recommend specific actions to take to meet various standards, e.g., where hydrogen chloride is a problem they recommend limiting PVC in waste to 0.25 percent of feed.

small scale industry, incineration, Canada

303

The Bangkok Solid Waste Management Study in Thailand. Prepared by Japan International Cooperation Agency. Tokyo, Japan. 1981. 523 pages.

This study provides a comprehensive analysis and implementation plan for developing a solid waste management policy in Bangkok, Thailand. The goals of this policy are to help clean up the city and promote effective use of compost.

A history of solid waste management is presented and includes present volume and properties of solid waste. Estimates are based on statistical data and results of field investigations. Forecasts of future volumes of waste for the year 2000 are made based on socio-economic data.

Short-term improvement of solid waste practices was considered from the point of view of management, collection, transport, compost plants, final disposal and management during floods.

Compost operations began in 1961 with four plants currently operating. An incinerator is attached to each plant to combust organic wastes classified as unsuitable for composting. The four plants' treatment capacity is 1,120 tons per 8 hour shift. The process begins with impact pulverization of delivered solid waste, classification, 5-day indoor primary fermentation, and 2-month outdoor secondary fermentation using an open-air storage method. Upgrading of compost for sale is conducted by a system of 12 rotating trommel screens. Quality and fertilizer aspects are described. Retail price for compost grades range from 370 Bhat/ton to 740 Bhat/ton. In 1980, total sales value was 7.7 million Bhat.

Ferrous metal is also recovered and sold. The amount of recovered ferrous metal by the magnetic separator from the raw waste entering the compost plants is approximately 0.8 tons for each 100 tons of raw waste. The recovered ferrous metal is compressed into blocks weighing 30 kg on average. There were 2,400,616 blocks (about 72,000 tons) recovered by the 4 compost plants in fiscal 1980. Retrieval of materials by workers is done during regular collection of solid waste. The recovered materials are purchased by junk dealers.

The monthly earnings by scavenging materials is about 1,500 Bhat. Coupled with other fees, a worker can almost triple his income.

Specific recommendations to improve composting operations include: a manual or mechanical system to remove glass, metal, and plastics; building a roof over the secondary fermentation yard; preparing an operating and quality control manual; changing the pricing policy to realize large scale sales at a low price; increase sales by selling composted material as landfill cover and for use on parks and road shrubbery; and encouraging trial applications on farm land.

Total estimated demand for city compost is 90,000 tpd, or 1,900 tpd of compost plant capacity. Since the existing compost plants have a total capacity of 1,120 tpd, additional plants with a capacity of 800 tpd could be constructed. New plants should use aerated composting which is low in production cost and easy to operate and maintain. Fertilizers derived from various types of wastes are detailed.

Methanation and feeding (conversion to cattle feed) were excluded from resource recovery evaluation since these technologies are not yet fully established.

Recommendations for improved environmental protection and public health include door-to-door collection, intermediate treatment (physical, chemical and/or biological processes) to make solid waste non-toxic, reduced in volume, and reusable.

solid waste management, composting, ferrous scrap, Thailand, scavengers

304
Bibliography on Disposal of Organic Refuse by Composting. Institute of Engineering Research, University of California. Berkeley, California, U.S.A. 1950. 80 pages. References.

This document is an annotated bibliography compiled by the Sanitary Engineering Research Project of the University of California, Berkeley, after a critical review of the literature. It includes selected articles pertaining to composting. The main source of references from which the bibliography was compiled were Chemical Abstracts, Industrial Arts Index, Engineering Index and the World Bibliography of Bibliographies.

The bibliography is divided into sections of general references, references to journals, and a subject index.

composting, developing country, organics, waste disposal/treatment

305
Compendium on Solid Waste Management by Vermicomposting. Prepared for U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory. By Camp Dresser and McKee, Inc. Boston, Massachusetts, U.S.A. March, 1980. 55 pages. References.

This report assesses the technical and economic feasibility of vermicomposting. It is based on a pilot study in Ogden, Utah, U.S.A. The species of earthworms used, the physical parameters of the worm culture and the physical and chemical changes that occur during vermicomposting are described. Facilities and costs for cities of 50,000 and 500,000 are detailed, using the Ogden model and compared with sanitary landfill, windrow composting, and modular combustion. The cost of US$24-32 per ton of processed waste was high compared to the other methods. The reason for this may have been the use of shredding and magnetic separation to homogenize materials. The Ogden test used shredded mixed waste subjected to one pass through a magnetic separator for ferrous metal. This material was windrowed for composting. Worms were added after three weeks. Additional mixed waste was added. After the prior separation of paper, glass, and metals, the study showed that for every 100 tons of waste, 36 tons of recyclables and 33 tons of worm castings are produced with 13 tons

lost as moisture and volatalized solids and 18 tons left as residue for land fill. Markets for the product and its environmental impact are discussed.

vermicomposting, solid waste management, economic analysis, markets, United States

306
Improving Soil Fertility Through Organic Recycling: Compost Technology Collected Lectures. Delivered during project training course held at New Delhi, India. October-November, 1980. Food and Agriculture Organization of the United Nations. 214 pages. 1980. References.

This course covered theoretical and practical aspects of composting. Both urban and rural composting techniques are discussed. Participants in the training course were from ten Asian countries. Lecture topics included fundamentals of composting, different methods, present state of composting, low cost technology, compost enrichment, agricultural aspects and more. Practical laboratory work and visits to compost factories were part of the course.

This training course is intended for use as the basis for a field manual.

technology, Asia, organics, soil amendment, recycling, composting

307
Improving Soil Fertility Through Organic Recycling: Management of Organic Recycling. Proceedings of Project Seminar held in Kathmandu, 9-14 March, 1981. Food and Agriculture Organization of the United Nations. New Delhi, India. 1981. 221 pages.

The proceedings of this seminar concluded that recycling of urban wastes has made substantial progress, although much research remains to be done. Reports came from Burma, Hong Kong, India, Indonesia, Korea, Malaysia, Nepal, Pakistan, Philippines and Thailand. Recommendations were: 1) it is important to consider the value of NPK in compost. Other benefits such as an improved environment, better health and long-term improvement of a country's soil need to be assessed when appraising proposals for compost plants. 2) Local and national agencies need to closely coordinate their efforts. This will aid marketing and promotion activities. 3) When compost is produced from municipal wastes, it is essential that monitoring programs be established to ensure that the product is safe. 4) It is advisable to start marketing compost in advance of the commissioning of plants. This could be accomplished by setting up a small (5 ton per day) plant during construction of the main plant. 5) More research should be done on the enrichment of compost in coordination with agricultural research institutions.

composting, organics, soil amendment, recycling, waste management, municipal wastes, Burma, Hong Kong, India, Indonesia, Korea, Malaysia, Nepal, Pakistan, Philippines, Thailand

308
Materials Reclamation Weekly 1981 Directory and Handbook. A. Cohen and Company, Limited. London, U.K. 1981. 432 pages. References.

This catalogue is an up-to-date source for equipment for handling secondary materials and market information. Primarily United Kingdom manufacturers are represented. Materials specifications for European, American and Indian industry are discussed for paper, nonferrous metals, ferrous metals, textiles, plastics, rubber, chemicals and oils. Technical test programs are reviewed. A glossary of terms is also presented for each material. Legislative developments are reviewed. There is an index to advertisers and directory of United Kingdom reclamation companies.

equipment, manufacturers, paper, textiles, rubber, plastics, chemicals, oils, United Kingdom, ferrous scrap, nonferrous scrap

309
Mechanical Sorting of Household Waste in Rome, Italy. Environment Committee, Waste Management Policy Group, Environment Directorate, Organization for Economic Cooperation and Development. Paris, France. 1979. 16 pages.

Italy has established a national policy which examines all types of resource recovery and reuse. This document is a case study of householdwaste collection and mechanical sorting in Rome.

There are two plants, 600 tpd and 1,200 tpd in operation. Residues are incinerated. Paper, iron, plastics, animal feed, compost, steam, glass and electric power are recovered. Incinerated wastes produce steam of 8 atm saturation used in internal technical process with part sold to neighboring industrial plants. Local markets for materials are described, including types of contracts, and processing required.

In 1973 a basic charge of 3,850 lire per ton processed was paid to the company by the Rome municipality. This includes a charge of 70 percent share for write-off. The average charge for the period 1973-78 was 6,100 lire per ton. This corresponds with costs per ton for a safe and effective treatment system.

sorting, municipal waste, animal feed, incineration, Italy, secondary materials recovery, recycling, energy recovery, collection

310
Recycling of Waste Paper from Federal and Provincial Buildings in Toronto. Environmental Conservation Directorate of Canada, Ottawa, Canada. 1977. 105 pages. References.

This document reports on the feasibility of collecting waste paper from federal office buildings in Toronto, Canada. A pilot project was initiated that determined volume, composition, potential markets, and costs. The pilot project indicated significant savings. Estimates of

revenues from sales and disposal cost savings are US$57,420 per year. Implementation costs are estimated at US$44,000. Total annual operating costs are estimated at US$21,000. Net revenue and savings of US$8,020 per year could be generated at an assumed % opportunity cost of capital (or market cost).

waste paper recovery, office building recycling, Canada, cost analysis

311
Waste Oil Reclamation. United States National Technical Information Service, United States Department of Commerce. Springfield, Virginia, U.S.A. July, 1981. pages 1964-1981. PB81-87471. References.

This published literature search contains state of the art data on oil recovery, reclaiming and re-refining, from both technical and economic perspectives. Generally, high technology systems are noted, although pilot scale and small scale applications are included.

oil, environmental management, resource recovery, state of the art, economics

312 Baldensparger, H. L.
The Akron Industrial Salvage Company: A Community Incorporated Waste-Saving Experiment. United States Department of Commerce. Waste Reclamation Service. Government Printing Office. Washington, D.C., U.S.A. 1919. 20 pages.

This historic article discusses a community operated salvaging program started in Akron, Ohio in 1918. Eventually a warehouse on a railroad siding was chosen for the sorting of salvaged materials. No heavy equipment was used. Material flow was: (1) offloading outside the facility; (2) movement of materials into a basement; and (3) material moved to a sorting room in an upper story. During a little more than a year, the operation handled 600,000 pounds of wastes and sold 220,000 pounds. Payment was based on weights of unsorted materials minus sorting charges. Several firms pooled their wastes, creating a greater volume of salvageable materials.

The document also discussed municipal source separation; prison labor systems; public building collections; training of salvage managers; and a British national waste saving program similar to the one in Akron.

source separation, community enterprises, recycling, salvaging, processing, marketing, historical, prison employment, United States

313 Bates, C.I.
Neilson, T.D.

Pulling Iron Out of the Fire: Extracting Tinplate from Domestic Refuse Prior to Incineration. Material Recovery, Ltd. and Staffordshire County Council. U.K. February, 1980. 19 pages. References.

This article discusses the removal of tinplate scrap from mixed waste. Detinners require that the scrap be relatively free of contaminants such as food and plastics and not be crushed to permit adequate cleaning. As a result, transportation costs for loose cans are very high.

The incorporating of a ferrous recovery system into an existing waste incineration plant in Stoke-on-Trent Staffordshire is described. The system constraints include: limited space, need to open plastic bags, and minimum nuggeting (crushing). A flail mill shredder was considered. It would open bags and not nuggetize cans and was the least costly of the options. However, it was rejected for its size and the vibrations it produced at high speeds. Eventually, a slow speed shear shredder was chosen. It shredded to minus 6" throughout at up to 30 TPH, opened all bags, did not overnuggetize the cans, handled bulky material and some white goods, and operated quietly.

After the first shredding, ferrous material is conveyed to a secondary magnetic separator for a finer secondary shred. The final product is baled for transport.

tinplate recovery, ferrous scrap, equipment, recycling, United Kingdom

314 Bowerman, F.R.
Compton, C.R.

Composting Operation in Los Angeles County. Compost Science Journal. Rodale Press. Emaus, Pennsylvania, U.S.A. Volume 1, Number 4, 1961. Pages 5-8. References.

This historical paper documents a unique pilot program in Los Angeles County, California, U.S.A. which involved low cost composting of combined refuse and sludge. A concrete drum dryer unit, alfalfa grinder, and miscellaneous conveyors were combined into a functioning pilot plant. Mechanical rotation and forced air feed prepared sorted raw refuse during a two day retention. This material was then windrowed for 4-6 weeks and sold. Internal temperatures reached 160°F for 2 days which was sufficient to destroy harmful bacteria. The mechanical unit was 5 feet in diameter, 30 feet long, and was rotated at 0.67 rpm or 10.5 feet per minute. The unit functioned as continuous batch process and was later compartmentalized to offset operating difficulties from the uniform mixing of stabilized and unstabilized materials. Principal advantages include low capital cost, use of readily available materials (dryer drum) and application of diverse technologies to the composting process.

composting, costs, equipment, processing, organics, pilot plant, United States, historical

315 Bowring, E.
Mitchell, G.

Small Scale and Low Technology Resource Recovery Study. United States Environmental Protection Agency. Municipal Environmental Research Laboratory. Cincinnati, Ohio, U.S.A. Prepared by SCS Engineers. January, 1979. 253 pages. References.

This study was conducted to assess the applicability of various approaches to resource recovery. Institutions, businesses, multi-unit residences and small cities were included. The resource recovery systems and technologies were limited to small scale operations, defined as less than 100 tpd input, or low technology approaches, defined as having more than 50 percent of operation and maintenance costs as labor. Out of seven systems evaluated, two were identified as economically and technically feasible for the study: modular incineration with energy recovery and source separation. A detailed analysis showed that modular incineration is best suited for larger organizations and institutions. Source separation was also found to be more suitable for larger situations, but better for smaller institutions than modular incineration.

Recommendations for future research and development include: more thorough waste characterization of the sources studied, investigation of the effects of building design on resource recovery feasibility, and further study of technologies.

waste recovery, technology, small scale industry, source separation, incineration, energy recovery

316 Chesnin, L.

Windrow Composting Municipal Sewage Wastes for Land Application. The Environmental Professional. Pages 85 to 91. Pergamon Press Ltd. London, U.K. 1981 (Author at University of Nebraska). References.

This article is a historical review of sewage composting, including pollution, technical and health problems. Examples of ongoing projects in Nebraska in the public and private sectors are discussed. Composting can reduce waste disposal costs. Windrow composting involves mixing filtered sludge or sludge slurry with a drying and/or bulking agent (organic) such as saw dust, leaves, straw, feedlot manure, ground corn cobs and husks. This mixture is placed in an extended pile or windrow. The moisture content should be less than 60 percent.

The author wrote a computer program which determines the optimum amount of drying and/or bulking agents necessary to compost sludge or slurry. The amounts depend on the temperature and differ seasonally. This approach is less capital intensive and more flexible than forced aeration systems despite the need for more land.

Windrow composting is an aerobic process which depends upon the pile to supply oxygen needed by the mirobial population. Mixing can be achieved by using modified manure spreaders, hydraulic feed mixing wagons or front end loaders.

High application rates of compost to agricultural soils were found to reduce soil density and fuel requirements for tillage operations. Also, the availability of nitrogen present in an organic form was greatly increased.

composting, technology, municipal waste, organics, land application, historical

317 Clasen, G.A.
Present State of Processing of Salvaged Glass. Erkelenyer Maschinenfabrik. Erkeleny, Federal Republic of Germany. (Reprinted from Sprechhsaal Ceramics, Glass, Cement. November, 1977. Pages 425-429 and pages 664-668).

The West German glass manufacturer Erkelenzer Maschinenfabrik pioneered work in the processing of salvaged glass cullet. They were the first to apply the principle of screening cullet after the breaking operation, in addition to traditional separation and removal of foreign contaminants by means of an air classifier.

The development of the combined labor and automatic process is described after tracing the evolution of glass cullet recovery processes from labor intensive manual processing in 1957 to its present state.

Crushing equipment used for in-house, homogeneous cullet, was modified for use on postconsumer glass. A circular vibratory screen with a gradation of size of the perforations and a considerably enlarged total screen area, 3,000 X 1,000 MM was used. After screening, freed paper, aluminum pieces and other contaminants are sucked off by two jets. Foreign contaminants are eliminated by a maintenance free, high performance cyclone with collects materials in container continuously.

Overall process implementation has led to the development of wire cloth reinforced conveyor belts and high quality wearing plates, among other improvements. Experiments in color sorting based on ore sorting equipment is ongoing.

Efficient handling procedures have lowered raw material costs and contributed to reducing glass in the municipal solid waste stream (8 percent by volume, 15 percent by weight).

glass, manufacturing, processing, equipment, municipal waste, glass recycling, cullet

318 Cointreau, S.J.
Environmental Management of Urban Solid Wastes in Developing Countries: Project Guide. World Bank. Washington, D.C., U.S.A. 1982. 165 pages. References.

The project guide provides information and procedures for planning and implementation of solid waste management improvements. It is designed to facilitate project preparation, appraisal and implementation of

World Bank financed solid waste projects in urban areas. Current World Bank objectives, policies, and project requirements are summarized. It should also be of use to a wide audience involved in solid waste collection and disposal in developing countries.

The project guide reflects the lessons and experience gained from World Bank solid waste projects. The text discusses establishment of an acceptable standard of collection and disposal service delivery, selection of appropriate technology, development of suitable phased action plans, arrangement of institutions for planning and management, arrangement of financial resources, development of regulatory and enforcement support services, provision of public education and participation programs, and incorporation of incentives and disincentives to facilitate project success.

Information on solid waste generation rates and compositions for countries of various levels of economic development is provided. Case study information on the formal and informal sector refuse collection and disposal activities prevalent in cities of developing countries is provided. Problems and issues to investigate when planning are highlighted through case study examples.

Annexes to the project guide include sample terms of reference for consultants, a data collection workbook for planning technical and management improvements, and worksheets for calculating municipal budget requirements to maintain, upgrade and expand solid waste management service.

waste composition, waste management, environmental management, developing country, municipal solid waste, waste disposal/treatment

319 Darnay, A.
Franklin, W.E.

Salvage Markets for Materials in Solid Wastes. U.S. Environmental Protection Agency. Washington, D.C., U.S.A. 1972. 182 pages. References.

This document discusses the structure, economics and institutions of the salvage and secondary materials industry. Data on raw and secondary materials usage is described. Technical, economic, institutional, and behavioral data are further detailed in 14 separate case studies. Trends are noted which affect industry concentration and market pricing and have resulted in a decline of the salvaging industry.

The salvage industry is noted as an old industry composed of several levels of activity. These include: scavenging and collection networks, dealers and brokers, and manufacturers. The industry has tried to keep pace with the virgin materials extraction industry by concentrating and mechanizing its operations. In the U.S. this has resulted in a dramatic loss of small scale, family owned enterprises and a decline in scavenging. Even so, paper, textiles and rubber are secondary materials losing markets to virgin materials.

The authors detail factors affecting recycling. Assuming the reasonableness of recycling, they ask why the declining rate? Some factors affecting the declining rate of recycling include: (1) costs of acquiring secondary materials are high; (2) virgin materials tend to be more homogeneous prior to processing; (3) sorting of wastes has become repugnant to many householders; (4) costs and benefits are somewhat equal and quality demands have tipped the scale toward virgin materials; and (5) the advent of synthetic materials and composites have limited the need for and cost of recovery.

Costwise, secondary industries expand (ca. 1972) between US$10 to $20 per ton on physical acquisition and processing of wastes, exclusive of price paid to suppliers and delivery. Such industries, though, can do little, considering the structure of the marketplace, to influence commodity demand. Instead, they encourage or discourage supply networks depending on demand and price.

A key to increased demand for recycled products is that virgin materials should reflect their true socio-economic cost which would make recycled goods competitive with virgin materials, thereby equalizing factors between the feedstocks.

secondary materials recovery, salvaging, economics, United States, solid wastes

320 Duckett, E.J.
Contaminants of Magnetic Metals Recovered from Municipal Solid Waste. National Center for Resource Recovery. Washington, D.C., U.S.A. November, 1977. 51 pages. References.

This publication contains three reports discussing recovery of magnetic fraction from mixed municipal refuse--primarily steel cans. The United States National Science Foundation funded the research to identify technological barriers to increased recycling, where they exist, and to present approaches mitigating their effects on the barriers themselves. While technological barriers were the focus, economic and institutional issues were discussed.

The document also presents data on the degree of mechanical specification achievable.

sorting, ferrous/nonferrous recovery, organics, technology, magnetic separation

321 Fukuda, H.
Research and Development of High Rate Composting Sub-System Proceedings of the International Recycling Congress (Recycling Berlin '79). Berlin, Federal Republic of Germany. Pages 1034-1039. E. Freitag--Verlag für Umwelttechnik. 1979. References.

This paper describes a high rate composting subsystem, as part of a complete material recovery system. The features of this subsystem

include quick composting within digester, mechanical turnover, aeration and forced draft of air, with the result that aerobic fermentation and decomposition forms compost in a short period. The compost which is produced has few contaminants in balanced particle distribution. The whole system is automated from input of refuse to output of product. This cuts operating and maintenance personnel to a minimum and reduces running cost. The eggs of parasites and other harmful bacteria are killed by the heat generated by aerobic decomposition.

Results of basic research are detailed as well as site layout, materials balance and equipment specifications.

Basic tests on fermentation conditions and the ability to separate contaminants have satisfactorily demonstrated its practicality. It is expected that the technology required for the design and operation of a production plant will be established in further trials.

composting, pilot plant, organics, health and safety

322 Golueke, C.G.
Biological Reclamation of Solid Wastes. Rodale Press. Emaus, Pennsylvania, U.S.A. 1977. 249 pages. References.

This is a comprehensive guide to biological and mechanical processes associated with reclamation of organics found in municipal and industrial refuse, animal manure, crop residues, and sewage sludge.

As opposed to burial or burn systems, organic reclamation systems recover one or more resources present in waste. They require less energy than strictly physical or chemical process systems and this aspect is important to developing countries which are usually resource and energy poor.

Technical and economic data on biological waste treatment are presented. Figures and exhibits illustrate the many techniques and equipment used in the processes.

composting, organics, soil amendment, solid wastes, municipal waste, industrial waste

323 Golueke, G.
Composting—A Study of the Process and Its Principles. Rodale Press. Emaus, Pennsylvania, U.S.A. 1975. 110 pages. References.

This book presents a modern historical perspective of composting, particularly as a solid waste management technique. The early trend to overmechanization is criticised as an attempt for quick profit. The use of inoculums led to the overselling of the process and an expectation that the sale of the end product would return all costs. Early reliable mechanized systems included the Dano, Naturizer, VAM, Fairfield-Hardy digester and the Terex-Cobey 74-51 composter.

Composting is the biological decomposition of the organic constituents of wastes under controlled conditions. Systems are classified on bases of oxygen usage (aerobic or anaerobic), temperature (mesophilic and thermophilic) and technology (open or windrow and mechanical or "enclosed"). Variable factors include the microbial population and the nature of the infeed (substrate).

Compost has a low NPK value relative to commercial fertilizers and potential problems of heavy metals and virus survival. Rate controlling factors are moisture, temperature, pH, nutrients, and oxygen. The major factors in the destruction of pathogens in the compost process are heat and antibiotic reactions. Temperatures in the upper 60s and low 70s C reached in the process are sufficient to kill most pathogens and parasites.

The product may be used as a soil conditioner and mulch, and has high potential for land reclamation.

composting, organics, appropriate technology, historical, health and safety, land reclamation

324 Golueke, C.
Manual de Composteo en Pilas Para La Ciudad de Toluca. Sanitary Engineering Research Laboratory. University of California. Berkeley, California, U.S.A. 1975. References.

This manual promotes the use of compost in Mexican agriculture. It provides useful information on how to make and use compost. Data is provided for farmers for using refuse derived compost to reduce fertilizer use, stabilize soils and increase water retention.

The author suggests that a local farmers plan and coordinate the composting program.

The first phase includes a demonstration project which monitors effects of refuse composts on land, crop yield and cost. The advantages of beginning with a small scale operation are (1) flexibility, (2) psychology (the prospect of 5 tons is not as overwhelming as 100 tons), (3) visual evidence to farmers, (4) transition benefits to larger scale, and (5) a basis for economic and technical evaluation.

The manual presents easy to follow instructions on constructing a pile, turning arrangements, and detailed directions for operating compost processes. Monitoring for heat release can be an excellent indicator of the maturing process. Managing the pile includes controlling basic conditions including nutrient levels, water balance, and oxygen. Turning involves breaking down and rebuilding a compost pile. This can be done with equipment on hand and should, ideally, involve placing interior material from the pile on the outside of the pile in restructuring. Uniform decomposition will result. Other aspects noted included frequency of turning, a monitoring program for oxygen, moisture, and process completion.

Excessively high carbon to nitrogen ratio is important to quantify as soil bacteria will compete succeasfully with plants for nitrogen, at least until the bacteria die off or the carbon is exhausted. Eventually, the nitrogen in the bacteria will also become available to plants; therefore immature compost can be applied to land but only well in advance of crop planting.

Mexico, composting, processing, marketing, agriculture

325 Gotaas, H.B.
Composting: Sanitary Disposal and Reclamation of Organic Wastes. World Health Organization. Geneva, Switzerland. 1956. 205 pages. (Author at University of California, Berkeley, U.S.A.) References.

This book is a world wide state of the art review of composting. The author presents sanitary methods to treat and dispose of organic waste materials which constitute health hazards. Proper utilization of wastes can also help alleviate nutrition problems and soil deficiencies.

Raw materials, processing fundamentals and methods of composting for cities, villages, small towns and individual farms are detailed.

composting, historical, state of the art, health and safety, organics

326 Hortenstine, C.C.
Rothwell, D.F.
Pelletized Municipal Refuse Compost as a Soil Amendment and Nutrient Source for Sorghum. Journal of Environmental Quality. Volume 2, Number 3. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America. 1973. Madison, Wisconsin, U.S.A. References.

This study evaluated pelletized compost versus nonpelletized compost for ease of handling and soil amendment value. Pelletized compost was used in a green house study as a soil amendment and as a nutrient for plants. The compost was first mixed with arrendondo sand and then spread on the plants. The application of 8 metric tons/hectare of compost increased the yields of two sorghum crops compared to the control. When compost was applied at a higher rate of 64 metric tons/hectare, yields again increased compared to 10-4, 4-8.3 fertilizer applied at 2 tons/hectare.

Compost applications increased all plant nutrients, except manganese. In addition, water retention and caution exchange capacity of the arrendondo sand were generally increased by compost applications.

composting, organics, municipal wastes, nutrients, soil amendment

327 Kaiser, R.
Wasson, R.P.
Daniels, A.C.W.

Automobile Scrappage and Recycling Industry Study, Overview Report. United States Department of Transportation. Washington, D.C., U.S.A. 1977. 398 pages. References.

The principal factors which influence the recovery of materials from junked automobiles are discussed in this report. These include: a list of the kinds of materials which can be reprocessed, how automobiles become part of the commercial recovery cycle, operations of the auto wrecking industry which salvage serviceable parts, operations of the scrap industry which take automobile hulks and make them into commercial grades of scrap metal and problems associated with junked cars. A legal review of key policies and legislation which effect the recovery of materials from junked autos is included. Currently there is a strong demand for auto hulks by ferrous scrap producers and this has helped alleviate the problem of an ever-increasing accumulation of junked autos. In 1974 the fractional recovery of metallic materials from approximately ten million automobiles was higher than from other forms of obsolete scrap. The estimated value of the recovered materials was in excess of one billion dollars. The report also discusses future trends and research, government policy and technical analyses.

secondary materials recovery, ferrous scrap, nonferrous scrap, recycling, plastics, rubber, government policy, automobiles

328 Volk, V.V.

Application of Trash and Garbage to Agricultural Lands. Land Application of Waste Materials Conference Papers. Des Moines, Iowa. 1976. Soil Conservation Sociey of America. Ankerry, Iowa. Pages 54-64. References.

This document is a review of technical papers pertaining to the application of shredded raw municipal waste and composted municipal waste on agricultural lands. Shredded or composted municipal refuse can be added to soils provided large objects such as glass, metal and plastics are removed. Most compost and all fresh municipal wastes have a high C/N ratio and require additional nitrogen fertilizer to maximize crop production. Composts generally increase soil pH unless large applications of acid-forming fertilizers are applied, or the soil has an initially high pH. The total amount of most plant nutrients is increased with solid waste application. The plant availability may not increase in proportion to elements added because of the increase in soil pH with compost additions and resulting precipitation of elements, such as copper, zinc, iron and manganese. Plant nutrients immobilized in organic fractions of the waste may become available over a long period of time. Before application of either compost or shredded garbage to soil, a chemical analysis should be completed, with special attention directed to cadmium, zinc, copper, nickel, boron, and electrical conductivity. Boron problems in soils can be alleviated by water management and careful selection of plants to be grown. The application of compost and shredded municipal waste improves the physical properties of the soil. The water holding capacity,

infiltration, and moisture retention in coarser textured soils at given stresses are increased; soil erosion by water and wind is reduced; soil structure is improved and friability of heavy soils is improved.

Composted refuse has greater flexibility than shredded garbage because of its aesthetic appearance, more stable nature, and higher nutrient content. Compost has been successfully used in roadside revegetation programs, city recreation areas, nurseries, and land reclamation areas. Compost application to agricultural soils on the basis of plant nutrient content is currently not economically feasible for most farms.

municipal waste, composting, land application, crop yield, nutrients, agriculture, soil amendment, land reclamation

329 McGinnis, J. L.
Opperman, J.
Stephenson, D.
Boileau, G.

An Evaluation of Handling Stations in Waste Reclamation Systems. Waste Management Advisory Board. Ontario, Canada. November, 1979. 196 pages. References.

This report evaluates handling stations/intermediate processing facilities in Canada. They are important as a link between collectors and users of recyclable materials. Materials flows, markets, feedstock arrangements, economics, energy balance, building design, labor, and general operations are covered. The study indicated a need for the following: 1) the handling station must be located near both sources and markets; 2) the station should act as a positive force aiding local collectors with program design, implementation and operations; 3) in addition to marketing materials, the station should be involved in more extensive marketing efforts; and 4) the program should support existing solid waste management. The study showed that five times as many jobs can be created using recycling collection centers, versus ordinary refuse collection. This is an important implication for developing countries, where job creation is a critical issue.

recycling, intermediate processing, economics, markets, equipment, Canada, waste management, animal feed

330 Ming, C.

The Recycling of Waste Acid, Oil Metal Scrap of the Shanghai Donghai Oil and Chemical Recycling Works. Conservation and Recycling, Pergamon Press. U.K. Volume 3, Number 3/4. 1980. Pages 323-325. Abstract from Profit From Pollution Prevention by Monica E. Campbell and William M. Glenn. Published by Pollution Probe Foundation, Toronto, Canada. 1982. Page 318.

In the last twenty years the Shanghai Donghai oil and chemical recycling works (Shanghai, Peoples' Republic of China), built in 1958 for the comprehensive utilization of waste acid, oil and metal scrap, has recovered more than 2.5 million tons of waste acid; extracted 8,200 tons of chemical products of 30 varieties including copper sulfate, copper

carbonate, nickel oxide, and cobalt chloride; and refined 15 tons of silver and 6,300 tons of oil from industrial residues, waste liquids, and oils.

Prior to the establishment of the materials recovery plant, 300,000 tons of waste acid were discharged annually from the industrial city of Shanghai. The rivers and farmland were seriously polluted, and an indemnity of 10 million yuan was paid annually.

Prior to the construction of the acid reutilization component of the recycling facility, investigations were completed to fully assess acid consumption and discharge of waste acid. After an education phase of informing acid utilizing companies in Shanghai on the benefits of recycling, recovery plant employees began reutilization trials.

To win the confidence of the acid utilizing factories, samples of processed waste acid were sent to individual companies for trial use. Because the factories were previously accustomed to high quality acids, they were not convinced that the recovered acids could ensure high product quality until test trials provided satisfactory results.

Today waste acids discharged by 60 factories are processed for use by 300 factories. For example, the waste liquid discharged by pharmaceutical and titanium-white factories contain 15 percent sulfuric acid and a high percentage of iron with a few impurities. After it is retrieved and used by iron and steel plants in cleaning rolled steel, it is returned to pharmaceutical plants for making iron protosulfide for medical use.

The waste organic sulfuric acid solution containing 70 percent of the acid discharged by dye works and chemical works is sent to chemical fertilizer plants to make phosphate fertilizer. Weak sulfuric acid and hydrochloric acid solutions are transferred to paper, printing and dyeing mills to neutralize waste alkali solutions, and to make ammonium salt of humic acid, a chemical fertilizer.

Waste hydrochloric acid is first used by electroplating plants and metal drawing plants for cleaning their products, and is then re-used in the manufacture of chemical reagents such as magnesium chloride and calcium chloride.

The recovering and reuse of waste acids at Shanghai not only minimizes environmental pollution but it also saves resources and cuts costs. For example, one iron and steel plant which used to clean rolled steel with virgin sulfuric acid saved 54,000 yuan a year by using recycled waste acid.

China, ferrous/nonferrous recovery, acids, oil, environmental management, pollution, chemicals, resource recovery, waste utilization, small scale industry, reuse

331 Prohmmanee, P.
Composting of Refuse with Sewage Sludge. Asian Institute of Technology. Bangkok, Thailand, 1968. 60 pages. References.

This thesis focuses on composting as the optimum approach for solving Bangkok's environmental problems. Both open windrow and mechanical composting were studied. Two mixtures, ground refuse and refuse mixed with sludge, were used. The mechanical methods studied were an enclosed chamber system and a rotary drum system. The composting materials were turned every day for the first week and then once a week for five weeks, for a total composting time of six weeks. Temperatures were recorded before turning and samples were analyzed for moisture content, volatile solids, carbon, total nitrogen, phosphate and potash. In most cases, pasteurizing temperatures were maintained and there were few problems from flies or odors. Results indicated that mechanical composting is better as less land is needed, odor and vector problems can be controlled and decomposition occurs faster. The major plant nutrients varied only slightly in finished compost between refuse, refuse sludge, and the mixture. As it is economically advantageous to dispose of two wastes by the same process, the mixture of refuse and sludge was favored.

composting, sludge, organics, Asia, recycling, Thailand, nutrients, health and safety

332 Riley, M.
Bubnick, J.
Pandya, V.
Peters, R.
Low Technology Solid Waste Management Options. Pollution Probe Ottawa Solid Waste Management Group. Ottawa, Canada. 1977. 55 pages. References.

This article analyzes the potential for recycling in Ottawa, Canada. Waste recovery projects in Canada, U.S. and the U.K. were contacted for information. Document excerpts and reprints are included. During a two month period local merchants, households, and government agencies were contacted to assess their attitudes towards recycling. A successful composting operation was carried out in an urban neighborhood, in order to demonstrate its viability. The authors recommend that further research is needed. The study found that source separation of waste and decentralized collection of separated wastes are technically and economically feasible. A system including local processing of recycled materials will improve the urban economy, help create jobs and encourage small scale industry development. A majority of the people surveyed were prepared to recycle their wastes, provided it is not too complicated and curbside collection service is provided.

source separation, collection, economics, surveys, Canada, solid waste management, recycling

333 Sathianaman, V.
New Shortcut Method of Making Compost (Kasala Menik) by the Dalpadado Process. Ministry of Agriculture, Sri Lanka. 1981. 2 pages.

This circular is distributed by the Ministry of Agriculture, Sri Lanka, as part of a pilot project to encourage small scale composting of municipal wastes in low income urban areas. The availability of finished compost will enhance urban gardening. Compost has numerous advantages. It can be produced by anyone, with a minimum of tools and technical training. A 12-day process for composting municipal wastes is described. Suitable organic wastes such as lawn clippings, cattle dung, human wastes, etc., should be well mixed, and gathered in a heap. The heap should be composed of 15 to 16 layers of material, each about six inches thick. The finished heap should be no more than six feet wide and three feet high. The length will depend on the site and availability of material. It should be kept moist at all times. Small materials decompose faster. Plastics, which do not break down easily, should be sorted out. Turn and add water on the second, sixth, ninth and twelfth days.

composting, small scale industry, Sri Lanka

334 Seldman, N.N.
Ospina, F.
Report to the World Bank Solid Waste Collection and Disposal Project for the Metropolitan Area of Medellin, Colombia. Institute for Local Self-Reliance. Washington, D.C., U.S.A. 1979. 32 pages. References.

This report assesses the potential application of new and developing waste utilization technologies which could maximize the productivity of working people already active in the informal waste recovery sector. The technologies, which are characterized by their labor intensive procedures, are of benefit to the economy and society in general and waste recyclers in particular.

The report documents the production aspects of the solid waste sector in Medellin. Approximately 4,000 people earn their living exclusively from recycling waste in Medellin. From 300 to 800 people hand pick recyclable materials at the landfill, and 3,500 buyers go from door-to-door purchasing or scavenging materials from households and businesses. Several thousand formal jobs in processing and manufacturing enterprises are supported by this flow of secondary materials to industries. Key aspects of the economic, organizational and technological structure of this activity are presented.

The report concludes that there is an immediate opportunity to increase the social welfare. The scale, efficiency and costs of establishing technologies/enterprises are estimated. These enterprises could rationalize existing recycling activity and integrate recyclers into the formal economic structure of the Medellin metropolitan area. A preliminary requirement is a nontraditional approach to solid waste planning which establishes as its goal the need to integrate and balance the requirements and scale of the solid waste collection/recycling system

with economic and social needs of people making a living from the waste. Alternative solid waste management recommendations are made and guidelines for investment in technologies are provided.

scavengers, landfill, recycling, research and development, community enterprises, waste disposal/treatment, Colombia, solid waste management

335

Stone, G.E.
Wiles, C.G.
Clemons, C.A.

Composting at Johnson City. Final report on Joint United States Environmental Protection Agency--Tennessee Valley Authority Project. EPA/530/SW-31r.2.U.S. EPA, Washington, D.C., U.S.A. 1975. 336 pages. References.

The technical feasibility of windrow composting of municipal refuse with or without sewage sludge was established. Windrow temperatures of 122°F to 130°F maintained for at least seven days destroyed pathogens predicted in refuse and known in sludge.

Sewage sludge, cow paunch, poultry manures, animal blood, and pepper canning wastes in varying amounts were successfully co-composted with municipal refuse.

The addition of urea-ammonium nitrate appeared to inhibit microbial activity while adding limestone aided composting. Both additions caused a loss of nitrogen. About 33,503 tons of refuse were processed, averaging 37 tons per day. Screened compost accounted for 44 percent of incoming refuse. Rejects accounted for 41 percent.

Upgraded screened compost samples contained an average carbon to nitrogen (C/N) ratio of 28. Nitrogen content of 1969-70 compost was 1.3 percent (dry weight). An air classifier removed most glass contamination from screened compost.

Total plant construction cost in US$960,452 plus US$61,280 for mobile equipment. Operating costs varied from US$18.45 to US$22.91 per ton of refuse processed and cost at operating capacity was estimated at $13.40 per ton. The most cost effective procedure was handsorting to remove selected materials for resale. Significant elements of cost were attributed to special projects. Costs per ton related to plant size were estimated ranging from about $10 per ton for a 200 ton/day plant to $19.70 for a 50 ton/day plant.

Yield tests for grain sorghum, corn, and bermuda grass were positive with compost application. In addition, physical properties of soil were improved as were soil content of potassium, calcium, magnesium, zinc, organic matter and pH value.

Market values varied, averaging US$5.80 per ton defined more as a user willingness to pay rather than actual worth.

composting, municipal waste, economics, sludge, organics, health and safety, sorting, small scale industry, United States

336 Vesilind, P.
Riinu, A.E.
Unit Operations in Resource Recovery Engineering. Prentice-Hall. Englewood Cliffs, New Jersey, U.S.A. 1981. 452 pages. References.

Accelerated extraction and continuing scarcity of raw materials, coupled with environmental and ethical constraints on the disposal of wastes, has resulted in a steadily increasing interest in the recovery of materials and energy from solid waste--especially mixed municipal wastes. The problems associated with mixed refuse processing and material extraction for sale has spawned a discipline popularly known as resource recovery engineering. The book literally borrows from diverse sources so as to develop a generic information base focusing on mixed waste materials separation and energy recovery operations from a fundamental viewpoint. As a state of the art of research, pilot scale, and benchmark applications, coverage is very analytical.

resource recovery, energy recovery, solid waste, municipal waste, state of the art, pilot plant

337 Vogler, J.
Municipal Refuse Composting. Materials Reclamation Weekly. A. Cohen & Company, Ltd. London, U.K. January 17, 1981. Pages 20-22. January 24, 1981. Pages 16-18.

This paper discusses composting facilities in several developing countries. Composting offers an excellent opportunity to fertilize and rebuild depleted or fallow soils. However, many countries ignore the advantages of long-term considerations in favor of short-term solutions. Transportation costs often preclude active marketing of compost.

Various programs in Mexico, Thailand, and India are described. Problems and solutions are presented. All plants are highly mechanized. Costs of construction and operation are greater than the return on the sale of compost. Mechanical failure and low quality compost resulted from the use of over sophisticated equipment and processes. Final screening of compoat through a 10 mm mesh is essential to produce a quality product, but was not used in the majority of plants studied. The compost was usually contaminated with pulverized glass and plastics. Other problems which need to be overcome are high moisture content and a lack of market research.

organics, composting, municipal waste, Mexico, Thailand, India

338 Weiss, D.B.

Intermediate Glass Processing. NCRR Bulletin. National Center for Resource Recovery. Washington, D.C., U.S.A. Volume 9, Number 3, September, 1979. Pages 52-61. References.

This article reviews the development of intermediate glass processing (IGP) which improves the quality of glass for recycling.

Virtually all glass supplied for recycling is derived through source separate recovery. However, most glass is not in a readily usable form. Intermediate processing in this category is defined as glass acquisition, beneficiating and sale to glass manufacturers. IGPs are intermediate in terms of (1) providing marketing and upgrading services needed by glass manufacturers; (2) acting as intermediaries between markets and collection programs/generation sources; and (3) the level of technology used. The level of technology may consist of varying combinations of labor or manual picking and small scale equipment including crushers, magnets, screens, washers, etc. With different combinations of equipment and labor, materials other than glass can be processed.

Three factors influence the success of an IGP: economies of scale, management of transportation, and management of labor. Larger operations (1,000 tons/month) are the most economically viable. Often these operations have successfully promoted backhaul arrangements. The number of employees may vary between three and thirty people, with the average being five to eight people.

processing, glass, equipment, labor

339 Yoda, T.
Mjazaki, T.
Machida, O.

Making Pulp from Municipal Wastes. Proceedings of the International Recycling Congress (Recycling Berlin '79). Berlin, Federal Republic of Germany. Pages. 1176-1179. E. Freitag--Verlag für Umwelttechnik, 1979. References.

This technical brief describes a pilot scale resource recovery system operated in 1977 in Japan. It contained a subsystem of 10 tons per day capacity which could process pulp from a subflow with an increased percentage of fiber.

Raw material is also contaminated by spoiled garbage and bacteria, so the system consists of: (1) shredding, course screening, washing, sterilizing and (2) bleaching and fine screening. The equipment consists of: a pulper for disintegrating; screen and cyclone for eliminating plastics and other foreign matter; Decker and Screw-thickner machine for washing; down for bleaching; and pulp machine for making pulp sheets.

The pulp endproduct may be used for middle or back layers of white board and corrugated fibreboard together with other pulp. If the amount of contamination of pulp is reduced and the mixing ratio with other pulp is increased, pulp may be used for lower grade of writing paper and toilet tissue paper.

paper, pulp, municipal waste, fiber, Japan, Asia, cardboard

WASTE UTILIZATION

401 Aleshin, E., ed.
Proceedings of the Sixth Mineral Waste Utilization Symposium: Industrial Wastes--Scrap Metal--Mining Wastes--Municipal Refuse. United States Bureau of Mines. Department of Interior. Washington, D.C., U.S.A. 423 pages. 1978. References.

The value of secondary materials is determined by many factors including changing technology, tax policies, transportation costs and new applications. This symposium examined technical and economic factors, highlighted progress over the last 10 years, and reviewed problems and solutions. The proceedings are comprised of 55 papers grouped in categories dealing with material and energy recovery technology; the categories are general, mining and mineral wastes, municipal refuse, industrial wastes, and scrap metal. The papers presented on municipal wastes focus on resource recovery from mixed waste. Plants in Albany (New York), Baltimore County (Maryland), Ames (Iowa) and plants built by AB Svenska Flakfabriken are discussed with regard to their operations and costs. Other papers focus on glass, aluminum and paper recovery. Various fuel preparation technologies are described. Complementary processes for benefication and utilization of paper, plastic magnetics and degradable organics are also described.

resource recovery, energy, secondary materials recovery, technology, United States

402 Alone, B. Z.
Pathe, P. P.
Titus, S. K.
Bhide, A. D.
Anaerobic Digestion of City Refuse and Dung. Indian Journal of Environmental Health. National Environmental Engineering Research Institute. Nagpur, India, Volume 20, Number 2. 1978. Pages 134-140. References.

Anaerobic digestion of animal dung has been extensively investigated, but the use of city refuse in digestion systems is relatively unknown. This report assessed the feasibility of combined feedstocks, using dung and an organic fraction of city refuse (OFR). The one year study at the National Environmental Engineering Research Institute in Nagpur, India characterized ORF and dung. This was used to design the laboratory scale system. To initiate the digestion, a "seed" was obtained from a nearby dung digestion plant. Critical to the design was that the town refuse fraction has only a 1-5% moisture content, indicating extensive drying prior to use. Results showed maximum gas production was obtained from a mixture of 62.5 percent dung and 37.5 percent OFR. Reduction of volatile matter ranged from 45 to 54 percent. Gas production ranged between 97 to 347 litre per 1000 kilograms of volatile matter depending

upon the temperature of digestion and composition of slurry feed. The study showed that OFR could be digested alone, although gas production was lower than that produced from the optimum mixture.

biogas, anaerobic digestion, organics, India, small scale units, energy

403

Anderson, M. W.
Lipshutz, T.
Cooey, J. T.
Savage, G.

Recycling Mixed Waste Paper into Innovative Products. U.S. Department of Energy. Performed by Garbage Reincarnation, Inc. Santa Rosa, California, U.S.A. January, 1982. 77 pages. References.

This report presents preliminary data on uses for mixed grade waste paper. A literature search and site visits produced two potential uses: paper-derived firelogs and agricultural products. Firelogs underwent a feasibility study that included technical, environmental and economic evaluation. Animal bedding was subject to field and laboratory testing. Emphasis in selecting technology was for environmentally sound products which could be locally produced and used with a low to moderate capital investment. Mixed paper is a low value material and normally cannot support extensive transportation, processing and marketing expenses. It was found that successful operations develop horizontally integrated products which can be produced in relatively small amounts, with shared equipment. The report summarizes paper grades (definitions and uses), availability and collection of mixed grades, firelogs and pellets (technical and economic data), agricultural products (bedding, compost process bulking agents, fiber mulches), cellulose insulation, and construction materials (construction board and molded products).

fiber, paper, agriculture, animal bedding, cellulose insulation, wood substitutes, cardboard, molded products, recycling, composting

404

Glass and Glassmaking. United Nations Industrial Development Organization (UNIDO). New York, New York, U.S.A. 1977. 111 pages. References.

This monograph is intended for those entering the industry and for experienced glassmakers who do not have a formal grounding in their subject. The monograph presents a history of the industry, a technical discussion of the theory and practice of glass making, a consideration of the economic problems involved in setting up a glass factory, and a survey of current trends.

Modern automatic glass making is a capital intensive industry depending on a large output to be viable. Profitability may be lost because of an inability to reach the projected output, as well as from insufficient demand. A target of perhaps 60% yield in the first year, working up to 90% in the third year, is reasonable and will probably correspond to the time it takes to penetrate the market, but substantial amounts of working capital will be needed.

Establishment of a glassmaking industry is usually proposed in developing countries as a substitute for imports. In theory, the demand should be known. In practice, the degree of potential market penetration is unknown unless the industry is protected by tariff walls, at least during the early stages of development. However, the possibility of using exports to expand demand is limited because the industry seldom grows out of its early stages; prices remain high and the quality tends to remain low. Market trends over the three years of building are very difficult to foresee; the establishment of the industry itself may have a significant effect on those trends. If the project is truly viable, it is likely to realize potential markets because it makes glass locally available, but if it has only an apparent viability because of tariff walls, it may have the opposite effect, by driving bottle customers to alternative containers such as cans and plastics, for example.

In developing possible glass industrial plants which could theoretically utilize cullet or scrap glass, three steps are considered:

- Pre-feasibility study with the purpose of determining whether a detailed study is warranted;
- Feasibility study to determine the best choice of product and technology, estimate the viability of the proposal, and establish the ground rules for seeking offers;
- Preparation of offers.

Comparison of firm offers and reappraisal of the project should not involve more than minor rethinking. However, it is probable that considerable economies in the capital cost can be made if capabilities already existing in the country are fully exploited.

The size of the market and consequently the scale of the operation to be considered has more aspects than the effect of volume in absorbing fixed cost. If the volume requires several production lines, production can be planned to make the load on the furnace substantially constant and a furnace designed to this capacity will provide economical melting. On the other hand, if one forming machine will meet the whole of the demand, melting efficiency is going to be very low when a light weight article is being made, and any breakdown will stop production altogether. Again, many of the capital items are required whatever the scale of operations is, and the cost of those which are scaled down in output is disproportionately high. In the same way, staff and labor requirements are relatively higher for small scale operations. The size of the individual orders is another important consideration; a production run on automatic machines must last long enough to absorb setting up costs.

Attempts to scale down a conventional factory must reach an absolute limit corresponding to a one furnace, two machine installation. For both glass containers and sheet-glass production, this limit corresponds to an annual output of about 10,000 tons, or 30 tons per day.

Import statistics seldom give any details of the size, shape, and color of containers or of the numbers in individual orders. This information, the market spectrum, is vital for automatic production. It usually happens that a country, without its own factory, imports a wider

variety of sizes and shapes than is necessary because they have had the whole world to choose from. The prospects of some degree of standardization must therefore be established, and the likely trend of future demand must be estimated.

While the monograph considers only factory cullet, the opportunities for use of locally derived waste cullet (post consumer) exists. The monograph concludes that a glass factory in a developing country has few advantages, and that the most must be made of them due to the competition from factories in industrialized countries, with their large markets, developed skills and know-how. The advantages include local materials, fewer import costs, and efficient use of labor. The cost of labor, when efficiently used, is usually lower in developing countries. The scope for optimization depends very much on efficient labor utilization. Certainly, the use of two persons to do one person's work is particularly inefficient in the glass industry, where "too many cooks spoil the broth."

glass, glass manufacturing, labor, small scale industry, developing country, industrial development, cullet

405
International Forum on Appropriate Industrial Technology. Prepared for Agency for International Development. Washington, D.C., U.S.A. 5 October 1978. Working Group Number 10--Appropriate Technology for the Manufacture of Pulp and Paper Products. Held at New Delhi/Arand, India on November 20-30, 1978. 18 pages. References.

This article describes a low temperature and low pressure pulping operation. It is designed for small, independent producers of paper board in areas where wood supplies are limited. Low pressure temperature pulping is operated in conjunction with a waste paper mill or packer. The system is designed for flexibility and low cost. Employee training is easily accomplished. Results of environmental studies showed low quantities of specific pollutants which are normally found and difficult to remove from water used in traditional high temperature/high pressure pulping systems.

small scale industry, developing country, pulp, waste paper recovery

406
Proceedings of Symposium on Utilization of Waste Glass in Secondary Products: A Study of the Technology, Marketing, and Economics of Manufacturing Valuable New Products from Waste Container Glass. Technology Application Center. University of New Mexico, Albuquerque, New Mexico, U.S.A. 358 pages. 1973. References.

This reports documents the first meeting devoted exclusively to the recycling of waste glass bottles and jars. Virtually all of the available technologies for turning used container glass into a variety of new and useful products are discussed by industry and university experts.

Papers are presented on topics including: road surfacing and construction; terrazzo and other glass products in existing buildings; refuse glass aggregate in Portland cement concrete; use of glass as a Pozzolan; vibrocasting glass containing construction panels; glass wool and other ceramic products; glass-polymer composites; foamed glass insulation; tiles; recycling glass in remote areas; and analysis of economics and markets for secondary glass products.

Back hauling in empty trucks is suggested as a remedy for high transportation costs. Material specifications and investment criteria are included for most papers. A contact list of industry officials is provided.

glass manufacturing, glass recycling, road surfaces, vehicles, small scale industry

407
Pulp, Tomlinsons Paper Pulp Molding System Booklet. Tomlinsons, Ltd. Rochdale, U.K. 6 pages.

This booklet describes a comprehensive range of paper pulp processing machines offered by Tomlinsons, Ltd. based on the unit originally conceived by E. F. Schumacher in his famous small scale egg carton production idea for Zambia.

Colorfully illustrated, the booklet covers the process, plant sizing requirements, resource requirements, and various products.

paper, pulp, molded product, small scale industry, fiber, equipment

408
Report of the First Year of Operations for ENCORE!s (Environmental Container Reuse) Wine Bottle Washing Project and a Look at the Potential for Wine Bottle Reuse. Ecology Center, Inc. Berkeley, California, U.S.A. March 1976. 43 pages.

This document is a report on the first year of operation of ENCORE!, a wine bottle washing project. It projects the potential for expanded wine bottle reuse. The operation is described in detail with economic data for the current facility and for a larger scale plant. ENCORE! links wineries, recycling centers, restaurants, stores, community groups and individuals in a program that demonstrates that glass bottles can be washed and reused. The process involves collecting bottles and transporting them to a central facility, where they are hand sorted, washed and sterilized in a hydraulic bottle washer. The bottle washer was custom engineered for ENCORE!. After processing, bottles are packed into new cartons and distributed to wineries.

ENCORE! is a self-supporting project, which employees six people. It processes 8,000 cases of wine bottles monthly, as of 1976.

bottle washing, economics, collection, recycling, equipment, labor, environmental management, glass

409
Technical Factors Governing the Recycling of Plastics. British Plastics Federation. London, U.K. #243/1. July, 1979. 12 pages. References.

All plastics recycling depends on remelting and reprocessing by extension and molding as reported by this document. It documents technical factors governing plastics recycling from technical and nontechnical perspectives. End products can be either feedstocks (resin or blends) or actual marketable items (such as fence posts).

Major constraints to increased polymer recycling include: (1) difficulty in identification of polymers during sorting; (2) inability to melt impurities as a means of quality control; (3) difficulty in transporting low bulk densities; (4) incompatibility among the wide range of polymers for blending.

Ideally, recycling occurs when a single polymer type of known and consistent formulation is used. An effective general rule is that the greater the mixture, then the dirtier, the wetter, and the less consistent the scrap will be; consequently, the cruder and less consistent the end products will become that use the mix as a feedstock. As a result, industrial scrap (known formulation, concentrated, and generally unmixed) is routinely reclaimed while post consumer polymers derived from municipal solid wastes are not.

plastics, plastics recycling, technical factors

410
Urban Waste Wood Utilization. Proceedings of a Conference on Alternatives to Urban Waste Wood Disposal. 26-28 March, 1979. Charleston, South Carolina, U.S.A. 126 pages. U.S. Department of Agriculture, Washington, D.C., U.S.A. 1979. References.

The Southeastern Forest Experimental Station sponsored a conference on the subject of urban waste wood. Seventeen papers were presented with topics focusing on: resources, utilization options, and planning. Urban waste wood is a source of fiber and construction materials. The best way to obtain it is via source separation. A significant benefit is that it does not enter the landfill. Potential products are: paper, stakes, mulch, firewood, and industrial fuel. Legal and environmental issues and consumer demand are the focus of planning efforts.

wood, fiber, source separation, environmental management, product development

411
Use of Agricultural and Industrial Wastes in Low Cost Construction. Department of Economic and Social Affairs. ST/ESA/51. United Nations. New York, New York, U.S.A. 1976. 56 pages. References.

Many countries produce large quantities of agricultural and industrial wastes as well as growing quantities of consumer wastes. None of these are adequately utilized. In order to assist developing countries to find ways to reduce construction costs through replacement of traditional and imported building materials with ones made of wastes, the United Nations Secretariat convened an ad hoc Expert Group Meeting on the use of Agricultural and Industrial wastes in low cost construction. This document presents information compiled at that convention.

Issues were reviewed concerning the development of the building materials industry, with particular reference to practical ways of utilizing agricultural and industrial wastes. They formulated recommendations that would ultimately help the building and construction industries of developing countries. Each country must be responsible for producing critical building materials which are increasingly expensive to buy. This situation is complicated by the fact that raw materials are not evenly distributed. Developing countries cannot continue to depend indefinitely on many of the raw materials that are currently used. Most of the developing countries rely heavily on imports of building materials, especially petro-chemicals. Building materials account for 14 to 40 percent of construction costs.

Ways have not yet been found to substitute wastes for expensive imports. Other topics considered were: survey of past and current research on the development of the production of building materials and components for low cost construction from organic wastes; inorganic industrial refuse and byproducts and consumer wastes; economic and technical aspects of collection and processing various agricultural and industrial wastes; adaptation of current technology to the use of agricultural and industrial wastes for the production of building materials and components; problems of marketing and promoting of building materials and components made from agricultural and industrial wastes; and, the role and importance ofstandards and quality control in the development of new products. Proposals for the development of building materials and components from wastes were presented.

industrial waste, agricultural waste, waste utilization, building materials

412
Using Municipal and Agricultural Waste for the Production of Horticultural Crops. Proceedings of the Symposium of the Industrial and Municipal Waste Utilization in Horticulture Working Group, American Society of Horticultural Science. Alexandria, Virginia, U.S.A. 1979. 20 pages. References.

This document contains six papers presented on processing and utilization technology, regulations and marketing of organic material. These were presented at a symposium for horticulturalists. The purpose was to make them aware of rapidly changing technology for recycling organic wastes and nutrient rich wastewater.

Horticulturalists are in a unique position to help solve pollution problems caused by disposal of certain waste materials. The industry utilizes large quantities of organic and inorganic material to grow a wide variety of food and non-food crops. Fertilizer needs can be reduced.

composting, organics, municipal waste, agricultural waste, agriculture, pollution, fertilizer

413
Utilization of Non-Ferrous Scrap Metal. Report of the Expert Group Meeting on Nonferrous Scrap Metal. Vienna, Austria. 25-28 November, 1969. United Nations Industrial Development Organization 1970. 74 pages. References.

A meeting was convened to examine state of the art in the secondary nonferrous metals industry and to make recommendations for improving this industry in developing countries. The report deals with aluminum, copper, lead and zinc. Resource recovery from home, prompt and obsolete scrap are discussed. The sources and recovery techniques, quality controls, and melting technology for each of the subject metals are presented in detail. The consumption of nonferrous metals in developing countries is increasing (estimated between 5-18 percent per year for the metals listed). The scrap supply is increasing concurrently. Metal recovery lends itself to both large and small scale operations, enabling countries to begin on a modest scale to utilize the best combination of techniques and labor intensive methods.

Recommendations include: promoting the establishment of collection and processing facilities and foundries which would use local scrap, surveying the potential scrap and residue resources, surveying potential uses, and investigating opportunities for technology transfer from well-developed industry sources. Additionally, it is noted that: in nonferrous metal recovery, 60-85 percent is the accepted maximum rate of recovery; the capital cost of secondary metal facilities is lower than the cost of primary metal an order of one to ten; increasing the use of scrap demands a highly efficient service for the acquisition and transportation of scrap to keep cost down; and, complete and accurate resource data are important to assure prudent use of secondary metals.

nonferrous scrap, labor, recycling, developing courtry

414 Barnett, C.J.
Remanufacture of Durable Metal Products: The Concept and Its Potential in the Countries of the Andean Region. Massachusetts Institute of Technology. Cambridge, Massachusetts, U.S.A. 1980. 160 pages. References.

This document examines remanufacturing in six Latin American countries: Venezuela, Colombia, Ecuador, Peru, Bolivia, and Chile. "Remanufacturing" describes a procedure which rebuilds products using discarded units of the product as the principal raw materials. By using techniques similar to those employed in the original manufacture of the product, remanufacturing yields a product which will meet new product performance and durability standards. Remanufacturing of certain types of durable goods is well established in developed countries. For those products, it is substantially less expensive than new product manufacturing. For this reason and because remanufacturing is labor intensive, the concept can be applied to developing countries. Factors which make its consideration in Latin America attractive include: a lack of repair and maintenance services, problems obtaining spare parts, high import duties, and a need for training and industrial skill development opportunities.

The most promising products for remanufacture in the Andean countries are those for which new product distribution networks and repair services are already well established. Light and heavy duty automotive products, mining and construction equipment, and distribution transformers are candidates. Of particular importance is the development of skills and technologies beginning with general repair, specialized repair, rebuilding and finally manufacturing. This evolutionary process by which industrialized nations enter remanufacturing is of direct use for the Andean countries. The role of government policy is critical in the development of remanufacturing, e.g., tariff barriers, government ownership. Some industries in developing countries have started largely on the basis of used machinery. The automotive industry in Argentina, textile manufacturing in India, Pakistan and Hong Kong, municipal and private transport companies in Peru and Chile, are examples where imported used equipment started a local industry.

In the U.S., remanufacturing is a small scale venture and in the Andean countries it is expected that this will also be the case.

remanufacturing, United States, labor, textiles, Venezuela, Colombia, Ecuador, Peru, Bolivia, Chile, processing, economic development, developing country

415 Bebbington, H.
Improving the Properties of Recycled Plastics--Successful Case Histories. Society of Plastics Engineers. Brookfield Center. Connecticut, U.S.A. 1980. 19 pages. References.

Based on programs at Western Electric-Bell system, this document discusses recycling of ABS polymer. There have been continuing improvements in the preparation and properties of flame retardant compositions used for making internal telephone parts. Attempts to upgrade the quality of molding material produced included color matching and a new recycling line for old telephones.

Most important of the areas considered was a processing line that grinds the plastic parts from used telephones and separates metals, paper, lint and dust. A new flotation separator removes contaminating metals, plastics, paper and cotton while preprocessing color separation of phones ensures color separability in end product. This eliminates expensive extrusion and screen packing neceasary in contaminated blends.

Improving impact characteristics of recycled ABS involves a 5 percent mixture of various additives or elastomers such as BS or NPR. Such mixtures double the impact resistance of the blend and are relatively inexpensive.

plastics, molded products, plastics recycling, technology, markets

416 Berndt, W.
De-Inking: An Optimum Waste Paper Recovery Method. Proceedings of the International Recycling Congress (Recycling Berlin '79). Berlin, Federal Republic of Germany. Pages 1153-1158. E. Freitag--Verlag für Umwelttechnik. 1979. References.

This paper discusses the process of deinking waste paper. Although recycling is well established in many applications using waste paper, the limiting factor of dyes and inks continues to preclude extensive use by the graphic arts and printing trades, where quality of paper is often associated with color.

Paper is deinked by the following process: (1) soaking and exposure to chemicals (the most common bleach is hydrogen or sodium peroxide); (2) elimination of contaminants; and (3) separation of inks from fibers via flotation or washing. Flotation carries out inks by suspension in surface forms. Washing removes inks by fine dispersion. Wash deinking is prevalent in North America. While investment costs are lower than flotation, the disadvantages are the high rate of fiber loss (the fiber rate is 75-85 percent yield compared to 85-95 percent yield with flotation) and the copious use of water. Flotation uses less water and has a better yield. Factors influencing deinking efficiency and economic considerations are presented.

waste paper recovery, fiber, deinking, recycling, economics

417 Bever, M. B.
The Recycling of Metals: Ferrous Metals and Non-Ferrous Metals. Conservation and Recycling. Pergamon Press. United Kingdom. Volume 1, Number 1. 1976. Pages 55-69 and 147-157. References.

This document discusses the recycling of ferrous and nonferrous metals. It is a highly developed secondary materials industry involving collection, sorting and physical processing.

Ferrous scrap is one of the two major raw materials in the iron and steel industry. Various steel making processes consume scrap in different ratios to other raw materials. Technical difficulties caused by the introduction of impurities into the steel are counterbalanced by advantages such as energy savings, pollution abatement and reductions raw material processing.

Ferrous scrap is supplied primarily via "home" scrap generated by the production process. Collection, transportation and processing problems are negligible. "Prompt" scrap is generated in the conversion of steel into various parts and products. Prompt scrap also has few problems. Nearly all home and prompt scrap are recycled. Obsolete scrap is generated by households, commercial and industrial firms, utilities and transportation firms. It is the most difficult scrap to recycle because of collection and transportation problems and the need to remove contaminants. Obsolete scrap recovered from municipal waste is potentially a large source of iron (6-7 percent of total iron consumption) but it is rarely developed to its full scale, due to the destabilizing impact this would have on the overall scrap market. Also, steelmakers fear contaminants will result in a low quality steel that could damage capital equipment. For these reasons only a small fraction of obsolete scrap is recycled.

Grading schemes for ferrous scrap have been established on a national and international basis. Grading is critical as different steelmaking processes require specific batch material characteristic to avoid technical problems. The growth of electric furnace steel production which can use high amounts of scrap is an encouraging developing for recycling.

Typically the movement of ferrous scrap is from the industrial countries to developing countries. The ferrous scrap industry in older industrialized countries relies heavily on exports during periods of depressed domestic demand. Periods of booming steel production and heavy demand for scrap have usually been accompanied by scrap shortages. When this happens, the domestic steel industry tends to seek an embargo on scrap exports to protect its own supply.

The recycling of nonferrous scrap accounts for a significant amount of nonferrous metals production (50 percent of current consumption for copper and lead, 20 percent for aluminum). Sources of nonferrous metals are primarily automobile body shredding/dismantling, construction debris, and aluminum product packaging. Secondary production of nonferrous

metals is less capital intensive, consumes less energy and tends to be less polluting than primary production. Consequently, entry into the nonferrous secondary metals industry is comparatively easy. This has resulted in a fragmented industry comprised of many small, local units, which together offer a sizable international market. Primary producers can process some secondary nonferrous metals and as a result these integrated firms are active in nonferrous metals recycling.

The contribution of nonferrous scrap as a percentage of consumption is substantial. There is significant opportunity for increasing the contribution of secondary ferrous metals derived from the post consumer waste stream. Production of metals from scrap reduces the the drain on ore deposits. Recycling also saves the indirect materials required by some production processes. For example, the production of aluminum from bauxite by the Hall-Heroult process uses large amounts of petroleum coke which is not needed in the processing of secondary aluminum. Recycling also provides the only indigenous sources of nonferrous metals in some countries. In addition to increasing supplies of materials, recycling can benefit the balance of payments of resource poor countries.

ferrous/nonferrous recovery, secondary materials recovery, energy, automobiles, processing

418 Bjorkengren, C. A., Nilsson, B.

REPAK, A Method for Using Packaging Waste as a Source for Production of Cores. Proceedings of the International Recycling Congress (Recycling Berlin '79). Berlin, Federal Republic of Germany. Pages 1170-1175. E. Freitag--Verlag für Umwelttechnik. 1979. References.

The authors present a unique method to reclaim mixed plastic waste from selected industrial packaging firms. The method, called "REPAK" utilizes packaging industry production waste to produce cores used in connection with reeling of web-materials such as paper, plastic films and various types of laminates. The conventional core for this purpose had earlier been made from paper (low quality) or from steel or plastics (high quality).

Waste from a plant is automatically transported to an intermediate plant, close to the packaging production. All material is ground to flakes to be stored in silos, and then blended. Special additives can also be used for specific needs.

After blending, the flakes are transformed to an extrudable resin agglomerate. The agglomerate is used for extrusion of cores of different sizes in a specially designed and equipped extruder.

The cores meet rigid specifications, concerning dimensional stability, water resistance, ability to withstand high impacts and low measurement tolerances.

A comparison of energy balances showed substantial energy savings compared with virgin polyethylene resins. Slight advantages were accorded REPAK over conventional unbleached paper, which has been known to produce nferior product cores.

plastics, extrusion, plastic recycling, small scale industry

419

Breakspere, R. J.
Heath, P. J.
Morgan, R. J.

Waste Glass—Reuse or Throw Away? Conservation and Recycling. Pergamon Press. U.K. Volume 2, Number 1. 1978. Pages 49-58.

This article presents test results of recycled glass products. Waste glass has been used as a filler in cements and resins for manufacturing floor and wall tiles, industrial castings, and sanitary fittings. Mechanical and physical properties of the products are discussed. Materials are produced by mixing a resin or cement with crushed glass derived from waste bottles (clear and colored). In order to improve the binding properties of the glass particles to the mix, it is generally necessary to pretreat the surface of the glass, which will act as a "key" between the glass and the mix being used. The work to date has been devoted to: (1) determining the physical and chemical properties of resin and cement based materials containing crushed glass of various sizes and pretreatments; and (2) using waste glass for making decorative panels and structural materials.

waste utilization, research and development, glass recycling, glass

420

Brown, A. W.
Needs, R. A.

Land Restoration in the Marston Vale, Bedforshire. Presented at International Symposium at Institution of Civil Engineers, "The Practical Implications of the Reuse of Solid Wastes," 11-12 November, 1981. Institution of Civil Engineers. Westminister, London, U.K. Paper 110.12. Pages 75-82. 1981. References.

This article discusses the reclamation of a worked-out clay excavation site by controlled landfill. Political, commercial and environmental issues are presented. A private company considered ramifications of controlled dumping to reclaim land. County council support was solicited. The company conducted a detailed investigation of site geology to ensure area/waste compatibility. Preparations included land dewatering and leachate control systems installation. Materials are buried in a controlled manner and compacted by heavy equipment. The possibility exists for methane extraction.

land reclamation, landfill, biogas, United Kingdom

421 Bundick, P., Ed.

Selected Appropriate Technology Information for Developing Countries (Abstracts from the National Technical Information Service Data File). National Technical Information Service. U.S. Department of Commerce, Office of International Affairs, 5285 Port Royal Road, Springfield, Virginia, U.S.A.

This bibliography contains 2,500 citations on "appropriate technology" from the National Technical Information Service. Appropriate technology is defined, in the context of this publication, as information which can be adapted and used to improve the quality of life for low income people. The information is broad in scope, covering many fields. Technologies presented are: small scale, labor intensive, low cost, revived, improved traditional, alternative, social and management, and selected modern technologies which can be adapted to local needs and environments.

The references are applicable to solid waste, waste recovery, and recycling, and small scale businesses which use waste materials.

appropriate technology, small scale industry, agriculture, technology, economic development, labor, costs, developing country

422 Callihan, C. D.
Dunlap, C. E.

Single-Cell Protein from Waste Cellulose. Report prepared under Grant No. EP-00328 for the Office of Research and Development. U.S. Environmental Protection Agency. Washington, D.C., U.S.A. October, 1973. 89 pages. References.

This report details a laboratory scale process to convert cellulosic wastes to microbial protein. The procedure involves treating the cellulose with a two to four percent caustic solution subjected to a temperature of 110 to 130° for thirty to sixty minutes which renders the material biodegradable and kills all contaminating organisms.

The intermediate material is then elutriated to remove a large portion of any heavy metals that might be present. This washing also removes soluble carbohydrates which repress cellulose enzyme activity. The intermediate is about 65 percent cellulose.

Fermentation is carried out using a mixed bacterial culture. The protein is harvested by adding cationic flocculating agents. The product can serve as an animal feed supplement and has potential for human feed should related nucleic acid research be successful. Productivity of about one gram per liter per hour yielded an economic estimate of final crude protein cost of 13 cents (U.S.) or less per pound.

cellulose conversion, nutrients, animal feed, health and safety, municipal solid waste

423 Cocqueral, M.A.T.
Burcher, M. G.

Aspects of Recycling Copper Scrap. Conservation and Recycling. Volume 2, Number 2. Pages 111-116. Pergamon Press. U.K. 1978. References.

This article describes problems encountered in designing systems to effectively recycle copper scrap. For example, it is necessary to deal with excessive heat and oxygen liberation and black particle smoke. Detailed discussion is provided on both issues.

Economies of scale are considered, concluding that larger plants are more economical. The average output is 100,000 tons per year. While acknowledging, and that several smaller subunits dealing with different aspects of scrap could have application as integrated units, the optimum solution to produce high quality copper from secondary sources is the larger plant.

The last few years have seen copper scrap change due to an increased use of composites and electronic component miniaturization. This has placed burdens on secondary refiners' ingenuity. Increased requirements for environmental protection, especially in urban fringe areas where much of the industry exists, represent another problem that needs to be dealt with.

nonferrous scrap, recycling, economics, resource recovery

424 Cook, R. F.

The Collection and Recycling of Waste Glass (Cullet) in Glass Container Manufacture. Conservation and Recycling. Pergamon Press. U.K. Volume 2, Number 1. 1978. Pages 59-69. References.

In this document the system for collecting and recycling glass containers is discussed from the point of view of economic and technical constraints and potential energy savings.

The use of cullet is a long-established practice in the glass container industry. Since broken glass is virtually the equivalent to original raw materials, and can be remelted many times, it has always been the practice to recover scrap from defective articles and to put it back into the furnace. The use of "foreign" cullet, from glass containers that have served their purpose, has become desirable for two basic reasons: to reduce the volume of solid waste, and to reduce the consumption of raw materials.

Quality control (temperature, purity, batch mixtures) during processing is crucial in order to meet requirements and protect equipment. Furnaces have operated successfully on 100% cullet, albeit for short periods under special circumstances. Several furnaces in Europe and elsewhere are currently using batches containing over 50 percent cullet. Glass treatment plants needed to eliminate contaminants are economically feasible.

In the United Kingdom, house-to-house collection is deemed uneconomical. Large containers for drop-off are provided in convenient locations. Consumers bring empty bottles with no financial incentive. This "bottle bank" system is similar to schemes in Switzerland, Germany and France. The scheme will break even if ten skips capable of holding 4 tons are placed where they are filled in 3 1/2 weeks; or 600 tons per year.

Potential energy savings can result in two areas: (1) extraction, processing and delivery of batch materials; and (2) melting. An analysis by the U.K. Glass Federation shows that cullet requires less energy than raw materials, given the same delivery distance. This simply means that one can afford to transport cullet further than raw materials, and thus the collection arc can be extended or the quantity of cullet increased. The melting of cullet (at approximately 1500°C) consumes about 70 percent of the energy used in bottle manufacture. It is this part of the process that offers most scope for energy saving. The Swiss glass manufacturer, Vetropak, has reported fuel savings of 2 percent for each 10 percent of raw material that is replaced by cullet.

Recycling old bottles into new ones is the approach to waste reduction favored by glass manufacturers throughout Europe who are convinced that the system can be viable from manufacturer, waste manager and consumer view points.

cullet, collection, glass manufacturing, glass recycling, United Kingdom

425 Deolalikar, A. B.
A Survey of the Indian Economy to Explore the Potential for Remanufacturing. Center for Policy Alternatives, Massachusetts Institute of Technology. Cambridge, Massachusetts, U.S.A. 1979. 80 pages. References.

Discarding products involves an economic loss particularly when goods are not completely consumed during use. The difference between scrap value and the value of the item in its prime is the value added--the labor and overhead costs of making and distributing the product. This can be a significant value. Remanufacturing as a strategy can help to mitigate this loss.

Remanufacturing takes place in both the formal and informal sectors of the Indian economy. Remanufacturing in the informal sector is widespread and includes: automobile engines, transistor radios, bicycles, household appliances, watches, and water heaters. A network of hundreds of thousands of small service agencies is scattered across the country, many concentrated in urban areas. Each employs 1 to 5 people. Surplus labor accounts for low service costs, which are a fraction of new product prices. This small scale sector is appropriate to India, where people are cognizant of scarce resources. It has historically been successful in providing employment and excellent technical training for millions of people, most of whom were previously unskilled.

A large potential exists for independent operators to remanufacture foreign consumer and capital goods for export. However, the government places a low priority on consumer goods and hence, remanufcturing is not encouraged. Also, there has been an overall decline in the small scale sector of the economy. In order for remanufacturing to expand, duty-free export processing zones, technical school graduates, and infrastructure are necessary.

The report concludes that the potential for remanufacturing is good.

remanufacturing, India, small scale industry, informal sector, survey, international trade

426 Dries, W. C.

Heating and Cooling of an Industrial Plant with Unusable Household Discards. Proceedings of the 2nd International Symposium: Materials and Energy from Refuse. Antwerp, Belgium. 20-22 October, 1981. Pages 8.23-8.26. European Federation of Chemical Engineering and International Solid Wastes and Public Cleaning Association. Author at University of Wisconsin-Extension, Madison, Wisconsin, U.S.A. References.

This paper describes the production of heat energy by Goodwill Industries in Milwaukee, Wisconsin. The energy comes from burning discarded household items which are donated to Goodwill and not usable or saleable. Included are shoes, cloth, plastics, paper, cardboard and wood. Large, bulky items such as mattresses and over-stuffed upholstery which do not burn well are not used.

Plastics are fed into the boiler in small quantities because the high heat liberated by burning is harmful to the refractory (which requires additional maintenance). Further, thermal efficiency is reduced due to the fouling of heat recovery tubes by acids created by the combustion process. The annual statement for 1980 showed gross savings of US$136,298 against costs of US$123,911 for a net savings of US$12,387.

incineration, United States, heating and cooling, fuels, household wastes, energy recovery

427 Dutt, B. L.
Levine, H.
McLeod, A.

A Study of the Feasibility of Utilizing Solid Wastes for Building Materials. Phase I Summary Report (154 pages). Phase II, III and IV (177 pages). PB 279 440, and PB 285 437, U.S. Environmental Protection Agency-MERL. Cincinnati, Ohio, U.S.A. 1978. References.

This series of reports presents data on utilization of all types of wastes for building construction. Laboratory evaluation and results are included.

In Phase I, a comprehensive literature search was conducted. The data were reviewed and evaluated for potential matrix, reinforcement, and filler candidates. The more promising candidates were evaluated with limited laboratory studies. From these studies, two types of matrices--furfural-phenolic and inorganic--were selected for further study. Seven reinforcement candidates and five filler candidates were selected for evaluation with the two matrices. A detailed Work Plan for Phase II based on the Phase I atudy is also presented.

Scrap plastics, paper, glass, sewage sludge and wood waste were post-consumer solid wastes considered among the many agricultural and industrial wastes studied. Waste plastics and paper received high positive use scores when tensil strength, surface volume ratio and other parameters were evaluated.

Phase II, July, 1974 to September, 1975, was an evaluation of the structural and aesthetic properties of the various waste composites. Satisfactory products were made using both inorganic and organic systems; structural and fire-resistant properties of several formulations were found to be superior to those of existing commercial products. Economic analyses were performed on the structurally promising products, and several appear to be commercially viable.

In Phase III, September, 1975 to November, 1976, attempts were made to produce full-scale products and qualify them for structural applications. Particle board panels, 4 by 4 feet, were made of peanut hulls and wood waste on production-type equipment.

In Phase IV of the study, structural tests were performed on wall panels fabricated from rice hulls and an inorganic binder. These tests completed generation of the data required for building code approval.

waste composition, building materials, glass, paper, solid wastes, sludge, agricultural wastes, industrial wastes, plastics, wood, waste utilization

428 Gleason, J.
Efficient Fossil and Solar District Heating Systems. Solar Energy Research Institute. Golden, Colorado, U.S.A. 230 pages. 1981. Author at Self-Reliance District Heating Group, Washington, D.C., U.S.A. References.

This report is a comprehensive review of cogeneration of both electrical and thermal energy for distribution from relatively centralized sources which for space cooling and heating, hot water and process heat needs of commercial, industrial and residential consumers. Building codes, storage systems, pipe materials, maintenance costs, and implementation are discussed with particular reference to urban settings. Solid waste derived fuels may be substituted for less available fuels because low distribution temperature and pressure requirements can be met by this relatively low quality fuel. Small scale systems have more flexibility with regard to energy conversion technology. Small scale low temperature systems can be adapted for use of solar, wind and geothermal energy. Energy conservation among end users is critical for realizing efficiencies. Plant technologies are discussed in detail.

The system was invented in the U.S. in 1877 and proliferated in the 1920s and 1930s. However, its use peaked just prior to World World II. Reasons for the decline include: availability of inexpensive fossil fuels, concurrent scaling up of electrical generation systems and removal of electrical generation facilities away from urban heat loads, decline of cogeneration design, and the limited capacity to transmit steam over long distances. Today, only 1 percent of the population in the U.S. is served by district energy systems.

In Northwestern Europe, primarily in Denmark, Sweden and the Federal Republic of Germany, the experience with cogeneration and district energy has been successful. Post World War II energy scarcity required optimizing less-efficient networks. Cogeneration which is the joint production of thermal and electrical energy, combined with district energy to evolve as a widely employed and efficient energy use system. Prefabricated insulated "pipe in pipe" systems was the European modification which allowed efficient supply and return of water through the system.

energy recovery, United States, Europe, resource recovery, fuels, small scale units, heating and cooling

429 Grabbe, K.
Zadrazil, F.

Organic Residues As Substrate for Mushroom Cultivation. Proceedings of the International Recycling Congress (Recycling Berlin '79). Berlin, Federal Republic of Germany. Pages 1256-1261. E. Freitag--Verlag für Umwelttechnik. 1979. References.

This article discusses technical considerations for using agricultural and industrial wastes for cultivating mushrooms. Special attention is focused on the microbial degradation of cellulosic containing wastes which could produce a suitable growing medium.

Traditionally, compost made from horse manure has been used as a substrate for over 200 years. In order for this to be efficient, the caves had to have the right climate, with few pests or molds. Today, artificial environments can be created which enhance production.

The production of substrates is divided into two stages: (1) composting of horse manure; and (2) compost product or grading. The latter is also called pasteurizing as temperatures reach 60° C for 20 to 30 hours.

Many valuable wastes can be used as mushroom substrate including straw, chicken manure, silage fluid, molasses, whey, sawdust, wood chips, swine manure, horse manure, and even municipal solid and liquid waste (organic fraction).

organics, composting, cellulose conversion

430 Hortenstine, C. C.
Rothwell, D. F.

Composted Municipal Refuse as a Soil Amendment. U.S. Environmental Protection Agency. National Environmental Research Center, Office of Research and Development. Cincinnati, Ohio, U.S.A. NTIS PB-222 422. 1973. 62 pages. References.

Processed residential refuse supplied by four compost plants was evaluated as a source of plant nutrient and as a soil amendment. Three compost products tested had high carbon to nitrogen ratio, resulting in delayed indicator plant growth. Total soluble salts in composts were high and had a damaging impact on seed germination. Positive results were obtained after a time for compost applications above 32 metric tons/hectare. Increased plant yields and improved soil action exchange and water retention capacities were achieved. When mixed with cow manure in equal parts, compost effectively curtailed nitrification by 100 percent. Fungal growth in compost/soil mixtures increased greatly as did bacteria, but bacterial numbers decreased greatly after 4 to 5 days.

Under strict interpretation of requirements that an organic material must meet for both fertilizer supplement and as a compost, only one of the four composts tested would be classified as acceptable. That compost had a C/N ratio of 17 as compared to 26, 43 and 55 for the others. It also was pelletized, free of moisture and agreeable to handle, all characteristics lacking in the other compost products.

composting, organics, testing methods, marketing, soil amendment, nutrients, household wastes, municipal wastes, fertilizer

431 Jackson, F. R.

Recycling and Reclaiming of Municipal Solid Wastes. Noyes Data Corporation. Park Ridge, New Jersey, U.S.A. 1975. 342 pages. References.

This book provides a comprehensive treatment of the collection, processing and recycling of municipal and light industrial solid wastes. It is based on studies conducted by the United States Environmental Protection Agency, other government agencies and system vendors. Case histories are used to explain material recovery via mechanical and labor intensive processes, markets for materials, data on individual materials, and subflows including glass, rubber, plastic and metals. Sources, problems, economics and technology are described.

source separation, processing, markets, glass, paper, plastics, rubber, ferrous/nonferrous recovery, secondary materials recovery, municipal solid waste, sorting, labor

432 Koller, T.

The Utilization of Waste Products: A Treatise on the Rational Utilization, Recovery, and Treatment of Waste Products of All Kinds. Scott, Greenwood and Sons. London, U.K. 1915. 327 pages. Translated from German. 2nd edition. References.

This document portrays municipal and industrial waste utilization between industrializing nations during 1890-1915. The solid waste chapter, "the waste of towns", is a description of materials and energy recovery techniques. High technology, resource recovery techniques implemented with a poor to mediocre performance record include the Arnold and Merz grease extraction processes, the Freyer combustion "destructors" process and the Budapest process. The "Budapest process" is described as involving large scale arrangements for sorting from conveyors by children. Residues are combusted. This process was adapted to a railroad siding at Puchheim, Germany, which had a 450-500 ton per day capacity. Each day two special trains of 30-40 wagons are shipped for processing. This method was eventually rejected for sanitary reasons.

A key concept advanced in the document was that primary separation of materials and waste utilization was considered of secondary importance when public health advocates attempted to overcome problems of waste buildup. Public officials viewed refuse management as removing wastes in the quickest time possible and, subsequently, wastes had to be destroyed. As a result, waste utilizaton decreased as a viable option.

The author also relates the general lack of marketing sophistication exhibited by vendors of high technology systems. For example, slag on incinerator grates was considered a possible marketable item by the vendors. Unfortunately, the glassy slag was earmarked for glass container manufacturers who could not possibly use it in batches, due to high levels of contamination. This illustrates the problem of marketing where data on specifications and user demand are unknown or misunderstood.

waste utilization, municipal waste, industrial waste, Europe, United States, resource recovery

433 LeRoux, N. W.
Wakerley, D. S.
Simpson, M. N.

Microbial Production of Methane from Household Waste: Fixed-Bed Anaerobic Digestion. Conservation and Recycling. Pergamon Press. United Kingom. Volume 3, Number 2. 1979. Pages 165-174. References.

Microbial production of methane from household waste using fixed-bed anaerobic digestion was studied. This article presents technical data. Economic data was inconclusive and varied depending on local conditions.

The fixed-bed anaerobic digestion system consists of a hole or trench lined with admix lining or plastic sheeting to prevent loss of

liquid and gas from putrifying wastes. A dome shaped cover aids in collecting gas. Each unit is large enough to contain a few days refuse on a batch basis.

Putrescible fractions of sorted household wastes were used in operational tests. Digestion was completed in 60 days at 30° C when unshredded waste was mixed with predigested sludge as a feedstock. Gas yield was 0.12 cubic meters per milligram of putrescible waste with an average molecular composition of 58 percent methane and 42 percent carbon dioxide. Tests showed that initial concentration of methane was low, while shredding wastes and adding water increased fermentation time. After digestion, the sludge and slurry are useful as soil conditioners.

biogas, soil amendment, organics, small scale units, household wastes, anaerobic digestion

434 Linley, B. D.
Tinplate Recycling. Resource Recovery and Conservation. Elsevier Scientific Publishing Company. Amsterdam, Netherlands. Volume 2, Number 3. May, 1977. Pages 225-240. References.

This article, which reviews recent activities in industrial tinplate waste recycling, covers melting, electrolytic and alkaline detinning practices. It describes extraction of tin cans from refuse and the preparation requirements prior to detinning. Effects of advanced can making technology on the detinning industry are discussed.

There are three mechanisms of tinplate recycling, actually a process of upgrading steel scrap. Melting processes the tin right along with the steel; and the tin is not recovered. Electrolytic detinning is a batch process involving electrolysis and produces a soft tin "sponge." Alkaline detinning is a continuous chemical stripping process producing the highest quality tin and steel. But is a slow reaction, especially when compared to the rapid transfer of stannous ions to negative poles in the aforementioned electrolytic detinning.

A model plant (100,000 tons annually) for the recovery of steel cans from mixed refuse is described. Shredding, magnetic extraction and conveyors comprise the operation which 1975 achieved an efficiency of 90 percent extraction.

ferrous/nonferrous recovery, processing, tinplate recovery

435 Liroff, S. D.
Management of Environmental Risk: A Limited Integrated Assessment of the Waste Oil Rerefining Industry. Prepared for the National Science Foundation. March, 1978. Prepared by Tekneknon, Inc. Berkeley, California, U.S.A. 200 pages. References.

This is a review of a project supported by the National Science Foundation to assess the waste oil rerefining industry. Five different areas critical to the industry were surveyed: (1) an assessment of seeral

rerefining technologies, (2) an analysis of future technologies, (3) a financial analysis, (4) disposal of acid sludge, and (5) state and local governments as a potential market for rerefined waste oil.

The potential for establishing recycled oil programs is evaluated for the 48 states comprising the continental United States. The major fi dings include: (1) although acid/day technology is still the major process, its use is rapidly decreasing (down 30 percent in the last 10 years); (2) total rerefined oil has increased; and (3) oil rerefining generates hazardous wastes and sludges.

oil, hazardous waste

436 Lund, R. T.
Energy Capture Through Remanufacturing: Final Report of Pre-Demonstration Study. Massachusetts Institute of Technology. Cambridge, Massachusetts, U.S.A. 1981. 199 pages. References.

Case studies of remanufacturers were developed in the product areas of automobile parts, heavy duty diesel engines and parts, refrigeration and air conditioning compressors, newly conditioned machine tools, and power plants. These were chosen using selection criteria and methods detailed in the report.

Remanufacturing preserves the functional value of durable products, and is the full scale disassembly of products, pooling of interchangeable parts, and production line reassembly in a fashion similar to the original manufacturing process, with some replacement of worn parts. The term remanufacturing does not refer to the unit-by-unit rebuilding of goods except in the case of large items that are originally assembled on a one-by-one basis. The process restores a product to the point where it meets or exceeds original product performance specifications. Using a variety of research approaches, researchers have obtained a comprehensive overview of the structure of the industry, the operating characteristics of firms in it, and the energy and resource conservation potential inherent in remanufacturing.

It was found that a successfully remanufactured product must be a durable end product or a durable component of an end product. The remanufacturing process is primarily labor intensive. It tends to require lower skill levels of its employees and so pays lower average wages than a comparable new product manufacturing. Because the process does not require complex equipment and because material (core) costs are relatively low, the capital investment requirements are modest.

Remanufacturers rely on cores or discarded products to supply the largest part of the materials requirement, typically recovering about 80% of core weight for reuse in the process.

Remanufacturing was found to be flexible, depending primarily on the nature of the product. Process methods, product ownership during the process and distribution channels all vary from product area to product ares. Because the remanufcturing process provides constant dealings with

failed products, remanufacturers tend to become familiar with inherent design weaknesses in the product. As a result, many incorporate appropriate changes in their process to correct the weakness, thus yielding a product with a longer life span. Remanufactured products typically sell for 50-70% of the comparable new product price.

energy recovery, automobiles, labor, product durability, remanufacturing

437 Mandels, M.
Disposal of Cellulosic Waste Materials by Enzymatic Hydrolysis. Army Natick Laboratories. Natick, Massachusetts, U.S.A. 1972. Ad-750-351. References.

Cellulose is first converted to glucose by enzymatic hydrolysis. Glucose is then converted to alcohol by natural fermentation. T. viriede was selected as the enzyme since it grows rapidly on simple media and consumes cellulose. A major problem is that cellulose is insoluble. The reaction rate depends on the available surface, so researchers introduced selected organic solvents to emulsify the cellulose. Many cellulosic materials (newsprint, etc.) contain substantial quantities of lignin, which limit access of the enzyme to the cellulose. Available surface is increased by both the additives and shredding.

hydrolysis, cellulose conversion, fiber, paper

438 Meinhardt, P.
Kolb, J.
Feeding Cattle at the Garbage Dump. Compost Science. Rodale Press. Emaus, Pennsylvania, U.S.A. Volume 12, Number 4. July/August, 1971. Pages 14-16.

The authors have reviewed literature and recommend using refuse derived organics as a feed supplement for cattle. This is especially useful for developing countries where grain is usually consumed by people rather than cattle.

For example, in Cuba surplus supplies of molasses and bagasse (residues from crushed sugar cane) are combined with elephant grass, three percent urea, and fish meal. Average daily weight gains of 2.8 pounds were achieved on diets totalling 12.6 pounds of feed per pound of weight gain. The reported cost was U.S. $0.5/lb. There is an advantage to keeping cattle near food supplies, since over 65 percent of livestock costs come from the transfer of livestock from one foraging area to another. Coupled with stress from shipping, the authors concluded that a steady, quality controlled waste derived feed source with low transportation costs could reduce losses.

Editors note: This article does not deal with any potential health risks that may be associated with feeding cattle mixed municipal refuse.

Cuba, animal feed

439 Minke, G.
Alternative Bauen. OKO-Buchversand. Kassel, Federal Republic of Germany. 140 pages. 1981. References.

This book discusses the potential of alternative construction techniques using a combination of natural surplus building (loam, sand, earth, living plants), waste products (sulphur, bottles and tins), and inexpensive industrialized components (cardboard, textiles, grid shells).

Good results were obtained by the Research Laboratory for Experimental Building, University of Kassel, Federal Republic of Germany on several research and development projects in low cost housing and self help construction were exemplary on several R&D projects on low cost housing construction.

waste utilization, building materials, Germany (Fed. Rep. of)

440 Minsaas, J.
Recycling of Domestic Food Wastes. Conservation and Recycling. Pergamon Press. U.K. Volume 3, Number 3/4, 1979. Pages 427-438.

This article examines food wastes in Norway. Collection systems and utilization systems are detailed. In a 14 week experiment of source separation, 50 percent of the total food waste was recovered. Processing and end use markets are suggested.

A formula is given to estimate the potential for animal fodder from the substantial amount of waste generated. Feeding experiments have shown a fresh food waste/fodder equivalency of 2.5 to 3 kg/fodder unit 1 kgof feed barley. Using a 50 percent collection efficiency (from the test situation), then the total subflow available as fodder would be equivalent to: total kg/waste food x 0.503 kg/fodder unit = N units.

Collection, segregation and treatment of food is equally important to maintain feed supplement quality. Several plans for moving wastes to end users are detailed. Source separation is also critical and must be easy and convenient for the householder.

The quality of the feed derived from the waste is also considered. Test results based on digestibility and feed nutrients showed excellent prognosis, depending on the type of food waste. If properly separated from potential contaminants, food wastes did not appear to have any heavy metals.

animal feed, organics, markets, source separation

441 Morris, D. J.
A Technical Assistance Handbook for Community Based Cellulose Fabrication Plants. Institute for Local Self-Reliance. Washington, D.C., U.S.A. 1977. 79 pages. References.

This report was prepared for the U.S. Community Services Administration (CSA) and descries a cellulose insulation business.

A business development plan is presented emphasizing current demand levels based on government procurement, the ability to leverage investment capital, and the possibility of forming minority and low income citizen ownership.

Pro forma income statements and balance sheets are calculated for a 2.5 ton per hour, 2 shift operation. Total fixed costs are estimated at US$220,000. The document notes that variable costs relate to supply of chemicals (particularly boric acid needed as a fire retardant for product safety), furnish, and product demand. A list and evaluation of international equipment suppliers is included along with discussion of lease, franchise, and purchase options. Total output equals 11,700 tons. Total revenue would equal US$3,120,000. It is estimated that the breakeven point would be 43 percent of peak capacity.

By establishing a manufacturing plant capable of paying up to US$60 per ton for secondary newsprint and other feedatock materials, community recycling programs and/or municipalities can have a guaranteed market for collected materials.

cellulose insulation, manufacturing, economic development, newsprint, paper, community enterprises, costs

442 Newsome, C. J.
The ITDG (Intermediate Technology Development Group) Paper Pulp Molding Project. Appropriate Technology. Intermediate Technology Publications Ltd. London, United Kingdom. Volume 5, Number 3. Pages 12-14. November 1978. References.

This article reports on a paper pulp molding system for manufacturing egg, fruit and meat trays, etc. from lower grade waste paper. This system was developed in 1971 and has been successfully demonstrated in 17 separate operations as an example of E. Schumacher's "small is beautiful" concept for commercially viable industrial manufacturing in LDCs.

Units are operating in Nigeria, Kenya, Zambia, Trinidad, Ghana, Tanzania, Panama, Haiti, El Salvador and others. Inquiries to the vendor have been received from over 50 countries.

Although it is possible to use the same plant to produce other products, including plant pots, and certain fiber building materials, 80 percent of all production is the standard 30 egg (5" x 6") tray.

The complete unit consists of three principal sub-assemblies: the pulping plant, the moulding assembly and the drying unit. Although the initial design was almost entirely manually operated, a certain amount of electronic equipment was included in the production models in order to control the molding process, particularly in relation to the vacuum and compressed air cycles. Simplicity and safety are major design factors throughout. Each state of the process is detailed in the article.

The major problems have not been of a technical nature, but rather ones of finance and marketing. Established firms are often unwilling to venture capital on R&D for intermediate technology because of lower rates of return versus risks and limited and unfamiliar market prospects.

paper, pulp, small scale industry, economic development.

443 Ouano, E. A. R.
Arellano, F.

Utilization of Waste Tin Cans in the Control of Chromium Plating Wastes. Conservation and Recycling. Pergamon Press. U.K. Volume 3, Number 3. 1980. Pages 130-133. References.

Based on the operation of a bench scale model in the Philippines, it was shown that the control of wastewater pollution in the chromium plating industry could be carried out economically using rusted tin cans as a reducing agent and calcium carbonate as a precipitating agent with effectiveness comparable with that of the conventional process used in the more sophisticated factories in developed countries.

The process has widescale applicability in developing economies such as the Philippines, Thailand, Malaysia and Indonesia where the chromium plating is basically a cottage industry with very low capitalization and technological sophistication. Chromium plating discharges highly acidic wastes with varying concentrations of heavy metals in the form of hexavalent chromium, cupric, nickel and iron salts.

The standard methods for treating such wastes (addition of sulfur dioxide gas or sulfite neutralization to pH 7.5 or 8) are difficult to apply in developing countries because of complex technical requirements and high maintainance costs.

The availability of large numbers of tin cans discarded even by scavengers due to low resale values, however, makes an alternative chromium plating waste treatment attractive. Passing the chromic acid solution through a stock of rusting cans will oxidize the tin and iron to stannous and ferrous oxidation states, and at the same time reduce the hexavalent chromium to the trivalent state during a 12-24 hours retention period. The procedure has the following advantages over the standard method of sulfite or sulfur dioxide reduction: (1) rusted tin cans are in the solid state, and there is no need to measure the stoichiometric requirements; (2) operation is very simple; (3) complete reduction may be observed with the disappearance of the orange color; (4) reactants are available at low cost; and (5) no mixing equipment or complicated instrumentation is required.

Economic evaluation of bench scale operation indicates that the conventional treatment process is twice as expensive as that of the new process. At the same time, a permanent local market for tin cans is created.

The cost of process instrumentation for the conventional process is estimated at US$5,000 for plants with a wastewater flow lower than 2000 m^3/day. This is unfeasible for plants in developing countries where wastewater flow rates range from 10 to 100 m^3/day. Using the new process for a 100 m3/day plant, daily cost is estimated at US$29.31 compared to US$59.71 for the conventional process.

hazardous waste, chromium plating wastes, environmental management, pollution, tinplate recovery

444 Overby, C. M.
A Study of Issues and Policies Related to Recycling of Products. Prepared for U.S. Congress, Office of Technology Assessment. Washington, D.C., U.S.A. 381 pages. References.

This document identifies problems and issues associated with product recycling. Technical and institutional impediments to product recycling are examined as are several advantages and disadvantages-economic, energy (embodied and life cycle energy), materials consumption, waste and pollution, and employment factors. Government policy is seen as a way to encourage product recycling. Implications of policies with national goals are briefly explored.

Product recycling is defined and related to other forms of recycling. It is characterized as "inner loop" recycling, whereas recycling back-to-basics materials is characterized as "outer loop" recycling. The former is a less entropic form.

Product recycling ranges from remanufacturing (which brings products to a central facility and works on a mass production basis)--to do-it-yourself repair and renovation by an individual. Tax, labeling ad other government policies will affect the process.

In remanufacturing, product parts are kept together and the original product is reassembled, usually with some new components. Repairing means simply fixing individual products, usually one at a time. Fixed structure renovation refers to buildings being revitalized.

Product recycling conserves materials, energy, and labor and power. Some see this as implying greater standardization and less variety of product choice and, hence, not desirable.

Products being remanufactured include automobiles, aircraft engines, machine tools, refrigerator and air conditioner compressors, copying machines, white goods, tires, electric power plants, agricultural and construction equipment. Institutions involved are the U.S. Government, General Services Administration, State of Texas Prison Industries System, U.S. Military, and organizations such as Good Will Industries, Inc.

Product recycling is a thriving enterprise for many different kinds of products. Benefits include extension of product life, energy

conservation, cost reduction, and job creation. The private sector has mixed feelings about government policies which encourage this form of recycling.

recycling, remanufacturing, product design, source reduction, government policy

445

Parteous, A.
Franzidis, J. P.

Acid Hydrolysis of Cellulose--A Critical Review of Progress Proceedings of the 2nd International Symposium: Materials and Energy from Refuse. Antwerp, Belgium. 20-22 October, 1981 Pages 2.1-2.14. European Federal of Chemical Engineering and International Solid Wastes and Public Cleaning Association. References.

This article describes a process to convert cellulose to glucose by continuous process hydrolysis, using a dilute acid (1 percent sulfuric acid) on waste paper in a plug flow reactor operated at 230° C. Recent results have consistently yielded up to 56 percent conversion of cellulose.

After the products are flash cooled to 134° C, which stops the reaction (glucose decomposition), the hydrolysate is fermented and distilled to 99.95 percent ethanol.

A model for a 500-ton per day newsprint feedstock plant is presented, based on laboratory scale tests. Daily products will be 91.27 tons per day of ethanol, 10 tons of furfural, 99 tons of CO_2 and lignin cake which is burned to generate steam for process heat.

Capital investment in 1981 sterling was estimated at 21, 562, 500 or £ 43,125 per input ton of paper.

fuel, acids, testing methods, hydrolysis, cellulose conversion

446

Pathe, P. P.
Alone, B. Z.
Titus, S. K.
Bhide, A. D.

Seasonal Variation of Anaerobic Digestion of City Refuse. Indian Journal of Environmental Health. National Environmental Engineering Research Institute. Nagpur, India. 1977. Volume 19. Number 4. Pages 240-245. References.

Laboratory investigations by the National Environmental Research Institute, Nagpur, India on anaerobic digestion of a mixed feedstock of animal dung and an organic fraction of refuse (OFR) indicated technical feasibility of the process. Hence, the performance of the process in a longer time frame in the laboratory as well as under actual field conditions was studied. This document provides the results of the field research.

Simple field units were made from used steel drums. An outer drum of approximately 200 liters served as a digestor tank while an inner drum of 100 liters functioned as a gas entrapment device. Using a startup seed from a working dung digestor, 580 gms of shredded organic refuse and 7.5 liters of water were added to the digestor daily from an inlet pipe for a solid concentration of 7.2 percent. Careful daily monitoring ensured appropriate pH, temperature and measurement of production of gas and volatile organic acids.

A technical problem occurred 5 months after startup. A "scum" buildup interfered with gas collection. A similar digestor was built,but with a number of moveable steel plates affixed to the interior to break up scum formation. This was done 2-3 times per day.

Analysis of the digested slurry showed it easy to drain and dry. NPK of the digested sludge had a slight increase over raw input valuea, and the value indicated potential use as a soil amendment fertilizer.

Gas production in small field units ranged from a maximum summer value of 0.33 m^3/kg of volatile matter added/day to a minimum winter value of 0.1 m^3/kg. The H_2S content of the produced gas was negligible. The pH of digesting mass remained constant around 6.8 + 0.2. Volatile solids destruction ranged between 40 and 56 percent.

anaerobic digestion, biogas, organics, municipal waste

447 Pawley, M.
Garbage Housing. Presented at International Housing Conference. Santiago, Chile. By Minimum Cost Housing Group. McGill University. Montreal, Canada. 1972. 58 pages.

This document demonstrates ways in which bottles, cans and other containers can be adapted as building materials for developing countries. This could provide low cost housing and prevent significant amounts of waste generation. It has long been a practice in developing countries to use discarded goods as building materials. This report suggests that governments should formalize and promote programs to encourage manufacturers to redesign their products. For example, beer or soda cans could be designed to interlock and be used as building blocks. It is stated that "the ten largest brewery corporations in the world could provide material for no less than 100 million dwellings per year. Even assuming a loss factor of 50 percent, such an output would more than double world housing production at the present time." In order to implement a successful program, more research needs to be done on building with bottles and cans. Tax incentives to encourage manufacturers to redesign their products, and small scale pilot projects to demonstrate feasibility are other needs.

building materials, Wobo (World Bottle), developing country, product design

448

Pettigrew, R. J.
Roninger, F. W.
Markiewica, W. J.
Gransky, M. J.

Rubber Reuse and Solid Waste Management: Part I—Solid Waste Management in the Fabricated Rubber Products Industry; Part II—Waste Rubber and Its Reuse. United States Environmental Protection Agency. Washington, D.C., U.S.A. 1971. 120 pages. References. Glossary.

This two part document presents industry wide solid waste disposal practices and profiles the rubber recycling industry. Part I concerns the solid waste problems which originate with the manufacture of rubber products. Part II outlines the problems associated with rubber products discarded by consumers. The reclamation industry is discussed, detailing its history, wastes used, equipment and processes and industry trends.

Broad solutions to achieve more effective waste management with specific conclusions and recommendations are noted.

rubber, solid waste management

449

Piggott, M. R.
Woodhams, R. T.

Recycling of Rubber Tires in Asphalt Paving Materials. Environmental Protective Service, Environment Canada. Contract Number OISU-RE-109-8-6374. March, 1979. Department of Chemical Engineering and Applied Chemistry. University of Toronto, Canada. 56 pages. References.

This report documents paving trials, laboratory evaluations, stability test results, viscosity considerations, temperature performance, and costs of modification and provides conclusions regarding the use of crumb rubber in road pricing materials.

Although the proportion of asphaltic binder is small (6%) in road surface aggregate construction, its function is critical to road performance. Despite the effort to improve road surfacing materials, the quality of asphalt binders is relatively unchanged. The use of waste rubber as an additive in road aggregate is generally ignored, even though it could add measurably to road performance, as tests have shown. The reasons are additional cost and changes required in conventional paving techniques. Tests and operating resulting in a 1 percent cost increase, could make the use of rubber additives feasible.

rubber, road surfaces, testing methods

450 Rao, J. K. S., Ed.

Status Report on Building Materials from Wastes. Sub-Group on Building Materials from Wastes, Planning Group on Materials Construction. National Committee on Science and Technology. New Delhi, India. 1975. 340 pages.

This document presents a model for using wastes generated by the construction industry in India. National and state governments have generally not dealt with the problem of disposal and/or utilization of wastes. No organizational structure for policy and implementation exists. The planning group assessed India's requirements over the next 5, 10 and 15 years. Potential uses of different wastes for remanufacturing building materials, with status reports of research and development efforts are presented. The possible impact of major research and development programs on identified gaps is discussed. During industrial and agricultural expansion programs in India the problems of waste disposal have become more pressing due to increasing costs, lack of land and environmental pollution. Finding a solution to the problem of disposal of millions of tons of waste has become imperative.

R & D committees have been established to oversee ongoing projects and provide an annual status report on this subindustry. R & D tasks include helping to create commercial pilot scale investigations, fostering multi-discipline research centers, education, and manpower development. Regional state and local implementation strategies are presented.

waste utilization, building materials, India, research and development

451 Ritter, W. F.
Malone, G. W.
Eastburn, R. P.

Potential of Using Recycled Paper Products for Broiler Litter. American Society of Agricultural Engineers/Canadian Society of Agricultural Engineering. Brock University, St. Catherines, Ontario, Canada. 1981. 13 pages. Authors at University of Delaware. References.

This paper evaluates a study done by the University of Delaware during 1978-79 to examine paper products as a potential source of broiler litter (chicken litter). The most common materials used for broiler litter, sawdust and woodshavings, have become expensive and difficult to obtain.

Waste paper products could be an abundant source of cheaper litter material. Several companies are selling waste paper products for animal bedding. In this test, hardwood sawdust was used as a control.Materials for testing were coarse shredded newspaper, processed newspaper, and processed cardboard. The shredded newspaper was made by passing it through a hammermill which made particles approximately 1.27 cm in width. The processed newspaper and processed cardboard were made with a patented process. They were also coarsely shredded and then placed in a

hydropulper where the paper was separated into individual cellulose fibers. The fibers were than compressed to partially remove water. A fiber board product emerged which was then separated into particles ranging from .64 to 2.54 cm in diameter. These materials were dried to approximately 30 percent moisture.

Body weight, feed conversion and the percent of mortality were determined for each trial of 200 straight run Ross & Arbor Acre chicks at both 28 and 49 days of age. Breast blisters and skin pigmentation were also scored. Litter and fat samples for selected chicks were obtained. A heavy metals analysis was done. Processed cardboard was found not suitable for several reasons. Shredded newspaper was found to cause increased litter caking. Processed newspaper was the most suitable of the paper products tested.

Litter material was also tested for effect on corn seed germination. Poor germination was obtained with shredded newspaper, apparently due to compounds in printing ink. Seed germination was also low for processed newsprint. Applying excessive rates of shredded newspaper to cropland may affect seed germination.

waste paper recovery, newsprint, cardboard, animal bedding, pulp, cellulose conversion, soil amendment

452

Rossi, B. A.
Manila, P. I.
Lundgren, E.

Annelidic Recycling of Organic Wastes. International Solid Waste Association Journal. Number 31/32. Pages 10-12. References.

The authors propose using earthworms to recycle organic wastes. Under proper conditions, the worms can consume up to three times their body weight daily, consuming all forms of organic waste. A single worm produces 1,000-1,500 offspring per annum and the average life span is six years. They breed in a temperature range of 5-35°C. Worm castings which are abundant in soluble minerals and richly balanced in nitrogen, phosphate, and potash, can markedly improve soil humus.

Dried red earthworms are 62-64 percent crude protein and are considered equal to fish metal in amino acids for use as a high protein supplement.

Tests conducted at the Tokyo Agricultural Chemistry Testing Station in Japan using castings as an alternative to a supplementary fertilizing medium are described. Increased yields of 14-40 percent were noted on soybeans, chinese cabbage, and green soybeans.

Currently, a mixture of 30 percent castings and 70 percent conventional chemical fertilizer is used in a granular form which releases its nutrients over time. The 30 percent castings contain:

Moisture	44.34 percent	Molybdenum	0.8 ppm
Nitrogen	0.70 percent	Boron	57.0 ppm
Phosphoric Acid	0.91 percent	Manganese	0.01 percent
Potassium	0.57 percent	Organisms	34.88 percent
Silicic Acid	12.22 percent	Ash Content	20.78 percent
Lime	1.28 percent	Fuminsan Acid	7.58 percent
Magnesia	0.55 percent	Base	60.06 ME/100g
Oxide of Iron	0.56 percent	pH	7.65

Worm castings are favored as a way to produce fertilizers without depending on natural gas or crude oil.

Estimates indicate that facilities required for 1,000 tons of wet mixed waste per month require less than 3 acres as follows:

	Land	Labor
Mixing Plant	700 m2	1
Worm Beds	10,000 m2	6
Packing Plant	700 m2	4
	11,400 m2	11

Equipment cost is estimated at US$52,000

Profits vary with cost of land, construction, and labor, costs and/or revenues of waste. Profits in developing countries will be higher as land, labor, and construction costs are low. Cold weather housing is generally unnecessary and imported fertilizers are expensive.

The size of the installation can be scaled down to 1/2 ton a day and still be profitable.

vermicomposting, fertilizers, nutrients, organics, crop yield, composting, soil amendment, costs, economics

453 Rossi, B. A., Ed.

International Recycling Group: Seminar/Workshop Proceedings, 1977. Rossi-Nayve Consultancy Services, Inc. 1978. Makati, Metro Manila, Philippines.

This document is a compilation of several papers on recycling in Asia. Both high technology and labor intensive small scale technologies for resource recovery are presented. Topics include: uses of agricultural wastes, oil, plastics, compost animal waste and metals. The economics of small scale technology are presented. It is noted that small scale technologies are economically feasible in a group, whereas singly they

would fail. Thus, horizontal integration provides a mechanism of sustainability.

Asia, small scale industry, economics, labor, resource recovery, technology

454 Shin, K. C.
The Optimalization of Methane Gas Recovery from Waste Material and Possibilities for Its Utilization. Conservation and Recycling. Pergamon Press. U.K. Volume 4, Number 3, 1981. Pages 129-136. Author at University of Stuttgart, Federal Republic of Germany. References.

This document discusses the amount of gas available from sewage sludge, household refuse and agricultural wastes. Sewer gas (biogas) can be generated from anaerobic decomposition of different waste substances, e.g., sewage sludge, household refuse, and agricultural wastes. In the Federal Republic of Germany, one-quarter of available digestor capacity is unused. This is expected to increase, in spite of current limitations, due to the price of energy and increased awareness of potential renewable sources. Laboratory digestion tests were carried out to examine making gas from household refuse. A maximum specific gas yield of 320 ml gas/gram organic dried matter per day was achieved at optimal space loading with organic substances, amounting to 3.1 grams of organic dried matter per litre of gas production yield per day. Based on a 34 percent dried organic matter content of one kg of household refuse, or 349 grams/kg refuse and a decomposition rate of 50 percent, litres of gas are obtainable per kg of domestic refuse. Thus, the quantity of gas yielded in laboratory tests approached the theoretical value. If the gas from only 50 percent of the refuse could be collected from landfills, some 492 x 106m3 of gas per year would be available. New trends in use of landfill gas include heating greenhouses, fuel for motor vehicles, and anaerobic digestion of pulverized refuse. Research programs are testing these applications. To obtain results that were achieved in laboratory tests, optimum working conditions need to be maintained. These are sufficient agitation, removal of scum, continuous charging of the digestor, and the exact digestor or temperature.

biogas, energy recovery, testing methods, sludge, household wastes, agricultural wastes, heating and cooling, fuels

455 Sklar, S.
McBride, J.
Transportation Technologies for Low Income People: A Few Promising Programs. Alternative Sources of Energy. Pages 12 to 15. Milaca, Minnesota, U.S.A. March/April, 1981. Authors at National Center for Appropriate Technology. Butte, Montana, U.S.A. References.

Automobile repair and retrofitting are discussed in this article as a way to promote energy conservation and prolong the life of automobiles, particularly for low income people who cannot afford to purchase new fuel efficient cars. For less than US$2,000 a car can be totally reconditioned, which will add about 50,000 miles to the life of the vehicle. Reconditioning possibilities include changing an 8-cylinder

engine to a 4-cylinder one, new peripheral engine parts, new brakes, new tires, etc. Direct fuel savings could be as much as 40 percent. This type of automobile repair can potentially save 28,000 barrels of crude oil per day in the United States. In addition, a sizeable economic potential exists for job creation through this labor intensive method.

Retrofitting automobiles is a second way to promote fuel economy. For a vehicle which gets 15 miles per gallon and a remaining life expectancy of 50,000 miles, and assuming a 12 percent annual fuel price increase, a US$400 investment would be cost effective if it produced a 10 percent increase in fuel economy. For US$750 a 20 percent saving should be realized. Options include: radial tires, tire inflation, advanced lubricants, routine maintenance, driver skill training, idle-off and coasting systems, water emulsified fuel, thermostatically controlled fans, preheating fuel, and microprocessor controlled fuel intake. Retrofits could save 170,000 barrels of crude or equivalent per day in the U.S. A third approach is local production of alcohol fuels for use in modified automobiles.

automobiles, reuse, remanufacturing, fuel, labor

456 Smith, H. V.
Klobbie--The Wood Maker/Waste User. Rehsifsa. London, U.K. Bulletin #400. 25 February 1982. 10 pages.

In this technical bulletin, plastics reclamation using a klobbie unit is described. This is an automatic extrusion molding machine designed to handle certain mixed polymers. Currently, klobbies operate by Rheem Australia, Limited, Australia, Superwood Limited in Dublin (Ireland), Lankhorst Touwfabricken BV, Sneek (Netherlands), and HVS Mouldings Limited, Fareham (England).

Rehsifsa, the manufacturer, presents specifiations for a 1,100 tons per year klobbie unit. The feeding system is described as being able to handle a wide variety of polymers including both fibrillated film waste and granulated HDPE. Homogenization and plasticization is effected by a high speed adiabatic extender with a normal running speed of 350 revolutions per minute. Extruded materials are forced into a rotating cylinder comprised of 10 molds. The automatic molding operation is conducted by the filling of molds triggering the cylinder to move to the next unfilled mold. A unique feature is that different molds may be used provided they are all of the same length.

The klobbie is rated as very rugged. The equipment is simple with principal wear occurring at (1) the extruder screw (normal use: 1 year before re-stelliting); (2) cutting blades in the mill; and (3) extruder barrel heaters (lasting from 1 to 2 years). Selling price based on U.K. costs (energy, materials, labor, etc.) must be 18.7 pence/kg in order to break even.

plastics, plastics recycling, extrusion, molded products, equipment, wood substitutes

457 Smith, H. V.

Some Criteria for the Successful Commercial Recycling of Heterogenous Plastic Wastes. Conservation and Recycling. Pergamon Press. U.K. Volume 2, Number 2, 1978. Pages 197-201. Geneva, Switzerland.

Six criteria for successful recycling of mixed plastic waste are presented in this article. They are: efficient homogenization; conservation of energy by adiabatic operation; one step conversion of waste to finished product; consistency of feedstock; maximization of plant utilization; and selection of finished product from the standpoint of marketability.

Recycling of heterogenous polymers requires efficient homogenization to produce a molding compound with consistent properties.

The Mitsubishi Reverzer is one machine which can achieve this. Contamination in mixed plastics waste is averted by forming end products in thick sections (2-3 cm). These products do not compete with the plastics industry, but with the concrete and woodworking industries.

Since pyrolysing waste plastics for fuel is not energy efficient, recycling is the best way to conserve energy. This is true because the Reverzer operates at close to adiabatic conditions. Also, the Reverzer obtains a simultaneoua transformation of the melt to the end product, conserving the energy otherwise necessary for the intermediate granular stage.

The Reverzer can homogenize almost any mixture of thermoplastics. It is critical that the feedstock for a given product be combined in generally equal proportions.

Choice of the final product determines how profitable the enterprise will be. The profit margin increases accordingly with the cost of wood.

plastics recycling, Europe, small scale industry, product substitution, equipment, pyrolysis

458 Steinberg, M.
Beller, M.

Glass-Polymer Composites for Sewer Pipe Construction. In Proceedings of the Fourth Mineral Waste Utilization Symposium. Chicago, Illinois, U.S.A. May, 1974. 12 pages. U.S. Bureau of Mines. Rockville, Maryland, U.S.A. References.

This article describes the development of a concrete substitute made by the Brookhaven National Laboratory, Concrete Polymer Materials Development program. For example, a glass-polymer composite (GPC) is produced by mixing crushed waste glass with monomer (either methyl methacrylate or polyster-styrene) and polymerizing by chemical initiation techniques. Monomer concentrations are 13 to 16 percent by weight in

ungraded crushed bottle glass. Graded sieved glass results in monomer loading of 9 to 10 percent. GPC is two to four times stronger than ordinary concrete. It is also more durable. Using GPC for sewer pipes is one way to use the large amount of waste glass in urban communities. Various casting techniques including centrifugal casting are being explored.

A field test was done in Long Island, New York. Ten lengths of 8-inch diameter 3.4 inch-wall, 42 inch long GPC were installed in a municipal sewer line. For the same wall thickness, the three edge bearing strength of a polyestyrene GPC pipe is greater than twice the requirements for concrete pipe of the American Society for Testing Materials. Cost estimates indicate that GPC is potentially competitive with asbestos cement, vitreous clay, concrete and plastic pipe in the 8 to 24 inch diameter pipe size range. The construction of large capacity solid waste separation plants within the next few years will create an assured supply of waste glass for producing GPC products such as sewer pipe and building brick.

glass, glass recycling, plastic, product substitution, building materials

459 Sunavala, P. D.

Recycling of Municipal, Agricultural and Industrial Wastes to Generate Renewable Sources of Energy, Journal of Scientific and Industrial Research. Volume 40, Number 9. Pages 543-614. Council of Scientific and Industrial Research. New Delhi, India. September, 1981. Author at Department of Chemical Engineering, Indian Institute of Technology, Bombay. References.

This article covers the state of the art of resource recovery in India. Using the energy crisis as the focal point for development efforts, the article presents thermochemical means of recovering the energy value inherent in wastes, especially from the municipal sector. Pyrolysis is seen as the best answer to refuse disposal problems.

Advantages to the pyrolysis process include available technology, ease of storage, gas volumes considerably less than those generated by incineration (consequently pollution control is lower in cost) and a product which can be used in conjunction with sewage sludge to produce a fertilizer. Charcoal could possibly be used as an activated carbon substitute.

India, pyrolysis, technology, environmental management, pollution, municipal wastes, agricultural wastes, industrial wastes, resource recovery, energy recovery

460 Sweetman, J.

Making Paper by Hand. Appropriate Technology. Intermediate Technology Publications, Ltd. U.K. Volume 6, Number 3, 1979. Pages 9-11.

This document gives the history of paper making and basic requirements for making paper by hand. Drawing on 30 years of experience, the author describes the technical process of paper making beginning with four requirements: vegetable cellulose fiber, water, power and a screen. The raw material must be cellulose because only suspended cellulose has the special property of forming fiber-to-fiber bonds by hydrogen in exchange as water is expelled. Processing is accomplished to break up raw material, soften the fiber and increase water absorption capacity and contact area. In making paper by hand, judicious skill and control in heating the fibers produces a quality paper. Pulping coloration, decolorization, molding, and screening follow. Pressing and sizing forms the final product.

The article discusses why paper making is a capital intensive industry. The author encourages the establishment of small scale, hand made paper factories, especially in rural and urban fringe communities.

historical, paper making, fiber, small scale industry

461 Upaa, R.
Lund, T. L.
Rao, K. N.

Is Re-Manufacturing Adaptable to Nigeria? Center for Policy Alternatives. Massachusetts Institute of Technology. Cambridge, Massachusetts, U.S.A. 1980. 22 pages. References.

This document is one of a series of working papers on opportunities for remanufacturing in developing countries. The potential development, constraints and possible disadvantages of remanufacturing are described.

There are three basic stages of remanufacturing: disassembly to make a pool of interchangeable parts, cleaning and refinishing, and reassembly to produce new or equivalent goods.

Remanufacturing could be of particular importance to Nigeria where 45 percent to 53 percent of the total value of imports are durable goods. Increasing the availability of products through local remanufacturing would have a positive impact on Nigeria's trade balance, and might lower costs by 40-80 percent.

Nigeria places high priority on developing industry, yet remanufacturing is not on the government's priority list. A review reveals that there are few sales and service facilities for imported equipment, and an unreliable power system causes malfunction and damage to industrial plants and domestic durable products. Favorable development characteristics include the sufficient availability of older units to support an industry,

and the high price of new equipment. Unfavorable characteristics include concentration of units for remanufacturing in large towns. insufficient skills training, and resistance to buying used products.

A list of candidate products for remanufacturing in Nigeria is suggested. Full feasibility studies are required. A strategy for implementing an industry includes: technical schools and vocational training centers; incentives for small independent firms; incentives for original equipment manufacturers to locate in Nigeria; and, product acceptance and marketing programs.

Skills transfer, low capital requirements and simpler technology design are factors which lead the authors to conclude that remanufacturing is appropriate for rural and urban development to benefit people in LDCs.

Background notes on manufacturing in Nigeria.

remanufacturing, economic development, small scale industry, Nigeria

462 Veal, F. J.
Whalley, L.
Renewable Resources as Chemical Feedstocks. Conservation and Recycling. Pergamon Press. U.K. Volume 4, Number 1. Pages 47-57. 1978. References.

The prospects for converting cellulosic materials into a wide range of chemical products and the economic implications for product substitution industries are reviewed in this article. At this time hydrolysis is not economically feasible. However, the actual methods, technology and research results are presented in the event that the economic situation may change.

fiber, cellulose conversion, hydrolysis, chemicals, product substitution

463 Vogler, J.
Glassmaking as in the Time of Yore. Materials Reclamation Weekly. A. Cohen & Company, Ltd. London, U.K. October 18, 1980. Pages 24-26.

This article diacusses case studies of small scale glassmaking enterprises now operating in Thailand, India, Egypt, Mexico, and Peru. For example, in Bangkok, Thailand, a 100 percent foreign cullet fed (broken glass) glass factory employs 50 people and products 4 metric tons per day. Material is collected by an informal recycling structure at bottling plants, and from merchants and residences. It is washed, stored in bunkers, and fed by elevators directly to a furnace. Most of the product is flint (clear) glass. The furnace is poorly constructed of thin brick and fire clay with corrugated iron to deflect 400°F heat from workers.

Three hour retention is followed by 5 hour cooling. Products are "seedy" but entirely acceptable. Small handmade operations elsewhere use potatoes or an arsenic oxide/sodium nitrate mixture to reduce impurities.

small scale industry, glass, cullet, glass manufacturing, job creation, product development, Thailand, India, Egypt, Mexico, Peru

464 Webber, H.
Meyer, M.

Utilization of Compost in Agriculture--Experiences in Europe and Especially in the Middle East. Proceedings of International Symposium "The Practical Implication of the Re-use of Solid Waste." 11-12 November, 1981. London, U.K. Pages 47-56. Institution of Civil Engineers, London, U.K. 1981. References.

This paper examines the significance of compost quality as a grading indicator. As a direct result of growing uneasiness about modern farming methods and use of chemical fertilizers in agriculture, compost marketing is encouraged. While compost products derived from agricultural and animal wastes can be routinely marketed, refuse-derived compost is as yet unmarketable. As a disposal method, it can have benefit.

A qualitative determination of biological processes is difficult. Normally, it is done by examining the individual parameters. The usual methods for testing the compost are as follows: determination of the degree of decomposition of the organic matter (the rate of decomposition per unit time indicates the digestion intensity); self heating test in the Dewar tank (because digestion is an exothermic process; a matured compost will no longer heat itself); determination of oxygen (O_2) demand by a given quantity of compost over a defined period of time. (The further the aerobic digestion process has advanced, the lower the O_2 demand); testing of nitrogen (N) present in its main form. (In fresh compost, N is mainly present in the form of ammonia, subsequently, it is first compounded as bacteria protein, and with subsequent digestion is increasingly mineralized, i.e. transformed into nitrates). The best indication of the degree of maturity of a compost is obtained from plant growing test with, for example, the sensitive and fast growing cress being ideal for the purpose.

Utilization and procurement specifications are ultimate determinants as to compost product fineness. Two criteria established by compost plant operators are (1) compost grade on the basis of moisture, impurities, ignition loss and application (see table below); and (2) the degree of maturity, i.e., pretreated, fresh, semi-matured, and matured compost.

CRITERIA FOR COMPOST PRODUCTS

Compost Grade	Mature Only	Mature Only	Fresh or Mature
moisture (% max.)	35	40	45
impurities (% max.)	1 per 4 mm mesh	1 per 65 mm mesh	1.5 per 8 mm mesh
ignition loss (% min.)	10	10	10
application	potting earth, sports lawns, piglet earth, etc.	horticulture	agri-, vini-, silvi-, fruiticulture, etc.

An important aspect in considering compost is the natural resource condition. In arid regions, compost fortified with fertilizer and equivalent water compared to a fertilizer only control, resulted in yield increases of 44 percent (cabbage), 53 percent (onions), 173 percent (tomatoes), and 270 percent (lettuce).

Calculations based on experimental results showed that processed town refuse without additives had fertilizer equivalencies of 43 percent for ammonium sulphate, 83 percent for thomas phosphate and 57 percent for manure peat.

composting, organics, Europe, Middle East, testing methods

465 Western, A. W.

Small Scale Papermaking.

Intermediate Technology Industrial Services (Intermediate Technology Development Group). Railway Terraces, Rugby, U.K. 1979. 217 pages. References.

This report evaluates small scale paper making in India. It presents information on a variety of mills which produce from one to thirty tons per day and use up to 100 percent secondary fiber. The history of paper, the influence of small economies of scale, current Indian state of the art, materials, processes and implications for developing countries are presented.

The economy of scale research concluded that the system must be appropriate for demand and consumption; supplies must be available; and that increasing plant size will create increased demands for capital and higher transportation costs and higher energy costs. Smaller mills are more flexible, require less training and skill to operate, cost less and provide greater employment per d llar. In a comparison between a 300-ton per day plant and 10 small mills of 30 tons per day, the smaller mills cost

50 percent less, generated twice as much employment and spread pollution on a wider basis, avoiding the problem of dealing with great amounts of pollution at one location.

paper, fiber, paper making, small scale industry, economics, India, cost analysis

466 Weygers, A. G.
The Recycling, Use, and Repair of Tools. Van Nostrand Reinhold Company. New York, U.S.A. 1978. 112 pages. Glossary.

This book is a practical guide to the repair and reuse of tools for small scale agricultural and cottage industries. How to salvage and recondition tools from scrapyards and landfills is discussed. Repairs are shown for simple and complex tools with the use of annotated illustrations. Lathes, chisels, and punches, bearings, grinding and drilling tools, and trip hammers are among the tools shown to be repairable.

tools, machine shop, reuse, ferrous scrap, nonferrous scrap, recycling, wood

467 Zaichik, T. S. R.
Automatic Bottle Washing Machine. Pishchevaya Promishlenost. Moscow, U.S.S.R. 1978. 129 pages. References.

This document describes bottle washing on the intermediate scale. Profusely illustrated, its five chapters describe: (1) machine design including design components, electrical schematics, resource requirements and parts; (2) installation, adjustment and service, including shakedown, bottle breakage reduction, and trouble shooting; (3) operation, including technology and processing, detergents, hardness reduction in water, and detergent recycling; (4) maintenance; and (5) safety, including requirements, operation and maintenance, hazards and hazard mitigation.

bottle washing, health and safety, Union of Soviet Socialist Republics, small scale industry

Economic Aspects

501
Iron and Steel Scrap: Its Significance and Influence on Further Developments in the Iron and Steel Industries. United Nations. Economic and Social Council. Economic Commission for Europe. Steel Committee. ECE/STEEL/24. 17 August, 1978. 223 pages. References.

This document reviews the role of ferrous scrap in iron and ferrous steel production. Ferrous scrap is becoming increasingly important because world production is derived almost equally from virgin ore conversion and remelting of scrap. Further, industrial dependence on scrap may increase because of changes in production techniques: abandonment of the Thomas process, marked decline of the open hearth process, increased utilization of electric furnaces, and increasing use of oxygen converters and rolling mill capacities.

The study outlines several considerations as a result including: sources, preparation, classification of scrap, economic and technical factors affecting the pig iron/scrap material balances, and the ultimate impacts on scrap market futures and investment prospects. The study also documents worldwide the flow of ferrous scrap.

ferrous scrap, recycling, economics

502 Butlin, J. A.
Economics and Recycling. Journal of Resources Policy. PC Science and Technology Press. Surrey, U.K. June, 1977. Pages 87-95. References.

This article documents the change from rural small scale agricultural based economies to urban, large scale industrial based ones, and discusses the economics of recycling. The opportunity cost of using the assimilative capacity of the environment to absorb the increasing generated waste has risen well above zero (the equivalent of treating the supply of environmental services as infinite); and is reflected in increasing costs and pollution.

Over time, the waste absorptive capacity of the globe has decreased in response to population and economic growth, and the technical changes which have altered the quantity and characteristics of generated waste. Past policies of raw material extraction have served their purpose and it is necessary to curb the current over-extraction of raw materials in order to utilize and invest in reclamation and recycling technology.

Aggregate collection of domestic waste solely for sanitation purposes poses great difficulty in terms of reallocating fiscal and technical resources away from disposal. Similarly, rapid depletion of exhaustible virgin resources by industry is built into economic practice by government economic policies.

Government regulatory measures are needed to reinforce socially desirable goals. Law enforcement is enhanced by positive social attitudes toward waste avoidance. Both can enhance economic conditions and reclamation practices, and make recycling viable. This will reduce local costs and improve the balance of payments.

The discussion applies to the United Kingdom but its approach can be applied to all industrialized and industrializing economies considering government intervention in materials flow and development.

economics, recycling, environmental management, United Kingdom

503 Claggett, R. E.
The Soda Ash Picture. The Glass Industry. New York, New York, U.S.A. December, 1981. Pages 28-31. Author: Texasgulf Chemicals Company, Raleigh, North Carolina, U.S.A.

This document examines developments affecting the production, consumption and distribution of soda ash in glass manufacturing. The United States may soon become the major world supplier of this key ingredient. Production from vast trona deposits in southwestern Wyoming has discouraged synthetic soda ash manufacturers from upgrading aging plants and covering the escalating costs of energy and strict environmental requirements. Syracuse, New York and Searles Lake, California are two other production areas using direct carbonation of natural brine with a combined capacity in 1981 of 2.3 million short tons/year.

In addition to the glass industry, soda ash is used in pulp and paper manufacture, soap and detergent manufacture, water treatment and air pollution control. United States export of soda ash is three times the level of domestic consumption, with Western Hemisphere countries (Mexico, Canada, Venezuela) leading consumers. Rail transportation is the predominant means of distributing natural soda ash to domestic markets and port terminals on the Gulf and west coasts for export. Manufacturers tend to maintain a 7 to 10 day supply to insure contained operation during bad weather which could disrupt delivery schedules. World production data are shown in table below.

WORLD SODA ASH PRODUCTION--1980

	1,000 short tons
United States	8,277
Western Hemisphere	1,233
Western Europe	7,534
Africa	257
Asia/Oceania	3,058
USSR/Eastern Europe	11,783
Total	32,142

soda ash, glass manufacturing, international trade

504 Grace, R.
Turner, R. K.
Walter, J.

Secondary Materials and International Trade. Journal of Environmental Economics and Management. Academic Press. London, U.K. Volume 5, Number 2, 1978. Pages 172-186. References.

This article discusses how international trade affects recycling. The sources of demand and supply that act as volume, composition and directional trade determinants are outlined. International material flows for secondary materials are described. A model case study on waste paper is focused on observed differences in various national recycling rates. The role of trade in reconciling those differences is presented.

The authors profile secondary materials flows as a complex mechanism. They describe home scrap as not important to international trade due to in-house use at individual plants. Present and post consumer scrap can play a role, though. Recovery is a function of concentration of supply, revenue over costs of collection, transport and separation, and alternative cost of disposal.

The price of virgin material acts as upper limit on secondary material price, although in some technical aspects, certain production processes demand selected proportions of scrap.

International secondary materials trade could prove to be a dynamic force in redistributing variations between countries of supply and demand.

institutions, secondary materials recovery, international trade, recycling

505 Henstock, M. E.

The Conflict Between First Cost and Recyclability in the Design of Manufactured Goods. Resources Policy. IPC Business Press. U.K. Volume 4, Number 3. September, 1978. Pages 160-165. References.

This article reviews the importance of product design to recyclability and the problems inherent in that strategy.

Many manufactured items cannot be recycled because they contain materials that contaminate each other. Moreover, modern construction methods often preclude simple and easy separation into usable pieces. Consideration, at the design stage, of subsequent recycling could facilitate a suitable choice of material and a mode of construction to aid reclamation. Such redesign is, however, likely to involve increased cost.

In addition, there are basic problems to overcome which can become institutional barriers if a clear cut strategy is not developed to eliminate or mitigate their effects. These include: prejudices by manufacturers and consumers towards secondary materials with which they may not have experience; the fact that certain grades of secondary materials lack the flexibility of high purity primary feed and are suitable for a restricted range of uses; and that only a fraction of the total demand for a material can normally be supplied from secondary sources. These factors encourage manufacturers to draw their principal supplies from primary producers except when there is a shortage of primary materials, or when prices in the secondary market are especially favorable.

The specification barrier is intensified due to product or material contamination inherent in product design. Contamination can be avoided by hand segregation, use of applications and products suited to mixed or contaminated characters, and design changes to reduce mixtures.

The nature of goods manufactured by modern, mass-production methods is such that self-contamination is, in many cases, almost unavoidable. Although redesign to avoid such problems is in principle possible, cost increases are very likely given the fact that most industries already manufacture at minimum cost and have substantial investment in existing manufacturing technology.

The author believes that consumers will not voluntarily pay a premium to ensure recyclability of products. Manufacturers are thus not likely to place themselves at a cost disadvantage relative to their competitors.

Design for recyclability will, it is generally conceded, come only as a result of legislation, as have other developments such as seat belts and catalytic converters for exhaust fumes.

source reduction, recycling, remanufacturing, product design

506 Lindberg, R. A.
Akagi, R. H.

Reclamation, 1975-2000: A Key to Economic Survival. Marketing/Management Services Division, National Credit Office, Dun and Bradstreet, Inc., New York, New York, U.S.A. November, 1974. 314 pages. References.

This document is an extensive economic forecast of the waste reclamation industry. The underlying concept is that the world economy must retreat from the current mode of linear production; that is, converting raw materials to waste through a single product state. "The human condition can no longer be maintained without a swift rise in the recycling of what we now call waste... Indeed, the very survival of the world culture may well depend on a quick and complete shift to the practice of returning materials at the end of product life to nature or to production. The world economy has loops to close. How quickly they are closed and how many materials they are closed for is likely to more profoundly influence the future of human history than any single event of the past."

The report deals with waste entering the public domain only. It is not concerned with waste recoverable in industrial plants. For example, mine tailings returned to mining pits are not included in the site, nor are any of the chemicals recovered in plant from process effluents. The demarcation is not precise, however. Agricultural wastes, which for the most part are not moved far from where they are generated, are dealt with in the study. Secondly, the study addresses itself to waste in any form that constitutes a major contributor to the waste total, not solid waste only. Heat and water, among other significant forms of waste, are also surveyed.

A key to the solution to the waste problem is to make parallel the growth in the supply of materials from reclaimed sources with the growth in population and consumption.

The authors are confident in the technologies for recovering energy from municipal solid waste, converting agricultural waste to proteins and fertilizers, as well as for manufacturing products from secondary materials. Among the assumptions made for forecasting economic trends are the following:

- The cost of energy will rise 300-400 percent above 1973 prices by the year 2000;

- Estimated costs of key fuels by the year 2000 are (1970 dollars):

Coal	-	$32 to $50 Standard Ton
Natural Gas	-	.85 to 1.10 Cubic foot
Oil	-	.15 to 20 Barrel
Uranium	-	9.25 to 14.80 Pound

Strategies for individual, government and international actions are discussed. The authors feel that comprehensive development of reclamation in the world economy can stabilize inflationary cycles.

"If mankind is to retain its present standard of living, it will be forced to reduce its rates of consumption of natural resources and production of goods and services must be stabilized at benign levels. This will require reclamation of consumed materials on an increasing scale. Should that, in turn, be accomplished, then waste conversion will likely have become the world's largest industry outside of agriculture by the turn of the century."

"The waste conversion industry cannot grow to a substantial size without deliberate, coordinated intervention. Despite the examples of the energy crisis and the shortages of raw materials such as fiber, manufacturers generally continue to look toward virgin materials to supply them with the ingredients for the products they create and have not yet seen the need to significantly alter their wasteful production, product design, and marketing strategies. Consumers still persist in their preference for newly used materials and their conspicuously consumptive ways. Govern-

ments, for the most part, remain indifferent to the potential disasters building up globally and in their own countries.

economics, agriculture, waste recovery, resource recovery

507 Page, T.
Conservation and Economic Efficiency. Johns Hopkins University Press. Baltimore, Maryland, U.S.A. 1977. 266 pages. References.

This author believes that the continued erosion of natural resource bases, which has been heightened in recent years, poses a great challenge to the world to provide and maintain a reasonable standard of living, and preserve a livable environment. Material wellbeing and the quality of the natural environment are integrally related; and policies established to address one will ultimately have an effect on the other. Complex interrelationships confuse and concern society, but the uneven distribution of resources, wealth and income, between developed and developing nations has far wider implications. The level of consumption of virgin materials, the reuse and recycling of materials, the durability of products, the substitution of materials and technological change, and the types and quantities of waste generated and subsequently discharged have profound impact on the level of per capita material wealth worldwide.

The book discusses: economic efficiencies (factors affecting virgin and secondary materials competition), long-term distributional implications (are we active enough to keep the resource base solvent for future generations), and then reconciles these diverse functions by combining the best properties of both.

The author concludes that resource depletion and waste generation are not market failures but distribution problems subject to equivalent macroeconomic policies used to treat unemployment and income distribution.

recycling, product durability, economics, conservation, government policy

508 Quimby, T. H. E.
Recycling, the Alternative to Disposal: A Case Study of the Potential for Increased Recycling of Newspapers and Corrugated Containers in the Washington Metropolitan Area. Johns Hopkins University Press. Baltimore, Maryland, U.S.A. 1975. 133 pages. References.

This book considers recycling as an economic phenomenon. In recent years, the focus on energy prices put more attention on mixed solid waste as a fuel substitute in thermal power plants or as a fuel in plants specifically designed to "recover energy" from mixed solid waste. This document points out celluloae fiber in the paper residuals of municipal solid waste will become more valuable in the future as a raw material for production of paper products than as a fuel. The relative values can change as a result of many factors including changing technology, tax policies, costs of other inputs, and costs of disposal. The generation and disposal of residuals is discussed in relation to cost alternatives with specific attention to the flow of paper from production to consumption.

The application of a least cost system analysis to solid wastes handling and disposal for the Washington, D.C., U.S.A. metropolitan area reveals the feasibility of source separation recycling of newspaper and corrugated containers. Recovery of the materials is feasible assuming relatively low 1971 prices and assuming no technological innovation or market alteration from the existing solid waste management system. A 10 percent diversion of total solid waste would result in a reduction in total annual disposal costs of 6 percent.

newsprint, cardboard, paper, United States, recycling

509 Streefland, P.
The Absorptive Capacity of the Urban Tertiary Sector in Third World Countries. Development and Change. Sage Publications. London, U.K. Volume 8. 1977. Pages 293-305. References.

This paper discusses aspects of the informal sector in absorbing workers. The author argues that the elasticity of the informal sector is regulated and restricted by a number of factors: urban environment; government policy; and capitalist penetration. Obaervations are based on literature and data collected during research among Christian Sweepers (CPS), who live in the Slaughterhouse area in old Karachi.

Due to their origins as "untouchables," and their particular work, the CPS are looked upon as second class citizens and are treated accordingly by the Moslem majority. The social position of the CPS is shown clearly in the comparative isolation in which they live, in restrictions on their behavior, and in the subordinate character of their interaction with the Moslems. Their economic position is quite strong, however, and they cannot generally be classified as the poorest economic strata. The work of the sweepers is indispensable. The result is a monopolistic situation that enables them to earn incomes often quite high compared to other unskilled laborers.

Some sweepers are employed by municipalities to perform several kinds of duties including waste scavengers, servants, kudimen (who attend the sewage system) and latrine cleaners. Scavengers work in squads and teams assigned to specific areas. Work is done by both men and women. Both municipal and private sweeper-work is hierarchically organized.

Mukyaddams or agents supervise the squads and teams, control recruitment, assignment, overall work situation (absenteeism, off-time) and job security.

Among themselves, sweepers speak of "ownership of a street" based on rules that have validity within their community. The "owner" may do work for himself or hire employees or grant share-contracts. It is easy to discern a class structure based on access to the main area of production, the street. "Big owners" who control several streets play an important role in Slaughterhouse politics.

The absorptive capacity of the urban informal sector is potentially limited by four broad groups of factors. One is reduced access to the control of resources either through ethnic, caste, and religious group monopolies. As a result, new migrants may face severe entry barriers. Within such groups, brokers (like the sweepers' mukyaddam) take on regulatory importance.

Another factor is the changing character of the urban environment such as new sewage and solid waste technologies which could eliminate the need for sweeper attendants and restrict physical access to salvagable materials.

A third factor is government policy restricting informal sector activities. One policy is the introduction of a licensing system. Another is a policy of shifting tertiary sectors population from one area to another.

Finally, the penetration of labor saving devices, irrepairable products, mechanical equipment and money lending by banks in competitive areas can have a potentially enormous negative influence on absorptive capacity. Capitalist penetration, as it is described by the author, may ignore the inherent flexibilities of native systems in the rush to maximize profit and ensure stable conditions necessary to long-term investment.

The absorptive capacity of additional labor in an even, relatively stagnant, urban economy is large, but limited. While the informal sector is elastic, various factors impact negatively. Investigation of impacts remains a priority area.

economics, informal sector, job creation, developing country, scavengers, waste management, Southeast Asia

510 Voorhoeve, J. J. C.
Organic Fertilizers: Problems and Potential for Developing Countries. World Bank Fertilizer Study, Background Paper No. 4. January, 1974. IFC-Office of the Economic Advisor. 15 pages. References.

This document considers the use of organics as fertilizer supplements. Organic fertilizers are generally associated with luxury concerns of organic agricultures. The subject is most important, though, when considered in face of high fertilizer costs, energy crises, foreign exchange limitations and soil erosion. These factors would appear to justify further attention.

It is estimated that total LDC production of soil nutrients (N, P, and K) from organic residues and wastes is approximately 7.8 times larger than consumption of commercial fertilizers by LDCs in 1971. Raw output of N, P, and K from just urban compost is estimated at 0.60, 0.48, and 0.71 million metric tons annually in LDCs.

An important source to defray costs of organic fertilizers is methane gas production. Methane gas can be produced from organic waste

without significantly reducing the fertilizer value of residue. Such a process for urban composts and sludges is now technically feasible.

Compost material and other organic fertilizers are considered more valuable as soil conditioners than as fertilizers (inhibit soil erosion and water runoff). In particular, erosion is a serious problem in LDCs because of minimal soil depth and silting of irrigation ditches. A comparison of topsoil loss with degree of compost added showed that applying 400 tons per hectare saved almoat 95 percent of soil from eroding.

Problems for increased use of organic fertilizers include farmer resistance, lack of financial support, public health problems, economic return and lack of research in LDCs.

composting, soil amendment, soil conservation, India, Netherlands, Mexico, developing countries

511
Office Paper Recovery: Role of Sheltered Workshop. Environment Conservation Directorate of Canada. Ottawa, Canada. 1980. 53 pages. References.

This document describes the use of handicapped people to perform cost effective labor intensive sorting operations. Three Ortawa sheltered workshops participated by setting up facilities to sort waste paper on their premises. The handicapped assisted in collecting the waste paper from two designated government buildings. They sorted a variety of wastepaper materials and helped to deliver the sorted paper to a local dealer.

Based on the handling of 26,244 kilograms of various paper grades, the study concluded that (1) the project was economically viable based on market prices and sorting times required per paper grade: (2) material satisfied dealer specificaitons; and (3) workers enjoyed the sorting tasks. It was recommended that the federal government expand employment opportunities of this type.

waste paper recovery, government policy, job creation, office building recycling

512
Plant Requirements to Set Up and Operate a Gray Iron Jobbing Foundry. Report prepared for the Agency for International Development. Prepared by George H. Andrews Engineering Associates, Inc. Washington, D.C., U.S.A. (PO-292-824) May, 1959. 29 pages. References.

This manual discusses how to establish a small gray iron foundry for a general or jobbing business, which producs about 8 tons per day of finished castings. This level is deemed to be an economical unit employing 30-35 workers. Manufacturing operations are described and illustrated, as is production equipment.

As a jobber, the foundry would get its business from many customers, ordering castings of varied shape and quantity. It is assumed that customers would supply their own patterns. The majority of castings would be in the 1/2 to 50 lbs. size, but sizes up to one ton are possible.

Details are provided for plant layout and site, building, power, water, fuel, supplies and materials. Direct and indirect labor needs, manufacturing costs, capital costs and sales revenues are projected, while budget operations, engineering, training, and safety are considered. Marketing, economic, legal and financial factor questions are raised, and a financial plan presented.

ferrous scrap, appropriate technology, small scale industry, developing country

513
Plant Requirements to Set Up and Operate a Small Steel Smelting Plant. Prepared by George H. Andrews Engineering Associates, Inc. Washington, D.C., for International Cooperation Administration. Washington, D.C., U.S.A. NTIS #PB 292 869. September, 1957. 26 pages. References.

This report describes a small steel melting plant which manufactures ingots or billets from scrap metal where demand exists and where such an operation would be feasible. For purposes of simplification only ingots were discussed. The market for this plant is a small steel rolling mill to produce bars, and merchant shops.

General assumptions, product specifications, operations, layout, resource requirements and an economic analysis are provided.

ferrous scrap, small scale industry

514
Recycling Poultry Waste as Feed. U.S. Department of Agriculture. Washington, D.C., U.S.A. Series #254. March, 1974. 46 pages. References.

The recycling of dried layer waste (DLW) as feed for livestock and poultry is examined in considerable detail. The cost of pollution abatement associated with alternative poultry waste management systems is also analyzed.

The cost of producing one ton of DLW is $25, $30, and $46 for flock sizes of 80,000, 50,000, and 20,000 respectively. Using available drying systems, farm processing and feeding of DLW does not appear to be economically feasible for the family sized (10,000 layer) operation. However, processing and feeding of DLW may be feasible for larger operations, which attained the highest net returns when DLW was fed as 12.5 percent of the ration.

Cost analysis of the alternative methods of waste abatement show land disposal and anaerobic lagoon treatment to be the least expensive. Mechanical drying, aerobic lagoon treatment, oxidation ditch treatment, and combined anaerobic-aerobic lagoon treatment fall within the intermediate cost range. Composting and incineration are the most expensive.

animal feed, cost analysis, waste recovery

515
Report on Compost Studies at the Pingtung Experimental Plant Organic Wastes Section. Taiwan Institute of Environmental Sanitation. Taipei, Taiwan, China. December, 1959. 39 pages.

This report documents an experimental composting plant constructed in Taiwan, China, in the 1950s to demonstrate feasibility of producing and marketing compost commercially. Technical and economic aspects are presented.

A one year trial was technically successful with 10 tons of organics processed each working day into 6 tons of marketable product. Of the 1,400 tons produced for sale, 400 tons were sold to government agencies and the rest to farmers at $NT40/ton, or US$1.10/ton. The facility operated at a slight loss (20 percent of the total operating cost), which was recoverable if compost price was increased slightly. Conclusions were favorable and resulted in construction of a 25 ton per day facility.

composting; economics; marketing; processing; organics; Taiwan, China

516
Small Brass Foundry. Report prepared for the International Cooperation Administration Office of Industrial Resources Technical Inquiry Service, by George H. Andrews Engineering Associates, Inc. Washington, D.C., U.S.A. (IR-26072-PR) October, 1960. 21 pages. References.

This report provides a general review of factors considered in deciding to establish a small brass foundry. All capital and operational costs are based on U.S. prices and conditions. Adjustments for local conditions must be made. It is assumed that power, water, and transportation are available and that the plant operates eight hours a day, five days a week, 50 weeks a year. Equipment and manufacturing operations are described and pictured.

Copper, aluminum, and nonferrous alloy casting may be substituted for brass production according to the report. The products for brass castings are building hardware such as hinges, hasps and locks. The plant is designed to produce 1,000 pounds of casting in eight hours.

Detail is provided for direct materials and supplies required, plant sites and layout, building specifications, power, water, and fuel needs; tools, equipment, furniture, and fixtures; and direct and indirect labor. Additional financial details include manufacturing overhead and cost, financing, fixed assets, working capital, capital requirements, and

sales revenues. Basic paperwork needed for operations, training, safety, and other work factors are discussed. Institutional factors such as marketing elements, laws, and regulations are also discussed briefly.

appropriate technology, developing country, foundries, nonferrous scrap, recycling

517
Study of Raw Material Costs for a Proposed Strawbased Pulping Mill in the Vicinity of Mobridge, South Dakota. Economic Development Administration. U.S. Department of Commerce. Washington, D.C., U.S.A. 1970. 40 pages.

This document shows that the cost to supply adequate straw and waste paper for a proposed mill in Mobridge would be at a competitve disadvantage to wood based and paper based pulp mills now operating in the midwestern United States and Mexico. Transportation costs of the finished product to market could also work against the mill's success. A study was initiated to see if economic advantage could be gained by using straw, an abundant and relatively little used resource, as a principal ingredient. A 250 ton per day capacity plant producing nine point corrugated medium would require 67,000 tons of straw annually and 60,000 tons of waste paper. Employment would be created for the community.

cost analysis, paper, pulp, waste paper recovery

518 Birkbeck, C.
Self-Employed Proletarians in an Informal Factory: The Case of Cali's Garbage Dump. Journal of World Development. Volume 6, Numbers 9/10. Pages 1173-1185. Pergamon Press. 1978. U.K. References.

This document presents data on the organization of work among the scavengers on the garbage dump in the city of Cali, Colombia. Garbage pickers can be characterized as working for the large industrial buyers of recovered materials, but as not being employed by them. Hence, their activities are organized, but in a special way. There is a certain degree of regularity in the hours and forms of work, and a certain amount of management by the dealers in waste materials. However, the majority of the garbage pickers work independently and are paid on a piece work basis. While this encourages competition, conflict between pickers is surprisingly rare. Garbage pickers have organized themselves to defend their right to work, but for a number of reasons are unlikely to press for improvements in their working conditions.

The author notes that low income workers in the "informal sectors" of LDCs have often been characterized as unskilled, unorganized, unproductive and unenterprising.

At the Cali garbage dump, "factory" workers are nicknamed "vultures" by the rest of Cali's populace--an allusion to the supposedly dirty and undignified work involved in sorting through trash. Yet these workers have very close ties that link garbage picking to industry.

Pickers are part of a recycling network which feed industries in Cali and other cities in Columbia and Ecuador. They are casual laborers, yet retain an illusion of being self employed. They "control" their work hours and habits (although everyone usually must pick during periods when trucks come in), but do not have any say in the critical factor of material prices.

Despite the apparent lack of written rules of overseers, there are internal and external factors which help organize and regulate the work. The above mentioned work hours issue and other informal machanisms have developed that contain the competitive tendencies that inevitably develop under the work conditions and temper the limited autonomy of the scavengers (e.g., no sick leave, social security, etc.).

Formerly the scale and nature of picking was oriented to poor people searching for cutlery, jewelry and clothing which were sold to second hand stores or brought into the low income household. Garbage picking in Cali has now evolved into a materials supply industry.

The work is both productive and efficient, although it is an efficiency based on poverty standards. The price paid to the pickers for waste paper, for example, is but one third the cost of pulp for the paper industry. The income of pickers averages only 80 pesos per day.

Birkbeck describes social conditions of the Cali dump workers. The age distribution of workers ranges from the very young to the old. Nearly half of the children have not gone to school beyond the second year. The length of time spent as a picker varies widely. As a refugee occupation, scavenging supports people with no other opportunities for earning a living. The author notes that many people prefer to "work for themselves" and profess no desire to leave, perhaps because they ard on good terms with a particular truck driver and have continued access to better materials.

The workers have developed skills and entrepreneur's instincts such as getting waste from factories and making new products, excavating for materials buried long ago, elevating themselves into buyers of materials, or starting partnerships and exclusive arrangements with factories.

Despite the conditions and nature of the"piece" work, conflict is very rare and the dump has witnessed impressive attempts at solidarity. There is almost a total lack of robbery of materials. The rest of the city continues to perceive the dump as an evil and lawless place.

Spontaneaous organizations of workers successfully warded off threats to close the dump to pickers by the city. Pickers' organization efforts have been concerned with the right to work, not the conditions of work. The only attempt to improve the terms of work originated outside the dump in the early 1960s by a local charitable foundation. A cooperative of 70 pickers was set up but closed down in the face of external pressure from the large companies and internal adminstrative problems.

Garbage pickers are not unskilled, or unproductive. Still these characterstics of entrepreneurship and innovation have not led, nor are

they likely to lead, to long-term solutions of their livelihood.

Specific policies which could help the workers include forming a permanent organization which would bargain with dealers for better prices and greater access to materials and the introduction of simple machinea to improve productivity.

Columbia, community enterprises, economics, informal sector, recycling, scavengers, secondary materials recovery

519 Bromley, R.
Organization, Regulation and Exploitation in the So-Called "Urban Informal Sector": The Street Traders of Cali, Columbia. World Development. Volume 6, Number 9. Pages 1161-1171. Pergamon Press, U.K. References.

Cali's street traders are analyzed in relation to prevailng ideas of the "informal sector," and are shown to have various forms of economic and political organizations. Most traders operate illegally, but official regulation results in containment rather than eradication. Over half the traders are "self employed." The remainder fall into one or both of two increasingly important and potentially exploitative working relationships with larger enterprises: "commission selling" and "dependant working." Official intervention to promote selected small enterprises is highly problematic because of: negative official and elite attitudes; "illegality" of most enterprises; factional self interest of vendors' trade unions; "leakage" of benefits to large enterprises using commission sellers and/or dependent workers; and upward mobility by a favored minority accompanied by worsening conditions for the majority.

Analysis of the informal sector in LDC economies remains an ill defined research frontier between employment research and social pathology. Informal sector principal characteristics--transience, mobility, the lack of an establishment, and the poverty and relatively low education of most of its participants--make research very difficult.

Street traders appear as an important and typical occupation of the informal sector of urban labor markets.

A wide variety of social research methods, inclulding questionnaire survays, participant and nonparticipant observers, semistructured interviews with officials, leaders and informants, tape recorded life histories, street counts, and newspaper and documentary research were conducted.

The view of the urban informal sector which has been recently institutionalized by the Interantional Labor Office emphasizes the growth potential of small, labor intensive business (Employment, Incomes and Equality, A Strategy for Increasing Productive Employment in Kenya. 1972, Geneva) and recommends major official assistance to this sector.

The small businesses are considered to be independent, unorganized, almost unregulated, little related to authorities or to big

business and essentially honest, legitimate and entrepreneurial. Government and industry practices both support operations in the informal sector and limit the development of entrepreneurial instincts and capacities.

Colombia, informal sector, job creation, labor

520

Croke, K.
Baum, J.
Rosenberg, R.

Municipal Financing of Integrated Community Energy Systems. Argonne National Laboratory. Argonne, Illinois, U.S.A. 1977. 52 pages. Authors at University of Illinois, Chicago, Illinois, U.S.A. References.

The authors document the effects of increased energy costs on the availability of community services. This has created a need for communities to seek new methods of ensuring adequate energy at reasonbly stable prices. One method is the integrated community energy system, which consists of district heating and cooling central heat pumps, solar and coal powered networks, cogeneration and resource recovery.

Advantages and disadvantages of six financing options are examined. These are: municipal general obligation bonds, corporate bonding with guarantees, tax exempt industrial revenue bonds, special revenue bonds, state and federal financial support and formation of municipal joint action agencies.

Resource recovery case studies focus on financing, including amount of financing, facility ownership, repayment schedules, methods of managing revenues, selection of outside consultants, scheduling projects and monitoring projects.

economics, energy recovery, resource recovery

521

Dalzell, H. W.
Gray, K. R.
Biddlestone, A. J.

Composting in Tropical Agriculture. International Institute of Biological Husbandry, Ipswich, U.K. 1981. 36 pages. References.

This report presents economic and technical information on composting processes. Composting is simple in technique, applicable to many agricultural situations in developing countries, and can be conducted with manual labor.

The report is to be used as a manual. It is based on 10 years online experience of the Indian Agricultural Center, Medak and British Compost Studies Group, University of Birmingham. Suitable materials for composting are described. Composting can be done totally by manual labor. However, a high degree of mechanization can be introduced in municipalities

where this would be more appropriate. At present, many of the wastes available in tropical countries are poorly utilized.

An economic analysis of composting concludes that developing countries can make use of lower labor costs and lower transportation costs (animal power). Modification of the farming system to produce and use organic materials can make composting more efficient. It is assumed that three man days are required for the production and spreading of one ton of compost, based on recent experience and equipment outlined in this manual. In considering the supply of the three major nutrients, potash, nitrogen and potassium, compost may compete economically on a nutrient basis with the more concentrated fertilizers. There is little risk if simple procedures are followed. Composting can be carried out at any time and hence can be fitted into slack periods in the farming year.

agriculture, composting, economics

522 Doedens, H.
Feasibility of the Separating Collection (Source Separation) of Recyclable Components in Refuse. Proceedings of the International Recycling Congress (Recycling Berlin '79). Berlin, Federal Republic of Germany. Pages 823-827. E. Freitag--Verlag für Umveltechnik. 1979. References.

This article covers (1) separate collection of glass at depots; (2) separate collection for single fraction material (fiber--which costs 50 percent more than it returns through revenue); (3) comparison of intergrated and separate collection systems; and (4) recommendations for cities to follow in implementing recovery or collection systems.

A key conclusion concerns the development of recycling. The author finds factors which limit separate collection are not as much as the participation rate of citizens, but more the limited uses for waste derived materials.

The author recommends separate collection only in areas of good markets. Integrated collection makes payback and compensation of savings in diverted disposal costs much easier.

collection, economics, resource recovery, secondary materials recovery, separate collection, solid waste management

523 Flintoff, F.
Solid Wastes Management in Cairo and Alexandra and at Sites and SErvices and Upgrading Projects. Report to Egyptian Arab Republic, and the International Bank for Reconstruction and Development. Essex, .K. December, 1977. 85 pages. References.

This document reports on waste managemet policy in Egypt. Two important factors were identified which must preceed technology transfer and investment: (1) government agencies have to decide on the future role of private collection and disposal contractors and the future form of the

management structure for municipally operated services; and (2) small scale pilot projects should be initiated to determine the applicability and cost of the technology being introduced. This will aid the detailed planning necessary for further capital investment.

In Cairo it was found that although solid wastes were being collected from less than half the population, management attention was focussed on disposal, often involving a high level of mechanization. The state of the Egyptian economy is likely to indicate labor intensive solutions and intermediate technologies. This could be best handled by developing the current infrastructure.

A general review of waste management in Cairo is also presented. Costs methods and current efficiencies are discussed. Factors affecting decisions and policy issues are described, especially with respect to the Zabbaleen or Coptic Christian sect who scavenge and recycle a large amount of urban wastes. Typically, Zarrabs were reported to collect material related to income level as shown below:

Type of Area	Estimated Percent of Waste Collected	Estimated Percent Wastes Thrown onto Streets for Collection by Municipal Services
Wealthy	100	-
Middle Class	95	5
Lower Middle Class	50	50
Low Income Class	-	100

Among technologies considered for upgrading the system, composting receives high priority. Intermediate technology composting plants are preferable to high technology ones. Economic analysis indicated costs of intermediate composting technology are about the same as for high standard landfills and should be studied further.

collection, composting, economics, Egypt, informal sector, institutions, scavengers, solid waste disposal, solid waste management, Zabbaleen

524 LeSieur, H. A.
Appropriate Technology and Scaling Considerations for Developing Nations. Central American University. Jose Simeon Canas (UCA). El Salvador. For U.S. Agency for International Development. Washington, D.C., U.S.A. 45 pages. References.

This paper presents the viewpoint that most chemical engineers have been educated to believe that large scale and high technology are essential for a project's viability. Most do not consider that large economy of scale is not always appropriate, feasible or even posaible in developing countries. High technology may be appropriate in certain cases, but more often intermediate or low technology is better, and fits with available resources. Four examples are cited, all based on salvaging

waste or underutilized raw materials for manufacturing food products or fertilizers: (1) banana waste, (2) the discharged sludge from palm oil processing (agricultural residues), (3) pryolytic conversion of rice hulls, logging, coconut, oil palm wastes, rubber and bagasse, and (4) mini fertilizer generator for farm use (the manufacture of modest amounts of fertilizer based on small, low quality phosphate and limestone deposits using alternate energy sources).

Emphasis is placed on "appropriate technology" as a process, rather than a prescribed formula for development. This process involves economic, environmental, and social priorities.

appropriate technology, economics, organics

525 Maung, M.
Composting of Municipal Wastes: UNIDO Experience. Presented at the Food and Agricultural Organization (FAO) of the United Nations Swedish International Development Agency Workshop on the Use of Organic Materials as Fertilizers in Asia. Held in Bangkok, Thailand. 26 October-5 November, 1976. Food and Agriculture Organization. Rome, Italy. 1978. Pages 287-300. References.

This document presents the important findings of municipal waste composting projects of the United Nations' Industrial Development Organization in Bujumbura, Burundi (1969), Conakry, Guinea (1970), Aden, People's Democratic Republic of Yemen (1971), Rabat, and Casablanca, Morocco (1974 and 1975). Technical and managerial problems are considered for sanitary disposal and reclamation of wastes for use in agriculture. A cost benefit analysis is included.

Plant size must be based on the availability and composition of raw materials. In developing countries an annual increase in refuse production is estimated at four percent (2.5 percent population growth and 1.5 percent increase in per capita refuse production, commensurate with the 1.2-1.75 percent per capita increase in GNP which is projected up to 1995). Characteristics of Moroccan municipal waste are contrasted with those of European cities. Differences include LDC to European country ratios as follows: moisture content (66-72 percent to 40 percent), density (.35-.45 to .18-.25), daily per capita production (.45 kilograms to .9 kilograms), and compostable material (range 70-85 percent to 35-55 percent).

For developing countries, the high bulk and low unit value of materials affects plant and choice of process. Quality of product often bears no relation to the degree of sophistication of machinery and process. The author notes that simplicity of plant design and composting process can reduce capital costs, increase labor intensiveness and encourage local production, repair and maintenance of equipment. Adapting composting to deal with the high amounts of organic matter and humidity is stressed.

One finding was that many municipalities are only prepared to pay a competitive price to the compost plant for accepting waste. However, no uniform method for economic evaluation of compost plants has been developed to establish this fee. One possible method is to consider economics on the basis of nutrient content equivalency. For Aden the minimum estimated value in terms of its contribution of nitrogen (1.12 percent) and phosphates (1.02 percent) to the soil is US$21 to US$47 per ton (1975 prices) for equivalent inorganic fertilizers. The value of potassium and other benefits such as improvements in soil structure and water retention, alleviation of the waste disposal problem, foreign exchange savings through reduction of fertilizer imports, creation of employment, etc., are not yet integrated. Another method is to estimate crop yield increments obtained through application of compost. Experience indicates that technical problems such as process adaptation, repair and maintenance of equipment are relatively minor and easily solved problems. There should be provisions for capital and working budgets, selection of plant site, organization of refuse collection to serve the plant, marketing , distribution and application of compost, and division of responsiblity between municipal and agricultural authorities in order to effectively start up a plant.

Composting plants using urban wastes can offer good opportunities for private investors, but assurances from municipal governments as to steady availablity and delivery of waste are critical to assure plant viability.

Urban refuse compost can meet only a small part of a country's fertilizer needs, but may be the only readily available fertilizer. National programs, as in Morocco, possibly with UNIDO's assistance, are recommended.

composting, economics, fertilizers, Middle East, Morocco, organics

526 Moser, C.
The Dual Economy and Marginality Debate and the Contribution of Micro Analysis: Market Sellers in Bogota. Journal of Development and Change. Sage Publications, Ltd., London, U.K. Volume 8. 1977. Pages 465-489. References.

This document discusses the dual economy debate with attention to macro and micro analyses. Itr presents insight into the informal scavenging sector, although it does not directly address that sextor. This document reports on the market system of the Plaza San Juan, Bogota, controlled and administered by the Empressa Distrital de Servicios Publicos, a public corporation responsible for public works such as slaughterhouses, garbage collection, cemeteries, street cleaning and public markets.

Sellers of scavenged waste operate with skill and intiative to build a secure economic base. Yet once recruited into this type of economic activity, few sellers can expand sufficiently beyond a low income level. There is only a minimal level of upward mobility, which empirically contradicts theoretical assumptions made by traditional economic

development analysts. Also, work histories and social characteristics show that aellers consititute a remoarkably stable work force, and are not a floating population of misfits and social outcasta, unwilling to or unable to cope with city life.

These characteristics are common not to a small marginal group in a peripheral urban profession, but are representative of a considerable portion of the working force. Selling, together with other service work, forms the basis of the urban informal sector--poorly paid labor producing the only means of livelihood for a considerable portion of the urban population. A principle constraint on increasing profits is the level of capital resources available to individuals. Sex and age are other critical factors in determining limits of upward mobility. Mobility, when it does occur, is in the direction of lucrative areas of self employment (show ownership and wholesale markets and not unskilled waste employment). Low income sellers provide a valuable service distributing cheap produce to sectors of the population at a cost which would double if the cost of their labor was taken into account. This occupation provides a minimal means of livelihood for those unable to enter the productive labor force. Thus, rather than a marginal occupation, this is an integral part of the urban economy, functioning within the constraints of an unequal exchange relationship with wholesale suppliers and consumers.

Micro studies highlight the internal dynamics of developing country urban economies. The long-term survival of "refugee occupations" is supportive rather than detrimental to the continuance of the existing urban economy.

economics, informal sector, scavengers

527 Neamatalla, M.
Solid Waste Management Practices in Cairo. Report No. 5. Solid Waste Component. First Egypt Urban Development Project. Prepared by Environmental Quality International for Governate of Cairo/Joint Housing Projects Committee/International Development Association. March, 1981. 120 pages.

This study (1) documents current refuse management activities in Cairo, including waste collection and utilization; (2) reports on several phases of a study of waste management practices including waste analysis, collection vehicles, economics of the informal recycling sector (Zabbaleen); and (3) presents data on several pilot projects.

The study focussed on the Zabbaleen waste collection and utilization practices. The ultimate objective of the study was to enable the Zabbaleen to upgrade their settlement at Manshiet Nasser. Ideas to increase productivity and provide better sanitation of waste collection and sorting procedures are detailed.

Economic analysis of the Zabbaleen system as of May 1980 showed that a net revenue of 2.8 LE/daily ton is available to the Zabbaleen. This

value was later used to estimate a "utility fee" to be paid for Zabbaleen service to poor sections of the city.

Egypt, municipal solid waste, scavengers, solid waste management, waste recovery, Zabbaleen

528

Rebong, J.
Elena, A.
Mangiang, M.

The Economics of Scavenging: Obscurity within the Recycling Business. Prisma. Institute for Economic and Social Research, Education and Information. Jakarta, Indonesia. December, 1978. Pages 36-45.

This report describes life among the "undesirables." Daily work activities, the actual pricing of materials, the intermediary agent system, and relations among the scavengers are detailed. In particular, it portrays the infrastructure as the "law of the jungle," interwoven with crime, violence and uncertainty.

The subject of scavengers is one that is repeated in many countries. In Jakarta, scavengers are considered problems and the city officials have attempted to forcibly move them outside the city. This has not been successful. In spite of their lack of status, "undesirables" can earn a fair amount of money and gain access to some segments of society. The authors conclude that scavengers are victims of urbanization who nonetheless contribute to urban economic life.

scavengers, Indonesia, informal sector

529

Rosenberry, P.
Knutson, R.
Harmon, L.

Predicting the Effects of Soil Depletion from Erosion. Journal of Soil and Water Conservation. Volume 35, Number 3. May-June, 1980. Pages 131-134. Soil Conservation Society of America. References.

Research was conducted at the Iowa Agricultural Experiment Station to predict the effects of current levels of soil erosion until 2020, and also to examine six methods of reducing erosion to tolerable levels. A tolerable level of erosion is that amount of land lost during the year which will not affect the sustainable yield.

Using four different crops and test plots, the Station computed the amount of fuel, fertilizer, pesticide and terraces needed to sustain yield. Soil depletion for each of the individual plots was estimated. To measure soil degrading, different soil phases (1-3) were used, with 3 being the worst. Reductions in yields, increases in the amounts of fuel, fertilizer, and pesticides to maintain sustained growth, were definitely tied to the lack of conservation. Almost 50 percent fuel use increase was estimated for a soil that degraded from phase 1 to 3.

For all soils an average cost of US$100 per acre was noted, although the authors caution that the figure may be conservative and could range upwards of several hundred dollars.

agriculture, fertilizers, organics, conservation

530 Shin, K. C.
Possibilities and Limitations of Refuse Treatment for Gaining Raw Materials and Energy. Proceedings of the International Recycling Congress (Recycling Berlin '79). Berlin, Federal Republic of Germany. Pages 26-31. E. Freitag--Verlag für Umwelttechnik. 1979.

Refuse is not "useless" but a valuable, potential source of raw material as described in this paper. Recycling is limited due to environmental and economic factors. In order to create more recycling, legislative and economic measures must be implemented. Legislation involves subsidizing beneficial operations and enacting laws against processes which harm the environment. There needs to be an organized economic system to stabilize markets for "waste products."

Refuse utilization by separation (separate collection, separation with machines in central plants), is discussed. Also discussed are uses for recovered paper, glass, steel, nonferrous metal, and plastics; utilization by conversion (landfill gas, sewer sludge composting, pyrolysis). Factors which limit utilization are examined.

institutional barriers to recycling, organics, waste utilization

531 Shuval, H. I.
Economics of Composting Municipal Refuse. Journal of the Sanitary Engineering Division. Pages 47-56. American Society of Civil Engineers. July, 1962. New York, New York, U.S.A. References.

A preliminary study was made of the economic aspects of two composting plants in Israel operated on a concession basis. One is an existing 50 ton per day enclosed DANO biostabilizer plant in Haifa producing 15,000 cubic meters (m^3) of compost per year or one m^3 of compost for every ton of raw refuse handled. The other is a 500 ton per day plant. It grinds refuse in two stages with equipment manufactured by Dorr-Oliver of Holland and composting is done using open windrows turned every three or four days for a period of approximately three weeks. This plant in Tel Aviv expects to produce approximately 100,000 m^3 of compost per year or 0.7 m^3 of compost for every ton of refuse handled. Cost comparison to incineration is discussed.

The economic analyses point out that compost plants in the U.S. may be in the same cost range as refuse disposal by incinerators. If a market for compost could be developed, even at a nominal price, it could become an economic solution for waste disposal in many American cities.

composting, cost analysis, economic analysis, incineration, Israel

532 Smith, T. E.
Conn, W. D.
Product Durability--Economics and Related Aspects: An Annotated Bibliography. School of Architecture and Urban Planning. University of California. Los Angeles, California, U.S.A. 1976. 28 pages.

This document is an annotated bibliography on product durability. There are 32 citations which are divided into historical aspects, theoretical discussions of durabilty and market structure, theoretical discussions of the demand for durable goods, empirical studies, and policy decisions.

product durability, source reduction

533 Thomas, C.
The Paper Chain: A Report on the Production, Use, Reclamation, and Recycling of Paper in the United Kingdom. Earth Resources Research, Ltd. 40 James Street, London, U.K. 1977. 100 pages. References.

This book presents an overview of papermaking. Topics covered include manufacturing raw material, basic processes, mechanical and chemical pulping, bleaching, sheet making, and sheet properties; environmental impact (raw materials use, water and energy consumption, pollution); economics (world supply, the EEC, Britain); and consumption (quality considerations and consumer attitudes are discussed for a variety of products).

Most waste paper is now used for packaging products. For other paper products only limited amounts of high grade waste paper are used. U.S. experience indicates that using lower grade waste paper is technically feasible to produce writing paper and tissues.

Increased use of lower grade mixed papers requires removal of contaminants and lowering unnecessary quality standards.

Appendix II examines potential production capabilities of smaller paper mills. Recycling of waste paper could be improved by a wider distribution of smaller paper mills.

Intermediate level of production is defined as a range of five tons per day (tpd) to 70 tpd. Less than five tpd is characterized as community workshop technology with very low capital costs. Machinery is available in West Germany, India, and Britain, in the intermediate range. For example, Tomlinson, Ltd. has a less than one tpd capacity pulp packaging unit at a capital cost of 35-40,000 pounds.

Smaller mills generally employ more people per ton of paper produced and the capital cost per workplace is generally lower.

intermediate processing, paper making, resource recovery, United Kingdom, waste paper recovery

534 Tichenor, R.
Economics of a Small Rural Town Recycling System: Implications of a Case Study. University of New Hampshire. Durham, New Hampshire, U.S.A. 1976. 42 pages. References.

This report examines an intermediate processing plant in a rural town. It provides input requirements and corresponding cost and capacity limitations; waste characteristics data; and household attitudes toward separation at source.

For the plant, estimated input requirements are smallest (and thus, processing cost per ton is the lowest and capacity the largest) for glass, followed by newspaper, tincan, mixed paper, cardboard, and aluminum. Bases on average daily weight, over 50 percent of the source separated waste from sample households is made up of the above categories of recycled materials. Less than one fifth of the survey sample were opposed to the source separations system, and less than one fourth reported problems with source separation. More than half of the respondents reporting problems were still in favor of the system.

Data are presented for energy and labor costs, hourly requirements and combined requirements per ton. The results show that (1) glass, newspaper, steel cans, and mixed paper achieved greater efficiency than cardboard and aluminum based on labor wage rates and on comparative weights; (2) glass and newspaper were more efficient to recover based on tonnages to electrical rates; and (3) annual production was consistent with both of the above indices.

community enterprises, cost analysis, household wastes, recycling, resource recovery, solid waste disposal, source separation, waste composition

535 Ullman, B.
Recycling in Israel: The Potential of Secondary Resources. Israel Institute of Technology. Technion City, Haifa, Israel. October, 1980. 30 pages. PN 06/111/80. References.

This working paper is part of a project series on "Mineral Resources in Israel's Future." Israel does not have the natural resources to sustain its level of economic growth without some dependence on foreign supplies.

Secondary resources are described as an essential material base for many necessary consumer items. Nearly nine million tons of wastes were generated in the country during 1980 with mineral, industrial, domestic and agricultural sectors responsible for 45 percent, 10 percent, 13 percent and 32 percent, respectively. Only 19 percent of the industrial wastes are recovered and the other sectors show lower rates.

The author presents data that show US$130 million may be saved in imports by recycling. He believes that recycling will not happen on its own and advocates specific measures for promotion: (1) removing discriminating tax measures; (2) stringently enforcing environmental

regulations; (3) encouraging product design for recyclability and durability; (4) giving research allowances to industry involved in recycling; (5) using pollution charges; (6) creating trade forums and material exchangea; (7) developing source separation programs; and (8) providing incentives for returnable goods.

glass, Israel, metals, paper, recycling, secondary materials recovery

Environmental Aspects

601 Anderson, A.
Influence of Organic Fertilizers On the Solubility and Availability to Plants of Heavy Metals in Soils, Department of Soil Sciences. Grundfor Battring. Uppsala, Sweden. Volume 27, Number 4. Swedish University of Agricultural Sciences. 1975/6.
Pages 159-164. References.

This document reports results of laboratory and field experiments of organic fertilizers on the solubility and availability to plants of heavy metals including: manganese, zinc, copper, nickel, cobalt, chromium, lead, aluminum, mercury. Test plots received applications of compost derived from solid waste and anaerobically digested sewage sludge and manure.

It was found that organic fertilizers added to soils under certain circumstances may reduce the solubility and uptake in plants of heavy metals, despite high levels of them. Effects seem to be particularly strong in the case of lead.

Whether the solubility and availability to plants are reduced or not depends on chemical conditions affected by the organic matter of the fertilizer and the total quantity of heavy metals.

composting, heavy metal uptake, fertilizers, testing methods

602
Regional Symposium on Solid Wastes, Santo. Boletin de la Oficina Sanitaria Panamericana. Volume LXXIV, Number 5, Mayo 1978. Pan American Health Organization. Washington, D.C., U.S.A. 1978. 250 pages. References.

This document is composed of papers discussing trends in solid waste management written by technical experts and planners. Socioeconomic and environmental health implications of solid waste management are discussed. Technical descriptions of collection, processing, incineration, and sanitary landfill are discussed on a country and city basis, including case studies. Composting, materials recovery, and energy recovery projects are described. Institutional development and planning case studies are presented.

Inadequate solid waste management practices are viewed as a growing threat to public health and the environment. Adequately funded collection and disposal services are a necessary development. Pretreatment processes (compaction, shredding, incineration, transfer) are described as suitable in combination with energy recovery and final disposal in sanitary landfills. Energy recovery technologies (waterwall incineration, coal substitute, pyrolysis and small modular incinerations) could only be used after careful study because of them are still being developed. Composting processes also must be carefully studied for success and failure rates.

Commercial recycling of source separated industrial wastes is encouraged. Scavenging is discouraged due to its "high social cost."

Institutional development of local service agencies/corporations must be a major focus of any planning effort. A program to establish a national policy for solid waste management is presented.

solid waste management, Latin America, developing country

603
Sanitary Effects of Urban Garbage and Night Soil Composting in China
Compost Science. Rodale Press, Emaus, Pennsylvania, U.S.A. Volume 18, Number 2. March/April, 1977. Pages 22-24. (Reprinted from Chinese Medical Journal. Volume 1. Number 6, November, 1975. Pages 407-412).

This report was prepared by the Department of Environmental Health, Institute of Health, Chinese Academy of Medical Sciences, Beijing,People's Republic of China on the sanitary effects of co-composting.

Co-composting is a simple method of garbage and night soil disposal. To evaluate its sanitary effects, one has to choose certain biological factors characteristic of composting. On the basis of practical observations and relevant data in the literature, the pile temperature, fly breeding and destruction of ascaris eggs were taken as important criteria for this evaluation, because they are representative and specific and require relatively simple testing procedures.

Two types of compost piles were used in the experiment. One compost pile consisted of 70 to 80 percent garbage and 20 to 30 percent night soil (by weight) with adequate mixing. The mixture was heaped in piles about 4 meters wide at the base, 2 meters wide at the top, 1.5 meters high and about 4 meters long. After piling about 30 cm high, sets of bamboo poles were laid horizontally on the pile in this form at every 1.5 to 2 meters, each set connected at the center with a bamboo pole held vertically. On completion, the pile was sealed with a 2 to 3 cm thick coat of 40 percent soil and 50 percent ash mixed with water. The day after piling, the bamboo poles were withdrawn, leaving flues for ventilation. The other type of compost pile had no flues. Eight piles were observed, the 4th, 5th and 8th with ventilation flues and the other five without.

High temperature fermentation was obtained when moisture content of the garbage and night soil mixture reached about 40 percent. Generally, compost pile temperature rose to over 50°C after 5 to 7 days. Also, the moisture content decreased gradually. On the 105th day, it dropped to 20 to 23 percent in all 8 compost piles. The directly available nitrogen content and total nitrogen content of the 8 piles during composting showed slight nitrogen loss in all piles during composting, probably because the piles were small and unsheltered.

The coliform bacilli and ascaris eggs were effectively destroyed. Maggots died rapidly at 50°C. Pupae survived and newly emerged adult flies were seen around ventilation holes. Biolytic heat produced in a given part of the compost pile often drove maggots to regions of lower temperature to complete their life cycle.

The newborn flies, too feeble to fly at once, were easily destroyed with a small amount of insecticide. Buried test samples containing bacillus dysenteriae and bacillus typhi were destroyed in laboratory conditions (uniform temperature in compost pile).

Garbage from the city of Beijing contained more ash and less organic material exhibiting low moisture content and nutrients needed by microorganisms. Since highly effective composting calls for proper control of moisture content, pH, ventilation and C/N ratio, it was necessary to add night soil to it. Experiments showed that a 40 percent moisture content gave better results with predominantly ashy garbage.

A pile temperature of 50-55°C is sufficient to accelerate putrefaction and ensure hygienic safety. Experience provide pile temperature can rise above 50°C, when basic composting conditions are strictly observed.

Activities centered on the extermination of pests and eradiction of disease. Sanitary control and proper disposal of garbage and night soil were among the basic measures taken to eliminate fly breeding.

organics, composting, health and safety, China

604
Selected Bibliographies and State of the Art Review for Environmental Health. International Health Planning Reference Series 2, PB80-18342. United States Department of Health, Education and Welfare. Prepared by Plog, Inc. for U.S. AID. Washington, D.C., U.S.A. (no date). 182 pages.

This combined literature review and annotated bibliography deals with environmental factors in health planning for developing countries. This is the second volume in a series of works known collectively as the International Health Planning Reference Series.

The Series was produced by the Office of International Health as requested by the Agency for International Development to provide AID advisors and national health officials in developing countries with critically needed references for incorporating health planning into national plans for economic development.

The literature in the field of environmental health is massive. For the purposes of this literature review and bibliography, the research focused primarily on the areas of clean water supply, wastewater and excreta disposal, treatment of disposal of solid wastes, and pest control including the use of pesticides.

Additionally, environmental health hazards were included on occupational health, radiation, air quality, food, sanitation, and housing issues relating to environmental health.

health and safety, solid waste

605
Solid Wastes Disposal and Control. World Health Organization. Technical Report Series No. 484. Geneva, Switzerland. 1971. 31 pages. References.

Solid waste management is detailed in this report. The effects of solid wastes on health and welfare are evaluated and special problems associated with developing and industrialized countries are discussed. The present knowledge and technology regarding sources, handling, treatment, recycling and final disposal are described. The planning and operation of solid waste systems are detailed and guidelines for policy and action are provided.

solid waste management, health and safety, developing country, waste composition

606 Bundi, U.
Wasmer, H. R.
Recycling: Fundamentals and Concepts. Journal of the International Solid Wastes and Public Cleansing Association. Number 18. International Solid Wastes and Public Cleansing Association. April, 1976. Zurich, Switzerland. References.

The theme of this paper is that the conversion of refuse to energy is just one aspect of recycling. Decisions concerning energy recovery can be reached only if viewed within a broad framework of overall energy and recycling problems. Correlations need to be drawn between the use of resources, environmental protection, economic, political and legal issues. Both national and international levels should be considered.

Recycling always raises the question of energy, eve if energy is not generated directly. A strategy is presented on how to reach a decision between recycling for energy or the material value.

In the past, recycling was mostly industrial and based on financial considerations to lower production costs, and as a source of additional income. Today it is seen as a way to reduce waste in the environment and preserve dwindling resources for everyone.

A comparison between initial mining and recycling is presented. Three major point are considered: conservation of natural resources, reduction of energy consumption, and reduction of wastes.

An international framework for decision-making is presented. The report concludes that the effects of recycling are limited (1) when resources are used in a dissipative way; (2) when it is conducted where clearly uneconomical or impractical; and (3) where due to growing consumption, only a fraction of the resources needed can be covered by recycling and benefits gained through recycling will soon be offset.

energy recovery, recycling, conservation, government policy

607 Conner, M. A.

Modern Technology for Recovering Energy and Materials from Urban Wastes--Its Applicability in Developing Countries. Conservation and Recycling. Pergamon Press. U.K. Volume 2. 1978. Pages 85-93.

This report examines three countries, Kenya, India and South Africa, which vary in population density, degree of urbanization, extent of industrialization and availability of domestic energy resources. For each of these countries the energy supply, use and distribution patterns, as well as current refuse disposal practices are described in this article. The future use of various refuse treatment methods, particularly those involving energy recovery, is examined for each country. The conclusions are generalized and applied to developing countries as a group.

The most important conclusion reached is that the use of high technology for refuse processing in developing countries is limited. Three of the main reasons for this are:

(1) High technology has been developed in areas where labor is generally expensive or organized and capital readily available. They are usually not appropriate for developing countries where capital is usually scarce, unemployment often severe and labor is cheap.

(2) In developing countries, a project's priority as far as the allocation of capital is concerned usually depends on the extent to which it contributes to providing employment, developing resources and infrastructure, and providing basic facilities needed by the usually rapidly growing population. Under such circumstances applications to introduce high technology methods of refuse disposal are likely to be assigned very low priorities.

(3) In most developing countries cheap disposal of refuse on the land is still possible. There is therefore little incentive for local authorities to invest in capital intensive and largely unproven technology.

Two methods of refuse disposal (other than disposal on the land) are presented. These are composting and the use of refuse as a supplementary fuel. Both of these methods are relevant to problems in developing countries: composting provides a soil conditioner which can improve soils deficient in organic matter, and use of refuse as a supplementary fuel can reduce pressure on resource development.

composting, government policy, technology, fuel, energy recovery, India, Kenya, South Africa

608 Gerretsen, F. C.

On the Content and Value of Trace Elements in Urban Refuse Compost.

International Research Group on Refuse Disposal Information Bulletins. References. Sekretariat: Eidg. Anstalt Für Wasserversdrugung Abwasserinigung und Gewasserschultz, Zurich, Switzerland.

Although urban refuse compost is valued chiefly for its organic content, it also contains numerous trace elements indispensable to normal plant growth. A single application of compost may be valuable for many years, especially in soils which are deificient in one or more trace elements or possessing them in a form not assimilated by plants. This report discusses numerous investigations in which trace elements are shown to be components of most enzymes. Manganese, for example, was found to be a component part of at least 13 enzymes.

Boron has special significance for those parts of the plant in which intensive cell division occurs. Plants become stunted or even die due to lack of boron.

Higher plants do not grow without copper. Wheat, oats, peas, and beets and carrots require more copper than such plants as buckwheat and serradella (European legume). The so-called "cultivation disease" (Urbarmachung-Skrankheit) is found not only on newly cultivated heath soils but also in older humus-rich sandy soils in which copper is in insoluble combination, and difficult to assimilate. It has been shown repeatedly in the Netherlands that a copper deficiency can occur without characteristic external evidence accompanying it. In such cases, application of copper sulfate or urban refuse compost results in considerable yield increases.

Molybdenum is important in the plants' assimilation of nitrogen from nitrates and in the enzymatic reduction to ammonia as the first step in protein formation. The element is also important in the fixation of atmospheric nitrogen into bacterial proteins by means of Azotobacter and other N-fixing bacteria.

Zinc is a vital trace element for legumes, grains, onions, and other plants, particularly horticultural plants. The great success with the use of one application of VAM compost in a few orchards in Wijster, resulting in 15% greater yields than plots receiving only fertilization, is likewise ascribed in part to the addition of trace elements. Deficiency in Zinc has been found to inhibit the formation of auxins (growth substances) and of chlorophyll. The term "zinc-yellow disease" (zinkgelbsucht) has been coined.

The Laboratory for Microbiology, State University, Groningen, Netherlands, determines various trace elements, in soils and plant materials, by the aspergillus method. Chemical analysis, using complex ions, is a new method which determines trace elements. The mycelial weight of the fungus aspergillus is closely related to the amount of magnesium, zinc, molybdenum, iron, and manganese contained in the nutrient medium. Spore color varies from black through brown to yellow and white, according to the copper content. Trace elements in minute amounts can be detected by

this method. Limits of analysis are 0.2 to 15 millionths of a gram for copper, and about 0.001 millionths of a gram for molybdenum.

Amounts of trace elements always vary in summer and winter compost. Results show that compost is not only a valuable organic manure but can supply plants with inorganic nutrients, resulting in increased yields in many cases, even where no trace element deficiency is suspected. A single application of compost provides a whole series of trace elements without risking yield reductions by trace element deficiencies.

agriculture, composting, crop yields, land application, municiple waste, nutrients, soil amendment

609 Giordano, P. M.
Movtvedt, J. J.
Mays, D. A.

Effect of Municipal Wastes on Crop Yields and Uptake of Heavy Metals. Journal of Environmental Quality. Volume 4, Number 3. Pages 394-399. American Society of Agronomy, Crop Science Society of Wisconsin, U.S.A. References.

In test situations, application of rather high rates of garbage compost and sewage sludge resulted in increased yields of corn although tissue concentrations of several heavy metals were higher. In contrast, sludge treated plots had lower yields of beans, possibly due to the greater sensitivity of beans to zinc. Although no differences in zinc solubility were detected, plant concentrations of zinc were always higher with sludge.

Repeated applications of waste products no not necessarily result in proportionally higher concentrations of heavy metals in plants, but the potential for toxicity still exists.

heavy metals uptake, health and safety, organics, composting

610 Gunn, T. L.

The Energy Optimal Use of Waste Paper. Energy Research Group. University of Illinois at Urbana-Champaign. Urbana, Illinois, U.S.A. 1978. 177 pages. References.

Mixed and other grades of waste paper can be burned as a fuel or used as a feedstock material. This document discusses burning and recycling waste paper to minimize energy use. The study was done in the U.S. in 1974.

Five cases are analyzed as to how the energy in wood and paper are treated. In one case, both wood and paper are assumed to have an energy value. In another, neither wood nor paper is assumed to have an energy value. In the other three cases, paper, but not wood, is assumed to have energy value which is utilized differently in each case. It was found in all cases that as much highgrade de-inking waste paper as can be

collected should be recycled. How much of the other grades of waste paper could be recycled depends on which of the various energy accounting schemes is used. The greatest energy savings are accomplished when both wood and waste paper are acknowledged to have an energy value. The greatest energy savings attainable in any case would be 30 percent of the energy actually used by the system. A government tax credit program was advocated to stimulate new capacity to produce recycled paper and to encourage the use of wood as a fuel.

Energy savings data are detailed in 11 technical appendices including paper recycling, energy conservation, paper manufacturing, energy recovery.

waste paper recovery, energy savings

611 Hannon, B. M.
System Energy and Recycling: A Study of the Beverage Industry. Center for Advanced Computation. University of Illinois at Urbana-Champaign. Urbana, Illinois, U.S.A. 1973. 39 pages. References.

An energy analysis was done on containers for soft drinks, beer and milk. The study shows that the energy required to deliver a unit of beverage to the consumer is about three times more in throwaway glass containers than in returnable bottles or bimetallic cans. The energy cost of recycling glass (collecting, separating and remelting) is less than the comparable cost of mining materials for new bottles. All aluminum cans are about 38 percent more energy intensive than bimetallic cans. Retail costs are about 30 percent more for soft drink throwaways, and slightly higher if litter and solid waste disposal costs are added.

If the beverage industry were converted entirely to returnable containers, the 1970 container system energy, which accounts for 0.48 percent of the total U.S. energy demand, would be reduced by about 40 percent. The energy savings in 1970 would have supplied the total electrical needs for Washington, D.C. Pittsburgh, San Francisco and Boston for about 5 months, or about 30 billion kilowatt hours.

An economic and labor study in the beverage industry was made for Illinois. If returnables were totally used, consumers would save 75 million dollars and a net increase of 1,500 jobs would result. Although jobs would be lost in the steel and container industries, more lower paid jobs would be created at the wholesale and retail levels.

Extrapolating data to the national level implies an increase of 130,000 jobs and an increase in consumer savings of US$1.4 billion. If the savings developed and the consumer spent the savings on average personal consumption, then about half of the estimated energy savings or 15 billion kilowatt hours would be realized.

To complete this study, it was necessary to examine the metal, paper, glass and plastics industries in considerable detail. Energy ratios

(energy used in returnables [15 fills] vs. throwaway) were calculated for varying container materials. A summary of the energy calculations derived in this report is presented.

This document provides a quantitative method for analyzing complex industrial-commercial-environmental problems.

energy, returnable containers, job creation, conservation

612 Kinako, P. D. S.
City Refuse Dumps: A Multi-Dimensional Environmental Problem of Nigerian Urban Areas. Journal of Environmental Management. Academic Press, Ltd., London, U.K. Volume 9, Number 3. November, 1979. Pages 205-212. References.

This document is a report on the roadside dumps common in Nigerian cities. Using Port Harcourt as the focus of the study, an environmental survey was conducted which determined that there is an average of 7 refuse dumps per km of road. The situation is described as critical. The dumps are breeding grounds for rats, flies, cockroaches and mosquitoes. In addition, the dumps block gutters and streets, causing serious flooding during the rainy season. Recommendations to improve the solid waste management system include new taxes, establishing transit depots where householders would bring their refuse, and educating the communities to recognize the scope and urgency of the problem.

Nigeria, city refuse dumps, health and safety, pollution, solid waste management, raw refuse factor, transit depots

613 Kurihara, K.
The Use of Industrial and Municipal Wastes as Organic Fertilizer. United Nations/Swedish Industrial Development Organization. Workshop on the Uae of Organic Materials as Fertilizers in Asia, held in Bangkok, Thailand. 26 October-5 November, 1976. Food and Agriculture Organization. Rome, Italy. 1978. 18 pages. References.

This document reports that municipal wastes contain not only essential plant nutrients but toxic substances, including heavy metals and organic compounds. If it is not possible to eliminate these harmful compounds by pretreatment, special attention must be paid to land application rates on food chain rates of application on crops. The three most important criteria concerning municipal wastes are: (1) to ensure an absence of substances that are injurious to the environment; (2) to maintain high content of organic matter and plant nutrients; and (3) to lower content of its undesirable substances. The important consideration that limits the land application rate for sludge is its high nitrogen content. Excessive use might result in fewer crops due to salt injury and ammonia physiological toxicity, as well as the pollution of water by nitrate nitrogen.

More than 30 composting plants were constructed and operated in relatively small cities in Japan in 1963. In recent years, construction has slowed due to a failure to make composting an accepted disposal method for urban wastes. Factors include government policy to increase incineration as the disposal method, marketing (farmers' refusal of product due to unwelcome and dangerous ingredients such as glass, plastic, and metal, and insufficient maturity of product for direct application to crop land), economic aspects (the economic imbalance between production costs and sale prices) and institutional lacks (no education by agricultural researchers and authorities concerning the value of compost).

Only seven plants remain producing 20,000 tons of compost annually, or one percent of the total urban waste generated. Renewed efforts are being initiated by private and government agencies to overcome the problems. The National Institute of Agricultural Science, Tokyo, has begun a study in conjunction with the government to compare the properties of chemical constituents of municipal compost. Preliminary findings of unwelcome substances, including toxic heavy metals, are presented. It is emphasized that in order to use urban wastes as fertilizers their heavy metal content needs to be reduced.

composting, Japan, hazardous wastes, fertilizers, government policy, municipal wastes, nutrients

614 Kusik, C.
Kenahan, C. B.

Energy Use Patterns for Metal Recycling. U.S. Department of the Interior. Bureau of Mines. IC 8781. Washington, D.C., U.S.A. 182 pages. References.

This study, conducted for the United States Department of the Interior, Bureau of Mines, provides data intended to increase the recycling of selected metals. Data were collected on energy requirements to recycle prompt (in plant) industrial and obsolete (post consumer) scrap for nine metal commodities: iron/steel, aluminum, copper, lead, nickel alloys, zinc, titanium, tin and stainless steel. Process routing for recycling was considered beginning with collection through enduse smelting equivalent to a primary metal. Energy balances for scrap reprocessing were detailed.

ferrous/non ferrous recovery

615 Love, P.

Net Energy Savings from Solid Waste Management Options. Solid Waste Management Branch, Environment. Canada. Toronto, Canada. 1976. 26 pages. References.

This document addresses the energy balance of different solid waste management options. Specifically, will energy be saved by using agiven ton of waste paper as an input in production rather than disposing of that ton through energy recovery or landfill?

An essential difference between solid waste management systems lies in their treatment of the large paper component. The study reveals that in the majority of cases considered for southern Ontario, net energy savings are attributed to recycling waste paper rather than using it as a source of energy. The following energy cost factors were considered: paper reclamation, wood harvesting, transportation, disposal, paper production, energy values of wood and paper, net savings from waste paper reuse.

It was also found that recycling waste paper could result in a net decrease in air and water pollution. Energy savings attributable to reducing of solid waste generation at the source are presented. Packaging reduction, for example, could have conserved 40.68 millions BTUs in Canada, had measures been in place in 1975.

Findings are expected to assist solid waste management decision makers to choose options that would have positive effects on macro level natural resource utilization, labor, capital, pollution and product quality issues.

waste paper recovery, energy savings, solid waste management, Canada

616 Nagar, B. R.
Energy Crisis, Food Crisis, Desertification and Organic Recycling. Journal of Scientific and Industrial Research. Volume 40, Number 3, 1981. Pages 147-208. Council of Scientific and Industrial Research. New Delhi, India. Author at School of Environmental Sciences, Jawaharial Nehru University, New Delhi. References.

This article presents organic recycling as a partial solution to the pending energy, food and desertification crises. Estimates based on current consumption, growth and energy price increases indicate that developing countries could be facing a sixfold increase in costs.

World Bank data show the potential for worldwide organic recycling has a total value of $20 billion (U.S.). Citing a documented shortfall in India for replacing organic constituents, the development of organic composting and other programs becomes very important.

A new strategy is presented. It includes selected agricultural program initiatives with increasing use of compost, biomass systems, and sewage sludge. A holistic, cooperative view of the problems and solutions to the world crisis is recommended.

organics, recycling, fertilizers, composting, economics, sludge, environmental management, India

617 Neudecker, Ch.

Toxicological Long-Term Feeding Studies on Carrots Cultivated with Composted Garbage and Sewage Sludge. (Langzeit-Tierfutterungsversuchzur Toxikologischen Prufung Mullklarschlammkompost-Degungter Mohren.) Qualitas Plantarum: Plant Foods for Human Nutrition. Volume 28. Number 2, 1978. Pages 119-134. Dr. W. Junk Publishers. Hague, Netherlands. Exhibits. References.

It has been reported that high levels of toxic heavy metals and carcinogenic substances (3,4-benzpyrene) can be present in composted garbage and sewage sludge. A long-term four generation study using over 900 Sprague-Dawley rats was performed to ascertain whether carrots cultivated with composted garbage and sewage sludge (MKK) induce toxic or carginogenic effects. The annual intake per rat was 3.6-5.0 kg carrots containing approximately 1 ppb benzpyrene. Four groups of rats were fed the following diets: Commercial (Altromin) diet (standard group, A); Altromin and untreated carrots (control group, B); Altromin and MKK-treated carrots(test group, C); Altromin and 10 ug 3,4-benzpyrene administered weekly to females (comparative group D). The level of benzpyrene in diet D was 25-30 times higher than in diets A, B and C. The parameters studied include food intake, body weight gain, fertility, reproductive performance, organ weights, average lifespan and tumor incidence.

After 28 months (F1 generation) and 24 months (f2 generation) no increased carcinogenic or chronic toxic effects were noted in the test animals fed carrots cultivated with composted garbage and sewage sludge in their diets compared to the control groups. No significant increase in tumour incidence was noted in the female rats (group D) fed additional benzpyrene.

health and safety, composting, sludge, heavy metal uptake

618 Ospina, F.

Final Disposal of Solid Waste in Medellin: Another Aspect of Environmental contamination. (Disposicion Final de las Basuras de Medellin: Otro Aspecto de la Contaminacion Ambiental.) Empressas Varias. Medellin, Colombia. 1975. 23 pages. References.

This document is a report to the Mayor of Medellin and the directors of a local municipal sanitation corporation. It outlines a recommended study and project goals to solve pressing problems of solid waste disposal and environmental pollution.

Approaches to solid waste managment are traced from 1955 to 1975. Population growth, economic development, and rising per capita income are correlated to an increasing solid waste problem. Dumping of untreated waste into the Medellin River and at the central city dump have led to air and water pollution and apparently contributed to the spread of disease. About 500 scavengers work at the two dumps recovering materials.Children, women and men comprise 36 percent, 14 percent and 50 percent of the workforce, respectively. Several cooperative organizations have been formed.

A 180 ton per day compost plant was started in the early 1970s but never became operational. The city dump is rapidly reaching capacity limits.

Possible solutions include incineration, composting and sanitary landfill which are not necessarily mutually exclusive. The preferred approach is to integrate the interests of the scavengers into the future solid waste management system. A solution is urgently needed, as the solid waste and contamination problems are directly affecting the quality of life in Medellin and the Aburra Valley.

Colombia, city refuse dumps, solid waste management

619 Sotomayor, I. R.
Solid Waste Compost as a Source of Organic Fertilization Compared with Chemical Fertilizer. (Compost de Basura como Fuente de Fertilizacion Organica Comparado con Fertilizante Quimico.) Agricultura Technica. Pages 152-157. October-December, 1979. Santiago, Chile. Exhibits. References.

Chemical fertilizers have replaced organic materials as the primary source of nutrients owing to improved short-term effects on cultivation. Organic farming enthusiasts have advocated increased use of organic fertilizers which they contend improve soil productivity over the long term. A permanent field experiment was undertaken between 1971 and 1975 at La Platina Experimental Station, close to Santiago, Chile, to evaluate the efficiency of mineral versus organic nutrition in terms of soil productivity.

Several vegetables were intensively cultivated using either urea and superphosphate (the mineral fertilizers) or composted solid waste (the organic fertilizer). Previously cultivated and unfertilized land was used. Two doses of nitrogen (200 and 400 kg/hectare/year) were used from either of the two sources, thus providing four different combinations.

The principal conclusion reached after the first four year cycle was that the anticipated accumulated effect of the organic materials did not manifest itself during the continuous use test. Mineral fertilizer proved a superior fertilizer. All high dose treatments for each fertilizer type yielded better results than low dose ones.

fertilizers, composting, Latin America, solid waste

620 Webber, L. R.
Incorporation of Nonsegregated, Noncomposted Solid Waste and Soil Properties. Journal of Environmental Quality. American Society of Agronomy. Madison, Wisconsin, U.S.A. Volume 7, Number 3. 1978. Pages 397-400. References.

Field experiments were conducted in Guelph, Ontario, to determine the effects of applying as much as 376 metric tons/hectare of raw, non-segregated, shredded solid waste plus 4.6 cm of anaerobically digested

sewage sludge on soil. Physical properties, soil nitrogen and carbon, and the yield of corn were examined.

Shredded waste and sewage sludge were applied to plots in July, 1971 and again in August, 1973. Corn was grown in 1972, 1974, 1975, and 1976 with chemical fertilizer being applied the last two years. Physical determination were made on soil samples collected prior to corn planting in 1976.

Soil carbon and nitrogen and water-stable aggregation increased, while bulk density decreased with increments of solid waste added. Soil moisture, expressed volumetrically (cm^3/cm^3) and retained at pressures of 0.04, 0.33, and 15 bars and available water, was not significantly affected by waste additions. No consistent relationship appeared to exist between kinds and amounts of wastes added and corn grain yields for four harvestings.

solid waste, nutrients, soil amendment, sludge

621 Zobac, J.
Zubr, J.

Agronomical Effectiveness of Commercially Produced Composts. (Agronomicka Ucinnost Prumyslovych Kompostu.) Hostlivna Vyroba. Volume 23, Number 9. Prague, Czechoslovakia. Pages 977-984. 1977. References.

A field experiment was performed on soil at the Brilice Station, Czechoslovakia between 1972-1976 to study the effects of applying composted household wastes and pig slurry to land in separate application or in combination with organomineral fertilizers. Rotated crops (beans, winter wheat, and spring barley) were tested. All variations were found to exert a positive influence upon the agrochemical properties of soil, on gross production, dry matter yield, uptake, and utilization. In separate applications, excellent results were obtained with composted household wastes. Combined organomineral fertilizers and compost showed no statisticaly significant differences from that in the organomineral dressing with compost from household wastes and pig slurry. Increasing application rates of commercial fertilizers above 52 kg for Nitrogen, 48 kg Phosphorus, and 96 kg for Potassium per hectare with organic fertilizers did not show any increased yield. This was probably due to plant limitations on uptake.

fertilizers, Czechoslovakia, composting

Cultural Aspects

701 Keyes, S. J.
Keyes, W. J.

Manila Scavengers: The Struggle for Urban Survival. Institute of Philippine Culture, Poverty Research Series No. 1. Manila University. Quezon City, Philippines. 1974. 51 pages. References.

This atudy is part of the urbanization, poverty and population policy research sponsored by the Asia Foundation in Tokyo, Japan. Scavenging is seen as an occupation symbolic of mass poverty in Manila neighborhoods. Research was oriented to both social-anthropological and economic questions; e.g., the adaptiveness of scavengers to variable market factors in the larger industrial economy; the comparative distribution of the economic benefits to scavengera, middle agents and factories.

Based on experiences in the Barrio Maligamgam, Sampaloo, scavenging reflects the basic human instinct for survival amidst high urban unemployment. Scavengers earn a borderline subsistence. Income is constrained by competition for materials by other small businesses, absence of leverage within the market place, unsympathetic government policies and lack of responsibility on the part of manufacturers to their scavenger/suppliers.

The report focuses on the actual path of scrap paper from scavengers, and through middle agents, to factories. Group and personal profiles, from each level, are based on interviews which highlight generalized findings. Daily work schedules, material values, industrial and labor relations and earnings as well as attitudes and aspirations are documented. Typically, a scavenger wants to move on to other, particulary formal full time occupations.

As long as urban poverty exists, the authors conclude, scavenging should be recognized as an industrial occupation. Changed social policy toward scavengers requires increased consciousness among the economically powerful. Practical and immediate changes include ending government prohibitions and restrictions on scavenger activity. Business policy toward the "scavenging problem" could recognize benefits of feedstock supply and pay for appropriate social costs.

Progressive thinking manufacturers could benefit from broadening their area of responsibility toward scavengers.

scavengers, Philippines, economic analysis, government policy, informal sector

702 Lowe, R. A.
Lee, C. S.

Proposed Composting Strategy. City of Seattle, Washington, U.S.A. Recycling and Resource Recovery Program. January, 1980. References.

After a brief review of the composting process, this document describes and evaluates three types of projects.: backyard, neighborhood and centralized composting.

Backyard composting may be cost effective for the individual homeowner and provide valuable soil enrichers for gardens. If not properly maintained, there can be problems with odors, vermin, and flies.

Neighborhood composting is carried out by residents taking their wastes to a central location and operating the project cooperatively. Advantages include a practical education for individuals and a medium for developing community spirit. Disadvantages include lack of organizing information, individuals dropping out of the program, and more difficulty in maintaining quality control.

Centralized composting involves a four step process of separation of compostables from waste, chipping, composting, and marketing. Advantages include service to citizens who can't compost and the capability to handle a wider range of feedstocks. Disadvantages include increased difficulty in maintaining quality control and the continuing need to haul waste to a central location.

A priority list is developed in the order of home, neighborhood, and central (if feasible) operation for the city of Seattle. Strategies for implementation emphasize public information, education, and market development.

composting, United States, community enterprises

703 Overby, C. M.

Remanufacturability and Repairability of Durable Products; Technology More Appropriate for Both Developed and Developing Countries. Presented at International Symposium of Engineering Technology Appropriate to Underdeveloped Countries. Jose Simeon Conas University. San Salvador. February, 1979. 42 pages. References.

This document explores remanufacturing and repairability for durable goods. Remanufacturability and repairability are important design criteria for both LDCs and DCs now facing resource and environmental constraints. Materials and energy are conserved and waste and pollution are reduced. Remanufacturing and repairing are more labor intensive than equipment manufacturing, and have obvious job creating potential. An overview of contemporary remanufacturing is presented. Questions from both public and private perspectives are presented. There are some indications of increased activity and interest in several countries. Much study and analysis remains to be done, however. If developed countries, driven by

resource and environmental constraints, were to produce durable goods that could be remanufactured and repaired in greater numbers, this technology model could be followed by developing countries.

Products designed with remanufacturability and repairability as critical design criteria can have immediate impacts on local economies. For example, one author has documented the savings in foreign exchange and the labor intensity dimension of using welding technology to repair and remanufacture worn and old parts in paper making machines in Peru. By salvaging and reconditioning these parts, quantity of "new" apare parts required was substantially reduced. The remanufacturing process (building up worn components with weld material) used local labor akills which were enhanced in the process.

The author suggests the need for further assessment in the following specific areas: (1) What is the character and nature of present remanufacturing and repairing activities in LDCs? How does it differ from that in DC?; (2) How do licensing and in general other technology transfer mechanisms relate to remanufacturing and repair in LDCs?; (3) Is it appropriate to conceive of national governmental control of technology transfer in terms of remanufacturability and repairability -- for example, with an instrument such as Mexican Technology Transfer legislation?; and (4) Do, and/or should national and international technical standards-setting organizations have a possible interaction with remanufacturability and repairability in the technology transfer process?

government policy, remanufacturing, economic analysis, product design

Institutional Aspects

801
City of Tacloban, Philippines Situation Report: Managing Energy and Resource Efficient Cities. U.S. Agency for International Development. Washington, D.C., U.S.A. 1980. 277 pages.

As part of the Managing Energy and Resource Efficient Cities Project of U.S. Agency for International Development (AID), a situational analysis was performed on the solid waste sector of Tacloban, Philippines, (population 103,433) reviewing historical data and trends. Topics include expenditure breakdown, waste generation by origin, waste variation, storage, collection and disposal, the role and effect of scavengers, average annual fuel consumption, equipment maintenance. Conservation problems and opportunities were described.

To improve waste collection efficiency, the report recommended dividing service areas into smaller sectors and initiating a preventive maintenance program for vehicles. Health and environmental consciousness could be increased through an effective public education program, coupled with enforcement of existing ordinances against dumping solid waste on streets. Resource recovery of organic waste via composting was suggested as a way to manage 50 percent of the city's waste. City parks, plazas and farms are potential areas for end use. Compilation and analysis of accurate composition data and coordination of private disposal site (possibly through government acquisition of its own dump site) were also recommended. An overall strategy matrix is presented.

waste composition, scavengers, landfill, Philippines, Asia

802
Pre-Test for Managing Energy and Resource Efficient Cities: Preliminary State of the Art Review. U.S. Agency for International Development. Washington, D.C., U.S.A. Prepared by Coopers and Lybrand, Inc. 1981. 180 pages. References.

This state of the art literature review covers several areas essential for managing the resources and energy of cities including land use, transportation, energy and electric power systems, water and sewer, solid waste management, building design and materials.

The solid waste management section reviews pertinent literature and introduces the importance of managing solid waste in LDC metropolitan areas. A complex combination of land, labor, capital, management and planning skills are required for proper sanitation. Environmental low cost protection alternative techniques are often overlooked in favor of more capital intensive, mechanical approaches. Often cities have not developed a master plan for solid waste that can be followed and will allow for equipment alternatives and changes.

Categories of solid waste include: household garbage and rubbish, commercial refuse, institutional refuse, street sweeping, construction and demolition debris, sewer sanitation residues, industrial wastes. Waste characteristics in LDCs include high organic fraction, lower per capita generation rates as compared to industrialized nations (0.5-0.6 kg vs. 1.25kg) and higher compaction of waste which make equipment designed for volume reduction by compaction unjustifiable.

Social and cultural customs affect solid waste management including levels of community cooperation, prevalence of "untouchable," and psychological and religious objections to using waste. The informal scavenging networks are a traditional activity which also affect solid waste management. Planners must integrate local conditions with functions of delivery and quality of service (e.g., levels of service). Techniques for service delivery include separate unit storage, communal storage, collection by human-powered, animal-powered or motorized vehicles; large or small scale transfer stations; open dump and sanitary fill disposal, institutional arrangements, financing arrangements, selection of appropriate technology. Implementation issues and strategies include development of the planning process, establishment of acceptable service, selection of technology, development of institutions, arrangement of financial resources and budget planning, and providing for public participation and education programs.

solid waste management, state of the art

803

Report of the Technical Official Level Meeting to the Ministerial Level Meeting, International Forum on Appropriate Industrial Technology, Part Two--Summary of the Twelve Industrial Sectoral Working Group Reports. United Nations Industrial Development Organization. New Delhi, India. November, 1978. 86 pages.

This document examines industries which contribute to better use of natural resources and provide a stimulus to upgrade employee skills. Analysis takes into account direct and indirect employment potential, industrial movement to urban fringe and rural areas, and provision of adequate impetus for the growth of a broad-based industrial structure. Reports are presented on policy aspects including a program of action for each sector.

Results indicate a need to reorient industrial and technological strategies so that benefits reach as lsrge a segment of the population as possible. The possibilities of dispersal of small scale industry are found to be much greater than conventionally thought. The exploration of such possibilities should be undertaken by developing countries in a systematic manner through appropriate policy and institutional mechanisms. Fiscal, industrial, trade and other economic policies which could significantly contribute to or adversely affect the policy objectives of appropriate industrial and technological development are noted. Emphasis is placed on strengthening the technological capabilities in developing countries and the development of a wide range of technological services for consultancy,

design and engineering, standardization, evaluation of technology, national capabilities for research and development.

Sector reports as detailed below stress (1) the need to compile, process and disseminate information, and (2) the need for greater cooperation among developing countries and for exchange of experience. Specific projects for further research and investigation are suggested.

Industrial sector reports include: iron and steel, chemicals and fertilizers, drugs and pharmaceuticals, textile industry, sugar industry, construction and building materials, food storage and processing, agricultural machinery and implements, light industries and rural workshops, oils and fats, paper products and small pulp mills, energy for rural requirements, and low cost transportation for rural areas.

technology, appropriate technology, developing country

804
Solid Waste Management in Cuba: Prospects for Recycling and Waste Utilization Systems. Presented at First National Conference on Cuba. New York, New York, U.S.A. 1979. 19 pages.

Solid waste management in Cuba is on the threshhold of formalization. However, no national system exists for solid waste management. Instead, responsibilities are divided among several agencies, most notably the Poder Popular and the Ministry of Public Health. However, as the costs and impact on the health and environment have increased, these agencies are increasingly aware of the need to develop a coordinated approach. They need a system that is reliable, meets public health needs, disposal requirements and conservation objectives.

Increases in the standard of living have caused an increased generation of waste.

This study presents data including: background information on Cuba; historical data on solid waste management; characterization of solid waste; review of current collection practices; resources availability; recycling and reuse activities; markets analysis; and legal developments and current issues.

solid waste management, waste composition, recycling, Cuba

805 Baldensperger, H. L.
Dollars in City Dumps: The Making of Money and Men Through the Chicago Salvage System. The American City. Bettenheim Publishing Corporation. New York, New York, U.S.A. Volume XVII, Number 4. October, 1917. Pages 305-308.

The Chicago House of Corrections employed prison labor to salvage materials from municipal waste. After one year of operation a return to the city equal to 50 percent of the maintenance cost of the institution had been realized.

This method of employing prison labor replaced the contract system. Conversion to salvage work coincided with demand for materials created by World War I. Materials were repaired and/or processed for resale to consumers. Products included light bulbs, shovels, and platinum. Prisoner counselling, and family welfare programs were supported by revenues. Prisoner attitudes were enhanced toward creative employment.

prison employment, salvaging, United States, historical

806 Baranson, J.
Boyle, N.
Harrington, A.
Hellinger, S.
Hellinger, D.

Informal Small Scale Enterprise Sector of the Urban Economy: Problems and Suggested Approaches. U.S. Agency for International Development. AID/CU/1A IA 147-518. Washington, D.C., U.S.A. March, 1976. 90 pages. References.

The global problem to improve the condition of the poor is addressed in this document. The problem is seen as formidable due to (1) vast numbers of people needing help; (2) geographic dispersion; (3) cultural barriers; (4) the lack of political leverage available to poor; and (5) lack of favorable political climates conducive to change. The project appraises potentially useful activities to be undertaken by international development agencies based on field studies. Analysis and resulting proposals focus on small, labor intensive enterprises, marketing systems for small producers and other institutions which enable the urban poor to fully participate in economic and social development of their country.

Key difficulties and deficiencies are noted as the need to (1) devise and implement new training models; (2) effect grass roots initiatives; and (3) develop networks more effective in serving the urban poor.

informal sector, appropriate technology, developing country, labor, marketing

807 Basalo, C.

Beneficiation of Organic Matter Contained in Household Refuse for Agricultural Use: Position in France. United Nations Environment and Settlement Division. March 1, 1975. Paris, France. 11 pages. References.

A brief history of organic waste use in French farming is presented. Data indicates a significant dropoff after 1850 when studies of mineral feeding of plants were published leading to an increasing use of chemical fertilizers. However, from 1935 on, compost usage was important in champagne viniculture. Tower composting had anaerobic problems, leading

to development of mechanical turning processes after 1960. Over promotion of nutrient value of compost plus presence of impurities such as glass, led to reduced demand for product.

In 1972, 350,000 tons of compost were sold in France with 77% going to vineyards and mushroom production. The average selling price in 1973 was FF 19 per ton for accelerated and FF 7 per ton for natural compost.

In 1938, 4 out of 6 disposal systems accepted by the Ministry of Public Health were compost processes. Since that time (1966, 1972, 1973, 1974) various regulations have set standards on organic products.Technical concerns include composition variability of urban organics, C/N ratio determinations, need for putrescibility testing standards, and soil improvement details.

Special uses such as mushroom culture and soils reconstitution need to be investigated. Pathogen control favors accelerated composting techniques. Advantages of compost include attraction for small municipalities, conservation of soils, enhanced food production, and positive reuse by phosphates rather than negative impact of discharges into natural waters.

composting, organics, France, costs, agriculture

808 Berke, J. G.
Hudson, C. H.

Procurement of Products Containing Recovered Materials: A Summary of Activities in Seven States. U.S. Department of Commerce. National Bureau of Standards. Office of Recycled Materials. Washington, D.C., U.S.A. 1981. 73 pages. References.

This document summarizes reports from seven states and one county within the United States on the procurement of products containing recovered materials, as specified in the U.S. Resource Recovery and Conservation Act (P.L. 94-580) and its amendments (P.L. 96-482).

The study identifies legal, institutional, economic, and technical barriers encountered by state agencies when they attempt to purchase such products. A list of products that contain recovered materials is included.

Many states do purchase products containing recycled materials although the purchasing agent is sometimes not aware of this fact due to inadequate labeling of the product. Many vendors choose not to disclose recycled contents of a product for fear that the product may be considered inferior.

Some states indicate that the lack of standards and specifications for recycled products inhibits procurement of products containing recycled materials. The importance of the link between products containing recycled materials and energy conservation is noted by several states.

The report is accompanied by volumes which detail the procurement practices for products containing recycled and recovered materials. They contain sample contracts, sample bids, legislation, agency memoranda, product specifications, and model motivation programs. Each report lists the top ten commodities procured by the state in dollars plus a list of products that have a high potential for the use of recycled or recovered materials. Each report also includes a list of recommendations or suggested actions that could be taken to potentially improve the manufacture, distribution, and procurement of products containing recovered or recycled materials.

product design, institutional barriers to recycling, government policy

809
Product Life Extension and Design in the Context of Materials Balance. School of Architecture and Urban Planning, University of California. Los Angeles, California, U.S.A. 1976. 18 pages. References.

This document is a policy analysis of the product lifetime issue. A review of existing literature determine the status of current knowledge and research projects. Factors which affect product life including direct regulation and indirect market pressures are discussed. Product life extension can significantly reduce the use of natural resources and promote general economic welfare. Life extension of one product may result in an increase in the overall material flow if consumers spend extra income on additional products. Attempting to influence product lifetimes is a first step toward resource recovery.

product design, product durability

810 Conn, W. D.
Urbanization and the Environment: Waste Reduction--Issues and Policies. Presented at the International Symposium on New Problems of Advanced Societies. (Hamburg, Germany. May, 1976). University of California. Los Angeles, California, U.S.A. 1976. 31 pages. References.

The State of California assessed proposed measures for reducing waste. This document analyzes the work of the Source Reduction and Packaging Policy Committee, of the State Solid Waste Management Board, established for this purpose.

Waste reduction (source reduction) is defined as the prevention of waste at its source, either by redesigning products or by otherwise changing patterns of consumption or waste generation. This is distinguished from resource recovery. Objectives include reduction of solid waste, management costs, adverse environmental impacts, litter, and conservation of natural resources. Conflict between different objectives was expressed by committee members reflecting private sector, environmental and government views. Three basic recommendations to reduce waste were made: reduce the quantity of material in packaging, increase product

lifetime, and substitute reusable packages for disposable ones. Effects on the solid waste stream, materials and energy utilization, environmental impacts, government revenues/costs, industry, and employment, fiscal incentives and voluntary efforts are presented.

Reducing waste may not be easily accomplished as benefits do not come without costs. Even if some waste reduction measures are justified as a way to restore market efficiency, there is still room for disagreement on the nature and scale of the "corrections" necessary.

waste reduction, solid waste management, source reduction, United States

811 Furmaier, B.
Necessity and Possibilities of Waste Treatment and Waste Recovery for Reuse: Shown by the Domestic Waste Disposal Program of Bavaria. Proceedings of the International Recycling Congress (Recycling Berlin '79). Berlin, Federal Republic of Germany. Pages 145-151. E. Freitag--Verlag für Umwelttechnik. 1979. References.

This document reviews the Bavarian, FRG Domestic Waste Program and the Hazardous Waste Program. The program sees the treatment and reutilization of wastes as a long-term objective.

Waste composition analysis reveals changes in the waste stream marked by the following features: (1) decrease of the mineral constituents of fine-grained waste from 57 wt % (1950) to 12 wt % (1980); (2) increase of paper and board from 14 wt % (1950) to 39 wt (1980); (3) a nearly constant proportion of organic kitchen wastes of about 16 to 18 %; (4) increase of the proportion of glass from 2.5 wt % (1950) to 9.5 wt % (1980) and (5) increase of the proportion of plastics from 2.3 wt % (1950) to 7.7 wt % (1980).

The following points need to be considered when choosing a waste disposal plan: (1) the strain on the environment should be minimal; (2) the plan should be adapted to local conditions; and (3) the system should be flexible.

A chief objective of waste management is to minimize the increase of waste on a long-term basis.

The following measures can help minimize the strain on the environment in the field of waste disposal: (1) recovery for reuse as far as possible; (2) to reduce the volume of waste as far as possible; and (3) using methods which allow for quantifying inputs and outputs.

The following proven methods of waste reutilization are available: (1) separate collection of the single waste components (e.g., glass, paper); (2) composting of domestic waste for the purpose of biological reutilization of the easily decomposable fractions; and (3) incineration of domestic waste with heat recovery to save primary energy.

Whereas in rural areas the deposit of untreated waste may represent an acceptable long-term solution even under ecological aspects, waste treatment and reutilization must be planned for cities and in areas with intensive land use.

In order to stimulate innovation, Bavaria integrated resource recovery into its planning and provided low interest loans for development of conventional and new technologies.

waste composition, government policy, waste recovery, Germany (Fed.Rep.of)

812

Goen, R. L.
Steele, R. V.
Samogyi, L. P.
Fishman, N.

The Potential for Reusable Homogenous Containers. National Science Foundation. Washington, D.C., U.S.A. 1977. 48 pages. References.

The widespread use of disposable packaging not only constitutes a large use of energy and materials, but also contributes to rapidly growing solid waste problems. The introduction of reusable, homogenous containers into the packaging industry could make a significant contribution to alleviating these problems. This document examines the feasibility of reusable containers for food. Beverages are not included. Concepts are formulated for reusable containers, including configuration and type of material. Comparisons are made of the amount of energy needed to produce reusable containers versus that needed for disposable containers.

In 1967, total direct and indirect energy use in the package related sectors (paperboard containers, metal cans, glass containers and plastics) was approximately 30 percent of the nation's primary energy consumption (1.6×10^{15} Btu). A change in packaging that resulted in reducing energy use by 50 percent would save the equivalent of over 500,000 barrels of oil per day. Energy savings can be accomplished via new container designs, use of returnables, and lower transportation distances. Food (wet, dry) container requirements can be met. The retortable pouch (made of laminate of aluminum foil and plastic) in which food can be sterilized and cooked, and the use of freeze-dried processes for foods instead for the canning process are alternative methods reducing material use for containers. Food packaging accounts for nearly half of the dollar volume of packaging in the United States. Packaging contributes 35 percent of the residential and commercial solid waste, or 55 percent of the nonfood product waste.

reuse, returnable containers, energy savings, costs, waste reduction

813 Gunnerson, C. G.

Debris Accumulation in Urban Areas--A Study of Municipal Lint. Appropriate Technology for Resource Conservation and Recovery. American Society of Civil Engineers. New York, New York, U.S.A. October, 1979. 46 pages. References.

This paper focuses on debris accumulation in cities which results when people carry more into their communities than they carry out. Options at the household, community, commercial, and industrial levels are to sell materials, give or throw them away, pay to have unwanted materials hauled away, or convert them to secondary use.

Debris accumulations in urban areas from Neolithic and Bronze Age communities to contemporary times vary from 5 to 150 cm (0.15 to 5 feet) per century but are not necessarily increasing over time. Bronze Age Troy and modern Manhattan, New York, U.S.A. have equivalent rates of 140 cm (4.7 ft.) per century, although the latter has a more efficient collection and disposal system which reduces accumulation.

Debris accumulation is represented mostly by inorganics, which are the least valuable materials. Catastrophic events, man made and natural, account for incremental debris accumulation but have little long-term effect.

Alternatives to debris accumulation involve recycling which recently tends to be more acceptable in developing countries than in industrial ones. The industrial view that high or capital intensive technology will solve all is still prevalent in many countries.

Resource recycling requires environmental, institutional, economic, and technological approaches. Also, finite national resources, shortages of professional and managerial skills in developing countries, and the need for public access are factors to be considered.

The author concludes that it is important to internalize the marginal costs of convenience, employment generation, and shadow pricing of costs in developing countries, and evaluate the full impacts of economic development.

For technology, it is concluded that greater sorting efficiencies of hand operations would make them more cost effective than machine operations and economies of scale tend to disappear when system stability or flexibility is considered. A conservation ethic, most importantly, has multiple positive impacts.

recycling, appropriate technology, developing country, sorting, municipal waste

814 Haynes, K. E.
El-Hakim, S. M.

Appropriate Technology and Public Policy: The Urban Waste Management System in Cairo. The Geographical Review. American Geographical Society. New York, New York, U.S.A. Volume 19, Number 1. January, 1979. Pages 101-108.

Issues concerning solid waste management and recycling in Cairo, Egypt are presented in this article. Policy considerations, problem solving and technology assessment efforts at the local level are detailed. Conclusions are that: (1) antagonism exists between the informal sector and the city as scavengers are frequently forced to move from temporary housing; (2) some government agencies desire importing sophisticated technology at the expense of the informal sector; (3) using appropriate technology can benefit agriculture, energy, water and the environment; and (4) policy considerations can help developing countries use appropriate technology to maximize resource recovery.

recycling, informal sector, appropriate technology, government policy, solid waste, composting, institutions, scavengers, Zabbaleen, Egypt, solid waste management

815 Julius, D. S.

Urban Waste as an Economic Good In: Sanitation in Developing Countries. Edited by Arnold Pacey. John Wiley and Sons. The Gersham Press. Old Working, Surrey, U.K. 1978. Pages 194-200. References.

The author explores goods and waste to develop theoretical implications of use in understanding and promoting environmental protection and waste recovery.

Three variables are noted as affecting the demand for consumer goods: price, substitutes, and consumer preference. The author also indicates that the income of the consumer may form a fourth determinant. As income increases, so does the demand for better of more expensive products. Conversely, the demand for inferior goods should decrease as the consumer income increases. This has been proven in Kyoto, Japan where farmers initially dropped low value organic fertilizer in favor of chemical fertilizer as country and individual wealth increased. However, the alleged effects of soil depletion are encouraging some farmers to return to low cost organic fertilizer. The author backs up this case study with income data and demand curves for organic fertilizers in Korea and Taiwan.

While the other three factors have demonstrated effects on demand as shown in several examples, the author notes that consideration of income level must be integrated into decision making. Currently, most developing nations have relatively low incomes, making selection of low cost technology seemingly correlative. However, another conclusion might be reached. If the current emphasis on developing low technology continues with improvements in the standard of living, then the biggest obstacle to continued use of new low technology, especially for waste utilization, may

be the response that waste derived products are inferior, therefore constraining use. In that case, a strategy of stressing the environmental and ecological benefits could present a positive approach to increasing waste recovery.

institutional barriers to recycling, economics, organics, health and safety, fertilizers

816

Kim, J. I.
Robinson, D. E.
Bazar, A. R.
Gump, B. H.

Solid Waste Resources from the Fresno-Clovis Metropolitan Area. Final Report, Volume II. Fresno-Clovis Metropolitan Solid Waste Commission. Fresno, California, U.S.A. 1981. 200 pages. References. Authors at California State University, Fresno, California.

The practicality of recovering resources, energy as well as materials, from solid wastes is governed not only by the availability of suitable markets for the recovered products, but also by the volume and composition of the waste. Operational costs for centralized processing facilities are particularly sensitive to seasonal variations of the quantity and quality of the waste and to the distribution of the waste sources. Planning for future needs, process improvements, and initial capital outlay must account for population growth and for per capita generation of wastes. This document is a comprehensive analysis of these factors conducted so that Fresno County, California, could implement an effective resource recovery program.

Over a nine month period, a waste characterization analysis was carried out by conducting weight and composition surveys of the refuse received at several disposal sites.

This information was used to develop an integrated resource recovery system and to reduce landfill demand. Mechanical (including compost, waterwall, pyrolysis) and source separation options were evaluated and compared.

Industrial markets for energy (electricity, steam, oil, gas) were examined with respect to stability, availability of waste, and technical difficulties. Material markets were explored for the following materials. ferrous (pig iron production (blast furnace)), steelmaking (basic oxygen open-hearth and electric furnaces), ferroalloy production, gray iron foundries, detinning, and copper precipitation; aluminum (secondary smelters, primary producers, fabricators and foundries); waste paper (paper and paperboard production, newsprint deinking, corrugated containers, highgrade pulp substitutes, highgrade deinking, mixed paper products, energy production, (combustion), composting, animal feed (cattle, sheep), soil conditioner, mushroom growing medium, fruit box lining material, and egg carton manufacturing material); glass (bottle manufacturing (amber, clear, green), wool-foam insulation, and wall panels); organics (soil additive, mulch, and animal feed supplement).

A market survey was conducted to identify actual firms willing to purchase specific amounts and quality of materials. Market trends and technological innovations were included for all materials.

secondary materials recovery, markets, energy recovery, pyrolysis, composting, deinking, energy, ferrous/nonferrous recovery, glass, organics, technology

817 Langer, H.
Strategies for the Use of Waste Paper Outside the Paper Industry. Proceedings of the International Recycling Congress (Recycling Berlin '79). Berlin, Federal Republic of Germany. Pages 1159-1165. E. Freitag--Verlag für Umwelttechnik. 1979. References.

Innovative uses of waste paper are examined in this paper.

Waste paper recycling has been standard for years in the industry. However, the introduction of paper hybrids has complicated the recycling process by increasing heterogenity in the lower or mixed grades.

Low grades of paper have traditionally been used in roofing, felt manufacture, and wallboard. However, saturation has occurred at some levels so these lower grades are no longer effectively utilized. The price/revenue for these papers also hinder recycling due to transportation costs.

Potential new uses for secondary mixed fibers include: alcohol production; biotechnical uses; insulation; molded parts; plant containers; fuel extraction (burning). Marketing concepts, possibilities for product substitution, and policy considerations are enumerated.

fiber, fuel, marketing, product substitution, waste paper recovery

818 Lomnitz, L.
Networks and Marginality: Life in a Mexican Shantytown. Academic Press. New York, New York, U.S.A. 1977. References.

This book describes patterns of social relationships between the shantytowns and the formal urban economy. Field data are taken from several Mexico City shantytowns.

The industrial economy has not developed fast enough to keep pace with the demand for jobs from rural migrants. Labor union closed shops and rising educational requirements for industrial jobs effectively barr migrants from access to skilled jobs.

Two types of relationships are explored: (a) exchange among equals, and (b) patron-client relationships. Of great interest is the latter form where research shows the highest flow of reciprocal exchange in the shantytown occurring usually between close neighbors related by kinship.

The kinfolk network can be organized into a labor "gang" with a wide variety of wage rates, work conditions, industrial relations; e.g., partnerships, patronage, brokerage, production brokers, political brokers. This does not, however, exclude a relationship with the dominant formal economy. Thus, the shantytowns are connected with the national system in their role as markets, as producers, and as sources of cheap labor and political resources.

scavengers, informal sector, Mexico

819 Melosi, M. V.
Garbage in the Cities: Refuse, Reform, and the Environment, 1880-1980. Texas A & M Press. College Station, Texas, U.S.A. 1980. 268 pages. References.

This book is a history of refuse management in the United States during the era of industrialization and urbanization. The author describes the growing awareness of environmental problems caused by open dumping in oceans and waterways. The rise of the professional sanitation bureaucracy, and impact of grassroots environmental organizations, and various technologies employed to manage and/or recycle wastes are also covered. Street cleaning, collection and disposal practices are detailed.

The author notes the origins of the public health vs. recycling debate and describes Col. George E. Waring, Jr.'s experimental efforts to start a resource recovery system. Waring constructed the first sorting plant in the U.S. based on primary separation at households. Failure is attributed to elimination of informal scavenging networks, and insufficient development time due to the political boss system.

Other aspects discussed are the affect of European practices on U.S. development, implementation of inappropriate high technology grease recovery and combustion systems, differences between professional sanitary engineers and grassroots organizations, and the role and composition of public interest groups. Post-1920 developments in the U.S. are briefly discussed.

historical, United States, Europe, waste management, pollution, environmental management

820 Milgrom, J.
Incentives for Recycling and Reuse of Plastics. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Washington, D.C., U.S.A. Prepared by Arthur D. Little, Inc. 316 pages. References.

This study had two objectives: (1) to develop a descriptive model of the plastics cycle; and (2) to develop strategies for promoting the recycling and reuse of plastics. The study is reported in five parts. Part I contains a discussion of the technology of plastics, which provides the basis for understanding the technical problems of recycling. Part II describes the economics of the plastics industry needed to develop and assess the strategies for recycling plastics and discusses the market for

both virgin and secondary materials. Part III describes the entire plastics cycle beginning with petrochemicals until the plastic becomes a consumer product. Part IV analyzes the existing state of the art of methods that isolate plastics from the solid waste stream and of uses for the scrap material. In Part V strategies for promoting recycling and the reuse of plastics are described in detail.

One strategy useful to improve secondary resins would have them meet industrial standards set by the American Society for Testing Materials.

Another action that the plastics industry could take to promote recycling would be to set up an inventory of all sources of scrap plastic. This inventory would describe the availability, location, physical, and chemical forms, etc., of the scrap, and be a resource for manufacturers interested in purchasing secondary material.

Because offgrade virgin resins, especially surplus, compete with secondary resins, an effective tactic would be to reduce the available volume of this surplus resin. If government and industry can cooperate to develop a program for monitoring and reporting virgin resin inventory levels, this will go a long way towards stabilizing resin prices and, therefore, prevent the production of large volumes of surplus off-grade resin.

A worthwhile use of some tax revenues would be to further research and development specifically directed to make reprocessing technically and economically more attractive. For example, research programs that develop new uses for scrap materials will be very helpful to the reprocessor and should promote recycling. Research to develop new technologies for collection and disposing of scrap plastic is another approach.

Often, the government itself impedes recycling because it uses purchase specifications that do not allow the uae of secondary resins, in spite of their limited effect on performance in certain applications. Therefore, governments are in an excellent position to take the lead by relaxing these restrictions wherever possible, and thus open up additional markets. Governments spend billions per year for a large array of products and, therefore, by modifying procurement policies, they can increase the recycling of secondary materials. By specifying the use of secondary materials in purchase, the government would not only open up new markets, but, more significantly, their actions would have an important positive effect on many segments of industry.

government policy, plastic recycling, secondary materials recovery, state of the art

821 Ming, C.
Organizational Techniques in Retrieving Waste Materials. Conservation and Recycling. Pergamon Press. U.K. Volume 3, Number 3/4. Pages 319-325. 1979. Presented at Second Recycling World Congress. Manila, Philippines. 20-22 March, 1979. Author at Shanghai Materials Recovery Company. Shanghai, People's Republic of China.

The structure for collecting, processing, and selling waste materials in the greater Shanghai area is described in this document.

Founded in 1957, the Shanghai Materials Recovery Company (SMRC) has 12 urban and several suburban branches with 16,000 employees (850 collecting, 11,000 processing and sorting, 1,850 transporting residues, and 2,300 neighborhood agents). Rural cooperatives and shops work on a commission basis.

Materials recycled include metals, rubber, plastics, paper, hemp, cotton, chemical fiber residue, animal bones, human hair, glass containers, broken glass, old machines, parts and accessories, acidic solution, oil and grease.

Collection is carried out by 24 purchasing agencies for industrial wastes and, under them, purchasing stations (one for 20,000 households) for residential and commercial wastes. There are both centers and mobile collectors for urban and rural residents. Collection is enhanced by an active propaganda campaign waged to encourage increased participation.

Processing is carried out in 70 factories (8 for metals, 21 for machines, appliances, hardware, 33 for sundries, 8 for chemicals) and include sorting, repairing, remaking, and refining.

Marketing includes close coordination with user production schedules, waste exchanges (example: acidic discharge of chemical works is used to clean rolled steel and reused by pharmaceutical plants to make iron protosulfide) and sales departments with sample display areas where potential users can make their selections.

recycling, remanufacturing, China, collection, processing, marketing

822 Purcell, A. H.
Tin Cans and Trash Recovery: Saving Energy Through Utilizing Municipal Ferrous Waste. Technical Information Project. Washington, D.C., U.S.A. 1980. 26 pages. Supported research by U.S. Department of Energy Appropriate Technology Small Grant Program. References.

The booklet explores the feasibility of using ferrous waste in local foundries. It is an established system for using material which minimizes transportation costs and which is compatible with nonhomogeneous material that varies in both quality and quantity. Foundries produce few types of materials, mostly grey iron (lower grade cast iron used in applications such as pipe, grates and covers). Metallurgically, this product is distinguished by microscopic flakes of carbon throughout its

structure. The use of ferrous scrap can significantly reduce the costs of feed to foundries. Recommended mixes of 75 percent pig iron (standard foundry material) and 25 percent municipal ferrous waste would result in a 17 percent cost reduction based on test application. High quality cast material approaching ductile iron could be produced by adding small amounts of noduloy, a commercial master alloy containing cerium and magnesium.

Identified obstacles to increased ferrous scrap recycling include the level of tin contamination for steel furnace processes, numerous grades of steel with their unique and delicate furnace chemistry requirements, unavailability of detinning facilities, and high transportation costs.

Fundamentals of material collection, preparation and foundry melting are described. A check list for municipal ferrous waste foundry melting, bibliography and list of 200 foundries in the U.S. are provided.

foundries, tin cans, ferrous scrap

823 Risch, R. W. K.
The Raw Material Supply of the European Community: The Importance of Secondary Raw Materials. Resource Policy. Science and Technology Press, Ltd. U.K. Volume 4, Number 3. September, 1978. Pages 181-188. References.

This document considers the availability and security of raw materials which have recently taken on a new political dimension. These issues influence the economic and political rank of nations, affecting their independence, their standards of living and the competitive position of their industries. Recent awareness of the risks of shortages of most essential materials, the limitation of nonrenewable resources, and in particular the awareness of the permanent and growing dependence of Europe on primary raw materials, have stimulated interest in the recovery of wastes and the rational use of natural resources. This concern has brought some economists and philosophers to consider secondary materials as a potential main industrial feedstock. In particular, for economies lacking primary raw materials, this would extend the availability of natural resources. Some economists are speaking of a future "society of secondary raw materials."

Waste management will become important for countries lacking natural resources as all wastes and residues represent the most secure raw materials source. This will help to reduce dependence on imported raw materials, to realize considerable energy savings and to contribute to environmental conservation. Waste management can become a new dimension of economic policy, constituting a link between environmental and economic policy. The objectives of waste management policy cannot be restricted to the safe disposal of waste, but must also include its prevention, reduction and increased processing.

secondary materials recovery, government policy, Europe, developing country, international trade, raw materials

824 Rolz, C.
Particular Problems of Solid Waste Reclamation in Developing Countries. Applied Research Division, Central American Research Institute for Industry. Guatemala. 1977. 40 pages. References.

This study investigates issues and problems faced by developing countries in the area of solid waste reclamation. Differences in approach between developed and developing countries are identified and a common need advanced: the imperative to utilize byproducts and wastes as possible aources of fiber, fuel, and feed/food products.

In developing countries, the least costly method is generally adopted. Collection, scavenging, and dumping are common. Land reclamation through landfilling is a common waste utilization method. An important point is that technology should not displace human labor. Otherwise, a technical problem is solved but a social one is created.

Selected high technology should not be totally rejected, but evaluated on the basis of each nation's individual requirements and realities.

collection, developing country, landfill, land reclamation, scavengers, solid wastes

825 Schumacher, E. F.
The Work of the Intermediate Technology Group--Africa International Labour Review. International Labor Organization. Geneva, Switzerland. Volume 106, Number 1. Pages 3-20. 1972. References.

The Intermediate Technology Development Group was formed in 1966 by people in the professions and industry in the United Kingdom in response to worldwide dangers inherent in the buildup of unemployment taking place in virtually every poor country. This document reviews the purposes and accomplishments of this agency.

The Group's goal is to compile practical data on intermediate technologies, to field test them and to disseminate them. Panels of experts are aasigned to each research project. Work is performed both in developed countries and developing countries. Projects include building construction materials and processes in Nigeria and Kenya; water projects in Botswana; agricultural tools and equipment in Zambia, Nigeria and Tanzania; small scale industry development in Nigeria; and food technology in Liberia and Tanzania. Consultancy assignments have been undertaken for the International Labor Organization, United Nations Economic Commission for Africa, and United Nations Industrial Development Economic Commission for Africa, and United Nations Industrial Development Organization through the Group's subsidiary Inter-Technology Services. Technology, equipment manufacture management training and local financing and marketing tasks were undertaken.

The Group's research and development program relies upon research grants and donations. The panel method of operation has proven successful as a means of bringing together three essential elements for a successful project: identifying gaps that can be filled by intermediary technology, assembling the necessary practical data, and engaging in field trials to demonstrate their uses. These so-called ABC elements of development are the administrators, the business and industrial community and the communicators, or academic fraternity.

The work of the Group is seen as an important contribution to technological choice for developing nations. Low cost technology efforts to date represent an insignificant fraction of total aid expenditure.

appropriate technology, developing country, small scale industry, job creation, research and development, institutions, technology

826 Seldman, N. N., Ed.

Final Report: National Recycling Research Agenda Project. National Science Foundation. Washington, D.C., U.S.A. 1979. 126 pages. References.

One hundred and eleven waste experts were identified and they addressed short and long-term research needs in the area of post consumer solid waste recycling projected funding needs.

The Project addressed nine technical problem areas: markets for secondary materials, compatability of recycling and combustion, technology and equipment, project initiation, waste reduction, participation, institutional barriers, hazardous wastes, and waste utilization.

Participants voiced strong support for more research and funding in areas of cost effectiveness, environmental impact, community and small business development, and general education on conservation. The Project recommended up to US$76,915,000 or R & D programming over the next 5 years to be supported by various federal agencies.

research and development, recycling, secondary materials recovery, technology, equipment, hazardous wastes, institutional barriers to recycling, United States

827 Taira, K.

Urban Poverty, Ragpickers, and the "Ants' Villa" in Tokyo. Economic Development and Cultural Change. University of Chicago, Chicago, Illinois, U.S.A. Volume 17, Number 1. January 1, 1969. Pages 155-177. References.

This case study of Japanese ragpickers shows how they were able to organize themselves into a productive cooperative known as "Ants' Villa"located on the waterfront of Tokyo Bay. Scavenging was organized on a communal basis with different teams in charge of collecting, processing, sorting, etc. The community built their own homes, restaurant and store.

824 Rolz, C.
Particular Problems of Solid Waste Reclamation in Developing Countries. Applied Research Division, Central American Research Institute for Industry. Guatemala. 1977. 40 pages. References.

This study investigates issues and problems faced by developing countries in the area of solid waste reclamation. Differences in approach between developed and developing countries are identified and a common need advanced: the imperative to utilize byproducts and wastes as possible sources of fiber, fuel, and feed/food products.

In developing countries, the least costly method is generally adopted. Collection, scavenging, and dumping are common. Land reclamation through landfilling is a common waste utilization method. An important point is that technology should not displace human labor. Otherwise, a technical problem is solved but a social one is created.

Selected high technology should not be totally rejected, but evaluated on the basis of each nation's individual requirements and realities.

collection, developing country, landfill, land reclamation, scavengers, solid wastes

825 Schumacher, E. F.
The Work of the Intermediate Technology Group--Africa International Labour Review. International Labor Organization. Geneva, Switzerland. Volume 106, Number 1. Pages 3-20. 1972. References.

The Intermediate Technology Development Group was formed in 1966 by people in the professions and industry in the United Kingdom in response to worldwide dangers inherent in the buildup of unemployment taking place in virtually every poor country. This document reviews the purposes and accomplishments of this agency.

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by organizing themselves on a communal basia the scavengers were able to exert more control over supply and demand for their products. In addition, they gained considerable self respect for themselves and from society.

Ragpicking is the least preferred form of gainful employment. Many of the poor would rather beg or steal than pick rags. Data indicate that the earnings from ragpicking are far below those from other activities of which the poor are capable. Ragpicking is on the borderline between employment and vagrancy. Closely related to ragpickers are ragbuyers who buy waste materials from households using capital advanced from the ragdealer. Ragdealers provided shelter in the junk yard for a nominal rent. Dealers sold materials to "processors" who specialized by category of material and who sold materials to factories.

These elements constitute the "resource regeneration industry" which conveys the sense of a dynamic process characteristic of the industry. It has favorable implications for the ragpicker who is regarded as an agent of resource regeneration. This psychological dimension is critical as one who regenerates resources may eventually regenerate oneself. The industry has demonstrated remarkable staying power, expanding in post World War II years to peak employment in 1952. Bicycle pulled carts, small three wheeled motor vehicles and trucks are commonly used tools of the profession.

The personality problems of ragpickers are revealed by voluntary admission that their unfortunate conditions are due to personal deficiencies and hence largely of their own making. The story of the "Ants' Villa" in Tokyo is one of the few examples of psychological rehabilitation, spiritual growth, and economic success among ragpickers.

Ants' Villa was a community of 50 households located on reclaimed land at the waterfront of Tokyo Bay, Toko-Ku administrative district. Daily scavenging work was organized on a thoroughly communal basis, beginning and ending with group prayer. Work was rationalized: large quantity collection for major business concerns in central Tokyo, transport to workshops, sorted out by teams, packed by machines and delivered to commercial processor. This organization compares favorably with any efficient small scale business firm. It supports a clean community with recreational and guest houses, restaurant and store.

Japan, scavengers

828 Thomas C.
Material Gains: Reclamation, Recycling and Reuse. Earth Research, Ltd. London, U.K. 1979. 130 pages. Exhibits. References.

This book presents a discussion of the issues related to national recycling materials policies: conservation, resource limits, waste reduction, reuse, packaging, reclamation and recycling. The impacts of reuse and recycling on environmental quality are detailed in terms of raw materials, energy, pollution, waste disposal, and general considerations with regard to European Economic Community countries. Current recycling

practices, waste management legislation and public policy are discussed. Future options for waste processing and utilization are reviewed including material collection, material separation, pyrolysis, composting, and refuse derived fuels.

recycling, Europe, waste utilization, reuse, waste recovery, conservation, fuels, sorting, pyrolysis, composting, collection, government policy

ANNEX I

ADDITIONAL BIBLIOGRAPHY

Some of the magazines and journals published on recycling include:

Biocycle, a Journal of Waste Recycling, the J G Press, Inc., Box 351, Emmaus, Pennsylvania 18049, United States.

Muell und Abfall Beseitigung, Erich Schmidt Verlag, 48 Bielfefeld, Federal Republic of Germany.

Resources and Conservation (formerly Resource Recycling and Conservation), Elsevier Scientific Publishing Company, P. O. Box 211, 1000AE Amsterdam, The Netherlands.

Conservation and Recycling, Pergamon Press, Inc., Maxwell House, Fairview Park, Elmsford, New York 10523, United States.

The Journal of Resource Management and Technology, Iraj Zandi, editor, University of Pennsylvania, 220 S. 33rd Street, Town Building, D3, Philadelphia, Pennsylvania 19104, United States.

Back issues of the Bulliten, published from 1971 to 1981 by the National Center for Resource Recovery, available from U. S. Conference of Mayors, 1620 I Street, N. W., Suite 600, Washington, D. C. 20006, United States.

There are a number of regularly scheduled specialty conferences on recycling, with published proceedings, including:

International Recycling Congress, held in Berlin, proceedings published by E. Freitag--Verlag für Umwelttechnick, Berlin.

National Waste Processing Conference, convened by the American Society of Mechanical Engineers, New York.

ANNEX II

GLOSSARY

ABS: acryloni trile butadiene styrene.

Absorptive Capacity: Ability of informal sector to create employment and skills training, thus reducing economic and social pressures caused by rural immigration and urban population growth.

Agents (intermediates): Informal/formal secondary commodity buyers who resell to brokers, dealers or factories.

Aggregation: Accumulation of waste commodities prior to processing and/or shipment to markets or disposal.

Appropriate Technology (intermediate or low technology): Technology that requires low capitalization and overhead, and is matched to local resource materials and human resources to produce goods and services for local consumption. Refers to institutional aspects as well.

Back End System: The portion of a high technology resource recovery facility where materials are recovered from the incinerated residues of refuse.

Back Haul: Unused transfer capacity returning to place of origin can carry secondary materials at low cost.

Bangalore Method: Low cost compost method devised in Bangalore, India. Involves the alternative layering of refuse and night soil with dirt. Digestion takes place under anaerobic (without oxygen) conditions during a four to five month retention time.

Batch Operation: Process which is run on a noncontinuous basis.

Bio-Conversion: The conversion of organic waste via biological decomposition to produce usable gas, liquid fuels, or compost products.

Bottle Bank: Beverage bottle return system devised by European glass bottlers and adopted throughout Europe. Specially designed containers (skips) are placed at convenient locations for people to "drop off" bottles for later collection.

British Thermal Unit (BTU): The amount of heat necessary to raise the temperature of one pound of water one degree farenheit. 1 BTU = 1055.1 Jouhes.

Brokers: Purchasers of materials who sell materials to factories or mills without processing.

Buy-Back Center: A facility where materials are purchased from suppliers and which may or may not be subsequently processed for delivery to market.

Capital Intensive: Indicates that a relatively large percentage of the total cost of production is associated with the initial cost rather than the operating cost. Also used to differentiate from technologies which are labor intensive.

Caste: Subgroup of cultural society which for religious and/or ethnic reasons has been economically segregated from mainstream society. Typically, low status castes often provide waste collection and street cleaning services. In turn, the caste system may preclude higher castes from recycling participation.

Cellulose: Fibers derived from wood sources. Can be used in alcohol production, paper manufacturing and/or energy production through combustion.

Cellulose Insulation: Insulation material made from shredded waste paper (newspaper, corregated) and treated with a fire retardant (boric acid). It forms a fluffy fiber product which is blown in walls and roof interiors.

Christian Punjab Sweepers: Network of workers in Karachi, Pakistan who perform street and sewer cleaning services and scavenging under contract with the city. As a minority group which performs tasks that Moslem majority rejects, these workers have a monopoly over scavenging.

Classical Recycling: The use of secondary materials to produce new products, as opposed to reuse or remanufacturing of secondary products.

Closed Loop System: Ideal production arrangement wherein the product of one process is the feedstock for another product process.

Collection Center: A place or facility designed to accept waste commodities such as glass bottles or cans. The term may also be used to mean a dropoff location for waste commodities collected by government or private agencies.

Combustible Fraction: Solid waste which can be incinerated with or without supplementary fuel.

Combustion: A process by which organic material is burned in the presence or near absence of air (i.e., stoves are a combustion device).

Commercial Fertilizer: Refers to nitrogen, phosphorus or phosphate fertilizers manufactured from virgin raw material feedstocks.

Commodity: A product or material which can be reused, repaired, remanufactured, recycled, processed, or disposed.

Communal Storage: A form of storage for multifamily dwellings or points of human aggregation.

Compost: The end product of the compost process. Variously referred to as humus, organic compost, and soil amendment.

Composting: The designation given those processes that involve decomposition of organic matter. Aerobic composting take place in the presence of oxygen. Anaerobic composting takes place in the absence of oxygen. The product of the two processes is the same in terms of conditions of the product; namely, a biologically stabilized residue.

Cost Reduction: Savings achieved through system efficiencies based on the recycling, reuse, or remanufacturing of secondary commodities.

Cottage Industry (small scale): Manufacturing and processing undertaken in small, often household scale, production units.

Crumb Rubber: Small grain rubber ground mechanically or tread cryogenically from old tires. Used in manufacture of roadways, construction material and industrial flooring. Differs from reclaim rubber in that it is vulcanized.

Cullet: Uncontaminated broken glass that is substituted for soda ash in glassmaking to reduce energy requirements, lower pollution and extend raw material supplies.

Cullet Dealer: Dealer who specializes in secondary glass materials.

Dealer: Entrepreneur who obtains and adds value to secondary commodities through processing prior to resale of commodities to an end user.

Deposit: Returnable fee paid by consumers when purchasing commodities.

Desertification: The process by which deserts are created. This term was originally used by a French scientist to describe the northward advance of the Sahara in Algeria and Tunesia. In human activities, slash and burn, intensive logging, overgrazing and soil mining contribute to desertification. Declining groundwater tables, salinary action of topsoil and water, reduction of surface waters, unnaturally high soil erosion, and desolation of native vegetation are noted impacts.

Discard: Residual following personal use or consumption of a product. Discard may still have original use value.

Economy of Scale: The scale of operation where the benefits per production unit exceed the unit cost.

End User: Entity (mill, factory, farm) which uses secondary commodity to produce product.

Energy Recovery: A form of resource recovery in which the organic fraction of waste is converted to some form of usable energy. Recovery may be achieved through the combustion of processed or raw refuse to produce steam (e.g., as supplemental fuel in electric utility power plant boilers or as the primary fuel in incinerators), through the pyrolysis of refuse to produce oil or gas; and through the anaerobic digestion of organic waste to produce methane gas.

Equity Option: Arrangement which allows for workers, community organizations and/or residents to acquire ownership and control over work products and operations.

Feasibility Study: Technical evaluation to determine economic or social viability of an industrial process, collection service or intermediate processing system.

Feeder Mechanism: Network of individuals, communities or businesses which generates secondary commodities to a recycling or remanufacturing process.

Feedstock (furnish): Raw material input to a process.

Formal Sector: Commercial and industrial sector which provides full time employment, social security, and other fringe benefits (see Informal Sector).

Front-End System: A system of labor intensive or mechanically intensive activities which subject solid wastes to physical or chemical action. These actions are designed to change commodity as received attributes.

Garbage: The household fraction of municipal refuse typified by kitchen residues and other organic wastes.

Generator: Producer of residual materials.

Glass: Vitreous material made from the high temperature fusion of sand (silica) and additives to form an impermeable, transparent, sanitary product. Colored glass is obtained by adding small amounts of selected metals, salts, or oxides.

Grading: Sorting of a uniform material into homogeneous categories by hand or using hand tools. (See Sorting).

Hazardous Waste: Residual of industrial process or individual consumption which is potentially dangerous to humans and/or the environment.

HDPE: High density polyethylene.

High Technology: Advanced, or sophisticated technology requiring large capital outlay and highly trained technicians for operation and management.

Home Scrap: Materials of a known quality generated at the manufacturing site that are reintroduced in the production process.

Horizontal Integration: Production process which includes one or more feedstocks or one or more end products; e.g., production of paper products for newsprint, insulation and alcohol.

Inferior Good: Low value commodity which has an inverse relationship to income in terms of demand.

Informal Sector: Extensive economic activity which takes place beyond the boundaries of formal sector activity. Activity is small scale, labor intensive, unregulated and competitive. Employment and income is irregular with no social security benefits (See Formal Sector).

Infrastructure: Equipment and organizational requirements for efficient collection, processing and end use of secondary materials.

Integrated Curbside Collection: A residential area service combining collection of source separated, recyclable materials and refuse simultaneously.

Integrated Resource Recovery: The recovery of materials and energy from waste in different sectors of the society which are compatible with each other.

Intermediate Processing Center: Operation which receives a variety of secondary materials and prepares (e.g., shreds, bales, crushes) them for end use processes.

Labor Intensive System: The maximization of labor in all resource recovery activities. For example, recyclables can be separated without sophisticated machinery in a collection center.

Lapale: Indonesian term for scavenger sorting site.

LDPE: Low density polyethylene.

Life Cycle Cost: Total cost over the lifetime of a piece of equipment or material; includes capital, operating and maintenance costs.

Litter: Haphazard disposal of waste along streets, roads, and alleys.

Marginality: Socioeconomic concept defined by two characteristic features; lack of formal access to urban industrial production processes, and chronic insecurity of employment and income.

Market: Processor or end user (e.g., factory, mill) of a waste commodity.

Marketing: Processing by which buyers and sellers are brought together.

Material Grade: Specific classification of one category of waste commodity (See Grading).

Material Specification: Exacting requirements set by secondary materials end users to be met by providers of raw materials.

Materials Handling: Activities involved in aggregation, storage and shipment of waste commodities.

Materials Recovery: Extraction of waste commodities from solid waste by manual, mechanical or combined means.

Mechanical Separation/Recovery: Mechanical means (magnet, shredder, air classifier) to segregate mixed waste into material categories for recovery.

Metal (ferrous): Metals which are predominantly composed of iron. Most common ferrous metals are magnetic. In waste commodities forms usually include "tin" cans, automobiles, old refrigerators, and stoves.

Mixed Waste: Residues from a variety of products which are mixed together for disposal. This reduces value of individual products and materials to lowest common denominator.

Municipal Solid Waste: Waste generated from households, commercial and industrial facilities.

Nonferrous Metal: Metal commodities composed of various elements; e.g., brass, copper, aluminum.

NPK: Refers to nitrogen, phosphorous and potassium.

Obsolete Scrap (post consumer waste): Materials returned for recycling after commodity consumption. Usually the most difficult materials to recycle due to dispersal of generators and contamination by contrary materials.

Oil: Petroleum based products used as a fuel or lubricant. Used oil can be rerefined or cleaned for use as a fuel.

Open Dump: Nonsanitary landfill or disposal area which results in environmental degradation and public health dangers. (See Sanitary Landfill)

Organic Waste (garbage, putrescibles): Fraction of solid waste which is organic in nature; e.g., food scraps, and garden clippings.

Partial Feedstock: Virgin or secondary material used in addition to primary feedstock in an industrial process.

Pelletizer: Hydraulic mechanism for densifying mixed waste or homogenous materials into pellets or cubes to argument combustion or animal feed operations.

PET: Polyethylene Terephthalate.

Plastics: Roughly 40 families of polymers (petroleum derivatives) which are increasingly being used as substitutes for glass, metal, wood, leather, etc. They are divided into two types: thermosets (nonremeltable) and thermoplastics (remeltable).

Pollution Abatement: Planned reduction of pollutants from an industrial process which can be accomplished by technological additions (pollution control via electrostatic precipitator, wastewater filtration, etc.) or management actions (the substitution of secondary commoditiea such as cullet for soda ash, the deletion of an offending element, etc.).

Primary Feedstock: Virgin or secondary material used in largest amount in an industrial process.

Primary Materials Industry: Production of products from materials extracted from virgin resources.

Product Charge: Surcharge imposed on the purchase price of consumer product used to disperse the cost of disposal among the population. A product charge on automobiles for instance, guarantees funds for removal of abandoned auto hulks.

Product Design: Integrating factors of reusability, repairability, recyclability and remanufacturability into the initial design of a product.

Prompt Scrap: Scrap of a known quality generated at the raw material production stage and sold to intermediates for foreign plant consumption.

Recyclable: Waste commodity which can be utilized readily in similar or altered form.

Recycling: The collection, processing, transportation, and end use of a waste commodity. Material recycling refers to the use of secondary materials to form new products. Product recycling refers to keeping an item in its original form for reuse, repair, or remanufacturing.

Refugee Occupations: Available work for populations arriving from countryside to urban areas. Scavenging is a common refugee occupation.

Refurbish: The process where products are brought to a central facility for disassembly, cleaning, and reassembly.

Refuse: Mixed waste materials discarded by households and commercial establishments.

Refuse Compaction Vehicles: Collection vehicles equipped with hydraulic system to compress voluminous waste materials enroute.

Refuse Derived Fuel (rdf): Material derived from processed mixed waste used as a primary or partial feedstock to incineration.

Remanufacturing: The process in which large quantities of similar product cores are brought to a central facility and disassembled. Parts from a specific product are not kept together. New products are assembled from parts which are cleaned and/or repaired.

Repair: The process of bringing individual products back to a functional state on a one-at-a-time basis.

Residue: The materials remaining after completion of a chemical or physical process, such as burning, evaporation, manufacturing, distillation, and filtration.

Resource Recovery: A general term referring to any method for reclaiming materials or energy from municipal waste.

Roll-Off Bin: Specially designed storage container which can be hydraulically pulled onto the bed of a vehicle for efficient transport.

Roofing Felt: Heavy construction paper that is impregnated with asphalt for use as a roofing material. Generally comprised of 55% secondary fiber.

Rubber: A natural or synthetic elastic material comprised of polymers. Chemical treatment can enhance properties required for tires, shoes, insulation and other products.

Salvage Industry: Infrastructure of formal and informal enterprises engaged in recovery and processing of secondary commodities.

Sampling: Methodological analysis of representative portions of municipal waste which indicates quantity and quality characteristics.

Sanitary Landfill: Site specifically engineered for disposal of waste on land which minimizes potential air and leachate pollution. Operations include layering, compaction and soil cover at the end of the day.

Sanitation: The process of collecting, transporting, and disposing of waste materials in a hygenic manner.

Scrap: Segregated waste commodities suitable for recycling (See Home Scrap, Prompt Scrap, and Obsolete Scrap).

Secondary Materials: Wastes which are channeled back into a production process.

Separate Collection: Scheduled or nonscheduled collection of source separated commodities by service other than regular refuse collection.

Sorting: Separation of secondary commodities into uniform categories (e.g., glass, metals, etc.). Also, separation of recyclable commodities from nonrecyclable commodities.

Source Reduction (waste reduction): The reduction of waste generation at the source, or site of manufacture, via new production techniques, product package redesign and/or institutional design.

Source Separation (source segregation): The separation of waste commodities by generating households, agencies, and industries.

Sustainability: The concept of contributing to the long term viability of the environment.

Thermal-chemical Conversion: The conversion of organic waste into energy through combustion or chemical processes.

Transfer Station: Aggregation point for efficient transfer of waste materials to distant disposal sites.

User Fee (tariff): Surcharge imposed on individuals or group who pay for service level.

Value Added: Incremental value of labor or energy by processing of material or improvement of commodity.

Vermicomposting: The use of earthworms to digest raw or stabilized organic waste.

Vertical Integration: Operation of a production system along successive stages of flow of commodities from source through manufacturing to distribution; e.g., integrated pulp and paper mill.

Virgin Material: Raw materials extracted from natural resources used in manufacturing.

Waste Management: Public role of assuring proper collection and disposal of municipal waste to insure efficiency and public hygiene.

Waste Utilization: Transformation of waste commodities into new products.

White Goods: Appliances comprised primarily of ferrous metal, such as refrigerators, stoves, and washing machines.

Wobo (World Bottle): Experimental bottles designed by Heineken Breweries for use as interlocking building units after contents are consumed.

Zabaleen: Generic term for several Christian minorities in Egyptian cities who are responsible for collection, recycling, and disposal of solid wastes.

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The World Bank

Headquarters:
1818 H Street, N.W.
Washington, D.C. 20433, U.S.A.

Telephone: (202) 477-1234
Telex: WUI 64145 WORLDBANK
RCA 248423 WORLDBK
Cable address: INTBAFRAD
WASHINGTONDC

European Office:
66, avenue d'Iéna
75116 Paris, France

Telephone: (1) 723-54.21
Telex: 842-620628

Tokyo Office:
Kokusai Building
1-1, Marunouchi 3-chome
Chiyoda-ku, Tokyo 100, Japan

Telephone: (03) 214-5001
Telex: 781-26838

UNDP

New York:
United Nations Development Programme
1 United Nations Plaza
New York, New York 10017

Telephone: (212) 754-1234
Telex. 125980 (domestic)
232-422 (overseas)
Cable address: UNDEVPRO
NEW YORK

Geneva Office:
Palais des Nations
CH-1211 Geneva 10
Switzerland

Telephone: 98-84-00
98-58-50
Telex: (UNDP) 28.96.20 or (UN) 28.96.96
Cable address: UNDEVPRO
GENEVA (SWITZERLAND)

Tokyo Office:
Shin Aoyama Building
Room 2255
1-1, Minami-Aoyama 1-Chome
Minato-Ku
Tokyo 107, Japan

Telephone: 03-475-1619/20
Telex: J28 334
AB TKOP1 J28 334
Cable: UNDEVPRO
TOKYO (JAPAN)

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Recycling opportunities after the pole shift

(1/14/2017)

- Everything will be saved by default, for there will be no trash collator showing up to take it away.

- One needs to attempt to find a use for everything. For eventually one will become overwhelmed with the mess one has around one.

- Use imagination to find how the item can be repurposed and reused.

Sort and save by similarities:
Provide a separate place or container for each type of item. The following is not a comprehensive list, but only a start.

- Plastic bottles one place.
- Glass bottles another place, --
- Plastic bags
- Paper bags
- Cardboard
- Clear hard plastic packaging used on new items.
- Paper products
- Food products
- Metal cans
- Electronics

Possible uses are:

- Some items can only be used to burn to keep a fire going, this depending on it's estimated future value as not having another use. This could be paper, cardboard products. Cardboard can be used for insulation.

- Metal cans can be used to cook or carry water or dig or to make a tool to cut with or to make a trap.

- Waste food products can be used to make compost or attract animals or insects when hunting or trapping.

- Anything that can hold water whether plastic, glass or metal has that use and possibly cooking or storage.

- Clear thin plastic that is the thrown away part of the packaging that is used on new items is very valuable and has many uses. This plastic is usually clear and has a form to it or is flat. The cut off edges as you open the package, can be used for plastic welding rod. The formed peaces can be used to hold things or as a mold. Heating and bending of this is very easy. A flat peace with holes in each end can be used to make A rudimentary goggles to keep sand and dirt out the eyes when the wind is blowing.

- Scrap plastic of all types can be used to help start and keep a fire going. For with the heat of a flame plastic turns back into profane wax and burns. Scraps of plastic can be heated in a pot until it turns to liquid wax and then pored over rolled up cardboard to make a wick that has been put in a small tuna fish type can. Once cooled this makes a good small long burning candle heat source for emergencies that can be used to start larger fires or for heat and light.

- Plastic bags can be used to make sand bags, keep things dry, food storage, assist in carrying small items, keep one warm when sleeping, or with dry grass or equivalent in a plastic bag can make for good insulation.

- Human shit can be used to attract animals and insects that can be hunted. It is not recommended to be used for fertilize for human food plants. Unless the plants will be used for pet or animal food. Pathogens tend to escalate when human shit is used in a short recycling loop for human food fertilizer.

- Plastic bottles can be used for flotation in raft or boat building. They can be part of water purification filtering process where it can be filled with charcoal or sand or rags or a combination.

Soon you will be an expert with more capability beyond this short write up and can pass on your innovations to others around you.

When you run out of junk to recycle at one place move on and find a new source. Being near a salvage yard or a garbage dump becomes way more desirable than being near any pre-pole shift store.

Red blood cell

From Wikipedia, the free encyclopedia

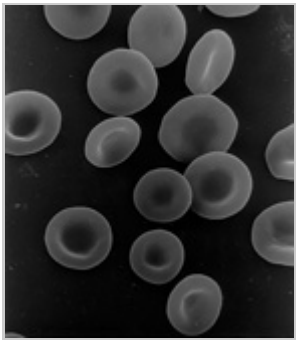

Scanning electron micrograph of human red blood cells (ca. 6–8 μm in diameter)

Red blood cells (**RBCs**), also called **erythrocytes**, are the most common type of blood cell and the vertebrate organism's principal means of delivering oxygen (O_2) to the body tissues—via blood flow through the circulatory system.[1] RBCs take up oxygen in the lungs or gills and release it into tissues while squeezing through the body's capillaries.

The cytoplasm of erythrocytes is rich in hemoglobin, an iron-containing biomolecule that can bind oxygen and is responsible for the red color of the cells. The cell membrane is composed of proteins and lipids, and this structure provides properties essential for physiological cell function such as deformability and stability while traversing the circulatory system and specifically the capillary network.

In humans, mature red blood cells are flexible and oval biconcave disks. They lack a cell nucleus and most organelles, in order to accommodate maximum space for hemoglobin; they can be viewed as sacks of hemoglobin, with a plasma membrane as the sack. Approximately 2.4 million new erythrocytes are produced per second in human adults.[2] The cells develop in the bone marrow and circulate for about 100–120 days in the body before their components are recycled by macrophages. Each circulation takes about 60 seconds i.e one minute.[3] Approximately a quarter of the cells in the human body are red blood cells.[4][5] Nearly half of the blood's volume (40% to 45%) is red blood cells.

Red blood cells are also known as **RBCs**, **red cells**,[6] **red blood corpuscles**, **haematids**, **erythroid cells** or **erythrocytes** (from Greek *erythros* for "red" and *kytos* for "hollow vessel", with *-cyte* translated as "cell" in modern usage). Packed red blood cells (pRBC) are red blood cells that have been donated, processed, and stored in a blood bank for blood transfusion.

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History

The first person to describe red blood cells was the young Dutch biologist Jan Swammerdam, who had used an early microscope in 1658 to study the blood of a frog.[7] Unaware of this work, Anton van Leeuwenhoek provided another microscopic description in 1674, this time providing a more precise description of red blood cells, even approximating their size, "25,000 times smaller than a fine grain of sand".

In 1901, Karl Landsteiner published his discovery of the three main blood groups—A, B, and C (which he later renamed to O). Landsteiner described the regular patterns in which reactions occurred when serum was mixed with red blood cells, thus identifying compatible and conflicting combinations between these blood groups. A year later Alfred von Decastello and Adriano Sturli, two colleagues of Landsteiner, identified a fourth blood group—AB.

In 1959, by use of X-ray crystallography, Dr. Max Perutz was able to unravel the structure of hemoglobin, the red blood cell protein that carries oxygen.[8]

The oldest intact red blood cells ever discovered were found in Ötzi the Iceman, a natural mummy of a man who died around 3255 BCE. These cells were discovered in May 2012.[9]

Vertebrate erythrocytes

Erythrocytes consist mainly of hemoglobin, a complex metalloprotein containing heme groups whose iron atoms temporarily bind to oxygen molecules (O_2) in the lungs or gills and release them throughout the body. Oxygen can easily diffuse through the red blood cell's cell membrane. Hemoglobin in the erythrocytes also carries some of the waste product carbon dioxide back from the tissues; most waste carbon dioxide, however, is transported back to the pulmonary capillaries of the lungs as bicarbonate (HCO_3^-) dissolved in the blood plasma. Myoglobin, a compound related to hemoglobin, acts to store oxygen in muscle cells.[11]

The color of erythrocytes is due to the heme group of hemoglobin. The blood plasma alone is straw-colored, but the red blood cells change color depending on the state of the hemoglobin: when combined with oxygen the resulting oxyhemoglobin is scarlet, and when oxygen has been released the resulting deoxyhemoglobin is of a dark red burgundy color. However, blood can appear bluish when seen through the vessel wall and skin.[12] Pulse oximetry takes advantage of the hemoglobin color change to directly measure the arterial blood oxygen saturation using colorimetric techniques. Hemoglobin also has a very high affinity for carbon monoxide, forming carboxyhemoglobin which is a very bright red in color. Flushed, confused patients with a saturation reading of 100% on pulse oximetry are sometimes found to be suffering from carbon monoxide poisoning.

The sequestration of oxygen-carrying proteins inside specialized cells (as opposed to oxygen carriers being dissolved in body fluid) was an important step in the evolution of vertebrates as it allows for less viscous blood, higher concentrations of oxygen, and better diffusion of oxygen from the blood to the tissues. The size of erythrocytes varies widely among vertebrate species; erythrocyte width is on average about 25% larger than capillary diameter, and it has been hypothesized that this improves the oxygen transfer from erythrocytes to tissues.[13]

The only known vertebrates without erythrocytes are the crocodile icefishes (family Channichthyidae); they live in very oxygen-rich cold water and transport oxygen freely dissolved in their blood.[14] While they do not use hemoglobin anymore, remnants of hemoglobin genes can be found in their genome.[15]

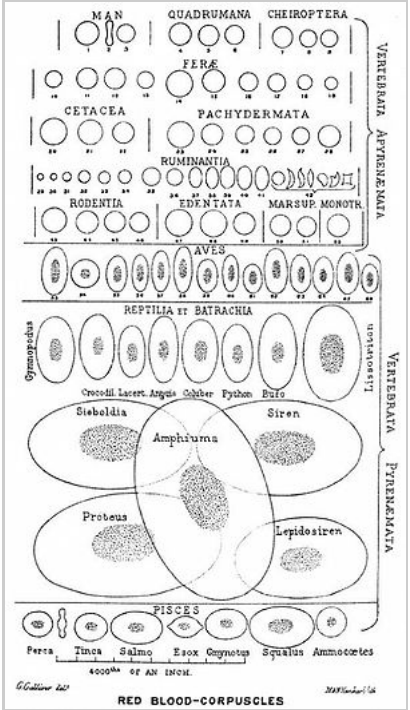

There is an immense size variation in vertebrate erythrocytes, as well as a correlation between cell and nucleus size. Mammalian erythrocytes, which do not contain nuclei, are considerably smaller than those of most other vertebrates.[10]

Nucleus

Erythrocytes in mammals are *anucleate* when mature, meaning that they lack a cell nucleus. In comparison, the erythrocytes of other vertebrates have nuclei; the only known exceptions are salamanders of the *Batrachoseps* genus and fish of the *Maurolicus* genus with closely related species.[16][17]

The elimination of the nucleus in vertebrate erythrocytes has been offered as an explanation for the subsequent accumulation of non-coding DNA in the genome.[18] The argument runs as follows: Efficient gas transport requires erythrocytes to pass through very narrow capillaries, and this constrains their size. In the absence of nuclear elimination, the accumulation of repeat sequences is constrained by the volume occupied by the nucleus, which increases with genome size.

Nucleated red blood cells in mammals consist of two forms: normoblasts, which are normal erythropoietic precursors to mature erythrocytes, and megaloblasts, which are abnormally large precursors that occur in megaloblastic anemias.

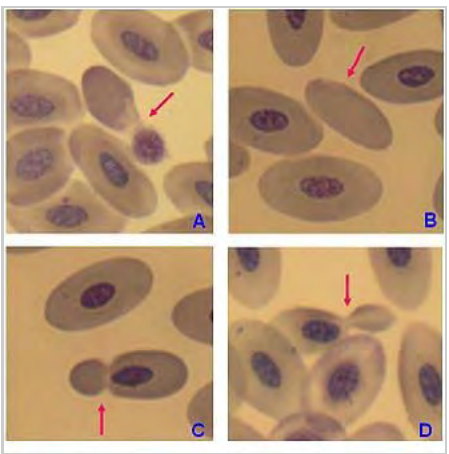

Mature erythrocytes of birds have a nucleus, however in the blood of adult females of penguin *Pygoscelis papua* enucleated red blood cells (**B**) have been observed, but with very low frequency.

Secondary functions

When erythrocytes undergo shear stress in constricted vessels, they release ATP, which causes the vessel walls to relax and dilate so as to promote normal blood flow.[19]

When their hemoglobin molecules are deoxygenated, erythrocytes release S-nitrosothiols, which also act to dilate blood vessels,[20] thus directing more blood to areas of the body depleted of oxygen.

Erythrocytes can also synthesize nitric oxide enzymatically, using L-arginine as substrate, as do endothelial cells.[21] Exposure of erythrocytes to physiological levels of shear stress activates nitric oxide

synthase and export of nitric oxide,[22] which may contribute to the regulation of vascular tonus.

Erythrocytes can also produce hydrogen sulfide, a signalling gas that acts to relax vessel walls. It is believed that the cardioprotective effects of garlic are due to erythrocytes converting its sulfur compounds into hydrogen sulfide.[23]

Erythrocytes also play a part in the body's immune response: when lysed by pathogens such as bacteria, their hemoglobin releases free radicals, which break down the pathogen's cell wall and membrane, killing it.[24][25]

Mammalian erythrocytes

Mammalian erythrocytes are unique among the vertebrates as they are non-nucleated cells in their mature form. These cells have nuclei during early phases of erythropoiesis, but extrude them during development as they mature in order to provide more space for hemoglobin. The enucleated erythrocytes, called reticulocytes, go on to lose all other cellular organelles such as their mitochondria, Golgi apparatus and endoplasmic reticulum.

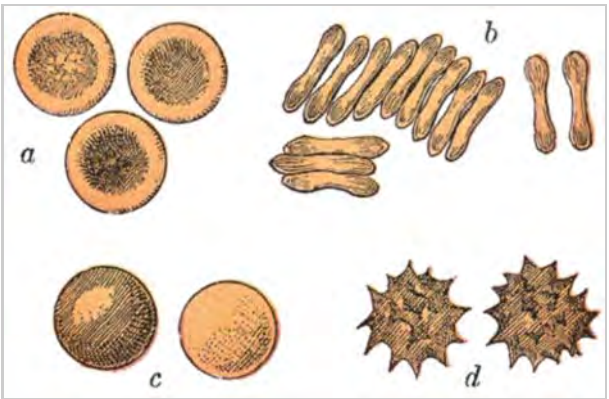

Typical mammalian erythrocytes: (a) seen from surface; (b) in profile, forming rouleaux; (c) rendered spherical by water; (d) rendered crenate by salt. (c) and (d) do not normally occur in the body.

As a result of not containing mitochondria, these cells use none of the oxygen they transport; instead they produce the energy carrier ATP by the glycolysis of glucose and lactic acid fermentation on the resulting pyruvate.

Because of the lack of nuclei and organelles, mature red blood cells do not contain DNA and cannot synthesize any RNA, and consequently cannot divide and have limited repair capabilities.[26] The inability to carry out protein synthesis means that no virus can evolve to target mammalian red blood cells.[27] However, infection with parvoviruses (such as human parvovirus B19) can affect erythroid precursors, as recognized by the presence of giant pronormoblasts with viral particles and inclusion bodies, thus temporarily depleting the blood of reticulocytes and causing anemia.[28]

Mammalian erythrocytes are typically shaped as biconcave disks: flattened and depressed in the center, with a dumbbell-shaped cross section, and a torus-shaped rim on the edge of the disk. This distinctive biconcave shape optimises the flow properties of blood in the large vessels, such as maximization of laminar flow and minimization of platelet scatter, which suppresses their atherogenic activity in those large vessels.[29] However, there are some exceptions concerning shape in the artiodactyl order (even-toed ungulates including cattle, deer, and their relatives), which displays a wide variety of bizarre erythrocyte morphologies: small and highly ovaloid cells in llamas and camels (family Camelidae), tiny spherical cells in mouse deer (family Tragulidae), and cells which assume fusiform, lanceolate, crescentic, and irregularly polygonal and other angular forms in red deer and wapiti (family Cervidae). Members of this order have clearly evolved a mode of red blood cell development substantially different from the mammalian norm.[10][30] Overall, mammalian erythrocytes are remarkably flexible and deformable so as to squeeze through tiny capillaries, as well as to maximize their apposing surface by assuming a cigar shape, where they efficiently release their oxygen load.[31]

In large blood vessels, red blood cells sometimes occur as a stack, flat side next to flat side. This is known as *rouleaux formation*, and it occurs more often if the levels of certain serum proteins are elevated, as for instance

during inflammation.

The spleen acts as a reservoir of red blood cells, but this effect is somewhat limited in humans. In some other mammals such as dogs and horses, the spleen sequesters large numbers of red blood cells which are dumped into the blood during times of exertion stress, yielding a higher oxygen transport capacity.

Human erythrocytes

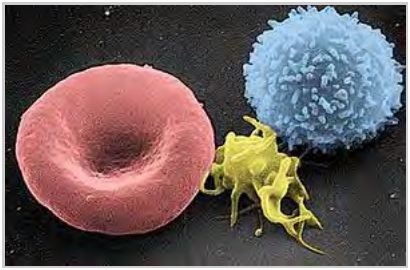

Scanning electron micrograph of blood cells. From left to right: human erythrocyte, thrombocyte (platelet), leukocyte.

A typical human erythrocyte has a disk diameter of approximately 6.2–8.2 µm[32] and a thickness at the thickest point of 2–2.5 µm and a minimum thickness in the centre of 0.8–1 µm, being much smaller than most other human cells. These cells have an average volume of about 90 fL[33] with a surface of about 136 μm^2, and can swell up to a sphere shape containing 150 fL, without membrane distension.

Adult humans have roughly 20–30 × 10^{12} (20–30 trillion) red blood cells at any given time, comprising approximately 70% of the total human body cell number.[34] Women have about 4 to 5 million erythrocytes per microliter (cubic millimeter) of blood and men about 5 to 6 million; people living at high altitudes with low oxygen tension will have more). Red blood cells are thus much more common than the other blood particles: there are about 4,000–11,000 white blood cells and about 150,000–400,000 platelets in each microliter of human blood.

Two drops of blood are shown with a bright red oxygenated drop on the left and a deoxygenated drop on the right.

Human red blood cells take on average 60 seconds to complete one cycle of circulation.[3][5][35]

As red blood cells contain no nucleus, protein biosynthesis is currently assumed to be absent in these cells.

The blood's red color is due to the spectral properties of the hemic iron ions in hemoglobin. Each human red blood cell contains approximately 270 million of these hemoglobin biomolecules, each carrying four heme groups; hemoglobin comprises about a third of the total cell volume. This protein is responsible for the transport of more than 98% of the oxygen (the remaining oxygen is carried dissolved in the blood plasma). The red blood cells of an average adult human male store collectively about 2.5 grams of iron, representing about 65% of the total iron contained in the body.[36][37] (See Human iron metabolism.)

Life cycle

Human erythrocytes are produced through a process named erythropoiesis, developing from committed stem cells to mature erythrocytes in about 7 days. When matured, in a healthy individual these cells live in blood circulation for about 100 to 120 days (and 80 to 90 days in a full term infant).[38] At the end of their lifespan, they become senescent, and are removed from circulation. In many chronic diseases, the lifespan of the erythrocytes is markedly reduced (e.g. patients requiring haemodialysis).

Erythropoiesis

Erythropoiesis is the development process by which new erythrocytes are produced; it lasts about 7 days.

Through this process erythrocytes are continuously produced in the red bone marrow of large bones, at a rate of about 2 million per second in a healthy adult. (In the embryo, the liver is the main site of red blood cell production.) The production can be stimulated by the hormone erythropoietin (EPO), synthesised by the kidney. Just before and after leaving the bone marrow, the developing cells are known as reticulocytes; these comprise about 1% of circulating red blood cells.

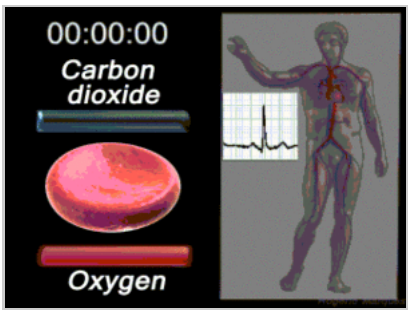

Animation of a typical human red blood cell cycle in the circulatory system. This animation occurs at a faster rate (~20 seconds of the average 60-second cycle) and shows the red blood cell deforming as it enters capillaries, as well as the bars changing color as the cell alternates in states of oxygenation along the circulatory system.

Functional lifetime

The functional lifetime of an erythrocyte is about 100–120 days, during which time the erythrocytes are continually moved by the blood flow push (in arteries), pull (in veins) and a combination of the two as they squeeze through microvessels such as capillaries.

Senescence

The aging erythrocyte undergoes changes in its plasma membrane, making it susceptible to selective recognition by macrophages and subsequent phagocytosis in the mononuclear phagocyte system (spleen, liver and lymph nodes), thus removing old and defective cells and continually purging the blood. This process is termed eryptosis, erythrocyte programmed cell death.[39] This process normally occurs at the same rate of production by erythropoiesis, balancing the total circulating red blood cell count. Eryptosis is increased in a wide variety of diseases including sepsis, haemolytic uremic syndrome, malaria, sickle cell anemia, beta-thalassemia, glucose-6-phosphate dehydrogenase deficiency, phosphate depletion, iron deficiency and Wilson's disease. Eryptosis can be elicited by osmotic shock, oxidative stress, energy depletion as well as a wide variety of endogenous mediators and xenobiotics. Excessive eryptosis is observed in erythrocytes lacking the cGMP-dependent protein kinase type I or the AMP-activated protein kinase AMPK. Inhibitors of eryptosis include erythropoietin, nitric oxide, catecholamines and high concentrations of urea.

Much of the resulting breakdown products are recirculated in the body. The heme constituent of hemoglobin are broken down into Fe^{3+} and biliverdin. The biliverdin is reduced to bilirubin, which is released into the plasma and recirculated to the liver bound to albumin. The iron is released into the plasma to be recirculated by a carrier protein called transferrin. Almost all erythrocytes are removed in this manner from the circulation before they are old enough to hemolyze. Hemolyzed hemoglobin is bound to a protein in plasma called haptoglobin, which is not excreted by the kidney.[40]

Membrane composition

The membrane of the red blood cell plays many roles that aid in regulating their surface deformability, flexibility, adhesion to other cells and immune recognition. These functions are highly dependent on its composition, which defines its properties. The red blood cell membrane is composed of 3 layers: the glycocalyx on the exterior, which is rich in carbohydrates; the lipid bilayer which contains many transmembrane proteins, besides its lipidic main constituents; and the membrane skeleton, a structural network of proteins located on the inner surface of the lipid bilayer. Half of the membrane mass in human and most mammalian erythrocytes are proteins. The other half are lipids, namely phospholipids and cholesterol.[41]

Membrane lipids

The erythrocyte cell membrane comprises a typical lipid bilayer, similar to what can be found in virtually all human cells. Simply put, this lipid bilayer is composed of cholesterol and phospholipids in equal proportions by weight. The lipid composition is important as it defines many physical properties such as membrane permeability and fluidity. Additionally, the activity of many membrane proteins is regulated by interactions with lipids in the bilayer.

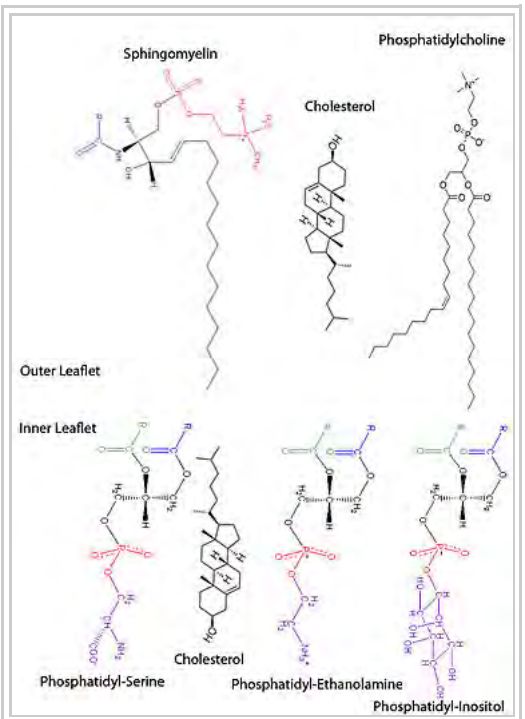

The most common erythrocyte cell membrane lipids, schematically disposed as they are distributed on the bilayer. Relative abundances are not at scale.

Unlike cholesterol, which is evenly distributed between the inner and outer leaflets, the 5 major phospholipids are asymmetrically disposed, as shown below:

Outer monolayer

- Phosphatidylcholine (PC);
- Sphingomyelin (SM).

Inner monolayer

- Phosphatidylethanolamine (PE);
- Phosphoinositol (PI) (small amounts).
- Phosphatidylserine (PS);

This asymmetric phospholipid distribution among the bilayer is the result of the function of several energy-dependent and energy-independent phospholipid transport proteins. Proteins called “Flippases” move phospholipids from the outer to the inner monolayer, while others called “floppases” do the opposite operation, against a concentration gradient in an energy dependent manner. Additionally, there are also “scramblase” proteins that move phospholipids in both directions at the same time, down their concentration gradients in an energy independent manner. There is still considerable debate ongoing regarding the identity of these membrane maintenance proteins in the red cell membrane.

The maintenance of an asymmetric phospholipid distribution in the bilayer (such as an exclusive localization of PS and PIs in the inner monolayer) is critical for the cell integrity and function due to several reasons:

- Macrophages recognize and phagocytose red cells that expose PS at their outer surface. Thus the confinement of PS in the inner monolayer is essential if the cell is to survive its frequent encounters with macrophages of the reticuloendothelial system, especially in the spleen.
- Premature destruction of thallassemic and sickle red cells has been linked to disruptions of lipid asymmetry leading to exposure of PS on the outer monolayer.
- An exposure of PS can potentiate adhesion of red cells to vascular endothelial cells, effectively preventing normal transit through the microvasculature. Thus it is important that PS is maintained only in the inner leaflet of the bilayer to ensure normal blood flow in microcirculation.
- Both PS and phosphatidylinositol-4,5-bisphosphate (PIP2) can regulate membrane mechanical function, due to their interactions with skeletal proteins such as spectrin and protein 4.1R. Recent studies have shown that binding of spectrin to PS promotes membrane mechanical stability. PIP2 enhances the binding of protein band 4.1R to glycophorin C but decreases its interaction with protein band 3, and

thereby may modulate the linkage of the bilayer to the membrane skeleton.

The presence of specialized structures named "lipid rafts" in the erythrocyte membrane have been described by recent studies. These are structures enriched in cholesterol and sphingolipids associated with specific membrane proteins, namely flotillins, stomatins (band 7), G-proteins, and β-adrenergic receptors. Lipid rafts that have been implicated in cell signaling events in nonerythroid cells have been shown in erythroid cells to mediate β2-adregenic receptor signaling and increase cAMP levels, and thus regulating entry of malarial parasites into normal red cells.[42][43]

Membrane proteins

The proteins of the membrane skeleton are responsible for the deformability, flexibility and durability of the red blood cell, enabling it to squeeze through capillaries less than half the diameter of the erythrocyte (7–8 μm) and recovering the discoid shape as soon as these cells stop receiving compressive forces, in a similar fashion to an object made of rubber.

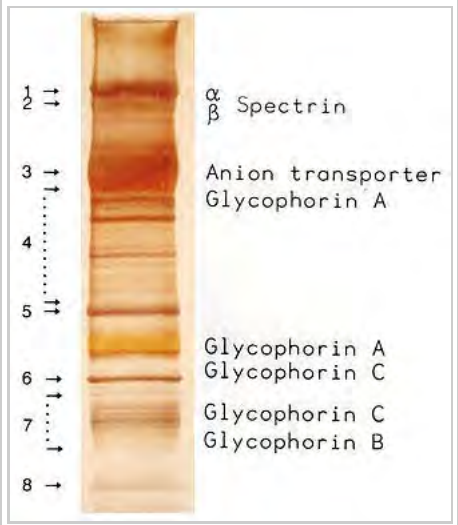

Red blood cell membrane proteins separated by SDS-PAGE and silverstained [44]

There are currently more than 50 known membrane proteins, which can exist in a few hundred up to a million copies per erythrocyte. Approximately 25 of these membrane proteins carry the various blood group antigens, such as the A, B and Rh antigens, among many others. These membrane proteins can perform a wide diversity of functions, such as transporting ions and molecules across the red cell membrane, adhesion and interaction with other cells such as endothelial cells, as signaling receptors, as well as other currently unknown functions. The blood types of humans are due to variations in surface glycoproteins of erythrocytes. Disorders of the proteins in these membranes are associated with many disorders, such as hereditary spherocytosis, hereditary elliptocytosis, hereditary stomatocytosis, and paroxysmal nocturnal hemoglobinuria.[41][42]

The red blood cell membrane proteins organized according to their function:

Transport

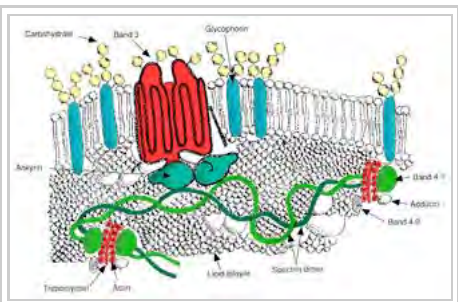
Red blood cell membrane major proteins

- Band 3 – Anion transporter, also an important structural component of the erythrocyte cell membrane, makes up to 25% of the cell membrane surface, each red cell contains approximately one million copies. Defines the Diego Blood Group;[45]
- Aquaporin 1 – water transporter, defines the Colton Blood Group;
- Glut1 – glucose and L-dehydroascorbic acid transporter;
- Kidd antigen protein – urea transporter;
- RhAG – gas transporter, probably of carbon dioxide, defines Rh Blood Group and the associated unusual blood group phenotype Rh_{null};
- Na^+/K^+ – ATPase;
- Ca^{2+} – ATPase;

- Na^+ K^+ $2Cl^-$ – cotransporter;
- Na^+-Cl^- – cotransporter;
- Na-H exchanger;
- K-Cl – cotransporter;
- Gardos Channel.

Cell adhesion

- ICAM-4 – interacts with integrins;
- BCAM – a glycoprotein that defines the Lutheran blood group and also known as Lu or laminin-binding protein.

Structural role – The following membrane proteins establish linkages with skeletal proteins and may play an important role in regulating cohesion between the lipid bilayer and membrane skeleton, likely enabling the red cell to maintain its favorable membrane surface area by preventing the membrane from collapsing (vesiculating).

- Ankyrin-based macromolecular complex – proteins linking the bilayer to the membrane skeleton through the interaction of their cytoplasmic domains with Ankyrin.
  - Band 3 – also assembles various glycolytic enzymes, the presumptive CO_2 transporter, and carbonic anhydrase into a macromolecular complex termed a "metabolon," which may play a key role in regulating red cell metabolism and ion and gas transport function);
  - RhAG – also involved in transport, defines associated unusual blood group phenotype Rh_{mod}.
- Protein 4.1R-based macromolecular complex – proteins interacting with Protein 4.1R.
  - Protein 4.1R – weak expression of Gerbich antigens;
  - Glycophorin C and D – glycoprotein, defines Gerbich Blood Group;
  - XK – defines the Kell Blood Group and the Mcleod unusual phenotype (lack of Kx antigen and greatly reduced expression of Kell antigens);
  - RhD/RhCE – defines Rh Blood Group and the associated unusual blood group phenotype Rh_{null};
  - Duffy protein – has been proposed to be associated with chemokine clearance;[46]
  - Adducin – interaction with band 3;
  - Dematin- interaction with the Glut1 glucose transporter.

[41][42]

Surface electrostatic potential

The zeta potential is an electrochemical property of cell surfaces that is determined by the net electrical charge of molecules exposed at the surface of cell membranes of the cell. The normal zeta potential of the erythrocyte is −15.7 millivolts (mV).[47] Much of this potential appears to be contributed by the exposed sialic acid residues in the membrane: their removal results in zeta potential of −6.06 mV.

Clinical notes

Separation and blood doping

Red blood cells can be obtained from whole blood by centrifugation, which separates the cells from the blood

plasma in a process known as blood fractionation. Packed red blood cells, which are made in this way from whole blood with the plasma removed, are used in transfusion medicine.[48] During plasma donation, the red blood cells are pumped back into the body right away and only the plasma is collected.

Some athletes have tried to improve their performance by blood doping: first about 1 litre of their blood is extracted, then the red blood cells are isolated, frozen and stored, to be reinjected shortly before the competition. (Red blood cells can be conserved for 5 weeks at −79 °C or −110 °F) This practice is hard to detect but may endanger the human cardiovascular system which is not equipped to deal with blood of the resulting higher viscosity. Another method of blood doping involves injection with erythropoietin in order to stimulate production of red blood cells. Both practices are banned by the World Anti-Doping Agency.

Artificially grown red blood cells

In 2008 it was reported that human embryonic stem cells had been successfully coaxed into becoming erythrocytes in the lab. The difficult step was to induce the cells to eject their nucleus; this was achieved by growing the cells on stromal cells from the bone marrow. It is hoped that these artificial erythrocytes can eventually be used for blood transfusions.[49]

Diseases and diagnostic tools

Blood diseases involving the red blood cells include:

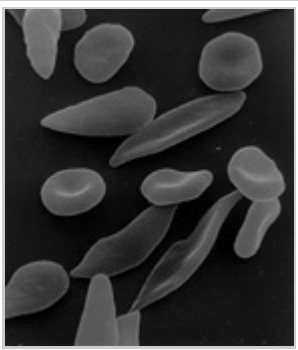

Affected by Sickle-cell disease, red blood cells alter shape and threaten to damage internal organs.

- Anemias (or anaemias) are diseases characterized by low oxygen transport capacity of the blood, because of low red cell count or some abnormality of the red blood cells or the hemoglobin.
    - Iron deficiency anemia is the most common anemia; it occurs when the dietary intake or absorption of iron is insufficient, and hemoglobin, which contains iron, cannot be formed
    - Sickle-cell disease is a genetic disease that results in abnormal hemoglobin molecules. When these release their oxygen load in the tissues, they become insoluble, leading to mis-shaped red blood cells. These sickle shaped red cells are less deformable and viscoelastic meaning that they have become rigid and can cause blood vessel blockage, pain, strokes, and other tissue damage.
    - Thalassemia is a genetic disease that results in the production of an abnormal ratio of hemoglobin subunits.
    - Hereditary spherocytosis syndromes are a group of inherited disorders characterized by defects in the red blood cell's cell membrane, causing the cells to be small, sphere-shaped, and fragile instead of donut-shaped and flexible. These abnormal red blood cells are destroyed by the spleen. Several other hereditary disorders of the red blood cell membrane are known.[50]
    - Pernicious anemia is an autoimmune disease wherein the body lacks intrinsic factor, required to absorb vitamin B_{12} from food. Vitamin B_{12} is needed for the production of hemoglobin.
    - Aplastic anemia is caused by the inability of the bone marrow to produce blood cells.

    - Pure red cell aplasia is caused by the inability of the bone marrow to produce only red blood cells.

- Hemolysis is the general term for excessive breakdown of red blood cells. It can have several causes and can result in hemolytic anemia.

    - The malaria parasite spends part of its life-cycle in red blood cells, feeds on their hemoglobin and then breaks them apart, causing fever. Both sickle-cell disease and thalassemia are more common in malaria areas, because these mutations convey some protection against the parasite.

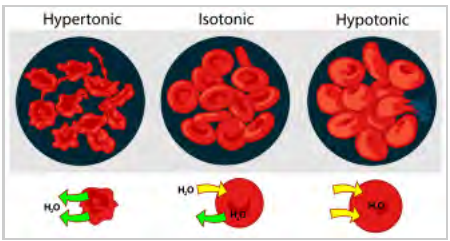

Effect of osmotic pressure on blood cells

- Polycythemias (or erythrocytoses) are diseases characterized by a surplus of red blood cells. The increased viscosity of the blood can cause a number of symptoms.

    - In polycythemia vera the increased number of red blood cells results from an abnormality in the bone marrow.

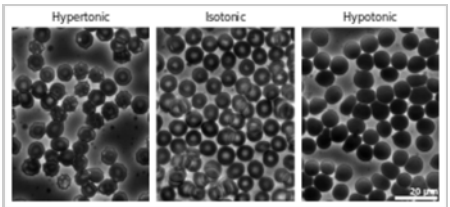

Micrographs of the effects of osmotic pressure

- Several microangiopathic diseases, including disseminated intravascular coagulation and thrombotic microangiopathies, present with pathognomonic (diagnostic) red blood cell fragments called schistocytes. These pathologies generate fibrin strands that sever red blood cells as they try to move past a thrombus.
- Hemolytic transfusion reaction is the destruction of donated red blood cells after a transfusion, mediated by host antibodies, often as a result of a blood type mismatch.

Several blood tests involve red blood cells, including the *RBC count* (the number of red blood cells per volume of blood), the hematocrit (percentage of blood volume occupied by red blood cells), and the erythrocyte sedimentation rate. Many diseases involving red blood cells are diagnosed with a blood film (or peripheral blood smear), where a thin layer of blood is smeared on a microscope slide. The blood type needs to be determined to prepare for a blood transfusion or an organ transplantation.

See also

- Altitude training
- Blood serum
- Erythrocyte deformability
- Erythrocyte fragility
- Hemoglobin-based oxygen carriers
- Packed red blood cells
- Red blood cell indices

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External links

- *Blood Groups and Red Cell Antigens* (http://www.ncbi.nlm.nih.gov/books/bv.fcgi?call=bv.View..ShowTOC&rid=rbcantigen.TOC&depth=2) by Laura Dean. Searchable and downloadable online textbook in the public domain.
- Database of vertebrate erythrocyte sizes (http://www.genomesize.com/cellsize/).
- Red Gold (http://www.pbs.org/wnet/redgold), PBS site containing facts and history

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Redox

From Wikipedia, the free encyclopedia

Redox (short for **reduction–oxidation reaction**) is a chemical reaction in which the oxidation states of atoms are changed. Any such reaction involves both a reduction process and a complementary oxidation process, two key concepts involved with electron transfer processes.[1] Redox reactions include all chemical reactions in which atoms have their oxidation state changed; in general, redox reactions involve the transfer of electrons between chemical species. The chemical species from which the electron is stripped is said to have been oxidized, while the chemical species to which the electron is added is said to have been reduced. It can be explained in simple terms:

- **Oxidation** is the *loss* of electrons or an *increase* in oxidation state by a molecule, atom, or ion.
- **Reduction** is the *gain* of electrons or a *decrease* in oxidation state by a molecule, atom, or ion.

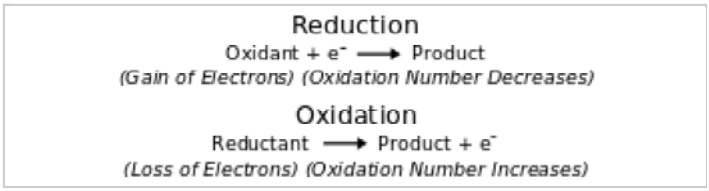

The two parts of a redox reaction

Rusting iron

A bonfire

As an example, during the combustion of wood, oxygen from the air is reduced, transferring electrons from the carbon.[2] Although oxidation reactions are commonly associated with the formation of oxides from oxygen molecules, oxygen is not necessarily included in such reactions, as other chemical species can serve the same function.[2]

The reaction can occur relatively slowly, as in the case of rust, or more quickly, as in the case of fire. There are simple redox processes, such as the oxidation of carbon to yield carbon dioxide (CO_2) or the reduction of carbon by hydrogen to yield methane (CH_4), and more complex processes such as the oxidation of glucose ($C_6H_{12}O_6$) in the human body.

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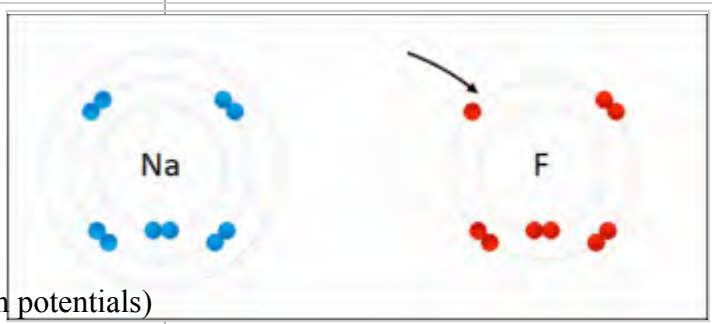

Sodium and fluorine bonding ionically to form sodium fluoride. Sodium loses its outer electron to give it a stable electron configuration, and this electron enters the fluorine atom exothermically. The oppositely charged ions are then attracted to each other. The sodium is oxidized, and the fluorine is reduced.

Demonstration of the reaction between a strong oxidising and a reducing agent. When few drops of glycerol (reducing agent) are added to powdered potassium permanganate (strong oxidising agent), a vigorous reaction accompanied by self-ignition starts.

Etymology

"Redox" is a combination of "reduction" and "oxidation".

The word *oxidation* originally implied reaction with oxygen to form an oxide, since dioxygen (O_2 (g)) was historically the first recognized oxidizing agent. Later, the term was expanded to encompass oxygen-like substances that accomplished parallel chemical reactions. Ultimately, the meaning was generalized to include all processes involving loss of electrons.

The word *reduction* originally referred to the loss in weight upon heating a metallic ore such as a metal oxide to extract the metal. In other words, ore was "reduced" to metal. Antoine Lavoisier (1743–1794) showed that this loss of weight was due to the loss of oxygen as a gas. Later, scientists realized that the metal atom gains electrons in this process. The meaning of *reduction* then became generalized to include all processes involving gain of electrons. Even though "reduction" seems counter-intuitive when speaking of the **gain** of electrons, it might help to think of reduction as the loss of oxygen, which was its historical meaning. Since electrons are negatively charged, it is also helpful to think of this as reduction in electrical charge.

The electrochemist John Bockris has used the words *electronation* and *deelectronation* to describe reduction and oxidation processes respectively when they occur at electrodes.[3] These words are analogous to protonation and deprotonation, but they have not been widely adopted by chemists.

The term "hydrogenation" could be used instead of reduction, since hydrogen is the reducing agent in a large number of reactions, especially in organic chemistry and biochemistry. But, unlike oxidation, which has been generalized beyond its root element, hydrogenation has maintained its specific connection to reactions that *add* hydrogen to another substance (e.g., the hydrogenation of unsaturated fats into saturated fats, $R{-}CH{=}CH{-}R + H_2 \rightarrow R{-}CH_2{-}CH_2{-}R$). The word "redox" was first used in 1928.[4]

Definitions

The processes of oxidation and reduction occur simultaneously and cannot happen independently of one another, similar to the acid–base reaction.[2] The oxidation alone and the reduction alone are each called a *half-reaction*, because two half-reactions always occur together to form a whole reaction. When writing half-reactions, the gained or lost electrons are typically included explicitly in order that the half-reaction be balanced with respect to electric charge.

Though sufficient for many purposes, these general descriptions are not precisely correct. Although oxidation and reduction properly refer to *a change in oxidation state* — the actual transfer of electrons may never occur. The oxidation state of an atom is the fictitious charge that an atom would have if all bonds between atoms of different elements were 100% ionic. Thus, oxidation is best defined as an *increase in oxidation state*, and reduction as a *decrease in oxidation state*. In practice, the transfer of electrons will always cause a change in oxidation state, but there are many reactions that are classed as "redox" even though no electron transfer occurs (such as those involving covalent bonds).

Oxidizing and reducing agents

In redox processes, the reductant transfers electrons to the oxidant. Thus, in the reaction, the reductant or *reducing agent* loses electrons and is oxidized, and the oxidant or *oxidizing agent* gains electrons and is reduced. The pair of an oxidizing and reducing agent that are involved in a particular reaction is called a **redox pair**. A **redox couple** is a reducing species and its corresponding oxidizing form, e.g., Fe^{2+}/Fe^{3+}.

Oxidizers

Substances that have the ability to **oxidize** other substances (cause them to lose electrons) are said to be **oxidative** or **oxidizing** and are known as oxidizing agents, oxidants, or oxidizers. That is, the oxidant (oxidizing agent) removes electrons from another substance, and is thus itself reduced. And, because it "accepts" electrons, the oxidizing agent is also called an electron acceptor. Oxygen is the quintessential oxidizer.

Oxidants are usually chemical substances with elements in high oxidation states (e.g., H_2O_2, MnO_4^-, CrO_3, $Cr_2O_7^{2-}$, OsO_4), or else highly electronegative elements (O_2, F_2, Cl_2, Br_2) that can gain extra electrons by oxidizing another substance.

Reducers

The international pictogram for oxidising chemicals.

Substances that have the ability to **reduce** other substances (cause them to gain electrons) are said to be **reductive** or **reducing** and are known as reducing agents, reductants, or reducers. The reductant (reducing agent) transfers electrons to another substance, and is thus itself oxidized. And, because it "donates" electrons, the reducing agent is also called an electron donor. Electron donors can also form charge transfer complexes with electron acceptors.

Reductants in chemistry are very diverse. Electropositive elemental metals, such as lithium, sodium, magnesium, iron, zinc, and aluminium, are good reducing agents. These metals donate or *give away* electrons readily. *Hydride transfer reagents*, such as $NaBH_4$ and $LiAlH_4$, are widely used in organic chemistry,[5][6] primarily in the reduction of carbonyl compounds to alcohols. Another method of reduction involves the use of hydrogen gas (H_2) with a palladium, platinum, or nickel catalyst. These *catalytic reductions* are used primarily in the reduction of carbon-carbon double or triple bonds.

Standard electrode potentials (reduction potentials)

Each half-reaction has a *standard electrode potential* (E^0_{cell}), which is equal to the potential difference or voltage at equilibrium under standard conditions of an electrochemical cell in which the cathode reaction is the half-reaction considered, and the anode is a standard hydrogen electrode where hydrogen is oxidized:

$$\tfrac{1}{2}\,H_2 \rightarrow H^+ + e^-.$$

The electrode potential of each half-reaction is also known as its *reduction potential* E^0_{red}, or potential when the half-reaction takes place at a cathode. The reduction potential is a measure of the tendency of the oxidizing agent to be reduced. Its value is zero for $H^+ + e^- \rightarrow \tfrac{1}{2}\,H_2$ by definition, positive for oxidizing agents stronger than H^+ (e.g., +2.866 V for F_2) and negative for oxidizing agents that are weaker than H^+ (e.g., −0.763 V for Zn^{2+}).[7]

For a redox reaction that takes place in a cell, the potential difference is:

$$E^0_{cell} = E^0_{cathode} - E^0_{anode}$$

However, the potential of the reaction at the anode was sometimes expressed as an *oxidation potential*:

$$E^0_{ox} = -E^0_{red}.$$

The oxidation potential is a measure of the tendency of the reducing agent to be oxidized, but does not represent the physical potential at an electrode. With this notation, the cell voltage equation is written with a plus sign

$$E^0_{\text{cell}} = E^0_{\text{red(cathode)}} + E^0_{\text{ox(anode)}}$$

Examples of redox reactions

A good example is the reaction between hydrogen and fluorine in which hydrogen is being oxidized and fluorine is being reduced:

$$H_2 + F_2 \rightarrow 2\ HF$$

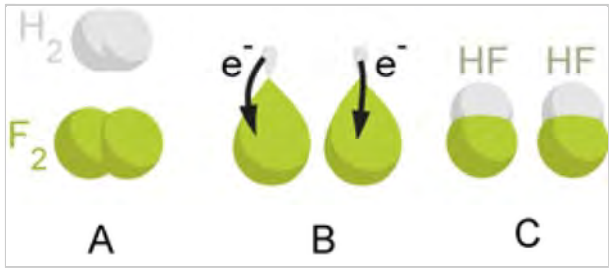

Illustration of a redox reaction

We can write this overall reaction as two half-reactions:

the oxidation reaction:

$$H_2 \rightarrow 2\ H^+ + 2\ e^-$$

and the reduction reaction:

$$F_2 + 2\ e^- \rightarrow 2\ F^-$$

Analyzing each half-reaction in isolation can often make the overall chemical process clearer. Because there is no net change in charge during a redox reaction, the number of electrons in excess in the oxidation reaction must equal the number consumed by the reduction reaction (as shown above).

Elements, even in molecular form, always have an oxidation state of zero. In the first half-reaction, hydrogen is oxidized from an oxidation state of zero to an oxidation state of +1. In the second half-reaction, fluorine is reduced from an oxidation state of zero to an oxidation state of −1.

When adding the reactions together the electrons are canceled:

$$\begin{array}{r} H_2 \rightarrow 2\ H^+ + 2\ e^- \\ F_2 + 2\ e^- \rightarrow 2\ F^- \\ \hline H_2 + F_2 \rightarrow 2\ H^+ + 2\ F^- \end{array}$$

And the ions combine to form hydrogen fluoride:

$$2\ H^+ + 2\ F^- \rightarrow 2\ HF$$

The overall reaction is:

$$H\ \ + F\ \ \rightarrow 2\ HF$$

2 2

Metal displacement

In this type of reaction, a metal atom in a compound (or in a solution) is replaced by an atom of another metal. For example, copper is deposited when zinc metal is placed in a copper(II) sulfate solution:

$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$

In the above reaction, zinc metal displaces the copper(II) ion from copper sulfate solution and thus liberates free copper metal.

The ionic equation for this reaction is:

$$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$$

As two half-reactions, it is seen that the zinc is oxidized:

$$Zn \rightarrow Zn^{2+} + 2\ e^-$$

And the copper is reduced:

$$Cu^{2+} + 2\ e^- \rightarrow Cu$$

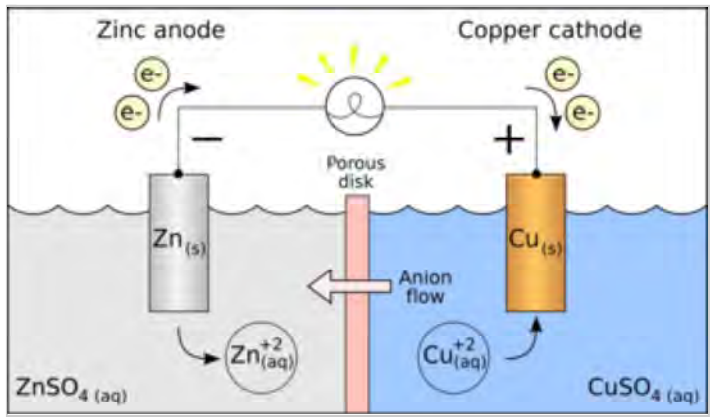

A redox reaction is the force behind an electrochemical cell like the Galvanic cell pictured. The battery is made out of a zinc electrode in a $ZnSO_4$ solution connected with a wire and a porous disk to a copper electrode in a $CuSO_4$ solution.

Other examples

- The reduction of nitrate to nitrogen in the presence of an acid (denitrification):

$$2\ NO_3^- + 10\ e^- + 12\ H^+ \rightarrow N_2 + 6\ H_2O$$

- The combustion of hydrocarbons, such as in an internal combustion engine, which produces water, carbon dioxide, some partially oxidized forms such as carbon monoxide, and heat energy. Complete oxidation of materials containing carbon produces carbon dioxide.
- In organic chemistry, the stepwise oxidation of a hydrocarbon by oxygen produces water and, successively, an alcohol, an aldehyde or a ketone, a carboxylic acid, and then a peroxide.

Corrosion and rusting

- The term corrosion refers to the electrochemical oxidation of metals in reaction with an oxidant such as oxygen. Rusting, the formation of iron oxides, is a well-known example of electrochemical corrosion; it forms as a result of the oxidation of iron metal. Common rust often refers to iron(III) oxide, formed in the following chemical reaction:

$$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$$

- The oxidation of iron(II) to iron(III) by hydrogen peroxide in the presence of an acid:

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$
$$H_2O_2 + 2\ e^- \rightarrow 2\ OH^-$$

Overall equation:

$$2\ Fe^{2+} + H_2O_2 + 2\ H^+ \rightarrow 2\ Fe^{3+} + 2\ H_2O$$

Oxides, such as iron(III) oxide or rust, which consists of hydrated iron (III) oxides $Fe_2O_3 \cdot nH_2O$ and iron(III) oxide-hydroxide (FeO(OH), $Fe(OH)_3$), form when oxygen combines with other elements

Iron rusting in pyrite cubes

Redox reactions in industry

Cathodic protection is a technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell. A simple method of protection connects protected metal to a more easily corroded "sacrificial anode" to act as the anode. The sacrificial metal instead of the protected metal, then, corrodes. A common application of cathodic protection is in galvanized steel, in which a sacrificial coating of zinc on steel parts protects them from rust.

The primary process of reducing ore at high temperature to produce metals is known as smelting.

Oxidation is used in a wide variety of industries such as in the production of cleaning products and oxidizing ammonia to produce nitric acid, which is used in most fertilizers.

Redox reactions are the foundation of electrochemical cells, which can generate electrical energy or support electrosynthesis.

The process of electroplating uses redox reactions to coat objects with a thin layer of a material, as in chrome-plated automotive parts, silver plating cutlery, and gold-plated jewelry.

The production of compact discs depends on a redox reaction, which coats the disc with a thin layer of metal film.

Redox reactions in biology

Many important biological processes involve redox reactions.

Cellular respiration, for instance, is the oxidation of glucose ($C_6H_{12}O_6$) to CO_2 and the reduction of oxygen to water. The summary equation for cell respiration is:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

The process of cell respiration also depends heavily on the reduction of NAD^+ to NADH and the reverse reaction (the oxidation of NADH to NAD^+). Photosynthesis and cellular respiration are complementary, but photosynthesis is not the reverse of the redox reaction in cell respiration:

$$6\ CO_2 + 6\ H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

Biological energy is frequently stored and released by means of redox reactions. Photosynthesis involves the reduction of carbon dioxide into sugars and the oxidation of water into molecular oxygen. The reverse reaction, respiration, oxidizes sugars to produce carbon dioxide and water. As intermediate steps, the reduced carbon compounds are used to reduce nicotinamide adenine dinucleotide (NAD^+), which then contributes to the creation of a proton gradient, which drives the synthesis of adenosine triphosphate (ATP) and is maintained by the reduction of oxygen. In animal cells, mitochondria perform similar functions. See the *Membrane potential* article.

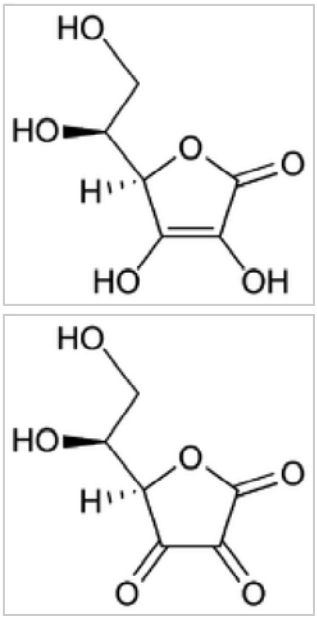

Top: ascorbic acid (reduced form of Vitamin C)
Bottom: dehydroascorbic acid (oxidized form of Vitamin C)

Free radical reactions are redox reactions that occur as a part of homeostasis and killing microorganisms, where an electron detaches from a molecule and then reattaches almost instantaneously. Free radicals are a part of redox molecules and can become harmful to the human body if they do not reattach to the redox molecule or an antioxidant. Unsatisfied free radicals can spur the mutation of cells they encounter and are, thus, causes of cancer.

The term **redox state** is often used to describe the balance of GSH/GSSG, NAD^+/NADH and $NADP^+$/NADPH in a biological system such as a cell or organ. The redox state is reflected in the balance of several sets of metabolites (e.g., lactate and pyruvate, beta-hydroxybutyrate, and acetoacetate), whose interconversion is dependent on these ratios. An abnormal redox state can develop in a variety of deleterious situations, such as hypoxia, shock, and sepsis. Redox mechanism also control some cellular processes. Redox proteins and their genes must be co-located for redox regulation according to the CoRR hypothesis for the function of DNA in mitochondria and chloroplasts.

Redox cycling

A wide variety of aromatic compounds are enzymatically reduced to form free radicals that contain one more electron than their parent compounds. In general, the electron donor is any of a wide variety of flavoenzymes and their coenzymes. Once formed, these anion free radicals reduce molecular oxygen to superoxide, and regenerate the unchanged parent compound. The net reaction is the oxidation of the flavoenzyme's coenzymes and the reduction of molecular oxygen to form superoxide. This catalytic behavior has been described as futile cycle or redox cycling.

Examples of redox cycling-inducing molecules are the herbicide paraquat and other viologens and quinones such as menadione.[8]

Redox reactions in geology

In geology, redox is important to both the formation of minerals and the mobilization of minerals, and is also important in some depositional environments. In general, the redox state of most rocks can be seen in the color of the rock. The rock forms in oxidizing conditions, giving it a red color. It is then "bleached" to a green—or sometimes white—form when a reducing fluid passes through the rock. The reduced fluid can also carry uranium-bearing minerals. Famous examples of redox conditions affecting geological processes include uranium deposits and Moqui marbles.

Mi Vida uranium mine, near Moab, Utah. The alternating red and white/green bands of sandstone correspond to oxidized and reduced conditions in groundwater redox chemistry.

Balancing redox reactions

Describing the overall electrochemical reaction for a redox process requires a *balancing* of the component half-reactions for oxidation and reduction. In general, for reactions in aqueous solution, this involves adding H^+, OH^-, H_2O, and electrons to compensate for the oxidation changes.

Acidic media

In acidic media, H^+ ions and water are added to half-reactions to balance the overall reaction.

For instance, when manganese(II) reacts with sodium bismuthate:

Unbalanced reaction: $Mn^{2+}(aq) + NaBiO_3(s) \rightarrow Bi^{3+}(aq) + MnO_4^-(aq)$

Oxidation: $4\ H_2O(l) + Mn^{2+}(aq) \rightarrow MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^-$

Reduction: $2\ e^- + 6\ H^+ + BiO_3^-(s) \rightarrow Bi^{3+}(aq) + 3\ H_2O(l)$

The reaction is balanced by scaling the two half-cell reactions to involve the same number of electrons (multiplying the oxidation reaction by the number of electrons in the reduction step and vice versa):

$$8\ H_2O(l) + 2\ Mn^{2+}(aq) \rightarrow 2\ MnO_4^-(aq) + 16\ H^+(aq) + 10\ e^-$$
$$10\ e^- + 30\ H^+ + 5\ BiO_3^-(s) \rightarrow 5\ Bi^{3+}(aq) + 15\ H_2O(l)$$

Adding these two reactions eliminates the electrons terms and yields the balanced reaction:

$$14\ H^+(aq) + 2\ Mn^{2+}(aq) + 5\ NaBiO_3(s) \rightarrow 7\ H_2O(l) + 2\ MnO_4^-(aq) + 5\ Bi^{3+}(aq) + 5\ Na^+(aq)$$

Basic media

In basic media, OH^- ions and water are added to half reactions to balance the overall reaction.

For example, in the reaction between potassium permanganate and sodium sulfite:

Unbalanced reaction: $KMnO_4 + Na_2SO_3 + H_2O \rightarrow MnO_2 + Na_2SO_4 + KOH$

Reduction: $3\ e^- + 2\ H_2O + MnO_4^- \rightarrow MnO_2 + 4\ OH^-$

Oxidation: $2\ OH^- + SO_3^{2-} \rightarrow SO_4^{2-} + H_2O + 2\ e^-$

Balancing the number of electrons in the two half-cell reactions gives:

$$6\ e^- + 4\ H_2O + 2\ MnO_4^- \rightarrow 2\ MnO_2 + 8\ OH^-$$
$$6\ OH^- + 3\ SO_3^{2-} \rightarrow 3\ SO_4^{2-} + 3\ H_2O + 6\ e^-$$

Adding these two half-cell reactions together gives the balanced equation:

$$2\ KMnO_4 + 3\ Na_2SO_3 + H_2O \rightarrow 2\ MnO_2 + 3\ Na_2SO_4 + 2\ KOH$$

Memory aids

The key terms involved in redox are often confusing to students.[9][10] For example, an element that is oxidized loses electrons; however, that element is referred to as the reducing agent. Likewise, an element that is reduced gains electrons and is referred to as the oxidizing agent.[11] Acronyms or mnemonics are commonly used[12] to help remember the terminology:

- "OIL RIG" — **o**xidation **i**s **l**oss of electrons, **r**eduction **i**s **g**ain of electrons.[9][10][11][12]
- "LEO the lion says GER" — **l**oss of **e**lectrons is **o**xidation, **g**ain of **e**lectrons is **r**eduction.[9][10][11][12]
- "LEORA says GEROA" — **l**oss of **e**lectrons is **o**xidation (**r**educing **a**gent), **g**ain of **e**lectrons is **r**eduction (**o**xidizing **a**gent).[11]
- "RED CAT" and "AN OX", or "AnOx RedCat" ("an ox-red cat") — **red**uction occurs at the **cat**hode and the **an**ode is for **ox**idation.
- "RED CAT gains what AN OX loses" – **red**uction at the **cat**hode gains (electrons) what **an**ode **ox**idation loses (electrons).

See also

- Bessemer process
- Bioremediation
- Calvin cycle
- Chemical equation
- Chemical looping combustion
- Citric acid cycle
- Electrochemical series
- Electrochemistry
- Electrolysis
- Electron equivalent
- Electron transport chain
- Electrosynthesis
- Galvanic cell
- Hydrogenation
- Membrane potential
- Nucleophilic abstraction
- Organic redox reaction
- Oxidative addition and reductive elimination
- Oxidative phosphorylation
- Partial oxidation

- Pro-oxidant
- Reduced gas
- Reducing agent
- Reducing atmosphere
- Reduction potential
- Thermic reaction
- Transmetalation

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External links

- Chemical Equation Balancer (http://www.berkeleychurchill.com/software/chembal.php) – An open source chemical equation balancer that handles redox reactions.
- Video – Synthesis of Copper(II) Acetate (https://www.youtube.com/watch?v=rF1ls-v7puQ) 20 Feb. 2009
- Redox reactions calculator (http://www.shodor.org/UNChem/advanced/redox/redoxcalc.html)

Wikiquote has quotations related to: ***Redox***

Wikimedia Commons has media related to ***Redox reactions***.

- Redox reactions at Chemguide (http://www.chemguide.co.uk/inorganic/redox/definitions.html#top)
- Online redox reaction equation balancer, balances equations of any half-cell and full reactions (http://www.webqc.org/balance.php)

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Categories: Soil chemistry | Chemical reactions

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Redox

From Wikipedia, the free encyclopedia

Redox (short for **red**uction–**ox**idation reaction) is a chemical reaction in which the oxidation states of atoms are changed. Any such reaction involves both a reduction process and a complementary oxidation process, two key concepts involved with electron transfer processes.[1] Redox reactions include all chemical reactions in which atoms have their oxidation state changed; in general, redox reactions involve the transfer of electrons between chemical species. The chemical species from which the electron is stripped is said to have been oxidized, while the chemical species to which the electron is added is said to have been reduced. It can be explained in simple terms:

- **Oxidation** is the *loss* of electrons or an *increase* in oxidation state by a molecule, atom, or ion.
- **Reduction** is the *gain* of electrons or a *decrease* in oxidation state by a molecule, atom, or ion.

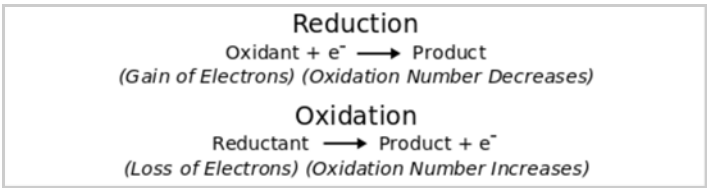

The two parts of a redox reaction

Rusting iron

A bonfire

As an example, during the combustion of wood, oxygen from the air is reduced, transferring electrons from the carbon.[2] Although oxidation reactions are commonly associated with the formation of oxides from oxygen molecules, oxygen is not necessarily included in such reactions, as other chemical species can serve the same function.[2]

The reaction can occur relatively slowly, as in the case of rust, or more quickly, as in the case of fire. There are simple redox processes, such as the oxidation of carbon to yield carbon dioxide (CO_2) or the reduction of carbon by hydrogen to yield methane (CH_4), and more complex processes such as the oxidation of glucose ($C_6H_{12}O_6$) in the human body.

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  - 3.1 Oxidizers
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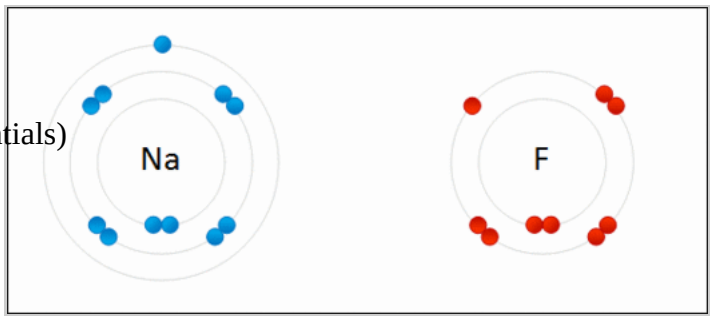

Sodium and fluorine bonding ionically to form sodium fluoride. Sodium loses its outer electron to give it a stable electron configuration, and this electron enters the fluorine atom exothermically. The oppositely charged ions are then attracted to each other. The sodium is oxidized, and the fluorine is reduced.

Demonstration of the reaction between a strong oxidising and a reducing agent. When few drops of glycerol (reducing agent) are added to powdered potassium permanganate (strong oxidising agent), a vigorous reaction accompanied by self-ignition starts.

Etymology

"Redox" is a combination of "reduction" and "oxidation".

The word *oxidation* originally implied reaction with oxygen to form an oxide, since dioxygen (O_2 (g)) was historically the first recognized oxidizing agent. Later, the term was expanded to encompass oxygen-like substances that accomplished parallel chemical reactions. Ultimately, the meaning was generalized to include all processes involving loss of electrons.

The word *reduction* originally referred to the loss in weight upon heating a metallic ore such as a metal oxide to extract the metal. In other words, ore was "reduced" to metal. Antoine Lavoisier (1743–1794) showed that this loss of weight was due to the loss of oxygen as a gas. Later, scientists realized that the metal atom gains electrons in this process. The meaning of *reduction* then became generalized to include all processes involving gain of electrons. Even though "reduction" seems counter-intuitive when speaking of the **gain** of electrons, it might help to think of reduction as the loss of oxygen, which was its historical meaning. Since electrons are negatively charged, it is also helpful to think of this as reduction in electrical charge.

The electrochemist John Bockris has used the words *electronation* and *deelectronation* to describe reduction and oxidation processes respectively when they occur at electrodes.[3] These words are analogous to protonation and deprotonation, but they have not been widely adopted by chemists.

The term "hydrogenation" could be used instead of reduction, since hydrogen is the reducing agent in a large number of reactions, especially in organic chemistry and biochemistry. But, unlike oxidation, which has been generalized beyond its root element, hydrogenation has maintained its specific connection to reactions that *add*

hydrogen to another substance (e.g., the hydrogenation of unsaturated fats into saturated fats, R−CH=CH−R + H_2 → R−CH_2−CH_2−R). The word "redox" was first used in 1928.[4]

Definitions

The processes of oxidation and reduction occur simultaneously and cannot happen independently of one another, similar to the acid–base reaction.[2] The oxidation alone and the reduction alone are each called a *half-reaction*, because two half-reactions always occur together to form a whole reaction. When writing half-reactions, the gained or lost electrons are typically included explicitly in order that the half-reaction be balanced with respect to electric charge.

Though sufficient for many purposes, these general descriptions are not precisely correct. Although oxidation and reduction properly refer to *a change in oxidation state* — the actual transfer of electrons may never occur. The oxidation state of an atom is the fictitious charge that an atom would have if all bonds between atoms of different elements were 100% ionic. Thus, oxidation is best defined as an *increase in oxidation state*, and reduction as a *decrease in oxidation state*. In practice, the transfer of electrons will always cause a change in oxidation state, but there are many reactions that are classed as "redox" even though no electron transfer occurs (such as those involving covalent bonds).

Oxidizing and reducing agents

In redox processes, the reductant transfers electrons to the oxidant. Thus, in the reaction, the reductant or *reducing agent* loses electrons and is oxidized, and the oxidant or *oxidizing agent* gains electrons and is reduced. The pair of an oxidizing and reducing agent that are involved in a particular reaction is called a **redox pair**. A **redox couple** is a reducing species and its corresponding oxidizing form, e.g., Fe^{2+}/Fe^{3+}.

Oxidizers

Substances that have the ability to **oxidize** other substances (cause them to lose electrons) are said to be **oxidative** or **oxidizing** and are known as oxidizing agents, oxidants, or oxidizers. That is, the oxidant (oxidizing agent) removes electrons from another substance, and is thus itself reduced. And, because it "accepts" electrons, the oxidizing agent is also called an electron acceptor. Oxygen is the quintessential oxidizer.

The international pictogram for oxidizing chemicals.

Oxidants are usually chemical substances with elements in high oxidation states (e.g., H_2O_2, MnO_4^-, CrO_3, $Cr_2O_7^{2-}$, OsO_4), or else highly electronegative elements (O_2, F_2, Cl_2, Br_2) that can gain extra electrons by oxidizing another substance.

Reducers

Substances that have the ability to **reduce** other substances (cause them to gain electrons) are said to be **reductive** or **reducing** and are known as reducing agents, reductants, or reducers. The reductant (reducing agent) transfers electrons to another substance, and is thus itself oxidized. And, because it "donates" electrons, the reducing agent is also called an electron donor. Electron donors can

also form charge transfer complexes with electron acceptors.

Reductants in chemistry are very diverse. Electropositive elemental metals, such as lithium, sodium, magnesium, iron, zinc, and aluminium, are good reducing agents. These metals donate or *give away* electrons readily. *Hydride transfer reagents*, such as $NaBH_4$ and $LiAlH_4$, are widely used in organic chemistry,[5][6] primarily in the reduction of carbonyl compounds to alcohols. Another method of reduction involves the use of hydrogen gas (H_2) with a palladium, platinum, or nickel catalyst. These *catalytic reductions* are used primarily in the reduction of carbon-carbon double or triple bonds.

Standard electrode potentials (reduction potentials)

Each half-reaction has a *standard electrode potential* (E^0_{cell}), which is equal to the potential difference or voltage at equilibrium under standard conditions of an electrochemical cell in which the cathode reaction is the half-reaction considered, and the anode is a standard hydrogen electrode where hydrogen is oxidized:

$$\tfrac{1}{2}\,H_2 \rightarrow H^+ + e^-.$$

The electrode potential of each half-reaction is also known as its *reduction potential* E^0_{red}, or potential when the half-reaction takes place at a cathode. The reduction potential is a measure of the tendency of the oxidizing agent to be reduced. Its value is zero for $H^+ + e^- \rightarrow \tfrac{1}{2}\,H_2$ by definition, positive for oxidizing agents stronger than H^+ (e.g., +2.866 V for F_2) and negative for oxidizing agents that are weaker than H^+ (e.g., −0.763 V for Zn^{2+}).[7]

For a redox reaction that takes place in a cell, the potential difference is:

$$E^0_{cell} = E^0_{cathode} - E^0_{anode}$$

However, the potential of the reaction at the anode was sometimes expressed as an *oxidation potential*:

$$E^0_{ox} = -E^0_{red}.$$

The oxidation potential is a measure of the tendency of the reducing agent to be oxidized, but does not represent the physical potential at an electrode. With this notation, the cell voltage equation is written with a plus sign

$$E^0_{cell} = E^0_{red(cathode)} + E^0_{ox(anode)}$$

Examples of redox reactions

A good example is the reaction between hydrogen and fluorine in which hydrogen is being oxidized and fluorine is being reduced:

$$H_2 + F_2 \rightarrow 2\,HF$$

We can write this overall reaction as two half-reactions:

the oxidation reaction:

$$H_2 \rightarrow 2\ H^+ + 2\ e^-$$

and the reduction reaction:

$$F_2 + 2\ e^- \rightarrow 2\ F^-$$

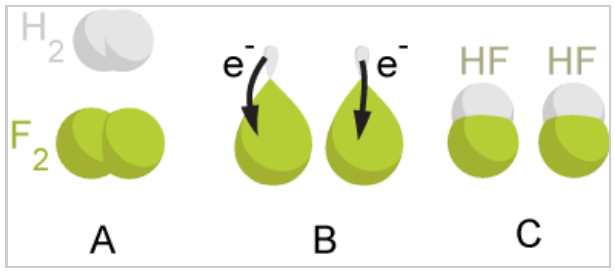

Illustration of a redox reaction

Analyzing each half-reaction in isolation can often make the overall chemical process clearer. Because there is no net change in charge during a redox reaction, the number of electrons in excess in the oxidation reaction must equal to the number consumed by the reduction reaction (as shown above).

Elements, even in molecular form, always have an oxidation state of zero. In the first half-reaction, hydrogen is oxidized from an oxidation state of zero to an oxidation state of +1. In the second half-reaction, fluorine is reduced from an oxidation state of zero to an oxidation state of −1.

When adding the reactions together the electrons are canceled:

$$\begin{array}{r} H_2 \rightarrow 2\ H^+ + 2\ e^- \\ F_2 + 2\ e^- \rightarrow 2\ F^- \\ \hline H_2 + F_2 \rightarrow 2\ H^+ + 2\ F^- \end{array}$$

And the ions combine to form hydrogen fluoride:

$$2\ H^+ + 2\ F^- \rightarrow 2\ HF$$

The overall reaction is:

$$H_2 + F_2 \rightarrow 2\ HF$$

Metal displacement

In this type of reaction, a metal atom in a compound (or in a solution) is replaced by an atom of another metal. For example, copper is deposited when zinc metal is placed in a copper(II) sulfate solution:

$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$$

In the above reaction, zinc metal displaces the copper(II) ion from copper sulfate solution and thus liberates free copper metal.

The ionic equation for this reaction is:

$$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$$

As two half-reactions, it is seen that the zinc is oxidized:

$$Zn \rightarrow Zn^{2+} + 2\ e^-$$

And the copper is reduced:

$$Cu^{2+} + 2\ e^- \rightarrow Cu$$

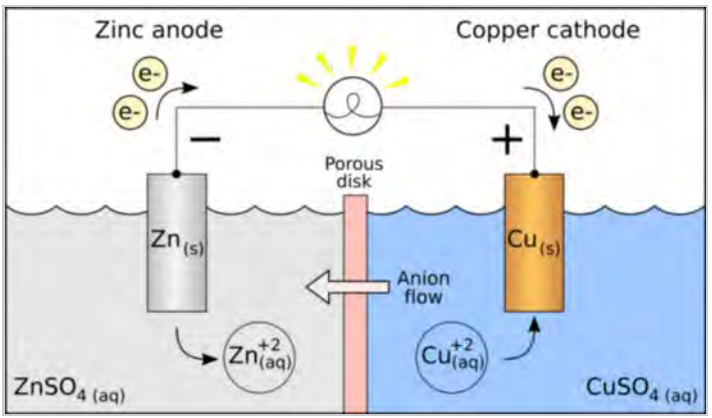

A redox reaction is the force behind an electrochemical cell like the Galvanic cell pictured. The battery is made out of a zinc electrode in a $ZnSO_4$ solution connected with a wire and a porous disk to a copper electrode in a $CuSO_4$ solution.

Other examples

- The reduction of nitrate to nitrogen in the presence of an acid (denitrification):

  $$2\ NO_3^- + 10\ e^- + 12\ H^+ \rightarrow N_2 + 6\ H_2O$$
- The combustion of hydrocarbons, such as in an internal combustion engine, which produces water, carbon dioxide, some partially oxidized forms such as carbon monoxide, and heat energy. Complete oxidation of materials containing carbon produces carbon dioxide.
- In organic chemistry, the stepwise oxidation of a hydrocarbon by oxygen produces water and, successively, an alcohol, an aldehyde or a ketone, a carboxylic acid, and then a peroxide.

Corrosion and rusting

- The term corrosion refers to the electrochemical oxidation of metals in reaction with an oxidant such as oxygen. Rusting, the formation of iron oxides, is a well-known example of electrochemical corrosion; it forms as a result of the oxidation of iron metal. Common rust often refers to iron(III) oxide, formed in the following chemical reaction:

  $$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$$
- The oxidation of iron(II) to iron(III) by hydrogen peroxide in the presence of an acid:

  $$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

  $$H_2O_2 + 2\ e^- \rightarrow 2\ OH^-$$

  Overall equation:

  $$2\ Fe^{2+} + H_2O_2 + 2\ H^+ \rightarrow 2\ Fe^{3+} + 2\ H_2O$$

Oxides, such as iron(III) oxide or rust, which consists of hydrated iron(III) oxides $Fe_2O_3 \cdot nH_2O$ and iron(III) oxide-hydroxide ($FeO(OH)$, $Fe(OH)_3$), form when oxygen combines with other elements

Redox reactions in industry

Cathodic protection is a technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell. A simple method of protection connects protected metal to a more easily corroded "sacrificial anode" to act as the anode. The sacrificial metal instead of the protected metal, then, corrodes. A common application of cathodic protection is in galvanized steel, in which a sacrificial coating of zinc on steel parts protects them from rust.

The primary process of reducing ore at high temperature to produce metals is known as smelting.

Oxidation is used in a wide variety of industries such as in the production of cleaning products and oxidizing

ammonia to produce nitric acid, which is used in most fertilizers.

Redox reactions are the foundation of electrochemical cells, which can generate electrical energy or support electrosynthesis.

The process of electroplating uses redox reactions to coat objects with a thin layer of a material, as in chrome-plated automotive parts, silver plating cutlery, and gold-plated jewelry.

The production of compact discs depends on a redox reaction, which coats the disc with a thin layer of metal film.

Iron rusting in pyrite cubes

Redox reactions in biology

Many important biological processes involve redox reactions.

Cellular respiration, for instance, is the oxidation of glucose ($C_6H_{12}O_6$) to CO_2 and the reduction of oxygen to water. The summary equation for cell respiration is:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

The process of cell respiration also depends heavily on the reduction of NAD^+ to NADH and the reverse reaction (the oxidation of NADH to NAD^+). Photosynthesis and cellular respiration are complementary, but photosynthesis is not the reverse of the redox reaction in cell respiration:

$$6\ CO_2 + 6\ H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

Biological energy is frequently stored and released by means of redox reactions. Photosynthesis involves the reduction of carbon dioxide into sugars and the oxidation of water into molecular oxygen. The reverse reaction, respiration, oxidizes sugars to produce carbon dioxide and water. As intermediate steps, the reduced carbon compounds are used to reduce nicotinamide adenine dinucleotide (NAD^+), which then contributes to the creation of a proton gradient, which drives the synthesis of adenosine triphosphate (ATP) and is maintained by the reduction of oxygen. In animal cells, mitochondria perform similar functions. See the *Membrane potential* article.

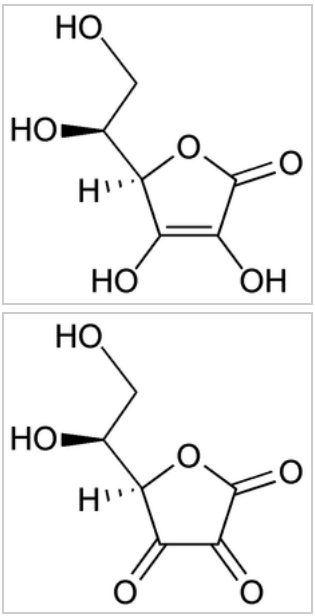

Top: ascorbic acid (reduced form of Vitamin C)
Bottom: dehydroascorbic acid (oxidized form of Vitamin C)

Free radical reactions are redox reactions that occur as a part of homeostasis and killing microorganisms, where an electron detaches from a molecule and then reattaches almost instantaneously. Free radicals are a part of redox molecules and can become harmful to the human body if they do not reattach to the redox molecule or an antioxidant. Unsatisfied free radicals can spur the mutation of cells they encounter and are, thus, causes of cancer.

The term **redox state** is often used to describe the balance of GSH/GSSG, NAD^+/NADH and $NADP^+$/NADPH in a biological system such as a cell or organ. The redox state is reflected in the balance of several sets of metabolites (e.g., lactate and pyruvate, beta-hydroxybutyrate, and acetoacetate), whose interconversion is dependent on these ratios. An abnormal redox state can develop in a variety of deleterious situations, such as hypoxia, shock, and sepsis. Redox mechanism also control some cellular processes. Redox proteins and their

genes must be co-located for redox regulation according to the CoRR hypothesis for the function of DNA in mitochondria and chloroplasts.

Redox cycling

A wide variety of aromatic compounds are enzymatically reduced to form free radicals that contain one more electron than their parent compounds. In general, the electron donor is any of a wide variety of flavoenzymes and their coenzymes. Once formed, these anion free radicals reduce molecular oxygen to superoxide, and regenerate the unchanged parent compound. The net reaction is the oxidation of the flavoenzyme's coenzymes and the reduction of molecular oxygen to form superoxide. This catalytic behavior has been described as futile cycle or redox cycling.

Examples of redox cycling-inducing molecules are the herbicide paraquat and other viologens and quinones such as menadione.[8]

Redox reactions in geology

In geology, redox is important to both the formation of minerals and the mobilization of minerals, and is also important in some depositional environments. In general, the redox state of most rocks can be seen in the color of the rock. The rock forms in oxidizing conditions, giving it a red color. It is then "bleached" to a green—or sometimes white—form when a reducing fluid passes through the rock. The reduced fluid can also carry uranium-bearing minerals. Famous examples of redox conditions affecting geological processes include uranium deposits and Moqui marbles.

Mi Vida uranium mine, near Moab, Utah. The alternating red and white/green bands of sandstone correspond to oxidized and reduced conditions in groundwater redox chemistry.

Balancing redox reactions

Describing the overall electrochemical reaction for a redox process requires a *balancing* of the component half-reactions for oxidation and reduction. In general, for reactions in aqueous solution, this involves adding H^+, OH^-, H_2O, and electrons to compensate for the oxidation changes.

Acidic media

In acidic media, H^+ ions and water are added to half-reactions to balance the overall reaction.

For instance, when manganese(II) reacts with sodium bismuthate:

Unbalanced reaction: $Mn^{2+}(aq) + NaBiO_3(s) \rightarrow Bi^{3+}(aq) + MnO_4^-(aq)$

Oxidation: $4\ H_2O(l) + Mn^{2+}(aq) \rightarrow MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^-$

Reduction: $2\ e^- + 6\ H^+ + BiO_3^-(s) \rightarrow Bi^{3+}(aq) + 3\ H_2O(l)$

The reaction is balanced by scaling the two half-cell reactions to involve the same number of electrons

(multiplying the oxidation reaction by the number of electrons in the reduction step and vice versa):

$$8\ H_2O(l) + 2\ Mn^{2+}(aq) \rightarrow 2\ MnO_4^-(aq) + 16\ H^+(aq) + 10\ e^-$$
$$10\ e^- + 30\ H^+ + 5\ BiO_3^-(s) \rightarrow 5\ Bi^{3+}(aq) + 15\ H_2O(l)$$

Adding these two reactions eliminates the electrons terms and yields the balanced reaction:

$$14\ H^+(aq) + 2\ Mn^{2+}(aq) + 5\ NaBiO_3(s) \rightarrow 7\ H_2O(l) + 2\ MnO_4^-(aq) + 5\ Bi^{3+}(aq) + 5\ Na^+(aq)$$

Basic media

In basic media, OH^- ions and water are added to half reactions to balance the overall reaction.

For example, in the reaction between potassium permanganate and sodium sulfite:

Unbalanced reaction:	$KMnO_4 + Na_2SO_3 + H_2O \rightarrow MnO_2 + Na_2SO_4 + KOH$
Reduction:	$3\ e^- + 2\ H_2O + MnO_4^- \rightarrow MnO_2 + 4\ OH^-$
Oxidation:	$2\ OH^- + SO_3^{2-} \rightarrow SO_4^{2-} + H_2O + 2\ e^-$

Balancing the number of electrons in the two half-cell reactions gives:

$$6\ e^- + 4\ H_2O + 2\ MnO_4^- \rightarrow 2\ MnO_2 + 8\ OH^-$$
$$6\ OH^- + 3\ SO_3^{2-} \rightarrow 3\ SO_4^{2-} + 3\ H_2O + 6\ e^-$$

Adding these two half-cell reactions together gives the balanced equation:

$$2\ KMnO_4 + 3\ Na_2SO_3 + H_2O \rightarrow 2\ MnO_2 + 3\ Na_2SO_4 + 2\ KOH$$

Memory aids

The key terms involved in redox are often confusing to students.[9][10] For example, an element that is oxidized loses electrons; however, that element is referred to as the reducing agent. Likewise, an element that is reduced gains electrons and is referred to as the oxidizing agent.[11] Acronyms or mnemonics are commonly used[12] to help remember the terminology:

- "OIL RIG" — **o**xidation **i**s **l**oss of electrons, **r**eduction **i**s **g**ain of electrons.[9][10][11][12]
- "LEO the lion says GER" — **l**oss of **e**lectrons is **o**xidation, **g**ain of **e**lectrons is **r**eduction.[9][10][11][12]
- "LEORA says GEROA" — **l**oss of **e**lectrons is **o**xidation (**r**educing **a**gent), **g**ain of **e**lectrons is **r**eduction (**o**xidizing **a**gent).[11]
- "RED CAT" and "AN OX", or "AnOx RedCat" ("an ox-red cat") — **red**uction occurs at the **cat**hode and the **an**ode is for **ox**idation.
- "RED CAT gains what AN OX loses" – **red**uction at the **cat**hode gains (electrons) what **an**ode **ox**idation loses (electrons).

See also

- Bessemer process
- Bioremediation
- Calvin cycle
- Chemical equation
- Chemical looping combustion
- Citric acid cycle
- Electrochemical series
- Electrochemistry
- Electrolysis
- Electron equivalent
- Electron transport chain
- Electrosynthesis
- Galvanic cell
- Hydrogenation
- Membrane potential
- Nucleophilic abstraction
- Organic redox reaction
- Oxidative addition and reductive elimination
- Oxidative phosphorylation
- Partial oxidation
- Pro-oxidant
- Reduced gas
- Reducing agent
- Reducing atmosphere
- Reduction potential
- Thermic reaction
- Transmetalation

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- Tratnyek, Paul G.; Grundl, Timothy J.; Haderlein, Stefan B., eds. (2011). *Aquatic Redox Chemistry*. ACS Symposium Series. **1071**. doi:10.1021/bk-2011-1071. ISBN 9780841226524.

External links

- Chemical Equation Balancer (http://www.berkeleychurchill.com/software/chembal.php) – An open source chemical equation balancer that handles redox reactions.
- Video – Synthesis of Copper(II) Acetate (https://www.youtube.com/watch?v=rF1ls-v7puQ) 20 Feb. 2009
- Redox reactions calculator (http://www.shodor.org/UNChem/advanced/redox/redoxcalc.html)
- Redox reactions at Chemguide (http://www.chemguide.co.uk/inorganic/redox/definitions.html#top)
- Online redox reaction equation balancer, balances equations of any half-cell and full reactions (http://www.webqc.org/balance.php)

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Reef knot

From Wikipedia, the free encyclopedia

The **reef knot**, or **square knot**, is an ancient and simple binding knot used to secure a rope or line around an object. It is sometimes also referred to as a **Hercules knot**. The knot is formed by tying a left-handed overhand knot and then a right-handed overhand knot, or vice versa. A common mnemonic for this procedure is "right over left; left over right", which is often appended with the rhyming suffix "... makes a knot both tidy and tight". Two consecutive overhands of the same handedness will make a granny knot. The working ends of the reef knot must emerge both at the top or both at the bottom, otherwise a thief knot results.

Although the reef knot is often seen used for tying two ropes together, it is not

Reef knot

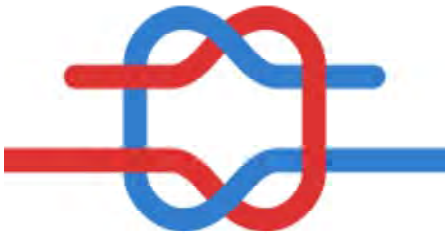

Names	Reef knot, Square knot, Hercules knot, Double knot
Category	Binding
Category #2	Bend
Origin	Ancient
Related	Thief knot, Granny knot, Grief knot, Surgeon's knot, Shoelace knot
Releasing	Jamming
Typical use	Joining two ends of a single line to bind around an object.
Caveat	Not secure as a bend. Spills easily if one of the free ends is pulled outward. Does not hold well if the two lines are not the same thickness.
ABoK	#74, #75, #460, **#1204**, **#1402**, #2096, #2573, #2574, #2577, #2580
Instructions	[1] (http://www.animatedknots.com/reef/)

recommended for this purpose because of the potential instability of the knot, and over-use has resulted in many deaths (see #Misuse as a bend).

Contents

- 1 Naming
- 2 Uses
- 3 Misuse as a bend
- 4 Physical analysis
- 5 Related knots
- 6 See also
- 7 Notes and references
- 8 External links

Naming

The reef knot is at least 4,000 years old. The name "reef knot" dates from at least 1794[1] and originates from its common use to reef sails,[2][3] that is to tie part of the sail down to decrease its effective surface area in strong winds. To release the knot a sailor could collapse it with a pull of one hand; the sail's weight would make the collapsed knot come apart. It is specifically this behavior which makes the knot unsafe for connecting two ropes together.[4]

The name "square knot" is found in Dana's 1841 maritime compendium *A Seaman's Friend*, which also gives "reef knot" as an alternative name.[5][6]

The name *square knot* is often used for the unslipped version of reef knot. *Reef knot* itself then is understood as the single slipped version, while the name **shoelace knot** is to indicate double slipped version. Sometimes the name **bowtie** also may be used to indicate a double slipped version, but tying a bowtie is usually performed on flat material, and involves a slip knot of one

end holding a bight of the other end i.e. not really a double slipped reef knot. The name "Square knot" is also used for completely different other knots such as the mathematical concept of square knot, or friendship knot; this last one earns the name by being flat and drawing a square on one face (and a cross on the other face).

Uses

The reef knot is used to tie the two ends of a single line together such that they will secure something, for example a bundle of objects, that is unlikely to move much. In addition to being used by sailors for reefing and furling sails, it is also one of the key knots of macrame textiles.[7]

The knot lies flat when made with cloth and has been used for tying bandages for millennia. As a binding knot it was known to the ancient Greeks as the Hercules knot (*Herakleotikon hamma*) and is still used extensively in medicine.[8] In his *Natural History*, Pliny relates the belief that wounds heal more quickly when bound with a Hercules knot.[9]

It has also been used since ancient times to tie belts and sashes. A modern use in this manner includes tying the obi (or belt) of a martial arts keikogi.

With both ends tucked (slipped) it becomes a good way to tie shoelaces, whilst the non-slipped version is useful for shoelaces that are excessively short. It is appropriate for tying plastic garbage or trash bags, as the knot forms a handle when tied in two twisted edges of the bag.

The reef knot figures prominently in Scouting worldwide. It is included in the international membership badge[10] and many scouting awards.[11] In the Boy Scouts of America demonstrating the proper tying of the square knot is a requirement for all boys joining the program.[12] In Pioneering (Scouting), it is commonly used as a binding knot to finish off specialized lashing (ropework) and whipping knots.[13] However, it is an insecure knot, unstable when jiggled, and is not suitable for supporting weight.

A surgeon's variation, used where a third hand is unavailable, is made with two or three twists of the ropes on bottom, and sometimes on top, instead of just one.

Detail of Egyptian statue dating from 2350 BC depicting a reef knot securing a belt

Ancient Greek jewelry from Pontika (now in Ukraine), 300 BC, in the form of a reef knot

Singly slipped reef knot

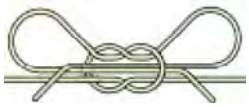

Diagram of common shoelace bow knot, a doubly slipped reef knot

Weight for weighing gold dust - Knot – MHNT

Misuse as a bend

The reef knot's familiarity, ease of tying, and visually appealing symmetry conceal its weakness. The International Guild of Knot Tyers warns that this knot should never be used to bend two ropes together.[14] A proper bend knot, for instance a sheet bend or double fisherman's knot, should be used instead. Knotting authority Clifford Ashley claimed that misused reef knots have caused more deaths and injuries than all other knots combined.[15] Further, it is easily confused with the granny knot, which is a very poor knot.

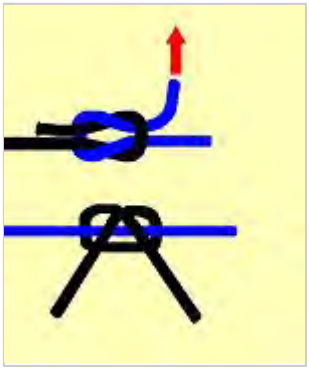

The reef knot can capsize (spill) when one of the free ends is pulled outward.

Physical analysis

An approximate physical analysis[16] predicts that a reef knot will hold if $2\mu e^{\mu\pi} \geq 1$, where μ is the relevant coefficient of friction. This inequality holds if $\mu \gtrsim 0.24$. Experiments show that the critical value of μ is actually somewhat lower.[17]

Related knots

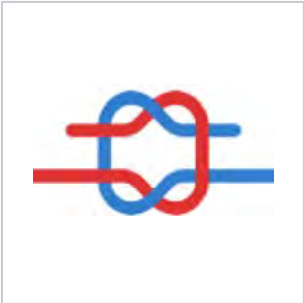

Reef (square) knot

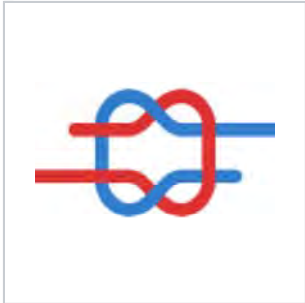

Thief knot

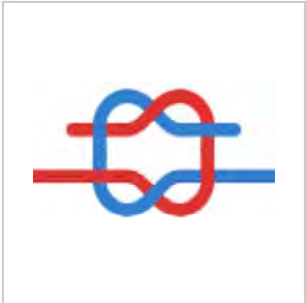

Granny knot

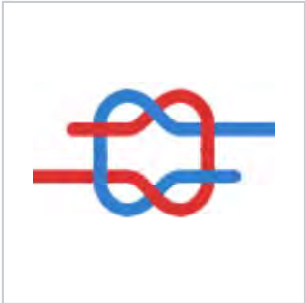

Grief knot

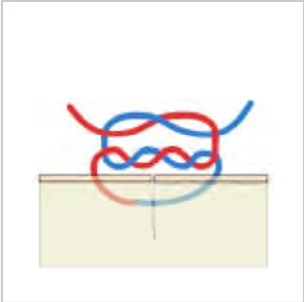

Surgeon's knot

See also

- Shoelace knot
- Granny knot
- Thief knot
- Surgeon's knot
- List of bend knots
- List of binding knots
- List of knots
- Square knot (emblem or insignia)
- Reefing

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Look up ***square knot*** in Wiktionary, the free dictionary.

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External links

- Knot of Hercules (http://symboldictionary.net/?p=3030)
- Ancient symbolism of Hercules knot (http://www.solnyc.com/webcat_retail/wc_greek/info/asymbols.htm)

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3 KB (261 words) - 11:10, 7 May 2016

Tolerable **daily intake**
Tolerable **daily intake** (TDI) refers to the **daily** amount of a chemical that has been assessed safe for human being on long-term basis (usually whole lifetime)
2 KB (286 words) - 22:51, 17 May 2016

Acceptable **daily intake**
Acceptable **daily intake** or ADI is a measure of the amount of a specific substance (originally applied for a food additive, later also for a residue of
5 KB (658 words) - 06:46, 3 October 2016

RDI
output data from an image sensor **Reference Daily Intake** or Recommended **Daily Intake**, a quantity of recommended nutrient **intake** Relationship Development Intervention
1 KB (197 words) - 05:22, 19 October 2016

Tolerable weekly **intake**
TWI, respectively. Tolerable **intakes**, whether **daily**, weekly, or monthly, should not be confused with **reference daily intake**, or RDI. RDI refers to the amount
7 KB (826 words) - 19:49, 10 July 2016

Guideline **Daily** Amount
by **reference intakes**. Traffic light label "Guideline **Daily** Amounts (Using the front of pack label)". Label. Retrieved August 12, 2016. **Daily** Intake
4 KB (528 words) - 15:17, 18 December 2016

Dietary **Reference** Values
recommended nutritional **intakes** for the UK population. The DRVs can be divided into three types: RNI - **Reference** Nutrient **Intake** (95% of the population's
8 KB (881 words) - 14:02, 18 December 2016

Pantothenic acid (section Dietary **reference intake**)
Dietary **Reference Intakes**. For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of **Daily** Value (%DV)
19 KB (1,879 words) - 17:04, 14 November 2016

Diet Coke Plus
nutrients only if it contains at least 10% more of the **Reference Daily Intake** or **Daily Reference** Value compared to the usual amount. Because Diet Coke
4 KB (416 words) - 23:45, 10 November 2016

Health effects of salt (section Recommended **intake**)
recommendation by several authorities "to reduce **daily** sodium **intake** to less than 2,300 milligrams and further reduce **intake** to 1,500 mg among persons who are 51
30 KB (3,203 words) - 19:06, 26 December 2016

Fluid balance
and on the environmental temperature and humidity. In the US, the **reference daily intake** (RDI) for water is 3.7 litres per day (l/day) for human males older
14 KB (1,852 words) - 01:15, 26 November 2016

List of engineering colleges affiliated to Visvesvaraya Technological University
ZERO **intake** for 2014-15 as per the Public notice issued by VTU in Prajavani,Kannada **daily** newspaper,Page number 5, dated 29-June-2014, VTU **Reference** number :
59 KB (592 words) - 08:59, 17 December 2016

Drinking (redirect from Fluid **intake**)
insipidus. A **daily intake** of water is required for the normal physiological functioning of the human body. The USDA recommends a **daily intake** of total water:
11 KB (1,148 words) - 19:33, 28 November 2016

Blooming onion (category Articles needing additional **references** from August 2007)
fat. For **reference**, the US **Reference Daily Intake** for fat is 65g and for sodium is 2300 mg, assuming a 2000 calorie diet, while typical **daily** food energy
5 KB (469 words) - 03:00, 11 December 2016

Serum chloride (category Articles needing additional **references** from November 2013)
serum chloride level. The North American Dietary **Reference Intake** recommends a **daily intake** of between 2300 and 3600 mg/day for 25-year-old males
2 KB (228 words) - 07:01, 13 September 2016

Low-fat diet
a low-carbohydrate diet (<40 g/day) and a low-fat diet (<30% of **daily** energy **intake** from total fat [<7% saturated fat]) revealed that low-carbohydrate
8 KB (943 words) - 15:21, 29 May 2016

Manganese deficiency (medicine)
is a vital element of nutrition in very small quantities (adult male **daily intake** 2.3 milligrams). However, in greater amounts manganese, like most metals
2 KB (291 words) - 18:55, 23 October 2015

Biotin (section Dietary **Reference Intake**)
AI. A table of the pre-change adult Daily Values is provided at **Reference Daily Intake**. Food and supplement companies have until July 2018 to comply with
25 KB (2,832 words) - 09:16, 13 December 2016

Emergen-C (category Articles needing additional **references** from January 2010)
4 times the vitamin B12, and 5 times the vitamin B6 of the USDA **Reference Daily Intake** based on a 2000 calorie diet. The efficacy of vitamin C megadoses
5 KB (541 words) - 13:31, 23 December 2016

GDA
Pakistan. Greater Dublin Area Guideline **Daily** Amount, UK equivalent of the North American term Dietary **Reference Intake**. GNU Data Access – the GNOME attempt
432 bytes (53 words) - 04:41, 19 October 2016

Co-carcinogen
daily consumption for supplement called Tolerable Upper **Intake** Levels (UL), for example World Health Organization suggest the Tolerable Upper **Intake** Levels
9 KB (1,247 words) - 12:12, 18 November 2016

Riboflavin (section Dietary **reference intake**)
Dietary **Reference Intakes**. For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of **Daily** Value (%DV)
40 KB (4,535 words) - 17:35, 30 December 2016

Protein (nutrient)
Standing Committee on the Scientific Evaluation of Dietary **Reference Intakes**. Dietary **Reference Intakes** for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol
38 KB (4,446 words) - 17:53, 1 December 2016

Vitamin B6 (category Articles needing additional medical **references** from October 2016)
Dietary **Reference Intakes**. For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of **daily** value (%DV)
31 KB (3,612 words) - 12:21, 30 December 2016

UL
microliter (µl), a unit of volume Tolerable Upper **Intake** Level, part of the Dietary **Reference Intake** system of the US National Academy of Sciences Ul
2 KB (225 words) - 04:05, 19 October 2016

Committed dose (redirect from Annual limit on **intake**)
radiological protection is a measure of the stochastic health risk due to an **intake** of radioactive material into the human body. Stochastic in this context
19 KB (2,676 words) - 18:01, 28 November 2016

Nutrition and pregnancy (category All articles lacking reliable **references**)
Nutrition and pregnancy refers to the nutrient **intake**, and dietary planning that is undertaken before, during and after pregnancy. Nutrition of the fetus
21 KB (2,594 words) - 04:13, 8 November 2016

Snacking (category Articles needing additional **references** from September 2011)
have a recommended **daily** calorie **intake** of about 2400 kcal. For sedentary women the **intake** is about 2000 kcal. The average calorie **intake** during a meal is
17 KB (2,487 words) - 11:49, 7 December 2016

Folic acid (category All articles lacking reliable **references**)
unchanged at 400 µg. A table of the pre-change adult **Daily** Values is provided at **Reference Daily Intake**. Food and supplement companies have until July 28
75 KB (8,441 words) - 14:25, 2 January 2017

Salt substitute
purac.com/purac_com/01d7a1a1dce330c46ada4f832de8e6ca.php/ "Dietary **Reference Intakes** : Electrolytes and Water" (PDF). The National Academies. 2004. Retrieved
3 KB (337 words) - 18:23, 2 December 2016

Vegetarian Diet Pyramid
the pyramid includes a table with recommended number of **daily** servings per **daily** calorie **intake**. According to the 2010 Dietary Guidelines for Americans
4 KB (423 words) - 01:59, 12 September 2016

Hungry Horse
nearly 100% of the recommended **daily** energy **intake** for adult women. It also contains 53g of saturated fat (the recommended **daily** allowance is 20g for women
2 KB (122 words) - 21:12, 19 October 2016

Food energy (section Recommended **daily intake**)
groups have varying **daily** activity levels, Australia's National Health and Medical Research Council recommends no single **daily** energy **intake**, but instead prescribes
18 KB (2,133 words) - 12:25, 2 January 2017

Acetylated distarch adipate
foods as a bulking agent, stabilizer and a thickener. No acceptable **daily intake** for human consumption has been determined. Dextrin (E1400) Modified
1 KB (56 words) - 09:33, 3 October 2016

Vitamin E (section Dietary **Reference Intake**)
revised to 15 mg. A table of the pre-change adult **Daily** Values is provided at **Reference Daily Intake**. Food and supplement companies have until July 28
40 KB (4,485 words) - 17:18, 1 January 2017

Rhodinol
cosmetics and perfumery to impart flowery odors. Rhodinol at The Good Scents Company Acceptable **daily intake** Citronellol Geraniol Perfume allergy
1 KB (37 words) - 07:14, 21 June 2016

Eating (redirect from Food **intake**)
For humans, eating is an activity of **daily** living. Some individuals may limit their amount of nutritional **intake**. This may be a result of a lifestyle
17 KB (2,214 words) - 12:13, 20 December 2016

Iron(II) fumarate
fumaric acid, occurring as a reddish-orange powder, used to supplement iron **intake**. It has the chemical formula C4H2FeO4. Pure ferrous fumarate has an iron
2 KB (82 words) - 16:30, 30 November 2015

Disodium ribonucleotides (category Articles needing additional **references** from July 2015)
available data (chemical, biochemical, and toxicological), the total **daily intake** of the substance arising from its use or uses at levels necessary to
3 KB (353 words) - 09:00, 3 January 2017

Essential amino acid (section Minimum **daily intake**)
based on the USDA National Nutrient Database Release. The recommended **daily intakes** for children aged three years and older is 10% to 20% higher than adult
17 KB (1,792 words) - 16:20, 13 December 2016

Vitamin
"Dietary **Reference Intakes**: Vitamins". The National Academies. 2001. Amount not determinable due to lack of data of adverse effects. Source of **intake** should
51 KB (5,137 words) - 23:33, 19 December 2016

Vitamin K (category Articles needing additional medical **references** from November 2015)
revised to 120 µg. A table of the pre-change adult **Daily** Values is provided at **Reference Daily Intake**. Food and supplement companies have until July 28
58 KB (6,928 words) - 21:09, 31 December 2016

Cod liver oil
4080 µg of retinol (vitamin A) and 34 µg of vitamin D. The Dietary **Reference Intake** of vitamin A is 900 µg per day for adult men and 700 µg per day for
11 KB (1,302 words) - 12:18, 4 December 2016

Saturated fat
daily energy **intake** and less than 7% for high-risk groups. If populations are consuming less than 10%, they should not increase that level of **intake**.
49 KB (4,958 words) - 16:57, 3 January 2017

Thiamine (section Dietary **Reference Intakes**)
Dietary **Reference Intakes**. For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of **Daily** Value (%DV)
33 KB (3,742 words) - 17:35, 30 December 2016

Fibre supplements
constipation. It is therefore better to regulate and moderate **daily** fibre **intake**. If increased fibre **intake** is desired, gradually increasing the amount over a few
18 KB (2,143 words) - 16:27, 20 December 2016

Shellfish Association of Great Britain
Reference Nutrient **Intake** (RNI) is a **daily** amount that is enough or more than enough for 97% of people. The RNI is similar to the Recommended **Daily** Amount
13 KB (1,840 words) - 07:05, 11 September 2016

Vitamin D (section Dietary **reference intakes**)
Accordingly, the Dietary **Reference Intake** for vitamin D assumes no synthesis occurs and all of a person's vitamin D is from food **intake**. As vitamin D is synthesized
116 KB (13,748 words) - 15:33, 30 December 2016

Vitamin C (section Recommended **intake**)
showed that their **daily intake** of vitamin C averaged between 52 and 62 mg/day, an amount approximately the dietary **reference intake** (DRI), even at times
115 KB (12,975 words) - 22:25, 1 January 2017

Canadian health claims (section Current Canadian **intakes** of fruits and vegetables)
providing a minimum of 5% of the Recommended **Daily Intake** of the nutrient per serving of stated size and **reference** amount of the food. Dietary sodium can
47 KB (6,343 words) - 02:42, 14 November 2016

Iodine in biology (section Recommended **intake**)
membranes, making them less reactive to free oxygen radicals. The **daily** Dietary **Reference Intake** recommended by the United States Institute of Medicine is between
33 KB (3,823 words) - 12:42, 16 December 2016

Hypervitaminosis A (category Articles needing more detailed **references**)
intake may occur. Children are particularly sensitive to vitamin A, with **daily intakes** of 1500 IU/kg body weight reportedly leading to toxicity. Provitamin
28 KB (3,246 words) - 13:08, 30 December 2016

Weight management (section Increase protein **intake**, especially at breakfast)
healthy eating and physical exercise to equate energy expenditure and energy **intake**. Developing healthy eating habits while using tips that will keep us fuller
28 KB (3,959 words) - 12:35, 14 December 2016

E-6837
active). Oral administration of E-6837 reduced food **intake**, but only transiently. In rats, twice **daily** administration of E-6837 over the course of 4 weeks
3 KB (340 words) - 18:33, 11 August 2016

Heterocyclic amine formation in meat (category Articles needing additional **references** from September 2015)
shows the average **daily** lifetime consumption of HCAs for subgroups of the U.S. population. This analysis was based on the food **intake** data of 27215 people
18 KB (2,136 words) - 02:01, 8 November 2016

Choline (category Articles needing additional medical **references** from January 2014)
Nutrients Database has choline content for many foods. Here are the **daily** adequate **intake** (AI) levels and upper limits (UL) for choline in milligrams, taken
75 KB (8,113 words) - 20:09, 1 January 2017

B vitamins (category All articles lacking reliable **references**)
planning to become pregnant are usually encouraged to increase **daily** dietary folic acid **intake** and/or take a supplement. Many of the following substances
39 KB (2,650 words) - 21:35, 28 December 2016

Vitamin C megadosage
Such dosages correspond to amounts well beyond the current Dietary **Reference Intake**. Oral dosages are usually divided and consumed in portions over the
24 KB (2,941 words) - 12:18, 17 December 2016

Vitamin A (section Recommended **daily** allowance)
Database for Standard **Reference**, Release 20[dead link] USDA, Feb. 2008 Chapter 4, Vitamin A[dead link] of Dietary **Reference Intakes** for Vitamin A, Vitamin
50 KB (6,257 words) - 12:26, 30 December 2016

Outline of nutrition
Prohormone Prostaglandins Recommended Dietary Allowances (RDA) **Reference Daily Intake** (RDI) Salad bar Saturated fat Seed Simple carbohydrate Somatotropin
15 KB (1,386 words) - 14:23, 11 October 2016

Zeaxanthin
acceptable **daily intake** level for zeaxanthin was proposed as 0.75 mg/kg of body weight/day, or 53 mg/day for a 70 kg adult. In humans, an **intake** of 20 mg/day
19 KB (2,094 words) - 15:30, 30 December 2016

Ponceau 4R
toxicity at the permitted dietary exposures; the European acceptable **daily intake** (ADI) is 0.7 mg/kg and the WHO/FAO ADI is 4 mg/kg. The production process
8 KB (808 words) - 10:44, 26 August 2016

Seaholm Power Plant (section Water **Intake** Structure)
The facility originally included a Turbine Generator Building, a Water **Intake** Structure and an Oil Heating Building. A guard booth and a storage building
8 KB (850 words) - 00:56, 1 December 2016

Resistant starch
the acceptable **daily intake** of resistant starch may be as high as 45 grams in adults, an amount exceeding the total recommended **intake** for dietary fiber
30 KB (3,178 words) - 12:22, 16 December 2016

Tocopherol
determined shortly thereafter in 1938. The U.S. Dietary **Reference Intake** (DRI) Recommended **Daily** Amount (RDA) for a 25-year-old male for Vitamin E is 15 mg/day
49 KB (6,303 words) - 16:01, 16 December 2016

Cryptoxanthin
Charles P; Rice, Terri; Il'yasova, Dora; Wrensch, Margaret (2010). "**Daily intake** of antioxidants in relation to survival among adult patients diagnosed
6 KB (437 words) - 07:35, 29 May 2016

Calcium (category All articles lacking reliable **references**)
sources suggest a correlation between high calcium **intake** (2000 mg per day, or twice the U.S. recommended **daily** allowance, equivalent to six or more glasses
55 KB (6,665 words) - 17:07, 25 December 2016

Copper in health (category Articles needing more detailed **references**)
this **daily intake** level is not recommended by any authority.[citation needed] The World Health Organization has not developed minimum **daily intakes** for
102 KB (12,035 words) - 15:18, 11 December 2016

Beta-Carotene
carotenoids before sale to improve the color and clarity. The average **daily intake** of β-carotene is in the range 2–7 mg, as estimated from a pooled analysis
27 KB (2,741 words) - 18:30, 31 December 2016

Saturated fat and cardiovascular disease controversy (category Pages with **reference** errors)
of cardiovascular diseases' recommends a low **intake** of SFA, less than 7% of **daily** calories, and **intake** of foods rich in myristic and palmitic acids should
55 KB (6,201 words) - 10:21, 26 December 2016

Iron(II) gluconate
Toxicity, Iron Iron overdose The British Pharmacopoeia Secretariat (2009). "Index, BP 2009" (PDF). Retrieved 5 July 2009. Acceptable **daily intake**
4 KB (323 words) - 20:17, 24 February 2016

Dal (category Articles needing additional **references** from March 2014)
= Copper; Mn = Manganese; Se = Selenium; %DV = %**Daily** value i.e. % of DRI (Dietary **reference intake**) Note : All nutrient values including protein are
19 KB (1,741 words) - 20:36, 3 January 2017

University of Bristol admissions controversy (section Notes and **references**)
engineering **intakes**". The **Daily** Telegraph. London. Paton, Graeme (2012-10-01). "Public schools threaten university boycott". The **Daily** Telegraph. London
33 KB (3,463 words) - 11:40, 13 December 2016

Dose
be exposed to Overdose, **intaking** more than your required dose. Absorbed dose, an amount of radiation received Defined **daily** dose, a World Health Organization
3 KB (452 words) - 18:15, 6 December 2016

Quinoline Yellow WS
principle, required labelling and temporarily reduced the acceptable **daily intake** (ADI) for the food colorings; the UK FSA called for voluntary withdrawal
8 KB (847 words) - 06:53, 16 August 2016

Index of topics related to life extension
Reliability theory Reliability theory of aging Redox (oxidation) **Reference Daily Intake** Regeneration Regenerative medicine Rejuvenation Reliability theory
9 KB (777 words) - 16:21, 27 August 2016

Food chemistry
consumed in excessive amounts. Bulk minerals with a **Reference Daily Intake** (RDI, formerly Recommended **Daily** Allowance (RDA)) of more than 200 mg/day are calcium
13 KB (1,791 words) - 13:11, 9 October 2016

Lutein
lutein and zeaxanthin **intake** lowers the risk of cataract development. Consumption of more than 2.4 mg of lutein/zeaxanthin **daily** from foods and supplements
23 KB (2,557 words) - 13:36, 31 December 2016

Hydrolyzed protein (category Articles needing additional **references** from April 2010)
threat. the hydrolyzed protein are also called zwitterions Acceptable **daily intake** Acid-hydrolyzed vegetable protein E number Food allergy Food intolerance
2 KB (205 words) - 22:51, 30 November 2016

Fasciculation (category Articles needing additional medical **references** from January 2015)
consume the recommended **daily** amount of magnesium, inadequate **intake** may also be a common cause. Treatment consists of increased **intake** of magnesium from dietary
8 KB (907 words) - 22:32, 13 November 2016

Secoisolariciresinol diglucoside
Charles P; Rice, Terri; Il'Yasova, Dora; Wrensch, Margaret (2010). "**Daily intake** of antioxidants in relation to survival among adult patients diagnosed
5 KB (366 words) - 14:02, 9 August 2016

Combined drug intoxication (redirect from Multiple Drug **Intake**)
Combined drug intoxication (CDI), also known as multiple drug **intake** (MDI) or lethal polydrug/polypharmacy intoxication, is an unnatural cause of human
18 KB (1,925 words) - 06:55, 27 December 2016

Sorbitan monostearate (category Articles needing additional **references** from March 2010)
Retrieved 18 March 2010. http://www.inchem.org/documents/jecfa/jecmono/v05je47.htm Acceptable **daily intake** Polysorbate Sorbitan tristearate (Span 65) Yeast
3 KB (175 words) - 02:05, 9 November 2016

Cylinder head porting (category Articles needing additional **references** from June 2008)
Cylinder head porting refers to the process of modifying the **intake** and exhaust ports of an internal combustion engine to improve the quality and quantity
21 KB (3,024 words) - 14:32, 29 November 2016

Medical News Bulletin (category Articles needing additional **references** from December 2016)
readers can determine their total **daily** energy expenditure, anxiety and depression levels, diabetes risk, water **intake**, ideal weight, and body mass index
4 KB (304 words) - 15:46, 28 December 2016

Weight loss effects of water (category Articles needing more detailed **references**)
drinking water **intake** (tap + bottled + carbonated water) in percentage of total water **intake** than non-consumers, and lower mean **intakes** of milk, bottled
9 KB (1,137 words) - 03:59, 11 December 2016

MedDietScore
and alcohol **intake**, were included. Based on the suggested **intake** monotonic functions were applied (by the exception of alcohol **intake**) in order to
5 KB (608 words) - 21:16, 16 May 2016

Okinawa diet (category Articles needing additional **references** from March 2016)
primarily only eaten at monthly festivals and the **daily** diet is almost entirely plant based. The dietary **intake** of Okinawans compared to other Japanese circa
9 KB (1,173 words) - 16:31, 9 December 2016

Disodium guanylate (category Articles needing additional **references** from February 2010)
of non-animal derived sources, such as seaweed or yeast. Acceptable **daily intake** Disodium inosinate http://pubchem.ncbi.nlm.nih.gov/summary/summary
3 KB (252 words) - 07:09, 25 September 2016

Protein-sparing modified fast (category All articles lacking reliable **references**)
daily intake of well under 1000 calories. For an average male with a TDEE (total **daily** energy expenditure) of 2500 calories/day, and a caloric **intake**
9 KB (1,232 words) - 14:40, 20 December 2016

Alcohol and cancer (section Recommended maximum alcohol **intake**)
cancers in men and one in 33 in women were caused by past or current alcohol **intake**. The International Agency for Research on Cancer (Centre International
92 KB (10,891 words) - 02:50, 4 January 2017

VR6 engine (category Articles needing additional **references** from September 2007)
the transversely mounted engine) has six cam lobes to control the three **intake** and three exhaust valves of the front cylinder bank, without using rockers
23 KB (2,366 words) - 16:12, 19 December 2016

Fecal impaction (category Articles needing additional **references** from November 2012)
under the supervision of a physician), an adequate **intake** of liquids (water) and dietary fiber and **daily** exercise. The treatment of fecal impaction requires
9 KB (1,091 words) - 00:18, 3 January 2017

Kidney stone disease
stone formation was used as an indicator of excess calcium **intake** by the **Reference Daily Intake** committee for calcium in adults. In the early 1990s, a study
101 KB (10,498 words) - 21:33, 27 December 2016

Medication overuse headache (category Articles needing additional **references** from July 2015)
"transforms" over time from an episodic condition to chronic **daily** headache due to excessive **intake** of acute headache relief medications. MOH is a serious,
18 KB (1,949 words) - 18:47, 30 September 2016

Nutrition facts label
for babies, the following Daily Values are used. These are called **Reference Daily Intake** (RDI) values and were originally based on the highest 1968 Recommended
29 KB (3,126 words) - 17:54, 25 December 2016

Cooking oil (category Articles needing additional **references** from May 2008)
institute of medicine of the national academies (2005). Dietary **Reference Intakes** for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein
34 KB (3,111 words) - 08:06, 28 December 2016

Drinking water (category All articles lacking reliable **references**)
glasses of water per day. In the United States, the **reference daily intake** (RDI) for total water **intake** is 3.7 litres per day (L/day) for human males older
43 KB (5,188 words) - 16:05, 2 January 2017

View (previous 100 | next 100) (20 | 50 | 100 | 250 | 500)

Retrieved from "https://en.wikipedia.org/wiki/Special:Search"

Reference Daily Intake

From Wikipedia, the free encyclopedia

The **Reference Daily Intake** or **Recommended Daily Intake** (**RDI**) is the daily intake level of a nutrient that was considered in 1968 to be sufficient to meet the requirements of 97–98% of healthy individuals in every demographic in the United States. While developed in USA it has been used in other countries though it is not universally accepted.

The RDI is used to determine the **Daily Value** (**DV**) of foods, which is printed on nutrition facts labels (as **%DV**) in the United States and Canada, and is regulated by the Food and Drug Administration (FDA) and Health Canada respectively.

The RDI is based on the older **Recommended Dietary Allowance** (**RDA**) from 1968;[1] newer RDAs have since been introduced in the Dietary Reference Intake system, but the RDI is still used for nutrition labeling. The Food and Drug Administration has indicated that it plans to update the DVs based on the newer RDAs.[2]

Contents

- 1 Food labeling reference tables
- 2 History
  - 2.1 Nutrition facts label
- 3 Sodium
- 4 See also
- 5 References
- 6 External links

Food labeling reference tables

DVs used by the FDA for the following macronutrients are Daily Reference Values (DRV).[3][4][5]

FDA issued Final Rule on changes to facts panel in July 2016. See: https://s3.amazonaws.com/public-inspection.federalregister.gov/2016-11867. The new Daily Values are on pages 903-906. New values can be used on labels now, but companies have until July 28, 2018 to be in compliance. In the interim, products with old or new facts panel content will be on market shelves at same time.

The following table lists the old and new DVs based on a caloric intake of 2000 kcal (8400 kJ), for adults and children four or more years of age.

Total Fat	65 g changed to 78 g
Saturated Fatty Acids	20 g unchanged, stays 20 g
Cholesterol	300 mg unchanged, stays 300 mg
Sodium	2400 mg changed to 2300 mg
Potassium	3500 mg changed to 4700 mg
Total Carbohydrate	300 g changed to 275 g
Added Sugars	newly established at 50 g
Dietary Fiber	25 g changed to 28 g
Protein	50 g unchanged, stays 50 g

For vitamins and minerals, the RDIs (100% Daily Values) are given in the following table, along with the more recent RDAs of the Dietary Reference Intakes (maximized over sex and age groups):[1]

Nutrient	RDI	highest RDA or DRI
Vitamin A	900 µg	900 µg
Ascorbic Acid Vitamin C	60 mg	90 mg
Calcium	1000 mg	1300 mg
Iron	18 mg	18 mg
Cholecalciferol Vitamin D	400 IU (10 µg)	800 IU
Tocopherol Vitamin E	30 IU	15 mg (33 IU of synthetic)
Vitamin K	80 µg	120 µg
Thiamin Vitamin B1	1.5 mg	1.2 mg
Riboflavin Vitamin B2	1.7 mg	1.3 mg
Niacin Vitamin B3	20 mg	16 mg
Pyridoxine Vitamin B6	2 mg	1.7 mg
Folate	400 µg	400 µg
Cobalamine Vitamin B12	6 µg	2.4 µg
Biotin	300 µg	30 µg
Pantothenic acid Vitamin B5	10 mg	5 mg
Phosphorus	1000 mg	1250 mg
Iodine	150 µg	150 µg
Magnesium	400 mg	420 mg
Zinc	15 mg	11 mg
Selenium	70 µg	55 µg
Copper	2000 µg	900 µg
Manganese	2 mg	2.3 mg
Chromium	120 µg	35 µg
Molybdenum	75 µg	45 µg
Chloride	3400 mg	2300 mg

History

The RDA was developed during World War II by Lydia J. Roberts, Hazel Stiebeling and Helen S. Mitchell, all part of a committee established by the U.S. National Academy of Sciences to investigate issues of nutrition that might "affect national defense" (Nestle, 35). The committee was renamed the Food and Nutrition Board in 1941, after which they began to deliberate on a set of recommendations of a standard daily allowance for each type of nutrient. The standards would be used for nutrition recommendations for the armed forces, for civilians, and for overseas population who might need food relief. Roberts, Stiebeling, and Mitchell surveyed all available data, created a tentative set of allowances for "energy and eight nutrients", and submitted them to experts for review (Nestle, 35). The final set of guidelines, called RDAs for Recommended Dietary Allowances, were accepted in 1941. The allowances were meant to provide superior nutrition for civilians and

military personnel, so they included a "margin of safety". Because of food rationing during the war, the food guides created by government agencies to direct citizens' nutritional intake also took food availability into account.

The Food and Nutrition Board subsequently revised the RDAs every five to ten years. Daily Values were established based on the 1968 RDAs and have not been updated as of 2016. The last four revisions of RDAs were published in 1968, 1974, 1980 and 1989. In 1997, at the suggestion of the Institute of Medicine of the National Academy, RDAs became one part of a broader set of dietary guidelines called the Dietary Reference Intake used by both the United States and Canada.

Nutrition facts label

On May 20, 2016, the FDA published guidance for a new Nutrition facts label for packaged foods to reflect updated scientific information.[6] The new label is intended to make it easier for consumers to understand the calorie and nutrient content of their foods in more common serving sizes.

Sodium

The daily maximum for sodium is higher in the U.S. than in other parts of the developed world, and is above estimated minimums.[7][8] For instance, the National Research Council (United States) has found that 500 mg of sodium per day (approximately 1.25g of table salt) is a safe minimum level.[9] In the United Kingdom, the daily allowance for salt is 6g (approximately 2.5 teaspoons, about the upper limit in the U.S.), but this is still considered "too high".[10][11]

See also

- Canada's Food Guide
- Dietary mineral
- Dietary Reference Intake
- Dietary Reference Values (United Kingdom)
- Essential amino acid
- Essential fatty acid
- Essential nutrient
- Food guide pyramid
- Healthy diet
- Nutrient
- Vitamins

References

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3. "Information for Consumers (Drugs)". Fda.gov. 2008-10-29. Retrieved 2011-03-30.
4. "Electronic Code of Federal Regulations:". Ecfr.gpoaccess.gov. Retrieved 2011-03-30.
5. "Guidance for Industry: A Food Labeling Guide (14. Appendix F: Calculate the Percent Daily Value for the Appropriate Nutrients)". *U.S. Food and Drug Administration*. January 2013. Retrieved 23 September 2015.
6. "Changes to the Nutrition Facts Label". *FDA Labeling and Nutrition*. US Food and Drug Administration. 20 May 2016. Retrieved 20 May 2016.
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8. "Statement from the National High Blood Pressure Education Program". Nhlbi.nih.gov. 1999-10-14. Retrieved 2011-03-30.
9. "Recommended Dietary Allowances: 10th Edition". Nap.edu. Retrieved 2011-03-30.
10. "Daily salt intake allowances 'were set too high' ". BBC News. 2009-11-25. Retrieved 2011-03-30.
11. "Health | Britons told to cut salt intake". BBC News. 2004-09-13. Retrieved 2011-03-30.

External links

- Daily Values, US (https://ods.od.nih.gov/HealthInformation/dailyvalues.aspx) National Institutes of Health
- USDA Reference Daily Intakes (http://fnic.nal.usda.gov/dietary-guidance/dietary-reference-intakes)

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Categories: Nutrition | Vitamins

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Reference Intakes

From Wikipedia, the free encyclopedia

Reference Intakes (RIs) are a means of communicating maximum recommended nutrient intake to the public. Reference Intakes replaced the term Guideline Daily Amount (GDA), although the principles behind both are the same. The major difference is that GDAs existed for men, women and children; there is only one set of RIs for an average adult.[1]

Energy or nutrient	Reference Intake
Energy	8400kJ / 2000kcal
Total fat	70 g
Saturates	20 g
Carbohydrates	260 g
Sugars	90 g
Protein	50 g
Salt	6 g

The values for the nutrients are all maximums, not targets. The information is for guidance only and should not be considered individual advice.

The change from GDA to RI on labels on pre-packaged food and drinks sold in the UK is due to a European Regulation.[2] [3] The intention of the EU Regulation is to harmonise across Europe the content, expression and presentation of the nutrition information given to consumers.

Since RIs are for an average adult, concerns have been raised by major retailers and manufacturers that they may face criticism for misrepresenting the contribution to the diet of products targeted at children, particularly given concerns around children's diet and obesity levels. [4]

RIs can be combined with traffic light labeling to make the information easily and rapidly understood. [5]

References

1. "Reference Intakes". Food and Drink Federation. Retrieved 27 April 2014.
2. EU Regulation 1169/2011 on the provision of food information to consumers
3. "New EU law on food information to consumers". European Commission. Retrieved 27 April 2014.
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5. "Traffic Light Labelling". *Traffic Light Labelling*. J Sainsbury plc. Retrieved 7 June 2014.

External links

- EU Register of nutrition and health claims made on foods (http://ec.europa.eu/nuhclaims/)

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Categories: Nutrition | Food stubs

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Reference ranges for blood tests

From Wikipedia, the free encyclopedia

Reference ranges for blood tests are sets of values used by a health professional to interpret a set of medical test results from blood samples.

Reference ranges for blood tests are studied within the field of clinical chemistry (also known as "clinical biochemistry", "chemical pathology" or "pure blood chemistry"), the area of pathology that is generally concerned with analysis of bodily fluids.

Blood test results should always be interpreted using the reference range provided by the laboratory that performed the test.[1]

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Interpretation

A reference range is usually defined as the set of values 95 percent of the normal population falls within (that is, 95% prediction interval).[2] It is determined by collecting data from vast numbers of laboratory tests.

Plasma or whole blood

In this article, all values (except the ones listed below) denote blood plasma concentration, which is approximately 60–100% larger than the actual blood concentration if the amount inside red blood cells (RBCs) is negligible. The precise factor depends on hematocrit as well as amount inside RBCs. Exceptions are mainly those values that denote total blood concentration, and in this article they are:

- All values in *Hematology – red blood cells* (except *hemoglobin in plasma*)
- All values in *Hematology – white blood cells*
- Platelet count (Plt)

A few values are for inside red blood cells only:

- Vitamin B_9 (Folic acid/Folate) in red blood cells
- Mean corpuscular hemoglobin concentration (MCHC)

Units

- Mass concentration (g/dL or g/L) is the most common measurement unit in the United States. Is usually given with dL (decilitres) as the denominator in the United States, and usually with L (litres) in, for example, Sweden.
- Molar concentration (mol/L) is used to a higher degree in most of the rest of the world, including the United Kingdom and other parts of Europe and Australia and New Zealand.[3]
- International units (IU) are based on measured biological activity or effect, or for some substances, a specified equivalent mass.
- Enzyme activity (kat) is commonly used for e.g. liver function tests like AST, ALT, LD and γ-GT in Sweden.[4]
- Percentages and time-dependent units (mol/s) are used for calculated derived parameters, e.g. for beta cell function in homeostasis model assessment or thyroid's secretory capacity.

Arterial or venous

If not otherwise specified, a reference range for a blood test is generally the venous range, as the standard process of obtaining a sample is by venipuncture. An exception is for acid-base and blood gases, which are generally given for arterial blood.

Still, the blood values are approximately equal between the arterial and venous sides for most substances, with the exception of acid-base, blood gases and drugs (used in therapeutic drug monitoring (TDM) assays).[5] Arterial levels for drugs are generally higher than venous levels because of extraction while passing through tissues.[5]

Usual or optimal

Reference ranges are usually given as what are the usual (or *normal*) values found in the population, more specifically the prediction interval that 95% of the population fall into. This may also be called *standard range*. In contrast, *optimal (health) range* or *therapeutic target* is a reference range or limit that is based on concentrations or levels that are associated with optimal health or minimal risk of related complications and diseases. For most substances presented, the optimal levels are the ones normally found in the population as well. More specifically, optimal levels are generally close to a central tendency of the values found in the population. However, usual and optimal levels may differ substantially, most notably among vitamins and blood lipids, so these tables give limits on both standard and optimal (or target) ranges.

In addition, some values, including troponin I and brain natriuretic peptide, are given as the estimated appropriate cutoffs to distinguish healthy people from specific conditions, which here are myocardial infarction and congestive heart failure, respectively, for the aforementioned substances.

Variability

References range may vary with age, sex, race, pregnancy,[6] diet, use of prescribed or herbal drugs and stress. Reference ranges often depend on the analytical method used, for reasons such as inaccuracy, lack of standardisation, lack of certified reference material and differing antibody reactivity.[7] Also, reference ranges may be inaccurate when the reference groups used to establish the ranges are small.

Sorted by concentration

By units

Units don't necessarily imply anything about molarity or mass.

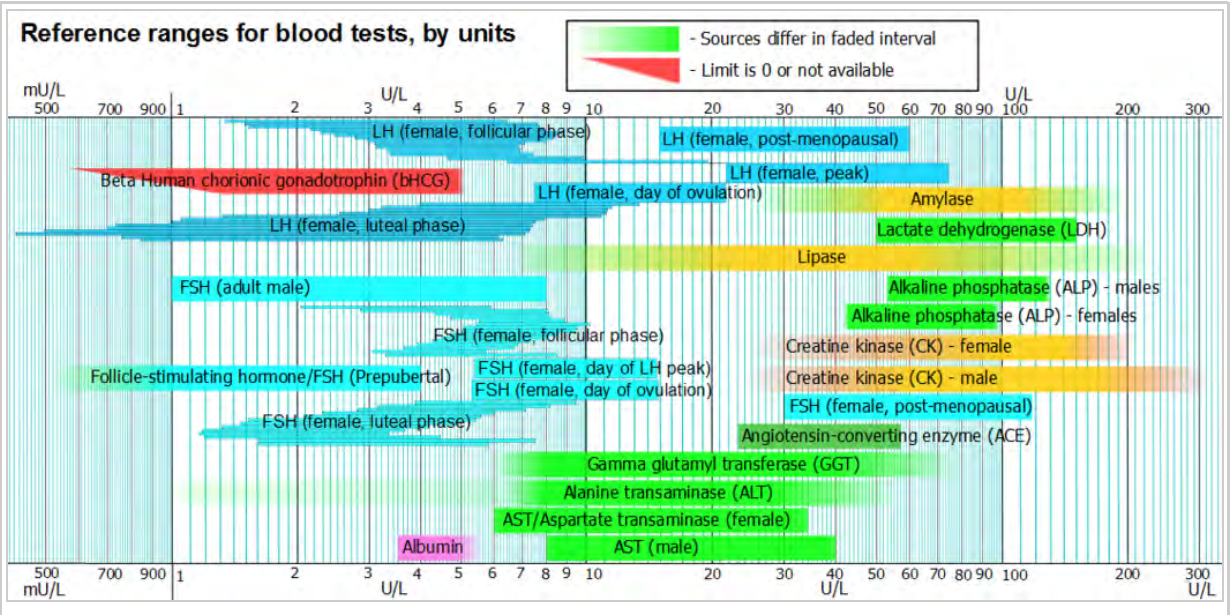

A few substances are below this main interval, e.g. thyroid stimulating hormone, being measured in mU/L, or above, like rheumatoid factor and CA19-9, being measured in U/mL.

By enzyme activity

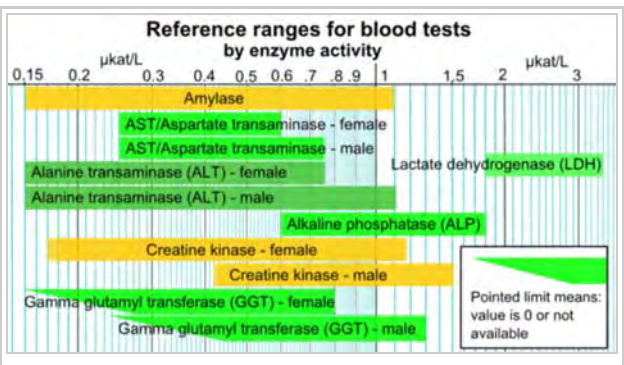

White blood cells

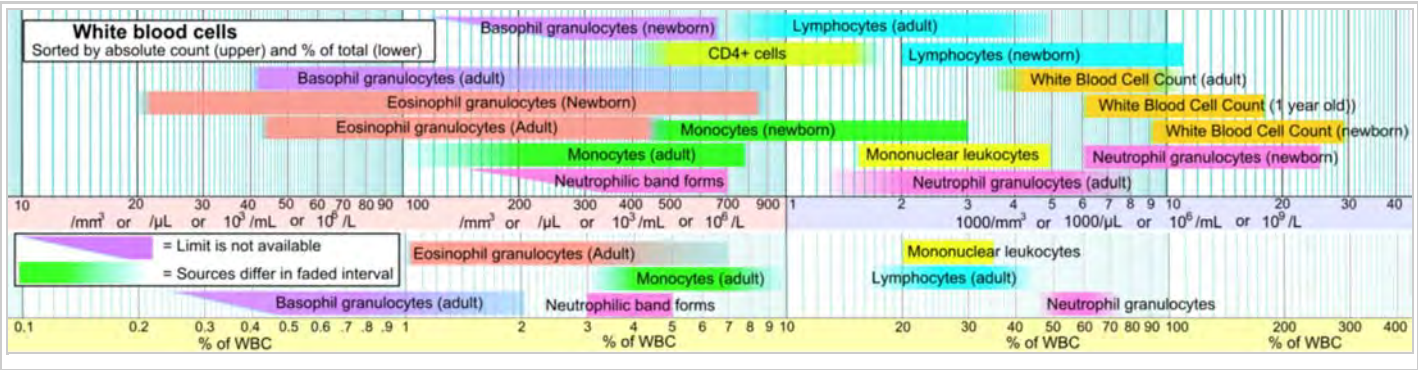

Sorted by category

Ions and trace metals

Included here are also related binding proteins, like ferritin and transferrin for iron, and ceruloplasmin for copper.

Test	Lower limit	Upper limit	Unit	Comments
Sodium (Na)	135,[9] 137[4][10]	145,[4][10] 147[9]	mmol/L or mEq/L[9]	See hyponatremia or hypernatremia
	310,[11] 320[11]	330,[11] 340[11]	mg/dl	
Potassium (K)	3.5,[4][9] 3.6[10]	5.0,[4][9][10] 5.1	mmol/L or mEq/L[9]	See hypokalemia or hyperkalemia
	14[12]	20[12]	mg/dl	
Chloride (Cl)	95,[9] 98,[13] 100[4]	105,[9] 106,[13] 110[4]	mmol/L or mEq/L[9]	See hypochloremia or hyperchloremia
	340[14]	370[14]	mg/dl	
Ionized calcium (Ca)	1.03,[15] 1.10[4]	1.23,[15] 1.30[4]	mmol/L	See hypocalcaemia or hypercalcaemia
	4.1,[16] 4.4[16]	4.9,[16] 5.2[16]	mg/dL	
Total calcium (Ca)	2.1,[9][17] 2.2[4]	2.5,[4][17] 2.6,[17] 2.8[9]	mmol/L	
	8.4,[9] 8.5[18]	10.2,[9] 10.5[18]	mg/dL	
Total serum iron (TSI) - male	65,[19] 76[10]	176,[19] 198[10]	µg/dL	See hypoferremia or the following: iron overload (hemochromatosis), iron poisoning, siderosis, hemosiderosis, hyperferremia
	11.6,[20][21] 13.6[21]	30,[20] 32,[21] 35[21]	µmol/L	
Total serum iron (TSI) - female	26,[10] 50[19]	170[10][19]	µg/dL	
	4.6,[21] 8.9[20]	30.4[20]	µmol/L	
Total serum iron (TSI) - newborns	100[19]	250[19]	µg/dL	
	18[21]	45[21]	µmol/L	
Total serum iron (TSI) - children	50[19]	120[19]	µg/dL	
	9[21]	21[21]	µmol/L	
Total iron-binding capacity (TIBC)	240,[19] 262[10]	450,[19] 474[10]	µg/dL	
	43,[21] 47[21]	81,[21] 85[21]	µmol/L	
Transferrin	190,[22] 194,[4] 204[10]	326,[4] 330,[22] 360[10]	mg/dL	
	25[23]	45[23]	µmol/L	
Transferrin saturation	20[19]	50[19]	%	
Ferritin - Males and postmenopausal females	12[24]	300[24][25]	ng/mL or µg/L	
	27[26]	670[26]	pmol/L	
Ferritin - premenopausal females	12[24]	150[24] - 200[25]	ng/mL or µg/L	
	27[26]	330[26] - 440[26]	pmol/L	
Ammonia	10,[27] 20[28]	35,[27] 65[28]	µmol/L	See hypoammonemia and hyperammonemia
	17,[29] 34[29]	60,[29] 110[29]	µg/dL	

Copper (Cu)	70[18]	150[18]	µg/dL	See hypocupremia or hypercupremia
	11[30][31]	24[30]	µmol/L	
Ceruloplasmin	15[18]	60[18]	mg/dL	
	1[32]	4[32]	µmol/L	
Phosphate (HPO_4^{2-})	0.8	1.5[33]	mmol/L	See hypophosphatemia or hyperphosphatemia
Inorganic phosphorus (serum)	1.0[9]	1.5[9]	mmol/L	
	3.0[9]	4.5[9]	mg/dL	
Zinc (Zn)	60,[34] 72[35]	110,[35] 130[34]	µg/dL	See zinc deficiency or zinc poisoning
	9.2,[36] 11[4]	17,[4] 20[36]	µmol/L	
Magnesium	1.5,[18] 1.7[37]	2.0,[18] 2.3[37]	mEq/L or mg/dL	See hypomagnesemia or hypermagnesemia
	0.6,[38] 0.7[4]	0.82,[38] 0.95[4]	mmol/L	

Acid-base and blood gases

If arterial/venous is not specified for an acid-base or blood gas value, then it generally refers to arterial, and not venous which otherwise is standard for other blood tests.

Acid-base and blood gases are among the few blood constituents that exhibit substantial difference between arterial and venous values.[5] Still, pH, bicarbonate and base excess show a high level of inter-method reliability between arterial and venous tests, so arterial and venous values are roughly equivalent for these.[39]

Test	Arterial/Venous	Lower limit	Upper limit	Unit
pH	Arterial	7.34,[10] 7.35[9]	7.44,[10] 7.45[9]	
	Venous	7.31[40]	7.41[40]	
$[H^+]$	Arterial	36[9]	44[9]	nmol/L
		3.6[41]	4.4[41]	ng/dL
Base excess	Arterial & venous[40]	-3[40]	+3[40]	mEq/L
oxygen partial pressure (pO_2)	Arterial pO_2	10,[9] 11[42]	13,[42] 14[9]	kPa
		75,[9][10] 83[18]	100,[10] 105[9]	mmHg or torr
	Venous	4.0[42]	5.3[42]	kPa
		30[40]	40[40]	mmHg or torr
Oxygen saturation	Arterial	94,[40] 95,[13] 96[18]	100[13][18]	%
	Venous	Approximately 75[13]		
Carbon dioxide partial pressure (PCO_2)	Arterial P_aCO_2	4.4,[9] 4.7[42]	5.9,[9] 6.0[42]	kPa
		33,[9] 35[10]	44,[9] 45[10]	mmHg or torr
	Venous	5.5,[42]	6.8[42]	kPa
		41[40]	51[40]	mmHg or torr
Absolute content of carbon dioxide (CO_2)	Arterial	23[40]	30[40]	mmol/L
		100[43]	132[43]	mg/dL
Bicarbonate (HCO_3^-)	Arterial & venous	18[18]	23[18]	mmol/L
		110[44]	140[44]	mg/dL
Standard bicarbonate (SBC_e)	Arterial & venous	21, 22[9]	27, 28[9]	mmol/L or mEq/L[9]
		134[44]	170[44]	mg/dL

Liver function

Test	Patient type	Lower limit	Upper limit	Unit	Comments
Total protein		60,[9] 63[10]	78,[9] 82,[10] 84[18]	g/L	
Albumin		35[9][45]	48,[10] 55[9]	g/L	see hypoalbuminemia
		3.5[10]	4.8,[10] 5.5[9]	U/L	
		540[46]	740[46]	µmol/L	
Globulins		23[9]	35[9]	g/L	
Total bilirubin		1.7,[47] 2,[9] 3.4,[47] 5[4]	17,[9][47] 22,[47] 25[4]	µmol/L	
		0.1,[9] 0.2,[10] 0.29[48]	1.0,[9][18] 1.3,[10] 1.4[48]	mg/dL	
Direct/conjugated bilirubin		0.0[9] or N/A[4]	5,[9] 7[4][47]	µmol/L	
		0[9][10]	0.3,[9][10] 0.4[18]	mg/dL	
Alanine transaminase (ALT/ALAT[4])		5,[49] 7,[10] 8[9]	20,[9] 21,[13] 56[10]	U/L	Also called *serum glutamic pyruvic transaminase* (SGPT)
	Female	0.15[4]	0.75[4]	µkat/L	
	Male	0.15[4]	1.1[4]		
Aspartate transaminase (AST/ASAT[4])	Female	6[50]	34[50]	IU/L	Also called *serum glutamic oxaloacetic transaminase* (SGOT)
		0.25[4]	0.60[4]	µkat/L	
	Male	8[50]	40[50]	IU/L	
		0.25[4]	0.75[4]	µkat/L	
Alkaline phosphatase (ALP)	Female	42[49]	98[49]	U/L	
	Male	53[49]	128[49]		
	(Enzyme activity)	0.6[4]	1.8[4]	µkat/L	
Gamma glutamyl transferase (GGT)		5,[49] 8[10]	40,[49] 78[10]	U/L	
	Women		0.63[51]	µkat/L	
	Men		0.92[51]	µkat/L	

Cardiac tests

Test	Patient type	Lower limit	Upper limit	Unit	Comments
Creatine kinase (CK)	male	24,[52] 38,[10] 60[49]	174,[18] 320[49]	U/L or ng/mL	
		0.42[53]	1.5[53]	µkat/L	
	female	24,[52] 38,[10] 96[18]	140,[18] 200[49]	U/L or ng/mL	
		0.17[53]	1.17[53]	µkat/L	
CK-MB		0	3,[10] 3.8,[4] 5[49]	ng/mL or µg/L[4]	
Myoglobin	Female	1[54]	66[54]	ng/mL or µg/L	
	Male	17[54]	106[54]		

Brain natriuretic peptide (BNP)	
Interpretation	**Range / Cutoff**
Congestive heart failure unlikely	< 100 pg/mL[55][56]
"Gray zone"	100-500 pg/mL[55][56]
Congestive heart failure likely	>500 pg/mL[55][56]

NT-proBNP		
Interpretation	**Age**	**Cutoff**
Congestive heart failure likely	< 75years	> 125 pg/mL[57]
	>75 years	>450pg/mL[57]

Lipids

Test	Patient type	Lower limit	Upper limit	Unit	Therapeutic target
Triglycerides	10 – 39 years	54[18]	110[18]	mg/dL	< 100 mg/dL[58] or 1.1[58] mmol/L
		0.61[59]	1.2[59]	mmol/L	
	40 – 59 years	70[18]	150[18]	mg/dL	
		0.77[59]	1.7[59]	mmol/L	
	> 60 years	80[18]	150[18]	mg/dL	
		0.9[59]	1.7[59]	mmol/L	
Total cholesterol		3.0,[60] 3.6[9][60]	5.0,[4][61] 6.5[9]	mmol/L	< 3.9[58]
		120,[10] 140[9]	200,[10] 250[9]	mg/dL	< 150[58]
HDL cholesterol	female	1.0,[62] 1.2,[4] 1.3[60]	2.2[62]	mmol/L	> 1.0[62] or 1.6[60] mmol/L > 40[63] or 60[64] mg/dL
		40,[63] 50[65]	86[63]	mg/dL	
HDL cholesterol	male	0.9[4][62]	2.0[62]	mmol/L	
		35[63]	80[63]	mg/dL	
LDL cholesterol (Not valid when triglycerides >5.0 mmol/L)		2.0,[62] 2.4[61]	3.0,[4][61] 3.4[62]	mmol/L	< 2.5[62]
		80,[63] 94[63]	120,[63] 130[63]	mg/dL	< 100[63]
LDL/HDL quotient		n/a	5[4]	(unitless)	

Tumour markers

Test	Cutoff	Unit	Comments
Alpha fetoprotein (AFP)	44[10]	ng/mL or µg/L	Hepatocellular carcinoma or testicular cancer
Beta Human chorionic gonadotrophin (bHCG)	5[10]	IU/l or mU/ml	in male and non-pregnant female
CA19-9	40[10]	U/ml	Pancreatic cancer
CA-125	30,[66] 35[67]	kU/L or U/mL	
Carcinoembryonic antigen (CEA) non-smokers at 50 years	3.4,[4] 3.6[68]	µg/l	
Carcinoembryonic antigen (CEA) non-smokers at 70 years	4.1[68]	µg/l	
Carcinoembryonic antigen (CEA) - smokers	5[69]	µg/l	
Prostate specific antigen (PSA)	2.5,[4] 4[10]	µg/L[4][10] or ng/mL[18]	below age 45 <2.5 µg/L
PAP	3[18]	units/dL (Bodansky units)	
Calcitonin	5,[70] 15[70]	ng/L or pg/mL	Cutoff against medullary thyroid cancer[70]

Endocrinology

Thyroid hormones

Test	Patient type	Lower limit	Upper limit	Unit
Thyroid stimulating hormone (TSH or thyrotropin)	Adults - standard range	0.3,[4] 0.4,[10] 0.5,[18] 0.6[71]	4.0,[4] 4.5,[10] 6.0[18]	mIU/L or µIU/mL
	Adults - optimal range	0.3,[72] 0.5[73]	2.0,[73] 3.0[72]	mIU/L or µIU/mL
	Infants	1.3[74]	19[74]	mIU/L or µIU/mL
Free thyroxine (FT4)	Normal adult	0.7,[75] 0.8[10]	1.4,[75] 1.5,[10] 1.8[76]	ng/dL
		9,[4][77] 10,[78] 12[79]	18,[4][77] 23[79]	pmol/L
	Child/Adolescent 31 d - 18 y	0.8[75]	2.0[75]	ng/dL
		10[77]	26[77]	pmol/L
	Pregnant	0.5[75]	1.0[75]	ng/dL
		6.5[77]	13[77]	pmol/L
Total thyroxine		4,[78] 5.5[10]	11,[78] 12.3[10]	µg/dL
		60[78][79]	140,[78] 160[79]	nmol/L
Free triiodothyronine (FT3)	Normal adult	0.2[78]	0.5[78]	ng/dL
		3.1[80]	7.7[80]	pmol/L
	Children 2-16 y	0.1[81]	0.6[81]	ng/dL
		1.5[80]	9.2[80]	pmol/L
Total triiodothyronine		60,[10] 75[78]	175,[78] 181[10]	ng/dL
		0.9,[4] 1.1[78]	2.5,[4] 2.7[78]	nmol/L
Thyroxine-binding globulin (TBG)		12[10]	30[10]	mg/L
Thyroglobulin (Tg)		1.5[78]	30[78]	pmol/L
		1[78]	20[78]	µg/L

Sex hormones

The diagrams below take inter-cycle and inter-woman variability into account in displaying reference ranges for estradiol, progesterone, FSH and LH.

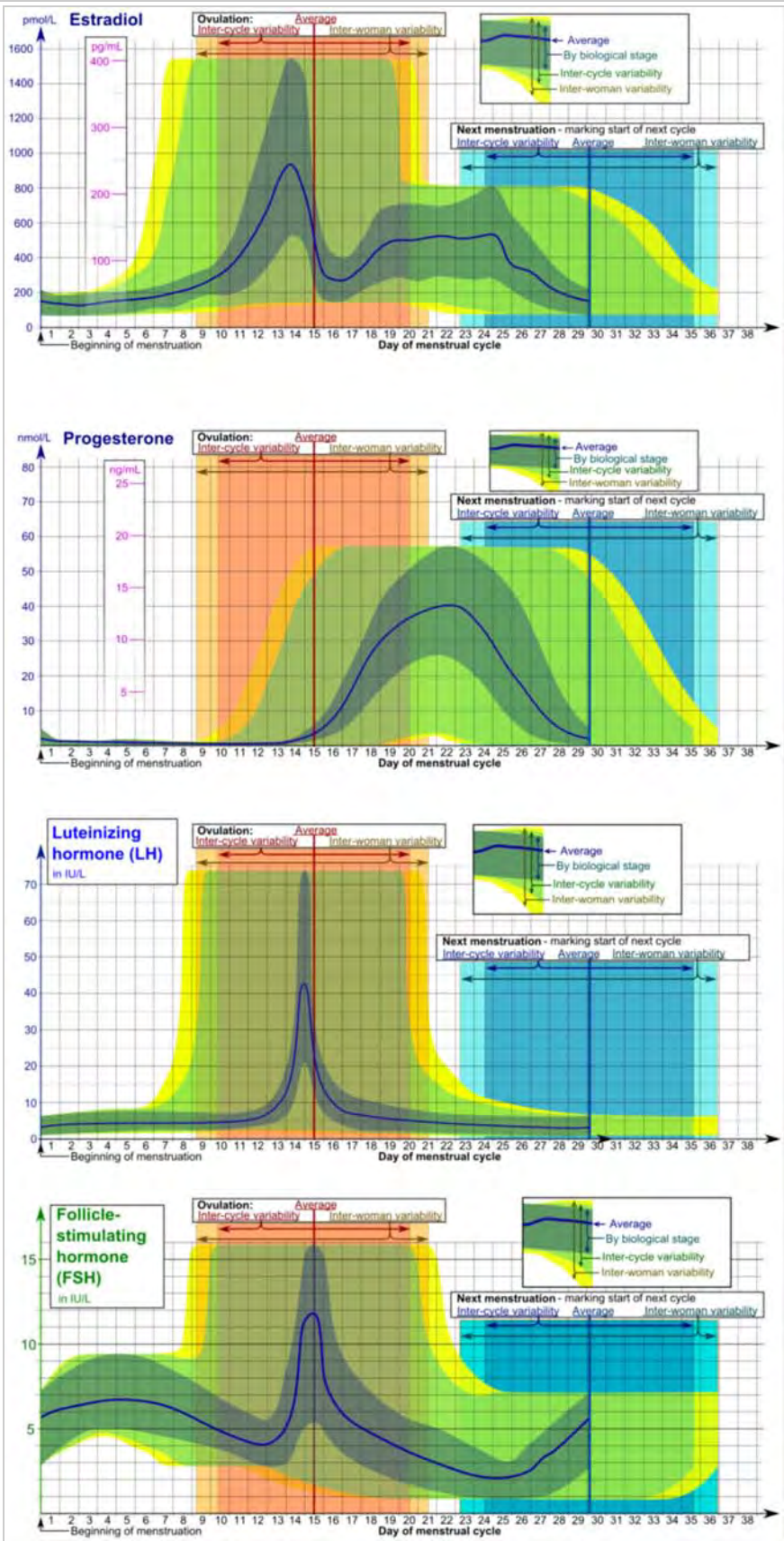

Levels of estradiol (the main estrogen), progesterone, luteinizing hormone and follicle-stimulating hormone during the menstrual cycle.

Test	Patient type	Lower limit	Upper limit	Unit
Dihydrotestosterone	adult male	30[82]	85[82]	ng/dL
Testosterone	Male, overall	8,[83] 10[84]	27,[83] 35[84]	nmol/L
		230,[85] 300[86]	780[85] - 1000[86]	ng/dL
	Male < 50 years	10[4]	45[4]	nmol/L
		290[85]	1300[85]	ng/dL
	Male > 50 years	6.2[4]	26[4]	nmol/L
		180[85]	740[85]	ng/dL
	Female	0.7[84]	2.8[84] - 3.0[4]	nmol/L
		20[86]	80[86] - 85[85]	ng/dL
17α-Hydroxyprogesterone	male	0.06[18]	3.0[18]	mg/L
		0.18[87]	9.1[87]	µmol/l
	Female (Follicular phase)	0.2[18]	1.0[18]	mg/L
		0.6[87]	3.0[87]	µmol/l
Follicle-stimulating hormone (FSH)	Prepubertal	<1[88]	3[88]	IU/L
	Adult male	1[88]	8[88]	
	Adult female (follicular and luteal phase)	1[88]	11[88]	
	Adult female (Ovulation)	6[88] 95% PI (standard)	26[88] 95% PI)	
		5[89] 90% PI (used in diagram)	15[89] (90% PI)	
	Post-menopausal female	30[88]	118[88]	
Luteinizing hormone (LH)	Female, peak	20[89] 90% PI (used in diagram)	75[89] (90% PI)	IU/L
	Female, post-menopausal	15[90]	60[90]	
	Male aged 18+	2[91]	9[91]	
Estradiol (an estrogen)	Adult male	50[92]	200[92]	pmol/L
		14[93]	55[93]	pg/mL
	Adult female (day 5 of follicular phase, and luteal phase)	70[92]	500,[92] 600[92]	pmol/L
		19[93]	140,[93] 160[93]	pg/mL
	Adult female - free (not protein bound)	0.5[94]	9[94]	pg/mL
		1.7[94]	33[94]	pmol/L
	Post-menopausal female	N/A[92]	< 130[92]	pmol/L
		N/A[93]	< 35[93]	pg/mL
Progesterone	Female in mid-luteal phase (day 21-23)	17,[89] 35[95]	92[95]	nmol/L
		6,[89] 11[96]	29[96]	ng/mL
Androstenedione	Adult male and female	60[90]	270[90]	ng/dL

	Post-menopausal female		< 180[90]	
	Prepubertal		< 60[90]	
Dehydroepiandrosterone sulfate	Adult male and female	30[97]	400[97]	µg/dL
SHBG	Adult female	40[98]	120[98]	nmol/L
	Adult male	20[98]	60[98]	
Anti-Müllerian hormone (AMH)	13–45 years	0.7[99]	20[99]	ng/mL
		5[100]	140[100]	pmol/l

Other hormones

Test	Patient type	Lower limit	Upper limit	Unit
Adrenocorticotropic hormone (ACTH)		4.4[101]	18,[102] 22[101]	pmol/L
		20[10]	80,[103] 100[10]	pg/mL
Cortisol	09:00 am	140[104]	700[104]	nmol/L
		5[105]	25[105]	µg/dL
	Midnight	80[104]	350[104]	nmol/L
		2.9[105]	13[105]	µg/dL
Growth hormone (fasting)		0	5[9]	ng/mL
Growth hormone (arginine stimulation)		7[9]	n/a	ng/mL
IGF-1	Female, 20 yrs	110[106]	420[106]	ng/mL
	Female, 75 yrs	55[106]	220[106]	
	Male, 20 yrs	160[106]	390[106]	
	Male, 75 yrs	48[106]	200[106]	
Prolactin	Female	71,[107] 105[107]	348,[107] 548[107]	mIU/L
		3.4,[107] 3.9[107]	16.4,[107] 20.3[107]	µg/L
	Male	58,[107] 89[107]	277,[107] 365[107]	mIU/L
		2.7,[107] 3.3[107]	13.0,[107] 13.5[107]	µg/L
Parathyroid hormone (PTH)		10,[108] 17[109]	65,[108] 70[109]	pg/mL
		1.1,[4] 1.8[110]	6.9,[4] 7.5[110]	pmol/L
25-hydroxycholecalciferol (a vitamin D) -Standard reference range		8,[18][111] 9[111]	40,[111] 80[18]	ng/mL
		20,[112] 23[113]	95,[113] 150[112]	nmol/L
25-hydroxycholecalciferol -Therapeutic target range		30,[114] 40[115]	65,[115] 100[114]	ng/mL
		85,[58] 100[115]	120,[58] 160[115]	nmol/L
Plasma renin activity		0.29,[116] 1.9[117]	3.7[116][117]	ng/(mL*hour)
		3.3,[118] 21[119]	41[118][119]	mcU/mL
Aldosterone	Adult		19,[118] 34.0[118]	ng/dL
			530,[120] 940[120]	pmol/L
Aldosterone-to-renin ratio	Adult		13.1,[121] 35.0[121]	ng/dl per ng/(mL·h)
			360,[121] 970[121]	pmol/liter per µg/(L·h)

Vitamins

Also including the vitamin B_{12})-related amino acid homocysteine.

Test	Patient type	Standard range		Unit	Optimal range	
		Lower limit	Upper limit		Lower limit	Upper limit
Vitamin A		30[18]	65[18]	µg/dL		
Vitamin B_9 (Folic acid/Folate) - **Serum**	Age > 1year	3.0[122]	16[122]	ng/mL or µg/L	5[123]	
		6.8[124]	36[124]	nmol/l	11[124]	
Vitamin B_9 (Folic acid/Folate) - **Red blood cells**		200[122]	600[122]	ng/mL or µg/L		
		450[124]	1400[124]	nmol/L		
	Pregnant			ng/mL or µg/L	400[122]	
				nmol/L	900[122]	
Vitamin B_{12} (Cobalamin)		130,[125] 160[126]	700,[125] 950[126]	ng/L		
		100,[127] 120[4]	520,[127] 700[4]	pmol/L		
Homocysteine		3.3,[128] 5.9[128]	7.2,[128] 15.3[128]	µmol/L		6.3[58]
		45,[129] 80[129]	100,[129] 210[129]	µg/dL		85[58]
Vitamin C (Ascorbic acid)		0.4[18]	1.5[18]	mg/dL	0.9[58]	
		23[130]	85[130]	µmol/L	50[58]	
25-hydroxycholecalciferol (a vitamin D)		8,[18][111] 9[111]	40,[111] 80[18]	ng/mL	30,[114] 40[115]	65,[115] 100[114]
		20,[112] 23[113]	95,[113] 150[112]	nmol/L	85,[58] 100[115]	120,[58] 160[115]
Vitamin E				µmol/L	28[58]	
				mg/dL	1.2[58]	

Toxins

Test	Limit type	Limit	Unit
Lead	Optimal health range	< 20[13] or 40[18]	µg/dL
Blood ethanol content	Limit for drunk driving	0,[131] 0.2,[131] 0.8[131]	‰ or g/L
		17.4[132]	mmol/L

Hematology

Red blood cells

These values (except *Hemoglobin in plasma*) are for total blood and not only blood plasma.

Test	Patient	Lower limit	Upper limit	Unit	Comments
Hemoglobin (Hb)	male	2.0,[133] 2.1[9][134]	2.5,[133] 2.7[9][134]	mmol/L	Higher in neonates, lower in children.
		130,[4] 132,[10] 135[9]	162,[10] 170,[4] 175[9]	g/L	
	female	1.8,[133] 1.9[9][134]	2.3,[133] 2.5[9][133][134]	mmol/L	Sex difference negligible until adulthood.
		120[4][9][10]	150,[4] 152,[10] 160[9][18]	g/L	
Hemoglobin subunits (sometimes displayed simply as "Hemoglobin")	male	8.0,[135] 8.4[135]	10.0,[135] 10.8[135]	mmol/L	4 per hemoglobin molecule
	female	7.2,[135] 7.6[135]	9.2,[135] 10.0[135]		
Hemoglobin in plasma		0.16[9]	0.62[9]	µmol/L	Normally diminutive compared with inside red blood cells
		1	4	mg/dL	
Glycated hemoglobin (Hb_{A1c})	< 50 years	3.6[4]	5.0[4]	% of Hb	
	> 50 years	3.9[4]	5.3[4]		
Haptoglobin	< 50 years	0.35[4]	1.9[4]	g/L	
	> 50 years	0.47[4]	2.1[4]		
Hematocrit (Hct)	male	0.39,[4] 0.4,[10] 0.41,[9] 0.45[18]	0.50,[4] 0.52,[10] 0.53,[9] 0.62[18]		
	female	0.35,[4] 0.36,[9] 0.37[10][18]	0.46,[4][9][10] 0.48[18]		
	Child	0.31[10]	0.43[10]		
Mean cell volume (MCV)	Male	76,[18] 82[10]	100,[18] 102[10]	fL	Cells are larger in neonates, though smaller in other children.
	Female	78[10]	101[10]	fL	
Red blood cell distribution width (RDW)		11.5[10]	14.5[10]	%	
Mean cell hemoglobin (MCH)		0.39[9]	0.54[9]	fmol/cell	
		25,[9] 27[4][18]	32,[18] 33,[4] 35[9]	pg/cell	
Mean corpuscular hemoglobin concentration (MCHC)		31,[10] 32[4][18]	35,[10] 36[4][18]	g/dL or %[note 1]	
		4.8,[136] 5.0[136]	5.4,[136] 5.6[136]	mmol/L	
Erythrocytes/Red blood cells (RBC)	male	4.2,[18] 4.3[4][9][10]	5.7,[4] 5.9,[9] 6.2,[10] 6.9[18]	$x10^{12}$/L or mln/mm^3	
	Female	3.5,[9] 3.8,[10] 3.9[4]	5.1,[4] 5.5[9][10]		
	Infant/Child	3.8[10]	5.5[10]		
Reticulocytes	Adult	26[4]	130[4]	$x10^9$/L	

	Adult	0.5[9][10]	1.5[9][10]	% of RBC	
	Newborn	1.1[10]	4.5[10]	% of RBC	
	Infant	0.5[10]	3.1[10]	% of RBC	

White blood cells

These values are for total blood and not only blood plasma.

Test	Patient type	Lower limit	Upper limit	Unit
White Blood Cell Count (WBC)	Adult	3.5,[4] 3.9,[137] 4.1,[10] 4.5[9]	9.0,[4] 10.0,[137] 10.9,[10] 11[9]	▪ $x10^9$/L ▪ $x10^3/mm^3$ or ▪ $x10^3$/µL
	Newborn	9[138]	30[138]	
	1 year old	6[138]	18[138]	
Neutrophil granulocytes (A.K.A. grans, polys, PMNs, or segs)	Adult	1.3,[4] 1.8,[137] 2[138]	5.4,[4] 7,[137] 8[138]	$x10^9$/L
		45-54[9]	62,[9] 74	% of WBC
	Newborn	6[138]	26[138]	$x10^9$/L
Neutrophilic band forms	Adult		0.7[138]	$x10^9$/L
		3[9]	5[9]	% of WBC
Lymphocytes	Adult	0.7,[4] 1.0[137][138]	3.5,[137] 3.9,[4] 4.8[138]	$x10^9$/L
		16-25[9]	33,[9] 45	% of WBC
	Newborn	2[138]	11[138]	$x10^9$/L
Monocytes	Adult	0.1,[4] 0.2[139][140]	0.8[4][138][140]	$x10^9$/L
		3,[9] 4.0	7,[9] 10	% of WBC
	Newborn	0.4[138]	3.1[138]	$x10^9$/L
Mononuclear leukocytes (Lymphocytes + monocytes)	Adult	1.5	5	$x10^9$/L
		20	35	% of WBC
$CD4^+$ T cells	Adult	0.4,[10] 0.5[13]	1.5,[13] 1.8[10]	$x10^9$/L
Eosinophil granulocytes	Adult	0.0,[4] 0.04[140]	0.44,[140] 0.45,[138] 0.5[4]	$x10^9$/L
		1[9]	3,[9] 7	% of WBC
	Newborn	0.02[138]	0.85[138]	$x10^9$/L
Basophil granulocytes	Adult	40[137]	100,[4][140] 200,[138] 900[137]	$x10^6$/L
		0.0	0.75,[9] 2	% of WBC
	Newborn		0.64[138]	$x10^9$/L

Coagulation

Test	Lower limit	Upper limit	Unit	Comments
Thrombocyte/Platelet count (Plt)	140,[10] 150[4][9]	350,[4][18] 400,[9] 450[10]	$x10^9$/L or x1000/µL	
Mean platelet volume (MPV)	7.2,[141] 7.4,[142] 7.5[143]	10.4,[142] 11.5,[143] 11.7[141]	fL	
Prothrombin time (PT)	10,[13] 11,[9][144] 12[10]	13,[13] 13.5,[144] 14,[10] 15[9]	s	PT reference varies between laboratory kits - INR is standardised
INR	0.9[4]	1.2[4]		The INR is a corrected ratio of a patient's PT to normal
Activated partial thromboplastin time (APTT)	18,[10] 30[4][13]	28,[10] 42,[4] 45[13]	s	
Thrombin clotting time (TCT)	11	18	s	
Fibrinogen	1.7,[10] 2.0[4]	3.6,[4] 4.2[10]	g/L	
Antithrombin	0.80[4]	1.2[4]	kIU/L	
	0.15,[145] 0.17[146]	0.2,[145] 0.39[146]	mg/mL	
Bleeding time	2	9	minutes	
Viscosity	1.5[147]	1.72[147]	cP	

Immunology

Acute phase proteins

Acute phase proteins are markers of inflammation.

Test	Patient	Lower limit	Upper limit	Unit	Comments
Erythrocyte sedimentation rate (ESR)	Male	0	Age÷2[148]	mm/h	ESR increases with age and tends to be higher in females.[149]
	Female		(Age+10)÷2[148]		
C-reactive protein (CRP)			5,[4][150] 6[151]	mg/L	
			200,[152] 240[152]	nmol/L	
Alpha 1-antitrypsin (AAT)		20,[153] 22[154]	38,[154] 53[153]	µmol/L	
		89,[155] 97[4]	170,[4] 230[155]	mg/dL	
Procalcitonin			0.15[156]	ng/mL or µg/L	

Isotypes of antibodies

Test	Patient	Lower limit	Upper limit	Unit	Comments
IgA	Adult	70,[4] 110[157]	360,[4] 560[157]	mg/dL	
IgD		0.5[157]	3.0[157]		
IgE		0.01[157]	0.04[157]		
IgG		800[157]	1800[157]		
IgM		54[157]	220[157]		

Autoantibodies

Autoantibodies are usually absent or very low, so instead of being given in standard reference ranges, the values usually denote where they are said to be present, or whether the test is a positive test. There may also be an *equivocal* interval, where it is uncertain whether there is a significantly increased level. All included values[158] are given for the ELISA test.

Test	Negative	Equivocal	Positive	Unit
anti-SS-A (Ro)	< 15[159]	15-25[159]	> 25[159]	Units per millilitre (U/mL)
anti-SS-B (La)	< 3[159]	3 – 4[159]	> 4[159]	
Anti ds-DNA	< 40[159]	40 – 60[159]	> 60[159]	
Anti ss-DNA	< 8[159]	8 - 10[159]	> 10[159]	
Anti-histone antibodies	< 25[159]	n/a[159]	> 25[159]	
Cytoplasmic/classical anti-neutrophil cytoplasmic antibodies (c-ANCA)	< 20[159]	21 - 30[159]	> 30[159]	
Perinuclear anti-neutrophil cytoplasmic antibodies (p-ANCA)	< 5[159]	n/a	> 5[159]	
Anti-mitochondrial antibodies (AMA)	< 10[159]	n/a[159]	> 10[159]	
Rheumatoid factor (RF)	< 20	20 - 30	> 30[10]	
Antistreptolysin O titre (ASOT) in preschoolers			> 100	
ASOT at school age			> 250[10]	
ASOT in adults			> 125[10]	

Test	Negative	Low/weak positive	Moderate positive	High/strong positive	Unit
Anti-phospholipid IgG	< 20[159]	20 –30[159]	31 – 50[159]	> 51[159]	GPLU/ml[159]
Anti-phospholipid IgM	< 1.5[159]	1.5 –2.5[159]	2 – 9.9[159]	> 10[159]	MPL /ml[159]
Anti-phospholipid IgA	< 10[159]	10 -20[159]	21 – 30[159]	> 31[159]	arb U/ml[159]
Anti-citrullinated protein antibodies	< 20[159]	20 – 39[159]	40 - 59[159]	> 60[159]	EU[159]

Other immunology

Test	Lower limit	Upper limit	Unit
Serum free light chains (FLC): kappa/lambda ratio	0.26[160]	1.65[160]	(unit-less)

Other enzymes and proteins

Test	Lower limit	Upper limit	Unit	Comments
Serum total protein	60,[9] 63[10]	78,[9] 82,[10] 84[18]	g/L	
Lactate dehydrogenase (LDH)	50[18]	150[18]	U/L	
	0.4[49]	1.7[49]	µmol/L	
	1.8[4]	3.4[4]	µkat/L	< 70 years old[4]
Amylase	25,[9] 30,[10] 53[18]	110,[10] 120,[161] 123,[18] 125,[9] 190[49]	U/L	
	0.15[4]	1.1[4]	µkat/L	
	200[152]	240[152]	nmol/L	
D-dimer	n/a	500[162]	ng/mL	Higher in pregnant women[163]
		0.5[4]	mg/L	
Lipase	7,[10] 10,[18] 23[49]	60,[10] 150,[18] 208[49]	U/L	
Angiotensin-converting enzyme (ACE)	23[49]	57[49]	U/L	
Acid phosphatase		3.0[49]	ng/mL	
Eosinophil cationic protein (ECP)	2.3[4]	16[4]	µg/L	

Other electrolytes and metabolites

Electrolytes and Metabolites: For iron and copper, some related proteins are also included.

Test	Patient type	Lower limit	Upper limit	Unit	Comments
Osmolality		275,[9] 280,[18] 281[4]	295,[9] 296,[18] 297[4]	mOsm/kg	Plasma weight excludes solutes
Osmolarity		Slightly less than osmolality		mOsm/l	Plasma volume includes solutes
Urea		3.0[164]	7.0[164]	mmol/L	BUN - blood urea nitrogen
		7[9]	18,[9] 21[10]	mg/dL	
* Uric acid[10]		0.18[9]	0.48[9]	mmol/L	
	Female	2.0[18]	7.0[18]	mg/dL	
	Male	2.1[18]	8.5[18]	mg/dL	
Creatinine	male	60,[4] 68[165]	90,[4] 118[165]	µmol/L	May be complemented with creatinine clearance
		0.7,[166] 0.8[166]	1.0,[166] 1.3[166]	mg/dL	
	female	50,[4] 68[165]	90,[4] 98[165]	µmol/L	
		0.6,[166] 0.8[166]	1.0,[166] 1.1[166]	mg/dL	
BUN/Creatinine Ratio		5[18]	35[18]	-	
Plasma glucose (fasting)		3.8,[9] 4.0[4]	6.0,[4] 6.1[167]	mmol/L	*See also* glycated hemoglobin (in hematology)
		65,[10] 70,[9] 72[168]	100,[167] 110[18]	mg/dL	
Full blood glucose (fasting)		3.3[4]	5.6[4]	mmol/L	
		60[168]	100[168]	mg/dL	
Random glucose		3.9[169]	7.8[169]	mmol/L	
		70[170]	140[170]	mg/dL	
Lactate (Venous)		4.5[18]	19.8[18]	mg/dL	
		0.5[171]	2.2[171]	mmol/L	
Lactate (Arterial)		4.5[18]	14.4[18]	mg/dL	
		0.5[171]	1.6[171]	mmol/L	
Pyruvate		300[18]	900[18]	µg/dL	
		34[172]	102[172]	µmol/L	
Ketones			1[173]	mg/dL	
			0.1[173]	mmol/L	

Medication

Test	Lower limit	Upper limit	Unit	Comments
Digoxin	0.5[174]	2.0[174]	ng/ml	Narrow therapeutic window
	0.6[174]	2.6[174]	nmol/l	
Lithium	0.4,[175] 0.5,[176][177] 0.8[178]	1.3[176][177]	mmol/l	Narrow therapeutic window
Paracetamol		30[179]	mg/L	Risk of paracetamol toxicity at higher levels
		200[179]	µmol/L	

See also

- Cardiology diagnostic tests and procedures
- Comprehensive metabolic panel
- Medical technologist
- Reference range

Notes

1. The MCHC in g/dL and the mass fraction of hemoglobin in red blood cells in % are numerically identical in practice, assuming a RBC density of 1g/mL and negligible hemoglobin in plasma.

References

Template:WBC 6.13/UL

External links

- *biochemical reference values (https://www.gpnotebook.co.uk/simplepage.cfm?ID=724893718)* at GPnotebook
- Descriptions at amarillomed.com (http://www.amarillomed.com/howto.htm)
- Values at lymphomation.org (http://www.lymphomation.org/CBC-blood-counts.htm)

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Reflector oven

From Wikipedia, the free encyclopedia

A **reflector oven** (sometimes known in older cooking literature as a **tin kitchen** [1]), is a polished metal container, often made of tin. It is designed to enclose an article of food on all but one side, to cause it to bake by capturing radiant heat from an open fire, and reflecting the heat towards the food. In its simplest form, a reflector oven is simply a box or collar that partially surrounds the food, with an open side that faces the heat source, which is generally either a hearth fire or a portable stove, depending on the situation in which the food is being prepared. In Colonial America this method of baking meat, fowl, quick bread, or pastries, was a very popular method for hearth cooking.

A homemade reflector oven

A reflector oven prior to use

The oven set directly on hot coals

A reflector oven that uses the Sun as its primary heat source is known as a solar cooker.

A Dutch oven, was another popular method of baking while using an open fire or a fire in a hearth. The Dutch oven, unlike the tin kitchen, is made of iron, and would collect and concentrate the heat of coals placed beneath and on top of the oven, while preventing the coals from direct contact with the food, and isolating smoke from the fire from the baking food.

A reflector oven for cooking game birds, at Stokestown Park House

A Reflector oven is set beside the fire to capture the radiant heat, and bake with it. It is often tin, new ones are made from aluminum. The picture with this article shows it being set directly on the coals.

Dutch ovens are normally cast iron, with lids, and outdoor fire ones have legs. It is set directly on coals, with additional coals on the top.

See also

- List of ovens
- Outdoor cooking

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Reforestation in Arid Lands

By: Fred R. Weber with Carol Stoney

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REFORESTATION IN ARID LANDS

Fred R. Weber
with
Carol Stoney

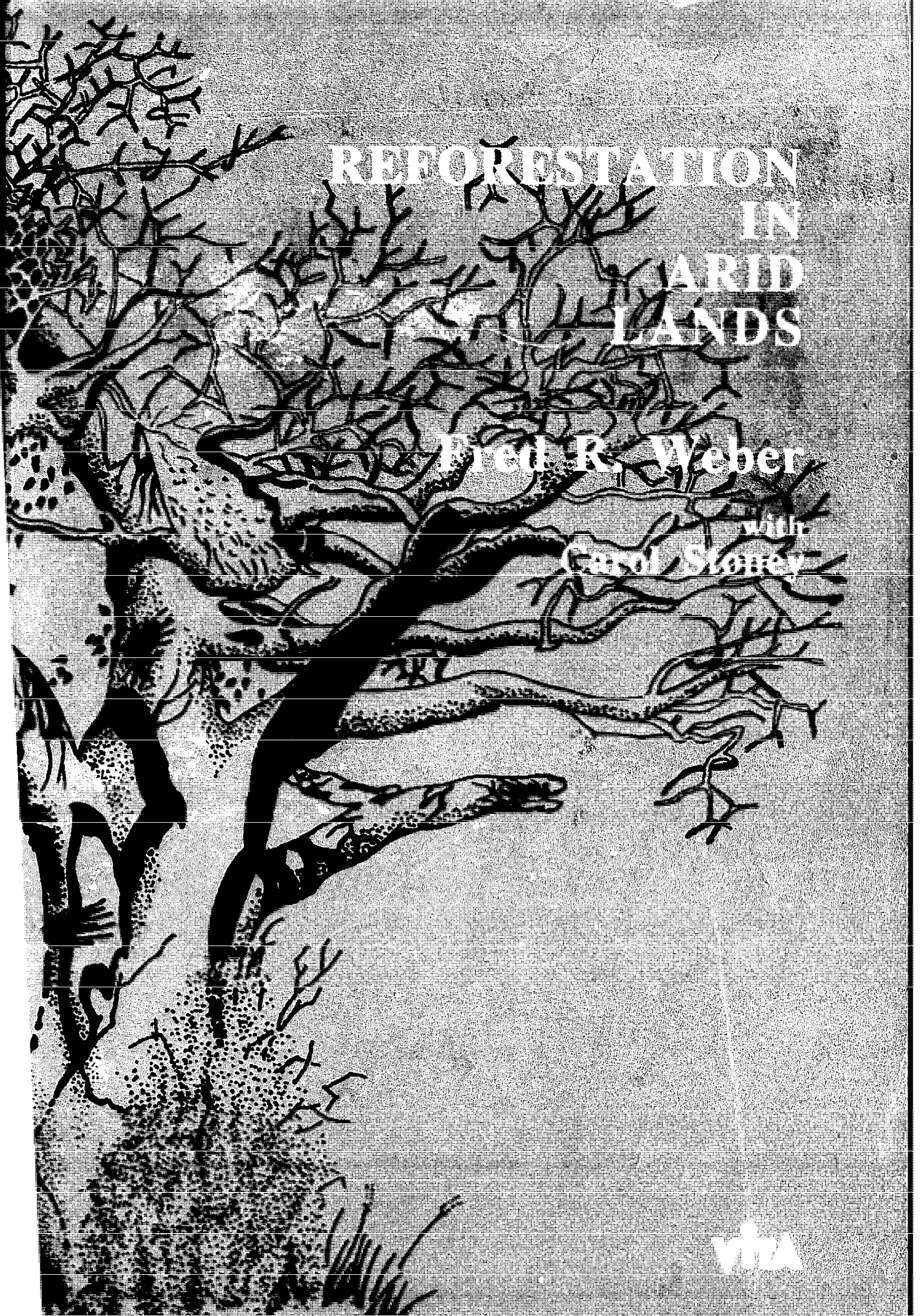

VITA

REFORESTATION IN ARID LANDS

By
Fred R. Weber

With
Carol Stoney

Illustrated By
Frederick J. Holman

Edited By
Margaret Crouch

Volunteers in Technical Assistance
1815 North Lynn Street, Suite 200
Arlington, Virginia 22209
USA

Reforestation in Arid Lands

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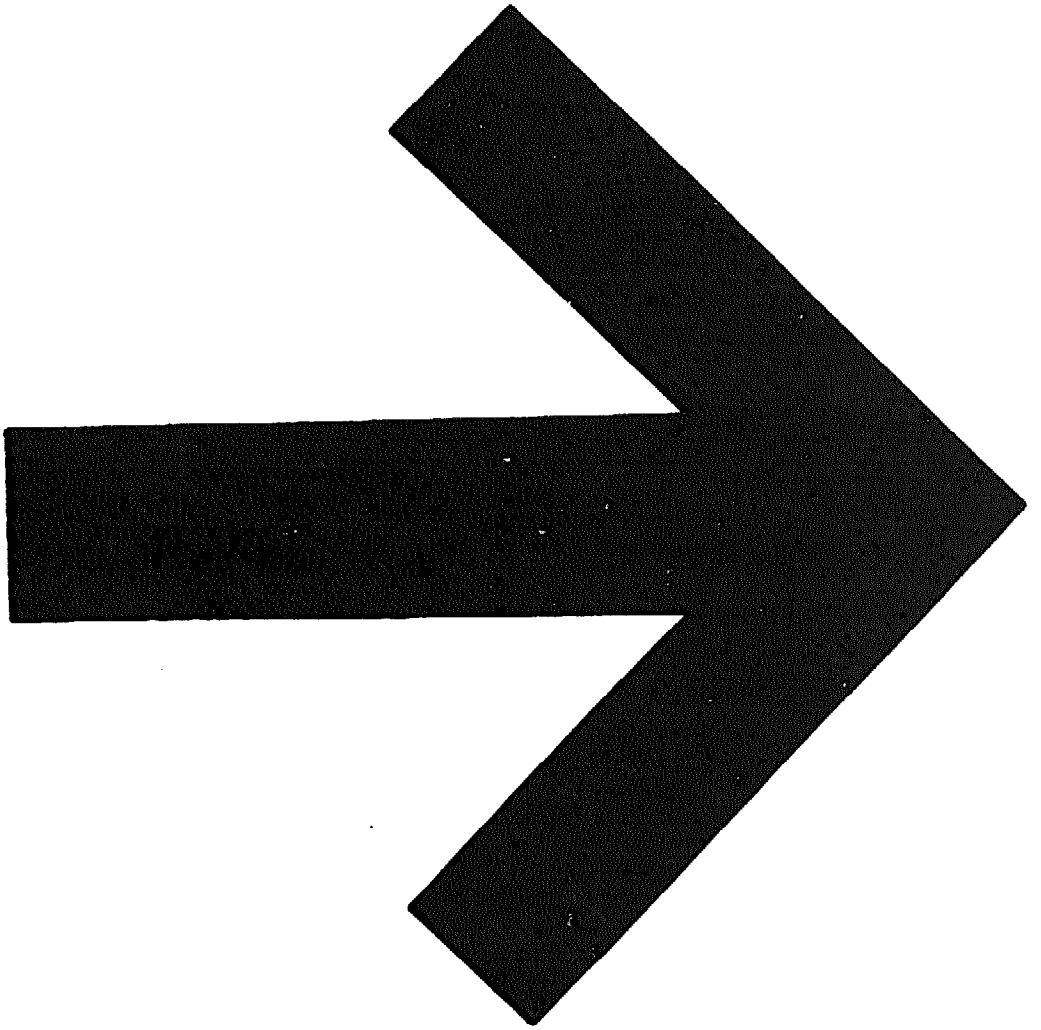

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This second edition of *Reforestation in Arid Lands* is based on ten years of practical field experience in forestry programs around the world. VITA acknowledges with thanks the hard work of all the people who helped translate that experience into the reality of this new edition.

Reforestation author Fred R. Weber, a pioneer in the community forestry concepts presented here, has advised on such projects for over 20 years. He wrote the original edition in 1977 based on a training manual he prepared for Peace Corps volunteers in Niger. Carol Stoney collaborated with Mr. Weber on the revisions for the new edition. They have prepared some entirely new sections, revised and updated the original text, and substantially reorganized the material to make the manual easier to use. Frederick J. Holman, the landscape architect who provided the illustrations for the original, also contributed more than 50 new drawings for this edition. Both Mr. Weber and Mr. Holman are longtime VITA Volunteers, and provided their considerable expertise on a voluntary basis. Ms. Stoney is a more recent member of VITA's volunteer roster, and worked on this project as a VITA Fellow. VITA staff who participated in the preparation of the new edition were Margaret Crouch and Suzanne Brooks.

The first edition of *Reforestation in Arid Lands* was the third manual in a series of publications prepared jointly by the United States Peace Corps and VITA, Volunteers in Technical Assistance. These publications combined Peace Corps' practical field experiences with VITA's technical expertise in areas for which useful resource materials were severely lacking. Peace Corps has also assisted VITA in the preparation of this new edition by reviewing draft versions of the revised text and new material as they were being written, and by providing technical and editorial suggestions and recommendations. VITA would particularly like to acknowledge the help of Peace Corps specialists Jacob Fillion and George Mahaffey, Office of Training and Program Support (OTAPS), and Maureen Delaney, director, Information Collection and Exchange (ICE).

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About VITA

Volunteers in Technical Assistance is a private, nonprofit, international development organization that provides a variety of information and technical resources aimed at fostering self-sufficiency. These resources include needs assessment and program development support, by-mail and on-site consulting services, information systems training, and management of long-term field projects.

VITA places special emphasis on the areas of agriculture and food processing, renewable energy applications, water supply and sanitation, housing and construction, and small business development--areas in which self-sufficiency in the community is an essential step toward the well-being of a nation. VITA is also prepared to provide access to high-tech innovations that will help these communities and countries assume their roles in the modern world.

VITA Volunteers are located all over the world; many have lived and worked in developing countries. They are engineers, scientists, business people, agriculturalists, architects, educators, foresters, and specialists in many other fields. Through VITA they use their particular knowledge to help other people, and thanks to their contributions of time and expertise, VITA has been providing technical assistance to people in developing nations for more than 25 years.

This manual is one of more than 100 titles published by VITA to document and support development projects. VITA publications have been used successfully by villagers, students, teachers, field agents, and extension workers throughout the world. Relevance of subject matter, clarity of instructions, and easy-to-follow plans and illustrations make these materials invaluable resources. VITA also publishes *VITA News*, a quarterly magazine.

FOREWORD

The decade since *Reforestation in Arid Lands* was first published has not been kind to Africa's arid lands. From Senegal to Sudan, each season from the mid-seventies to 1984 brought less rain to nurture crops, water livestock, and sustain households than the average of the previous 70 years. By the early 1980s, food shortages and the threat of famine had followed drought across a vast crescent of savannas from the Sahel through eastern and southern Africa. Millions of people faced starvation; for hundreds of millions of others, the hardships of rural life steadily deepened.

Statistics on Africa sketch a troubled future. The continent's population, just over 400 million people in 1975, has expanded to 583 million in 1986, and will increase by an additional 16 million this year. The UN Food and Agriculture Organization estimates that 2.3 million hectares of Africa's open woodlands--an area nearly the size of Rwanda--are stripped for fuel or cleared to make way for new cropland each year. Much of this farmland, unsuited to sustained cultivation, produces less millet and sorghum per acre than more fertile areas tilled a generation ago. Despite the increase in cropland, harvests per person are declining.

The statistics don't measure the degradation of standing trees, the overcollection of branches for fuel and foliage for fodder, or the careless supervision of flocks of sheep and goats that nibble tree seedlings as they sprout. Savanna woodlands, the natural plant and animal diversity they once sustained, and the fertility of cropland are, like Africa's rural people, the victims of environmental deterioration that is difficult to quantify but impossible to escape.

Few circumstances could be more hostile to the success of reforestation efforts. And yet the last decade has been one of notable progress. Support for forestry has increased in both aid agencies and African governments, and tree planting projects today are better matched to the needs of rural communities. Early emphasis on plantation-based fuelwood production has given way to more centralized community forestry approaches that involve local people in project planning. Recognition that trees can enhance the fertility of agricultural land has prompted research on agroforestry. Native African trees ranging from *Acacia albida*, planted in millet fields to fix nitrogen and boost crop yields, to windbreaks and living fences of *Ziziphus spinachristi*, are today considered a key to restoring agricultural productivity on West Africa's degraded croplands. Prominent and well-publicized success stories, like CARE's windbreak project in the Majjia Valley in Niger, show that tree planting compatible with community needs can succeed even in harsh settings.

Reforestation has become a centerpiece of rural development in arid lands, a key to conserving soil and water supplies, securing food production, and reducing the hardships of rural life. Accordingly, the challenge of reforestation has grown more complex. Foresters must understand how tree species interact with their environments, match trees to the cultural needs, predispositions, and idiosyncracies of rural communities, and coordinate the agendas of development agencies with the limitations of local bureaucracies. It is no longer enough to know forestry alone; foresters must be advocates, lobbyists, accountants, fund raisers, negotiators, and diplomats as well, perhaps all in the same afternoon.

This new edition of *Reforestation in Arid Lands* is a comprehensive reference for people planting trees. Part field guide, part planting manual, part introduction to the legal and social context of reforestation, the book distills the lessons of forestry successes in dozens of countries. Few development activities confront so directly the fundamental human and environmental problems that undermine development and prolong impoverishment throughout Africa's arid lands. Few can match the lasting satisfaction derived from tree planting projects that become self sustaining.

Edward C. Wolf
Worldwatch Institute
Washington, D.C.

1 INTRODUCTION

Wherever people live, they make demands upon the earth. People need land and water to raise crops and livestock; they use wood to build houses and cook food. Trees provide a myriad of other products that are used as household necessities, as well as to add comfort, beauty and flavor to daily existence. The demands of human populations on forests, lakes, and agricultural land are increasing, while resources are decreasing. Fire, overgrazing, and uncontrolled use of already limited resources have added to the hardships caused by drought. Although natural resources are being rapidly used up throughout the world, the demand for them can be met if people plan for their continued, sustained use. More and more countries around the world are now trying to solve such problems and are taking steps to stop the depletion of their national resources. Reforestation and revegetation projects are among the most effective approaches to bringing about a restored, sustainable resource base.

The subject of this manual is reforestation in arid and semi-arid lands, specifically in Sub-Saharan Africa. The first edition of this manual, published jointly by Peace Corps and VITA, was an attempt to present current state-of-the-art examples of reforestation methods used in West Africa. This new edition has a broader geographic focus, drawing on experience in dry regions of eastern and southern Africa as well.

While the manual focuses on Africa, many of the problems that project planners face are similar throughout the world. The major obstacles to reforestation programs are usually caused by a lack of understanding of the social context within which the programs must be carried out, rather than by a lack of technical expertise, equipment, or funding. Local acceptance of a project is indispensable to widespread participation in project activities, which in turn is essential to ensure seedling protection and survival. Reforestation projects will be willingly accepted only if they address specific needs that are locally recognized as high priority problems within the community. This book deals with the broad subject of project design and implementation, and presents methods and planning guides useful in different cultural contexts.

Reforestation efforts are generally begun for three important reasons: 1) to conserve and protect soil and watersheds; 2) to increase the availability of

forest products; and 3) to enhance the physical environment of human habitations. Reforestation programs have been undertaken to provide:

- o erosion control -- trees and shrubs to keep water and wind from carrying away rich topsoils that contain the nutrients that make the land fertile.
- o production of adequate supplies of specific products--wood for fuel and construction, fruit and nuts for food, fodder for livestock, etc.
- o protection--trees to provide shade for people and animals.

But reforestation is only one component of larger land management endeavors. Increasingly projects are being designed with the understanding that it is unrealistic to separate reforestation from overall revegetation and conservation programs. Range and farm management, sand stabilization, agroforestry, and other similar activities are undertaken--ideally--as interdependent parts of an integrated land use system.

The tree planting techniques covered in the first edition dealt mainly with the establishment of small woodlots and community forestry projects. These small, isolated stands of trees, usually planted on communally owned land, have only a minimal effect on the environment. In the almost ten years that have elapsed since then, the importance of thinking more broadly in terms of revegetation is now apparent. More projects are now aimed at encouraging farmers to plant trees on their own property, as well as on public land. Establishment of shrubs, bushes, grasses, and other ground cover, as well as trees, is needed on many sites that do not have sufficient vegetative protection. Recognizing the evolution of this understanding, a new chapter on Agroforestry and Soil Conservation reflects the broader range of activities that comprise reforestation methods.

The first edition of this manual was based on the collective experience of project planners, foresters, nursery workers, and local farmers and herders. Additional information on nursery operation and seedling production has been included in this edition, and sections have been added covering propagation from cuttings, harvesting methods, and special procedures for tree planting on difficult sites. Chapter 4, Soil Properties, has also been rewritten to be more practical for actual field conditions.

The book has also been reorganized to give the material a more logical flow. Chapter 2 presents the environmental and political framework of an agroforestry project, and lists key elements for success. Subsequent chapters progress through the various steps involved in the start-up of a reforestation program. Project design and other aspects of planning are covered in Chapter 3. Chapter 4 provides some background on soil properties that influence site and species selection, which are discussed further in Chapter 5. Chapter 6 gives more detailed information on nursery planning and preparation, and Chapter 7 outlines the steps involved in the organization of tree-planting activities. Chapter 8 describes various methods used in the design of

agroforestry and soil conservation systems, and Chapter 9 covers some additional special subjects.

The appendixes are also worthy of special note:

- Appendix A--a directory of 165 tree species found in arid Africa. Synonyms and common names are given as available. Brief pictorial views of each tree--a leaf, flower, branch, etc.--are provided for most of the species. Where possible, information is given on the uses of the tree (not a comprehensive listing, but an indicator of the value of that tree for certain purposes).

- Appendix B--an expanded look at 30 of the trees highlighted in Appendix A. Each of the trees is treated individually in an attempt to show the value of having comprehensive data sheets that can be used to guide field activities. For example, the sheet has spaces for listing relevant nursery data (such as time needed in the nursery bed or pot) and for noting planting criteria (such as the soil and water requirements of each tree). Hopefully, as reforestation efforts continue and more project data are recorded, these information sheets will become a more complete and important data bank.

- Appendix C--maps and charts explaining climate and rainfall, soil, vegetation, and characteristics of sub-Saharan Africa.

- Appendix D--a listing--expanded for this edition--of other information sources and of bibliographic material which those who require further information and assistance will find extremely valuable.

The manual assumes basic familiarity with reforestation terms and methods. For example, it takes for granted that the reader will be familiar with laterite soils and with the use of such forestry tools as climate maps and vegetation charts.

The text uses only one Latin name for each tree. However, some trees are known by two or more Latin names; these synonyms are given in Appendix A. More than one name per tree can result from any of several causes: a tree may have been "discovered" and named by several different people; disagreement may exist among the experts as to whether a certain tree is a species or a variety of a species; the difference may simply be in spelling because of phonetic dissimilarities among the languages of forestry people.

2 PROJECT FRAMEWORK

This chapter presents some guidelines or characteristics of forestry and conservation programs that must be taken into consideration early on in the planning process. Some decisions must be made as early as possible, in order for the next phase in the project planning process to follow smoothly. This chapter discusses some of the issues that require careful consideration at the outset of project initiation. At all stages of a project, members of the affected community should be drawn into the decision-making process. Community participation is particularly important in project initiation, especially in the identification of specific problems that need to be solved and the setting of resource management goals and objectives.

Each individual project will require much more detailed planning as well. Selecting suitable sites, determining the best trees to plant for a given purpose, and making sure that equipment and materials are available are preparations that require good coordination and organization from the beginning. All of these decisions, which are discussed in detail in subsequent chapters, must be made in the context of the political, social, and environmental considerations presented here.

Preliminary Considerations

Among the many variables that must be considered early on, good land management involves:

- taking into account social and cultural issues;
- using resources only on a sustained yield basis, that is, replacement of resources at the same rate that they are being used;
- producing the highest possible net income obtainable for any given area through the best use of land as determined by the local community;
- improving, developing, and conserving natural resources for the future; and

- recognizing that conservation and production are interdependent, and that in the long run, neither is possible without the other.

All programs to conserve or develop natural resources--land, water, soil, trees, and other vegetation--must keep these factors in mind.

Project Goals

The primary conservation concern may be protection of the soil from erosion and loss of fertility, protection of watersheds, protection of the natural vegetation and wildlife, or all of the above. Production oriented projects often give priority to increasing the amount of wood available for fuel or construction; however, many other tree products have value to rural populations. In determining the objectives of a project, production and conservation goals are not necessarily incompatible. Agroforestry approaches are now receiving widespread attention, because they allow land to be used for a variety of mutually beneficial purposes (see Chapter 8).

The first step in planning, then, is to determine what specific problems exist *that the community wants to solve*. Once a problem has been identified, it is then possible to discuss what the project's goals should be. It is important to plan realistically in determining the project goals, the time frame within which they are to be accomplished, and how they can be achieved within an overall resource management framework. Some questions that should be asked are:

- What problems will the project address? How will the project help to solve these problems?

- Does the project have a predominant objective--either protection or production? Are there multiple objectives?

- What will the social effects of the project be? Is the project oriented towards communal efforts or individual farmers and households? How will it affect different people's lives and incomes?

- If the project is a community or cooperative effort, how are its benefits and responsibilities to be distributed? Will some people benefit more than others?

Community Involvement

Early input from local people is crucial to success. Foresters and other conservation personnel should encourage community members to take part in all aspects of project design, planning, and implementation. This is not always easy, because there are usually local, national, and international concerns that may conflict. Nonetheless, a conservation project must be supported by the people living in the area or it will not work.

Although land and resource use is largely controlled by government agencies, most communities have had some experience in managing their own environment. Strong traditions often exist to regulate use of natural resources, as well as procedures for allocating these resources among members of the community. There may also be customs regarding individual or cooperative efforts on projects, decision making, and distribution of benefits. It is up to project planners to find out what approaches will be acceptable within the local traditions and community structures.

Local people are often the ones who are asked to give land for a project, provide labor, or participate in other ways. Usually a reforestation effort will have to be supported by people for several years before results can be seen. A project should not be started, therefore, before communities are ready to sustain the effort. To make this commitment, residents must believe that 1) the project will address problems that they have identified and consider to be high priority needs; 2) the project will affect their environment and lives positively; and 3) the results will be worth the effort.

Ideally the impetus for starting a reforestation project should come from within the community itself. Sometimes erosion and wood shortages may be recognized as growing problems, but the community may not actively initiate efforts to counteract the problem for various reasons. Other problems or shortages may seem more urgent, or there may be a widespread belief that the environment is beyond the resources or power of the community to change. Environmental problems are closely linked, however, with other problems that most concern rural people, such as those affecting agricultural production and health. There is a growing awareness within conservation circles of the importance of these linkages to rural development programs.

Project planners, therefore, often try to create interest in projects that will control wind and water erosion, and which will also result in increased food, forage, and wood production. In such cases project planning should always be in line with what people can and want to do. If the results of such projects are likely to take years to show, local residents may look for more immediate benefits, such as individual potted trees they can plant for shade or fruit. The project should make every effort to respond to this level of need by providing the requested trees. This will lead to increased community support for the project, making it easier to convince the community of the necessity of the project over the long term.

The Conservation Community

The conservation community includes everyone. Particularly when projects are being carried out locally, foresters and extension agents often must act as the intermediaries between the people involved at various levels. They must contact farmers individually, work through such traditional authorities as village chiefs and elders, and involve representatives of various local, district, and national

government bureaus and agencies. They must also work cooperatively with representatives of all sectors of the local economy to ensure maximum cooperation between technical representatives and those concerned with social programs.

There is a lot of informal instruction to be done in order to sell a forestry or resource management project and plan for smooth program operation. This "teaching," when done well, lays a good foundation for the entire effort, and the project has a much better chance of success. Often it is necessary to explain, bring together, and reconcile a number of interest groups, some of which have widely differing ideas about the same project. Such cooperation sometimes means filling an advisory role to a certain agency or undertaking responsibility for a special project. Of course, coordinating the groups and interests involved in a forestry project is all part of project planning; it requires patience, diplomacy, and skill to resolve the potential conflicts between local populations' need to utilize the available resources and the national agencies' mandate to protect them.

Natural Resource Policies

Among the first issues to consider in initiating a new project are national policies, the laws and regulations that govern natural resource use. In most African countries, concern for natural resource management has led to the establishment of certain areas for special purposes. These areas, called forest reserves, classified forests, wildlife preserves, parks, or special reserves, can be identified on large-scale government maps. The use of these public lands is regulated by government agencies through national legislation. In areas that have not been set aside in this manner, land use and tenure are frequently controlled by the government as well. Regulations can be complex, and vary a great deal from country to country, according to national laws and local customs. These laws can have far-reaching effects on the lives of rural inhabitants. For example:

- The setting of bush fires to clear fields may be controlled, limited to certain times of the year, or prohibited altogether.

- Permits may be required to harvest certain species of trees, even if they are growing on private property or were planted by the person who wishes to use them. Obtaining a permit often involves payment of a fee to the regulating agency.

- Other tree species may be protected by law. Cutting, grazing, or any destructive use of these trees may be forbidden under any circumstances.

- Forest service agents may often be responsible for the enforcement of these laws as well as for the collection of fees and fines. Rural residents may tend to regard the foresters as police, rather than as extension agents, conservationists, or natural resource managers.

Most countries have at least one agency that is responsible for developing, managing, and protecting natural resources. Revenues raised from permits and fines may be used to pay administrative and operating costs of these and other government agencies, often through a specially established "forestry fund."

Project planners must determine why the land is being used or not used for a particular purpose. They must become aware of the policies and regulations regarding resource and land use if they are considering any change in the current pattern. One cannot begin a tree-planting program without thoroughly assessing the given location in terms of all the natural resources and the current land use situation.

Present Land Uses

What is the land suited for now? What could the land produce if changes were made? Would the new use be better than the old? Local customs, soils, topography, vegetation, and water supply all must be studied before these questions can be answered fully. Rural inhabitants who will participate in a forestry project or be affected by it in any way should be involved in all aspects of land use planning. Procedures for making these decisions at the local level should be agreed upon at an early stage in the project planning process.

Because the issues regarding distribution of benefits and responsibilities become so complicated in community projects, it is sometimes more effective to work with individual farmers or households. The individual project sites may be smaller, but they can serve as demonstrations for other members of the community. This often has the effect of motivating others to join the project on an individual basis as well.

An important aspect to consider when evaluating a location is whether or not land can be used for growing crops that allow people to support themselves. Above all else, the people living in that area must get enough from the land to live. For each tree that is planted, a certain amount of land is taken out of production for other agricultural purposes. Because trees take a comparatively long time to mature and be harvested, it is difficult for many farmers to take the risk of committing their land to forestry for so long. As a result, even if a staple crop they grow is not as valuable by itself as a cash crop might be in market terms, the land may already be serving its most important function.

First priority always is and must be given to agricultural products that are needed for food or for market. It probably would not be the best use of the land to plant a woodlot on a site where rice or bananas can be grown, and where there is a good market for such crops. What might be called secondary subsistence needs must also be kept in mind. These are uses of the land and trees that fill other needs--wood for fuel; grass for thatch; fruits and plants for medicine and food; material for cordage, detergents, tanning, and dyes.

If the area is now filling one or several important purposes certain questions should be raised. Would land use be improved by a forestry or conservation

project? Which conservation efforts would improve land use? Where should they be located? What special efforts--such as firebreaks, planting field trees, terracing, or planting an orchard--would increase the value and usefulness of the land?

Are wind erosion controls, such as windbreaks, or water erosion controls needed around farm lands? Are there places that are not now being farmed where crops could grow if they were protected? Gentle side slopes may be a good place to grow some farm crops if the field can be protected against erosion. Careful observation and detailed study of the project area provide answers to such questions.

Once the project planners have completed an initial assessment of land and resource use, have carefully evaluated the local situation in terms of needs and problems, and have agreed upon the project goals, it is necessary to begin a more detailed planning process: the project design.

Key Elements for Project Success

The following is a checklist of keys to successful forestry projects. These are particularly important to keep in mind during the planning stages. Some of these topics have already been mentioned in this chapter, while others are discussed in more detail elsewhere in the text.

- **Start small.** Initial project efforts should be kept to a modest scale. If they are successful it will be easy to expand them later on.

- **Encourage existing conservation activities.** Village level nurseries, woodlots, windbreaks, and other erosion control measures may already exist in the area. Concentrate efforts on improving and extending technologies that are already in place, rather than introducing new ones.

- **Individual vs. communal activities.** Projects that can be implemented only through communal efforts may not take into account the most effective means for extending reforestation efforts. Project planners should consider working with individuals on their own property as well.

- **Local participation.** Rural inhabitants have a wealth of knowledge about their environment that they can contribute to project planning. Their participation is necessary to encourage that local needs and expectations are met.

- **Soil and water studies.** It is vital to obtain all available data on soil and water quality. If possible, samples should be analyzed by a qualified laboratory. This should take place early so that the information can be used in species and site selection.

- **Species selection.** Indigenous species should be considered as well as exotics. If possible, use a mixture of several species.

- **Seed sources.** Select species and identify seed sources early. If seed is to be obtained locally it will be necessary to locate good quality parent trees and train seed collectors. The genetic quality of the planting stock can make the difference between success and failure.

- **Land use.** The productivity of farming systems should be maximized through integration of conflicting land uses (agriculture, forestry, livestock).

- **Protection.** Many planted trees die due to a lack of protection from pests, livestock, fire, and other threats. Prepare a protection package to deal with these problems.

- **Benefits.** An equitable distribution of benefits will ensure continued interest in the project.

- **Evaluation plan.** Once project goals have been decided, a set of criteria for ongoing project monitoring and future project evaluation will help ensure that goals are reached.

3 PROJECT DESIGN

Once the long-range goals of a project have been determined, community participation established, and alternative land uses carefully evaluated, the way in which the project will be implemented must be decided. The project design involves detailed technical planning and other considerations that must be integrated into the overall forestry or agroforestry project. One of the most complex aspects of project design is the choice of sites for reforestation efforts, and the matching of appropriate species to the site conditions. Because these decisions are so important, they are discussed in separate chapters. Chapter 4 provides an introduction to site evaluation in terms of soil properties and their influence on plant growth. Chapter 5 deals with the effect of other environmental factors on site and species selection, as well as considerations such as project purpose, human preferences, and legal constraints.

Other issues in project design involve options for regeneration of plantations or natural forests, seasonal considerations, water availability, site use planning, and protection of the growing stock. Project planning also includes preparations to direct activities and work effectively with crew members. In addition a successful project requires accurate record keeping. These issues and their implications for project design are discussed below.

Regeneration Options

One of the first steps in designing a forestry or conservation project is to examine various regeneration options. The key decision at this point is whether it is necessary to establish a nursery for selected species or whether revegetation can be accomplished in some other way. Some alternatives to raising seedlings in a nursery and transplanting them at the project include: direct seeding of the area, planting cuttings directly on the site, or simply protecting the area and leaving it alone so that it can regenerate naturally.

Most current reforestation efforts in dry lands use a nursery to produce seedlings, because these other methods are not considered feasible for one reason or another. Establishing and maintaining a sizable nursery can be expensive, however, and it may be worthwhile to try some of these alternative

techniques on an experimental basis to determine if they are practical. The principal consideration at this point is the type of reforestation or revegetation effort needed.

Natural Regeneration

Areas selected for reforestation are often marginal lands, unusable for intensive agriculture because of soil quality, topography, lack of water, or other factors. However, some trees will grow almost anywhere. If no examples of an indigenous species can be found on a site where it should be possible for it to grow, the forester tries to find out what is preventing it from occurring there.

Very often the major reason is a lack of seeds in that particular area. If there are no adult trees nearby producing seeds that can be carried by natural methods (for example by wind or water, or by animals depositing the seeds on the ground in their manure), the seeds will be scarce. Even if seeds are available, they may be unable to germinate or the newly sprouted seedlings may not survive, because of overgrazing, fires, or blowing sand in the area. If site conditions continue to deteriorate, the species will become even more sparsely distributed because new vegetation cannot become established.

Before any natural revegetation project can be undertaken, it is necessary to make sure that the factors preventing a species from growing on the site are not still present, or that they can be overcome in the course of the project. Nature can heal a barren area if given enough time, but in most cases, natural regeneration cannot occur unless special efforts are made to help it along. Such efforts might include fencing the area, protecting it from over-grazing, and setting up good local cooperation so that the residents realize the importance of leaving the area alone. Sometimes a certain area can be helped best simply by making arrangements to ensure that the area is left undisturbed for a number of years.

Direct Seeding

If the species chosen for planting in a given area responds well to direct seeding, this method is certainly worth trying. Obviously, it is cheaper to sow seeds directly on the planting site than it is to establish a nursery, maintain the seedlings for several months, and then transfer the young trees to the planting site. It is even possible to direct seed by feeding pods of certain trees to cattle or sheep that graze on the land. They deposit their manure, containing the seeds, on the ground, and sometimes this method achieves a high germination rate.

Some direct seeding results have been good in areas with rainfall as low as 700mm, but there is still much to be learned about direct seeding techniques on dry sites. One of the reasons this method has not been used more often in the past has undoubtedly been the scarcity of seeds. Direct seeding requires relatively large quantities of seed.

Good results from direct seeding have been obtained in sub-Saharan Africa with *Borassus aethiopum* and *Anacardium occidentale*. *Acacia albida* seeds have been sown in clumps in fenced-in areas and have started to grow. Good regeneration has also been obtained with seeds scattered in bushy areas where the young trees were at least partially protected by thorny branches and twigs.

Some trees simply cannot be grown using direct seeding techniques. One of the major constraints in dry areas is the irregularity of rainfall patterns. After a few rains have fallen, it is not uncommon for a dry spell to occur. When this happens, newly sprouted seedlings rarely survive. While the water supply of seedlings can be easily controlled in a nursery, it is usually impractical to water direct seeded plants in the field. Nursery raised seedlings are better able to withstand drought, because their root systems are more developed.

Cuttings

It is sometimes possible to take cuttings of trees and transfer them directly to a planting site. Successfully propagated cuttings sprout new roots and leaves, and develop into genetically identical replicas of the parent tree. *Commiphora africana* and several *Euphorbia* species are possible choices for this method of revegetation. However, use of cuttings is still only experimental on dry sites. This method has the advantage of being low-cost, because little is needed in the way of equipment, and cuttings are easy to transport. As with direct seeding, however, even brief dry spells can cause heavy losses if they occur before the cutting has established an adequate root system. A section on Propagation from Cuttings is included in chapter 9, Special Subjects. This section describes procedures for seedling production in the nursery, or direct on-site revegetation using cuttings.

Nursery Production

Although seedlings raised in a nursery may go through a short period of transplant shock, they already have well developed root systems when they are placed in the field. By the end of the first growing season, their roots should extend to deeper sources of soil moisture, enabling them to survive long periods of drought. An analysis of the regeneration options described above may indicate, therefore, that the best method for seedling production is a nursery.

If so, there are a number of decisions and plans to make before beginning. Is the nursery to be permanent or temporary? In other words, is there a need for one that can continue to supply trees even after the completion of a project? Is a large, centralized nursery needed, or would small, village-based nurseries be better? Moreover, the nursery should be designed to meet the specific requirements for the type of reforestation activities that are envisioned.

Other details regarding the nursery should be considered during the project design process. What type of soil does the nursery site have? Will fertilizers be needed? Should seeds be planted in plastic pots or other containers (clay jars,

leaves, cardboard, etc.) or directly into seedbeds (open-rooted)? These decisions depend in part on the species to be grown, the size seedlings that are needed, the amount of nursery space available, and the costs involved.

Obtaining seeds is often a major problem, and the question of seed supply should be addressed early in the planning process. Seeds must be ordered or collected locally, and they must be treated and prepared. What is the time-frame for the project? How long will it take to set up the nursery? When should seeds be planted? When is the best time to transplant? Is there an adequate water supply? Is the land cleared? Does a fence have to be built? Each of these important points is discussed in further detail in Chapter 6.

Water Supply

Water supply and costs are critical to nursery planning and operation. Much money and time could have been saved in some nurseries if the first year had been used only to test and observe the water supply and perhaps raise a few thousand trees on a trial basis. While this kind of testing may not be possible, one cannot be too careful when it comes to the subject of water supply. All too often what looks like a good water source turns into a dry, or nearly dry, hole just at the time the water is needed most. This is when the trees in the nursery are requiring the most water for growth, or when temperatures are highest, and the plants are losing more water through transpiration and evaporation.

Water Quantity

It is essential to be completely realistic about water supply, the project's need for water, and the costs involved. A method for calculating daily water requirements for the nursery is given in Chapter 6. It is important not to underestimate any of these factors. In sub-Saharan Africa it is usually not possible to get a steady water supply without 1) lifting the water from deep under the ground (as in a deep well), or 2) carrying it considerable distances from the source to the nursery. Both of these methods are expensive.

If the project has access to a deep well with a steady supply of water, it makes sense to include the cost of a pump in the project budget. While it is possible to handlift a few hundred liters of water a day from a deep, open well, pumps are necessary when quantities as much as 400 liters, twice a day, are called for. Large projects that use a well for a water source cannot rely on that well if it does not have an adequate water lifting or pumping system. These systems ensure that sufficient water is available at all times with the least possible effort. It is worth taking extra time and effort to plan a well and water-lifting system carefully.

Water Quality

Many water sources, whether they are wells or surface depressions, contain considerable amounts of salt. In fact, in some areas along coastlines, a well may contain mostly salt water with only a thin layer of fresh water floating on the surface. Even water that may not contain much salt originally can collect salt as it flows over the ground; salt remains after the water evaporates. Sometimes salt concentrations are so heavy that trees cannot be grown in the area.

Some trees and crops can stand more salt than others. Salt tolerance (the amount of salt a plant can take and still survive) of farm crops has been studied, and information is available for selecting crops that can live in water containing some salt. Unfortunately, however, relatively little is known about how much salt trees can absorb and still grow well. It does seem, however, that *Casuarina equisetifolia* (Australian pine), *Conocarus lancifolius*, *Phoenix dactylifera* (date palm), and *Tamarix* spp. (Tamarisk) are all rather salt tolerant. As a general rule, however, water containing more than 550 parts per million of dissolved salt seems unfit for nursery use.

Sometimes there is no way to keep from using water that contains some salt. In a borderline situation--where it seems the trees might be able to live even if the water has some salt in it--the usual practice is to "over-irrigate." Over-irrigation is accomplished by putting on too much water so that any damaging substances in the water are likely to be washed down or leached and are less likely to build up and remain on the surface of the nursery beds. See Chapter 4 for a further discussion of salinity problems.

Water Sources

Ground Water and Wells

Water in the ground can be reached by constructing various types of wells using methods that have been studied extensively in Africa, for example, by local governments, international organizations, consultants, and engineering firms. Most nurseries use wells as their principal source of water.

Traditional wells in Africa are dug by hand. This is practical where the water under the earth's surface is only a few meters below ground level. In such cases, well construction is relatively easy and little more than a simple hole is needed. When the ground water is below 10-15 meters, well-digging becomes somewhat more complex, but still can be accomplished by hand-digging methods at reasonable costs.

In other areas, deeper wells are necessary, which require even more complicated construction procedures. In some places, it is necessary to dig 100 meters before reaching aquifers (water-bearing layers of the earth). And even when water is reached, the well may not give enough water to make the effort worthwhile.

One point cannot be stressed enough: when wells are dug, they must penetrate the water-bearing layers as deeply as possible so that the well will continue giving water even during the dry season when the water table in the aquifer drops. Failure to plan adequately in terms of any of these factors can lead to trouble for the project.

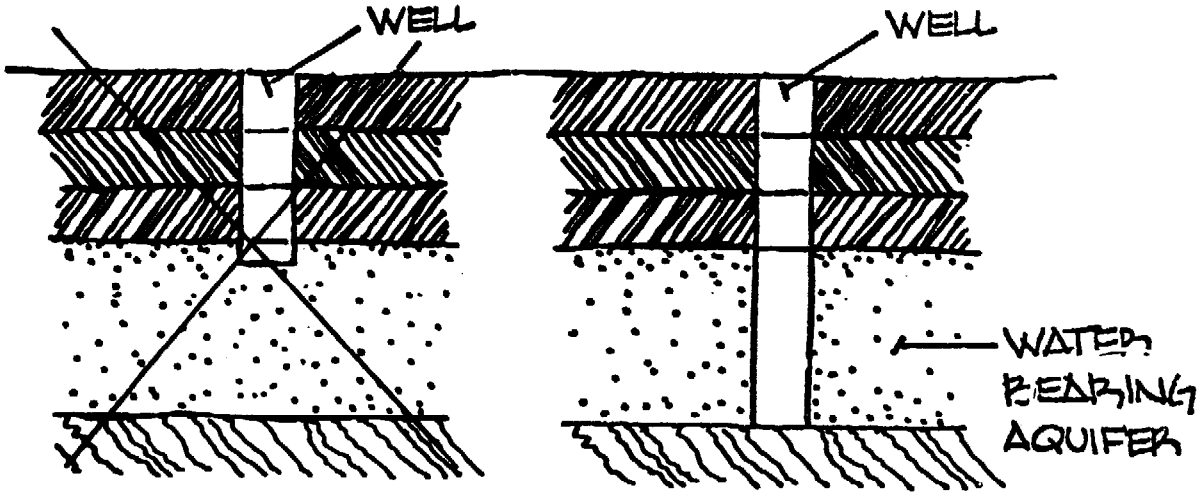

This well does not penetrate the aquifer completely, therefore, not enough water will be available during the dry season.

This well penetrates the aquifer and will give sufficient water during the dry season.

Surface Water Development

Reforestation programs in semi-arid regions can also benefit from surface water development. Catching the rainwater and storing it for later use is possible, and several methods involving micro-catchments and ridge construction are described in Chapter 7. However, using available water resources such as rivers, lakes, and streams is often difficult for a number of reasons.

In many dry areas of Africa, for example, the terrain is flat and the soils are often sandy. Even when water is available, the soil cannot hold it well enough to support vegetation. In places where running streams occur, the surrounding land is often so flat that there is not enough slope to make an effective diversion channel. Under these circumstances, gravity feed systems cannot carry the water effectively from the source to the nursery or plant site.

The typical flatness of the topography in many dry areas causes water to pool in large shallow depressions or basins. This water is difficult to use because it:

- usually evaporates before it is needed most;

- frequently contains large amounts of silt;
- has to be lifted and transported to be used.

There are successful techniques for surface water development, although most methods require substantial investments of money, labor, tools, equipment, and maintenance. Some techniques involve reducing evaporation from water surfaces, reducing infiltration losses, and reusing water. These all are described in various texts listed in the bibliography at the end of this handbook.

Seasonal Considerations

Planting Schedule

The timing and duration of the rainy season are the principal factors that determine a reforestation project's planting schedule. In areas where there is one long dry season and a short rainy season, the period during which seedlings can be successfully established is fairly short. Some parts of the tropics have what is called a bi-modal rainy season. In these regions two separate rainy seasons occur each year, one usually longer than the other, alternating with several months of dry season.

Where bi-modal rains occur, it is possible to plan two planting seasons per year. During the longer rains, efforts are concentrated on the initial plantation establishment. Replacement planting is planned to take place during the short rainy season, to replace any seedlings that did not survive the initial planting. When there is only one rainy season per year, replacement planting usually has to wait until the year following the initial plantation.

Other seasonal changes also affect the nursery schedule. Seeds for different species mature and must be collected at different times of the year. Some species must be sown earlier than others so the trees will be large enough for transplanting at the beginning of the rainy season. These considerations are discussed in Chapter 6 and additional information is given for some species in Appendix B.

Labor Availability

In planning a project it is crucial to find out what other activities will be going on during the period you have scheduled for planting. The beginning of the rainy season is a very important time for farmers as well as foresters. For most of the rural population, planting and cultivation of crops will take precedence over any other activity during this period. If local labor will be needed to plant trees, there are some possible solutions to this potential conflict in the planting schedule. Alternatives should always be discussed well in advance with everyone involved to prevent misunderstandings. The following are some alternatives to consider:

- Find out when farmers will be busiest. Sometimes there is a lull in farming activities during the first few weeks after the rains, when the crops have been sown, but weeding has not yet begun. It may be possible to plan on planting trees during this period.

- In some projects most of the ground preparation is done before the rainy season begins. This involves digging the holes and doing any other micro-site improvements that are necessary such as individual water catchments, or ridge construction. This advance preparation reduces the actual planting time required after the rains begin. Pre-digging the holes may not be advisable on some dry sites however (see chapter 7 for more information).

- If seedlings are produced in a centralized nursery, they can be lifted out early and transported to the planting site in advance. They should be kept in a temporary nursery until time for planting. Having the seedlings already at the site can save time, but this is only practical if they can be watered while there. This plan is particularly advantageous in areas where the roads become impassable during the rainy season.

- Many villages have a traditional practice of setting aside one day a week for community projects, even during the rainy season. These community activity days can be used to support a wide variety of reforestation and conservation efforts.

Site Use Planning

Once it has been decided that a site is available for use as part of a reforestation effort, it is time to plan for the fullest use of the site. In other words, the area should be utilized as completely as possible. Incorporating other land uses, such as traditional or improved grazing or intensified agricultural practices (e.g., rotation from peanuts to cereal crops to fallow), must be taken into account during the planning process. This is particularly important if the site is located near relatively high density population centers.

Whenever possible, sites are chosen so that local residents receive some immediate benefits while the trees are growing, and so that the land is being put to optimal use. Some of the land uses that increase benefits during revegetation efforts are intercropping, grass cutting by hand, collection and gathering of forest products, and controlled grazing. These subjects are discussed briefly below and in more detail in Chapter 8, Agroforestry and Soil Conservation.

Intercropping

Intercropping is the practice of planting and growing agricultural crops between the rows of planted trees and shrubs. If left uncultivated, the area between the trees would soon be covered with grass and other vegetation.

This vegetation would compete with the seedlings for water, nutrients, and sunlight.

It has been found, however, that competition for growing space is not as severe when crops such as peanuts and beans are grown between the trees and the area is kept free from weeds.

At the few places where intercropping has been tried in the drier zones (500-700mm annual rainfall), excellent results have been obtained for the trees and the farmers. Even where results were poorer, intercroppping may still be cheaper than hand-weeding grasses. This is especially true during the rains, when labor is short, because everyone is busy raising crops. Machine weeding and cultivation are expensive, particularly when maintenance and depreciation of the machines are included in the cost.

Successful intercropping benefits trees, crops, and farmers alike. It requires that farmers be aware of the special restrictions and conditions necessary for good plant growth. For example, the spacing of individual crops in relation to the young trees must provide enough room for both to grow without depriving either of sufficient water, light, or nutrients. Young trees that are hard to distinguish from other plants (such as *Acacia albida* or *Gmelina arborea*) can be marked with colored stakes or tape.

Of course, the choice of crop makes a big difference as to the success or failure of intercropping. Peanuts, cowpeas, and other legumes have worked well, but millet, sorghum, and corn have affected some trees badly. The decision about which crops to raise as part of an intercropping program must be based on information about the crops, the nature of the site, and the type of tree that will be planted there.

It is particularly useful to grow crops in firebreaks. These are spaces left between blocks of trees or other vegetation so that fires which may break out can be stopped before they burn down an entire plantation or nursery. Firebreaks in tree plantations are often quite wide, thus giving a lot of space for growing crops. For them to be effective, it is very important that they be kept free of weeds: planting and cultivating crops such as peanuts serves this purpose. When the area is completely cleaned after harvest, a relatively trouble-free firebreak is created that lasts until the next growing season. Of course, the need for a complete cleaning of the area after each harvest must be stressed and enforced.

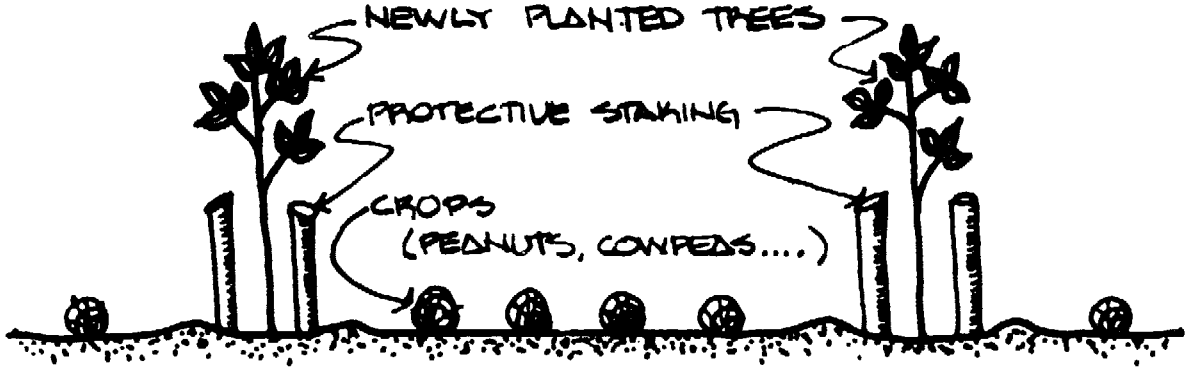

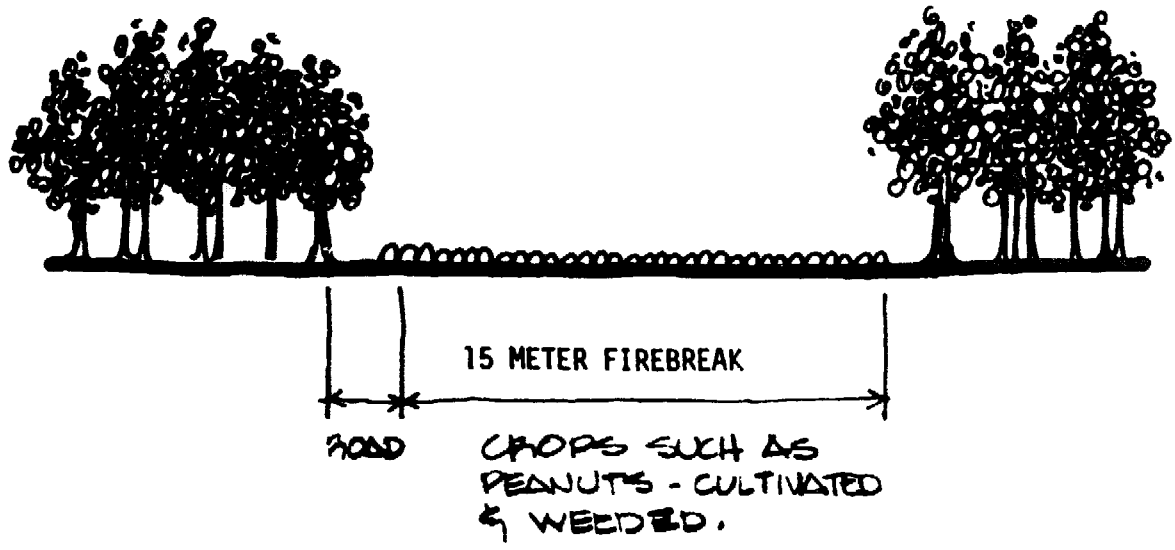

Cutting and Gathering

Strictly controlled cutting of grass for fodder, thatch, or mats may be feasible. Forest products such as leaves, nuts, fruits, gums, or resins may also be collected. These commodities often have an important place in the local economy which should not be overlooked, especially because they may be a significant source of income for rural women.

As a communally owned area becomes more and more attractive to individuals, it becomes increasingly important to be sure that any use of the land, even cutting grass for animal feed, is controlled by an authority that everyone recognizes. It may be necessary to charge a fee for such uses of the land. Land use fees will probably not bring in a lot of money, but they are important for laying a good and fair framework for the future of the area. Usually a national conservation agency is responsible for resource use and establishes limits for all cutting, grazing, or farming allowed on the land. Receipts can and should be used to sustain project efforts.

Grazing

Good land use projects may include introduction (planting, seeding, or natural) of vegetation that can be used for grazing in or near the same area where trees are planted. This kind of overall revegetation effort illustrates the fact that the divisions between forestry and range management programs are becoming less rigid than they once were.

Grazing is possible within the tree planting site as long as certain conditions are kept in mind:

- The number and kind of animals, as well as the length of grazing time, must be controlled.

- Grazing is not permitted until the trees are tall and strong enough to escape damage done to their foliage and bark by animals. A goat, for example, can stand on its hind legs and reach up to two meters. Donkeys also stand on their hind legs to reach leaves.

- Grazing cannot be allowed to continue in one spot for too long. If grazing does continue there is a danger that the soil will become so compacted that air and water can penetrate the soil only with great difficulty.

If grazing can be controlled, the combination of forestry and range management programs can lead to good land use projects. Livestock will contribute to nutrient cycling, increasing soil productivity for both the grasses and the trees.

Protection

Whether in a nursery or planting site, trees have practically no chance to survive without protection from animals. Two possibilities exist to protect the trees: hiring people to keep animals or indiscriminate human users out of the area, or putting up fences. Some combination of both methods may be most effective.

Surveillance

This approach calls for protecting the trees by having people watch over the area to keep animals and other unwanted visitors from disturbing the trees. Surveillance may be possible and practical at one site, but not at another. Two of the factors that must be considered with respect to this method are 1) whether people are available who can and want to do the job, and 2) how much it would cost to have them do it. Experience shows that it is too much to ask villages or individuals to bear the burden of watching a planting site without some form of compensation. If the people protecting the site receive a return for their services, they are more likely to do the job well. Providing free seedlings may be a way to create additional incentives for the job.

Fencing

There are two important considerations in the use of fences in a project: custom or habit, and cost. A fence should be arranged so it requires the fewest possible changes in land use patterns. Fences can be social as well as physical barriers. If residents of the area are used to letting nomads graze their herds inside harvested fields, this practice must be considered before those same fields are fenced. Such grazing serves economic and social needs, as well as helping fertilize the land through the manure that is deposited. In order to take customs into account, it may be necessary to plan a different kind of fence, place it

differently, or even change the layout of the site before the land use problem can be solved satisfactorily.

No matter what type of fence is to be built, there are going to be materials, construction, and maintenance costs. The most expensive fences are those built to protect individual trees, although there are situations that justify such fences--as when establishing individual shade trees in fields, along roads, or in market places. The least expensive fences cover large blocks of land, for example, 50-100 hectares. Actual protection costs per tree are estimated for different materials, sites, and areas--from individual trees to areas of over 100 hectares.

It simply is not possible to generalize that a particular plot size is the most effective unit from either an economic or social point of view. It is a good thing to remember, however, that the larger the block of land, the more likely there is to be a problem with regulating its use. The two most important considerations in fencing operate in direct conflict with each other: the method requiring the fewest changes in land use patterns is the most expensive (fencing individual trees); the cheapest method of protection (fencing larger pieces of land) may require the most change in traditional habits.

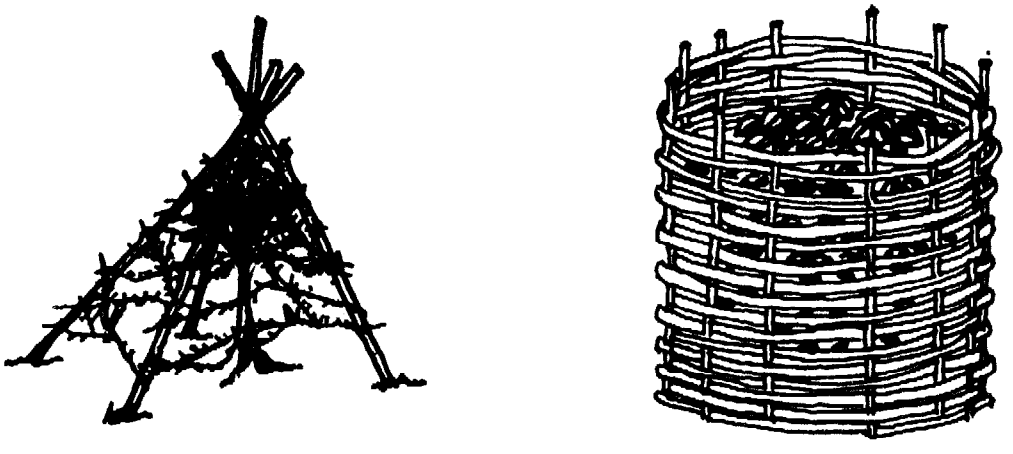

Individual Tree Protection

Maintenance must be included in the budgeted costs of a fence. Bitter experience shows that money spent on building expensive, strong fences is wasted if they are not kept repaired. Otherwise the fences become useless or disappear entirely long before the trees are ready to stand without protection. The fence around the nursery or permanent site can be constructed to demonstrate several kinds of fences and fencing material. It should be tight and sturdy, and the gates easy to open and close.

Fences may be built from imported or local materials or a combination of both. There are advantages and disadvantages to each of these approaches. Whatever materials are used, the fence should be designed to fit the needs of the project. For example, if grazing animals are cattle only, a four-stranded barbed wire fence is sufficient. This fence will not keep out goats and sheep, however. If there are goats and sheep in the area, either a different type fence must be built or the barbed wire fence must be improved.

Imported Materials
In many countries of arid Africa items such as metal posts, barbed wire, or wire mesh may have to be imported. Their major disadvantage is their extremely high cost. Salvaged materials, such as steel banding used for crating, are sometimes available, and, if used well, will produce sturdy, durable fences.

Traditional materials
Traditional materials for fencing include:

- o local woods for posts;
- o sticks and thorny branches from brush and bushes;
- o woven mats of bamboo or palm leaves;
- o stalks of millet or sorghum
- o banco (earthen) blocks

Fence posts are made from those local woods that are most resistant to rot and insect damage. *Borassus aethiopum,* for instance, is relatively resistant to termite damage. *Hyphaene thebaica* can be substituted, although it does not last as long and is much harder to split for posts.

It is possible to prune large branches from some species without killing the tree. *Azadirachta indica* responds particularly well to this method of harvesting. The tree will sprout new branches that can in turn be removed. This practice is called pollarding, and is often used to cut fence posts or firewood when it is not desirable to remove an entire tree.

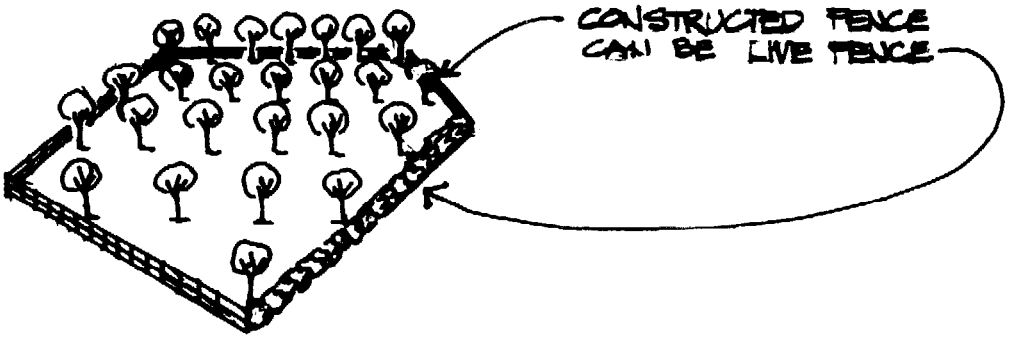

Combination live and constructed fence.

Most posts should be treated with insecticide before they are used. *Azadirachta indica* branches can be used, once they have been given the barrel treatment with an insecticide (as shown on the following page) to increase their resistance to termites. Limbs and branches should be at lea: about 10cm in diameter and about 2m long. The largest ones are used for corners, gateposts, and line braces.

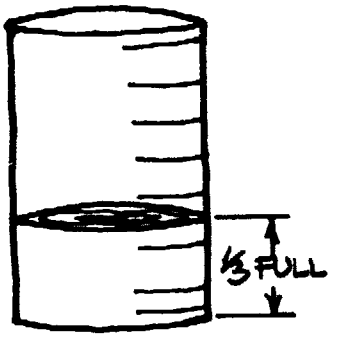

Fill 200 liter drum 1/3 full of insecticide solution

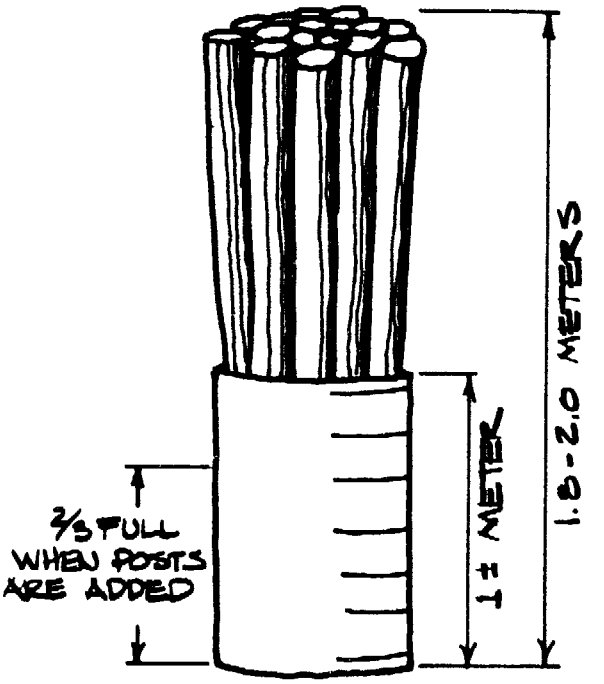

Set posts into drum and soak for 4 hours minimum

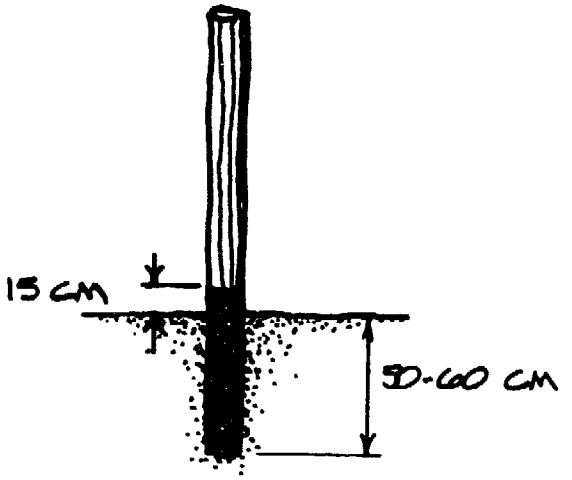

Posts should be immersed in solution to a level at least 15cm above anticipated ground line.

Treating Posts with Insecticide before Use

Any sort of thorny or sharp branch is useful and can be woven into fence wires. For example, although stems from palm trees cannot be used for fence posts, they make ideal staywires or pickets, because they are strong and durable, and some of them have sharp barbs.

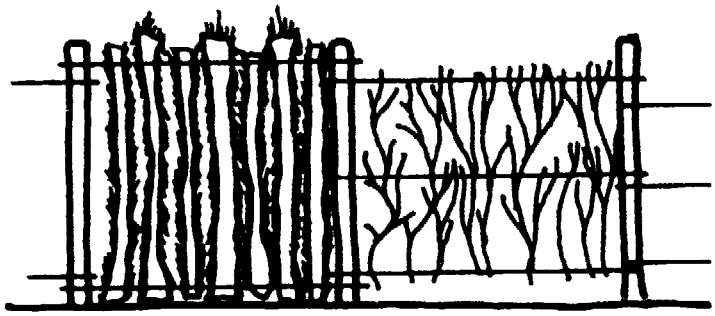

Posts: Borassus aethiopum *or Doum palm*, Comiphora spp. *(treated)*

Railing: *Branches, sticks, Doum "lath"*

Filler: *Thorn limbs, millet stalks (temporary), palm-leaf stems*

LOCAL MATERIAL FENCE TYPES

More information on wire fencing is given in Chapter 9 Special Subjects. An alternative approach to building a fence though is to plant a live fence.

Live Fencing

Live fences are thickets or hedges that are planted to protect small areas like gardens or orchards. These fences are established entirely by growth of cetain species rather than by constructions of wood and wire. The establishment of live fences is one of the agroforestry techniques discussed in greater detail in Chapter 8. Live fencing possibilities are interesting to foresters and conservationists, but there are practical problems that have not yet been solved.

In spite of extensive efforts to raise and transplant live fencing in a short period, no practical and rapid methods have been found. The fences, of course, are necessary from the beginning of the reforestation project, and one cannot wait ten years for them to grow. One practical solution may be to construct temporary fencing in front of the live fence while the latter is grown to an effective size. Then when the live fence is large enough, the other materials (posts, wires, etc.) can be moved to another site and reused.

Combined Protection

In most areas it is a good idea to use a combination of fencing and surveillance. Often fencing materials themselves are attractive for a number of other uses and may disappear unless the area is under regular surveillance.

There does not seem to be any one method of protection that is clearly the best. The decision must be based on such factors as local customs, willingness and ability of community residents to contribute to the protection of the trees, cost per tree, and effectiveness of the methods.

When possible, foresters often try several protection methods in one project. Then it becomes easy to see when one is working better than another. It is

sometimes the case that a method that did not work at one site is successful at another because of differences in the factors mentioned above.

Personnel Management

Dependable, well-trained work crews are essential to the success of a forestry project. Crew members should understand conservation and reforestation concepts, and should be trained to work independantly to be most effective. Start training relatively early with small groups so that activities can be thoroughly explained and shown in detail. People who have more experience, and who are willing and able to accept responsibility, are natural candidates for leadership positions. As these people are identified, they can be given extra training and prepared to become supervisors or crew chiefs.

Having good crew chiefs means that during times of maximum effort, the routine work will be carried out competently and automatically. Project managers will have more time for dealing with urgent, special problems as they arise.

Project managers should teach by demonstration, as well as through discussion. During this teaching process, there will be an opportunity to watch different people and see how they master techniques. The manager will get a good idea of those who are the most capable. Activities and jobs may have to be explained more than once, but explanations must be done positively in order to provide encouragement and to build enthusiasm and support for the project.

High quality work and proper tool use and maintenance are far more important to the effort than is speed. The most effective means of teaching this is to provide the crew with a good model. If the project manager makes a point of maintaining the equipment by cleaning it and putting it away properly, the lesson will be effectively taught. Everything a project manager does, whether the crew members are watching or not, should be consistent with the techniques and values encouraged in the other personnel.

Project managers who are on time, plan well, and do what they say they are going to do will have more support and better projects. People enjoy working with someone who is in control of a situation and knows what to do. The ability to self-analyze and the willingness to accept suggestions from crew members are indicators of a good project manager.

All of these personnel development activities should be started well in advance. The goal is to establish a team of people used to working together, so that when the actual work arrives, each knows what to do without being told. The crew chiefs will work without being supervised all the time. Staff briefing sessions provide both information and encouragement, and can help to prevent problems and misunderstandings from arising.

Project Record Keeping

Record keeping procedures should be set up during the project planning phase. In addition to helping the project managers keep the project on track, accurate detailed nursery records make the project a valuable resource to others--whether the result was a success or failure. Some project managers find that keeping a diary is a good way to record important facts. Information that relates to the amount of labor and time spent on nursery activities goes into the diary. The project manager records what is done, by whom, and how many hours were spent by each person on which activity. This information can then be used to 1) fill out time sheets for payroll records; 2) calculate how many work-hours it took to build 100m of fence or to stack 1,000 pots; and 3) make cost and time estimates for future projects.

Other important data relate to the technical details of the project. For example: how were the seeds collected and pre-treated? When were the seeds planted? How many were planted in each bed or pot? How many of the seeds germinated and how long after they were planted? How much water did the seedlings receive? Were they treated with insecticides or any other chemicals? Appendix B is a start at gathering in one place relevant nursery and planting data for certain African species. This kind of information greatly facilitates planning of future projects.

Every funder or sponsoring agency wants to know how its projects are doing. Field personnel should be prepared to keep the following records, in addition to the diary mentioned above:

A *Monthly Report* should include:

- o A summary of the activities of the previous month, based on the more detailed accounts in the diary;
- o A basic plan of activities for the coming month;
- o A brief explanation whenever actual activities differ from those that had been planned for the month.

Such comparisons and explanations enable both the project manager and the sponsoring agency to understand and support the project better, and thus lead to fewer problems arising from lack of communication.

Special *Project Reports*, if necessary, such as separate reports of special project activities, can be prepared using material from the diary and monthly report.

Technical Notes are notes made of conclusions and specific observations. This kind of information can be sent to the funding agency, evaluated, and, where appropriate, incorporated into new projects and training programs.

4 SOIL PROPERTIES

Before selecting a project site, it is necessary to evaluate soil conditions as thoroughly as possible. The extent to which soil properties can be measured will depend on the availability of equipment in the field or access to laboratory facilities elsewhere. This chapter deals with on-site assessment of certain soil characteristics and their effects on plant growth, for use in situations where a complete soil analysis is unobtainable.

The chemical properties of soil layers near the surface, especially the amount of available nutrients, are not as important to trees and shrubs as they are to agricultural crops. Tree roots, particularly in arid areas, go much deeper and can extend laterally farther than those of crop plants. Therefore they can reach nutrients and water that plants with smaller root systems cannot. How well this takes place depends on *physical* soil properties rather than *chemical* ones. Without adequate soil moisture even an abundant supply of nutrients will be useless to the plant, unless sufficient water is available to act as a carrier for them.

The major soil characteristics that influence growth and health of trees and shrubs on arid sites are:

- soil texture
- water holding capacity
- soil reaction (pH)
- soil depth

Other factors can be important too, especially for younger, smaller trees. The organic content of the soil layers in the area of the root zones influences the physical properties of the soil as well as the pH and the availability of nutrients. Soils with a high organic content are better able to store rainwater that has filtered down to the areas where roots can absorb it. Another important factor is soil salinity, especially on very dry sites where runoff accumulates or groundwater tables are high.

Soil Texture

Certain soil types are best for trees and shrubs because of their texture. In analyzing soil texture, what counts is the relative proportion of the various sizes of soil particles (the individual grains of soil). Apart from gravel or pebbles, soil is made up of sand, silt, and/or clay particles.Soil particle classifications are shown in the box.

Soils with a high capacity for holding moisture that plants can absorb have a texture consisting of a blend of coarse and fine particles. Some tree and shrub species like *Acacia raddiana* and *A. senegal* grow well in loose, light, sandy soils. Others, like *Acacia nilotoca* or *Bauhnia reticulata,* prefer heavy, clayey soils that may become waterlogged during the rainy season

Many species prefer a balanced soil texture. Based on current information, most species can be roughly grouped into three broad categories: heavy, medium, or light soil requirements. More data on different species are now becoming available that can be added to the existing knowledge base (see Von Maydell's *Arbres et Arbustes du Sahel*).

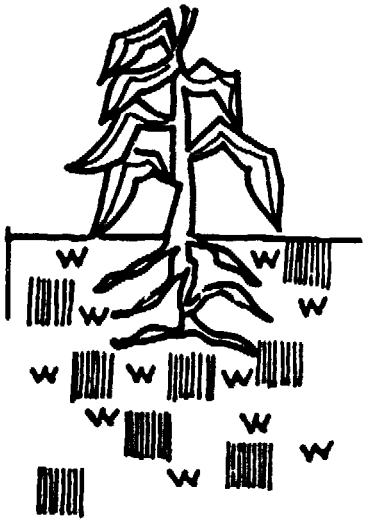

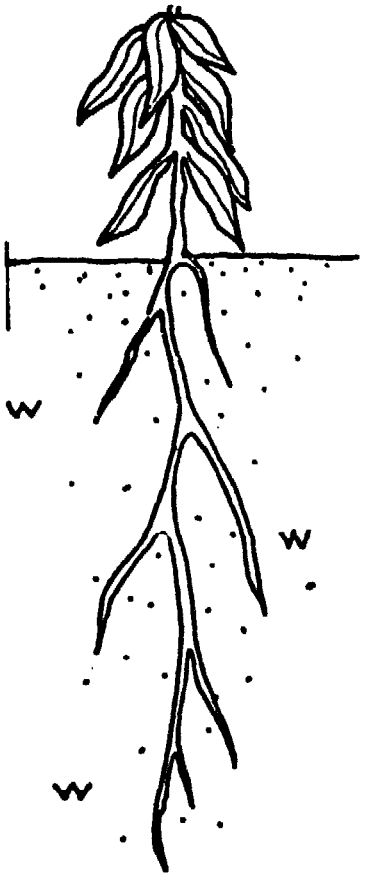

Heavy, clay soil (above):
- *o water available*
- *o slow, stunted root growth*

Loose, sandy soil (right):
- *o little water available*
- *o rapid root growth*

Soil Particle Diameter Range (in millimeters)

		USDA System	International System
Light Soils/ Coarse Particles	Very coarse sand	2.0-1.0	
	Coarse sand	1.0-0.5	2.0-0.2
	Medium Sand*	0.5-0.25	
	Fine Sand*	0.25-0.1	0.2-0.02
	Very Fine sand	0.1-0.05	
	Silt	0.05-0.002	0.02-0.002
Heavy Soils/ Coarse Particles	Clay	Below 0.002	Below 0.002

* Particles in this range make up the largest portion of dunes in arid Africa.

Soil Structure

Soil structure should not be confused with soil texture. The concept of soil structure deals with the aggregation of primary soil particles, their size and their disparities. Four principal types of structure are recognized. They are mentioned for the purpose of acquainting the reader with the terms. It is important to keep the distinction between texture and structure in mind.

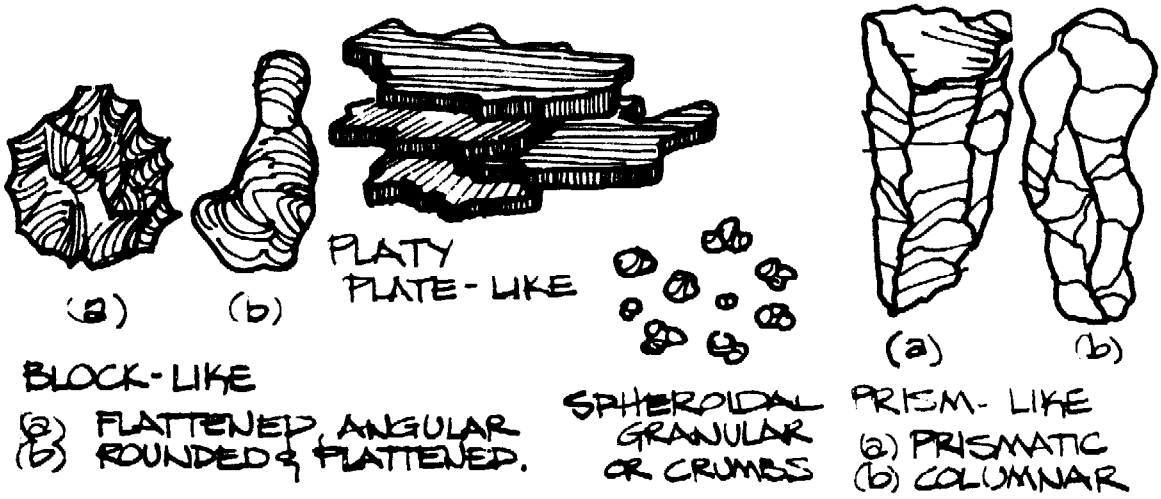

The four principal structure types are illustrated above.
Soil particle aggregates are shown greatly enlarged.

Water Holding Capacity

All soils can hold certain amounts of water. When a soil is saturated, some of the water will filter down through the open spaces around individual particles and will be lost to plant roots. This "drip-dry" process can take from several hours to several days. At the point when the downward movement of the water stops, the soil is at "field capacity." Some moisture stays behind after the excess water has moved through the soil. It is held in place by capillary forces. Plant roots have the ability to absorb this moisture and utilize it for growth and transpiration. The remaining moisture in the soil is held so tightly by individual soil particles that roots cannot absorb it. This is hygroscopic water, which is unusable by plants.

For a plant to grow, the soil moisture must be between field capacity and the wilting point (a low moisture level beyond which a plant cannot recover if additional moisture is not supplied). These two levels, field capacity and the wilting point, will vary from one soil to another.

The main factors that determine this range are:

- Soil Texture: generally, the coarser the overall soil texture, the less water it will hold. Inversely, the finer the texture the more water it can retain; however, there will be a higher percentage of hygroscopic moisture.

- Organic Matter: organic content is very important, because decomposed organic matter (humus) acts like a sponge. It soaks up excess water and stores it so that roots can absorb it later on.

- Other Factors: porosity and surface conditions can influence soil moisture levels, but to a lesser degree.

In general terms, the heavier the soil, the more moisture it can hold after it has been soaked by infiltrating rainwater or excessive flooding. Sandy soils tend to dry out faster than soils consisting of finer particles. There are two soil types that contradict this general rule, and both have important implications for tree growing and reforestation activities.

Heavy clays (no sand and little silt) become hard when dry, severely hindering root development and killing young trees unless they are especially adapted to these conditions. In addition, the surface layers of clay soils, which show typical shrinkage cracks when dry, have a tendency to "slam shut" when wet. The upper soil layer expands when moist and keeps water from penetrating further down into the root zones of trees and shrubs. Even though the surfaces of these soils are waterlogged, the moisture is unable to descend to the lower horizons. Unless these soils are constantly loosened, this water is lost to surface runoff or evaporation. Organic matter will greatly help to create space for air and water in an otherwise compact soil medium. Termites can also excavate space in soils that are severely compacted.

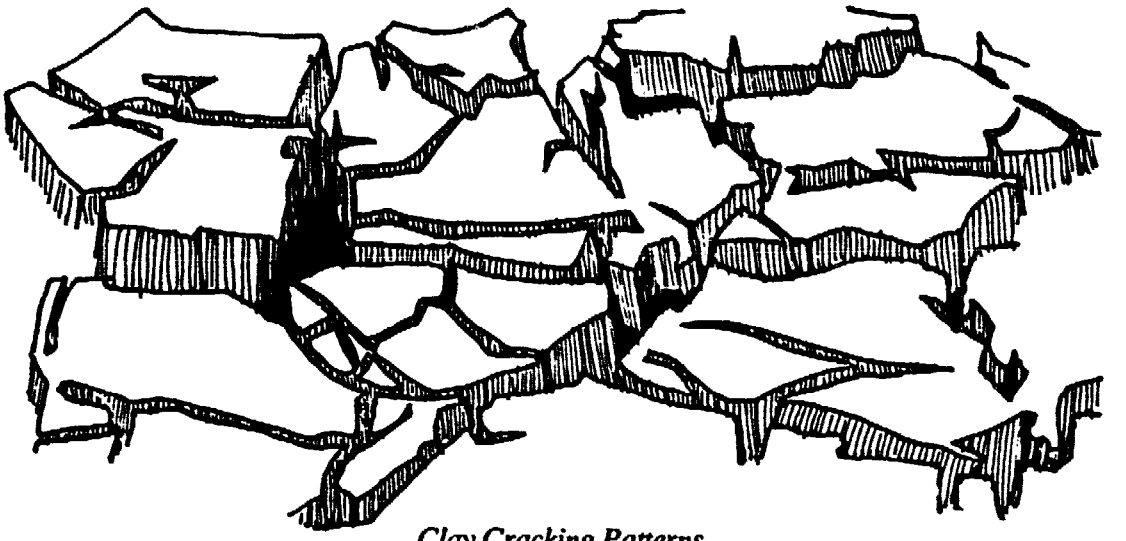

Clay Cracking Patterns

The second type, dune sand, although very porous, can retain water relatively close to the surface (within 2-4m). Adequate levels of soil moisture can be maintained for a surprising length of time. Biological sand stabilization activities have had good success on dunes that appeared to be quite dry. Two-inch soil augers can be used to ascertain the presence of moisture near the surface on these sites.

As every farmer or gardener knows, plant growth can be greatly enhanced by increasing a soil's water holding capacity. While not much can be done to change the texture of a soil, organic matter can be added to help a soil retain moisture better. Apart from the additional nutrients it supplies, humus also helps keep soils crumbly and well aerated. This facilitates root development and plant growth in general.

Farmers as well as foresters increase the soil's water holding capacity in several other ways:

- reducing wind velocities to slow down evaporation and transpiration;
- reducing soil surface temperatures (using shade);
- loosening and break up top layers to increase infiltration and produce a crumbly structure;
- mulching to reduce surface drying;
- practicing sub-soil plowing or "ripping" to break up compacted layers;
- using green manure cover crops to provide additional organic matter and to protect the surface during dry seasons;

- adding compost or animal manures, crop residues, or leaf litter from trees and shrubs;

- practicing contour cultivation as well as other soil and water conservation techniques.

In some areas these approaches are practical only for crop or vegetable production because of the expense or labor involved. Those techniques that are applicable to reforestation involve breaking up soil layers (by preparing deep holes for planting seedlings), weeding and loosening the soil surfaces around newly planted trees, and the addition of leaf litter. Soil conservation techniques, such as windbreaks and mulching, can also be appropriate, depending on local conditions.

Emphasis in dryland reforestation is placed on conserving and retaining surface water that accumulates during the rains. Even in extremely arid areas rain often falls with high intensities. A water surplus builds up temporarily in the soils and on the surface that may be lost to runoff or evaporation. With some additional efforts much of this moisture could be stored and made available to trees and shrubs. Retaining and conserving water is one problem; getting it to and keeping it in the plants' root zone is another. In any case, a soil's water holding capacity remains one of the key factors in successful reforestation efforts in arid zones. Those techniques that have been given good results are covered in Chapter 8, Agroforestry and Soil Conservation.

Soil Reaction (pH)

Soil reaction is an important variable because it can limit or enhance survival and growth of trees and shrubs. The measurement of soil pH can also be a highly useful indicator of other soil characteristics that are more difficult to determine in the field, such as organic content and soil salinity. Inexpensive and reasonably accurate "pH kits" are becoming increasingly available, making pH tests feasible on almost any site. The information that can be derived from these tests makes them well worth the effort and investment.

The symbol pH stands for "potential of hydrogen." It measures the hydrogen ion concentration in a given soil sample, which indicates the intensity of soil acidity or alkalinity. A neutral substance has a pH level of 7. Values below 7 indicate acidity, and those above show alkalinity. The pH range of soils generally varies between 3.5 and 9.5.

A pH value of 7.5 or more indicates that some free carbonates of calcium or magnesium are present. Soils over 8.5 nearly always contain exchangeable sodium. Low pH values in tropical climates, on the other hand, indicate free aluminum levels, which can hinder plant growth considerably.

For a given soil, pH values can vary quite a bit, depending on the depth of the soil profile from which samples are taken. Soils that show high acidity close to the surface may be more alkaline at lower levels. The reverse can also be true, particularly in dry valleys subjected to an arid climate.

Tree and shrub species vary in their requirements for best or at least tolerable pH ranges. *Casuarina equisetifolia, Acacia auriculiformis, Tamarix* spp., and date palms are among those species that tolerate highly alkaline soils. Pines and mountain bamboos do better where soil acidity is relatively high and pH values therefore low (4.0-5.5). As a general guideline, trees and shrubs in arid zones will do well within pH ranges of 4.5 to 7.5. Proper choice of species is important, however, because some species are particularly sensitive to pH requirements.

Much time and effort has been lost when pH requirements of newly introduced species have not been properly checked against conditions at the planning site. A striking example is that of the many disappointing efforts to introduce *Leucaena leucocephela* in the Sahel. Poor survival rates and weak performance of most varieties of this species have been due to the fact that pH values of the soils were much lower (6 or below) than the ranges required (6.5 or higher). There are a few varieties of *Leucaena* that are better adapted to more acid soils, but most require a relatively alkaline soil reaction, such as limestone soils.

Anytime the pH is suspected of being as high as 7.7, caution is indicated, not only in choosing the appropriate species, but also for planting techniques and micro-site improvements. Furthermore, cultivation around young trees will be necessary to reduce alkalinity on the surface. At the other end of the scale, acidity levels of pH 5.3 and lower also require special planting techniques and soil restoration efforts. The addition of organic matter to the soil will affect pH levels, at least temporarily.

Soil Depth

Many of the soils in arid Africa are far shallower than one might expect. One reason is that in many instances the upper soil layers have been washed or blown away by erosion. Sometimes rock layers are covered with only a thin layer of soil, and lateritic rock outcroppings are common throughout these regions. The soils of the plateaus that exist in many areas of Africa are seldom really deep. In much of the African continent soils can be broadly categorized as being highly weathered, old soils. Erosive forces have had a particularly great impact over a long period of time.

It is unfortunate that in many instances trees are planted on sites where soils are too shallow to support the chosen species adequately. Reforestation should not be undertaken without first determining how deep the soil layers are. Tree roots can sometimes burrow into underlying rock and through cracks and fissures, but often they will become stunted and deformed, inhibiting growth and leading to early mortality.

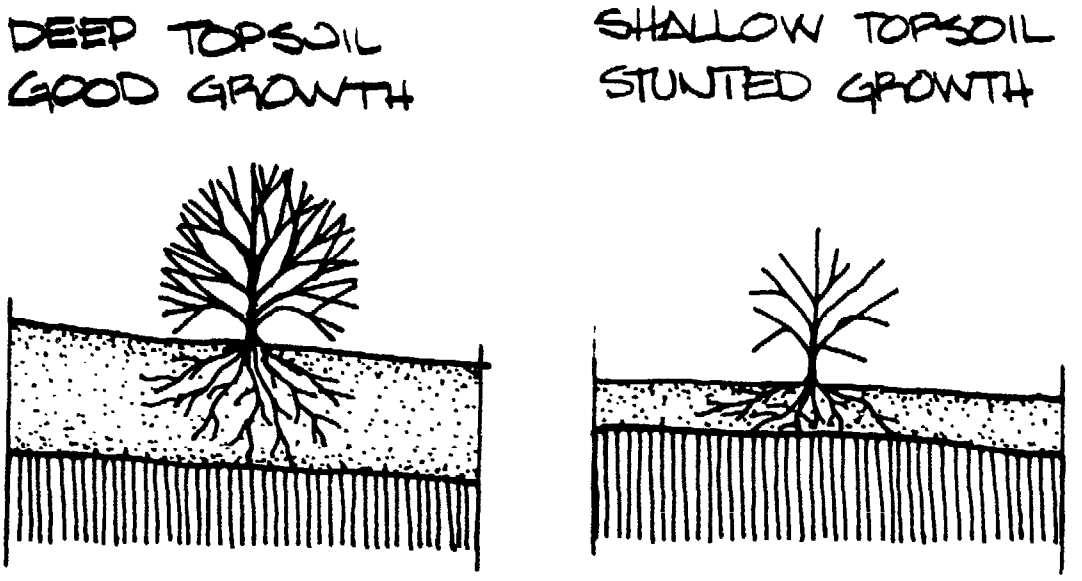

A general impression of soil depth can be gathered by looking at profiles along road cuts and at other construction sites. Hand dug wells provide a good source of information about sub-surface conditions. As a rule of thumb, trees will have difficulties if soils are less than three to five feet deep. If soils are less than 30 inches deep, problems will undoubtedly occur unless only those species are used that do not need deeper soils. Species selection becomes even more complicated under these conditions. As a first indicator one should always look at what is currently growing at the site, or what, according to the local people, grew there in the past.

Of all the recommendations that can be made on this subject, the single most important one is to dig before you plant. A soil pit can provide considerable preliminary information about soil conditions. A pit does not have to be deeper than about six feet. It will become readily apparent if hard crusty layers or "pans" are present. If no obstacles are met, most trees will have adequate room in which to develop their roots, although it is known that some indigeneous species send their roots to much greater depths. A three-year-old *Acacia albida* that was carefully excavated had a fine tap root that reached 30 feet into the ground before it broke and could not be traced any further.

In addition to the location of hard layers, a soil pit will reveal useful data about other soil characteristics. The color of a soil profile normally changes, sometimes abruptly, from darker tones to lighter ones below. Soil texture and pH can also change with depth. Where wind deposits occur, upper layers may vary considerably from lower ones. The same thing can happen where water-borne sediments have been deposited. As a rule, lower layers are less productive than those closer to the surface where organic content is usually higher. This is an important limitation when "deep planting" is being considered.

In summary, soil depth greatly influences tree and shrub growth, more so than in smaller plants. On soils less than three feet deep, only specially selected species will do reasonably well, particularly if impervious layers prevent the free movement of water. Three to six feet of soil are sufficient for tree growth, especially if the layers below can be penetrated by tree roots. Any soil deeper than six feet should pose no particular problem as far as adequate depth goes.

Erodibility of Soils

Soil erosion is caused by two major environmental forces: wind and water. Wind is an especially common factor affecting loss of topsoil in arid and semi-arid regions. Erosion by water is caused by surface runoff. Soil particles are loosened by the impact of the runoff, then carried down slope by the water. A similar process of detachment and transportation occurs in wind erosion. Several revegetation methods for use in erosion control are described in Chapter 8, Agroforestry and Soil Conservation.

Water has carried topsoil away and left deep ditches or channels in the earth.

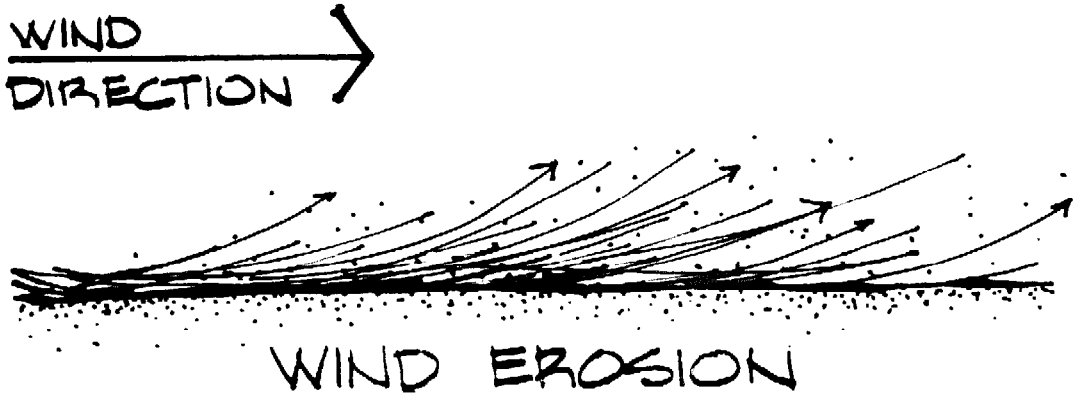

Fine, light dry sand, with no organic matter, being blown by the wind.

The rate of soil erosion is influenced by topography, climate, land use--particularly cultivation methods--and vegetation cover. The degree to which a particular soil type may be susceptible to erosion is also a function of various soil properties:

- Texture: soils with a high percentage of silt and very fine sand particles (0.002-0.1mm) are more easily transported by wind and water than coarser material or finer particles, which tend to cling together more.

- Organic content: all other things being equal, the higher the organic content, the less erodible the soil.

- Soil structure: the particles in more stable soil structures are less likely to be dislodged from the aggregate.

- Permeability: the ability of water to infiltrate through the soil can affect erodibility by decreasing surface runoff.

Soil Classification

Soils are classified in the United States according to a number of physical and chemical soil properties, including those discussed above. In some African countries other soil taxonomies may be used, however, and soils may be given different names under these classification systems. Soil type is determined by properties such as moisture, color, texture, structure, organic content, pH, presence of salts and other minerals, soil depth, and parent material. Many standard soil survey texts describe distinctions between the classes in much greater detail. An introductory overview is given here that explains terms that many forestry and conservation texts and project reports use.

Soil classification uses a special terminology to designate different *soil textural classes*, which are determined by the relative presence or absence of different particle size fractions. Soils rarely consist of only one fraction (dune sand is the major exception, but it frequently contains some finer particles). They usually consist of a mixture of sand, silt, and clay.

The basic soil textural classes, in order of increasing proportions of fine particles are: sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. "Loam" is an old English word sometimes applied to crumbly soils rich in humus. In soil classification terms, however, it is used to describe a soil that has about equal parts of sand, silt, and clay.

The following basic diagram gives the relative position of various soil classes to each other:

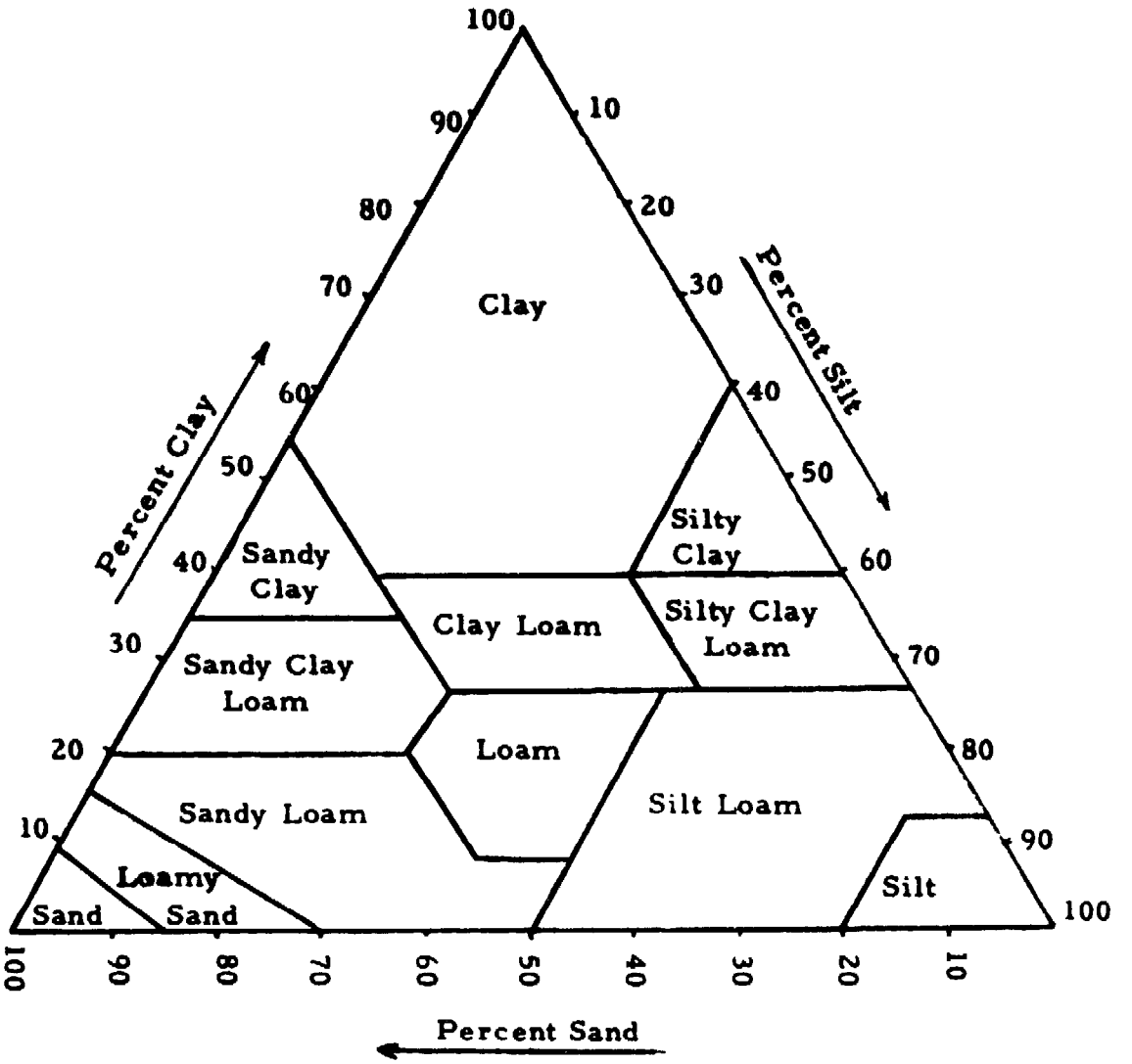

University of California Agricultural Extension Service

The particle distribution of a given soil can be measured using sieves to separate the grains into different size classes. Gradation of particle sizes can be determined this way only for fractions larger than about 0.05mm. To measure smaller particle sizes (silt and clay), other methods can be used that involve separation in water. These require laboratory equipment not normally available at project sites.

The different components of a soil sample can be separated by following the instructions in the box. This method gives a rough estimate of the proportions of sand to finer soil particles.

Estimating Soil Components

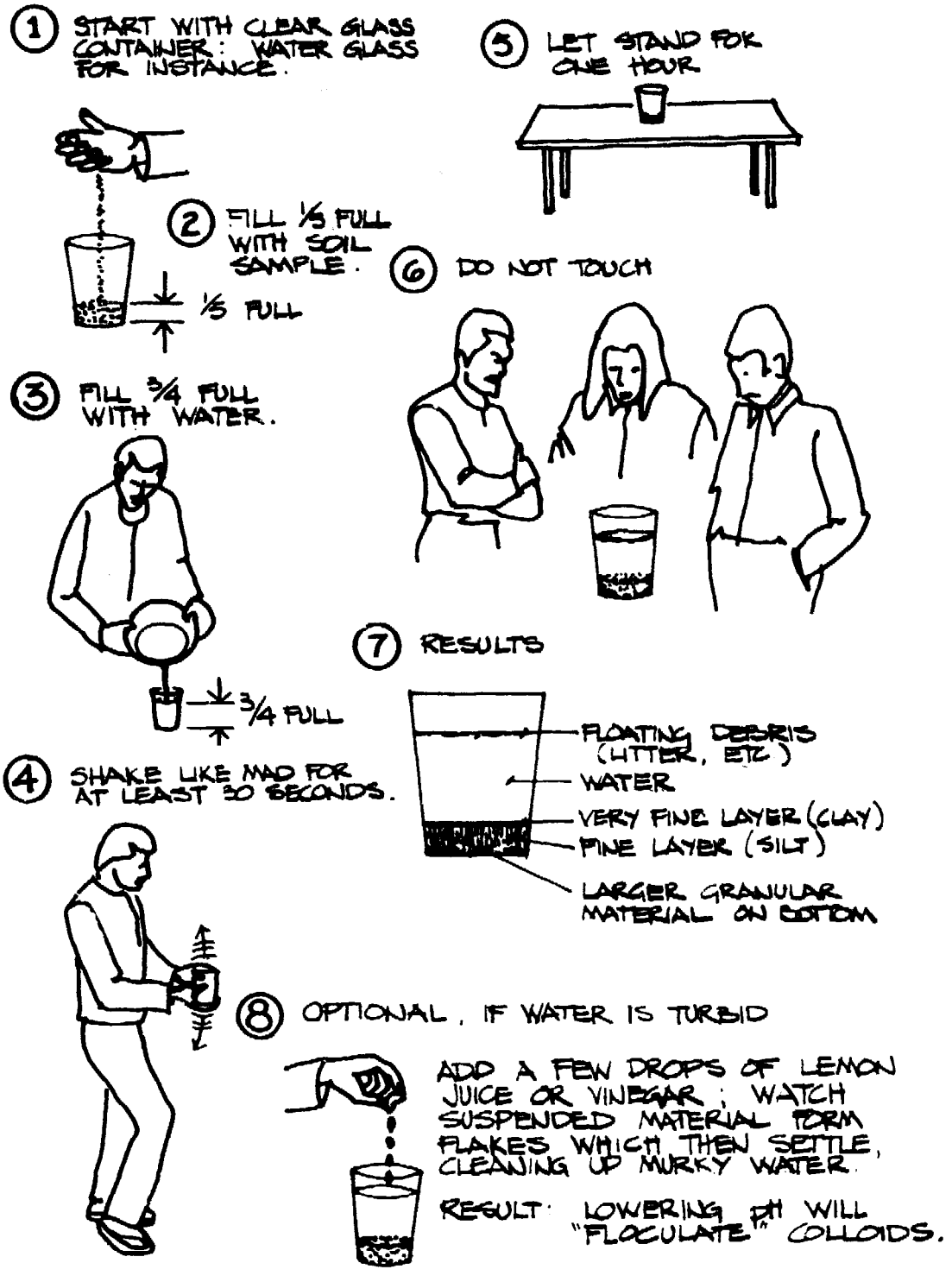

Field assessment of soil texture, including the finer particles, involves the following method. It relies mainly on the feel of the soil and the observer's experience.

- Sand: loose individual grains can be seen or felt. It forms a cast if squeezed when moist, but crumbles when touched.
- Sandy loam: mainly sand, but contains enough silt and clay to make it somewhat cohesive. If squeezed when dry it forms a cast that readily falls apart. If squeezed when moist, the cast will bear careful handling.
- Loam: a relatively even mixture of sand, silt, and clay. It feels slightly gritty, but is smooth and somewhat plastic. Squeezing when moist will produce a cast that can be handled quite freely.
- Silt loam: when dry it appears cloddy, with lumps that can be broken easily. When pulverized it feels soft and floury like dry cement. It cannot be squeezed between thumb and finger to make "worms".
- Clay loam: it breaks into clods or lumps that turn hard when dry. It can be rolled into "worms" when moist. If suspended the "worms" will barely keep from breaking apart under their own weight. Clay loam tends to turn into a compact mass when kneaded.
- Clay: it forms very hard lumps when dry. When clay is wet it is plastic and sticky. It can be made into "worms" easily.

Common Soil Problems

Two common and troublesome soil characteristics, salinity and laterite, create particularly difficult conditions for reforestation. They are also problems that are frequently overlooked during site assessment because they are not always easy to recognize or diagnose in the field. If problems with salinity or laterite are suspected, additional soil sampling and laboratory analysis may be called for. For more information on these subjects, refer to the bibliography in Appendix D.

Soil Salinity

The soil properties that influence salinity are related to soil chemistry and mineralogy, soil-water movement, and soil pH. Saline soils occur frequently in arid zones, especially in depressions and basins where evaporation or evapotranspiration is high. The normal downward movement of water tends to wash or leach the upper soil layers, flushing salts out of the soil. In areas where evaporation is much higher than rainfall, moisture in the upper soil layers is transported upwards. The result of moisture rising to the surface is the appearance of sodium salt crystals, which can cover an entire valley bottom.

These "white alkali" soils are often, but not necessarily, found where intensive irrigation has been practiced.

"Black alkali" soils are formed when rains dissolve sodium and potassium carbonates, dispersing the organic matter that colors the soil brown or black. Sodium carbonate can also break down the structure of inorganic clay particles, forming a gel that becomes impervious and hard when dry. This impervious layer reduces infiltration of water through the soil, so that leaching cannot take place. Calcium should be added to the soil to counteract the effect of the sodium.

High concentrations of salts in the soil are toxic to most plants. A few species are tolerant of soil salinity to some extent. The concentration of salt in soil or water may be expressed or measured generally in one of three ways:

- o milliequivalent per liter (me/l)
- o parts per million (PPM)
- o electrical conductivity (ECw) in millimhos per cm (mmho/cm)

A direct relationship between these values exists. Of the three measures, only conductivity can be readily measured in the field. It is the inverse (reciprocal) of electrical resistivity.

A second phenomenon greatly affects site conditions where salt problems occur. Even in soils where salt levels are relatively low (below 4 mmho/cm), strong concentrations of sodium salts can be a significant obstacle to reforestation efforts. This soil property is expressed in terms of the soil's Exchangeable Sodium Percentage (ESP). If the ESP value is above 15, reforestation efforts are likely to fail unless precautions are taken. Salt tolerant species must be selected and other site conditions must be favorable. Often on sites with high ESPs, pH values will also be high (around 8.5). This should be recognized as an indication of problems to come.

Frequently the soils at a proposed project site have not been analyzed to the extent that either pH, conductivity, or ESP are known. Reports from other projects on soils and soil resources of the region or country may provide some information. Local farmers should also be questioned about the productivity of local soils and site indicator plants.

Site Analysis

The obvious problem is to know what to ask and what to look for to avoid unsuitable sites. In terms of salinity problems in general, the following are specific situations that indicate potential trouble. Such sites require more thorough analysis, and it may be necessary to request assistance from a qualified soil scientist.

- o White alkali saline soils typically have high conductivity (over 4 mmho/cm), an ESP below 15, and a pH of 8.5 or above. Heavy leaching through over-irrigation can make them more productive.

- Saline-alkali soils (over 4 mmho/cm, ESP above 15, and pH around 8.5) can also be made more productive through leaching. Nevertheless, the calcium concentration of the soil must be increased to prevent dispersion of soil particles and reduction of permeability so that leaching can take place. Obtain additional advice before planting on these sites.

- Alkali "sodic"soils and "black alkali" soils show relatively low conductivity (below 4 mmho/cm), but ESP is over 15, and pH values are in the range of 8.5 to 10. Again calcium must be added for leaching to take place. Obtain additional advice before planting on these sites.

- For sites with ECw values of 6 mmho/cm, species must be selected with caution. At high levels of conductivity, fruit tree species such as citrus, plum, prune, and avocado are at their productive limits, even under otherwise favorable conditions.

Salinity Problems in the Nursery

The conductivity of water on irrigated sites should not be higher than 4mmho/cm, especially if species such as *Azadirachta indica* are to be planted. For all but the most salt tolerant species, problems with irrigation water will begin in the range of 2 mmho/cm. At higher ECw values, a sandy mix in seedling containers and deliberate overwatering will still give reasonable results in the nursery, although at a higher cost. The germination medium must be well drained and regularly leached. In village nurseries in Senegal, well water with a conductivity of about 3 mmho/cm proved to be too saline for reliable seedling production, in spite of cautionary measures that were taken.

Laterite Soils

Laterite and lateritic soils in dryland Africa pose special problems for forestry and soil conservation in many areas. Often they restrict vegetation growth and limit the choice of species that can be used in reforestation efforts. As underlying parent material to soils that are often shallow and easily eroded, they can dominate the landscape where extensive formations occur.

The term laterite can be confusing because it is used for both:

- the ongoing process of soil formation that takes place in semi-arid climates where temperatures are quite high, and

- geologic rock formations that developed millions of years ago; for example, aluminum oxide, which is mined as bauxite.

Laterite and soils in the process of laterization can be described as zones rich in sesquioxides (Al_2O_3 and Fe_2O_3) that, when cut into bricks, become hard as they dry. This naturally occurring process of secondary cementation is used in making adobe blocks for construction materials.

Soils with these kinds of properties pose special challenges as a medium in which to grow trees and shrubs. Lateritic soils are deficient in basic plant nutrients, because typically most of the soluble iron, magnesium, sodium, potash, phosphorus, and nitrogen have been leached out of the surface horizons. In addition, these soils become extremely hard and impenetrable to plant roots during the dry part of the year. When rains fall, most of the water either runs off or evaporates at the surface. What moisture does infiltrate will contribute to further leaching of plant nutrients.

Certain vegetation types are productive on lateritic soils in spite of these drawbacks. These woodland and pasture resources can be utilized and developed as long as harvesting and access to grazing are limited to sustainable levels. Once trees or shrubs are removed, however, these soils will rapidly lose their ability to support plant life. The soil building and restoration process has to be tediously re-established, with substantially decreased productivity.

Physical site improvement is necessary for degraded lateritic soils, even to the extent of micro-site improvements for individual trees. Surface treatment is required to increase infiltration and water retention where runoff occurs even if slopes are minimal. Deep pits or trenches can be dug to loosen up the soil layers so that water can penetrate and roots have room to develop. Soil surfaces must be kept loose around young trees and as much organic matter as possible must be provided in the form of leaf litter and other plant residues. With careful ground preparation and maintenance, revegetation is possible on such sites.

In many areas throughout arid Africa, the sites that have been designated as communal lands for grazing and wood-cutting are typically those on which lateritic soils are encountered. These over-exploited, fragile sites form large areas of "useless brush," which nevertheless still constitute the major source of fuelwood for many rural communities. Many foresters in arid Africa have traditionally foregone natural forest management in favor of plantations and woodlots. Recent attention, however, has focused on the potential for silvicultural alternatives to the use of fast-growing, exotic species. Management of the existing vegetation of communal woodlands may be the best alternative on lateritic soils.

Experience has shown that many of the exotic species introduced for fuelwood production are totally out of their element under these harsh, demanding conditions. Naturally occurring species, on the other hand, have a remarkable potential for natural regeneration, provided that basic conservation techniques are adhered to. Some indigenous species have also shown much faster growth than traditional forestry lore would predict.

Of particular interest along these lines is the recent experience in the Sahel in the restoration and management of the shrub savanna, where local species of *Combretaceae* and *Acacia* make up the dominant vegetation. In the Bandia Forest in Senegal, management of existing stands of *Acacia seyal* may have

more potential for biomass production on lateritic sites than fuelwood plantations using *Eucalyptus camaldulensis*. In the Guesselbodi Forest in Niger, research into the management of natural stands of *Combretum nigricans*, *C. micranthum*, and *Guiera senegalensis* is also underway.

On sites where existing vegetation and soil resources are not severely depleted, natural forest management is not only preferable from a conservation point of view, but is also more cost effective than artificial reforestation projects. Silvicultural techniques that can be used in natural forest regeneration include promotion of stump and shoot sprouting, enrichment plantings, and soil preparation to increase natural seeding and germination.

5 SITE/SPECIES SELECTION

Site Selection

For the type of reforestation effort with which this manual is mainly concerned, it is usually necessary for the planner to think in terms of at least two locations: a site for the nursery (the place where young trees will be seeded and grown until they are large enough to have a good chance for continued growth in another place), and the location where the trees will finally be planted. This planting site may be known from the beginning, because, as a site in need of reforestation, it may have been the key element in determining the scope of the project. Planting sites may, however, be chosen at a later stage in the planning, after an analysis of land use and resource needs has been completed.

Nursery Site

The nature and scope of the project determines the type and size nursery that is necessary. State operated nurseries are usually permanent and are established at a centralized location within the region they serve. These nurseries produce trees on an ongoing basis for a variety of needs, such as forest plantings, shade trees, woodlots, or soil conservation projects. Such centralized nurseries are frequently maintained by government funds.

Temporary nurseries are used when seedlings are needed only for a project that will be completed within a relatively short time. These nurseries are set up near the planting site to minimize transportation costs. They may be maintained for several years or for only one planting season.

Small permanent nurseries that are locally owned and managed may be feasible. These nurseries can be operated by individuals, families, cooperatives, youth or women's groups, or as a community effort. They may be located within family compounds, in community garden areas, or wherever an adequate water source is available. The seedlings can be used for agroforestry efforts on private land holdings and for village reforestation projects, or they can be sold to raise money for other purposes. Fruit tree nurseries are particularly popular at the village level.

The best sites are those that are close to 1) a dependable source of water, 2) a road that is passable for heavy trucks during the rains, and 3) the nursery supervisor's or workers' living quarters.

If plastic pots or other containers (plant leaves, cardboard boxes, clay jars) are used, finding a good site is not difficult. Pots can be filled with soil brought in from elsewhere, and they can be stacked and tended in areas where nothing else will grow. If seeds are to be planted directly into the ground at the nursery site, that is, if the stock is to be open-rooted, the nursery soil must be rich, deep, and well drained. The best soil has a loamy texture and a loose crumbly structure.

A slight slope will help surface water drain away, and protection from prevailing winds is also desirable. Often a large shade tree in one corner of the nursery is useful to protect very young seedlings from extreme sunlight. It is a good idea as well to find out whether the land next to the nursery site would be suitable and available if the nursery had to expand.

The main factors to be considered when deciding upon a nursery site are:

- availability of water year round
- protection from prevailing winds
- access to the planting site

Planting Site

The choice of a planting site is a complex decision. In selecting a site, it is essential that issues of ownership, tenure, risks and benefits be discussed in advance so that the expectations of government officials and local project participants are mutually understood. Officials and community members must meet to consider the following points when choosing a site:

- Who owns the land? Who has the water rights, if anyone? Who will own the trees once they are planted? Who uses the land currently or has used it in the past? What are their claims to it now?

- Who will be responsible for planting and maintaining the trees? Who will be allowed to harvest various products? If products are to be marketed, who will sell them and who will receive the proceeds from the sale?

- Will permits or taxes be required by government agencies? Are there any resource use or management regulations that must be followed on this site?

- How will grazing and other land uses be controlled on the site? Who will be responsible for enforcing the controls?

If protection of the land is the main goal, sites are selected to give the best possible conservation results. If production is the primary objective, issues

such as transportation and marketing become important. The site in turn determines which species and planting methods will be most successful. Forestry and conservation efforts are often undertaken to protect productive farmland against the adverse effects of flood and erosion damage. Frequently it is the area above the fields that requires treatment. In any drainage basin it is important to protect the upper portions of the slopes and hills.

Once a site has been decided upon, an agreement should be drawn up between the various parties involved. This should outline project goals, responsibilities, and a management plan for the site. The agreement is necessary to protect the participants, to ensure that everyone's expectations have been met, and to prevent future misunderstandings.

Species Selection

Foresters who are managing projects must analyze both tree species and sites before matching particular species to given sites. To do this successfully it is necessary to consider 1) environmental constraints, 2) purposes of the project, 3) human factors, and 4) legal constraints. For an additional discussion of species selection for agroforestry projects, see Chapter 8, Agroforestry and Soil Conservation.

Environmental Constraints

Performance of trees and shrubs is limited by the amount of moisture available to the plants, as well as certain other factors. Over time, different species have evolved that can exist where moisture is relatively scarce. Adaptations to arid site conditions can take on many forms. Some species develop roots that grow extremely fast or that spread out far beyond the radius of the trees' crowns. Others are able to store moisture and use it during the dry season. Some reduce their needs for moisture during the dry season by dropping their leaves or by closing them during the hottest part of the day to reduce transpiration. During an extreme drought many species have an unusual die-back/recovery capability: portions growing above the ground die back completely, but new shoots emerge from the root-stock when soil moisture conditions are again favorable.

The important question here, then, is which species can survive and grow well given the soil, water, and climatic characteristics of the site. To determine environmental constraints, foresters study climatic records for given areas.

Climate

In dry areas of Africa, the single most limiting climatic factor is rainfall. Before the project can be started, managers must find answers to a number of questions. How much rain falls during the rainy season (the period when young trees are planted)? How is the rainfall distributed during the rainy season? If the timing of the rains is wrong--for example, if the total rainfall occurs within two days instead of over several weeks--the project can be ruined.

There are other things about rainfall to consider. For example:

- How hard does the rain fall? Gentle, spread-out rains are more likely to soak into the soil than heavy, torrential rains.
- What is the temperature? If temperatures are very high, the moisture evaporates much more quickly.
- When do the rainy seasons occur?

As noted earlier, some areas have two rainy seasons; others have only one, in the hot summer months. Still others have one rainy season in the cooler winter months. A tree species that grows well in a region where the rain falls during the winter usually does not adapt well to an area where it rains during the warmer weather--even though the amount of the rainfall is the same.

The single most useful rainfall measurement is the mean annual precipitation, measured in millimeters (mm) per year. In the tropics, however, annual rainfall tends to vary greatly, so it is necessary to consider the variation from year to year in determining the figures upon which to base a choice of species.

It is a good idea to make a list of tree species and the water needs of each in any area in which forestry projects are being implemented. If two species look good, but one requires less water and the project area is one where the supply of water is uncertain, choose the one requiring less water. The list on the following page was prepared for three rainfall zones in Africa.

Drought

No one can accurately predict when a drought will occur, but foresters should make use of previous records in drought prone areas to determine the suitability of a species for a given site. Unfortunately, the drier the area, the less reliable the average rainfall figures usually are, and the greater the range of averages will be. Furthermore, there are many areas where accurate rainfall records do not exist, and it is necessary for project managers to use very general information such as that presented on the maps in Appendix C, and upon the basis of information from local residents.

Project results also indicate that in a dry climate, local species will grow more slowly, but may survive better than exotics--species brought in from other areas or countries. Obviously, under arid conditions, plant growth is not as vigorous as it is if more moisture is available. Since native plant species in arid zones have adapted to withstand prolonged drought, it is natural that they have different, often slower, growth characteristics than plants that evolved in more humid climates.

Common African and Introduced Tree Species by Water Requirement

Dry Sites--200 to 500mm Mean Annual Precipitation

Acacia albida
Acacia radiana
Acacia senegal
Annona senegalensis
Balanites aegyptiaca
Boscia salicifolia
Commiphora africana
Conocarpus lancifolius
Dobera glabra
Euphorbia balsamifera
Maerva crassifolia
Parkinsonia aculeata
Prosopis juliflora
Ziziphus spp.

Medium Sites--500 to 900mm

Adansonia digitata
Anacardium occidentale
Azadirachta indica
Bauhinia spp.
Cassia siamea
Combretum spp.
Eucalyptus camaldulensis
Ficus sycomorus
Haxoxylon persicum
Parkia biglobosa
Salvadora persica
Sclerocarya birrea
Tamarix articulata
Terminalia spp.

Moist Sites--900 to 1200mm

Albizia lebbeck
Anoegeissus leiocarpus
Borassus aethiopum
Butyrospermum parkii
Casuarina equisetifolia
Cordia abyssinica
Dalbergia melanoxylon
Erythrina abyssinica
Markhamia spp.
Tamarindus indica

On the other hand, species introduced from more favorable climatic zones may undergo severe stress when things get dry. They are often less able to survive than those species that occur naturally on dry sites. Even if these exotics are able to survive drought conditions, they may not grow normally or rapidly. In fact, their growth may be slower than the indigenous vegetation. This is the main problem in trying to introduce species from other areas into marginal sites.

In parts of Africa where the mean annual rainfall is less than 1,000mm, therefore, it is recommended that rapidly growing species such as *Eucalyptus camaldulensis* or *Leucaena leucocephala*, which originally came from other continents, be compared with other possibly more suitable species. If these species are used in low rainfall regions, they should be planted where the water table is near the surface, so that trees will have access to sufficient water.

Soil

Trees and shrubs need soils that have a high capacity for holding moisture, and a texture consisting of a blend of coarse and fine particles. They also should have a fair amount of organic matter that is renewed annually. Soil surfaces should be protected from strong, constant winds and they should not be

compacted. Preferably they should also be free draining, although this benefits some species more than others. Soil characteristics and their influence on species selection were discussed in the preceding chapter. Among the specific points to be considered are: What kind of texture does the soil have? Does it retain water well? How deep is the soil? Are there any potential problems with pH or salinity?

The presence of "indicator plants" on a site can provide clues as to the soil type that one can expect to find. *Calatropis procera* , for example, is often found on degraded soils where the nutrient pool has been depleted through intense cultivation. Close observation of the tree and shrub cover in specific landscapes will lead to a first feel for the type of soils that different species prefer. It is evident that *Mitrangina inermis*, *Anogeissus leiocarpus*, or *Borassus aethiopum* prefer low lying areas where soils contain a relatively large proportion of fine particles. What is already growing on the site can be the best clue as to which species will be compatible. On deforested sites, the most ecologically sound solution may be to restock the area with the original natural vegetation.

Other Environmental Factors

In addition to climate, soil, and water there are other factors in the environment that affect the choice of species:

- Elevation - some species will thrive only above or below a certain altitude.
- Slope - some species are especially useful for erosion control on steep slopes and unstable soils because they have lateral root systems (*Acacias, Balanites aegyptiaca, Anacardium occidentale).*
- Topography - rough, broken terrain may have a great deal of variation in micro-site conditions. Species that can tolerate a wide range of site conditions are needed.
- Fire history of the area - are there frequent or few fires? Some trees are more fire-resistent than others.
- Pests - some trees are more affected by certain pests than others. A planting site that has several kinds of trees is less likely to be destroyed by insects or disease, because a pest that attacks one species of tree may not be attracted to another species.
- Animals - do the livestock in the area prefer the leaves and bark of certain trees more than those of the other species being considered?

Project Purpose

While considering the species in terms of environmental constraints, it is necessary to keep in mind the purpose or objective of the project. What is the objective of the reforestation (or revegetation) effort? Is the project aim to

conserve resources, as in a sand stabilization program for an eroded area? Or does it seek to increase production of certain forest products, such as fuelwood or poles for construction?

Certain species can be used for one purpose and not the other, but some species can be used to fill a number of requirements. To meet several objectives, a plantation may also include more than one species. An example of a multiple-use species, *Anacardium occidentale*, is very valuable for soil reclamation and protection. It also produces fruits and nuts (cashews) that can be used for local consumption or as a cash crop. In addition, it can provide fuelwood, tanins, dyes, and medicines from different parts of the plant. The tree can tolerate a wide range of soil type, elevation, and rainfall variations.

Eucalyptus camaldulensis is a more limited species. Introduced to Africa for use in woodlots and large-scale plantations, it grows rapidly if conditions are favorable. It can produce large quantities of wood for fuel and construction in a short period of time. It is not particularly useful for soil conservation, however, because it produces little leaf litter, and there is evidence that it actually inhibits the establishment of other vegetation. The soil beneath a stand of *E. camaldulensis* is sometimes bare and thus is more susceptible to surface runoff and soil erosion. It also is not suited for use in intercropping or windbreaks and is fairly demanding in terms of site conditions.

In selecting species, therefore, it is important to weigh the production/conservation trade-offs, and determine priorities based on the project's purpose. Project goals should be formulated with consideration for local expectations and preferences.

Human Factors

The key is to discover what the residents of an area would like the project to do, and what is attractive to them. For example, if *Acacia albida* is highly thought of locally and can be grown on the site (i.e., it meets the environmental constraints), and it serves the project's purposes well, then it is a good choice of species: everyone takes better care of something that is highly valued. It is also important to investigate local preferences or prejudices towards certain species. The two species mentioned above, *A. occidentale* and *E. camaldulensis*, serve as examples to illustrate this point as well.

In parts of Senegal, the cashew tree is regarded with superstition because it is believed to attract ghosts (Hoskins, 1979). In other countries the cashew apple is thought to be poisonous if eaten with dairy products. In some areas where the trees have been planted, the cashews are not even harvested, because an oil in the nutshell causes skin irritations. In these cases the many beneficial characteristics of the tree may be outweighed by the negative perceptions of it.

The other example, *Eucalyptus*, has been widely promoted as a fuelwood species. But it tends to be smoky and it has a characteristic "cough drop" odor imparted by resins in the wood that are released when burned. In some areas

people have developed a taste for *Eucalyptus* and prefer it to other woods; but in other areas people object to the flavor the smoke gives to food--as well as to the smoke itself.

Legal Constraints

As mentioned earlier, many countries protect and regulate the use of natural resources and of certain tree species. In some cases, traditional laws give a specific tree special status. In West Africa, for example, *Acacia albida* was protected by local customs even before the national government protected it for ecological reasons.

It is impossible to give universally applicable information in this manual on such restrictions. Such information is readily available on a local basis, however, and foresters familiar with an area will know the restrictions that are enforced. Appendix B, which provides details for some of the common trees of arid lands in Africa, does note when a species has certain legal status.

A number of tree species of sub-Saharan Africa have been regulated by law (see box). This list can be referred to in considering the final choice of species. Species that are already protected by law may be more appropriate for a conservation project than species with no such restrictions. On the other hand, a species that requires special permits for use may be less desirable for a production oriented project.

Tree Species Regulated By Law in Africa

Use, cutting, and removal limited by law in at least one country:

Acacia albida
Acacia scorpiodes
Acacia senegal
Adansonia digitata
Balanites aegyptiaca
Bombax costatum
Borassus aethiopum
Butyrospermum parkii
Hyphaene thebaica
Khaya senegalensis
Parinari macrophylla
Parkia biglobosa (Benth.)
Pterocarpus erinaceus
Sclerocarya birrea
Tamarindus indica

Classified as "Specially Useful" in at least one country:

Acacia macrostachya
Acacia scorpioides
Adansonia digitata
Anogeissus leiocarpus
Balanites aegyptiaca
Boswellia dalzielli
Ceiba pentandra
Dalbergia melanoxylon
Detarium senegalense
Elaeis guineensis
Guiera senegalensis
Landolphia heudelotti
Lannea microcarpa
Prosopis africana
Pseudocedrela kotschyi
Pterocarpus erinaceus
Pterocarpus lucens
Saba senegalensis
Sterculia setigera
Teclea sudanica
Vitex cuneata
Ziziphus mauritiaca

6 NURSERY MANAGEMENT

Nursery Design and Layout

Sound nursery management begins with the design of the facility. Particularly in larger nurseries, a well thought out design is necessary to allow for rational traffic patterns and adequate work space.

A good way to begin planning the nursery design is to prepare a detailed sketch of its layout. Show the size and location of the beds and water storage facilities. Plan for irrigation during dry seasons and drainage during the rains. Allow room for walkways, driveways, and turnaround space as needed. Leave enough space for storage rooms and tool space. The storage area or construction shed should be large enough to provide shelter for the crew in times of intense heat and driving rain. Space is needed for research plots, germinating beds, compost bins, and safety or fire prevention strips (especially along the fences).The layout must also consider the special needs of open-rooted and potted seedlings.

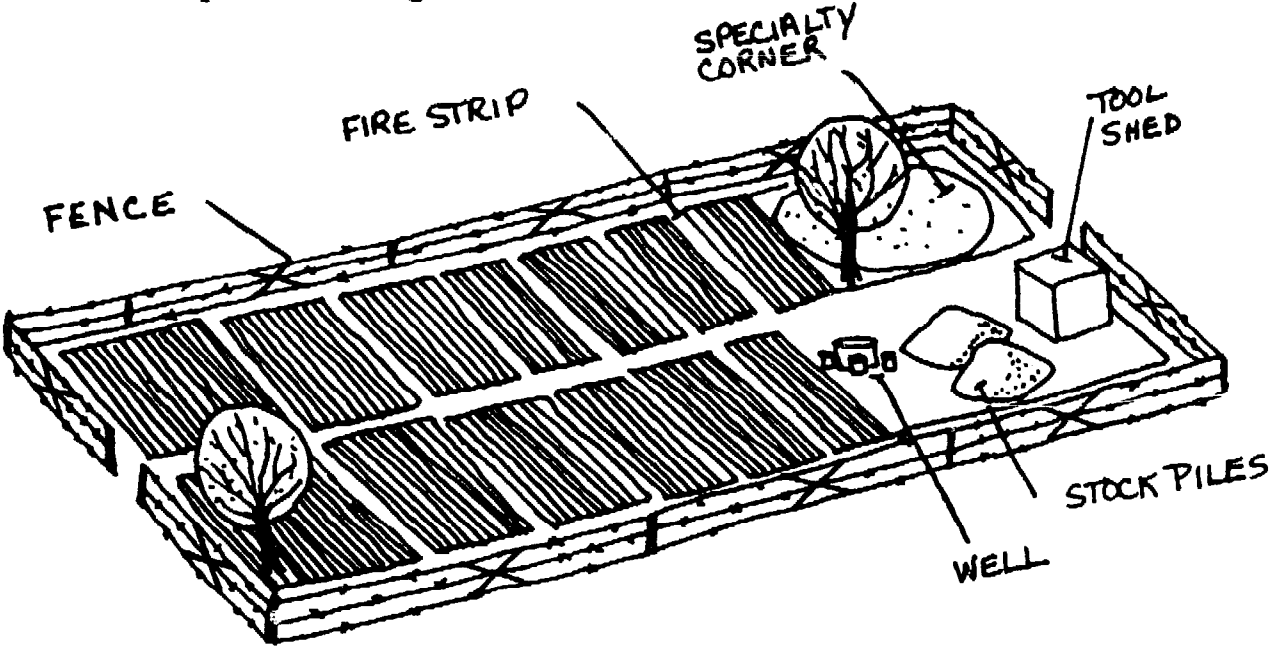

NURSERY LAYOUT

Open-Rooted or Potted Seedlings

Some species cannot be moved easily or transplanted safely from a nursery to a planting site unless they are grown and transported in pots; other species cannot grow well in pots. While the open-rooted stock method is cheaper to use, some species require the use of pots. If, however, a species will grow either in pots or as open-rooted stock, each method has advantages and disadvantages that should be considered.

In Africa, most of the *Azadirachta indica* (neem) trees are raised by the open-rooted method, and it is also used for *Cassia siamea*, *Khaya senegalensis*, *Sclerocarya birrea*, and some species of *Prosopis*.

Open-rooted Stock

The advantages of open-rooted stock are:

- o There is less weight to transport from the nursery to the permanent site--pots are heavy.
- o It takes less time to transplant open-rooted stock.
- o Less care of open-rooted seedlings is required in the nursery.
- o Seedlings are usually larger and so require less protection after transplanting.

The disadvantages of this method are:

- o Open-rooted seedlings need more space.
- o They need more time in the nursery.
- o The nursery location must have good soil conditions.
- o Roots are exposed to air when the plants are lifted out of the nursery soil and again when they are planted at the permanent site. This can damage the plants.

Potted Stock

The most commonly used containers in Africa are usually referred to as plastic pots, even though they are actually plastic bags. They are also sometimes called sleeves or tubes. Other types of containers may be used, and if they are made from locally available materials, they may be more affordable.

The advantages of using containers are:

- o Good soil is not required at the nursery site.
- o Seedlings can be placed closer together than in the open rooted method.
- o The time in the nursery is shorter, and although pots require expense at the beginning, the shorter nursery time cuts down on other expenses.
- o The pots can be easily moved to the permanent site well before outplanting starts, just as long as watering continues.
- o Root growth is contained in a package that is easy to transport, and there is little or no exposure of hair roots to the air during transporting and transplanting.
- o On difficult sites, potted plants may have better survival rates than open-rooted seedlings.
- o Soil diseases may not spread as rapidly to potted seedlings as in open-rooted beds.

The disadvantages of using containers are:

- o The seedlings require root pruning while in nursery pots.
- o Pots cannot be piled up for transport.
- o They are heavier and more difficult to transport.
- o Pots must usually be purchased, which may or may not be a problem (depending upon time saved in the nursery or on the expense of making certain soils ready for open-rooted planting).
- o Seedlings are normally smaller at the time of transplanting and require extra protection from grazing livestock until they are larger.

If pots are needed, they should be ordered well ahead of time. Only one size plastic pot is necessary for most species, which makes ordering easier. The plastic should not be too flimsy or the pots will collapse; a plastic that is 4 to 8 mils thick should be strong enough. Usually the pot is a standard 8cm (3 in.)

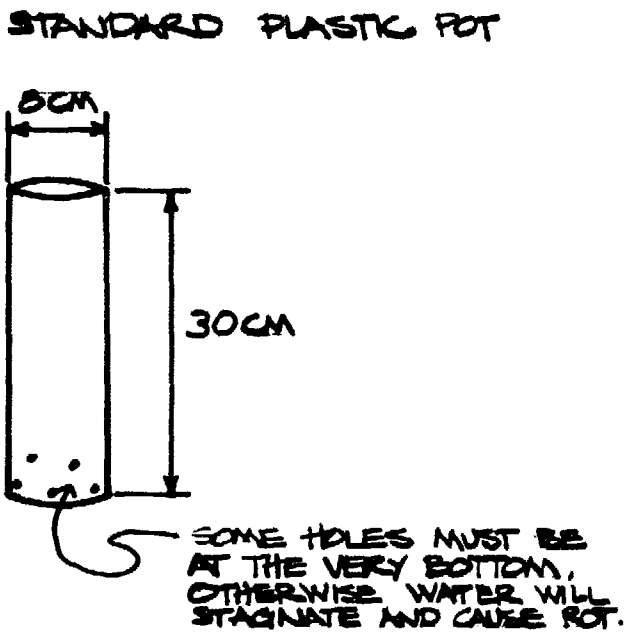

diameter by 30cm (9 in.) depth. Larger pots are needed for some species, particularly fruit trees, such as *Mangifera indica* (mango) and *Citrus* spp.

Some experiments have been done with much smaller seedling containers (2.5cm diameter by 5 to 30cm depth) in the United States and the Caribbean. These are made of styrofoam, cardboard, or plastic, and are much easier to transport than the larger pots. It is not clear, however, if they are appropriate for use on dry sites, and they are likely to be considerably more expensive than the widely used plastic sleeves.

Planning Nursery Beds

The amount of land needed for beds (the land within the nursery where the seeds will be sown) will depend on whether the seedlings will be grown in pots or will be open-rooted. If the open-rooted stock method is being used, figure that each group of 1,000 trees needs about 10 square meters. The same number of potted seedlings needs only about seven square meters. Add at least 20 percent to the figure calculated for the nursery beds. The 20 percent will be for additional space for roads, work areas, construction sheds, etc. Walkways between the beds must be wide enough to permit foot and wheelbarrow traffic, a minimum of 60cm (24 in.).

If at all possible, plan the beds so that their longer dimension is placed in an east-west direction and their narrower side faces north-south. Orienting the beds in this way gives trees on the inside the same exposure to the sun as those in the outside rows. Beds should not be wider than 1m so that weeding in the center can be done easily. A bed that is 1m wide and approximately 6 to 7m long can hold about 1,000 plastic pots in 12 rows of 83 pots.

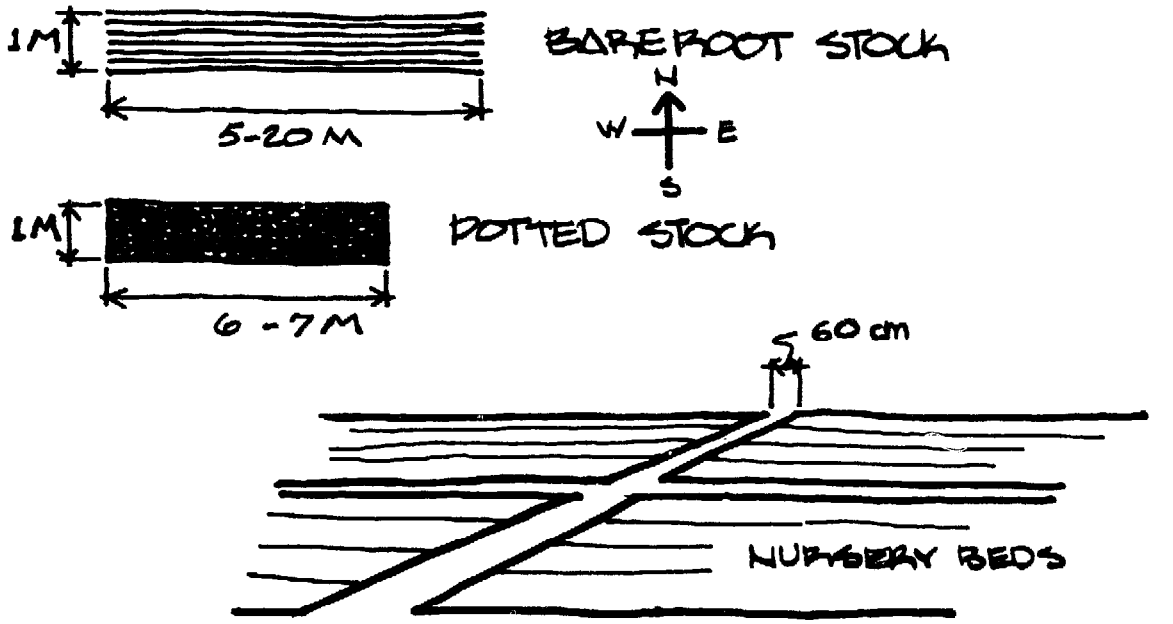

For open-rooted stock, standard sized beds contain five rows of trees and are approximately one meter wide. The length of the beds varies from 5 to 20 meters, depending partly on handling needs and the amount of labor and transportation available. Always allow room for extra beds.

Beds are usually either sunken or raised, depending on species and site conditions. Sunken beds retain moisture much in the same way that micro-catchments work, and thus are used where water availability is limited. Raised beds are prepared for open-rooted stock using the double-digging method. They provide seedlings with a well-drained and aerated rooting zone for optimal growth.

OPEN ROOTED STOCK

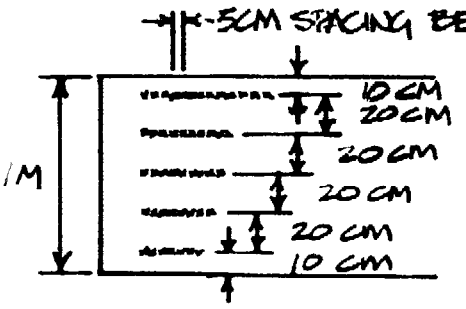

IN $1M^2$ THERE ARE 5 ROWS OF TREES SPACED 5CM APART = 5×19 TREES = 95 TREES

A 1M×6M BED (6×95 = 570 TREES) REQUIRES A TOTAL SPACE OF (1.0 + 0.6) × (6.0 + 2.0) = $12.8M^2$

$12.8M^2$ + 10% = $14\ m^2$/BED

570 TREES = $14\ M^2$
40.5 TREES / m^2

SPECIAL SUBJECT – NURSERIES

PLASTIC POTS

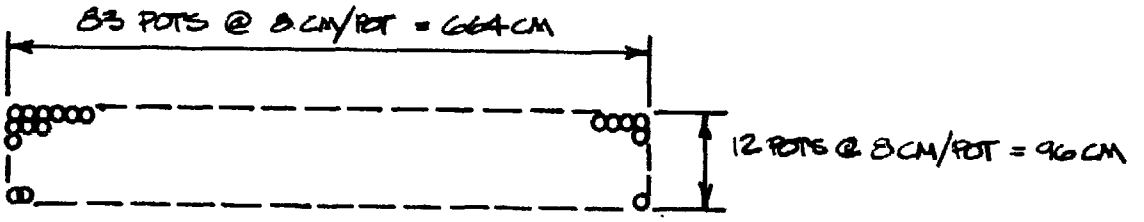

12 × 83 POTS = 996 POTS OR TREES
6.64 M × 0.96 M = 6.37 M²

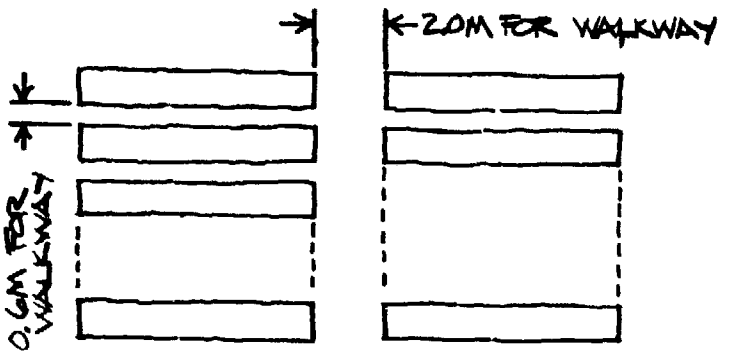

ONE BED REQUIRES:

(0.96 + 0.6) × (6.64 + 2.0) = 13.5M²

13.5 M² BED AND WALKWAY
+ 1.5 M² 10% WORK AREA AND FENCE
14.8 M² TOTAL AREA / BED

966 TREES = 14.8 M² =
65 TREES / M²

TOTAL SURFACE AREA REQUIRED m^2	ILLUSTRATIVE DIMENSIONS m	NUMBER OF TREES THAT CAN BE RAISED AS EITHER (-10% LOSS OR REJECTS)	
		Plastic Pots	Open-Rooted
10	4 X 2.5	585	360
50	10 X 5	2,925	1,800
100	15 X 6.7	5,850	3,600
500	30 X 17	29,250	18,000
1,000	40 X 25	58,500	36,000
5,000	71 X 70	292,500	180,000
10,000	100 X 100	585,000	360,000

SPACE REQUIREMENTS CALCULATION

(Including walk space and work area)

ON THE BASIS OF :
PLASTIC POT STOCK = 65 TREES/m^2
OPEN-ROOTED STOCK = 40 TREES/m^2

TYPICAL LAYOUT FOR NURSERY PRODUCING APPROXIMATELY 20,000 SEEDLINGS PER YEAR (BOTH POTTED AND OPEN ROOTED STOCK)

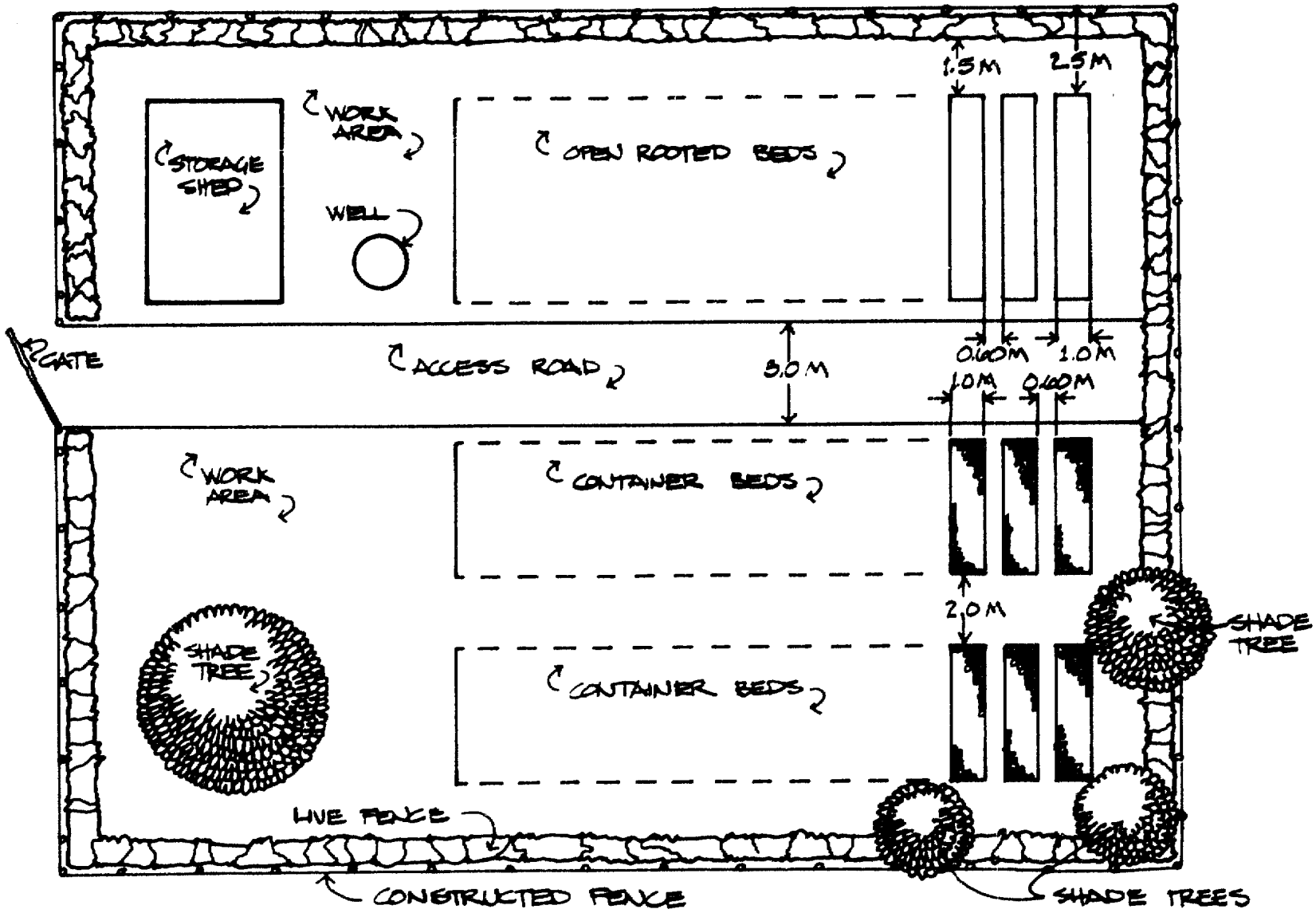

Other Nursery Design Considerations

Access

Long distances for hand carrying can be avoided by planning driveways in the layout. A small truck should be able to drive into the center of any nursery that holds 10,000 seedlings or more. It is even more useful if the nursery has a central access road that runs the full length of the nursery, with a turnaround or drive-through facility at the far end.

Research

Small research plots can be placed in a corner of the nursery. The location of these beds should be planned so that they do not interfere with the regular nursery efforts. Experimental plantations are also often located on a parcel adjacent to the nursery, for easy observation and to serve as a demonstration of new techniques for visitors to the nursery.

Shade

Young trees usually need some shade during their first weeks, especially when they have just been transplanted from a germination box into pots, or during the worst weeks of hot, dry weather. Shade can be used as a technique to cut down loss of plant moisture through transpiration if it is difficult to provide adequate water year round in the nursery through irrigation.

Too much shade, however, will cause seedlings to be spindly and weak. They should be protected from the sun only when necessary. Some seedlings are raised in full sunlight from the time they germinate. Usually shading is only necessary for a short time. Most species adapt themselves early and quite well to full sunlight.

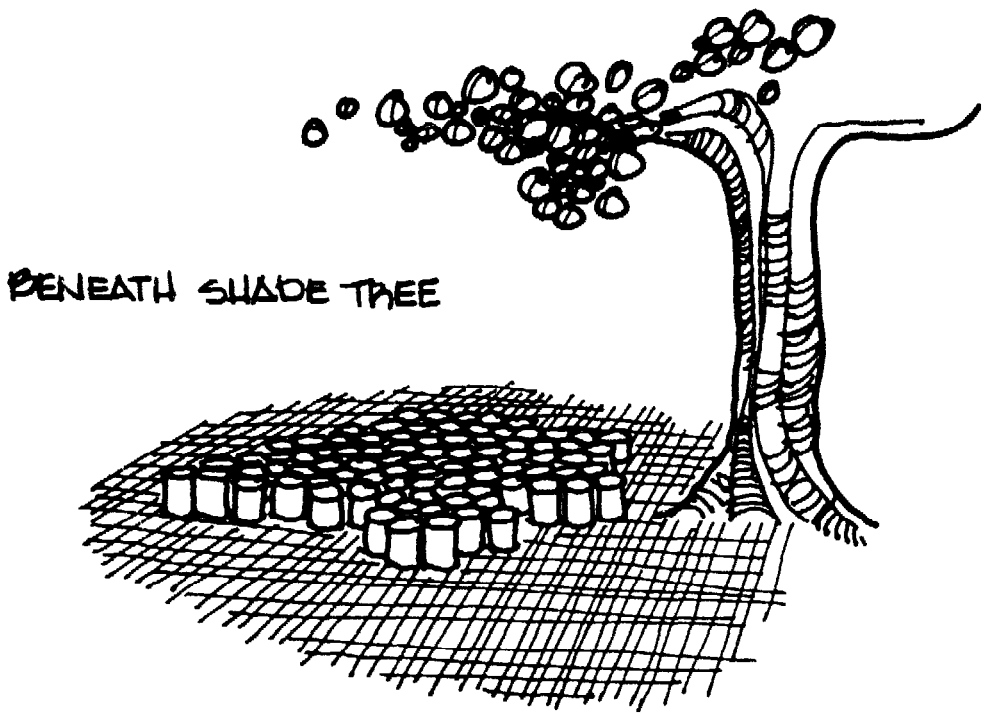

If a large shade tree is available in the nursery, seedlings in plastic pots can be started underneath it and later moved into partial or full sunlight. If there are no shade trees in the nursery or for open-rooted plants, another possiblility is to rig straw or reed mats over some of the beds. The advantage of this method is that the screens can be adjusted to regulate the amount of sunlight at different times of the day.

SHADE

SCREENED CONSTANTLY

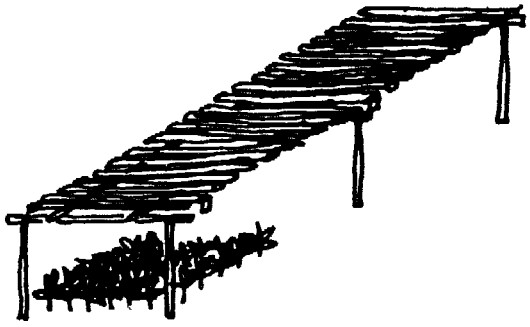

TOOMUCH SHADE WILL CAUSE SEEDLINGS TO BE SPINDLY AND GROW WEAK STEMS. PROTECT ONLY WHEN PROVEN NECESSARY

EXPOSE TO MORE DIRECT SUN AS TREES GET OLDER

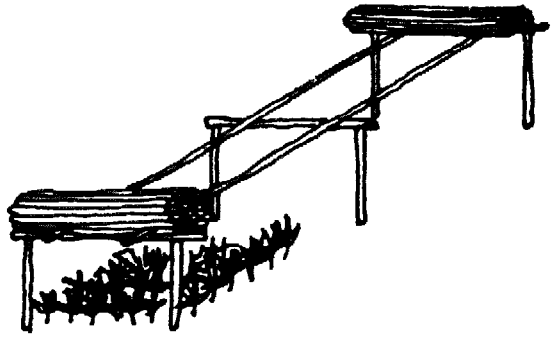

SOME TREES IN SAHEL NURSERIES NEVER GET SHADED AND DO WELL!

Gradually move the seedlings into the full sunlight: this will help prepare them to survive full exposure to the sun at the planting site. Seedlings should, however, be shaded when they have just been lifted out of the nursery, while

they are being transported, and during any delays prior to transplanting, to relieve the stress of moisture loss during the transplanting process.

Ground and Soil Preparation

Clearing the Site

The first step in preparing the nursery is to remove all but a few trees that may be there already. These trees are kept for shading young seedlings until they can stand full sunlight. Aside from these shade trees, old trees and quantities of young trees simply do not mix: the competition for light and water damages young trees. If it seems wrong to cut trees down, it is sometimes possible to move them elsewhere. All remaining roots, stumps, and other vegetation should be removed from the area.

Providing for Nutrients

If open-rooted stock is being raised, ideally the soil should be fertilized to add nutrients. Open-rooted seedlings draw large amounts of nutrients from the soil and special fertilizing efforts should be made, particularly when preparing the beds for a new crop. Nitrogen, potassium and phosphorus are nutrients of particular importance. Plants can take up these nutrients from organic compost, animal manure, and green manures, which also can help build or keep good soil structure. Commercially produced fertilizers are often needed to supply sufficient phosphorus. In many areas, however, these chemical fertilizers are not available, or are too expensive to purchase.

Beds for Open-Rooted Seedlings

Beds for open-rooted seedlings can be either raised or sunken. In either case the subsoil must be broken up and loosened to allow drainage and root development, and composted organic matter should be thoroughly mixed into the soil. There should be no large clumps of soil or organic matter. Sunken beds are usually about 15cm deep, although the sides of the beds may be built up above the surface. Their purpose is to retain additional moisture in areas where extreme aridity is a problem. In more humid zones sunken beds may retain too much water, causing stagnation and fungus problems.

Raised beds are prepared using the double-digging method (see box). This technique involves loosening the subsoil, turning the topsoil, and adding compost in a way that avoids compacting the soil and increases porosity for air and water infiltration and root development. Raised beds can be framed with side supports, such as bricks or boards, to keep the edges from eroding. Often these materials are scarce or too expensive, however, and the beds are simply maintained regularly.

Preparing Raised Beds

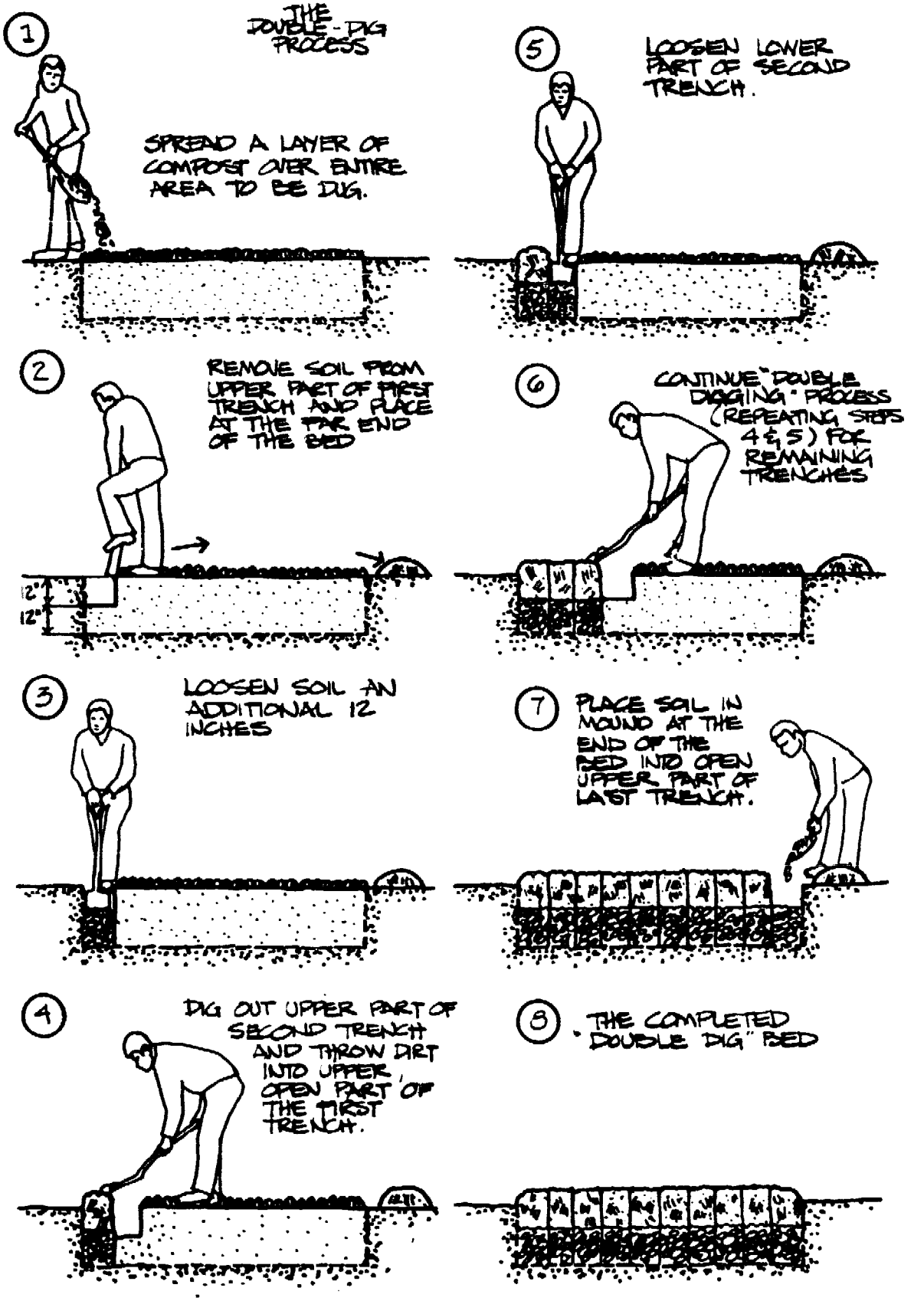

Procedures for Potted Seedlings

Potting Mixture

The potting mix should be loose and light to encourage good root development, but not so much so that the root ball crumbles when handled. Good results have been achieved by mixing plain sand with sieved cattle manure at a ratio of 1:1. It may also be desirable to include some clay in the mixture so that the root ball holds together well during transplanting. Old termite mounds are often a good source of clay. Other ingredients that may be included in the potting mix are charcoal dust, compost, insecticides or fungicides, and chemical fertilizers.

Clay and organic matter should always be sieved to get rid of any large clumps. Sand, on the other hand, normally does not need sifting unless it contains a lot of debris. A large screen can be constructed using a heavy wire mesh (1-cm openings) with a wooden frame for support. This is propped up at an angle, and the potting mixture is shoveled through it. Any clumps that are too big to pass through the screen can be dried and pounded to break them up.

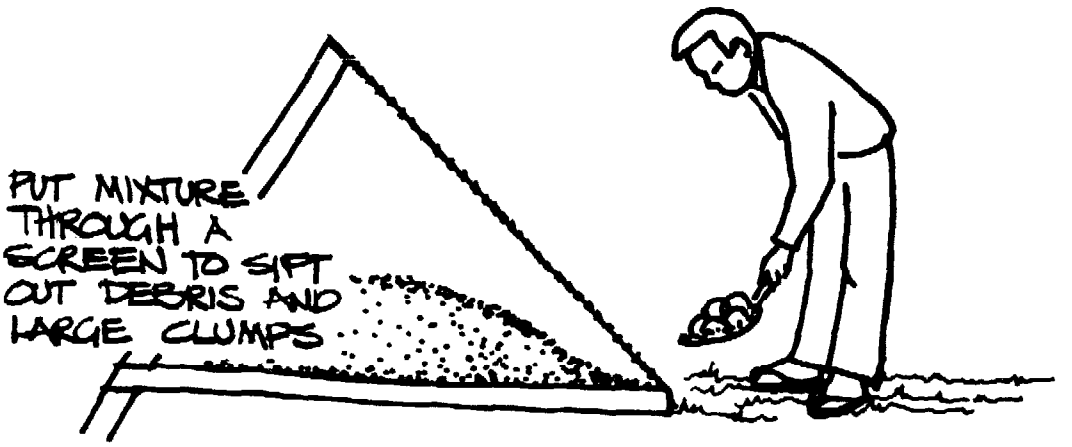

Manure should be sifted before it is used to make the potting mixture

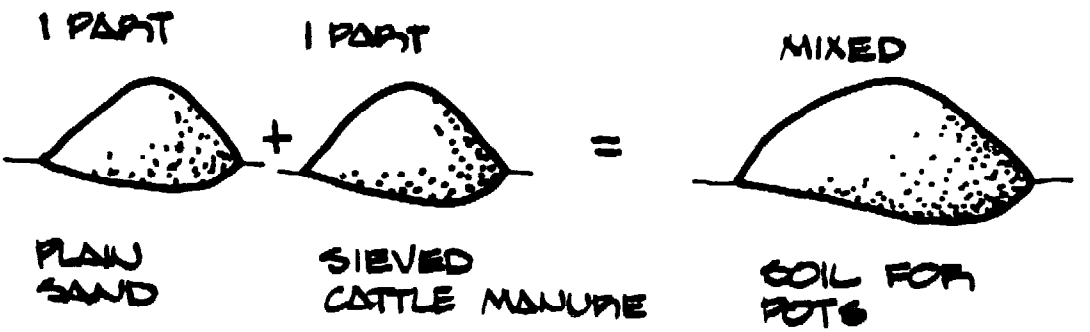

Heap the mixture in sizable piles in the nursery work area

Filling Pots

Once the ingredients have been thoroughly combined the pots are filled. It is important to teach nursery workers to fill the pots properly in order to ensure efficiency as well as good quality seedlings. The following pages illustrate how to fill and sink pots for the best results.

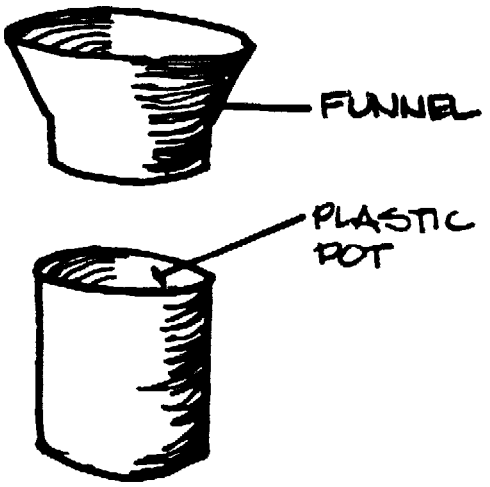

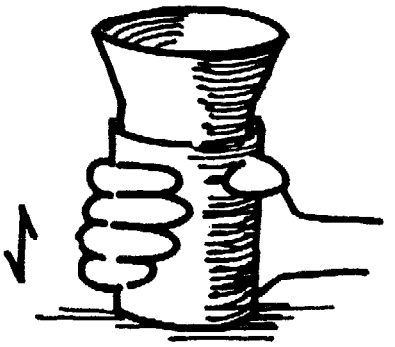

Fill the pots using a metal or plastic funnel just large enough to fit the top of the pot.

Fill the pots full. Watering will cause the mixture to settle to about 1/2cm below the top of the pot.

Scoop the mix into the funnel. The soil is lightly packed as the pot is being filled by tapping the pot on the ground with the funnel held in place.

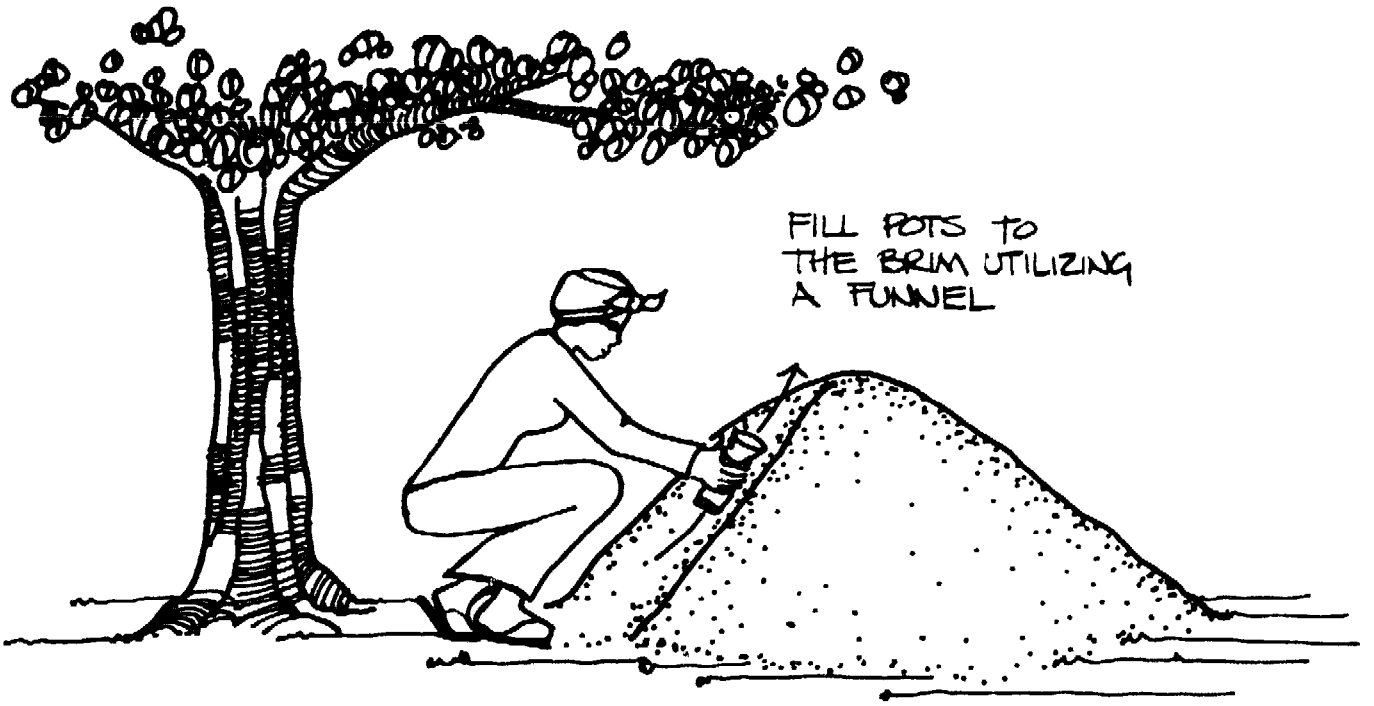

POTS SHOULD BE FILLED TO THE TOP

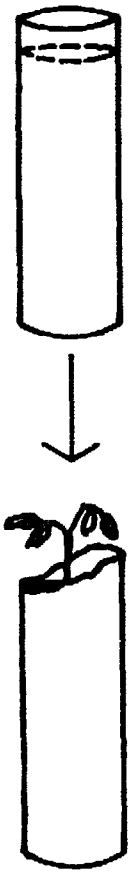

NOT PROPERLY FILLED TO THE TOP

SURFACE WILL SETTLE WITH WATERING

PART OF POT WALL FALLS IN. TREE WILL NOT GET ALL THE WATER.

PROPERLY FILLED

WHEN "COLLAR" BECOMES GREATER THAN 1.5 CM, REFILL WITH SCREENED SOIL OR SAND.

PROPER COMPACTION

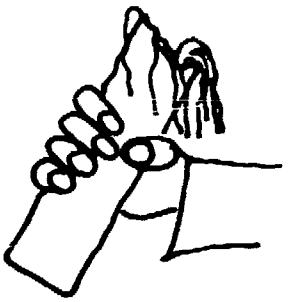

BAD

SOIL WILL RUN OVER TOP WHEN SQUEEZED.

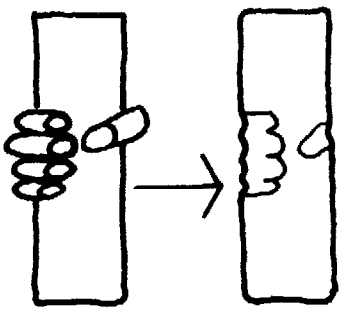

SLIGHT IMPRINT OF FINGERS LEFT AFTER POT WAS FIRMLY SQUEEZED.

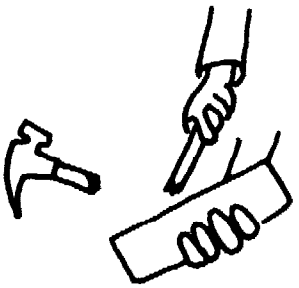

BAD

TOO HARD

Sinking Pots

As some workers fill the pots, others set them in neat lines and rows. Although lining the pots up perfectly is extra work, it greatly reduces the effort required during the rest of the nursery operations. Seedlings planted in the outside row of pots should be protected against sunburn and excessive heat. Slightly countersinking or burying the rows of pots helps. Use the earth dug out from this operation to build a wedge against the outside pots to protect them.

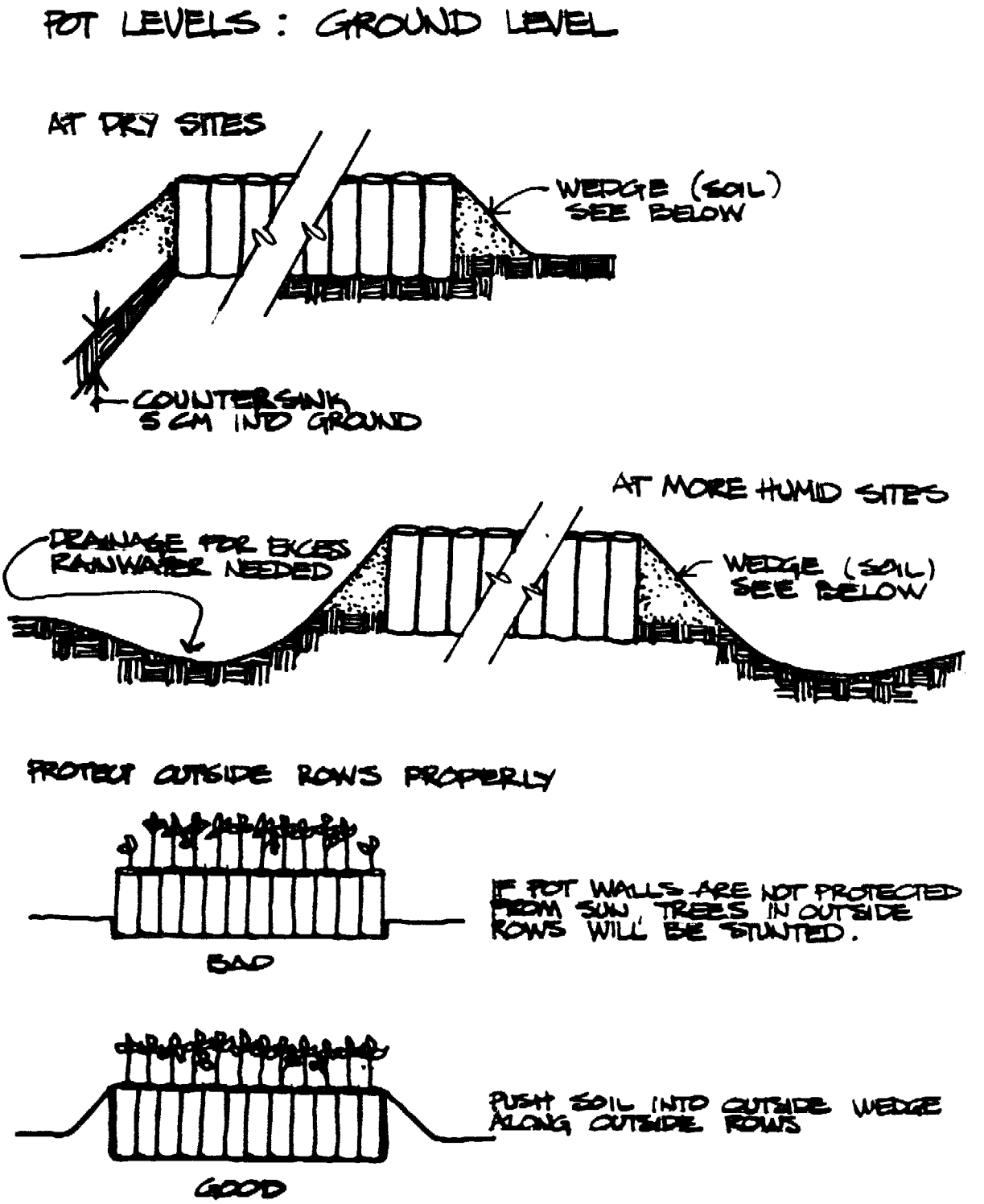

It is very important that the beds be level and smooth. Stack the pots in straight even rows so that they do not lean. Separating the pots into units of 100 or 1,000 makes it easy to keep track of how many seedlings are in the nursery.

BED SHOULD BE LEVEL TO AVOID LEANING

BAD

NO ROWS AND LINES, SURFACES UNEVEN, LEANING INSTEAD OF STRAIGHT

RESULTS:

UNEVEN WATERING
DIFFICULT TO ORGANIZE WORK
LOW PRODUCTION
POOR QUALITY SEEDLINGS

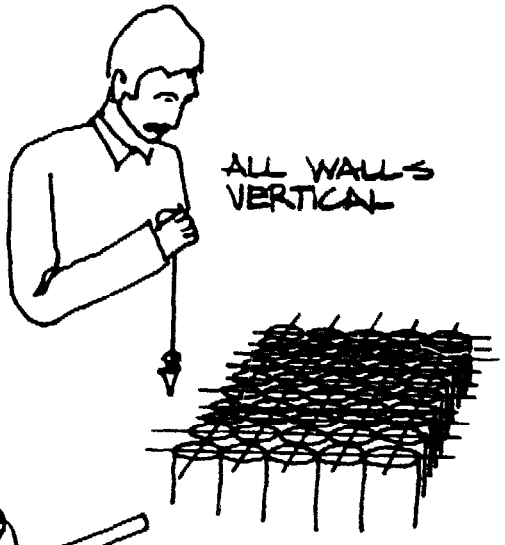

GOOD

PLUMB BOBS AND LEVELS ARE NOT NORMALLY USED IN STACKING POTS, BUT BEDS SHOULD LOOK AS IF THEY WERE.

Determining Planting Dates

Survival chances of the young trees depend directly upon their size when they are transplanted and upon planting them at exactly the right time of year. Therefore, the timing of the seeding operation must be carefully planned. Ideally, a tree should have as large a root system as possible before transplanting--this increases its survival chances. But trees must also be reasonably light and small so that transportation and transplanting can be done more easily.

Location, soil, the amount of sunlight and water, and other factors can affect the time needed in nursery beds. These differences make exact scheduling difficult, but much good information is often available from local experience and carefully kept records of other projects. For some species, it is important that seedlings be past the early emergent stage to survive the extreme dry heat and winds occurring in sub-Saharan Africa during dry season months. This kind of information must be considered when deciding the seeding dates.

The planting schedule is set up so that the trees will be strong and well-developed for transplanting to their permanent sites immediately after the first rains. To time the planting correctly, foresters determine how long each species to be grown has to remain in the nursery. Then they calculate the dates for seeding by subtracting the estimated time in the nursery from the number of weeks left before the predicted start of the rains. Thus if *Acacia albida* is to be seeded in plastic pots (see chart on following page) and if the rains are due to start in 24 weeks, it can be figured that the pots must be seeded in nine or ten weeks, thus:

24 weeks left before rains
-14 weeks necessary in nursery
10 weeks= time for planting

The following chart lists some species commonly found in Africa and classifies them according to the time needed in nursery beds with controlled irrigation and shade. If these conditions are not well controlled, more time in the nursery may have to be scheduled.

PLASTIC POTS

6-10 Weeks	10-14 wks.	14-18 wks.	18-24 wks.
Parkinsonia aculeata	*Acacia albida*	*Acacia nilotica*	*Balanites aegyptiaca*
	Acacia radiana	*Acacia senegal*	*Butyrospermum parkii*
		Anacardium occidentale	*Casuarina equisetifolia*
		Azadirachta indica	*Eucalyptus spp. (2)*
		Eucalyptus spp. (1)	*Parkia biglobosa*
		Prosopis spp.	*Tamarindus indica*
			Tamarix spp. (3)
			Ziziphus spp.

OPEN-ROOTED STOCK

30-35 Wks.	35-40 wks.
Cassia siamea	*Azadirachta indica*
Sclerocarya birrea	*Gmelina arborea*

(1) Transplanted into pots
(2) Seeded directly into pots
(3) Propagated from cuttings

Seed Supply

Some seeds may have to be ordered, and this should be done early. Sometimes seeds are purchased locally in the market, but it is difficult to guarantee good genetic quality. The buyer has no control over the parent tree selection. Often it is necessary to gather seeds from trees in the area, and prepare them for use. Seed tree selection and seed collection should be supervised by trained personnel.

Seed Collection

The best seeds come from strong, healthy parent trees. Fully ripened fruits are picked directly from the trees or collected at least daily as they fall. If fruits are being picked, long handled pruning shears can be used to reach higher branches. Collection can be made more efficient by spreading large pieces of cloth, mats, or tarpaulins under the trees to catch the seeds as they fall. Whenever possible, seeds are collected as soon as they are ripe, otherwise many of them may be eaten or damaged by birds, animals, or insects. Damaged seeds are less likely to germinate. Seeds should be fresh and reasonably dry, without being dried out.

The timing of the rainy season also has an effect on flowering and fruiting of trees. If the seeds are to be collected locally, information on when the seeds will be ripe is needed to plan seeding operations. The fruits of many species in Africa mature during the dry season. If the timing of the fruiting season does not correspond with the planting schedule, seed must be collected in advance and stored for use during the following year. The seed of such species as *Azadirachta indica* cannot be stored for more than a few weeks, so collection and seeding in the nursery must be planned to take place as soon as possible after the seeds become ripe.

Appendix B has additional information on seed collection for certain species. Another good source is Von Maydell's *Arbres et Arbustes du Sahel*.

Seed Tree Selection

Seed trees should not be selected at random or on the basis of proximity or convenience to the seed collectors. The genetic quality of the parent tree is an important consideration in seed collection because characteristics such as fast growth, tree form, and resistance to diseases and insects can be passed on from one generation to the next. It may be difficult to determine which parent trees will produce superior offspring, however, because environmental variables can complicate the picture. A tree with high genetic potential, for instance, may appear to have slow growth because it is growing on a poor site.

In selecting a seed tree, the project's purpose will also determine the characteristics that are sought. Trees with straight, clear trunks are preferable for production of poles for construction, but bushy trees and shrubs that coppice easily are appropriate for firewood or live fencing. If foliage or food production are the primary project goals, then the amount of leaf or fruit production a specimen is capable of is more important than its form. In soil conservation projects, the longevity of a potential seed tree should be considered as well as rapid growth.

These characteristics are usually difficult to measure when comparing individual trees. Furthermore, the combination of traits that are sought can rarely all be found in one specimen. Generally, several seed trees for each species are selected. In selecting seed trees, look for places where site conditions do not limit the the trees' growth. Try to find a stand with several individuals of the same species growing together and choose the healthiest, most vigorous representative that typifies the characteristics that are being selected. Seed trees should be marked so that they can be easily identified from year to year.

Extraction

Seeds must be removed from the fruits and pods that contain them, and there are various ways to do this.

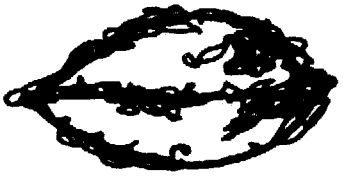

Fruit containing seed

Dry fruits can be pounded carefully in mortars or bowls or on clean, hard surfaces to separate the fruit from the seed. Then the seeds are cleaned by hand or by winnowing them through the air (mortar and wind separation). Most of the *Acacias* and *Cassia simea* seeds can be extracted by this method.

The fruit of pulpy species, like *Balanites aegyptiaca* and *Azadirachta indica,* must be soaked before the pulp can be removed and the seeds extracted and dried. Some seeds, like *Ziziphus spina-christi* must be soaked to soften the pulp, and only then can the remaining hard shell be cracked with a hammer to remove the seeds.

Others, like *Parkinsonia aculeata,* can be easily shelled by hand.

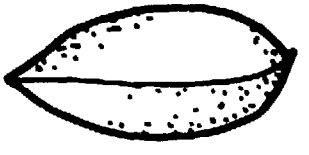

Extracted Seed

Drying and Storing Seeds

The two most important factors in good seed storage are keeping the seeds dry and keeping them cool. Wet seeds spoil and rot in storage, so they must be dried in the air first. Then they can be stored in dry containers such as jars, boxes, or bags. Care must be taken to keep the containers off floors and away from walls. This practice helps keep insects and dampness away from the seed containers.

Store the containers so that air can circulate around them. This helps keep the seeds drier and cooler. Extreme heat can destroy the seed's ability to germinate.

Seeds should not be left to dry under a hot sun for the same reason. For example, the viability of seeds like *Eucalyptus* spp. is destroyed at temperatures above 40 degrees Celsius.

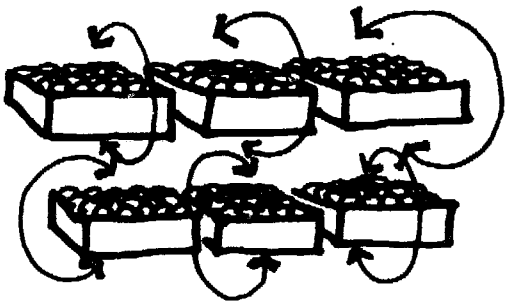

Seeds should be stored so that air can circulate around them

If at all possible, the seeds should be treated with a general pesticide to keep weevils and worms away. The containers should be checked frequently for damage to the seeds; the seeds should be turned over in their containers at that time.

Each container of seeds should be labeled with the following information:

Species:	Name
Collection:	Date Location Name of Collector
Storage:	Beginning date treatment
Quantity:	Number of seeds in the container

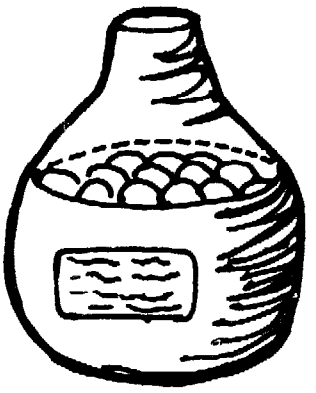

JARS

Seeding

Prewatering and Weeding

The beds or pots should be watered daily beginning two weeks before sowing the seeds. Regular and gradual prewatering in small amounts (rather than adding a lot of water at the last moment) allows the water to mix evenly and thoroughly with the soil. The top 20cm of soil should be moist. Water

penetration of the soil can be checked by opening some of the pots to check the moisture levels inside.

Prewatering will cause weed seeds already in the soil to germinate and become visible before the tree seeds are planted. Then all the newly emerged weeds can be removed before sowing. Weeding at this point saves time later and increases the young trees' chances for survival.

Pretreatment of the Seeds

Most seeds must be treated in some way to give reliable germination results. Some seed coats are impermeable to water and will not germinate without help. Pretreating the seeds also causes them to germinate faster. This is important because if some seeds do not germinate, the beds or pots can be reseeded without too much loss of valuable time.

As a rule any seed that has a glossy, hard cover (for example, most of the *Acacias*) must be treated before it is planted. Usually, treatment involves soaking the seed (stratification) and/or scratching or nicking the hull (scarification). Different species respond best to certain treatments or a combination of treatments. Some seeds like *Azadirachta indica* do not need any pretreatment once they have been extracted from the fruit. The following are some examples of pretreatment methods:

Warm stratification process:

- Bring water to a boil in a suitable container.
- Remove from heat and let stand for five minutes.
- Add the seeds and let them soak overnight.
- Plant the seeds next day.

Scarification methods:

- Use sand paper to scratch the hull (this can be time consuming).
- Mix the seeds in a container with wet coarse sand and shake the container.
- Use fingernail clippers to crack or nick the seed coat, being careful not to clip the seed germ.
- Immerse the seeds in an acid bath for a few seconds (be careful to store acid solutions very securely).

Sowing

Seeds are planted in either pots or open beds according to the steps in the illustration below. This seeding method is used for most species.

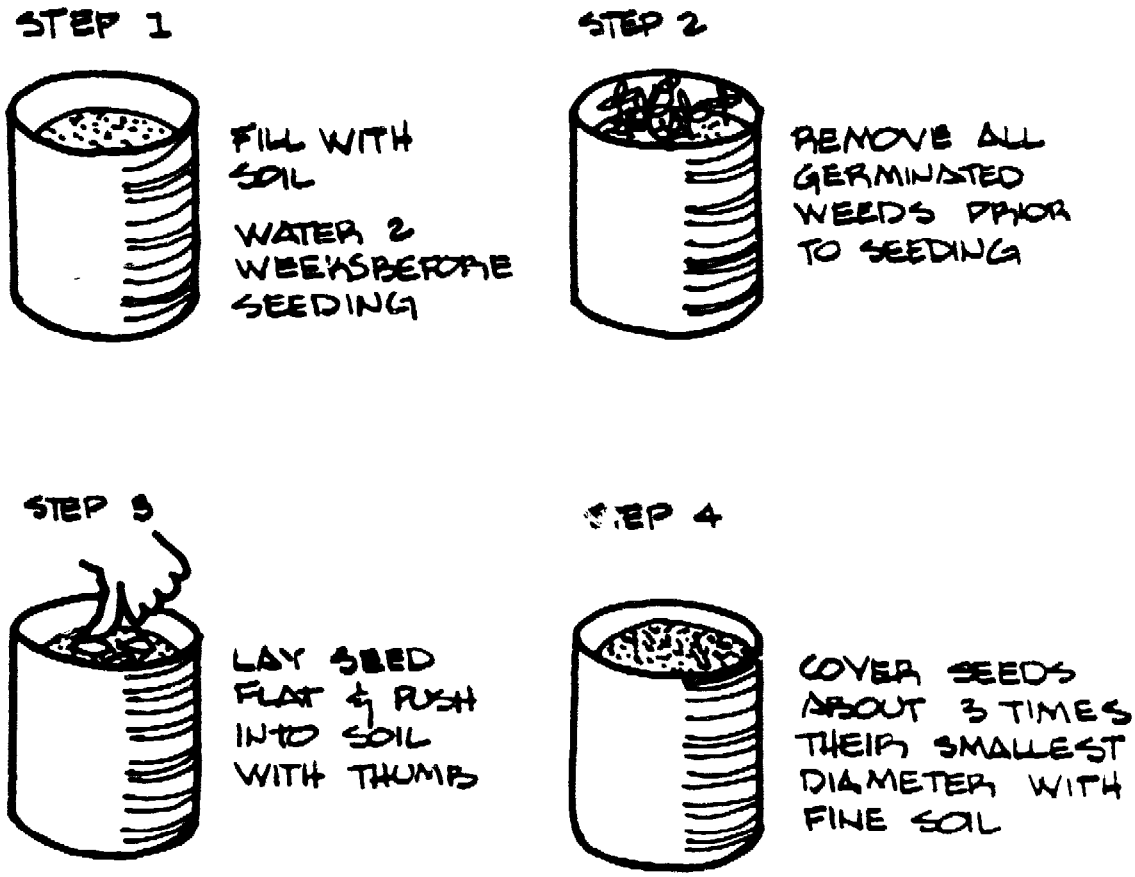

Planting seeds

One notable exception is *Anacardium occidentale*, which is planted upright rather than flat. *Eucalyptus* seeds are also an exception, because they are very small and must be planted and watered using special methods (see following pages).

Seeds are spaced according to their predicted germination rates. In other words, if germination results are expected to be high, fewer seeds are planted. Generally one or two seeds are placed in a pot, depending upon the germination rate. In open-rooted seeding, extra seeds are planted. The seedlings are thinned to the desired spacing later. String can be used to lay out straight lines in the open beds. Planting the seeds in straight lines makes weeding and cultivating much easier.

Seeding Eucalyptus

Eucalyptus seeds can be started in a separate germination box and later pricked out and transplanted into pots, or they can be seeded directly into pots, using the method illustrated below.

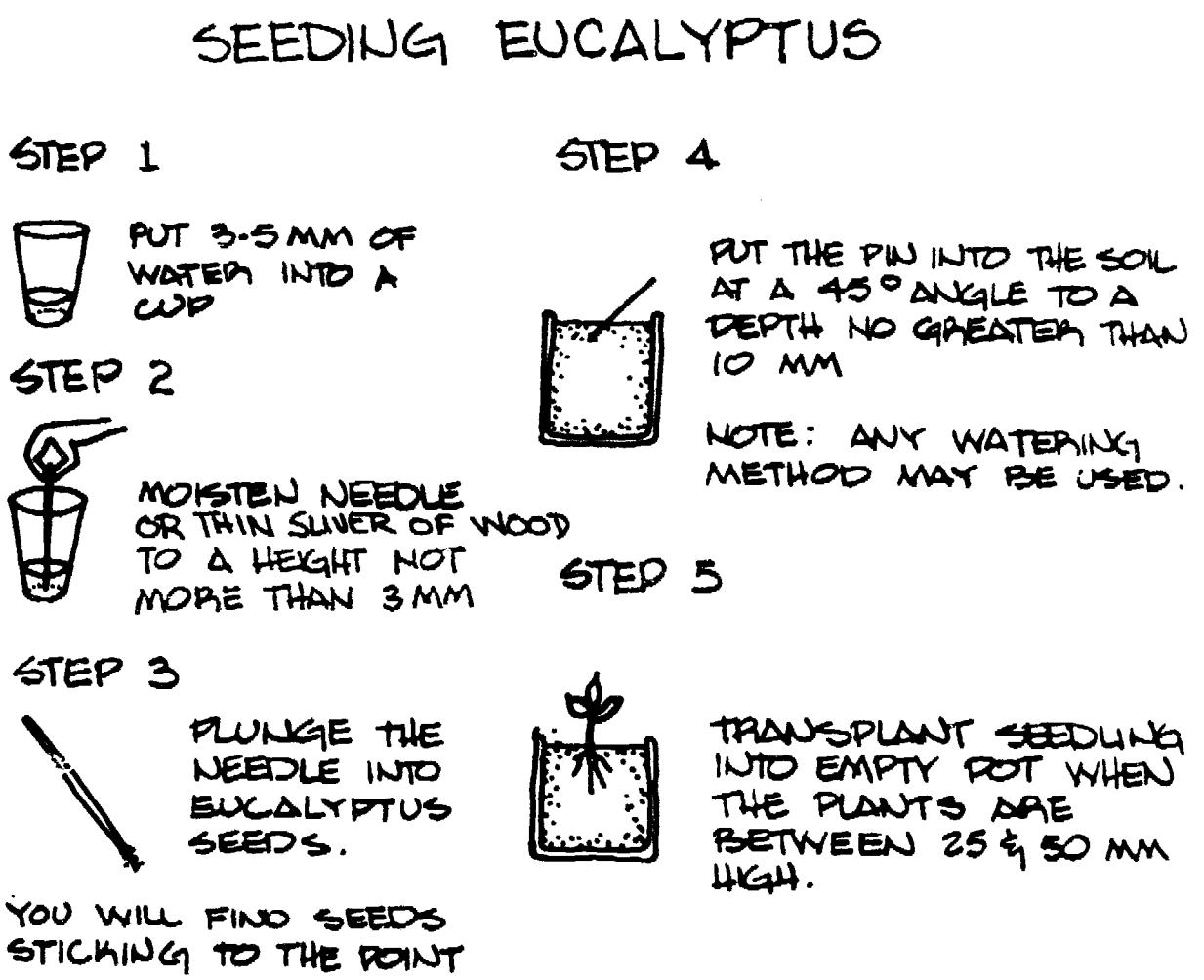

If *Eucalyptus* seeds are sown directly into pots, they should be watered using a fine mist sprayer. Large droplets of water will wash the seeds to the edge of the pot, and will break the stems of the newly emerged seedlings. If a mist sprayer is not available, the Nobila method, illustrated on the following pages, can be used.

Nobila Method

In the Nobila method, capillary action in a special sand germinating mix is used to provide constant moisture around the seeds without having to use elaborate spraying or watering arrangements. Normal watering methods cannot be used because the seeds are so small that they would be washed away by large droplets of water.

Nobila Method for Germinating Seeds

STEP 1

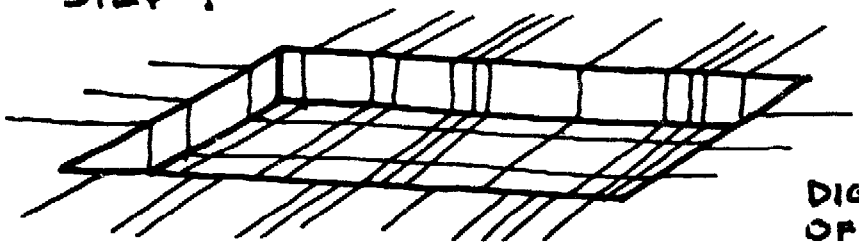

DIG A PIT 3/4 HEIGHT OF POTS USED

STEP 2

LINE SIDES WITH WOOD OR CEMENT BLOCKS OR SOMETHING SOLID TO FORM A FRAME. MAKE WATER PROOF "BASIN" WITH PLASTIC SHEET.

STEP 3

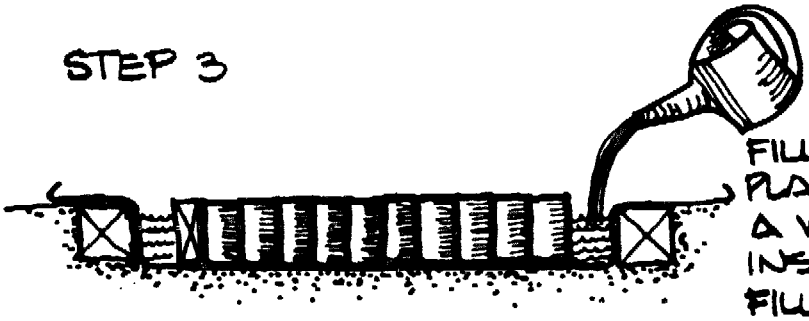

FILL BASIN WITH EITHER PLASTIC POTS OR BUILD A WOODEN FRAME INSIDE DEPRESSION; FILL FRAME WITH SOIL.

WATER SOIL & FILL BASIN WITH WATER TO WITHIN 5-10 CM OF TOP OF SOIL. LEAVE TO DRAIN OVER NIGHT.

STEP 4

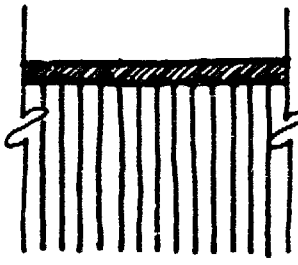

MIX SEEDS WITH FINE SAND & SPRINKLE OVER TOP. PUT 1MM LAYER OF FINE SAND/MANURE MIX OVER SEEDS.

NOTE:

KEEP SEEDLINGS MOIST BY FILLING BASIN WITH WATER

STEP 5

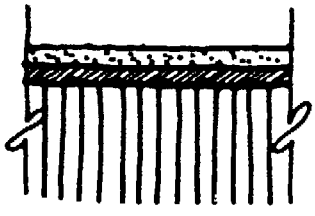

COVER SEEDS WITH ANOTHER 2-4 MM SAND

Transplanting* Eucalyptus *Seedlings into Pots

Eucalyptus seedlings started in germination boxes should be transplanted into pots when they are about 25-50mm tall and have several leaves. In transplanting the tiny seedlings, grasp them by their leaves and not by the stem, because the stem is too fragile to be handled. Also make sure that they are placed in the center of the pot and that there are no large air spaces around the roots. Keep them in the shade after transplanting them into pots until they have completely revived from the transplanting shock.

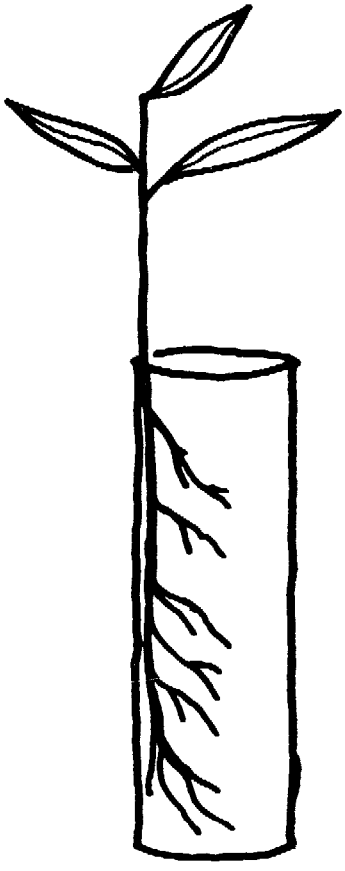

DIRECT SEEDING INTO POTS CAN RESULT IN OFF-CENTER GERMINATION. IF THE SEEDS ARE WASHED TO THE SIDE OF THE POT ROOTS ARE THEN EXPOSED TO THE WALLS OF THE POT RATHER THAN SURROUNDED BY SOIL.

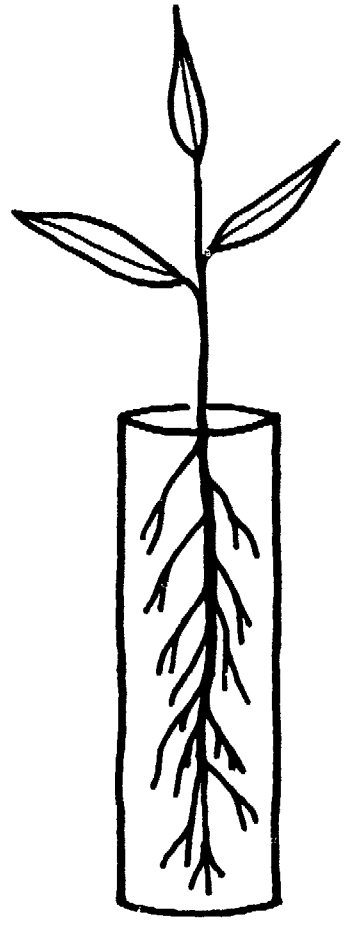

TRANSPLANTING FROM A GERMINATION BOX INTO A POT WILL ENSURE GOOD ROOT DEVELOPMENT.

Tending Seedlings in the Nursery

Mulch

If it is possible, the seed beds should be mulched. Mulch is the term for materials (for example, decayed leaves) laid on the seed bed to keep down soil temperature, inhibit weed growth, lessen erosion damage, and help the topsoil remain loose and crumbly. Some ideas for mulch materials include shredded newspaper, plastic sheeting, straw, and bark. Rodent damage to young plants can be reduced further by covering the mulch with small branches. One problem that mulch might actually encourage is termites. If there are termites in the area, the seedlings should be checked often for damage and insecticide applied if necessary.

Watering

Watering is relatively easy if plans have been made carefully. Even such improvements as water storage tanks beside the nursery beds are useful. The general rule for watering is simple: adequate amounts of water are needed at regular intervals. The water must be added gradually so that it does not form puddles or run off before it has a chance to soak in. The plants should be watered every day, including holidays. A strictly followed watering schedule will promote germination and seedling survival.

The seeds should be watered as soon as they are planted. For at least the first month, watering should be done twice a day (of course, it is often necessary to make allowances for soil types and locations that make more or less water necessary). Watering should take place in the early morning and late afternoon or evening. The plants should receive about 5mm of water each time. The top 20cm of soil in the pot or bed must be kept moist. Checking the pots or beds regularly will show whether the soil is sufficiently moist. Moisture levels should never be allowed to drop near the wilting point.

Water Need Calculation

DAILY REQUIREMENT:

$10 \times 50 \times 0.02 = 01\ M^3$

$= 100\ L$ OR

APPROX. 25 GAL.

AT 5 ROWS & 5CM INTERVALS, THIS BED CONTAINS 500 TREES.

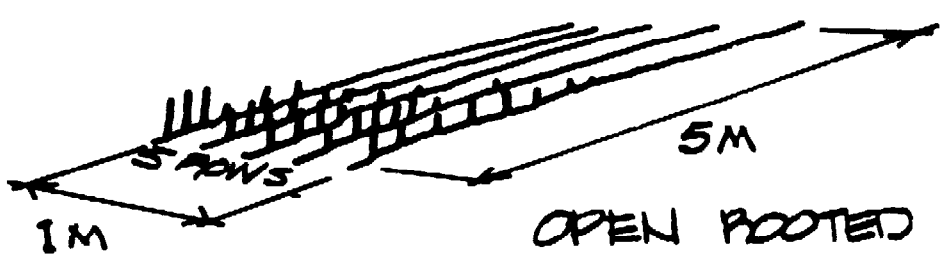

OPEN ROOTED STOCK

If this calculation is used and followed, there will be enough water even under the most demanding circumstances. If all the conditions in the nursery remain good during the project--if there is enough shade, protection from the wind, effective watering during the coolest part of the day, and good water retention by the soil or nursery mix--the amount of water needed will be less than this. In fact, if all of these conditions remain good, only half the amount of water calculated may be needed. However, experienced project managers plan for maximum need. It is far better to have the problem of not using all the water than it is to plan poorly and risk losing the entire stock.

PLASTIC POTS

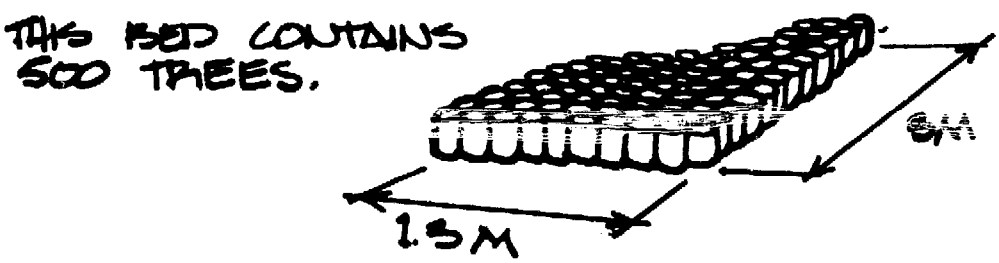

DAILY REQUIREMENT: 1.5 × 3.0 × 0.02 = 78 L OR
APPROX 20 GAL.

Cultivating

Young nursery plants should be weeded about once every ten days. No fancier techniques are needed than those used in a vegetable garden. The object is to get rid of weeds and to keep the surface of the soil loose and crumbly. Sticks or hand weeding tools are all that is necessary.

Thinning and Root Pruning

Thinning Open-Rooted Stock

Young trees must be thinned out: the single most frequently made mistake in raising open-rooted stock is failure to thin the young plants. When there are too many young plants in crowded conditions, the resulting trees are of uneven size and have poor root development. Many trees will die if thinning is not done at the proper time.

Seedlings should be thinned before root competition becomes severe. The best time is usually when the plants are between 10 and 15 cm tall. Thinning is done by removing enough seedlings from the bed to result in an approximate spacing of 5cm between each stem. The seedlings that are chosen to remain should be the ones growing the most vigorously.

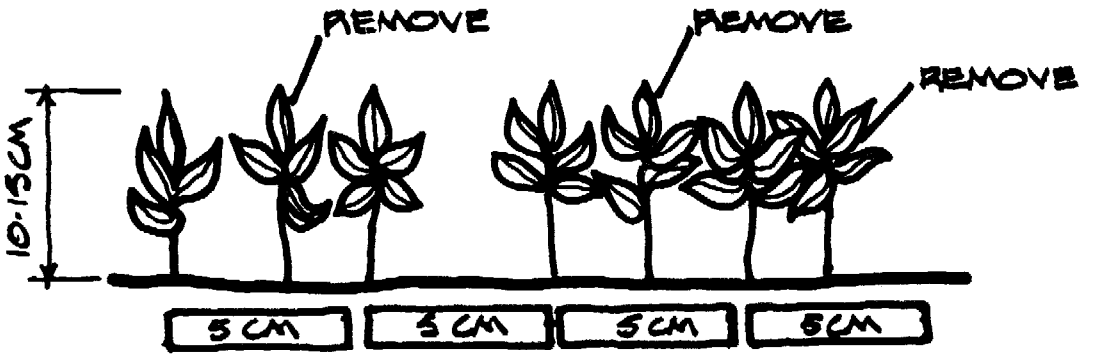

THINNING OPENROOTED STOCK

Sometimes empty spaces in beds can be filled with plants that become available as a result of a thinning operation that took place in nearby beds. This has been done successfully with *Azardichta indica*, *Parkinsonia aculeata*, and even with some *Acacias*. Such an operation will succeed if the following precautions are taken:

- Roots of trees being transplanted do not exceed 5cm in length.
- Dirt is left around the roots when the seedling is lifted out.
- Plants are handled carefully to avoid injury.
- Roots are exposed to air as little as possible.
- Experienced workers with proper tools do the work.
- Air pockets around roots are eliminated by gentle pressure--earth must not be packed too hard.
- Trees are planted at the proper collar height.
- Freshly transplanted roots are kept moist.
- Plants are kept shaded until they are growing well in their new location.

If there is enough seed available and time is not a problem, it is probably better, in the long run, to reseed empty beds or pots than it is to transplant young plants from the thinning operation.

Root Pruning

Plastic pots must have some drainage, and thus are perforated in the bottom. Small roots will grow out of the holes into the soil below, and if nothing is done to prevent it, the tree will develop a second root system below and outside the pot. Consequently, those roots that grow below the pot and which are the major part of the root system will be destroyed when the pots are moved. This kind of situation defeats the main objective of using pots, which is to allow trees to be moved and planted with the least disturbance of the root structure.

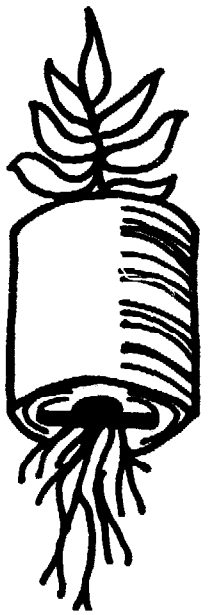

CUT ALL ROOTS WHICH ARE GROWING OUT OF THE BOTTOM OF THE POT

Root pruning prevents the development of a root system outside the pots. Generally, after the first 6 to 8 weeks (it is earlier for *Acacia*), all trees in plastic pots must be moved twice a month, the outside roots cut off, and the pots set back in place.

To reduce work, each block of pots can be shifted, pot by pot, a convenient arm's length distance. To do this a worker picks up a pot with one hand, prunes the roots with pruning shears, transfers the pot to the other hand and puts the pot down on the other side. When pruning is finished, the entire block of pots will have been moved.

Pest Management

The nursery manager and other project personnel must watch constantly for signs of disease or insect attack and be prepared to respond immediately when problems are first noticed. Pests can spread quite rapidly in the nursery, and delay in treating the seedlings has been known to result in loss of much of the stock.

The Integrated Pest Management (IPM) approach involves the use of chemical, biological, and cultural practices for economical and environmentally sound plant protection. Although the dangers of chemical pesticides are now

recognized, they are still widely used in situations where other pest control methods are ineffective. Biological controls are being researched and introduced to take the place of pesticides where possible.

Biological methods involve the introduction of a new species into the agro-ecosystem that acts as a predator, disease, or repellant of the pest species. Insects are preyed on by birds, lizards, snakes, frogs, spiders, and other insect species. Diseases can kill insect pests or affect their growth and reproduction cycles. Repellant species are often other plants that produce substances that discourage certain insects from remaining in the vicinity. The Neem trees (*Azadirachta indica*) are believed to have this property of repelling a wide variety of insects. Compounds made from various parts of the Neem are being tested as organic insecticides.

Possibly the most effective approach to prevent pest incursions in the nursery is through sound cultural practices. Maintaining healthy seedlings is the best means of reducing losses due to pests. Plants that have not been properly tended and watered, or that are deficient in some nutrient, will be more susceptible to insect and disease attack than will well cared for seedlings.

Insects

In dry tropical regions, insects are most active and numerous during the rainy season. The life cycles of many insect species have adapted to the climate so that they do not hatch out until after the first rains have fallen. Because seedling production takes place during the dry season for the most part, insects may not be as great a problem in the nursery as they can be later, when seedlings are moved to the planting site. Nevertheless, insect pest outbreaks can occur in the nursery.

Often the most commonly found insects in the nursery are termites. While they can do extensive damage to seedlings, not all species of termites are pests. Some species consume manure and other compost, thereby aiding in the decomposition of organic matter, but do not bother live plants. Termites can also improve the soil structure by breaking up hard layers and increasing porosity, through their tunnel-building activities. Some termite species will, however, eat seedlings. In addition there are numerous other insect pests that can cause problems in the nursery.

Many tropical plants produce secondary compounds that poison or discourage herbivores. In spite of this natural immunity, however, a given plant species may be highly susceptible to certain insect species that are not affected by these compounds. Thus it is not uncommon for one tree species to be under attack in the nursery, even though the other seedlings are unaffected. Before beginning any sort of treatment, it is very important to assess the extent of the damage and whether or not it is confined to one plant species. This can help in the identification of the insect and in the evaluation of various control methods.

The first step in dealing with an insect attack is to try to identify the pest species. Insect identification is not always easy, particularly in the tropics where many species have yet to be classified. If the insect cannot be identified without expert assistance, collect samples in as many stages of its life-cycle as possible.

The next step is to determine what control measures can be used. Because so little is known about many of these insect species, the use of non-specific insecticides is far more widespread than the use of biological controls. More research into insect ecology is needed to identify natural predators and diseases that can regulate insect pest populations. It may be possible to remove and destroy the insects by hand, however, rather than resorting to chemical extermination, if:

- the insect outbreak is caught early enough,
- the insects are easy to see and grasp,
- the insects will not bite or sting nursery workers, and
- sufficient labor is available.

If other insect eradication methods cannot be used, most insect problems can be controlled by insecticides. Their application is discussed below under Pesticide Use.

Disease

The most common disease problem in the nursery is caused by fungi. This disease, which can be caused by many different varieties of fungus, is generically referred to as "damping off." The fungi occur in the soil of seedbeds and pots and attack the roots or stems of the young plants. Often the first noticeable symptom of damping off is a discolored, "pinched" stem. Sometimes, however, the leaves of the seedling seem to be drying out, although the stem still appears to be healthy. Shortly thereafter the seedling begins to wilt and die. Fungal diseases can spread rapidly, and there is little that can be done to revive the plants once they have been infected.

Beds and potting mixtures can be treated with fungicides before seeding, but this will destroy the beneficial fungi in the soil as well as the disease varieties. Damping off can be prevented to some extent by avoiding overwatering and stagnation in the beds and pots. Soils with high pH (6.0 or above) are less susceptible to infection, and some species, such as *Eucalyptus* and pines, are more vulnerable to fungal attack than others. *Eucalyptus* seedlings can be started in germination boxes containing soil that has been sterilized, then transplanted into pots when they are 25-50mm tall, and more resistant to the disease.

Other diseases in the nursery can be caused by bacteria and viruses. Viruses are usually transmitted to the host plant by some other organism, which is called the vector. Vectors can be either animals or plants, and they are often

normally aimed at eliminating the vector. Bacteria can be transmitted by vectors, as well as spread by water. Some fungicides are also used to combat bacterial diseases, but chemical applications do not work against viruses.

If the disease causing agent is not known, use of non-specific chemicals may destroy many organisms in the soil that are beneficial to plants. Preventive measures include removal of weeds that may be host to the parasites, turning the soil in the beds after each planting, and using resistant tree species.

Pesticide Use

It is best to be prepared for insect attack by having certain pesticides on hand, or by knowing where they can be found quickly. A number of products are available in the bigger towns throughout sub-Saharan Africa. Pesticides kept at the nursery site must be stored with extreme care and handled only by trained personnel.

Dieldrin (also called Aldrin) is one of the most widely used chemicals in nurseries and plantations in Africa, although its use has been suspended or controlled in some countries because it causes cancer. It is also highly persistant, that is, it does not break down quickly into less toxic chemicals, but rather remains in the environment for a long time. Dieldrin is very effective against termites, maggots, and other soil insects when it is used according to directions. It is important to follow the warnings given on the label, however, because it is also extremely toxic. Improper use of dieldrin can cause severe illness and even death. In addition, Dieldrin must be applied so that none of the insecticide gets on the foliage of the trees--even small quantities will burn holes in the leaves. See box for usage precautions.

In many countries, pesticides are sold in containers that are not adequately labeled. Pesticide labels should always include the following information:

- Trade name (with name and address of manufacturer)
- Common names of the product
- Chemical ingredients of the product
- Type of formulation (dust, water soluble powder, etc.)
- Registration or license number
- Pests for which the product is intended
- Net contents of the container (by weight or volume)
- Instructions for mixing and applying the product
- Instructions for storage or disposal of the product and container
- Warnings and precautions (of health or environmental hazards)
- Emergency treatment

Do not use a pesticide if you are uncertain about any of the criteria listed above. Lack of information about the concentration of the chemical or the amount needed for a given area can lead to harmful consequences. Wear protective clothing such as gloves, boots, face masks, and goggles, when mixing or applying chemicals. Two good sources of information about pesticides for

DIELDRIN

Other names: Aldrin

Type: Contact insecticide

Formulations: Emulsion concentrate (EC), wettable powder (WP), dust, and granules.

Warning: Do not touch. Dieldrin can be absorbed through the skin. It is extremely dangerous to man if not used correctly.

Do not apply directly to animals or let animals eat treated crops.

Do not dump extra solution into lakes, streams, or ponds. It will kill fish, and it can kill people who eat the fish.

It is poisonous to bees.

Do not use to treat grain or any product to be used for food, animal feed or oil purposes.

Helping someone who has been poisoned by Dieldrin

1. These are signs of poisoning:

HEADACHE	WEAKNESS
NAUSEA	SWEATING
DIZZINESS	VOMITING

2. If the person feels sick while using Dieldrin or soon afterward:
   - o Get the poisoned person to the doctor, dispensary, or health officer as soon as possible.
   - o Bring the insecticide container or label so the doctor will know what poisoned the person.
3. If the person swallowed Dieldrin and is awake, and cannot see a doctor RIGHT AWAY:
   - o Mix a tablespoon of salt in a glass of warm water and make the victim vomit, or stick your finger down the person's throat. Make him vomit!
   - o Make the victim lie down. Keep him warm, and do not let him move until help comes.
4. If the person spilled Dieldrin on either skin or clothing:
   - o Get the clothing off and wash the skin with soap and plenty of water.
   - o Get medical attention as soon as possible.

project planners include *34 Pesticides: Is Safe Use Possible*, published by the National Wildlife Federation and *Agro-pesticides: Their Management and Application*, by Jan H. Oudejans.

Preparing Seedlings for Transplanting

The general rule of thumb for judging whether a tree is the right size for transplanting is that the above-ground growth of potted stock should not be less than 0.2m and no more than 1m tall. Open-rooted stock can have between 1.5m and 2m of growth above ground.

Great variations exist among species in the ratio of above-ground growth to root systems. For example, *Acacias* have very long root systems compared with their growth above ground; *Azadirachta indica* develop rather tall, single shoots over a limited root growth. The only way to find out the relationship of above-ground growth to root system is to expose the root systems of a few sample trees of each species.

When lifting out open-rooted stock, it is usually the case that no more than 20cm of the root depth can be excavated without damage. Obviously a tree that has a major portion of its roots below this level cannot be transplanted safely, therefore the seedlings must be checked periodically so that they may be transplanted on time.

Hardening Off

Hardening off is the gradual reduction in watering rates during the last few weeks in the nursery. This lessening of water intake helps prepare trees for the less steady water supplies they are likely to receive at the planting site. About four to six weeks before removal, watering is reduced to once per day. After about a week at that rate, the young trees should be watered every other day. If the trees do not begin to wilt, the amount of water can be reduced further. If the trees do wilt, however, additional water must be applied immediately to prevent permanent damage.

Culling

It is a standard nursery management practice to cull the seedlings before transplanting. The seedlings are graded in terms of their size and vigor, and any that are not within acceptable limits are rejected or culled. Generally about 15 percent of the nursery stock is culled before a planting operation. Some of the culls can be kept in the nursery until they are larger and stronger, but often it is better to start over with new stock.

Seedlings should be rejected on the basis of size either if they are too small or if they are too large. Potted plants that have been kept in the nursery for too long often outgrow their pots, causing their root systems to be deformed. Overgrown seedlings will have a higher chance of mortality than smaller

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Culling

It is a standard nursery management practice to cull the seedlings before transplanting. The seedlings are graded in terms of their size and vigor, and any that are not within acceptable limits are rejected or culled. Generally about 15 percent of the nursery stock is culled before a planting operation. Some of the culls can be kept in the nursery until they are larger and stronger, but often it is better to start over with new stock.

Seedlings should be rejected on the basis of size either if they are too small or if they are too large. Potted plants that have been kept in the nursery for too long often outgrow their pots, causing their root systems to be deformed. Overgrown seedlings will have a higher chance of mortality than smaller seedlings with normal root development. Any seedling that looks unhealthy or diseased should be culled. It is better not to plant poor quality seedlings than to expend a lot of energy on trees that are unlikely to survive.

7 THE PLANTING SITE

Site Management

Planning and Organization

The planting site should be completely ready well before the first rains are due, because the trees must be transplanted as soon as sufficient rain has fallen to moisten the top 20cm of soil. The tree roots cannot be placed into dry ground if they are to survive.

When planting is delayed, survival rates decrease greatly. Transplanted trees need the entire rainy season to get a good start. Therefore, nothing can be gained by planting in the second half of the rainy season even if there is more cloudy, wet weather than usual. The limited time span during which successful planting takes place requires proper planning and advance preparation, which should include alternative plans for action and substitute resources in case difficulties occur.

While it is difficult to give specific guidelines for organizing planting work because each project is distinctly different, foresters often find the following pointers helpful:

- Make contingency plans, especially for transportation and labor. It is very important that no delays occur. Planting is the time where careful planning and good relationships with the workers and the community pay off.

- Plan realistically and attempt only what can be accomplished. A small, solid job, well done, is worth more than a marginal performance on a larger scale. Goals should not be set so high that they cannot be achieved.

- Each planting effort is worthwhile, and is worthy of the same degree of personal commitment.

- Weather factors can, perhaps, be planned for, but not controlled. There is a limit to the project manager's ability to guide the project, and it is important to realize that the impossible cannot be done.

Site Preparation

Site preparation includes delineating the site, clearing the ground, marking the space for each tree, and digging the holes.

Site Delineation

Well before the trees arrive, the fence or other protection should be in place. The control of land use at the site and the lines of authority should be clear to everyone in the area.

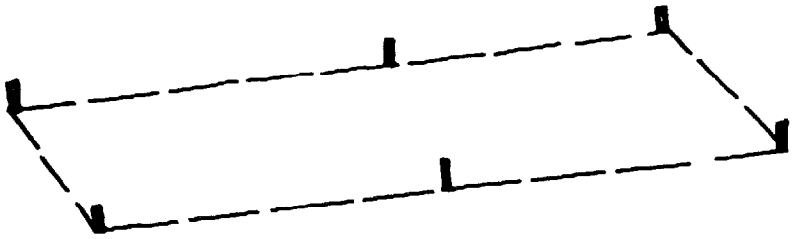

Planting area staked out.

Access routes to large sites should be established, and road work completed, if necessary. In large plantations, a four meter strip should be left just inside the fence so that a truck can pass, and the fence can be repaired easily. If the site is large enough to have firebreaks in addition to space left for the roadway, firebreak areas at least 6m wide should be planned and completely cleared.

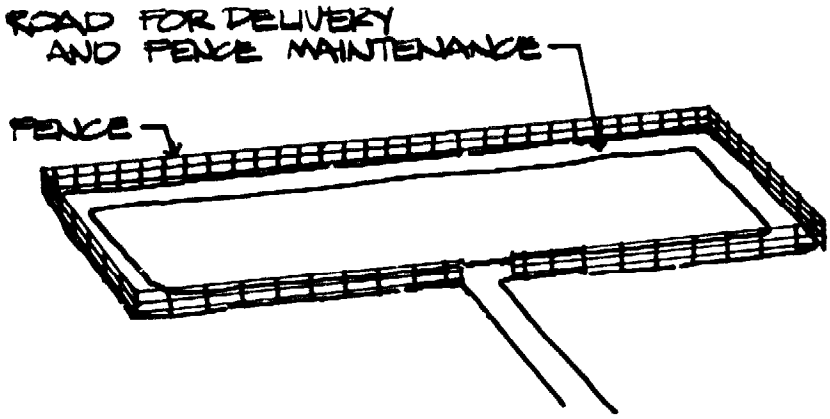

Roads and fences in place.

Clearing
The area around each tree's location should be cleared of all vegetation, including roots. Each tree should have a cleared area of at least 1 square meter in which to grow. This spacing eliminates competition for food and water and gives the tree a better chance for a good start in the new location. If the planting site already has some trees on it, space the transplanted seedlings so that they will not be in the shade of the existing trees.

Spacing
Based on experience relating to ground water tables, most trees in dryland Africa are now planted with an average of 3-4m between the trees. This of course differs depending upon the kind of tree and its needs. The following figures can be used as a guide in determining the number of trees that can be planted on a site according to the area needed by the tree:

Area Per Tree	Trees per Hectare
2m x 2m	2,500 per hectare
3m x 3m	1,100 per hectare
4m x 4m	600 per hectare
10m x 10m	100 per hectare

Some, if not most, of the large trees of Africa seem to be loners. *Acacia albida* and *Tamarindus indica*, for example, are rarely found growing naturally in dense stands. Plant these and other similar species in small clumps to ensure that one plant will survive.

Sometimes a lot of time is spent spacing trees very exactly. This is often done in areas where cultivation will be practiced using tractors and other vehicles. This use of vehicles is not as likely in a village situation, however, nor where the ground is very rough. In these cases, precision spacing is not called for, and it is better not to waste time trying to space the trees exactly. Spacing can be done very simply and easily by determining how many shovel lengths or steps must be left between each of the trees being planted. The first line of trees is planted along a boundary line such as a firebreak or road. The second line is then oriented parallel with the first.

Digging
In areas with less than 1,200mm mean annual precipitation, holes should not be dug before they are to be used. The purpose of pre-digging holes is to save time once the rains have begun, and to allow rain to fall directly into the hole, thus supplying extra moisture.

However, this technique may not work in dry areas for two reasons:

- Rains are usually driven by the wind so that the drops hit the sides of the hole, rather than reaching the bottom.

- o As soon as the showers stop, the sun and wind dry out the holes and piles of excavated dirt. This drying process leaves the soil drier than it was before digging.

Each hole should be approximately 40cm wide and 40cm deep. This size should hold either open-rooted or potted seedlings easily. When digging, the soil is placed in two equal piles, one on each side of the hole. This technique greatly speeds backfilling.

Transplanting

Lifting Out and Transportation

Throughout the operations of uprooting, transporting, and planting, the workers must have plenty of room. It is a good idea to set up a number of small deposit points for unloading trees so that hand carrying can be kept to a minimum. Each team should know in advance the exact area in which it will be working. As soon as the work plan is ready, it should be discussed at staff meetings. The crew chiefs will know what is expected of them and their assistants. If everyone is sure of their job, the work will go much more smoothly.

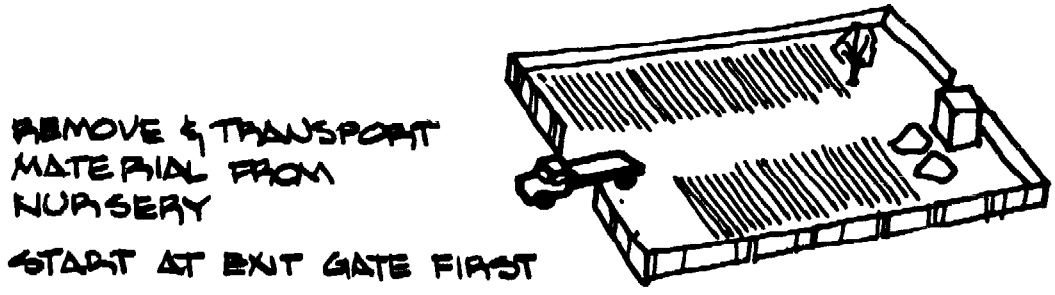

Moving Potted Stock
Transporting plants in plastic pots is relatively easy for the plants, but is more difficult in other ways (the pots are heavy, for example). However, since well-watered pots can be loaded and transported to the site at any time, it is possible to start moving potted stock beforehand in smaller batches.

Moving Open-Rooted Stock
The young stock must be dug up slowly and carefully using shovels or other strong tools to dig carefully around the roots.

Even during careful digging, the majority of roots break. These breaks sometimes leave long, tearing wounds through which the tree loses moisture, and disease can enter. Therefore, as soon as open-rooted seedlings are lifted out of the ground, the roots, especially the big ones, must be cut off neatly. Lifting out and root pruning must be done as quickly as possible.

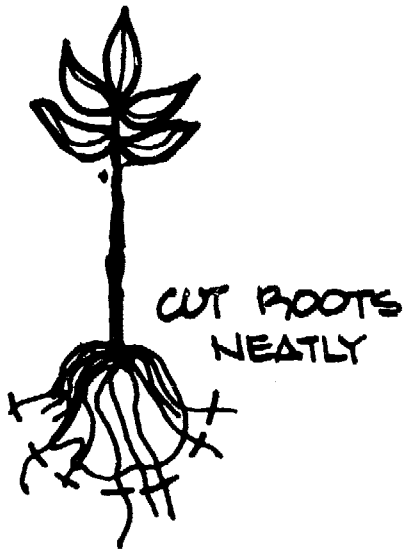

After the roots are pruned, the trees are bunched in groups of 20 to 50. Wet mud is packed around the bunched roots. A layer of wet grass or leaves is then placed over the mud, and the entire bundle is tied together well. Water should be poured over the bundle before it is loaded and taken to the site.

Some special preparations are used to reduce transpiration (loss of moisture through the leaves) when lifting out open-rooted stock. These preparations help maintain the balance between root and leaf functions until the roots have a chance to re-establish their supply functions. Otherwise, the fluids in the plant are used up faster than the newly transplanted roots can take in a new supply.

Some trees, such as *Azadirachta indica* and *Khaya senegalensis*, should be stripped of all leaves, except for the terminal bud and the last two or three leaves near it. The plant must not be ripped and torn, so stripping has to be done carefully. The terminal bud must not be damaged. The leaves are stripped as soon as the tree is lifted out and before bundles are made. The stripped leaves can be used for packing and wrapping material to protect the roots during transport.

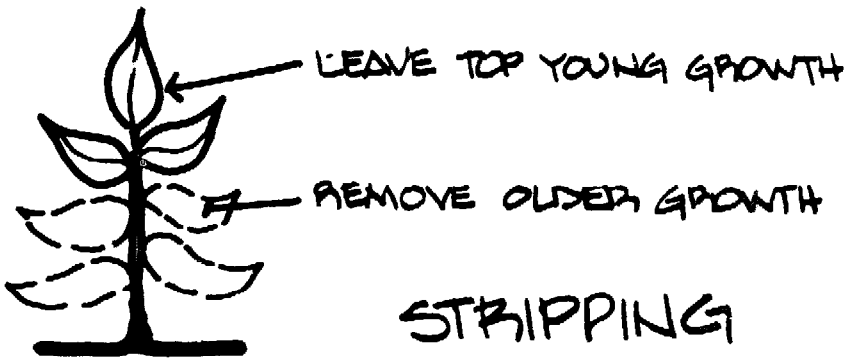

Other trees, *Cassia simea* and *Gmelina arborea*, for example, can stand even more extensive cutting. In fact, they seem to recover best if the entire top portion of the tree is cut back to 5-15cm above the ground line. The result is a rather odd-looking short stem, attached to the first 15cm of its roots. This is called the stump method. Many stumps can be transported in very little space. In both the stump and stripping methods, roots must be kept moist.

Remove entire top from *Cassia siamea* and *Gmelina arborea*.

It is, of course, vital to know which species respond to which treatment; some will die if cut back to stumps. Workers must be carefully instructed to avoid loss.

Replanting

Plant the tree so that its root collar is even with the ground. The collar is the point where the tree's stem came through the surface of the soil in the pot or the nursery bed. This is an important step. If the collar is misplaced by as little as 1cm, the chances of survival for some species can be much poorer. The first small roots often start right under the collar, and must be carefully covered if the tree is to grow well.

Finding the collar of open-rooted stock is more difficult, because the collar of the potted stock is right at the top of the soil in the pot, and the soil remains around the plant. It is worth taking time to be sure that everyone handling the plants knows where to look for the collar.

Backfilling is done carefully by hand. The soil from the top of the piles is put around the bottom root structure of the open-rooted stock or the bottom soil of the potted stock. The person doing the planting should tamp the soil with the heel to get rid of the air pockets. Tamping is done diagonally against the bottom of the roots.

PLANTING OPEN ROOTED STOCK

STEP 1

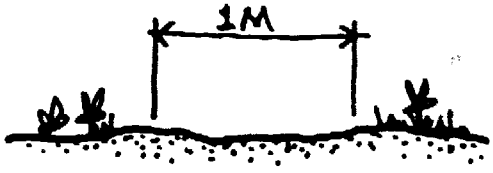

CLEAR THE GROUND OF ALL VEGETATION AT THE TREE LOCATION

STEP 2

DIG HOLE PLACING SUBSOIL ON TOP

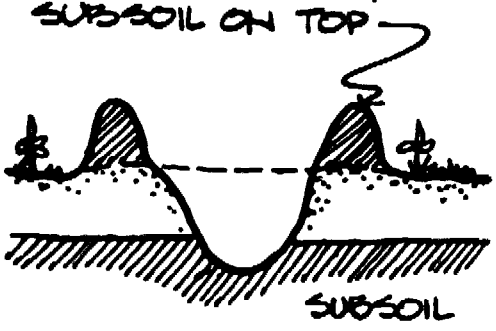

STEP 3

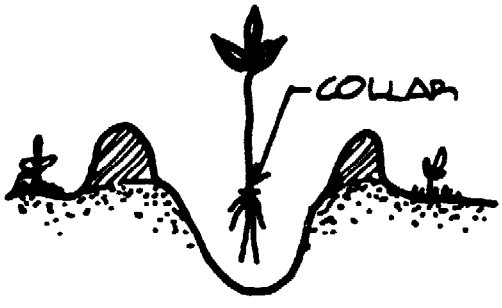

HOLD TREE ABOUT 3CM BELOW ITS FINAL POSITION

STEP 4

RAISE TREE TO FINAL POSITION AFTER SOME SOIL HAS BEEN PLACED AROUND ROOTS

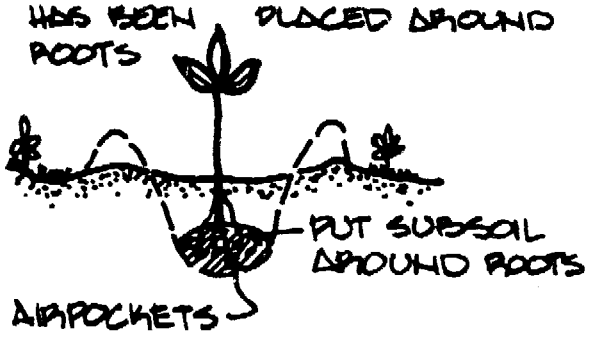

STEP 5

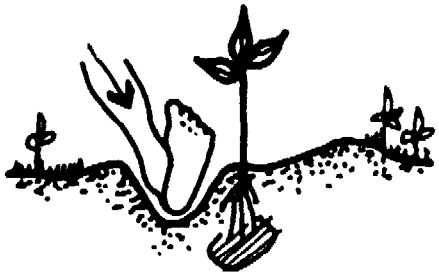

REMOVE AIR POCKETS

STEP 6

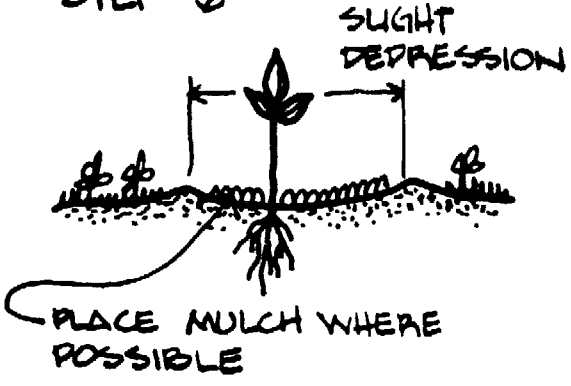

NOTE:
PACK SOIL WITH HEEL (AS SHOWN, STEP 5) FROM 2 OR 3 DIFFERENT DIRECTIONS

PLANTING POTTED STOCK

STEP 1
DIG HOLE PLACING SUBSOIL ON TOP (AS FOR OPEN ROOT)

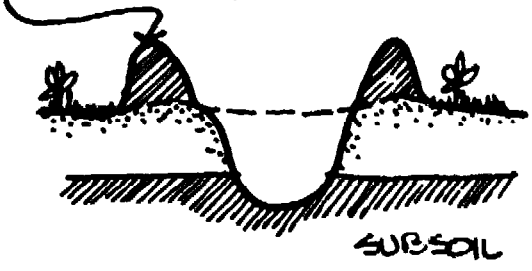

STEP 2
CUT BOTTOM FROM POT

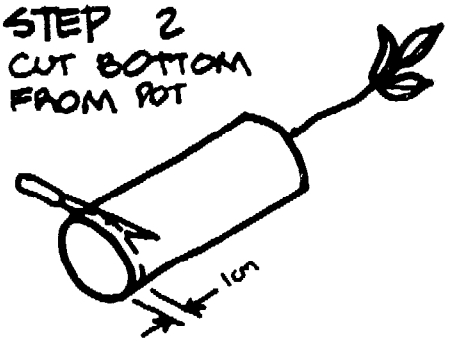

STEP 3
CUT POT LENGTHWISE

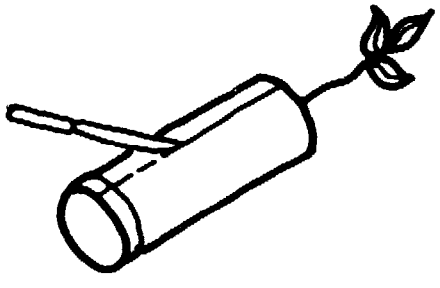

STEP 4
PLACE POT IN HOLE (HOLD POT TOGETHER WITH HANDS)

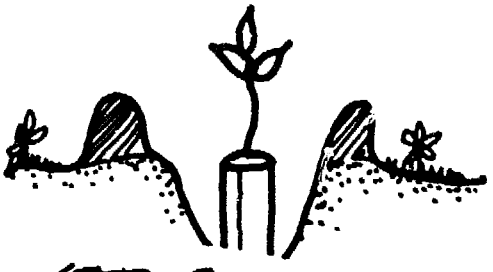

STEP 5

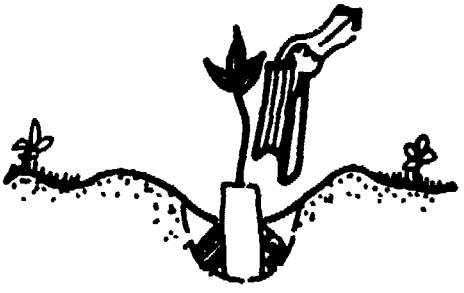

BACKFILL, THEN REMOVE POT

STEP 6

REMOVE AIR POCKETS. PACK SOIL FROM 2 OR 3 DIRECTIONS AS SHOWN.

STEP 7

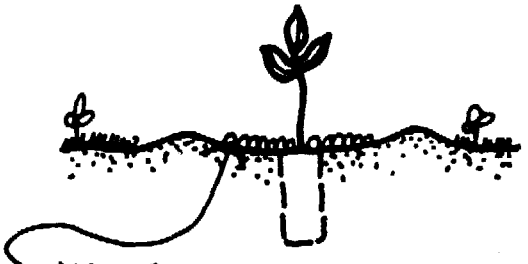

MAKE SLIGHT DEPRESSION AND MULCH WHERE POSSIBLE

After the hole is filled, a layer of loose soil is left around the tree. This loose soil is shaped into a shallow depression that acts as a basin to catch additional water. These depressions are called micro-catchments. Their construction is described further on in this chapter under Preparations for Difficult Sites.

Decayed organic matter (mulch) can be put around the newly planted trees if such material can be found. Again, it is necessary to watch for termites when mulch is used. The illustrations on this and the next page note the steps involved in planting open-rooted and potted stock.

Coping with Delays

Delays in planting the seedlings after they have been lifted out of the nursery can be a major cause of losses. This is particularly true of open-rooted seedlings, but delays can also have an adverse effect on potted plants. The trees must be watered abundantly the moment they arrive at the site. If delays in planting are unavoidable (whether overnight or longer, and at either the nursery or the planting site), special techniques are called for.

Potted seedlings that cannot be transplanted immediately after they are lifted from the nursery should be placed in sunken beds at the planting site.

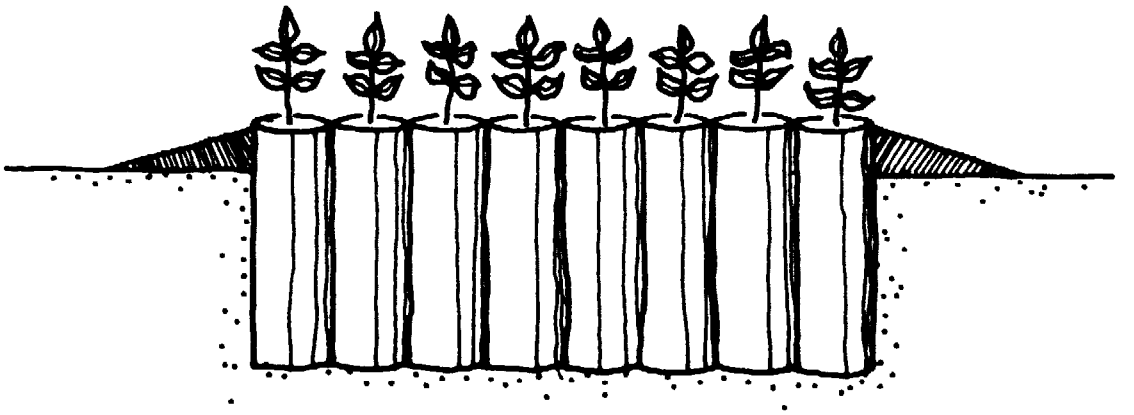

POTS COUNTERSUNK IN SOIL

Open-rooted stock must be "heeled-in" to keep the roots from drying out. The seedlings are temporarily laid in trenches at the planting site until they can be transplanted.

HEELING IN OPEN ROOTED STOCK

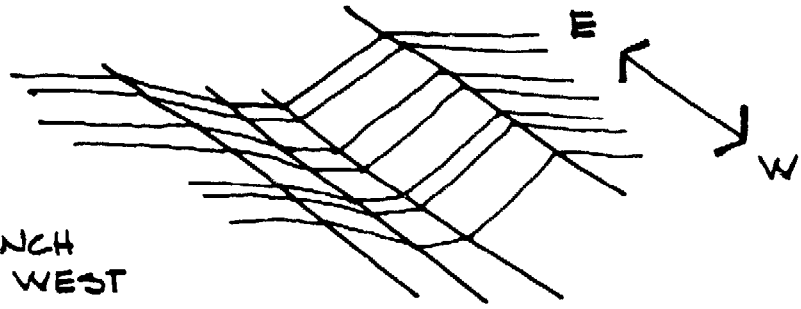

STEP 1

DIG TRENCH
EAST TO WEST

STEP 2

LAY PLANTS
IN ROWS ALONG
THE SIDE OF THE
DITCH

REMOVE ANY WRAPPINGS

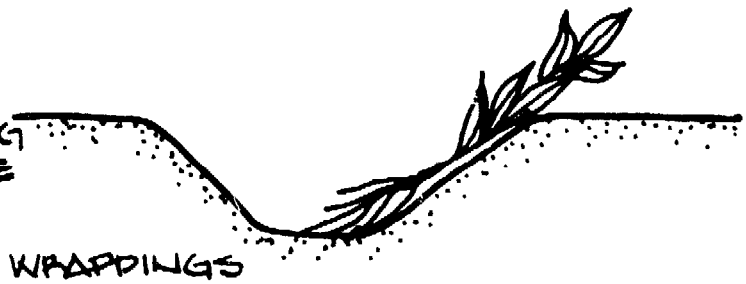

STEP 3

COVER WITH
SOIL ALMOST
TO THE TOP OF
THE BRANCHES

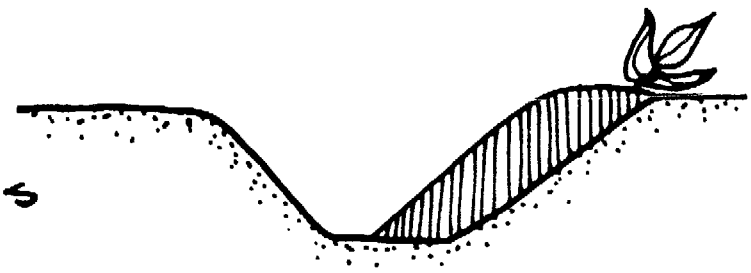

STEP 5

LAY IN NEXT
ROW OF PLANTS
& COVER THEM AS
BEFORE

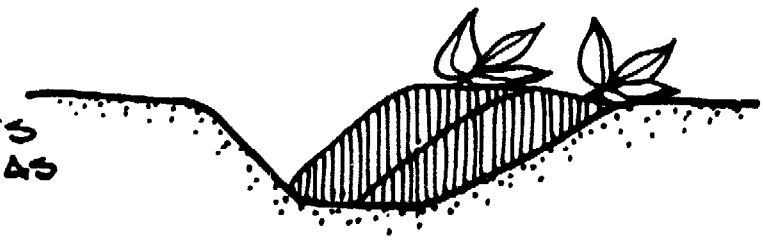

REPEAT PROCEEDURE UNTIL ALL PLANTS ARE HEELED IN.

Preparations for Difficult Sites

Sometimes it may be cost-effective to try special procedures at very dry sites. These procedures may include water jar reservoirs, micro-catchments, or contour ridges.

Water Jar Reservoir

A special planting technique, primarily used at present for planting shade trees around villages, should be considered. In this method an unglazed clay jar is buried in the ground, with neck exposed, close by the seedling. The jar is filled with water, which seeps through the clay to provide the young tree with a steady supply of moisture. The clay jar reservoir method has a number of advantages and disdavantages.

The advantages are:

- The soil does not become hard and crusty around the base of the tree.
- The roots are kept evenly moist, not being subjected to alternate wetting and drying.
- The roots will grow down around the base of the clay jar in search of moisture.
- The amount of water needed is reduced (from one to two-thirds) because evaporation from the soil does not take place.
- The growth rate of the tree can be doubled in the first year or two and its heartiness is greatly increased.
- The survival rate is increased.

The disadvantages of the clay jar method are:

- Initial planting is more expensive and time consuming.
- The clay jars must be protected from breaking and from becoming filled with sand or trash.

In most African markets, clay jars 40-50cm deep and 25-30cm in diameter are available. Make a hole in the jar about 4cm up from the bottom. The size of the holes depends on the soil and the planting site. In sandy locations a small hole (half the diameter of a pencil) should be sufficient; in a site with very heavy soils, two or more (pencil sized) holes located side-by-side may be needed.

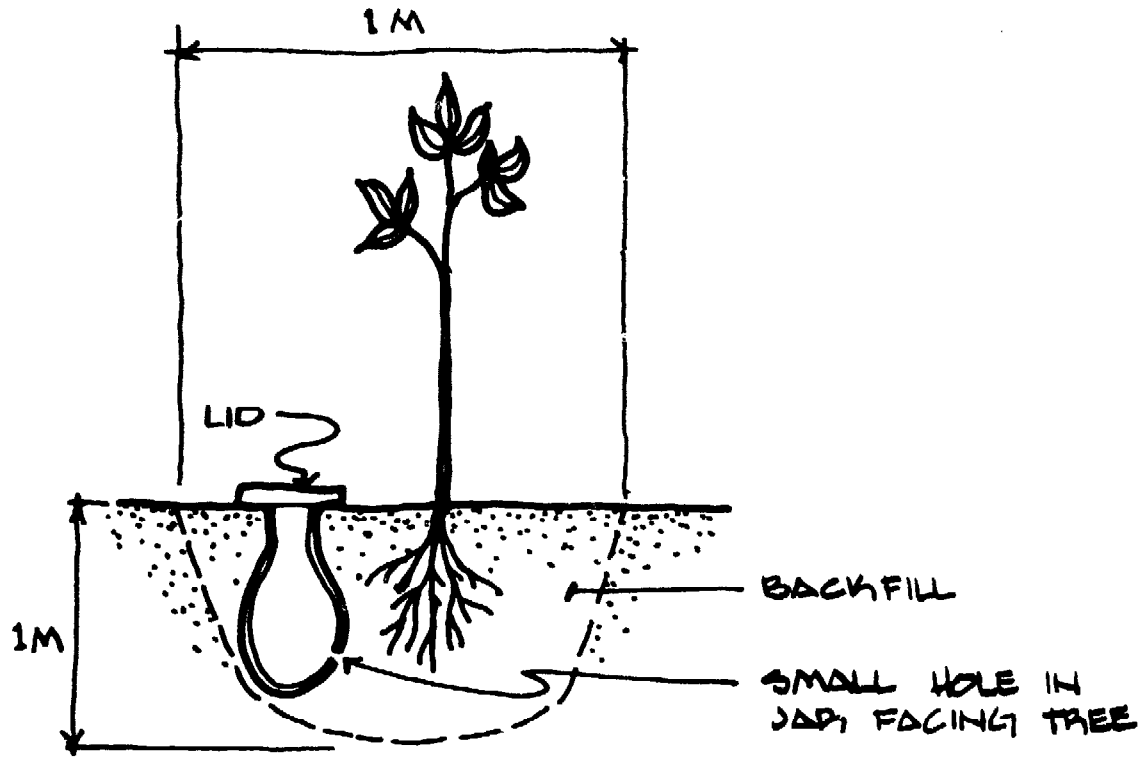

To plant the jar:

- o Dig a large hole about one meter square and one meter deep.
- o Partly refill the hole with soil and some organic fertilizer (if available).
- o Place the clay jar to one side of the dug-out space with the holes in its bottom facing the center of the area where the tree will be planted. The mouth of the jar should show above ground level only a few centimeters.
- o Plant the tree in the center of the hole about 20cm from the clay jar.
- o Continue refilling the hole in the ground with the mixture of soil and fertilizer.
- o Fill the jar with water and cover the top to keep the water clean and prevent evaporation.

For the first three or four weeks after planting, the tree roots grow toward the moist soil at the bottom of the jar. During this time keep the jar full, but also water the tree by pouring water around its base.

After this time, the tree is watered only by filling the jar with water. If the hole has been correctly matched to the soil consistency, a jar of water should take about one week to flow through the hole into the ground. Keep the level of the water in the jar high by adding water every two or three days. The holes can be made larger, if necessary:

- o Dig out entire jar, enlarge holes, and replace. This must be done very carefully, or the tree may be injured.
- o If the mouth of the jar is large, reach in with a sharp nail or drill bit and carefully enlarge the existing holes or add another.

Remember: keep the level of water high by adding water every two or three days. However, just a trickle of water is necessary to keep the tree watered. Do not make the holes too large.

Micro-catchments

On marginal sites, it is better to plant fewer trees and to concentrate efforts on micro-site improvement, than to plant a large quantity of trees without consideration for the area immediately around them. Reshaping the terrain around each individual tree ensures that as much moisture as possible is available to the roots. A micro-catchment is, in effect, a small basin around each tree that is planted.

Micro-catchments can make the difference between survival and mortality. This means an extra, often substantial, investment of energy in the location on which the tree will be planted, but it may also mean a chance for trees to grow in areas where they otherwise could not. Over-excavation is necessary where the sub-surface is hard or rocky. The root zone must be loose enough to allow root growth, and to let scarce water infiltrate. Although it is necessary to encourage normal drainage so that water does not stagnate, the micro-catchments are designed to reshape the area around the tree, so that excess runoff will collect around the base of the seedling and accumulate in the root zone.

Several shapes and construction methods have been tried. The most common are a series of "half moon" or "fish scale" shaped low dikes on the downslope side of the seedlings. An area of about two to four square meters around each plant is reshaped to provide a slight depression that catches water falling immediately around and up-slope from the tree.

Micro-catchments can be surprisingly effective even on sites with little slope. Some have been so successful that trees can survive on the water from only one rainfall each year. One site where this has been demonstrated well is located in Northern Kenya, west of Lake Turkana. A key element to success lies in providing a large enough catchment volume so that runoff from a 7mm

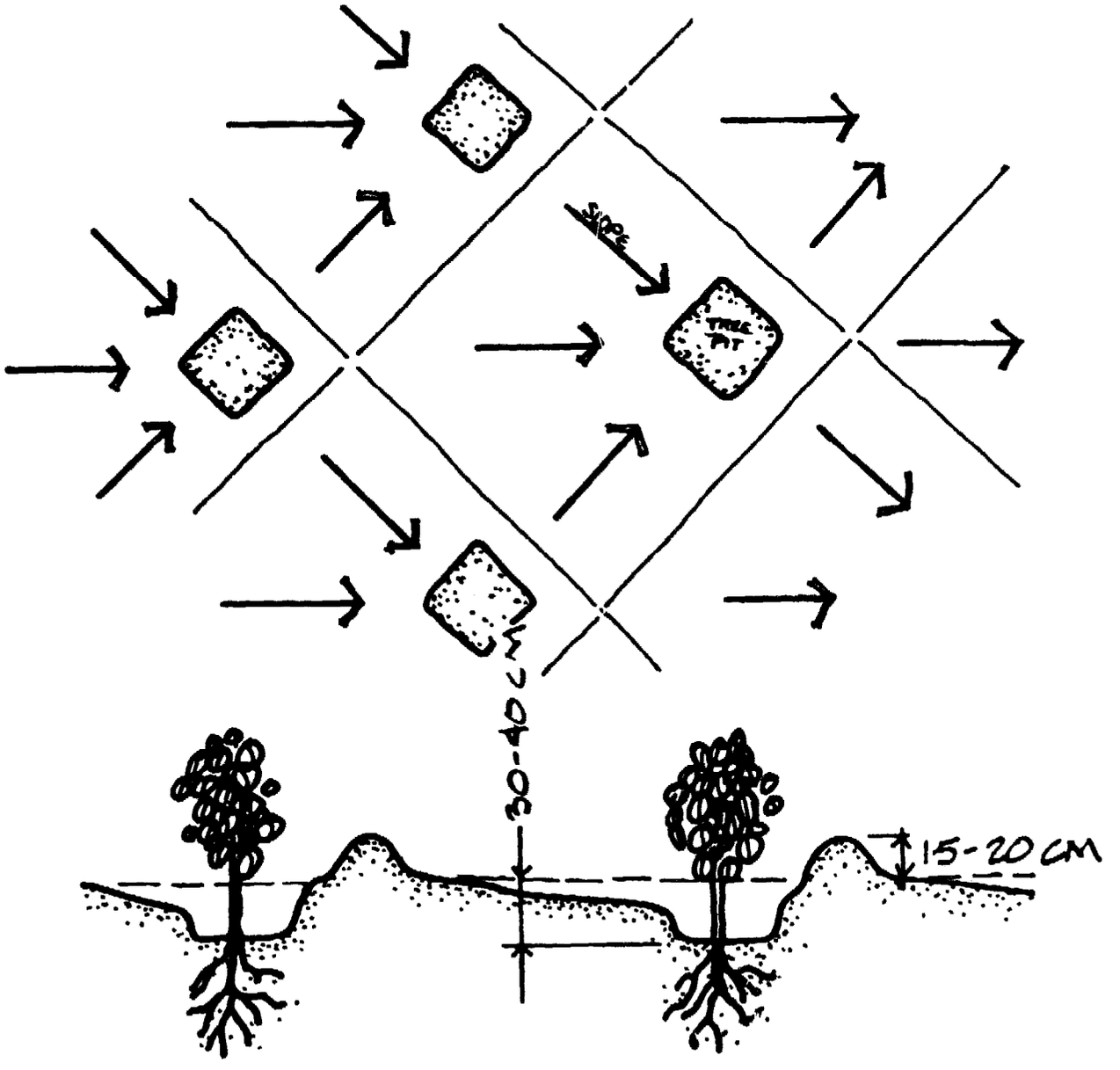

MICROCATCHMENT

LENGTH CAN BE FROM 2 METERS TO 50 METERS DEPENDING ON TERRAIN, SOIL, RAINFALL, TREE SPECIES, ETC.

Note: Dimensions of surface areas, as well as excavation and fills, vary according to slope and infiltration.

rain can be stored without overflowing the banks of the catchment. This requires a trial and error approach, as well as calculation of simple volumes based on more or less regular geometric figures.

A second key element is proper construction of the dikes. Their contours and grades must be geometrically correct, without low points or wavy crowns. The dike must also be keyed into the existing ground, and great care must be taken to compact the soil in the dike walls. Compaction works best if the soil is moist. Clay must be tamped thoroughly, in thin layers, so that no voids exist between the lumps of soil. If properly constructed, individual basins will hold and collect the runoff from rains and increase growth and survival where only marginal results would be obtainable under ordinary circumstances. *Prosopis* species particularly benefit from this method. In addition to the trees, grasses, which are harvested for forage, and in favorable cases even sorghum, can be grown in the moist area of the lowest portion of each basin.

Contour Ridges

A method similar in concept and purpose to micro-catchments, but on a larger scale, has been used on agricultural sites and is also appropriate for tree plantations or agroforestry projects. This method involves the construction of contour ridges, or *diguettes,* using rock or tamped earth walls built along the contour line. The ridges help prevent soil erosion as well as increase infiltration of moisture into the soil. They do, however, require substantial investments in terms of tools, labor, and maintenance.

Like micro-catchments, contour ridges can significantly increase survival and growth rates even on relatively flat land. The distance between ridges depends on the degree of slope--on steep hillsides they should be constructed closer together than on flatter sites. It is important to follow the contour closely in laying out the ridges. Once the ridges are in place, farmers should use contour plowing and cultivating techniques, if they are not doing so already.

The first step is to mark the contour using a level. In areas where there is an adequate supply of rock to use as a building material, the ridges are constructed by digging a furrow in which the boulders are lodged. Smaller rocks and soil are used to fill in gaps between the boulders. If rock is not available, the ridges are constructed using tamped earth. A shallow trench is excavated along the contour, and the earth is shaped into a ridge on the downhill side of the trench. The soil is packed using a wooden tamp. The soil must have a clay texture to retain water. Soils with a high sand content will not work.

After heavy rainfalls, some water normally passes over or through the ridges. Occasionally a channel of water will break through the ridges. These breaks must be repaired promptly to prevent gully formation.

Although contour ridges are usually constructed with the idea of using the increased soil moisture retention to improve crop production, trees and shrubs can also be planted at intervals along the contour ridge. Chapter 8, Agroforestry and Soil Conservation, gives a more complete description of this technique.

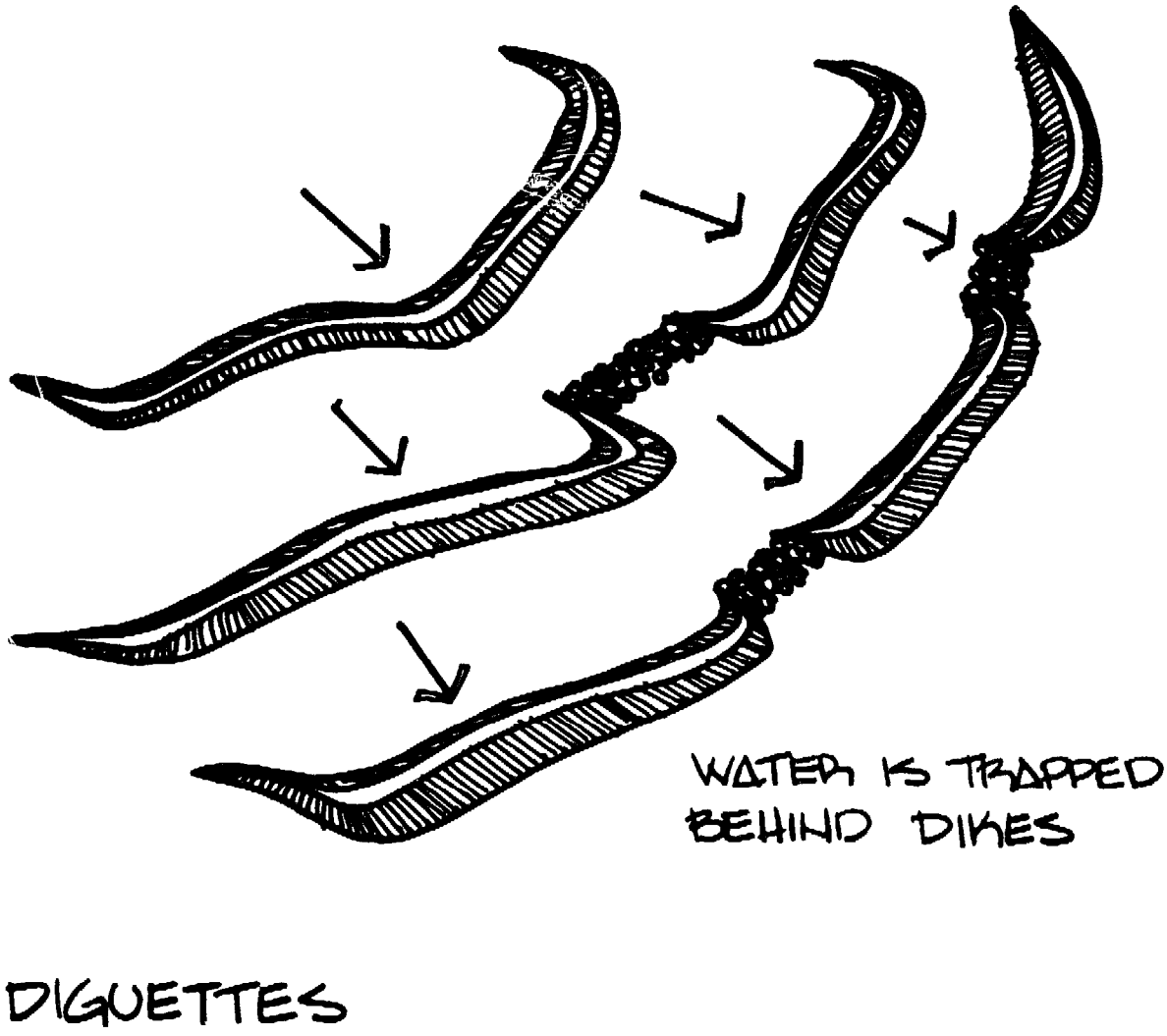

Contour ridges like these in use in Burkina Faso allow the growth of rice where rice was not previously able to grow .

Plantation Maintenance

Watering

General Considerations

Normally tree plantations in drylands Africa are rainfed; that is, they depend on rain and groundwater to supply all their moisture needs, rather than being watered or irrigated. The cost of irrigating a large area is usually too large for a forestry or conservation project. This hold true for most forest tree species and planting configurations, but there are some exceptions.

Shade trees are generally watered frequently because they are often located near enough to a water source that watering does not require much effort. Fruit tree orchards are also sometimes irrigated, because the crop is considered valuable enough to make the cost worthwhile. Research plots may be watered, if it will not interfere with the results of the experiment. Sometimes demonstration parcels are watered to ensure that the trees survive, in the hope of encouraging people to adopt the technique being demonstrated. This is misleading if the technique does not ordinarily involve watering.

Watering Trees At Extremely Arid Sites

In areas of less than 250mm mean annual precipitation, the survival chances of seedlings planted at the onset of rains are low at best. If sufficient rains do not materialize, seedlings must be watered. As long as provisions for watering must be made, it may be just as well to *plant trees during the cool, dry period*. This is a major deviation from the basic principle of planting during the rainy season. Experience in Mauritania has shown that planting and watering of trees during the cool season requires much less water to get them started.

Always provide water where it is needed, in the root zone rather than at the surface. Also, provide sufficient water to bring soils in root zone to field capacity in one application. The special procedure for watering trees at extremely arid sites is as follows:

- Dig a hole or test the soil with an auger to determine the existing moisture conditions. Dune sands may contain capillary water at 1-2m below the surface. If that is the case, only the dry layer above these areas need be watered.

- Apply the correct amount of water to each tree through a tube or pipe attached to a metal container placed on a stand. The container can be removed for refilling.

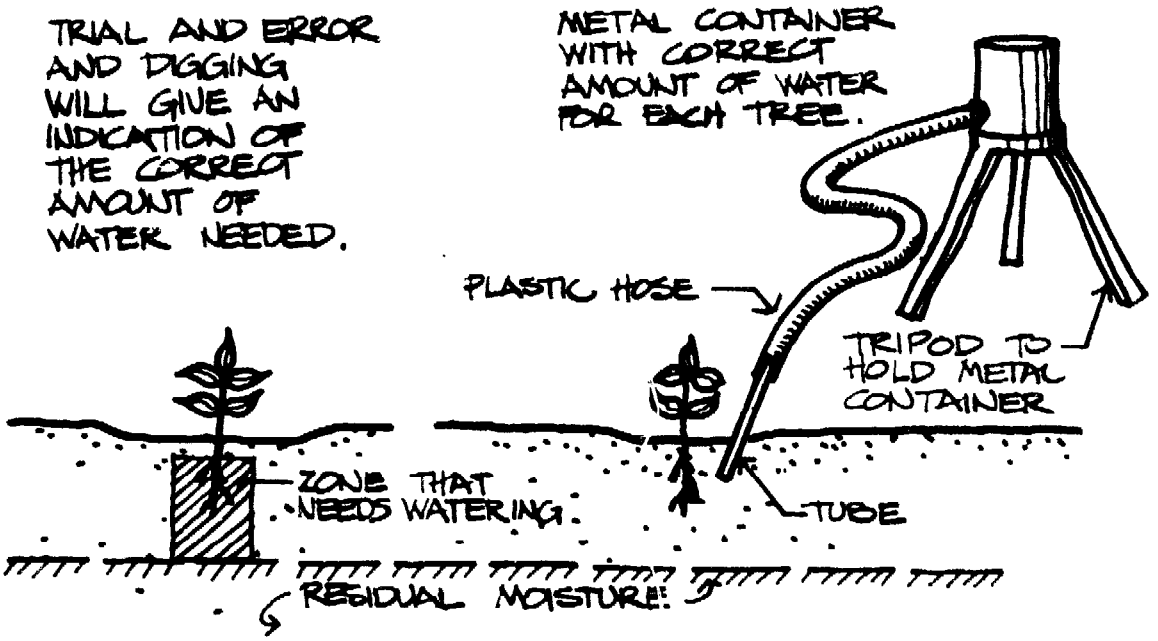

Weeding

There are two reasons why it is important to weed around young trees: 1) to reduce competition for moisture and growing space; and 2) to reduce the risk of damage from brush fires. Climbing vines can also strangle a seedling if they are not quickly removed. It is not necessary to weed the entire area of a plantation; clearing a radius of about 1m around each tree is sufficent.

Weeding is most necessary during the rainy season. If the trees have been properly tended during the rains when the weeds are most prolific, additional weeding operations should not be necessary during the dry season. If there is a considerable amount of dry vegetation on the ground surrounding the trees, however, fire becomes a major concern once the rains have ended.

The grasses and other vegetation removed from the plantation during weeding operations can be used as animal fodder or as mulch around the young plants. Weeding may be necessary for several years after the seedlings are planted--at least until they are taller than the other vegetation, and their root systems are deep enough so that they are not competing for surface moisture and nutrients.

Survival

If the trees have been properly cared for, if no animals get into the planting area, and if there are no serious attacks by insects or rodents, survival of the trees depends directly on the weather immediately after planting. Cloudy weather with frequent showers for the first three or four days after planting can mean that up to 90 percent of the trees will survive. A dry spell lasting several

days after planting can reduce the survival percentage to 30 percent. Abundant precipitation during the rainy season helps plants to build up reserves and roots that are long enough to reach down to lower water tables during the dry season.

Generally only those trees that are weak, diseased, or slow starting are affected by insects, rodents, and disease. Sometimes trees that look dead above the surface may resprout from the ground up the following year if conditions are good. While they may always be stunted, they can add to the ground cover.

A survival count should be undertaken during the planning stages for the next year's planting season, to determine how many seedlings will be needed to replace trees that have died. A site assessment is sometimes necessary to determine if high mortality rates are due to an inherent problem in site conditions. If a problem is identified that cannot be easily corrected, it may not be worthwhile to replant on that site the following year. In areas where there are two rainy seasons per year, replacement planting can take place during the second, shorter rains, if site conditions are favorable.

Because mortality losses may be due to more than one cause, it may be necessary to plan several survival counts at intervals during the dry season. The first count, taken shortly after the end of the rainy season, indicates losses due to transplanting shock, or to spotty, inadequate rainfall. Survival counts taken later in the year may show a higher overall mortality due to the cumulative effects of drought combined with other factors.

It is unrealistic for project managers to expect to maintain 100 percent survival even under the most favorable conditions. Although reasonable efforts should be made to reduce mortality as much as possible, a total survival rate of 60 percent of the nursery stock one year after planting should not be considered disappointing under arid land conditions. Total survival includes the seedlings still living after counting losses in the nursery, seedlings that are culled during grading, and seedlings that die following transplanting.

8 AGROFORESTRY METHODS

Agroforestry Systems in Africa

Agroforestry is a topic that has received considerable attention since the first edition of this book. This interest is largely due to evidence that trees and shrubs can be managed to enhance significantly and, to some extent, guarantee the *sustainability* of agricultural systems. Moreover, trees of appropriate species in suitable locations can *increase agricultural productivity*. Agroforestry offers an alternative approach to intensive agricultural "development" schemes that in the past have often resulted in decreased soil fertility and loss of soil restoration potential.

Even the widespread adoption of the term agroforestry indicates that development specialists now recognize the validity of indigenous farming systems. Farmers and pastoralists in dryland Africa have over a long period of time evolved complex strategies that utilize trees and shrubs as essential components of natural resource use systems (land, water, natural vegetation, etc.). In many parts of Africa, a form of shifting cultivation known as fallow or slash and burn agriculture has traditionally been practiced.

Under this farming system, small parcels of land are cleared. Fire is often used to clear the vegetation, releasing plant nutrients into the soil. The plots are intensively cultivated for a few years until soil nutrients are depleted. They are then left fallow (unplanted) for as long as several decades, allowing the regrowth of the natural vegetation. Soil fertility is gradually restored, and after a sufficient interval the land can be cleared and farmed in another rotation. Because of population pressures and recurring food shortages in Africa, however, many farmers find it difficult to practice traditional fallow agriculture. They are forced to lengthen cropping periods, while reducing the number of years the land is in fallow. This results in a loss of soil fertility and consequent reductions in crop yields. Wind and water erosion also increase.

Agroforestry or soil conservation techniques, often combined, can help to stabilize cultivation on a given piece of land. Certain of these methods help prevent or reverse environmental damage in areas where fallow cropping is no longer practical. Adding trees and shrubs as permanent features in the

landscape in the form of field trees, border and alignment plantings, windbreaks, and live fencing can protect the soil against erosion and improve nutrient cycling. Proper maintenance of trees in agroforestry or soil conservation systems may allow permanent cultivation of farm fields, that previously could only be fallow cropped. Many of the techniques described in this chapter are based on farming systems that evolved in Africa to allow long-term sustainable production systems to take the place of shifting cultivation.

An attempt to describe the role that trees and shrubs play in the overall management of natural resources is condensed in the following definition of agroforestry by the International Council for Research on Agroforestry:

> "A land use system that integrates trees with agricultural crops and/or animals, simultaneously or sequentially, to get higher productivity, more economic returns, and better social and ecological benefits on a sustained yield basis, than are obtainable from monoculture on the same unit of land, especially under conditions of low levels of technological inputs and on marginal sites." (ICRAF, 1982)

This means that trees and shrubs are deliberately managed (that is, established, tended, protected, harvested, etc.) and considered as one of the resource elements used by the people or their livestock, even though the trees may appear to be randomly dispersed in the landscape. Trees and shrubs need not be forests, woodlots, orchards, or other discrete stands, especially set aside for a single purpose or product. Rather, they are planted wherever people have not allocated the space to some other use.

Forestry specialists in the past have paid too little, if any, attention to trees and shrubs outside of specifically designated forest areas. Throughout arid Africa, governments have established areas of land set aside to be managed by technical services for forest (wood products) or wildlife resources: gazetted forests, classified forests, various types of reserves, parks, etc. Agroforestry takes place outside of these boundaries and includes trees that have regenerated naturally as well as those that are intentionally planted. The goals of land and resource management for agroforestry systems can vary greatly as long as trees and shrubs are integrated with crops and/or animals. This definition of agroforestry includes a broad range of activities from hunting-gathering systems involving minimal technological input, to intensive intercropping patterns where trees are established, pruned, and harvested according to carefully controlled production schedules.

It has also become evident that, from the local people's point of view, integrating trees into traditional operations and land use patterns makes much more sense than setting aside specific areas of usable farm land for woodlots. In many areas the most acute problem is lack of food, not lack of wood. Certain tree species may provide food (fruit, leaves, edible seeds, etc.) not only for people but also for livestock, particularly during seasons when food supplies from other sources are low.

In addition to producing wood for fuel, construction, implements, tools, and art objects, other important and locally appreciated by-products of agroforestry include fiber for mats, baskets, and rope, or plant materials for medicines, dyes, tanning, cosmetics, and glue. These raw materials were easily obtainable a few generations ago when extensive woodlands still existed throughout the dry regions of Africa. Today they are scarce because much of the "useless brush" has been converted to farm fields or plantations of rapid growth species, the use of which is usually limited to only a single product.

Trees, Soil, and Farming Systems

Trees and shrubs play a critically important conservation role. They can reduce soil surface temperatures, increase infiltration and retention of soil moisture, provide organic matter, pump nutrients, fix nitrogen, reduce erosion from water and wind, form live fences, and provide shade, all of which create better growing conditions for crops and grasses.

Some methods currently being promoted as agroforestry interventions--windbreaks, for example--can be equally well categorized as soil conservation methods. For the purposes of this text, it is not necessary to classify techniques into one discipline or the other. By its definition, agroforestry attempts to achieve "higher productivity, more economic returns, and better social and ecological benefits on a sustainable basis...." These objectives should be compatible with the goals of soil conservation and sound farm or range management programs, and should also be in line with efforts focusing on response farming or farming systems research.

It is natural to ask which of these interventions, agroforestry, soil conservation, or farm management, will yield the best results. Experience shows that any one of the three, used alone, can produce significant results. It is becoming even more obvious, however, that better and more balanced effects can be achieved if the three systems are used in combination. Research shows that in many instances soil conservation efforts can have a synergistic effect when combined with agroforestry systems. This holds true for modifications of farm or range management practices. In fact, the three types of activities often complement and reinforce each other, to produce better results than could be achieved through the separate use of any one approach. Agroforestry systems should be designed, then, with careful consideration of methods that traditionally fall into the realm of soil conservation and farm or range management.

The table on the following page illustrates how the three technical fields relate to each other. Pilot projects should test different combinations of techniques, using a farming systems research approach, before introducing an agroforestry package to a rural area on a large scale.

Factors Affecting Sustainablity and Productivity	AGROFORESTRY	FARM/RANGE MANAGEMENT		SOIL CONSERVATION
		FARM	RANGE	
Soil Moisture Retention	- Alley cropping, line plantations and dispersed trees to provide: • Organic matter • Shade to reduce surface temperature	- Use of compost, cover-crops - Crop-residue left in fields - Mulch	- Controlled grazing - Rotational grazing - Fire Management	- Incorporating organic matter into the soil - Preparing micro-catchments, contour ridges or other micro-site improvements.
Soil Fertility	- Nutrient cycling and Nitrogen fixation	- Crop rotation (including legumes)	- Use of Animal Manure	- Contour vegetation strips
Water Erosion Control	- Surface Runoff reduction through: • Establishment of trees/ shrubs along physical conservation features • Trees along canals and waterways	- Contour farming - Maintaining soil tilth - Maintaining maximum plant cover	- Range rotation - "Grazing reserves" - Contract grazing linked to vegetation rehabilitation or protection. - Controlled lopping for fodder	- Berms, ditches, ridges - Benches or terraces - Waterway and gully control - Protection of stream banks
Wind Erosion Control	- Wind reduction through: • Dispersed Trees • Borderline Trees	- Maintaining maximum plant cover - Natural vegetation strips left when clearing new land - Minimum till cultivation		- Windbreaks - Palisades, other physical treatment in extreme cases - Dune stabilization
Access Control	- Live fencing - Alignment of livestock trails	- Stock driveways left when laying out fields. - Borderline Trees	- Herding as opposed to letting animals roam freely - Tethering or corraling livestock	- Layout of soil conservation plantings to reinforce fencelines and livestock trails.

LINKAGES BETWEEN AGROFORESTRY, LAND MANAGEMENT, AND SOIL CONSERVATION

Species Selection

Sustainability is the key feature that agroforestry offers to people who depend on a limited and fragile resource base for their daily subsistence. An appropriate, properly managed species mix will result in sustainable land use systems that *produce as well as conserve.*

No other single issue is as important as species selection in planning an agroforestry intervention. In some instances, the choice is not hard to make. In the Sahel, *Acacia albida* is frequently identified as the species that is most appropriate for a given site. *Moringa oleifera* is a good candidate for intercropping with vegetable gardens in areas where people are familiar with it, but it may be more difficult to introduce to new areas. Another "classic" agroforestry species in dryland East Africa is *Dobera glabra*, which is very much appreciated and in demand from Lake Nyanza to Saudi Arabia.

The task of recommending species for windbreaks can become controversial. Many windbreaks established in Africa are composed of a single species, most frequently the Neem tree. It is widely agreed that a more diverse species mix would be preferable, but few data exist to indicate which species can be combined to achieve the desired effect. Fast-growing species are needed for windbreaks because they can begin to reduce wind erosion a few years after their establishment. The more slow-growing species, however, are often longer-lived, and provide protection for the crops and soil long after the fast-growing species have died. An ideal windbreak species mix should also contain multiple-use trees.

The same problem exists for many other experimental techniques such as live fencing and contour strips. The decision is complicated by the question of specific site requirements and conditions, but aspects such as resisitance to browsing, or local preference (not to mention taboos, prejudices, and unfamiliarity with a new species) often severely limit the choice.

Much can be said for experimentation and trials, but research takes time, and project funding organizations are often in a hurry for results. They want and need short-term successes. Consequently, they tend to select from a limited number of key species, based on the best information available at the moment. This tendency to depend on the same few species for almost every application has resulted in a concentration of knowledge and experience with a few exotics at the expense of a number of other, potentially more valuable, species.

Agroforestry project planning should not take a cookbook approach. Rather, the project design should be adapted to specific site conditions and current land use patterns. Species trials are required to meet site requirements. Demonstration plantations using more varied species, including more indigenous species, are needed throughout dryland Africa so that future selection can be made on the basis of what has worked.

Species Selection Based On Rainfall

Rainfall	Below 500mm	500-1000mm
West Africa	*Acacia albida* *Acacia nilotica* *Acacia raddiana* *Acacia scorpiodes* *Acacia senegal* *Acacia seyal* *Azadirachta indica* *Balanites aegyptiaca* *Bauhinia reticulata* *Combretum spp.* *Commiphora africana* *Hyphaene thebaica* *Mitragina inermis* *Moringa oleifera* *Prosopis juliflora* *Pterocarpus lucens* *Salvadora persica* *Tamarindus indica* *Tamarix spp.* *Ziziphus spp.*	*Acacia albida* *Acacia nilotica* *Acacia scorpiodes* *Adansonia digitata* *Anogeissus leiocarpus* *Azadirachta indica* *Balanites aegyptiaca* *Borassus aethiopum* *Butyrospermum parkii* *Carica papaya* *Citrus spp.* *Diospyros mespiliformis* *Eucalyptus camaldulensis* *Leucaena leucocephala* *Mangifera indica* *Moringa oleifera* *Parkia biglobosa* *Prosopis africana* *Prosopis juliflora* *Psidium guava* *Pterocarpus erinaceus* *Sclerocarya birrea* *Tamarindus indica*
East Africa	*Acacia melifera* *Acacia nilotica* *Acacia tortilis* *Azadirachta indica* *Balanites aegyptiaca* *Cassia spp.* *Commiphora ellenbeckii* *Conocarpus lancifolia* *Cordia abyssinica* *Dobera glabra* *Grewia tenax* *Jatropha dichtar* *Leucaena leucocephala* *Moringa oleifera* *Prosopis chilensis* *Prospis juliflora* *Salvadora persica* *Schinus molle* *Sesbania sesban*	*Acacia polyacantha* *Acacia senegal* *Azadirachta indica* *Balanites aegyptiaca* *Calliandra calothrysus* *Calodendrum capense* *Carica papaya* *Casuarina equisetfolia* *Citrus spp.* *Cordia abyssinica* *Croton megalocarpus* *Eucalyptus spp.* *Gliridicia sepium* *Gmelina arborea* *Grevillea robusta* *Leucaena leucocephala* *Mangifera indica* *Psidium guava* *Schinus molle* *Sesbania grandiflora* *Sesbania sesban*

This list should be used as a guideline, a basis for further discussion and observation in the field and at the specific project sites.

Agroforestry and Soil Conservation Techniques

A wide assortment of different agroforestry techniques is being used today, based on traditional practices that have been carried out by local people for generations. Others are relatively new, "invented" by technicians working with local farmers or pastoralists and still being adapted to varying site conditions. The methods described here are presented in "tech-sheet" format. They provide a practical guide for use in the field, rather than extensive coverage of background information, theory, and reference sources. The bibliography and Information Source List in Appendix "E" should be consulted for further documentation.

Many of the technical requirements, design, and field work details that are used in agroforestry systems are similar to or the same as those of standard forestry and conservation activities. The information regarding establishment and maintenance techniques for reforestation efforts that has been discussed in the preceding chapters is also generally applicable for agroforestry applications. Several points, however, deserve special attention when implementing agroforestry-related projects. Additional information is provided in the following pages for specific factors that should be considered, such as spacing requirements, intercropping, plant protection, pruning, and harvesting.

Particular emphasis should be placed on extension of the agroforestry techniques presented here so that local people are encouraged to try them on their own land. Traditional plantation forestry methods often involve recruitment of a large labor force to carry out work on publicly owned land with high levels of technological and material inputs. Although some projects of this sort may fall within the broad definition of agroforestry, most of the techniques shown here are specially selected and modified to be implemented by rural households or communities using locally available materials.

Agroforestry and soil conservation techniques can be grouped or classified in different ways. Some of the techniques described in this chapter, therefore, could be equally well categorized as soil conservation or farm/range management measures. They are all grouped here, nevertheless, because they can contribute to the increased productivity and sustainability of land use systems. All of the techniques included involve the establishment of vegetation cover, primarily trees and shrubs. Some also involve physical soil conservation methods as well, such as contour ridges, terraces, or walls. This approach is intended to increase awareness of ways in which vegetative methods can be used interactively with physical methods.

The following outline shows the format that has been followed in organizing the information in this text. The main categories and sub-categories distinguish the various techniques according to their functions and the spatial arrangements in which trees appear in a rural landscape. The techniques are illustrated on the following pages and described in detail in the sections that follow.

Outline of Individual Techniques

On-farm

Dispersed Trees (1)
Alley Cropping (2)
Line Plantations (3)
Borderline Trees (4)
Live Fencing (5)

Off-farm

Roads and Trails (6)
Water Courses (7)
Shade Trees (8)

Soil Conservation

Windbreaks (9)
Sand Stabilization (10)
Contour Strips (11)
Trees Along Contour Ridging (12)
Gully Reclamation (13)

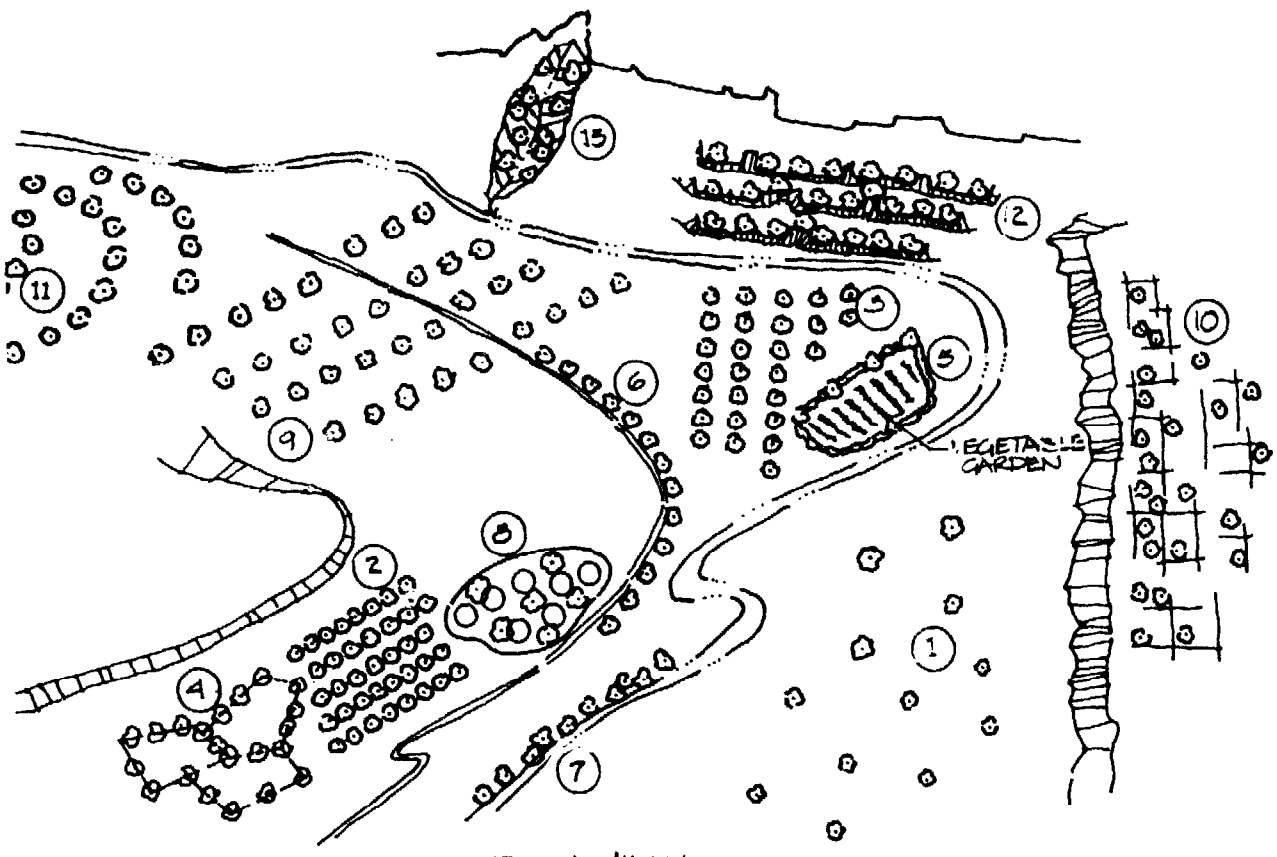

PLAN VIEW

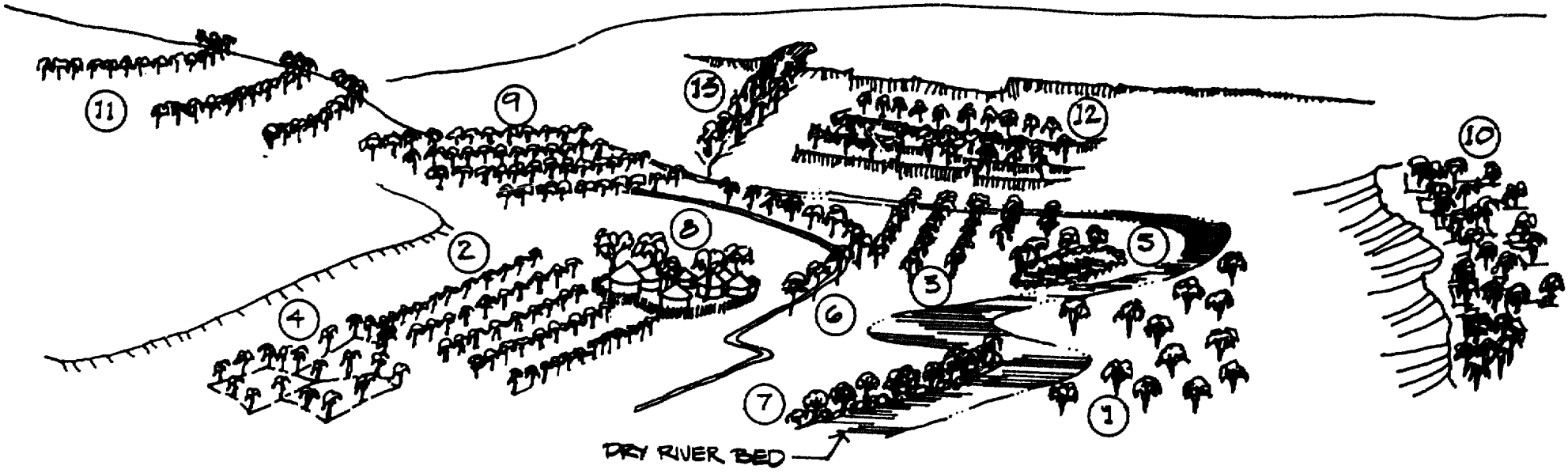

OBLIQUE VIEW

KEY

1 DISPERSED
2 ALLEY CROPPING
3. LINE PLANTATIONS
4. BOARDERLINES
5. LIVE FENCING
6. ROADS, TRAILS
7. WATER COURSES
8. SHADE
9. WIND BREAKS
10. SAND STABLIZATION
11. CONTOUR STRIPS
12. TREES ALONG CONTOUR RIDGING
13 GULLY RECLAMATION

On-Farm Techniques

Trees can be integrated with crops in a number of ways. They may be dispersed randomly across a field, planted in careful rows between rows of other plants, or planted as separate stands for orchards or woodlots. Trees may also be used to mark borders or as live fencing.

1. Dispersed Trees (On-Farm)

Intensive interaction between crops and trees occurs when they are grown together. The classic farm/park landscape that covers large parts of the Sahel is a perfect example of a traditional agroforestry arrangement where trees dispersed in farm fields form an integral part of a cropping system. Different species are found in these dispersed, park-like stands, depending on site conditions. The best known are *Acacia albida, Butyrospermum parkii, Parkia biglobosa,* and *Borassus aethiopum.*

In traditional systems these trees regenerate naturally, and so they are more or less homogenously distributed across fields in random patterns. Where they have been regenerated through human efforts they are planted in lines (normally 10mx10m). Regular spacing is particularly important if mechanized cultivation, such as animal traction, is practiced. The main feature of this approach is that the trees are more or less uniformly dispersed either in a natural, irregular pattern or more systematically in a grid pattern.

There are some problems that have arisen in the use of this technique. The seedlings are difficult to protect from grazing when they are young (up to five years). Brush fences or woven baskets can be placed around individual trees, as described in Chapter 3, but this is expensive. Birds are also attracted to the trees, especially when they are established near rivers and lakes. The birds can cause problems for farmers if they eat crops and seed.

Efforts to introduce *Acacia albida* in farm fields in the Sahel have been particularly successful, however, because of a unique property of this species. During the rainy season it drops its leaves, and it does not leaf out again until well into the dry season. Cereal crops can be grown under the leafless trees during the rainy season. The crowns of almost all other tree species compete with light-demanding crops for space, thus the areas shaded by the trees cannot be used for crop production. Even small trees can create enough shade during the rainy season to take a significant part of a farmer's land-holding out of production.

During the dry season the *Acacia albida* leaves and pods provide a welcome source of food for livestock. The trees also seem to have a remarkable effect on soil fertility, and dramatically increased crop yields have been noted on a number of sites. Especially in Senegal, Niger, and Chad, some fairly old stands of *A. albida* can be found that were established in farm fields. In spite of little or no government or donor follow-up beyond the first two to three years, these 10 to 50-year-old plantations of *A. albida* are doing well. Their survival is probably due to the high value placed on the trees by local farmers.

Contrary to traditional forestry lore, which often describes *A. albida* as a slow-growing species, it can grow quite rapidly. The crowns of some stands, planted at a 10mx10m spacing in 1972, are beginning to close. These trees are 5-7m tall and have begun to produce flowers and fruits as well.

Dispersed Trees

2. *Alley Cropping (On-Farm)*

Small trees or shrubs, pruned frequently to prevent them from producing too much shade, are grown in relatively compact rows (between 2 and 4m, never more than 6m apart). Crops are grown in the space--the "alley"--between the rows of trees. This method was developed in more humid areas of the tropics, and it is being tried in drier regions of Africa, Asia and Latin America. The International Institute of Tropical Agriculture (IITA) has been experimenting with alley cropping in Nigeria for a number of years. Arid lands versions of this approach are still in the trial stages, however, and experience in these zones has been much more limited. Most research is focused on obtaining the right species combination, but the question as to which crops respond best to which tree species also varies according to site conditions.

Fast growing tree species such as *Leucaena leucocephela, Gliricidia sepium*, and *Gmelina arborea* have been used in various research efforts. Other species that can be used for alley cropping include *Calliandra calothrysus* and *Sesbania grandiflora*, but these also have high moisture requirements. They should be tried in arid regions in vegetable gardens that are irrigated during the dry season. Acidic soils are also not suitable for alley cropping with the species that have been suggested above. Species that would be more appropriate for dry sites and low pH soils need to be identified. Such diverse crops as corn, millet, cowpeas, yams, and manioc can be grown in the alleys.

The trees/shrubs are pruned as often as five times per year. The clippings are laid down as a mulch around both trees and crops, gradually decomposing and becoming incorporated into the soil as organic matter. The shade and mulch

from the tree rows also reduce weed growth. Yields of some crops are higher between the mulched rows than in comparable fields that are not being alley cropped. The IITA found that yields from maize were three times greater after four years of mulching with *Leucaena leucocephala* clippings (IITA, 1986).

In addition to the increased complexity of matching compatible crop and tree species to specific site conditions, several other problems may limit the widespread adoption of alley cropping in Africa. A major consideration to farmers who are considering various intercropping schemes is the amount of arable land that the trees will take up. Farmers tend to favor methods that will take as little land out of crop production as possible. Alley cropping requires fairly close placement of tree rows, which can substantially reduce the amount of land left for the crop rows. Where land scarcity is a problem, therefore, alley cropping is probably not the best method to use.

ALLEY CROPPING

1

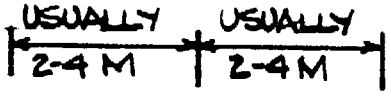

TREES PLANTED IN LINES

2

CROPS ARE HARVESTED

3

WHEN SHADE BEGINS TO INTERFERE WITH CROPS TREES ARE COPPICED OR POLLARED.

4. BRANCHES ARE PLACED BETWEEN TREE ROWS. LEAVES WILL FALL TO GROUND THE BRANCHES AND TWIGS CAN ALSO BE USED AS FUEL WOOD, FOR CONSTRUCTION OR OTHER PURPOSES.

5

TREES MEANWHILE WILL BEGIN TO RESPROUT.

6

CYCLE IS REPEATED:

DEPENDING ON SPECIES, SPACING & GROWING CONDITIONS, INTERVAL OF COMPLETE CYCLE VARIES FROM 6 MONTHS TO 1 YEAR RARELY MORE.

Alley cropping also requires fairly strict adherence to planting and pruning schedules in order for the technique to give good results. If the trees are not cut back at regular intervals, they will create too much shade for the intercropped plants. For light sensitive crops like corn, too much shade over a period of just a few days can interrupt flowering and fruiting processes. Other crops simply do not thrive in excess shade. Trained extension personnel are needed to work closely with farmers on crop and tree species selection and on setting up planting and pruning schedules.

Farmers may want to use the pruned branches for poles or firewood. The clippings can also be used as fodder for livestock. If the leaves and branches are not used to mulch the crops, alley cropping may not have the effect of increasing crop yields, but it will still be an effective technique for controlling soil erosion, increasing the availability of tree products, and maintaining agricultural sustainability.

3. *Line Plantations (On-Farm)*

Another alternating row arrangement involves planting larger trees at a wider spacing (7 to 10m) with crops planted between the rows. In this system, species that provide fuelwood and timber, such as *Greviliea robusta,* or fruit trees like avocado and citrus, are often used. As much as 60 percent of the species composition of the line plantations may be shrubs. Other possibilities such as *Markhamia platycalyx* or *Maesopsis eminii* are being studied on trial sites, where they serve as shade trees for coffee plantations. Several species of *Acacia* can also contribute to honey production. The species mix should include trees that provide different products as well as nitrogen fixing plants.

As in the case of alley cropping, this system has not yet reached full-scale production in the drier parts of Africa. It has, however, been tried at higher elevations in East Africa and its basic principle may some day prove of value in drier areas as well. The trees and shrubs are planted in rows with 1m-2m spacing between trees in the row. The rows are 7m-10m apart. The trees are not as intensively pruned as in alley cropping, although branches may be lopped to let more light through to the crops below.

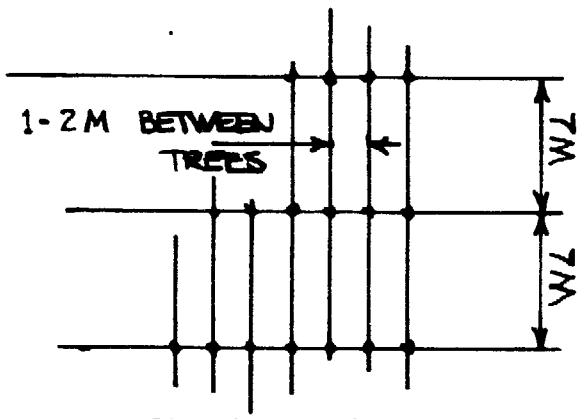

Line Plantation Spacing

It was found in Rwanda that as few as 70 trees (depending on species mix and the frequency of harvesting) will supply all the wood needed by a family of six for a year. Harvesting is done by lopping branches, and roots are also sometimes cut if they encroach too far into cultivated fields. An average tree provides about 20kg of dry fuelwood per year on a sustained yield basis under this agroforestry system.

TREE-LINES IN FIELD

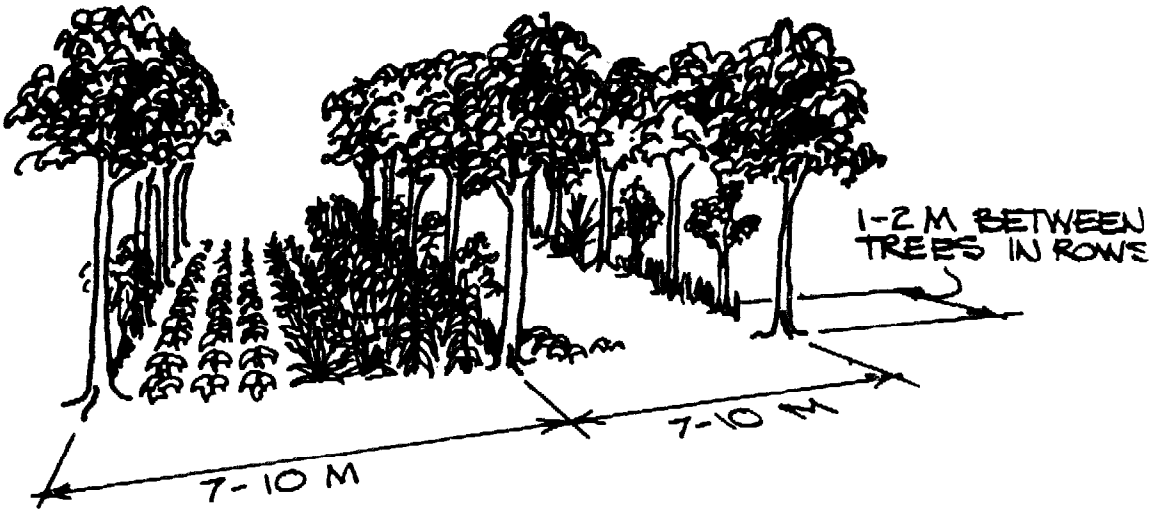

PROFILE OF A TYPICAL TREE-ROW IN RWANDA

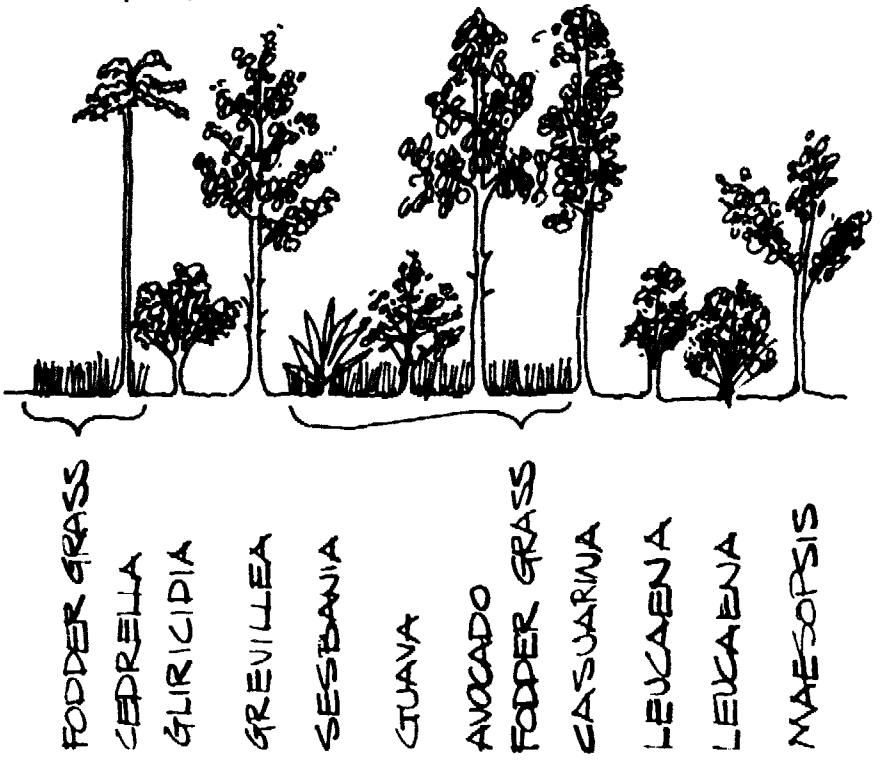

4. Borderline Trees (On-Farm)

Borderlines consist of trees, shrubs, and grasses established to delineate individual farm fields. They serve as property markers while they provide wood and other products for various purposes. They do not occupy too much space, nor do they shade large areas of the fields. Because the tree rows are not actually in the fields, they do not interfere with regular farming operations. As in line plantations, wood and other products can be harvested from the trees.

Grasses such as *Andropogon guiana* are traditionally used to mark property boundaries, especially around farm fields. In dry areas, *Calatropis procera* and *Euphorbia* and *Commifera* shrub species are also used for this purpose. Sometimes trees, particularly fruit-bearing species such as *Tamarindus indica, Annona senegalensis,* and *Borassus aethiopum*, are grown in borderlines or to mark the corners of fields.

The promotion of additional species for borderline plantation has potential, if species selection takes into consideration local preferences. Protection of young trees is necessary unless the species being used are unpalatable to livestock. *Euphorbia* and *Prosopis* species have proven somewhat resistant to grazing in Somalia, Kenya, and Niger.

Issues of land and tree tenure should be carefully researched and discussed with a community before this technique is tried. If the trees are planted on a borderline between two farmers' property, to whom do the trees and the harvesting rights belong? There may be several alternative approaches to resolve this question, but all parties involved should agree in advance as to how the situation will be handled.

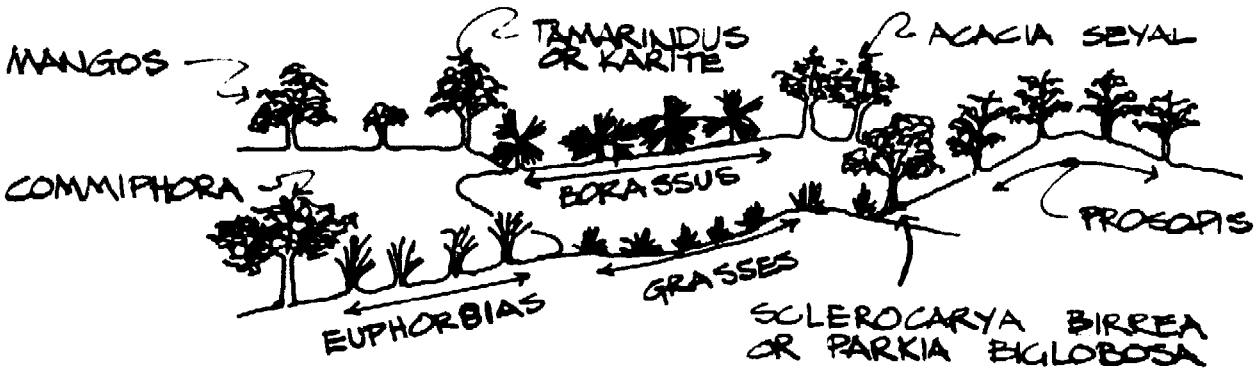

Borderline Trees

5. *Live Fencing (On-Farm)*

Live fencing consists of dense hedges or thickets usually planted around a garden or farm field to protect it from free ranging livestock. They are also planted around family compounds and other buildings. This technique differs from borderline plantations in that shrubbier species are used, the shrubs or trees are tightly spaced (0.5-1m), and they are intensively pruned to maintain a compact, dense barrier. This is a very important alternative to traditional fences that are constructed and annually repaired using interwoven thorny branches.

A number of species have shown that they adapt well to use as live fences. Members of the *Euphorbia* family are especially good because animals will not eat them (people too must be careful--when *Euphorbias* are cut, the milky sap can cause severe irritation if it touches the skin). Other species that are suitable for live fencing include *Acacia ataxacantha, Acacia machrostachya, Acacia nilotica, Acacia pennata, Acacia senegal, Acacia seyal, Balanites aegyptiaca, Calatropis procera, Comiphora africana* (mainly for posts), *Euphorbia balsamifera, Leucaena leucocephala, Parkinsonia acculeata, Prosopis juliflora,* and *Zyziphus* spp.

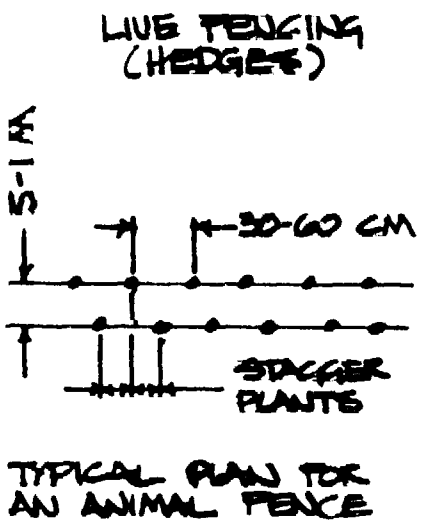

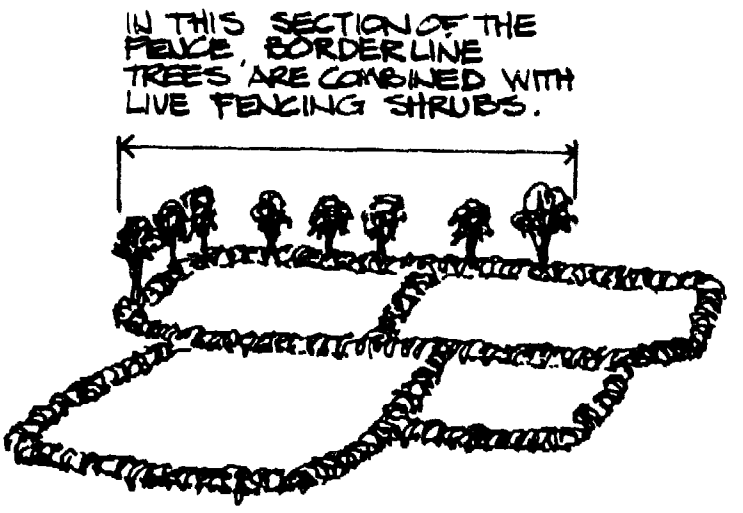

Spacing

Frequently, the main function of a hedge is to keep animals out. If this is the case, plants must be spaced tightly and kept well pruned. Select species that are:

- o Thorny
- o Easily coppiced (sprout back)
- o Relatively unpalatable
- o Fast growing

No one species will meet all these requirements. Trade-offs are inevitable although a mixture of species may provide the most protection. Final choice

depends much on specific site conditions. If protection from animals is not a primary concern, the spacing between plants can be wider. Hedges can have many other advantages and functions besides keeping out animals:

- o Demarcation of property boundaries
- o Protection against wind
- o Addition of organic matter from leaf litter
- o Fruit and forage, when combined with borderline trees
- o Privacy

As garden fences, or wherever irrigation is possible, trees for a live fence can be started by direct seeding. The seeds should be planted in furrows or in small pockets placed at intervals along the fence row.

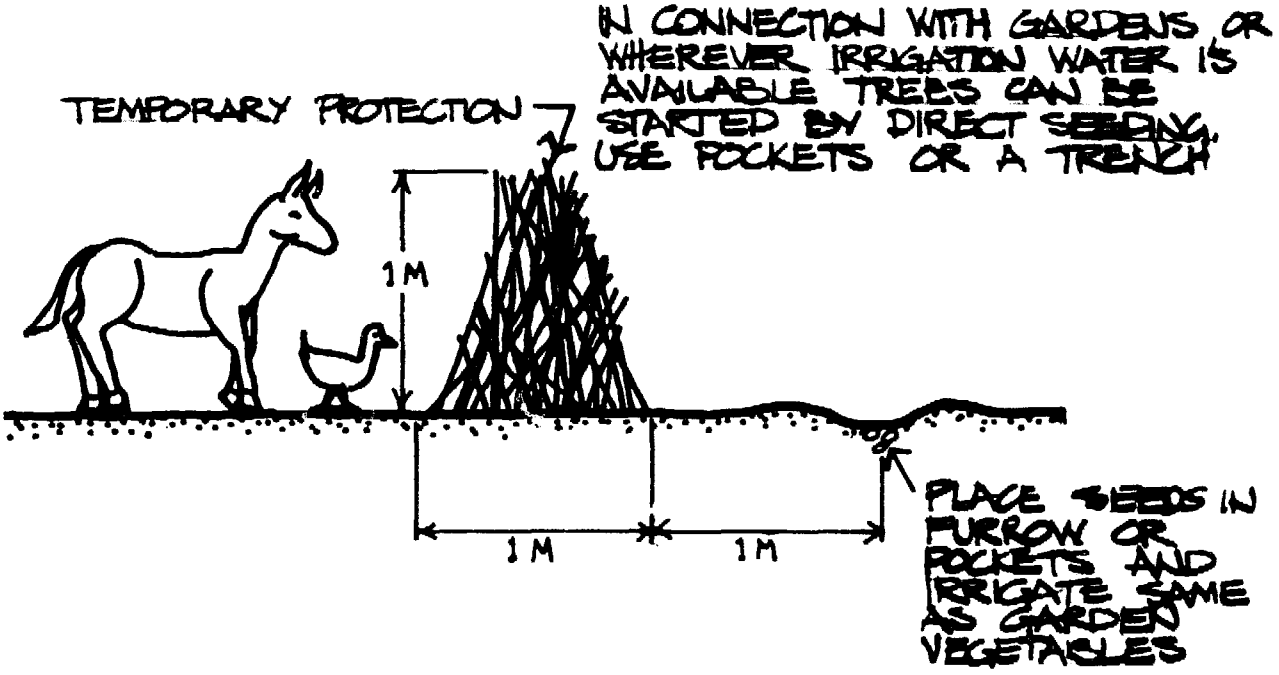

Direct Seeding Live Fences

Live fences can also be established from cuttings, especially from some species such as members of the *Euphorbia* and *Commiphora* genera and some perennial legumes. Freshly cut branches from these species are likely to take root and sprout if they are planted at the beginning of the rains. These species are therefore, particularly useful for establishing live fences. Normally, one would not wait until the beginning of the rainy season to build fences, but this might be done when using post materials that may take root. Care should be taken not to damage the bark or wood when attaching wire for the fence. See Chapter 9 for more information on propagation by cuttings.

ALTERNATE DESIGNS

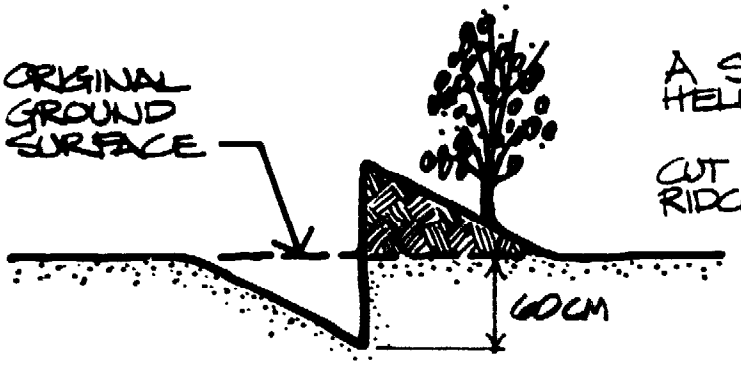

A STEP-OFF (LEDGE) WILL HELP DISCOURAGE ANIMALS.

CUT 60 CM TRENCH, MAKE RIDGE WITH EXCAVATED MATERIAL

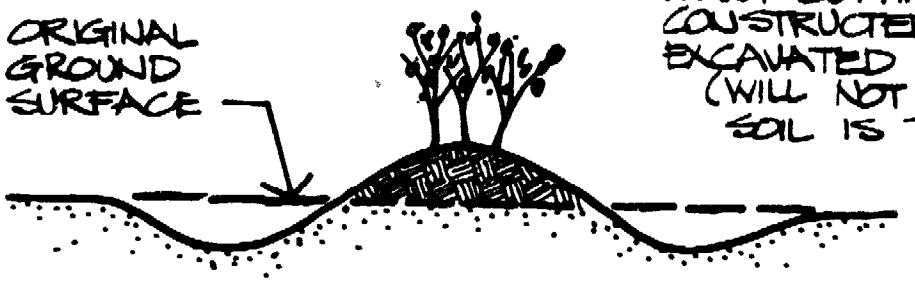

PLANT CUTTINGS ON RIDGE CONSTRUCTED FROM EXCAVATED MATERIAL. (WILL NOT WORK WHERE SOIL IS TOO SANDY)

PROPER FENCE PRUNING (ONLY ONE ROW IS SHOWN)

TREES IN FENCE LINE ARE GETTING ESTABLISHED. AT THIS STAGE, THEY MAY WELL NEED PROTECTION UNTIL THEY BECOME STRONGER

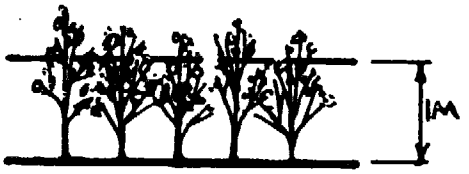

READY FOR PRUNING. CUT ALL BRANCHES ABOVE DESIRED HEIGHT. USE CUT BRANCHES TO PLUG HOLES BETWEEN PLANTS.

AFTER PRUNING, THE FENCE LOOKS LIKE THIS. FURTHER GROWTH WILL FILL IN REMAINING VOIDS.

FROM THIS STAGE ON, HEDGE ONLY NEEDS PERIODIC TRIMMING.

Off-Farm Techniques

In most rural areas as well as in towns and urban areas, there are unused spaces along roads and water courses, and around houses and public buildings. While they may traverse agricultural land, these open spaces are not used for agricultural production. Trees planted in these spaces can enhance the environment by providing erosion control and shelter from the sun and wind for both people and animals.

6. Road and Trail Alignment (Off-Farm)

A long standing tradition throughout Africa is to line roads with trees, mainly for shade, but also for wood and other tree products. This practice can be extended to include foot paths and trails. Certain species (*Eucalyptus* spp. or *Grevillea robusta,* for example) can be pollarded extensively every three to five years, yielding considerable amounts of fuelwood and poles for construction.

A frequently made mistake has been to plant trees too close to the road. On major roadways, enough room must be left for two vehicles to pass with additional space on the roadside for vehicles to pull over in an emergency. Less than six meters of space between tree rows creates traffic hazards. Additional width is needed around curves, because the trees reduce the distance ahead that drivers can see.

Trees are also established along livestock and bicycle trails and footpaths, sometimes in combination with live fencing or rock walls to control access to adjacent fields. Shade and fruit trees are favored for footpaths.

ALIGNMENT

TREES AND LIVE-FENCING (HEDGES) ARE PLANTED ALONG A TRAIL IN COMBINATION WITH EACH OTHER

TRAIL, FOOTPATH

TREES PLANTED AT REGULAR INTERVALS 2-5 M, OFTEN IN COMBINATION WITH ROCK WALLS OR FENCE (LIVE) TO CONTROL ACCESS TO ADJACENT FIELDS. USE SHADE OR FRUIT TREES OR A COMBINATION

Alignment Plantings

ROADS & TRAILS

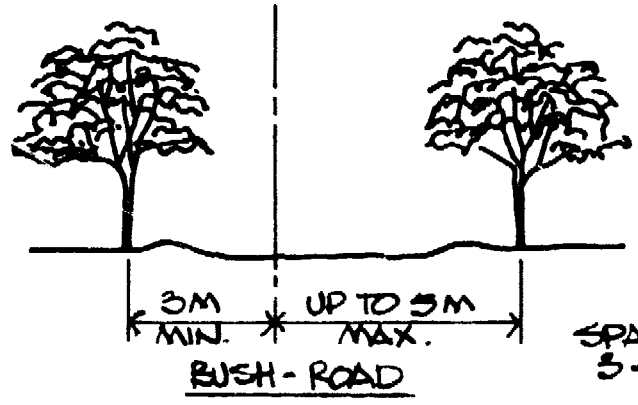

SPACING IN LINE:
3-5 METERS

COMMON MISTAKE IN THE PAST: TREES WERE PLANTED TOO CLOSE TO THE ROAD. ENOUGH ROOM MUST BE LEFT FOR TWO CARS TO PASS PLUS SOME EXTRA SPACE: LESS THAN 6M BETWEEN TREES CREATES HAZARDS TO TRAFFIC. EXTRA WIDTH IS NEEDED ON CURVES.

TREES DO REDUCE SIGHT DISTANCE IN CURVES.

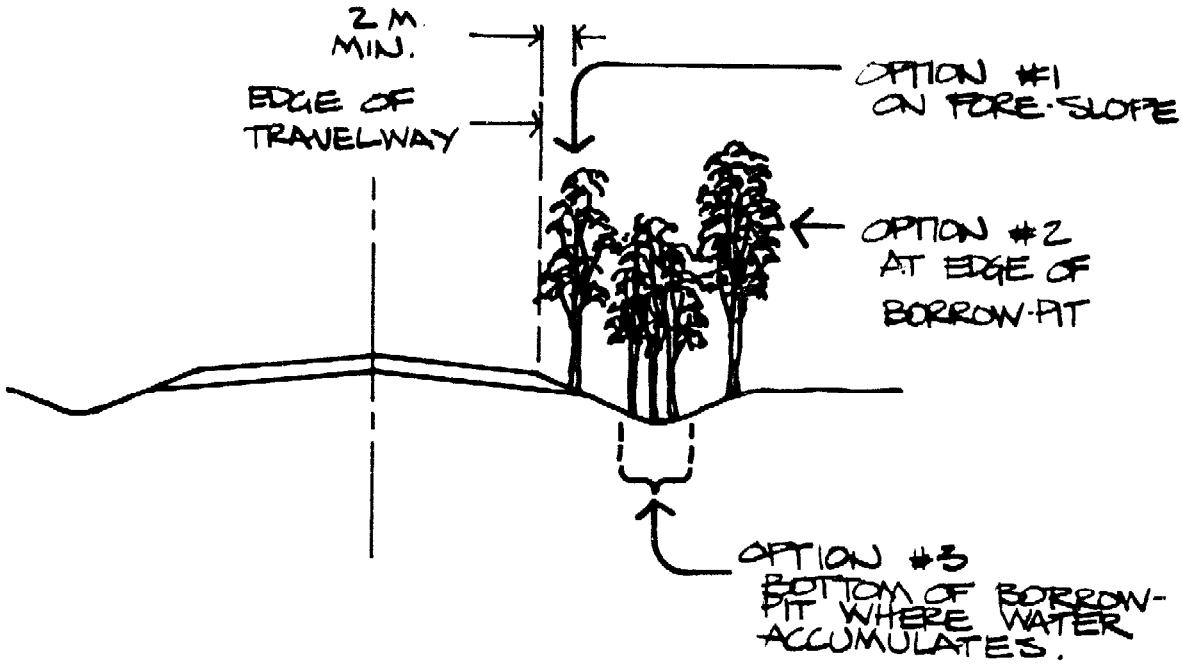

7. *Water Course Alignment (Off-Farm)*

The banks of streams are frequently cleared for cultivation of cereal crops or irrigated gardens. They are extremely susceptible to erosion once the natural vegetation has been removed. These areas can be protected by restoring tree and shrub cover along the stream banks. Water course alignments also create good habitats for wildlife.

Trees and shrubs can be established around water sources in much the same way as alignment plantings along roads. Rivers, ponds, or drainage canals in irrigation schemes provide excellent growing conditions for trees. Exotics like *Eucalyptus* spp., *Casuarina equisetifolia,* or *Cassia siamea* will grow rapidly on these sites. Fruit trees (mangoes, citrus) should be given special consideration because of their value as food sources. Dry river beds (*wadis*) provide a suitable site for species such as *Tamarix, Anogeissus leiocarpus, Prosopis* spp., or other more drought-resistant varieties.

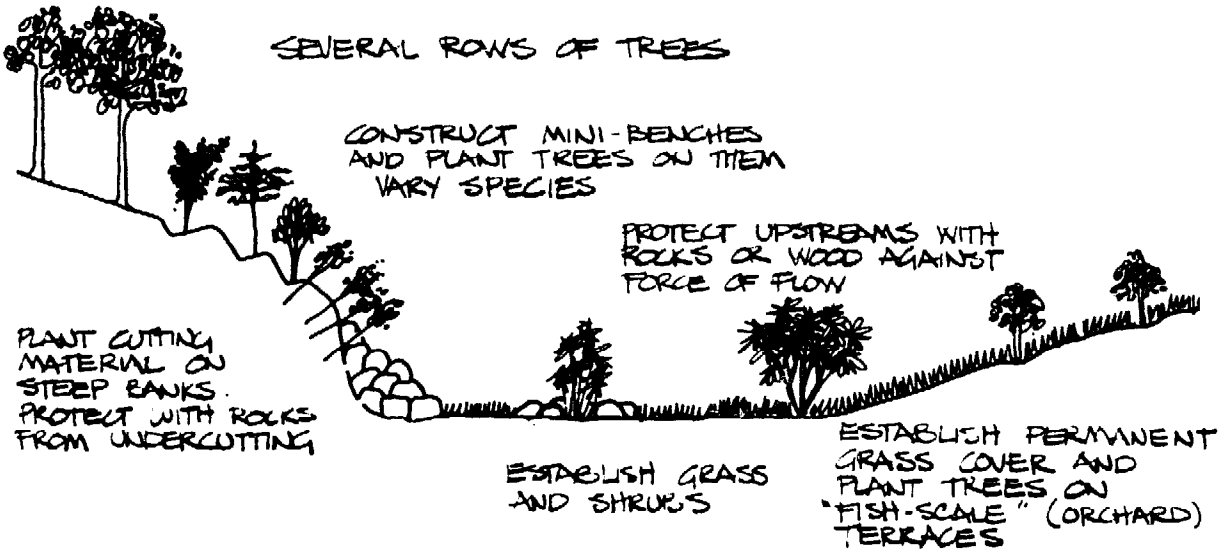

WATERWAY PROTECTION

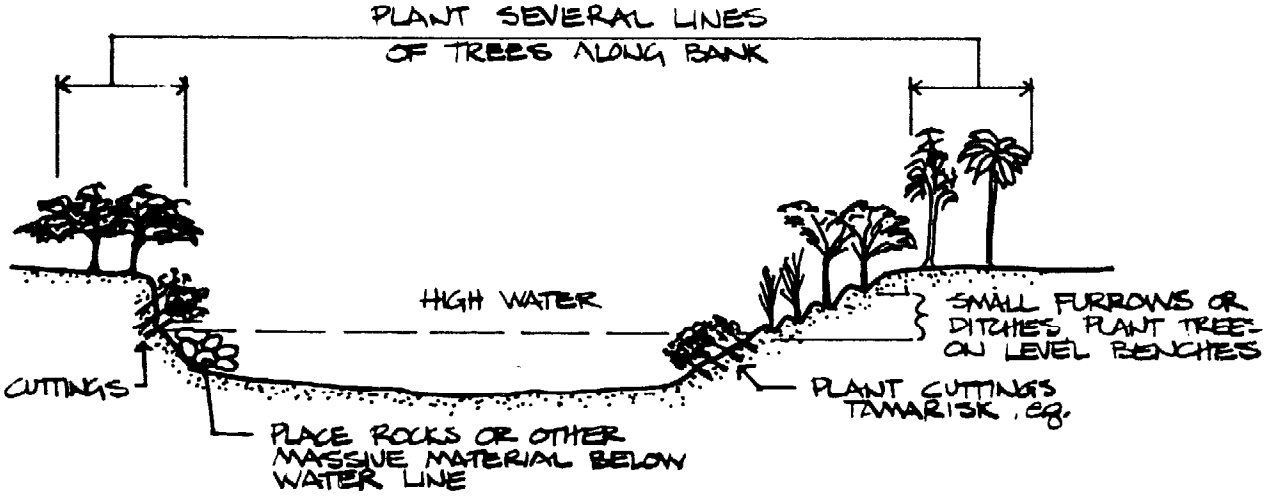

TYPICAL BED OF INTERMITTENT STREAM

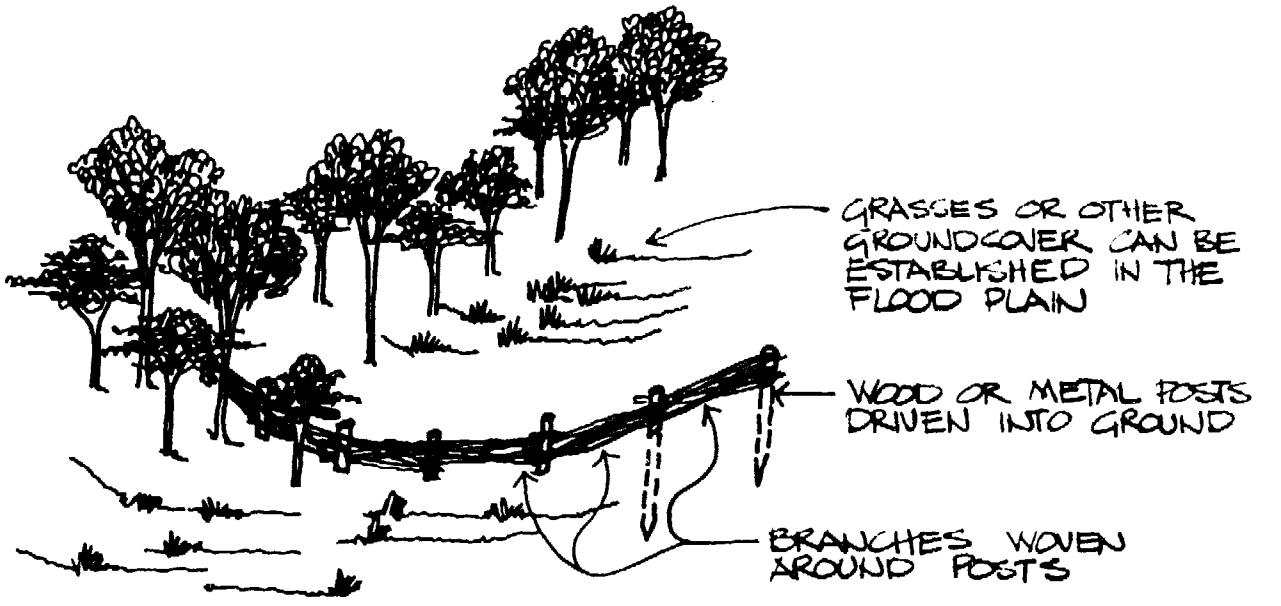

BOTH POSTS AND BRANCHES MAY BE FROM SPECIES THAT CAN BE PROPAGATED FROM CUTTINGS

TYPICAL LOCATION FOR ESTABLISHING TREES OR SHRUBS ALONG WATERWAYS

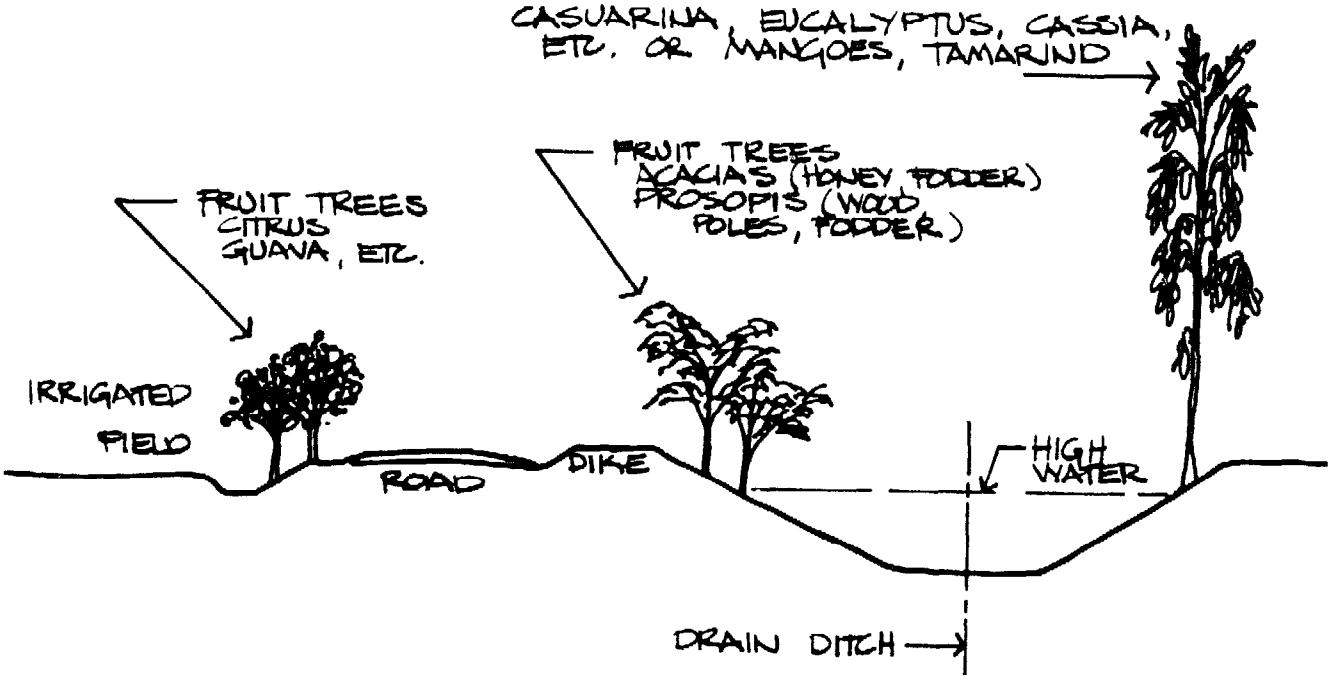

TREES ALONG DRAINAGE STRUCTURE

8. Shade Trees (Off-Farm)

In many parts of dryland Africa, the most striking impact of tree planting programs can be observed near houses, in compounds where people live. Protection is easier and questions of ownership arise less where trees are growing inside family compounds. A great diversity of species is found at such locations, particularly introduced species and ornamentals. The neem (*Azadirachta indica*), for instance, has found rapid and wide acceptance throughout Africa as a shade tree.

The pollarding method can be used to harvest wood from shade trees, particularly the neem (see Chapter 9, Harvesting Methods). The branches are cut at a point about two meters above the ground. They sprout back quickly forming a new crown, so that the tree continues to provide shade where needed.

Shade trees planted in public places around government buildings, schools, market places, churches, and mosques serve an important function. These are areas where people congregate during the day, and shade is an essential part of the environment. These are also places where trees can be established and maintained quite easily by local people themselves with minimal assistance from outside.

Trees planted in public places usually need individual tree fences to protect them until their branches are out of reach of free-ranging animals. Even after they are no longer threatened by livestock, good local cooperation is needed to keep people from over-harvesting the trees. For example, the twigs of the neem tree are very popular in Africa for toothpicks. A seemingly harmless practice like breaking off an occasional twig can, however, stunt the growth of young neems if the stems are continuously stripped by passers-by.

Although farmers generally try to restrict the amount of shade in areas where crops are grown, shade trees are used to protect livestock from intense heat during the day. Shade trees are particularly necessary wherever animals are corraled or fenced in, and around watering spots.

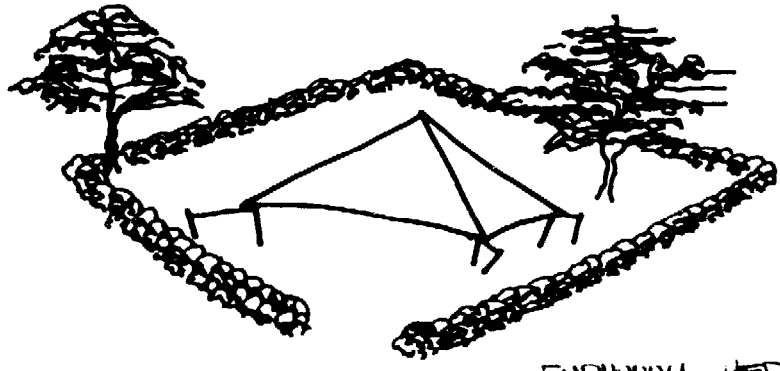

INDIVIDUAL PERMANENT ENCAMPMENT (PASTORALIST AREAS)

EUPHORBIA HEDGE: AROUND A COMPOUND IN MAURITANIA WITH INDIVIDUAL TREES INSIDE

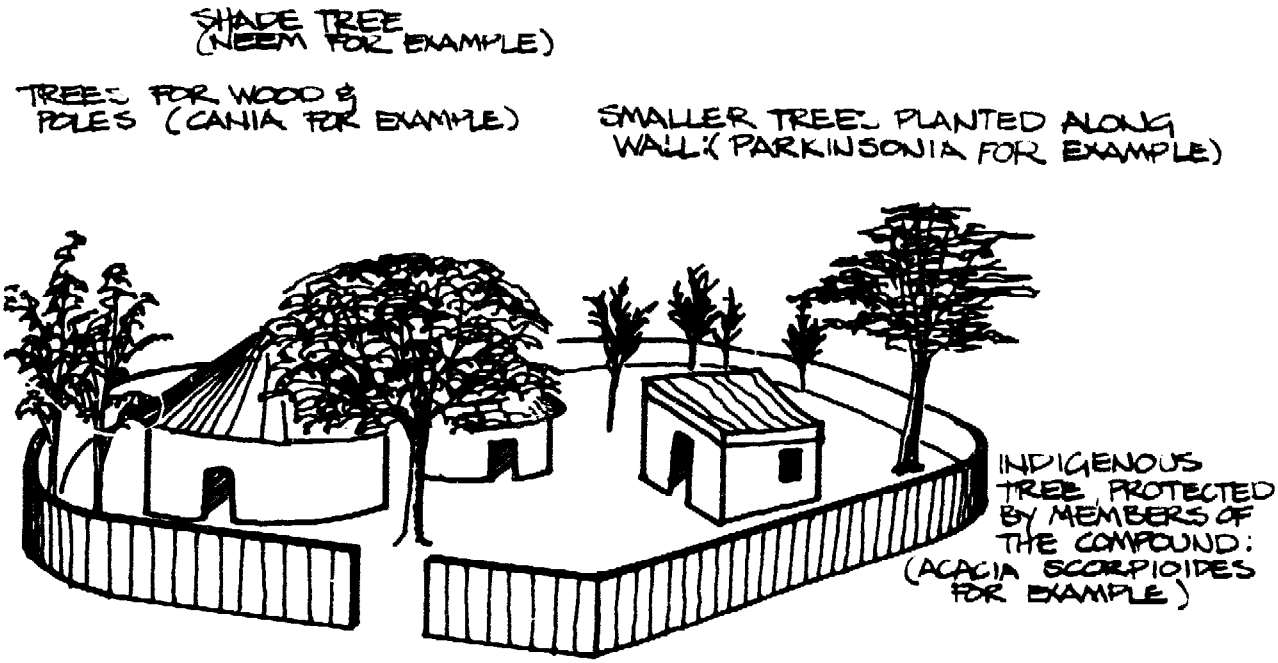

NOTE: WALLS IN MANY PLACES ARE TRADITIONALLY MADE OF ADOBE BRICK IN SOME PLACES THEY CONSIST OF LIVE FENCES OR HEDGES

INDIVIDUAL COMPOUND
SEDENTARY FARM AREA

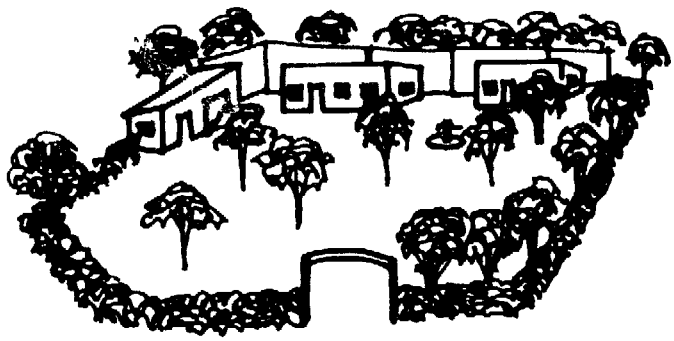

GOVERNMENT COMPOUND
(SCHOOL, DISPENSARY, ETC)

WITH LIVE FENCE AND TREES PLANTED INSIDE

Soil Conservation Techniques

Soil conservation efforts protect the soil from the two primary forces of erosion, wind and water. Windbreaks and dune stabilization are effective methods of halting wind erosion. Planting trees and other vegetation in contour strips or along contour ridges and gully control plantings are techniques used in combination with physical control measures to reduce soil erosion from water.

9. *Windbreaks (Soil Conservation)*

Windbreaks are strips of trees and other vegetation that slow the flow of the wind, reducing wind erosion, evaporation, and wind damage to crops. They are sometimes referred to as shelterbelts, although this term usually implies a wider strip of vegetation, which incorporates more rows of trees and shrubs than are usually found in a windbreak.

The most successful windbreak projects to date are those found on enclosed farm lands and in some demonstration or pilot projects under government or private control. The major obstacle to windbreak establishment in other areas has been the difficulty and high cost of protecting the trees against animal grazing. Some large-scale successes have been achieved in areas where donors, government agencies, and local people have worked closely together.

Highly impressive results have been observed in Niger, where crop yields from fields protected by windbreaks are consistently higher than those from unprotected fields. Studies conducted at a CARE project in the Majjia Valley indicate that total yields are approximately 20 percent higher, even after accounting for losses from land that has been taken out of crop production to provide space for the windbreaks (Dennison, 1986).

Windbreaks have an especially high potential in farming areas where cereal crops such as millet and sorghum are grown. The windbreak trees, if properly harvested, can also provide significant quantities of fuelwood and poles without jeopardizing their primary function.

The effectiveness of a windbreak depends on how efficiently the wall of vegetation blocks the wind and confines the wind's turbulence to the zones close to the windbreak. A vegetation density of 60 to 80 percent seems to work best in arid zones. A barrier dense enough to block wind passage completely will cause turbulence close to the ground, loosening soil particles that can then be picked up by the wind. As well as removing needed topsoil, wind that is carrying soil particles causes damage to crops through the abrasive effect of the sediment load on plant tissues.

MODERATELY DENSE
(PERMEABLE)

DENSE
(SOLID)

A row of trees that provides less complete wind reduction will also ensure that the effects of the wind are felt further away. Gaps or openings in the windbreak should be avoided as much as possible. Wind is funneled through gaps in the tree rows, concentrating its force and speed, so that the final effect can be very damaging.

Windbreaks can furnish protection for downwind areas up to 10 times the height of the trees, provided the windbreak consists of at least two rows of plants of different heights. Large trees should be chosen for one row (see A, below). Fast-growing species can be mixed with slower growing, longer-lived trees, depending on local preference. Row B should be composed of shorter species, chosen if possible for their by-products, and rows C and D are auxillary rows. These are planted with lower, bushier trees, shrubs, and grasses. A well chosen vegetation mix for windbreak composition will not only provide protection from the wind, but will yield secondary products as well.

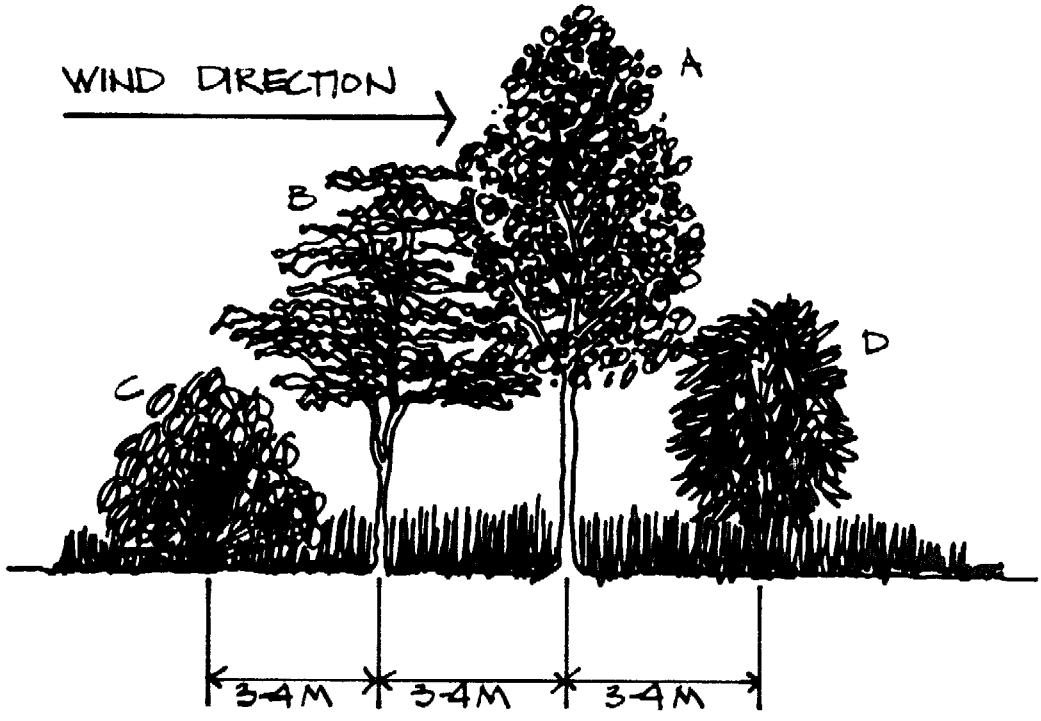

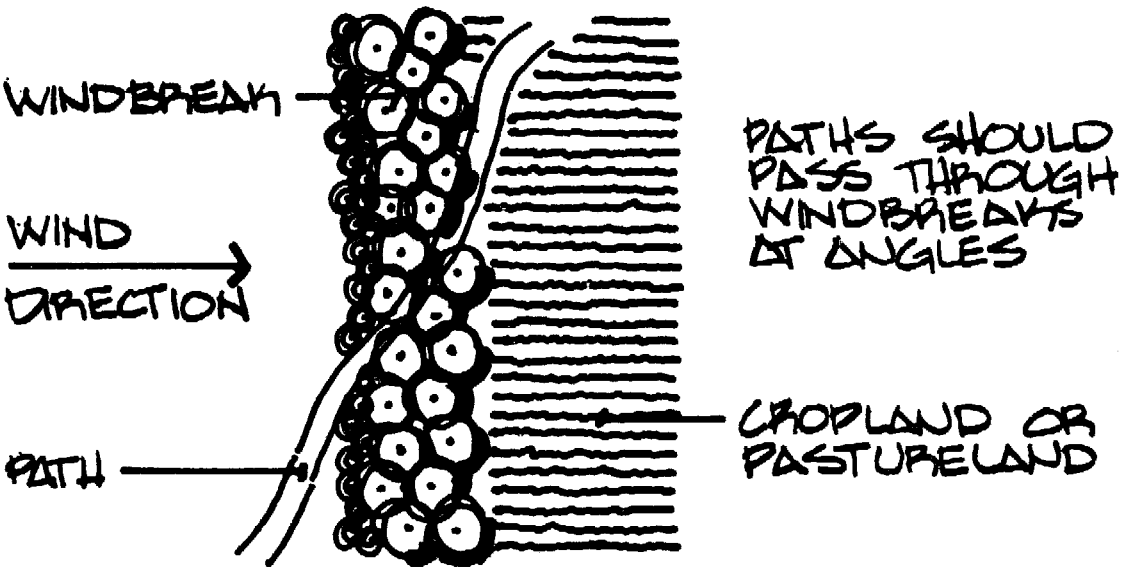

This windbreak is protecting the cropland from high winds, which would carry away topsoil and make the land useless for farming.

Windbreaks and shelterbelts can be laid out to include roads, trails, or driveways for livestock. In this way, animals and people can benefit from a shaded passageway that otherwise would be very hot. Any path through the windbreak should be at an oblique angle rather than perpendicular to the tree rows. This will allow people and livestock to move through the windbreak without opening a gap for the wind to roar through.

Some other points to consider about windbreaks:

- The selection of species for the windbreak should follow the general guidelines given for the different rainfall zones. Good selections can be made from species protected by law. Use only species that local residents themselves have chosen and value.

- Although double lines of *Azadirachta indica* have been used with satisfactory results, a strip three or five lines wide is better. Low growing bushes like *Bauhinia*, *Combretacae*, and *Salvadora* should also be considered. The most efficient windbreaks are those with one or two rows of low-growing shrubs or trees on the outside and two or three rows of taller trees on the inside.

- The utility of the wider shelterbelts can be enhanced by the selection of multiple use species for the middle rows. *Acacia senegal* has been used in some areas, and species that provide locally consumed fruits and medicines, such as *Tamarindus indica*, should definitely be considered.

- Frequently a combination of planting methods is highly practical when establishing windbreaks. In other words, a combination of nursery

transplants, live fencing, cuttings, and stumps can be used (depending on the best time of the year for planting in the area).

- Preparation and protection of the site involved are possibly more important for windbreaks than for regular plantations. During the rainy season when crops are being cultivated, the fields are effectively protected from livestock; however, after the harvest the animals are usually allowed to browse the crop residues left in the fields. Keeping the animals away from the windbreaks during this time is difficult, and fencing in a long narrow strip of land is costly.

- Where complex land ownership patterns exist, it may not be possible to establish continuous straight tree rows across individual fields and parcels. In this case windbreaks may be staggered so that they conform with established boundaries such as borders of fields, roads, trails, streams, and other natural or man-made features. Staggered windbreaks can also provide the most effective protection around towns and villages, where they are laid out in a pattern of overlapping blocks.

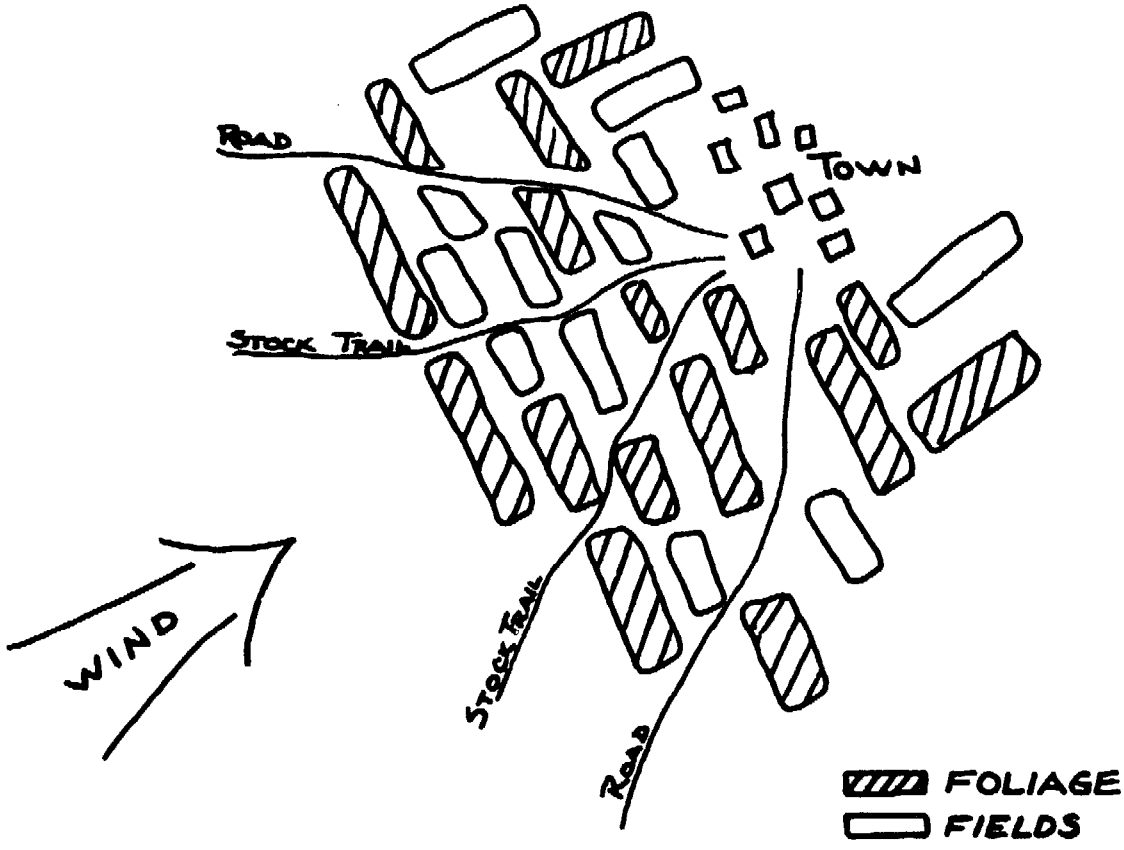

Shelterbelts

- Another possible planting pattern is to line farm fields with wide windbreaks and to plant dispersed trees such as *Acacia albida* inside the field.

- Many nurseries in arid zones could benefit from the establishment of a windbreak to protect the seedlings from drying winds. The nursery windbreak also serves as a demonstration to visitors to the nursery. If the nursery is very small, however, a tall windbreak might cast too much shade on the seedlings.

10. Sand Stabilization (Soil Conservation)

Shifting and blowing sand causes great damage to farmland, buildings, installations, and roads. Entire settlements can be threatened by the movement of shifting dunes. Sand stabilization is an important aspect of revegetation and conservation activities in many arid areas. Some of the most successful examples of erosion control efforts have resulted from reforestation projects.

The best protection against drifting or blowing sand is to prevent the sand from being picked up by the wind and becoming airborne. Conservation of existing grass and other vegetation cover is necessary to hold the sand in place. Even a small disturbance such as a footpath can start the process of erosion on fragile dunes. Once airborne, drifting sand can be made to settle, nevertheless, and can be kept from further shifting.

The first step is to determine why the natural vegetation has not recolonized the area that is being eroded. Various options that will remove any constraints to natural vegetation should then be considered. Often the problem is being caused by animals. Under these circumstances, little if anything will be gained by planting trees, unless access is first controlled.

There are basically two approaches to dune fixation: biological and physical. The best ultimate results are obtained when the open area where sand is picked up can be permanently covered by vegetation. Biological methods include:

- Fencing off the area to protect it from animals, so that the vegetation can regenerate naturally

- Establishing hedge rows of species such as *Euphorbia balsamifera* , which can be successfully regenerated from cuttings even in areas where annual rainfall does not exceed 300-400mm. Freshly cut branches of *Euphorbia balsamifera* are partially buried in rows of shallow trenches. For further details on propagation from cuttings, see Chapter 9.

- Direct seeding, particularly of grasses, but also of woody plants such as vines, shrubs, and trees.

o Transplanting seedlings from a nursery onto the site.

Certain vines and creeping plants are well adapted to grow in almost pure sand, covering the ground with runners and shoots. With the sand thus held in place, site conditions improve enough to permit the introduction of grasses and other small plants. Eventually seedlings raised in the nursery can be transplanted onto the site. This method of sequential revegetation gradually builds up the soil and improves growing conditions for other plants.

Often before grasses and other ground cover can be reestablished, however, the movement of the sand must be halted. Physical dune stabilization measures include:

o Wind-baffles (palisades), which are constructed of a variety of materials, generally whatever is locally available.

o "Fore-dunes," which consist of sand or soil ridges set at right angles to the major winds. They can be 1-5m high and stretch over hundreds of meters in length. Heavy construction equipment is required for large-scale efforts.

o Mechanical surface stabilization, which is accomplished by covering exposed areas to reduce further erosion. Plastic sheeting, nets, cloth or some other fiber is used.

o Chemical surface stabilization, which involes spraying a binder (rubber, oil, or plastic base) on the surface to bind particles together. Grass seeds and mulch can also be mixed with the binder and sprayed on the area to be protected.

Preference should be given to biological control measures whenever possible because of the high continuous maintenance costs of the physical methods. In exposed situations where plant survival is limited, however, some physical construction is needed for initial plant establishment. The construction of wind-baffles or palisades can be justified if low-cost materials are locally available. This barrier can take many forms and be made of a variety of materials.

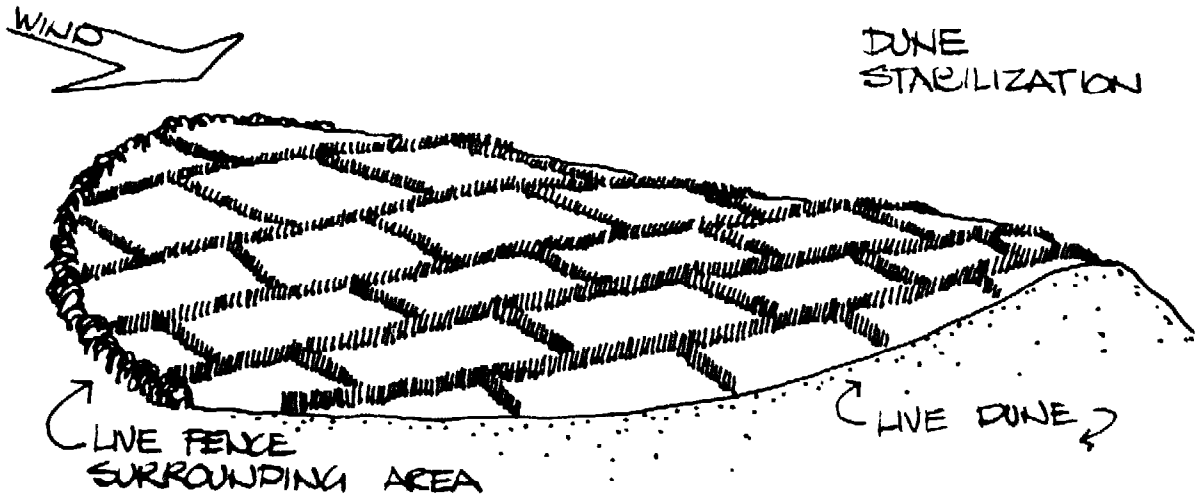

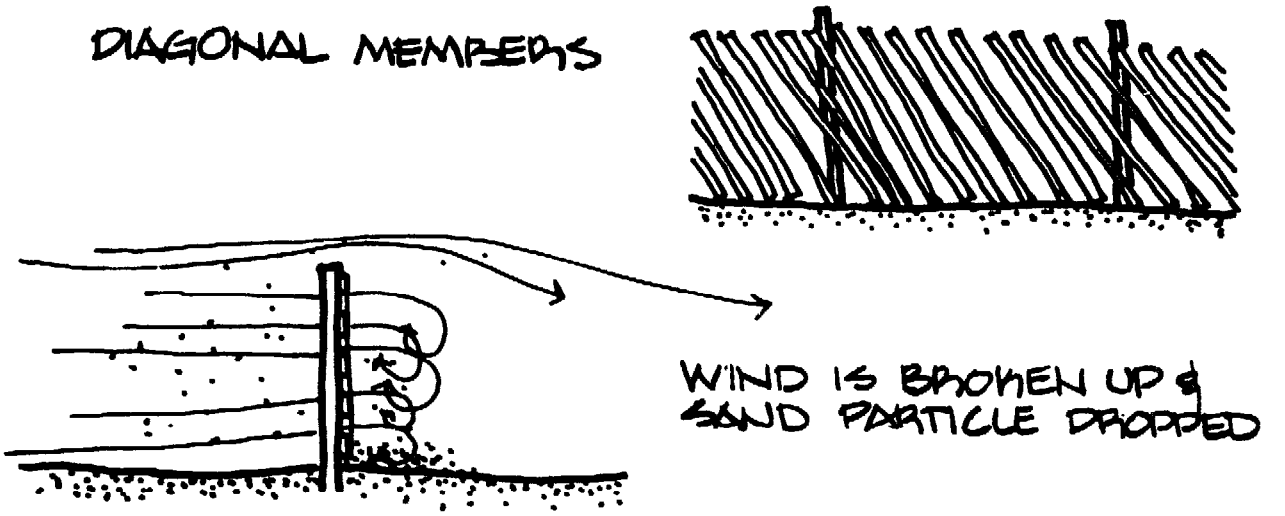

Windbreak fences used for sand stabilization

Stems and poles (3-8cm in diameter and up to 2m long) can be used to construct a diamond pattern of criss-cross rows across areas of open sand. Branches of tamarisk can be staked out in dense rows, or fences can be woven from branches of species such as *Guiera senegalensis* to construct the palisade. By breaking the force of the wind, the palisades keep the exposed sand from being picked up, and the sediment load already carried by the wind is deposited in or behind the barrier. Sand will become entrapped in such rows, and ridges will gradually form. Plant growth then becomes possible in the protected areas behind the ridges.

TYPICAL WIND BARRIER PATTERN

Fenced in squares and other sand traps can also be constructed of materials as basic as bundles of millet stalks or other crop residues. Additional possibilities include palm fronds, sticks, branches, cardboard, or any material that is reasonably sturdy, easily available, and low cost. Some of the problems that may be encountered in maintaining the barriers include damage from animals and termites that are attracted to them for food. Where sand accumulations are heavy, the barriers may have to be raised or added to periodically.

The following steps are followed in implementing a dune fixation project:

1) Establish a perimeter around the area to be treated, either with fencing material or by establishing a live fence.

2) Construct a network of palisades to prevent sand movement by cross currents. The primary gridlines should be perpendicular to the direction of the major prevailing winds, and the secondary lines should be at right angles to the principle lines.

3) Once the grid of palisades has been established and the movement of sand has been effectively reduced, vegetation can be introduced into the protected areas. Use methods described under biological control.

4) Begin protection and maintenance efforts. Voluntary participation, cooperation, and commitment to the project objectives on the part of the local inhabitants is essential.

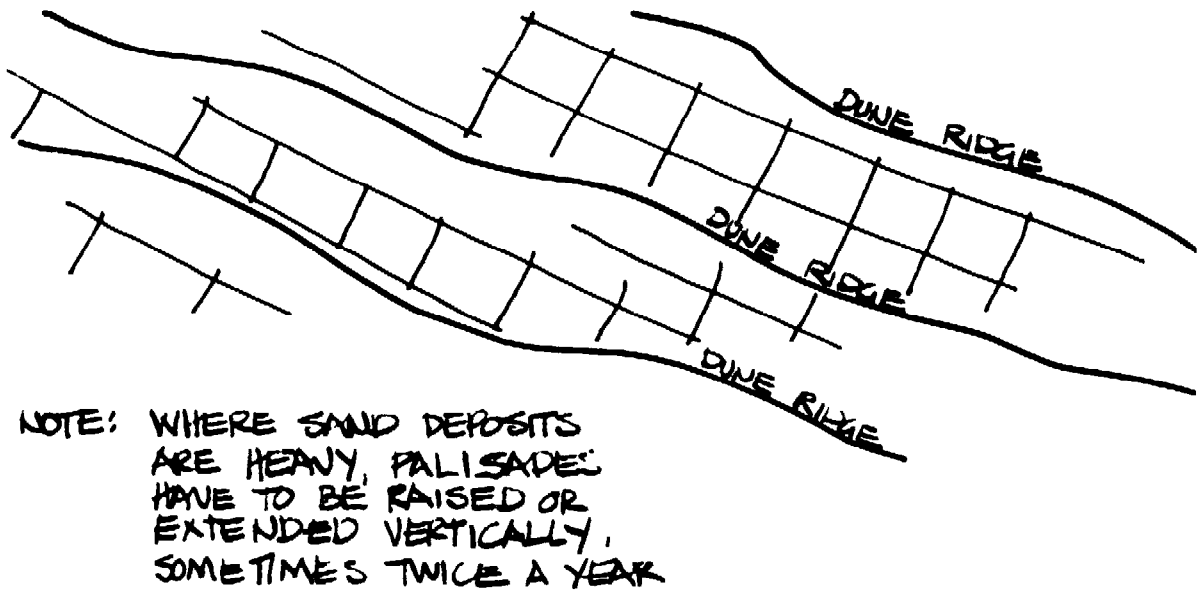

DETAILS OF PALISADE NET-WORK

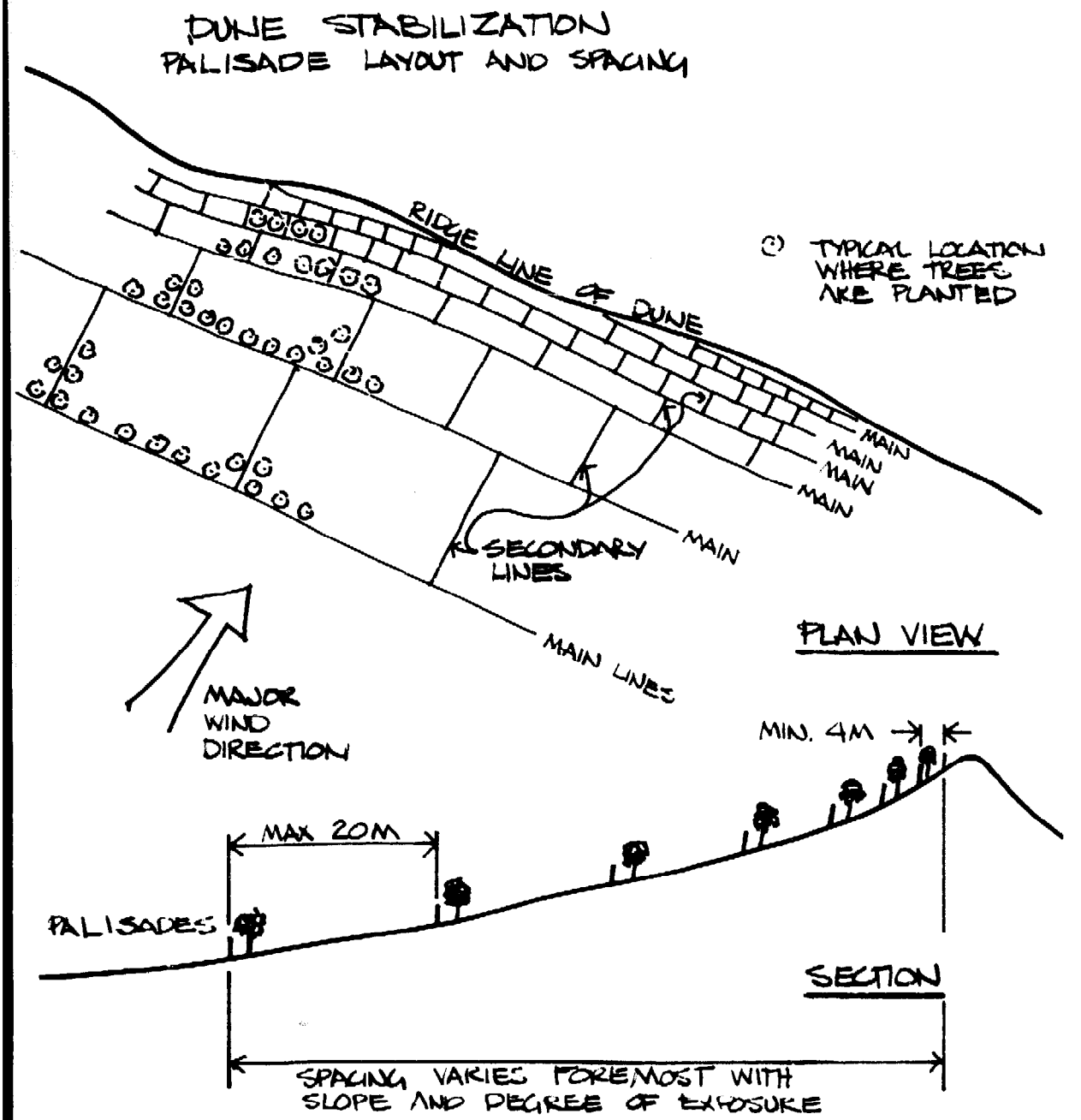

Before beginning a sand or dune stabilization project, planners should consider the following:

- Dune fixation is not an appropriate conservation investment if the area that is being threatened by shifting sands has no inherent value. Unless some benefit will accrue in terms of protection of farmland, homes, or other property, the cost is prohibitive. Furthermore, those who will gain the most from the project should also be willing to exert the most effort, particularly in terms of sustaining and protecting the vegetation cover.

- Dune fixation projects should not be undertaken without first carefully evaluating traditional and current land use attitudes, especially those governing grazing and wood cutting. If these are incompatible with the restrictions needed to protect the vegetation, then changes in land use policies must take place before dune fixation activities are initiated.

- The shifting of live dunes is influenced by a complex set of variables, and may change with the seasons. It is worthwhile to observe and measure dune movements for a period of 12 months before starting stabilization activities.

- Except under extreme desert conditions, it is more effective to stabilize the zone of origin of the shifting sand, rather than concentrating efforts on the areas where the sand is being deposited. It is important, therefore, to determine the location from which the sand is being removed by the wind.

- Project sites that are close to or within actual desert zones will require more intensive efforts to stabilize shifting dunes. Maintenance inputs will also be higher.

- The more exposed a specific location is to the wind (near the crest of large dunes, or in saddles between ridges), the more difficult it is to establish vegetation. Physical protection is often needed. If it is not possible to use physical control measures, however, the area can still sometimes be stabilized after the top has been lost to wind erosion.

- Locally occurring trees and shrubs have great resiliency. In species selection, the indigenous vegetation should receive priority over exotics, particularly for large-scale projects.

- A few outstanding examples are on record of communities that have controlled sand encroachment for generations, alone and unassisted by outside organizations. Local approaches may be more appropriate for a particular site than imported techniques that rely on heavy investments and foreign equipment.

11. Contour Strips (Soil Conservation)

The most likely, logical place to use trees and shrubs to halt erosion caused by water is across slopes, particularly where hillside cultivation is practiced. Properly maintained trees and shrubs, planted in combination with grasses and other vegetation, can effectively control surface runoff, thereby reducing soil losses. One successful technique involves establishing parallel vegetation bands along contour lines.

These contour strips will reduce runoff from the slopes above if they are designed and maintained to ensure a dense, multi-layered permanent ground cover. The ground surface is protected by successive layers of litter, grasses, other ground plants, bushes, and trees. A dense vegetation belt will not only

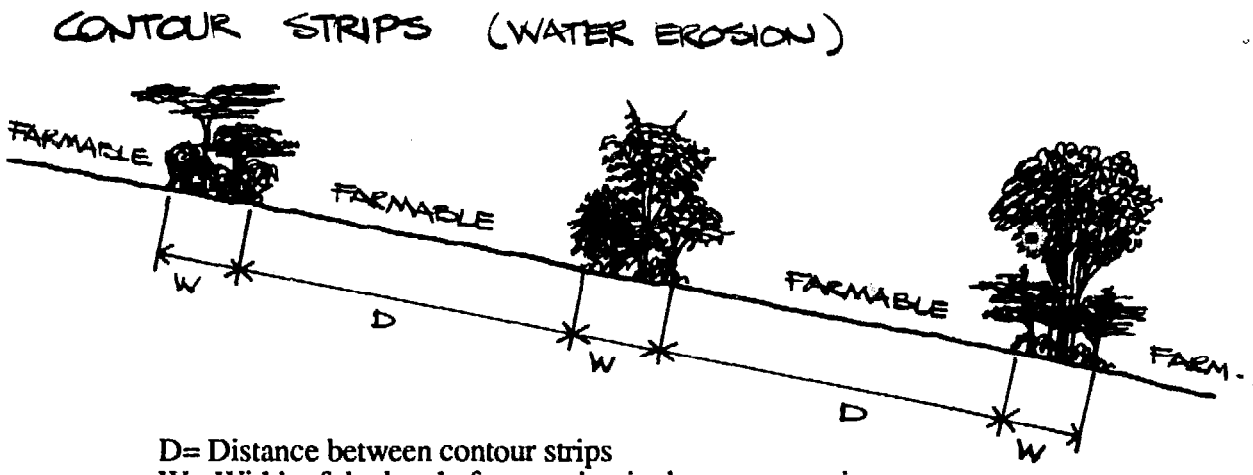

D= Distance between contour strips
W= Width of the band of vegetation in the contour strip

stop or slow down runoff, but will also trap soil particles suspended in the water that have been removed from the more exposed areas between the strips.

Correct dimensioning of the D and W variables indicated in the illustration above is important. Many factors affect the spacing of the strips, but the degree of slope is the most important. If previous efforts to establish contour strips in the area are available for study, these sites should be observed for evidence of erosion to determine if the dimensions are in proportion. Conservation services may also have tables or formulas appropriate for local site conditions. If no information of this kind is available, dimensions can be calculated using the following table as a rough indication of spacing.

Slope	W(meters)	D(meters)
0	2	50
5	4	47
10	5	43
20	8	38
30	10	33
40	13	28
50	17	24
60	20	20

Basis: 0-600mm mean annual precipitation

In areas with rainfall between 600-1,000mm: increase W by 20%
decrease D by 10%

In areas with rainfall greater than 1,000mm: increase W by 50%
decrease D by 20%

Revegetation efforts on these strips can be approached in many ways. To simply establish some groundcover, scarification of the ground along the contour may be sufficient site preparation. Furrows can be dug by hand or using a harrow or disc blade. More intensive effort may consist of additional seedbed preparation, for instance, loosening up the soil surface and raking along the contour. Direct seeding of desirable trees and shrubs may be feasible for such species as *Leucaena leucocephala*. Some trees can be established by cuttings. The most direct, but also most costly, method of establishing contour strips is by planting nursery raised seedlings.

The primary consideration for species selection should be local preference, because the contour strips take a certain percentage of the land out of cultivation, even though they are intended to increase productivity of the total area. Many different species can be used, some in combination with each other. Fruit trees are often a high priority on farmland. In other areas, trees that produce poles for construction, rafters, and fences may be preferred, such as *Casuarina equisetifolia* or *Tectona grandis*.

Particular attention should be given to vegetation layers nearer the ground surface. Fodder plants, such as Guinea, napier, or elephant grasses, may be of interest for feeding to penned livestock. Perenniel bean species, produced on small woody shrubs for human consumption, may appeal to the local inhabitants. Contour strips can be a good location for introducing new species on a small-scale, experimental basis as well.

12. Trees Along Contour Ridges (Soil Conservation)

For information on the various applicable soil conservation measures that involve construction of contour ridges, or terraces, or excavation of infiltration ditches, a number of texts are available for arid areas in the tropics. The *Centre Technique Forestier Tropical* (CTFT), the *Centro Agronomico Tropical de Investigacion y Enseñanza* (CATIE), the International Council for Research in

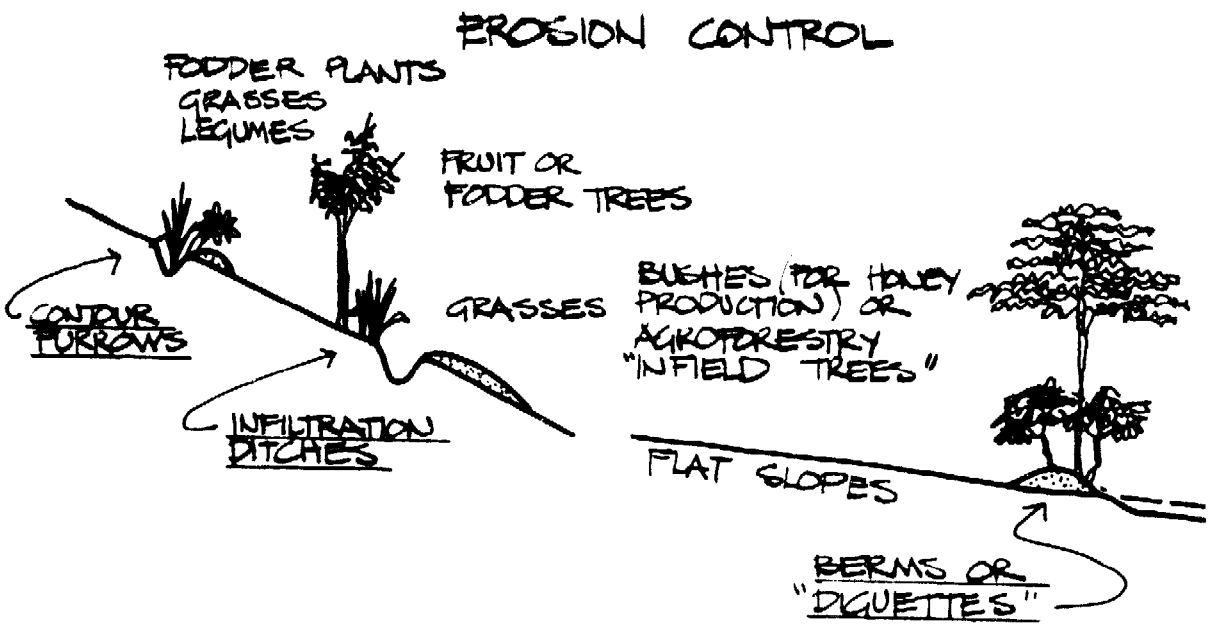

Agroforestry (ICRAF), and the United Nations Food and Agriculture Organization (FAO) have all published handbooks and technical materials on the subject. In addition, many of the bilateral donor organizations have developed standard texts on the subject during the past decade. Construction designs and extension materials have been developed specifically for certain countries, among them Honduras, Kenya, Burkina Faso, and the Philippines. See Appendix E for a list of information sources and bibliography for related materials. See also Chapter 7 for discussion of micro-catchments and contour ridges.

There is still relatively little information available, however, that deals with the effective combination of biological and physical erosion control measures. Vegetation, especially trees and shrubs, can play a vital role in increasing the effectiveness of soil and water conservation efforts. Properly established and managed woody plants can reduce maintenance and costs on hillside erosion control projects as well.

The following sketches show some specific, typical cases where trees and shrubs can make an important contribution to physical ridge or ditch formations along the contour lines of sloping surfaces.

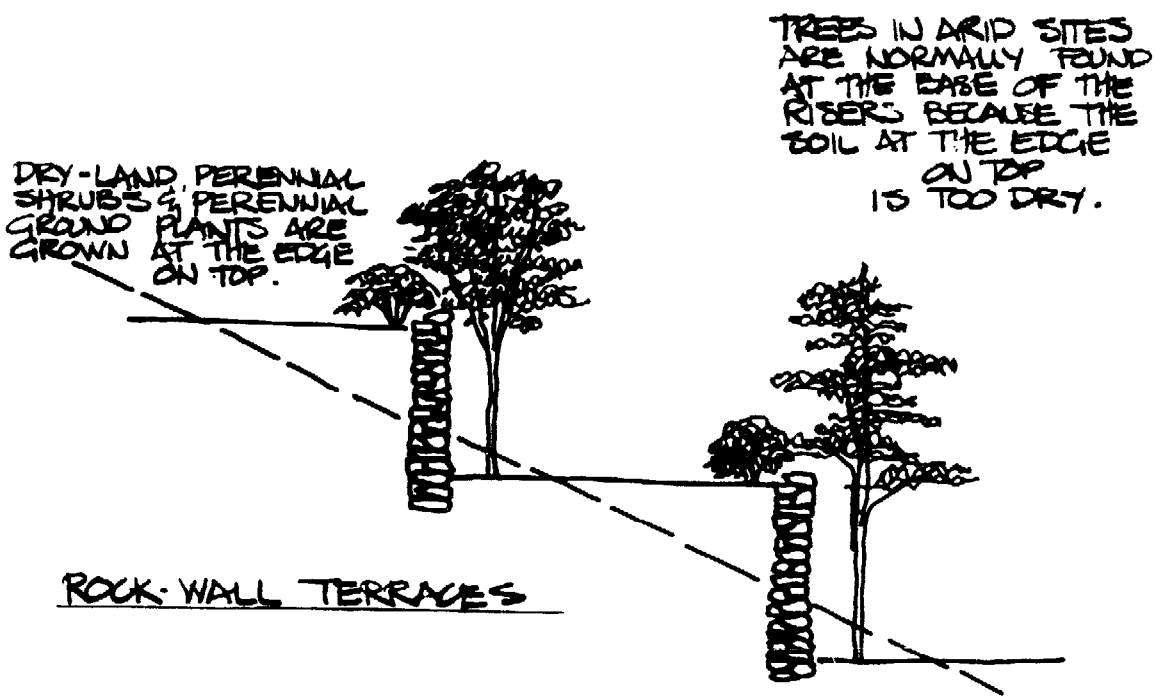

BENCH TERRACES FOR EROSION CONTROL

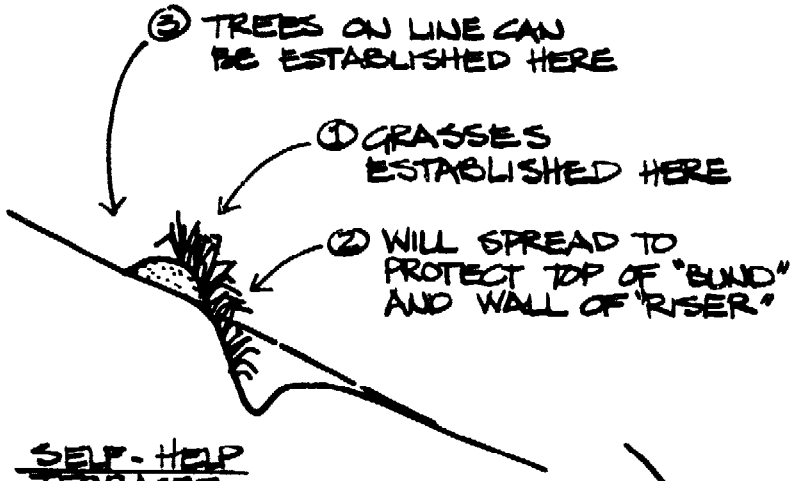

SELF-HELP TERRACES (Kenya)

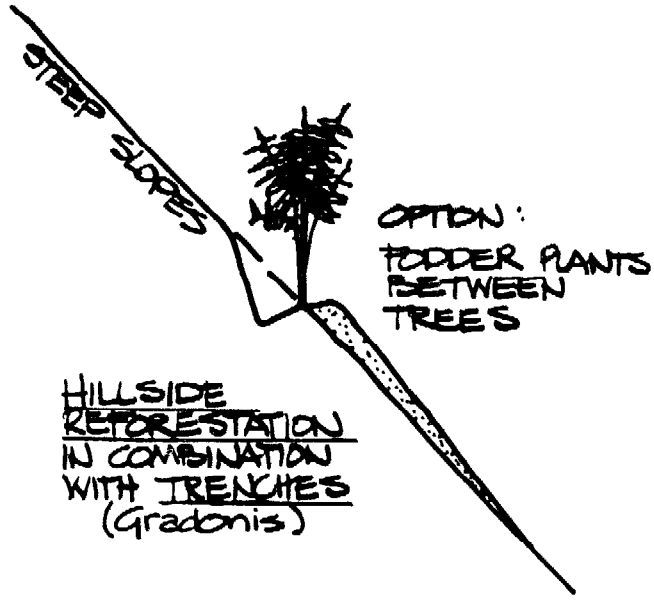

HILLSIDE REFORESTATION IN COMBINATION WITH TRENCHES (Gradonis)

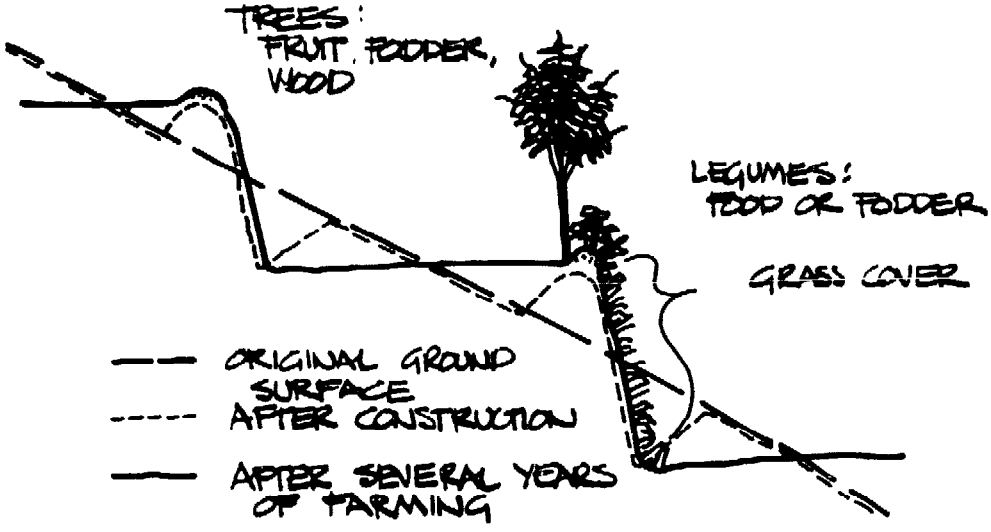

GRADUALLY DEVELOPING BENCH TERRACES

13. Gully Reclamation (Soil Conservation)

Permanent vegetation, especially shrubs and trees, can reduce bank or channel bottom erosion as long as the flow of water is not too powerful. Vegetation can also help stabilize mechanical protection materials, such as large rocks positioned along banks or bottom (rip-rap), wire mesh boxes filled with rocks (gabions), or bales of straw or branches staked in place to reduce water velocities.

Gullies present special problems, because they occur on steep slopes, and even brief peak flows can cause serious damage. Gully erosion is difficult to reverse once it has gotten started, and it can quickly destroy valuable agricultural land.

To prevent the formation of gullies along waterways, line the banks with trees and shrubs, as has been described above under Water Course Alignment (7). Trees, shrubs, and other vegetation can be established within the gullies to control further erosion and to help rebuild the soil layers that have been removed. Improperly placed trees can, however, have the undesired effect of narrowing the channel and increasing the speed of steam flow. The following sketches show how to combine vegetation with mechanical gully erosion control methods for optimal results.

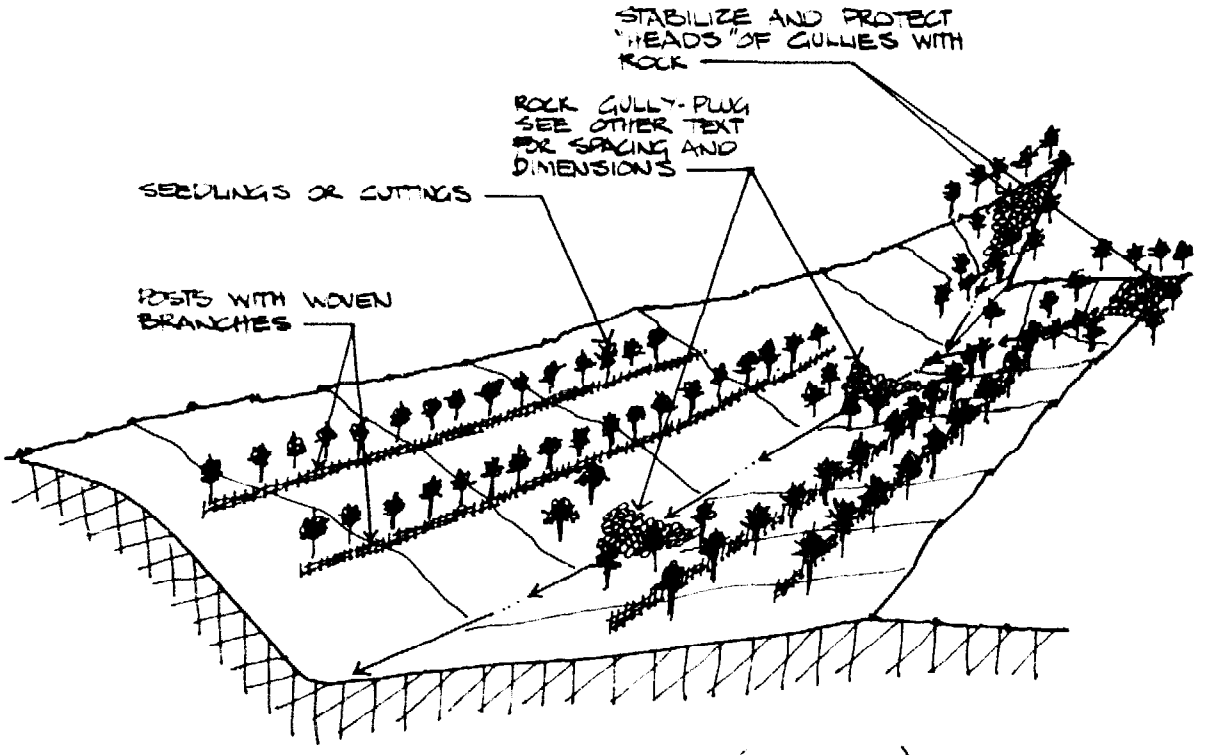

GULLY CONTROL (OVERVIEW)

IMPORTANT DIFFERENCES BETWEEN:
ALLEY CROPPING (2)
CONTOUR STRIPS (11) AND
TREES ALONG CONTOUR RIDGING (12)

ALLEY CROPPING:
ONE OR TWO ROWS OF TREES, FREQUENTLY TRIMMED. FEW PLANTS (WEEDS) COVERING GROUND SURFACE. TOO MUCH SHADE, GROUND OFTEN CULTIVATED. RUNOFF FLOWS AROUND STEMS. LESS EROSION PROTECTION.

CONTOUR STRIP:
SOLID BAND OF MULTI-LAYERED PERMANENT VEGETATION, SEVERAL METERS WIDE. SLOWS RUNOFF AND TRAPS SEDIMENT.

TREES ALONG CONTOUR RIDGING:
HERE, VEGETATION (CAN BE GRASS, SHRUBS OR TREES) IS INTEGRATED INTO SURFACES WHICH HAVE BEEN MECHANICALLY CHANGED. EROSION IS REDUCED MAINLY BY CHANGING SURFACE FEATURES TO WHICH VEGETATION HAS BEEN ADDED TO INCREASE THEIR EFFECTIVENESS AND REDUCE MAINTENANCE WORK.

9 SPECIAL SUBJECTS

Fire

Uses and Prevention

Mention has already been made of the need for firebreaks around both the nursery and the permanent planting site. These serve as protection from fire. Fire does, however, have some important positive uses.

In arid zones, fires are used to burn off old grass. Once that growth is gone, fresh tender grass is more likely to sprout. This happens quite quickly and can help bring relief to starving herd animals. It also limits the tendency of scrub trees and bushes to take over the grass range.

Where vegetation is plentiful, methodical burning is a traditional method of clearing land before planting, keeping snakes and insects in check, ridding the soil of crop diseases, and driving wildlife into traps or within range so that they can be killed for food.

Fire requires oxygen and fuel; if either is eliminated, the fire will not burn. Fire prevention and control consist of removing one of these elements. Normally, the easiest to remove is fuel.

Firebreaks

Prevailing winds in sub-Saharan Africa tend to be high and constant. Thus the spread of a fire can be reasonably well predicted, and the necessary width and direction of firebreaks fairly accurately calculated. Firebreaks should be constructed at right angles to the direction of prevailing winds, with secondary lanes dividing the resulting strips of land or trees.

The high winds dictate wide fire lanes in order to minimize the danger of a fire jumping the lane. Inside planting areas, maintenance and access roads can be combined with strips of cultivated land, adding additional width to the firelanes. As previously mentioned, good protection has been achieved by clearing strips of land 15m wide of all vegetative matter and allowing the land

to be used for cultivating beans or as roadways--either use guaranteeing elimination of dry grasses and weeds.

Plowing the natural vegetation under provides only temporary relief; in the long run, the area becomes a greater fire hazard. Disking and plowing eliminate perennial plants, but make more room for annuals, which tend to become dense and dry. When this happens, the fire spreads more rapidly in the firebreak than on the adjacent land.

Firefighting

Most firefighting efforts are limited to what materials can be found on the spot. Provided the fire is not yet large or too hot, the front of the fire can be attacked directly with branches, brooms, and mats. This is an effort to beat out the flames and kill the fire by shutting down its supply of oxygen.

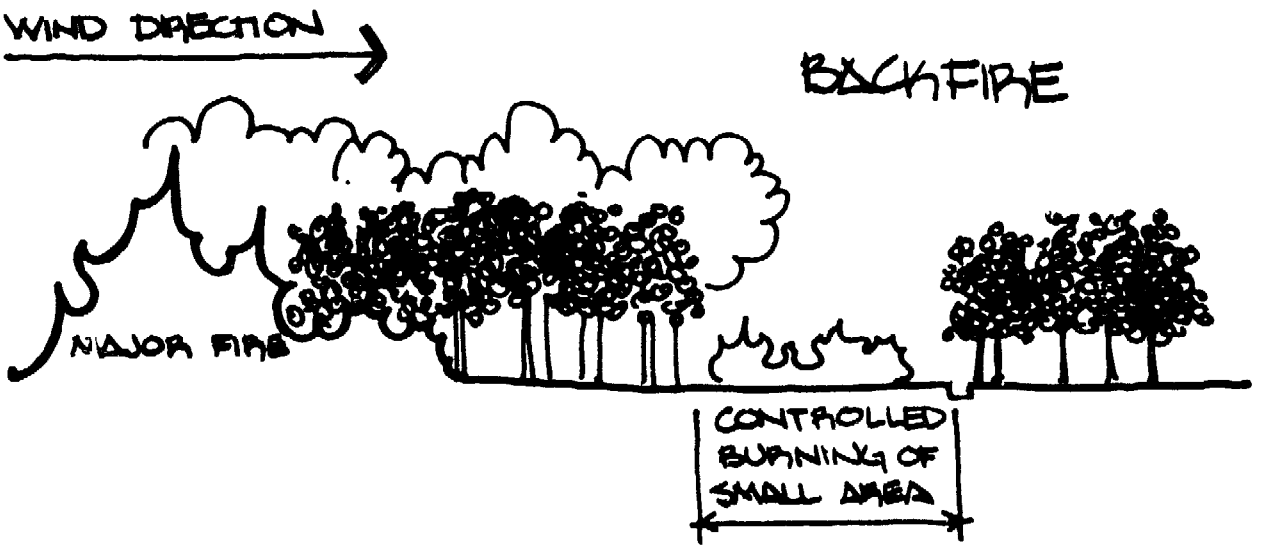

Backfires can be quite effective, particularly in areas where the normal vegetative cover is sparse, the prevailing winds are constant, and necessary control lines can be constructed quickly and easily. A backfire is simply a small controlled fire started in the path of a larger fire. The backfire destroys fuel, and thus halts the larger fire, which has no new fuel to burn.

More on Fencing

The following illustrations show ways of constucting fences to keep out the widest possible number of animals.

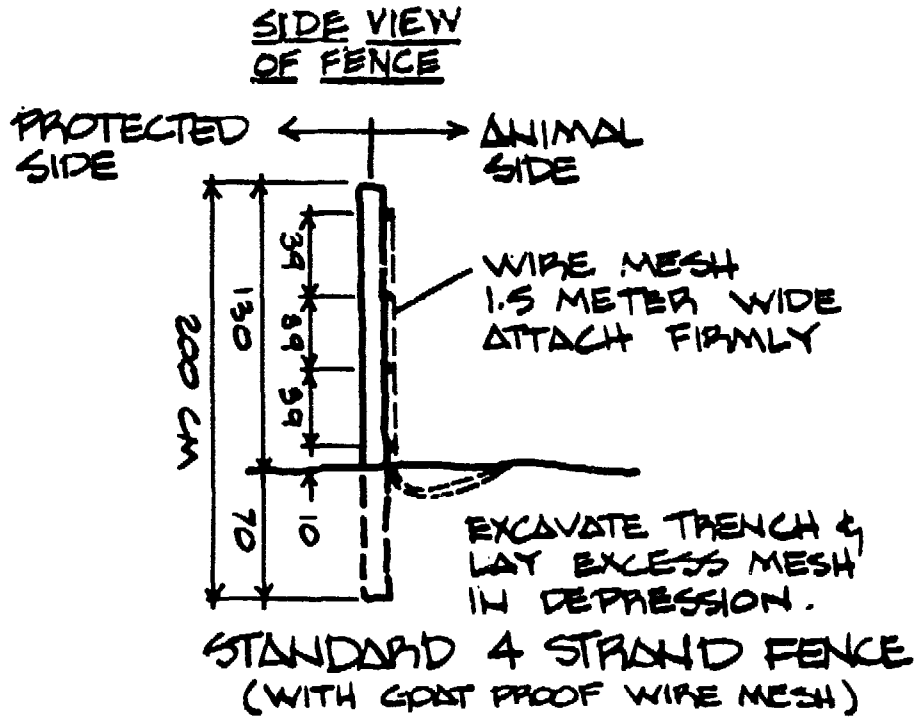

STANDARD 4 STRAND FENCE
(WITH GOAT PROOF WIRE MESH)

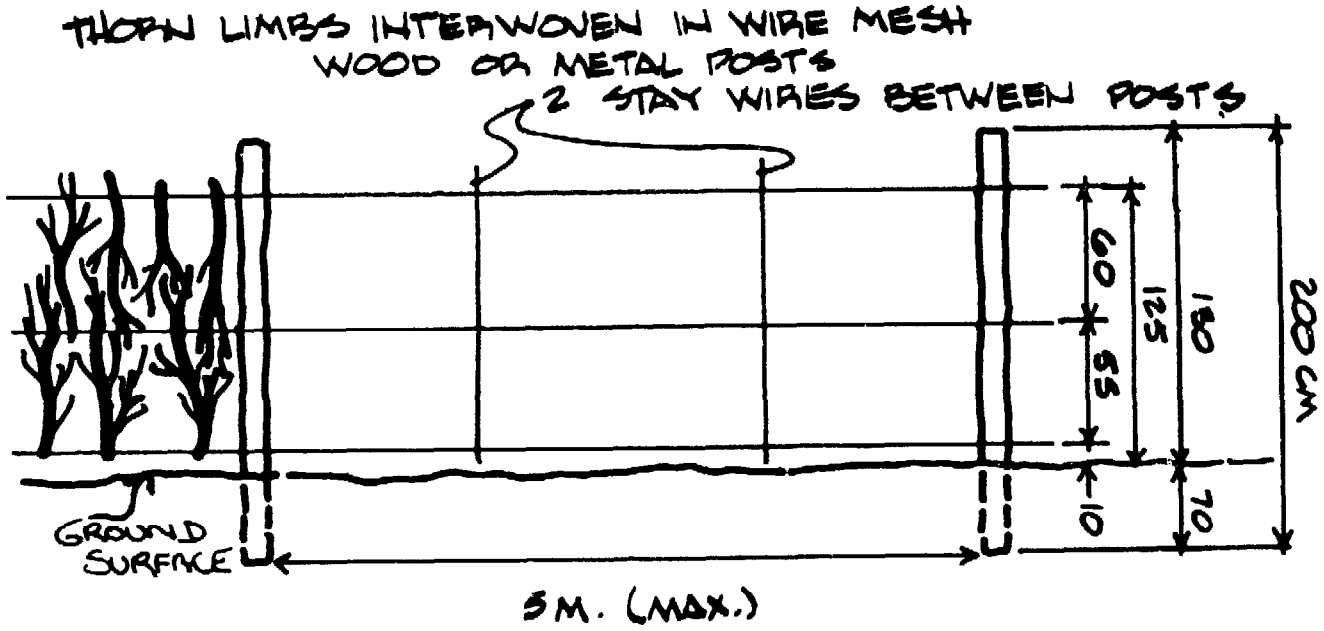

STANDARD 3 STRAND FENCE

(NOTE: MINIMUM IMPORTED MATERIALS)

When using wire for fences, the wire must be stretched tightly between the fence posts if the fence is to remain strong. Tension can be maintained along the fence by making sure that the wire is stretched tightly between posts, and that it cannot slip out of place. When the wire is placed correctly, each post exerts an equal pull against the next post, and this equal pressure creates a tension that keeps the fence posts strong and in place. However, if the tension on one section of the fence is lessened, the posts in this section will begin to lean toward that part of the fence having the stronger pull, and the fence will become weaker and weaker.

Tension becomes harder to maintain as fences get longer or when there are larger spaces between posts. It is generally a good idea to use a line brace every 120-150m. A line brace is pictured below. Sticks are inserted into loops in the wire as shown. These sticks can be twisted to tighten the wire and thereby increase tension.

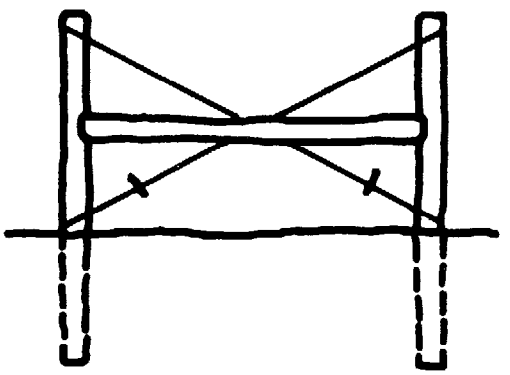

LINE BRACE EVERY 120-150M

Using a Deadman

Corners and openings (for roads, gates) require additional bracing for strength. One such way of providing extra support is by using a deadman. A deadman is simply a heavy stone or block of cement or piece of metal used as an anchor. One end of the fence wire is wrapped securely around the deadman, which is then buried in the ground where it can serve as a permanent anchor. The illustrations following give a clearer idea of the use of the deadman.

A sloping trench is dug as shown. The fence wire is placed around a rock or piece of metal. About midway along the wire, between the top of the post and the deadman, a stick is inserted into a loop of the wire. This stick can then be

Deadman anchoring a gate post

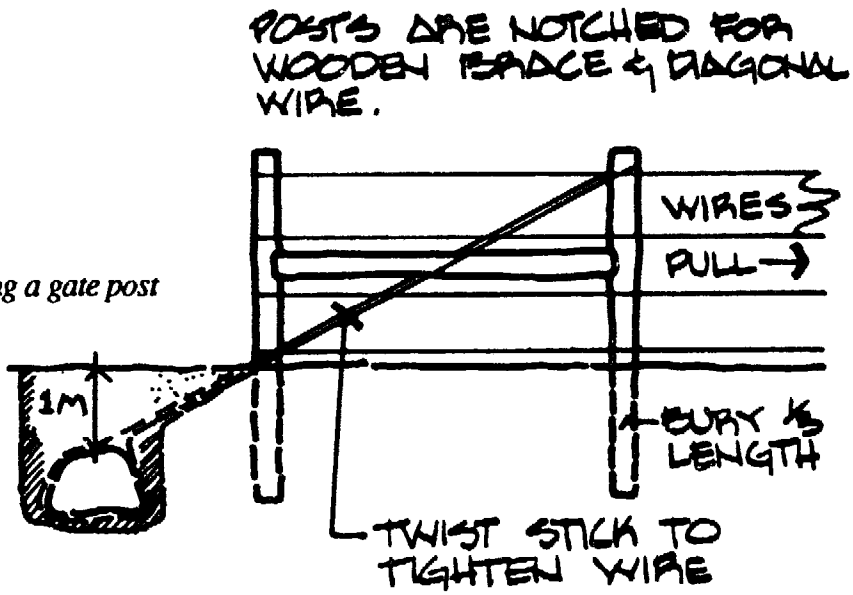

twisted as necessary to tighten the wire and maintain tension. The deadman is placed in the hole so that the wire is tight, and there is a strong diagonal pull. The dirt is piled back into the hole and packed down tightly around the deadman.

The following figure shows one deadman being used to support two posts. The deadman is creating a pull on the posts equal to that being created by the tension of the wire being stretched in the opposite direction.

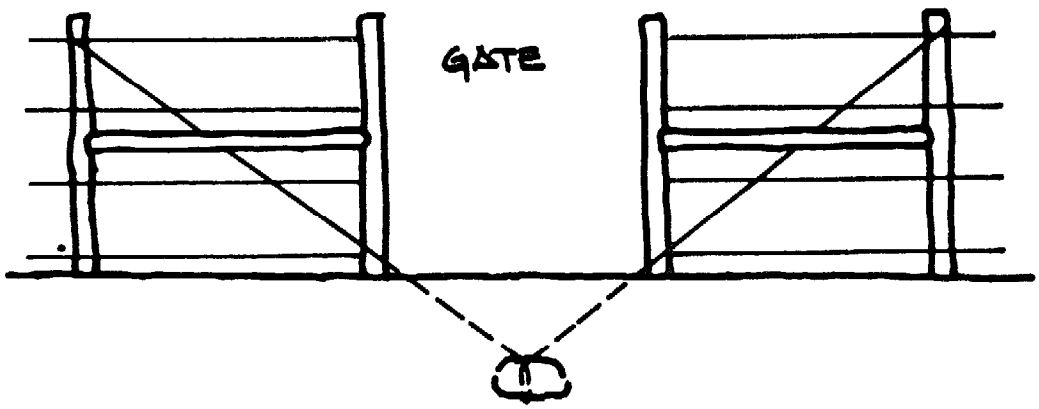

Single deadman anchoring two posts.

DOUBLE DEADMAN

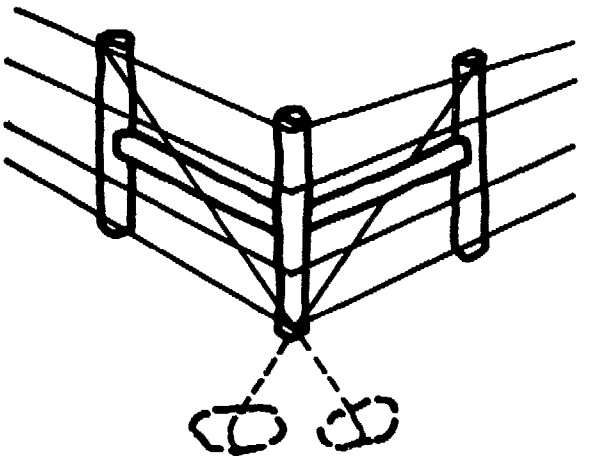

AT CORNERS

A deadman is not the only way to support a corner. The illustration presented here shows how rocks can be used to strengthen corner posts and help maintain tension on the wires.

4 POSTS WRAPPED WITH WIRE MESH/ BARBED WIRE, AND THEN FILLED WITH ROCK.

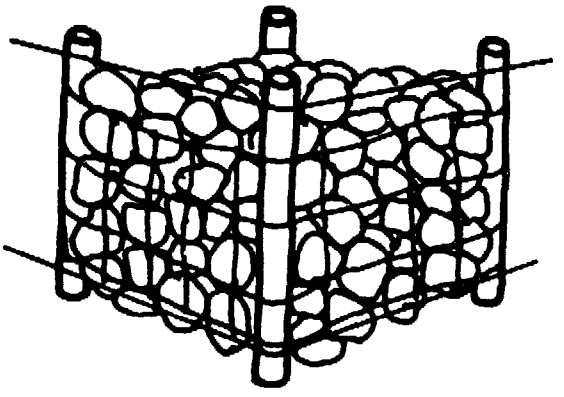

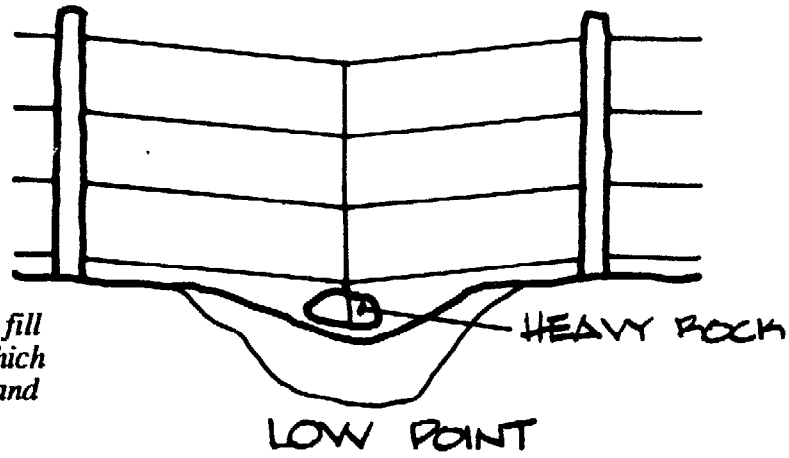

A heavy rock used to fill in a space through which animals might crawl and to maintain tension.

A Self-Closing Gate

Any strong gate that closes tightly is fine. A self-closing gate, however, is even better. People passing through do not have to stop, put down their loads, close the gate, and pick up the load again before going on. Most important, the gate cannot be left open to let animals through by accident.

The gate shown on the following page consists of a strong frame with a diagonal base. Wire fencing material is stretched between the pieces of the frame. The gate is supported by a pair of heavy, well-greased strap hinges. The gate operates very simply: when the gate opens, wood piece "C" swings away from post "F" and pulls the rope through the pulley. The gate closes when the weight on the end of the rope pulls wood piece "C" back into position.

To Make This Gate:

- Wood piece "C" attaches to the gate at the hinge side. "C" should be about one third of the length between posts "A" and "B" (length "AB").
- "C" is braced by pieces "D" and "E."
- Strong cord or rope is attached to the end of "C" and passed through a pulley. The end of the cord is attached to a large rock or other weight.
- Post "F" prevents the gate from opening too far. Allow room for the pulley and knot for attaching rope to "C."
- Hinges, pulley, and weight must work easily for the gate to close properly.

- Gate opens outward from the protected area so animals cannot push it open. No latch is necessary.
- Gate posts are braced to prevent the pull of the wire fencing from tilting them.
- Although pieces "C," "D," and "E" can be made of wood, it is better to use iron if at all possible.

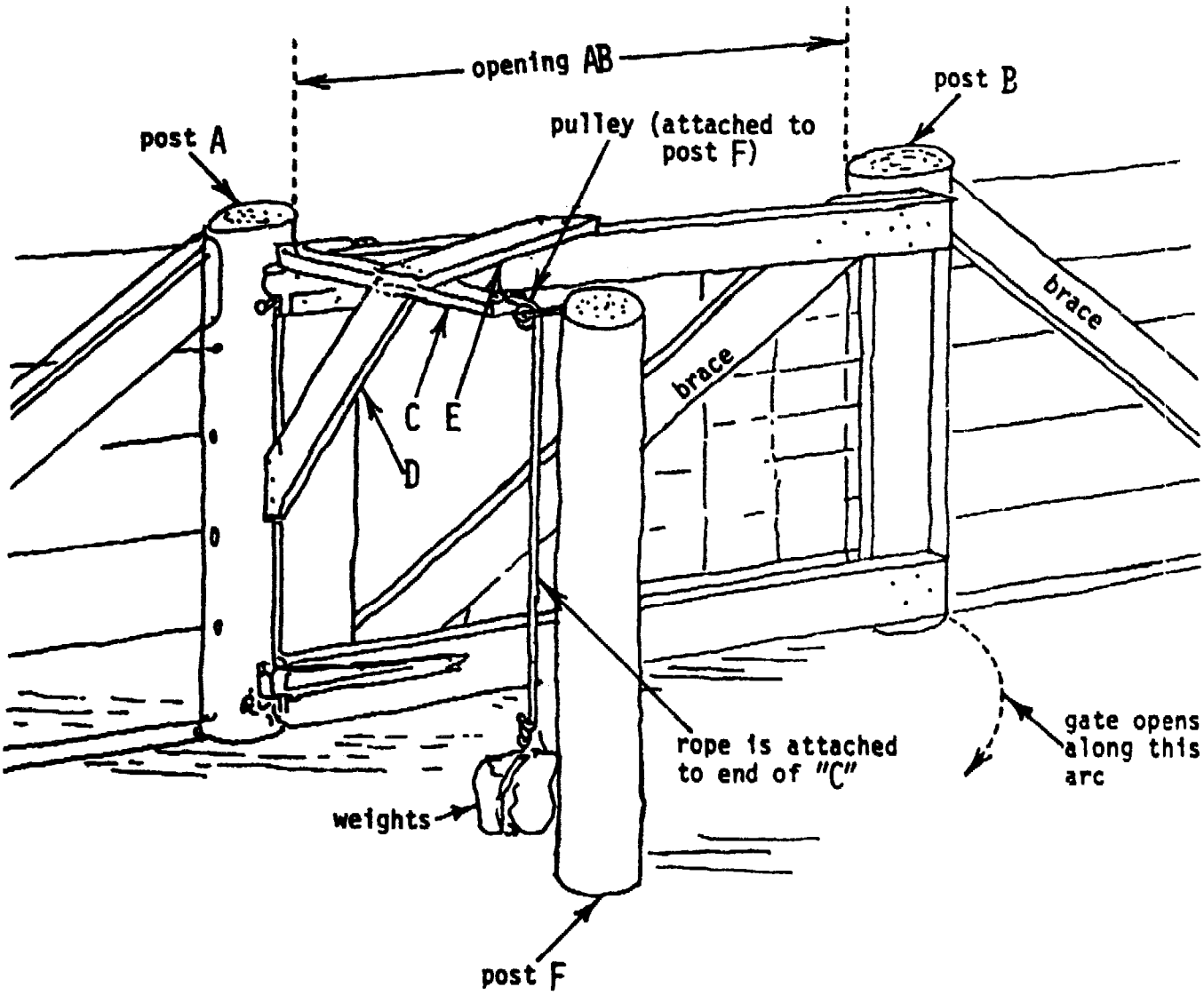

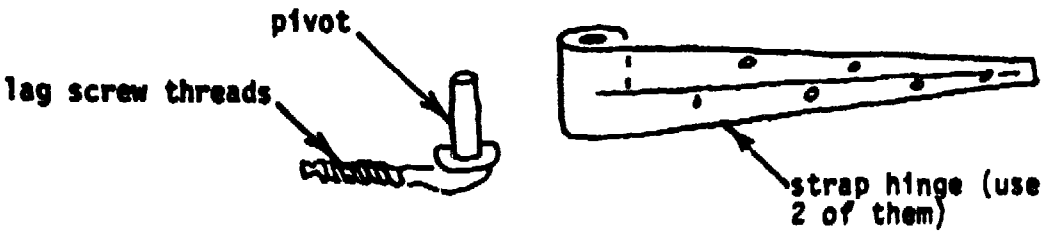

Propagation by Cuttings

Vegetative propagation is the asexual reproduction of individual plants, as opposed to reproduction from seeds. Various methods include grafting, budding, layering, tissue culture, and cuttings; these can be used for different purposes. There are numerous advantages to using vegetative propagation methods; among these the most important are that:

- o Seedlings develop rapidly.
- o Genetic origin can be controlled.
- o Some plant species can only be reproduced asexually. For other species, vegetative methods may be preferred because seed supplies are unavailable or unreliable.

Of the several possible vegetative propagation techniques, one of the fastest and easiest ways to reproduce seedlings is through cuttings. This technique can be used both in the nursery and directly in the field, although only certain species lend themselves readily to this process.

A few species, such as members of the *Euphorbia, Commiphora*, and *Tamarix* genera, which can be established on site from cuttings, also respond well to vegetative propagation in the nursery. Other species, which can be rooted in the nursery and transplanted to the site once the root system is fully developed, include: *Albizzia lebbeck, Azadirachta indica, Cassia siamea, Erythrina seneganensis, Ficus gnaphalocarpa, Guiera senegalensis, Moringa oleifera, Prosopis juliflora, Tamarindus indica,* and *Ziziphus mauritiana.*

An important feature of some tree and shrub species is that cuttings can be established directly at the site where they are to be permanently located. This saves time and expense by bypassing the need for initial propagation in the nursery. Of particular importance to arid areas are species that require relatively little rainfall and soil moisture. *Euphorbias* and *Tamarix* can be propagated this way on very dry sites that receive no more than 200mm per year.

For species that must be produced in the nursery, plastic pots or specially prepared cutting beds are used to start the new plants. The cuttings must not be allowed to dry out, or their ability to regenerate new roots will be diminished, if not destroyed. The pots or beds must have both good water retention capacity and good drainage. The rooting medium should have a high organic matter content; chaff from grain husks can be added to the soil mixture for this purpose. Cuttings started in the nursery are often initially shaded to reduce moisture loss as well.

It is important to adhere to specific procedures for selecting the plant material, and preparing the cuttings. If the prescribed methods are not followed, survival results may be disappointingly low.

Plant Material Collection

The age of the plant material is a primary consideration in collecting cuttings. Rooting responses in plants are controlled by hormones and auxins. The juvenile tissues of some plant species show more active rooting responses than those of older stems. New growth should not be used for cuttings, however, as only wood that has one full year's growth will have buds that will develop during the rooting process. The optimal diameter for plant material selection will vary with different species, but is generally within the range of 1-2cm. Stems that are less than 1cm in diameter will not usually give good regeneration results.

Healthy, vigorously growing specimens should be selected. The criteria described in Chapter 6 under the heading of Seed Tree Selection, can also be applied to the choice of genetically appropriate parent trees for cuttings. The genetic origin of the plant material is even more important in vegetative reproduction than in propagation from seeds, because the individual parent trees are cloned. The reproduced seedlings have the identical genetic makeup as the plant from which the cuttings are taken, unlike offspring from seeds, which will inherit only some of the characteristics of the seed tree.

Cuttings should be taken from dormant plants, so collection of plant material normally takes place during the dry season. The stems should have several buds that have not yet begun to swell or open. A sharp blade should be used to get a clean cut. It is often a good idea to mark the root end of the cutting in some manner, so that it will not be accidentally inserted in the ground upside-down. To prevent cuttings from drying out, store them in plastic bags and protect them from the sun until they can be planted, preferably as soon after collection as possible.

Sometimes cuttings are treated with synthetic substances that stimulate root formation. This is done by dipping the end of the cutting into the rooting solution before placing it into the ground. Although rooting solutions can improve overall plant response, they are not required for many species.

Preparing Cuttings

Just before placing the cuttings in pots or beds, remove about 1cm of stem from the root end of the cutting by making a clean diagonal cut. This is done to remove the tissues that have been exposed to the air, and that consequently are less likely to regenerate. The freshly cut stem can then be placed in the ground or in pots, with 5-10cm above ground. It is important to make sure that the cuttings are completely surrounded by soil, with no air pockets.

Preparing Cuttings for Planting

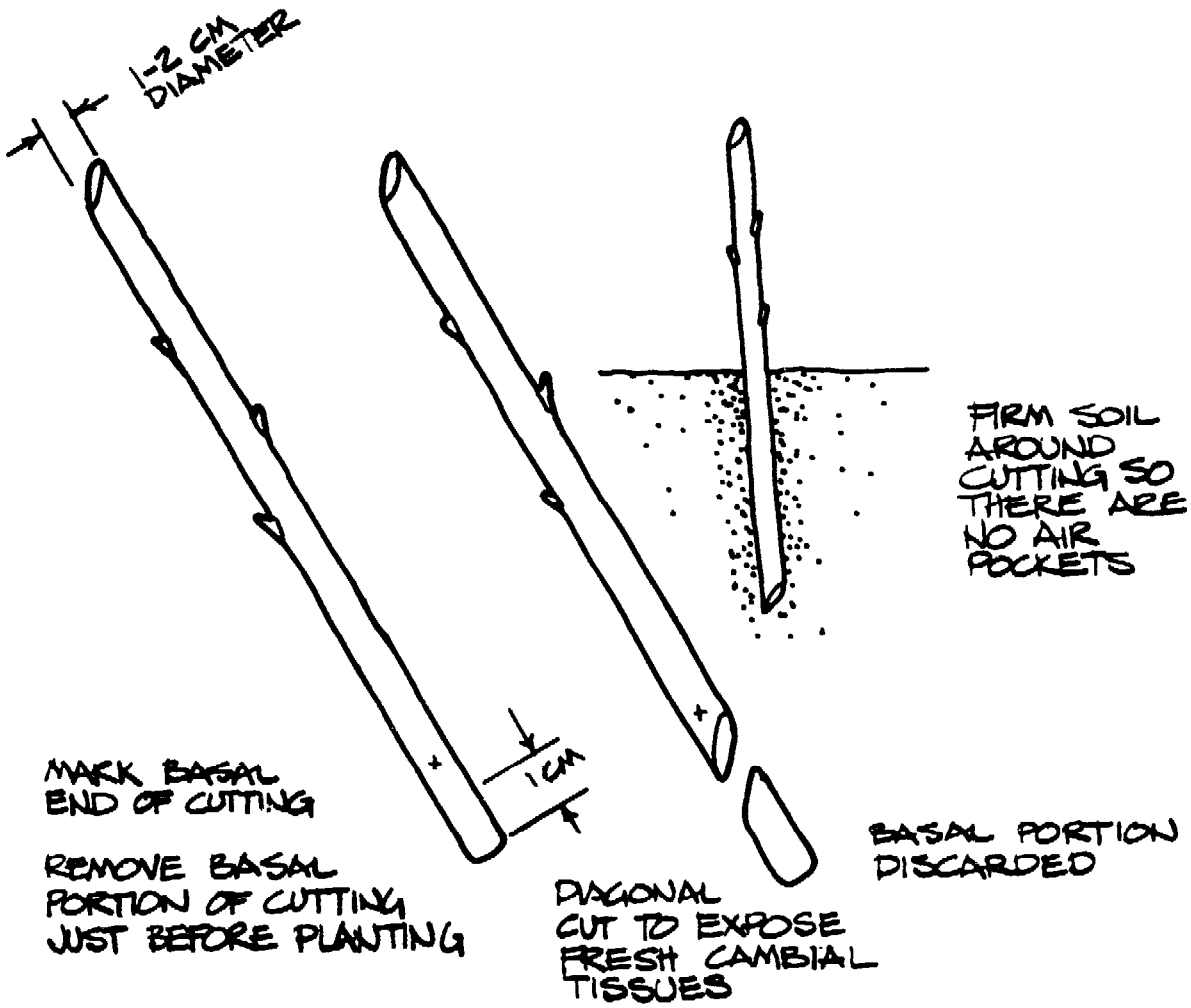

Planting Cuttings

Shallow Planting

The following procedure was developed under a project in Niger for on-site propagation of *Euphorbia balsamifera* cuttings. (Government of Niger, Project PAF, 1985):

- o Length of cuttings: 50-100cm
- o Diameter of cuttings: 1-2cm (although thicker stems can give satisfactory results, provided they are started during the cool season).
- o Provenance/Variety: The natural vegetation found on dune soils will be the best source of plant material for dune stabilization efforts.

- o Depth of hole: 30cm (minimum depth: 20cm)

- o Other important requirements: Cuttings must be planted at their final location no later than 24 hours after they have been cut from the parent plants. To stimulate latex flow, cut a few centimeters of the base of the stem with a sharp blade *immediately* before placing it into the ground.

- o Seasonal limitations: There are two periods during the year in Niger during which the best response to propagation from cuttings was observed:

  --November to February (coolest months) for all cuttings;
  --May to mid-June (hot period before rainy season) for young stems only.

- o Spacing: For complete area coverage, a grid pattern of 2m x 2m (shown below) has given good results at several sites. For establishment of live fencing or for the construction of wind-baffles for dune fixation, single or multiple rows of cuttings are laid out according to the diagrams below:

SPACING

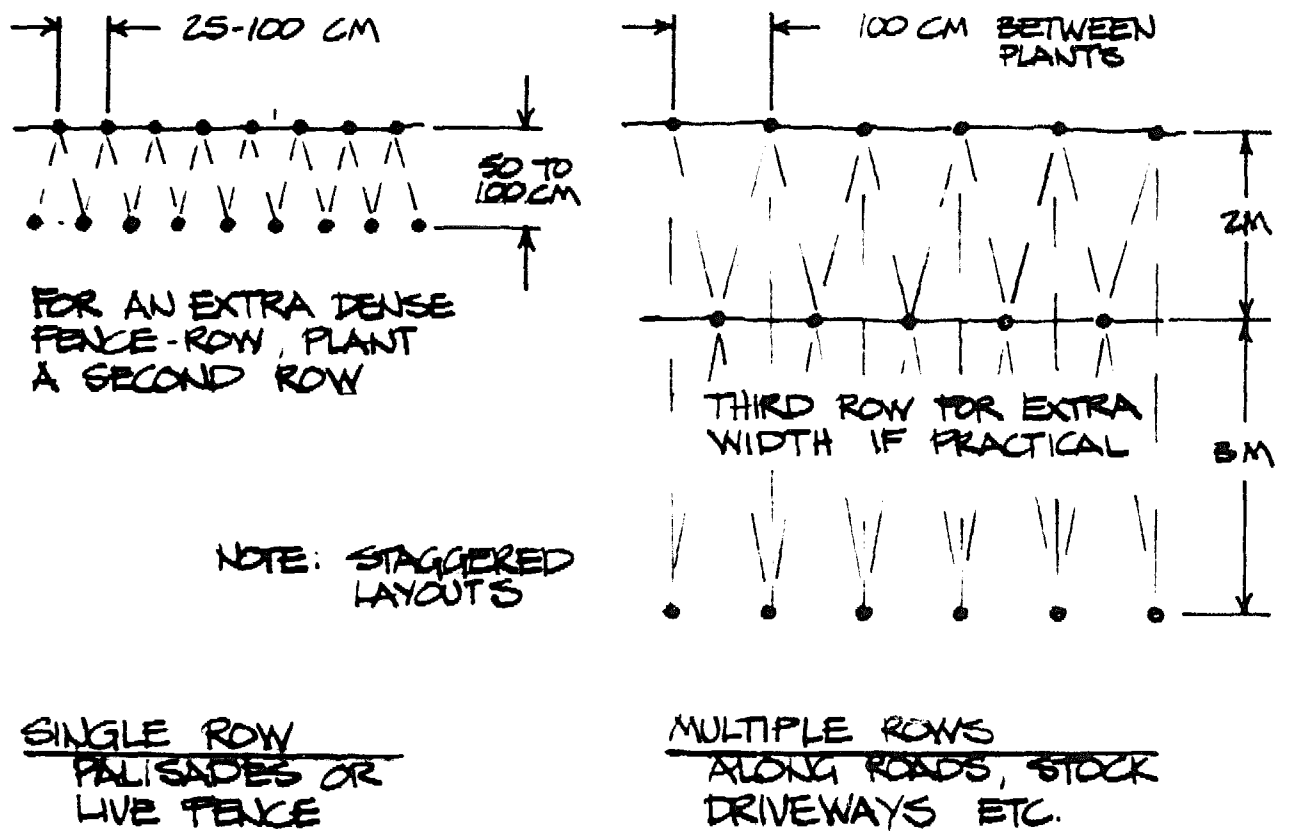

Deep Planting

Another technique for establishing plants from cuttings directly on the site is the deep planting method. Dune afforestation with tamarix cuttings has been quite successful where the following procedures have been used:

- Using a 2-inch soil auger, carefully bore a hole through the dune sand to a depth of two meters. If the sand at the bottom of the hole is dry, choose another spot and try again.
- In the bore holes where moist sand is encountered, insert a tamarix cutting deeply in the hole. Cuttings up to 2m in length have been tried using this method and early rooting and survival results have been over 80 percent.
- Backfill the hole with the cutting in place. This can be done by first pouring 2-4 liters of water down the hole, which will settle the sand at the bottom. Then refill the remaining hole space by hand.

The deep planting technique described above has been successfully used in propagation of other tree species as well. Sometimes a deep pit is dug rather than a bore hole. Deep planting may also provide a solution to problems of establishing trees in soils high in salinity.

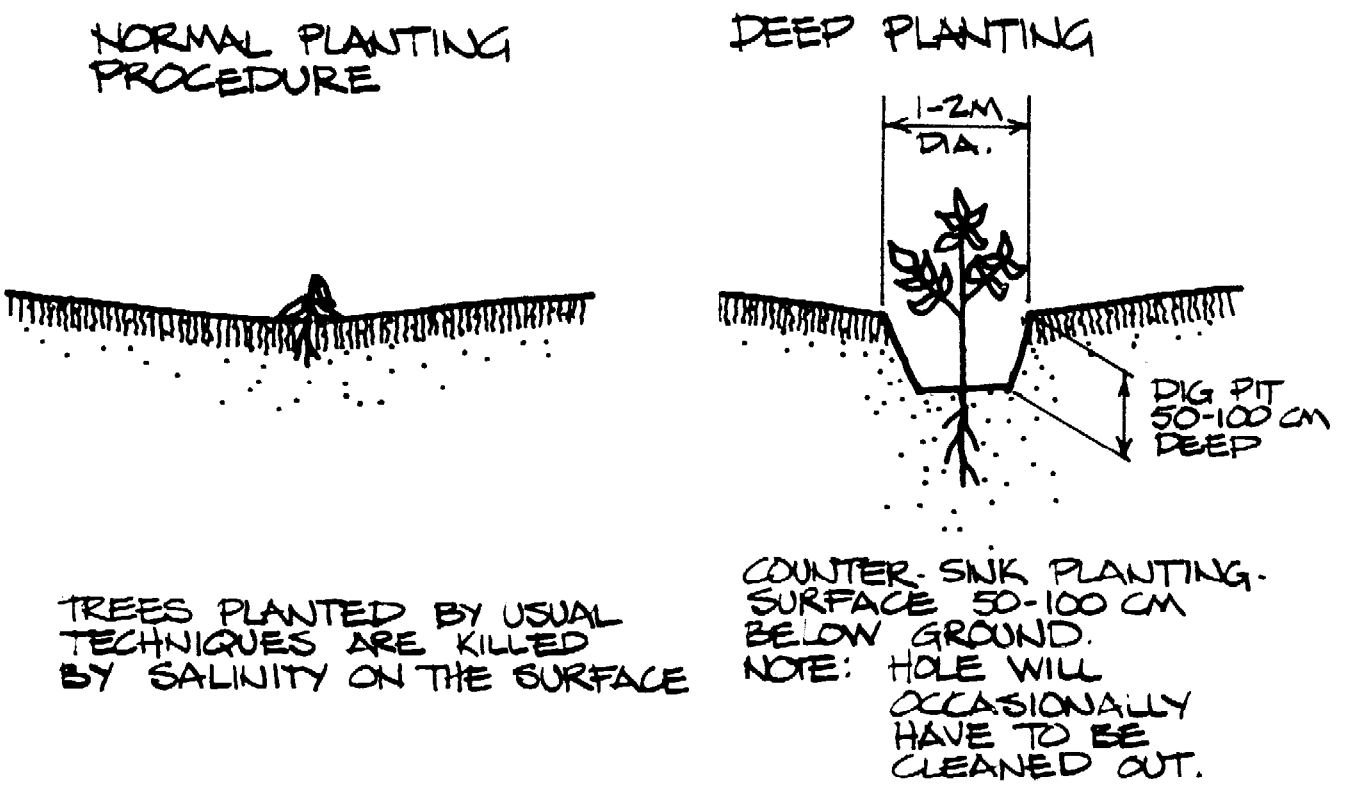

Organizing Planting Operations Using Cuttings

A well organized plan of operation is necessary to ensure that the work can be carried out efficiently, following the correct procedures for vegetative propagation. This plan should include the following elements:

- Coordination of crew assignments, vehicle and equipment needs, collection of planting material, and planting operations
- Training of work crews in how to collect and prepare the cuttings, planting methods, and proper spacing. Work crews should be familiar with the planting site and should be instructed in the plan of operation.
- Location, size, and extent of the natural occurrence of the planting stock must be surveyed.
- Once the stems have been cut, they should be planted with as little delay as possible, at least within 24 hours.
- Although the actual planting process is simple, quality controls are necessary for good survival. In the case of *Euphorbias*, for example, failure to make fresh cuts at the base of the stem, to dig deeply enough, and to backfill properly, can result in high mortality rates.
- Initial efforts should not be overly ambitious, especially when working with a crew that is not highly experienced in propagation techniques.

Other vegetation can be introduced along with the cuttings, to achieve as close to complete vegetation cover as possible. The following species and methods are suggested:

- *Panicum turgidum*: this drought tolerant grass can be direct seeded using the same methods as for millet or sorghum.
- *Cassis occidentalis*: this sturdy plant is sown in pockets or broadcast.
- *Balanites aegyptiaca, Acacia raddiana, Leptadenia pyrotechnica,* and *L. hastata*: these and other indigenous trees and shrubs can be seeded directly or raised in pots and transplanted at the site.

Harvesting Methods

Many of the tree and shrub species mentioned in this text have the capacity to regenerate new growth from stumps, roots, or branches after being cut. This survival mechanism probably evolved in response to fires and drought. In arid areas where it is sometimes difficult to re-establish trees once they have been cut, this adaptation is a particularly valuable characteristic. Wood products can

be repeatedly harvested from such trees and shrubs without destroying the plant.

The time of year that cutting or harvesting occurs can influence the sprouting response. Generally it should take place while the plant is dormant. Species of *Eucalyptus* seem to be fairly flexible as to the time of harvest, but more research is needed to determine the optimal cutting period for these and other species.

The tools that are used to harvest the stems and branches may also affect the plants' ability to send out new shoots. There are some indications that saws, especially chain saws, may damage the cambial tissues to the extent that sprouting is inhibited. Machetes or axes, which may give a cleaner cut, and which are in any case more widely available in rural Africa than saws, may be the best tool for harvesting if regeneration from sprouts is desired. More research is needed on this subject as well.

Several different harvesting methods allow the plant to regenerate through sprouting. The ones that are described here include coppicing, pollarding, lopping, and pruning. Because these terms have been mentioned elsewhere in the text without being defined, short descriptions of each technique are provided below.

Coppicing

This is one of the most widely used harvesting methods for arid land species. When the main stem has reached the desired dimensions, it is cut at the base of the trunk. New shoots develop from the stump or roots. These shoots are sometimes referred to as suckers or sprouts. Only three to four of the most vigorous shoots should be allowed to continue to grow to full size; the others should be cut back to prevent competition for growing space. In subsequent harvests the sprouted stems are removed.

Several rotations of coppicing are usually possible with most species. The length of the rotation depends on the size of the specific wood products that are needed. Some species, such as *Leucaena leucocephala* can be coppiced on a yearly rotation for more than 30 years in more humid zones. Eventually, after several harvests, sprouting vigor will diminish, although this period of viability varies for different species.

Coppice harvesting is a particularly suitable method for production of fuelwood. Coppicing can also be used to increase the density of windbreaks. Most *Eucalyptus* species and many members of the legume family as well as most naturally occurring shrubs (*Combretaceae,Terminaliae,* etc.), can be harvested by coppicing.

Pollarding

With this harvesting system, all of the branches--including the top of the tree--are removed, while the main trunk is left standing. After the branches are cut, new shoots are allowed to sprout from the main stem to form a new crown. The main stem continues to increase in diameter, although not in height. When the tree loses its sprouting vigor, the main stem can also be cut for use as large diameter poles. An advantage of this method over coppicing is that the new shoots are high enough off the ground that they are out of reach of most grazing livestock.

The neem tree, *Azadirachta indica*, is usually harvested in this manner, and its branches can be used for poles, fuelwood, and toothbrushes. Because it is widely planted as a shade tree, pollarding is usually more appropriate for neems than coppicing. Neem trees can be pollarded as often as twice a year; however, it is important to allow the tree to become well established before the first cut. Some other species that also respond well to pollarding include *Eucalyptus* spp. and *Grevillea robusta*.

Lopping

Lopping is a form of harvesting in which only some of the branches are removed. Usually the lower branches are cut, while the upper part of the crown is allowed to continue to grow. New branches then resprout along the lower portion of the stem. This harvesting method can be used to reduce shading when trees are intercropped with other species. As with pollarding, the cut branches are used for a variety of products.

Lopping can also be used to shape a main trunk with a long, clear bole, if the purpose is to produce wood that can be sawn into planks. In this case any new shoots that sprout from the trunk should be removed to prevent the formation of knots in the wood. Branches and shoots should be trimmed as close to the main stem as possible.

Pruning

Pruning, as a harvesting system, usually involves the removal of smaller branches and stems, but these clippings can constitute a major source of wood for fuel and other purposes. Pruned branches are also used as a mulch between tree rows in alley cropping systems.

Pruning is often required for the maintenance of fruit and forage trees, alley cropping, and live fences. For fruit trees, pruning is undertaken to stimulate fruit production and to open up space in the center of the crown, thus facilitating harvesting of the fruit. The same principles can be applied to encourage leaf formation for production of forage. Pruning can also increase the bushiness of trees and shrubs when they are planted for live fencing.

HARVESTING METHODS

COPPICING

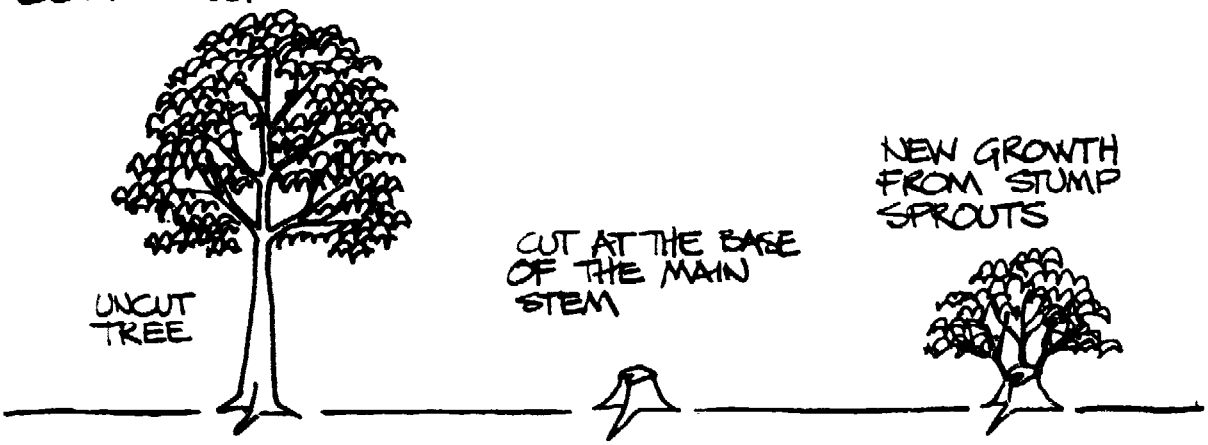

POLLARDING

ALL BRANCHES ARE CUT AT A HEIGHT OF APPROXIMATELY 2 METERS ABOVE GROUND.

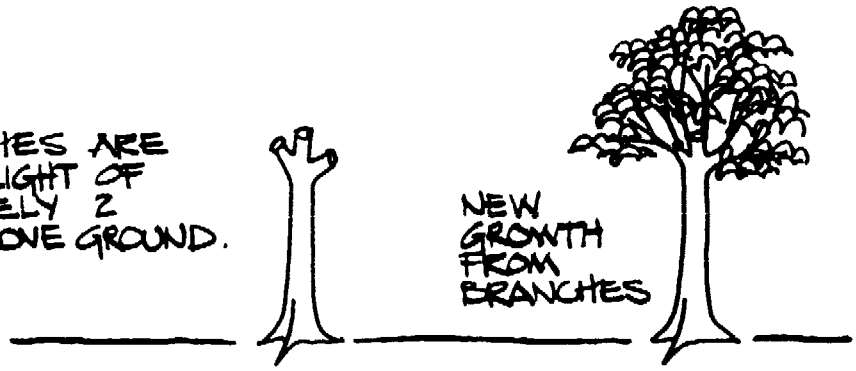

LOPPING

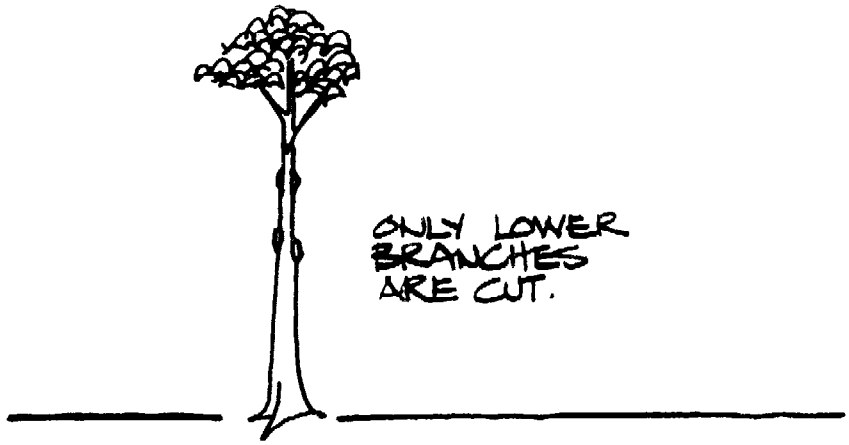

PRUNING

SMALLER BRANCHES ARE TRIMMED TO STIMULATE NEW SHOOT GROWTH.

SEE ILLUSTRATION OF LIVE FENCE PRUNING, PAGE 130

Appendix A

Species Identification

Appendix A

SPECIES IDENTIFICATIONS

This appendix identifies 165 of the species found in West African lands by pictures, Latin names, and common names. Synonyms (other Latin names) for a species, common names in up to 12 languages, and some very brief notations on uses of a species are given where this information is available; it is not intended to be definitive. All the species which appear in Appendix B, where further information is given, are included here, with the notation "Also see APPENDIX B."

Pictures include leaves, branch configurations, fruits, flowers, and inflorescences (arrangement of flowering branches and the flowers on them). They are not labelled individually, but the different items should be recognizable. There is no consistent scale relative to life-size. Illustrations are drawn from Flore Forestiere Soudano-Guineenne by A. Aubreville, Flore Illustree du Senegal and Flore du Senegal by Jean Berhaut, West African Trees by Dr. D. Gledhill, and Trees for Vana Mahotsava by S. K. Seth, M. B. Raizada, and M. A. Waheed Khan. The artists are J. Adams, M. J. Vesque, Jean Berhaut, Douglas E. Woodall, and P. Sharma.

A NOTE ON LATIN NAMES

- The genus and species of each tree appear in boldface type (genus first, species second).
- An abbreviation of the name of the author of the tree name follows the boldface type in lighter faced type.
- "var." means variety. The name of the variety appears in boldface immediately following the abbreviation "var."
- An abbreviation of the name of the author of the variety name follows the name of the variety in lighter faced type.
- "L." is an abbreviation for "Linnaeus," a Swedish botanist who initiated the development of this present, widely used system of nomenclature.

Drawings in this appendix are reprinted, with permission, from the following sources:

Aubreville, A., *Flore Forestiere Soudano-Guinéene*, Paris, Société d'Editions Geographiques, Maritimes et Coloniales, 1950.

Artists: J. Adams, M. J. Vesque

Berhaut, J., *Flore Illustrée du Sénégal*, Direction des Eaux et Forêts, Government du Sénégal, 1975.

Artist: J. Berhaut

Gledhill, D., *West African Trees*, London, Longman Group Ltd., 1972.

Artist: Douglas E. Woodall

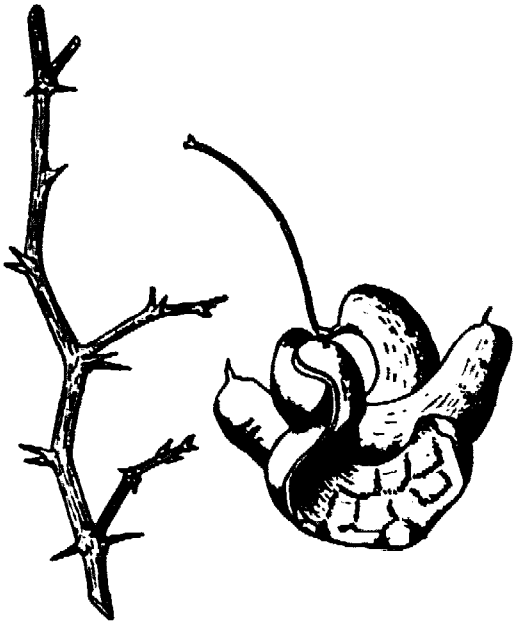

1. **Acacia albida** Del.

Also see APPENDIX B

SYNONYMS:

Faidherbia albida (Del.) Chev.
Acacia gyrocarpa Hochst.
Acacia saccharata Benth.

ENGLISH	gao	FULANI	tlaiki
FRENCH	gao	HAUSA	gao
ARABIC	harraz	KANOURI	haragu
CHAD ARABIC	eraza	MORE	zanga
BAMBARA	balanzan	SONGHAI	gao
DJERMA	gao	WOLOF	cadde

2. **Acacia ataxacantha** D.C.

BAMBARA	bonsoni	DJERMA	kougou
	sofakaueni	HAUSA	goumbi
	korr		

Use for live fences, posts, firewood, fodder (valuable), branch fencing

3. **Acacia caffra** Willd. var. **campylacantha** Aubr.

Also see APPENDIX B

SYNONYMS:

Acacia campylacantha Hochst., ex A. Rich.
Acacia catechu W.
Acacia polycantha Willd. subsp. *campylacantha* (Hochst.) Prenah

CHAD ARABIC	al guetter	HAUSA	karo
BAMBARA	kuroko		tserkakia
FULANI	fatariahi	KANOURI	golawai
		MORE	guara

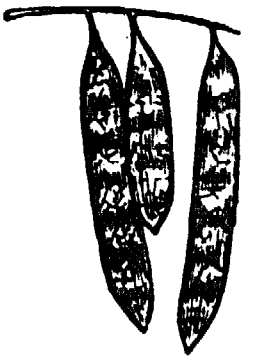

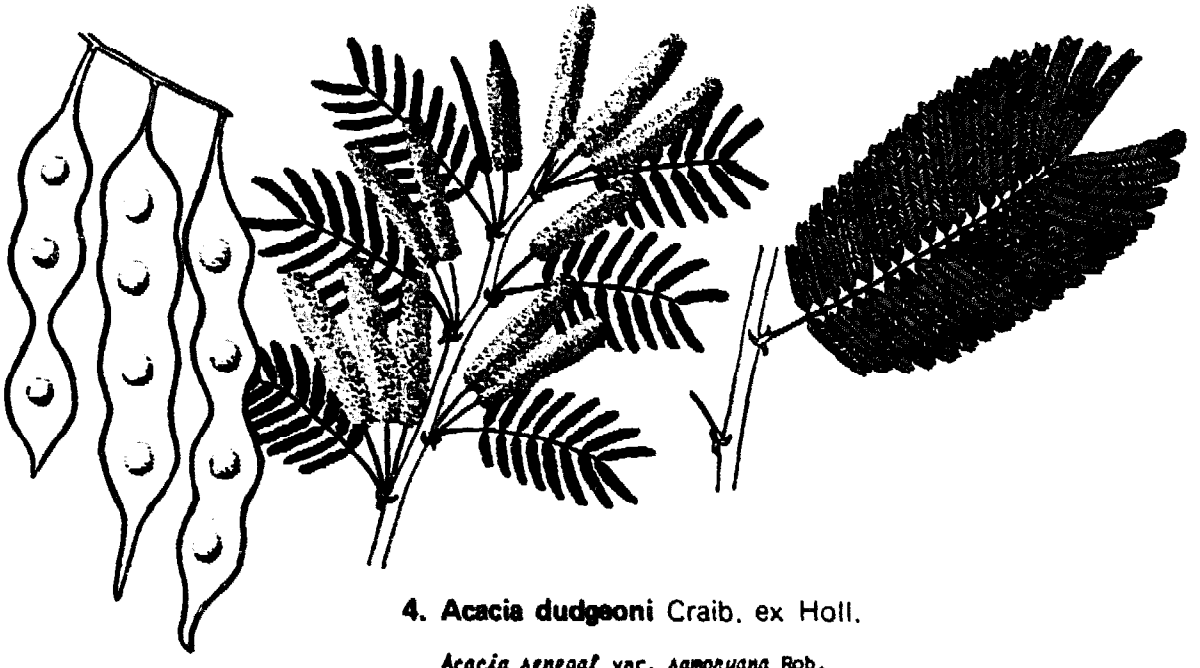

4. Acacia dudgeoni Craib. ex Holl.

Acacia senegal var. *samoryana* Rob.
Acacia samdry

5. Acacia farnesiana Willd.

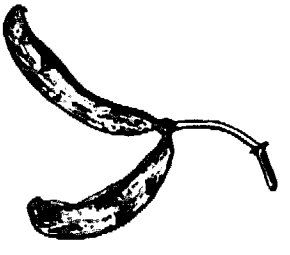

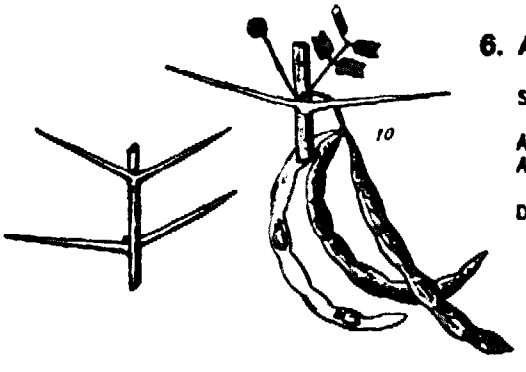

6. Acacia flava (Forsk.) Schwfth.

SYNONYMS:

Acacia flava ver. *atacorensis*
Acacia atacorensis

DJERMA tamat monne HAUSA tamat

7. Acacia gourmaensis A. Chev.

not illustrated

MORE gonponiali
gonsablega

Like *Acacia mellifera* in East Africa

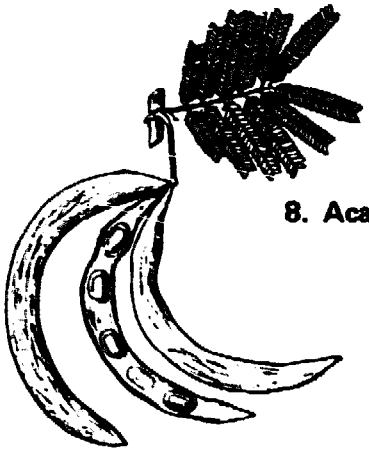

8. Acacia hebecladoides Harms.

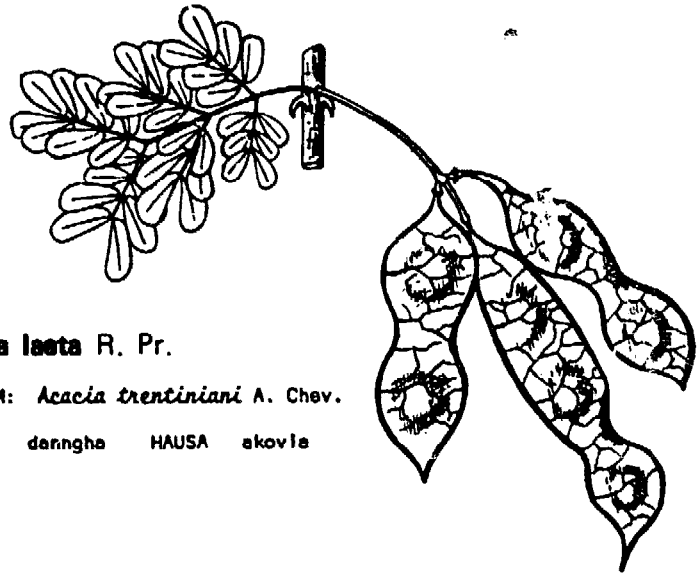

9. Acacia laeta R. Pr.

SYNONYM: *Acacia trentiniani* A. Chev.

DJERMA danngha HAUSA akovia

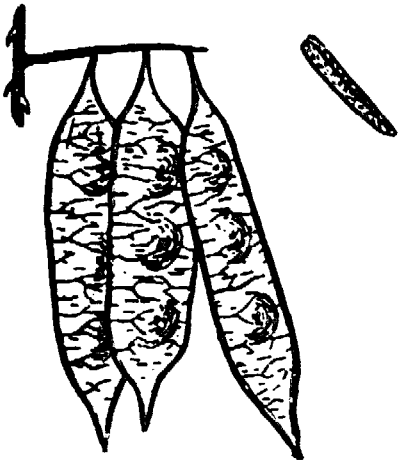

10. Acacia macrostachya Reichenb.

BAMBARA	ouenidie	FULANI	chidi
	kordontinio		paterhami
	mbourour	MORE	karedega
DJERMA	goumbi		guembaogo

Use for edible seeds, leaves to graze, live fences, posts, firewood, fodder (valuable), branch fencing

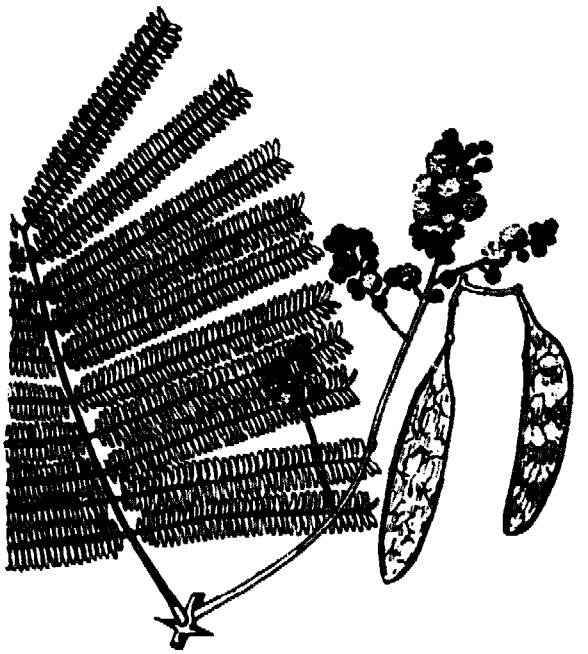

11. Acacia macrothrysa Harms.

SYNONYMS:
Acacia dalzielii Craib.
Acacia prorsispinnata Stapf.
Acacia buchananii Harms

KANOURI gardaye

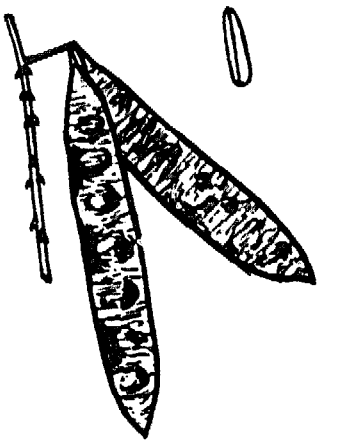

12. Acacia pennata Willd.

13. Acacia raddiana Savi.

SYNONYMS:
Acacia tortilis Hayne
Acacia fasciculata Guill. & Perr.

CHAD ARABIC	salale	FULANI	chilluki
BAMBARA	sayele	HAUSA	kandili
DJERMA	bissau	KANOURI	kandii

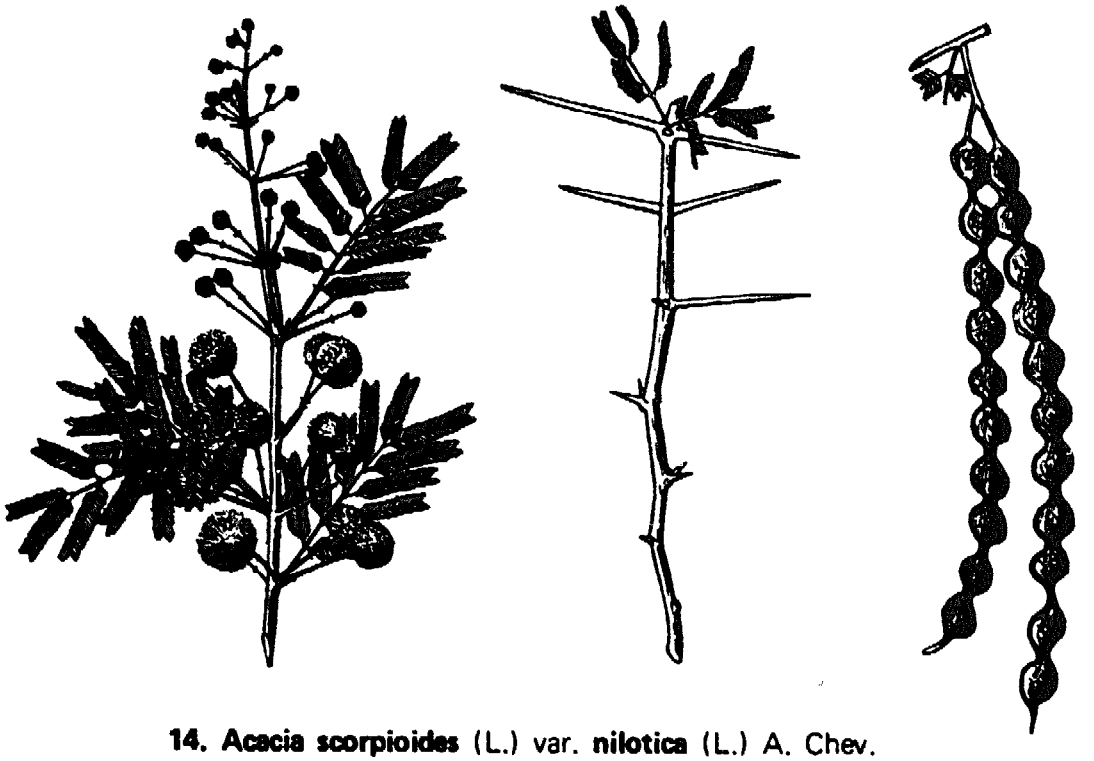

14. **Acacia scorpioides** (L.) var. **nilotica** (L.) A. Chev.

Also see APPENDIX B

SYNONYMS: *Acacia nilotica* (L.) Willd.
Mimosa nilotica L.
Acacia arabica (Lam.) var. *nilotica* (L.) Benth.

FRENCH	gonakier	DJERMA	bani
CHAD ARABIC	sunta, charat, senet, sunt	FULANI	gaudi
		HAUSA	bagarua
BAMBARA	barana	MORE	peguenega
	diabe		
	boina		

Found in lowlands; near water or in moist soils

15. **Acacia scorpioides** (L.) var. **adstringens** Bak.

SYNONYM: *Acacia adansonii* Guill. & Perr.

FRENCH	gonakier	DJERMA	bani
CHAD ARABIC	sunta, charat, senet, sunt	FULANI	gaudi
		HAUSA	bagarua
BAMBARA	barana	KANOURI	kangar
	diabe		kissau
	boina	MORE	perananga

Found in highlands, in drier environments

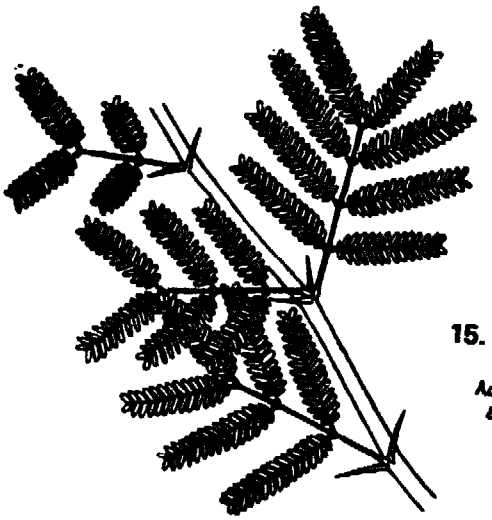

15.

Acacia scorpioides var. *adstringens*

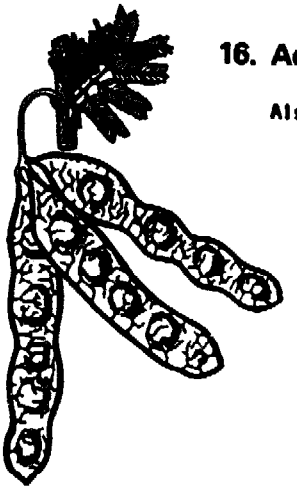

16. **Acacia senegal** (L.) Willd.

Also see APPENDIX B

SYNONYM: *Acacia verek* Guill. & Perr.

ENGLISH	gum arabic	FULANI	dibehi
FRENCH	gommier		patuki
CHAD ARABIC	asharat	HAUSA	dakworo
	kitr al ablod	KANOURI	kolol
BAMBARA	donkori	MORE	goniminiga
DJERMA	danya		

Source of gum arabic

17. **Acacia seyal** Del.

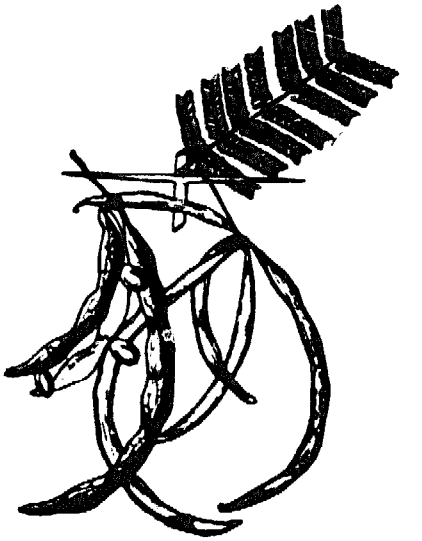

SYNONYMS: *Acacia stenocarpa* Hochst.
Acacia boboensis Aubr.

CHAD ARABIC	talhaye	HAUSA	farin kaya
BAMBARA	sagnie	KANOURI	karamga
DJERMA	saykire	MORE	gompelaga
FULANI	bulki		

Use for firewood, fodder

18. **Acacia sieberiana** D.C.

Also see APPENDIX B

SYNONYMS:

Acacia verugera Schweinf.
Acacia singuinea Guill. & Perr.
Acacia rehmanniana
Acacia villosa
Acacia fischerii
Acacia monga
Acacia verhmoensis
Acacia nefasia Schweinf.

CHAD ARABIC	kuk
BAMBARA	bakl
FULANI	gle danejl
HAUSA	boudjl
	dushe
KANOURI	katalogu
MORE	golponsgo

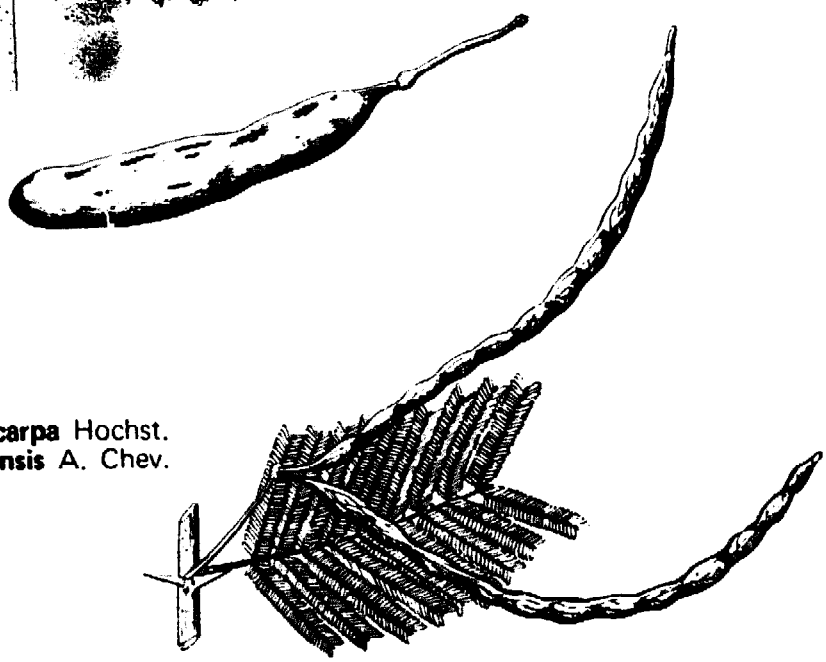

19. **Acacia stenocarpa** Hochst. var. **chariensis** A. Chev.

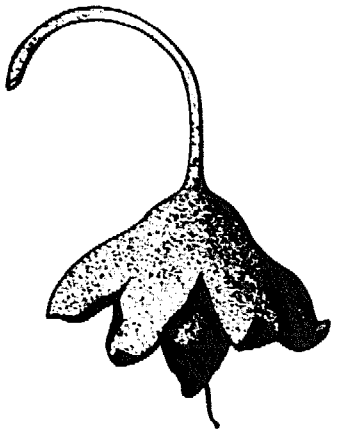

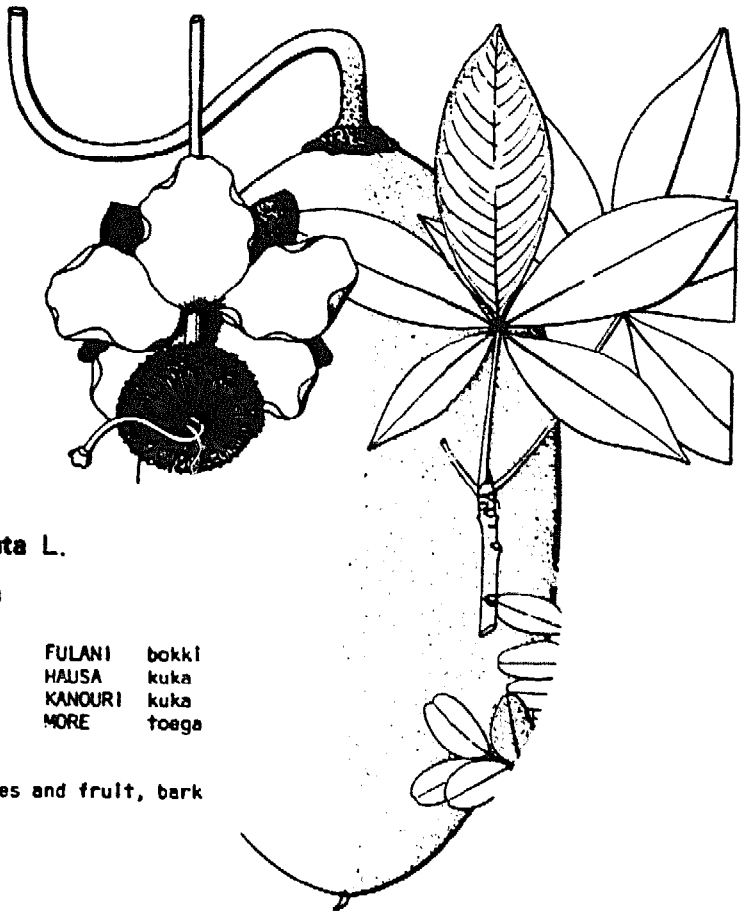

20. Adansonia digitata L.

Also see APPENDIX B

ENGLISH	baobab	FULANI	bokki
FRENCH	baobab	HAUSA	kuka
CHAD ARABIC	hahar	KANOURI	kuka
BAMBARA	sito	MORE	toega
DJERMA	konlan		

Use for edible leaves and fruit, bark for fiber products

21. Adenium obaesum (Forsk.) Roem. et Schult.

SYNONYMS: *Adenium arabicum* Palf. f.
Adenium coetaneum Stapf.
Adenium hongkel A. x.

CHAD ARABIC	kuka meru
BAMBARA & SONRE	foukala sitandi kongosita
FULANI	leki peouri
HAUSA	karya

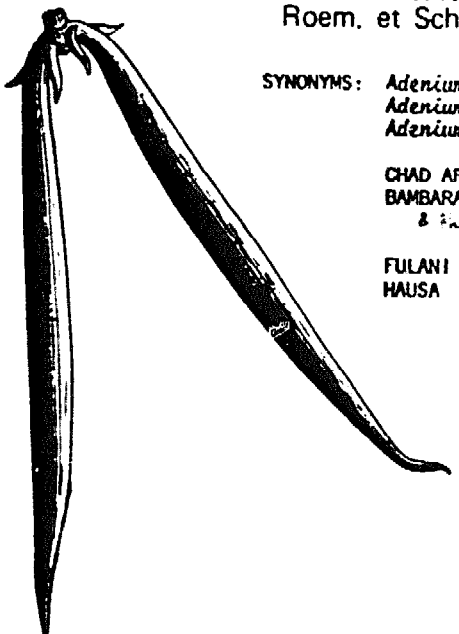

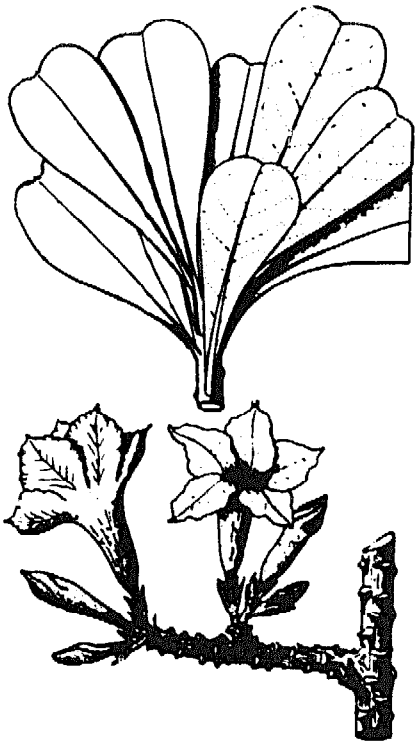

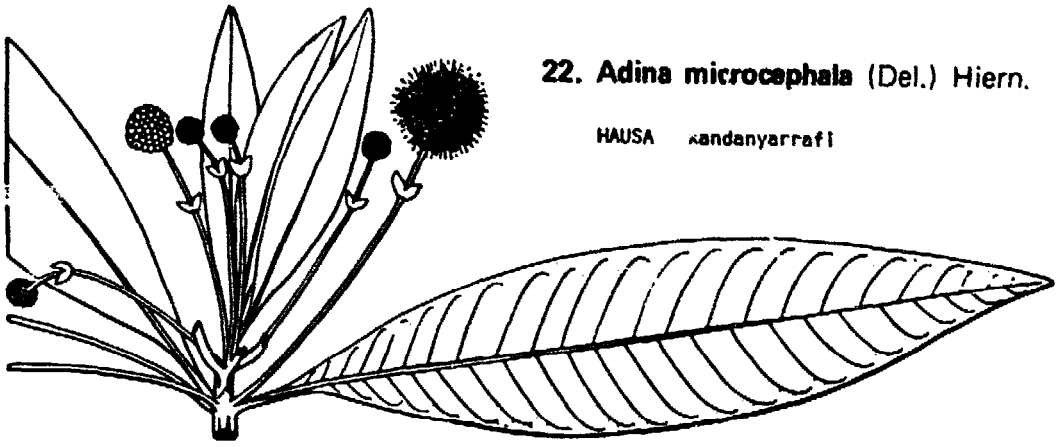

22. Adina microcephala (Del.) Hiern.

HAUSA kandanyarrafi

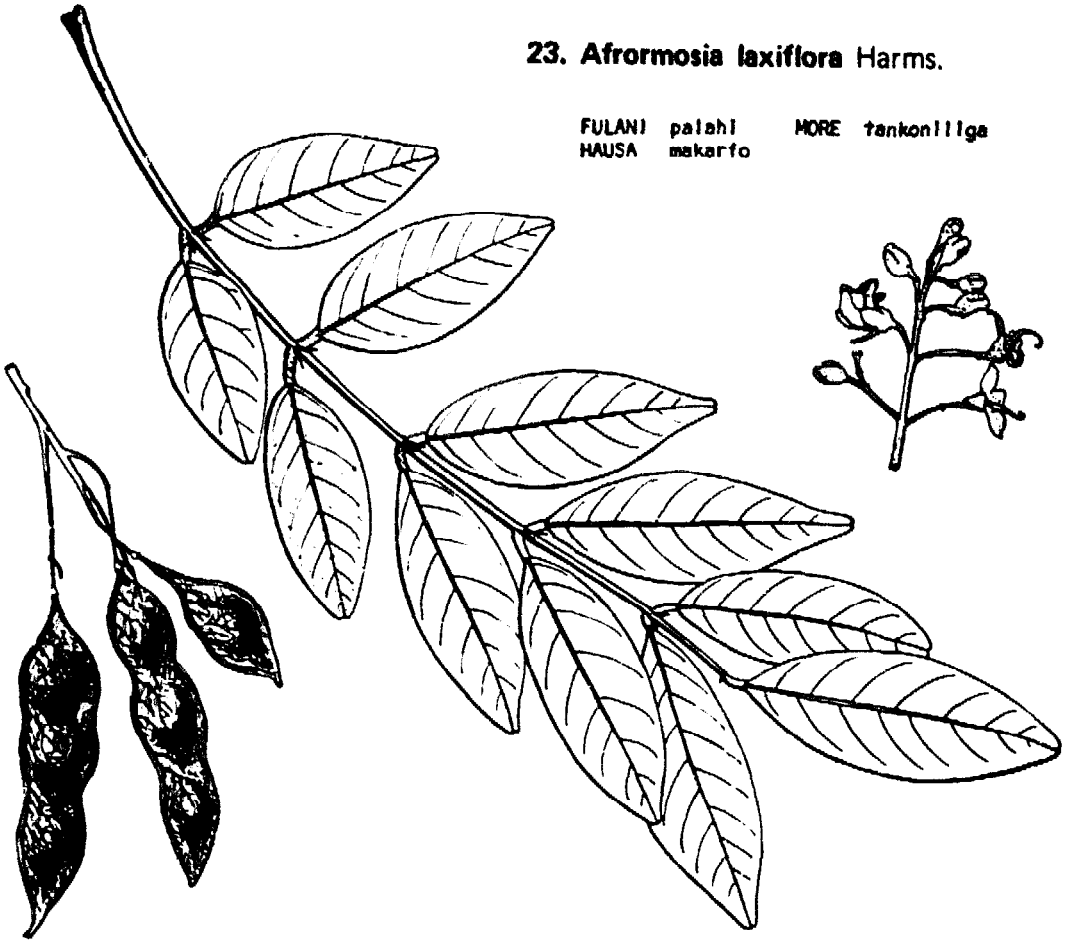

23. Afrormosia laxiflora Harms.

FULANI palahi MORE tankonilliga
HAUSA makarfo

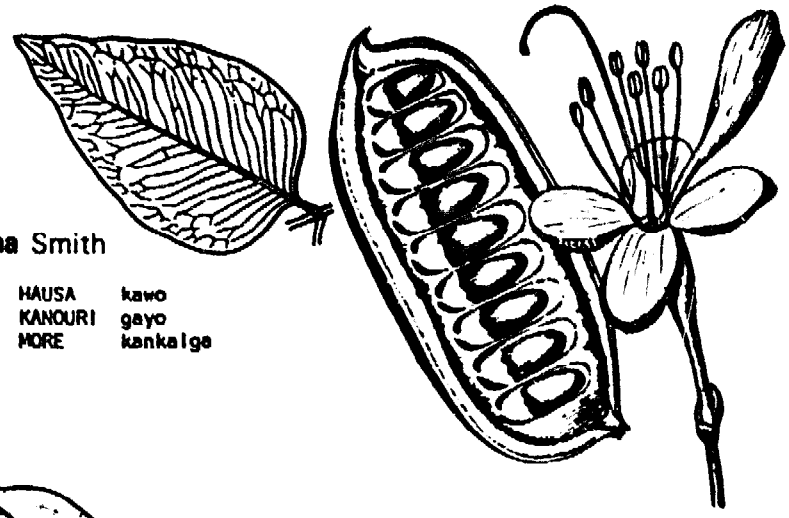

24. **Afzelia africana** Smith

FRENCH	linguo	HAUSA	kawo
DJERMA	kao	KANOURI	gayo
FULANI	gayohi	MORE	kankaiga

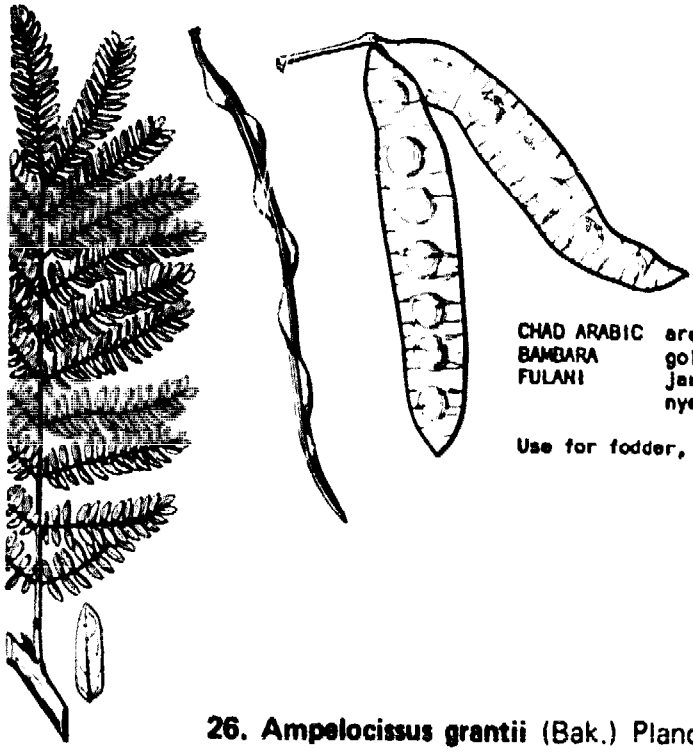

25. **Albizzia chevalieri** Harms.

Also see APPENDIX B

CHAD ARABIC	ared	HAUSA	katsari
BAMBARA	golo iri	KANOURI	tsagie
FULANI	jarichi	MORE	ronsedonga
	nyebai		

Use for fodder, construction, roots to repair gourds

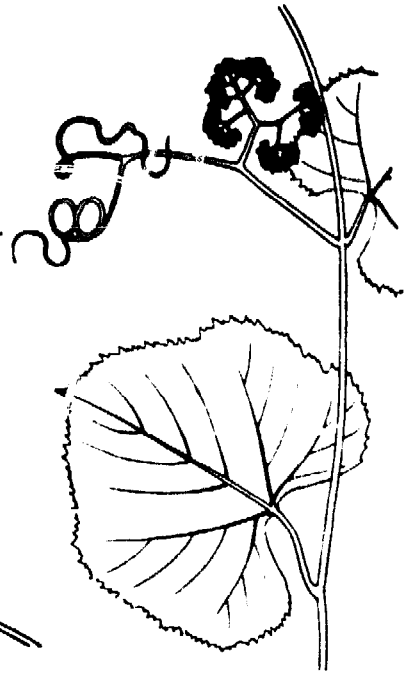

26. **Ampelocissus grantii** (Bak.) Planch.

HAUSA	rogon daji
FULANI	gufugafai

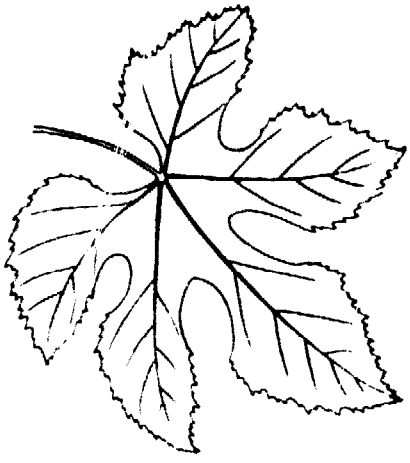

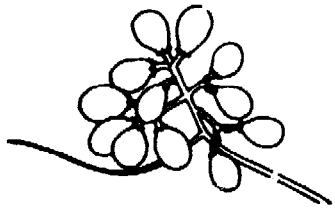

27. Anacardium occidentale L.

Also see APPENDIX B

Use for edible nut (valuable), firewood, construction, soil regeneration

28. Anciomanes difformis not illustrated

HAUSA cakara KANOURI gazamangal

29. Andira inermis H.P. & K.

FULANI daluhi
HAUSA madobia
gwaska
MORE ouenlebende

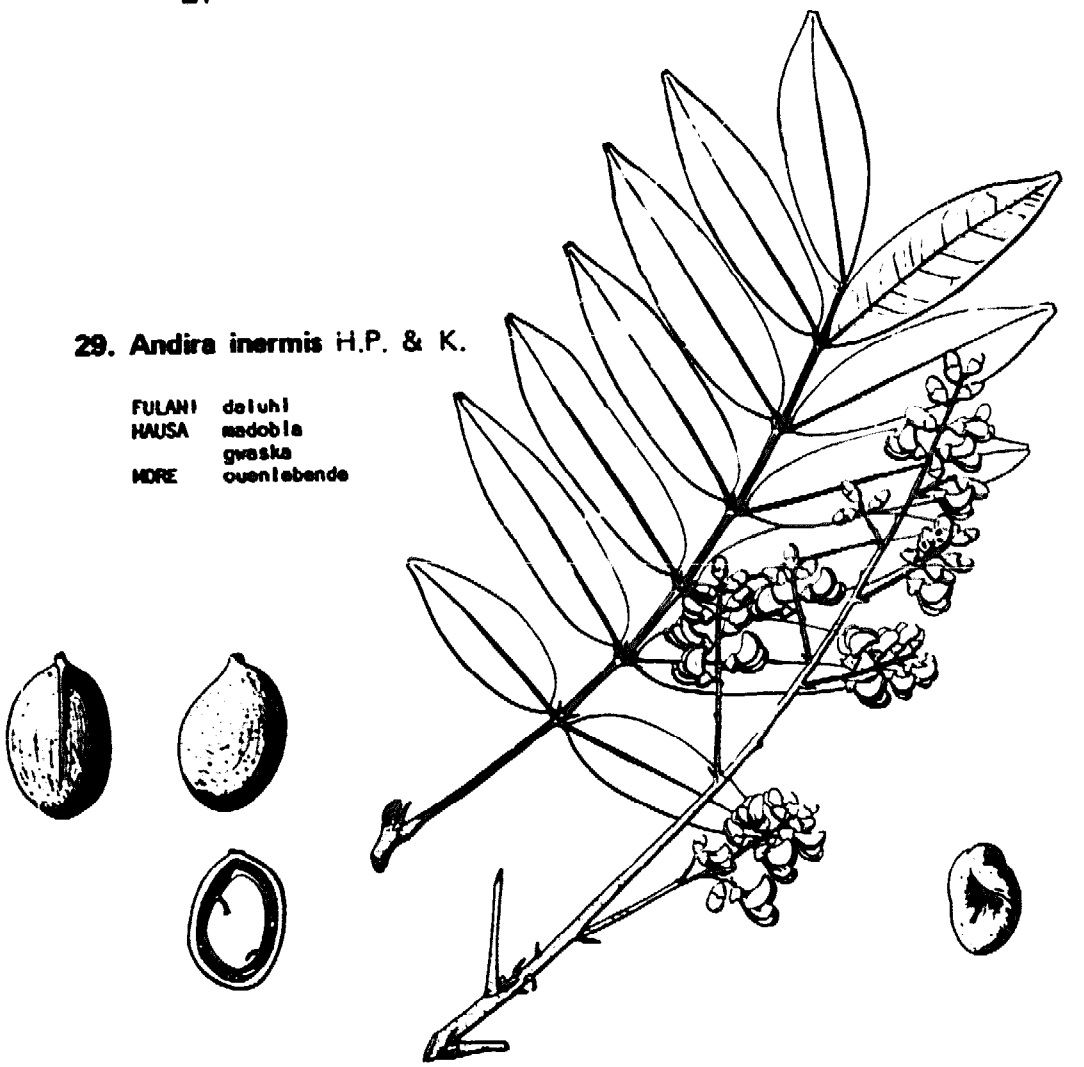

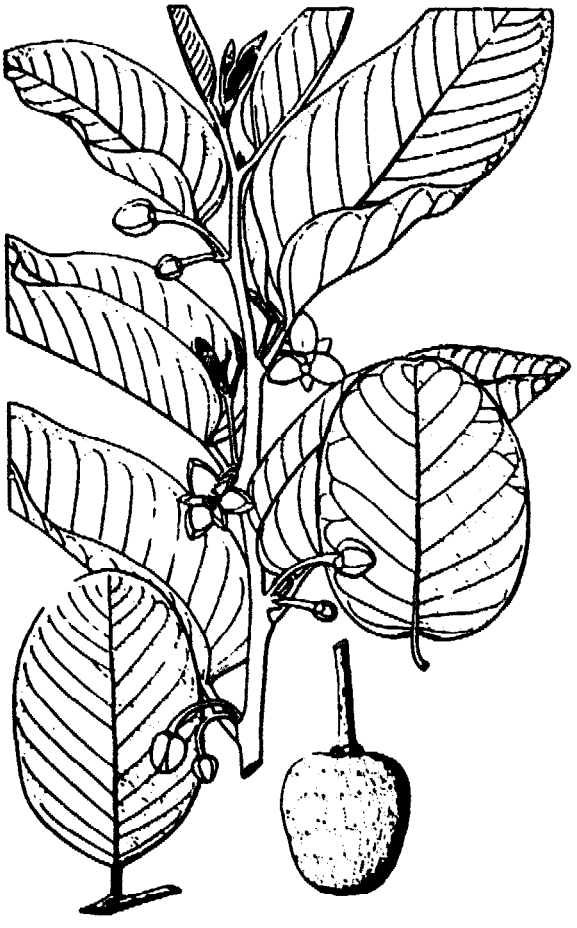

30. Annona senegalensis Pers.

CHAD ARABIC	um toro
BAMBARA	sunsun
DJERMA	moupa
FULANI	dukuhi
HAUSA	gouanda
KANOURI	tissa
	ngonowo
MORE	bakikudiga

31. Anogeissus leiocarpus Guill. & Perr.

Also see APPENDIX B

SYNONYM:

Anogeissus schimperi Hochst. ex Hutch & Dalz.

CHAD ARABIC	sahab
BAMBARA	krekete
DJERMA	gonga
FULANI	kojoli
HAUSA	marika
KANOURI	annum
MORE	sigha
	piega

32. **Azadirachta indica** A. Juss.

Also see APPENDIX B

ENGLISH Neem FRENCH Neem

Use for firewood, poles, construction, brush your teeth with the bark

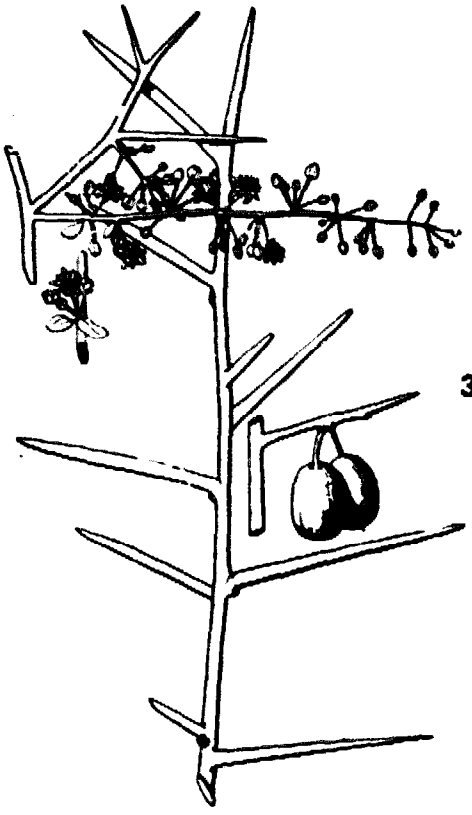

33. **Balanites aegyptiaca** (L.) Del.

Also see APPENDIX B

CHAD ARABIC	hajlij	KANOURI	chingo
BAMBARA	seguene		bito
DJERMA	garbey	MORE	tlegaliga
FULANI	tanni		
HAUSA	adoua		

Use for edible fruits, firewood, tool handles, soap, poison

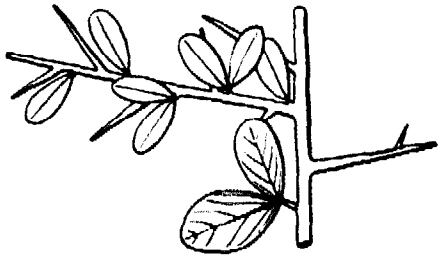

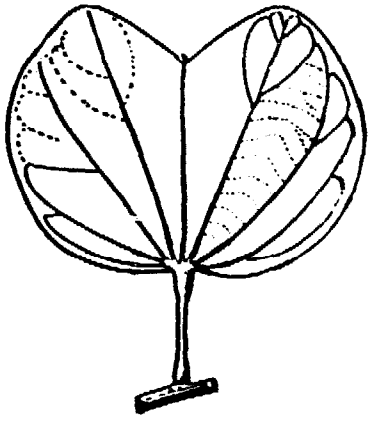

34. **Bauhinia reticulata** D.C.

Also see APPENDIX B

SYNONYMS: *Bauhinia glabra* A. Chev.
Bauhinia glauca A. Chev.
Piliostigma reticulatum (D.C.) Hochst.

CHAD ARABIC	harum	HAUSA	calgo
BAMBARA	nlamaba	KANOURI	kaldul
DJERMA	kosseye	MORE	barani
FULANI	barkevi		

Use for smoking wood

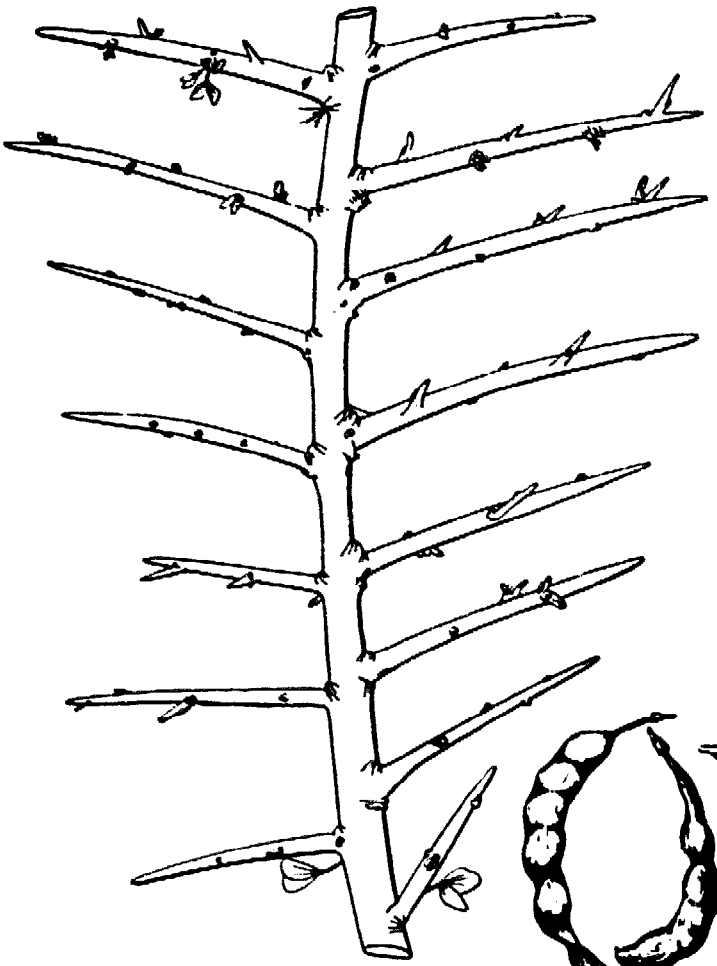

35. **Bauhinia rufescens** Lam.

SYNONYMS:

Bauhinia adansoniana Guill. & Perr.
Bauhinia parvifolia Hochst.

CHAD ARABIC	kule kule
BAMBARA	guesembr
DJERMA	namari
FULANI	namai
HAUSA	dirge
KANOURI	sisi
MORE	tipoega

Use for firewood, medicine

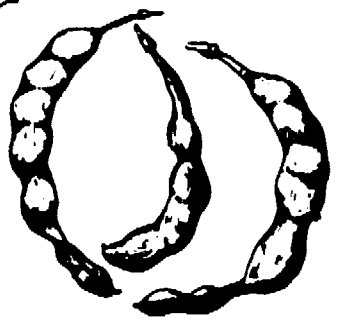

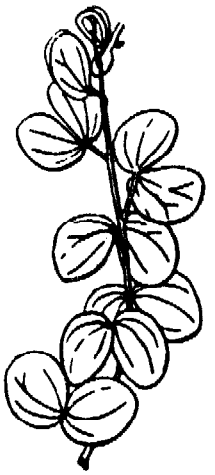

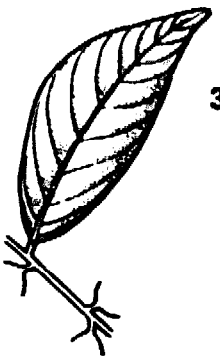

36. **Berlinia grandiflora** (Vahl) Hutch. & Dalz.

SYNONYM:

Berlinia auriculata

HAUSA rafi

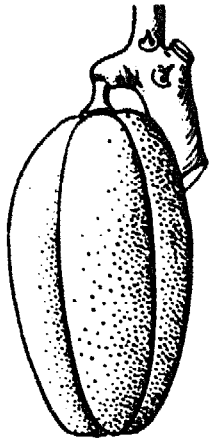

37. Bombax buonopozense Beauv.

ENGLISH kapok tree
FRENCH kapokier

Use for kapok fiber - not as fine as *Ceiba petandra* (see #54, this appendix, and appendix B)

39

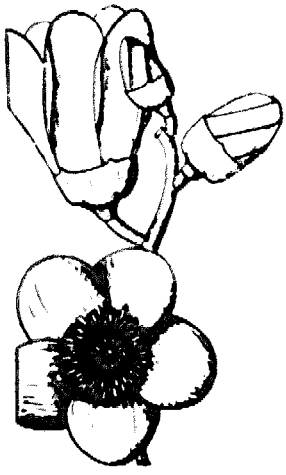

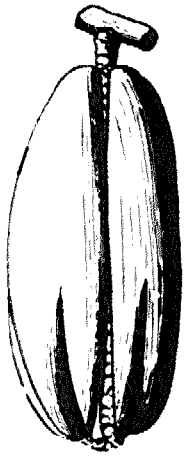

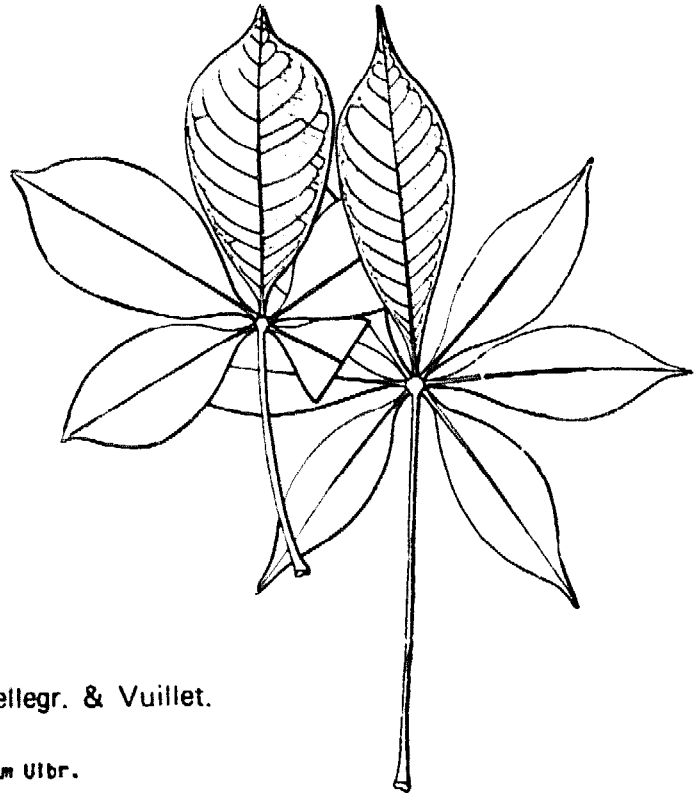

38. Bombax costatum Pellegr. & Vuillet.

SYNONYM: *Bombax flammeum* Ulbr.

ENGLISH	kapok tree	DJERMA	forogo
FRENCH	kapokier	FULANI	kuruhi
CHAD ARABIC	johe	HAUSA	kurie
BAMBARA	zoumbou	KANOURI	yelta
		MORE	ouaka

Use for kapok, edible leaves

39. **Borassus aethiopum** Mart.

Also see APPENDIX B

SYNONYM:

Borassus flabellifer L. var. *aethiopum* (Mart.) Warb.

FRENCH	ronier
CHAD ARABIC	deleb
DJERMA	sabouze
FULANI	dubbi
HAUSA	giguniа
KANOURI	ganga
	kamelutu

Use for termite-proof posts for construction, fences, etc., leaves and "stems" for fencing reinforcement. Slow growing.

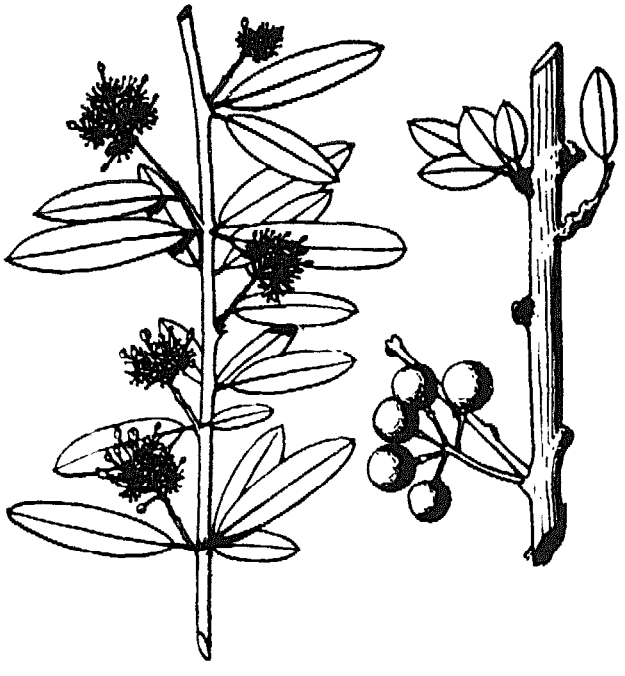

40. **Boscia angustifolia** A. Rich.

BAMBARA	dieba
	guinadiou
	foutigui
FULANI	anzagi
HAUSA	agajini
KANOURI	marga
MORE	kisinkinde

41. **Boscia salicifolia** Oliv.

CHAD ARABIC	mahkel
HAUSA	zoure

Use for edible leaves

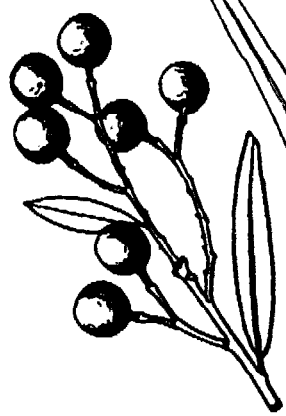

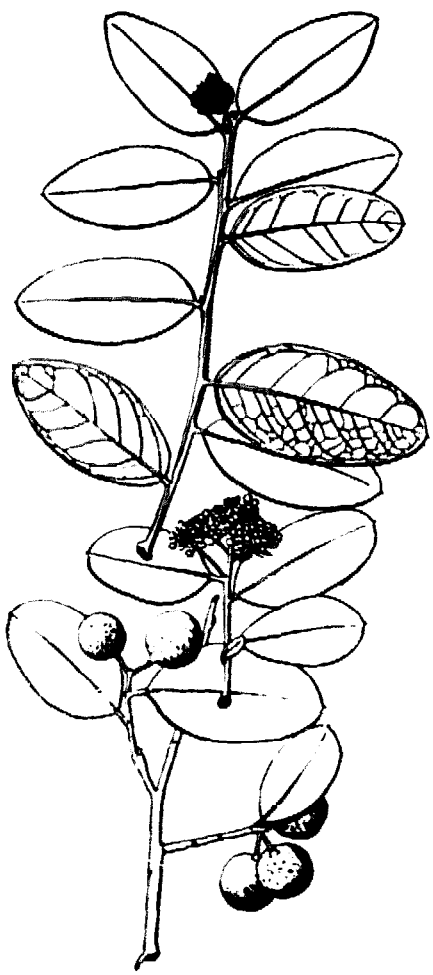

42. **Boscia senegalensis** Lam.

CHAD ARABIC	hemmet-moheb
BAMBARA	bere
DJERMA	orba
	dilo
FULANI	gulgulle
HAUSA	anza
	dielow
KANOURI	bultus
MORE	nabedega
	lambolga

Use for construction, edible fruits and seeds

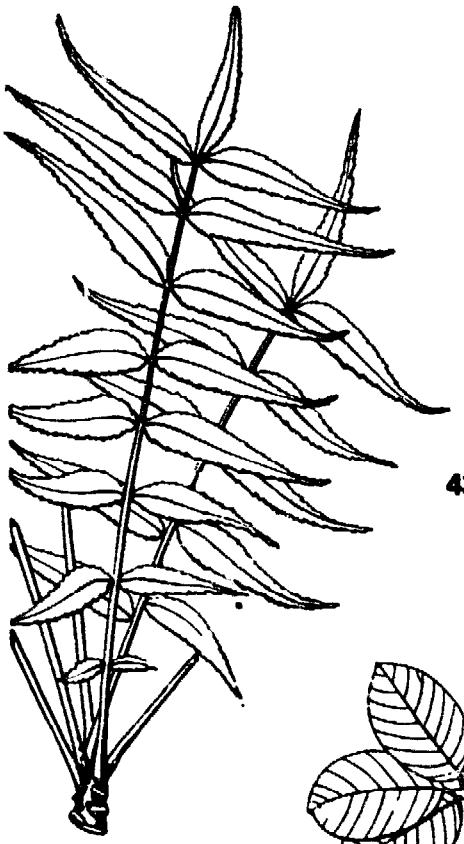

43. Boswellia dalzielli Hutch.

FULANI andakehi KANOURI kafi dukan
HAUSA hano

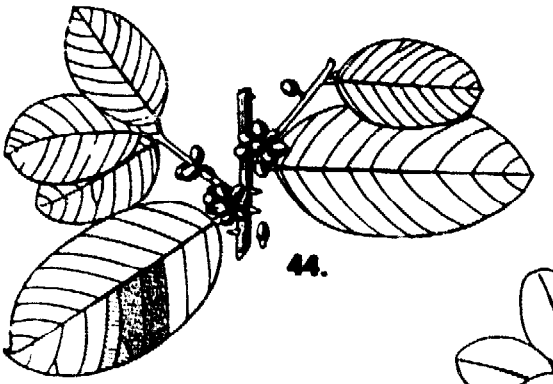

44.

44. Bridelia ferruginea Benth.

BAMBARA baboni HAUSA kirni
sagua KANOURI zindi
FULANI mareni MORE tansaloga
dafi

Use for firewood, fodder

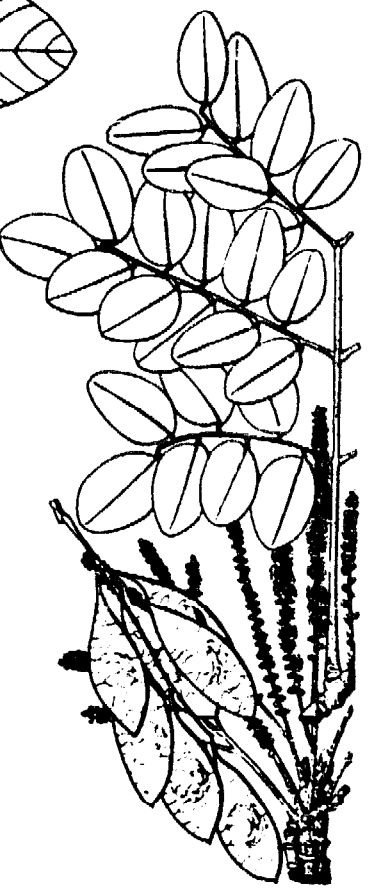

45. Burkea africana Hook.

CHAD ARABIC azrak ana
FULANI kokobi
HAUSA bakin-makarfo
MORE sienra

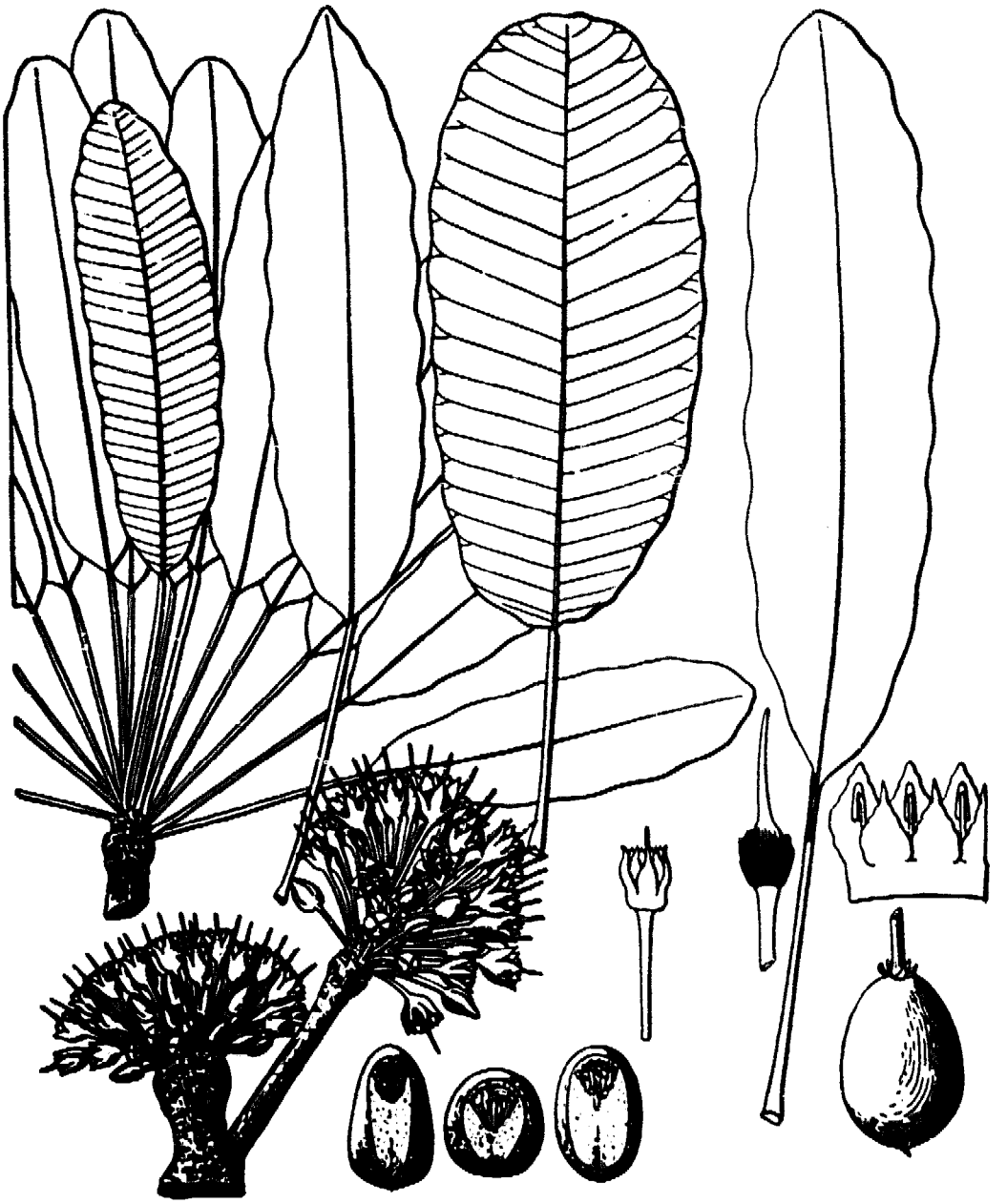

46. **Butyrospermum parkii** Kotschy

Also see APPENDIX B

SYNONYM: *Butyrospermum paradoxum* (Gaertn. f.) Hepper

ENGLISH	shea nut tree	FULANI	karehi
FRENCH	karite	HAUSA	kandanya
CHAD ARABIC	um kurum	KANOURI	toso
DJERMA	boulanga	MORE	tanga

Use for shea butter, hard wood for mortar

47. Cadaba farinosa Forsk.

CHAD ARABIC	sirreh
BAMBARA	berekunan
	tamba
HAUSA	bagay
KANOURI	marga

48. Calotropis procera (Ait.) Dryand

CHAD ARABIC	rhalga
BAMBARA	fugolri
	ngounyo
FULANI	bambami
HAUSA	tumfafya
KANOURI	kayo

Use for construction

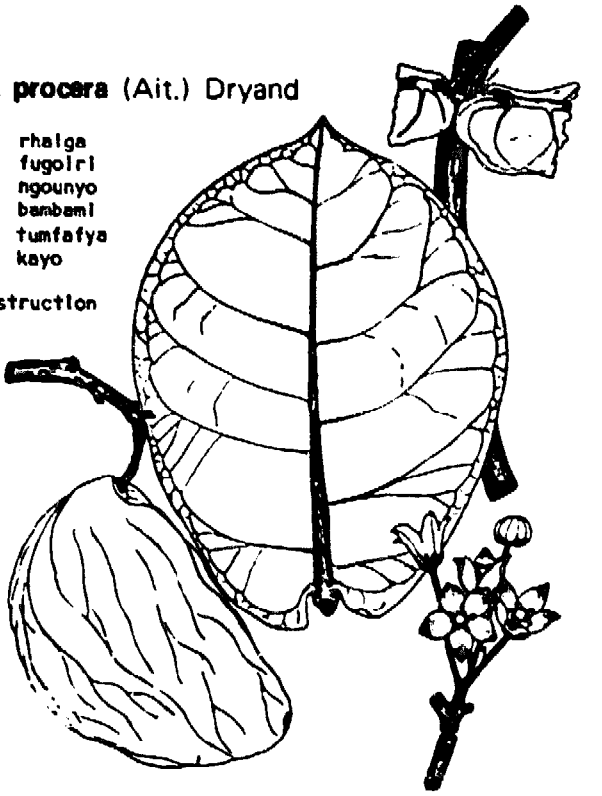

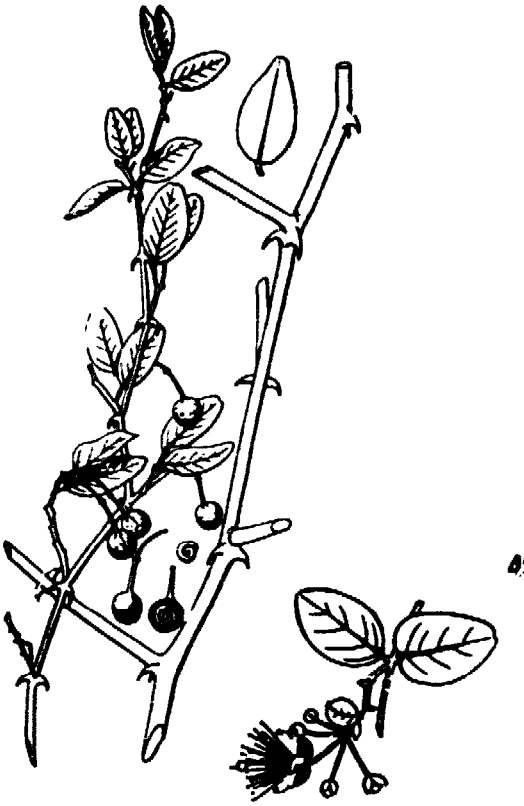

49. Capparis corymbosa Lam.

CHAD ARABIC	mardo
HAUSA	haujari-mutane
KANOURI	pido
	damsa

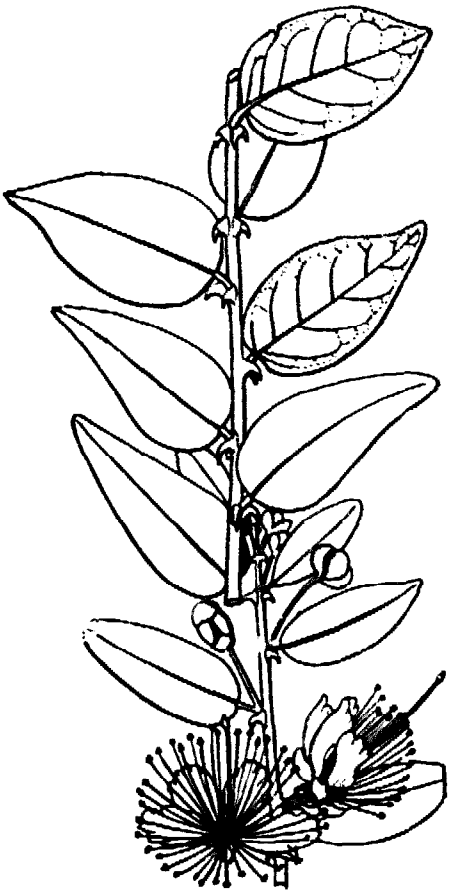

50. Capparis tomentosa Lam.

SYNONYM:

Capparis polymorpha A. Rich.

CHAD ARABIC gulum
HAUSA haujari
KANOURI zaji

Use for fodder

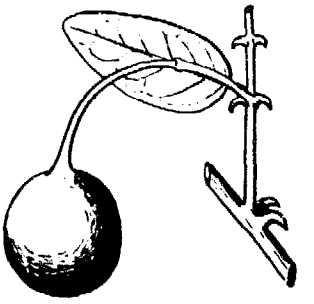

51. Cassia siamea Lam.

Also see APPENDIX B

FRENCH cassia

Use for construction, firewood, windbreaks

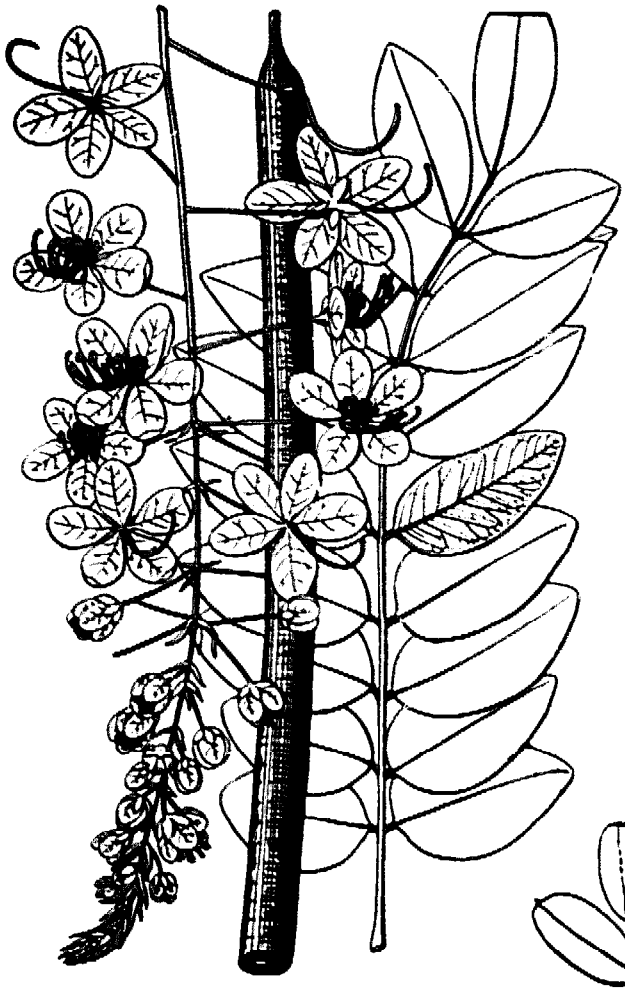

52. Cassia sieberiana D.C.

CHAD ARABIC	sireih
BAMBARA	sinia
	sinedian
DJERMA	samturi
FULANI	malagahi
HAUSA	maiga
KANOURI	badin zikki
	marga
MORE	kombissaka

Use for hard firewood

53. Cassia singueana Del.

SYNONYM:
Cassia goratensis Fres.

CHAD ARABIC	shadarat-ai bashima
FULANI	rumfuhi
	wabiihi
HAUSA	rumfu
KANOURI	tuguiele
MORE	gueleponsgo

Use for fodder, firewood

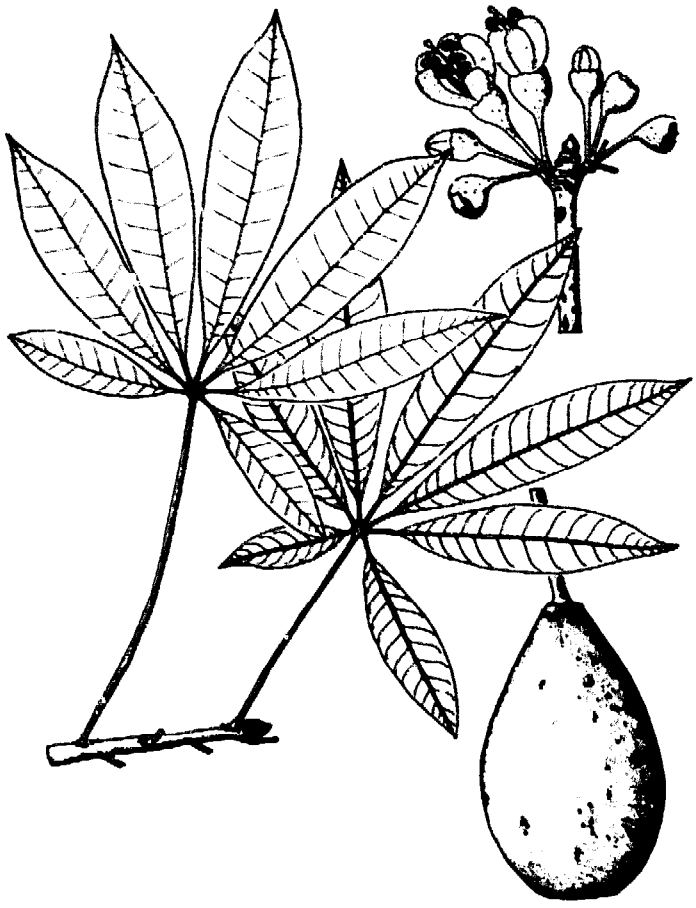

54. **Ceiba petandra** (L.) Gaertn.

Also see APPENDIX B

SYNONYM:
Eriodendron orientale

ENGLISH	silk cotton tree
FRENCH	fromager
CHAD ARABIC	rum
FULANI	bantahi
HAUSA	rimi
KANOURI	tom
MORE	gunga

Best source of kapok fiber

55. **Celtis integrifolia** Lam.

CHAD ARABIC	abun gatu
BAMBARA	gaua
	kameguan
FULANI	genki
HAUSA	dikki
	zuwo
	kouka
KANOURI	nguso
MORE	tintigeliga

Use for fodder, firewood

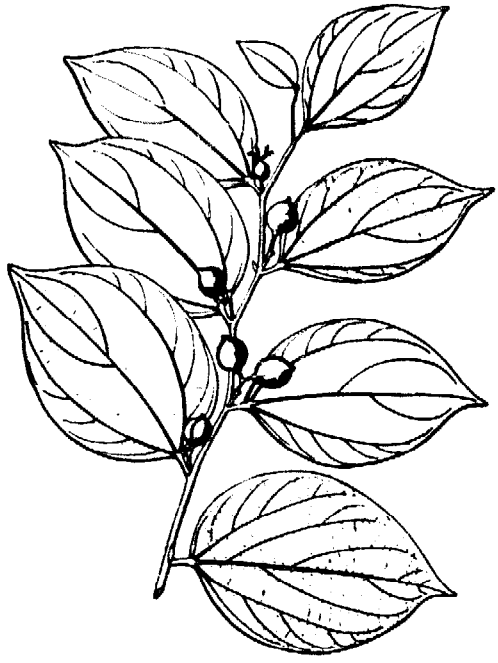

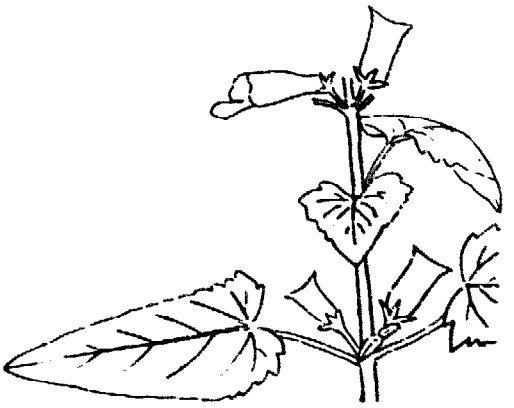

56. Ceratotheca sesamoides Endl.

FULANI wanko
HAUSA karkashi
KANOURI kembulubul

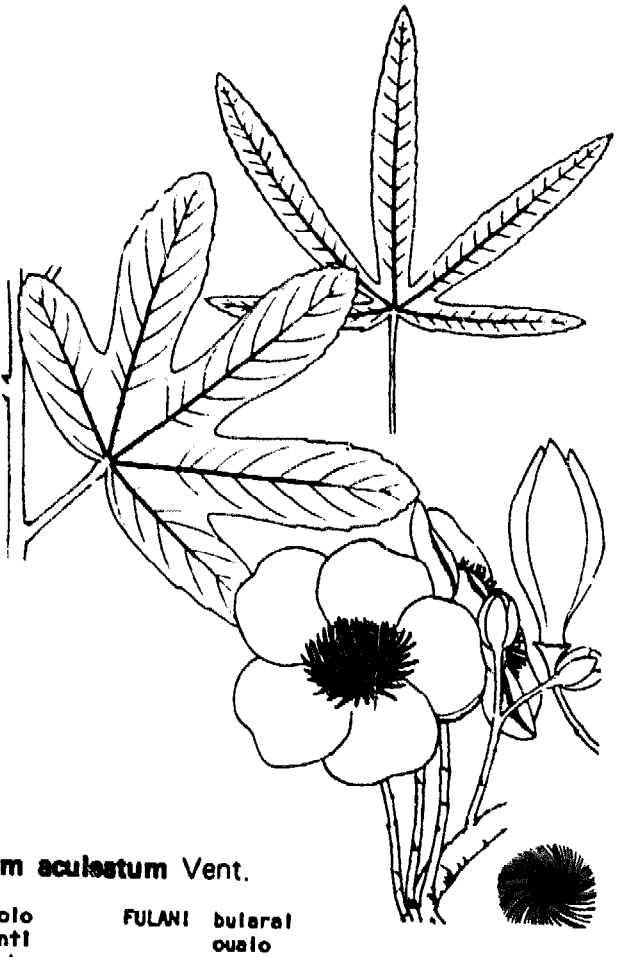

57. Cochlospermum tinctorium Perr.

CHAD ARABIC maghr
FULANI jarundai
HAUSA rawaya
KANOURI masauwa

58. Combretum aculeatum Vent.

BAMBARA ouolo
konti
DJERMA bouboure
FULANI bularai
ouaio
HAUSA bubukya
MORE koditambiga

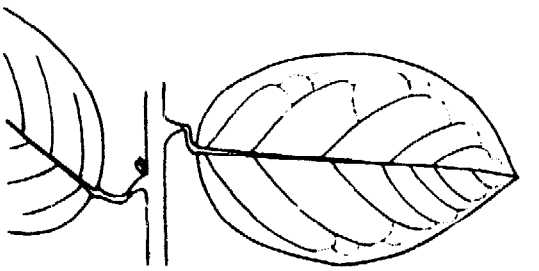

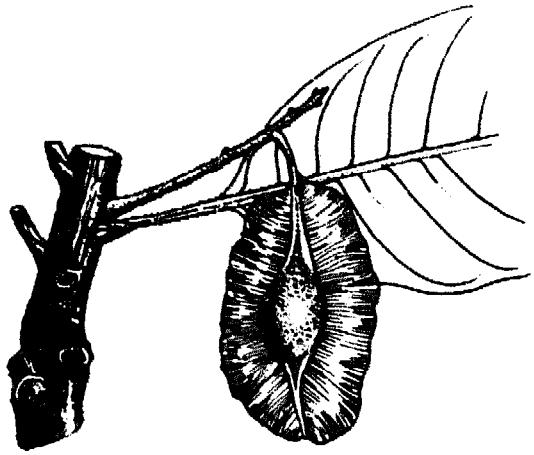

59. Combretum binderianum Kotschy

HAUSA fara geza

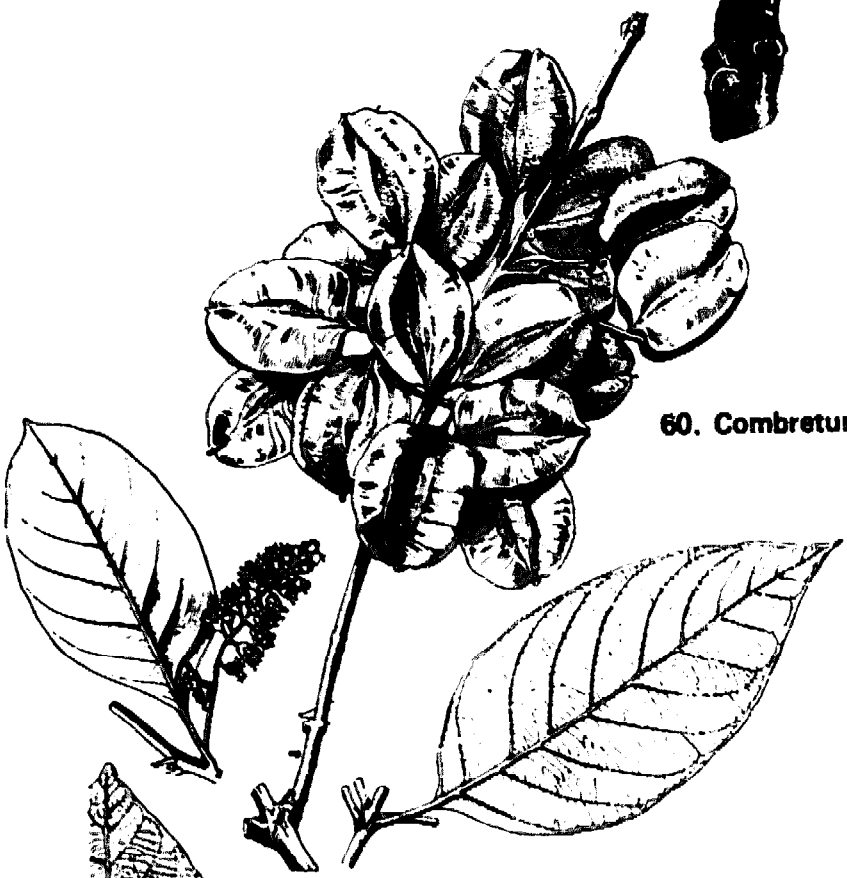

60. Combretum ghasalense Engl. & Diels

SYNONYM:
Combretum dalzielii

HAUSA bakin taramnya
KANOURI zindi

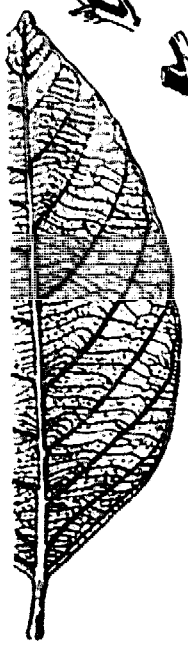

61. Combretum glutinosum Perr.

CHAD ARABIC	hebli	HAUSA	taramnya
BAMBARA	demba	KANOURI	katagar
DJERMA	kokorbe	MORE	kwenga
FULANI	buski		

Use for gum, firewood, charcoal

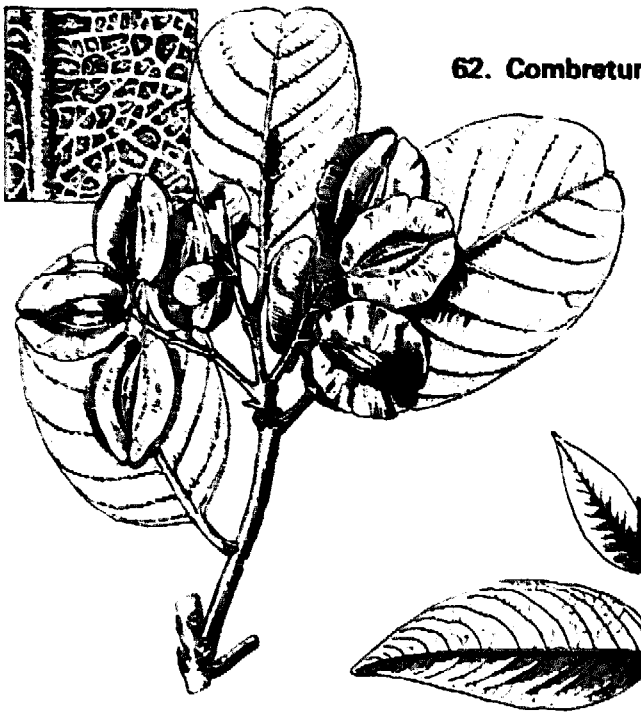

62. Combretum glutinosum var. **passargei** Aubr.

HAUSA taramnya

Use for firewood

63. Combretum hypopilinum Diels

HAUSA Jan
taramnya

64. Combretum lamprocarpum Diels

SYNONYM: *Combretum verticillatum*

HAUSA taramnya

65. **Combretum micranthum** G. Don.

BAMBARA	kolobe	HAUSA	gieza
DJERMA	koubou	MORE	landaga
FULANI	taili		
	gugumi		

Use for hut sticks, medicine, gum, firewood

66.

66. **Combretum molle** R. Br. ex G. Don

SYNONYMS:
Combretum velutinum D.C.
Combretum sokodense
Combretum leonense

FULANI damoruhi
HAUSA wuyan daho

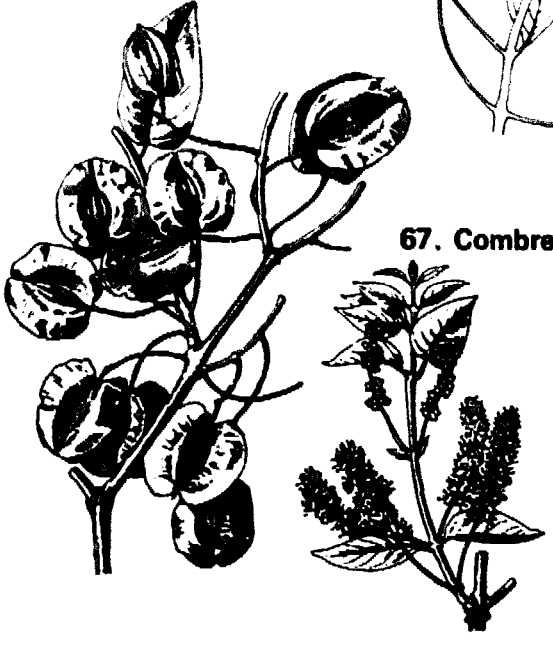

67. **Combretum nigricans** Leprieur var. **elliotii** Aubr.

SYNONYM:
Combretum lecananthum Engl. & Diels.

BAMBARA	diangara
DJERMA	delignia
FULANI	dokigori
HAUSA	dagera
MORE	kuarehtuaga

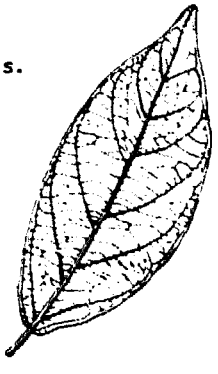

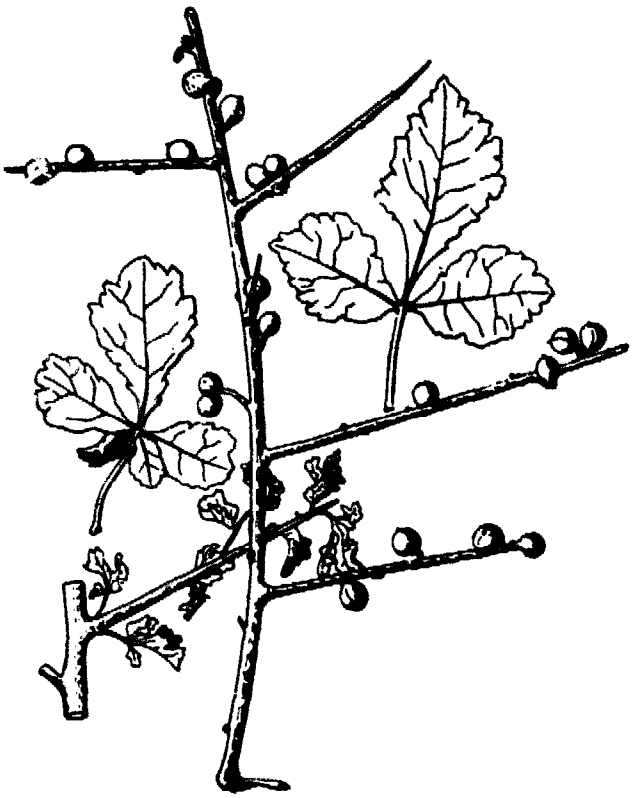

68. Commiphora africana (Rich.) Engl.

SYNONYMS: *Balsamodendron africanum* Arn.
Heudelotia africana Rich.

CHAD ARABIC	hbarkat	HAUSA	dashi
	gafal	KANOURI	kabi
FULANI	badadi	MORE	kodematabega

Use for live fences

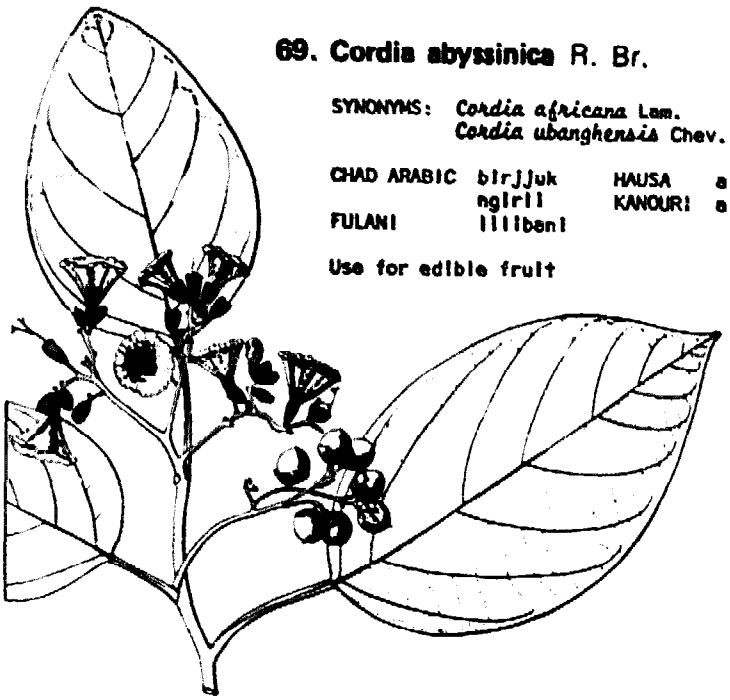

69. Cordia abyssinica R. Br.

SYNONYMS: *Cordia africana* Lam.
Cordia ubanghensis Chev.

CHAD ARABIC	birjjuk	HAUSA	alilibe
	ngirii	KANOURI	aluba
FULANI	lilibani		

Use for edible fruit

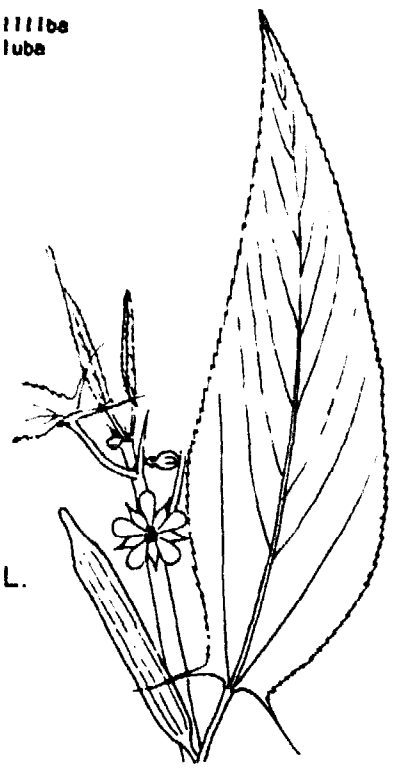

70. Corchorus olitorius L.

CHAD ARABIC	mulkhiye
HAUSA	malafya
KANOURI	ganzaino

71. Courbonia virgata Brongn.

SYNONYMS:
Courbonia pseudopetalosa Glig. & Ben.
Maerua pseudopetalosa (Glig.) de Wolf

HAUSA lalo
KANOURI kumkum

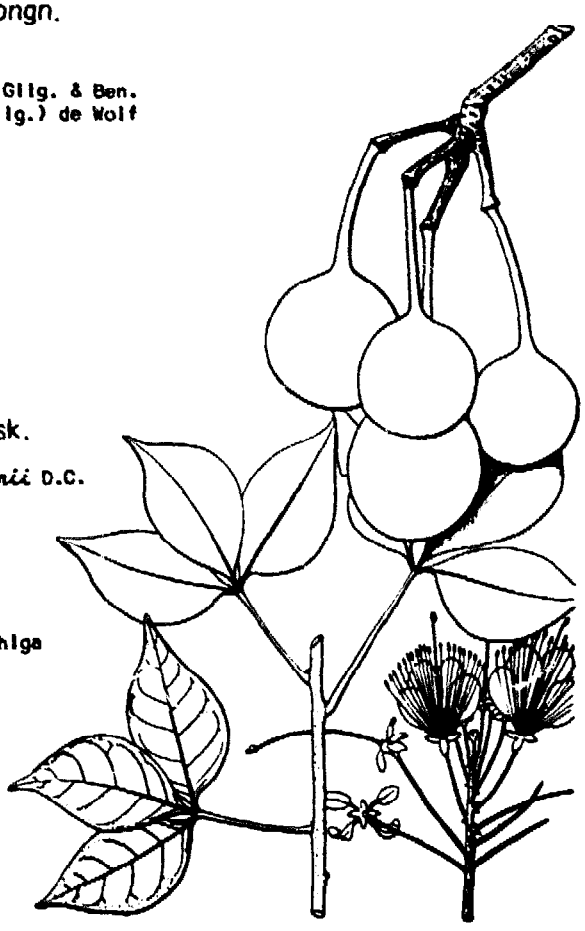

72. Crataeva religiosa Forsk.

SYNONYM: *Crataeva adansonii* D.C.

CHAD ARABIC dabkar
FULANI landam bani
HAUSA ungududu
goude
KANOURI ngulido
MORE kaelegain-tohiga

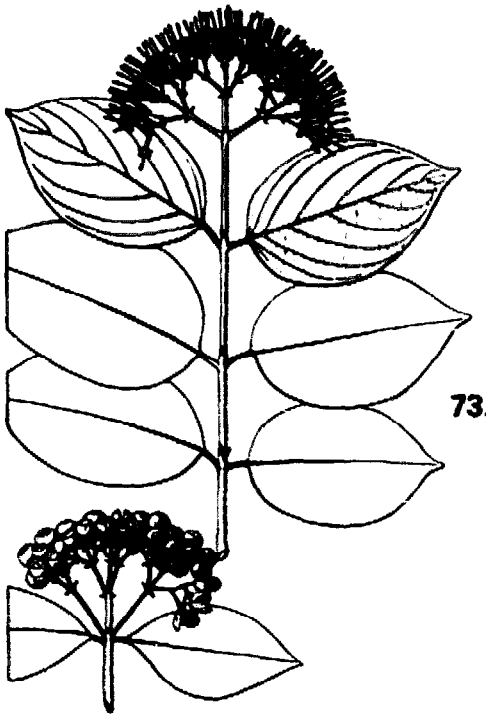

73. Crossopteryx febrifuga Benth.

SYNONYMS:
Crossopteryx africana Bell.
Crossopteryx kotschyana Fenzl.

BAMBARA balimba
klenke
FULANI brakoll
HAUSA kasf'ya
MORE kumronanga

74. Croton macrostachys Hochst. ex A. Rich.

SYNONYM: *Croton amabilis* Muell.

CHAD ARABIC	deepa
HAUSA	koribe
KANOURI	moromoro

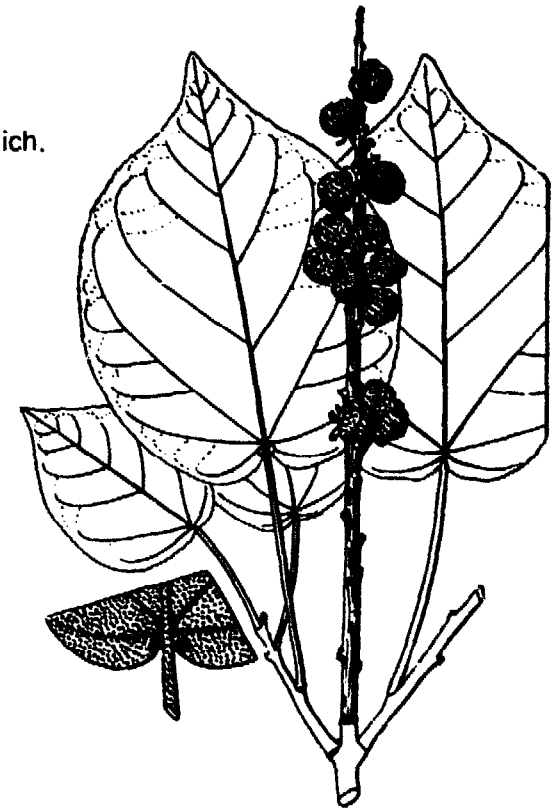

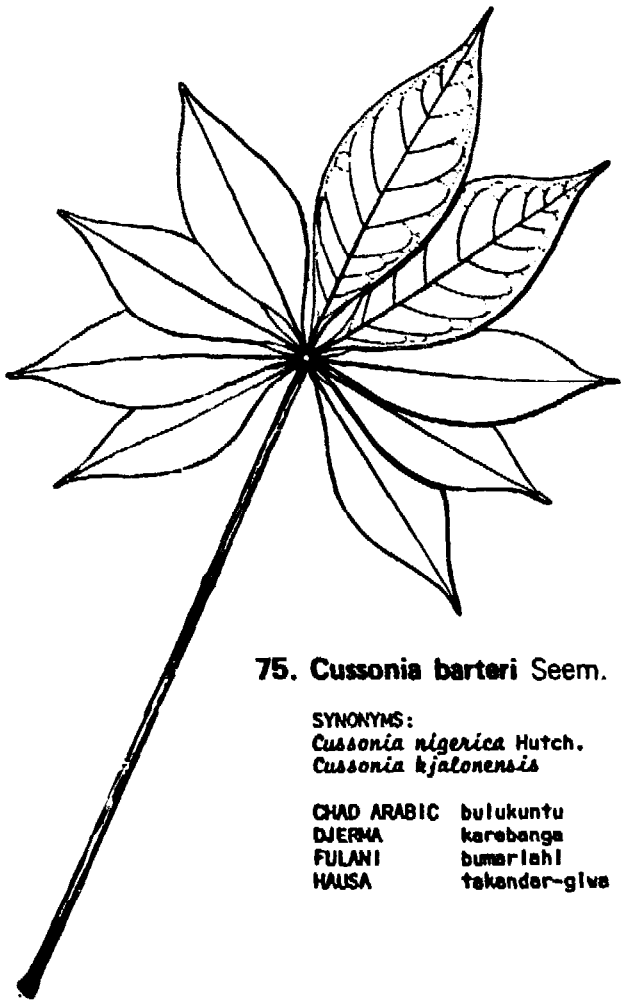

75. Cussonia barteri Seem.

SYNONYMS:
Cussonia nigerica Hutch.
Cussonia kjalonensis

CHAD ARABIC	bulukuntu
DJERMA	karebanga
FULANI	bumarlahi
HAUSA	takander-giwa

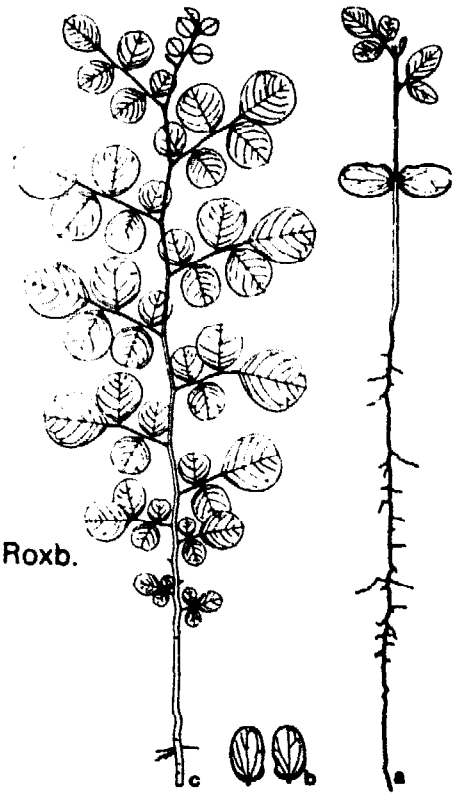

76. Dalbergia sissoo Roxb.

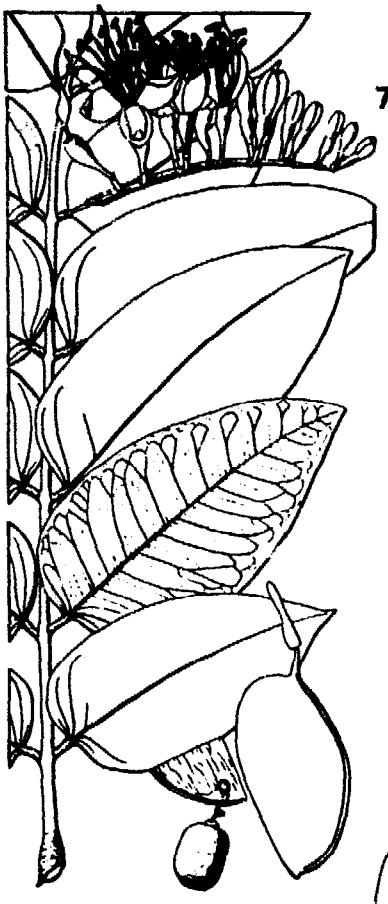

77. Daniella oliverii (Rolfe) Hutch. & Dalz.

SYNONYM: *Paradaniellia oliveri* Rolfe.

FRENCH	santan
CHAD ARABIC	samelm
DJERMA	farmoy
FULANI	kaharlahi
HAUSA	maje
KANOURI	majo
MORE	honga

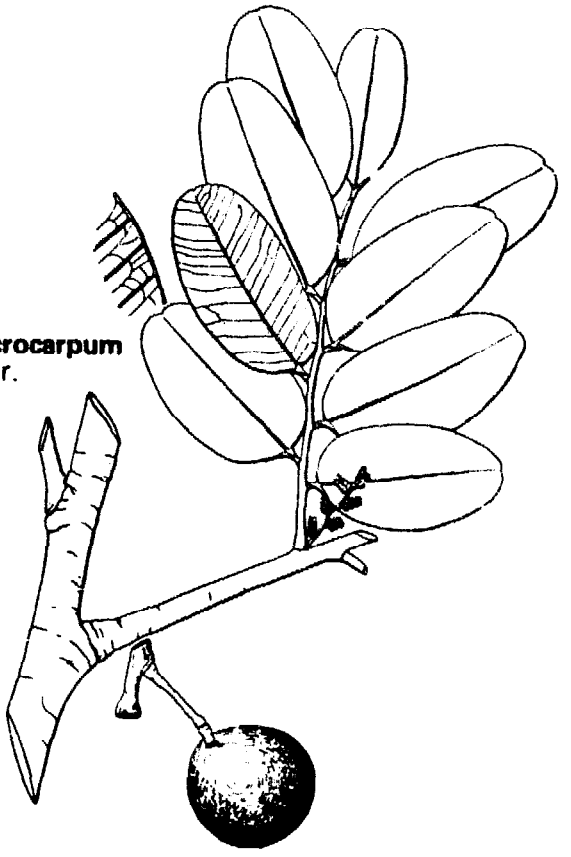

78. Detarium microcarpum Guill. & Perr.

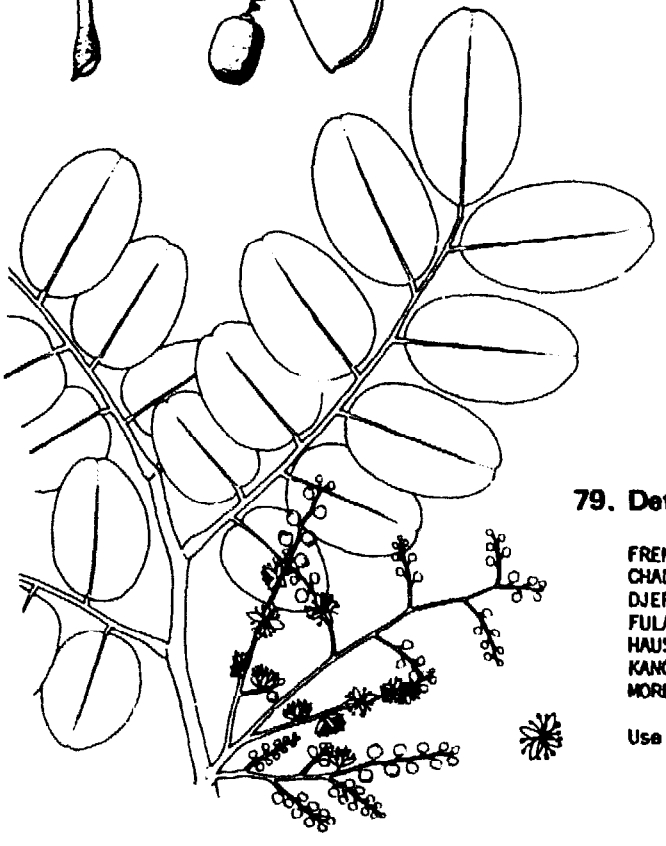

79. Detarium senegalense Gmel.

FRENCH	moroda
CHAD ARABIC	abulelle
DJERMA	fantou
FULANI	konkehi
HAUSA	taura
KANOURI	gatapo
MORE	kagtega

Use for drum-wood

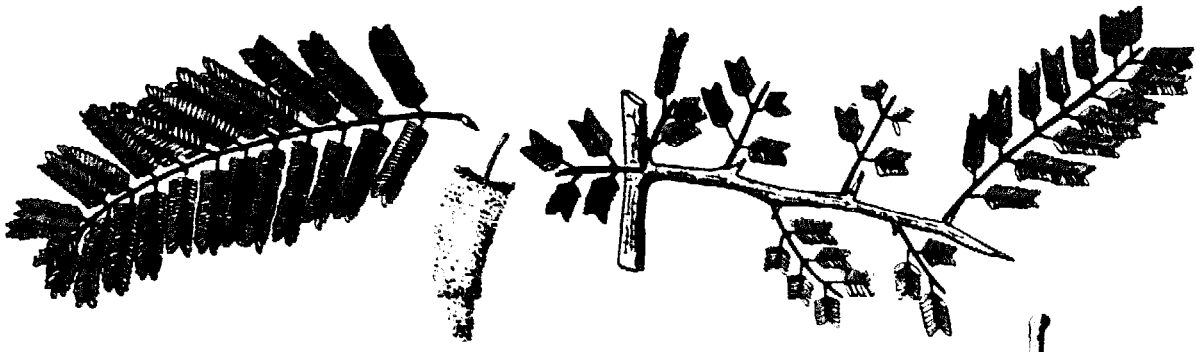

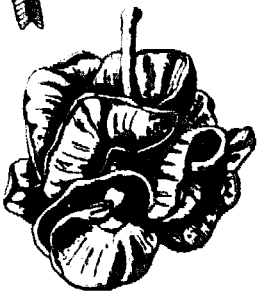

80. Dichrostachys glomerata (Forsk.) Hutch. & Dalz.

SYNONYMS: *Dichrostachys arborea* N.E. Br.
Dichrostachys cinerea (L.) Might & Arn.
Dichrostachys nutans Benth.
Dichrostachys platycarpa Welw.
Gaillica dichrostachys Gulll. & Perr.

CHAD ARABIC	dhigingap	HAUSA	dundu
BAMBARA	gilki-goro	KANOURI	garbinna
	ntilligui	MORE	sunsutiga
FULANI	burll		
	patrulaki		

Use for thorn fencing, **medicine**, root fibers

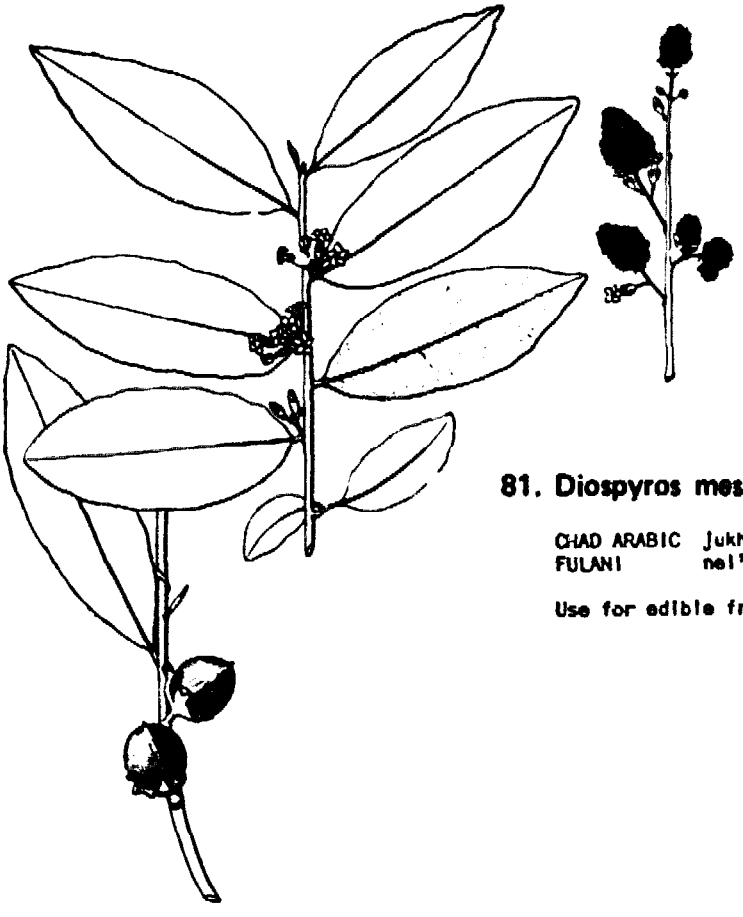

81. Diospyros mespiliformis Hochst.

CHAD ARABIC	jukhan	HAUSA	kanyan
FULANI	nel'bi	KANOURI	burgum

Use for edible fruit, firewood

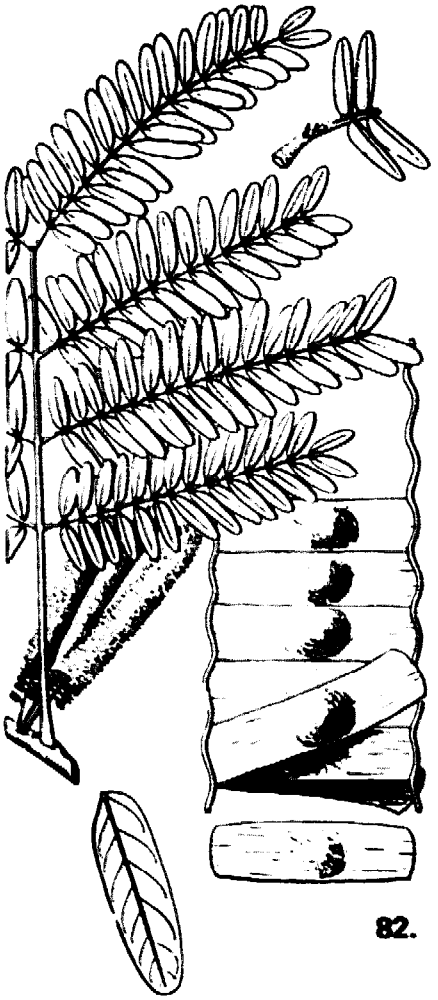

82.

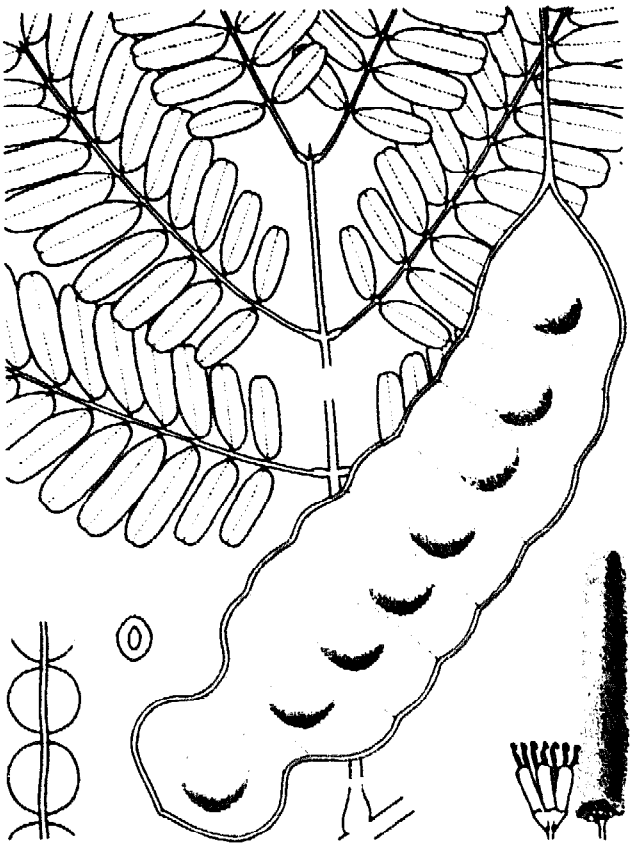

83.

82. Entada africana Guill. & Perr.

83. Entada sudanica Schweinf.

Also see APPENDIX B

CHAD ARABIC	dorot	HAUSA	tawatsa
BAMBARA	dlamba	KANOURI	falofala
	samanere	MORE	slanlogo
FULANI	faóo-wanduhi		

Use for firewood, medicine

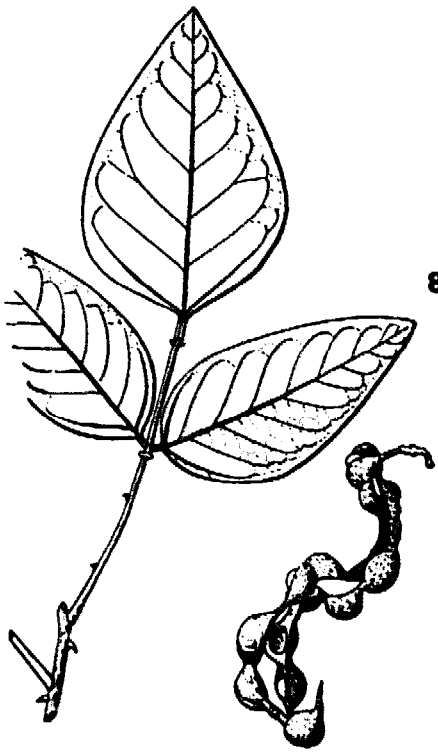

84. Erythrina senegalensis D.C.

BAMBARA timeba
lerung
HAUSA madjirya

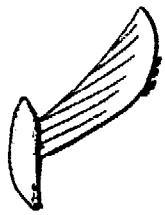

85. Eucalyptus camaldulensis Dehnh.

Also see APPENDIX B

SYNONYM:
Eucalyptus rostrata Schlecht.

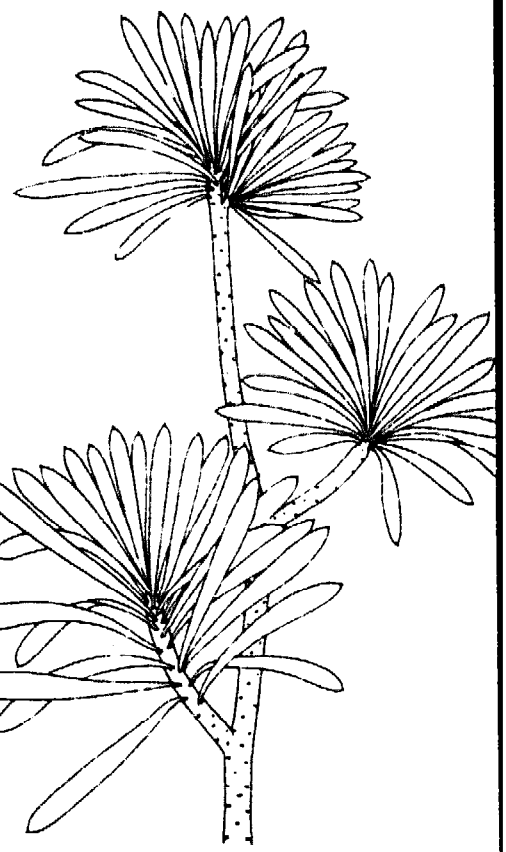

86. Euphorbia balsamifera Ait.

SYNONYMS: *Euphorbia rogeri* N.E. Br.
Euphorbia sepium N.E. Br.

DJERMA berre
FULANI yaro
magara
HAUSA agoua
KANOURI yaro
magara

Use for live hedges

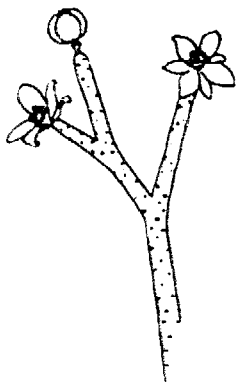

87. **Ficus gnaphalocarpa** A. Rich.

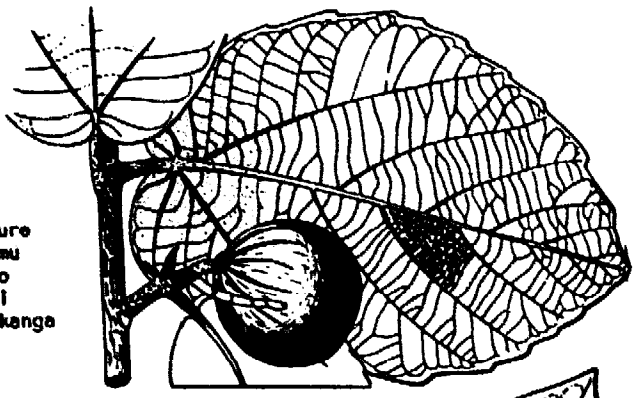

SYNONYMS:
Ficus sycomorus L.
Ficus trachyphylla Fenzl.
Grosse crenata Warb.

CHAD ARABIC	Jameiz	HAUSA	baoure
	al abiad	KANOURI	tarmu
BAMBARA	nituro		obbo
	toro n'toro		jivi
FULANI	yibe	MORE	kankanga
	obbi		

Use for edible fruit, medicine, bark

88. **Ficus ingens** Miq.

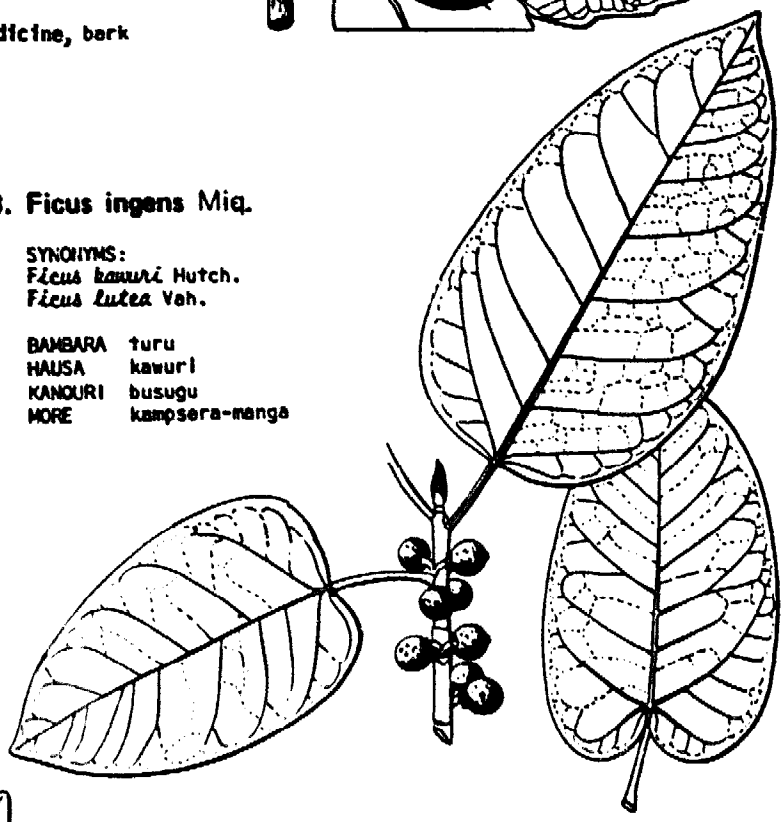

SYNONYMS:
Ficus kawuri Hutch.
Ficus lutea Vah.

BAMBARA	turu
HAUSA	kawuri
KANOURI	busugu
MORE	kampsera-manga

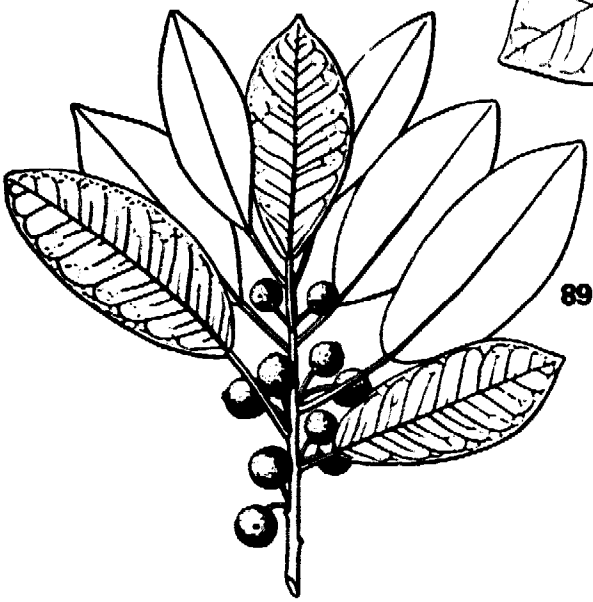

89. **Ficus iteophylla** Miq.

SYNONYMS:
Ficus bongoensis Warb.
Ficus spragueana

FULANI	sekehi
HAUSA	shirya
KANOURI	nja-nja

Use for firewood

90. **Ficus platyphylla** Del.

SYNONYMS:
Ficus bibracteata Warb.
Ficus umbrosa Warb.

CHAD ARABIC	jameiz el ahmahar
BAMBARA	n'kobo
FULANI	dundehi
HAUSA	gamji
KANOURI	ngabare
MORE	kempsaogo

Use for shade, medicine

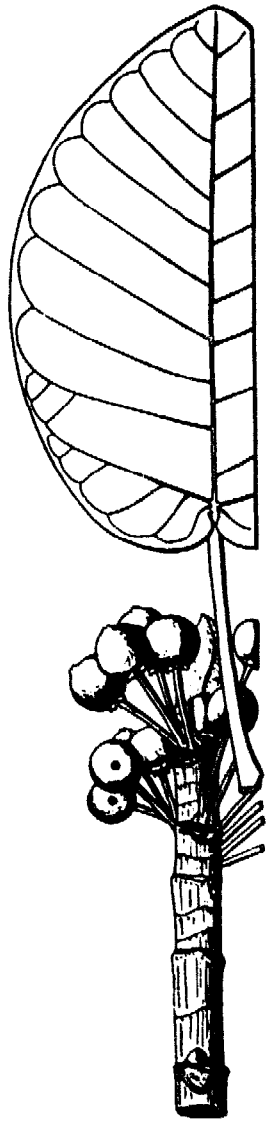

91. **Ficus polita** Vahl

SYNONYMS: *Ficus niamniamensis* Warb.
Ficus stenosiphon Warb.
Ficus syringifolia Warb.
Ficus syringoides Warb.

CHAD ARABIC	djimeimb azrak	HAUSA	duruni
		KANOURI	rito
FULANI	litahi	MORE	pampanga

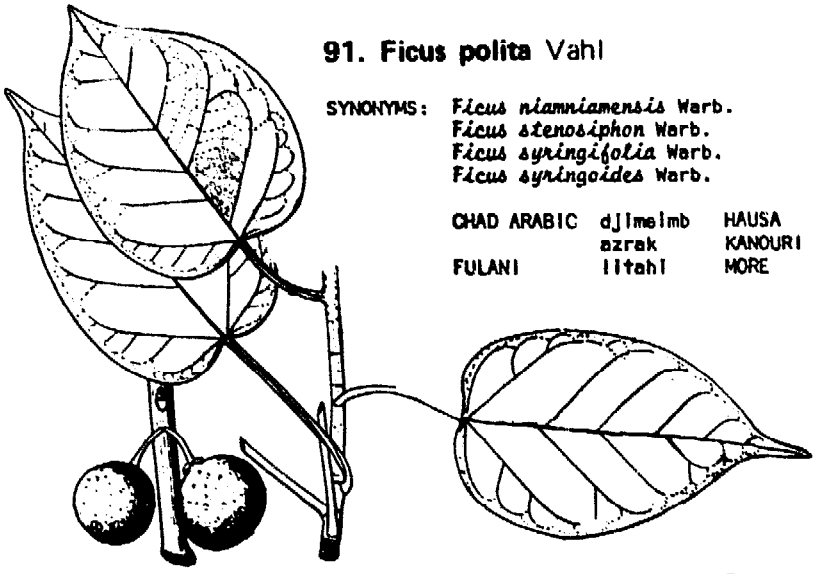

92. **Ficus thonningii** Blume

CHAD ARABIC	jameiz el abied	HAUSA	tchedia
		KANOURI	jeja
BAMBARA	dubale	MORE	kusga
FULANI	biskehi		

Use for medicine

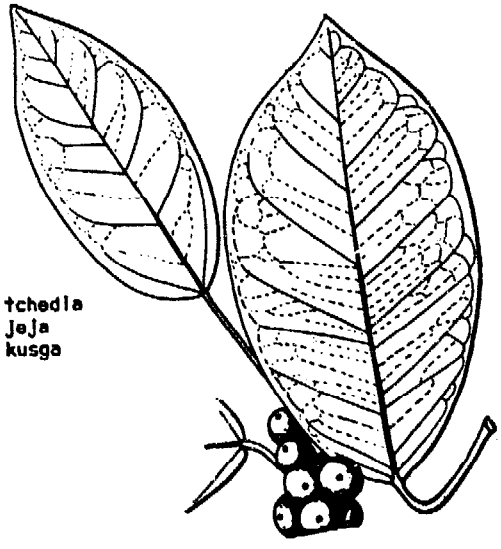

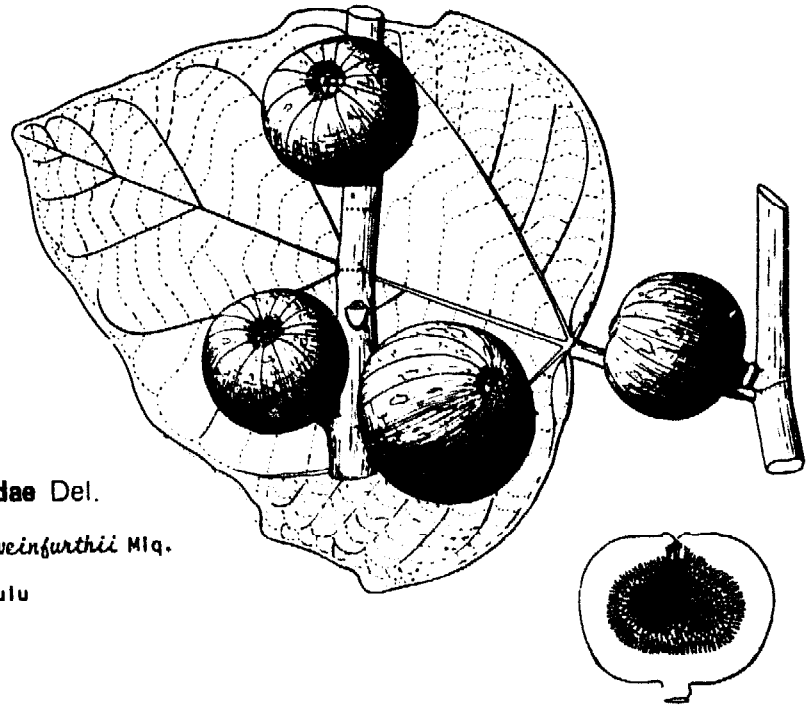

93. Ficus vallis choudae Del.

SYNONYM: *Ficus schweinfurthii* Mlq.

HAUSA dulu

94. Fluggea virosa (Roxb. ex Willd.) Baill.

SYNONYMS:
Fluggea microcarpa Blume
Fluggea virosa Buch.-Ham. ex Wall.
Securinega microcarpa (Blume) Pax & Hoffin
Phyllanthus virosus Roxb.

HAUSA daghirto
tsa
KANOURI shim shim

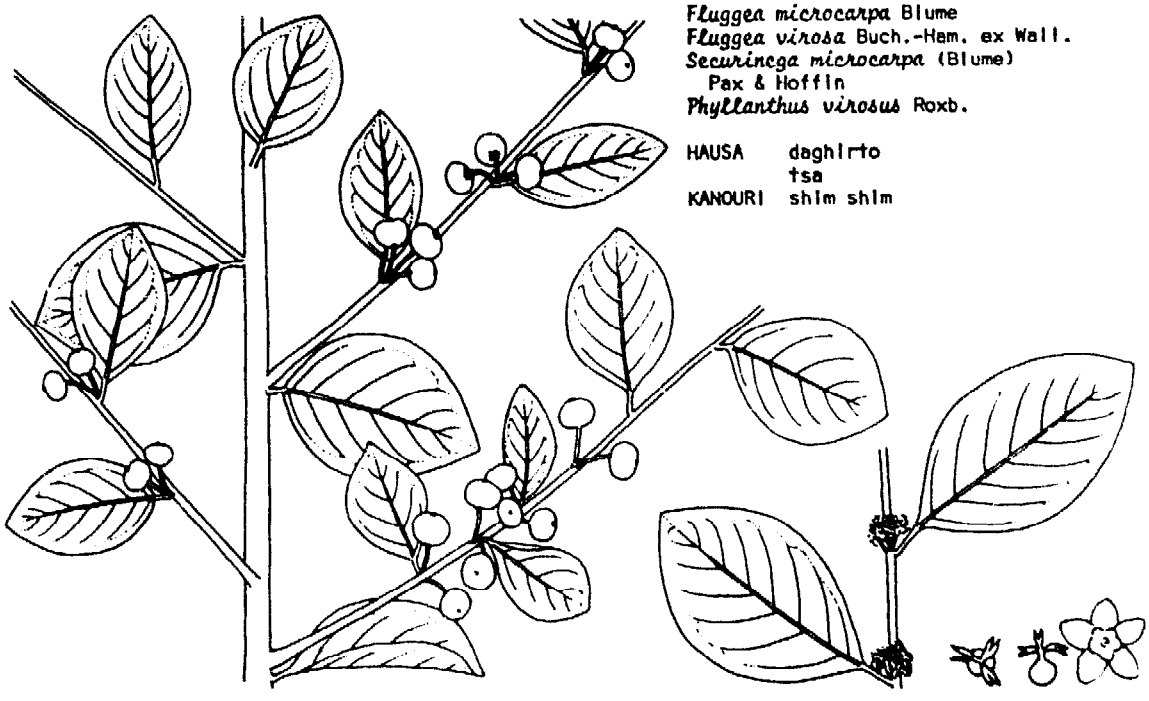

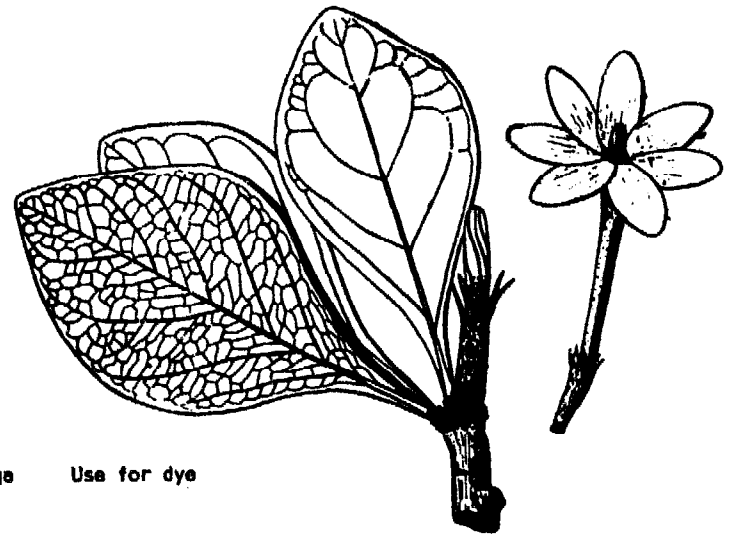

95. Gardenia erubescens Stapf. & Hutch.

CHAD ARABIC	am mifilfene
BAMBARA	m'bure
	mussama
DJERMA	sinesan
FULANI	dingall
HAUSA	gaoude
KANOURI	gursime
	gogut
MORE	tankorah-gonga

Use for dye

96. Gmelina arborea Roxb. not illustrated

Also see APPENDIX B

ENGLISH melina

Use for soft wood (for matches, boxes, etc.)

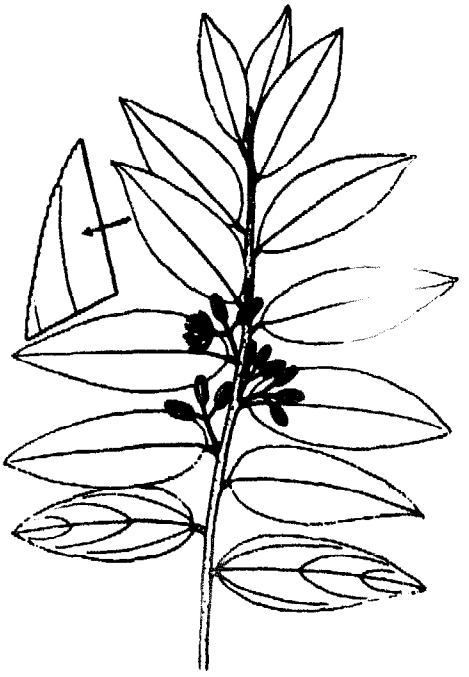

97. Grewia bicolor Juss.

CHAD ARABIC	abesh
FULANI	leloko
KANOURI	djimdjime
MORE	tonlage

Use for edible fruit

98. Grewia flavescens Juss.

CHAD ARABIC	gueddeb
HAUSA	kamanmoe
KANOURI	karnal
MORE	somkondo

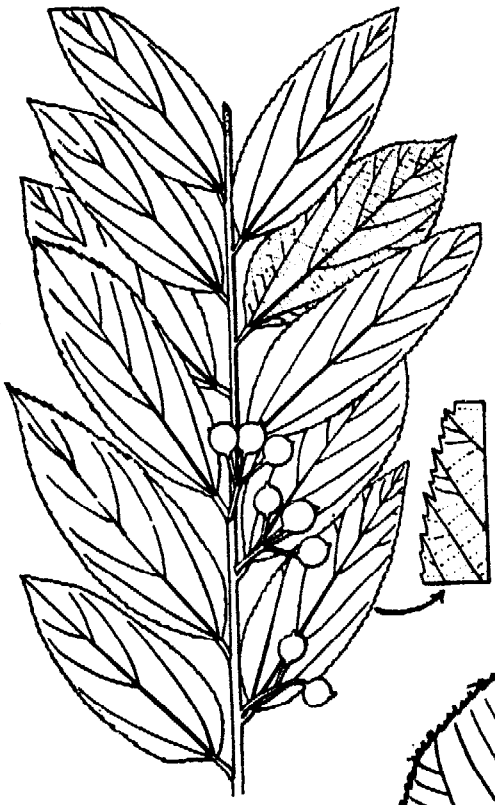

99. **Grewia mollis** Juss.

CHAD ARABIC	ghebbesh	HAUSA	dargaza
BAMBARA	nogo nogo	KANOURI	karno
FULANI	kelli	MORE	munimuka

Use for salt from ashes

100. **Grewia villosa** Willd.

SYNONYM:
Grewia corylifolia
Guill. & Perr.

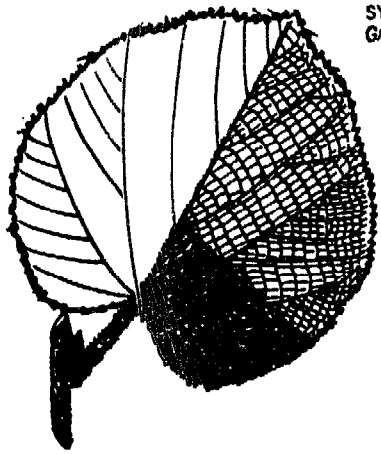

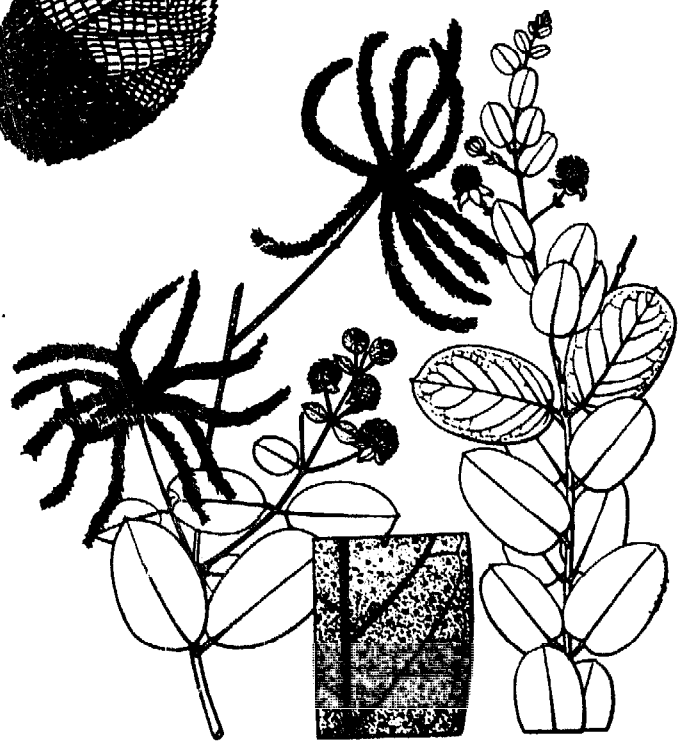

101. **Guiera senegalensis** Lam.

Also see APPENDIX B

CHAD ARABIC	kabeah
BAMBARA	kudlengbe
DJERMA	sabara
FULANI	galloki
HAUSA	sabara
KANOURI	kasasal
MORE	unuiga

Use for firewood, seeds for dysentery **medicine**

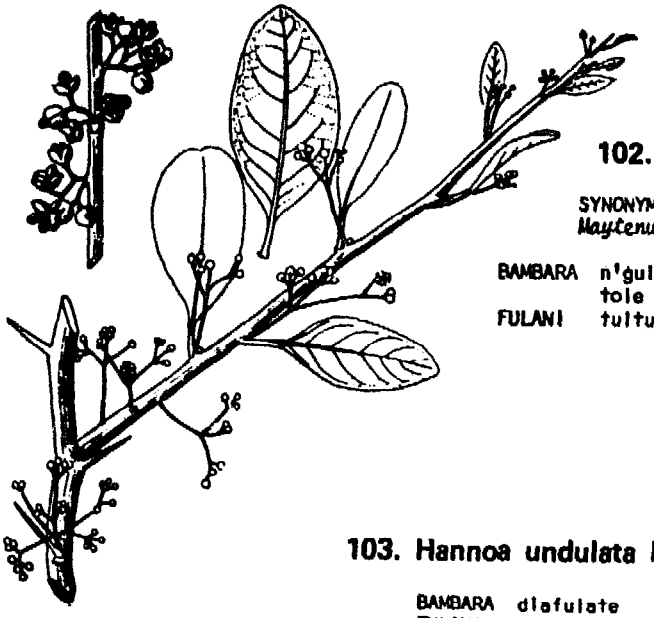

102. **Gymnosporia senegalensis** Loes.

SYNONYM:
Maytenus senegalensis (Lam.) Excell

BAMBARA	n'guigue	HAUSA	namijin-tsada
	tole	MORE	tokuvugurl
FULANI	tultulde		

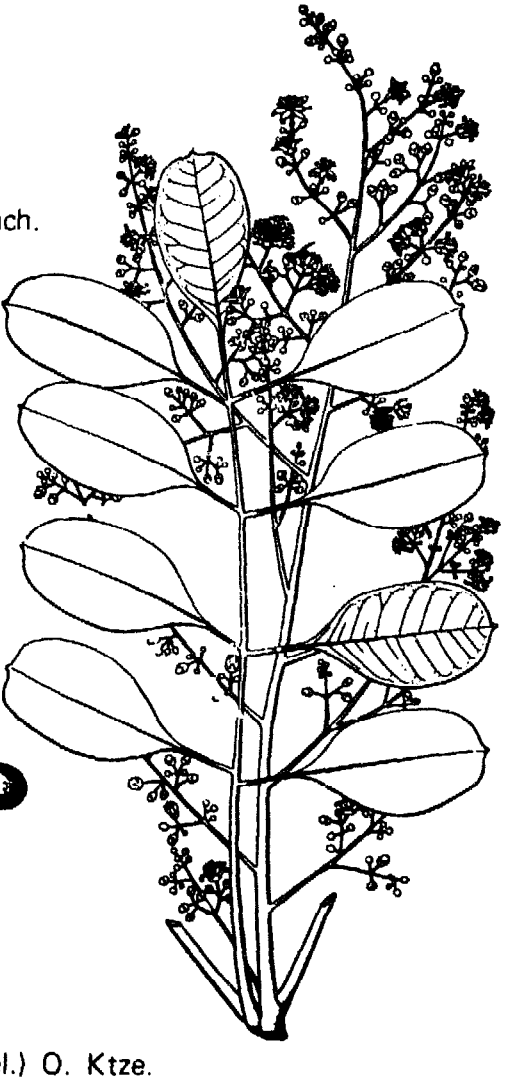

103. **Hannoa undulata** Planch.

BAMBARA	diafulate
FULANI	bummere
	badi
HAUSA	takandar
	giwa

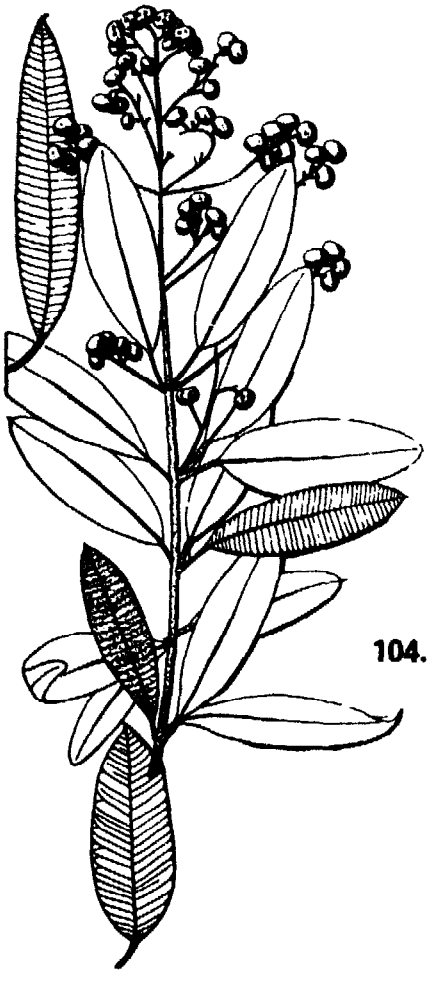

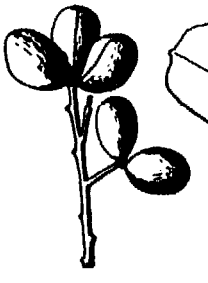

104. **Heeria insignis** (Del.) O. Ktze.

SYNONYMS:
Anaphrenium abyssinicum Hochst.
Rhus insignis Del.

BAMBARA	kalakari	HAUSA	kasheshe
FULANI	badi	MORE	nilnore

105. Hibiscus asper Hook.

not illustrated

FULANI	follere
HAUSA	yakuwar dajl
KANOURI	karasu

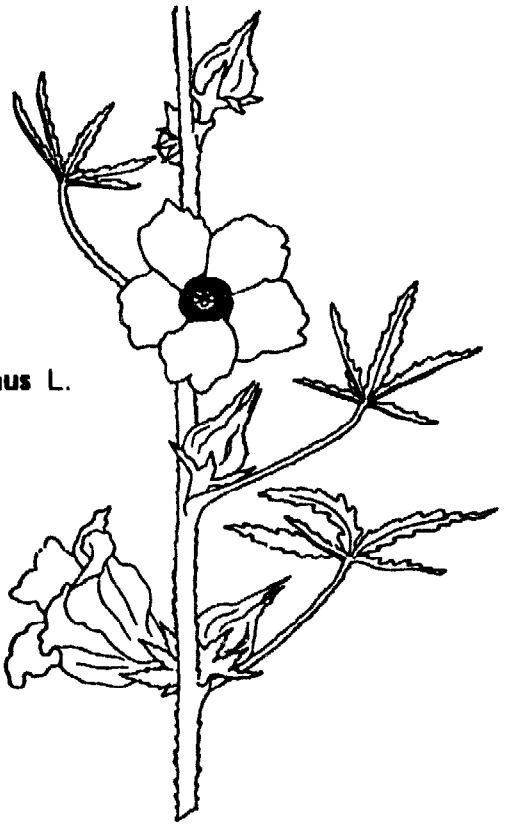

106. Hibiscus cannabinus L.

CHAD ARABIC	tll libe
FULANI	gabal
HAUSA	rama
KANOURI	ngabal

107. Hibiscus esculentus L.

not illustrated

CHAD ARABIC	bamiya
FULANI	takeyl
HAUSA	kubewa
KANOURI	nubalto

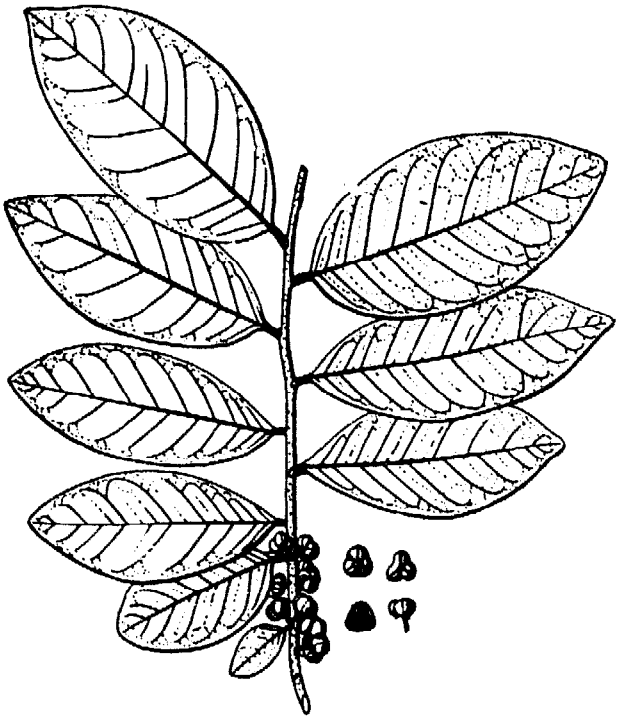

108. Hymenocardia acida Tul.

BAMBARA	tanloro
FULANI	yawa sotoje bodehl
HAUSA	jan-yaro djan-itche

Use for red-colored wood

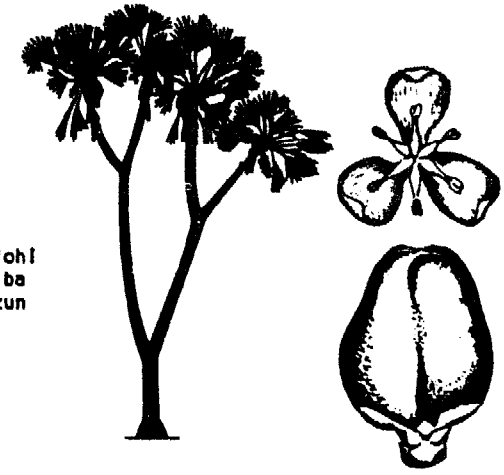

109. Hyphaene thebaica (L.) Mart.

FRENCH	doum	FULANI	gellohi
CHAD ARABIC	dom	HAUSA	goriba
DJERMA	kangau	KANOURI	kerzun

Use for construction, edible fruit

110. Isoberlinia dalzielii Craib & Stapf. not illustrated

SYNONYM: *Isoberlinia tomentosa* (Harms.) Craib. & Stapf.

BAMBARA	sau	HAUSA	fara doka
	slo	MORE	kaisaka
FULANI	kubahi		

111. Isoberlinia doka
Craib & Stapf

HAUSA doka

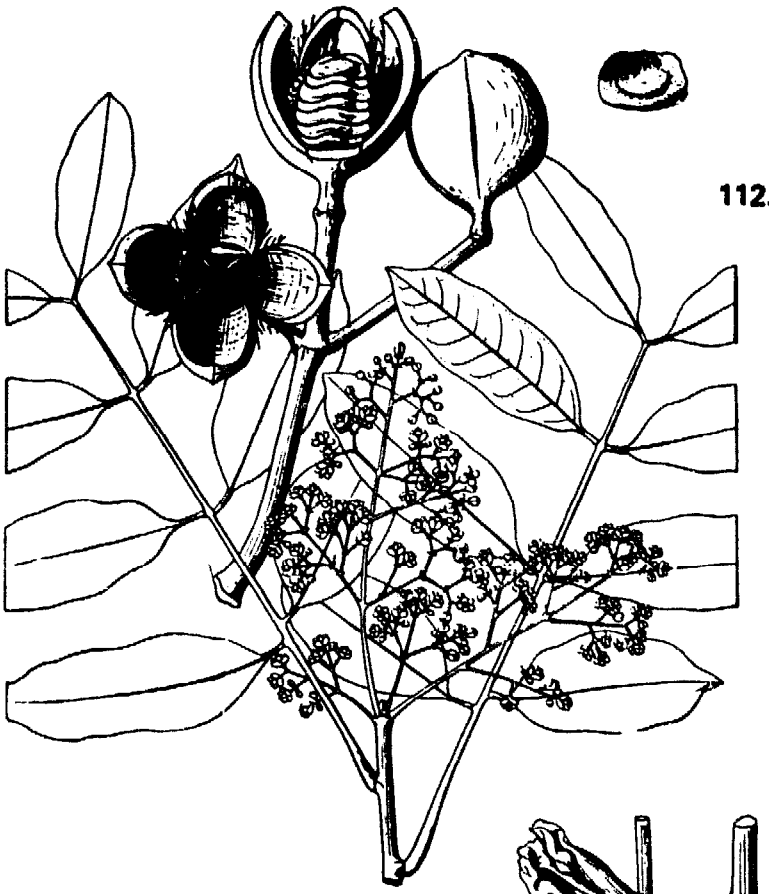

112. **Khaya senegalensis** Juss.

ENGLISH	African "mahogany"
FRENCH	caïlcedrat
CHAD ARABIC	muray
BAMBARA	diala
DJERMA	farei
FULANI	daleki
	cali
HAUSA	madadji
KANOURI	kagam
MORE	kuga

Use for fodder

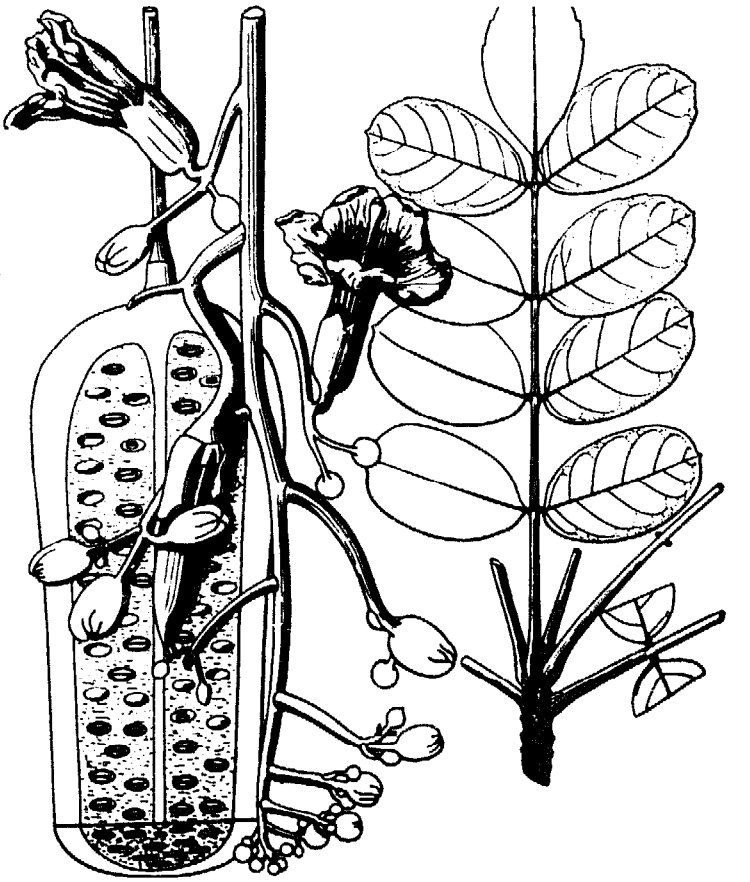

113. **Kigelia africana** Benth.

SYNONYMS:
Kigelia aethiopica Decne.
Kigelia africana var. *aethiopica* Aubr.

CHAD ARABIC	kouk
FULANI	giriahi
HAUSA	rahma
	baouria
KANOURI	bulungu
MORE	dindon
	limbi

114. Lannea acida A. Rich.

Also see APPENDIX B

FULANI	faruhi
HAUSA	farou
KANOURI	adarazagal
MORE	pekuni
	sabga

Use for edible fruit

115. Lannea afzelii Engl.

SYNONYMS:
Lannea glabberima Engl. & Krause
Lannea grossularia A. Chev.
Lannea nigritana (Sc. Ell.) Keay

HAUSA daoya

Use for **medicine**

116. Lannea humilis (Oliv.) Engl.

SYNONYMS: *Lannea bagirmonsis* Engl.
Odina humilis Oliv.

KANOURI kurubulul

117. Lannea oleosa not illustrated

SYNONYM: *Odina acida*

118. **Leptadenia lancifolia** Decne.

SYNONYMS:
Leptadenia hastata (Pers.) Decne.
Cynanchum hastatum Pers.

CHAD ARABIC	sha'alob
FULANI	yehi
HAUSA	yadiya
KANOURI	njara

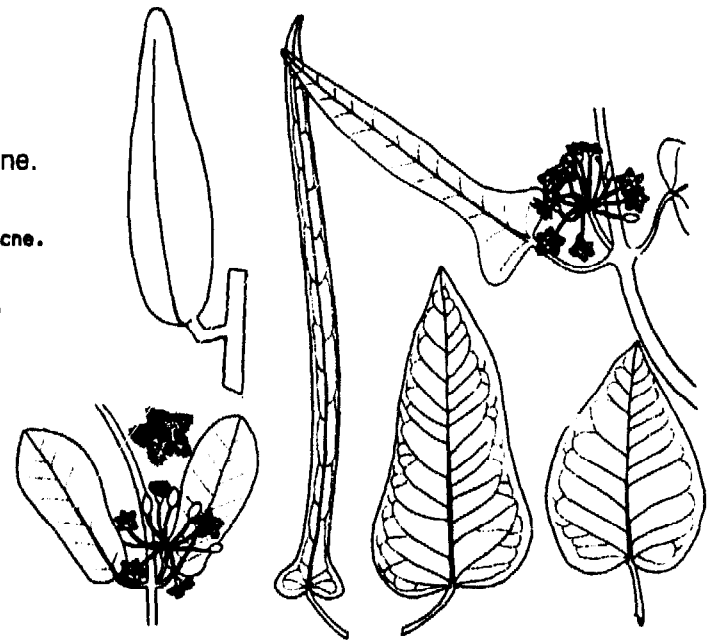

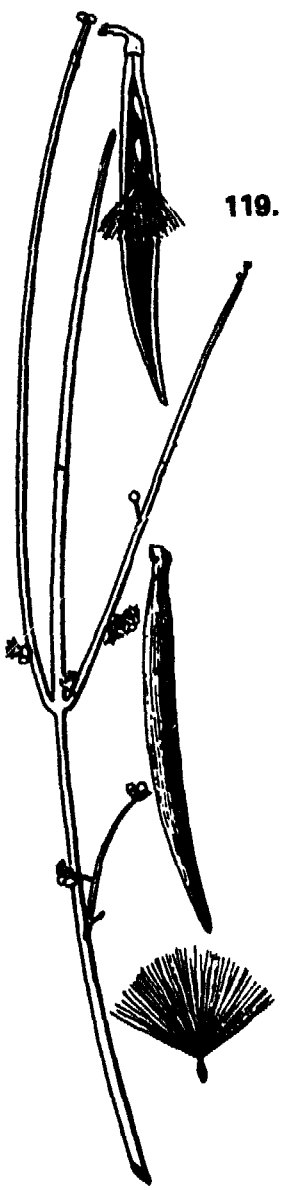

119. **Leptadenia spartium** Wright

SYNONYM:
Leptadenia pyrotechnica (Forsk.) Dec.

CHAD ARABIC	marakh
FULANI	sabale
HAUSA	kalumbo
KANOURI	karimabo

120. **Lophira alata** Banks

SYNONYM:
Lophira lanceolata
Van Tiegh. ex Keay

BAMBARA	mana
FULANI	kareki gori
HAUSA	nanijin kadai

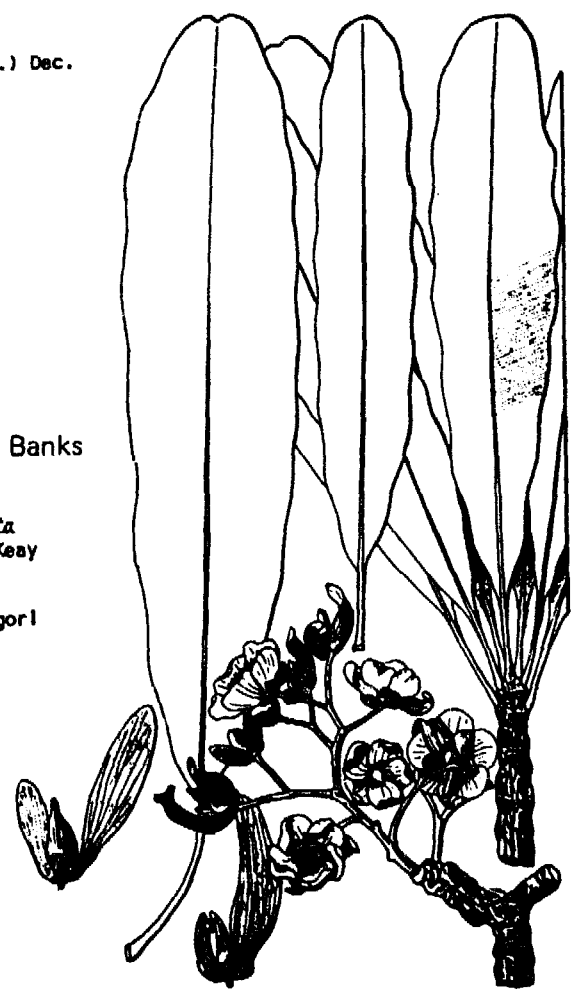

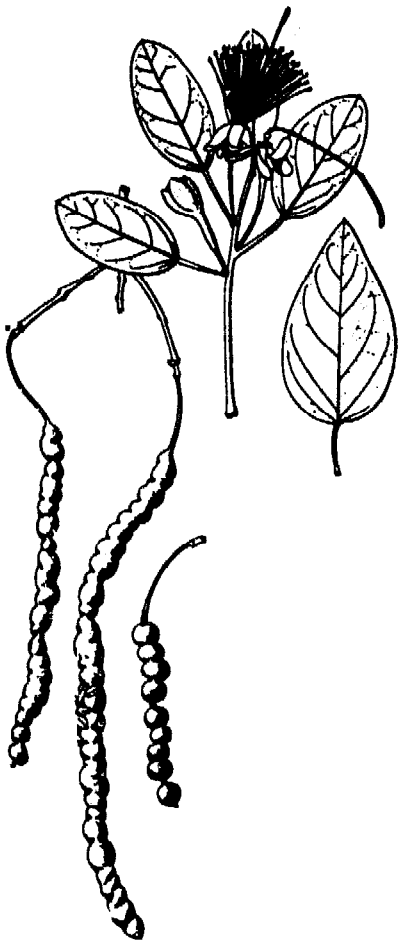

121. **Maerua angolensis** D.C.

CHAD ARABIC	shegara el zeraf
BAMBARA	bre-bre kokali
FULANI	leggal bali
HAUSA	ciciwa
KANOURI	abchi
MORE	kessiga

Use for fodder

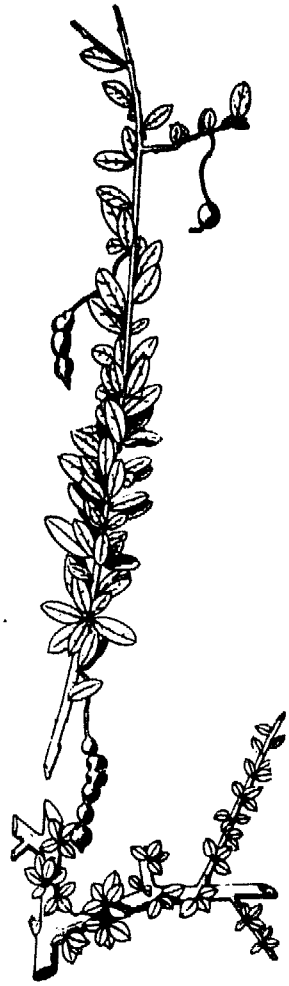

122. **Maerua crassifolia** Forsk.

CHAD ARABIC	zorhale sarah
BAMBARA	beredlou
FULANI	sogui
HAUSA	jiga
KANOURI	jiga
MORE	kessiga

Use for tool handles, firewood, fodder

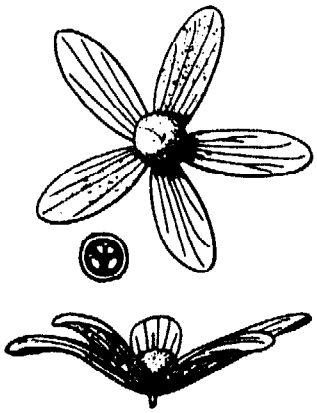

123. **Menotes keratingii**

FULANI	jangi
HAUSA	farin rua

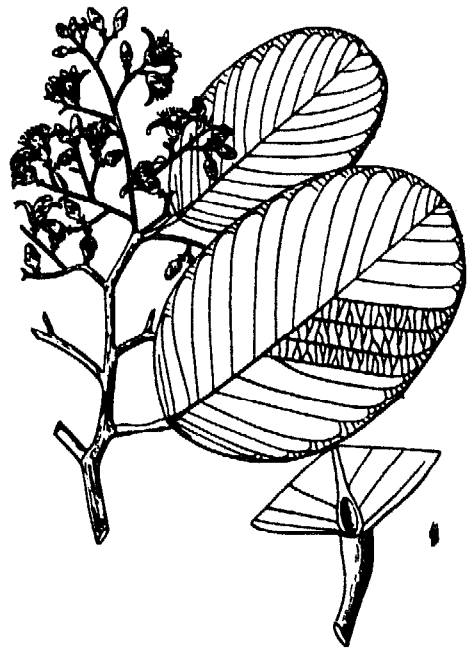

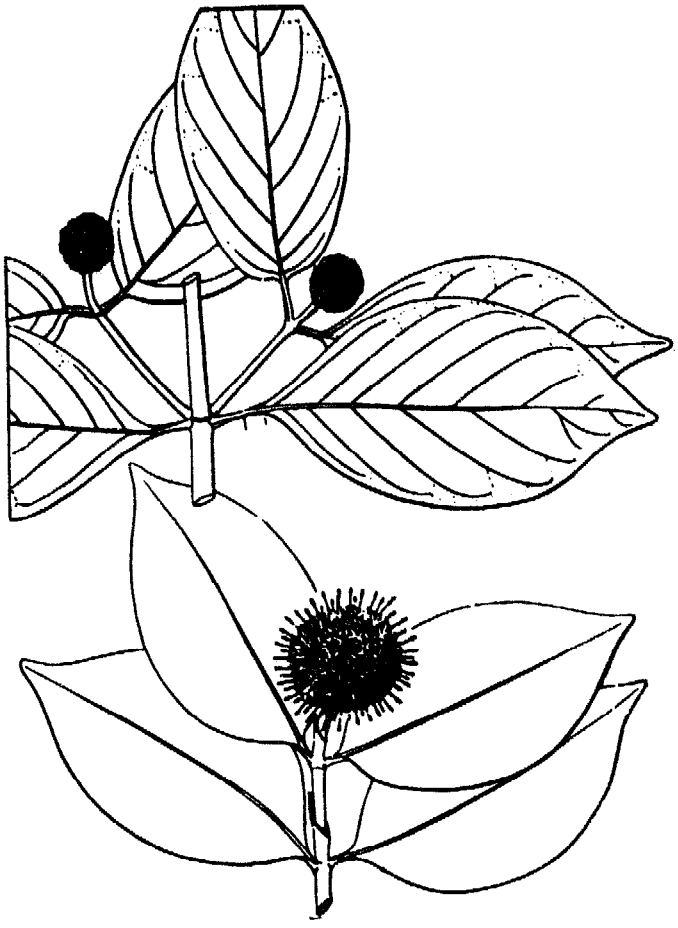

124. Mitragyna inermis O. Kuntze

SYNONYM:
Mitragyna africana Korth.

CHAD ARABIC	ngato
BAMBARA	dioun
FULANI	koli
HAUSA	guijeja
KANOURI	kawui
MORE	iioga

Use for firewood, medicine, fish baskets

125. Momordica balsamina L.

HAUSA	garafuni
KANOURI	dugdoge

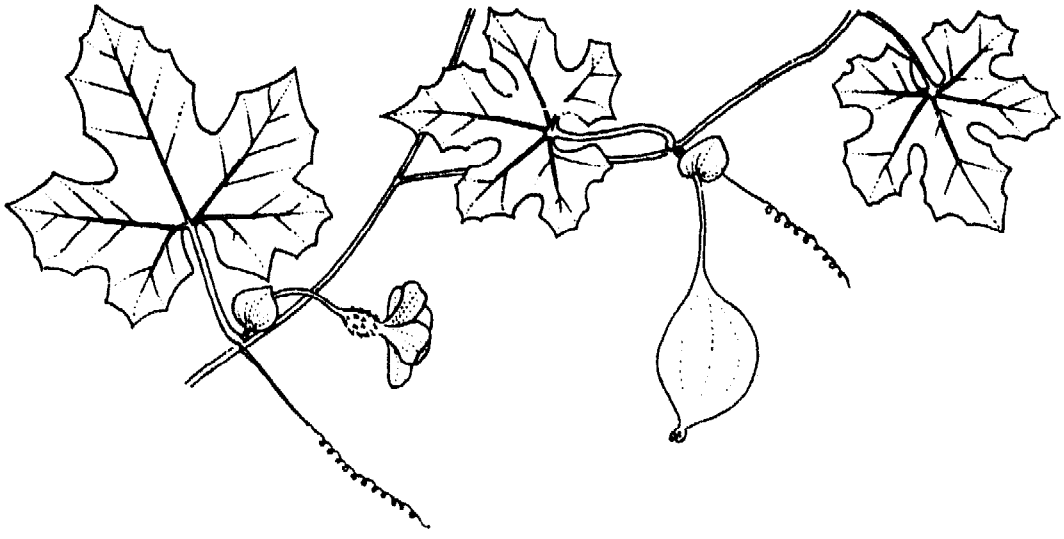

126. **Moringa pterygosperma** Gaertn.

SYNONYM: *Moringa oleifera* Lam.

CHAD ARABIC	alim
FULANI	guligandani
HAUSA	zogolangandi
KANOURI	alum
MORE	argentiga

Use for edible leaves

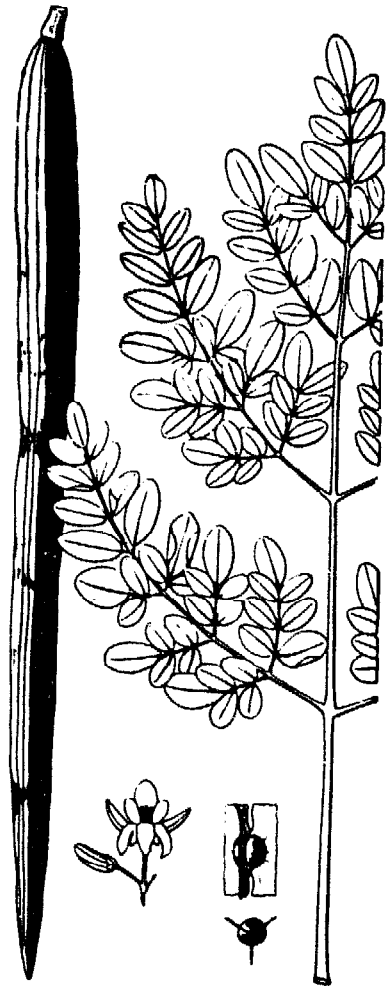

127. **Nauclea esculanta**

not illustrated

FULANI	bakurehi
HAUSA	tafashiya

128. **Nauclea latifolia** Smith

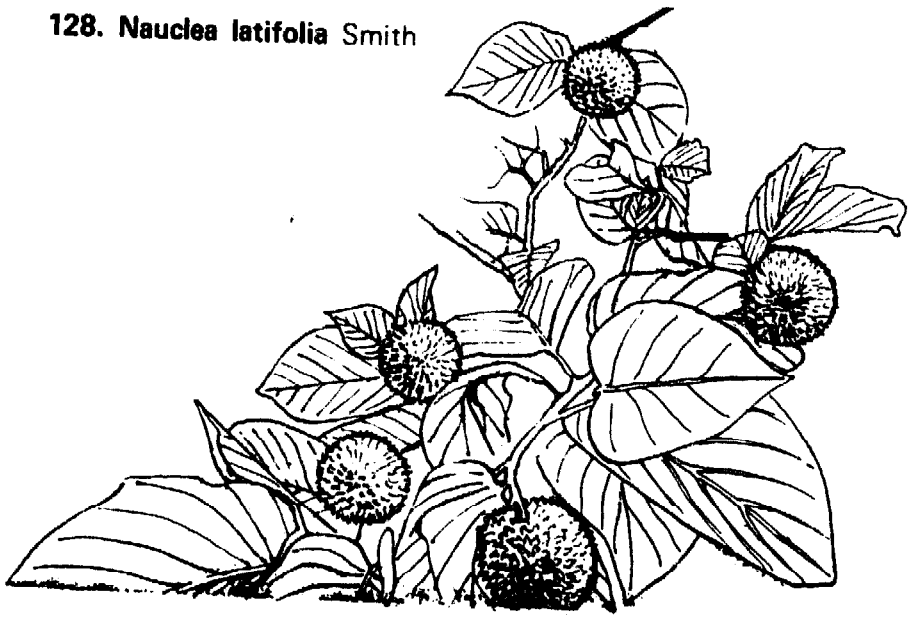

129. Nymphaea lotus L.

CHAD ARABIC	sitteib
FULANI	tabbera
HAUSA	bado
KANOURI	dəmbi

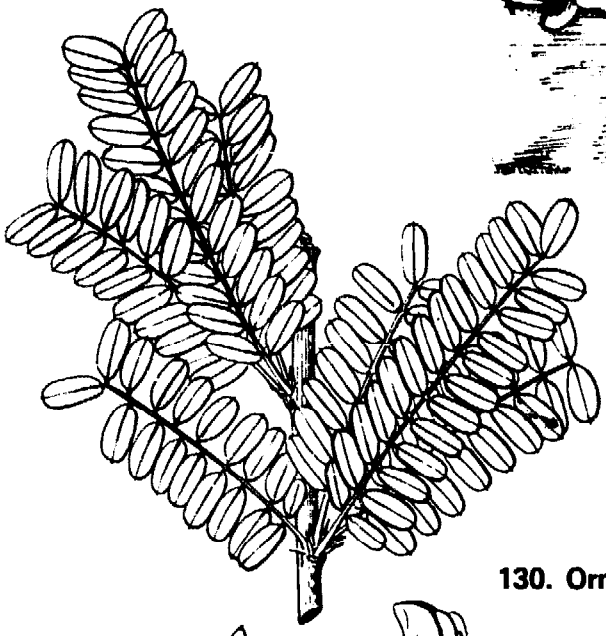

130. Ormocarpum bibracteatum Bak.

HAUSA	fashkara
	giwa
KANOURI	sabrəm

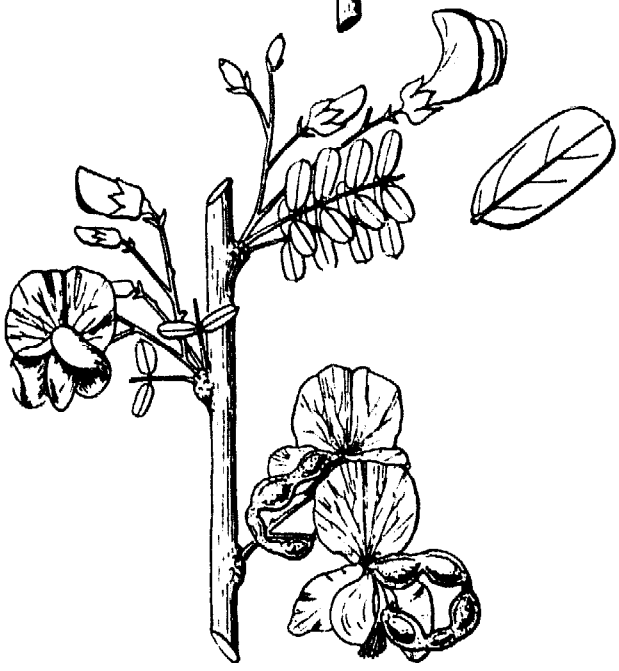

131. Oryza barthii

not illustrated

HAUSA shimkafa

132. **Ostryoderris chevalieri** Dunn

SYNONYM: *Ostryoderris stuhlmannii* (Taub.) Dunn ex Harms.

BAMBARA	mussa sana
	fugu
HAUSA	burdi
MORE	baombanko

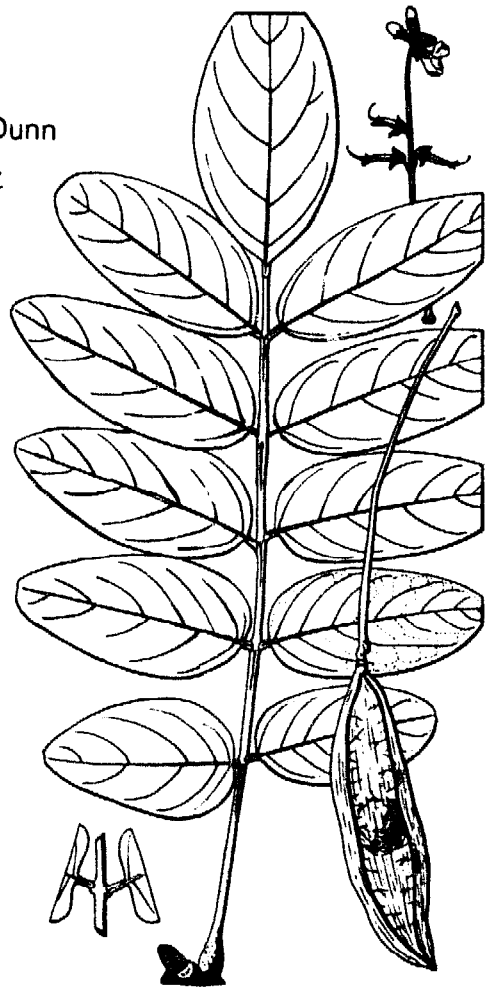

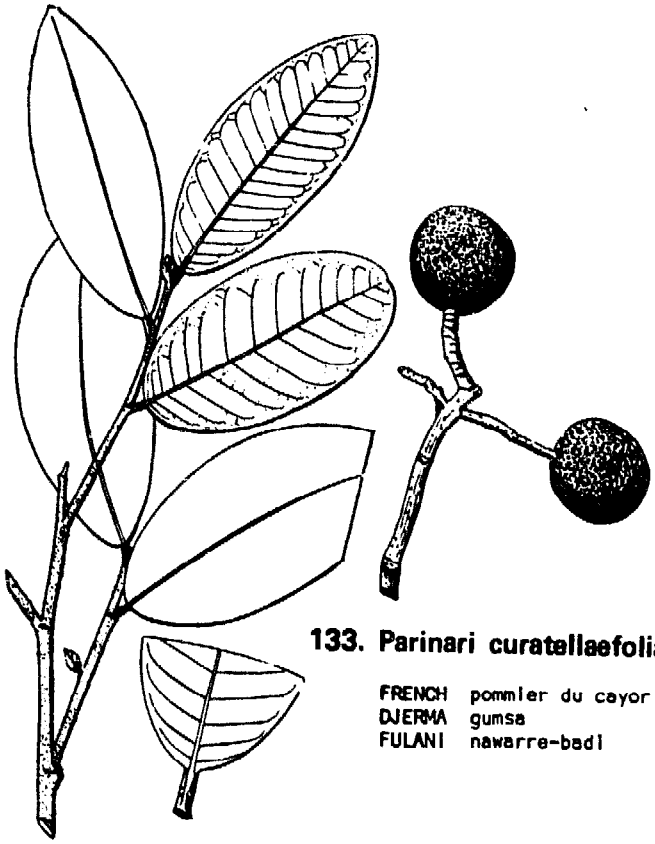

133. **Parinari curatellaefolia** Planck.

FRENCH	pommier du cayor	HAUSA	rura
DJERMA	gumsa		gawassa
FULANI	nawarre-badi	KANOURI	mande

134. **Parinari macrophylla** Sabine

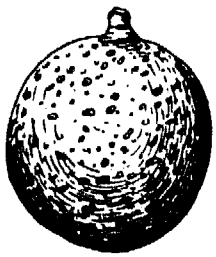

FULANI	nawarre
HAUSA	gawasa
MORE	ouamtanga

Use for edible fruit

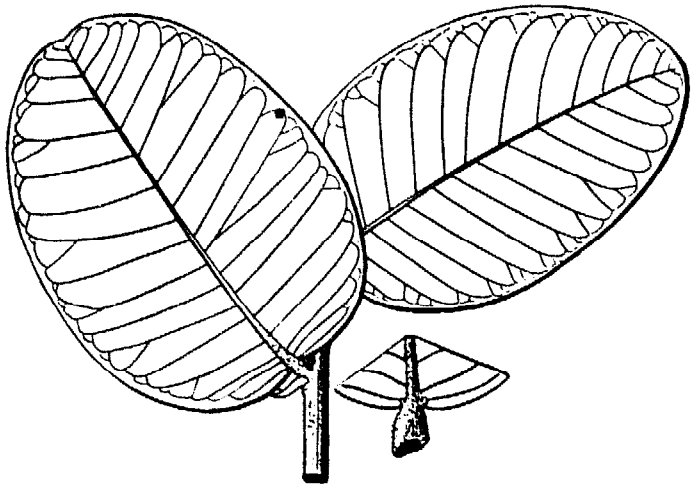

135. **Parkia biglobosa** Benth.

Also see APPENDIX B

SYNONYMS:
Parkia clappertonia Keay
Mimosa biglobosa Jacq.

FRENCH	nere
CHAD ARABIC	malto
BAMBARA	nere
DJERMA	dosso
FULANI	narghi
HAUSA	dorowa
KANOURI	runo
MORE	rouaga

Use for edible fruit

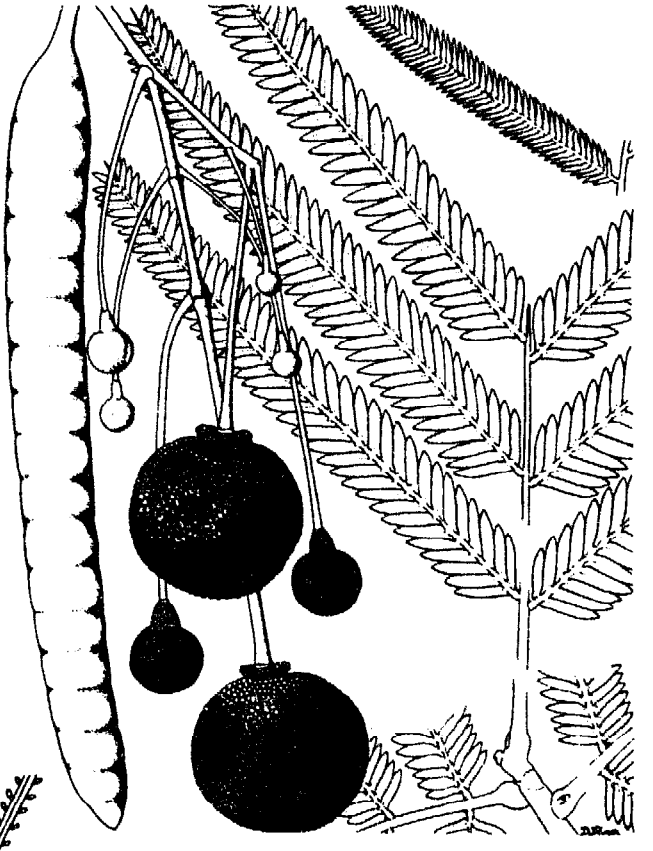

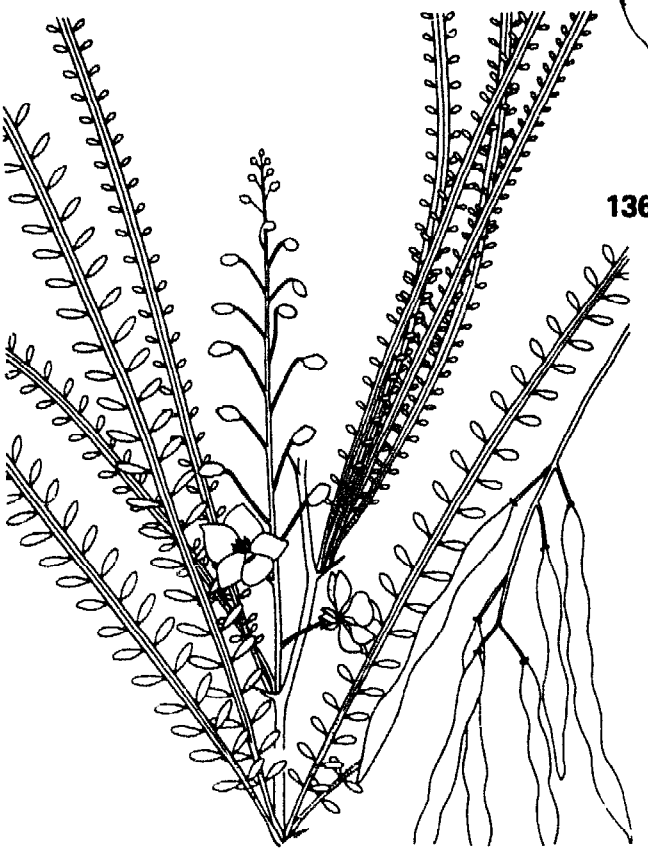

136. **Parkinsonia acculeata** L.

Also see APPENDIX B

DJERMA	sassa bani
HAUSA	sharan abi
KANOURI	sharan labi

Use for firewood, live fencing, windbreaks, soil cover

137. **Phoenix dactylifera** L.

not illustrated

ENGLISH	date palm
FRENCH	palmier dattier
CHAD ARABIC	tamrai
FULANI	bukki dibinobi
HAUSA	dabino
KANOURI	difono

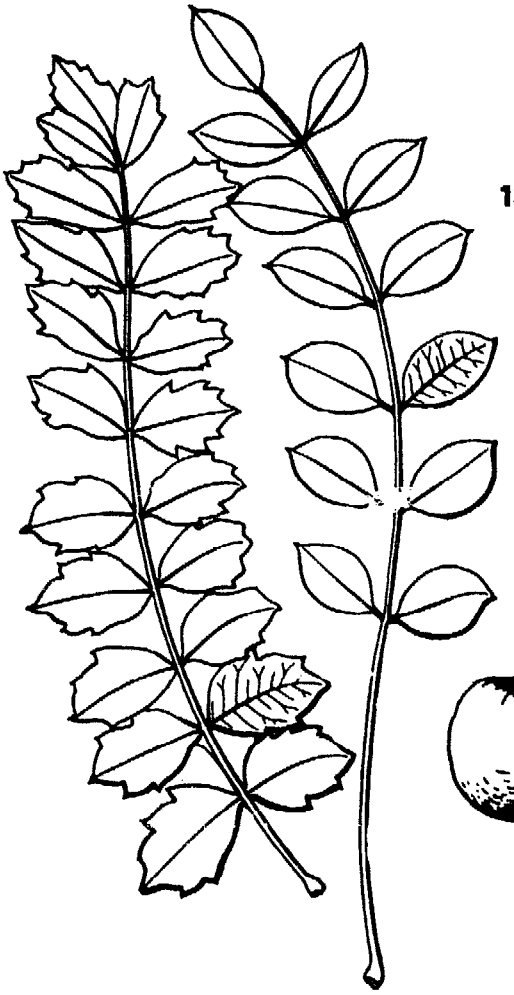

138. **Poupartia birrea** (Hochst.) Aubr.

Also see APPENDIX B

SYNONYM: *Sclerocarya birrea* Hochst.

FRENCH	dine	HAUSA	danya
CHAD ARABIC	homeid	KANOURI	kumagu
BAMBARA	kuntea	MORE	nobega
FULANI	heri		

Use for edible fruit, light woodworking

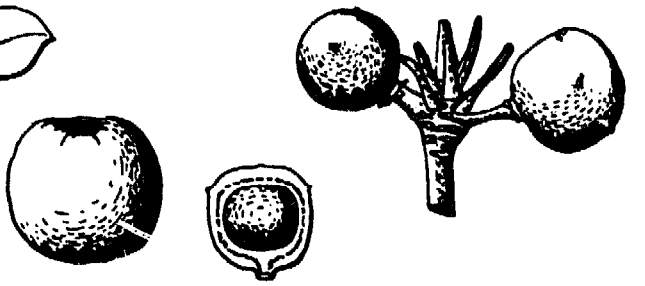

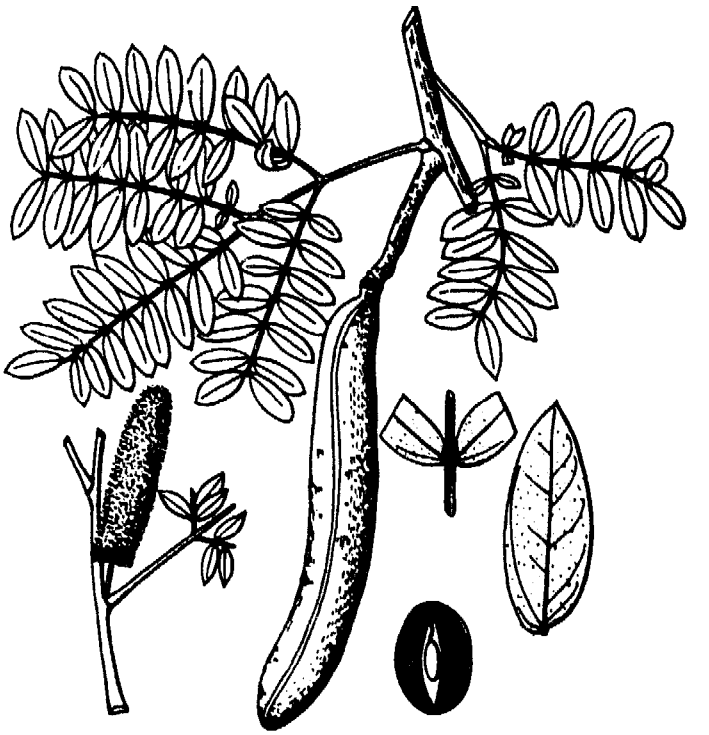

139. **Prosopis africana** Taub.

Also see APPENDIX B

SYNONYM:
Prosopis oblonga Benth.

BAMBARA	guele
FULANI	kohi
HAUSA	kiriya
KANOURI	simaim
MORE	niuri-segue

Use for construction, woodworking, charcoal, tanning

140. **Prosopis juliflora** (Sw.) D.C.

Also see APPENDIX B

SYNONYMS:
Prosopis chilensis (Mol.) Stuntz
Ceratonia chilensis Mol.

ENGLISH (USA) mesquite

Use for fence posts, firewood, live fencing, windbreaks, fodder

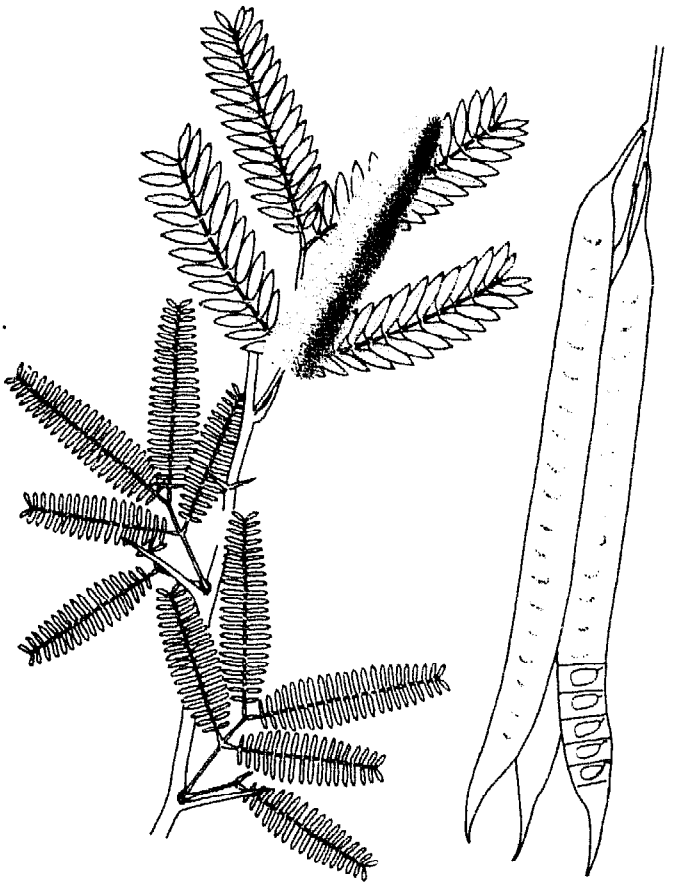

141. **Pseudocedrala kotschyi** Harms.

SYNONYM:
Cedrala kotschyi Schweinf.

FULANI	bodo
HAUSA	tuna
KANOURI	kngarakagum
MORE	seguedere

142. Pteleopsis suberosa
Engl. & Diels.

SYNONYM:
Pteleopsis keratingii Glig.

HAUSA wyan damo

Use for fodder

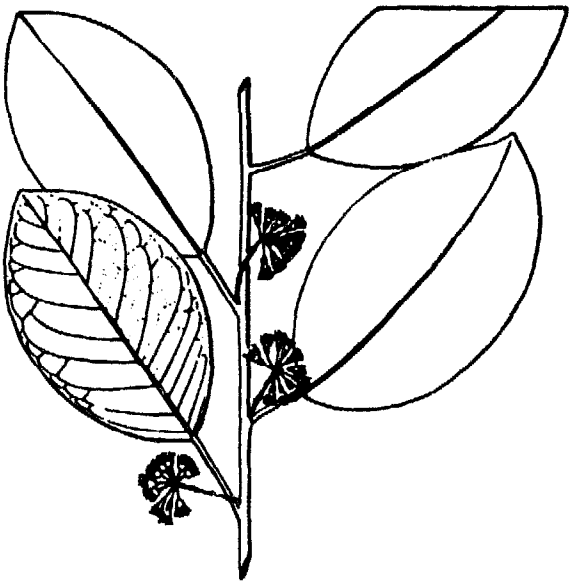

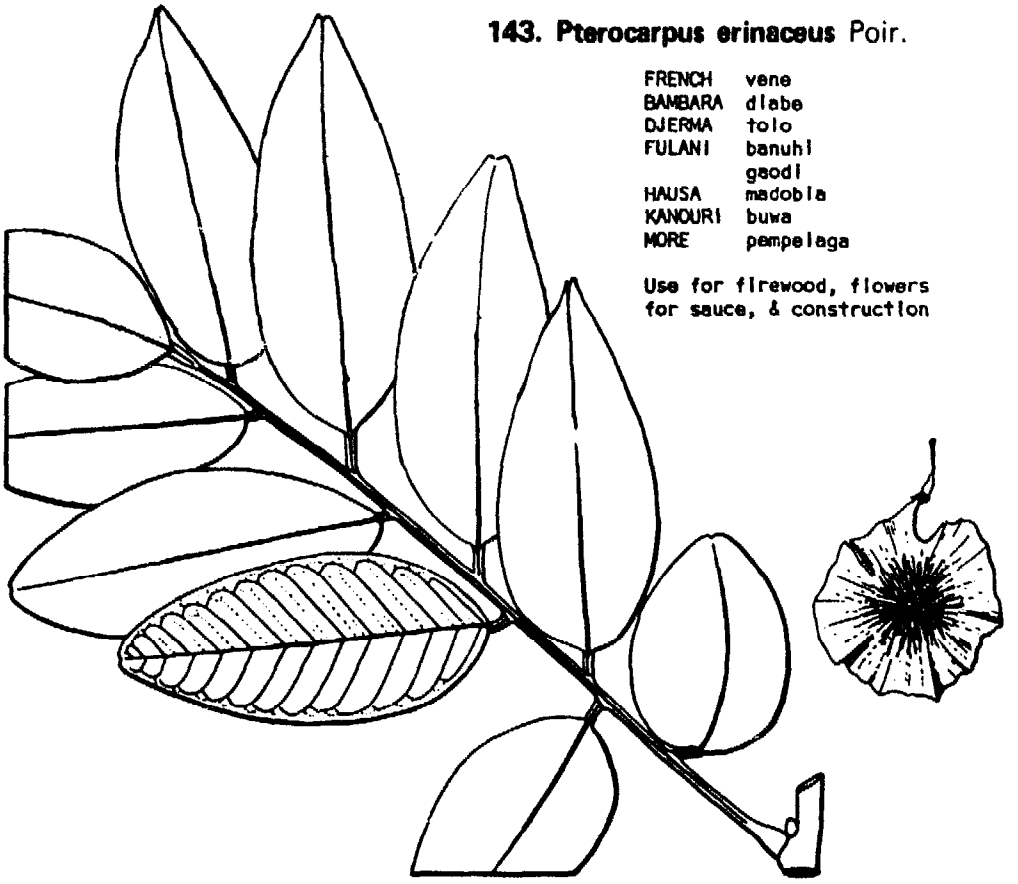

143. Pterocarpus erinaceus Poir.

FRENCH	vene
BAMBARA	dlabe
DJERMA	tolo
FULANI	banuhi
	gaodi
HAUSA	madobla
KANOURI	buwa
MORE	pempelaga

Use for firewood, flowers for sauce, & construction

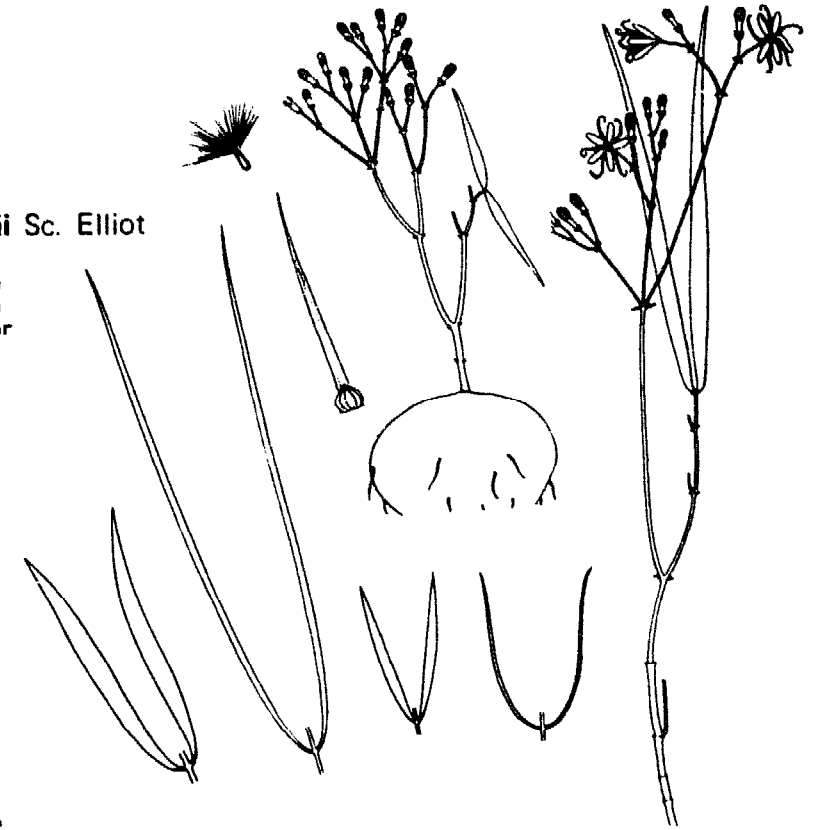

144. Raphionacme brownii Sc. Elliot

FULANI	fugore
HAUSA	rujiya
KANOURI	gadagar

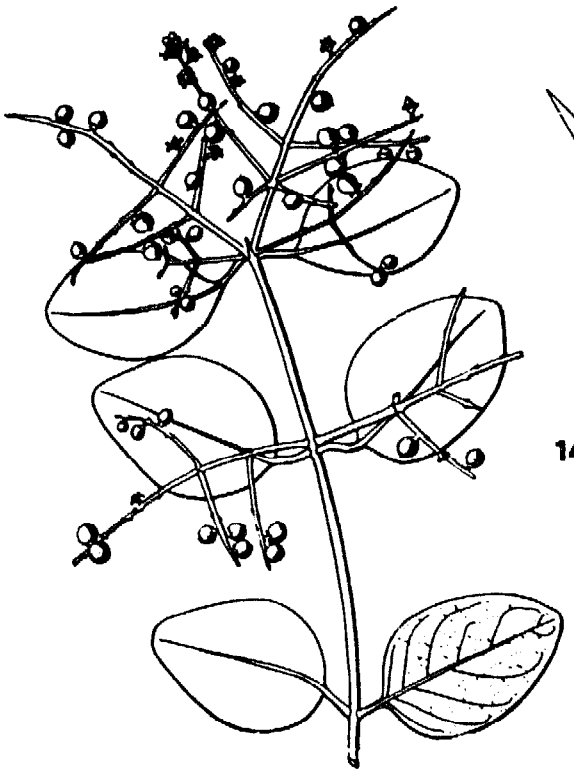

145. Salvadora persica L.

CHAD ARABIC	arak	FULANI	hirohi
	siwak	HAUSA	talakia
BAMBARA	hiriguesse	KANOURI	babul
DJERMA	hiro	MORE	irak

Use leaves for stocksalt

146. Securidaca longipedunculata Fres.

CHAD ARABIC	alali
BAMBARA	diota
FULANI	alali
HAUSA	magunguna
KANOURI	gazaboro
MORE	pelaga

Use for firewood

147. **Sterculia setigera** Del.

SYNONYM:
Sterculia tomentosa Guill. & Perr.

CHAD ARABIC	shadarat al damn
BAMBARA	koko kongurani
FULANI	bo'boli
HAUSA	kukuki
KANOURI	sugubo
MORE	pupunga

Use for gum

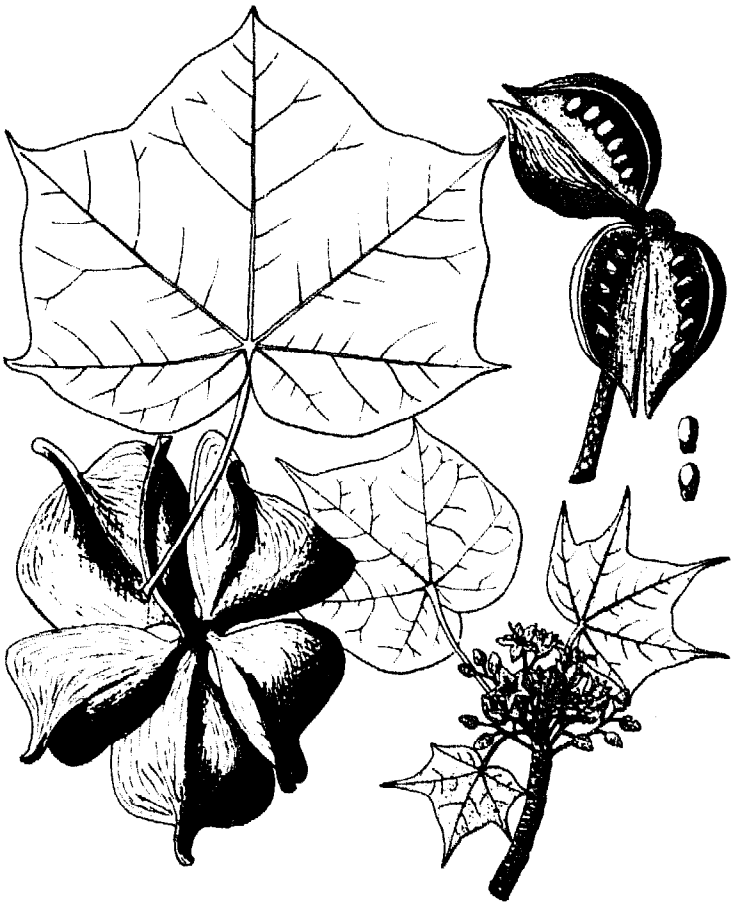

148. **Stereospermum kunthianum** Cham.

CHAD ARABIC	ess arad
BAMBARA	mogo kolo
FULANI	golombi
HAUSA	sansami
KANOURI	golombi
MORE	vulga nihilenga

Use for firewood

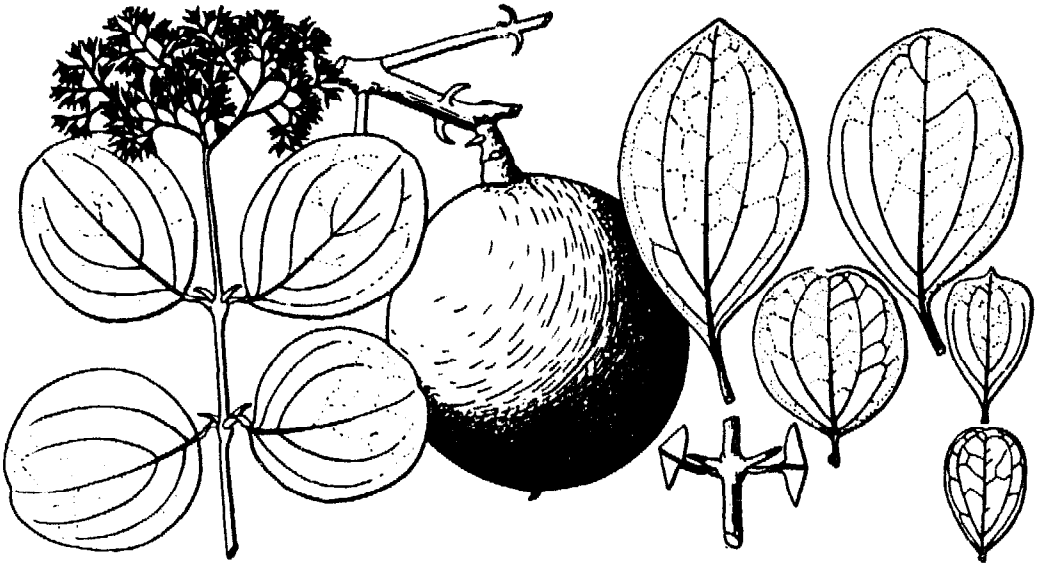

149. Strychnos spinosa Lam.

SYNONYMS:
Strychnos courteti Chev.
Strychnos dulcis Chev.
Strychnos emarginata Bak.
Strychnos gracillima Gilg.
Strychnos lokua A. Rich.
Strychnos volkensii Gilg.

BAMBARA	kankoro	HAUSA	koklya
FULANI	kumbija	KANOURI	toria

Use for edible fruit

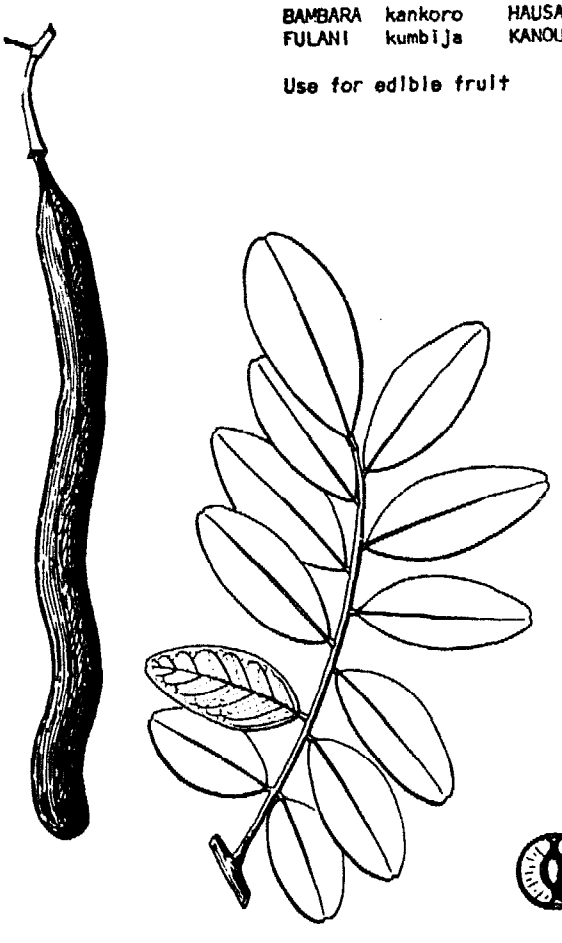

150. Stylochiton warneckii Engl.

not illustrated

HAUSA	gwandai
KANOURI	ngura

151. Swartzia madagascaraensis Desv.

HAUSA	gwaskia
	gama fada

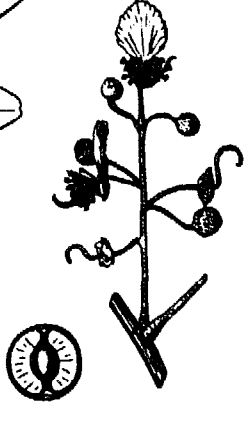

152. Syzygium guineense D.C.

BAMBARA	kissa
FULANI	asurahi
HAUSA	maimo
KANOURI	kunar

153. Tamarindus indica L.

Also see APPENDIX B

ENGLISH	tamarind tree
FRENCH	tamarinier
CHAD ARABIC	tamr hindi
BAMBARA	tombi
DJERMA	bossaye
FULANI	jtatami
HAUSA	tsamiya
KANOURI	tamsugu
MORE	pousiga

Use for juice from fruit, woodworking, charcoal

154. Terminalia avicennioides Guill. & Perr.

SYNONYMS:
Terminalia dictyoneura Diels.
Terminalia lecardii Engl. & Diels.

BAMBARA	oudiotieni	HAUSA	bauchi
DJERMA	farkahanga	KANOURI	kumanda
FULANI	bodeyi		barbar
		MORE	kutruagale

Use for fodder, firewood, roots for dye

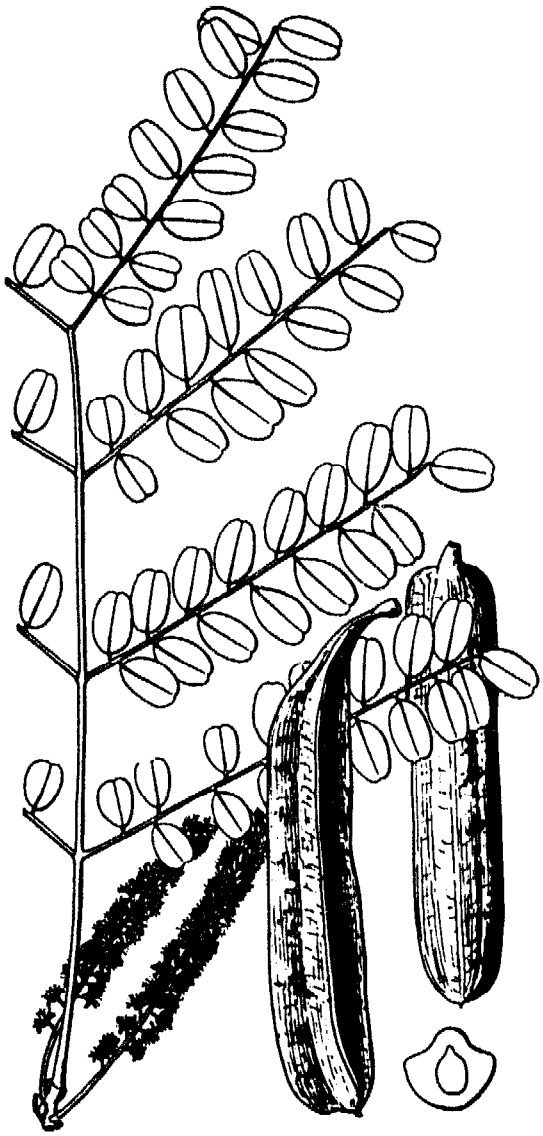

155. Tetrapleura andongensis Welw. var. schweinfurthii Aubr.

SYNONYMS:
Tetrapleura obtusangala Welw.
Tetrapleura nilotica Taub.
Tetrapleura schweinfurthii Taub.
Amblygonocarpus andongensis Welw. ex Oliv.
Amblygonocarpus schweinfurthii

FULANI	jigarehi	HAUSA	kirya te mata tsage

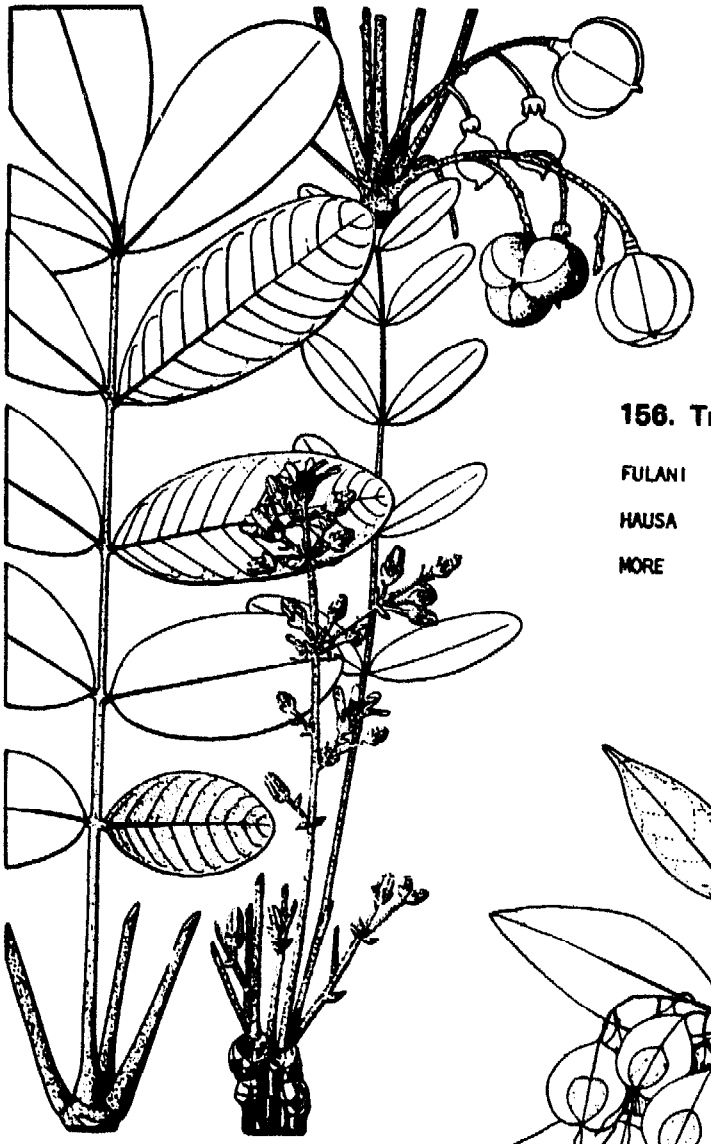

156. Trichilia emetica Valh.

FULANI	baszi
	bakurchi
HAUSA	kusa
	Jansaye
MORE	kikiramtanga

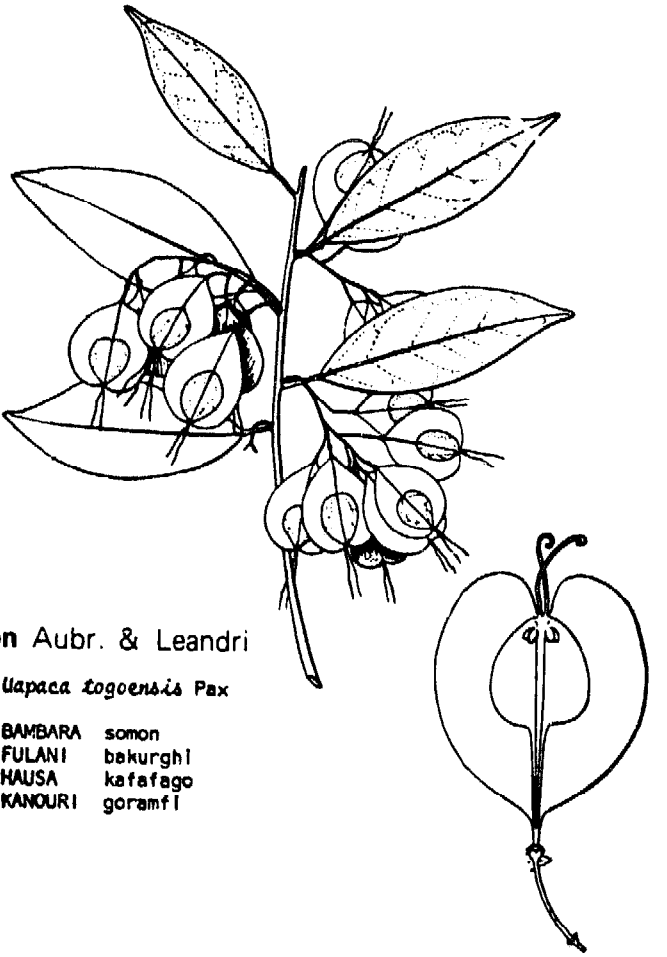

157. Uapaca somon Aubr. & Leandri

SYNONYM: *Uapaca togoensis* Pax

BAMBARA	somon
FULANI	bakurghi
HAUSA	kafafago
KANOURI	goramfi

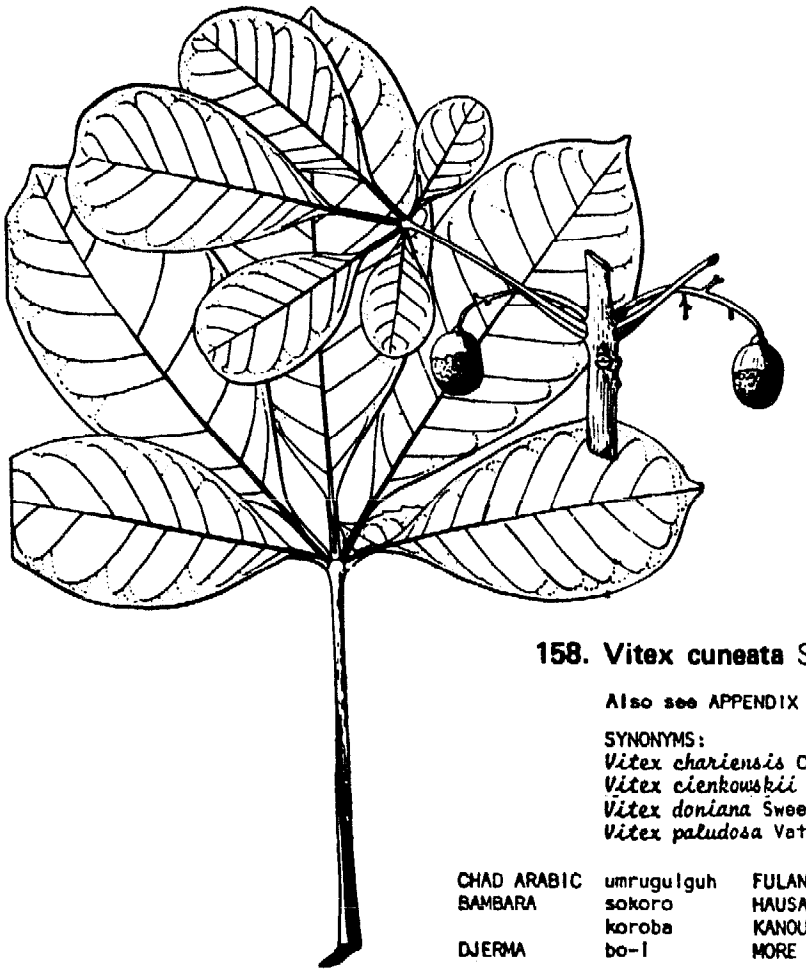

158. **Vitex cuneata** Schum. & Thonn.

Also see APPENDIX B

SYNONYMS:
Vitex chariensis Chev.
Vitex cienkowskii Kotschy & Perr.
Vitex doniana Sweet
Vitex paludosa Vatke

CHAD ARABIC	umrugulguh	FULANI	galbihi
BAMBARA	sokoro	HAUSA	dumnjaa
	koroba	KANOURI	ngaribi
DJERMA	bo-i	MORE	andega

Use for edible fruit, light woodworking, leaves for dysentery **medicine**

159. **Vitex diversifolia** Bak.

SYNONYM:
Vitex simplicifolia Oliv.

BAMBARA	kotoni
FULANI	bummehi
HAUSA	dinyar

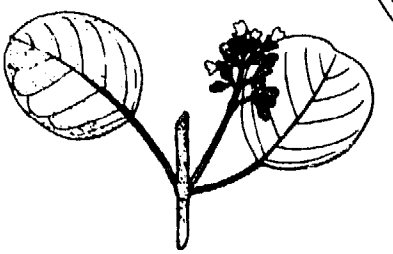

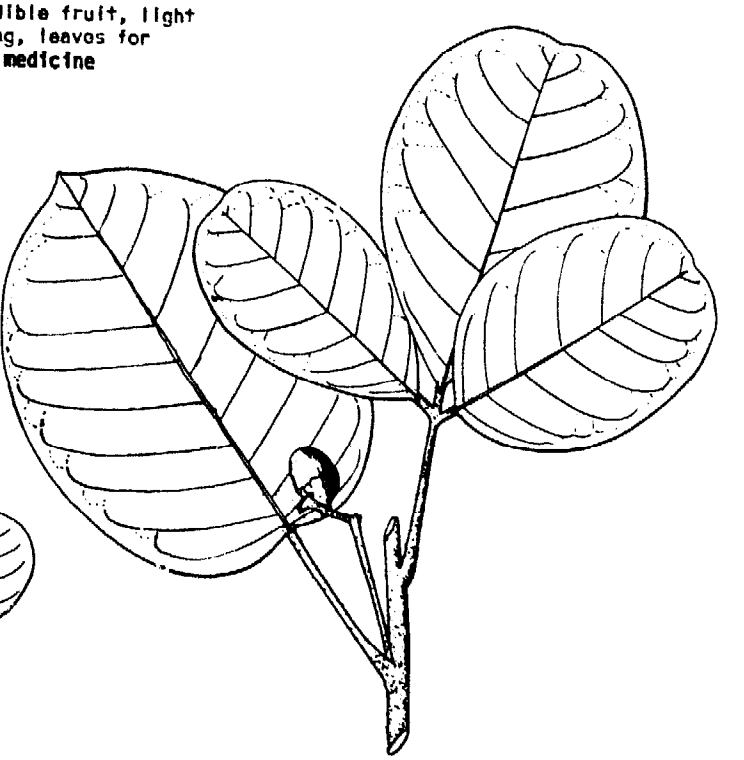

160. **Xeromphis nilotica** (Stapf.) Keay

not illustrated

SYNONYMS:
Randia nilotica Stapf.
Lachnosiphonium nil-ticum (Stapf.) Dandy

FULANI	gloigoti
HAUSA	kwanaria
KANOURI	bantatai

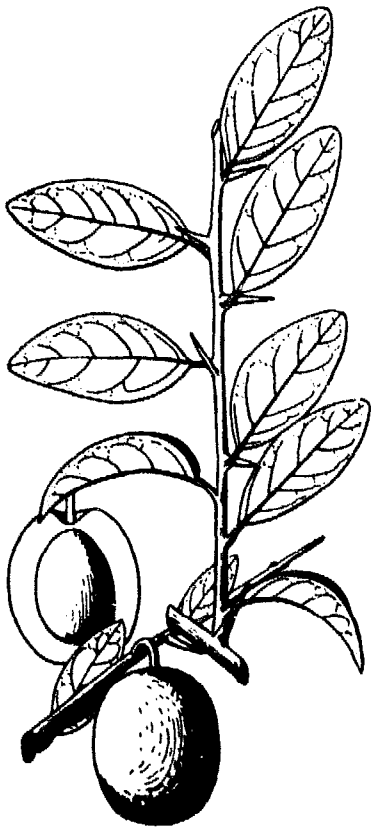

161. **Ximenia americana** L.

SYNONYM:
Ximenia nilotica

CHAD ARABIC	kalto
BAMBARA	tonkain
	guani
FULANI	chabuli
	sene
HAUSA	tsada
KANOURI	dadin
MORE	leanga

Use for edible fruit

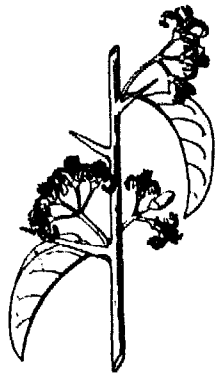

162. **Ziziphus abyssinicus** Hochst. ex A. Rich.

not illustrated

SYNONYMS:
Ziziphus atacorensis Chev.
Ziziphus baguirmine Chev.

CHAD ARABIC	nabaga
DJERMA	dare
FULANI	gulum jabi
HAUSA	magaria-kura
KANOURI	kululu bina

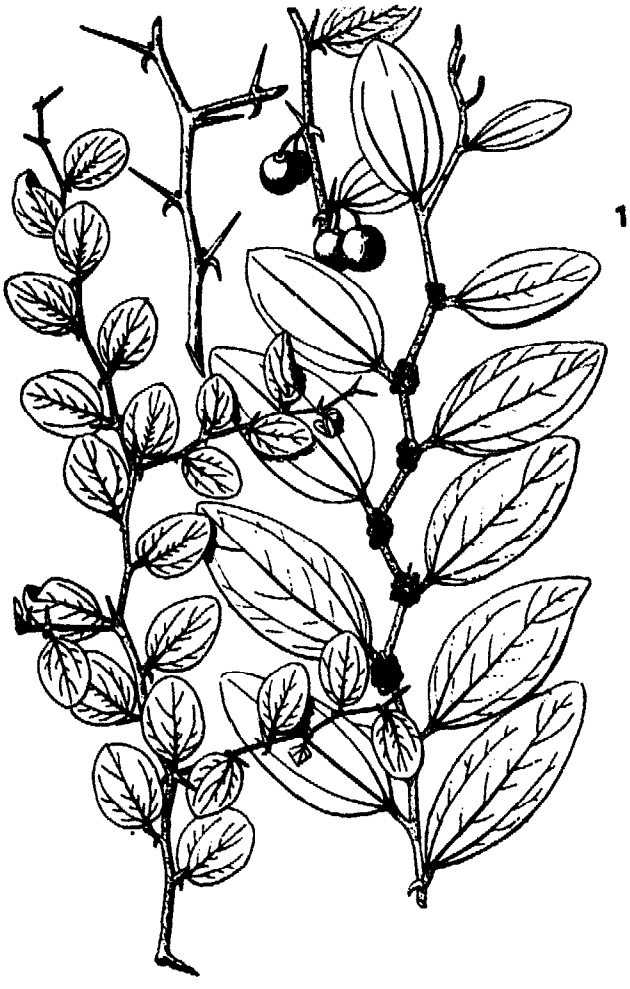

163. Ziziphus mauritiaca Lam.

SYNONYMS:
Ziziphus mauritiana Lam.
Ziziphus orthacantha D.C.
Ziziphus jujuba (L.) Lam.

CHAD ARABIC	nabagale
BAMBARA	tomboron
	niame ba
FULANI	jall
	barkevi
HAUSA	magaria
KANOURI	kusuiu
MORE	mugunuga
	bagandre

Use for sweet edible fruit, & leaves

164. Ziziphus sieberiana

not illustrated

HAUSA magaria-kura

165. Ziziphus spina christi (L.) Willd.

Also see APPENDIX B

CHAD ARABIC	karno
FULANI	kurnahi
HAUSA	kurna
KANOURI	korna

Use for edible fruit (bitter)

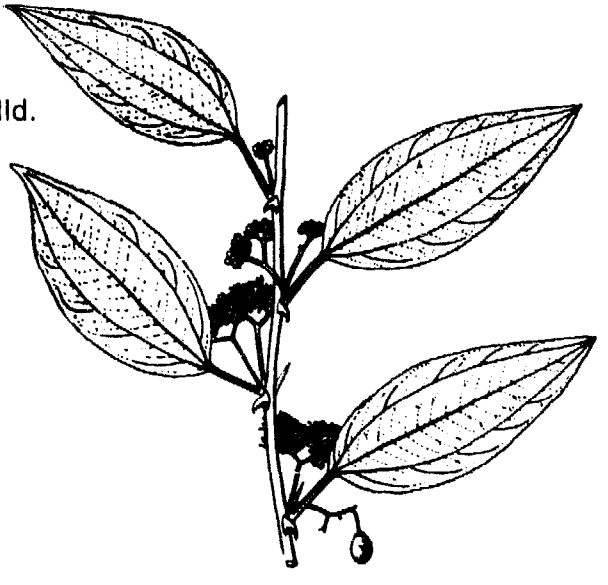

Appendix B

A Field Guide to 30 Tree Species
Commonly Found in Africa

Acacia albida Del.

Synonyms: *Faidherbia albida* (Del.) Chev.
Acacia gyrocarpa Hochst.
Acacia saccharata Benth.

Common Names:

ENGLISH	gao	FULANI	tiaiki
FRENCH	gao	HAUSA	gao
ARABIC	harraz	KANOURI	haragu
CHAD ARABIC	araza	MORE	zanga
BAMBARA	balanzan	SONGHAI	gao
DJERMA	gao	WOLOF	cadde

Legal Restrictions: Cutting and Removal

GENERAL DESCRIPTION

Large tree, growing as tall as 10m with a large spread-out crown. The bark is dull grey, fissured and scaly. Branchlets are white; spines are thick, white, straight and point downward. Leaves are grey-green; 3-10 pairs pinnules and 6-23 pairs leaflets. A. albida flowers with creamy white blossoms. Seeds are dark brown inside yellow pods which are 8-15cm long. A. albida is highly valued in conservation efforts. It is the only species which loses its leaves during the rainy season; therefore, farming under these trees is not only possible but profitable.

SEEDS

Source: Strong, healthy parent trees.
Collection: Collect pods from ground; seeds ripen January - February (Upper Volta).
Watch for small-size worm holes -- worms destroy the seeds.
Extraction: Mortar/wind separation.
Storage: Stores well.
Pre-Treatment: Necessary; soak in hot water or scarify hull.

NURSERY

Pots/Open-rooted: Only grow in pots because of long tap root.
Time: 10-14 weeks for good size plants. Earlier seeding may be required so plants get somewhat larger before hot weather.
Other Notes: Attempts to collect young plants in the wild not successful because of long tap root.
Frequent root pruning required because of tap root. Watch for caterpillar and locust attacks which destroy young leaves. Spray with ordinary insecticide.

PLANTING/SITE REQUIREMENTS

Soil:	Sandy soil; grows well in same type of ground where millet grows (ask farmers). Also can be grown in heavier soils and will stand occasional flooding.
Water:	350-500mm mean annual precipitation;,may be necessary to water newly planted trees in areas where precipitation is at the low end of the scale.
Direct Seeding:	Can be tried under good conditions. Seeds can be fed to livestock. Livestock then graze over the desired area and eliminate seeds with their manure. Leads to natural regeneration.
Other Notes:	Do not disturb potted mix more than necessary when transplanting. Wide spacing of plants (10m X 10m) is required.

USES

- Good soil conservation tree (can lead to higher yields of crops planted underneath).
- Pods good food for cattle.
- Branches useful for fences.
- Leaves used for animal feed.
- Wood -- for carving.
- Bark contains tannin.

SPECIAL NOTES

-- Introduction of Acacia albida is considered important and worthwhile by many farmers, a fact which helps gain acceptance of a project using this tree.

-- A. albida trees have reached heights of 2 to 4m after only three and four years of growth (Niger and Upper Volta).

-- It is not clear yet just how much Acacia albida does enrich the ground around the tree.

-- Young trees are hard to protect. The young branches and leaves are enjoyed by animals; young trees are small and hard to see and may be lost during hoeing if not marked. It is usually necessary to protect these trees for 5 - 8 years depending upon area and site conditions.

-- The benefits of planting Acacia albida, in terms of initial investment, are not clear. Thus, it may be hard to justify a project when seeking funds from certain agencies. However, to eliminate

grazing so that the tree can regenerate naturally is harder to do than to raise the young plants in protected areas.

-- A. albida until recently was able to regenerate naturally because the seeds were eaten by and passed from the bodies of animals. Now land and grazing pressures have increased so much that the young trees are being destroyed by browsing animals and cleaning operations.

Acacia caffra Willd. var. **campylacantha** Aubr.

Synonyms: *Acacia campylacantha* Hochst., ex A. Rich.
Acacia catechu W.
Acacia polycantha Willd. subsp. *campylacantha* (Hochst.) Prenah

Common Names:

CHAD ARABIC	al guetter	HAUSA	karo
BAMBARA	kuroko		tserkakia
FULANI	fatarlahi	KANOURI	golawai
		MORE	guara

Legal Restrictions:

GENERAL DESCRIPTION

Tall, slender tree. Short, curved spines. Seed pods are flat and thin and hang in clusters. Brown seeds are small, flat, and thin.

SEEDS

Source: Strong, healthy trees.
Collection: Pods mature January and February.
Extraction:
Storage:
Pre-Treatment: Put in hot water and soak overnight.

NURSERY

Pots/Open-rooted: One project planted 50 pots with 3 seeds each. 41% of seeds germinated.
Time:
Other Notes: Good germination; grows rapidly.

PLANTING/SITE REQUIREMENTS

Soil: Heavy soil, has adapted to variety of conditions.

Water: Along water courses.

Direct Seeding:

Other Notes:

USES

- Localized use for construction purposes. Heartwood very hard and resistant to insects.
- Leaves used for fodder.
- Bark yields tannin.

SPECIAL NOTES

Acacia scorpioides (L.) var. **nilotica** (L.) A. Chev.

Synonyms: *Acacia nilotica* (L.) Willd.
Mimosa nilotica L.
Acacia arabica (Lam.) var. *nilotica* (L.) Benth.

Common Names:

FRENCH	gonakier	DJERMA	bani
CHAD ARABIC	sunta, charat, senet, sunt	FULANI	gaudi
		HAUSA	bagarua
BAMBARA	barana diabe boina	MORE	peguenega

Legal Restrictions: Classified as "Specially Useful"; Cutting and Removal.

GENERAL DESCRIPTION

Small or medium tree 3-8m with long white or grey spines and very dark, almost black, fissured bark. It grows rapidly. Balls of yellow flowers, narrow whittish grey flattened pods.

SEEDS

Source: Strong, healthy trees.
Collection: Seeds ripen in November-December, Upper Volta, and December-January, Niger.
Extraction:
Storage:
Pre-Treatment: Soak overnight.

NURSERY

Pot/Open-rooted: Pots
Time: 14-18 weeks
Other Notes:

PLANTING/SITE REQUIREMENTS

Soil: Heavy soil

Water: Likes a lot of water. Plant where water table is close to surface. Will do well even in areas where periodic flooding occurs.

Direct Seeding:

USES

Live fences and windbreaks. Pods and bark provide natural tanning material.

SPECIAL NOTES

Acacia senegal (L.) Willd.

Synonyms: *Acacia verek* Guill. & Perr.

Common Names:

ENGLISH	gum arabic	FULANI	dibehi
FRENCH	gommier		patuki
CHAD ARABIC	asharat	HAUSA	dakworo
	kitr al abiod	KANOURI	kolol
BAMBARA	donkori	MORE	goniminiga
DJERMA	danya		

Source of gum arabic

Legal Restrictions: Cutting and removal. The nature, site, and propagation requirements of this species place its development, protection, and production under control of forest services.

GENERAL DESCRIPTION

Bush or small tree usually less than 5m high, but sometimes is as tall as 9m. Bushes are low-branched with flat crowns and form thickets. Pale brown or grey bark. Branches have short, curved thorns or spines in groups of 3. Grey-green leaves, 3-6 pairs of pinnules and 8-18 pairs of leaflets. A. senegal has creamy white flowers; brown seed pods which are flat and papery. Each pod contains 1-5 greenish brown seeds. A. senegal produces gum arabic between ages of 4 and 18.

SEEDS

Source: Strong, healthy parent trees.
Collection: Seeds ripen in November-December, South-central Niger, and January, Upper Volta.
Extraction:
Storage:
Pre-Treatment: Put seeds in hot water and soak overnight.

NURSERY

Pot/Open-rooted: Pots or open-root. One project planted 50 pots with 3 seeds per pot. 27% germination.
Time: 14-18 weeks in pots.
Other Notes: Only fair germination.

PLANTING/SITE REQUIREMENTS

Soil: Sandy soils, dry savanna, abandoned fields or dunes stabilized by grasses.

Water: Driest sites; 350mm mean annual rainfall.

Direct Seeding: Can be directly seeded easily. Watch for insect and rodent damage.

Other Notes:

USES

- Produces gum arabic, a money crop on world market.
- Live fencing.
- Source of tannin.
- Browse for animals.
- Firewood and charcoal.

SPECIAL NOTES

-- It is not known how this tree will grow in regions of heavier rainfall.

-- Because this tree produces a special product (gum arabic), it is being studied in many ways. Extension activities are underway to advise people on how to get higher yields from tapping procedures and how to market the product. Countries are seeking ways to increase output of gum arabic for world markets.

-- It may be more feasible to protect and encourage natural regeneration than to start extensive planting efforts.

Acacia sieberiana D.C.

Synonyms:	*Acacia verugera* Schweinf.	
	Acacia singuinea Guill. & Perr.	
	Acacia rehmanniana	
	Acacia villosa	
	Acacia fischerii	
	Acacia monga	
	Acacia verhmoensis	
	Acacia nefasia Schweinf.	
Common Names:	CHAD ARABIC	kuk
	BAMBARA	baki
	FULANI	gie daneji
	HAUSA	boudji
		dushe
	KANOURI	katalogu
	MORE	golponsgo

Legal Restrictions:

GENERAL DESCRIPTION

Acacia sieberiana is a large acacia, up to 15m tall. It has long white, straight spines and fairly smooth, light olive or yellowish-colored bark. Crown is flat-topped, umbrella-shapped or irregular. 10-25 pinnules; 20-40 folioles. Seed pods are brown and thick-skinned. The wood is semi-hard and termite resistant.

SEEDS

Source:
Collection:
Extraction:
Storage:
Pre-Treatment: Put in hot water and soak seeds overnight.

NURSERY

Pots/Open-rooted: Pots; one project planted 50 pots, 3 seeds per pot. 8.7% germination.
Time:
Other Notes: Varying germination results.

PLANTING/SITE REQUIREMENTS

Soil: Prefers low-lying, heavy soil, but grows in a variety of soils.

Water: Grows well in areas with higher rainfall.

Direct Seeding:

Other Notes:

USES

- Wood is easy to work with and is used to make tool handles and other light objects.
- Good firewood and charcoal.
- Bark is a source of tannin.
- Some value in live fencing and windbreaks.
- Produces a type of gum arabic.

SPECIAL NOTES

Adansonia digitata L.

Synonyms:

Common Names:				
	ENGLISH	baobab	FULANI	bokki
	FRENCH	baobab	HAUSA	kuka
	CHAD ARABIC	hahar	KANOURI	kuka
	BAMBARA	sito	MORE	toega
	DJERMA	konian		

Legal Restrictions: "Specially Useful"; Cutting and Removal;

GENERAL DESCRIPTION

Large tree up to 18m tall with an enormous trunk. Roots which extend far from base of tree. Seeds do not germinate well; therefore, young trees in wild are hard to find. Adult tree flowers with white blossoms; fruit hangs from long stem and is good to eat. Seeds are acid and may be cooked or eaten fresh. Leaves are palmately divided into 5-7 segments.

SEEDS

Source:
Collection: Seeds ripen December-February, Upper Volta.
Extraction:
Storage:
Pre-Treatment:

NURSERY

Pots/Open-rooted: Good results with open-rooted stock.
Time:
Other Notes: In pot culture, some seeds can take up to a year to germinate.

PLANTING/SITE REQUIREMENTS

Soil:

Water:

Direct Seeding:

Other Notes:

USES

- A major food tree of Hausas -- leaves dried and used for flavoring sauces.
- Bark used to make mats, paper

SPECIAL NOTES

Albizzia chevalieri Harms.

Synonyms:

Common Names:	CHAD ARABIC	ared	HAUSA	katsari
	BAMBARA	golo iri	KANOURI	tsagle
	FULANI	jarichi	MORE	ronsedonga
		nyebal		

Legal Restrictions:

GENERAL DESCRIPTION

Small to medium tree with a branching crown. Leaves contain 8-12 pinnules and 20-40 folioles. Pods are thin and oblong and contain flat round seeds. It is found throughout the region.

SEEDS

Source:
Collection:
Extraction:
Storage:
Pre-Treatment: Put in hot water and soak overnight.

NURSERY

Pots/Open-rooted: Pots planted in one test -- 40 pots with 3 seeds each -- showed 61% germination.
Time:
Other Notes:

PLANTING/SITE REQUIREMENTS

Soil: Sahel and Sudan zones.

Water:

Direct Seeding:

Other Notes:

USES

- Primarily firewood.
- Some uses for root fiber.

SPECIAL NOTES

Anacardium occidentale L.

Synonyms:

Common Names:

Legal Restrictions: The nature of the tree places its development and production under protection of forestry service programs.

GENERAL DESCRIPTION

Small spreading evergreen tree which grows to about 9m. Bark is rough; flowers are small. Fruit is a kidney-shaped nut with a hard covering which contains bitter black juice. Stalk of the flower swells into a juicy pear-shaped body. A hardy tree for planting in poor soil and dry areas.

SEEDS

Source: Ripe fruit.
Collection: Pick fruit from trees in late February, Southwest Niger.
Extraction: Separate hull from fruit.
Storage: Leave in hull and dry; stores well.
Pre-Treatment: None necessary.

NURSERY

Pots/Open-rooted: Plant only in pots; open-rooted stock almost impossible to transplant without root damage.
Time: 14-18 weeks in pots.
Other Notes: Plant seed with convex side up. Cover with 3cm of dirt. Watch for termite problems during germination and again when transplanting. Spray with Dieldrin or Chlordane.

PLANTING/SITE REQUIREMENTS

Soil: Will grow in many types of soil; grows well in sandy soil, low country up to 150m; grows well on eroded and other poor sites.

Water: At least 500-700mm annual precipitation.

Direct Seeding: Possible; some projects have had good results; many seeds are needed.

Other Notes:

USES

- Tree produces the cashew nut -- a valuable product in foreign markets.
- Construction - packing cases; boat-building; firewood.

SPECIAL NOTES

-- Ideal tree for soil cover and conservation purposes.

-- Seems to grow in all soils, except for rock, down to about 500mm mean annual precipitation. However, in areas of lower rainfall, the tree produces less fruit.

-- Bark contains up to 10% tannin.

Anogeissus leiocarpus Guill. & Perr.

Synonyms: *Anogeissus schimperi* Hochst. ex Hutch & Dalz.

Common Names:

CHAD ARABIC	sahab
BAMBARA	krekete
DJERMA	gonga
FULANI	kojoli
HAUSA	marike
KANOURI	annum
MORE	sigha
	piega

Legal Restrictions: Classified as "Specially Useful."

GENERAL DESCRIPTION

Anogeissus leiocarpus is a medium to large tree which often gets very tall. Leaves are small and lanced; fruits are small, yellowish-brown colored cones containing many seeds. The wood is heavy and hard.

SEEDS

Source:
Collection:
Extraction:
Storage:
Pre-Treatment: None necessary.

NURSERY

Pots/Open-rooted: Experiments with growth in pots proved non-successful.
Time:
Other Notes: Slow growth discourages artificial propagation. There has been little success in germinating.

PLANTING/SITE REQUIREMENTS

Soil: Moist, low-lying soil along water courses.

Water: 900-1,200mm mean annual precipitation.

Direct Seeding:

Other Notes:

USES

- Hard wood useful for fence posts. Construction and woodworking.
- Ashes of the wood used for potash in soap-making and dyeing.

SPECIAL NOTES

-- This is an impressive tree because of its large size. But growth is very slow, and discouraging nursery results make its potential doubtful at the moment. More research is needed.

Azadirachta indica A. Juss.

Synonyms:

Common Names: ENGLISH Neem FRENCH Neem

Legal Restrictions:

GENERAL DESCRIPTION

Moderate-sized to large evergreen tree (11m tall) with dense, rounded crown. Grows fairly rapidly. Bark is thick and dark grey. Flowers with bunches of small white blossoms, from March to May; fruit ripens from mid-May.

SEEDS

Source:	Local trees; use fresh seeds only.
Collection:	For best harvest, clean area under tree and collect freshly fallen seeds only.
Extraction:	Soak seeds and pulp in water. Separate by hand while under water; spread seeds out to dry.
Storage:	Seeds do not store well; viability drops near zero within a few weeks unless special storage is possible.
Pre-Treatment:	None required, but pre-germinating in moist sand helps reduce empty space in nursery. Bury seeds in sand and keep wet for one week. Plant only seeds which are swollen.

NURSERY

Pots/Open-rooted:	Can be planted in pots -- good-sized trees in 3 months. Usually planted as open-rooted stock.
Time:	Leave open-rooted stock 8-11 months (trees average 1m high).
Other Notes:	Plant seeds in horizontal position in beds or pots. When transporting open-rooted stock, strip to terminal bud and wrap roots. Keep roots moist.

PLANTING/SITE REQUIREMENTS

Soil:	Grows on most kinds of soil, even clay; will grow on rocky ground with good drainage; not suitable for laterite outcrops.

Water: Plant in areas having 500-700mm mean annual precipitation. Grows well where groundwater is available within 9-12m of the surface.

Direct Seeding: Works well in good locations; best to plant as individual trees or in lines

Other Notes: Needs rain within 4-6 days after planting or survival is doubtful.

USES

- Firewood
- Construction wood
- Fence posts, when treated with pesticide
- Reforestation purposes
- Seeds yield oil for soap and burning

SPECIAL NOTES

Balanites aegyptiaca (L.) Del.

Synonyms:

Common Names:	CHAD ARABIC	hajlij	KANOURI	chingo
	BAMBARA	seguene		bito
	DJERMA	garbey	MORE	tiegaliga
	FULANI	tanni		
	HAUSA	adoua		

Legal Restrictions: Classified as "Specially Useful"; cutting and removal.

GENERAL DESCRIPTION

Small or medium tree, up to 10m high, with small, oval, grey-green leaves and long, straight, green spines. Bark is greyish green to brown and is fissured. Fruits resemble dates and are yellow when ripe. The wood is hard and heavy and has a fine texture. This tree is fairly resistant to termites.

SEEDS

Source:
Collection: Seeds ripen in September-October, Upper Volta; October-December, Niger;
Extraction: Soak fruit in water and separate seeds from pulp.
Storage:
Pre-Treatment: Soak in lukewarm water overnight.

NURSERY

Pots/Open-rooted: Seeds planted in pots -- 50 pots, 2 seeds per pot -- showed 61% germination.
Time: 18-24 weeks in pots.
Other Notes:

PLANTING/SITE REQUIREMENTS

Soil: Dry sites, prefers sandy soil which occasionally floods.

Water: 350-500mm mean annual precipitation.

Direct Seeding: Possible and worth doing.

Other Notes:

USES

- Construction from light woodworking to heavy carpentry
- Fruit is sweet and is a favorite food
- Animals, particularly camels, use for browse
- Strong emulsions of fruits may be used to poison fish

SPECIAL NOTES

-- An excellent, all-around species well worth propagating, either in plastic pots or by direct seeding.

-- The wood is fine-grained, easy to work, durable, and resistant to insects.

Bauhinia reticulata D.C.

Synonyms: *Bauhinia glabra* A. Chev.
Bauhinia glauca A. Chev.
Piliostigma reticulatum (D.C.) Hochst.

Common Names:

CHAD ARABIC	harum	HAUSA	calgo
BAMBARA	niamaba	KANOURI	kaldul
DJERMA	kosseye	MORE	barani
FULANI	barkevi		

Legal Restrictions:

GENERAL DESCRIPTION

Bush or small tree up to 6m with spherical crown. Leaves are large grey-green color and consist of two distinct symmetrical lobes. Bark is dark brown to grey or nearly black. Seed pods hang and are large, thick and reddish-brown in color.

SEEDS

Source: Local trees.
Collection: Seeds ripen December-January; as early as October, November in some areas (parts of Upper Volta, for example).
Extraction:
Storage:
Pre-Treatment: Hot water overnight.

NURSERY

Pots/Open-rooted: Pots; 3 seeds per pot.
Time:
Other Notes: Poor germination results in nursery.

PLANTING/SITE REQUIREMENTS

Soil: Wide variety of soil, including sand, laterite and heavy clay.

Water:

Direct Seeding: Possible.

Other Notes:

USES

- Firewood.
- Local medical purposes.
- Shade tree because of large crown.
- Bark contains tannin.

SPECIAL NOTES

-- This is an abundant tree, and this fact makes it of questionable value for a nursery project. Nevertheless, it should be encouraged in fallow areas by direct seeding or cuttings.

Borassus aethiopum Mart.

Synonyms: *Borassus flabellifer* L. var. *aethiopum* (Mart.) Warb.

Common Names:

FRENCH	ronier	FULANI	dubbi
CHAD ARABIC	deleb	HAUSA	gigunia
DJERMA	sabouze	KANOURI	ganga, kemeiutu

Legal Restrictions: Cutting and Removal; the nature, site, and propagation requirements of this species place its development, protection, and production under control of forest services.

GENERAL DESCRIPTION

Tall palm up to 25m. Stem is straight and smooth in old trees. Bark is dark grey; fan-shaped leaves up to 4m long. Orange fruit about 15cm long and 12cm wide. Each fruit contains 3 hard-coated edible seeds surrounded by edible flesh. Hard, heavy wood very resistant to termites.

SEEDS

Source: Local trees.
Collection: Pick from ground.
Extraction: Not applicable.
Storage:
Pre-Treatment: None required.

NURSERY

Pots/Open-rooted:
Time:
Other Notes: Not raised in nursery.

PLANTING/SITE REQUIREMENTS

Soil: Moist, low spots.

Water: Over 800mm annual precipitation; lowland areas with high watertable; swamp grass sites.

Direct Seeding: Any method possible. Good results in likely sites.

Other Notes:

USES

Construction -- housing, fencing, etc. It is especially useful as rafters in mudwall housing. It is rarely attacked by termites and natural oils make it one of the most durable natural post materials known.

SPECIAL NOTES

-- Tree grows slowly. May take 10 years for good crown to develop.

-- Borassus brings prices on the construction market almost equal to imported structural steel.

-- Regeneration attempts have shown good results.

Butyrospermum parkii Kotschy

Synonyms:

Common Names:	CHAD ARABIC	sirreh	HAUSA	bagay
	BAMBARA	berekunan	KANOURI	marga
		tamba		

Legal Restrictions: Cutting and Removal.

GENERAL DESCRIPTION

Small tree with thick, dark-grey, deeply fissured bark and long strap-like leaves. Flowers with white blossoms between May and August. Mature fruit is green and about 5cm long. Each fruit contains one seed (shea nut); collected in July.

SEEDS

Source: Strong, healthy trees.
Collection: Find newly fallen seeds.
Extraction: Shells easily.
Storage:
Pre-Treatment: None required.

NURSERY

Pots/Open-rooted: Pots.
Time: 14-24 weeks in pots.
Other Notes: Plant with the point of the white part of the seed down.

PLANTING/SITE REQUIREMENTS

Soil: Moist, medium-to-heavy soil;

Water: Above 700mm mean annual precipitation or along mares and low spots.

Direct Seeding: Possibilities unknown.

Other Notes:

USES

- Hard wood used for mortar.
- Hard to work but accepts a polish.
- Nut produces butter -- useful for cooking, lamp burning and cosmetic purposes -- both for local and export use.

SPECIAL NOTES

-- Tree is tolerant of annual burning.

Cassia siamea Lam.

Synonyms:

Common Names: FRENCH cassia

Legal Restrictions:

GENERAL DESCRIPTION

Moderate-sized evergreen with dense crown and smooth grey bark. Yellow flowers in large bunches. Pods 10-25cm long hanging in clusters. Foliage is especially attractive to pigs. However, the leaves are poisonous and animals must not be allowed to browse on these trees. Tree grows fairly rapidly.

SEEDS

Source: Strong, healthy trees.
Collection: December and January collect unopened pods.
Extraction: Dry in sun and beat with stick. Mortar and wind separation.
Storage:
Pre-Treatment: Cut; soak in warm water.

NURSERY

Pots/Open-rooted: Pots only in special situations. Most seeds are open-rooted.
Time: 4-5 months in pots; 30 weeks to one year open-rooted.
Other Notes: Potted plants require pruning; plant as a "stump."

PLANTING/SITE REQUIREMENTS

Soil: Moist soil with good drainage.

Water: 500-700mm minimum annual precipitation; trees do better with more rainfall.

Direct Seeding: Possible, but not done extensively.

Other Notes: Plant a stump 10cm above ground; cut roots to 20cm.

USES

- Firewood, but is smokey.
- Construction.
- Good, dense windbreaks with no undergrowth.
- Reforestation purposes.

SPECIAL NOTES

Ceiba petandra (L.) Gaertn.

Synonyms:	*Eriodendron orientale*	
Common Names:	ENGLISH	silk cotton tree
	FRENCH	fromager
	CHAD ARABIC	rum
	FULANI	bantahi
	HAUSA	rimi
	KANOURI	tom
	MORE	gunga

Legal Restrictions: Classified as "Specially Useful."

GENERAL DESCRIPTION

Ceiba pentandra is an impressive tree up to 60m with a wide trunk and large base roots. The trunk gradually tapers to a narrow tip. Bark is smooth and grey; it is valued for beauty, shade and cotton-like material yielded from seed pods. This is an important plantation crop tree.

SEEDS

Source: Healthy trees.
Collection:
Extraction:
Storage:
Pre-Treatment:

NURSERY

Pots/Open-rooted: Open-rooted.
Time:
Other Notes:

PLANTING/SITE REQUIREMENTS

Soil: Forest conditions, low elevations.

Water: Prefers sites where water is near or on the surface or areas having heavy rainfall.

Direct Seeding:

Other Notes:

USES

- Shade tree.
- Cotton-like fiber (kapok) used for stuffing.
- Canoes from wood.
- Cuttings used as living fence posts.
- Seeds edible fresh, germinated or after extracting oil for cattle feed.
- Leaves yield hair lotion and medicine.

SPECIAL NOTES

Entada sudanica Schweinf.

Synonyms:

Common Names:				
	CHAD ARABIC	dorot	HAUSA	tawatsa
	BAMBARA	diamba	KANOURI	falofala
		samanere	MORE	sianlogo
	FULANI	fado-wanduhi		

Legal Restrictions:

GENERAL DESCRIPTION

Small tree with leaves containing 5-7 pairs of pinnules and 14-24 pairs of folioles. Pods are shaped like large, flat plates.

SEEDS

Source:
Collection:
Extraction:
Storage:
Pre-Treatment: Hot water overnight.

NURSERY

Pots/Open-rooted: Pots.
Time:
Other Notes: 10 pots planted with 3 seeds per pot showed 67% germination.

PLANTING/SITE REQUIREMENTS

Soil: Sudan savanna.
Water:
Direct Seeding:
Other Notes:

USES

- Firewood (fair).
- Bark used for rope.
- Medical purposes.

SPECIAL NOTES

Eucalyptus camaldulensis Dehnh.

Synonyms: *Eucalyptus rostrata* Schlecht.

Common Names:

Legal Restrictions:

GENERAL DESCRIPTION

A fast-growing, tall (18-45m) tree. Bark of older tree rose-pink; flowers profusely; seed germinates well. Moderately heavy, hard wood.

SEEDS

Source: Nearest seeds available in Northern Nigeria (Eucalyptus camaldulensis, Australian origin). There are, however, reports of the first fruit-bearing by some of the oldest trees planted in Niger. Seeds can be ordered direct from Australia. Israel also has seeds available and so does the French Tropical Forestry Research Agency (C.T.F.T.). Considerable lead time is needed. Varieties selected must be drought resistant and termite proof in both green and dead stage.

Collection:
Extraction:
Storage:
Pre-Treatment:

NURSERY

Pots/Open-rooted: Pots.
Time: 18-24 weeks in plastic pots.
Other Notes: Seeds are very, very small and can be germinated by Nobila Method (See SPECIAL NOTES) or planted directly into plastic pots.

PLANTING/SITE REQUIREMENTS

Soil: Heavy or rocky soils at altitudes under 610m.

Water: At least 800mm of rain or access to plentiful groundwater. Where mean annual rainfall is 1,00mm or less, plant only along water courses.

Direct Seeding:

Other Notes: May require additional care and watering during first year.

USES

- Reforestation -- root system useful in protecting banks of water courses from erosion.
- Bark yields tannin.

SPECIAL NOTES

Nobila Method: (see Section 6, "Nursery Management", page 63)

-- Prepare germination beds.
-- Screen materials (sand and manure) for top 4 inches.
-- Treat with Dieldrin solution, 0.5% to 1% concentration.
-- Mix seeds with fine sand and spread over bed.
-- Cover lightly with screened sand.
-- Keep top layer moist at all times.
-- Apply water as fine spray.
-- Transplant into plastic pots after trees have developed 3 or 4 primary leaves.
-- Water frequently with fine spray.
-- Keep in complete shade for first week.

Direct seeding into pots:

-- Prepare soil mixture for the pots by adding HCH or Dieldrin -- 1 kilogram/2500 pots.
-- Fill pots as usual.
-- Put seeds into soil.
-- Put 3-5mm of water into a cup.
-- Moisten needle with the water to a height not exceeding 3mm.
-- Plunge the needle into the eucalyptus seeds (you will find several seeds clinging to the point of the needle).
-- Pierce the surface of the soil in the pots with the needle at an angle of 45° and to a depth of not over 10mm.
-- Any sort of watering method may now be used.
-- When transplanting seedlings into empty pots, one should only use seedlings which are between 25mm and 50mm high.

Gmelina arborea Roxb.

Synonyms:

Common Names: ENGLISH melina

Legal Restrictions:

GENERAL DESCRIPTION

Rapidly growing species, up to 15-80m. Many wonderfully scented yellow and brown flowers and yellow fruits. Wood lasts well under water. Introduced as a firewood tree from tropical Asia; suffers from infection in certain areas.

SEEDS

Source: Old trees (scarce); import from other countries.
Collection: Seeds ripen in March-April, Upper Volta.
Extraction:
Storage:
Pre-Treatment: Soak overnight.

NURSERY

Pots/Open-rooted: Not planted in pots. Open-rooted.
Time:
Other Notes:

PLANTING/SITE REQUIREMENTS

Soil: Good, well-drained soils.

Water: Where mean annual rainfall is 1,000mm or less, plant only along water courses or in irrigated areas.

Direct Seeding: Possible in tropical forests.

Other Notes: Plant as a stump.

USES

- Wood for match sticks.
- Boxes.

SPECIAL NOTES

Guiera senegalensis Lam.

Synonyms:

Common Names:		
	CHAD ARABIC	kabeah
	BAMBARA	kudiengbe
	DJERMA	sabara
	FULANI	gelloki
	HAUSA	sabara
	KANOURI	kasasai
	MORE	unuiga

Legal Restrictions: Classified as "Specially Useful."

GENERAL DESCRIPTION

Bush or small tree. Small grey-green leaves opposite one another on the branches. Fruits are long, narrow capsules covered with large hairs.

SEEDS

Source:
Collection:
Extraction:
Storage:
Pre-Treatment: None necessary.

NURSERY

Pots/Open-rooted: Pots.
Time:
Other Notes: Project which planted 10 pots, 3 seeds per pot, showed 10% germination. Poor germinator.

PLANTING/SITE REQUIREMENTS

Soil: Sandy areas, particularly fields in fallow.

Water:

Direct Seeding: Probably best method; reproduces rapidly.

Other Notes: Worthwhile to plant cuttings.

USES

- Firewood -- a principal firewood species.
- Browse for camels.
- Local medicine against dysentery.

SPECIAL NOTES

Lannea acida A. Rich.

Synonyms:

Common Names:

FULANI	faruhi
HAUSA	farou
KANOURI	adarazagai
MORE	pekuni
	sabga

Legal Restrictions:

GENERAL DESCRIPTION

Small-to-medium tree with scaly, fissured, dark-colored bark on a red trunk. Leaves consist of 3-6 pairs elliptical folioles. Fruits look like cherries.

SEEDS

Source:
Collection:
Extraction: Soak fruit to separate seed and pulp. Dry seeds.
Storage:
Pre-Treatment: Soak in lukewarm water overnight.

NURSERY

Pots/Open-rooted: Good germination in pots.
Time:
Other Notes: 10 pots planted with 2 seeds per pot showed 80% germination.

PLANTING/SITE REQUIREMENTS

Soil: Sudan zone.

Water:

Direct Seeding:

Other Notes:

USES

- Firewood -- high quality.
- Rope from bark.
- Food -- fruits widely eaten.

SPECIAL NOTES

-- A valuable tree for firewood and food whose propagation should be encouraged.

Parkia biglobosa Benth.

Synonyms: *Parkia clappertoniana* Keay
Mimosa biglobosa Jacq.

Common Names:

FRENCH	nere	FULANI	narghi
CHAD ARABIC	maito	HAUSA	dorowa
BAMBARA	nere	KANOURI	runo
DJERMA	dosso	MORE	rouaga

Legal Restrictions: Cutting and Removal.

GENERAL DESCRIPTION

Medium-to-large tree, up to 15m, with dense, spreading crown. Leaves consist of 14-30 pairs of pinnules and 50-70 pairs of small leaflets. Tree has hanging red flowers; seeds develop in long, narrow pods. Bark is thick and deeply fissured. The wood is hard and heavy but is easily attacked by termites.

SEEDS

Source: Strong, healthy trees; local market.
Collection: Pick the largest, freshly fallen seeds.
Extraction: Remove from pod.
Storage: Viability better when used right away.
Pre-Treatment: Soak overnight in hot water.

NURSERY

Pots/Open-rooted: Pots only.
Time: 10-14 weeks.
Other Notes: Special care; germination results variable depending upon age of seeds.

PLANTING/SITE REQUIREMENTS

Soil: Deep, heavy sand (type where sorghum grows well); known to survive on poor, rocky sites as well.

Water: 500-700mm mean annual precipitation.

Direct Seeding: Worth trying.

Other Notes:

USES

- Light woodworking.
- Pulp of seed dried and used as flour.
- Seeds produce flavoring for sauces.
- Bark yields tannin for tanning and dyeing.

SPECIAL NOTES

-- *Parkia* is often left standing in millet fields for its shade and fruits. It is one of the few species farmers will actually plant themselves.

-- There is great demand for this tree. Given the demand and the ease of raising the tree, it may be good to consider as a cash crop. In some areas, there is enough market for the seeds to warrant establishing special plantations.

Parkinsonia acculeata L.

Synonyms:

Common Names:

DJERMA	sassa bani
HAUSA	sharan abi
KANOURI	sharan labi

Legal Restrictions:

GENERAL DESCRIPTION

Tree grows to about 10m. Long branches which are covered with 3cm-long spines and which droop. Many bright-yellow flowers.

SEEDS

Source: Local trees.
Collection: Seeds ripen in December-January, Upper Volta. Pods containing viable seeds often remain on tree for several months. Pick dry pods only.
Extraction: Shell by hand; shells come off easily.
Storage:
Pre-Treatment: Soak overnight in hot water, or clip end for faster germination (few days only).

NURSERY

Pots/Open-rooted: Pots.
Time: 6-10 weeks in pots.
Other Notes: Easy to raise, but roots need pruning.

PLANTING/SITE REQUIREMENTS

Soil: Dry sites.

Water: 350-400mm mean annual precipitation.

Direct Seeding: Worth trying.

Other Notes:

USES

- Firewood.
- Live fences.
- Windbreaks and soil cover for conservation.

SPECIAL NOTES

Poupartia birrea (Hochst.) Aubr.

Synonyms: *Sclerocarya birrea* Hochst.

Common Names:

Legal Restrictions:

GENERAL DESCRIPTION

Small tree with well-developed crown. Leaves contain 7-8 pairs of folioles. Fruits are large, round, and yellow when ripe.

SEEDS

Source:
Collection: Seeds ripen in April-May, Niger.
Extraction:
Storage:
Pre-Treatment: Lukewarm water overnight.

NURSERY

Pots/Open-rooted: Pots.
Time:
Other Notes: 10 pots, 2 seeds per pot, had germination rate of 90%.

PLANTING/SITE REQUIREMENTS

Soil: Throughout Sahel and Sudan zones.

Water:

Direct Seeding:

Other Notes:

USES

- Light woodworking, particularly in manufacture of mortars.
- Pulp of fruit is a popular food and is used to produce a kind of beer.
- Local value for medical purposes.

SPECIAL NOTES

The tree's high germination rate and the value of its wood and fruit seem to justify propagation in the nursery.

Prosopis africana Taub.

Synonyms: *Prosopis oblonga* Benth.

Common Names:

BAMBARA	guele
FULANI	kohi
HAUSA	kiriya
KANOURI	simain
MORE	niuri-segue

Legal Restrictions: Classified as "Specially Useful."

GENERAL DESCRIPTION

Medium tree with light-colored foliage. It grows rapidly. Leaves have 2-4 pinnules and 6-12 folioles. There is a gland between each pair of pinnules and folioles. Pods are dark-brown cylinders which are thick and hard. Wood is hard and semi-heavy and has fine texture.

SEEDS

Source:
Collection: Seeds ripen in February-March, Niger.
Extraction:
Storage:
Pre-Treatment: Warm stratification. Hot water overnight.

NURSERY

Pots/Open-rooted: Pots.
Time: 14-18 weeks.
Other Notes:

PLANTING/SITE REQUIREMENTS

Soil: Usually grows in abandoned fields or where forest has been replaced by savanna.

Water:

Direct Seeding:

Other Notes: Grows singly, not in clusters.

USES

- Heavy carpentry and light woodworking uses.
- Charcoal for blacksmithing.
- Bark of the roots used for tanning hides.

SPECIAL NOTES

-- Should be encouraged in the nursery because of rapid growth and high-quality of wood.

Prosopis juliflora (Sw.) D.C.

Synonyms: *Prosopis chilensis* (Mol.) Stuntz
Ceratonia chilensis Mol.

Common Names: ENGLISH (USA) mesquite

Legal Restrictions:

GENERAL DESCRIPTION

SEEDS

Source: Order trees.
Collection: Pick when yellowish and partly dry.
Extraction: Messy. Mortar and wind, or hand separation; powder is sticky.
Storage:
Pre-Treatment: Hot water; clipping is possible but difficult.

NURSERY

Pots/Open-rooted: Pots. Open-root possible, but needs special lifting-out care.
Time: 12-14 weeks.
Other Notes:

PLANTING/SITE REQUIREMENTS

Soil: Rich, heavy soil; prefers some clay.

Water: Areas under 600mm mean precipitation.

Direct Seeding: Should be encouraged on a trial basis.

Other Notes:

USES

- Wood useful for fence posts.
- Firewood.
- Live fencing and windbreaks.
- Food for animals.

SPECIAL NOTES

Tamarindus indica L.

Synonyms:

Common Names:	ENGLISH	tamarind tree
	FRENCH	tamarinier
	CHAD ARABIC	tamr hindi
	BAMBARA	tombi
	DJERMA	bossaye
	FULANI	jtatami
	HAUSA	tsamiya
	KANOURI	tamsugu
	MORE	pousiga

Legal Restrictions: Cutting and Removal.

GENERAL DESCRIPTION

Tree of medium-to-large size up to 15m recognized by its dense, well-rounded crown. Bark is reddish-grey and is fissured. Leaves consist of 10-15 pairs of folioles. Seed pods are reddish-brown and cylindrical. Pale yellow wood bends well and is strong.

SEEDS

Source:
Collection: January-March, depending upon location.
Extraction: Soak fruit to remove pulp; dry the seeds.
Storage:
Pre-Treatment: None required.

NURSERY

Pots/Open-rooted: Pots.
Time: 18-24 weeks.
Other Notes: Project planted 50 pots, 3 seeds per pot; 63% germination. Germinates well and grows rapidly in pots.

PLANTING/SITE REQUIREMENTS

Soil: Grows best in sandy soil along coasts.

Water: More than 800mm annual precipitation or along mares and low spots.

Direct Seeding:

Other Notes:

USES

- Wood for furniture and boatbuilding.
- Excellent charcoal.
- Produces tamarind fruit, which is used to make drinks and soups.
- Shade.
- An herb/spice to add flavor to main dishes.

SPECIAL NOTES

-- In some areas, there is sufficient demand for the fruit to justify special plantations.
-- Some countries export the fruit.

Vitex cuneata Schum. & Thonn.

Synonyms: *Vitex chariensis* Chev.
Vitex cienkowskii Kotschy & Perr.
Vitex doniana Sweet
Vitex paludosa Vatke

Common Names:

CHAD ARABIC	unrugulguh	FULANI	galbihi
BAMBARA	sokoro	HAUSA	dumnjaa
	koroba	KANOURI	ngaribi
DJERMA	bo-i	MORE	andega

Legal Restrictions: Classified as "Specially Useful."

GENERAL DESCRIPTION

Small or medium savanna tree, 10-12m high. Dark green, rounded crown. Bark is pale brown to greyish white with fissures. Leaves are large with oblong folioles. Fruits are large, black, and good to eat. Wood is semi-hard and susceptible to insect attack.

SEEDS

Source:
Collection: October in Niger.
Extraction: Soak fruit to remove pulp; dry seeds.
Storage:
Pre-Treatment: Soak seeds in lukewarm water overnight.

NURSERY

Pots/Open-rooted: Pots.
Time:
Other Notes: Project planted 50 pots, 3 seeds per pot; germination of 2%.

PLANTING/SITE REQUIREMENTS

Soil: Dense forest, wooded savanna, river borders, and cultivated fields.

Water: Needs access to water for good growth.

Direct Seeding:

Other Notes: Widely distributed throughout Africa.

USES

- Wood used for light woodworking and building small boats.
- Fruits are popular food.
- Leaves used in sauces and as medicine against dysentery.

SPECIAL NOTES

-- This is a popular tree mainly because of its fruits. Unfortunately, it is a slow and poor germinator and propagation is difficult.

Tamarindus indica L.

Synonyms:

Common Names:	ENGLISH	tamarind tree
	FRENCH	tamarinier
	CHAD ARABIC	tamr hindi
	BAMBARA	tombi
	DJERMA	bossaye
	FULANI	jtatami
	HAUSA	tsamiya
	KANOURI	tamsugu
	MORE	pousiga

Legal Restrictions: Cutting and Removal.

GENERAL DESCRIPTION

Tree of medium-to-large size up to 15m recognized by its dense, well-rounded crown. Bark is reddish-grey and is fissured. Leaves consist of 10-15 pairs of folioles. Seed pods are reddish-brown and cylindrical. Pale yellow wood bends well and is strong.

SEEDS

Source:
Collection: January-March, depending upon location.
Extraction: Soak fruit to remove pulp; dry the seeds.
Storage:
Pre-Treatment: None required.

NURSERY

Pots/Open-rooted: Pots.
Time: 18-24 weeks.
Other Notes: Project planted 50 pots, 3 seeds per pot; 63% germination. Germinates well and grows rapidly in pots.

PLANTING/SITE REQUIREMENTS

Soil: Grows best in sandy soil along coasts.

Water: More than 800mm annual precipitation or along mares and low spots.

Direct Seeding:

Other Notes:

USES

- Wood for furniture and boatbuilding.
- Excellent charcoal.
- Produces tamarind fruit, which is used to make drinks and soups.
- Shade.
- An herb/spice to add flavor to main dishes.

SPECIAL NOTES

-- In some areas, there is sufficient demand for the fruit to justify special plantations.
-- Some countries export the fruit.

Vitex cuneata Schum. & Thonn.

Synonyms:	*Vitex chariensis* Chev.			
	Vitex cienkowskii Kotschy & Perr.			
	Vitex doniana Sweet			
	Vitex paludosa Vatke			
Common Names:	CHAD ARABIC	unrugulguh	FULANI	galbihi
	BAMBARA	sokoro	HAUSA	dumnjaa
		koroba	KANOURI	ngaribi
	DJERMA	bo-i	MORE	andega

Legal Restrictions: Classified as "Specially Useful."

GENERAL DESCRIPTION

Small or medium savanna tree, 10-12m high. Dark green, rounded crown. Bark is pale brown to greyish white with fissures. Leaves are large with oblong folioles. Fruits are large, black, and good to eat. Wood is semi-hard and susceptible to insect attack.

SEEDS

Source:
Collection: October in Niger.
Extraction: Soak fruit to remove pulp; dry seeds.
Storage:
Pre-Treatment: Soak seeds in lukewarm water overnight.

NURSERY

Pots/Open-rooted: Pots.
Time:
Other Notes: Project planted 50 pots, 3 seeds per pot; germination of 2%.

PLANTING/SITE REQUIREMENTS

Soil: Dense forest, wooded savanna, river borders, and cultivated fields.

Water: Needs access to water for good growth.

Direct Seeding:

Other Notes: Widely distributed throughout Africa.

USES

- Wood used for light woodworking and building small boats.
- Fruits are popular food.
- Leaves used in sauces and as medicine against dysentery.

SPECIAL NOTES

-- This is a popular tree mainly because of its fruits. Unfortunately, it is a slow and poor germinator and propagation is difficult.

Ziziphus spina christi (L.) Willd.

Synonyms:

Common Names:

CHAD ARABIC	karno
FULANI	kurnahi
HAUSA	kurna
KANOURI	korna

Legal Restrictions:

GENERAL DESCRIPTION

Medium-sized tree which lives a long time. Small, elliptical leaves on slender branches with short, curved spines.

SEEDS

Source: Strong, healthy trees.
Collection: October-January, depending on location.
Extraction: Soak fruit to remove pulp; crack shell with hammer to extract seeds.
Storage:
Pre-Treatment: Soak in lukewarm water overnight.

NURSERY

Pots/Open-rooted: Pots.
Time:
Other Notes: Project planted 50 pots, 2 seeds per pot; 35% germination. Grows fairly rapidly in pots.

PLANTING/SITE REQUIREMENTS

Soil: Extends into dry, desert areas but prefers alluvial plains with deep soils.

Water: Likes sites where some ground water is available; has long tap root.

Direct Seeding:

Other Notes: Strong regenerative powers and is resistant to heat and drought.

USES

- Conservation uses for erosion control: windbreaks, shelterbelts and dune fixation.
- Wood used for fuel, tools and charcoal.
- Branches and leaves weed for animal browse.

SPECIAL NOTES

Appendix C

Climate, Vegetation, and Soils Of Sub-Saharan Africa

MAP 1
CLIMATE

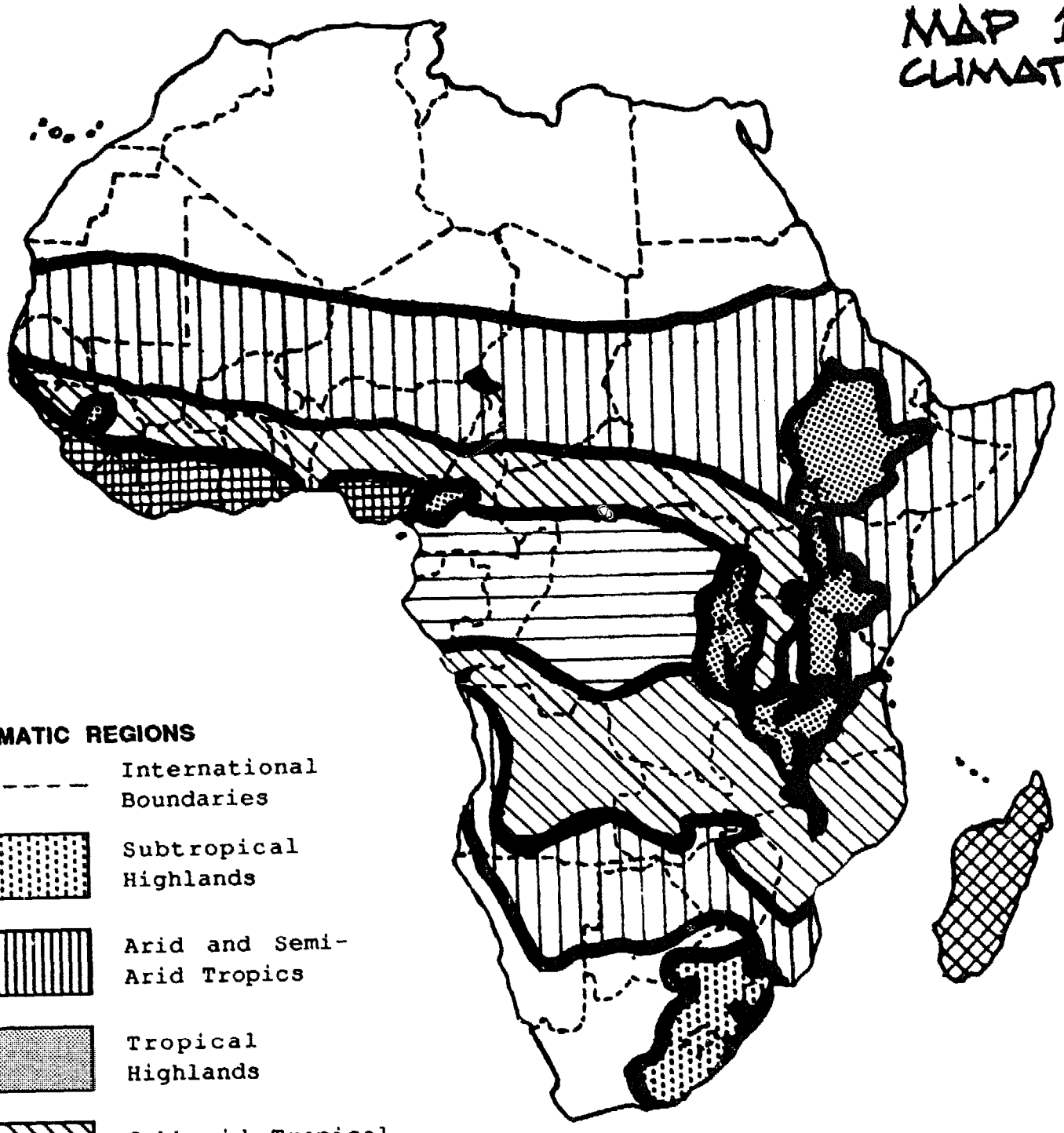

CLIMATIC REGIONS

- International Boundaries
- Subtropical Highlands
- Arid and Semi-Arid Tropics
- Tropical Highlands
- Subhumid Tropical Uplands
- Humid Equatorial Lowlands
- Madagascar and Indian Ocean Islands
- Humid Coastal Lowlands

MAP 2
MEAN ANNUAL PRECIPITATION

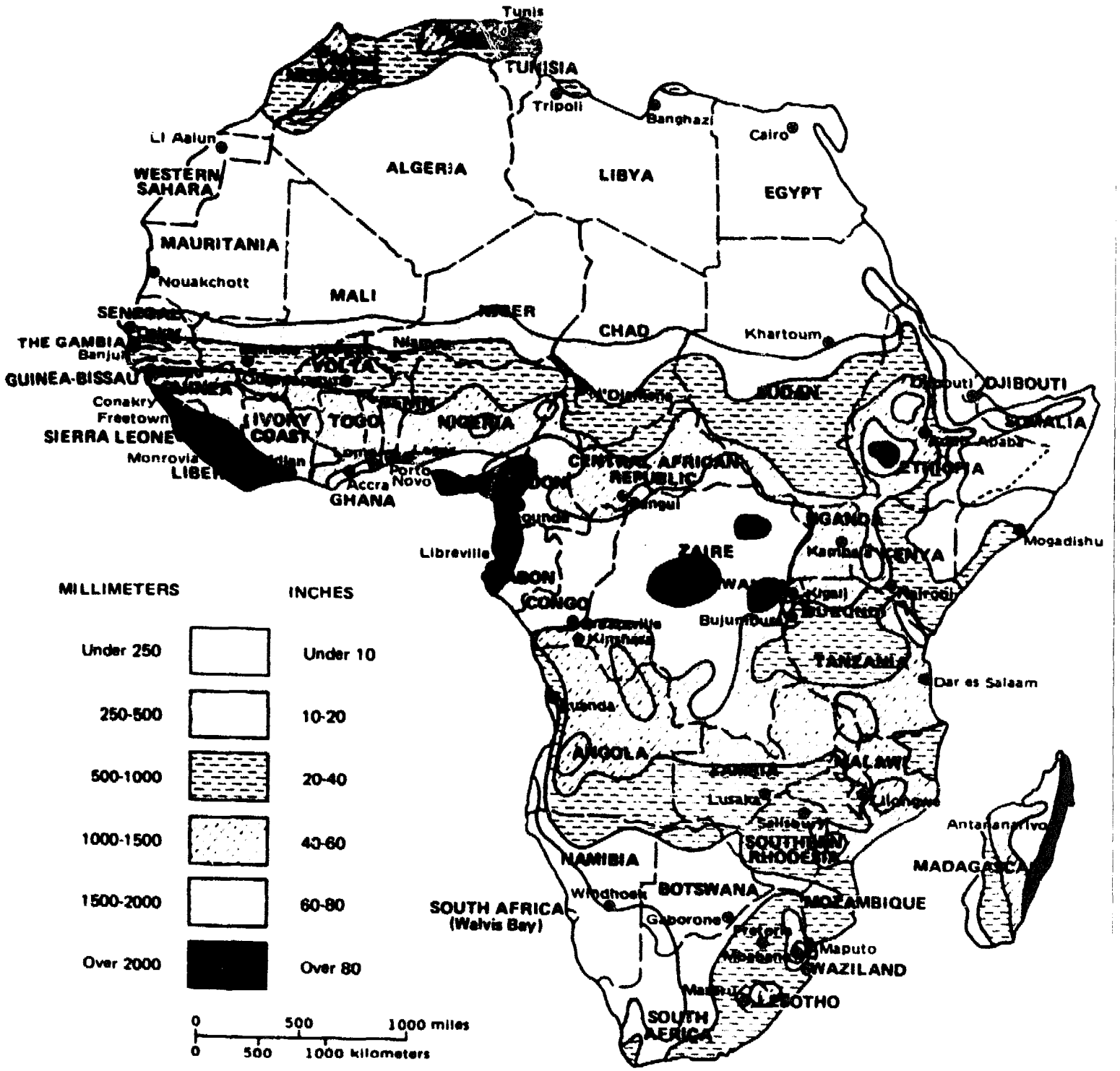

COMPARISON OF TERMINOLOGY

Mean Annual Precipitation in millimeters	2500	2000	1500	1000	500	100	0
Aubreville Climatic-francophone			Sudano-Guinéen	Soudaneen	Sahelo-Soudanais	No. Sahel	Saharien
Anglophone terms Nigeria		Derived Savanna	Guinea Savanna	Sudan Savanna	Sahel Savanna		
Vegetation Map Map 4	Mosaic	Woodland	Wooded Savanna	Shrub Savanna	Tree Steppe	Grass Steppe	

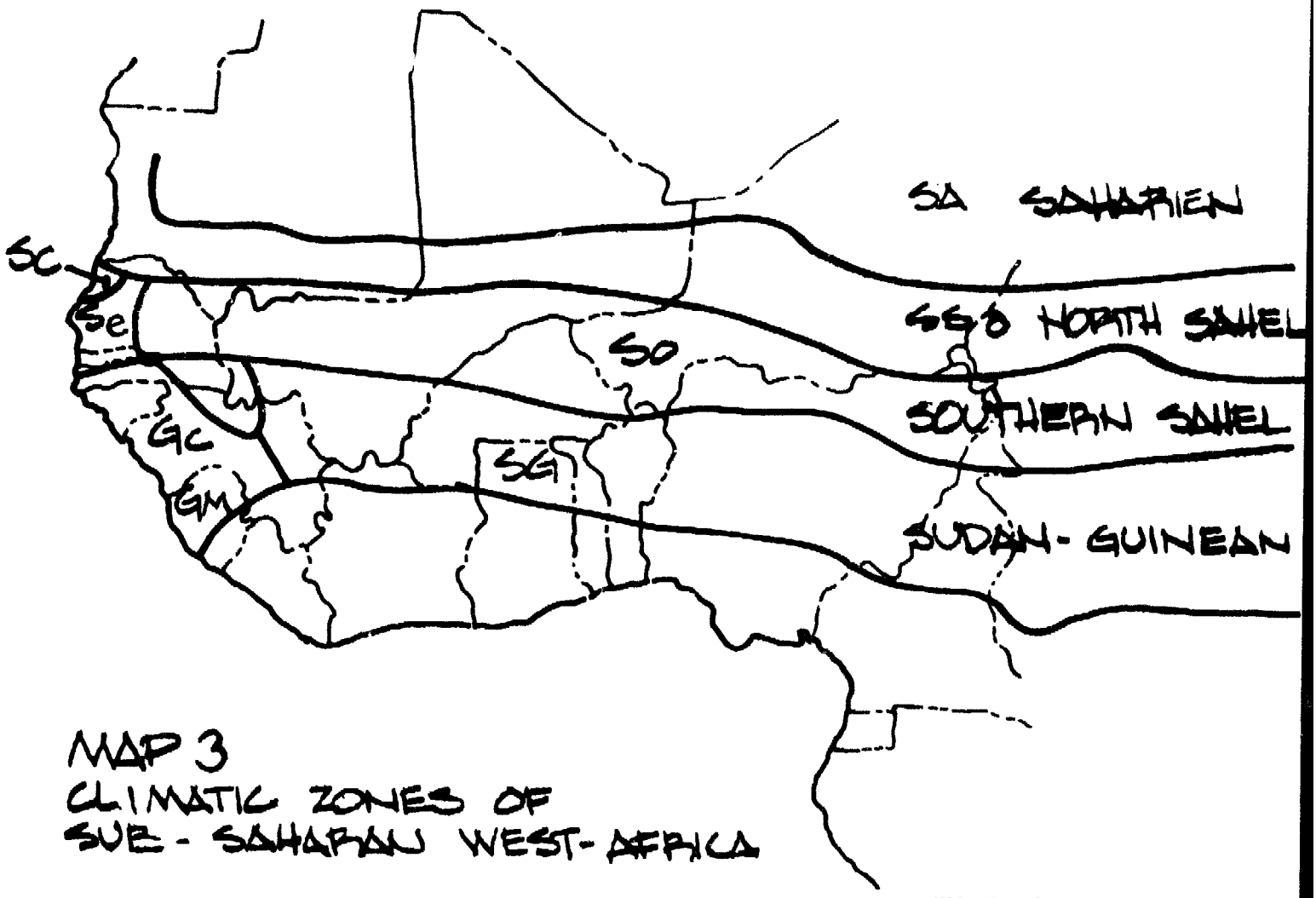

MAP 3
CLIMATIC ZONES OF
SUB-SAHARAN WEST-AFRICA

SYMBOL	DESCRIPTION FRENCH	DESCRIPTION ENGLISH	MEAN ANNUAL PRECIPITATION	MEAN ANNUAL SATURATION DEFICIT
SA	Saharien	Saharan	less than 200	20mm
SSa	Sahélo-saharien	Northern Sahel	200 to 400	15mm
Sc	Sahélo-Côte sénégalais	Senegal Coastal Sahel	400 to 500	5.3-7mm
Se	Sahélo-sénégalais	Senegal Sahel	500 to 900	9-12mm
So	Sahélo-soudanais	Southern Sahel	400 to 1200	11.5-22mm
SG	Soudano-Guinéen	Sudan-Guinean	950 to 1750	7-12mm
Gc	Guinéen basse Casamance	Casamance Guinean	1200 to 1750	6.5-7mm
Gm	Guinéen-maritime	Costal Guinean	1950 to 4500	4.4-5.5mm
Gf	Guinéen - foutanien	Fouta Guinean	1800 to 2050	6-7mm

Source "Flore forestière Soudano-Guinéene"

This terminology used here is commonly used in sub-Saharan West Africa and is based on the work of Aubreville. (As such it came into use prior to the creation of the Yangambi classification of African vegetation types.)

MAP 4
VEGETATION ZONES

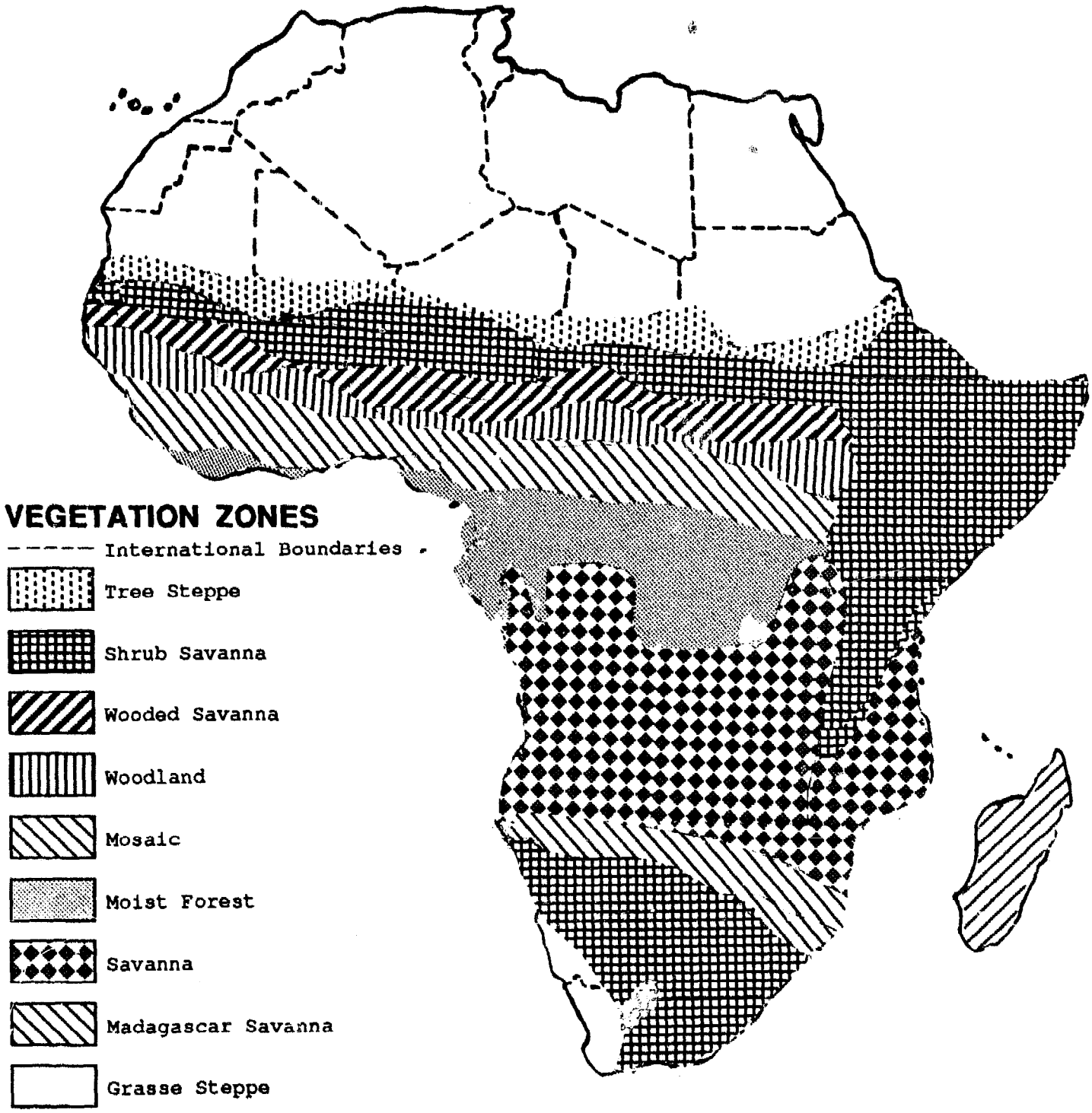

Vegetation zones in this map are based on the Yangambi classification created by a 1950 meeting of the Commission for Technical Cooperation in Africa South of the Sahara and used in the U.N. Food and Agriculture Organization publication, *Tree Planting Practice in African Savannas*.

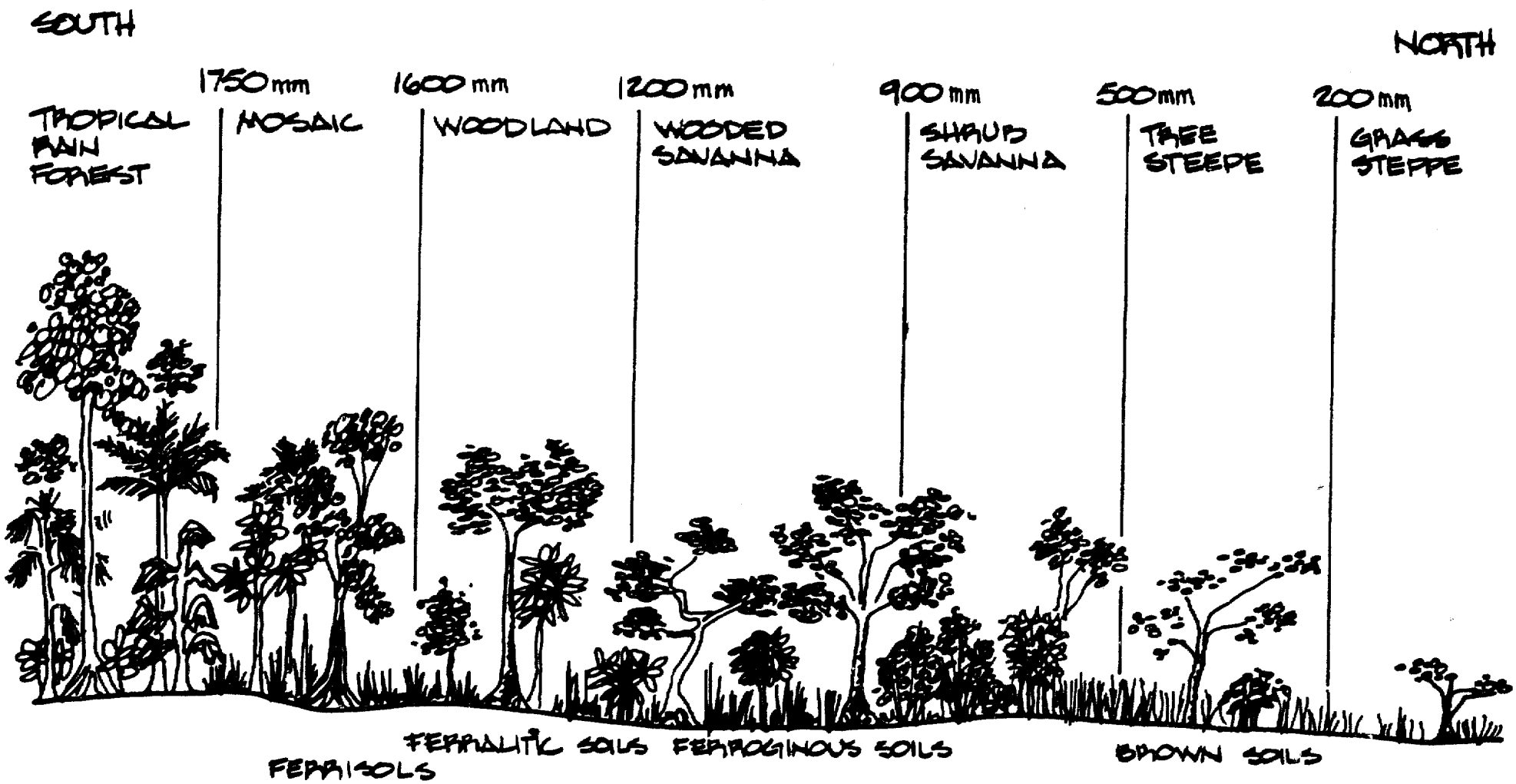

VEGETATION PROFILE NORTH - SOUTH

* SEE CHART BEGINNING NEXT PAGE FOR MORE INFORMATION

ZONE	SUB-AREA	MEAN ANNUAL RAINFALL (in millimeters)	GRASSES	BUSHES & TREES	SOILS
SAVANNA		900-1200mm	Thick, tall grasses	Terminalia Butyrospermum Parkia Borassus	Ferruginous Soils: See "Shrub Savanna".
SAVANNA		1200-1600mm		soberlinia doka Khaya Hyparrhenia Andropgon gayanus	Ferralitic Soils: Begin over 1200mm rainfall. Cation exchange capacity very poor. SiO_2/Al_2O_3 ratio less than 2. Often, these soils are very deep. (Oxisols USDA). Similar to laterized* red earth soils of East Africa. Sometimes layers of iron oxides but not as common as in ferruginous soils. Low Fertility

* The term "laterite" is frequently used especially in connection with tropical soils. In spite of voluminous writings it is not possible to define this term to everyone's satisfaction. In its purest sense the following description is given: "zone(s) rich in sesquioxydes (Al_2O_3 and Fe_2O_3) that, when cut into bricks, become hard as they dry."

Geologists, on the other hand, frequently use the term to describe ferruginous layers, already hard and cellular or clinkerlike, including concretionary coatings of iron oxides.

As a given parent material is slowly transformed into laterite under the influence of its exposure to a certain climate, great chemical changes take place to considerable depths. Much of the original silica is removed. Aluminum oxide (Al_2O_3) leading -- in its purest form -- to commercially exploitable accumulations of bauxite.

ZONE	SUB-AREA	MEAN ANNUAL RAINFALL (in millimeters)	GRASSES	BUSHES & TREES	SOILS
SAVANNA	MOSAIC	1600-1750mm	Patches of moist forest surround areas of dense, coarse savanna grass.	Hymenocardia acida Lophira lanceolata	Ferralitic Soils: Ferrisols, Kaolinite and oxides in clay complex. See also "Woodland".
SAVANNA	TROPICAL RAIN FOREST	over 1750mm			

Appendix D

Information Sources
Suggested Reading

INFORMATION SOURCES

The following organizations work in arid forestry, range management, or agriculture, and can be contacted for information on specific problems:

RESEARCH ORGANIZATIONS

Centro Agronomico Tropical de Investigacion y
Ensenanza (CATIE)
Dept. de Recurses Naturale
Turrialba
Costa Rica

Centre Technique Forestier Tropical (CTFT)
45 Bis Avenue de la Belle Gabrielle
94 Nogent Sur Marne
France
(Regional Offices in Dakar; Stations in Ndjamena
Niamey, and Ouagadougou)

Commonwealth Forestry Institute (CFI)
University of Oxford
South Parks Rd.
P.O. 13 RD
Oxford, England OX1 3RB

Consultive Group on International Agriculture
Research (CGIAR)
1818 H Street
Washington, D.C. 20433 USA

Environment and Policy Institute
East-West Center
1777 East-West Road
Honolulu, HI 96848 USA

Institute for Development Anthropology
99 Collier St., Suite 302
P.O. Box 818
Binghamton, N.Y. 13902 USA

Institute of Tropical Forestry
Post Office Box AQ
Rio Piedras, PR 00928

International Council for Research in Agroforestry
(ICRAF)
P.O. Box 30677
Nairobi, Kenya

International Crops Research Institute for the
Semi-Arid Tropics (ICRISAT)
Patancheru P.O.
Andhra Pradesh 502 324
India
(Offices in Mali and Niger)

International Development Research Centre
(IDRC)
60 Queen St.
P.O. Box 8500
Ottawa, Canada

International Institute for Environment and
Development (IIED)
1717 Massachusetts Ave., N.W. , Suite 302
Washington, D.C. 20004 USA

International Institute of Tropical Agriculture
(IITA)
PMB 5320
Ibadan, Nigeria

International Livestock Centre for Africa (ILCA)
P.O. Box 5689
Addis Ababa, Ethopia

International Tree Crops Institute
P.O. Box 888
Winters, CA 95694 USA

National Academy of Sciences
Board on Science and Technology for
International Development (BOSTID)
2101 Constitution Ave., N.W.
Washington, D.C. 20418 USA

Nitrogen Fixation by Tropical Agricultural Legumes (NifTAL)
Project
P.O. Box 0
Paia, Hawaii 96779 USA

Office of Arid Lands Studies
University of Arizona
Tucson, AZ 85719 USA

Tropical Products Institute
56/62 Gray's Inn Rd.
London WC1 X8LU
England

Tropical Resources Institute
Yale School of Forestry and Environmental Studies
205 Prospect St.
New Haven, CT 06511 USA

U.S. GOVERNMENT AGENCIES

Forestry Support Program
FSP Room 1208 RPE
USFS P.O. Box 2417
Washington, D.C. 20013 USA

Office of International Development and Cooperation (OICD)
U.S. Dept. of Agriculture
Room 4405 Auditors Building
Washington, D.C. 20250 USA

Office of Technology Assessment (OTA)
600 Pennsylvania Ave. S.E.
Washington, D.C. 20510 USA

Peace Corps
OTAPS/Forestry and Natural Resources
806 Connecticut Ave., N.W.
Washington, D.C. 20526 USA

Smithsonian Tropical Research Institute
1000 Jefferson Dr.
Washington, D.C. USA

Soil Management Support Services
Soil Conservation Service
P.O. Box 2890
Washington, D.C. USA

USAID (Agency for International Development)
Department of State
Washington, D.C. 20520 USA
(AID field offices can be contacted through the respective U.S. Embassies)

USAID
Science and Technology/FENR
Dept. of State
Washington, D.C. 20520 USA

International Forestry Staff
Romm 1208 RPE
USDA/FS
P.O. Box 2419
Washington, D.C. 20013 USA

AGENCIES RESPONSIBLE FOR NATURAL RESOURCE MANAGEMENT IN ARID LANDS

Conservator of Forests
Ministry of Animal and Forest Resources
Private Mail Bag #3022
Kano, Nigeria

Direction des Eaux et Forets/Burkina Faso
B.P. 7044
Ouagadougou, Burkina Faso

Direction des Eaux de Forets/Mali
B.P. 275
Bamako, Mali

Direction des Eaux de Forets/Niger
B.P. 578
Niamey, Niger

Direction des Eaux de Forets/Senegal
B.P. 1831
Dakar, Senegal

Direction des Forets des Chasses
et de L'Environnement
Lome, Togo

DNAREF
B.P. 1341
Yaounde, Cameroon

Forestry Association of Botswana
Box 2008
Gabarone, Botswana

Forestry Office
Box 30048
Lilongwe 3, Malawi

Forestry Research Center
P.O.Box 658
Khartoum, Sudan

Forest Research Institute
P.O. New Forest
Dehra Dun
U.P. India

Forestry Research Institute of Nigeria
P.M.B. 5054
Ibadan, Nigeria

Land Utilization Division
Private Bag 003
Gabarone, Botswana

Ministry of Ag and Natural Resources
Box 596
Yundum, Gambia

Ministry of Energy
PO Box 30582
Nairobi, Kenya

Ministry of Forestry
Box 426
Dar es Salaam, Tanzania

Ministry of Water Resources and Environment
5 Marina Parade
Banjul, Gambia

Ministere pro Nature
B.P. 4055
Dakar, Senegal

National Range Agency
PO Box 1759
Mogadishu, Somalia

Proection de la Nature
B.P. 170
Nouakchott, Mauritania

Reforestation Service
Keren Kayemet
BP 45 Kiryat Haim
Haifa, Israel

INTERNATIONAL ORGANIZATIONS

CBLT (Lake Chad Basin Commission)
Forestry Division
B.P. 727
N'Djamena, Chad

CIEH (Interafrican Committee for Hydraulic Studies)
B.P. 369
Ouagadougou, Burkina Faso

Comittee Inter-Etat pour la Lutte Contre
la Secheresse du Sahel (CILSS)
Projects and Programs Division
B.P. 7049
Ouagadougou, Burkina Faso

Environmental Liaison Centre
P.O. Box 72461
Nairobi, Kenya

International Society of Tropical Foresters
5400 Grosvenor Lane
Bethseda, MD 20814 USA

International Tree Project Clearinghouse (ITPC)
Non-governmental Liaison Service
2 UN Plaza
DC-2-RM 1103
New York, NY 10017 USA

International Union for Conservation of Nature and Natural Resources
Avenue de Mont Blanc
CH - 1196 Gland
Switzerland

UN Development Programme (UNDP)
1 United Nations Plaza
New York, NY 10017 USA

UN Environment Programme (UNEP)
Ecosystems Natural Resource Division
P.O. Box 30552
Nairobi, Kenya

UN Food and Agriculture Organization (FAO)
Forest Resources Division
Via delle Terme di Caracalla
00100
Rome, Italy

UN Sahelo-Soudanian Office
1 United Nations Plaza
New York, NY 10017 USA

World Bank
Africa - Forestry Division
1818 H Street, N.W.
Washington, D.C. 20433 USA

PRIVATE VOLUNTARY AND NONGOVERNMENTAL ORGANIZATIONS

Arid Lands Information Center
845 N. Park Ave.
Tucson, AZ 85719 USA

Africare
1601 Connecticut Ave. N.W.
Suite 600
Washington, D.C. 20009 USA
CODEL
79 Madison Ave.
New York, NY 10016 USA

CARE International
Agriculture and Natural Resources Program
660 First Avenue
New York, NY 10016 USA

Chambre D' Agriculture, De L'Elevage et Des Forets du Cameroun
B.P. 287
Yaounde, Cameroon

Conseil Des Organisations Non Gouvernementales D'Appui Au Developpement Du Senegal (CONGAD)
Rue 41 X Boulevard General De Gaulle
B.P.4109
Dakar, Senegal

Environnement Et Developpement du Tiers Monde (ENDA)
B.P. 3370
Dakar, Senegal

IUCN Bulletin
International Union for Conservation of Nature and Natural Resources
CH-1196 Gland
Switzerland

Joint Energy and Environment Projects (JEEP)
Plot 14 A Main Street Jinja
Opposite Upper Bata
P.O.Box 1684
Jinja, Uganda

Kenya Energy Non-Governmental Organizations (KENGO)
Westlands, Karuna Road
P.O. Box 48197
Nairobi, Kenya

Kweneng Rural Development Association
Private Bag 7
Molepolole, Botswana

Lutheran World Relief
360 Park Ave. South
New York, NY 10016 USA

Mazingira Institute
P.O.Box 14550
Nairobi, Kenya

National Wildlife Federation
International Program
1412 16th Street, N.W.
Washington, D.C. 20036 USA

Natural Resources Defense Council
International Project
1350 New York Ave., N.W., Suite 300
Washington, D.C. 20005 USA

Resources for the Future
1755 Massachusetts Ave., N.W.
Washington, D.C. 20036 USA

Sierra Club
228 East 45th St.
New York, NY 10017 USA

Sierra Leone Environment and Nature Conservation
Association (SLENCA)
P/M.B. 376
Freetown, Sierra Leone

Sudan Council of Churches
P.O.Box 469
Khartoum, Sudan

Tanzania Environment Society
P.O.Box 1309
Dar Es Salaam, Tanzania

Volunteers in Technical Assistance (VITA)
1815 North Lynn St., Suite 200
Arlington, VA 22209 USA

Winrock International Institute for Agricultural
Development
Rt. 3
Morrilton, AR 72110 USA

World Resources Institute
1735 New York Ave., N.W.
Washington, D.C. 20006 USA

Worldwatch Institute
1776 Massachusetts Ave.
Washington, D.C. 20036 USA

ARBORETUMS AND HERBARIUMS

Arnold Arboretum
Cambridge, Mass. USA

Boyce Thompson Southwestern Arboretum
P.O. Box AB
Superior, Arizona 85273 USA

KICEPAL
Royal Botanical Gardens
Kew, Richmond, Surry
TW9 2AE, U.K.

Missouri Botanical Garden
St. Louis, MO USA

New York Botanical Gardens
Bronx, NY 10458 USA

University of Hawaii Instructional Arboretum
Waimanalo, Hawaii 96795 USA

JOURNALS AND BULLETINS

Agroforestry Review
International Tree Crops Institute USA
Route 1
Gravel Switch, Kentucky 40328 USA

Agroforestry Systems
Martinus Nijhoff
Kluwer Academic Publishers
101 Philip Drive
Assinippi Park
Norwell, Mass. 02061 USA

AMBIO
Royal Swedish Academy of Sciences
Box 50005
5 - 104 05
Stockholm, Sweden

Arid Lands Newsletter
University of Arizona
845 No. Park Ave.
Tucson, AZ 85719 USA

Farm Forestry News
Winrock International Institute for Agricultural Development
1611 North Kent Street
Arlington, VA 22209 USA

FSSP Newsletter
Farming Systems Support Project
3028 McCarty Hall
University of Florida
Gainesville, FL 32611 USA

ISTF Newsletter
International Society of Tropical Foresters
5400 Grosvenor Lane
Bethseda, MD 20814 USA

ICRAF Newsletter
International Council for Research in Agroforestry
P.O. Box 30677
Nairobi, Kenya

IITA Research Briefs
International Institute of Tropical Agriculture
PMB 5320
Oyo Road
Ibadan, Nigeria

International Tree Crops Journal
A.B. Academic Publishers
P.O. 97
Berkhampstead, Herts.
HP4 2PX, England

IUSF Newsletter
International Union of Societies of Foresters
Canadian Institute of Forestry
151 Slater Street, Suite 815
Ottawa, Ontario
Canada K1P5H3

Leucaena Research Reports
Nitrogen Fixing Tree Association
P.O. Box 680
Waimanalo, Hawaii 96795 USA

Nitrogen Fixing Tree Research Reports (NFTRR)
Nitrogen Fixing Tree Association
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New Forests
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Social Forestry Network Newsletter
Overseas Development Institute (ODI)
Agricultural Administrative Unit
Regent's College
Inner Circle, Regent's Park
London
NW1 4NS England

The Tree Project News
International Tree Project Clearinghouse
Non-governmental Liaison Service
2 UN Plaza
DC-2-RM 1103
New York, NY 10017 USA

UNASYLVA
UNIPUB
P.O. Box 1222
Ann Arbor, MI 48106 USA

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Refrigeration

From Wikipedia, the free encyclopedia

Refrigeration is a process of moving heat from one location to another in controlled conditions. The work of heat transport is traditionally driven by mechanical work, but can also be driven by heat, magnetism, electricity, laser, or other means. Refrigeration has many applications, including, but not limited to: household refrigerators, industrial freezers, cryogenics, and air conditioning. Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible, but are otherwise similar to air conditioning units.

Commercial refrigeration

Refrigeration has had a large impact on industry, lifestyle, agriculture and settlement patterns. The idea of preserving food dates back to at least the ancient Roman and Chinese empires. However, mechanical refrigeration technology has rapidly evolved in the last century, from ice harvesting to temperature-controlled rail cars. The introduction of refrigerated rail cars contributed to the westward expansion of the United States, allowing settlement in areas that were not on main transport channels such as rivers, harbors, or valley trails. Settlements were also developing in infertile parts of the country, filled with new natural resources. These new settlement patterns sparked the building of large cities which are able to thrive in areas that were otherwise thought to be inhospitable, such as Houston, Texas and Las Vegas, Nevada. In most developed countries, cities are heavily dependent upon refrigeration in supermarkets, in order to obtain their food for daily consumption. The increase in food sources has led to a larger concentration of agricultural sales coming from a smaller percentage of existing farms. Farms today have a much larger output per person in comparison to the late 1800s. This has resulted in new food sources available to entire populations, which has had a large impact on the nutrition of society.

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History

Earliest forms of cooling

The seasonal harvesting of snow and ice is an ancient practice estimated to have begun earlier than 1000 B.C.[1] A Chinese collection of lyrics from this time period known as the Shih king, describes religious ceremonies for filling and emptying ice cellars. However, little is known about the construction of these ice cellars or what the ice was used for. The next ancient society to harvest ice may have been the Jews according to the book of Proverbs, which reads, “As the cold of snow in the time of harvest, so is a faithful messenger to them who sent him.” Historians have interpreted this to mean that the Jews used ice to cool beverages rather than to preserve food. Other ancient cultures such as the Greeks and the Romans dug large snow pits insulated with grass, chaff, or branches of trees as cold storage. Like the Jews, the Greeks and Romans did not use ice and snow to preserve food, but primarily as a means to cool beverages. The Egyptians also developed methods to cool beverages, but in lieu of using ice to cool water, the Egyptians cooled water by putting boiling water in shallow earthen jars and placing them on the roofs of their houses at night. Slaves would moisten the outside of the jars and the resulting evaporation would cool the water. The ancient people of India used this same concept to produce ice. The Persians stored ice in a pit called a Yakhchal and may have been the first group of people to use cold storage to preserve food. In the Australian outback before a reliable electricity supply was available where the weather could be hot and dry, many farmers used a "Coolgardie safe". This consisted of a room with hessian "curtains" hanging from the ceiling soaked in water. The water would evaporate and thereby cool the hessian curtains and thereby the air circulating in the room. This would allow many perishables such as fruit, butter, and cured meats to be kept that would normally spoil in the heat. [2][3]

Ice harvesting

Before 1830, few Americans used ice to refrigerate foods due to a lack of ice-storehouses and iceboxes. As these two things became more widely available, individuals used axes and saws to harvest ice for their storehouses. This method proved to be difficult, dangerous, and certainly did not resemble anything that could be duplicated on a commercial scale.[4]

Despite the difficulties of harvesting ice, Frederic Tudor thought that he could capitalize on this new commodity by harvesting ice in New England and shipping it to the Caribbean islands as well as the southern states. In the beginning, Tudor lost thousands of dollars, but eventually turned a profit as he constructed icehouses in Charleston, Virginia and in the Cuban port town of Havana. These icehouses as well as better insulated ships helped reduce ice wastage from 66% to 8%. This efficiency gain influenced Tudor to expand his ice market to other towns with icehouses such as New Orleans and Savannah. This ice market further expanded as harvesting ice became faster and cheaper after one of Tudor's suppliers, Nathaniel Wyeth, invented a horse-drawn ice cutter in 1825. This invention as well as Tudor's success inspired others to get involved in the ice trade and the ice industry grew.

Ice harvesting in Massachusetts, 1852, showing the railroad line in the background, used to transport the ice.

Ice became a mass-market commodity by the early 1830s with the price of ice dropping from six cents per pound to a half of a cent per pound. In New York City, ice consumption increased from 12,000 tons in 1843 to 100,000 tons in 1856. Boston's consumption leapt from 6,000 tons to 85,000 tons during that same period. Ice harvesting created a "cooling culture" as majority of people used ice and iceboxes to store their dairy products, fish, meat, and even fruits and vegetables. These early cold storage practices paved the way for many Americans to accept the refrigeration technology that would soon take over the country.[5][6]

Refrigeration research

The history of artificial refrigeration began when Scottish professor William Cullen designed a small refrigerating machine in 1755. Cullen used a pump to create a partial vacuum over a container of diethyl ether, which then boiled, absorbing heat from the surrounding air.[7] The experiment even created a small amount of ice, but had no practical application at that time.

William Cullen, the first to conduct experiments into artificial refrigeration.

In 1758, Benjamin Franklin and John Hadley, professor of chemistry, collaborated on a project investigating the principle of evaporation as a means to rapidly cool an object at Cambridge University, England. They confirmed that the evaporation of highly volatile liquids, such as alcohol and ether, could be used to drive down the temperature of an object past the freezing point of water. They conducted their experiment with the bulb of a mercury thermometer as their object and with a bellows used to "quicken" the evaporation; they lowered the temperature of the thermometer bulb down to 7 °F (−14 °C), while the ambient temperature was 65 °F (18 °C). They noted that soon after they passed the freezing point of water (32 °F), a thin film of ice formed on the surface of the thermometer's bulb and that the ice mass was about a quarter inch thick when they stopped the experiment upon reaching 7 °F (−14 °C). Franklin wrote, "From this experiment, one may see the possibility of freezing a man to death on a warm summer's day".[8] In 1805, American inventor Oliver Evans described a closed vapor-compression refrigeration cycle for the production of ice by ether under vacuum.

In 1820, the English scientist Michael Faraday liquefied ammonia and other gases by using high pressures and low temperatures, and in 1834, an American expatriate to Great Britain, Jacob Perkins, built the first working vapor-compression refrigeration system in the world. It was a closed-cycle that could operate continuously, as he described in his patent:

> I am enabled to use volatile fluids for the purpose of producing the cooling or freezing of fluids, and yet at the same time constantly condensing such volatile fluids, and bringing them again into operation without waste.

His prototype system worked although it did not succeed commercially.[9]

In 1842, a similar attempt was made by American physician, John Gorrie,[10] who built a working prototype, but it was a commercial failure. Like many of the medical experts during this time, Gorrie thought too much exposure to tropical heat led to mental and physical degeneration, as well as the spread of diseases such as malaria.[11] He conceived the idea of using his refrigeration system to cool the air for comfort in homes and hospitals to prevent disease. American engineer Alexander Twining took out a British patent in 1850 for a vapour compression system that used ether.

The first practical vapor compression refrigeration system was built by James Harrison, a British journalist who had emigrated to Australia. His 1856 patent was for a vapour compression system using ether, alcohol or ammonia. He built a mechanical ice-making machine in 1851 on the banks of the Barwon River at Rocky Point in Geelong, Victoria, and his first commercial ice-making machine followed in 1854. Harrison also introduced commercial vapour-compression refrigeration to breweries and meat packing houses, and by 1861, a dozen of his systems were in operation. He later entered the debate of how to compete against the American advantage of unrefrigerated beef sales to the United Kingdom. In 1873 he prepared the sailing ship *Norfolk* for an experimental beef shipment to the United Kingdom, which used a cold room system instead of a refrigeration system. The venture was a failure as the ice was consumed faster than expected.

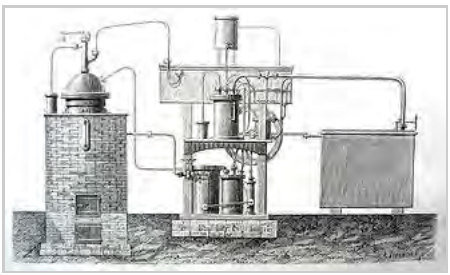

Ferdinand Carré's ice-making device

The first gas absorption refrigeration system using gaseous ammonia dissolved in water (referred to as "aqua ammonia") was developed by Ferdinand Carré of France in 1859 and patented in 1860. Carl von Linde, an engineer specializing in steam locomotives and professor of engineering at the Technological University of Munich in Germany, began researching refrigeration in the 1860s and 1870s in response to demand from brewers for a technology that would allow year-round, large-scale production of lager; he patented an improved method of liquefying gases in 1876.[12] His new process made possible using gases such as ammonia, sulfur dioxide (SO_2) and methyl chloride (CH_3Cl) as refrigerants and they were widely used for that purpose until the late 1920s.

Thaddeus Lowe, an American balloonist, held several patents on ice-making machines. His "Compression Ice Machine" would revolutionize the cold-storage industry. In 1869, other investors and he purchased an old steamship onto which they loaded one of Lowe's refrigeration units and began shipping fresh fruit from New York to the Gulf Coast area, and fresh meat from Galveston, Texas back to New York, but because of Lowe's lack of knowledge about shipping, the business was a costly failure.

Commercial use

In 1842, John Gorrie created a system capable of refrigerating water to produce ice. Although it was a commercial failure, it inspired scientists and inventors around the world. France’s Ferdinand Carre was one of the inspired and he created an ice producing system that was simpler and smaller than that of Gorrie. During the Civil War, cities such as New Orleans could no longer get ice from New England via the coastal ice trade. Carre’s refrigeration system became the solution to New Orleans ice problems and by 1865 the city had three of Carre’s machines.[13] In 1867, in San Antonio, Texas, a French immigrant named Andrew Muhl built an

ice-making machine to help service the expanding beef industry before moving it to Waco in 1871. In 1873, the patent for this machine was contracted by the Columbus Iron Works, a company acquired by the W. C. Bradley Co., which went on to produce the first commercial ice-makers in the US.

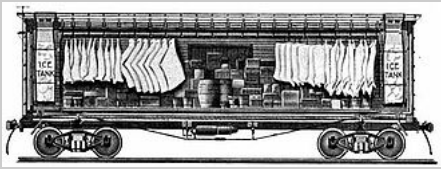

An 1870 refrigerator car design. Hatches in the roof provided access to the tanks for the storage of harvested ice at each end.

By the 1870s, breweries had become the largest users of harvested ice. Though the ice-harvesting industry had grown immensely by the turn of the 20th century, pollution and sewage had begun to creep into natural ice, making it a problem in the metropolitan suburbs. Eventually, breweries began to complain of tainted ice. Public concern for the purity of water, from which ice was formed, began to increase in the early 1900s with the rise of germ theory. Numerous media outlets published articles connecting diseases such as typhoid fever with natural ice consumption. This caused ice harvesting to become illegal in certain areas of the country. All of these scenarios increased the demands for modern refrigeration and manufactured ice. Ice producing machines like that of Carre's and Muhl's were looked to as means of producing ice to meet the needs of grocers, farmers, and food shippers.[14][15]

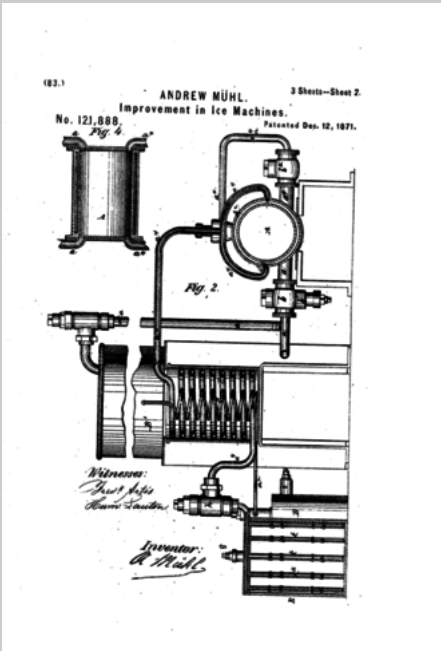

Icemaker Patent by Andrew Muhl, dated December 12, 1871.

Refrigerated railroad cars were introduced in the US in the 1840s for short-run transport of dairy products, but these used harvested ice to maintain a cool temperature.[16]

Dunedin, the first commercially successful refrigerated ship.

The new refrigerating technology first met with widespread industrial use as a means to freeze meat supplies for transport by sea from the British Dominions and other countries to the British Isles. The first to achieve this breakthrough was an entrepreneur who had emigrated to New Zealand. William Soltau Davidson thought that Britain's rising population and meat demand could mitigate the slump in world wool markets that was heavily affecting New Zealand. After extensive research, he commissioned the *Dunedin* to be refitted with a compression refrigeration unit for meat shipment in 1881. On February 15, 1882, the *Dunedin* sailed for London with what was to be the first commercially successful refrigerated shipping voyage, and the foundation of the refrigerated meat industry.[17]

The Times commented "Today we have to record such a triumph over physical difficulties, as would have been incredible, even unimaginable, a very few days ago...". The *Marlborough*—sister ship to the *Dunedin* – was immediately converted and joined the trade the following year, along with the rival New Zealand Shipping Company vessel *Mataurua*, while the German Steamer *Marsala* began carrying frozen New Zealand lamb in December 1882. Within five years, 172 shipments of frozen meat were sent from New Zealand to the United Kingdom, of which only 9 had significant amounts of meat condemned. Refrigerated shipping also led to a broader meat and dairy boom in Australasia and South America. J & E Hall of Dartford, England outfitted the 'SS Selembria' with a vapor compression system to bring 30,000 carcasses of mutton from the Falkland Islands

in 1886.[18] In the years ahead, the industry rapidly expanded to Australia, Argentina and the United States.

By the 1890s, refrigeration played a vital role in the distribution of food. The meat-packing industry relied heavily on natural ice in the 1880s and continued to rely on manufactured ice as those technologies became available.[19] By 1900, the meat-packing houses of Chicago had adopted ammonia-cycle commercial refrigeration. By 1914, almost every location used artificial refrigeration. The big meat-packers, Armour, Swift, and Wilson, had purchased the most expensive units which they installed on train cars and in branch houses and storage facilities in the more remote distribution areas.

By the middle of the 20th century, refrigeration units were designed for installation on trucks or lorries. Refrigerated vehicles are used to transport perishable goods, such as frozen foods, fruit and vegetables, and temperature-sensitive chemicals. Most modern refrigerators keep the temperature between –40 and –20 °C, and have a maximum payload of around 24,000 kg gross weight (in Europe).

Although commercial refrigeration quickly progressed, it had limitations that prevented it from moving into the household. First, most refrigerators were far too large. Some of the commercial units being used in 1910 weighed between five and two hundred tons. Second, commercial refrigerators were expensive to produce, purchase, and maintain. Lastly, these refrigerators were unsafe. It was not uncommon for commercial refrigerators to catch fire, explode, or leak toxic gases. Refrigeration did not become a household technology until these three challenges were overcome.[20]

Home and consumer use

During the early 1800s, consumers preserved their food by storing food and ice purchased from ice harvesters in iceboxes. In 1803, Thomas Moore patented a metal-lined butter-storage tub which became the prototype for most iceboxes. These iceboxes were used until nearly 1910 and the technology did not progress. In fact, consumers that used the icebox in 1910 faced the same challenge of a moldy and stinky icebox that consumers had in the early 1800s.[21]

General Electric (GE) was one of the first companies to overcome these challenges. In 1911, GE released a household refrigeration unit that was powered by gas. The use of gas eliminated the need for motor and decreased the size of the refrigerator. However, electric companies that were customers of GE did not benefit from a gas-powered unit. Thus, GE invested in developing an electric model. In 1927, GE released the Monitor Top, the first refrigerator to run off electricity.[22]

In 1930, Frigidaire, one of GE's main competitors, synthesized Freon.[23] With the invention of synthetic refrigerants based mostly on a chlorofluorocarbon (CFC) chemical, safer refrigerators were possible for home and consumer use. Freon led to the development of smaller, lighter, and cheaper refrigerators. The average price of a refrigerator dropped from $275 to $154 with the synthesis of Freon. This lower price allowed ownership of refrigerators in American households to exceed 50%.[24] Freon is a trademark of the DuPont Corporation and refers to these CFCs, and later hydro chlorofluorocarbon (HCFC) and hydro fluorocarbon (HFC), refrigerants developed in the late 1920s. These refrigerants were considered at the time to be less harmful than the commonly-used refrigerants of the time, including methyl formate, ammonia, methyl chloride, and sulfur dioxide. The intent was to provide refrigeration equipment for home use without danger. These CFC refrigerants answered that need. In the 1970s, though, the compounds were found to be reacting with atmospheric ozone, an important protection against solar ultraviolet radiation, and their use as a refrigerant worldwide was curtailed in the Montreal Protocol of 1987.

Impact on settlement patterns

In the last century refrigeration allowed new settlement patterns to emerge. This new technology has allowed for new areas to be settled that are not on a natural channel of transport such as a river, valley trail or harbor that may have otherwise not been settled. Refrigeration has given opportunities to early settlers to expand westward and into rural areas that were unpopulated. These new settlers with rich and untapped soil saw opportunity to profit by sending raw goods to the eastern cities and states. In the 20th century, refrigeration has made “Galactic Cities” such as Dallas, Phoenix and Los Angeles possible.

Refrigerated rail cars

The refrigerated rail car, along with the dense railroad network, became an exceedingly important link between the marketplace and the farm allowing for a national opportunity rather than a just a regional one. Before the invention of the refrigerated rail car it was impossible to ship perishable food products long distances. The beef packing industry made the first demand push for refrigeration cars. The railroad companies were slow to adopt this new invention because of their heavy investments in cattle cars, stockyards, and feedlots.[25] Refrigeration cars were also complex and costly compared to other rail cars, which also slowed the adoption of the refrigerated rail car. After the slow adoption of the refrigerated car, the beef packing industry dominated the refrigerated rail car business with their ability to control ice plants and the setting of icing fees. The United States Department of Agriculture estimated that in 1916 over sixty-nine percent of the cattle killed in the country was done in plants involved in interstate trade. The same companies that were also involved in the meat trade later implemented refrigerated transport to include vegetables and fruit. The meat packing companies had much of the expensive machinery, such as refrigerated cars, and cold storage facilities that allowed for them to effectively distribute all types of perishable goods. During World War I, a national refrigerator car pool was established by the United States Administration to deal with problem of idle cars and was later continued after the war.[26] The idle car problem was the problem of refrigeration cars sitting pointlessly in between seasonal harvests. This meant that very expensive cars sat in rail yards for a good portion of the year while making no revenue for the car’s owner. The car pool was a system where cars were distributed to areas as crops matured ensuring maximum use of the cars. Refrigerated rail cars moved eastward from vineyards, orchards, fields, and gardens in western states to satisfy Americas consuming market in the east.[27] The refrigerated car made it possible to transport perishable crops hundreds and even thousands of miles. The most noticeable effect the car gave was a regional specialization of vegetables and fruits. The refrigeration rail car was widely used for the transportation of perishable goods up until the 1950s. By the 1960s the nation's interstate highway system was adequately complete allowing for trucks to carry the majority of the perishable food loads and to push out the old system of the refrigerated rail cars.[28]

Expansion west and into rural areas

The widespread use of refrigeration allowed for a vast amount of new agricultural opportunities to open up in the United States. New markets emerged throughout the United States in areas that were previously uninhabited and far-removed from heavily populated areas. New agricultural opportunity presented itself in areas that were considered rural such as states in the south and in the west. Shipments on a large scale from the south and California were both made around the same time although natural ice was used from the Sierras in California rather than manufactured ice in the south.[29] Refrigeration allowed for many areas to specialize in the growing of specific fruits. California specialized in several fruits, grapes, peaches, pears, plums, and apples while Georgia became famous for specifically its peaches. In California, the acceptance of the refrigerated rail carts lead to an increase of car loads from 4,500 carloads in 1895 to between 8,000 and 10,000 carloads in 1905.[30] The Gulf States, Arkansas, Missouri and Tennessee entered into strawberry production on a

large-scale while Mississippi became the center of the tomato industry. New Mexico, Colorado, Arizona, and Nevada grew cantaloupes. Without refrigeration this would have not been possible. By 1917, well-established fruit and vegetable areas that were close to eastern markets felt the pressure of competition from these distant specialized centers.[31] Refrigeration was not limited to meat, fruit and vegetables but it also encompassed dairy product and dairy farms. In the early twentieth century large cities got their dairy supply from farms as far as 400 miles. Dairy products were not as easily transported great distances like fruits and vegetables due to greater perishability. Refrigeration made production possible in the west far from eastern markets, so much in fact that dairy farmers could pay transportation cost and still undersell their eastern competitors.[32] Refrigeration and the refrigerated rail gave opportunity to areas with rich soil far from natural channel of transport such as a river, valley trail or harbors.[33]

Rise of the galactic city

"Edge city" was a term coined by Joel Garreau, whereas the term "galactic city" was coined by Lewis Mumford. These terms refer to a concentration of business, shopping, and entertainment outside a traditional downtown or central business district in what had previously been a residential or rural area. There were several factors contributing to the growth of these cities such as Los Angeles, Las Vegas, Houston, and Phoenix. The factors that contributed to these large cities include reliable automobiles, highway systems, refrigeration, and agricultural production increases. Large cities such as the ones mentioned above have not been uncommon in history but what separates these cities from the rest are that these cities are not along some natural channel of transport, or at some crossroad of two or more channels such as a trail, harbor, mountain, river, or valley. These large cities have been developed in areas that only a few hundred years ago would have been uninhabitable. Without a cost efficient way of cooling air and transporting water and food great distances these large cities would have never developed. The rapid growth of these cities was influenced by refrigeration and an agricultural productivity increase, allowing more distant farms to effectively feed the population.[33]

Impact on agriculture and food production

Agriculture’s role in developed countries has drastically changed in the last century due to many factors, including refrigeration. Statistics from the 2007 census gives information on the large concentration of agricultural sales coming from a small portion of the existing farms in the United States today. This is a partial result of the market created for the frozen meat trade by the first successful shipment of frozen sheep carcasses coming from New Zealand in the 1880s. As the market continued to grow, regulations on food processing and quality began to be enforced. Eventually, electricity was introduced into rural homes in the United States, which allowed refrigeration technology to continue to expand on the farm, increasing output per person. Today, refrigeration’s use on the farm reduces humidity levels, avoids spoiling due to bacterial growth, and assists in preservation.

Demographics

The introduction of refrigeration and evolution of additional technologies drastically changed agriculture in the United States. During the beginning of the 20th century, farming was a common occupation and lifestyle for United States citizens, as most farmers actually lived on their farm. In 1935, there were 6.8 million farms in the United States and a population of 127 million. Yet, while the United States population has continued to climb, citizens pursuing agriculture continue to decline. Based on the 2007 US Census, less than one percent of a population of 310 million people claim farming as an occupation today. However, the increasing population has led to an increasing demand for agricultural products, which is met through a greater variety of crops, fertilizers, pesticides, and improved technology. Improved technology has decreased the risk and time involved

if agricultural management and allows larger farms to increase their output per person to meet society's demand.[34]

Meat packing and trade

Prior to 1882, the South Island of New Zealand had been experimenting with sowing grass and crossbreeding sheep, which immediately gave their farmers economic potential in the exportation of meat. In 1882, the first successful shipment of sheep carcasses was sent from Port Chalmers in Dunedin, New Zealand to London. By the 1890s, the frozen meat trade became increasingly more profitable in New Zealand, especially in Canterbury, where 50% of exported sheep carcasses came from in 1900. It wasn't long before Canterbury meat was known for the highest quality, creating a demand for New Zealand meat around the world. In order to meet this new demand, the farmers improved their feed so sheep to be ready for the slaughter in only seven months. This new method of shipping lead to an economic boom in New Zealand by the mid 1890s.[35]

In the United States, the Meat Inspection Act of 1891 was put in place in the United States because local butchers felt the refrigerated railcar system was unwholesome.[36] When meat packing began to take off, consumers became nervous about the quality of the meat for consumption. The Jungle, a book written by Upton Sinclair, brought negative attention to the meat packing industry, by drawing to light unsanitary working conditions and processing of diseased animals. The book caught the attention of President Theodore Roosevelt, and the 1906 Meat Inspection Act was put into place as an amendment to the Meat Inspection Act of 1891. This new act focused on the quality of the meat and environment it is processed in.[37]

Electricity in rural areas

In the early 1930s, 90 percent of the urban population had electric power, in comparison to only 10 percent of rural homes. At the time, power companies did not feel that extending power to rural areas would produce enough profit to make it worth their while. However, in the midst of the Great Depression, President Franklin D. Roosevelt realized that rural areas would continue to lag behind urban areas in both poverty and production if they were not electrically wired. On May 11, 1935, the president signed an executive order called the Rural Electrification Administration, also known as REA. The agency provided loans to fund electric infrastructure in the rural areas. In just a few years, 300,000 people in rural areas of the United States had received power in their homes.

While electricity dramatically improved working conditions on farms, it also had a large impact on the safety of food production. Refrigeration systems were introduced to the farming process, which helped in food preservation and kept food supplies safe. Refrigeration also allowed for production of perishable commodities, which could then be shipped throughout the United States. As a result, the United States farmers quickly became the most productive in the world.[38]

Farm use

In order to reduce humidity levels and spoiling due to bacterial growth, refrigeration is used for meat, produce, and dairy processing in farming today. Refrigeration systems are used the heaviest in the warmer months for farming produce, which must be cooled as soon as possible in order to meet quality standards and increase the shelf life. Meanwhile, dairy farms refrigerate milk year round to avoid spoiling.[39]

Effects on lifestyle and diet

A trip to the market before refrigeration became widespread would have been different from a trip today. In the late 19th Century and into the very early 20th Century, other than staple foods (sugar, rice, and beans), your diet was affected heavily by the seasons and what could be grown relatively close to your region.[40] Today, thanks to refrigeration, we are no longer restricted by these limitations. Refrigeration played a large part in the feasibility and then popularity of the modern supermarket. If you are willing to pay slightly more for a fruit or vegetable that is out of season in your region, your local supermarket will most likely have what you are looking for. Refrigerators have led to a huge increase in meat and dairy as a portion of overall supermarket sales.[41] As well as changing the goods purchased at the market, the ability to store these foods for extended periods of time has led to an increase in leisure time. Prior to the advent of the household refrigerator, people would have to shop on a daily basis for the supplies needed for their meals.

Impact on nutrition

The introduction of refrigeration allowed for the hygienic handling and storage of perishables, and as such, promoted output growth, consumption, and nutrition. The change in our method of food preservation moved us away from salts to a more manageable sodium level. The ability to move and store perishables such as meat and dairy led to a 1.7% increase in dairy consumption and overall protein intake by 1.25% annually in the US after the 1890s.[42] People were not only consuming these perishables because it became easier for they themselves to store them, but because the innovations in refrigerated transportation and storage led to less spoilage and waste, and drove the prices of these products down. Refrigeration accounts for at least 5.1% of the increase in adult stature (in the US) through improved nutrition including the indirect effects associated with improvements in the quality of nutrients and the reduction in illness, the overall impact was considerably larger. Recent studies have also shown a negative relationship between the number of refrigerators in a household and the rate of gastric cancer mortality.[43]

Current applications of refrigeration

Probably the most widely used current applications of refrigeration are for air conditioning of private homes and public buildings, and refrigerating foodstuffs in homes, restaurants and large storage warehouses. The use of refrigerators in kitchens for storing fruits and vegetables has allowed adding fresh salads to the modern diet year round, and storing fish and meats safely for long periods. Optimum temperature range for perishable food storage is 3 to 5 °C (37 to 41 °F).[44]

In commerce and manufacturing, there are many uses for refrigeration. Refrigeration is used to liquify gases - oxygen, nitrogen, propane and methane, for example. In compressed air purification, it is used to condense water vapor from compressed air to reduce its moisture content. In oil refineries, chemical plants, and petrochemical plants, refrigeration is used to maintain certain processes at their needed low temperatures (for example, in alkylation of butenes and butane to produce a high octane gasoline component). Metal workers use refrigeration to temper steel and cutlery. In transporting temperature-sensitive foodstuffs and other materials by trucks, trains, airplanes and seagoing vessels, refrigeration is a necessity.

Dairy products are constantly in need of refrigeration, and it was only discovered in the past few decades that eggs needed to be refrigerated during shipment rather than waiting to be refrigerated after arrival at the grocery store. Meats, poultry and fish all must be kept in climate-controlled environments before being sold. Refrigeration also helps keep fruits and vegetables edible longer.

One of the most influential uses of refrigeration was in the development of the sushi/sashimi industry in Japan. Before the discovery of refrigeration, many sushi connoisseurs were at risk of contracting diseases. The

dangers of unrefrigerated sashimi were not brought to light for decades due to the lack of research and healthcare distribution across rural Japan. Around mid-century, the Zojirushi corporation, based in Kyoto, made breakthroughs in refrigerator designs, making refrigerators cheaper and more accessible for restaurant proprietors and the general public.

Methods of refrigeration

Methods of refrigeration can be classified as *non-cyclic*, *cyclic*, *thermoelectric* and *magnetic*.

Non-cyclic refrigeration

This refrigeration method cools a contained area by melting ice, or by sublimating dry ice.[45] Perhaps the simplest example of this is a portable cooler, where items are put in it, then ice is poured over the top. Regular ice can maintain temperatures near, but not below the freezing point, unless salt is used to cool the ice down further (as in a traditional ice-cream maker). Dry ice can reliably bring the temperature well below freezing.

Cyclic refrigeration

This consists of a refrigeration cycle, where heat is removed from a low-temperature space or source and rejected to a high-temperature sink with the help of external work, and its inverse, the thermodynamic power cycle. In the power cycle, heat is supplied from a high-temperature source to the engine, part of the heat being used to produce work and the rest being rejected to a low-temperature sink. This satisfies the second law of thermodynamics.

A *refrigeration cycle* describes the changes that take place in the refrigerant as it alternately absorbs and rejects heat as it circulates through a refrigerator. It is also applied to heating, ventilation, and air conditioning HVACR work, when describing the "process" of refrigerant flow through an HVACR unit, whether it is a packaged or split system.

Heat naturally flows from hot to cold. Work is applied to cool a living space or storage volume by pumping heat from a lower temperature heat source into a higher temperature heat sink. Insulation is used to reduce the work and energy needed to achieve and maintain a lower temperature in the cooled space. The operating principle of the refrigeration cycle was described mathematically by Sadi Carnot in 1824 as a heat engine.

The most common types of refrigeration systems use the reverse-Rankine vapor-compression refrigeration cycle, although absorption heat pumps are used in a minority of applications.

Cyclic refrigeration can be classified as:

1. Vapor cycle, and
2. Gas cycle

Vapor cycle refrigeration can further be classified as:

1. Vapor-compression refrigeration
2. Vapor-absorption refrigeration

Vapor-compression cycle

The vapor-compression cycle is used in most household refrigerators as well as in many large commercial and industrial refrigeration systems. Figure 1 provides a schematic diagram of the components of a typical vapor-compression refrigeration system.

The thermodynamics of the cycle can be analyzed on a diagram[46] as shown in Figure 2. In this cycle, a circulating refrigerant such as Freon enters the compressor as a vapor. From point 1 to point 2, the vapor is compressed at constant entropy and exits the compressor as a vapor at a higher temperature, but still below the vapor pressure at that temperature. From point 2 to point 3 and on to point 4, the vapor travels through the condenser which cools the vapor until it starts condensing, and then condenses the vapor into a liquid by removing additional heat at constant pressure and temperature. Between points 4 and 5, the liquid refrigerant goes through the expansion valve (also called a throttle valve) where its pressure abruptly decreases, causing flash evaporation and auto-refrigeration of, typically, less than half of the liquid.

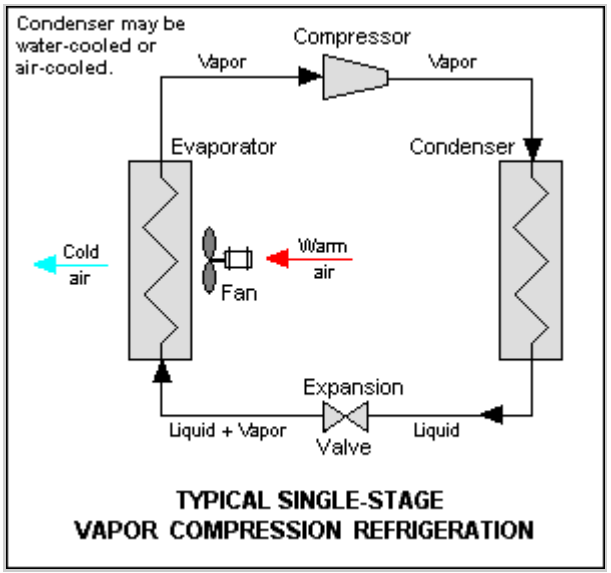

Figure 1: Vapor compression refrigeration

That results in a mixture of liquid and vapor at a lower temperature and pressure as shown at point 5. The cold liquid-vapor mixture then travels through the evaporator coil or tubes and is completely vaporized by cooling the warm air (from the space being refrigerated) being blown by a fan across the evaporator coil or tubes. The resulting refrigerant vapor returns to the compressor inlet at point 1 to complete the thermodynamic cycle.

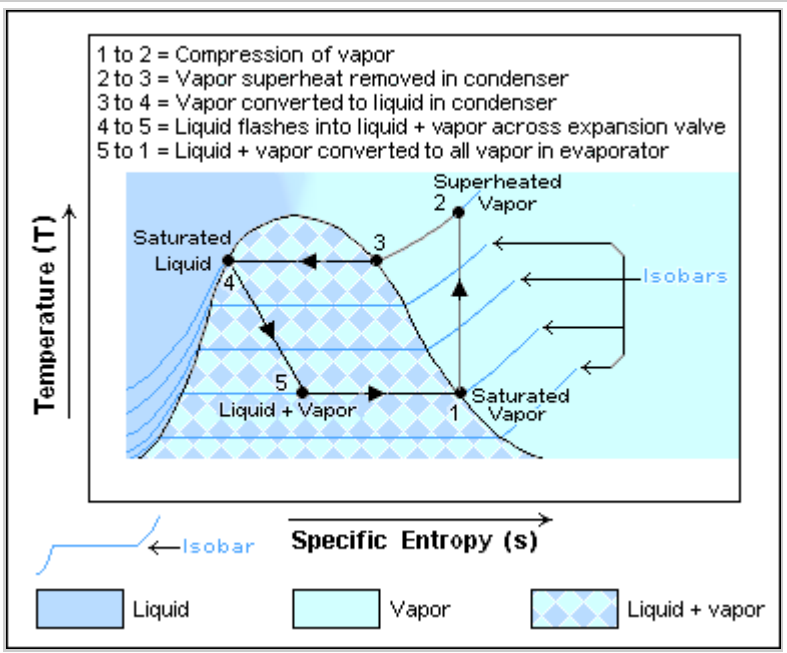

Figure 2: Temperature–Entropy diagram

The above discussion is based on the ideal vapor-compression refrigeration cycle, and does not take into account real-world effects like frictional pressure drop in the system, slight thermodynamic irreversibility during the compression of the refrigerant vapor, or non-ideal gas behavior, if any.

More information about the design and performance of vapor-compression refrigeration systems is available in the classic *Perry's Chemical Engineers' Handbook*.[47]

Vapor absorption cycle

In the early years of the twentieth century, the vapor absorption cycle using water-ammonia systems was popular and widely used. After the development of the vapor compression cycle, the vapor absorption cycle lost much of its importance because of its low coefficient of performance (about one fifth of that of the vapor

compression cycle). Today, the vapor absorption cycle is used mainly where fuel for heating is available but electricity is not, such as in recreational vehicles that carry LP gas. It is also used in industrial environments where plentiful waste heat overcomes its inefficiency.

The absorption cycle is similar to the compression cycle, except for the method of raising the pressure of the refrigerant vapor. In the absorption system, the compressor is replaced by an absorber which dissolves the refrigerant in a suitable liquid, a liquid pump which raises the pressure and a generator which, on heat addition, drives off the refrigerant vapor from the high-pressure liquid. Some work is needed by the liquid pump but, for a given quantity of refrigerant, it is much smaller than needed by the compressor in the vapor compression cycle. In an absorption refrigerator, a suitable combination of refrigerant and absorbent is used. The most common combinations are ammonia (refrigerant) with water (absorbent), and water (refrigerant) with lithium bromide (absorbent).

Gas cycle

When the working fluid is a gas that is compressed and expanded but doesn't change phase, the refrigeration cycle is called a *gas cycle*. Air is most often this working fluid. As there is no condensation and evaporation intended in a gas cycle, components corresponding to the condenser and evaporator in a vapor compression cycle are the hot and cold gas-to-gas heat exchangers in gas cycles.

The gas cycle is less efficient than the vapor compression cycle because the gas cycle works on the reverse Brayton cycle instead of the reverse Rankine cycle. As such the working fluid does not receive and reject heat at constant temperature. In the gas cycle, the refrigeration effect is equal to the product of the specific heat of the gas and the rise in temperature of the gas in the low temperature side. Therefore, for the same cooling load, a gas refrigeration cycle needs a large mass flow rate and is bulky.

Because of their lower efficiency and larger bulk, *air cycle* coolers are not often used nowadays in terrestrial cooling devices. However, the air cycle machine is very common on gas turbine-powered jet aircraft as cooling and ventilation units, because compressed air is readily available from the engines' compressor sections. Such units also serve the purpose of pressurizing the aircraft.

Thermoelectric refrigeration

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junction of two types of material. This effect is commonly used in camping and portable coolers and for cooling electronic components and small instruments.

Magnetic refrigeration

Magnetic refrigeration, or adiabatic demagnetization, is a cooling technology based on the magnetocaloric effect, an intrinsic property of magnetic solids. The refrigerant is often a paramagnetic salt, such as cerium magnesium nitrate. The active magnetic dipoles in this case are those of the electron shells of the paramagnetic atoms.

A strong magnetic field is applied to the refrigerant, forcing its various magnetic dipoles to align and putting these degrees of freedom of the refrigerant into a state of lowered entropy. A heat sink then absorbs the heat released by the refrigerant due to its loss of entropy. Thermal contact with the heat sink is then broken so that the system is insulated, and the magnetic field is switched off. This increases the heat capacity of the refrigerant, thus decreasing its temperature below the temperature of the heat sink.

Because few materials exhibit the needed properties at room temperature, applications have so far been limited to cryogenics and research.

Other methods

Other methods of refrigeration include the air cycle machine used in aircraft; the vortex tube used for spot cooling, when compressed air is available; and thermoacoustic refrigeration using sound waves in a pressurized gas to drive heat transfer and heat exchange; steam jet cooling popular in the early 1930s for air conditioning large buildings; thermoelastic cooling using a smart metal alloy stretching and relaxing. Many Stirling cycle heat engines can be run backwards to act as a refrigerator, and therefore these engines have a niche use in cryogenics. In addition there are other types of cryocoolers such as Gifford-McMahon coolers, Joule-Thomson coolers, pulse-tube refrigerators and, for temperatures between 2 mK and 500 mK, dilution refrigerators.

Fridge Gate

The Fridge Gate method is a theoretical application of using a single logic gate to drive a refrigerator in the most energy efficient way possible without violating the laws of thermodynamics. It operates on the fact that there are two energy states in which a particle can exist: the ground state and the excited state. The excited state carries a little more energy than the ground state, small enough so that the transition occurs with high probability. There are three components or particle types associated with the fridge gate. The first is on the interior of the fridge, the second on the outside and the third is connected to a power supply which heats up every so often that it can reach the E state and replenish the source. In the cooling step on the inside of the fridge, the g state particle absorbs energy from ambient particles, cooling them, and itself jumping to the e state. In the second step, on the outside of the fridge where the particles are also at an e state, the particle falls to the g state, releasing energy and heating the outside particles. In the third and final step, the power supply moves a particle at the e state, and when it falls to the g state it induces an energy-neutral swap where the interior e particle is replaced by a new g particle, restarting the cycle.[48]

Capacity ratings

The measured capacity of refrigeration is always dimensioned in units of power. Domestic and commercial refrigerators may be rated in kJ/s, or Btu/h of cooling. For commercial and industrial refrigeration systems, most of the world uses the **kilowatt** (kW) as the basic unit of refrigeration. Typically, commercial and industrial refrigeration systems in North America are rated in **tons of refrigeration** (TR). Historically, one TR was defined as the energy removal rate that will freeze one short ton of water at 0 °C (32 °F) in one day. This was very important because many early refrigeration systems were in ice houses. The simple unit allowed owners of these early refrigeration systems to measure a day's output of ice against energy consumption, and to compare their plant to one down the street. While ice houses make up a much smaller part of the refrigeration industry than they once did, the unit TR has remained in North America. The unit's value as historically defined was approximately 11,958 Btu/hr (3.505 kW), and has now been conventionally redefined as exactly 12,000 Btu/hr (3.517 kW).

A refrigeration system's **coefficient of performance** (CoP) is very important in determining a system's overall efficiency. It is defined as refrigeration capacity in kW divided by the energy input in kW. While CoP is a very simple measure of performance, it is typically not used for industrial refrigeration in North America. Owners and manufacturers of these systems typically use **performance factor** (PF). A system's PF is defined as a system's energy input in horsepower divided by its refrigeration capacity in TR. Both CoP and PF can be applied to either the entire system or to system components. For example, an individual compressor can be

rated by comparing the energy needed to run the compressor versus the expected refrigeration capacity based on inlet volume flow rate. It is important to note that both CoP and PF for a refrigeration system are only defined at specific operating conditions, including temperatures and thermal loads. Moving away from the specified operating conditions can dramatically change a system's performance.

See also

- Air conditioning
- Auto-defrost
- Beef ring
- Carnot heat engine
- Cold chain
- Coolgardie safe
- Cryocooler
- Darcy friction factor formulae
- Einstein refrigerator
- Freezer
- Heat pump
- Heat pump and refrigeration cycle
- HVAC
- Icebox
- Icyball
- Laser cooling
- Pot-in-pot refrigerator
- Pumpable ice technology
- Quantum refrigerators
- Redundant refrigeration system
- Reefer ship
- Refrigerant
- Refrigerated container
- Refrigerator
- Refrigerator car
- Refrigerator truck
- Seasonal energy efficiency ratio (SEER)
- Steam jet cooling
- Thermoacoustics
- Vapor-compression refrigeration

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External links

- Green Cooling Initiative on alternative natural refrigerants cooling technologies (http://www.green-cooling-initiative.org/)

- "The Refrigeration Cycle", from HowStuffWorks (http://home.howstuffworks.com/refrigerator4.htm)
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (http://www.ashrae.org/)
- International Institute of Refrigeration (IIR) (http://www.iifiir.org/)
- British Institute of Refrigeration (http://www.ior.org.uk/)
- Scroll down to "Continuous-Cycle Absorption System" (http://www.nh3tech.org/absorption.html)
- US Department of Energy: Technology Basics of Absorption Cycles (http://www.eere.energy.gov/de/thermally_activated/tech_basics.html)

Wikiversity has learning materials about ***Underground refrigerated storage room***

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July/August 1994 Backwoods Home Magazine

Here's a low-cost, low-tech refrigerator that really works

By J.D. Hooker

A friend was recently preparing to shell out well over $1000 for a kerosene-fired refrigerator. While these are useful and valuable devices in many circumstances, I didn't think he needed one.

He had a 4-inch, 200 foot deep well to supply the water needs for his household and livestock. After he examined my water-cooled refrigerator closely, he built himself a duplicate the same weekend.

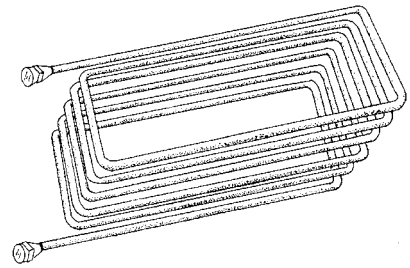

Fashion cooling coils from copper or plastic water line. Even garden hose would work.

For inhabitants of many rural areas, a similar owner-built unit can offer the same cost savings and reliability they do for our households. There are no moving parts, no chemicals like freon, almost no maintenance, no operating cost, nothing to wear out, and they can be put together from salvage material in only a few hours.

Cold well water needed

The only real requirement is a deep well water supply, with a steady water temperature between 35° and 50° F.

In most of the country, deep wells have become a necessity for those outside the public water supply lines, due to lowering water tables, ground water pollution in shallow wells, and similar circumstances.

Check your water temperature by allowing the water to run for several minutes, emptying the lines and tank. Then fill a bucket with fresh water and insert a thermometer. If your water temperature is above 50°, you are probably one of the people who should look into a kerosene or LP gas refrigerator, or stick with electric.

It's simple

Really, the whole idea is extremely simple. At the point where the water supply enters your dwelling, the incoming cold water is routed through a coil of pipe or hose installed inside an insulated box before it goes anywhere else. Whenever water is used for dish washing, laundry, showering, flushing the toilet or whatever, fresh cold water circulates through this coil and cools the interior of the insulated box.

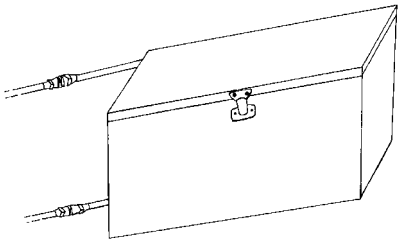

Install the cooling coil in an insulated box and hook it up to household plumbing. An old, worn-out chest-style freezer is ideal, but any sort of insulated box will work.

Construction

Any sort of well-insulated box will serve. Depending on your tastes, abilities, and what is available, you might opt for anything from an ultra-fancy oak and brass ice-box replica to something rigged together from plywood and sheet metal scraps.

For me, the best solution was to use a worn out chest freezer. I knew my

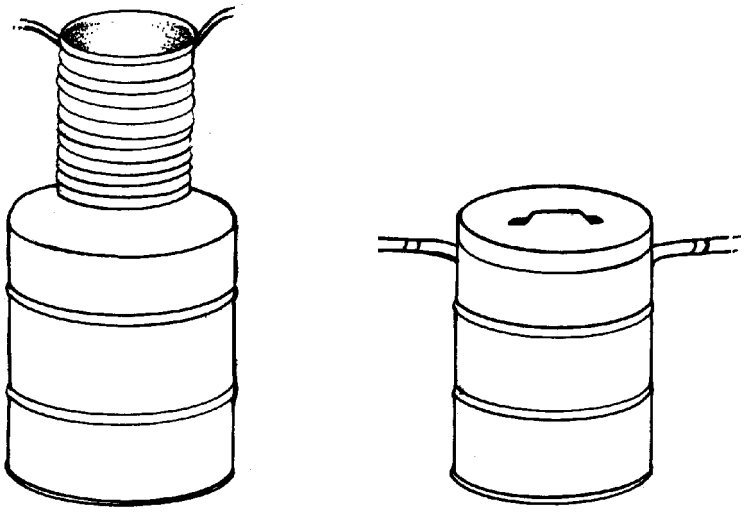

For a smaller cold storage space, wrap a 30-gallon drum with garden hose and insert it into a 55-gallon drum. Fill the space with insulation or very dry sawdust. Make a lid from styrofoam or other insulating material.

wife would never go along with this project if I didn't end up with something that looked like a normal and attractive household appliance. The chest type is superior to upright freezers because all your cool air won't spill out when you open the door.

The very first thing I did was cut off the power cord. The next step was to repaint the unit with appliance enamel. Then I cut a hole in the bottom and installed a PVC sink drain in case of spills or condensation.

Using a conduit bender, I then formed ½" soft copper tubing to match the interior dimensions of the compartment. Hard copper and sweat-on fittings—or even plastic pipe—would probably work just as well. I already had the soft copper tubing, so I used it.

After putting the unit in place, hooking it into the water line, and checking for leaks, we had to wait almost two days for the inside temperature to drop to 42°. Since then it has held that same reading for almost five years.

Cold water refrigeration is not a new concept. Nor is it adaptable to each and every situation. If, however, you are already drawing your water supply from a deep well with a fairly constant water temperature, why would you want to keep throwing your hard earned money away for electricity, kerosene, or any other fuel when you can refrigerate for free? Δ

The care of lead acid batteries

By Larry Elliott

Storage batteries are used in just about every independent energy system. The lead acid storage battery is a familiar sight in your car. Usually these batteries give years of trouble-free service and the average driver rarely has to be concerned about the chemistry of the battery, cycle life, or charge/discharge rates. The lead acid batteries used in an independent energy system are another story. If there is one item that is least understood or abused in these systems, it's the battery. If you follow the list of do's and don'ts outlined below, living with the storage battery will be a lot easier and less costly.

Rule 1. This comes as a shock to most people, but a 12-volt lead acid battery is almost dead when the voltage at rest (no loads or discharge) is 12 volts. Less than 25% of the battery's capacity remains. The voltage of a 12-volt lead acid battery will vary between 11.6 and 12.6 volts discharged and fully charged. This one volt range can be used as an approximate indicator of the state of charge and illustrates the need for an accurate digital voltmeter.

Rule 2. In order to obtain long life from your batteries they should be discharged to no more than 50% of capacity. This is not easy to accomplish, especially in a solar electric system in winter. A backup generator or, if you have the wind, a wind generator, can make this a lot easier to do reliably. Hydroelectric systems don't usually have this problem.

Rule 3. Don't use car batteries in an independent system. They are not made to be deep-cycled and will have an early death when used in this way. A good golf cart or forklift battery like the Trojan L-16 is a much better choice.

Rule 4. Never let a lead acid battery sit in a discharged state. Recharge as soon as possible. Every time you let them set for any length of time (even a few days) you will begin to accumulate lead sulfate on the plates that reduces their capacity.

Rule 5. If you live in a cold climate, be sure and provide insulation or a warm area for your batteries. The useful capacity and the batteries' ability to deliver power are greatly reduced in cold temperatures. Your batteries can also freeze when in a discharged state, so keep them warm.

Rule 6. Never draw large amounts of current from your batteries when in a discharged state. Damage to the plates can occur.

Rule 7. Batteries should have an "equalize charge" at least every other month or sometimes once a month depending on how severe the service. An equalize charge is a form of controlled overcharge that helps to place all the cells at an equal voltage. Large currents are needed to equalize, so once again you can see the need for a backup generator. An ideal method of equalization is to purchase an inverter with a built-in battery charger and an equalize function.

Rule 8. Never attempt to adjust the electrolyte level in the battery. Raising or lowering the specific gravity not only voids the warranty, but can ruin the batteries or pose an unhealthy risk of acid burns. Adding distilled water when needed should be as far as you go.

Rule 9. Always keep battery terminals and the tops of the batteries clean and free of corrosion. The batteries can self discharge rapidly, and badly corroded terminals can cause electrical problems, especially when drawing a lot of current.

Rule 10. Do some follow-up study on charge and discharge rates for your batteries. Consult a reputable battery dealer or the supplier/designer of your system as to the best way to treat your batteries. Nothing can kill a good set of batteries faster than improper charging and discharging. Δ

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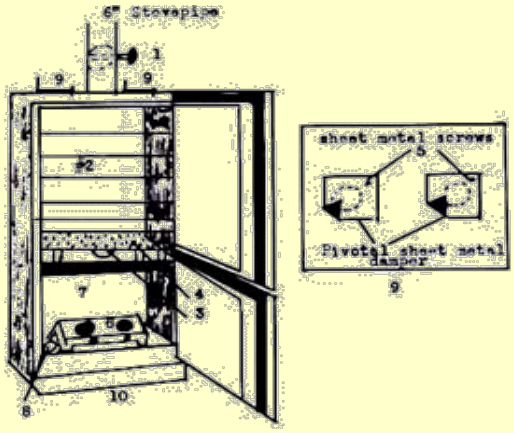

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1. Damper control
2. Shelves or racks
3. Smoke inlet hole
4. Metal baffle supported at 3” to 4” above smoking inlet perforated with many holes
5. Sheet-metal screws
6. Heat source:
   - Electric hot plate
   - Hibachi
   - Butane gas burner
7. Old frozen food compartment, or refrigeration unit space
8. 2 or 3 — 2” or 4” holes for draft
9. Alternate draft control
10. If refrigerator has no lower compartment, heat source may be placed right in the refrigerator, but preferably raise the refrigerator and build a lower compartment for the heat source.

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A good smoke oven can be made from an old refrigerator. It is well insulated and so will hold heat, save fuel, and finish off food more quickly, for example, than the shed-type smoke house. The refrigerator already has a number of removable metal racks. It has a full-length door that is convenient for loading and unloading. Here are some hints for conversion.

It is best to keep the smoke-making equipment outside the storage compartment. This permits maximum use of the inside capacity for the meat or fish being smoked. Cut a hole about 8" diameter in the floor; one inch above it, mount a horizontal metal plate as a baffle, to dissipate the smoke.

If the refrigerator is of the type that has the machinery underneath the storage compartment, remove the motor and compressor. Utilize this space for making smoke with a hotplate and a pan of hardwood chips. If the bottom section is a removable vegetable bin, do the same. Or, for maximum capacity, raise the refrigerator on four concrete blocks, cut a hole in the bottom, and set the smoke apparatus outside. Build an enclosure of plywood, metal or concrete blocks around the smoke source, so that the smoke cannot drift aside, but is forced into the refrigerator.

In the top of the refrigerator cut one 3" or two 2" holes. Arrange something—pivoted metal flaps, bricks, etc.—to control the aperture of these vents. Alternatively, fit a two-foot length of stovepipe with a butterfly damper

Operating Notes:

To avoid cutting large holes, removing compressors, or making other major alterations, the hotplate and pan of chips may be placed in the main storage compartment.

It is well to bear in mind that a refrigerator is *not* designed to withstand heat! The author once converted a 'fridge by cutting a hole in the bottom, then lit a fire of charcoal briquettes underneath, using green boughs to make smoke. Around the edge of the hole, the insulation was exposed. All at once, the refrigerator caught fire and the insulation burned up! Several similar incidents have been reported. So, for safety's sake, use no other heat source than a hot plate inside a 'fridge. With an outside heat source, do not let flames come near the insulation. Whatever smoke generating system is used, beware of excessive heat.

To use the cold-smoke process, dig a fire pit as described for the box-smoker, and lead the smoke into the refrigerator from a distance.

From - *Home book of Smoke-Cooking Meat, Fish & Game*
By Jack Sleight & Raymond Hull

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GENEVA December 1982

Using the handbook

Chapters may be located quickly using the key opposite. Each chapter starts with an annotated list of contents. In chapters 5-11 this is followed by an overview page setting out key considerations. Sections within these chapters and chapter 12 start with summaries. Points worthy of special attention are underlined throughout the text. Cross-references are by chapter, section and paragraph, e.g. "see ch.9.5.3."

For convenience, "Representative" is used to refer to the High Commissioner's representative in the country where the emergency occurs, regardless of the representative's official title. "Headquarters" refers to UNHCR Headquarters in Geneva. As is explained on page 1, "refugee" is used to describe any person of concern to UNHCR. "Statute" and "statutory" refer to the Statute of the High Commissioner's office (General Assembly resolution 428 (v) of 14 December 1950). "Operational partner" is used for convenience to describe an organization implementing all or part of the UNHCR emergency programme, without distinction as to funding. (The phrase more correctly describes an organization contributing its own resources to the programme; an organization wholly funded by UNHCR is termed an "implementing agency".)

Part One of the handbook may be freely reproduced and adapted, with acknowledgement to UNHCR. It is also available in French and will be produced in Spanish; UNHCR would be grateful for copies of any translations into other languages.

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NATIONS UNIES
LE HAUT COMMISSAIRE
POUR LES RÉFUGIÉS

UNITED NATIONS
THE HIGH COMMISSIONER
FOR REFUGEES

Palais des Nations
CH-1211 Genève 10
Suisse

December 1982

FOREWORD TO THE FIRST EDITION

This first edition of the Handbook for Emergencies is intended to provide guidance on the management of refugee emergencies. It is the result of a considerable process of consultation, review and improvement. It replaces the provisional version issued in 1981 on which comments were invited. Although the Handbook will be subject to modification and change in the light of future experience, I believe that as it now stands it provides a common basis for action for all those, both inside and outside UNHCR, involved in the management of refugee emergencies.

Poul Hartling

INTRODUCTION

The handbook is in two parts. This, the first part, is a guide to setting up emergency operations for large-scale influxes of refugees. The second part deals specifically with the internal UNHCR dimension of decision-making and organization in emergencies. The first is available to all those who work with refugees; the second part is for staff members of UNHCR.

The handbook was first produced as a single volume in a provisional version in September 1981. Comments were invited from reviewers and UNHCR staff members. Clearly the most tangible of the many suggestions that have been incorporated is the change in size: the provisional edition in its bulky binder is replaced by two smaller more compact volumes.

In addition to UNHCR, many international and national organizations have important roles, while governments of asylum have, of course, a special and unique responsibility. Although addressed primarily to UNHCR staff, the first part of the handbook seeks to offer a basis for common action for all those involved. The need and responsibility for the action suggested in the different chapters will, however, vary greatly in each emergency. Unless this qualification is borne in mind, a reader may get the false impression that the necessary action is always the responsibility of UNHCR.

This first edition reflects the growing attention both within UNHCR and outside to improving the management of refugee emergencies. These sudden and sometimes large-scale threats to life call for an organized systematic response. At all levels, from the solution to a technical problem in the settlement itself up to that of co-ordination between a government and participating international and voluntary agencies, there are lessons from past emergencies which should inform the management of new ones.

Drawing on this accumulated experience, the handbook is a manager's guide. Principles of response and possible solutions are proposed. However it makes no pretence to have all the answers. Each emergency poses its own set of problems. Those interested should look at some of the growing number of actual case studies of emergencies: both UNHCR evaluation reports, which are limited to internal circulation, and published articles.[1/] Although not itself including case studies, the handbook has set out to distil these experiences into useful principles.

Better informed management is not however a substitute for professional expertise. Indeed a major theme of the handbook is how to select the right expert advice. Nor does the handbook replace initiative, commitment and the other personal qualities which have enabled managers in the field and at Headquarters to put together successful emergency programmes in the past. But a UNHCR officer who confronts an emergency can now employ the handbook, and as a consequence will be much less likely to repeat the mistakes of the past. Those who suffer most from management errors are of course those whose voice is usually least clearly heard in the confusion of an emergency, the refugees themselves.

During the drafting of the handbook it sometimes seemed that there should be a third part in addition to the present two parts.

1/ See, for example, Disasters, the journal of the International Disaster Institute, which often contains articles on refugee emergencies, and Ross Institute (1982) Publication No. 14: Refugee Camp Health Care: Selected Annotated References.

This last part would be a "Refugees' Handbook" and would suggest to them ways of coping with relief and the relief worker. In the last few years much thought has been given to developing services and infrastructure for refugee settlements that are simple enough to work yet capable of meeting the needs of large numbers of people concentrated together. Interest has too often not gone beyond this essentially technical puzzle to the next step: how the refugees might overcome the strangeness of their crowded new environment and actively participate in its evolution. Too often the refugee remains daunted, a passive recipient of a relief whose system he or she does not understand.

Indeed improvements in the techniques of relief alone that are not matched by an increased refugee involvement can be self-defeating. It is increasingly clear that a refugee's first reception in the country of asylum can critically determine his or her ability to become self-sufficient.2/ Ill-considered assistance at the start, however efficiently delivered, can create a dependency syndrome which may last for years. A first rush of inappropriate and unfamiliar relief goods can stifle the potential enterprise of the refugees and increase their sense of alienation. The cowed and silent refugee squatting on inhospitable terrain awaiting a relief handout has become an image of our times. Relief can impose its own imprisonment.

Within the limits of the host government's laws, refugees must be persuaded to take responsibility for their own welfare; inputs of outside assistance must be a sensitive response to needs that the refugees genuinely cannot meet on their own.

The refugees are often most able to help themselves, and thus be least reliant on outside assistance, if they are not grouped together in highly organized camps. Programme planners must overcome their instinct to endorse camps because they are convenient for the efficient delivery of outside emergency assistance. That early convenience too often becomes a long-term burden for refugee, host government and donor alike. Small, less formal groupings of refugees, provided their protection, access to land and related economic rights are assured, often enjoy much better prospects of self sufficiency than large highly planned but artificial settlements.

Nevertheless refugee settlements of the camp type seem to be here to stay. The various pressures of mass influx on countries of asylum and the occasional need to group refugees together for their own protection make it probable that these unsatisfactory and artificial institutions will survive. This handbook seeks to make even these institutions as "un-camplike" as possible and ensure that with active refugee participation they achieve an appropriateness in terms of services and infrastructure that neither sets them too far apart from local communities around them nor puts them in so close a dependence on international assistance that they can never escape it.

Acknowledgements

Very many individuals and organizations have helped UNHCR in the preparation of the handbook, not only directly but also indirectly through their work with UNHCR in recent emergencies. This help is most gratefully acknowledged. Particular mention should

2/ See, for example, Robert Chambers "Rural Refugees in Africa: Past Experience, Future Pointers", Disasters, Vol.6, No.1, 1982.

be made of the assistance received from the Centers for Disease Control (USA), The International Committee of the Red Cross, The International Disaster Institute, Intertect, The League of Red Cross Societies, Oxfam, The Oxford Polytechnic Disasters and Settlements Unit, The Refugee Health Unit of the Ministry of Health, Somalia, The Register of Engineers for Disaster Relief (UK), The Ross Institute of the London School of Hygiene and Tropical Medicine, UNDRO, UNICEF, WHO and WFP. Mr Ludovic van Essche of UNDRO kindly prepared the graphics. The handbook has also drawn on many of the publications listed as "further references" at the end of chapters.

The handbook will be revised periodically; important changes will, of course, be communicated to UNHCR staff without delay. Responsibility for errors rests with UNHCR. Readers are requested to bring these, and suggestions for improvements, to the attention of:

The Emergency Unit,
UNHCR, Palais des Nations,
CH 1211 Geneva 10,
Switzerland.

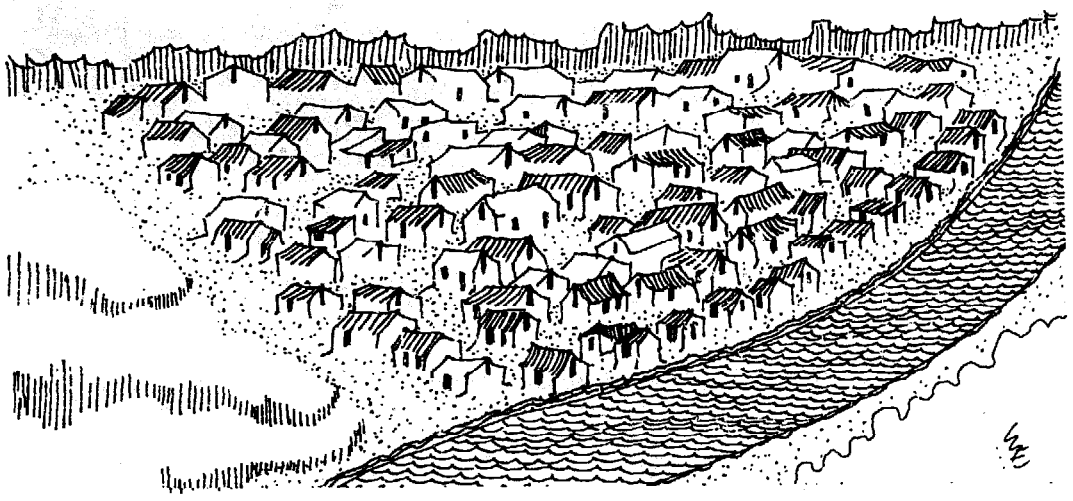

ABBREVIATIONS

FAO	Food and Agriculture Organization of the United Nations
ICM	Inter-Governmental Committee for Migration
ICRC	International Committee of the Red Cross
ILO	International Labour Organization
LRCS	League of Red Cross Societies
NGO	Non-governmental organization (voluntary agency)
OAU	Organization of African Unity
PAHO	Pan American Health Organization
UNDP	United Nations Development Programme
UNDRO	Office of the United Nations Disaster Relief Co-ordinator
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
UNIPAC	UNICEF Packing and Assembly Centre, Copenhagen
WFP	World Food Programme
WHO	World Health Organization

CHAPTER 1: AIM AND PRINCIPLES

1

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1.1 Definition and aim

1. The majority of UNHCR's programmes begin as a result of an emergency: a sudden influx of refugees 1/. The organization and procedures of UNHCR reflect this; much of UNHCR's normal work is in effect an emergency response. There are, however, situations that are clearly exceptional. This handbook addresses the needs of such situations.

2. The distinction is one of degree: a theoretical definition for the purposes of this handbook might be that an emergency is any situation in which the life or well-being of refugees will be threatened unless immediate and appropriate action is taken, and which demands an extraordinary response and exceptional measures. It should be noted that an emergency can develop in an existing programme.

3. What is important is less a definition than the ability to recognize in time the development of situations in which an extraordinary response will be required of UNHCR in order to safeguard the life or well-being of refugees.

4. Much of the handbook is concerned with guidelines on the material assistance likely to be needed when large numbers of refugees, often of rural origin, cross frontiers to seek asylum. Such emergencies are, of course, not the only situations which demand an extraordinary response of UNHCR. Equally swift action and intervention will be required in emergencies that concern protection, for example when events suddenly place in danger refugees who had previously enjoyed asylum in safety. However, action in these emergencies will depend to such a large extent on the specific circumstances that too detailed guidelines are unlikely to be useful.

5. The aim of UNHCR's emergency response is to provide protection to persons of concern to UNHCR and ensure that the necessary assistance reaches them in time.

1.2 Responsibilities

Governments and UNHCR

1. Governments are responsible for the security and safety of, assistance to and law and order among, refugees on their territory. UNHCR provides material assistance to refugees at the request of governments. The statutory function of providing international protection to refugees and seeking permanent solutions for their problems is, however, always UNHCR's responsibility.

2. Whatever the organizational manner in which UNHCR provides emergency assistance in response to a government request, UNHCR is responsible for ensuring that the immediate needs of the refugees are met in an effective and appropriate manner. However responsibilities for practical implementation are allocated, all those involved, both inside and outside the UN system, should have clearly defined responsibilities within a single overall programme, whether the aid is provided through multilateral or bilateral channels. Only thus will duplication of effort and gaps be avoided.

UN organizations

3. Responsibility for co-ordinating the response of the UN system to a refugee emergency normally rests with UNHCR. In certain cases special arrangements may be made by the Secretary-General.

1/ For convenience, "refugee" is used in this handbook to refer to all persons of concern to UNHCR. The different categories are described in chapter 2.2.

4. The material needs of refugees are likely to cover sectors for which other organizations in the UN system have special competence, as, for example, FAO, WFP, WHO and UNICEF in the food, health and water supply sectors. UNHCR will seek assistance and expertise from such organizations and from UNDP as appropriate, and the implementing arrangements agreed with the government may give specific responsibilities to other UN organizations.

5. There is a clear distinction between UNHCR's responsibilities and those of the Office of the United Nations Disaster Relief Co-ordinator, the focal point in the UN system for disaster relief matters. UNDRO is, inter alia, responsible for the co-ordination of relief assistance to persons compelled to leave their homes as a result of, or as a precautionary measure against, the effects of natural and other disasters such as earthquakes, volcanic eruptions, droughts, floods, storms, and epidemics and also aviation, maritime, industrial or nuclear radiation accidents. Where victims of such disasters include refugees, UNHCR is responsible for helping to provide the refugees with the necessary assistance in close co-ordination with UNDRO.

6. In exceptional or complex disasters which do not fall solely within the mandate of any single organization, for example one with both natural and man-made origins, causing both internal and external population displacements, special arrangements will be made by the Secretary-General to designate a lead entity with overall responsibility for co-ordinating the response of the UN system.

Other organizations

7. The International Committee of the Red Cross (ICRC), the League of Red Cross Societies (LRCS) and the national Red Cross and Red Crescent societies have long provided assistance to refugees in emergencies. So have a great many non-governmental organizations (NGOs). These organizations often act as UNHCR's operational partners, in which case the division of responsibilities is determined by the implementing arrangements agreed between them, the government and UNHCR. Similar arrangements would set out the responsibilities of any intergovernmental or other governmental organizations involved.

The refugees

8. Beyond the right to international protection under the Statute of UNHCR and under the 1951 Refugee Convention and 1967 Protocol, if applicable, all refugees - as indeed all persons - have certain basic human rights. These are enshrined in the Charter of the United Nations and in the Universal Declaration of Human Rights: the fundamental right to life, liberty and security of person; the protection of the law; freedom of thought, conscience and religion; and the right to own property. Refugees have the right to freedom of movement, although it is recognized that, particularly in cases of mass influx, security considerations and the rights of the local population may dictate restrictions. Chapter 2, Protection, describes in more detail the rights of refugees in humanitarian law.

9. Refugees and displaced persons also have, of course, responsibilities towards the country where they have sought refuge. These are set out in Article 2 of the Convention: "Every refugee has duties to the country in which he finds himself, which require in particular that he conform to its laws and regulations as well as to measures taken for the maintenance of public order."

1.3 Principles of response

1. Whatever the framework of responsibility for a particular refugee emergency, certain prin-

ciples of response are likely to be valid. Some of these are common themes in the chapters that follow, where they are discussed in more detail.

2. By definition, the needs of a refugee emergency must be given priority over other work of UNHCR. This is essential if the aim of ensuring protection and timely assistance is to be met. Of particular importance is the priority given to deploying enough UNHCR staff of the right calibre and experience to the right places and arming them with the authority, funds, material and logistical support needed. Leadership and flexibility are required of UNHCR in an emergency.

The measures must be appropriate

3. An appropriate response in the provision of material assistance requires an assessment of the needs of the refugees that takes into account not only their material state and the resources available, but also their culture and background and those of the nationals in whose country they are granted asylum. What is appropriate will vary with time: in the early stages of a major emergency special measures that rely heavily on outside assistance may be necessary but, as a general principle, the response should draw to the extent possible on local resources, materials and methods, and should, for example, avoid regimented refugee camps. Solutions should be sought that can be readily implemented with existing resources and simple technologies.

4. It is an important responsibility of UNHCR to determine with the government and operational partner(s) the standards of assistance that are appropriate. This requires expertise in a number of disciplines. The guidelines in chapters 6 to 11 suggest general considerations, to be modified in light of the circumstances of each emergency. What is to be decided for each sector is the correct level of total assistance from all sources.

5. As a general principle, the standards of assistance must reflect the special needs of the refugees as a result of their condition, physical situation and experiences, while at the same time taking account of the standards enjoyed by the local population.

6. If the standards have been correctly determined, they cannot later be lowered without risk to the refugees. The refugees must, for example, receive a minimum basic food ration. The outside contribution required to meet the standards will, however, naturally be reduced as the refugees become self-sufficient.

7. A final general principle in considering the appropriateness of the measures is that from the start resources must be divided between the immediate needs and action aimed at longer-term improvements and the prevention of problems. For example, resources must be devoted to general public health measures as well as to the treatment of individual diseases, which will include many that could be prevented by better water and sanitation.

Involve the refugees and promote their self-sufficiency

8. Inherent in the foregoing is the need to involve the refugees in the measures taken to meet their needs and to plan all components of the operation in such a way as to promote their self-sufficiency. Obvious as this principle is, the pressures of an emergency often make it easier to organize a programme from the outside for, rather than with, those whom it is to benefit.

9. There are three levels to the involvement of refugees. The first is in the overall planning and organization, for example the determination of what is the best

and culturally most appropriate solution to a problem, given the constraints of the situation. This level requires that the refugees have a social organization within their community that is properly representative. As the previous social structures may have been severely disrupted, this may take time to develop but will be important to the success of the emergency operation and the future of the refugees. Meanwhile, urgent action to meet evident needs must of course be taken.

10. The second level of involvement is in the practical use of the refugees' skills and resources wherever possible for the implementation of the programme. Where suitably qualified or experienced refugees exist, such as nurses, teachers and traditional health workers, they must obviously be used. Where they do not, outside assistance should ensure that refugees are trained to take over from those who are temporarily filling the gap. The appropriateness of this is evident: the refugees themselves should run their own community services to the extent possible.

11. At the same time, other traditional skills - for example in construction or well-digging - should be harnessed. While specific measures to develop self-sufficiency will vary with each situation, their aim should always be to avoid or reduce the refugees' dependence on outside assistance. The more successful measures are generally those based on methods and practices familiar to the refugees.

12. The third level is the education of the community on life in their new situation, which may be markedly different from their previous experience. Public health education in such matters as the importance of hygiene in crowded conditions, mother and child care and the use of unfamiliar latrines is an example. As another example, if unfamiliar foods or preparation methods have to be used, immediate practical instruction is essential. Education and guidance of this sort are best given by the refugees, with outside assistance.

13. If the emergency operation involves the refugees in this way from the start, its effectiveness will be greatly enhanced. Furthermore, such an approach will allow the refugees to maintain their sense of dignity and purpose, encourage self-reliance and help to avoid dependency.

Work for durable solutions

14. When an emergency occurs, actions taken at the very outset can have important longer-term consequences. To secure protection may be of crucial importance; intervention may be necessary to save lives, and a clear and consistent policy from the beginning will have an important long-term effect. Similarly, the immediate response of the international community to a major influx of refugees must take into account the ultimate aim of promoting a durable solution to the problem. This requires that the response both encourages the self-sufficiency of the refugees and avoids prolonged dependency on outside relief, and that it does nothing to prevent the promotion of a long-term solution as soon as possible.

15. As a general principle, the best solution is always voluntary repatriation. Where this is not possible, assimilation within the country of asylum (local settlement) is in most circumstances preferable to assimilation within another country (resettlement), particularly for large groups and in cases where resettlement would take place in a cultural environment alien to the refugees. There may, however, be situations in which resettlement is the only way to ensure protection. It is evident that resettlement is a solution that in some circumstances may effectively foreclose the possibility of voluntary repatriation.

Monitor the effectiveness of the response

16. Whatever the nature of the emergency, the action required of UNHCR is likely to vary with time and as circumstances change. It is essential that the effectiveness of the response is kept constantly under review and action adjusted as necessary and in time. This will require sound monitoring and reporting systems, to detect deterioration or change, and also a continuous review of the aims of UNHCR's assistance, both in terms of bringing the emergency to an early end and for the promotion of a durable solution.

17. Such monitoring must also ensure that the funds provided voluntarily to UNHCR by governments, NGOs and private individuals are being used to the best advantage. This is inherent in the principle of appropriate response. It should be borne in mind that whatever funds may be available in the early stages of an acute humanitarian emergency, the passage of time will produce financial constraints. Thus it is important that potential donors can see that the action proposed is indeed essential.

CHAPTER 2: PROTECTION

2

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2.1 Introduction

1. In an emergency it must first be established that the persons involved are of concern to UNHCR and thus entitled to protection. The legal basis for securing this protection and its aim must be clearly understood. This chapter addresses these questions.

2. All UNHCR staff must be familiar with the key international instruments covering the protection of refugees. Of fundamental importance are the "Statute of the Office of the United Nations High Commissioner for Refugees" (General Assembly resolution 428 (V) of 14 December 1950), which sets out the High Commissioner's functions and responsibilities towards those who fall within its scope, the two universal international instruments that set out the responsibilities of States parties to them: the "1951 Convention Relating to the Status of Refugees" and the "Protocol Relating to the Status of Refugees of 31 January 1967", and on the regional level, the Organization of African Unity "Convention Governing the Specific Aspects of Refugee Problems in Africa" of 10 September 1969. The Collection of International Instruments Concerning Refugees (UNHCR, Geneva 1979), the Handbook for Determining Refugee Status (UNHCR, Geneva 1979) and the collection of Conclusions on the International protection of Refugees adopted by the Executive Committee of the UNHCR Programme are essential complementary reading.

3. The High Commissioner's protection responsibilities have been placed on him by the General Assembly. Thus the international protection activities of UNHCR are not dependant upon a request by the government concerned. These activities reflect UNHCR's universally recognized right of initiative in exercising its protection responsibilities as an entirely non-political humanitarian and social body.

4. The need for immediate action to secure protection will frequently occur before a determination of status is possible. Where those seeking refuge may be of concern to UNHCR, the Statute of the Office calls for action on their behalf. Furthermore, the aim is to secure treatment in accordance with universally recognized humanitarian principles not directly linked to the status of those in need. In short, when in doubt, act.

5. Speed of intervention to secure protection where necessary is thus the first priority. The most effective means of securing protection is a UNHCR presence where the refugees are.

6. It should be borne in mind that action taken at the outset in an emergency may have significant long-term consequences, both for continued protection, including perhaps for other groups of refugees within the country, and for the promotion of durable solutions.

2.2 Persons to whom UNHCR extends protection

1. UNHCR's fundamental task is to provide international protection to refugees and to seek permanent solutions for their problems. The need for international protection arises from the fact that refugees, unlike ordinary aliens, no longer have the protection of their former home country. The reasons for this are evident from the definition contained in UNHCR's Statute of a refugee as a person who is outside his country of origin and who, due to well-founded fear of persecution, is unable or unwilling to avail himself of that country's protection. Persons who meet this definition are refugees irrespective of whether or not they have been formally recognized as refugees by a national authority or UNHCR.

2. Persons wishing to be admitted into a country as refugees are generally described as asylum seekers. In some cases they may be

considered as refugees as a result of a group determination, as explained in paragraph 3 (2) below. If, however, a decision on a group determination cannot yet be made, which may be the case at the start of an emergency, the High Commissioner nevertheless intervenes on behalf of asylum seekers in order to ensure that they are granted at least temporary asylum, and that they are not sent back to their country of origin or to any other country where they may fear persecution, pending the determination of their refugee status and the granting of durable asylum.

3. A person's refugee status may be established in three main ways:

(1) by the High Commissioner, as the result of an individual determination that the criteria in paragraph 6 of the Statute are met;

(2) by the High Commissioner, as for (1) but for a caseload as a whole on the basis of a so-called prima facie group determination. This is common at the start of an emergency, where (1) would be impracticable;

(3) by States party to the 1951 Convention/1967 Protocol.

4. Various General Assembly resolutions have widened UNHCR's original competence to act, extending this beyond refugees within the meaning of UNHCR's Statute to:

(1) displaced persons, in the sense of persons outside their country of former habitual residence who may not necessarily qualify as refugees within the terms of the Statute but who are nevertheless in refugee-like situations;

(2) former refugees and displaced persons repatriated to their country of origin;

(3) in specific cases (subject to a request by the Secretary-General or the General Assembly), persons displaced as a result of man-made disasters within the territorial limits of their country of origin.

5. These extensions of UNHCR's competence mean that the Office also has protection responsibilities towards displaced persons as described in (1). Persons described in (2) and (3) fall outside the terms of the Statute, the 1951 Convention and the 1967 Protocol. When providing assistance to persons in these categories, UNHCR nevertheless acts in the spirit of the Statute and has at least a moral responsibility to ensure that fundamental and internationally recognized humanitarian standards are adhered to.

6. There are, however, some groups of persons where caution may need to be exercised: UNHCR is not competent to intervene on behalf of active combatants and persons bearing arms. Protection of such persons may fall within the competence of the ICRC. Attention is also drawn to the exclusion clauses in Chapter II, 7(d) of the Statute relating to persons for whom there are serious reasons to consider that they have been guilty of crimes against peace, war crimes, crimes against humanity, serious non-political crimes outside the country of refuge, or acts contrary to the purposes and principles of the United Nations. It should be noted that the provisions of the Universal Declaration of Human Rights on asylum from persecution are similarly qualified by the exclusion of such persons. Persons thus excluded do not fall under the High Commissioner's competence. It is, however, unlikely that all those in a major influx would be so excluded, and when protection is clearly an urgent humanitarian need, the benefit of the doubt should be accorded at least until a considered opinion is available. Headquarters must, of course, be informed immediately of action

taken and advice sought as necessary.

2.3 The aim and action to achieve it

1. The aim of international protection is to ensure that treatment of refugees is in accordance with internationally accepted basic standards, and especially the principle of non-refoulement according to which refugees may not be forcibly returned to a country where they have reason to fear persecution. This principle figures in paragraph 1 of Article 33 of the 1951 United Nations Convention, to which acceding States may not make a reservation: "No Contracting State shall expel or return ("refouler") a refugee in any manner whatsoever to the frontiers of territories where his life or freedom would be threatened on account of his race, religion, nationality, membership of a particular social group or political opinion." (Paragraph 2 of Article 33 provides for very limited exceptions for refugees reasonably regarded as a danger to the security or community of the country where they are.)

2. Before this aim can be realized, asylum seekers must of course be admitted to the State in which they seek refuge, without any discrimination as to race, religion, nationality, political opinion or physical incapacity. "Everyone has the right to seek and to enjoy in other countries asylum from persecution" (Universal Declaration of Human Rights, Article 14 (1)). Operative paragraph 2 of General Assembly Resolution 428(V), adopting the Statute, calls on governments to co-operate with the High Commissioner in the performance of his functions, inter alia, by "admitting refugees to their territories".

3. Thus when an influx of persons who may be of concern to UNHCR occurs, the overriding priority is to ensure that at least temporary asylum is granted to them. An on-the-spot presence and quick action are generally crucial to the attainment of UNHCR's objectives, particularly where there is danger of refoulement or abuses of human rights such as arbitrary detention or mistreatment. It should be noted that UNHCR does not, as a principle, favour the granting of merely temporary asylum or refuge, preferring rather to emphasize the need to grant durable asylum. However, this may not be immediately possible, and Representatives and field officers may decide that in the circumstances only temporary asylum should be requested, without prejudice to subsequent efforts to obtain durable asylum.

4. The conclusions of the Expert Group on Temporary Refuge in Situations of Large-Scale Influx which met in Geneva from 21-24 April 1981 state that it is essential that after admission asylum seekers should be treated in accordance with the following minimum basic human standards:

(a) they should not be penalized or exposed to any unfavourable treatment solely on the ground that their presence in the country is considered unlawful and they should not be subjected to restrictions on their movements other than those which are necessary in the interests of public health and order;

(b) they should enjoy the fundamental rights internationally recognized, in particular those set out in the Universal Declaration of Human Rights;

(c) they should be treated as persons whose tragic plight requires special understanding and sympathy; they should receive all necessary assistance and they should not be subject to cruel, inhumane or degrading treatment;

(d) there should be no discrimination on the grounds of race, religion, political opinion, nationality or country of origin;

(e) they are persons before the law enjoying free access to courts of law and other competent administrative authorities;

(f) the location of asylum-seekers should be determined by their safety and well-being as well as by the security needs of the receiving State. Asylum-seekers should, as far as possible, be located at a reasonable distance from the frontier of their country of origin. They should not become involved in subversive activities against their country of origin or any other State;

(g) they should be provided with the basic necessities of life including food, shelter and basic sanitary and health facilities;

(h) family unity should be respected;

(i) all possible assistance should be given for the tracing of relatives;

(j) adequate provision should be made for the protection of minors and unaccompanied children;

(k) the sending and receiving of mail should be allowed;

(l) material assistance from friends or relatives should be permitted;

(m) appropriate arrangements should be made, where possible, for the registration of births, deaths and marriages;

(n) they should be granted all the necessary facilities to enable them to obtain a satisfactory durable solution;

(o) they should be permitted to transfer assets which they had brought into the territory to the country where the durable solution is obtained; and

(p) all steps should be taken to facilitate voluntary repatriation.

5. The same conclusions continue: "Asylum-seekers shall be entitled to contact the Office of UNHCR. UNHCR shall be given access to asylum seekers. UNHCR shall also be given the possibility of exercising its function of international protection and shall be allowed to supervise the well-being of persons entering reception or other refugee centres."

6. These conclusions were endorsed by the forty States Members of the Executive Committee of the High Commissioner's Programme at the Committee's 32nd Session. The standards reproduced above should form the basis and framework for action by UNHCR, and particularly by field officers, to ensure protection in an emergency. Some of the international instruments that may be invoked are discussed in the next section. Actual courses of action to secure the rights described in this chapter are outlined in Part 2.

2.4 International instruments

1. In addition to the Statute, 1951 Convention and 1967 Protocol, there are a number of international instruments that may help protect refugees. In all circumstances, the Charter of the United Nations and the Universal Declaration of Human Rights place certain general obligations on Member States of the United Nations of particular relevance to UNHCR's international protection function. The Charter and Universal Declaration are the two best known and least challenged of the expressions of humanitarian principle that may be invoked by UNHCR, reaffirming as they do faith in fundamental human rights, the principles of justice and international law and the equality of all before the law.

2. Attention may also be drawn to the International Covenants on human rights, and in particular paragraph 1 of Article 2 of the International Covenant on Civil and Political Rights:

"Each State Party to the present Covenant undertakes to respect and to ensure to all individuals within its territory and subject to its jurisdiction the rights recognized in the present Covenant, without distinction of any kind, such as race, colour, sex, language, religion, political or other opinion, national or social origin, property, birth or other status."

3. The principle of non-refoulement has found specific expression in various international instruments adopted at the universal or regional levels. The principal instruments are the United Nations Declaration on Territorial Asylum, the Final Act of the United Nations Conference on the Status of Stateless Persons, the OAU Refugee Convention, and the American Convention on Human Rights. For example:

"No person (entitled to invoke article 14 of the Universal Declaration of Human Rights) shall be subjected to measures such as rejection at the frontier or, if he has already entered the territory in which he seeks asylum, expulsion or compulsory return to any State where he may be subjected to persecution." U.N. Declaration of Territorial Asylum, adopted by G. A. resolution 2312 (XXII), 1967, Article 3, para. 1.

"In no case may an alien be deported or returned to a country, regardless of whether or not it is his country of origin, if in that country his right to life or personal freedom is in danger of being violated because of his race, nationality, religion, social status, or political opinions." American Convention on Human Rights ("Pact of San José, Costa Rica") 1969, Article 22, paragraph 8.

4. Instruments for the benefit of refugees established at the regional level have important implications for UNHCR's protection function. A notable example is the OAU Convention, under which the term "refugee" is defined in Article 1 not only as in the Statute of the Office, 1951 Convention and 1967 Protocol but, more broadly, as applying:

"to every person who, owing to external aggression, occupation, foreign domination or events seriously disturbing public order in either part or the whole of his country of origin or nationality, is compelled to leave his place of habitual residence in order to seek refuge in another place outside his country of origin or nationality."

In this particular case the wider definition of the term "refugee" is broadly consistent with the term "displaced person" as used in paragraph 2.2.4 (1) and has the same implication for UNHCR's protection responsibility. Where both universal and regional instruments with different definitions or provisions apply, UNHCR should seek to ensure that the more liberal is followed.

5. In countries that are parties to the relevant instrument(s) UNHCR's protection function is naturally facilitated. Article 35 of the 1951 Convention obliges States parties to the Convention to co-operate with UNHCR in the exercise of its functions and in particular to facilitate UNCHR's duty of supervising the application of the Convention's provisions. Even when an emergency occurs in a country not party to the international instruments, these may nevertheless be brought to the attention of the government, for they define standards of treatment which are internationally recognized, as evidenced by the large numbers of Contracting States. Similarly, the moral strength of conclusions of the Executive Committee is not limited to States Members, for the Members are elected by and act on behalf of the international community as a whole.

2.5 The Geneva Conventions and Protocols and the International Committee of the Red Cross (ICRC)

1. The ICRC, as a promoter of international humanitarian law, plays an important role in reinforcing the international protection of refugees and displaced persons, particularly in situations of armed conflict: protection of refugees is an important preoccupation of international humanitarian law applicable in armed conflicts. In addition to the functions of supervision entrusted to the Protecting Powers by the four Geneva Conventions of August 1949 and their additional Protocols of 1977, the ICRC is also entitled to visit and assist all the persons protected by the Conventions. It may even assume the humanitarian tasks imparted to the Protecting Powers by the Conventions whenever no such Powers could be designated.

2. Refugees and displaced persons are protected persons under the Fourth Geneva Convention when they "find themselves, in case of a conflict or occupation, in the hands of a Party to the conflict or Occupying Power of which they are not nationals". This Convention further provides for the reunion of dispersed families, for the supervision of all places where protected persons are, and for general humanitarian activities.

3. Article 44 of the Fourth Convention provides:

"In applying the measures of control mentioned in the present Convention, the Detaining Power shall not treat as enemy aliens exclusively on the basis of their nationality de jure of an enemy State, refugees who do not in fact enjoy the protection of any government." (emphasis added)

4. Article 70 of the Fourth Geneva Convention, dealing with offences committed before occupation, also provides:

"Nationals of the Occupying Power who, before the outbreak of hostilities, have sought refuge in the territory of the occupied State, shall not be arrested, persecuted, convicted or deported from the occupied territory, except for offences under common law committed before the outbreak of hostilities which, according to the law of the occupied State, would have justified extradition in time of peace." (emphasis added)

Persons who fled their home country before the outbreak of hostilities and found refuge or asylum in the occupied country thus rank as refugees.

5. The relevant provisions were further strengthened by Article 73 of Protocol I additional to the Geneva Conventions and relating to the protection of victims of international armed conflicts, which states:

"Persons who, before the beginning of hostilities, were considered as stateless persons or refugees under the relevant international instruments accepted by the Parties concerned or under the national legislation of the State of refuge or State of residence shall be protected persons within the meaning of Parts I and III of of the Fourth Convention, in all circumstances and without any adverse distinction." (emphasis added)

6. Concerning the reunification of dispersed families, Article 26 of the Fourth Geneva Convention provides:

"Each Party to the conflict shall facilitate enquiries made by members of families dispersed owing to the war, with the object of renewing contact with one another and of meeting, if possible. It shall encourage, in particular, the work of organizations engaged on this task provided they

are acceptable to it and conform to its security regulations." (emphasis added)

This Article is concerned with the re-establishment of family ties and therefore applies solely to members of dispersed families. The parties to the conflict not only must allow members of dispersed families to make enquiries, they must facilitate such enquiries. The main aim of this Article is the safeguarding of family unity and the re-establishment of contacts between members of a family group. The obligations on the parties in this regard are reaffirmed and reinforced in Article 74 of the Additional Protocol I.

7. Concerning the supervision of places where protected persons are, Article 143 of the Fourth Geneva Convention, inter alia, provides:

"Representatives or delegates of the Protecting Powers shall have permission to go to all places where protected persons are, particularly to places of internment, detention and work.

"They shall have access to all premises occupied by protected persons and shall be able to interview the latter without witnesses, personally or through an interpreter.

"The delegates of the International Committee of the Red Cross shall also enjoy the above prerogatives."

Owing to the role it plays in armed conflicts, the ICRC can therefore sometimes visit detainees who are of concern to the High Commissioner but to whom UNHCR representatives may have no access. These visits, which can have great humanitarian value, are a direct complement to the action of UNHCR.

8. Concerning general humanitarian activities, Article 10 of the Fourth Convention provides:

"The provisions of the present Convention constitute no obstacle to the humanitarian activities which the International Committee of the Red Cross or any other impartial humanitarian organization may, subject to the consent of the Parties to the conflict concerned, undertake for the protection of civilian persons and for their relief."

The above Article allows any initiative or activity that may appear necessary for the benefit of protected persons, even if not explicitly or implicitly foreseen by the Convention. Such right of initiative granted to the ICRC or to any other impartial humanitarian organization is considered as a prerogative of utmost importance by the International Red Cross.

9. Close working relationships and regular consultations exist between the ICRC, the League of Red Cross Societies and UNHCR in matters of common interest. It should be noted that the services of the ICRC Central Tracing Agency (see chapter 11) and ICRC travel documents can be a valuable source of protection for refugees.

CHAPTER 3: NEEDS ASSESSMENT AND IMMEDIATE RESPONSE

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3.1 Introduction

1. To be effective, emergency assistance has to be based on a sound assessment of the refugees' most immediate needs and no two refugee emergencies are alike.

2. The initial assessment must be carried out as quickly as possible to allow immediate action. More detailed assessments will follow as the emergency phase dovetails into longer-term programmes. Needs evolve in the course of an emergency operation so assessment never stops.

3. Guidelines for specific sectors of assistance follow in chapters 5 to 11. Here the initial needs assessment is linked to the immediate response.

4. A number of organizations may already be delivering emergency assistance. They will be a valuable source of information on the situation, and the assistance they are giving and intend to give must be taken into account in deciding UNHCR's immediate response. There may be other programmes, established before the emergency, which can be extended to the refugees.

5. Where the emergency concerns the immediate protection of refugees, rather than their need for material assistance, the priority will be to obtain information on the actual situation, position of the government(s) and possibilities for resolution. An on-the-spot UNHCR presence will be very important. Action in such emergencies will depend on the circumstances and is not considered in this chapter. Certain general guidelines are given in the previous chapter.

3.2 Needs assessment

Organization

1. An initial assessment of the situation and needs must be carried out on the spot as soon as it is clear that a refugee emergency may exist. This must involve the government. Immediate access to the area where the refugees are located is, of course, a prerequisite. The emphasis must be on quick, practical steps: establishing a presence at or near the refugee site for first-hand information, interviewing refugees, utilizing other available sources of information both in the area and in the capital, and mobilizing local expertise and resources. Rarely will relief aid from abroad arrive in time to preserve life in the first days of an emergency.

2. While an organized approach is necessary, time must not be lost because the desired expertise is not immediately available. A quick response to obviously urgent needs must never be delayed because a comprehensive assessment has not yet been completed.

3. A detailed assessment must be undertaken as soon as possible. Brief indications of the types of expertise that may be required are given below, with more detail given by sectors in later chapters. Local expertise is generally best when available. Sources include government departments, the UN system, bilateral aid and voluntary agencies, universities and consulting firms in the country. Headquarters' assistance should be requested if necessary.

4. Where UNHCR is not already present in the country, the assessment mission will be organized by Headquarters. Whenever possible, the assessment team would include those who are going to implement the emergency operation in the field. The participation of one or more officers who will return to Headquarters with the results of the assessment has obvious advantages, but where UNHCR is already present, initial action must not be delayed pending the arrival of a Headquarters mission.

5. Participation in the needs assessment by other organizations

and individuals likely to be involved in the emergency programme will be extremely valuable.

6. To assess the material needs of refugees in an emergency is to measure, as quickly and effectively as is possible, their actual condition and the resources at their disposal against what is needed for their survival and immediate well-being. So standards establishing what is needed must be set. To the extent possible, the needs assessment should first answer the questions in the following paragraphs. Some of these questions may seem from a field perspective less important than others. However this is in fact the essential minimum information required for the launch of an emergency programme which includes, among other non-field but vital aspects, the alerting of potential donors. The exercise will also prove to be a foundation for the field's own subsequent programming process.

Numbers, location, pattern of arrival and characteristics

7. (1) Approximately how many refugees are there?

(2) Where are they located?

(3) Are more arriving? Where? How many? Up to how many could come?

(4) Are they arriving in groups of scattered individuals or as families, clans, tribal, ethnic or village groups and by what means are they travelling?

(5) Did those already there arrive in a similar manner?

(6) What are the approximate proportions of men, women, children (ages 0-4, 5-14, 15 and over)?

(7) Ethnic/geographic origin (urban or rural)?

(8) Sedentary or nomadic background?

(9) Skills and language(s)?

(10) Customary basic diet?

(11) Customary shelter?

(12) Customary sanitation practices?

Health status (chapters 7 and 8)

8. (1) Are there significant numbers of injured or sick persons?

(2) Signs of severe malnutrition?

(3) A high mortality rate?

(4) Specially vulnerable groups?

(5) What was their condition before the emergency?

Assessment of the health status of refugees requires expertise; nevertheless an early assessment is essential and preliminary conclusions must be reached as soon as possible.

Material condition

9. Have the refugees brought or are the following available:

(1) Sufficient clothing, blankets, etc. to meet immediate needs?

(2) Food?

(3) Shelter material?

(4) Domestic utensils?

(5) Livestock?

(6) Funds (and can they be fairly exchanged for local currency)?

(7) Other possessions (vehicles etc.)?

Characteristics of location

10. These are given as site selection criteria in chapter 6; an assessment based on the following criteria will provide the information on which a decision can be made to try and move the refugees if the location is very unsatisfactory; if this is not necessary, it nevertheless establishes the advantages and drawbacks of particular sites allowing corrective actions to be incorporated in the emergency action plan.

(1) Space;

(2) Security;

(3) Accessibility (all-season) and proximity to sources of essential supplies (building materials, cooking fuel etc);

(4) Environmental conditions and seasonal variations;

(5) Water (chapter 9);

(6) Soil topography and drainage;

(7) Vegetation;

(8) Land rights and impact on local population.

(9) Is there grazing land and potential areas for cultivation?

Expertise may be required in geology, physical planning and public health engineering, especially water and sanitation.

Social needs (chapter 11)

11. (1) Are there individuals or groups with special social needs (for example, the mentally or physically disabled, unaccompanied children, single parent families, the sick and destitute, unsupported elderly refugees)?

(2) Are their immediate material and emotional needs being met satisfactorily and if not what outside assistance is needed?

(3) Are many refugees separated from other members of their families?

Spontaneous arrangements and assistance being provided

12. (1) What arrangements have the refugees already made to meet their most immediate needs?

(2) What assistance is already being provided by the local population, the government and other organizations?

(3) Can the above provide a durable basis for their survival and well-being at their present location?

(4) Is present assistance likely to continue, increase, decrease?

Means to deliver assistance

13. (1) Can effective implementing arrangements be made quickly and locally (chapter 4)?

(2) If not, what are the alternatives?

(3) Is there already an identified refugee leadership with whom it will be possible to co-ordinate the delivery of assistance?

(4) What are the logistical needs and how can they be met (chapter 5)?

- Where will the necessary supplies come from?

- How will they reach the refugees?

- What storage is needed, where and how?

- Are there essential items which can only be obtained outside the region and whose early supply will be of critical importance (e.g. food, trucks)?

(5) What arrangements are required to co-ordinate the emergency programme with all concerned (chapter 12)?

(6) What are the needs for UNHCR personnel, and experts not provided under implementing arrangements (chapter 4) and UNHCR programme support (offices, vehicles, communications, equipment, etc.)?

3.3 Immediate response

Protection

1. Unless the refugees' right to asylum is assured there can be no assistance programme. Action to this end, and to ensure their security and fundamental human rights, as set out in chapter 2, will be the overriding priority. The importance of a UNHCR presence where the refugees are has been stressed in that chapter. Specific measures may be needed, for example to meet the special protection needs of the vulnerable (unaccompanied children, single young girls, minorities etc.), and to protect the refugees against arbitrary actions of outsiders and against groups within their own number who may pose a threat to the safety of other refugees.

Organizational considerations

2. The priority once needs have been assessed will be to provide vital assistance wherever the refugees are. There will also, however, be key organizational or planning decisions to take, some of which may determine the future shape of the whole operation. These often include the points summarized below; decisions on them should be seen as a part of the immediate response. If they go by default or are wrong they will be very difficult to correct later.

(1) The location of the refugees. This will have a major influence on all sectors of assistance: If the refugees are not concentrated together in settlements, they should not be brought into them unless there are compelling reasons for breaking their present pattern of spontaneous informal settlements. If they are already in settlements which judged by the criteria in 3.2.10 above are unsatisfactory, move them. The difficulty in moving refugees from an unsuitable site increases markedly with time. Even if those already there cannot be moved, divert new arrivals elsewhere.

(2) Reception or transit centres. These are generally recommended when an influx is likely to continue. In some circumstances they are essential for the protection of asylum seekers.

(3) Control at the sites. Determine the optimum population in advance and plan for new sites accordingly. Keep careful control of actual occupation of the site as refugees arrive, so that sections prepared in advance are filled in an orderly manner.

(4) Numbers and registration. An accurate estimate of numbers is a prerequisite for any effective assistance. Delivery of help to all in need will require at least family registration and a fair distribution system. The sooner this is established the better. (See ch.12.6)

Material assistance

3. While certain immediate material needs will usually be obvious, the specific types and amounts of emergency assistance required will depend on the standards established for each situation. An indication of appropriate general standards is given by sectors of assistance in the chapters that follow. These standards must be adjusted in the light of three main considerations: the general condition of the refugee popula-

tion (people in extreme distress will need extraordinary measures); immediately available resources (for example, unfamiliar food may have to be used if there is nothing else); and the customs and levels to which the refugees and the local population are used. The standards established for emergency assistance must be consistent with the aim of ensuring the survival and basic well-being of the refugees, be fairly applied for all refugees, and be respected by all involved.

4. Gathering the information summarized in paragraphs 7-13 of the previous section, on the one hand, and the establishment of standards, on the other, will allow the immediate unmet needs to be determined. The most urgent actions must be taken with whatever local material and organizational resources are available, even if the information at hand is incomplete. The following paragraphs indicate actions that are likely to be priorities.

5. Ensure the capacity to act. The first priority is to provide the organizational capacity required to meet the needs of the emergency. Enough UNHCR staff of the right calibre and experience must be deployed. Emergency procedures for the allocation of funds, implementing arrangements, food supply, local purchase, and recruitment of personnel may need to be invoked. With the government, the resources of other UN organizations, particularly UNDP, UNICEF, WHO and WFP, and of the NGO sector must be mobilized within the framework of a plan for immediate action.

6. UNHCR must establish a presence where the refugees are, with assured communications with the main office and thence with Headquarters. The organization of the necessary logistical capacity to deliver the assistance will be of critical importance.

7. Meet the most urgent survival needs: food, water, emergency shelter, health care and sanitation, ensuring fair distribution.

(i) Involve the refugees and promote their self-sufficiency from the start. Involving the refugees in outsiders' plans for their welfare is often difficult. But if it is not done the effectiveness of the emergency assistance will be severely reduced, and an early opportunity to help the refugees to start to recover from the psychological effects of their ordeal may be missed.

(ii) Food. Ensure that at least the minimum need for energy is met; a full ration can follow. Set up special feeding programmes if there are clear indications of malnutrition. Establish storage facilities.

(iii) Water. Protect existing water sources from pollution and establish maximum storage capacity with the simplest available means. Transport water to the site if the need cannot otherwise be met.

(iv) Emergency shelter. Meet the need for roofing and other materials from local sources if possible. Only request outside supplies (e.g. tents) if absolutely necessary.

(v) Health care. Provide the necessary organizational assistance, health personnel and basic drugs and equipment in close consultation with the national health authorities. Although the immediate need and demand may be for curative care, do not neglect preventive and particularly environmental health measures.

(vi) Sanitation. Isolate human excreta from sources of water and accommodation.

8. Take steps to meet the social needs and reunite families if necessary. Surveys may be neces-

sary to identify those in need, who often do not come forward. Tracing may be required. If groups of refugees have been split they should be reunited. Special measures to ensure the care of any unaccompanied children will be a priority.

9. Once these and other priority measures are underway, begin the wider planning process.

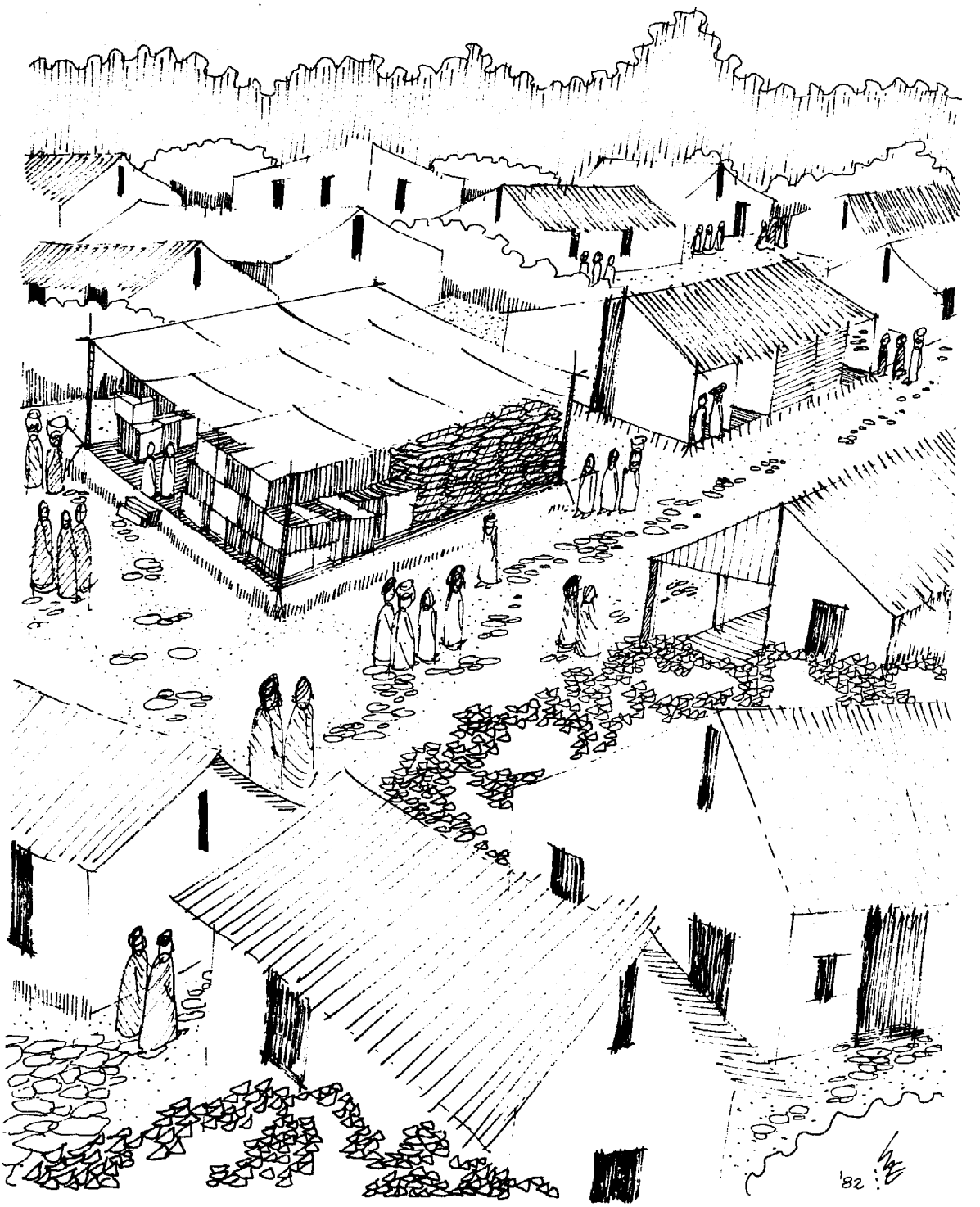
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CHAPTER 4: IMPLEMENTING ARRANGEMENTS AND PERSONNEL

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4

4.1 Introduction

1. Appropriate arrangements to implement an emergency programme will be fundamental to its success. The single most important factor in determining whether or not sufficient emergency assistance reaches the refugees in time will probably be the people involved in organizing and implementing the programme, whether they work directly for UNHCR, the operational partner(s), other organizations or are from among the refugees themselves. The right people must be available where and when needed.

2. Whenever possible, UNHCR seeks to implement material assistance programmes through an operational partner, rather than directly. There are a number of reasons for this policy, the origins of which are reflected in the Statute of UNHCR. Article 1 requires the High Commissioner to seek "permanent solutions for the problem of refugees by assisting Governments and, subject to the approval of the Governments concerned, private organizations...". In accordance with the first sentence of Article 10, "The High Commissioner shall administer any funds, public or private, which he receives for assistance to refugees, and shall distribute them among the private and, as appropriate, public agencies which he deems best qualified to administer such assistance."

3. UNCHR has an unique statutory responsibility for providing international protection to refugees and seeking permanent solutions for their problems. No such uniqueness, of course, characterizes arrangements for the actual provision and distribution of emergency assistance to the refugees. There are obvious advantages in implementing a programme through national organizations or those already familiar with the country. Many organizations and agencies, both governmental and non-governmental, have as much, or more, experience and expertise as UNHCR in directly implementing assistance programmes for refugees, because this is not normally UNHCR's role.

4. Whatever the implementing arrangements, overall responsibility remains with the government, assisted by UNHCR. In a non-operational role, UNHCR is responsible for assisting governments in the assessment of needs and the development of assistance programmes to meet them, and for monitoring and controlling the implementation by others of programmes financed by UNHCR. UNHCR always retains responsibility for accounting to donors for the proper expenditure or use of their contributions, and ensuring, within the limits of available means, that basic needs are met.

5. There are circumstances in which it may be clearly in the interests of the refugees for UNHCR to assume greater operational responsibility, at least during the initial emergency phase of the programme. No general guidance can be given on the most appropriate implementing arrangements and the desired degree of UNHCR's operational involvement. These will vary for each emergency situation, and also with time as the programme evolves. UNHCR's role may therefore range from completely non-operational to a high degree of operational responsibility. Where the latter is the case, UNHCR must take swift direct action to ensure that the necessary personnel and expertise are available.

6. Mechanisms to ensure the coordination of the overall programme are discussed in chapter 12.

7. UNHCR's responsibility for the security, well-being and proper administration of its own staff is self-evident. While UNHCR has no legal obligation towards others working for the refugees, there is a clear moral responsibility for UNHCR to do all that is

reasonably possible to help the government to ensure their security. Administrative aspects, for example visas, communications and transport, are the responsibility of individuals or their parent organization, not UNHCR. It is, however, obviously in everyone's interests that such matters do not hinder the delivery of assistance. Some common arrangements in the context of a NGO co-ordination mechanism may be possible.

8. Figure 4-1 overleaf shows some of the considerations discussed in this chapter in diagrammatic form in the context of the overall emergency response.

4.2 Implementing arrangements

Role of the government

1. The government's concurrence must, in accordance with Article 1 of the Statute, be sought on the proposed implementing arrangements. There are often a number of factors, both practical and political, to consider. At the start of an emergency, the government itself frequently has full operational responsibility. For example, a new influx is often first assisted by the local district and provincial authorities. If the government assumes the role of operational partner, UNHCR's direct operational responsibilities are likely to be limited.

Role of UN organizations

2. In addition to UNDP, particularly where UNHCR was not previously present, the two UN organizations most likely to be directly concerned in the early stages of a refugee emergency are WHO and WFP. Their roles are described in chapters 7 and 8 respectively. Other possible formal implementing arrangements in the emergency phase might involve UNICEF, especially with regard to water supply.

Other operational partners

3. The scale and needs of the emergency may be such that a number of different implementing arrangements are needed in the various sectors. One organization might have operational responsibility for health care, for example the national Red Cross Society supported by the LRCS, and another for logistics. Even within a sector, operational responsibility may have to be "sub-contracted". For instance, under the overall responsibility of the national Red Cross Society, different NGOs might have responsibility for the health care of different refugee groups or communities. Overall operational responsibility should not, however, be divided.

4. Where the government is not the operational partner, there would be obvious advantages in the selection, with the government's approval, of a national organization with the required capacity, or a NGO active in the country. Some locally-based organizations may already be delivering emergency assistance. At least for the initial relief phase, consideration should be given to using the national Red Cross or Red Crescent Society in a wider implementing role than just health care; any approach to them should be co-ordinated with the LRCS through UNHCR Headquarters. The LRCS may be able to help strengthen quickly the capacity of the national society to implement the emergency programme. Similarly, non-national NGOs already working in the country may be strengthened by their headquarters.

5. Where no suitable operational partner is immediately available within the country, UNHCR may initially have to assume a considerable degree of direct operational responsibility. At the same time, steps should be taken to identify and organize others to assume these responsibilities as soon as possible. Direct UNHCR operational involvement will require the rapid

- Implementing arrangements and personnel -

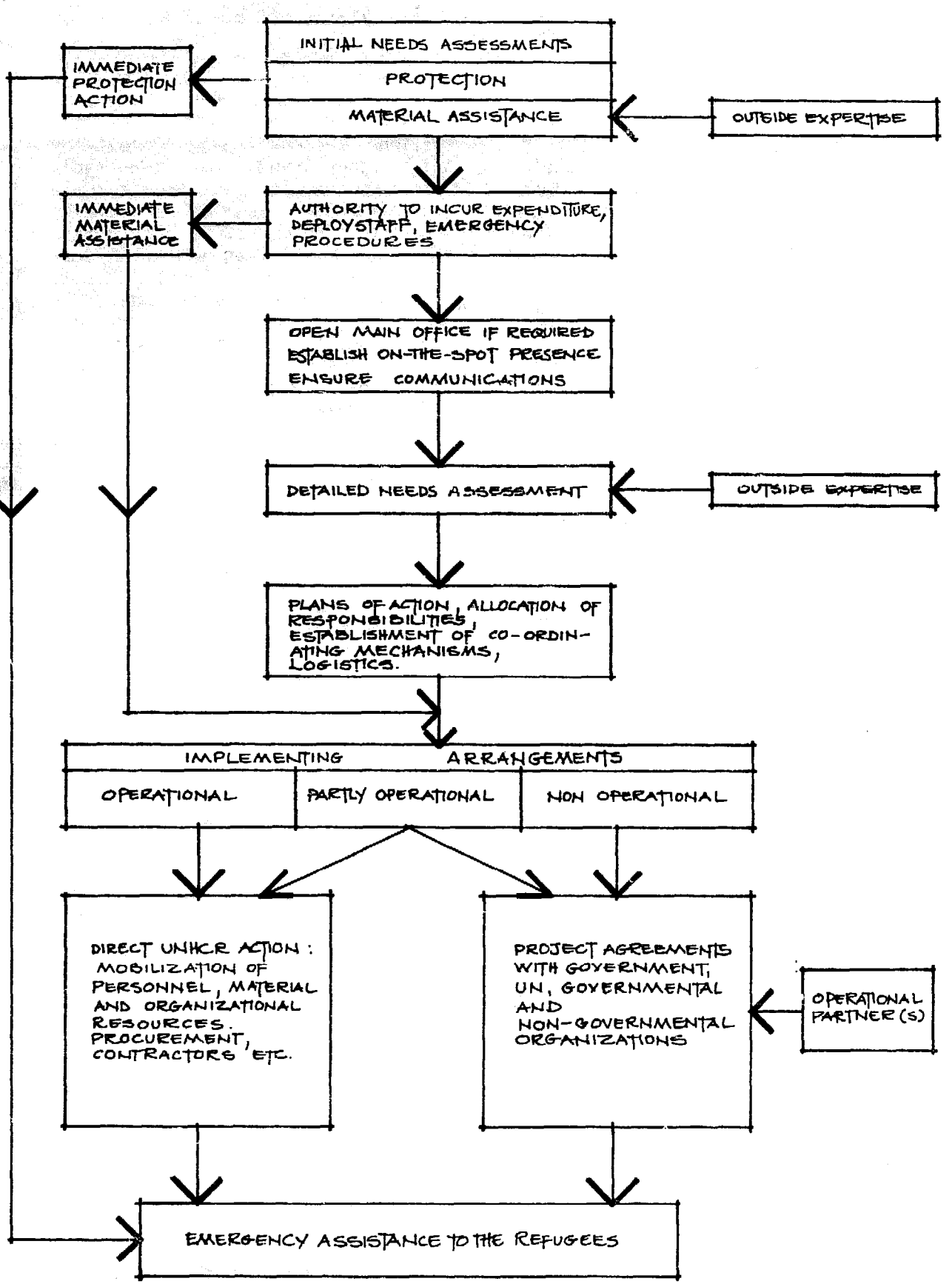

4-1 EMERGENCY RESPONSE

deployment of more UNHCR staff than would otherwise be necessary. Key members of the team should already have direct operational experience of the management of an emergency programme, that is of the immediate delivery of assistance at the site level which is normally the responsibility of the operational partner.

6. UNHCR's operational responsibility may extend beyond the overall management to some or even all of the sectors of assistance. In extreme cases this may also require UNHCR to employ the specialists, such as doctors, nurses and public health engineers, who would otherwise be employed by the operational partner(s). However, every effort should first be made to find organizations with the expertise to implement these programmes. Many NGOs have great experience of refugee emergencies and some can deploy teams at short notice, both for specific sectors and for general management. In addition to their own staff, they will also know of a wide circle of individuals with the appropriate skills and experience.

7. A number of governmental organizations have relevant expertise. These include national disaster corps, organizations concentrating on a specific sector, such as health, and certain governmental overseas aid organizations. National disaster corps are able to intervene quickly for a limited duration, and are generally best used for urgent, clearly-defined and self-contained tasks.

8. Headquarters should be consulted on the proposed implementing arrangements. If suitable operational partners are not available from within the country, detailed information on requirements, with possible suggestions for meeting them and other relevant factors (for example, political constraints), should be conveyed to Headquarters as soon as possible. In certain circumstances, commercial contractual arrangements may be made with organizations, agencies or industry.

9. Special implementing arrangements may be needed in a protection emergency where as a last resort refugees have to be moved from one country of asylum to another, often by air. UNHCR's traditional operational partner in many such situations has been the Inter-governmental Committee for Migration (ICM), while the ICRC may be closely involved and issue travel documents. Transportation arrangements should, of course, not be delayed, but Headquarters' advice must be sought at once, both on implementing arrangements and on financial aspects, including reductions in commercial air fares and procedures for chartering aircraft if necessary.

Contractual arrangements

10. A formal signed agreement is required between UNHCR and any party disbursing UNHCR funds and certain standard clauses must figure in any such agreement. Conclusion and signature of the agreement may take time. Where a suitable operational partner is available locally, it may be necessary to exchange letters of intent to conclude the agreement, in order not to delay disbursement of funds and the start of the programme. Guidance is given in Part 2.

11. The Financial Rules for Voluntary Funds Administered by the High Commissioner provide that sub-agreements may be concluded under the authority of a letter of instruction "when a representative has to cope with an urgent situation and must conclude a sub-contract with a local agency without delay". Subsequent agreements with operational partners would normally be drawn up by Headquarters for signature in the field.

12. The form of the agreement will depend on the circumstances, and on the identity of the operational

partner. Where the government is not an operational partner, a tripartite agreement is sometimes concluded between the government, UNHCR and the operational partner, setting out the responsibilities of each party, for example the government's undertakings in respect of such matters as the facilitation of the import and transport of relief supplies (traffic and landing rights, tax and customs exemptions, etc.), communications, and its own contributions to the programme (land, services, etc.). Alternatively, separate agreements may be concluded between UNHCR and the government, and UNHCR and the operational partner(s).

13. The agreement with the government covering the provision of assistance is quite separate from the administrative agreement that governs the status of the High Commissioner's representation in the country. Where such an agreement, often referred to as the "Branch Office Agreement", needs to be concluded, special instructions will be given by Headquarters.

14. For implementing arrangements with partners not already in the country, agreements will generally be concluded by Headquarters in close consultation with the Representative, particularly where the transfer of funds takes place at Headquarters and not at the field level. Operational arrangements with other UN organizations are generally made at Headquarters' level.

Administrative expenditure by operational partners

15. As a general principle UNHCR does not meet the administrative costs of other organizations or agencies. However, the actual cost of direct programme support expenditure incurred by the operational partner may be met, if necessary, by UNHCR under the terms of the agreement, whose text and budget should make clear exactly what administrative expenditures are to be covered. Where the government is the operational partner, the necessary personnel are generally regarded as a "matching" contribution. UNHCR does not meet unspecified general administrative overhead costs or percentage service charges. Headquarters' advice should be sought on levels of administrative expenditure by operational partners.

Direct UNHCR expenditure

16. Even when UNHCR has no direct operational responsibility, there is likely to be a need for direct UNHCR project as well as programme support expenditure. This might include, for example, international procurement by UNHCR, clearing, storage and internal transport expenses for contributions in kind, and a limited direct operational expenditure, particularly initially, by UNHCR field officers at the site of the refugees. Contractual arrangements with operational partners should take account of this as necessary, clearly identifying any funds foreseen for such direct expenditure by UNHCR if there would otherwise be risk of misunderstanding. A three-column budget or schedule may be helpful, showing direct expenditure by the operational partner, by UNHCR and the total.

4.3 Personnel

General

1. Many chapters in this handbook, including this one, stress the importance of experts and appropriate expertise and experience, particularly that gained in the country or region, for the effective management of refugee emergencies. This is indeed essential, and an unprofessional approach can have disastrous consequences for the refugees. However, experience suggests that the other qualities of those who manage refugee emergencies, at whatever level and whoever they work for,

are even more important. No amount of expertise and experience can substitute for organizing skills, flexibility, a readiness to improvise, the ability to get on with others and work under pressure no matter how difficult the conditions, tact, sensitivity to other cultures and particularly to the plight of refugees, a readiness to listen, and, not least, a sense of humour.

2. Responsibility for meeting agreed personnel needs rests with Headquarters, except where specific authority for local recruitment has been given to the Representative. Where staff are made available to UNHCR by organizations, the financial arrangements will depend on the circumstances.

UNHCR field staff requirements

3. A staffing table should be drawn up as soon as possible. Much will depend on implementing arrangements, but, depending on the scale of the emergency, the need for at least the following international staff should be considered:

- Representative
- Deputy Representative
- Field Officers deployed at the site of the refugees
- Protection Officer
- Programme Officers
- Public Information Officer
- Finance Officer
- Personnel Officer
- Administrative Assistant
- Secretary

4. Particular attention must be paid to the administrative staff. An experienced administrative assistant will be an essential member of the team if a new office is being opened, and in large emergencies experienced finance and personnel officers are likely to be necessary. Without persons with these skills, the effectiveness of the whole operation will be prejudiced, and the senior staff will have to devote a disproportionate amount of time to UNHCR internal administration at the expense of the refugees. Local administrative staff must, of course, be identified and trained, but this in itself requires experienced supervision.

5. The overriding staffing priority is to fill the key managerial posts, at the very least those of the Representative, Deputy, Senior Programme Officer and the Heads of field or sub-offices outside the capital, with experienced UNHCR staff of the right calibre. Prior experience of an emergency operation is, of course, a great advantage. This requirement may mean changing, at least for the duration of the emergency, the Representative in a country where a major emergency is added to a previous small-scale programme. For emergencies in countries where UNHCR was not previously present, it will inevitably mean very short notice re-deployment of senior and middle-level staff. Filling the key field posts quickly and correctly is difficult, but it is generally simply a question of determining relative priorities, and in a refugee emergency there is no doubt where the priority lies.

6. If the need for professional field staff cannot be fully met from within UNHCR, the choice is broadly between turning to individuals known to UNHCR, or to organizations. The former may be the better option where UNHCR is less operational and the latter where UNHCR is more operational when, as has already been suggested, it may be better to meet the needs with a team rather than piecemeal. There is, however, one special case of the former: where some suitable UNHCR professional staff can be recruited locally. The procedures to be followed in such circumstances are given in Part 2. The UN Volunteers Programme is a potential source of more junior-level personnel.

Experts

7. Each refugee emergency will require a certain number of specialist skills. Whether these persons work for UNHCR or the operational partner will depend on the implementing arrangements. Expertise may also be required directly by the government and UNHCR for the needs assessment and initial phases of the emergency. To a certain extent this may be available from within UNHCR, in the Emergency and Specialist Support Units. An indication of the types of expertise which may be needed in each sector is given in the chapters that follow.

8. The use of specialists already in the country and familiar with it has obvious advantages. Experience in refugee emergency situations will also be very valuable. Sources include the government, universities and other teaching centres, the UN system and the NGO community. Where suitable persons are not available within the country, how they are obtained will again depend on the implementing arrangements. As a general rule, it is better for UNHCR to seek specialist assistance from organizations known to have such expertise and relevant experience before approaching individuals directly.

9. In summary, provided both UNHCR Headquarters and the field have a clear indication of who is required and why, and of what resources are already available within the country, it should be possible to meet the immediate personnel needs in a refugee emergency quickly. This task must be recognized as the prerequisite to the success of the operation.

CHAPTER 5: SUPPLIES AND LOGISTICS

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CHAPTER 5: SUPPLIES AND LOGISTICS

Need

Refugee emergencies are often in locations removed from the main sources of supply and communications arteries. Exceptional efforts may be needed to ensure logistical support. Without it the whole programme will fail.

Aim

The timely delivery of the basic material needs of the refugees.

Principles of response

- Arrangements must provide a single, centrally co-ordinated logistics operation, with standardized procedures.
- Most immediately needed supplies are often available locally. Avoid overseas supply if possible.
- Transport and storage arrangements must have a spare capacity: things go wrong and more refugees arrive.

Action

- Make logistical arrangements an integral part of overall planning from the start.
- Identify and take the critical leadtime actions (for example overseas procurement of trucks).
- Take expert advice on local conditions and assess implementing possibilities.
- Seek outside assistance if necessary.

5.1 Introduction

1. The ability to deliver the right supplies where and when they are needed is a prerequisite for an effective emergency operation. The vital role of logistic support must not be overlooked in the initial planning, and a logistics specialist may be required on any assessment mission. The more remote the location of the refugees, the more difficult will be the logistical problem, yet these are the situations where logistic support or the lack of it becomes the key to success or failure.

2. Logistical arrangements must provide for a spare capacity beyond that which would suffice if all goes well. There are high risks for the logistical support of any emergency operation as a result of many factors outside the control of UNHCR: delays, breakdowns, the vagaries of nature and the unpredictable. Furthermore, the numbers requiring assistance generally increase through the emergency phase of an operation.

3. This chapter does not cover all the points that may need to be considered in light of local conditions, nor is this a subject where a single general plan can be adapted to any local situation. Special expertise is available in this sector as in others and must be sought if necessary. However, it is not hard to recognize when things are going wrong in this sector.

5.2 Organization of logistical support

- A single, centrally co-ordinated operation is essential and duplication of logistical services must be avoided.

- This requires a clear understanding of overall needs and the responsibilities for meeting them.

- Local knowledge must be sought, and outside logistical expertise obtained if necessary.

1. Every effort must be made to avoid duplication of logistical services by different organizations and to ensure a single, centrally co-ordinated operation. This is particularly important when local transport is inadequate and priorities have to be set for what is carried.

2. A clear understanding by all concerned of the needs is therefore essential: what is being or is to be supplied, when, how, and by whom. The UNHCR planning must be comprehensive, covering, for example, all the food needs regardless of action taken or being taken by other donors, and all blankets regardless of possible sources of supply. Where contributions in kind, or purchases with UNHCR funds, have been made against the total target by the time the UNHCR programme is promulgated, this must be taken into account, but the "start" figure must be the total needs. For example: "200,000 blankets are required to provide two for each refugee. By (date) 50,000 had been purchased and delivered by UNHCR and 80,000 known to be delivered or en route as contributions in kind (whether through UNHCR or bilaterally)". Requirements can of course be altered at any time in light of developments.

3. The actual sources of funding or contributions in kind may differ, but an easily understood, comprehensive list of requirements is essential as the starting point for meeting the basic material needs. Without it, great confusion can result. With such a starting point, the balance of needs can be continuously monitored, and the effect on this of donations in kind, whether through UNHCR or bilaterally, will be immediately apparent, as will whether these are within or outside the scope of the UNHCR programme.

Only with such a comprehensive approach will it be possible to determine whether the refugees' needs are being met.

4. The circumstances of each emergency will determine what arrangements are required of UNHCR for logistical support, but whether directly by UNHCR, through an operational partner or as a commercial service, these arrangements must provide when necessary for overseas purchase and transport, swift unloading and duty-free clearance on arrival, local purchase, temporary storage, onward transportation, regional storage and final distribution, with proper stock control at every stage. Figure 5-1 shows the likely major components of the system in diagrammatic form. Where there is a developed local economy and an adequate internal transport network, such arrangements may not present major problems. Where there is not, action to ensure logistical support will be a - perhaps the - priority task for the field manager.

5. A close exchange of information between the field and Headquarters on all logistical aspects is essential. Particular attention should be paid by Headquarters to giving the field as much notice as possible of overseas transport arrangements, estimated times of arrival (ETAs) and changed schedules, and of contributions in kind in general; and by the field, to acknowledging receipt of consignments, and advising Headquarters of contributions in kind declared locally that fall within the programme.

6. An early assessment of the logistical support requirements is essential. The national authorities, local UN community and the supply or materials managers of large commercial concerns operating in the country will be important sources of advice on local capabilities. If it is clear that logistical support will present major problems, and if local expertise is not available, the assistance of a logistics expert should be requested from Headquarters.

7. Specific arrangements to operate the logistical support system should depend on local resources and knowledge to the extent possible. Where there is a strong existing warehousing and distribution system, outside assistance should not be necessary. Where outside assistance is required seek Headquarters' advice. Possible sources include:

- a governmental disaster or emergency corps;
- a (large) NGO with appropriate experience;
- the ILO, which has experience in this field and would identify outside consultants as necessary;
- a specialist organization or commercial firm.

8. Where the local capacity is sufficient and the main requirement is organization of the food supply, this may be done by WFP. In any event, the operation must be very closely co-ordinated with WFP.

9. Whatever the arrangements in the field, the line of responsibility to UNHCR (or the operational partner) must be clear. The major policy decisions about both supply and transport should be taken by the same person. Decentralization of operational decisions to the regional level may be necessary, and should equally be to a single person.

10. While it is rarely necessary to have mobile communications sets on surface transport, assured communications between dispatch and arrival points is often essential. In some circumstances existing in-country radio or telephone communications links will be inadequate and a special network must be set

5-1 MAIN COMPONENTS OF LOGISTICS SYSTEM

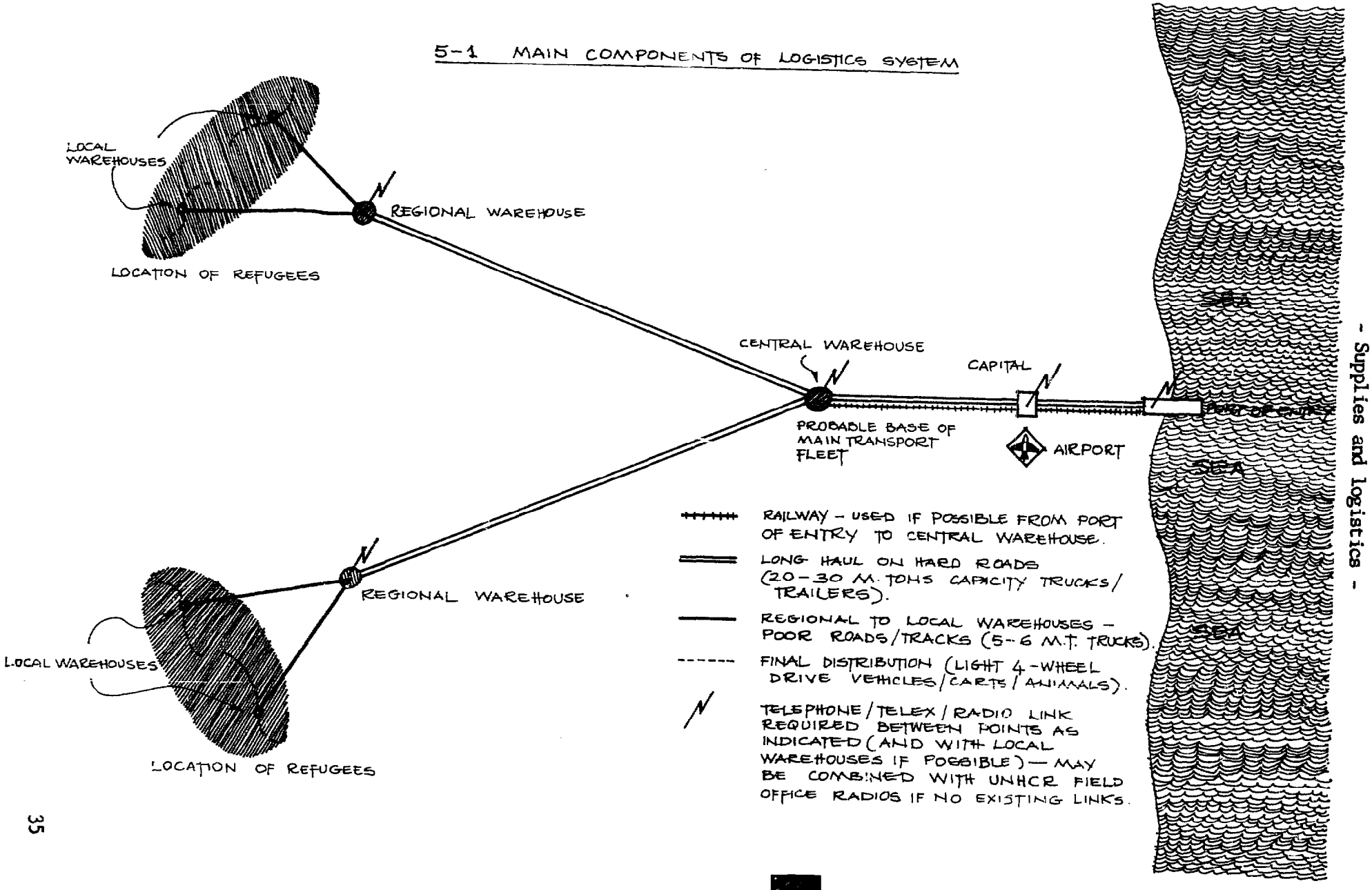

up. Details of how to establish a UNHCR radio network are given in Part 2.

5.3 Supplies

- Make at least initial purchases locally if possible; it is quicker and the supplies are likely to be more appropriate.

- Standard specifications have been developed for common items.

1. The consumable and durable supplies, equipment and material required in a refugee emergency generally fall under the following headings: food, water, medical supplies, sanitation, shelter (materials both for dwellings and community service buildings), domestic needs (utensils, soap and cooking fuel), cloth or clothing, education materials, the means of transport that may be necessary to deliver the foregoing, sufficient spare parts, and the fuel for vehicles and communal services. More details of what may be needed are given in the appropriate chapter.

2. At least for an initial period, the material needs can probably be met from within the country. This possibility must be fully explored before resorting to outside sources: the emergency supplies that must come at once from abroad are often limited to a few essential air-transportable items of relatively small bulk. The local purchase of immediately needed supplies has obvious advantages including quick delivery, more likely acceptability and stimulation of the local economy, though local suppliers often overestimate their ability to supply large quantities on time. To the extent possible, local purchases should require delivery to the store nearest to the location of the refugees, but where there are several suppliers it may be better to consolidate orders and deliveries.

3. Local purchase would normally be undertaken by UNHCR's operational partner, and it is important that field staff are able to monitor the progress of this. Details of procedures for local purchase by UNHCR are given in Part 2. Advice should in any case be sought from the local purchasing officers of other UN organizations, particularly UNICEF, and procurement advice or personnel assistance requested from Headquarters if necessary.

4. While local purchase is indicated given comparability in cost, quality and availability, in major emergencies local suppliers may be unable to meet continuing demand. This is particularly likely when the refugees form a substantial part of the total population of a region or even the country. In such circumstances bulk purchases from abroad will become necessary; these will generally be made by UNHCR Headquarters. Otherwise, local prices will rapidly increase as local purchases dislocate the market, at the same time causing resentment among nationals.

5. In a major emergency and when the capacity of the market is limited, care must in any case be taken to avoid prices being forced up by humanitarian organizations bidding against each other for the same supplies. Provided there is clear agreement on the needs, coordination of purchases and even combined orders among the organizations concerned should be possible. Where supplies are limited, which organization actually purchases the available stocks is obviously less important than ensuring that this is done at a price that is not inflated by needless rivalry.

6. Particularly for shelter, local materials and types of construction should be used where possible, combined with tarpaulins or polythene sheeting as necessary. While, except for nomadic tribes, tents are not a satisfactory type of long-term shelter,

they are a valuable last resort in emergencies. Groundsheets should be supplied with tents. Remember that tents may deteriorate rapidly if stored for any length of time, particularly if humidity is high.

7. Standard specifications have been developed on the basis of previous experience for a number of items that may be required at short notice. These are given in annex 1 to this chapter. The purpose is two-fold. Where such items are available locally, the standard specifications may help in drawing up tender requests or in negotiations with suppliers. Where items are not available locally, Representatives will be able to request supply through Headquarters with a clear idea of exactly what will be supplied, while the standardization itself enables more rapid supply. The purpose is not to impose supplies with these specifications but rather to simplify and expedite supply. More generally, care should be taken to avoid variations in quality (and of course quantity) of items supplied to different sites or groups. Other standardized items include the emergency health kit. (See ch.7.7.3)

8. A large number of other items with standard specifications are available through the UNICEF Packing and Assembly Centre in Copenhagen (UNIPAC). Some are already assembled in kits for specific purposes. Full details, including illustrations, are available in the UNIPAC catalogue held by the local UNICEF or UNDP office. The catalogue includes the emergency stockpile of items whose availability is guaranteed. Certain emergency supplies are held by UNICEF, WHO, the Red Cross and NGOs in regional or national stockpiles and may be available to UNHCR.

9. Used clothing is commonly offered in emergencies but is generally an unsatisfactory way of meeting a need for clothing and should be discouraged. Experience suggests that much will arrive in poor shape, some will be dirty and badly sorted and little will be appropriate to the customs of the refugees. Furthermore, because of its volume it is expensive to airfreight, will arrive too late by sea, and can be expensive to store and transport internally. First priority should be given to meeting clothing needs by the provision of cloth (and sewing machines etc. as necessary) for the refugees to make up themselves, or buying locally made new clothes. In either case care must be taken that what is provided is culturally acceptable.

10. The Procurement Unit will provide field offices with an indication of international prices of the items listed in annex 1 and of other commonly required items. This may be of assistance when preparing an emergency budget in the field, but for items not available locally either make sure that the basis of the calculation is clear - for example: 20,000 blankets at unit cost 'X' plus transport 'Y', estimated total 'Z' - or leave costing to Headquarters. Where common relief items are available locally, cable an indication of prices to the Procurement Unit so that these may be compared with the international market, and consideration given to overseas procurement of further needs if major savings would result.

5.4 Means of transport

- Advance arrangements will be necessary for expeditious handling of supplies from abroad.
- Expert local advice must be sought on internal transport arrangements.
- If vehicles are needed and not available locally their procurement, with spares, will be a very high priority.
- Standardize vehicle fleets.

- Ensure sufficient drivers, fuel, lubricants, spares (especially tyres) and maintenance facilities.

- If a special fleet is necessary, consider "grafting" it on to an existing haulage operation.

- Improve access roads if necessary.

International

1. In the emergency phase, supplies from overseas may arrive by air. Standing arrangements should be made in advance with the authorities for clearance and landing rights for relief flights and for priority handling of freight. If a considerable volume of air traffic (whether international or internal) is expected, a démarche should be made to have relief flights exempted from the 'tax' element of their operations (landing fees, fuel tax) and charged for services at cost (handling fees). If this is done, proper account of any concessions must be taken in the contract with the carrier, otherwise the company and not UNHCR will benefit.

2. Many ports are congested. As soon as details of the arrival of relief supplies by sea are known, arrangements should be made for a priority allocation of an alongside berth (if possible, always the same one) or lighterage. In principle, relief supplies should be loaded only on vessels with the capacity for self-discharge, and whenever discharging alongside they should do so directly onto trucks. With the possible exception of food, vessels are unlikely to be carrying only relief supplies and will be subject to diversion and frequent delays. Nevertheless, the arrangements for onward movement of the supplies and any interim storage necessary must be made well in advance of the ETA.

3. If supplies are being transported from neighbouring countries by road or rail, careful consideration must be given to the destination. Trucks should of course unload as close to the refugees as practicable, while the best discharge point for a train may not be that commonly used for rail freight between the two countries.

Internal

4. Three modes of internal transport are likely to be needed: long haul to regional centres, intermediary from these to the local stores, and final distribution to the refugees.

5. In many countries, existing internal transport services do not have a large spare capacity even on normal networks, which in any case may not serve the location of the refugees. Expert local advice will be essential, to cover such points as rail capacity and delays, a short list of reputable haulage contractors, freight rates per mt/km, age and serviceability of the fleets, fuel supplies and maintenance facilities.

6. Where a suitable rail network exists, this can be an effective way of moving heavy supplies internally. However, many railway systems are either congested or short of rolling stock and long delays may be encountered. WFP often moves food for its own projects by rail but the requirement for speed may make road transport preferable even if it is more expensive. In most cases, onward movement by road to the final destination will be necessary. In some countries heavy loads can be moved by inland waterways.

7. Road transport is likely to be an essential component of the internal transport arrangements. Where there is a government transport agency or suitable commercial fleet, these should be used if possible. Local suppliers should be encouraged to quote prices that

include delivery. At least in the emergency phase, this will be preferable to having to make separate transport arrangements. However, in the worst case no suitable capacity will exist and UNHCR will have to arrange for the establishment of a complete transport system. Some suitable vehicles may be available locally or in the region; consider purchasing second-hand if suitable vehicles in good condition are available. If the overseas supply of vehicles is necessary, this procurement action will have a very high priority.

8. The fleet must be standardized to suitable type(s) already operating in the country and with adequate backup and servicing facilities. Depending on the road conditions, three basic types of vehicle may be needed: a truck with trailer with a combined capacity of 20-30 MT for long-haul on hard roads, a 5-6 MT truck with 4-wheel drive and if necessary a recovery winch for intermediary distribution on poor roads and tracks, and a 1 MT, 4-wheel drive vehicle or even animal or hand carts for final distribution. Observe how local movement of supplies normally takes place. If a mixture of types of the long-haul truck is unavoidable, it may still be possible to standardize to a single trailer type. Particular attention must be paid to the tow-bar strength. The vehicles exclusively involved in the operation should be individually numbered and distinctively painted (for example, white with blue markings).

9. Assured supplies of fuel and lubricants must be available where they are needed. This may require separate secure storage arrangements and an additional fleet of fuel tanker vehicles.

10. Other consumable items (filters, shock absorbers, brake linings etc.), spare parts and proper back-up services must be available. For a small number of vehicles, a carefully selected set of spares per vehicle may suffice, but for a fleet of any size, separate arrangements will be necessary and base and regional workshops may have to be established solely for the operation. Alternatively, existing government or UN facilities may be strengthened. In some countries ILO, UNDP, or UNICEF have special workshops servicing project vehicles. Mobile workshops and heavy recovery vehicles may be necessary. Particular attention should be paid to adequate supplies of tyres: tyre life may be no more than 10,000 km in rough desert or mountain conditions.

11. Sufficient numbers of properly trained drivers must be available. Local UN offices may be able to advise on existing schemes and possibilities. Ensure that recommended working hours are not exceeded: accident rates increase markedly with over-tired drivers. In some situations careful briefing will be required on alternative routes in case usual roads are impassable. A system must be established to monitor and control vehicle use.

12. Control of a transport fleet requires strong administrative skills, good communications and very close co-ordination with the supply arrangements. Careful consideration should be given to the possibility of "grafting" the transport fleet onto an existing operation, for example a large national or regional haulage organization. A large bus company might serve equally well. That organization's infrastructure, including workshops, inspection pits, offices, etc. would then be immediately available, as would be its accumulated experience of operating in the country. A clear understanding on priorities for fuel and services is, however, essential. Nationals should in any case be employed, and trained to take over from expatriates, to the extent possible. Unless there is no practical alternative, setting up a separate establishment should

be avoided, but major emergencies may require a logistical organization that includes a self-sufficient transport unit.

13. In some situations urgent action may be necessary in order to improve access roads. Local advice will be of paramount importance in deciding how improvements should be made. These would normally be undertaken by the national road construction and maintenance authority, perhaps supported by refugee labour. Short-term outside assistance can be provided through Headquarters if necessary.

5.5 Transport capacities

- Food accounts for the greater part of the required capacity.
- A substantial margin of spare capacity must be provided.

1. The key commodity to be moved is usually food; in the worst case the refugees will need total outside food support: approximately 500g/person/day or 15 MT/1000 refugees/month. The bulk of this is likely to be a cereal, packed in 50kg bags (20 bags per MT). The chartering of vessels for overseas movement of food requires specialized knowledge (which, inter alia, WFP has) and is not covered here. It is essential that arrivals are scheduled in a way that takes account of port capacity (berths, unloading and storage) as well as overall needs.

2. The theoretical capacity necessary to move sufficient food inland to the refugees will depend on how long a round trip takes, including routine maintenance. A margin should be allowed to cover the unpredictable but inevitable, such as breakdowns, accidents, bad weather, road and bridge repairs. The size of this margin will depend on many factors including delivery delays of new vehicles, the likelihood of new arrivals and the need for extra capacity while building up reserve stocks near the refugees. In difficult conditions, the theoretical capacity might need to be increased by 25% or more.

3. To give an example: if the rainy season journey time from the port of entry to a regional store serving 30,000 refugees is 3 days out and 2 days back, one day per trip is allowed for routine maintenance, and the road surface can take a truck and trailer with a combined payload of 20 MT, then the theoretical requirement is for 4.5 such trucks/trailers. (1 truck/trailer can move 20 MT every six days; for six days 30,000 refugees require 90 MT of food). In such circumstances, it is clear that six trucks/trailers would be the prudent minimum.

4. Table 5-2 gives an indication of the capacities of different means of transport.

5.6 Storage

- Adequate storage capacity and reserve stocks of essential items must be provided.

1. Supplies may require initial storage near the port of entry. Regional (axial) stores may be required at certain key locations and local (radial) stores will be required near the refugees. Stores must be accessible in all seasons and weather. Arrangements to meet this need must be made quickly. Existing government warehousing should be used if possible. Security of supplies in stores and transit must be ensured. Storage for local purchases should be the responsibility of the supplier whenever possible. Particular attention must be paid to those items requiring special storage. Organize the distribution and storage system so that supplies are loaded and unloaded a minimum number of times. Remember the maxim "first in, first out".

2. A warehouse should be of sound construction, dry and well-ventilated and provide protection from

5-2 Transport capacities

Surface

Carrier	Payload (1)
Standard Railway truck	30MT ($52m^3$)
Standard container 20ft/ 6.1m 40ft/12.2m	18MT ($30m^3$) 26MT ($65m^3$)
Large lorry and trailer	22MT
Large articulated lorry	30MT
Medium lorry	6-8MT
Long wheel base Landrover/ Cruiser type pickup	1MT
Hand-drawn cart	300kg
Camel	250kg (more for short distances)
Donkey	100kg
Bicycle	100kg

Air

Type	Payload/volume (1)	Runway length (2)
B747	100MT/$460m^3$	3000m
DC10/30F	65MT/$340m^3$	3000m
DC8/63F	44MT/$240m^3$	2300m
B707/320C	40MT/$165m^3$	2100m
CL44	26MT/$180m^3$ (3)	1900m
L-100-30 (Hercules)	21MT/$120m^3$ (ramp loading)	1500m
DC9/33F and B737/200	14MT/$105m^3$	1700m
DC3	3MT/$40m^3$	1200m

(1) Approximate indication only: always check exact specification. In particular, figures for aircraft will vary depending on configuration (e.g. if cargo is palletized usable volume may be reduced), operating range, airport characteristics etc. Also establish the size of aircraft doors and, if the airport lacks facilities, whether or not the aircraft has self-loading/discharge and self-start capability.

(2) Also very approximate, for full load, sea level, 15°C, no wind. Markedly influenced by aircraft weight, altitude and temperature. Always check with local aviation authorities which aircraft types can operate.

(3) Certain versions take considerably greater volume.

rodents, insects and birds. The floor should be flat and firm and the building should be easy of access, with suitable arrangements (e.g. ramp or platform) for loading and unloading. The warehouse must be secure against theft, and should be lit if possible. As long as it has sufficient loading doors a single large building is better than several small ones.

3. If suitable storage facilities do not exist, they may have to be built. Local techniques, materials and practices are likely to be the most appropriate, but there are also a number of specialized techniques or structures allowing swift construction of field stores. Expert advice should be sought locally or through Headquarters if required. It may even be necessary to use tents as stores as a temporary measure. The tents should be carefully sited, protected by ditches from surface water if necessary, and with raised platforms inside (e.g. pallets or a groundsheet on sand). The contents must not touch the tent. Within the tent, food should be further protected by plastic sheets.

4. The capacities required of the main, regional and local stores will depend on the numbers of refugees they serve and what outside support they need. Reserve stocks of essential items, particularly food, should be built up close to the refugees. Sufficient stocks should be on hand in secure storage to cover likely interruptions in the delivery schedule, for example during the rainy season. Conversely, care should be taken not to hold in store, against some unspecified future need, items that are immediately required by the refugees, such as blankets or hand tools.

5. The physical dimensions of a warehouse necessary to store a given tonnage may be roughly estimated as follows. First calculate the volume of the goods. As an indication:

1 MT of	occupies approx.
grain	$2m^3$
medicaments	$3m^3$
blankets (compressed) (approx. 700 heavy blankets)	$4\text{-}5m^3$
tents (approx. 25 family ridge tents)	$4\text{-}5m^3$
blankets (loose)	$9m^3$

Assuming storage to a height of 2m, the minimum surface area occupied by the goods will be half their volume. Increase this surface area by at least 20% to allow for access and ventilation. For example, the approximate size of a store to hold 2 months' supply of the cereal staple for 30,000 refugees receiving an individual cereal ration of 350g/day would be:

350g x 30,000 x 60 days
= 630 MT = $1260m^3$
$1260m^3$ stored to a height of 2m
gives a surface area of $630m^2$,
add 20% for access = $756m^2$
of floor space

i.e. a building some 50m long by 15m wide.

5.7. Stock control, inspection and insurance

- Effective stock control and security are imperative and must cover the whole chain through to final distribution to families or individuals.

- Ensure inspection and register insurance claims: supplies can arrive damaged or be lost.

1. A sound control of stock levels and distribution is essential if losses are to be avoided, potentially critical shortages identified in time and final delivery to the beneficiaries assured. The system should identify what has been ordered, where

the goods are and when they will arrive. This information must be available to all who need it and particularly those responsible for final distribution. Control mechanisms will range from those verifying the bulk consignments on arrival down to individual ration cards or distribution checks at the sites and carefully calibrated measures for final distribution. The nature of these mechanisms will depend on the circumstances, but they must be in place from the start and they must provide a real and not just a paper control. The supplies actually distributed to the refugees must be reconcilable with those known to have arrived and those remaining in store.

2. In the emergency phase certain basic controls should be established at once, in addition to the controls over actual distribution discussed in chapter 12. They are described in annex 2.

3. In addition to safeguarding the security of relief supplies, they must be protected from damage. This may be physical, for example as a result of bad handling or improper stacking; climatic, the adverse effects of the sun, rain, cold or humidity; attacks by pests; and bacteriological, the decomposition of perishable commodities with time or when containers are damaged.

4. Some damage is inevitable and considerable sums may be involved. All overseas procurement by or on behalf of UNHCR, and the great majority of all supplies, will have been fully insured against loss or damage in transit. Overseas procurement by UNHCR will also be subject to inspection by a professional agency (superintendence). Where supplies are purchased locally, particular care must be taken not to accept supplies that do not meet contract specifications. Purchases, especially food, should be inspected on arrival at the site and rejected if necessary. If large quantities are involved, organize professional quality control and inspection at the point of final delivery from the first orders. If local superintendence companies are unable to do this, seek outside assistance through Headquarters. Insurance claims must be registered at once and for overseas supplies Headquarters should be informed by cable of major damage or shortfalls. Special arrangements may be necessary for the disposal of spoilt food or goods.

5.8 Consignment procedures and customs clearance

- ☐ Have a single consignee and address.
- ☐ Use the internationally accepted marking and consignment procedures.
- ☐ Plan customs clearance procedures in advance and develop and promulgate a clear policy for NGOs and other suppliers.

Consignment procedures

1. Much trouble can be avoided by using a single consignee and address for all items required from abroad for the UNHCR emergency programme. This would normally be the Representative, with an indication in brackets of any special instructions, for example "For (name of NGO)". However, where UNHCR was not previously present it may be better to consign c/o a UN organization already well known in the country, for example UNDP, provided no delays will result. Similarly, there should be a single consignee and address at the regional or site level.

2. Whether purchases are made locally or abroad, but particularly in the latter case, proper packing, labelling, marking, consignment and insurance procedures are essential. Long experience in different international relief operations has shown that all organizations and donors need to use a uniform system for marking

or labelling relief consignments. UNHCR emergency operations should adopt the procedures the League of Red Cross Societies has developed in co-ordination with United Nations organizations. The following is adapted from Annex 8, Red Cross Disaster Relief Handbook (Geneva, League of Red Cross Societies, 1976):

(1) Colour code. The colours used for the relief supplies most often required after disasters are: red for foodstuffs, blue for clothing and household equipment, and green for medical supplies and equipment.

(2) Labelling. Make sure the consignment also bears one of the international hazard warning signs (fragile, no hooks, keep dry, etc.) if necessary. Consignments of medicines, banded with green, should state on the outside of the package the content and the medicines' expiration date and whatever temperature controls are necessary. English should be used on all labels and stencilled markings, though a second language may be added. It is essential that the final destination (or arrival port) appears at the bottom of the label in very large letters.

(3) Size and weight. Containers should be of a size and weight that one person can handle (ideally, 25kg; up to a maximum of 50kg) since mechanical loading and unloading devices are rarely available at the receiving end.

(4) Contents. Relief supplies should always be packed by type in separate containers. Mixed consignments create many problems in warehousing and ultimate distribution at the receiving end. The colour code recommended loses its value if, for example, medical supplies are packed in the same container as food.

(5) Advance notice to the consignee. To cover in one document all the details necessary for safe transport and ease of handling at the receiving end, the following information is essential: (1) name of sender; (2) name of consignee; (3) method of transport, including the name of the vessel, flight or truck number and its date and port or airport of departure; (4) a detailed list of contents, including weight, dimensions, and number and type of packages; (5) value in the currency of the sending country; (6) type of insurance, name of company, etc.; (7) the carrier's agent, including the name of the person to be contacted in the receiving country; (8) estimated time of arrival and (9) instructions or special requirements for handling and storing the supplies. It should be noted that in most instances a pro forma invoice is required by the authorities in the sending or receiving country or both.

(6) Acknowledgement by the consignee. It is important that an acknowledgement be sent to Headquarters as quickly as possible after consignments are received.

Customs clearance

3. UNHCR's basic or project agreement with the government should, of course, allow for the duty-free import of all items from whatever source, provided that they are required for the programme. The supplies coming in for the operation may far exceed the scope of the routine arrangements between the authorities and the local UN community for the normal handling of office vehicles and equipment and domestic supplies. The customs officials at the airport or ports may be unused to clearing, for example, many tons of airfreight or a shipment of heavy trucks. Problems and delays

may be avoided by discussing the procedures to be followed by UNHCR with senior officials in the foreign ministry, customs department and airport and port authorities before the first arrival. The aim is immediate release of incoming supplies, and special procedures adapted to the needs of the emergency may have to be developed.

4. UNHCR should be prepared to undertake the customs clearance of NGO relief supplies, provided these meet the purposes of the emergency operation. This will allow some control over the dispatch of clearly unsuitable goods, help in the co-ordination of response in kind and help to ensure equitable distribution. As NGOs may otherwise face considerable problems in duty-free customs clearance, it would be in their interest to co-operate in this way. Representatives should be flexible when deciding what falls within the purposes of the emergency operation. Some items unlikely to be covered by UNHCR funds could nevertheless be considered as appropriate. However, as a general rule, do not undertake to clear duty-free for NGOs supplies for their own programme support items such as office cars or equipment. The only vehicles that should be cleared in this way are those foreseen in the UNHCR programme and which will be placed fully at the disposal of the programme (for example, trucks for the movement of bulk food). National Red Cross and Red Crescent Societies have their own standing arrangements for the clearance of relief supplies consigned to them.

5. The expenses incurred in customs clearance, handling, storage and onward movement of supplies belonging to UNHCR - contributions in kind or UNHCR procurement - may be met by UNHCR if necessary, for example initially through an emergency letter of instruction. Subsequently, Representatives should propose a specific project to cover any such continuing expenses. Where NGO supplies are concerned, UNHCR will be the "consignee of convenience", not the "owner" or "donee". All expenses involved should normally be borne by the NGO. However, in certain circumstances and provided the supplies are items directly foreseen in the UNHCR programme (for example blankets, tents), UNHCR may also meet inland transportation costs, as would have been necessary had UNHCR had to purchase these items itself.

6. It is strongly recommended that local guidelines on this be drawn up as early as possible in the operation. They should make it clear to all potential consignors that UNHCR will undertake to clear only supplies for which notification is received prior to dispatch and which are considered appropriate. The guidelines should be made available to all NGOs active in the operation and to new NGOs on arrival. This could be done through the NGO Co-ordinating Committee. A copy of these guidelines should be shared with Headquarters and reference to this general procedure made in any NGO briefings at Headquarters and in the first few general telex sitreps.

Further references

Hall D.W. (1970)	Handling and Storage of Food Grains in Tropical and Subtropical Areas	FAO Agricultural Development Paper No. 90
Licross/Volags Steering Committee for Disasters (1982)	Emergency Supply Logistics Handbook Basic guidelines for the procurement of supplies for disaster relief operations. Includes a number of specimen forms and explanation of commonly used trade terms. (Also in French and Spanish)	(c/o LRCS)
UNITAR (1982)	Model Rules for Disaster Relief Operations One of the proposed sets of rules is for a bilateral agreement between an assisting organization and a receiving state, covering such matters as waivers, traffic rights, priority handling of relief supplies and facilities for relief personnel. (UNDRO is seeking to develop these into a draft agreement or convention).	Policy and Efficacy Studies No. 8
	Also relevant in this context, although on natural disasters, are: (1) Annex II of the Report of the Secretary-General on UNDRO of 12 May 1977 (A/32/64): Measures to expedite international relief. The recommendations were adopted by consensus by the General Assembly, and by participants at the 1977 International Conference of the Red Cross. (2) Rapport spécial sur un project d'accord-type relatif aux actions de secours humanitaire adopted by the 59th Conference of the International Law Association, Belgrade 1980.	
WFP (1979)	Food Storage: Handbook on Good Storage Practice Clear illustrated guidance for storekeepers.	

Standard specifications for certain common relief items

These specifications have been developed with UNICEF to assist Representatives in drawing up tender requests where local purchase is possible and to give a clear indication of what could otherwise be supplied at short notice through Headquarters. The UNIPAC catalogue reference is given in brackets where applicable; the actual source of supply through Headquarters would depend on the circumstances and in particular on any regional availability.

1. Blanket, heavy (similar E50 035 05)

Woven, 30-40% wool and rest other fibres (cotton, polyester) blanket with stitched ends, size 150 x 200cm, weight 1.3kg, packed in pressed bales of 50 pcs. Each bale of 50 pcs would be about $0.35m^3$ volume and weigh 65-70 kg. Large quantities are generally available.

2. Blanket, light

Cotton, size 140 x 190cm, weight approx. 850g, usually packed in pressed bales of 100 pcs. Each bale of 100 pcs would be about $0.4m^3$ volume and weigh 85-90kg. Fairly large quantities generally available ex-stock in Asian region, more limited availability elsewhere.

3. Bucket, plastic (21 700 00)

Bucket/pail 10 litre capacity, polyethylene with plated steel-wire bail handle, conical seamless design, suitable for stacking, reinforced or turned lip. Plastic or galvanized buckets are likely to be available locally and are very useful.

4. Family cooking set, emergency (20 365 10)

12 pcs aluminium utensils as follows:

- Cooking pot, 6 litre, with bail handle and cover
- Cooking pot, 4 litre, with bail handle
- Dinner plate, aluminium (4 each)
- Plastic mug (4 each)
- Coffee pot, aluminium, 2 litre.

The set is packed in a cardboard carton 25 x 25 x 20cm, weight 2kg. The set does not contain cutlery: five stainless steel soup spoons and one stainless steel cook's knife, blade 15-17cm, could be supplied separately if not available locally. Utensils of a heavier gauge aluminium are normally supplied by UNHCR when some delay can be accepted. The advantages of the emergency set are lower weight, packed volume and price. It is therefore particularly suitable when supply by air is necessary.

5. Plastic sheeting

Black seamless polyethylene sheeting, 250 microns (1000 gauge), width 5-8m, supplied double-folded in lengths usually of 100-800m, approx. weight $1kg/4m^2$. For multipurpose use: roofing, walls, ground sheets, linings, etc. Widely available. (There is a guide to its use, see page 67.)

6. Tarpaulin material (E 50 860 10)

4m wide, 50m long (200sqm), in centre-folded roll of 2m wide, 250mm diameter. Reinforced polyethylene, ultraviolet ray resistant; 0.25mm thick (275g/sqm). Plastic eyelets both sides every metre, double row of eyelets across every 5m. Colour green. Approx. 50kg. Considerably stronger than item 5.

7. Tent, family, for use in emergencies, 12sqm (E50 880 02)

Round type (single bell). 300g/sqm cotton or cotton/polyester canvas, water and rot proofed, natural, with ground strip. Diameter 4m, centre height 2.5m, wall height 600mm. Heavy duty sectional steel tube centre pole, plasticlad or galvanized. Complete with ropes, pegs, mallet and patching kit, with loose, reinforced PVC groundsheet 250g/sqm. In packsack. Ceiling ventilation flaps. Approx weight 22kg. Apart from a better resistance to high winds, the only general advantage of this tent over item 8 is its lighter weight when supply by air is necessary. Not recommended for use with camp beds but can accommodate up to 8 persons.

8. Tent, house, ridge type, rectangular, 12sqm (approx 3 x 4m) (E50 880 04)

400g/sqm cotton or cotton/polyester canvas, water and rot proofed, natural, with ground strip and fly sheet. Centre height 2m, wall height 600mm with 150mm clearance between tent and fly sheet. Heavy duty sectional steel tube poles, plasticlad or galvanized. Complete with ropes, pegs, mallets, and patching kit, with loose, reinforced PVC groundsheet, minimum 250g/sqm. In packsack. Approx. weight 40kg. The standard family tent, available from a variety of suppliers worldwide. Can accommodate 6 camp beds. See notes for tent suppliers below.

Notes for tent suppliers

Tent specifications are to be understood as minimum in material weight and floor space. Only quality, heavy duty, finished tents must be offered. Canvas to be equally strong in warp and weft. Chemicals used for treatment of the canvas must not smell offensive; salamander flame retardant, rot and water proofing process, or equivalent. Sufficient iron or steel pegs and pins to be supplied to anchor tent and fly every 50cm (pegs 40cm, pins 15cm long). Stitching - machine stitched with extra strong, weatherproof thread. Ridges to be canvas or cotton tape reinforced. Cabs and taps strongly stitched at outer and inner ridge for upright poles. Eyelets must be non-ferrous. Hems to be wide enough to accept eyelets. Entrance fasteners, zippers, clips, ties to be of heavy duty, where applicable non-ferrous quality, flaps well overlapping, unless zippered. All openings for ventilation or windows to be protected with mosquito netting. Zippered door flaps to have spare ties sewn on, in case zipper breaks. Guy ropes to be equivalent in strength to 12mm sisal rope, ultra-violet stabilized. Wooden or bamboo poles are not acceptable. Lengths of pole sections not to exceed 1.5m. Mallet with 40cm handle (10cm diameter wooden or hard rubber head).

Tolerances: ground area plus 10% acceptable. Canvas weight plus 10% acceptable. Lightly dyed colours (olive, green, brown) might be acceptable but must be indicated on offers or stock reports.

Each tent to be packed and bundled with poles, accessories and hardware in single packsack.

Logistics control systems

1. The minimum level of controls necessary will vary with each operation. This annex gives an indication of the basic components of a system. Simple controls and accounting established from the start will be much more effective than a sophisticated system later. No system is likely to be effective unless it is understood by those required to work it. Specific training will generally be required for storekeepers.

Central controls

2. An overall control card should be kept for each order or consignment (including contributions in kind), on which is recorded all stages from the initial request for goods through, as applicable, requests for tenders, placing of order/notification of shipment, planned delivery time/place/ETA, actual delivery/arrival etc.

3. A simple state board where progress can be monitored visually is likely to be very useful and can be set up at once. An example is given on page 51.

The purchase order

4. This is the document that defines the order: specifications, number of units ordered, price/unit, total price, packaging, date of purchase, supplier, destination etc. It should make reference to the legally enforceable standard conditions of contract (the conditions under which UNHCR is willing to do business, which should have been part of the request for tenders - see UNHCR Procurement Manual).

At each warehouse/store

5. Whatever the size of the warehouse or store and wherever it may be located, the minimum recommended book-keeping controls are those outlined below. They must be complemented by routine inspection to ensure goods are properly stored and protected, and by a periodic audit.

(1) Supply note/Waybill. Accompanies goods from supplier in duplicate to enable warehouse staff to check against goods actually received. Duplicate copy used by procurement staff to verify goods dispatched against those ordered (i.e. against purchase order form). Where the movement is between warehouses e.g. regional to local, use (4).

(2) Store inwards ledger. Basic details of all inward consignments are recorded here: description of goods, quantity, supplier, name of person receiving and date of receipt, with cross reference to supply note.

(3) Stock card. One for each different item. This gives the complete history, being used to record every in and out movement with cross reference to appropriate ledger entry. Gives running balance. Where possible this should be maintained independently of those actually receiving and issuing the goods. An example is given on page 52.

(4) Requisition/Dispatch form. The authority for dispatch, with the requisition signed by authorized signatory and verified against list of authorized signatures held by storekeeper. An example is given on page 53.

(5) Store outwards ledger. Similar purpose to (2) for dispatches: at its simplest can be just the file of triplicates of (4).

Movement of goods

6. The easiest control to ensure that goods reach their destination may be to make (final) payment (for the goods, of the driver or transporter, as applicable) conditional on return of the receipted duplicate of the Supply Note/Waybill or the Requisition/Dispatch form. More comprehensive controls and measures (e.g. monitors) may be required later, and are anyway needed to ensure that goods reach their destination (in the worst case, this control only indicates that they did not). But provided the signatories for both requisition and receipt are carefully chosen, and signatures controlled (combining them with a UNHCR/stamp is recommended), this should be an effective initial safeguard.

Example of Logistics State Board (1)

Ref. No.	Carrier/ Supplier	Item	Quantity	Port of entry delivery point	ETA	Actual arrival/ delivery time	Final destination/remarks (2)
(e.g.: telex no. purchase order no.) Also include reference to file where full info. available	(ship's name, flight no., manufacturer/ transporter etc.)						

Notes:

(1) The columns should be modified as required by each emergency.

(2) Cross reference to Waybill or Dispatch form covering any onward movement. In some circumstances two state boards may be helpful, one as above, covering out-of-country supply; and one covering internal procurement and transport.

Example of
S T O C K C A R D
(maintained for each item)

INCOMING					OUTGOING					BALANCE		Remarks
Date	Ref.no.	Quantity	Units*	From	To	Date	Ref.no.	Quantity	Units	Quantity	Units	
	(of Supply note or Waybill)	e.g. 200 MT (grain) or 2000 pcs. (blankets)	*(record details of packing, e.g. sacks of 50kg. or bales of 50 pcs.)	not needed if always same			(of Dispatch form)					(short-falls, breakages, spoilage, unusual packing etc.)

Example of Requisition/Dispatch Form

Ref. No._____

Requisitioned by _____ Signature _____ Date _____

Destination _____

Goods	Quantity required	Quantity supplied	Quantity received	Remarks (discrepancies etc.)

Dispatched by _____ Signature _____ Date _____

Received by _____ Signature _____ Date _____

Raised in triplicate

Original and duplicate sent with goods. Original serves as supply note for records at destination. Duplicate returned receipted to place of dispatch and filed with triplicate, showing transaction complete. Triplicate retained and filed, forming 'stores outward ledger'.

Conversion factors

To convert from		To	Multiply by
Length			
Yards	(1 = 3ft = 36 inches)	Metres	0.9144
Metres	(1 = 100cm)	Yards	1.0936
Miles (1)	(1 = 1,760 yds)	Kilometres	1.609
Kilometres	(1 = 1,000m)	Miles	0.6214
Area			
Yards^2	(1 = 9ft^2)	Metres^2	0.836
Metres^2	(1 = 10,000cm^2)	Yards ^{2}	1.196
Acres	(1 = 4840 yd^2)	Hectares	0.405
Hectares	(ha, 1 = 100 ares = 10,000m^2)	Acres	2.471
Miles^2	(1 = 640 Acres)	Kilometres^2	2.590
Kilometres^2	(1 = 100 ha)	Miles^2	0.386
Volume			
US gallons		UK gallons	0.8327
UK gallons		US gallons	1.2009
US (UK) pints		Litres	0.473 (0.568)
Litres		US (UK) pints	2.113 (1.76)
US (UK) gallons (1 = 8 pints)		Litres	3.785 (4.546)
Metres^3 (1 = 1 x 10^{6}cm^3 = 1000 litres)		Yards^3	1.308
Yards^3 (1 = 27ft^3)		Metres^3	0.765
Weight			
Ounces (oz)		Grams (g)	28.35
Grams		Ounces	0.0353
Pounds (lb, 1 = 16oz)		Kilos	0.4536
Kilo (kg, 1 = 1,000g)		Pounds	2.205
US short tons (1 = 2,000lb)		Metric tons	0.907
US long tons (= UK tons, 1 = 20 hundredweight (CWT) = 2240lb)		Metric tons	1.016
Metric tons (MT, 1 = 1,000kg)		US short tons	1.102
		US long tons, UK tons	0.984
Temperature			
Centigrade		Fahrenheit	1.8 and add 32°
Fahrenheit		Centigrade	subtract 32° and multiply by 0.555

Weight of water (at 16.7°C, 62°F)

1 litre = 1kg; 1 US gal = 8.33lb; 1 UK gal = 10lb; 1ft^3 = 62.3lb

(1) Statute (land) miles. The international nautical mile = 6,076ft = 1.825km

CHAPTER 6: SITE SELECTION, PLANNING AND SHELTER

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6

Need

The lack of a suitable and well planned site and adequate shelter is common in the early stages of a refugee emergency. This can adversely affect the well-being of the refugees, and in some cases their protection, as well as the delivery of assistance.

Aim

To meet the need for suitable shelter and related buildings and services on an appropriate and properly planned site.

Principles of response

- ☐ Avoid high-density refugee camps.
- ☐ Involve the refugees, whose home it will be.
- ☐ Only select a site where the basic needs, especially for water, can be met.
- ☐ Site planning is essential, and should reflect a decentralized, small community approach, preserving past social arrangements as far as possible.
- ☐ Shelter must provide protection from the elements, space to live and a sense of home. Local materials and designs are best: take account of local standards.
- ☐ So-called temporary arrangements often come to last much longer than expected; thus a well planned response is necessary from the start.
- ☐ Site selection, planning and the provision of shelter require expertise and must be closely integrated with the planning of other services especially water and sanitation.

Action

- ☐ Assess the suitability of the refugee site and ensure that it meets the basic criteria.
- ☐ Simultaneously assess the need for emergency shelter and provide the necessary materials to meet immediate needs.
- ☐ Take the most urgently required measures to improve site planning and layout, and upgrade these as soon as possible.

6.1 Introduction

1. This chapter covers considerations relating to the site where the refugees live, the physical layout and organization of their community, and the shelter they need. These factors will have a major influence on the well-being of the refugees.

2. The need for somewhere to live is a corollary to the granting of asylum, and the role and responsibility of the national authorities in site selection is obvious, and of fundamental importance. Equally, the refugees themselves must be involved; ideally, the needs of the refugee community would determine the location, size and organization of the site where they live. In practice there has to be a compromise between these needs and external factors, both practical and political.

3. Land may be scarce in the country of asylum and no site may be available that meets the desired criteria. If, however, the present or intended site is clearly unsuitable, every effort must be made to move the refugees to a better site as quickly as possible. The problems which result both from a bad site and the difficulties inherent in a move increase with time.

4. The location of the refugees may range from spontaneous settlement over a wide area, through organized rural settlement, to concentration in a very limited area. Circumstances can make this last possibility unavoidable, but the establishment of refugee camps must be only a last resort. A solution that maintains and fosters the self-reliance of the refugees is always preferable.

5. The prospects for a durable solution must be taken into consideration. Protection or political considerations may also be important. If no durable solution is in sight, this must be recognised and the planning should assume a long stay. Unsatisfactory temporary arrangements can be hard to change once established.

6.2 Organization of response

- Site selection, planning and shelter have a major bearing on the provision of other assistance.
- This subject must therefore be considered as an essential part of an integrated approach to needs assessment and response.
- Expertise is necessary as is swift action for the co-ordinated planning of a new site or the improvement of existing conditions.

1. Site selection, planning and the provision of shelter have a direct bearing on the provision of other assistance and these will be important considerations in the overall assessment of needs and planning of response. Decisions must be taken as part of an integrated approach and in light of the advice of experts and views of the refugees.

2. Expertise may be required in the fields of geology, settlement, planning, engineering (for example, water supply, sanitation, construction), public health and perhaps social anthropology. Familiarity with local conditions in both the country of origin and asylum is important. Prior experience in similar emergency situations and a flexible approach are particularly valuable.

3. Expertise and advice should be sought from government, university or local industry sources, or from local offices of organizations such as UNDP, the World Bank, WHO, UNICEF and voluntary agencies. If necessary, Headquarters assistance should be requested.

4. Whenever possible, set up a task force at the site level of

all those concerned with planning the site (construction, water supply, sanitation etc.) and organizing its occupation. The task force should prepare a comprehensive plan of action.

5. The organization of the refugees' physical environment and level of services should be appropriate to the needs of the emergency and conditions in the country of asylum, while taking full account of both the traditions of the refugees and the special requirements as a result of the typically crowded and dependent circumstances of a refugee emergency. In the particular case of refugees who were normally nomadic, their own solutions are generally to be preferred, provided space and suitable materials are available and other considerations allow.

6. The following sections provide guidelines for advance site selection and planning, for example when refugees are to be transferred to a new location. In the first phase of an emergency, however, it is rare that this will be possible in practice. There may be little opportunity for advance planning, and the immediate priority will be action to improve existing sites.

7. There may be a need for reception or transit centres, through which the refugees pass en route to a longer-term settlement site. Many of the considerations set out in this chapter are also relevant to such temporary centres.

8. When a refugee influx is continuing, new sites must be identified and planned well in advance and the design capacity of existing settlements respected.

6.3 Criteria for site selection

In addition to considerations specific to the refugees and their background, criteria include water supply, topography and drainage, adequate surface area, security and protection, accessibility, environmental and soil conditions, vegetation, and land rights.

1. General: The social and cultural background of the refugees will be an important determinant of the most appropriate type of site, and must be a primary consideration whenever possible. However, in many circumstances choice will be limited and any land that meets even minimum standards may be scarce. In this regard, it may be wise to establish why the site was not already in use, and examine whether the reason - for example no water or because it floods in the monsoon - does not also exclude use by the refugees.

2. Water supply: The availability of an adequate amount of water on a year round basis has proved in practice to be the single most important criterion, and commonly the most problematic. A site should not be selected on the assumption that water can be acquired merely by drilling, digging, or hauling. Drilling may not be feasible and may not provide adequate water. No site should be selected where the hauling of water will be required over a long period. Professional assessment of water availability should be a prerequisite in selecting a site. More information on water is provided in chapter 9.

3. Topography and drainage: Where water is readily available, drainage often becomes the key criterion. The whole site should be located above flood level, preferably on a gently sloping area. Flat sites can present serious problems for the drainage of waste and storm water. If possible, the site should be a minimum of 3m above the water table: avoid marshes or areas likely to become marshy or soggy during the rainy season. The watershed of the area itself may be a consideration.

4. Surface area: The site must allow sufficient usable space for the refugees. WHO recommends 30 sq. metres per person, plus the necessary land for communal and agricultural activities and livestock, as a minimum overall calculating figure. Of this, $3.5m^2$ is the absolute minimum floor space per person in emergency shelter. The allocation of the other space between housing, communal services, roads etc. is discussed in the sections that follow. More refugees may arrive and the site selected should allow for a major expansion beyond the area theoretically required for present numbers.

5. Security and protection: Sites should be removed from the frontier and potential military targets in order to provide security and protection for the refugees, and to prevent hostile activities by the refugees against the authorities of their country of origin which would undermine the principle that the granting of asylum is not an unfriendly act. This criterion is specifically mentioned in Article II, paragraph 6 of the OAU Refugee Convention: "For reasons of security, countries of asylum shall, as far as possible, settle refugees at a reasonable distance from the frontier of their country of origin". Only where the interests of the refugees would be better served, for example if there are good prospects for early voluntary repatriation and security and protection considerations allow, should exceptions be made to this rule. Experience has, however, shown that the arguments in favour of settling refugees away from the frontier often increase with time. Therefore, when in doubt always locate or move the site away from the frontier.

6. Accessibility: The site must be accessible and therefore close to assured communications links, and preferably also to sources of the necessary supplies such as food, cooking fuel and shelter material. Proximity to national community services is desirable, particularly with regard to health care. There are generally advantages in choosing a site near a town, subject to consideration of possible friction between local inhabitants and refugees.

7. Environmental conditions: The area should be free of major environmental health hazards such as malaria, onchocerciasis (river blindness), schistosomiasis (bilharzia) or tsetse fly. Climatic conditions should be suitable the year round and careful account taken of seasonal variations: a suitable site in the dry season may be untenable in the rains. A daily breeze is an advantage, while emergency and temporary housing, especially tents, need shelter from high winds. As far as possible, refugees should not be settled in an area where the climate differs greatly from that to which they are accustomed. For example, settling refugees from malaria-free high ground in a marshy area where the disease is endemic can be disastrous.

8. Soil conditions: The soil should allow water absorption and the retention of human waste. Avoid excessively rocky or impermeable sites. If possible, select a site where the land is suitable at least for vegetable gardens and small-scale agriculture. Specific criteria for the selection of a suitable site for rural settlement are given in the UNHCR handbook "Planning rural settlements for refugees".

9. Vegetation: The site should have a good ground cover (grass, bushes, trees). Covering vegetation provides shade, and reduces erosion and dust. During construction care should be taken to do as little damage as possible to this vegetation and topsoil. If bulldozers are being used make sure the topsoil is not scraped off the whole site, as often occurs. If wood must be used, at least initially, as domestic cooking fuel,

this should not come from vegetation on the site. Alternative sources (and more efficient cookers) that will avoid irreplaceable loss of surrounding wood must be found as soon as possible.

10. Land rights: The land should be exempt from right of use by other people (ownership, grazing rights, etc.). This can be a major cause of local resentment, and there may be occasions when the authorities proposing the site are unaware of customary rights exercised by the local population. Often, sites are provided on public land by the government. Any use of private land must be based on formal legal arrangements in accordance with the laws of the country. UNHCR does not purchase land for refugees (see ch.12.8.1). If this is a problem, consult Headquarters at once.

6.4 Site planning: general considerations

- At the start of a refugee emergency the immediate provision of essential goods and services is generally more important than efforts to change the way people have already arranged themselves on a site.

- As soon as time and needs permit, or when refugees are to be moved to another site, site planning is essential.

- Site planning should start from the characteristics and needs of the individual family, and reflect the wishes of the community as much as possible.

- However, a refugee settlement is not a natural community and particular care will be required to ensure that special needs are met.

- The overall physical layout of a site as well as other aspects of site planning should reflect a decentralized community-based approach focusing on family, village or ethnic groups.

1. Site planning is necessary because the physical organization of a settlement can markedly affect the health and well-being of a community. The smaller the area available for a given number of refugees the greater the importance of site planning, though any site must be planned to allow the equitable, efficient and economic distribution of goods and services.

> Whatever the circumstances, the overriding aim must be to avoid artificial, high density, refugee camps.

2. Any refugees who are already present on the site will of course have arranged themselves in some way. Even if desirable, radical changes in their patterns of location may be a lesser priority than meeting the immediate need for services and relief goods. However, for new arrivals the layout must be carefully planned in advance. Once refugees are settled they will understandably resist movement of their houses. If the refugee leadership can be persuaded early on of the importance of planning, it should soon be possible for the refugees to take responsibility for the organization of new housing (demarcating plots etc.) within the designated areas, with the added advantage of releasing relief workers for more urgent tasks. Other site planning guidelines, for example on the layout of non-housing areas, can be more fully applied later. For a new site, comprehensive but swift planning is essential.

3. An important consideration in site planning is the layout preferred by the refugees and to which they are accustomed. For example, some communities may traditionally site their place of worship in the middle of their community, some may wish to have open space and common ground in the centre, others may

attach particular importance to communal meeting places and their siting, such as by water distribution points. Site planning should therefore be a locally-controlled exercise to the extent possible.

4. However, it must be recognized that the community's preferred layout will rarely be that which would allow the most expeditious delivery of outside emergency assistance, and that lack of space or of familiar materials will often necessitate some outside assistance. Furthermore, a refugee settlement is not a natural community. Circumstances force large groups of refugees to live together, often in limited space, with minimal resources and without their accustomed source of livelihood. For this reason, the regulating mechanisms of traditional communities may not work, at least initially. Refugee site planning requires special care to ensure that goods and services are equitably provided and communal responsibilities are met. Compromise solutions will be required to reconcile conflicting considerations. For example, there may be particular security problems or serious difficulties as a result of social disruption that can be lessened by organizing the housing, even when space is available, in more compact formations than is customary, thus allowing an important measure of self-policing by the refugees.

5. Outside assistance in site planning should start from the perspective of the needs, preferences, and traditions of the individual refugee family. Begin by considering the needs of the individual household, such as distance to water and latrines; the relationship to other members of the community (other relatives, clan, or ethnic groupings); and traditional housing and living arrangements. Developing the small community layout in this way, and then considering the larger issues of overall site layout, is likely to yield much better results than beginning with a preconception of the complete site layout and breaking it down into smaller communities, finally considering how the individual family fits into the scheme.

6. The social organization of the refugee population should be taken into consideration as much possible. Whether it is made up of extended families and/or clans, or nuclear families, whether the refugees come from urban or rural, village or nomadic backgrounds, are all factors that will influence the physical organization of a site. Initially, this information, which is part of the basic needs assessment described in chapter 3, should be gathered through discussions with the refugees and others knowledgeable about their society. A full socio-economic survey of the refugee population should be conducted once resources allow, and will be important in subsequent planning, particularly for self-sufficiency and durable solutions.

Organization and control

7. The greater the density of occupation that has to be imposed on a given site, the more important will be firm, co-ordinated control of its planning. A task force should be established of all concerned with construction, sanitation, water supply etc. and a plan of action drawn up. The aim of the plan should be to (1) encourage the refugees to help themselves; (2) reduce the hazards of density as far as possible (public health measures, fire control etc.); (3) facilitate control of the emergency operation and the delivery of assistance. Figure 6-1 overleaf shows some of the considerations for an ideal layout of a high density site; in practice compromises will have to be made to reconcile them.

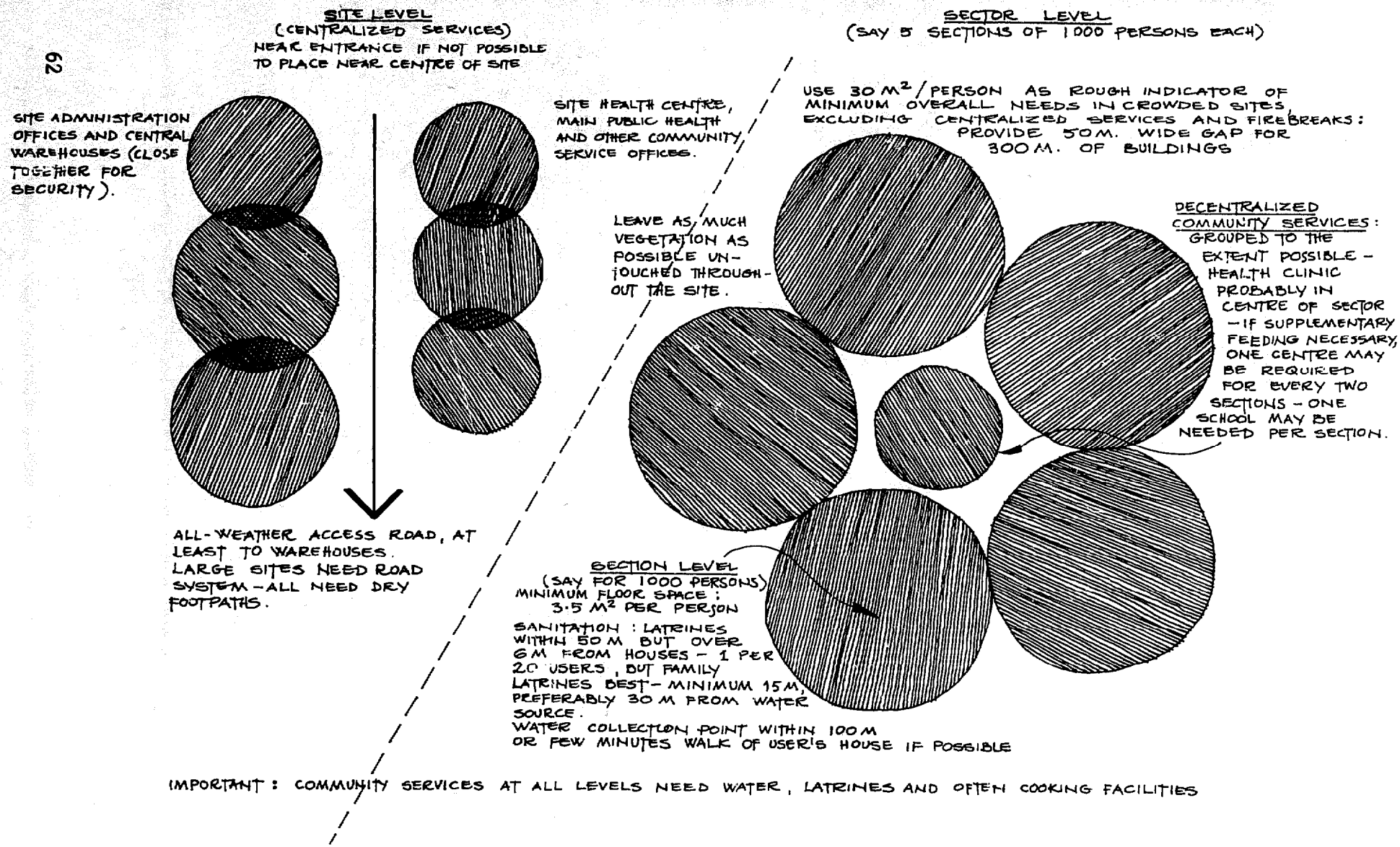

6-1 SOME CONSIDERATIONS WHEN PLANNING CROWDED SITES

8. Where space is extremely limited, control of the percentage allocated to different uses (housing; communal and administrative services; roads, firebreaks and open space) will be more important than calculations based on desired minima.

9. Together with the layout plan, there must be a plan setting out the timescale for completion and progressive occupation of the settlement by the refugees, whenever this is possible. It is particularly important that, having allowed space for expansion, including family reunion, this is safeguarded until really needed. Otherwise the initial settlement will occupy all the space, and major upheavals of existing arrangements will be necessary as more refugees arrive. Sections prepared in advance should be filled in an orderly manner and early arrivals should, of course, play a major part in the completion of the site. In some circumstances it may be possible to have an advance party of refugees assisting at the site from the start of work.

10. Provided sufficient land is available, the total number of refugees at each site should be determined by practical considerations rather than arbitrary limits. The importance of respecting this number, and having other sites ready for further new arrivals once it is reached, has already been stressed. Previous groupings should be maintained to the extent possible. Any hostile groups or factions among the refugees should be kept apart. Much more important than absolute size is the planning of the site to foster communities and a sense of family and small group identity.

11. Thus, as many services as possible should be provided at the small community level, for distinct family, village, ethnic or other groups, and with the convenience of the refugees as the criterion. Centralized and impersonal services should be avoided to the extent practicable.

6.5 Site planning: specific infrastructure design considerations

/ Under-estimation of space required for communal services is a common problem.

1. Sanitation: While water requirements often determine site selection, sanitation requirements often dictate site layout. If latrines are used, at least one should be provided for every 20 persons. They should be no further than 50 metres from any house, with the minimum distance from a house determined by the type of latrine and space available: as a guide, 6 metres. Sufficient space must be left for replacement latrines. If communal latrines are unavoidable, they should be accessible by road to facilitate maintenance. Latrines must not contaminate water sources. The site must also have an effective drainage system, which is easy to maintain and repair, both for rainwater and wastewater. (See chapter 10.)

2. Water supply: Where possible, the maximum distance between any house and a water distribution point should be 100 metres or no more than a few minutes' walk. Water will often be pumped from the source to an elevated point in order to allow gravity feed distribution. Planning of the site should take this into account. (See chapter 9.)

3. Roads: Some communities will not be accustomed to metalled roads but provision must be made to deliver the assistance. A site should have access and internal roads and pathways connecting the various areas and facilities. Roads should be above flood levels and have adequate drainage. If there has to be a significant amount of vehicle traffic on the site, it should be separated from pedestrian traffic.

4. Fire prevention: A firebreak (area with no buildings) 50 metres wide is recommended for approximately every 300 metres of built-up area. This will be an ideal vegetable growing or recreation area. If space allows, the distance between individual buildings should be great enough to prevent a collapsing burning building from touching adjacent buildings. The direction of any prevailing wind will be a consideration.

5. Administrative and community services: At the start of an emergency it may be difficult to foresee all the administrative and community services that are likely to be required. Where adequate space is available, free areas must be allocated for future expansion of these services. Underestimation of the space required for future communal needs is a common problem in sites of limited area. Buildings for administrative and community services should be traditional structures, if possible of a multipurpose design to facilitate alternative use, for example buildings for initial emergency services which could later be used as schools or other community facilities. The following list is of those administrative and community services which are often required; provision of the necessary space and buildings must be considered in site planning. The division is indicative only; the importance of maximum decentralization has already been stressed.

(1) Likely to be centralized

Site administrative office

Essential services co-ordination offices (health care, feeding programmes, water supply, education, etc.)

Warehousing and storage

Initial registration/health screening area

Tracing service

Therapeutic feeding centre (if required)

(2) Likely to be decentralized

Bathing and washing areas

Community services (health centres, social service centres, etc.)

Supplementary feeding centres (if required)

Education facilities

Institutional centres (for example, for the disabled and unaccompanied children, if required)

Recreation space

Physical layout

6. Even after taking due account of space availability, topography, preference, traditional living patterns and the specific design considerations, many different layouts are possible. The basic principle should be to organize the site into small community units or villages containing the decentralized community services mentioned above. These village units are in turn organized around the central core services. There are obvious advantages in a pattern that allows the addition of further units while preserving open space.

7. The location of the centralized services will depend on the specific situation and in particular on the space available. Again, the views of the refugees must be taken into account. Where sufficient space is available, there may be clear advantages in having the centralized services in the centre of the site. Where space is scarce, it may be better to have the centralized services located near the entrance to the site. In particular, this will avoid the trucks delivering supplies, etc. having to drive through a densely populated site,

with the attendant problems of dust, noise and danger to pedestrians, and even of drivers getting lost in a large site. If some form of closed camp is unavoidable, at least the centralized administrative services will probably have to be located near the entrance. Whatever the layout, the warehouses should be near the administrative office for reasons of security.

8. The linear or grid layout, with square or rectangular areas separated by parallel streets, has often been used but should be avoided if possible. It has the advantage of simplicity of design and speed of implementation, and allows a high population density. However, as has already been emphasized, environmental health problems and disease are directly proportional to population density. Furthermore a rigid grid design makes the creation of community identity difficult, as the refugees are not usually accustomed to living in such a pattern. Where space is very scarce, a broadly rectangular grid layout may be unavoidable, but should be adapted to the landscape, with variations in the shape of the basic community unit rectangle and flexibility in the layout of houses within the community unit.

6.6 Shelter

- Shelter must provide protection from the elements, space to live, privacy and emotional security.
- Provide blankets and clothing if necessary.
- Assess the adequacy of whatever emergency shelter arrangements refugees have already made themselves and meet immediate needs through provision of simple local materials. The first step is to put a roof over people's heads.
- Except for tents in certain circumstances, prefabricated or special emergency shelter has not proved to be a practical option on either cost or cultural grounds.
- Refugee housing must be culturally and socially appropriate and familiar. Suitable local materials are best if available.
- Individual family housing should be built whenever possible, unless multi-family units are traditional.
- Shelter must be suitable for the different seasons.
- Wherever possible, refugees should build their own housing, with the necessary organizational and material support.

General

1. Shelter must at a minimum provide protection from the elements, space to live and store belongings, privacy and emotional security. Shelter is likely to be one of the most important determinants of general living conditions and is often one of the largest items of non-recurring expenditure. While the basic need for shelter is similar in most emergencies, such considerations as the kind of housing needed, what materials and design are used, who constructs the housing and how long it must last will differ significantly in each situation.

2. Particularly in cold climates or where there are daily extremes in temperature, lack of adequate shelter and clothing can have a major adverse affect on health and nutritional status. Thus, in addition to shelter, provision when necessary of sufficient blankets, appropriate clothing and perhaps even heaters will be a high priority. (See chapter 5.)

3. To date neither pre-fabricated building systems nor specially developed emergency shelter units have proved effective in refugee emergencies. Reasons include inappropriateness, high unit cost, transport problems including cost, inflexibility and the fact that emergency shelter arrangements will have been made before these systems can arrive. For similar reasons, tents are often not an effective means of providing shelter. They are difficult to live in and provide little insulation from extremes of temperature. There are, however, circumstances in which tents may be useful and appropriate, for example when local materials are either not available at all or are only seasonally available or for refugees of nomadic background. The life of an erected tent depends on the climate; it may be as much as two years. Where tents are appropriate, repair materials should be provided to the occupants. A limited number of tents may also serve as transit accommodation while more appropriate shelter is constructed. Standard specifications for two types of tent are given in annex 1 to chapter 5.

4. The best way to meet emergency shelter needs is to provide the same materials or shelter as would be normally used by the refugees or the local population. Only if adequate quantities cannot be quickly obtained locally should emergency shelter material be brought into the country. The simplest structures, and labour-intensive building methods, are to be preferred. Care should be taken to treat traditional materials with preservative where this is necessary (e.g. against termites). Seek local advice on effective methods.

5. The design of shelter and more permanent housing should if possible provide for modification by the occupants to suit their individual needs.

Immediate action

6. The provision of shelter is a high priority, even when not essential to survival. Shelter must be available before other services can be developed properly. Immediate action should be taken to assess the adequacy of any arrangements already made, and to meet obvious short-comings through the provision of local materials, such as bamboo poles, thatch, rope, matting, wooden boards and timbers and perhaps metal roofing. This may be supplemented if necessary by canvas or plastic sheeting. Details of suitable plastic sheeting are given in annnex 1 to chapter 5. To the extent possible, emergency materials should allow re-use later in the construction of improved housing. Where local materials are in short supply or have a short life, consideration should be given to other, more permanent materials. If a continued high density of occupation is unavoidable, fire resistant materials may be indicated. (See ch.10.7.2)

7. The key to providing an adequate shelter is provision of a roof. If materials for a complete shelter cannot be provided, provision of adequate roof materials will be the priority, as walls can usually be made of earth or other materials found on site or locally available.

8. Some shelter may initially be found in national public buildings such as schools. This is, however, usually a very temporary solution, unsuited to large numbers and resented by the local population, and to be avoided if possible.

9. While different cultures have different minimum individual needs, WHO recommends a minimum usable floor space of 3.5 sq. metres per person in an emergency. Overcrowding is a common problem and has serious implications for health.

Improved shelter

10. Housing must meet the cultural and social requirements of a home. Appropriate housing will help reduce the disorientation and emotional stress suffered by refugees. To the extent possible, longer term housing must be similar in design and construction to that with which the refugees are familiar, while reflecting local conditions and practice. This will generally mean single-family shelters, unless the refugees are used to multi-family units. Although more costly, the benefits to the refugees of individual homes cannot be over-estimated. The risk of communicable diseases increases enormously in communal shelters. If multi-family shelters must be used, no more than 35 persons, say some seven families, should normally be assigned to any one structure. Experience has shown that there are likely to be social and environmental problems above this number, while buildings made from local materials may be approaching their structural limits at this size.

11. Materials and design should meet minimum technical standards for the different local seasons. Thus roof material may have to provide shelter from the sun, rain and snow and resist strong winds. Raised flooring may be required in areas of high rainfall.

12. Wall material must afford privacy and protection from the elements. Where the site lies in a hazard-prone area, for example subject to earthquakes or cyclones, the design of buildings and their siting should conform to the hazard-resistant criteria: consult the national authorities and UNDRO. In buildings where cleanliness and hygiene are particularly important, for example the kitchens of feeding centres or in hospitals, the floor should be cement or at least washable.

13. Even in an emergency, shelter, including communal buildings, can - and should almost always - be constructed by refugees themselves, provided adequate organization and material support is given. This will help to ensure that the housing will meet their particular needs, will reduce their sense of dependance, and can cut costs considerably.

Further references

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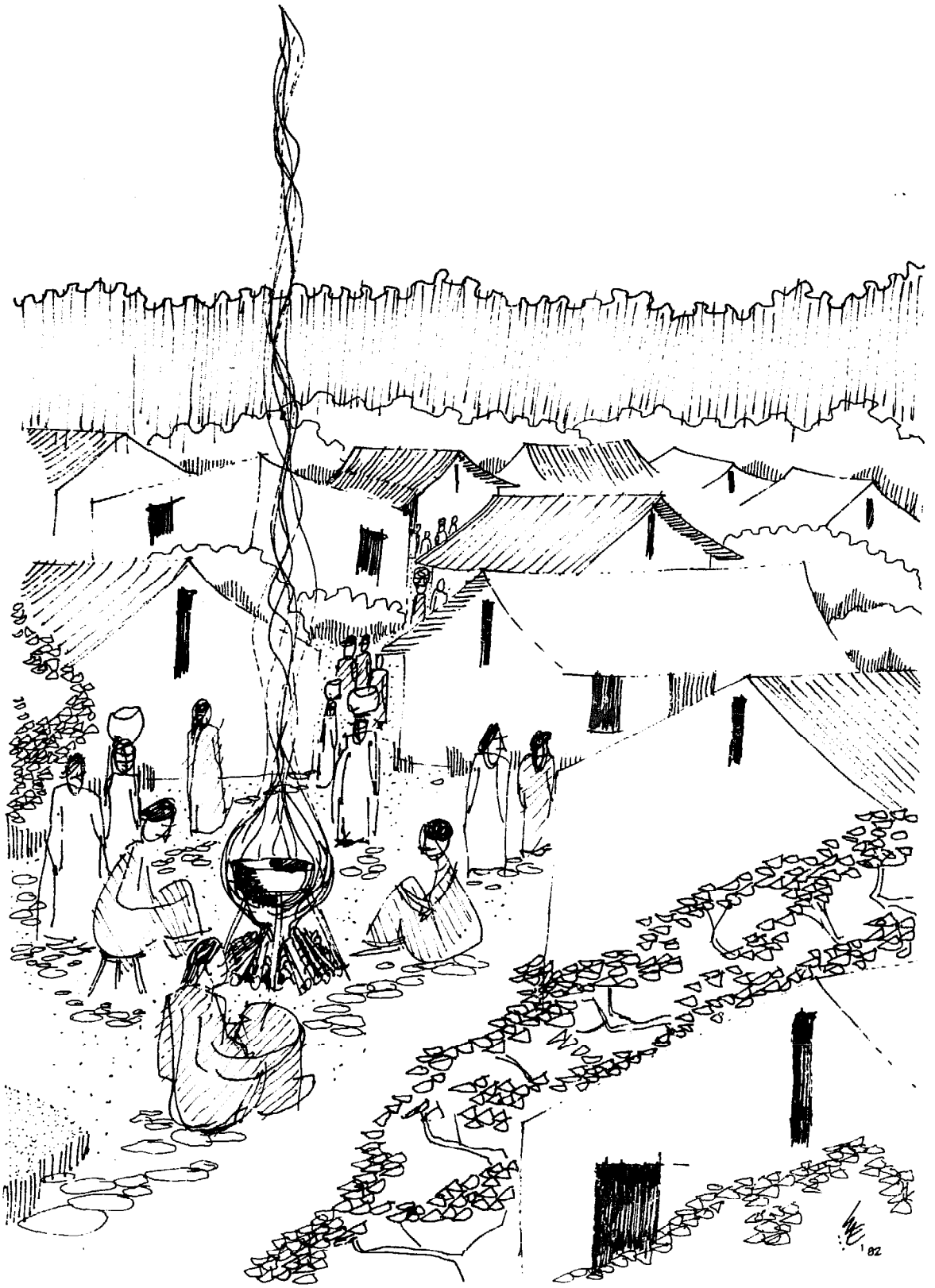

CHAPTER 7: HEALTH

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7

CHAPTER 7: HEALTH

Need

Refugees, particularly in an emergency, are exposed to many factors which increase the risks of disease. Typically, these factors include overcrowding, inadequate water, poor sanitation and inadequate food supply. Urgent measures are therefore required to minimize the effects of these hazards, ensure an appropriate level of health care and reduce the number of new cases of disease.

Aim

Through effective organization to promote good health and to prevent, control and treat disease.

Principles of response

- Refugees must be given responsibility for their own health and therefore be directly involved in the development and provision of health services.
- Health services should reflect actual needs as determined by proper assessment and surveillance.
- Priority should be given to nutrition and public health measures, as the health of the majority of the refugees is more likely to be affected by these measures than by individual care. Therefore a proper health strategy will go well beyond the scope of this chapter to include all sectors of assistance.
- A health co-ordinator should be appointed with responsibility for these measures and for ensuring standard and appropriate treatment and services, in close co-ordination with the national health authorities and other organizations.

Action

- Assess the health and nutritional status and environmental conditions in order to identify needs and establish priorities.
- In accordance with these priorities, set up a community-based health service with the necessary referral facilities.
- Monitor and evaluate the effectiveness of these actions and adjust them as necessary.

7.1 Introduction

1. Good health, depending as it does on so many non-medical factors, is too big a subject to be left only to doctors. This chapter is directed at the administrator. It does not pretend to give "medical answers" to health problems. It does however seek to show that good organization of public health and medical services, and an appropriate primary health strategy are more important to the overall health status of refugees than curative medicine alone. These crucial organizational factors are often the responsibility of the UNHCR field manager.

2. The conditions faced by many refugees do not favour good health. In an emergency, the dangers to the health of the refugees will often be increased because of poor shelter and overcrowding, lack of sufficient safe water, poor sanitation, inadequate or inappropriate food supplies and a possible lack of immunity to the diseases of the new environment. These factors heighten the risk of communicable diseases. Furthermore, on arrival the refugees may already be in a debilitated state from disease, malnutrition or fatigue.

3. The health services provided to the refugees should be based on the concept of primary health care. The general approach is summarized by WHO as follows. "Primary Health Care is essential health care made accessible to everyone in the country, care given in a way acceptable to individuals, families, and the community, since it requires their full participation; health care provided at a cost the community and the country can afford..... Though no single model is applicable everywhere, Primary Health Care should include the following: promotion of proper nutrition, an adequate supply of safe water; basic sanitation, maternal and child care, including family planning, appropriate treatment for common diseases and injuries; immunization against major infectious diseases, prevention and control of locally endemic diseases; education about common health problems and what can be done to prevent and control them." In other words, at the heart of such a strategy there is an emphasis on preventive, as against curative, care.

7.2 Organization of the health services

- The health services must be developed with not just for the refugees.
- Early emphasis should be on correcting environmental factors which adversely affect health.
- Early appointment of a suitably experienced health coordinator to UNHCR's staff is important.
- Outside assistance can be mobilized quickly, but the use and development of local expertise is preferable.
- The national health authorities and services must be as closely involved as possible.
- The World Health Organization must be closely involved.

1. At the start of an emergency, the first priority is to obtain information on the number of the refugees, their state of health and immediate needs, and an indication of their age/sex distribution. This information will help establish priorities for immediate action. These may well be the improvement of water and food supply rather than the provision of medical assistance.

2. The health services must aim, from the start, to prevent as well as cure illness: to make and keep the refugees healthy. The health of a community, and therefore of the majority of the refugees, is

generally more influenced by public health measures than by individual care. Only through preventive measures, combined with the control of communicable diseases, can good health be maintained and the number of new cases of disease be reduced. Safe water, environmental health measures, appropriate nutrition, communicable disease control, mother and child care, health education and training of the refugees are integral parts of refugee health care. Equally, the location of the site and the amount of individual living space will directly affect health. Figure 7-1 illustrates the likely relative impact of these measures.

3. The level of health care provided will be determined by the condition of the refugees and resources available. Extraordinary efforts may be necessary initially. Indeed in theory the peak of curative medical care should be at this early stage, when refugees are most vunerable to their new environment with the health hazards it poses, and before it has been possible to complete any major public health improvements in the sectors of housing, water supply and sanitation. In practice the medical staff often arrive later and begin to build up curative services at just the time when there is the possibility of dramatic improvement in the over-

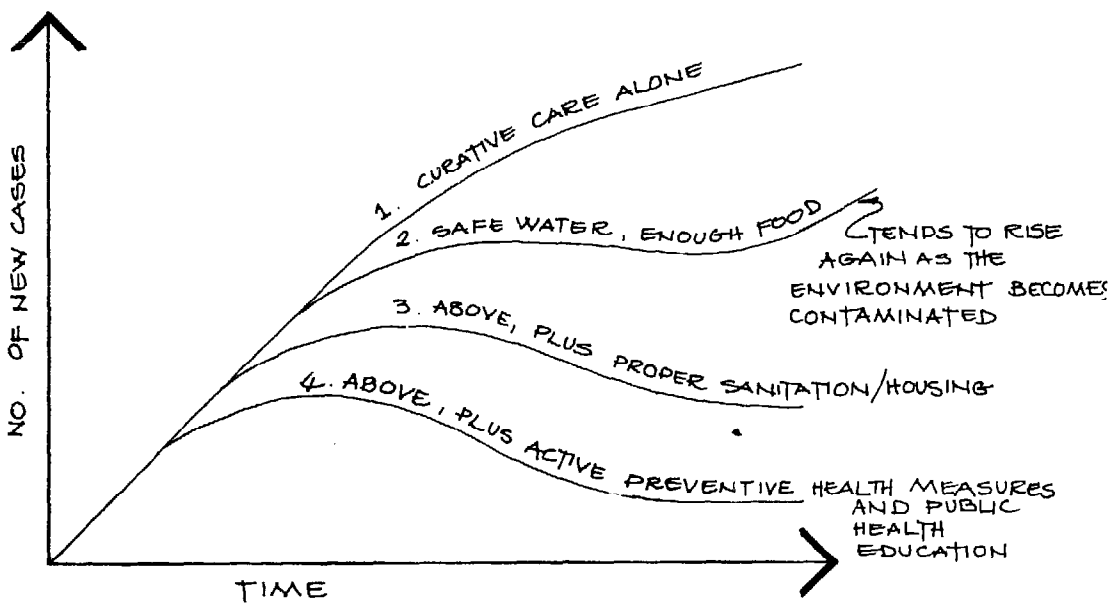

7-1 LIKELY RELATIVE IMPACT OF HEALTH MEASURES

all health status of the refugees if the emphasis is placed instead on preventive care. Once the immediate health problems are controlled the level of health care should broadly reflect what would be appropriate for the local population and must be one that can be maintained. Services and levels of care available to the refugees should be standardized.

4. Each refugee emergency will have its particular health needs and problems, and possibilities for response. The following broad headings cover considerations that are likely to be common: surveillance, reporting, control of communicable diseases and immunization, curative health care, the referral system, mother and child health, health education, medical supplies, and the personnel and organizational resources required to establish and operate the services, including the training of refugee health workers.

5. Community services such as curative health care, mother and child services, supplementary feeding programmes, social services, and health and nutrition education are clearly interrelated and must be co-ordinated. Circumstances will dictate how they should be arranged, for example whether around the health clinic or supplementary feeding centre. There are obvious advantages in grouping these services for the convenience of the refugees.

The refugees

6. The refugees must be given responsibility for their own health. Outside health workers must understand the refugees' own concepts of health and disease. From the beginning, services should be developed and operated with rather than for the refugees. If not, the services will be less effective, may be distrusted by the refugees, and are likely to collapse when key outside personnel leave.

Personnel needs

7. Strong emphasis should be placed on the training and upgrading of medical skills of selected refugees, particularly in their former roles within the community: full account should be taken of the experience of the traditional healers and midwives. Provided there is proper supervision and referral where necessary, experience has demonstrated the advantages of encouraging traditional methods of health care in parallel with the other organized health services. Refugees may seek traditional treatments for a variety of problems which are beyond the capacity of outside services.

8. Even refugees with no prior experience can be very effective health workers following basic on-the-spot instruction in a few relevant tasks. It should be borne in mind however that the educated young refugee who is frequently drawn into medical work may often not enjoy the full confidence of other refugees; also time invested in his or her training should be weighed against the fact that if there is any third country resettlement, such people are typically among the first to go.

9. As a general principle, the order of preference for selecting health personnel, in co-operation with the national services, is:

refugees;
experienced nationals or residents;
outsiders.

Most emergencies will require some combination of these sources. An important consideration may be the government's attitude to foreign medical personnel, including such matters as the recognition of qualifications and authority to practice medicine.

10. In major emergencies, UNHCR will immediately seek the assistance of WHO in identifying a health co-ordinator, who will be a

key member of the UNHCR Representative's programme staff. The co-ordinator would be responsible for planning and developing appropriate health care programmes, establishing standards (see 7.2.18), monitoring the quality of the services and ensuring proper liaison and co-ordination with the health ministry and with other international organizations on health matters. Particular attention should be paid to the co-ordination of the activities of NGO and other non-national health teams. The creation of a health sub-committee within the overall NGO co-ordinating mechanism should be encouraged.

11. If outside medical assistance is required, Headquarters must be informed. Besides WHO, sources include the International Red Cross, (the ICRC can field medical teams at short notice and the local Red Cross/Crescent, which should anyway be involved from the start, can be strengthened through the LRCS, and, in case of war, through ICRC), governmental disaster organizations, and NGOs. Indications of suitable sources should be given by the Representative, for example an NGO already working in the country might be able to expand its health programme.

12. Any requests should be for specific types of health workers: not simply for so many doctors and nurses, but, for example, for staff with relevant experience as general practitioners, epidemiologists, or as specialists in public health, nutrition, tropical medicine, paediatrics, midwifery and health visiting, depending on priority problem areas. Experienced personnel with the right personality are more important than highly trained specialists, whose skills are often inappropriate. Familiarity with the local culture, patterns of disease, and the public health services is as important as an advanced knowledge of medicine and medical techniques.

13. A particular requirement in a large emergency may be for a pharmacist, to co-ordinate all aspects of the provision of appropriate medical supplies (see 7.7). There may also be a need for an experienced health administrator, for example, to organize a vaccination campaign.

14. For international health workers three months is considered the absolute minimum period of stay for those with prior experience of refugee emergencies, and six months the minimum for others.

The national health authorities

15. Whatever the implementing arrangements, early involvement of the government's central, provincial and district health services is essential. To the extent possible, the services to the refugees should be integrated with national services. Direct co-ordination of certain treatment, immunization, communicable disease control and surveillance practices will be particularly important. Promoting the good health of the refugees is clearly in the interest of the local population.

Role of the World Health Organization (WHO)

16. There are WHO representatives 1/ in almost every country working directly with the health ministry. For normal operational matters in their country, they depend on the WHO Regional Director, while for emergencies they may deal directly with both their Regional Offices and WHO Headquarters. Because the major focus of its work is health programme development WHO has only limited financial resources available in a

1/ Called either WPC (WHO Programme Co-ordinators) or NPC (WHO National Programme Co-ordinators).

refugee emergency, but is able to provide advice and guidance, mobilize specialists and, through its Supply Services in Geneva and certain emergency regional stocks, provide urgently needed medicaments and supplies with UNHCR funds. The response to the health needs of the refugees should be closely co-ordinated with WHO.

Organization of response

17. A possible hierarchy of health services is outlined in figure 7-2 overleaf. It assumes a large-scale emergency which engages a very large number of health personnel, both national and international. A smaller influx will require fewer levels of organization. In such cases one health administrator in the capital can service a team which is otherwise exlusively deployed in the settlements and in reinforcing existing local health facilities. The indication of numbers of staff needed as a ratio of the caseload is no more than that, an indication. Actual numbers will depend on the health needs, the degree of isolation of the settlements and so on. There is often a minimum staffing need as even in a small settlement it is sometimes difficult to get by with less than two senior health workers.

18. Once the pattern of disease and overall needs have been determined, guidelines on standard procedures for health workers should be prepared. These should cover all aspects of the services, including such subjects as the basic principles, how the services are to be organized, including any selective feeding programmes, standardized treatment schedules, drug lists and supply, vaccination and reporting. The guidelines should be prepared by the UNHCR health co-ordinator in consultation with all concerned, issued under the aegis of the health ministry if possible, and reviewed periodically, for example by a health co-ordination sub-committee. The guidelines should be translated into the language of the community health workers. All organizations providing health care to the refugees should be required to observe the guidelines, which should also specify the minimum period of stay for international health workers. An example of such guidelines is listed in the further references at the end of this chapter.

7.3 Health assessment and surveillance

- An assessment of the health and nutritional status is an essential start to the provision of health services.
- This must be done by experts with experience of emergencies and, if possible, local knowledge.
- The factors affecting the health of the refugees must be identified and a surveillance and reporting system established.

Initial assessment

1. The aim of the initial health and nutritional assessment is to identify needs and establish priorities. The factors contributing to health or disease in the refugee community must be determined by establishing the pattern of disease, the effect of the cultural and social influences on the refugees' health, and the effectiveness of any existing health services. This assessment is called epidemiology.

2. Much information can be collected by observation, for example on the adequacy of the water supply and sanitation. Health workers are an obvious further source of information. Sample surveys will reveal symptoms and disease patterns and indicate distribution in the community. Where possible, mass screening on arrival is the most effective method of initial assessment. At least at first, many sick refugees will be unaware or shy of the health services.

7-2 - Possible organization of health services in a major emergency

Unit/Location		Health staff	Outline of major responsibilities
Refugee Health Unit (with Ministry of Health if possible or as part of UNHCR programme team). Health Co-ordinating Committee with NGOs	Capital/National level	UNHCR Health Co-ordinator Health professionals Nutritionist Pharmacist Health Administrator	- Planning and implementing programmes - Preparation of guidelines on standard procedures - Overall co-ordination and supervision - Procurement and supply of drugs and equipment
Regional/district Hospital	Regional level	If necessary: say, 1 doctor, 2 nurses to help existing staff (plus material support if required, especially drugs)	- Complicated maternity cases and surgical emergencies on referral from settlement
Health Centre (with limited beds for overnight stay, say, 1/5,000 refugees)	Each refugee settlement	Say, 2 doctors, 8-10 nurses/20,000 refugees (of whom 1 doctor in centre and 1 covering sector level, plus 1 nurse/sector)	- Supervision of settlement health services including training health workers and any selective feeding programmes - Treatment/referral of cases not handled at sector level - Security, distribution and use of drugs
1 clinic for each sector of, say, 5,000 refugees	Sector level	Say, 1 nurse (from above) and 2-3 refugee or national health workers per sector	- Sector level services, both preventive and curative - supervision of outreach services
The community	Outreach services (organized by section of, say, 1,000 refugees)	Refugee community health workers	- Identification of public and individual health and nutritional problems, treating simple, referring more difficult cases - Home visiting - Mother and child care - Basic surveillance and health education

Therefore an initial screening, in the rare cases when the relief workers arrive at a site before the refugees, may be the only early chance to reach some potential patients. This can be done at the same time as the registration on arrival. (See ch.12.6.7) Health workers should make a quick examination checking in particular for communicable diseases. They should refer any sick person for treatment; it is usually impractical to try to give treatment in the screening line itself.

3. A swift response is vital, but to be effective the initial assessment should be made by one or more experienced persons with an understanding of epidemiology. Relevant practical experience is important. There are obvious advantages in using national or locally-based personnel, but appropriate outside expertise can be made available quickly and should be requested through Headquarters if necessary.

4. Figure 7-3 overleaf illustrates some management considerations for action in light of the initial assessment.

Surveillance

5. A surveillance system must be established quickly. Careful and controlled monitoring of health and nutritional status is essential if problems are to be identified in time for preventive action. As an example, the incidence of diarrhoeal diseases may be an important pointer to environmental problems. Although the health status of the settlement should improve as public health services start to function adequately and the refugees adjust to their new environment, seasonal variations in the incidence of disease will remain because changes in temperature, and the rainy season in particular, will have an impact on health. So a vigilant surveillance system must be maintained. Continued monitoring of the health status and disease patterns will allow the health services to be adjusted and resources reallocated as necessary. The form of this surveillance, the data required, who will interpret it and how to ensure action on the results will be matters for early, and expert, decision. Only simple arrangements are effective in emergencies. The system should be centrally co-ordinated.

6. If the initial assessment or subsequent reports indicate specific deficiencies or communicable diseases, special measures must be taken to organize specific surveys by persons with appropriate experience.

Records and reporting

7. Records take two forms: on individuals and on the community as a whole. The purpose of each is different. Individual record cards will be needed for recording immunizations and the treatment of illnesses. These cards should usually be kept by the refugees and in the case of young children by the mother. Experience has shown that the cards will generally be well cared for. Community reporting has a different purpose. It is an essential tool for the planning of services and the monitoring of disease patterns. Statistical data on the numbers of cases identified and treated should be regularly collected and analysed. A simple standard reporting form is suggested in annex 1. This will ensure standardized reporting from different settlements. National health authorities require specified "notifiable" communicable diseases to be reported at once.

Laboratory services

8. To be fully effective, surveillance requires rapid access to laboratory services, but the refugees are often remote from such facilities. This is a problem that should be raised with the national health authorities at an early stage. Very simple laboratory ser-

7-3 ASSESSMENT AND RESPONSE

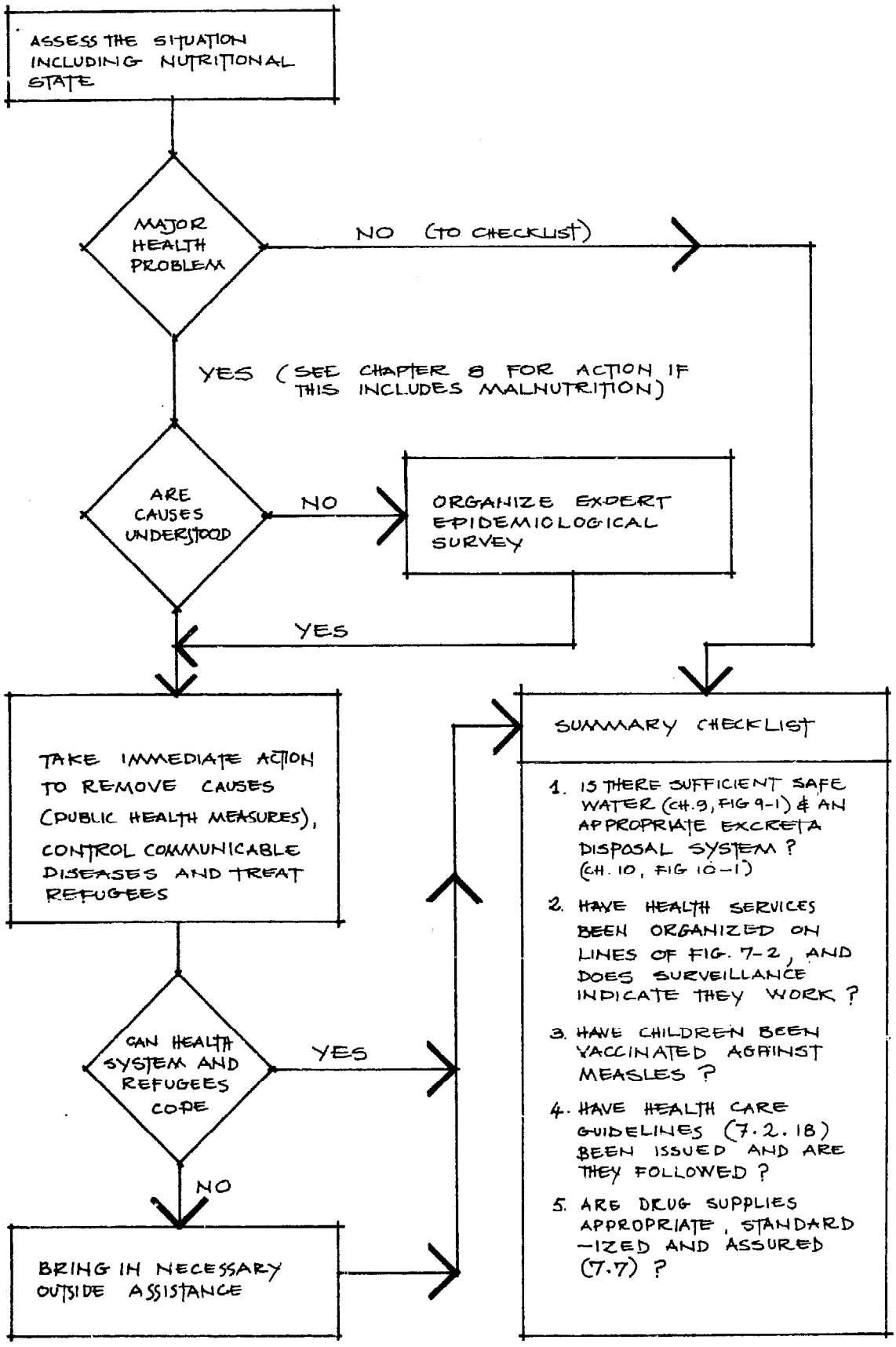

vices at the site level are usually adequate.

7.4 Disease control

- The conditions likely to be encountered, particularly overcrowding, will encourage the spread of communicable diseases.
- The aim is to prevent, detect, control and treat disease.
- Improvement in environmental conditions will play a major role in prevention.
- Avoid mass immunization in the emergency phase, except against measles.
- After the emergency phase, children should be immunized within the framework of the national immunization programme.
- Specifically medical emergencies such as epidemics require an immediate on-the-spot expert assessment and close co-ordination of the response with the national authorities and WHO.

1. The risks of communicable (infectious) diseases are increased in a refugee emergency by overcrowding and poor environmental conditions and often further exacerbated by the debilitated state of the refugees. There is, for example, a close association between malnutrition and the effects of communicable disease, particularly childhood diarrhoea. It is however, important to realize that the infectious organism has to be present to spread: for example, if no one is carrying typhoid, it will not suddenly appear.

2. Measures to improve environmental health conditions are therefore very important: enough safe water, soap proper disposal of excreta and garbage, rodent and vector control and general public health education and awareness.

3. Expert advice is essential for communicable disease control and the management of epidemics. Some communicable diseases have a seasonal pattern and timely preventive measures must be taken.

Immunization

4. There is often considerable pressure for an immediate mass immunization programme. There are strong reasons, both medical and practical, why this should be resisted. The most common causes of disease and death in the emergency phase are generally infections, often aggravated by malnutrition, that cannot be effectively prevented by immunization. Mass immunization programmes require large numbers of workers, the handling of vaccine in controlled refrigerated conditions and careful supervision, all of which are difficult, and not necessarily the best use of resources even when these are available.

5. The only immunization indicated in the early weeks of an emergency is of young children against measles. This is a high priority even when resources are scarce.

6. All other necessary immunizations (for example, DPT, Polio and BCG) should usually only be given later once facilities allow, and to the extent possible within the framework of the government's own expanded programme of immunization (EPI). Details of immunization schedules and vaccine storage are given in annex 2.

Common diseases

7. The most commonly occurring symptoms and diseases among refugees are generally not far removed from those normally to be expected in any community in a developing country. diarrhoea, nutritional deficiencies, respiratory infections, malaria, worms, anaemia and genito-urinary problems. However

the artificial crowded conditions are likely, at least initially, to cause a higher than normal incidence of these diseases. In particular diarrhoea, as a consequence of a new environment, unfamiliar density of population and poor environmental services, usually poses the major threat to refugee health in the first weeks of a settlement's life. It remains a major risk should there be a sudden deterioration in some aspect of the communal services, such as contamination of the water supply. The more common of these diseases are outlined in table 7-4 below which illustrates the environmental impact on disease and indicates those improvements in living conditions which will bear directly on the health of the refugees.

7-4 Common diseases

Disease	Major contributing factors	Preventive measures (1)
1. Diarrhoeal diseases	Overcrowding, contamination of water and food.	Adequate living space, public health education, good personal and food hygiene, safe water supply and sanitation as specified in chapters 6-10.
2. Measles	Overcrowding.	Minimum living space standards as defined in chapter 6. Immunization of children 9 mths to 5 yrs.
3. Respiratory diseases	Poor housing, lack of blankets and clothing.	Minimum living space standards and proper shelter (chapter 6), adequate clothing, sufficient blankets.
4. Malaria	New environment with a strain to which the refugees are not immune. Stagnant water which becomes a breeding area for mosquitoes.	Destroying mosquito breeding places, larva and adult mosquitoes by spraying. However the success of vector control is dependent on particular mosquito habits and local experts must be consulted. (See ch.10) Provision of mosquito nets. Drug prophylaxis only for those (e.g. young children) who otherwise might die on first attack, rather than start to develop immunity.

(1) Malnutrition increases vulnerability to serious attacks of all these illnesses; proper feeding is thus effectively a preventive measure.

Disease	Major contributing factors (1)	Preventive measures (1)
5. Meningococcal meningitis	Overcrowding in areas where disease is endemic (often has local seasonal pattern).	Minimum living space standards (chapter 6). Immunization only after expert advice when surveys suggest necessity. Immunity is only achieved after a week.
6. Tuberculosis	Overcrowding.	Minimum living space standards (chapter 6) but where endemic will remain a problem.
7. Typhoid and cholera	Overcrowding. Poor personal hygiene, contaminated water supply, inadequate sanitation.	Minimum living space standards, safe water, proper sanitation (chapters 6, 9 and 10). WHO does not recommend vaccination; it offers only low, short-term individual protection and little or no protection against the spread of the disease. Good personal, food and public hygiene and public health education are the most effective measures.
8. Worms especially hookworms	Overcrowding. Poor sanitation.	Minimum living space standards, proper sanitation (chapters 6 and 10). Good personal hygiene. The wearing of shoes.
9. Scabies (skin disease caused by burrowing mites)	Overcrowding. Poor personal hygiene.	Minimum living space standards, enough water and soap for washing (chapters 6 and 9).
10. Xerophthalmia (child blindness)	Vitamin A deficiency. (Xerophthalmia is often precipitated by measles or other acute infections.)	Adequate dietary intake of vitamin A. If not available, provide vitamin A fortified food. If this is not possible, vitamin A capsules. Immunization against measles.
11. Anaemia	Malaria, hookworm, poor absorption or insufficient intake of iron and folate.	Prevention/treatment of contributory disease. Correction of diet inluding food fortification.
12. Tetanus	Injuries to unimmunized population. Poor obstetrical practice causes neo-natal tetanus.	Good first aid, immunization of pregnant women and subsequent general immunization within EPI. Training of midwives and clean ligatures, scissors, razors etc.

7.5 Refugee health care

- Diagnostic techniques and the treatment of the major acute diseases should be simplified, standardized and appropriate.

- Most health problems do not need sophisticated care or treatment and should be provided through health centres and clinics within the community, and to the extent possible, by health workers from the community.

- Health workers must spend time among the community, not simply wait in clinics for sick persons to come to them.

- Pregnant and lactating women and young children are vulnerable and special attention must be given to their needs.

1. Refugee health care must embrace both preventive and curative measures. The need for and scope of the latter will vary with each emergency and will depend on the degree of prevention achieved.

2. Particularly where several organizations are involved, close attention must be paid to ensuring a common standard of appropriate health care and a fair distribution of available services both within and among sites. Opinion as to treatment can vary; thus centrally developed and clearly understood standardized treatment schedules are essential, and will also be of great importance to the training programme and in avoiding confusion among local and refugee health workers. Hence the importance of the guidelines described in 7.2.18. Where qualified personnel are scarce and confirmed diagnosis not possible, the standard treatment should be given for the presenting symptoms. Unless treatment is administered on the spot, clear oral and written guidance on dosage and schedule must be given to each patient in his or her language.

3. All concerned should be aware that treatment inappropriate to the needs and circumstances may not only be useless and wasteful, but can have an important negative effect on the refugees' attitude to health care and preventive measures. Examples are the fostering of the belief that only injections, rather than tablets, are effective, that intravenous fluids are better than oral rehydration, or that imported milk rather than breast-feeding can save the malnourished baby.

Triage

4. This is the selection and classification of the sick and wounded patients for attention in the face of overwhelming needs and insufficient resources. The aim is to provide priority assistance to those most likely to benefit. While it is a likely requirement after a severe natural disaster or in times of conflict, triage is rarely necessary in refugee emergencies. If there is a need for triage, classification is usually by three categories: those who cannot benefit from the treatment available under the emergency conditions and are therefore not treated, the seriously ill or injured, who should be attended to first; and those who, after initial first aid, can wait for medical attention until after the second category. The selections must be made by the most experienced health worker available but the administrator may well need to impress on the health staff the vital importance of a triage system.

5. In many emergencies some 75-90% of patients present with minor ailments, which in most cases will cure spontaneously. These patients should not be treated at all during emergencies if, as is likely, resources are scarce. Public health measures will probably reduce the incidence of such minor ailments.

The provision of health care

6. The refugees must have easy access to appropriate treatment. If the local national health facilities cannot be strengthened to meet the needs, alternative arrangements will be required. Unless treatment is provided at the right level, the hospitals or major health centres will be swamped by refugees demanding treatment for simple conditions. Thus what is required is a community-based health service that both identifies those in need of health care and ensures that this is provided at the appropriate level. Close co-ordination with other community services is essential.

7. The first level is therefore the community health worker, responsible for a section of the refugees and working among them, home visiting, case finding and following up, and responsible for the basic community-wide preventive measures, including public health education. The community health worker, who should be a refugee, with the appropriate training, would identify health and nutritional - and often social - problems and if simple on-the-spot treatment was not possible, refer patients to the clinic. Refugees will, of course, also present directly at the clinic but it is important to realize that some of those most in need will not go to the clinic, and that the diseases of those who do may not reflect the most common problems in the community.

8. As a general guide, one clinic might be appropriate for every 5,000 refugees in crowded conditions but otherwise in reasonably good health. This should be a simple building with facilities for consultation, clinical procedures such as dressings and injections, a small lock-up pharmacy, simple equipment and sterilization facilities (electricity may not be available). Water and sanitation are essential services at all health facilities.

9. In support of the clinics, there should be a health centre for each refugee settlement. Very large settlements may require more than one, while for small settlements, a single health centre/clinic may suffice. The health centre should be able to handle all but the most complicated maternity cases and surgical emergencies. More facilities should be available than at the clinics, including basic laboratory services and a few beds for overnight observation, perhaps in the order of one per 5,000 refugees.

10. An indication of the numbers of health staff required is given in figure 7-2 on page 76. Referral of the relatively few cases that cannot be treated at the health centre level is covered in the next section (7.6).

Mother and child health

11. In a normal community, children, especially those under five, and pregnant and lactating women are recognized as being vulnerable to malnutrition, infection and other health problems. In a refugee emergency the risks are greatly increased and health services should provide particular care and supervision for these women and children. This should be integrated with any supplementary feeding programme. Details of this, and important information on correct infant feeding, are given in chapter 8.

12. As soon as schools are established, special health programmes should be arranged for the pupils.

13. The need for and nature of dental programmes should be considered once resources allow. The promotion of oral hygiene and preventive dental treatment is of greater benefit than individual dental work. The use of simple traditional methods such as chew sticks and tooth picks is more appropriate than the introduction of tooth paste and brushes.

14. Family planning information should be available. After proper education suitable temporary methods of contraception (child spacing) should be provided on a voluntary basis ensuring that the refugees understand their free choice in the matter.

Health education

15. The importance of health education is perhaps more widely recognized than are the difficulties in persuading those most at risk to change long-established habits, however compelling the case for such a change may appear to outsiders. At least in the emergency phase, the priority topics should be those directly related to the immediate public health problems, for example the disposal of human excreta and refuse. Many governments and organizations produce simple health education materials that may be useful. Trained teachers and respected elders from the refugee community are likely to be more effective than outsiders in communicating the basic principles and practices of health to their own people.

7.6 Referral services

- The health centre must be able to refer patients to hospitals for treatment.
- This treatment should be made available in local hospitals if possible.
- Arrangements must be made to provide suitable transport to and from the hospital.

1. In order to ensure that patients who cannot be cared for or treated at the site health centre receive the necessary attention, an effective referral system to a hospital or rehabilitation institute is required. Unless there are large numbers of injured, once settlement health services have been established the numbers of such patients should not be high. Arrangements must be such that only those specifically referred from the health centres are seen, with no refugees presenting themselves directly to the hospital.

2. At least in the emergency phase, such referrals should only be to save lives.

3. Referral to the nearest national hospital should be the aim; this has obvious advantages, not least that of immediate availability. Close and direct co-ordination with the district medical officer is essential. The possibility of expanding the existing hospital(s), for example with tents in the grounds and additional health personnel, should be considered. Care must be taken not to swamp the hospital. Facilities at the hospital must also provide for the needs of relatives and allow parents to be with young children. Financial and material support should be provided as necessary. For example, if Emergency Health Kits (see 7.7) are dispatched some of the drugs might be placed at the disposal of the hospital treating refugees.

4. Special refugee hospitals should be avoided if at all possible. They are skilled-labour intensive but provide only curative services, can rarely continue to be properly run once outside support is withdrawn, and are in any event unlikely to be appropriate to the longer-term needs. Once established they are extremely difficult to close. Thus such hospitals should only be provided if a clear and continuing need exists that cannot be met by existing or strengthened national hospitals. Where such a hospital is unavoidable priority consideration should be given to the local construction of a simple appropriate structure, to be staffed and equipped to a level determined by the local pattern of disease and likely demand rather than a theoretically possible need for highly specialized treatment. From the start, planning of such a hospital

must take account of environmental factors such as sanitation, the disposal of hospital waste, security of drugs and supplies, and the provision of latrines. Hospital floors should be solid, washable and well-drained.

5. The number of hospital beds required will depend on the state of health of the refugees. As an indication only, one bed might be required per 2,000 refugees in the early stages of an emergency. Again as an indication only, a refugee hospital with 50 beds might require two doctors and six nurses plus auxiliary support.

6. Field hospitals may be offered. While this is an alternative to be considered in certain circumstances, for example a major expansion of a local hospital through a field hospital in the grounds, field hospitals may have several limitations including delays in establishment and cost (especially transport), and can be technologically inappropriate. Often over-sensitive equipment or equipment dependant on outside sources of power cannot be made to work. A field hospital is rarely a satisfactory way of meeting a continuing need. It should also be recognized that because of their great public relations value, donors encourage such hospitals even when unsuitable.

7. Refugee emergencies are not usually characterized by large numbers of injured. However, when this is the case there may be an initial requirement for the rapid deployment of a surgical unit. Such a need will generally be self-evident, and such units are normally quickly available, for example through ICRC.

8. Whatever arrangements are made for hospital treatment and referral, suitable transport must be available.

7.7 Medical supplies

- Drugs should be limited to a few basic standardized items.
- Special emergency kits have been developed on this principle for immediate needs and should be requested if local sources are inadequate.
- Vaccine requires careful handling. It should be obtained locally against subsequent replenishment if possible.
- Unsolicited medical supplies are often unsuitable and should be subject to clearance prior to dispatch.

1. Emergency supply arrangements should draw on in-country resources and distribution channels to the extent possible. However, initially special arrangements may be necessary. Unplanned response can lead to long and inappropriate requests, often by brand rather than generic names. Experience has shown that what is needed are adequate quantities of a few basic drugs and a strict control of unsolicited donations. WHO and UNHCR have drawn up standard lists of drugs and equipment for use in emergencies to meet this requirement. The lists cover some 30 basic drugs/preparations for use by health workers, some 35 drugs/preparations for use by doctors and senior health workers, and basic medical equipment. Together they comprise the contents of the Emergency Health Kit. The lists should be amended as necessary in light of local conditions, using only drugs in the current report of the WHO Expert Committee on the Selection of Essential drugs (see page 88), and then adopted as the standard medical supplies for health care in the emergency.

2. When local sources cannot meet the initial demand for medical supplies, the Emergency Health Kit can be obtained in prepacked form at short notice. One kit

theoretically covers the needs of 10,000 refugees for three months. Details of the kit and a number of related practical considerations are given in Part 2 and are also available separately from UNHCR and WHO (see page 88). As soon as Representatives, in consultation with the local health authorities, WHO and the operational partner, consider that the kits may be required they should cable a request giving details, including the number of kits needed and destination. The fact that one kit can effectively cover the needs of 30,000 for one month as well as 10,000 persons for three months should be borne in mind when considering the number of kits needed. Attention is also drawn to the UNIPAC catalogue which contains certain specialized kits (e.g. midwifery).

3. Once immediate material needs are assured, arrangements should be made by the operational partner responsible for health services to the refugees for a regular supply of appropriate quantities of the standard medical supplies. These are generally available locally and this is the preferred source, but if necessary, consideration should be given to bulk ordering abroad, as substantial savings may be possible. It should be noted that the Emergency Health Kits are intended to meet initial needs only, pending these arrangements, and not for resupply. Re-ordering procedures should be standardized and centralized. In a major emergency this will be a full-time task for a pharmacist. Requests for overseas procurement should be made through, or co-ordinated with, Headquarters, who in turn will maintain close co-ordination with WHO, UNICEF, ICRC, LRCS and other potential suppliers or donors to avoid duplication.

4. When necessary vaccine should be borrowed from local stocks if available, against subsequent replenishment. The WHO Representative or medical co-ordinator will advise on this and also on any regional availability of WHO stocks (for example, in Africa there are stocks in the WHO stores at Brazzaville, Dakar, Kinshasa, Nairobi and Niamey). If it is apparent that immediate overseas supply is necessary, UNHCR Headquarters should be informed by cable. Whatever the source, most vaccines require refrigeration and careful handling if they are to remain effective. The transportation links from manufacturer to individual immunization are known as the "cold-chain". The national health authorities' network of cold-chains should be used to the extent possible, but these may not extend to the vicinity of the refugees, without a cold-chain the immunization programme will fail. Time/temperature indicator cards should be ordered and kept with the vaccines. Further information on vaccines is given in annex 2.

5. Medical supplies will require tight security control to prevent misuse and theft.

6. Donations of unsolicited drugs may be a problem in an emergency. Quantities and quality may vary greatly; typical donations are small quantities of mixed drugs, free samples, expired medicines, inappropriate vaccines, and drugs identified only by brand names or in a foreign language. One of the health administrator's most important functions may be to say "No". UNHCR's policy is that overseas medical supplies should be sent only in response to a specific request or with prior clearance; locally, the WHO Representative, diplomatic missions and all others concerned should be briefed accordingly.

Further references (1)

Benenson A.S. (ed) (1980)	Control of Communicable Diseases in Man Standard reference book for a wide variety of communicable diseases and their control. Discusses disaster implications of each. (Also in French, Portuguese and Spanish).	American Public Health Association 13th edition
Cairncross S. Feachem R. (1983)	Environmental Health Engineering in the Tropics: An Introductory Text A copiously illustrated introduction to the principles and practices of tropical environmental health.	Wiley, John
Centers for Disease Control (1981)	Assessment and Surveillance of Health Problems: Refugee Populations Written primarily for CDC epidemiologists but a useful guide for general health personnel, nutritionists and environmental health workers. Provisional version, first edition expected in 1983.	US Public Health Service
International Disaster Institute	Disasters Volume 5 No. 3 Medical Care in Refugee Camps Covers a wide variety of public health topics.	IDI
King M & F Martodipoero S. (1981)	Primary Child Care Book One: A Manual for health workers Comprehensive child care in simple language with many illustrations. Book Two: A Guide for the Community Leader, Manager and Teacher.	Oxford University Press/WHO
PAHO (WHO) (1981)	Emergency Health Management after Natural Disaster A guide for decision makers and senior administrators that contains much that is relevant to refugee emergencies. (Also in Spanish)	PAHO Scientific Publication No.407
PAHO (WHO) (1982) (Western K.A.)	Epidemiologic Surveillance after Natural Disaster Also relevant to refugee emergencies. (Also in Spanish)	PAHO Scientific Publication No.420
PAHO (WHO) (1982)	Environmental Health Management after Natural Disaster Also relevant to refugee emergencies, particularly with regard to immediate action in temporary settlements where very high population density is unavoidable. (Also in Spanish)	PAHO Scientific Publication No.430

(1) See also the further references at the end of chapters 8, 9 and 10, only some of which are repeated here.

Simmonds S. Vaughan P. Gunn S.W. (1983)	Refugee Community Health Care Comprehensive guidance on planning, management and delivery of refugee health services.	Oxford University Press
Simmonds S. Gabaudan M. (1982)	Refugee Camp Health Care: Selected Annotated References A companion to above	Ross Institute Publication No.14
Somali Ministry of Health, Refugee Health Unit (1982)	Guidelines for Health Care A good example of guidelines of the sort referred to in 7.2.18.	Third edition, printed in booklet form by Oxfam
Werner D. (1980)	Where There is No Doctor A very practical village health care handbook with many illustrations. (Also in Khmer, Portuguese and Spanish).	Macmillan
UN (1977)	A Guide to Food and Health Relief Operations for Disasters (Also in French and Spanish)	Protein-Calorie Advisory Group of the UN
de Ville de Goyet C. Seaman J. Geijer U. (1978)	The Management of Nutritional Emergencies in Large Populations Essential reading (Also in French and Spanish)	WHO
WHO (1982)	Control of Vitamin A Deficiency and Xerophthalmia (Also in Arabic, French and Spanish)	Technical Report Series 672
WHO (1982)	The Emergency Health Kit Lists of basic drugs and supplies with a high probability of being required in any refugee emergency. Includes quantities for 10,000 persons for 3 months and possible standard treatments. (Developed jointly with UNHCR)	WHO
WHO (1980)	A manual for the Treatment of Acute Diarrhoea (Also in French and Spanish)	WHO/CDD/SER.80.2
WHO (1979)	The Selection of Essential Drugs Second report of the WHO Expert Committee Third report expected in 1983. (Also in French and Spanish)	Technical Report Series 641
WHO (1981)	The Treatment and Management of Severe Protein-Energy Malnutrition (Also in French and Spanish)	WHO

Example of a Standard Monthly Refugee Health Surveillance Report (1)

Serial no. of report .....

Location of refugees ..... Month ..... Year .....

Name of reporting officer .....

1. Refugee population

(1)	Total (end of last month)	.....	+
(2)	New arrivals (this month)	.....	+
(3)	Births "	.....	+
(4)	Deaths "	.....	-
(5)	Left "	.....	-
(6)	Total (end of this month)		=

2. Numbers of health personnel directly working with refugees (2)

(1)	Doctors	.....
(2)	Nurses	.....
(3)	Midwives	.....
(4)	Sanitarians	.....
(5)	Nutritionists	.....
(6)	Medical technicians	.....
(7)	Community Health Workers	.....
(8)		
(9)		
(10)		

7

(1) A separate report should be made for each major location of refugees. A copy of any corresponding monthly report by the national health authorities should be attached.

(2) Add others as applicable, e.g. traditional health workers, dentists, ophthalmic personnel. Indicate those who are refugees.

3. Mortality

Possible cause/ category (3)	Age					Total
	under 1 month	1-11 months	1-4 years	5-14 years	15+ years	
Diarrhoea						
Measles						
Malaria						
Trauma/ accident						
Neonatal						
Maternal						
Total						

(3) Add others as necessary. The object is to list deaths which may reflect on effectiveness of health care programmes.

4. Morbidity

Number of individual cases seen at all health centre(s) with one of the following headings as the major presenting condition. Record the first visit for this condition only, i.e. number of new cases.

Symptom/Disease (4)	Number	%
1. Fever, no cough		
2. Fever + cough		
3. Fever + chill		
4. Diarrhoea, no blood		
5. Diarrhoea, + blood		
6. Measles		
7. Whooping cough		
8. Eye infection		
9. Skin disease		
10. Venereal disease		
11. Malaria		
12. Dental		
13. Trauma/accident		
14.		
15.		
16.		
17.		
18.		
19.		
20.		
Total		100%

7

5. Data on communicable disease control programmes, for example:

Tuberculosis

Number of patients under treatment (end last month) ..... +

Number new patients (this month) ..... +

Number patients discharged after full treatment (this month) ..... -

Total number patients registered for treatment (end this month) ..... =

of whom percentage attending regularly ..... %

(4) Add other specific diseases e.g. schistosomiasis (bilharzia) as necessary. The object is to monitor effectiveness of public health measures.

6. Supplementary feeding

Category (5)	No. enrolled (end last month)	Admissions (this month)	Discharges (this month)	Total (end this month)	Attendance rate %
Malnourished (under 80% weight/height)					
Other young children (under 115cm tall)					
Pregnant					
Lactating					
Medical referrals					
Total					

(5) Add other categories within vulnerable groups as appropriate.

7. Therapeutic feeding

Category	No. enrolled (end last month)	This month			Total (end month)
		Admissions	Discharges to SFP/ hospital	Left although not discharged	
Marasmus (no oedema)					
Oedema					
Others (e.g.medical or siblings)					
Total					

8. Remarks: (summary assessment of overall situation, roles of agencies, surveys, particular problems, remedial action taken or envisaged, timescale, visiting health personnel during month, etc.)

Immunization and Vaccines

Suggested immunization timetable

Vaccine (1)	Age
BCG	At birth
DPT 1st dose Polio 1st dose	2-3 months
DPT 2nd dose Polio 2nd dose	At least 4 weeks after the first dose
DPT 3rd dose Polio 3rd dose	At least 4 weeks after the second dose.
Measles (2)	As soon as possible after 9 months
DT	When the child goes to school.

Temperature requirements for vaccine storage (3)

LEVEL: MAXIMUM STORAGE TIME:	CENTRAL STORE up to 8 months	REGIONAL up to 3 months	HEALTH CENTRE up to 1 month	TRANSPORT up to 1 week
MEASLES (4) ORAL POLIO (4)	Deep frozen -15°C to -25°C			
DPT (5) TETANUS TOXOID (5) BCG (4)	+4°C to +8°C maximum			

(1) BCG for protection against tuberculosis; DPT against diptheria, pertussis (whooping cough) and tetanus; DT against diptheria and tetanus.

(2) Immunization of young children against measles is a priority in a refugee emergency. The vaccine can be given simultaneously with DPT and polio vaccines.

(3) Storage times are maximum figures - remember to check expiry dates. Time/temperature indicator cards should be kept with the vaccines. The cards can be ordered separately if they are not supplied with the vaccine.

(4) The live virus vaccines are sensitive to sunlight - avoid direct exposure.

(5) Never freeze DPT or TETANUS (which both freeze at temperatures below -3°C).

CHAPTER 8: FOOD AND NUTRITION

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8

CHAPTER 8: FOOD AND NUTRITION

Need

In an emergency refugees will need partial or complete food support. Some may need nutritional rehabilitation.

Aim

To provide the refugees with sufficient quantities of appropriate food to maintain their health and where necessary to improve the condition of those who are already malnourished.

Principles of response

- ☐ Measures to meet food needs should be appropriate and standardized, with responsibilities clearly defined, and the overall co-ordination ensured by a single organization.
- ☐ Specialist nutritional advice should be available.
- ☐ Whenever possible use familiar foods that meet nutritional needs and maintain sound traditional food habits.
- ☐ Organize food distribution to allow families to prepare their own meals if possible.
- ☐ Pay particular attention to infant feeding and the needs of children and others vulnerable to malnutrition.
- ☐ Maintain close co-ordination with the health and other community services.

Action

- ☐ Assess the health and nutritional status and food needs as soon as possible.
- ☐ Ensure the availability of appropriate food and the necessary transport, storage, cooking fuel and utensils.
- ☐ Organize a general feeding programme for all refugees and additional selective feeding programmes to meet the extra needs of the vulnerable and/or malnourished if necessary.
- ☐ Monitor the effectiveness of the feeding programme(s).

8.1 Introduction

1. In an emergency refugees may be completely dependent on external food sources. Their numbers and condition must be assessed as soon as possible. The types of programmes needed will be determined by this initial assessment. Continuous monitoring of nutritional status will ensure the emphasis between programmes is adjusted to reflect changing conditions.

2. Co-ordination of the feeding programme(s) with the health and other community services is essential.

3. Assistance must be appropriate to the nutritional needs of the refugees and culturally acceptable. Foods prepared locally with local ingredients are preferable to imported special foods. Infant feeding policies require particular attention.

4. Certain groups are more vulnerable to malnutrition than others. These include infants, children, pregnant and lactating women, the sick and the elderly. Special action is required to identify the malnourished and vulnerable and meet their additional needs. Where the refugees have already suffered a prolonged food shortage, many will be malnourished by the time of the first assessment of their condition and needs.

5. If the refugees are already suffering the effects of severe food shortage, immediate action must be taken to provide whatever food is available locally and acceptable to the refugees. The first priority is to meet energy, rather than protein requirements. The supply of a bulk cereal is the first objective of the general feeding programme. If insufficient acceptable food is available locally, it must be brought in from outside, initially by air if necessary. Flexibility and improvisation will be required, and time may be needed to develop the full response set out in this chapter.

6. A summary of basic facts about food and nutrition is given at the end of this chapter together with a brief description of protein-energy malnutrition. Particularly where there is malnutrition, this chapter should be read in conjunction with "The Management of Nutritional Emergencies in Large Populations" (WHO).

8.2 Organization of food support

- WFP should be closely involved in meeting food needs.
- Co-ordination and a clear definition of responsibilities are essential.
- A single organization must have overall responsibility for all aspects of food support.
- Most refugee emergencies warrant the early appointment of an experienced nutrition specialist as the feeding programme co-ordinator.
- The refugees must be involved in the organization and management of their feeding programmes.
- Simple nutrition education is a part of effective food support.
- Special arrangements may be needed to provide cooking fuel and utensils.

Role of the World Food Programme (WFP)

1. WFP has special responsibility for food within the UN system and WFP's procedures specifically recognize refugee emergencies as qualifying for assistance. It is important to note, however, that WFP food aid does not provide all components of a complete general ration. The UNDP Resident Representative acts as WFP Representa-

tive, but WFP has its own professional field staff in many countries. If necessary, WFP will consider sending a field officer on mission. The advice of the local WFP field staff should be sought from the start of an emergency.

2. WFP has certain resources in food and cash to meet emergency food needs, and is also prepared to undertake procurement and shipping with funds made available by UNHCR. Swift action must be taken to ensure that the additional food items which will be required but are not available through WFP are also procured and delivered. Use of WFP resources in a refugee emergency requires a government request to the Director-General of FAO, and the latter's approval of an emergency project on the advice of the Executive Director of WFP. Pending or in the absence of a government request, the practical role of WFP will be little changed, but different procedures and funding arrangements will be necessary. Details of UNHCR/WFP emergency procedures are given in Part 2.

Responsibilities and personnel

3. UNHCR and WFP staff, together with the national authorities, the operational partner(s) and other organizations, must be clear on responsibilities for assessing and meeting the food needs. Close co-ordination with bilateral donors is essential. Offers of inappropriate food should be refused.

4. Subject to the role of the government and any special arrangements, UNHCR will have overall responsibility for the emergency operation. Thus UNHCR's initial planning must cover all food needs, including those items of the general ration which will not be provided by WFP. Depending on sources of supply and implementing arrangements, UNHCR may entrust specific practical arrangements to WFP. However, every effort should be made to avoid dividing the overall responsibility: a single person must be responsible for co-ordinating the provision of all food supplies.

5. In most emergencies the appointment of a feeding programme co-ordinator will be warranted. This is likely to be a separate responsibility to that for food logistics outlined in the previous paragraph. The co-ordinator would be responsible for the establishment of appropriate standard procedures, the co-ordination of feeding programmes, the monitoring and evaluation of their effectiveness and ensuring close co-ordination with the health and other community services. The co-ordinator should be a nutrition specialist with current experience in nutritional emergencies and local knowledge if possible. A co-ordinator will be particularly necessary in situations where non-specialist organizations and individuals have no alternative but to involve themselves in feeding operations. If initially there is not a nutrition specialist to assign to this position, the acting co-ordinator should seek immediate professional guidance from government nutritionists, or from within the local UN (WHO, WFP or UNICEF) and NGO community.

Role of the refugees and nutrition education

6. The refugees must be involved from the start in the organization and management of the feeding programmes. Special training will be necessary for selected refugees.

7. The provision of simple nutrition education for the refugees is important when unfamiliar foods or new methods of cooking and preparation cannot be avoided and have to be introduced to the refugees. This should be organized in conjunction with other health education activities to provide guidance on proper infant feeding, feeding sick children, treatment of diarrhoea, basic food hygiene and the preparation of available foods for maximum nutritional benefit.

Organization of response

8. Sound organization and planning are the key to success. The logistical arrangements must ensure the delivery of sufficient food in time. Adequate secure storage must be provided and the food must be protected against insects, rodents and rain damage both in the store and in the home. The necessary cooking pots and utensils must be available.1/ The distribution system must be fair and effective. (See ch.12.6).

9. Particular attention must be paid to the provision of cooking fuel. This is often a major problem and failure to provide fuel can quickly lead to destruction of the vegetation in and around the site causing lasting damage to the environment and friction with the local population. Special arrangements may thus be necessary to supply cooking fuel. As a rough indication, a family cooking on a simple wood stove requires some 5kg of wood per day. It may be possible to utilize local technology to modify existing types of wood or charcoal burning stoves in order to make them more fuel efficient. In some areas solar cooking equipment may be an appropriate solution at least for communal needs; a number of simple devices are now being developed. Advice should be sought on this from local experts, and through Headquarters if necessary.

8.3 Assessment and surveillance

- The first requirement is a knowledge of the numbers, nutritional status and former diet of the refugees.
- This assessment should, if possible, be the responsibility of an experienced nutrition specialist.
- Arrangements will be necessary both to monitor the nutritional status of the community and identify individuals who need special food relief.

1. An initial assessment of the health and nutritional status of the refugees should be made as soon as possible. Preferably this should be done by a nutrition specialist; however if one is not immediately available, field staff should carry out a preliminary survey of their own. Guidance on how to do this is given in annex 1. The amount of malnutrition must be established as this has important implications for what form the emergency response will take. Other basic information which will be required to formulate a food aid plan includes the number of refugees, their age/sex breakdown, their present access to food supplies, cooking fuel and utensils. In addition information must be gathered on traditional food and cooking habits, and the local availability of suitable food.

2. This information will enable the field and Headquarters to take early decisions on the components of the rations, total amounts needed, the logistical support necessary and on the requirement for any additional selective feeding programmes. Figure 8-1 on page 101 gives an indication of the considerations.

3. The initial assessment should be followed by regular nutritional

1/ Special kits have been developed by Oxfam to help set up selective feeding programmes. The kits may be useful at the start, pending local supply arrangements, and can be provided through Headquarters at short notice. Kit 1 contains equipment for nutritional surveillance and assessment. Kit 2 provides equipment to cover supplementary feeding of 250 children. Unless otherwise requested, Kit 2 is also supplied with equipment identical to Kit 1. Kit 3 provides equipment to cover therapeutic feeding of up to 100 severely malnourished children. The kits do not contain cookers.

surveillance under specialist supervision to monitor the condition of the population as a whole and the individual progress of the vulnerable and the malnourished. In an emergency a high child mortality rate is very often associated with high levels of malnutrition and this is therefore an important statistic to record in health/nutrition surveillance programmes.

4. Nutritional surveillance of the population as a whole should be done by weighing and measuring a random sample of the child population at regular intervals. In times of food shortage young children are the first to show signs of malnutrition and are the most severely affected. For this reason it is usually a random sample of children less than 5 years of age (or less than 115cm tall) who are measured regularly in a surveillance programme. Their condition is used as an indicator of the amount and degree of malnutrition in the population as a whole. For a refugee population of under 10,000 a random sample of 200 children will provide a reasonably accurate estimate of overall child malnutrition. For a population of 10,000-20,000, a sample size of at least 400 is required. Initially such surveys should be made every two months. When conditions have stabilized once every 3-6 months is sufficient. Any change or trend in nutritional status can thus be detected and adjustments made in the relevant feeding programmes.

5. Where conditions and/or results of the initial assessment indicate a need for supplementary or therapeutic feeding, individuals will need to be identified and registered for these programmes. Their individual progress should then be monitored through more frequent weighing at the feeding centres.

6. Thus nutritional surveillance takes two forms: first, monitoring the effectiveness of the food provided to the whole community (the general feeding programme) by measuring a random sample of children; second, monitoring the progress of vulnerable individuals and thereby the need for or effectiveness of selective feeding programmes.

7. Malnutrition can be recognized by clinical signs (see the descriptions on page 111 of marasmus, kwashiorkor and marasmic-kwashiorkor) and by body measurements. Measurements are required for objective assessment of nutritional status and for purposes of comparison with regular surveillance data. The weight-for-height method expressed as a percentage of a reference standard is the most sensitive indicator of acute malnutrition and is preferred for nutritional surveillance and for measuring individual progress in emergencies. Children of less than 80% weight-for-height[2/] are classified as malnourished and those of less than 70% weight-for-height as severely malnourished. For rapid screening of the young child population the less sensitive arm circumference measurement described in annex 1 can be used.

8.4 General feeding programme

/_/ Every effort should be made to provide familiar foodstuffs and maintain traditional food habits.

2/ Percentages are those of the WHO International Standard

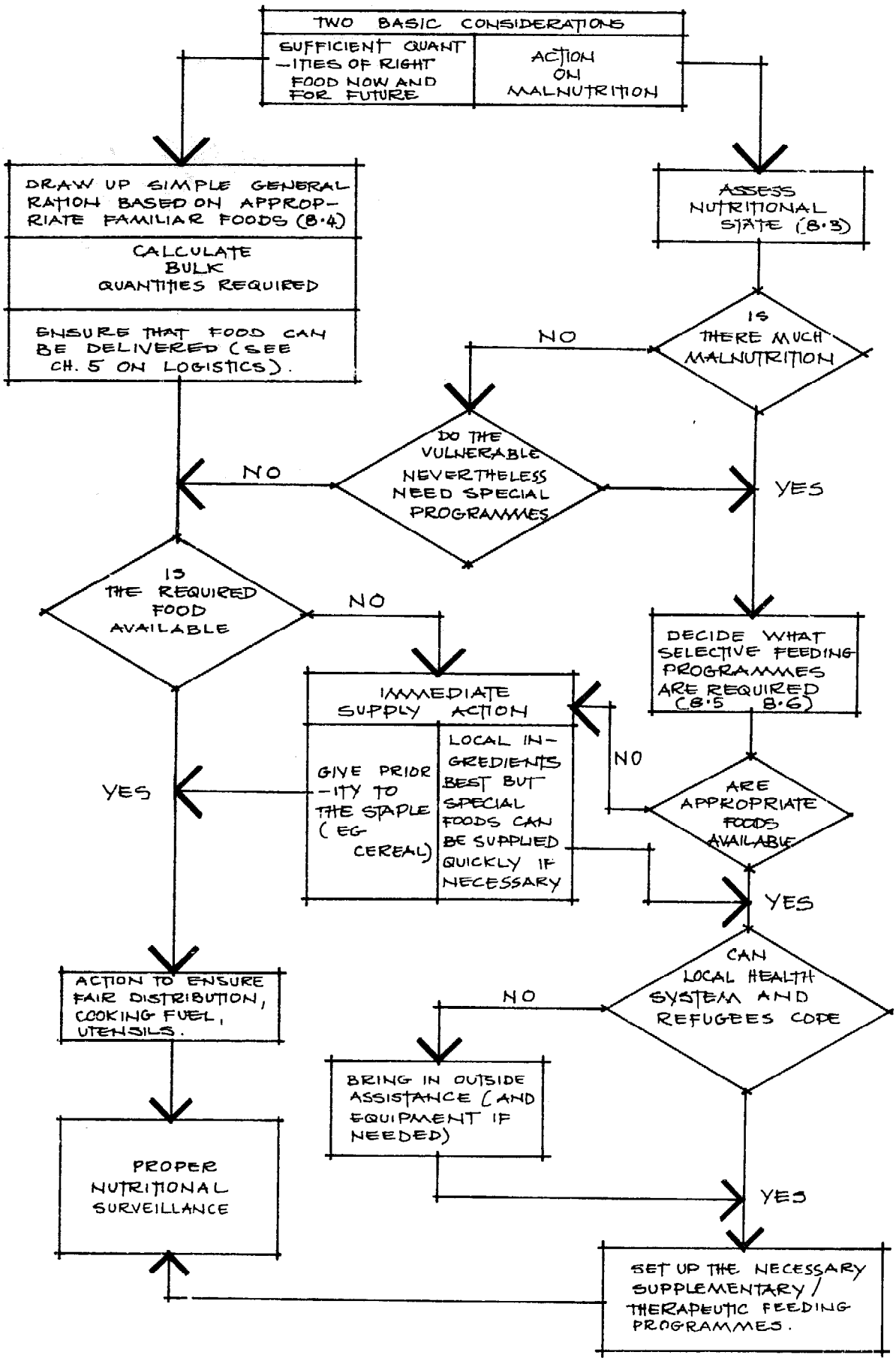

8-1 RESPONSE TO FOOD AND NUTRITIONAL NEEDS

- Average rations must provide the following amounts of energy: at least 1500 Kcal (6.3 MJ)[3/] for initial survival and over 2000 Kcal (8.4 MJ) for longer term maintenance.

- The diet must satisfy protein and basic vitamin requirements.

- Pay particular attention to locally prevalent nutrient deficiencies.

1. Every effort should be made to provide familiar foodstuffs and maintain sound traditional food habits. Expert advice on the ration is essential and should take full account of local availability. Staple foodstuffs should not be changed simply because unfamiliar substitutes are readily available. Inappropriate foods often lead to wastage and malnutrition, and lower the morale of the refugees.

2. The amount and quality of food provided must satisfy energy and protein requirements. A survival ration should provide at least 1500 Kcal, while over 2000 Kcal (and 50g of protein) are required for longer-term maintenance. Active adults may require considerably higher energy intakes. Although there is a marked difference between the needs of a young child and an active adult it is strongly recommended that a standard ration is provided for each refugee without distinction. A typical daily ration to provide sufficient calories and protein would be built around:

- a staple food which provides the bulk of the energy and protein requirement, e.g. cereal 350-400g
- an energy-rich food, e.g. oil 20-40g
- a protein-rich food, e.g. beans 50g

Other items such as vegetables, sugar, spices, condiments, fruits, and tea, should be provided according to cultural and nutritional needs. However absolute priority must be given to the staple food. A few items and assured delivery are better than a complex ration, some of which fails to arrive. Advice on the logistical aspects of food supply, in terms of amounts to be moved, is contained in chapter 5.

3. Essential vitamin and mineral requirements must also be met: a varied diet is the best means of doing so. Where adequate quantities of certain nutrients cannot be provided in the diet, the inclusion of seasonally available vegetables will usually prevent vitamin and mineral deficiencies arising. Whenever possible the refugees should be encouraged to grow appropriate varieties of vegetables themselves. Local food markets within the settlement should be encouraged. Particular attention must be paid to any locally prevalent deficiencies and efforts made to include food items which are rich in the missing nutrients. The distribution of multivitamin tablets to the entire refugee population is a waste of time and money, since they contain insufficient quantities of individual vitamins to correct deficiences.

4. Two deficiencies are commonly seen among refugees: vitamin A deficiency and anaemia. Vitamin A deficiency in malnourished populations, especially in children, leads to blindness. Anaemia, which

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3/ Energy values are expressed in the thermochemical kilocalorie. However, as a scientific unit this has been superseded by the megajoule (MJ). 1000 Kcal = 4.184 MJ; 1 MJ = 239 Kcal.

is commonly associated with parasitic diseases or an insufficient intake of iron and folate, can lead to cardiac failure and death in the most severe cases. Both conditions can be prevented by a proper diet.

5. The need for a fair, efficient and regular ration distribution cannot be over-emphasized. An accurate census is needed and a monitoring system must be established to ensure that the food is actually reaching every refugee as intended. Disruption, diversion and corruption will inevitably lead to widespread discontent and suffering.

6. There are two main types of distribution: dry ration and cooked meals. Whichever is used, it is important to ensure that those doing the distribution have exact instructions on the size of the rations and are seen to follow them. If scales are not available or not a convenient way of measuring out food then cans or containers should be provided whose weight/volume comparison is known for each commodity.

7. The distribution of food as pre-packed rations is an unsatisfactory solution and is to be avoided.

Dry ration distribution (take home)

8. This method has major advantages over cooked food distribution. It allows families to prepare their food as they wish, permits them to continue to eat together as a unit and is generally more culturally and socially acceptable.

9. Distribution is usually made at weekly intervals. Where an accurate census is available and families have food distribution cards, some form of delegated family or group distribution is possible, but in the initial stages the best way to guarantee a fair distribution may be to have every individual present. For a discussion of ration cards see ch.12.6.

10. In addition to cooking pots, fuel and utensils, the refugees must have containers and sacks to protect and store their food rations. Oil tins and grain bags will be useful, and contracts with suppliers, at least for initial deliveries, should not require their return.

Cooked food distribution

11. This requires centralized kitchens with adequate utensils, water and fuel (although obviously less than the amounts required for family cooking), and trained, healthy personnel. The refugees usually sit together in a feeding compound, although in some circumstances families can carry the cooked food to their accommodation. At least two meals must be served each day and the efficient organization of cooked food distribution for large numbers is difficult. Every effort should be made to avoid having to resort to mass cooked food distribution for the general ration. Such distribution may, however, occasionally be necessary in the initial stages, for example, pending the availability of sufficient cooking utensils and fuel. It may also, although rarely, be preferred by the refugees.

Monitoring the general feeding programme

12. A general feeding programme matching the standards elaborated in 8.4 is the minimum necessary to maintain a good nutritional status in a healthy population. Its effectiveness must be closely monitored through the surveillance programme. The quality and the quantity of the rations should be regularly discussed with the refugees. Where there are complaints, these should be investigated. Proper arrangements must be made for the inspection of food supplied by contractors.

8.5 Supplementary feeding programmes

- In addition to the general feeding programme, extra food may be required for the malnourished or to prevent malnutrition.
- The programme must actively identify those who need supplementary food and ensure they receive it.
- The aim is to provide at least one high energy, high protein, low bulk extra meal daily.

The need

1. Where malnutrition exists or the needs of the vulnerable groups cannot be met from the general ration, special arrangements are required to provide extra food. This is organized through a supplementary feeding programme (SFP). Infants, children, pregnant and lactating women and the sick are the most seriously affected by food shortage. Their vulnerability stems from the greater nutrient requirements associated with growth, the production of breast milk, repair of tissues and production of antibodies. Because children are unable to eat a large volume of food, it is necessary both to prepare food in a concentrated form, giving more nutrients in less volume, and also to provide more frequent meals. Malnutrition results in lower resistance to infection, which in turn results in further malnutrition. Small children are particularly susceptible to this cycle of infection and malnutrition. Sick children must eat and drink, even if they have no appetite, are vomiting or have diarrhoea. They must receive additional food whenever possible.

2. Certain other groups or individuals may be vulnerable to malnutrition for social or economic reasons. These include unaccompanied children, the disabled, single-parent families, and perhaps the elderly, particularly those without family support. In some communities specific social or cultural practices and taboos may put constraints on meeting the nutritional needs of certain persons, for example pregnant and lactating women or even sick children.

3. Where the refugees are predominantly women and children, it may be impossible (or unnecessary) to provide this whole group with supplementary food. Under such circumstances it is better to adjust the general ration to the needs of the majority, for example by increasing the overall protein content. Supplementary feeding programmes are an increasingly common feature in refugee emergencies; however, they may not always be the most effective response. Table 8-2 outlines general considerations when deciding on the need for such a programme.

Aim and content

4. The aim is to provide extra high energy, high protein, low bulk meals, once or twice a day to those who need it. The number of meals depends on the nutritional status of the population, the nutritional value of the general ration and the age of the beneficiaries. The size of the supplement also depends on the nutritional status of the beneficiaries: but at least 350 Kcal and 15g protein per day should be provided.

5. Supplementary meals should be prepared as porridge or soup which are easily digestible and can be eaten by people of all ages. The food is generally based on cereal and legume blends with edible oil added to increase the energy content. Other ingredients can be added to give additional nutrients and variety of flavour (e.g. sugar, vegetables, fish, milk). There are some prepacked cereal/legume blended supplementary foods available through UN agencies (e.g. CSM, corn-soya-milk; WSB,

8-2 Indicators of likely need for a supplementary feeding programme

Major indicator (1)	Other factors	Type of SFP
General ration averaging less than 1500 Kcal/person/day	None	For all vulnerable groups (see 8.5.1 and 2) if resources allow, as soon as possible
over 20% children malnourished		
10-20% children malnourished	General ration averaging less than 2,000 Kcal/person/day	
	Severe public health hazards	
	Significant diseases (esp. measles) prevalent or imminent	
	None	Selective within vulnerable groups: at least for all mal-malnourished. See 8.5.8.
5-10% children malnourished	Any of above	
	None	No SFP: individual attention to malnourished. (Whatever the other factors, available resources are probably better used correcting/minimizing them)
under 5% children malnourished	Any of above	

(1) Percentages are of children under 5 years old under 80% weight-for-height.

wheat-soya-blend). These may be useful at the start of an emergency feeding programme if the ingredients are familiar to the refugees. However, local foods should be substituted as quickly as possible and prepared in a more traditional and appropriate way.

Admission and discharge

6. The supplementary feeding programme must be based on the active identification and follow up of those considered vulnerable. This requires a regular house-by-house or family-by-family assessment, usually made by public health workers operating a referral system. As well as encouraging those in need to participate in the supplementary feeding programme and ascertaining the reasons for non-participation, continued home-visiting is required to monitor the progress of infants

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and children. Those identified for the programme should be registered and issued with a numbered identity bracelet or card to facilitate follow-up.

7. In practice, a supplementary feeding programme that does not actively identify those in need but simply operates on an open "come-if-you-wish" basis is most unlikely to benefit those in greatest need and is a very questionable use of food and organizational resources.

8. The criteria for admission to a supplementary feeding programme will depend on the condition of the refugees and the resources available. The order of priority within the vulnerable groups is, generally, any malnourished person (less than 80% weight-for-height - WHO International Standard), young children (less than five years old or 115cm in height), women during the last 3 months of pregnancy and the first 12 months of lactation, medical referrals and the socially vulnerable. Should restrictive selection be necessary because of lack of resources this will in part change the nature of the programme from preventive to curative.

9. The amount of food required for supplementary feeding is likely to be about 3MT per 1,000 beneficiaries per month. Table 8-3 below shows how this estimate was arrived at.

10. Children should not be discharged from supplementary feeding until they have been more than 85% weight-for-height for at least one month.

11. Once begun, supplementary feeding must be considered necessary until such time as an appropriate general ration is provided that meets the needs of the vulnerable, and as long as living conditions remain hazardous. It is a mistake to discontinue supplementary feeding as soon as the nutritional status of vulnerable individuals or groups starts to improve. The programme should not be discontinued until the surveillance results reflect sustained improvement and not more than 5% of the children remain malnourished.

Organization

12. An effective programme requires the regular attendance of all those registered. The identification of those in need is a prerequisite, to be followed by careful control of attendance and progress. Trained staff should weigh and measure children on admission to the SFP and reweigh regularly, preferably monthly, thereafter to monitor individual progress.

13. As for general rations, the supplementary feeding programme may be organized either using the 'take home' or 'on-the-spot'

8-3 Supplementary food quantities

Typical daily ration				Monthly amount for 1000 in MT (Daily amount x 30 x 1000)
Item	Amount (g)	Energy (Kcal)	Protein (g)	
cereal	60	210	6	1.8
oil	10	90	-	0.3
DSM	25	90	9	0.75
Sugar	5	20	-	0.15
	100	410	15	3.0

method. Both require careful registration and control. The take home system is relatively simple to administer but the supplement is likely to be shared within the family. On-the-spot supplementary feeding is the preferred method. Supervision is improved, the intended beneficiary is seen to eat the correct amount of food and follow-up is easier as those in need are seen more often and under more controlled conditions.

14. Any supplementary feeding programme must be closely integrated with the community health care programme. The supplementary feeding programme will give the opportunity for health problems to be identified. Certain daily medications may best be given in the course of the supplementary feeding programme, for example iron and folate preparations for anaemia.

15. Feeding centres and kitchens must be well organized and kept clean. Long waiting periods must be avoided and the schedule must not clash with family meal times or other essential community activities. Parents must be made to understand that the supplementary feeding programme is given in addition to normal meals. Utensils, bowls, scales and other equipment will be required and can generally be obtained locally. (See 8.2.8)

16. One supplementary feeding centre can usually handle up to 500 beneficiaries. The centres should be run by trained refugees: an experienced nurse should be able to supervise 4 or 5 centres. Where different organizations establish their own supplementary (or therapeutic, see 8.6) feeding programmes it is most important that these are appropriate to the needs, centrally co-ordinated, and procedures standardized. The health guidelines described in ch.7.2.18 should cover selective feeding programmes. See pages 92 and 93 for examples of standard reports. The programmes must avoid such a dependence on outside assistance that they collapse when individuals or organizations leave.

8.6 Therapeutic feeding programme

- A therapeutic programme may be needed to save the lives of severely malnourished children.
- Treatment of the severely malnourished requires medical supervision.
- The treatment consists of food of high energy and protein content given according to the individual's nutritional requirements.

1. Therapeutic feeding (TFP) is required to reduce deaths among infants and young children with severe protein-energy malnutrition (PEM). The forms of PEM are described in section 9. If severe PEM exists, therapeutic feeding will initially be a priority to save lives. However, if introduction of supplementary feeding is delayed because resources, particularly trained personnel, are concentrated on therapeutic feeding, there may quite quickly be such a deterioration in other less malnourished children that the life-saving achievements of a therapeutic programme will be overtaken by the life-threatening consequences of not having an adequately functioning supplementary programme, benefiting many more people.

2. Food is the treatment for PEM. Unlike supplementary feeding, therapeutic feeding is solely a curative measure and thus in theory a short-term programme. The need for its continuation will depend on the effectiveness of the general and supplementary feeding programmes and the nutritional condition of any new arrivals.

3. The usual criteria for admission to a therapeutic feeding programme are oedema (kwashiorkor), or severe marasmus (weight-for-height less than 70%). Patients

should remain on therapeutic feeding until they are free from illness; at least 80% of weight-for-height and without oedema. On recovery patients would be discharged to the supplementary feeding programme.

4. Therapeutic feeding should take place on an in-patient basis whenever possible, as food must be given every 3-4 hours. Infection and dehydration are the major causes of death and patients must be closely watched for medical complications. If weight does not increase quickly on a properly run TFP, the explanation is likely to be that the individual also has an illness which must be treated. The immunization of young children against measles is a priority because of the high mortality associated with this disease in a malnourished population.

5. A therapeutic feeding programme must be run by experienced and suitably qualified personnel. One centre can usually handle about 50 children and will require two experienced supervisors full-time. It should be noted that most doctors and nurses have little training in nutrition or experience in treating severe PEM. They must therefore be given the necessary guidance. The refugees and particularly the mothers of patients must be involved in running the therapeutic feeding centre.

6. In addition to a suitable building and services, the centre will require a kitchen and the necessary utensils and equipment, which can usually be obtained locally (see 8.2.8). Treatment is a diet which provides at least 150 Kcal and 3-4g of protein per kilo body weight per day for each patient, via 5-7 meals at 3-4 hourly intervals throughout the 24 hours. Boiled water mixed with a dried skimmed milk/oil/sugar mixture, or with a UNICEF K Mix II/ oil mixture, can be used to initiate treatment. A mixed diet is introduced once the patient's condition starts to improve (usually after 4-5 days).

8.7 Infant feeding and milk products

- Breast-feeding is best for babies and must be promoted and continued for as long as possible.
- Ban baby bottles completely.
- Weaning foods must be appropriate; foreign baby foods and special foods often are not.
- Infant formulae should be avoided, and never used except under strictly controlled conditions, with a cup and spoon.
- Milk products and especially powdered milk can cause problems and are often inappropriate.

1. The vital importance of correct infant feeding in an emergency must be understood.

2. Human milk is the best and safest food for infants and children under 2 years. Breast-feeding provides a secure and hygienic source of food, often initially the only source of food, as well as antibodies giving protection against some infectious diseases. Breast-feeding must be encouraged for as long as possible. Every effort must be made to promote or restimulate lactation even among sick and malnourished mothers. Experience has shown that this can be done. Mothers may need to receive extra food to encourage breast-feeding and provide the additional calories and nutrients required. This should be done through the SFP.

3. The problems associated with infant formulae and feeding bottles are exacerbated in a refugee emergency. Clean boiled water is essential but rarely available, careful dilution of the feeds is of critical importance but difficult to control, mothers are unlikely to be familiar with the use

of infant formulae, and the instructions are often in a foreign language. Infant formulae, if unavoidable, should be distributed from health or feeding centres under strictly controlled conditions and proper supervision. Infant feeding bottles must never be distributed or used; they are almost impossible to sterilize and keep sterile under such conditions and are therefore dangerous. Babies should be fed by clean cup and spoon if necessary.

4. While continuing breast-feeding, appropriate weaning foods should be introduced at between four and six months of age. Weaning foods should be locally available foodstuffs and as far as possible be prepared in the traditional manner. Overseas donations of tinned baby foods are rarely appropriate.

Other milk products

5. Some populations have long considered milk as an ideal food, while others rarely consume it in either its natural or powdered form, and may even have a lactose (milk sugar) intolerance. Milk should not be distributed if it is not a traditional part of the refugees' diet.

6. Major practical problems are often associated with milk powder. Both proper hygiene and proper dilution will be difficult to ensure, and contaminated milk, for example because of unsafe water or exposure to dust and flies, provides an ideal environment for bacterial growth. For these reasons, milk should not form part of the general ration, except as a possible source of protein for refugees with a nomadic background whose main food was previously milk and meat; meat is likely to be difficult to supply in an emergency.

7. In addition to infant formula, the products commonly offered in emergencies include dried whole milk (DWM), dried skimmed milk (DSM), sweetened and unsweetened condensed milk and evaporated milk. Their appropriateness must be ascertained before acceptance. It should be noted that if used, DSM must be vitamin A fortified (when it will have a shelf-life of six months).

8. Milk products are useful in supplementary and therapeutic feeding programmes, administered under supervision. For example, milk can be added to SFP cereal mixtures to boost the protein content. Milk powder is the usual basis for early stages of treatment in therapeutic feeding. Whenever used it is imperative that the milk be correctly prepared and served under controlled and hygienic conditions. Instruction and guidance must be given.

8.8 Provision of the necessary food

- Logistical aspects must be considered from the start.
- All possible local sources of the appropriate food must be explored before resorting to overseas supply.

1. This section assumes that the refugees have no food supplies of their own. Considerations relating to the choice of the ration and the importance of familiar foodstuffs that meet the nutritional needs and maintain sound traditional food habits have been covered in earlier sections. Details of UNHCR/WFP procedures for emergency food supply are given in Part 2.

Logistics and storage

2. Adequate logistics will be the key to a successful emergency operation, and food will be the major item to be transported. Logistical considerations are thus very important and sometimes determining. Particular attention must be paid to proper storage, protection against both the elements and pests, and losses through theft. Effective stock

control will be essential. Considerable reserve stocks may be necessary. Guidance on logistics, including a guide to calculating probable total amounts to be moved, is given in chapter 5.

Sources of supply

3. Sources of food will be determined by local circumstances, which the ration selected will naturally reflect. The timely provision of a complete ration may require a combination of the following sources:

(1) Borrowing from national stocks, WFP stocks on hand in the country (direct WFP stocks or those available to WFP under reciprocal drawing rights) or stocks of other donor organizations on hand in the country;

(2) Purchase on the local market or from neighbouring countries;

(3) Overseas supply, either as a result of diversion of WFP or other stocks already at sea, or overseas procurement, or through contributions in kind;

(4) Bilateral donors, including NGOs.

4. In cases of extreme urgency, it may be necessary for Headquarters to make interim arrangements for the supply of appropriate essential food by air, but every effort must be made to find acceptable local supplies first. Air transport is unsuitable for large quantities of the appropriate staple foods, while the processed foods usually airlifted are often inappropriate to the traditional food habits of the refugees.

8.9 Basic facts about food and nutrition 4/

Nutrients

1. All foods are made up of five basic types of nutrient: carbohydrates, fats, proteins, vitamins, and minerals, in addition to variable amounts of water. Carbohydrates are mostly starches and sugars of vegetable origin, being, for example, a major component of cereals and tubers. They are a source of energy. Fats and oils provide the most concentrated source of energy, having more than twice the energy content per weight of carbohydrates and proteins. In most poor countries, most of the energy is derived from the staple foods, especially cereals, fats accounting for a much smaller proportion. Proteins are body-building substances required for growth and tissue repair. Protein is found in foods of animal origin and in cereals and legumes. Vitamins and minerals are needed in small quantities for the adequate functioning of the body. Individual vitamins and minerals or combinations are found in all foods in very variable amounts.

Energy and protein intakes

2. If the energy intake is inadequate, some protein will be burnt to provide energy and not used for body growth or repair, that is, it will be used in the same ways as carbohydrate or fat, which are usually less expensive. Not less than 20% of the energy requirement should be supplied from fats and oils which greatly enhance the palatability of the diet and increase energy density (important for younger children). Energy requirements vary widely even in normal individuals. They are also increased by physical activity. Much higher intakes are

4/ Adapted from "The Management of Nutritional Emergencies in Large Populations".

required for the treatment of malnutrition, when the aim is rehabilitation rather than maintenance.

Food and diets

3. Most diets in most countries [5/] contain adequate amounts of all the nutrients required for good health if enough of the diet is taken to satisfy the individual's energy requirements. Even a growing child, if healthy, requires no more than 10% of the calories to be supplied from protein sources. The commonly used foods are listed in table 8-4 overleaf.

Protein-energy malnutrition (PEM)

4. PEM is a problem in many developing countries, even in normal times. Most commonly it affects children between the ages of six months and five years (especially at the time of weaning). Severe PEM is usually precipitated by low food intake associated with infection. Refugees are particularly vulnerable and UNHCR staff should be able to recognize severe PEM, which has three forms, described below. See also annex 1.

5. Nutritional marasmus results from prolonged starvation. The main sign is a severe wasting away of fat and muscle, which have been expended to provide energy. The child is very thin and may have an "old man" face and loose folds of skin. The children affected may, however, appear relatively active and alert. This is the most frequent form of PEM in cases of prolonged food shortage.

6. Kwashiorkor is seen most commonly in areas where the staple food is mainly carbohydrate, for example tubers and roots like cassava, but it is precipitated by many factors other than protein deficiency. The main sign of kwashiorkor is oedema, that is a swelling usually starting at the lower extremities and extending in more advanced cases to the arms and face. Oedema must be present for the diagnosis of kwashiorkor but can also occur in other diseases. Where there is gross oedema, the child may look "fat" and be regarded by the parents as well-fed. Associated signs of kwashiorkor, which do not always occur, include hair changes (colour becomes lighter, curly hair becomes straight, comes out easily with a gentle pull) and skin changes (dark skin may become lighter in places, the skin may peel off, especially on the legs, and ulceration may occur). Children with kwashiorkor are usually apathetic, miserable and withdrawn and often refuse to eat. Profound anaemia is a common complication of kwashiorkor.

7. Marasmic kwashiorkor is a mixed form, with oedema occuring in children who are otherwise marasmic and who may or may not have the other associated signs of kwashiorkor. In practice, mixed forms will often be seen.

8

5/ Appendix 7 of "A Guide to Food and Health Relief Operations for Disasters" gives information on the major foods and acceptable alternatives in adult diets in over 100 countries.

8-4 Characteristics of common foods

Food type	Approx. energy per 100g	Approx. protein per 100g	Vitamins and minerals	Comments
1. Cereal grains (rice, corn, sorghum, oats etc.)	350 Kcal	8-12g	Contain vitamin B and iron. However these reduced by milling, i.e. the whiter the flour the greater the loss of vitamins.	The main source of both energy and protein in most diets.
2. Legumes/oilseeds (beans, peas, soya, groundnuts etc.)	350/500-700 Kcals Provides energy in a a compact form but relatively expensive and requires careful storage.	20-25g some beans can be up to 40% protein e.g. soya	B complex vitamins. Most contain significant quantities of iron and calcium.	Legumes are particularly useful when eaten with cereals as the proteins complement each other.
3. Whole tubers and roots (yams, taro, cassava, sweet potato, potato etc.)	75-110 Kcals. In flour form contain 300-350 Kcals.	Very low in protein	Variable but generally low.	Bulk and low protein content makes them unsuitable as staple foods in emergencies.
4. Vegetables and fruits	Low in energy	Low in protein	Important source of vitamins. Variable quantities of B and C vitamins. Dark green leaves or yellow/red pigmentation usually indicates vitamin A compounds.	

5.	Meat, milk and dairy products, eggs, etc.	150-550 Kcals depending on fat content	Generally in range 10-20g except for liquid milks 3-6g	Good sources of B vitamins. Whole milk and eggs also good source of vitamin A. Milk and eggs provide significant amounts of calcium.	Usually consumed in very small quantities in normal times. They are more readily utilized by the body than proteins of vegetable origin. Therefore small quantities useful to improve the quality and palatability of diet.
6.	Fish, dried	300 Kcals	63g	Rich source of calcium and iron. Contains B vitamins.	A concentrated source of protein for those who like it. Therefore acceptability trials essential before use.
7.	Fats and oils	900 Kcals i.e. the most concentrated energy source	nil	Rich source of Vitamin A, except for lard, other animal fats and vegetable oils.	Useful way to increase energy intake without increasing bulk of diet. Improves palatability and helps in food preparation.

Further references (1)

Cameron M. Hofvander Y. (1976)	Manual on Feeding Infants and Young Children Third edition expected in 1983 (Also in French and Spanish)	Protein-Calorie Advisory Group of the UN FAO 2nd edition
Centers for Disease Control (1981) (Graitcer P.L.)	A Manual for the Basic Assessment of Nutritional Status in Potential Crisis Situations Provisional edition, revision expected in 1983.	US Public Health Service
Peel S. (1979)	Selective Feeding Procedures A simple guide for those running feeding programmes. Revised edition expected in 1983.	Oxfam
Rajagopalan S. Shiffman M. (1974)	Guide to Simple Sanitary Measures for the Control of Enteric Diseases Contains a section on food sanitation. (Also in Arabic, French and Spanish)	WHO
Simmonds S. Vaughan P. Gunn S. W. (1983)	Refugee Community Health Care Comprehensive guidance on planning, management and delivery of refugee health services	Oxford University Press
Simmonds S. Gabaudan M. (1982)	Refugee Camp Health Care: Selected Annotated References A companion to above	Ross Institute Publication No.14
UN (1977)	A Guide to Food and Health Relief Operations for Disasters. (Also in French and Spanish)	Protein-Calorie Advisory Group of the UN
de Ville de Goyet C. Seaman J., Geijer U. (1978)	The Management of Nutritional Emergencies in Large Populations Essential reading. (Also in French and Spanish)	WHO
WHO (1981)	Guidelines for Training Community Health Workers in Nutrition (Also in French)	WHO offset publication No.59
WHO (1981)	The Treatment and Management of Severe Protein-Energy Malnutrition (Also in French and Spanish)	WHO

(1) See also the further references at the end of chapter 7, only some of which are repeated here.

Rapid assessment of the nutritional status of young children using the arm circumference method

Explanation of the principle

1. The arm circumference technique is suitable for a rapid assessment of the nutritional status of young children. It measures a part of the arm whose circumference does not normally change significantly between the ages of one and five, but which wastes rapidly with malnutrition. The technique is not suitable for monitoring the progress of individual children.

2. If professional help is available it should of course be used but this assessment can be done by those with no previous nutritional experience provided the guidelines below are followed. The technique thus allows any UNHCR field officer to provide an objective assessment and hard facts rather than be limited to subjective reporting. This in turn allows a much more effective response.

Selection of the children

3. If the refugee population is 10,000 or less a random sample of not less than 200 children aged between one and five years should be chosen. This can be done on a house to house basis or by assembling all the children at one site and measuring, for example, every fifth child. If a "cluster" sample method is used (e.g. sampling in different sections of a large settlement) not less than 30 children per cluster should be measured to allow a comparison between sections. Take care that the adults do not just produce sick children in the belief that the test is to be followed by medical attention; this will distort the result. A quick but crude way of ascertaining that children are approximately within the age range of one to five years is to check they have more than six teeth but are less than 115cm in height. For most people this would mean the children come up to about waist height.

4. The assessment must be put in context: information about where the children come from and when they arrived should be obtained and reported, as the condition of this particular group may not reflect that of the whole caseload.

The measurement

5. If custom-made measuring tapes (possible sources ICRC and Headquarters) are not available, take a thin strip of plastic of about 30cm in length and mark off clearly a zero point, then 12.0cm and 13.5cm.

6. Before measuring any child check for the presence of oedema (the swelling seen in kwashiorkor) by pressing a finger against the front of the child's foot for about 3 seconds. If a dent ('pitting') is seen the child has oedema and should not be measured but marked down as having oedema and being severely malnourished. (See the suggested report form on the next page.)

7. If there is no oedema, the circumference of the child's left upper arm should then be measured at the midway point. The tape should be wrapped closely (but not tightly) around the left arm midway between the elbow and the point of the shoulder. The arm should be hanging loosely.

The results

8. Classification of nutritional status can be made as seen on the attached form. The amount and degree of malnutrition can be calculated as percentages of the sample.

NUTRITIONAL SURVEY REPORT FORM

Arm circumference method

District ..... Site ..... Date .....

Total refugee population at site .....

Total number of children from whom random sample taken ..... Method of sampling .....

Surveyor's name/Organization .....

Satisfactory (A)	Malnutrition (B)	Severe Malnutrition (C)	
More than 13.5cm (approximately equivalent to over 80% weight-for-height)	12.0-13.5cm (approximately equivalent to 70%-79% weight-for-height)	Less than 12cm (approx. equivalent to under 70% weight-for-height)	Oedema
(Record numbers only. As this is for statistical purposes there is no need to keep any other details on those measured)			

Total sample = A + B + C =

% Malnutrition = $\frac{(B + C) \times 100}{A + B + C}$ =

% Severe Malnutrition $\frac{C \times 100}{A + B + C}$ =

of which % Kwashiorkor = $\frac{\text{Oedema} \times 100}{C}$ =

Observations .....

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CHAPTER 9: WATER

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9

CHAPTER 9: WATER

Need

Water is essential to life and health. In emergencies it is often not available in adequate quantity or quality, thus creating a major health hazard.

Aim

To provide enough safe water for the refugees and to meet communal needs.

Principles of response

- ☐ Seek expert advice, co-ordinate closely with the appropriate national services and involve the refugees.
- ☐ Ensure consideration of the water supply at the site selection and planning stage and co-ordinate response closely with public health and environmental sanitation measures.
- ☐ Provide a reserve supply and spare capacity, to meet temporary difficulties and the needs of new arrivals.
- ☐ Take account of seasonal variations.
- ☐ If at all possible, avoid the need to treat water.

Action

- ☐ Organize an immediate, competent assessment of water supply possibilities in relation to needs.
- ☐ Protect existing sources of water from pollution.
- ☐ Develop sources and a storage and distribution system that supplies a sufficient amount of safe water, including a reserve.
- ☐ Ensure regular testing of water quality.

9.1 Introduction

1. Safe water is essential to life and health. People can survive longer without food than without water. Thus the provision of water demands immediate attention from the start of a refugee emergency. The aim is to assure availability of enough water to allow unrestricted distribution, and to ensure that it is safe to drink. Adequate storage capacity and back-up systems for all aspects of water supply must be assured, since interruptions in the supply may be disastrous. To avoid contamination, all sources of water used by refugees must be separated from sanitation facilities and other sources of contamination. As a rule, in this as in other sectors, the simplest possible technologies are the most appropriate in refugee emergencies.

2. Availability will generally be the determining factor in organizing the supply of sufficient quantities of safe water. It may be necessary to make special arrangements for extraction of the water, storage and distribution. Measures will be required to protect the water from contamination and in some circumstances treatment will be needed to make the water safe to drink. The safety of the water must be assured right through to consumption in the home. The dangers of drinking contaminated water are discussed in 9.7.1.

3. Improvements in the existing water supply may take time, particularly where it is necessary to drill or dig wells. In many refugee emergencies only contaminated surface water (standing water, streams or rivers) is initially available and immediate action must be taken to stop further pollution and reduce contamination. If it is evident that available sources are inadequate, arrangements must be made to bring in water by truck. Where even the most basic need for water cannot safely be met from existing sources in the area, and when time is needed for further exploration and development of new sources, the refugees should be moved to a more suitable location. Figure 9-1 overleaf shows some of the considerations in diagrammatic form.

4. Water and sanitation are the subjects of separate chapters. The considerations are, however, largely interdependent and this chapter should be read in conjunction with chapter 10 on sanitation.

9.2 Assessment and organization

- An immediate, competent assessment of local water supply possibilities, involving the government authorities, is essential.
- Expertise is required, and local knowledge is most important.
- Involve the refugees, use their special skills and train them to operate and maintain the system.
- Technology and equipment should be simple, reliable, appropriate and familiar to the country.

General

1. An immediate on-the-spot assessment of local sources of water in relation to needs is essential. The government's central and local water authorities and experts should be involved in this assessment. Knowledge of the local terrain and conditions is indispensable and expertise from outside the country should be brought in only when clearly necessary. An influx of refugees may over-strain water resources used by the local population.

2. Available sources must be protected from pollution at once. Rationing of scarce water may be needed initially in order to ensure survival of the weak and equity in distribution to the rest of the refugee population. The

9-1 GENERAL CONSIDERATIONS IN EMERGENCY WATER

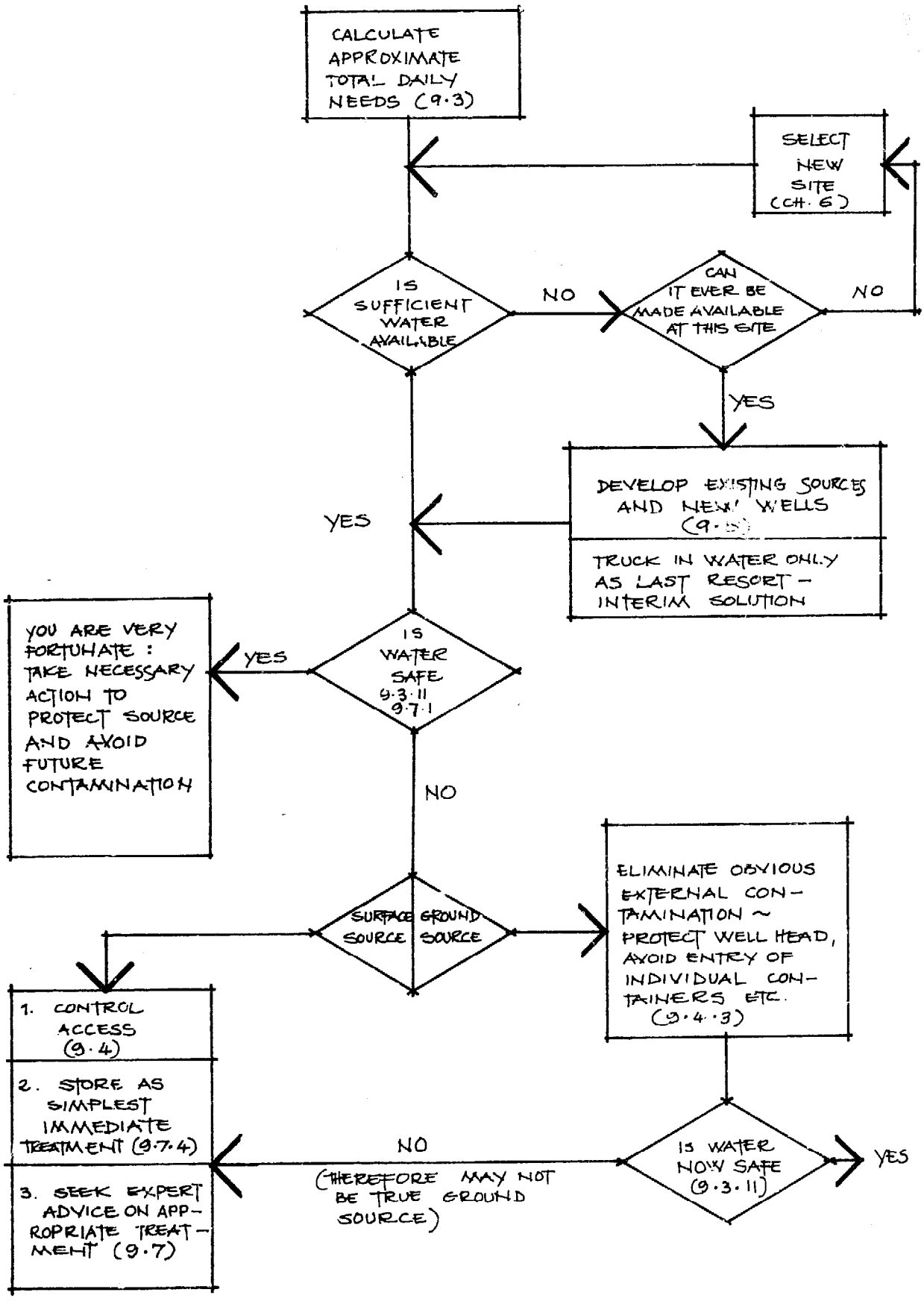

design, establishment and functioning of a water supply and distribution system must be closely co-ordinated with the site planning and layout and with health and environmental measures, and in particular sanitation.

Assessment

3. While estimating the need for water does not require special expertise, assessment of supply possibilities does. A distinction may be useful between the identification of sources on the one hand, and their development and exploitation on the other. Depending on the situation, sources of water and their characteristics may be identified by: the local population; the refugees themselves; the lie of the land (ground water is often near the surface in the vicinity of rivers and in low places generally, or is indicated by richer vegetation); maps and surveys of water resources; and national and expatriate experts (hydrologists); water diviners may be useful. The assessment of water sources, which must be the basis for decisions on a water supply and distribution system generally, requires expertise in water engineering, sanitation (testing, purification) and in some cases logistics.

4. Seasonal factors must be carefully considered. Supplies that are adequate in the rainy season may dry up at other times. Local knowledge will be essential.

Personnel and material

5. Local sources of information and expertise are best and may include: central and local government departments (e.g. interior, public works, agriculture, water resources), the UN system, especially UNICEF, bilateral aid programmes, NGOs and engineering consultants and contractors. If it is clear that locally available expertise will not suffice, Headquarters' assistance should be requested without delay. If outside assistance is necessary, this should be provided whenever possible in support of local experts. Where a water supply and distribution system has to be established with the help of expatriates and mechanized technology, running and maintenance by refugees and other local personnel must be assured before the departure of the expatriates. If this is not done, even the best system will break down.

6. As the provision of safe water is essential to the health of the community, and impossible without its understanding and co-operation, the system must be developed with the refugees and operated by them from the start to the extent possible. The refugees, particularly if of rural background, may themselves have relevant skills. For example, some rural communities contain individuals who are expert at digging and maintaining wells. Others may be familiar with simple pumps or common pump motors. Such skills must be fully utilized in planning, developing and operating the water system. Refugees without prior experience should be trained as necessary. Basic public health education, for example on the importance of avoiding pollution of the water by excreta and the use of clean containers in the home, will be essential.

7. While special equipment may be required in the exploration for new ground water sources or for purification of surface water, material and equipment to establish a water supply and distribution system should be found locally to the maximum possible extent. As a general rule, technology should be kept simple. It should be appropriate to the country and draw on local experience. Where pumps and other mechanical equipment are unavoidable, supplies should be standardized as far as possible, with local familiarity, availability of spares and fuel and ease of maintenance the priority considerations.

8. Both organizational and technical aspects of the complete water supply system need to be carefully monitored. Use of the system must be controlled and water wastage or contamination prevented, maintenance must be assured, and technical breakdowns quickly repaired.

9.3 The need

- Calculate on at least 15 litres per person per day plus communal needs and a spare capacity for new arrivals.

- To preserve public health, a large amount of reasonably pure water is preferable to a smaller amount of very pure water.

- The water must nevertheless be safe: test new sources before use and periodically thereafter, and immediately following any outbreak of a disease which might be caused by unsafe water.

Quantity

1. Minimum water needs will vary with each situation and will increase markedly with air temperature and physical exercise. As a general indication, the following amounts of water are desirable:

Individuals:
15-20 litres per person/day;

Health centres:
40-60 litres per patient/day;

Feeding centres:
20-30 litres per patient/day.

Further needs may include livestock, sanitation facilities, other community services, and irrigation. The more convenient the supply, the higher will be consumption.

2. Reduction in the quantity of water available to individuals directly affects their health. As supplies are reduced, clothes cannot be washed, personal hygiene suffers, cooking utensils cannot be properly cleaned, food cannot be adequately prepared and finally the direct intake becomes insufficient to replace moisture lost from the body. The reduction is reflected in increased incidence of parasitic, fungal and other skin diseases, eye infections, diarrhoeal diseases and the often fatal dehydration associated with them. Even those individuals who may have traditionally lived on less than the normally recommended amount of water, for example nomads, will require more in a refugee community because of crowding and other environmental factors.

3. The needs of community services vary widely, for example from sufficient water to swallow a pill and wash hands in a health centre to the large quantities required in a health centre. Proper supplementary and therapeutic feeding programmes will be impossible unless sufficient water is available for preparation of food and for basic hygiene.

4. The availability of water will be a factor in deciding on a sanitation system. For example, one aquaprivy has a water tank volume of 1,000 litres, to which some five litres per user must be added daily to maintain the water seal; the Oxfam Sanitation Unit requires up to 3,000 litres per day to serve 1,000 persons.

5. Water will be needed for any livestock but care should be taken to avoid pollution or depletion of scarce water sources by livestock. As a rule of thumb, cattle need about 30 litres of water daily and small stock about five.

6. Water for irrigation will be necessary for the cultivation of food by the refugees. In the initial stages of an emergency, only waste water after domestic use may be available, and may suffice for small vegetable patches. Large-scale irrigation is a matter for

expert advice and not considered here, though sources should be identified and reserved at an early stage if possible.

7. Water will probably be of little use in controlling major fires on refugee sites owing to a lack of sufficient quantity and pressure.

8. If more refugees are likely to arrive, plans must allow for a substantial spare capacity over present needs. As has been explained in chapter 6, water is often the determining factor in both site selection and site capacity.

Quality

9. The water must be both acceptable to the refugees and safe to drink. If it tastes and looks acceptable, it will be drunk, with the main dangers being from microbiological organisms. However these "water-borne" diseases are not usually as serious or widespread a problem as the "water-washed" diseases, such as skin and eye infections and diarrhoea, which result from insufficient water for personal hygiene. Thus a large quantity of reasonably safe water is preferable to a smaller amount of very pure water. The most serious threat to the safety of a water supply is contamination by faeces: once the water has been contaminated it is hard to purify quickly under emergency conditions. Possible treatment measures are considered in section 9.7.

10. Where drinking water is scarce, brackish or even salt water, if available, may have to be used for domestic hygiene.

11. New water supplies should be tested before use, and existing ones periodically, and immediately after an outbreak of a typically water-borne disease. The most useful tests are those that detect and enumerate common faecal bacteria, such as faecal coliforms, *Escherichia coli* or faecal streptococci. The presence of any of these indicates that the water has been contaminated by faeces of humans or other warm-blooded animals. The actual test done will depend on the normal practice of local water laboratories and the experience of the local sanitarians. The most widely used tests are those that detect and enumerate faecal coliforms. Concentrations of faecal coliforms are usually expressed per 100 ml of water. As a rough guide:

0-10	faecal coliforms/100ml = reasonable quality
10-100	faecal coliforms/100ml = polluted
100-1,000	faecal coliforms/100 ml = very polluted
over 1,000	faecal coliforms/100 ml = grossly polluted

In cases where the water is disinfected by chlorination (9.7.9.) it is easier and more appropriate to test for the presence of free chlorine than for bacteria. The presence of free chlorine at around 0.2 mg/l at the distribution point indicates that the bacteria have almost certainly been killed and that the water cannot be heavily polluted with faecal or other organic matter.

12. The water in storage tanks and any tanker trucks should also be tested periodically. The water must, of course, be safe at the time of consumption or use in the home, not just at the distribution point. Domestic hygiene and environmental health measures to protect the water between collection and use are important.

9.4 Immediate response

/7 If even the minimum amount of water cannot be made available in time from local sources, the refugees should be moved.

- ☐ Whatever the water source, take immediate action to prevent pollution by excreta.
- ☐ Organize a distribution system that prevents pollution of the source and ensures equity if there is insufficient water.

1. Short-term emergency measures may be necessary while the longer term supply system is being developed or pending the move of the refugees to a more suitable site. If the locally available water supply is insufficient to meet the minimum needs of the refugees arrangements must be made to bring in water by truck. If this is not possible, the refugees must be moved without delay. Often, however, the quantity of water available will meet initial minimum needs and the immediate problem is its quality: it is likely to be dangerously contaminated.

2. The refugees will be using either surface water or, less often, ground water (well or spring). This is usually whatever water is closest, regardless of quality. The best immediate response is likely to be organizational and should be arranged with the refugee community leaders. Whatever the water source, take immediate steps to prevent pollution by excreta. If the source is flowing, supplies must be drawn off upstream and a special area set aside for this. Then allocate an area for washing and finally, downstream of the settlement, allow any livestock to water. See figure 9-2. Fence off parts of the river bank as necessary, and beware of any dangers in the water, such as crocodiles.

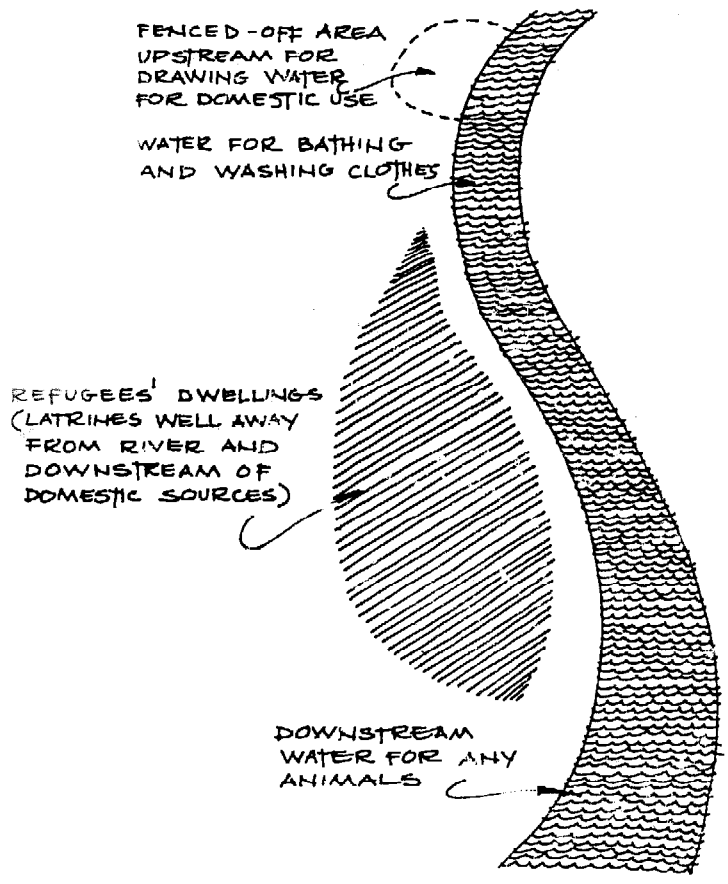

9-2 DRAWING WATER FROM A RIVER

3. Where the source is a well or spring, fence off, cover and control the source. Prevent refugees drawing water with individual containers which may contaminate the source. If possible make immediate arrangements to store water and to distribute it at collection points away from the source. Not only does this help avoid direct contamination but storage can make water safer.

4. At the same time, action must be taken to improve the quantity from existing sources and the effectiveness of any distribution system.

5. From the start, families will need to be able to carry and store water at the household level. Suitable containers (10-20 litres) are essential. Sometimes empty cooking oil containers or the like are available but if not, buckets or other containers must be supplied. These must be kept clean.

6. If the immediately available supplies of water are insufficient, action to ration supplies and ensure equitable distribution will be a priority. Rationing is difficult to organize. The first step is to control access to the sources, using full-time watchmen if necessary; uncontrolled distributions are open to abuse. Distribution at fixed times for different sections of the site should be organized. Vulnerable groups may need special arrangements. Every effort must be made to increase the quantity of water available so that strict rationing is unnecessary.

7. In parallel to these steps, action must be set in hand to plan how the need for water may best be met in the longer term and implementation of this plan set in hand as soon as possible. The following sections outline the main considerations.

9.5 Water sources and their protection

- Rain water, ground water from springs and wells, and water from municipal and private systems is usually of better quality than surface water from sources such as rivers, lakes or dams, and should be used if available.
- Physical protection of the source from pollution will be essential.
- Avoid sources that require treatment if at all possible.
- Expert advice and local knowledge are necessary before sinking wells.
- New or repaired sources and equipment should be disinfected.

General

1. There are three main natural types of fresh water: surface water (streams, rivers, lakes), ground water (underground or emerging at springs) and rain water. Considerations in choosing between alternative sources of water in an emergency include:

(1) speed with which source can be made operational;

(2) volume of supply;

(3) reliability of supply (taking into account seasonal variations and, if necessary, logistics);

(4) water purity, risk of contamination and ease of treatment if necessary;

(5) rights and welfare of local population;

(6) simplicity of technology and ease of maintenance;

(7) cost.

2. Take careful account of systems and methods already in use locally. Adoption of well-proven and familiar techniques, combined with action to improve protection against pollution, is often a sound solution.

3. In addition to organizational measures to protect the water supply, some form of treatment may be necessary. However, sources which would require treatment should be avoided if at all possible. The purification of unsafe water, particularly in remote areas, can be difficult and requires trained supervision to be reliable. The following paragraphs provide general information on different sources of water and indicate the likely need for treatment. Table 9-3 shows some of the considerations.

Surface water

4. Water from streams, rivers, ponds, lakes, dams and reservoirs is rarely pure, and its direct use is likely to require treatment measures; direct access may also cause difficulties with the local population. However, where such a source holds water year-round, the water table in the vicinity can be expected to be near the surface. It is generally preferable to use such ground water, as it will have passed through the natural filter of the soil, rather than the surface water directly. One or more suitable types of well may be used. If the ground is not sufficiently porous to allow extraction of enough water from wells, surface water may be the only option. In such circumstances, emergency treatment measures such as storage, sand filtration or even chlorination will probably be necessary. If surface water must be used, the physical control of access described in 9.4.2 is essential.

Springs

5. Springs are the ideal source of ground water. Water from a spring is usually pure at the source and can be piped to storage and distribution points. It should be taken off above the site if possible. Care should nevertheless be taken to check the true source of spring water, as some apparent springs may really be surface water which has seeped or flowed into the ground a short distance away. It is essential that spring water be protected against pollution at the source by means of a simple structure built of bricks, masonry or concrete, from which the water flows directly through a pipe to a tank or collection point. Care must also be taken to prevent contamination above the take-off point. The supply of water from a spring may vary widely with the seasons and will be at its minimum at the end of the dry season: seek local advice.

Other ground water

6. If the need for water cannot be met by springs, the next best option is to raise ground water by means of tube wells, dug wells or boreholes. Ground water, being naturally filtered as it flows underground, is usually microbiologically pure. The choice of method will depend on circumstances in each case, including the depth of the water-table, yield, soil conditions and availability of expertise and equipment. Table 9-4 on page 128 gives some basic characteristics of the different types of wells.

7. Without good water resource surveys, preliminary test drilling or clear local evidence from nearby existing wells, there is no assurance that new wells will yield the necessary amount of water of the right quality. They can also be expensive. A hydrogeological survey must be undertaken before starting any extensive drilling programme. It is often better to try and improve an existing well that has an inadequate yield rather than dig a new one.

9-3 Some general considerations related to water sources

Source	Treatment (1) (see 9.7)	Extraction (see 9.6)	Distribution (see 9.6)	Remarks
A. Rain	Unnecessary	Simple: off suitable roofs	Individual collection	Seasonal, unlikely to meet total demand. See 9.5.11
Ground water				
B. Spring	Unnecessary	Simple: controlled access	Individual collection or via storage tanks, optionally through piped system	Yield may vary seasonally
C. Deep well (low water table, outside assistance may be required. Each well likely to serve more people than D)	Unnecessary	Hand pump if possible motorized if necessary	As for B	See table 9-4
D. Shallow well (high water table, likely to be many, often self-dug)	Unnecessary if properly located, constructed and maintained	Hand pump or hand drawn container	Individual collection	As for B
Surface water				
E. Flowing (e.g. stream, river)	Often necessary: sedimentation/ filtration/ chlorination	Controlled access (see figure 9-2) Motorized pump to treatment and storage	As for B	Yield often varies seasonally
F. Standing (e.g. pond, lake)	Nearly always necessary: as for E	As for E	As for B	As for E

(1) An approximate ranking of sources by likely quality would be: rain (unlikely to be polluted), spring, borehole, deep well, shallow well, stream or river, lake, pond (very likely to be polluted).

9-4 Characteristics of wells

Type of well	Approximate maximum depth	Technique	Comments
Driven Tube well	10-15 metres	Simple: special pipe hammered into ground; can be sunk in 1 or 2 days	Small; cannot be sunk in heavy clay,soil or rock; needs special filter "well point" at tip of pipe
Bored Tube well	25 metres	Simple: handbored hole using an auger; can be sunk in 2-3 days	Larger than driven tube well; augers may need to be imported, but locally available boring tools can often be used
Hand Dug well	30-40 metres	Requires skilled workers otherwise dangerous. Speed depends on soil conditions. For team of 4 men perhaps up to week per 10 metres depth	Often the most appropriate solution, especially if the refugees traditionally dug such wells
Jetted Tube well	80 metres	More difficult: water pumped down a hole and over-flowing to carry out and loosen soil, enabling pipe to be pushed down	Requires considerable amount of water to sink, and special drilling equipment
Borehole	Over 100 metres	Large drilling rig	If more than some 50 metres deep,hand pumps cannot be used

8. The yield of a well depends on the geological formation in which it is sunk, the contours and gradients of the land, the well construction, and the pump. Any new well or borehole must first be "developed" to full yield by an initial period of pumping at a fast rate. This has the effect of pumping out finer soil particles and thus allowing water to pass more easily into the well. Yield can be raised by increasing the size of the well below the water-table, for example in the case of a shallow well, by an infiltration gallery across the line of ground water flow. If wells are sited too close together yields will be reduced.

9. Wells, boreholes and pumps should be disinfected immediately after construction, repair or installation, as they may have been polluted during the work. Two or three buckets of a 0.2% chlorine solution in water would be a suitable disinfectant and the techniques are described in the technical guides.

10. Like springs, wells must be protected from pollution. They should be located where surface water, and in particular any seasonal rain or flood water, will drain away from the well head. They should be above and at least 15, preferably 30 metres away from any sanitation facilities and their discharge. A well-head, consisting of a headwall and drainage apron, running off to a soakway, is essential to avoid direct contamination down the well. The headwall should not be so wide that people can stand on it. Rollers, pulleys or a windlass should be provided to avoid people leaning over the well. Individual buckets must never be allowed down the well, and close supervision and control will be essential. See figure 9-5. As numbers using an open well increase so does the risk of pollution and difficulty in raising sufficient water by bucket. It is then better to cover the well and use a pump.

9-5 PROTECTING AN OPEN WELL

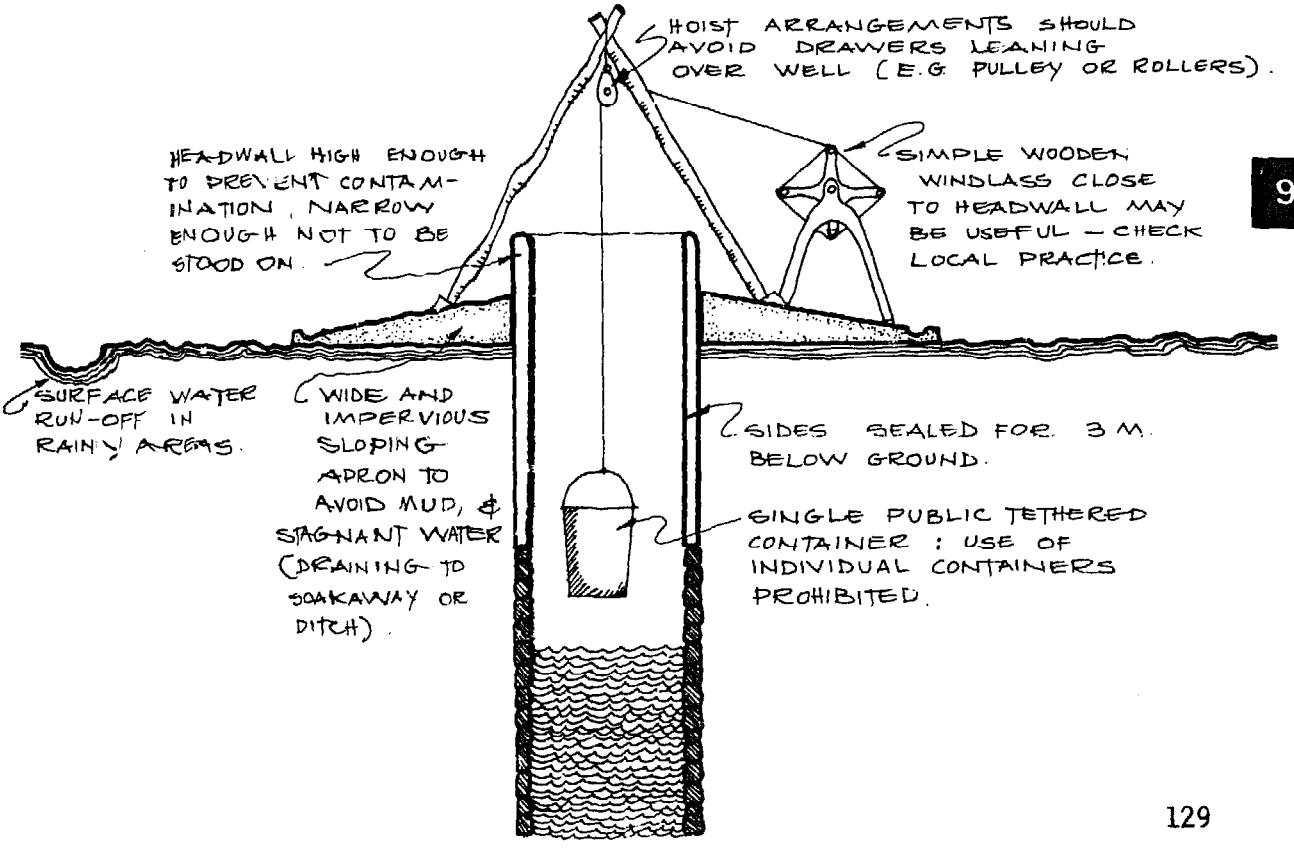

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Rain water

11. Reasonably pure rain water can be collected from the roofs of buildings or tents if these are clean and suitable. This method can only be the major source of water in areas with adequate and reliable year-round rainfall, and it requires suitable shelter as well as individual household storage facilities. It is, therefore, not generally the solution in refugee emergencies. However, every effort should be made to collect rainwater and small collection systems, for example using local earthenware pots under individual roofs and gutters, should be encouraged. Allow the first rain after a long dry spell to run off, thus cleaning the catchment of dust etc. The supply of water which it is possible to collect by this method is estimated as follows:

One millimetre of yearly rainfall on one square metre of roof will give 0.8 litres per year, after allowing for evaporation. Thus, if the roof measures 5 x 8 metres and the average annual rainfall is 750 mm, the amount of rain water which can be collected in a year equals: 5 x 8 x 750 x 0.8 = 24,000 litres per year or an average of 66 litres per day (on many days there will be none).

12. Rain water may be a useful supplement to general needs, for example through special collection for the community services such as health and feeding centres, where the safety of the water is most important. It should also be noted that surface water is particularly likely to be contaminated in the rainy season. Thus rain water may be a useful source of safe water for individual use at a time when other water is plentiful but unsafe.

Sea water

13. Sea water can be used for almost everything but drinking, thus reducing fresh water requirements. In locations where no adequate sources of fresh water exist but where sea water is near, desalination is one possible but costly option. Neither of the two basic methods - distillation using the sun's heat or the use of modern desalination plants - is likely to meet immediate fresh water needs in a major emergency, so relocation of the refugees must be considered as a matter of urgency.

Municipal and private systems

14. Existing municipal and private water systems in the vicinity of the refugees, for example those belonging to industrial or agricultural establishments, may be able to meet part or all of the need during the emergency phase, and should obviously be utilized where possible before unnecessary measures to create other sources are taken. A substantial increase in the yield and quality of such systems may be possible if expert advice is taken.

9.6 Pumps, storage and distribution

- Mechanical pumps will often be needed. Seek expert local advice on what is suitable and remember the operators, fuel and spares.
- Water storage facilities will be essential.
- Distribution points should be within a few minutes' walk of the users' dwellings.
- Site the distribution points carefully and protect the ground around them.
- Standpipes and taps are usually best but vulnerable: one tap per 200-250 refugees.

1. Once an adequate source of water has been established, arrangements are necessary to store and distribute the water in a way that guarantees minimum

needs are met on a continuing and equitable basis.

2. In areas subject to seasonal flooding, or where the level of a river source varies markedly, great care must be taken in the siting of any pumps, distribution, storage and treatment systems. It may even be necessary to mount a pump on a raft.

3. Water can be raised in two basic ways: by hand using some kind of bucket or by using pumps. A captive rope and bucket carries a low pollution risk and is more reliable and much cheaper than any pump. Where this system can meet the demand it is to be preferred. The importance of preventing refugees putting their own containers directly into the source has already been stressed.

Pumps

4. However, in a major refugee emergency, pumps will generally be required, either to raise water for direct distribution at the well or to move it to storage tanks or other distribution points. All pumps have moving parts and require regular maintenance. Professional advice, particularly from locals, should be sought on the selection and siting of pumps. The basic hand pump can lift water some 50 metres (the piston is in a cylinder at the bottom of the well). Such positive displacement pumps use simple low technology and are relatively easy to install and maintain, and generally more reliable than motorized pumps. As an appropriate solution, which will minimise dependence on an outside supply of spare parts and fuel, the handpump is strongly to be preferred. Surrounding villages are likely to have handpumps. However, in a refugee emergency a sudden and large concentration of people requires that the output of available water sources be maximized. Motorized pumps have a far greater output and may therefore be indispensable. If motors are required, local advice should be sought. Local familiarity, fuel supplies, spares, ease of maintenance and above all reliability will be major considerations in pump selection. Self-priming centrifugal pumps are usually recommended when water has to be lifted a considerable height (up to 100 metres) or pumped over a long distance.

5. In some circumstances pumps powered by solar panels may be suitable. The present generation are expensive for their output but very reliable and involve no direct running costs. The next generation of solar pumps should be much cheaper. The pumps naturally work best in direct sunlight but will still work with light cloud cover. As a rough indication, a solar pump powered by panels rated at 250W would lift 1-2 litres/sec. through 6 metres on a sunny day. Thus a solar pump might be a solution when the output of a hand pump would be insufficient but large mechanized pumps are not necessary.

6. The theoretical capacity required of the pump depends on available storage as well as likely demand, as the demand will not be constant throughout a 24 or even 12 hour period. A reserve for breakdowns, new arrivals etc. should be provided. The minimum daily period during which a pump should be idle is that required to allow the level of water in the source to recover to its old level. Pumps should not be operated at night. Always have a standby pump on a major supply system to cover repairs and maintenance.

Storage

7. In nearly all systems it will be necessary to store water in covered tanks between the source and distribution points. This will provide an essential reserve, can greatly facilitate distribution, particularly when water is pumped up to elevated tanks, and helps purify water (see 9.7.4). Where sedimentation tanks are in use,

their capacity alone should equal a day's consumption, thus allowing sedimentation to take place overnight. All refugee sites must be provided as soon as possible with facilities to store an adequate reserve of water. The size of the reserve will depend, beyond the number of people, on the nature of the water supply system in each case and particularly on its logistical aspects. Tank capacities are calculated as follows (use internal dimensions and overflow pipe heights):

(a) Rectangular tanks: length x breadth x height (in metres) x 1,000 = capacity in litres;

(b) Cylindrical tanks: height x radius^2 (in metres) x 3140 = capacity in litres.

8. In certain circumstances, notably in areas with pronounced dry and rainy seasons and where alternative sources of water are limited, the construction of a reservoir to collect water to be used during the dry season may be an option, despite the dangers of pollution and of mosquitoes breeding. An erosion-protected overflow spillway should always be provided. Catchment tanks for collection of surface water can also be considered in the drier parts of the world. Pits are dug in the ground to catch and hold the water which runs off hard ground during heavy storms. They need special lining in order to hold the water, and should be covered if possible.

9. Above-ground tanks may be needed where the water-table is very high and contamination cannot otherwise be avoided. A number of types of simple, air-portable, butyl rubber storage tanks are available and some can be supplied together with a complete distribution system. Headquarters' advice should be sought if local resources cannot meet this need.

Distribution

10. The refugees must have easy but controlled access to water. Ideally, no dwelling should be further than 100 metres or a few minutes' walk from a distribution point. Experience has shown that where persons have to fetch water from considerable distances, they tend either not to fetch enough to limit water-washed diseases or to collect water from closer but contaminated sources. Hence the importance of availability. Water distribution will be an important consideration in the layout of the site. The distribution points should not be in hollows. The area round the point should be paved with stones or gravel, or protected by boards, with a run-off to allow proper drainage.

11. Water can be distributed to individual users in a number of ways, depending on local conditions. Uncontrolled access by individual consumers to primary water sources must be avoided. A distribution system should have a sufficient number of sources and/or outlets in relation to the size of the population to ensure that people do not need to wait for long periods to have access. Equity in the distribution of scarce water is an extremely important consideration. While vulnerable groups (the sick, wounded, most severely malnourished, children, pregnant and lactating women and the disabled) should have adequate and assured allocations, scarce water must be evenly shared among the rest of the population. Refugees should be encouraged to assume responsibility for equitable distribution, and arrangements carefully monitored in order to detect and prevent abuses. In some situations, water meters have proved a cheap and efective way of identifying excessive users and reducing their consumption.

12. The most appropriate method of distributing water to large populations will depend on a number of variables in each specific

situation, such as the kind, number and location of primary sources and the availability of materials, equipment and expertise. Between source/storage and distribution point, water for domestic use should flow only in pipes in order to protect its quality. These must be watertight: leaking pipes will suck in pollution when the pressure drops or the system is turned off. Pipes may be made of plastic, metal, cement or bamboo. Bamboo is unlikely to be suitable in the majority of emergencies and polythene pipes are often the cheapest and easiest to lay. Polythene piping is available in lengths of coiled, flexible pipe as well as in the form of rigid lengths, commonly of 3m. Pipes should be buried for protection and sections of the system should have isolating valves.

13. As outlets, standpipes and push taps are recommended where possible. Taps are, however, very vulnerable and spares must be available. Where water supplies are limited and the site is crowded, valve distribution points which can be chained shut may be the only effective solution. There should be one tap per 200-250 refugees. The larger the number of people using a single source or outlet of water, the greater the risk of pollution and damage. Whatever the final distribution system, this must be carefully controlled and supervised; watchmen are often needed.

14. A certain amount of waste water will be generated in the community, both at the individual and communal service level. This must not be allowed to become a danger to public health, but it may be usefully recycled, for example to water livestock, irrigate vegetable gardens or in flush latrines.

9.7 Treatment

- All methods of water treatment require some expertise, regular attention, and maintenance.
- The most serious threat to the safety of a water supply is contamination by faeces.
- Covered storage is the simplest method of improving water quality.
- Sand filtration is an effective method of water treatment.
- Chemical disinfection for large-scale water treatment is generally only recommended if storage and/or sand filtration cannot meet the need.
- Water purification tablets and boiling are not generally appropriate for large-scale water treatment.

The dangers

1. The water may contain pathogens, particularly certain viruses, bacteria, protozoal cysts and worm eggs which are transmitted from faeces to mouth. Water contamination by human faeces is the major concern, although animal faeces in water may also cause disease transmission. Water contamination by urine is a significant threat only in areas where urinary schistosomiasis (Schistosoma haematobium) is endemic. By far the greatest risk associated with polluted drinking water is the spread of diarrhoeas, dysentries and infectious hepatitis (hepatitis A). The diarrhoeas and dysenteries are caused by a variety of viruses, bacteria and protozoa. The numbers of viruses and protozoa in water will always decrease with time and will decrease most rapidly at warm temperatures. Bacteria behave similarly, but in exceptional circumstances may multiply in polluted water. The infectious dose of the viruses and protozoa is typically very low, whereas the dose of bacteria needed to establish an infection in the intestine may be large.

Treatment

2. The importance of trying to find a source that does not require treatment has been stressed. If treatment is necessary, it should be the minimum required to ensure acceptably safe water, using appropriate technology and a method that is reliable. Determining how to treat water on a large scale is best done by experts, and if possible professional engineering advice should be sought. However, simple and practical measures can be taken before such help is available. Full explanations of types of treatment are given in the technical guides; the main systems are summarized below. All methods require regular attention and maintenance.

3. In addition to the physical measures to protect water at its source and initial disinfection of wells and boreholes (usually by chlorine), there are four basic methods of treatment: storage, filtration, chemical disinfection, and boiling. These can be used singly or in combination.

4. Leaving water undisturbed in containers, tanks or reservoirs improves its quality. Storage causes some pathogens to die off and any heavy matter in suspension to settle (sedimentation). In an emergency where water supplies cannot be assumed to be safe, immediate action to provide maximum water storage capacity is a logical first step. Storage of untreated surface water for 12 to 24 hours will already bring about a considerable improvement in its quality; the longer the period of storage and the higher the temperature, the greater the improvement. The clarification of cloudy water can be greatly speeded up by the addition of aluminium sulphate. A two tank system is often used, the first tank being a settling tank with the second storing the clarified water. If treatment is required this can be done in the second tank, and a third used for storage if necessary. While clear water may only require chlorination, turbid surface water will usually require sedimentation and/or filtration before chemical disinfection; even so greater doses of chlorine may be required.

5. Great care should be taken to prevent pollution of stored water. Storage tanks must always be covered: the dangers of contamination of open tanks more than offset the advantages of direct sunlight. The storage area should be fenced off, and if necessary guarded, to prevent children playing or swimming in the water.

6. Longer storage can help control schistosomiasis (bilharzia), as the parasites die if they do not reach the fresh water snail within 24 hours of excretion by an infected person, or a human or animal host within 48 hours of leaving infected snails. Thus two days' storage would provide an effective barrier to transmission of the disease, provided snails do not enter the tank.

7. Sand filtration can be an effective method of treatment. A proper slow sand filter works in two ways. Passage of the water through the sand physically filters out solids and, more important, a thin and very active layer of algae, plankton, bacteria and other forms of life develops on the surface of the sand bed. This is called the "schmutzdecke", where micro-organisms break down organic matter. The rate of filtration depends on the surface area, depth and type of sand through which the water is passed, and the head of water. The usual size range of the sand is 0.3 - 1mm. Provided the rate of filtration is slow enough, the quality of the treated water is very good.

8. The types of sand filters are described in the technical guides. A packed drum filter can be improvised if drums and sand are available and may be a good way of providing limited quantities of safer water quickly, for example for a

health centre. The water passes down through sand on a 5cm. layer of gravel and is drawn off at a rate that should not exceed 60 litres per hour for a 200 litre drum. If a tap is used, unfiltered water equal to the amount drawn off is simply added to the top. Other types of sand filters include the horizontal sand filter and the river bed filter (suitable only where the bed is permeable). These can be used to treat larger amounts of water but are likely to be more difficult to set up quickly and effectively. For a river source a possible intermediate measure is to dig a well close to the bank. The water recovered will be river water but will have been filtered through the bed and bank.

9. Chemical disinfection as a method of water treatment on a large scale is, as a rule, recommended only in situations where storage and/or filtration cannot meet the need. It will, however, be required initially to purify wells, sand filters, pumps and piped water systems. Both iodine and various forms of chlorine can be used; chlorine is more widely used, cheaper and often more readily available. The most generally suitable form of chlorine for refugee emergencies is calcium hypochlorite powder. Methods of chlorination are described in the technical guides. Expert advice is essential for large-scale chlorination. All systems require regular attention and will be of little value if not fully reliable. Chlorination should take place after any sedimentation or filtration process. It requires at least thirty minutes to act.

10. Care must be taken to ensure strict control of any chemical disinfection process and particularly to test the water for chemical residual levels after each disinfection and before distribution. After chlorination there should still be at least 0.2 parts of "free active chlorine" per million in the water, in other words, still available to kill bacteria. The amount of chlorine required to achieve this is usually a broad indication of the level of pollution. If the amount of "free active chlorine" is much above 0.5 parts per million, people may not be prepared to drink the water: over-chlorinated water tastes unpleasant and will have the reverse of the desired effect if people therefore prefer untreated water. Chlorine and iodine water purification tablets are also available, but are rarely suitable as a method of water treatment for large populations. They may be used in health or supplementary feeding centres.

11. Boiling is the surest method of water sterilization, and at low altitudes simply bringing water to the boil will destroy all pathogens that may be transmitted by drinking water. Boiling should, however, be continued for one minute for every 1,000 metres of altitude above sea level, as the boiling temperature reduces with altitude. Prolonged vigorous boiling is often recommended but is not necessary to destroy the faecal-orally transmitted pathogens; it is wasteful of fuel and will increase the concentration of nitrates in the water. Water with a high concentration of nitrates is dangerous for very young babies. Domestic fuel supplies may in the longer term be the determining factor; boiling requires about 1kg of wood per litre of water. However, if the refugees have traditionally boiled their water and can continue to do so, this should be encouraged and, at least initially, may make the need for other types of treatment less urgent.

Further references (1)

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(1) See also the further references at the end of chapters 7 and 10, only some of which are repeated here.

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10

CHAPTER 10: SANITATION AND ENVIRONMENTAL SERVICES

Need

The social disruption, overcrowding and lack of sanitation facilities that characterize refugee emergencies can quickly lead to conditions that are hazardous to health and offensive unless action is taken.

Aim

To prevent the spread of disease and promote a safe environment for the refugees.

Principles of response

- ☐ The co-operation of the refugees is essential for success, and programmes must be developed with and to the extent possible run by them. The measures taken must be culturally acceptable to the refugees.
- ☐ The advice of an experienced public health engineer with local knowledge is required.
- ☐ Swift provision of a basic system for human waste disposal is better than delayed provision of improved systems.
- ☐ The simplest technologies possible should be applied.
- ☐ Individual family allocation of appropriate latrines is the best guarantee of maintenance and use.
- ☐ Co-ordinate with other public health programmes.

Action

- ☐ Localize defaecation and prevent contamination of the water supply.
- ☐ Develop an appropriate excreta disposal system.
- ☐ Establish effective services for disposal of garbage and waste water, insect and rodent control, disposal of the dead, dust control where necessary, and fire prevention and control.
- ☐ Establish an inspection and reporting system for all sanitation and environmental services, linked to health surveillance.
- ☐ Provide education on sanitation and environmental services as a part of general public health education.

10.1 Introduction

1. Disruption and the crowding together of people who are accustomed to living in different and less crowded conditions makes adequate sanitation of critical importance. The facilities to which the refugees were accustomed are no longer available, basic services are often lacking and habits may have to be changed. In these conditions, indiscriminate disposal of human and other waste will pose serious threats to the health of individuals, family groups and finally the whole community.

2. Environmental sanitation is often considered to include: the provision of safe water; disposal of human excreta, waste water and garbage; insect and rodent control; safe food-handling practices; and site drainage. All these services, and the provision of health care, are very much interrelated and should be considered together. In particular, this chapter should be read in conjunction with chapter 9 on water.

3. The key to reducing health hazards is an acceptable and practical system for the disposal of human excreta. This must be developed in co-operation with the refugees and be culturally appropriate, even if circumstances necessitate a departure from traditional practices. Special public health education may be required; the system must be one which the refugees will use.

4. The refugees must also run the services to the extent possible. Control will be essential: the effectiveness of the services will depend to a significant degree on regular and thorough maintenance and inspection.

10.2 Organization

- Take full account of sanitation needs in site selection and particularly layout.
- Seek professional advice from those with local knowledge and above all consult and involve the refugees.
- Ensure maintenance and cleanliness of the system and the supervision of its operation.
- Educate the refugees as part of the public health education programme.

1. As has been stressed in chapter 6, environmental sanitation will be a very important consideration in site layout, and the organization and operation of the sanitation services must be integrated with other community services.

2. Developing adequate sanitation in a refugee emergency is difficult and correcting mistakes is more difficult. Expert advice should be sought from a public health engineer who is familiar with the habits of the refugees and nationals of the country of asylum, and if possible has experience of refugee emergencies. Assistance should first be sought from local sources such as government departments, the UN system, NGOs, universities, consultants or contractors. If these cannot meet the need, Headquarters' assistance should be requested. There are, however, effective measures that can and should be taken at once. Figure 10-1 overleaf illustrates some of them in diagrammatic form.

3. Good sanitation depends to a great extent on the attitudes of the community and the people who run the system. The systems and services developed should be able to operate effectively with a minimum of outside involvement. Selected refugees must be trained to run the sanitation and environmental programmes.

4. The most common cause of complete failure of a sanitation system is selection of the wrong system as a result of inadequate discussion with the refugees and a

10 – 1 CONSIDERATIONS IN EXCRETA DISPOSAL

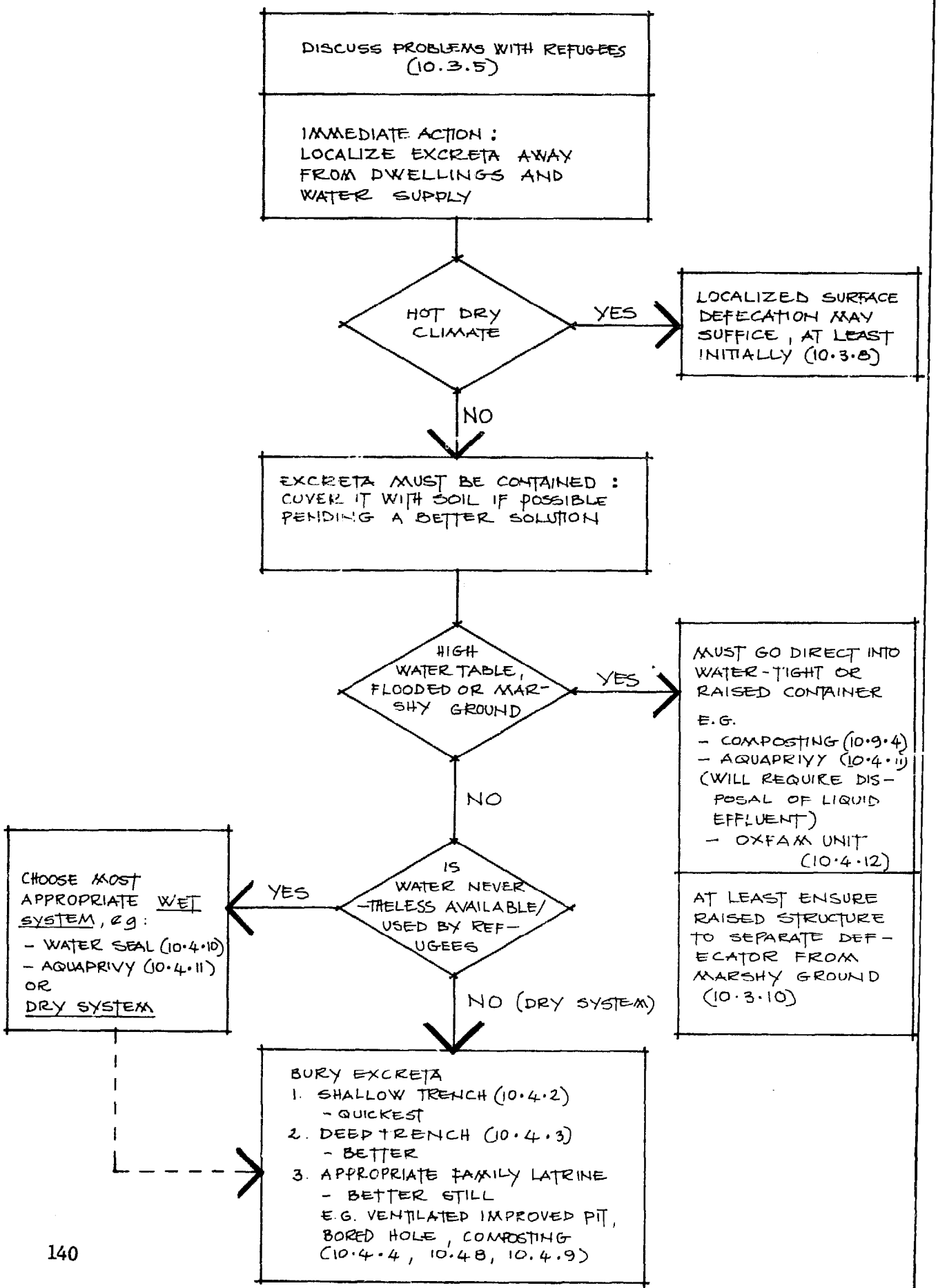

failure to take all relevant factors into consideration.

5. The most common cause of breakdown is inadequate maintenance, even for properly designed and installed systems. The best guarantee of proper maintenance is the individual family allocation of latrines. Breakdown of latrines will lead to contamination of the environment and a high risk of infection and disease. There must be regular inspection and maintenance.

6. Even when in working order, latrines will not be used unless they are clean. Individual families will be responsible for their own units, but where communal latrines are unavoidable, special arrangements to keep them clean will be essential. Particular attention must be given to the maintenance and cleanliness of the latrines serving community facilities such as health centres. Refugee workers and proper supervision will be required, and it may be necessary to pay or otherwise compensate those who are responsible for keeping communal latrines clean and operational. Latrines must be cleaned daily. It should be noted that disinfectants should not be poured into the pits or tanks of latrines which dispose of excreta by biological degradation. The regular addition of soil, ashes or oil, if available, to trench or pit latrines may help control insect breeding and reduce odour.

7. The public health education programme must place proper emphasis on the importance of sound environmental sanitation practices. The link between excreta contamination and disease must be clearly understood by all. Whatever the success of the sanitation system with adults, children will present a special challenge. Children are both the main sufferers from excreta-related diseases and also the main excreters of many of the pathogens that cause diarrhoea. Children are often frightened by unfamiliar latrines and particular care will be needed to ensure that the latrines are safe and physically suitable for children.

10.3 Disposal of excreta

- Take immediate action to localize excreta disposal and prevent contamination of the water supply.
- Carefully consider cultural and physical factors.
- Trench latrines may be needed initially, but in most circumstances individual family latrines are much better.
- Ensure that latrines can be used at night and that appropriate anal cleaning materials are available.

General

1. Safe disposal of excreta is necessary because the agents of most important infectious diseases are passed from the body in excreta and may reach other people. These are called the excreted infections and fall into four main groups: viruses, bacteria, protozoa, and worms (helminths). Furthermore, unless properly isolated, excreta can provide a breeding ground for insects, which then act as direct or indirect transmitters of disease.

2. The specific link between the incidence of diseases and the sanitation system may not always be obvious, as often the most important human link in transmission of an infection is a carrier who shows little or no sign of disease. Conversely, persons in an advanced state of disease may have little or no importance in transmission. The links between diseases, infections, the means of transmission, and the sanitation system must be kept under constant surveillance.

3. The safe disposal of human excreta is more important than disposal of animal waste, because more diseases affecting humans are transmitted by human waste than animal. Human faeces are much more dangerous than urine. For urine, it is probably sufficient in an emergency just to prevent contamination of the water, but in the areas of Africa and the Middle East where the Schistosoma haematobium species of bilharzia occurs, and in all areas where typhoid is common and endemic, disposal of urine also requires special attention.

4. Two main factors will affect the choice of an excreta disposal system: the traditional sanitation practices of the refugees and the physical characteristics of the area, including the geology, the availability of water, rainfall and drainage. Failure to take proper account of either of them can easily result in the system itself rapidly becoming a health hazard.

5. Consideration with the refugees of their traditional sanitation practices and how these can be modified or adjusted to reduce health hazards in the circumstances of a refugee emergency is the essential starting point. Over half the world's population does not use latrines. Of those who do, some cultures require privacy, some separate the sexes physically or by time, others do not. Such factors, and the method of anal cleaning, must be considered at the planning stage and will directly affect the type of system. Once they have been taken into account, the cleanliness of latrines and their ease of access will determine whether or not they are used. The following may help as a check list:

(1) Previous sanitation system and practices;

(2) Method of anal cleaning;

(3) Preferred position (sitting or squatting);

(4) Need for privacy;

(5) Segregation of sexes and other groups or individuals with whom it is culturally unacceptable to share a latrine;

(6) Cultural practices for children;

(7) Cultural taboos (for example, against contact with anything that may have touched excreta of others);

(8) Social factors, including likelihood of community action to ensure proper use of proposed system;

(9) Need for special orientation (direction) of latrine in some cultures;

(10) Systems used locally in neighbourhood of site.

6. Arrangements must be made to assure the availability of appropriate anal cleaning materials at or near all latrines. This is essential to the maintenance of hygiene.

7. The latrines must be safe for children, and must be able to be used at night. For individual units, families may be able to arrange their own lamps, but for communal units some form of lighting should be provided.

Immediate action

8. The refugees are likely to be defaecating indiscriminately, contaminating their environment and often the water supply. In consultation with the community leaders, the best first step is to try and localize excreta: controlled surface defaecation. If space allows, designate an area or areas away from the dwellings and down wind, but sufficiently close to be used. Fence the area(s) and provide privacy and a shallow trench and spades, if necessary and possible. Covering excreta lessens risks.

Site such areas where the surface run-off during rain will not cause contamination and protect the area with cut-off ditches.

9. A publicity campaign will be required to encourage refugees to use these areas and not defaecate indiscriminately near dwellings. At the same time measures must be taken to prevent defaecation or urination in or near the water supply. This immediate action can already significantly reduce public health hazards.

10. If the ground is flooded or marshy or there is a high water table, arrangements must be made as soon as possible to try and physically contain the excreta: in such circumstances the risks to public health are greatest and location of the area away from the dwellings and water source is even more important. Pending a proper containment system, simple raised structures, for example a wooden stage some 50cm high, may be essential to avoid the refugees immediately being contaminated by their own excreta. Alternatively empty 200 litre (45 gallon) oil drums can be used. One end of the drum is cut out and the drum inserted that end down into the ground, after digging a hole as deep as the water allows. The last half metre of the drum is left out of the ground and a small hole cut into the end of the drum to transform it into a squatting plate.

11. Where the site is not yet occupied, immediate action will be determined by the type of system adopted (see below). The first refugees moved to the site should construct the system if this has not been done earlier.

Longer-term options

12. Expert advice will be required on the most appropriate system. The nature of the soil will be important; if it is highly impervious some systems will be precluded. The availability of water will be another factor, and the importance of cultural considerations has already been stressed. There are many simple options that, if properly constructed and maintained, will meet all public health requirements.

13. In hot, dry climates, where sufficient space is available, localized defaecation areas away from the dwellings may also be the best continuing arrangement, particularly for those whose normal practice it would be. In time, the heat and sunlight render the faeces harmless. Black rock is the best surface. If this solution is adopted keep the potential health hazards under review and watch out for increased numbers of rats in the area. In most emergencies, however, some sort of latrine will be required, even for refugees unaccustomed to them. The broad division is into dry latrines - trenches, pits or holes in the ground - and water-dependent latrines, which are flushed. In addition there are also systems based on composting or the cartage of excreta.

14. If the site is on the coast, local practice may be to defaecate in the sea. While this is less harmful for the refugees than indiscriminate defaecation on land, it should be discouraged unless there is no other option. The dangers increase greatly with numbers. Faeces will contaminate the high-water line, and the practice will increase the health hazards of washing in the sea. Where defaecation in the sea is unavoidable, it should be localized by fencing off an area. Structures should be built that permit defaecation away from the immediate shore line and both the location of these and organization of the system should make use of tides, currents and prevailing winds to avoid direct contamination of the foreshore. Pumping untreated excreta far enough out to sea so that it is carried away from the coastline is one possibility. Defaecation in bays, estuaries or lagoons where fish or shellfish

are caught should be discouraged since this may be a source of infection.

Selection of a system - basic considerations

15. The selection of an excreta disposal system suitable for a particular situation requires consideration of a number of factors. In an emergency, however, time is the critical factor. Pollution of the environment by excreta, with all its attendant risks, cannot be stopped without immediate sanitation measures. Thus the range of choice is always much more limited at the very outset of an emergency; weeks or months cannot be lost in waiting for expert advice, construction to be completed or material to arrive. Temporary systems to meet the most immediate needs will have to be improved or replaced by others as soon as possible, in order to maintain adequate sanitation standards. In emergency sanitation act first and improve later.

16. Emergency conditions may therefore dictate at least the initial use of trench latrines. These can be dug quickly and need less space than individual family units. While shallow trenches may be a quick-action solution for a very short initial period, deep trench latrines are incomparably more effective. Where space and soil conditions allow, the simplest and commonest individual family unit is the pit latrine. Details of various types of latrine are given in section 10.4. Once a system has been selected, a pilot project may yield valuable lessons.

Specific considerations

17. There are three basic options for the allocation of latrines: individual family units, centralized units with each latrine allocated to an individual family and communal systems. People will always make more effort to keep their own latrine clean and in good order than to do the same for a communal facility, and dirty and smelly latrines will not be used. Consequently, individual family units are, under normal conditions, the preferred solution.

18. Cost, installation and maintenance. The most appropriate system is likely to be the one that is cheap, simple to install and easy to maintain. Maintenance problems often prevent satisfactory operation of otherwise well designed and installed systems. Particularly important, the latrine must be easy to clean and the surfaces round the hole washable. Avoid uncovered wood if possible.

19. Number and siting of latrines. As a rule, at least one latrine should be provided for every 20 people. Latrines should be at least 6 metres from dwellings if possible, further away from feeding and health centres, say a minimum of 10 metres, and over 15 and preferably over 30 metres from wells or other drinking water sources though all these distances depend on latrine and soil type. Latrines should be located no more than 50 metres from user accommodation and be easy of access. Figure 6-1 on page 62 shows these considerations in the context of site planning. If people have to walk a considerable distance to a latrine they will defaecate in a more convenient location regardless of the health hazard.

20. Population density will affect the space available for the excreta disposal system and thus the type of system. One of the major health hazards as a result of overcrowding is that latrines are too close to dwellings and there may be insufficient space for individual units. This must be considered in site planning. The site layout should be determined, among other things, by the needs of the most suitable sanitation system, not vice versa. Space must be available for replacement latrines where necessary.

21. The nature of the soil may exclude certain options. For example, rocky soil may prevent the digging of pit-type systems; sandy soil will demand special measures for preventing side wall collapse of pits; impervious clay soils may exclude any system dependent upon seepage. Account should be taken of the difference between dry season and wet season soil conditions. If the ground freezes in winter this may limit the choice of systems. Soil conditions can vary over a short distance and a thorough survey is necessary. Where there is a high water-table, perhaps only seasonally, care must be taken to ensure it is not contaminated by seepage from the latrines. In flood or swampy conditions the excreta must be contained.

22. The amount of water available will determine whether disposal systems which require water are a possibility. These systems are generally more expensive than those which do not need water. Refugee situations are often characterized by a lack of reliable water sources, which usually means that the excreta disposal system should not be dependent on water availability. However, whatever the system, many communities require water for anal cleaning.

23. All sites have rain at some time and seasonal rains may be very heavy; it is necessary to anticipate where surface run-off will flow and it may need to be diverted by cut-off ditches. The possibility of flooding should be considered and drainage provided if necessary. If flood water enters the latrines large areas may be contaminated.

24. Construction material will be needed. The structure should be made of local materials and these should be used for reinforcing the pit where necessary. Refugees not used to latrines will generally prefer a large enclosure with no roof but there are often strong arguments for covering latrines in order to prevent rain water filling the latrine, causing contamination around it, or weakening the surrounds. Make sure proper drainage off the roof is provided, away from any soakaway. Special measures will be necessary for the manufacture of squatting or sitting slabs, and U-pipes and other material for wet systems, if these are not available locally. Where refugees or locals have an established method of covering latrines, for example with a wooden lattice, this is generally to be preferred, even if it is less easy to clean than a special plate. There are, however, a number of simple techniques which exist for making the latter on site, for example with reinforced cement or fibreglass from moulds. Guidance is given in the technical references. Seek advice on local methods.

25. Biogas can be produced from excreta, with fertilizer as a by-product. While rarely likely to be a priority in an emergency, this possibility should be considered where fuel is short and effective local biogas systems already exist. The applications are generally in communal services: there is a minimum effective plant size and conversion of a family's excreta to biogas only yields up to a quarter of their needs in cooking fuel.

10.4 Types of latrine

There are many potentially satisfactory types of latrine: low cost, simplicity of construction and ease of maintenance are the priorities once cultural and physical factors have been considered. The basic division is into wet and dry systems.

Dry systems

1. In dry systems, keep the squatting hole as small as possible and ensure a close fitting cover is provided and used, except with VIP latrines (see 10.4.4).

2. Shallow trench latrines (very cheap). Shallow trenches can be dug with picks and shovels and last for only a few days. The shallow trench is usually 30 cm wide and 90-150 cm deep. For every 100 people 3.5 metres of length is recommended. After every use the excreta should be covered with soil from the digging of the trench, which is left on one side. When the trench is filled to within 30cm of the top, it must be covered with soil and compacted. Simple platforms which can be cleaned without much difficulty and moved on may be placed over the trenches.

3. Deep trench latrines (cheap). Deep trenches can be used for a few months. If necessary, and where space is available, this solution can continue for longer periods, with new trenches being dug as old ones fill up. They should be dug 1.8 to 2.5m deep and 75-90cm wide. Recommended length per 100 persons is again 3.5 metres. A platform and structure will be needed, providing a seat or squatting hole, as appropriate, with lid, and the trench should be fly-proofed to the extent possible. Adding earth, ashes or oil will reduce flies. Trench sides must be shored up if there is a danger of collapse.

4. Pit latrines (cheap). The most common excreta disposal system around the world is the individual family pit latrine (figure 10-2), which has major advantages over a trench latrine. It consists of a superstructure for privacy, and a squatting place (or seat) above a hole in the ground. Individual families can dig the pit and build the superstructure and if used by only one family these latrines are usually well maintained. Pit latrines can also be used in clusters as communal facilities. While the basic variety has both odour and insect problems, the simple improvements shown in the diagram can reduce these considerably, as will the addition of oil and use of lids. Where pit latrines are used, the ventilated improved version (VIP) should be built whenever possible.

10 - 2 PIT LATRINES

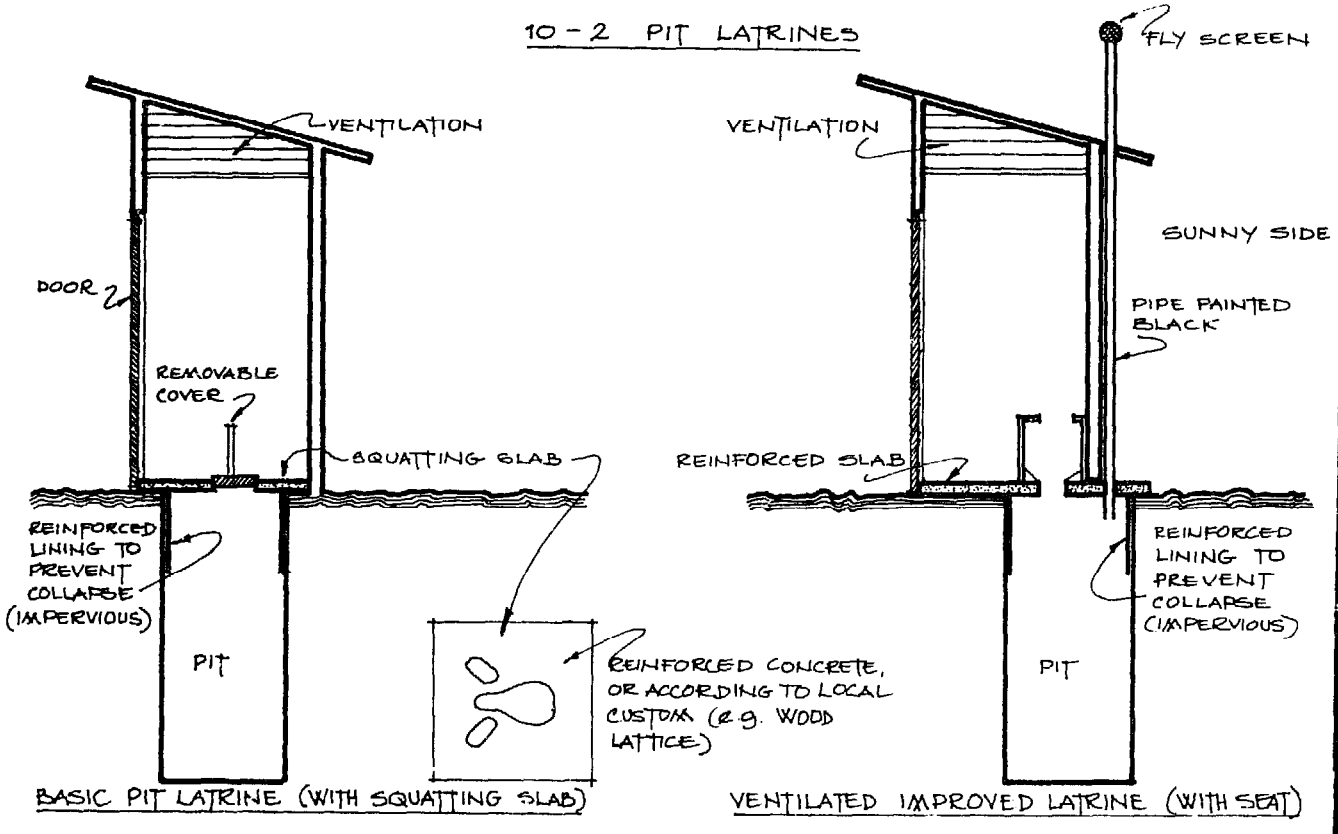

5. Pit latrines are most suitable in conditions of low to medium population density - up to about 300 persons/hectare - but have been used satisfactorily in areas with twice this density. Space should be available not only for the construction of one pit latrine per family, but also for the digging of new pits when the old ones are full. This is an important consideration when pit latrines are used as communal facilities. When the pits are three-quarters full, they must be filled with soil and the superstructure and squatting plate moved to a new pit. If layers of ashes are applied as the pit fills the excreta will decompose and in time the site can be used again.

6. The pit should be about one metre across and over two metres deep. The rim of the pit should be raised about 15cm and cut-off ditches dug to divert surface run off. The pit should always be reinforced and the sides may need to be reinforced for one metre below ground level to prevent collapse. A light wooden squatting plate or wooden lattice, although harder to clean, may be more practical than a heavy concrete one. The danger of collapse may be further reduced by digging the pit as a trench only 50-60cm wide or by having a circular pit, when the use of oil drums as described in 10.3.10 could be considered.

7. The vent pipe in a VIP latrine should be at least 15cm in diameter, about 2 metres high, painted black and placed on the sunny side of the latrine for maximum odour and insect control. It must be fitted with an insect-proof gauze screen, when it will work as an excellent fly trap. The hole should not be covered by a lid as this impedes the air flow.

8. Bored-hole latrines (cheap)

Bored-hole latrines (figure 10-3) are dug with a hand auger or mechanical drill and require a smaller slab than a pit. The bore-hole is 35-45cm in diameter and any depth up to 7 metres. The advantage of the bored-hole latrine is that it can quickly be constructed as a family unit if augers are available. The disadvantages are that the side walls are liable to fouling and fly breeding, they are smellier than vented systems and the risk of ground water contamination is greater because of the depth.

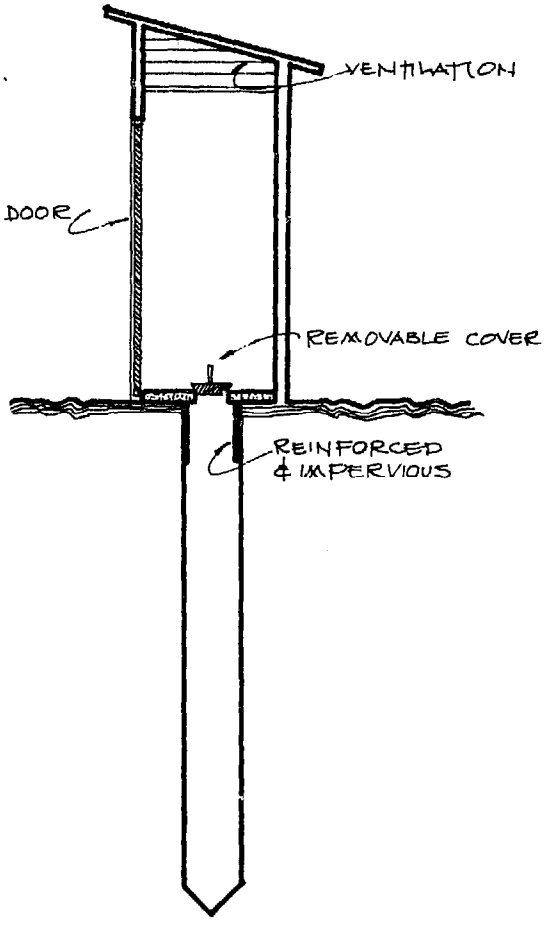

10 - 3 BORED HOLE LATRINE

9. Composting latrines (cheap). Such latrines render excreta harmless with time and produce fertilizer. Figure 10-4 shows one of proven effectiveness, the Vietnamese double septic bin, suitable for a family of 5-10. Urine does not enter the bin, being diverted into a container. After each defeacation ashes are sprinkled over the faeces. Once filled, the bin is sealed (e.g. with lime cement or clay) and the adjoining bin used. A full bin is left to compost for at least two months and the contents then removed through the rear access door, which has also been hermetically sealed during composting.

Wet systems

10. Water seal (pour-flush) latrines (cheap). Water seal latrines (figure 10-5) are simple in technical design but require a permeable soil for their soakaway. A water seal is made by a U-pipe filled with water below the squatting pan or seat. It is flushed by hand with some 1-3 litres of water into a pit or soakaway. This system is suitable where water is used for anal cleaning and where refugees are used to flushing. It is not suitable where paper, stones, corncobs or other solid materials are used for anal cleaning. Water seal latrines will be used properly only if water is readily available. A large container with a 3 litre dipper should be close by the latrine. Pit latrines can be modified to become water seal latrines where soil conditions allow.

11. Aquaprivies (more expensive). Aquaprivies (figure 10-6) consist of a squatting plate or seat above a small septic tank from which effluent drains to an adjacent soakaway. The aquaprivy requires a minimum water tank volume of one cubic metre (1,000 litres), to which some five litres per user must be added daily. In areas with impermeable soil such as clay it is not possible to use a soakaway. The liquid run off can be carried in pipes and passed to an area suitable for disposal. The most common difficulty with aquaprivies is failure to maintain the water seal, causing serious odour and insect problems. Experience has shown they do not work satisfactorily where water has to be carried to the latrine, but as long as the aquaprivy is kept topped up with water there are few things that can go wrong. Aquaprivies are not recommended where solid materials are used for anal cleaning. Seek

10-4 DOUBLE BIN COMPOSTING LATRINE
(ENCLOSURE NOT SHOWN)

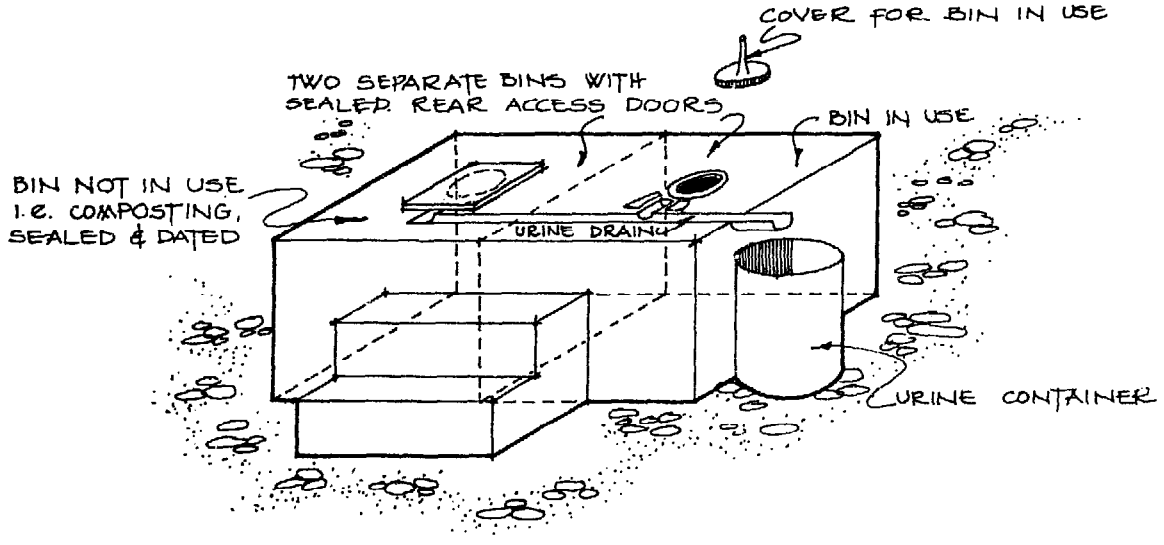

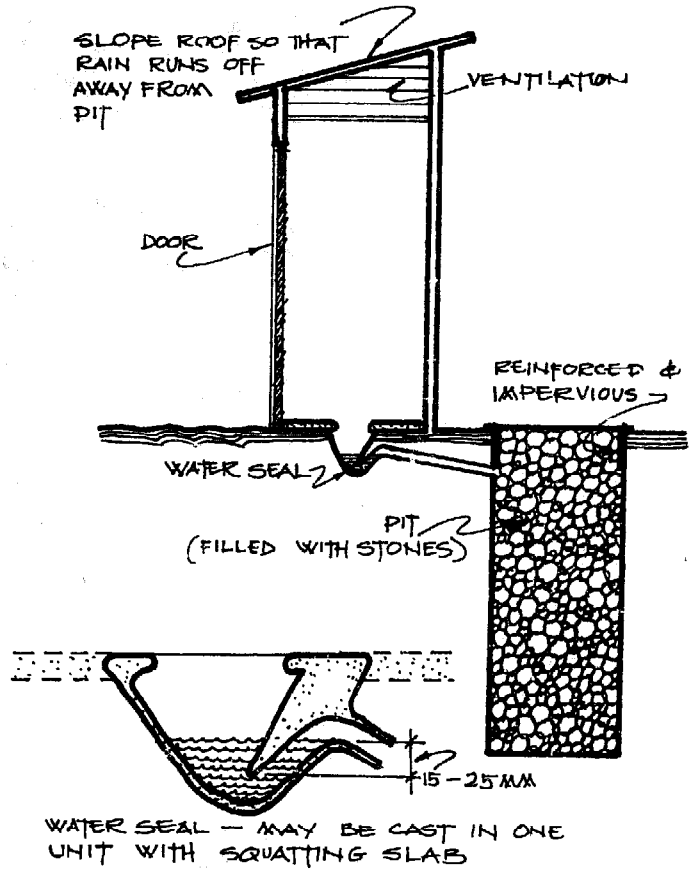

10-5 POUR-FLUSH (PF) LATRINE

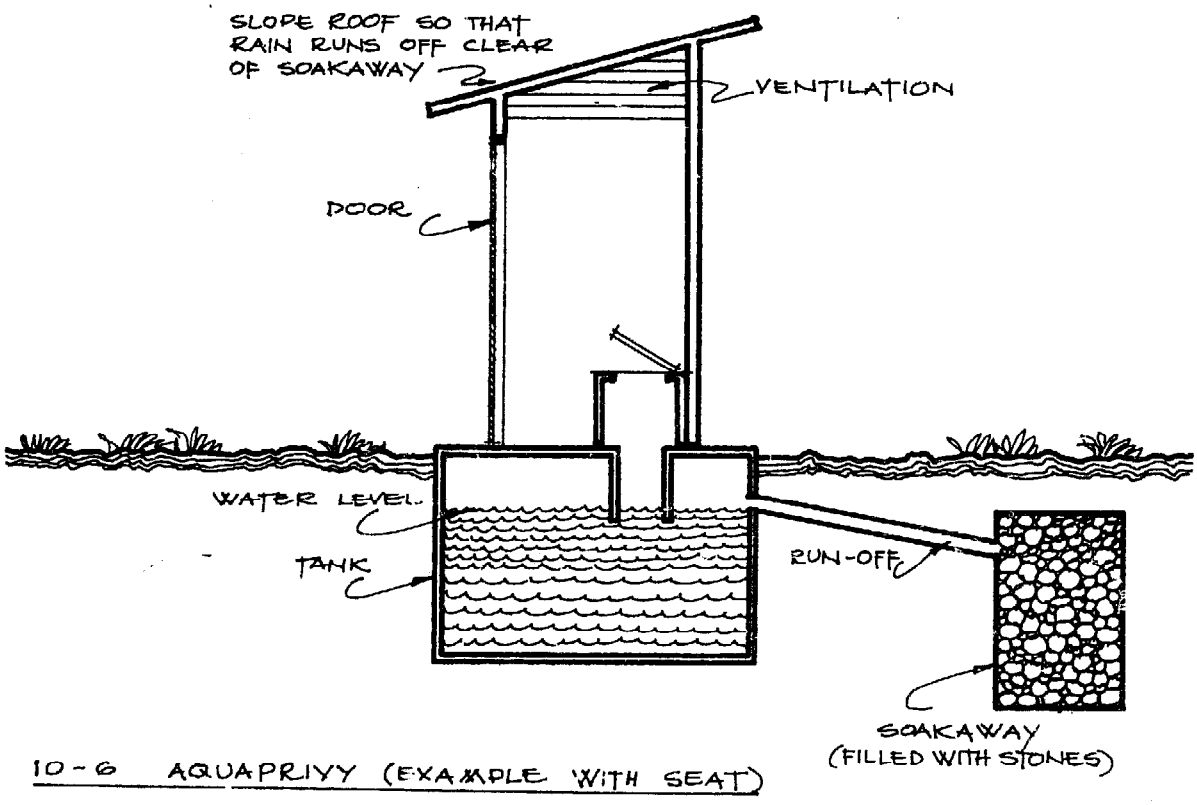

10-6 AQUAPRIVY (EXAMPLE WITH SEAT)

local advice before deciding between aquaprivies and water seal latrines. The former are less easily blocked but have no other major advantage over the latter, which are cheaper.

12. Oxfam Sanitation Unit (more expensive still). The unit is a pre-packaged, communal treatment system in which 20 squatting plates, two flexible tanks made of nylon-reinforced butyl rubber for sewage treatment, and all necessary pipes and fittings are provided. As a unit designed specifically for emergencies, it has the advantage of being a proven system which can be assembled quickly and is not affected by soil conditions. One unit can serve up to 1,000 persons per day. Apart from cost and problems of unfamiliarity, the main disadvantage is that it requires about 3,000 litres of water a day at full design capacity. The unit is not suitable for communities using solids (stones, corn-cobs etc.) for anal cleaning. The water must not be saline. The unit requires a good soakaway or alternate effluent disposal. It also requires a reliable operator. Before deciding on this system, the advice of someone familiar with it should be taken.

Waste stabilization (oxidization) ponds

13. Where a liquid effluent has to be disposed of, for example from a 'wet' system in impermeable soil, waste ponds can provide a simple and cheap solution. Treatment is by natural biological and physical processes. As the rate of treatment increases with temperature, ponds are particularly effective in hot climates. Various systems are described in the technical references. If ponds are used they must be securely fenced off.

10.5 Waste water, garbage and dust

- Sources of waste water must be localized as much as possible and drainage provided.
- Improper garbage disposal increases the risk of insect and rodent-borne diseases, and an effective system must be established for the storage, collection and disposal of garbage.
- Garbage disposal areas must be designated and access to them restricted.
- Large amounts of dust can damage health. Preventing destruction of vegetation is the best preventive measure against dust; spraying of roads and traffic control are additional measures.

1. Waste water is created by washing, bathing and food preparation. The problem of waste water should be dealt with by localizing sources of waste water as far as possible, and by providing local drainage. If this water is not drained away, it will stand in malodorous, stagnant pools providing breeding places for insects, especially mosquitoes, and becomes an additional source of contamination of the environment. Washing, for example, is often done near water sources, causing many problems. In other circumstances, refugees may wish to use the latrine, with its privacy, impervious floor and drainage, for washing. To avoid these problems, special separate washing areas with duckboards or stones and proper drainage should be constructed.

2. All communities generate garbage, and the uncontrolled accumulation of garbage is both unpleasant and unhealthy. Rodent and insect-borne diseases increase with improper garbage disposal. An effective disposal of garbage must therefore be provided and the needs reflected in the initial site planning. Free range chickens, goats and pigs, when available, will help control garbage; dogs will spread it. The suggestions that follow particularly concern high-density sites, where the problem and dangers will be

greatest. Established routines for the storage, collection and disposal of garbage and control measures will be required. Disposal should be accomplished by burying at designated locations on the site, or removal off the site. The open burning of garbage on site should be avoided, and incinerators used if garbage is to be burnt.

3. For solids storage, garbage containers made of metal or plastic and with a minimum capacity of 50 litres should be provided. A 200 litre oil drum cut in half is often used. They should have lids if possible and drainage holes in the bottom. A ratio of one container per 10 families has proved to be effective. The containers should be placed throughout the site in such a manner that no dwelling is more than about 15 metres away from one.

4. The collection of garbage from the containers should take place regularly, daily if possible. Daily collection arrangements will also need to be made for the waste from feeding centres. The safe disposal of all medical waste requires particular attention.

5. Needles and scalpels are especially dangerous. Medical waste should be treated separately, burning as much of it as possible without delay. The designated areas where garbage is to be buried should be well away from dwellings, and be fenced to restrict access. If garbage has to be burnt, after each burning it should be covered with a layer of soil.

6. Large amounts of dust carried in the air can be harmful to human health by irritating eyes, respiratory system and skin, and by contaminating food. Dust can also harm some types of equipment which may be needed on refugee sites. The best preventive measure is action to stop the destruction of vegetation round the site. Dust control can be achieved by spraying roads with water or oil, especially around health facilities and feeding centres, limiting traffic and banning it from certain areas if necessary.

10.6 Insect and rodent control

- Insects and rodents carry and spread diseases and can spoil food supplies.
- Physical screens are the best immediate measures.
- Preventive action to eliminate or limit breeding areas and conditions favourable to the vectors is the best long-term solution.
- Specialist supervision of all chemical measures and local knowledge of resistances is necessary.

1. The environment in a refugee emergency is typically favourable to the proliferation of disease-carrying insects and rodents (vectors), which can also destroy or spoil large quantities of food. Flies tend to breed in areas where food or human excreta are present, mosquitoes where there is stagnant water, and rats where there is food, garbage and cover. For both flies and mosquitoes, the life-cycle from egg to adult can take less than two weeks. As a result of overcrowding and inadequate personal hygiene, lice, fleas, mites, ticks and other arthropods may also cause health problems. Table 10-7 overleaf gives an indication of common vectors and related diseases.

2. Reducing the numbers of flies, mosquitoes and rodents quickly in an emergency is difficult and physical screens may be the best immediate measure. The most effective method of controlling insects and rodents over the longer term is preventive: to improve personal hygiene, sanitation, drainage, garbage disposal and food storage and handling practices and thus make the envi-

ronment less favourable for the vectors. Examples of practical measures are the removal of stagnant waste water, regular garbage collection, use of oil in latrines and provision of soap and sufficient water for washing. The programme should provide for regular inspection and be integrated with other public health measures.

3. The problems should be discussed with the refugees and education given on the significance of vector control. Where solutions unfamiliar to the refugees are employed these must be carefully explained.

4. Detailed descriptions of vector control methods using insecticides and poisons are given in the technical references. Specialist advice and supervision of all chemical measures is essential. These must be closely co-ordinated with national programmes and practices, especially with the national malaria control programme. Whole areas or specific insect breeding grounds, and perhaps the refugees' dwellings, can be sprayed. Insects may already have and can quickly develop a resistance to chemicals; a rotation system, using different sprays, may be necessary. Local knowledge of existing resistances is required. Poison and traps may be used against rats in food storage and handling areas but particular care must be taken in disposing of dead rats, which may carry plague-bearing fleas. Chemical spraying and rodent poisons can be dangerous to humans.

5. The body louse is the only proven vector of louse-borne (epidemic) typhus and epidemic relapsing fever. The lice are found on inner clothing, particularly at the seams. If there is a serious increase in body louse infestation quick action is required by properly trained personnel. This generally takes the form of dusting individuals' inner clothing and bedding with an insecticide or the use of clothing fumigants. There is widespread resistance of lice to some insecticides, especially DDT, and expert local advice must be sought. Mass washing of clothing is unlikely to be a solution as a water temperature of at least 52°C must be maintained to kill the lice.

10-7 Vectors which may pose significant health risks

Vector	Risks
Flies	Eye infections (particularly among infants and children); diarrhoeal diseases
Mosquitoes	Malaria, filariasis, dengue, yellow fever, encephalitis
Mites	Scabies, scrub typhus
Lice	Epidemic typhus, relapsing fever
Fleas	Plague (from infected rats), endemic typhus
Ticks	Relapsing fever, spotted fever
Rats	Rat bite fever, leptospirosis, salmonellosis

10.7 Fires

- Refugee sites are often very vulnerable to fires. An alarm system is essential at high-risk sites.

- The most effective preventive measure is the proper spacing and arrangement of all buildings. Other measures include controlling the use of fire, protecting cooking areas and safe storage of fuel.

- Water is unlikely to be available for major fire control on refugee sites. Forcible creation of additional firebreaks, manually or by bulldozer, may be a better control measure.

1. Refugee sites are often overcrowded, use light and highly combustible shelter materials, and have many individual cooking fires. Thus they are very vulnerable to major fires. Measures to prevent and control fires must be considered from the start of emergency assistance at refugee sites.

2. The most basic and effective preventive measure is the proper spacing and arrangement of all buildings to provide fire breaks (see ch.6.5.4). Other measures include allowing individual fires for cooking only, outdoors if possible. Where cooking takes place indoors, and especially in wooden or wattle-and-daub buildings, the cooking area should be protected with asbestos sheeting if possible. Where large scale cooking is taking place indoors, for instance in a supplementary feeding centre, an asbestos ceiling and walls or their equivalent, should be mandatory. Fire retardants can be applied to thatch roofing in dwellings. Proper precautions must be taken with regard to the storage and uses of fuels, and highly inflammable synthetic materials avoided.

3. All fires can be controlled in the first few minutes with modest resources providing quick action is taken. Therefore an alarm system, fire fighting teams and beaters must be organized in advance and plans prepared. Sand buckets are effective if sand is available. Water will generally not be available in sufficient quantity and at adequate pressure for the control of major fires. The creation of a new firebreak by taking down one or more rows of dwellings may be necessary. This can be done manually or with a bulldozer if available. Take great care to ensure that dwellings are empty: children may be left at home by parents fighting the fire. When fighting a large fire with scarce resources, the first priority is to contain it, rather than put it out.

10.8 Disposal of the dead

- Suitable arrangements for disposal of the dead are required from the start of an emergency, although dead bodies are generally not a health risk.

- Action should be co-ordinated with the national authorities.

- Burial is the simplest and best method where acceptable and physically possible. Arrangements should be made to allow traditional rituals.

- Before burial or cremation, bodies must be identified and the identifications recorded.

1. Suitable arrangements for the disposal of the dead are required from the start of a refugee emergency. The mortality rate after a new refugee influx may well be higher than under "normal" conditions. The authorities should be contacted from the outset to ensure compliance with national procedures, and for assistance as necessary.

2. Dead bodies present a negligible health risk unless the cause of death was typhus or plague,

when they may be infested with infected lice or fleas. Bodies must be protected from rodents, animals and birds. Burial is the simplest and best method of disposal if it is acceptable to the community and physically possible. Health considerations provide no justification for cremation, for which sufficient fuel may often not be available. Whenever possible, the customary method of disposal should be used, and the traditional practices and ritual should be allowed. Material needs, for example for shrouds, should be met. The necessary space for burial will need to be taken into account at the site planning stage, particularly in crowded conditions.

3. Before burial or cremation, bodies must be identified and the identification and, if possible, cause of death recorded. This is of particular importance to disease control, registration and tracing. If the whereabouts of relatives are known, the most immediate relation should be notified; steps must be taken to assure the care of minors who, as the result of a death, are left without an adult to look after them. (See ch.11.5)

Further References (1)

Feacham R. Cairncross S. (1978)	Small Excreta Disposal Systems A clear presentation with simple diagrams and practical advice.	Ross Bulletin No.8
Rajagopalan S. Shiffman M. (1974)	Guide to Simple Sanitary Measures for the Control of Enteric Diseases Covers water supply and all aspects of sanitation including food sanitation. (Also in Arabic, French and Spanish)	WHO
PAHO (WHO)	Emergency Vector Control after Natural Disaster (1982) General principles also relevant to refugee emergencies. (Also in Spanish).	PAHO Scientific Publication No.419
Oxfam	The Oxfam Sanitation Unit A guide to the unit. (A July 1975 Oxfam Technical Paper describes the design and testing of the unit.)	Oxfam
UNDRO (1982)	Disaster Prevention and Mitigation: Sanitation aspects Covers natural disasters but parts also relevant to refugee emergencies. (Also in French and Spanish)	Volume 8 in Compendium of Current Knowledge series
World Bank	Appropriate Technology for Water Supply Sanitation A 12 volume series. Volume 11: A Sanitation Field Manual (1980) is particularly relevant.	World Bank
WHO (1982)	Manual on Environmental Management for Mosquito Control (with special Emphasis on Malaria Vectors). (Also in French)	WHO offset publication No.66

(1) See also the further references at the end of chapters 7 and 9, only some of which are repeated here.

CHAPTER 11: SOCIAL SERVICES AND EDUCATION

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11

CHAPTER 11: SOCIAL SERVICES AND EDUCATION

Need

The trauma of becoming a refugee can be very great. Social and psychological problems are created or exacerbated and appropriate measures for resolving these problems are essential.

Aim

To help meet the special social and psychological needs of refugees.

Principles of response

- ☐ Recognize the need for the refugees to be able to talk over their own problems among themselves and in their own language, and to fashion their own responses where possible.
- ☐ Build on the community's own resources to the extent possible and encourage individual, family and group self-reliance.
- ☐ Provide decentralized services within a co-ordinated community plan, and ensure they reach those in need.
- ☐ Where special institutions for the socially, physically or mentally disabled are necessary, they should be small and a part of the community, drawing on communal rather than outside services.
- ☐ Ensure that social services are developed as essential components of the overall assistance programme, and in a co-ordinated approach to agreed standards.

Action

- ☐ Assess the needs, paying particular attention to identifying those who may have particular difficulty meeting basic subsistence needs, such as unaccompanied children or the disabled.
- ☐ Develop services to meet their needs.
- ☐ Take immediate action to reunite families.
- ☐ Organize an appropriate education programme.

11.1 Introduction

1. Previous chapters have considered the material needs of refugees in an emergency. The shock of having to leave home and the circumstances of life as a refugee, particularly in the early stages of an emergency, create major emotional and social problems and exacerbate existing problems. The trauma of the flight and its aftermath may leave the refugees confused, frightened, lonely and insecure, facing an unknown future in a strange or even hostile environment. Separation from or loss of other family members is common in refugee emergencies, and a major cause of emotional stress. Family reunion is a priority.

2. The most important action that can be taken to help reduce the shock and stress for the community as a whole is to provide security and a sense of stability as quickly as possible. In part this can be done materially, and in part by ensuring protection and involving the refugees from the beginning in the organization of all aspects of their new lives, and in particular in the search for durable solutions. Social work is in the broadest sense the vital bridge between the refugee and the goods and services of the new settlement. Without help in adjusting to this new environment the sense of loss and isolation can deepen even in circumstances of relative material well-being.

3. In every emergency there will be refugees with family or individual social and psychological needs of a nature that require particular attention. Examples are: the disabled (the mentally handicapped, blind, paraplegic, limbless, deaf, lepers etc.); unaccompanied children; single parent families; single young women; the sick and elderly and the victims of such special problems as rape, drug abuse, physical abuse or family conflicts. For convenience, "social" is used in this chapter to embrace all such needs.

4. In stable non-emergency situations, the community itself usually develops methods for meeting at least some of these needs. However, the social disruption of refugee emergencies not only aggravates many problems but can also result in these special needs being overlooked unless appropriate measures are taken. The vulnerable are even less able to "cope" in a new and strange environment. The services to meet these needs will require personal attention to individual or family problems. This is best given through a community-based social welfare programme. The provision of the social welfare services that may be required by special groups, such as unaccompanied children and the severely disabled, usually requires the establishment of specific units within the settlement.

5. The immediate objective of a social welfare service in an emergency situation should be the identification of and assistance to those persons whose basic needs for food, water, shelter and health care are not being adequately met. Particular attention should be given to persons who may be vulnerable if they lack family support: children, disabled and elderly persons, and women. Other groups within the general refugee population may also experience problems in meeting their basic needs due to their status as a religious or ethnic minority, inequities in distribution systems or other factors.

6. A social welfare service should mobilize appropriate community resources, with outside help as necessary, to screen the refugee population for those facing urgent problems; see these needs are met and ensure the general welfare of all refugees. Having established such a foundation, a social welfare service can proceed to deal with such special needs as rehabilitation of the disabled, establishing self-reliance and training programmes, and developing community activities.

11.2 Organization of the general services

- Plan the social welfare services with the refugees.
- Individual problems will need individual attention.
- Special measures may be required for persons with similar needs.
- Assess the needs by screening the whole community; the most vulnerable rarely come forward themselves.
- Take account of national policies and resources.
- Develop a community-based service.
- Co-ordinate closely with other community services, particularly health care.

1. The organization of the necessary social welfare services must be considered as early as possible in a refugee emergency and the refugees themselves must be involved in developing the services. A co-ordinated approach by all organizations concerned is essential, with clear policy guidelines and agreed standards.

2. Experience suggests that even in an emergency many social welfare needs can best be met by resources that exist within the community. A social welfare programme should thus be designed to mobilize these resources through the establishment of community-based services. Every community has its own beliefs, social values, customs, traditions and preferences for how problems should be resolved. A social welfare programme should seek to enhance and improve existing "coping mechanisms". These may be based on the community's secular or religious leaders or elders or on other arrangements, for example through traditional medicine practitioners or midwives.

3. The first priority will be a careful initial assessment to determine the most pressing social problems; to be effective, this should cover the whole community. In many cases the refugees themselves can identify those in need, but special surveys may be required to identify persons with serious social welfare needs, because typically they are least likely to seek assistance and may otherwise be overlooked. There is a need for a social welfare programme to deal with individual/family problems in most emergencies. The need for additional special programmes, such as for family reunification or unaccompanied children, will depend on the circumstances. Tracing and family reunion will be important programmes in many refugee emergencies. The programme developed to meet the assessed needs should take account of policies and resources in the country of asylum.

4. The basic case work - identification of individual or family problems, assessment of needs, development of solutions or referral - will necessarily take place at the individual, family or small group level. Social welfare programmes therefore generally require a decentralized structure, allowing community workers to work regularly among the same refugees, getting to know and be known by them.

5. The general community activities, for example cultural events and recreation, will be important to the creation of a greater sense of normality and security, and the reduction of stress, as well as in fostering the refugees' sense of community.

6. Regular home visiting is necessary both for identifying the persons or groups with special needs and for monitoring the effectiveness of the response to these needs. Those with social and psychological problems will be even more reluctant to come forward and volunteer for assistance

when they find themselves confused by their new environment

7. Up-to-date records and confidential individual dossiers should be kept, and a simple periodic reporting system instituted, focusing on the needs identified and services provided rather than giving just statistical data. It is important that case records are transferred with refugees when they are moved. Unnecessary repetition of basic interviewing is not only a waste of time but it can also be psychologically damaging.

8. Co-ordination is required between the social welfare services and other community-based services, particularly health care. Home visiting services should be closely co-ordinated: health workers can often identify social problems and vice-versa. Regular social welfare clinics at health or community centres may be a useful complement to home visiting. In general, an active social welfare service is likely to be the major referral unit, helping to direct people with needs to available resources and identifying areas of need to which other services may be directed.

11.3 Personnel

- The refugees themselves should play the central role.
- Appropriate outside assistance will be required to co-ordinate the services, for training and for problems beyond the resources of the refugees.
- Continuity of personnel is very important.

1. The refugees must be able to talk over their problems in their own language among themselves. Thus the refugees themselves should play the central role. In some cultures the traditional healers are especially skilled at resolving psychological problems. Outside assistance will be required for the problems that are beyond the resources of the refugees. This outside assistance is likely to compromise both local nationals whose cultural knowledge and understanding of the refugees will be important and international personnel whose role may be limited principally to overall co-ordination, support, training and liaison with the authorities and other organizations concerned.

2. Community workers who have the necessary training should be the backbone of the services. They would be responsible for assisting groups and individuals through outreach work within a given section of the community. The number of such workers required will depend greatly on the community's own response mechanisms. As an indication, in some situations one per 2,000 to 3,000 refugees has been found appropriate. In addition, social workers are also likely to be needed in the health centres, as there is a tendency for people with special needs to be directed to these even when the problem may not be medical.

3. Training of refugee community workers is a priority task and should draw both on the knowledge of the community and outside expertise, from within the host country if possible, in social work, community development and public health.

4. Familiarity with social values and customs is essential, and language barriers can also severely limit what outsiders can achieve in individual case work. Sympathy with and understanding of the kinds of problems faced, and a knowledge of local preferences for their resolution, are essential. Guidelines should be provided on the role of outside personnel. The importance of professional impartial conduct cannot be overstressed. Favours to individual refugees in obtaining resettlement places, for example, can be very disruptive.

5. The personnel that may be required for tracing, care of unaccompanied children and education are considered separately.

6. Continuity of personnel, whether from among the refugees or outside, is especially important for effective social welfare services because of the fundamental part played in these services by human contact and trust.

11.4 Tracing and family reunion

- Tracing and reunion of separated family members must be organized as quickly as possible.
- The International Committee of the Red Cross (ICRC) has a special expertise.
- Refugees must be able to send and receive mail.

1. The overriding concern of refugees separated from their families and friends will be for exchange of news and for reunion as quickly as possible. In exercising the mandate given to it by the international community in times of armed conflicts, the ICRC has acquired a special experience in the field of tracing. Hence its expertise and advice should be sought at once, either from their field delegation or via UNHCR Headquarters from their Central Tracing Agency in Geneva.

2. The possibilities for ensuring communication between those separated, and for tracing and reunion, will vary greatly with each emergency. Individual tracing may take a long time and will only really be possible once the emergency is stabilized and the refugees are registered; it may involve the country of origin. However, immediate action is often possible, for example to reunite members of an extended family or village who fled at different times or by different means, and are thus in different locations in the country of asylum.

3. Procedures for the reunion of refugees separated within the country of asylum should be agreed with the authorities and implemented as soon as practicable. For example, lists of names with photographs, posted on the community notice boards in the different locations, may provide a simple and effective tracing mechanism. The tracing arrangements must be widely promulgated; a central contact point in each site is likely to be needed. Tracing is a delicate task, and has to be organized by people who have the necessary experience and skills. It of course requires the involvement of the refugees themselves, who will play a key role in any tracing service.

4. Refugees have the right to send and receive mail. A properly organized exchange of news may considerably diminish the workload of a tracing service and also accelerate the reunion of families. Refugee mail services may be organized with the assistance of NGOs. Close liaison is required with the national postal authorities. UNHCR should provide stamps where necessary and appropriate: a franking machine in each location may be a practical solution. If normal postal services do not exist, the ICRC may organize the exchange of special Red Cross messages.

11.5 Unaccompanied children

- Identify unaccompanied children and initiate tracing as soon as possible.
- Ensure that the children are cared for in ways that meet both their physical and emotional needs; individual care is all important.
- Take no action that may prevent family reunion.

- Where child care centres are necessary, they should be small, decentralized within the community, and integrated into community activities.

- Ensure respect of the principles herein by all involved.

Introduction

1. Children may be separated from their immediate next-of-kin during a refugee emergency. Those who are, are often cared for by the refugee community, frequently within an extended family. Where this cannot happen, special measures will be required to care for such children. In some circumstances there may be considerable outside pressures for immediate adoption and for third country resettlement. There are very strong reasons for resisting this until the possibilities for family reunion or local solutions have been exhausted.

2. International humanitarian law has as a fundamental objective the unity of the family, and therefore places particular emphasis on the maintenance of family ties and on family reunion. The welfare of children overrides all other considerations. Great importance is attached to keeping children who have been separated from their families within their own cultural environment.

3. Every child's emotional development and future well-being is dependent on the bond between the child and the individual who cares for the child (who is usually a parent, but may be someone else acting as a parent). This emotional bond, the source of the tender, loving care that is as important as physical care and the meeting of material needs, is particularly critical for younger children. The bond has been broken for unaccompanied refugee children as defined below, and a great responsibility rests on those who organize the care for such children: to ensure that each is placed in the care of a substitute parent to whom the child can become affectionately attached. Every effort must be made to keep the child with the same substitute parent until the blood parents are found. The child will then need time to re-attach to his or her blood parent(s). How long this will take depends on the child's age and the strength of attachment to the substitute parent(s) which now has to be broken. Where years have elapsed, it has been found that the child's interests may even be better served by remaining with the substitute family.

Definition

4. An unaccompanied child is defined as a child under fifteen years of age who has been separated from both parents and for whose care no person can be found who by law or custom has primary responsiblility. This section addresses the needs of children so defined. Special measures may also be necessary for those of fifteen and over; assistance should be given in a flexible way. For instance if there are unaccompanied young women of over 15 they may well require special measures in order to ensure their welfare. It is the usual UNHCR practice to allow unaccompanied children over 15 to take decisions concerning durable solutions for themselves; however, the legal age of majority is determined by the laws of the country of asylum.

5. The description "unaccompanied children" should always be used in place of "orphans". The parents cannot be considered dead merely because the child is not in their immediate care. Even an assertion by the child that the parents are dead must be treated with caution, as experience has shown such assertions to be unreliable, for a variety of psychological and social reasons. Furthermore, the determining factor is not the death of the parents but rather the separation from them and the absence of any person who

by law or custom could take primary responsibility for the child.

Causes of separation

6. A comprehensive assessment of the causes of separation is important because the varied ways in which children can be separated from their families may significantly affect tracing programmes and planning for long-term solutions. Common causes of separation, other than the death of parents, include:

(1) Accidental separation, particularly during large population movements, fighting or organized refugee movements when families become split up;

(2) Older children leaving parents/family out of choice;

(3) When the facilities and services provided for unaccompanied children are significantly better than those otherwise available, parents/family may actually place children in such special care;

(4) Similarly, before or during the flight families may place their children in the care of others if they believe this will increase the chances of the children's survival;

(5) Outsiders, for example ambulance drivers, relief workers or volunteers, may remove a child from an apparently dangerous situation without informing parents, family or the community. This is particularly common if the child clearly needs medical care;

(6) Inadequate or inaccurate hospital records and tagging in an emergency.

7. Thus it can never be assumed that an apparently unaccompanied child has been abandoned or is without parents, guardian or family until a sustained and concentrated effort to locate them has been made.

8. Nor should a narrow limiting definition of the family be adopted in a cultural context where, despite the absence of the blood parents, a child remains an integrated part of an extended family. Otherwise an unaccompanied minors programme may even contribute to creating rather than solving the problem of unaccompanied minors.

General rules

9. Care must be provided for unaccompanied children through measures that meet their physical and emotional needs in a way that is culturally appropriate. A clearly identified responsible authority appointed by the government or UNHCR must take responsibility for the children. But although UNHCR may not have operational responsibility, its international protection responsibilities for these children remain clear: hence the obligation to ensure that these rules are enforced.

10. As long as there is any chance that enquiries may lead to the reunion of a family, no change in the situation of unaccompanied children which might prevent this should be contemplated. In particular there must be no adoption or change of name. There must be no transfer to a third country or any other removal unless such movement is vital for the health and safety of children generally, and therefore not organized specifically for unaccompanied children.

11. Every effort must be made to find an appropriate durable solution as soon as possible. In most cases this has proved to be family reunion as a result of successful tracing.

12. Where children do have to be moved, full records allowing tracing of the child's location at all times are essential. Any agreement to move children must include assurances from all the parties involved (governments of asylum and resettlement agencies) that

family reunion will be expedited immediately the missing members are located. Where this reunion should take place will depend on the circumstances.

Identification and registration

13. Unaccompanied children must be identified as soon as possible. The first source of information is the refugees themselves and the community leaders. A general registration or census of the refugees may provide a suitable occasion for initial identification. A general registration or census will also identify those children not alone but not with their immediate family, who thus require tracing, an important consideration which should not be overlooked. A selective initial registration may give the impression that children so identified will have special status and advantages, which may lead parents or relatives temporarily to abandon their children.

14. Nevertheless time lost before interviewing the children is also information lost; particularly about the circumstances of a family separation which has taken place recently. As soon as identified, unaccompanied children should be specially registered. The information required will depend on the circumstances: the annex gives a model registration form, developed by ICRC, as an indication. The children should be photographed, and the photograph should include, for example on a small blackboard, the child's name, reference number and location. Use a film that allows subsequent copies to be made.

15. Individual dossiers must be developed and maintained for each child, recording all relevant information including arrangements for care and tracing.

16. A sympathetic and imaginative approach to interviewing the children is very important. Interviews are best conducted by carefully trained refugees, if possible by someone the child already knows and trusts. If an interview has to take place through an interpreter, the interpreter must be well briefed, with his or her role limited to direct translation, and must not be allowed to break personal contact between interviewer and child.

17. Children may react very differently when asked to give information on themselves and their families, depending, for example, on the degree of their trauma, fear and shyness. Often a child will confide in other children. In some cases the presence of the child's friend(s) at the interview can not only reassure the child but also yield important information. Any accompanying adults or persons who brought the child forward should also be interviewed. Consideration should be given to tape recording interviews in order that answers may be transcribed or checked later.

Tracing

18. As soon as unaccompanied children are identified, efforts must start to trace their parents or families, and ensure family reunion. Tracing for unaccompanied children requires special skills and techniques. As in general tracing, the expertise of ICRC will be very useful. Photographs of the children are generally the key to a successful tracing programme. One of the simplest and most effective methods has proved to be posting the photographs, which contain the reference number and name, on special bulletin boards, for example in community centres, for public view. Other methods may include putting names and/or photographs in newspapers. Also, the data sheets, including photographs, can be reproduced, bound into volumes and circulated among the refugees. Certain NGOs have acquired considerable experience in implementing such programmes.

19. When the parents or family of a child appear to have been traced and a child is claimed, an adequate verification will be required, perhaps involving a follow-up. Careful record of the verification, as of the movements of all unaccompanied children, is essential.

Assessment of needs

20. The needs of the children will vary greatly with their age and individual circumstances and must be assessed individually. All unaccompanied children should be medically screened periodically and those with special needs and problems identified. Regular assessment of the needs of unaccompanied children and evaluation of how they are being met is required to ensure that adequate care is provided.

Guidelines for care

21. One of the most important principles in the care of any child is that relationships must be stable. Unaccompanied children will develop very close bonds with other children and adults. Development and maintenance of a strong bond with the guardian of the child, whether in foster homes or in child care centres, is of crucial importance. Thus, continuity of the arrangements and personnel involved in the care is fundamental. Even for outside organizational involvement, six months should be considered the minimum. For those in intimate contact with the children a longer minimum stay is necessary. As national staff are usually available for longer periods, this is another reason for using national rather than international staff at the casework level.

22. The care of unaccompanied children should be undertaken, as far as possible, by persons of the same cultural heritage and social background as the children. Every effort should be made to place children under five in an appropriate and caring foster family within the community; this is essential for children under three. Arrangements for older children should be made on a case-by-case basis, seeking the solution that provides most stability. In general, foster care is preferable to residential care. Proper material support must be given to the foster family. However foster care must be closely monitored and relationships must be documented by a signed undertaking to release the child should family reunion become possible. Careful account should be taken of cultural attitudes towards fostering. For instance, in some situations the family may find it hard to conceive of taking in a child except as a servant.

23. The advantage of small residential centres is over the short term: if reunification with the parents is expected to take place quickly, such centres provide an efficient way of caring for the children while at the same time not losing sight of them during the upheaval and confusion at the start of an emergency. However, as tracing usually takes some time, residential centres are, in most cultural contexts, a less happy intermediate solution from the children's point of view than fostering.

24. Where special residential centres are required, small units of five to eight children are preferable, with the numbers of houseparents determined in light of the ages and particular needs of the children. The centres should be decentralized and integrated in the local community but must be carefully supervised. Large centres should be avoided. Apart from the likelihood that individual attention will suffer in large centres, experience has shown that there is a tendency to provide special services in such centres. As these services are not available to other children, this can actually attract children who are not unaccompanied.

25. Siblings should live together. In certain circumstances unaccompanied children may have been living together as a group and have close emotional bonds within the group. It may be in the interests of the children to preserve such groupings, or relationships within them, where possible, while at the same time establishing a substitute parent relationship.

26. Material needs should be met to the level and, to the extent possible, in the manner available to other refugee children. Thus, every effort should be made to integrate the children into the life of the community. They should go to community, not special, schools, be treated at community health centres, and play with other children on common recreational areas. It is better to avoid special clothes or distinguishing tags which set them apart.

Organization of care

27. Where there are considerable numbers of unaccompanied children, the establishment by the UNHCR office of a special unit for the care of unaccompanied children is recommended. The assistance of the appropriate national authority, UNICEF, and qualified NGOs should be sought. The advice of a person with proven experience in the care of such children in similar emergencies is likely to be valuable in assessment and programme formulation. If suitable expertise is not available locally it should be requested from Headquarters.

28. The best child care workers are likely to be respected adults within the refugee community, for example older parents with child rearing experience. Child care workers must be properly supervised, and supported with training programmes. Unaccompanied young women who may themselves be particularly vulnerable can be recruited as assistant child care workers, thus giving them useful work as well as some measure of security.

29. Where outside assistance is required, the criterion must be competence to manage the specialized services needed. Any organization involved by UNHCR in the care of unaccompanied children must be in agreement with the principles set out herein, and not have conflicting objectives, such as adoption, resettlement or religious conversion.

30. Programmes for the care of unaccompanied children must be carefully co-ordinated with all involved to ensure common aims and standards.

11.6 Education

- Every child has a right to education. Even in an emergency, start providing appropriate education as soon as possible.
- The priority is to make primary schooling available to all.
- Special account must be taken of the fact that the children are probably already educationally deprived.
- The educational system should be organized and run by the refugees to the extent possible, with proper outside support.

1. Every child has a right to education. Schools for the refugees are thus essential. Setting up an education programme will make a significant contribution to the well-being of the whole community, and this should only be delayed if the characteristics of the emergency are such that it is clearly going to be short-lived. Although priorities in the emergency phase may mean that the full elaboration and implementation of an education programme is not possible, a start must be made. Even with inadequate educational supplies, establishing the discipline of schooling through regular classes and organized activities for

the children is important. Simply gathering the children together for a set period each day and keeping them occupied is a valuable first step.

2. The time before a durable solution is possible and the likely nature of such a solution are the key factors influencing the type and content of an education programme. Adult and vocational education facilities and community development programmes will be important matters for consideration once priorities allow and the longer-term prospects for the refugees are clearer.

Aim and guidelines

3. The first aim of the education programme should be to provide basic education, free but compulsory, to all refugee children. The level of the programme will depend on the educational background of the refugees and on the national education services. As a general indication, it should reflect the level of education available in the host country, with the minimum objective being literacy in the first language of the refugees and simple numeracy.

4. It is probable that refugee children will have had both their formal education and the informal family-based learning process disrupted. The design of the programme must take account of this, and, in particular, must cater in a consistent way for the needs of children already educationally deprived, regardless of age.

5. A single, unified primary school system should be developed, equally serving the needs of all the refugee children without discrimination between children or schools. Priority should be given to this over the establishment of second-level programmes. The language of instruction and text books should be the first language of the refugees.

6. Rapid regeneration of the informal learning processes of the home will be equally important. This should start to take place automatically as the emergency situation becomes stabilized and general family life returns to normal. Because of the disruptions, the involvement of parents in their children's education, for example through parent-teacher contacts, will be particularly helpful.

7. Smaller, decentralized schools are generally preferable to large schools. The school buildings themselves should be of equal standard and in keeping with others in the community and with local practice. Local materials and construction styles are usually the most appropriate.

Organization

8. The organization should take account of the education systems in both the country of origin and asylum. Specialized advice on the establishment of appropriate educational programmes should be available locally and may also be sought from UNESCO, the World Bank, bilateral aid programme organizers and qualified NGOs. An education director may be useful to develop and supervise the overall programme.

9. The provision of education may give the refugees a privilege not enjoyed by the local population. In such situations it is, if the government is in agreement and there is a common language of instruction, usually appropriate to open the schools to the local population. The education programme should from the start aim at a realistic level of service which it will be possible to sustain when international support is withdrawn.

10. To the extent possible, the educational service at the community level should be organized and administered by the refugees themselves, through such structures as

education committees. The most appropriate teachers are likely to be refugees with teaching experience. Refugee teachers may need to receive some remuneration if the programme is to be sustained in the longer term. However, the remuneration must be structured in such a way that it can later be continued without international funding.

11. Outside support will be required for the development of common curricula, to ensure equality of standards between schools within a community, and between different sites if applicable. Help will also be needed from outside in the provision of education materials. As it is likely that more teachers will be needed than are available and suitably qualified within the community, special teacher training programmes should be developed. National education institutions, such as teacher training colleges, may be a valuable source of expertise and may be able to provide both teacher training and teachers for the refugee programme.

Further reference

UNHCR (expected 1983)	UNHCR Handbook for Social Services Guidelines for the provision of social services to refugees in both rural and urban situations, with a strong emphasis on ensuring that the basic needs of the vulnerable are met. Contains list of key references. (French and Spanish editions will follow)

Model Form for Registration of Unaccompanied Children

1. Each form shall bear, whenever possible and whenever it involves no risk of harm to the child, the information listed below.

2. Information may be added as required by the situation.

3. As with any registration, standard code indicators should be used to record replies whenever possible.

Reference no.
.....

Date and place of Registration: .....

photo Present Location of the Child: .....

1. Family name .....
2. First name and/or other given names .....
3. Alias or informal name used by family or others .....
4. Sex ..... 5. Date of birth .....
6. Place of birth (village/city, province, country) .....
7. Nationality .....
8. Ethnic origin ..... 9. Native language .....
10. Religion ..... 11. Other language spoken .....
12. Home address .....
13. Any distinguishing physical characteristics .....
14. State of health ..... 15. Blood group .....
16. Mother living? yes .... no .... don't know ....

    Name/maiden name last known address date of last contact

17. Father living? yes .... no .... don't know ....

    Name last known address date of last contact

18. Other relatives

	name	date of birth	last known address	date of last contact
Grandfather				
Grandmother				
Sister				
Brother				
Aunt				
Uncle				
Cousin				
Guardian/ Godmother				
Guardian/ Godfather				
Other (specify)				

19. Date and place of arrival in country of asylum

20. Date of arrival in present location

21. Date and location of last contact with parents/family

Description of how they became separated.

22. Remarks (including names of adults at present location who know child/ family).

Date completed
Name of interviewer

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CHAPTER 12: FIELD-LEVEL MANAGEMENT

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12

12.1 Introduction

1. This chapter discusses the management of assistance in a refugee emergency within the country of asylum: that is, the mechanisms and organization required to combine the many different actions, persons and priorities into a coherent overall approach that meets the refugees' needs. Successful management requires leadership; subject to the role of the government, leadership may be the most important single contribution of UNHCR. Leadership requires that once decisions are reached, they are properly implemented. This discipline is essential in emergencies, when there is often not time to explain the considerations involved. As far as possible, those directly concerned should contribute to decisions that affect them, but final responsibility rests with the Representative.

2. The nature of a refugee emergency makes its management a complex and frequently difficult exercise in which practical and political problems must be resolved quickly and effectively. Much will depend on the role of the government and the implementing arrangements. Management of a refugee emergency is likely to have two levels: that of the capital and that of the location of the refugees, the site level, which will involve the provincial or district authorities of the government's administration. While the principles suggested here are likely to be generally valid, action must be adapted to the imperatives of the situation.

3. The initial stages in the management process comprise: the needs assessment, which determines what must be done; the planning, which determines priorities within a framework for action; the allocation of responsibilities for action; ensuring the means for action, including co-ordinating mechanisms, personnel and material.

4. From the start, the management of a refugee emergency must include continuous monitoring, reporting and evaluation in order to ensure that plans are adjusted and that the action remains appropriate as circumstances change.

12.2 Needs assessment and planning

☐ A comprehensive plan of action is essential, drawn up with the people who will implement it and taking account of the views of the refugees.

1. Assessment has been discussed in chapter 3; it is the prerequisite to any response. To the extent possible, the assessment must involve those who are to be responsible for the response, including the refugees. Needs can only be assessed against a knowledge of what is required. The determination of the standards to which assistance should be delivered is, therefore, of fundamental importance. This must take full account of social and cultural factors, including the background of the refugees and the conditions of nationals in the country of asylum; the response must be appropriate. Experience suggests that failure to set appropriate standards from the start is a common cause of management problems in emergencies.

Plans of action

2. Response to the needs must be planned. The best management tool for this is a simple plan of action for each administrative level. At the start of an emergency there is a tendency to postpone planning, both because information is not available and because there are obvious urgent needs which can be met piecemeal without a plan. This tendency should be resisted: the more critical the situation, the more important it is for the Representative to find the time to take stock, determine priorities and develop a plan for what needs to be done, when, by whom and how.

3. A further indication of points that might be considered in drawing up the overall field plan of action is given in Part 2. The overall plan should include a plan for each refugee site, drawn up by the organization with overall operational responsibility at the site level. The plans at the two levels are interdependent.

4. The most effective plans of action are those developed by or with the people who will implement them. Drawing up the plans should be a team effort to the extent possible; clear direction must, however, come from the government and/or UNHCR. The plans must be comprehensive, covering all needs whether these are being or will be met through UNHCR or by other organizations and sources of funds. Not only will such a plan clarify issues of management and responsibility; it will also provide a head-start for the programming exercise.

5. In drawing up the plan, take account of the views of the refugees. They are the single most important resource in meeting their own needs, and will have definite ideas on how this may best be done. The plan must strengthen the refugees' own resources and self-sufficiency and avoid creating dependency through the well-intentioned provision of outside assistance that is either inappropriate or unnecessary. The plan should also reflect the aim of a durable solution.

6. The plans of action must be available to all who need them.

12.3 Allocation of responsibilities and personnel management

/_/ Responsibilities must be clearly defined and understood.

/_/ The personnel necessary to implement the plan of action must be made available; local staff will be particularly useful.

/_/ The quality of personnel management and leadership will directly affect the success of the emergency operation.

1. The roles and tasks of all involved must be clearly stated. Delay in the definition of responsibility usually leads to each party defining goals independently and setting their own limits of responsibility. This in turn can lead quickly to confusion, gaps and duplication. Responsibilities should be defined for each administrative level, and for both organizations and individuals. With responsibility, which should be delegated to the lowest possible level, must go the necessary authority. Responsibility without authority is useless.

2. Implementing arrangements and personnel needs have been discussed in chapter 4. Organizational responsibilities for UNHCR's operational partners will be defined, in time, in the contractual arrangements governing the co-operation. If, however, formal sub-agreements etc. have not yet been drawn up, and the basis of co-operation remains a letter of intent, the definition of responsibilities contained in the plan of action is more essential than ever. The responsibilities of organizations delivering assistance but who are not operational partners of UNHCR must also be defined. This may create problems, particularly where individual NGOs wish to have responsibility for a specific sector. Final authority rests with the government, and the Representative should consult closely with the authorities. To the extent possible, however, any conflicts of interest should be resolved within the framework of an NGO co-ordinating mechanism, such as that described in the next section.

3. Defined responsibilities of organizations must reflect fully those allocated in the plans of action.

4. Job descriptions, even if the imperatives of an emergency mean their frequent revision, are the most common management tool for defining individual responsibilities. Job descriptions are important for regular UNHCR staff, and even more so for temporary staff and people working as volunteers.

5. A document setting out the assumptions, concepts and principles behind the emergency operation has proved a valuable complement to the plans and detailed definitions of responsibility, especially in large programmes. Such a document should include an explanation of the role and responsibilities of the government, UNHCR, other UN organizations, operational partners, and any bilateral donors, together with the standards in the various sectors and any specific guidelines necessary. Details of the co-ordinating mechanisms should be given.

Personnel

6. There should be no delay in committing the necessary personnel to emergency situations. The organizational needs of an emergency cannot, however, be met by the simple addition of personnel; the plan of action and definition of responsibilities must determine personnel needs, not vice versa. Staffing must be flexible and numbers are likely to vary over time. Locally-hired staff usually prove particularly valuable.

7. It is important that the different advantages of local and international staff are understood, and that these different strengths are properly incorporated into a staffing plan. Very obviously, local staff members understand the local situation. They are sensitive to issues that often escape the notice of the international staff member. In addition, the local staff members will often enjoy a wide range of contacts that enable them to "get things done". Finally, and very significantly, they may speak the refugees' language. Correspondingly, it must be recognized that in the eyes of many of those involved the international staff members bring to the programme an impartiality, an embodiment of its international character, which is essential. They will also have experience from elsewhere to contribute to the management of the emergency.

8. Local volunteers - both nationals and members of the diplomatic and expatriate communities - may come forward to help in the face of evident needs. The value of outside volunteers will vary considerably with the situation, the skills of the volunteers, the time they can devote and the availability of the management personnel needed to co-ordinate and support them. Lack of proper supervisory support often leads to the volunteer taxing already overextended staff, with the result that the services rendered become ineffective while the volunteer becomes disillusioned.

Personnel management

9. Sound personnel management, supervision and leadership are very important to the success of an emergency operation, but can easily be over-looked. Administrative aspects of UNHCR personnel management are discussed in Part 2. The initial motivation of those involved is a major asset but, for persons at levels that do not allow an overview of the operation, this can be replaced by disappointment and frustration if supervisors are too busy to plan, organize, direct, control and continue to motivate their staff.

10. Staff meetings should be convened regularly from the start, and everyone made to feel part of the team. The welfare of that team will have an important bearing on the success of the emergency operation. Very long hours will often be necessary, but supervisors must ensure that staff have

time off, away from the refugee site, and do not get so overtired that their efficiency and the professionalism of their approach suffer.

11. All field staff have a particular responsibility to safeguard their own health, for example, through the regular taking of the correct anti-malaria drug, ensuring vaccinations are up to date and avoiding obvious health hazards like unsafe water.1/ The need to hospitalize or evacuate key staff can cause a major disruption in an emergency operation.

12. In an emergency there may be many occasions when staff see clearly that by devoting time to helping individual refugees or families in distress they could alleviate suffering directly. To seek to do so would be very understandable, but it can lead to a personal emotional involvement at the expense of the staff member's wider responsibilities towards the refugees as a whole, and to resentment among other refugees. Some staff may have direct responsibility for individual care, though this is often best assumed by the refugee community, but for all staff, compassion must be tempered by a professional approach. Guidance by supervisors is often needed on this point.

12.4 Organization and co-ordination

/_/ A single co-ordinating authority is required.

/_/ UNHCR should take the lead to ensure effective NGO co-ordination if this is not already ensured.

/_/ The actions of UNHCR staff must be properly co-ordinated.

General

1. Effective co-ordination is the result of sound management. Co-ordination mechanisms set up without the establishment of clear objectives and assignment of responsibility and authority will be ineffective and substitute words for action. If co-ordination is not based on a good information exchange, particularly with the site level, it may even be counter-productive.

2. A framework within which the implementation of the programme can be co-ordinated and management decisions taken is essential, both for the overall response and within UNHCR. Co-ordination at central and site levels will involve frequent informal contacts between UNHCR, the government, other UN organizations directly involved, the operational partner(s) and other parties concerned. These contacts should be complemented by more formal regular meetings where the overall progress is reviewed and plans adjusted. Arrangements for the general briefing of the diplomatic corps and the UN system are discussed in Part 2.

3. Whatever the implementing arrangements, experience suggests that there are major advantages in the establishment by the government of a single co-ordinating authority (task force, commission, operations centre etc.) on which all the ministries and departments involved are represented. This authority should also be represented at the site level. In countries already granting asylum to other refugees, such a focal point is likely to exist, and may simply need strengthening.

1/ The Ross Institute booklet "Preservation of personal health in warm climates" (1980) gives comprehensive guidance.

NGO co-ordination

4. Effective co-ordination with and among the NGOs will be essential to the success of the emergency operation. Much will depend on the position of the government, which may wish to control and co-ordinate NGO activity itself. Where a NGO is an operational partner of UNHCR, co-ordination should already be assured, but many NGOs may be operating their own programme for the refugees with their own funds. Some will have been active before the UNHCR programme started and many more may arrive in a major refugee emergency. Where there has previously not been a habit of inter-agency co-ordination, the exchange of information may well not go beyond those who have participated in the co-ordinating meeting. To get the information passed "down" to the site level can initially be as hard as it was to get information passed "between" the agencies.

5. Subject to the policy of the government, where a NGO co-ordinating structure does not already exist it is strongly recommended that UNHCR takes the lead in encouraging the NGOs to set up their own co-ordinating committee and mechanisms. The role of the government on such a committee will depend on the situation; at the least, a representative of the government's own co-ordinating authority should attend as an observer. UNHCR's status might be that of an observer, but an active one, as the meeting of the committee will provide an important opportunity to brief all NGOs on progress, future plans and problem areas, to request specific assistance and to answer the questions on UNHCR's aims and policies that the NGOs may have little other chance of asking. In the absence of other arrangements, there is a strong case for UNHCR itself organizing and chairing such meetings, at least in the first weeks. This may be a crucial component of UNHCR's leadership role.

6. In a large-scale refugee emergency, the NGO co-ordinating committee should also be encouraged to create sectoral sub-committees, for example for health and nutrition. The committee, and particularly such sub-committees, could play an important part in the development of the specific standards for the delivery of assistance. See for example, ch.7.2.18 on guidelines for health care.

7. Some experience has been gained in the working of NGO co-ordinating committees in refugee emergencies. Annex 1, "Elements of a co-ordinating body", might be helpful to those considering the establishment of a committee.

8. A NGO co-ordinating committee can also be of considerable value when new agencies arrive, both in integrating their assistance in the overall programme and with the practical administrative and general briefing arrangements. If there is no such committee, agencies new to the country are likely to turn to UNHCR for initial administrative support, hotel reservations, transport etc. This can quickly become a major preoccupation for UNHCR field staff at the expense of their own work.

Within UNHCR

9. Within UNHCR itself, in addition to the staff meetings already recommended, regular and frequent meetings of key personnel will be essential, both centrally and at site level. In a critical situation, a daily early morning planning meeting and another in the evening for reporting will often be useful. Summary minutes and/or decision sheets are an important management tool in emergencies, otherwise under the pressure of events what was decided, and who was to take what action when, may be forgotten.

12.5 Management at the site level

- Common standards are essential.
- Proper involvement of the refugees is fundamental to success at this level.

1. The framework for the organization and co-ordinating mechanisms at the site level is likely to reflect broadly that established centrally, but it will be more affected by the implementing arrangements.

2. Clear understanding of the aims and objectives of the emergency programme and proper co-ordination are even more important at the site level than centrally, for it is here that failures and misunderstandings will directly affect the refugees. Of particular importance will be the adoption of common standards when a number of organizations are providing similar assistance. Regular meetings of those concerned are essential: an overall co-ordinating mechanism chaired by the operational partner may be complemented by sectoral committees.

3. A rapid changeover of outside personnel can create major problems for site-level management. Six months is a suggested minimum length of service for staff involved in running services in the settlement. Some specialists may obviously be required for shorter periods. The importance of continuity is directly proportional to the closeness of contact with the refugees. Only some of the problems can be overcome by the overall operational partner at the site having a standard orientation and briefing procedure to ensure continuity of action and policy despite personnel changes.

4. Certain programme activities are interdependent or have a common component and will need particularly close co-ordination. Examples are environmental sanitation measures and the health services, and the home visiting component of health care, feeding programmes and social services.

5. There is one fundamental difference between management at the two levels: at the site level the refugees themselves should play a major role. The social organization of the refugee community must support and enhance the refugees' own abilities to provide for themselves. The importance of working with the refugees and using and developing their own skills and organizational structures has been a common theme in the preceding chapters.

6. Refugee settlements are not, typically, simple replicas of former community life, as large numbers of refugees may be living temporarily outside their traditional community leadership structures. In nearly every emergency, refugee leaders, spokesmen, or respected elders will, however, be present. It will be necessary to define with the community the method of choosing leaders to ensure fair representation and proper participation in both the planning and implementation of the emergency programme. The more the settlement differs from former community life, the more important this action is likely to be to the success of the programme.

7. To ensure adequate representation and access for the individual refugee, various levels of representatives and leaders are likely to be required. Bear in mind that there is no reason why a refugee should be representative of the community simply because he or she has a common language with those providing outside assistance. Arrangements should be based on traditional leadership systems to the extent possible. It is natural that other, perhaps less traditional, power bases may emerge within the community. Particular attention should be paid to the sources of such power. A specific consideration is the need, if possible, to separate

physically any previously hostile groups among the refugees.

8. Subject to traditional social patterns, the basic planning unit is likely to be the family, and the basic organizational unit is likely to be groupings of refugees according to living arrangements. A good-sized basic organizational unit might be 80-100 people: this is sometimes referred to as a community unit. Above this comes the section which usually consists of some 1,000. Many settlement services are decentralized to this level. Five or so sections might be grouped together to form a sector for certain organizational and representational purposes. For instance in chapter 7 it is suggested that there should be a health clinic for every 5,000 refugees. Similarly, the participation of elected sector representatives on a settlement management committee, would be appropriate. As to how many sectors might make a settlement, there is no hard and fast advice. It depends on the circumstances. But generally the smaller a settlement the better. Physical layout of the site will have a major influence on social organization, and the importance of preserving and promoting a sense of community has been stressed in chapter 6. The system of refugee representation, which may be a several-tiered one with community-elected representatives selecting from among their number section representatives who in turn choose sector representatives, should be consistent with these physical divisions.

9. The social organization of the refugees must also make use of their specific skills and provide the personnel to run the community services. Details of what might be required have already been given in the relevant chapters, but as a check list:

(1) health services (traditional practitioners, including midwives, home visiting, health centres, public health education, etc.);

(2) feeding programmes;

(3) water supply system (construction, maintenance, protection/treatment and distribution);

(4) sanitation (maintenance and cleaning of latrines, drainage, garbage disposal, vector control, etc.);

(5) shelter construction including communal buildings;

(6) social services (caring for unaccompanied children and the disabled);

(7) tracing;

(8) education programmes;

(9) general administration.

12.6 Registration and distribution

- No programme can work properly unless the number of beneficiaries is known: there are several ways of determining this with sufficient accuracy.
- A fair distribution system must be established.

Registration

1. All planning, as well as fair distribution, will require an accurate census of the population. This will be an essential component of the needs assessment. It should be noted that under the Statute (8(f)) UNHCR obtains "from Governments information concerning the number and condition of refugees in their territories". Although it is UNHCR's statutory responsibility to seek refugee numbers from the government, it must be made clear from the start that it is not possible for UNHCR to mount a programme of assistance without a precise measure of the number of beneficiaries.

2. While an accurate census is essential, a formal mass registration should not necessarily be an

automatic response at the start of an emergency. The arguments for and against initially going further than establishing numbers and an indication of the age/sex breakdown must be weighed carefully, and the objective and benefits determined.

3. The main advantage is that registration provides a unique opportunity to secure basic information, including on health and nutritional status, on which subsequent programming can be based. In addition registration allows a much tighter system of ration distribution. A drawback is that a detailed registration may have an effect on a refugee's attitude to possible durable solutions. For example, in certain circumstances a refugee who was aware his identity was officially recorded might be reluctant to repatriate spontaneously. Equally, registration can, in certain circumstances, give a refugee the impression of a possibility of resettlement that does not exist.

4. In some emergencies registration may be an important factor in protecting refugees. Registration will be an essential component of any individual tracing programme and in this respect there are arguments for registering as early as possible.

5. If a registration is undertaken, the form used and arrangements made must be carefully planned. Whatever the purpose of the registration, certain questions are likely to be common. An indication of these is given in Part 2. Try to avoid the need for a re-registration because key questions were omitted, a common error. After the immediate emergency is over, there may be a need for specific registrations, for example a socio-economic survey, and a phased approach to gathering the further information required should be adopted.

6. Registration requires sufficient numbers of properly briefed and trained registration clerks or social workers who speak the language of the refugees, understand the purpose of the questions and can assess answers and eliminate obvious distortions. They must have a common code for transliteration between alphabets if necessary, particularly for proper names. If time allows, much will be learned from a small pilot registration.

7. The most practical time to register refugees is on arrival at the site, for example in conjunction with the health screening. Much will depend on the type and rate of any continuing influx. In any large influx there are advantages in passing arriving refugees through a reception/transit centre. This allows their registration and the issue of ration cards. It can ease later programme management problems and help avoid disputes about refugee numbers. Transfer of the refugees to a new site always provides a good opportunity for a mass registration.

8. Where a card is issued on the basis of a registration, a photograph identity card sealed inside unbreakable plastic is probably the least likely to be forged, altered, sold, or exchanged.

Numbers

9. With time, a discrepancy in numbers may arise between official figures and the best estimate of those working closest to the refugees. Unless this is swiftly resolved major problems will follow. Representatives and particularly field officers must discuss any such discrepancies with the authorities as soon as they occur, informing Headquarters of significant differences that cannot be resolved. Small discrepancies are likely, given the difficulties already discussed. Large ones can be avoided by timely action.

10. Where registration is deemed inappropriate and wh[illegible]t has not been possible to co[illegible]ugees as

they enter through a transit centre, every effort should still be made to arrive at an accurate verifiable estimate of the number of refugees. If refugees cannot be counted on arrival, there are certain well-established demographic techniques which can be used: the number of refugee dwellings can be counted, if necessary through the use of aerial photography. Assuming there is some conformity of house size, a random sample of dwellings will provide an average number of inhabitants per house. The population of the settlement can then be estimated as a multiplication of the number of houses by the average house size. As settlement services develop it will be possible to cross-check the estimate of settlement population. Random sampling can establish the demographic make-up of the camp in terms of age breakdown. Then, for example, a vaccination campaign for under fives is carried out. If its out-reach is successful and parents' support for it strong, it should reach nearly all of the target group. If the proportion of under fives in the camp is known, it is then possible to double check the estimate for the total site population. Whenever possible, within each separate community, dwellings should in any case be individually numbered.

11. However, without a system of ration cards (which, if they have been issued at the start, should make this counting exercise redundant) it will be difficult to keep abreast of subsequent changes in the settlement population. If new arrivals do not have to report themselves as there are no ration cards to be issued, the best method is likely to be to make the reporting of new arrivals a responsibility of the refugee leadership. Alternatives to be considered are, either good enough control over house lay-out to ensure that new arrivals build on designated spaces; or if many of the new arrivals are actually joining family members and not building houses of their own, sample censuses should be considered to try and establish how much the settlement as a whole is growing i.e. the same community units would have to be surveyed each time. The rate of growth in these units would then be taken to reflect that of the settlement as a whole. Sample surveying is a scientific procedure and must be done properly if authoritative figures are required: seek expert advice from local demographers if possible.

Distribution

12. An effective and fair system for the distribution of goods and supplies will be an essential part of site-level organization, and of critical importance when supplies are short. Monitoring the distribution to ensure that it is fair, including to vulnerable groups, will be an important management responsibility of UNHCR. Monitoring must also ensure that the refugees actually receive the supplies paid for by UNHCR in the contracted specifications.

13. The type of distribution system will depend on the circumstances. Daily distributions are generally to be avoided. At least a weekly interval might be appropriate for dry rations. A decentralized system, initially in bulk to community units or groups and then to families or individuals, is the preferred method. In certain situations, for example where supplies are short or abuses likely, centralized mass distribution direct to heads of family or individuals may be the only way to ensure reasonable equity. Guidance on other aspects of distribution is given in chapters 5 (logistics) and 8 (food).

14. There are two principal means of ensuring fair distribution: a ration card system and an honest refugee leadership. In perfect circumstances a ration card system might be regulated and enforced by such a leadership. However ingenious the distribution system devised, it is most unlikely to work

fairly without the basic support of the leadership. Ration cards are most easily issued when the refugees arrive at the time of initial registration. Done subsequently it is more likely there will be a margin of abuse or, at least, inaccuracy. A simple, effective system is to have colour cards with the number of family members the ration is to serve marked on the card. The refugee is initially, for example, issued a blue card. When the first week's ration is distributed that card is collected and a yellow card indicating the same number of family members issued. This card will be valid for the distribution in a week's time. Obviously the card must not be forgeable. Distribution has nevertheless in many cases been done successfully through an honest refugee community leadership without a ration card system. Whatever system is employed, spot-checks and the nutritional surveys should be used to ensure that the system is working fairly.

15. Responsibility for distribution is thus often delegated to refugee leaders. This can confer considerable power and should be closely supervised. Unless numbers are accurately known, there will be wide scope for abuses at several levels: censuses will need to be repeated as numbers change.

12.7 Reporting, monitoring, and evaluation

- Sufficient information must be available to the decision-makers so that the operation can be adjusted to meet changing needs or correct short-comings.

- Situation reports should be sent as a matter of routine.

- Do not waste energy on exchanging information that is not acted upon.

1. In order that the emergency operation can be implemented and monitored, a reliable and effective communications system which allows daily contact between UNHCR at the site, any regional base, for example for supplies and storage, and the capital will be essential. The requirement will be for a voice and/or cable link and a mail or courier service. Options are discussed in Part 2.

2. Reporting systems provide the information necessary for monitoring and evaluation, as well as the wider information needed for donors and public information. Regular routines should be set up, and the specific information required defined in standard formats which ensure that important information is there but avoid unnecessary detail. Annex 2 gives an example of a suggested format to be used, adapted as necessary, for reports from both the site level to the capital and the capital to Headquarters.

3. Specific reports will be required for various sectors. Annex 1 to chapter 7, Health, gives an example of a health surveillance report, also covering feeding programmes. Other specific reports might include those on social services, particularly unaccompanied children, tracing and family reunion. Responsibility for preparing reports must be defined, as must those who need to see them. A report that is not read and acted upon, at least by evaluating its information, is a waste of paper and time.

12.8 Special considerations

- A number of difficult or sensitive issues may arise. A clear policy on these, promulgated in advance to those who need to know, can help defuse many problems.

1. In a refugee emergency the Representative may be faced with a number of other common management or policy questions on which guidance may be helpful. The question of what is acceptable administra-

tive expenditure by an operational partner has been discussed briefly in chapter 4.2.15. The question of UNHCR paying for the purchase or rent of land occupied by the refugees may also arise. UNHCR's policy is that the provision of land is a matching contribution by the government, though construction on it may be financed by UNHCR. In certain extreme circumstances, a possible solution is to find a voluntary agency which is able to buy land on UNHCR's behalf. Headquarters' approval is required for such arrangements. Obviously, donors are reluctant to fund land purchases and when necessary it should be made clear from the start that the international community, however extensive its other forms of support, does expect the government of asylum to provide land.

2. The question of the payment of refugees in cash or kind for community services will inevitably arise. The issue of paying refugees can have a crucial effect on a settlement's character. On the one hand, payment can break any sense of responsibility the refugees should continue to feel for their welfare despite their dependence on outside assistance. On the other, the absence of payment may mean tasks essential to the settlement's well-being are either not done or have to be done by paid outside labour. In the first days of a settlement's existence it is most unlikely that the payment of refugees would be appropriate. In this start-up phase refugees should understand that they have a responsibility to themselves and their fellows to participate in the establishment of their settlement. Even a food-for-work scheme is probably wrong at this stage. In addition to the unfortunate impression of condoning a right to payment, it may also involve commitments which cannot continue to be met, or have to be met at the expense of the whole settlement's general ration. Problems with the supply system are almost inevitable at the beginning of a settlement's life and no group should in such circumstances get extra food to the direct detriment of others.

3. In the longer-term, certain types of community-wide work frequently start to emerge as areas where standards will drop if some form of payment is not given. This is often the case with key public health services whose importance is not always correctly understood by the refugees. Before any payment scheme is entered into its full potential costs should be calculated and the funds or extra food assured. The amounts involved for a large caseload may be very considerable once the precedent has been set. It should be borne in mind that after payment is introduced every group of workers will clamour to be included in the scheme. It will be necessary to have some very clear but restricted criteria on inclusion. Further, UNHCR should look to those agencies responsible for different sectoral services to meet the wage costs of refugees working in that sector. Also no wage system should be introduced which will inhibit progress towards a settlement achieving self-sufficiency.

4. As important as the level of remuneration - which, as the refugees are already supported, should be well below the national rates - is its fair application to all refugees doing broadly the same work. A major cause of discord at many refugee sites has been the payment by different NGOs of markedly different rates to refugees for the same work. A standard scale is essential. Whether or not there are differentials recognizing different levels of skill will be a matter to decide in consultation with the refugees.

5. Another common question concerns the provision of services to the local population. UNHCR does not have a mandate to provide direct assistance to local populations affected by the presence of refugees. It should be noted that

other organizations, both within and outside the UN system, and bilateral aid programmes may be able to help affected nationals. Recalling the principle that the assistance available to the refugees should take account of the conditions of nationals in the area, there may be circumstances in which a flexible approach will be in everyone's interest. For example, if a large number of refugees are located in a previously sparsely populated area, and have health services that are not available locally, these could be offered to nationals on the assumption they would represent a small proportion of the patients. Conversely, financing the construction of a hospital in the local town, where it was clear that a substantial proportion of the beds would be reserved for nationals, would not be within UNHCR's mandate. Headquarters' advice should be sought when in doubt.

6. The problem of corruption may arise in an emergency, when large sums of money and quantities of attractive relief supplies are being spent or distributed. Every effort must be made to prevent the diversion or misappropriation of funds or goods intended for the refugees. UNHCR has an obligation to ensure that what is paid for actually reaches the refugees; careful monitoring and control, including of quality, is essential. As different attitudes to the problem exist, this task will be made easier if all concerned with the provision of assistance know clearly UNHCR's policy and principles with regard to UNHCR-funded assistance. In other words, no one should be in doubt as to what practices UNHCR regards as proper and of UNHCR's intention to have them respected.

7. The question of political activities may also arise. Responsibility for security and public order at the refugee site always rests with the government. The refugees have obligations to conform to the laws and regulations of the country as well as to the measures taken for the maintenance of public order. UNHCR's responsibility is clear: "the work of the High Commissioner shall be of an entirely non-political character; it shall be humanitarian and social ..." (paragraph 2 of the Statute). No general guidelines can be given on political activities within the refugee community. The matter may be extremely delicate and Headquarters' advice must be sought immediately on any specific problems.

8. Finally, mention should be made of religious activities among the refugees by outsiders. Organizations active in the delivery of emergency relief may also have a religious aspect in their normal work. Some are traditional partners of UNHCR, with the separation between these two roles long established and well understood, but for others it may be useful to recall the basic principle. Religious activities by those outside the refugee community, where permitted by the authorities, must be clearly dissociated from the delivery of assistance and services to refugees. In particular, no proselytizing should take place in association with the provision of such general community services as education, health and social welfare.

Further references

International Disaster Institute (1981)	Disasters Volume 5 No.3 Medical Care in Refugee Camps	IDI
Oxfam (1980)	Field Directors' Handbook	Oxfam
UN (1977)	A Guide to Food and Health Relief Operations for Disasters. (Also in French and Spanish)	Protein-Calorie Advisory Group of the UN.
de Ville de Goyet C. Seaman J., Geijer U. (1978)	The Management of Nutritional Emergencies in Large Populations (Also in French and Spanish)	WHO

All the above cover considerations relevant to the management of refugee emergencies.

10.0. Elements of a Co-ordinating Body (1)

No two relief efforts are identical. Nevertheless, it is possible to list many of the issues that will require consideration in the course of initiating co-ordination mechanisms. Each of the factors listed below would need to be evaluated against the particular context and the policy of the host government.

I. Membership

The nature of the co-ordinating body and its services will be determined by decisions on the composition of the membership. These decisions will be based on the degree of agency participation in the provision of services. Furthermore, these decisions must identify an appropriate role for organizations excluded from full membership.

a. Eligibility criteria for full membership

(1) full-time representation in country
(2) provision of direct services
(3) minimum size of programme
(4) attendance at co-ordination meetings
(5) compliance with service guidelines
(6) approval of host government
(7) regular financial contributions to co-ordination mechanism
(8) inclusion and considerations of indigenous agencies

b. Associate status for organizations without full membership

(1) external organizations (UNHCR, unless a full member, etc.)
(2) voluntary agencies which may choose not to become members
(3) funding organizations
(4) public interest groups

II. Services provided by co-ordination mechanism

The following services should be selected according to their ability to facilitate the increased effectiveness of the collective services provided by voluntary agencies. Meetings provide the forum for both the formal and informal exchange of information that results in complementary programming, elimination of waste, prevention of duplication and the sharing of technical information. This co-ordination will occur to various degrees depending upon the needs and on the willingness of the participating agencies.

a. Meetings

(1) committee of the whole
(2) working sub-committees

b. Administrative services vis-a-vis host government offices

12

(1) Abridged from "Associations and Committees Serving Voluntary Agencies at the Country Level: A Study of Eight Organizations in Five Countries", by Clifford Olson, March 1981 (prepared for the International Council of Voluntary Agencies).

c. Information collection and dissemination

(1) description of agencies
(2) periodic reporting of services
(3) personnel lists
(4) newsletters
(5) collection and dispersal of technical information

d. Conferences

e. Representations to external organizations

f. Identification of needed services and soliciting of voluntary agencies to assume responsibilities for the provision of these services

g. Co-ordination of emergency responses

h. Allocation of donated commodities and financial contributions

i. Guidelines for the provision of services

j. Orientation of newly-arrived agencies

k. Orientation of incoming voluntary agency employees

l. Research and documentation

m. Support for settlement co-ordination committees

n. Co-ordination with agencies outside the country

o. Fund raising.

III: Relations with host government

Voluntary agencies are guests of the host government. It is important to build into the co-ordinating body, mechanisms which encourage co-operation and communication with appropriate levels of that government.

Consideration should be given to relations with officials:

- at the central level;
- at the provincial levels;
- at the local level;
- who are technical specialists (education, public health, etc.) in the civil service and academia;
- who are camp administrators, and
- who are in the military forces.

IV. Governing procedures

Governing procedures will describe the mechanisms through which representatives of member agencies choose to come to decisions. In some cases representatives meet frequently and are actively involved in all types of decision-making. In other instances, representatives delegate certain responsibilities to a smaller executive committee, sub-committee or staff.

a. Voting procedures
b. Election of Officers
c. Selection of Executive Committee
d. Frequency of meetings

V. Source of funding

The source of funding will predict better than any other single parameter, the beneficiaries of the services provided by the co-ordinating body.

Agencies will make best use of opportunities provided by the co-ordinating mechanism if they are assured of control over the decision-making process within that mechanism. The degree to which that mechanism depends financially upon member agencies is a measure of that control. Secretariats with independent sources of funding are at times subject to temptations to develop in directions independent of the desires of member agencies.

a. Willingness to accept external support
b. Portion of expenditures covered by member contributions
c. Assessment by size of agency involvement in relief effort versus equal contributions
d. Provision of exemptions or partial exemptions from required contributions.

VI. Staffing

The number of staff must be both large enough to provide the required services and small enough to be paid by available funding. The authority and supervision of the staff should be clearly delineated. Three sets of alternatives should be considered:

a. Personnel seconded from member agencies versus professionals employed by the co-ordinating body
b. Expatriates versus host country nationals
c. Generalists (co-ordinators) versus technical specialists.

Again, the specific site context is a determining factor in designing the co-ordinating mechanism. Individuals working at the site and representing participating agencies are best able to determine which organizational structure will achieve a co-ordination that will result in increased effectiveness and efficient use of resources.

Example of a Standard Situation Report

1. In emergencies, it is essential that regular situation reports reach Headquarters. The frequency of such reports will be determined by the characteristics of the situation; more frequent reports will be necessary in the initial stage of an emergency. Situation reports should give an overall view of the situation with sufficient factual content and explanation of changes since the last report to answer rather than raise substantive questions. By indicating progress achieved, problems encountered and steps being taken or planned to overcome these, the reports should give a cumulative picture of how the needs of the refugees are being met.

2. A suggested format is given opposite. Major headings should as a rule be the same in each report, indicating "no change" if appropriate. Depending on the situation, headings E through K may either be presented as shown, with locations covered under each sector of assistance, or alternatively by locations, with sectors of assistance covered under each location. In either case, the information under each sector of assistance and for each location should cover as applicable:

(1) Current situation;
(2) Particular problem areas, remedial action planned or necessary,[1] with time frame;
(3) Any variation from overall implementing arrangements in DDD;
(4) Personnel and facilities available.

3. The reports should be sequentially numbered, copied to RO New York and to other UNHCR field offices as appropriate. The report may be used as the basis for any wider situation report issued from Headquarters.

4. A similar format may be useful for situation reports to the Representative by field officers at the site level.

---

(1) Specific action requested of Headquarters should be the subject of a separate cable, which could of course make reference to an earlier sitrep. Where relevant, reference should be made to such requests in the sitrep.

HICOMREF GENEVA INFO HICOMREF NEW YORK (and other offices concerned)
SITREP (number) COVERING PERIOD (date) TO (date)

A GENERAL SITUATION

PRIMO
SECUNDO
etc.

(Summary of major developments including protection, assessment of situation generally and by refugee location, and field deployment of UNHCR staff.)

B REFUGEE STATISTICS AND REGISTRATION

(By location, country of origin or distinct groups if not self-evident, with explanation of changes since last report, and indicating source, e.g. government, UNHCR, etc.)

C CO-ORDINATION

(Government departments, UN system, NGOs, both at capital and field levels. Arrangements for briefing diplomatic corps.)

D OVERALL IMPLEMENTING ARRANGEMENTS

(Role of authorities
Operational role of UNHCR (if any)
Role of UNHCR's operational partners
Other sources of significant assistance)

E SUPPLIES AND LOGISTICS

(Including information on internal transport arrangements, arrival of major consignments of multilateral or bilateral relief supplies, outstanding needs, etc.)

F SHELTER

(Site layout, housing, etc.)

G HEALTH

H FOOD AND NUTRITION

I WATER

J SANITATION AND ENVIRONMENTAL SERVICES

K SOCIAL SERVICES AND EDUCATION

(Including disabled refugees, unaccompanied children, and tracing etc. as applicable.)

L PUBLIC INFORMATION

(Significant events/media coverage.)

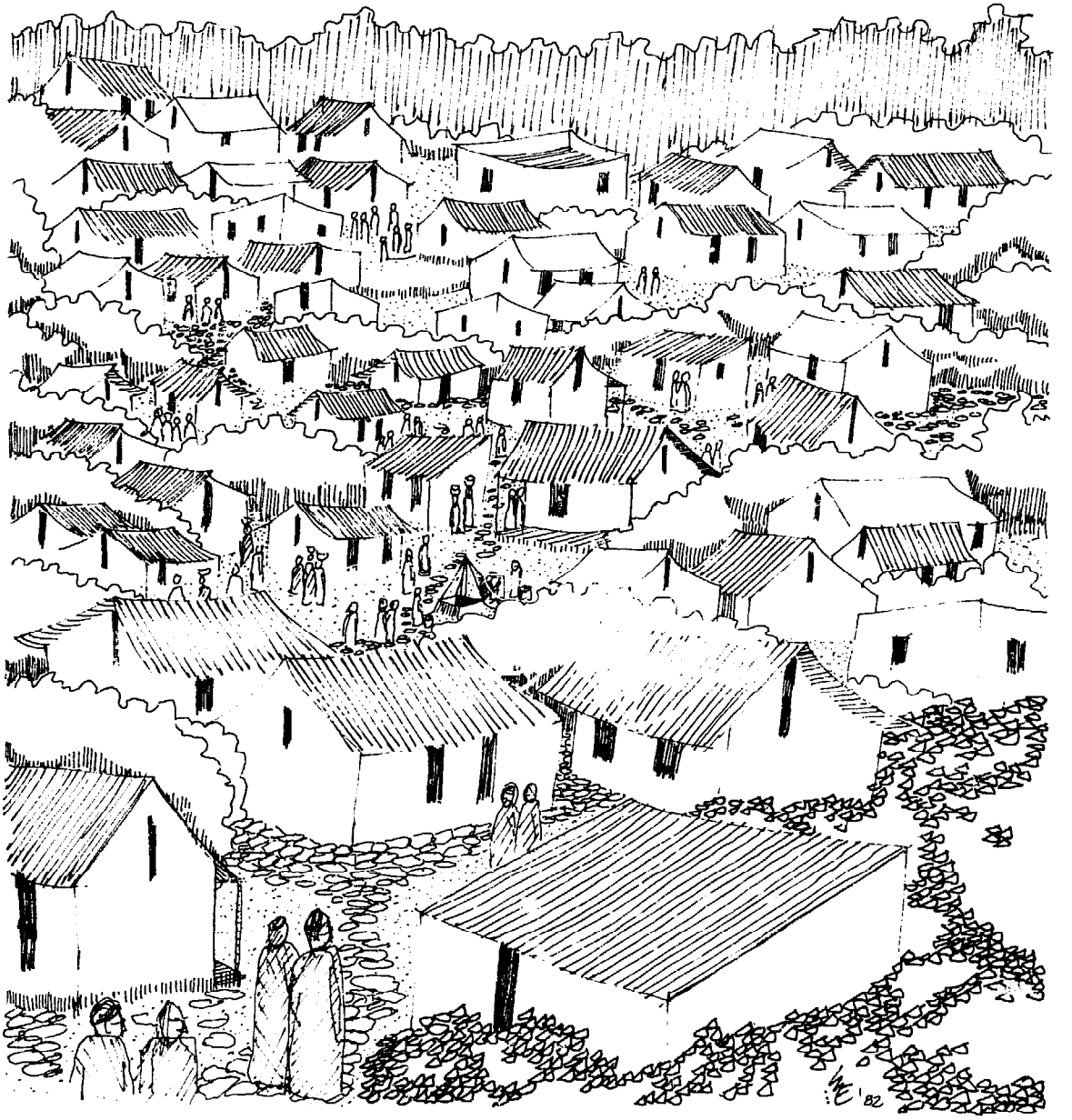

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Regulator for Permanant Magnet Alternators

Click the Photo

to check out a 15-second MPEG movie (343K) which shows the regulator in operation. Watch close, and you'll see the sudden change on the voltmeter as the regulator changes the wiring of the stator from series to parallel. This is clearly visible both on acceleration of the alternator and deceleration.

This page results from an effort I made to regulate the voltage from permanent magnet alternators. In making wind generators it is important to start with a good low-rpm generator/alternator. Generally, good low-rpm generators require permanant magnets to supply the field. The main reason for this, of course, is if the field of a

generator is supplied by electromagnets, they require electricity (inefficient) and simply the space required by copper wire can make it impractical. By using permanent magnets, it is possible to have many strong magnetic poles, packed into a small space so that fairly low rpm can offer a fairly high output voltage.

The disadvantage of permanant magnet generators is that they are difficult to regulate over a range of rpm. In a normal generator or alternator, the voltage is regulated easily, by adjusting it to the field windings. In a permanent magnet machine, the strength of the field is predetermined and fixed simply by the strength of the permanent magnets used. When charging batteries, as in the case of most wind generators, the machine might be very efficient at a certain speed, but at high speeds most of the work done by the propellor is wasted by simply heating up the windings in the generator! For example, in this alternator which I used in this experiment, if all the coils are hooked into series, at 120 rpm it hits 12 volts, open voltage. At 1200 rpm, it's around 120 volts! When charging batteries (12 volts) it runs fairly efficiently at 200 rpm charging aroun 5-6 amps into the batteries. At higher speeds, it charges only a little more, and most of the work into the shaft of the alternator serves only to heat up the windings in the alternator.

If the alternator could be wired differently at higher speeds only, then it could serve efficiently at a wider range of rpm. This voltage regulator works in the following way. The alternator stator is divided into two halves. Depending upon the speed of the alternator, the two halves will be hooked either in series (at low speeds) or in parallel (at high speeds). Such a regulator on any permanant magnet alternator could increase the usable output significantly at both low and high speeds. There is certainly argument that "simpler is better" and it may well be worth the lack of trouble to leave certain machines completely unregulated in the spirit of simplicity and reliability, but - I've thought about this problem for a while since making windmills and this is one possible alternative.

The regulator is really very simple. It consists of a set of contacts which in one position wire the stator in series, and in the other wire the stator in parallel. The whole thing is controlled by some magnets, in close proximity to an Aluminium (Copper would work even better) disc which is mounted to the alternator shaft. Of course, magnets are NOT attracted to Aluminium (or Copper), but...both are very good conductors. Spinning the disc in close proximity to magnets generates current, which is shorted out and has no place to go. This is called the "Lenz Effect." The magnets are pulled (and repelled) by the disc. It is the "pulling" force which is used here. Once the alternator is going a certain speed, the magnets and the electrical contacts they are attached to are physically pulled up to connect to the contacts above - thus re-wiring the two halves of the alternator stator into parallel, halving the voltage and doubling the current. This works exactly like a mechanical Relay, except it is triggered to switch by the Lenz Effect instead of an electromagnetic coil.

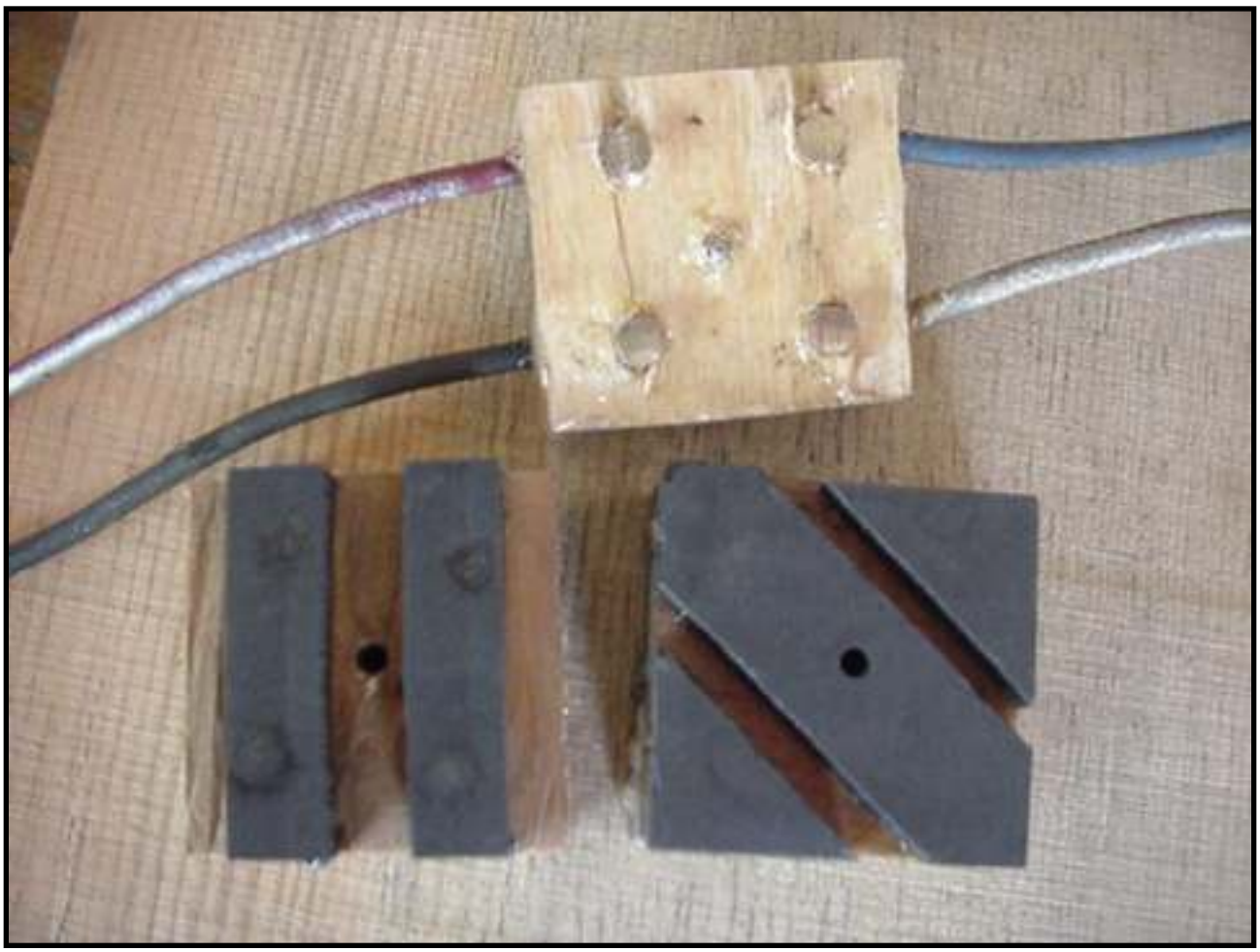

Above are pictured the contacts involved. They are carbon graphite, the same stuff they make motor brushes out of. I cut out the pieces on a saw, and they are arranged to hook two seperate lines (the halves of the stator) into either series (for low rpm) or parallel(for high rpm). The piece with the brass contacts is the moving part and hooks directly to the stator. All the parts are made from plywood. The carbon graphite pieces are super-glued on. I drilled holes in the brass contact and pressed brass rod through them. All were sanded flat with the belt sander. It's very important that they be flat! This would've worked a lot better had I made the brass contacts somehow spring loaded, or flexible, so they could always be assured of making good contact with the carbon. As it is, I'm surprised that it works at all...it actually so far, works very reliably.

Again, a picture of the moving contacts. Notice the magnet in the center of the block. The rod (1/8" steel) that serves to move the block up and down, is attached ONLY by the force of this magnet. This allows for some flexibility between the block and the rod, to aid in making good contacts between the brass and the carbon. For my first try, I drilled out the block and the rod fit tightly into the brass contact block. I had real troubles getting it to work, and this "flexible magnetic coupling" solved the problem.

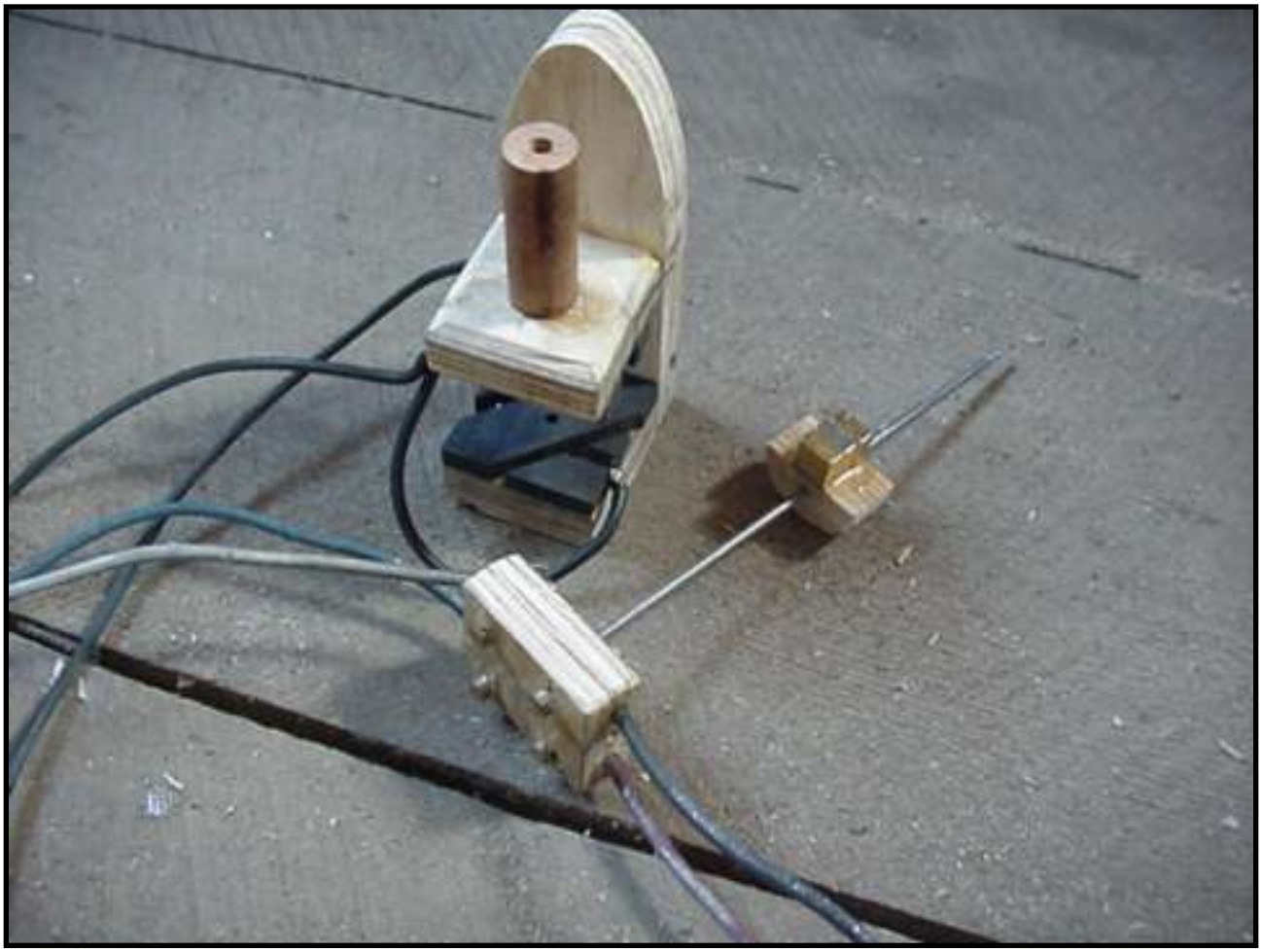

Above are pictured all the parts of the regulator, it's really very simple!

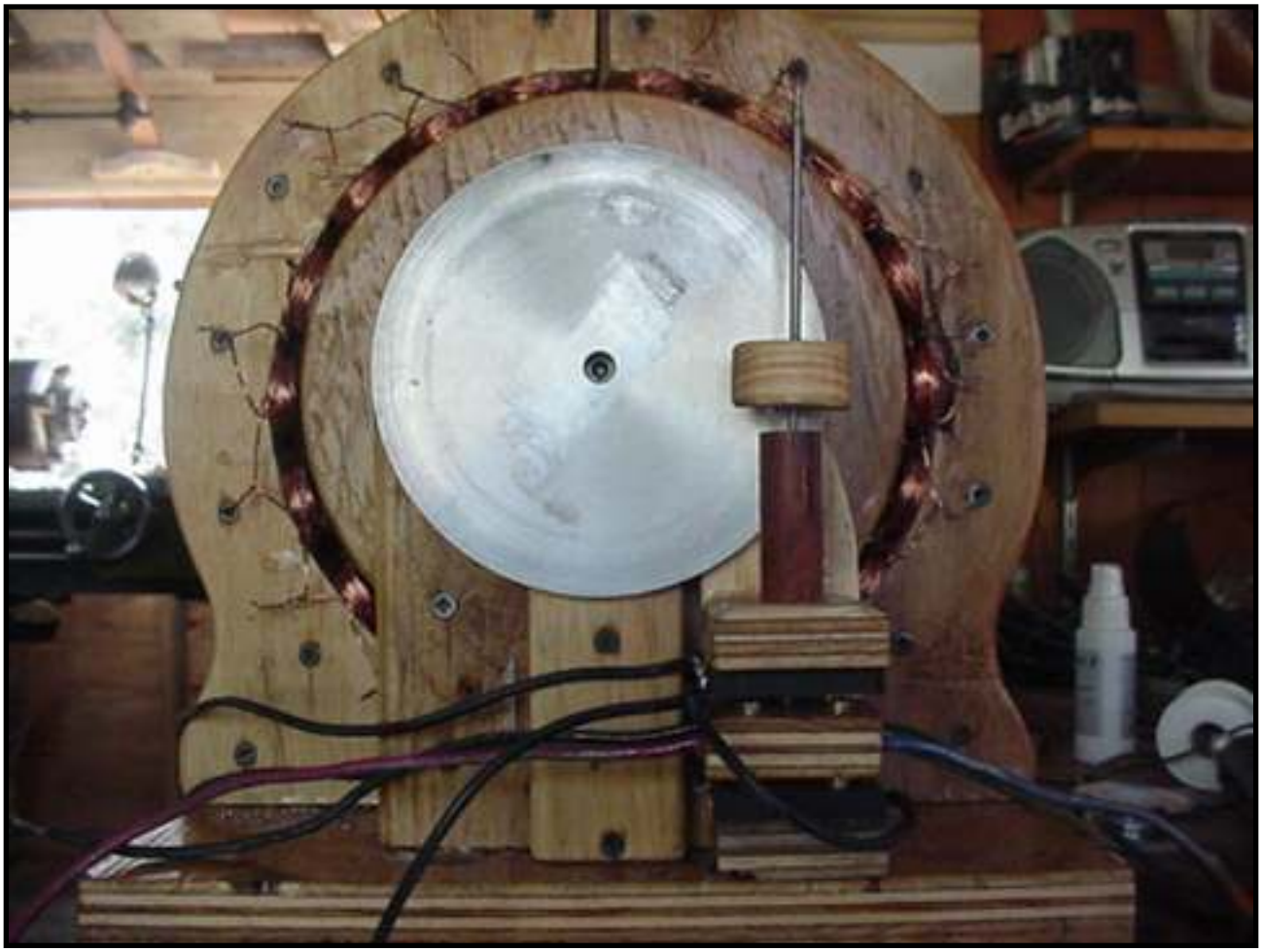

The photo above shows the regulator mounted to the back of the alternator. The Aluminium disc fits just perfectly between the back of the regulator and the magnets. The regulator works pretty well, though lots of little things could be done to adjust it. Changes which would affect performance include: More or less weight on the moving parts, a thicker(or thinner) Aluminium disc, more or less magnets near the disc, and distance between the disc and the magnets. Another thing I did to it (not shown in any pictures) is include a small magnet and a washer which it was attracted to, which serves to pull down on the moving contacts. It helped to insure a tight contact at low rpm, and also a much faster switching action! It actually makes a fast clicking sound, and it never floats between the contacts. As it is adjusted now, when the altnerator comes up from 0 rpm the stator is hooked in series, until it hits around 300 rpm (about 30 volts. It then changes to parallel, and the voltage drops to around 15 and available current doubles. The curve is different on the way down, due mostly to the magnet which holds the bottom contact tightly together. It stays hooked in parallel down to about 10 volts, and then switches back to series and the voltage jumps back up to around 20.

Again, there are a bunch of adjustments that could be made. Simple improvements should definitely include some spring loaded contacts - or some sort of flexibility there. Although my contacts worked in testing, slight wear could render the contacts I

made useless. I believe that for currents over 10 amps they should be larger. I was surprised at how hot the carbon graphite got when charging my batteries at 15 amps! Overall though, I think if scaled up some and well made, this sort of regulator could squeeze a good bit of extra power out of an otherwise unregulated alternator, giving better startup performance (starts charging at a lower rpm) and better high-speed performance (halving voltage to double current).

I know there are some alternative, solid-state approaches to solving this problem--but they involve high-power semiconductors, which I can't fabricate in my shop! As we learn more about other approaches we will certainly post information and links. Please let us know via email or our discussion board if you have any ideas or experience with regulating permanant magnet alternators.

mailto:info@otherpower.com

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Reichstein process

From Wikipedia, the free encyclopedia

The **Reichstein process** in chemistry is a combined chemical and microbial method for the production of ascorbic acid from D-glucose that takes place in several steps. This process was devised by Nobel Prize winner Tadeus Reichstein and his colleagues in 1933 while working in the laboratory of the ETH in Zürich.

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Reaction steps

The reaction steps are:

- hydrogenation of D-glucose to D-sorbitol, an organic reaction with nickel as a catalyst under high temperature and high pressure.
- Microbial oxidation or fermentation of sorbitol to L-sorbose with acetobacter[1] at pH 4-6 and 30 ° C.
- protection of the 4 hydroxyl groups in sorbose by formation of the acetal with acetone and an acid to Diacetone-L-sorbose (2,3:4,6−Diisopropyliden−α−L−sorbose)
- Organic oxidation with potassium permanganate followed by heating with water gives the 2-Keto-L-gulonic acid
- The final step is a ring-closing step or gamma lactonization with removal of water.[2]
- Intermediate **5** can also be prepared directly from **3** with oxygen and platinum

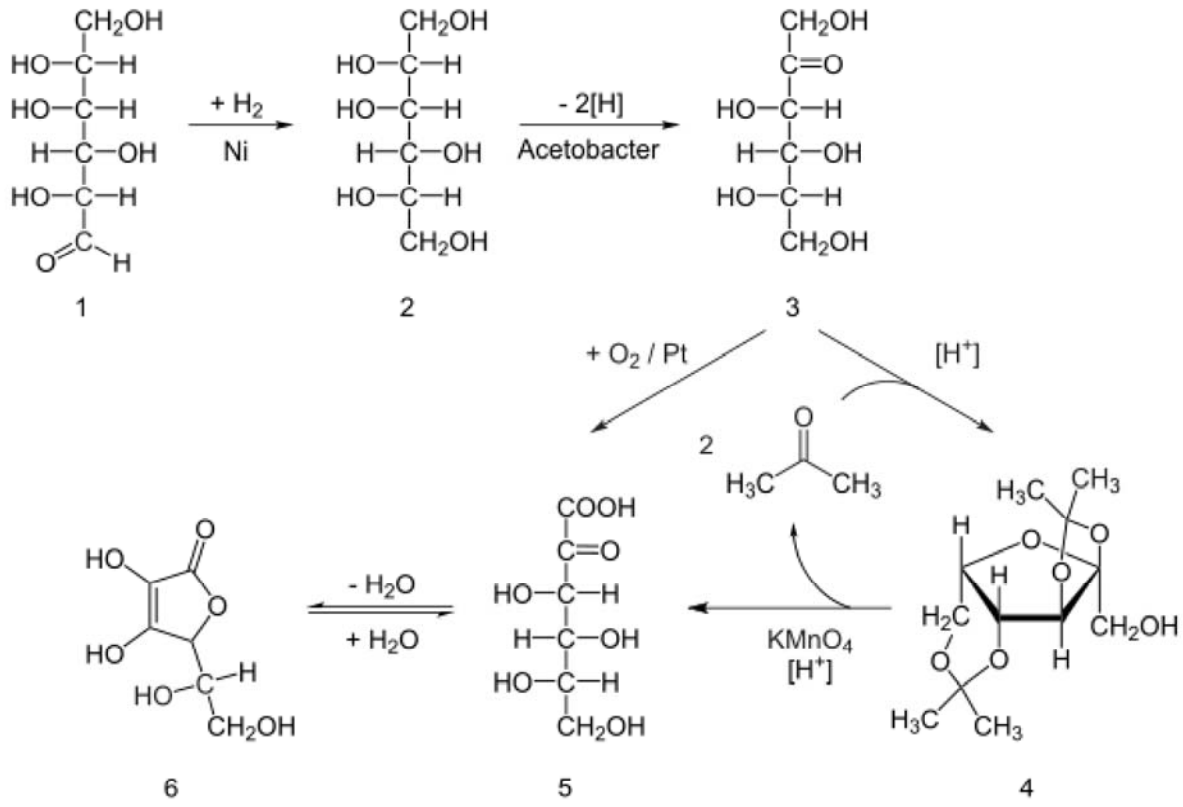

The microbial oxidation of sorbitol to sorbose is important because it provides the correct stereochemistry.

Importance

This process was patented and sold to Hoffmann-La Roche in 1935. The first commercially sold vitamin C product was called *Cebion* from Merck.

Even today all industrial methods for the production of ascorbic acid are based on the Reichstein process. In modern methods however, sorbose is directly oxidized with a platinum catalyst (developed by Kurt Heyns (1908–2005) in 1942). This method avoids the use of protective groups. A side product with particular modification is 5-Keto-D-gluconic acid.[3]

Novel methods involve genetically modified bacteria.[4]

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Categories: Organic reactions

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Reinforced concrete

From Wikipedia, the free encyclopedia

Reinforced concrete (RC) is a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength or ductility. The reinforcement is usually, though not necessarily, steel reinforcing bars (rebar) and is usually embedded passively in the concrete before the concrete sets. Reinforcing schemes are generally designed to resist tensile stresses in particular regions of the concrete that might cause unacceptable cracking and/or structural failure. Modern reinforced concrete can contain varied reinforcing materials made of steel, polymers or alternate composite material in conjunction with rebar or not. Reinforced concrete may also be permanently stressed (in compression), so as to improve the behaviour of the final structure under working loads. In the United States, the most common methods of doing this are known as pre-tensioning and post-tensioning.

The novel shape of the Philips Pavilion was allowed by reinforced concrete.

For a strong, ductile and durable construction the reinforcement needs to have the following properties at least:

- High relative strength
- High toleration of tensile strain
- Good bond to the concrete, irrespective of pH, moisture, and similar factors
- Thermal compatibility, not causing unacceptable stresses in response to changing temperatures.
- Durability in the concrete environment, irrespective of corrosion or sustained stress for example.

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History

François Coignet was a French industrialist of the nineteenth century, a pioneer in the development of structural, prefabricated and reinforced concrete.[1] Coignet was the first to use iron-reinforced concrete as a technique for constructing building structures.[2] In 1853 Coignet built the first iron reinforced concrete structure, a four story house at 72 rue Charles Michels in the suburbs of Paris.[2] Coignet's descriptions of reinforcing concrete suggests that he did not do it for means of adding strength to the concrete but for keeping walls in monolithic construction from overturning.[3] In 1854, English builder William B. Wilkinson reinforced the concrete roof and floors in the two-storey house he was constructing. His positioning of the reinforcement demonstrated that, unlike his predecessors, he had knowledge of tensile stresses.[4][5][6]

Joseph Monier, a French gardener and known to be one of the principal inventors of reinforced concrete, was granted a patent for reinforced flowerpots by means of mixing a wire mesh to a mortar shell. In 1877, Monier was granted another patent for a more advanced technique of reinforcing concrete columns and girders with iron rods placed in a grid pattern. Though Monier undoubtedly knew reinforcing concrete would improve its inner cohesion, it is less known if he even knew how much reinforcing actually improved concrete's tensile strength.[7]

Before 1877 the use of concrete construction, though dating back to the Roman Empire and reintroduced in the mid to late 1800s, was not yet a proven scientific technology. American New Yorker Thaddeus Hyatt published a report titled *An Account of Some Experiments with Portland-Cement-Concrete Combined with Iron as a Building Material, with Reference to Economy of Metal in Construction and for Security against Fire in the Making of Roofs, Floors, and Walking Surfaces* where he stated his experiments on the behavior of reinforced concrete. His work played a major role in the evolution of concrete construction as a proven and studied science. Without Hyatt's work, more dangerous trial and error methods would have largely been depended on for the advancement in the technology.[3][8]

G. A. Wayss was a German civil engineer and a pioneer of the iron and steel concrete construction. In 1879 Wayss bought the German rights to Monier's patents and in 1884 started the first commercial use for reinforced concrete in his firm Wayss & Freytag. Up until the 1890s Wayss and his firm greatly contributed to the advancement of Monier's system of reinforcing and established it as a well-developed scientific technology.[9]

Ernest L. Ransome was an English-born engineer and early innovator of the reinforced concrete techniques in the end of the 19th century. With the knowledge of reinforced concrete developed during the previous 50 years, Ransome innovated nearly all styles and techniques of the previous known inventors of reinforced concrete. Ransome's key innovation was to twist the reinforcing steel bar improving bonding with the concrete.[10] Gaining increasing fame from his concrete constructed buildings Ransome was able to build two of the first reinforced concrete bridges in North America.[11] One of the first concrete buildings constructed in the United States, was a private home, designed by William Ward in 1871. The home was designed to be fireproof for his wife. One of the first skyscrapers made with reinforced concrete was the 16-storey Ingalls Building in Cincinnati, constructed in 1904.[12]

Use in construction

Many different types of structures and components of structures can be built using reinforced concrete including slabs, walls, beams, columns, foundations, frames and more.

Rebars of Sagrada Família's roof in construction (2009)

Reinforced concrete can be classified as precast or cast-in-place concrete.

Designing and implementing the most efficient floor system is key to creating optimal building structures. Small changes in the design of a floor system can have significant impact on material costs, construction schedule, ultimate strength, operating costs, occupancy levels and end use of a building.

Without reinforcement, constructing modern structures with concrete material would not be possible.

Behavior of reinforced concrete

Materials

Concrete is a mixture of coarse (stone or brick chips) and fine (generally sand or crushed stone) aggregates with a paste of binder material (usually Portland cement) and water. When cement is mixed with a small amount of water, it hydrates to form microscopic opaque crystal lattices encapsulating and locking the aggregate into a rigid structure. The aggregates used for making concrete should be free from harmful substances like organic impurities, silt, clay, lignite etc. Typical concrete mixes have high resistance to compressive stresses (about 4,000 psi (28 MPa)); however, any appreciable tension (*e.g.,* due to bending) will break the microscopic rigid lattice, resulting in cracking and separation of the concrete. For this reason, typical non-reinforced concrete must be well supported to prevent the development of tension.

If a material with high strength in tension, such as steel, is placed in concrete, then the composite material, reinforced concrete, resists not only compression but also bending and other direct tensile actions. A reinforced concrete section where the concrete resists the compression and steel resists the tension can be made into almost any shape and size for the construction industry.

Key characteristics

Three physical characteristics give reinforced concrete its special properties:

1. The coefficient of thermal expansion of concrete is similar to that of steel, eliminating large internal stresses due to differences in thermal expansion or contraction.
2. When the cement paste within the concrete hardens, this conforms to the surface details of the steel, permitting any stress to be transmitted efficiently between the different materials. Usually steel bars are roughened or corrugated to further improve the bond or cohesion between the concrete and steel.
3. The alkaline chemical environment provided by the alkali reserve (KOH, NaOH) and the portlandite (calcium hydroxide) contained in the hardened cement paste causes a passivating film to form on the surface of the steel, making it much more resistant to corrosion than it would be in neutral or acidic conditions. When the cement paste is exposed to the air and meteoric water reacts with the atmospheric CO_2, portlandite and the calcium silicate hydrate (CSH) of the hardened cement paste become progressively carbonated and the high pH gradually decreases from 13.5 – 12.5 to 8.5, the pH of water in equilibrium with calcite (calcium carbonate) and the steel is no longer passivated.

As a rule of thumb, only to give an idea on orders of magnitude, steel is protected at pH above ~11 but starts to corrode below ~10 depending on steel characteristics and local physico-chemical conditions when concrete becomes carbonated. carbonatation of concrete along with chloride ingress are amongst the chief reasons for the failure of reinforcement bars in concrete.[13]

The relative cross-sectional area of steel required for typical reinforced concrete is usually quite small and varies from 1% for most beams and slabs to 6% for some columns. Reinforcing bars are normally round in cross-section and vary in diameter. Reinforced concrete structures sometimes have provisions such as ventilated hollow cores to control their moisture & humidity.

Distribution of concrete (in spite of reinforcement) strength characteristics along the cross-section of vertical reinforced concrete elements is inhomogeneous.[14]

Mechanism of composite action of reinforcement and concrete

The reinforcement in a RC structure, such as a steel bar, has to undergo the same strain or deformation as the surrounding concrete in order to prevent discontinuity, slip or separation of the two materials under load. Maintaining composite action requires transfer of load between the concrete and steel. The direct stress is transferred from the concrete to the bar interface so as to change the tensile stress in the reinforcing bar along its length, this load transfer is achieved by means of bond (anchorage) and is idealized as a continuous stress field that develops in the vicinity of the steel-concrete interface.

A heavy reinforced concrete column, seen before and after the concrete has been cast in place around the rebar cage.

Anchorage (bond) in concrete: Codes of specifications

Because the actual bond stress varies along the length of a bar anchored in a zone of tension, current international codes of specifications use the concept of development length rather than bond stress. The main requirement for safety against bond failure is to provide a sufficient extension of the length of the bar beyond the point where the steel is required to develop its yield stress and this length must be at least equal to its development length. However, if the actual available length is inadequate for full development, special anchorages must be provided, such as cogs or hooks or mechanical end plates. The same concept applies to lap splice length mentioned in the codes where splices (overlapping) provided between two adjacent bars in order to maintain the required continuity of stress in the splice zone.

Anti-corrosion measures

In wet and cold climates, reinforced concrete for roads, bridges, parking structures and other structures that may be exposed to deicing salt may benefit from use of corrosion-resistant reinforcement such as uncoated, low carbon/chromium (micro composite), epoxy-coated, hot dip galvanised or stainless steel rebar. Good design and a well-chosen concrete mix will provide additional protection for many applications. Uncoated, low carbon/chromium rebar looks similar to standard carbon steel rebar due to its lack of a coating; its highly corrosion-resistant features are inherent in the steel microstructure. It can be identified by the unique ASTM specified mill marking on its smooth, dark charcoal finish. Epoxy coated rebar can easily be identified by the light green colour of its epoxy coating. Hot dip galvanized rebar may be bright or dull grey depending on length of exposure, and stainless rebar exhibits a typical white metallic sheen that is readily distinguishable from carbon steel reinforcing bar. Reference ASTM standard specifications **A1035/A1035M** Standard Specification for Deformed and Plain Low-carbon, Chromium, Steel Bars for Concrete Reinforcement, **A767** Standard Specification for Hot Dip Galvanised Reinforcing Bars, **A775** Standard Specification for Epoxy Coated Steel Reinforcing Bars and **A955** Standard Specification for Deformed and Plain Stainless Bars for Concrete Reinforcement.

Another, cheaper way of protecting rebars is coating them with zinc phosphate.[15] Zinc phosphate slowly reacts with calcium cations and the hydroxyl anions present in the cement pore water and forms a stable hydroxyapatite layer.

Penetrating sealants typically must be applied some time after curing. Sealants include paint, plastic foams, films and aluminum foil, felts or fabric mats sealed with tar, and layers of bentonite clay, sometimes used to seal roadbeds.

Corrosion inhibitors, such as calcium nitrite [$Ca(NO_2)_2$], can also be added to the water mix before pouring concrete. Generally, 1–2 wt. % of [$Ca(NO_2)_2$] with respect to cement weight is needed to prevent corrosion of the rebars. The nitrite anion is a mild oxidizer that oxidizes the soluble and mobile ferrous ions (Fe^{2+}) present at the surface of the corroding steel and causes them to precipitate as an insoluble ferric hydroxide ($Fe(OH)_3$). This causes the passivation of steel at the anodic oxidation sites. Nitrite is a much more active corrosion inhibitor than nitrate, which is a less powerful oxidizer of the divalent iron.

Reinforcement and terminology of beams

A beam bends under bending moment, resulting in a small curvature. At the outer face (tensile face) of the curvature the concrete experiences tensile stress, while at the inner face (compressive face) it experiences compressive stress.

Rebar constructed to properly reinforce a beam element, awaiting concrete to be poured.

A **singly reinforced** beam is one in which the concrete element is only reinforced near the tensile face and the reinforcement, called tension steel, is designed to resist the tension.

A **doubly reinforced** beam is one in which besides the tensile reinforcement the concrete element is also reinforced near the compressive face to help the concrete resist compression. The latter reinforcement is called compression steel. When the compression zone of a concrete is inadequate to resist the compressive moment (positive moment), extra reinforcement has to be provided if the architect limits the dimensions of the section.

An **under-reinforced** beam is one in which the tension capacity of the tensile reinforcement is smaller than the combined compression capacity of the concrete and the compression steel (under-reinforced at tensile face). When the reinforced concrete element is subject to increasing bending moment, the tension steel yields while the concrete does not reach its ultimate failure condition. As the tension steel yields and stretches, an "under-reinforced" concrete also yields in a ductile manner, exhibiting a large deformation and warning before its ultimate failure. In this case the yield stress of the steel governs the design.

An **over-reinforced** beam is one in which the tension capacity of the tension steel is greater than the combined compression capacity of the concrete and the compression steel (over-reinforced at tensile face). So the "over-reinforced concrete" beam fails by crushing of the compressive-zone concrete and before the tension zone steel yields, which does not provide any warning before failure as the failure is instantaneous.

A **balanced-reinforced** beam is one in which both the compressive and tensile zones reach yielding at the same imposed load on the beam, and the concrete will crush and the tensile steel will yield at the same time. This design criterion is however as risky as over-reinforced concrete, because failure is sudden as the concrete crushes at the same time of the tensile steel yields, which gives a very little warning of distress in tension failure.[16]

Steel-reinforced concrete moment-carrying elements should normally be designed to be under-reinforced so that users of the structure will receive warning of impending collapse.

The **characteristic strength** is the strength of a material where less than 5% of the specimen shows lower strength.

The **design strength** or **nominal strength** is the strength of a material, including a material-safety factor. The value of the safety factor generally ranges from 0.75 to 0.85 in Permissible stress design.

The **ultimate limit state** is the theoretical failure point with a certain probability. It is stated under factored loads and factored resistances.

Reinforced concrete structures are normally designed according to rules and regulations or recommendation of a code such as ACI-318, CEB, Eurocode 2 or the like. WSD, USD or LRFD methods are used in design of RC structural members. Analysis and design of RC members can be carried out by using linear or non-linear approaches. When applying safety factors, building codes normally propose linear approaches, but for some cases non-linear approaches. To see the examples of a non-linear numerical simulation and calculation visit the references:[17][18]

Prestressed concrete

Prestressing concrete is a technique that greatly increases the load-bearing strength of concrete beams. The reinforcing steel in the bottom part of the beam, which will be subjected to tensile forces when in service, is placed in tension before the concrete is poured around it. Once the concrete has hardened, the tension on the reinforcing steel is released, placing a built-in compressive force on the concrete. When loads are applied, the reinforcing steel takes on more stress and the compressive force in the concrete is reduced, but does not become a tensile force. Since the concrete is always under compression, it is less subject to cracking and failure.

Common failure modes of steel reinforced concrete

Reinforced concrete can fail due to inadequate strength, leading to mechanical failure, or due to a reduction in its durability. Corrosion and freeze/thaw cycles may damage poorly designed or constructed reinforced concrete. When rebar corrodes, the oxidation products (rust) expand and tends to flake, cracking the concrete and unbonding the rebar from the concrete. Typical mechanisms leading to durability problems are discussed below.

Mechanical failure

Cracking of the concrete section is nearly impossible to prevent; however, the size and location of cracks can be limited and controlled by appropriate reinforcement, control joints, curing methodology and concrete mix design. Cracking can allow moisture to penetrate and corrode the reinforcement. This is a serviceability failure in limit state design. Cracking is normally the result of an inadequate quantity of rebar, or rebar spaced at too great a distance. The concrete then cracks either under excess loading, or due to internal effects such as early thermal shrinkage while it cures.

Ultimate failure leading to collapse can be caused by crushing the concrete, which occurs when compressive stresses exceed its strength, by yielding or failure of the rebar when bending or shear stresses exceed the strength of the reinforcement, or by bond failure between the concrete and the rebar. [19]

Carbonation

Concrete wall cracking as steel reinforcing corrodes and swells. Rust has a lower density than metal, so it expands as it forms, cracking the decorative cladding off the wall as well as damaging the structural concrete. The breakage of material from a surface is called *spalling*.

Carbonation, or neutralisation, is a chemical reaction between carbon dioxide in the air and calcium hydroxide and hydrated calcium silicate in the concrete.

When a concrete structure is designed, it is usual to specify the concrete cover for the rebar (the depth of the rebar within the object). The minimum concrete cover is normally regulated by design or building codes. If the reinforcement is too close to the surface, early failure due to corrosion may occur. The concrete cover depth can be measured with a cover meter. However, carbonated concrete incurs a durability problem only when there is also sufficient moisture and oxygen to cause electropotential corrosion of the reinforcing steel.

One method of testing a structure for carbonatation is to drill a fresh hole in the surface and then treat the cut surface with phenolphthalein indicator solution. This solution turns pink when in contact with alkaline concrete, making it possible to see the depth of carbonation. Using an existing hole does not suffice because the exposed surface will already be carbonated.

Chlorides

Chlorides, including sodium chloride, can promote the corrosion of embedded steel rebar if present in sufficiently high concentration. Chloride anions induce both localized corrosion (pitting corrosion) and generalized corrosion of steel reinforcements. For this reason, one should only use fresh raw water or potable water for mixing concrete, ensure that the coarse and fine aggregates do not contain chlorides, rather than admixtures which might contain chlorides.

It was once common for calcium chloride to be used as an admixture to promote rapid set-up of the concrete. It was also mistakenly believed that it would prevent freezing. However, this practice fell into disfavor once the deleterious effects of chlorides became known. It should be avoided whenever possible.

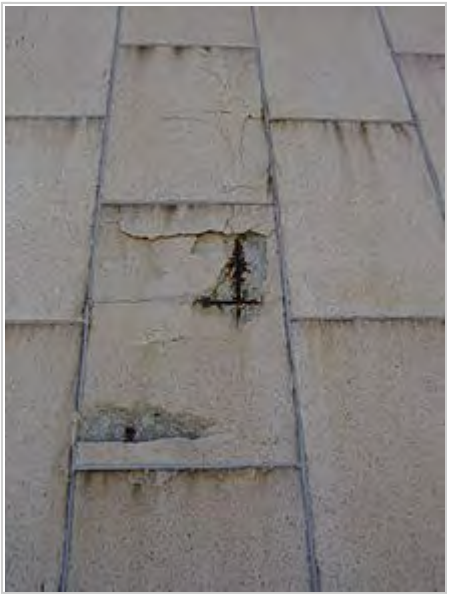

Detailed view of spalling probably caused by a too thin layer of concrete between the steel and the surface, accompanied by corrosion from external exposure

The use of de-icing salts on roadways, used to lower the freezing point of water, is probably one of the primary causes of premature failure of reinforced or prestressed concrete bridge decks, roadways, and parking garages. The use of epoxy-coated reinforcing bars and the application of cathodic protection has mitigated this problem to some extent. Also FRP (fiber-reinforced polymer) rebars are known to be less susceptible to chlorides. Properly designed concrete mixtures that have been allowed to cure properly are effectively impervious to the effects of de-icers.

Rebar for foundations and walls of a sewage pump station.

The Paulins Kill Viaduct, Hainesburg, New Jersey, is 115 feet (35 m) tall and 1,100 feet (335 m) long, and was heralded as the largest reinforced concrete structure in the world when it was completed in 1910 as part of the Lackawanna Cut-Off rail line project. The Lackawanna Railroad was a pioneer in the use of reinforced concrete.

Another important source of chloride ions is sea water. Sea water contains by weight approximately 3.5 wt.% salts. These salts include sodium chloride, magnesium sulfate, calcium sulfate, and bicarbonates. In water these salts dissociate in free ions (Na^+, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-) and migrate with the water into the capillaries of the concrete. Chloride ions, which make up about 50% of these ions, are particularly aggressive as a cause of corrosion of carbon steel reinforcement bars.

In the 1960s and 1970s it was also relatively common for magnesite, a chloride rich carbonate mineral, to be used as a floor-topping material. This was done principally as a levelling and sound attenuating layer. However it is now known that when these materials come into contact with moisture they produce a weak solution of hydrochloric acid due to the presence of chlorides in the magnesite. Over a period of time (typically decades) the solution causes corrosion of the embedded steel rebars. This was most commonly found in wet areas or areas repeatedly exposed to moisture.

Alkali silica reaction

This a reaction of amorphous silica (chalcedony, chert, siliceous limestone) sometimes present in the aggregates with the hydroxyl ions (OH^-) from the cement pore solution. Poorly crystallized silica (SiO_2) dissolves and dissociates at high pH (12.5 - 13.5) in alkaline water. The soluble dissociated silicic acid

reacts in the porewater with the calcium hydroxide (portlandite) present in the cement paste to form an expansive calcium silicate hydrate (CSH). The alkali–silica reaction (ASR) causes localised swelling responsible for tensile stress and cracking. The conditions required for alkali silica reaction are threefold: (1) aggregate containing an alkali-reactive constituent (amorphous silica), (2) sufficient availability of hydroxyl ions (OH^-), and (3) sufficient moisture, above 75% relative humidity (RH) within the concrete.[20][21] This phenomenon is sometimes popularly referred to as "concrete cancer". This reaction occurs independently of the presence of rebars; massive concrete structures such as dams can be affected.

Conversion of high alumina cement

Resistant to weak acids and especially sulfates, this cement cures quickly and has very high durability and strength. It was frequently used after World War II to make precast concrete objects. However, it can lose strength with heat or time (conversion), especially when not properly cured. After the collapse of three roofs made of prestressed concrete beams using high alumina cement, this cement was banned in the UK in 1976. Subsequent inquiries into the matter showed that the beams were improperly manufactured, but the ban remained.[22]

Sulphates

Sulfates (SO_4) in the soil or in groundwater, in sufficient concentration, can react with the Portland cement in concrete causing the formation of expansive products, e.g., ettringite or thaumasite, which can lead to early failure of the structure. The most typical attack of this type is on concrete slabs and foundation walls at grades where the sulfate ion, via alternate wetting and drying, can increase in concentration. As the concentration increases, the attack on the Portland cement can begin. For buried structures such as pipe, this type of attack is much rarer, especially in the eastern United States. The sulfate ion concentration increases much slower in the soil mass and is especially dependent upon the initial amount of sulfates in the native soil. A chemical analysis of soil borings to check for the presence of sulfates should be undertaken during the design phase of any project involving concrete in contact with the native soil. If the concentrations are found to be aggressive, various protective coatings can be applied. Also, in the US ASTM C150 Type 5 Portland cement can be used in the mix. This type of cement is designed to be particularly resistant to a sulfate attack.

Steel plate construction

In steel plate construction, stringers join parallel steel plates. The plate assemblies are fabricated off site, and welded together on-site to form steel walls connected by stringers. The walls become the form into which concrete is poured. Steel plate construction speeds reinforced concrete construction by cutting out the time-consuming on-site manual steps of tying rebar and building forms. The method results in excellent strength because the steel is on the outside, where tensile forces are often greatest.

Fiber-reinforced concrete

Fiber reinforcement is mainly used in shotcrete, but can also be used in normal concrete. Fiber-reinforced normal concrete is mostly used for on-ground floors and pavements, but can be considered for a wide range of construction parts (beams, pillars, foundations, etc.), either alone or with hand-tied rebars.

Concrete reinforced with fibers (which are usually steel, glass, or plastic fibers) is less expensive than hand-tied rebar, while still increasing the tensile strength many times. The shape, dimension, and length of the fiber are important. A thin and short fiber, for example short, hair-shaped glass fiber, is only effective during the first hours after pouring the concrete (its function is to reduce cracking while the concrete is stiffening), but it will not increase the concrete tensile strength. A normal-size fiber for European shotcrete (1 mm diameter, 45 mm length—steel or plastic) will increase the concrete's tensile strength.

Steel is the strongest commonly available fiber, and comes in different lengths (30 to 80 mm in Europe) and shapes (end-hooks). Steel fibers can only be used on surfaces that can tolerate or avoid corrosion and rust stains. In some cases, a steel-fiber surface is faced with other materials.

Glass fiber is inexpensive and corrosion-proof, but not as ductile as steel. Recently, spun basalt fiber, long available in Eastern Europe, has become available in the U.S. and Western Europe. Basalt fibre is stronger and less expensive than glass, but historically has not resisted the alkaline environment of Portland cement well enough to be used as direct reinforcement. New materials use plastic binders to isolate the basalt fiber from the cement.

The premium fibers are graphite-reinforced plastic fibers, which are nearly as strong as steel, lighter in weight, and corrosion-proof. Some experiments have had promising early results with carbon nanotubes, but the material is still far too expensive for any building.

Non-steel reinforcement

There is considerable overlap between the subjects of non-steel reinforcement and fiber-reinforcement of concrete. The introduction of non-steel reinforcement of concrete is relatively recent; it takes two major forms: non-metallic rebar rods, and non-steel (usually also non-metallic) fibres incorporated into the cement matrix. For example, there is increasing interest in glass fiber reinforced concrete (GFRC) and in various applications of polymer fibres incorporated into concrete. Although currently there is not much suggestion that such materials will in general replace metal rebar, some of them have major advantages in specific applications, and there also are new applications in which metal rebar simply is not an option. However, the design and application of non-steel reinforcing is fraught with challenges. For one thing, concrete is a highly alkaline environment, in which many materials, including most kinds of glass, have a poor service life. Also, the behaviour of such reinforcing materials differs from the behaviour of metals, for instance in terms of shear strength, creep and elasticity.[23][24]

Fibre-reinforced plastic/polymer (FRP) and glass-reinforced plastic (GRP) consist of fibres of polymer, glass, carbon, aramid or other polymers or high-strength fibres set in a resin matrix to form a rebar rod, or grid, or fibres. These rebars are installed in much the same manner as steel rebars. The cost is higher but, suitably applied, the structures have advantages, in particular a dramatic reduction in problems related to corrosion, either by intrinsic concrete alkalinity or by external corrosive fluids that might

penetrate the concrete. These structures can be significantly lighter and usually have a longer service life. The cost of these materials has dropped dramatically since their widespread adoption in the aerospace industry and by the military.

In particular, FRP rods are useful for structures where the presence of steel would not be acceptable. For example, MRI machines have huge magnets, and accordingly require non-magnetic buildings. Again, toll booths that read radio tags need reinforced concrete that is transparent to radio waves. Also, where the design life of the concrete structure is more important than its initial costs, non-steel reinforcing often has its advantages where corrosion of reinforcing steel is a major cause of failure. In such situations corrosion-proof reinforcing can extend a structure's life substantially, for example in the intertidal zone. FRP rods may also be useful in situations where it is likely that the concrete structure may be compromised in future years, for example the edges of balconies when balustrades are replaced, and bathroom floors in multi-story construction where the service life of the floor structure is likely to be many times the service life of the waterproofing building membrane.

Plastic reinforcement often is stronger, or at least has a better strength to weight ratio than reinforcing steels. Also, because it resists corrosion, it does not need a protective concrete cover as thick as steel reinforcement does (typically 30 to 50 mm or more). FRP-reinforced structures therefore can be lighter and last longer. Accordingly, for some applications the whole-life cost will be price-competitive with steel-reinforced concrete.

The material properties of FRP or GRP bars differ markedly from steel, so there are differences in the design considerations. FRP or GRP bars have relatively higher tensile strength but lower stiffness, so that deflections are likely to be higher than for equivalent steel-reinforced units. Structures with internal FRP reinforcement typically have an elastic deformability comparable to the plastic deformability (ductility) of steel reinforced structures. Failure in either case is more likely to occur by compression of the concrete than by rupture of the reinforcement. Deflection is always a major design consideration for reinforced concrete. Deflection limits are set to ensure that crack widths in steel-reinforced concrete are controlled to prevent water, air or other aggressive substances reaching the steel and causing corrosion. For FRP-reinforced concrete, aesthetics and possibly water-tightness will be the limiting criteria for crack width control. FRP rods also have relatively lower compressive strengths than steel rebar, and accordingly require different design approaches for reinforced concrete columns.

One drawback to the use of FRP reinforcement is their limited fire resistance. Where fire safety is a consideration, structures employing FRP have to maintain their strength and the anchoring of the forces at temperatures to be expected in the event of fire. For purposes of fireproofing an adequate thickness of cement concrete cover or protective cladding is necessary. The addition of 1 kg/m^3 of polypropylene fibers to concrete has been shown to reduce spalling during a simulated fire.[25] (The improvement is thought to be due to the formation of pathways out of the bulk of the concrete, allowing steam pressure to dissipate.[25])

Another problem is the effectiveness of shear reinforcement. FRP rebar stirrups formed by bending before hardening generally perform relatively poorly in comparison to steel stirrups or to structures with straight fibres. When strained, the zone between the straight and curved regions are subject to strong bending, shear, and longitudinal stresses. Special design techniques are necessary to deal with such problems.

There is growing interest in applying external reinforcement to existing structures using advanced materials such as composite (fiberglass, basalt, carbon) rebar, which can impart exceptional strength. Worldwide there are a number of brands of composite rebar recognized by different countries, such as Aslan, DACOT, V-rod, and ComBar. The number of projects using composite rebar increases day by day around the world, in countries ranging from USA, Russia, and South Korea to Germany.

See also

- Concrete cover
- Concrete slab
- Cover Meter
- Falsework
- Ferrocement
- Formwork
- Kahn System
- Precast concrete
- Types of concrete
- Structural robustness

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External links

- The Concrete Reinforcing Steel Institute (CRSI) is a national trade association that stands as the authoritative resource for information related to steel reinforced concrete construction. (http://www.crsi.org)
- Concrete Research: http://www.concreteresearch.org (http://www.concreteresearch.org)
- Timeline of concrete (http://www.auburn.edu/academic/architecture/bsc/classes/bsc314/timeline/timeline.htm)

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Categories: Concrete buildings and structures | Reinforced concrete | Structural engineering

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First a bit of history about the remarkable development of this 'relay' device. Joseph Henry (1797-1878), a brilliant US scientist who invented and used the electro-magnetic relay in his university laboratory. His low-power electro magnet could control a make-and-break switch in a high-power circuit. Henry believed the potential was in the relay's use as a control system in manufacture, but he was only really interested in the science of the electricity. The relay was a laboratory trick to entertain students. Samuel Morse later used Henry's relay device, after re-designing it using thinner wire, to carry morse-code signals over long kilometers of wire.

In 1846, Joseph Henry was professor of natural philosophy (physics) at the College of New Jersey (now known as Princeton University). He had published scientific articles on a wide variety of subjects, including electro magnetism, optics, acoustics, astrophysics, molecular forces, and terrestrial magnetism, but his reputation was built primarily on his work in basic and applied electro magnetism. Among his discoveries in electro magnetism were mutual induction, self-induction, the electro magnetic relay--enabling him to devise the first electro magnetic telegraph that could be used over long distances--and the concept of the electric transformer. He also invented the first electric motor. Henry was often referred to as the scientific successor to Benjamin Franklin. Today, it is the general opinion that Joseph Henry was the inventor of the telegraph and not Samuel Morse, who did not have a technical background to begin with. Samuel Morse adapted the ideas and inventions of Henry (and Vail) into his own and patented it, making him the owner.

It is certain that Joseph Henry was important to the history of the telegraph in two ways. First, he was responsible for major discoveries in electro magnetism, most significantly the means of constructing electromagnets that were powerful enough to transform electrical energy into useful mechanical work at a distance. Much of Morse's telegraph did indeed rest upon Henry's discovery of the principles underlying the operation of such electromagnets.

Below are a couple other thoughts collected from the Smithsonian Institute (of which Henry was First Secretary), and Harvard University:

"... Secondly, Henry became an unwilling participant in the protracted litigation over the scope and validity of Samuel Morse's patents. ..."

"... Joseph Henry began his research into electro magnetism in 1827, while he was an instructor at the Albany Academy in New York. By 1830, he achieved two major breakthroughs .... His first crucial innovation, which he demonstrated in June 1828, was to combine Schweigger's multiplier with Sturgeon's electro magnet to obtain an extremely powerful magnet. While Sturgeon loosely wrapped a few feet of uninsulated wire around a horseshoe magnet, Henry tightly wound his horseshoe with several layers of insulated wire. In March 1829 he demonstrated an electro magnet with 400 turns, or about 35 feet, of insulated wire. This magnet, Henry remarked later, "possessed magnetic power superior to that of any before known."

"... Henry did set out to demonstrate the practicality of an electro magnetic telegraph immediately after his paper appeared. His prototype consisted of a small

battery and an "intensity" magnet connected through a mile of copper bell-wire strung throughout a lecture hall. In between the poles of this horseshoe electro magnetic he placed a permanent magnet. When the electro magnetic was energized, the permanent magnet was repelled from one pole and attracted to the other; upon reversing battery polarity, the permanent magnet returned to its original position. ... Henry caused the permanent magnet to tap a small office bell. He consistently demonstrated this arrangement to his classes at Albany during 1831 and 1832."

In short, this man, Joseph Henry, was a scientist and physicist by heart and a true teacher to his students. As a reward, they (not his students) stole his ideas and scientific experiments. For that reason I'm convinced that Morse was a fraud, preying on the ideas and inventions (like the telegraph) of others and putting his patent on it (obtained on October 3, 1837). I do credit Samuel Morse, however, for the morse-code, which is still used to this date and no person without a 5-wpm morse-code qualification exam can call him/herself a Advanced Radio Amateur! (see Fig. a).

Morse Code:

A .—	E .	I ..	M — —	Q — — .—	U ..—	Y —.— —
B —...	F ..—.	J .— — —	N —.	R .—.	V ...—	Z — — ..
C —.—.	G — — .	K —.—	O — — —	S ...	W .— —	
D —..	H	L .—..	P .— — .	T —	X —..—	

International Alphabet:

Alva	Echo	India	Mike	Quebec	Uniform	Yankee
Bravo	Foxtrot	Juliet	November	Romeo	Victor	Zulu
Charley	Golf	Kilo	Oscar	Sierra	Wiskey	
Delta	Hotel	Lima	Papa	Tango	Xray	

Fig. a

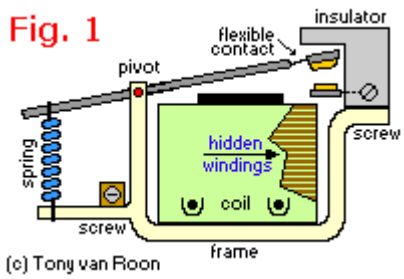

Since this important day in 1836, when Joseph Henry transmitted a small electrical current down a wire to energize a remote coil and the completed circuit ringing a bell some 150 years ago, the relay has undergone steady evolution and today's relays are far removed from the crude and clumsy relays of Henry's days. In our millennium, solid-state has replaced the actual relay in many circuits, especially in AC applications. To sum it all up, the relay (and solenoids) have survived the tube, transistor, and integrated circuit (IC) eras.

Basically, a relay is an electrically operated switch, and actually the predecessor of the transistor. Solenoids are relays also but the very large types which carry huge amounts of current. Relays are the smaller types. Relays come in three types: electro mechanical, solid-state, and so-called hybrids which are a combination of the first two. There are also some specialized types that fall into neither category but I will deal with them later in this tutorial. Lets take electro-mechanical types first, they are available in three main models; armature, plunger, and reed. The **Armature Relays** are the oldest (see **Fig. 1**) but elegant. Plenty turns of very fine magnet-wire are wound around an iron core to form an electro-magnet. The movable metal armature has an electrical contact that is positioned over a fixed contact attached to the relay frame. A spring holds the armature up so that the movable and fixed contacts are normally separated (open). When the coil is energized, it attracts the pivoting armature and pulls it down, closing (make) the SPST contacts and completes the power circuit. Vice-versa, this relay can be made to open the contacts instead of closing them, or can do both either way. The armature relay is pretty old and no longer used in new applications, they do still exist however and are being used still at the time of writing this document.

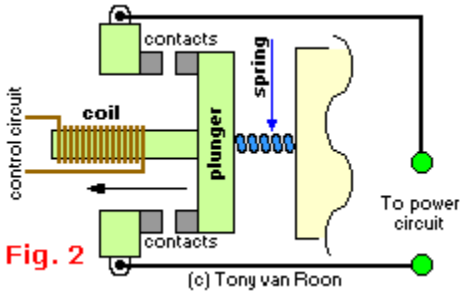

The **Plunger-Relay** type have a plunger instead of a pivoting armature, as shown in **Fig. 2** and uses a solenoid action to close the contacts. The electro magnetic core is hollow and a metal rod or plunger extends halfway through it when the relay is not energized.
When energized, the coil draws the plunger in and a shorting-bar, attached to the end of the plunger, closes the contacts. When the coil is de-energized, the spring (which is mounted over a section of the plunger) retracts the plunger and positions the assembly in the idle position breaking the contacts.
The coil plunger design allows much greater contact travel than the pivoting armature design, thus allowing wide contact separation. The increased space allows plunger systems to be used with higher voltages than armatures. The higher closing force of the solenoid permits the use of larger contacts and provides greater current handling capability. One application of a plunger-type relay is an electronic lock or door opener.

Since their inception, electro-magnetic relays have improved in sensitivity, switching complexity, current handling, response time, and reliability. It

allowed for miniaturization in radios, cassette recorders, Radio Control (R/C), NASA, cameras, and other home electronics applications. Being relatively small, **Reed Relays** fill the demand for all sorts of 'small' stuff. The use of flexible reeds and self-attraction distinguishes the reed relay, see **Fig. 3**, from other electro magnetic relays. Note that the drawing shows the reed-relay without the actuator coil. The contacts are mounted on thin metal strips (reeds) and hermetically sealed in a glass tube. This tube is surrounded by a magnetic coil which, when activated, magnetizes the reeds and causing them to attract each other which closes the contacts. When the coil is de-energized, the spring tension in the reeds causes them to separate again. This type of design has the advantages of high speed operation, long life, and very low price. One of the great advantages reed relays share with other electro magnetic relays is the relative ease with which they can be fitted with multiple contacts. As in the armature and plunger designs, the contact mechanisms can be stacked to provide multiple circuit-close or open designs, or even a combination of both, all activated by a single coil. In reed relays, multiple contact pairs, but in individual tubes, can be stacked and used with a single coil in a very small space. This is not a feature of solid-state relays.

Some Relay-driver Examples using regular components:

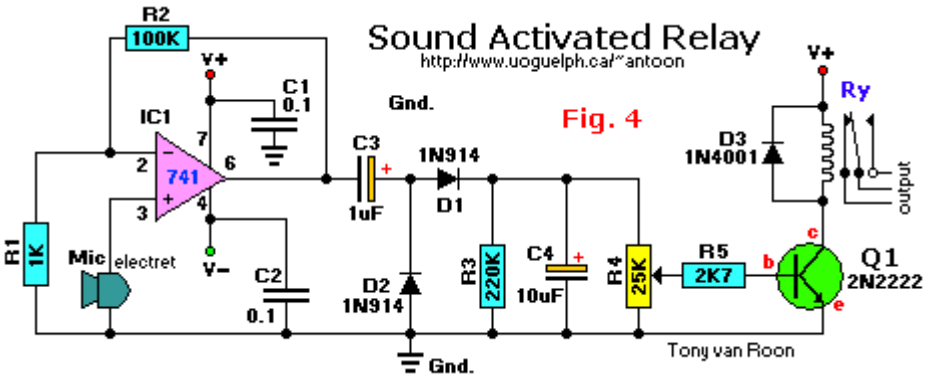

Fig. 4 **Sound-Activated** type. The relay remains dormant until the op-amp activates upon sound via the electret-microphone. The input stage is a regular off-the-shelf 741 operational amplifier and connected as a non-inverting follower audio amplifier. Gain is approximately 100 which you can raise by increasing the value of R2. The amplified signal is rectified and filtered via C3, D1/D2, and R4 to an acceptable DC level. Potentiometer R5 is used to set the audio level to a desired sensitivity value to activate the relay via transistor Q1. Diode D3 is mounted over the relay coil to absorb sparks. The op-amp configuration in this particular drawing needs a dual voltage power supply which can be made from two 9-volt batteries.

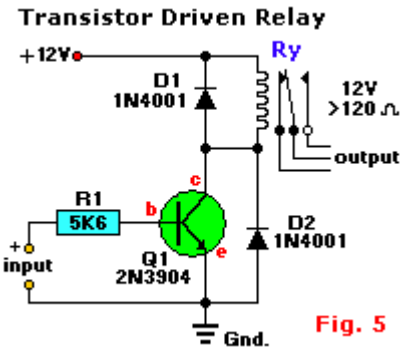

Fig. 5 This relay driver **boosts** the input impedance with a regular 2N3904 transistor. Very common driver. It can drive a variety of relays, including a reed-relay. Transistor Q1 is a simple common-emitter amplifier that increases the effective sensitivity of the 12 volt relay coil about a 100 times, or in other words, the current gain for this circuit is 100. Using this setup reduces the relay sensitivity to a few volts. R1 restricts the input current to Q1 to a safe limit (the impedance is equal to the value of R1 plus 1K). Diodes D1 and D2 are EMF dampers and filter off any sparking when the relay de-energizes.

Fig. 6-1 is a **delayed turn-on** relay driver and can produce time delays for up to several minutes with reasonable accuracy.
The 14001 (or 4001) CMOS gate here is configured as a simple digital inverter. Its output is fed to the base of a regular 2N3906 (PNP) transistor, Q1, at the junction of resistor R5 and capacitor C2. The input to IC1 is taken from the junction of the time-controlled potential divider formed by R2 and C1. Before power is applied to the circuit, C1 is fully discharged.

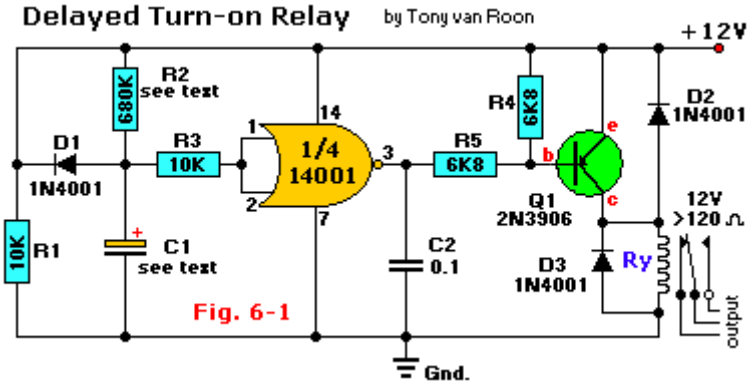

Therefore, the inverter input is grounded, and its output equals the positive supply rail; Q1 and RY1 are both off under this circuit condition. When power is applied to the circuit, C1 charges through R2, and the exponentially rising voltage is applied to the input of the CMOS inverter gate. After a time delay determined by the RC time constant values of C1 and R2, this voltage rises to the threshold value of the CMOS inverter gate. The gate's output then falls toward zero volts and drives Q1 and relay RY1 'ON'. The relay then remains on until power is removed from the circuit. When that occurs, capacitor C1 discharges rapidly through diode D1 and R1, completing the sequence. The time delay can be controlled by different values for C1 and R2. The delay is approximately 0.5 seconds for every µF as value for C1. The delay can further be made variable by replacing R2 with a fixed and a variable resistor equal to that of the value of R2. Taken the value for R2 of 680K, it would be a combination of 180K for the fixed resistor in series with a 500K variable trim pot. The fixed resistor is necessary.

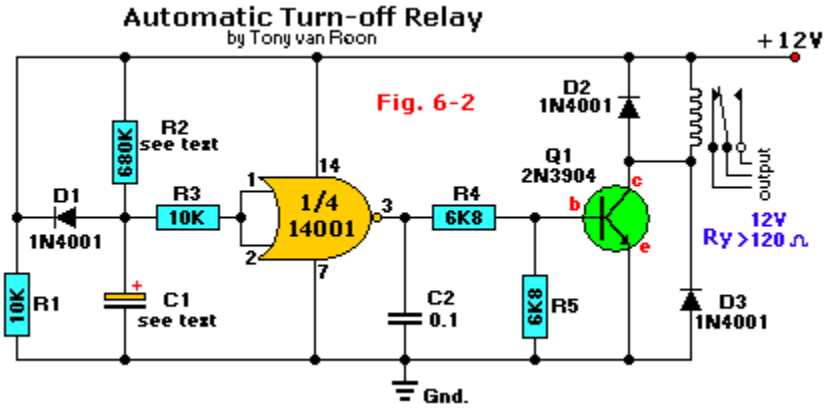

Fig. 6-2 is configured in an automatic turn-off mode. It shows how the circuit function of Fig. 6-1 can be reversed so that the relay turns on when power is applied but turns off again automatically after a preset delay. This response is obtained by modifying the relay-driving stage for an NPN transistor like the 2N3904. It is worth noting again that the circuits in **Fig. 6-1** and **Fig. 6-2** each provide a time delay of about 0.5 seconds for every micro-Farad in the value of capacitor C1. This permits delays of up to several minutes. If desired, the delay periods can be made variable by replacing resistor R2 with a fixed *and* variable resistor in series whose nominal values are approximately equal of the total value of R2 (680K).

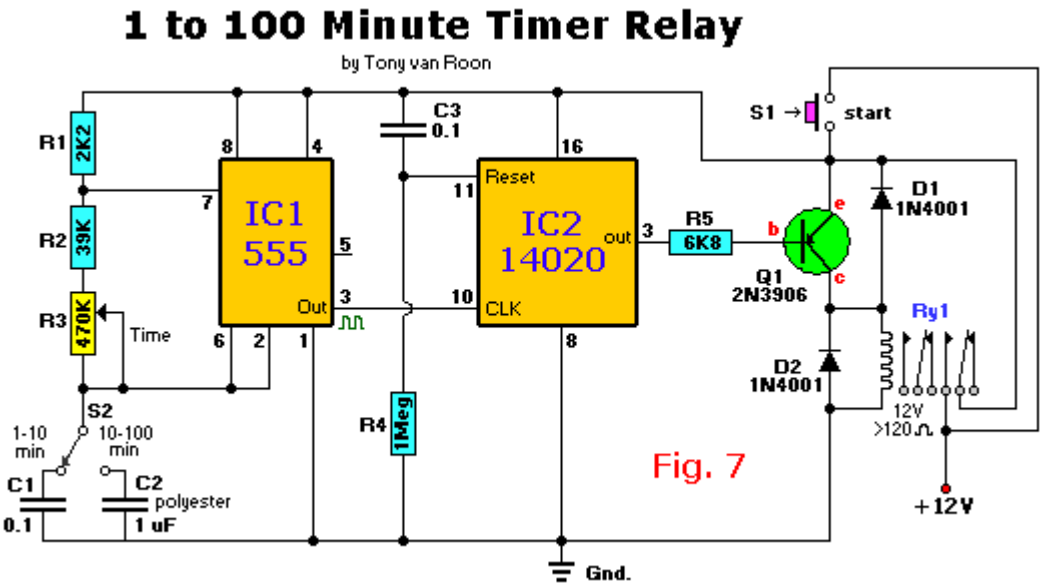

Fig. 7 This is an accurate **long-duration** time delay driver, switchable between 1 and 10 minutes or 10 to 100 minutes and whose function does not depend on electrolytic capacitors. Film dielectric caps have been selected. IC1 is configured as a free-running astable multivibrator which frequency is divided down by IC2, a 14020 (or 4020) CMOS 14-stage, ripple-carry binary divider. Consequently relay RY1 turns on as soon as switch S1 is closed, and it turns off again when the 8192nd astable pulse arrives. This method provides time periods ranging from 1 to 100 minutes, depending on the switch setting of S2.

Solid State Relays:

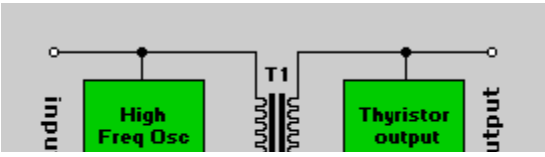

"Solid-State-Relay" (referred to as 'SSR' for short) means switching without any mechanical means. A solid-state **relay** is nothing more than a electronic switch, which can be a Triac, SCR, HexFet, or a High Speed MosFet, and an opto-isolator. Some are application dependent.

Control-to-load isolation is provided either by opto-isolators or transformers. Solid-state relays are available in AC and DC versions; **Fig. 8a/b/c/d/e** shows typical block diagrams. All approaches shown use an opto-isolator to separate the control and drive segments.

Virtually all solid-state relays are **S**ingle-**P**ole **S**ingle-**T**hrow, **N**ormally **O**pen (SPST-NO) devices, where the outputs turn on in response to a control voltage. The majority take operating power from the control I/O, although some require separate DC logic power. The simplest DC input circuits use an LED optoisolator and series current-limiting resistor.

The resistor is usually sized for a 5-volt logic input, and results in a specified "ON" range of 3-6 volts DC. For wider operating ranges (typically 4-32 volts DC), the resistor is replaced by a constant-current diode. Then, AC input circuits rectify and filter the control input before applying it to the LED. Typical AC/DC LED currents can vary from 5 to 22mA.

AC and DC Outputs:

The optoisolator photocurrent is amplified and used to drive whatever output device the relay is connected to, whether a transistor for DC outputs, a thyristor for AC, or a power MOSFET for either. The power for the drive circuitry is taken either from the output load or is supplied separately. In some MOSFET designs, the photocurrent is sufficient to drive the output device.

Table 1

Output	AC or DC	Package Style	Max Load Currents	Max Load Voltages	Volt Drop (on) at Rated Load	Leakage Current (off) At 25°C
Bipolar Transistor	DC	Dual Inline (DIP)	500mA 50mA	60Vdc 250Vdc	1 - 1.5V	20µA
		Input/ Output Module	3.5A 1A	60Vdc 200Vdc	1.2 - 1.75V	10µA - 1mA
		Power	2 to 20A	50Vdc	1.5 - 2V	5 - 15mA
		Power (High Voltage)	to 5A	250Vdc	2V	10µA
Thyristor (Triac or SCR)	AC	Dual Inline (DIP)	0.3 to 1A RMS (to 3A RMS on heat sink)	140 or 280V RMS	1.5V max	10µA - 1mA
		Input/ Output Module	3.5A RMS	140 or 280V RMS	1.5V max	2 - 5mA
		Power	10 - 40A RMS	140 to 280V RMS	1.5V max	2 - 15mA
Power MOSFET	AC DC	Dual Inline (DIP)	100 - 500mA (Some to 1A)	60 - 300V	Resistance 0.25 - 50 ohms	Resistance typically 100Meg

Table 1 summarizes typical specifications.

Normally, DC output devices like those in Figs. 8-Fc and Fd use an NPN transistor and may include a Zener diode across the output for transient suppression. The transistor will drop some voltage in the "ON" state, and the drive circuit will need some current to operate. Typical output drop is 1-2 volts at the full rated load current, while the "OFF"-state leakage may range from approximately 10µA-1mA.
Most AC output devices include zero-voltage-switching circuitry. Logic detects when the AC load voltage crosses zero (changes polarity) and delays the triac turn-on pulse until then. The triac turns on a the next zero crossing after the input goes high. Once triggered, it remains on until its current goes to zero. Zero-voltage and zero-current switching minimize transients and **E**lectro**M**agnetic**I**nterference (EMI). The RC snubber in Fig. 8-Ff suppresses rapid voltage changes that can inadvertently turn on the thyristor.
In some applications, having the output turn on instantly is desirable. Relays referred to as "random turn-on" are designed without zero-voltage switching. Turn-off still occurs at zero-current, due to the inherent latching effect of thyristors. As with DC output relays, the thyristor drops voltage while conducting, while the drive circuitry requires power to operate. In addition, th snubber passes AC leakage in the "OFF" state. Typical "ON"-state

voltage 1.6 volts, while "OFF"-state leakage is 2-20mA for 60Hz power.
With recent advantages in power MOSFET's, solid-state relays can be designed with lower "ON"-state voltage drops, and greatly reduce "OFF"-stage leakage. These MOSFET's (and HexFets) offer bidirectional current flow, near-zero gate-drive current, no inherent source-to-drain offset voltage, and low "ON"-state (rDS) resistance and "OFF"-state leakage.

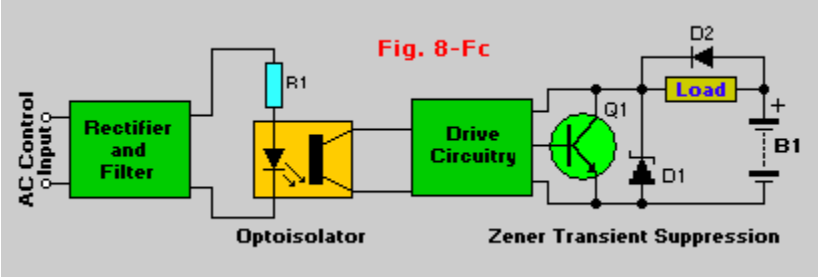

Most FET-output relays are housed in Dual-Inline-Packages (DIP's). Their main use is as a replacement for reed relays, where low offset and low leakage are important, and for control of low-power AC/DC loads. High power AC loads are best controlled by thyristors, which are easily controlled for zero-voltage turn-on; they also offer inherent zero-current turn-off, and produce lower output-voltage drop at high currents.
However, FET design involves tradeoffs in voltage, current and resistance specs. In particular, high-voltage FET's have higher "ON" resistances, making them unsuitable for switching high-current line-voltage loads. Typical DIP relays have 70-500mA current ratings, "OFF"-state leakage resistances of 100 MegaOhms or more, and "ON" resistances from about one ohm for a 60-100 volt rating, to 25-50 ohms for a 300-400 volt rating. Switching times range from 10-100µSec.

I/O Isolation:

The majority of solid-state relays use opto-isolators. All off at least 1.5 kilo-volt RMS I/O breakdown, and 2.5 or 4 kilo-volt ratings are common. Most of them have been rated, listed, or approved by safety agencies like UL, CSA, and VDE. Transformer coupling is also used to isolate solid-state relays.

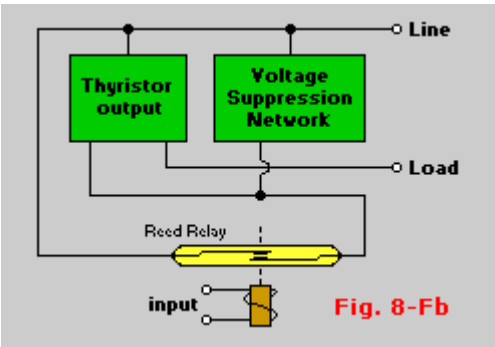

Fig. 8-Fc shows a transformer-coupled AC-output relay; DC and AC/DC FET relays are also available with transformer coupling. The control input powers an oscillator, the output which is coupled through a small pulse transformer to trigger the output thyristor. Circuitry of the type shown produces random turn-on operation; transformer-coupled relays generally don't include zero-voltage switching circuitry.
Transformer coupling allows faster switching. The oscillator frequency is typically 1-3MHz, resulting in switching times as low as 1µSec. Opto-isolators exhibit slower response, with times for DC versions typically 10 to 100µSec. They can be designed for slightly higher temperatures, being free of LED limitations. However, achieving breakdown voltages above 1.5 kilovolts is easier using optical techniques.

Hybrid Relays:

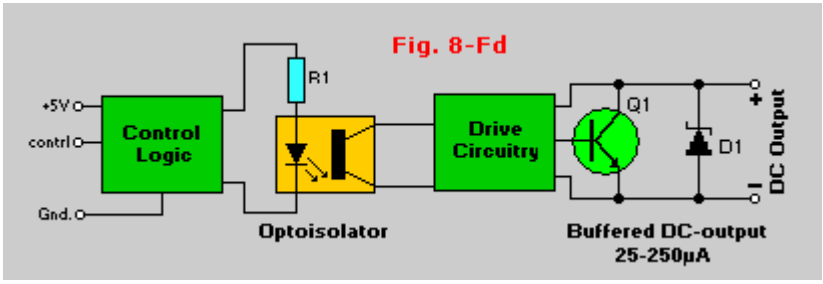

Hybrid relays marry reed relays with a solid-state power output. **Fig. 8-Fb** shows a thyristor version; DC outputs are also offered. The hermetically sealed reed contacts switch only low power, and last 10 million operations or even longer. The turn-on time is that of the reed relay, about 1 mSec. Other hybrid relays are the reverse, using a solid-state input amplifier driving a reed-relay output, the obvious advantage being high input sensitivity. The term "hybrid" sometimes describes construction technique, rather than method of operation. In some catalogs you'll find hybrid solid-state relays with no mechanical components at all.

Self-Powered and Buffered Relays:

So far, all the relays that have been discussed until now have been "self-powered," in that they take operating power from the applied signals. All models, whether optoisolated, transformer coupled, of hybrid, require approximately 5-50mA at their inputs. Some, notably thyristor-output relays with zero-voltage switching, also take operating power from output loads, although none require separate power connections.

Buffered relays offer improved input sensitivity at the expense of needing separate DC power, and are usually used in systems that already include DC power supplies (not as stand-alone devices). **Fig. 8-Fd** shows a buffered DC-output relay. The input circuitry and the LED are powered from a separate logic supply, allowing the logic input current to be typically 25-250µA.

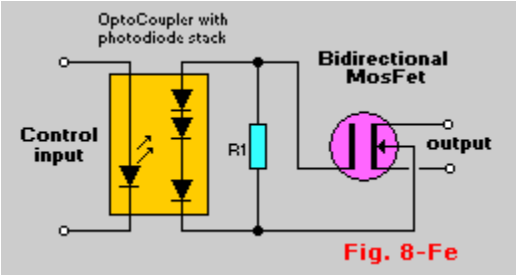

Fig. 8-Fe

Due to near-zero gate current, power MOSFet's can be driven directly from a series stack of photodiode junctions. The "photo voltaic-generator" stack from International Rectifier shown in **Fig. 8-Fe** is constructed using IC fabrication techniques, and exposes a series of photo diodes to LED illumination. No operating power is required from the load.

Package Styles:

Solid-State relays are generally grouped into DIP's, power relays, and I/O modules. DIP relays are available with transistor (DC), thyristor (AC), or MOSFET (AC/DC) outputs, and with optoisolator or transformer coupling. Most power relays are used to switch AC power, and use thyristor switching with optoisolator coupling. Transistor (DC) outputs and transformer coupling are also available. I/O modules are always opto-coupled, and don't offer MOSFET outputs;

Safety Issues:

Building an SSR requires putting 115/220 volts on a printed circuit board. From an electrical point of view, that can be perfectly safe. However, it is good practice to cover all printed circuit tracks on the 115/220VAC side with a silicon sealer, varnish, lacquer, or even nail polish. Couple layers will do fine. Also, try to use only isolated Triacs (where the case is electrically isolated from the Triac), and ground the heat sink to the AC safety wire (earth ground, or green wire).

Choosing a Triac:

There are three basic requirements when choosing the output Triac. First is to make sure that it will handle the voltage required. The minimum for a 115-volt AC line requires a 200-volt Triac. A 220-volt line requires a 400-volt Triac. Remember that those are the minimum so, for a few cents more, it pays to use the next highest voltage rating.

The next requirement is current. A 6-amp Triac will handle 6 amps only if it is properly heat sinked. As a word of warning, motors draw a lot more current on start-up than they do during normal operation, sometimes as much as ten time more. Keep that in mind when you design your own.

The third requirement is the gate current. The Motorola MOC3010 optoisolator will provide about 100 milliamps of drive current for the output Triac. That should be adequate for any Triac you can find in a TO-220 package. Just in case it is not sufficient for your design, you can use a transistor as a current-sink.

Although not really a strict requirement, an isolated Triac is good practice and a good safety precaution. Isolated Triacs (usually listed in catalogs as iso-tab) provide electrical isolation from the electrical connections to the case. Early Triacs were not normally isolated. That meant that you had to use mica washers and thermal grease. Thermal grease is still a good idea, but the mica washer isn't required for isolated Triacs. If you don't know whether or not your Triac is isolated, simply measure the resistance from each lead to the case. An isolated Triac will measure open on all three leads.

Warning: The Radio Shack 400-volt, 6-amp Triac (part number 276-1000) will work well but is NOT isolated. You ***must*** use a TO-220 mica washer and thermal grease if you plan to use that device.

Zero-Voltage Switching:

I can hear you mumbling already... "what the heck is zero-voltage switching..."? In normal operation the trigger side of the relay is totally asynchronous to the AC side. That means that a trigger could occur during any part of the sine wave. If the trigger occurs near a peak (90 or 270 degrees), a large current will flow into the load almost instantly. That creates a lot of RFI (Radio Frequency Interference) and also is very hard on the filament of ordinary light bulbs. In order to prevent that, zero-crossing SSR's accept the trigger at any time but delay turning on the AC load until the next time the AC voltage passes through zero volts. Now you know. I personally don't use any other type.

Construction of a SSR:

Below is good working Solid State Relay using an opto-isolator and a Triac. Use of the shown printed circuit board is highly recommended but not required. **Remember to isolate the AC tracks when you're all done!**

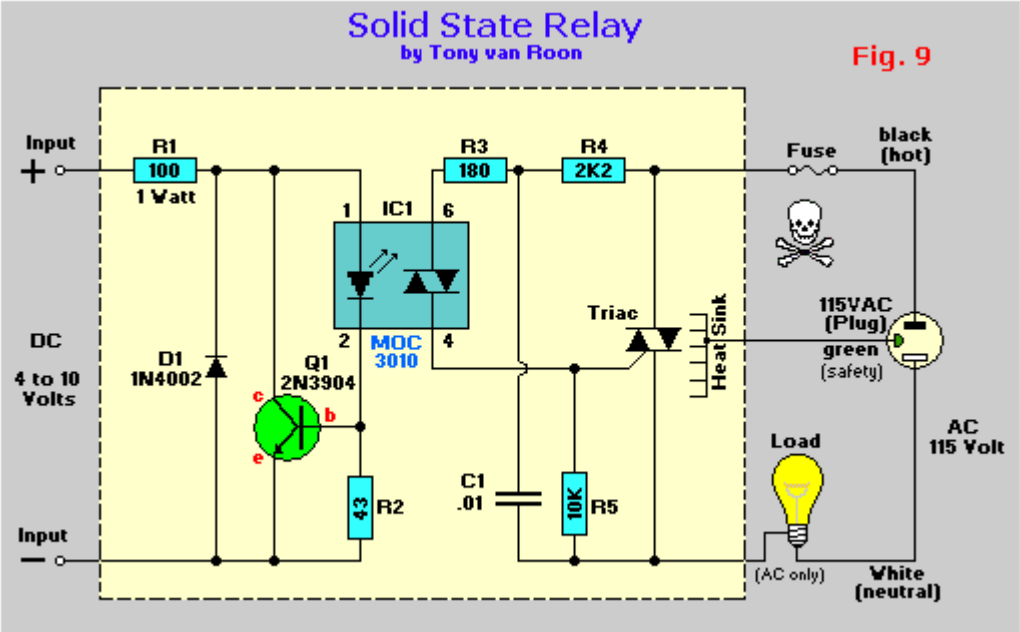

For a simple SSR, an optoisolator such as the Motorola MOC3010 or the NTE3047 will be sufficient. For a zero-crossing SSR, a MOC3031 or NTE3049 will do. May companies make optoisolators. Make sure yours has a "Triac output" and that the pinouts are compatible with your design. Table 2 shows some typical Triac output optoisolator specifications. The models shown are already a decade old but still widely used and available.

Again, although the SSR can certainly be build without using the PCB, using one makes assembly using the layout in **Fig. 9** a snap.

The only precaution, other than the one about working with 115/220/220 AC volts, is to heatsink the Triac. If you leave the leads on the Triac long, it should be simple matter to find some heat sink to attach to the Triac. Just remember to connect the heat sink to earth-ground. Even if you're using an isolated tab Triac, the earth ground is still necessary. Otherwise you should buy your solid-state relays from a reliable company--don't build them yourself.

Remember that SSR's can only switch an AC line. Trying to switch a DC line will result in a relay that closes but never opens... Have fun!

Couple More Circuits To Play With:

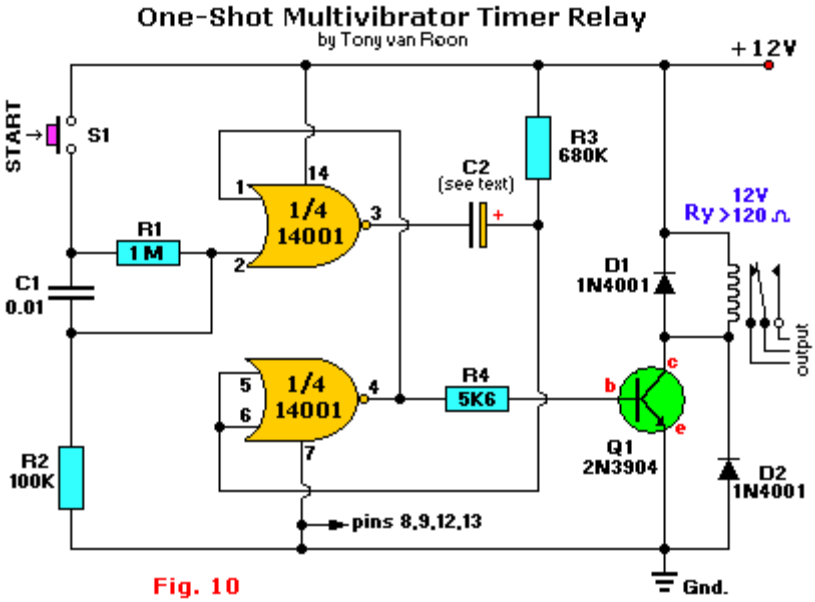

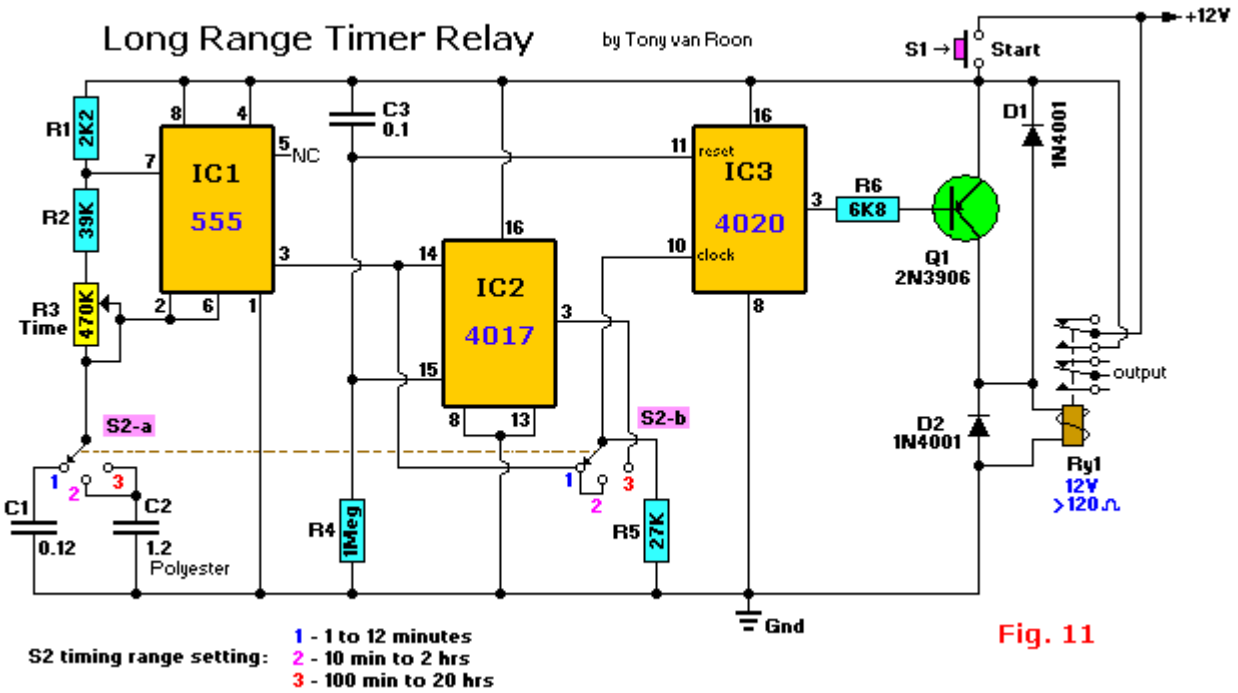

Fig. 10: This circuit shows a pair of CMOS NOR gates which form a push-button-activated one-shot multivibrator relay-switching circuit that provides delays up to several minutes with resonable accuracy. The relay turns on as soon as the START switch S1 is closed. However, it turns off again after a preset delay of about 0.5 seconds per microFarad (µF) of the value of capacitor C2. The two CMOS gates are configured as a manually-triggered monostable multivibrator whose output is fed to the relay through R4 and transistor Q1.

Fig. 11: This one shows a 'long-range timer relay' switching circuit which spans 1 minute to 20 hours in three ranges using a three-step, two-deck mechanical rotary switch. IC1, the 555 timer/oscillator does the time
IC2 (4017) is a CMOS decade counter IC, a five-stage Johnson counter with 10 decoded outputs. Inputs include a CLOCK, a RESET, and a CLOCK INHIBIT signal. This IC, together with IC3 and the 3-step rotary switch, can provide a maximum division ratio of 81,920 making it possible to time for periods up to 20 hours or so. Circuits like this are used in battery chargers and area security lighting systems with time-controlled turn-off.
IC3 (4020) is a CMOS 14-stage, ripple-carry binary divider. Normally a 'high' would occur as soon as switch S1 is closed and a 'low' when the 8192nd astable pulse arrives. All counter stages of IC3, the 4020, are master-slave flip-flops. The state of a counter advances one count on the negative going transition of each input pulse, and a high level on the RESET line resets the counter to its all zeros state. All inputs and outputs are buffered.

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Remanufacturing: the Experience of the United States and Implications for Developing Countries

By: Robert T. Lund
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Integrated Resource Recovery

UNDP Project Management Report Number 2

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GLO/80/004

Number 2

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WORLD BANK TECHNICAL PAPER NUMBER 31

Remanufacturing

The Experience of the United States and Implications for Developing Countries

Robert T. Lund

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Washington, D.C., U.S.A.

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Robert T. Lund is a research professor at the Center for Technology and Policy and a professor of manufacturing engineering at Boston University.

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ABSTRACT

This paper discusses all phases of remanufacturing: the disassembly, inspection, refurbishing, reassembly, and final testing of worn durable products which are then rendered less costly but otherwise useable. The process is particularly applicable to developing countries because it requires less capital and fewer labor skills than that of the original equipment manufacturer. For those developing country locations having an assured supply of unserviceable products and meeting the minimum requirements for labor and investment, this report reveals that the financial and economic viability of remanufacturing can be assured.

CONDENSE

Le présent document examine toutes les phases de la réfection de matériel, à savoir le démontage, l'inspection, la remise en état, le remontage et les essais finals de produits durables, toutes ces opérations étant centralisées et moins coûteuses que le remplacement de ce matériel tout en offrant un produit de qualité égale ou même supérieure à l'original. Cette technique est particulièrement indiquée pour les pays en développement car ses besoins en capitaux et en main-d'oeuvre spécialisée sont moindres que pour la fabrication de ce même matériel. Selon le rapport, la viabilité financière et économique de cette réfection est assurée quand cette activité se déroule dans des régions de pays en développement où les approvisionnements en matériel pour lequel il n'existe pas de service après-vente et qui répond aux critères minimums en matière de main-d'oeuvre et d'investissement sont assurés.

EXTRACTO

En este trabajo se analizan todas las fases de la remanufacturación, es decir, las actividades centralizadas de desmontaje, inspección, restauración, nuevo montaje y prueba final de bienes de consumo duraderos, que resultan luego menos costosos pero en los demás aspectos iguales o mejores que en su estado original. Esto es especialmente interesante para los países en desarrollo, debido a las menores necesidades de capital y mano de obra calificada que las del fabricante original del equipo. En el caso de aquellos países en desarrollo cuya ubicación les asegure el suministro de bienes que no pueden repararse y que cumplan con unos requisitos mínimos en cuanto a mano de obra e inversión, este informe revela que puede garantizarse la viabilidad financiera y económica de la remanufacturación.

WORLD BANK TECHNICAL PAPER NUMBER 31

Integrated Resource Recovery

Remanufacturing: The Experience of the United States and Implications for Developing Countries

Robert T. Lund

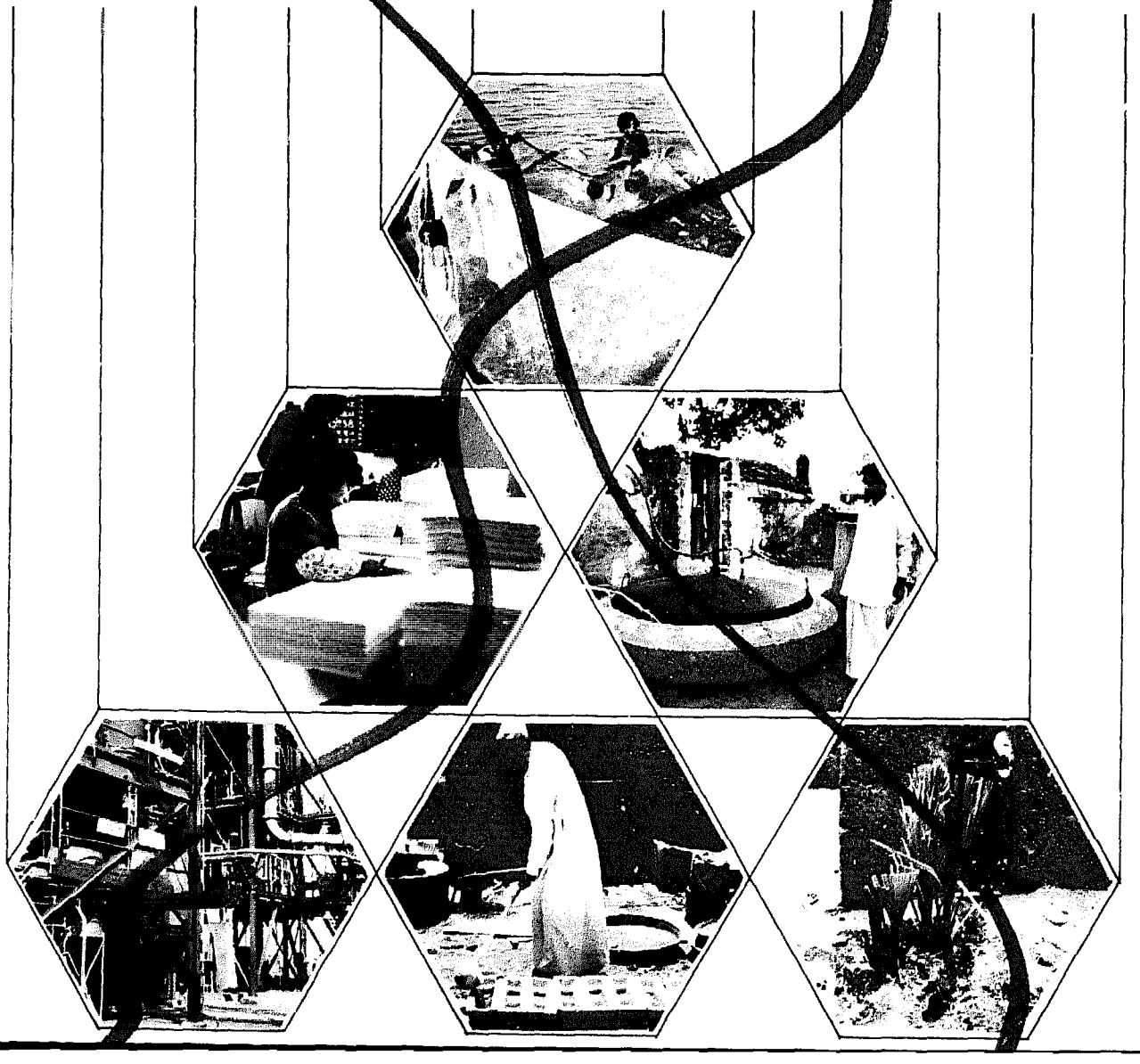

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FOREWORD

The dependence of economic growth upon domestic and environmental sanitation and upon sustainable use of human, natural and financial resources is revealed in ancient and modern systems for recycling wastes. Among those, remanufacturing is a recently rationalized technology for capturing energy, material, and labor value added in the original manufacturing of tools and machines. This report is one of a series being published by the World Bank as executing agency for the UNDP Resource Recovery Project (GLO/80/004). Other technologies are presented in companion reports.

We are soliciting comments and case study information from which future editions will benefit.

PREFACE

This report on remanufacturing is a summary of the major findings of a series of studies on the subject conducted at the MIT Center for Policy Alternatives beginning in 1978. This state-of-the-art overview is sponsored by the World Bank's Integrated Resource Recovery Project, a three-year program of research and development having the following goals:

- to achieve sustainable health, environmental employment, energy, economic and financial benefits through sustainable resource recovery and utilization projects in developing countries; and

- to assemble, assess, and disseminate technological, economic and financial information for resource recovery projects in developing countries.

We are pleased that remanufacturing has been included as a topic in the World Bank project, because it has a major role to play, not only in resource recovery but also in establishing an industrial base in developing countries. Remanufacturing is an appropriate technology for industrialized and industrializing countries alike and it provides an impressive list of benefits.

We are grateful for the encouragement given to this project by S. Arlosoroff and Charles G. Gunnerson of the World Bank. This report also owes much of its existence to the continuing interest and support of the U.S. Department of Energy, and more specifically to Dr. Jerome F. Collins and Mr. Stuart Natof of that agency.

The contents of this report are a synthesis of sixteen reports prepared at the Center on various aspects of remanufacturing. The process of selecting what topics should be discussed and the level of detail to be provided necessarily has involved substantial condensation, and the reader is referred to the original documents for elaboration.

While recognizing the contributions of many researchers that have made this report possible, I accept responsibility for what is written herein. The opinions, findings, conclusions and recommendations are mine and do not necessarily reflect the view of the Center for Policy Alternatives, Massachusetts Institute of Technology or the World Bank.

Robert T. Lund
Principal Investigator

1 REMANUFACTURING DEFINED

1.1 Introduction

When a durable product (machine, vehicle, appliance, tool, or other mechanical system) reaches the end of its normal life, it is typically disposed of landfill or it is scrapped for recovery of its material. In either of these actions the costs associated with collection and operation of a landfill or the costs of shredding, sorting and melting down the reclaimable materials exceed the direct economic benefits of these operations.

Remanufacturing is often an economically advantageous alternative that can significantly extend the lifetime of a product and thereby reduce the amount of material that must be treated by recycling or as landfill. Remanufacturing is the restoration of used products to a like-new condition, providing them with performance characteristics and durability at least as good as those of the original product. Through a series of industrial processes, worn-out or discarded products are completely disassembled, their useable component parts are cleaned and refurbished, new parts are provided where necessary, and the parts are reassembled and tested to produce units meeting new product performance standards. These operations are performed in a factory environment and the assembly processes are usually very similar to those employed in making the product originally.

Because remanufacturing recovers a substantial fraction of the materials and the value added to a product in its first manufacture, and because it can do this at low additional cost, the resulting products can be offered on the market at substantial savings to the user.

Although it has had a very low visibility in all world economies, remanufacturing has been a viable economic activity (at least in the United States) for three or four decades. Very little has been written and virtually no research has been conducted on the subject outside of a series of studies launched by MIT's Center for Policy Alternatives in late 1978. Through these studies the Center for Policy Alternatives has been able to:

- define the nature of remanufacturing[1*]
- study the characteristics of specific U.S. remanufacturing operations[2]
- determine some of the major operating characteristics of known American remanufacturers[3]
- establish criteria for selecting product candidates for remanufacturing[2]

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* References are found at the end of each chapter.

- perform a screening of currently made durable products to recommend products for remanufacture[4, 5]
- provide guidelines for individuals and firms considering establishing remanufacturing operations[6, 7]
- identify the social and economic benefits of remanufacturing in the United States
- suggest possible public and private policy issues relating to the activity.

All of these studies have been sponsored by the Waste Products Utilization Branch of the Office of Industrial Programs of the U.S. Department of Energy. Because the sponsor was an agency of the U.S. Government, the principal focus of the studies was domestic remanufacturing. In addition to the Center's sponsored research, five theses by Favreau,[12] Gonzalez,[13] Holzwasser,[14] Kutta,[15] and Skeels[16] further expanded our understanding of remanufacturing, particularly in the automotive (car, truck and motorcycle) components and chain saw sectors.

Shortly after the U.S. studies began, however, it became apparent that certain aspects of remanufacturing should make this an advantageous activity for developing countries. In particular, the opportunity to develop industrial skills within the indigenous workforce, to transfer technology at an operating level and to obtain capital equipment at low foreign exchange cost were appealing features.

As a consequence, the Center began a low level effort to examine some of the possibilities for remanufacturing in other countries. This effort has been carried on primarily by students who conducted the research for their bachelors or masters degree theses. Their reports provide some insights into the applicability of remanufacturing in a variety of countries: the Andean region of South America,[8] India,[9] Nigeria,[10] Turkey and Pakistan.[11] These studies generally support our early hypothesis that remanufacturing should be attractive to a country that is trying to enlarge its industrial base.

When the MIT studies came to the attention of members of the World Bank's Integrated Resource Recovery Project, it commissioned this report, a state-of-the-art paper on remanufacturing, as the initial step in what is expected to become one or more remanufacturing demonstration projects in developing countries.

This report is a survey of available information on remanufacturing. In the chapters that follow we will discuss remanufacturing in the United States, the economics of remanufacturing, what constitutes a favorable environment for remanufacturing, selection criteria for products that can be successfully remanufactured, preliminary findings from studies related to other countries, and benefits of remanufacturing in the United States and in other countries. We conclude with recommendations for a program to apply remanufacturing concepts in developing countries.

In the balance of this chapter we examine the kinds of products that are remanufactured, describe the process steps involved, explain terminology, give perspective to remanufacturing in its relationship to resource utilization and recovery, and, finally, summarize the societal benefits of remanufacturing.

1.2 Process Stages and Terminology

There are three types of remanufacturers:

- The OEM (original equipment manufacturer) remanufacturer, who makes and sells both new and remanufactured versions of its product. Some OEM firms lease, rather than sell, their products; for them, remanufacturing becomes a means of rehabilitating their own equipment.

- The independent remanufacturer, who buys non-functioning products and remanufactures them for resale.

- The contract remanufacturer, who rehabilitates a product under contract from a customer who retains title to the product. This latter category of firm can be either an independent or an OEM. The essential characteristic of this category is that the remanufacturing is performed as a service to some other person or firm that owns the product.

The remanufacturing cycle begins at the point where a user relinquishes a product (through trade-in, sale, abandonment or contract) to the system that collects and forwards these items, called "cores", to a remanufacturer. Because of the trade-in aspect of cores, dealers tend to be the initial collection points. If the product is one being remanufactured by an OEM, the collection system is likely to be just the reverse of the firm's distribution channels for its new products. Dealers supplying cores to independent remanufacturers may sell both new and remanufactured products, accepting non-functioning units as trade-ins when customers buy replacement units.

Further consolidation of cores may occur at intermediate points such as warehouse distributors or regional warehouses before they are forwarded to the remanufacturer. Payment for cores is by a series of credits that can be applied to the purchase of remanufactured units for resale. Additional cores may be obtained from scrap dealers or independent collectors, called core brokers. An objective for a domestic remanufacturer is to get back a core for each remanufactured unit sold, thus assuring a continuous supply. There are losses in the system, however, and the core brokers and scrap dealers help to augment the stream.

Core collection, pricing, evaluation and inventory levels are all important facets of remanufactuaring and will be discussed in greater detail later in the report.

When cores are received by the remanufacturer, they pass through three processing stages:

- Disassembly and cleaning
- Refurbishing of component parts
- Reassembly and testing

After initial cleaning and examination of each core to determine its condition and to identify it by model and year of manufacture, the core is disassembled. This may be done in stages, first by subassembly and then into individual parts. Each part is thoroughly cleaned. Parts that are corroded, painted or discolored are blasted by or rolled in abrasives to restore the surface in preparation for refinishing. Throughout disassembly and cleaning all parts are inspected for damage or flaws that would require repair or rejection. Parts are sorted by part number and, where volume permits, are handled in batches through the balance of the operations.

Component refurbishing may take several forms. In addition to surface cleaning and preparation, worn areas may be built up by welding and machined to original dimensions, out-of-round holes may be bored to a larger size to accept an insert having the correct internal diameter. bent shafts may be straightened, electrical wiring cleaned and re-insulated, and precision surfaces re-ground and scraped. In each instance, the objective is to restore a part to its original condition, or, in instances where the original design has proved to cause premature failure, to rebuild or replace the part in a way that eliminates the weakness. Measurement, testing and quality control methods used during refurbishing are similar to those used in original manufacture. The one important exception is that inspection must be made on a 100% basis. When all parts must be presumed faulty until proved otherwise, sampling plans are inappropriate.

Good refurbished parts are put into a parts inventory awaiting assembly. Replacements for items that must be discarded (seals, washers, bearings, gaskets, pins, etc.) are ordered from suppliers or made by the remanufacturer, and these are also put into stock.

When the schedule calls for production of a quantity of a given product, the parts for that product are issued to the assembly floor, where subassemblies and final assemblies are completed and the units are tested to original product specifications. Small units being made in batch quantities (25 or more) are likely to be produced on an assembly line. Larger items, such as machine tools, stationary engines and the like, or smaller products produced one at a time will be assembled entirely at one station, where one or more assemblers will perform all the assembly steps. After assembly, each unit is tested and adjusted. There may be a final painting and labeling operation, followed by packaging and shipping. Shipping cartons are frequently designed to facilitate return of a core when the remanufactured unit is sold.

Throughout the remanufacturing process, quality control is an essential feature. Every person working on the product must be aware of and alert for faults that have occured in the parts that are being used. This requirement obligates management to train all employees in

rudimentary inspection techniques, to provide appropriate measuring and inspection equipment and to motivate people to maintain high quality standards. The reputation of the remanufacturer and its ultimate success rests almost entirely upon the quality of the finished product.

1.3 Nature of Products Remanufactured

Although the range of products currently being remanufactured is broad, most share certain common characteristics. Obviously, there must be a core; the product cannot be consumed in its use. The product must be capable of being disassembled (remanufacturers become adept at disassembling even the most intractable units: welded joints, swaged fasteners, hermetic seals, corroded unions and so forth). Its parts must be capable of repair, refurbishing or economic replacement. The final characteristic, from a physical standpoint, is that the original function of the product and its level of performance can be restored by remanufacturing.

From an economic point of view, the core must have a sufficiently high value added (labor, energy, capital) embodied in it even at the end of its useful life. Another way of stating this is that the realizable worth of the core, as measured by the recoverable value still embodied in it, is much higher than its market value as a nonfunctioning product. For many products the market value may approach or even become negative (people are paid to remove the carcass), although there is a high value added still residing in the product.

Another essential characteristic of a remanufactured product is that it must have a market at the level of prices that must be charged. In large measure, this aspect has to do with the technological stability of the product. The fact that the remanufactured product may be as much as ten years older than current models cannot be a deterrent to purchasers. An electromechanical adding machine, for example, might satisfy all other physical and economic criteria for remanufacturing, but the electronic calculator has destroyed its market. The technology of a remanufacturable product will change only slightly over the years.

Products being remanufactured today in the United States can be divided into four general market categories:

- Automotive. The largest number of remanufacturers are concentrated in the replacement parts business for automobiles and trucks. Parts that are remanufactured vary in complexity from simple starter solenoids to complete diesel engines. The remanufacture of whole automobiles on a routine basis (as opposed to custom rebuilding) is a recent and promising innovation.

- Industrial equipment. This category includes such products as process valves, hydraulic equipment, heavy-duty diesel engines, production metalworking machinery, and oil rig drilling equipment. Products in this sector are frequently custom-made for a specific application and must be remanufactured on a one-by-one basis.

- o Commercial products that are commonly remanufactured include office machinery, refrigeration compressors, vending machines, and communications equipment. As with industrial equipment, complex or custom-made products tend to be remanufactured one-by-one.

- o Residential products remanufacturers are relatively rare. The combination of a large, highly disaggregated market for used products, a long product life, and high transportation costs coupled with consumer prejudice towards "rebuilts" limits the number of products in this sector. A small amount of remanufacturing of power tools, lawn mowers, and appliances is being done.

The largest remanufacturer in the United States is the Department of Defense. Weapons systems and military equipment ranging from rifles to radar to aircraft carriers are regularly remanufactured to keep the equipment in optimal operating condition and to incorporate new technology into older equipment.

Chapter 4 contains a description of a systematic approach to screening products for manufacturability. This was developed by the MIT study team to locate prime candidates for remanufacture in the United States.

1.4 Relationship to Resource Use and Recovery

No matter whether a product is destined for industrial, commercial or consumer use, the alternatives for the product after its first use are about the same. There is a kind of hierarchy of these alternatives in terms of the costs of maintaining or retrieving economic value in the product. Each stage represents a different level of cost to recover a given amount of financial value in the product after it has been used.

Figure 1 is a rather complete model prepared by Michael Bever[17] to describe materials flows in the production-consumption system. In this diagram, loop 3a is the remanufacturing loop, with recycling to recover basic materials indicated by loops 3 and 3'.

Figure 1:

The Materials Production-Consumption System

Source: Bever [17]

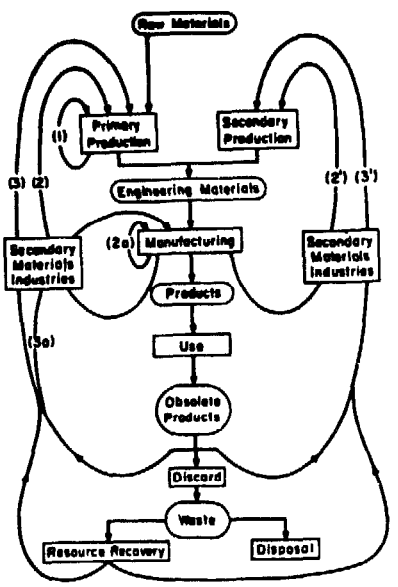

Figure 2 is a somewhat simpler diagram in which the five alternatives--repair, re-use, remanufacture, recycle, and disposal--are depicted. Each stage has its place in the rational utilization of economic value. Repair is the logical first recourse in the event of product malfunction or wear. At some point in use, however, one of several things may occur:

1. The capacity, functions or utility of the product no longer match user needs. Sale of the product and re-use by another party retains a high level of value at low additional cost.

2. It becomes no longer financially attractive to repair the product as an individual unit. Remanufacture may then be indicated.

3. The product is made obsolete by alternative technology or elimination of any need for the product functions. Recycling at least recovers material value.

4. The product is so worn out that it cannot be economically returned to use, and it must be recycled or discarded.

5. The product is lost from the system by corrosion, depletion, dissolution or disposal as landfill.

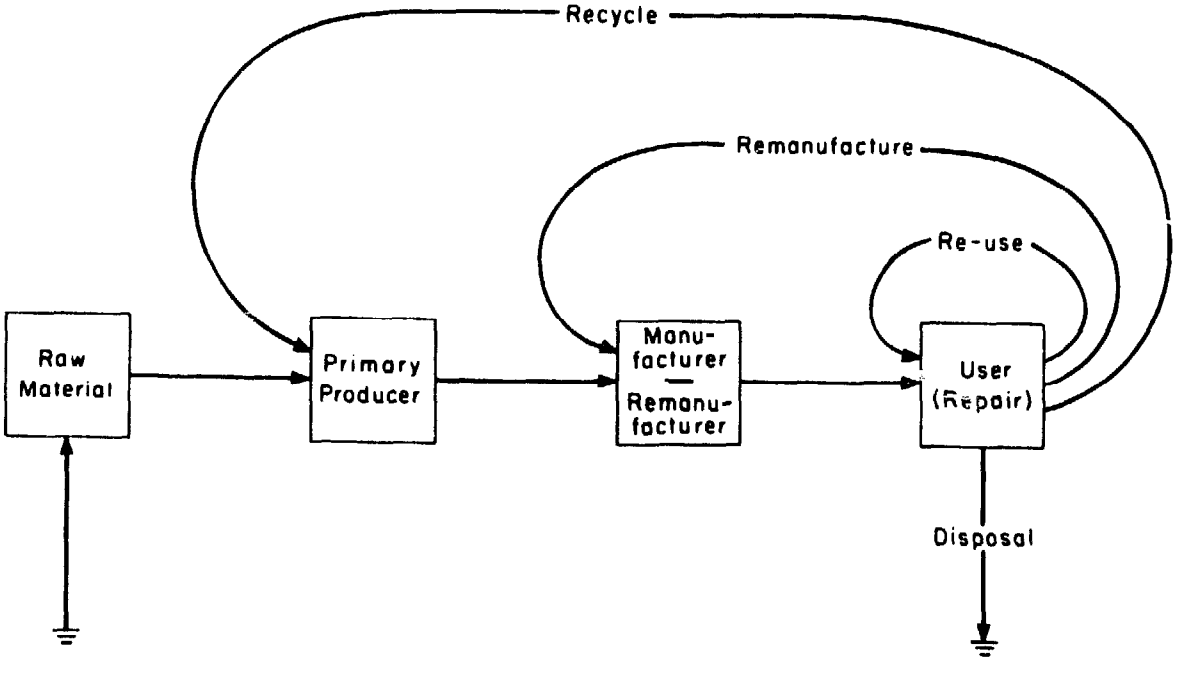

Figure 2: Materials Resource System

For some products there can be added variants in the cycles of use. A major unit, such as an automobile, may be cannibalized or dismantled to provide major components (alternators, clutches, starter motors, engines, etc.) for re-use or remanufacture. Another variant may be to find secondary or tertiary uses for all or part of the product (trailers made from auto chasses, for example). In this latter case, such products might legitimately be considered part of remanufacture, although we have not done so up to this point.

It is not uncommon for products to go through each of the stages of repair, re-use and remanufacture on their way to recycling. In some cases a product may pass through a given stage repeatedly before moving to the next lower stage. The larger remanufacturers of auto components frequently receive cores that have already been remanufactured by them at some earlier time.

The lower in the hierarchy the product sinks, the lower is the value that can be recovered per dollar of recovery effort. By the time the recycling stage is reached, the total input costs to accomplish recycling, which include collection, disaggregation, smelting and/or refining and primary shape formation (ingot, bar, billet, etc.) may actually exceed the value of the recovered material. The only reason that recycling is done at all in these cases is that it has the least net cost for collecting and disposing of the materials.

1.5 Summary of Benefits

Remanufacturing provides an impressive array of benefits for both industrialized and developing nations and for both society as a whole and for the entrepreneur. These benefits are described in detail in Chapter 6, and are summarized briefly here.

Societal and Economic Benefits

- Conservation of resources -- energy, materials, capital and labor
- Reduced costs of durable products mean higher standard of living and greater range of product choice
- Employment opportunities, particularly for low to moderately skilled workers
- Reduced solid wastes and waste processing costs

Benefits to the Remanufacturer

- Low barriers to entry in terms of capital requirements, labor skills and technical know-how
- Profitability
- Added benefits to the OEM remanufacturer: broader market appeal, control of brand reputation, and feedback on product failure modes for improvement of product design.

Benefits to Developing Countries

- Development of an indigenous industrial base through training of a workforce, acquisition of capital goods, and direct technology transfer
- Augmentation of foreign exchange by export of remanufactured goods
- Development of a service and repair infrastructure to keep industrial and commercial equipment operating
- Opportunity for bringing industrialization to rural areas

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2 REMANUFACTURING IN THE UNITED STATES

2.1 Types of Remanufacture

Remanufacturing enterprises can be classified in several ways: by type of organizational form or structure, by product type or by size. Just as we find a wide variety of products being remanufactured, we also find a variety of organizational forms and sizes.

A major distinction in organizational form is between the independent remanufacturer, whose sole business is the remanufacture of items produced by others, and the original equipment manufacturer (OEM), whose main business is the manufacture of new products and who remanufactures its own products as an added business. Although our statistics are incomplete it is likely that independent remanufacturers outnumber OEM remanufacturers by a wide margin. In terms of annual sales volume, however, the figures may be reversed, because many of the independents are quite small.

The typical independent remanufacturer is a private corporation with ownership closely held. It is an integrated operation, in that it purchases cores, remanufactures them and markets them under its own name or for private labels of others. In some cases, the independent may be operating under a franchise from a major OEM such as Ford or GM's Detroit Diesel/Allison Division, in which case technical assistance and parts are available from the OEM. In a 1980 report the Center for Policy Alternatives presented detailed case studies of two independent remanufacturers: Arrow Automotive Industries (automotive parts) and Rockware International Corporation (power plants). These two cases present several contrasts. Arrow is one of the leading automotive parts remanufacturing companies in the United States, with plants in several locations across the country and with more than a thousand employees. It is a publicly held corporation selling a broad line of automotive components in a national market through about 10,000 jobbers. Rockware International, on the other hand, is an operation run essentially by a single entrepreneur, William Ware, who purchases defunct industrial or municipal power plants, arranges to have them dismantled and the operating units (boilers, headers, tubes, burners, generators and ancillary equipment) reconditioned. He then proceeds to sell units to firms in this country and abroad (a number have been sold in Central and South America). Details of the operations of these two firms are found in Energy Savings Through Remanufacturing: A Pre-Demonstration Study, Interim Progress Report.[1] The description of Arrow Automotives operations is comprehensive and furnishes a particularly helpful perspective of the integrated independent remanufacturer.

Some independent remanufacturers operate solely under contract to others who supply the cores and retain ownership of them. Contract remanufacturers essentially perform a rebuilding or reconditioning service for their clients and they have the advantage of not having to purchase and maintain inventories of cores or finished goods. In some cases the remanufacturer has only a few large OEM's as clients and does all of the remanufacturing work for them. This kind of relationship has some advantages for both parties. For the remanufacturer there is likely to be a fairly consistent stream of business with fewer working capital requirements and risks, and the company can expect to obtain assistance

from the OEM in terms of replacement parts, design and testing specifications, and even tooling. For the OEM the advantages lie in being able to provide remanufactured goods to its customers without having to set up an operation considerably at variance with new product manufacture, requiring different labor classifications, wage rates and skills. Our-Way, Inc., in Atlanta, Georgia, is an example of a contract remanufacturer. Its products are refrigeration compressors for industrial and commercial applications. Its clients are Carlyle Compressor Company, a division of Carrier Corporation; Copeland Corporation and Dunham-Bush, Inc. Before arranging a contract remanufacturing agreement with Our-Way and others, Carlyle handled its own remanufacture of its compressors but found it to be more cost effective to have others do the work. A detailed description of Our-Way operations and of the remanufactured refrigeration compressor market can also be found in the study mentioned above. A second contract remanufacturing operation related to industrial process valves is also described briefly in the same report.

Some independent remanufacturers operate in both the integrated and the contract mode. One machine tool remanufacturing firm specializes in installing numerical controls into conventional machine tools during rebuilding. It will remanufacture specific machines sent by customers to the firm and deliver them back to their owner. At the same time, however, it is in the market for used equipment that it can purchase and remanufacture for resale. This firm, formerly known as D and D Electronics, and now operating as U.S. Machine Tool Company, Hartford, Connecticut, provides an excellent example of the opportunities for upgrading the performance or features of a product through remanufacture. Because of its pertinence to possible remanufacturing operations in other countries, a more complete description of this company's operations is found in Appendix A, a section taken from the Interim Progress Report referred to above.

Original equipment manufacturers (OEM's) that go into remanufacturing as a part of their business do so for a variety of reasons, all of which boil down to one fact: it is good business. Not only is the OEM more likely to retain a loyal customer by offering a good trade-in value for the old unit, but it can also give the customer a wider price range on the replacement unit. In addition, the OEM learns first hand what goes wrong with its product during use. This information can be used to improve product designs of future models and to devise modifications that will prevent similar problems in remanufactured units. In other instances the OEM may merely act defensively, to discourage entry of independent remanufacturers of its products. These reasons are important to OEM remanufacturing operations, but a key factor in virtually every remanufacturing operation is that it is highly profitable. During the recent recession the head of the remanufacturing division of a major U.S. firm remarked that his division was the only part of the company that kept the firm from losing money.

Two examples of OEM remanufacturing operations can be found in the diesel engine field. Caterpillar Tractor Company has a sizeable remanufacaturing plant at Bettendorf, Iowa. Diesel ReCon, a division of Cummins Engine Company has its headquarters in Memphis, Tennessee, but has plants in Chicago and Los Angeles. In both firms the engines that are remanufactured come through their dealer/distributor networks as trade-ins. To some extent both firms compete with local dealers or

service people who will attempt to repair or rebuild diesel engines on a one-at-a-time basis. Diesel ReCon cites several reasons why they can compete effectively with the small local rebuilder:

- They have higher worker productivity because of their factory methods
- They use facilities, specialized equipment, and energy more effectively
- The quantities they produce are large enough to justify machines requiring less skilled workers
- They salvage more materials, thereby greatly reducing their new materials or new parts costs.

A description of Disel ReCon's activities is provided in the Interim Progress Report.

Another form of OEM remanufacturing operation occurs in the electronic equipment industry. A company may remanufacture replacement circuit board modules or other components returned as a result of warranty or service repairs to their products. One television manufacturer has set up a line to remanufacture defective circuit boards returned to the field. By doing this they are able to offer replacement units to the serviceman (and customer) at considerably lower prices, reduce their warranty claims costs, and monitor both the performance of their equipment and of the people that service it.

Some OEM's, such as AT&T and IBM, lease a large share of their products to their customers. If something goes wrong with the equipment or if the customer returns the equipment for some other reason, there is a need to put the equipment back into first-class condition for use by the next customer. Western Electric, AT&T's manufacturing arm, has operated a very extensive remanufacturing and salvaging operation for many years. Annual volume is in the order of several hundred million dollars. Both telephone handsets and switching equipment are remanufactured in 31 different plants having a total of 3,000,000 sq. ft. of floor space and employing 12,000 people. At a national remanufacturing conference at MIT in 1981, Robert Egan of Western Electric stated that 70% of all handsets then in use in the United States had been remanufactured.[2] During remanufacture the equipment is upgraded, such as converting a rotary dial to a touch-tone or changing incandescent lamps to light-emitting diodes.

At IBM, as at Western Electric, the prospect of having to remanufacture a unit sometime in its lifetime becomes an important consideration during initial product design. By designing for easy access to modules and to easy disassembly of its equipment, both companies reduce the turn-around costs during remanufacture and usually reduce field servicing costs as well.

While we are on the subject of organizational structure of the industry it may be useful to include mention of the supporting enterprises in the remanufacturing system. We have already mentioned

distributor/dealer networks though which the products are marketed and thrugh which cores are returned to the producer. On the supply side, however, there are other actors as well. In some sectors there are professional dismantlers who will take apart major structures to salvage re-usable items. This is a substantial business in the automotive sector, for example, where 18,000 firms are engaged in scrapping cars, trucks, buses, motorcycles and farm and construction equipment. It is a $6-8 billion industry that processes 8 million vehicles per year.[3] It has an industry association, Automotive Dismantlers and Recyclers of America (ADRA), that represents about 1/3 of the firms in the industry. About 73% of automotive dismantlers' sales are in the form of used parts. About 4% of sales are to "core brokers," people who collect specific types of used parts for resale to remanufacturers. The combination of dismantlers and core brokers serve to make up for the loss of cores in the normal circuit between remanufacturer, dealer and customer. In the automotive area a large remanufacturer will typically acquire about 30% of its cores through dismantlers and core brokers.

New replacement parts suppliers are another part of the remanufacturing infrastructure. For the most part, these suppliers are the same firms that supply standard bearings, seals, gaskets, assembly hardware, paint, etc. to the OEM's. For parts that are peculiar to a given design and that may be fabricated by the OEM, the remanufacturer has three options. It may attempt to buy parts from the OEM; in many instances the OEM or its dealers will be cooperative, but the parts prices are likely to be high. In other cases the OEM will view the remanufacturer of its products as a competitor and will refuse to furnish parts. The remanufacturer then can either attempt to make the replacement parts itself or try to locate a replacement parts manufacturer who is either currently making the part or who is willing to produce it. In the automotive area, replacement parts manufacturers exist both in this country and abroad. When replacement parts for a given unit are either unobtainable or too costly, that unit will not be rebuilt. Any useable parts obtained from the core are kept for use on other units and the non-useable parts are sold as scrap. A small, but persistent fraction of a remanufacturer's sales income is from the sale of scrap materials that are the segregated discards from the disassembly process.

In addition to parts suppliers there are a few firms that specialize in supplying equipment used by remanufacturers. This includes special machines used in disassembly, in cleaning and refurbishing and in inspection and testing. Most of these firms are found in the automotive sector, where they serve dismantling and repair service businesses as well as remanufacturers.

2.2 Remanufacturers by Product Sector

In addition to identifying each firm with the U.S. Standard Industrial Classification (SIC) code number for the product(s) it produces, it is convenient to aggregate remanufacturers into four general product groupings. As was mentioned in Chapter 1, these four market segments are:

1. Automotive-- including automobiles, trucks, buses, motorcycles and parts.
2. Industrial-- all forms of machinery or equipment used in manufacturing or construction.
3. Commercial-- equipment used in trade or service businesses.
4. Residential-- durable products other than automobiles used by consumers.

These groupings were used in classifying data obtained in a United States national survey described in the section that follows.

2.3 Survey Findings

In 1979 the Center for Policy Alternatives conducted a survey of all remanufacturers known to the research group at that time. A total of 358 questionnaires were sent out and 156 were returned. Of those returned, 143 had useable information. Where time was a factor, respondents were asked to supply the information as of the end of 1978. A copy of the survey document, with the replies to each question tabulated, is appended to this report as Appendix B. Several of the more salient points in the analysis of the data, which was reported in Remanufacturing Survey Findings,[4] are presented in the following paragraphs.

The data base of the survey included firms from all four product sectors, and from both independent and OEM remanufacturers (see Table 2-1). Because there are no national statistics on the number of remanufacturers extant in the United States, we were unable to state what fraction of remanufacturers our sample represented, or whether the sample was a truly representative sample. Because our knowledge of the existance of 358 remanufacturers came through a networking approach, it is likely that the larger, better known and more active firms are represented in the sample than would have been true of a perfectly random selection from the total population. For that reason, it is not appropriate to use these data to characterize the entire industry. With respect to practices and policies followed by remanufacturers, however, we consider the data meaningful and useful.

2.3.1 Skill Levels

Among the remanufacturers surveyed, about 40% of the labor force was skilled or salaried, with the remainder being semi- or unskilled. More precisely, 21% of remanufacturing personnel were unskilled, 39% semiskilled, 28% skilled, and 12% salaried. These ratios differed with product market and by regions. The automotive rebuilders employed the largest percentage of unskilled workers (32%), while remanufacturers in the industrial and commercial markets had a much higher percentage of skilled workers. Table 2-2 shows the percentage of workers at each skill level by product market.

Table 2-1 Types of Firms Responding to Remanufacturing Survey

	Automotive	Industrial	Commercial	Residential
Independent	54 (89%)	26 (57%)	18 (60%)	4 (67%)
Remanufacturer Unit of OEM	7 (11%)	18 (39%)	9 (30%)	2 (33%)
Other (primarily authorized)	0	2 (4%)	3 (10%)	0
Totals	61 (43%)	46 (32%)	30 (21%)	6 (4%)
GRAND TOTAL	143			

TABLE 2-2
LABOR SKILL LEVEL BY MARKETS (%)

Product Market	Unskilled	Semiskilled	Skilled	Salaried	Count
Automotive	33	37	20	9	56
Industrial	12	43	35	11	46
Commercial	15	36	32	18	30

Note: Percentages in this and following tables may not total to one hundred percent (100%) due to rounding error and/or due to missing data.

2.3.2 Wages

Table 2-3 presents the mean wage rate for firms grouped by product market.

TABLE 2-3
WAGE BY PRIMARY PRODUCT MARKET
(US$/hr)

Primary Market	Wage: Unadjusted	Wage: Adjusted for Skill level	Count
Automotive	5.56	5.68	54
Industrial	6.71	6.61	44
Commercial	6.37	6.29	28

The significance of the market groups is high (p - .01) with or without skill level considered, but skill level does explain a considerable portion of the raw differences in wage levels. Thus firms primarily remanufacturing automotive parts pay a lower mean wage partly because they employ a larger proportion of unskilled workers and partly because they pay lower wages to workers at each "skill level."[5] (See question 29 of the survey.)

Wages paid by independent remanufacturers were also compared with wages paid by remanufacturing units of original equipment manufacturers (OEMs). These wage rates were virtually identical, being $5.98 for independents and $6.01 for the OEMs. When wage rates were adjusted for regional differentials,[6] the difference between OEM and independent wage rates was slightly larger, but still far from significant.

Finally, wages in remanufacturing were also compared with wages in new manufacture. Table 2-4 shows the mean wage computed for each 3 digit SIC group and a comparable figure for new manufacture. The new manufacturing wage is adjusted from the 1976 wage rate.[7]

From these data it is clear that the mean wage for remanufacturers is lower than it is for manufacturers of new products. This is particularly evident in the automotive sector (SIC 371). Differentials among other industry groups tend to be substantially less.

TABLE 2-4

WAGES IN REMANUFACTURING AND NEW MANUFACTURE BY SIC GROUP

SIC Code	Product	Remanufacturing Survey (1978)	New Manufacture (1976 adjusted to 1978 equiv.)	New Manufacture (1976)*	Count
349	Fabricated Metal Products	6.49	6.33	5.42	3
351	Engines and Turbines	6.76	8.19	7.02	24
352	Farm Machinery	3.00	7.40	6.34	1
353	Construction Machinery	6.62	7.63	6.54	2
354	Metalworking Machinery	7.15	7.25	6.22	5
355	Industrial Machinery, Special	7.32	6.50	5.57	2
356	Industrial Machinery, General	6.80	7.10	6.08	5
357	Office, Computing Machinery	6.00	5.89	5.05	1
358	Refrigeration Machinery	6.31	6.65	5.70	20
361	Elect. Dist. Equipment	5.45	6.28	5.38	5
362	Industrial Elect. Equipment	6.95	6.19	5.30	2
363	Household Appliances	3.90	5.95	5.10	2
365	Radios & Television Sets	6.50	5.64	4.83	1
367	Electronic Parts	5.21	5.23	4.48	4
369	Misc. Electric	5.06	6.59	5.65	7
371	Motor Vehicles & Parts	5.66	8.87	7.60	48
372	Aircraft & Parts	5.50	8.12	6.96	1
					133
MEANS:		6.04	7.70	6.60	

* Annual Survey of Manufactures, 1976, U.S. Department of Commerce

2.3.3 Labor Cost and Productivity

Labor cost per unit sales dollar in remanufacturing is more than double that for new product manufacturers. These ratios vary by product market. The survey indicated that labor costs constituted 24% of the sales dollar in the automotive market, 29% in the commercial market, and 35% in the industrial market. For the small group of remanufacturers engaged in remanufacturing consumer goods for the residential market (e.g. lawn mowers, washing machines), labor cost constituted a very high 55% of total sales revenue. Table 2-5 presents these results.

TABLE 2-5
MEASURES OF LABOR PRODUCTIVITY BY PRODUCT MARKET

Product Market	Average Firm Labor Cost per Sales Dollar	Total Average Labor Cost per Output Unit	Average Firm Sales Dollar Per Worker	Total Average Output Units Per Worker	Count
Automotive	.24	2.62	59,717	4,453	57
Industrial	.35	13.30	68,981	1,048	42
Commercial	.29	151.4	55,258	88	22
Residential	.55	3.87	30,866	2,457	5
Mean	.30	3.52	60,881	3,585	126

Most firms generate about $60,000 in sales for each worker. This figure is shared among the market segments, except for the five firms in the "residential" market. The fact that the five "residential" consumer good firms reported an average per worker sales figure of half this amount may help explain the relatively small number of remanufacturers in that market. $60,000 sales revenue per worker is a remarkably high figure, even when compared with figures for automotive manufacturers having relatively high capital equipment investments.

2.3.4 Core Supply

Remanufacturers draw on several sources in their attempts to acquire a sufficient number of cores. Table 2-6 shows the average fraction of total core supply from each source broken down by market segment.

The automotive market relies heavily on nonwarranty service exchanges (37.2%) as a source of cores, followed by core brokers (23.2%) and products returned by owner for rebuild (21.9%). There is some indication that respondents may have been confused about the meaning of each category. The category "returned by owner for rebuild" was intended to mean that the owner maintains title of the product throughout the remanufacturing process. However, in the automotive market survey results show that while an average of 22% of cores are returned by owner

TABLE 2-6
SOURCES OF CORES BY MARKET SEGMENT (%)

SOURCE OF CORES	AUTOMOTIVE	INDUSTRIAL	COMMERCIAL
Warranty Returns	5	5	6
Core Brokers	23	8	8
Nonwarranty Service Exchange	37	17	23
Lessor/Renter	4	1	5
Returned by Owner for Rebuild	22	56	47
Salvage Operators	9	11	11
COUNT	61	43	29

for rebuild, only an average of 4% of users retained ownership during the process. Given the typical operating method in the automotive market, the 18% difference probably should be assigned either to nonwarranty service exchanges or warranty returns instead of the "returned by owner for rebuild" category.

In contrast, the industrial and commercial markets rely primarily on users to return products for rebuilding. User returns account for approximately half of the core inflow, which is an indication of differences between the industrial and commercial markets and the automotive market. For example, industrial and commercial markets often establish direct user-remanufacturer relationships, in contrast to the automotive market, where dealer and distributor networks provide very little contact between the ultimate user and the remanufacturer. Products manufactured in the industrial and commercial markets are more likely to be customized to user specifications. Such products tend to be larger and more costly, and the customer wants a product that meets certain specifications. Nonwarranty service exchanges constitute the other major source of cores for industrial and commercial products.

Core scarcity is a problem for both independent and OEM remanufacturers. Given a list of eight factors, independent and OEM remanufacturers ranked core scarcity as the major limiting effect on growth. Table 2-7 shows the rank each factor received, where the lowest numbers indicate the factors which are most troublesome to respondents.

2.3.5 Materials Costs

The Remanufacturing Survey asked respondents what fraction of total materials costs is invested in used parts and what fraction is invested in new parts and materials. As indicated in Table 2-8, respondents indicated that the materials costs are divided almost equally.

TABLE 2-7
FACTORS WHICH LIMIT GROWTH BY ORGANIZATIONAL FORM

FACTORS	INDEPENDENT RANKING	OEM RANKING
Scarcity of quality cores at an acceptable price	1	1
Labor cost	2	4 (tie)
Unavailability of sufficiently skilled workers	3	6
Cost of new capital equipment	4	4
Competition from other remanufacturers	5	2
Plant production capacity	6	3
Federal and state regulations	7	7
Competition from new products	8	5

TABLE 2-8
MATERIALS COST BREAKDOWN BY MARKET SEGMENT

	TYPE OF MATERIAL	
MARKET SEGMENT	USED PARTS	NEW PARTS AND MATERIALS
Automotive	47%	52%
Industrial	50	50
Commercial	54	46

2.3.6 Product Ownership

When a used product comes to a firm to be remanufactured, it is not necessarily owned by the firm as it would be in a manufacturing operation. Results of the Remanufacturing Survey indicate that remanufacturers sometimes have other ownership arrangements. The respondents were asked if the used product is owned by themselves, the user of the product, the original equipment manufacturer (OEM) or by some other entity. The answers to this question were analyzed by market served (automotive, industrial or commercial) and by firm ownership (independent remanufacturer or OEM/remanufacturer). Table 2-9 below shows the response to this question by market segment where the numbers represent the mean percentage of products in each class of ownership.

TABLE 2-9

PRODUCT OWNERSHIP BY MARKET SEGMENT

Market Segment	Class of Ownership (percent of market segment) Remanufacturer	User of Product	OEM	Other	Count
Automotive	94	4	2	0	54
Industrial	64	25	6	5	45
Commercial	51	39	6.	4	28

Differences in product ownership are predominantly a market segment phenomenon. There was relatively little difference in ownership of cores reported by OEM's as opposed to independent firms.

2.3.7 Product Design

The design maturity of a product is an important factor in the remanufacturability of a particular product. The firms in this survey show a definite tendency to stay away from those products which are undergoing rapid changes in design or materials of construction. Rather, products being remanufactured are described as having a moderate to slow rate of product change from year to year. Because remanufacturers rely heavily on a steady supply of used products, it is important that discarded products can be fed into the core loop for a number of years and do not become obsolete in a short time.

Although only a small percentage of cores are returned with a request for technological updating, the majority of firms do make some kind of change in the product. Only 26 of the 134 firms who responded to a question on reasons for design modification said they did not make any design changes.

The top five reasons given by respondents for making design changes in the automotive market are:

(1) Correct design weakness to yield longer product life
(2) Consolidate models
(3) Improve operating efficiency
(4) Make the product easier to remanufacture
(5) Update to current technology.

2.3.8 Reasons for Market Entry

Although an appreciable number of remanufacturing firms have developed out of service and repair operations, the largest percentage, we found, entered remanufacturing directly as a main area of business (Table 2-10).

TABLE 2-10

REASON FOR ENTERING INTO REMANUFACTURING FOR VARIOUS GROUPS OF FIRMS

Type of Firm	Directly As Main Area of Business	Indirectly, As Original Equip. Manufacturers	Indirectly As a Repair Service	Indirectly, Other	Count
Independent	61%	3%	28%	8%	100
OEM	39%	25%	31%	6%	36
Product Market					
Automotive	62%	5%	23%	10%	60
Industrial	40%	13%	42%	4%	45
Commercial	59%	7%	28%	7%	29
Residential	67%	33%	0	0	6
Sales Category					
Under $1 Million	68%	11%	22%	0	37
$1 Million to $10 Million	54%	6%	34%	6%	65
Over $10 Million	52%	9%	22%	17%	23

Responses by product market do not reveal any marked differences in reason for entry with the possible exception of the industrial market. In this market the largest single mode of entry was as a repair service (42%). Indeed, because of the degree of one by one rebuilding and the extent to which the customer retains ownership in this market, industrial remanufacturing is still similar to repairing.

2.3.9 Competition

Remanufacturers face potential competition from new products, used products and remanufactured products. Respondents were asked to rank the importance of each source of competition.

Overall, remanufacturers believed other remanufactured products to be the most important source of competition. New products were second in importance, while used products were least important. This order of pressure from competitive products was the same for independent remanufacturers and OEM's and for all three major product markets (automotive, industrial and commercial). Only in the residential market (where little competitive remanufacturing exists) was the order different: new products being the most important source of competition followed by remanufactured and used products.

Respondents were asked to assess how important various factors are to potential purchasers of their products. Table 2.11 shows the ranking of these factors, from most important to least.

TABLE 2-11

IMPORTANCE OF PRODUCT FACTORS TO POTENTIAL PURCHASERS BY MARKET

	RANK BY MARKET		
FACTOR	AUTOMOTIVE	INDUSTRIAL	COMMERCIAL
Availability	1	1	1
Performance	2	2	2
Service	3	3	3
Price	4	4	3
Appearance	5	6	5
Warranty Terms	6	5	4
Other Factors	7	7	7

There is uniformity in the importance of these factors across markets. Several of the factors more important to customers than price seem to relate primarily to minimizing costs due to delay. Availability and service are closely related. Both are important in minimizing the delay (or "downtime") associated with a non-functioning unit.

2.3.10 Prices

Respondents were asked to assess the prices of their remanufactured product(s) as a fraction of the price of a similar new product. Table 2-12 lists this fraction by market.

The differences by market in the relative price of remanufactured products are significant. The higher value for the commercial market (in large part consisting of air conditioning compressors) may indicate lower competitive pressures among the products in the commercial market, or it may represent a real difference in costs of cores and remanufacturing operations in this market.

TABLE 2-12

PRICE OF REMANUFACTURED PRODUCT AS A FRACTION OF NEW PRODUCT PRICE

MARKET	PRICE (% of New)	COUNT
Automotive	57%	59
Industrial	51%	45
Commercial	67%	28
Overall Mean	57%	132

2.3.11 Distribution Channels

There are significant differences in distributor channels employed by remanufacturers depending on the product grouping they are in (Table 2.13).

TABLE 2-13

FRACTION OF SALES DISTRIBUTED THROUGH VARIOUS CHANNELS BY MARKET GROUP

DISTRIBUTION CHANNEL	AUTOMOTIVE	INDUSTRIAL	COMMERCIAL	RESIDENTIAL
Direct Sales to User	10%	41%	52%	34%
Distributor Network	85%	39%	25%	65%
To New Lessor/Renter	0%	0%	2%	0%
Other Channel	5%	19%	17%	1%

"Other" distribution channels seem to account for a sizeable fraction of the sales, especially in the industrial and commercial markets. These other channels include sales through the parent company or direct to the original equipment manufacturers, and through service contractors or service organizations.

2.3.12 Sales Levels

The average annual sales revenue per firm differs by market segment. In all categories the average sales figure indicates that the typical firm is the small-to-medium size range (Table 2.14).

TABLE 2-14

SALES REVENUE BY MARKET SEGMENT [3]

MARKET	AVERAGE SALES*	TOTAL SALES*	COUNT
AUTOMOTIVE	$10,060.	$573,410.	57
INDUSTRIAL	$4,790.	$200,369.	43
COMMERCIAL	$3,550.	$78,092.	22
RESIDENTIAL	$3,290.	$16,451.	5

* Thousands of dollars.

Sales volume was found to be positively correlated with the length of time the firm had been engaged in remanufacturing, and with the fraction of its output processed on a production line or in large batches.

Exports accounted for less than 5% of sales in all four market categories. The principal export difficulties listed by respondents were core return problems, lack of a distribution system, and lack of foreign trade experience.

2.3.13 Warranties

The warranty is a specific part of the purchase agreement that guarantees the user service at no cost if all conditions of the warranty are met. Respondents were asked to compare their warranty terms with those of a comparable new product (Table 2.15).

TABLE 2-15
WARRANTY TERMS BY MARKET SEGMENT

COMPARISON OF WARRANTY TERMS RELATIVE TO NEW	MARKET SEGMENT		
	Automotive (n = 61)	Industrial (n = 46)	Commercial (n = 30)
More liberal	24	6	5
The same	27	32	19
Less liberal	7	8	4
Missing cases	3	0	2

For the most part, respondents described their warranty terms as being either "the same" or "more liberal" than the warranty terms of a comparable new product. Less than 20% of the firms in all market segments described their warranty terms as being less liberal than those of a comparable new product.

2.3.14 Key Success Variables

The Remanufacturing Survey report concluded with a summary of six factors evidently critical to the success of an American remanufacturing enterprise:

1. Product design stability. The maturity of the product -- the length of time the product has been in the market without substantial design change -- and the future vulnerability of the product to mandated or voluntary design change.

2. Collection and distribution loop. The source, quantity, quality, and means of collection of cores is a primary limitation to the size of the operation. The compatibility of materials sources with the distribution system for the remanufactured product will affect the overall efficiency of the operation.

3. Relations with OEM's. Not a serious problem if the OEM is the remanufacturer, but important to the independent. Part specifications, product performance specifications, parts sourcing, and information regarding design changes are all needed from the OEM.

4. Competition. Other remanufacturers operating in the same product market constitute the major competition.

5. Marketing strategy. Product availability, performance, service and price are the primary marketing considerations. Price to the customer will be in the range of 50% to 70% of a comparable new product. Warranties must be competitive with new product warranties.

6. Mode of entry. The relatively low capital investment entry fee to remanufacturing makes direct entry feasible, but prior experience in servicing and repair is a useful starting point.

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3. Russell F. McKinnon as quoted in Id.

4. Lund, Robert T., F. Doyle Skeels, Tomas A. Gonzalez, Daryl L. Beardsley, George R. Heaton, Jr., and Ronald Grand, An Engineering Feasibility Study of the Remanufacturing of Chain Saws, The Center for Policy Alternatives No. 82-12, August 1982, MIT, Cambridge, MA.

5. It is important to note that these skill level ratings are subjective and may vary from firm to firm or industry to industry. The difference in unadjusted wage rates between automotive and industrial markets is significant at the 95% level of confidence (p - .05), while the significance of the difference between commercial market wages and the other two is lower.

6. From published BLS data.

7. An adjustment factor of .167 was used which represents the increase in average manufacturing wages in current dollars between 1976 and 1978. The mean in each column is weighted for number of firms.

3 ECONOMICS OF REMANUFACTURING

A major consideration in the MIT studies of remanufacturing has been the economic impact of this form of industrial activity on the resources (energy, materials, labor and capital) of the country. Remanufacturing was viewed as having the potential for substantial conservation effects, but there were no data on the subject. There was no National Association of Remanufacturers (we subsequently suggested the need for such an organization), nor were there any nationally collected statistics on this activity. The economic analysis was a ground-breaking exercise from the start.

We have been able to establish that remanufacturing is, indeed, a socially desirable function from the standpoint of resource conservation. Using data collected from case studies, the national survey, and a variety of federal statistics we were able to establish several findings relative to resource effects, all highly favorable to the industry.

The basic function of the remanufacturer is in recapturing original value added (labor, energy, capital equipment contributions) to the materials in the core. This is done at a small additional input relative to the original value added. Unless this value added is reclaimed by remanufacturing it is of relatively little worth to either its owner or to anyone else. If the product cannot be reused or remanufactured in whole or in part, only the basic materials content (the value of which may typically be in the order of a few percent of the price of the product) provides some residual worth. The gap between what an owner is willing to accept for a defunct durable good and the recoverable embodied value added is the area of opportunity for the remanufacturing entrepreneur.

3.1 Energy

The potential for energy savings was of great interest to the study, because the energy crisis had raised the national consciousness on this issue, and our sponsor, the Department of Energy, was interested in an assessment of remanufacturing's possible contribution. We found that while the figures for energy use per unit of output were at about 60% of that required by new product manufacturers, the real savings in energy came from recovery of the energy embodied in the materials and purchased parts assembled by the new product manufacturer.

Energy is used in every stage of manufacture, from ore smelting and refining through primary and secondary process steps to assembly and test. When the total energy used in producing a product the first time is added up and this figure is compared to the energy required to remanufacture the product, the ratios are in the order of 4:1 or 5:1.[1] What this means is that remanufacturing is able to recapture the benefits of the energy already expended at only a small fraction of that original energy expenditure. For every kilowatt-hour of energy spent in remanufacturing, between 4 and 5 kilowatt-hours are recovered. This is almost tantamount to producing energy.

Appendix C at the end of this report is a reproduction of the section of the report Remanufacturing Survey Findings, in which the development of energy leverage ratios is explained.

One other issue concerning energy must be faced, however. In many cases the products being remanufactured are, themselves, consumers of energy. Diesel engines, automobiles, refrigerators, electric motors, and locomotives are all remanufactured and all consume energy. If, by extending the life of an older machine, we keep in operation a less energy-efficient unit than is now available in the market, are we not actually causing energy waste? It is possible, but as was examined in a recent masters thesis,[2] the question of market acceptance of such remanufactured products will tend to decide whether the product will, in fact, be remanufactured under these circumstances. Market acceptance will tend to be a financial decision. As long as the price of energy to the user is a fair representation of its real economic price, the decision to buy a remanufactured unit can be made in a straightforward manner.

We prefer to think of such issues in terms of the present value of the total life cycle costs of a product. Total life cycle costs include acquisition costs, operating costs, repair and maintenance and salvage or disposal costs.[3] The future stream of expenditures for operation, service and salvage or disposal is reduced to a present value by discounting each year's outlay, and the sum of these discounted values is added to the acquisition cost to arrive at a total life cycle cost for the product. This approach can be used for both the manufactured and the remanufactured product. For the remanufactured product, the lowered acquisition cost may be offset by higher expected operating costs. If these latter costs are sufficiently high, they may serve to discourage purchasers from buying the remanfactured unit.

It is possible, under certain circumstances, that a unit will be bought on economically justifiable grounds, and still waste more energy than is saved by remanufacture. This could be true where the rate of energy consumption is low. If a unit is grossly inefficient and its consumption of energy is high (as in a continuously running stationary engine), it is quite unlikely that it will be a good candidate for remanufacture. If the price of energy is kept artificially low by regulation or subsidy, this would distort the financial costs and could lead to energy waste.

3.2 Materials

The statistics on materials losses from cores that are remanufactured indicate that a leverage in materials recovery exists that is similar to that in energy, but its magnitude is considerably greater. Core losses include about 10% by weight discarded before release to manufacture and a further equivalent of about 12-15% of core weight issued to manufacture that is lost during processing. This latter figure means that a remanufactured product will have about 85-88% by weight of used components, and the two loss figures combined suggest a core yield of about 80% by weight of usable parts. The 85-88% figure means that for every pound of new materials employed in remanufacture, between 5 and 7 pounds of old material is recovered and used. For the more efficient remanufacturers this ratio may be as high as 8 or 9:1.

Both the energy and the materials conservation figures should be important to countries lacking in domestic resources. For such countries, importing low-cost cores for remanufacture may be considered an inexpensive means of importing energy and materials, in addition to importing the technological know-how.

3.3 Labor

Remanufacturing is labor intensive. Its processes depend on significant human input at each stage. A large fraction (in the order of 60% according to our survey) of the labor force is unskilled or semi-skilled. Some technicians, machinists and mechanics are needed in refurbishing, testing and inspection of some products, but many of these higher skill levels can be acquired on-the-job.

The lower level skills are also those that can be job-acquired and do not entail special education. Disassembly skills are somewhat different from assembly skills, and disassemblers must also learn how to identify model numbers of cores and to classify their component parts. Cleaning, refurbishing, assembly and materials handling pose no unusual skills requirements, except that all personnel regardless of job classification or title must posess a high level of quality consciousness. When each product starts out with materials that are known to be defective in some manner not yet discovered, the only way to ship products that are guaranteed to function properly is to train each member of the workforce in quality vigilance.

For most remanufactured products the location of a remanufacturing operation is not a critical matter, as long as a workforce can be recruited in the vicinity and the sources of cores are not too remote. In many respects this is a highly "portable" industry, one that could be set up in more rural areas, counteracting urbanization pressures.

From a labor resource point of view, remanufacturing is highly suited as an introductory industrial activity in a country whose labor force has had limited industrial experience. It provides initial training in industrial skills and practices and an introduction to both product and process technologies. It can become the starting point from which other industrial activities can draw trained workers and managers.

3.4 Capital

In the survey of remanufacturers we obtained crude ratios of assets to annual sales that ranged from about $.12 to $.36 per dollar of sales. This contrasts with a figure of about $.30 for new product manufacture. We infer from these figures and from other more direct observations that the capital requirements of remanufacturing firms are relatively modest. There are two reasons for this. The equipment needed to make component parts--metal cutting machine tools, presses, molding machines, forges, and the like--tend to be expensive. They are generally not needed in remanufacture, because the parts have already been formed. Except for a few machines for cleaning, refurbishing and testing, the predominant equipment consists of hand tools, jigs and fixtures. Working capital needs are likewise modest, because the major raw material is an inexpensive core, whose cost is substantially lower than its economic worth.

3.5 Operating Costs

We did not attempt to obtain information on operating costs in our national survey, so we have limited information. What we have tends to be quite similar to operating data from conventional manufacturers who have a high labor content in their goods. In the case study of Arrow Automotive Industries,[4] the Hudson Division's figures for costs of sales as a fraction of total costs were as follows:

Labor	29%
Materials	54
Depreciation	1
Overhead	16
Total Cost of Sales	100%

At the time of the study the division was producing automotive and truck alternators, starter motors, water pumps and clutches. Data from annual reports of another major automobile parts remanufacturer, Champion Parts Rebuilders, Inc. of Chicago, show a similar breakdown:[5]

Factory Costs	82.4%
Overhead	17.6
Total Cost of Sales	100.0%

A small remanufacturer of auto parts (33 employees and annual sales of $760,000) had operating cost ratios that showed higher overhead costs as a fraction of total cost of sales:[6]

Labor (including supervision)	35.8%
Materials	41.3
Overhead	29.9
Cost of Sales	100.0%

The calculated cost ratios for estimates used in the study of the feasibility of remanufacturing chain saws[7] varied significantly with the size of the operation:

	Small Scale (2500 saws/yr)	Large Scale (25,000 saws/yr)
Labor	12.3%	6.1%
Materials	42.5	70.0
Overhead	45.2	23.9
Cost of Sales	100.0%	100.0%

In all studies we have made thus far, there are clear indications of economies of scale, particularly in labor productivity and in the distribution of fixed and semi-variable overhead.

3.6 Chain Saw Case Study

On the basis of the screening procedure developed for the selection of product candidates for remanufacturing,[8] we selected chain saws as a product area having high potential for remanufacturing but not yet being remanufactured in any appreciable volume in the United States. During

1981 and 1982 we conducted an engineering feasibility study for the remanufacture of chain saws. The study included an overview of the chain saw industry and appraisals of the market, dealer structure, pricing, product and process technology, core and replacement parts supply, financial and economic aspects and legal considerations for chain saw remanufacture.

Our conclusion was that chain saws could be remanufactured profitably, particularly if the operation concentrated on saws at the high end of the line (professional and commercial saws) and if the volume of saws produced could be in excess of 2000 - 2500 units per year. At 25,000 units per year the operation was seen to be highly profitable. This level of operation still is less than two percent of the average annual sales of chain saws in the United States.

In addition to developing detail process flow charts and parts requirements lists for selected saws, the study also constructed pro forma income statemenets and cash flow analyses to indicate the levels of capitalization required and the time required to recover the investment.

The chain saw study served as the basis for the preparation of two recently issued "guidelines" reports for individuals or firms considering the possibility of launching a remanufacturing operation. One of the manuals is for the establishment of independent remanufacturing ventures;[9] the companion volume is for OEM's wishing to remanufacture their own products.[10]

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4 WHAT CONSTITUTES A FAVORABLE REMANUFACTURING ENVIRONMENT?

It is evident that there are a set of conditions for remanufacturers in the United States that are favorable to the establishment and continuing success of their venture. In the absence of these conditions an enterprise faces a difficult struggle. It is possible that the key success factors in the United States may not be the same for all other countries. Official attitude, as expressed by regulations, laws, ethical codes or behavior patterns, may be so opposed to re-use of certain products, for example, that all other factors have little influence. Because of national differences of this kind it is essential that the climate for remanufacturing in any country be assessed directly.

This chapter summarizes our observations on what are the critically important success variables for remanufacturing in the United States, and their possible application to remanufacturing in other countries. In addition, a methodology is presented for screening product candidates for the selection of those likely to be most successful. This screen can also be adapted for use in other countries.

4.1 Factors Favoring Remanufacturing

As was pointed out in Chapter 1, the nature of the product has a major influence with respect to both physical feasibility and economic value. From a physical standpoint the product must have a reasonably long useful life and its functions should be based on a stable or slowly evolving technology. It should be capable of being disassembled without excessive damage to the unit, and its normal failure modes should be repairable. Failure should leave a large fraction of the product in re-usable condition though refurbishment and only a relatively few parts should require replacement.

The economics of the product require that the original product cost have a large value added component (labor, energy, capital equipment costs) as compared to the material costs. The price of the remanufactured product should be sheltered by well-established prices for comparable new products. Finally, the scale of remanufacture should be large enough to be competitively superior to repair or one-at-a-time rebuilding alternatives.

The type and size of the market is a second major factor. One feature of the receptive market is that the buyers in it are knowledgeable; they know how or they have the means to evaluate remanufactured goods in comparison with new products. The price advantage afforded by remanufacturing is a valid inducement to buy only if the buyer knows his risks are no greater in buying the remanufactured unit than they would be for a newly made unit. Typically, buyers of this kind can be found in industrial and commercial markets, and we find a large fraction of remanufacturers are in these two product markets. Automotive remanufacturing also caters to the knowledgeable buyer, but here the expert is the service mechanic who chooses the unit and reassures the ultimate customer that the part will function satisfactorily, and at a saving. Other forms of consumer products still seem to have a difficult time catching on. Continued economic adversity

and/or resource scarcities may cause gradual attitudinal shifts among customers, but this is not likely to occur overnight. Branded products having a reputation for longevity will have some advantage in this market.

The minimum feasible market size depends on the price of the product and the remanufacturer's ability to recover a sufficient number of cores. The number of locomotives in the national market, for example, needs not be large if your firm is assured that you will see a very large fraction of all engines in need of overhaul.

The availability of cores, as has already been intimated, is a critically important factor. It was given by virtually all respondents to our survey as the most important limit to growth of remanufacturing. Cores must be readily available, in good quality and at a reasonable price. Availability involves ease of transportation as well as cooperative sources.

In the U.S. remanufacturing industry a cycle of product sale and core collection through the same distribution system keeps cores flowing to the remanufacturer. This is supplemented in some instances by core suppliers who specialize in collecting them. To establish such a system, the remanufacturer must be able to reach the present product user either directly or through permanently established channels.

In developing countries where the supply of durable products may still be very limited, core supply from within the country may be difficult to establish. In the early years of remanufacture, at least, it may be necessary to obtain cores from used equipment and scrap markets in developed countries. If reliable connections can be established, such an approach could yield high quality cores at moderate cost. This approach requires some study to determine both its advantages and disadvantages, but it may be a very useful way of acquiring capital goods for industrial and commercial growth at low levels of foreign exchange.

A fourth key factor is the presence of a supporting infrastructure. By this we mean the various activities that provide goods and services needed to keep the remanufacturer in operation. They range from a distribution network and transportation system to suppliers of replacement parts, cleaning materials and packaging. As was shown in Chapter 1, remanufacturing is part of a system and is dependent on that system for its success.

A workforce that can be trained in remanufacturing skills is also essential. For many products the skills required for remanufacturing are not very demanding and can be learned on the job. Some key skills will be required--mechanics, welders, technicians, maintenance trades, etc.--to set up and maintain equipment, run product tests and to handle some of the more difficult parts refurbishing operations. If these few skilled occupations can be found, the workforce question becomes a matter of whether other laborers can be found who are willing to be trained in industrial skills.

As with any industrial venture capital funds are required to provide plant and equipment and to provide working capital for inventories, accounts receivable, and operating cash. These capital funds tend to be substantially less than would be required for a factory producing an equivalent volume of new products of the same type. The total asset value of a medium to large sized remanufacturing activity appears to be about 1/2 to 2/3 of its annual sales volume. Because 90 - 95% of the assets are in working capital, careful management of accounts receivable and core inventories can increase asset turnover substantially.

Legal and regulatory leeway is another essential part of a favorable remanufacturing environment. By this we mean that there should be no laws or rules that prohibit, tax excessively or establish unreasonable risks for the remanufacturing venture. A country that forbids the import of used equipment, or taxes it heavily, will not be a good country in which to attempt remanufacture where the cores must be brought in from abroad. Laws designed to protect and encourage infant new product industries may serve to discourage remanufacturing. A favorable regulatory climate, on the other hand, would be one in which remanufacturing is viewed as a desirable industrial activity deserving equal encouragement along with other forms of industrial enterprise.

An enterprising, resourceful management is also important. Remanufacturers are opportunists; they must be constantly looking for new markets, new product opportunities, new sources for cores, and new ways of processing materials for greater savings. At the same time, they must be able to control cash flows, minimize investments and manage both product and core pricing. They must be able to recruit and train people who become highly quality conscious, loyal employees, and they must establish good working relationships with their customers and the distribution network that serves them. Many of these management skills are those demanded of any industrial manager. The emphasis on quality, resourcefulness and training skills is perhaps greater, however, than in most industries.

As a final item in the list of critical success variables, warranties are essential to bolster buyer confidence in the product. Polls that are taken to determine what criteria are important to a buyer when considering a purchase generally show that warranty terms rank fairly low on any list. The absence of any warranty, however, would be a strong signal to a buyer that the purchase is entirely at his or her risk, with little or no recourse to the remanufacturer. Most remanufacturers offer warranties that are at least as liberal as those offered on comparable new products.

4.2 Product Selection Criteria

The following section, taken from reference 1, describes an approach taken by the MIT study team to select desirable products for remanufacture.

In 1980 the Center for Policy Alternatives conducted an exhaustive survey of all products manufactured in the United States, using a series of screens to locate those products having greatest potential for remanufacture.[2] Each successive set of criteria represents a finer "mesh" through which candidate products must pass. The criteria used in that study are listed briefly here. The screening process is not infallible. Many remanufacturable products with only limited remanufacturability may pass through. For a more complete exposition of the approach, the reader is referred to the original report.

Stage 1 Criteria. (First Screen)

1. The product is a durable end product or durable component of an end product.

2. The product typically fails functionally rather than by dissolution or dissipation.

3. There is a "core" - a discarded, malfunctioning, or used product - that becomes the basis for the remanufactured product.

4. Remanufacturing processes can restore the product to its original shape, nature, or condition.

5. The product would be remanufactured with intent to restore its original function.

Stage 2 Criteria. (Second Screen)

1. The product is repairable.

2. The product is factory-built as opposed to field-assembled.

3. The product is standardized and made with interchangeable parts.

4. The product has a high percentage of recoverable value added relative to the original market price of the product. Value added is defined as all product costs and profit above basic raw materials costs.

5. The product has high economic potential (core "economic value" minus core "market value"). Market value is measured by the price a potential remanufacturer is willing to pay and an owner is willing to accept for the core. Economic value is the recoverable materials value and recoverable value added in the core. (In general, the product must have a failure mode that renders it substantially less valuable to its owner, but that still leaves it with a high economic value.)

Stage 3 Criteria. (Third Screen)

1. The product is not currently remanufactured, or, if it is remanufactured, the market in the region under consideration has room for significant growth.

2. There is a high ratio between the value of the original manufacturer's assets and the number of its employees. This ratio gives an indication of the recoverable value added in the product. A high assembly labor cost component,for example, is lost in remanufacturing.

4.3 Feasibility Score

At this stage of screening, it is necessary to examine individual products in detail to determine their potential for remanufacturing. Many important product characteristics are interrelated. Technological life (the rate at which a product is made obsolete by technological change) is a factor to be considered in connection with product durability, for example. Product population, price and life are similarly related. Although important for product selection, these characteristics cannot be used singly for simple accept/reject decisions. However, these characteristics can be scaled as continuous rather than dichotomous measures of remanufacturability and applied as a group to each product to determine a "feasibility score" which gives a general indication of overall product remanufacturability.

Data needed to establish a feasibility score are not commonly published, so experts familiar with the products must be consulted. A questionnaire was developed to evaluate feasibility scores in the 1981 Center for Policy Alternatives study. This questionnaire and its scoring system are included in Table 4.1. A list of all products surviving the first three screens and arranged in order of feasibility score was included in the 1981 study. The questionnaire is here condensed into a fourth screen:

Stage 4 Criteria. (Fourth Screen)

1. There is a high ratio of expected technological life to product life. This ratio screens out products likely to become obsolete before they wear out.

2. Product and core transportation costs from the remanufacturer to the user and back again must be less than the value added by the remanufacturer.

3. There is a low ratio of undifferentiated material to total material in the product. Undifferentiated materials are those which are not formed or wowrked specifically for the product, but which could be used for other products. This is a measure of the amount of value added likely to be found in the product. A length of chain or a brick wall, for example, would have a high percentage of undifferentiated material.

4. The product is serviced or installed by an organized service agency network. This gives an indication of the ease of core recovery.

5. There is a high ratio of the current product population value to average life of the product. This gives an estimate of annual sales as a measure of the size of the potential remanufacturing market.

One other criterion for evaluating market acceptance of a remanufactured product today is that the buyer (or buyer's agent, in the case of a repair person) be knowledgeable regarding the product. There is greater chance of success if the buyer is able to make an informed judgement about the remanufactured product relative to its performance and worth.

As an example of the use of the screening technique, the U.S. SIC Code 35463 category, Power Driven Hand Tools, Engine (Internal Combustion) Driven, passed through all of the go/no-go criteria of the first three screens and received a 6.4 score on the fourth screen ranking. The dominant product in this classification is the powered chain saw, and a further detailed analysis of this product then confirmed that it was, indeed, an appropriate candidate. Hand saws and saw blades (SIC Code 3425), on the other hand, did not survive the second cut, failing on the basis of lack of economic potential.

TABLE 4-1. FEASIBILITY SCORE QUESTIONNAIRE

Responses to these questions are given both a Code and a Score. Where applicable, the score has been listed immediately after the response. For Questions 1, 2, and 7 where the score must be computed from the response, see the instructions after the question.

	CODE	SCORE
1. Product technology becomes largely obsolescent in:		
about 5 years	1	
about 10 years	2	
about 15 years	3	
about 20 years	4	
about 30 years or more	5	
2. Product life is:		
about 5 years	1	
about 10 years	2	
about 15 years	3	
about 20 years	4	
about 30 years or more	5	
SCORING of Questions 1 and 2, ratio of product technology to product life (Answer 1/Answer 2):		
20/5 30/5	1	+2
15/5 20/10 30/10 30/15	2	+1
10/5 10/10 15/10 15/15 30/20 20/15	3	0
5/5 5/10 10/15 15/20 20/20 10/20 20/30	4	-1
5/15 5/10 10/30 30/30 15/30	5	-2
5/30	6	-3
3. Value of undifferentiated material (e.g., tin, sheet, pipe, wire) in factory price is:		
less than 20%	1	+.5
from 20% to 50%	2	-.5
greater than 50%	3	-2
4. Service, and/or installation is done primarily by:		
service agency (authorized or factory owned)	1	+1
independent service agency (e.g., plumber)	2	0
knowledgeable user (e.g., in-house mechanic)	3	-.5
repairable but not currently serviced	4	-1
5. Transportation costs from manufacturer to user as a fraction of new sales price are:		
less than 2%	1	+3
from 2% to 8%	2	-1
greater than 8%	3	-3
6. The average unit price of the (new) product is:		
less than $50 (and the product is either serviced by a knowledgeable user or not at all)	1	-2
Otherwise	2	0

7. Value of current population at replacement cost is:

less than $200 million	1
from $200 million to $1 billion	2
greater than $1 billion	3

To score this question, divide the code for current population value by the code for product life (Question 2). Subtract 1.15. Divide by 0.62. (Scores can range from -1.5 to +3).

The overall score for the product is the sum of the individual questions scores (only one score for the combination of Questions 1 and 2). Scores typically range from -4 to +7.5 for products which might be considered for remanufacturing.

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5 REMANUFACTURING IN DEVELOPING COUNTRIES

During the five years of formal studies of remanufacturing, a number of students have been attracted to the program and have subsequently written student reports and/or theses on various aspects of the subject. Of particular interest to this report are the four studies that have been done on the potential for remanufacturing in developing economies. The titles, authors and regions covered are listed in Table 5.1 Each of these reports is summarized in the paragraphs that follow.

Table 5.1 Studies of Remanufacturing in Developing Countries

Author	Title	Countries
Barnett, Christopher J.	Remanufacture of Durable Metal Products: The Concept and its Potential in the Countries of the Andean Region. (M.S. Thesis, 1980)	Bolivia, Chile, Columbia, Ecuador, Peru, Venezuela
Upaa, Raphael	Is Remanufacturing Adaptable to Nigeria? (CPA Working Paper, 1980)	Nigeria
Deolalikar, Avinash B.	A Survey of the Indian Economy to Explore the Potential for Remanufacturing (CPA Working Paper, 1979)	India
Alauddin, Arif	Remanufacturing in Developing Countries	Turkey, Pakistan

5.1 Andean Region

Barnett looks at three issues he considers important to the question of feasibility of remanufacturing in the Andean region:

1. The scale of remanufacturing activities possible in the restricted markets of the six countries.
2. The logistical and structure framework (system infrastructure) needed to support remanufacturing.
3. Government and private industry acceptance of remanufacturing as a desirable activity.

Barnett found consideration of volume requirements reassuring. Using examples from the automotive sector he found that large and small remanufacturers were able to co-exist in the U.S., so despite the much smaller markets for such goods in the Andean region he felt that it would be possible for such activities to exist in that area. Core supply, on the other hand, presents a serious logistics problem: "Core exchange policies are weakened because the factors which keep the quality of exchanged cores high in the United States do not work or work differently in less-developed countries. The domestic supply of used equipment in the Andean countries is of poor quality and too small to provide a steady turnover of cores. This turns the prospective remanufacturer to overseas

sources of supply, where a core exchange policy is impracticable, and where the inspection of cores prior to purchase incurrs high costs in time, administrative effort, and money."

Costs of transportation and handling overseas core purchases are not seen as penalties, however, because new product imports also experience these costs, but "the major cost which is unique to remanufacturing is the cost associated with reducing the uncertainty of core quality. The Andean remanufacturing firm must secure a dependable overseas supply of rebuildable cores, without burdening itself with the need to inspect each lot of cores prior to shipment. This is particularly important if the cores must be of specific makes, models and model years, as in the case of products which, when remanufactured, will be used as spare or replacement parts."

Obtaining an economical and reliable supply of replacement parts is also seen as a problem: "If parts production and supply are the controlled exclusively by the original manufacturer, remanufacture in the Andean countries will depend on the manufacturer's willingness to supply parts to a prospective remanufacturing venture there. ... There is little incentive for the original manufacturer to supply parts to a remanufacturing firm if the firm is outside of the manufacturer's distribution system . . ."

Barnett sees remanufacturing as possible "where new replacement parts are available in the requisite volume for the United States or other foreign countries," even though costs for these parts may be somewhat higher than would obtain for U.S. remanufactures. He suggests that cannibalization of cores should be a source of parts in all cases except where parts are routinely replaced, as in the case of bearings and seals.

The availability of product and process technology and of requisite labor skills are seen as limiting factors for the remanufacture of certain types of products. Barnett identifies several categories of product, however, where neither of these factors are likely to be constraints: light and heavy duty automotive products, mining and construction equipment, and distribution transformers are examples.

After citing examples of Andean countries acquiring used machines and equipment from abroad with government sanction, Barnett describes instances of abuse or fraud that have led countries to ban the import of used equipment. One commonly practiced abuse was to overprice the used equipment in order to siphon funds out of a country. He concludes by recommending an approach to overcome such barriers: "Remanufacturing, by its nature, does not lend itself to large, showy industrial development projects. It is a relatively small-scale activity in the United States, and it is likely to be even more so in any of the Andean countries. Policy intiatives to encourage remanufacturing (and for the moment, we can extend this argument to lower-volume rebuilding activities) should entail a commensurately low level of effort and risk. This suggests that the thrust of such initiatives should not be to create conditions in which remanufacturing can flourish, but rather, to selectively lessen the obstacles that stand in the way of the small firm setting out to remanufacture. This could mean, for example, devoting energies to securing the lifting of bans on the import of used goods, where such goods are to be imported for the sole purpose of complete rebuilding."

5.2 Nigeria

In his short working paper on prospects of remanufacturing for Nigeria, Raphael Upaa points out that 45-53% of the total value of Nigeria's imports are for durable goods and equipment. This represents a substantial outflow of foreign exchange. To stem this flow the Nigerian government has set about developing its own industries, giving this effort a priority second only to its agricultural development. To encourage development of local industry, the government has, among other things, placed high tariffs and import restrictions on certain products (autos and trucks, for example).

Service and repair agencies are rare and poorly equipped. Their personnel are ill-trained. Replacement parts are difficult to obtain. The consequence is that fairly new equipment is frequently abandoned or discarded for lack of service or repairs. Because of inefficient scrap collection systems in the country, many of these abandoned items of equipment are likely to be available, still having "high retained value due to early failure of a few parts." Another element in favor of remanufacturing is the fact that high tariffs tend to inflate the prices of new products, thus increasing the profit potential for remanufacturing of these product types within the country.

Problems for remanufacturing, as seen by Upaa, include high internal transport costs, requiring the remanufacturer to establish its own means of transporting cores and products. Basic labor skills are being taught in the nation's schools, but advanced skills will have to be taught by the remanufacturing firm. Importation of replacement parts will be expensive and difficult to arrange. Perhaps the most difficult problem cited by Upaa is a general attitudinal bias against used goods by people in Nigeria. This attitude, which is not unique to Nigeria, seems to couple a strong national sense of pride with unfavorable experience with unscrupulous firms who have taken advantage of buyers' technical naivete in sales of useless equipment.

Upaa lists three possible strategies for the introduction of remanufacturing to Nigeria:

1. Set up remanufacturing operations as training centers for industrial skills in conjunction with technical or vocational schools. The remanufactured items would be considered "byproducts" until the value of these items became apparent in the economy.

2. Encourage small independent remanufacturing firms with incentives of the kind extended to other industrial ventures.

3. Encourage existing OEM's to establish remanufactuaring operations.

5.3 India

It is not appropriate to consider India a "developing country," when it is in truth the tenth largest industrial nation in the world. Its severe problems of poverty, unemployment and resource scarcity, however,

put it in need of even much greater economic development. It is in this context that Avinash Deolalikar examines the remanufacturing situation in India. In his working paper he surveys what was known about U.S. remanufacturing in 1979, reviews the Indian economy with respect to supply of capital, skilled and unskilled workers and technology, and assesses the prospects for remanufacturing for India and for lesser developed countries.

Deolalikar describes the rapid development of heavy industry in India since 1950, during which a ten-fold increase in output of the engineering industries has occurred. Currently, over 2,000,000 people are employed in these industries and annual sales are approximately $10 billion. With its present capacity, India's heavy industry is able to export significant quantities of its products. About half of the production in these industries comes from small scale enterprises, many of which are suppliers to the larger firms.

In contrast to this industrial growth, largely confined to urban areas, rural regions of India have remained depressed, causing population migrations that exacerbate the unemployment problems of the nation as a whole. The rate at which people eligible to work have joined the ranks of the unemployed has exceeded the rate at which new job opportunities are being created. The result is that over 20,000,000 are unemployed.

High unemployment is not linked to lack of industrial skills, however. Deolalikar points out that India's greatest asset is its enormous numbers of skilled people, trained in many different disciplines. India "has the third largest reservoir of qualified scientists, engineers and technicians in the world."

Remanufacturing that is presently carried out in India is largely concentrated in the heavy industry sector: "Among the products that are being reconditioned are: machine tools, equipment needed for power generation, transmission and distribution, machinery for iron and steel plants, sugar, cement, paper, textile, jute, rubber, chemicals, petro-chemicals, fertilizers and dairy and food processing, road transportation equipment, rail transportation equipment, tractors and farm machinery, mining and metallurgical equipment, earth moving and other construction equiment and defense equipment.

"Remanufacturing is carried out by original equipment manufacturers. The raw material, i.e., the used machines are either warranty returns due to defects or just worn out machines. Remanufacturing is offered as a service to loyal customers of the OEM's."

In addition to remanufacture by OEM's, "remanufacturing in the unorganized sector is wide-spread. Among the products that are being reconditioned in this sector are: automobile engines and other auto parts, transistor radios, bicycle parts, other household appliances including small kitchen appliances, refrigerators and air-conditioners, sewing machines, watches and water heaters.

"Remanufacturing is carried out by hundreds of thousands of small service agencies scattered across the country. Many are concentrated in urban areas. These service agencies mostly employ from one to five employees who receive on the job training. They enter the trade as unskilled workers but within a short time pick up enough skills to be classified as semi-skilled. The production process in these units is also area or bench work type. They are basically repair shops but their work often goes beyond repairs. Selective remachining and also manufacturing of components is a regular activity of these shops.

"Most often products are not remanufactured to a point of complete restoration of their original value. Remanufacturing stops when the functional value of the product is restored."

Deolalikar points up the differences between the U.S. and Indian economy relative to remanufacturing: "Unlike the U.S., product durability does govern the life of consumer durables in India.

"Moreover, factors like rising service costs relative to new appliance prices, consumer affluence, population mobility, and product appearance which cause premature product discard in the U.S. are evidently absent in India.

"Because of surplus labor, service costs are a fraction of the new product prices. This encourages servicing or selective reconditioning rather than outright discard.

"Moreover, the Indian consumer is less affluent than his American counterpart and is therefore more aware of resource scarcity. Discard of anything runs counter to an Indian's belief.

"If the product fails, the consumer takes it to his neighborhood service facility. Reconditioning is done only to an extent where the functional value is restored. Cosmetic repairs are avoided as they add to the service costs.

"Consumer durable manufacturers are aware that factors like product durability figure prominently in the purchase decision of the consumer. The products are therefore made to last."

In India, "remanufacturing in the organized sector is mostly carried out by OEM's. This is because spare parts are more easily available with the OEM's, and also, due to low volume of remanufacturing, independent remanufacturers have been reluctant to enter this market. ... the remanufacturing industry in the unorganised sector is thriving and its present small-scale structure is appropriate to Indian conditions. It has been successful in generating employment for millions and has acted as an excellent technical education trainer to millions of unskilled workers in the country.

"Its further growth depends on increased production of consumer durables. ... the consumer durables industry is at present in demand recession due to the goverment's policy of restricting output by heavy taxation. The government believes that agriculture and heavy industry must receive priority over consumer durables, which it considers as mainly luxury items."

Deolalikar find the potential for future remanufacturing initiatives lie mainly in the area of remanufacturing foreign consumer and capital goods to be sold in foreign markets. He suggests the establishment of remanufacturing operations in duty free export processing zones such as the one at Santa Cruz airport near Bombay. He states that India has the plants, capital goods, skilled and semi-skilled labor and technological know-how. It can remanufacture complex products. His preliminary evaluation is that because of low labor costs such ventures in India could be highly profitable despite the transportation costs for cores and products.

As part of his paper on India, Deolalikar made several observations about developing countries of Asia, Africa and Latin America, emphasizing the differences that exist between these nations and India: "Unlike India, the manufacturing industry in many of these countries is in an embryonic stage. There is a shortage of skilled and semi-skilled labor in these countries. Moreover, many of them are also short of natural resources.

"Many of these countries import most of their consumer and capital goods from the developed world. Because of the uneven trade with the developed world the foreign exchange reserves of many countries is negative."

Deolalikar's conclusion relative to developing countries is that "potential for remanufacturing of simple durables for home and foreign markets is great. These countries do have facilities to handle such an activity and the gains realized from such operations should make it economically worthwhile.

"Firstly, these countries could remanufacture the products at considerable savings due to low wage rates prevailing in these countries.

"Secondly, export of these products could bring in much needed foreign exchange earnings.

"Thirdly, it could provide jobs to the unemployed and increase the skill levels of the workforce.

"However, remanufacturing is not a panacea for all their problems. The importance of the task of building infrastructural capability cannot be underestimated if balanced development is to be made possible."

5.4 Turkey and Pakistan

Arif Alauddin prepared a masters thesis on the subject of remanufacturing refrigerators in Turkey and then expanded it to include consideration of the same subject for his native country, Pakistan. Alauddin describes Turkey as being advantageously placed with industrially developed countries on its west, developing oil-rich nations to its east, and undeveloped nations in the south and southeast. It is financially troubled by high inflation, inability to maintain a satisfactory balance of payments, and a shaky international credit standing. It has poor domestic energy resources, and tends to be dependent on foreign sources parts to keep its industries running. Over half the aggregate industrial output is from state owned or controlled

enterprises. The country offers substantial incentives to investors in the development of certain priority industries. To stimulate exports the Turkish government has granted liberal incentives and is proposing to set up export free zones and ports to facilitate trade and export-oriented industry.

Although Pakistan's economy has grown substantially since it was established as a nation, it shares with Turkey the economic problems of development. It has the same resource constraints and financial difficulties. Manufacturing represents 15% of GNP, but its growth rate of 9% per year is approximately double that of the large agricultural sector. As in the case of Turkey, Pakistan has a trade deficit, is trying to stimulate exports, and has established a tariff-free export processing zone at Karachi.

Remanufacturing is seen to be a desirable economic activity for Turkey, especially if the products can be exported for consumption by neighboring countries. Alauddin uses the product selection screening process developed by the MIT research team to identify potential candidates for remanufacturing and then performs a market survey before selecting, somewhat subjectively, household refrigerators as the case example. He then examines availability and sources of cores, sites for a remanufacturing operation, marketing strategies, and extent of a supporting industrial infrastructure. Remanufacturing ventures for both domestic and export markets are considered.

Based on his findings, Alauddin recommends that the Turkish government explore further the prospects for remanufacturing, with the intent of sponsoring a demonstration project. He supports the idea of refrigerator remanufacturing, both as a domestic enterprise and in an export processing zone in Istanbul.

Because of similarities between the two countries, it is likely that the same recommendation can be made up for Pakistan, but, in the case of refrigerators, both domestic and export ventures would be dependent on foreign core sources.

6 REMANUFACTURING BENEFITS AND BARRIERS

The basic function of remanufacturing is to prolong the lifetime of products, thus conserving their useful value. Longer product life provides the advantage of less wasteful consumption of resources for a given standard of living. Viewed another way, it can yield a higher standard of living for a given level of expenditure. It reduces the size of the solid waste stream. A four-year increase in the lifetime of a product currently lasting eight years, for example, means a 33% reduction in the amount of that product that has to be collected, processed and recycled, or disposed of.

6.1 Strategies that Increase Product Life

There are various approaches that can be used to prolong product life, and remanufacturing has a place in these strategies. To keep matters in perspective, however, it is useful to consider some of these alternatives before focusing on the advantages and disadvantages of remanufacturing.

There are at least six ways in which the functional life of a durable product can be prolonged:[1]

1. Make it more durable. A manufacturer can design a product so it will not wear, corrode or break at an early date. Stainless steel can be substituted for common steel, ball bearings for bronze bushings, and solid state parts can replace mechanical switches, timers and relays. Greater durability has appeal because it implies lower future repair costs and a long period of uninterrupted service. It may mean higher initial prices, however. Non-corroding materials are more expensive than those more vulnerable to the elements. Low wear designs are more costly than simple sliding contacts. Stronger parts may use more materials or use more expensive materials, or both. The results are likely to produce higher first costs. Perhaps, because of added weight, as in an automobile, higher durability will mean higher operating costs as well.

2. Make the product easy and inexpensive to repair. Where durability is an expensive or technically difficult alternative, products can be designed to make repair and replacement of worn or damaged parts simple and economical. This can involve designs that make parts easily accessible, parts that are standardized and available locally, and clear instructions on repair routines. Ease of repair provides the user with low maintenance expense and assurance that when the product fails it need not be out of service long. The product lifetime may not be trouble-free, but it can be long. Repair service, however, frequently involves calling in a person to handle the repair, sometimes from considerable

distances. The costs of a service call, even if the parts costs and the time to diagnose and fix the problem are small, can be high because of travel time. This strategy also implies that stocks of replacement parts will be maintained at convenient locations to cover the entire lifetimes of products that could operate for 20 to 30 years or more.

3. Train the user in product use and care to reduce failure due to neglect, overstress or accident. Both manufacturers and users would agree this is a desirable objective, but both fail to do as much as they might to accomplish it. Companies spend large sums preparing operating manuals, conducting training classes and providing field representatives, but instructions are frequently inadequate or overly complex and users seldom heed them. Further, for commercial or industrial equipment employee turnover may result in a loss of operating know-how.

4. Provide incentives to people to repair rather than replace, durable products. This is an public policy alternative, not one likely to be favored by manufacturers. It might be possible, for example, to allow repair agencies and parts warehouse distributors to write off the cost of the parts they stock as they are obtained, rather than holding them in inventory as a capital asset until sold. This would make longer-term holdings of parts more feasible and increase the chances that an older item of equipment would be repaired at reasonable cost when it fails. Allowing consumers to treat the cost of repairs as a deduction for income tax purposes (as is now done for health maintenance expenses) might encourage them to hold products longer. Businesses already have this option, so this incentive only applies to individuals.

5. Encourage used goods markets. Used product markets exist for industrial and commercial equipment, but such markets are very weak in all consumer durable areas other than automobile parts. The simple rules of supply and demand appear to operate effectively in these markets, except that customer bias against used equipment tends to discourage demand, especially in the individual consumer area. There is little government encouragement of used product markets, but there is little government interference, either.

6. Remanufacture the product when it can no longer be repaired economically. Remanufacture is a generally viable alternative when re-use is no longer possible or when the uncertainties of re-use without overhaul are too great. It is a strategy frequently overlooked in an affluent, resource-rich society such as that of

the United States, and it appears to be underutilized in countries lacking in affluence or resources. A better appreciation for the benefits of and the barriers to remanufacturing may serve to put this activity more solidly in the array of strategies for longer product life.

6.2 Remanufacturing Benefits

Remanufacturing activities in the United States provide general social and economic benefits as well as more restricted benefits to the entrepreneur or operator of a remanufacturing venture. Virtually all of the general benefits are appropriate to other countries, whether industrialized at present or trying to develop an industrial base. There are additional opportunities we believe exist for the application of remanufacturing practices in developing countries, and these are detailed after our cataloging of the advantages for U.S. society and industry.

6.2.1 Social and Economic Benefits

First among the general economic benefits of remanufacturing is its conservation of resources. It recaptures value of energy, labor and capital equipment going into the original manufacture of a product, and it maintains the product's materials in a high value state. Relatively small amounts of additional energy, labor, capital equipment and materials are needed to recapture most of the product's original value. The ratios of energy leverage are on the order of 4:1 to 5:1. The ratios of materials leverage are about 5:1 to 7:1 or better. In a society troubled by energy and materials scarcity and rising prices, these features of remanufacturing are important contributions to the country's future well-being.

Because of the relatively low value attached to an inoperable, worn out product, the differential between the cost of a core and the price that can be obtained for a remanufactured product can be substantial, yet the price will average 40% less than that for a comparable new product. This means that users can buy equipment at lower cost or in some instances, buy higher grade equipment at prices competitive with new but lower grade items. The ability to get more goods and service for a given level of expenditure is an increase in standard of living. A greater range of product choice is available to the buyer and the lower prices stimulate competition from new product manufacturers.

Despite the fact that remanufacturing serves to recapture labor that does not have to be duplicated, the activity itself is labor intensive, and furnishes employment opportunity for a range of laborers, particularly those entering with only moderate skills. It can contribute to the re-employment of people in labor surplus areas, because it is a fairly portable activity. Its activities also bring income to other suppliers of goods and services in the area.

The fourth societal benefit from remanufacturing has already been described earlier in this chapter. By prolonging product life remanufacturing reduces waste. Although the amount of durable products in the solid waste stream is only a very small fraction of the total, in the United States it is still measured in the millions of tons annually in the United States.

6.2.2 Benefits to the Remanufacturer

The barriers to entry into remanufacturing are low. Capital requirements are modest and can be scaled with growth. For remanufacturers in developed countries, labor skills requirements are rather easily met. In developing countries skills may be less available, but most can be provided by plant-level training. Technological know-how is readily available or can be developed through means such as "reverse engineering," the process of deducing the design of a product by disassembly and analysis of individual parts and their interactions.

Modest levels of investment, however, can produce high return. Remanufacturing has been a profitable form of enterprise in the United States. Two factors seem to account for this. Few prospective entrepreneurs are even aware of the opportunities in this business because of its low visibility and status. Secondly, there remains a large economic gap between the market value of a non-functioning core and its economic worth to a remanufacturer. This gap is the remanufacturers' profit source.

For the OEM, remanufacturing offers several additional benefits. If there is price elasticity in its product markets, an OEM may be able to offer remanufactured versions of its products at substantially lower prices. This can broaden market appeal and increase overall sales. (For products in an inelastic market the converse can be true -- remanufactured goods could cut into new product sales.) Arrangements for good trade-in prices for old units creates customer loyalty to the company's brands. By controlling remanufacture of its products a company also protects the reputation of its brand or trademark from inferior workmanship.

Knowledge gained from the condition of products returned as cores gives the OEM valuable information on what goes wrong with the product. The effect of the environment in which the product is used is also readily apparent. Where there are design flaws that lead to excessive wear or breakage, the OEM can correct these faults and upgrade the performance of its older products as well as improve its new products. Finally, the prospect of having to disassemble the product for remanufacture forces the company to adopt design practices that facilitate both repair and remanufacture, a benefit to both the firm and its customers.

Many firms today are moving strongly toward advanced forms of automation that have the potential to displace a great many workers. Those companies that do not wish to see these employees laid off or terminated may find that the establishment of a remanufacturing operation helps to absorb these displacements in a gainful manner.

6.2.3 Benefits to Other Countries

For other highly industrialized countries the benefits of remanufacturing are likely to run parallel to those listed above for the United States. We have indications that this is true from a paper by Warnecke and Steinhilper of the Frauenhofer Institute for Manufacturing Engineering and Automation[2], where benefits similar to those cited by our studies were reported for Germany.

The position of a highly industrialized country such as India is almost unique in its great contrasts between aggregate capability and individual deprivation. For this country, and others like it, remanufacturing must be a way of life. The extension of the concept to the remanufacture of imported cores for export as products is a logical and potentially advantageous move, since it provides employment and foreign exchange with minimal drain on the country's energy and materials resources.

For developing countries, where there is likely to be a shortage of cores, the concept of core import seems to be a reasonable way of starting or augmenting a remanufacturing venture. Remanufacturing can be viewed as an easily achievable early step in the development of an indigenous (as opposed to foreign-owned) industrial base in the country. It provides training in essential industrial skills and management. It accomplishes permanent transfer of the technology of the goods being remanufactured by requiring managers and workers to develop solutions to problems of disassembly, refurbishing, reassembly and test. This approach provides excellent opportunities for learning, regardless of whether the product is a refrigeration compressor, a truck, an electric motor or a computer.

Remanufacturing provides a bootstrap approach to countries that need capital goods for industry, transport, communications, and other vital services but are lacking in foreign exchange. If remanufacturing were to concentrate on these essential products, its activities would not only provide trained workers but it would also provide the machines for them to use.

A remanufacturing operation can also supply replacement parts and service people for maintenance of equipment already in the country but which is only marginally productive because of lack of repair. As was pointed out in the Nigerian study[3], relatively new equipment is frequently abandoned because of the user's inability to keep it in working condition. A remanufacturing firm could provide parts and repair service as an adjunct to its main rebuilding operations.

Remanufacturing can be the first stage of development for a firm that eventually will be producing its own new products. Barnett[4] cites the experience of two South American firms that started out as remanufacturers but when they had assimilated the technology began to manufacture the products as well. This would appear to be a reasonable evolutionary path for many remanufacturing ventures.

For some developing countries, too rapid urbanization has had a destabilizing effect on the economy. The fact that remanufacturing operations can be located wherever cores can be brought, makes this a possible instrument of government policies aimed at bringing industrialization to rural areas.

6.3 Barriers to Remanufacturing

As any person who has gone into remanufacturing can attest, this is not a perfect world. There are serious barriers to this form of activity, and these must be recognized and dealt with if the venture is to be successful. Some of these are the normal problems incurred in starting up or operating any form of business, but there are others that are peculiar to remanufacturing. These are the barriers discussed here.

Market attitudes against used products can be a very intractable problem, particularly in product areas in which the customer is not likely to be an expert buyer, or where newness is considered at least as important as utility. The price advantage enjoyed by remanufactured products is a powerfully persuasive argument, but if buyers are convinced that a used product, even if remanufactured, is inferior and entails high risk, the product will not sell. This attitude may carry over into public policies that are designed to discriminate against used products. Laws requiring that products containing used parts be so labeled serve to discourage firms from adopting practices that might, in fact, provide real savings to the customer.

A lack of cores of high quality and reasonable cost can limit the scale of a remanufacturing operation. This aspect of remanufacturing should be checked out carefully before launching any new venture. This was considered a serious barrier by most of the respondents to our remanufacturing survey.

Independent remanufacturers face other obstacles to their success. Opposition from OEM's that make the products being remanufactured can make life very difficult. An OEM can refuse to sell replacement parts to the remanufacturer at reasonable prices. It can refuse to divulge design or specifiction information needed by the remanufacturer to make the parts and/or to test product performance. An OEM can use its influence with its suppliers to discourage them from dealing with a remanufacturer, and it can exercise similar influence over its dealer network. Relationships between OEM's and independent are seldom cordial (unless the remanufacturer is under contract to the OEM), but it is fairly rare that an OEM will actually campaign actively against a remanufacturer.

There are also more subtle ways of causing trouble for the remanufacturer. Frequent design changes that make parts for newer models incompatible with older units tends to discourage remanufacturers from taking on a given brand of products. Suarez' study on motorcycle remanufacture[5] indicated that this tended to be the situation for Japanese-made motorcycles.

Remanufacturers in developing countries may experience additional antipathy toward used equipment because of prior unfavorable experiences with unscrupulous importers or with multi-national firms that used the mechanism of charging high prices for "used machinery" that was little more than scrap metal as a means of repatriating earnings from a subsidiary. Tariff barriers that are designed to encourage domestic industry may make it difficult to obtain new replacement parts, and this can discourage remanufacturing.

It is expected, however, that the greatest barrier to remanufacturing in developing countries will be the lack of demonstrated successes in remanufacturing, which will lead to entrepreneurs having an appreciation for the opportunities of remanufacturing and the know-how to establish such an activity. This basic problem must be resolved before any appreciable progress can be made.

6.4 Societal Issues

It would not be appropriate to close this chapter on the benefits of remanufacturing without mentioning two fundamental issues that need to be considered before making decisions on the appropriateness of remanufacturing for any given situation.

6.4.1 Labor Effects

The first of these issues is that of its effect on labor. Remanufacturing both saves labor and uses labor. Is the net effect beneficial or adverse to labor? The answer to this question, it would seem, depends on the market response to the remanufactured product. If the lifetime of a product is prolonged and its average cost reduced by remanufacturing, one of three things can happen:

1. People need not buy as many of that product, or
2. People can now afford to have more of the product, or
3. More people can afford to have some of the product.

In the first case people will spend that part of their income saved to buy other items, in effect shifting demand to other products, or they may bank their savings and thus supply others with the capital to spend on other things. In either of these actions there will be a reduction in annual demand for the product whose life is prolonged, and the effect will be displacement of workers from OEM producers. Some of the displacement will be offset by employment in the remanufacturing sector and some by employment in the companies whose products are now more in demand.

In the second and third cases there may be no labor reduction in the OEM's because other customers are attracted to the remanufactured products and demand for new products is unaffected.

In all three scenarios, more goods are available to society than heretofore and at minimum increase in economic cost. The efficiency of the system has improved. This is a net increase in the standard of living for the society.

The problem for labor, then, is the perennial problem of displacement that can occur with any change in technology, market response or economic conditions. It is the problem of the inequitable burden placed on those who must adjust to the change with little or no compensation for doing so. The long-term effect is societal gain, but the short-term consequence may be transitional hardships for some of society's members.

6.4.2 Innovation Effects

The second major issue concerns the effect of prolonging product life on innovation. If the system of manufacturing/remanufacturing operates so as to keep things functioning virtually forever, will that not stifle technlogical change and product and process improvement?

This is a subject that deserves more consideration than can be be devoted to it here, and the views that follow are offered as only a very preliminary assessment.

Longer product life will not serve to stop truly innovative, "breakthrough" technology. The durability of electromechanical adding machines did not deter the sweep made by electronic calculators, nor did the durability of steam locomotives stop the transition to diesel engines. Important changes that modify the performance or cost of a product will continue to cause switching to new products.

Remanufacturing may even facilitate the transition to new technology, particularly if the new technology is somehow compatible with major parts of the old product. The installation of microprocessor controls in conventional machines is an example of an instance where remanufacturing serves to speed technological change.

Remanufacturing may also facilitate change by providing a ready market for used equipment. Firms wishing to make changes may do so at lower cost because of the trade-in value of the old equipment. Changes may not necessarily be for reasons of modernization; they may be to increase capacity, shift products or modify processes.

On the other hand, remanufacturing may serve to discourage more superficial product changes, because the market may be smaller and the rewards from making trivial changes may be small. Whether this effect is ever seen will depend heavily on the presence or absence of competition, because the forces of competition are more likely to influence product change much more strongly than product life.

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7 IMPLEMENTATION OF REMANUFACTURING IN DEVELOPING COUNTRIES

The MIT studies summarized in this report are the first comprehensive approach to the subject of remanufacturing that has been attempted. Most importantly, the studies have made it quite clear that remanufacturing remains an area of economic opportunity both in industrial and developing countries of the world.

Our studies reveal an industrial activity that has low visibility in society, has only rudimentary organization as an industry, obtains very little public encouragement for its efforts and yet provides an impressive list of benefits to society. The members of this industry have profited from the opportunities that exist and they are proud of the service they provide.

Economic trends in the United States and abroad point toward the need for encouragement of remanufacturing. Growing demands for increasingly scarce materials and energy resources, unemployment in developed countries, and underemployment and rising expectations in third world countries are all conditions that remanufacturing addresses. Few other activities produce as much good while placing such a small claim on our physical resources. The question is, what needs to be done to stimulate remanufacturing activities? The following sections present some of our views on this subject.

7.1 Recommendations for Industrialized Countries

Most industrialized countries or regions of countries have the sources of capital funds, technical know-how, core supply, replacement parts and product markets that make remanufacturing feasible. When financial and economic opportunities for remanufacturing become manifest, entrepreneurs and agencies will show up to exploit them. In this environment, three forms of encouragement appear appropriate:

1. A program of information dissemination that calls attention to opportunities for remanufacturing and that provides guidelines to people interested in starting a remaufacturing operation.

2. An examination of the public and private policy climate for remanufacturing, with the objective of (a) identifying unnecessary barriers and suggesting ways to eliminate them and (b) recommending policies that could stimulate growth of this activity.

3. A cooperative study of remanufacturing practices and policies in other developed countries for the purpose of exchanging ideas, identifying opportunities, and raising public awareness.

These suggestions imply that, with sufficient information and a favorable environment, market forces will operate to stimulate the growth and development of remanufacturing operations in these countries.

7.2 Options for Developing Countries

In countries where many of the essential ingredients for spontaneous industrial development are missing or in very short supply, a very different program is called for. Because it appears that some of the most impressive opportunities for remanufacturing reside in these developing countries, this is an area that deserves attention and support from international agencies for economic development as well as allocation of national resources on its behalf.

At this time our understanding of all the issues involved in the application of remanufacturing to developing countries is far from complete. For this reason it is impossible to identify all the measures needed to promote remanufacturing among these countries. Some of the main thrusts for a program of this kind, however, are fairly clear. They include:

1. The development of international sources of and markets for cores.

2. The establishment of remanufacturing operations within developing countries.

3. The development of internal and foreign markets for remanufactured goods.

Some of the steps that are needed to accomplish these objectives are presented below. If a program of this type is initiated it is very likely that other tasks will become apparent as a result of problems or opportunities encountered.

7.2.1 Survey of Existing Remanufacturing Activities

An assessment of existing remanufacturing activities in selected countries is needed as a first step in providing knowledge about the local economic climate for remanufacturing, local sources of expertise, problems being experienced, and the extent of support needed to establish new remanufacturing pursuits. There is a high probability that some form of remanufacturing or rebuilding is being carried out in every country that has ambitions for industrial development. It is necessary to examine these activities for clues on how to expand them or to introduce new modes of remanufacture such as that of using imported cores. In any event, the four phases listed in Section 4.2 and 4.3 for selecting a product for remanufacture are essential.

7.2.2 Investigation of Core Sources

Because core supply is such a critical item in any remanufacturing operation, a key study will be the evaluation of core sources for selected industrial and commercial products. It probably will be necessary to do such studies with reference to a specific country or group of countries because trade relationships vary. Each study should have two facets, one being the location of core sources in readily accessible industrial countries such as the United States, Germany, France, Italy, Japan, Sweden and Great Britain. The second facet would be to find and appraise possible core sources from within the developing country or its neighbors.

7.2.3 Detailed Market Surveys

In each country embarking on a remanufacturing program it will be necessary to conduct a product selection screening and surveys of the markets for prime candidates. These surveys will guide the selection of a product for demonstration purposes. Markets to be examined should include not only that indigenous to the country but also markets within their trading neighbors and, more broadly, international markets.

7.2.4 Demonstration Projects

It is essential to establish one or more demonstration remanufacturing activities in each country of interest. The purpose would be to show how it can be done and to identify the problems likely to be encountered. The several demonstrations should be based on different models. Four options have been identified:

1. An "educational" model, based on a connection with a technical or vocational training institute

2. A commercial model in which the venture is an independent enterprise

3. A commercial model in which the remanufacturing is done by a branch of an OEM.

4. A public agency model, where the remanufacturing operation would be a governmental or quasi-governmental function.

7.2.5 Information Agency

A final recommendation in this preliminary listing of the elements of a remanufacturing program for developing countries is the establishment of an organization or agency that acts as a clearinghouse for information on all aspects of remanufacturing, provides expert support for demonstration projects and is an advocate for greater recognition of remanufacturing. Such an agency would serve as a repository of data, and would assist in the exchange of information on materials sources and product markets. It would probably be associated in some manner with an organization responsible for international industrial development programs.

7.3 Conclusion

In putting together this series of recommendations we have focused on concepts, not on how each step should be accomplished or on who should do it. These latter items are best left until a sponsor or sponsors for these tasks are found. The World Bank has taken a first step in sponsoring the preparation of this report. It is hoped that that agency will take the lead in championing the development of an international program for remanufacturing.

APPENDIX A

CASE DESCRIPTION OF A U.S. MACHINE TOOL REMANUFACTURER

(Excerpt from Energy Savings Through Remanufacturing: A Pre-Demonstration Study, Interim Progress Report, CPA-80-6, MIT Center for Policy Alternatives, August, 1980.)

V. A U.S. MACHINE TOOL REMANUFACTURER

A. INDUSTRY BACKGROUND

1. The U.S. Machine Tool Industry

The U.S. machine tool industry is a small industry in terms of sales (value of 1978 shipments is estimated to have been about $4.5 billion), but it is one which is critical to the performance of other sectors of manufacturing. The most recent Census of Manufactures (1972) reported more than 1,200 machine tool building establishments, but of these, nearly two-thirds employ fewer than 20 persons.* Only ten machine tool builders employ more than 1000 employees, with an average for this group of 2,500 employees per firm. Geographically, the industry is concentrated in the Middle Atlantic and Midwestern states, with smaller concentrations of firms in New England and on the West Coast.

Metal cutting machines make up about 73 percent of shipments by value (value of shipments is estimated to have been $3.25 billion in 1978). They are produced by 894 establishments, of which 275 have more than 20 employees.

The major types of metalcutting machine tools are drilling, milling, boring, turning, and planing and shaping machines. All of these machines remove metal from a workpiece by the relative motion of a cutting tool and the workpiece. Other types of machines usually included in the metal cutting category are grinding machines and machines which remove metal by electrical or electrochemical action.

2. Numerical Control of Machine Tools

The direction of cutting tool paths by electronic means, using servomechanisms and position feedback devices, was first accomplished in the early nineteen-fifties. Numerical control, in which a tool path is generated off the machine and fed to the control as a sequence of numerically-coded instructions, was promoted by the U.S. Air Force as a means of performing some of the complex milling and drilling operations required in aerospace work.

Although numerical control did permit the machining of complex hole patterns and contours without the use of templates, the technology was hampered by the limitations of available controls and electronics. The first electronic controls were bulky and unreliable, consisting as they did of hundreds and even thousands of discrete electronic and hydraulic components (the control for the Pratt & Whitney Tape-O-Matic Model "A"

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* The Census of Manufactures tends to focus on large establishments; coverage of small firms is thus not reliable.

drill, introduced in 1958, contained over 160 separate printed circuit cards). The number of electronic components and electrical connections created very high opportunities for failure. These were increased by the surroundings in which the controls were placed; the dirt and vibration of the shop environment, and the heat dissipated by the electronics themselves all contributed to machine downtime.

Developments in electronics have brought rapid improvements in machine tool controls. The relays and vacuum tubes used in the earliest controls have been replaced successively by transistors, integrated circuits, and micro-computers and microprocessors. The increasing reliability and sophistication of these controls has greatly expanded machine capabilities, while at the same time lessening many of the drawbacks of early machines.

Electromechanical equipment has been improved as well, although less dramatically than electronics. Tape readers have all but replaced the plug board program loading devices used on some early machines. The readers themselves have been upgraded, from the slow and failure-prone mechanical readers of the nineteen-sixties to pneumatic readers, and finally to the optical readers used on many machines today. Even these readers are increasingly being bypassed, with flexible magnetic disks becoming the main means of active program storage and retrieval. Electromechanical memory may itself be replaced with semiconductor or magnetic bubble memory storage in the near future.

Improvements have also been made in drive motors, actuators and position feedback mechanisms. DC shunt motors have replaced AC motors and speed reduction units for many machine tool applications; work table positioning, for example, can now be accomplished directly by DC motors driving the ends of the table lead screws. Developments of this type have permitted simplification of machine tools, and diminished many of the inaccuracies and inefficiencies inherent in mechanical transmissions.

Simplified machines and controls have reduced the complexity of shop maintenance for numerically-controlled machines. The early controls, besides being prone to failure, contained so many components and connections that tracing a malfunction became a difficult and time-consuming task. Although the use of plug-in modular circuit boards did somewhat simplify maintenance of early controls, diagnosis of malfunctions did not become significantly easier until the nineteen-seventies, with the advent of integrated circuit controls with built-in diagnostic capabilities.

The development of numerically-controlled machine tools has been a process of gradual integration of machines and control units. Within recent years, as controls have become more flexible and machines have been adapted to their capabilities, the control has become a part of the machine tool, rather than a unit that was added on to it. This process has opened up many opportunities for machine redesign.

As a consequence of the evolution of controls and machine/control units, many early numerically-controlled machine tools have become outdated. Their mechanical elements remain sound, but their aging drives

and controls cannot match current machines for reliability, accuracy, repeatability, or maintainability. Moreover, they are outdated by the lower noise levels and electric power consumption of current models.

3. Machine Tool Rebuilding

Machine tool rebuilding characteristically takes two forms; (1) the rebuilding of a machine by its owner or an outside contractor, and (2) rebuilding by dealers in used machinery. These two types of rebuilding differ in several important respects.

Many dealers in used machine tools maintain some machine repair capability on the premises, and it is common for a machine to be functionally tested, cleaned, repaired and repainted before being offered for sale. These machines are sold as "refurbished" or "reconditioned," and may be covered by some limited form of warranty (many dealers offer a 30-day return policy). Occasionally a used-machinery dealer will completely dismantle a machine and rebuild it to original specifications (machines rebuilt in this way are also referred to as "reprecisioned"). High-value or high-precision machines, such as boring mills, are rebuilt in this way, but for most used machinery, complete rebuilding does not raise the value of the machine sufficiently to offset the additional cost.

Users of machine tools rebuild their own machines to preserve their accuracy or to upgrade them to current standards. This is usually less expensive than buying a new machine, and avoids the long lead times associated with new-machine orders. Larger manufacturing establishments, particularly in industries which are heavy users of machine tools, may have dedicated machine tool rebuilding and repair facilities. Several aerospace companies rebuild their own machine tools at regular intervals over a machine's lifetime, so as to maintain new-machine precision for as long a period as possible. One incentive for this is the high cost of new machines; rebuilding programs of this nature may help explain why over 50 percent of the machine tools in the aerospace industry are over 20 years old (This compares with 34 percent for metalworking as a whole).

In-house rebuilding programs of this type are, however, vulnerable to economic cycles. At Boeing Aerospace, for example, the decline in aircraft orders at the end of the 1960s forced the in-house rebuilding shop to seek outside work in order to survive.

This vulnerability, together with the high cost of maintaining a dedicated rebuiding shop, make the use of outside rebuilding services attractive to many firms. Some of these rebuilding services will perform work on the customer's floor, while others operate rebuilding facilities of their own.

A number of machine tool manufacturers offer rebuilding of machines as a service to their customers. At least one of these firms also buys and rebuilds popular models of its milling machines and machining centers.

In addition to these services provided by original manufacturers, there are independent firms which specialize in machine tool rebuilding. Some of these companies have specialized further; one firm, for example,

rebuilds only large, one-of-a-kind machines, while at least six have specialized in numerically-controlled (N-C) machines. D & D Electronics, one of the leading N-C machine rebuilders in the United States, is the subject of this case study.

B. D & D ELECTRONICS*

1. Company History

D & D Electronics, located in Hartford, Connecticut, is an independent rebuilder of numerically-controlled drilling, milling and boring machines, and also manufactures a sophisticated N-C chucker.

The company was formed in 1967, by two specialists in N-C electronics. Both partners had worked for Pratt & Whitney Aircraft until 1962, and were skilled in the service and repair of the first-generation electronic machine tool controllers which began to be introduced into the aerospace industry in 1957. After leaving Pratt & Whitney, they started an independent N-C repair service. The type of service they provided, troubleshooting and repair of N-C controllers, was very much in demand at that time, as experienced N-C technicians were in short supply even among the larger firms in the area. They continued as a repair service until 1964, occasionally rebuilding complete controllers for clients. Gradually they began to coordinate the rebuilding of complete machines on the customer's premises, although their work still concentrated primarily on machine electronics.

During this time, the partners purchased a broken-down N-C machine tool, which they rebuilt, renting some space in a warehouse for the purpose. David Duquette, now President of D & D Electronics, recalls that they showed the machine to a prospective buyer before it had been tested as a unit. When he turned the machine on for the customer, the fuses blew out in the building. He recalls that the buyer calmly wrote them a check in the dark.

D & D has grown steadily since its formation. In 1967, the company occupied 3,000 square feet of leased shop space. In 1971, it moved into a 10,000 square foot facility, and by 1977 it had ougrown this shop, and moved to its present 25,000 square foot plant. With each move, the number of persons employed by the firm doubled, reaching a total of 70 employees, of which 45 are shop employees, after its most recent move.

2. Product Line

D & D Electronics' remanufacturing activities began with the remanufacture of Pratt & Whitney Tape-o-Matic drills. The Tape-o-Matic was introduced by Pratt & Whitney Machine Tool (now a division of Colt Industries) in 1958. At the time, the machine, a numerically-controlled drill, was the least expensive N-C machine tool on the market. It had a

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* Since publication of the report containing this case, the name of the firm has been changed to U.S. Machine Tool Company.

simple point-to-point positioning control, and the Model A, which had a 30" by 20" table, could be purchased for $8,500. The Tape-o-Matic was popular, and it introduced a great many machine shops to N-C. Pratt & Whitney subsequently added a Model B, which included a more powerful spindle drive and longer quill travel, and a Model C, with a larger table (45" by 29"), a 5 hp spindle, and improved features. Paul Seelbach, Vice President of Marketing of D & D Electronics, estimates that over 3,500 Tape-o-Matics had been sold in the United States by the time Pratt & Whitney discontinued the model line in 1971.

Pratt & Whitney Machine Tool is located in Hartford, Connecticutt, and many early Tape-o-Matics were sold to metalworking firms in the New England region. D & D's specialization on the Tape-o-Matic was natural. In its early years, the company repaired and rebuilt a wide variety of numerically-controlled machine tools, but it frequently was asked to rebuild Tape-o-Matic drills. Moreover, the Tape-o-Matic was attractive to D & D because it was mechanically simple by comparison with other N-C machines. It had only 2 axes of table positioning, and contained no hydraulic components. Its control hardware was, in fact, more costly than the rest of the machine tool. In addition, Pratt & Whitney's location in Hartford provided convenient access to machine documentation and spare parts.

In addition to the Tape-o-Matic, D & D Electronics specialized in the remanufacture of Cincinatti's Cintimatic line of vertical and horizontal machining centers (according to Paul Seelbach, "it was a toss up as to which machine we would concentrate on. We chose the Tape-o-Matic because Pratt & Whitney was nearby."). The Cincinnati machines, which were introduced a little later than Pratt & Whitney's Tape-o-Matic, were similar in their simplicity and rugged mechanical features. Like the Tape-o-Matic, the Cintimatics were built in relatively large numbers as standard machines.

D & D Electronics also remanufactures boring machines, chiefly numerically-controlled Lucas and DeVlieg (Jigmil) horizontal boring mills. These machines are extremely rigid and durable, built for precision in heavy production work. Both the Lucas and DeVlieg machines were well-established before the advent of N-C, and numerically-controlled versions of both have been popular.

In addition to these four machine tool types, D & D occasionally rebuilds other machines which have not become part of the regular remanufacturing product line. These include multifunction numerically-controlled machining centers, N-C lathes, N-C drilling, milling and boring machines of other manufacturers, and a small number of manually-controlled jig borers.

The company does not plan to remanufacture numerically-controlled lathes on a regular basis. Paul Seelbach explains that because N-C lathes were developed later than N-C milling, drilling and boring machines, they are not yet available for remanufacture in large numbers. Furthermore, turning machines are quite different from other metal cutting machine tools (This distinction is evident among machine tool builders as well - turning machine manufacturers tend not to build other machine types, and vice-versa). D & D has also chosen not to rebuild

multifunction machining centers, because these machines employ hydraulic or pneumatic actuators for clamping, indexing, and tool changing. These actuators cannot be satisfactorily replaced with electronic devices, and they add significantly to the cost and complexity of remanufacturing a machine.

The company intends to continue adding new machine models to their product line, but plans to do so slowly. There is a temptation, its managers say, to add models too rapidly, which they fear would strain the firm's engineering resources, increase shop floor and administrative costs, and reduce profitability. Instead, they prefer to wait until they have turned down a number of requests to rebuild a specific model of machine before considering its addition to their remanufacturing line.

Ralph Thompson, who joined D & D as Vice President of Engineering in 1977, explains that requests for quotes on specific machines are a first indication that the machine may be a good candidate for remanufacture. If D & D is interested in the sales potential of a machine model, he adds, it is frequently possible, through the firm's contacts in the machine tool industry, to learn roughly how many units of that model have been sold. Since most machine tools which are sent to D & D for remanufacture are between 8 and 15 years old (10 to 12 years is the most frequent age range) the sales data of interest to D & D are often a matter of historical record to the manufacturer, and are thus available.

According to Ralph Thompson, other criteria used in the initial evaluation of the "remanufacturability" of a machine tool include the original cost of the machine, the current cost of a comparable model, and the proportionate cost of the "iron" (machine bed, table, column and headstock) and the control and drive system. Rework and replacement of the controls and drives constitute a major part of the cost of remanufacture, as the castings and major mechanical components of the machine tool can nearly always be remanufactured for a small fraction of their new cost. The cost of remanufacture relative to original cost therefore varies according to the type of machine. In the case of early-model Tape-o-Matics, for example, the cost of the control originally exceeded the cost of the mechanical assemblies, and the cost of remanufacturing the machine is therefore high relative to original cost (and may even exceed it), although it is between 50 and 60 percent of the cost of a comparable new model.

D & D Electronics has added one machine model to its product line each year since Ralph Thompson joined the company, and expects to continue expanding its product line at this rate.

C. REMANUFACTURING OPERATION

1. Engineering

Remanufacturing of machine tools at D & D Electronics almost always includes the updating of machine controls and drives. The principal exceptions are the Pratt & Whitney Tape-o-Matics. The controls for these machines are rebuilt to original specifications, because this is less expensive than fitting the machine with a modern control (the

Tape-o-Matics require only point-to-point positioning; modern controls offer continuous-path capabilities which could not be used on these machines). Updating may include replacement of the AC spindle motors and hydraulic axis drives with DC silicon-controlled rectifier (SCR) motors driving the spindle and axis lead screws directly. In addition, the numerical control unit may be replaced with a new, more reliable and more compact unit, and new features may be added to the operator control panel.

The addition of these systems requires considerable re-engineering of the machine. This is a time-consuming process, and D & D is unwilling to invest the engineering effort necessary to remanufacture a machine unless a sizeable pool of machines of that model and vintage exists. The company expects to break even or even lose money on the first one or two units of each new model it remanufactures, and remanufacturing may not become profitable until 3 to 5 units have been remanufactured. The profitablility of D & D's remanufacturing depends on continuing to attract machines of a specific model after it has made the initial investment in learning how to remanufacture that model. The company has therefore concentrated on widely-used models, which it can expect to remanufacture frequently. For these machines, D & D can develop comprehensive documentation and standards, and apply systematic rebuilding procedures, thus streamlining the process of rebuilding.

The involvement of the engineering department in the remanufacture of a machine begins as soon as the Sales Department receives a request for a quote. The engineering department requests from the prospective customer any documentation and manuals the customer may have for the machine. Engineering will accept or turn down the job based on D & D's experience with the machine type, its similarity to machines already in the model line, and the existing engineering work load.

When D & D undertakes the remanufacture of a new type of machine tool, the machine is put into the hands of the engineering staff from the moment a quote is prepared. Redesign and re-engineering of the machine begins with a decision on the level of technology to be incorporated into the machine. Depending on the machine and on customer requirements, the unit may be:

1. remanufactured to original specifications,
2. fitted with new DC axis drives and new numerical control or computer numerical control, or,
3. fitted with new DC axis drives, a DC spindle drive, a computer numerical control, and contouring capability.

In the second of these cases, the rebuilt machine exceeds original performance characteristics, but may not match the performance of current models. The third level of remanufacture not only exceeds original specifications, but may even match the performance and features of new machines.

The level of technology to be incorporated into the machine is decided before a cost estimate for the job is submitted. Once the decision has been made, the engineering department must select DC axis-drive and spindle-drive motors, transmissions, and spindles and axis

lead screws. Spindle drive motors must be sized to deliver the same horsepower as the original drive motor in each spindle speed range, and must be able to fit within the headstock. The design of adaptors, brackets and modifications to castings may be required to accept the new components. Great care must be taken when upgrading the machine so as not to exceed its original design specifications. New axis and spindle drive specifications are submitted to the customer as part of D & D's remanufacturing quote.

When a new job arrives at the plant, the engineering staff dissasembles the machine, inspecting parts before and during disassembly. Parts which will need to be replaced routinely during remanufacture are identified, as are parts which may be reusable or reworkable on a case-by-case basis. Original horsepower, speeds, accuracies, and features of the machine tool are determined from its accompanying documentation, inquiries to the manufacturer, and inspection of the machine.

Following the receipt and disassembly of the machine, orders are placed for those items which have long order lead times. On the first machine of a new type, these orders are placed once inspection of the machine has corroborated the preliminary engineering work. Such orders have customarily been placed within two weeks of the arrival of the machine at D & D Electronics. Long-lead items required for the remanufacture of a machine tool typically include the electronic control, delivery of which may take 24 weeks; lead screws, which are either sent to the manufacturer for regrinding or replaced, in which case lead time will be between 8 and 10 weeks for a low precision screw; and axis and spindle drive motors, which can usually be obtained in 8 weeks. High-precision leadscrews take 3 times as long to obtain and cost twice as much as low-precision versions. Their accuracy is seldom necessary, however, as modern controllers can be calibrated to compensate for the positional errors of less accurate lead screws.

The engineering and documentation of a remanufactured machine tool requires the production of drawings for some 70 to 80 engineered parts, and represents between 200 and 300 hours of engineering effort. The engineering department also produces drawings, electrical layouts and wiring diagrams for use in the assembly of the machine.

Fitting the new control unit to the machine, and testing and debugging the machine and control, can take two to three weeks for a new combination of machine and control. A typical state-of-the-art control has some 96 input-output (I/O) terminals that must be tested. Once this work is completed, each axis is calibrated by means of laser interferometry. Finally, the engineering department prepares owner's and operator's manuals for the machine.

The function of the engineering department has changed over the past two years. When Ralph Thompson became Vice President of Engineering, he and the rest of his staff were spending approximately 70 percent of their time in the shop, and 30 percent on design development. Today, he estimates that the department spends 50 percent of its time on development, and that only 50 percent is spent in the shop. This reduction in time spent in the shop may be a result of improved

engineering documentation, or it may indicate that Engineering is no longer involved in documenting procedures that had been developed and implemented before the effort to develop comprehensive standards began. The engineering department is continuing to develop remanufacturing programs for machines which D & D has not remanufactured before.

2. Process

The thoroughness of D & D's "new" product engineering plays a role in the subsequent remanufacture of machines in the product line. Inquiries from prospective customers are relayed to the engineering department, which prepares a quote and cost estimate based on its own documentation for the machine type, additional documentation supplied by the customer, and special customer requirements (which range from the degree of updating desired to choice of control and specification of special tool holders). The final quote includes a delivery forecast, based on current workload and known component lead times. D & D currently offers delivery within 12 to 16 weeks of receiving a machine, although lead times vary considerably according to the type of machine being rebuilt, from as little as 8 weeks for a small Pratt & Whitney Tape-o-Matic, to nearly a year for a large boring mill. If the quote is accepted, D & D supervises the removal of the machine from the customer's shop floor and its shipment to Hartford.

When the machine arrives in the shop it requires little involvement on the part of the engineering department, except inspection of the machine during disassemby to verify critical machine details which may vary from unit to unit or from one model year to another, and to make any consequent adjustments to the standard remanufacturing procedure.

Once it arrives at D & D, the machine is first stripped down to its castings. Worn parts, including bearings, bushings, ball bushing blocks, springs, belts, and seals, are discarded. Electrical wiring and pneumatic and lubrication tubing is also discarded. Other parts, including motors, pulleys, clutches, gears, shifter forks, guide rails, spindle assemblies and lead screws are inspected and either reworked to original specifications or replaced.

The castings themselves, including the machine bed, column, headstock, saddle, and table, are cleaned and resurfaced. Resurfacing of large areas, such as bed ways, requires planing to restore flatness, followed by scraping to a finished surface. Castings are sent out to local machine shops for planing, as D & D's volume is insufficient to keep a large planer fully employed. Work tables are resurfaced by drilling out and plugging any holes and gouges. This work is done at D & D, after which the table is sent out for final planing and, if necessary, milling of the "T" slots. All castings are sealed and repainted after machine work is complete. Tables and ways are then scraped to restore their surface to original condition. Scraping is a very specialized manual operation, and skilled scrapers are in short supply. D & D employs three scrapers.

All other components which affect the accuracy of the machine tool also receive attention. Leadscrews are inspected for wear and, if required, are sent to the manufacturer for regrinding and lapping. The quill sleeve, in which the quill slides, is replaced with a hardened steel sleeve which is ground on its inside diameter and shrink-fit into the headstock. The new sleeve is then lapped to the quill to produce a rigid, exact fit. Electrical motors which are not replaced with new DC motors are cleaned, tested, fitted with new bushings, and rewound if necessary.

When remanufacturing Pratt & Whitney Tape-o-Matics, D & D cleans and thoroughly restores the existing electrical system, which is then reused. The machines' electrical panels are removed and completely disassembled. Printed wiring boards are cleaned ultrasonically and tested, and any faulty electronic components are replaced. Solenoids are cleaned and their contacts changed if they are to be re-used. Printed wiring board backplanes are reworked to ensure positive contact of all boards.

In the case of all machines except Tape-o-Matics, the existing electrical system is removed entirely and replaced with new components and wiring, in panels and housings of D & D's own design. The panels are designed to Joint Industrial Congress standards, and are laid out in roomy housings, which simplify both installation and subsequent service of the electrical system.

When remanufacturing machines other than Tape-o-Matics, the machine's existing numerical control is removed, partially disassembled and stored. It is replaced with a new NC or CNC unit and optical tape reader. The point-to-point control originally used on the Tape-o-Matic is retained, because no inexpensive comparable new unit is available. The Tape-o-Matic control, which consists of up to 160 separate printed wiring boards (by comparison, the McDonnell Douglas Actrion III control, a typical newer unit, has between four and seven circuit boards), is completely disassembled. Each board is cleaned and tested individually, and its connector pins are tightened and gaged to ensure good electrical contact. Damaged components and boards are replaced and the control is reassembled and tested. The mechanical tape reader which is usually found on Tape-o-Matics is replaced with a more reliable photo-electric tape reader.

D & D stores salvaged controllers, tape readers, and other accessories as a source of spare parts both for use in rebuilding machine tools and for customer service. It also actively searches for certain types of parts for older N-C machines, as some of these are now scarce. One transistor required in the Tape-o-Matic control, for example, is no longer manufactured, and no satisfactory substitute exists.

Reassembly of the machine tool takes place in the same manner as original assembly. Like original assembly, it is a labor intensive process, requiring careful attention to the flatness of surfaces and the alignment of the bed, column, saddle, table and headstock. Documentation prepared by the engineering department for use in the shop includes assembly drawings and assembly procedures. Once mechanical, electrical amd electronic assembly are complete, the control and machine-control

unit are calibrated, functionally tested and debugged. Precise measurement of positioning accuracy and repeatability is accomplished using a laser interferometer and positional deviations are recorded and corrected by calibrating the controller's error compensator.

Final inspection and testing may include a customer acceptance test at D & D's plant. D & D then ships the machine back to its owner, and supervises its installation, connection and testing in the customer's shop. Calibration and software tapes for the machine are generated by D & D's applications engineers and supplied to the customer. In addition, D & D trains the customer's machine operators, programmers, and maintenance technicians in the use and servicing of the remanufactured machine.

3. Infrastructure Requirements

D & D Electronics relies on outside suppliers for many products and services. In addition to having heavy machine work done by outside machine shops, the company obtains weldments, many machined parts, and sheetmetal work for housings and enclosures from independent suppliers. In some instances, D & D sends parts to the machine tool builder for rework; regrinding of ball lead screws is an example.

Original manufacturers of machine tools and independent component manufacturers are the source for most of the standard parts D & D replaces or incorporates into the machine tools it remanufactures. Both Ralph Thompson, Vice President of Engineering, and Paul Seelbach, Vice President of Marketing, point out that in this respect D & D is, like the majority of the small machine tool builders in the United States, a sophisticated assembler of specialized components. Controls, electric motors, position feedback devices, and even parts such as ball screws and ball bushing blocks can be obtained from specialty firms. In addition, rebuilding of machine tools is a common practice, and machine tool manufacturers are therefore well prepared to supply parts which may be necessary for rebuilding.

D & D's reliance on outside vendors for machining and fabricating work stems in part from the company's background as an electronics firm, and in part from a combination of the large variety of machining and fabricating tasks required with the relatively low volume in any single type of work. In the company's early years, it did not remanufacture sufficient numbers of machines to justify extensive in-house machining capabilities. Now, as its sales volume expands, D & D is beginning to do more machine work in its own shop. In addition, the company has turned a small part of its plant into a job shop, turning out screw machine products on its own Mini-Turn II bar machines. This job shop serves the double purpose of testing the Mini-Turn II design and familiarizing D & D with the operation of a machine shop. Concern over quality and delivery of machine work from outside suppliers may dictate the expansion of D & D's part fabricating and reworking capabilities.

4. Workforce

D & D's workforce has, since the beginning, been a highly skilled group of individuals. Initially, the company hired service technicians with several years of experience with N-C electronics from the larger metalworking firms in the Hartford area. As work volume increased, D & D added specialists in various aspects of machine repair to its payroll. Technicians have been attracted to D & D by working conditions which are better than those encountered in field or plant maintenance.

Remanufacturing of numerically-controlled machine tools requires a wide range of skills. In addition to the engineering work already described, remanufacturing involves a thorough understanding of electronic machine tool controls and interfaces between the control and the machine. As with new machine tools, the selling of remanufactured numerically-controlled machines requires expertise in applications and in field installation. The remanufacturing process requires mechanical and electrical skills even at the disassembly stage, not only to dismantle the machine without damaging it, but also to identify worn or damaged components and pinpoint the sources of any unusual damage. The rework of parts and subassemblies which are rebuilt at D & D requires specialists in machine repair, asthough some employees have been trained on the job in this type of rework. Finally, reassembly is perfomed by experienced machine fitters and electrical specialists. The remanufactured machine tool and its subsystems are then tested. These tests are conducted by assembly technicians and by the engineering and applications engineering staff, and include tests of machine functions, and measurement of positioning accuracy and repeatablility. Many of the tests require knowledge of electronic systems, and familiarity with the uses of sophisticated measuring instruments.

D. MARKETING

1. Sales

D & D Electronics' marketing department consists of a Vice President and five regional sales managers, who service the accounts of some 25 machine tool dealers nationwide. Marketing activities are split between sales of the company's new products, the Mini-Turn II chucker and bar machine (soon to be joined by a Mini-Turn III slant-bed design) and sales of remanufactured machines and remanufacturing services.

Sales of the Mini-Turn II are carried out through dealers who receive a commission on their sales. Dealers in the machine tool industry carry little or no inventory of machines (although they may have a demonstrator unit on hand), and usually represent several machine tool builders. The dealer places an order for a machine only after securing and order from a customer.

This method of selling has not proved entirely satisfactory for D & D's remanufactured machines, and D & D's ways of selling remanufactured machine tools and remanufacturing services have remained much the same as they were before the company introduced the Mini-Turn and acquired a dealer network. Although dealers are paid a finder's fee

for each remanufacturing customer they locate, their sales efforts center on new machines. A dealer who knows that a customer needs a boring mill, for example, is more likely to try to sell the client a new one than to suggest the remanufacture of one of the firm's existing machines. Dealers do, however, know which firms in their sales area own older N-C machine tools of the types that D & D remanufactures, and can be sources of this information. Occasionally, a dealer may accept a used machine as a trade-in, and offer it to D & D for sale.

Most sales of remanufactured machine tools and inquiries about custom remanufacturing, however, take place directly between D & D and the customer, rather than through one of the dealers. Inquiries are frequently initiated by the customer, and repeat orders, primarily from large, sophisticated metalworking firms, result in an important fraction of sales.

2. Advertising

D & D relies heavily on advertising as a means of establishing contact with prospective customers. Advertisements are placed in national and regional metalworking trade publications, and are backed up with brochures which describe D & D's remanufacturing program for specific machines. A sample advertisement is reproduced in Exhibit 1; Exhibit 2 is a sample brochure. D & D's advertising and promotional literature stresses the thouroughness of its remanufacturing work, the improvement in machine performance and productivity which can be realized through remanufacturing, the low cost of remanufacturing when compared to replacement, and the short turn-around time D & D can offer compared to lead times for obtaining new machines. In addition, D & D makes an effort to establish remanufacturing as a concept, and to distinguish remanufactured machine tools from used or refurbished machines. It does so by contrasting its work with that of military remanufacturing programs (e.g. the periodic renewal and updating of airframes and avionics on military aircraft). The company also eagerly discusses its remanufacturing activities with trade magazines and other interested parties. As Paul Seelbach puts it, "Before you can sell a remanufactured product, you have to break the association between it and used or refurbished machinery."

3. Collection of Used Machines for Remanufacture

D & D's "custom remanufacturing" makes marketing the remanufactured product and collection of the old machine, or "core", a single activity. When a machine tool is remanufactured for its owner, the sale of the remanufacturing service automatically provides D & D with a used machine to work on. The customer, in effect, supplies the castings from which the remanufactured machine is built.

The collection and purchase of used machines for remanufacture and sale as remanufactured machines presents different problems. D & D has found that sound, used N-C machine tools are scarce and frequently expensive. They are seen as too valuable to scrap, with owners preferring to have them repaired or rebuilt. Those which appear on the used machine tool market (and a reading of publications which list used

machine tools for sale will show that few are advertised) are usually offered in running condition, and are expensive. Figure #1 lists recent asking prices for used machines of the types which D & D remanufactures, taken from the September, 1979, issue of Industrial Machinery News.

D & D prefers to purchase only Tape-o-Matics, which are comparatively inexpensive (a used Model B can be bought for $10,000 or $11,000), easy for the company to remanufacture, and in great demand. A remanufactured Tape-o-Matic Model B or C may sell for $40,000 or more, depending on the model and level to which it has been updated. Used Tape-o-Matics are, however, difficult to find for sale in any condition, and, although D & D advertises aggressively to its dealers and customers, it has not succeeded in attracting as many machines as it would like.

FIGURE 1

Sample Prices for Selected Used* Machine Tools, September 1979
(Prices advertised by various dealers)

Pratt & Whitney	
Tape-o-Matic Model A, 1962,	$9,500
Cincinatti	
3 HP Single Spindle, 1969	$19,750
Cim-X-Changer, rotary table, 1967	$29,500
DeVlieg, horizontal boring mills	
3" Spiramatic, 1955 (manual control)	$97,500
4" Spiramatic, Tapac III NC, 1962	$95,000
3" Jigmil, rotary table, Cincinatti Milacron point-to-point NC, tooling, 1968	$198,500
3" Spiramatic, 1970 (manual control)	$139,500
Lucas, horizontal boring mills	
3" 41B48, 1955, rebuilt 1969 (manual control)	$59,500
4" NC	$95,000
Other	
Brown & Sharpe Hydrotape NC Drill, 1970	$35,000
Burgmaster 2BHTL 6-spindle Turret Drill, 1968	$19,500
Burgmaster 3BHTL-SH 8-spindle T. Drill, 1964	$32,500
Burgmaster 25BHTL-SH 8-spindle T. Drill, 1964	$24,500
Burgmaster 3BHTL-SH 8-spindle T. Drill, 15 HP	$45,000
Burgmaster 8-spindle Turret Drill, 2000 RPM	$42,500
Giddings & Lewis 1-spindle Numerimite, 1963	$12,750
Kearney & Trecker Milwaukee-Matic EA Machining Center, 5 HP, 1964	$32,500
Kearney & Trecker Milwaukee-Matic EA, 1965	$37,500

Source: Industrial Machinery News, September 1979.

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* Not remanufactured.

APPENDIX B

REMANUFACTURING SURVEY FORM

Company Name:_____

Address:_____

_____Zip_____

* * *

Person Responding:_____

Title:_____

Department:_____

Telephone:( )_____Extn._____

Response Date_____

Alternative Contact:_____

* * *

This survey is intended to provide information from which we can create a comprehensive picture of remanufacturing in the United States. There are questions on your plant operations, products, markets, resources and problem areas. Your cooperation in this voluntary survey is valuable because remanufacturing is a field about which little data are available. Individual company responses will be kept completely confidential, and will not be available outside of the immediate M.I.T. project team. Our reports to the Department of Energy will be statistical summaries and sector aggregates -- you will in no way be identifiable with your response. This cover sheet will be detached upon receipt.

If you have any questions, please contact:

Robert T. Lund
Center for Policy Alternatives
Room W59-21, M.I.T.
Cambridge, MA 02139
Telephone: (617) 253-1666

U.S. Department of Energy Form CS-405, (authorized under P.L. 93-577)
Approved by Office Of Management and Budget No. 038 - S 79081

EXHIBIT 1 SAMPLE ADVERTISEMENT FOR NC MACHINE TOOLS

WHY SOME MACHINE TOOLS CAN GET BETTER WHEN THEY GET OLDER.

Let's say you're working with an old NC machine tool. Maybe 15 or 20 or 25 years old. The machine tool is still servicable, but you're logging a lot of downtime and it's getting tougher and tougher to maintain consistent accuracy.

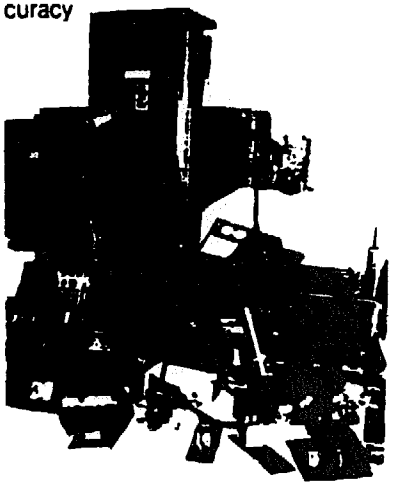

What do you do? You can scrap the machine, or trade it in on a newer model, or continue to put up with it. Or you can call D&D.

We'll take that old machine of yours, strip it right down to the frame, and replace every worn or out-of-spec component. We'll replace the old NC control with the most up-to-the-minute NC system. We'll upgrade the machine to improve productivity and reliability by adding DC drives in place of hydraulics. Then we'll refinish every square inch until it looks better than the day it left the factory in

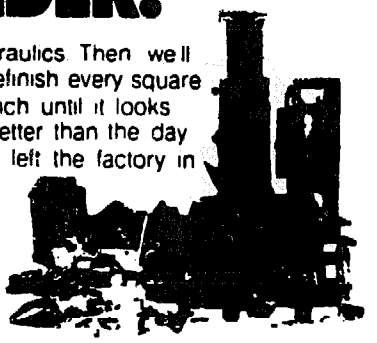

the first place, and we'll run it in to make sure it holds the tolerances you expect it to. Finally we'll give you an unconditional parts and labor warranty on the whole system.

The cost? As little as half what you'd pay for a comparable new machine.

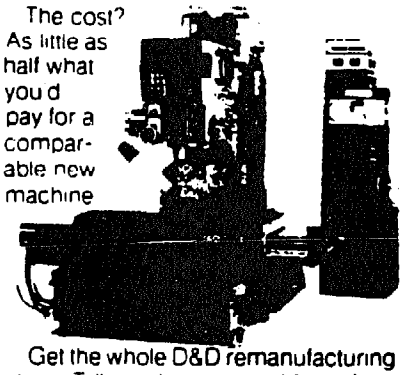

Get the whole D&D remanufacturing story. Tell us about your old machine and we'll tell you how much better it will be when we finish with it. Write now. We're D&D Electronics Incorporated, 90 Murphy Road, Hartford, Connecticut 06114.
203/522-8306

D&D

REMANUFACTURING.

EXHIBIT 2 PORTION OF D & D BROCHURE

8 STEPS TO RE-MANUFACTURING

Re-manufacturing your Cintimatic machining center involves a complex sequence of operations. Regardless of machine, model, or capacity, however, these are the basic things we do to all Cintimatics that we re-manufacture:

1 COMPLETE RECONDITIONING . . .

Your Cintimatic is disassembled and cleaned, with the major casting components repainted to seal and protect them from corrosion and rust. Critical surfaces including the worktable are plugged, planed, and scraped. Lead screws are either re-manufactured to original tolerances or replaced, and new Thompson rails are fitted and installed together with new ball bushings and seals. And, of course, all other worn parts also replaced.

2 HYDRAULIC DRIVE SYSTEM . . .

The old hydraulic drive system is replaced by a 3-phase SCR drive motor system to improve machine setting time and accuracy. The new SCR drive also eliminates the problems of noise, heat, oil, dirt, downtime, and maintenance associated with the hydraulic system. To control vertical positioning of the carriage assembly, horizontal positioning of the worktable, and the quill feed, three new 1.5 HP DC permanent magnet drive motors are fitted.

3 CONTOUR MILLING CAPABILITY . . .

With the installation of analog feedback resolvers along with new carriage and table drive motors, we provide 2-axis contour milling ability. For full 3-axis contour milling, analog feedback scales are installed to control the quill feed drive.

4 SPINDLE DRIVE ASSEMBLY . . .

To enhance spindle stability, greatly improve tapping ability, and provide infinitely variable spindle speeds, we replace the variable sheave pulley system in your Cintimatic with a new, 7 HP SCR drive unit. This new drive provides greater speed selection and better control of machining operations and eliminates many mechanical parts.

5 SPINDLE HEAD ASSEMBLY . . .

Also removed and replaced is the original spindle head assembly. In its place we fit a new Universal #300 Qwik-Switch to enable you to make tool changes with much greater speed, ease, and efficiency.

6 ELECTRICAL SYSTEM . . .

The original electrical system is completely eliminated and replaced with new components and D&D-engineered interface wiring. By completely refurbishing the electrical system, we eliminate several sources of maintenance problems which might, otherwise, later appear as downtime on your production floor.

7 NUMERIC CONTROL SYSTEM . . .

To replace your older numeric control system, we offer smaller, more reliable, NC or CNC units, representing the latest state-of-the-art electronic reliability, capability, and flexibility. D&D warrants and services all these controls to provide a single source for all machine subsystems.

8 PENDANT STATION . . .

Although the original pendant station is retained, the features in your Cintimatic are changed to allow better on-station operator control. For instance, while feed rate and spindle speeds are normally controlled through programming, they can now be easily and immediately overriden by the operator right from his work station.

These major machine tool modifications make a D&D re-manufactured Cintimatic the most reliable and precisely re-manufactured machine tool you can use to cut metal.

REMANUFACTURING SURVEY FORM

Instructions:

* Partial responses are preferred to omissions.
* Where you find it necessary to make multiple answers to a question in order to answer it completely, please do so.
* Where an explanation or a longer answer is needed, please use the back of the page.
* The term "core" is used throughout to indicate non-functioning products which are returned to you for remanufacture.

I. OPERATIONS

1. What classification best describes your firm?
   a. 102 Independent remanufacturer
   b. 36 Original Equipment Manufacturer (OEM) and remanufacturer
   c. 5 Other _____

2. List principal products remanufactured and enter code of primary market served: (categorized by 3-digit SIC list)

	Product		Market
a.	SIC 349-- 3	SIC 357-- 1	SIC 367-- 4
b.	SIC 351--26	SIC 358--22	SIC 369-- 7
c.	SIC 352-- 1	SIC 359-- 1	SIC 371--50
d.	SIC 353-- 2	SIC 361-- 5	SIC 372-- 1
e.	SIC 354-- 5	SIC 362-- 2	SIC 374-- 2
f.	SIC 355-- 2	SIC 363-- 2	SIC 375-- 1
	SIC 356-- 5	SIC 365-- 1	

Code:
A = Automotive
C = Commercial
F = Farm
I = Industrial
R = Residential

3. How long has your firm been involved in remanufacturing? 24.15 years

4. What were your total remanufacturing dollar sales and number of units of production for 1978?

	MEAN	RANGE
a. Sales	$ 6,837,188.	Min -$17,424. to $81,000,000.
b. Units	76,017,938	Min - 3o to ?

5. What portion of your total sales is associated with your remanufactured products?

21 0-10%	12 11-25%	14 26-50%	12 51-75%	20 76-95%	58 96-100%

6. Is your firm 37 publicly held, or 105 privately owned? (Missing - 1)

7. How many employees are engaged in remanufacturing? 134.7 employees Range: 3 to 2650

8. What average hourly wage is paid to shop or factory employees (remanufacturing only)? $ 6.066 per hour Range: $3.00 to 12.00

9. How many separate remanufacturing plants do you operate? 2.6 plants

10. What is the area of your remanufacturing production space? 93,236 square feet Range:450 to 1,916,640

11. For your remanufacturing operation only, what is your total asset bracket (current and fixed assets)?

    a. 16 Up to $100,000
    b. 41 $100,000 to $500,000
    c. 16 $500,000 to $1,000,000
    d. 62 Over $1,000,000

    (8 Missing Cases)

12. For your remanufacturing operation only, what is your total investment in production equipment?

    a. 32 Up to $100,000
    b. 37 $100,000 to $250,000
    c. 27 $250,000 to $500,000
    d. 15 $500,000 to $1,000,000
    e. 29 Over $1,000,000

    (3 Missing Cases)

13. What percent of your remanufacturing volume is processed by each of the following methods?

a. One at a time	38.7 %
b. Batches of like items	34.89%
c. Continuous production lines	25.57%
d. Other _____	1.31%
	100 %

14. What is your average lot size? 210.8 units Range: 1 to 10,000

15. In addition to remanufacturing activities, does your company:

	Yes	No	Missing
a. Rebuild or repair products on a one-by-one basis?	112	30	1
b. Perform general services (e.g. machining)?	64	72	7
c. Undertake salvage activities?	73	59	11

16. Rank your sources of replacement parts (1 = largest dollar volume, 2 = next largest, etc.):

		TOTAL # of responses	(Total Possible = 143)	
Over-	a.	3	82	Make them ourselves
all	b.	4	66	Have made for us by subcontractors
	c.	1	119	Purchase from Original Equipment Manufacturers
Rank-	d.	2	100	Purchase from other parts vendors
ing	e.	5	26	Other_____

17. If your company is not an operating unit of an OEM, what assistance do you get from the OEM?

	Much	Some	None	NA/OEM	M.C.
a. As source of parts	49	62	12	16	4
b. Drawings	20	52	48	16	7
c. Manufacturing specifications	37	53	32	16	5
d. Collection of cores	4	34	78	16	11
e. Marketing and distribution	8	27	83	16	9
f. Other: _____	3	6	89	16	13

g. _____ Not Applicable, we are the OEM.

18. About what percentage of cores do you obtain from each of the following sources?

a. Warranty returns	4.99 %
b. Core brokers	14.66 %
c. Non-warranty service exchanges	27.91 %
d. Returned by lessor/renter	3.27 %
e. Returned by owner for rebuild	38.00 %
f. Salvage operators	10.39 %
	100%

19. What portion of your cores become available to you for each of the following reasons?

a.	Worn out, damaged, or defective	91.75 %
b.	Expiration of lease/rental	1.39 %
c.	For technological updating	5.07 %
		100%

20. What portion of the cores that you receive are immediately rejected as unusable? a. 10.08 % Range: (0-60)

For those cores that you accept, what percent by weight is discarded during remanufacture? b. 12.85 % (0-60)

21. What is the average yearly change in the following quantities, over the last three years?

	% Decrease	No Change	% Increase
a. Remanufacturing sales ($)	____	____	____
b. Unit volume	____	____	____
c. Order backlog	____	____	____

d. If increases are indicated, were they due primarily to acquisition of other firms? 4 Yes 113 No 26 Missing

22. Break down product ownership during remanufacture?

a.	Remanufacturer (respondent)	74.5 %
b.	User of the product	18.5 %
c.	Other owner (OEM, other)	4.46%
d.	Other _____	2.57%
		100 %

23. How do your inventories break down into the following categories?

a.	Cores	27.46 %
b.	New replacement parts	24.39 %
c.	Work in process	18.34 %
d.	Finished goods	29.84 %
		100%

e. What was the value of your total remanufacturing inventories as of the end of the 1978 accounting year? $ 1,824,714.
Range 0 - 20,000,000

24. For a typical product, how are your materials costs divided among the following?

		Percent of Total Materials Cost
a.	Re-used Parts	48.94 %
b.	New Parts	44.44 %
c.	Other Mat'ls	6.24 %
		100%

25. Rank the following factors in order of their limiting effect on your ability to grow. (1 = most important, etc.)

		# of responses		(Total possible = 143)
Over-	a.	1	123	Scarcity of quality cores at an acceptable price
all	b.	7	114	Competition from new products
	c.	3	118	Competition from other remanufacturers
Rank-	d.	2	115	Labor cost
ing	e.	4	121	Unavailability of sufficiently skilled workers
	f.	6	117	Plant production capacity
	g.	8	108	Federal and state regulations
	h.	5	109	Cost of new capital equipment
		9		Other

26. How important are the following factors to your selection of a remanufacturing plant location for your product line? (Circle the appropriate number on each line.)

Overall			Very Important			Not Important	Missing
6	a.	Location of parent facility	1-32	2-24	3-30	4-46	5
2	b.	Skilled workers available	1-51	2-38	3-35	4-11	8
1	c.	Access to good transportation	1-59	2-42	3-17	4-12	13
3	d.	Market concentration	1-50	2-43	3-22	4-20	8
5	e.	Core availability	1-40	2-33	3-33	4-27	10
4	f.	Low-cost labor	1-43	2-44	3-31	4-15	10

27. Which statement best describes each stage of your remanufacturing process? (More than one "X" may be appropriate.)

Missing		Energy Intensive	Cap'l Equip. Intensive	Labor Intensive	Energy & Equip	Energy & Labor	Equip &Labor	All Three
3	a. Disassembly	4	1	117	-	5	10	3
3	b. Cleaning	15	21	45	28	12	11	8
9	c. Reworking	3	33	52	8	2	29	7
3	d. Assembly	2	10	101	1	1	20	5

28. For the remanufacturing portion of your production only, what was the cost of your total 1978 annual consumption of:

a.	Oil	$ 4,789	Range: 0 -- 75,000
b.	Gas	$ 14,519	Range: 0 -- 118,085
c.	Coal	$ 147	Range: 0 -- 8,978
d.	Electricity	$ 38,321	Range: 0 -- ?
e.	TOTAL ENERGY COST	$ _____	0 -- 850,000

29. For direct labor employed in each major remanufacturing activity, enter the average skill level required and how this skill is acquired:

Average Skill Level
1 = Highly skilled
2 = Semi-skilled
3 = Unskilled

Training Mode
1 = Formal, in-house
2 = Learn by doing
3 = Trained elsewhere

	Missing	1	2	3	1+2	1+3	2+3	1	2	3	1+2	1+3	2+3	Missing
a. Disassembly	2	6	78	57	-	-	-	25	101	1	9	1	1	5
b. Cleaning	2	2	53	84	-	1	1	19	84	-	6	-	-	34
c. Reworking	4	69	51	4	4	-	1	45	57	4	14	9	3	9
d. Assembly	3	61	67	7	5	-	-	53	53	2	11	9	2	8
e. Inspection	2	105	34	2	-	-	-	65	39	4	8	10	3	8

30. What is the percentage breakdown of remanufacturing personnel in each of the following classifications:

Hourly		
Unskilled	a.	21.5
Semi-skilled	b.	38.72
Skilled	c.	11.6
Salaried	d.	_____
Total		100%

31. Does your staff include professional specialists in the following areas:

	Yes	No	Missing
a. Process and plant engineering	61	78	4
b. Production control	79	60	4
c. Design	44	93	6
d. Quality assurance	91	48	4
e. Purchasing	90	49	4
f. Industrial engineering	52	87	4

II. MARKET FACTORS

32. When your firm entered into remanufacturing, did it do so

a. 76 directly, as the main area of business, or indirectly, as a result of being

b. 13 original product manufacturer

c. 41 repair service for product

d. 10 other _____

3 missing

33. How important are the following sources of competition to your business? (Circle the appropriate number on each line.)

	Overall	Very Important			Not a Concern	Missing
a. New products	2	1-36	2-33	3-40	4-27	7
b. Used products	3	1-18	2-21	3-39	4-58	7
c. Remfg. products	1	1-81	2-31	3-15	4-10	5

34. How important are the following factors to a potential purchaser of your remanufactured product:

	Overall	Very Important			Not a Concern	Missing
a. Availability	1	1-123	2- 12	3- 2	4- -	5
b. Price	4	1- 69	2- 56	3-12	4- 1	5
c. Warranty terms	6	1- 42	2- 62	3-30	4- 3	6
d. Performance	2	1-105	2- 27	3- 6	4- -	5
e. Appearance	5	1- 49	2- 58	3-26	4- 4	6
f. Service	3	1-84	2- 36	3-11	4- 5	7
g. Other _____	7	1- 8	2- 3	3- 1	4- 2	129

35. What is the price of your remanufactured product relative to that of a new product? 57.79 percent. Range: 20%-90%

36. To whom do you advertise?

	Yes	No		Missing
a.	75	63	End users	5
b.	76	62	Dealers	5
c.	77	61	Distributors	5
d.	15	123	Others	5

37. What percentage of your remanufactured products do you sell directly to the United States government? 1.34 %

Range: 0 - 15%

38. What portion of your sales volume is distributed through each of the following channels?

a.	Direct sales to users	29.96%
b.	Distributor network	56.58%
c.	To new lessor/renter	.58%
d.	Other _____	12.10%
		100 %

39. What is the approximate number of your:

a.	Own salespeople	8.9	Range: 0 - 100
b.	Distributors	247.6	Range: 0 - 16,000
c.	Dealers	1212.9	Range: 0 - 50,000
d.	End-user customers	9808.9	Range: 0 - 600,000

40. This question applies only to companies which remanufacture several different products (not just multiple models of the same product). Do your products share the following features?

		Yes	No	Missing
a.	Same group of users	66	9	68
b.	Same collection/distribution system	68	7	68
c.	Same field service facilities	62	9	72
d.	Same product technology	55	18	70
e.	Same remanufacturing technology	54	21	68

41. a. Do the products you remanufacture become part of larger products (e.g. engines become part of automobiles)? 99 Yes 37 No 7 Missing

b. If YES, what portion of the value of the overall product is represented by the value of the remanufactured component?

33 0-10%	22 11-25%	20 26-50%	10 51-75%	3 76-99%	2 100%

42. What portion of your remanufacturing sales volume is presently exported?

79 None	49 1-10%	5 11-25%	1 26-50%	51-75%	76-100%

Missing-9

43. Have you experienced any of the following difficulties in exporting your remanufactured products?

	Yes	No	Missing
a. Lack of foreign trade experience	49	41	53
b. Core return problems	69	26	48
c. Domestic market already adequate	22	63	58
d. Distribution system lacking	50	37	56
e. Management indifference	19	64	60
f. No foreign market for product	10	70	63
g. Other _____	14	56	73

III. PRODUCT DESIGN

44. What factors significantly hinc your remanufacturing activity?

Missing		Yes/No	Characterist	Example
			Materials:	
32	a.	32/ 79	Component construction	_____
33	b.	16/ 94	Hazardous materials	_____
33	c.	20/ 90	Other	_____
			Original Manufacturing Processes:	
33	d.	7/103	Forming	_____
33	e.	25/ 85	Assembly & fastening	_____
33	f.	4/106	cher	_____
			Other actors:	
33	g.	57/ 5	Number of models	_____
33	h.	40/ 7	Technology changes	_____

45. How stable i the design of the products you remanufacture?

a. 13 Undergoing rapid changes in design and/or materials.

b. 69 Moderate change from year to year.

c. 58 Slow rate of product change.

3 Missing

46. Do you remove the original nameplate or other identifying marks from the product? a. 41 Yes 93 No 9 Missing

Do you affix your own nameplate or label? b. 109 Yes 29 No 5 Missing

47. If the product is still being manufactured, have you recommended product design revisions to the OEM? a. 57 Yes 77 No 9 Missing

How has the OEM responded?

b. 36 Made changes
c. 16 No response
d. 3 Refused
88 Missing

48. Rank the reasons for which you make design modifications during the remanufacturing process? (1 = most important, etc.)

Overall rank/# of responses (Total possible = 143)

a. 2/ 83 Update to current technology.
b. 6/ 49 Comply with current product, health and safety regulations.
c. 7/ 44 Comply with current pollution control regulations.
d. 3/ 82 Improve operating efficiency.
e. 1/ 89 Correct design weakness so as to yield longer product operating life.
f. 4/ 56 Consolidate several models.
g. 5/ 60 Make the product easier to remanufacture.
h. 8/ 35 Use different materials of construction.
i. 9/ 6 Other: _____
j. 10/ 26 Not applicable -- we do not make any design changes.

49. Has your company ever experienced difficulties arising from a need for proprietary (patented) information or processes? 26 Yes 111 No 6 Missing

If YES, whom we may contact for further information:

Name: _____ Phone: _____

50. Has your firm been party to a products liability suit concerning a remanufactured product?
24 Yes 111 No 8 Missing

If YES, whom in your company we may contact for more information:

Name: _____ Phone: _____

51. Does your remanufacturing process or product involve any unusually hazardous materials or operations? 29 Yes 104 No 10 Missing

IV. PRODUCT SERVICE

52. Who commonly performs service on your product?

	Missing	Yes	No	
a.	8	59	76	Customer
b.	8	18	117	OEM's service representative
c.	8	60	75	Dealer or contractor
d.	8	53	82	Independent service agency
e.	8	70	65	Your own service representatives

53. What is the most common method for servicing the products that you remanufacture?

	Missing	Yes	No	
a.	2	116	25	Replace inoperative unit
b.	3	44	96	Repair in field
c.	2	9	132	Other _____

54. What is the warranty period of your remanufactured products? _____

55. What is the warranty period of comparable new products? (If your product is used as a replacement part, what would be the warranty of a new part used in replacement service?) _____

56. How do your warranty terms compare with those of a comparable new product?

a. 39 more liberal

b. 80 the same

c. 19 less liberal

5 missing

Please enclose a copy of your standard warranty statement

Thank you for your cooperation.

APPENDIX C:

Excerpt from Remanufacturing Survey Findings, MIT Center for Policy Alternatives Report 81-12, January 1981.

Energy

Survey data has shown that the remanufacturing process relies significantly on used products as a source of material, and also to be labor intensive. These factors lead to the hypothesis that remanufacturing requires less energy than a new manufacturing operation, if the product and volume are equal.

A. Energy Consumption

The Remanufacturing Survey provided limited data on energy consumption. One question asked respondents to describe each stage of the remanufacturing process by its energy, capital equipment or labor intensiveness. Only the cleaning process was described with some frequency as being energy intensive (see section on process). All other stages were described as being labor or capital equipment intensive.

Another survey question asked respondents to state the dollar value of their energy consumption in 1978. This information was used together with sales data to calculate energy cost per sales dollar. First, aggregate totals for sales and energy (for 1978) were found, using the data from all firms that responded to both questions. Then a ratio of total dollar value of energy to total dollar value of sales was computed. For the 94 firms which contributed to the totals, the ratio for remanufacturers was .88%, which would appear to be a remarkably low energy cost.

Calculations for comparable new product manufacturers produced a ratio similar to that for remanufacturers. The SIC codes that best described each survey respondent were used as a basis for comparing manufacturers and remanufacturers of the same group of products. Data giving total sales and total energy consumed were gathered for new manufacturers in each respective SIC code.[1] Because the information required was only published to 1976, appropriate inflators[2] were used to adjust both sales and energy to 1978. The producer sales index was 1.14 and the energy index was 1.21. Using the inflated 1978 figures, the same procedure used to calculate the remanufacturing energy ratio was followed. Total figures for sales and energy consumed were found by aggregating the data from each SIC code. Then the ratio of total energy dollars to total sales dollars was computed. For new manufacturers, this ratio was .89%. However, because this ratio is based on sales, it is important to remember that remanufacturers typically sell products for 60-70% of the new product price. It thus appears that the average energy consumed by the remanufacturer is less than the average energy consumed by the new manufacturer. Table 2-19 shows this calculation.

TABLE 2-19

RATIO OF ENERGY COSTS TO VALUE OF SHIPMENTS FOR NEW MANUFACTURERS[3]

SIC CODES	1978 Weighted Fuels & Electric Energy ($ mil)	1978 Weighted Value of Shipments ($ mil)
349	.252	16.439
351	22.258	1963.87
352	.004	.362
353	2.117	203.708
354	3.878	257.165
356	8.757	667.315
358	2.429	203.750
359	.120	6.741
361	1.634	139.561
362	10.131	584.260
363	.286	24.136
367	3.847	248.002
371	528.149	61,256.375
372	.825	83.408
374	1.462	128.792
	587.659	65,903.913

$$\frac{587.659}{65,903.913} = .0089 = .89\%$$

* Each column is weighted by the proportion of sales represented by remanufacturing respondents in a particular SIC group to total remanufacturing sales.

B. Embodied Energy

The above ratios of operating energy costs fail to account for the most important aspect of energy conservation through remanufacturing, however. The cores used in remanufacturing have energy embodied in them that was used originally to produce the materials and process the parts. This energy does not have to be respent to make any of the parts re-used during remanufacture. In contrast, a firm making a new product must purchase, through intra- or inter-firm transactions, 100% of the materials required for the final product.

As we have seen, new materials cost is about one-half the remanufacturer's materials cost. Because core costs are significantly lower than the equivalent new parts costs, the amount of embodied energy salvaged is well over half of the energy embodied in an equivalent new product.

To pursue this concept a bit farther, we attempted to calculate the value of embodied energy as a percent of sales for two new product areas using input-output tables. The calculations were carried far enough to demonstrate it is highly likely that the final product producer "buys" more energy in the materials and parts that make products typically remanufactured than it buys directly as energy.

The picture for inputs into a manufacturing process would, on a highly aggregated level, be similar to Figure 2-1.

FIGURE 2-1
SCHEMATIC DIAGRAM OF MATERIAL FLOWS IN MANUFACTURING

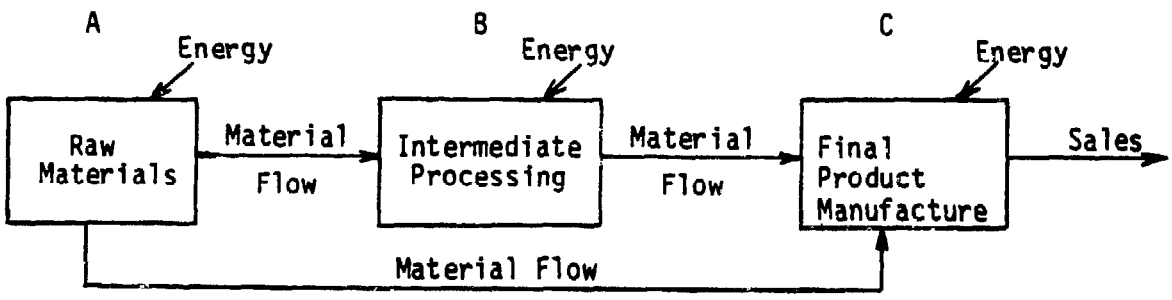

Each box in the diagram represents a point where processing of some form is done; each arrow represents a possibility for material transfer from one process point to another. Embodied in the material flow is the energy used at the processing point from which the material is coming. For example, there is a material flow from point A to point B. Material going into point B has embodied in it the value of energy consumed at point A. To get an estimate of the total energy used to produce the goods that flow to the market from point C, one must consider not only the energy used at point C but the energy used to produce the material that flows from A to B, B to C, and A to C. Using two SIC codes as examples (351 - Engines and Turbines, 371 - Motor Vehicles and Motor Vehicle Equipment), the above schematic was used as a framework to trace energy inputs into a finished product. A publication called The Detailed

Input-Output Structure of the U.S. Economy: 1972[3] has one table which is a complete matrix of the dollar value of material inflows from one industry to another. Although this publication has its own system of classifying industries, it also includes an index to cross-reference their classification system with the SIC code. It was therefore possible to get a list of all material inflows into SIC numbers 351 and 371. The list of inputs can be divided into two mutually-exclusive groups: those which fall into major SIC group 33, Primary Metal Industries, and those which do not. The sum of each group provides an approximation of the dollar value of raw materials flowing to the final product manufacturer (A to C) and the dollar value of intermediate goods flowing to the final product manufacturer (B to C). In addition, by cross-referencing to the index, the group of SIC codes which contributed to each total can be obtained. Referring back to the schematic diagram, two arrows, theoretically now, depict the value of material flows (indicated by the double lines).

FIGURE 2-2
SCHEMATIC DIAGRAM OF VALUE FLOWS IN MANUFACTURING

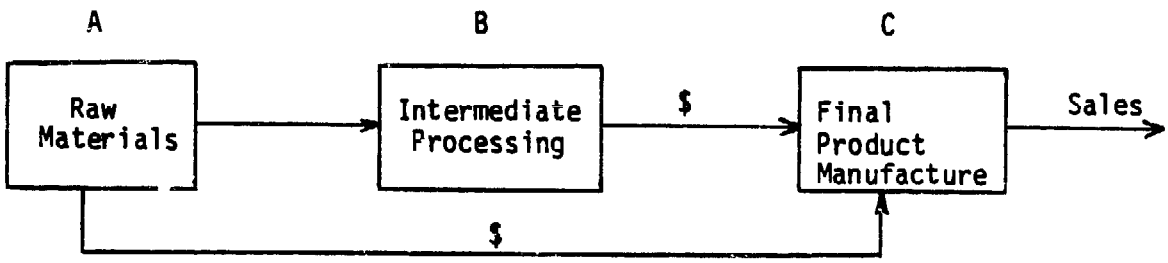

The next step is to determine what portion of the materials value can be attributed to energy costs. A ratio to establish the relationship of energy cost to sales revenue is calculated for process A and process B. If the appropriate ratio is then applied to the dollar value of shipments from A to C and B to C, a dollar value representing the energy expenditure in each flow of materials will result. Earlier in this section, a method was used to estimate the ratio of energy cost to total sales revenue for original equipment manufacturers of final products and remanufacturers. A similar process is used to find that ratio here, described in general terms so as to apply to any SIC code and to any particular stage of the process. The steps are listed below.

(1) Establish the group of SIC codes (at the 3 digit level) which contribute to the flow of materials from one stage of processing to another (e.g., from A to C).

(2) For each 3 digit SIC code in the group, establish the value of shipments (sales) for 1972.[4]

(3) Adjust each value of shipments from 1972 to 1978 with an appropriate inflation index.[5]

(4) For each 3 digit SIC code, establish total value of purchased fuels and electric energy for 1972.

(5) Adjust each fuel value from 1972 to 1978 using an appropriate inflation index.[5]

(6) Sum the adjusted values of purchased fuels and electric energy so there is one total which includes all SIC groups.

(7) Sum the adjusted values of shipments so there is one total which includes all SIC groups.

(8) Establish a ratio of energy cost to sales dollars for a particular process by dividing the sum of energy expenses (from Step 6) by the sum of value of shipments (from Step 7).

$$\frac{\text{(Sum of Energy Cost)}}{\text{(Sum of Value of Shipments)}}$$

Table 2-20 illustrates a specific example of this method. The ratio of energy to value of shipments is calculated for primary inputs (raw materials) into SIC 351. On the diagram, this ratio is for the flow of materials from point A to point C.

TABLE 2-20

RATIO OF ENERGY COST TO VALUE OF SHIPMENTS AT POINT A

Primary Inputs to SIC 351	1972 Value of Shipments ($ mil)	1978 Adjusted Value of Shipments ($ mil)	1972 Purchased Fuels and Electric Energy ($ mil)	1978 Adjusted Fuels and Electric Energy ($ mil)
331	28,671	53,901	1,437.6	3,908.8
332	5,686	10,689	255.5	694.7
333	6,004	11,287	340.3	925.2
335	12,651	23,783	203.3	552.7
336	2,344	4,406	53.4	145.1
339	805	1,513	39.1	106.3
		105,579		6,332.8

$$\frac{\text{(Sum of Energy Cost)}}{\text{(Sum of Value of Shipments)}} = \frac{6,332.8}{105,579} = .0599 \text{ or } 5.99\%$$

At point A, which represents the processing of primary materials, the estimate of energy usage in this case is 5.99% of sales. The input tables detail the dollar value of shipments from this group of primary metal industry groups to SIC 351. Inflated to 1978 dollars, this value times the energy ratio would give an approximation of the dollar value of energy embodied in the primary material shipments to SIC 351.

Value Shipments ($ mil)	X	Energy Ratio	=	Value of Energy Used ($ mil)
1,414.3	X	.0599	=	84.71

On the schematic diagram the above value of energy used represents the energy value embodied in the flow of materials from A to C. The same procedure used to calculate this value can be used to calculate the energy embodied in materials flowing from B to C. The energy used at point C comes directly from a Purchased Fuels and Electric Energy Chart for SIC 351, inflated to 1978.[6] All of these values are shown in Figure 2-3.

FIGURE 2-3

SCHEMATIC DIAGRAM OF ENERGY COST FLOWS IN MANUFACTURING SIC 351
($ million)

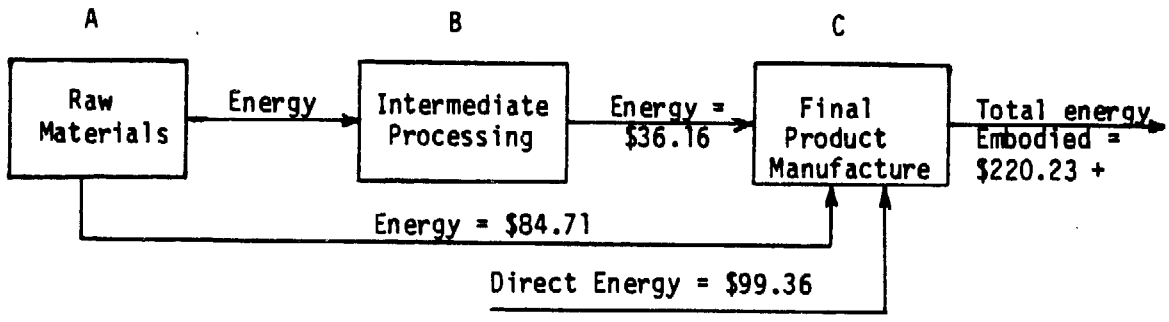

The information in the material input table leads directly to the calculation of energy embodied in the material flow from A to C and B to C. However, the data on material flow from A to B are not readily accessible. This would require tracing all inputs to 23 SIC groups which flow out of B to C and even then, only a fraction of these inputs are attributable to the material flowing to SIC 351. The point of the exercise described in this section is to draw attention to the total energy picture rather than just that energy consumed in the final production stage. The analysis also shows how the energy consumed increases when the material flow is considered, important because the survey data indicate that in remanufacturing, only about 50% of material costs are for new materials. Calculating the material flow from A to B was not necessary to highlight the above points.

As mentioned earlier in this section, this analysis was done for two SIC groups: 351 - Engines and Turbines and 371 - Motor Vehicles and Motor Vehicle Equipment. When considering the energy consumed in only the final production stage, the ratio of energy consumed for each dollar of sales was 1.19% for SIC 351 and 0.91% for SIC 371. When the value of energy embodied in raw and intermediate material flows were included, the

ratio for SIC 351 increased to 2.64% and for SIC 371, to 2.12%. Both ratios more than doubled in size. Also, because the material flow from A to B has been excluded, the increases observed are conservative estimates. Though the increases may not look too impressive, the dollar values involved are large enough to make a small percentage increase into a fairly substantial dollar volume. For example, the value of shipments for SIC 371 in 1978 was approximately $80 billion. An increase in the ratio of energy consumed to value of shipments from .91% to 2.12% is an actual dollar increase in energy expenditures of $ 970 million.

Energy Leverage

If we use the logic and data developed in the preceding section, plus other information obtained by the survey, we can get a feel for the potential for energy savings represented by remanufacturing. Let us take the case for SIC 351 -- Engines and Turbines. For new product manufacture the energy embodied was shown to be at least 2.6% of the value of shipments, with an important energy component (the energy embodied in raw materials shipped to intermediate processors) missing. The survey found that the energy used to remanufacture all products was about 0.9% of the value of shipments. Because a substantial fraction of the survey respondents were automobile component remanufacturers, this value is probably similar for the above SIC sector.

We can then infer the ratio of the cost of energy to remanufacture a product to the cost of energy embodied in that product that is saved by remanufacture. First we must adjust the remanufacturing energy value to make it a fraction of the equivalent new product price. Remanufactured goods prices average about 60% of new product prices. (See section 4-C.) Thus the amount of energy used in remanufacturing a product is 0.9% x 60% or .54% of the price of a new manufactured product. The ratio between energy of remanufacture and embodied energy in SIC 351, then, is 0.54/2.6, or about 1:5. This means that, for every dollar spent on energy to remanufacture an engine, at least five dollars of embodied energy are saved. For the automotive sector (SIC 371) the ratio is 0.54/2.12, or about 1:4.

A dollar example may be useful. According to our calculations, the 1978 value of shipments of SIC 371 of $80 billion contained at least 2.12% or $1.7 billion of embodied energy. If only 1% of the output of SIC 371 were to be salvaged through remanufacture, the remanufactured output would contain $17 million of embodied energy. The amount of energy used to remanufacture this amount of product would be roughly 0.9% x60% x 1% x $80 billion, or $ 4.3 million. Thus, the $4.3 million energy expenditure would have "saved" $17 million of energy needed for an equivalent amount of new product.

To be more rigorous would require that we identify the raw-to-intermediate energy component for new products (the energy between points A and B of our diagram), and that we take into account the embodied energy in the new parts and materials purchased by the remanufacturer to replace unusable components. Transportation energy costs would also have to be included for both manufacturing and

remanufacturing. These corrections tend to offset each other, however, and it is not likely that the sense of energy efficiency inferred here would be greatly altered by a more comprehensive treatment.

This concept of energy leverage is an important reason for encouraging this form of reclamation of discarded durable products. No other mode of producing a finished product is as energy efficient.

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1. From Annual Survey of Manufactures, 1970-71, Department of Commerce.

2. Taken from statistical tables in Economic Report of the President, 1980.

3. U.S. Department of Commerce: Bureau of Economic Analysis.

4. 1972 data are used in this exercise for value of shipments and energy consumed to be consistent with the input-output data, which is published only as recently as 1972.

5. Can be obtained from Economic Report of the President, 1980 which has a section on indices.

6. From Annual Survey of Manufacturers, 1970-1971, Department of Commerce.

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Remanufacturing

From Wikipedia, the free encyclopedia

Remanufacturing is the rebuilding of a product to specifications of the original manufactured product using a combination of reused, repaired and new parts.[1] It requires the repair or replacement of worn out or obsolete components and modules. Parts subject to degradation affecting the performance or the expected life of the whole are replaced. Remanufacturing is a form of a product recovery process that differs from other recovery processes in its completeness: a remanufactured machine should match the same customer expectation as new machines.

In 1995, the United States Environmental Protection Agency (EPA) implemented the Comprehensive Procurement Guideline[2] (CPG) program to promote waste reduction and resource conservation through the use of materials recovered from solid waste, and to ensure that the materials collected in recycling programs will be used again in the manufacture of new products. The EPA is required to designate products that are or can be made with recovered materials, and to recommend practices for buying these products. Once a product is designated, state and federal procuring agencies are required to purchase it with the highest recovered material content level practicable.

In 2004, the EPA published its third CPG update (CPG IV) which designated seven additional products and revised three existing product designations. One of the new product categories to be added was Rebuilt Vehicular Parts.[3] The EPA defines rebuilt vehicular parts as "vehicle parts that have been **re-manufactured**, reusing parts in their original form. Rebuilt parts undergo an extensive **re-manufacturing** and testing process and must meet the same industry specifications for performance as new parts."

In the UK, a market potential of up to 5.6 billion GBP has been identified in remanufacturing, with the benefits said to be improvement to business margins, revenues and security of supply.[4]

Contents

- 1 Other forms of product recovery
- 2 Range of products being remanufactured[6]
- 3 Different types of remanufacturing
  - 3.1 Remanufacturing with loss of original product identity
- 4 Rebuilding
- 5 Benefits of Engine Remanufacturing
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Other forms of product recovery

1. Reuse implies that items are used by a second customer without prior repair operations or as originally designed.
2. Repair: the process of bringing damaged components back to a functional condition.
3. Refurbishing/Reconditioning is the process of restoring components to a functional and/or satisfactory

state to the original specification, using methods such as resurfacing, repainting, etc.
4. Recycling is the process of taking a component material and processing it to make the same material or useful degraded material.
5. Cannibalization (parts)

Many formal definitions of remanufacturing exist in the literature, but the first published report on remanufacturing, by R. Lund (1984), describes remanufacturing as "... an industrial process in which worn-out products are restored to like-new condition. Through a series of industrial processes in a factory environment, a discarded product is completely disassembled. Useable parts are cleaned, refurbished, and put into inventory. Then the product is reassembled from the old parts (and where necessary, new parts) to produce a unit fully equivalent and sometimes superior in performance and expected lifetime to the original new product".[5]

Furthermore, the Automotive Parts Remanufacturers Association (APRA) realized that communication problems can arise when people from different countries with different language skills talk about remanufacturing. Certain terms can have different meanings as definitions between countries and individuals vary. In 2013, APRA was able to solve these communication problems by publishing a common translation list (http://www.apra-europe.org/main.php?target=remanufacturing) in many different languages in order to unite all those who deal with the automotive industry.

Range of products being remanufactured[6]

- Aerospace
- Air-conditioning units
- Bakery Equipment
- Carpet tiles
- Compressors
- Computer and telecommunication equipment.
- Defense equipment
- Electrical motors and apparatus
- Excavation equipment
- Fashion apparel and accessories
- Gaming Machines
- Industrial food processing equipment
- Machine tools
- Musical Instruments
- Office furniture
- Office photocopiers (laser toner cartridges)
- Power bearings
- Pumps
- Robots
- Rolling stock (railway vehicles)
- Toner Cartridges
- Vehicular Parts
- Vending Machines

Different types of remanufacturing

There are three types of remanufacturing activities, each with different operational challenges.

1. *Remanufacturing without identity loss*; with this method, a current machine is built on yesterday's base, receiving all of the enhancements, expected life and warranty of a new machine. The physical structure (the chassis or frame) is inspected for soundness. The whole product is refurbished and critical modules are overhauled, upgraded or replaced. If there are defects in the original design, they are eliminated. This is the case for customized remanufacturing of machine tools, airplanes, computer mainframes, large medical equipment and other capital goods. Because of its uniqueness, this product recovery is characterized as a project.
2. *Remanufacturing by recoating of worn engine parts*; many engine parts, components are large and expensive and after a period of use become worn. An example of such a part is the engine block, in

particular the cylinder engine bores, which must withstand explosions during piston firing. Instead of disposing of large engine blocks, remanufacturing has resulted in re-use of the parts by coating them with plasma transferred wire arc spraying (PTWA) Caterpillar known for manufacturing very large industrial trucks and machinery has started such remanufacturing programs of equipment parts using PTWA, resulting in a greener environment. Remanufacturing by recoating of parts is also very popular in the aircraft field, the geothermal pipe field and the automotive engine field.

3. *Repetitive remanufacturing without identity loss*; in this method, there is the additional challenge of scheduling the sequence of dependent processes and identifying the location of inventory buffers. There is a fine line between repetitive remanufacturing without loss of identity and product overhaul. Again, the critical difference is that remanufacturing is a complete process. The final output has a like-new appearance and is covered by a warranty comparable to that of a new product.

Remanufacturing with loss of original product identity

With this method, used goods are disassembled into pre-determined components and repaired to stock, ready to be reassembled into a remanufactured product. This is the case when remanufacturing automobile components, photocopiers, toner cartridges, furniture, ready-to-use cameras and personal computers. Once the product is disassembled and the parts are recovered, the process concludes with an operation not too different from original manufacturing. Disassembled parts are inventoried, just like purchased parts and made available for final assembly.

Remanufacturing with loss of original product identity encompasses some unique challenges in inventory management and disassembly sequence development. Some of the open questions relate to the commonality of parts in products of different generations, the uncertainty in the supply of used products, and their relationship with production planning. The National Center for Remanufacturing and Resource Recovery (NCR3) at Rochester Institute of Technology (NY) is researching remanufacturing processes including testing standards for remanufactured products.

Rebuilding

Rebuilding is an old name for remanufacturing. It is still widely used by automotive industry. For example, the Automotive Parts Remanufacturers Association (APRA),[7] have the new term in their name, but to be safe on their own website use the combined term 'rebuild/remanufacture'.

The term 'rebuilding' is also often used by railway companies; a steam locomotive may be rebuilt with a new boiler or a diesel locomotive may be rebuilt with a new engine. This saves money (by re-using the frame, and some other components, which still have years of useful life) and allows the incorporation of improved technology. For example, a new diesel engine may have lower fuel consumption, reduced exhaust emissions and better reliability. Recent examples include British Rail Class 57 and British Rail Class 43.

Benefits of Engine Remanufacturing

1. **Lower Cost -** One of the biggest factors in choosing a remanufactured engine is cost. Remanufactured engines cost up to 50 percent less than a new Tier 4 Final engine, not including associated engineering costs, and offers even greater savings over the purchase of a new piece of equipment. Maintenance on some new Tier 4 Final engines can be costly as well. In addition to being more complex to service, additional costs for after treatment cleaning and DEF fluid can add up quickly. [8]

2. **Less Downtime** - Opting to replace your existing engine with a new one typically requires significant engineering time that can render rental equipment out of service for months. The integration and testing process also takes significantly longer with a new Tier 4 Final engine than with remanufactured engines. [8]
3. **Increased Equipment Resale Value** - There are two main factors currently making it difficult to sell Tier 4 Final-powered equipment in lesser regulated countries: serviceability and fuel availability. The lack of established service programs for the new technology makes supporting the product difficult. This coupled with high product costs, have companies shying away from Tier 4 Final powered equipment. In addition, many lesser regulated countries don't have high availability for ultra-low sulphur diesel fuel, which is required by Tier 4 Final engines to operate effectively. Without it, the diesel particulate filter can clog rapidly and cause significant operation issues.[8]
4. **More Sustainable Option** - Purchasing a remanufactured engine keeps an old engine core and many usable components out of a landfill, which can greatly reduce the impact on the environment. According to Perkins Pacific's Andy Machin, approximately 73 percent of the old engine can be salvaged during the remanufacturing process saving millions of pounds of waste out of landfills. New engine production requires all new materials, substantial amounts of energy for the production process and additional transportation costs. By utilizing recycled components, a remanufactured engine typically uses about 80 percent less energy than new engine production, making it a much greener option. For rental fleet owners, reman offers the opportunity to expand their sustainability practices while saving money. [8]

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External links

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- http://www.remanufacturing.org.uk
- apra-europe.org (http://www.apra-europe.org/main.php)
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Categories: Design for X | Production and manufacturing | Waste management

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RURAL ELECTRIFICATION - THE OPPORTUNITY

Rural communities need electricity -

- **to sustain their economic development, and**
- **to improve the standard of living**

so that the rural populations would stop migrating to the already over-crowded cities.

OPTIONS

The cost of **extending a grid line** over dry flat land is **US$15,000 per kilometer** and up to US$1 million per kilometer under water. As grid extensions are cost-prohibitive for many remote regions, the **only options for electrical power are stand-alone systems using renewable energy and diesel fuel.** The positive and negative attributes of using different available equipment to tap these resources are listed in the table below.

GENERATOR	POSITIVES	NEGATIVES
DIESEL GENSETS	Low initial cost Portable Easy to use AC power but low quality Predictable fuel supply	Fluctuating load shortens the life expectation Low efficiency at low loads High maintenance High fuel cost, especially transportation cost Noise and air pollution
CONVENTIONAL FIXED-AXIS WIND TURBINES	Low operating cost "Free" and "clean" energy AC power, grid-type high quality No air pollution	High initial cost Intermittent power generation depending on wind conditions Needs ≥ 8m/s wind speeds to generate power Have to be shut down at high wind speeds
SOLAR PANELS	Low operating cost "Free" energy Lowest entry cost but only suitable for very limited use	Highest unit cost of energy delivered over time Intermittent daytime-only power generation DC (battery-type) power Not made to endure high temperature or high humidity environments Needs high effective solar radiation levels
MINI-HYDRO	Low operating costs "Free" and "clean" energy	High unit cost of energy delivered over time Needs to be near a constant water source
WIND HYBRID SYSTEMS (combining some or all of the above)	Utilizes all available renewable resources Lowest unit cost of energy delivered over time Low operating costs Fail-safe ensured by back-up diesel genset	High initial cost Problems in integrating, balancing and controlling system components
DIESEL-BATTERY HYBRID SYSTEMS	Lower initial cost than a wind hybrid system Lower operating cost and longer life expectancy than just a diesel genset Easy to install and to use Renewables can be added later	Higher operating cost than the renewables High fuel cost and transportation problems Noise and air pollution

RURAL ELECTRIFICATION - THE SOLUTION

From an evaluation of the attributes of the different options, a **Wind Hybrid System** is the most appropriate system for rural electrification provided that sufficient wind resource is available and that the objective is for a long-term sustainable economic development. However, if initial capital is limited and the cost of fuel is reasonable, a good alternative is a Diesel-Battery Hybrid system that can be expanded to include renewable sources at a later stage. Synergy Power Corporation has addressed the problems listed in the table above and has developed a wind hybrid system using a revolutionary wind turbine.

A "Synergy System" comprises:

- **SYNERGY WIND TURBINES**
  - deliver **200% more energy** than conventional turbines in its class at less initial cost and unit cost.
  - generate rated power in **low wind speeds** (4.5m/sec).
  - perform to rated power in **80%+ of the world's land mass**.
  - operate in high wind speeds when conventional wind turbines have to shut down.

- **BATTERY BANK**
  - stores the energy generated for 24-hour use.
  - has a depth of discharge ("DOD") of 30% for long life.
  - is intelligently managed by electronic controls.

- **INTERACTIVE INVERTERS AND CONTROLS**
  - provide grid-quality sinewave 220V single-phase and 380V three-phase AC power.
  - are fully automated for independent operation.
  - have high efficiency and minimize losses.

- **DIESEL GENERATOR SET**
  - provides back-up energy to guarantee supply.
  - allows the use of a smaller battery bank which reduces cost.
  - is fully automated with start/stop action according to need.

- **SOLAR PANELS** (OPTIONAL)
  - add energy during the day when winds may be low.
  - are easy to install.

How A Synergy Remote Area Power System Works

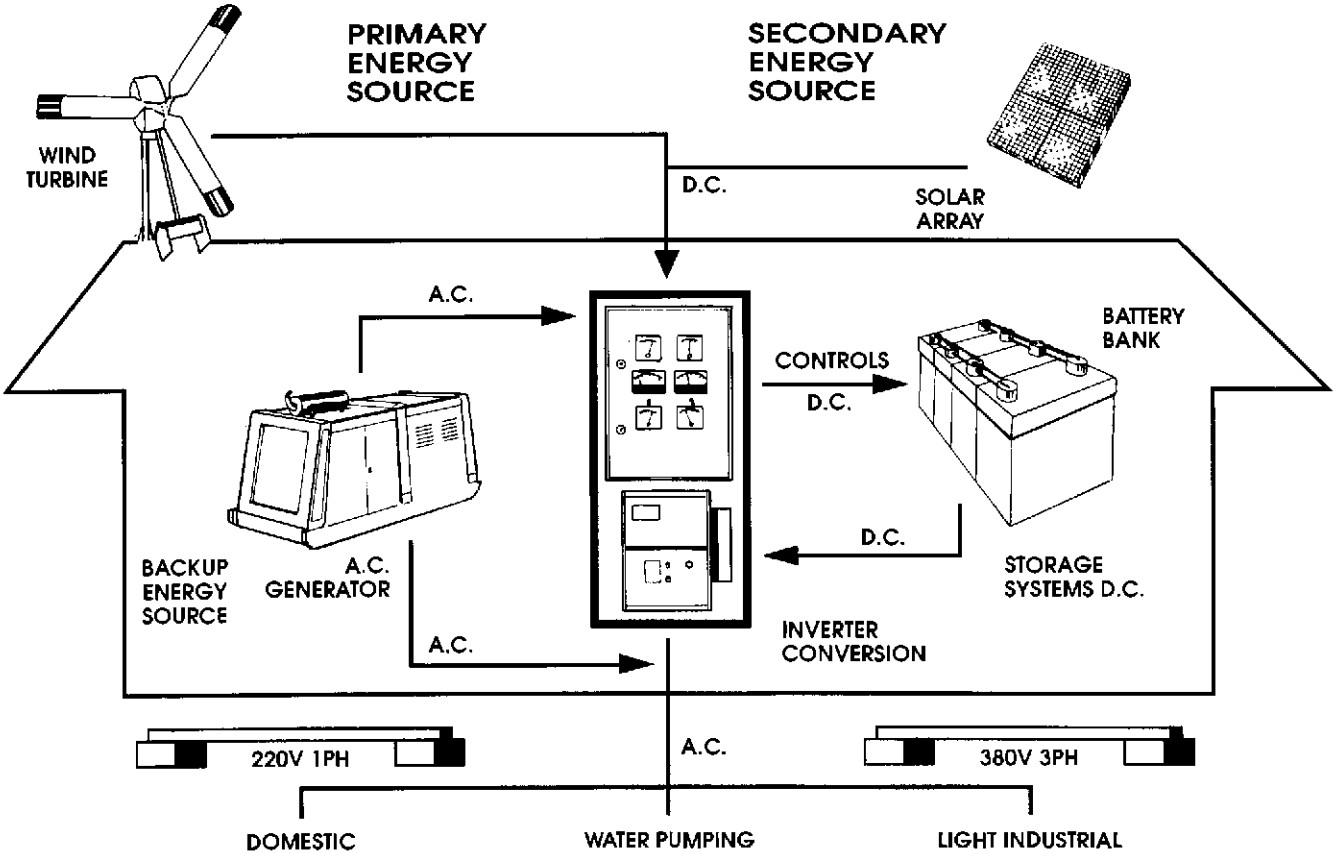

ADVANTAGES OF THE SYNERGY SYSTEM

- **Lowest cost of energy**

  A Synergy wind turbine uses a small generator to deliver a large amount of energy. When a Synergy System is designed, the cost effectiveness of different components, as in battery storage and back-up generators, is taken into consideration. Therefore, the capital cost and operating cost are minimized. The system's efficiency is also enhanced by the use of "smart" and fully-automated controls developed by Synergy. All these factors contribute to bringing down the cost of energy.

- **Provides power for light industrial use**

  A Synergy System provides grid-quality AC power that can run modern and readily available household appliances to light industrial tools and machines. Contrasting it with a system that can only provide lighting and TV/radio, a Synergy System can provide electricity for activities that could improve the economy and generate repayments for the system's cost.

- **Transportable components**

  The componentry of a Synergy System has been designed to be of small enough size and low enough weight to make it easy to transport to remote regions where the infrastructure may not be well established.

- **Easy to install and maintain**

  Synergy Systems have also been designed for easy installation and maintenance. A Synergy System can be installed within days without the use of any heavy equipment. Synergy will also provide training to the local staff on installation and maintenance. We have developed comprehensive manuals that have been used in many different countries and have trained many people over the last six years.

- **Reliable**

  The Synergy Wind Turbines and Systems have been tested in Australia, the United States, Indonesia, Malaysia, South Africa and Saudi Arabia, and have performed well under the harshest conditions.

- **Durable**

  The Synergy System is designed to perform for twenty years if maintained and operated in accordance with recommended standards.

SYNERGY SYSTEM PERFORMANCE - FOR RURAL COMMUNITIES

- Turbine captures wind energy for direct supply or storage.
- Batteries store excess energy for use in times of low wind.
- Diesel genset provides fail-safe backup.

Daily Electricity Demand and Supply Curve

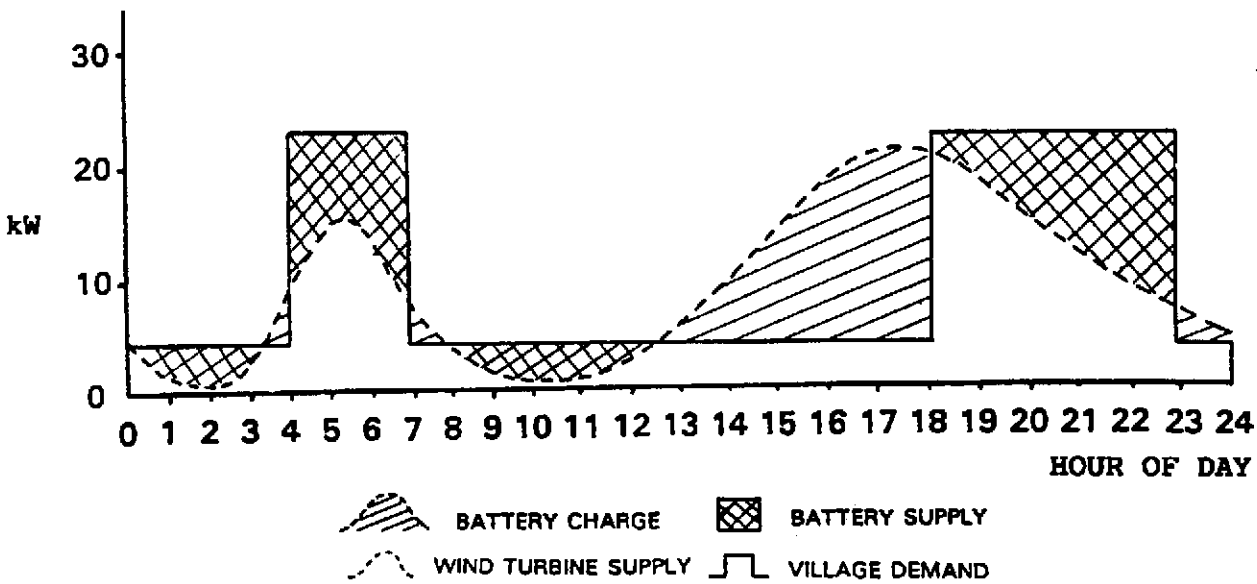

The Synergy System supplies 24 hours of 220V (single phase) AC power for domestic use and/or 380V (three phase) AC power for light industrial use.

380V (three phase) AC power can be used for light industry in applications such as :

- Rice grinding
- Salt farming
- Ice making
- Irrigation
- Coffee bean peeling and drying
- Fish meal production
- Other light industries

220V (single phase) AC power can be used for domestic use such as :

- Lighting
- Household appliances like refrigerators and microwave ovens
- Computers, televisions and telecommunications
- Water pumping

SYNERGY SYSTEM PERFORMANCE
- FOR GROWING RURAL COMMUNITIES

The **Synergy System** is **ADAPTABLE** and **EXPANDABLE**. As local economies grow, the existing supply can be **allocated to specific applications** and additional supply capacity can be **modularly added**.

Daily Electricity Supply and Demand Curve with Light Industry

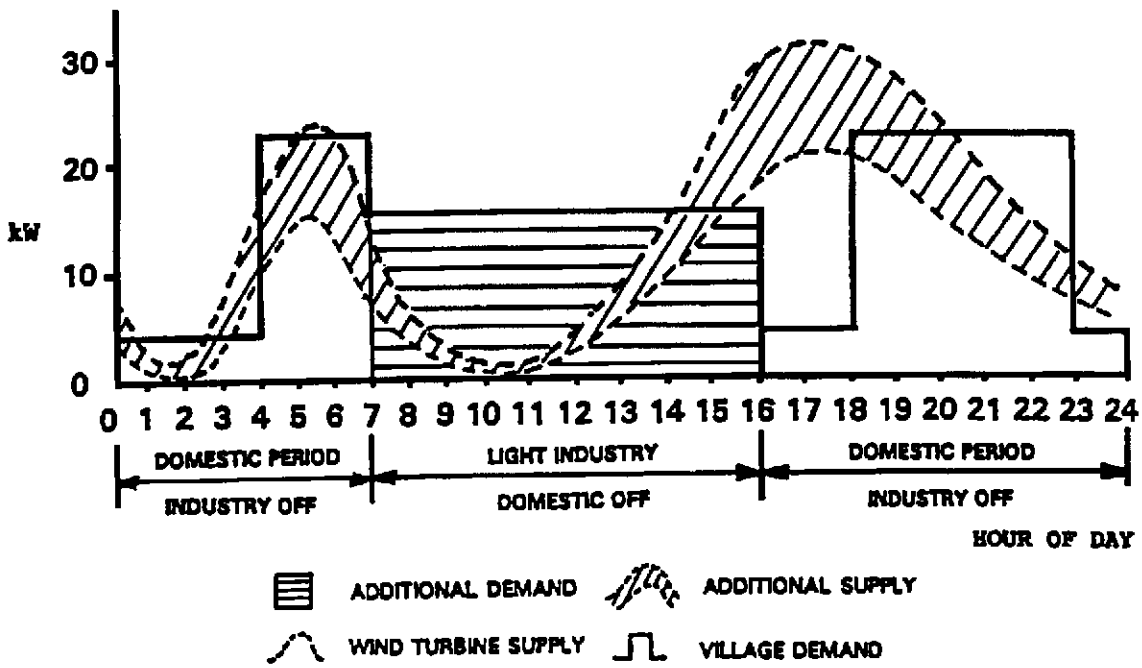

Electric Power can be first allocated to Light Industrial use during day time. Then as increased demand from light industry grows it can be supplied by additional Synergy wind turbines and/or solar panels. The example Synergy System above could provide:

22 kWh/day is consumed for domestic uses
13 kWh/day is consumed for economic uses

RURAL ECONOMY

A community has the ability to meet the expanding demand of electricity from their domestic, light industrial and agricultural uses by simply adding low cost modular components such as wind turbines.

The community's **ability to pay for their power consumption also increases** as the portion of power dedicated to these industrial and agricultural uses increases.

This creates a dynamic environment of **GROWTH** and **DEVELOPMENT**.

Remote pumping buyer's guide

Moving water is a requirement on nearly every remote and rural property. We take a look at the different types of pumping systems, and what pumps are on the market

Pumping water is a task that is often necessary on many remote and rural properties. Whether it be for watering stock, plant irrigation, or for providing potable water for the occupants, the pumping systems must be reliable, easy to maintain, and will usually have to be other than mains electricity powered, simply because many rural properties have to supply their own power.

Sometimes, water may need to be pumped from a creek or river, sometimes from a dam, and often, water needs to be drawn up from a well or bore. These tasks all require different pumps, and the amount of water, and the head it needs to be pumped to, all vary from one site to another.

Because of these variations in pumping requirements, there are now many different types of pumps on the market. These include the well-known windmill-powered bore pumps, solar bore pumps, reticulation pumps and pressure pumps. There are also numerous types of each of these categories, making selecting a pump for a particular job a less than simple task.

One type of pump we will not look at in this guide is the 240-volt powered pump. There are so many of these on the market, in so many shapes and sizes, that it would simply be impossible to cover them all, and in most cases, they are unsuitable for remote pumping, as they require AC power to operate, necessitating the use of batteries and inverters, thus increasing system cost and complexity.

Pumps work in a number of different ways. Windmill bore pumps, for instance, use pistons, buckets or cups to lift the water up inside a plastic or metal tube that runs down inside the bore to below water level.

Then you have electric pumps, which can be either centrifugal, similar to a pump used on a swimming pool, diaphragm, helical rotor or piston. The latter type can be either single or double acting, and are often just a standard windmill-style bore pumping arrangement with an electric motor and gearbox replacing the windmill.

In putting together this guide we found many different pumps, being sold in all sorts of configurations. Some companies will sell a specific pump on its own, while others will sell a package with that pump, some solar panels, a maximiser and wiring harness. This has made it difficult to give accurate prices for some of the pumps, as the costs of the packages vary from supplier to supplier.

What to look for

Things to look for in a pump include the use of non-corrosive fittings and components, particularly stainless steel, as this is very strong and long-lasting.

Many of the bore pumps now use PVC pipe in place of the older galvanised steel pipe, and are not prone to early failure due to corrosion from salty water.

In general, the pumps known as positive displacement pumps will have higher efficiencies than centrifugal types, especially when pumping to high heads, so if getting the most out of your solar panel pumping system is important to you, a positive displacement pump would be best. If you are not sure that the pump you are looking at is this type, ask your supplier.

A Southern Cross windmill pumping system, very common in rural areas in Australia.

There are also a few terms that you should understand, including head, lift and flow rate.

Head is how high the pump can push water above it. It is not the total dis-

tance up a hill, only the vertical height component. In a bore pump, it also includes the depth from the pumping head, inside the bore, to the surface.

Lift is sort of the opposite of head. It is generally how far a pump can raise water from below it. A pump's lift rating is usually a lot lower than its head rating, and some pumps cannot lift water at all.

The flow rate is the amount of water that the pump will move over a given time period. For electric pumps, the flow rate depends on several factors, including the amount of electrical input power, the head and lift the pump must deal with and the diameter of the pipes connected to the pump.

Wind-powered pumps are dependent on wind speed, head, lift and pipe diameter.

DC pumps

There are a large variety of pumps made to run on extra-low-voltage DC power supplies. Some are meant to be run from battery systems, while others are run directly from solar panels via a maximiser-style device, which matches the load of the pump motor to the panels.

The pumps usually consist of a DC motor, either electronically commutated (brushless) or brushed, connected to a pump head of some kind.

Some pumps have all of the components in a compact package, such as the Shurflo submersible bore pumps, while others have them mounted separately and coupled via a shaft or belt drive. The Sunergy Mono is an example of this type of pump, using a standard Mono helical rotor pump coupled to a $^1/_3$ horsepower DC motor.

Circulation pumps

These are used to circulate water through a closed system, such as through a remote coupled solar hot water system where the tank is lower than the panels.

They can also be used for many other purposes that do not require high differential pressure across the pump, though many can withstand high system pressures, making them suitable for use in mains pressure systems. They are generally not suited to pumping to high heads.

General purpose pumps

These include all sorts of small and large pumps. They are often used for moving water or other liquids from one place to another, over relatively short distances, and at low pressures and heads. An example of these are bilge pumps, which are often used to move water from one tank to another, or in water fountains and low-pressure irrigation. Bilge pumps are available from marine supply shops, and are not included in this guide, as they are not designed to run continuously.

Pressure pumps

These are used to provide the equivalent of mains pressure water to a house from a water tank, dam or other reservoir.

Pressure pumps usually come complete with a pressure switch that allows them to run only when the system pressure drops below a certain level. They are normally used in conjunction with a small pressure vessel or tank that helps maintain an even system pressure, and acts as a pressure reservoir (the pressure vessel contains a 'bubble' of compressed air).

Bore pumps

Submersible bore pumps are generally cylindrical in shape, with a wire mesh screen intake at one end. They are mounted inside the bore itself, and can pump water at relatively high flows and to high heads. They usually pump up to a water tank or dam for storage.

Most bore pumps can pump silty water without damage, though, as with many pumping systems, regular maintenance will need to be carried out.

Another type of bore pump is the remotely coupled piston pump, where a pump at the bottom of the bore is connected to the driving motor at the surface by rods and couplings.

Wind-powered pumps

You can pump water with the wind in a number of different ways. The most well-known is the use of a low-speed, high torque wind turbine to drive a mechanical pump directly at the base of the turbine tower. The Oasis windmill is an example of this type of pumping system. This is a tried and proven pumping method, and pumps of this type have been providing water to farms and remote buildings around the world for over a century.

Another way of pumping with the wind is to use an electricity-producing wind turbine to drive an electric pump.

A third method is to use a wind turbine to compress air, which can then be used to drive a pump of some sort. Two examples of home-built pumps of this type appeared in issue 66 of *ReNew*.

This floating pump consists of a Mono Sunray pump mounted on a floating pontoon.

Water-driven pumping

It may sound strange, but running water can indeed be used to pump water, and to quite high heads.

The Glockemann ram pump is an example of such a system. A relatively large flow at low pressure, such as the diverted flow from a river or stream, is used to pump a much lower volume of water to much higher pressure, so that it may be pumped to a high head.

Maximisers

A maximiser, or maximum power point tracker, is a small electronic device used with solar panels that enable a pump or motor to keep operating in conditions of cloud and low light levels.

Many pumps will simply stop when a cloud causes the solar panel output to reduce. This happens because the pump motor places too-high a load on the panels, and their voltage drops dramatically, thus reducing their output power. The maximiser works by preventing this, and will allow the pump to keep operating, thus pumping more water than it otherwise would.

If you are installing a solar-powered pumping system, then you really should consider a maximiser in the system. Most pumping suppliers have them, and they range in price from less than $100 to over $1000, depending on their power handling capabilities and features.

What's available

The pumps are listed in three separate tables—solar and DC pumps, wind-powered pumping systems, and water-powered pumps.

Many of the pumps listed in table two actually come as pumping packages, including solar panels, and sometimes a maximiser-style controller. If panels are included, this is detailed in the comments column in the table.

The wind-powered pump table also includes those systems that just consist of a pump pipe, rods and buckets etc, without a wind turbine or tower. These can usually be attached to any standard water pumping windmill, but can also be used in conjunction an electric motor and solar panel system. ✲

Using water to pump water! The Glockemann Peck pump does just that.

Contact details

Below is a list of manufacturers and distributors. Due to space constraints, it is not possible to list all of their dealers. We suggest that you contact those companies listed below, or your local solar dealer and see what they can supply.

Choice Electric Co, 3 Prospect St Bowen Hills Qld 4006, ph: 1800 074 007, email: choice@powerup.com.au, www: www.choiceelectric.com.au

Davy Industries, RMB 1036, Barnawartha Nth VIC 3688, ph:(02)6026 7711.

Grundfos Pumps P/L, unit 3/2 Sarton Rd Clayton VIC 3168, ph:(03)9561 0111, fax:(03)9561 0211.

Laing: Solar Charge Pty Ltd, 115 Martin St Brighton VIC 3186, ph:(03)9596 1974, fax:(03)9596 1389.

LVM: Quirk's Victory Light Co PO Box 440, Rose Bay NSW 2029, ph:(02)9371 6600, fax:(02)9371 6623

March: Solar Charge Pty Ltd, 115 Martin St Brighton VIC 3186, ph:(03)9596 1974, fax:(03)9596 1389.

Mondesh Pumps: New Mill Solar P/L, 2/6 Duffy St, Burwood VIC 3125, ph:(03)9888 9953, fax:(03)9888 9954.

Mono pumps: Mono Pumps Pty Ltd, 338-348 Lower Dandenong Rd, Mordialloc VIC 3195, ph:(03)9580 5211, fax:(03)9580 6659.

OASE: Quirk's Victory Light Co PO Box 440, Rose Bay NSW 2029, ph:(02)9371 6600, fax:(02)9371 6623

Shurflo Pumps, 27 Treforest Drive, Clayton VIC 3168, ph:(03)9562 6162, www.sureflo.com

Solarjack: WD Moore and Co, ph:1800 654 766

Solar Energy Systems Pty Ltd, 3/81 Guthrie St, Osborne Park WA 6017, ph:(08)9204 1521.

Southern Cross: Southern Cross machinery Australia, ph: 131 786.

Sunergy Mono Mini: Solar Charge Pty Ltd, 115 Martin St Brighton VIC 3186, ph:(03)9596 1974, fax:(03)9596 1389.

Thumpa Pumpa: Southwest Pumps N Solar, 46 Wyndham St, Roma QLD 4455, ph:(07)4622 4528.

Table 1. Wind-powered pumps and pump heads

Make	Model	Pump type	Blade diameter	Tower	Maximum head (m)	Used for	Comments	Warranty	Price
New Mill Solar	Mondesh	multi-cup PVC bore pump	NA	NA	60	Bore pumping	Multi-cup system. Designed to be self-cleaning. Available in 2, 2.5 and 3 inch versions.	1 year	POA
Oasis		¾" to 1½" double acting bore pump	1350mm	3, 4.5m lattice	80m	Bore pumping	Four different pump sizes and gear ratios available.	1 year	$1,450 (3m tower) $1,800 (4.5m tower)
Southern Cross	IZ series	Stainless steel piston pump	1.8m to 4.3m	6m to 18m	up to 135m	Bore pumping	Five different rotor sizes, six different tower heights and two different tower types available.	3 years	POA
Southwest Pumps N Solar	PolyRod	Windmill column and rod	NA	NA	60	Bore pumping	Used in conjunction with standard bore pump. Replaces galvanised steel pipes and rods.	1 year	POA
	Flexi-column	Windmill column and rod	NA	NA	52		Flexible, one-piece bore pipe. Used in conjunction with standard bore pump. Replaces galvanised steel pipes and rods. Standard or heavy duty units.		POA

Table 2. DC pumps and pumping packages

Make	Model	Pump type	Voltages	Max. current	Solar panels	Flow (L) at head (m)	Maximum head (m)	Used for	Comments	Warranty	Price
Choice	Floating solar pump	Shurflo positive displacement	24	—	2 x 53 or 2 x 80 watt	up to 50,000L/day	up to 22	Pumping from dams, streams and wells	General purpose pontoon pump, supplied in various packages with Solarex modules and pump controller.	1 year	POA
Davy Industries	Solar piston pump	Chang Seng piston pump	29	—	up to 200 watts	12,000L/day @ 12m	30m	Pumping from dams, streams and wells	8m suction lift capacity @ sea level. Available on own or as a kit.	1 year	POA
			58	—	up to 300 watts	10,300L/day @ 36m	36m				
Grundfos	400	Multistage centrifugal	45, 60, 75, 90	—	150 to 400 watt array	up to 40,000L/day	up to 40	General pumping and supply	All stainless steel construction. PV or battery power. Built-in fault monitoring. Eleven different pump/motor combinations.		POA
	SP series	See comments		—	350 to 2000 watt array	up to 24,000L/Hr	up to 120		All stainless steel construction. PV or battery power. Built-in fault monitoring. Six different pump combinations available.		POA
Laing		Magnetic drive impeller	12	0.25	—	up to 420L/Hr	—	Circulation pumping	Suitable to 100˚C. Can be used for hot water systems.	1 year	$336
LVM	Congo	Centrifugal submersible and inline pump	12, 24	6 @ 12V	—	2200L/Hr	14psi	Fresh and sea water transfer, diesel transfer	Small diameter inline pump suitable for general use.	150 hours of pumping	$125, $135
	Amazon			4.5 @ 12V		1100L/Hr	14psi		Small diameter inline pump suitable for general use. Temperatures to 80˚C.		$100, $110
	Nile		12	2.5		764L/Hr	11psi				$79
	Niagara			2.8			14psi	Fresh and sea water transfer	Small diameter inline pump suitable for general use. Temperatures to 80˚C.		$65
	Zambezi	Centrifugal inline	12, 24	4.5 @ 12V		1100L/Hr	15psi	Fresh water transfer	Water temperature to 80˚C		$92, $100
	Missouri	flexible impeller inline	12, 24	9 @ 12V		1100L/Hr	16psi	Diesel, fresh and sea water transfer	Temperatures from 4 to 60˚C. Cannot run dry for more than 30 seconds		$275, $290
March	809BR	Magnetic drive impeller	12	1.1	—	up to 900L/Hr	—	Circulation pumping	Suitable to 120˚C. Can be used for hot water systems.	1 year	$420
New Mill Solar	Big Red	Bore pump head	24	—	—	up to 1200L/Hr	60	Bore pumping	Designed to be coupled with the Mondesh PVC bore pump or other bore pumps	1 year	from $3,357
Mono	Sun Sub series	Submersible helical rotor	180	—	2 to 21 x 60 watt	up to 90,000L/day	120	Bore pumping	Comes with fixed or tracking solar array and controller. Has 240V AC input.	1 year	$6,000 to $20,000
	Sun Ray series	Helical rotor	24	—	2, 3 or 4 panels	up to 17,300L/day	30	Low-head surface water transfer	Available in 2, 3 and 4 solar module packages. available in surface mount or with floating pontoon.		POA
	Sun Rotor		180	—	2 to 24 panels	up to 140,000L/day	100	High flow, long distance pumping	Slow-speed pump for long life. 240V AC input option.		
	Sun Downer		180	—				Borehole pumping	Surface mount motor with lineshaft drive bore pump. 240V AC input option.		
OASE	Aquasolar 700	Centrifugal	12 - 24	8 watts	—	720L/Hr @ 24V	2	Fountains and water features	Also available as a package with solar panel, fountain and nozzels	3 years	$255
	Aquasolar 1500			17 watts	—	1500L/Hr @ 24V	3				$338
Shurflo	2088 series	Diaphragm	12, 24	4	—	up to 640L/Hr	—	Mains pressure pumping	Comes complete with filter and pressure vessel. Designed for intermittent use.	1 year	$204
	8000 series	Diaphragm	12	7.2	—	up to 390L/Hr	40	General delivery	Designed for intermittent use.	1 year	$160
	9300 series	Submersible diaphragm	12, 24	4.1	1 or 2 x 53 or 2 x 80 watt	443L/hr @ 6m 310L/hr @ 70m	70	General bore pumping	Replacement of diaphragm every 12 months recommended. Available as a complete package.	1 year	$1,250
Solar Energy Systems	Poly-Pisto-n-Pump	Double-acting piston pump	30, 60	—	2 x 32 to 6 x 90	up to 36,000L/day	54	Bore and transfer pumping	Available in several pump sizes, with many different configurations of pump and solar panel combinations.	2 years	POA
Solarjack	SDS series	Submersible diaphragm	12 to 30		up to 2 x 83 watt	up to 840L/Hr	up to 40	General and bore pumping	Can be used in open vented or pressurised system. Available to suit 4 or 5 inch bores.	1 year	POA
Southwest Pumps N Solar	Thumpa Pumpa	Piston pump	58	—	2 x 60 watt to 8 x 60 watt	up to 28,000L/day	up to 48	General water pumping	A complete package available in 6 different versions to suit requirements Uses AERL controller.	1 year	$3950 to $7850
Sunergy	Mono Mini	Helical rotor	12, 24	—	2 x 60 or 2 x 83 watt	6600L/day @ 5m	25	General moderate head pumping	Solar panels included. Good for silted and sandy water. Toothed belt drive.	1 year	$2,500 to $2,700 ex tax
WD Moore	Sola-Flo	Positive disp. bore pump	48	—	4 x 64 watt	up to 10,000L/day	up to 200	Bore pumping	Includes low water level sensing, stainless steel construction. Fits 4 inch bore casing.	1 year	POA
	SF series	Positive disp. surface pump	12, 24	—	2 x 64 to x 64 watt	up to 18,000L/day	up to 30	Pumping from dams and lakes	Capable of lifting water 4.5 metres. Low water level sensing built in. Also available as a floating pontoon system.		

Table 3. Water-powered pumps

Make	Model	Pump type	Pumping Flow rate	Supply fall	Supply flow rate	Maximum head (m)	Used for	Comments	Warranty	Price
Glockemann Peck	160 Water Dragon	Diphragm piston pump	up to 5,000L/day	0.5 to 2m 1.5L/sec or more	1.5L/sec minimum	100	General water supply pumping	Available with 35, 48 and 60mm pump bores. Flow rate depends on supply head.	1 year	$990
	320 Oasis		up to over 22,100L/day	0.4 to 2m		200		Available with 35, 48, 60, 73, 98 and 124mm pump bores. Flow rate depends on supply head.		$1950

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Removal of Lead Ion from Industrial Wastewaters by Activated Carbon Prepared from Periwinkle Shells (*Typanotonus fuscatus*)

M. A. O. BADMUS, T. O. K. AUDU and B. U. ANYATA
Department of Chemical Engineering, University of Benin, Benin-City-NIGERIA
e-mail: badmusolalekan@yahoo.com

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Abstract

Lead adsorption from industrial wastewater was studied with the aim of detoxifying industrial effluents before their safe disposal onto land or into river waters. Activated periwinkle shell carbon (PSC) was prepared and characterised for various physiochemical properties. To determine lead(II) removal capacity, the performance of PSC was compared with that of commercial activated carbon (CAC) and a mixture of PSC and CAC (PSC: CAC) in a ratio 1:1. The effect of various parameters such as adsorbent dose, contact time, pH, agitation speed, and particle size of the adsorbent was studied to optimise the conditions for maximum adsorption. Batch adsorption kinetic experiments revealed that the adsorption of Pb(II) onto PSC involved fast and slow processes. The mechanisms of the rate of adsorption were analysed using the Elovich equation and a pseudo-second-order model. It was found that the adsorption mechanisms in the lead/adsorbent system follow pseudo-second-order kinetics with a significant contribution from film diffusion. The adsorption isotherms were described by means of the Langmuir and Freundlich isotherms and both models represent the adsorption process. The percentage removal of lead onto PSC, PSC:CAC, and CAC was 82.78%, 92.68%, and 88.44%, respectively.

Key words: Lead, Adsorption, Kinetics, Periwinkle shell, Wastewater.

Introduction

Metals and their compounds are indispensable to the industrial, agricultural, and technological advancement of any nation. The numbers of applications of metals for commercial uses continue to grow with the developments in modern science and technology.

Industrial processes and spent commercial (metallic) products generate large quantity of metallic waste products, which are discharged into the water or land-dump sites. It has been estimated that the toxicity due to metallic discharge annually into the environment far exceeds the combined total toxicity of all radioactive and organic wastes as measured by the quantity of waste required to dilute such wastes to the drinking water standard (Nriagu, 1981; Bready and Weil, 1999; Abdus-Salam and Adekola, 2005).

Lead contamination of the environment is primarily due to anthropogenic activities, making it the most ubiquitous toxic metal in the environment (Amdur et al., 1991; WHO and ILO, 1995). Research on Pb has become a dominant topic for environmental and medical scientists for 2 obvious reasons: (i) it has no known biological use, and (ii) it is toxic to most living things (Abdus-Salam and Adekola, 2005).

Lead is a metal ion toxic to the human biosystem, and is among the common global pollutants arising from increasing industrialisation. The assimilation of relatively small amounts of lead over a long period of time in the human body can lead to the malfunctioning of the organs and chronic toxicity. The toxic effects of lead ions on humans, when present above the threshold level in the hydrosphere, are well documented (Khurshid and Qureshi, 1984). Previously, various researchers have studied the adsorption of heavy metal ions from solution using

naturally occurring minerals. Pyrolusite has been used for adsorption of lead and magnesium ions from their aqueous solution (Ajmal et al., 1995). Zeolites have been used for the removal of heavy metals from wastewater (Yuan et al., 1999). Sigworth and Smith (1972), and Muscas (1995) have also used adsorption techniques for the removal of heavy metals from polluted water. Other adsorbents that have been used for the removal of heavy metals solution include soils (Campbell and Davies, 1995) and carbonaceous material developed from fertiliser waste slurry (Srivestava et al., 1989). Adsorption of heavy metal ions from polluted water by activated carbons from date pits (Girgis and Hendawy, 1997) and by ferrite and chelating resin method (Tokunaga and Uthium, 1997) has also been studied. Other researchers reported the adsorption of lead on oxide of silicon, manganese, aluminium (Bilinshi et al., 1977), bentonite (Kozar et al., 1992), hydrated titanium dioxide (Abe et al., 1989), modified silica gel (Volkan et al., 1987; Mareira et al., 1990), dithizone-anchored poly (EDGMA-HEMA) micro beads (Salih et al., 1998), anionic micro gel (Morris et al., 1997), ZnS surface (Pattrick et al., 1998), magnetite (Georgeaud et al., 1998), pedogenic oxides, ferrihydrite and leaf compost (Sebastein et al., 2000), sawdust (Yu et al., 2001), lateritic minerals (Ahmad et al., 2002), and carbon (Akhtar and Qadeer, 1997; Qadeer and Akhtar, 2005).

Marine snails in general are part of the family Gastropoda and vary in size. They are found in oceans all over the world. The common periwinkle (Littorina littorea) is one of the most abundant marine gastropods in the North Atlantic but T. fuscatus is commonly found in the Niger Delta, Nigeria. Periwinkles distribute themselves in different positions on the shore. They are usually 1.3 to 2.5 cm in height, and colouration is grey to black. The shell is fairly heavy and solid. They live in the intertidal zone (the area of the shore that has alternating periods of exposure to air and then water). One of the main advantages of lead ion removal using activated carbon prepared from periwinkle shells (PSC) over the other chemical treatment methods and commercial activated carbon (CAC) is that it is in abundance and its easy availability makes it a strong choice in the investigation of an economical way of lead removal.

In this study, PSC as an alternative to CAC was used for the removal of lead ion from industrial wastewater. Parameters affecting adsorption like contact time between the wastewater and the adsorbent, adsorbent dose, pH of the sample, agitation speed, and size of the adsorbent particles were investigated, and data on adsorption isotherm were obtained and fitted to common isotherm models, Langmuir and Freundlich.

In recent years, development of surface modified activated carbon has generated a diversity of activated carbon with far superior adsorption capacity. The use of periwinkle shell with surface modification to improve its metal removal performance would add to its economic value, help reduce the cost of waste disposal, and, most importantly, provide a potentially inexpensive alternative to existing commercial activated carbon.

Materials and Methods

Three types of adsorbents, PSC, CAC, and ratio 1:1 mixture of PSC and CAC (PSC:CAC), were used as the media (precipitating agent and/or adsorbent) to remove lead ion from industrial wastewater. Industrial effluent was collected from a stream carrying wastewater from an industrial plant. Materials used for sample collection were pretreated by washing the container with dilute hydrochloric acid and later rinsed with distilled water. The containers were later dried in an oven for 1 h at 110 ± 5 °C and allowed to cool to ambient temperature. At the collection point, containers were rinsed with samples 3 times and then filled with sample, corked tightly, and taken to the laboratory for treatment and analysis. The method of analysis was consistent with the standard methods (Goltermann, 1978; APHA, 1985). The pH of the sample was measured at the site and other parameters were measured in the laboratory. Samples were stored at below 3 °C to avoid any change in physico-chemical characteristics. An atomic absorption spectrophotometer was used: model Phillip PU 9100 × with a hollow cathode lamp and a fuel rich flame (air acetylene). Each sample was aspirated and the mean signal response recorded at the metal ion's wavelength. This was used to compute the concentrations of metal ions absorbed by the adsorbents. Batch experiments were carried out in different sets by taking PSC in the range of 20-70 g/100 ml of wastewater sample. The steps of the experiments are described below:

Effect of adsorbent dose: The experiments were individually set up for each adsorbent. For each 100 ml of wastewater sample, the amounts of PSC used

were 20, 30, 40, 50, 60, and 70 g. Samples were withdrawn regularly after a fixed time interval, filtered, and analysed for residual lead. The experiment was repeated for CAC and PSC:CAC.

Effect of mixing time: The experiments were performed by varying mixing time from 30 to 300 min. The adsorbent dose used was obtained from the best value received from previous experiments.

Effect of pH: pH plays an important role in the precipitation and adsorption mechanisms. The experiments were performed by varying pH level of the samples wastewater ranging from pH 2 to 12 before adding adsorbents. The amount of adsorbents and time used were obtained from the best values received from the previous experiments. The experiment was carried out using PSC, CAC, and PSC:CAC, in that order.

Effect of mixing speed: Studies on mixing speed was performed by comparing the removal efficiency of lead at various mixing speeds from 100 to 700 rpm. The best treatment conditions for time, pH, and adsorbent dose were obtained from the 3 sets of experiment described above.

Effect of particle size: The experiments were performed by varying particle sizes from 0.5 to 3.0 mm. The best conditions for mixing speed, time, pH, and dosage were obtained from the 4 sets of experiments described above.

Periwinkle shell

Periwinkle shell was collected from a large dumpsite in Port Harcourt, Nigeria. The samples were transported to the laboratory for immediate use.

The periwinkle shell was washed to remove dirt and sorted out by removing unwanted ones. The samples were charred by carbonising them in a furnace at 300 °C for about 2 h, after which it was ground using a hammer mill (Scotmec model) and later sifted with 180 μm Standard Tyler Sieve No. 80. The ground sample was later kept in a plastic container and stored at room temperature.

Periwinkle carbon activation

Activation of the charred periwinkle was carried out using the method recommended by Mansfield (1998) with slight modifications as follows: 200 g of the charred sample was mixed with 250 ml of 5.5 M HCl and refluxed by boiling for 2 h. After slight cooling, the slurry was filtered, washed free of acid, and dried at 110 °C for 3 h, ground using a mortar and pestle, and sifted using mesh of different sizes to obtain various particle sizes. The charred periwinkle was characterised for its bulk density as described by Okaka and Potter (1979). The SiO_2, Al_2O_3, Fe_2O_3, CaO, Na_2O, K_2O, and MgO were determined according to Jackson (1998). The major compositions of the sample are alumina, silica, iron oxide, and calcium oxide. Physical properties such as density and surface area were also determined.

Commercial activated carbon

The commercial carbon, Calgon carbon (F-300), was obtained from Calgon Carbon Inc., Pittsburgh, PA, USA.

Results and Discussion

Table 1 shows the physico-chemical analysis of the wastewater sample, depicting the level of lead in the wastewater sample.

Table 1. Characterisation of the effluent wastewater.

Parameter	Value
pH	8.7
TSS (mg/l)	42
Lead (mg/l)	19.1
Temperature (°C)	31
Turbidity (NTU)	22.5

The composition of typical Niger Delta (Nigeria) periwinkle shell carbon is shown in Table 2. The analysis showed that the periwinkle shell carbon is predominantly siliceous, followed by the insoluble oxides of aluminium, iron, calcium, magnesium, titanium, alkali oxides, and negligible amounts of phosphorus pentoxide and sulphur oxides.

In the case of periwinkle shell carbon as an adsorbent, the metal salt hydrolyses in the presence of natural alkalinity to form metal hydroxides. The multivalent cations present in periwinkle shell carbon can reduce the zeta potential while the metal hydroxides are good adsorbents.

Calculation of Pb^{2+} adsorbed

Two important physiochemical aspects for the evaluation of the adsorption process as a unit operation are the equilibria of the adsorption and the kinetics. Equilibrium studies give the capacity of the

Table 2. Characterisation of activated carbon and ash obtained from periwinkle shell.

Chemical composition (%)		Proximate analysis (%)		General characteristics	
Silicon dioxide (SiO_2)	60.2	Ash	4.6	Surface area, m^2/g	840
Aluminium oxide (Al_2O_3)	20.5	Loss on ignition	20.8	Bulk density, kg/m^3	0.147
Iron oxide (Fe_2O_3)	7.0	Volatile matter	1.7	Mean particle size, mm	1.75
Calcium oxide (CaO)	3.7	Fixed carbon	54.9		
Magnesium oxide (MgO)	1.12	Moisture	18.0		
Phosphorus pentoxide (P_2O_5)	1.82				
Titanium oxide (TiO_2)	2.1				
Alkali oxide (Na_2O/K_2O)	2.3				
Sulphur trioxide (SO_3)	1.37				

adsorbent (Ho et al., 1995). The equilibrium relationships between adsorbent and adsorbate are described by adsorption isotherms, usually the ratio between amount of solute adsorbed per unit amount of adsorbent (solid phase concentration) and concentration of solute in solution at a fixed temperature at equilibrium.

The amount of metal ion adsorbed during the series of batch investigations was determined using a mass balance equation:

$$q = \frac{v}{m}\,(C_o - C_f) \tag{1}$$

where q is the metal uptake (mg/g); C_o and C_f are the initial and equilibrium metal concentrations in the wastewater sample (mg/l), respectively; v is the wastewater sample volume (l); and m is the mass of adsorbent used (g).

The definition of removal efficiency is as follows:

$$Removalefficiency(\%) = \left(\frac{C_0 - C_f}{C_o}\right) \times 100 \tag{2}$$

where C_o and C_f are the metal concentrations in the wastewater sample before and after treatment, respectively.

Comparison of different adsorbents for $^{2+}$ removal

Equilibrium studies were performed for analysing the performance of all the adsorbents. The data were generated by varying the adsorbent doses (20 to 70 g/l) at room temperature with PSC, CAC, and a ratio 1:1 of PSC:CAC (Figure 1). The influence of adsorbent dose on adsorption of lead at constant adsorbate concentration was studied for the purpose of determining the right adsorbent mass that will bring about a better decontamination of Pb-contaminated effluent. The result suggests that after a certain dose of adsorbent the maximum adsorption sets in and hence the amount of ions bound to the adsorbent and the amount of free ions remain constant even with further addition of the dose of adsorbent. About 47.86% of Pb(II) can be removed with PSC and PSC:CAC, and about 26.42% can be removed with CAC.

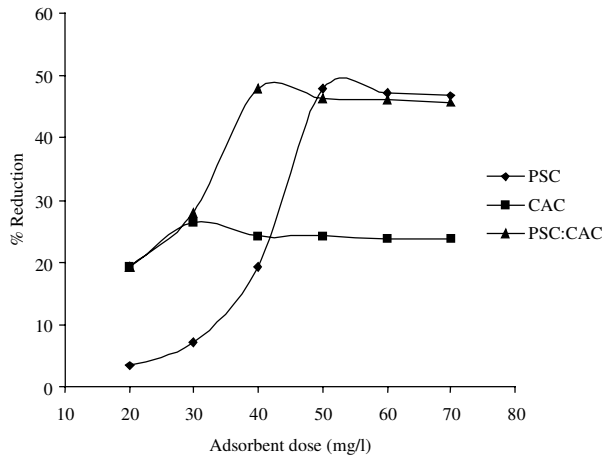

Figure 1. Effect of adsorbent dose on the adsorption of lead.

The distribution of lead between the liquid phase and the solid phase is a measure of the position of equilibrium in the adsorption process and can be expressed by the most popular isotherm models — Langmuir and Freundlich adsorption isotherms.

Effect of reaction time: Figure 2 shows removal of lead ion from water sample using different adsorbents as a function of time. The result shows that for PSC the removal rate was rapid within the first 30 min, sharply increased for 90 min, slowing

down between 150 and 180 min, and then gradually approaching equilibrium after 180 min. For CAC, the removal rate was rapid within the first 60 min, sharply increased for 30 min, slowing down between 120 and 180 min, and then gradually approaching equilibrium after 180 min, whilst for PSC:CAC the adsorption process was rapid, being complete in 90 min.

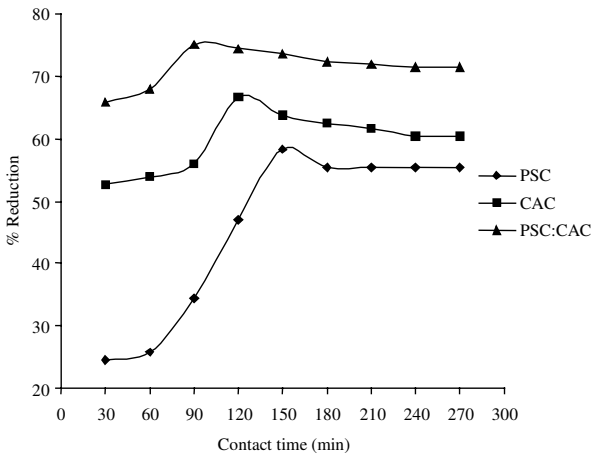

Figure 2. Effect of reaction time on the adsorption of lead.

The initial faster rate may be due to the availability of the uncovered surface area of the adsorbents, since the adsorption kinetics depend on the surface area of the adsorbents. The lead adsorption takes place at the more reactive sites. As these sites are progressively filled the more difficult the sorption becomes, as the sorption process tends to be more unfavourable. This is the general characteristic of adsorption of this metal ion (Smith, 1970; Johnson, 1990; Appel and Lena, 2002; Abdus-Salam and Adekola, 2005; Qadeer and Akhtar, 2005).

These changes and differences in metal ion uptake rate could be attributed to 2 different adsorption processes, namely a fast ion exchange followed by chemisorption (Low, 1993).

Effect of pH: pH is an important parameter for adsorption of metal ions because it affects the solubility of the metal ions, concentration of the counter ions on the functional groups of the adsorbent and the degree of ionisation of the adsorbate during reaction.

The removal of metal ions from wastewater sample by adsorption is related to the pH of the sample, as the latter affects the surface charge of adsorbents, the degree of ionisation, and the species of adsorbate. The pH of the aqueous solution is an important controlling parameter in the adsorption process (Baes and Mesmer, 1976) and thus the role of H^+ concentration was examined from samples at different pH covering a range of 2-12 (Figure 3). The result shows that adsorption of Pb(II) increased at a steady rate as pH increased up to about 8, attaining a maximum value of around 78.53%, 88.44%, and 88.44% for PSC, CAC, and PSC:CAC, respectively. However, after pH 8, there was a decrease in the adsorption. This decrease may be due to the formation of soluble hydroxyl complexes. According to Low et al. (1995), at low pH values the surface of the adsorbent would be closely associated with hydroxonium ions (H_3O^-), by repulsive forces, to the surface functional groups, consequently decreasing the percentage removal of metal. As the solution pH increase, the onset of the metal hydrolysis and the precipitation began at pH > 8 and the onset of adsorption therefore occurs before the beginning of hydrolysis (Baes Mesmer, 1976). When the pH of the adsorbing medium was increased from 2 to 8, there was a corresponding increase in deprotonation of the adsorbent surface, leading to a decrease in H^+ ion on the adsorbent surface. This creates more negative charges on the adsorbent surface, which favours adsorption of positively charge species and the positive sites on the adsorbent surface (Ghanem and Mikkelsen, 1988; Kadirvelu and Namasivayam, 2003; Abdus-Salam and Adekola, 2005).

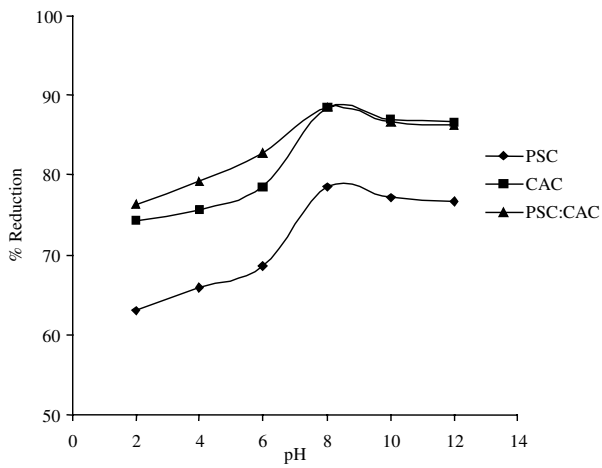

Figure 3. Effect of pH on the adsorption of lead.

The hydrolysis of cations occurs by the replacement of metal ligands in the inner coordination sphere with the hydroxyl groups (Badmus et al.,

2007). This replacement occurs after the removal of the outer hydration sphere of metal cations. In addition, the results obtained agreed with the findings of some researchers showing that the dependence of metal ion adsorption on pH over a wider range of pH (3-12) has an S-like adsorption curve (Johnson, 1990; Bruce, 2000; Glover II et al., 2002). The solubility of metals is known to be lowered at higher pH (at pH > 8) values (Inbaraj and Sulochana, 2002; Abdus-Salam and Adekola, 2005) due to the likelihood of precipitation of the hydroxide forms of the adsorbate species. Thus, results that gave the S-like curve were a reflection of adsorption and precipitation processes on adsorbents rather than adsorption only.

Adsorption may not be related directly to the hydrolysis of the metal ion, but instead of the outer hydration sphere that precedes hydrolysis. Most probably, the removal of Pb(II) from wastewater samples by adsorbents involves a complex mechanism that is partly controlled by adsorption and partly by chemical precipitation at the solid wastewater sample interface and also by the pore filling mechanism.

Effect of agitation speed: The effect of agitation of the sorbent/sorbate system in lead adsorption was monitored at low, medium, and high speed of agitation as shown in Figure 4.

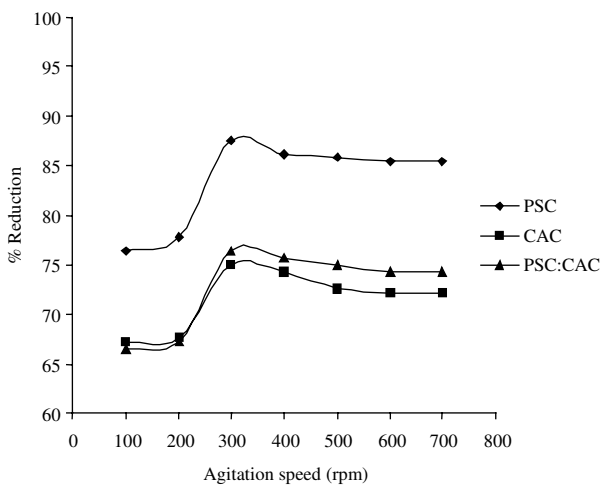

Figure 4. Effect of agitation speed on the adsorption of lead.

The slight increase in adsorption is primarily due to the fact that agitation facilitates proper contact between the metal ions in solution and the adsorbent binding sites and consequently promoting effective transfer of sorbate ions to the sorbent sites. This also indicates that a shaking rate in the range 300-700 rpm is sufficient to assure that all the surface binding sites are made readily available for lead uptake. Then the effect of external film diffusion on adsorption rate can be assumed to be not significant.

Effect of adsorbents' particle size: The effect of altering adsorbents' particle size on % removal showed that, between 0.5 and 2 μm, there was a more rapid removal of Pb(II) by small particles (Figure 5). This was most probably due to the increase in the total surface area, which provided more adsorption sites for the metal ion. The breaking of larger particles tends to open tiny cracks and channels on the particle surface of the material, resulting in more accessibility to better diffusion, owing to the smaller particle size (Weber and Morris, 1963; Karthikeyan et al., 2004). The enhanced removal of sorbate by smaller particles has been noted previously during a study into the removal of colour by silica (McKay et al., 1980) and during study on the use of sago waste for the sorption of lead and copper (Quek et al., 1998).

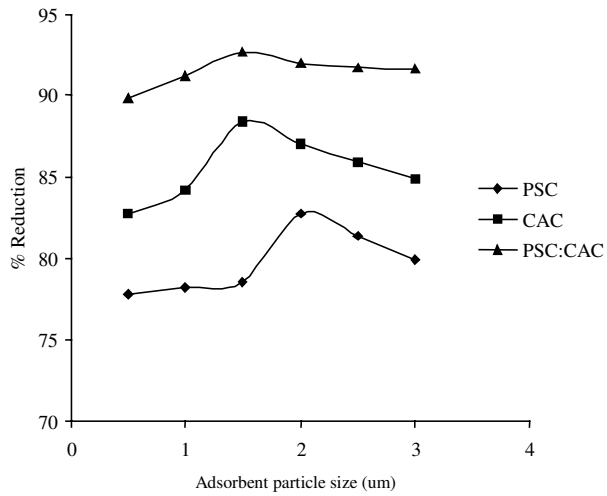

Figure 5. Effect of adsorbent particle size on adsorption of lead.

Adsorption studies

All the experiments were carried out at ambient temperature in batch mode. Batch mode was selected because of its relative simplicity. The batch experiments were run in different glass flasks of 250 ml capacity using a mechanical shaker. Prior to each experiment, a pre-determined amount of adsorbent was added to each flask. The stirring was kept constant for each run throughout the experiment, ensuring

equal mixing. The desired pH was maintained using dilute NaOH/HCl solutions. Each flask was filled with a known volume of sample having the desired pH before the stirring commenced. The flask containing the sample was withdrawn from the shaker at the predetermined time interval and filtered through Whatman No. 44 filter paper. The experiments were carried out under different experimental conditions.

Adsorption model: The result of batch equilibrium was used to obtain metal adsorption isotherms as illustrated in Figure 6. The adsorption isotherm was used to characterise the equilibrium between the amount of adsorbate that accumulated on the adsorbent and the concentration of the dissolved adsorbate. In this study, the experimental isotherm data set obtained was fitted using adsorption models including the Langmuir and Freundlich isotherms.

The Langmuir adsorption isotherm and the Freundlich isotherm are 2 common isotherms used to describe equilibria (Domenico and Schwartz, 1990; Reddi and Inyang, 2001; Nitzsche and Vereecken, 2004). The Langmuir isotherm is based on the theoretical principle that only a single adsorption layer exists on an adsorbent and it represents the equilibrium distribution of metal ions between the solid and liquid phases. The basic assumption of the Langmuir adsorption process is the formation of a monolayer of adsorbate on the outer surface of the adsorbent and after that no further adsorption takes place.

The equation is described by

$$q_e = \frac{x}{m} = \frac{q_o k C_e}{k C_e + 1} \tag{3}$$

where x is the amount of metal adsorbed, m is the unit mass of adsorbent, and q_e is the amount of metal ion adsorbed per unit mass of adsorbent; q_o and k are empirical constants, and C_e is the equilibrium concentration of adsorbate in wastewater sample after adsorption; q_o is the maximum adsorption capacity corresponding to complete monolayer coverage (mg of adsorbate per g of adsorbent).

Equation (3) can be re-arranged to yield

$$\frac{C_e}{q_e} = \frac{C_e}{q_o} + \frac{1}{q_o k} \tag{4}$$

The linearised Langmuir isotherm allows the calculation of adsorption capacities and the Langmuir constants.

C_e is the equilibrium concentration of adsorbate (mg/l);

q_o and k are the Langmuir constants and are the significance of adsorption capacity (mg/g) and energy of adsorption (l/mg) respectively;

q_o and k are obtained from the intercept and slope of the plot of C_e/q_e and C_e.

Figures 6 shows the adsorption isotherms of lead, while Figure 7 shows Langmuir isotherms of lead on the different adsorbents used.

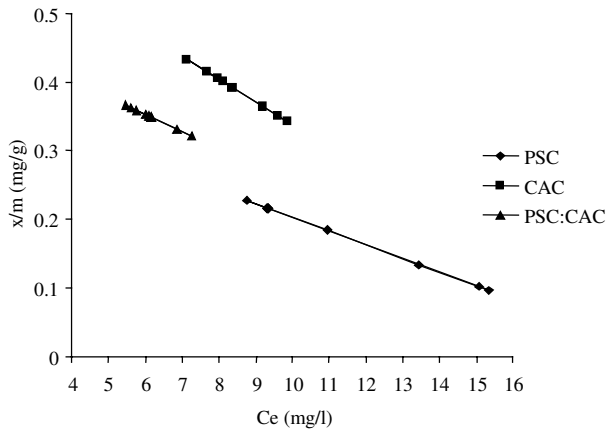

Figure 6. Adsorption isotherm of lead on activated periwinkle shell carbon (PSC).

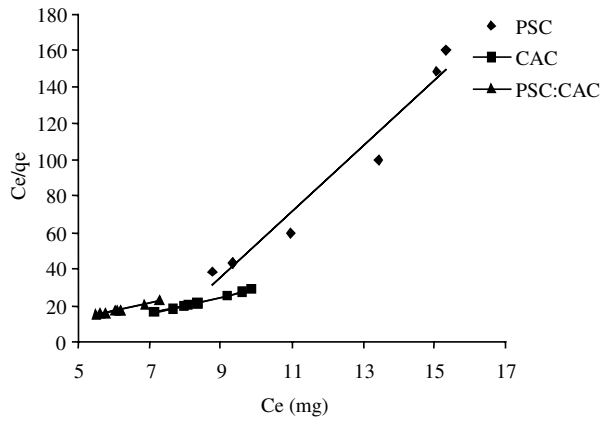

Figure 7. Comparison of Langmuir isotherms of activated periwinkle shell carbon (PSC), commercial activated carbon (CAC), and mixture of PSC and CAC (1:1).

The Freundlich adsorption isotherm is an indicator of the extent of heterogeneity of the adsorbent surface. The general form of the isotherm is given as

$$q_e = k C_e^{\frac{1}{n}} \tag{5}$$

A linear form of this expression is given as

$$\log\left[\frac{x}{m}\right] = \log k + \frac{1}{n} \log C_e \tag{6}$$

k and n are the Freundlich constants and represent the significance of adsorption capacity and intensity of adsorption, respectively. Values of k and n were calculated from the intercept and slope of the plot log q_e and log C_e (Figure 8).

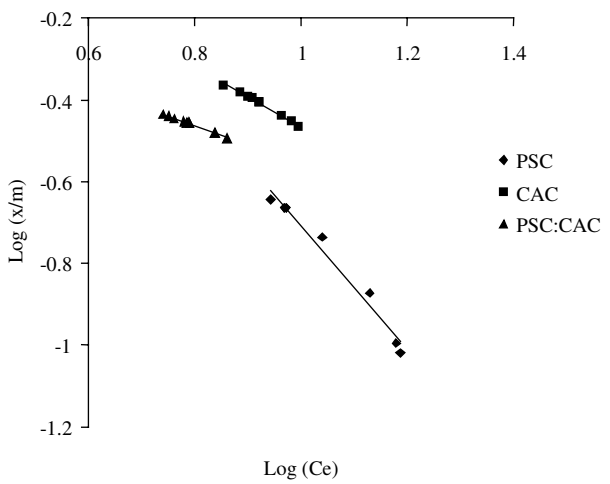

Figure 8. Comparison of Freundlich isotherms of activated periwinkle carbon (PSC), commercial activated carbon (CAC), and mixture of PSC and CAC (1:1).

This Freundlich type behaviour is indicative of the surface heterogeneity of the adsorbents, i.e. the adsorptive sites (surface of activated carbon) are made up of small heterogeneous adsorption patches that are homogeneous in themselves. The activation of adsorption site takes place, leading to increased adsorption probably through the surface exchange mechanism.

A comparison of isotherm parameters for all 3 adsorbents was done to determine the effectiveness of the adsorbents. The coefficients of determination (r^2) and the isotherm constants are given in Table 3. The high values of r^2 (>95%) for both isotherms show that the adsorption of Pb(II) could be well described by both the Langmuir and Freundlich isotherms.

Adsorption kinetics: Several steps can be used to illustrate the adsorption mechanism. To investigate the mechanism of lead adsorption and the potential rate controlling steps, such as diffusion mass transport and chemical reaction processes, it is necessary to characterise the main adsorption mechanisms. The diffusion process can be controlled by film/external boundary layer diffusion, diffusion in the liquid filled-pores of adsorbents, or surface diffusion of adsorbed-soluble molecules that migrate along the surface of the adsorbent. The rate controlling mechanism may be one diffusion mass transfer resistance or a combination of 2 or 3 of these processes.

When the water sample is shaken, the adsorbate species, i.e. lead, are transported to the solid phase by the intraparticle transport phenomenon. The intraparticle transport is supposed to be the rate controlling step. The rate of particle transport through this mechanism is slower than adsorption on the exterior surface site of the adsorbent. The amount of adsorbed species, lead, varies proportionately with a function of retention time. The equation can be expressed as

$$X = K.t^n \tag{7}$$

where X is the % reduction, t is the contact time in minutes, n is the slope of the linear plot (Figure 9), and Kt is the constant coefficient. The deviation of the line from the origin shows that intraparticle transport is not the only rate limiting step (Badmus et al., 2007). Probably, the transport of the water sample through the particle-sample interface into the pores of the particles, as well as the adsorption on the available surface of the adsorbents, is responsible for adsorption.

The study of the adsorption kinetics is the main factor for designing an appropriate adsorption system and quantifying the changes in adsorption with time requires that an appropriate kinetic model is used.

Table 3. Adsorption isotherm constants and coefficient of determination for different adsorbents.

Adsorbent	Langmuir isotherm constants			Freundlich isotherm constants		
	q_o (mg/g)	k (l/mg)	r^2	k (mg/g)	n	r^2
PSC	0.0558	- 0.1430	0.972	6.5509	- 0.6554	0.981
CAC	0.2191	0.2751	0.996	1.8621	- 1.3587	0.998
PSC:CAC	0.2344	0.4983	0.999	0.8043	- 2.1744	0.996

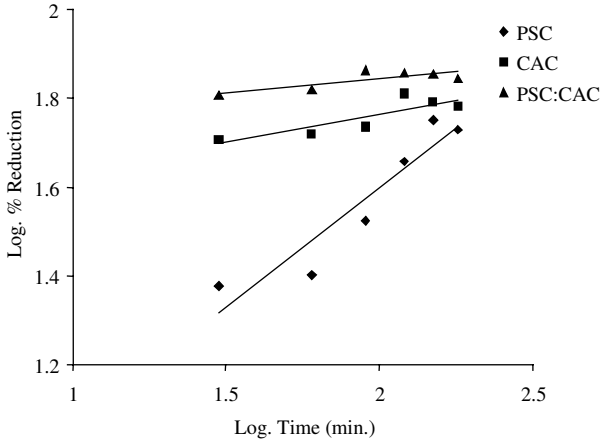

Figure 9. Log % reduction vs. log time.

The Elovich equation was developed to describe the kinetics of chemisorption of a gas onto solids (Low, 1960), and its differential form is represented in Eq. (8). The parameter α represents the rate of chemisorption at zero coverage and the parameter β is related to the extent of surface coverage and the activation energy of chemisorption. The application of the Elovich equation is rapidly gaining popularity (Aharomi and Ungarish, 1976; Sparks, 1986). Taylor et al. (1995) successfully used the Elovich equation for the sorption of zinc ions onto solids. Ho and McKay (2004) studied the sorption of copper from aqueous solution by peat, and Juang and Chen (1997) studied the sorption kinetics of metal ions from sulphate solutions onto solvent impregnated resins. Other applications include work on radioisotopes (Mishra and Singh, 1995; Mishra et al., 1996; Raouf and Daifullah, 1997).

The Elovich equation is generally expressed as

$$\frac{dq_t}{dt} = \alpha \exp\left(-\beta q_t\right) \tag{8}$$

where q_t is the amount adsorbed at time t, and α and β are constants during any one experiment. The constant α can be regarded as the initial rate since $\frac{dq_t}{dt} \rightarrow \alpha$ as $q_t \rightarrow 0$. Integration of Eq. (8) assuming the initial boundary conditions $q_t = 0$ at $t = 0$ yields

$$q_t = \left(\frac{1}{\beta}\right) In\left(1 + \alpha\beta t\right) \tag{9}$$

To simplify the Elovich equation, Chien and Clayton (1980) assumed $\alpha\beta t >> 1$ and applying the boundary conditions $q_t = 0$ at $t = 0$ and $q_t = q_t$ at $t = t$ Eq. (9) becomes (Sparks, 1986)

$$q_t = \left(\frac{1}{\beta}\right) In\left(\alpha\beta\right) + \left(\frac{1}{\beta}\right) In\left(t\right) \tag{10}$$

Hence, the constants can be obtained from the slope and intercept of the linearised plots of q_t against In(t). Equation (10) will be used to test the applicability of the Elovich equation to the kinetics of lead adsorption.

For the rate constant of the pseudo-second-order chemical adsorption process,

$$\frac{dq_t}{dt} = k\left(q_e - q_t\right)^2 \tag{11}$$

The concentrations are expressed in terms of lead adsorbed on adsorbent, q, and for a second-order process the rate of lead adsorption is expressed to the power of the adsorbed lead loading difference to the power of 2.

In Eq. (11), q_e is the amount of lead adsorbed at equilibrium, (mg/g); q_t is the amount of lead adsorbed at time t, (mg/g) and k is the equilibrium rate constant of pseudo-second-order adsorption, (g/mg min). Assuming that $q_t = 0$ at $t = 0$, the integrated form of Eq. (11) becomes

$$\frac{1}{q_e - q_t} = \frac{1}{q_e} + kt \tag{12}$$

Equation (12) can be rearranged to give

$$\frac{t}{q_t} = \frac{1}{kq_e^2} + \frac{1}{q_e}t \tag{13}$$

h can be regarded as the initial adsorption rate since $t \rightarrow 0$, hence,

$$h = kq_e^2 \tag{14}$$

hence, Eq. (13) becomes

$$q_t = \frac{t}{\frac{1}{h} + \frac{t}{q_e}} \tag{15}$$

and

$$\frac{t}{q_t} = \frac{1}{h} + \frac{1}{q_e}t \tag{16}$$

Thus, a plot of $\frac{t}{q_t}$ *against* $t$would yield a linear relationship with the slope of $\frac{1}{q_e}$ and intercept of $\frac{1}{h}$ *or* $\frac{1}{kq_e^2}$.

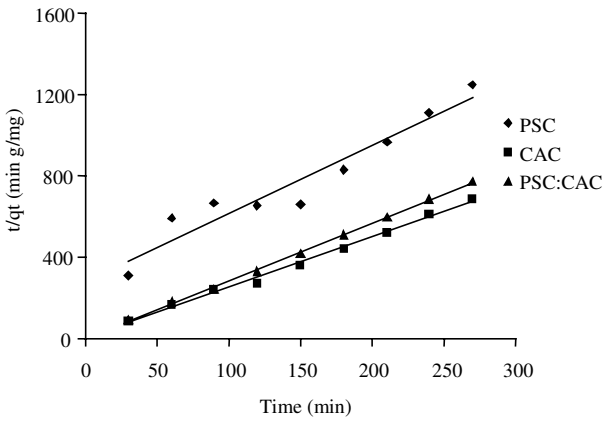

Figure 10. Pseudo-second-order adsorption kinetics of lead on activated periwinkle shell carbon (PSC).

Figure 10 shows the linearised form of the pseudo-second-order model for the adsorption of lead on PSC. The correlation coefficients, r^2, and the pseudo-second-order rate parameters are shown in Table 4.

Table 4. Pseudo-second-order parameters and coefficient of determination for different adsorbents.

Adsorbent	Pseudo-second-order equation			
	q_e	H	k	r^2
PSC	0.2962	0.0036	0.0412	0.927
CAC	0.4054	0.1178	0.7168	0.994
PSC:CAC	0.3513	- 1.3184	- 10.6829	0.999

The data show a good compliance with the pseudo-second-order equation, and the regression coefficients for the linear plots were 0.927, 0.994, and 0.999 for PSC, CAC, and PSC:CAC, respectively. The results are also shown in Figure 11 as a plot of q_t against In(t) for adsorption of lead for the Elovich equation. The correlation coefficients, r^2, and the Elovich equation parameters, α and β, are shown in Table 5. Comparison of the 2 models reveals that the r^2 for both pseudo-second-order and the Elovich equations show that the results can be well represented by the pseudo-second-order model. Hence, on the basis of the excellent fit of the pseudo-second-order and the correlation of the experimental results with the pseudo-second-order model, the main adsorption mechanism is probably a chemisorption reaction.

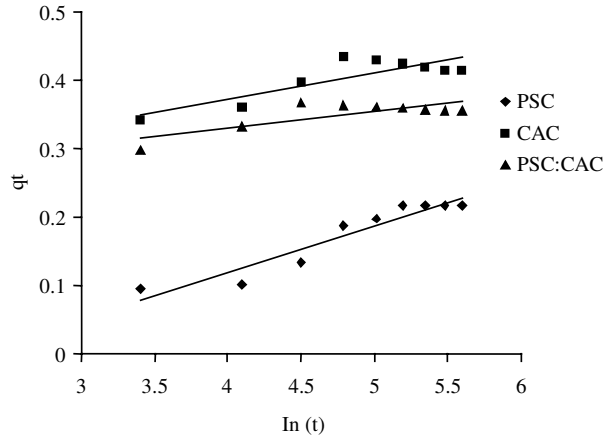

Figure 11. Plot of Elovich equation of lead on activated periwinkle shell carbon (PSC).

Table 5. Elovich equation parameters and coefficient of determination for different adsorbents.

Adsorbent	Elovich equation		
	β	α	r^2
PSC	14.7493	0.0073	0.903
CAC	26.2467	12.4595	0.726
PSC:CAC	41.4938	392.1138	0.630

Conclusion

PSC has been successfully used to produce high quality activated carbon because of its inherent high densities and carbon content.

Experiments conducted on the adsorption of Pb^{2+} by PSC, CAC, and PSC:CAC showed similarity in quantity of lead adsorbed. The result showed that PSC can compete favourably with CAC. Equilibrium data were well plotted by both Freundlich and Langmuir models. For the kinetic adsorption studies, adsorption data indicate the applicability of the pseudo-second-order kinetics and the Elovich model. Due to the high correlation coefficients obtained by using the pseudo-second-order kinetic model, the results can be represented well by the pseudo-second-order model. Consequently, the main adsorption mechanism is probably a chemisorption reaction. Hence this model should be used in design applications.

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May 26, 1959

To the Graduate Council:

I am submitting herewith a thesis written by David Gene Easterly entitled "Removal of Strontium-89 and Calcium-45 from Milk by Use of Ion Exchange Resins." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Dairying.

B. J. Stewart

Major Professor

We have read this thesis
and recommend its acceptance:

C. E. Wylie

R. G. Cragle

Accepted for the Council:

Dean of the Graduate School

REMOVAL OF STRONTIUM-89 AND CALCIUM-45 FROM MILK BY USE OF ION EXCHANGE RESINS

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

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by

David Gene Easterly

June 1959

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INTRODUCTION

The increased usage of nuclear power and the testing of atomic weapons have brought the problem of damaging effects of radiation to public attention. In recent months much publicity has been given the passage of strontium from the atmosphere into food and its accumulation in bone.

Due to its long half-life and its biological similarity to calcium, strontium is generally regarded to be one of the principal fission products which are of concern to the health of humans. The strontium level in milk has been steadily rising since 1954, the year adequate routine measures were first made. Since milk is the principal source of calcium of most Western Countries (people in the United States receive 85 per cent of their dietary calcium from milk products) (17) it has received attention as a source of strontium.

If the strontium content of milk could be reduced the overall strontium in the diet would be reduced.

The object of this investigation was to determine the feasibility of the use of ion exchange resins to remove strontium from milk.

REVIEW OF THE LITERATURE

Ion Exchange

Although the treatment of water by solid adsorbents such as sand is probably as ancient as civilization itself, the phenomenon of ion exchange was first recognized as such in soil experiments. In 1850, two Agricultural Chemists, Thompson (28) and Way (29) reported on exchange properties of certain soils. Their experiments showed that upon treating certain types of soils with either ammonium sulfate or ammonium carbonate most of the ammonia was adsorbed and lime was released. After further study they decided that such action was due to the complex silicates present in the soils, and concluded that ion exchange was taking place.

The first industrial use of ion exchange was attempted by Harms (13) in 1896. His effort to purify sugar juice by use of base exchange silicates was only partly successful. Gans (9), in 1906 also attempted to utilize ion exchange for industrial purposes. This experimenter employed both natural and synthetic aluminum silicates for the purpose of softening waters and for treating sugar solutions. A significant step in ion exchange history was the observation by Adams and Holmes (1) in 1935, that certain synthetic resins were capable of exchanging ions.

The explanation for the phenomenon of ion exchange may be grouped into three theories; the crystal-lattice exchange theory, the double-layer theory, and the Donnan membrane theory.

The crystal-lattice theory explains ion exchange by assuming that in an ionic solid the constituents of the crystal lattice are present as ions instead of molecules. Complete dissociation of the ionic solid is assumed. Each ion in the crystal is surrounded by a fixed number of ions of opposite charge, and since the coulomb attractive force between these ions is dependent upon the charge on the ions and the distance between them, the ions on the surface are bound less closely than those beneath the crystal surface. When placed in a medium such as water, these surface ions may be easily replaced by ions in solution.

The ease with which the surface ions may be replaced by another ion depends on (a) the nature of the forces binding the ion to the crystal, (b) the concentration of the exchanging ion, (c) the charge of the exchanging ion, (d) size of the two ions, (e) the accessibility of lattice ions, and (f) solubility effects (16).

The double-layer theory, as an explanation of the electrokinetic properties of colloids, has been considered by many to explain ion exchange. The exchange material is believed to be a fixed inner layer of charges surrounded by a diffuse and mobile outer layer of charges which extend into the external liquid media. There is no sharp boundary between the ions in the diffuse outer layer and those in the equilibrium external medium. It may be considered that the concentration of the ions constituting the diffuse layer as varying continuously and depending upon the concentration and pH of the external solution. Therefore, any change in the concentration of the ions in the external solution

upsets the equilibrium and a new equilibrium is obtained. Some of the ions held in the diffuse outer layer will be replaced by some of the new ions.

The Donnan membrane theory pertains to the unequal distribution of ions on two sides of a membrane, when one side contains ions too large to diffuse through the membrane. An unequal distribution will occur because of the undiffusible ions and the necessity of maintaining electroneutrality.

In applying the latter theory to ion exchange, the exchange material is assumed to be the ion too large to diffuse, and although in ion exchange no membrane is used, the interface between the solid and liquid phases is assumed to represent a membrane (16).

Otting (25) discusses the problems involved in the changing of equipment used for water treatment to a design which would be satisfactory from the sanitary viewpoint for ion exchange work in milk. The gravel in the bottom of the water softening device was replaced by a wire screen and a perforated plate to reduce the milkstone. Before a commercially feasible process resulted many changes in design of equipment and revival methods were necessary.

Milk can be modified by treatment with various types of organic ion exchange materials to produce certain desired characteristics. Haller and Morin (12) found that the type and extent of modification can be controlled at will by using the proper exchangers or combination of exchangers and by the proper regeneration of these exchangers. In one treatment these workers produced a soft curd milk of normal pH.

In another, approximately 20 per cent of the citrates, phosphates, and chlorides in addition to calcium and other cations were removed. Still another treatment removed citrates and chlorides and small amounts of calcium and other cations, but no phosphates.

In order to make cow's milk more suitable for the feeding of infants, modifications of the milk is necessary, particularly in the matter of curd tension. In 1930 Lyman (21) revealed that calcium could be removed from cow's milk by placing it in contact with greensand, a highly siliceous sand containing a little magnesia and alumina, and that the resulting milk exhibited soft-curd properties. This application of base-exchange silicates to the commercial treatment of dairy products was probably the first successful use of this principle in connection with a food product.

Murthy and Whitney (23) investigated the effect of mixed cation and anion resins upon the salt content of milk. The batch process was used to treat fresh raw skimmilk with cationic and anionic resin mixtures at four different levels each. The pH and the calcium, sodium, and potassium content decreased with increases in cation resin concentration. Citrate, chloride, and sulfate content decreased with increases in anion resin concentration. The nitrogen content was not affected except when coagulation occurred.

Sasaki, et al. (26) studied the effects of treatment with ion exchange resin on heat coagulation of milk. Calcium was adsorbed on a cation exchanger of sulfonic acid structure but no clear relationship was observed between the removal of calcium and the temperature of heat coagulation of milk.

Gehrke and Almy (10) investigated the adsorption affinity to synthetic ion exchange resins of the cations and anions normal to milk. The relative order of adsorption of the cations from the synthetic whey solution was found to be Ca^{++} Mg^{++} K^{+} Na^{+}.

Baker and Gehrke (4) developed an ion exchange resin contact time method to study the equilibria of calcium in milk and to measure directly the ion-exchangeable calcium. They also reported (5) that heating skimmilk to 40°, 60°, and 80° C. for 30 minutes had no noticeable effect on the exchangeability of calcium. However, the exchangeable calcium was significantly decreased as the temperature of heating increased from 100° to 120° C. for holding times of 30 minutes. Similar results were reported by Gehrke and Smith (11) who also observed that as the pH is increased the per cent of instantaneously exchangeable calcium decreases.

Two methods of recovering lactose from cheddar cheese whey were studied by McGlasson and Boyd (22). One method involved passing the original whey through ion exchange resins, removing the whey protein by heat treatment and further purifying the removed lactose solution with ion exchange resins. The second method differed from this only in that the original whey was not treated with ion exchange resins prior to the recovery of the protein fraction. Lactose with a higher degree of purity was recovered by the second method.

Josephson and Reeves (14) found that when mineral ion exchange treated milk was added to evaporated milk it was capable of stabilizing the evaporated product against coagulation during steriliza-

tion at 240° F. for 15 minutes. Mineral ion exchange milk was found to be effective in stabilizing milks exhibiting a wide range of instability to heat.

Nervik, et al. (24), by both a column and a bulk technique, removed nearly 90 per cent of the tracer isotopes of calcium and strontium from milk to which they had added isotopes, using Dowex-50W resin in the sodium form.

Radioactive Strontium

The strontium isotopes (mass numbers 84 through 94 and 97) may be formed as fission products and from the bombardment of other isotopes by nuclear particles. In the fission of Uranium-235 the strontium isotopes have a relatively large yield (about 5.8 per cent strontium-90). No radiation problem is presented by the stable isotopes of strontium 84, 86, 87 and 88. An isomeric form of strontium-87 and the isotopes 91, 92, 93, 94 and 97 have relatively short half-lives (range from ten hours to less than two minutes) and consequently, would decay rapidly compared to an isomeric form of strontium-85 and the isotopes 89 and 90, which have half-lives of 65 days, 55 days, and 25 years, respectively.

Strontium is one of the alkaline earths metals, belonging to Group II of the Periodic Table along with calcium, barium, and radium. Strontium-90 is generally regarded as the principal health hazard among the fission products since it is taken up by the human skeleton where it remains deposited for many years. The metabolism of stron-

tium has been found similar to that of calcium (2, 17, 15). Schulert and Peets (27) found that intravenously administered strontium-85 and calcium-45 in man were somewhat equally divided between bone and soft tissue for the first few days after administration but that after four months, about 99.5 per cent of the isotopes which were retained in the body were found in bone. The retention among the bones was greatest in vertebrae and least in long bone shaft and skull. Initially, the bone exhibited no marked preference for one isotope over the other, however, as strontium-85 was preferentially excreted by the kidney, the relative ratio of calcium-45 to strontium-85 remaining in bone gradually increased. The net retention of the isotopes appeared to level off at about 60 per cent for calcium-45 and 25 per cent for strontium-85. Although strontium retention in the body is less than calcium, the distribution throughout the body seems very similar.

Factors influencing the health hazards of strontium have been estimated by health physicists according to (1) quantities available, (2) initial body retention, (3) fraction going from blood to critical body tissue, (4) radiosensitivity of the tissue, (5) size of the critical organ, (6) biological half-life, (7) radioactive half-life, (8) energy of radiation produced by the radioisotope, and (9) specific ionization and attenuation of energy in tissue.

With the present knowledge, it is hardly possible to do more than broadly indicate the biological damage caused by strontium-90. However, the likely biological damage from ingestion of strontium-90 may be described under four headings: leukemia, bone tumor, life-shortening and genetic damage (6, 18).

According to Lewis (19) leukemia in man can be induced by ionizing radiations and can also occur spontaneously. He estimated that a 5 to 10 per cent increase in the current spontaneous incidence of leukemia would occur if the population were to reach and maintain a body level of strontium-90 amounting to one-tenth of the "maximum permissible concentration". The maximum permissible levels are recommended by the National Committee on Radiation Protection and Measurement and represent concentrations which are currently considered safe over a lifetime and which may occasionally be exceeded for short periods of time.

It has been demonstrated in laboratory animals that acute doses of radiostrontium cause bone tumors. As yet, nothing definite is known regarding the quantitative relationship between the magnitude of the dose and the incidence probability of bone tumors.

Radiostrontium Movement from Atmosphere to Milk

Radioactive fallout is the settling to earth of particles which are radioactive as a result of a nuclear explosion. Radiostrontium comes down mainly in raindrops. Part of the radiostrontium descending will lodge in plants, and part will enter the soil and then enter plants through their roots. The fraction which falls on leaves of growing plants is partially absorbed directly into the plant (7, 20).

Soil, like ion exchange resins, readily absorbs and retains most metal ions, including strontium. Approximately 80 per cent of the strontium-90 deposition is held in the top 2 inches of soil (7, 20).

About 50 per cent of the total is contained in the top one inch layer and the remaining portion in the soil to a depth of about 6 inches. The period for which radiostrontium stays in top-soil without becoming buried relatively deep, due to plowing, dispersion, or transformation into insoluble compounds, is not easily estimated, but probably extends over several years. Many factors, however, such as the nature of the soil, the extent of leaching by rain, the action of worms, and the cracking of the soil in dry weather, will affect the depth of penetration (7).

Very little is known about the actual mechanism of absorption and uptake of metal ions by plants but as strontium is chemically similar to calcium, it is reasonable to assume that calcium and strontium are absorbed in the same manner. The growing plant discriminates against strontium in favor of calcium at the ratio of about 2 to 1 (20). The absorption of strontium-90 by plants in a season is of the order of one per cent of the amount present in soil, the highest values in plants being in leaf tissue (7).

Animals markedly discriminate against strontium relative to calcium in their absorption of these elements from feed. The strontium activity in milk expressed as per gram of calcium present, is much below its value in the animal's ration. The experiments of Comar, et al. (7) and those of Cragle and Demott (8), have shown that the ratio of the strontium concentration in the animal's ration to that in the milk to be about 7-10 to 1. The cow acts as a barrier resisting the flow of strontium along the food-chain from soil to man. This

means that the strontium concentration (per gram of calcium) in milk is only about one-seventh to one-tenth of what it is in the feed the cow eats.

Since strontium and calcium metabolism are very closely associated, concentrations of strontium are generally expressed in terms of calcium. The most common and convenient unit for this purpose is the sunshine unit or sometimes called the Strontium Unit (S.U.), which is equal to the number of micromicrocuries of strontium-90 per gram of calcium. In itself it is not an absolute amount of strontium-90 but applies only to calcium contamination with strontium-90; and it provides a direct measure of this specific contamination. The maximum permissible body burden of strontium-90 for the general public is 0.1 microcurie, corresponding to 100 S. U. (as of April 22, 1959, unofficially 200 S. U.). On the basis of extensive experience of radiologists and technicians in work with X-rays and radium therapy, limited animal experimentations, experience with man and comparison with background concentrations of naturally occurring radioisotopes in our bodies, in the air we breathe and in the water and food we consume, the U. S. National Committee on Radiation Protection has recommended maximum permissible amounts and concentrations of radiation exposure.

The yearly average for the period ending July 1958 for strontium-90 in milk ranged from 4.2 to 10.2 micromicrocuries per liter, as compared to the permissible limit of 80 (unofficially 100 as of

April 22, 1959) micromicrocuries per liter (3). However, the strontium-90 level in milk has been steadily rising since the first adequate measurements were taken in 1954, roughly, in proportion to the rise in the level of strontium-90 deposition in soil. There has been approximately a fourfold increase in the average world strontium-90 content of milk from 1954 to the level of 5-6 S. U. in 1958 (17).

EXPERIMENTAL PROCEDURE

Removal of Strontium-89 and Calcium-45 from Milk of Dosed Cow

Eight daily milk samples from four Jersey cows dosed orally with one dose of calcium-45 and strontium-89 was separated mechanically by use of a DeLaval Junior Model 3300 separator and the skimmilk passed through an ion exchange column at room temperature. The columns were 18 mm in diameter and 24 inches long and contained 50 grams of either Dowex 50-W, 50-100 mesh cross linkage of 4 per cent; Duolite C-20; or Dowex 50-W, 50-100 mesh with a cross linkage of 12 per cent. These resins are strongly acidic, cross-linked polystyrene cation exchangers. Preliminary results indicated that the conventional downflow system could not be used due to packing of the resin, making it impossible to put the desired quantity of effluent through the column. Therefore, the upflow system was used (see Fig. 1) in which solutions were passed in at the bottom and out at the top of the container. Due to the turbulent action caused by the milk entering the bottom this system can not be called a true column action since the "layering" effect associated with column action is not present. Flow rate was adjusted to approximately 7 milliliters per minute to avoid channeling and control contact time.

Both the calcium and sodium form of each of these resins were tested for its effectiveness in the removal of strontium-89 and calcium-45 from skimmilk. After initial conditioning of the resin, one liter of milk was passed through each column before the resin was

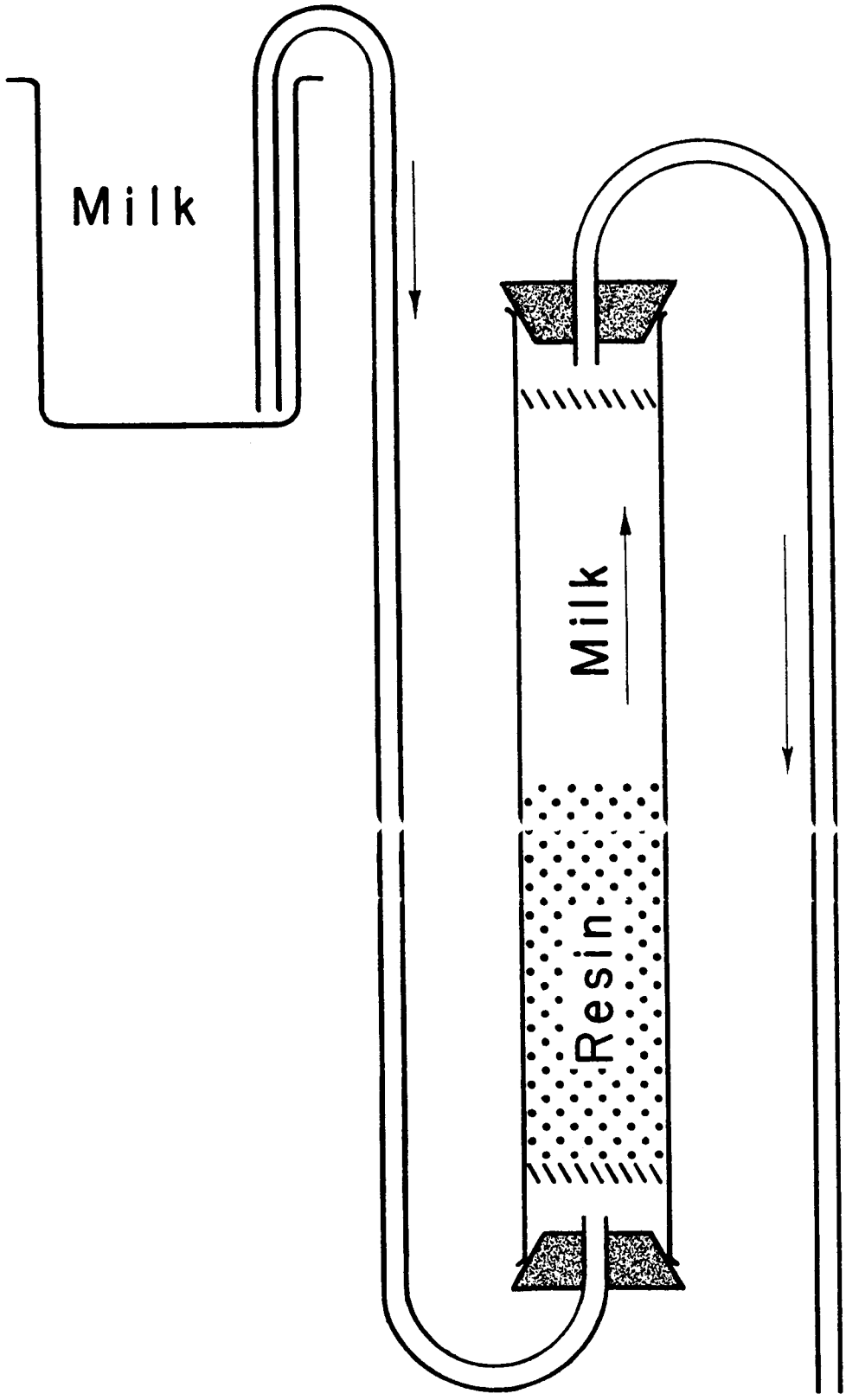

Figure 1. Modified Ion Exchange Column.

again regenerated. After each operation the cations bound by the resin were eluted by treatment with approximately 1500 milliliters of approximately 3 N hydrochloric acid. The columns were then washed with sufficient quantities of calcium chloride or sodium chloride to convert the exchangers into the desired form, followed with 100 to 200 milliliters of distilled water to wash the excess calcium or sodium chloride from the resin. The 2nd, 6th and 10th 100 milliliter portions coming through the column were sampled for analysis. Two twenty-five milliliter samples of milk were taken from each of the 100 milliliter portions. The samples were transferred to porcelain crucibles and dried in an oven at 90-100° C. for a minimum of 16 hours. They were then transferred to a muffle furnace and ashed at 600° C.for approximately 16 hours. Approximately 2 ml of hydrochloric acid was added to the ashed samples to bring the calcium and strontium into solution. The samples were then transferred quantitatively to a 40 milliliter centrifuge tube. One drop of methyl red was added as an indicator. The calcium and strontium were precipitated by adding 3 milliliters of saturated ammonium oxalate, then, by neutralizing the sample with ammonium hydroxide until the solution was faintly alkaline, and by adjusting the solution to a final pH of approximately 5.0 using acetic acid. After the solution was allowed to stand overnight for complete precipitation of the calcium and strontium oxalate, it was centrifuged and the precipitate washed twice with distilled water and transferred quantitatively into a tared cup-and-tube assembly. This assembly consisted of a tapered-end polyethylene cylinder with a

stainless-steel Tracerlab cup forming the bottom. The 4-inch plastic tube was pressed securely into the cup until the assembly was water-tight.

Following centrifugation at 1800 revolutions per minute (920 times gravity) for 10 minutes in a 20 inch diameter International centrifuge, the supernatant was drawn off and the cup removed and dried to a constant weight in an oven at approximately 60° C. The samples were then measured for radioactivity by conventional methods using a thin mica window Geiger-Müller tube connected to a scaler unit.

The activity measurements of calcium-45 are greatly dependent upon the mass of the sample measured primarily because of self-absorption of its relatively low beta energy (0.26 Mev.). The total calcium and the correction for self-absorption were calculated from the mass weight of the oxalate in the dry cup.

All samples were counted with an aluminum absorber of 54.5 or 66.6 mg/cm^2 and again with no absorber. Both of these absorbers will stop essentially all the calcium-45 beta rays from the sample and will reduce the strontium-89 counts by factors of 1.39 and 1.50 respectively. Therefore, when no absorber was used the activity was due to both isotopes but when the same sample was measured again with an absorber the activity represented a portion of the strontium-89 only. The calcium-45 contribution was calculated by difference. The observed count with the aluminum absorber present, times the appropriate factor represents the corrected strontium-89 count. The total observed count

with no absorber present, minus the corrected strontium-89 count, times the mass correction factor for calcium oxalate self-absorption represents the corrected calcium count.

The same procedure as described above was used for duplicate samples of standards, having no resin contact.

Removal of Strontium-89 and Calcium-45 from Dosed Milk

In this experiment "dosed milk" was used instead of milk from "dosed cows". Here the calcium-45 and strontium-89 were put directly into the milk instead of being administered to the cow. Calcium-45 and strontium-89 were put into fresh raw whole milk at approximately 4 P. M., mixed thoroughly and left undisturbed for 16 hours at 40° F. The following morning the milk was thoroughly mixed again, heated in a water bath to 30° C., and mechanically separated. After bringing the skimmilk to room temperature the procedure described previously was followed.

Resin-milk and Isotope-milk Equilibrium Studies

In order to determine how long an ion exchange resin must be in contact with milk containing calcium-45 and strontium-89 to reach equilibrium, a liter of raw skimmilk was dosed with calcium-45 and strontium-89, mixed thoroughly and left undisturbed for approximately 16 hours at 40° F. After heating the milk to room temperature, four-100 milliliter samples were put into 250 milliliter beakers and 5 grams of Dowex 50-W, X-12, 50-100 mesh, in the calcium form were added to each beaker. After one minute of mixing, sample one was filtered and two

25 milliliter milk samples ashed, precipitated with ammonium oxalate and counted. The same procedure was followed for samples two, three and four after 10, 60, and 120 minutes of agitation respectively. All samples were mixed by hand for the first minute and by use of a mechanical agitator thereafter. Two 25 milliliter samples of milk having no resin contact were used as standards. The percentage removal of calcium-45 and strontium-89 was calculated for each contact time.

In order to determine how long a sample of milk must be in contact with calcium-45 and strontium-89 for the sample to reach equilibrium, four - 100 milliliter samples of raw skimmilk at room temperature were dosed with calcium-45 and strontium-89. After mixing for 1, 10, 30 and 60 minutes the samples were treated by exposure to 5 grams of Dowex 50-W, X-12, 50-100 mesh, in the calcium form for 60 minutes after which the samples were filtered by use of a suction funnel. Two 25 milliliter samples from each exposure time were ashed, precipitated with ammonium oxalate and counted. The percentage removal of calcium-45 and strontium-89 was calculated for each exposure time.

Removal of Calcium-45 and Strontium-89 from Milk by Use of a Series of Four Columns

One liter of milk was passed through a series of four columns, each containing 12.5 grams of Dowex 50-W, X-12, 50-100 mesh in the calcium form. The 2nd, 6th and 10th 100 milliliter portions passing through the last column were sampled for analysis in the same manner as described previously. This experiment was repeated four times. Following the last run the four columns were disconnected and the

resin was washed with 1 liter of 3 N hydrochloric acid. Samples of the eluate from each of the four columns were assayed for radioactivity.

Removal of Strontium-89 and Calcium-45 from Dosed Milk by the Batch Method

Raw skimmilk was dosed with calcium-45 and strontium-89, agitated thoroughly by hand and left undisturbed for approximately 16 hours at 40° F. After heating the milk to room temperature six - 200 milliliter samples were put into 400 milliliter beakers and 1, 5, 10, 20, 40, and 100 grams of Dowex 50-W, X-12, 50-100 mesh, in the calcium form, were added. After mechanical agitation for four hours the samples were filtered by use of a suction funnel. Two - 25 milliliter milk samples from each beaker were dried, ashed, precipitated with ammonium oxalate, dried and counted. Two 25 milliliter samples of milk having no resin contact were used as standards. The percentage removal of calcium-45 and strontium-89 was calculated for each quantity of resin.

RESULTS AND DISCUSSION

Values for the percentage of removal of strontium and calcium, from milk of dosed cows, by use of ion exchange resins are summarized in Table I. Significant differences were noted between resins, between ionic form of the resin as well as between portions passed through the column. Results indicate that Dowex 50-W, with a cross linkage of 12 per cent, in the calcium form is the most effective resin tested for removal of strontium-89 and calcium-45 from milk. From these data it is suggested that exchange of like (Ca-Ca) or similar (Ca-Sr) ions is more easily accomplished than the exchange of unlike (Na-Ca or Na-Sr) ions from milk. All three resins in the calcium form showed a slightly higher percentage of removal of strontium than calcium for all samples tested, although the degree varied with resins and the portion of milk passed through the column. A higher removal of strontium and calcium was attained in the first portion of milk passed through the columns as compared to other portions. The percentage removal decreased as the amount of milk passed through the column increased.

The same general conclusions may be drawn from the data presented on removing strontium and calcium from dosed milk (Table II). However, between resins, between ionic form of the resin and between the portion of milk passed through the column, no significant differences for removal of calcium were shown. There was no significant difference between resins for removal of strontium from dosed milk, whereas in the case of milk from dosed cows, between resins, between

TABLE I

PER CENT REMOVAL OF Sr^{89} AND Ca^{45} FROM MILK OF DOSED COWS BY EXCHANGE RESIN COLUMNS

		Ca form of resin						Na form of resin					
	100 ml. Portion of Elutriated	Dowex 50W-4X		Dowex 50W-12X		Duolite C-20		Dowex 50W-4X		Dowex 50W-12X		Duolite C-20	
Trial	Milk Sample	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca
1	2nd	67	80	73	79	66	62	14	48	44	68	1	47
	6th	55	53	60	59	38	52	5	39	16	52	1	51
	10th	52	40	38	51	44	52	0	31	0	34	0	48
2	2nd	75	80	78	78	64	56	31	48	69	71	12	35
	6th	50	50	68	61	54	45	13	30	42	51	3	28
	10th	55	38	55	48	48	39	0	16	17	30	0	26
3	2nd	60	61	61	52	63	58	29	36	65	70	0	22
	6th	67	58	53	53	48	41	7	19	34	35	0	10
	10th	35	34	44	41	46	39	0	2	18	21	0	10
4	2nd	84	72	82	77	68	59	49	60	79	80	19	50
	6th	59	58	54	56	54	53	9	36	46	56	5	39
	10th	48	46	46	50	50	44	0	22	12	36	9	29
5	2nd	76	74	76	74	65	69	40	57	54	78	0	43
	6th	60	57	60	53	65	54	10	33	38	55	0	34
	10th	36	41	52	48	45	43	0	17	35	31	0	26

TABLE I (continued)

PER CENT REMOVAL OF Sr^{89} AND Ca^{45} FROM MILK OF DOSED COWS BY EXCHANGE RESIN COLUMNS

		Ca form of resin						Na form of resin					
	100 ml. Portion of Elutriated	Dowex 50W-4X		Dowex 50W-2X		Duolite C-20		Dowex 50W-4X		Dowex 50W-12X		Duolite C-20	
Trial	Milk Sample	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca
6	2nd	86	74	67	70	70	58	33	42	67	69	4	40
	6th	56	56	60	64	66	44	0	38	40	54	0	28
	10th	58	37	48	45	41	36	3	18	7	39	3	11
7	2nd	81	81	85	89	73	71	37	46	67	64	0	44
	6th	69	53	58	55	65	46	13	26	31	66	4	34
	10th	48	38	50	48	50	35	0	21	2	30	0	19
8	2nd	82	81	86	74	89	77	23	51	64	43	0	30
	6th	59	18	50	46	48	49	7	26	25	40	0	43
	10th	23	39	48	36	43	43	0	20	0	25	0	40
Average	2nd	76	75	76	74	70	64	32	49	64	68	4	39
	6th	59	50	58	56	55	48	8	31	34	51	2	33
	10th	44	39	48	46	46	41	0	18	11	31	2	26

TABLE II

PER CENT REMOVAL OF Sr^{89} AND Ca^{45} FROM DOSED MILK BY EXCHANGE RESIN COLUMNS

Trial	100 ml. Portion of Elutriated Milk Sample	Ca form of resin: Dowex 50W-4X Sr	Ca	Dowex 50W-12X Sr	Ca	Duolite C-20 Sr	Ca	Na form of resin: Dowex 50W-4X Sr	Ca	Dowex 50W-12X Sr	Ca	Duolite C-20 Sr	Ca
1	2nd	83	83	89	79	78	71	61	70	87	88	20	38
	6th	71	64	68	70	55	54	33	30	59	66	0	24
	10th	61	53	65	62	43	44	12	36	34	39	0	16
2	2nd	75	79	75	78	68	65	33	50	57	69	6	40
	6th	64	61	62	65	56	62	14	32	40	49	0	20
	10th	54	45	59	59	50	57	0	39	12	36	0	22
3	2nd	76	81	78	80	62	60	31	49	60	74	8	45
	6th	56	57	62	64	49	47	9	40	38	56	0	30
	10th	50	54	58	49	41	55	0	22	9	41	0	18
4	2nd	84	72	80	76	64	56	30	54	68	74	16	34
	6th	73	15	67	62	55	49	21	35	36	55	6	19
	10th	63	41	58	38	35	41	0	22	22	28	0	20
5	2nd	81	77	72	72	72	69	60	61	62	60	28	35
	6th	61	61	61	47	55	47	28	32	48	42	15	28
	10th	55	35	53	34	47	35	6	22	30	33	0	11

TABLE II (continued)

PER CENT REMOVAL OF Sr^{89} AND Ca^{45} FROM DOSED MILK BY EXCHANGE RESIN COLUMNS

		Ca form of resin						Na form of resin					
	100 ml. Portion of Elutriated	Dowex 50W-4X		Dowex 50W-12X		Duolite C-20		Dowex 50W-4X		Dowex 50W-12X		Duolite C-20	
Trial	Milk Sample	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca
6	2nd	81	74	81	82	78	88	47	55	69	71	34	50
	6th	64	53	67	61	60	56	28	38	54	56	17	34
	10th	54	44	62	57	54	49	30	26	34	33	11	28
7	2nd	76	59	75	63	63	41	48	38	71	68	18	9
	6th	55	30	66	40	55	29	27	3	50	36	9	0
	10th	52	21	54	26	41	3	7	0	30	0	22	0
8	2nd	73	78	76	82	66	69	38	46	59	70	6	42
	6th	56	57	63	63	53	57	20	36	38	50	0	26
	10th	52	45	52	50	41	41	5	19	20	28	0	17
Average	2nd	79	75	77	76	69	64	44	53	67	72	17	37
	6th	63	50	65	59	55	50	23	31	45	51	6	23
	10th	55	42	58	47	44	41	8	22	24	30	4	17

ionic forms of the resin and between portions of milk passed through the column were all significantly different. Using Dowex 50W-X12 in the calcium form, the percentage removal of strontium decreased at a faster rate, as measured by the amount of milk passed through the column, when metabolized milk was used, as compared to milk which was dosed 16 hours before the exchange treatment. The average of eight trials showed 76, 59 and 45 per cent removal of the strontium from metabolized milk on samples from the 2nd, 6th and 10th 100 milliliter portions of milk respectively and 79, 63 and 55 for the equivalent samples when dosed milk was used. The removal of strontium from dosed milk is significantly different ($P < .01$) from the removal of strontium from milk of dosed cows while no significantly different removal of Ca^{45} was noted under the same circumstances. This may be due to the incorporation of strontium into the protein molecule in metabolic milk, whereas in dosed milk this would not likely be the case.

Data from eight trials on removal of calcium and strontium from milk of dosed cows and data from a similar experiment using dosed milk were subjected to analyses of variances. The F values for the main effects, and first and second order interactions in these experiments are presented in Table III. Significant differences were noted between resins for the removal of both calcium-45 and strontium-89 milk of dosed cows but not for the removal of either from dosed milk. Significant differences were noted between days following dosing of the cow for the removal of calcium-45 from milk and also

TABLE III

ANALYSES OF VARIANCES FROM EIGHT TRIALS ON REMOVAL OF Ca^{45} AND Sr^{89} FROM MILK OF DOSED COWS AND EIGHT TRIALS ON REMOVAL OF Ca^{45} AND Sr^{89} FROM DOSED MILK

	Dosed Cows - Sr^{89}		Dosed Milk - Sr^{89}		Dosed Cows - Ca^{45}		Dosed Milk - Ca^{45}	
Total	F Value	Tested by	F value	Tested by	F Value	Tested by	F Value	Tested by
Resins	8.12*	RFS	3.02 NS	RF	23.15**	RD	4.35	RF
Days	2.55 NS	DF	2.50 NS	DF	4.88**	RD	29.62**	Error
Form	657.45**	DF	21.76*	RF	77.81*	FS	15.33 NS	RF
Samples	18.85**	RFS	25.37**	RFS	75.10*	FS	40.38**	RS
RD	NS	Error	2.2*	Error	3.28**	Error	1.60 NS	Error
RF	NS	RFS	6.43**	RFS	6.08 NS	RFS	16.54**	Error
RS	NS	RFS	NS	RFS	3.44 NS	RFS	5.33**	Error
DF	2.56*	Error	8.70**	Error	2.21 NS	Error	1.19 NS	Error
DS	2.00 NS	Error	1.05	Error	1.57 NS	Error	0.98 NS	Error
FS	NS	Error	NS	RFS	4.38*	Error	0.43 NS	Error

TABLE III (continued)

ANALYSES OF VARIANCES FROM EIGHT TRIALS ON REMOVAL OF Ca^{45} AND Sr^{89} FROM MILK OF DOSED COWS AND EIGHT TRIALS ON REMOVAL OF Ca^{45} AND Sr^{89} FROM DOSED MILK

	Dosed Cows - Sr^{89}		Dosed Milk - Sr^{89}		Dosed Cows - Ca^{45}		Dosed Milk - Ca^{45}	
Total	F Value	Tested by	F Value	Tested by	F Value	Tested by	F Value	Tested by
RDF	NS	Error	2.05 NS	Error	1.64 NS	Error	0.62 NS	Error
RDS	NS	Error	1.05 NS	Error	1.28 NS	Error	0.68 NS	Error
RFS	14.00**	Error	16.95**	Error	3.46*	Error	1.68 NS	Error
DFS	1.59 NS	Error	0.7 NS	Error	3.75**	Error	0.68 NS	Error
CV	15.7%		10.2%		11.4%		15.3%	

*P < .05
**P < .01

between trials conducted on different days on dosed milk. Strontium-89 removal was not significantly different for either. Significant differences on the removal of calcium-45 and strontium-89 between portions passed through the column (samples) were noted on both dosed milk and milk from dosed cows.

Raw skimmilk, without the addition of isotopes, was passed through an exchange column identical to the ones used for milk containing the isotopes. Data on the titratable acidity, curd tension, pH, and rennet coagulation time are shown in Table IV. Before the milk was passed through the exchange column the average pH was approximately 6.71, titratable acidity 0.162 per cent, coagulation time 490.6 seconds, curd tension 61 grams, and the taste was that of normal raw skimmilk. The first 100 milliliters of milk passed through the column had a slightly lower pH, a higher titratable acidity, higher curd tension and a lower rennet coagulation time compared to the standard. Under conditions which removed the highest percentage of strontium and calcium from milk, these effects were more pronounced. Therefore, as more milk was passed through the column the closer these properties approached normal milk with the exception of curd tension which continued to increase. The shorter rennet coagulation time is partially indicative of a higher calcium content in treated milk. As calcium concentration increases it tends to form calcium hydrogen phosphate, releasing hydrogen ions from calcium dihydrogen phosphate consequently lowering the pH. Milk so treated (without added radioactivity) was

TABLE IV

COAGULATION TIME, CURD TENSION, pH AND TITRATABLE ACIDITY OF MILK PASSED THROUGH AN ION EXCHANGE COLUMN CONTAINING DOWEX 50W-X12 CALCIUM FORM

Trial		Control	100 ml. Portion of Klutriated Milk Sample										
			1	2	3	4	5	6	7	8	9	10	11
1	Coagulation Time (Sec)	480	40		52		98		85		113		121
	Curd Tension (grams)	60	110		108		85		140		160		120
	pH	6.75	6.1	6.07	6.11	6.18	6.21	6.28	6.29	6.31	6.38	6.41	6.41
	Per Cent Acidity	.164		.18		.20		.195		.19		.195	
2	Coagulation Time (Sec)	485	26		36		43		61		81		108
	Curd Tension (grams)	60	80		130		115		132		130		127
	pH	6.7	6.1	6.00	6.05	6.1	6.15	6.2	6.22	6.28	6.3	6.35	6.38
	Per Cent Acidity	.16		.195		.20		.195		.19		.19	

TABLE IV (continued)

COAGULATION TIME, CURD TENSION, pH AND TITRATABLE ACIDITY OF MILK PASSED THROUGH AN ION EXCHANGE COLUMN CONTAINING DOWEX 50W-X12 CALCIUM FORM

Trial		Control	100 ml. Portion of Elutriated Milk Sample										
			1	2	3	4	5	6	7	8	9	10	11
3	Coagulation Time (Sec)	525	26		36		54		75		90		110
	Curd Tension (grams)	58	70		120		135		150		190		140
	pH	6.7	5.98	6.05	6.1	6.1	6.2	6.21	6.25	6.32	6.38	6.38	6.39
	Per Cent Acidity	.165		.195		.20		.195		.19		.185	
4	Coagulation Time (Sec)	522	26		35		54		82		90		114
	Curd Tension (grams)	60	80		130		135		140		150		135
	pH	6.7	6.2	6.05	6.1	6.18	6.25	6.24	6.25	6.32	6.38	6.44	6.45
	Per Cent Acidity	.16		.19		.195		.19		.195		.19	

TABLE IV (continued)

COAGULATION TIME, CURD TENSION, pH AND TITRATABLE ACIDITY OF MILK PASSED THROUGH AN ION EXCHANGE COLUMN CONTAINING DOWEX 50W-X12 CALCIUM FORM

Trial		Control	100 ml. Portion of Elutriated Milk Sample										
			1	2	3	4	5	6	7	8	9	10	11
5	Coagulation Time (Sec)	455	24		34		53		69		89		108
	Curd Tension (grams)	58	76		120		140		150		160		140
	pH	6.7	6.2	6.01	6.1	6.2	6.23	6.29	6.32	6.33	6.38	6.4	6.45
	Per Cent Acidity	.165		.195		.205		.200		.195		.19	
6	Coagulation Time (Sec)	485	23		34		54		67		91		111
	Curd Tension (grams)	70	80		140		144		142		152		140
	pH	6.68	6.12	6.1	6.18	6.19	6.23	6.28	6.3	6.33	6.35	6.4	6.4
	Per Cent Acidity	.165		.195		.20		.20		.195		.19	

TABLE IV (continued)

COAGULATION TIME, CURD TENSION, pH AND TITRATABLE ACIDITY OF MILK PASSED THROUGH AN ION EXCHANGE COLUMN CONTAINING DOWEX 50W-X12 CALCIUM FORM

Trial		Control	100 ml. Portion of Elutriated Milk Sample										
			1	2	3	4	5	6	7	8	9	10	11
7	Coagulation Time (Sec)	488	26		43		64		72		93		114
	Curd Tension (grams)	60	70		110		128		140		130		125
	pH	6.72	6.12	6.12	6.18	6.22	6.29	6.38	6.39	6.4	6.48	6.48	6.49
	Per Cent Acidity	.16		.195		.195		.195		.195		.185	
8	Coagulation Time (Sec)	485	22		36		54		71		92		116
	Curd Tension (grams)	63	90		120		138		145		135		119
	pH	6.7	6.08	6.03	6.1	6.2	6.28	6.3	6.33	6.39	6.4	6.46	6.48
	Per Cent Acidity	.16		.195		.20		.195		.19		.19	

TABLE IV (continued)

COAGULATION TIME, CURD TENSION, pH AND TITRATABLE ACIDITY OF MILK PASSED THROUGH AN ION EXCHANGE COLUMN CONTAINING DOWED 50W-X12 CALCIUM FORM

Trial		Control	100 ml. Portion of Elutriated Milk Sample										
			1	2	3	4	5	6	7	8	9	10	11
Avg.	Coagulation Time (Sec)	490.6	26.6		38.2		59.1		71.5		92.3		112.7
	Curd Tension (grams)	61	82		121.9		127.5		142.4		158.7		130.8
	pH	6.71	6.12	6.05	6.12	6.17	6.23	6.27	6.29	6.34	6.38	6.41	6.43
	Per Cent Acidity	.162		.192		.199		.196		.192		.189	

tasted and found to have a slightly bitter flavor in those samples which exhibited the largest pH drop.

Data on the removal of strontium and calcium from milk as influenced by the resin-milk contact time are presented in Table V. All contact times were made on a milk-resin ratio basis of 20 to 1 using the batch techniques. Times of 1, 10, 30 and 60 minutes were used. The average of three trials showed 62 per cent strontium-89 and 52 per cent calcium-45 were removed after a contact time of one minute, while 76 per cent strontium-89 and 67 per cent calcium-45 were removed after 120 minutes, the greatest difference being from one to ten minutes ($P < 0.05$). This is illustrated more clearly in Fig. 2 which indicates that the solution had approached equilibrium after 10 minutes but not at the end of one minute.

The data for the removal of strontium and calcium as influenced by the isotope-milk contact time are presented in Table VI. Each sample was intermittently hand agitated for either 1, 10, 30 or 60 minutes, then treated by exposure to Dowex 50W-X12 in the calcium form for 60 minutes under constant agitation. The milk to resin ratio was 20 to 1. Results show approximately 80 per cent removal of strontium-89 and approximately 75 per cent removal of calcium-45 with very little difference between milk agitated for one minute and that agitated for 60 minutes before exchange treatment. The isotopes are fully incorporated into the milk within one minute or the rate of incorporation at this stage is so slow that 60 minutes is not suffi-

TABLE V

EFFECT OF RESIN-MILK CONTACT TIME ON PER CENT REMOVAL OF Sr^{89} AND Ca^{45} FROM DOSED MILK

Trial	Resin-milk Contact Time (minutes)	Per Cent Sr^{89} Removal	Per Cent Ca^{45} Removal
1	1	66	56
	10	69	54
	60	77	70
	120	76	69
2	1	57	44
	10	71	64
	60	68	55
	120	78	70
3	1	64	55
	10	75	62
	60	77	72
	120	75	60
Average	1	62	52
	10	72	60
	60	74	66
	120	76	67

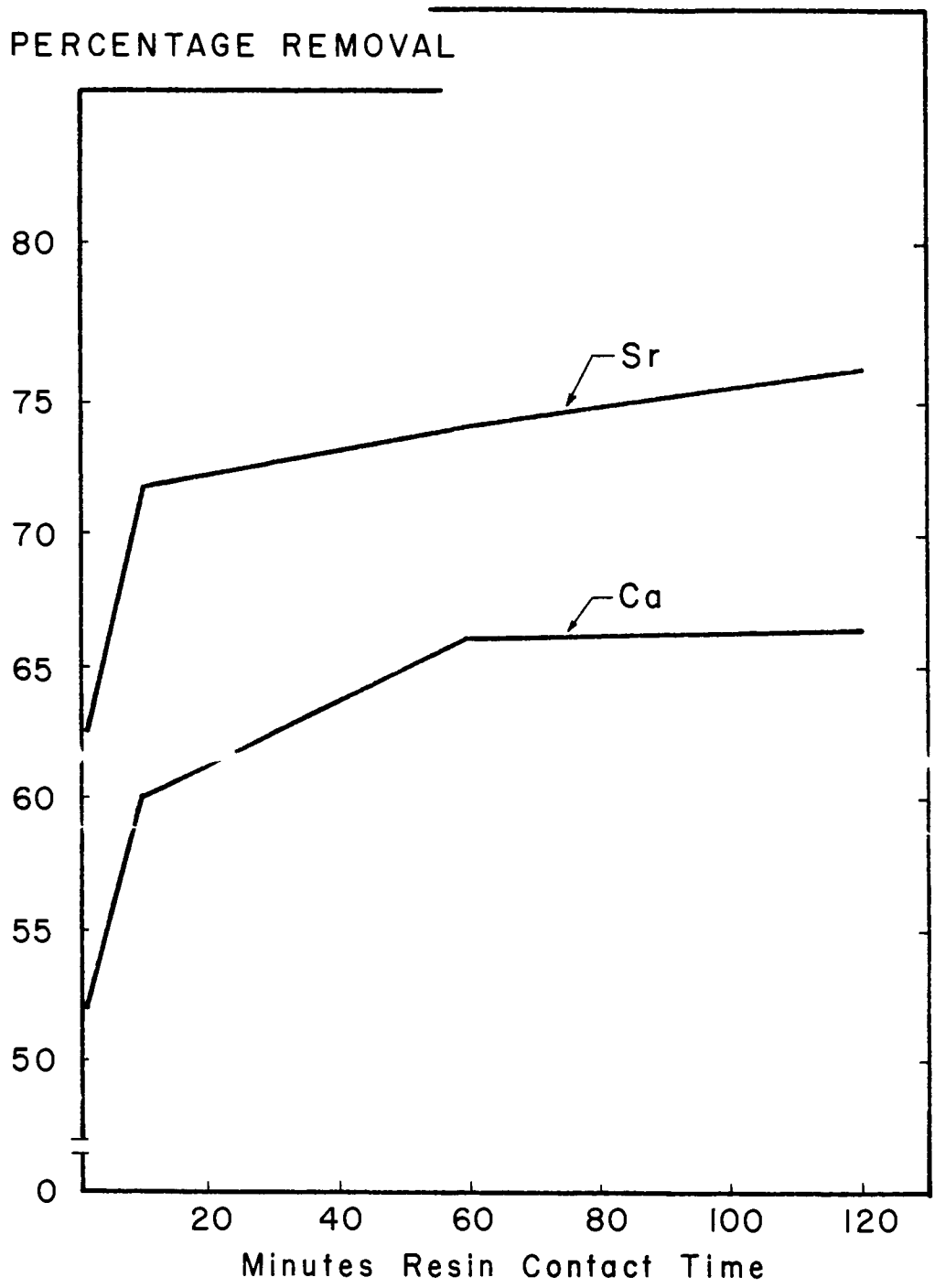

Figure 2. Effect of Resin-Milk Contact Time on Percent Removal of Sr^{89} and Ca^{45} from Dosed Milk.

TABLE VI

EFFECT OF ISOTOPE-MILK CONTACT TIME ON PER CENT REMOVAL OF Sr^{89} AND Ca^{45} FROM DOSED MILK

Trial	Isotope-milk Contact time (minutes)	Per Cent Sr^{89} Removal	Per Cent Ca^{45} Removal
1	1	78	71
	10	79	70
	30	76	72
	60	72	61
2	1	83	78
	10	84	77
	30	73	71
	60	80	70
3	1	83	81
	10	73	73
	30	82	87
	60	81	78
4	1	80	73
	[illegible]	[illegible]	[illegible]
	30	83	74
	60	73	61
Average	1	81	76
	10	79	72
	30	79	76
	60	77	68

cient time to show a definite trend, the latter probably being the case since less of the isotopes were removed after contact with the milk 16 hours than 60 minutes.

The data on removal of strontium and calcium from milk by use of a series of four ion exchange columns are shown in Table VII. This experiment was conducted to compare the action of four columns in a series, each containing 12.5 grams of resin, to one column containing 50 grams of resin (Table 2). No differences were noted in the percentage removal of strontium and calcium between the two methods.

Following the last trial each of the four columns of resin was washed with 1 liter of 3 N hydrochloric acid. Forty milliliter samples of the eluate from each of the four columns were assayed and the radioactivity of both calcium and strontium was found to decrease in the resin from the first column to the last (Table VIII).

The data in Table IX and Fig. 3 indicate a direct relationship between the percentage of strontium and calcium removed from milk and the amount of resin used. Because Dowex 50W-X12 in the calcium form had appeared to be more effective in the removal of strontium and calcium from milk than either Dowex 50W-X4 or Duolite C-20 (Tables I and II), it was used in this batch experiment. The percentage removal of strontium-89 ranged from a high of 94, where one part resin was used per two parts of milk, to a low of 21, where one part resin per 200 parts of milk was used. Similarily the percentage calcium-45 removal ranged from a high of 93 to a low of 16

TABLE VII

PER CENT REMOVAL OF Sr^{89} AND Ca^{45} FROM MILK BY USE OF A SERIES OF FOUR EXCHANGE RESIN COLUMNS

Trial	100 ml. Portion of Elutriated Milk Sample	Per Cent Sr^{89} Removal	Per Cent Ca^{45} Removal
1	2nd	74	75
	6th	67	63
	10th	62	51
	14th	45	38
2	2nd	77	72
	6th	52	59
	10th	57	50
	14th	55	42
3	2nd	71	73
	6th	67	52
	10th	46	30
	14th	40	31
4	2nd	82	74
	6th	73	51
	10th	51	36
	14th	36	31
Average	2nd	76	73
	6th	65	56
	10th	54	42
	14th	44	36

TABLE VIII

RADIOACTIVITY RETAINED BY RESIN AFTER PASSAGE OF MILK CONTAINING Ca^{45} AND Sr^{89}

Column	Sr^{89} Counts/Min/ 40 ml. Eluate	Ca^{45} Counts/Min/ 40 ml. Eluate	Sr^{89}/Ca^{45}
1	82	451	0.1818
2	66	427	0.15456
3	39	308	0.12662
4	18	180	0.100

TABLE IX

EFFECT OF MILK-RESIN RATIO ON PER CENT REMOVAL OF Sr^{89} AND Ca^{45} FROM MILK

Trial	Ratio of Milk to Resin (wt. basis)	Per Cent Sr^{89} Removal	Per Cent Ca^{45} Removal	Increase of Ca Compared to Non-treated milk (%)
1	2	94	93	56.7
	5	89	85	20.2
	10	85	76	21.5
	20	67	56	23.7
	40	50	28	20.4
	200	17	8	6.9
2	2	94	94	54.4
	5	88	83	23.6
	10	83	78	22.5
	20	69	57	20.3
	40	56	42	- 3.8
	200	18	17	9.4
3	2	93	92	60.7
	5	87	83	22.6
	10	82	74	21.8
	20	73	60	22.0
	40	56	34	- 0.5
	200	28	23	- 6.5
Average	2	94	93	57.3
	5	88	84	22.1
	10	83	76	21.9
	20	70	57	22.0
	40	54	34	5.4
	200	21	16	3.3

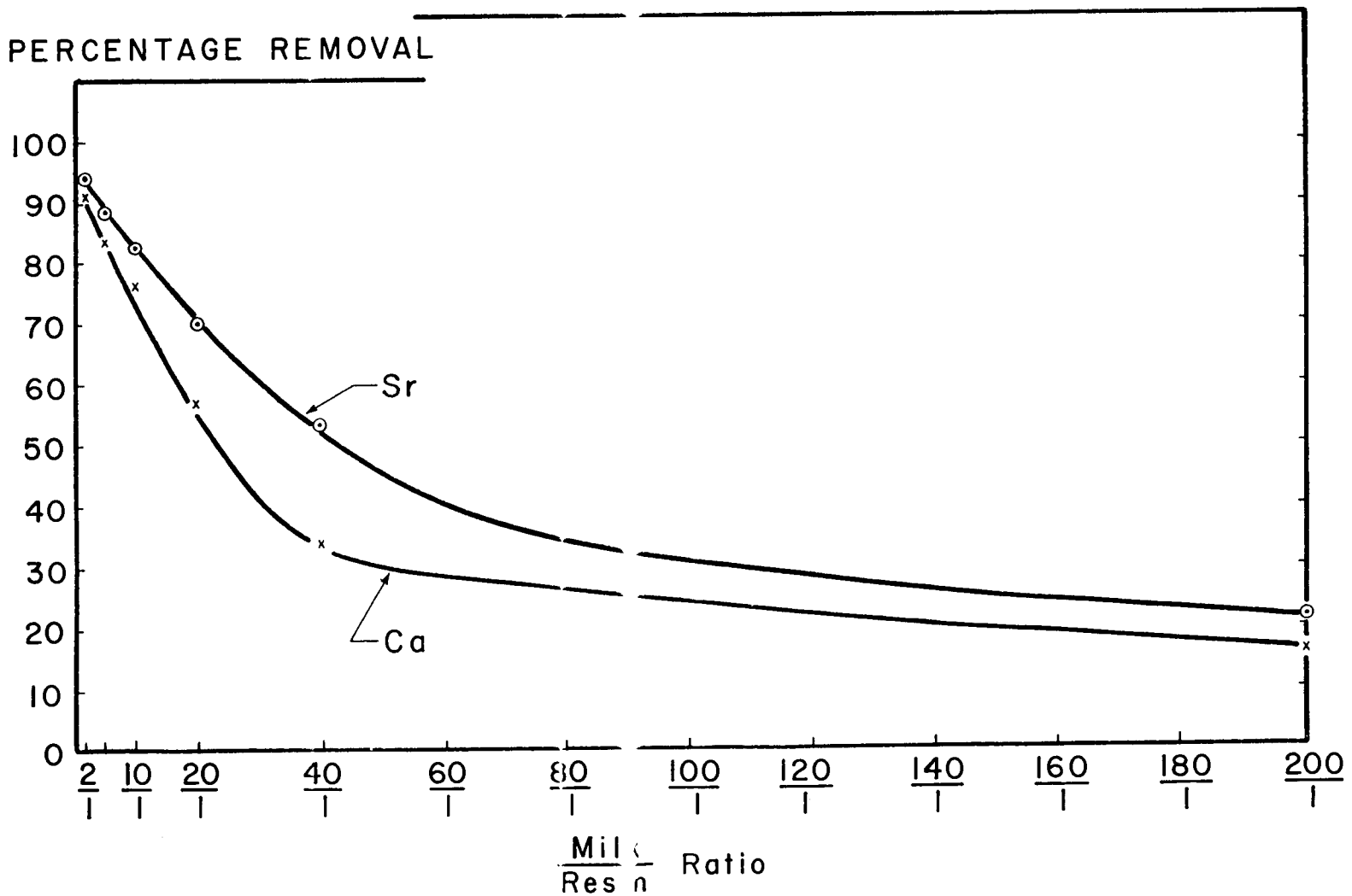

Figure 3. Effect of Milk-Resin Ratio on Percent Removal of Sr^{89} and Ca^{45} from Milk.

per cent. The total resin exchange capacity (Meq./gm.) was approximately twice the amount required for complete removal of the calcium from the milk at a milk-resin ratio of 20 to 1. At the 20 to 1 ratio the average percentage removal of strontium was approximately 70 and calcium 57.

Relationships between resin weight and exchange of calcium-45 and strontium-89 from milk are useful for predictions for different ratios. Since calcium in milk is in a very high concentration (6.23 meq./100 ml.) in relation to strontium (.00093 meq./100 ml.) a linear equation was derived for calcium-45 exchange on the assumption of isotope dilution.[1] This equation is:

$$w = a \frac{1 - f_m^e}{f_m^e}$$

where: w = weight of moist resin

$$a = \text{slope } \frac{\text{quantity of resin}}{\frac{\%\text{ removed}}{\%\text{ not removed}}}$$

$f_m^e = Ca^{45}$ percentage found in milk.

This is plotted in Fig. 4 with w on the y axis and $\frac{\text{per cent of isotope removed from milk}}{\text{per cent of isotope not removed from milk}}$ on the x axis.

This equation was tested for strontium also and a non-linear relationship was observed which may have been due to ion selectivity of the resin.

---

[1]Preliminary calculations on these relationships were made by R. C. McIlhenny, Radiochemist, UT-AEC Agricultural Research Laboratory.

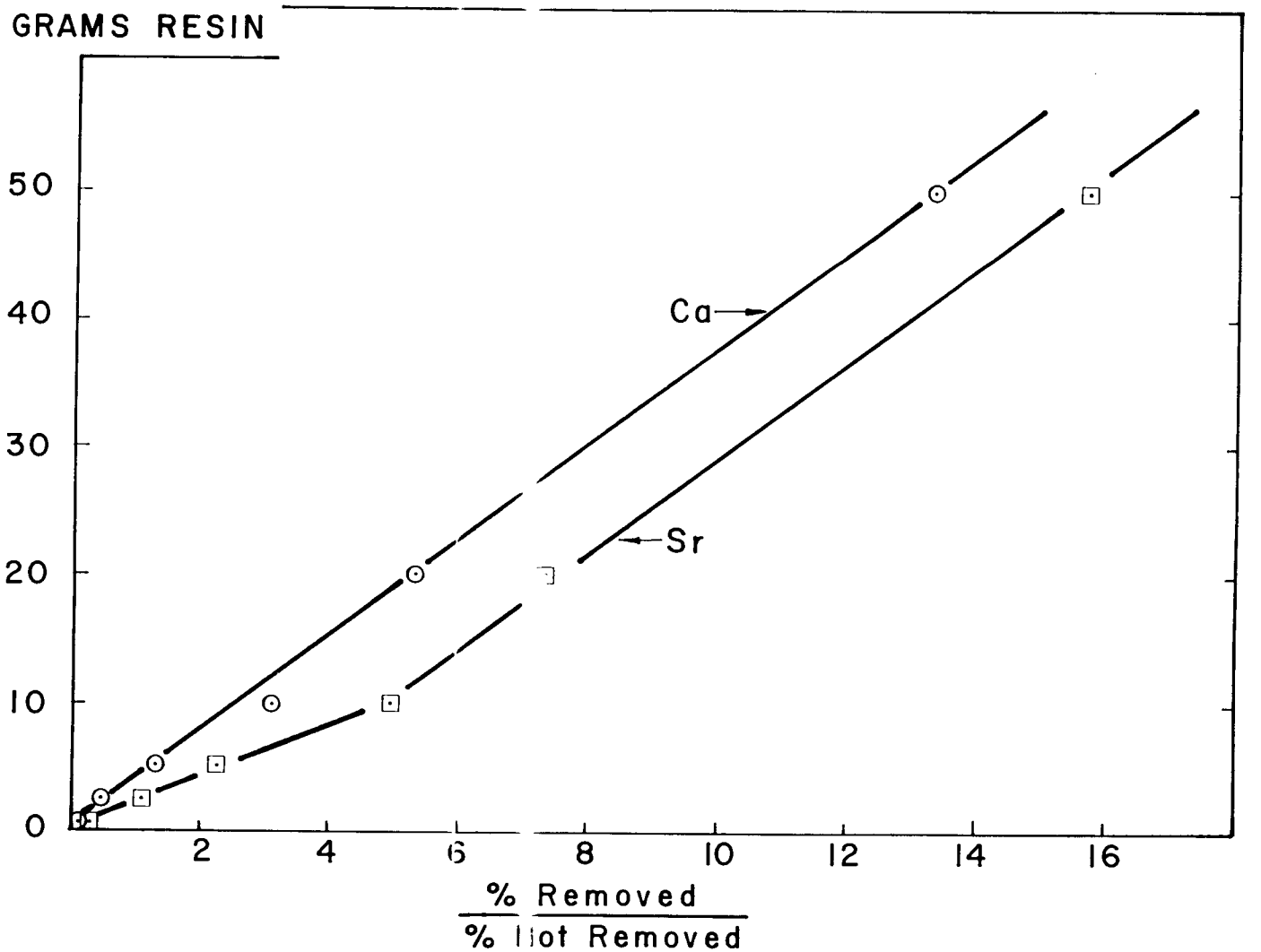

Figure 4. Relationship of Milk-Resin Ratio and the Percentage Exchange of Ca^{45} and Sr^{89}.

On the basis of calcium oxalate weights, milk treated with the resin contained more calcium than the non-treated milk (Table VIII). This may be due to the excess calcium chloride not being washed from the recharged resin when the batch system was used. Some additional calcium may also come from the exchange of calcium on the resin for strontium and other ions in milk. In general the percentage of calcium removal from milk was less than strontium based on the total calcium and strontium in the untreated milk.

An estimation of the efficiency of the column system versus the batch system was made. The following four equations were derived by the method of least squares from the data presented in Tables 1 and 2.

Ca^{45} dosed milk:

$$y = -33.26 + 1.48736X + \frac{117.8174}{1.063x}$$

Milk from Ca^{45} dosed cows

$$y = -154.0086 + 6.75665X + \frac{238.6207}{1.061x}$$

Sr^{89} dosed milk

$$y = -187.0063 + 5.58810X + \frac{269.86}{1.037x}$$

Milk from Sr^{89} dosed cows

$$y = -98.6204 + 4.20296X + \frac{183.4547}{1.059x}$$

Where y = % removal and X = 100 ml. portions passed through the column.

The integrated forms of these equations for determining the area under the curve were respectively:

$$A = -33.26X + .74368X^2 - \frac{1928.5873}{1.063x} + 1928.5873$$

$$A = -154.0086X + 3.3783X^2 - \frac{4030.0743}{1.061x} + 4030.0743$$

$$A = -187.0063X + 2.7940X^2 - \frac{7430.0660}{1.037x} + 7430.0660$$

$$A = -98.6204X + 2.10X^2 - \frac{3199.895}{1.059x} + 3199.895$$

Since the columns contained 107 milliliters of milk and 50 grams of resin when completely filled, a convenient point of comparison was the per cent of removal for some volume less than 107 ml. and a comparable volume in the batch system. Therefore the area under the curve was determined for 100 milliliters of milk. The comparisons of the systems are presented in Table X. It is estimated that the column was only 86 per cent as efficient as the batch system for removal of Sr^{89}. The corresponding value for Ca^{45} was 88 per cent. The lower efficiency for the column can be attributed to the milk-ion and resin-ion complex not being allowed to come to equilibrium. Milk was found to contain an average of 6.23 meq. of calcium per 100 milliliters and is estimated to contain 0.00096 meq. of strontium per 100 milliliters. The calculations presented in Table X are based on these values.

TABLE X

PER CENT OF RESIN CAPACITY EXCHANGE BY CALCIUM AND STRONTIUM USING THE BATCH AND COLUMN SYSTEM

System used	Ratio Milk Resin or portion through column	Resin Capacity (meq.)	Isotope Removed	Percentage removed	Meq. Exchanged	Per Cent Resin Capacity Exchanged
Batch	2 - 1	135	Ca^{45}	93	5.79	4.27
Batch	5 - 1	54.3	Ca^{45}	84	5.24	9.6
Batch	10 - 1	27.1	Ca^{45}	76	4.74	17.4
Batch	20 - 1	27.1	Ca^{45}	56	7.10	26.2
Batch	40 - 1	13.5	Ca^{45}	34	4.24	31.3
Batch	200 - 1	2.7	Ca^{45}	16	1.99	73.6
Batch	2 - 1	135	Sr^{89}	94	--	--**
Column	1st 100 ml.	135	Ca^{45}	82	5.10	3.77
Column	1st 100 ml.	135	Sr^{89}	81	--	--**
*Column	1st 100 ml.	135	Sr^{89}	81	--	--**
*Column	1st 100 ml.	135	Ca^{45}	74	4.62	34.1

*Milk from Dosed cows. All other samples were dosed milk.

**Stable strontium in milk is negligible compared to calcium.

SUMMARY

Much publicity has been given the passage of strontium from the atmosphere into food and its accumulation in bone in recent months. The strontium level in milk has been accumulating at a rate which is causing some alarm due to the damaging effect it may have on the health of humans.

Modified ion exchange resin columns and the batch system have been used to remove strontium-89 as well as calcium-45 from both dosed milk and milk from dosed cows. Dowex 50W-X12, Dowex 50W-X4 and Duolite C-20 were used, the first found to be most effective, by removing 76 per cent of the strontium and 74 per cent of the calcium from milk of dosed cows and 77 and 76 per cent respectively from dosed milk. These data represent only the second 100 milliliter portion of one liter passed through the column.

Using this modified column technique the per cent resin capacity exchanged was only 86 per cent as effective for removal of strontium-89 and 88 per cent for the removal of calcium-45.

Dowex 50W-X12 resin was left in contact with milk for periods of 1, 10, 60 and 120 minutes to study the exchange rate. Differences existed between the 1 and 10 minute periods only.

Using the batch system and dosed milk, the percentage of removal of strontium-89 and calcium-45 decreased as the ratio of milk to resin increased. The percentage of removal ranged from a high of 94 and 93

for strontium and calcium respectively at a milk-resin ratio of 2 to 1 to a low of 21 per cent strontium and 16 per cent calcium at a milk-resin ratio of 200 to 1.

An approximately linear relationship was found between the ratio of calcium-45 removed over that not removed and the quantity of resin used.

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Rendering (animal products)

From Wikipedia, the free encyclopedia

Rendering is a process that converts waste animal tissue into stable, value-added materials. Rendering can refer to any processing of animal products into more useful materials, or, more narrowly, to the rendering of whole animal fatty tissue into purified fats like lard or tallow. Rendering can be carried out on an industrial, farm, or kitchen scale.

The majority of tissue processed comes from slaughterhouses, but also includes restaurant grease and butcher shop trimmings and expired meat from grocery stores. This material can include the fatty tissue, bones, and offal, as well as entire carcasses of animals condemned at slaughterhouses, and those that have died on farms, in transit, etc. The most common animal sources are beef, pork, sheep, and poultry.

The rendering process simultaneously dries the material and separates the fat from the bone and protein. A rendering process yields a fat commodity (yellow grease, choice white grease, bleachable fancy tallow, etc.) and a protein meal (meat and bone meal, poultry byproduct meal, etc.).

Rendering plants often also handle other materials, such as slaughterhouse blood, feathers and hair, but do so using processes distinct from true rendering.

The occupation of renderer has appeared in "dirtiest jobs" listicles.[1]

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- 1 Process variations
- 2 Rendering processes for edible products
- 3 Rendering processes for inedible products
- 4 History

- 5 Advantages and disadvantages
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Process variations

The rendering process varies in a number of ways.

- Whether the end products are to be used as human or animal food depends on the quality of input material and the processing methods and equipment.
- The material may be processed by wet or dry means. In wet processing, either boiling water or steam is added to the material, separating fat into a floating phase. In dry processing, fat is released by dehydrating the raw material.
- The temperature range used may be high or low.
- Rendering may be done either in discrete batches or in a continuous process.
- The processing plant may be operated by an independent company which buys input material from suppliers, or by a packing plant that produces the material in-house.

Rendering processes for edible products

Edible rendering processes are basically meat processing operations and produce lard or edible tallow for use in food products. Edible rendering is generally carried out in a continuous process at low temperature (less than the boiling point of water). The process usually consists of finely chopping the edible fat materials (generally fat trimmings from meat cuts), heating them

with or without added steam, and then carrying out two or more stages of centrifugal separation. The first stage separates the liquid water and fat mixture from the solids. The second stage further separates the fat from the water. The solids may be used in food products, pet foods, etc., depending on the original materials. The separated fat may be used in food products, or if in surplus, it may be diverted to soap making operations. Most edible rendering is done by meat packing or processing companies.

One edible product is greaves, which is the unmeltable residue left after animal fat has been rendered.

An alternative process cooks slaughterhouse offal to produce a thick, lumpy "stew" which is then sold to the pet food industry to be used principally as tinned cat and dog foods. Such plants are notable for the offensive odour that they can produce and are often located well away from human habitation.

Rendering processes for inedible products

Materials that for aesthetic or sanitary reasons are not suitable for human food are the feedstocks for inedible rendering processes. Much of the inedible raw material is rendered using the "dry" method. This may be a batch or a continuous process in which the material is heated in a steam-jacketed vessel to drive off the moisture and simultaneously release the fat from the fat cells. The material is first ground, then heated to release the fat and drive off the moisture, percolated to drain off the free fat, and then more fat is pressed out of the solids, which at this stage are called "cracklings" or "dry-rendered tankage". The cracklings are further ground to make meat and bone meal. A variation on a dry process involves finely chopping the material, fluidizing it with hot fat, and then evaporating the mixture in one or more evaporator stages. Some inedible rendering is done using a wet process, which is generally a continuous process similar in some ways to that used for edible materials. The material is heated with added steam and then pressed to remove a water-fat mixture which is then separated into fat, water and fine solids by

stages of centrifuging and/or evaporation. The solids from the press are dried and then ground into meat and bone meal. Most independent renderers process only inedible material.

History

The development of rendering was primarily responsible for the profitable utilization of meat industry by-products, which in turn allowed the development of a massive industrial-scale meat industry that made food more economical for the consumer. Rendering has been carried out for many centuries, primarily for soap and candle making. The earliest rendering was done in a kettle over an open fire. This type of rendering is still done on farms to make lard (pork fat) for food purposes. With the development of steam boilers, it was possible to jacket the kettle to make a higher grade product and to reduce the danger of fire. A further development came in the nineteenth century with the use of the steam "digester" which was simply a tank used as a pressure cooker in which live steam was injected into the material being rendered. This process is a wet rendering process called **"tanking"** and was used for both edible and inedible products, although the better grades of edible products were made using the open kettle process. After the material is "tanked", the free fat is run off, the remaining water ("tank water") run into a separate vat, and the solids removed and dried by both pressing and steam-drying in a jacketed vessel. The tank water was either run into a sewer or it was evaporated to make glue or protein concentrate to add to fertilizer. The solids were used to make fertilizer.

Upton Sinclair wrote an expose (1906) on the Chicago, IL meat processing industry which created public outrage. His work helped the passage of the Pure Food and Drug Act of 1907 which paved the way for the creation of the FDA.

The pressure tank made possible the development of the Chicago meat industry in the United States, with its huge concentration in one geographic area, because it allowed the economic disposal of byproducts which would otherwise overwhelm the environment in that area. At first, small companies

that sprang up near the packers did the rendering. Later the packers themselves took up the industry once they saw the potential. Gustavus Swift, Nelson Morris, and Lucius Darling were among the early pioneers of the U.S. rendering industry with their personal backing and/or direct participation in the developing rendering industry.

Technological innovations came rapidly as the 20th century advanced. Some of these were in the uses for rendered products and others were in the rendering methods themselves. In the 1920s, a batch dry rendering process was invented, in which the material was cooked in horizontal steam-jacketed cylinders that were similar to the fertilizer dryers of the day. Advantages claimed for the dry process were economy in energy use, a better protein yield, faster processing, and fewer obnoxious odours attending the process. Gradually, over the years, the wet "tanking" process was replaced with the dry process, so that by the end of World War II, most rendering installations used the dry process. In the 1960s, continuous dry processes were introduced, one using a variation of the conventional dry cooker and the other making use of a mincing and evaporation process to dry the material and yield the fat. In the 1980s, high energy costs popularized the various "wet" continuous processes. These processes were more energy efficient and allowed the re-use of process vapours to pre-heat or dry the materials during the process.

After World War II synthetic detergents came on the scene which eventually displaced soaps for both domestic and industrial washing. In the early 1950s over 50% of the inedible fat market disappeared. Diversion in these materials into animal feeds soon replaced the lost soap market and eventually became the single largest use for inedible fats.

The widespread use of "boxed beef" in which the beef was cut up into consumer portions at the packing plant rather than at the retail level in local butcher shops and markets meant that the fat and meat scrap raw materials for renderers stayed at the packing plants and were rendered there by packer renderers, rather than by the "independent" rendering companies.

The rejection of animal fats by diet-conscious consumers led to a surplus of edible fats and their resultant diversion into soapmaking and oleochemicals, displacing inedible fats and contributing to the market volatility of this commodity.

Advantages and disadvantages

The rendering industry is one of the oldest recycling industries, and made possible the development of a large food industry. The industry takes what would otherwise be waste materials and makes useful products such as fuels, soaps, rubber, plastics, etc. At the same time, rendering solves what would otherwise be a major disposal problem. As an example, the USA recycles more than 21 million metric tons annually of highly perishable and noxious organic matter. In 2004, the U.S. industry produced over 8 million metric tons of products, of which 1.6 million metric tons were exported.

Usually, materials used as raw materials in the rendering process are susceptible to spoilage. However, after rendering, the materials are much more resistant to spoiling. This is due to the application of heat either through cooking in the wet rendering process or the extraction of fluid in the dry rendering process. The fat obtained can be used as low-cost raw material in making grease, animal feed, soap, candles, biodiesel, and as a feed-stock for the chemical industry. Tallow, derived from beef waste, is an important raw material in the steel rolling industry providing the required lubrication when compressing steel sheets. The meat and the bones (which are in a dry, ground state) are converted to what is known as meat and bone meal.

In the absence of the rendering industry, the cost of waste disposal of waste animal material would be very high and would place a significant economic and environmental burden on areas involved in industrial scale slaughtering. This cost may manifest itself through the expensive use of sanitary landfills, incinerators and other similar waste disposal techniques without yielding profit directly out of it leading to the incurrence of opportunity costs. Using substitute products to rendering products may not necessarily prove to be lesser in cost.

BSE

For many years meat and bone meal was fed to cattle. This practice is now prohibited in developed countries because it is believed to be the main route for the spread of bovine spongiform encephalopathy (mad-cow disease, BSE), which is also fatal to human beings.

Kitchen rendering

Rendering of fats is also carried out on a kitchen scale by chefs and home cooks. In the kitchen, rendering is used to transform butter into clarified butter, suet into tallow, pork fat into lard, and chicken fat into schmaltz.

See also

- Animal slaughter
- Animal euthanasia
- Dead Horse Bay
- Flensing
- Vegetable oil
- Whale oil

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About the Book

The energy situation in developing countries is desperate. Because these countries are primarily dependent on fossil fuels--chiefly oil--for industrial growth, they have been hard hit by oil price increases. Further, in the rural areas, where most of the population lives, there are limited supplies of increasingly expensive diesel fuel or kerosene. Noncommercial energy sources such as firewood, dung, and agricultural residues are generally used in rural areas, but under the pressure of growing populations the forests are disappearing. This is resulting in a critical shortage of firewood for cooking and heating, as well as in the destruction of the environment. In addition, when dung and agricultural residues are burned, valuable fertilizers are destroyed. Thus, the rural areas--the sources of food and fiber--face a particularly alarming situation.

Small-scale, decentralized technologies for exploiting the sun's energy, received directly or as wind, flowing water, or biomass, provide potential solutions to the problem of rural energy needs. These technologies have been the subject of numerous studies, including two by the National Academy of Sciences. In this volume, members of the two academy study panels have joined with other experts to discuss the status of these technologies and to place them in a realistic context.

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Foreword

The *AAAS Selected Symposia Series* was begun in 1977 to provide a means for more permanently recording and more widely disseminating some of the valuable material which is discussed at the AAAS Annual National Meetings. The volumes in this *Series* are based on symposia held at the Meetings which address topics of current and continuing significance, both within and among the sciences, and in the areas in which science and technology impact on public policy. The *Series* format is designed to provide for rapid dissemination of information, so the papers are not typeset but are reproduced directly from the camera copy submitted by the authors, without copy editing. The papers are reviewed and edited by the symposia organizers who then become the editors of the various volumes. Most papers published in this *Series* are original contributions which have not been previously published, although in some cases additional papers from other sources have been added by an editor to provide a more comprehensive view of a particular topic. Symposia may be reports of new research or reviews of established work, particularly work of an interdisciplinary nature, since the AAAS Annual Meeting typically embraces the full range of the sciences and their societal implications.

WILLIAM D. CAREY
Executive Officer
American Association for
the Advancement of Science

About the Editor and Authors

Norman L. Brown is country program specialist with the Office of International Affiars at the Department of Energy. As such, he is chief technical adviser to DOE's program of energy development with less developed countries. His international interdisciplinary background in science and technology, particularly energy and food problems, has involved him in seeking and encouraging appropriate technological solutions. He was the staff study director for **Energy for Rural Development** *(National Academy of Sciences, 1976).*

Joseph J. Ermenc, professor of engineering at Dartmouth College, specializes in mechanical engineering and the history and philosophy of technology development. He is the author of an 8-volume series, **Dartmough Readings on Technology,** *and 38 volumes of interviews with outstanding innovators. He was a member of the NAS panel that contributed to* **Energy for Rural Development** *(NAS, 1976).*

Raymond C. Loehr, director of the Environmental Studies Program and professor of civil, environmental and agricultural engineering at Cornell University, has published over 100 technical papers and three books, including **Agricultural Waste Management** *(Academic Press, 1974) and* **Land as a Waste Management Alternative,** *which he edited. He is also an advisor to various governmental and private organizations.*

George O. G. Löf, director of the Solar Energy Applications Laboratory at Colorado State University and vice-president of the Solaron Corporation in Denver, is the author of over 100 books and papers on energy conservation, solar energy utilization, heat transfer, and environmental engineering. He is former president of the International Solar Energy Society and in 1976 received the Lyndon Baines Johnson Foundation award for contribution to the betterment of

mankind. He too was a member of the NAS panel on Energy for Rural Development.

José M. Miccolis is special assistant to the president of the National Council for Scientific Development of Brazil in Rio de Janeiro, and director of the Brazilian Science Policy Project at George Washington University. He is the author of several publications concerning energy policy in Brazil.

John W. Powell, director of the Technology Consultancy Centre at the University of Science and Technology in Kumasi, Ghana, has conducted a six-year study of small industries in Ghana. He is the author and editor of two books in mechanical engineering.

Morton B. Prince is acting director for photovoltaics of the Division of Solar Energy at the Department of Energy. In 1954, he developed the Bell Solar Battery at the Bell Telephone Laboratories, and later developed commercial applications of the silicon photovoltaic cell at the Hoffman Electronics Corporation.

Roger Revelle is professor of science and public policy at the University of California, San Diego, and the Richard Saltonstall Professor of Population Policy at Harvard University. He is former president of the American Association for the Advancement of Science, a member of the National Academy of Sciences, and the recipient of numerous honorary degrees. His numerous publications in the areas of geophysics, national resource development, and population studies include Survival Equation: Man, Resources, and His Environment *(Houghton Mifflin, 1971) and* Population and Social Change *(Crane-Russak, 1972), both of which he coedited.*

Sharat K. Tewari, a scientist with the Wind Energy Group at the National Aeronautical Laboratory in Bangalore, India, is involved in analysis of wind energy as an alternative energy source, and hardware development in wind power. He has written several papers in this field.

Renewable Energy Resources and Rural Applications in the Developing World

Introduction

Norman L. Brown

The developing countries that are not fortunate enough to be oil producers are faced with energy needs that are growing more and more difficult to meet. Primarily dependent on oil for industrial growth and agricultural development, they have been hard hit by oil price increases. With little or no flexibility to meet these energy needs with other energy resources and generally unable to compensate for increased oil prices by increasing their exports, the less developed countries (LDCs) find themselves in a progressively worsening position to compete for the limited supplies of fossil fuel.

In most of these countries only a small proportion of the population is served by a power distribution network. The rural areas, where the majority of the LDC population lives, generally depend on limited supplies of diesel fuel or kerosene -- with more or less uncertain transport -- or "noncommercial" energy sources such as firewood, dung, and agricultural residues.

Thus, the LDCs have two distinct energy needs. On the one hand, industrial growth is dependent on conventional urban energy systems that use commercial energy sources and technologies that are already in use or are being developed in the industrialized countries. Agricultural development schemes -- the "green revolution," for example -- pegged to mechanization and manufactured nitrogenous fertilizers also depend on these energy sources and technologies. On the other hand, the majority of the population in most LDCs, living in the rural areas, is isolated from central power distribution. They would therefore particularly benefit from development of technologies to exploit renewable energy resources of the sun, wind, and flowing water.

Most of the energy-related assistance that has been provided the less developed countries to-date has focussed attention on urban/industrial-sector requirements. Only recently have development-assistance organizations focussed attention on the needs of the rural areas. This shift stems from a growing awareness of the importance of the way energy is gathered and used, and an increased understanding, on the part of the donor nations, of the necessity to focus on the needs of the rural populations of the less developed countries.

The choice of energy technology made by developing countries will have a long-term impact on their development that is more widespread and significant than that of any other technological choice currently facing them. Choosing conventional large-scale capital-intensive technologies implies a priori decisions, conscious or not, about many important policies. These include the course of urban development, expanding industrialization, environmental impact, large-scale borrowing (or foreign investment) with long-term indebtedness and problems of debt servicing, increased dependence on fossil fuels or commitment to nuclear energy, and last but not least, the foreign policy stance dictated by these requirements.

On the other hand, the choice of small-scale decentralized power systems (e.g., solar heating, cooling, and generation of electricity; windmills; small-scale hydroelectric plants) implies a different set of a priori decisions. These include, for example, de-emphasis of western-style industrialization as the sole or primary immediate goal of development; dispersal of industry and, perhaps, changes in financial mechanisms; and a shift from western agricultural techniques to emphasis on improvement of indigenous agricultural practices, with consequent reduced demand for energy-consuming nitrogenous fertilizers. All of these factors could contribute significantly to a slowing down of migration to the cities and urban growth, with important effects on the rate of growth of dependence on commercial energy supplies.

In making these choices, less developed countries must decide on the relative importance of the commercial-sector energy needs versus those of the traditional rural sector. Interest in small-scale technologies for exploiting energy received from the sun - whether directly or in the form of biomass, wind, or flowing water - has been increasing recently in both the industrialized and the developing world. In a recent report (1) the National Academy of Sciences examined these technologies in terms of their near- and long-term availability, particularly for use in rural areas of the less

developed countries. The report concluded that, for the most part, these technologies will have little short-term effect on energy-use patterns in urban areas. However, application of these technologies to improving the quality - and productivity - of rural life may have significant long-term effects on the trend toward urbanization.

It was the objective of the symposium from which this collection of papers was drawn to examine these technologies and their near-term applicability in the developing country rural setting, and place them in a realistic economic context.*

A discussion of energy uses in developing countries by Roger Revelle provides an appropriate introduction to the symposium. An analysis of estimated per capita uses of energy in rural areas of seven developing countries shows dramatically the overwhelming portion that is devoted to domestic activities and agriculture. Furthermore, the analysis demonstrates the importance of taking into account the noncommercial energy sources in developing countries. In two of the countries examined, no commercial energy at all is available in rural areas, and in four others, the ratio of noncommercial to commercial energy ranges from 6.3 to 157. Using Nepal as an example, Professor Revelle points out the serious environmental consequences of the incessant search, by rural people, for the most common noncommercial fuel available to them--firewood. The discussion serves as an illustration of the need to make renewable energy resources available to villagers in rural areas of developing countries in order to make it possible for them to improve the quality of their lives.

In a down-to-earth assessment of solar thermal technologies, George O. G. Löf contrasts the cost of converting solar heat to mechanical and electrical energy, based on current manufacturing costs in the United States, with conventional means of producing mechanical or electrical power. The comparison is discouraging, and accounts for the slow growth of the solar technology industry in the industrialized countries. Nevertheless, this pessimism must be tempered with a realization that in many developing countries, for a variety of reasons - often simply transportation costs and uncertainties, and maintenance problems - the cost of generating electricity is much higher than in the U.S.

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*The paper presented by Dr. Ibrahim Sakr, referred to in the "Summary and Discussion" by Roger Revelle, was not available for publication in this volume.

For example, the cost of producing electricity in Mauritania is over $1.00 per kilowatt hour. Thus, in such areas solar technologies not yet economically competitive in the United States would certainly be economically attractive. Most important, of course, are those technologies that could find immediate application, such as crop drying and distillation.

Morton Prince's discussion of the U.S. National Photovoltaic Program similarly describes the cost factors that are the main concern of development programs in the United States. The goal of this program is a cost reduction to US $.50 per peak watt by 1985, and there is reason to believe that this goal may be reached earlier. Although some of the cost reduction is expected to result from development of thin-film techniques and novel devices, the bulk is expected to come from automation techniques that reduce the amount of hand labor involved in fabrication of solar cells. The argument is made that "the market for photovoltaic systems is not sufficiently large to justify additional investment by private industry" to accelerate initiation of these cost-reduction procedures. It must be borne in mind, however, that this argument is made in the context of appraisal of the known domestic market and labor costs in the United States. The potential market in LDCs has yet to be ascertained; there are parts of the developing world where electricity costs from photovoltaics are almost competitive now with solar arrays at US $15 per peak watt.

Second, the history of the semiconductor industry has shown that labor-intensive fabrication can be economically performed in developing areas. Thus the medium-term prospects of the use of photovoltaic technology for generation of electricity in developing countries are not necessarily as dim as would be inferred from the description of the U.S. National Photovoltaic Program.

Brazil is currently engaged in a coherent, long-range program to make use of its vast resources to supply the increasing needs of its long-term development goals. With oil accounting for half the total commercial energy used, the government is emphasizing the development of alternative energy technologies. Jose Miccolis' paper details the current energy picture of Brazil and the multitude of schemes for conserving and supplementing scarce supplies that are being considered.

Solar energy is seen as playing an important role in Brazil's medium- and long-term plans, in view of Brazil's 8.5 million square kilometers lying almost entirely between the Equator and the Tropic of Capricorn. Development of

solar thermal technologies has received substantial support, but institutional changes are seen as needed to accelerate this activity.

Bioconversion, however, is the subject of a major effort. The production of ethyl alcohol as a fuel for internal-combustion engines, by fermentation of sugar and cassava, is being substantially supported. Serious consideration is being given to the use of hydrocarbon-producing plants, as a way of converting sunlight, via photosynthesis, to valuable chemical feedstocks, and fermentation processes to produce fuel (methane) and valuable nutrients (vitamins, enzymes, amino acids) are included in biomass conversion plans.

Mr. Miccolis' description of the energy needs and resources of Brazil is illustrative of the problems facing a country that has recently "graduated" from most foreign assistance programs, but finds itself facing not only a rapidly developing industrial sector, but continued problems of rural development.

One of the earliest concerted programs of development of wind-energy conversion systems for use in rural areas of a developing country was started in India more than twenty years ago. However, S. K. Tewari points out that the "optimism of cheap electricity from the grids," based on the assumption of cheap and plentiful petroleum supplies, was responsible for halting the program in 1966. The oil price increase of 1973 triggered a new and more intense interest in renewable energy resources in India, and the wind-energy conversion program was resumed. In common with many other developing countries, India is primarily concerned with the use of windmills to provide shaft power for pumping water and grinding grain, replacing the muscle power of people and animals. Generation of electricity by windmill systems seems of secondary importance in the near term for several reasons. Although the high costs of transmission lines would seem to argue for decentralized electricity generation, statistics show that in the 20-30% of India's half-million villages that are electrified, the primary use of electricity is to operate irrigation pumpsets and grind grain, *i.e.*, to provide shaft power. Electricity for lighting can be afforded only by the rich villagers. Thus, India's wind-energy conversion program is aimed primarily at providing mechanical power.

Mr. Tewari makes a point that is important in evaluating the use of all the so-called non-conventional energy technologies in developing countries. Conventional methods of cost/benefit analysis frequently fail to give adequate weight

to the social benefits that result from making energy available where it had not been and would not be available for some time to come if conventional sources were relied on. The value of supplying irrigation water can be estimated in terms of increased crop production. But the long-term benefits in improvement of the quality of rural life are difficult to quantify and are easily glossed over in economic comparisons. The unique ability of solar technologies - heat, wind, biomass, hydropower - to provide power in isolated communities, without the necessity of building roads, providing transport, or constructing transmission lines - to say nothing of avoiding the burden of increasing costs and scarcity of petroleum-based fuels - must be given appropriate weight in national planning schemes.

The issue of using conventional economic analysis, developed for use in the industrialized countries, to evaluate energy technologies in rural areas of the developing world arises again in considering the potential of small-scale hydropower. In a detailed history of the development of water wheels and turbines, Joseph J. Ermenc describes the important role that these devices played in the development of rural areas in the industrialized world. He notes, however, that this technology was displaced by the advent of large-scale central thermal and hydropower stations, rural distribution of electricity, the internal combustion engine, and improved rural transportation. But all of these factors were - and are - based on the availability of cheap and plentiful petroleum. Although cheap and plentiful are relative terms, fossil fuels are obviously not cheap and plentiful in developing countries. With a realistic awareness of the implications of this situation in terms of such things as road building, transportation, transmission line construction, and materials, and manufacturing costs for large-scale power equipment, the exploitation of small-scale hydropower sites for decentralized power systems becomes well worth examining. In this, the People's Republic of China seems to be leading the way, with thousands of unites of less than 100-kW capacity installed in rural areas. It is encouraging to note that interest in this approach has been developing rapidly in the United States, both in commercial manufacture of small turbines and as part of the national development program of the new Department of Energy.

The deforestation of many parts of the world resulting from the incessant search for cooking fuel is an issue of world-wide concern. Nepal estimates, for example, that at current rates of removal and regrowth only 12 to 13 years of accessible forest are left in that country. For countries

fortunate enough to have forests to support a substantial lumber industry, however, it behooves them to use their forest waste efficiently in order to maintain, or even improve, their present resources. Dr. John W. Powell describes Ghana's efforts to minimize the wood waste from its forests by a research and development program to utilize sawdust for cooking and to improve the efficiency of traditional methods of making charcoal. There is no doubt, however, that one of the most significant ways to reduce the denudation of forests for firewood is by improving the efficiency of traditional wood-burning cookstoves. With efficiencies of the order of 10 percent, even small improvements would significantly reduce the amount of firewood consumed - whether as wood or as charcoal.

Conversion of biomass into a particularly useful form of energy by anaerobic digestion is discussed by Raymond C. Loehr. In a lucid paper describing the state of the technology, the technical and institutional requirements, raw material needs, and advantages and disadvantages, Professor Loehr puts the process in a meaningful overall context. He points out that the use of alternative energy technologies in rural areas of developing countries should be aimed at reduction of human drudgery, minimum capital investment and operating expense, and production of energy in a form convenient for storage. In addition, where biomass conversion is concerned, agricultural productivity should be increased, the efficiency of the use of biomass (wood, cattle dung, crop residues) must be increased, and the use of plant fuels in general must be decreased to prevent deforestation and maintain soil tilth. The production of methane by anaerobic digestion of human, animal, and agricultural wastes comes close to meeting most of these goals by producing a combustible gas that can be stored and a stabilized residue that is a valuable fertilizer, in equipment that can be built and maintained on a village level.

The experience that has already been gained at the village level in countries such as Taiwan, India, Korea, and the People's Republic of China justifies optimism about the prospects of increasing the use of this process. Nevertheless, competent technical guidance and a careful evaluation of social and economic feasibility are needed in each situation.

Two things are apparent from the papers presented in this symposium and from the variety of developments reported in other forums. First, the developing countries themselves have begun to awaken to the implications of the commitment to fossil fuels and central-power station technologies, by

pressing for technologies that rely on renewable resources. Second, the principal barrier to greater use of these technologies has been their high initial cost per unit output and the almost universal access to the power distributions systems associated with larger-scale alternatives in the industrialized countries. The existence of these alternatives has inhibited the development and mass production of small-scale devices that would simplify their design and lower their cost. Without these alternatives, therefore, the developing countries will constitute the major market for small-scale decentralized power systems for the next five to ten years.

Thus, it is encouraging to note that the U.S. Energy Research and Development Administration, recently incorporated in the Department of Energy, has stated that it is taking steps to "initiate research, development, demonstration, and related activities aimed at helping to meet the energy needs of developing countries" in a program that "will seek technological solutions appropriate to the resources and the social, economic, and political goals of the developing countries. By providing a vehicle for consideration of alternatives that combine exploitation of renewable energy resources with technologies of use on a scale suited to rural community and single-family needs, the activities work to achieve maximum benefit for both the United States and developing countries." (2)

Furthermore, it is not merely a question of transferring technology to developing countries--all too often technology developed in the context of an industrialized society is irrelevant, at best, or harmful, at worst, to developing countries. What is needed, in the long run, are technologies suited to the needs and constraints of the country where it is to be used. And perhaps most important is the need to develop technologies to help meet what Roger Revelle has referred to as our uniquely human needs. In a discussion of technology transfer in another forum (3), Professor Revelle noted that". . . we human beings have some uniquely human needs, because of our special characteristics as human beings. One of the ways in which we are special is that we are able to remember the past and to think about the future. We go beyond satisfying the veterinary needs [food, warmth, shelter, sexual satisfaction, and health], and provide the means for satisfying the uniquely human needs that depend upon our character as time-binding animals. Four of these needs are hope, security, participation, and remembrance. Every human being must have hope, the hope that the future will be better than the present. Every human being needs some feeling of security, that the future won't be worse than

the present. Every human being needs a faith that he will attain some kind of immortality or remembrance, that is, soemthing that goes beyond his own short lifespan, not forever, but for a while.

"Most poor people in most less-developed countries satisfy these needs by having children; their hope for the future lies in children; children are their security in old age or sickness; children give them a sense of participation in the future; and they give them remembrance. Unless we can satisfy these uniquely human needs in other ways, the world is heading for a Malthusian catastrophe, and the problems of technology transfer will disappear in a grand Armageddon."

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1

Requirements for Energy in the Rural Areas of Developing Countries

Roger Revelle

There is a paradox of energy in the rural areas of developing countries. Both too little energy and too much energy are used, and the basic problems are to find ways to provide more energy and at the same time to conserve energy.

The economic chasm that divides the world separates two vastly different levels and kinds of energy use. More than 5/6 of all the energy obtained from fossil fuels and hydroelectric and nuclear power is used by the 12 hundred million inhabitants of the rich countries, and less than 1/6 by the nearly 3 billion inhabitants of the poor countries. Just the reverse is true of the traditional sources of energy: human and animal labor, firewood, crop residues and animal wastes. These were the predominant--indeed almost the only--sources of energy everywhere in the world until about 200 years ago. A man was actually hanged in England during the 15th century for burning coal.

The total quantities of energy obtained from traditional sources in the poor countries today are larger than their consumption of fossil fuels and they greatly exceed the uses in the rich countries. In the rural areas of the poor countries energy obtained from local, noncommercial sources by the people themselves is 5 to 10 times that obtained from commercial sources. Nevertheless, usable energy is in very short supply and the needs both for a large increase in supplies and for conservation--more efficient utilization--are great. From an energy standpoint, the rural areas of less developed countries can be

Table 1. Estimated per capita use of energy in rural areas of seven developing countries

	India (1)	China, Hunan (2)	Tanzania (2)	Northern Nigeria (2)	Northern Mexico (2)	Bolivia (2)	Bangladesh (6)
				10^3 Kcal/day			
Human Labor	.67	.64	.64	.61	.75	.71	.67
Animal Work	1.00	.92	--	.13	1.30	1.83	1.00
Fuel Wood	2.86		15.07	10.27	9.70	22.83	.93
Crop Residues	1.16	13.69					1.65
Dung	.67						.57
Total Non-commercial	6.36	15.25	15.71	11.01	11.75	25.37	4.82
Coal, Oil, Gas and Electricity	.53	2.05	--	.02	19.81	--	.27
Chemical Fertilizers	.22	.34	--	.05	5.33	--	.10
Total Commercial	.75	2.39	--	.07	25.14	--	.37
Total All Sources	7.11	17.64	15.71	11.08	36.89	25.37	5.19

thought of as partly closed ecosystems in which energy derived by people and animals from the photosynthetic products of plants is used to grow and prepare food, which in turn provides an essential energy input to grow more food and so on in an endless cycle. These ecosystems are being disrupted by rapid population growth.

Energy in Seven Countries

Table 1 shows the estimated per capita use of energy in rural regions of seven developing countries. To allow an easy comparison with human food intake the units used are thousands of kilocalories per person per day. In India and Africa the food energy contained in the average diet is about 2100 kcal; in Latin America, about 2400. Total energy use is much more than the intake of food energy, ranging from about 2½ times in Bangladesh to close to 15 times in northern Mexico. Except for the latter, most of the energy is from noncommercial sources; it is provided by the people themselves.

Five different kinds of noncommercial energy are listed in Table 1: human labor, animal work, fuel wood, crop residues and animal dung. Energy provided by human labor is assumed to be about 1/3 of the energy in the food eaten by the entire population. This assumption is based on a detailed study of the human energy required for different agricultural, domestic and other tasks in rural India (1), in which it was concluded that between 40 and 45% of the total food energy intake of adults and older children is utilized in manual work. The remaining food energy is utilized in basal metabolism and nonwork activity. Energy utilized in animal work is estimated to be 40% of the food energy intake of bullocks and other draft animals (1). The energy used in human labor and animal work is relatively small compared to the energy obtained from fuel wood, crop residues and dung.

Table 2 shows how energy is used in rural India and Bangladesh. About 20% of the total energy is allocated to agriculture. This is mostly human and animal labor, plus relatively small quantities of energy from commercial sources, used for pumping irrigation water and for

Table 2. Energy uses in rural India and Bangladesh

	India (1)		Bangladesh (6)	
	Total 10^{14} Kcal	Daily per caput 10^3 Kcal	Total 10^{14} Kcal	Daily per caput 10^3 Kcal
Agriculture	2.52	1.57	.333	1.32
Domestic Activities and Food processing	7.31	4.55	.852	3.38
Lighting	0.48	.30	.050	.20
Pottery, Brickmaking & Metal work	0.76	.47	.014	.06
Transportation & other use	0.35	.22	.055	.22
Total	11.42	7.11	1.304	5.18

production of chemical fertilizer. Between two and three times as much energy is used in domestic activities as in agriculture, mainly for cooking, food processing, and procuring fuel. In many rural areas at least one member of the family must spend most of his or (usually) her working time gathering fuel for cooking, and for space and water heating. Much less energy is used for lighting and for the traditional energy-intensive village industries--pottery, brickmaking, metal work, and blacksmithing--than for agriculture or domestic activities. Transportation represents a significant use, but in India it is the least energy-consuming of all rural uses. In Bangladesh, energy used for transportation is about equal to that used for lighting. Most of the energy for transportation represents animal work, and to a lesser extent human labor, (people are the draft animals in much rural transportation) or modern transport in trucks and tractors.

Table 3 summarizes some of the characteristics of energy uses in the 7 countries listed in Table 1. The total per capita use varies widely from about 37000 kcal per day in the relatively modern agricultural economy of northern rural Mexico to about

5000 kcal in Bangladesh. Energy use in the Chinese province of Hunan is 2½ times that in rural India. Except for northern Mexico, domestic uses are much larger than nondomestic uses, ranging from a factor of slightly more than 2 in India and Bangladesh to 18 in northern Nigeria and 37 in Tanzania. In these African areas hardly any animal draft power is used in agriculture, and no commercial fertilizers.

Nondomestic uses are more than twice as large as domestic uses in northern rural Mexico because agriculture has been modernized. Much of the energy here is utilized in the manufacture of commercial fertilizer, in pumping irrigation water and in mechanized agricultural equipment (2). Domestic uses are highest in Bolivia and Tanzania and relatively high in northern Nigeria and northern Mexico because of the large quantities of wood used as fuel. In northern Mexico most energy comes from commercial sources; in the other six countries noncommercial energy is overwhelmingly predominant.

One of the energy units tabulated in United Nations statistics are kilograms or tons of coal equivalent, taking 7.5 million kcal as the energy in a ton of "standard" coal. Table 3 shows that on the average in rural areas of developing countries about 600 kg of coal equivalent are used per person per year, more than twice what is generally ascribed to these countries in the United Nations statistics. The difference lies in our inclusion of noncommercial energy sources, which are not tabulated by the UN. On a per capita basis, commercial energy is used principally in urban areas as may be seen from Table 4 which shows total commercial and noncommercial energy use in urban and rural areas of India and Bangladesh.

Table 3 indicates that there is a rough relationship between nondomestic energy use and cereal yields per cultivated hectare. Northern Mexico and the Chinese province of Hunan, with the highest nondomestic energy use, also have the highest cereal yields. Cereal yields in India, Tanzania, northern Nigeria, Bolivia and Bangladesh are very low compared to those obtainable with modern agriculture. Typical yields in European and Japanese agriculture and in the Corn Belt of the United

Table 3. Characteristics of Energy use in rural areas of seven developing countries

	India	China, Hunan	Tanzania	Northern Nigeria	Northern Mexico	Bolivia	Bangladesh
				10^3 Kcal/day/caput			
Total use	7.11	17.64	15.71	11.08	36.89	25.37	5.18
Domestic uses	4.85	13.92	15.30	10.51	11.85	23.09	3.58
Non-domestic uses	2.26	3.72	.41	.57	25.04	2.28	1.60
Domestic/non-domestic uses	2.1	3.7	37.3	18.4	.47	10.1	2.2
Non-commerical/commercial	8.5	6.3	No com.	157.3	.47	No com.	13.0
Annual use, Kg coal equivalent	346	858	765	539	1795	1235	252
Cereal yields, Kg/ha	800	1750	700	900	2750	900	1100

Table 4. Total commercial and non-commercial energy in India and Bangladesh

	India (1)		Bangladesh (6)	
	10^6 Total tons coal equivalent	per caput tons coal equivalent	10^6 Total tons coal equivalent	per caput tons coal equivalent
Total Energy	267	.486	19.5	.260
Urban	115	1.045	1.9	.317
Rural	152	.346	17.6	.253
Commercial	103	.187	2.0	.027
Urban	87	.790	0.8	.134
Rural	16	.036	1.2	.017
Non-commercial	164	.298	17.5	.233
Urban	28	.255	1.1	.183
Rural	136	.309	16.4	.238

States are 5000 to 6000 kg per hectare compared to 700 to 1100 kg per hectare in India, Tanzania, northern Nigeria, Bolivia and Bangladesh. Some developing countries, for example Egypt, obtain yields close to those of the developed countries. One of the critical differences between the high yielding agriculture of the advanced countries and the traditional agriculture of the Indian subcontinent and sub-Saharan Africa is the much larger use of energy per hectare (but not per ton of food produced) in the advanced countries.

In contrast, energy use for cooking in the rural areas of developing countries is higher than in many United States households, because the energy is used very inefficiently. Fuel wood, for example, is burned partly in open fires and partly in inefficient mud or stone stoves. The fire is started before the pot of rice (in countries where rice is the dietary staple) is placed on it, and the fire keeps on burning after cooking has been completed. Only a small fraction of the heat of combustion actually serves to boil the rice; most of it escapes outside the cooking pot. As a result the quantity of energy going into the cooking process is about 10% of the total energy in the fuel, in contrast to about 30% in a modern gas stove (1). This inefficient use of fuel is likely to have serious consequences for many developing countries if their rural populations continue to increase. The principal source of domestic energy is wood, the "poor man's oil," and trees and other vegetation are being destroyed for fuel faster than they can grow.

Agricultural Need for More Energy

Additional energy is needed in agriculture for four purposes:

a. to provide a larger and more stable water supply;

b. to allow increased application of chemical fertilizers, especially nitrogen fertilizer;

c. to allow more rapid seedbed preparation;

d. for improved transportation.

Taking India as an example, estimates by the Indian Irrigation Comission (3) indicate that about 10^{14} kcal should be used for pumping water--4 times the bullock, diesel and electric power now being used for lifting water. This is equivalent to 620 kcal per day for each person in rural India in 1971 (4).

Chemical fertilizer manufacture is quite energy-intensive, especially nitrogen fertilizer, which requires close to 17500 kcal per kilogram of nitrogen (5). Yet chemical fertilizers are essential if advantage is to be taken of the tropical climate, which allows two or three crops to be grown on the same land each year. Where nitrogen in chemical fertilizer is not available, the land must be left fallow for most of the year, to allow time for the soil bacteria to fix nitrogen from the air. The wasteful use of fallow is one of the principal reasons why yields in the developing countries are so low. Applications of nitrogen fertilizer should be raised to around 100 kg per hectare per crop. With 100 million double cropped hectares in India, 20 million tons of nitrogen would be required, corresponding to 2180 kcal per rural inhabitant per day.

Rapid harvesting and seedbed preparation are necessary if two or more crops are to be grown per year. But the bullocks and other farm animals now used for cultivating the land are often too small, or too weak from malnutrition, to be able to pull the cultivating equipment hard enough and rapidly enough so that the ground can be prepared after harvesting one crop in time to plant another one. Makhijani and Poole (2) estimate that an additional 5×10^5 kcal per hectare per crop are required in construction and operation of small tractors. In rural India this would amount to 620 kcal per rural inhabitant per day, supposing that 100 million hectares can be double cropped. Cultivation of two crops per year would greatly improve farm employment, probably by at least 50%, corresponding to an added human energy input of 190 kcal per rural inhabitant per day (1).

Improved transportation is needed to bring off-farm inputs to the farm--fertilizers, pesticides, high-yielding seed varieties, farm tools, farm machinery and knowledge--and to facilitate

exporting part of the crops to cities and towns. It is obvious that farmers will not be able to purchase the off-farm inputs necessary for modern agriculture unless they are able to sell a portion of their crops to non-farmers. In general, modernization of agriculture demands improved transportation both to lower the cost of getting inputs onto the farm and the costs of tranportation of farm products to people in the cities and towns.

The total additional energy requirement would be more than twice the energy now used in Indian agriculture. It would then be possible, in principle, to approximate the average U.S. yield of 3.3 tons of food grain per hectare per crop, instead of the present 0.8 tons. Even with an assumed yield of two tons per hectare per crop the increased value of farm production could be about 10 times the cost at 1976 prices of the fossil fuels used for fertilizer, pumping water, transportation and farm machinery. However there are problems in the use of fossil fuels, the principal ones being the difficulties of obtaining foreign exchange in many developing countries and problems of transportation and distribution in rural areas.

We need to look for other sources of energy that can be produced locally. One promising possibility is the use of crop residues. For every ton of the ordinary indigenous rice grown in India, Bangladesh, or Africa, close to two tons of straw are produced, with the same energy content per ton as the rice. In modern agriculture about half as much energy is used (not counting solar energy) as the energy in the food produced. Thus crop residues contain about 4 times as much energy as the amount needed for modern agriculture. If these residues could be processed to produce the kinds of fuels needed, viz., liquid or gaseous fuels, even at a 40% loss of energy in the process, there would still be roughly twice as much energy available as that required for modern agriculture. But this would be true only if the energy used in domestic activities could be greatly reduced, i.e., domestic energy could be conserved.

Conservation and Storage

For energy conservation, perhaps the most important single development would be not a new

source of energy but a better stove, a better way of cooking food, a cheap and inexpensive, easily used device that would enable the efficiency of fuel use to be raised from 10% or less, to 30 or 40%, as it is in a modern gas stove in the United States--at least a gas stove without a pilot light.

Problems of energy storage must be solved if local energy sources are to be fully utilized. The requirement for storage arises because both the uses and the energy sources are intermittent. Energy must be stored to obtain synchronism between the uses of energy and the sources of energy. One way to store energy is in chemical fertilizers and other chemical products. Another is in hydrogen, methane or alcohol. Another is by pump-back storage of water into reservoirs. Another may be the use of solar energy pools of hot water.

The Hills of Nepal

The problems of energy use in rural areas are particularly critical in mountainous regions. In the hills of Nepal the people have traditionally terraced the lower valley areas and hillsides to make them flat for better cultivation. As the population has rapidly grown in recent decades the people are making desperate efforts to grow more food, with the result that areas that should not be cultivated are being used for agriculture. Terraces are being constructed further and further up the hillsides on steeper and steeper slopes, in some places all the way to the top of the hillsides. Rainwaters during the monsoon season run off on the backsides of these terraces and form a slippery surface between the terraces and the hill. And as a result landslides occur in which the terraces are destroyed and the soil is denuded. Driving west from Kathmandu for 40 or 50 kilometers one sees many landslide scars where the whole side of the mountain has simply slid down and destroyed any possibility of agriculture. Even where landslides do not occur, the terraces are being rapidly eroded, and the numerous streams that lace the hill country are choked with sediment during the monsoon season. When these streams debouch on the Ganges Plain of India, the sediment load is dropped, and the rivers are diverted from their courses, causing devastating

floods that are becoming more common and more severe each year. At the same time pasture lands in the hills are being over-grazed, and forests are being rapidly destroyed for fuel wood and for forage for livestock.

What is happening in Nepal is happening equally in the mountainous regions of India and Pakistan, and in Latin America. Because of rapid population growth, the need to produce more food is becoming greater each year, and because it has not been possible to increase the very low yields per hectare, cultivation is being extended to unsuitable, easily eroded areas. The resource base for agriculture is literally being destroyed and the future looks very grim indeed. But it may be possible to solve the problem by introducing new sources of energy. In the Nepalese hills two sources might be combined: small-scale village hydropower plants and plantations of fast-growing trees. These possibilities were explored at a recent conference in Nepal, sponsored by the Council on Science and Technology of His Majesty's Government of Nepal and the Asia Society.

From a technological point of view, farming should be concentrated on the lower terraces near the valley bottoms. With irrigation and sufficient fertilizer it should be possible to raise yields during the monsoon season and to grow a second--possibly even a third--crop on these lower terraces during the dry season. If hay could be cut from the pastures during the monsoon and dried, it would provide feed for livestock in the dry season, and the over-grazing of the pastures and destruction of trees for forage could be curtailed. If the livestock could be kept in pens and fed on hay, the nitrogen in their urine (2/3 of the total excreted) as well as the nitrogen in the dung could be recovered to fertilize the fields.

So far as is known, Nepal has no deposits of oil, coal, or natural gas which could serve as a feed stock for nitrogen fertilizers. It does possess abundant limestone. The relatively small amounts of fertilizers now used are imported from India or from world suppliers through the port of Calcutta. Very few roads exist in the hill country, and imported fertilizers must be carried on human backs to most villages. Even at quite

high production costs, fertilizers manufactured locally in each village would be economical.

For the average hill village of 250 people, 50 tons of milled rice or corn would provide the basic staple for an adequate diet. At a yield of two tons per cropped hectare, this quantity of cereals could be grown on 12 double-cropped hectares. About 2 tons of nitrogen in chemical fertilizer would be required to obtain these yields, in addition to the nitrogen in animal dung and urine. Irrigation water would need to be pumped from the rivers for the second crop during the dry season, plus supplemental irrigation in the monsoon season. With an average pumping lift of 15 meters, the energy required for pumping sufficient irrigation water would be around 10,000 kilowatt hours. An equal amount of energy would be needed to lift domestic water supplies 300 meters. This is estimated to be the average elevation of village houses above the river bed. Using the old electric arc process, which requires about 45,000 kwh per ton of nitrogen, 2 tons of nitrogen in chemical fertilizer could be produced for an energy expenditure of 90,000 kwh. This process generates large quantities of waste heat which could in principle be used for drying hay.

The required amount of energy, about 110,000 kwh, could be provided by a 15 kw hydroelectric plant operated for 310 days a year. For an installation utilizing high-head (about 100 meters) and small flow, the estimated cost of turbines and generators would be $7,500. The cost of the "civil works," utilizing buried PVC pipe to transport water from a simple "run of the river" intake to penstocks giving 100 meters of head would be $22,500, or a total cost of $2,000 per kilowatt for turbines, generators, and "civil works." The entire installation, including the equipment for electric-arc nitrogen fixation and production of calcium nitrate fertilizer, using the abundant limestone to combine with the nitrogen oxide provided by the electric arc process, could be operated by one or two retired Gurkha soldiers. These retired soldiers have gained considerable familiarity with simple machinery during their period of service in the British army. After retirement, they often utilize this experience to establish and operate small industries in the more

accessible parts of the hills.

The problem of energy for cooking and heating water could probably best be solved by establishing plantations of fast-growing trees in each village. The existing forests used for fuel wood consist of very slowly maturing trees, which do not produce new growth rapidly enough to meet the village needs--hence the present rapid depletion of the forests. Each hill villager uses about three quarters of a ton of fuel wood per year, or about 185 tons per year per village of 250 people. With fast growing trees, this quantity of fuel could be provided on a sustained basis by a 30 hectare fuel wood plantation. The estimated cost of a forest plantation of this area would be around $20,000, including fencing to protect the young trees from livestock.

The total cost per village of a hydropower and fertilizer installation, plus the forest plantation would be approximately $60,000, or $250 per inhabitant of the hills, a total of 1.5 billion dollars for the present population of 6 million people. This cost appears to be very high in view of Nepal's extremely limited resources, but it could be more than justified by the probable reduction in flood damage in India's eastern Ganges Plain, let alone the conservation of agricultural soils in the hills of Nepal. From Nepal's standpoint, the investment might be considered a social cost, to be borne by the government in the same manner as the cost of roads and schools.

A serious social problem might be expected, however. It is likely that the lower terraces, on which production should be concentrated, belong to the richest groups in the villages, while the higher terraces, which should be abandoned, are the source of livelihood for the poorest village groups. To ensure social equity, it might be necessary to supplement provision of small-scale hydropower installations and forest plantations by strong governmental action, such as rigorously enforced land reforms, which would allow a sharing of the benefits by all the inhabitants of the villages.

More Energy for Rural Industries

With the small and decreasing size of agricultural land-holdings per farm family and the growing numbers of rural people without land, it will probably be impossible to raise rural average incomes to a satisfactory level unless employment can be increased through development of small industries in the countryside. At the same time, the agricultural modernization that can result from increased energy supplies for agriculture will facilitate development of agriculture-related industries in villages and small cities and towns of rural regions, provided that additional energy beyond the needs of agriculture can be made available.

With the coming of electrification to villages in Thikriwala Thana of District Lyallpur in Pakistan, many villagers have been able to install and operate small power looms for production of grey goods, which are shipped to the city for final processing. Elsewhere in Pakistan and India, diesel engines and pumps for irrigation are being manufactured in small machine shops located in the cities and market towns of the countryside. In the Kaira district of the Indian state of Gujarat, the "Amul" dairies provide milk and other dairy products to Ahmadabad and Delhi, and many farmers have been able to increase their incomes by maintaining dairy cattle.

In the small city of Comilla in Bangladesh a foundry and repair shop for irrigation pumps and other agricultural machinery has been established, together with a cold storage plant for potatoes, a meat packing plant and a dairy. Other possibilities for rural industries include: leather and wood working, sugar and flour mills, and food and vegetable preservation. Even electric lights can be used to increase productivity by enabling people in villages and small towns to work at night.

For development of rural industries which can be competitive with some of the more centralized industries of large cities, an essential requirement is relatively low-cost energy to operate lathes, looms and other machinery, and to provide heat for metal-working, dairies, and food-

processing. Here, just as in agriculture, we are concerned with increasing human productivity by supplementing (but not supplanting) human labor with electrical, chemical, or mechanical energy. In the long run there is no other way to raise incomes.

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2

Solar Energy in the Less Developed Countries

George O.G. Löf

There are two primary reasons that solar energy has not been successfully applied in the developing countries of the world. The first reason, applicable also to the developed world, is that solar energy is expensive. Although "raw" solar energy is essentially free, when converted to a useful form, it is one of the most expensive sources of energy we have.

The second reason for lack of success in applying solar energy in the developing countries is a poor understanding of needs in those areas, particularly among solar energy specialists. Since needs have not been identified and assessed, assumptions pertaining to solar applications have been faulty.

My remarks are directed mainly at these two problems which impede application of solar energy in the developing countries. I shall discuss a number of examples that illustrate these points. I would like to divide potential solar applications into two main categories; first the heat applications, and then, secondly and briefly, the uses for work or electric power.

Why is solar energy expensive? Let me begin my answer by providing a few numbers. In a reasonably favorable climate for space heating in the United States, or in any other favorable solar climate where space heating is needed for more than half the year, about one and a half therms (150,000 Btu) of useful heat can be supplied per heating season per square foot of solar collector. That is equivalent to about a gallon and a half of fuel oil at normal efficiency of combustion. For solar water heating, a year around need, nearly four therms can be usefully delivered per square foot of well-designed collector per year in a favorable climate. At a near-future cost of buying and installing a solar water heating system, approaching $20 per square foot of solar collection surface, and a ten percent annual cost of capital, solar heat for this application has a cost of {(0.10 x 20/400,000) x 100,000} = 50 cents per therm. So, the cost of solar heat delivered for this continuous use in a

sunny climate should be near 50 cents per therm if the chosen conditions apply. Simpler, home-made hardware might not cost as much, but it usually works badly in the U.S. and it is going to work even less effectively in the developing countries. Although a system at $10 per square foot appears attractive, it is no bargain if it has to be thrown away in three years. And in the developing countries maintenance may be difficult.

Borrowing money at 8 percent interest in a developing country may also be difficult -- 20 percent is a more typical rate. With a $10 per square foot collector, a 20 percent interest loan, and a 10-year amortization period, the solar heat again would be about 50 cents per therm. There does not seem to be much chance of getting the cost below 50 cents per therm for solar heat delivery.

Number 2 fuel oil is about 50 cents per gallon in the U.S., but its price is higher in most other countries. Oil at this price provides heat at about 50 cents per therm. So it looks as though solar heat may now be competitive with fuel oil under particularly favorable solar conditions.

This favorable comparison rests on several assumptions. A continuous use for solar energy was selected. If less than four therms per year are recovered and used, the solar heat cost increases. Solar cooling probably requires heat supply less than a fifth of the time, so instead of recovering four therms per year, perhaps half a therm per square foot is actually used per year. Hence the equivalent cost of the energy delivered is five to ten times higher. A high efficiency system was also assumed, otherwise less than four therms will be delivered. Durability is also important, because the investment will have to be amortized in less than ten years if the system life is short.

Electricity has higher value than heat, so conversion of solar heat to electricity should be evaluated. If we convert one therm (100,000 Btu) of solar heat to electricity with presently available equipment, we will be doing very well if we obtain five percent conversion. So one therm (100,000 Btu) at five percent conversion efficiency will produce one to two kilowatt-hours. If four therms of heat are recoverable per square foot of collector per year, five to six kilowatt-hours of electricity may be obtained per year. The cost of heat for this electric production may be in the 50 cents range, so the heat cost per kilowatt-hour of electricity would be about ten cents. With the additional costs of turbine, generator, and other power plant facilities, solar electricity costs approach 20 cents per kilowatt-hour. There are some places in the world where electricity prices are as high as 20 cents per kilowatt-hour, so solar electricity may be competitive in regions where central station electric power is not available.

Solar energy applications may be subdivided in several ways, and for this discussion, I would like to divide them into the two categories of heat and electricity. Most of the potential uses for solar energy in the developing countries appear to be concerned with heat, so I shall emphasize those applications.

Figure 1 shows a simple type of solar water heater. Residential water heating is a year-round need in the developed countries, and it appears that sanitation, health, and comfort would be improved by water heating in many parts of the world where it is not now being practiced. I say, "appears" because, as a solar specialist rather than an anthropologist, I am not qualified to assess the requirements, limitations, social, economic, and political factors involved in the introduction of new concepts and practices in very different environments. The solar specialists and the experts in such appraisals in the developing countries should jointly attack this important problem.

The photograph is of a unit developed in Japan a number of years ago. A simple plastic bag on a flat roof is filled in the morning with water. The bottom surface of the bag is black and the top surface is clear. The water is heated during the day by absorption of radiation on the black surface, and drained into the tube in the evening for the family bath. It is a practical unit, many thousands were made. The heaters lasted one or two years and then were discarded. Their low cost compensated for their short life, so cost-effectiveness was reasonably good. Now an improved model of greater durability is available.

Figure 2 shows a solar water heater which is commercially made in Australia, obviously much more durable. The solar collector in the glass-covered panel and the storage tank in the insulated jacket provide most of the hot water requirements of a typical family in Australia.

Another Australian model, shown in Figure 3, is even more widely used. The photograph shows a number of panels being tested in an experimental facility. In typical installations, three to six collector panels are connected to an elevated insulated storage tank, in a thermosiphon circulation arrangement requiring no pump. Figure 4 shows a "home-made" solar water heater on an Indian reservation on the California-Arizona border.

Solar water heating is not a difficult technology, as can be seen, but careful attention must be given to numerous requirements. The tubing in the absorber plates must be of corrosion-resistant material, or premature failure will occur. A durable glazing material must be provided for reduction of heat losses, otherwise low efficiency will result. Solar heating is a very "forgiving" technology -- most solar equipment will deliver useful heat, but the attainment of good

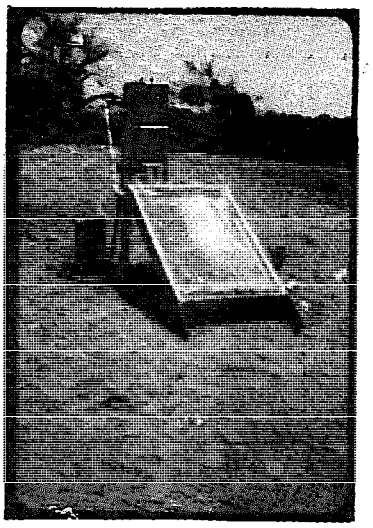

Figure 1

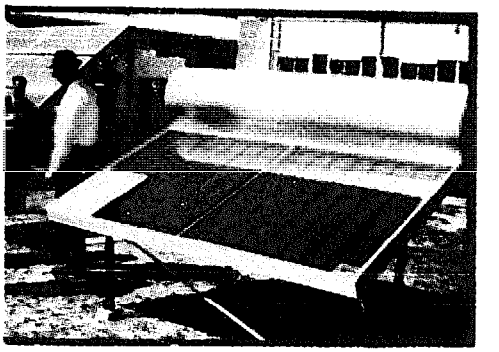

Figure 2

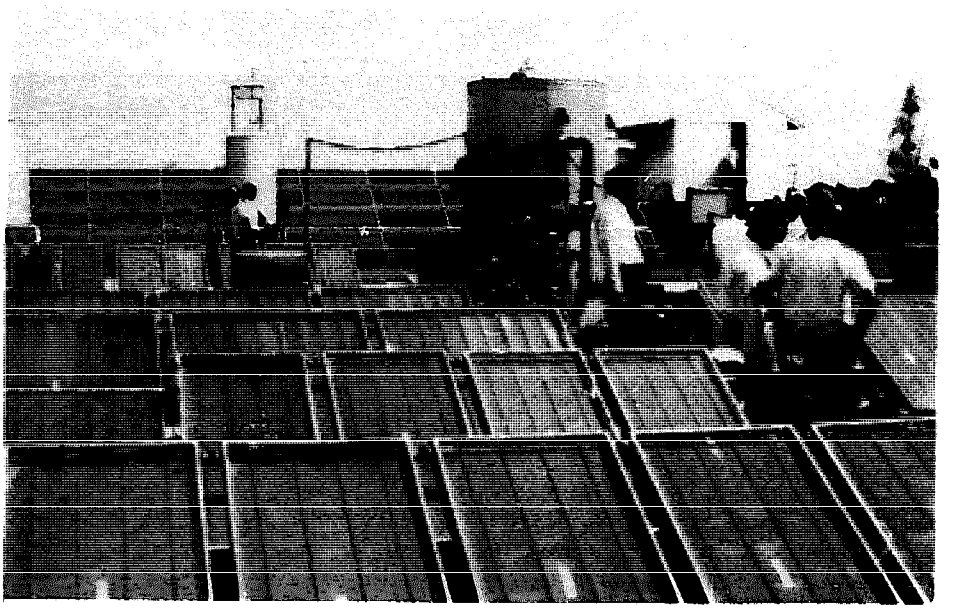

Figure 3

Figure 4

Fig. 1. Solar Water Heaters--Plastic Bag Type (Japan)
Fig. 2. Solar Water Heater--Storage Tank (Australia)
Fig. 3. Solar Water Heaters--Collector Testing (Australia)
Fig. 4. Solar Water Heater--Site-Built (United States)

performance over long periods with virtually no maintenance requires careful, capable design.

Another solar heat application is space heating. Although the need for space heating is not great in most of the developing countries, winter heating is a requirement in many areas. Particularly in the more developed sections of these countries, the space heating of public buildings, schools, and business enterprises which have the capability for underwriting the cost of the system, appears to be a practical application of solar energy.

In a commercial U.S. system, shown in Figure 5, air is heated by passing it through a solar collector. For overnight heat storage, the hot air is circulated through a bin of small rocks (pebble-bed) which are heated by the air. When heat is needed in the rooms, Figure 6, the hot air is delivered by the blower to the living space and then returned to the collector. Figure 7 shows that, when heat is needed at night, house air is circulated through the warm rocks. Finally, an auxiliary heat source is used when there isn't enough solar heat in storage.

A simpler way of heating a building is used in this structure in southern France (Figure 8), where a black-painted, south-facing, thick concrete wall absorbs solar energy passing through two layers of vertical glass surfaces. The concrete is heated, and room air circulates through slots in the bottom of the wall, up the space between the wall and the glass, and back into the rooms through slots at the top. This passive system provides partial solar heating by warm air to the rooms.

Space cooling may be a more important need than heating in most of the developing countries, but I want to state again that expert analysis of needs and capabilities is first required. One method for cooling with solar energy, illustrated in Figure 9, is by use of an absorption refrigeration cycle. The principle is similar to that in the gas refrigerator. For commercial buildings and larger structures in the developing countries, where cooling is needed, this system may become practical after further development. It is not free of electrical requirements, because power is needed for circulation of heat transfer fluids. This system is in the development stage so far as solar application is concerned, and it is going to be some time before we know whether it has practical application even in the U.S.; until we know that prospect, we probably will not be able to appraise its potential elsewhere.

A structure combining a greenhouse with a dwelling may be useful in a developing country. Figure 10 shows a new building at Colorado State University, comprising a small dwelling in the rear with a greenhouse in front. There are about 800 square feet of greenhouse area and 800 square feet

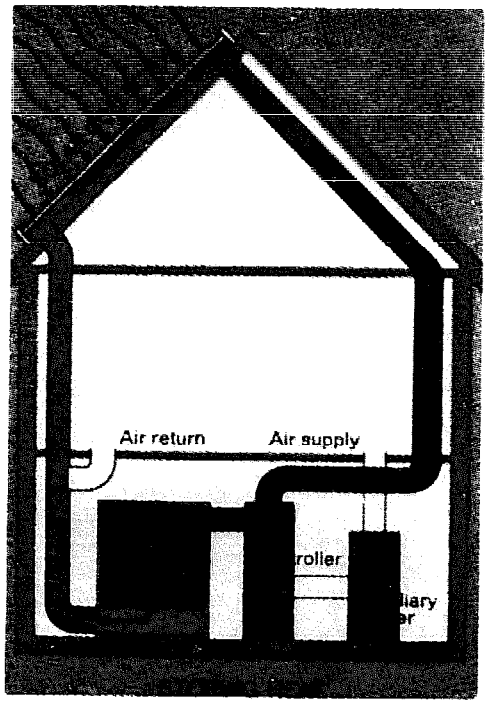

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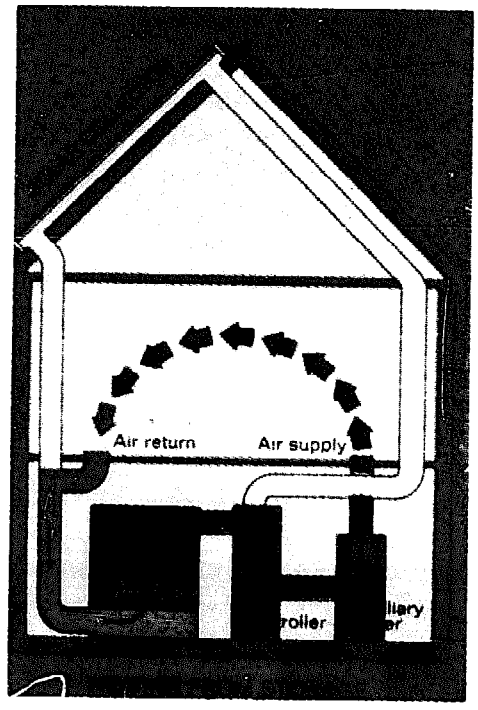

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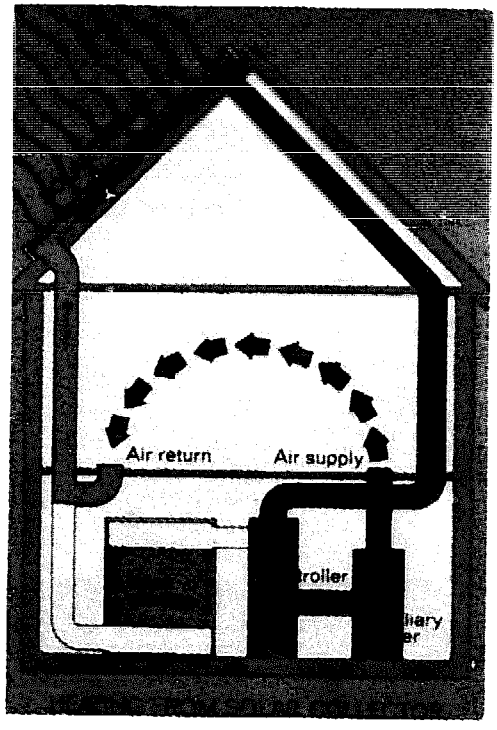

Figure 6

Fig. 5. Space Heating with Solar Warm Air--Storage

Fig. 6. Space Heating with Solar Warm Air--Heating from Collector

Fig. 7. Space Heating with Solar Warm Air--Heating from Storage

Figure 8

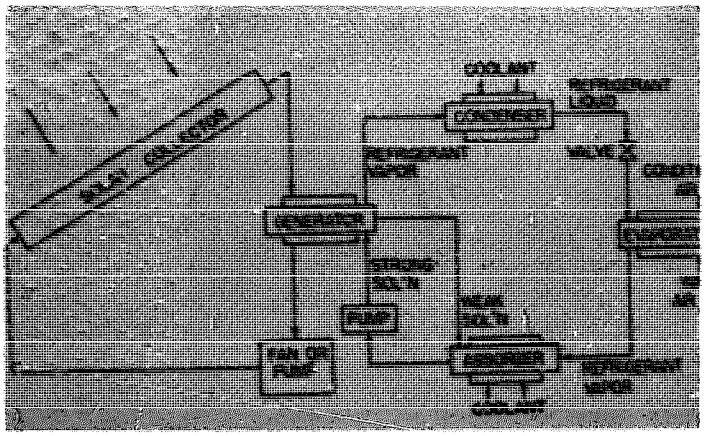

Figure 9

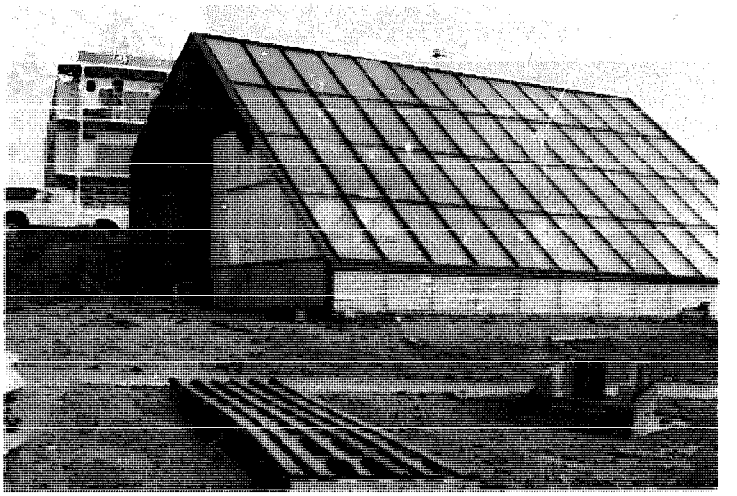

Figure 10

Fig. 8. Solar Heating with Passive Systems (France)

Fig. 9. Space Cooling with Solar Energy--Absorption System

Fig. 10. Experimental Solar Heated Dwelling and Greenhouse (Colorado State University)

Figure 11

Figure 12

Fig. 11. Experimental Solar Grain Drying Equipment (Colorado State University)

Fig. 12. Regeneration of Batch-Type Refrigeration Unit with Solar Heat

Fig. 13. Solar Refrigeration with Ammonia Absorption System (USSR)

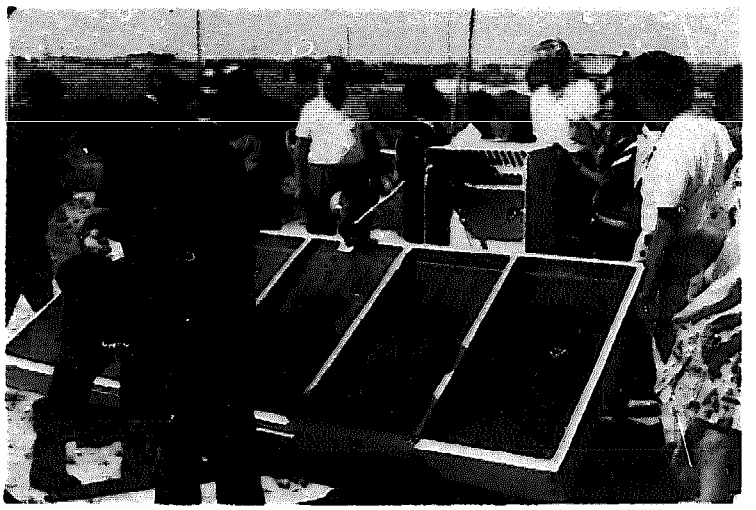

Figure 13

of living area. The combined use of solar heat in this installation supplies most of the heat requirements of the dwelling plus part of the heat requirements of the greenhouse. The greenhouse is double glazed throughout, thereby minimizing heat demand. Food crops are now being produced in this building, and performance and cost-effectiveness are being evaluated.

Drying of crops is another use of solar heat. Figure 11 shows an experimental system at Colorado State University where air is being heated in a solar collector. The hot air is then used to dry grain in a bin. Crop drying is an ancient solar application, usually accomplished by spreading the crop in the field and letting the sun dry it naturally. Losses are sometimes high by that method and the possibility of increasing food yield by effective drying is extremely important. Major studies of the potential and practice of this technology are needed.

Refrigeration is another application which is a possibility for the developing countries. Food refrigeration to reduce spoilage and increase effective productivity appears to be a need in many regions. Figure 12 shows a small-scale experiment with a household size refrigerator in which concentrated solar energy is used to generate a refrigerant in a simple two-chambered device. The refrigerant is generated for a few hours by distilling it out of a solution in one vessel into a water-cooled second vessel; after the refrigerant is collected in the second vessel, the device is lifted from its solar heat source and put inside the refrigerator box. Slow evaporation of the refrigerant then produces cooling for about a day. This system was used on some American farms about 50 years ago, with kerosene supplying the energy for operation. The solar adaptation is workable but inconvenience and cost are serious impediments to use.

Another solar refrigeration development is under investigation in Turkmenia, USSR. Figure 13 shows a flat-plate solar collector supplying ammonia refrigerant to an insulated food cooler (refrigerator). Again, high cost is a deterrent to individual household use. Food refrigeration with solar energy probably has a more practical application in large central refrigeration plants where the high capital costs of the equipment can be more readily borne. Food could be preserved in community-size refrigeration plants by one of these solar-operated methods.

Solar heat can be used to produce fresh water from salt water. Figure 14 shows a solar water distiller built in Chile one hundred years ago. It was used to desalt brackish water at a mining operation in the high desert. For nearly 20 years, this plant produced distilled water to supply the mules that worked in the mine.

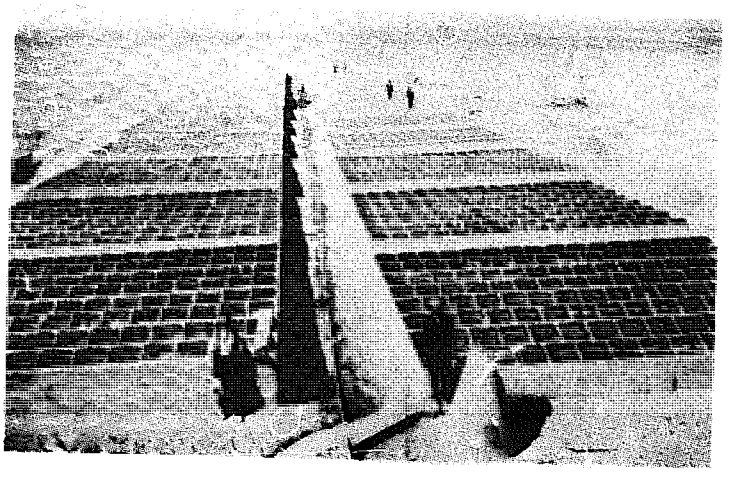

Figure 14

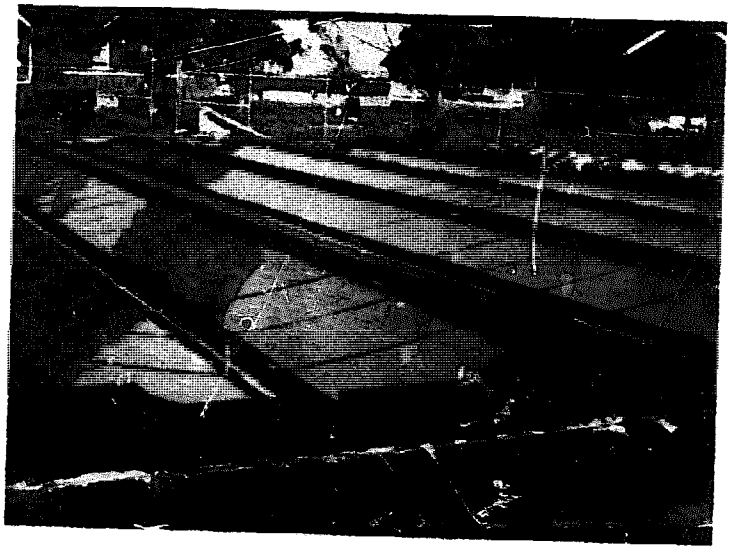

Figure 15

Figure 16

Fig. 14. Solar Distillation of Salt Water (Chile, circa 1870)
Fig. 15. Solar Distillation of Sea Water (Florida, circa 1965)
Fig. 16. Solar Still for Desalting Water--Under Construction (Australian Design, 1972)

A hundred years later this solar still (Figure 15) was built in Daytona Beach, Florida. The design is nearly the same as the Chilean still, but improved materials were used. A shallow basin of salt water is covered by sloping sheets of glass. The salt water slowly evaporates by solar absorption, the vapor condenses on the glass, and the condensed water runs into troughs and out to storage. A portion of the salt water is discharged to waste so that salts will not be deposited in the still. This process has been used for supplying drinking water in a number of parts of the world. Figure 16 shows an Australian design of a slightly different type. Glass covers are supported by two concrete curbs, between which a slab of insulation (to reduce heat loss to the ground) and a waterproof butyl rubber liner are installed. Figure 17 shows the completed solar still. A solar distiller in a sunny climate will produce about 5000 gallons of water per day per acre. The water is expensive, several dollars per thousand gallons, due to the amortization of the relatively high capital cost of the still. But if there is a need for desalted water in quantities up to 25 to 50 thousand gallons per day, a solar still can probably produce it at lower cost than any other distillation method using fuel. Figure 18 shows the dedication of an 80,000 square foot solar still on the island of Patmos in the Aegean Sea a few years ago. There is no source of fresh water on this island except rain water collected on roofs. Although solar distilled water is expensive, it may be the cheapest source.

A Russian solar distiller in Turkmenia (Figure 19), contains a series of ledges over which the salt water trickles and evaporates; the distillate condenses on the glass cover and runs into a separate channel at the bottom. The sloping concrete tray is coated with black asphalt to absorb the radiation.

On the Island of Symi in the Aegean Sea, a solar still recently occupied the only sizable flat area in the town (Figure 20). Plastic film supported by slight internal pressure served as the condensing cover surfaces. Although of lower construction cost than a glass-covered still, this unit deteriorated and failed completely in less than a year. This experience shows the importance of using sound design and durable materials in solar systems, in the developing countries as well as in the industrialized regions of the world.

Solar cooking has long been a popular concept among solar designers. One of the first, Figure 21, was developed by a group in India. This unit was on display at a solar conference 20 years ago. Another type, shown in Figure 22, is an oven with bright metal vanes to reflect solar radiation through a glass cover into an insulated box. In Figure 23, a solar cooker is being demonstrated in a Soviet laboratory

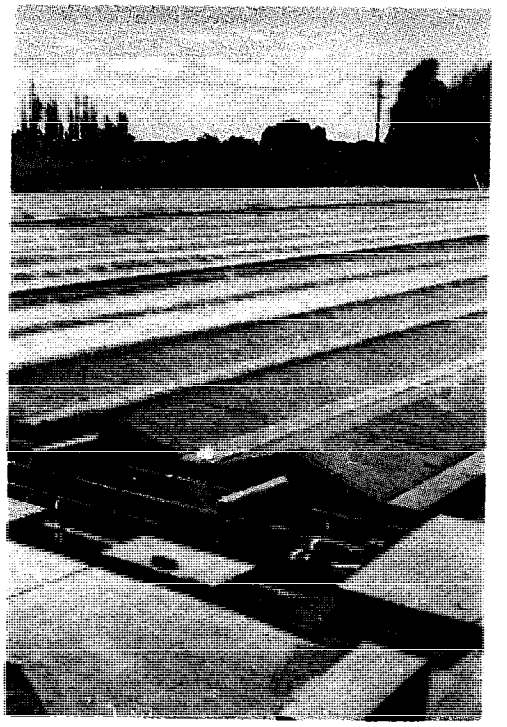

Figure 17

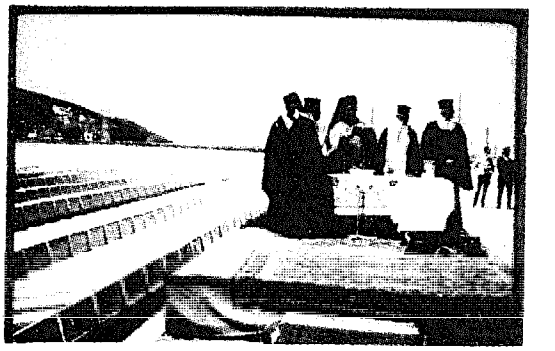

Figure 18

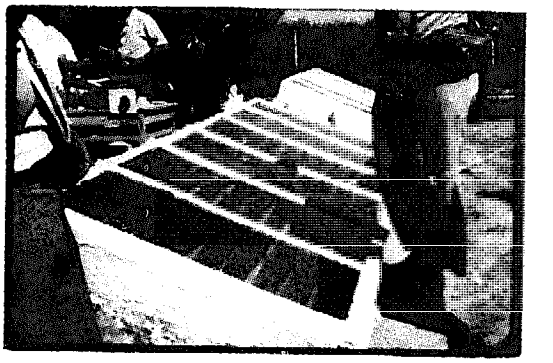

Figure 19

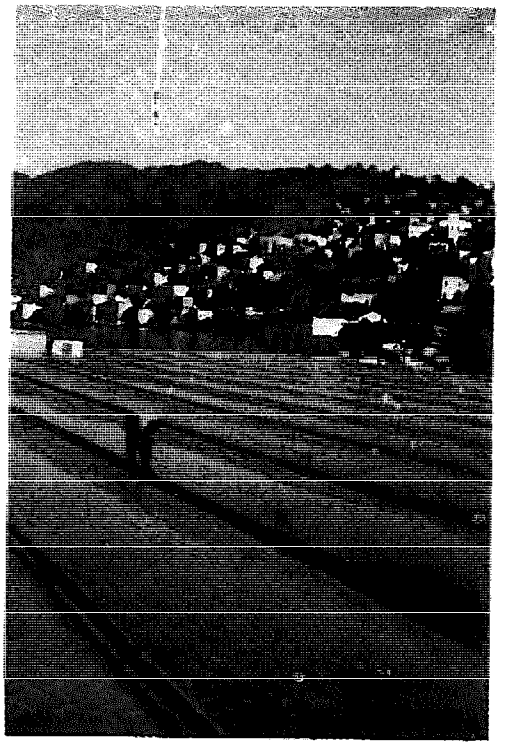

Figure 20

Fig. 17. Solar Still for Desalting Water--Completed (Australian Design, 1972)
Fig. 18. Solar Still for Desalting Sea Water (Potmos, Greece, 1967)
Fig. 19. Sloping, Ledge-Type Solar Still (USSR, 1975)
Fig. 20. Plastic Solar Still (Syme, Greece, 1965)

Figure 21

Fig. 21. Reflecting Solar Cooker (Indian Design, 1955)

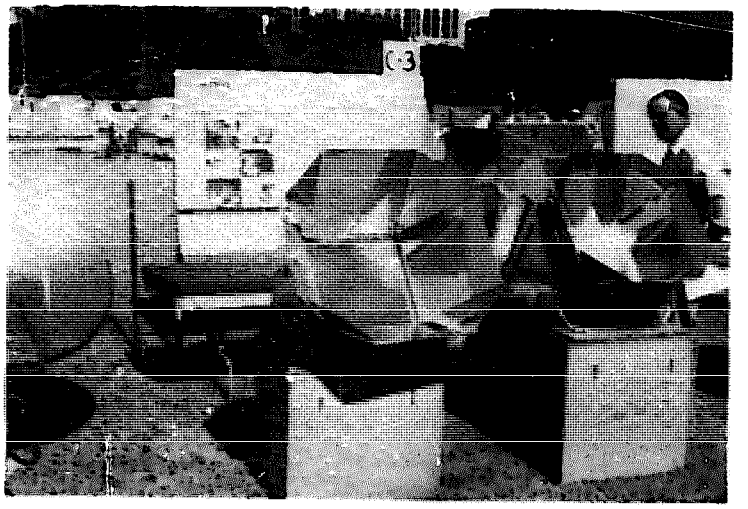

Figure 22

Figure 23

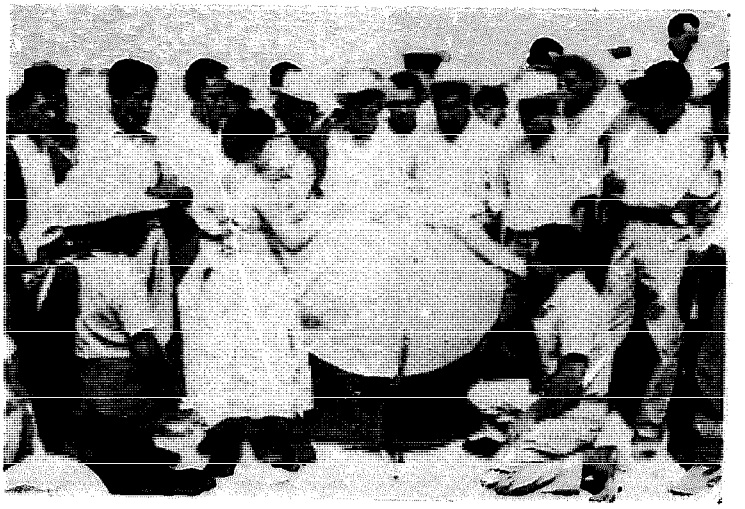

Figure 24

Fig. 22. Solar Oven (United States Design)

Fig. 23. Reflecting Solar Cooker (USSR Design, 1975)

Fig. 24. Solar Cooker, Concentrating Type (United States, 1960)

Figure 25

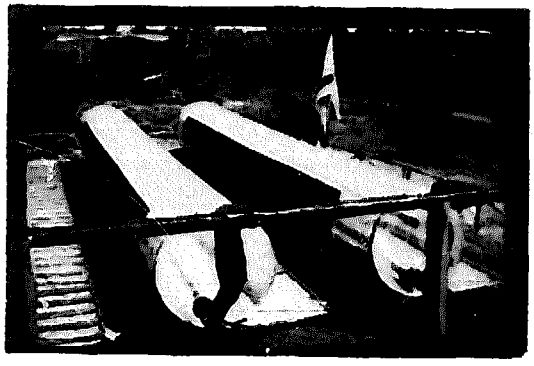

Figure 26

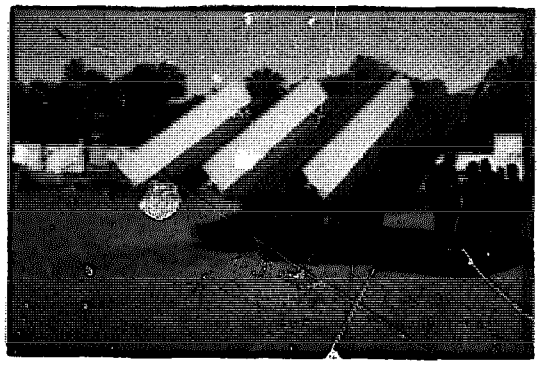

Figure 27

Fig. 25. Solar Power Plant (Egypt, 1913)
Fig. 26. Cylindrical Plastic Film Solar Concentrators for Small Electric Power Generator (Israel, 1960)
Fig. 27. Solar Power Generator--Augmented Flat Plate (Italy, 1955)

near Tashkent. Several small aluminum reflectors focus the sun on the cooking vessel.

Figure 24 shows an effective cooker developed by the University of Wisconsin. The metallized plastic reflector focuses about a kilowatt onto the bottom of the cooking vessel. The photograph shows a group of people, mainly farmers in rural Mexico, watching a cooking demonstration. Nearly two hundred cookers were distributed and evaluated in several Mexican communities, with remarkably consistent results. The cooker was a technical success and a social failure. The idea failed because people didn't like to cook in this unfamiliar way. Even though in some areas people did not have enough food, they preferred to buy kerosene for cooking what little food they had. Social customs and many other factors clearly must be reckoned with. I don't think solar cooking is going to be used anywhere except as a novelty in the United States.

Turning now to the other large potential application of solar energy, we see in Figure 25 the first large solar power plant built in Egypt in 1913. Long metal troughs focused the sun on axial tubes in which steam was generated for use in a pumping engine. This 50 horsepower plant operated a year or two, but when maintenance became expensive, the project was abandoned.

Figure 26 is a photograph of the solar collectors experimentally used in 1960 for the supply of heated fluid to a three kilowatt electric turbo-generator designed in Israel. Cylinders of plastic film, inflated by a bit of air pressure, are about 30 feet long and five or six feet in diameter. They focus solar radiation onto a metal tube in which fluid is heated for delivery to a heat storage vessel and a small engine.

About 20 years ago, the solar pump shown in Figure 27 was displayed at an exhibit in Arizona by an Italian company. Sulfur dioxide was vaporized in the 400 square foot flat-plate collector and supplied to a reciprocating engine which drove a one-horsepower water pump. Although hoped to be a commercial product, high cost forced cancellation of manufacturing plans.

Although numerous solar power generators have delivered energy, the cost of the electricity produced has been very high and certainly not competitive with other sources, if other sources are available. But if power must be supplied in areas where no other source exists, solar might be a practical source. Most of the solar electric research effort in the Soviet Union has been oriented to this objective. If electricity is needed hundreds of miles from the nearest power line, much higher costs of site-generated power can be tolerated. Figure 28 shows one of several types of solar concentrators focusing the sun onto small receivers in which

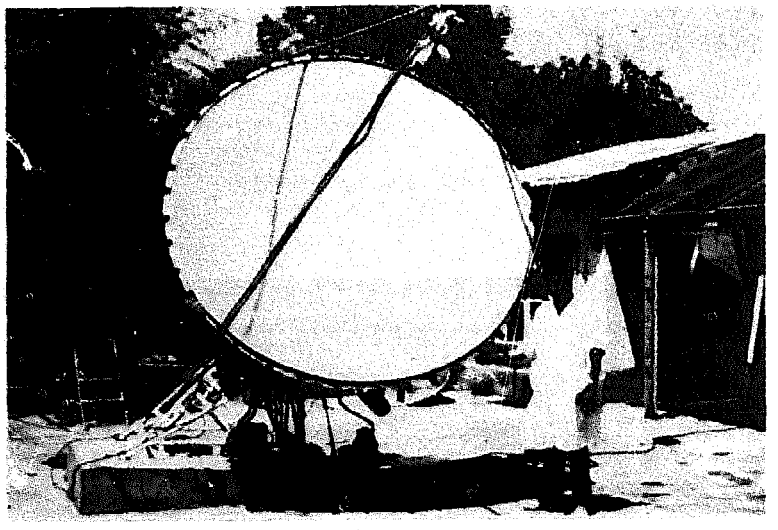

Figure 28

Figure 29

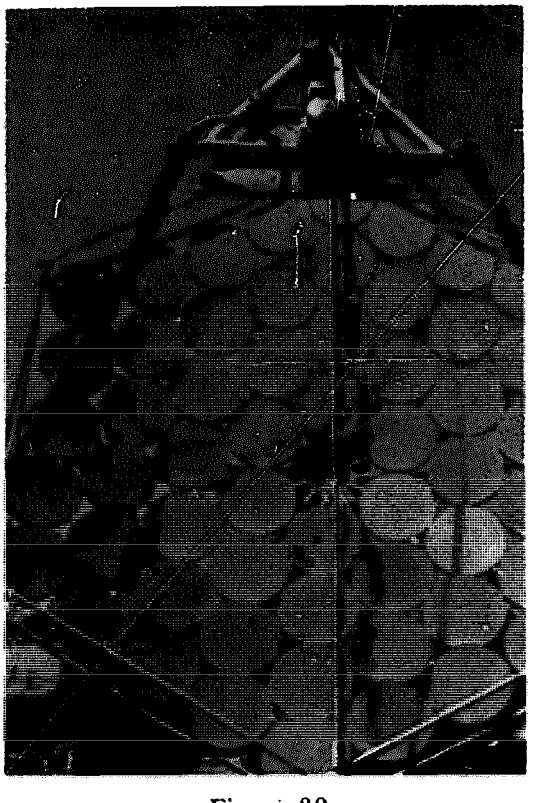

Figure 30

Fig. 28. Solar Power Generator--Stretched Plastic Film Concentrator (USSR, 1960)

Fig. 29. Solar Power Generators--Faceted Glass Mirror Concentrators (USSR, 1975)

Fig. 30. Solar Power Generator--Faceted Round Glass Mirror Concentrator (USSR, 1975)

steam or some other fluid is produced. The steam is then supplied to a small engine for electric generation. A thin metallized plastic film is stretched across a dish, on the back side of which slight suction is applied by means of a small pump. The suction pulls the plastic film into a curved contour which focuses the sun on a small boiler. About one horsepower would be developed by this unit.

Figure 29 shows another concentrator, in Tashkent, consisting of an array of glass mirrors that focus the radiation on a boiler which supplies steam to an engine driving a three to five kilowatt generator. Figure 30 shows a variation on this design. Although the USSR is an industrialized country, there are large regions that have the characteristics of undeveloped countries. The prospects for solar power supply in such circumstances need to be thoroughly evaluated.

In summary, it is important to note that, compared to conventional energy technologies in the industrialized countries, solar energy is expensive. However, the higher energy costs in many parts of the developing world make some of the solar technologies currently economically attractive in LDCs. Second, the history of attempts to introduce solar cooking amply demonstrates that efforts to introduce such technologies must take into account not only the economics of a given situation, but also local customs.

3

Photovoltaic Technology

Morton B. Prince

INTRODUCTION

The U.S. National Photovoltaic Program, which is the responsibility of the Division of Solar Energy of the Energy Research and Development Administration (ERDA), will be described with its goals, objectives, strategy, and plans. Since photovoltaics today is relatively expensive compared to other sources of energy, its terrestrial uses are limited today. Some of these applications will be reviewed and shown to be applicable to the developing world. As the cost of photovoltaics is reduced significantly, more and more applications will become cost effective, especially in rural areas in the developing world.

Photovoltaics is the direct conversion of sunlight into electrical energy with no intermediary processes.

Photovoltaic systems offer the potential of clean, highly reliable power. They are capable of operating efficiently in a variety of applications ranging from small, low power devices such as remote instruments, to dispersed systems (residences, shopping centers, schools, industry), to large central power stations for intermediate and peak load operations.

Present sales consist primarily of moderate efficiency, highly reliable silicon-based solar cell arrays, at a median cost of $25,000 per peak kilowatt (kW). Due to the high cost, annual production of solar cell arrays has been limited to several hundred kilowatts.

The cost of photovoltaic systems will be reduced by automation or the use of thin film or novel devices in arrays. However, none of the cost-reduction approaches is sufficiently developed for commercial use, and the market for photovoltaic systems is not sufficiently large to justify additional investment by private industry.

Market information indicates that photovoltaic power can be rapidly expanded both in volume and type of application as the cost of solar cell arrays is reduced. It is expected that photovoltaic arrays can find broad commercial applications if the associated array costs were reduced to the order of $100-$300 per peak kilowatt.

The U.S. Photovoltaic Program is designed to overcome the critical problem of high initial cost resulting in low array production. This will allow for significant growth in the use and application of Solar Photovoltaic Conversion Systems (SPCS).

PROGRAM GOALS AND OBJECTIVES

The overall goal of the photovoltaic program is to develop reliable, low-cost photovoltaic systems and to stimulate the creation of a viable industrial and commercial capability to produce and distribute these systems for widespread use in residential, industrial, and commercial and governmental applications. More specifically, a major goal of the SPCS program is the development and demonstration of photovoltaic systems providing electric energy at costs of 40-60 mills/KWH as compared to present conventional systems costs of 10-30 mills/KWH for intermediate and peak load operations.

In pursuit of these goals, three primary objectives should be accomplished by 1986:

- The reduction of solar array costs to $500 per peak kilowatt with an annual production of 500 megawatts (MW) per year.
- The combined costs of collectors and cells for systems using concentration to be $250 per peak kilowatt.
- The demonstration of thin-film array technology feasibility leading to array costs of $100-$300 per peak kilowatt.

Specific non-technical objectives have also been identified, including studies on:

- Environmental, institutional and legal issues such as the ownership of on-site systems, systems financing, availability of investment capital, sun rights, local building and safety codes, land use restrictions and interfaces with local utility networks.
- Development of performance standards for photovoltaic systems and components that can be used as a basis for warranties, insurance, and consumer protection legislation.

It is anticipated that achievement of the primary objectives will make photovoltaic systems economically competitive (for selective applications) with alternative energy sources for on-site residential and industrial applications, as well as for central power generation.

STRATEGY

As indicated, the cost of photovoltaic arrays must be reduced if the market for these systems is to be expanded. Four concurrent sets of activities have been defined to assist in achieving the programs goals and objectives. These activities relate to the use of existing technology to expand the market, development of large sheet silicon technology, thin-film and new material development, and development of concentrators and high intensity cells.

1. Market Expansion of Existing Technology - Market stimulation through government purchase of a significant fraction of early annual cell production is planned. Solar cell manufacturers will thus have an incentive to use more automated, lower cost production techniques.

Government involvement will provide the industry with a large initial market and the public with a basis for technology comparison. The solar cells purchased will be carefully tested, evaluated, and used in various government and non-government applications. It is expected that ERDA purchases of approximately 600 kW through 1978, coupled with purchases by other Federal agencies, should result in a factor of 4 reduction in the present cost of silicon-based solar cells to approximately $5000 per peak kilowatt by 1979. A total government purchase of approximately 11 MW through 1983 is planned. Costs for silicon solar arrays are expected to drop to $1000 per peak kW by 1984.

2. Develop Large Area Silicon Sheet Technology - Most currently marketed photovoltaic systems use silicon-based solar cells which are hand-processed and individually mounted on a supporting structure. Though the technology and operation of silicon solar arrays are well established, present costs limit their application.

One approach to cost reduction is the development of high capacity, low unit cost production techniques for silicon cells. The acceleration of this activity, involving silicon sheet technology, will provide for: (a) an early reduction in production costs of solar cell grade silicon from $65 per kilogram (KG) to $10 per KG; (b) increased efficiency of the solar cell production fabrication (over 75 percent of the silicon material is now wasted); (c) improvement in the ratio of cell to array area (packing factor); (d) development of suitable encapsulation materials to increase array lifetime; and (e) automated production of

silicon solar cell arrays.

Production processes, techniques, equipment and experimental process production plants will be developed to support the commercial adoption of silicon sheet technology. It is expected that this process will reduce the silicon-based solar cell array costs to $500 or less per peak kilowatt.

3. Conduct Thin Film and Novel Materials Research - Use of thin film deposition techniques utilizing silicon, cadmium sulphide, gallium arsenide and other materials may allow the production of solar arrays costing $100-$300 per peak kilowatt. However, the physics, engineering and manufacturing of high efficiency, reliable, low-cost thin film arrays is poorly understood at present. In particular, present thin film arrays have efficiencies of only 3 to 7 percent.

Studies are underway to develop a better understanding of basic processes, fabrication techniques and costs. The objectives of this research are to develop and demonstrate thin-film, 10 percent efficient solar cell arrays by 1980, and to demonstrate the feasibility of $100-$300 per peak kilowatt arrays by 1986.

4. Develop Concentrators and High Intensity Solar Cells - For a given power output, photovoltaic system costs may be reduced by employing solar concentrators to increase the solar energy received by each cell. This reduces the number of relatively high-priced cells required. The use of concentrators, combined with cells from low-cost silicon arrays costing $500 per peak kW, should lead to combined collector/cell costs of $250 per peak kilowatt by 1986. Systems using such arrays may be competitive with conventional power for residential and central station applications. Analyses of concentrators, cells, cooling requirements, and uses of available thermal energy are now being conducted.

ADDITIONAL STRATEGY ACTIVITIES

The program strategy also includes studies to determine the necessary costs for photovoltaic systems for on-site and central station applications. The effects of institutional, legal, and socio-economic factors on the introduction of photovoltaic systems will be analyzed. Parallel design studies of residential, commercial, and central station applications of photovoltaic power will be carried on to define system, subsystem, and component specifications including cost, reliability, performance, and efficiency. Definition planning activities through the 1980's will support and receive input from test activities and the research and development program. These studies will be instrumental in guiding the direction of the photovoltaic

program and will aid in evaluating results from tests, experiments, and early applications of photovoltaic systems.

Marketing studies now in progress will estimate the size and characteristics of the market for early applications of photovoltaic power in both the government and commercial sectors. An initial estimate for near-term (1975-1985) applications indicates that wide-spread application of photovoltaic power could include such items as impressed current corrosion protection of gas well casings and gas and oil pipelines, as well as providing power for railroad crossing signs, navigational buoys, and highway signs. Applications such as water sampling systems, food and medicine refrigeration, and security surveillance systems are under consideration for implementation on a cost-sharing basis.

New and more detailed market and mission studies are being initiated to: (a) define the domestic and foreign market for photovoltaic systems as a function of system cost, performance requirements and uses; (b) define the technical, financial, institutional, legal and local factors affecting photovoltaic system acceptance; (c) analyze certain potentially attractive applications to define modifications in existing design approaches; (d) develop and maintain a plan that defines the necessary activities, responsibilities, and actions for the successful commercialization of potentially attractive applications; (e) evaluate the effects of the introduction of photovoltaic systems on the size and characteristics of the photovoltaic market; and (f) assure effective implementation of commercialization activities.

These marketing studies will develop a description of the application and market potential of photovoltaic systems. Necessary technical developments, required changes in institutional, legal or local conditions, and required experimental pilot and demonstration facilities and activities will be delineated.

PROGRAM PLAN

The Photovoltaic Conversion Program is designed to expand the commercial use of photovoltaic systems as rapidly as possible through research, process development, testing, and application. The cost and risk of photovoltaic systems, both to potential purchasers and the Federal government, will be limited as a result of this program. By encouraging government purchase of a significant fraction of the early annual solar cell production, ERDA will provide industry with the incentive to adopt low cost production techniques. Industry will be able to produce solar cells at decreasing cost per peak kilowatt.

The development of automated processes and experimental production facilities will aid industry in reducing solar array production costs. To take advantage of the understanding of silicon cell technology developed over the past 20 years, emphasis will be on the development of processes that can provide low cost silicon solar arrays. In addition, reduction of solar array costs through the use of thin film deposition techniques and novel materials and devices, and development of concentrating systems will be pursued.

Early residential, commercial, and other applications of photovoltaic systems will be implemented to develop information on operational costs, reliability, and performance, and to acquaint potential customers with the characteristics and feasibility of such systems.

APPLICATIONS SUITABLE FOR RURAL AREAS OF DEVELOPING COUNTRIES

ERDA has been pursuing early low power applications for photovoltaics that could be useful for rural areas in developing countries. This work has been done primarily through the NASA/Lewis Research Center (LeRC). In addition ERDA has been interacting with the World Bank and the Agency for International Development (Department of State). These latter organizations have been involved in searching for low cost, reliable power supplies to help upgrade the quality of life in developing countries. The LeRC has been cooperating with these organizations and with the U.S. Department of Interior, Bureau of Indian Affairs on similar activities for our own Indian reservations. The results of testing on the Indian reservations will be applicable to many other parts of the rural world.

One of the earliest experiments carried out by the LeRC was in India with the Satellite Instructional TV Experiment (S.I.T.E.). Panels of photovoltaic cells were used to charge batteries for powering village television sets for receiving instructional material from a stationery satellite. The experiment was concluded last year when the satellite was moved and the test was considered successful.

Another useful application for rural villages is the solar powered refrigerator. Two installations have been made in the United States as part of the ERDA program. These are small (4 ft^3) camper size refrigerators used to hold medicines such as vaccines and other perishable items. One installation was on a remote island in the Isle Royale National Park in upper Michigan for supplying a construction crew. The second is operating in a rural health dispensary on an Indian reservation at Sil Nakya in the south part of Arizona. Each is powered by a 200 watt photovoltaic panel.

Under consideration for development are shallow well water pumps powered by photovoltaics to supply water for

human and animal consumption. Also under consideration is a photovoltaic powered cereal grinder. These latter two applications would relieve the rural villagers of the tedious work of drawing water and grinding meal and allow their time to be spent on more productive activities which in turn could help improve their quality of life.

Several developing countries have indicated that they would like to encourage tourism to remote village areas but that tourists are reluctant to stay at such areas without a modicum of their normal comforts. By powering small appliances with photovoltaics it is expected that tourism could be increased with the villagers benefiting from the resulting commerce.

All of the above applications require daily energy in the 100 watt-hour to 10 kilowatt-hour energy range. Photovoltaic power systems capable of delivering such energy requirements are available. However the cost of such systems leads to problems in most capital scarce developing countries since these photovoltaic systems are associated with up-front costs. Even though the operating costs of such systems are minimal due to lack of fuel needs, the initial investment requirements does pose a serious problem.

With the cost reduction program under way at ERDA, this problem will be reduced significantly during the next ten years.

4

Alternative Energy Technologies in Brazil

José M. Miccolis

Introduction

It is imperative that Brazil consider alternative energy production and conservation techniques in order to cope with one of the most demanding crises of its modern history: the so-called "energy crisis." To mention just one of the most serious consequences of the current situation, Brazil imports about 650,000 barrels of petroleum per day, which accounts for more than 78 percent of total consumption, at an annual cost of more than 3 billion dollars. Oil amounts to 50 percent of the total energy utilized in Brazil. Over the past few years several steps have been taken in the direction of reducing Brazilian dependence on external sources of energy. Alternative energy production technologies have been examined. Some of them are very promising medium-term solutions, and are mostly in the research and development stage. Others offer attractive short-term possibilities and are currently in the initial stages of implementation.

Energy conservation measures that have been undertaken in the past three years have not been very successful. Despite sharp rises in fuel prices, internal consumption is rising consistently at a rapid rate. More recently, however, the Brazilian government has enacted much tougher conservation measures that are expected to change substantially the energy consumption pattern in the country.

This paper is an attempt to report the major alternative energy activities underway in Brazil. Due to the range of possibilities which could be considered, and the limited amount of time and space available, relevant technical details will not be included; such details are, however, available upon request.

The Brazilian Energy Picture

Natural Resources

Brazil's waterpower resources are among the greatest in the world, with an estimated potential output equivalent to that of 4.5 million barrels of oil per day. While the installed capacity of generating plants increased from about 7 million kilowatts in 1964 to 22 million kilowatts in 1977, the vast majority of Brazil's estimated 120 million kilowatts is still untapped. The potential sites are distributed all over the country. The Northern region, where the Amazon basin is located, accounts for about 40 percent of that total; the densely populated and impoverished Northeast has 11.3 percent; the South and Southeast, the most prosperous and industrialized regions in the country, have 48 percent, of which most of the economically feasible sites will be totally tapped by the year 1985. The Amazon tributaries located on the north border of the river would alone be able to meet Brazil's requirements over the next several decades. However, transporting this energy to the main energy-consuming centers about 2000 miles away poses several technological problems which are yet to be resolved.

While water power resources are abundant, petroleum and natural gas reserves are relatively small. Total proven petroleum reserves are estimated at 780 million barrels, with additional investigations now taking place on the continental shelf. Usable natural gas reserves are calculated at 15 billion cubic meters (530 billion cubic feet).

Suitable coal reserves, mostly in Southern Brazil, are estimated at 2.2 billion tons, and total reserves at about 4 billion tons. The additional reserves consist mainly of high ash, high sulfur coal which yields a low-grade fuel.

It has been determined that shale deposits extend from Southern Brazil right up to the Amazon basin. Estimates indicate that shale reserves could be the source of 3.1 billion barrels of shale oil.

Uranium reserves are estimated at between 7500 tons and 12,000 tons. Newly discovered radioactive anomalies in Northern Brazil show definite signs of potentially large uranium deposits. Thorium, an alternative material to be used as fuel for gas-cooled high-temperature nuclear reactors, can also be found in large monazite sand deposits, as well as in niobium deposits that are estimated to be from several hundred thousand to about one million tons.

Energy Supply and Demand

Table 1, below, shows Brazil's changing reliance on various energy sources from 1952 to 1972.

Table 1. Energy sources in Brazil (1).

Energy sources	1952	1972
Coal	6.1%	3.6%
Petroleum	28.0%	44.8%
Gas	0%	0.3%
Hydroelectric Power	11.2%	20.8%
Other Fuels	54.7%	30.5%
Firewood	(49.9%)	(27.0%)
Sugar Cane Bagasse	(2.1%)	(2.0%)
Charcoal	(2.7%)	(1.5%)
TOTAL	100.0%	100.0%

Overall, energy consumption has tripled in absolute value in this 20-year period. Petroleum consumption increased from 128.9 million barrels in 1964, to 302.4 million barrels in 1974, of which 78 percent was imported. The petroleum industry is under fairly extensive government control through Petrobras, the government-owned oil company which has almost full responsibility for exploration, production, and refining of petroleum in Brazil. Private enterprise accounts for 12 percent of the country's refinery output. The Brazilian government has recently signed "risk contracts" -- in which the government shares in any profits, but does not incur losses -- with foreign oil companies for drilling on the Brazilian continental shelf.

Electricity consumption in Brazil has grown in the period from 1968 to 1975 at an average annual rate of 11.8 percent. The electricity generating capacity, over the same period, has increased at an average annual rate of 12 percent. In 1975, the overall installed generating capacity was almost 20,000 megawatts, of which 82.7 percent was hydroelectric and the remainder thermoelectric. Also in 1975, total electricity consumption was about 68 million megawatt-hours. Thus, for a population of little more than 100 million people the per capita consumption was about 650 kilowatt-hours, or 14 times smaller than that of the U.S. Overall energy consumption has been growing at a rate of 6.5 percent, well above the rates for the U.S. and Europe. Table 2 shows on a percentage basis the Brazilian energy market in 1970.

Table 2. Brazilian energy market in 1970 (2).

Uses	% of Total		Uses	% of Total	
Agriculture		5.79	Transportation		22.03
Fishing		0.19	Highway	18.25	
Mining		0.30	Railway	1.08	
Industrial		34.35	Oceans and Rivers	1.57	
Steel	7.70		Air	0.98	
Metallurgy	1.82		Others	0.17	
Minerals	5.43		Construction		0.67
Mechanical	1.48		Commerce		2.32
Chemical	3.02		Services		0.65
Textile	1.82		Government Services		2.48
Paper & Pulp	2.33		Domestic		31.22
Food	8.98		Urban	12.50	
Others	1.75		Rural	18.71	

In 1975 Brazil agreed with West Germany to purchase a complete nuclear fuel cycle. The terms of the purchase include a joint effort to mine Brazil's uranium and thorium resources, and to design, build, and test eight nuclear power plants totalling 10,200 megawatts. It also includes transferring the technology for the construction of both uranium enrichment and fuel reprocessing plants in Brazil. The reactors will be light water reactors, using enriched uranium as the fuel. The Brazilian Atomic Energy Authority has set a target of 70,000 nuclear megawatts to be installed by the turn of the century.

Alternative Energy Production Technologies

Solar Energy

Brazil occupies a vast region in which solar energy is conveniently available. The country encompasses an area of more than 8.5 million square kilometers, almost entirely located between the Equator and the Tropic of Capricorn. Solar energy is now considered capable of playing an important supporting role on a medium- and long-term basis in the country's energy matrix, since the economic comparisons that always made it unwise to convert solar energy into other forms of energy are no longer valid. Although several scattered efforts to develop solar energy applications in Brazil occurred before 1973, by the end of that year the first comprehensive government attention was devoted to solar energy with the creation of a task force, within the government's planning structure, to examine all possible

alternative energy technologies that could be applicable to the Brazilian situation. Solar energy was chosen as one of the potentially successful candidates. A national solar energy research and development plan was prepared by the task force, and following approval by the proper authorities resources were allocated and the plan's implementation started by the end of 1974.

The underlying philosophy of the R&D plan for solar energy in Brazil took into account several different factors: socio-economic and natural resources particular to the country, which differ from region to region; the immediately available and easily improvable capability of local research institutions; and what appeared to be the state-of-the-art of solar energy conversion techniques at that time.

The plan's budget for the period 1974-75 was 2.5 million dollars, in 1974 prices, and focused mainly on solar energy conversion processes that could be classified as "low-technology" applications. Some basic research was also funded. The main projects within the plan are listed below. A list of participating research institutions is available upon request. The first Brazilian national solar energy research and development plan consists of the following projects:

Collectors. Design, construction of prototypes, testing and evaluation of flat plate collectors. Determination of best geometry, materials, configuration, and costs.

Dryers. Design construction, and testing of small-scale tropical fruit dryers. Identification of fruits more suitable to the process. Establishment of quality control standards for the end products. Development of prototypes of industrial scale agricultural product solar dryers (e.g., cocoa, coffee, manioc, wood, beans, and grain) equipped with air preheaters and functioning by natural or forced convection. Studies of mass and heat transfer processes involved in solar drying.

Distillation. Development of a small-scale still for brackish underground water. Testing of different systems and construction of modular prototypes. Feasibility studies for the construction of a middle-sized solar still to serve small communities. Cost-comparison studies of solar distillation versus rain collection and water purification methods.

Refrigeration. Construction of an absorption cycle solar icemaker, for application in food preserving. Technical and economic evaluation. Construction of a demonstration scale solar-cooled food storage facility for semi-perishable agricultural products such as potatoes, onions, garlic and other vegetables.

Bioconversion. Experimental tests and feasibility studies of different processes for high water content bio-mass fermentation. Anaerobic fermentation of solid organic wastes. Feasibility studies of the pyrolysis of organic matter.

Solar architecture. Design, construction and testing of low-income housing units, exploring locally available materials and architectural concepts suitable to prevailing climate conditions. Incorporation into the architectural design of solar energy devices like water heaters, organic waste recyclers, and solar stills.

Thermal engines. Development of a low-power organic fluid Rankine cycle solar engine for water pumping. Testing of commercially available systems.

Photovoltaics. Basic research on phenomena of the interactions of photons with matter. Investigation of photocells with polycrystalline structures.

Energy storage. Study of low temperature energy storage systems. Research on heat transfer processes for water, air, rocks, plastics, metals, and eutectic salts.

Solarimetry. Rehabilitation of existing solar energy data. Mapping of monthly total solar radiation for the whole territory of Brazil, by means of both direct and indirect data. Establishment of a new solar radiation measurement network of ground stations.

Ocean Thermal Gradients. Harvesting the solar energy collected and stored in tropical waters (Ocean Thermal Energy Conversion: OTEC) has received considerable attention in the U.S. in the past few years. A heat engine can operate by means of using warm surface water as a heat source, and the much colder deep ocean water as a heat sink. The idea is not technically new and it seems feasible with current technology. Some regions along the Brazilian coast present optimum natural conditions for the development of this process. In the Cabo Frio region of the Brazilian coast, east of Rio de Janeiro along the Tropic of Capricorn, the deep sea water, cold and nutrient-rich, comes to

the surface. An attempt will be made to generate power using this water, related to an aquaculture research project which is also using this water for ice making, and as a basic feed for its marine cultures.

Wind Power. Although windmills have been traditionally used in some regions of Brazil, regional wind patterns are not well known. A small-scale research project aimed at developing a vertical axis (Savonius) wind conversion system is underway.

Solar Energy Perspectives. If solar energy is going to play any role in the Brazilian energy picture, then the Northeast would have to be considered as the most suitable region for successful solar energy applications. Occupying a considerable portion of the Brazilian territory, the Northeast includes all of the country's semi-arid region, where droughts are common, heavy rains occur within a very short period of time, and the average daily temperatures are very high. Furthermore, even measured by Brazilian standards, the Northeast is an underdeveloped region. The average annual per capita income is well below the national level, birth and mortality rates are rather high, the economy is basically rural and based upon an outdated ownership and land use model. The national solar energy research and development plan took into consideration all these factors. That is why several projects were recommended and funded: solar stills for areas where an adequate source of fresh water is not available, and where it is not relevant to make economic comparisons with technologies that cannot even be applied; crop dryers designed so that a variety of crops, maturing at different times, can be dried in sequence by use of the same equipment; solar refrigeration intended primarily for food preservation and for the storage of seasonal and perishable crops; water pumping with small solar engines for irrigation purposes; and others.

The program has thus far failed to accomplish the development of most of the prototypes intended for an eventual industrial production and commercialization in Brazil. This failure cannot be attributed merely to the fact that only two years have passed since the initial projects were funded and that, naturally, some projects have been more successful than others. It was also in part due to a lack of coordination among several government agencies which could have taken a much more active role in the process. For example, the federal housing agency in charge of financing thousands of low-income units throughout Brazil could have made economically feasible the

large-scale production of solar water heaters to replace the widely used, inefficient, and electricity-hungry electric resistance water heaters. Simply by changing current building regulations and by incorporating into construction costs and financing the added costs for the solar heater, an insured market would have existed, thus creating an incentive for industrial production of solar heaters. The government could also have provided incentives for the replacement of conventional fuels with solar energy to provide the low-temperature process heat used in several industries.

Bioconversion is another very promising solar energy conversion technology. Due to recent developments in Brazil and to the considerable attention that it has recently received, bioconversion possibilities in Brazil will be discussed as a separate topic in this paper.

Bioconversion

Green plants are known to be able to capture the sunshine and convert it into stored chemical energy, usually but not necessarily in the form of carbohydrates. Currently, with the stored production of ancient photosynthesis -- fossil fuels -- running out, it appears that harnessing the renewable energy stored in green plants is not only highly desirable but increasingly feasible. The stored chemical energy can be recovered by different processes, at the end of which solid, liquid, and gaseous fuels, as well as chemical feedstocks and other products, can be obtained.

Brazil is in a very privileged position to make use of this natural energy collection process, not only because Brazil occupies a huge area where the incident average solar energy is abundant, but also due to particular local conditions such as a satisfactory combination of appropriate soils, water resources and rainfall needed for growing green plants. Furthermore, the labor-intensive characteristics of the related agricultural processes, coupled with the availability of relatively inexpensive and arable land, could very well match the socio-economic requirements of a developing nation like Brazil. It should also be noted that due to the extensive forest resources that are available in Brazil, it is quite probable that a number of other possibilities might exist in addition to the ones that are mentioned here. However, the possibilities described below do represent current knowledge and give a fairly accurate view of projects under consideration or presently being carried out.

Fuels and Chemical Feedstocks from Sugar Cane. Since early in the sixteenth century, sugar cane has been one of the major Brazilian agricultural products. In 1972 Brazil became the world's largest producer of cane sugar (6 million tons per year), with about one-third of domestic production going for export. High prices in world markets during 1973-1974 stimulated further increases in production to a level of 7.2 million tons per year.

--Ethyl Alcohol--Among the many by-products of the sugar cane industry, ethyl alcohol or ethanol has been traditionally obtained in Brazil by fermentation of surplus molasses from sugar manufacture and used as an adjunct in gasoline. The percentages of alcohol in gasoline have varied over the years (2 to 15 percent alcohol content); ethanol has served as a regulatory device to maintain a reasonable and profitable level of sugar cane production in the country. Whenever there was a surplus of sugar, the production of alcohol was increased and greater amounts added to gasoline.

Over the past several years ethyl alcohol production in Brazil has oscillated between 570 and 700 million liters per year (150 to 185 million gallons), of which about half was anhydrous (for mixing with gasoline).

Measures recently taken by the federal government have insured the sugar cane growers that whenever it is possible to obtain ethanol or sugar from a sugar cane crop, both commodities would be worth the same; that is, the price is set so that the 90 kilograms of sugar or the 30 liters of ethanol obtainable from 1 ton of sugar cane yield the same monetary return.

Those measures are clearly designed to stimulate ethanol production in the country, and are tied to an ambitious plan to have 75 percent of the total liquid fuels consumed in Brazil replaced by ethyl alcohol. According to one scenario being considered, domestic petroleum production will increase from the 1975 level of 200,000 barrels per day to 500,000 bpd in 1980, and to 1 million bpd in 1990, remaining at that level to the year 2000. In the first phase (to 1980) ethyl alcohol would be blended with gasoline at a 1:10 ratio, which does not require any major adjustments to automobile engines. In the following decade, engines would be gradually adapted to use pure alcohol so that by 1990, 50 percent of all liquid fuels could be replaced by ethanol. By the year 2000, ethyl alcohol would account for 75 percent of the country's consumption of liquid fuels (3).

In order to achieve the goals set forth by the plan, about 400 new distillaries would have to be operational by 1980, 1,150 by 1990, and 3,500 by 2000 (4). This assumes distillaries of an average capacity (12,500 liters/day) and harvesting periods of 160 days. It should be noted, however, that of the approximately 200 sugar mills that are responsible for the current sugar production in Brazil, more than 50 percent are operating at only marginal profits.

Ethyl alcohol has further useful properties. Blended with gasoline, it increases the octane rating of the fuel, thus reducing the need for cyclic hydrocarbons. Also, as an anti-knock additive, ethanol makes the use of lead unnecessary. As a pure fuel, ethanol does have a lower energy content per unit weight than does gasoline; however, the energy content per unit weight is not the determining factor for the power generated by an internal combustion engine. Factors like the heat of combustion, thermal efficiency, etc., are important. When these factors are taken into account for gasoline and for pure ethanol, it is clear that ethanol generates about 18 percent more power. That is one of the reasons, by the way, that several racing engines use ethanol as a fuel. Ethanol consumption, though, is about 50 percent higher than gasoline consumption in a conventional, unadjusted automobile engine. However, for higher compression rates, about 10:1, and with some pre-heating of the air-ethanol mixture in the carburator, ethanol consumption has been experimentally demonstrated to be about 15 to 20 percent higher than that of gasoline (5). It should also be noted that an ethanol-fueled engine drastically reduces the emission of pollutants such as nitrogen oxides, carbon monoxide, and cyclic hydrocarbons.

Brazil is considering not only sugar cane as the source for ethanol. Cassava, or manioc, a root crop that grows everywhere in the country, has been the focus of considerable government attention, and will be discussed later.

Just recently the Brazilian government approved about US$500 million for implementation in 1977 of a National Alcohol Program that includes both sugar cane and manioc as raw materials for ethanol production.

--Other Fuels--Besides ethanol, a number of other fuels could be obtained from the sugar cane biomass. By means of thermal conversion processes, the fiber could either be used as a boiler feed (combustion), which is currently done in Brazil and which makes the sugar cane industry practically self-sufficient in energy, or converted to synthesis gas by means of processes such as Bailie, Kellog, Koppers-Totzek,

Syngas, Purox, etc. Synthesis gas is a mixture of carbon monoxide and nitrogen with smaller proportions of water, carbon dioxide, ethane, and propane. It can be directly used as a low BTU gas, or processed into a pipeline gas (methanation), and/or methanol and a motor fuel by processes such as Fischer-Tropsch, Mobil. Also, by microbiological conversion techniques, similar to those used for the fermentation of molasses or cane juice into ethanol, substitute natural gas (SNG) could be obtained by fermenting the bagasse (6).

--Chemical Feedstocks--A number of chemical feedstocks are obtainable from sugar crop biomass. Through fermentation the sugar cane juice, or the surplus molasses, can be transformed into acetone, isopropanol, butanol, butadiene, ethylene, acetaldehyde, acetic acid, xanthane, and several other polymers (7). Some of those products would require an initial fermentation and additional chemical synthesis steps, for which the technology is already available. Furthermore, recent advances in the field of microbial biosynthesis that make possible the production of a specific organic chemical by microbial fermentation could indeed shorten the additional chemical synthesis steps that are currently necessary, dramatically changing the economics for the production of those products.

--Other Products by Fermentation--Sucrose is an excellent raw material for fermentation. Together with starch and starch-derived sugars it served well as a feedstock for the microbial production of several chemicals. During the post-World War II petroleum-glut period, many of these fermentation processes were discontinued in lieu of lower-cost petroleum-based chemical syntheses. However, some products, such as citric acid, penicillin and other antibiotics not readily derived from petroleum, continued to use fermentation as their commercial source. Since raw materials account for at least 60 percent of the total cost of the average fermentation end product, the low cost of petroleum led to the demise in 1945-1973 of many fermentation processes.

It must also be mentioned that for the most part the current reconsideration of fermentation does not yet take into account the new capabilities of present-day microbiology. Rapid, automated, systematic, genetic strain improvement skills can now replace improvement efforts that were formerly the province of chance. Achievements in the antibiotic field stand as evidence of such claims.

While an in-depth study is needed to determine for local Brazilian conditions the best of the many specific product opportunities, numerous candidates may be suggested for consideration: amino acids, such as L-lysine, L-methionine, L-tryptophan; vitamins like vitamin C (ascorbic acid), vitamin B12 (cyanocobalamin), vitamin B2 (riboflavin); food chemicals such as acetic acid, citric acid, nucleotides, and microbial polysaccharides; antibiotics like penicillins G and V, tylosin, gentamicin, and the cephalosporins (8).

--Ethyl Alcohol from Manioc (Cassava)--Manioc is a large, somewhat bushy herb which grows everywhere in Brazil. The roots, which have the appearance of sweet potatoes, yield a starchy product. Although 2.1 million hectares were planted in 1973, no commercial-scale operations have been established. All the manioc is grown in small farming units, manually planted and harvested.

The starch content of manioc, about 25 percent, is far greater than the 13 percent sucrose content in sugar cane. The result is that a ton of manioc yields considerably more ethyl alcohol than does a ton of sugar cane. However, one hectare of sugar cane crop yields about 50 tons of cane, and one hectare of manioc yields only about 15 tons.

Manioc crops for energy purposes present problems related to mechanization, and to the fermentation process itself. Since starch cannot be directly fermented, it requires enzymatic action, and there is a lack of industrial experience with its processing. Furthermore, an overall energy balance would probably reflect the fact that the manioc industry cannot benefit from burning the residues of its industrial processing, as the sugar cane industry does by burning bagasse.

Anyway, manioc crops are very much within the government plans for ethyl alcohol production. A pioneer manioc distillary is being built, a fairly large manioc research program is under way, and official estimates assume an increasingly large contribution of manioc to alcohol production, even surpassing that of sugar cane in less than a decade.

--Socio-economic Considerations of Ethanol Production--Brazil has abundant land and can continue expanding its cultivated cropland at present rates for most of this century. Thus, a major agricultural issue consists of finding ways to make the land resource contribute more toward raising national and per capita incomes. Brazil is currently dependent on foreign petroleum, for which the country has to

pay about 10 million dollars per day, and it needs to change both the pattern of the farm labor force, which constitutes a disproportionately large component of the low-income group, and to modify somewhat land ownership distribution. Therefore, it is not only very welcome, but necessary, to expand acreage for energy crops, and thus cash crops.

Estimates indicate that more than 200,000 people are directly employed by the sugar cane industry in Brazil, including factory, sugar cane farm, cane and sugar transportation, and other service workers. Most of these people reside in the areas in which they work. Given the government goals for ethyl alcohol production, and the increasingly larger contribution of manioc, by 1980 about 700,000 new hectares will be planted, with the corresponding settlement of 65,000 farm worker families; by 1990 about 9 million new hectares will be added to production and 730,000 families will be settled; and by 2000 there will be 18 million new hectares and 1.4 million families (9).

Considering that the growth rate of another cash crop, soybeans, has been an amazing 34.8 percent per year over the period 1967-1972 (about 5 million hectares), the goals set forth by the plan do not seem unattainable. Much to the contrary, they represent a unique opportunity for tackling the problem of poverty in the agricultural sector, for embarking on a land redistribution program, and for implementing a large-scale credit program for the acquisition of agricultural machinery, fertilizers, and other modern agricultural inputs. Such development offers the possibility of solving most of the current problems caused by petroleum imports which are now facing the Brazilian economy.

The economics of ethanol production in Brazil are such that right now its market price is highly competitive with that of gasoline. However, there are many different and attractive technologies and products which are alternates to obtaining ethanol from sugar cane, and which should be considered together with ethanol production for the establishment of a more complete and efficient industrial complex. A comprehensive feasibility study is very much needed. Raw material considerations, disposition of by-products, marketing of all products, costs of different processes, availability of appropriate technologies and overall energy balances are but a few of the topics that should be investigated.

Additional Bio-Conversion Alternatives. --Charcoal-- Charcoal produced by carbonization of wood is widely used in Brazil as a raw material for the production of pig iron

and steel. Currently more than 2.5 million tons of pig iron and more than 1 million tons of steel are produced in this manner in the state of Minas Gerais alone.

Due to the limited availability of Brazilian coal and its characteristics (it is mainly high-ash, high sulfur content, low-grade coal), charcoal production will have to be increased by more than two-fold in the next five years. However, production methods still being used are quite outdated. By switching to the more modern technique of wood distillation, considerable amounts of various by-products could be obtained. For example, from the production of 1 million tons of pig iron using charcoal, it is technically feasible to recuperate 146,000 tons of fuel gas, 18,000 tons of acetic acid, 12,000 tons of methanol, and 70,000 tons of tar, which add up to an additional value of about 200,000 dollars (10).

A fairly comprehensive feasibility study encompassing different aspects of charcoal production has been conducted for the state of Minas Gerais. Commercial charcoal production utilizing more appropriate technology will follow. Furthermore, considering the very extensive forest areas that are currently being cleared for agricultural production (more than 2 million hectares in the northern state of Para alone), wood pyrolysis could be of significant value in the overall Brazilian energy matrix.

--Hydrocarbon Producing Plants--Hydrocarbon (rubber) producing plants that naturally grow in the Amazon basin are being considered as a potential source for the direct photosynthetic production of hydrocarbons. It has been suggested that proper manipulation of rubber tree (*Hevea*) production could control the molecular weight of its principal hydrocarbon product, polyisoprene, which has a chemical composition similar to that of petroleum, thus obtaining a renewable "fuel" tree (11). This is still only a research idea. However, other *Euphorbia* species (of which there are more than 3000 different species in Brazil), like the *Euphorbia Tirucalli*, are also potential candidates for this kind of chemical manipulation and are being investigated.

--Waste Recycling--Organic wastes might prove to be of considerable significance on the local level for supplying energy whenever large waste concentrations occur within a relatively small area. A project that includes the future construction of a pilot plant for pyrolyzing the municipal solid wastes of the city of Rio de Janeiro (5 million habitants) is currently in the stage of feasibility studies.

Pyrolysis consists of heating organic material at high temperatures for a prolonged period of time in the absence of oxygen. Different combinations of gas, oil, and residues can be obtained, depending on the organic waste composition, and on the temperature, pressure, and duration of the process.

The anaerobic fermentation of sewage is another way of disposing of organic wastes. The methane produced by bacteria (typically 60 percent methane and 40 percent carbon dioxide) can provide the energy needs of the sewage treatment plant itself, or be used as a pipeline gas. The residues, unfermented sludge, can be used as a fertilizer. The process is simple; presently it is being used in several locations in the world, and could contribute to the overall economic feasibility of treating sewage in Brazil. Small-scale sewage digestors are now being built for future larger scale developments.

--Water Hyacinth/Fresh Water Algae--Water hyacinth, or *Eichhornia Crassipes*, is widespread in tropical and subtropical regions. Submitted to anaerobic digestion it yields methane and carbon dioxide. Fresh water algae, like *Chlorella*, can grow in a sewage oxidation pond, and are readily subject to bacterial attack. Algae are also a good protein source, and can be grown very efficiently, with productivity greater than that of agriculture, although at somewhat higher costs. Experiments with water hyacinth and fresh water algae anaerobic digestion are being conducted in Brazil to determine both their possible use as a fuel and as a protein source, and the possibility of growing them in sewage oxidation ponds.

The Hydrogen Economy

Although not exactly an energy production technology, the "hydrogen economy" was chosen to be included with other production technologies since its appropriate uses can result in a very interesting, almost unique, possibility for Brazil. Due to the huge waterpower resources available in Brazil, and due to the large distances between the major electric energy consumer centers, hydrogen was initially regarded as a possible "energy vector" that could conveniently solve the energy transportation and storage problems associated with those conditions which are almost peculiar to Brazil.

However, studies conducted in 1974 by the above-mentioned task force on alternative energy technologies concluded that other useful hydrogen characteristics should

be regarded on a priority basis for a short-term R&D program, and that they would be more readily applicable to satisfying the national needs.

The National Hydrogen R&D Program was completed in the beginning of 1975. It incorporated two different but interrelated lines of projects: research projects, and technical-economic feasibility studies. The former was intended to foster research both in some frontier areas and in some established areas in which the development of Brazilian know-how was thought to be necessary. The latter was designed to answer questions concerning the applicability of already available technologies and processes to short-term industrial developments.

The Program was approved for its implementation in a two-year period. A list of projects follows. A list of participating research institutions is available upon request. The Brazilian National Hydrogen R&D Program consists of the following projects:

Feasibility Studies:

Primary Electricity Production for Electrolysis:
For already-developed or under-construction hydro-electric power plant sites. Data gathering and estimation of water availability based upon historical data series. Availability of electricity generating equipment. Price of electricity projections for hydrogen production by electrolysis, both for peak and off-peak conditions. Feasibility of using already-developed or under-construction power plants for supplying necessary electricity.
For non-developed potential waterpower sites. Site location. Feasibility of A.C. and D.C. electricity generation at those sites. Economic studies for construction of a power plant specifically designed for providing electricity to a nearby hydrogen facility.

Hydrogen Production. Study of electrolytic hydrogen production techniques and associated costs.

Hydrogen Transportation:
For short distances. Feasibility studies for building a hydrogen pipeline of about 200 kilometers in a site where hydrogen is currently used as a feedstock for different industries (São Paulo).
For long distances. Development of a computer model for assessing technical and economic variables of a 500 to 1500 kilometer hydrogen pipline.

Hydrogen Storage:
For gaseous hydrogen. Studies of natural formations like caves and depleted oil and gas wells, for gaseous hydrogen storage.
For liquid hydrogen. Costs and processes for storage of large quantities of liquid hydrogen.

Hydrogen Utilization:
As an industrial feedstock. Studies related to the supply-demand market of hydrogen as an industrial feedstock.
For ammonia production. Processes and cost estimates for ammonia production from electrolytic hydrogen. Economic comparisons with alternative processes. Site location for an ammonia plant using pure, electrolytic hydrogen as a raw material.
As a fuel. Testing of different kinds of pipelines for urban distribution of gaseous hydrogen. Feasibility of supplying a more hydrogen-rich street gas mixture, and of introducing exogenous hydrogen into the conventional street gas production processes.

Research Projects:
Production. Evaluation of existing electrolysis installations. Optimization techniques. Research on electrodes and catalyzers.

Storage. Processes and containers for liquid storage. Metal hydrates.

Transportation. Material for pipelines. Compressors suitable for hydrogen pipelines. Development of hydrogen-compatible plastic materials.

Utilization. Catalytic burners. Conventional burners. Industrial catalyzers. Hydrogen-fueled engines.

Demonstration-experimental facility. Construction of a laboratory scale facility for testing hydrogen production, storage, utilization, and transportation, of different processes, methods, and according to various end uses.

Preliminary Results and Future Trends of the Hydrogen Program. Petroleum and fertilizer imports are causing an extremely acute balance-of-payments problem for Brazil. As a natural consequence, a major portion of the hydrogen program effort has been dedicated to studying the feasibility of producing ammonia from pure electrolytic hydrogen. The results of several studies conducted by FINEP indicate that ammonia production near a hydroelectric power plant is

competitive with the naphtha reforming process currently used in Brazil, provided that electricity could be supplied at a cost of about 12 mills per kilowatt-hour (at 1975 prices), and provided that the plant would produce at least 600 tons per day of ammonia (12). Even for an ammonia plant located up to 400 kilometers from the power station, and thus from the hydrogen producing plant, the studies found that for an installation producing in excess of 1000 tons per day, the ammonia so obtained would still be economically competitive with that from other processes. Those conditions (12 mills/kwh electricity, proximity to a power plant, and ammonia production of more than 600 tons/day) are very much feasible today in Brazil.

Plans are now under way for building an industrial-scale ammonia plant which, if successful, would constitute a major contribution of the hydrogen program to the country's energy and economy picture, and would also serve as a catalyst for the several other research activities being funded by the program.

Fossil Fuel Alternative Technologies

Coal Gasification. Coal gasification processes are under consideration in Brazil. Different technologically established processes (Winkler, Lurgi, Koppers-Totsek, Otto) were examined as alternatives for ammonia production, and for the direct reduction of iron ore in steel production. However, due to the high-ash content of Brazilian coal (55 percent) it is not at this point clear whether any one of those applications will find its way from the feasibility-study stage to the pilot and demonstration plant scale.

Shale Oil. Petrobras, the state-owned Brazilian oil company, has developed the technology for shale oil production. A pilot plant (1000 barrels per day) has been operating for the past several years in Southern Brazil. Plans were recently announced for building the first commercial-scale shale processing plant. The plant is expected to yield 51,000 barrels of shale oil, and 1.8 million cubic meters (63.5 million cubic feet) of pipeline gas per day. For that production, approximately 112 thousand tons of shale will be necessary. About 94,000 tons of residue will result. An advanced research project is under way for determining other possible applications for Brazilian shale, as well as for the residues of shale oil distillation (polymers, fertilizers, medicines, construction materials, etc.).

Energy Conservation Measures

Forced by the increase in petroleum products consumption, despite stepwise price increases during the past three years, the Brazilian government most recently (January 1977) enacted very tough fuel conservation regulations. Those regulations consist basically of:

Gasoline surtax of about 63 cents per gallon. The surtax is to be returned to the consumer after two years, without any value corrections to compensate for inflation (about 50 percent in 1976), and no interest paid. Gasoline prices, as a result of the surtax, will be about US$2.20 per gallon.

Similar measure for fuel oil. The surtax will be US$21 per ton of fuel oil.

Prohibit automobile circulation in downtown areas in major Brazilian cities.

Closing of gasoline stations all over the country on Sundays and holidays.

The establishment of different working schedules for industry, commerce, and government agencies, including staggered hours.

Raising by 50 percent the toll fares on state and federal highways during weekends.

Incentives for the use of alternative energy sources.

Incentives for the use of electricity as opposed to energy from fossil fuels.

Incentives for the expansion of public transportation systems.

Reduction by 10 percent of fuel bills of government agencies.

Limitation of power output of government automobile engines to 89 HP.

Enforcing the national maximum speed limit (50 mph).

Fining owners of badly tuned diesel engines.

Surtaxing gasoline or diesel oil-fired electricity generators.

Restricting imports of airplanes by the government.

Raising diesel oil prices.

Since those measures were taken quite recently, there is no way to evaluate how effective they really are. Furthermore, it is not very clear at this stage what the meaning is of some of them which were phrased more as recommendations than as regulations. However, it is fair to assume that their reach and potential use open up a wide spectrum of possibilities for stimulating the development of alternative energy technologies in Brazil.

Incentives for the use of alternative energy sources include not only the gradual replacement of gasoline and other liquid fuels by ethyl alcohol, but also the "more efficient use" of other natural resources. Notwithstanding the possibilities that have been mentioned, at this point it is not possible to determine definitively which of them will be developed on a priority basis.

Some implications for conservation can be suggested. Public transportation systems (buses) are responsible for 75 percent of the total number of passengers in the ten largest metropolitan areas in Brazil. Increasing this number, say to 85 or 90 percent, could save an estimated 430 to 640 thousand gallons of fuel per year. Also, increasing the person-per-automobile average number (now 1.35 in the largest metropolitan areas) to 2.0 could save an estimated 10 percent of the total annual gasoline consumption in the country. The government hopes to achieve these goals not only by restricting the use of automobiles in downtown areas, but also by a number of complementary measures such as creating special traffic lanes for buses and car pools, charging special toll fares for cars carrying only one motorist, stimulating the production of electrically-powered trolleys and of small, low gasoline consumption automobiles, increasing parking rates at areas near downtown, and a number of other measures. Also, the federal investment in railroads and construction and in electrically powered railroad equipment will be substantially increased and the highway construction program will be kept at a minimal acceptable level.

Conclusions

The possibilities for developing alternative energy technologies in Brazil are many and varied. Some of them are peculiar to the country; others are applicable elsewhere. Some are fairly well-developed and need only be adapted or improved, to take advantage of local conditions. Others, although very promising, are still a few years away from being used on a commercial scale.

Nevertheless, for a country like Brazil, as for many other countries, there is no simple solution for meeting its energy needs. Different possibilities, though, are not mutually exclusive. They should contribute to the overall solution by solving some specific, local problems. It seems clear that the country's energy policy cannot restrict itself to short-term planning in this field. Research and development efforts have to be considered as an integral part of the policies being formulated -- which, in all fairness, cannot be said to have happened in the past.

The variety of methods, technologies, processes, and end-products that appear to be feasible in the Brazilian case, require a very well-coordinated and executed comprehensive approach toward the problem. A systems treatment is a must. In the first few iterations, a definite answer is not going to be found; however, a trial and error process should be conducive to a much better solution than the random approach which results from focusing attention on isolated alternatives.

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5

Wind Energy Conversion in India

Sharat K. Tewari

It appears that practically no serious attempt was made to utilize wind energy in India until the 1950s. While wind power has been utilized in propelling and guiding ships and boats, for several reasons no other utilization of wind energy could develop. One reason probably was the ready availability of animate energy derived from the muscle power of draft animals. Rural India has been utilizing bullock work in transportation, in grinding of food grains, extraction of oil from seeds, in preparing lime mortar used in building construction, for drawing water from wells, etc. With its large rural population, India has been significantly drawing upon manual labour also in several domestic and agricultural tasks. Only during the last two to three decades have electricity and oil been able to make an entry into the rural energy scene. However, conventional forms of energy, both animate and inanimate, suffer from some drawbacks. Energy obtained as human and bullock work is expensive and reliance on this form of energy decreases the opportunities for a more productive alternative activity. Bullock work cannot meet the additional energy needs simply because the number of bullocks have not been increasing. Electricity drawn from the grids is available in only one-third of the half a million villages and it will be quite some time before all the villages obtain electricity under the conventional rural electrification schemes. Utilization of oil for energy generation causes an additional drain on foreign exchange resources apart from having the problems of maintenance and repairs in rural areas. From this very brief description of the Indian energy scene, it could be inferred that there is a

need for deriving energy from alternative sources for use in rural India. I will attempt to establish here that energy derived from winds is highly appropriate for use in some applications and deserves serious consideration.

In this paper the approach adopted for designing wind energy utilization in India during the last 25 years will be briefly mentioned. From this, we shall proceed on to a systematic analysis for obtaining a rightful place for wind energy in the energy scene of rural India.

In 1952 a wind power sub-committee was constituted under the Council of Scientific and Industrial Research, New Delhi. This committee recommended conducting wind surveys at several locations, adapting a suitable windmill originally developed abroad, and simultaneously taking steps to design a windmill indigenously. The anemographic records of wind velocity were being obtained at the several installations of the India Meterological Department. Some of these records were studied and processed from the wind-energy point of view. This analysis was conducted at the National Aeronautical Laboratory and helped in characterizing locations in terms of annual and monthly average wind speeds, velocity-duration curves, frequencies of unacceptably low wind spells, etc. About 160 water-pumping windmills of the Southern Cross type were imported in the late fifties and installed at several locations in the country. During the 1959-64 period, the windmill WP-2, indigenously developed at the NAL, was produced in batches and about 80 of these were erected for field trials at several places in the country. This windmill has 12 blades mounted on a 5-metre diameter rotor wheel. The cut-in speed is 8 kph (kilometres per hour) and the furling speed is about 40 kph. A few electricity generating windmills such as 'Algaier,' 'Dunlite,' and 'Elektro' were also tested for performance in Indian winds. By 1966 wind power activity was closed down at NAL.

What were the achievements of this programme, which lasted just over a decade and operated at full steam for about 3 years? First of all, it was established through this programme that windmills are acceptable in the tradition-bound society of rural India. Therefore, if only the wind

energy could match with other alternatives in terms of the economics, its utilization would not present any social problem. Another achievement to the credit of this programme was to map out wind energy distribution for some parts of the country. It was shown that the annual average wind speeds at most places in India range from 9 to 17 kph. However, no serious effort could be made under this programme to identify windy locations apart from what had been indicated from the normal meteorological data.

The optimism of cheap electricity from the grids and a lack of proper appreciation for renewable sources of energy, along with some other factors had led to the closure of the NAL wind-power programme by 1966. The oil price hike after 1973 has been responsible for the restarting of the wind energy studies and a fresh look is being taken at this alternative source of energy. Since then the following studies have been initiated.

1. After the publication of reports from the National Research Council of Canada, a few groups in India, appreciating the advantages of the Darrieus rotor, began constructing its prototypes. At NAL attempts were made to energize a commercially available centrifugal water pump with the help of a 4.5-metre Darrieus rotor. However, even with the addition of two large Savonius rotors co-axially mounted with the Darrieus rotor, it was not possible to obtain the starting torque required by the pump. At the Bharat Heavy Electricals Ltd., Hyderabad and at the Indian Institute of Technology, Madras, projects have been initiated for developing a Darrieus rotor for generating electricity at around one- to five-kW capacity levels. Another programme at NAL is directed towards studying a parallel-blade variation of the Darrieus rotor, thus deviating from the usual catenary shape selected earlier.

2. Another line of development has followed the route of the Savonius rotor. The Application of Science and Technology in Rural Areas (ASTRA) Cell at the Indian Institute of Science, Bangalore has developed a modified design of the Savonius rotor for field trials in a village near Bangalore. A 4 x 3-metre prototype has been fabricated from wood, iron wires, and cloth and it is proposed to couple this with an improvised dia-

phragm water pump.

3. The third line of experiment has gone in the direction of the Cretan Sail Windmill. Such windmills utilize relatively cheaper materials for rotor construction and provide opportunities for utilizing low wind speeds, and at the same time remain cost competetive. A sail windmill having a rotor diameter of 10 metres was erected at Madurai in 1974 to pump water with the help of a reciprocating pump. Recently designs utilizing efficient sail wings have been finalised for a windmill having a 10-metre diameter and it is proposed to match it with a rotary pump in order to minimize energy losses in transmission mechanisms.

In addition to these, a few other design and development programmes are being carried out, but the types mentioned are quite typical. It should be appreciated that while the design and development of hardware is essential, it is equally necessary to study all related aspects of wind energy in a systematic manner so that an appropriate policy could be formulated at the national level for promoting wind energy utilization. Answers to the following questions are needed:

1. Which are the applications where utilization of wind energy could be recommended on the basis of its being more appropriate than other alternatives.

2. Are wind speeds and associated durations as given by a velocity-duration curve for various locations in India adequate for the applications; and

3. What are the economic implications of wind energy.

The most common method of using wind energy is by conversion into shaft work. Electricity may be derived from shaft work simply by coupling a suitable generator to the windmill shaft. This procedure does not involve any serious losses in energy availability, and overall efficiencies as high as 40% have been obtained for converting wind energy into shaft work. Therefore, such of those applications that depend on shaft work can be readily served through wind-energy conversion. Applications such as water pumping, grinding of

food grains, and other agro-industrial activities are typical of those for which wind energy can be utilized.

Wind-energy conversion into electricity through shaft work could be examined on the basis of the mode of utilization of electricity in Indian villages. In those villages where electricity has been made available, it is a common feature that over 80% of its consumption is in energizing irrigation pumpsets. The rest of it is consumed in domestic and street lighting. The use of electricity in cooking, space, and water heating is practically non-existent.

From this analysis it would appear that wind-energy conversion could be considered primarily for providing mechanical work, and if electricity is generated through this conversion, it is ultimately going to be used mainly for generating mechanical work also. We would now examine the appropriateness of other alternatives vis-à-vis wind energy for generating mechanical work.

Prof. Roger Revelle has calculated that about 9% of the total energy used in rural India is obtained from the muscle work of human beings, and another 14% is contributed from bullock work. Even though only 1/10th of the total bullock time is utilized in raising water, nevertheless their contribution amounted to as much as 40% in terms of water lifted for irrigation in 1971. As mentioned earlier, the bullock population is not growing and the incremental energy available from this source is therefore not likely to be significant, except for the fact that there is room for more efficient utilization of the existing bullock force.

It may be stressed here that energy needs are going to increase, especially for irrigation facilities required to support medium and high energy-intensive methods in future, in the place of the current practice of subsistence agriculture.

The cost of energy derived from manual labour in tasks like lifting water from wells and canals is estimated to be about 20 times higher than the commercial price for electricity. Perhaps human beings are not best suited for such of those tasks

that could be carried out by utilizing inanimate energy. It is a known fact that a prerequisite for improving the quality of life of human beings is to avoid excessive energy dissipation that takes place in the manual labour deployed, for instance, in water lifting. Therefore, a reduced dependence on this source of energy should be the focal point of an energy utilization study like ours.

India is currently meeting two thirds of its consumption of oil from imports. After the OPEC price hike, curbs were introduced on non-essential uses in order to control the demand. However, the demand is bound to increase in the near future from the fertilizer industry and transportation sector. It is estimated that import requirements would be somewhat reduced with the availability of oil in the near future from offshore wells. Even then, it would be desirable to substitute alternatives such as electricity for oil in applications such as irrigation water pumping. In fact a trend indicating a preferential use of electricity in place of oil for this application was shown to exist even before the oil price hike. The electricity is preferred in villages mainly because it calls for less initial capital from a consumer. Use of diesel-powered pumpsets requires the availability of technical skill for maintenance and repairs, which is not easily available in remote areas. Also it is estimated that the unit cost of electricity obtained by smaller diesel generators is four to five times higher than the price of electricity purchased from the grids. This also explains the preference for centrally generated electricity in comparison with the alternative of using diesel pumpsets or generators.

Of the half-million villages in India, about one third have been covered under the rural electrification schemes. Transmission and distribution networks have to be set up for providing electricity to the remaining villages and this will take time. The villages that have been electrified so far are those that happened either to be located near the larger load centres of cities and towns or were large enough themselves to warrant their own generating facilities. This is clearly indicated from the statistics of rural electrification, which show that about 92% of the villages with population exceeding 10,000 were electrified in 1971 whereas only 12% of the villages with

population under 500 had this facility. Smaller villages constitute over 60% of the total number of villages. It is likely that more time would be required to take electricity to far-flung remote smaller villages under the conventional practice.

Apart from the time factor, supplying electricity to distant villages results in diseconomies to the system. Energy losses in transmission are significant and load factors are rather low - just about 10%. The rural electrification programmes have the Government's support on account of social priorities but probably there are other ways of implementing this programme, apart from the current practice of distributing electricity generated at at large power stations. Suggestions have been made for supplying electricity to a group of villages from aerogenerators installed at the neighboring windy sites. We may like to examine the economics of such a possibility.

The data on rural electrification in India show that a 25-kW installed capacity is adequate for a village with a population under 1000. Under the current practice a distribution line has to be run to each village and this distance has been found to be about 8 kilometers on the average. For remote villages yet to be electrified this distance would surely be longer. The cost for laying down these lines over a given distance and the cost of transformers and switchgear can be calculated. One could add to this the bought price of electricity at the last point on the main network to arrive at the actual cost of the electricity supplied in a village. On the other hand one could assume a reasonable capital cost for a well designed and mass-produced aerogenerator and arrive at its annual cost by making assumptions concerning the cost of its spares and maintenance. It has been shown on the basis of a comparison of the cost factors involved with aerogenerators on one hand and the existing practice of rural electrification on the other that the former could be economically competetive in many villages yet to be electrified. However, the optimised cost-effective aerogenerator is yet to be demonstrated in actual practice.

Having examined the conventional sources of energy we may now proceed to study the availability of shaft work or electricity from non-

conventional alternatives, including renewable ones. Some of the alternatives are: (1) Solar-energy utilization directly for water pumping and for generating electricity or shaft work; (2) liquid-piston pumps operating on bio-gas combustion, or internal-combustion engines operating with bio-gas; (3) water wheels converting the energy of river flow into shaft work. These are the promising examples. Out of these the water wheels can be operated only at those very few villages that have the advantage of a rapid flowing river or a stream and we shall not consider this possibility in our analysis here.

Solar pumps have been designed to pump water from wells with water levels as deep as 30 metres. Such pumps utilize flat-plate collectors, an evaporator, a condenser, a few valves, and a couple of water chambers lowered into a well. The capital cost of such pumps is rather high today as compared to the cost of water-pumping windmills. The energy-conversion efficiency of solar pumps is several times lower than the efficiencies of some of the well-designed windmills.

Solar-energy conversion resulting in shaft work or electricity through a turbine and generator has also been suggested for use in rural areas. The costs and efficiencies of these schemes are comparatively less favourable than windmills and aerogenerators. In addition the complexity is much higher in such conversions of solar energy while wind-energy conversion remains relatively simpler.

Cow dung and other animal wastes are currently dried and burnt for deriving heat mainly for domestic cooking in villages. Conversion of such waste material into bio-gas through anaerobic fermentation and using the gas so collected has been shown to be a more efficient technique from the point of view of energy availability. It has also been suggested that bio-gas could be burnt in an internal-combustion engine to obtain shaft work. Alternatively it could be burnt in a liquid-piston pump for direct pumping of water. Two issues confront us here. The first concerns the limited availability of bio-gas and the other its priorities in utilization. It is estimated that with a 75% efficiency in dung collection, the bio-gas that can be generated in Indian villages can meet

three fourths of the domestic energy requirements. Since bio-gas replaces dung cakes that are being used currently in cooking and water heating, the bio-gas must first satisfy these requirements. Therefore, unless additional availability of bio-gas is assured from sources other than cow dung, and this is yet to be considered on a serious basis, it would not be possible to recommend bio-gas conversion into mechanical work. One must also consider the thermodynamic losses in energy availability involved with the energy conversion from bio-gas into shaft work or electricity.

Therefore, it appears that wind-energy conversion into shaft work or electricity for use in rural India is the main contender provided the energy availability from winds can be matched with demand for energy in the applications. We may now consider these aspects.

The annual average hourly mean wind speed is generally used as the parameter for depicting the wind energy potential for a particular location. An analysis of the available wind speed data has indicated that at most places in India this figure falls in the range of 9-17 kph. While designing a windmill or aerogenerator one picks up a rated wind speed at which full rated power is generated. The rated wind speed is normally higher than the annual average speed though the number of hours of operation at full output are reduced. For instance, if one selects a rated windspeed as the one to maximize energy availability during a year with a typical aerogenerator, then the rated speed would be found to fall in the range of 20-25 kph corresponding with the range of 9-17 kph of annual average speed. The number of hours during any year when wind speed would equal or exceed this rated wind speed at a given place would probably fall in the range of 1000-2000 hours. The question then arises whether this many hours of operation are acceptable and also whether wind energy is equitably distributed among the 12 months, or even better, if it is concentrated in the months from November to March, as these are the months maximum irrigation is required. Unfortunately, it is just the other way about with winds in India. The three months of May, June, and July account for about one half of the annual energy availability. Wind speeds during November to March are relatively weaker. Therefore, under such circumstances, the

rated wind speeds might turn out to be just about the same as the annual average wind speed. Under these circumstances, is the utilization of wind energy economical or even feasible?

There is no difficulty in utilizing low wind speeds for wind-energy conversion, except for the fact that low wind speeds require a proportionately larger diameter for the rotor in order to produce a given amount of power. Now the important thing is to ascertain the size of windmill required and then examine whether this size happens to be too big to be handled in large numbers in the villages. It was mentioned earlier that about 40% of the water lifted in 1971 from wells was based on bullock or human work. The statistics indicate that on the average an open well irrigates an area of over 1 hectare. Using the data for water requirements per season, we find that about 0.75 hectare-metre of water is normally pumped during a four-month season. Assuming the number of hours of operation of a windmill per season as 500, we find a likely pumping rate of 70-100 litres per minute coupled with a typical head of 10 metres. This pumping could be obtained from windmills having a rotor diameter not exceeding 12 metres. This is not at all a difficult situation.

The important concern then is the economics of wind-energy utilization. It should be noted that the worth of utilizing an easily available source of energy such as winds in a rural community is much higher than indicated in terms of commercial factors. Availability of energy at the right time in desired quantities could catalyze developments that were hitherto just not possible. Indirectly in commercial terms, the high value and price of agricultural production more than justifies relatively insignificant cost of water pumping. It is expected that the total worth of wind energy would be high despite some diseconomies in its application, as this would be adequately compensated by overriding social benefits.

In conclusion it may be stated that wind-energy conversion has attractive possibilities in India and for some applications like water pumping it is perhaps the most appropriate alternative among the several choices available or likely to be available in the future. On account of low

cash surplus in villages it might be necessary for the Government to support wind-energy utilization in the same manner as the programmes of rural electrification, and the economics of these two alternatives would be comparable. In addition, the technology of wind energy could be disseminated in a short period of time owing to its simplicity, which is not likely to be surpassed by another alternative.

Small Hydraulic Prime Movers for Rural Areas of Developing Countries: A Look at the Past

6

Joseph J. Ermenc

Historical Perspective

The two hydraulic prime movers, which have been important instruments of change in rural areas of developing nations in the past, are the waterwheel and the small water turbine which superseded it during the +19C.

The basic difference between the two is that there is a contrived flow of water with respect to the energy conversion elements (blades/vanes/buckets) of the water turbine and not of the waterwheel.

The waterwheel was the first prime mover used extensively (other than persons and animals). It dominated the power scene for about 2000 years. It was at first integrated with traditional hand-craft methods which led to changing patterns of making and doing things and with revolutionary increases of goods and services. But the power limitations of the waterwheel (less than 20 horsepower) essentially limited the size of these operations. Its use was therefore characterized by a diffusion of mills throughout rural areas. In Europe and the United States this was the prelude to their Industrial Revolutions; Mumford has called this the Eotechnic Phase of a developing country based on wood as a material of machine construction, water as a source of power, and the native craftsman as the dominant technological figure. (1)

During the Roman Empire all species of waterwheels appear in rural areas. They were used primarily for grain and saw mills. A three horsepower (2.2 kilowatts) waterwheel powered grain mill near Cassino, Italy was capable of supplying the flour needs of about 400 people. A conglomerate of 16 waterwheels at Barbegal in southern France supplied power to produce up to 28 tons of flour per day for the

GALLO-ROMAN FLOUR MILL AT BARBEGAL, NEAR ARLES, PRODUCING 28 TONS OF FLOUR PER DAY. A.D. 308-16.

TWO SERIES OF EIGHT WHEELS; EACH 6.9 FT. (220 CM) DIA. AND 28 IN. (70 CM) WIDTH.

TOTAL HORSEPOWER c 170; HEAD - 65 FT (20M)
(ISIS, 38, 1947-48)

FIG. 1

Roman Legions.(2) Though these were examples of the revolutionary possibilities of the waterwheel, vested interests and social-political restraints seem to have prevented its wider and more intensive use. (Fig. 1)

The collapse of the Roman Empire and its slave-based economy swept away the restraints against the use of the waterwheel in the West.

By the +11C the waterwheel was well established in rural Europe, driving saw and grist mills and pumping water. Even in England which was then, in comparison with Europe, considered as a backward country, there were,according to the Domesday Book of 1085, 5624 water-powered mills operating in 3000 communities in southern and eastern England.

By the +14C Europe was experiencing an escalating use of the waterwheel in many handcrafts. Two principal stimuli set this off:

1. The exemplary use of the waterwheel in monasteries.
2. The labor shortages brought on by the Black Plague.

By the +16C, the use of the waterwheel had been extended to such traditional handcrafts as:

1. Mining(drainage, ore transport and crushing).
2. Metallurgy (blast furnace blowers, rolling and strip mills).
3. Metal working (forging, turning, grinding, wire drawing); agricultural tools.
4. Woodworking.
5. Leather processing(tanning, harness).
6. Paper making
7. Oil manufacture
8. Cosmetics (powder, perfume).
9. Polishing (lenses, ivory, minerals).

The number of waterwheels in Europe by this time was reckoned in the tens of thousands. Their site selection, design and construction was attended to by a superior group of craftsmen called millwrights.(3)

In the American colonies the use of waterwheels begins within a few years of the establishment of settlements. In 1647, only 20 years after the Pilgrims had landed at Plymouth, waterwheels were used in an iron mill at Saugus, Massachusetts; here bog iron ore (limonite) was processed into wrought iron bars (merchant iron) at a rate of eight tons per week.

But small mills were far more prevalent than the Saugus iron mill. By the end of +18C there were about 10,000 waterwheels in New England driving a variety of mills on tributaries of main-line rivers and tributaries of those tributaries. It was not uncommon to have a dozen mills on a brook use its entire flow in succession.

In China, the first reference to the waterwheel occurs in +31. It was used for the job of operating an air bellows in metallurgical processing (cast iron and wrought iron) and fabrication (casting and forging). By +230, iron tools became three times as abundant as in pre-waterwheel times. (4)

By the +13C, in the Chinese province of Szechwan, "tens of thousands of waterwheels for hulling and grinding rice, and for spinning and weaving machinery, were established along the canals (in the plain of Chhengtu) and operated throughout the four seasons."

During 1780, a Korean scholar passing through an area 40 miles east of Peking wrote, "I saw waterpower used for all kinds of things; blowing air for furnaces and forges, winding silk off cocoons, milling cereals,. There was nothing for which the rushing force of water to turn wheels was not employed."

So by the beginning of the +19C, areas of Europe, the United States, and China were well prepared technologically to receive the next beneficence of hydraulic power, the water turbine.

(Since World War Two up to a hundred watermills in succession have been seen on small rivers in rural areas of the provinces of Shansi, Kansu, and Yunnan. Some waterwheels, made of wood, have been connected to small electric generators (for lighting) via pulleys, belts, or ropes.)

The water turbine was a French triumph. It was preceded by the development of sound turbine theory by French scientists during the +18C. This guided the French engineer, Benoit Fourneyron, between 1825 and 1833, to produce several small water turbines which demonstrated superiority over the waterwheel in almost all respects. (5)

They could operate adequately at higher heads or lower heads than the waterwheel - and even submerged. They could replace the waterwheel at a site and develop twice the power at ten times the speed. They occupied only a small fraction of the volume of the waterwheel. They could also be placed as high as twenty feet above the tailwater (using a draft

tube) without appreciable loss of power.

By 1838, the news of Fourneyron's turbine had already reached the United States. A few were built in the Boston area, strictly following Fourneyron's design. But in the hinterlands it was rapidly taken over by blacksmiths and foundrymen who found it easy to make, in great demand and an extremely profitable business. Changes came very quickly and by the middle of the century the Fourneyron turbine had been so radically altered by rural craftsmen that American turbines began to take names of their many improvers. Changes continued throughout the century; during this period there were more than 60 varieties of small, cheap, cast iron turbines on the market as replacements for waterwheels. (6)

Efficiency and cost were often not the main criteria in turbine selection by mill-owners. Many rural New England small mill operators rated turbines on their capability of passing bodies of small animals.

The last quarter of the +19C was the heyday of the small turbine. When a waterwheel needed to be replaced or the power increased at a millsite, a turbine was selected. An 1885 census reported over 900 turbine powered mills operating on the 110 mile long Merrimac River and its tributaries. (The Merrimac River flows from central New Hampshire south, then east through Massachusetts.) The average power of these turbines was about 30 h.p. (22 kilowatts).

The mills were highly specialized and were duplicated at least four times in the Merrimac watershed indicating their limited areas of service.

They turned out such household products as cutlery and edge tools, brooms and brushes, looking-glasses, furniture, paper, buttons, woodenware, stone and earthen-ware, pencil lead, vinegar, combs, ivory and bone-work, toys and games, baskets, needles and pins, watches and clocks, and even washing machines.

For the farm they turned out fertilizers, gunpowder, axles, agricultural implements, barrels, ax handles, wheels, carriages. There were woolen, cotton, flax and linen mills; hosiery, lace, worsted, glove and mitten, mattress, cordage, twine, shoddy and bagging mills.

There were tannery, boot and shoe, and leather-board mills.

There were also mills turning out surgical appliances,

MILLS ON THE THREE MILE LONG NEWFOUND RIVER IN NEW HAMPSHIRE, 1885

KIND	NUMBER	HEAD	HORSEPOWER
WOOLEN	1	16	30
PAPER	3	40	297
CARPENTERING	2	-	30
FLOUR & GRIST	3	30	130
BLACKSMITHING	1	12	15
WOODTURNING	1	16	30
CARRIAGES & WAGONS	1	12	50
GLOVES	1	18	76
TANNERY	2	38	150
MACHINERY	1	8	2
STRAWBOARD	1	12	-
WOOD PULP	1	22	200
SAW	1	12	50
TOTAL	19		1060

(FROM "REPORTS ON THE WATER POWER OF THE UNITED STATES", DEPARTMENT OF INTERIOR, CENSUS OFFICE, 1885.)

FIG. 2

musical and scientific instruments.(7) (Fig.2)

After 1900, in the United States, the advent of large central thermal and hydro-power stations, rural distribution of electricity, the internal combustion engine, and better rural transportation all contributed to the decline of the small turbine powered mill.

Today there is only one nationally known manufacturer of small turbines in the United States; and the last manufacturer of waterwheels closed shop in 1967.

So in the United States and Western Europe, both Eotechnic prime movers, the waterwheel and water turbine, have gone through complete cycles of existence from the rise of invention, development, and acceptance to a gradual slide into obsolescence just short of oblivion. (Fig.3)

In China, it appears that century of foreign interference has delayed the introduction of the small turbine; but this is now in progress with particular emphasis on small scale hydro-power stations.

A BBC broadcast, during 1970, informed that thousands of units of less than 100 kw were being installed in rural areas. This parallels the installation of small, simple hydro-electric stations in the United States at the beginning of this century. (10,11,12,13,14) (Fig.4)

Since World War Two, small hydro-electric package units of less than 20 kilowatts have appeared in West Germany, Hungary, Canada, Russia, and the United States.(9) But the cost of these units indicate that Western manufacturers have priced themselves out the rural market not only in developing countries but in our own as well. But beyond this they represent refinements unnecessary in rural areas of developing countries and unwise in that their complexity and maintenance is beyond the understanding and the resources of the rural craftsmen. (Fig. 5,6)

Waterwheels

By the +4C in the Roman West, and perhaps earlier in China, the waterwheel had evolved into two distinct species which converted different forms of hydraulic energy into mechanical energy (force-velocity combinations).

1. The undershot wheel receives energy from the impact of a flowing stream of water on flat (later curved) radial vanes/paddles.(Fig. 7)

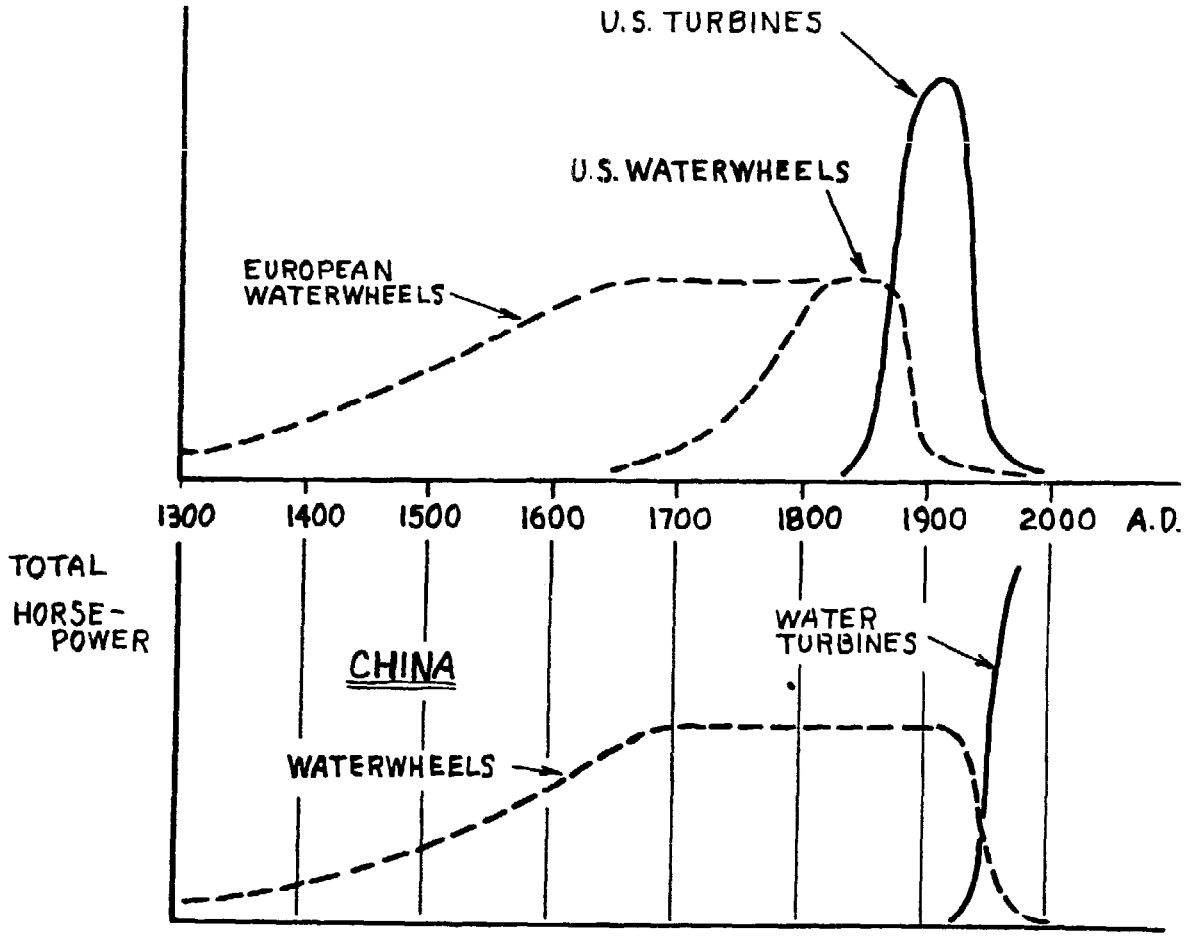

SMALL (LESS THAN 100 HORSEPOWER) HYDRAULIC PRIME MOVER CYCLES.

FIG. 3

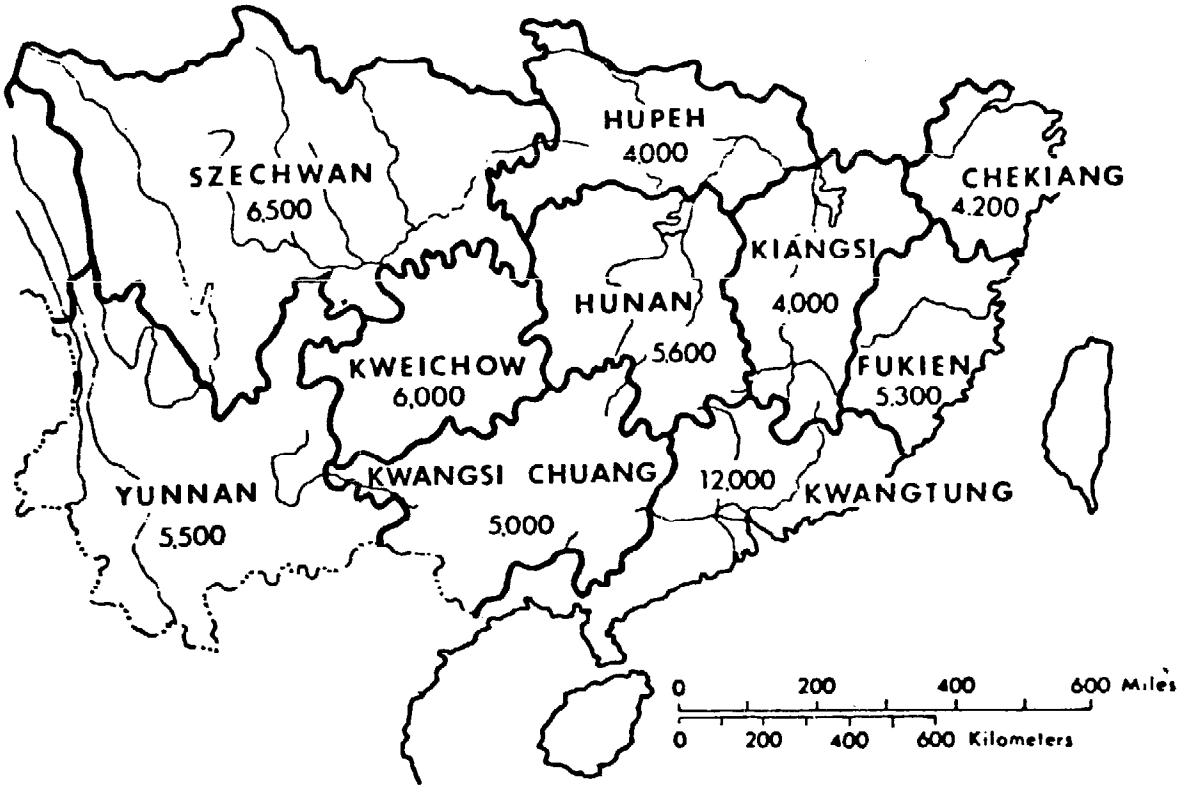

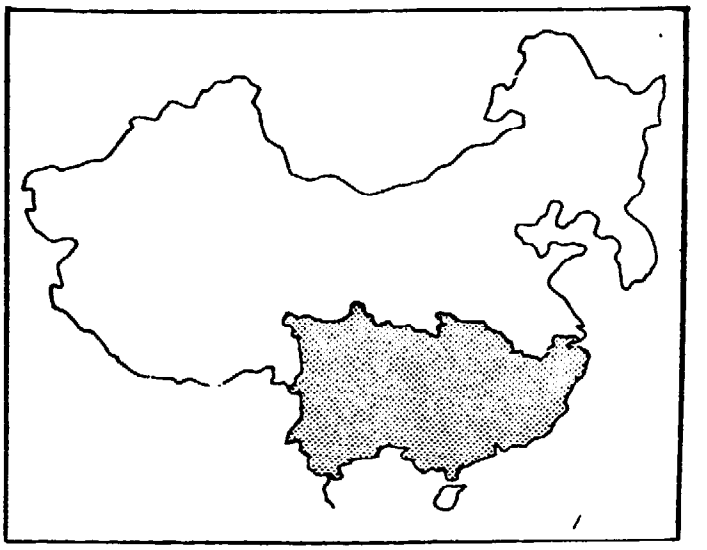

SMALL HYDRO-ELECTRIC STATIONS
(AVERAGING 40 KW)
IN
SOUTH CHINA

(V. SMIL, BULL. ATOMIC SCIENTISTS, FEB. 1977)

FIG. 4

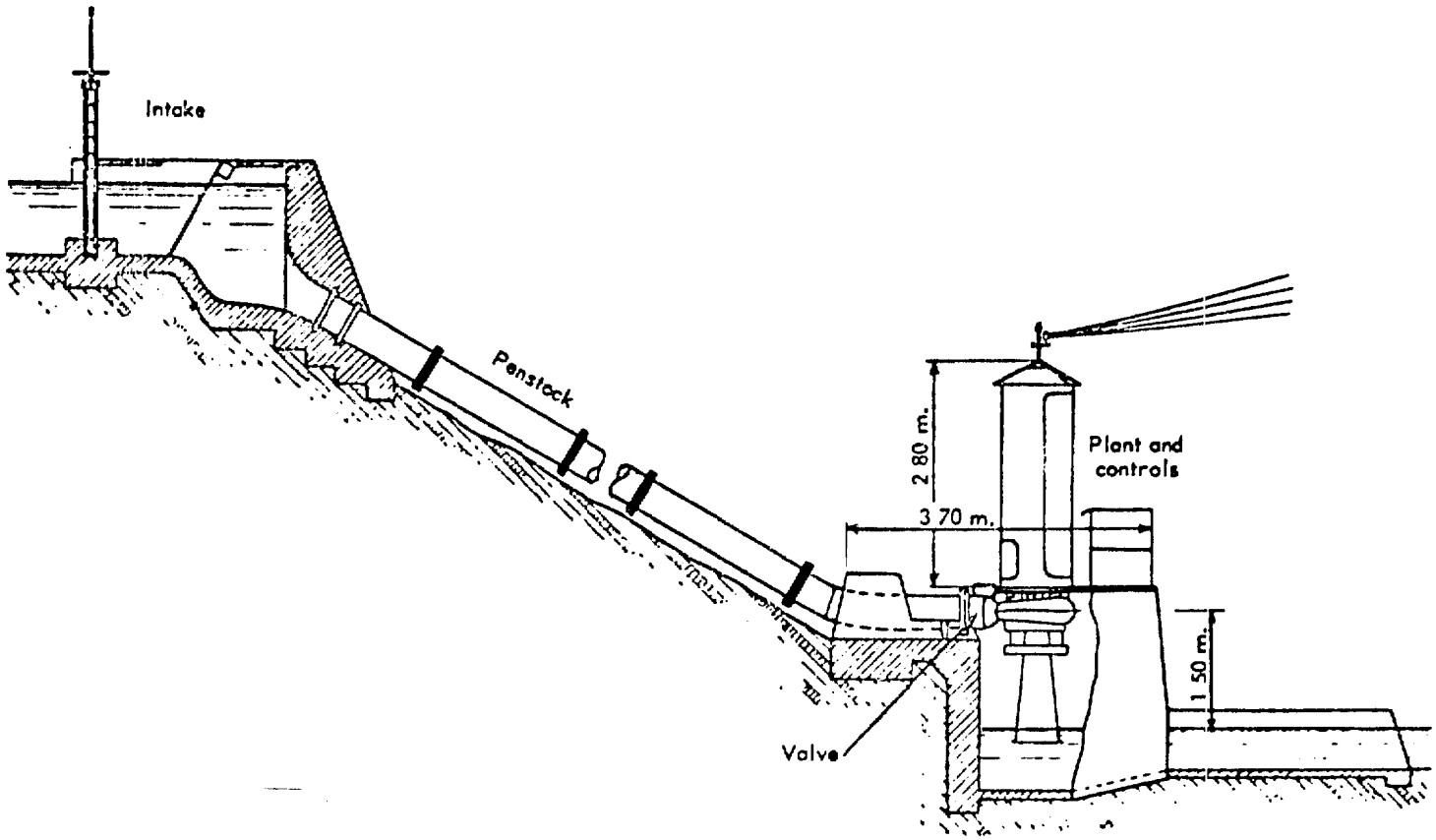

Typical layout of micro hydro-plant. [From: *Small-Scale Power Generation*, United Nations, New York, 1967. UN Publication Sales No. 67.II.B.7.]

FIG. 5

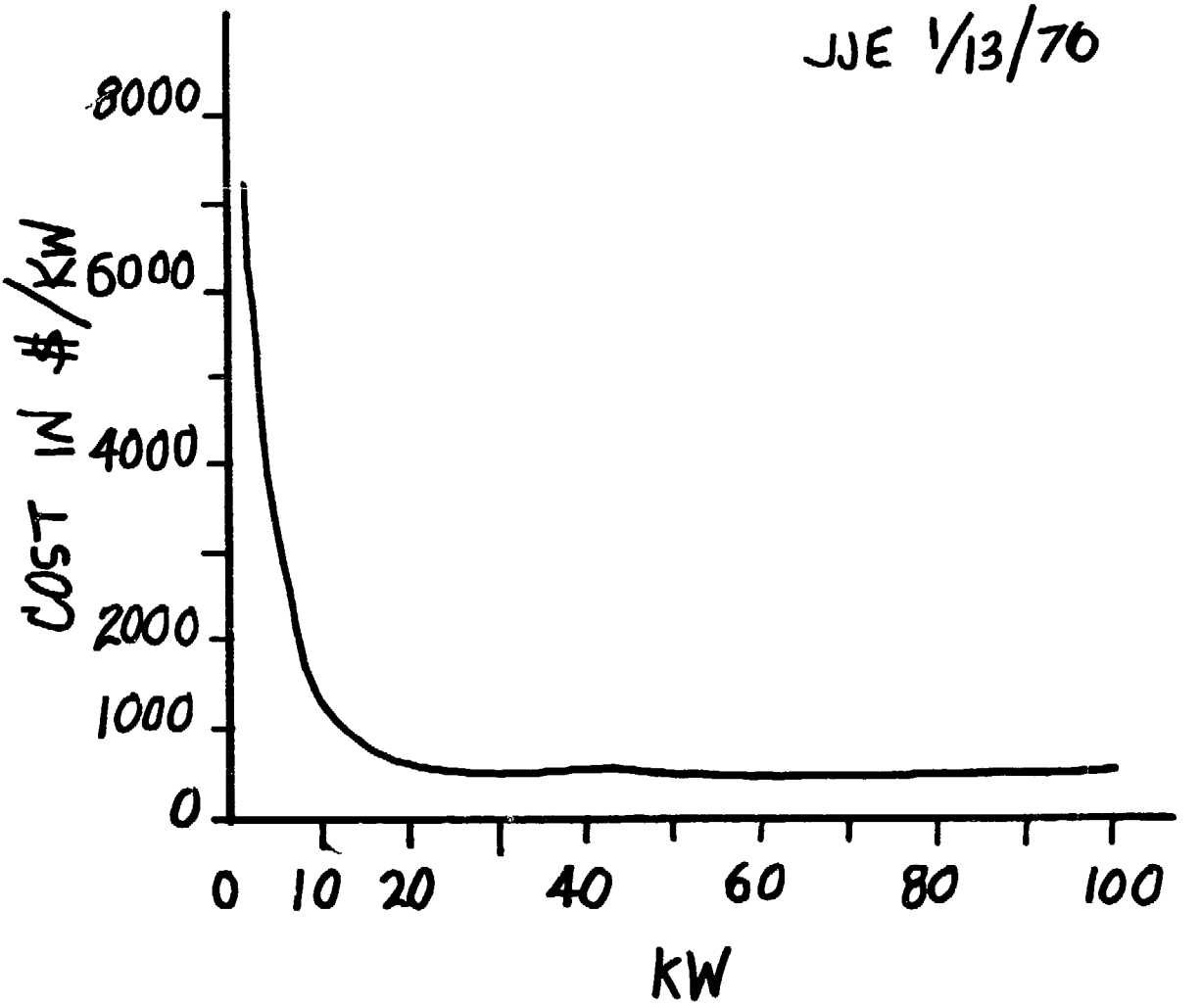

COST PER KW OF SMALL SCALE HYDRO-ELECTRIC PACKAGE UNITS (NOT INCLUDING INSTALLATION OR DAM COSTS)

FIG. 6

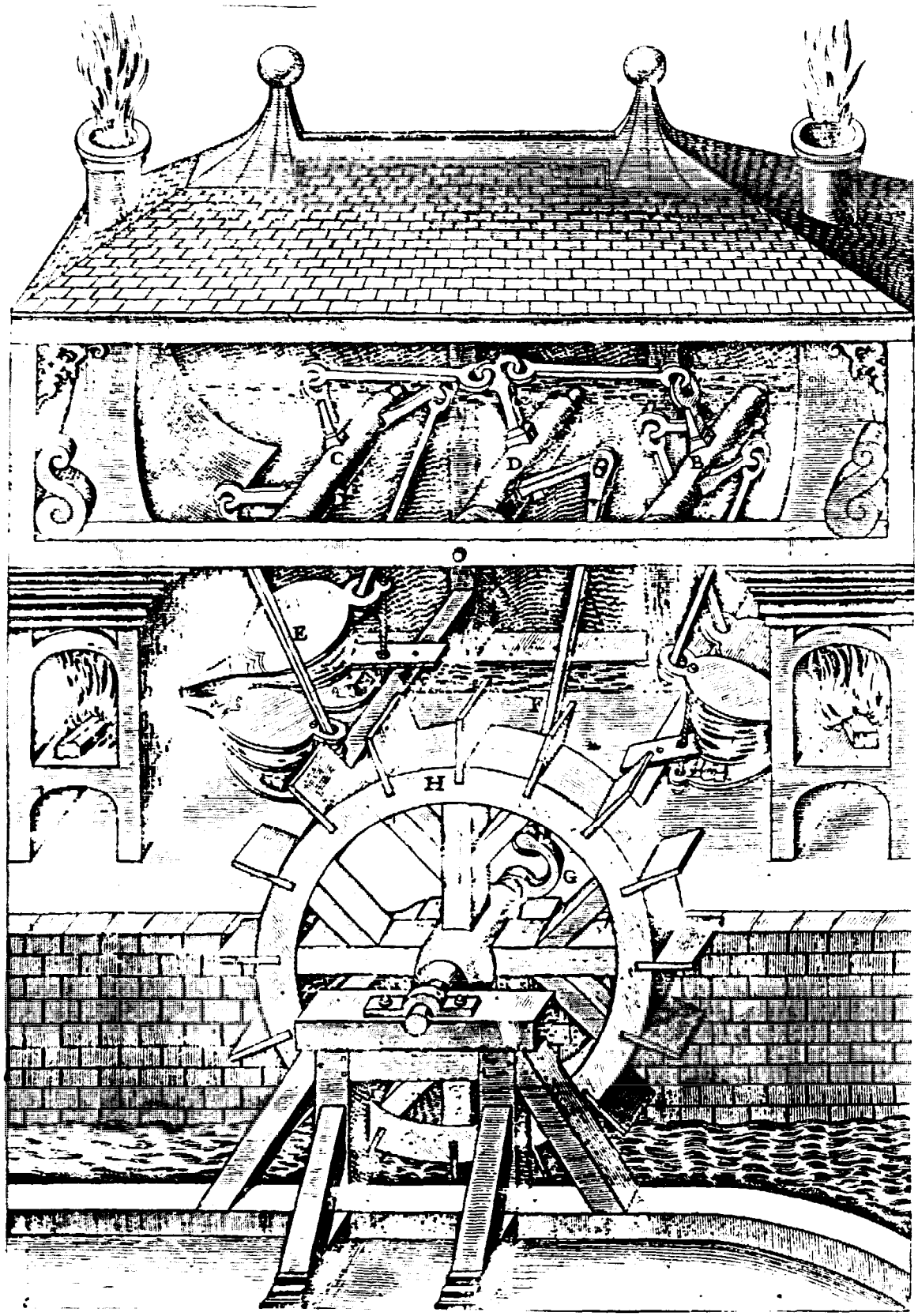

UNDERSHOT WATERWHEEL
OPERATING
AIR BELLOWS FOR TWO IRON HEARTHS
FROM
AUGUSTINO RAMELLI, "LE DIVERSE ET ARTIFICIOSE MACHINE", PARIS, 1

FIG. 7

2. The overshot wheel has 'buckets' on its periphery. These are filled at the top of the wheel's rotation and empty as they approach the bottom, (the breast wheel receives water, in buckets, at about radial height). The overshot wheel always rotates in a vertical plane. (Fig. 8)

The undershot wheel may rotate in either a horizontal plane or a vertical plane.

The vertically rotating wheel was the dominant form used in the West though the horizontally rotating wheel was to be found in the hilly regions of the Balkans, France, Italy, Scandinavia, Ireland, the Shetlands, and the Faroes. (Fig. 9)

In China, the horizontal wheel was dominant.

Until the +19C, both types of waterwheel were generally made of wood with cast and wrought iron used sparingly where extra strength or wear resistance was required.

The Overshot Wheel

The overshot waterwheel had an efficiency around 80 percent which was several times higher than that of the undershot waterwheel. Indeed it was often higher than the efficiency of the early small turbines. Further its efficiency remained high despite variations in load imposed upon it; this superior characteristic was not obtained with the undershot wheel or with the early turbines.

For the mill operator the overshot wheel was most economical of water and this explained its use well into the +20C and particularly on small streams. But on the debit side, the overshot wheel was limited to speeds of less than 20 rpm for wheel diameters of 15 feet (4.6 m) and for horsepowers of less than 20 (15 kw). These limits were imposed by the use of wood as the material of construction before the +19C.

Because grain milling required higher speeds than achieved with the conventional wheel, power transmission units had to be inserted between the water wheel and the millstones to increase the rotational speed. The units consisted of gears or pulleys and belts or ropes.

When the available heads were greater than the usual wheel diameters, the overshot wheel was used in series. This was to be seen in surprising fashion at the Gallo-Roman

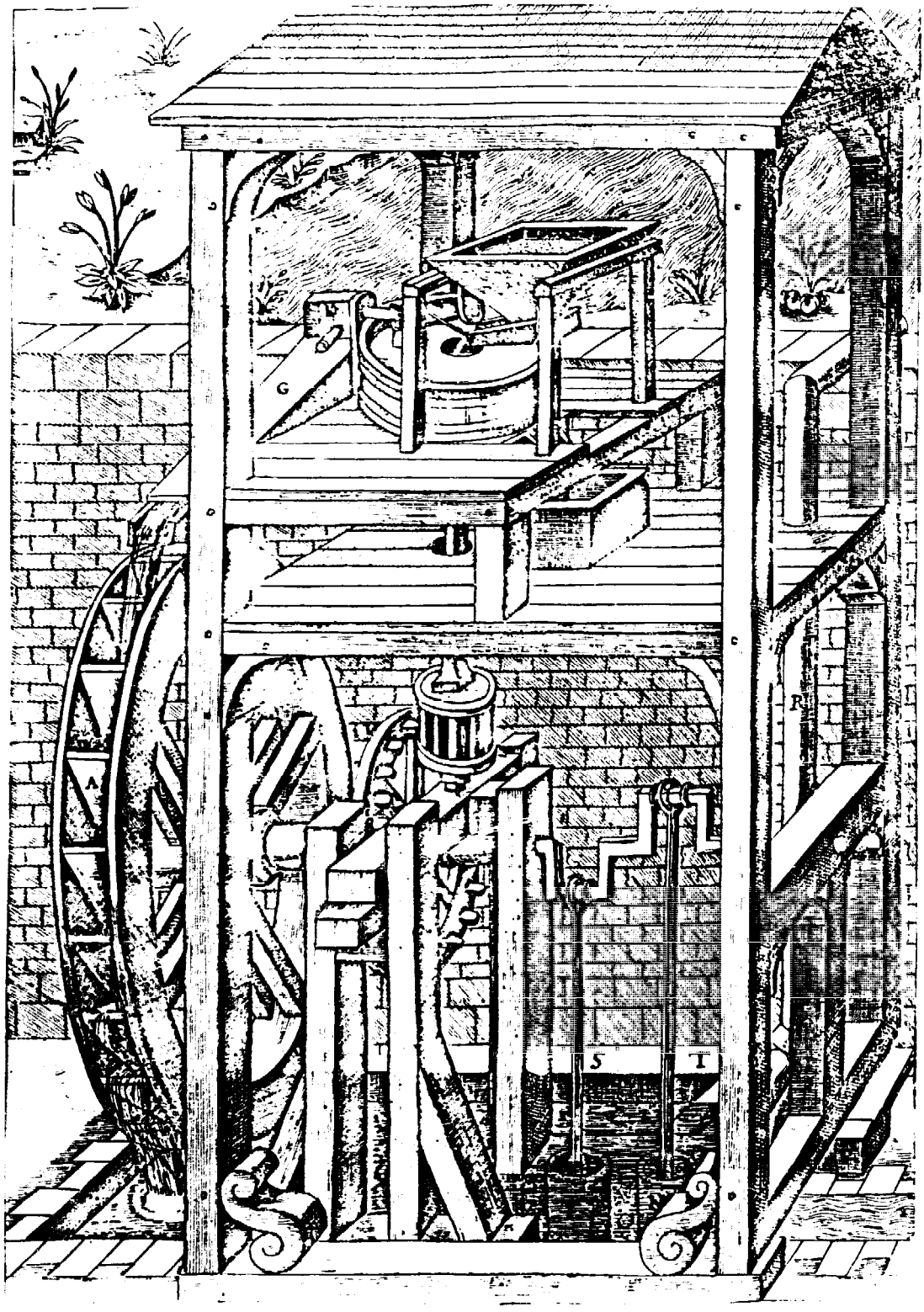

OVERSHOT WATERWHEEL
OPERATING
A GRIST MILL AND A PISTON PUMP
(RAMELLI 1588)

FIG. 8

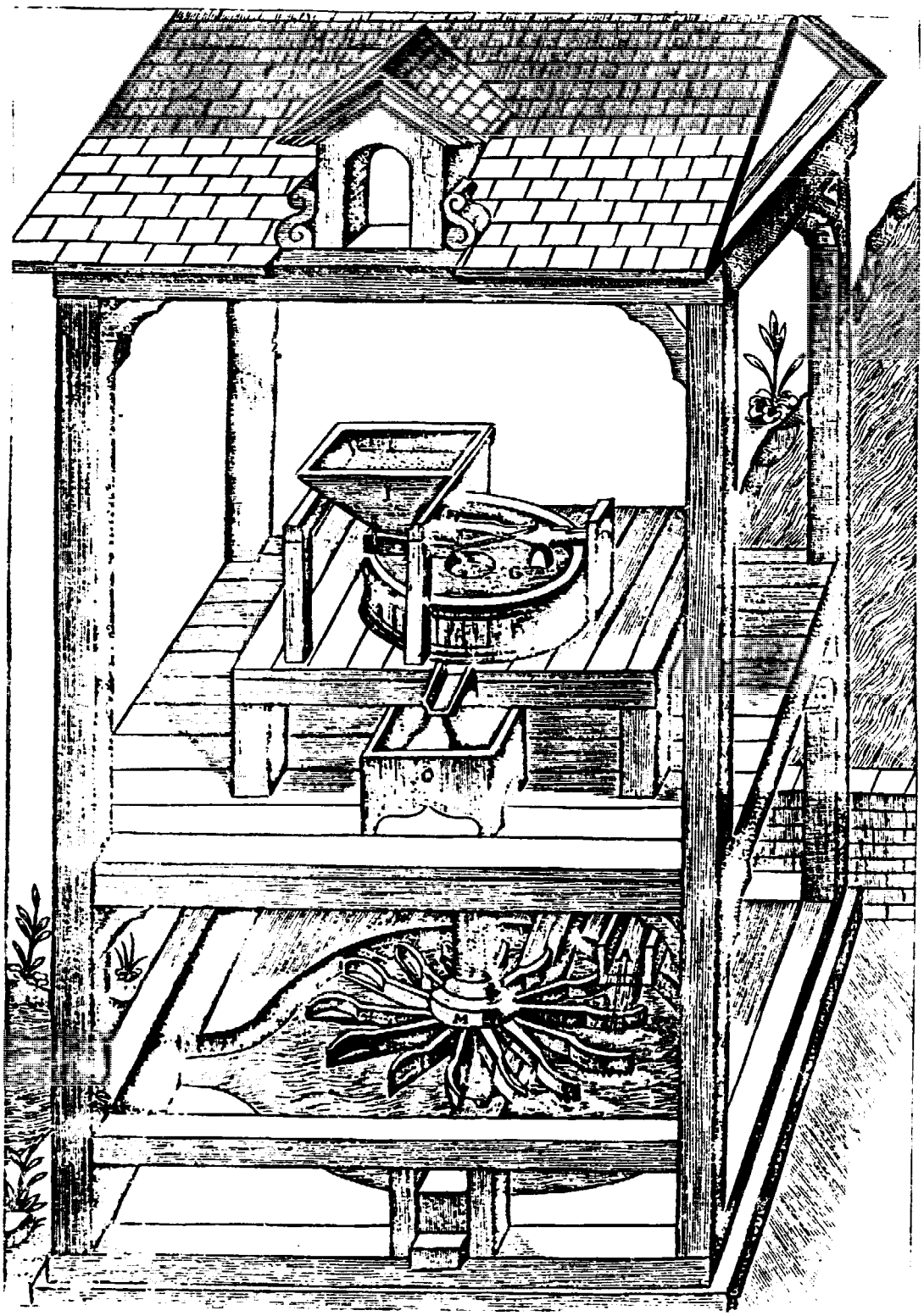

HORIZONTAL WATERWHEEL
OPERATING
A GRIST MILL

(RAMELLI 1588)

FIG. 9

flour mills at Barbegal in southern France; they were built between 308 and 316 AD and represented the largest hydraulic power plant the world was to see for fifteen hundred years: the total power developed there was about 170 horsepower (127 kilowatts).

There were two series of eight overshot wheels, each of which was geared up to drive two sets of millstones. Each series of wheels received water from the aqueduct supplying the city of Arles. They used the water in succession along a slope of 30 degrees and through a vertical height of about 61 feet (18.6 m). Each wheel had a diameter of 7.2 feet (220 cm) and a width of 2.3 feet (70 cm). (Fig. 1)

All together they produced 28 tons of flour per day, mainly for the Roman Legions in southern France. A similar mass production flour mill was built at Prety in Burgundy for the Legions of Northern Gaul.

During the nineteenth century the overshot waterwheel, in responding to demands for increasing power, made increasing use of iron forgings for axles and hubs and cast iron for rims.

In 1854 the largest diameter Western overshot wheel was constructed on the Isle of Man, in the Irish Sea, to pump water from a lead mine. It was 72 ft(22 m) in diameter, 6 ft (1.8 m) in width. It developed about 125 horsepower (86 kw) at 2 rpm. It could pump 250 gallons per minute from a depth of 1200 feet.

In the United States, in 1851, the largest overshot waterwheel was installed at the Burden Iron Works in Troy, New York, for the manufacture of railroad spikes. It was 60 ft (18.3 m) in diameter and 22 ft(6.7 m) in width; it delivered about 200 horsepower at a speed of 2½ rpm.

The Undershot Vertical Waterwheel

The efficiency of the undershot vertical wheel with flat vanes set in a stream ranged from 10 to 20 percent; with curved blades this rose to 20-30 percent. If water was conveyed to either a vertical or horizontal wheel via a close fitting channel or if the wheel was shrouded to minimize the effect of turbulency, these efficiency ranges were doubled. But these efficiencies are maximums which are attained only when the speed of the wheel is roughly

half that of the approaching stream of water: on either side of this wheel-speed, the efficiency decreases; this would happen with variations of load or water supply.

Except for curved blades, the Romans had developed the undershot wheel with shrouds into a standardized piece of equipment which often was of better design and construction than most rural wheels of the +18C. An impression of one in lava was found near Cassino, Italy. It had a diameter of 6.1 ft (1.85 m), a width of 10 inches (0.25 m) and flat paddles. It was estimated that this wheel developed about three horsepower at about 10 rpm. Since millstones required a higher velocity for some of its products, a set of wooden peg tooth gears were used which, in Roman waterwheel practice, stepped up the speed by a factor of five. (Fig. 10)

The output of this rural Roman flour mill was estimated to be 300 lbs (136 kg) per hour. Compared with 20 lbs (9 kg) per hour which could be done by two men on a quern this was indeed revolutionary.

A novel use of the undershot water wheel was developed during a siege of Rome during the +6C. This was the boat/floating mill. It consisted of an undershot wheel suspended between two rigidly connected boats. They were widely used on swift flowing sections of navigable streams in many European countries and China. It has been estimated that on the River Po, in Italy at the beginning of the +19C, there were about 600 boat mills. (8)

The use of boat mills in China begins about the same time as in the West; on them trip hammers were often used for such tasks as:

1. Hulling and grinding rice.
2. Pulping fibrous materials for paper.
3. Pulverizing materials for drugs and perfumes.

In the United States the undershot vertical wheel was used where terrains were unfavorable to the building of dams to impound water and create heads. In the West, the Roman noria, the undershot wheel with buckets attached to raise water, was used occasionally. At Ellensburg on the Columbia River, two crudely constructed wooden undershot waterwheels, one of 42 feet in diameter, and the other 30 feet were used to irrigate 40 acres of land for alfalfa and fruit.

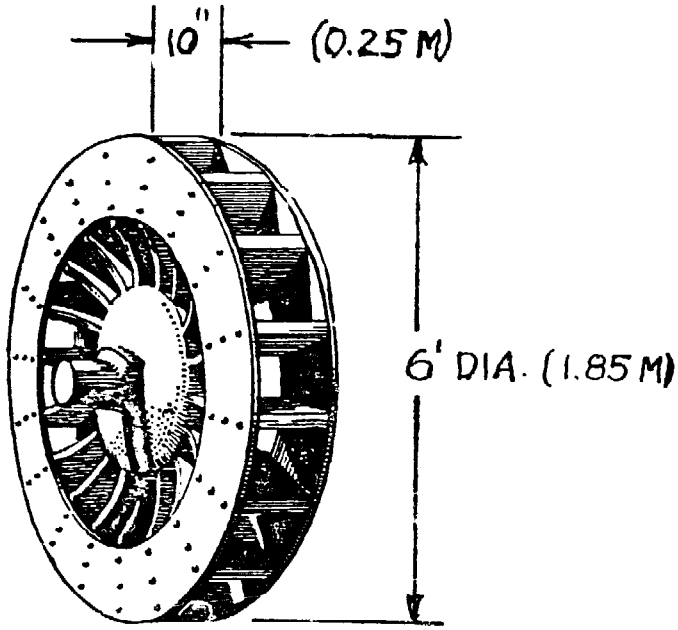

ROMAN UNDERSHOT WATERWHEEL (VENAFRO)

3 HP @ 46 RPM → 330 LBS (150 KG) FLOUR PER HOUR
DONKEY MILL → 15 LBS (7KG) " " "

FIG. 10

And some Alaskan Indians constructed wooden undershot wheels of the noria type but with nets instead of buckets. The nets scooped fish out of the water and dumped them into a chute.

Undershot vertical wheels were also used to develop tidal power along the Atlantic coasts in Europe, England, and the United States. They were generally used as adjuncts to inland water mills or windmills.

The Undershot Horizontal Waterwheel

This wheel rotates in a horizontal plane (its shaft is vertical). Water is conveyed to it by an open or closed channel from water at some elevation usually under 10 ft (3 m).

By the +17C, it had evolved into a high speed elementary turbine in southern France, the Balkans, and China. With curved blades it reversed the flow of water to secure a reactive effect which produced speeds four and five times that of vertical wheels. It could therefore be directly connected to millstones and saws without the intermediary gears or pulleys and belts. They also made use of large diameter shafts for their 'flywheel effect' in smoothing out sudden velocity variations caused by vagaries in water flow and load.

Indeed it was the alleged remarkable performance of the horizontal water wheels at the Basacle flour mills, near Toulouse, France, which, during the +18C attracted the attention of such early French hydro-dynamicists as Euler, Bernovilli, d'Alembert. Their studies of this wheel found focus in the invention of the first practical water turbine by Benoit Fourneyron from 1825 to 1833.

During the +19C, horizontal waterwheels using flat blades were used in northeastern United States for grist and saw mills.

In China, as late as 1958, wooden horizontal wheels, with blades of extreme curvature exhibiting high speed characteristics were being built for connection to small electric generators (under 5 kilowatts) via pulleys, belts or ropes.

From 1910 to 1960, a horizontal wheel was in operation in central New Hampshire grinding grain for animal and poultry feed. It is 7 ft (2.1 m) in diameter and received

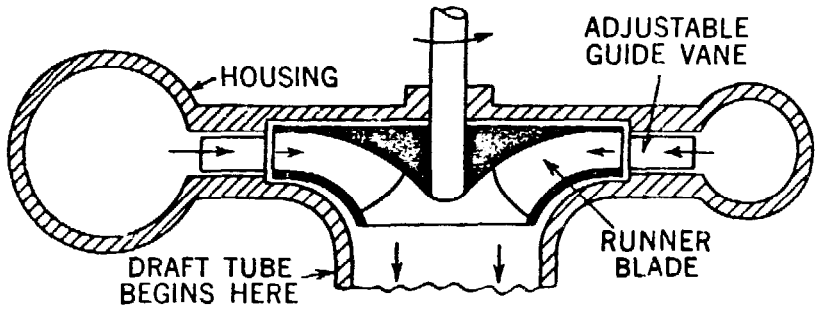

FRANCIS (RADIAL-INWARD FLOW) TURBINE

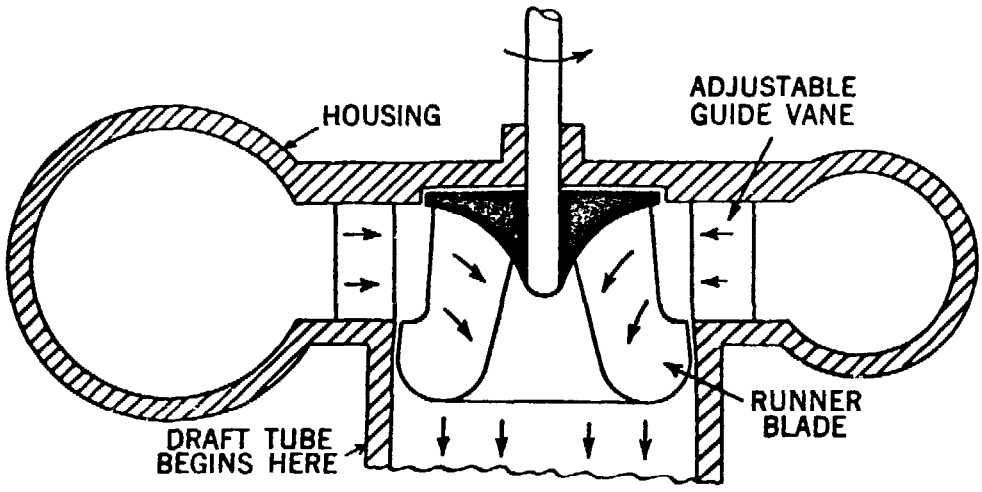

AMERICAN/FRANCIS (MIXED FLOW) TURBINE

FIG. 11

water under a head of 6 ft (1.8 m) through a 2 ft (0.6 m) square closed channel bound with iron straps. It probably developed about 10 h.p. (7.5 kilowatts) at 30 rpm. Its shaft is of steel and 5 inches (12.7 cm) in diameter.

The Water Turbine

The water turbine differs from the waterwheel in that there is a flow of water relative to the blades/vanes; under design conditions the water enters the moving blades smoothly and leaves with minimum energy.

There are three well established classes of turbines which are generally known by the names of their inventors, developers, or promoters. They are in historical order:

1. Francis (reaction, pressure change across blades, full admission, inward mixed-flow). (Fig.11)
2. Pelton (impulse, no pressure change across blades, partial admission, tangential flow).(Fig. 12)
3. Nagler (fixed propellor, or reaction, pressure change across blades, full admission, axial flow). (Fig. 13)
4. Kaplan (variable pitch propellor, reaction, full admission axial flow.

The Francis, Nagler and Kaplan turbines are propelled mainly by reaction forces and appear to be lineal descendants of the Alexandrian (Hero/Ctesibius) steam turbine (-1C or -2C), the first jet engine.

The Pelton turbine/wheel appears to be a descendant of the horizontal waterwheel but it had an independent conception and development in California following the Gold Rush of 1849.

The inward flow Francis turbine was a radical transformation of Fourneyron's outward flow turbine to keep it a high rpm machine while responding to demands for more power. This was done by keeping the rotor diameter increase minimal while increasing the rotor (blade) depth. This resulted in a compact rotor of considerable complexity but not beyond the fabrication capability of the village blacksmith or small town pattern-maker and foundryman.

It was this small Francis turbine which was the principal successor to the waterwheel in northeastern United States. Due to its full admission, steady flow features it was able to approximately double the power of the overshot waterwheel at a given site where the flow of water was adequate. However on small brooks the waterwheel was preferred

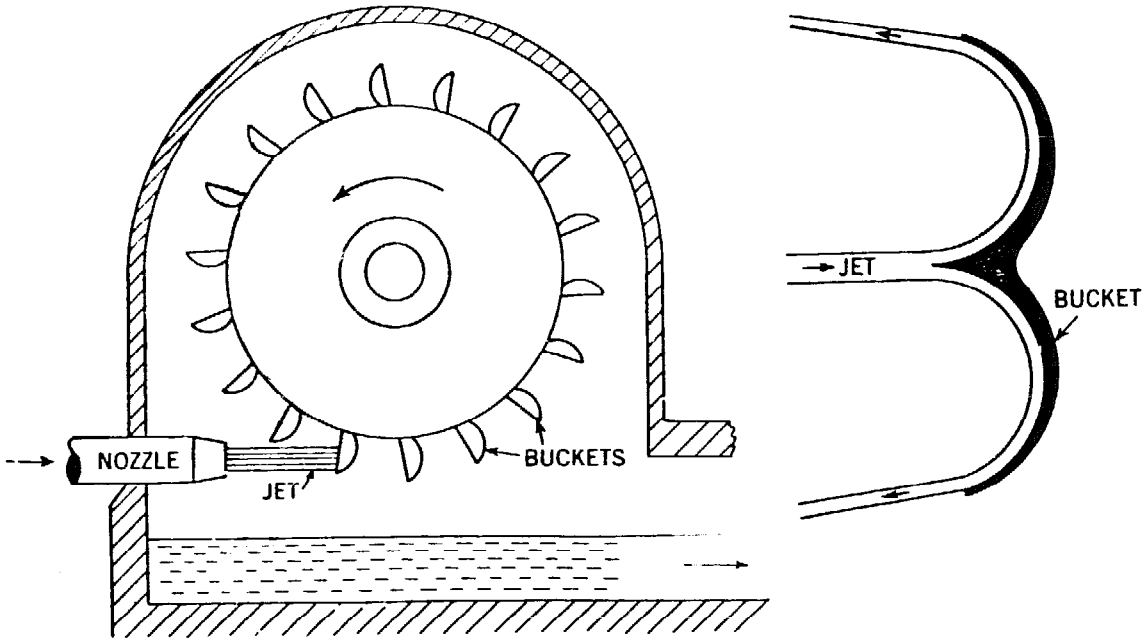

PELTON TURBINE FIG. 12

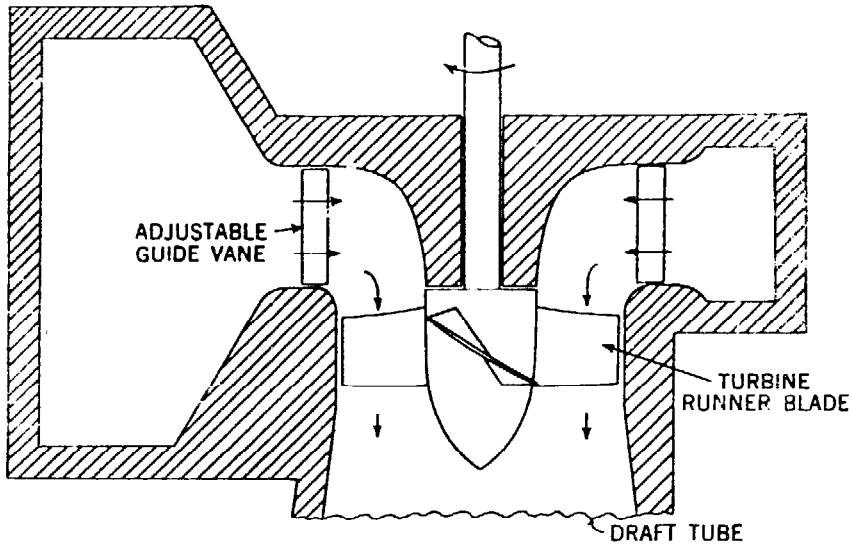

PROPELLOR TURBINE

FIG. 13

because it was more efficient at part loads than the turbine.

The Nagler fixed propellor turbine resembles a ship propellor. This suggests it to be an invention via the inversion method. It is a simpler structure than the Francis turbine and is particularly compatible with the usual waterwheel heads. It came on the scene after World War One with the rise of large central hydro-electric stations and was built for this market as a competitor of the Francis turbine. Its high speed often permitted direct coupling with an electrical generator.

The Kaplan turbine uses a variable pitch propellor. It maintains a higher efficiency under load fluctuations than the other types. But it is mechanically more complex and is generally used only in large hydro-power, efficiency oriented stations.

The Pelton impulse turbine is a partial admission prime mover in which high pressure water is received in a nozzle, converted into a high velocity jet of water and directed onto hemi-spherical blades. It is generally used with heads greater than 100 ft (30 m). Their requirement of long, high pressure pipes/penstocks would preclude their use in many developing countries.

Hydraulic Power Sites

The development of hydraulic power is limited to sites where the evaluation of the following factors must be favorable:

1. Topography (slopes, water storage, evaporation).
2. Geology (run-off, dam sites).
3. Stream flow (rainfall, water shed area).

In developing countries of the past this was done by experienced millwrights; today it is a formalized procedure described in engineering textbooks and handbooks.

The drop in elevation may be of natural origin or artificially created by a dam which also serves to store water. For small mills, economy generally required that the connection (penstock or pentrough) between the dam and turbine or waterwheel be kept a minimum. But with small hydro-electric stations of 1000 kw or less, in New England, it was not uncommon to see penstocks of five and six ft (1.5-1.8 m) in diameter and several miles in lengths.

Log dams of the 'eave' or 'rafter prop' type were generally used in New England. They were cheap and easy to maintain and replace. Their stability was obtained by the weight of water above the 'eave' rather than by the mass of the dam itself. The cost of monolithic concrete or stone dams was generally prohibitive for small New England mill owners.

Summary

The waterwheel and small hydraulic turbine were of basic importance in the development of rural areas of the United States and Europe. Indeed their use may be seen, from an historical perspective, as the springboard from which hydraulically endowed areas were transformed from handcraft economies into diffused machine-based economies with consequential revolutionary increases in the production of goods and services.

The major role in this development was played by the simple waterwheel. The advent of the small hydraulic turbine provided more power at a given site than was feasible with the waterwheel.

The introduction of the small water turbine appears to be taking place in China at the present in much the same way as it did in the United States a century ago. Though large central thermal and hydro-power technology are available to the Chinese, it appears that there is considerable emphasis, at the present, on small hand-controlled machines.

It seems that the history of small scale hydro-power development provides sound suggestions of how to aid hydraulically endowed rural areas of developing countries in achieving an improved standard of life not only for their areas but also for less advantaged areas of their country.

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7

Wood Waste as an Energy Source in Ghana

John W. Powell

THE TROPICAL HIGH FOREST OF GHANA

Kumasi is the capital of the ancient kingdom of Ashanti which now comprises the Ashanti Region of Ghana. Almost the whole of Ashanti is covered by tropical forests and more than half of the sawmills in Ghana are located in or around Kumasi. It is therefore an ideal location for the study of the tropical high forest and the industries which it supports.

Two important institutions located at Kumasi are engaged on research connected with the cultivation and uses of timber. The Forest Products Research Institute of the Council for Scientific & Industrial Research is the principal institution engaged upon research into the industrial utilisation of the produce of the forests. It is situated on the Campus of the University of Science & Technology which is the only technological university in Ghana and includes a course in Timber Technology among its curricula. The University has established a Technology Consultancy Centre to stimulate the development of small industries through the introduction of intermediate technologies and several of its projects involve the use of wood as a fuel or as a raw material. The present paper draws mainly upon the experience of the Forest Products Research Institute and the Technology Consultancy Centre.

The tropical forests of Ghana cover perhaps one third of the land area or about 30,000 square miles. Much of the remainder of the Country supports more limited tree cover of savanna species. It is variously estimated that between 150 and 300 species of trees grow in Ghana. Of these, only 18 are listed as Prime Species with timber that is acceptable on the international market. Only 8 species account for 70% of Ghana's timber exports. These 8 are Mahogany,

African Mahogany, Wawa, Sapele, Utile, Makore, Kokrodua and Anthotheca. Although much effort is expended in attempting to export the so-called secondary species, the situation is changing only very slowly. It is true therefore to say that the vast majority of the trees growing at the present time are not used as timber. According to Siwek[1], about 80% of the Ghanaian species are suitable for use as fuel wood.

There is no doubt that the land area of the tropical forest is reducing and has been reducing for several centuries. The historical cause has been the slash and burn agricultural practice but in recent years, the timber companies have taken out trees faster than the reforestation programme can replace them. The savanna lands drift southwards pursued by the Sahara across the whole of the Sahelian region, and this effect can be seen in Northern Ghana. There is also no doubt that the ecological balance is being upset in other ways especially by the selective re-planting of commercial species in the forest area and fast growing species for firewood in the savanna area. However, this consideration is beyond the scope of the present paper.

THE TIMBER INDUSTRY

According to Siwek, a total of 10 million cubic metres of wood is obtained in Ghana every year. This figure is assumed by the present author to represent the total quantity of wood cut or burned from the forest by all methods. Of this total, Addo[2] states that in 1973, 2.075 million m^3 were won as logs by the logging companies. Approximately half of this timber was exported, some after sawing, and the remainder went to the sawmills and plywood and veneer factories. It is the policy of the Government of Ghana to restrict the export of logs and to encourage the export of sawn timber and wood products. As a result, the quantity of logs exported has been falling and the quantity handled by the sawmills has been rising, although the latter trend is slower. For the purpose of the present paper, the 1973 data and some 1974 data is used.

In 1973, the sawmills of Ghana were said to number 70 located according to region as follows[2]:

Ashanti Region .. .. .. -	36
Eastern Region .. .. .. -	17
Western Region .. .. .. -	8

Brong Ahafo Region .. .. - 6

Central Region .. .. .. - 3

They utilised a total of 0.85 million m^3 of logs. Plywood and veneer factories utilised a total of o.14 million m^3 of logs. It has been estimated[2] that the conversion factor in sawmilling is about 45% while that of plywood manufacture is 39% and that of veneer manufacture is 29%. Hence it can be estimated that waste from the sawmills and factories totalled some 0.56 million m^3 in 1973. This waste was in the form of off-cuts, sawdust, shavings and log cores from the veneer and plywood plants. Off-cuts are used for firewood and as a principal source of material for the charcoal burning industry. Sawdust is little used except for sealing charcoal kilns and some sawmills have a smouldering heap as a means of reducing the accumulation. It is estimated that 25,500 tons of sawdust are produced annually. At least one plywood factory in Kumasi has introduced a wood-fired boiler which burns a proportion of sawdust with wood off-cuts and this trend can be expected to increase.

In addition to the sawmills, there were in Ghana in 1962, (1962 Industrial Census Report Vol.1 - Industry) 1,251 wood sawing establishments. These would include traditional carpenters in informal industrial areas and a few small furniture manufacturers. Approximately, one third to one half of the timber produced by the sawmills and plywood factories is processed further by these establishments with the conversion of a proportion of the sawn timber into additional waste. Much of this waste is in the form of wood shavings produced by planing and some is used for mattress filling and some for land reclamation. Allowing a conversion factor of about 80%, it can be estimated that an additional 0.04 million m^3 of waste results from the local processing of sawn timber and plywood. Hence the total wood waste from the timber industry in Ghana can be estimated to be about 0.6 million m^3.

AVAILABILITY OF WOOD WASTE AND GHANA'S ENERGY NEEDS

The quantity of wood waste produced by the timber industry of Ghana must be considered to be only the smaller part of the total quantity produced by logging, reforestation and farming operations. Using the available data for the years 1973 and 1973, the chart shown in Figure 1 has been derived. The data are only approximate and also change from year to year. It is quite clear that the overall picture is dominated by the 60% which is taken by informal cutting and burning. Included in this amount is about 1.5 million m^3 felled in land clearance for

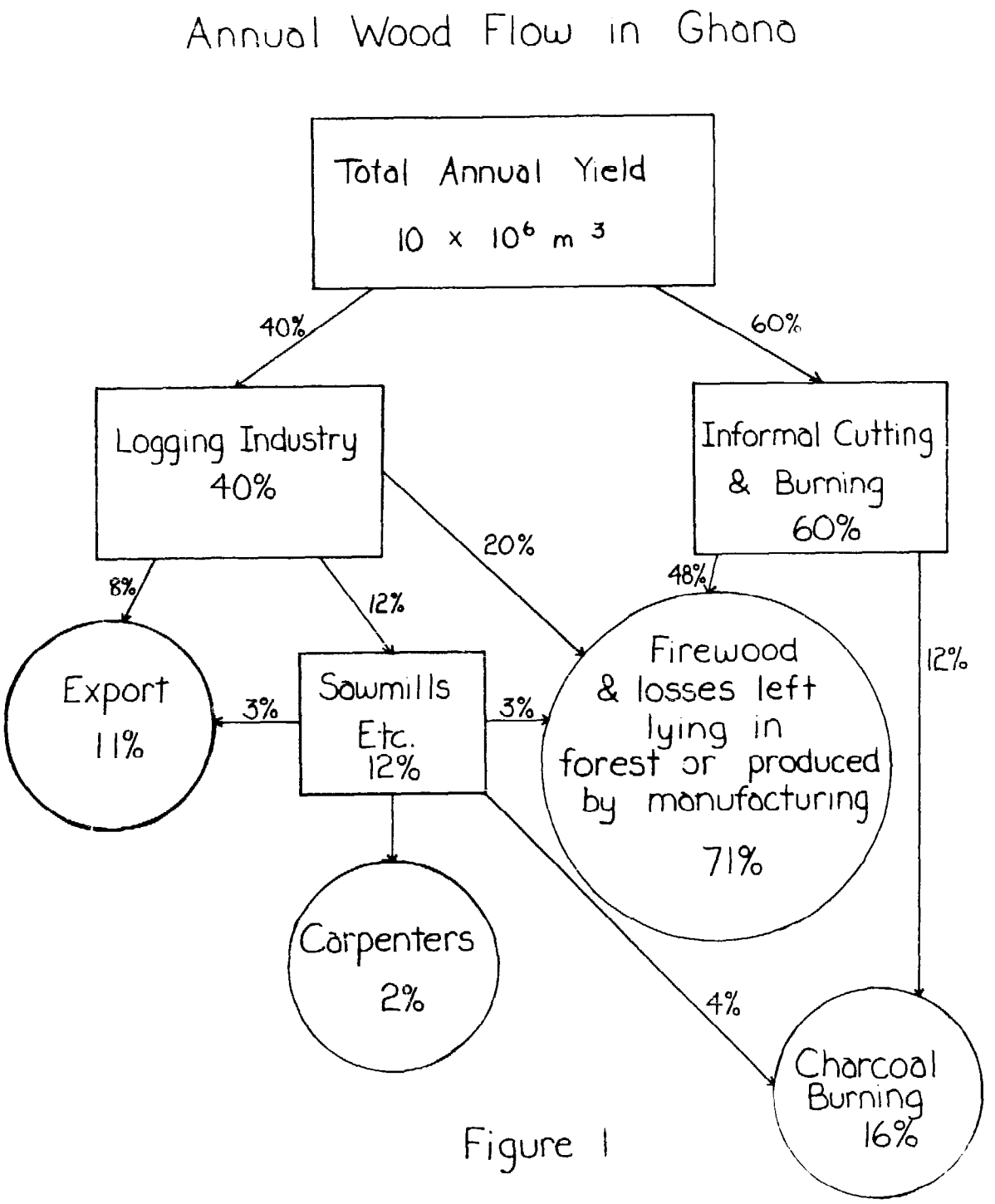
Annual Wood Flow in Ghana
Total Annual Yield
10 x 10⁶ m³
40%
60%
Logging Industry
40%
Informal Cutting
& Burning
60%
20%
8%
12%
48%
12%
Export
11%
3%
Sawmills
Etc.
12%
3%
Firewood
& losses left
lying in
forest or produced
by manufacturing
71%
Carpenters
2%
4%
Charcoal
Burning
16%

Figure 1

reforestation. Ofei[4] estimates that logging operations leave behind in the forest as much felled timber as they take out. This accounts for about 20% of the annual yield. The wood waste available to provide energy as firewood and charcoal represents a very large resource. The quantity of wood involved could total some 8.7 million m^3 according to the available data. Assuming after Siwek that 80% of the Ghanaian species are suitable for use as fuel, the actual quantity of wood available to produce energy might be as low as 7 million m^3 if one allows that non-fuel species are cut down when land is cleared for farming, logging and reforestation. The heat of combustion of this quantity of wood amounts to about 10^{14}KJ. Burning steadily throughout the year, this combustion is equivalent to an energy flow of 3500 MW.

The hydro-electric power station at Akosombo on the Volta River has an installed capacity of 912 MW and represents some 95% of Ghana's electricity generating capacity. The total installed capacity in the Country is therefore less than 1000 MW. However, the power consumed by Ghana's population of 10 million is very much less than this, because the Akosombo plant does not operate at full capacity, 30-40% of its output is exported to the American Volta Aluminion Company smelter at Tema and more power is exported to Togo and Dahomey. The Volta River Authority supplied 3.9×10^9kwh in 1975 which is equivalent to a mean power consumption of 445 MW.

It has been stated[7] that in 1973, Ghana consumed energy amounting to 4.3×10^{13}KJ. About 70% of the total was imported in the form of fuel oils and some coal. These data therefore suggest that the power consumed in Ghana is equivalent to 1500 MW of which only some 450 MW originate in Ghana. It seems probable that the latter takes no account of firewood utilisation and considers only hydro-electric power. What is more clear is that the potential power output of the wood wastes of Ghana is well in excess of the total national power consumption and about seven times the domestic electricity consumption.

No reliable estimate has yet been made of the total utilisation of wood waste for energy production in Ghana. Some estimates have been made of the size of the charcoal burning industry but these vary widely from 70,000 tons to 300,000 tons per annum. The most likely figure seems to be about 100,000 tons which is the conclusion drawn by the Capital Investment Board of Ghana. More than 99% of this total is made in traditional earth kilns with a conversion

factor of from 5 to 15%. Taking a mid value of 10% gives an annual utilisation of about 1.6 million m^3 of wood waste for the charcoal burning industry. About a quarter of this total may come from the sawmills. Referring again to Figure 1 suggests that the balance of 7.1 million m^3 is used as firewood or is lost. All investigators observe that a large proportion of timber is left to rot where it falls. Losses include the branches of trees felled for logging, secondary species felled and left lying in reforested areas and large trees left lying on cleared farm land. Much timber remains unused because it is too large to be cut into pieces for head loading from the forest to the village. However, in savanna areas, where wood is scarce and trees are smaller, all of the felled timber is used and most is consumed as firewood.

PRESENT USES OF FIREWOOD AND CHARCOAL

The greatest proportion of firewood and almost all the charcoal is burned to provide heat for domestic purposes, mainly cooking. It is easy to form the impression in the town that every home has a charcoal stove. The two largest towns, Accra and Kumasi, consume about 70% of total charcoal production. However in the rural areas, large numbers of women and children are seen cutting and carrying wood to their homes. No doubt the cost of charcoal (¢7.50 = $6.52 per sack of 72lbs.) is too high for most families. It is apparent that in the Country as a whole, most families use firewood for cooking. The firewood is burned in a small mud stove of traditional design (Bokyea). A few families have metal stoves, others use old car wheels, concrete blocks or large stones to support the cooking pots. Most of the firewood is collected from the bush and costs nothing in cash terms. The women and children who do this work would not be able to spend the time to earn a cash income and so their time is regarded as free. Near sawmills, wood waste may be obtained for a small charge.

If it is assumed that 1 million Ghanaians use charcoal for cooking in the main towns of Accra, Kumasi, Takoradi, etc. and that the other 9 million use firewood to produce an equal energy supply per capita, then the firewood used for cooking in Ghana would amount to about 2.7 million m^3 or 27% of the total annual yield. Experience suggests that the industrial uses of firewood are unlikely to total more than half the domestic consumption. Hence one arrives at a very approximate total firewood utilisation of 4.0 million m^3. This represents a little over a half of the wood available and although the remainder includes some

species not suitable for firewood, it is clear that a great abundance remains unused. This conclusion accords with the observation made by several investigators that the logging and reforestation operations leave large quantities of wood to rot in the forest. It is also consistent with the fact that firewood is considered to be a free commodity in the forest zone; this being a sure indication that the supply exceeds the demand by a substantial margin.

Most rural industries use firewood as their main source of energy. The wood is burned in furnaces and open fires of varying degrees of efficiency. As examples, one can consider the industries making soap, glass beads, brass castings and hand printed cloth (Adinkra). The soap boiling tank is made of steel and has a capacity of ½ ton of soap. It stands on a metal frame around which a stove is made from bricks and mud. A short section of drain pipe serves as a vent for the smoke. At the Soap Pilot Plant at Kwamo, Ashanti, established by the Technology Consultancy Centre, both electrically heated and firewood plants were assessed. The fuel cost for firewood was less than one half of the cost of electricity. The firewood plant was cheaper to make and easier to operate. There was no doubt that the firewood plant was the appropriate technology even in areas where electrical power was available. In most rural areas, there is no choice of fuel at the present time.

The furnaces for glass bead making at Dabaar, Ashanti and elsewhere are made of brick and clay and use lorry or car front axles for the grid which supports the clay moulds. The furnace operates at 700–750°C. The furnaces used for the lost wax brass casting industry at Kurofofrom, Ashanti are made of similar materials but they are smaller, use a hand operated bellows and operate at a higher temperature. The design has been adversely criticised and is probably inefficient. The Adinkra cloth printers of Ntonso, Ashanti boil their dye over an open fire in the form of a trough formed by large stones or concrete blocks.

Many rural industries making foods and drinks use firewood for heating. Some examples are bread baking, fish smoking, gari making from cassava, pito (beer) brewing and akpeteshi (gin) brewing.

Blacksmiths generally use palm kernel charcoal for their hearths. It is an excellent fuel for this purpose and has replaced the use of imported coke at the Technology Consultancy Centre Workshop.

SOME DEVELOPMENTS IN THE USE OF WOOD WASTE

The University of Science & Technology has become involved in some attempts to increase the utilisation of wood waste. In particular, the prospect of using the large quantities of sawdust from the sawmills presents a great challenge. Mr. R. S. Nijjhar of the Department of Mechanical Engineering has devised a domestic stove that burns sawdust. It appears to be successful and has created some interest locally. Attempts have been made to use the sawdust stove as a heat source for other applications. The development of a superheated-steam bread-baking oven has made some progress. An attempt to link the sawdust stove to a fan driven dryer for agricultural produce failed because the smoke tainted the product.

An application in which smoke is intended to affect the taste of the product is fish smoking. An improved fish smoking oven has been designed by Dr. B. A. Ntim of the Technology Consultancy Centre. Trials have been successfully completed at Kumasi and several ovens are now being constructed at Elmi , on the coast of the Gulf of Guinea. The project is being undertaken for the Food Research Institute of the Council for Scientific & Industrial Research.

The soap boiling tank with firewood heating developed by the T.C.C. has already been described. It was designed with help from Mr. G. Prakash a Consultant from India who visited Kumasi for 3 months in 1975.

DEVELOPMENTS IN THE CHARCOAL BURNING INDUSTRY

Charcoal is made almost exclusively in the traditional earth kiln. The wood is piled and thoroughly ignited. When judged to be sufficiently hot, the pile is covered with leaves or sod and then with soil to exclude practically all air but leaving openings for the escape of smoke and controlled ventillation. When in the judgement of the charcoal burner the charring is complete, all openings are tightly closed and the pile is allowed to cool. By this method, some of the wood is burned to produce the heat required to produce the carbonisation. The yield is poor and the charcoal contains quantities of earth and ash.

Some charcoal burners have established themselves beside sawmills and use exclusively the waste timber for the pile and sawdust for the covering. This system makes use of all the waste and works to the advantage of the

sawmill in that it is relieved of the need to burn its sawdust.

According to Siwek, the traditional charcoal kilns used in Ghana have an efficient of conversion of only 5 to 15% whereas efficient carbonisation should provide yields of around 25%. It is clear therefore that the annual production using the same quantity of raw material could increase from say, 100,000 tons to 250,000 tons if the industry could be converted to the use of modern kilns.

The Department of Forestry has undertaken tests with several types of kiln including the Princes Risborough type of kiln, the Chinese kiln, Unique kiln and Tranchant kiln. The Risborough type kiln was made from mud dried bricks. It suffered from the disadvantage of a long cooling time, although it achieved yields of up to 26%. The Chinese kiln gave yields of only up to 15%. The best results were given by the Tranchant kiln. This kiln was made of steel and was portable. It consisted of two cylindrical sections and a lid. Four air inlets and four flues were arranged at the base of the bottom shell. The average volume was about 1 cord of wood.

Welsing[5] reports some comparative tests carried out with the Tranchant kiln and the traditional kiln. The results are given in Table 1.

TABLE 1

AVERAGE WEIGHT OF WOOD AND CHARCOAL PER CORD RUN
(1 CORD = APPROX. 3.6 m^3 OR 128ft^3)

TYPE OF KILN	WOOD			CARBONI-SATION TIME (HOURS)	CHARCOAL YIELD		
	VOL. (CORDS)	MOISTURE CONTENT	WEIGHT OF CORD lb.		BAGS PER CORD	% GREEN WOOD	% DRY WOOD
Tranchant Kiln	1	48%	3900	50	7	12.9	19.1
Traditional Earth Mound Kiln	3.75	42%	3580	180	2.1	4.2	5.9

Other reports give the yield for the Tranchant kiln based on dry wood weight as 23% and 26%. It clearly provided a considerable advance on the traditional kiln in terms of both yield and process time.

Experiments were carried out in several places using the Tranchant kiln and people were given careful training in its use. However, the kiln has not gained acceptance and many have been abondoned. The main difficulties are the need for skilled operators and the high cost (¢800.00 in 1975) compared to traditional earth kilns which require no cash investment. This fate has befallen other attempts to introduce improved kilns. It may well be that while the availability of waste wood exceeds the demand, there is no economic incentive to seek higher efficiency. Also, Welsing reports that 98% of all workers in the charcoal burning industry received no education of any kind. Such a situation must retard the pace of technological progress. In 1975, there were reported to be only 33 modern kilns in use producing a total of 500 tons per annum[7].

The T.C.C. is hoping to collaborate with the Building & Road Research Institute (BRRI) of C.S.I.R., also located at Kumasi, to construct a pyrolytic converter developed at Georgia Institute of Technology[7]. The pyrolytic converter would be located at the B.R.R.I. brickworks at Fumesua, Ashanti and would supply fuel oil for the brick kilns as well as charcoal for local sale. The process would be continuous and the consumption of dry sawdust would be about 6 tons per day.

Siwek maintains that some species of Ghanaian timber can yield up to 30 or 40% of charcoal by weight. There is no shortage of local supplies of good quality wood, the local demand for charcoal is great and there are prospects for exporting any surplus. One estimate of the local demand for domestic use is 140,000 tons per annum. A proposed ferro-silicon plant would require a further 30,000 tons a year. In addition, Ghana imports over 600 tons per annum of activated charcoal for the sugar and pharmaceutical industries which could be produced locally by pyrolytic converters.

An excellent raw material for producing activated charcoal is coconut shell. The T.C.C. has assisted the village of Elmina to export raw coconut shells to Yugoslavia for this purpose. Together with the available waste palm kernels, another excellent raw material, waste coconut shells could be converted in Ghana into an estimated[7] 2,000 tons of activated charcoal per annum.

This operation could earn or save foreign exchange of over $1 million every year.

Siwek expresses the view that large organisations should be established to take up charcoal production by modern methods. These should be situated near sawmills or firewood plantations. However, such an approach could have unfortunate social consequences and could lead to the demise of the indigenous industry. This has happened to some other industries and advocates of the intermediate technology approach to development prefer to stimulate the gradual upgrading of the indigenous industry. The traditional charcoal burning industry has resisted change and it is to be hoped that it can be persuaded to accept some technological evolution before it is swept away by the power of big business.

GREATER UTILISATION OF WOOD WASTE

There is much evidence to suggest that the waste from the sawmills and the informal wood-working industry is reasonably fully utilised. Most wood waste finds its way into the charcoal burning industry, use as firewood and other informal industrial uses. The one area of improvement is the utilisation of sawdust about which something has been said. However, there is much which could be done to improve the utilisation of the wood waste produced in the forest by the logging operations and by land clearance for farming and reforestation. It may be no exaggeration to suggest that 3 or 4 million m^3 of timber per annum is either burned in land clearance or left to rot in the forest where it falls.

It is difficult to envisage a rapid change in farming methods which would avoid burning useful timber in land clearing operations. One can only suppose that as firewood becomes scarcer, it will become economically necessary to remove all useful firewood before burning the land. This trend can already be discerned from the effects of population growth and the diminishing area of the forest. On the other hand, much could be done to improve the utilisation of non-commercial trees felled in land clearance and logging operations and the branches of the trees felled for logs. It has been estimated[4] that logging operations leave behind 40 to 50% of the wood of all trees felled. Almost no use is made of this wood because it is too large to be cut by hand methods, too heavy to carry by head portage and often located in remote areas. It has been suggested that mobile sawmills could answer this problem. The felled timber would then be cut into manageable proportions for use as firewood or for

charcoal burning. One proposal combines the mobile sawmill with a mobile charcoal kiln. The impediment to this type of development would appear to be that the low value of firewood does not allow for the cost of sawing. In the populus South of Ghana, most firewood is regarded as free and a lorry load of off-cuts from a sawmill costs only ¢25.00 ($22.00) for soft wood and ¢45.00 for hard wood. Until this situation changes, it seems to be unlikely that any rapid development will occur in wood waste utilisation.

It cannot be doubted that the wood waste of Ghana represents a large reservior of energy which can be tapped when it is needed, firstly by making use of present losses and secondly by introducing more efficient methods of utilisation. Perhaps the most immediate prospect lies in the introduction of more industries using wood as fuel. It is perhaps surprising that no wood burning steam engine is known in the Country. The railways use steam engines burning imported coal and, increasingly, diesel locomotives. Unlike East Africa where wood burning steam engines were supplied with fuel from specially prepared plantations, Ghana never seems to have made use of its wood resources in this way. There may be much resistance to the introduction of steam engines for transport or industrial use at the present time. However, the possibility may intrigue some practitioners of intermediate technology who may find some applications where steam power might be both technically and economically feasible. The possibility of power generation using charcoal, residual oil or combustible gas from wood carbonisation or distillation might also be explored. At a time when so much foreign exchange is expended on petroleum products, the incentive to produce fuels and lubricants from indigenous raw materials is very great.

There can be little doubt that the further utilisation of wood waste could reduce importation, support new industries and even boost exports to the great economic advantage of the Country.

APPENDIX 1

SOME APPROXIMATE STATISTICS

Precise data are not available on many aspects of energy consumption and wood utilisation in Ghana. The following data should be taken as only very approximate. In particular, no reliable data is available on the consumption of firewood. Estimates of the quantity of charcoal produced vary by a factor of 4:1. A lower estimate is favoured as a higher one could suggest a gross utilisation of wood as charcoal and firewood in excess of the total available whereas all investigators agree that a large proportion remains unused.

Power Consumption in Ghana

Source	Mean Power Consumption (MW)
Imported oil and coal	1050
Hydro-electricity	450
Firewood (Heat of Combustion)	1035
Charcoal (Heat of Combustion)	115
TOTAL:	2650

Annual Wood Utilisation in Ghana

Use	Volume (Millions of m^3)
Export	1.1
Local Use as Timber	0.2
Charcoal Production	1.6
Firewood	4.0
Unused	3.1
TOTAL: ..	10.0

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8

Methane from Human, Animal and Agricultural Wastes

Raymond C. Loehr

Introduction

In considering alternatives to meet the energy needs in developing countries, there are several key items that should be recognized and achieved. These are: a) in general current methods of producing energy for domestic use, such as burning of cattle dung, crop residues, and wood, are inefficient; b) less plant fuels should be used for combustion to avoid denuding of forests and to maintain soil tilth; c) there should be higher agricultural yields; d) human drudgery should be reduced; e) the energy that is produced should be storable, and f) capital and operating expense should be minimum. In addition, the technologies that are used should be environmentally sound and adapted to and compatible with the local economic, social, and political situation. The most appropriate technology would serve the dual purpose of resource conservation and environmental protection.

Although there is no "ideal" technology that can meet all of the above goals, methane generation is a waste management technology that comes close to achieving many of the goals. The utilization of human, animal and agricultural wastes for methane generation has many positive aspects, including: a) the production of an energy resource that can be stored and is independent of fossil fuel supplies; b) the creation of a stabilized residue (sludge) that retains the fertilizer value of the original material; and c) the saving of the amount of energy required to produce an equivalent amount of nitrogen-containing fertilizer by synthetic processes. Other positive but indirect benefits of methane generation include public health such as a reduction of human pathogens if human wastes are used and a decrease of plant pathogens that may be associated with the crop residues. By using human, animal, and agricultural wastes

for methane generation, the additional value of the methane can be gained while realizing other benefits. The original nutrients in the digested material can be returned to the soil as a fertilizer and to improve soil structure and organic matter content.

In many countries in which methane is produced for domestic or farm use, the drudgery of collecting wood, dried dung, or crop residues and the smoke of burning these materials has been reduced. In addition, when applied to fields, the stabilized wastes resulting from the methane generation have helped increase agricultural yields, control erosion, and maintain desirable soil characteristics.

Background

The interest in non-fossil fuel energy supplies has focused increasing attention on the production of methane from the anaerobic fermentation or digestion of organic matter such as wastes since methane is a high energy by-product. The production of methane from wastes is centuries old and the general technology is well known. The largest application of methane generation has been with municipal sewage sludge. Anaerobic digestion has been widely applied in municipal and industrial wastewater treatment plants for biologically stabilizing organic solids, reducing sludge volumes requiring ultimate disposal, odor control and recovery of the resultant methane for plant heating and energy requirements.

In countries with low natural energy supplies and/or where there is concern over the loss of fertilizer value by alternative uses of agricultural wastes such as burning, methane has been generated from available wastes to meet the existing needs. Extensive work on methane generation has occurred in many countries, especially India, Taiwan, the United States, and Europe and several extensive reports have been published describing design, construction, operation, and results (1-5).

Individual family methane generating units have been used in diverse climatic and cultural conditions. Several thousand units are operative in Taiwan using primarily pig manure and by-products from individually owned and operated pig farms. Crop residues and cow dung have been used in family and village operated units in India for decades. Over 30,000 small methane generation units have been installed in India using some 66.9 million tons of manure which otherwise would be burned. During 1974-75 alone, some 10,000 new methane plants were installed with a goal of 100,000 being

installed by 1980 (6). Units also are reported to be operating in Korea, the Peoples Republic of China, Uganda and in other countries of Asia and Africa.

All organic wastes can be fermented to produce methane. Examples of animal and agricultural wastes that can be used to produce methane are noted in Table 1. Those that have been studied or utilized most extensively are animal wastes, slaughterhouse wastes, and wastes from certain food processing industries. Much more information is available on the digestion of manure and human wastes than on crop residues.

Factors Affecting Methane Production

Biodegradability. The quantity and composition of the gases produced during anaerobic digestion are a function of the fraction of the total waste that is available to the anaerobic bacteria, i.e., the biodegradable fraction, and the operating environmental conditions of the process. The more biodegradable the waste material, the greater the quantity of methane generated per quantity of waste added to a digester. Table 2 indicates the estimated gas production from the manure of various animals produced under conditions in the United States.

As much as 8 to 9 ft^3 of gas (containing 60 to 70% methane) can be produced per pound of volatile solids added to the digester (0.5 to 0.6 m^3/kg) when the organic matter is highly biodegradable such as untreated human wastes or fresh manure. Not all wastes are equally biodegradable and effective in producing methane. The biodegradable fraction of a waste will vary being a factor of the characteristics of the material, the food ingested to generate the human or animal wastes, and how the wastes were handled prior to digestion. For example, only 40 to 50% of the volatile solids of dairy cattle manure may be biodegradable and thus available to produce methane. To use anaerobic digestion effectively, the inclusion of inert material such as sand and dirt in wastes should be minimized and wastes as fresh as possible should be utilized. When a waste is exposed to the natural environment, such as by lying on the ground, natural degradation of the organic fraction takes place and the biodegradable fraction will decrease. In addition, significant losses of nitrogen will occur.

The data in Table 2 incorporate average values obtained from the literature for manure production and biodegradability. The highest amount of gas produced per 1000 pounds live weight was from chickens, indicating the higher amount of biodegradable organics in that material. Under U.S.

Table 1. Agricultural residues having potential for methane generation

- Animal wastes including bedding, wasted feed, poultry litter, and manure
- Crop wastes: sugar cane trash, weeds, crop stubble, straw, and spoiled fodder
- Slaughterhouse wastes, animal by-products such as blood, meat, fishery wastes, leather, and wool wastes
- By-products of agricultural based industries such as oil cakes, wastes from fruit and vegetable processing, bagasse and press-mud from sugar factories, sawdust, tobacco wastes and seeds, rice bran, tea waste, and cotton dust from textile industries
- Forest litter
- Wastes from aquatic growths such as marine algae, sea weeds, and water hyacinths

Table 2. Estimated manure and bio-gas production from animal wastes (7)

	Dairy Cattle	Beef Cattle	Swine	Poultry
Manure production (lb/day/1000 lb live weight)	85	58	50	59
Volatile solids (lb dry solids/day/1000 lb live weight)	8.7	5.9	5.9	12.8
Digestion efficiency of the manure solids (%)	35	50	55	65
Bio-gas production (ft^3/lb VS added)	4.7	6.7	7.3	8.6
(ft^3/1000 lb live weight/day)	40.8	39.5	43.1	110.9

(lb x 0.454 = kg: ft^3/lb x 0.062 = m^3/kg)

conditions, the minimum animals to produce the energy equivalent to one liter of gasoline is approximately: 2 beef cattle, 3.2 dairy cattle, 330 chickens, and 16 swine. These values and those in Table 2 depend on the weight and feed ration of the animals and will vary over a wide range. The data in Table 2 estimates the gross energy possible from digestion and does not include energy required to operate the process.

The ratio of carbon to nitrogen (C:N) in the raw materials is important for the production of methane. Nitrogen is needed for the synthesis and activity of the microorganisms in the anaerobic process. If there is insufficient nitrogen to allow the anaerobic bacteria to reproduce, carbon dioxide will be the principal gas produced. For optimum methane production, the C:N ratio should be below about 30-35.

When largely cellulosic material is being contemplated for methane generation, such sawdust or crop residues, nitrogen in the form of urine, nitrogen rich manures, or urea may have to be added to have the C:N ratio in the feasible range for best methane production.

If the waste material contains quantities of nitrogen such that not all of the nitrogen will be used for synthesis of the anaerobic microorganisms, the ammonia concentration will increase. If excessive nitrogen is contained in the wastes, the ammonia concentration may reach levels that are inhibitory to the organisms and gas production will slow or even cease. Should such conditions occur, the ammonia concentration should be reduced by removing portions of the digester contents, adding water to dilute the remaining ammonia concentrations and adding carbonaceous materials to the feed materials to restore the C:N balance. Types of wastes that have a high nitrogen content are fish scraps, blood, and fresh poultry manure.

It should be realized, however, that if organic material has little biodegradable content and is resistant to microbial action, it wll not be digested even if it has a favorable C:N ratio. In summary, wastes from similar sources may yield quite different quantities of gas. In interpreting the feasibility of waste materials for methane production, both the C:N ratio and the relative ease of degradation of the material needs to be known. Caution is advised in examining results or data obtained from systems using residues having characteristics different from those under consideration. The biodegradable fraction may be different and the residues may have components that may cause inhibition of the digestion process. When wastes for which there is no specific

data are being considered for methane generation, investigations should be made to determine the operating conditions that are needed and the gas generation that will result. Knowledge of the gas production per unit of wastes added to a digester is important to the entire feasibility of methane generation since it determines the quantity of gas available for utilization and the required size of the system.

Microbial Reactions. The oxidation of organic carbon-containing compounds represents the mechanism by which heterotrophic organisms obtain the energy for their activity and for the synthesis of new organisms. In aerobic treatment systems organic carbon is transformed, via many steps to synthesized microbial protoplasm, $C_5H_7O_2N$, and carbon dioxide.

$$\text{Organic carbon} + O_2 \rightarrow C_5H_7O_2N + CO_2 \qquad (1)$$

The uptake of oxygen and formation of carbon dioxide represent the effects of respiration.

In anaerobic systems, molecular oxygen is not the terminal electron acceptor and all of the respired carbon will not be transformed to carbon dioxide. Under anaerobic conditions, organic carbon is converted to microbial solids, carbon dioxide, methane, and other reduced compounds. Anaerobic metabolism leading to the formation of methane occurs in a series of steps. For simplicity these can be summarized as the conversion of complex organics to simpler compounds:

$$\text{Organic carbon} \rightarrow \text{microbial cells} + \text{organic acids, aldehydes, alcohols, etc.} \qquad (2)$$

and the conversion of the simpler compounds to gaseous end products:

$$\text{Organic acids} + \text{oxidized organic carbon} \rightarrow \text{microbial cells} + \text{methane} + \text{carbon dioxide} \qquad (3)$$

Little stabilization of organic matter occurs in the first step. Stabilization of the organic matter occurs in the second step in which the carbon compounds, carbon dioxide (CO_2) and methane (CH_4), are released to the atmosphere and removed from the substrate. The oxygen demand of the waste is thus reduced. At standard conditions, the production of 5.6 ft^3 of methane results in the stabilization of 1 lb of ultimate oxygen demand. Methane generation is a process that results in the stabilization of the wastes, i.e., reduces the biodegradability of the residual material.

These reactions must occur simultaneously since if the reactions become seriously unbalanced, the process can fail. The organic acids, generally referred to as volatile acids, produced during the first stage of the fermentation process tend to depress the pH. This effect is counteracted by the destruction of volatile acids and reformation of bicarbonate buffer during the second stage. If volatile acids build up in the system, the buffer capacity may be overcome and a precipitous drop in pH may occur. Buffering with an inexpensive base such as lime may be necessary to return the system to equilibrium. Other bases can be used but care must be exercised to avoid chemicals that may result in other inhibitory conditions.

The bacteria in the anaerobic systems are sensitive to changes in pH. The optimal pH range for methane production is between 7.0 and 7.2, and gas production is satisfactory between 6.6 and 7.6. When the pH drops below 6.6 there is a significant inhibition of the methanogenic bacteria, and acid conditions below a pH of 6.2 are toxic to these bacteria. Under balanced digestion conditions, the biochemical reactions tend to automatically maintain the pH in the proper range.

Methane bacteria are sensitive to other environmental factors. Because they are obligate anaerobes, their growth is inhibited by small amounts of oxygen and it is essential that a highly reducing environment be maintained to promote their growth. Not only oxygen, but any highly oxidized material, such as nitrites or nitrates, can inhibit the methanogenic bacteria. If chemical additives are required to help balance a digester or provide nutrients, they should be added in the most reduced forms.

The concentrations of any additives should be maintained below concentrations that may be inhibitory. A number of chemicals have been shown to be toxic to the anaerobic bacteria. The toxicity can result in a reduction of gas production, an increase in volatile acid concentration or both. Examples of inhibitory compounds are: ammonium ion (>3000 mg/ℓ) of total ammonia nitrogen at any pH; soluble sulfites (>50-200 mg/ℓ); and soluble salts of metals such as copper, zinc, and nickel. Alkaline earth-metal salts, such as those of sodium, potassium, calcium, or magnesium, may be either stimulatory or inhibitory, depending on the concentration.

With the exception of possibly ammonia, the above inhibitory materials are not likely to cause problems with "typical" human, animal, and agricultural wastes. Such wastes rarely contain the above compounds in amounts likely to be inhibitory.

One exception might be when the human wastes are combined with municipal wastes that include wastes from industry. Certain industrial wastes can add chemicals in amounts that can be inhibitory to anaerobic digestion.

Because methane production is a microbiological process, the factors affecting the process must be understood in both the selection of the material for the process and in its operation. Conditions that inhibit the process must be avoided.

Time and Temperature. The microbial reactions require time to be completed. Time is needed to degrade and solubilize the complex organic compounds in the waste and convert the soluble compounds into the gaseous and other end products (Equations 2 and 3). This time is related to the rate at which microorganisms metabolize the wastes and that rate, in turn, is a function of the temperature of the system. Thus time and temperature are interrelated.

The measure of time usually used for design or operation of biological waste treatment systems, including anaerobic digestion, is the solids retention time (SRT) sometimes referred to as MCRT (mean cell residence time) or θ_c by various authors. SRT is the time that the microbial mass is retained in the biological system.

Fundamentally, SRT should be determined using the quantity of active microorganisms in the system. However, measuring the active microbial mass in biological treatment systems is difficult. Fortunately, other parameters can be used. Assuming that there is a uniform distribution of the active microorganisms and other solids in the methane unit, SRT can be determined by using the quantity of other solids in the system, i.e., volatile suspended solids, total suspended solids, or total solids. In practice, the SRT of the system can be determined by:

$$\text{SRT} = \frac{\text{weight of solids in the system}}{\text{weight of solids leaving the system/time}} \qquad (4)$$

The actual SRT of a biological treatment system must be greater than the minimum time it takes for the microorgansims to reproduce in the system. If this does not occur, the microorganisms will be removed from the system at a faster rate than they can multiply and failure of the system will result. Minimum SRT values for anaerobic systems have been estimated to be in the range of two to six days.

The temperature of the anaerobic digester will affect its performance since it affects the activity of the microorganisms. The optimum temperature of mesophilic anaerobic treatment is 30°C to 37°C. Although the time to obtain a desired degree of treatment is less with thermophilic treatment than with mesophilic treatment, thermophilic conditions have not been demonstrated as practical or economic to date.

It does not follow that anaerobic treatment must occur at optimum mesophilic temperatures. Anaerobic activity can occur if an adequate mass of active microorganisms and a sufficiently long SRT are provided for the system. At reduced temperatures, there will be less active organisms in the system. Total gas production may be reduced if the system is operated at low temperatures. An example of the relationship between SRT, temperature, and gas production that was obtained in one study is presented in Figure 1.

Only in very large digesters is it feasible to consider heating to maintain a controlled temperature at all times. Gas utilization must be planned with the expectation of smaller amounts being generated during the colder periods.

The SRT can be increased by having large enough units so that the input wastes are held long periods of time or by separating the solids from the discharged material and recycling them to the anaerobic system (9). For locations lacking skilled manpower having the knowledge needed to operate a complex anaerobic system, solids recycle is not likely to be used.

In practice, the temperature range of 25° to 35°C and a solids retention time of 10 to 15 days appears to be the most convenient and economic. Reasonably constant temperatures are important to the process. A system with a larger SRT than necessary has only increased digester size and system costs without obtaining appreciably more methane per unit of biodegradable solids.

It may be difficult, especially in colder climates and in the winter, to maintain mesophilic temperatures in the anaerobic digester. Supplemental heat can be used to maintain the necessary microbial activity. Such heat can come from the methane that is generated but will obviously reduce the amount of methane available for other purposes. The anaerobic digestion unit should be well insulated, either artificially or by constructing the unit in the ground.

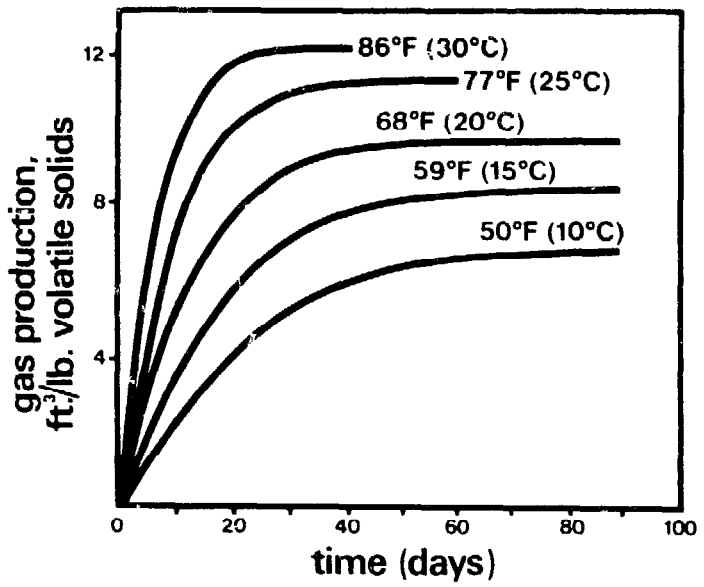

Figure 1. Bio-Gas Production as Related to the Temperature of the Digester and the Time of Digestion (7)

Sludge Utilization

The residue from a methane generation process will contain lignin, lipids, material protected from bacterial degradation, synthesized microbial cells, metabolic degradation products such as volatile acids and other soluble compounds, inert material in the original waste, and water. The residue will be a liquid with a solids concentration of 4-8 percent. Anaerobically digested sludges can be stored and spread on land with less risk of creating conditions for odor and insect breeding problems than exists with similar handling procedures for untreated or partially treated organic waste materials.

Methane generation conserves the nutrient elements needed for crop production. The only materials removed from the system, other than in the sludge, are the generated gases. Practically all of the nitrogen present in the waste entering a digester is conserved. If the sludge is properly stored, and when applied to soils is immediately incorporated to reduce the loss of nitrogen by volatilization, most of the nitrogen present in plant residues can be available for use by the growing plants. To minimize ammonia nitrogen losses, the digested sludge should be stored in lagoons or tanks which present a minimum of surface area for ammonia evaporation. Other chemical elements contained in the added waste will be conserved in the digested sludge.

The end result of applying digested sludge on soils is the same as that resulting from the application of any other kind of organic matter. The humus materials can improve soil physical properties such as aeration, moisture holding capacity, increase cation exchange capacity, and improve water infiltration capacity. The sludge can serve as a source of nutrients for crops grown on the soil. When human, animal, and agricultural wastes are used for methane generation, there is little likelihood that any items in the sludge will cause adverse conditions to the crops or to animals fed the crops grown on land where digested sludge is used as a fertilizer.

The application of the digested sludge to the crop land should be done in an environmentally sound manner, generally at rates consistent with the need of the crops being grown. Runoff that can contaminate surface waters and loadings that result in ground water contamination must be avoided.

An important aspect to be considered with methane generation is that the total volume of sludge that must be handled for final disposal is equal to or greater than the initial

amount of dry wastes that are to be digested because of the liquid added to obtain a solids concentration that can be mixed. Although considerable solids decomposition occurs in a digester, approximately 50%, little reduction of the total volume to be handled results.

Gas Utilization

Key items in the successful operation of a methane generation system are: (a) acceptance by the potential user, (b) ability to use the gas when produced, (c) sufficient demand for the gas, (d) enough raw material available to meet the production requirements, and (e) suitable maintenance and operational control.

Pure methane is a colorless and odorless gas which generally constitutes between 60 and 70% of the gas produced by anaerobic digestion. The other constituents are primarily carbon dioxide and smaller concentrations of other gases such as hydrogen sulfide and hydrogen. Digester gas (biogas) burns with a blue flame and has a heat value ranging about 600 to 700 Btu/ft^3 (22,000 to 26,000 kj/m^3) when its methane content ranges from 60 to 70 percent.

Many options exist for utilizing the digester gas. It can be used directly in gas-burning appliances for heating, cooking, lighting and refigeration or it can be used as fuel for internal combustion engines having a compression ratio of 8:1 or greater. However, to use digester gas in internal combustion engines, it is necessary to a) reduce the hydrogen sulfide content of the gas to less than 0.25 percent to prevent corrosion of metal surfaces, b) provide a system to remove the carbon dioxide to increase the heat content per unit volume of the resultant gas, c) compress the gas to a volume that would fit on a vehicle or adjacent to a stationary engine, and d) have an internal combustion engine converted to use either gasoline or methane.

Another possible use is the production of electricity using methane. However, the cost of converting the methane to electricity currently results in an energy cost that is higher than that available from other sources. As the cost of more traditional energy sources increases, the costs of electricity production from methane may become more attractive.

For small units, it is not practical to compress and store the gas for subsequent use. Major use of such gas must be at the production site. The gas is generally and most simply used for heat or light in appliances that use the gas directly from low-pressure collection units. A small digester

with a floating cover can provide the needed gas storage. Another approach is to have gas from a digester with a fixed cover piped for collection in an auxiliary gas holder with a floating cover. A gas delivery line is connected to the gas storage unit with an on-off control valve. This delivery line must contain a flame trap installed between the gas storage unit and the appliance being used. Systems of this type are in current use in India, Taiwan and other warm climate areas.

The size of the digester and gas collection unit is related to the rate of gas that is utilized and the number of appliances that are connected. Consumption rates for gas burning appliances (Table 3) are useful in determining the necessary sizes.

Although general information on the design of anaerobic digesters is available, the state-of-the-art of anaerobic digestion of agricultural wastes is not such that all producers can successfully operate an anaerobic digester nor utilize the resultant gas. Considerable investigation and full scale testing in specific situations may be needed to show the practicality and feasibility of energy recovery from the anaerobic digestion of the available human, animal, and agricultural wastes.

Collection and Preparation

An important aspect of methane generation is the collection and preparation of the materials to be used in the process. When considering the feasibility of a methane production system, all of the components, i.e., collection, preparation, storage of the raw material, generation, storage of the gas and residue, and utilization of the gas and residue must be considered. Capital and labor requirements and annual costs must be determined for all the components and related to the local labor, material, and cost conditions.

In labor-intensive economies, methods that can utilize the human and animal resources available for the handling and processing of these wastes should be considered. Since the intent of anaerobic digestion is to produce an energy source, methods that utilize fossil fuel or other conventional sources of energy for handling, processing, heating and mixing these wastes may not be appropriate unless there is a significant net benefit.

The collection and processing of raw waste materials depends on their nature, which may vary between countries and regions, as well as the quantities in which they are available.

Table 3. Quantities of bio-gas required for a specific application (10)

Use	Specification	Quantity of Gas Required	
		ft^3/hr	m^3/hr
Cooking	2" burner	11.5	0.33
	4" burner	16.5	0.47
	6" burner	22.5	0.64
Gas lighting	per mantle	2.5-3.0	0.07-0.08
	2 mantle lamp	5	0.14
	3 mantle lamp	6	0.17
Gasoline or diesel engine [a]	Converted to bio-gas	16-18 per hp	0.45-0.51 per hp
Refrigerator	per ft^3 capacity	1	0.028
Incubator	per ft^3 capacity	0.45-0.6	0.013-0.017
Gasoline	1 liter	47-66 [b]	0.013-0.017
Diesel fuel	1 liter	53-73 [b]	1.50-2.07 [b]
Boiling water	1 liter	2.2 [c]	0.62 [c]

[a] Based on 25 percent efficiency

[b] Absolute volume of bio-gas needed to provide energy equivalent of 1 liter of fuel

[c] Absolute volume of bio-gas needed to heat 1 liter of water to boiling

Hence the method for collecting and handling the waste materials may vary. The materials available for methane generation may be solid, semi-solid or liquid. Thus the collection methods that will be needed will be related to the characteristics of the wastes and the socially acceptable methods of handling them.

Crop residues such as spent straw, hay, sugar cane trash, plant stubble, grasses, and bagasse can be used for the generation of methane. To enhance gas production, facilitate their mixing and transport in and out of the digester, and to avoid clogging, such material should be finely chopped or shredded. In rural areas manually operated shredders could be used.

When different wastes are to be added, they should be mixed prior to their addition to the digester. The wastes should be added daily to the digester to insure a continuous supply of gas and to avoid a deterioration of the methane generation process. Accumulated wastes can be stored briefly before being added to the digseter. Care should be taken to avoid losses of nutrients, fly breeding, or odors during the storage.

Equipment

The main components of a methane generation system are a raw waste feeding unit, a digestion unit, a gas holder, a moisture trap, and an outlet for the gas to be utilized and the digested solids. A sketch of a small scale system for heating and lighting use is shown in Figure 2. For larger systems and other uses, a methane generation system may include a raw waste storage unit and units for hydrogen sulfide and carbon dioxide removal and gas compression.

The pieces of equipment can be made from many types of material. Where available, brick, cement, concrete, and steel pipe can be used. The gas holder may be a steel drum. Lime mortar can be used if cement is in short supply. Other material such as glazed pottery rings cemented together and similar local materials can be used to construct the needed equipment. Hand plungers can be used to force the feed material into the digester. Both horizontal and vertical digesters have been used with vertical units being predominant in countries where biogas plants are in operation. For small systems and needs, large inner tubes have been used as gas collectors. The simplest system consistent with the need and labor available should be constructed. Materials that are long lasting and require minimum maintenance should be used.

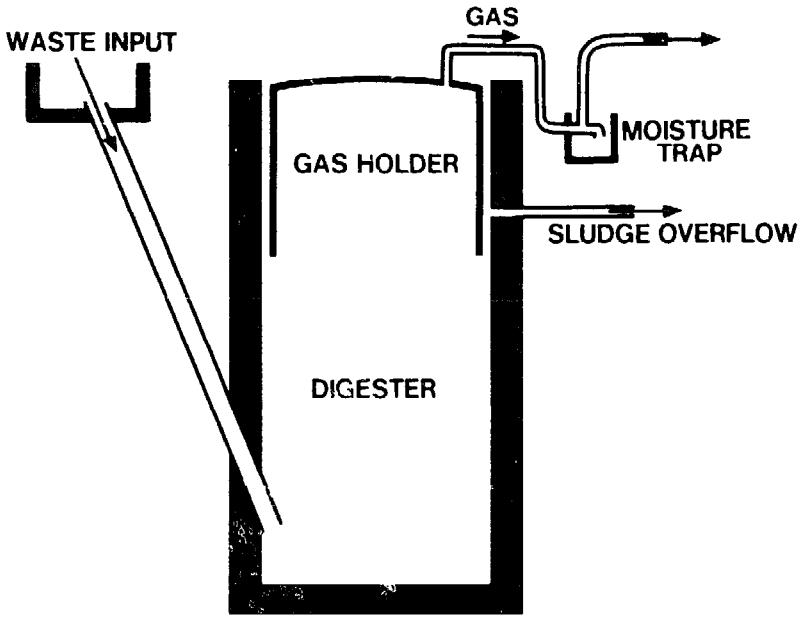

Figure 2. Schematic of a Small Scale Bio-Gas Digester

When the raw wastes are added to the digester, the digested slurry automatically overflows and should be captured for subsequent use as a fertilizer. The slurry can overflow into a container filled with straw, leaves or similar material and used as a solid or semi-solid fertilizer. It can also be collected as a liquid and used in that form.

Operation

In a developing country and a rural setting it is unlikely that a continuous anaerobic digester would be used, because of the necessary feeding and controlling mechanisms. A batch or semi-continuous operation is the more common method of operation. A digester may operate on a "fill and draw" basis with a one-day to one-week cycle, or it may be designed on an "all-in, all-out" basis where the reactor is charged and emptied when gas production is almost completed or at a very low level. A combination of the two systems also may be considered depending upon particular needs. The semi-continuous digesters are used for waste that is available on a frequent, preferably daily, basis. Most digesters in developing countries operate as semi-continuous units.

Batch-fed digesters can be constructed where raw waste materials are difficult to obtain on a daily basis. The wastes are added to the digesters, covered and permitted to digest. After an initial interval that will depend upon the temperature of the digester and whether the digester has been seeded with active anaerobic organisms, gas production will begin and continue until all the biodegradable material is used. When gas production ceases the digesters are opened, cleaned, and the slurry is disposed of on land as a fertilizer. Because of the batch nature of the system, it is desirable to have two or more digesters, so that one or more can always be in operation and gas production be fairly continuous. Periodic emptying of the digesters is labor intensive and can be unpleasant. When batch units are emptied, about one quarter of the digester contents should be left to seed the incoming raw material.

Biogas production is dependent upon the concentration of solids in the influent material. Too thick of a material will retard natural mixing in the digester and may require mechanical mixing. Investigations indicate that, in the absence of toxic materials, optimum gas production is obtained with a total solids concentration of about 7 to 10% in the effluent slurry. This may require a dilution of one part manure to two or three parts of water depending upon the initial condition of the manure.

Economics and Feasibility

Although methane generation has been successful in specific areas such as in India and Asia, economic considerations may preclude or limit its adoption in other countries. The economic feasibility of methane generation from wastes can vary widely and is dependent on factors that include the availability of domestic sources of energy, the cost of imported fuel, the uses and actual benefits from methane production, public and private costs associated with the development and utilization of methane, the availability of wastes to produce a consistent supply of methane, and on the equipment and manpower need to generate methane.

The availability and accessibility of other domestic energy sources and the opportunities to use the methane are important determinants of the feasibility of methane production. The opportunity costs associated with the use of other energy sources, such as the use of coal or petroleum for industrial expansion, need to be taken into account.

Studies in industrialized countries with access to fossil fuels indicate that methane generation is not economical even for farm and small communities with the present technology and energy costs. Methane generation is likely to have its greatest use in areas remote from fossil fuels or other energy sources, where available fuels are better used for other purposes, and for small villages and activities where the methane is used at or close to the production site.

Generally, the cost of a methane generation system and its operation has been charged against energy production. The direct benefits are those accruing from heating, cooking, lighting, refigeration, pumping irrigation water, or running other power units. However, other benefits also may accrue as a result of methane generation, such as improved public health, agricultural productivity increases, and increased employment. The use of village scale digesters can provide a sanitary means of human waste disposal that might otherwise be lacking. These benefits, although less tangible than direct energy use should be taken into account when distributing the costs of methane generation.

In addition, the wastes would have required some expense for environmentally sound management. The costs charged to methane generation should be those that are in addition to the waste handling and pollution control costs that would normally occur.

In order for a methane generation program to be successful in most developing countries, some financial and continuing technical assistance from central and local governments will be needed. Part of the material and equipment cost of individual methane generators might be the responsibility of central and/or local governments. Trained technical personnel can be important to help the local people learn to install, operate, and maintain methane digesters. The importance of technical assistance should not be minimized. Demonstration facilities may be required, and early adopters may need to be subsidized as an incentive to aid the large-scale adoption of this technology. The particular educational means to obtain wide scale use of methane generation can vary among regions and countries.

It is technically feasible to generate methane from human, animal, and agricultural wastes if the factors discussed earlier are understood and properly utilized. The economic feasibility of methane generation will depend upon the particular set of circumstances and can only be evaluated on an individual basis. In addition to the cost of the equipment, manpower, disposal, and opportunity costs of alternatives, of particular interest are the needs and goals of the areas, countries, and regions, and the impact on the culture and social fabric of the individuals and communities to be involved.

Methane generation must be considered as part of a total resource conservation and utilization system. Factors such as availability of the wastes, collection, transport, methane generation, gas and sludge use, energy needs, manpower, and the social and cultural effect need to be considered in an inter-related and holistic manner. Only in such a manner can the actual feasibility of methane generation in a developing country be ascertained.

Summary

Extensive experience with methane generation, especially at the village or smaller level, has been obtained in several countries and over several decades. Methane generating plants can be designed either to process a given amount of waste material, or to produce a given quantity of gas required for a specific use or uses. Irrespective of which approach is taken, an understanding of the parameters that govern the process of anaerobic digestion is essential for proper design and use of biogas plants.

Digester design, waste input, and gas utilization must be tailored to the manpower and other resources, energy and

social needs, climatic conditions, and materials [illegible] each locale. All of these factors must receive close [illegible]nsideration when the feasibility of a methane generatio[illegible] system is evaluated. A technical assistance program may [illegible] needed in areas where methane generation is determined t[illegible] feasible. It is desirable to have local involvement in t[illegible] planning, construction, and operation of the digester a[illegible]n the utilization of the gas and the sludge. Use of su[illegible]e local materials and equipment should be investigated.

Before methane generation is utiliz[illegible] in any area or with specific wastes, the equipment should be demonstrated to be functional at the scale of the proposed operation, the operation should be simple, the system should have clear, preferably written, instructions for operation, the equipment and its capacity should be suitable for the quantities and types of material(s) to be handled and compatible with other components, and users and/or operators must be capable of properly maintaining and operating the methane generating and utilization equipment.

Individuals who have experience with the methane generation are cautiously optimistic about its prospects. The fundamentals of the process are well known, there is a signilicant quantity of human, animal, and agricultural wastes that may be available, and these wastes can produce large quantities of methane gas. The present technology can be utilized and adapted to local conditons where appropriate. Such utilization should occur only with competent guidance and after a careful evaluation of the technical, economic, and social feasibility.

Acknowledgements

The material that is presented is a brief summary of the important factors affecting the use and operation of methane generation facilities. Many comprehensive reports and articles (1-6, 10-13) are available on the subject, some with specific emphasis on the use of methane generation in developing countries and rural areas. Individuals wishing to pursue the subject in greater depth are encouraged to read the noted articles and reports as well as others that are available.

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Summary and Discussion

Roger Revelle

We had a wonderfully interesting discussion today. In different ways nearly all of it was about solar energy. Mr. Löf started out this morning by talking about the direct absorption of solar radiation and its use for heating and cooling. Mr. Prinz discussed the conversion of the radiant energy coming from the sun into electricity by the photovoltaic method, and the further utilization of the high temperatures generated in this process as a source of useful heat. Mr. Tewari talked about the uses of wind energy in India, but of course the energy of the wind results from the differential heating of the earth by the sun, so it too is a form of solar energy. Mr. Ermenc talked about small-scale hydroelectric power. Here, the radiant energy from the sun is converted into gravitational energy through the hydrologic cycle, and the hydroelectric plant in turn converts this gravitational energy into electrical energy. This afternoon Mr. Sakr discussed the use of flat plate collectors and concentrators for the direct conversion of solar energy into heat in Egypt, and Mr. Loehr talked about the use of biological materials as a means of converting solar energy into humanly useful work. From an energy point of view, as he pointed out, the non-edible portions of agricultural crops are just as much a potential resource as the part that can be eaten by human beings, because energy for cooking is an integral part of the human food system everywhere. If we were forced to subsist on raw food, there simply would not be enough to eat for the large

numbers of human beings who now live on this planet, not to mention all the other things we do with energy that make the difference between living like human beings and living in an inhuman way. Then Dr. Powell talked about another biological device for converting solar energy--the use of wood in Ghana and the potential for using a good deal more. And finally Mr. Miccolis talked about the very impressive new energy program in Brazil, in which sugar cane and other biological converters of solar energy will be used in an attempt to solve their severe energy crisis. Brazil apparently has very little oil (at least on land) and not much usable coal, and the four or five-fold rise in the price of imported fossil fuels is causing serious economic problems. These same problems will be faced by every country in about 30 years, when the oil reserves start to run out. So the Brazilians are simply pioneers in a situation that may become universal within our lifetimes.

If we summarize what we have learned about all these methods of using solar energy it is clear that we are really concerned with the best allocation of resources, which is the central theme of economics. One characteristic of resources is that they are scarce. There aren't enough of them to go around, and consequently there are always competing uses and needs for resources. Unless we allocate resources as economically, rationally and prudently as possible in the face of competing needs, the processes of development in the poor countries will become much more difficult. The economic objective of development can be quite simply defined: to increase human productivity. How can resources be best allocated to increase human productivity, which is the only way that real incomes can be raised? Incidentally, when we think about appropriate technologies for the developing countries, our criterion should be whether these technologies are in fact likely to increase productivity. This can be accomplished in two ways, either by producing more per man-hour, or by increasing the number of man-hours, i.e. by increasing employment.

In choosing among energy sources and uses for the rural areas of developing countries, we are concerned with scarce resources and their most economical allocation, both the natural resources

of land, water, fertilizer, metals, and fuels, and the human resources of capital, labor, human energy, skills, management and organization. The scarcest resource of all in most developing countries is trained management ability--the ability to organize and administer, to create an organization and to make it work.

We must also ask what are the needs for new sources of energy? One need is to reduce human drudgery, as Professor Loehr pointed out this afternoon. Theodore Schultz, the great agricultural economist of the University of Chicago, tells a wonderfully illustrative story. He talked to some women in a village in Senegal, who were threshing millet by pounding a heavy pestle into a large wooden mortar. They had to do this all day to separate the millet grains from the chaff. It was very hard, very dull work. They said "We've heard about a thresher in the next village that does this mechanically. If we had one we wouldn't have to do this task by hand. Why can't we have one?" We tend to think of people in less developed countries with high levels of unemployment and underemployment as being eager to work in hard drudging tasks if they have the opportunity, tasks which will require them to use about half their food energy in work. We think of such drudgery as being natural for them, but we don't think of it as being natural for us. In fact, there are probably few human beings anywhere who are fond of continuous hard manual labor, such as the labor involved in traditional farming.

A second need for new sources of energy is to reduce costs. The most expensive form of energy is human energy, as can easily be seen if we consider how much food it takes to keep a man going at hard manual labor. Ricardo's "iron law" says that wages always tend to go down to the subsistence level, i.e. to the level where a working man is able to buy with his wages barely enough food to feed himself and his family. But the corollary to Ricardo's law is that wages can't go below the level of subsistence, and this level is not cheap. It takes about 15 cents a day to feed a man even on the least expensive of diets, and he is able to put out somewhat less than a kilowatt hour per day of useful work. Even at present costs of fossil fuels a kilowatt hour from gasoline costs about 3 cents.

Animal energy is also expensive. Consider for example the opportunity costs of feeding a bullock. A farmer can use part of his land to grow fodder for his bullock, but he could grow wheat or rice or corn on that same land.

Finally, new sources of energy are needed in order to increase the total amount of energy available. In my talk this morning, for example, I showed that by increasing the quantity of energy used in agriculture, the annual yields per hectare could be tripled or quadrupled.

What are the specifications or characteristics to be kept in mind in evaluating potential new energy sources? To be most useful in less developed countries, any potential energy source should have a low capital output ratio, the income obtained each year should be at least half and preferably equal to the capital investment. The capital costs should be low for another reason: capital is scarce in developing countries and correspondingly interest rates are, or should be, very high. If the capital costs for a new energy source are a large part of the total costs high interest rates are likely to make it uneconomical. For the same reason it should be possible to amortize the investment over a long lifetime, i.e. the rate of depreciation should be low. Small unit costs are desirable in order to keep the investment from being "lumpy." For this reason "micro" or "mini" hydropower plants using "run-of-the-river" installations are attractive.

Any energy source for developing countries at the present time should be manpower-intensive rather than capital-intensive. Its development should use people rather than capital because people are less expensive and more abundant than capital in most less developed countries. In other words, energy investments, like other investments, should take account of the factors of production. But one scarce kind of manpower is skilled manpower. Hence new energy installations should be as simple as possible, because there are so many competing demands for skilled manpower. If possible there should not be other competing uses for a new energy source. For example wood can be used for industrial purposes as well as for fuel, and in mountainous regions it is essential to leave the trees

where they are to prevent erosion. Straw, if it is not burned for energy, can be used for animal feeding and for compost to fertilize farm fields.

In the hills of Nepal the farmers are reluctant to use the new dwarf varieties of rice because these new varieties don't produce much straw. They need straw to feed their livestock. They need the livestock to produce dung to fertilize their fields. During the monsoon season the cattle and buffalo gather nitrogen from pasture land, and part of this nitrogen is excreted in their dung. The farmers collect the dung and carry it to the fields as fertilizer. During the dry season little nutrient material remains in the pastures, and the livestock must be fed on straw. Here is a closed farming system which is very hard to break into or to change. From an energy standpoint the farmers would be unable to convert the energy in the straw into some other form of energy because they must feed it to their livestock.

In many cases, in less developed countries, local energy sources should be used rather than centralized sources, and local energy conversion plants should be constructed rather than central energy conversion plants. For example, the load factors for electric power are usually quite low, and consequently the capital costs of electric transmission systems from central plants per unit of energy are very high.

Problems of energy storage arise because local energy sources are not available all the time. Energy storage is essential if the inedible parts of crops such as corn stalk or rice straw are to be used as an energy source. When these inedible portions are left standing in the fields after the end of the growing season, their contained energy quickly disappears into the air. They must be used when they are freshly cut. Similarly the contained energy of sugar cane rapidly disappears after it is harvested. If one attempts to use run-of-the-river hydropower in Nepal or elsewhere in the Indian subcontinent, there will be a great excess of river flow in the monsoon season (from the middle of June to the middle of September) and very little flow during the other eight months of the year. Some way must be found to store the energy that is present in great abundance during the monsoon season

for use during the dry season.

Storage is one of the problems of methane production from biological materials. Methane is difficult to store because it is so light. A large volume of storage is required, or else an expensive high-pressure tank. This argues for making liquid fuels such as methanol or ethanol from biological materials, rather than gaseous fuels.

Even the direct conversion of solar energy by photocells or by heat absorption has the problem that sunshine varies a lot, not only between day and night, but during the course of the year, particularly in the monsoon climates of the tropics. During four months of the year the radiation from the sun is obscured by heavy clouds, and considerably less radiation is received at the ground than during the wintertime. As Mr. Sakr pointed out, this is not true for Egypt or other desert areas, where there are hardly ever any clouds. But the populations of deserts are sparse, orders of magnitude smaller than those of India, Pakistan, Bangladesh, Southeast Asia and Indonesia, where the monsoon dominates the climate.

One way to store energy is to make nitrogen fertilizer. Even with the most efficient modern processes for nitrogen fixation, about 15000 kilowatt hours are required to produce a ton of fixed nitrogen. With the old electric arc process, perhaps more than 45000 kilowatt hours are required per ton of nitrogen. With the Norwegian electrolysis process, hydropower can be used to produce hydrogen by electrolyzing water. The hydrogen is then used as an electron acceptor for nitrogen in making ammonia.

Other possibilities for energy storage are other chemical products. With present fossil fuel costs it may actually be less expensive to make many chemical products out of ethanol or methanol than out of petroleum. This may not be true at present in the United States, because we have sunk so much capital in petrochemical plants, but thirty years ago a good deal of technological research was devoted to the development of methodologies for using organic sources to make what are now called petrochemicals.

So-called pump-back storage--pumping water up into a high reservoir during off-peak hours, and using this water to augment power production during peak load periods--is another way to store energy, at least over short periods, in order to minimize required generator capacities.

Careful studies are needed of energy systems in rural villages. I have mentioned the farmers in the hills of Nepal, whose energy system is tightly locked into their food system, with the result that it is hard to break into either. Village energy systems are also likely to interact with village social systems. For example, village level biogas plants using human wastes might be constructed to provide energy for a large fraction of the village population. Such centralized plants would require that the village people defecate in a central latrine instead of the shady bamboo groves they have been using for thousands of years. For several reasons--some of them obvious--village people don't like to use latrines. It may be necessary to find ways of paying them to change their ancient habits so that the human wastes can be collected for use in a central village biogas plant. Small family biogas plants will provide enough energy to be useful only for those farmers who have five or more dung-producing cattle. In this case, the rich farmers will be better off and the landless laborers worse off than they are at present. The landless laborers and other dependent people in a village now usually have a time-honored agreement with the landowner to provide them with straw and dung to cook with, in return for certain traditional services. These agreements will be broken if the landowner finds a profitable use for the dung. This is simply one example of the fact that the entire energy system of a village must be carefully examined in ways that have not received much attention from anthropologists--because anthropologists are usually uninterested in economics--to find out what actually can be done to improve the quality of village life and particularly the quality of life of the poorest people in the village.

If we attempt to apply the criteria I have outlined, it is clear that choices among different potential energy sources will depend upon differences in environmental condition, including the

social environment. For example, wind energy may be most useful in coastal regions, where average wind speeds are likely to be higher than 5 meters per second (more than 10 miles per hour). In desert areas where there is plenty of sunshine but little or no water, direct conversion of solar energy, using photocells or other types of collectors, may prove to be economical, provided costs can be sufficiently lowered, at least in areas such as Saudi Arabia, the Persian Gulf states, or the southwestern United States, in which investment capital is easily available. Small-scale, "run of the river" hydropower may be preferable in hilly or mountainous regions with many perennial streams, such as Nepal and the Himalayan foothill regions of India and Pakistan. Plantations of quick-growing trees or coarse grasses will be most promising in regions with abundant water supply and large areas of non-arable land, including parts of Africa and South America. In large, sparsely populated countries such as Brazil, where there is an excess of well-watered, potentially arable land, biological conversion of solar energy by production of methanol or ethanol from sugar cane or other high-yielding crops may be an optimal energy source.

The most difficult problems arise in densely populated regions with relatively small areas such as Japan, Bangladesh, and the island of Java. Useful supplements to existing energy sources can be obtained in these regions from the non-edible portions of agricultural crops, but it may be impossible to satisfy their future energy needs without extensive reliance on fossil fuels, and in the long run, on nuclear energy.

Questions and Answers

Question: This morning you discussed the relationship between nondomestic consumption of energy and productivity. Later in your talk you talked about one way of using energy more efficiently, viz., a better stove and a better cooking pot. So what you are referring to at this point is domestic use of energy. Now when domestic uses of energy become more efficient what is going to keep people from still channeling most energy into domestic rather than nondomestic uses? Let me give you an example. In many of the less developed countries people cook

their meals once a day. If they have more energy available, why not cook twice a day? Or why not wash their clothes in hot water? How are you going to keep from widening the gap between domestic and nondomestic uses of energy? In other words what would keep people in the less developed countries from emulating their cousins in more developed countries by becoming more consumptuous?

Mr. Revelle: I would not object to that if the energy were available. After all, the purpose of life is to live as much as you can. But the problem is that these poor people don't have the energy. As I said today, one person in a family may spend his (or usually her) entire time just gathering fuel. This chore is getting harder and harder all the time as populations grow. So that you have a tradeoff here of resources: the fuel-gatherer will work less, gathering less fuel if he gets a better stove. Or he may decide it's alright to continue to work hard and cook twice a day. He would at least have more choice than he has right now. He has no choice at all. He is just barely making it now.

Comment from the floor: I think basically the problem hinges upon making the nondomestic uses of energy and food for that matter more attractive economically than the domestic ones. I can't help thinking about the situation in the north of Ghana where it is commonly understood that to increase the food production by 20% will achieve nothing because the people can eat 20% more food, and in fact they are hungry for two months of the year. They call it the hungry season. They virtually have nothing to eat. So I think we should all realize that we have this backlog to make up. Yes, people are going to use more energy domestically, yes they are going to eat more food domestically, but let's give them the chance to make that forward step first. Then we must think about ways of using their time, their energy and their resources for economic activities which will be to their own personal benefit. And then they will choose for themselves how they use their resources and their energy.

Question: Can any of the panel members identify strategies for development of energy and other resources which are more likely to encourage

demographic transition or whatever you choose to call it, such that the proceeds won't tend to be eaten up?

Mr. Revelle: I don't know that there is any simple relationship. But I guess I should have amplified my statement about increasing productivity by saying that it should be increased more rapidly than populations grow. That of course is in a sense the definition of productivity per man. We need to remember that people have hands as well as mouths. They can produce as well as consume. In general, it seems to be true that if the poorest people see a way in which their lives can be improved and in which their children's lives can be improved, they are very likely not to have so many children. That seems to be the experience of many countries where this kind of improvement has taken place.

Question: For example on the Indian subcontinent?

Mr. Revelle: Oh yes. For example in Sri Lanka, where there is a fairly good income distribution compared to the rest of the subcontinent--everybody in Sri Lanka receives a free kilogram of rice once a week and pays only 2 annas for another kg; every village has a dispensary, every market town has a clinic, every little city has a hospital, all free for everyone in the country; education up to and including the university is free, and there are about as many educated women as men. And Sri Lanka has the lowest birthrate in the subcontinent. Taiwan, Korea, Singapore, Hongkong, Malaysia, particularly West Malaysia, Costa Rica, countries where there is a relatively good income distribution, where living conditions of the poor have been and are improving, all have low birth rates. Improving the living conditions of the poor may be a necessary if not a sufficient condition for reducing population growth. This improvement may well depend on obtaining and distributing more energy.

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Renewable energy

From Wikipedia, the free encyclopedia

Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat.[2] Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services.[3]

Wind, solar, and hydroelectricity are three emerging renewable sources of energy

Based on REN21's 2016 report, renewables contributed 19.2% to humans' global energy consumption and 23.7% to their generation of electricity in 2014 and 2015, respectively. This energy consumption is divided as 8.9% coming from traditional biomass, 4.2% as heat energy (modern biomass, geothermal and solar heat), 3.9% hydro electricity and 2.2% is electricity from wind, solar, geothermal, and biomass. Worldwide investments in renewable technologies amounted to more than US$286 billion in 2015, with countries like China and the United States heavily investing in wind, hydro, solar and biofuels.[4] Globally, there are an estimated 7.7 million jobs associated with the renewable energy industries, with solar photovoltaics being the largest renewable employer.[5] As of 2015 worldwide, more than half of all new electricity capacity installed was renewable.[6]

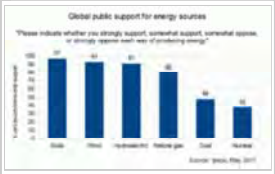

Global public support for different energy sources (2011) based on a poll by Ipsos Global @dvisor[1]

Renewable energy resources exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy and energy efficiency is resulting in significant energy security, climate change mitigation, and economic benefits.[7] The results of a recent review of the literature[8] concluded that as greenhouse gas (GHG) emitters begin to be held liable for damages resulting from GHG emissions resulting in climate change, a high value for liability mitigation would provide powerful incentives for deployment of renewable energy technologies. In international public opinion surveys there is strong support for promoting renewable sources such as solar power and wind power.[9] At the national level, at least 30 nations around the world already have renewable energy contributing more than 20 percent of energy supply. National renewable energy markets are projected to continue to grow strongly in the coming decade and beyond.[10] Some places and at least two countries, Iceland and Norway generate all their electricity using renewable energy already, and many other countries have the set a goal to reach 100% renewable energy in the future. For example, in Denmark the government decided to switch the total energy supply (electricity, mobility and heating/cooling) to 100% renewable energy by 2050.[11]

While many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas and developing countries, where energy is often crucial in human development.[12] United Nations' Secretary-General Ban Ki-moon has said that renewable energy has the ability to lift the poorest nations to new levels of prosperity.[13] As most of renewables provide electricity, renewable energy deployment is often applied in conjunction with further electrification, which has several benefits: Electricity can be converted to heat (where necessary generating higher temperatures than fossil fuels), can be converted into mechanical energy with high efficiency and is clean at the point of consumption.[14][15] In addition to that electrification with renewable energy is much more efficient and therefore leads to a significant reduction in primary energy requirements, because most renewables don't have a steam cycle with high losses (fossil power plants usually have losses of 40 to 65%).[16]

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Overview

Renewable energy flows involve natural phenomena such as sunlight, wind, tides, plant growth, and geothermal heat, as the International Energy Agency explains:[17]

Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.

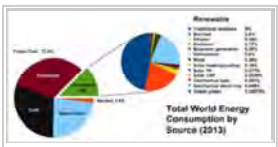

World energy consumption by source. Renewables accounted for 19% in 2012.

Renewable energy resources and significant opportunities for energy efficiency exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy and energy efficiency, and technological diversification of energy sources, would result in significant energy security and economic benefits.[7] It would also reduce environmental pollution such as air pollution caused by burning of fossil fuels and improve public health, reduce premature mortalities due to pollution and save associated health costs that amount to several hundred billion dollars annually only in the United States.[18] Renewable energy sources, that derive their energy from the sun, either directly or indirectly, such as hydro and wind, are expected to be capable of supplying humanity energy for almost another 1 billion years, at which point the predicted increase in heat from the sun is expected to make the surface of the earth too hot for liquid water to exist.[19][20]

PlanetSolar, the world's largest solar-powered boat and the first ever solar electric vehicle to circumnavigate the globe (in 2012)

Climate change and global warming concerns, coupled with high oil prices, peak oil, and increasing government support, are driving increasing renewable energy legislation, incentives and commercialization.[9] New government spending, regulation and policies helped the industry weather the global financial crisis better than many other sectors.[21] According to a 2011 projection by the International Energy Agency, solar power generators may produce most of the world's electricity within 50 years, reducing the emissions of greenhouse gases that harm the environment.[22]

As of 2011, small solar PV systems provide electricity to a few million households, and micro-hydro configured into mini-grids serves many more. Over 44 million households use biogas made in household-scale digesters for lighting and/or cooking, and more than 166 million households rely on a new generation of more-efficient biomass cookstoves.[23] United Nations' Secretary-General Ban Ki-moon has said that renewable energy has the ability to lift the poorest nations to new levels of prosperity.[13] At the national level, at least 30 nations around the world already have renewable energy contributing more than 20% of energy supply. National renewable energy markets are projected to continue to grow strongly in the coming decade and beyond, and some 120 countries have various policy targets for longer-term shares of renewable energy, including a 20% target of all electricity generated for the European Union by 2020. Some countries have much higher long-term policy targets of up to 100% renewables. Outside Europe, a diverse group of 20 or more other countries target renewable energy shares in the 2020 –2030 time frame that range from 10% to 50%.[10]

Renewable energy often displaces conventional fuels in four areas: electricity generation, hot water/space heating, transportation, and rural (off-grid) energy services:[3]

- **Power generation**

  By 2040, renewable energy is projected to equal coal and natural gas electricity generation. Several jurisdictions, including Denmark, Germany, the state of South Australia and some US states have achieved high integration of variable renewables. For example, in 2015 wind power met 42% of electricity demand in Denmark, 23.2% in Portugal and 15.5% in Uruguay. Interconnectors enable countries to balance electricity systems by allowing the import and export of renewable energy. Innovative hybrid systems have emerged between countries and regions.[24]

- **Heating**

  Solar water heating makes an important contribution to renewable heat in many countries, most notably in China, which now has 70% of the global total (180 GWth). Most of these systems are installed on multi-family apartment buildings and meet a portion of the hot water needs of an estimated 50–60 million households in China. Worldwide, total installed solar water heating systems meet a portion of the water heating needs of over 70 million households. The use of biomass for heating continues to grow as well. In Sweden, national use of biomass energy has surpassed that of oil. Direct geothermal for heating is also growing rapidly.[25] The newest addition to Heating is from Geothermal Heat Pumps which provide both heating and cooling, and also flatten the electric demand curve and are thus an increasing national priority[26][27] (see also Renewable thermal energy).

- **Transportation**

  Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn, sugarcane, or sweet sorghum. Cellulosic biomass, derived from non-food sources such as trees and grasses is also being developed as a feedstock for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the USA and in Brazil. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe.

  A bus fueled by biodiesel

  A solar vehicle is an electric vehicle powered completely or significantly by direct solar energy. Usually, photovoltaic (PV) cells contained in solar panels convert the sun's energy directly into electric energy. The term "solar vehicle" usually implies that solar energy is used to power all or part of a vehicle's propulsion. Solar power may be also used to provide power for communications or controls or other auxiliary functions. Solar vehicles are not sold as practical day-to-day transportation devices at present, but are primarily demonstration vehicles and engineering exercises, often sponsored by government agencies. However, indirectly solar-charged vehicles are widespread and solar boats are available commercially.

History

Prior to the development of coal in the mid 19th century, nearly all energy used was renewable. Almost without a doubt the oldest known use of renewable energy, in the form of traditional biomass to fuel fires, dates from 790,000 years ago. Use of biomass for fire did not become commonplace until many hundreds of thousands of years later, sometime between 200,000 and 400,000 years ago.[28] Probably the second oldest usage of renewable energy is harnessing the wind in order to drive ships over water. This practice can be traced back some 7000 years, to ships on the Nile.[29] Moving into the time of recorded history, the primary sources of traditional renewable energy were human labor, animal power, water power, wind, in grain crushing windmills, and firewood, a traditional biomass. A graph of energy use in the United States up until 1900 shows oil and natural gas with about the same importance in 1900 as wind and solar played in 2010.

In the 1860s and '70s there were already fears that civilization would run out of fossil fuels and the need was felt for a better source. In 1873 Professor Augustine Mouchot wrote:

> The time will arrive when the industry of Europe will cease to find those natural resources, so necessary for it. Petroleum springs and coal mines are not inexhaustible but are rapidly diminishing in many places. Will man, then, return to the power of water and wind? Or will he emigrate where the most powerful source of heat sends its rays to all? History will show what will come.[30]

In 1885, Werner von Siemens, commenting on the discovery of the photovoltaic effect in the solid state, wrote:

> In conclusion, I would say that however great the scientific importance of this discovery may be, its practical value will be no less obvious when we reflect that the supply of solar energy is both without limit and without cost, and that it will continue to pour down upon us for countless ages after all the coal deposits of the earth have been exhausted and forgotten.[31]

Max Weber mentioned the end of fossil fuel in the concluding paragraphs of his Die protestantische Ethik und der Geist des Kapitalismus, published in 1905.[32]

Development of solar engines continued until the outbreak of World War I. The importance of solar energy was recognized in a 1911 *Scientific American* article: "in the far distant future, natural fuels having been exhausted [solar power] will remain as the only means of existence of the human race".[33]

The theory of peak oil was published in 1956.[34] In the 1970s environmentalists promoted the development of renewable energy both as a replacement for the eventual depletion of oil, as well as for an escape from dependence on oil, and the first electricity generating wind turbines appeared. Solar had long been used for heating and cooling, but solar panels were too costly to build solar farms until 1980.[35]

The IEA 2014 World Energy Outlook projects a growth of renewable energy supply from 1,700 gigawatts in 2014 to 4,550 gigawatts in 2040. Fossil fuels received about $550 billion in subsidies in 2013, compared to $120 billion for all renewable energies.[36]

Mainstream technologies

Wind power

Airflows can be used to run wind turbines. Modern utility-scale wind turbines range from around 600 kW to 5 MW of rated power, although turbines with rated output of 1.5–3 MW have become the most common for commercial use. The largest generator capacity of a single installed onshore wind turbine reached 7.5 MW in 2015. The power available from the wind is a function of the cube of the wind speed, so as wind speed increases, power output increases up to the maximum output for the particular turbine.[37] Areas where winds are stronger and more constant, such as offshore and high altitude sites, are preferred locations for wind farms. Typically full load hours of wind turbines vary between 16 and 57 percent annually, but might be higher in particularly favorable offshore sites.[38]

The 845 MW Shepherds Flat Wind Farm near Arlington, Oregon, USA

Wind-generated electricity met nearly 4% of global electricity demand in 2015, with nearly 63 GW of new wind power capacity installed. Wind energy was the leading source of new capacity in Europe, the US and Canada, and the second largest in China. In Denmark, wind energy met more than 40% of its electricity demand while Ireland, Portugal and Spain each met nearly 20%.

Globally, the long-term technical potential of wind energy is believed to be five times total current global energy production, or 40 times current electricity demand, assuming all practical barriers needed were overcome. This would require wind turbines to be installed over large areas, particularly in areas of higher wind resources, such as offshore. As offshore wind speeds average ~90% greater than that of land, so offshore resources can contribute substantially more energy than land stationed turbines.[39] In 2014 global wind generation was 706 terawatt-hours or 3% of the worlds total electricity.[40]

Hydropower

In 2015 hydropower generated 16.6% of the worlds total electricity and 70% of all renewable electricity.[41] Since water is about 800 times denser than air, even a slow flowing stream of water, or moderate sea swell, can yield considerable amounts of energy. There are many forms of water energy:

The Three Gorges Dam on the Yangtze River in China

- Historically hydroelectric power came from constructing large hydroelectric dams and reservoirs, which are still popular in third world countries. The largest of which is the Three Gorges Dam(2003) in China and the Itaipu Dam(1984) built by Brazil and Paraguay.
- Small hydro systems are hydroelectric power installations that typically produce up to 50 MW of power. They are often used on small rivers or as a low impact development on larger rivers. China is the largest producer of hydroelectricity in the world and has more than 45,000 small hydro installations.[42]
- Run-of-the-river hydroelectricity plants derive kinetic energy from rivers without the creation of a large reservoir. This style of generation may still produce a large amount of electricity, such as the Chief Joseph Dam on the Columbia river in the United States.

Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 percent of global hydropower in 2010. For counties having the largest percentage of electricity from renewables, the top 50 are primarily hydroelectric. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use. There are now three hydroelectricity stations larger than 10 GW: the Three Gorges Dam in China, Itaipu Dam across the Brazil/Paraguay border, and Guri Dam in Venezuela.[43]

Wave power, which captures the energy of ocean surface waves, and tidal power, converting the energy of tides, are two forms of hydropower with future potential; however, they are not yet widely employed commercially. A demonstration project operated by the Ocean Renewable Power Company on the coast of Maine, and connected to the grid, harnesses tidal power from the Bay of Fundy, location of world's highest tidal flow. Ocean thermal energy conversion, which uses the temperature difference between cooler deep and warmer surface waters, has currently no economic feasibility.

Solar energy

Solar energy, radiant light and heat from the sun, is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaics, concentrated solar power (CSP), concentrator photovoltaics (CPV), solar architecture and artificial photosynthesis.[44][45] Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air. Active solar technologies encompass solar thermal energy, using solar collectors for heating, and solar power, converting sunlight into electricity either directly using photovoltaics (PV), or indirectly using concentrated solar power (CSP).

A photovoltaic system converts light into electrical direct current (DC) by taking advantage of the photoelectric effect.[46] Solar PV has turned into a multi-billion, fast-growing industry, continues to improve its cost-effectiveness, and has the most potential of any renewable technologies together with CSP.[47][48] Concentrated solar power (CSP) systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Commercial concentrated solar power plants were first developed in the 1980s. CSP-Stirling has by far the highest efficiency among all solar energy technologies.

Satellite image of the 550-megawatt Topaz Solar Farm in California, USA

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating climate change, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared".[44] In 2014 global solar generation was 186 terawatt-hours, slightly less than 1% of the worlds total grid electricity.[40]

Geothermal energy

High Temperature Geothermal energy is from thermal energy generated and stored in the Earth. Thermal energy is the energy that determines the temperature of matter. Earth's geothermal energy originates from the original formation of the planet and from radioactive decay of minerals (in currently uncertain[49] but possibly roughly equal[50] proportions). The geothermal gradient, which is the difference in temperature between the core of the planet and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface. The adjective *geothermal* originates from the Greek roots *geo*, meaning earth, and *thermos*, meaning heat.

Steam rising from the Nesjavellir Geothermal Power Station in Iceland

The heat that is used for geothermal energy can be from deep within the Earth, all the way down to Earth's core – 4,000 miles (6,400 km) down. At the core, temperatures may reach over 9,000 °F (5,000 °C). Heat conducts from the core to surrounding rock. Extremely high temperature and pressure cause some rock to melt, which is commonly known as magma. Magma convects upward since it is lighter than the solid rock. This magma then heats rock and water in the crust, sometimes up to 700 °F (371 °C).[51]

From hot springs, geothermal energy has been used for bathing since Paleolithic times and for space heating since ancient Roman times, but it is now better known for electricity generation.

Low Temperature Geothermal[26] refers to the use of the outer crust of the earth as a Thermal Battery to facilitate Renewable thermal energy for heating and cooling buildings, and other refrigeration and industrial uses. In this form of Geothermal, a Geothermal Heat Pump and Ground-coupled heat exchanger are used together to move heat energy into the earth (for cooling) and out of the earth (for heating) on a varying seasonal basis. Low temperature Geothermal (generally referred to as "GHP") is an increasingly important renewable technology because it both reduces total annual energy loads associated with heating and cooling, and it also flattens the electric demand curve eliminating the extreme summer and winter peak electric supply requirements. Thus Low Temperature Geothermal/GHP is becoming an increasing national priority with multiple tax credit support[52] and focus as part of the ongoing movement toward Net Zero Energy.[53][54] New York City has even just passed a law[55] to require GHP anytime is shown to be economical with 20 year financing including the Socialized Cost of Carbon.[56][57]

Bio energy

Biomass is biological material derived from living, or recently living organisms. It most often refers to plants or plant-derived materials which are specifically called lignocellulosic biomass.[58] As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: *thermal*, *chemical*, and *biochemical* methods. Wood remains the largest biomass energy source today;[59] examples include forest residues – such as dead trees, branches and tree stumps –, yard clippings, wood chips and even municipal solid waste. In the second sense, biomass includes plant or animal matter that can be converted into fibers or other industrial chemicals, including biofuels. Industrial biomass can be grown from numerous types of plants, including miscanthus, switchgrass, hemp, corn, poplar, willow, sorghum, sugarcane, bamboo,[60] and a variety of tree species, ranging from eucalyptus to oil palm (palm oil).

Sugarcane plantation to produce ethanol in Brazil

Plant energy is produced by crops specifically grown for use as fuel that offer high biomass output per hectare with low input energy. Some examples of these plants are wheat, which typically yield 7.5–8 tonnes of grain per hectare, and straw, which typically yield 3.5 –5 tonnes per hectare in the UK.[61] The grain can be used for liquid transportation fuels while the straw can be burned to produce heat or electricity. Plant biomass can also be degraded from cellulose to glucose through a series of chemical treatments, and the resulting sugar can then be used as a first generation biofuel.

A CHP power station using wood to supply 30,000 households in France

Biomass can be converted to other usable forms of energy like methane gas or transportation fuels like ethanol and biodiesel. Rotting garbage, and agricultural and human waste, all release methane gas – also called landfill gas or biogas. Crops, such as corn and sugarcane, can be fermented to produce the transportation fuel, ethanol. Biodiesel, another transportation fuel, can be produced from left-over food products like vegetable oils and animal fats.[62] Also, biomass to liquids (BTLs) and cellulosic ethanol are still under research.[63][64] There is a great deal of research involving algal fuel or algae-derived biomass due to the fact that it's a non-food resource and can be produced at rates 5 to 10 times those of other types of land-based agriculture, such as corn and soy. Once harvested, it can be fermented to produce biofuels such as ethanol, butanol, and methane, as well as biodiesel and hydrogen. The biomass used for electricity generation varies by region. Forest by-products, such as wood residues, are common in the United States. Agricultural waste is common in Mauritius (sugar cane residue) and Southeast Asia (rice husks). Animal husbandry residues, such as poultry litter, are common in the United Kingdom.[65]

Biofuels include a wide range of fuels which are derived from biomass. The term covers solid, liquid, and gaseous fuels.[66] Liquid biofuels include bioalcohols, such as bioethanol, and oils, such as biodiesel. Gaseous biofuels include biogas, landfill gas and synthetic gas. Bioethanol is an alcohol made by fermenting the sugar components of plant materials and it is made mostly from sugar and starch crops. These include maize, sugarcane and, more recently, sweet sorghum. The latter crop is particularly suitable for growing in dryland conditions, and is being investigated by International Crops Research Institute for the Semi-Arid Tropics for its potential to provide fuel, along with food and animal feed, in arid parts of Asia and Africa.[67]

With advanced technology being developed, cellulosic biomass, such as trees and grasses, are also used as feedstocks for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the United States and in Brazil. The energy costs for producing bio-ethanol are almost equal to, the energy yields from bio-ethanol. However, according to the European Environment Agency, biofuels do not address global warming concerns.[68] Biodiesel is made from vegetable oils, animal fats or recycled greases. It can be used as a fuel for vehicles in its pure form, or more commonly as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe. Biofuels provided 2.7% of the world's transport fuel in 2010.[69]

Biomass, biogas and biofuels are burned to produce heat/power and in doing so harm the environment. Pollutants such as sulphurous oxides (SO_x), nitrous oxides (NO_x), and particulate matter (PM) are produced from the combustion of biomass; the World Health Organisation estimates that 7 million premature deaths are caused each year by air pollution.[70] Biomass combustion is a major contributor.[70][71][72] The life cycle of the plants is sustainable, the lives of people less so.

Energy storage

Energy storage is a collection of methods used to store electrical energy on an electrical power grid, or off it. Electrical energy is stored during times when production (especially from intermittent power plants such as renewable electricity sources such as wind power, tidal power, solar power) exceeds consumption, and returned to the grid when production falls below consumption. Water pumped into a hydroelectric dam is the largest form of power storage.

Market and industry trends

Growth of renewables

From the end of 2004, worldwide renewable energy capacity grew at rates of 10–60% annually for many technologies. In 2015 global investment in renewables rose 5% to $285.9 billion, breaking the previous record of $278.5 billion in 2011. 2015 was also the first year that saw renewables, excluding large hydro, account for the majority of all new power capacity (134GW, making up 53.6% of the total). Of the renewables total, wind accounted for 72GW and solar photovoltaics 56GW; both record-breaking numbers and sharply up from 2014 figures (49GW and 45GW respectively). In financial terms, solar made up 56% of total new investment and wind accounted for 38%.

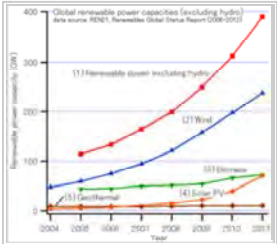

Global growth of renewables through to 2011[73]

Projections vary. The EIA has predicted that almost two thirds of net additions to power capacity will come from renewables by 2020 due to the combined policy benefits of local pollution, decarbonisation and energy diversification. Some studies have set out roadmaps to power 100% of the world's energy with wind, hydroelectric and solar by the year 2030.

According to a 2011 projection by the International Energy Agency, solar power generators may produce most of the world's electricity within 50 years, reducing the emissions of greenhouse gases that harm the environment. Cedric Philibert, senior analyst in the renewable energy division at the IEA said: "Photovoltaic and solar-thermal plants may meet most of the world's demand for electricity by 2060 – and half of all energy needs – with wind, hydropower and biomass plants supplying much of the remaining generation". "Photovoltaic and concentrated solar power together can become the major source of electricity", Philibert said.[22]

In 2014 global wind power capacity expanded 16% to 369,553 MW.[74] Yearly wind energy production is also growing rapidly and has reached around 4% of worldwide electricity usage,[75] 11.4% in the EU,[76] and it is widely used in Asia, and the United States. In 2015, worldwide installed photovoltaics capacity increased to 227 gigawatts (GW), sufficient to supply 1 percent of global electricity demands.[77] Solar thermal energy stations operate in the USA and Spain, and as of 2016, the largest of these is the 392 MW Ivanpah Solar Electric Generating System in California.[78][79] The world's largest geothermal power installation is The Geysers in California, with a rated capacity of 750 MW. Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugar cane, and ethanol now provides 18% of the country's automotive fuel. Ethanol fuel is also widely available in the USA.

Selected renewable energy global indicators	2008	2009	2010	2011	2012	2013	2014	2015
Investment in new renewable capacity (annual) (10^9 USD)[80]	182	178	237	279	256	232	270	285
Renewables power capacity (existing) (GWe)	1,140	1,230	1,320	1,360	1,470	1,578	1,712	1,849
Hydropower capacity (existing) (GWe)	885	915	945	970	990	1,018	1,055	1,064
Wind power capacity (existing) (GWe)	121	159	198	238	283	319	370	433
Solar PV capacity (grid-connected) (GWe)	16	23	40	70	100	138	177	227
Solar hot water capacity (existing) (GWth)	130	160	185	232	255	373	406	435
Ethanol production (annual) (10^9 litres)	67	76	86	86	83	87	94	98
Biodiesel production (annual) (10^9 litres)	12	17.8	18.5	21.4	22.5	26	29.7	30
Countries with policy targets for renewable energy use	79	89	98	118	138	144	164	173
Source: The Renewable Energy Policy Network for the 21st Century (REN21)–Global Status Report[81][82][83][84][85]								

Economic trends

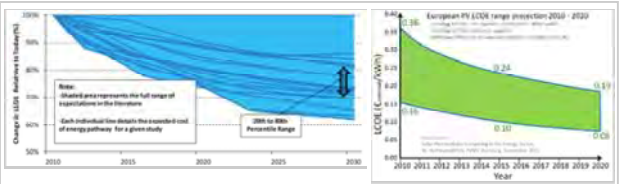

Projection of levelized cost for wind in the U.S. (left) and solar power in Europe[86][87]

Renewable energy technologies are getting cheaper, through technological change and through the benefits of mass production and market competition. A 2011 IEA report said: "A portfolio of renewable energy technologies is becoming cost-competitive in an increasingly broad range of circumstances, in some cases providing investment opportunities without the need for specific economic support," and added that "cost reductions in critical technologies, such as wind and solar, are set to continue."[88]

Hydro-electricity and geothermal electricity produced at favourable sites are now the cheapest way to generate electricity. Renewable energy costs continue to drop, and the levelised cost of electricity (LCOE) is declining for wind power, solar photovoltaic (PV), concentrated solar power (CSP) and some biomass technologies.[89] Renewable energy is also the most economic solution for new grid-connected capacity in areas with good resources. As the cost of renewable power falls, the scope of economically viable applications increases. Renewable technologies are now often the most economic solution for new generating capacity. Where "oil-fired generation is the predominant power generation source (e.g. on islands, off-grid and in some countries) a lower-cost renewable solution almost always exists today".[89] A series of studies by the US National Renewable Energy Laboratory modeled the "grid in the Western US under a number of different scenarios where intermittent renewables accounted for 33 percent of the total power." In the models, inefficiencies in cycling the fossil fuel plants to compensate for the variation in solar and wind energy resulted in an additional cost of "between $0.47 and $1.28 to each MegaWatt hour generated"; however, the savings in the cost of the fuels saved "adds up to $7 billion, meaning the added costs are, at most, two percent of the savings."[90]

Hydroelectricity

Only 25% of the worlds estimated hydroelectric potential of 14,000 TWh/year has been developed, with Africa, Asia and Latin America having the greatest potential.[91] The Three Gorges Dam in Hubei, China, has the world's largest instantaneous generating capacity (22,500 MW), with the Itaipu Dam in Brazil/Paraguay in second place (14,000 MW). The Three Gorges Dam is operated jointly with the much smaller Gezhouba Dam (3,115 MW). As of 2012, the total generating capacity of this two-dam complex is 25,615 MW. In 2008, this complex generated 98 TWh of electricity (81 TWh from the Three Gorges Dam and 17 TWh from the Gezhouba Dam), which is 3% more power in one year than the 95 TWh generated by Itaipu in 2008.

Wind power development

Wind power is widely used in Europe, China, and the United States. From 2004 to 2014, worldwide installed capacity of wind power has been growing from 47 GW to 369 GW—a more than sevenfold increase within 10 years with 2014 breaking a new record in global installations (51 GW). As of the end of 2014, China, the United States and Germany combined accounted for half of total global capacity.[92] Several other countries have achieved relatively high levels of wind power penetration, such as 21% of stationary electricity production in Denmark, 18% in Portugal, 16% in Spain, and 14% in Ireland in 2010 and have since continued to expand their installed capacity.[93][94] More than 80 countries around the world are using wind power on a commercial basis.[69]

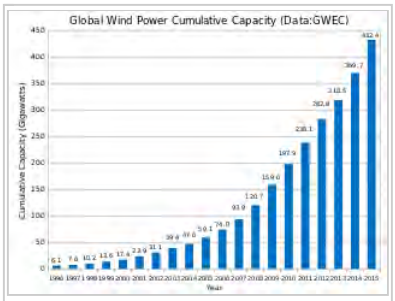

Worldwide growth of wind capacity (1996–2014)[92]

- Offshore wind power

  As of 2014, offshore wind power amounted to 8,771 megawatt of global installed capacity. Although offshore capacity doubled within three years (from 4,117 MW in 2011), it accounted for only 2.3% of the total wind power capacity. The United Kingdom is the undisputed leader of offshore power with half of the world's installed capacity ahead of Denmark, Germany, Belgium and China.

- List of offshore and onshore wind farms

  As of 2012, the Alta Wind Energy Center (California, 1,020 MW) is the world's largest wind farm.[95] The London Array (630 MW) is the largest offshore wind farm in the world. The United Kingdom is the world's leading generator of offshore wind power, followed by Denmark.[96] There are several large offshore wind farms operational and under construction and these include Anholt (400 MW), BARD (400 MW), Clyde (548 MW), Fântânele-Cogealac (600 MW), Greater Gabbard (500 MW), Lincs (270 MW), London Array (630 MW), Lower Snake River (343 MW), Macarthur (420 MW), Shepherds Flat (845 MW), and the Sheringham Shoal (317 MW).

Four offshore wind farms are in the Thames Estuary area: Kentish Flats, Gunfleet Sands, Thanet and London Array. The latter is the largest in the world as of April 2013.

Solar thermal

The United States conducted much early research in photovoltaics and concentrated solar power. The U.S. is among the top countries in the world in electricity generated by the Sun and several of the world's largest utility-scale installations are located in the desert Southwest.

The oldest solar thermal power plant in the world is the 354 megawatt (MW) SEGS thermal power plant, in California.[97] The Ivanpah Solar Electric Generating System is a solar thermal power project in the California Mojave Desert, 40 miles (64 km) southwest of Las Vegas, with a gross capacity of 377 MW.[98] The 280 MW Solana Generating Station is a solar power plant near Gila Bend, Arizona, about 70 miles (110 km) southwest of Phoenix, completed in 2013. When commissioned it was the largest parabolic trough plant in the world and the first U.S. solar plant with molten salt thermal energy storage.[99]

The 377 MW Ivanpah Solar Electric Generating System with all three towers under load, Feb 2014. Taken from I-15.

The solar thermal power industry is growing rapidly with 1.3 GW under construction in 2012 and more planned. Spain is the epicenter of solar thermal power development with 873 MW under construction, and a further 271 MW under development.[100] In the United States, 5,600 MW of solar thermal power projects have been announced.[101] Several power plants have been constructed in the Mojave Desert, Southwestern United States. The Ivanpah Solar Power Facility being the most recent. In developing countries, three World Bank projects for integrated solar thermal/combined-cycle gas-turbine power plants in Egypt, Mexico, and Morocco have been approved.[102]

Photovoltaic development

Photovoltaics (PV) uses solar cells assembled into solar panels to convert sunlight into electricity. It's a fast-growing technology doubling its worldwide installed capacity every couple of years. PV systems range from small, residential and commercial rooftop or building integrated installations, to large utility-scale photovoltaic power station. The predominant PV technology is crystalline silicon, while thin-film solar cell technology accounts for about 10 percent of global photovoltaic deployment. In recent years, PV technology has improved its electricity generating efficiency, reduced the installation cost per watt as well as its energy payback time, and has reached grid parity in at least 30 different markets by 2014.[103] Financial institutions are predicting a second solar "gold rush" in the near future.[104][105][106]

At the end of 2014, worldwide PV capacity reached at least 177,000 megawatts. Photovoltaics grew fastest in China, followed by Japan and the United States, while Germany remains the world's largest overall producer of photovoltaic power, contributing about 7.0 percent to the overall electricity generation. Italy meets 7.9 percent of its electricity demands with photovoltaic power—the highest share worldwide.[107] For 2015, global cumulative capacity is forecasted to increase by more than 50 gigawatts (GW). By 2018, worldwide capacity is projected to reach as much as 430 gigawatts. This corresponds to a tripling within five years.[108] Solar power is forecasted to become the world's largest source of electricity by 2050, with solar photovoltaics and concentrated solar power contributing 16% and 11%, respectively. This requires an increase of installed PV capacity to 4,600 GW, of which more than half is expected to be deployed in China and India.[109]

Solar Towers of the PS10 and PS20 solar thermal plants in Spain

Photovoltaic power stations

Commercial concentrated solar power plants were first developed in the 1980s. As the cost of solar electricity has fallen, the number of grid-connected solar PV systems has grown into the millions and utility-scale solar power stations with hundreds of megawatts are being built. Solar PV is rapidly becoming an inexpensive, low-carbon technology to harness renewable energy from the Sun.

Many solar photovoltaic power stations have been built, mainly in Europe, China and the USA.[110] The 579 MW Solar Star, in the United States, is the world's largest PV power station.

Many of these plants are integrated with agriculture and some use tracking systems that follow the sun's daily path across the sky to generate more electricity than fixed-mounted systems. There are no fuel costs or emissions during operation of the power stations.

However, when it comes to renewable energy systems and PV, it is not just large systems that matter. Building-integrated photovoltaics or "onsite" PV systems use existing land and structures and generate power close to where it is consumed.[111]

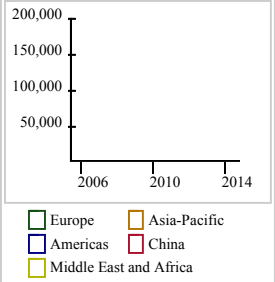

Worldwide growth of PV capacity grouped by region in MW (2006 –2014)

Biofuel development

Biofuels provided 3% of the world's transport fuel in 2010.[69] Mandates for blending biofuels exist in 31 countries at the national level and in 29 states/provinces.[69] According to the International Energy Agency, biofuels have the potential to meet more than a quarter of world demand for transportation fuels by 2050.[112]

Since the 1970s, Brazil has had an ethanol fuel program which has allowed the country to become the world's second largest producer of ethanol (after the United States) and the world's largest exporter.[113] Brazil's ethanol fuel program uses modern equipment and cheap sugarcane as feedstock, and the residual cane-waste (bagasse) is used to produce heat and power.[114] There are no longer light vehicles in Brazil running on pure gasoline. By the end of 2008 there were 35,000 filling stations throughout Brazil with at least one ethanol pump.[115] Unfortunately, Operation Car Wash has seriously eroded public trust in oil companies and has implicated several high ranking Brazilian officials.

Solar panels at the 550 MW Topaz Solar Farm

Nearly all the gasoline sold in the United States today is mixed with 10% ethanol,[116] and motor vehicle manufacturers already produce vehicles designed to run on much higher ethanol blends. Ford, Daimler AG, and GM are among the automobile companies that sell "flexible-fuel" cars, trucks, and minivans that can use gasoline and ethanol blends ranging from pure gasoline up to 85% ethanol. By mid-2006, there were approximately 6 million ethanol compatible vehicles on U.S. roads.[117]

Nellis Solar Power Plant, photovoltaic power plant in Nevada, USA

Geothermal development

Geothermal power is cost effective, reliable, sustainable, and environmentally friendly,[118] but has historically been limited to areas near tectonic plate boundaries. Recent technological advances have expanded the range and size of viable resources, especially for applications such as home heating, opening a potential for widespread exploitation. Geothermal wells release greenhouse gases trapped deep within the earth, but these emissions are much lower per energy unit than those of fossil fuels. As a result, geothermal power has the potential to help mitigate global warming if widely deployed in place of fossil fuels.

The International Geothermal Association (IGA) has reported that 10,715 MW of geothermal power in 24 countries is online, which is expected to generate 67,246 GWh of electricity in 2010.[119] This represents a 20% increase in geothermal power online capacity since 2005. IGA projects this will grow to 18,500 MW by 2015, due to the large number of projects presently under consideration, often in areas previously assumed to have little exploitable resource.[119]

In 2010, the United States led the world in geothermal electricity production with 3,086 MW of installed capacity from 77 power plants;[120] the largest group of geothermal power plants in the world is located at The Geysers, a geothermal field in California.[121] The Philippines follows the US as the second highest producer of geothermal power in the world, with 1,904 MW of capacity online; geothermal power makes up approximately 18% of the country's electricity generation.[120]

Brazil produces bioethanol made from sugarcane available throughout the country. A typical gas station with dual fuel service is marked "A" for alcohol (ethanol) and "G" for gasoline.

Developing countries

Renewable energy technology has sometimes been seen as a costly luxury item by critics, and affordable only in the affluent developed world. This erroneous view has persisted for many years, but 2015 was the first year when investment in non-hydro renewables, was higher in developing countries, with $156 billion invested, mainly in China, India, and Brazil.[122]

Renewable energy can be particularly suitable for developing countries. In rural and remote areas, transmission and distribution of energy generated from fossil fuels can be difficult and expensive. Producing renewable energy locally can offer a viable alternative.[123]

Technology advances are opening up a huge new market for solar power: the approximately 1.3 billion people around the world who don't have access to grid electricity. Even though they are typically very poor, these people have to pay far more for lighting than people in rich countries because they use inefficient kerosene lamps. Solar power costs half as much as lighting with kerosene.[124] As of 2010, an estimated 3 million households get power from small solar PV systems.[125] Kenya is the world leader in the number of solar power systems installed per capita. More than 30,000 very small solar panels, each producing 12 to 30 watts, are sold in Kenya annually. Some Small Island Developing States (SIDS) are also turning to solar power to reduce their costs and increase their sustainability.[126]

Micro-hydro configured into mini-grids also provide power. Over 44 million households use biogas made in household-scale digesters for lighting and/or cooking, and more than 166 million households rely on a new generation of more-efficient biomass cookstoves.[23] Clean liquid fuel sourced from renewable feedstocks are used for cooking and lighting in energy-poor areas of the developing world. Alcohol fuels (ethanol and methanol) can be produced sustainably from non-food sugary, starchy, and cellulostic feedstocks. Project Gaia, Inc. and CleanStar Mozambique are implementing clean cooking programs with liquid ethanol stoves in Ethiopia, Kenya, Nigeria and Mozambique.[127]

Geothermal plant at The Geysers, California, USA

Renewable energy projects in many developing countries have demonstrated that renewable energy can directly contribute to poverty reduction by providing the energy needed for creating businesses and employment. Renewable energy technologies can also make indirect contributions to alleviating poverty by providing energy for cooking, space heating, and lighting. Renewable energy can also contribute to education, by providing electricity to schools.[128]

Industry and policy trends

U.S. President Barack Obama's American Recovery and Reinvestment Act of 2009 includes more than $70 billion in direct spending and tax credits for clean energy and associated transportation programs. Leading renewable energy companies include First Solar, Gamesa, GE Energy, Hanwha Q Cells, Sharp Solar, Siemens, SunOpta, Suntech Power, and Vestas.[130]

Solar cookers use sunlight as energy source for outdoor cooking

Many national, state, and local governments have also created green banks. A green bank is a quasi-public financial institution that uses public capital to leverage private investment in clean energy technologies.[131] Green banks use a variety of financial tools to bridge market gaps that hinder the deployment of clean energy.

The military has also focused on the use of renewable fuels for military vehicles. Unlike fossil fuels, renewable fuels can be produced in any country, creating a strategic advantage. The US military has already committed itself to have 50% of its energy consumption come from alternative sources.[132]

The International Renewable Energy Agency (IRENA) is an intergovernmental organization for promoting the adoption of renewable energy worldwide. It aims to provide concrete policy advice and facilitate capacity building and technology transfer. IRENA was formed on 26 January 2009, by 75 countries signing the charter of IRENA.[133] As of March 2010, IRENA has 143 member states who all are considered as founding members, of which 14 have also ratified the statute.[134]

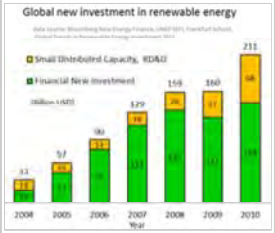

Global New Investments in Renewable Energy[129]

As of 2011, 119 countries have some form of national renewable energy policy target or renewable support policy. National targets now exist in at least 98 countries. There is also a wide range of policies at state/provincial and local levels.[69]

United Nations' Secretary-General Ban Ki-moon has said that renewable energy has the ability to lift the poorest nations to new levels of prosperity.[13] In October 2011, he "announced the creation of a high-level group to drum up support for energy access, energy efficiency and greater use of renewable energy. The group is to be co-chaired by Kandeh Yumkella, the chair of UN Energy and director general of the UN Industrial Development Organisation, and Charles Holliday, chairman of Bank of America".[135]

100% renewable energy

The incentive to use 100% renewable energy, for electricity, transport, or even total primary energy supply globally, has been motivated by global warming and other ecological as well as economic concerns. The Intergovernmental Panel on Climate Change has said that there are few fundamental technological limits to integrating a portfolio of renewable energy technologies to meet most of total global energy demand. Renewable energy use has grown much faster than even advocates anticipated.[136] At the national level, at least 30 nations around the world already have renewable energy contributing more than 20% of energy supply. Also, Professors S. Pacala and Robert H. Socolow have developed a series of "stabilization wedges" that can allow us to maintain our quality of life while avoiding catastrophic climate change, and "renewable energy sources," in aggregate, constitute the largest number of their "wedges".[137]

Using 100% renewable energy was first suggested in a Science paper published in 1975 by Danish physicist Bent Sørensen.[138] It was followed by several other proposals, until in 1998 the first detailed analysis of scenarios with very high shares of renewables were published. These were followed by the first detailed 100% scenarios. In 2006 a PhD thesis was published by Czisch in which it was shown that in a 100% renewable scenario energy supply could match demand in every hour of the year in Europa and North Africa. In the same year Danish Energy professor Henrik Lund published a first paper[139] in which he addresses the optimal combination of renewables, which was followed by several other papers on the transition to 100% renewable energy in Denmark. Since then Lund has been publishing several papers on 100% renewable energy. After 2009 publications began to rise steeply, covering 100% scenarios for countries in Europa, America, Australia and other parts of the world.[140]

In 2011 Mark Z. Jacobson, professor of civil and environmental engineering at Stanford University, and Mark Delucchi published a study on 100% renewable global energy supply in the journal Energy Policy. They found producing all new energy with wind power, solar power, and hydropower by 2030 is feasible and existing energy supply arrangements could be replaced by 2050. Barriers to implementing the renewable energy plan are seen to be "primarily social and political, not technological or economic". They also found that energy costs with a wind, solar, water system should be similar to today's energy costs.[141]

Similarly, in the United States, the independent National Research Council has noted that "sufficient domestic renewable resources exist to allow renewable electricity to play a significant role in future electricity generation and thus help confront issues related to climate change, energy security, and the escalation of energy costs … Renewable energy is an attractive option because renewable resources available in the United States, taken collectively, can supply significantly greater amounts of electricity than the total current or projected domestic demand." .[142]

The most significant barriers to the widespread implementation of large-scale renewable energy and low carbon energy strategies are primarily political and not technological. According to the 2013 *Post Carbon Pathways* report, which reviewed many international studies, the key roadblocks are: climate change denial, the fossil fuels lobby, political inaction, unsustainable energy consumption, outdated energy infrastructure, and financial constraints.[143]

Emerging technologies

Other renewable energy technologies are still under development, and include cellulosic ethanol, hot-dry-rock geothermal power, and marine energy.[144] These technologies are not yet widely demonstrated or have limited commercialization. Many are on the horizon and may have potential comparable to other renewable energy technologies, but still depend on attracting sufficient attention and research, development and demonstration (RD&D) funding.[144]

There are numerous organizations within the academic, federal, and commercial sectors conducting large scale advanced research in the field of renewable energy. This research spans several areas of focus across the renewable energy spectrum. Most of the research is targeted at improving efficiency and increasing overall energy yields.[145] Multiple federally supported research organizations have focused on renewable energy in recent years. Two of the most prominent of these labs are Sandia National Laboratories and the National Renewable Energy Laboratory (NREL), both of which are funded by the United States Department of Energy and supported by various corporate partners.[146] Sandia has a total budget of $2.4 billion[147] while NREL has a budget of $375 million.[148]

- Enhanced geothermal system

  Enhanced geothermal systems (EGS) are a new type of geothermal power technologies that do not require natural convective hydrothermal resources. The vast majority of geothermal energy within drilling reach is in dry and non-porous rock.[149] EGS technologies "enhance" and/or create geothermal resources in this "hot dry rock (HDR)" through hydraulic stimulation. EGS and HDR technologies, like hydrothermal geothermal, are expected to be baseload resources which produce power 24 hours a day like a fossil plant. Distinct from hydrothermal, HDR and EGS may be feasible anywhere in the world, depending on the economic limits of drill depth. Good locations are over deep granite covered by a thick (3–5 km) layer of insulating sediments which slow heat loss.[150] There are HDR and EGS systems currently being developed and tested in France, Australia, Japan, Germany, the U.S. and Switzerland. The largest EGS project in the world is a 25 megawatt demonstration plant currently being developed in the Cooper Basin, Australia. The Cooper Basin has the potential to generate 5,000–10,000 MW.

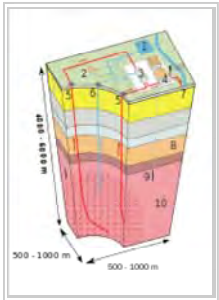

Enhanced geothermal system *(see file description for details)*

- Cellulosic ethanol

  Several refineries that can process biomass and turn it into ethanol are built by companies such as Iogen, POET, and Abengoa, while other companies such as the Verenium Corporation, Novozymes, and Dyadic International[151] are producing enzymes which could enable future commercialization. The shift from food crop feedstocks to waste residues and native grasses offers significant opportunities for a range of players, from farmers to biotechnology firms, and from project developers to investors.[152]

- Marine energy

  Marine energy (also sometimes referred to as ocean energy) refers to the energy carried by ocean waves, tides, salinity, and ocean temperature differences. The movement of water in the world's oceans creates a vast store of kinetic energy, or energy in motion. This energy can be harnessed to generate electricity to power homes, transport and industries. The term marine energy encompasses both wave power – power from surface waves, and tidal power – obtained from the kinetic energy of large bodies of moving water. Reverse electrodialysis (RED) is a technology for generating electricity by mixing fresh river water and salty sea water in large power cells designed for this purpose; as of 2016 it is being tested at a small scale (50 kW). Offshore wind power is not a form of marine energy, as wind power is derived from the wind, even if the wind turbines are placed over water. The oceans have a tremendous amount of energy and are close to many if not most concentrated populations. Ocean energy has the potential of providing a substantial amount of new renewable energy around the world.[153]

Rance Tidal Power Station, France

#	Station	Country	Location	Capacity	Refs
1.	Sihwa Lake Tidal Power Station	South Korea	37°18′47″N 126°36′46″E	254 MW	[154]
2.	Rance Tidal Power Station	France	48°37′05″N 02°01′24″W	240 MW	[155]
3.	Annapolis Royal Generating Station	Canada	44°45′07″N 65°30′40″W	20 MW	[155]

- Experimental solar power

  Concentrated photovoltaics (CPV) systems employ sunlight concentrated onto photovoltaic surfaces for the purpose of electricity generation. Thermoelectric, or "thermovoltaic" devices convert a temperature difference between dissimilar materials into an electric current.

- Floating solar arrays

  Floating solar arrays are PV systems that float on the surface of drinking water reservoirs, quarry lakes, irrigation canals or remediation and tailing ponds. A small number of such systems exist in France, India, Japan, South Korea, the United Kingdom, Singapore and the United States.[156][157][158][159][160] The systems are said to have advantages over photovoltaics on land. The cost of land is more expensive, and there are fewer rules and regulations for structures built on bodies of water not used for recreation. Unlike most land-based solar plants, floating arrays can be unobtrusive because they are hidden from public view. They achieve higher efficiencies than PV panels on land, because water cools the panels. The panels have a special coating to prevent rust or corrosion.[161] In May 2008, the Far Niente Winery in Oakville, California, pioneered the world's first floatovoltaic system by installing 994 solar PV modules with a total capacity of 477 kW onto 130 pontoons and floating them on the winery's irrigation pond.[162] Utility-scale floating PV farms are starting to be built. Kyocera will develop the world's largest, a 13.4 MW farm on the reservoir above Yamakura Dam in Chiba Prefecture[163] using 50,000 solar panels.[164][165] Salt-water resistant floating farms are also being constructed for ocean use.[166] The largest so far announced floatovoltaic project is a 350 MW power station in the Amazon region of Brazil.[167]

- Solar-assisted heat pump

  A heat pump is a device that provides heat energy from a source of heat to a destination called a "heat sink". Heat pumps are designed to move thermal energy opposite to the direction of spontaneous heat flow by absorbing heat from a cold space and releasing it to a warmer one. A solar-assisted heat pump represents the integration of a heat pump and thermal solar panels in a single integrated system. Typically these two technologies are used separately (or only placing them in parallel) to produce hot water.[168] In this system the solar thermal panel performs the function of the low temperature heat source and the heat produced is used to feed the heat pump's evaporator.[169] The goal of this system is to get high COP and then produce energy in a more efficient and less expensive way.

  It is possible to use any type of solar thermal panel (sheet and tubes, roll-bond, heat pipe, thermal plates) or hybrid (mono/polycrystalline, thin film) in combination with the heat pump. The use of a hybrid panel is preferable because it allows to cover a part of the electricity demand of the heat pump and reduce the power consumption and consequently the variable costs of the system.

- Artificial photosynthesis

  Artificial photosynthesis uses techniques including nanotechnology to store solar electromagnetic energy in chemical bonds by splitting water to produce hydrogen and then using carbon dioxide to make methanol.[170] Researchers in this field are striving to design molecular mimics of photosynthesis that utilize a wider region of the solar spectrum, employ catalytic systems made from abundant, inexpensive materials that are robust, readily repaired, non-toxic, stable in a variety of environmental conditions and perform more efficiently allowing a greater proportion of photon energy to end up in the storage compounds, i.e., carbohydrates (rather than building and

sustaining living cells).[171] However, prominent research faces hurdles, Sun Catalytix a MIT spin-off stopped scaling up their prototype fuel-cell in 2012, because it offers few savings over other ways to make hydrogen from sunlight.[172]

- Algae fuels

  Producing liquid fuels from oil-rich varieties of algae is an ongoing research topic. Various microalgae grown in open or closed systems are being tried including some system that can be set up in brownfield and desert lands.

- Solar aircraft

  An electric aircraft is an aircraft that runs on electric motors rather than internal combustion engines, with electricity coming from fuel cells, solar cells, ultracapacitors, power beaming,[173] or batteries.

  Currently, flying manned electric aircraft are mostly experimental demonstrators, though many small unmanned aerial vehicles are powered by batteries. Electrically powered model aircraft have been flown since the 1970s, with one report in 1957.[174][175] The first man-carrying electrically powered flights were made in 1973.[176] Between 2015-2016, a manned, solar-powered plane, Solar Impulse 2, completed a circumnavigation of the Earth.[177]

In 2016, *Solar Impulse 2* was the first solar-powered aircraft to complete circumnavigation of the world.

- Solar updraft tower

  The Solar updraft tower is a renewable-energy power plant for generating electricity from low temperature solar heat. Sunshine heats the air beneath a very wide greenhouse-like roofed collector structure surrounding the central base of a very tall chimney tower. The resulting convection causes a hot air updraft in the tower by the chimney effect. This airflow drives wind turbines placed in the chimney updraft or around the chimney base to produce electricity. Plans for scaled-up versions of demonstration models will allow significant power generation, and may allow development of other applications, such as water extraction or distillation, and agriculture or horticulture. A more advanced version of a similarly themed technology is the Vortex engine which aims to replace large physical chimneys with a vortex of air created by a shorter, less-expensive structure.

- Space-based solar power

  For either photovoltaic or thermal systems, one option is to loft them into space, particularly Geosynchronous orbit. To be competitive with Earth-based solar power systems, the specific mass (kg/kW) times the cost to loft mass plus the cost of the parts needs to be $2400 or less. I.e., for a parts cost plus rectenna of $1100/kW, the product of the $/kg and kg/kW must be $1300/kW or less.[178] Thus for 6.5 kg/kW, the transport cost cannot exceed $200/kg. While that will require a 100 to one reduction, SpaceX is targeting a ten to one reduction, Reaction Engines may make a 100 to one reduction possible.

- Carbon-neutral and negative fuels

  Carbon-neutral fuels are synthetic fuels (including methane, gasoline, diesel fuel, jet fuel or ammonia[179]) produced by hydrogenating waste carbon dioxide recycled from power plant flue-gas emissions, recovered from automotive exhaust gas, or derived from carbonic acid in seawater.[180] Such fuels are considered carbon-neutral because they do not result in a net increase in atmospheric greenhouse gases.[181] T

  Carbon-neutral fuels offer relatively low cost energy storage, alleviating the problems of wind and solar variability, and they enable distribution of wind, water, and solar power through existing natural gas pipelines.[182] Nighttime wind power is considered the most economical form of electrical power with which to synthesize fuel, because the load curve for electricity peaks sharply during the warmest hours of the day, but wind tends to blow slightly more at night than during the day, so, the price of nighttime wind power is often much less expensive than any alternative.[182] Germany has built a 250 kilowatt synthetic methane plant which they are scaling up to 10 megawatts.[183][184][185]

  The George Olah carbon dioxide recycling plant in Grindavík, Iceland has been producing 2 million liters of methanol transportation fuel per year from flue exhaust of the Svartsengi Power Station since 2011.[186] It has the capacity to produce 5 million liters per year.[187]

Debate

Renewable electricity production, from sources such as wind power and solar power, is sometimes criticized for being variable or intermittent, but is not true for concentrated solar, geothermal and biofuels, that have continuity. In any case, the International Energy Agency has stated that deployment of renewable technologies usually increases the diversity of electricity sources and, through local generation, contributes to the flexibility of the system and its resistance to central shocks.[188]

There have been "not in my back yard" (NIMBY) concerns relating to the visual and other impacts of some wind farms, with local residents sometimes fighting or blocking construction.[189] In the USA, the Massachusetts Cape Wind project was delayed for years partly because of aesthetic concerns. However, residents in other areas have been more positive. According to a town councilor, the overwhelming majority of locals believe that the Ardrossan Wind Farm in Scotland has enhanced the area.[190]

A recent UK Government document states that "projects are generally more likely to succeed if they have broad public support and the consent of local communities. This means giving communities both a say and a stake".[191] In countries such as Germany and Denmark many renewable projects are owned by communities, particularly through cooperative structures, and contribute significantly to overall levels of renewable energy deployment.[192][193]

The market for renewable energy technologies has continued to grow. Climate change concerns and increasing in green jobs, coupled with high oil prices, peak oil, oil wars, oil spills, promotion of electric vehicles and renewable electricity, nuclear disasters and increasing government support, are driving increasing renewable energy legislation, incentives and commercialization.[9] New government spending, regulation and policies helped the industry weather the 2009 economic crisis better than many other sectors.[21][194]

Gallery

Burbo, NW-England

Sunrise at the Fenton Wind Farm in Minnesota, USA

The CSP-station Andasol in Andalusia, Spain

Ivanpah solar plant in the Mojave Desert, California, United States

Three Gorges Dam and Gezhouba Dam, China

Shop selling PV panels in Ouagadougou, Burkina Faso

Stump harvesting increases recovery of biomass from forests

A small, roof-top mounted PV system in Bonn, Germany

The community-owned Westmill Solar Park in South East England

Komekurayama a photovoltaic power station in Kofu, Japan

Krafla, a geothermal power station in Iceland

See also

- Design feasibility of Wind turbine systems
- Distributed generation
- Efficient energy use
- Energy harvesting
- Energy storage
- Thermal energy storage

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Renewable fuels

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Renewable fuels are fuels produced from renewable resources. Examples include: biofuels (e.g. Vegetable oil used as fuel, ethanol, methanol from clean energy and carbon dioxide[1] or biomass, and biodiesel) and Hydrogen fuel (when produced with renewable processes). This is in contrast to non-renewable fuels such as natural gas, LPG (propane), petroleum and other fossil fuels and nuclear energy. Renewable fuels can include fuels that are synthesized from renewable energy sources, such as wind and solar. Renewable fuels have gained in popularity due to their sustainability, low contributions to the carbon cycle, and in some cases lower amounts of greenhouse gases. The geo-political ramifications of these fuels are also of interest, particularly to industrialized economies which desire independence from Middle Eastern oil.

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Rationale for renewable fuels

The International Energy Agency's *World Energy Outlook 2006* concludes that rising oil demand, if left unchecked, would accentuate the consuming countries' vulnerability to a severe supply disruption and resulting price shock. Renewable biofuels for transport represent a key source of diversification from petroleum products. Biofuels from grain and beet in temperate regions have a part to play, but they are relatively expensive and their energy efficiency and CO2 savings benefits, are variable. Biofuels from sugar cane and other highly productive tropical crops are much more competitive and beneficial. But all first generation biofuels ultimately compete with food production for land, water, and other resources. Greater efforts are required to develop and commercialize second generation biofuel technologies, such as biorefineries and ligno-cellulosics, enabling the flexible production of biofuels and other products from non-edible plant materials.[2]

Hubbert's peak oil theory suggests that petroleum is a finite resource that is rapidly depleting. Of the worldwide total remaining petroleum reserves of approximately 1,277,702,000,000 barrels (203.1384 km^3) (about one half of the original virgin reserves) and a worldwide usage rate of 25,000,000,000 barrels (4.0 km^3) per year, only about 50 years worth of petroleum is predicted to remain at the current depletion rate. Petroleum is imperative for the following industries: fuel (home heating, jet fuel, gasoline, diesel, etc.) transportation, agriculture, pharmaceutical, plastics/resins, man-

made fibers, synthetic rubber, and explosives. If the modern world remains reliant on petroleum as a source of energy, the price of crude oil could increase markedly, destabilizing economies worldwide. Consequently, renewable fuel drivers include: high oil prices, imbalance of trade, instability in oil exporting regions of the world, the Energy Policy Act of 2005, the potential for windfall profits for American farmers and industries, avoidance of economic depression, avoidance of scarcity of products due to a volatile 'peak oil' scenario expected to begin as early as 2021,[3] (though peak oil is not a new idea) and a slowing of global warming that may usher in unprecedented climate change.

Furthermore, the global debate on climate change, along with regional geopolitical instabilities have challenged nations to act to develop both alternative and carbon-neutral sources of energy. Renewable fuels are therefore becoming attractive to many governments, who are beginning to see sustainable energy independence as a valuable asset.

On December 19, 2007, President Bush signed into law the Energy Independence and Security Act, establishing a requirement that at least 36 billion US gallons (140,000,000 m^3) of renewable fuel be used in the marketplace by 2022.[4]

According to the International Energy Agency (IEA), cellulosic ethanol commercialization could allow ethanol fuels to play a much larger role in the future than previously thought.[5] Cellulosic ethanol can be made from plant matter composed primarily of inedible cellulose fibers that form the stems and branches of most plants. Dedicated energy crops, such as switchgrass, are also promising cellulose sources that can be produced in many regions of the United States.[6]

Biofuel

Biofuel is a type of fuel whose energy is derived from biological carbon fixation. Biofuels include fuels derived from biomass conversion, as well as solid biomass, liquid fuels and various biogases.[7] Although fossil fuels have their origin in ancient carbon fixation, they are not considered biofuels by the generally accepted definition because they contain carbon that has been "out" of the carbon cycle for a very long time. Biofuels are gaining increased public and scientific attention, driven by factors such as oil price spikes, the need for increased energy security, concern over greenhouse gas emissions from fossil fuels, and support from government subsidies.

Information on pump regarding ethanol fuel blend up to 10%, California

Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn or sugar cane. Cellulosic biomass, derived from non-food sources such as trees and grasses, is also being developed as a feedstock for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the USA and in Brazil. Current plant design does not provide for converting the lignin portion of plant raw materials to fuel components by fermentation.

Biodiesel is made from vegetable oils and animal fats. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe.

A bus fueled by biodiesel

In 2010 worldwide biofuel production reached 105 billion liters (28 billion gallons US), up 17% from 2009, and biofuels provided 2.7% of the world's fuels for road transport, a contribution largely made up of ethanol and biodiesel.[8] Global ethanol fuel production reached 86 billion liters (23 billion gallons US) in 2010, with the United States and Brazil as the world's top producers, accounting together for 90% of global production. The world's largest biodiesel producer is the European Union, accounting for 53% of all biodiesel production in 2010.[8] As of 2011, mandates for blending biofuels exist in 31 countries at the national level and in 29 states/provinces.[9] According to the International Energy Agency, biofuels have the potential to meet more than a quarter of world demand for transportation fuels by 2050.[10]

Pyrolysis oil is another type of fuel derived from the lignocellulosic fraction of biomass. By rapidly heating biomass in the absence of oxygen (pyrolysis), a liquid crude can be formed that can be further processed into a usable bio-oil. As opposed to other biofuels, pyrolysis oils use the non-edible fraction of biomass and can occur on the order of milliseconds and without the need for large fermentation reactors.[11]

Hydrogen fuel

Hydrogen fuel refers to the use of hydrogen gas (H_2) as an energy carrier. Broadly speaking, the production of renewable hydrogen fuel can be divided into two general categories: biologically derived production, and chemical production.[12] This is an area of current research, and new developments and technologies are causing this field to evolve rapidly.

Hydrogen fuel requires the development of a specific infrastructure for processing, transport and storage.

The biological production of hydrogen fuel has been a topic of research since at least the 1970s. Hydrogen gas can be produced from biomass sources like agricultural and forest residues, consumer waste and other specific agricultural crops.[12] Specifically, hydrogen fuel is produced by a process called gasification, where biomass is processed into a combustible gas and then burned, or by pyrolysis, a related process which can lead to hydrogen gas suitable for fuel-cell applications. One continuing subject of research regards the production of unwanted co-products in both of these processes. The presence of other contaminant gases often depend on specific composition of the biomass source, which can be difficult to control.[12] Another source for biological production of hydrogen fuel is algae. In the late 1990s it was discovered

that if algae are deprived of sulfur they will switch from the production of oxygen, as in normal photosynthesis, to the production of hydrogen.[13] Experimental algae farms are attempting to make algae an economically feasible energy source.[14]

There are also several physico-chemical methods for producing hydrogen; most of these methods require electrolysis of water. When this process draws its power from renewable energy sources like wind turbines or photovoltaic cells, the production requires little consumption of non-renewable resources. Hydrogen fuel, when produced by renewable sources of energy like wind or solar power, is a renewable fuel.[12]

Processed engineered fuel

PEF is a partial replacement for fossil fuels in cement kilns. It has significant calorific value and can be used as a fuel substitute for coal and gas in high-combustion facilities. PEF facilities typically divert waste from landfill, reducing demand for non-renewable coal and reducing waste to landfill.

See also

- Climate change
- Global warming
- IRENA
- Syngas

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PREFACE

The current volume is the second in a series of sectoral directories on renewable sources of energy to be issued under the ESCAP publications programme on co-operation among developing countries. With this volume the title of the series has been changed from TCDC to ECDC-TCDC to reflect the expanding scope and contents of the volumes intended to promote and support economic as well as technical co-operation among developing countries.

The present volume, like the preceeding one on solar energy and the others to follow, carries not only inventories of experts and institutions and the projects undertaken by them but also technological as well as economic details of the designs, prototypes and hardware developed in ESCAP member countries in Asia and the Pacific. While it is hoped that more details will be made available, the information contained in these volumes may be found adequate for initiating programmes of co-operation among developing countries.

In preparing the roster of experts and institutions, the ESCAP secretariat has relied on the information provided by the experts and institutions concerned and expresses its appreciation of the co-operation extended by them. While every endeavour has been made to include as many experts and institutions as possible the coverage may not be exhaustive. The secretariat will greatly welcome suggestions for improving the coverage of this volume as well as material for publications in the series now under preparation on wind energy and mini-hydro plants and the others envisaged. It is hoped that all the volumes in the series will be found particularly useful in connexion with the forthcoming United Nations Conference on New and Renewable Sources of Energy.

Like the earlier publications issued in the TCDC series, funds for the present volume have been made available by the Netherlands Government as extrabudgetary assistance to ESCAP. This exemplifies "triangular co-operation" under which developed countries contribute to a joint undertaking to promote co-operation among developing countries.

INTRODUCTION

The decay of organic matter, particularly human, animal and plant wastes, in the absence of air produces an inflammable gas which consists mainly of methane (CH_4) and carbon dioxide (CO_2). The gas is known as biogas and the process as anaerobic digestion or fermentation. This process can be used to the great benefit of the rural community for a number of reasons. First, it produces a smoke-free fuel. Secondly, it produces an excellent fertilizer. Thirdly, it destroys most of the disease-carrying pathogens and parasites. Fourthly, the raw materials needed in the construction of the digestion and in its operations are available in rural areas. Finally, the biogas technology is appropriate to rural conditions as comparatively sophisticated devices and highly qualified expertise are not involved.

The main handicap in biogas application is the relatively high capital cost which small-scale farmers cannot afford on an individual basis. Besides, as with any new technology, it needs well-planned programmes for promotion and extension.

The present introduction is meant to give a brief account of the stage of development of and of the economic, social and environmental issues in biogas technology in developing countries in the ESCAP region. Several more comprehensive technical reviews of the subject have been published.[1 2 3 4 5]

I. BIOGAS PLANTS INSTALLED IN THE ESCAP REGION

There are two main types of biogas plant that have been developed in this region; the fixed-dome digester, which is commonly called the "Chinese digester" (see figure 1) and the floating gas holder digester known as the Indian (KVIC) digester (see figure 2). The digesters used in the other developing countries in the ESCAP region, with the exception of the bag digester, are slightly modified forms of one or the other of these two main types.

---

1 *A Chinese Biogas Manual*, translated from the Chinese by Michael Crook and edited by Ariane van Buren from the original by the Office of the Leading Group for the Propagation of Marshgas, Sichuan Province, China (London, Intermediate Technology Publications, 1979)

2 "Guidebook on biogas development", *Energy Resources Development Series*, No. 21 (United Nations publication. Sales No. E.80.II.F.10).

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4 Sichuan Provincial Institute of Industrial Buildings Design, "Construction of marsh-gas-producing tanks (digesters) in simple ways".

5 *Simplified Biogas Digester Drawings*. Compiled by the South-west Engineering Institute, Beijing, China, 1979 (in Chinese).

A. THE BIOGAS DIGESTER

1. Fixed dome digester (China)

This digester which was developed and is widely used in China runs on a continuous-batch basis (see figure 1). Accordingly, it could digest plant waste as well as human and animal wastes. It is usually built below ground level; hence it is easier to insulate in a cold climate. The digester can be built from several materials, e.g. bricks, concrete, lime concrete and lime clay. This facilitates the introduction and use of local materials and manpower. The variable pressure inside the digester was found to cause no problems in China in the use of the gas.

2. Floating gas holder digester (India)

This type was developed in India and is usually made of masonry (see figure 2). It runs on a continuous basis and uses mainly cattle dung as input material. The gas holder is usually made of steel, although new materials such as ferrocement and bamboo-cement have already been introduced. The original version of this floating gas holder digester was a vertical cylinder provided with partition wall except for the small sizes of 2 and 3 m^3 of gas per day. The main characteristic of this type is the need for steel sheets and welding skill.

3. Flexible bag digester

This digester is made usually of Hypalen-Neoprene (see figure 3). It is portable, could be easily erected and has low capital cost. It has, however, a short lifespan in view of its low resistivity to ultraviolet rays and rodents.

4. Other types of digesters

(a) *Taper digester with floating gas holder (Nepal)*

This digester (see figure 4) is more suitable than the vertical type digester in sites with a high water-table.

(b) *Floating gas holder with water seal (Pakistan)*

This type (see figure 5) eliminates the smell and decreases gas leakage and corrosion of the gas holder. It is, however, considered more expensive than the original model.

(c) *Two-chamber digester (Philippines)*

Clogging problems hindered the widespread use of this digester (see figure 6), requiring more appropriate designs of the inlet and outlet.

(d) *Oil drum digester (Indonesia)*

This digester has been used for research purposes (see figure 7). The oil drum tends to rust out within a few years.

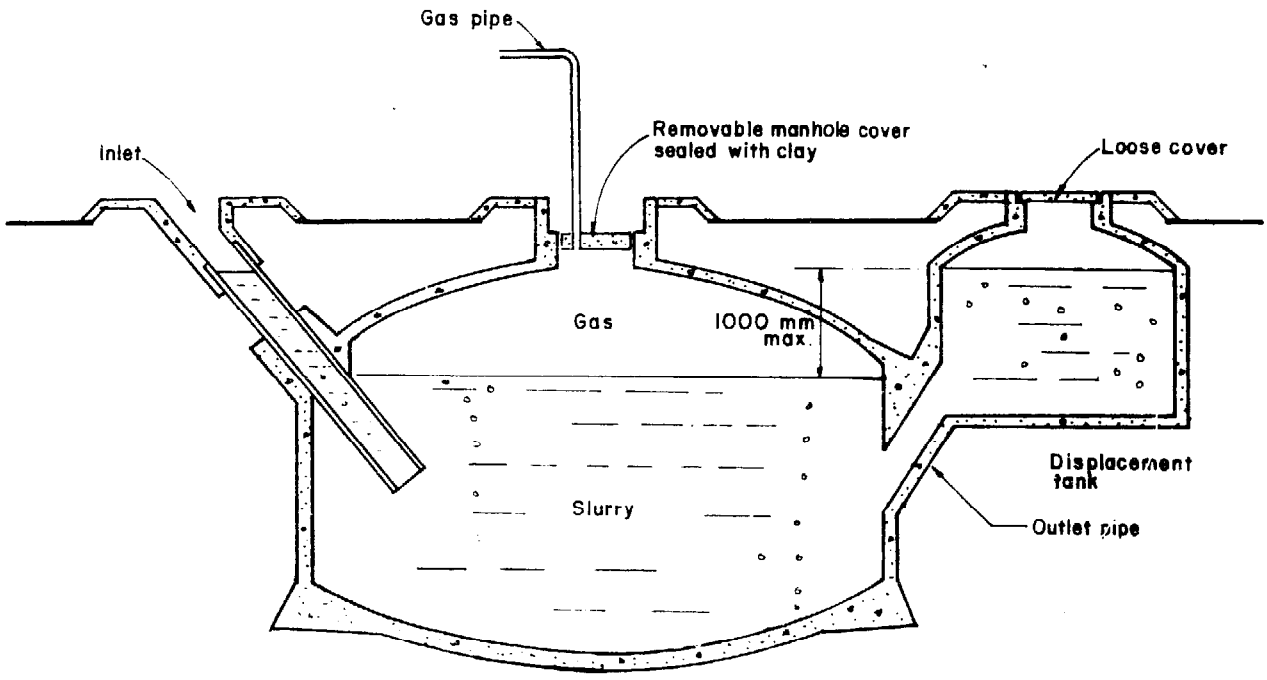

Figure 1. Common circular fixed dome digester (China)

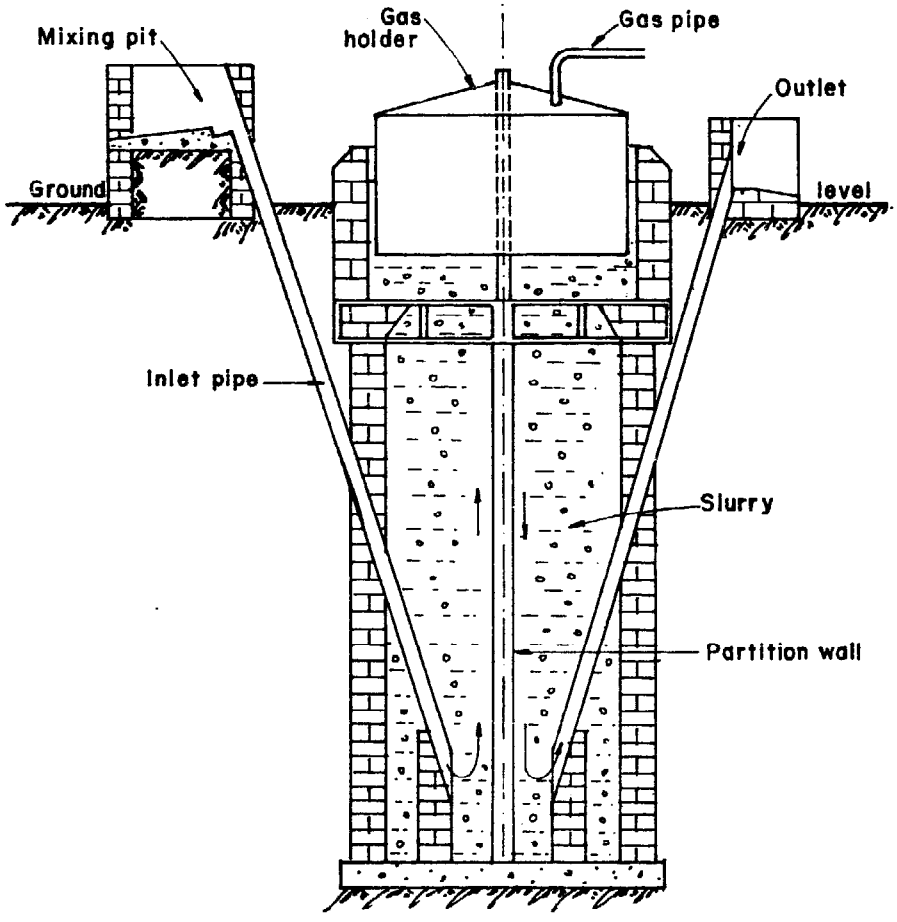

Figure 2. Common circular digester with floating gas holder and no water seal (India)

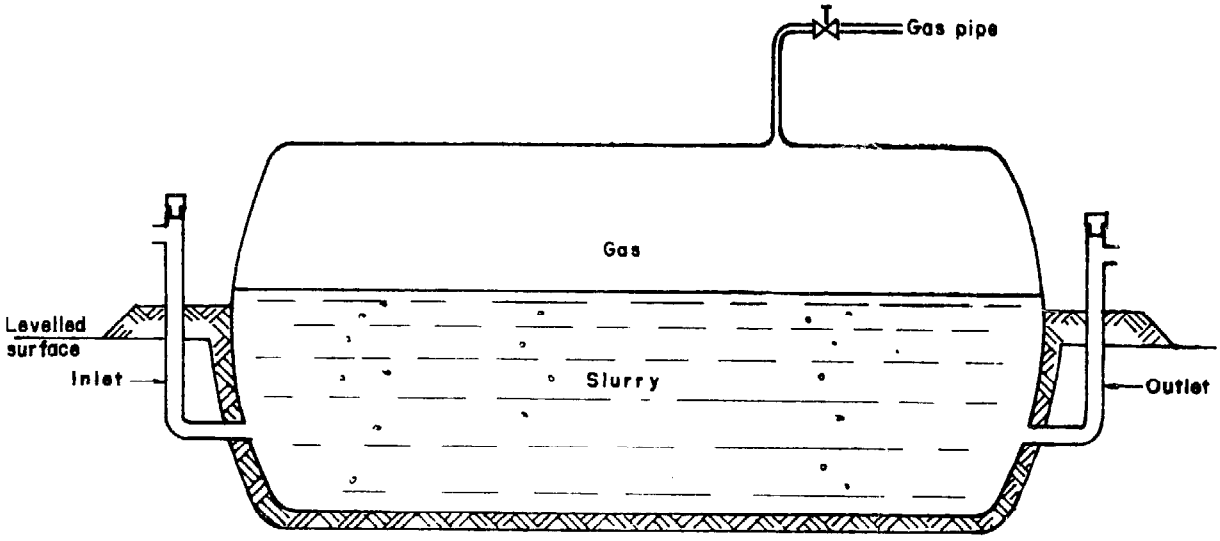

Figure 3. Flexible bag type combined digester/gas holder

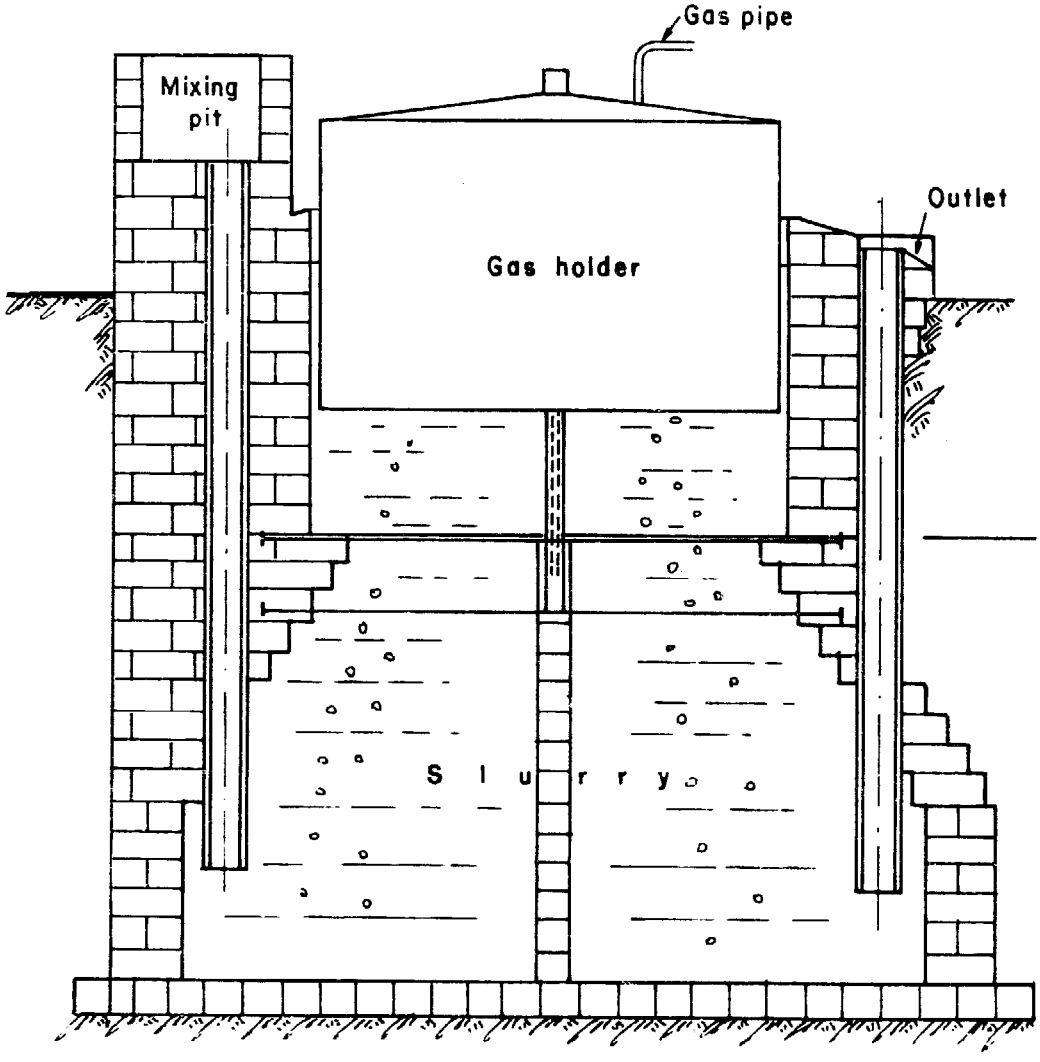

Figure 4. Taper digester with floating gasholder (Nepal)

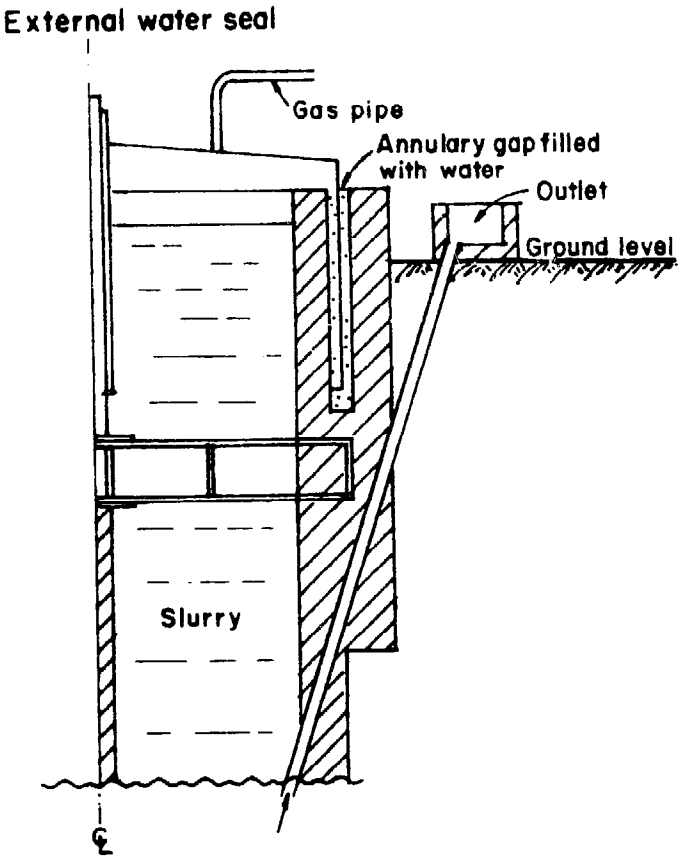

Figure 5. Digester with floating gas holder and water seal (Pakistan)

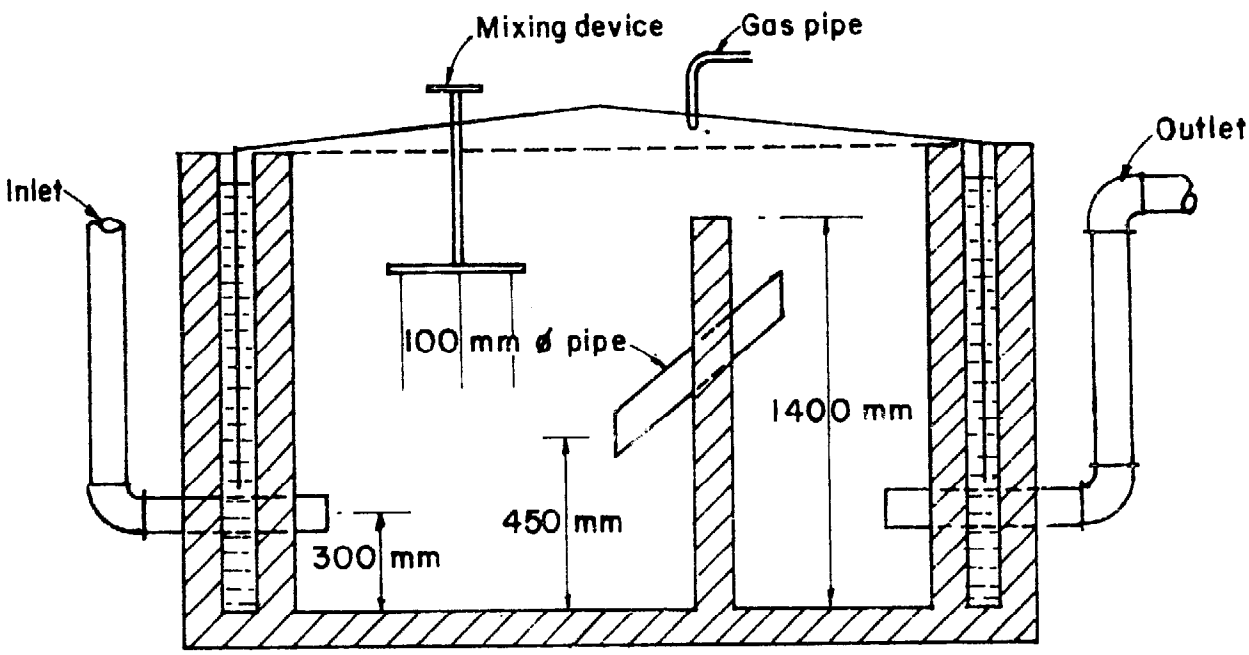

Figure 6. Two-chamber rectangular digester with floating gas holder and water seal (Philippines)

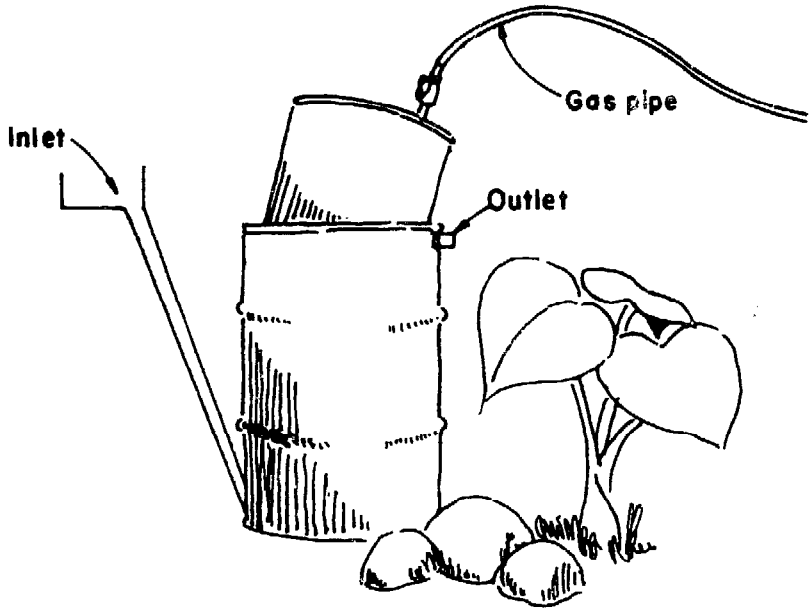

Figure 7. Oil drum digester (Indonesia)

(e) *Jar digester with separate gas holder (Thailand)*

This type (see figure 8) is cheaper than the floating gas digester and is easier to construct and maintain. However, it tends to leak and fails easily owing to cracking.

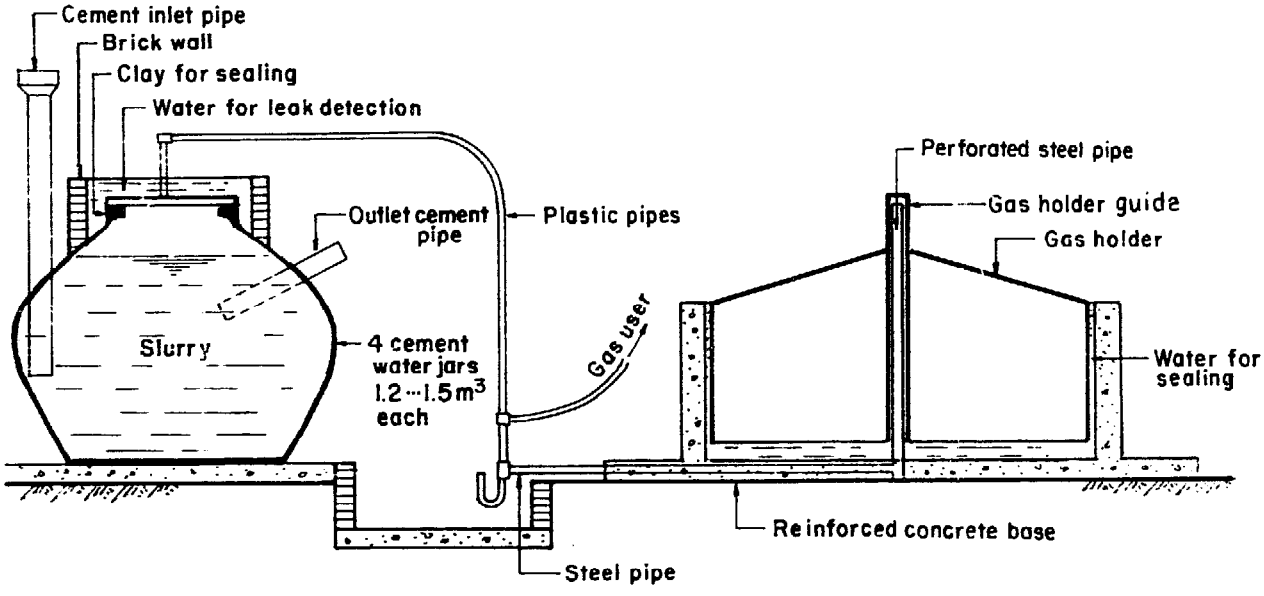

Figure 8. Jar digester with separate gas holder (Thailand)

(f) *Fixed dome digester with separate gas holder (China)*

The digester (see figure 9) in this plant is subjected to a less but more constant pressure. Additional work and cost are, however, involved in building the water tank and the gas holder.

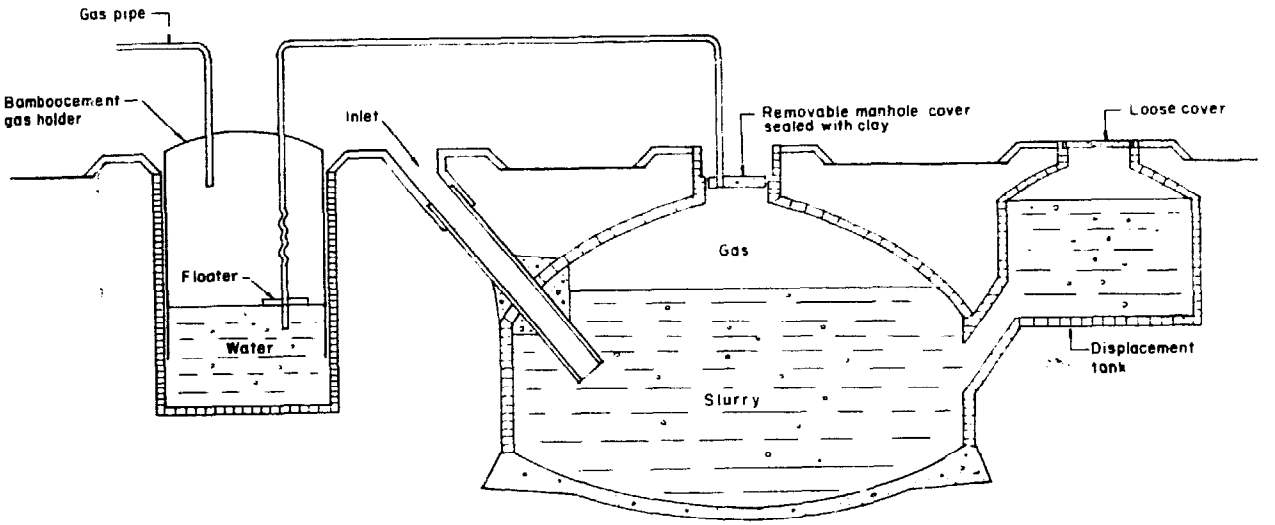

Figure 9. Fixed dome digester with separate gas holder (Sichuan, China)

B. THE REST OF THE BIOGAS PLANT

1. Gas removing system

This usually consists of a flexible pipe made of rubber or plastic (see figure 10). A hooked pipe or a pipe passing through the gas holder could be also used.

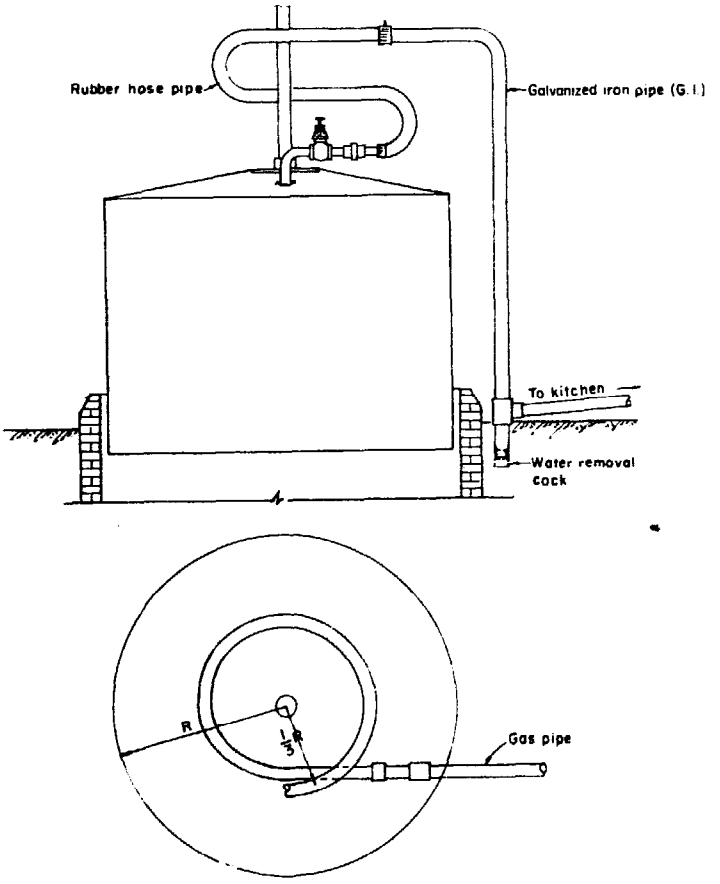

Figure 10. Gas removing system through a flexible pipe

2. Gas holder support system

This system is necessary only in the floating gas holder types. The most common systems are the internal and the external ones (see figure 11). The other systems like the wheel and the counter balance systems are not trouble-free.

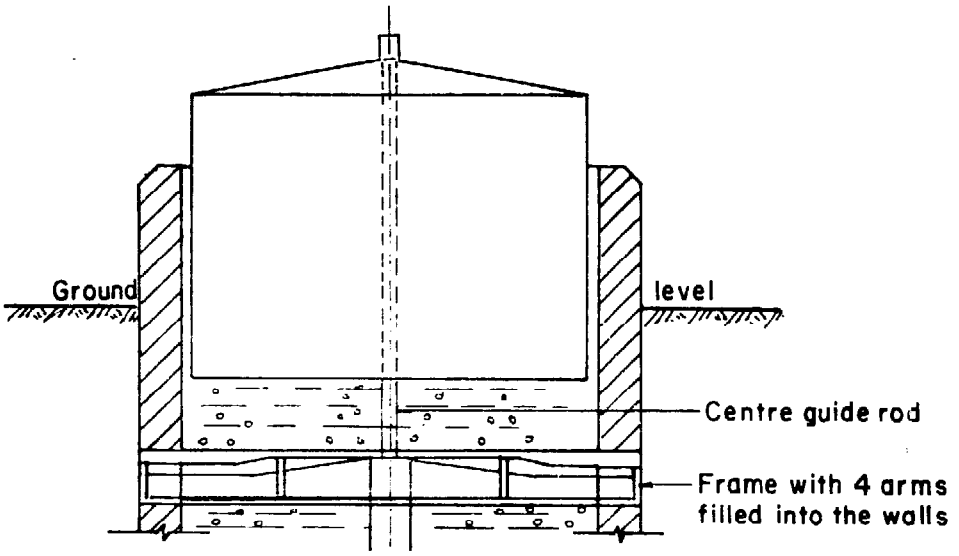

Figure 11a. Gas holder internal guide system

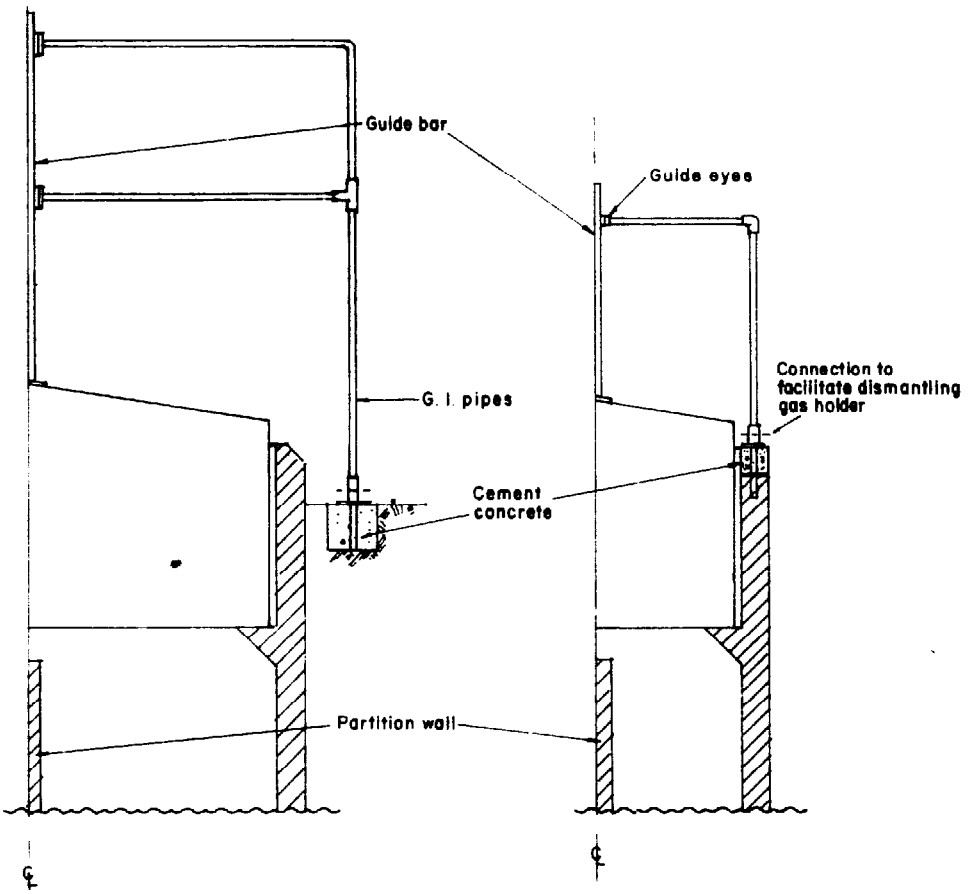

Figure 11b. Gas holder external guide system fixed to the earth (for large sizes)

Figure 11c. Gas holder external guide system fixed to digester wall

3. Monometer

This device is one of the typical attachment of the fixed dome (Chinese) digester (see figure 12). In addition to its use as indicator of pressure, and thus of the amount of the gas in the digester, it functions also as a safety device in case of excess increase of the gas pressure.

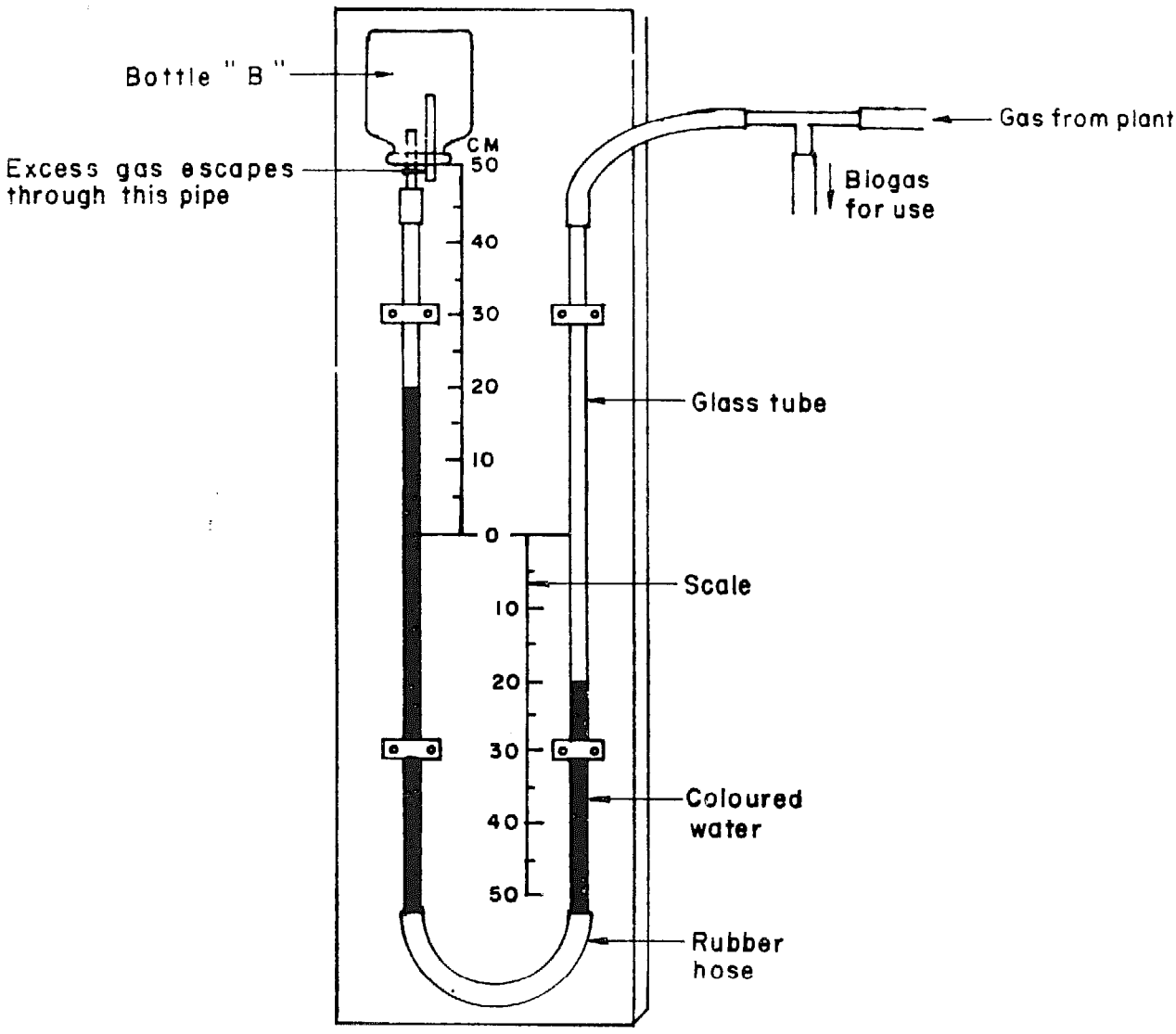

Figure 12. Monometer and safety valve combined

4. Biogas stoves

Biogas can be used like any other inflammable gas; LPG or natural gas. Air must be thoroughly mixed with the gas before it reaches the flame ports. In order to burn, the air to biogas ratio should be in the range of 1:1 to 4:1. The optimum area of the flame ports to the gas jet is between 80:1 and 200:1. There are many different types of stoves usually locally made from cast iron, mild steel or clay (see figure 13).

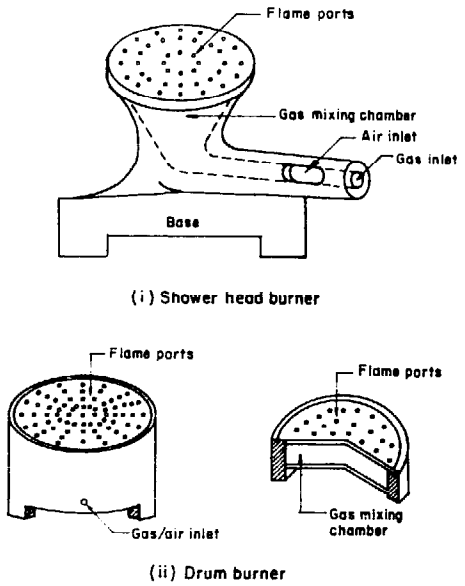

Figure 13. Clay burners (China)

5. Biogas lamps

The most efficient use of biogas in lighting is by generating electricity and using an electric bulb: 1 m^3 of biogas can generate 1.25 kWh and would be sufficient to ignite a 60 W electric bulb for 20 hours. The same amount of biogas will ignite a mantle gas lamp, equivalent to 60 W for about seven hours only. In most cases, however, the cost of the engine and generator may not be justified; hence a simple gas lamp can be used in spite of its low efficiency. There are also different types of biogas lamps; some are commercially made and others are village made (see figure 14).

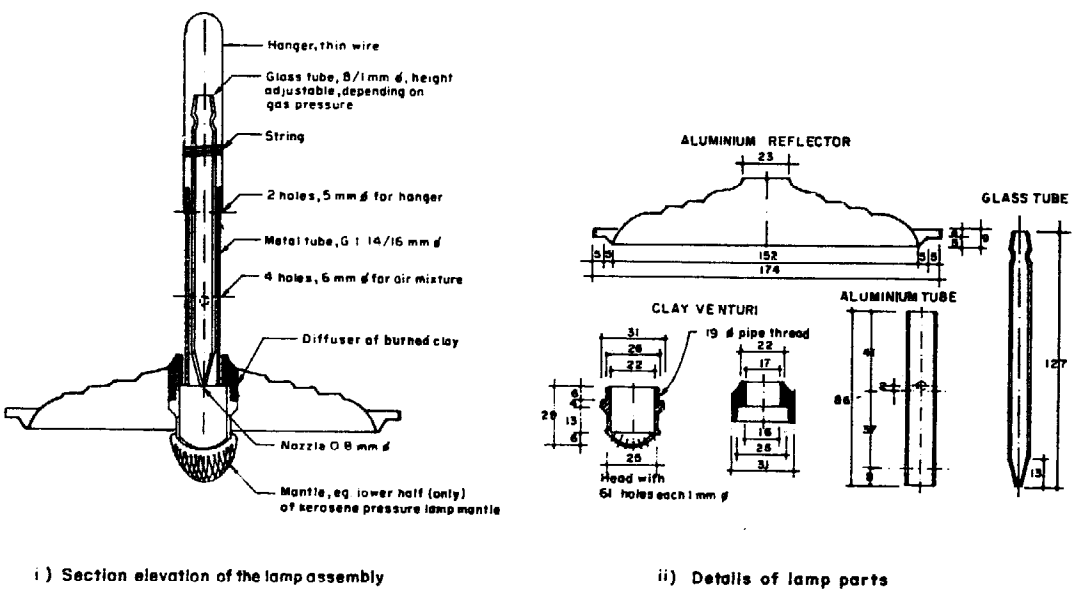

Figure 14. Simple biogas lamp (China)

5. Composting around the digester

The idea is to use the heat generated in aerobic digestion to heat the digester by constructing composting pits around and against the digester sides. It is important to empty and refill the compost pits regularly in rotation to avoid temperature fluctuation of the slurry.

B. MECHANICAL METHODS

The mechanical methods include stirring (mixing) and recycling of slurry.

1. Stirring (mixing)

Stirring is effective in helping to bring the bacteria closer to the digestion sites. A few minutes of stirring several times a day is desirable. Stirring also helps to break up any scum and to release the trapped gas bubbles. A number of mechanisms has been suggested for different digesters. A simple manual one with a minimum number of moving parts is desirable.

2. Recycling of slurry

In this method about 2 litres of old slurry are added to the new slurry in order to seed it with bacteria and increase gas production.

C. CHEMICAL AND MICROBIOLOGICAL METHODS

In these methods urine, urea fertilizer, molasses, sugar waste products etc. are added to increase gas production. One litre of urine per 1.4 m^3 of digester volume may be added every day. If urea is used a teaspoon per 3 m^3 of digester volume per day will be sufficient. About 70 grams per m^3 of molasses or sugar waste may also be added per m^3 of digester volume per day. Chopped water hyacinths and algae were also found to give significant increase in gas production.

IV. ACTIVITIES IN THE ESCAP REGION

Several countries in the region are undertaking and/or initiating projects on the research, development, demonstration and promotion of biogas. The information available is summarized below.[6]

1. Plant construction and operation

In Bangladesh research and development is being carried out on both the fixed dome and the floating gas holder digester. Investigation is also going on for optimizing the cost and efficiency of the different designs.

In China an extensive programme for testing different types of digesters including floating gas holder digester, separate gas holder and fixed dome digester are being undertaken. At present more than 8 million biogas units have been constructed in the

[6] For full details see the entries under individual expert and institution.

various provinces with more than 4 million units in Sichuan Province. The present goal is to bring the total number of the plants to 100 million units, thus utilizing the major part of human, animal and plant wastes in the country. In addition, the units that are out of function are under repair; the reasons for their malfunctioning are being investigated and the digesters are being renovated.

In Fiji research and development work is being undertaken by the University of the South Pacific. About 20 units have already been constructed. Small digesters utilizing animal, agricultural and vegetable waste are being investigated.

In Indonesia biogas plants are being considered as part of village energy development studies being undertaken by seven universities and one research institute, covering approximately 400 villages.

In India a major programme of biogas development has been underway for a number of years under the auspices of the Khadi and Village Industries Commission. Several educational and research institutions have been engaged on various aspects of biogas plant design, simpler construction, installation and maintenance techniques and cheaper materials such as ferrocement for gas holders etc. Two types of designs – one floating drum type and the other fixed dome type – are being pursued. So far approximately 80,000 plants of the floating drum type designs have been installed and about 2000 fixed dome type designs have also been introduced mainly in the northern provinces. A few community type biogas plants have also been set up and more of such types are envisaged. During the next five years India plans to reach a target of 500,000 plants.

In Malaysia a movable gas holder digester is being tested.

In Pakistan, plans have been drawn up for providing 160 villages with compact (community-type) biogas systems as part of the rural energy project, on which work has been initiated. Prefabricated ferrocement biogas plants are under investigation.

In Papua New Guinea large biogas systems have been designed for the conversion of human waste and coffee pulp into fuel and fertilizer.

In the Philippines industrial-size batch and continuous digesters with floating gas holders are being designed and constructed. Small biogas plants with separate digesters and gas holders are also being constructed. Regional biogas demonstration plants are being established for promotion purposes.

In the Republic of Korea about 24,000 family size biogas plants were built from 1969 to 1975. Owing to problems arising from low temperature, modified designs of underground digesters are under consideration.

In Sri Lanka the fixed dome digester is under investigation in view of its comparatively low cost. In addition promotional work for biogas plant is also continuing.

In Thailand about 600 biogas plants of the floating gas holder type have been constructed. Jar and fixed dome type digesters are also being experimented with.

2. Gas production and utilization

In Bangladesh gas yield from animal, agricultural and vegetable wastes is under study.

In China the gas is being used in cooking, for lighting, for running tractors, trucks and buses, for running engines and for electricity generation. The biogas after being compressed in bottles and put in the buses is released to a large neoprene balloon usually placed on the bus roof, then connected to the engine. A wide range of biogas lamps and stoves has been developed and manufactured in villages.

In India biogas is mainly used for cooking and lighting and for running engines for water pumping in agriculture, drinking water supply and in small agro-industries. Research is progressing on the use of biogas in welding and on increasing gas yield through techniques of maintaining optimum temperature conditions in the digester.

In Indonesia the utilization of biogas in refrigeration and for cooling is being studied.

In the Philippines biogas is being used in engines for pumping water, electricity generation and processing of meat.

In the Republic of Korea biogas is used in the rural areas mainly for cooking and space heating.

In Samoa, Sri Lanka and Thailand the gas is used mainly for cooking.

In Thailand a study on gas production using different plant wastes is being undertaken.

3. Microbiological aspects

In Bangladesh a study is planned for the identification and isolation of active methanogenic bacteria.

In China various microbiological studies are being undertaken in a number of institutions, e.g. bacteria production for village biogas plants, fermentation kinetics, use of enzymes, bacterial decomposition and use of additives to increase biogas production etc.

In India various microbiological studies involving fermentation kinetics in the mesophillic and thermophyllic ranges, isolation of specific microbiological strains, development of techniques for production and maintenance of enriched cultures of methanogenic bacteria and on enzyme hydrolysis of hynocellulosic materials etc. are being carried out.

In the Philippines studies are being undertaken on the microbial actions on biodegradable materials for improving the gas yield.

In the Republic of Korea microbiological research on isolation of specific bacteria and improving their effectiveness with particular reference to low temperature operations are being undertaken.

In Thailand studies are planned and/or being undertaken on the effluent from biogas plant as a source for single cell protein production and kinetic and population studies of methanogenic micro-organisms.

4. Effluent and its uses

In China the aspects being investigated include fertilizing efficiency and effectiveness of the bio-plant effluent and sludge, and potentiality of various uses of biogas plant fermentation residue.

In India investigations are being carried out on the effluent for enhancing its manurial value and on aspects relating to slurry handling and application as farm manure.

In the Philippines and Thailand the use of effluent for mushroom production is being studied. The utilization of digested slurry with local rock phosphate to increase crop yield is also being investigated in Thailand.

V. ECONOMIC, SOCIAL AND ENVIRONMENTAL ASPECTS[7]

Like any renewable source of energy, socio-economic evaluation of biogas systems faced problems in quantification, particularly of indirect costs and benefits of the economic, social and environmental aspects of biogas technology.

A. SOCIAL FACTORS

The socio-economic aspects of biogas economy included:

(a) Employment created in biogas construction work and related industries;

(b) Improving facilities in villages, thus decreasing migration to urban areas;

(c) Positive effects on the health of the farmers by improving hygiene in the village, providing better lighting and decreasing smoke hazards;

(d) Income redistributive effects, where access to biogas technology utilization is limited to comparatively affluent farmers;

(e) Costs involved in promotion and extension of biogas technology.

B. ENVIRONMENTAL FACTORS

The main environmental factor associated with the biogas is the introduction of a substitute to firewood which could mean conservation of forests and decrease in air pollution.

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[7] For full discussion, see "Guidebook on biogas development", *op cit.*, chap. XV, pp. 95-97. For actual applications in a specific country's context, see the following chapter.

II. USE OF PRODUCTS OF BIOGAS PLANT

As was mentioned before the main products of the biogas plant are the gas and the slurry. Both products are valuable and arrangements should be made to make use of both of them.

A. USE OF BIOGAS

A summary of the possible uses of the biogas is given in figure 15.

1. Cooking and lighting

A brief account was given in the last chapter on biogas stoves and lamps. Cooking and lighting represent over 90 per cent of the main uses of the biogas in developing ESCAP countries. The use of biogas in engines for motive power and electricity generation and for refrigerators will be considered briefly in what follows.

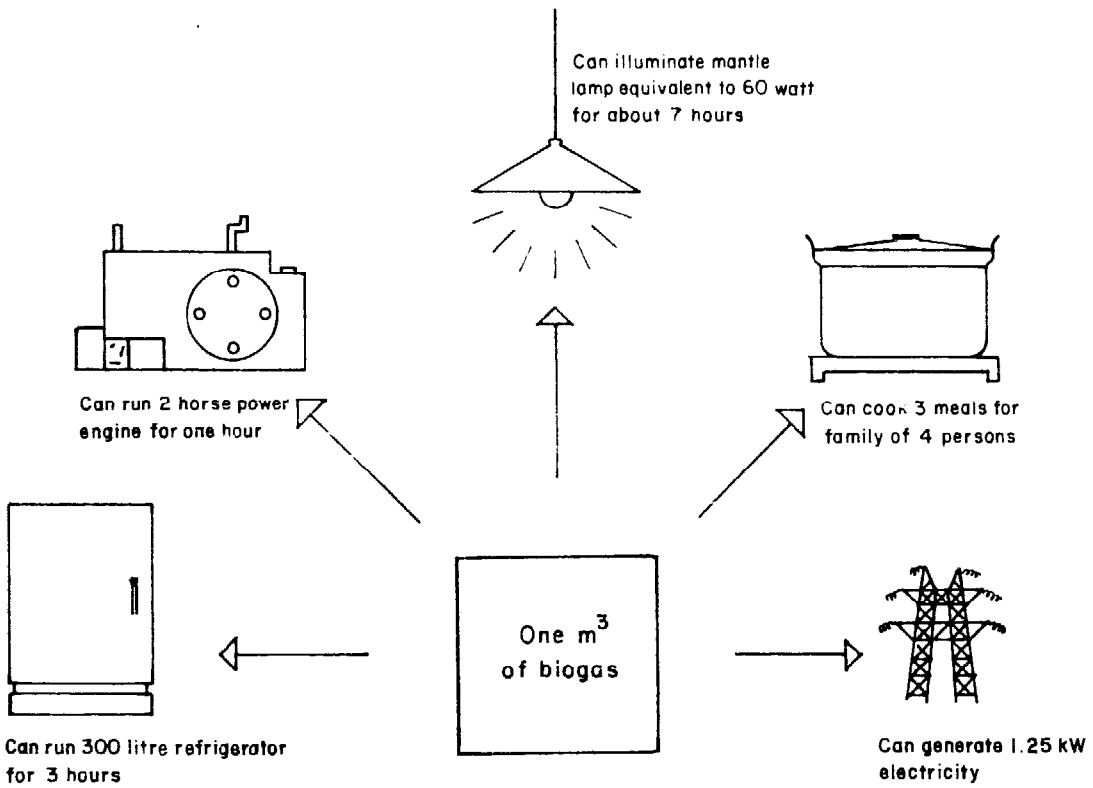

Figure 15. Possible applications of biogas

2. In engines

A petrol engine can run on 100 per cent biogas. It is common, however, to use a little petrol for starting up. The biogas is simply supplied to the intake pipe either through a venturi (see figure 16), without any modifications in the carburettor, or by replacing it by the gas carburettor shown in figure 17 if the engine is to run continuously on petrol.

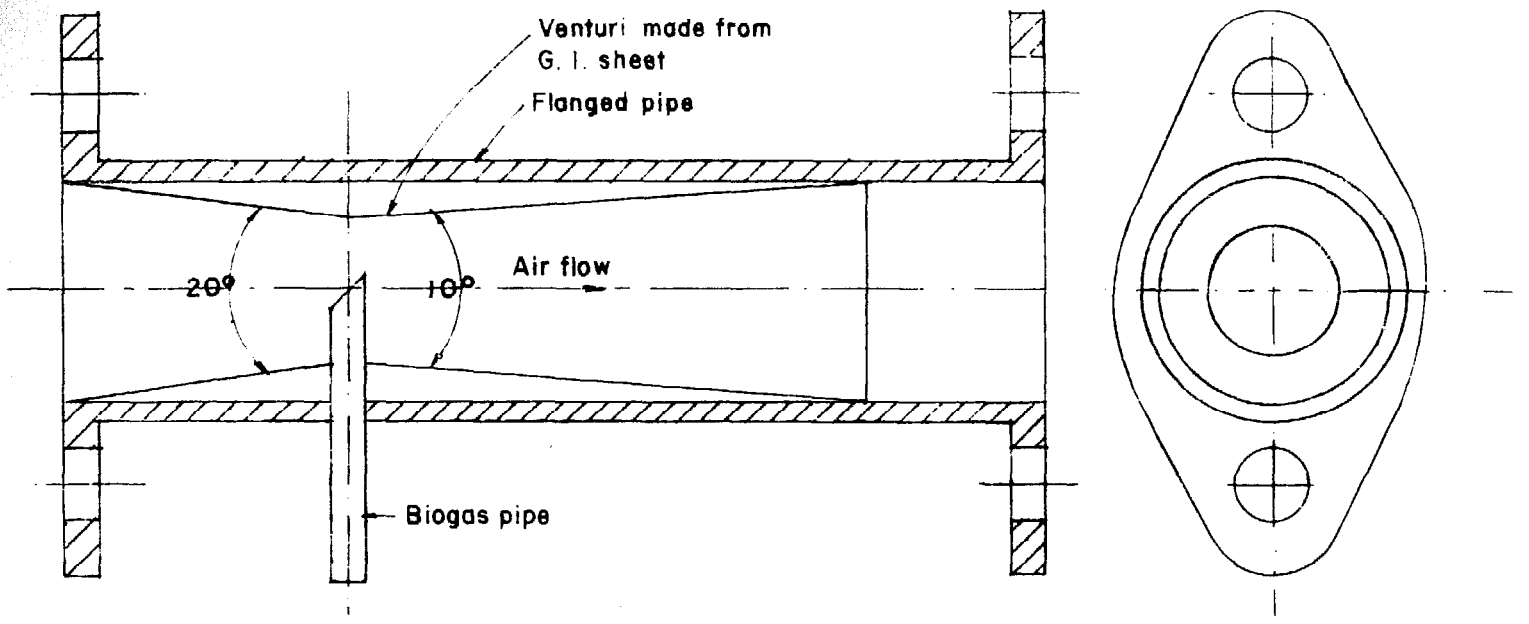

Figure 16. Gas venturi (Pakistan)

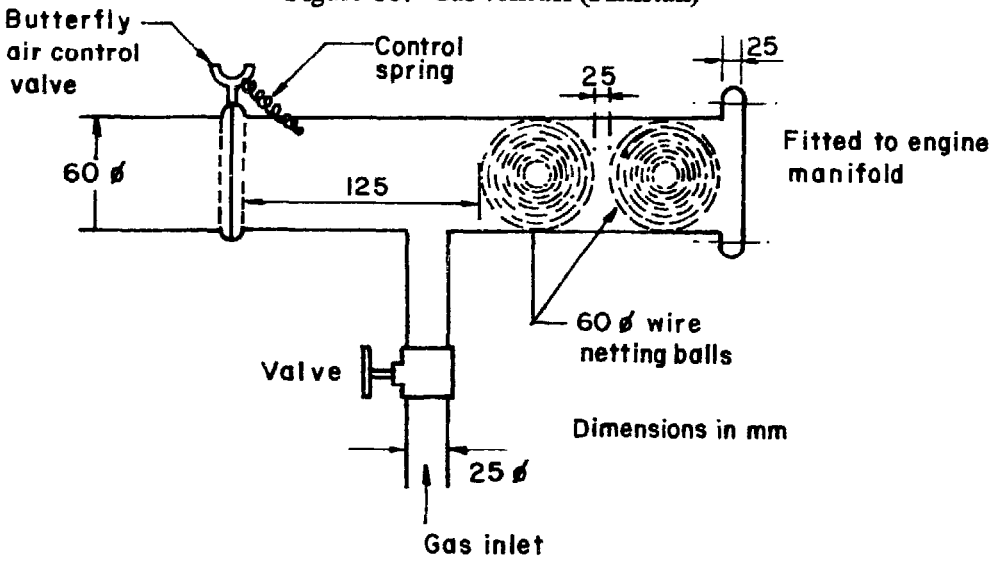

Figure 17. Carburettor for 10 bhp petrol engine running on biogas

In diesel engines the temperature at the end of the compression stroke is usually not more than 700° C, whereas the ignition temperature of the biogas/air mixture is 814° C. Hence the injection of a little diesel fuel just before the end of the compression stroke, to ignite the gas mixture, can ensure the normal running of the engine. Arrangements to take care of this are already included, as all types of diesel engines are normally set with an advance injection angle. Accordingly, it is usually enough to connect the biogas pipe to the air intake of the diesel engine (see figure 18). Some users in the Philippines have noticed that diesel engines run more smoothly on dual fuel when the compression ratio is lowered. Others in China added spark plugs. These optional solutions may increase the amount of the biogas used but will also decrease the rated power of the engine. Two connexions are given in figures 18 and 19 for the biogas pipe to the engine intake pipe.

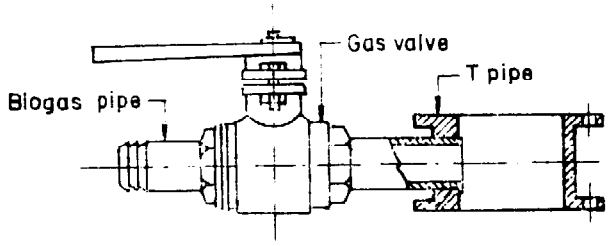

Figure 18. Direct connexion of biogas pipe to inlet pipe (China)

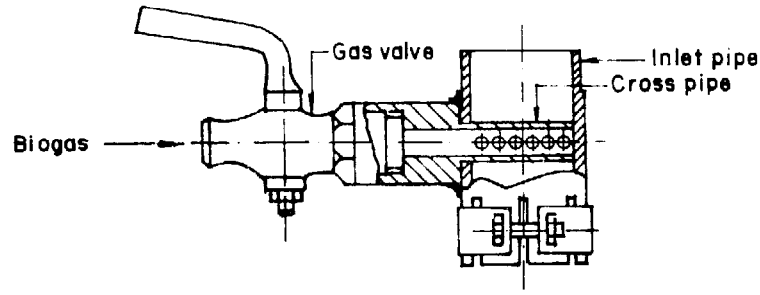

Figure 19. Cross flow connexion (China)

3. In refrigerators

Absorption type refrigerators can be run on biogas by adjusting a modified burner, e.g. Bensin or Telcu, to give the correct amount of heat.

B. USE OF SLURRY

In the floating gas holder digester the slurry consists of the effluent that comes out from the outlet pit. In the fixed dome digester, where plant wastes are usually added, the slurry consists of the effluent and the sludge which precipitates at the bottom of the digester and is formed mostly of the solid substances of plant wastes.

1. Use of effluent

The effluent can be used directly as fertilizer on plants. In China, it is sometimes diluted by irrigation water which carries it to the field. In India it is often used in composting. This is done as follows: a layer of straw or plant waste is first put in the pit then a layer of effluent. Again a layer of plant waste or straw is added followed by another layer of effluent and so on until the pit is full. In the Philippines a part of the effluent is recycled and mixed with the feed of the pigs as it contains vitamin B16.

2. Use of sludge

The sludge which is obtained twice, or more frequently from the fixed dome digester, is usually composted as above or mixed with chemical fertilizers as it contains a higher percentage of parasite and pathogens than the effluent.

III. METHODS OF IMPROVING PLANT PRODUCTIVITY

The methods that are generally adopted for improving plant productivity could be divided into thermal, mechanical, chemical and microbiological.

A. THERMAL METHODS

Gas production increases significantly when the temperature of the slurry is raised. The optimum temperature for the types of plant discussed earlier is about 35°C. At temperatures lower than 10°C gas production is insignificant. It is also necessary to maintain the temperatures constant within ± 1°C, as the bacteria cannot tolerate fluctuating temperatures.

1. Insulation of the digester

In this method the whole plant is insulated, including the gas holder. Insulating materials such as straw are usually used and they should be kept dry. The thickness of the insulating layer is about 5 to 8 cm. Experimental work on this subject was undertaken in India.

2. Heating of input slurry

In this method the input material is heated either by solar energy or by using a part of the gas produced. Excessive heating of the slurry, which would kill the bacteria, should be avoided. This technique was experimented with in different countries.

3. Glasshouse

In this method, a plastic tent is erected over the gas plant. This gives a greenhouse effect, provided the joints are made airtight. Plastic sheets deteriorate usually after one year due to aging under sunlight conditions. In some reports from Pakistan it is mentioned that this method increases gas production by about 50 per cent.

4. Solar heating of digester

Attempts to incorporate a solar water heater and heating coil in the digester were made in China and India. The idea is technically feasible and could be adopted if economically justifiable. One example of this technique, which has been tried in India, is illustrated in figure 20.

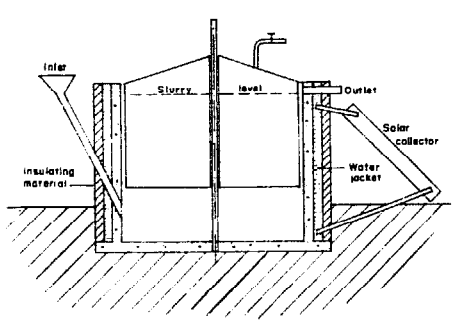

Figure 20. Solar-heated digester

C. METHODS OF QUANTIFYING SOCIO-ENVIRONMENTAL FACTORS

The social and environmental factors mentioned above are difficult to quantify at the level of the individual farmer. However, in carrying out comprehensive studies at the community or country level they should be taken into account. A few methods have already been suggested to quantify these factors. For example, the environmental factors may be accommodated by adding the capital cost to the costs of devices etc., needed in the case of conventional resources, in order to obtain the same environmental conditions prevailing when the biogas plants are used. Also, the cost of reforestation of an area that would have been deforested had firewood been used instead of biogas may be added to the capital costs.

Methods of quantifying the social factors may be also introduced by evaluating the possible social expenditure on non-employment should the labourers who are engaged in the construction work remain unemployed. Also the possible savings in foreign currency resulting from decreasing fossil fuel imports may be evaluated and taken into account.

As mentioned earlier these factors may be taken into account only in a large-scale comprehensive analysis. If the only interest is an analysis seen from the farmer's point of view, it would be enough to enumerate these factors in addition to a simple economical analysis.

D. ECONOMIC ANALYSIS

The two products of the biogas plant that should be evaluated at the individual farmer's level are the biogas and the fertilizer. There exist different approaches for the evaluation of the products of the biogas plant. A review of some of these methods may be found in the literature. One possible way of carrying out this analysis will be described below: the figures used are for illustrative purposes only.

1. Value of biogas

The gas should be compared with the fuels that it substitutes. Thus, in cooking it may be compared with firewood, butane, or charcoal. In lighting it may be compared with kerosene. It may be taken that 12.3 kg of dried dung cakes is equivalent to 61.5 kg wet dung, assuming 20 per cent solids in the wet dung.

If this dung were processed in a gas plant, it would be expected to produce 2 m^3 of gas (calorific value about 20 MJ/m^3) which is double the amount of heat obtained from the dung cakes (calorific value about 8.8 MJ/kg), taking into account the efficiency of the biogas stove which is about 60 per cent in comparison to the efficiency of the cattle dung stove (open hearth) which is usually less than 10 per cent. Besides, there is the further direct advantage of the subsequent fertilizer value of the effluent.

A few assumptions that simulate the conditions in rural areas and simplify the calculations will be made with illustrative figures to compare the cost against the benefits.

It will be assumed that the farmer obtains a loan for building the plant. The interest on the loan will be calculated using the annuity factor, but the effect of inflation will be ignored. The method can be illustrated with numerical examples.

(a) *Capital cost*

The total cost of the floating gas holder digester in India was from $US 50 to 60 per m^3 of digester volume. The volume of a 3 m^3/day biogas plant is about 8.5 m^3. Thus the total cost of the plant could be about $US 500.

Assuming that the farmer receives a loan at 10 per cent interest to be repaid over 10 years, the annual payment may be calculated from the formula:

$$C_a = \frac{C_c}{a} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where: a = the annuity factor, and is calculated from:

$$a = \frac{1 - (1+i)^{-n}}{i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

i = interest rate (percentage)

n = repayment period in years

Substituting i = 10 per cent and n = 10 in equation (2).

We find $a = 6.14$

Therefore $C_a = \frac{500}{6.14} = \$US\ 81$

The total cost of the loan including the interest will be 81 x 10 = $US 810.

(b) *Annual cost*

Assuming that the life of the gas plant is 20 years and that the repairs and maintenance costs are about 2 per cent of the capital cost, the annual cost will be

$$\frac{810}{20} + \frac{2 \times 500}{100} = \$US\ 50$$

(c) *Cost of energy*

It will be assumed that 70 per cent of the gas will be used, instead of wood, for cooking and 30 per cent, instead of kerosene, for lighting. Using the figures given in (a) for the calorific value of biogas (20 MJ/m^3), kerosene (38 MJ/litre) and firewood (20 MJ/kg), and assuming stove efficiencies of 60 per cent for the biogas and 10 per cent for the firewood and the same lamp efficiency for biogas and kerosene it is possible to arrive at the figures of the effective heat equivalent to 1 m^3 biogas. For firewood in cooking this will be 6 kg and for kerosene in lighting 0.53 litre.

Assuming further an average cost of $US 0.20/litre for kerosene and $US 0.02/kg for firewood, the cost of equivalent effective heat using 1 m^3 of biogas will be

0.2 x 0.53 = $US 0.10 for kerosene

and 6.0 x 0.02 = $US 0.12 for firewood.

From these figures it is easy now to calculate the annual benefits of using biogas instead of kerosene and firewood as follows:

Kerosene 0.1 x 3 x 0.3 x 365	=	$US 32.80
Firewood 0.12 x 3 x 0.7 x 365	=	$US 92
Total benefits of biogas as energy source	=	$US 124.80

2. Value of fertilizer

In order to set a value for the effluent as fertilizer in comparison to the raw or the coke dung, it will be assumed that (a) all elements except nitrogen remain constant no matter how they are used; (b) the fresh dung has initially 0.12 per cent nitrogen and that for each m^3 of biogas produced 32 kg of cattle dung is used per day, i.e. 11,700 kg/year.

Accordingly, in 11,700 kg dung at 0.12 per cent nitrogen there is 14.1 kg nitrogen. This is equivalent to about 31 kg of urea fertilizer which has normally about 46 per cent nitrogen. If urea costs about $US 0.20/kg and contains 46 per cent nitrogen then 1 kg nitrogen is $US 0.44.

From the above it follows that in the example of the last section the value of nitrogen in cattle dung for 3 m^3/day biogas plant = 14.1 x 3.0 x 0.44 = $US 18.60/year.

In the current method of making manure (piling the dung for 30 days before use) the manure value of nitrogen decreases by about 50 per cent, hence the value of nitrogen = 18.6 x 0.5 = $US 9.30/year.

If the new practice of drying the effluent is adopted, then only 15 per cent of the nitrogen will be lost. Accordingly, the value of nitrogen = 18.6 x 0.85 = $US 15.80.

The improved nitrogen value of the manure = 15.8 – 9.3 = $US 6.50/year.

3. Benefit/cost ratio

Continuing with the preceeding example the benefits to total cost ratio can be calculated:

Total benefit = 124.8 + 6.5 = $US 131.30/year

Total cost = $US 50

Benefit/cost = $\frac{131.3}{50}$ = 2.6/1

It is clear in the above example that the benefits from using biogas instead of firewood was the main factor affecting the above analysis. In many cases in the rural areas of the region all the firewood or part of it is being collected by family members, making it rather difficult to fix a value for it, even excluding the cost of the damage caused by deforestation to the society which is much higher than the value of the fuelwood given above. The benefits of not using firewood in the farmer's view in the above example may thus vary between $US 0 and 92/year. Consequently the benefit/cost ratio may accordingly vary between 0.77/1 and 2.6/1 depending on the ratio of firewood collected by family members to that purchased.

4. Case studies

Some comprehensive studies on biogas economics are being undertaken in the region. A survey of cost-benefit evaluation techniques as carried out in a developing ESCAP country is given in the next chapter, illustrative of their practical application in the context of a developing mixed economy, and of the methodological problems faced not only in a particular context but of general interest. It is hoped that more case studies will be available for other developing ESCAP countries, providing an expanding basis for interchange of knowledge and experience in this vital area.

VI. SCOPE FOR ECDC AND TCDC

Biogas technology has evolved as a mature technology in the developing countries largely as a result of their own efforts and under conditions obtaining in their rural areas. Hence there can be ample scope for fostering TCDC and ECDC activities among interested developing countries. Significant developments in biogas technology have taken place in developing ESCAP member countries, notably in China and India where its application has already become quite widespread. Considerable interest in it exists in Fiji, Indonesia, Nepal, the Republic of Korea, Pakistan, the Philippines and Thailand. A series of co-operative activities among developing countries can be envisaged and some illustrations are provided below.

There can be sharing of knowhow in areas such as biogas plant design, construction techniques, alternative construction materials, operation with different feedstocks and under different agro-climatic conditions, techniques for enhancement of gas production, and maintenance. This could be facilitated through:

(a) Interchange of drawings, specifications, design details, technical and socio-economic reports and other relevant information;

(b) Exchange of scientific and technical personnel;

(c) Offer of consultancy services under concessional terms for adaptation of existing designs to suit individual country's skills and raw materials;

(d) Mutual sharing of training facilities and training programmes.

Areas for mutual extension of technical assistance can include:

(a) Strengthening planning and programming capabilities at various levels including socio-economic evaluation techniques of biogas systems;

(b) Developing appropriate schemes for popularization of biogas programme;

(c) Strengthening of local institutions responsible for implementation;

(d) Developing appropriate financial institutions for administering loans, subsidies and other incentives.

Economic co-operation in this field can take place through grants for purchase of hardware such as biogas stoves, lighting mantles, biogas engines, biogas-operated tractors equipped with plastic bags (for storing biogas), valves and fittings, paints and others. There can also be promotion of trade in such hardware.

Joint ventures can be established among developing countries for production of prefabricated components for the construction of biogas plants, and for the manufacture of biogas stoves and other appliances such as space heaters, ovens, lighting mantles, plastic sheets and bags, repair and maintenance kits, small engines and other accessories.

There can be technical and economic assistance for setting up facilities for the testing, standardization and quality control of hardware/materials used for construction of biogas plants, for the measurement of the performance of gadgets for using biogas such as stoves, heating and lighting devices and engines, and for the study of fermentation kinetics, microbiological aspects etc. Biogas experimental stations can also be established through such co-operation.

In addition to regional workshops/seminars and other group meetings for interchange of knowledge and experience, joint research and development programmes either on a bilateral or multilateral basis can be developed. A regional network can be established of leading agencies, institutions and field-level organizations for exchange of experiences on plant operation with different feedstocks, maintenance problems etc. for collection and dissemination of information on scientific and technical developments and for facilitating exchange of technical personnel. Regional demonstration projects can be usefully evolved, involving village-level biogas plants supplying energy for cooking, lighting, agricultural pumping and agro-industries.

COST-BENEFIT ANALYSIS OF INDIAN BIOGAS SYSTEM: A CASE STUDY*

I. COST-BENEFIT ANALYSIS AND SOME EMPIRICAL RESULTS

A. USEFULNESS OF COST-BENEFIT ANALYSIS

In recent times there has been increasing emphasis in discussion among researchers of the development and expansion of not only commercial fossil fuel sources but also of new and renewable sources of energy such as solar energy, biogas, wind and tidal power, mini-hydro electric plants and power alcohol.

The use of biogas (popularly known as gobar gas in India) plants to generate methane gas from animal and plant wastes has been studied in India for over thirty years. The Government of India has been promoting biogas plants as alternative technology for energy supply in rural India through such measures as government subsidy and institutional credit. Until recently, the biogas technology being extended in India has been a simple KVIC (Khadi and Village Industries Commission) design named Gramalaxmi. To date about 70,000 small, family-size biogas plants, with a capacity range of 60-400 cu ft of gas per day, have been installed around the country. So far the very few large-size community plants installed have been for use in organized institutions. It is only recently that the Government of India has undertaken a programme to install large-size community plants is actual village situations on a pilot basis with a view to their popularization. During the last two to three years there have been attempts to popularize the fixed-dome biogas plant, popularly known as the "Janata" model.

The various studies made in India on the cost-benefit analysis of biogas plants are basically related to the small, family-size technology of KVIC design. Similar analysis of village-community plants as well as of Janata plants are constrained by a lack of adequate field data. However, even with the limited available data, some attempts are made to develop a framework of cost-benefit analysis of large-size community plants.

Broadly speaking, the cost-benefit analysis is an integral part of the process of project planning for decision-making over time. In essence, however, it examines the stage of feasibility in the project cycle limiting the alternatives to a few of the most promising ones. Thus, the cost-benefit analysis is an evaluation process for elimination in order to maximize the benefits by choosing the best alternatives for investment and minimize the incidence of unproductive and nonviable investments.

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* Based on a study, prepared for this publication, by T.K. Moulik, Professor, Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad, Gujarat, India.

Theoretically, a project is identified during the planning process itself. In the planning exercise a set of output targets for various sector-wise commodities, such as, energy, can be projected over the next five-year period considering the expected rate of growth of the economy and the pattern of income distribution. With sectoral targets known, the investment plan is determined in relation to domestic production or imports. It is this sectoral target which forms the basis of project identification. However, a mere identification of a project does not help in making final investment decisions. There are always several alternatives in terms of choice of technology, location, size, foreign exchange requirement, allocation of skilled manpower and other resources and welfare effects etc., which need to be examined before a final decision for investment is made. Even when there is only a single version of a project, there are two implicit alternatives: to do or not to do the project. The cost-benefit analysis is one of the most commonly used methodologies to determine the economic and financial viabilities of various alternatives of a project.

In general, any developmental project assumes a complex nature, particularly, in resource-constrained developing countries. With the help of cost-benefit studies, a project's viability and efficiency with respect to the economy-wide use of resources can be conveniently established. The next stage in the project cycle in terms of final investment decisions, implementation of the project and monitoring can follow after the feasibility of the project is evaluated and established through cost-benefit analysis.

A caveat should be added here about the use of cost-benefit analysis as the sole criterion for investment decision. The cost-benefit analysis is basically an exercise in predicting outputs and inputs in quantitative terms, which are more often than not subject to margins of error due to various assumptions, the nature of data base and other unforeseen circumstances. Nevertheless, the cost-benefit analysis provides some useful messages for investment decisions. A high internal rate of return (IRR), for example, signifies a good investment. An IRR somewhat below but approaching the opportunity cost of capital deserves tolerance since there are several other secondary benefits of social importance that cannot be measured. Low and very low IRRs, however, may signal an ineffective project, wrong priorities and the possibility of non-viability.

B. APPROACH OF COST-BENEFIT ANALYSIS

The cost-benefit analysis as conventionally applied to appraise a project investment is basically concerned with calculating costs and benefits. The enumeration and quantification of costs and benefits, however, differ according to the point of view from which profitability is being considered. "Primary benefits and costs" refer to project outputs and inputs. "Secondary costs and benefits" are related to more efficient alternative uses of resources.

Financial, economic and social evaluation are the three basic aspects of project appraisal. While the financial analysis deals with the profitability of the project at market prices, economic analysis is concerned with the determination of a set of prices reflecting "efficiency" benefits to the nation, that is, an analysis at efficiency

prices. Social analysis refers to social profitability in terms of welfare implications, such as, equity and distribution of income. The basic parameter in all the three aspects of cost-benefit analysis is to work out actual flows of income and expenditure in order to determine the financial, economic and social rates of returns out of the project investment.

Operationally, the conventional cost-benefit analysis is broken down to a number of measures of investment performances, such as:

(a) Financial cash flow or economic net benefit stream or social net benefit stream;

(b) Net present value (NPV) or the discounted net benefits;

(c) IRR;

(d) The payback period or capital recovery;

(e) The present value of capital or the benefit-cost ratio (PV/K).

C. APPLICATION

The performance measures in cost-benefit analysis, given above, are applied here to the small, family-size, KVIC-design biogas plants. The data for this analysis were obtained through a field survey of 173 small individual biogas plants of varying sizes distributed over four States of India, Madhya Pradesh, Uttar Pradesh, Haryana and Andhra Pradesh.[1]

1. Analysis of costs

Following the usual tradition, the costs of biogas plants are broken down into investment and operating cost components. The investment (or capital) costs of a biogas unit cover capital expenditure items, such as, cost of land and compost pits, cost of civil construction of the digester well, and costs of gasholder, pipes and appliances. The operating costs of a biogas unit are divided into variable and fixed components, the former covering items like cost of cowdung used as major inputs, the cost of labour for dung collection and for operating the plant, and cost of water, while the latter includes the cost of painting, repairs and replacement of the component parts.

In calculating the cost streams of the sample biogas units, the KVIC estimates[2] are used with necessary modifications derived from field observations. In the KVIC estimates, the capital costs of a biogas unit cover only the cost of gasholder, the cost of civil construction and the cost of pipeline and appliances. All the three items of capital costs are derived through component-wise break-down. Since the land area required for biogas installation and for compost pit construction is small (e.g. only 342 sq ft of land area for a 60 cu ft plant), it is assumed that it would have insignificant alternative economic use and therefore its cost can be taken as zero. Similarly,

[1] T.K. Moulik, U.K. Srivastava and P.M. Shingi, *Biogas System in India: A Socio-Economic Evaluation* (Ahmedabad, Centre for Management in Agriculture, Indian Institute of Management, 1978).

[2] Khadi and Village Industries Commission, *Gobar Gas Plants: Why and How* (Bombay, KVIC, 1975).

Table 1. Capital costs of biogas plants (in Rs)

Plant size	Cost of gasholder	Cost of civil construction	Cost of pipeline and appliances	Total initial cost
60	932	1 143	256	2 331
100	1 207	1 478	331	3 016
150	1 344	1 646	370	3 360
200	1 670	2 055	450	4 175
250	1 920	2 352	528	4 800
300	2 000	2 450	550	5 000
500	3 400	4 165	935	8 500

the cost of compost pit construction is taken as zero assuming that the cost of cement and labour used for this purpose would be the same as in the case of the usual process of composting manure without a biogas unit.

The major components of the operating costs of biogas plants are: the costs of cowdung, the labour costs for collecting cowdung and for operating and maintaining the plant, and the repair and replacement costs of various components of the plant. Using the KVIC estimate of conversion ratio, 1.3 cu ft of gas to 1 kg of wet dung, the total annual requirement of wet dung for a biogas unit is estimated. The values of this wet dung are assessed on the basis of its use as farmyard manure (FYM). Taking the estimated price of FYM as Rs 40 per ton, the cost of dung is included into the cost stream. Since the villagers do not usually hire labour exclusively for biogas plant operation, it is difficult to calculate the labour cost for maintenance and operation. However, following the KVIC estimate, Rs 100 per annum is taken as the labour cost for maintenance and operation. The costs for repair and replacement are calculated on the basis of the following observations in the field:

(a) Biogas plants are usually painted to prevent corrosion and rust every second year. The average cost of paint for each size is taken into the cost stream.

(b) The gasholder is repaired every fifth year and finally replaced after eight years. Thus, the average life of a gasholder before it becomes corroded beyond repair is taken to be eight years as against the KVIC estimate of 10 years. Similarly, hosepipes are replaced every third year and the pipelines are repaired during the third year. The central guide-pin is replaced every third year and burners every fifth year. The market prices for the repair and replacement of the component parts are included in the cost stream of the economic life of the plants.

(c) The KVIC estimate of the economic life of the plants is 40 years. However, the economic life of digester, pipelines and appliances vary between 20

and 40 years. For the purpose of our analysis, the economic life of the plant is taken as 30 years.

The cost stream taking into account both capital costs and operating costs of various sizes of biogas plants over the economic life of 30 years is presented in table 2.

Table 2. The cost stream of varying plant sizes (in Rs/year)

Economic life	Size of plant in cu ft/day							
	60	100	150	200	250	300	350	500
0	2 332	3 016	3 360	4 175	4 800	5 000	6 100	8 500
1	368	487	648	850	1 018	1 188	1 375	1 861
2	268	381	521	662	802	942	1 083	1 504
3	401	517	668	839	993	1 148	1 312	1 766
4	272	385	525	666	806	946	1 087	1 508
5	447	564	714	885	1 040	1 195	1 359	1 812
6	494	607	748	888	1 028	1 168	1 309	1 730
7	322	438	589	760	914	1 069	1 233	1 687
8	268	381	521	662	802	942	1 083	1 504
9	1 334	1 724	2 012	2 509	2 913	3 148	3 752	5 166
10	297	410	550	691	831	971	1 112	1 533
11	461	577	727	899	1 053	1 208	1 372	1 825
12	351	464	604	745	885	1 025	1 166	1 587
13	427	542	693	865	1 019	1 174	1 338	1 791
14	268	381	521	662	802	942	1 083	1 504
15	427	542	693	865	1 018	1 173	1 337	1 791
16	415	528	668	809	949	1 089	1 230	1 651
17	1 251	1 641	1 929	2 426	2 830	3 065	3 669	5 083
18	351	464	604	745	885	1 025	1 166	1 587
19	322	438	589	760	914	1 069	1 233	1 687
20	293	406	546	687	827	967	1 100	1 529
21	791	764	915	1 086	1 240	1 395	1 559	2 013
22	272	385	525	666	806	946	1 087	1 508
23	318	434	585	756	910	1 065	1 229	1 683
24	351	464	604	745	885	1 025	1 166	1 687
25	1 280	1 670	1 958	2 455	2 859	3 094	3 698	5 112
26	411	524	664	805	945	1 085	1 226	1 647
27	401	517	668	839	993	1 148	1 312	1 766
28	272	385	525	666	806	946	1 087	1 508
29	318	434	585	756	910	1 065	1 229	1 682
30	268	381	521	662	802	942	1 083	1 504

2. Analysis of benefits

Quantification of the benefits of a biogas system is a crucial step in the cost-benefit analysis. It is equally a difficult process given the existing situations in villages in India. The two major outputs of the biogas unit, the biogas and digested manure, are not usually traded commodities in Indian villages and therefore no market prices are readily available. Hence, it becomes essential to find an alternative way to evaluate these two benefits. In addition, there are genuine problems of quantifications of various secondary or indirect benefits of the biogas system, just as in the case of various indirect costs. For the present, however, let us consider the benefits from a small, family-size plant in relation to two major outputs, biogas and manure.

The average rate of manure production from a biogas unit is an imputed figure from the average input-output data in KVIC research stations.

According to the KVIC estimate, the manure obtained through the biogas plant is about 45 per cent more than the quantity obtained from the compost pit. With this assumption, the total value of annual manure production through a biogas unit is calculated in monetary terms at the average price of manure per cartload (i.e. 0.5 ton) as observed in the survey area.

In the valuation of biogas, the first problem is the seasonal variation in the rate of gas production. Taking into account the seasonal variation, the total quantity of gas produced by a biogas unit is converted into firewood equivalent using the conversion factor as given by KVIC.[3] Taking an average price of firewood as 20 paise per kilogram, as observed in some parts of the survey area, the estimated annual value of biogas from various sizes of plants are calculated.

Table 3. Seasonal variation in the rate of gas production

Seasons	Average rate of gas production (in percentage of plant capacity)
Summer (122 days)	100
Winter (120 days)	78
Monsoon (123 days)	86

It is now possible to present the estimated streams of benefits derived from the two major outputs of biogas plants.

[3] The KVIC estimate is: 1 kg firewood = 3.474 m^3 biogas.

Table 4. The benefit stream of varying plant sizes (in Rs/year)

Size of plant (in cu ft/day)	Value of gas (at Rs 0.20/kg of firewood equivalent of gas)	Value of manure	Total annual revenue (in Rs)
60	379.36	316.00	695.36
100	632.29	526.00	1 158.29
150	948.44	790.00	1 738.44
200	1 264.58	1 053.00	2 317.58
250	1 580.73	1 316.00	2 896.73
300	1 896.88	1 579.00	3 475.88
350	2 213.03	1 843.00	4 056.03
500	3 161.47	2 632.00	5 793.47

It should be pointed out here that in a large part of rural India, firewood is still obtained at zero private cost; the villagers do not purchase firewood and therefore there is no available market price for firewood in many villages. The price of 20 paise per kg of firewood used in the present analysis is, in fact, the observed average price of firewood prevailing in or around the survey areas, mostly in the nearby towns. Yet the social cost of indiscriminate cutting of firewood is certainly greater than the market price used in the analysis although many may not realize this. It may perhaps be more rational to use a varying level of prices of firewood starting from zero considering the private individuals' villager's point of view of investment decisions for biogas plants. The implication of the varying firewood prices on the benefit stream of biogas units is quite obvious.

3. Cash flow

Having worked out the inflow of income (benefit stream) and outflow of expenditure (cost stream), the financial cash flow stream of varying sizes of biogas plant can be analysed, taking the economic life of the plants as 30 years. The cash flow for 60 cu ft size plants is shown as an example.

4. Net present value (NPV)

Having established the financial or net economic flows, as shown in table 5 in relation to a 60 cu ft plant size, the problem now is to derive a present value by discounting all items in the net cash flow back to year 0. Denoting P_0 for the present value and $P_1, P_2 \ldots, P_t$ for the stream of payments accruing from years 1 to t, the general form of the discounting expression becomes:

$$NPV = \sum_{t=0}^{T} P_t(1+R)^t$$

Table 5. Cash flow for biogas plants of 60 cu ft (in Rs)

Year	Costs	Revenue	Cash flow
0	2 332	0	−2 332.00
1	368	695.36	327.36
2	268	695.36	427.36
3	401	695.36	294.36
4	272	695.36	423.36
5	447	695.36	248.36
6	494	695.36	201.36
7	322	695.36	373.36
8	268	695.36	427.36
9	1 334	695.36	−638.64
10	297	695.36	398.36
11	461	695.36	234.36
12	351	695.36	344.36
13	427	695.36	268.36
14	268	695.36	427.36
15	427	695.36	268.36
16	415	695.36	280.36
17	1 251	695.36	−555.64
18	351	695.36	344.36
19	322	695.36	373.36
20	293	695.36	402.36
21	791	695.36	−95.64
22	272	695.36	423.36
23	318	695.36	377.36
24	351	695.36	344.36
25	1 280	695.36	−584.64
26	411	695.36	284.36
27	401	695.36	294.36
28	272	695.36	423.36
29	318	695.36	377.36
30	268	695.36	427.36

What is important to remember here is that the use of a single discounting parameter, R, assumes that the time value of benefits falls at a constant rate, where R is an annual rate of interest. For financial analysis, the discount rate is normally the interest rate at which bank loans are available, that is, the opportunity cost. However, for the present analysis, three different discount rates, 10 per cent, 13 per cent and 15 per cent, are considered in view of the effect of likely inflation rates. It is assumed that the inflation rate is identical for costs and benefits.

The calculation of NPV at different discount rates can be shown by considering the cash flow stream for a 60 cu ft biogas plant.

Table 6. Discounted cash flow[a] and NPV for 60 cu ft plant (in Rs.)

Year	Cash flow	Discounted cash flow (10 per cent)	Discounted cash flow (13 per cent)	Discounted cash flow (15 per cent)
0	–2 332.00	–2 332.00	–2 332.00	–2 332.00
1	327.36	297.57	289.71	284.80
2	427.36	352.99	334.62	323.08
3	294.36	221.06	203.99	193.69
4	423.36	289.15	259.52	242.16
5	248.36	154.23	134.86	123.43
6	201.36	113.57	96.65	86.99
7	373.36	191.53	158.68	140.38
8	427.36	199.58	160.69	139.75
9	–638.64	–270.78	–212.67	–181.37
10	398.36	153.77	117.52	98.39
11	234.36	82.03	61.17	50.39
12	344.36	109.85	79.55	64.40
13	268.36	77.82	54.75	43.74
14	427.36	112.40	77.35	60.26
15	268.36	64.14	42.94	33.01
16	280.36	61.12	39.53	30.00
17	–555.64	–110.02	–69.45	–51.67
18	344.36	61.98	38.22	27.89
19	373.36	61.23	36.59	26.13
20	402.36	59.95	35.00	24.54
21	–95.64	–12.91	–7.36	–5.07
22	423.36	52.07	28.79	19.47
23	377.36	42.26	22.64	15.09
24	344.36	35.12	18.25	12.05
25	–584.64	–53.79	–27.78	–17.54
26	284.36	23.89	11.94	7.39
27	291.36	22.37	10.89	6.77
28	423.36	29.21	13.97	8.47
29	377.36	23.77	10.94	6.41
30	427.36	24.36	11.11	6.41
NPV		137.52	–294.32	–512.56

[a] The discounted cash flow at interest rates of 10, 13 and 15 per cent over 30 years are obtained by multiplying the cash flow figures in colume 1 by the multipliers in any standard set of discount tables.

Following the above example, the NPV for different sizes of biogas plants are worked out at 10, 13 and 15 per cent discount rates as shown in table 7.

The NPV provides a very simple investment decision rule which is to "accept if NPV > 0". In other words, an investment in a biogas plant of particular size is deemed acceptable if the value of NPV is positive.

Table 7. Net present values of investment in plants of various sizes

Size of the plant (cu ft/day)	Discount rate (percentage)	NPV (without deducting subsidy from initial cost) (Rs)	NPV (20 per cent subsidy deducted from initial cost) (Rs)
60	10	137.64	524.20
	13	–299.40	105.95
	15	–512.50	–98.38
100	10	2 558.28	3 166.82
	13	1 497.38	2 103.96
	15	938.80	1 589.51
150	10	6 204.33	6 876.33
	13	4 332.35	5 004.35
	15	3 427.98	4 099.98
200	10	9 108.66	9 943.65
	13	6 488.71	5 004.35
	15	5 223.48	4 099.98
250	10	12 362.90	13 323.5
	13	8 960.89	9 921.29
	15	7 318.53	8 278.83
300	10	16 157.8	17 157.8
	13	11 939.2	12 939.2
	15	9 903.62	10 903.6
350	10	18 748.9	19 950.3
	13	13 796.8	15 000.6
	15	11 407.0	12 612.0
500	10	27 883.2	29 583.2
	13	20 621.4	22 321.4
	15	17 117.0	18 817.0

Considering the government subsidy towards the cost of biogas plant installation, the whole analysis is done into two ways:

(a) Economic analysis, in which the entire cost of the biogas plant is entered into the cost stream;

(b) The financial analysis in which the government subsidy of 20 per cent is deducted from the initial cost.

In terms of an investment decision, it is clear that except in the case of 60 cu ft plant, the NPV is positive for all other plant sizes at varying discount rate. For a 60 cu ft plant, the NPV is negative at 13 per cent and 15 per cent discount rates in the case of economic analysis (without subsidy) and at the 15 per cent discount rate in the case of financial analysis (with subsidy). Even at a 10 per cent discount rate, the

NPV for a 60 cu ft plant, even though positive, comparatively smaller than in the case of other plant sizes. It is also clear from the analysis that the value of NPV increases with the increase in size of the biogas plants. One more significant point from the policy point of view is the observation that both the economic and financial analyses (with and without subsidy) show a similar trend in NPV. That raises the question of the rationale for giving a subsidy, particularly for a flat rate of subsidy. Since the valuation of biogas is at firewood equivalent, it would be relevant to find out the opportunity cost of firewood at which the NPV turns positive indicating the financial viability of the investment.

The IRR value implies that if the investor perceives the opportunity cost of firewood below the break-even level, the investment in a biogas plant does not seem financially viable for him. Yet it is clear from table 8 that except for a 60 cu ft plant, the larger size plants remain viable at an opportunity cost of firewood less than the market price of 20 paise per kg. In fact, the required opportunity cost of firewood at which NPV turns positive decreases with the increase in the size of plants. Following the trend it was observed[4] that a plant size of 3000 cu ft or above is viable even at zero opportunity cost of firewood at varying discount rates. If the perception of an investor about the opportunity cost of firewood is zero, as is most often the case in the rural areas, then a smaller size biogas plant does not seem to be viable for investment. It is on this basis that the case for a large-size, community plant and a subsidy for small family-size plants rest.

5. Internal rate of return (IRR)

Being a "pure number", IRR is widely used in project appraisal allowing projects of different size to be compared directly.

To define operationally, IRR is that discount rate at which NPV for a project is exactly zero. The decision rule corresponding to IRR is to accept the project if IRR is greater than the cost of capital ($R > C$).

Like NPV, IRR also shows a similar pattern in the sense that the values of IRR increase with the increase in plant size. Thus, even using IRR as criterion for making a decision for investment, the relatively larger plant sizes get preference over the smaller ones. Again, whether with or without considering the subsidy into the cost stream, the trend of IRR values remain the same except the fact that IRR with a subsidy (financial analysis) are greater in values than their corresponding values without a subsidy (economic analysis).

6. Capital recovery

One of the commonly used criteria for assessing the relative desirability of two or more projects is the payback period or the capital recovery criterion; the decision rule is to choose that project which recovers its capital costs in the shortest period.

[4] T.K. Moulik, U.K. Srivastava and P.M. Singi, *op. cit.*

Table 8. Opportunity cost of firewood at which NPV turns positive

Plant size (cu ft)	Discount rate (percentage)	Opportunity cost of firewood (paise/kg)
60	10	20
	13	Not even at 20
	15	Not even at 20
100	10	12
	13	14
	15	16
150	10	7
	13	8
	15	9
200	10	5
	13	7
	15	8
250	10	4
	13	5
	15	6
300	10	3
	13	4
	15	5
350	10	3
	13	4
	15	5
500	10	3
	13	4
	15	5

Table 9. Internal rates of return (IRR) for plants of various sizes (in percentages)

Size of the plant (cu ft)	Economic analysis (without subsidy)	Financial analysis (with subsidy)
60	10.82	13.98
100	20.74	26.63
150	32.19	40.75
200	35.75	45.09
250	40.03	50.36
300	47.10	59.09
350	45.28	56.82
500	47.52	59.59

The calculation of the payback period of a project investment is normally done by dividing the capital cost by the cumulative sum of the undiscounted net cash flow. However, for the present analysis the discounted cash flow is used, which does not after the ranking of the projects except that it leads to longer payback periods.

As table 10 indicates, the payback period also reveals a scale economy. This means that the capital recovery period is shorter as the size of the plant increases. The most interesting aspect is that the recovery period for a small, family size plant of 60 cu ft is too long to be recovered in the life of the plant, particularly at the discount rates of 13 per cent and 15 per cent in the case of economic analysis (without subsidy) and 15 per cent in the case of financial analysis (with subsidy). However, with the exclusion of subsidy into the cost-stream (financial analysis), the payback period reduces slightly.

Table 10. Payback period for biogas plants of varying sizes (in years)

Size of the plant (cu ft)	Discount rate (percentage)	Payback period (without subsidy)	Payback period (with subsidy)
60	10	23	13
	13	–	20
	15	–	–
100	10	7	5
	13	8	5
	15	8	6
150	10	4	3
	13	4	4
	15	5	4
200	10	4	3
	13	4	3
	15	4	3
250	10	3	3
	13	4	3
	15	4	3
300	10	3	2
	13	3	2
	15	3	3
350	10	3	2
	13	3	2
	15	3	3
500	10	3	2
	13	3	2
	15	3	3

7. Benefit-cost ratio (PV/K)

Another crude index of investment efficiency, popularly used by the economic planners is output-capital ratio, defined as the average (undiscounted) value-added produced per unit of capital expenditure. The PV/K or benefit-cost ratio is simply a discounting version of the above. The benefit-cost ratio compares the discounted net revenue stream with the discounted capital costs. Thus, the numerator (PV) does not include initial capital costs and may be taken as a gross rather than a net present value. The decision rule in this case is to accept the project if PV/K > 1. However, it must be noted that any project with a positive NPV will automatically have PV/K greater than unity. Hence, the criterion of benefit-cost ratio does not provide any extra information except that it may be additionally useful as a capital rationing device where the available public funds do not get exhausted at the discount rate used for planning purpose.

As expected, the PV/K ratios given in table 11 also confirm the scale economy for investment in biogas plants.

Table 11. Benefit-cost ratio of biogas plants of various sizes

Size of the plant (cu ft)	Rate of discount (Percentage)	PV/K
60	10	1.02
	13	0.94
	15	0.89
100	10	1.30
	13	1.20
	15	1.14
150	10	1.60
	13	1.49
	15	1.42
200	10	1.71
	13	1.59
	15	1.52
250	10	1.82
	13	1.70
	15	1.62
300	10	1.96
	13	1.83
	15	1.74
350	10	1.96
	13	1.83
	15	1.74
500	10	2.04
	13	1.90
	15	1.81

8. Sensitivity analysis

In the preceding section the measures of cost-benefit analysis, such as NPV, IRR and PV/K, are obtained under some specific valuation of some important parameters under certain assumptions. It is likely that the estimates of the key parameters used in the foregoing cost-benefit analysis will vary according to location, time-period, technological development and various other extraneous factors. Hence it is useful to analyse the effect of varying the key parameter values on the social profitability of a biogas unit.

It will be noted that the measures of cost-benefit analysis as presented above are calculated by varying the plant sizes and depreciation rates. However, in order to provide a more realistic basis for making an investment decision, the results of varying other key parameter values need to be examined to take account not only of differential impacts of optimistic and conservative assumptions, but also of the likely impact of the ongoing research and development efforts. To illustrate, an earlier study[5] carried out its analysis by valuing biogas at the market price of kerosene equivalent (instead of firewood equivalent as used in the present case) and using separately the KVIC estimates and observed sample estimates. The results of the analysis are shown in tables 12, 13 and 14.

It is interesting to note that the results obtained with kerosene equivalent valuation of biogas are similar to those obtained with firewood equivalent price used in the present case. However, there are some differences in the results obtained with KVIC data and the sample data. With the KVIC data, the payback period for various sizes of biogas units, for example, is shorter than those estimated with the sample data. Similarly, NPVs are smaller with the sample data as compared to those estimated with the KVIC data. Thus, the results indicate clearly the optimistic estimates of KVIC as compared to those obtained in the field situations.

One of the most crucially important sensitivity analyses should be in relation to the capital costs of biogas technology. There is considerable research and development effort going on to reduce the capital costs of biogas technology. The use of ferrocement or polythene bag instead of mild steel for gasholder has direct effect on capital costs of the plants. Similarly, the use of fixed-dome Chinese-type Janata plant has direct bearing on the capital cost structure of biogas plants. By replacing the movable steel gasholder of the KVIC model by the fixed dome of brick and cement, the Janata model of biogas plant is reported to reduce the costs (both capital and maintenance costs) by as much as 20 to 40 per cent. The effect of this cost reduction on the results of cost-benefit analysis is quite apparent. Bhatia[6] carried out a sensitivity analysis under two assumptions: 20 per cent and 30 per cent reduction of capital costs of biogas units. Bhatia observed that, "even if capital costs were reduced by 30 per cent, investment in a biogas unit would continue to be socially unprofitable if gas is mainly

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5 T.K. Moulik and U.K. Srivastava, *Biogas Plants at the Village Level: Problems and Prospects in Gujarat* (Ahmedabad, Indian Institute of Management, 1975).

6 Ramesh Bhatia, "Economic appraisal of biogas units in India: framework for social benefit cost analysis", *Economic and Political Weekly* (Bombay), vol. XII, Nos. 33-34, August 1977.

Table 12. Payback period and net present value of investment in plants of various sizes

Size of the plant (cu ft)	Discount rate (percentage)	Economic analysis: Using KVIC data: payback period (years)	Economic analysis: Using KVIC data: Net present value (Rs)	Economic analysis: Using sample data: payback period years)	Economic analysis: Using sample data: Net present Value (Rs)	Financial analysis: Using KVIC estimates with 25 per cent subsidy on initial cost: payback period (years)	Financial analysis: Using KVIC estimates with 25 per cent subsidy on initial cost: Net present value (Rs)	Financial analysis: Using sample data with 25 per cent subsidy on initial cost: payback period (years)	Financial analysis: Using sample data with 25 per cent subsidy on initial cost: Net present Value (Rs)
60	10	9	1 402.97	13	628.12	6	1 985.97	7	1 211.13
	13	10	638.35	23	77.24	7	1 221.35	8	660.24
	15	16	280.39	–	–190.72	7	863.40	12	392.28
100	10	5	4 406.55	6	2 788.45	4	5 160.56	5	3 542.45
	13	6	2 850.56	7	1 671.74	4	3 604.56	5	2 425.74
	15	6	2 125.13	8	1 130.58	4	2 879.13	5	1 884.58
150	10	4	8 695.68	4	6 638.47	3	9 535.67	3	7 478.47
	13	4	6 131.29	4	4 670.14	3	6 971.29	3	5 510.14
	15	4	4 938.56	5	3 718.63	3	5 778.56	3	4 558.62
200	10	3	12 203.60	4	9 857.84	3	13 247.60	3	10 901.80
	13	4	8 708.47	4	7 080.35	3	9 752.47	3	8 124.36
	15	4	7 083.59	4	5 738.39	3	8 127.59	3	6 781.39
250	10	3	16 074.70	3	12 651.50	2	17 274.70	3	13 851.50
	13	3	11 608.20	4	9 187.92	2	12 808.20	3	10 387.90
	15	3	9 532.64	4	7 514.95	3	10 732.60	3	8 714.95
300	10	3	20 541.90	3	12 651.50	2	17 274.70	3	13 851.50
	13	3	15 055.20	3	13 394.10	2	16 305.30	2	14 644.10
	15	3	12 507.20	3	11 176.50	2	13 757.20	2	12 426.50
350	10	3	23 781.40	3	18 978.48	2	25 306.40	2	20 503.40
	13	3	17 368.80	3	13 981.20	2	18 893.80	2	15 506.20
	15	3	14 390.30	3	11 568.40	2	15 915.30	3	13 093.40
500	10	3	35 002.90	3	31 535.00	2	37 127.90	2	33 660.00
	13	3	25 661.20	3	23 530.50	2	27 786.20	2	25 655.50
	15	3	21 322.80	3	19 667.30	2	23 447.80	2	21 792.30

Table 13. Internal rate of return on investment for plants of various sizes

Size of the plant (cu ft)	Economic analysis		Financial analysis (in percentage)	
	Using KVIC estimates	Using sample data	Using KVIC estimates (with 25 per cent subsidy on initial cost)	Using sample data (with 25 per cent subsidy on initial cost)
60	19.99	13.53	23.53	19.04
100	26.39	21.45	35.57	29.35
150	38.23	33.34	51.15	44.95
200	41.65	37.53	55.63	50.44
250	46.04	40.53	61.43	54.38
300	53.80	50.90	71.67	68.04
350	51.66	45.66	68.85	61.12
500	53.97	52.15	71.93	69.71

Table 14. Benefit-cost ratio of plants of various sizes

Size of the plant (cu ft)	Rate of discount (percentage)	Using KVIC data	Using sample data
60	10	1.23	1.10
	13	1.12	1.01
	15	1.05	0.96
100	10	1.55	1.34
	13	1.42	1.24
	15	1.32	1.17
150	10	1.87	1.66
	13	1.73	1.54
	15	1.64	1.47
200	10	1.97	1.78
	13	1.82	1.65
	15	1.72	1.57
250	10	2.07	1.84
	13	1.92	1.71
	15	1.82	1.63
300	10	2.23	2.07
	13	2.07	1.94
	15	1.98	1.86
350	10	2.21	1.96
	13	2.05	1.83
	15	1.95	1.75
500	10	2.29	2.16
	13	2.12	2.02
	15	2.02	1.93

Table 15. Comparative estimated costs of biogas plants (in Rs)

Size of plant (cu fit)	KVIC model	Janata model
60	2 332.00	1 650.00
100	3 016.00	2 250.00
150	3 360.00	2 910.00
200	4 175.00	3 760.00

Source: K.C. Kandelwal, *Janata Gobar Gas Plant* (New Delhi, Directorate of Extension, Ministry of Agriculture and Irrigation).

consumed for cooking purposes. Thus, in areas where electricity is already available for lighting, there is no case for providing subsidy for investment in biogas unit."

Bhatia[7] also did a sensitivity analysis using the varying delivered costs of soft coke and the calorific values of biogas and soft coke in determining the profitability of biogas units. Similarly, Susan Deo[8] used varying efficiency rates of gas production with the assumption of modification of the technology in the sensitivity analysis of biogas plants. All these exercises indicate the necessity to do sensitivity analysis with varying estimates of key parameters in order to arrive at a relevant and practical criterion for decision making. Such analysis assumes a critical role not merely in relation to the estimated values of required inputs (costs) but also, and perhaps more importantly, the estimated values of outputs (benefits). The results of such analysis may change drastically in favour of investments if and when reliable estimates of some of the secondary or indirect benefits could be imputed to the benefit streams.

9. Janata plants

As mentioned earlier, there are currently two common types of biogas plants which are being popularized in India – the KVIC model and the Janata model. The Janata plant is a drumless (no steel gasholder), fixed-dome, closed-type biogas unit made entirely of brick and motar, similar to those being used in China. The cost difference between the KVIC and Janata models is quite substantial. Since the Janata model does not require the steel gasholder the KVIC model does, the former is about 40 per cent cheaper than the latter (see table 15). It is also interesting and equally important to note that since 1978, the cost of constructing the KVIC model plant has gone up by as much as 20 per cent as against 10 per cent in the case of the Janata model.

The advantages of a reduction in the construction cost of a biogas plant as happens in the case of the Janata model are obvious for a third world country like India. Considering the cost factor alone, the Janata model may be more suitable to

[7] Ramesh Bhatia, *loc. cit.*

[8] Susan Ruth Rothrock Deo, "An economic analysis of biogas technology for a hypothetical village in rural India" (M.Sc. Thesis, University of Illinois, Urbana, 1980).

the large masses of the economically weaker sections for whom the KVIC model plant is mostly beyond reach. Considering the cost factor, the Government of India has been making special efforts since 1979 to popularize the Janata plants through the Ministry of Agriculture and Irrigation, New Delhi, and the Planning Research and Action Division, Uttar Pradesh.[9] In fact, it is hoped that about 50 per cent of Indian farmers will opt for the KVIC model, while the rest of the farmers will opt for the Janata model. In Uttar Pradesh alone already 7000 such plants have been set up.

In a recent study done for the Ministry of Agriculture, Government of India, the Agricultural Finance Corporation, Bombay, compared the economic and financial viability of the KVIC and PRAD (Janata) models.[10] It was found in the study that the 2 cu m and 3 cu m plants of KVIC models were not economical, while the 3 cu m plant of PRAD design (Janata model) was economically feasible. On account of cost reduction, the benefit cost ratios were found to be comparatively higher in the case of Janata plants than the benefit cost ratios of the KVIC models. The results as shown in table 16 clearly indicate that the financing of 2 cu m biogas plants would be uneconomical irrespective of models. In respect of a 3 cu m plant, the KVIC model would become financially feasible only at a 4 per cent rate of interest and with a subsidy of 50 per cent of the cost. It was also observed that the benefit cost ratios increased with the increase in size of the plants irrespective of the models. The study, however, concluded that under the existing subsidy the biogas plants of both KVIC and PRAD (Janata) models would be economical.

Table 16. Benefit-cost ratio, KVIC and Janata models (by size)

Model		Beneficiary group	(size in cu m) *Benefit-cost ratio*			
			2	3	4	6
KVIC	(a)	General (at 11 per cent rate of interest)	0.70	0.98	1.15	1.35
	(b)	Weaker section (at 4 per cent rate of interest)	0.74	1.03	1.22	1.43
Janata	(a)	General (at 11 per cent rate of interest)	0.88	1.25	1.42	1.60
	(b)	Weaker section (at 4 per cent rate of interest)	0.94	1.35	1.53	1.70

Some mention about the technical problems of the Janata plants must be mentioned here. First, considering the design and the building materials used, the economic life of the Janata plant is very likely to be shorter than the conventional KVIC model. In the absence of any reliable data and based on field observation, the economic life of a Janata plant can be assumed to be not more than 15 years as compared to 30-40 years in the case of KVIC plants. Secondly, it has been generally observed under field conditions that the rate of gas production fluctuates more widely between summer and winter months in the Janata plant than in the KVIC plant. Again,

9 In this connexion, see *Janata Biogas Model 1 Nirman Pusti Ka* (Lucknow, Uttar Pradesh, Planning Research and Action Division (PRAD), 1978) and P.B. Ghate and K.K. Singh, *Action Research in Biogas Development* (Lucknow, PRAD, 1978).

10 Agricultural Finance Corporation, *A Draft Note on National Biogas Project (1980-85)* (Bombay, September 1980).

there are no established scientific data to confirm or reject this impression. Lastly, and perhaps more serious, is the complaint usually made against the Janata plant that its gas yield is about 30 to 40 per cent lower than is the case with the KVIC model. Whether or not the lower yield is a scientifically established fact, it is a fact that the Janata plant suffers more from the leakages as compared to the KVIC model. Of late, there have been some successful experiments in tackling the leakage problem in biogas plants (both for KVIC and Janata models) by using a specially formulated paint.

However, in a few years time many of the technical problems of Janata plants will likely have been verified and scientifically established under varying field conditions in India. Meanwhile, the Government of India, the Ministry of Agriculture and PRAD in particular, have worked out plans to promote Janata plants on the same scale as the conventional KVIC units simply because of cost considerations.

10. Summary analysis

To recapitulate, the results to the cost-benefit analysis as presented above indicates that biogas units of higher than 60 cu ft. size were viable and there were scale-economies. In the economic analysis, the payback period for the 60 cu ft plant is found to be 23 years at 10 per cent, but at 13 and 15 per cent rate of discount, payback is not achieved during the life of the plant. In the financial analysis, at 10 per cent the payback is 13 years while at 15 per cent payback is not obtained during the life of the plant. The economic analysis shows a range of net present values from Rs 299.40 (for a 60 cu ft plant at 13 per cent) to Rs 27,883.20 (for a 500 cu ft plant at 10 per cent). The internal rates of return range from 10.82 per cent (for a 60 cu ft plant) to 47.52 per cent (for a 500 cu ft plant).

The corresponding range of values of NPV and IRR in the financial analysis are Rs 98.38 (for a 60 cu ft plant at 15 per cent) to Rs 29,583.20 (for a 500 cu fit plant at 10 per cent), and 13.98 per cent (for a 60 cu ft plant) to 59.59 per cent (for a 500 cu fit plant) respectively. The results are similar to those obtained when biogas is valued at kerosene equivalent market price.

It is also observed in the analysis that if the price of firewood (biogas was valued in firewood equivalent) is less than 20 paise per kg, even some of the larger biogas plants become less viable. At a 13 per cent discount rate, for example, the price of firewood has to be 14 paise per kg for the 100 cu ft plant to remain viable, while the 500 cu ft plant requires a price of only 3 paise per kg. Thus, the bigger sizes of plants can withstand quite low prices of firewood and still maintain their economic viability. From these results, it can be concluded that the small, family-size plants can be promoted only with massive subsidy, while the large-size, community plants can be a worthwhile viable investment even without subsidy, ignoring the problems of organization.

In its methodological approach and assumptions, the present analysis is to some extent different from many other studies made on the economic aspects of biogas units in India. The present analysis is largely at micro level in the sense that the costs and benefit streams are estimated from the point of view of individual private villagers.

Hardly any attempt has been made to concern itself with macro level societal or national considerations except that a subtle difference has been made between economic and financial analysis in relation to government subsidy. The economic analysis in the present study, by including the subsidy amount in the cost stream, also has covered part of the costs and benefits accruing to society or nation at large. However, financial analysis has been done mainly from the point of view of the villagers and only the cash inflows and outflows accruing to the villagers have been considered, the subsidy being treated as a reduction in cost. Even if such distinctions between economic and financial analysis, as in the study, are not conceptually and methodologically rigorous, the study has attempted to take into account a significant fact of life in terms of government policy concerning the subsidy.

At the same microlevel, the present analysis also differs from many other studies in three important aspects. First, all the costs and benefits of biogas plants have been estimated in relation to domestic market price rather than the "shadow price" or the foreign exchange equivalent price. Secondly, the present study deliberately used firewood equivalent and kerosene equivalent prices of biogas for the simple reason that these two are the most likely alternative fuels in rural India; alternatives in the form of electricity, soft-coke and other commercial fuel have been thus neglected. Lastly, the present analysis has been done by considering only one kind of functional use of biogas, that is, cooking or heating for which the dungcake and firewood are reported to be the most commonly used fuel in rural India. Hence the use of biogas for cooking or heating could save cowdung and firewood for better alternative uses and other social benefits, such as prevention of deforestation, provision of sanitation, and soil improvement through increased use of dung manure.

The methodological approach as followed in the present analysis has both advantages and limitations. How some of these limitations could be overcome have been referred to in the other cost-benefit studies of biogas systems. For the present, however, it would be interesting to compare the findings of the present study with some important similar studies on biogas systems in India.

One of the first detailed cost-benefit analyses was done by Parikh.[11] He evaluated the costs and benefits accruing to the national economy. The benefits were measured in terms of increase in foodgrain yield due to the use of digested manure and firewood saved. The value of the biogas was determined in relation to diesel and gasoline. Parikh also used costs of six different village situations: the 60 cu ft size with 50 plants at one plant per family; 10 plants at one plant for 5 families and 20 plants at one plant for 5 families; two 2500 cu ft plants for 50 families; one 1000 cu ft plant for 50 families and one 2000 cu ft plant for 100 families. As in the present study, Parikh also found that the larger size plants were less expensive. In another study, Parikh[12] observed that for a private owner of a biogas unit, it yielded "a gross return of 14 to 18 per cent purely in financial terms." His analysis showed that, with an

[11] K.S. Parikh, "Benefit cost analysis of biogas plants in India", (Ph.D. thesis, Massachusetts Institute of Technology, January 1963).

[12] K.S. Parikh, *Second India Studies: Energy* (New Delhi, MacMillan, 1976).

investment of Rs 2000 on a 2 cu m plant, the annual saving due to a biogas plant over the alternative of burning dung as cakes was Rs 298. The corresponding saving was Rs 364 when the alternative was the use of the entire dung for composting. However, it should be noted that the results of Parikh's studies were highly dependent on assumptions regarding the increase in the nitrogen-content in digested manure and the price of dung cake.

Prasad, Prasad and Reddy[13] compared the costs and benefits of biogas plants with that of rural electrification in order to meet the energy demands for cooking, irrigation pumping, industries and lighting. They estimated that a 5000 cu ft plant with a capital cost of Rs 41,000 excluding cost of pipelines, compressors etc., would have an annual cost of Rs 12,206 and an annual benefit of Rs 19,160 from the use of 4450 cu ft gas per day and they also estimated indirect benefits in terms of 22 tons of additional foodgrains due to the use of digested manure, foreign exchange saving on 2 tons of napththa, saving of 0.4 acres of forest per year and improvement in sanitation and health.

The results of the cost-benefit analysis as presented in an ICAR study[14] were overwhelmingly positive in favour of investment in biogas plants. Ascribing cash value to dung fuel, manure and cowdung, the ICAR study found the NPVs, in all the 18 cases under consideration, positive for all sizes of biogas unit. The report also analysed the private cost-benefit of a biogas unit from the farmer's point of view, in which the additional comforts and the saving of fuel costs from the use of gas were non-monetized. The study concluded that, "from the individual farmers's point of view also, the cowdung gas plant is an economically viable proposition."

Sirohi[15] one of the authors of the ICAR report, further extended the analysis to observe that the commercial benefit-cost ratio (at 10 per cent rate of interest) for a 70 cu ft plant was estimated to be 1.388 for North India and 1.504 for South India. However, considering the partly monetized benefit cost ratio, he concluded "that the monetized benefits of the gobar gas plant are not sufficient to cover the cost of gobar gas plant in the longrun."

Sanghi and Day[16] did a cost-benefit analysis by separately evaluating benefits in terms of coal and electricity (both subsidized and non-subsidized). They concluded that "the monetary benefits do not outweigh the cost incurred by an individual household that constructs a 100 cu ft plant." However, they were emphatic to mention that if all the indirect social benefits could be quantified and taken into account, benefits would outweigh costs.

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13 C.R. Prasad, K.K. Prasad and A.K.N. Reddy, "Biogas plants: prospects, problems and tasks", *Economic and Political Weekly*, vol. IX, Nos. 32-34, August 1974.

14 Indian Council of Agricultural Research, *The Economics of Cowdung Gas Plants: A Report* (Delhi, ICAR, 1976).

15 A.S. Sirohi, "Economics of gobar gas plant", *National Symposium on Biogas Technology and Usage*, Delhi, November 1977.

16 A.K. Sanghi and Dekle Day, "A cost-benefit of biogas production in rural India: some policy issues", in N. Lock Heretz (ed), *Proceedings of the Conference on Energy and Agriculture* (New York, Academic Press, 1977).

Bhavani[17] published a detailed social cost-benefit study of the small 2 cu m plant. She listed the outputs of fuel and manure as benefits and the capital and operating (including the opportunity cost of dung in terms of nutrient content of FYM) as costs. Biogas was valued in terms of soft-coke. An important point made in this study was that the results of such analysis were contingent on the previous uses of the raw materials. Bhavani analysed three alternatives for previous use of dung: one third fuel and two thirds manure, all manure and all fuel. The results of the analysis indicated that if any of the dung was used previously for fuel the use of a biogas plant was cost-effective. Yet, if all the dung was used previously for manure the benefit-cost ratios were found to be lower than with other alternatives.

Bhatia[18] made a significant contribution in the cost-benefit analysis of biogas plants in India by providing an outline of the range of costs and benefits to be considered and how they should or should not be included in an analysis. He also provided an illustration of how different uses of the products from biogas plants could vary in value. In his analysis, Bhatia reviewed a long list of primary and secondary benefits and direct and indirect costs of installing small biogas plants. He assumed 20 years plant's life and valued gas for lighting as kerosene equivalent and for cooking as soft-coke equivalent. He chose two cases for the value of manure: the same nutrient content as compost and a value greater than compost. With all these estimates, Bhatia found that the benefit-cost retios for a 70 cu ft plant at a social rate of discount of 10 per cent were less than 1. At a reduction of 30 per cent in investment cost this became 1.33 for the case where additional value of manure was assumed and 20 cu ft gas used for lighting and the remaining 50 cu ft used for cooking. Bhatia made two significant observations in his analysis. He concluded, for example, that the investment in a biogas unit would "continue to be socially unprofitable if gas is mainly consumed for cooking purposes." Secondly, on the basis of some specific assumptions he also found that the investment in a biogas unit to run an irrigation pump was not economic from the point of view of the society. However, he concluded that the profitability of biogas units could improve if gas was utilized both for cooking as well as for powering other machines.

Ghate[19] analysed the advantages of large-size, community biogas plants over smaller, family-size plants. Based on the ongoing experimental data on two pilot large, community-size plants (35 cu m and 45 cu m) in Uttar Pradesh, Ghate observed that "biogas based energy system is socially profitable when credit is taken for uses other than cooking and lighting." Following Bhatia, Ghate valued biogas is soft-coke equivalent for cooking and kerosene or electricity equivalent for lighting, i.e. without considering any credit for the manurial value. It turned out in the analysis that the direct gas lighting alternative was socially more profitable than the use of a generator. He, how-

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17 S. Bhavani, "Biogas for fuel and fertilizer in rural India: a social benefit cost analysis", *Indian Journal of Agricultural Economics*, vol. 31, July-September 1976.

18 Ramesh Bhatia, *loc. cit.*

19 P.B. Ghate, "Biogas: a decentralized energy system: a pilot investigation project", *Economic and Political Weekly* (Bombay), vol. XIV, No. 27, July 1979.

ever, rightly cautioned about the unreliability of the assumptions for much of the data used in the analysis.

In her recent study, Susan Deo[20] observed that the costs and benefits of community biogas plants were more consistently favourable than those of individual plants. Economies of size were substantial. She concluded that, "if the societal benefits, including improved health, less strain on dwindling forest resources and increased local and national energy self-sufficiency, were also incorporated the value of benefits might surpass costs in even the more questionable cases."

In two recent studies by Dandekar[21] and Kelkar, Malhans and Sanghera,[22] several social economic and cultural problems were evaluated in relation to popularization of biogas plants in rural India, with special reference to the fixed-dome Janata plant. These two studies were important in the sense that they gave insight into the socio-cultural factors that contributed to non-adoption of biogas plants at the village level.

A comparative review of the above mentioned studies via-a-vis the cost benefit analysis presented here clearly indicates that the profitability of biogas plants was crucially dependent on the various assumption of estimates of costs and benefits. However, all these studies seemed to confirm that inspite of various bottlenecks and substantial room for technical improvements, the investment in biogas plants even at the present level of technology was largely viable and attractive.

II. SOME METHODOLOGICAL PROBLEMS

Some basic conceptual as well as theoretical problems arise in the application of conventional cost-benefit analysis to renewable sources of energy like biogas systems, as is evident from the empirical analysis above. In comparison, many of these problems are either non-existent or are easier to solve in the case of alternative conventional non-renewable sources of energy, such as electricity generation and petroleum oil production.

Basically, the problems arise as the cost-benefit analysis is based on limited information to make predictions about the future. Any energy project and for that matter any project, involves one or more outputs and a whole series of inputs. Hence, the result of a cost-benefit analysis of a project is entirely dependent on the accuracy of a stream of calculations based on projected physical quantities and prices. It is unwise to rely excessively on the reasoning that overestimates in one place will be balanced by underestimates in another. For, there are variations in the importance of some variables in influencing the ultimate results. This means that the result of cost-

20 Susan Ruth Rothrock deo, *op. cit.*

21 H. Dandekar, "Gobar gas plants: how appropriate are they", *Economic and Political Weekly* (Bombay), vol. XV, No. 20, May 1980.

22 G. Kelkar, N. Malhans and J. Sanghera, "Showpice of Saidqpura". *Economic and Political Weekly* (Bombay), vol. 16, No. 9, February 1981.

benefit analysis is limited to the extent of reliability of available information, particularly about the key variables. While working on cost-benefit analysis of a project on renewable energy sources like biogas plants, one feels more constrained with the problems of accurate measurements of inputs and output than in the case of a project on non-renewable conventional energy sources like, say, thermal power stations. Comparatively speaking the problems of measurement of cost and revenue streams are of lesser magnitude in the case of conventional non-renewable energy sources simply because of the long tradition of experience in this sector providing a reliable basis of past trends under varying regional conditions and the far more advanced technological development aiding in reliable quantification of data based on technical judgement.

A. TECHNOLOGICAL DATA GAP

As noted earlier, many crucial technical data about the operation of biogas systems are yet to be standardized beyond any doubt. To illustrate, no clear scientific results are confirmed yet about the quality and quantity of digested manure from biogas systems as compared with compost or farm-yard-manure (FYM). It is claimed by KVIC[23] and ICAR[24] that the "manure obtained from a gas plant is about 45 per cent more in quantity" and contains "nearly twice as much N as compared with FYM per unit weight of dry matter." These claims have been equally forcefully contested: Sanghi and Day,[25] for example, have referred to the results of tests reported by Hart, which clearly indicates that the total nitrogen content of the dung does not change during digestion, even though there is a qualitative change in nitrogen.

The quality and rate of production of both digested manure and gas are affected significantly by various factors, such as, the composition of feeding materials used and its quality, the weather and temperature. Although ICAR and KVIC provide some average estimates, they do not take into account the wide-ranging situational variations.

As a result, any calculations done on the basis of the above mentioned available estimates remain merely a "second best" assumption in the absence of accurate and propery quantified scientific information.

As compared to the biogas system, the technical data on inputs and outputs of non-renewable energy sources are fairly standardized technologically. Also they are not affected by varieties of largely uncontrollable extraneous factors as is the case of renewable sources of energy. Hence, to the extent the data on non-renewable sources of energy are technologically standardized with less margin of variations, its cost-benefit analysis is easier for predicting more reliable results.

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23 Khadi and Village Industries Commission, *op. cit.*

24 Indian Council of Agricultural Research, *op. cit.*

25 A.K. Sanghi and Dekle Day, *op. cit.*

B. ECONOMIC LIFE

A problem which often causes concern is the question of how to calculate the economic life of a project, particularly in relation to renewable energy projects due to lack of data under varying conditions. Although KVIC claims the economic life of a biogas plant is of the order of 40 years, the field observations of various researchers (e.g. Moulik and Bhatia) differ. The same is true concerning the timing of repair and the replacement of various components of the biogas plant. This variation has a definite bearing on the results of any economic and financial analysis.

A project on non-renewable energy sources is usually made up of sophisticated engineering machinery, high value capital items. The economic life is simply determined at a point when borrowing money to replace it is cheaper than repairing it. As the sophisticated engineering machinery is widely used all over the world, there are sufficient data available to determine the point at which it becomes cheaper to replace equipment. However, even in this case the calculation of the economic life is becoming increasingly difficult because of the obsolescence of the old technologies by rapid technological change.

C. DECENTRALIZED VERSUS CENTRALIZED SYSTEM

Unlike the non-renewable energy sources (e.g. thermal power), which are basically a centralized operational units, the renewable sources of energy (e.g. biogas plants) are operated, by and large, at a decentralized level. Thus, assuming that there is no bottleneck on the supply side of the inputs, it is easy to estimate on the basis of technical and cost information, the input-output parameters of a non-renewable source of energy and its capacity in a fairly controlled manner. In the case of, say, a biogas plant owned by a villager, the input-output parameters will depend largely on the kinds of food eaten by his animals and their age, size and general health; whether latrines are connected with the plant; whether agricultural waste is used; the handling practices of collection of feed-stock of digesters and biogas slurry; and lastly the operating conditions and practices followed by the owner of the biogas plant. Since it is difficult to predict accurately the supply-response factors in such uncontrolled decentralized operations, the input-output parameters are usually estimated at the ideal experimental conditions, which most often are far away from the actual field situations.

Thus, for a renewable energy source like a biogas unit, the results of cost-benefit analysis tend to be more based on controlled ideal conditions than those that can be obtained in the real field situations.

D. PRICING

Like the quantification of physical input and output, the quantification of prices needs to be based on accurate prediction in order to work out a realistic cost-benefit analysis of a project. It is on this question of pricing, that those concerned with renewable energy sources face the most crucial and major problems. Interestingly, by its very technological nature, the problem of pricing in the case of non-renewable sources

of energy is relatively more difficult for both inputs and outputs. There are various seemingly insurmountable issues.

In doing financial analysis, for example, which is mainly concerned with the profitability of a project at market prices, one will take into account domestic market prices. There are two broad questions to be resolved in relation to the domestic market prices. First, whether the project itself is likely to have an impact on prices and if so, how does one take it into account. Secondly, there are likely to be price movements in the future under the influence of various extraneous factors. This is a question of price forecasting, in which the problem of inflation is one aspect since one would like to know how prices of inputs and outputs are likely to change relative to each other in relation to some base year.

In the case of economic analysis, one is concerned with that set of prices which best reflects "net efficiency" benefits to the nation. In a broader sense, the "efficiency" measure of a project output is related to the question of its contribution (actual or potential) to foreign exchange earnings (import or export). Likewise, the opportunity cost of any project input is concerned with its contribution to or claim on foreign exchange. In other words, for economic analysis, the world price rather than the domestic market price becomes relevant.

Within this broad framework of price-related issues, the most immediate and crucial problem with the cost-benefit analysis of renewable energy sources like a biogas system (in relation to both production and use) is the fact that in a large part of the rural areas in a country like India, there are no organized and stable markets for the major inputs (animal and plant waste) or outputs (biogas and digested manure). In other words, this is a typical problem of non-traded items, which also includes labour, particularly, unskilled labour. As mentioned earlier, in most Indian rural areas the inputs and outputs of a biogas plant, cowdung, plant waste, manure and cooking fuel, are obtained at zero private cost. Thus the perceived opportunity cost of these inputs and outputs for an Indian villager may be zero, while from the nation's point of view it could be substantial depending upon the way in which they are considered, such as, saving of commercial energy, of plant nutrients, of forests and also of foreign exchange.

Almost the same question arises about the valuation of the unskilled labour which again in the labour-surplus situation of Indian villages has zero opportunity cost. Yet, in principle, the economic cost of employing labour in the cost-benefit analysis is most often taken as the foreign exchange equivalent of labour consumption.

In short, the problem of pricing inputs and outputs in the renewable energy sources like biogas systems is more acute than in the case of non-renewable energy sources, like, a thermal power station, due to the preponderance of non-traded items. It is a complex question of rational and relevant estimates of "shadow prices" for most of the inputs and outputs. It must, however, be pointed out that the use of world prices as "shadow prices" in the new social cost-benefit analysis (SCBA), brings the

considerations of trade efficiency and distribution to the forefront, raising many critical questions just as it answers many others.

E. SECONDARY COSTS AND BENEFITS

Tracing through the various secondary costs and benefits of a project, irrespective of whether it is in the field of renewable or non-renewable sources of energy, is often exceedingly difficult. The problem is often insurmountable if one wants to quantify them for inclusion in the cost-benefit streams of the project. What is involved is the total impact of the project on the economy which cannot be readily identified and easily priced. To illustrate, the impact of an energy project on the generation of extra employment in the service sector, on the quality of life and environment, on the current distribution of personal incomes and on the foreign exchange situation, are important parameters for social cost-benefit analysis. Yet, in actual practice it becomes extremely difficult to obtain reliable quantified estimates.

In case of biogas units, for example, there are a number of indirect benefits one can identify, such as, improving environmental pollution and hygienic conditions, saving forests by preventing indiscriminate felling of firewood, preventing erosion and flood, making available pollution-free energy, making cooking more convenient and less laborious, saving the economic life of cooking utensils and reducing the uncertainty of commercial fuel supply. Ideally, a special premium should be attached to such benefits in cost-benefit analysis.

Similarly, on the cost side, there are indirect cost elements like the cost of benefiting the rich farmers and thereby increasing the income disparity, the likely cost of depriving the landless labourers and poorer-sections from the availability of cowdung and employment in collection of cowdung. These are broad social costs which would vary between regions. Again, for SCBA, these costs in quantified terms should ideally be incorporated.

Because of the lack of data, many of these indirect costs and benefits are ignored in the conventional cost-benefit analysis. This is perhaps one of the problems which is encountered almost with equal degrees of difficulty both in the case of renewable and non-renewable sources of energy.

F. RISK AND UNCERTAINTY

In many cost-benefit analysis exercises, often a single estimate of NPV or IRR is presented on the basis of which an "accept-reject" decision has to be made. One must bear in mind that this estimate of NPV or IRR is only one value amongst all possible values of outcomes. It is obvious, therefore, that some outcomes are more likely than others, given a particular set of assumption and estimates of variates entering the calculation of NPV. Thus, there is an implicit risk of reaching a particular outcome in cost-benefit analysis, which is formally known as "quantifiable uncertainty". Since the critical parameters of a project on energy sources, particularly renewable sources, are widely varying and are often estimated on the basis of some assumptions rather than

empirical-evidence, it is perhaps imperative to present a probability distribution of outcomes, P (NPV), rather than a single point estimates of profitability, in which the variables assume various values.

G. MULTIPLE USES OF OUTPUT

Any project on energy sources, be it renewable or non-renewable, has the potentiality of its energy output being used for multiple purposes. This means apportioning the evailable energy for using it into the best possible combination of functions in order to maximize benefits. For a biogas plant, for example, depending on the size of the plant, biogas can be used for cooking, lighting, operating irrigation pumps and for generating power for, say, running various small industries. The same is true for commercial non-renewable sources of energy. This point is often overlooked. For a realistic cost-benefit analysis, however, the patterns of potential multiple use of energy output should be assessed and alternative possibilities generated.

III. SOME APPROACHES TO METHODOLOGICAL PROBLEMS

The methodological problems of cost-benefit analysis as outlined above encounter varying degrees of difficulties to solve. Some of them require more research in order to generate reliable data, while others can be reasonably solved with the help of the existing state of knowledge and data. What follows are some suggested approaches to solving scientifically the methodological problems of cost-benefit analysis related to renewable sources of energy, particularly biogas system. It must be noted, however, that similar approaches are equally applicable to non-renewable energy sources.

A. TECHNOLOGICAL DATA GAP

As referred to earlier, there are conflicting claims about the quality and quantity of gas and digested manure production from biogas plants. In addition, there is still some confusion about the calorific value of biogas and cowdung cake. As a result, various estimates of values of these important parameters are used in different studies. Similarly, the knowledge about the quantified estimates of various social and economic impacts of biogas units is limited.

It is not that there are no data or estimates available for the many variables mentioned, but that there is confusion about the authenticity and source of such estimates. Given the varying experimental and field conditions in a decentralized technology system this is not totally unexpected. What is necessary is to co-ordinate and generate sufficient reliable data on the relevant variables by setting up carefully planned experiments in the field under varying conditions. For secondary costs and benefits, however, it is necessary to trace through the impact over a period of time in different field conditions.

Until such time as reliable technological data become available, one of the following approaches could be used by the analysts:

(a) Work out separate cost-benefit analysis with all available alternative estimates of the technological data or even with some reasonable hypothetical data. To illustrate, Bhatia did the analysis separately: first assuming that there was no significant additional benefit in terms of quantity and quality of digested manure from a biogas plant; secondly, by assuming that the increase in digested manure was 46 per cent (i.e. taking the KVIC estimate) and the nitrogen content of the digested manure was 1.6 per cent as compared to 1 per cent in compost manure.

(b) In the case where there are various conflicting estimates available for a particular variable, as in the case of calorific value of biogas, then one may do the analysis taking the average value. Bhavani, for example, used the median value (112 kil/cu ft) of a range of calorific values of biogas reported by Sathianathan.

B. ECONOMIC LIFE OF BIOGAS PLANTS

Bhatia, for example, assumed a 20-year plant life, while KVIC claimed 40 years and Moulik *et al* assumed 30 years. Again, given the effects of varying external conditions in which biogas plants are installed and operated, it is difficult to establish an accurate and consistent life of plant and equipment. One way to tackle this problem is to take the estimates of life of plant and equipment as observed under different conditions and then work out cost-benefit analysis separately for each assumption. A more prudent approach would be to use different rates of discount rate. In fact, if the set of discount rates used is realistic, it will make little difference to the net economic profitability with varying assumptions of economic life of the plant. The only caution one has to keep in mind in the last approach is the fact that lower discount rates, the results of the cost-benefit analysis will be more sensitive to the changes in the estimates of economic life.

C. PRICING

First is the problem of inflation. The crucial question here is whether the cost and benefit streams are given in current prices while discounting the net cash flow of a project. One way to tackle this problem is to estimate the rate of inflation and then add it to the relevant discount rate. Here the assumption is that a particular rate of inflation affects the cost and revenue of a project identically, which is hardly the case in a real situation. It is therefore a general and preferred practice to express all prices in constant terms for the purposes of financial analysis with domestic market prices. Likely movements in constant prices over time can then be determined by analysing the trend data. The most widely used prediction technique in this regard is the simple regression analysis with the historical time series data on prices. In other words, there are statistical techniques available which can solve even more complex problems encountered in price forecasting, which can be worked out by the statistician. What is, however, suggested here is that the key task of a project analyst is to properly utilize these statistical techniques for improving the financing analysis of a project.

Secondly, a more serious pricing problem is encountered in the case of economic analysis wherein it is now broadly accepted that the input and output prices of a project should be set in relation to their contribution to or claim on foreign exchange. In other words, the analysis of economic profitability is increasingly understood in relation to world price-relations rather than domestic price-relations indicating trade efficiency against which actual investment performance should be measured. In operational terms, this means the use of the shadow exchange rate (SER) to value the foreign exchange equivalent of the input and output prices expressed in home currency. SER is broadly that rate of exchange which accurately reflects the worth of an extra dollar in terms of one's own currency.

In determining the shadow prices, inputs and outputs need to be broken down into traded, potentially traded, and non-traded goods and basic factors of production including labour (both skilled and unskilled). Most projects will have these three types of goods in their input-output stream. In the case of a biogas plant in India, for example, inputs like cement, steel and bricks are easily recognised as the traded goods, whereas cowdung as input and digested manure as output can be treated at best as potentially traded goods. The agricultural wastes, if used as input, and biogas output are non-traded goods.

The practical difficulties encountered in setting the price for all the three categories of inputs and outputs can be illustrated, beginning with the case of traded goods. Traded goods are defined using the principle that the opportunity cost of any commodity, as long as it can be traded under present or predicted future conditions, is its border price. The difficulty in valuation of traded goods is solved by various methodological approaches:

(a) If the input or output is actually to be purchased from or sold abroad, price data can be obtained directly from the foreign supplier or buyer;

(b) If the input or output is domestically purchased or sold and a perfectly similar traded item cannot be found in the domestic markets, a useful approximation is to take the border price of the nearest equivalent traded goods and multiply it by the ratio of the domestic price of the home variety to the domestic price of the imported variety;

(c) Where there is a wide gap between the f.o.b. (export) and c.i.f. (import) prices of a commodity, a convenient shortcut is to take an average of f.o.b. and c.i.f. prices;

(d) In dealing with the problems of tariffs, taxes and subsidies of traded goods, the most common practice preferred is to use accounting ratios (AR) following World Bank conventions.[26]

Various methods have been applied in the different studies cited to estimate the price of traded goods in relation to biogas units. In the present case study on the

[26] M.F.G. Scott, J. MacArthur and D.M.G. Newbery, *Project Appraisal in Practice: The Little-Mirrlees Method Applied in Kenya* (London Heinemann, 1976).

Indian biogas system, for example, the land, labour and capital costs are taken directly from the KVIC estimates, which seem to be based on prevalent (1975) domestic prices and therefore not adjusted to foreign exchange equivalents at future time periods. Bhatia estimated in 1977 the price of cement and steel by giving a 20 per cent premium on market price, but at the same time suggesting a method of calculating the true shadow price of the two traded goods, cement and steel, by taking the f.o.b. price adjusted for a premium on foreign exchange and adding to it the transport and distribution costs. In the same study Bhatia used a zero "shadow wage rate" for unskilled labour, the existing market wage rate for skilled labour and a zero opportunity cost for land required for installing biogas units. Verma, however, in 1976 included the cost of land at the market rate as the opportunity cost of the land.

The valuation of potentially traded goods depends on the view taken as to how the situation will hold in future. In general, the potentially traded goods should be treated as fully traded goods if there is any indication that they will develop into this category in the foreseeable future, or as non-traded goods if the opposite is the case. It is with this consideration in mind that most of the cost-benefit analysis studies on biogas plants have so far considered cowdung and digested manure from biogas units as potentially traded goods. In the case of cowdung as an input to a biogas unit, the opportunity cost is taken to be its use as FYM and/or dung-cake as fuel. With the slowly developing market for FYM and dungcake (in fact, this trend can already be observed in many parts of India, particularly, in view of the green revolution), one may value cowdung by some local market price of FYM and cowdung cake. This was the approach used in the present case study on Indian biogas plants. A still better approach is to value the opportunity cost of cowdung in terms of plant nutrient contents (NPK) of FYM. Bhavani used this method and analysed three alternatives for previous use of cowdung: one third fuel and two thirds manure, all manure and all fuel. She used the same approach in valuing digested manure from a biogas plant assuming increases in nutrient contents. Many other studies (ICAR; Prasad, Prasad and Reddy; and Bhatia) used a similar approach. The important merit of this methodological approach is that such valuation can easily be converted into a foreign exchange equivalent of commercial fertilizers and therefore fulfils the criterion of the trade efficiency of the economic analysis as discussed earlier.

Lastly, concerning the valuation of non-traded goods, that is, those goods which do not enter into trade by their very nature, a useful approach could be to work out a long-term average AR for non-traded goods and then determine a suitable range of AR values sensitive to cost-benefit analysis. In the case of a biogas plant, the non-traded goods to be considered is biogas. It has been argued that the value of biogas is best determined by using the market price of an equivalent amount of the next best alternative fuel. The difficulty arises because of the differing views about the next best alternative fuel. Many studies (e.g. ICAR; Moulik and Srivastava; and Parikh) used the kerosene equivalent price of biogas, while an earlier case study and Susan Deo calculated the value of biogas in terms of firewood equivalent. Bhavani and Bhatia valued biogas in terms of soft coke, while Prasad, Prasad and Reddy used electricity equivalent prices of biogas. For macro level national planning, it is quite reasonable

to use soft coke or electricity equivalent values of biogas, but from the villagers' point of view at micro level such valuation perhaps has no direct relevance. The major sources of domestic fuel in rural India still remain to be dung cake, agricultural waste, firewood and kerosene. Thus, there is the divergence of interests and perceptions between the micro level villagers (beneficiaries) and the macro level planners. The task becomes still more difficult owing to extreme variation among the villages in relation to available energy sources and use patterns. The best methodological approach, therefore, could be to work out independent cost-benefit analysis taking all possible alternative fuels' equivalent values as a pricing mechanism for biogas and using the one relevant to a specific region or villages suited to its available energy resource position and use pattern.

D. MULTIPLE USE AND COST-BENEFIT ANALYSIS

The problems are directly related to the size of the plant or more specifically to larger than family-size plants. Very few studies have been done on biogas plants wherein the use of biogas is assumed to be for multiple functions, such as, cooking, lighting and generating power. Bhatia did a fairly detailed analysis for 70 cu ft and 105 cu ft per day size plants assuming various proportions of biogas being used for cooking and lighting. In a recent study by Susan Deo an interesting analysis was done by working out a total energy demand of a hypothetical village in relation to cooking, pumping water, lighting homes and industry. Taking the estimate of total energy demand of a village, she worked out the sizes most appropriate for the village and the cost-benefit ratios for combinations of community biogas systems. There is hardly any difference in methodologies for cost-benefit analysis of such systems except the higher capital and distribution costs. It is necessary to work out the basic parameters of cost-benefit analysis for such a large system based on direct observations under varying field conditions.

E. INDIRECT COSTS AND BENEFITS

The data required to predict various indirect costs and benefits, which is conventionally termed as secondary costs and benefits, particularly those related to social or welfare parameters, are formidable to collect. It is essentially a methodological problem of quantification of such data, which can either be collected over a period of time under fairly controlled conditions or at best can be hypothetical estimates. To illustrate, the effects of biogas plants constituting secondary costs and benefits would require baseline data against which the effects are to be measured and quantified. Even then, these quantified effects would have to be statistically explained in terms of the contribution due to biogas plants. Not that this is methodologically impossible, but the task is enormous and therefore in most analyses so far the substitution possibilities of these parameters are ignored. However, Prasad, Prasad and Reddy reported some of these secondary benefits in evaluating biogas plants versus rural electrification to meet the rural energy demand for cooking, irrigation pumping, industries and lighting. They estimated that a 5000 cu ft per day biogas plant would have an extra benefit stream of 22 tons of additional foodgrain from 4.4 tons of nitrogen, a foreign exchange saving

on 2 tons of naphtha for fertilizers, and a reduction of deforestation saving 0.4 acres forest per year.

In view of the reservation about the reliable estimates of various secondary costs and benefits, it is methodologically prudent to concentrate solely on those parameters for which a reliable set of quantified estimates are available. However, conscious efforts need to be made to carry out a comprehensive survey of villages and regions over a period of time where biogas plants have been installed in order to generate reliable estimates of secondary costs and benefits. Short of this survey, there cannot be any other alternative approach to tackle this particular methodological problems of social cost-benefit analysis.

F. CHOICE UNDER RISK AND UNCERTAINTY

All the above-mentioned alternative methodological approaches lead us to the problem of the probability of a particular outcome of cost-benefit analysis under different assumptions, to the problems of choice under risk and uncertainty. The calculations of cost-benefit analysis, or more precisely the values of NPV or IRR, depend largely on various assumptions under which the estimates of inputs and outputs are quantified. Given the nature of the project, particularly for a project like a biogas plant the operational parameters of which vary widely under equally varying exogenous factors, the assumptions and estimates are bound to vary. One of the most commonly used methodological approach to tackle this problem is sensitivity analysis, through essentially varying key parameter values, preferably one at a time but sometimes in combination, and then calculating a large number of NPVs. One can then assess the effect of changes in parameters on the central tendency estimate of profitability of the project. The decision rule for such analysis is to use the mean expected value as a criterion of central tendency of the probability distribution of NPV, that is, P(NPV), for project evaluation.

The application of sensitivity analysis in the case of cost-benefit analysis of biogas plants can be illustrated from almost all the studies cited. The resulting NPVs taking various fuel equivalent values of biogas, different depreciation rates, sizes of plants, different valuations on inputs and outputs, and considerations of costs with and without subsidy, are some examples of such attempts.

IV. CONCLUSION

In the foregoing analysis several conceptual and methodological issues have been raised about the cost-benefit studies of biogas plants as an alternative source of energy. Given the energy crisis these issues assume added relevance and importance, particularly for the net oil-importing third world countries. Under the circumstances, for most of the third world developing countries, the biogas technology appears to offer a logical alternative source of energy with considerable potential since both a more efficient fuel and a good quality organic fertilizer can be obtained from the system.

The results of various cost-benefit studies and the arguments presented earlier have suggested that the case for investment in biogas plant lies, in general, in the probable private profitability. Also, from the point of view of social benefit-cost, biogas plants seem to be an even more attractive and viable investment, given the import content and the general scarcity of fertilizers and commercial energy. However, there has been a strong indication of substantial economies of size of biogas plants when comparing the large plants with the smaller, family-size ones.

The enormous difficulty in quantifying all the benefits of a biogas system is amply demonstrated in the foregoing analysis. Since there is hardly any direct cash flow of benefits, it is difficult for many, particularly, the villagers, to see the advantages of installing biogas plants.In spite of this difficulty, it is shown in the present study how reasonable attempts can be made at quantifying the major benefits, with particular reference to the micro-level individual villager's point of view. However, the difficulty for quantification of benefits increases many times when one attempts to quantify macro-level societal benefits of biogas system, such as, improved health and sanitation, prevention of deforestation, improved soil structure and agricultural production due to additional use of digested manure, increased local and national energy self-sufficiency leading to saving of scarce foreign exchange, increased female labour efficiency etc. From the national point of view, these long-term, macro-level benefits are crucially important in determining national plan priorities. The present study concluded that if all the societal benefits are incorporated in the cost-benefit analysis, even the most questionable cases for investment in biogas plants will become viable. Considering such possibilities, both micro- and macro-level analyses are highly useful in order to determine the private as well as the social profitability of biogas plants.

One of the critical aspects for evaluating the potentiality of biogas plants is the appropriate uses for biogas. Since fuel for cooking is by far the greatest demand for energy in rural India, and the fact that the use of biogas for cooking immediately replaces cowdung cake and firewood, the two most important fuels used for cooking, and having a more profitable and worthwhile alternative use, many cost-benefit studies have considered the use of biogas mainly for the purpose of cooking. This is quite logical and appropriate. However, various studies referred to in the report have clearly demonstrated other more profitable uses of biogas energy such as, running engines, pumping water and powering small-scale industrial operations. It is therefore reasonable to conclude that the optimum use of a biogas system should be a package of multiple functions like cooking, pumping water, lighting, powering industrial operations etc. rather than simply cooking.

The present study also brings out various methodological uncertainties and limitations of cost-benefit analysis of biogas systems. It is, therefore, suggested that the results of the cost-benefit analysis should be used with caution for taking investment decisions for postponement or rejection of biogas programmes until priorities are sorted out, and various uncertainties and limitations are overcome. Keeping these limitations in mind, the study concluded with some suggestions for some methodological improvements of cost-benefit analysis and some future research needs.

It would be worthwhile briefly to recapitulate here some of the suggested future research needs which have larger policy implications for third world countries.

First, it has been consistently and clearly established that there is a scale economy for biogas plant sizes indicating popularization of large, community-size plants. This calls for setting up a number of pilot community plants under varying conditions and then comparing them more accurately with those of the family plants. Also, it is in these pilot projects, the management and organizational parameters of the community plants are to be worked out.[27]

Secondly, irrespective of large or small biogas plants, there is a clear and urgent need to conduct field experiments under varying conditions and regions in order to standardize or to arrive at realistic values of input and output parameters of biogas system. These field experiments should take into consideration alternative biogas technologies (e.g. KVIC and Chinese-type Janata models), use of different types of raw materials, various combinations of biogas use patterns, different plant size, different management and organizational patterns for community plants etc. It is through these field experiments under varying conditions that appropriate designs and distribution systems can be developed apart from realistically establishing the viability of the system.

Thirdly, if large-scale adoption of biogas technology is projected in the third world countries, there has to be a detailed analysis of the nation-wide changes in resource allocation, as well as, a comparative assessment of various other alternative energy sources, including a solar system, tidal and wind power, energy from forests, improving efficiency of burning current fuels etc., is required. A correct analytical comparison between various alternative energy technologies would provide the basis for choosing a particular combination of energy technologies suitable for specific communities leading to optimum available resources within the community. In other words, any future research on biogas technology should be undertaken keeping the broader objectives of rural development and energy needs in mind in which the biogas system is merely a part. In this context a most relevant question to be researched is whether allocating the current construction materials for massive development of biogas systems is an optimum use. There is, therefore, the urgent necessity for research on reduction of the use of expensive construction materials, to reduce the cost of biogas plants and to bring them within the economic reach of a wider section of the population than at present. It is in this context, the importance of the Chinese-type Janata model as compared to the KVIC model needs to be understood.

Lastly, there is an urgent need for a detailed analysis and quantification of the various secondary costs and benefits related to biogas systems. In fact, there has been a consensus among all concerned that there are important and significant secondary benefits both at private and societal levels to the extent that if properly assessed and

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[27] The Department of Science and Technology, Government of India, has recently sponsored about 20 such pilot community plants to be set up and studied for three-year period. The present author has taken up 10 of the 20 pilot plants for action research studies. Some analytical results should be available from these pilot plants after a year.

incorporated into the conventional analysis, a biogas system becomes viable even under seriously questionable assumptions. In spite of consensus about the importance of the secondary benefits, most of them have so far remained qualitative and unmeasured. Whatever few attempts were made to quantify these benefits and incorporate them in the analysis, they were largely based on hypothetical assumptions rather than actual field observations. The problem of measuring these secondary costs and benefits lies in the fact that it requires a fairly well-planned time series data on the basis of "before and after" surveys of the project areas. Such research effort is undoubtedly costly, but equally invaluable to planners and decision makers. In fact, there has been some deliberate attempts in China to collect these kinds of data on secondary benefits and to use them in persuading the villagers to opt for a biogas popularization programme in the communes.[28] Similar research efforts are needed in order to measure realistically all the secondary costs and benefits of biogas systems under varying field conditions.

In conclusion, it must be emphasized again that the major decisions regarding a future biogas programme in third world countries need not necessarily wait until the concept and methodology of cost-benefit analysis and its parameters are realistically developed. Even if there are various limitations, the present stage of analysis does certainly indicate significant pointers for decision making in relation to the investments in biogas programmes. While the attempts to overcome the conceptual and methodological limitations continue, it is essential for all nations to make concerted efforts for collaborative research and development on a long-term basis for mutual sharing of information and experiences related to use of alternative energy technologies, including biogas technology.

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[28] T.K. Moulik, "Biogas system and rural energy supply", in the author's forthcoming book, *China After Mao* (Bombay, Somaiya Publications, 1981).

ABBREVIATIONS

ADB	Asian Development Bank
AFPRO	Action for Food Production
AIT	Asian Institute of Technology
ASEAN	Association of South-East Asian Nations
BCSIR	Bangladesh Council of Scientific and Industrial Research
BUET	Bangladesh University of Engineering and Technology
CIAE	Central Institute of Agricultural Engineering
CIDA	Canadian International Development Agency
CSIR	Council of Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organization
CUSO	Canadian University Services Overseas
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
FCIC	Fellow, Chemical Institute of Canada
FIE	Fellow, Institution of Engineers
FIIPHE	Fellow, Indian Institute of Public Health Engineers
FRDI	Fellow, Resources Development Institute
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
IDRC	International Development Research Centre
IIT	Indian Institute of Technology
KSCST	Karnataka State Council for Science and Technology
KVIC	Khadi Village Industries Commission
MASE	Member, American Society of Engineers
MIDC	Member, International Dairy Congress (London)
MIE	Member, Institution of Engineers
MIME	Member, Institute of Military Engineers
MIPE	Member, Institute of Power Engineering
MISAE	Member, Indian Society of Agricultural Engineers

MISCA	Member, Indian Science Congress Association
MISES	Member, International Solar Energy Society
MIWWE	Member, Institute of Water Works Engineers
MRIC	Member, Royal Institute of Chemistry (London)
MSDT	Member, Society of Dairy Technology (London)
NDRI	National Dairy Research Institute
NEA	National Energy Administration
NIST	National Institute of Science and Technology
NRCP	National Research Council of the Philippines
NSDB	National Science Development Board
PAAS	Philippine Association for Advancement of Science
PPS	Philippine Phytopathological Society
PSM	Philippine Society for Microbiology
SAR	Society for the Advancement of Research
SATA	Swiss Association for Technical Assistance
SIDA	Swedish International Development Agency
SPATF	South Pacific Appropriate Technology Foundation
SPC	South Pacific Commission
SWD	Steering Committee on Wind Energy for Developing Countries
TERI	Tata Energy Research Institute
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
UPCA	University of the Philippines College of Agriculture
USAID	United States Agency for International Development
USP	University of the South Pacific
VITA	Volunteers in Technical Assistance

KEY TO NUMBERS IN ENTRIES UNDER EXPERTS AND INSTITUTIONS

Experts

1. National of
2. Date of birth
3. Academic and professional qualifications
4. Languages
5. Employment record
6. Primary fields
7. Other fields
8. Projects
9. Publications*
10. Address

Institutions

I. Information on institutions

1. Address; phone no.; cable address; telex no.
2. Established in
3. Chief executive
4. Officers concerned
5. (a) Number of technical staff
   (b) Number of digesters constructed/operated
6. Field station
7. Formal linkages with other institutions
8. Nature of work
9. Fields of work
10. Services
11. Training courses
12. Publications*
13. Projects

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* Where publications are included in the bibliography

II. Information on biogas plants

A. *Digester type and design*

1. Gas holder
   (a) Fixed (b) Movable
2. Digester size (m^3)
3. Materials used in constructing:
   (a) Digester body
   (b) Gas holder
   (c) Inlet
   (d) Outlet

B. *Digester feed*

1. Type of feed
   (a) Continuous (b) Batch
2. Feed material most common
3. Pretreatment and mixing of feed
4. Daily quantity of feed for continuous digester
5. Quantity of feed and frequency of feeding for batch type
6. Water to feed ratio

C. *Use of digester products*

1. Quantity of gas
   (a) Volume of gas produced/day (m^3)
   (b) Main uses
2. Use of effluent and the amount of effluent used in each of the following purposes:
   (a) Direct fertilizer on soil (kg/day)
   (b) Composting (kg/day)
   (c) Aquaculture (kg/day)
   (d) Recycling to digester (kg/day)
   (e) Recycling as feed to animals (kg/day)
   (f) Waste (kg/day)
   (g) Other applications (kg/day)
3. Effluent treatment for disease control

D. *Other information*

1. Cost of the plant in $US
2. Outside average temperature
   (a) Summer (°C) (b) Winter (°C)

3. Position of plant
   (a) Shadow (b) Sun
4. Additional heating of slurry and method used
5. Troubles in digester operation, their sources and methods of overcoming them
6. Percentage of digesters in operation to the total number of digesters constructed
7. Other comments on design to assist in trouble-free operation of plants

EXPERTS

A

1.	Mr. Romeo V. ALICBUSAN	Philippines
2.	Mr. M. AMARATUNGA	Sri Lanka
3.	Mr. Y.P. ANAND	India
4.	Mr. Muchidin APANDI	Indonesia

B

5.	Mr. Andreas BACHMANN	Switzerland
6.	Mr. Julian BANZON	Philippines
7.	Mr. Ajit Kumar BASU	India
8.	Mr. T.D. BISWAS	India
9.	Mr. Piyawat BOON-LONG	Thailand

C

10.	Mr. CAO Guo-Qiang	China
11.	Mr. CAO Ze-Xi	China
12.	Mr. CHAI Chang-Da	China
13.	Mr. Sompongse CHANTAVORAPAP	Thailand
14.	Mr. CHEN Sheng-Geng	China
15.	Mr. CHONG Chok-Ngee	Malaysia
16.	Mr. M. Yusuf CHOWDHURY	Bangladesh

D

17.	Mrs. Revadee DEEMARK	Thailand
18.	Mr. A.K. DHUSSA	India
19.	Mr. J.A. D'SOUZA	India

E

20.	Mr. Muhammad EUSUF	Bangladesh

F

21.	Mr. FENG Wei-Cheng	China
22.	Mr. Nigel FLORIDA	Canada

G

23.	Mr. H.P. GARG	India
24.	Mr. K.V. GOPALAKRISHNAN	India
25.	Mr. K.P. GOSWAMI	India
26.	Mr. GU Zhen-Gang	China
27.	Mr. Chaman L. GUPTA	India

H

28.	Mr. Kiyonori HAGA	Japan
29.	Ms. HU Li-Na	China
30.	Mr. Ishrat HUSSAIN	India

I

31.	Mr. S.G. ILANGANTILEKE	Sri Lanka
32.	Mr. M.M. ISLAM	Bangladesh

J

33.	Mr. R.C. JAIN	India
34.	Mr. S.C. JAIN	India
35.	Mr. D.S. JOSHI	India
36.	Mr. Vishnu JOSHI	India

K

37.	Mr. Jagdish Chandra KAPUR	India
38.	Mr. Amrit Bahadur KARKI	Nepal
39.	Mr. K.C. KHANDELWAL	India
40.	Mr. Ghulam KIBRIA	Pakistan
41.	Mr. Kyun Uk KIM	Republic of Korea
42.	Mr. Suchart KLINSUWAN	Thailand
43.	Mr. C.P. KOTHANDARAMAN	India
44.	Mr. Savang KULAPATRAPA	Thailand

L

45.	Mr. LI Chang-Sheng	China
46.	Mr. LI Fang-Qiang	China
47.	Mr. LI Nian-Guo	China

48.	Mr. LING Dai-Wen	China
49.	Mr. LIU Ke-Xin	China
50.	Mr. LIU Ting-Wei	China

M

51.	Mr. Felix D. MARAMBA, Sr.	Philippines
52.	Mr. MEI He-Xiao	China
53.	Mr. T.K. MOULIK	India
54.	Mr. Raymonds M. MYLES	India

N

55.	Mr. Ram Krishnan NAIDU	Fiji
56.	Mr. V.P. NARAYANASWAMY	India
57.	Mr. S. NEELAKANTAN	India
58.	Ms. Watana NOPAKOON	Thailand

O

59.	Mr. Enrico D. OBIAS	Philippines

P

60.	Mr. V. PADMANABHAN	India
61.	Mr. Mohan PARIKH	India
62.	Mrs. P.P. PARIKH	India
63.	Mr. G.L. PATANKAR	India
64.	Mr. T.M. PAUL	India
65.	Mr. PENG Wu-Hou	China
66.	Mr. Chongrak POLPRASERT	Thailand
67.	Mr. G.G. PURI	India

Q

68.	Mr. QIAN Ze-Shu	China

R

69.	Mr. S.K. RAJAPAKSE	Sri Lanka
70.	Mr. M.A. Sethu RAO	India

71.	Mr. P. Sreenivasa RAO	India
72.	Mr. Sermpol RATASUK	Thailand
73.	Mr. REN Yuan-Cai	China

S

74.	Mr. M.A. SATHIANATHAN	India
75.	Mr. B.R. SAUBOLLE, S.J.	India
76.	Mr. Iqbal Hussain SHAH	Pakistan
77.	Mr. J.B. SINGH	India
78.	Mr. Ongart SITTHICHAROENCHAI	Thailand
79.	Mr. Pichit SKULBHRAM	Thailand
80.	Mr. Koentoro SOEBIJARSO	Indonesia
81.	Mr. Richard K. SOLLY	Australia
82.	Mr. W. Robert STANTON	United Kingdom
83.	Mr. D.J. STEWART	New Zealand
84.	Mr. SUN Guo-Chao	China
85.	Mr. Calixto C. TAGANAS	Philippines
86.	Mr. Morakot TANTICHAROEN	Thailand
87.	Mr. Boontham TESNA	Thailand
88.	Mr. Y.R. TIPNIS	India
89.	Mr. Hiroji Narayan TODANKAR	India
90.	Mr. TSE Shu-Chien	China
91.	Mr. TU Jia-Bao	China
92.	Mr. Sornthep TUMWASORN	Thailand

W

93.	Mr. WANG Da-Si	China
94.	Mr. WANG Meng-Jie	China
95.	Mr. WANG Xin-Quan	China
96.	Mr. Myo WIN	Burma
97.	Mr. Dong Han WOOK	Republic of Korea
98.	Mr. WU Chang-Lun	China
99.	Mr. WU Jin-Peng	China

X

100.	Ms. XIAO Ying-Chang	China
101.	Mr. XU Jie-Quan	China

102.	Mr. XU Ke-Nan	China
103.	Mr. XU Yi-Zhong	China
104.	Mr. XU Zeng-Fu	China

Z

105.	Mr. ZHANG Chang-Ming	China
106.	Mr. ZHANG Guo-Zheng	China
107.	Mr. ZHANG Wei	China
108.	Mr. ZHOU Meng-Jin	China
109.	Mr. ZOU Yuan-Liang	China

ADDITIONS

110.	Mr. J.H. FINLAY	United Kingdom
110(a).	Mr. M. Sohail QURESHI	Pakistan
110(b).	Mr. P. RAJABAPAIAH	India
110(c).	Mr. TIAN Feng	China
110(d).	Mr. B.V. UMESH	India

INSTITUTIONS

Bangladesh

111. Bangladesh Agricultural University
112. Bangladesh Council of Scientific and Industrial Research, Institute of Fuel Research and Development

China

113. Artificial Biogas Experimental Station, Nanhui County
114. Beijing Academy of Agricultural Science, Research Institute for Soil and Fertilizer
115. Chengdu Biogas Research Institute
116. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture
117. Chengdu Biological Research Institute, Chinese Academy of Sciences
118. Chengdu Institute of Biology, Chinese Academy of Sciences
119. China Research and Designing Institute of Agricultural Engineering
120. Chongqing Teachers Training College
121. Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences
122. Hangzhou City Biogas Extension Office
123. Institute of Microbiology, Chinese Academy of Sciences
124. Jiangsu Province Wujin Biogas Research Institute
125. The Office of National Leading Group for Biogas Development, Ministry of Agriculture
126. Research Institute for Soil and Fertilizer, Academy of Agricultural Science
127. Shandong Province Energy Resource Research Institute
128. Shanghai Institute of Industrial Microbiology
129. Shanghai Science and Technology Association
130. Xinan Teachers Training College, Biogas Research Institute
131. Zhejiang Agricultural University, Laboratory of Soil Microbiology
132. Zhejiang Biogas and Solar Energy Scientific Research Institute

Fiji

133. University of the South Pacific, Institute of Natural Resources

India

134. Action for Food Production (AFPRO)
135. Agricultural Tools Research Centre
136. Centre of Science for Villages
137. Delhi Water Supply and Sewage Disposal Undertaking
138. Gobar Gas Research and Training Centre
139. Indian Agricultural Research Institute, Division of Soil Science and Agricultural Chemistry
140. Indian Institute of Management
141. Indian Institute of Technology (Bombay)
142. Indian Institute of Technology (Madras)
143. Indian Institute of Technology (New Delhi), Centre of Energy Studies
144. Kapur Solar Farms
145. Khadi and Village Industries Commission, Gobar Gas Research and Development Centre
146. L.G. Balakrishnan and Brothers Limited
147. Maharashtra Gandhi Smarak Nidhi
148. Ministry of Agriculture, Department of Agriculture and Co-operation
149. Municipal Corporation of Greater Bombay, Dadar Sewage Treatment Plant
150. National Dairy Research Institute, Indian Council of Agricultural Research
151. National Institute of Waste Recycling Technology
152. Orissa Cement Limited
153. PSG College of Technology
154. Punjab Agricultural University
155. Resources Development Institute
156. Sobic Industrial Consultants
157. Sri Parasakthi College for Women
158. Structural Engineering Research Centre
159. Tata Energy Research Institute, Field Research Unit

Indonesia

160. Development Technology Centre, Institute of Technology Bandung (DTC-ITB)
161. Industrial Research Institute, Centre for Chemical Industry.

Japan

162. Ministry of Agriculture, Forestry and Fisheries, National Institute of Animal Husbandry

Malaysia

163. Standards and Industrial Research Institute of Malaysia (SIRIM)

New Zealand

164. Invermay Agricultural Research Centre

Pakistan

165. Appropriate Technology Development Organization, Government of Pakistan
166. Merin Limited
167. Ministry of Petroleum and Natural Resources, Energy Resources Cell

Philippines

168. Liberty Flour Mills, Inc., Maya Farms Division
169. Ministry of Energy, Centre for Nonconventional Energy Development
170. National Institute of Science and Technology

Republic of Korea

171. Office of Rural Development

Samoa

172. University of the South Pacific, School of Agriculture

Sri Lanka

173. University of Peradeniya, Department of Civil Engineering

Thailand

174. Asian Institute of Technology (AIT)
175. Department of Health, Ministry of Public Health
176. Kasetsart University, Faculty of Agriculture
177. King Mongkut's Institute of Technology
178. Maejo Institute of Agricultural Technology
179. Mahidol University
180. Ministry of Agriculture and Co-operatives, Department of Agriculture
181. National Energy Administration
182. Thailand Institute of Scientific and Technological Research

ADDITIONS

India

183. Indian Institute of Science, Centre for the Application of Science and Technology to Rural Areas (ASTRA)

184. Shri A.M.M. Murugappa Chettiar Research Centre, Photosynthesis and Energy Division

Nepal

185. Development and Consulting Services

1. Mr. Romeo V. ALICBUSAN

1. Philippines 2. 28 February 1930

3. B.Sc. (Agriculture), M.Sc. (Plant Pathology)

4. Filipino, English

5. 1972 to-date Supervising Scientist (1972-1974) and then Science Research Supervisor, Microbiological Research Department, National Institute of Science and Technology, Manila

   1955-1971 Assistant Instructor (1955-1960), Instructor (1961-1965) and then Assistant Professor, University of the Philippines College of Agriculture

6. Cultivation of edible mushrooms. Biogas production

7. Fermentation of food products. Alcohol production

8. Research and development towards establishing mushroom industry in the Philippines. Biogas production utilizing food wastes (ASEAN)

9. *

10. Microbiological Research Department, National Institute of Science and Technology, P.O. Box 774, Pedro Gil Street, Ermita, Manila, Philippines

2. Mr. M. AMARATUNGA

1. Sri Lanka 2. 9 February 1936

3. B.Sc. (Engineering), Ph.D.; C. Eng., FIE (Sri Lanka)

4. English, Sinhalese

5. 1963 to-date Lecturer, Senior Lecturer, Associate Professor and then Professor, Department of Civil Engineering, University of Peradeniya, Sri Lanka

   1968-1969 and 1972-1973 Lecturer in civil engineering, Kingston Polytecnic, UK

   1962-1963 Engineer, Felix J. Samuely & Partners, London

6. Civil engineering structures. Biogas technology

7. Low-cost housing. Solar energy

8. Development of biogas digesters for integrated systems. Development of gas burners

9. *

10. Department of Civil Engineering, University of Peradeniya, Peradeniya, Sri Lanka

3. Mr. Y.P. ANAND

1. India
2. 12 December 1934
3. B.Sc. (Hons.) (Civil Engineering)
4. English, Hindi, German, Urdu, Punjabi
5. 1957 to-date Assistant Engineer, Executive Engineer, Deputy Director (Research), Joint Director (Research), Deputy Chief Engineer (Construction), Divisional Superintendent, Additional Chief Engineer and then Chief Engineer, Indian Railway Service of Engineers

   1956-1957 Assistant Engineer (Design), PWD, Chandigarh
6. Railway engineering (track, bridges, structures, management)
7. Studies in various aspects of energy with special emphasis on solar energy and bioconversion
8. Biogas plants for disposal and recycling of domestic and vegetable wastes
9. Design, instruction sheets and drawings
10. 31, N.E. Railway Colony, Gorakhpur 273 001, India

4. Mr. Muchidin APANDI

1. Indonesia
2. 14 January 1927
3. M.Sc. (Food Technology), Ph.D. (Animal Husbandry)
4. Indonesian, Dutch, German, English
5. 1975 to-date Senior Lecturer and staff member, Development Technology Centre, Institute of Technology Bandung

   1967-1975 Senior Lecturer, University Padjadjaran Bandung

   1955-1967 Lecturer, Institute of Agriculture, Bogor
6. Animal husbandry. Food technology
7. Biogas technology
8. Projects on microbial enzymes for high fructose syrups, alcohol, proteins. Biogas
10. Development Technology Centre, Institute of Technology Bandung, P.O. Box 276, Bandung, Indonesia

5. Mr. Andreas BACHMANN

1. Switzerland 2. 24 February 1946

3. Dipl. San. Inst.; Member: International Solar Energy Society; Swiss Solar Energy Society

4. German, French, English

5. 1974 to-date Advisor. Swiss Association for Technical Assistance (SATA), Nepal

   1969-1971 Technician, Swiss Association for Technical Assistance (SATA), Cameroon, Africa

6. Sanitary installations

7. Appropriate technology. Renewable energy resources for rural areas: solar energy, biogas

8. Information dissemination: *Biogas Newsletter*, Nepal

10. c/o Swiss Association for Technical Assistance, P.O. Box 113, Kathmandu, Nepal

6. Mr. Julian BANZON

1. Philippines 2. 25 March 1908

3. Ph.D. (Chemistry)

4. English, Filipino

5. 1973 to-date Maya Farms Division, Liberty Flour Mills, Inc.

   1977 to-date Philippine Coconut Research and Development Foundation

   1959-1964 Philippine Atomic Energy Commission

   1930-1959 and 1964-1973 University of the Philippines

6. Chemistry. Biochemistry

7. Fermentative processes

8. Fermentative/chemical processes for energy concentration

10. University of the Philippines at Los Banos, College, Laguna, Philippines; or c/o Maya Farms Division, Liberty Flour Mills, Inc., Liberty Building, Pasay Road, Makati, Metro Manila, Philippines

7. Mr. Ajit Kumar BASU

1. India 2. 1 January 1932

3. D.Sc. (University of Liege, Belgium); FCIC, MIIChemF, FIIPHE

4. English, Spanish, French, Bengali

5. 1956 to-date Scientist-in-Charge, NEERI Zonal Laboratory, Calcutta
Pollution Expert, FAO
Senior Consultant, UNEP Regional Office, Bangkok
Expert (pollution and waste water management), Asian Development Bank

6. Treatment of waste water and water pollution

7. Environmental impact assessment. Air pollution. Solid waste water treatment. Environmental planning. Teaching environmental studies

8. Recycling of agricultural wastes, with particular reference to piggery waste water treatment in the Laguna de Bay, Philippines. A demonstration biogas plant, constructed with concrete and steel with movable gas holder, continuous feed of pig manure of 5000 kg per day, 145 m^3 of gas produced per day to be used for heating, cooking and lighting purposes; effluent used for fish culture, algae production and animal feed

9. About 95 scientific publications

10. Official: NEERI Zonal Laboratory, 23 R.N. Mukherjee Road, Calcutta-1, India
Residence: 59 Lake Road, Apartment No. 8C (2nd Block), Calcutta 700 029, India. Tel: 46-7753, 42-4191

8. Mr. T.D. BISWAS

1, India 2. 3 November 1920

3. M.Sc., Ph.D.

4. English, Hindi, Bengali

5. 1946 to-date Research Assistant (1946-1956), Assistant Soil Survey Officer (1956-1958), Soil Scientist (1958-1968), Professor of Soil Science and Agricultural chemistry (1968-1972) and then Head, Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi

6. Research in soil science (soil physics, soil chemistry, soil genesis, micronutrient)

7. Biogas technology and usage

8. Production of fuel gas and manure by anaerobic fermentation of agricultural wastes and other organic materials. Soil productivity and soil physical conditions as influenced by long term and intensive crop management practices.

9. *

10. Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi 110 012, India

9. Mr. Piyawat BOON-LONG

1. Thailand 2. 1951

3. Ph.D. (Engineering)

4. Thai, English

5. Present Lecturer, Faculty of Engineering, Chiang Mai University, Chiang Mai

   Visiting Assistant Professor, Kansas State University, USA

6. Heat transfer. Renewable energy resources

8. Solar-heated biogas digesters

10. Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand

10. Mr. CAO Guo-Qiang

1. China 2. 26 June 1941

3. Graduate, Shanghai Tongji University (specialization in applied mechanics)

4. English, Chinese

5. 1980 to-date Chengdu Biogas Scientific Research Institute, Ministry of Agriculture

   July - August 1980 FAO Advisor to the Philippines (Middle Lu Song University) for establishment and management of a small-scale biogas plant, with 15 m^3 round-shaped water pressure style bio-digester and production capacity of 0.75 m^3 per day.

   1964-1979 Sichuan Construction Science and Research Institute, Structure Department

   1977 Biogas digester construction in Sichuan

6. Designing and conducting experimental research on housing structure including biogas digester, its design, construction and materials; provision of techniques involving material mechanics, structural mechanics, shell mechanics etc; theory of elasticity; reinforced concrete; prestressed concrete; knowledge and capability for initiative in planning and designing various kinds of structure.

7. Further pursuit of experience in construction with regard to biogas plant structure.

8. Among the important projects completed at Sichuan Construction Science and Research Institute: improvement in light crane beam; plastic-coated pump for apertures and its practical application in structures; research test with arched crane beam; research in hoisting of structure; participation in the compilation of specifications for reinforced concrete; improvement of factory structure; reports on research on various aspects in the construction of biogas plants, as follows: (a) synthesis of the techniques of biogas plant construction; (b) synthesis of the conclusions of engineering techniques in biogas plant construction; (c) publication of rural scientific magazines introducing often used materials in construction of biogas plants; (d) publication of correspondence and writings on construction and use of round hydraulic-pressure-type biogas plant; (e) simplified diagram for making biogas plants; (f) research on chemical preparation for medium-sized medium temperature digester; and (g) research on casing of reinforced concrete with less reinforced steel.

9. Compilation of *Biogas technology study* (2nd volume), for publication by United Nations University and in China. Lectures and teaching materials for the Joint UNEP-Chinese State Department Environment Office Study Group on Biogas in 1979 at Chengdu.

10. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Chengdu, Sichuan, China

11. Mr. CAO Ze-Xi

1. China 2. June 1934

3. South-West Airforce Pre-University Contingent, 5th Aviation School, (specialization in aviation machinery) (June 1950 – May 1951)

4. Ordinary ability to understand and write Russian (elementary), speak Japanese.

5. 1959 to-date Engineer, Chief, farm power and hydraulic machine, 3rd Research Office, Sichuan Province Agricultural Machinery Research Institute

   1950-1951 Mechanical Engineer, Chief, Armament Contingent, 3rd Middle Contingent, 34th Regiment, 12th Army, Airforce

6. Research on techniques of practical application of biogas as motive power in rural areas.

7. Research on small-scale internal-combusion engine

8. Research on utilization rate on north-west Sichuan grasslands of waste gas propelled turbo weight attached to a tractor.

9. For the National Science Commission, chief editor of teaching materials on biogas for the United Nations University. "Views concerning some practical aspects of combustible fuel for farm machinery".

10. Sichuan Province Agricultural Machinery Research Institute (3rd office), Sichuan, China

12. Mr. CHAI Chang-Da

1. China 2. 12 March 1943

3. Graduate, Hangzhou Agricultural College, Agriculture Department (1961)

4. English (elementary), Chinese

5. 1974 to-date Technician, Hangzhou City Biogas Extension Office

   1962-1973 Technician, agricultural microbiology, Agricultural science Research Institute, Hangzhou City

6. Biogas fermentation. Biogas digester construction techniques

7. Agricultural science

8. Design and construction of separable type gas holder for rural households Constructional technique improvements in the moulding and hauling of biogas plants. Synthesized use of the biogas fermentation remainder in mushroom cultivation, rearing of earthworm, feeding of pig, chicken, fish etc. Experimentation on fertilizer efficiency of fermentation remainder.

9. "Effective way of extension work regarding agricultural energy resources", *Energy Resources Journal,* 1980 first issue. *Popular Science Book on Biogas,* published by Zhejiang People's Publishing House. "Report on experiment on biogas production with movable gas holder", *Means of Production,* collected edition, vol. 4.

10. Biogas Extension Office, Hangzhou city. China

13. Mr. Sompongse CHANTAVORAPAP

1. Thailand 2. 1935

3. B.Eng. (Hons.) (Chulalongkorn University, Bangkok), M.Eng. (SEATO Graduate School of Engineering, Bangkok); Engineering Professional License in the category of Fellow Engineer from the Board for the Control of the Engineering Profession

4. Thai, English

5. 1976 to-date Special grade engineer, in charge of Design and Energy Research Section; Chief, alternative energy study and development project; and Assistant

Director, USAID-Thai Government nonconventional renewable energy project, National Energy Administration, Bangkok

1970-1975 First grade engineer, in charge of Design Section and Assistant Director, Lam Dom Noi hydro electric construction project, National Energy Administration

1967-1969 Seconded by National Energy Administration to work as System Analysis Engineer at the Mekong Secretariat

1961-1966 Third grade engineer (1961-1963) and the second grade engineer, Design Section, National Energy Administration

6. Civil engineering

7. System analysis. Development planning, sectoral planning and project analysis.

8. Alternative energy study and development project in which biogas/biomass energy is included.

9. "Utilization of biogas digesters in Thailand", presented at the Expert Group Meeting on Biogas Development, ESCAP, Bangkok, 20-26 June 1978. *Biogas Handbook* (Thai version), 1978. "Cement water jars as a biogas digester for Thailand", 1979.

10. National Energy Administration, Pibultham Villa, Bangkok 5, Thailand

14. Mr. CHEN Sheng-Geng

1. China 2. July 1938

3. Graduate, Fudan University (1964)

4. Chinese

5. 1979 to-date Shanghai Biogas Laboratory, Association for Science and Technology

1974-1979 Shanghai Biogas Research and Co-ordination Group

1964-1974 Shanghai Association for Science and Technology

6. Bio-fermentation. Biogas construction

8. Small and medium sized digesters. Automation of multi-stage mesophillic fermentation digesters.

9. *Biogas* (in Chinese)

10. Science and Technology Commission, 47 Nan Zhong Road, Shanghai, China

15. Mr. CHONG Chok-Ngee

1. Malaysia 2. 30 June 1943

3. B.Sc. (Hons.) (Chemistry), B.Ed., Ph.D.; AMIC, MRIC, C. Chem.

4. English

5. Present Head, Research Unit, Standards and Industrial Research Institute of Malaysia (SIRIM)

6. Chemistry of biologically active compounds

8. Supervise a range of projects in the fields of ceramics technology, building materials, energy technology and pollution technology.

9. Technical papers/reports covering the above fields.

10. Standards and Industrial Research Institute of Malaysia (SIRIM), P.O. Box 35, Shah Alam, Selangor, Malaysia

16. Mr. M. Yusuf CHOWDHURY

1. Bangladesh 2. 1 April 1934

3. M.Sc. (Applied Chemistry) (Dacca), M.S. (Chemistry) (New York State University), Ph.D. (Agricultural Chemistry)

4. Bengali, English, German

5. 1964 to-date Senior Lecturer (1964), Associate Professor (1973) and then Head, Department of Agricultural Chemistry, Bangladesh Agricultural University

   1958-1964 Lecturer in chemistry (1958) and then Professor and Head, Department of Chemistry, AM College

6. Agricultural chemistry with special interest in utilization of agricultural wastes

7. Organic wastes in plant nutrition and fish production. Water chemistry. Fertilizer technology and chemical instrumentation.

8. Biogas production (since 1971). Effect of organic manures with and without supplemental chemical fertilizers on the yield and qualities of the agricultural produce.

10. Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh, Bangladesh

17. Mrs. Revadee DEEMARK

1. Thailand 2. 17 August 1940

3. B.Sc. (Chemistry), M.Sc. (Agriculture) (College of Sweden)

4. English, Thai

5. Present Scientist/Chief, Fertilizer Research Section, Agricultural Chemistry Division, Department of Agriculture, Bangkok

6. Study of organic fertilizer including digested slurry from biogas production.

7. Chemistry and technology and chemical fertilizers.

8. Studies on the manurial value of digested slurry from biogas plant. Examination of the nitrogen balance of dung during anaerobic digestion. Studies on the manurial value of digested slurry from biogas plant on sandy loam soil. Study on industrial waste for fertilization. Utilization of biogas as alternative source of energy. (completed)

   Study on low-cost biogas digester. Biogas production from various plant wastes. Biogas production in dome digester. Biogas production by using slurry and combination plants. (ongoing)

   Cost reduction of small-scale biogas plant. Utilization of organic waste other than animal waste. Biogas-based integrated farming system. Utilization of digester manure with local rock phosphate. (planned)

10. Fertilizer Research Section, Division of Agricultural Chemistry, Department of Agriculture, Bangkhen, Bangkok, Thailand

18. Mr. A.K. DHUSSA

1. India 2. 3 March 1955

3. B.Sc., B.E. (Chemical)

4. English

5. Present Research Officer/Senior Scientific Associate, Gobar Gas Research Station, Ajitmal

6. Fermentation technology. Reaction kinetics and plant design.

7. Training

8. Designing gas generation and distribution systems for large communities.

9. *Janata biogas plants: introduction and design* and a construction manual in Hindi language

10. Gobar Gas Research and Training Centre, Ajitmal 206 121, Etawah, India

19. Mr. J.A. D'SOUZA

1. India
2. 21 February 1931
3. B.Sc.
4. English
5. 1968 to-date Refining Superintendent, Madras Refineries Ltd.
   1972-1974 Deputation to Sri Lanka
   1966-1968 Senior Engineer, Cochin Refineries Ltd.
   1954-1966 Manufacturing Assistant, Burmah-Shell Refineries Ltd., Bombay
6. Energy conservation
7. Alternate sources of energy: solar, biomass and wind energy.
8. Solar water heater. Solar cooker. Biogas plant. Windmill for pumping water.
10. 5V. N.G. Road, Madhavaram Milk Colony, Madras 600051, Tamil Nadu, India

20. Mr. Muhammad EUSUF

1. Bangladesh
2. 11 October 1936
3. M.Sc. (Chemistry) (Dacca), Ph.D. (Chemistry) (Ottawa)
4. English, German, Bengali, Urdu, Arabic
5. 1977 to-date Project Director, Institute of Fuel Research and Development, BCSIR, Dacca
   1966-1977 Editor, Bangladesh Journal of Scientific and Industrial Research, BCSIR
   1964-1976 Senior Research Officer (1964-1973) and then Principal Scientific Officer, Fuel Research Division, BCSIR Laboratories, Dacca
6. Fuel and energy.
7. Activated carbon. Petrochemicals.
8. Increasing gas yield. Reduction in seasonal variation of gas yield. Cost reduction. Slurry making from agricultural wastes. Development of low-cost burners and lamps.
9. *
10. Institute of Fuel Research and Development, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dacca, Bangladesh

21. Mr. FENG Wei-Cheng

1. China 2. December 1932

3. Graduate, Air Force School No. 6 (1952)

4. Chinese, English (can read periodicals and manuals in own area of specialization)

5. 1964 to-date Engineer, Sichuan Province Agricultural Machinery Research Institute

   1953-1964 Instructor (engines), Air Force School No. 10

   1952 Teaching Assistant (engines), Air Force School No. 6

6. Research on techniques of biogas as motive power

7. Research on biogas and speed-adjustor in diesel engine moving parts

8. Research on S195 biogas and diesel engine.

9. "Practical application of biogas as motive power"

10. Sichuan Province Agricultural Machinery Research Institute (3rd Office), Sichuan, China

22. Mr. Nigel FLORIDA

1. Canada 2. 7 June 1942

3. Diploma in Technical Education (Queen's University, Canada), Diploma in Electronics Technology (Ryerson Polytechnical Institute, Toronto)

4. English

5. 1977 to-date Associate Director, South Pacific Appropriate Technology Foundation (SPATF). Organized and directed the Foundation. Initiated a nine point programme for an integrated appropriate technology development package.

   1974-1977 Technical Officer, Technical Team, Canadian University Services Overseas (CUSO), Ottawa. Responsible for the selection and placement of prospective business and technical volunteers in CUSO overseas programmes.

   1972-1974 Recipient of international development scholarship, sponsored by the Canadian International Development Agency (CIDA). Research topic on village or appropriate technology. Studied and implemented a number of ideas of an appropriate technology nature in a small village in rural India.

   1969-1971 Instructor, Commission for Technical Education and Vocational Training, Zambia. CUSO contract to start Zambia's first radio and TV repair course. Entailed design and building of workshop, ordering equipment and drafting syllabus.

6. Appropriate technology administration

8. Small-scale industry in Ghana, a potential for CIDA support. Small agricultural tool production unit, under USAID/VITA in Zaire. Reconstruction project to the district of Totonicapan following the 1976 Guatemala earthquake, involving housing, mobile medical services and groundwater surveys. Collect and co-ordinate information on appropriate technology under CUSO in Canada.

9. *

10. c/o P.O. Box 6937, Boroko, N.C.D., Papua New Guinea (Permanent: c/o 38 St. Claire, Ottawa, Canada K2G 2A2)

23. Mr. H.P. GARG

1. India

3. M.Sc. (Physics), Ph.D. (Solar Energy); MISES

4. Hindi, English

5. 1979 to-date Professor, Centre of Energy Studies, Indian Institute of Technology, New Delhi

   1972-1978 Physicist and then Senior Physicist, Central Arid Zone Research Institute, Jodhpur

   1965-1972 Scientist, Central Building Research Institute, Roorkee

   1964-1965 Lecturer, MMH College, Ghaziabad

6. Solar energy applications for domestic, industrial and agricultural purposes

7. Wind power utilization and bioconversion. Biogas and energy conservation.

8. Design and optimization of family size biogas plants.

9. *

10. Central of Energy Studies, Indian Institute of Technology, Hauz Khas, New Delhi 110 016, India

24. Mr. K.V. GOPALAKRISHNAN

1. India 2. 25 November 1936

3. Ph.D. (Mechanical Engineering)

4. English, German, Tamil

5. 1962 to-date Lecturer (1962-1972) and then Assistant Professor, Department of Mechanical Engineering, Indian Institute of Technology, Madras

6. Development of biomass – biogas energy for rural areas of developing countries. Development of alcohols and hydrogen as alternative fuels for internal combustion engines

7. Control of air pollution from internal combustion engines

8. Investigator: project on combustion of alcohols and biogas, financed by the National Science Foundation, Washington, D.C. Alternative fuels for internal combustion engines, supported by the German Academic Exchange Service (DAAD), Federal Republic of Germany

9. *

10. Department of Mechanical Engineering, Indian Institute of Technology, Madras 600 036, India

25. Mr. K.P. GOSWAMI

1. India 2. 2 April 1938

3. B.Sc. (Agriculture), M.Sc. (Indian Agricultural Research Institute, New Delhi), Ph.D. (University of Hawaii, USA)

4. English, Hindi, Spanish, Bengali, Punjabi

5. 1974 to-date Associate Professor in soil microbiology, Soils Department, Punjab Agricultural University, Ludhiana

   1971-1973 Junior Soil Scientist, Agronomy and Soils Department, University of Hawaii

   1961-1967 Senior Research Fellow (1961-1964) and then Senior Scientific Officer, Central Fuel Research Institute, Dhanbad

   1960-1961 Research Assistant, Agricultural Chemistry Laboratory, Udaipur

6. Soil science and agricultural chemistry. Soil microbiology and biochemistry. Biogas production from fibrous plant wastes.

7. CO_2 – fertilization. Decomposition of organic matter. Nitrogen fixation.

8. Development of a kachara-gas plant for biogas and manure production from fibrous plant wastes.

9. *

10. Soils Department, Punjab Agricultural University, Ludhiana, 141004, India

26. Mr. GU Zhen-Gang

1. China 2. February 1930

3. Graduated from the Aviation Special School, from the Mathematics Department in a university and then from a class for training teachers

4. Learnt English many years ago

5. 1978 to-date Artificial Biogas Experimental Station of Nanhui County

1970-1978 Worked in a machine tool plant

1964-1970 In-charge, Section of Food Processing, County Grain Bureau

1950-1964 Mechanist, Chief Mechanic and then Deputy Squadron Leader

6. Mechanical engineering

7. Artificial biogas production

8. Utilization of waste heat from biogas power generation and design for heat preservation. Design and research for a biogas digester with integral fermentation. Mechanical unloading of the residue out of a digester.

10. The Artificial Biogas Experimental Station of Nanhui County, Shanghai, China

27. Mr. Chaman L. GUPTA

1. India 2. 27 March 1933

3. B.Sc. (Hons.) (Physics), M.Sc. (Applied Mathematics), Ph.D. (Heat Transfer)

4. English, Hindi

5. 1968 to-date Professor, Sri Aurobindo International Centre of Education, Pondicherry

1975 to-date Director, Tata Energy Research Institute, Field Research Unit, Pondicherry

1968-1970 Visiting Scientist (thermal optimization), CSIRO, Division of Building Research, Melbourne

1954-1968 Scientist and then Head of Section, Central Building Research Institute, Roorkee

6. Solar energy systems including domestic, industrial and agricultural applications. Thermal designing of buildings. Mathematical modelling

7. Biogas and integrated energy systems

8. Solar communities. Solar ponds. Passive solar heating

9. *

10. Sri Aurobindo Ashram, Pondicherry 605 002, India

28. Mr. Kiyonori HAGA

1. Japan 2. 8 October 1948

3. M.S.

4. Japanese, English

5. 1973 to-date Laboratory of Animal Waste Management, National Institute of Animal Industry, Ministry of Agriculture, Forestry and Fisheries, Japan

6. Biogas production from animal wastes

7. Animal waste management

8. Biogas production from animal wastes and its utilization

9. *

10. Laboratory of Animal Waste Management, National Institute of Animal Industry, Ministry of Agriculture, Forestry and Fisheries, Tsukuba Norindanchi, P.O. Box 5, Ibaraki 305, Japan

29. Ms. HU Li-Na

1. China 2. 28 December 1932

3. Graduate, Beijing Agricultural University (1954)

4. English, Chinese

5. 1958 to-date In-charge, Fertilizer Research Office and Chief, Biogas Office, Beijing Academy of Agricultural Science, Beijing

   1956-1958 Assistant, Pesticides Teaching Group, Beijing Agricultural University

   1954-1956 Technician, Plant Disease Quarantine Station, Shanxi Province

6. Biogas techniques (biogas fertilizer and fermentation)

7. Soil fertilizer science. Agricultural environmental protection. Botanical chemical protection

8. Farmer household-fuel biogas experimental station and consultancy and extension, Beijing suburban district. Small-scale experimental pig farm biogas power station. Research on biogas fermentation process and important changes in fertilizer effectiveness and composition. Research on the efficiency of the biogas fermentation remainder as fertilizer and its use in soil improvement. Research on types of feeding materials and the amount of gas produced.

9. *Study of Biogas Techniques* (under publishing process)

10. Beijing Academy of Agricultural Science, Ban Jin Village, Beijing, China

30. Mr. Ishrat HUSSAIN

1. India 2. 15 July 1940

4. Hindi, English

5. Present Supervisor, demonstration-cum-training of Janata biogas plants scheme, Action for Food Production (AFPRO), New Delhi

Gobar Gas Technician, Gobar Gas Research Station, U.P. Government

6. Biogas plants

7. Drafting and civil structure (rural latrines)

8. Biogas training and extension scheme for Janata plant

9. Drawings and sketches

10. Action for Food Production (AFPRO), C-17 Community Area, Safdarjang Development Area, New Delhi, 110 016, India

31. Mr. S.G. ILANGANTILEKE

1. Sri Lanka 2. 26 October 1944

3. B.Sc. (Agriculture) (Ceylon), M.S., Ph.D. (Agricultural Engineering) (Michigan State University)

4. English, Sinhalese

5. 1970 to-date Head, Department of Agricultural Engineering, University of Sri Lanka, Peradeniya

6. Post-harvest technology and energy development for rural technology

7. Farm machinery design for intermediate rural technology

8. Construction of biogas unit as a demonstrational unit for secondary schools. Evaluation of locally available materials to enhance biogas production. Determining the pressure losses in conveyance of biogas to the lighting point.

10. Department of Agricultural Engineering, University of Sri Lanka, Peradeniya, Sri Lanka

32. Mr. M.N. ISLAM

1. Bangladesh 2. 1 August 1946

3. B.Sc. (Chemical Engineering), Ph.D.

4. Bengali, English

5. 1973 to-date Assistant Professor (1973-1977) and then Associate Professor, Department of Chemical Engineering, Bangladesh University of Engineering and Technology, Dacca

1972-1973 Senior Research Associate, University of Newcastle-upon-Tyne

1968 Lecturer in chemical engineering, EPUET, Dacca

6. Chemical engineering

7. English engineering. Environmental engineering.

8. Design, construction and operation of a biogas plant suitable for the rural area of Bangladesh (1977-1979), sponsored by the University Grants Commission, Bangladesh. Social and economic evaluation of biogas technology in Bangladesh (1978-1980), sponsored by IDRC, Ottawa, Canada

9. *

10. Department of Chemical Engineering, Bangladesh University of Engineering and Technology, Dacca 2, Bangladesh

33. Mr. R.C. JAIN

1. India 2. 5 January 1950

3. B.E. (Mechanical Engineering) (Bhopal University); Member (Scholar) Director, Resources Development Institute

4. Hindi, English

5. 1979-1980 General Manager, Small-scale Industries, Chindwara District, Government of Madhya Pradesh

   1978-1979 Industries Promotion Officer, Jorhat, Assam

   1974-1978 Junior Engineer, Design Research and Computorized Inventory Centre, Irrigation Department

   1974-1979 Part-time Research Scholar, Resources Development Institute, Bhopal (Honorary)

6. Mechanical engineering. Computer systems and programming. Small-scale industries.

7. Biogas technology. Solar energy

8. Biogas technology: portable biogas plant; small biogas turbine; biogas filter, biogas conversion kit etc. Solar energy: cheap solar cookers; solar pump; aqua ammonia-absorber turbine system; reflected concentrator modified Stirling engine system.

9. *

10. c/o Resources Development Institute, E6-00, 1100 Quarters Area, Bhopal 462016, India

34. Mr. S.C. JAIN

1. India

3. B.Sc. (University of Delhi), AIC (equivalent to M.Sc. in Chemistry) (Medical College, Calcutta)

4. Hindi, English, Urdu, German

5. 1959 to-date Assistant Chemist (1959-1961), Assistant Superintendent-cum-Chemist (1961-1969) and then Assistant Chief Water Analyst, Delhi Water Supply and Sewage Disposal Undertaking, Municipal Corporation of Delhi

   1958-1959 Research Chemist, CSIR Scheme attached to Delhi Water Supply

6. Water treatment and sewage treatment including biogas

7. Industrial waste water treatment

8. Sewage treatment. Industrial waste water treatment. Biogas (town supply)

9. *

10. Sewage Disposal Works, Okhla, New Delhi 110 020, India

35. Mr. D.S. JOSHI

1. India

3. B.Sc. (Bombay University); Certificate in Chromatography and Library Science. Completed short-term course conducted by Central Public Health Engineering Research Institute. William D. Hatfield Award winner (Water Pollution Control Federation, United States of America)

4. English, Marathi, Hindi

5. Present Superintending Chemist, Dadar Sewage Treatment Plant Laboratory, Bombay

   22 years experience of sewage, industrial effluents, sludge and gas analysis at Dadar Sewage Treatment Plant of Municipal Corporation of Greater Bombay and also past experience in ink analysis, pathological analysis and asphalt and road materials analysis

6. Analysis of sewage, sludge, grit and gas for the control of activated sludge plant, trickling filter and biogas digesters. Administration and management of laboratory

8. Tertiary treatment. High-rate digestion. H_2O removal from sludge gas. Infiltration of sea water.

9. "Performance of activated sludge plant", *Indian Journal of Environmental Health*, 1976. "Use of Orsat apparatus in gas analysis", SGEMA Souvenir, 1976. "Upsets in biological treatment plant" (contribution to a course on industrial waste treatment). "Air pollution control in industries", Seminar on Air Pollution Control.

10. ¼, Dadar Sewage Treatment Plant, Senapati Bapat Marg, Dadar, Bombay 400 028, India

36. Mr. Vishnu JOSHI

1. India 2. 14 February 1927

3. B.E. (Bombay University). Post-graduate in structural engineering (Cambridge University). Member of Institution of Civil Engineers, London

4. English, German

5. 1973 to-date Self-employed for development of appropriate technology and as a part-time consultant to Stein and Associates, New Delhi

   1960-1973 Architect, engineer and town planner, Stein and Associates

   1956-1960 Consulting Engineer, Felix Samudy and Partners, London

   1949-1955 Construction, design, planning of National Defence Academy of India

6. Structural engineering planning and design. Civil engineering. Project planning and co-ordination. Construction management.

7. Development and application of ferrocement technology especially for benefit of rural population.

8. Rural employment in the manufacture of ferrocement, water tanks, septic tanks, grain storage bins, biogas plants and fishing boats. Agro service centre

10. Sarang, Post Pen, Kolaba District, Maharashtra 402 107, India

37. Mr. Jagdish Chandra KAPUR

1. India 2. 16 February 1920

3. B.Sc. (Mechanical Engineering and Electrical Engineering) (Punjab University); M.S. (Engineering) (Cornell University). Post-graduate studies in aeronautical engineering (Indian Institute of Science, Bangalore). Industrial and labour relations studies (Cornell University). Fellow: Nuclear Energy Society; Indian Standards Institute. Life Member, Indian Science Congress. Member: International Solar Energy Society; American Society of Heating, Refrigeration and Air-conditioning Engineering; World Future Society.

4. English, Hindi, Punjabi

5. Present Founder-Proprietor, Kapur Solar Farms. Chairman, Denfoss (India) Ltd., New Delhi and Kapcompany General Ltd., New Delhi. President, All India Council of Refrigeration and Air-conditioning Industry

1972 General Manager, Larsen and Toubro Ltd., Bombay

1966 Founder-Director, York (India) Ltd., and Taylor Instrument Co., Ltd. President and Chief Executve Officer, Air-conditioning Corporation Ltd.

6. Refrigeration and air-conditioning. Heat exchange. Solar energy. Instrumentation and control technology

7. Bioconversion systems

8. Integrated solar energy and bioconversion projects at Kapur Solar Farms

10. Kapur Solar Farms, Bijwasan Najafgarh Road, P.O. Kapas Hera, New Delhi 110 037, India

38. Mr. Amrit Bahadur KARKI

1. Nepal 2. 10 March 1940

3. Ph.D. (Soil Microbiology)

4. Nepali, English, French, Hindi

5. Present Reader/Chairman, Plant Science Instruction Committee, Institute of Agriculture and Animal Science, Tribhuwan University, Kathmandu

April – June 1980 FAO Consultant on biogas in Guinea

1962-1977 Soil Scientist, in charge of soil microbiology organic manure and biogas programme, Department of Agriculture, Government of Nepal

Senior Consultant in resource conservation and utilization project and alternate energy and appropriate technology under Agricultural Project Service Centre (APROSC), Lazimpat, Kathmandu

6. Soil microbiology. Soil fertility

7. Biogas. Compost. Blue green algae.

8. Energy needs of food system (HMG/Nepal in collaboration with USAID). Resource conservation and utilization project. Alternate energy and appropriate technology – rural development project (APROSC, Lazimpat, Kathmandu)

9. *

10. c/o Biogas Newsletter, P.O. Box 1309, Kathmandu, Nepal

39. Mr. K.C. KHANDELWAL

1. India 2. 1 January 1948

3. B.Sc. (Agriculture), M.Sc. (Microbiology), Ph.D. (specialization in soil organic matter). Participated in FAO/UNDP Study Tour on Cold Weather Biogas Plants to the Republic of Korea, May 1980.

4. English, Hindi, Russian (elementary)

5. 1976 to-date Assistant Commissioner (Biogas) (1976-1979) and then Specialist, Department of Agriculture and Co-operation, Ministry of Agriculture, New Delhi

   1970-1976 Assistant Professor (Microbiology), Haryana Agricultural University, Hissar.

6. Biogas fermentation.

7. Bio-fertilizer. Soil organic matter.

8. National project on developent and promotion of biogas technology.

9. *

10. Department of Agriculture and Co-operation, Ministry of Agriculture, 112, 'B' Wing, Shastri Bhavan, New Delhi 110 001, India

40. Mr. Ghulam KIBRIA

1. Pakistan 2. 1 April 1926

3. B.Sc. (Engineering); President, Pakistan Association of Electrical and Mechanical Engineers (1967-1968)

4. English, Urdu, Punjabi, Hindi, German

5. Present Development Consultant, Karachi

   1974-1978 Chairman, Appropriate Technology Development Organization, Government of Pakistan, Islamabad

   1953-1959 Senior Executive, Gillanders Arbuthnot & Co. (Pakistan) Ltd.

   1952-1953 Training abroad: Foster Gwynnes Ltd., Lincoln, United Kingdom; Brush Group Ltd., Loughbrough, United Kingdom; Klöckner Humbölt Deutz, Köln, Federal Republic of Germany

   1948-1951 Junior Executive, Volkart Brothers, Lahore

   1946-1948 Lecturer in mechanical engineering, Muslim University, Aligarh, India

6. Development consultancy

7. Biogas technology and low-cost hydro technology for Pakistan

8. Biogas and low–cost hydroelectric projects.

9. *

10. 5-E, 7th Central Street, Defence Housing Society, Karachi, Pakistan

41. Mr. Kyun Uk KIM

1. Republic of Korea

3. M.S., Ph.D.

4. Korean, English

5. 1974 to-date Associate Professor, Seoul National University, College of Agriculture

   January-July 1974 Food Research Institute, University of Wisconsin

6. Food and fermentation microbiology

7. Fermented foods

8. Growth and resistance of lactic acid bacteria. Bioconversion of biomass.

9. *

10. College of Agriculture, Seoul National University, Suwon 170, Republic of Korea

42. Mr. Suchart KLINSUWAN

1. Thailand 2. 1955

3. B. Eng. (Institute of Technology and Vocational Education, Bangkok)

4. English, Thai

5. 1979 to-date Alternative energy study and development project, National Energy Administration, Bangkok

6. Machine design and heat transfer

7. Auto-mechanics

8. Alternative energy study and development (biogas energy)

9. Report on experiment on engine fuelled by biogas

10. National Energy Administration, Pibultham Villa, Bangkok 5, Thailand

43. Mr. C.P. KOTHANDARAMAN

1. India 2. 10 August 1933

3. B.E. (Hons) (Mechanical Engineering), M.S. (Heat Power), Ph.D. (Metal Fatigue)

4. English, Tamil

5. 1958 to-date Teaching and research, PSG College of Technology, Coimbatore

6. Heat power engineering.

7. Refrigeration. Solar energy. Biogas

8. Development of a turbo charger for a 100 hp diesel engine. Development of a 500 W wind power generator. Gobar gas utilization in I.C. engines. Development of devices like solar water heater, solar still and solar air heaters. CSIR research scheme on thermal fatigue. Development of refrigeration plant.

9. *

10. PSG College of Technology, Coimbatore 641 004, Tamil Nadu, India

44. Mr. Savang KULAPATRAPA

1. Thailand 2. 6 January 1949

3. B. Eng. (Chulalongkorn University, Bangkok), M.S. (Oklahoma State University, USA)

4. Thai, English

5. 1976 to-date Engineer, in-charge of Biomass Energy Unit, Alternative Energy Study and Development Project, National Energy Administration, Bangkok

   1972-1974 Engineer, in-charge of Telephone Repair Section, Workshop Division, Telephone Organization of Thailand

6. Industrial engineering. Energy planning and development. Biomass energy research and development.

7. Systems planning and analysis. Engineering economics analysis. Renewable energy planning and development.

8. Biomass energy development, sub-project of alternative energy study and development project. Demonstration and promotion of biogas energy in rural areas. Pilot scale production of biogas and fertilizer from pineapple cannery waste. Biogas pumping station.

9. Numerous working papers and unpublished reports on new and renewable sources of energy.

10. National Energy Administration, Pibultham Villa, Bnagkok 5, Thailand

45. Mr. LI Chang-Sheng

1. China 2. 1941

3. Graduate, Nanjing Agricultural College, Farm Mechanization Department (1964)

4. English, Chinese

5. 1978 to-date Engineer, Research on bio-energy resources, China Research and Designing Institute of Agricultural Engineering, Beijing

   1964 Scientific Researcher, China Agricultural Mechanization Science Research Institute

6. Engineering. Biogas energy resource.

7. Agricultural mechanization. Hydraulic pressure techniques.

8. Participation in a project on the state of national tractor technology: inspection techniques without dismantling. Country-wide management of design of small-scale ORBIT hydraulic pressure motor set. Currently research on large-scale design of biogas power station in Mou Mou County and on increasing the effectiveness of biogas products.

10. China Research and Designing Institute of Agricultural Engineering, Beijing, China

46. Mr. LI Fang-Qiang

1. China 2. 1944

3. Graduate, China Chengdu Science and Technology College (1961)

4. 1979 to-date Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Chengdu

   1971-1978 Sichuan Provincial Biogas Office

   1961-1971 Sichuan Provincial Agricultural Science College

6. Combining techniques of manufacture with use of biogas

7. Agricultural soil chemistry

9. Chief editor: "Production and utilization of biogas for villages", Sichuan Provincial Publishers. "Building biogas plants in the villages", China National Science Publisher. "Questions and answers in establishing biogas in the village" (3 volumes), China National Agriculture Publisher (one of the volumes translated into English by the British Intermediate Technology Publishing Company)

10. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Chengdu City, Sichuan Province, China. Tel: 7737

47. Mr. LI Nian-Guo

1. China 2. May 1930

3. Advanced education in College of Agriculture, Lingnan University, Guangdong

4. Chinese, English

5. Present Head, Information Division, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences

   Teacher, Fujian Pedagogic College

6. Information collection and evaluation for energy from biomass, geothermal, solar, ocean, wind and other renewable sources, as well as energy storage and conservation.

7. Foreign affairs. Editor-in-chief of publications

8. Foshan biogas pilot power plant. Fengshun goethermal pilot power plant. Hainan solar-distill pilot power plant.

9. In English, on digesters for developing countries; design, construction and operation of digesters in China; fermentation technology for Chinese rural digesters etc.

10. 81 Martyrs Road, C.P.O. Box 1254, Guangzhou, China

48. Mr. LING Dai-Wen

1. China 2. 25 March 1934

3. Graduate, Beijing Agriculture University, Department of Microbiology

4. English, Chinese

5. 1957-1980 Research Associate, Department of Bacteriology, Institute of Microbiology, Chinese Academy of Sciences, Beijing

6. Taxonomy of bacteria

8. Studies on taxonomy of bacillus, lactobacillus and coryform bacteria; taxonomy of microbes in the biogas digester (in progress)

9. Ling Dai-Wen. Identification of lactobacilli, *Acta Microbiologica Sinica,* 11(4): 600-605, 1965.

   ——— A new species of cellulomonas – cellulomonas variants. *Acta Microbiological Sinica* (to be published)

   Ling Dai-Wen and Wang Da-Si. Two new species of corynebacterium – corynebacterium thermophilum and corynebacterium deparaffinicum. *Acta Microbiologica Sinica* (to be published)

Ling Dai-Wen, Jiang Shu-Qin and Fu Ta-Fuh. Identity of aerobic sporeforming bacteria. *Acta Microbiologica Sinica,* 2(6):275-288, 1960.

Wang Da-Si, Ling Dai-Wen, Zhen Like and Hond Jun-Hua. Numerical taxonomy of gram positive rod-shaped bacteria from Tianshan and other sources. *Acta Microbiologica Sinica* (to be published)

10. Institute of Microbiology, Chinese Academy of Sciences, Beijing, China

49. Mr. LIU Ke-Xin

1. China 2. October 1936

3. University of Wuhan (specialization in microbiology)

4. Russian, English, Chinese

5. 1961 to-date Engineer, Chengdu Institute of Biology, Chinese Academy of Sciences. Research in microbiology and biogas fermentation

6. Microbiology

7. Biogas fermentation

8. Technology of biogas fermentation. Enrichment, isolation and culture of methanogenesis. Improvement of anaerobic digester

10. Chengdu Institute of Biology, Chinese Academy of Sciences, Chengdu, Sichuan, China

50. Mr. LIU Ting-Wei

1. China 2. October 1932

3. Graduate, Beijing Mechanical Engineering College (1960)

4. English, Chinese, Russian

5. 1979 to-date Engineer, China Research and Designing Institute of Agricultural Engineering, Beijing

   1978 Design Engineer, Luoyang Area Machine Factory

6. Mechanical engineering

8. Research and testing of medium temperature village biogas fermentation engineering

10. China Research and Designing Institute of Agricultural Engineering, Beijing, China

51. Mr. Felix D. MARAMBA, Sr.

1. Philippines 3. 7 January 1897

3. B.S. (University of Illinois), M.S. (Iowa State University), D.Sc. (Honoris causa) (Gregorio Araneta University Foundation). Registered Professional Agricultural Engineer; Registered Professional Mechanical Engineer

4. English, Filipino, Spanish

5. President and Director, Liberty Flour Mills, Inc.

   Dean of engineering and graduate studies, Gregorio Araneta University Foundation

   Professor of mechanical engineering, Far Eastern University

   Manager, Land Settlement and Development Corporation

   Director, Bureau of Plant Industry

   Chief, Industrial Enginering Division, Bureau of Science

   Assistant Professor, University of the Philippines, College of Agriculture

6. Bio-energy. Farm mechanization. Indigenous sources of energy.

7. Processing of agricultural products. Waste recycling.

8. Biogas works at Maya Farms. Producer gas as fuel for internal combusion engines. Straight hydrous alcohol as fuel for internal combustion engines. Biogas and waste recycling. Coconut oil as motor fuel. Recycling system for farming.

9. *

10. Official: Liberty Building, Pasay Road, Makati, Metro Manila, Philippines

    Residence: 9 Magallanes Avenue, Magallanes Village, Makati, Metro Manila, Philippines

52. Mr. MEI He-Xiao

1. China 2. 15 May 1937

3. Graduate, Xian Architectural Engineering Institute, Department of Civil Engineering

4. Russian, English, Japanese

5. 1980 Wujin Biogas Research Institute, Jiangsu Province

   1960-1980 After advanced study at Fudan University, engaged in construction and design

6. Construction. Design

8. Research and construction of modernized biogas plants in villages

10. Provincial Biogas Research Institute, Ben Niu Zhen, Wujin County, Jiangsu Province, China

53. Mr. T.K. MOULIK

1. India 2. 11 March 1936

3. M.Sc. and Ph.D. (Agricultural Development Extension) (Indian Agricultural Research Institute, Delhi)

4. Bengali, Hindi, English Pidgin

5. 1974 to-date Professor, Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad

   1970-1974 Senior Fellow, Research School of Pacific Studies, Australian National University, Canberra

   1969-1970 Associate Professor, Indian Agricultural Research Institute, Delhi

   1967-1969 Programme Analyst, USAID, Delhi

   1965-1967 Assistant Professor, Indian Agricultural Research Institute, Delhi

   1958-1960 Agricultural Extension Office, Department of Agriculture, West Bengal, India

6. Development economics

7. Sociology. Organization behaviour

8. Co-ordinator of the action research project on rural development for rural poor. Rural energy projects. Transfer of technology for backward area development

9. *

10. Indian Institute of Management, Vastrapur, Ahmedabad 380 015, Gujarat, India

54. Mr. Raymond M. MYLES

1. India 2. 31 July 1943

3. B.Sc. (Agricultural Engineering) University of Allahabad), M.Sc. (Agricultural Engineering) (University of Guelph, Canada); MASE, MISAE

4. English, Hindi

5. Present Senior Specialist (appropriate technology), Action for Food Production, New Delhi. Involved in the promotion of biogas plants.

   About 17 years experience, in different capacity as engineer, specialist, consultant and manager in the field of agricultural engineering

6. Farm power and machinery. Agro engineering services and appropriate/rural technology. Utilization of alternative energy under rural conditions. Biogas technology.

7. Extension and training in agriculture and rural development field

8. Extension and systematic promotion of Janata biogas plant, through demonstration-cum-training. Field evaluation of small tractor (self helper-7 hp) under different agro-climatic conditions in India

9. "Promotion of biogas plants for small and marginal farmers on individual and community basis". "Construction of a 2 cu m (70 ft) demonstration-cum-training model Janata biogas plant in the Union Territory of Delhi". "Biogas technology: a review of approach adopted by AFPRO in the systematic promotion of Janata plant". "Field evaluation of Hinomotor tractor (7 hp)".

10. Action for Food Production (AFPRO), C-17 Community Centre, Safdarjung Development Area, New Delhi 110 016, India

55. Mr. Ram Krishnan NAIDU

1. Fiji 2. 7 July 1927

3. B.Sc. (Agriculture) (Massey), B.Sc. (Agriculture) (Allahabad)

4. English, Hindi, Fijian, Tamil

5. Present Secondment to South Pacific Commission, as consultant on integrated farming

   1976-1978 Agriculture Department, Government of Fiji

   1965-1975 Self-employed as farmer

   1953-1958 and 1961-1964 Agriculture Department, Government of Fiji

6. Animal husbandry. Tree crops.

7. Agriculture in general and fresh water fish raising (livestock and crops)

8. South Pacific Commission has projects in Tonga, Cook Islands, Tahiti, Fiji, Samoa, Solomon Islands – a total of 23 digesters

10. c/o South Pacific Commission, Department of Agriculture, Box 358, Suva, Fiji

56. Mr. V.P. NARAYANASWAMY

1. India 2. 26 April 1941

3. B.E. (Civil Engineering), M.Sc. (Structural Engineering), Ph.D. (Structural Engineering)

4. English, Tamil, Hindi, German

5. 1968 to-date Scientist, Structural Engineering Research Centre, Roorkee
July – November 1978 Fellow, Asian Institute of Technology, Bangkok
1963-1964 Associate Lecturer, Sri Venkateshwara University, Tirupati

6. Structural engineering.

7. Biogas technology

8. Development of ferrocement gas holder for biogas plants (completed). Development of ferrocement components for biogas plants (ongoing).

9. *

10. Structural Engineering Research Centre, Roorkee (U.P.) 247 672, India

57. Mr. S. NEELAKANTAN

1. India 2. 11 March 1941

3. B.Sc. (Agriculture), M.Sc. (Agriculture), Ph.D.

4. English, Tamil, Hindi

5. 1972 to-date Scientist, Dairy Bacteriology Division, National Dairy Research Institute, Karnal
1968-1972 Assistant Microbiologist, Haryana Agricultural University

6. Microbiology and chemistry of anaerobic digestion into biogas. Soil microbiology – legume inoculants. Silage microbiology – lactic fermentation

7. Composting of cattle manure. Blue green algae inoculation to rice fields.

8. Isolation of efficient rhizobium for fodder legume. Microbial and nutritional studies of some silages. Composting of dairy farm wastes with desirable fermentation. Biogas production during winter and utilization of slurry. Improved and efficient dairy farming through harnessing locally available energy sources.

9. *

10. Dairy Bacteriology Division, National Dairy Research Institute, Karnal 132 001, India

58. Miss Watana NOPAKOON

1. Thailand 2. 1949

3. B.Sc. (Chulalongkorn University)

4. Thai, English

5. 1976 to-date Scientist, Alternative Energy Study and Development Project, National Energy Administration, Bangkok

   1972-1976 Scientist, Energy Research and Development Section, National Energy Administration, Bangkok

6. Chemical technology

7. Food technology

8. Experiment on: solid fuels from waste materials; biogas production from agricultural waste; analysis of solid fuels.

10. Technical Division, National Energy Administration, Pibultham Villa, Bangkok 5, Thailand

59. Mr. Enrico D. OBIAS

1. Philippines 2. 3 October 1933

4. English, Filipino

5. 1960 to-date Chief Chemist (1960-1971), Assistant Vice President for Research and Development and Quality Control (1971-1975) and then Vice President for Operations, Maya Farms Division, Liberty Flour Mills, Inc., Manila

   1959-1960 Researcher, H.G. Henares and Sons

   1958-1959 Instructor, University of the Philippines

6. Food processing

7. Waste recycling

8. Biogas works at Maya Farms.

9. Co-author: "Biogas and Waste Recycling", 1978. "The Small Biogas Plants", 1977

10. 51 Fordham Street, White Plains, Quezon City, Metro Manila, Philippines; or c/o Maya Farms Division, Liberty Flour Mills Inc., Liberty Building, Pasay Road, Makati, Metro Manila, Philippines

60. Mr. V. PADMANABHAN

1. India 2. 19 September 1923

3. Graduate in science, trained in village industries

4. English, Tamil

5. 1976 to-date Secretary (1976-1978) and then Managing Trustee, Gandhigram Trust

1972-1976 Special Officer (village industries), Khadi and Village Industries Commission, Bombay

1960-1972 Secretary, Tamil Nadu Khadi and Village Industries Board

1956-1960 Deputy Director, Industries and Commerce, in charge of village industries of the Tamil Nadu State

1952-1956 Personal Assistant to Project Executive Officer, Assistant Project Officer and Block Development Officer of Community Development Programme of Periyar Division, Madurai District, Tamil Nadu

1947-1952 Secretary, Gandhigram

6. Village industries. Village reconstruction and training. Village industries including biogas and other occupations like spinning, weaving, soap manufacture, leather manufacture, carpentry and blacksmithy, lime manufacture, processing of cereals and pulses, oil extraction, bee-keeping etc.

7. Agriculture. Animal husbandry. Silk-worm rearing.

8. Ferrocement digester and gas holder with the gas drawn from below. Ferrocement digester and gas holder with water jacket system. Ferrocement digester and mild steel gas holder, square type. Brick masonry digester with high density polyethylene gas holder. Chinese design of biogas plant with fixed dome. Conventional Khadi and Village Industries Commission design with movable floating drum.

9. Articles on rural development and village industries in *Commerce, Khadi Gramodyog, The Mail* and other journals

10. Gandhigram Trust, Madurai District, Gandhigram 624 302, Tamil Nadu, India

61. Mr. Mohan PARIKH

1. India

4. English, Hindi, Gujarati

5. Present Director, Agricultural Tools Research Centre, Bardoli

Director, Yantra Vidyalaya, Bardoli (an institute for rural development)

Managing Trustee, Suruchi Chhapshala, Bardoli (a school of printing technology)

6. Social service and rural development. Improved agricultural hand tools and bullock – driven implements for small and marginal farmers.

7. Biogas energy – cow dung gas plant; garbage gas plant; gas plant with fixed R.C.C. roof. Solar energy utilization – solar cooker.

8. Design and development of about 60 improved agricultural tools and implements. Prototype experimental garbage gas plant with different raw materials. Design and development of a gas plant with fixed R.C.C. roof on Chinese pattern. Conversion of conventional gas plants with iron dome to store gas into fixed R.C.C. roof gas plant.

9. *

10. Agricultural Tools Research Centre, Suruchi Campus, Post Box 4, Bardoli 394 601, India

62. Mrs. P.P. PARIKH

1. India

3. Ph.D. (Mechanical Engineering); MIE (India), MAIE (India)

4. English

5. Present Assistant Professor, Mechanical Engineering Department, Indian Institute of Technology, Bombay

6. Internal combustion engines

7. Environmental engineering. Combustion engineering

8. Utilization of biogas in diesel engines. Environmental aspects of biogas engines

9. Monogram on recent developments in gobar gas technology

10. Mechanical Engineering Department, Indian Institute of Technology, Bombay 400 076, India

63. Mr. G.L. PATANKAR

1. India

3. B.Sc. (Chemistry – Physics); A.I.C. (Fuels and Gas Water and Sewage); Diploma in advertising and public relations.

4. English, Hindi, Marathi

5. 1962 to-date Laboratory Supervisor (1962-1963), Fuel Chemist (1963-1973), Assistant Director (1973-1976) and then Deputy Director, Gobar Gas Scheme, Khadi and Village Industries Commission

6. Biogas technology

7. Solar energy for village uplift

8. Simplification in the design of biogas plant (domestic). Problems of corrosion of biogas plant. Design of community gas plant. Development of commercial

gas appliances. Gas plant for cold region. Fermentation kinetics and environment.

9. *

10. Gobar Gas Research and Development Centre, Kora Gramodyog Kendra, Borivli (West), Bombay 400 092, India

64. Mr. T.M. PAUL

1. India 2. 10 September 1916

3. B.Sc. (Chemistry), M.Sc. (Chemistry), Ph.D. (Dairy Science); MISCA, MRIC, MIDC, MSDT

4. English, French, Malayalam, Hindi, Tamil, Telugu

5. Present Director, National Institute of Waste Recycling Technology. Consultant to the Indian Institute of Technology, Madras, on community development and integrated rural development

   1977-1978 Consultant to FAO on recycling of agricultural and animal wastes, Bangkok

   February-July 1977 Regional Adviser on biogas, Natural Resources Division, ESCAP, Bangkok

   1976-1977 Consultant to the South Pacific Commission on rural development based on integrated farming system

   1967-1976 Head, National Dairy Research Institute, Bombay

   1965-1967 Head, Division of Dairy Extension, National Dairy Research Institute, Karnal

   1962-1965 Chief, Quality Control Officer, Delhi Milk Chem, New Delhi

6. Environmental pollution control through biogas and compost. Waste-recycling for energy as biogas and rural agricultural production and sanitation. Biogas and compost production from human and animal waste. Intensive mixed farming through use of liquid compost plants for biogas production and compost.

7. Dairy farming, biogas and compost production. Waste-land reclamation for increased agricultural production. Integrated rural development through mixed farming.

8. Rural development based on dairy-farming through integrated farming systems. Workshop on biogas for the Pacific island community. Recycling agricultural and animal wastes in the south and south-east Asian countries. Developed a system of intensive farming based on recycling of all wastes, solid, liquid and gaseous, making all agricultural practices independent of all outside-supplies of energy, chemical fertilizer etc. Developed a system for co-operative urban and rural habitation in and around cities and towns to make use of all waste-mater-

ials generated in urban areas, to develop a green-belt around, to make use of all city wastes, solid, liquid and gaseous, to produce all perishable agricultural commodities needed in the urban-centres.

9. *

10. National Institute of Waste Recycling Technology, A-18, Juhu Apartments, Juhu Road, Bombay 400 049, India

65. Mr. PENG Wu-Hou

1. China 2. 21 July 1939

3. Graduate, Shanghai Science and Technology University (specialization in biochemistry and physical chemistry) (1963)

4. English, Chinese

5. 1966 to-date In-charge, Comprehensive Research Office, Shanghai Institute of Industrial Microbiology, Shanghai

   1963-1966 Research on fermentation for industries, Shanghai Light Industry Research Institute, Shanghai

6. Biochemistry

7. Microbiological fermentation

8. Research on biogas fermentation and on utilization of waste heat from power generation. Research on potential raw materials for biogas fermentation. Research on disposal of urban waste for biogas fermentation.

9. "Approaches to some aspects of increasing the volume of biogas production", *Energy Resources* No. 3, 1979. "Research on the effect of acetic acid, sodium, cellulose enzymes etc. in biogas fermentation". "Chemicals to stop formation of mildew", *Chemical World* No. 5, 1980. "Research on artificial biogas", parts I and II, *Industrial Microbiology*, December 1979 and 1980. "Report on utilization of waste heat from biogas power generation", ID/WG 321/4, June 1980.

10. Shanghai Institute of Industrial Microbiology, Shanghai, China

66. Mr. Chongrak POLPRASERT

1. Thailand 2. 25 October 1949

3. Ph.D. (Civil Engineering)

4. English, Thai

5. 1977 to-date Assistant Professor of environmental engineering, Asian Institute of Technology, Bangkok

6. Sanitation. Waste recycling.

7. Environment

8. Recycling rural and urban nightsoil in Thailand, a two-year research project sponsored by the International Development Research Centre, Canada

10. Asian Institute of Technology, P.O. Box 2754, Bangkok, Thailand

67. Mr. G.G. PURI

1. India 2. 16 August 1924

3. B.Sc. (Electrical and Mechanical Engineering). Director, Institute of Regional Analysis. Technical Member, NWWA, USA. Chairman, Institute of Engineers, Madhya Pradesh Centre

4. Hindi, English, Marathi, French, Urdu, Gujarati

5. 1974 to-date Founder/Executive Director (honorary), Resources Development Institute, Bhopal

   1973 to-date Chief Engineer, Irrigation Department, Government of Madhya Pradesh

   1977-1978 Managing Director, M.P. Lift Irrigation Corporation

   August-October 1979 Consultant, Asian Development Bank, Mission IV, agriculture credit project, Lao People's Democratic Republic

   1970-1973 Director, ground water surveys and tubewells, Government of Madhya Pradesh; also Expert, World Bank

   1968-1970 Superintending Engineer, Directorate tube wells, Madhya Pradesh; also Consultant, Development Resources Corporation, USA

   1958-1968 Executive Engineer, EIM, Irrigation Department, Government of Madhya Pradesh

   1958-1960 Consultant to Chief Engineer, Irrigation Department, Madhya Pradesh

   1950-1958 Assistant Engineer, Public Works and Irrigation Department and Bhilai Steel Plant

   1949-1950 Engineer (power), Empress Mills, Nagpur

6. Construction machinery, workshops, stores, projects construction and mechanization. Ground water development: wells, tube wells, drilling and pumping machinery

7. Resource development: all aspects including biogas technology and solar energy.

8. Research and research guidance on resource development projects, including biogas and solar energy technology. Auto-lift impulse pumps.

10. Resources Development Institute, E-3/76, Arera Colony, Bhopal, M.P., India

68. Mr. QIAN Ze-Shu

1. China 2. 1925

4. Chinese, English

5. Present Associate Professor of Microbiology, Zhejiang Agricultural University, Zhejiang

6. Soil microbiology

7. Biogas (methane fermentation)

8. Nitrogen fixation. Methane fermentation

9. "Studies of observation on methane fermentation in farmyard digesters in China". (in English)

10. Zhejiang Agricultural University, Zhejiang, China

69. Mr. S.K. RAJAPAKSE

1. Sri Lanka 2. 19 June 1952

3. National Diploma in Technology (Chemical Engineering); Specially trained in China on small and large scale biogas technology.

4. English

5. Present Chemical Engineer, Industrial Development Board, Katubedda, Moratuwa, Sri Lanka

6. Biogas and other alternate sources of energy.

8. Promotion of biogas in Sri Lanka in collaboration with World Vision International Organization. Training of technicians for construction of biogas works. Undertaking of design and construction works.

10. Industrial Development Board of Ceylon, 615, Galle Road, Katubedda, Moratuwa, Sri Lanka

70. Mr. M.A. Sethu RAO

1. India 2. 27 September 1924

4. English, Kannada

5. Present Joint Secretary, Karnataka State Council for Science and Technology, Indian Institute of Science, Bangalore

Reader in chemistry, University of Mysore, Karnataka

6. Physical chemistry

7. Science and technology. Planning. Popularization of science.

10. Karnataka State Council for Science and Technology, Indian Institute of Science, Bangalore 560012, India

71. Mr. P. Sreenivasa RAO

1. India 2. 5 July 1931

3. M.Sc., Ph.D.

4. English

5. 1961 to-date Scientist (1961-1976) and then Assistant Director, Central Salt and Marine Chemicals Research Institute, Bhavnagar

   1958-1961 Lecturer, M.R. College, Vijayanagaram

   1957-1958 Lecturer, A.C. College

   1950-1957 Demonstrator, Hindu College

   1970-1971 Reader in bioscience, Saurashtra University, Bhavnagar

6. Marine algae

7. Marine microbiology and marine biomedicals

8. All-India co-ordinated project on algae – energy from sea weeds and other organic wastes

10. Central Salt and Marine Chemicals Research Institute, Waghawadi Road, Bhavna gar 364 002, India

72. Mr. Sermpol RATASUK

1. Thailand 2. 18 October 1943

3. B.Sc. (Hons.) (Chemical Engineering) (Chulalongkorn University, Bangkok), M.Eng. (Environmental Engineering) (AIT, Bangkok), Ph.D. (Environmental Engineering) (University of Newscastle-upon-Tyne)

4. Thai, English

5. Present Environment and Development Department, Thailand Institute of Scientific and Technological Research, Bangkok

6. Chemical engineering. Environmental engineering.

8. Evaluation of treatment alternatives for molasses distillery stillage

9. On anaerobic filter treatment of strong organic wastes; anaerobic filter for biogas production

10. Thailand Institute of Scientific and Technological Research, 196 Paholyothin Road, Bangkhen, Bangkok 9, Thailand

73. Mr. REN Yuan-Cai

1. China 2. December 1933

3. Graduate, Chongqing Architectural Engineering Special School (1955) and Architectural Construction Special Night University (third year) (1959)

4. Self-educated in English

5. 1980 Chief, Biogas Digester Scientific Research Group, Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Chengdu

   1976 In-charge, Central Experimental and Research Institute, Ministry of Construction, Third Bureau, responsible for environmental protection and scientific research, Division of Science and Technology, Urban Construction Commission, Chengdu, Sichuan

   1965 Chief, Scientific Research Group, Office of Structures, Xinan Construction Science and Research Institute, Ministry of Construction, Chengdu, Sichuan

   1959 Head, refining factory for reinforced concrete, Mao Ming City, Guandong Province

6. Scientific research and management of biogas digester construction

7. Techniques of welding reinforcing bars. Techniques of practical application of concrete

8. Design and construction of standardized small biogas plants for farm households and research on collective or decentralized gas supply. Design and construction of medium-scale (60-200 m^3) biogas plants. Research on power station for coordinated electricity generation and refining of by-products of agriculture. Design and construction of large-scale (300-1200 m^3) biogas plants. Biogas fermentation techniques at general and medium temperatures. Research on a complete set for electricity generation.

9. "Collected fruitful scientific research results", Ninth information collection on digester construction, Sichuan Province Biogas Office compilation and publication. *Biogas techniques: design and construction of digesters,* Book II, textbook and reference for United Nations University, 1980.

10. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Ren Min Nan Lu, Chengdu City, Sichuan Province, China

74. Mr. M.A. SATHIANATHAN

1. India 2. 5 January 1924

4. English, Hindi, Malayalam, French

5. 1978 to-date Co-ordinator, Energy and Environment Centre of Science for Villages; and also Director, Eco-Living Centre

   1969-1978 Secretary, Progressive Education Association; and also Vice-Chairman, Village Industrialization Association

   1967-1969 Director, Sevagram Rural Technical Training Centre (an Indo-German project)

   1965-1967 President, Rural Higher Education Institute, Sevagram

   1955-1964 Field work in Kerala and Gwalior as a village worker

   1947-1955 Head, Science and Handicrafts Department at Sevagram, Mahatma Gandhi's Village Headquarters.

6. Education. Biogas technology. Rural industrialization

7. Taking science to the villages

8. Studies on: equipment design engineering and improvement of digesters; digestion process engineering studies; feed stock processing and plant design, selection of biogas system for its use in rural industries; systems approach to biogas utilization (ongoing)

9. *

10. Kakawadi, Wardha 442 001, India

75. Mr. B.R. SAUBOLLE, S.J.

1. India
2. 1 October 1904
3. Jesuit priest
4. Hindi, English, French, Nepali, Latin
5. 1965 to-date Experimented in solar energy

   1953-1980 Experimented in biogas

   1951-1980 Education

   1940-1950 Parish work in India

6. Priesthood. Education, Primary and middle school
7. Biogas. Solar energy. Appropriate technology.
8. Introduction of biogas and solar water heaters in Nepal. Member of Editorial Board of *Biogas Newsletter Nepal.* Consultant member of periodical *Shakti* (Energy). Development of smokeless stoves.
9. On, fuel gas from cow dung, home brew, mini-technology
10. Post Box 50, Kathmandu, Nepal

76. Mr. Iqbal Hussain SHAH

1. Pakistan 2. 11 November 1934

3. B.Sc. (Mechanical Engineering), MME (Colorado State University), M.Sc. (Thermo) (University of Birmingham), Post Graduate Diploma (Industries) (Norway)

4. English, Pashto, Urdu, Persian

5. 1978 to-date Dean/Director Research, Faculty of Engineering, University of Peshawar, Pakistan

   1976 Affiliated Professor, Colorado State University

   1975 Visiting Professor, Sri Lanka, under UNESCO

   1956-1969 Senior Lecturer (1956-1961), Reader (1961-1969), and then Professor, Engineering College, University of Peshawar

   1955-1956 Assistant Engineer, Hydro-electric Project, Warsak

6. Mechanical engineering. Croyogenic engineering. Thermodynamic power in general. Refrigeration. Air-conditioning. Solar energy. Biogas

7. Appropriate technology research projects. Solar energy. Biogas

8. Design and construction of sealed type, variable pressure biogas plant. Determination of heat of temperature on biogas production. Conversion of 5 hp petrol engine to run on biogas (tested for 2 years and can be directly started with biogas). Conversion of 6 hp diesel engine to run on biogas and diesel. Design and construction of vertical type biogas pump. Utilization of solar energy in production of biogas. Biogas as a fuel for power production on agricultural farm.

9. *

10. Faculty of Engineering, University of Peshawar, P.O. Peshawar University, N.W.F.P., Pakistan

77. Mr. J.B. SINGH

1. India 2. 23 May 1926

3. M.Sc. (Agriculture) (Agro-economics)

4. English, Hindi

5. Present Executive Director, Action for Food Production (AFPRO), New Delhi

6. Agricultural economics and extension. Community development

7. Appropriate/rural technology. Biogas technology

8. Chief co-ordinator: extension and systematic promotion of Janata plant through demonstration-cum-training of Janata plants scheme; field evaluation of small tractor (self helper – 7 hp) under different agro-climatic conditions in India

9. Promotion of biogas plants for small and marginal farmers on individual and community basis

10. Action for Food Production (AFPRO), C-17 Community Centre, Safdarjang Development Area, New Delhi 110 016, India

78. Mr. Ongart SITTHICHAROENCHAI

1. Thailand

3. B.Sc. (Sanitation), MPH (Environmental Health)

4. English, Thai

5. 1970 to-date Department of Health, Ministry of Public Health, Bangkok

6. Environmental sanitation

7. Environmental health

10. Sanitation Division, Department of Health, Ministry of Public Health, Bangkok, Thailand

79. Mr. Pichit SKULBHRAM

1. Thailand

3. B.Sc. (Sanitary Science) (Mahidol University), MPH (Environmental Health) (University of Minnesota)

4. English, Thai

5. 1957 to-date Instructor (1957), Assistant Professor (1971) and then Associate Professor, Sanitary Science Department, Faculty of Public Health, Mahidol University, Bangkok

6. Environmental health, majoring in water and wastewater

7. Teaching in general sanitation

8. Biogas production from various organic matters; two research projects completed at Sanitation Region Centre 1, Prabhudtabat District, Saraburi Province.

9. Two final reports on biogas research published in the Journal of the National Research Council of Thailand (in Thai)

10. Faculty of Public Health, Mahidol University, 420/1 Rajavithi Road, Bangkok 4, Thailand

80. Mr. Koentoro SOEBIJARSO

1. Indonesia 3. 17 October 1944

3. Faculty of Agricultural Technology, Gajah Mada University

4. English, Indonesian

5. 1976 to-date Research staff, Laboratory of Industrial Gases, Industrial Research Institute, Centre for Chemical Industry, Indonesia

   1973-1976 Research staff, Laboratory of Microbiology, Indonesian Leather Research Institute, Indonesia

6. Industrial gases.

8. Research and development of biogas and its prototype

10. Industrial Research Institute, Centre for Chemical Industry, Jalan Karanganyar 55, Jakarta, Indonesia

81. Mr. Richard K. SOLLY

1. Australia (resident of Fiji)

3. B.Sc., M.Sc., Ph.D.; ARACI

4. English

5. Present Senior Lecturer in chemistry, University of the South Pacific, Suva, Fiji

6. Investigation of mass and energy flows in the biogas system as a function of the system parameters. Development of biogas systems appropriate to the rural areas of developing countries

7. Utilization of vegetable matter in biogas systems

8. Investigation of rural digesters in the South Pacific. Installation and operation of polymer rubber biogas digesters in appropriate locations in the South Pacific. Development of simple durable biogas digesters. Utilization of water hyacinth and vegetable matter in biogas digesters. Development of integrated biogas systems

9. *

10. University of the South Pacific, P.O. Box 1168, Suva, Fiji

82. Mr. W. Robert STANTON

1. United Kingdom 2. 24 February 1923

3. B.Sc., Ph.D. (London); FIBiot, FIFST

4. French, German, Italian, Malay, English

5. Professor of Botany, University of Malaya, Malaysia

   Consultant and Member, UNEP/UNESCO/ICRO Panel for Applied Microbiology in south-east Asia

   Head, Microbiology Section, Tropical Products Institute, London

   Senior Botanist, Nigeria

   UK Research Institutions

6. Processing tropical and equatorial crops and by-products

7. Fermented foods

8. Vegetable oil recovery from vegetable oil processing wastes. Equatorial starches for establishment of food and gasohol industries – palm starches and sugar. Biogas plant, constructed with mild steel and with digester volume of 2 x 3000 m^2 at a cost of approximately US$ 600,000, with continuous feed of about 400 tons/day of effluent and palm oil processing, producing 9 tons/day methane, at present utilized for hot air drying with the effluent used as direct fertilizer on soil.

10. 346 Lorong 10C, United Gardens, Old Klang Road, Kuala Lumpur, Malaysia

83. Mr. D.J. STEWART

1. New Zealand

2. March 1942

3. B.Sc., M.Sc., Ph.D.

4. English, French

5. 1972 to-date Scientist, Ministry of Agriculture and Fisheries, New Zealand

   1970-1971 Assistant Professor, Dalhousie University, Halifax, N.S., Canada

   1968 Post-Doctoral Fellow, Dalhousie University, Halifax, N.S., Canada

   1967 Junior Lecturer in chemistry, Victoria University, Wellington, New Zealand

6. Chemistry. Biochemistry

7. Physics. Engineering.

8. Effects of industrial pollution on agriculture. Production of biogas from crops and wastes. Energy farming. Energy in agriculture. Farm scale biogas and ethanol plants.

9. *

10. Section Leader, Energy and Environment Section, Invermay Agricultural Research Centre, Private Bag, Mosgiel, New Zealand

84. Mr. SUN Guo-Chao

1. China 2. January 1941

3. Graduate, Nanjing Agricultural College, Department of Agriculture (specialization in agriculture)

4. English, Chinese

5. 1968 to-date Lecturer and Deputy Chief, Biogas Group, Chengdu Biological Research Institute, Chinese Academy of Sciences

6. Microbiology

7. Biogas fermentation and biochemical analysis

8. Microbiological biogas fermentation. Biogas fermentation techniques

10. Chengdu Biological Research Institute, Chinese Academy of Sciences, Chengdu City, Sichuan, China

85. Mr. Calixto C. TAGANAS

1. Philippines 2. 21 October 1921

3. B.S.C.E., S.E.

4. English, Filipino

5. Assistant Vice President, Liberty Flour Mills, Inc., in charge of biogas works design, construction and operations and civil works

   Administrative Officer and Officer-in-Charge, Civil Department, Liberty Flour Mills, Inc.

   Head Miller, Liberty Flour Mills, Inc.

   General Superintendent, Ysmael Wood Industries

   Shift Miller, Liberty Flour Mills, Inc.

   Assistant Civil Engineer, Liberty Flour Mills. Inc.

   Construction Inspector, National Power Corporation

   Engineer Aide, Ministry of Public Works and Communication

   Instructor, Aurora College (formerly Baler Institute)

6. Design, construction and operation of biogas works. Construction of multi-rise structures

7. Flour milling, veneer and plywood manufacturer

8. Biogas works at Maya Farms and other stock farms

9. "Biogas and waste recycling". "The small biogas plant".

10. Official: Liberty Flour Mills, Inc., Liberty Building, Pasay Road, Makati, Metro Manila, Philippines

    Residence: 149 K-6 Kamias, Quezon City, Philippines

86. Mr. Morakot TANTICHAROEN

1. Thailand 2. 13 October 1947

3. Ph.D. (Microbiology) (University of Rhode Island)

4. English, Thai

5. 1978 to-date Head, Department of Microbiology, King Mongkut's Institute of Technology, Thonburi Campus, Bangkok

   1972-1977 Teaching and Research Assistant, University of Rhode Island, USA

   1968-1971 Research Assistant, SEATO Medical Research Laboratory, Bangkok

6. Microbiology

7. Renewable energy (bio-energy conversion)

8. Biogas mechanism generated from plant materials. Isolation of cellulolytic micro-organism from soil and digester sludge

10. King Mongkut's Institute of Technology, Thonburi Campus, 48 Suksawad Road, Rajburana, Bangkok 14, Thailand

87. Mr. Boontham TESNA

1. Thailand 2. 19 June 1928

3. B.Sc. (Agriculture) (Kasetsart University), M.S. (Agricultural Education) (Oklahoma State University), Ph.D. (Co-operative Extension)

4. English, Thai

5. Government official, serving as an instructor in vocational agriculture school for nine years and lecturer, assistant professor, associate professor for ten years both at Khon Kaen University and Maejo Institute of Agricultural Technology

6. Agricultural education

7. Interested in biogas primarily in the interests of manure collection, sanitation and gas for cooking

8. Has encouraged many rural and farm population to build biogas units with different designs; with or without gas tanks, different shapes-round, rectangular, cubic, square; with inside outlet and outside for draining spent manure. Good units for showing to interested groups or individuals; 10 in Chieng Mai, 1 in Lumpang, 2 in Pitsanulok and 2 in Lampoon

9. A paper presented to Universiti Pertanian Malaysia about social-economic outcome of the extension of biogas technology

10. Dean, Faculty of Agricultural Business, Maejo Institute of Agricultural Technology, Maejo, Chieng Mai, Thailand. Tel: 236-602

88. Mr. Y.R. TIPNIS

1. India 2. 19 December 1907

3. B.A., B.Sc., B.E. (Civil Engineering); Life Member: Indian Institute of Geohydrologists, Calcutta; FIE, FRDI, MIWWE, MIPE, MIME

4. English, Hindi, Marathi, Gujarati

5. 1970 to-date Trustee and Director, Rayalaseema Development Trust, Anantapur (during October 1975 – December 1976, with Pentajen Engineering as coordinating sales engineer for indented equipment)

1970-1969	Adviser, Udain Engineering Co. (contractors and builders)
1967-1970	Consultant
1965-1967	Chief Engineer, Sikkim P.W.D., Ganjtole, Sikkim
1962-1965	Chief Engineer, Indian Institute of Petroleum Research
1959-1962	Chief Civil Engineer, Gantrati Refinery Noomati, Assam
1957-1959	Chief Plant Engineer, Hindustan, Bangalore

6. Composite civil engineering and indential projects

7. Water supply survey, planning implementation, conservation and replenishment. Agro-oriented projects like biogas plants and solar cooker. Social work with emphasis on experience of work and rural education

8. Among others, construction of biogas plants and cheap solar cookers.

10. c/o Resources Development Institute, 1100 Quarters Area, Bhopal, 462016, India

89. Mr. Hiroji Narayan TODANKAR

1. India 2. 7 December 1918

3. Practical experience with nightsoil and cattle dung gas plants over the past 22 years; also learned the technique of constructing inexpensive hygenic latrines for Indian villages.

4. Marathi (mainly), Hindi and English (working knowledge)

5. 1959 to-date Organizer of the Bhangi Mukti (improved rural hygene scheme without the hired services of scavangers) under the aegies of Gandhi Memorial Fund for the State of Maharashtra (India).

   1949-1959 Social worker in Government-sponsored Sarvodaya (integrated rural development organization) at Gopuri.

6. Rural hygene. Biogas

7. Rural education

8. Introduction in villages of improved, inexpensive hygenic latrines and nightsoil gas plants. During the past 20 years constructed over 56,000 latrines and over 100 nightsoil biogas plants. Earlier organized 14 schools on Gandhijis model of occupation oriented basic education.

9. One informative handout on nighsoil gas plant (in English)

10. Gandhi Bhavan, Kothrud, Pune 411 029, Maharashtra, India

90. Mr. TSE Shu-Chien

1. China

4. English, Chinese

5. Present Head, Department of Soils and Agricultural Chemistry, Zhejiang Agricultural University

6. Soil microbiology

7. Biogas

9. Experimental reports

10. Laboratory of Soil Microbiology, Zhejiang Agricultural University, Hangzhou, Zhejiang, China

91. Mr. TU Jia-Bao

1; China 2. March 1939

3. Graduate, Beijing Agricultural University (1964)

4. Chinese

5. 1978 to-date Planning and managing biogas research and implementation

   1964-1977 Planning and managing agricultural scientific instruments and equipments

6. Biogas research, planning and managing

7. Biogas implementation and administration

8. Programmes under National Biogas Office

9. Reports at UNDP/ESCAP 1978, UNAPDI 1978, FAO 1980 and UNIDO 1980

10. National Biogas Office, Ministry of Agriculture, Ho Pin Lee, Beijing, China

92. Mr. Sornthep TUMWASORN

1. Thailand 2. 25 July 1951

4. English, Thai

5. 1978 to-date Junior Lecturer, Animals Science Department, Kasetsart University, Bangkok

   1977 Research Assistant, Rockefeller Foundation

6. Animal breeding and production

7. Agricultural waste management

8. Integration of biogas with agricultural system under village conditions

10. Animal Science Department, Kasetsart University, Bangkok 9, Thailand

93. Mr. WANG Da-Si

1. China 2. 23 April 1923

3. Graduate, Catholic University (1945). Post-graduate, Peking Union Medical College (1949)

4. English, Chinese

5. 1959 to-date Institute of Microbiology, Chinese Academy of Sciences

   1949-1959 Institute of Forestry and Soil, Chinese Academy of Sciences

6. Bacteriology

7. Industrial bacteriology

8. Bacterial taxonomy. Bacteria in biogas production

9. "Foundation for bacterial taxonomy", Science Press, 1977

10. Institute of Microbiology, Chinese Academy of Sciences, Beijing, China

94. Mr. WANG Meng-Jie

1. China 2. 1935

3. University graduate, Herbin North-east Agricultural University (1957-1962)

4. Chinese, Japanese

5. 1978 to-date Engineer/Chief, Energy Sources Engineering Office, China Research and Designing Institute of Agricultural Engineering

   1962-1978 Engineer, Farm Machinery Repairing and Research Institute, Heilongjiang Province

6. Mechanical engineering. Energy resources engineering

7. Farm mechanization. Utilization of plasma as arc heat source

8. Medium temperature biogas engineering. Standardization of small-scale biogas plants. Utilization of solar energy for seeing biogas plants through winter. New energy sources for village construction

9. "Norms for farm machinery maintenance". "Renovation of old tractors".

10. China Research and Designing Institute of Agricultural Engineering, Beijing, China

95. Mr. WANG Xin-Quan

1. China 2. July 1940

3. Graduate, Shanghai Special School for Electrical Industry (specialization in manufacture of steam turbine)

4. Can translate written texts into English, with the help of dictionary.

5. 1963 to-date Chief Engineer (power machinery), Sichuan Agricultural Machinery Research Institute, Sichuan

6. Research on practical applications of biogas as motive power for agriculture

7. Research on forming a complete set machinery for biogas. Research on small horsepower diesel machine

8. Research on installation for stirring in biogas plant and on small horsepower diesel engine

9. "Practical applications of biogas as motive power in agriculture", in the study compiled for United Nations University on biogas engineering

10. Agricultural Machinery Research Institute, Sichuan Province, China

96. Mr. Myo WIN

1. Burma

3. B.E. (Agriculture), M.Eng.Sc. (Melb)

4. Burmese, English

5. 1979 to-date Lecturer, Agricultural Engineering Department, University of the South Pacific, Alafua, West Samoa

   1965-1979 Instructor (1965-1971), Assistant Lecturer (1971-1978) and then Lecturer (1978-1979), Mechanical Engineering Department, RIT

6. Mechanical and agricultural engineering

7. Soil and water conservation

8. Supervised undergraduate and post-graduate theses. Testing of small farm implements

10. c/o Agricultural Engineering Department, University of the South Pacific Alafua, Samoa

97. Mr. Dong Han WOOK

1. Republic of Korea

3. B.S. and M.S. (Agricultural Chemistry) (Korea University), Ph.D. (Agricultural Science) (Hokkaido University, Japan)

4. English, Japanese

5. Present Agricultural Senior Researcher/Chief, Rural Energy Resources Research Division, Institute of Agricultural Science, Office of Rural Development

6. Biogas production and utilization

8. Studies on material resources for biogas production. Development of biogas plant types and biogas utilization

9. Studies on biogas generation from animal wastes. A feasibility study of village scale biogas plant during winter season

10. Institute of Agricultural Science, Office of Rural Development, Suweon, Republic of Korea

98. Mr. WU Chang-Lun

1. China 2. December 1937

3. Graduate, Beijing Agricultural Mechanization Institute (1959)

5. Present Engineer, China Research and Designing Institute of Agricultural Engineering, Beijing

   1978 Engineer, Agricultural Mechanization Research Institute, Chinese Academy of Agricultural Science

6. Agricultural mechanization

8. Currently, on aspects of area energy resource planning for villages in China

10. China Research and Designing Institute of Agricultural Engineering, Beijing, China

99. Mr. WU Jin-Peng

1. China 2. July 1931

3. Graduate, Zhejiang Agricultural University (1955). Lecturer in microbiology

4. Chinese, English

5. 1973 to-date Zhejiang Agricultural University

   1964-1973 Zhejiang Light Industrial Research Institute

   1955-1964 Zhejiang Chemical Industrial Research Institute

6. General microbiology

7. Biogas (methane fermentation). Industrial fermentation

8. Methane fermentation

9. "Studies of observation on methane fermentation in the farmyard digesters in China" (in English)

10. Zhejiang Agricultural University, Zhejiang, China

100. Ms. XIAO Ying-Chang

1. China 2. December 1933

3. Graduate in biology, Northwest University (1956)

4. Can use English for translating technical documents and reference materials

5. 1971 to-date Chief of Microbiology Teaching Group, Chongqing Teachers College, Chongqing

   1961-1971 Teaching botany, Chongqing Teachers College

   1956-1961 Teaching botany, Shandong Agricultural College

6. Microbiology. Biogas

7. Botany

8. Laser induced mixing of bacteria at low temperature biogas plant. Addition of formaldehyde, acetone acid to raise the effect of the rate of gas production. Experiment with putting in bacteria. Plants as a source of energy – water hyacinth. Research on water hyacinth, green grass increasing the volume of biogas. Research on potentiality of water hyacinth for producing biogas and on methods of introducing feed materials. Comparison of results of single stage and multi-stage fermentation with respect to biogas production. Separate appraisal of methane bacteria

9. "Flora in Shandong economy", Shandong People's Publishing House (1978). "Water hyacinth and green grass are good raw materials for fermentation", Chongqing Microbiology Society (1979). "Production at dew point low temperature (reddish brown requirement, 9.2): a summing up", Sichuan Microbiology in Agriculture, second anthology

10. Microbiology Department, Chongqing Teachers College, Chongqing, Sichaun Province, China

101. Mr. XU Jie-Quan

1. China 2. March 1945

3. Graduate, University of Fudan (specialization in microbiology – biochemistry)

4. English, Chinese

5. 1968 to-date Engineer, Chengdu Institute of Biology, Chinese Academy of Sciences, research in biogas fermentation

6. Biochemistry

7. Biogas fermentation

8. Two-phase anaerobic digestion

10. Chengdu Institute of Biology, Chinese Academy of Sciences, Chengdu, Sichuan, China

102. Mr. XU Ke-Nan

1. China 2. September 1927

3. Graduate, Department of Agricultural Chemistry, Sichuan University (specialization in biochemistry) (1952)

4. English (reading), Chinese

5. 1952 to-date Technician, Agricultural Technician, Deputy Chief, Research Office, Research Institute for Soil and Fertilizer, Academy of Agricultural Science, Sichuan

6. Agricultural chemistry

8. Accelerated composting. Manufacturing granulated fertilizer from urban garbage. Ground phosphate rock. Fertilizer nutrition survey. Nitrogenous and phosphatic nutrition for rapeseed and fertilizer application for high yield. Techniques of application, effectiveness and utilization of biogas fertilizers

9. "Acceleration in composting", Sichuan People's Publishing House (1956). "Methods of manufacture and use of granulated fertilizer", Sichuan People's Publishing House (1955). "Ammonia water and hydro carbonic acid", joint publication of Sichuan Province Agricultural Bureau, Fertilizer Division and Sichuan Province Agricultural Investment Corporation (1974). "Simplified method of measuring content of humic acid and carbonic acid in rational application of fertilizers for raising its effectiveness", Sichuan Provincial Information Centre for Chemical Industry Techniques (1976). "Anthology on means of production", *Research and Utilization of Biogas Fertilizer,* Sichuan Provincial Biogas Office (1979). "Severe toxic gas formation during decomposition process: examination of early signs", *Sichuan Agricultural Science and Technology,* No. 4 (1980)

10. Research Institute for Soil and Fertilizer, Academy of Agricultural Science, Chengdu City, Sichuan Province, China

103. Mr. XU Yi-Zhong

1. China
2. 15 October 1934

3. University graduate (biology)

4. Chinese

5. Present Engineer, Chengdu Biogas Scientific Research Institute, Sichuan
   July – August 1980 UNDP biogas consultant in the Philippines

6. Biology. Biogas digestion. Biogas fermentative bacteria

8. Some conclusions from biogas experiments (1974). Investigation of general conditions for use of biogas in the village in spring (1975). Experiments to strengthen management and increase the rate of biogas production (1975). Tests of rules for fermentation (1976). Relation between different siting of biogas plants and increase in production (1976). Experiments with production rates at various pressures (1977). Relations between different fermentation materials and fertilizers (1978). Research on absence of oxygen in the digester (1980). Use of pig manure (1980)

9. Eight articles on biogas published in Chinese biogas magazines

10. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture, Chengdu, Sichuan, China

104. Mr. XU Zeng-Fu

1. China 2. 1921

3. Fudan University, Shanghai (1946)

4. English, Japanese, Chinese

5. Present Vice-director, Zhejiang Biogas and Solar Energy Scientific Research Institute, Hangchow

6. Biogas technology and economy

7. Solar energy application

8. Biogas drying technique. New type of mesophillic biogas plant

9. *Biogas Technology*, to be published by United Nations University, Tokyo

10. Zhejiang Biogas and Solar Energy Scientific Research Institute, Hangchow City, China

105. Mr. ZHANG Chang-Ming

1. China 2. November 1936

3. Graduate, Sian Communication University (specialization in internal-combustion engines) (1961)

4. Chinese, English, Russian

5. 1961 to-date Technician, internal-combustion engine (1961-1965) and then Engineer, internal-combustion engine, Sichuan Province Agricultural Machinery Research and Design Institute

6. Biogas application for energy in agriculture

7. Gas engines. Diesel engines

8. Gas fuelled engine. Research and manufacture of S195 – small-scale model

10. Sichuan Province Agricultural Machinery and Design Institute (3rd Office), Sichuan, China

106. Mr. ZHANG Guo-Zheng

1. China 2. 10 March 1936

3. Graduate in biology, China South-west Normal College (1961)

4. Chinese, English

5. 1959 to-date Assistant in botany (1959-1962), Assistant in microbiology and Lecturer (1963-1980), Chief of Biogas Research Section (1974-1978) and then Head of Bio-energy Research Institute, China South-west Normal College

6. Specialist in microbiology and fermentation research

8. Research on mixture ratio among fermentation materials, fermentation conditions, fermentation bacteria, fermentation materials in the city and in the village. Scientific management of small digesters

9. Experiments with activities of micro-organisms. Research on ratio of feed materials for digester. Pretreatment of feed materials. Survey of biogas development inside and outside the country

10. China South-west Normal College, Biogas Bio-energy Research Institute, Xinan, China

107. Mr. ZHANG Wei

1. China 2. October 1922

3. Graduate, University of Chongqing, Department of Architectural Engineering

4. Chinese, English

5. 1952 to-date Architect, S.W. Institute of Building Design, Chengdu, Sichuan

   1979 Lecturer, Chengdu Biogas Seminar

   Participant in Bremen Biogas Workshop, 1979 and in Indo/Sino/German Joint Biogas Group

6. Architecture

7. Planning. Biogas (in co-operation with National Biogas Office)

8. Information and translation of materials concerning biogas study

9. "Construction of biogas digester in Sichuan, China", *Agricultural Waste*, November 1979 (in English)

10. S.W. Institute of Building Design, 168 Jin Hwa Street, Chengdu, Sichuan, China

108. Mr. ZHOU Meng-Jin

1. China 2. 25 February 1935

3. Graduate, Department of Biology, Beijing Teacher's College (1961)

4. Chinese, English

5. 1961 to-date Teacher, Department of Biology, Beijing Teacher's College

6. Microbiology

8. Pure cultural isolation of methanogenic bacteria. Study of kinetic of methane fermentation

10. Department of Biology, Beijing Teacher's College, Beijing, China

109. Mr. ZOU Yuang-Liang

1. China 2. August 1937

3. Graduate, Shandong University, Biology Department (specialization in microbiology) (1960)

4. Chinese, Russian

5. 1978 to-date Engineer, Deputy Chief, Biological Energy Office, Energy Research Institute, Shandong Academy of Sciences

   1966-1978 Chief, Chemistry Teaching Group, Shandong Special Teachers College

   1960-1966 Assistant Professor, Biology Faculty, Shandong University

6. Microbiology

7. General chemistry

8. Screening and breeding of anti-cancer antibiotics. Marine actinomyces. Breeding of actinomyces 2321 amino acidic nourishment defective type. Research on management of biogas plant through winter. Biogas seeding. Research on potential of digester materials for gas production and the optimum combination of materials.

10. Shandong Province Energy Resources Research Institute, Jinan City, Shandong Province, China

110. Mr. J.H. FINLAY

1. United Kingdom 2. 3 July 1938

3. C. Eng., MI Prod. E.

4. English

5. 1974 to-date Biogas Consultant, Development and Consulting Services, Butwal, Nepal

   1980 Consultant, compilation of UN ESCAP Guidebook on Biogas Development, 1980

6. Biogas plant design, Biogas appliances designs

7. Engineering

8. Design and construction of floating gas holder drum type gas plant, cu ft per day of 100, 200, 350 and 500; drumless gas plants of 10, 15, 20 and 50 m^3; gas production equipment; hard gobar mixer; 1300 mm water pressure gauge. (completed)

   Gas taps; tunnel plant; attaching small generator to biogas/diesel engine water pump for lighting 15 lamps in village. (ongoing)

   Gas lamp; large gas store; pressure regulator. (planned)

9. *

10. Development and Consulting Services, Butwal, Nepal

110(a). Mr. M. Sohail QURESHI

1. Pakistan 2. 16 September 1934

3. B.Sc. (Hons.) (Punjab), B.Sc. (Non-med) (Punjab), M.Sc. (Chemical Engineering) (Birmingham), M.Sc. (Hons.) (Punjab)

4. English, Urdu, Punjabi

5. 1978 to-date Director-General (Energy Resources), Ministry of Petroleum and Natural Resources, Government of Pakistan

   1973-1978 Principal Officer to Vice-Chairman, BIM & State Petroleum Board

   1973-1976 Chief, in charge of Economic Wing in the Prime Minister's Secretariat

6. Chemical engineering. Petroleum refinery. Development and management of energy resources

7. Marketing development. Management development

8. Installation 100 family biogas units for demonstration. Rural energy project. Rural electrification project. Solar energy development project. Conservation of energy. Biogas development project (1,200 biogas plants)

10. Energy Resources Cell, Ministry of Petroleum and Natural Resources, Government of Pakistan, Islamabad, Pakistan

110(b). Mr. P. RAJABAPAIAH

1. India

3. B.Tech. (Chemical Engineering). At present doing research for the doctoral degree in the biogas field.

4. English, Telugu, Hindi, Kannada

5. 1978 to-date Staff Member and Investigator, project on further studies in biogas technology, ASTRA (Centre for the Application of Science and Technology to the Rural Areas), Indian Institute of Science, Bangalore

   Worked for two years in the research project on development of biogas technology and five years in small-scale chemical industries in Andhra Pradesh, India

6. Chemical engineering. At present specializing in the biogas fields such as process, production, construction, utilization (burners, lamps, engines and electricity generation), environmental improvement etc.

7. Interested in the treatment of wastes such as sewage wastes, alternative energies such alcohol, solar and wind energies; low-cost appropriate technologies for the rural development of India

8. Studies in biogas technology: performance of the conventional Indian biogas plant; optimization of plant dimensions; thermal analysis of biogas plants and innovation of a novel solar-heated biogas plant (completed).

   Further studies in biogas technology (improvement of the solar-heated biogas plant, gas production from alternative materials for dung such as water hyacinth, recycling of water in biogas plants etc.); community biogas systems for villages (production and distribution of biogas, viz. fertilizer and water including hot water, electricity generation and small-scale industries using biogas as energy source); design and construction of ultra low-cost rural-oriented biogas plants (modified Indian and Chinese biogas plants) (ongoing).

   Modelling of lowest biogas reactors (continuous, semi-continuous and batch reactors using all materials available in rural areas such as animal, human and agricultural wastes as well as industrial wastes such as from the sugar factories, fermentative industries and sewage wastes); low-cost biogas appliances (burners, lamps, engines etc) (planned).

9. *

10. ASTRA (Centre for the Application for Science and Technology to the Rural Areas), Indian Institute of Science, Bangalore 560 012, India

110(c). Mr. TIAN Feng

1. China 2. February 1927

3. Graduate, Nan Jing University (formerly Zhong Yang University), Foreign Languages Faculty (Russian)

4. Can read reference materials in Japanese and English

5. 1980 to-date Director, Sichuan Province Biogas Office

   May 1980 Director, Joint FAO-China study group on biogas technology

   February 1979 In charge, Sichuan Province Biogas Office

August 1974 Supervising design and operation of biogas plant, Sichuan Province Biogas Office

6. Administration of biogas extension work

7. Research on biogas plant design and operation

9. "Construction of biogas plants", *Rural Biogas: Questions and Answers.* Sichuan People's Publishing House, Agricultural Publications, 1979. pp. 4-50.

   "Popularization of biogas plant construction with common materials", *Biogas,* Vol.III:23-25. Science and Technology Documentation Publishing House, Chong qing Branch.

   "Greater efforts for biogas", *Farming Techniques,* 20 July, 24 July, 27 July, 31 July, 3 August, 7 August, 10 August, 1980.

   "Biogas and its utilization". A statement at UNIDO discussion group on large-scale biogas, Beijing, July 1980.

10. Sichuan Province Biogas Office, Chengdu, Sichuan Province, China

110(d). Mr. B.V. UMESH

1. India 2. 22 Feburary 1955

3. English, Tamil, Kannada

4. Post-graduate in chemical engineering, University of Madras (1979)

5. 1979 to-date Shri A.M.M. Murugappa Chettiar Research Centre, Madras

6. Low-cost designs for construction of biogas plants with major emphasis on utilizing the locally available materials and skills. Studies on anaerobic digestion of water-hyacinth without the loss of protein value

7. Mass culture of algae for food and feed purposes. Construction of solar cookers and dryers. Comfort conditioning by dehumidification process.

8. Implementation of biogas plants of the Centre's latest design. Performance data regarding gas production, life of the plant, use of the gas in diesel engines. Further studies in making a low-cost digester.

10. Shri A.M.M. Murugappa Chettiar Research Centre, Photosynthesis and Energy Division, Tharamani, Madras 600 042, India

111. Bangladesh Agricultural University

I

1. Mymensingh, Bangladesh
   Tel: PBK-2191-93
   Cable: AGRIVARSITY
2. 1961
3. Vice-chancellor
4. Dr. M. Yusuf Chowdhury, Associate Professor and Head, Department of Agricultural Chemistry
5. (b) 6/5
8. Teaching, research and extension of biogas in the rural areas.

II

A.

1. (a) fixed
   (b) movable
2. 2-8 m^3
3. (a) bricks, cement sand and gravel
   (b) M.S. sheet
   (c) M.S. pipe, bricks, cement, sand and gravel
   (d) pipe, bricks, cement, sand and gravel

B.

1. (a) continuous
   (b) batch
2. Cow dung
3. Frequently lime is added to control pH.
4. 40-50 kg
5. 40-55 kg every 2-5 days
6. Almost 1:1 (green weight)

C.

1. (a) 6-9 m^3
   (b) domestic and laboratory
2. (a) 30-50 kg/day

D.

1. $US 500-700 depending on the size and design
2. (a) summer 35°C
   (b) winter 10°C

3. (a) shadow
   (b) sun
4. None
5. Investigation is going on to optimize cost and efficiency of biogas plants of different designs for the farmers.
6. Almost all of the biogas plants for the purpose of investigation are in operation. Those constructed for the farmers are not in constant use due to scarcity of cow dung resulting from low cattle population during certain time of the year.
7. A survey on cattle population among the farmers in neighbouring areas is being undertaken.

112. Bangladesh Council of Scientific and Industrial Research, Institute of Fuel Research and Development

I

1. Dacca, Bangladesh
   Tel: 315116–19/246
   Cable: CONSEARCH
2. 1976
3. Dr. M. Eusuf, Project Director
4. 4
5. (a) 2
   (b) 4/3
8. Research and development work on fuel, energy and allied subjects
9. Fuel, energy and allied subjects
10. Dissemination and demonstration of new technology developed through research
11. Training towards M. Phil and Ph.D. is provided.
12. Over 50 publications on fuel, energy and allied subjects; three publications on biogas and six other are under preparation.
13. Gas yield from cow dung under various conditions. Plant studies utilizing cow dung. Gas yeild from water hyacinth. (completed)

    Increasing gas yield. Reduction in seasonal variation in gas yeild. Cost reduction alternatives. Slurry making from agricultural wastes. Development of cost burners and lamps. (ongoing)

    Identification and isolation of active methanogenic bacteria and studies on their performances. Biogas-based integrated farming systems. (planned)

II

A.

1. (a) fixed (one)
   (b) movable (three)
2. 220 cu ft (each)
3. (a) brick, cement and sand
   (b) mild steel for movable and reinforced concrete for fixed holder
   (c) and (d) RCC pipe

B.

1. (a) continuous
2. Cow dung
3. Mixing with water
4. 58 kg
6. 1:1

C.

1. (a) varies from 50 cu ft in winter to 90 cu ft in summer
   (b) laboratory, cooking and experimental study

D.

1. $US 650
2. (a) summer 30.4°C (fortnightly average)
   (b) winter 16.6°C (fortnightly average)
5. Leakage in fixed holder
6. 75 per cent
7. Further work on fixed gas holder to make it leak-proof needed

113. Artificial Biogas Experimental Station, Nanhui County

I

1. The County Town of Nanhui County, Shanghai, China
   Tel: 987660
2. 1977
3. Mr. Gu Ming-Long
4. 3
5. (a) 10
   (b) 40/35
6. The County Town of Nanhui County, Shanghai, China

7. The Shanghai Research Institute of Industrial Microbiology. The Shanghai Research Institute of Plastics. The Shanghai Research Institute of Diesel Engine

8. Research and experiment on biogas production

9. Designs four types of biogas digester. Experiments for fermentation. Study on unloading the residue mechanically from the digester. Experiment in manure. Better biogas power generation. Experiment on solar energy.

10. Stress on improving the technology of household biogas digesters and small-sized biogas power stations in rural areas. Experiments on methane production from municipal wastes.

12. *Research for Biogas Production in Nanhui County, Shanghai,* China Issue No. 1 and No. 2. In these two issues some major articles are: "Effect of some additives on the rate of decomposition in biogas fermentation". "Effect of pressure and stirring on giogas productivity under ambient temperature". "Exploration of biogas productivity from conventional materials in the rural area of Shanghai suburbs". "Biogas fertilizer and experiment on its effect".

13. Household biogas digester of spherical type in rural areas. Biogas digester with a movable floating cover. Utilization of wastes from a pharmaceutical factory to produce biogas. Research on additives for biogas production. (completed)

    Research on a 56 m^3 mesophilic ground biogas digester. Continuous improvement in the property of the biogas digester sealed airtight. Experiment on fertilizer effect of the fermented waste. Research on a biogas digester on integral fermentation. (ongoing)

    Two-phase fermentation method. Experiment on different kinds of concentration of the material fed into the digester. Research on the ratio of carbon to nitrogen to the digester. (planned)

II

A.

1. (a) fixed
   (b) movable
2. 8 m^3, 56 m^3, 200 m^3 etc.
3. (a) concrete, brick vault, soil mixed with lime
   (b) concrete, brick vault, steel plate
   (c) concrete, steel tube
   (d) concrete, brick wall

B.

1. (a) continuous
   (b) batch
2. Animal wastes, stalks, weeds etc.
3. First cutting stalk into pieces then making compost

4. For a 8 m^3 digester feeding 10 kg a day
5. For a 56 m^3 digester feeding 5 tons a week, i.e. 5,000 kg per week, every seven days
6. About 80 per cent

C.

1. (a) for a 8 m^3 digester 1.6 m^3 gas being produced each day
   (b) for daily use and to generate electricity
2. When crops in the field need fertilizer to be applied, the residue in the digester has to be discharged. Generally speaking, farmers carry the fertilizer into the fields on a large-scale three times a year.

D.

1. About $US80 (8 m^3 digester)
2. (a) summer 27°C
   (b) winter 4° – 5°C
3. (a) shadow
   (b) sun
4. Through solar energy
5. Leaks sometimes occur; but the digester can still be used by fixing and maintaining it.
6. 87 per cent
7. Summing up and interchange of experiences once a year

114. Beijing Academy of Agricultural Science, Research Institute for Soil and Fertilizer

I

1. Ban Jin Cun, Beijing, China
   Tel: Beijing 811431-38
2. 1978
3. Mr. Hu Li-Na
4. Mr. Zhang Chun-Mei, Mr. Yuang Qing-Liang, Mr. Jiang Xiao-Xu
5. (a) 7
6. Laboratory within the organization. Experimental pond at Beijing village centre.
7. Part of National Biogas Science and Research Co-ordination Group. One of the units responsible for research on special problems of biogas fertilizer
8. At present, mainly, research on biogas fermentation techniques and use of biogas fertilizer
9. Biogas fermentation techniques. Biogas fertilizer application techniques

10. Practical application of biogas in Beijing suburban district. Research on crucial technical problems and consultancy service
11. Annual biogas training courses in the area. Responsibility for important lectures.
12. Internal materials; not formally published.
13. Beijing suburb farmer household – fuel biogas experimental station (elementary engineering design, basic fermentation technique, hygiene design for comprehensive technical innovation). Research on organic fertilizer stored up in biogas plant, important changes in its effectiveness, composition and growth. (completed)

    Research on the efficiency as fertilizer of biogas fermentation remainder and its use in soil improvement (ongoing)

    Research for fermentation at normal temperature to increase the rate of biogas production. (planned)

II

A.

1. (a) fixed
2. 10 or 100 m^3
3. Cement mixed with congealed mud or brick arch, mortar
   (a) cylindrical or circular
   (b) hydraulic type
   (c) slanting type
   (d) outlet at middle layer inverted pipe and hydraulic type or vertical shaft hydraulic pressure type

B.

1. (a) continuous
   (b) batch
2. Wheat straw, corn straw; pig, human and ox waste
3. Barnyard straw and waste materials mixed or barnyard straw wetted with biogas fermented liquor
4. Because of variations in season and in materials, research on appropriate volume under way
5. As above
6. 8 per cent

C.

1. (a) because of the changes in the seasons, variety of feed materials and differences in their volume, the volume at ordinary temperature can reach 0.8 m^3 but, in general, 0.1 m^3 to 0.3 m^3
   (b) directly, as fuel for daily life; research under way for its use as power

2. (a) about 30,000 kg/hectare
   (b) mostly, for demonstration, no regular quantity
   (d) to be used for straw digestion
3. For the middle level effluent, no need of hygienic treatment. Addition of liquid ammonia is recommended for sedimentary dregs; however, in many cases, this is not compiled with.

D.

1. About $US 50
2. (a) summer 36°C
   (b) winter −16°C
3. (a) shadow
4. At present, the methods being popularized do not heat the digester. Research is being undertaken on the use of solar energy and heat preservation in winter.
5. (i) After a few years of use the plant made in part of mortar develops cracks in the vault and the gas leaks due to the following reasons: late feeding at materials, no cover and effect of severe drought.
   (ii) At many plants, the mixers cannot stir after the start of fermentation.
6. If there is a systematic way and there are men specific for the operations, more than 90 per cent in the rate of utilization can be reached.
7. (i) As set out by the realities of farm practices in China and as testified by the experience already gained, among the most important in the management of biogas is the synthesizing of its utilization. The most required is paying special and simultaneous attention to fertilizers and energy sources. Otherwise biogas energy cannot take firm root or develop.
   (ii) To be assured of the technique and its reliability it is required that the design be standardized, spare parts be supplied from stock and commercialized, and installation be specialized.

115. Chengdu Biogas Research Institute

I

1. Ministry of Agriculture, Chengdu, Sichuan, China
   Tel: 7737 Telex: 3049
2. 1978
3. Mr. Zheng Shou-Zhou
5. (a) 40
   (b) 19/17
6. Chengdu
7. State and provincial biogas offices. Related research institutes

8. Biogas research

12. Drawings – small rural digesters construction

13. 17 (completed), 2 (ongoing), 36 (planned)

II

A.

1. (a) fixed
   (b) movable
2. 6–300 m^3
3. (a) concrete, masonry, lime-clay
   (b) fixed, bamboo-cement
   (c) and (d) cement, concrete

B.

1. (a) continuous

C.

1. (a) 0.15 – 0.3 m^3
   (b) domestic use; power

D.

1. $US 20-40 (materials cost) (for 10 m^3)
2. (a) summer 26°C
   (b) winter 12°C
3. (a) shadow
   (b) sun
4. Common method. Heated to 35°C. Mixed
5. Leakage
6. 98 per cent

116. Chengdu Biogas Scientific Research Institute, Ministry of Agriculture

I

1. Ren Min Nan Lu, Chengdu City, Sichuan, China
   Tel: 7737 Cable: 3049
2. 1978
3. Mr. Xue Bin-Kui, Director
4. Mr. Zheng Shou-Zhu, Mr. Zhang Geng-Xin, Deputy Directors

5. (a) 42
   (b) In Sichuan Province, over 4 million, of which more than 70 per cent are in operation
6. At Ren Min Nan Lu, Chengdu City
7. With digester construction throughout the country. Two assistance groups for biogas fermentation
8. Specialized research institute for biogas scientific research
9. Scientific research on digester construction, biogas fermentation, all-purpose agricultural machinery. Information on means of production.
10. Priority to biogas research. Technical series. Specialized supplementary instruction on techniques
11. Within the country four times, to more than 120 persons. Twice for the United Nations, to more than 40 persons
12. Biogas, fourth issue, 1980. *Biogas Scientific Technique*, first issue, 1981
13. Medium and small scale biogas plants for farm households. Medium-sized biogas plants in Sichuan Province. A popular handbook on biogas fermentation: relationship between pressure and biogas production. (completed)

    Collection of standard diagrams for medium-sized biogas plants for farm households in the whole country. Technological process and techniques for medium-temperature fermentation with large and medium scale horizontal type digester. (ongoing)

    Experiments on potential digester materials. Survey of experimental norms. (planned)

II

A.

1. (a) fixed
   (b) movable
2. 6, 8, 10 m^3
3. Concrete, standard brick
   (a) about 80 per cent capacity (height/diameter 1/2.5)
   (b) 20 per cent gas holder (height/diameter 1/5.5)
   (c) straight pipe with the dipperinserted type (25 cm diameter)
   (d) straight pipe with hydraulic-pressure operated opening (with a volume at 1/10 of the volume of the digester)

B.

1. (a) continuous
   (b) batch
2. Stems; pig, ox, human waste; partly wheat straw
3. Stems and waste, made into wet compost

4. 20 kg
5. 300-500 kg two times a year
6. Fresh waste, human to pig 1:1

C.

1. (a) at ordinary temperature: 0.2 m^3/1 m^3 liquid feed; at medium temperature: 1.0 m^3 / 1 m^3 liquid feed
   (b) small plants: lighting, cooking; medium and big plants: electricity generation and processing
2. (a) direct fertilizer on soil
   (b) composting
   (c) aquaculture
3. To the sediments and dross add ammonia water or ground phosphate rock etc. After composting, use as field manure

D.

1. $US 30-40 (exclusive of wage payment to about 30 workers)
2. (a) summer 23-27°C
   (b) winter 7° – 5°C
3. (a) shadow
   (b) sun
4. Additional heating by steam, hot water, solar energy, waste heat from electrical machinery
5. Gas leakage. At present studying the use of coating. More closely knitting the gas holder. Feed decomposition rate rather low; presently improving the design of digester.
6. 60–94 per cent (in Sichuan)
7. Interchange of detailed information on construction, meetings for interchange of positive results. Area-wise co-operative working groups for construction, design of new types of digesters. A proposal for the establishment of a co-operative experimental station in Thailand for comparative experiments and conclusions with regard to the Indian and the Chinese small type digesters.

117. Chengdu Biological Research Institute, Chinese Academy of Sciences

I

1. Chengdu City, Sichuan Province, China
   Tel: 7080 Cable: 0406
2. 1958
3. Mr. Deng Guo-Biao

4. Mr. Hou Yong-Sheng
5. (a) 105
   (b) 10
6. At the Institute
8. Botany. Zoology. Microbiology etc.
9. Theory and application
10. Extension of successful results of scientific research
13. Research on biogas fermentation techniques in villages in China. Research on bacteria production for village biogas plants. (completed)

    Research on fermentation techniques in villages in China. Research on microbiological biogas fermentation. (ongoing)

II

A.
1. (a) fixed
2. 27 – 6 m^3
3. (a) (b) (c) and (d) brick and cement

B.
1. (a) continuous
2. Human and animal wastes. Stems
3. Management of wet compost

C.
1. (a) 0.2 – 0.5 m^3

D.
2. (a) summer 24° – 28°C
   (b) winter 8° – 16°C
3. (b) sun
4. Materials which will add heat. Preserving the heat of haystack. Construction of biogas plant facing the sun and out of the wind

118. Chengdu Institute of Biology, Chinese Academy of Sciences

I

1. Chengdu, Sichuan, China
   Tel: 7080 Cable: 0416
2. 1958
3. Mr. Deng Guo-Biao
4. Mr. Hou Yong-Sheng

5. (a) 103
   (b) 10
6. Chengdu, Sichuan
8. Research and application
9. Animal, plant and microbiology

II

A.
   1. (a) fixed
      (b) movable
   2. 2 – 3.3 m^3
   3. (a) (b) (c) and (d) brick

B.
   1. (a) continuous
      (b) batch
   2. Manure and straw
   3. Pretreatment

C.
   1. (a) 0.2 – 0.4 m^3

D.
   2. (a) summer 33°C
      (b) winter –2°C
   3. (b) sun

119. China Research and Designing Institute of Agricultural Engineering

I

1. Beijing, China
   Tel: 594961
2. 1978
3. Mr. Tao Ding-Lai
4. Mr. Zhang Ji-Gao
5. (a) 50
6. Beijing
7. Farm mechanization. Utilization of plasma as arc heat source
8. Research, designing and installation of large and medium sized biogas plants
9. Biogas engineering, design and servicing

10. Biogas servicing team inside and outside the country
11. Training courses on biogas plants at ordinary temperature
12. On Chinese agricultural engineering
13. Research, designing and installation of medium tempeature biogas plants. Designing of biogas plants at Beijing ordinary temperature. (ongoing)

II

A.

1. (a) fixed
2. 100 m^3, 10 m^3
3. Brick, cement

B.

1. (a) continuous
2. Barnyard straw, waste
4. Depends on the volume, which is not uniform
6. 6 per cent

C.

1. (a) 10 m^3 (small pond at normal temperature)
   (b) cooking, lighting

D.

2. (a) summer 35°C
   (b) winter −20°C
3. (b) sun
4. Gas, solar energy, heat left from the generator
5. (i) in the north, during winter the raising of temperature and heat preservation;
   (ii) sealing up of the materials

120. Chongqing Teachers Training College

I

1. Sha Ping Ba, Chongqing, Sichuan, China
   Tel: 61275
2. 1954
3. Mr. Wang Hou-Fu
4. Mr. Jiang Dai; Mr. Lui Ping-Zhi
5. (b) 2,000

6. Sha Ping Ba, Chongqing
7. National Co-ordination Group for Biogas Research
8. Academic institution
9. Teaching. Research
10. For the villages
11. For the administrative division and the communes in it
12. On use of water hyacinth and green grass for fermentation; application to cellulose of peptone and acetaldehyde and its influence on formation of methane
13. Laser induced mixing of bacteria at low temperature biogas plant. Experiment with putting in bacteria. Addition of formaldehyde, acetone acid to raise the effect of the rate of gas production. Application to cellulose of peptone and acetaldehyde and its influence on methane formation. (completed)

    Research on potentiality of water hyacinth producing biogas and on methods of introducing feed materials. Comparison of results of single stage and multi-stage fermentation with respect to biogas production. Separate appraisal of methane bacteria. (ongoing)

II

A.

2. 0.25 m^3
3. Brick
   (c) direct pipe
   (d) valve switch

B.

1. (a) continuous
   (b) batch
2. Water hyacinth often used. Pig and ox manure
3. 2 per cent limewash to the cellulose nature of the wet compost in the digester
4. 4 kg
6. 50 – 88 per cent

C.

1. (a) 287 litre/day
   (b) laboratory lighting; boiling and developing culture medium; cooking

D.

3. (b) sun
5. In two experimental plants the movable cover leaked gas because of lack of adhesiveness of the mud plaster. After it was pasted with cement, the leak stopped at once

6. Nearly 100 per cent
7. (i) select a good foundation for the gas holder;
   (ii) for the construction site to preserve the quality of materials, it is important that it conforms to the norm – no leakage of water or gas;
   (iii) the digester feed should be adequate;
   (iv) strengthen management;
   (v) practicable economic policy regarding biogas

121. Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences

I

1. 81 Martyrs' Road, C.P.O. Box 1254, Guangzhou, China
   Tel: 76042 Cable: 0508
2. September 1978
3. Dr. Wu Wen, Director
4. Mr. Kuang Zhe-min, Deputy Director Mr. Chen Ru-Chen, Head of Biomass Division
5. (a) 90
6. Foshan Biogas Pilot Power Plant; Xinfu Production Brigade (experimental spot) etc.
7. National Leading Group of Biogas Utilization; United Nations University etc.
8. Research and development on renewable energy conversion
9. Biomass, geothermal, solar, ocean wind energy. Energy storage and conservation.
10. Resources and development
11. Short courses for biomass and solar energy conversion techniques
12. "Renewable Energy Conversion" Prompt reports on energy
13. Foshan biogas pilot power plant and rural family digesters. Hainan solar-distill site. (completed)

    Renewable energy village from biogas and solar energy. Hainan solar dryer for rubber production. (ongoing)

    Slaughterhouse heating from biogas and solar energy. Solar-heated swimming pool. Solar refrigerator. (planned)

II

A.

1. (a) fixed (family digesters)
   (b) movable (power plant)

2. 4-10 m^3 (family digesters)
   47 m^3 x 28 = 1316 m^3 (power plant)
3. (a) brick and cement
   (b) PVC film (power plant)
   (c) and (d) brick and cement

B.

1. Semi-continuous
2. Night-soil (family digesters) Pigsty waste and waste water (power plant)
4. 50 kg (family digesters) 60,000 kg (including water) (power plant)

C.

1. (a) 1–1.2 m^3 (family digesters) 363 m^3 (power plant)
   (b) cooking and lighting (family digesters). Power generation (power plant)
2. (a) 50 kg/day (family digesters) 60,000 kg/day (power plant)
3. Germ and parasite egg killing by heating in the digesters up to 50°C or higher

D.

1. Family digesters: $US 30–50 (purchased material). Power plant: $US 200,000 (estimated)
2. (a) summer 26-27°C
   (b) winter 12-13°C
3. (a) shadow (family digesters)
   (b) sun (power plant)
5. Family digesters: Low gas production rate with sludge and scum accumulating (also in power plant). Power plant: Acidic gas corrosion after H_2S ignited through engine. To be solved by injection stirring of sludge and scum and gas purification by desulfurization
6. Around 93 per cent
7. The only economically available way for stirring sludge and scum in family digesters is to re-inject supernatant from the digester back through the inlet pipe with agricultural artificial shower plus a plastic or rubber tube attached to its spray nozzle

122. Hangzhou City Biogas Extension Office

I

1. Yuan Sha Lu, Hangzhou, China
   Tel: 26828
2. 1976
3. Mr. Zhang Jia-Zhi

4. Mr. Cai Chang-Da, Mr. Zhan Ju-Xian, Mr. Zhu Cai-Fu, Mr. Xu Shun-Cai, Mr. Huang Shu-Nan
5. (b) 59744/51193
8. Consultancy. Training of technicians
9. Biogas extension work in Hangzhou City suburb, village and the eight countries allied to it
10. Design and construction of biogas plants in villages
11. In construction of biogas plants and management of technicians
12. Technical materials
13. Design and construction of household biogas plants with movable type gas holders. Constructional technique improvements in the moulding and hauling of biogas plants. (completed)

Synthesised use of biogas plant fermentation residue. Experimentation on fertilizer efficiency of fermentation remainder. (ongoing)

Research on coating to seal up biogas plant (planned)

II

A.

2. 6–10 m^3
3. Reinforced concrete materials

B.

1. (a) continuous
   (b) batch
2. Human, pig, sheep and ox waste; green grass; rice and wheat straw
3. Rice straw and grass cut to pieces and wet-composted for ten to fifteen days, then mixed with human and animal waste to make feed material
4. 20 kg (pig waste)
5. Animal waste padded wity straw, 250 kg once in 15 days
6. 1:1 (new waste to water)

C.

1. (a) 1.5 m^3/day
   (b) cooking and lighting
2. (a) 40 kg/day (8 m^3 biogas plant)
   (e) at present, at the experimental stage
   (f) rearing earthworm
   (g) cultivation of mushrooms
3. At the time of over-all change of feed materials, clear the sediments. For every 100 kg and 2 grams of dipterex for killing insect eggs. Wet-compost should be used only after being stirred for 24 hours

D.

1. $US 40 (8 m^3)
2. Monthly average:
   (a) summer 28°C
   (b) winter 8°C
5. Where the gas holder part is not tightly sealed there is seepage, overcome at once by plastering afresh or by pasting up by a coasting paint
6. 85 per cent

123. Institute of Microbiology, Chinese Academy of Sciences

I

1. Zhongguancum, Beijing, China
2. 1959
3. Mr. Xue Yue-Gu
4. (a) 230
8. Research work
9. Research taxonomy, physiology, biochemistry, economy, cytology and genetics of microbiology.

124. Jiangsu Province Wujin Biogas Research Institute

I

1. Ben Niu Zhen, Wujin County, Jiangsu Province, China
   Tel: 265
2. 1978
3. Mr. Zhu Bin
4. Mr. Shen Jie-Sheng, Mr. Gao Ya-Ping
5. (a) 18
   (b) 11/9
7. Electric Construction Institute, Ministry of Electric Power. Guangzhou Energy Resources Institute. Nanjing Soil Institute, Academy of Sciences. Jiangsu Province Agricultural Science Institute. Sichuan Agricultural Machinery Institute
8. Scientific research on biogas application
9. Jiangsu Province
10. For the villages, to provide farmers with new types of biogas plants, new designs and fermentation techniques

13. Research on techniques of utilizing biogas in manufacturing CCl_4. Research on oil gas for dynamo battery. (completed)

Designing of modernized biogas plants for villages. Research and manufacture of biogas fired dynamo battery. Research on improving the effects of fermentation materials. Research on techniques of raising the rate of biogas production. (on-going)

II

A.

1. (a) fixed
2. 8, 10, 12 m^3
3. (a) (b) (c) and (d) cement and brick

B.

1. (a) continuous
2. Human, animal wastes. Stems of crops
3. Wet-composting of stems of crops, before feeding
4. 50 kg
6. 1:7

C.

1. (a) 0.15 – 0.2 m^3
   (b) in households, as fuel; big plants' gas used for lighting
2. (a) about 80 per cent
   (b) about 15 per cent
   (g) a small amount for cultivation mushrooms
3. Apply ammonium bicarbonate to the wet compost

D.

2. (a) summer 28° –30° C
   (b) winter 10° C
3. (a) shadow

125. The Office of National Leading Group for Biogas Development Ministry of Agriculture

I

1. Ministry of Agriculture, Beijing, China
   Tel: 463652
2. 1976
3. Mr. Zhang Chen-Yao, Director

7. All related biogas offices and research institutes
8. Administration and management

126. Research Institute for Soil and Fertilizer, Academy of Agricultural Science

I

1. Chengdu, Sichuar China
   Tel: 7761 Cable: 2814
2. 1949
3. Mr. Zhou Jing-Ying, Director
4. Mr. Chu Ti-Yun, Mr. Liao Si-Zhang, Deputy Directors
5. (a) 8 (biogas fertilizer)
6. At the Institute, at Congqing County and at Ren Shou County Village Centre (concerning biogas fertilizer)
7. Sichuan Provincial Biogas Extension Office. Biogas extension offices at Chongqing County and Ren Shou County
8. Experiment. Demonstration.
9. Co-ordination of biogas extension work in the province. Launching of biogas fertilizer and development of its effectiveness. Research on its application techniques and concerned consultancy work
11. Jointly with the United Nations and at province and county level
12. "Experiments on effectiveness of biogas fertilizers", *Soil and Fertilizer Science,* 3rd issue, 1975. "Biogas application and research", *Biogas,* Chongging Branch of the Scientific and Technological Information Institute of China, 3rd monthly issue, 1979. "Examination of biogas fertilizer effectiveness", *Journal of Soil,* 2nd issue, 1979.
13. Effectiveness of biogas fertilizer (completed)
    Biogas fertilizer application techniques (ongoing)
    Establishment of a system to give priority to organic fertilizer (planned)

127. Shandong Province Energy Resource Research Institute

I

1. Jinan City, Shandong Province, China
   Tel: 43449
2. 1979
3. Mr. Dong Xian-Jun, Deputy Director

4. Mr. Zou Yuan-Liang, Deputy Chief, Biological Energy Research Group
5. (a) 5
   (b) 41/41
6. Jinan City
7. Guangzhou Energy, Source Research Institute, Chinese Academy of Sciences. Chengdu Biogas Research Institute, Ministry of Agriculture.
8. Scientific research
9. Research and utilization of new energy sources
13. Research on m_nagement of biogas plant through winter. (completed)

    Breeding of fermentation seeding. Research on the potential of feed materials for optimum gas production. (ongoing)

    Research on household biogas plants. (planned)

II

A. Underground. Hydraulic pressure type. Stone plate structure.

1. (a) fixed
2. 2 m^3
3. Stone plate and some cement

B.

1. (b) batch
2. Wheat straw. Human, pig manure
3. After mixing, pilling up and soaking for 9 days at 10° –20° C
5. 1350 kg. every 170-180 days (nearly every half-year change of feed once; 90 per cent change and the rest for seeding)
6. Strictly maintain solid content density with water at 10 per cent

C.

1. (a) winter: 0.6 m^3/day
   summer: 1.5 m^3/day
   (b) fuel
2. (a) on an average, 7 kg/day

D.

1. $US 30
2. (a) summer 25°C
   (b) winter 10°C
3. (b) sun
6. 100 per cent

128. Shanghai Institute of Industrial Microbiology

I

1. Shanghai, China
   Tel: 565411
2. 1966
3. Mr. Shen Tien-yi
4. Mr. Tao Yi-Wen, Mr. Ru Zhung-Wei
8. Industrial fermentation
9. Research assignments by the ministry, bureau and departments
10. Research and development
13. Amino acid, organic acid, fermentation. Research on enzymes. Comprehensive research on anti-mildew formation industry and in biogas.

II

A.
   1. (a) Fixed
   2. 56 m^3
   3. (a) steel reinforced cement
      (b) materials reinforced by steel and retempered
      (c) and (d) brick and cement

B.
   1. (b) batch
   2. Pig, ox waste
   5. 6000 kg. every seven days

C.
   1. (a) 20 – 30 m^3
      (b) lighting

129. Shanghai Science and Technology Association

I

1. 47 Nan Zhong Road, Shanghai China
2. 1958
3. Mr. Jiang Zheng-Fan
5. (a) 230

II

A.

1. (a) fixed
   (b) movable
2. 4.5 – 129 m^3
3. (a) concrete
   (b) steel, ferrocement, porcelain

B.

1. (a) continuous
   (b) batch
2. Human and animal waste; crops

C.

1 (a) 0.25 – 0.8 m^3
   (b) domestic use, sewerage treatment

D.

1. US$ 70-1000
2. (a) summer 26°C
   (b) winter 13°C
3. (a) shadow
   (b) sun
4. Heating from generators (using steam)

130. Xinan Teachers College, Biogas Research Institute

I

1. Xinan, China
3. Mr. Zhang Guo-Zheng, Head
5. (a) 4
   (b) 16
8. Research, experiment and extension
9. Research office and agricultural production experimental station
10. Extension of small-scale rural biogas plants, provision of research data for use and demonstration of ways of increasing biogas production
11. Can provide training courses and lectures
13. Experiments: on biogas fermentation conditions; with sieving of activated mud before its insertion in the biogas plant; on additions to raise the rate of biogas

production. Communications on experiments with the rate of utilization of biogas feed materials. (completed)

Research on: increasing the rate of production of small rural biogas plants; on gas production potential of all kinds of organic materials; on bacteria decomposition. (ongoing)

131. Zhejiang Agricultural University, Laboratory of Soil Microbiology

I

1. Hangzhou, Zhejiang, China
4. Prof. Tse Shu-Chien, Head, Department of Soil and Agricultural Chemistry

II

A.

1. (a) fixed
   (b) movable
2. 8–10 m^3
3. All concrete

B.

1. (b) batch
2. Stable manure and nightsoil
5. 3,500 kg every 180 days
6. 1:1 (about 90 per cent water content)

C.

1. (a) 1.6 m^3/day
   (b) as fuel
2. (a) direct fertilizer on soil

D.

1. $US 30–40
2. (a) summer 30°C
   (b) winter 10°C
3. (a) shadow
6. 80 per cent (in Chekiang province)

132. Zhejiang Biogas and Solar Energy Scientific Research Institute

I

1. Hangchow, China
   Tel: 2291 Ext. 459
2. 1980
3. Mr. Mie Wen-Hai (Director, Zhejiang Biogas Development Office)
4. Mr. Xu Zeng-Fu, Vice-Director
5. (a) 40
   (b) 364900/32500
6. Zhejiang Province
7. United Nations University, Use and Management of Natural Resources Programme Office
8. Research and Development
9. Information. Research. Training
11. Biogas technique training
12. Biogas, Zhejiang Press and Publishing Commission. Biogas Technology, United Nations University.
13. Biogas drying technique of crops. New type of mesophilic biogas plant

II

A.

1. (a) fixed
   (b) movable and separated
2. 8–10 m^3
3. (a) and (b) brick and cement or lime-clay with soil
   (c) and (d) cement tube

B.

1. (b) batch
2. Swine, human feces
3. Feed material pretreatment in various ways such as composting etc.
4. The amount of raw material added and fermentation circle greatly vary.
5. Every 40 days
6. 1:9

C.

1. (a) 0.15 – 0.3 m^3
   (b) cooking; power for fabricating agriculture products; generating electricity for lighting

D.

1. $US 35–40
2. (a) summer 35° – 39°C
   (b) winter 0° – 5°C
3. (a) shadow
   (b) sun
4. Solar energy. The vast heat from dual-fuel engine
5. There is more attention paid to digester building, but less to management. A lot of digesters do not yield sufficient gas. Scientific research also has not been followed up.
6. 88 per cent

133. University of the South Pacific, Institute of Natural Resources

I

1. P.O. Box 1168, Suva, Fiji
   Tel: Suva 313900
   Cable: UNIVERSITY SUVA
   Telex: FJ 2276
2. 1969
3. Vice-Chancellor
4. Dr. Richard K. Solly
5. (a) approx. 48 (whole University)
   (b) 17 (all-Fiji)
6. University is adjacent to rural areas
7. Associated with University campuses in 11 South Pacific countries and respective Departments of Agriculture
8. Development of biogas technology
9. Laboratory and field investigation of biogas systems
10. Information Research and development. Advisory. Consultancy. Education. Training. Problem solving.
11. Run under the sponsorship of international organizations
12. Installation and operation of biogas bag digesters. A study of methane digesters in the South Pacific region. Biogas production from water hyacinth
13. Manual for installation and operation of biogas bag digesters. Investigation of field digesters in the South Pacific region. (completed)

    Biogas production from water hyacinth and other vegetable matter. Development of low-cost durable biogas systems. (ongoing)

Manual for livestock food production from the effluent from biogas systems. (planned)

II

A.

1. (a) fixed (one or two)
   (b) movable (main type)
2. 5 – 25 m^3
3. (a) largely concrete brick, some polymer rubber
   (b) largely welded steel, some concrete brick, some polymer rubber
   (c) and (d) generally PVC pipe

B.

1. (a) continuous (mostly)
   (b) batch (one or two experimental)
2. Pig wastes
3. Washings of pig pens
4. Variable
5. Variable

C.

1. (a) 0.1 m^3 per pig per day
   (b) ring burner
2. (a) a few digesters
   (c) none viable
   (f) most digesters
3. None except exodation ponds

D.

1. $US 500 to 3,000
2. (a) summer 28° – 32°C
   (b) winter 18° – 22°C
5. Two problems predominate: blockage of the digester inlet pipes and leakage of the gas holder
6. Approximately 70 per cent in Fiji; 0–10 per cent in the other South Pacific island countries
7. A reliable low-cost durable digester is not generally available, especially for the digestion of vegetable matter

134. Action for Food Production (AFPRO)

I

1. C-17 Community Centre, Safdarjang Development Area, New Delhi 110 016, India
   Tel: 667445, 660319 Cable: AFPRO
2. 1966
3. Mr. J.B. Singh, Executive Director
4. Mr. J.B. Singh, Chief Co-ordinator, Biogas Programme, Mr. Raymond M. Myles, Co-ordinator, Biogas Programme
5. (a) 7
   (b) 9
7. AFPRO provides technical assistance to its several grass-root level voluntary agencies operating throughout India, in biogas and other agricultural and rural development fields.
8. Construction of demonstration-cum-training Janata plants and training of rural masons, selected by AFPRO related voluntary agencies operating throughout India.
9. Technical Services in the field of agriculture, livestock, water resources and appropriate/rural technology
10. Information. Advisory. Consultancy. Extension. Training. Promotion. Seminars etc.
11. All-India course on biogas technology – with special emphasis on the construction of Janata biogas plant, 1979, for senior project staff. Regional courses on biogas technology for grass-root level workers of voluntary agencies. Training of masons on the construction of Janata plant at the time of construction of demonstration-cum-training Janata plants. Several training workshops for rural masons during 1980 and 1981 in different regions of India.
12. A Janata model gobar gas plant. Community biogas plant. Promotion of biogas plant for small and marginal farmers on individual and community basis. A 2 cu m (70 cu ft) Janata plant con' ructed in Union Territory of Delhi. Biogas technology: a review of approach adopted by AFPRO in the systematic promotion of Janata plant.
13. Nine demonstration-cum-training Janata plants (2, 3, 4, 6 and 15 cu m capacities) (completed). Two Janata plants one 6 cu m (210 cu ft) and another 2 cu m (70 cu ft) using stones (ongoing). Six more by 1980 (planned).

II

A.

1. (a) Fixed
2. 2, 3, 4, 6, 9 and 15 m^3
3. (a) (b) (c) and (d) bricks and cement

B.

1. (a) continuous
2. Cattle dung
3. Dung mixed with water in the ratio of 1:1
4. Average quantity of dung required for different size of Janata plants:

Size of plant (gas production per day) cu m (cu ft)	Approximate number of cattle	Daily requirement of wet dung (kg)	Gas utilization for cooking (number of persons)
2 (70)	3 – 4	45 – 50	6 – 8
2 (105)	4 – 5	70 – 75	10 – 12
4 (140)	5 – 7	75 – 90	12 – 16
6 (210)	7 – 10	100 – 120	16 – 20
9 (315)	14 – 18	140 – 180	30 – 35
15 (525)	25 – 30	250 – 300	50 – 60

6. 1:1 (for cattle dung)

C.

1. (b) Cooking and sometimes lighting
2. (c) composting

D.

1. All the Janata plants constructed by AFPRO so far are 30 to 40 per cent cheaper than the conventional plants with movable steel gas holder, according to AFPRO.
5. The main trouble reported is leakage of gas because of faulty construction. Proper training of masons can correct the situation; supervision and right type of construction material is also necessary.
6. 100 per cent

135. Agricultural Tools Research Centre

I

1. Suruchi Campus, Post Box 4, Bardoli 394601, India
   Tel: 95258
2. 1959
3. Mr. Mohan Parikh, Director
4. Mr. Rahul Parikh
5. (a) 3
   (b) 4

6. Suruchi Campus, Bardoli
7. Gujarat State Khadi Board
8. Appropriate technology. Rural development. Training centre.
9. Agricultural tools and implements. Solar energy. Biogas energy.
10. Youth training for rural development work. Technical advisory and consultancy service
12. On agricultural tools, design of a flat-plate solar cooker, garbage gas plant, biogas, fertilizer gas plant, agricultural hand tools for small and marginal farmers
13. Prototype experiments on garbage gas plant with different feed stock. Gas plant with fixed RCC roof – prototype. Double digester gas plant with fixed RCC roof.

II

A.

1. (b) movable
2. 17 m^3
3. (a) RCC
   (b) iron
   (c) and (d) cement pipe

B.

1. (a) continuous
2. Cow dung
3. Homogeneous mixture of cow dung and water with a churner
4. 120 kg
5. 4500 kg every 60-90 days
6. 1:1

C.

1. (a) 4m^3
   (b) cooking
2. (a) direct fertilizer on soil

D.

1. $US 500 (in March 1979)
2. (a) summer 32°C
   (b) winter 20°C
3. (b) sun
6. 95 per cent
7. Application of some anticorrosive paint or bituminous paint on outer surface of iron gas holder gives trouble-free operation for longer periods.

136. Centre of Science for Villages

I

1. Magawadi, Wardha 442 001, India
   Tel: 2412 Cable: GRAM VIGYAN
2. 1976
3. Mr. Devendra Kumar, Director
4. Mr. M.A. Sathianathan, Co-ordinator, Energy and Environment Department
5. (a) 17
   (b) 76 in the area
6. Dattapur with eight plants. Four more under construction
7. All other Gandhian Institutions. The Department of Science and Technology, Government of India
9. Biogas system. Animal and manpowered devices for rural industries. Solar energy and wind power energy balance studies on rural industries and designing of appropriate energy systems
10. Information. Research and development. Advisory. Consultancy. Education. Training.
11. In biogas technology, pulp and paper from agricultural residues, construction techniques, construction materials and heavy pottery.
12. Monthly bulletin *Science for the Villages.* Occasional publications
13. Studies on equipment design engineering and improvement of digesters; digestion process engineering studies; feed stock processing and plant design, selection of biogas system for its use in rural industries, systems approach to biogas utilization (ongoing).

137. Delhi Water Supply and Sewage Disposal Undertaking

I

1. M.C.D. Link House, Bahadur Shah Zafar Marg, New Delhi 110002, India
   Tel: 274333 Cable: WATER
2. 1938 (Delhi Sewage Disposal Works, Okhla)
3. Mr. M.N. Jain, Chief Engineer
4. Mr. Jai Narain, Superintending Engineer
5. (a) 3 engineers and 7 assistants
   (b) 15/10
6. Sewage Disposal Works, Okhla, India
7. Central Public Health Environmental Engineering Organization (CPHEEO), Ministry of Works and Housing, Government of India. National Environmental

Engineering Research Institute, Nagpur. Central Board for Prevention and Control of Water Pollution.

8. Sewage system
9. Collection, treatment and disposal of city waste water
10. Information. Advisory. Education. Training
11. Sewage supervisors training courses, sponsored by CPHEEO, Ministry of Works and Housing, Government of India
13. 125 MGD – complete sewage treatment plant. Biogas for domestic use, 1000 families. 66 MGD sewage treatment plant. Biogas for 500 families. 22 MGD primary sewage treatment plant. (completed)

    Biogas for 1000 families. 125 MGD – complete sewage treatment plant. (ongoing)

    Biogas for 10,000 families (planned).

II

A.

1. (b) movable
2. 200,000 cu ft
3. (a) RCC structure
   (b) mild steel plates 8 mm thick
   (c) and (d) cast iron pipes range 6 in to 10 in diameter

B.

1. (b) batch
2. Sludge from primary sedimentation of raw-sewage
5. 0.3412×10^6 kg in every 3 days in each digester
6. 94–95 per cent moisture at 105°C

C.

1. (a) 14300 m^3
   (b) domestic fuel supply and power generation (standby)
2. (a) 136.5×10^6 kg/day
   (f) 204.7×10^6 kg/day

D.

1. $US 2.5 million
2. (a) summer 40°C
   (b) winter 20°C
3. (b) sun
5. Frequent chockages due to incoming grit. Grit chamber flow to be regulated every day. Application of back pressure with raw sewage to remove chockages
6. 66 per cent

7. To have at least 8 in to 10 in diameter C.I. pipe for withdrawal of digesters sludge and one central screw pump for mixing effectively.

138. Gobar Gas Research and Training Centre

I

1. Ajitmal, Etawah, India 206121
2. 1957
3. Director, Planning Research and Action Division, Government of Uttar Pradesh, Lucknow
4. Senior and other research officers
5. (a) over 20
8. Planning, research and extension of biogas technology
9. Biogas
10. Research and development. Training
11. On constructional methodology and technical details of biogas digesters.
12. On action research in biogas technology; design and introduction of Janata biogas plants; Janata biogas plants; biogas.
13. A community biogas plant completed. Three ongoing. More planned.

II

A.

1. (a) fixed
2. 6-18 m^3 (common range)
3. (a) (b) (c) and (d) brick and cement

B.

1. (a) continuous
2. Cattle dung
3. Mixed with same quantity of water
4. 25 kg/m^3 of gas
6. 1:1

C.

1. For family-size digesters
   (a) 2-10 m^3
   (b) cooking and lighting
2. (b) (c) and (d) composted and applied twice a year

D.

2. (a) summer 35°C
   (b) winter 15°C
3. (b) sun
5. As long as digesters are fed with requisite quantity of dung fixed with water it runs trouble free. If feeding is not proper and other things (agricultural wastes etc.) are also fed then the problems of scum formation and sedimentation arise.
6. Over 90 per cent.

139. Indian Agricultural Research Institute, Division of Soil Science and Agricultural Chemistry

I

1. New Delhi 110 012, India
   Tel: 581494 Cable: KRISHIPUSA
2. 1905
3. Dr. T.D. Biswas, Head
4. Drs. R.K. Chibber, M.C. Jain, P.K. Chhonkar, O.P. Chawla, Sushil Kumar
5. (a) 6
   (b) 6 in farmers premises and 6 in institutions
6. Delhi
7. Co-ordination of research on biogas in universities and institutes, including pilot studies and feed back
8. Research on biogas technology and usage
9. Chemical, biological engineering and extension
10. Research and development. Information. Advisory. Consultancy. Training
11. For individual scientists. Seminar etc. Extension
12. *
13. Kinetics of gas production in relation to different physical, chemical and biochemical parameters. Screening of various additives for stimulating production etc. (completed)

    Survey and possibility of utilization of various cellulosic waste materials for better production and investigations on the biochemical changes in the substrate, particularly the extent of cellulose decomposition to be taken up in the second phase. Detailed investigations on the residual slurry for enhancing its manurial value and easier handling will then be carried out in the third phase. Microbiological aspects: (a) Development of techniques for production and maintenance of enriched cultures of methanogenic bacteria. (b) Production of enriched culture of metha-

nogenic bacteria from various habitats including hilly areas for naturally selected cold adapted strains. These above experiments will be carried out in the first year. (c) Development of techniques for monitoring methane producing efficiency of enriched cultures and physiological investigations on selected strains for thermal sensitivity and identification of stimulatory parameters will follow in the second phase. (d) Investigations on commensural relationship between non-methanogenic cultures and fermentation kinetics of various cellulosic waste materials, will be taken up in the third phase. (Ongoing)

Installation of a community gas plant in Holombi Kalan Village of Delhi and study of the various socio-economic parameters. (planned)

II

A.

1. (b) movable
2. 3 m^3 and 9 m^3
3. (a) bricks and cement
   (b) mild steel sheet
   (c) cast iron pipe
   (d) brick lined channel at the top

B.

1. (a) continuous
2. Cow dung
3. Dung and water in equal volume thoroughly mixed to form uniform slurry
4. 50/150 kg
6. 1:1 (by volume)

C.

1. (a) 3 m^3 and 9 m^3
   (b) cooking, lighting and running engines
2. (b) 40-100 kg (wet)/day

D.

1. $US 300 for 3 m^3 and
   $US 500 for 9 m^3
2. (a) summer 33°C
   (b) winter 17°C
3. (b) sun
5. During summer, whenever the slurry dries out to form a hard scum on the surface, a few buckets of water are directly added to the thickened slurry around the gas holder and stirred well with a pole. Dirt and straw which form scum should be removed from the dung slurry. Precaution should be taken so

that scrapings of earth from the cowshed are not introduced in the digester otherwise there may be a silting up of the digester.

6. 100 per cent
7. Twice a week or more frequently the condensed moisture in the gas pipe must be removed; otherwise the burner flame will flicker. Once in a year, preferably after the monsoon, the gas holder and other iron components must be painted with anti-corrosive paint.

140. Indian Institute of Management

I

1. Vastrapur, Ahmedabad-380015, Gujarat, India
   Tel: 450041 Cable: INDINMAN
   Telex: 012-351 IIMA IN
2. 1962
3. Prof. V.S. Vyas
4. Four faculty members
5. (a) 100 (faculty), 50 (research staff)
6. Action programmes in Dharampur Taluka of Gujarat and Jawaja Block and Deogarh Blocks of Rajasthan
8. Post-graduate teaching, training, research and consultancy in the field of management
9. Agriculture and rural development. Industrial development. Industrial management. Planning and control system in private and public sectors etc.
10. Information. Research and development. Advisory. Consultancy. Education. Training.
11. Apart from regular post-graduate courses, the Institute offers about 50 different training course in a year for various levels of functionaries in various field of activities.
12. Reports on project completed.
13. Biogas: a socio-economic evaluation for Gujarat State. Biogas in India: a socio-economic evaluation (completed). Socio-administrative aspect of community size biogas plants. Rural energy demand/supply balance (ongoing).

141. Indian Institute of Technology (Bombay)

I

1. Department of Mechanical Engineering, Powai, Bombay 400076, Mahrashtra, India.
   Tel: 581421, 584141
2. 1959
3. Prof. A.K. De, Director
4. Dr. (Mrs.) P.P. Parikh
5. (a) 2 (b) 1
6. At the Institute
7. In contact with KVIC, Gobar Gas Research Centre, Ajitmal, Itawa; NDRI
8. Investigations of parameteric influence on generation of biogas and its utilization in engines and otherwise, research aspects
10. Research and development. Advisory. Consultancy. Education.
11. The topic of biogas is given full coverage in the energy courses for B.Tech. students.
13. Utilization of biogas in small diesel engines: conversion of existing machine (completed). Study of biogas cum kerosene engine (ongoing). Use of heavy fuels (residual fuels) with biogas in compression ignition engines (planned).

II

A. KVIC design
   1. (b) movable
   2. For 35 m^3
   3. (a) cement concrete
      (b) mild steel
      (c) and (d) cement pipe

B.
   1. (a) continuous
   2. Cow dung and sometimes water hyacinth
   4. 500 kg
   5. 1:1

C.
   1. (a) 35 m^3
      (b) in engine and for cooking canteen
   2. (b) composting

D.

1. $US 500
2. (a) summer 32°C
   (b) winter 28°C
3. (a) shadow
6. Only one digester

142. Indian Institute of Technology (Madras)

I

1. Madras 600 036, Tamil Nadu, India
   Tel: 414342 Ext. 236 Cable: TECHNOLOGY MADRAS
   Telex: TECHMAS-MS (041)7362
2. 1959
3. Prof. P.V. Indiresan, Director
4. Dr. S. Radhakrishna, Department of Physics, Dr. K.V. Gopalakrishnan, Department of Mechanical Engineering
5. (b) 2
6. Taramani House, IIT, Madras; Narayanapuram, 10 km from the Institute.
8. Research and development. Extension of biogas technology
9. Development of biogas engines. Design and development of biogas digesters. Development of comprehensive biomass biogas energy systems.
10. Research and development. Extension of biogas technology
11. Graduate and post-graduate degree courses
13. Improvement of dual-fuel engines using biogas. Demonstration and popularization of different implements working with biogas. (completed)

    Cultivation of water hyacinth as biomass for biogas. Design and development of new digesters. (ongoing)

    Development of comprehensive biomass systems. (planned)

II

A.

1. (b) movable
2. 8 m^3 and 50 m^3
3. (a) brick and cement
   (b) mild steel
   (c) and (d) asbestos cement pipe

B.

1. (a) continuous
2. Cow dung and water hyacinth
3. Solid impurities are removed, an equal amount of water added and a smooth slurry prepared.
4. 100 kg of wet dung (for 8 m^3)
   500 kg of wet dung (for 50 m^3)
6. 1:1 (by volume)

C.

1. (a) 4 m^3 (for 8 m^3) and 20 m^3 (for 50 m^3)
   (b) to run engine, lamps and pumpsets
2. (a) 60–70 kg/day (for 8 m^3) and 200–300 kg/day (for 50 m^3)
   (c) 30–40 kg/day for (50 m^3)
   (d) 10–20 kg/day (for 8 m^3) and 40 kg/day (for 50 m^3)

D.

1. $US 500 (for 8 m^3) and $US 1,250 (for 50 m^3)
2. (a) summer 35°C
   (b) winter 25°C
3. (b) sun
5. Blocking, cleared with bamboo poles
6. 100 per cent
7. The inlet and outlet passages should be made much larger in diameter

143. Indian Institute of Technology (New Delhi) Centre of Energy Studies

I

1. Hauz Khas, New Delhi 110016, India
   Tel: 654054 Cable: TECHNOLOGY
2. 1962
3. Prof. O.P. Jain, Director
4. Prof. H.P. Garg
5. (a) 10
   (b) 3
8. Research and development
10. Research and development. Education. Consultancy
11. M. Tech. Course in Energy Studies
12. Several

II

A.

1. (b) movable
3. (a) masonry
   (b) steel
   (c) and (d) cement pipe

B.

1. (b) batch
2. Cow dung
4. 100 kg
5. 100 kg/day
6. 1:1

C.

1. (a) 3 m^3/day
   (b) cooking and lighting
2. (a) direct fertilizer on soil

D.

1. $US 300
2. (a) summer 33°C
   (b) winter 17°C
3. (b) sun
4. In winter slurry was made with solar heated water
5. Gas holder corrosion is a problem. Cleaning of digester well is required because of the settling of other things like small stones, sand etc.
6. 100 per cent
7. Gas holder should be made of some cheaper but durable material. Suitable trap for the moisture in the gas line should be designed. Cleaning of digester is a problem. In winter some simple and effective heating of slurry arrangement should be devised.

144. Kapur Solar Farms

I

1. Bijwasan Najafgarh Road, P.O. Kapas Hera, New Delhi 110 037, India
   Tel: 391747
2. 1968
3. Mr. J.C. Kapur

5. (a) 5 (b) 1
6. New Delhi
8. Solar energy and bioconversion systems
9. Integration of solar energy and bioconversion systems
10. Research and development
13. Integrated solar energy and bioconversion systems

II

A.

1. (b) movable
2. 3–20 cu ft
3. (a) brick lined with cement plaster on both sides. Insulated with 2" insulating materials
   (b) mild steel drum
   (c) and (d) RCC pipe

B.

1. (a) continuous
2. Cow dung, at present
3. Feed being mixed with water in mixing tank before feeding
4. 125 kg
6. 1:1

C.

1. (a) 200-250 cu ft
   (b) cooking of food
2. (b) composting

D.

1. Nearly $US 8000 (including instrumentation)
2. (a) summer 40° C
   (b) winter 5° C
3. (b) sun
4. Heating of slurry in winter by passing hot water from solar conductors through a heat exchanger

145. Khadi and Village Industries Commission, Gobar Gas Research and Development Centre

I

1. Kora Gramodyog Kendra, Borivli (West), Bombay 400 092, India
   Tel: 662485
2. July 1962
3. Mr. G.L. Patankar, Deputy Director
5. (a) 5
   (b) 80,000 (In India)
7. National Environmental Engineering Research Institute, Nagpur. Bhabha Atomic Research Centre, Bombay. Planning Research and Action Institute, Lucknow. Indian Agriculture Research Institute, New Delhi
8. Research and development on biogas
10. Advisory on biogas (India and other developing countries)
11. On biogas plant construction.
12. Recent Development in Gobar Gas Technology (monogram)
13. Designing of domestic gas appliances including gas lamps, conversion kits for engines (completed).

    Light weight gas holders (plastic and galvanised iron). Liquid jacked gas holder. (ongoing)

    Designing of prefabricated domestic biogas plant, digester and gas holder. (planned).

II

A.

1. (b) movable
2. 3 m^3
3. (a) bricks, stones
   (b) mild steel (galvanized iron, PVC on small scale)
   (c) and (d) cement asbestos

B.

1. (a) continuous
2. Cattle dung, human excreta
3. Mixing the feed in 1:1 proportion by weight with water
4. 80 kg
6. 1:1 or 1:1.25 for 16 per cent, 18 per cent solids respectively

C.

1. (a) 3 m^3
   (b) cooking and lighting
2. (a) 50% 60 kg/day (limited scale)
   (b) 50% 100 kg/day (limited scale)

D.

1. $US 550
2. (a) summer 30° C
   (b) winter 20° C
3. (a) shadow
   (b) sun
5. The digester works normally unless there is heavy acidity due to a particular type of feed
6. Exact number is not known, but 10 per cent of the 80,000 plants might be working
7. Prefabricated design of gas plant will solve a number of problems. Proper laying of gas pipe-line requires careful consideration. Technicians should be trained properly, so that accumulation of water condensate should not become a frequent source of trouble in operation.

146. L.G. Balakrishnan and Brothers Limtied

I

1. India House, Trichy Road, Coimbatore 641 018, India
   Tel: 30355 (10 lines) Cable: CONVEYANCE
   Telex: 085-222
2. 1956
3. Mr. L.G. Varadaraj, Managing Director
5. (a) 16
6. Coimbatore
8. Promotion of information on biogas, assistance in developing low-cost plants and encouraging use of plants to conserve energy.
10. Research and development

II

A.

1. (a) fixed (one plant)
   (b) movable (three plants)
2. 6 m^3 (fixed), 15 m^3, 11.5 m^3 and 3.5 m^3 (movable)

3. (a) bricks
   (b) bricks for fixed type mild steel for movable type
   (c) and (d) asbestos pipes

B.

1. (a) continuous
2. Cattle dung
3. Mixed with water
4. 75 kg for fixed type
6. 1:1 (by weight)

C.

1. (a) 2.5 m^3 for fixed type. 4.3 m^3, 4.5 m^3 and 2.15 m^3 for movable type
   (b) experimental
2. (a) 686 kg/day of wet slurry
   (b) 147 kg/day of wet sluge

D.

1. $US 108 (fixed)
   $US 500, 365 and 259 (movable)
2. (a) summer 27° C
   (b) winter 20° C
3. (b) sun
4. For a small 60 cu ft/day Indian (movable) type of plant (3.5 m^3 is the digester volume), solar heating method is being tried.
5. (i) movable type: scum formation, which is taken by rotating the gas holder. Corrosion which is minimized by painting very often. (ii) Fixed type: sealing inside the dome (using gas proofing compound), painting etc. Moisture in gas, with water forming in pipe-lines and trapping of water.
6. 100 per cent
7. (i) Movable type: Ferrocement gas holders may solve to some extent the corrosion problems. Moisture removal from gas is an important problem.
   (ii) Fixed type: Perfect sealing inside the plant to prevent gas leakage. Pressure should be maintained uniformly at least in a certain definite range.

147. Maharashtra Gandhi Smarak Nidhi

I

1. Gandhi Bhavan, Kothrud, Pune 411 029, Maharashtra, India
   Tel: 56905
2. In 1949 as a branch of Central Gandhi Smarak Nidhi; in 1969 as an autonomous body

3. M . T.S. Bharde, Chairman

4. Mrs. Savitribai Madan, Executive Member; Mr. H.N. Todankar, Organizer

5. (a) 28 technical assistants all over the State of Maharashtra
   (b) 100 night soil and cattle dung gas plants constructed. In operation 95. 56,000 latrines constructed

6. In 16 districts of Maharashtra

7. Grant-in-aid from the Government of Maharashtra. Collaboration with Khadi and Village Industries Commission

8. Gandhi Smarak Nidhi itself is an organization engaged in propagating the Gandhian philosophy. Propagation of rural hygiene and biogas. Also village industries with special emphasis on training-cum-production programme

10. Consultancy. Training. Publication of Gandhian literature

11. Short-courses of one month each in construction of biogas plant and inexpensive hygienic rural latrines. Training for self-employment in village industries

12. Over 60 publications in Marathi on Gandhian philosophy, and small booklets on biogas and rural latrines

13. Construction of 56,000 rural latrines and 110 biogas plants. (completed)

    Survey of the village oil-pressing industry in Maharashtra and Rajasthan. Establishment of rural industrial estate near Poona. (ongoing)

    Establishment of dairy for breeding of cows. (planned)

II

A. Digester is constructed underground with a steel or fibre-glass collector floating on the digesting slurry. Water jacketed to avoid odour.

   3. (a) bricks in cement mortar, duly plastered
      (b) steel or fibre-glass and piping GI or PVC
      (c) and (d) asbestos cement pipes

B.

   1. (a) continuous

   2. Night soil and cattle dung

   3. With night soil no mixing is done. With cattle dung water and dung are hand-mixed in the proportion of 5:4.

   4. Will vary according to number of latrines and cattle. Most common sizes require night soil of 40 persons and droppings of 11-12 animals. There are smaller and bigger sizes also. Per cubic meter of gas requires cattle dung equal to 18 kg or night soil of 30 persons per day.

C.

   1. (a) according to size of plant, 2 m^3 to 35 m^3 per day

      (b) Gas from smaller-size plants is used mainly for kitchen. Occasionally also for lighting. From large plants gas is used for fuel in industry.

2. Used as such in the farm along with irrigation water or converted with other vegetable to refuse

D.

1. $US 375, the smallest (2 m^3) plant
2. (a) summer 40°C
   (b) winter 8°C
3. (b) sun
5. Occasionally the pH of the slurry goes down and use of lime to correct the pH is required. In winter, owing to low temperature gas production is depressed some time to even less than half the normal quantity. No simple remedy has so far been found.
7. Water jacketed plants are necessary to avoid odour and flies in case of night soil gas plants. Rapid rusting of steel gas holders could be avoided with the use of glass fibre reinforced polyester gas holders

148. Ministry of Agriculture, Department of Agriculture and Co-operation (India)

I

1. Krishi Bhavan, New Delhi 110 001, India
   Tel: 388911 Cable: AGRINDIA
2. 1947
3. The Honourable Minister of Agriculture
4. Commissioner (Fertilizer Promotion), Specialist (Biogas).
5. (a) 4
   (b) over 80,000
6. A large number under the auspices of State Governments and Khadi and Village Industries Commission
7. State Governments, Khadi and Vollage Industries Commission
8. Planning, programming, co-ordination and monitoring of biogas programme at national level
9. Planning, financing in the form of subsidy, arranging of finances from banks, supply for raw materials etc.
10. Information. Advisory. Consultation.
11. Regional training courses are being organized in collaboration with the Directorate of Extension, New Delhi.
12. A Gobar Gas Plant for You (1978). Janata Gobar Gas Plant (1979). Organic Recycling in Agriculture (1979).

13. About 80,000 biogas plants have been set up in the country. Programme for the year 1980-81 with a target of setting up of 40,000 plants is in progress. A national project on development and promotion of biogas for years 1980-85 is being planned.

II

A.

1. (a) fixed
   (b) movable
2. Fixed gas holder: 2, 3, 4 and 6 m^3; Movable gas holder 2, 3, 4, 6, 8, 10 to 85 m^3
3. (a) bricks, stone slabs.
   (b) steel
   (c) and (d) bricks, stone slabs

B.

1. Semi-continuous
2. Cattle dung
4. Minimum of 50 kg/day for a small size i.e. 2 m^3 gas production capacity plant.
6. 1:1.

C.

1. (a) 2 to 85 m^3 depending upon size.
   (b) cooking
2. (b) 85-95 kg/day (including water)
   (g) sun drying and its use as compost: 15-20 kg/day

D.

1. $US 200 to 10,000 depending upon size
2. (a) summer 30-35°C
   (b) winter 10-20°C
3. (b) sun
5. Accumulation of water in the pipe-line which can be overcome by installation of a tape at the lowest level in the pipe-line and its periodic use to remove water. Corrosion of gas holders can be overcome by painting of gas holder at least once in two years.
6. It is estimated that about 80-90 per cent of 80,000 plants installed in the country are in operation at any one given time.
7. In gas plants having steel gas holder, designing for insultation and heating may be included. In gas plants having fixed dome, designing should be perfected to make it gas-leak proof.

149. Municipal Corporation of Greater Bombay, Dadar Sewage Treatment Plant

I

1. Senapati Bapat Road, Dadar, Bombay 400 028, India
   Tel: 451158
3. Executive Engineer (Mechanical) Sewerage, Western Suburbs
4. Assistant Engineer (Mechanical); Superintending Chemist (Purification)
5. (a) 35
   (b) 2/2
6. Dadar, Bombay
8. Sewage treatment
9. Gas distribution and sewage treatment. Manure production

II

A.

2. Two digestion tanks having 63' diameter and total depth 70' hopper bottom type – 4700 cu m of each unit.
3. (a) RCC
   (b) mild steel
   (c) and (d) cast iron

B.

1. (a) continuous
2. Raw sludge (primary sludge having 5 per cent to 6 per cent solids)
3. Consolidation for increasing the solids contents
4. 12,500 kg
6. 19:1

C.

1. (a) 3000–3500 m^3
   (b) domestic fuel, fuel for running hospitals, and fuel for running hotels
2. (f) 70 million litres per day

D.

1. $US 1 million
2. (a) summer 33-34° C
   (b) winter 18-20° C
5. Pipe choking and screw pump jamming overcome by water recirculation. Scum formation, by moving the screw pump in forward and backward directions.
6. 100 per cent

150. National Dairy Research Institute, Indian Council of Agricultural Research

I

1. Karnal 132 001, Haryana State, India
   Tel: 2851 Cable: DAIRYSEARCH, KARNAL
2. 1923 (formerly known as Imperial Dairy Research Institute, Indian Dairy Research Institute.)
3. Dr. D. Sundaresan, Director
4. Joint Director, Heads of Divisions, Scientists.
5. (a) 240 scientists
   (b) 3
6. Regional stations in the south (Bangalore), west (Bombay) and east (Kalyani).
7. The Dairy Science College attached with NDRI is affiliated to Kurukshetra University and offers B.Sc. (Dairy Science), M.Sc. and Ph.D. degree. Recognized as centre of excellence for dairy production and processing by UNDP.
8. Research on dairy production with cattle, buffalo and goats, dairy processing and dairy management. Teaching for B.Sc. (Dairy Science), M.Sc. and Ph.D. and guidance for research. Collaborative research with national and international institutions.
9. Increasing milk yield of cattle. Production of good quality milk and milk products. Better management of dairy farm and mixed recycling of dairy farm wastes and of farms for fodder cultivation.
10. Research. Education. Training. Advisory
11. In addition to degree courses, short term courses: 13 in dairy production, 10 in dairy processing, and 4 in dairy management
12. Annual Report. Quarterly Newsletter. Research and Technical Bulletins and Monthly Documentation on Dairy Science.
13. 393 (completed) and 52 (ongoing).

II

A. Khadi and Village Industries Commission design

   1. (b) movable
   2. 7 m^3
   3. (a) cement, brick
      (b) galvanized iron
      (c) and (d) cement brick and asbestos cement pipe

B.

1. (a) continuous
2. Cattle dung
3. Mixed dung with water in inlet trough
4. 125 kg (dung)
6. 1:1

C.

1. (a) 3-7 m^3 (winter and summer months)
   (b) cooking and lighting
2. (a) 250 litres digested slurry/day

D.

1. $US 600
2. (a) summer 28-33°C
   (b) winter 13-15°C
3. (b) sun
5. Less gas yield during winter. The gas yield can be slightly increased by charging the dung during winter months with warm water at noon. Besides 20 per cent urine addition will supplement nutrient deficiency
6. 100 per cent

151. National Institute of Waste Recycling Technology

I

1. A-18, Juhu Apartments, Juhu Road, Bombay 400 049, India
   Tel: 543517 Cable: RECYCLING BOMBAY, Scz. 400 049
2. 1978 (Registration in the process)
3. Dr. T.M. Paul, Executive Directory (Honourary)
4. A band of honourary, part-time technical officers, both Indian and foreign.
5. (a) 12 Indian and 12 foreign
   (b) 1
7. The Bharathiya Vidya Bhavan, Bombay. The Kosbad Agricultural Institute, Maharashtra. The Municipal Corporation, Bombay.
8. Designing and operating a pollution – free system of waste-recycling, to produce compost for manurial use, biogas for energy and reclaimed water for irrigation, industrial and domestic uses of flushing and washing and for rearing fish etc.
9. Redesign of a pollution free septic tank (completed and is under application for a patent in India and UK). Designing a simple biogas plant, without any metallic or domeshaped gas holder, but pollution-free (completed and under issue of a patent in India and UK)

10. Research and development. Consultancy, on non-profit basis

12. Liquid Compost Plant for Rural Sanitation: Part A: Basic Principles and Objectives (Under publication in International Reference Centre for Waste Disposal News No. 15, WHO.) Part B will publish the design of the new plant, after the patent is issued.

13. Pollution free septic tank. Liquid compost plant. drumless and domeless biogas plant (completed).

    Field trials of the designs (ongoing).

II

A.

1. (b) movable
2. 35 m^3
3. (a) brick and cement
   (b) brick, cement and mild steel
   (c) and (d) 3 in size asbestoes pipe

B.

1. (a) continuous
   (b) batch
2. Cow dung (other wastes also under trial)
3. Only mixing
4. Up to 5000 kg (approximately)
5. 10 kg every 30 days
6. 1:1

C.

1. (a) 100 m^3
   (b) running an irrigation pump, on a fodder farm, for about 8 years.
2. (b) up to 5000 kg/day (used for feeding chicks and calves)
3. Only compost (treatment) making is recommended

D.

1. $US 625 (in 1967) (approx.)
2. (a) summer 35°C
   (b) winter 25°C
3. (b) sun
4. Not necessary
5. None experienced in Bombay, where the annual rainfall has been about 100 in compost making could be carried out even in the rainy season.
7. Drum-free and dome-free digester will be trouble-free, but needs field trials which are under consideration.

152. Orissa Cement Ltd.

I

1. Rajgangpur 770 017, District Sundargarh, Orissa State, India
   Tel: 32-RGP Cable: ORISACEMENT
   Telex: 0635 240
2. Gobar gas plant established in 1977
3. Mr. M.L. Chand, General Manager
4. Mr. K.S. Singh, Horticulture Officer
5. (a) 2 (b) 3/2
6. Rajgangpur
7. Khadi Village Industries Commission, Bombay. Khadi Research Institute, Sewapuri, Varanasi.
8. Industry
9. Rural development and welfare
10. Research and development
13. 2 (completed), 1 (ongoing) and 1 (planned).

II

A.

1. (b) movable
2. 1000 cu ft and 300 cu ft
3. (a) brick, cement and sand
   (b) steel sheet
   (c) and (d) brick, sand, cement and asbestos pipe

B.

1. (b) batch
2. Cow dung, cutgrass, waste cattle feed, fodder etc.
3. Mixing water, chopping grass in small
5. 1000 kg every day
6. 1:1 ± 10 per cent

C.

1. (a) 1300 cu ft
   (b) cooking food, boiling water etc.
2. (b) 1000 kg/day
   (g) as fertilizer for flower pots, lawns etc.

D.

2. (a) summer 40°C
   (b) winter 15°C
3. (a) shadow
   (b) sun
4. During winter, use of hot water and covering gas holder with jute gunny bags
5. The 300 cu ft plant was blocked due to silting of cement and stone chips. This trouble was removed by lifting gas holder, pumping slurry out and cleaning the waste manually.
6. 100 per cent
7. To avoid stone chips, brickbats etc. get in through inlet, the inlet must be fitted with a steel strainer.

153. PSG College of Technology

I

1. Coimbatore 641 004, India
   Tel: 24177 Telex: PSGCB/0855/261
2. 1951
3. Dr. R. Subbayyan, Principal
4. Dr. C.P. Kothandaraman, Mr. P.R. Thiyagarajan
5. (a) 2 (b) 1
6. Coimbatore
7. PSG Industrial Institute under the same management provides special fabrication facilities.
8. Investigative
9. Teaching. Research
10. Research and development. Consultancy. Education. Training.
12. Papers dealing with biogas application to engines were presented in the National Conference on I.C. Engines and Combustion.
13. Use of biogas in I.C. engines (completed). Gas production using weeds leaves, bio wastes (ongoing). Construction of a fixed volume type (masonry) plant (planned).

II

A.

1. (b) movable
2. 12 m^3

3. (a) brick masonry
   (b) M.S.
   (c) and (d) stoneware pipe

B.

1. (b) batch
2. Cow dung
5. 150 kg every 7 days
7. 1:10

C.

1. (a) 8 m^3
   (b) running of diesel/petrol engines
2. (b) 40 kg/week

D.

1. $US 1200
2. (a) summer 35°C
   (b) winter 30°C
3. (a) shadow
7. The inlet and outlets should be of adequate size. Sand, stones etc. should be removed from the feed.

154. Punjab Agricultural University

I

1. Ludhiana, Punjab 141 004, India
   Tel: 22960 Ext. 242 Cable: AGRIVERSITY LUDHIANA
2. 1962
3. Vice-Chancellor
4. Associate Professor, Soil Microbiology
5. (a) 3 (b) 1
6. In the University
7. Recognized by the University Grants Commission and the Indian Council of Agricultural Research, Government of India.
8. Research, teaching and extension
9. Agricultural, veterinary and animal science. Horticulture. Forestry etc.
10. Teaching. Research and extension.
11. B.Sc., B.Tech. B.V.Sc. M.Sc. M.Tech. Ph.D.
12. *

13. Two ongoing in biogas: Development of kachara-gas plant; cheaper materials for construction of biogas plants.

II

A.

1. (b) movable
2. 20 m^3
3. (a) bricks and cement mortar
   (b) and (c) mild steel sheet 18 gauge
   (d) masonry tank

B.

1. (a) continuous
2. Dry paddy straw, wheat straw
3. Straw is chopped to less than 8 cm pieces.
4. 10 kg
6. 18:1 (water:straw)

C.

1. (a) 1 m^3
   (b) farm labour makes tea and cooks food; rest is just burnt off.
2. (a) 200 kg used for an experiment.

D.

1. $US 1,000
2. (a) summer 27.5°C
   (b) winter 14°C
3. (b) sun
5. The plant design can use any material that is of non-liquified plant origin, chopped to 8 cm size. The digester has stirring arrangement. The load on the stirrer needs to be reduced. The installation cost is higher than the KVIC design. It requires more space than the KVIC design.
6. Constructed: two. Operating: two

155. Resources Development Institute

I

1. 1100 Quarters Area, Arera Colony, Bhopal 462 016, India
   Tel: 62361 Cable: SADHANVIKAS
2. 1974
3. Mr. G.G. Puri, Executive Director

4. Board of Directors (Chairman: Shri R.P. Norohna; Secretary: Professor S.D. Dube)

5. (a) 7 researchers, 3 technicians, 3 co-ordinators.
   (b) 5 constructed (one high pressure, portable, one overground on rock, one conventional, one all clay, and one in concrete)

6. Bhopal

7. Independent, voluntary society, recognized by the University Grants Commissions and Bhopal University as research centre

8. Research and development. Extension and application of technology to rural poor. Consultancy

9. Biogas technology. Solar energy. Rural – housing. Appliance and tools

10. Research and development. Information and training. Extension. Consultancy

12. Propose to publish a quarterly or technique which will be a journal of the RDI dealing with research, resource development, technology extension and integrated development

13. Biogas – conversion kit for diesel engines Biogas filter. Substitution of acetylene by biogas in welding. Biogas turbine. High pressure portable biogas plants. (completed)

    Cheap solar cookers – clay and local materials costing $US 2 to 3. Solar pumps – reflection concentrator modified Sterling engine system. Rural cold storage – aqua-amonia-absorber- and gas turbine system. Solar-cum-wind energy converter. Complete clay biogas plants. Clay ring wells for small farmers. (nearly completed)

    Baked clay – pre-fab houses for rural poor. Strain – relieving and effort boosting mechanism for hand carts. (ongoing)

    Fibre from plantain stalks. Solar cycle. Chemical storage of solar energy. Development of cheap solar cells. Hollow-burnt clay bricks. Fertilizer and soil fertility boosters from manganese wastes. (planned)

II

A.

1. (b) movable
2. 4 m^3
3. (a) baked clay: rings assembled
   (b) baked clay
   (c) clay – pipe
   (d) rubber or plastic pipe – secured in clay

B.

1. $US 50
2. (a) summer 40° C
   (b) winter 25° C
3. (b) sun

156. Sobic Industrial Consultants

I

1. 5, V.N. G. Road, Madhavaram Milk Colony, Madras 600051, Tamil Nadu, India
   Tel: 647102
2. 1979
3. Ms. L.M. D'Souza, Director
4. Ms. Christine D'Souza, Farm Manager
5. (b) 10/2
6. 5, V.N.G. Road, M.M.C., Madras 600 061
10. Research and development. Advisory. Consultancy. Education. Training
11. Non-formal training to village children mainly in the form of exposure by joining in the operation of feeding the plant and using effluent.
13. Biogas plant, one for S.O.S. children's village, one for Mother Teresa's orphanage, three for poor educational institutions and five for individuals (completed).

    12 biogas plants for a rural housing project based on a radial design. (ongoing)

    Biogas plant for a factory having 2000 workers. Low-cost biogas plants for village applications. (planned)

II

A.

1. (b) movable
2. 7.8 m^3
3. (a) brick and cement mortar
   (b) mild steel
   (c) 4 in A.C. pipe, bottom entry, seperated by partition wall
   (d) 6 in A.C. pipe, bottom exit, seperated by partition wall

B.

1. (a) continuous
2. Night soil, chicken dung, cowdung pig dung, chicken entrails, kitchen peelings, straw, cut grass, banana plant stalks, spoiled fodder, chicken deep litter
4. 25 kg approx.
6. Average 1:1

C.

1. (a) 2.8 to 3.0 m^3
   (b) cooking
2. (a) 30 kg/day approx.
   (b) very marginal
   (d) 10 kg/day approx.

3. Have tried it and found to be effective for vegetable e.g. brinjals, cluster beans etc.

D.

1. $US 500
2. (a) summer 40°C
   (b) winter 27°C
3. (b) sun
5. Setting up of inlet lines due to sand accumulation at digester bottom. Light component of feed floating due to poor feed slurry mixing. High rates of water to feed where digester is connected to sewage system. Cracks in digester feed lines and digester walls.
6. 100 per cent
7. Development of a good feed slurry mixer is very important. Arrangements to be made for removing sand from feed. At least the digester will silt in course of 2-4 years. Arrangements should be made to desilt without taking digester out of service. Good follow-up is necessary at construction stage to make sure that digester and associated pipes/lines are leak-tight.

   Larger digesters to be provided with a stirrer to provide agitation which will promote good digestion.

157. Sri Parasakthi College for Women

I

1. Courtallam 627 802, Tamil Nadu, India
2. 1970
3. The Principal
5. (b) 5
6. Courtallam
11. Five batches of training courses
13. Indian Council of Agricultural Research scheme on biogas technology

II

A.

1. (b) movable
2. 2.9, 4, 14.5, 10 and 17 m^3
3. (a) brick and cement
   (b) (c) and (d) steel

B.

1. (b) continuous
2. Cow dung, urine, waterhyacinth

4. 200 kg of dung

6. 1:1

C.

1. (a) 20 m^3
   (b) cooking, lighting and laboratory uses.

2. (b) 150 kg/day
   (c) 100 kg/day

D.

1. $US 445[illegible] (5 plants)

2. (a) summer 39°C
   (b) winter 31°C

3. (b) sun

5. The gas holders often get corroded due to the gas contaminants in the biogas. Hydrogen sulphide has to be eliminated from the constituents of biogas

6. 100 per cent

7. The design should be modified in such a way that it should work even during winter.

158. Structural Engineering Research Centre

I

1. Roorkee, U.P., India
   Tel: 480 Cable: SERCENTER

2. 1965

3. Dr. S.P. Sharma, Scientist-in-charge

4. Dr. S.P. Sharma, Dr. V.P. Narayanaswamy, Dr. G.V.S. Kumar, Dr. P.C. Sharma and Dr. S.S. Jain

5. (a) 4 (b) 6

7. Through the All-India Co-ordinated Project o[illegible]gas sponsored by Department of Science and Technology, Government of India

8. Research and development relating to structural engineering and construction technology

9. Structural analysis and design. Construction materials and technology.

10. Information. Research and development. Consultancy. Training

11. On ferrocement technology in June 1979

12. *

13. On biogas, one completed and one ongoing

II

A.
1. (b) movable
2. 3.6 m^3
3. (a) brick in cement mortar
   (b) ferrocement
   (c) and (d) brick in cement mortar

B.
1. (a) continuous
2. Cattle dung
3. Mixing of dung and water manually
4. 66 kg
6. 1:1 (by weight)

C.
1. (a) 2 m^3 (average)
   (b) demonstration of use for cooking and lighting

D.
1. $US 250
2. (a) summer 35°C
   (b) winter 15°C
3. (a) shadow
6. 50 per cent

159. Tata Energy Research Institute, Field Research Unit

I

1. 7 rue Suffren, Pondicherry 605 001, India
   Tel: 3483 Cable: AUROBINDO
2. 1975
3. Dr. C.L. Gupta, Director
5. (a) 12
   (b) 4 constructed; 3 designs finished; construction to start
6. 1 (10 km away)
7. IIT, Delhi, Centre of Energy Studies and TERI Headquarters, Bombay
8. Research in alternative sources of energy
9. In biogas field: small-scale biogas plants
10. Research and development. Consultancy. Education. Advisory
13. Cook stoves and small biogas systems (ongoing). Biogas system for field station (planned)

160. Development Technology Centre, Institute of Technology Bandung (DTC – ITB)

I

1. ITB Campus, Jalan Ganesha no. 10, P.O. Box 276, Bandung, Indonesia
   Tel: 83307 and 82768 Telex: 28262 DTCITB BD
3. Dr. Filino Harahap, Director
4. 8
5. (a) 20 (b) 10
6. 2
8. Extension service in appropriate technology
10. Information. Research and development. Advisory. Consultancy. Training.
11. Several
12. "Biogas development in Indonesia", presented at ESCAP meeting 1978. "Biogas and fishculture", presented at the UNESCO training course on microbiology in service of an environmental management based rural development. Three publications in the Indonesian language on technology of biogas, biogas from city waste and biogas and animal husbandry.
13. Biogas from city waste (ongoing).

II

A.

1. (b) movable
2. Drum size: 5 m^3 and 15 m^3
3. (a) concrete and ferrocement
   (b) metal
   (c) and (d) pralon and metal

B.

1. (a) continuous
2. Cow dung and buffalo dung
4. Retention time 30 days
6. 1:1

C.

1. (a) 1/6 – 1/3 digester volume
   (b) cooling
2. (a) direct fertilizer on soil
   (c) aquaculture

D.

1. $US 500 (5 m^3), $US 1,000 (15 m^3)
2. (a) summer 25° – 30°C
3. (b) sun
6. 50 per cent

161. Industrial Research Institute, Centre for Chemical Industry

I

1. Jalan Karanganyar 55, Jakarta, Indonesia
   Tel: 625980
2. 1938
3. Ir. Koentoro Soebijarso
4. Ir. Karsini
5. (a) 10 (b) 2
6. Jakarta, Central Java and East Java
8. A five-year development plan project
9. Design and construction of small and medium biogas plants
10. Research and development
12. Annual reports. Research papers.
13. A biogas digester at West Jakarta, with a capacity of 1.50 m^3 (completed).

    A biogas digester at Semarang (Central Java), with a capacity of 10 m^3 (ongoing).

    A biogas digester at Klaten (Central Java), with a capacity of 20 m^3 and a biogas digester at East Java, with a capacity of 30 m^3 (planned).

II

A.

1. (a) fixed
2. 1.5 m^3
3. (a) concrete tube
   (b) steel plate (3 mm thick)
   (c) and (d) concrete tube

B.

1. (a) continuous
2. Pig excrement and eichhornia crassipes.
3. Putrefaction of eichhornia crassipes by soaking in water (30 days)
4. 20 kg.
6. 1:1

C.

1. (a) 1 m^3
   (b) lighting and cooking
2. (a) 10 kg/day

D.

2. (a) summer 35°C
3. (b) sun
6. 100 per cent
7. A sprayer for cleaning biogas digester and a stirrer for homogenizing sludge, both of them constructed together with biogas dome.

162. Ministry of Agriculture, Forestry and Fisheries, National Institute of Animal Industry

I

1. Tsukuba Norindanchi, P.O. Box 5, Ibaraki 305, Japan
   Tel: 02975–6–8600
2. 1916
3. Dr. Takeo Abe
4. 236 (Researchers: 118, biogas 3)
5. (a) 67 (biogas: 1) (b) 1
7. Other governmental research institutes. (For biogas, with Fermentation Research Institute, Agency of Industrial Science and Technology, Ministry of International Trade and Industry)
8. Basic research
9. Animal science. Animal husbandry. Animal waste management. Animal products processing.
10. Research and development.
12. Research papers in "Bulletin of National Institute of Animal Industry" and other scientific journals: "J. Anim. Sci.", "J. Nutr.", "J. Sci. Food Agric.", "Jpn. J. Zootech. Sci.", "Endocrinol. Jpn.", Agric. Wastes", "J. Dairy Sci.", "Agric. Biol. Chem." and the like.
13. On animal waste management: Activated sludge process for swine wastewater; High-rate animal wastewater treatment by contact aeration. (completed)

    Biogas production from animal wastes and its utilization. Aerobic composting of animal wastes. Control of odours from animal wastes. (ongoing)

    System analysis and standardization of animal waste management. More efficient utilization of biological resources including animal wastes. (planned)

II

A.

1. (b) movable (separated from the digester)
2. 0.2 m^3
3. (a) FRP (Fibre-glass reinforced plastic)
   (b) iron
   (c) FRP pipe
   (d) vinyl pipe

B.

1. (a) continous
2. Swine wastes
4. 10 kg
6. 3:4

C.

1. (a) 0.2 m^3
   (b) fuel
2. (a) 10 kg/day

D.

2. (a) summer 27° C
   (b) winter 4° C
3. (a) shadow
4. A submersible pump in the digester stirs and heats slurry simultaneously.
5. Main trouble is clogging of the submersible pump by gross organic residues such as straw mixed in the wastes. The method of overcoming is the removal of these residues before feeding digester.

163. Standards and Industrial Research Institute of Malaysia (SIRIM)

I

1. Lot 10810 Phase 3, Federal Highway, P.O. Box 35, Shah Alam, Selangor, Malaysia
   Tel: 362601-4 Cable: SIRIMSEC
2. 1975
3. Mr. Abdullah bin Mohd Yusof, Controller
4. 2
5. (a) 156 (b) 1
6. Selangor
8. Standards and industrial research

10. Information. Research and development. Advisory. Consultancy.

12. Malaysian Standards. Technical Report (research and development)

13. On biogas: one completed and two ongoing.

II

A.

1. (b) movable
2. 4 m^3
3. (a) concrete – bricks and cement
   (b) mild steel
   (c) and (d) PVC pipe

B.

1. (b) batch
2. Chicken droppings
5. 30 kg every 7 days
6. 1:1

C.

1. (a) 100 ft^3
   (b) cooking and lighting
2. (a) 10 kg/day

D.

1. $US 400
2. (a) summer 31°C
3. (b) sun
5. Due to a defect in the design, difficulty was encounterd in the discharge of the digested by-products. To overcome this problem an outlet pipe of a bigger diameter was used together with an inclined concrete screed to ease flow.
6. About 50 per cent
7. In the present design adopted, feeding is done manually, hence it is necessary that the opening of the inlet (or feed) pipe be within reach of the operator. With this, a digester embedded in the ground is found most fitting besides the fact that the digested material can be maintained at a constant temperature.

164. Invermay Agricultural Research Centre

I

1. Private Bag, Mosgiel, New Zealand
   Tel: Mosgiel 4132 Telex: INV

2. 1950
3. Dr. A.J. Allison, Director
4. Dr. D.J. Stewart, Mr. M. Badger and Mr. M. Bogue
5. (a) 2
   (b) 1 farmscale
   6 laboratory
6. At the Centre
8. Research and development
10. Information. Research and development. Advisory
13. Effects of industrial pollution on agriculture. Production of biogas from crops and wastes. Energy farming. Energy in agriculture. Farm-scale biogas and ethanol plants

II

A.

1. (b) fixed
2. 45 m^3
3. (a) steel frame holding insulating panels, rubber liner
   (b) butyl rubber bag, steel frame
   (c) and (d) pump

B.

1. (a) continuous
2. Crops: maize, oats, kale, straw
3. Storage as silage (chopped) and mixed with recycled effluent
4. 200 kg
5. 250 kg DM every day
6. No water added

C.

1. (a) 75 m^3
   (b) vehicle fuel
2. (a) 50 per cent at 1500 kg/day at 2 per cent T.S.
   (b) 50 per cent at 1500 kg/day at 2 per cent T.S.

D.

1. $US 17,500
2. (a) summer 14°C
   (b) winter 6°C
3. (b) sun
4. Gas heating/water heat exchange or electric hot water heating/heat exchanger

6. In New Zealand, 7 operating, 8 constructed and 5 under construction
7. Design of mixing system must suit material to be used.

165. Appropriate Technology Development Organization Government of Pakistan

I

1. 1-A, 47 Street, F-7/1, Islamabad, Pakistan

II

A.
1. (a) fixed
2. 10, 50 and 100 m^3
3. (a), (b), (c) and (d) cement, steel bars, bricks

B.
1. (b) batch
3. Cow and buffalo dung
5. 50 to 70 kg every day
6. 50 per cent

C.
1. (b) cooking
2. (c) 50 kg/day

D.
3. (b) sun

166. Merin Limited

I

1. Dada Chambers, M.A. Jinnah Road, Post Box 4145, Karachi 2, Pakistan
   Tel: 221783, 231332, 233595 Cable ORGANISE
   Telex: PAK 24675
2. 1948
3. Mr. Mahmood Futehally, Managing Director
4. Miss Shama Futehally, Adviser; Mr. S.A. Rahman, Manager
5. (a) 2 (b) 2
6. Sohana Bagh, Block 2, Gulshan-e-Iqbal, Karachi

7. Appropriate Technology Development Organization, Ministry of Science and Technology, Government of Pakistan; Intermediate Technology Development Group, Ltd., London; SWD Steering Committee on Wind Energy for Developing Countries DHV Consulting Engineers, Amersfoort, the Netherlands
8. Manufacture and sale of windmills, prefabricated biogas plants and propagation of productive plants and trees
9. Manufacture, sale, publicity, plant nursery services
10. Information. Research and development. Training
12. Paper presented at the 19th All Pakistan Annual Science Conference, 1979
13. Seven 12ft diameter windmills installed at various places in Pakistan. (completed)

    Repair of old windmills belonging to the Government at various parts of Pakistan. (ongoing)

    Development, manufacture and sale of 10 ft, 12 ft, 18 ft and 24 ft windmills. Development, manufacture and sale of prefabricated biogas plants of 10 cu m capacity. Development of water-proof fabric for construction of water-storage ponds. Development of "Ipil" forests along the roads and streets of Karachi. (planned)

II

A. Experiments are being made with the construction of ferrocement digesters made of prefabricated sections which can be easily transported to site, quickly assembled and charged with feed within a day or two. One of the important requirements is to have a very impervious plastering substance which would make the whole structure leak-proof with only a single coat. A plaster has been produced and a small experimental plant constructed wherein this type of plaster has been used, and which has been producing since the last six months. A bigger plant of 10 m^3 capacity is shortly to be installed. When this also has proved successful, its manufacture on a commercial scale is planned.

C. So far the sole use of effluent has been for fertilizer.

167. Ministry of Petroleum and Natural Resources, Energy Resources Cell

I

1. H. No. 3, St. 88, G-6/3, Islamabad, Pakistan
   Tel: 21416
2. 1973
3. Director General
4. Director, Deputy Director, Assistant Director, Research Investigators
5. (a) 13 (b) 100 family biogas units and two community biogas plants
6. Islamabad

8. Recommendation on national energy policy. Development and demonstration of renewable sources of energy. Conservation of energy

13. Installation of 100 family units for demonstration purposes and two community biogas plants (45 m^3 gas/day and 90 m^3 gas/day) (completed).

Projects on rural energy, rural electrification and solar energy development (on-going).

Installation of 1200 biogas plants (planned).

II

A.

1. (b) movable
2. 18 m^3
3. (a) bricks, cement and sand
   (b) M.S. sheet
   (c) and (d) bricks, cement and sand

B.

1. (a) continuous
2. Dung
3. Dung is mixed with water in the form of slurry in the inlet tank
4. 90 kg
6. 1:1

C.

1. (a) 4.3 m^3
   (b) cooking
2. (a) 80 kg/day

D.

1. $US 80
2. (a) summer 35°C
   (b) winter 20°C
3. (b) sun
6. A few units were out of operation because of defective masonry work

168. Liberty Flour Mills, Inc., Maya Farms Division

I

1. Liberty Building, Pasay Road, Makati, Metro Manila, Philippines
   Tel 86-50-11 Cable: LIBFLOUR
2. 1972

3. Dr. Felix D. Maramba, Sr.
4. Dr. F.D. Maramba, Sr., Dr. E. Obias, Dr. C. Taganas, Dr. J. Banzon
5. (a) 18 (b) 68
6. Angono, Rizal, Philippines
8. Integrated animal raising – meat processing – waste processing/recycling – and biogas energy utilization
9. Design, construction and operation of biogas works. Operation of integrated farming
10. Consultancy. Research and development
12. On small biogas plant; biogas and waste recycling
13. Design, construction, testing of 2 sets of industrial-size batch-fed digesters. Design, construction, testing of 4 sets of industrial continuous digesters with gas holder and sludge conditioning systems. (completed)

    Design, construction of industrial-size (set of 6) digesters for continuous operation with gas holder and sludge conditioning system. (ongoing)

II

A.

1. (a) movable
2. Total volume 2753 m^3
3. (a) concrete, hollow blocks, reinforcing bars
   (b) concrete, reinforcing bars, steel sheet, pipes
   (c) and (d) concrete or polyethelene pipes

B.

1. (a) continuous
   (b) batch
2. Hog waste
3. Admixture with water
4. 20,000 kg (total)
5. Total 10,000 kg every day, but 2 out of 48 batch digesters charged each day
6. About 2:1

C.

1. (a) 1700 m^3
   (b) pumping water, generation of electricity, needs of meat processing and canning plants
2. (e) 3,000 kg/day
3. Prolonged aeration and settling

D.

1. $US 266,000 (total)
2. (a) summer 30-34°C
   (b) winter 24-28°C
3. (b) sun
6. 100 per cent

169. Ministry of Energy, Centre for Nonconventional Energy Development

I

1. PNPC Complex, Merritt Road, Fort Bonifacio, Metro Manila, Philippines
   Tel: 85–38–11 or 89–19–66 Telex: 2660 (RCA)
2. 1977
3. Dr. Ernesto N. Terrado, Administrator
8. Research and development. Demonstration
10. Information. Research and development. Advisory. Consultancy. Training
11. Biogas seminars and workshops. Seminars on alternative energy sources.
13. Cow manure biogas production and utilization in an integrated farm system. Regional biogas demonstration plants. Practical application of producer gas from agricultural wastes residues as alternative fuel for diesel engine. Application of alternative sources of energy in an integrated village food processing system (completed)

    Pyrolysis of wastes. Communal biogas system for San Jose, Batangas. Techno-economic study of a communal biogas system using human wastes. Alternative energy system in a development model for a rice producing community. Communal system for converting waste to energy. Pilot dendrothermal plant for rural power. Domestic biogas promotion in human settlements. Biogas production from swine manure at the Reliable Farms Development Corporation. Integrated research on selected renewable energy systems. (ongoing)

II

A.

1. (b) movable
2. 2 units of 14.5 m^3
3. (a) cement, sand gravel bars
   (b) gauge 16 G.I. sheets
   (c) and (d) cement pipe

B.

1. (a) continuous
2. Cattle manure

3. Wastes and washings only
4. 200 kg/digester
6. 1:2

C.

1. (a) 10-21.5 m^3
   (b) 1 gas range, 1 gas burner and 1 refrigerator
2. (a) 1 kg/day/plant (for vegetables)
   (c) 8 kg/day
   (e) 5,000 kg/day/algae seeding
   (f) 0.2 kg/day/animal (sludge as animal feed)

D.

3. (b) sun
5. Lack of sufficient manure coming from the dairy parlor. Cattle manure is being collected from animals in the cattle shed, the wastes placed in drums and mixed with water to form a slurry.
7. The split designs offer more trouble than the continuous integrated ones

170. National Institute of Science and Technology

I

1. Pedro Gil Street, Ermita, Metro Manila, Philippines
   Tel: 50–30–41
3. Commissioner
4. Project Leader
5. (a) 6 (b) 72
6. 13 regional offices of NSDB
7. Technical support to Bureau of Animal Industry and Human Settlement in their biogas project.
8. Research and development. Extension
9. Designs and construction. Operation and utilization
10. Research and development. Information. Consultancy. Training
11. Biogas and mushroom production
12. On biogas technology with emphasis on microbial actions on the substrata to improve the yield and quality of gas produced.
13. Four projects (completed). One big project supported by ASEAN (ongoing)

II

B.

1. (a) continuous
2. Hog manure
3. 3 days of aerobic fermentation prior to changing
4. 20 kg
6. 3:1

C.

1. (a) 1.5 m^3
   (b) cooking
2. (a) 10 kg/day
   (c) 5 kg/day
   (f) 3 kg/day

D.

1. $US 470
2. (a) summer 33° C
   (b) winter 28° C
3. (b) sun
5. Leaks in the joints of sidings and flooring. Poured monolitic concrete is advised.
6. 95 per cent

171. Office of Rural Development

I

1. Rural Energy Resources Research Division, Institute of Agricultural Science, Suweon, Republic of Korea
   Tel: Suweon 6–1057
2. 1977
3. Dr. Young Dae Park
5. (a) 9 (b) 3/3
6. Yu Name Livestock technical College
7. Farm Machinery Institute. Livestock Experiment Station. Horticultural Experiment Station.
8. Study feasibility of village scale biogas plant in the Republic of Korea
9. Gas production, utilization of effluent, reduction methods of BOD in effluent.
10. Research and development

12. Studies on biogas generation from animal wastes. A feasibility study of village scale biogas plant during winter season.
13. Studies on material resources for biogas production. Development of biogas plant types and biogas utilization. Solar energy utilization. (ongoing)

    Integrated biogas research. (planned)

II

A.

1. (b) movable
2. 100 m^3
3. (a) cement concrete
   (b) iron made
   (c) and (d) cement concrete

B.

1. (a) continuous
2. Animal manures (pig)
3. Pretreatment: manure mixed with small amount of water and keeping it as it is for one day for melting the manures
4. 1900 kg/day
6. Manure 2: water 3

C.

1. (a) 185 m^3
   (b) cooking and heating the rooms

D.

1. About $US 23,450 in 1979
2. (a) summer 19°C
   (b) winter -8°C
3. (b) sun
4. Digester temperature was controlled at 35°C as much as possible by heating with biogas produced
6. This digester is operating as prototype-village scale biogas plant

172. University of The South Pacific, School of Agriculture

I

1. Alafua Campus, P.O. Box 890, Apia, Western Samoa
2. 1977
3. Dean and Head of School

4. Lecturer in Agricultural Engineering
5. (b) 1
7. As a regional university linkages with many institutions worldwide.
8. Degree and diploma training. Research and extension
9. Agriculture and related fields
10. Education. Training. Research. Extension
11. Degree in Agriculture. Diploma in Tropical Agriculture.

II

A.

1. (b) movable
2. 1.57 m^3
3. (a) reinforced concrete tank
   (b) G.I. sheet
   (c) and (d) ceramic pipe

B.

1. (a) continuous
2. Pig waste
3. Wastes washed down and screened to prevent big lumps going into digester.
4. 30 kg
6. 15:1 (including washing water)

C.

1. (b) cooking
2. (g) fish/duck pond

D.

2. (a) summer 85° C
   (b) winter 80° C
3. (b) sun
4. Not necessary
5. This digester was constructed in 1977, but no record is available about its performance. It has recently been repaired by students as part of their project. It has started to operate in April 1980 and the gas is coming out fairly well.
6. Only one digester in USP.
7. The inlet and outlet pipes need to be modified. Excess water going into the digester should be properly regulated.

173. University of Peradeniya, Department of Civil Engineering

I

1. Peradeniya, Sri Lanka
   Tel: 08-8029
2. 1950
3. Head of the Department
4. Professor M. Amaratunga
5. (a) 1 (b) 4
7. Ceylon Electricity Board; In-service Training Centre, Department of Agriculture
8. Research. Teaching
9. Development of burners. Integrated systems
10. Consultancy. Education
11. A short course on biogas technology is taught in B.Sc. (Engineering)
13. Collaboration with In-service Training Centre, Department of Agriculture in establishing an integrated system. Survey of biogas potential of a district in Sri Lanka. (completed)

    Setting up biogas units in Matale District based on the survey. (ongoing)

II

A.

1. (a) fixed (This type is now being used in view of prohibitive costs of steel movable holders.)
3. (a) and (b) brick work
   (c) and (d) clay pipes

B.

1. (a) continuous
2. Cattle dung
4. Depends on digester. Usually 1 lb of cattle dung is used to obtain 0.5 cu ft of gas produced.
6. 1:1

C.

1. (b) cooking
3. A layer retention time (about 60 days) is often used in the design for purposes of disease control.

D.

1. About $US 200 for a 10 m^3 fixed-dome unit
2. (a) summer 25°C

3. (b) sun
5. Gas leaks. Inadequate feeding and attention to maintenance
6. Only about 50 have been constructed in the country. Of these about 20 per cent may be said to be working.

174. Asian Institute of Technology (AIT)

I

1. P.O. Box 2754, Bangkok, Thailand
   Tel: 5168311-5 Cable: AIT BANGKOK
3. Dr. Robert B. Banks, President
4. Dr. Chongrak Polprasert
5. (a) 3 (b) 4
6. AIT Campus
7. With various local and international institutions
8. Teaching graduate levels and research
9. Civil engineering
10. Education. Research and development. Advisory. Consultancy
13. Recycling rural and urban nightsoil in Thailand (ongoing)

II

A.

1. (a) fixed
2. 3.5 m^3
3. (a) and (b) ferrocement
   (c) and (b) PVC pipe

B.

1. (a) continuous
2. Nightsoil with water hyacinth and straw
3. Mixing twice a day
4. 5.8 kg (mixture dry weight)
6. 11.5:1

C.

1. (a) 1.5 m^3
2. (c) 270 kg/day (4 fish ponds)

D.

1. $US 200
2. (a) summer 35°C
   (b) winter 20°C
3. (b) sun

175. Department of Health, Ministry of Public Health

I

1. Sanitation Technique 2, Sanitation Division, Department of Health, Ministry of Public Health, Bangkok
   Tel: 2828117, 2819461
3. Mr. Chit Chaiwong
4. Mr. Udom Churnoi
5. (a) 10
6. Sanitation centre, Region 1–9
7. Faculty of Public Health, Mahidol University. The National Institute of Energy. Department of Agriculture, Ministry of Agricultural and Co-operatives
8. Environmental sanitation
9. Public health
10. Demonstration of biogas plant in public, health centers, temples and schools. Technical assistance. Equipment: casing molds.
11. Training local health officials
12. The production of biogas from animal excreta.
13. Support for construction of 517 biogas plants (completed). Experimental project on fixed-dome type, as earlier designs leaked gas (ongoing). Research on production of biogas by anaerobic digestion of human wastes and other organic materials (planned).

II

A.

1. (b) movable
2. 3.4–9.4 m^3
3. (a) concrete tank
   (b) metal
   (c) and (d) asbestos pipe

B.

1. Semi-continuous
2. Pig excreta

4. 20 kg (for semi-continous digester)

6. 1:1

C.

1. (a) depend on excreta used
   (b) cooking
2. (a) 20 kg/day
3. No effluent treatment, because the digestion of excreta in the biogas tank greatly reduces the health hazard by killing pathogenic bacteria, parasite eggs and so on.

D.

1. $US 250
2. (a) summer 37°C
   (b) winter 25°C
3. (b) sun
5. There are several problems in digester operation: pH, toxicity, temperature and mixing.
6. 68.9 per cent digesters are in operation to the total number of digesters constructed (517 units)
7. Movable design is too expensive for rural people

176. Kasetsart University, Faculty of Agriculture

I

1. Animal Science Department, Bangkhen, Bangkok, Thailand
   Tel: 5790113 Ext. 350
2. 1978
3. Prof. Phaitoon Ingkasuwan, Rector
4. Dr. Pravee Vijchulata
5. (a) 2
   (b) 44 (big scale 2, medium 4, small 38)
6. Kamphaeng Saen
7. Division of Chemical Agriculture, Department of Agricultural Technology, Ministry of Agriculture and Co-operatives
8. Applied research for development
9. Biological science
10. Information. Education. Consultancy. Training.
11. Provided for undergraduate, graduated students and others interested.
13. Ongoing and planned.

II

A. 1. (b) movable

2. 200 m^3

3. (a) brick, cement and sand
(b) metallic and bamboo sheet
(c) and (d) cement

B.

1. (a) continuous

2. Manure

4. 800 kg

5. 10, 50, 100 kg/m^3 every 1 and 3 days

6. Cattle and buffalo = 1; Chicken and swine = 3

C.

1. (a) 30 m^3
(b) electricity

2. (a) 400 kg/day
(b) 100 kg/day
(c) 50 kg/day
(d) 50 kg/day
(e) 100 kg/day
(g) 100 kg/day (gardening)

D.

1. $US 900

2. (a) summer 31°C (b) winter 23°C

3. (a) shadow

7. Gas outlet should be connected at the digester wall itself. For the small scale say 6-8 m^3 of digester volume, bamboo sheet should be used as container. This will certainly be well adapted for the low income small farmers.

177. King Mongkut's Institute of Technology

I

1. Thonburi Campus, Bangkok 14, Thailand
Tel: 462-5719 Ext. 73

2. 1978

3. Dr. Morakot Tanticharoen

5. (a) 4 (b) 1

6. King Mongkut's Institute of Technology, Thonburi

8. Basic research. Research and development. Pilot testing
9. Microbiology. Engineering design of digester.
10. Research and development. Education.
12. Biogas from plant material
13. Biogas from plant material. Microbial populations in methanegenesis (ongoing)

Effluent from biogas digester as a source of single cell protein production (planned).

II

A.

1. (a) fixed
2. 2.40 m^3
3. (a) fibre-glass reinforced plastic
   (b) FRP
   (c) PVC pipe with brassgate valve
   (d) FRP cover bolts.

B.

1. (b) batch
2. Aquatic weeds
3. Mechanical mixer
5. 80(dry) kg every 21 days
6. 20:1 (dryweight of weed)

C.

1. and 2. under investigation

D.

1. $US 350
2. (a) summer 40° C
   (b) winter 30° C
3. (a) shadow
5. Leakage and seepage of gas through joints of tank and materials. These problems may be overcome by vacuum injection method in fabrication of tank.

178. Maejo Institute of Agricultural Technology

I

1. Maejo, Chiangmai, Thailand
   Tel: 236602
2. 1934

3. Prof. Vipata Boonsri Wangsai, Rector
5. (a) 3 part-time voluntary
   (b) 20
6. At the Institution
10. Training. Demonstration. Servicing directly. Advisory.
11. Integrated agricultural technologies like mushroom culture, crops etc.
12. Many in Thai, as handouts
13. Ongoing.

II

A.

1. (a) fixed: 3 (b) movable: 17
2. 10-12 m^3
3. (a) brick and cement
   (b) iron sheet
   (c) and (d) cement tube or brick and cement

B.

1. (a) continuous (b) batch
2. Swine or cow-buffalo dung
4. one to four buckets
5. 10-30 kg every day and other days
6. Half and half generally

C.

1. (a) 3-12 m^3
   (b) cooking
3. No, the process already kills everything, except the thriving anaerobic bacteria

D.

2. (a) summer 30° C
   (b) winter 22° C
3. (a) shadow (b) sun
6. 85 per cent
7. No design is trouble-free. The design without gas holder is most trouble-free but less efficient in thorough turn-over of old spent manure than design with gas holder but the latter is more expensive.

179. Mahidol University

I

1. Faculty of Public Health, 420/1 Rajavithi Road, Bangkok 4, Thailand
   Tel: 2827827
2. 1949
3. Dr. Debhanom Muangman, Dean
5. (a) 148
6. Phyathai, Bangkok
7. Providing technical advice to the Health Department and Provincial Health Offices. To do research projects with Sanitation Divisions.
8. Teaching and research in public health science
9. Environmental health science. Sanitary science
10. Teaching. Advisory. Consultancy. Research and development
12. Environmental sanitation. School health environment. Biogas from animal manures. Biogas from various organic materials. Fibre-glass – sanitary utensils
13. Biogas from animal manures and from various organic materials. Fibre-glass – sanitary utensils. (completed)

    Biogas engine. (ongoing)

    Socio-economic survey of digesters in rural areas of Thailand. (planned)

II

A.

1. (b) movable
2. 1.50 – 2.00 m^3
3. (a) concrete, casing rings and masonry
   (b) iron sheet, galvanized iron sheet, fibre-glass cement
   (c) 4 in diameter as minimum
   (d) 2 in diameter for over flow and 3 in diameter for sludge drainage pipe with gate valve

B.

1. (a) continuous
   (b) batch (for research project in some aspects)
2. Animal manures
3. None for animal manures, cutting and grinding or pounding for grass and water-hyacinth
4. 30-80 kg (for 2.5 m^3 digester)
5. 1/30 of total volume of digester (daily feeding)
6. 1:1 by volume

C.

1. (a) 2 m^3 (from 2.5 m^3 digester volume)
   (b) cooking
2. (a) 30-80 kg/day
3. The human excreta had been used as feeding material for research project in 1979. The over flow liquid was treated by sand filter before use. The digested sludge, after completed digestion (about 2 months), was put in the sun for 2-3 days for drying on sand beds before use.

D.

1. $US 150–200
2. (a) summer 33.88°C
   (b) winter 24.44°C
3. (a) shadow
5. Slurry feeding must be loaded to desirable amount. Space between digester and gas holder must be optimum (1" as min.), if smaller than 1" it will cause clogging. The digested sludge remaining at the bottom of the digester must be drained out periodically to provide the optimum volume for slurry as food of the organisms to produce biogas.
6. 100 per cent
7. The fibre-glass cement is being used as the new approach to solve corrosion problem and cheaper material. Chinese dome design is being used to get more and more experience. The Chinese dome type may be useful for the biogas project in rural areas in Thailand

180. Ministry of Agriculture and Co-operatives, Department of Agriculture

I

1. Bangkhen, Bangkok 9, Thailand
   Tel: 5790159, 5791994
2. Biogas research work in 1975
3. Mr. Paderm Titatan
4. Mrs. Revadee Deemark
5. (a) 4 (b) 11
6. Rice experimental stations at Supanburi, Rajburi, Sanpatong (Chiengmai), Kongan
7. National Research Council. National Energy Administraion. Health Department. Agricultural Extension Department.
8. Organic fertilizer production and utilization for farmers' self-sufficient and better crop yield

9. Research on appropriate technology: biogas application from crop waste and as manure

10. Information. Research and development. Consultancy. Advisory

12. Bi-monthly publication by the Department of Agriculture. Annual reports.

13. Studies on manurial value of digested flurry from biogas plants and from plant on sandy loam soil. Examination of the nitrogen balance of dung during anaerobic digestion. Utilization of biogas as alternative source of energy. (completed)

    Study on low-cost biogas digester. Biogas production from various plant wastes. Biogas production in dome digester. Biogas production by using slurry as seeding with plant wastes. (ongoing)

    Utilization of organic waste other than animal waste in biogas plant. Utilization of digested slurry with local rock phosphate to increase crop yield. (planned)

II

A.

1. (a) fixed (b) movable
2. 6 m^3 (fixed); 4, 5, 7 m^3 (movable)
3. (a) brick masonry (fixed) concrete (movable)
   (b) brick masonry (fixed); galvanized iron sheet, ferrocement (movable)
   (c) and (d) precast concrete pipe (fixed and movable)

B.

1. Semi-continuous
2. Cow dung, buffalo dung, pig and water-hyacinth
3. No pretreatment, completely mixed with water
4. 10 kg fresh dung/m^3
6. 1:1 by volume

C.

1. (a) 0.3 – 0.5 m^3/m^3 digester
   (b) cooking
2. (a) direct fertilizer on soil
   (b) 1:1 by weight
   (d) on trial
3. Ammonium fertilizer addition

D.

1. Movable 5 m^3 digester: $US 200 (excluding labour cost);
   Fixed type 6 m^3 digester: $US100 (excluding labour cost)
2. (a) summer 32°C (b) winter 28°C
3. (b) sun

5. Scum formation: attach stirrer for breaking scum and stir daily.

   Too low gas pressure for thin iron sheet gas holder: need to be loaded with heavy stone on top.

   Ferrocement gas holder leak: proper plastering and covering needed.

6. 100 per cent

7. Ferrocement gas holder is more advantageous due to lower cost and durability for movable gas holder. The Chinese fixed dome type is most convenient and inexpensive but laborious, requiring demonstration.

181. National Energy Administration

I

1. Pibultham Villa, Bangkok 5, Thailand
   Tel: 223-0021 Cable: NATPOWER

2. 1953

3. Mr. Pravit Ruyabhorn, Secretary-General, Mr. Prapath Premmani, Deputy Secretary-General

4. Mr. Phol Songpongs, Director, Technical Division. Mr. Sompongse Chantavorapap, Chief, Design and Energy Research Section. Mr. Savang Kulapatrapa, Chief, Biomass Energy Unit, Alternative Energy Study and Development Project

5. (a) biogas: 4 (b) 44

6. Technical Centre for Natural Energy and Fuel Test

7. Local universities and institutions through the Subcommittee for Co-ordination of Natural Energy Research under the auspices of National Research Council of Thailand and through the Subcommittee for Co-ordination of Study and Development of Alternative Energy under the auspices of National Energy Administration. USAID-Thai Nonconventional Renewable Energy Project in which biogas is included. Institute for Food Research and Product Development through Subcommittee on Management and Utilization of Food Waste Materials.

8. Resource assessment. Need assessment. Research and development. Development and demonstration. Demonstration and promotion or extension. Promotion or extension and popularization of biogas energy.

9. Biogas energy for lighting, cooking, pumping and driving engine

10. Information. Research and development. Technical service

12. "Thai cement water jar as a biogas digester of Thailand" (1979). "Utilization of biogas digesters in Thailand" (1978). "Manure on operation and maintenance of a biogas plant" (1978). "Report of experiment on engine fuelled by biogas".

13. Development of a low-cost biogas digester and a biogas engine system. Demonstration and promotion of biogas plants in rural areas. (ongoing)

Microbiology of methanization. Integrated system. Biogas pumping station. Popularization of rural biogasification. (planned)

182. Thailand Institute of Scientific and Technological Research

I

1. 196 Paholyothin Road, Bangkhen, Bangkok 9, Thailand
   Tel: 5791121–30 Cable: RESCORP BANGKOK
2. 1964
3. Dr. Samith Kampempool
5. (a) 5 (b) 2
7. Department of Health
8. Research and development
10. Information. Research and development. Advisory. Consultancy
12. Pre-feasibility study of the biogas application in rural areas of Thailand. Production of biogas from wastes using anaerobic packed digester. Anaerobic filter for biogas production
13. Production of biogas from animal wastes using anaerobic packed digester. Pre-feasibility study of the biogas technology application in rural areas of Thailand. (completed)

    Production of biogas using horizontal plug-flow digester. (ongoing)

II

A.

1. (b) movable
2. 0.2 m^3
3. (a) 200 l oil drum
   (b) galvanized sheet
   (c) and (d) steel pipe

B.

1. Semi-continuous
2. Pig waste
3. Screened and diluted
4. 1.34 kg (semi-continuous digester)
6. 14 litres

C.

1. (a) 0.1 m^3
   (b) lighting

D.

1. $US 35
2. (a) summer 34°C
   (b) winter 25°C
3. (a) shadow
5. There were, a few times, blockage problems due to the solid accumulation at the bottom part of the digester. The problems were overcome by opening the drainage pipe at the digester bottom.
7. Feed materials should be free from sand and soil

183. Indian Institute of Science, Centre for the Application of Science and Technology to Rural Areas (ASTRA)

I

1. Bangalore 560 012, India
   Tel: 3441 Ext. 447 Cable: 043 326
2. 1974
3. Professor A.K.N. Reddy
4. Mr. P. Rajabapaiah
5. (a) 10 (b) 4
6. Bangalore, India and Ungra village (extension centre), Karnataka, India
8. Research
9. Development of appropriate biogas systems for Indian villages. Low-cost modified Indian and Chinese type of plants. Community and family size plants. Usage of all possible materials for biogas production. Proper utilization of biogas process development (optimum gas production)
10. Research and development. Advisory. Consultancy. Information. Education. Training
11. In the formulation stage
12. *
13. Studies on biogas technology: performance of the conventional Indian biogas plant; optimization of plant dimensions; thermal analysis of biogas plants and innovation of a novel solar-heated biogas plant. (completed)

    Further studies on biogas technology: improvement of the solar-heated biogas plant, gas production from alternative materials for dung such as water hyacinth, recycling of water in biogas plants etc. Community biogas systems for villages (production and distribution of biogas, viz. fertilizer and water, including hot water, electricity generation and small-scale industries using biogas as energy source). Design and construction of ultra low-cost rural-oriented biogas plants (modified Indian and Chinese biogas plants). (ongoing)

II

A.

1. (a) fixed (b) movable
2. 3.5 to 100 m^3
3. (a) bricks, cement, sand etc.
   (b) mild steel, ferrocement etc.
   (c) and (d) bricks, cement, sand, A.C. pipes etc.

B.

1. (a) continuous (b) batch
2. Cattle dung
3. Mixing of water and dung, pretreatment for feed such as water hyacinth
4. Depends upon the size
6. 1:1 (by weight) for cattle dung

C.

1. (a) depends upon the size
   (b) mainly for laboratory use; in the extension centre, for cooking, lighting, engines etc.

D.

1. Floating type: $US 300
   Fixed type: $US 125 (family size)
2. (a) summer 30°C
   (b) winter 20°C
3. (b) shadow
4. Solar heating
5. Floating type: corrosion is minimized by proper painting.
   Fixed type: leakage is overcome by proper scaling.
6. 100 per cent

184. Shri A.M.M. Murugappa Chettiar Research Centre Photosynthesis and Energy Division

I

1. Tharamani, Madras 600 042, India
   Tel: 41 19 37 Cable: WELDABLE
   Telex: MCRC CARE TUBEIND 041 301
2. 1977
3. Dr. C.V. Seshadri

4. Dr. B.V. Umesh, Dr. C.V. Seshadri
5. (a) 5 (b) 8/5
6. Tharamani, Madras
7. With other institutions involved in the development of biogas plants
8. Research and development, fabrication and field level demonstration of biogas plants
9. Solar, wind and biomass for village level self-reliance
10. Research and development. Consultancy. Training
11. 2-week programme under consideration
12. A monograph on MCRC design of biogas plant is under preparation
13. Field testing of the present design. (ongoing)

    Incorporation of water-hyacinth utilization in the present design. (planned)

II

A.

1. (a) fixed
2. 6 m^3
3. (a) bricks, cement, sand and blue-mental jelly
   (b) wooden geodesic frame, low density polyethylene sheet 1000 gauge
   (c) and (d) ceramic pipe

B.

1. (a) continuous
2. Cattle dung
4. 100 kg
6. 1:1 when the dung is fresh or 2:1 to 3:1 depending on the age of the dung

C.

1. (a) 4 m^3
   (b) laboratory purposes and cooking for staff
2. (b) 50 kg/day
   (g) 50 kg/day (for algal ponds)

D.

1. $US 250
2. (a) summer 30-38°C
   (b) winter 20-28°C
3. (b) sun
5. (i) The LDPE sheet is vulnerable for damages especially from playful child-

ren in villages. This requires protective cover over the balloon and can be of thatched or bamboo structure.

(ii) Removal of scum is required once in 8 or 10 months. However the simplicity with which the gas holder can be removed does not make it a problem. The whole process of cleaning and replacing the dome hardly takes 2 hours and again by evening the plant is ready for supplying the gas.

(iii) Punctures caused accidentally can be easily located with soap water and patched up with any self-adhesive tapes available in the market.

6. 62. 5 per cent

7. (i) It is desirable to remove any fibrous material prior to charging the digester.

(ii) Proper protection of the LDPE sheet would save plenty of trouble in locating the punctures and can give trouble-free service for a long time

185. Development and Consulting Services

I

1. Butwal, Nepal Cable: DSC BUTWAL
2. 1971
3. Mr. Martin Arnhorn, Director
4. Mrs. M. Wong, Mr. D. Fulford, Mr. A. Bulmer, Mr. J. Finlay
5. (a) 2 (b) 500
6. Butwal
7. Butwal Technical Institute; United Mission to Nepal
9. Biogas. Small turbines. Solar water heaters. Grain processing. Village electrification
10. Information. Research and development. Advisory. Consultancy. Education. Training
11. As requested

12 *

13. Design and construction of floating gas holder drum type gas plant, cu ft per day of 100, 200, 350 and 500; drumless gas plants of 10, 15, 20 and 50 cu m; gas production equipment; hard gobar mixer; 1300 in water pressure gauge. (completed)

    Tunnel plant. Maximizing gas production in village gas plants. Gas taps for high pressure gas. Attaching small generator to biogas/diesel engined water pump for lighting 15 lamps in village. (ongoing)

    Gas lamp. Large gas store. Pressure regulator. (planned)

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* This bibliography is not intended to be comprehensive. Along with the entries under experts and institutions, it is aimed at indicating current trends in research and development of biogas in regional member countries of ESCAP.

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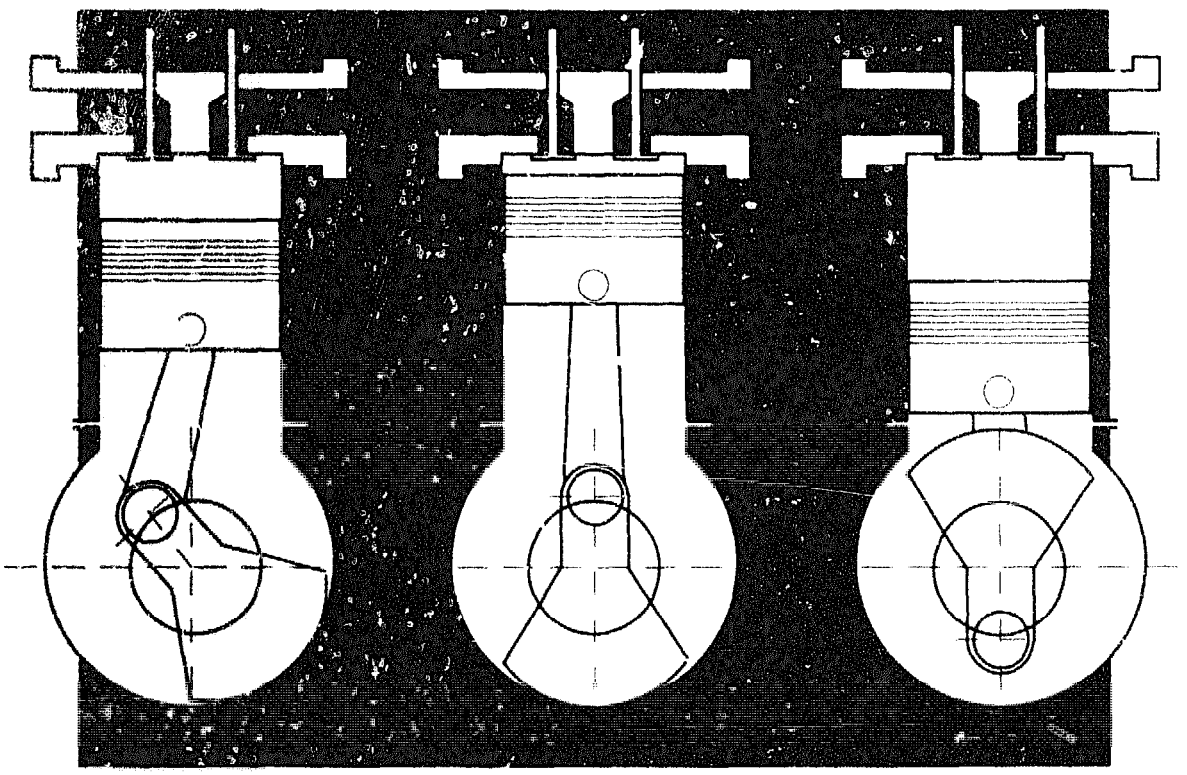

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Preface

We have decided to publish this edition of the Rural Mechanics Course in response to the many requests from people involved in training for technical vocations and in general development work.

The main aim of this set of books is to provide technical training information in understandable language and with illustrations suited to the understanding of those involved.

The contents of these books reflect the rural development taking place in the agricultural sector in particular, where many urgent needs have to be looked after and solved in order to achieve sound development at all levels.

This Rural Mechanics Course has been compiled for teaching in Technical Vocation Centres in addition to a Rural Building Course, which deals with skills such as carpentry and masonry.

We are grateful to the Stichting Brothers F.I.C., Stichting TOOL for their technical assistance, Stichting Cebemo for their financial support and the German Volunteer Service for so many volunteers who have contributed in no small way to the compilation of these books.

It is our sincere wish that the contents of these books may be of assistance in stimulating the use of appropriate techniques to aid agriculture and general development.

Bro John van Winden F.I.C.

Introduction

In many situations radical and urgent changes are taking place in rural areas in order to restore land to agriculture, to bring about better living conditions and secure health and educational facilities - the basis for a healthy economy.

Needs arising from these changes are not always dealt with because many technical institutions do not provide appropriate technical training geared to solving problems which have gone unnoticed in the past.

It can also be noted that small co-operative workshops are being started these days in the interests of agriculture and these too may develop as they deal with the upkeep of small mechanized farm implements and diesel engines used for water supply or with making ploughs, handcarts, gardening tools, etc.

Integrated and relevant technical training and grouping young people together into co-operative movements should be emphasized to ensure sound agricultural and general development. That is why an attempt has been made to achieve appropriate technical training for rural mechanics, who will contribute in no small way towards the necessary development.

Since the technical needs in rural areas are many but do not on the whole need highly specialised technicians to solve them, the rural mechanic - because his training covers a broad basis - will often be solving problems arising from the introduction of new implements or tools.

The course lasts four years, almost two years of which are set aside for so-called 'on-the-job training'. This is practical training provided in various workshops under the guidance of qualified technicians as well as a centre instructor who visits the workshop at intervals to see for himself how the trainees are progressing. During 'on-the-job training' the trainee is rewarded for his work which may help him later to buy the set of tools he has used during his training, so he can start working immediately after completing the course successfully.

Rural mechanics course

A set of four books has been compiled to accompany the four-year course for rural mechanics:

1 - General metal work, sheetmetal work and handpump maintenance
2 - Blacksmithing, welding and soldering
3 - Maintenance and repair of stationary diesel engines
4 - Technical drawing

While each of these books covers the full material of one course, a lot of additional information needed besides the contents of one particular book will be found in another book. So it is difficult to use just one of these books without consulting the others. The text on the properties of metals, for example, is to be found in the general metal work book. But this information is also needed when you are dealing with other subjects, such as diesel engines, blacksmithing etc.

As mentioned above, this course is made up in such a way that most of the practicals can be carried out with a limited set of tools. You will however notice that [illegible] equipment or tools are needed sometimes and these must be available in the Vocational Centre s workshop.

It is believed and hoped that with the formation of co-operatives these additional tools and equipment will be available in the workshops because, though they are more expensive, they can be owned by the group.

The main aim of this course is that the trainee, besides acquiring a good formative background, will learn to master such skills as:

- working with and maintaining all the tools explained
- blacksmithing to such a degree that he will be able to shape different metals to the required implements, tools, etc.
- repairing, maintaining and installing hand waterpumps
- dismantling, repairing and assembling stationary diesel engines
- sketching or drawing simple items in orthographic, oblique and isometric form; reading engine or machine manuals.

This set of books can be used partly in the classroom but must also be used during workshop practice, where the reality of what can be seen will add greatly to the text and illustrations in the books. Practical exercises recommended in the books can be varied since the practical nature of this course calls for articles to be made which can be used directly by people who may order them. But care should be taken that, though production may be necessary for one reason or another, all the skills which must be mastered are incorporated in each practical, so as to ensure sound training.

It is very important to study the proposed timetable given in each book to ensure that all skills are given the necessary attention. Apart from the progress made by each trainee, the time recommended for each skill may vary as well. Some skills take more time to master than others.

You will note the absence in this course of the science which may be important in explaining the diesel engine in particular. Providing this background theory is however beyond the scope of the course. But if the need arises, the relevant science should be included during part of the related subject time.

This Rural Mechanics Course is the result of many years' observation and experimentation with different techniques. The contents have frequently been revised to serve all those interested in rural development, and it is hoped this course will be used in many technical vocation centres and communities. It is also the sincere wish of the founders of this course that the trainees should feel on completion of their training that they are able to contribute personally to the development of the rural areas, which is of such importance to any general development.

Rural mechanics course lay-out and timetable

Four year training course

a - Full Centre training: workshop practicals, trade theory, technical drawing and related subjects. Two years = 80 weeks

b - Partly Centre training: trade theory, technical drawing, related subjects. Practicals take place outside the Vocational Centre. One year = 40 weeks

c - On-the-job training: practicals take place outside the Vocational Centre. (Practicals are however controlled by Centre staff and marks are awarded for any progress made.) One year = 40 weeks

Total vocational training time
Four years = 160 weeks

Weekly timetable for related subjects and practicals

a - Trade theory	4	hours
b - Technical drawing	1½	hours
c - Mathematics	2	hours
d - Language	2	hours
e - Other related subjects	2½	hours
Total related subjects	12	hours
Total hours workshop practice	28	hours
Total training time in centre	40	hours

Four-year timetable, workshop practicals

One full year reserved for Centre workshop practice:

a - General metal work
b - Blacksmithing
c - Welding and Soldering
d - Sheetmetal work 1120 hours

One full year reserved for Centre workshop practice:

a - Stationary diesel engines
b - Agricultural machinery 1000 hours
c - Water pumps and water supply 120 hours

Two full years reserved for on-the-job training:

a - One year partly practicals 1120 hours
b - One year full on-the-job training outside the Centre. (Care should be taken that the time is evenly divided for practical training in all skills.) 1760 hours

Three-year Centre timetable for trade theory

a - General metal work	240 hours
b - Welding and soldering	
c - Blacksmithing	
d - Sheetmetal work	
e - Stationary diesel engines	220 hours
f - Waterpumps and supply	20 hours
Total theory time:	480 hours

General

Stationary diesel engines

With the introduction of mechanically driven water pumps, small agricultural machinery and electric plants for all kinds of purposes in modern agriculture and general development, an urgent need has grown up for skilled people able to look after diesel engines – the main power source for these machines.
That is why a widely trained mechanic who owns certain tools and equipment should be able to carry out most of the common repairs and maintain these engines used in rural areas.
This part of the Rural Mechanics Course provides the necessary information for technical training on water and air cooled 1, 2, 3 and 4 cylinder stationary diesel engines, including:

- reading engine manuals,
- installing stationary diesel engines,
- dismantling an engine,
- checking parts,
- repairing certain items,
- knowing how to order engine parts,
- assembly of the engine,
- ensuring sound running of the engine,
- keeping up the maintenance of the engine.

Diesel engine theory

This diesel engine theory book can be used in the classroom as well as in the workshop, where text and illustrations will help the instruction on the operation of the diesel engine and ensuring sound running of the engine.

During workshop or classroom theory lessons, making use of large technical aids is very much encouraged. The aids may be real parts cut in sections or self-made parts from all kinds of material made and coloured, to show the trainee clearly the function(s) of that particular part.

It is advisable to start instruction on diesel engines only when the trainee has finished the major part of the whole Rural Mechanics Course, technical drawing and general metal work, which can be seen as preparatory to this part of the course.

Although some science is needed for the instruction on diesel engines, it is left to the instructor to find the time and the suitable materials to teach this science.
Going through this book you will rightly note that no very detailed explanations are given on the construction of the diesel engine. This is because the course is only meant to teach the trainee the principles behind the working of the stationary diesel engine and not the composition of special metals or materials used in these engines, or the repair of very complicated parts.

During theory lessons in the classroom or workshop, ample time should be given the trainee to make the necessary notes and any question should be correctly formulated before explanations are asked for.

Diesel engine workshop practice

During workshop practice where several trainees are working on one engine, it is advisable to appoint one trainee supervisor of the group. He should be responsible for organizing the work to be done, recording all technical data, final checking of all parts, for assembly and smooth running of the engine. The engine may only run with permission from the instructor and in his presence. Each trainee should be appointed to the position of supervisor by rota.

Enough time should be set aside for instruction on how to install diesel engines and, if required, to the attachment of equipment. Special attention should be paid to ventilation in an engine room, because high temperatures reduce the life of diesel engines considerably. The storage of fuel should be given the necessary attention because in rural areas fuel is mostly bought and stored in bulk, which must be done under the correct conditions.

During workshop practice trainees should be encouraged to carry out many jobs on the engine with a limited set of tools or equipment. But, however the limited set of tools, the trainee should learn to use the correct ones. Too often spanners or tools are used which do not fit correctly, resulting in damage to nuts and bolts in parts of vital importance.

Correct teaching of this course makes it necessary to have additional tools and equipment in the workshop and to instruct trainees in how to work with them. This is necessary, because the trainee himself may not be able to buy this equipment but he may be able to use them at a later stage when working in a co-operative workshop where the group owns these tools or equipment.

It is left to the discretion of the instructor to use his creativity to teach trainees how to make and construct additional equipment which they can make by themselves during other workshop practicals.
Working with limited equipment also means that trainees must learn to judge when to go to more specialized workshops where more complicated engine parts, such as fuel pumps and injectors, can be checked and repaired.

As a lot of time in this course is set aside for practical training, especially during on-the-job training, not much time will be available for repairing all kinds of diesel engines which may need repairs.
Instruction on cleaning and systematic working is very important. During the practicals in the workshop, parts should be handled with care, recorded and stored in a box and locked in a storeroom after the lessons.
The progress made by trainees in the workshop and also during on-the-job training should be recorded. In general, marks should be given for constructional skills and other marks for the way in which the work is carried out. These marks will differ in value when a final mark is calculated.

Stationary diesel engines

Following the technical development in rural areas you will notice that, besides newly developed tools and equipment, the diesel engine has also been introduced to ensure extra power supply where this is necessary.
Small electric plants used in hospitals, schools and co-operative workshops, grinding mills for flour, bore-hole water supply etc. demand power that can be supplied by diesel engines.
The need for more power supplied by diesel engines is accompanied by the urgent question of how to install and maintain these engines.
Since the power requirements are mostly moderate, this book explains installation, maintenance and smooth running of only stationary diesel engines.

When you look at a stationary diesel engine, you may be confused at first to see so many external parts mounted on the engine and you may also wonder about their purpose. But basically there are only a few real differences, such as the number of cylinders, the actual fuel supply to the cylinders and the cooling which can be either water or air cooling. Many other parts are installed to ensure high engine performance.

A typical air cooled stationary diesel engine is shown on page 13 and all external parts are named. This kind of engine is used widely and is either air or water cooled, depending on requirements. As you rightly note, this engine has one cylinder and one fuel pump which is located behind the fuel pump cover. When more power is needed, a similar engine is possible with a longer crankcase onto which more cylinders are mounted. For each injector a separate fuel pump may be installed or a common fuel pump from which all injectors are supplied with fuel.
Whatever the difference may be, you should first understand that during performance, maintenance and testing the engine should be mounted ridgidly to a firm base.

Installation of stationary diesel engines

During maintenance in the workshop and operation in the engine room a stationary diesel engine should be bolted to a firm base in such a way that it cannot vibrate excessively during operation. You must make sure that all points of the crankcase with holes for the bolts are resting correctly on the base, to avoid stress when the nuts are being fastened.

In dusty places, such as rooms where flour is ground or woodwork is done, a water cooled diesel engine is recommended, because dust in the air may jam the fan blades and also block the fins around the cylinders, reducing the essential optimum flow of fresh air.

Especially in tropical areas, diesel engines should be installed in such a way that a generous supply of fresh air is ensured and precautions are taken against dust. It is very important to keep in mind that clean air is very important for correct performance by a diesel engine.

When working on a diesel engine it is essential to have the manufacturer's manual in addition to this book to ensure correct settings and dimensions of parts.

Let us take a look at the next page where you will see figures of the external parts of a typical air cooled one-cylinder diesel engine.

Typical air cooled diesel engine

Front view:
- Fuel tank **1-A**
- Fuel pump cover **1-B**
- Stop/start handle **1-C**
- Crankcase cover **1-D**
- Starting shaft **1-E**
- Flywheel **1-F**
- Fan cover **1-G**
- Cylinder head cover **1-H**
- Valve lifter **1-I**
- Fuel overflow **1-J**

Back view:
- Fuel tank cover **2-A**
- Air filter **2-B**
- Exhaust **2-C**
- Fuel filter **2-D**
- Lubrication oil dip stick **2-E**
- Speed adjustment **2-F**
- Fuel pipe **2-G**
- Camshaft extension **2-H**
- Gear cover **2-I**
- Fuel tank cover **2-J**

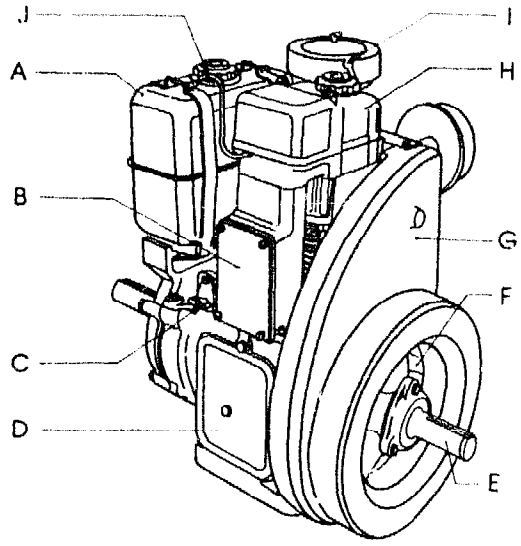

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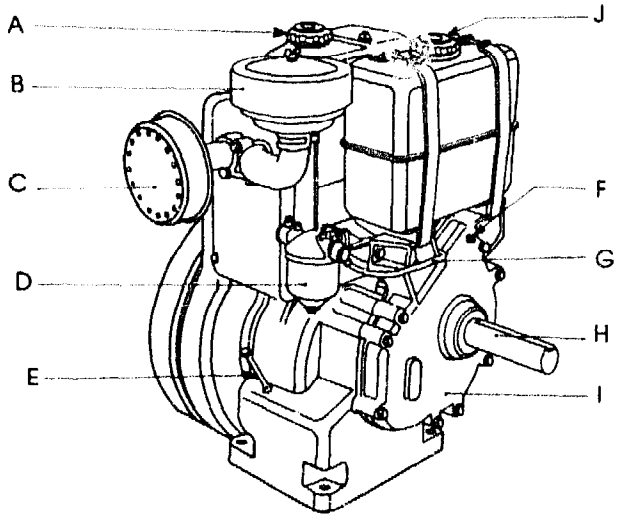

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Water cooled one-cylinder diesel engine

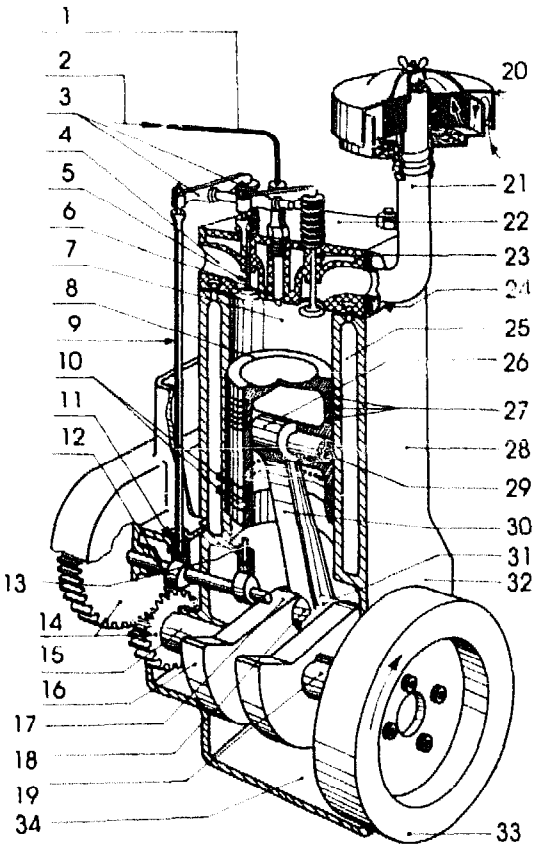

1

Figure 1 shows a section of a one-cylinder water cooled diesel engine. From the previous page you have learned the most important external parts. Now you have to learn the most important internal parts of the diesel engine.

1 – Fuel pipe
2 – Fuel from fuel pump
3 – Rocker arms
4 – Exhaust
5 – Exhaust valve
6 – Injector
7 – Cylinder
8 – Piston
9 – Push rod
10 – Oil scraper rings
11 – Tappet
12 – Camshaft
13 – Push rod
14 – Timing transmission
15 – Crankshaft
16 – Counterweight
17 – Throw
18 – Big end
19 – Journals
20 – Air filter
21 – Manifold (inlet)
22 – Cylinder head
23 – Inlet valve
24 – Cylinder head gasket
25 – Cooling compartment
26 – Small end (connecting rod)
27 – Piston rings
28 – Gudgeon pin
29 – Cylinder block
30 – Connecting rod
31 – Big end (connecting rod)
32 – Crankcase
33 – Flywheel
34 – Sump

Water cooled one-cylinder diesel engine

Figure 1 shows a cross-section of a one-cylinder, water cooled diesel engine. The most important parts connected to the functioning of the diesel engine are shown.

1 – Valves
2 – Combustion chamber
3 – Top Dead Centre (T.D.C.)
4 – Full stroke
5 – Bottom Dead Centre (B.D.C.)
6 – Entrance coolant
7 – T.D.C. crankshaft
8 – Throw
9 – Journal
10 – Counterweight
11 – B.D.C. crankshaft
12 – Sump
13 – Injector
14 – Cylinder head
15 – Cylinder head gasket
16 – Cylinder bore
17 – Top, piston
18 – Piston rings
19 – Piston
20 – Gudgeon pin
21 – Engine block
22 – Cooling compartment
23 – Connecting rod
24 – Crank case
25 – Big end (connecting rod)
26 – Crankshaft
27 – Distance half stroke
28 – Distance full stroke

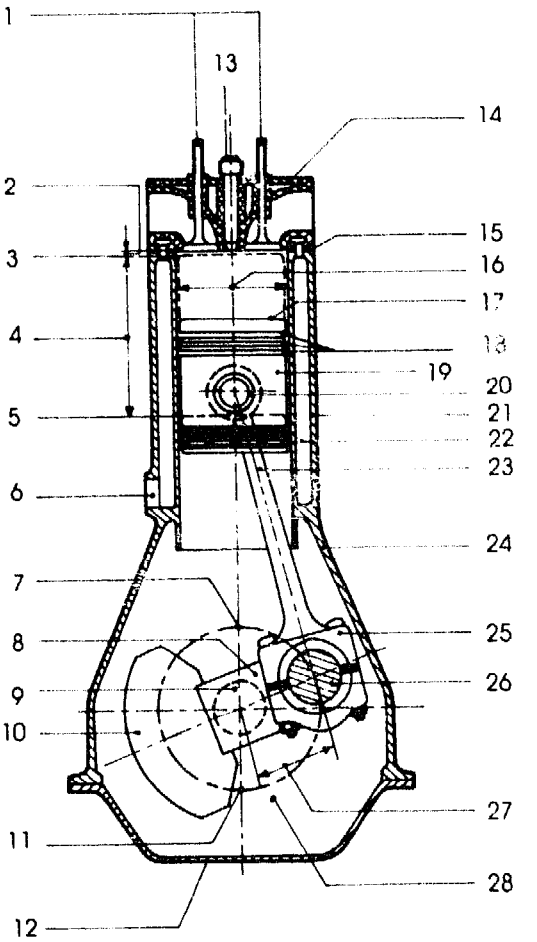

1

How the diesel engine operates

Internal combustion engine

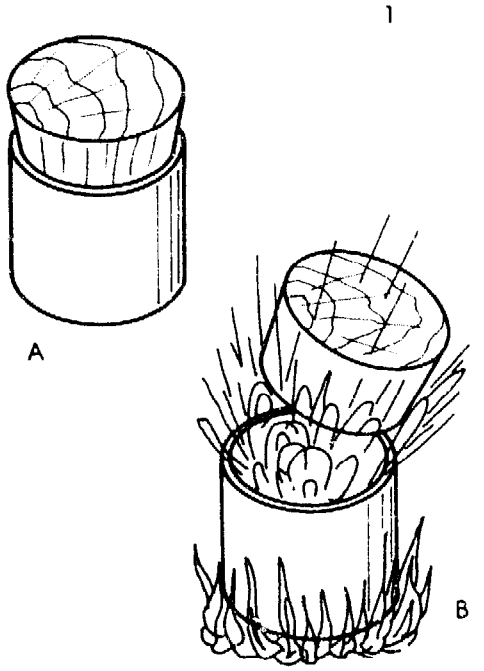

An internal combustion engine is an engine which burns fuel *internally*. This engine is basically a container, see Fig. **1**, into which *fuel* and *air* can be fed and made to burn. Figure **1-A** shows just such a container, closed with a stopper, in which there is a mixture of *fuel* and *air*. The mixture of fuel and air is highly flammable. If by any means the mixture is ignited, the container explodes, throwing the stopper out of the container with force, as shown in Fig. **1-B**.

Air has two properties which affect the engine:
- Air can be compressed.
- Air gets hot when it is compressed.

Fuel should mix readily with air and ignite easily by vaporizing. Vaporizing helps each particle of the fuel to contact enough hot air to burn fully.

Combustion is the actual igniting and burning of the fuel/air mixture. It is the oxygen in the air which combines with fuel to cause combustion.

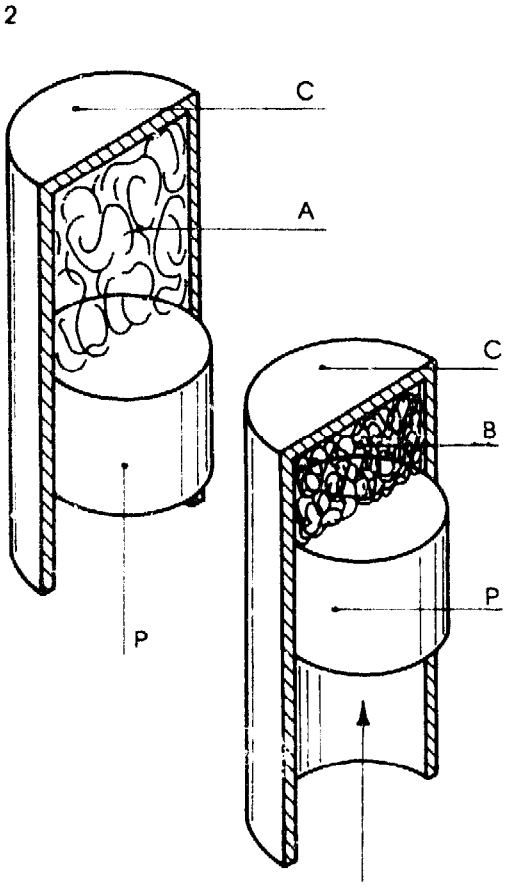

Fast burning fuel

If a container with diesel fuel is ignited in calm outside air, it burns rather lazily, because the air contacts only the surface of the fuel. To make it burn faster we have to:
- heat the fuel,
- vaporize the fuel.

But too powerful an explosion damages an engine, so we have to control the rate of burning. The rate of burning depends on:
- how much the air is compressed and thus heated,
- how much fuel is used,
- how volatile the fuel is.

Figure **2** shows the fuel/air mixture **2-A** trapped in a strong cylinder which is closed at one end. A piston **2-P** is fitted into the cylinder in such a way that it can move up and down inside the cylinder, but while moving, it keeps the gases tightly locked inside the cylinder.

When the piston is moved upwards the fuel/air mixture is compressed in chamber **2-B**. When the compressed fuel/air mixture is ignited it explodes, creating a high pressure in the cylinder **2-C** above the piston **2-P**. The pressure then pushes the piston down in the cylinder and this produces mechanical energy.

Reciprocating and rotary motion

The up-and-down motion occurring in the cylinder is called *reciprocating motion*, see Fig. **1-R**. In the engine the reciprocal motion of the piston must be converted into *rotary motion*, to be able to drive any gears. Four basic parts are needed to make the engine work this way:

- cylinder
- piston
- connecting rod
- crankshaft

As explained before, the piston and the cylinder are mated parts. They are fitted so closely that no gases can escape, but with a little clearance at the sides to ensure a smooth reciprocating motion. See Fig. **2**.

The link transmitting the reciprocating motion of the piston to the crankshaft is called the connecting rod, **2-A**. The crankshaft **2-B** has a section off the centre line of the shaft so that it 'cranks' when the shaft is turned. This rotary motion is basically the same as pedalling a bicycle. Your leg is like the connecting rod, while the pedal crank and the sprocket are like the crankshaft.

The whole combination shown in Fig. **2** makes it possible to convert the reciprocating motion **2-C** into a rotary motion **2-D**.

1

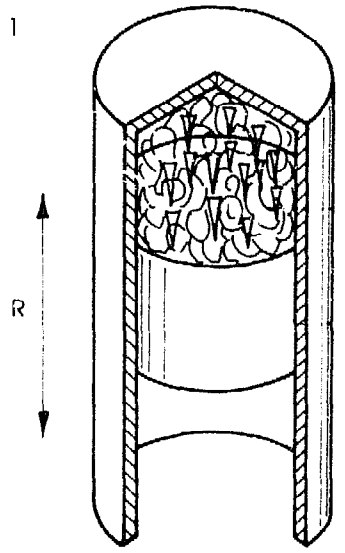

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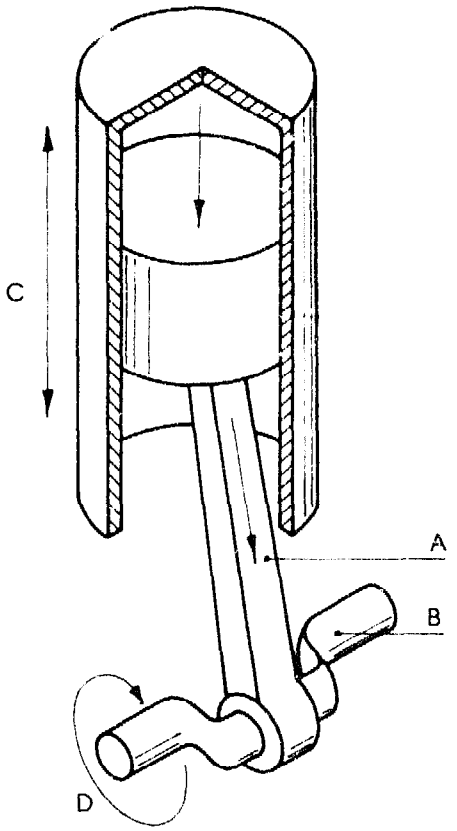

T.D.C., B.D.C., stroke, bore, volume throw and compression ratio

1

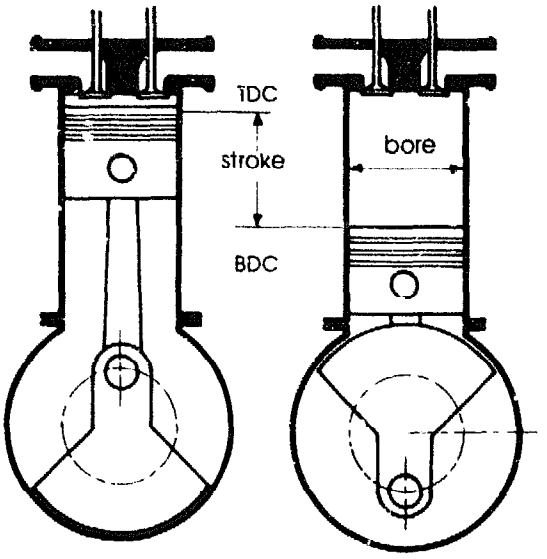

Top dead centre
When the piston is at its highest position, the piston is at *top dead centre* (T.D.C.), see Fig. **1**

Bottom dead centre
When the piston is at its lowest position, the piston is at *bottom dead centre* (B.D.C.), see Fig. **1**.

Stroke
The distance between T.D.C. and B.D.C. is called *stroke* (S), see Fig. **1**. The stroke is measured in mm.

Bore
The inside diameter of the cylinder is called *bore* (B), see Fig. **1**. The bore is measured in mm.

Throw
The distance between the centres of the crankshaft and connected rod journals is called *throw* (T). The throw is half the distance of a stroke, see Fig. **2**.

2

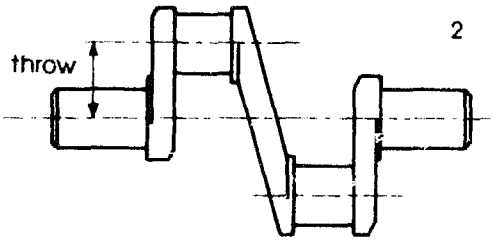

Compression ratio
Compression ratio is the total volume of air in a cylinder when the piston is at B.D.C. compared to the volume in the combustion chamber when the piston is at T.D.C. – for example 16 to 1 in a diesel engine. Refer to Fig. **3**:

Compression ration =

in principle:

(Stroke (**A**) + Combustion Chamber (**B**)) / Combustion chamber =

= Stroke volume = $\pi/4 \times D^2 \times$ Stroke length (**A**)

Comb volume = $\pi/4 \times D^2 \times$ Comb chamber height (**B**)

Compression ratio = (**A** + **B**)/**B**

Described, for example, as 16:1.

3

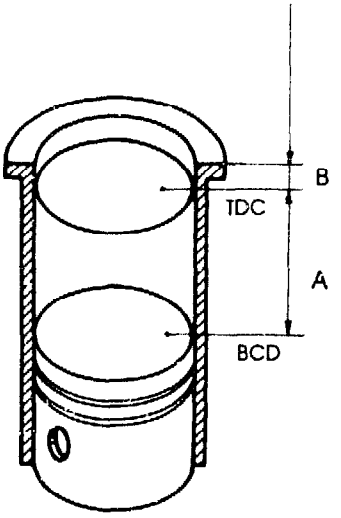

The four-stroke cycle engine

For the operation of this engine, a series of events must take place in sequence:

- *Induction stroke* **1-A**
  Clean air is drawn through an air filter into the cylinder. The air enters through the open *inlet* **1-I** valve as the piston moves down on the induction stroke.
- *Compression stroke* **1-B**
  The inlet valve closes and, as the piston *rises*, the trapped air is compressed to the required pressure. Fig. **1-X** shows the moment the air is compressed and the fuel is injected.
- *Power stroke* **1-C**
  At second the fuel is sprayed, particles vaporise almost instantaneously and start to burn. The heat needed to ignite the particles comes from the very high pressure of the compressed air charge. As combustion continues, the pressure in the cylinder rises very rapidly and the piston is forced down to give the power stroke.
- *Exhaust stroke* **1-E**
  Towards the end of the power stroke, the exhaust valve opens to allow the waste products of combustion to escape. With the exhaust valve **1-E** fully open, the cylinder is completely emptied of the waste products as the piston rises for the second time.
  Figure **1-Y** shows the moment the exhaust valve closes and the inlet valve opens again.

1

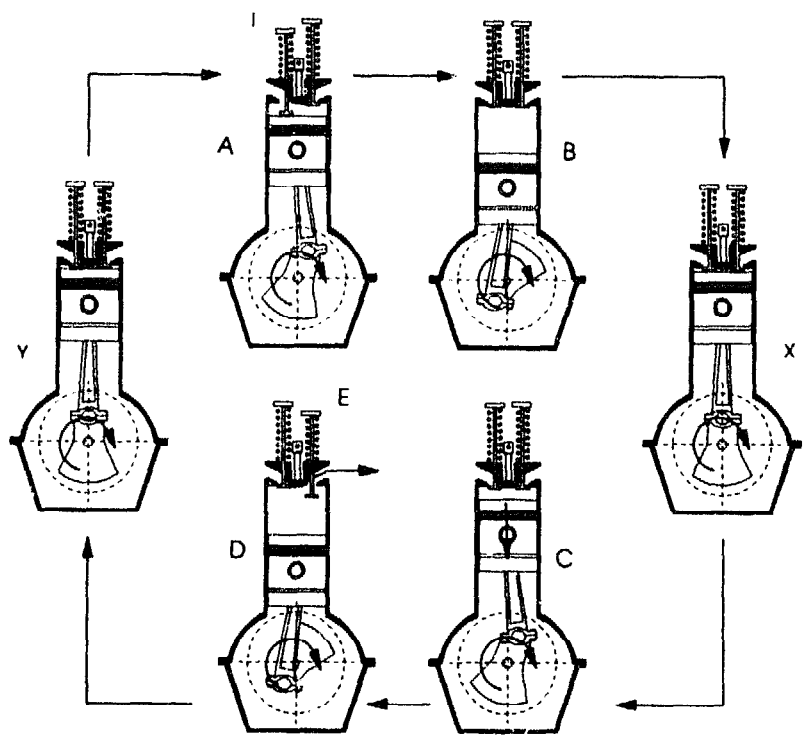

Multiple cylinder engines

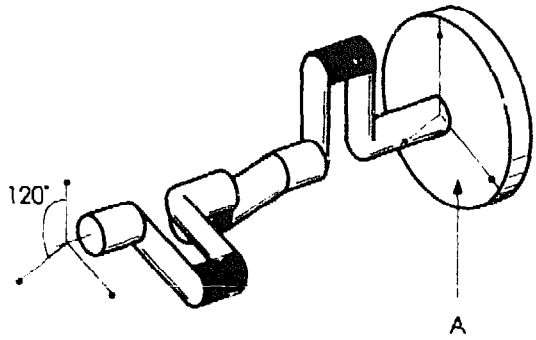

So far we have seen the operation of one cylinder in an engine, but since this cylinder gives only one power stroke every two revolutions of the crankshaft, it produces power only one quarter of the time.
For more continuous power, extra cylinders are added to the engine and each one delivers one power stroke during the two revolutions of the crankshaft.

The power strokes thus follow each other more closely, resulting in a fairly continuous delivery of power to the crankshaft. For example, in a typical four-stroke cycle engine with three cylinders, the cranks are set 120° apart on the crankshaft, see Fig. **1**.

The cylinders normally fire and deliver their power strokes in the following order: 1 – 3 – 2. The power strokes follow each other closely, thus ensuring continuous and smooth delivery of power to the crankshaft.
The heavy flywheel **1-A** attached to the crankshaft at the rear gives it momentum to return the pistons to the tops of the cylinders after each power stroke. Counterweights on the crankshaft are used to help balance the forces created in the engine by the fast moving parts.

2

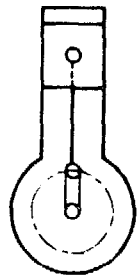

A

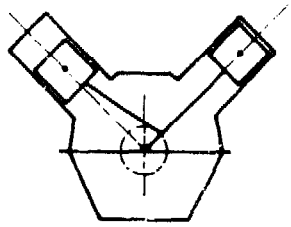

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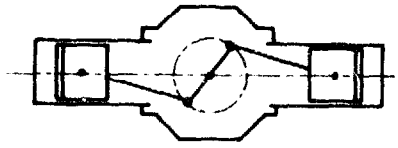

C

Different types of engines
Besides the *in-line engine* shown in Fig. **2-A**, you may see some other types of engines, such as an engine with the pistons lined up in a 'V'. So Fig. **2-B** shows an engine called a *V-engine*. Another arrangement of pistons is shown in the engine in Fig. **2-C**. This is called a *boxer engine*. It has the pistons situated opposite to each other on the side of the engine.

Components of the engine

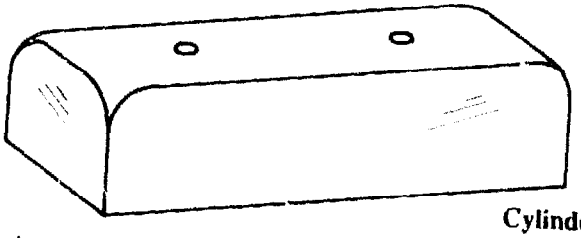

Cylinderhead cover

gasket

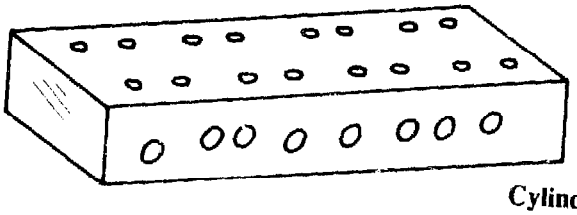

Cylinderhead

gasket

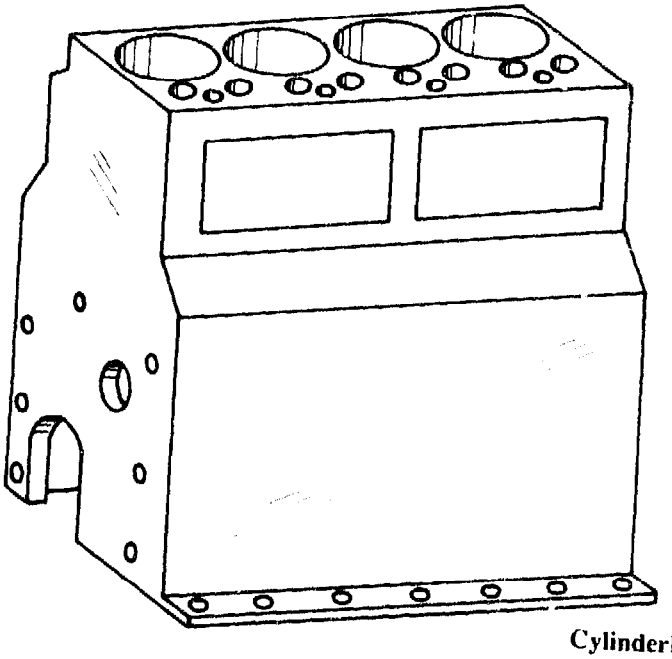

Cylinderblock

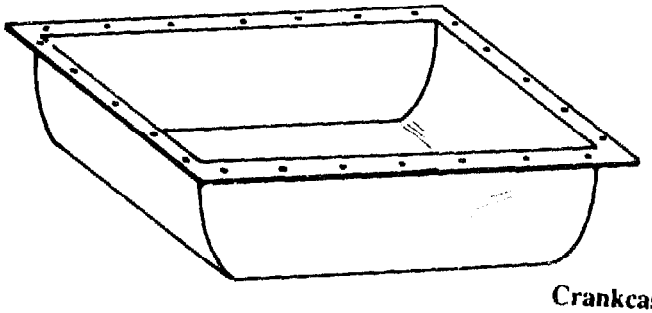

Crankcase

Components of the engine

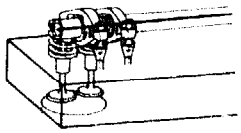

Cylinderhead: valve assembly

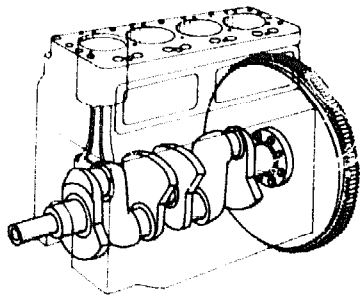

Engine block: flywheel and crankshaft

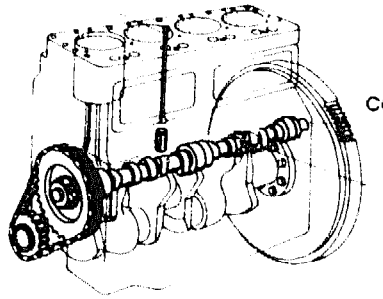

Engine block: camshaft

Cylinder head and valves

Cylinder head

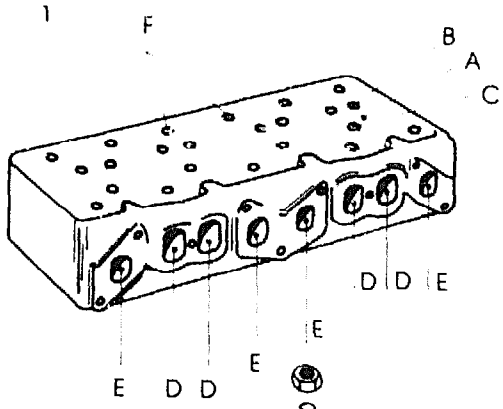

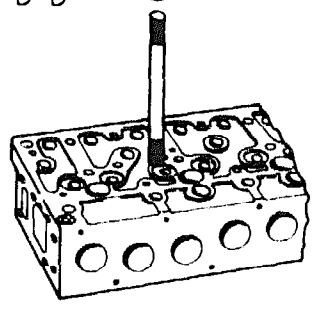

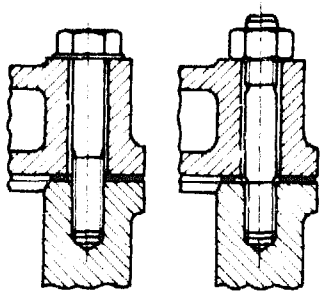

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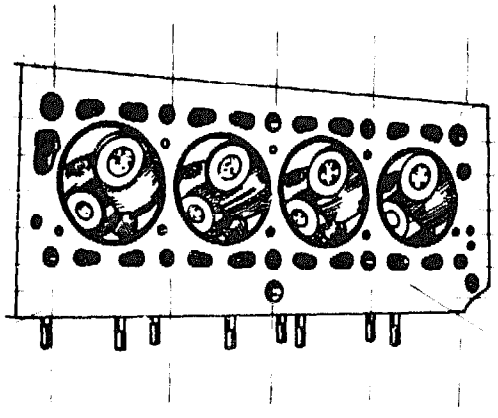

4

The cylinder head is fitted at the top end of the cylinder block and secured with studs or bolts passing through the head to the cylinder block. Most cylinder heads are cast from an alloy of iron and copper or aluminium. The intake and exhaust passages are cast or bored into the cylinder head as shown in Fig. **1**:

- Cylinder head **1-A**
- Holes for valves **1-B**
- Holes for pushrods **1-C**
- Holes for air inlet **1-D**
- Holes for exhaust **1-E**
- Holes for bolts or studs **1-F**

Part of a typical cylinder head is shown in Fig. **2** with an exploded view of the stud with a nut. Figure **3** shows an enlarged detail of a cylinder head bolt **3-A** and nut **3-B**.

Servicing the cylinder head

First remove the rocker arm assembly before taking off the cylinder head. Then carefully loosen the cylinder head nuts and bolts. Leave the injectors in the cylinder head, because as the crankshaft turned pressure built up in the cylinders and this helps loosen the cylinder head. Light tapping with a soft hammer may make the cylinder head come off more easily. Never use a screwdriver or cold chisel between the head and the cylinder block, since this will damage the edges of the cylinder head and the engine block. After removal, check the surface of the cylinder head for damage. Clean all carbon deposits from the head by scraping or brushing with a wire brush. Also check the water passages for lime deposits.

After a long period of service or overheating, the heat may have caused the head to warp. So check the surface as follows, see Fig. **4**.

- Use a heavy accurate straight edge and feeler gauge to check for warp at each end and between the cylinders.
- Check too for end-to-end warp in at least six places.
- Decide whether the cylinder head must be re-installed or re-faced. Re-facing is done in a specially equipped shop.
- Also check the head for any cracks.

Cylinder head gasket

A typical cylinder head gasket is shown in Fig. **1-A** and an enlarged detail in Fig. **1-B**. This gasket is placed between the cylinder head and the cylinder block and is used to make the connection between these two; it is gas and water-tight.

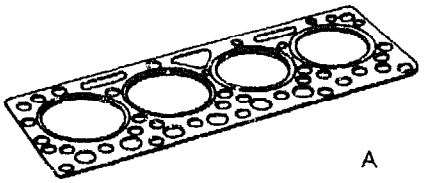

Gaskets are made up from different materials. For example, the one shown is composed of one layer of copper **1-C** and three layers of soft iron **1-D**. When installing the cylinder head, mind the top and front of the gasket.

1

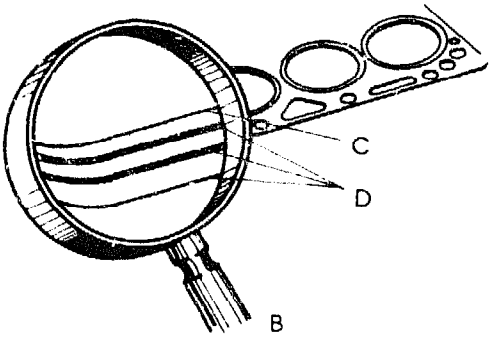

Installing the cylinder head
After checking the valve seats, which will be explained at a later stage, the cylinder head can be installed again. First check the surface of the cylinder block. Install a new cylinder head gasket, following the manufacturer's recommendations about application of a sealing compound on one or two sides of the head gasket. Carefully set the cylinder head on the cylinder block, without disturbing the head gasket.
Make sure the ends of the bolts or studs are clean and lightly oiled.
Press down the cylinder head gradually and evenly. This is very important to ensure a good seal between the cylinder head and the cylinder block.

2

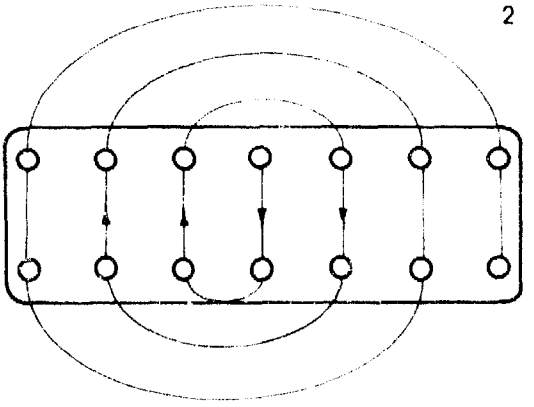

Tighten the nuts or bolts fingertight. Use the sequence shown in Fig. 2 for tightening the head bolts or nuts, turning them one by one about one-half turn until the torque specified by the manufacturer is reached. Sometimes nuts or bolts are tightened in a way discribed by the engine manufacturer.

Cylinder head nuts or bolts should usually be re-tightened to the specified torque after a warming-up period!

1

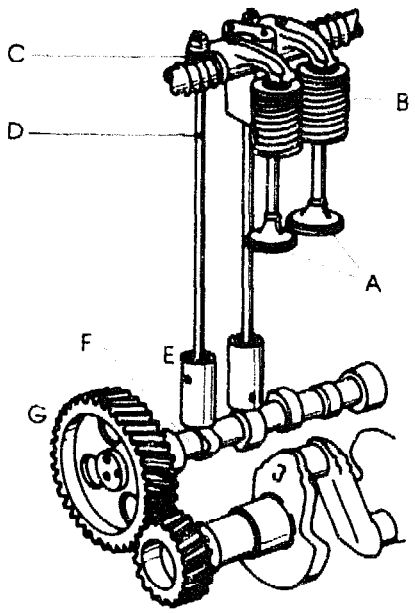

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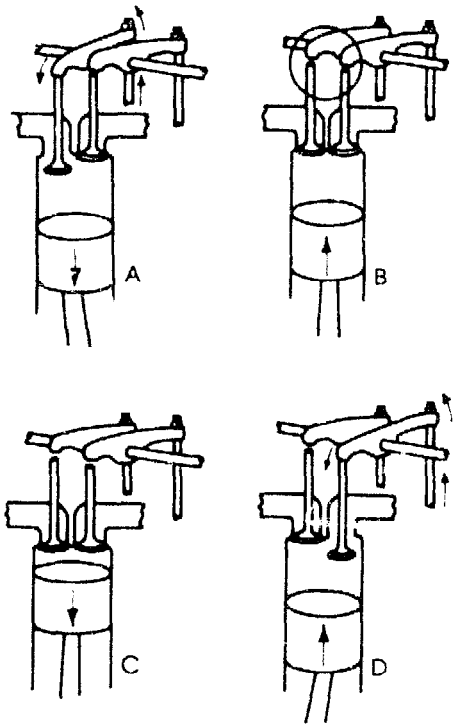

Valve mechanism

As you know, an engine must take in fuel/air and exhaust burned gases. Intake and exhaust must occur at precise intervals. Valves as shown in Fig. **1-A** are used to do this job. The whole valve operating system is called the *valve train*:

- Valves (inlet small, exhaust large) **1-A**
- Valve springs **1-B**
- Valve rocker arm **1-C**
- Push rod **1-D**
- Valve lifter **1-E**
- Camshaft **1-F**
- Gear transmission **1-G**

The position in which the valves operate here is called *overhead valve mechanism*.

Sequence of valve operation

Figure **2** shows once again the sequence of the valve operation in a typical four-cycle engine. Each cylinder has one intake and one exhaust valve in this case.

- *Intake*
  During the intake stroke, the inlet valve opens as shown in Fig. **2-A**. The fuel/air mixture is drawn into the cylinder through the open inlet valve while the piston moves down.
- *Compression*
  Both valves are closed, see Fig. **2-B**, when compression takes place during the upward movement of the piston.
- *Power*
  Both valves remain closed while the compressed fuel/air mixture is ignited and expanded gases force the piston down, see Fig. **2-C**.
- *Exhaust*
  The exhaust valve opens when the piston is moving upwards and thus forces the burned gases through the open exhaust valve, see Fig. **2-D**.

Valve lifting system

A typical valve lifting system is shown in Fig. 1. It consists of:
- Combustion chamber **1-A**
- Valve seat **1-B**
- Port **1-C**
- Valve guide **1-D**
- Valve stem **1-E**
- Valve springs **1-F**
- Valve spring retainer **1-G**
- Valve key **1-H**
- Rocker arm **1-I**
- Valve clearance adjusting screw **1-J**
- Push rod **1-K**
- Valve lifter **1-L**
- Camshaft **1-M**

Valve detail
- Valve head **2-A**
- Margin **2-B**
- Face **2-C**
- Seat **2-D**
- Stem **2-E**
- Guide **2-F**

Poppet valve detail
- Inner valve spring **3-A**
- Outer valve spring **3-B**; note that the inner and outer springs are winded in opposite directions
- Valve spring retainer **3-C**
- Valve stem **3-D**
- Valve key (in two halves) **3-E**
- Valve cap **3-F** allows the valves to rotate during operation

Cooling the valves
Valves have to be cooled while the engine is hot due to operation. See Fig. 4. The valve heat is transferred to the head **4-B** and from there to the water passages **4-C**, which are cooled with coolant (see arrows). At all times the heat of the valve is transferred to the valve guide **4-A** and from there to the cylinder head.
The cylinder head is cooled with coolant. You must ensure that all passages in the cylinder head are clean and wide open so the coolant can pass freely during engine operation.

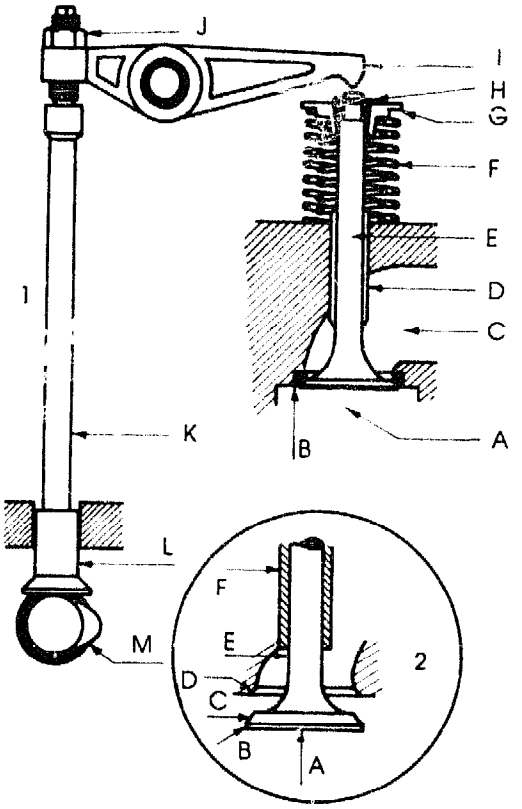

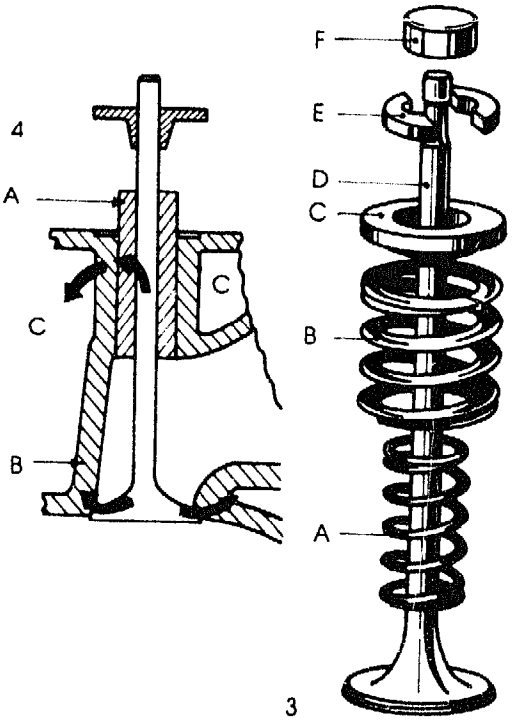

Removal of valves

1

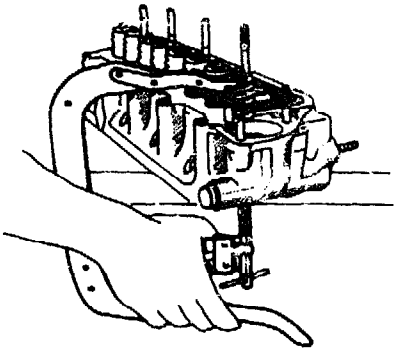

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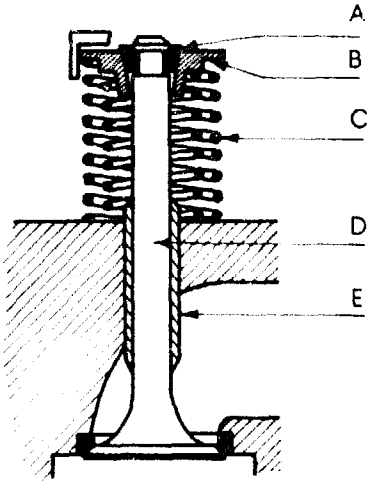

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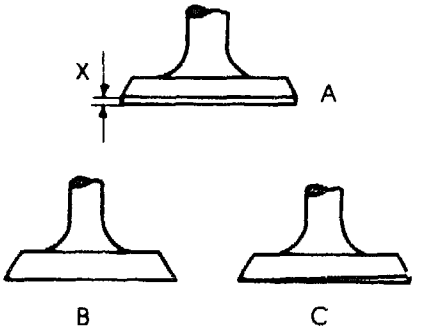

Follow this procedure when removing the valves from the cylinder head:

- Using a valve spring compressor, compress the valve springs, Fig. **1**.
- Place the valve spring compressor absolutely straight on the valve head and at the other side on the valve spring retainer, see Fig. **2**.
- When you turn the handle of the spring compressor, the valve spring retainer **2-B** should move down and release the two halves of valve key **2-A**. Place the two halves for easy replacement in their original position.
- Remove the valve spring retainer **2-B** and the two springs **2-C**. Place them in order.
- Before pushing out the valve, check whether the rotation of the valve has produced a burr on the tip of the valve stem **2-D**. If so, remove the burr as it might otherwise damage the valve guide bore **2-E**.
- Push the valve out of the valve guide and place it carefully in order.

Checking valves

Check all valves for:

- distortion and deposits on the valve face and valve stem,
- burned and broken valve heads,
- erosion under the valve heads,
- fatigue and broken valves,
- worn valve guides,
- the thickness of the margin on the valve head. If it is less than 1 mm, the valve must be replaced, see Fig. **3**.

Correct shape of valves

A correctly shaped valve is shown in Fig. **3-A**. The margin **3-X** is the same on all sides and the face is perfectly round. Fig. **3-B** shows a valve with a knife head. This valve cannot be used any more. A warped and knife-edged valve head is shown in Fig. **3-C**.

Setting the valve clearance in a four-stroke diesel engine

- Depending on the type of engine, the valves should be set on a cold or a warm engine. Consult the manufacturer's manual.
- Remove the valve cover from the cylinder on which the valve clearance is to be set. Sometimes there is only one valve cover for all the cylinders.
- Find (by looking at the manifolds, for instance) the intake and exhaust valves of the cylinder you are working on.
- Rotate the crankshaft in the correct direction until the exhaust valve is completely opened (seen from above it is pressed).
- Now rotate the crankshaft slowly until the exhaust valve is almost closed and the intake valve starts to open. At this moment the cylinder concerned is between the exhaust stroke and the inlet stroke, with the piston in approximately TDC.
- Mark the position of the crankshaft pulley and make one complete revolution (360°).
- Now you can set both intake and exhaust valves on this cylinder. You should always use a feeler gauge of the correct size. To ensure correct setting you also need the feeler gauge of the next size up, which is 0.05 mm thicker. The correct feeler gauge should just fit between the rocker and the valve stem. The next larger feeler gauge should not fit.
- Repeat this procedure for the other cylinder.

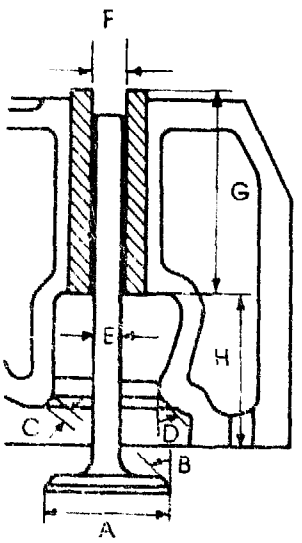

1

Reconditioning valves

The correct technical data on valves is essential when they have to be ordered or reconditioned. Take care that you know the following measurements:

- Diameter, valve head **1-A**
- Angle, valve face **1-B**
- Width, valve seat **1-C**
- Angle, valve face **1-D**
- Diameter, valve stem **1-E**
- Diameter, valve guide **1-F**
- Length, valve guide **1-G**
- Distance, guide from head **1-H**

Note that inlet and exhaust valves are different.

Intake valve seat inserts
If the engine has valve seat inserts fitted, the maximum amount that can be removed from the valve seat insert during re-shaping is such that a 45° cutter makes contact with point **2-B**. To provide sufficient clearance between the head and the piston crown, the intake valve seats are machined approximately 1 mm below the cylinder head joint face.

Exhaust valve seat inserts
If a 45° cutter makes contact with point **2-A**, the valve seat insert must be removed and exchanged for a new one. The valve seat should be 1.5 to 2 mm wide.

Intake valve seats
If an engine has valve seats cut directly into the cylinder head casting, the maximum amount that can be removed from the seat is such that a step remains at **3-A**. The width of the valve seat should be about 1.5 to 2 mm.

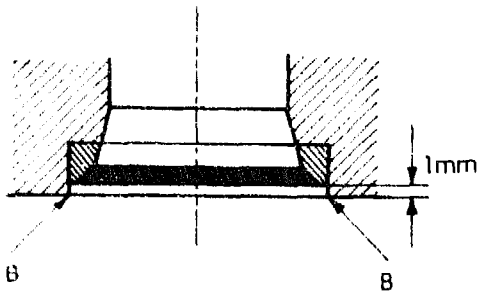

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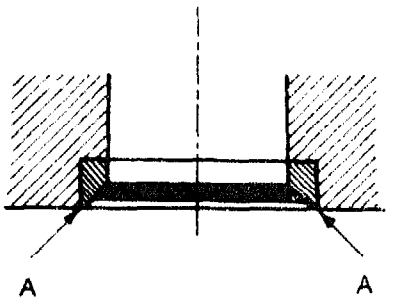

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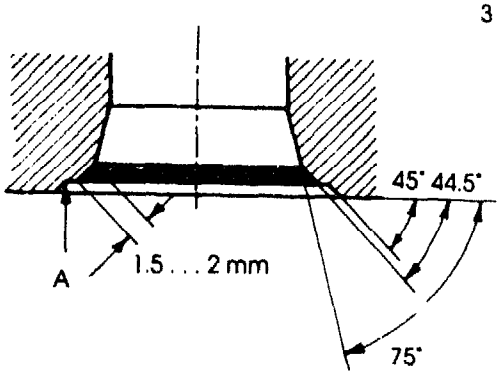

Grinding precautions

- Do not grind too long.
- Do not use too much pressure.
- Keep the work area clean.
- Check the seat width and contact with blueing.

Grinding-in the valve seats
When removing valves from the cylinder head, remember to place them in a numbered rack or mark them, to ensure that all valves return to their own valve guides. If all valves, valve guides and valve seats are in good condition, each valve should be ground in.

It is important to know that the distance between the valve head and the cylinder head joint face must not exceed 2.5 mm.

Procedure
- Place the cylinder head on the work bench with the cylinder head joint faced up.
- Coat one valve face lightly with grinding paste. The grain size of the paste depends on the condition of the valve seat.
- Insert the valve into its guide and rotate the valve clockwise and counterclockwise using a rubber suction type of grinding tool as shown in Fig. **1**.
- While grinding in the valve seat, lift the valve several times and press it down again, allowing the paste to enter the gap.
- Examine the valve seat at intervals, until a smooth dull ring is formed around the seating face.
- Carefully remove all grinding paste from the valve and the valve seat.
- Place the valve in its guide again and drop diesel fuel onto the valve head. If the valve seals through its own weight, the valve seat is sufficiently ground in.
- Repeat this procedure for the remaining valves.

Valve guides
The valve guide ensures that the valve is exactly centered, which in turn ensures a proper valve seating. The wear of the valve guide should also be checked when valve seats are reconditioned.
To check the wear of the valve guide, raise the valve with a piece of distance pipe to about 10 mm above the cylinder head, see Figs. **2-A**, and **2-B**. Place a piece of steel on top of the cylinder head and against the margin of the valve head. Move the valve left and right. If the allowance is more than 1.5 mm the valve guide must be renewed.

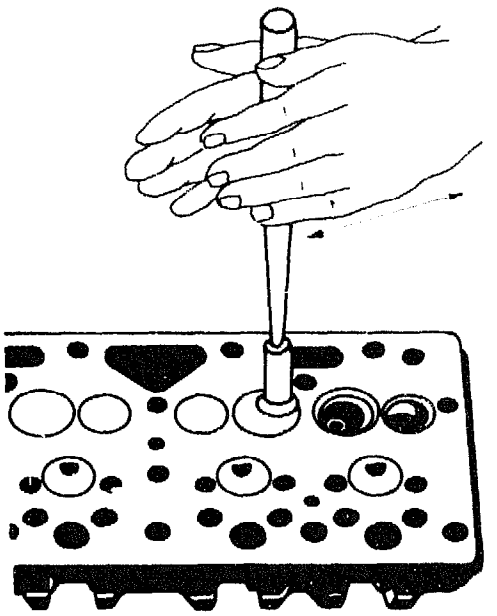

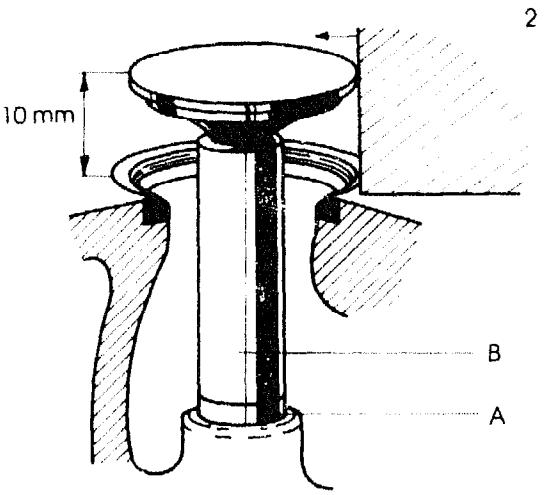

Camshaft and timing mechanism

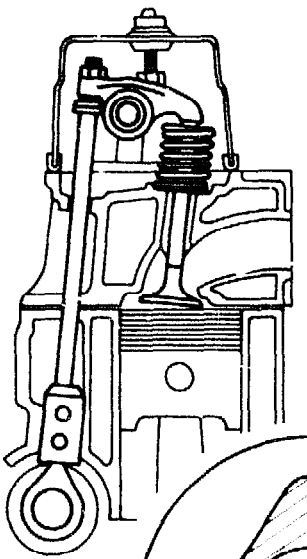

1

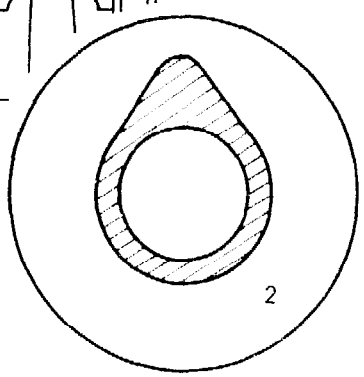

2

The camshaft is fitted into the engine block on the lefthand side, above the crankshaft, see Fig. **1**. In small and medium sized engines it is generally made of a one-piece casting or forging and is supported by three bearings. Most camshafts are made of low-carbon alloy steel. The cam and journal surfaces are carburized before grinding them to their final shape.

The intake and exhaust cams on the camshaft are fitted in pairs for each cylinder. The arrangement of the cams on the shaft determines the firing order of the engine. The contour of the cam, see Fig. **2**, decides the time and the opening rate of each valve.

Camshafts may also drive oil pumps and fuel pumps using extra lobs or a gear on the shaft.

The timing transmission

The camshaft, that is running at half the speed of the crankshaft, can be driven by different kinds of transmission, the most common are:

- *Gearwheel transmission*
  The gearwheel transmission uses a steel gearwheel on the crankshaft, driving the camshaft. See Fig. **3**. To obtain a quiet drive, this gear can also be made of other material, such as pressed fibre or a light alloy. Both gears have timing marks. When these are aligned, the crankshaft movement and valve timing will always be in correct relation to each other, see Fig. **3-A**.
- *Chain transmission*
  This transmission is used when the camshaft is a long way from the crankshaft. See Fig. **4**. The timing sprockets on both crankshaft **4-A** and camshaft **4-B** also have timing marks **4-C**. Both marks should be in line with the centre line of the sprockets for correct timing of the engine.

The timing chain is designed so that it will not stretch during operation. But to improve transmission efficiency and reduce noise, a chain tensioner is placed on the non-pulling side of the chain to maintain the proper tension in the chain.

3

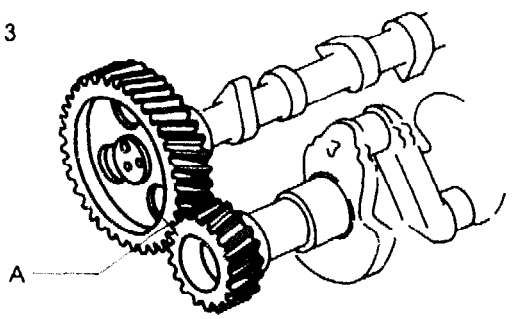

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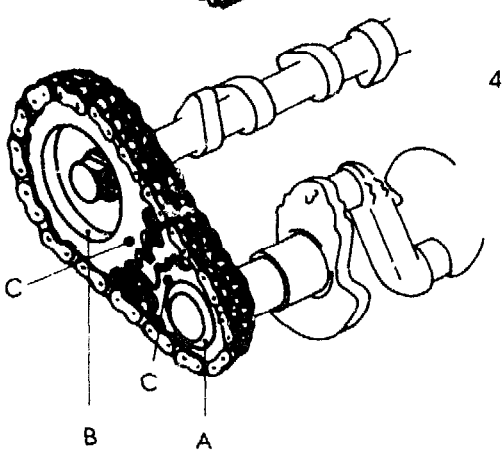

Valve timing

Valve timing is very important in obtaining the best combination of:
- power – efficiency
- economy – long engine life

A key factor in achieving these objectives is correct filling of the cylinder with fuel/air mixture.

Valve timing diagram
Figure **1** shows a section of the inlet and outlet port, the inlet valve **1-I**, the exhaust valve **1-E**, the piston, the connecting rod and a revolution of the crankshaft, shown as a circle.
The inlet valve opens when the piston is just about to reach the Top Dead Centre (TDC) during its exhaust stroke. The valve remains open during the inlet stroke and closes after the piston has passed the Bottom Dead Centre (BDC), see Fig **2**.
This period when the valve is open (shown as a dotted area) is given as degrees of the revolution of the crankshaft in relation to the position of the piston.

Valve timing degrees
Figure **3** shows a diagram with degrees, shown as **A**, **B** and **C**. In this case the inlet valve opens when the position of the crankshaft is 20° before the piston reaches TDC, see **3-A**. It closes when the position of the crankshaft is 60° after the piston has passed BDC, see **3-C**.

The total time the valve remains open is therefore 20 + 180 + 60 = 260°.

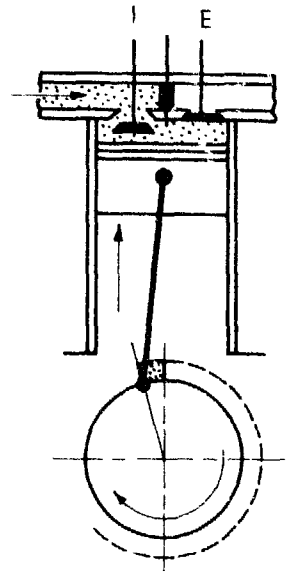

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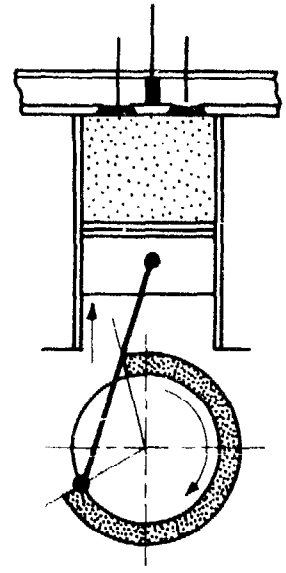
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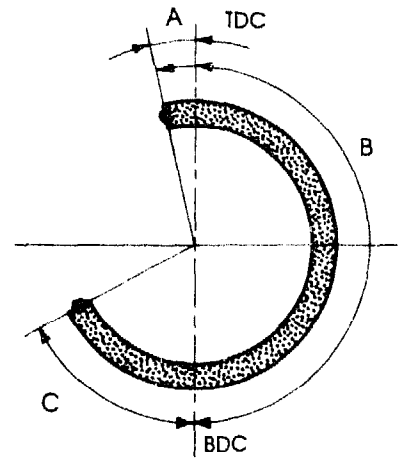

3

Valve timing degrees (exhaust)

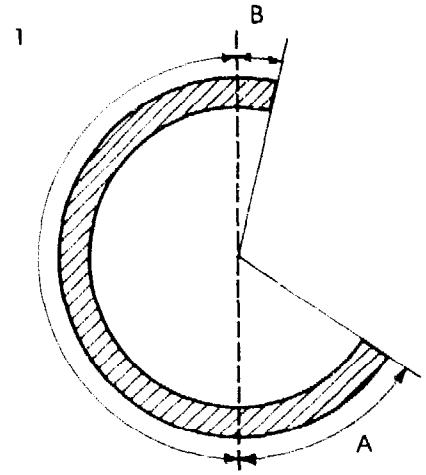

Figure **1** shows the diagram with degrees for the exhaust valve timing, where **1-A** = 65° and **1-B** = 20°. The exhaust valve opens at 65° before BDC (BBDC). The exhaust valve closes at 20° after TDC (ATDC).

The total time the valve remains open is therefore 20 + 180 + 65 = 265°.

Valve timing diagram
If we combine the inlet diagram and the exhaust diagram in one drawing, we have a valve timing diagram as shown in Fig **2**. Valve timing diagrams are supplied with each engine according to the manufacturer's recommendations.

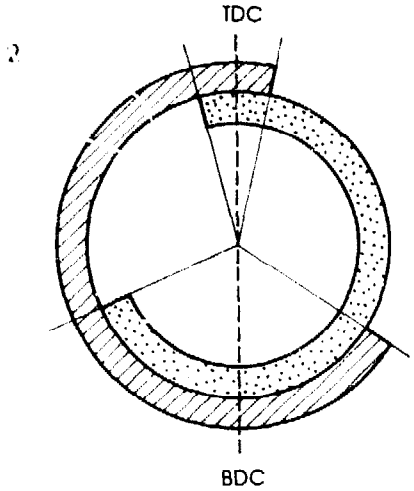

Typical engine valve timing
Sometimes a whole work cycle diagram is supplied, as shown in Fig **3**, where:
A = 20°
B = 65°
C = 60°
D = 19°
The intake valve opens: 20 + 180 + 65 = 265°.
Both valves are closed during the compression and power stroke:
180 - 65 = 115°
180 - 60 = 120°
Total time 235°

The exhaust valve opens:
60 + 180 + 19 = 259°

This means the crankshaft rotates 265 + 235 + 259 = 759° to complete the work circle.

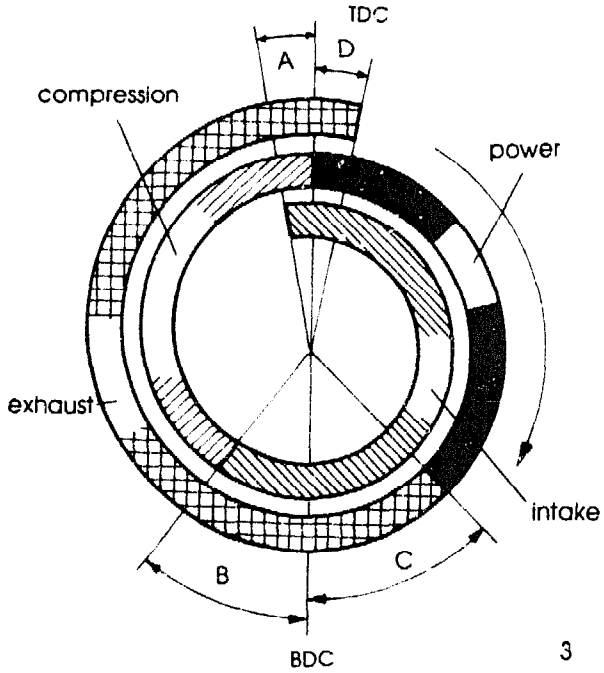

Servicing the camshaft

A cam profile as shown in Fig. 1 includes the *nose* **1-A** which holds the valve open, and the *back* **1-B** which allows the valve to close.
If you look at the shape of the cam you will see that it has curved faces. The right curved face **1-C** causes the valve to open gradually until it reaches the top of the nose. Face **1-D** allows the valve to close gradually.
Figure 2 shows how tappet **2-B** rests on a face of the cam prior to being pushed open by the nose of cam **2-A** following the direction of the arrow.

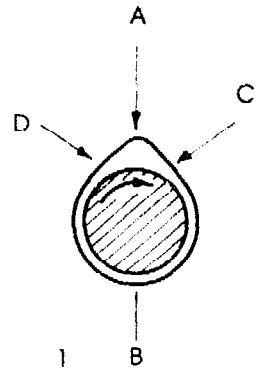

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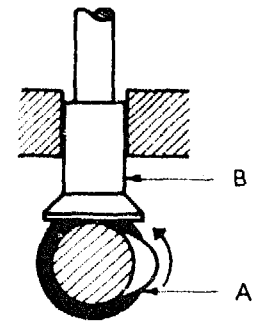

2

Dismantling the camshaft
- Clamp the camshaft in a soft-jaw vice.
- Bend back the tab of the lock washer at the front of the camshaft.
- Loosen the lock nut, remove the lock washer, take off the drive gear and collect the Woodruff key.
- Take off the front end of the camshaft bearing.
- Take out the camshaft from the front of the engine; be careful not to damage the cams while removing the shaft.
- Clean the camshaft and the camshaft bores with clean diesel fuel.

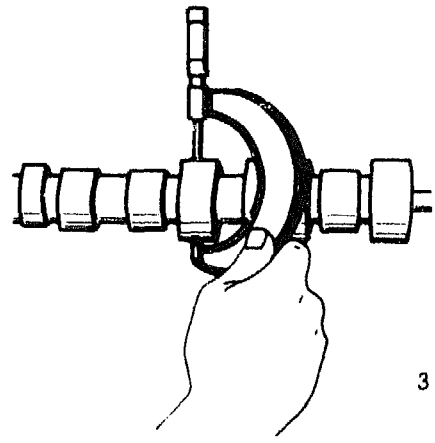
3

Checking the camshaft
A micrometer is needed to measure the cams and journals of the camshaft and to check the camshaft bores.
- First measure the camshaft journals for signs of wear or out-of-round condition, see Fig. 3. This is done with an outside micrometer.
- Measure the camshaft bores with an inside micrometer, see Fig. 4.

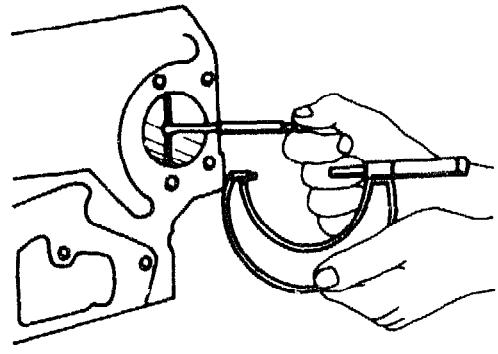
4

Compare the results with the technical data provided with the engine.
- Check for wear and scratches on the cam lobes. Use the micrometer to check the height and width of each cam lobe, see Fig 5.
- Compare the intake valve cam lobes with each other. Compare the exhaust valve cam lobes with each other as well.
- Check the wear of the injection drive gear.
- Check whether the faces of the cams are polished and examine the surface for fatigue. The nose of the cams should be polished and flat.
- The end float, see Fig. 5, can be adjusted by adding shims if it is too big or removing material from the bearing bush if it is too small. Carefully rub the bearing bush on emery cloth until the correct end float is obtained. Measure with a feeler gauge.

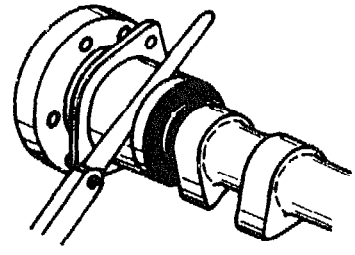
5

Tappets

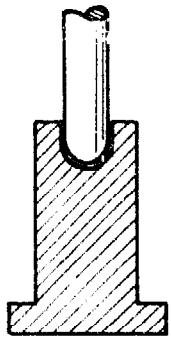

1

The movement of the cam is transferred by the tappet first, see Fig. **1**. When the tappet is raised by the cam, some pressure is applied to one side of it, see Fig. **2**. To enable the lifter to take this side pressure it is designed with a rather large diameter, see Figs. **1** and **2**.

As you see in Fig. **3**, the tappet is slightly offset from the centre of the cam **3-C**. This is done so that the contact friction creates rotary movement of the tappet. The result is that wear is distributed evenly over the contact surface of the tappet and lubrication is improved.

Figure **4** shows tappet **4-A** which has been turning satisfactorily and the wear is spread evenly over the whole surface. Tappet **4-B** has not been turning and the wear is concentrated in one place.

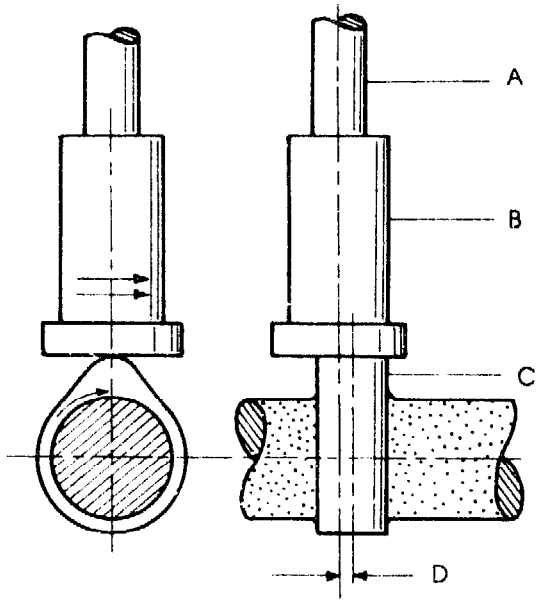

2 3

Check tappets
- Examine each tappet for wear and scratches
- Examine the tappets to see whether they have been turning in their bores
- Check the seating of the push rods

Names of tappet related parts
- Push rod **3-A**
- Tappet **3-B**
- Camshaft cam **3-C**
- Distance off-centre **3-D**

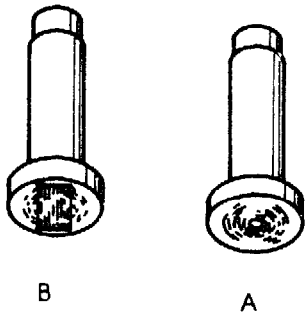

4

Push rods

The push rod in Fig. **1-A** transfers the motion from the tappet to the rocker arm **1-B**. It is usually made of hollow steel pipe with solid steel ends, see Fig. 2. The upper end is sometimes cup-shaped to fit the ball-shaped end of the adjusting screw. The other end is slightly ball-shaped to fit the tappet. When removing the pushrods, mark each rod so it can be re-assembled with the same mating parts.

Check whether the push rods have become bent. Place the rods on a flat steel plate and roll them over. They must be replaced if they are bent more than the tolerance specified by the manufacturer.

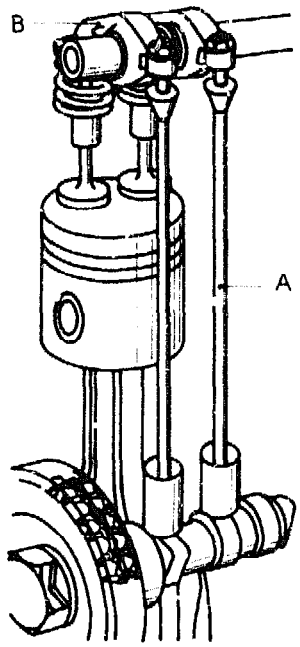

1

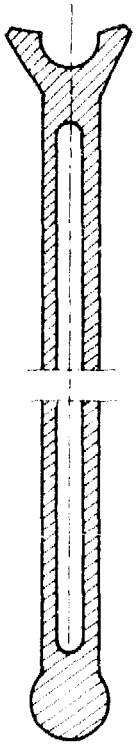
2

Valve springs

The main function of the valve springs is to close the valve and keep it closed until it is forced open again by the camshaft. Cylindrical springs as shown in Fig. 3 are installed in most engines:

- Valve stem **3-A**
- Spring cap **3-B**
- Outer spring **3-C**
- Inner spring **3-D**

Inspecting valve springs

- After taking off the springs, check the casting on the cylinder block where the springs rotate.
- Check that spring caps are of the correct thickness, see Fig. **3-E**.
- Check the end of the springs.
- Also check the springs by placing them on a flat surface, using the tee square.
- Check the force of the springs with the spring tester, see specifications.
- Do not worry if the springs are of different lengths. Lengths may differ, yet the springs will be the same length and have the same force when they are in the compressed position.
- Note that after valves and valve seats have been re-ground there may be less spring tension than before, because as the ground valve seat is deeper the spring operating height is longer. This can be remedied with a few washers.

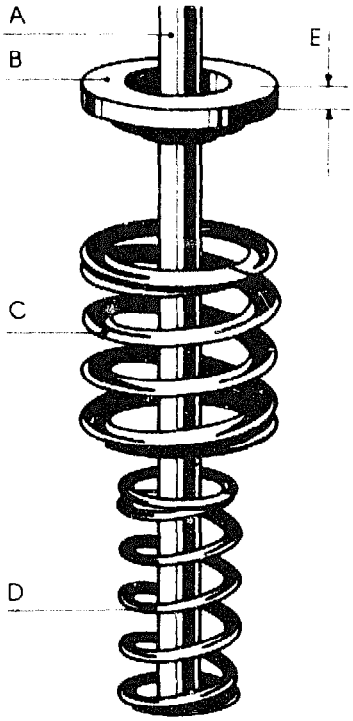

3

Rocker arm

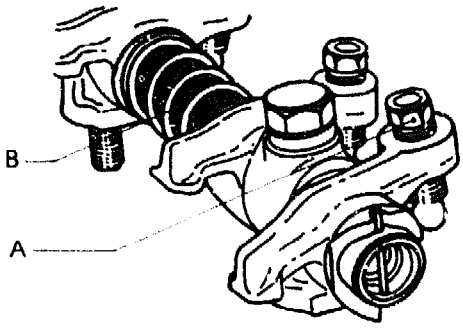

1

The rocker arm transmits the camshaft motion to the valves. The rocker arms shown in Fig. **1** are mounted on a hollow shaft **1-B** which is secured with brackets and bolted to the cylinder head. Lubricating oil is pumped through the hollow shaft to lubricate all rocker arms. Springs are positioned between the rocker arms to keep them in place. A valve adjusting screw is shown at **1-A**.

Rocker arm tip

A rocker arm tip is shown in Figs. **2-A** and **2-B**. This tip **2-C**, which comes into contact with the valve cap **2-D**, may exhibit concave wear after some time and this will affect the correct valve clearance. Sometimes a special screw may be fixed in the rocker arm tip to allow easy replacement of worn parts and extra adjustment. When installing rocker arms, make sure you install the arms and springs in the same sequence as they were removed.

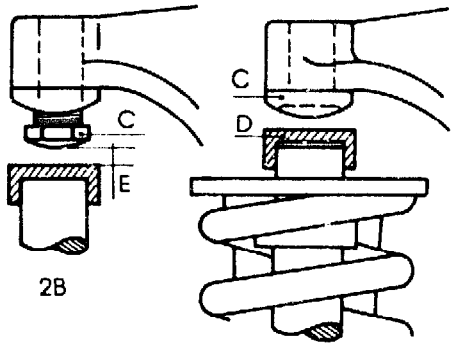

2B

2A

Valve clearance

When valves are properly adjusted, there is a small clearance between the valve tip and the valve cap, see **2-E**. This clearance is called *valve lash* or *valve clearance*. Valve clearance is essential to allow for heat expansion in all the parts involved. Without clearance, expansion of the heated parts means the valve stays partly open during operation.

According to the manufacturer's specifications, the valve clearance may depend on whether the engine is hot or cold.

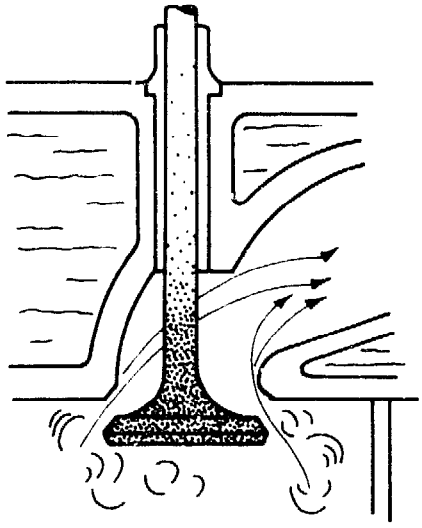

3

Too little valve clearance

Too little valve clearance affects the timing of the engine. It may make the valve to open too early and close too late. Additional it may cause bending of the push rods, because they expand in length due to the heat. Too little valve clearance can also make the valves burn, because hot combustion gases passing round the valve can cause overheating. This is because the valve has not been in contact with the valve seat long enough and therefore cannot cool down. See Fig. **3**.

Too much valve clearance

Too much valve clearance may cause the situation shown in Fig. 1. Contrary to the situation shown in Fig. 3 on the previous page, the combustion heat is transferred to the cooled cylinder head, but the exhaust gases are sealed into the cylinder and cannot escape because the exhaust valve closes too early and the fuel/air mixture is late entering the cylinder during the intake stroke.
The valve itself may also be damaged, because in a normal situation the shape of the cam means the camshaft slows the speed of the valve movement as it closes. With too much valve clearance, the valves close with great impact, cracking or breaking the valve and damaging the cam and the tappets as well.
Refer to Fig. 2:
- Valve clearance **2-A**
- Rocker arm **2-B**
- Valve head **2-C**
- Screw **2-D**
- Valve **2-E**

Follow the manufacturer's specifications when adjusting the valve clearance!

- Make sure the engine is at the recommended temperature.
- Check which are the *intake* and which are the *exhaust* valves, because the clearance is usually different for both.
- Most engines have timing marks on the flywheel. Turn the flywheel until the first cylinder is at Top Dead Centre (TDC) of its compression stroke.
- A method of finding out whether the piston is exactly at TDC is to remove the injector and close the hole with your finger. On the compression stroke, air is then forced out through the hole against your finger until the piston reaches exactly the TDC point. Never try to feel where the piston is with your little finger through the injector hole – this is very dangerous.
- Check the valve clearance when the piston is at TDC. If necessary, adjust the valve clearance with a feeler gauge as shown in Fig. 3, turning adjusting screw **2-D** up or down until the correct valve clearance according to the specifications is obtained.
- Rotate the flywheel in its firing order and adjust all valve clearances when each piston reaches the TDC on its compression stroke.
- Check again after running in.

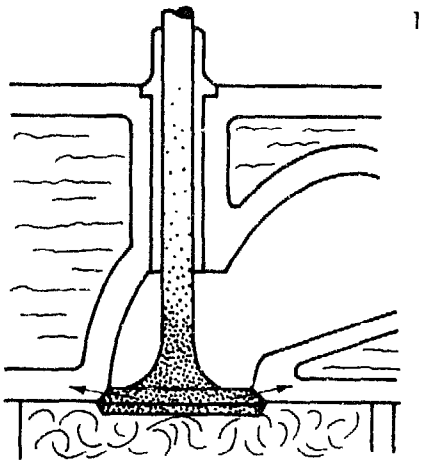

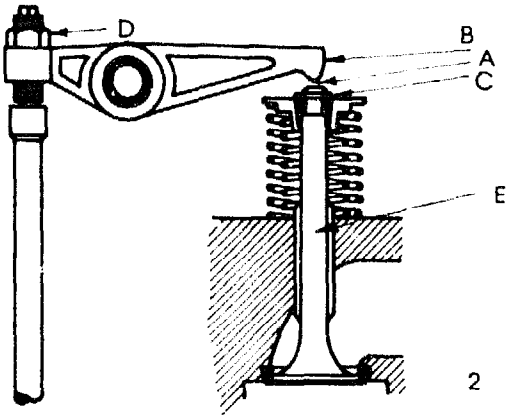

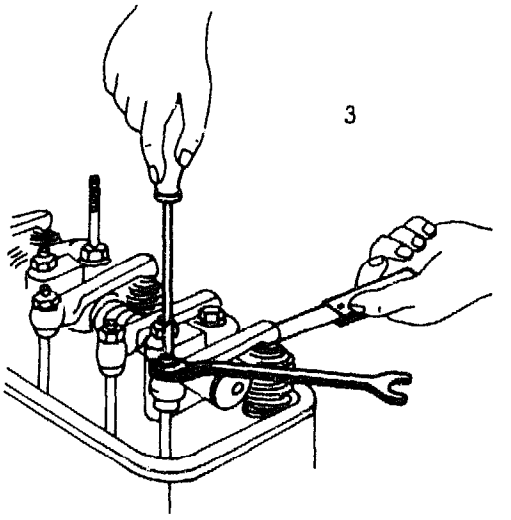

Cylinder block and cylinders

Cylinder blocks

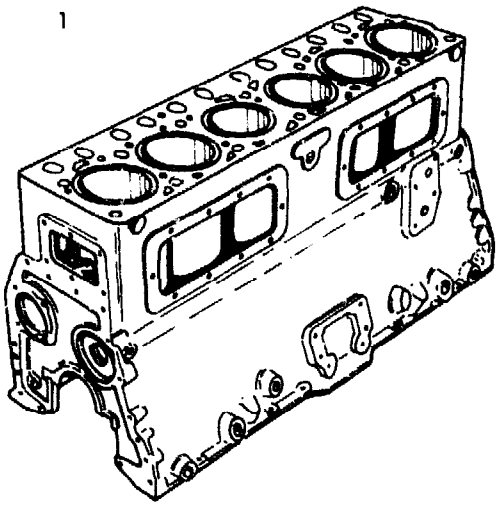

1

Figure 1 shows a typical cylinder block. This block is made of grey cast iron as a one-piece casting. Cylinder blocks are cast with centre webs to support the crank and camshaft. They have enlargements in their walls for coolant and oil passages.
The cylinders in the cylinder block are sometimes cast into the block or bored in the block at a later stage to lodge replaceable cylinder liners.

Cleaning cylinder blocks
After stripping, scrape all gasket material from the surface of the block. Remove all oil gallery and core hole plugs to facilitate cleaning inside. Cleaning can be done with hot water or any other recommended solution. A special solution should be used in particular when the water passages are heavily scaled. It is very important to clean the passages well to avoid overheating of the cylinder block.

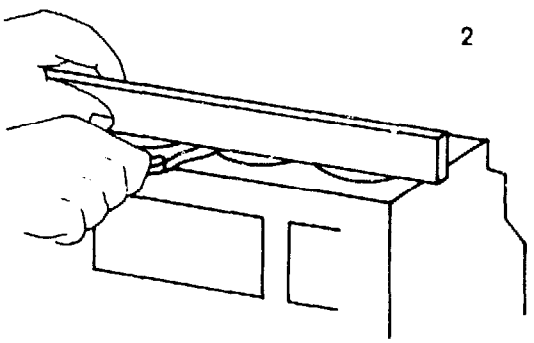

2

Inspecting the cylinder block
Cracks and leaks can be checked with water and air pressure. Check the cylinder block top surface as shown in Fig. 2. The surface is checked in all directions with a straight edge and a feeler gauge, see Fig. 3. This checking must be very accurate, because the surface must seal off the area to water, oil and compression.

Inspect all studs, dowels, pins, pipe plugs etc. for looseness, damage or wear and replace parts as necessary. Inspect the cylinder bores carefully. After cleaning and inspection, spray the whole cylinder block with thin engine oil.

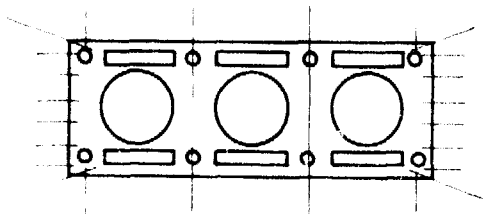

3

The cylinder

A cylinder is basically a hollow tube which guides the piston and forms the combustion chamber together with the cylinder head and the piston. There are two basic types of cylinders:
- Cast-in-block
- Individual castings

Cast-in-block
In a cast-in-block engine design, the cylinders are cast and polished into the cylinder block, thus forming a single unit.

Individual castings
In this type of casting the cylinder is made together with the cooling fans and bolted separately to a base. The main advantage of such a system is that it is possible to build up an engine with any number of cylinders. Another advantage is that, if failure occurs in one of the cyclinders, it can be replaced individually.

Dry and wet liners
Another type of cylinder casting is one in which the cylinder is made and shaped like a hollow tube which fits into the cylinder block. There are two types:
- Dry liners, see Fig. **1**
- Wet liners, see Fig. **2**

Dry liners
Dry liners are sleeves which fit inside an already completed cylinder casting in the cylinder block, see Fig. **1-C**. The liner is in fact a wearing surface for the piston, because the material the cylinder block is made of is not able to withstand forces applied during operation. As shown in Fig. **1** this liner is not exposed to the engine coolant in **1-A** and **1-B**, so it is called a *dry liner*.

Wet liners
An engine with a wet liner is shown in Fig. 2. You note that this liner **2-C** has two functions: it is the actual cylinder and it also forms the inside of the water jacket **2-A** and **2-B**.

Two sections of wet liners are shown in Fig. 3. As you see, both liners have flanges at the top to seat in a mating counter-bore at the top of the cylinder block. The bottom of the liner is sealed with two rubber rings **3-A** or with a copper ring **3-B**.

1

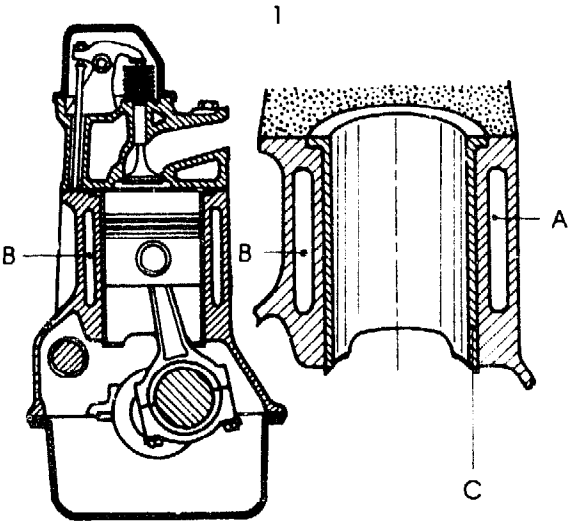

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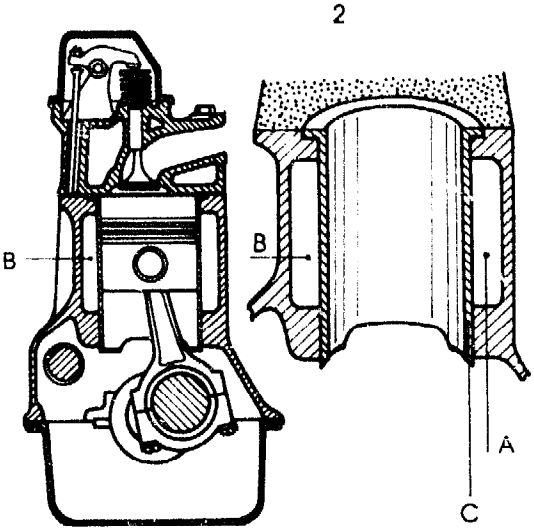

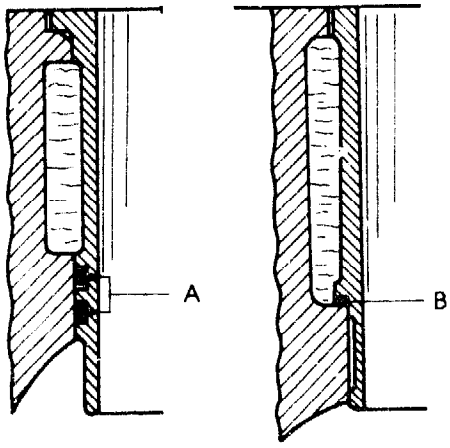

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Servicing cylinders

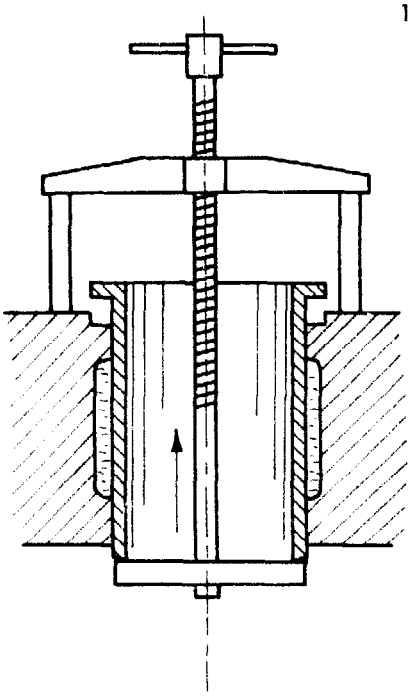
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A cylinder is removed with a cylinder puller as shown in Fig. 1. After removing the cylinder the rubber or copper seals can be taken off. Then clean the counter-bores on top of the cylinder block and remove the scale from the water jackets with a wire brush. Also clean the lower sealing surface in the cylinder block where the rubber or copper seals are positioned.

When removing the cylinders, mark them and place them in the same sequence as you take them out of the cylinder block.

Checking cylinders
Measure the cylinders for taper shape and out-of-roundness. This means measuring the top and bottom parallel to the crankshaft. Measure too the top and bottom parallel and at right angles to the crankshaft. Then compare the differences.
The tolerances depend on the manufacturer's specifications for exact wear limits, which should generally not exceed 0.127 mm. After measuring decide what should be done:
- replace the cylinder,
- re-bore the cylinder,
- hone the cylinder,
- de-glaze the cylinder.

Replace the cylinder when the wear is beyond the tolerance. The piston is usually replaced as well.

Cylinder liners for larger engines are re-bored when necessary to the smallest oversize diameter. Oversized pistons should then be fitted to provide the correct piston-to-liner clearance. Re-boring is done with special machinery complying with the manufacturer's specifications.

Honing

Honing is done to smooth the cylinder and produce a special finish which must be neither too rough nor too smooth. A finish which is too smooth can retard piston ring seatings and a rough finish may wear out the rings too quickly.
A typical honing tool is shown in Fig. 1. Insert the hone in the cylinder bore and adjust stones **1-A** to the narrowest section. When it is adjusted correctly, move the hone up and down at low speed with a stroke overlapping by about 2.5 mm. Concentrate first on the high spots. When they are removed, the drag of the hone becomes lighter. When honing, use a mix of 50% diesel fuel and 50% engine oil to ensure the honing stones are cooled and to avoid excessive wear.
Remove the hone and measure the bore. It should be clear that moving the hone from top to bottom inside the cylinder will not take away the out-of-round shape. Make sure that you do not remain in one place too long while honing, because the bore will become irregular. Thoroughly clean the cylinder, and if necessary the cylinder block, to remove all particles caused by the honing.

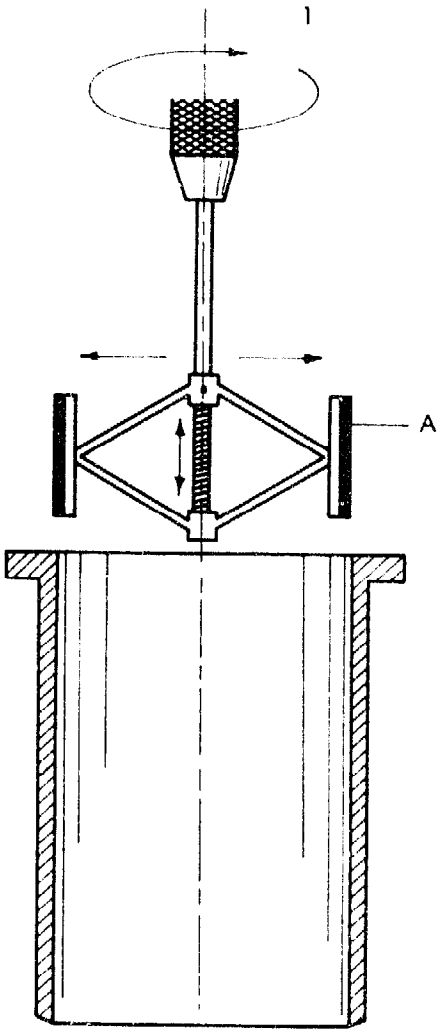

De-glazing

De-glazing is done with a special de-glazing tool as shown in Fig. 1. This tool is brush-like with coated tips. Move the tool at low speed for at least 10 complete strokes. Move it at such a speed that the result is a cross-hatch pattern as shown in Fig. 1.

Installing dry cylinder liners
First read the manufacturer's recommendations on installing the dry liners. Clean all parts correctly and insert the liner carefully, placing each liner in the bore from which it came before.

Installing wet cylinder liners
Clean the cylinder flange and the lower sealing surface. Also clean the cylinder block bore and the lower sealing surface inside the cylinder block.

Install the liner first without a seal and check its height in relation to the top of the cylinder block. See Fig. 2. Check whether the liner is seated squarely. All cylinder liners should be of the same height to avoid cylinder head gasket leaks. Take out the liners and place the new seals. If necessary, lubricate the seals and the mating surfaces in the cylinder block. At the same time make sure the seals are not twisted. Press the liner as far into position as possible by hand. Finish the job by placing a hard wooden block over the liner and tapping it lightly with a hammer, moving it into position, see **2-A**. The liner may protrude above the cylinder block **2-C**, see **2-B**. The cylinder head **2-D** will finish the rest and press the bottom seal together. The top of the liner is sealed off with the cylinder head gasket **2-E**.

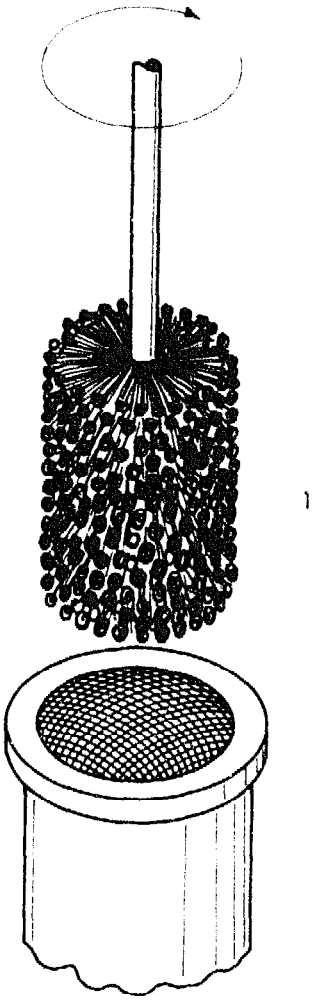

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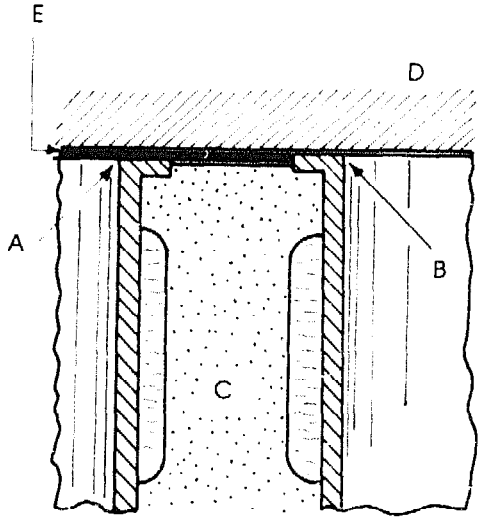

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Pistons and piston rings

Pistons

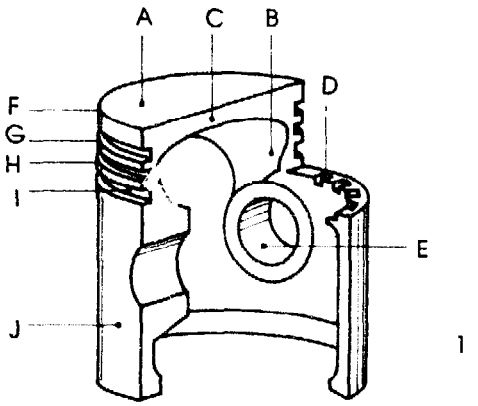

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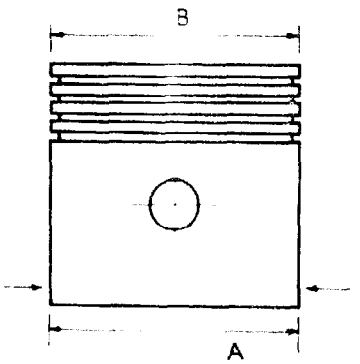

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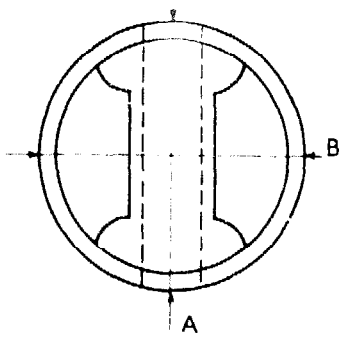

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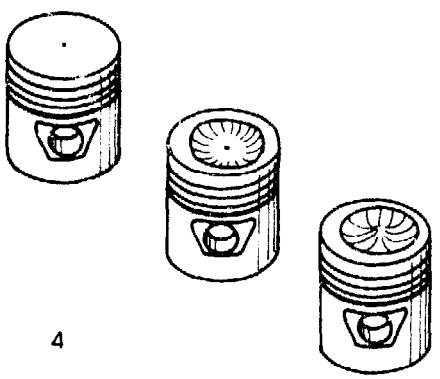

4

The piston is basically a plunger which moves up and down inside the cylinder. It seals off the crank case from the combustion chamber. Its main functions are:
- Sealing off the crank case from the combustion chamber.
- Providing vacuum during the intake stroke.
- Receiving the force of the expanding gases and passing it on to the connecting rod etc.
- Pushing out the exhaust gases.
- Compressing air prior to ignition.

Pistons are made of:
- cast iron,
- aluminium alloy.

Parts of the piston are (see Fig. 1):
- Piston head **1-A**
- Reinforcement **1-B**
- Head rib **1-C**
- Lubrication holes **1-D**
- Piston pin boss **1-E**
- Top land **1-F**
- 2nd land **1-G**
- 3rd land **1-H**
- Ring groove **1-I**
- Skirt **1-J**

Piston construction

Ribs inside the piston reinforce it and at the same time transfer the heat from the head to the piston rings. The skirt, see Fig. **2**, keeps the piston in alignment. It is usually tapered, so the diameter of the skirt **2-A** is slightly larger than the diameter **2-B** at the piston head. The elliptical shape shown in Fig. **3** should be slightly more across the thrust face in diameter **3-B** than diameter **3-A**.

Types of heads
- Flat head
- Irregular head
- Concave head

The different shapes of the piston faces are shown in Fig. **4**. They allow for more or less compression and swirling. Remember that diesel engines sometimes have swirling chambers in the cylinder head, which will be explained at a later stage.

Piston rings

Ring grooves are cut round the piston to accommodate the piston rings. A typical piston ring is shown in Fig. 1. Piston rings have three functions:

- They form a gas-tight seal between the piston and the cylinder.
- They transfer the heat from the combustion, affecting the piston to the cylinder.
- They control the lubrication between the piston and the cylinder wall.

Compression rings

Compression rings can have various shapes as shown in Fig. 2, where you see:

- Rectangular type **2-A**
- Taper-faced type **2-B**
- Key-stone type **2-C**
- Barrel-face type **2-D**
- Other types are available

Compression rings can have different joints, see Fig. 1. Three types are shown:

- Step joint **1-A**
- Angle joint **1-B**
- Straight joint **1-C**

Oil rings can also have different shapes. The ring shown in Fig. 3 has an expander spring inside the ring. A detail of the function of the oil ring is shown in Fig. 4. The oil control ring is marked **4-A**. The piston section is marked **4-C**. The oil return holes are marked **3-A** and **4-B**.

Oil consumption must be controlled to avoid waste and a smokey exhaust. So the oil ring must wipe any excess oil from the cylinder wall and allow it to return through the oil return holes in the oil rings and in the piston. From there it returns to the crank case.

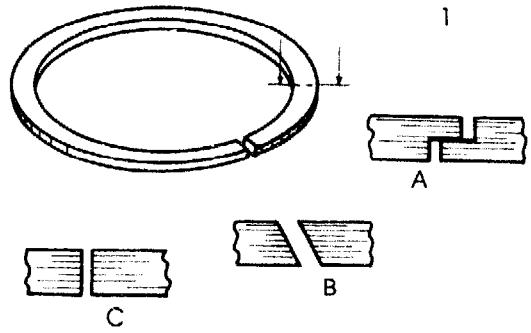

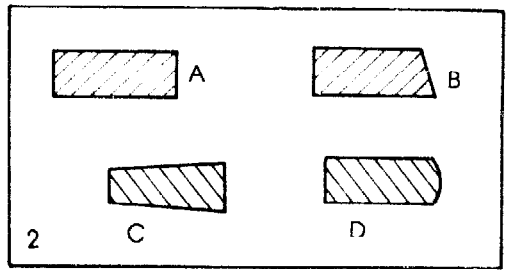

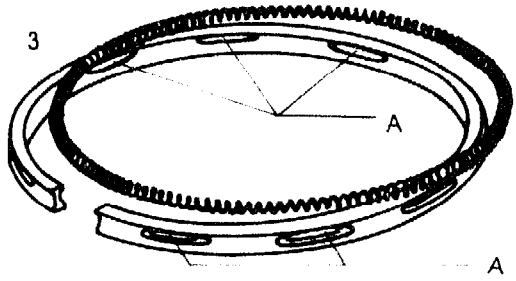

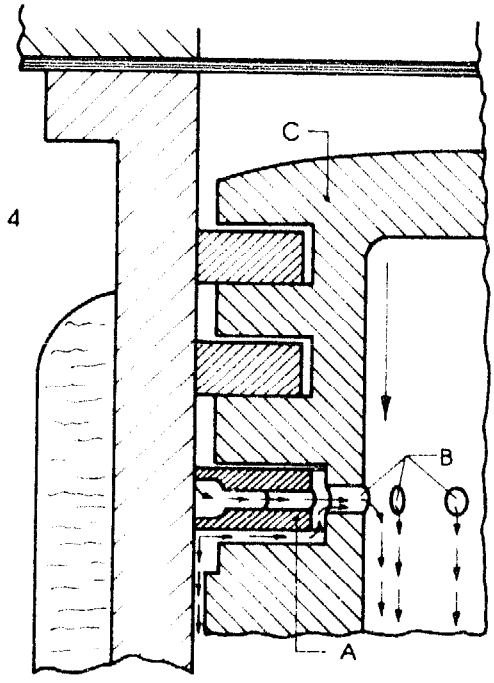

Piston and piston rings

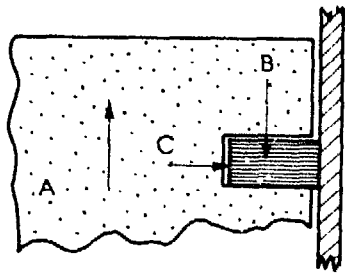

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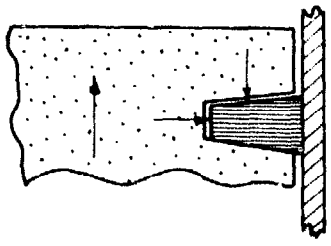

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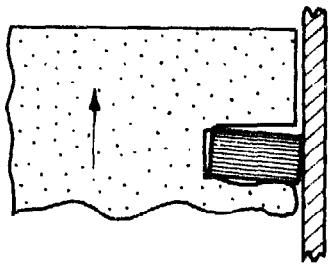

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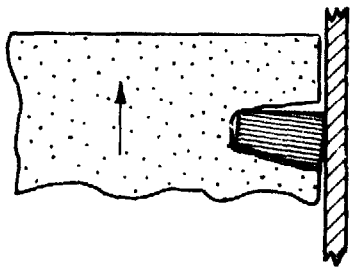

4

To obtain a good seal between cylinder wall and piston, the piston rings should have the correct shape and tension and be installed in the specified sequence. If piston rings are installed in the wrong sequence, are of the wrong type or size or are overstretched, oil and gases may pass and cause overheating and other problems.
Overheating, unburned fuel or an excess of lubrication oil collected by the rings during operation may cause them to *stick* or become *plugged* into their grooves. Rings often break when they are stuck or plugged.

If you look at the power stroke **1-A** illustrated in Figs. **1** and **2**, you see that combustion forces the ring down against the lower side of the groove **1-B**. The gases which pass behind the ring force it out against the cylinder wall, resulting in a tight seal, see **1-C**.
A new rectangular or tapered ring installed in an old groove is shown in Figs. **3** and **4**. The worn sides of the old groove do not permit the new ring to mate correctly, giving a bad seal between both the face and the side of the ring. The result will be broken rings and damaged pistons.

The top piston ring is very important because it acts as a compression ring and at the same time as the final oil control ring. The top ring and its groove wear a lot because they are exposed to most of the heat, pressure and dirt and get the least lubrication. Rings must fit correctly in their grooves and have the correct side clearance. The grooves must be smooth and parallel.

Lubrication oil consumption

As explained before, the function of the piston and the piston rings is to seal off the combustion chamber from the rest of the engine and prevent from:
- excessive lubrication oil consumption,
- gases passing to the crankcase.

Excessive oil consumption can occur due to the pumping action of a piston with worn piston rings. The more the cylinder and piston rings are worn, the greater the oil consumption. Piston rings must however let a small amount of oil pass for correct lubrication, thus leaving a film of oil on the cylinder wall to avoid wearing out too fast.
Correct oil consumption is shown in the illustrations, where you will see:
- Cylinder wall **1-A** to **4-A**
- Piston and rings **1-B** to **4-B**
- Lubrication oil (shaded areas) **1-C** to **4-C**
- Blow-by gases **4-D**

As the piston moves down, oil is forced into the ring grooves by the scraping action of the rings on the cylinder wall, see shaded area **1-C**. This happens during the *intake stroke*.
During the *compression stroke*, see Fig. **2**, the piston rings are forced to the bottom of the ring grooves, with the result that the oil is trapped above the rings in the grooves **2-C**.
The *power stroke* makes the piston move down and the oil is then transferred to the cylinder wall. The piston rings are held down against the ring land by the force of expansion, see Fig. **3**.
During the *exhaust stroke* the oil is forced from the cylinder wall into the combustion chamber, where it is burned. See Fig. **4**.

When cylinders or piston rings are worn, gases can pass by between the cylinder wall and the rings. This is called *blow-by*. A small amount of gas always passes between the cylinder and the rings. The crank case must therefore be well ventilated, see Fig. **4-D**. Blow-by can cause the pistons to overheat and expand, thus scoring both piston and cylinder wall. The lubrication oil is then contaminated and causes wear. Compression is lost, leading to loss of power.

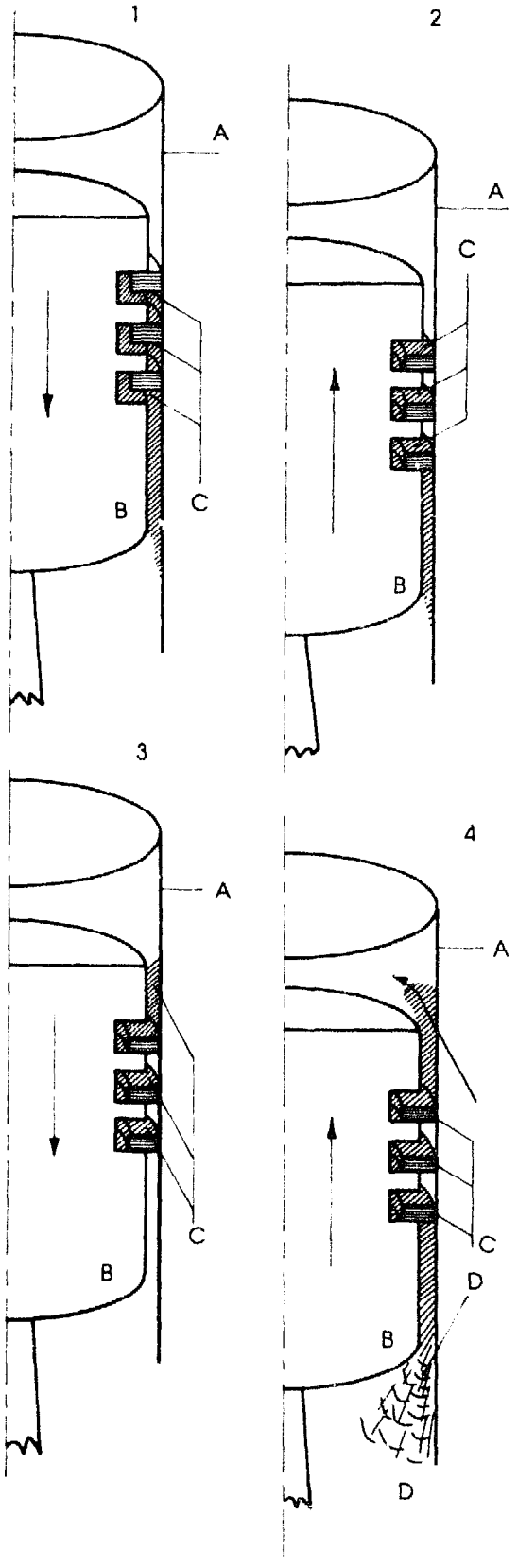

Wear of piston and piston rings

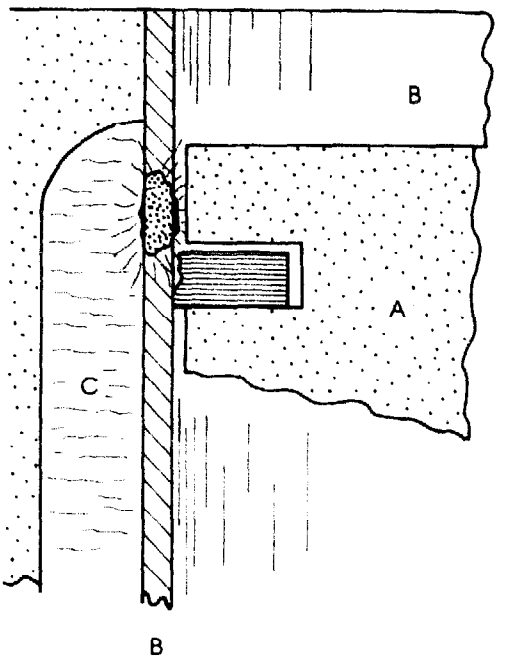

1

Wear of piston and piston rings may be caused by dirty lubrication oil, wrong air intake and dirty fuel. Another cause of wear is *scuffing*, what happens when two metal parts rub together. Heat builds up to the melting point due to the friction, after which some of the melted metal is pulled out and deposited on the cooler surface, as shown in Fig. **1**. The coolest part is of course the cylinder **1-B**, which is cooled with water **1-C**. If no coolant is present the piston **1-A** may be the hottest part. Scuffing is difficult to identify. If it develops to the extent of becoming noticeable, it is called *scoring*.

Another cause of piston and cylinder wear is corrosion. Leaking coolant, the wrong lubrication oils or cold engine operation can cause this problem. Corrosion will leave a mottled, grayish pitted surface on the pistons and cylinder walls.

Burning the piston and breaking or sticking rings may occur due to *knocking*. This is the result of fuel in the cylinder combusting too early, too fast or unevenly. Another cause of knocking may be:
- wrong fuel,
- ignition timing advanced too much,
- over-fuelling,
- cooling system not working.

Piston damage
A piston may be damaged if:
- The piston is handled carelessly before installation.
- The ring grooves are damaged while cleaning out the carbon deposits.
- The gudgeon pin locks are faulty or wrongly installed.
- The cylinder bore is out of alignment.
- The crankshaft has too much float or the journal has too much taper.

Cleaning the piston
Do not use a wire brush to clean the piston. Avoid scratching the sides of the piston ring grooves.

Inspecting the piston

After taking the piston out of the cylinder, take off the piston rings with a ring expander and place the rings on the workbench in the correct order, see Fig 1.
After cleaning, check the piston for cracks in the head and skirt and for bent or broken lands. Check the whole piston for score marks, signs of overheating and finally for damaged ring grooves.

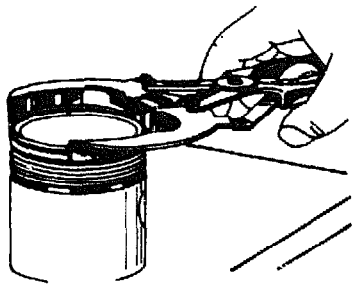

1

Piston to cylinder clearance
To find the clearance between the cylinder and the piston you must:
- measure the inside cylinder diameter with a micrometer at rightangles to the crankshaft in the lower area of the cylinder,
- measure the diameter of the piston with a micrometer across the thrust face, see Fig. 2.

The difference between these measurements is the clearance. Always compare the results with the technical data in your engine manual.

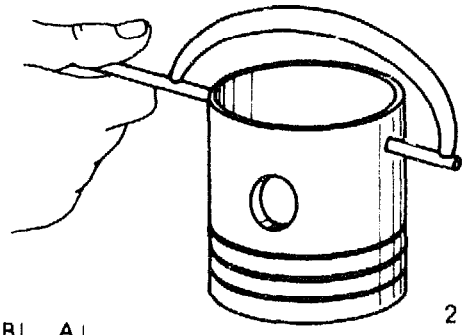

2

Checking the ring grooves
A ring groove must be checked as shown in Fig. 3. Place a corresponding ring **3-B** into the groove. Insert a feeler gauge **3-A** between the upper face of the new ring and the piston land. The clearance is now found by reading the result on the feeler gauge blade. Check the groove at several points.
Grooves of different designs can be checked with special wear gauges supplied by the manufacturer, see Fig. 4. Donnot forget to check at the same time whether the oil ring holes are open.

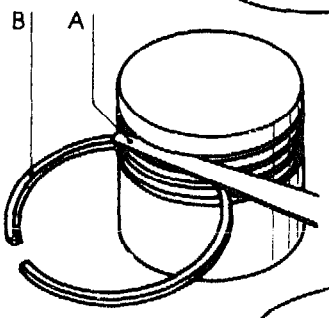

3

Damaged pistons can be re-conditioned in special workshops. Always replace damaged pistons to avoid further damage.

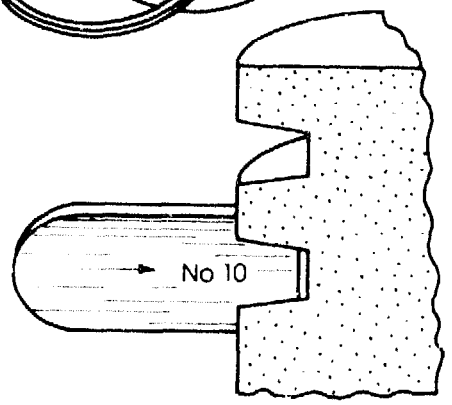

4

Checking piston rings
Piston rings can be checked by comparing the old ring with a new one, see Fig. 5. First measure the radial wall **5-A** of the new ring with a micrometer. Compare the reading with the radial wall dimensions of the old ring **5-B** and **5-C**.

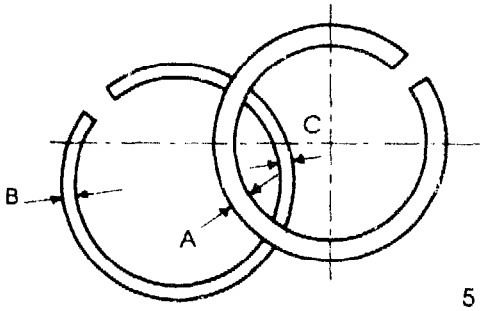

5

Ring gap measurement

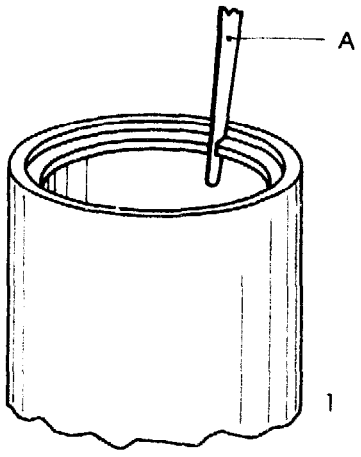

1

The ring gap is measured as illustrated in Fig. 1. Insert the ring into the cylinder and find the clearance of the gap with a feeler gauge **1-A**.

Installing piston rings

After ensuring that the piston grooves and oil return holes are clean, the rings can be placed according to the manufacturer's specifications. See Fig. 2. Rings are marked with a T, which means Top side.

Use a ring expander to prevent the rings twisting or stretching during installation. If you twist or expand the rings too much, you distort them permanently and thus reduce their performance. Place the rings in such a way that the ring ends are staggered round the piston.

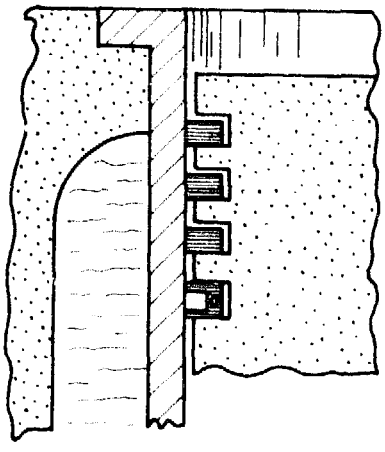

2

Installing the piston

Before installation, lubricate each piston thoroughly with engine oil. This is necessary because of engine cranking during the installation until the *oil throw-off* from the connecting rod journals is sufficient. Note that several hundred revolutions are needed before the engine lubrication system is working adequately.

Different types of ring compressors can be used for installation. Sometimes a special compressor is recommended by the manufacturer. Press the rings, together with the compressor, into their grooves. Place the piston with the compressor in the cylinder, applying gentle pressure on the piston as shown in Fig. 3, where **3-A** is the piston and **3-B** the compressor. The piston may be tapped lightly on the edge – never tap the piston head, because this will damage the head. The whole piston assembly should move into place during light tapping. If the piston sticks, compress the rings again and check the cylinder for any obstruction.

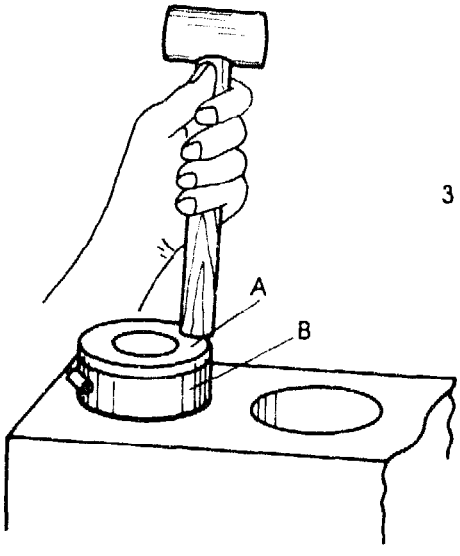

3

Prior to installation, the gudgeon pin and connecting rod must be assembled.

Piston-connecting rod assembly

Figure **1** shows a piston-connecting rod assembly, consisting of:
- Shank **1-A**
- Shank **1-B**
- Head **1-C**
- Cap **1-D**
- Bolt **1-E**
- Gudgeon pin **1-F**
- Circlip **1-G**
- Small end bush **1-H**
- Piston **1-I**
- Crankshaft **1-J**
- Bearing **1-K**

Before the piston assembly can be placed in proper position, the connecting rod with the gudgeon pin assembly must be checked and maintained.

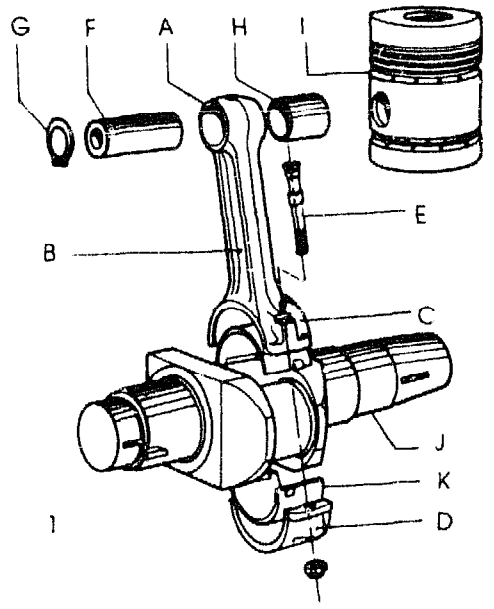

Removing the gudeon pin
The gudeon pin may be removed from the piston, see Fig. **2**, with a tool **2-A** or with the help of a special shaped wooden block **2-B**. Before removing the gudeon pin, heat the piston to 50 °C and then remove the pin in a gentle way and with moderate force.

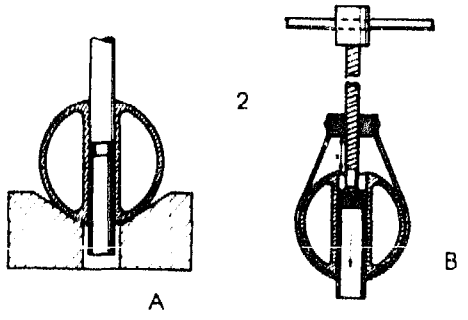

Gudgeon pins
The gudgeon pin connects the piston to the connecting rod. The gudgeon pin can be fastened in three ways:
- Most pistons are *full floating*. This is shown in Fig. **3**. The gudgeon pin can turn in the cylinder bore and the connecting rod small end round the gudgeon pin. The pin must therefore be locked in the piston bore with two circlips as shown.
- A *fixed gudeon pin* is shown in Fig. **4**. The pin is fixed in the cylinder bore with screw **4-A**. The gudgeon pin cannot move anymore and the small end of the connecting rod moves around the pin.
- Sometimes the gudgeon pin is fastened in the small end of the connecting rod with a bolt. This is shown in Fig. **5**. The assembly is called *semi-floating* because it turns only in the piston. A bushing **5-A** prevents wear of the piston bore.

In high-speed engines, floating pins bear directly on the piston material.

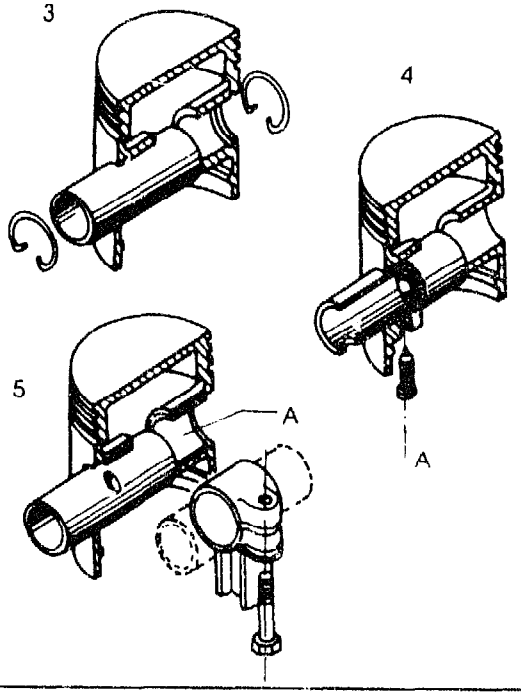

Checking the piston bore and rod bearing

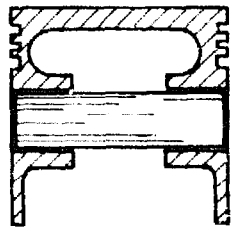

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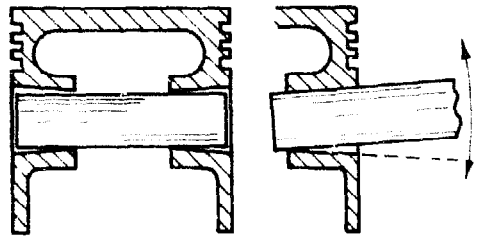

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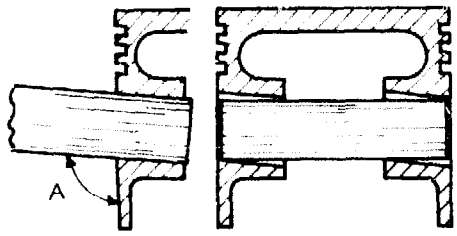

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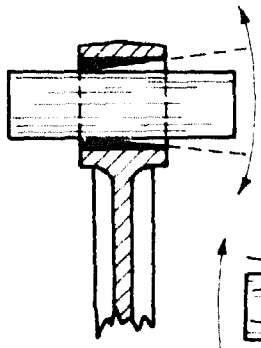

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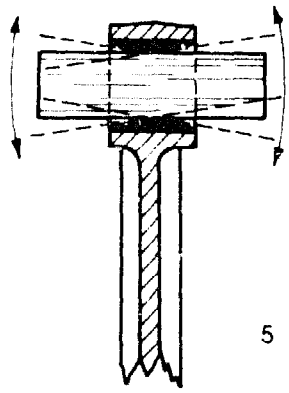

5

Before the piston is assembled in the cylinder, the gudgeon pin bearing in the piston and the connecting rod must be checked for tapered or misaligned holes.
To check for taper or misalignment between the holes, check each hole in the piston separately with the gudgeon pin. Both holes must be straight and of equal size. The pin must enter and be positioned square to the skirt of the piston without any side play.
If the hole is not tapered, push the pin through towards the second piston bore. The pin must enter this bore without any force or binding and also without a 'click'. A good gudgeon pin bearing should have equal *drag* (resistance) through both holes, see Fig. **1**.

Figure **2** shows a piston with tapered gudgeon pin holes. The taper can be checked by inserting the gudgeon pin in one side. If the pin moves up and down, the hole is tapered.
Misaligned holes can be checked as shown in Fig. **3**. Insert the pin in one side. If the pin is not positioned square to the skirt of the piston, the hole is misaligned. See **3-A**.

A method of checking the gudgeon pin fit in the small end bush of the connecting rod is shown in Figs. **4** and **5**. To check the bushing for out-of-roundness or looseness, clamp the pin carefully in the bench vice and move the connecting rod a small end back and forth over the gudgeon pin several times. After removing the rod, examine the bushing for shiny contact points. A good pin should show contact over the entire surface of the bushing in the small end.
While holding the gudgeon pin in the vice, move the connecting rod left and right and note the allowance in the bushing.

Figure **4** shows a tapered hole in the small end bushing. Figure **5** shows a bell-mouthed hole in the small end bushing.
Check in the manual the exact clearance between the gudgeon pin and the bearing to sustain and support an adequate oil film.

Connecting rod and crankshaft

1

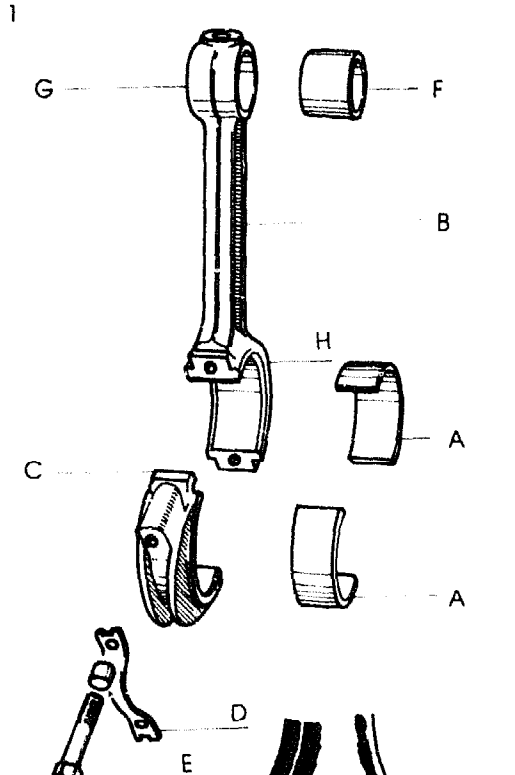

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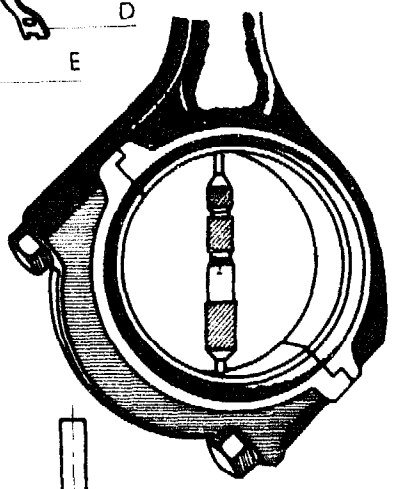

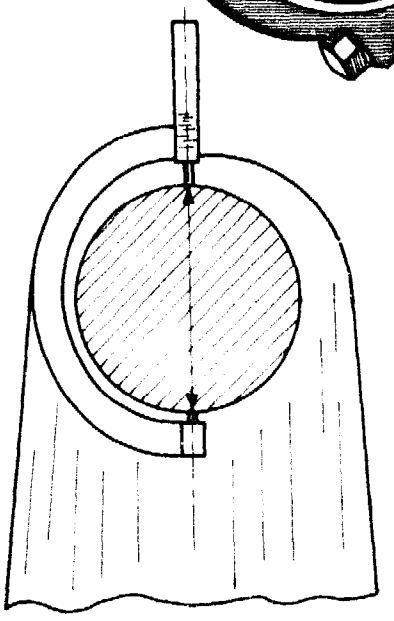

3

Connecting rods

The function of a connecting rod is to transmit the thrust of the piston to the crankshaft, see Fig. 1. It is shaped in such a way that less material is needed and a maximum of strength is obtained. Parts are:

- Bearing **1-A**
- Shank **1-B**
- Cap **1-C**
- Lock plate **1-D**
- Locking bolt **1-E**
- Bushing **1-F**
- Small end **1-G**
- Big end **1-H**

Most connecting rods are forged from one piece of metal and the cap is cut off at a later stage. Two split *bearing halves* are inserted into the head and the cap.

Connecting rods must be aligned with close limits. If this is not so, the piston cannot work squarely in the cylinder which causes oil consumption and blow-by. Big loads are imposed on rod bearings, pistons and cylinder walls if the connecting rod is not correctly aligned.
Corrections can be made to connecting rods. But heavy rods may return to their distorted shape and it is therefore better to replace them with a new rod

Replacing a bushing
The old bushing can be removed from the small end of the connecting rod with a recessed pin. Be careful not to damage the edges of the bore which have to receive the new bushing. The new bushing must be pressed into place exactly in line with the bore. Tap the bushing into place on all sides with light taps. Never use force because you may damage the bore and the bushing will be loose in its bore.

Bearing clearance
Fix the cap back on the head with the old bearings in place. Measure the inside diameter as shown in Fig. 2. Measure at several points. Measure the crankshaft connecting rod journals as shown in Fig. 3. Measure at several points and compare the results to find the bearing clearance.

The crankshaft

A one-piece drop-forged crankshaft is shown in Figs. 1 and 2. This crankshaft is for a four-piston engine and can be mounted in three main bearing housings.
- Main bearing journals **1-A**
- Connecting rod bearing journals **1-B**
- Counterweights **1-C**
- Crankshaft throws **1-D**
- Flywheel **1-E**
- Lubrication oil passage **1-F**

An engine block with main bearing bores is shown in Fig. 3, where the bearing half inserts are also shown, see **3-A**. Five main bearings are located in this engine block. This is not the case with all engines. Sometimes a four cylinder engine may have three main bearings. The cross-section in Fig. 4 shows how the main bearing caps are secured with bolts to the bearing bores.
- Crankshaft **4-A**
- Engine block **4-B**
- Top bearing insert **4-C**
- Bottom bearing insert **4-D**
- Main bearing cap **4-E**

Crankshaft throws
Crankshaft throws as shown in Fig. 1 are placed in such a way that they counterbalance each other when the crankshaft rotates at high speed. They are designed to:
- balance the engine and reduce vibration during performance,
- affect the loads on the main bearings.

Counterweights
To balance the force of the pistons and connecting rods on the crankshaft, counterweights are placed opposite the connecting rod journals. This also helps to control the vibration affecting the crankshaft.

Flywheel
The weight of the flywheel also helps to stabilize the rotating crankshaft.

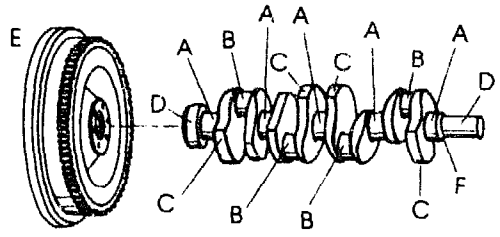

1

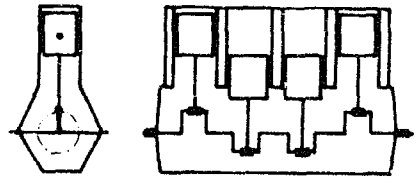
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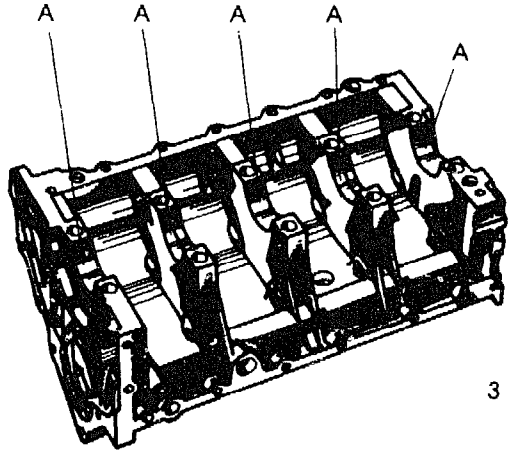

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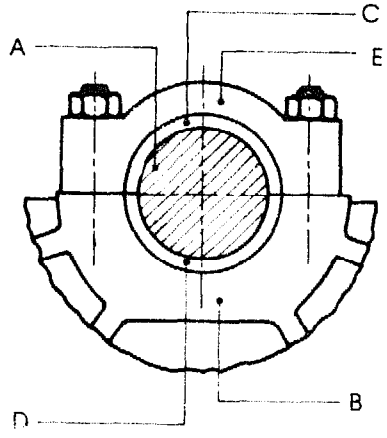

4

Inspecting the crankshaft

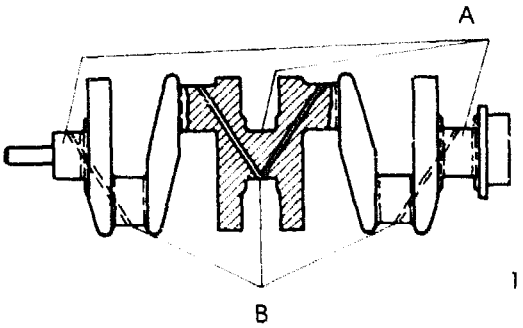

1

After the crankshaft has been removed it should be washed with fuel oil. Special care must be taken to ensure the oil passages are clean and open.
Figure 1 shows a crankshaft with a part section of the oil passages:
- Main bearings **1-A**
- Oil passages **1-B**

Almost all engines have pressurized oil lubricating the crankshaft. See Fig. 2. Holes leading in from the engine block via the main bearings provide a path for the lubrication oil **2-A** to reach the connecting rod journals, see **2-B**. As the oil is under pressure, the excess oil will spray out via **2-C** to help lubricate the piston and the cylinders.

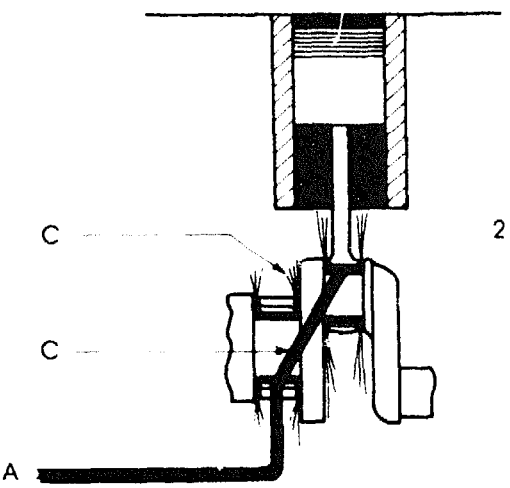

2

- Measure all the connecting rod bearing journals. As instructed in previous lessons, measure at several points and also round the journal to find the smallest diameter.
- Then measure the main bearing journals in the same way as the connecting rod journals.
- Install the main bearing caps again and tighten the bolts to the correct torque. Use an inside micrometer to measure the main bearing inserts.
- Compare all the readings and calculate the difference between the two.
- Check in the manual for the correct specifications.
- Inspect the journals for ridges and the whole crankshaft for cracks due to fatigue.

A ridged journal is shown in Fig. 3. Ridge **3-A** is caused by the oil groove in the bearing shell shown at **3-B**.

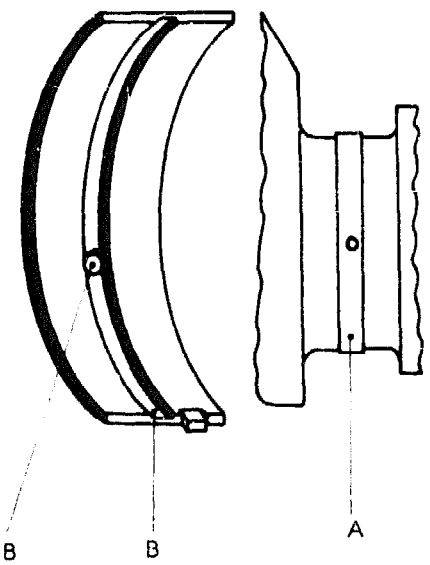

3

Crankshaft float
A crankshaft must have a certain amount of float. Separate thrust washers on both sides of the main bearing or bearing inserts with two thrust flanges on it are used to keep the crankshaft in place.
- Measure the thrust and compare the result with the manufacturer's specifications.

Bushings and bearings

Bushings and bearings are used on rotating load bearing points in an engine to reduce friction. Bearings are used in the engine for the camshaft, connecting rod journals and main bearing journals where heavy loads and high speeds are imposed. See Fig. **1-A**.
Bushings are used round the gudgeon pin, rocker arms, oil pump and other places where speed is not high and the load imposed is rather light. See Fig. **2**.
Bushings are pressed into place. This must be done gently, with great care. They must be inserted exactly straight, the pressure being applied on all sides simultaneously.

Bearing inserts are placed in their housings and bearing locks prevent rotation of the bearing. One lug **1-B** on the insert prevents from rotation of the insert in one direction and the other lug **1-C** prevents from rotation in the opposite direction.

The connecting rod bearing is slightly larger than the housing, to keep it tightly in place. The difference in diameter is called the *crush fit*. Refer to Fig. **3**. When tightening cap **3-A** over bearing **3-B**, the crush height shown at **3-C** makes the bearing fit tightly.

Bearing oil grooves
As you have already learned, lubrication oil for the bearing is supplied from the engine block via the crankshaft to the bearings. Inserts have an oil groove as shown in Fig. **1-D** to spread oil over the bearing journals. Sometimes other shapes of oil grooves are used, depending on the function.

Thrust bearings
Thrust washers and thrust flanges on bearings have already been mentioned in the explanation of the crankshaft float. Figure **4** shows a section of a bearing with thrust washers (**4-A**) and a bearing with thrust flanges (**4-B**). These bearings are used near the flywheel and must be on both halves of the bearing.

1

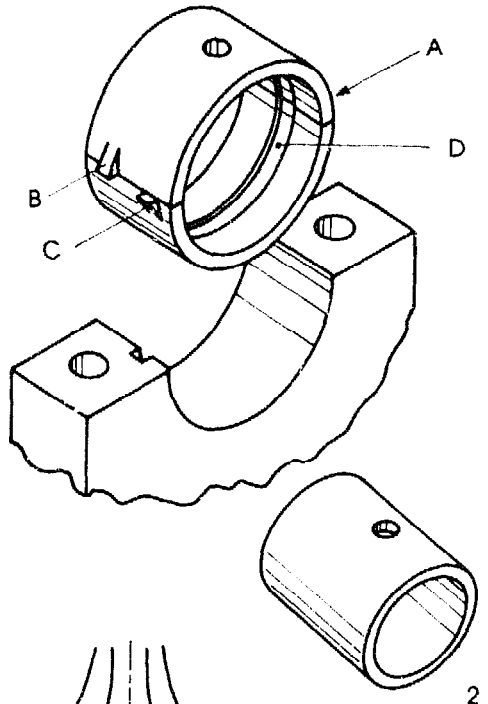

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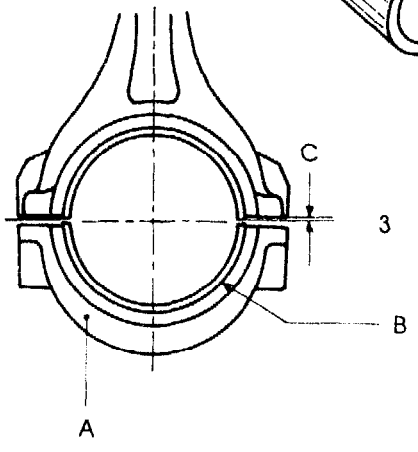

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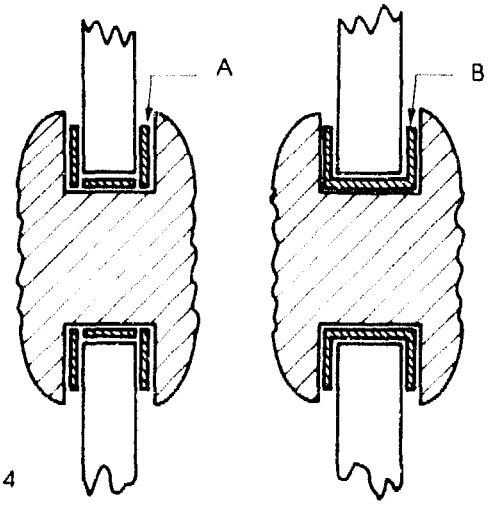

4

Bearing metal alloys

1

In general a bearing (see Fig. **1**) has a body made of steel **1-A** with some linings of different material **1-B** and **1-C**. The bearing material depends on the expected stresses. Lining on bearings may be:

- copper or aluminium alloys and silver combinations,
- copper or aluminium alloys,
- tin or lead-base babbitt,
- special alloys.

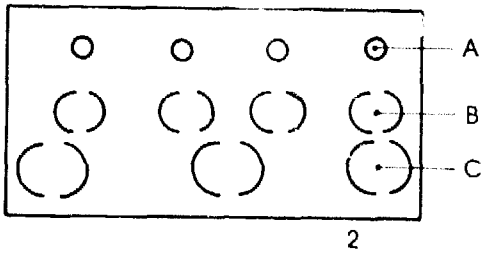

2

Bearing inspection

Before taking out the bearings, clean the top of the workbench so that all bearings can be placed in the same sequence as they are removed, see Fig. **2**. Use one line for the gudgeon pin bushings **2-A**, one line for the connecting rod bearings **2-B** and one line for the main bearings **2-C**.

- After cleaning the bearings, mark them with a soft pencil to remember their position, see Fig. **3**.
- Check whether all the bearings fit correctly into their housings.
- Fix the connecting rod and main bearings back into their housings and measure with a micrometer for wear.

Remember that a bent connecting rod can damage bearings. So you must pay special attention to the connecting rod.
If the supply of lubrication oil is not adequate, bearings show score marks. If fuel oil drips into the crankcase, it dilutes the lubrication oil and causes the same problem.

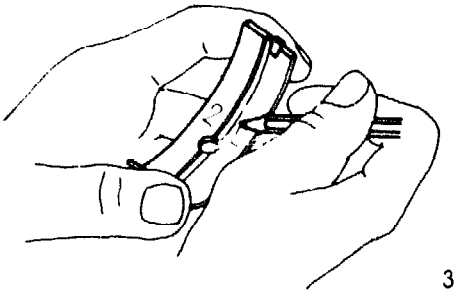

3

A finely pitted surface exhibits corrosion due to acid formation in the lubrication oil, excessive blow-by or the oil temperature exceeding 150 °C. It may also be due to stop-and-go operation which causes condensation in the crankcase.
Other damage can be caused by tapered journals and dirt.

Do not just replace the bearings; first find the cause of the damage and repair it. Then replace the bearings.

Measuring practice

Once you have worked through the chapters on pistons, cylinders etc., it is good practice to measure the diameters of;

- Cylinders
- Pistons
- Connecting rod bearings
- Crankshaft journals
- Crankshaft bearings

To do this you need an inside and outside micrometer, the use of which has already been explained in volume 1 of the Rural Mechanics Course: *General metal work, sheet metal work and handpump maintenance.*

Copy the tables as shown on this and the next two pages and fill in the correct diameters you measure. After each practical, consult your instructor.

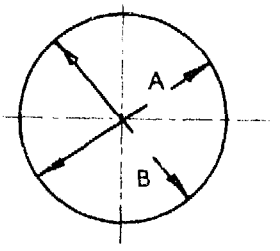

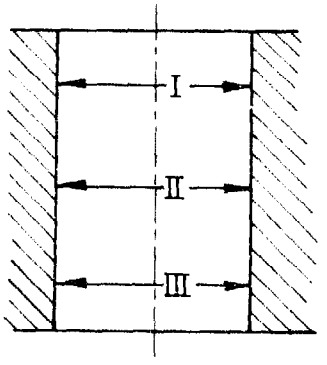

Find the difference between the nominal size and the actual size of the cylinder at positions **1-A** and **1-B** at levels I, II and III.
Enter the sizes in the table below.

Manufacturer and engine no.:								
Nominal diameter of cylinder:								
Cylinder	1		2		3		4	
Position	A	B	A	B	A	B	A	B
I								
II								
III								

Measuring practice

Check the diameter of the pistons in positions **1-A** and **1-B** at levels I, II and III.
Enter the sizes in the table below

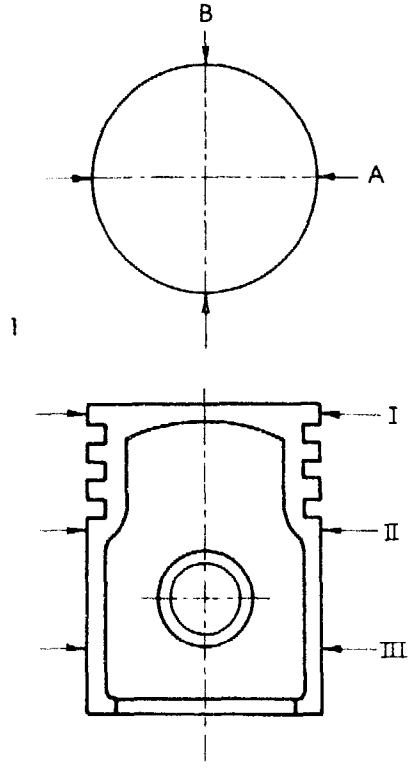

1

Manufacturer and engine no.:								
Nominal diameter of pistons:								
Piston no.:	1		2		3		4	
Position	A	B	A	B	A	B	A	B
I								
II								
III								

Clean the bearings thoroughly and tighten them again with the torque wrench. Use the micrometer to measure the bearings at the positions **2-A1**, **2-A2**, **2-B1**, **2-B2**.
Enter the sizes in the table below.
Find the difference between the nominal size and the actual size.

Nominal diameter of bearing:				
Bearing no.:	A1	A2	B1	B2
A				
B				
C				
D				

2

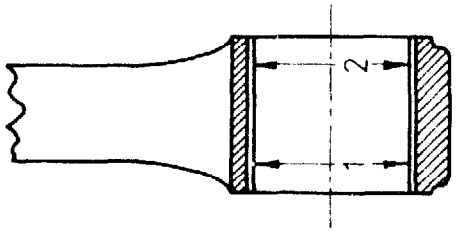

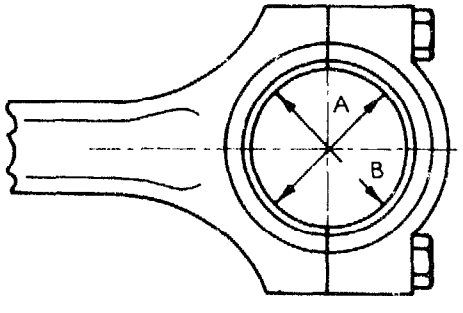

Measuring practice

Check the crank journals at the points **1-A1, 1-A2, 1-A3, 1-B1, 1-B2** and **1-B3**.
Enter the results in the following tables.

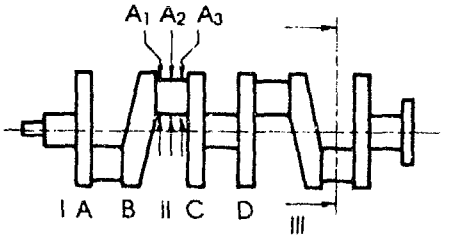

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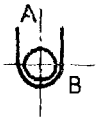

Manufacturer and engine no.:												
Crank journal	A			B			C			D		
Position	1	2	3	1	2	3	1	2	3	1	2	3
A												
B												

Main journal	I			II			III		
Position	1	2	3	1	2	3	1	2	3
A									
B									

2

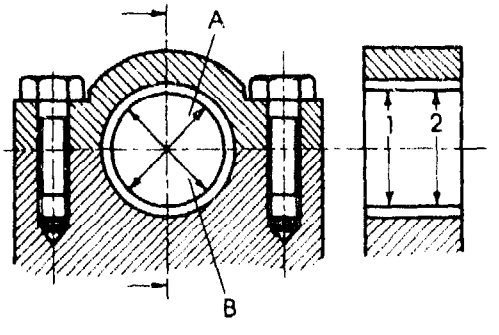

Clean the bearings thoroughly and tighten them with the torque wrench.
Use the micrometer to measure the bearings at positions **2-A1, 2-A2, 2-B1** and **2-B2**.
Enter the sizes in the table. Find the difference between the nominal size and the actual size.

Manufacturer and engine no.: Nominal diameter of bearing:				
Bearing no.:	A1	A2	B1	B2
I				
II				
III				
IV				

The flywheel

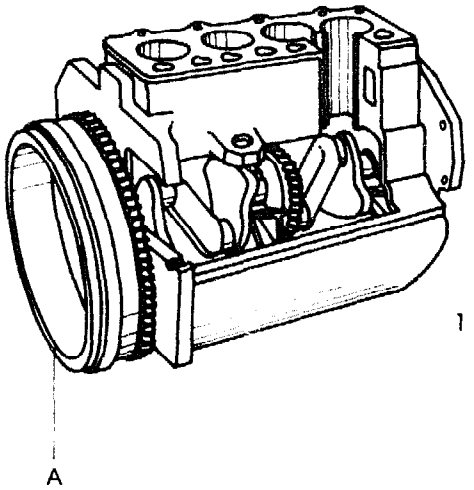

1

A flywheel is heavy in weight and construction. It is usually made of steel or cast iron, see Fig. **1-A**. The flywheel is mounted on the crankshaft at the rear of the engine and its purpose is to stabilize the engine. A flywheel is used to:

- store energy for dead moments between the power strokes,
- ensure a regular crankshaft rotation,
- transmit power via a clutch or pulley to any machinery attached,
- start the engine, if fitted with a ring gear.

Parts of the flywheel

Figure **2** shows an illustration of a flywheel, where you will see:

- Holes to balance the flywheel **2-A**
- Possible bearing hole **2-B**
- Holes for bolting the crankshaft to the flywheel **2-C**
- Dowel hole **2-D**
- Flywheel body **2-E**
- Starter ring gear **2-F**
- Locking plates **2-G**
- Bolts **2-H**

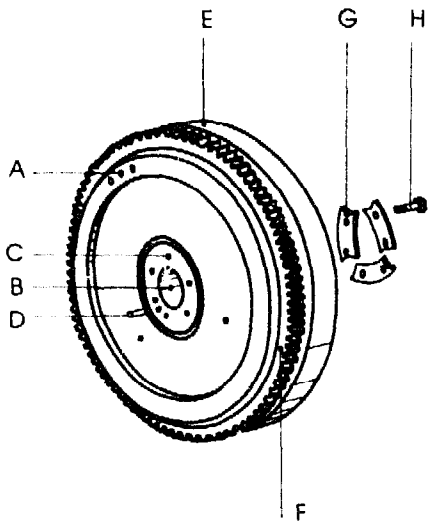

2

Starter ring gear

The starter ring gear may be integrated in the flywheel body or may be separated and shrunk into place on the flywheel rim.

If the teeth are damaged the ring must be replaced. To make it easier to remove the ring, it is best to drill an 8 mm hole (Fig. **3-A**) as near as possible to the inside edge of the ring and then cut off the remaining part with a hacksaw (**3-B**). Immerse the new ring in boiling water. Do not heat it more, because the material may lose its hardness.
Place the flywheel on a solid base. With the ring in place, fix clamps and with light turns and taps drive it into place squarely against its flange. Make sure the ring is correctly fixed with the tapered edge of the teeth facing away from the flywheel.

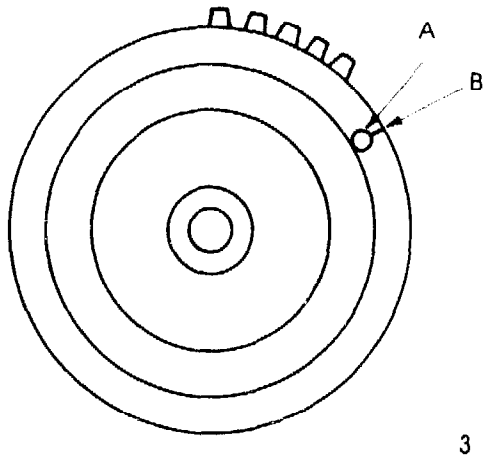

3

Fixing the flywheel

When re-fitting the flywheel, make sure it is mounted in the same position as it was taken off. The dowel pin must return in exactly the same hole and the bolt and locking plates must be fixed securely.

Timing transmission

Transmission from the crankshaft to the camshaft is via gearwheels, as shown in Fig. 1 The crankshaft gear wheel **1-A** has straight teeth, square to the shaft. The camshaft gear wheel **1-B** runs with a reduction of only half the speed and in the opposite direction. Wheels **1-C** and **1-D** have helical teeth, which reduces the noise when the engine is running at full speed.

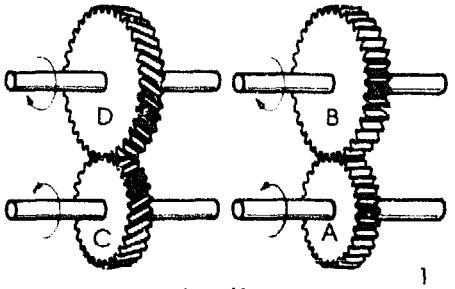

1

The timing gear train

The timing gear train is made up of two or more gear wheels to drive the camshaft or other engine parts, such as the lubrication oil pump, fuel pump etc., see Fig. 2.

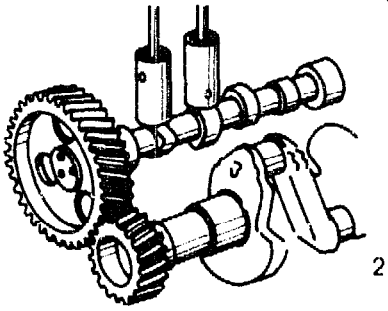
2

The power transmission can be realised by:
- a gearwheel transmission as shown in Fig. 3,
- a chain transmission as shown in Fig. 4,
- a toothed belt transmission, used mostly in car engines.

Timing the gear train

Many gears in the engine's gear train must be synchronized to ensure correct engine operation. The camshaft operating the valves must be synchronized with the pistons and the crankshaft.
To make it easier to set the gears correctly after overhauling, mark the gearwheels with either a short line or a punch dot. Figure **3** shows a short line made on the camshaft gearwheel (**3-A**) and a punched dot (**3-B**) on the crankshaft gearwheel. Figure **4-B** shows a punch dot made on both wheels.
In some cases the two marks must match each other exactly, see Fig. 3. In other cases the punch dot on one of the teeth must match the other punch dot between the gearwheel teeth of the other wheel, see Fig. 4.
Other timing marks may be used. Check in the engine operating manual on how to synchronize the engine.

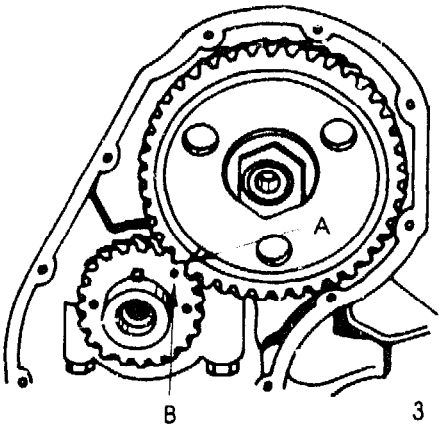

3

Gear train backlash

Teeth of the gearwheels may be slightly worn. The clearance between the teeth is called *backlash* and the allowance for backlash is given in the engine's specifications. Chain tension **4-A** reduces the backlash.

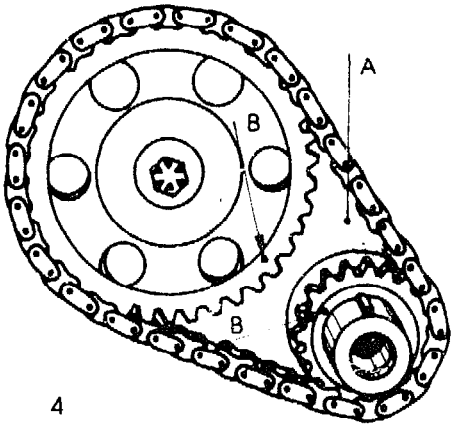

4

Fuel systems

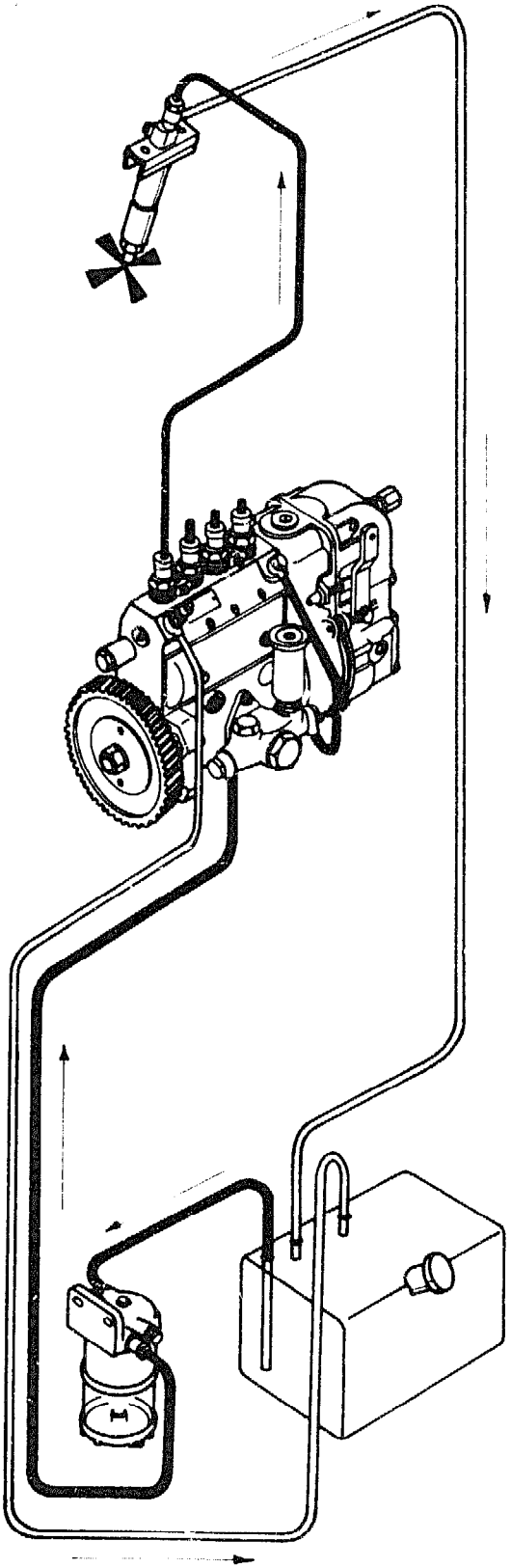

Fuel and fuel storage

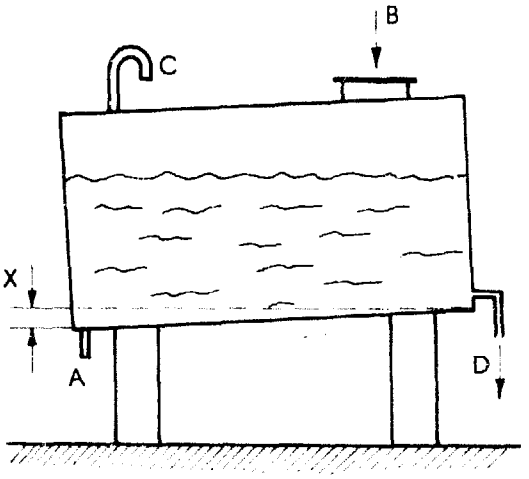

1

Fuel as received from the supplier is usually stored in a bulk tank, which should be situated outside the engine room. The main storage tank is normally made of steel and it is essential to make sure the steel is *not* galvanised internally, because all fuels are to a certain extent acid. Acid dissolves zinc plating, producing a gas that is highly explosive. It also leaves a sludge deposit in the bottom of the tank that could enter the fuel system, causing much damage.

The storage tank should be installed with a sloping bottom, see Fig. 1. The slope **1-X** may be between 100 to 150 mm and there must be a drain plug **1-A** at the lowest point, so that water and sludge can be drained at regular intervals. A filler opening with a filter must be positioned at the top of tank **1-B** and a vent pipe in the shade shown in **1-C** should allow air to enter. As mentioned before, the supply outlet **1-D** should be some 120 mm above the drainpipe.
Fuel is taken from the main supply tank to the daily fuel tank. This tank must contain sufficient fuel for the required operating hours. Use a funnel with filter. If a drum is used as a fuel tank, leave the drum for at least 12 hours to ensure that dirt and water have been able to settle.

2

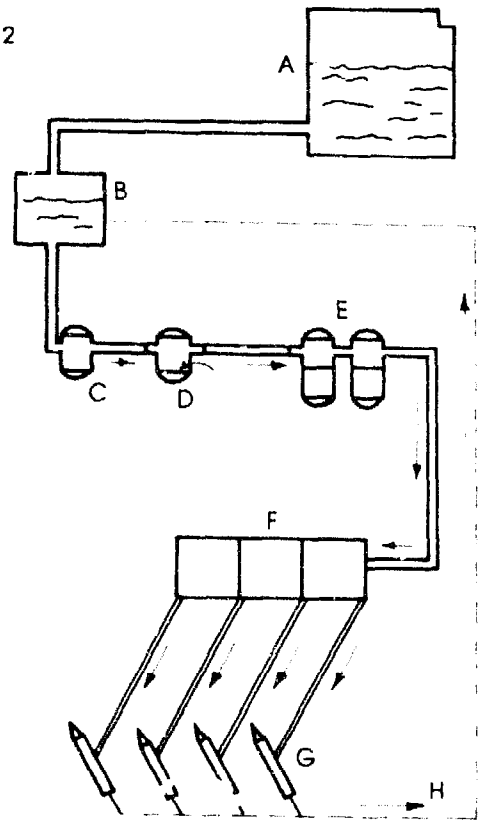

Diesel fuel systems
No matter what diesel fuel equipment is fitted, you must realize that the main function of the system is to supply an exact amount of atomized and pressurized fuel to a cylinder at a precise moment. As you have already learned, combustion occurs in a diesel engine when a charge of fuel is mixed with hot compressed air.

As shown in Fig. 2, the main parts of a diesel fuel system are:
- Fuel storage tank **2-A**
- Daily fuel storage tank **2-B**
- Sediment bowl **2-C**
- Fuel transfer pump **2-D**
- Fuel filter(s) **2-E**
- Injection pump(s) **2-F**
- Injection nozzle(s) **2-G**
- Spalway **2-H**

Sediment bowl

A sediment bowl is used to let any dirt settle down into a bowl made of glass. Through this glass you can see how much dirt has settled and when it must be taken out. As shown in Fig. **1**, a fuel valve assembly **1-A** is fixed to a glass bowl **1-B**. A retainer **1-C** and a knurled nut **1-D** attach the sediment bowl to the valve assembly. A rubber gasket **1-E** and a filter gauze **1-F** are placed between the sediment bowl and the valve assembly. A fuel valve **1-G** is located in the valve assembly.

When installing the bowl, fill it with fuel prior to tightening, making sure no air is trapped in the bowl.

Fuel feed pump
Fuel is pumped from the sediment bowl by a mechanically operated diaphragm fuel supply pump, see Fig. **2**. This pump is mounted on the side of the cylinder block and is operated by the engine's camshaft **2-A** and cam lob **2-B**. The fuel feed pump has a hand priming lever **2-C** for bleeding the fuel system after it has been drained or when air has entered the system. The main parts of the pump are given on the next page.

One of the most important parts of the fuel supply pump is the diaphragm **2-D**. This diaphragm can be made of different materials and carries out the pumping action in the pump. After removing the diaphragm, check it thoroughly for wear and cracks. Also check the length of the pin **2-E** and the strength of the spring **2-F**.
When checking the pump, pay special attention to the operation of the valves **2-G** and **2-H**, they are of vital importance.

When assembling the diaphragm, tighten all screws lightly at first, then gradually tighten them further. If you tighten the screws too much on one side at first, it is difficult to achieve a leak-proof connection.

Handle valves with the greatest care because they are made of a very light material and distort easily.

Cleaning the fuel filter **2-I** prior to assembly is essential.

1

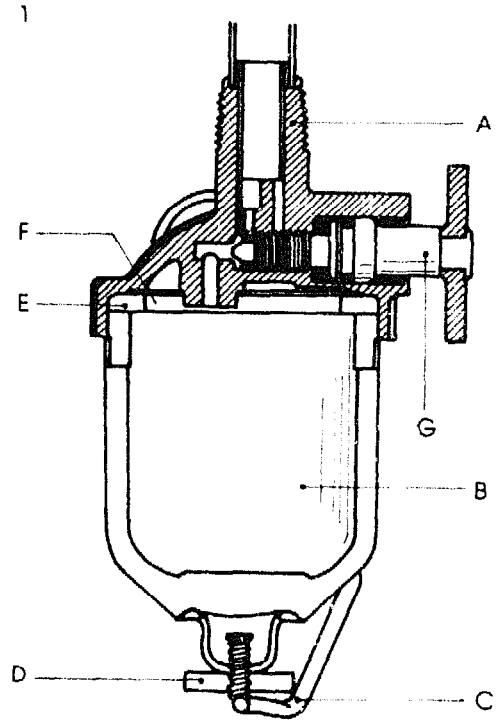

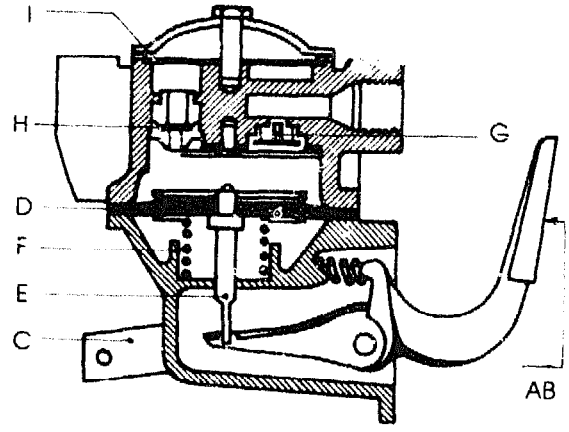

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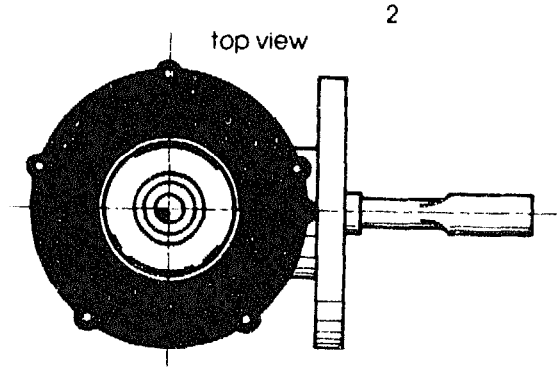

Typical fuel supply pump assembly

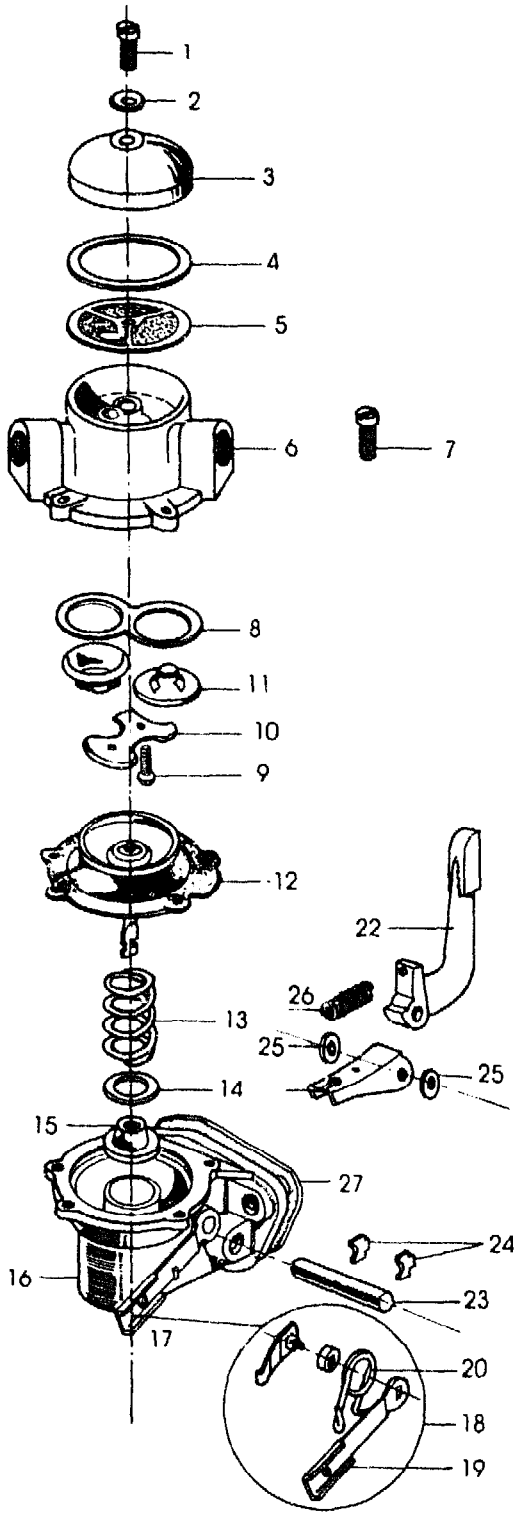

1 – Filter cover screw
2 – Screw gasket
3 – Cover
4 – Cover gasket
5 – Filter gauze
6 – Upper housing
7 – Upper housing screw
8 – Gasket valve plate
9 – Valve retainer screw
10 – Valve retainer
11 – Valve assembly
12 – Diaphragm assembly
13 – Diaphragm spring
14 – Diaphragm spindle seal
15 – Retainer seal
16 – Body
17 – Hand primer assembly
18 – Hand primer parts set
19 – Hand primer
20 – Primer lever spring
21 – Rocker arm lever
22 – Rocker arm
23 – Rocker arm pin
24 – Rocker arm pin retainer
25 – Plain washer
26 – Rocker arm return spring
27 – Joint

Assembling the pump

- Flush the valves in diesel fuel; this improves the seal between the valves and the seats.
- Fit the outlet valve spring in the centre on the four cast webs in the upper housing and place the outlet valve on the spring.
- Place the inlet valve on the valve seat in the upper housing and the valve spring on the centre of the inlet valve.
- Place the valve plate gasket and the valve retainer in position and secure them with three screws.
- Use a piece of wire to test whether the valves are moving freely.
- Place the filter screen, cork gasket, cover and fibre washer in position and fix them with the retaining screw.
- Assemble the connecting rod link, the two washers and the rocker arm spring inside the lower housing, then spring the retaining clips into their grooves.
- Insert the fabric washer first, then the metal washer and position the diaphragm spring in the lower housing.
- Fix the upper and lower housings together with screws.

Fuel filters

Fuel filters can be installed singly or in pairs to prevent harmful dirt and abrasive substances finding their way into the delicate parts of the injection pump and injectors.
Dual filters connected in cascade are shown in Fig 1. Fuel enters the first filter through inlet **1-A**. After the large particles are filtered, the fuel moves to filter **1-B**, from where it runs to the fuel pump through **1-C**. Excess of fuel is returned via **1-D**.

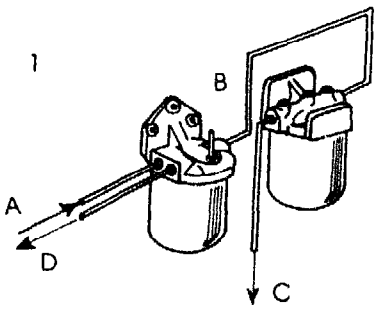

Typical fuel filter parts
- Filter bowl **2-A**
- Drain plug **2-B**
- Drain plug washer **2-C**
- Dished plate **2-D**
- Dished plate steel **2-E**
- Centre bolt **2-F**
- Circlip **2-G**
- Spring **2-H**
- Plain washer **2-I**
- Washer, centre bolt sealing **2-J**
- Plate **2-K**
- Sealing ring **2-L**
- Filter element **2-M**
- Sealing ring **2-N**
- Sealing head to bowl **2-O**
- Filter head **2-P**
- Bleeding plug **2-Q**
- Bleeding plug washer **2-R**

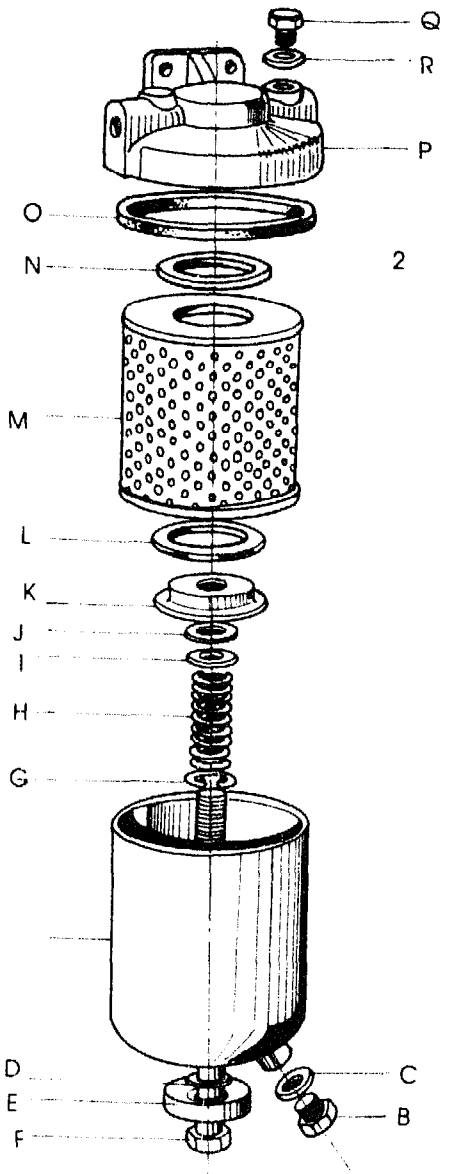

Assembling the fuel filter
- Replace filter head assembly
  Replace all fuel pipes, make all unions finger tight and check whether the connections are centred correctly. Tighten the connections correctly, do not over-tighten them.
- Refit the filter bowl with the new filter element and O-ring. Engage the head assembly with the centre stud and screw firmly. Again, do not over-tighten.
- Close the drain plug.
- Open the fuel supply valve at the tank and bleed the fuel system.
- Check all connections for leaks.

Note: some fuel filters can not be washed.

Injection and combustion

Spontaneous combustion through high compression in a diesel engine may be difficult to understand, since it is by no means an uncontrolled explosion. Though the charge of fuel may be injected into the cylinder in a hundredth of a second, the resultant combustion is a general process which occurs in stages. These stages can be controlled to ensure optimum performance.

First stage of combustion
The first stage of combustion is a *warming up* stage during which the fuel, as it is sprayed into the combustion chamber under high pressure, is raised from its normal temperature almost to that of the compressed air in the combustion chamber.
The compression temperature is higher than the ignition temperature of the fuel. So obviously, after a certain delay, the fuel must actually burn.
The delay between injection and the beginning of combustion is known as the *Ignition Delay Period* and sometimes takes as much as one third of the total injection time. It is important to reduce this delay period as much as possible, especially in diesel engines which run at high speed.
The Ignition Delay Period is influenced by several factors:
- the ignition quality of the fuel,
- the fineness of the fuel atomization,
- the difference between the air and fuel temperatures.

For these reasons it is important to use the best quality fuel available, because the fineness of the atomized fuel during injection determines the time taken for the fuel to mix with the air charge. The temperature difference between the injected fuel and the compressed air in the combustion chamber is directly related to the temperature of compression and hence to the compression ratio of the engine.

Second stage of combustion
After combustion has taken place, the temperature inside the cylinder rises very gradually since heat is still absorbed by most of the fuel particles created by atomization. The delay period is thus prolonged until the heat caused by the burning fuel is more than sufficient to offset the heat required to prepare for further fuel combustion. Following the delay period there is a stage of uncontrolled combustion as the flame spreads to the entire charge of fuel which has been injected throughout the delay period. This naturally causes a very high cylinder temperature and along with it a high cylinder pressure.

Third stage of combustion
The final stage of the combustion process is a direct burning phase when the fuel already in the combustion chamber continues to burn and the fuel still being injected ignites almost instantaneously on entry. The pressure attained during this period depends almost entirely on the rate of fuel injection. That is why combustion can be partly controlled by the design of the camshaft-fuel cam profile.
When fuel injection is completed, combustion continues until the fuel charge has expanded, which is accompanied by expansion of the gases being produced as a direct result of combustion and displacement of the piston on its power stroke.

Combustion conditions
Two essential conditions for complete combustion are:
- The fuel must be injected into the cylinder in a highly atomized condition.
- An adequate supply of air must be available so the fuel can mix with it intimately.

To make sure the fuel is in a highly atomized condition, various fuel pumps and injectors are used which are explained in detail in the following lessons.
An adequate supply of clean fresh air is also explained at a later stage.

Fuel injection pumps

Each cylinder in a diesel engine has its own injector and each injector has its own fuel supply through a fuel pump.
Only a single-element fuel pump is installed in a one-cylinder diesel engine. This fuel pump is powered by the engine's camshaft. See Fig. 1.
Single-element pumps are sometimes installed in a multi-cylinder diesel engine. These pumps are powered by the camshaft. They are joined together with a fuel control bar, so that all pumps work correctly at the same time.

In-line pump
The in-line pump provides for each cylinder a different fuel pump. Basically the in-line pump is similar to the single-element pump. The difference is that this pump is not powered by the engine's camshaft, but by the timing gear via a small camshaft located inside the in-line pump housing, from where each injector is supplied via a built-in pump. See Fig. 2.

Distributor fuel pump
Multi-cylinder engines may also have a distributor type of fuel pump. See Fig. 3. This pump is also connected to the timing gear 3-A but the fuel supply to the different injectors is different from that of the in-line pump, as we will see at a later stage.

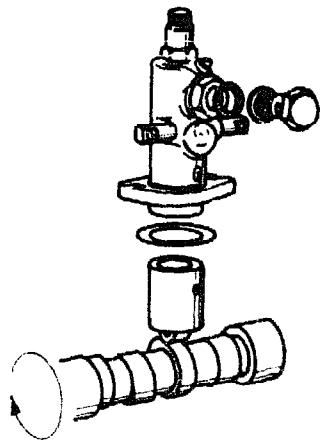

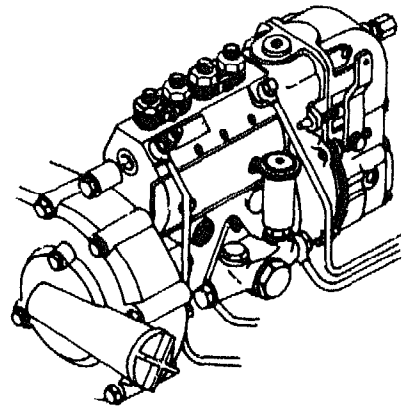

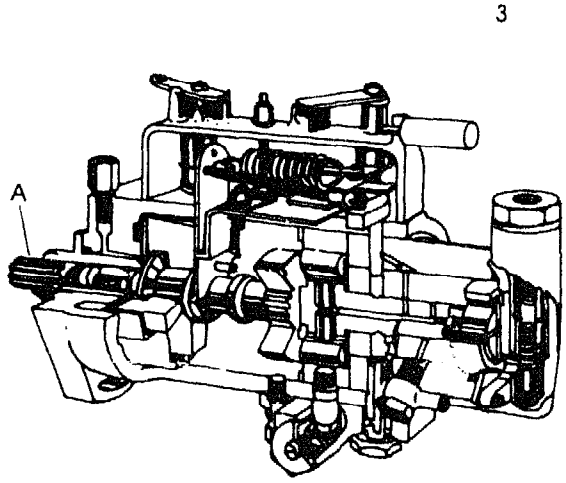

Single-element fuel injection pump

Figure 1 shows a cross-section of a single-element fuel injection pump. A pump element consists of a highly ground steel plunger operating in a barrel which is also precision ground. The fitting clearance for these components is so precise that the plunger and barrel are matched as pairs by the manufacturer. It is important to note that, if a new element must be fitted, both the barrel and the plunger must be replaced.
If for any reason the elements of several pumps are removed at the same time, care must be taken to ensure that plungers are re-assembled in their correct barrels. The delivery valve fitted at the upper end of each barrel is mitre-fitted and has a cylinder body with an angular groove cut into it. The lower part of the valve has four longitudinal grooves communicating with the annular groove. The upper part forms a small piston, which fits very accurately in the valve guide. In Fig. 1 you will see the following parts:

- Opening to fuel pipe **1-A**
- Pipe connection **1-B**
- Delivery valve spring **1-C**
- Delivery valve **1-D**
- Element locking screw **1-E**
- Pump barrel **1-F**
- Pump plunger **1-G**
- Control sleeve **1-H**
- Plunger part **1-I**
- Plunger return spring **1-J**
- Fuel control bar **1-K**
- Fuel supply inlet **1-L**
- Bleed screw **1-M**

Pump action
The fuel injection pump plunger is moved with power from the camshaft. If you study Fig. 2, you will see how the plunger in the fuel injection pumps is moved via a roller in a tappet from the fuel cam on the camshaft:

- Single fuel pump element **2-A**
- Shim **2-B**
- Tappet **2-C**
- Camshaft **2-D**
- Pushrod tappet **2-E**
- Fuel cam on camshaft **2-F**
- Guide, fuel pump element **3-A**
- Cap **3-B**
- Tappet **3-C**
- Roller pin **3-D**
- Retaining pin **3-E**
- Bushing **3-F**
- Roller **3-G**
- Washer **3-H**
- Locating pin **3-I**

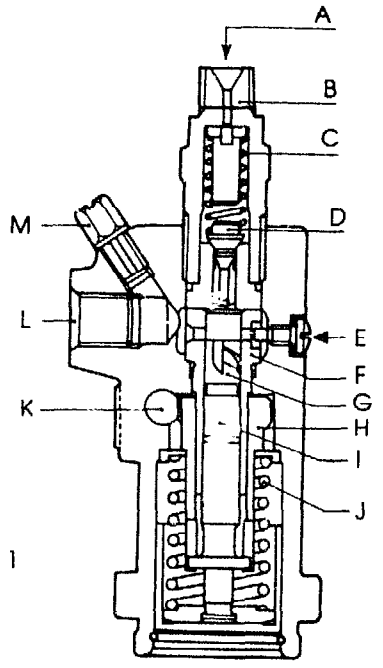

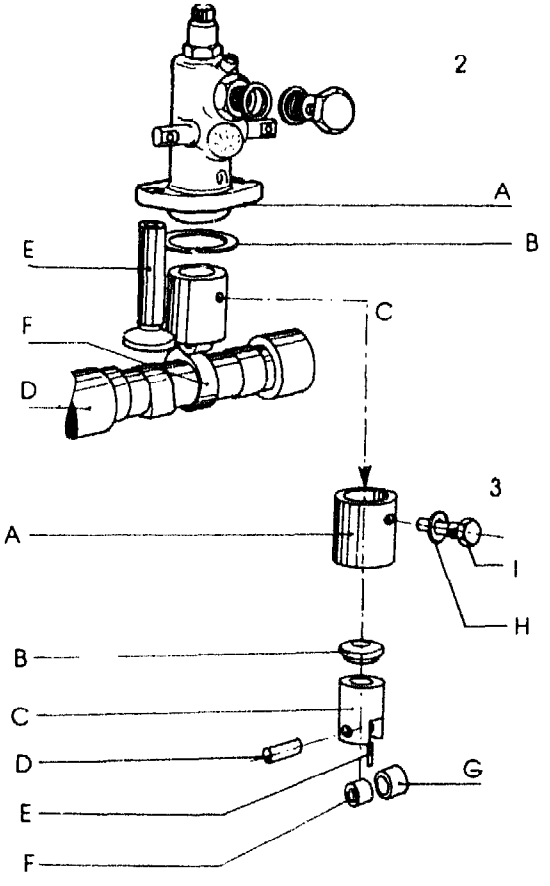

Operation of the fuel pump element

When the plunger is at its lowest point as shown in Fig. 1, the fuel is free to flow into the barrel through the fuel port. The injection pump is constantly flooded by a supply of fuel from a fuel booster pump or by gravity feed.
The different parts are called:
- Delivery valve spring **1-A**
- Delivery valve **1-B**
- Fuel inlet port **1-C**
- Vertical slot in plunger **1-D**
- Helical land in plunger **1-E**
- Fuel spill port **1-F**

As the plunger rises to the position shown in Fig. 2, the top of the plunger closes the inlet and spill ports to the barrel. Further movement of the plunger causes the pressure to rise on the fuel trapped in the pump barrel. The only outlet for the fuel is through the delivery valve into the pipe leading to the injector.
Make sure the delivery pipe is flooded during operation, then the pressure rise is transmitted to the fuel injector valve, causing it to open and the nozzle to spray fuel into the cylinder combustion chamber.
Injection continues in this way until the pump plunger has risen to the position shown in Fig. 3, where the helical land on the bottom of the plunger has uncovered the ports in the pump barrel, thus allowing the pressurised fuel to flow back to the suction side of the pump via the vertical slot in the plunger. This causes an immediate pressure drop in the delivery line, so the delivery valve at the top of the pump closes under the action of its spring. The pressure drop also causes the injector nozzle valve to snap-shut on its seat.

To vary the fuel supply the control rod **4-A** on the pump element can rotate the plunger **4-B** as shown in Figs. 4, 5, 6 and 7. The plunger stroke is always constant, but that part of it which is actually effective can be varied by rotating the plunger in its barrel. This rotation alters the position of the bottom of the plunger helix in relation to the ports in the barrel, so the point of cut-off can be made to occur earlier or later in the stroke.
The effective stroke shown in Figs. 4 and 5 is long and corresponds to almost maximum load, where – as in Fig. 6 – the plunger has been rotated in such a way that the helix opens the barrel ports earlier in the stroke, corresponding to a very light load. In the stop position, Fig. 7, the vertical slot actually registers with the suction port over the entire plunger stroke. The result is a total absence of pressure build-up and the fuel simply circulates from the delivery side to the suction side of the pump in a continious cycle.

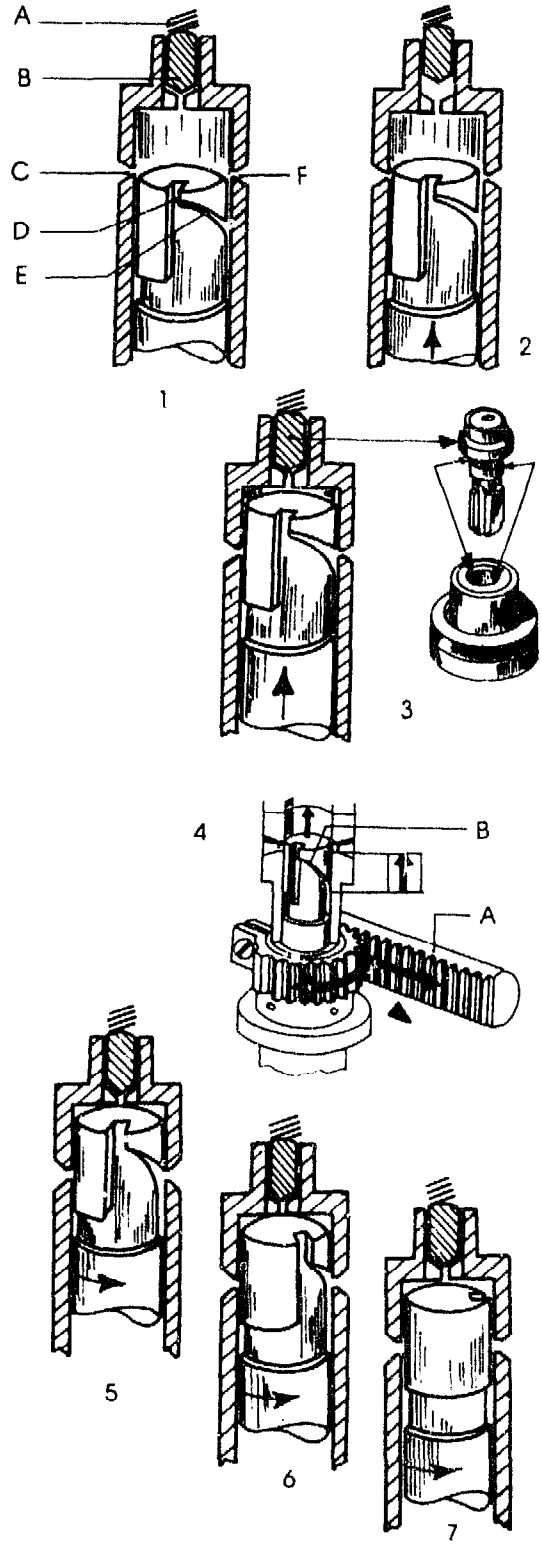

Typical fuel injection pump

In Fig. 1 you will see the parts of a typical fuel injection pump:
- Governor weights **1-A**
- Drive hub screw **1-B**
- Drive shaft **1-C**
- Drive hub **1-D**
- Back leak connection **1-E**
- Shut-off lever **1-F**
- Governor spring **1-G**
- Idling stop **1-H**
- Control lever **1-I**
- Maximum speed stop **1-J**
- Metering valve **1-K**
- Fuel inlet **1-L**
- Pressure regulating valve **1-M**
- Hydraulic head **1-N**
- Rotor **1-O**
- Fuel filter **1-P**
- Regulating piston **1-R**
- Priming spring **1-S**
- Transfer pump **1-T**
- To injector **1-U**
- Advance device **1-V**
- Cam ring **1-W**
- Plungers **1-X**

Typical rotary (D.P.A.) Fuel pump
The distributor type of fuel pump, an example of which is shown in Fig. 1, is very compact. It is flange-mounted to the side of the crankcase. The pump is driven by a shaft through a gear attached to the camshaft and is self-lubricated by fuel.

Fuel entering the pump through the main inlet connection **1-L** is pressurised by a sliding vane transfer pump **1-T** carried on the rotor inside the hydraulic head **1-N**. The pressure rise is controlled by a regulating valve assembly **1-M** located in the pump end plates. The fuel then passes from the regulating valve to the pumping elements **1-X**.
The internal cam ring, mounted in the pump housing, normally has as many lobes as there are engine cylinders, see **1-W**, and operates the opposed pump plungers **1-X** via cam rollers. The plungers are forced inwards simultaneously as the rollers contact the diametrically opposed cam lobes. This is the injection stroke. The plungers are returned by pressure of the in-flowing fuel. This is the charging stroke.
Figures **2** and **3** show that, as the rotor turns, the inlet port **2-A** is cut off and the single distributor port in the rotor registers with an outlet port **3-A** in the hydraulic head. At the same time the plungers **3-B** are forced inwards and fuel under injection pressure passes up the central bore of the rotor through the aligned ports to one of the injectors.

The rotor normally has as many inlet ports as the engine has cylinders and a simular number of outlet ports in the hydraulic head of the pump.

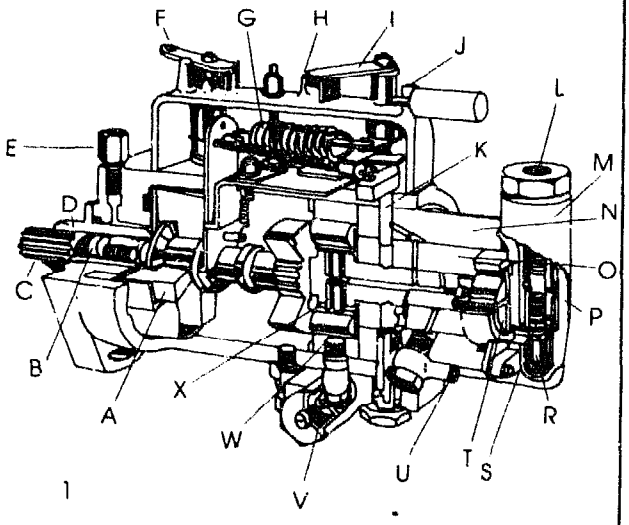

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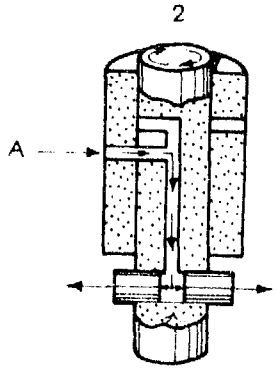

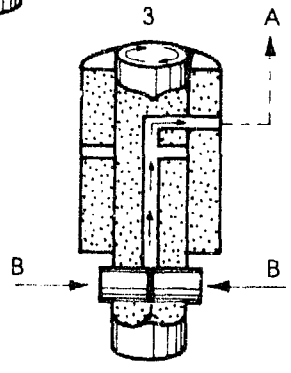

Governor systems

To understand the working principle of the governor, study carefully Figs. **1** and **2**. Two pieces of rope with weights at the end are attached to the disk in Fig. **1**. If you rotate the disk at a certain speed as in Fig. **2**, the weight swings outwards due to centrifugal force. If you decrease the speed, the weight moves inwards again. Both weights must be exactly the same to avoid vibration during rotation.

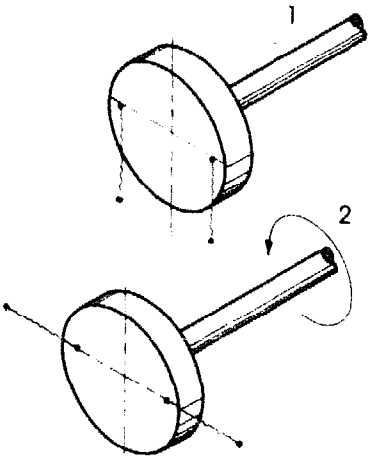

The governor
The governor is a method of regulating the amount of fuel delivered by the fuel pump so that a specific engine speed can be maintained during operation.
In the multi-cylinder pump the governor is inside the housing of the fuel pump and is an integral part of the pump.
Single element pumps have a common governor, a typical lay-out of which is shown in Figs. **3**, **4** and **5**.

Figure **3** shows at **3-D** the last part of the fuel pump rack. This rack is moved by a governor sleeve **3-C**, which in turn is moved up and down by forces produced by the governor's weights **3-A** and **3-B**. When the speed increases, the weights of the governor move outwards and the fuel pump rack is then moved in such a way that it closes off the fuel supply and so reduces the speed.
When the speed decreases, the weights move inwards and the fuel pump rack is then moved in such a way that engine speed increases again. See Fig. **4**.
The type of governor shown is called a variable speed governor. The speed is finally controlled with a lever or cable, operating between set limits.

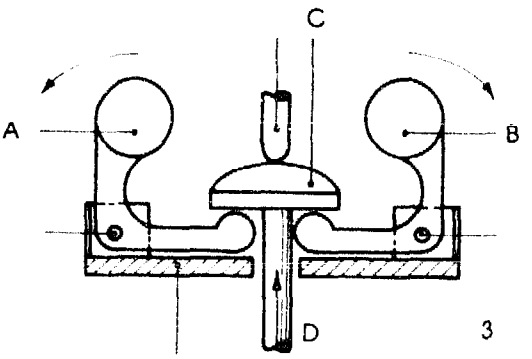

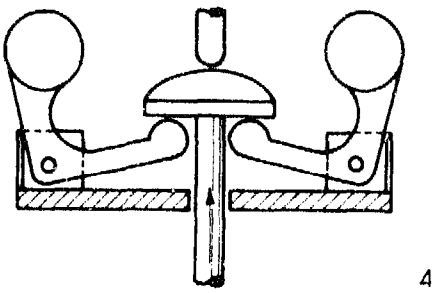

Figure **5** shows a constant speed governor. The special spring **5-A** allows the governor weight to return to a position as required. You must understand that not just any spring may be used – this spring is made precisely for that particular governor and that particular speed. Always check the manufacturer's technical data when working on the governor.

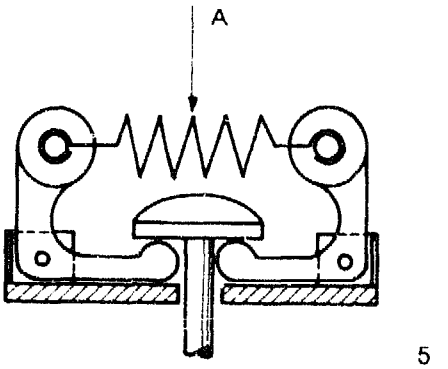

Fuel and governor setting

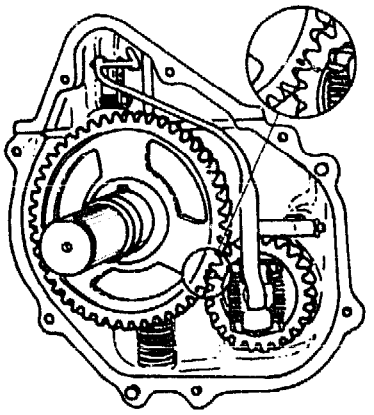

1

Since the fuel pump pumps with the action of the camshaft, make sure that the mark on the pin coincides with the gearwheel mark, see Fig. 1.

Typical governor setting for a one-cylinder diesel engine

Figure 2 shows a typical fuel pump setting assembly. Study this lay-out carefully and name all the parts. To set the fuel pump and governor for a single fuel injection pump you have to set the control on the *run* position **2-R**. Then adjust the linkage **2-A** in such a way that the calibration mark **2-B** coincides with the side of the fuel pump, see Fig. **2**.
Adjust the linkage with the nut **2-C** in such a way that the calibration mark **2-B** coincides with the side of the fuel pump within a tolerance given by the manufacturer. However, the fuel pump rack must move freely after this adjustment.

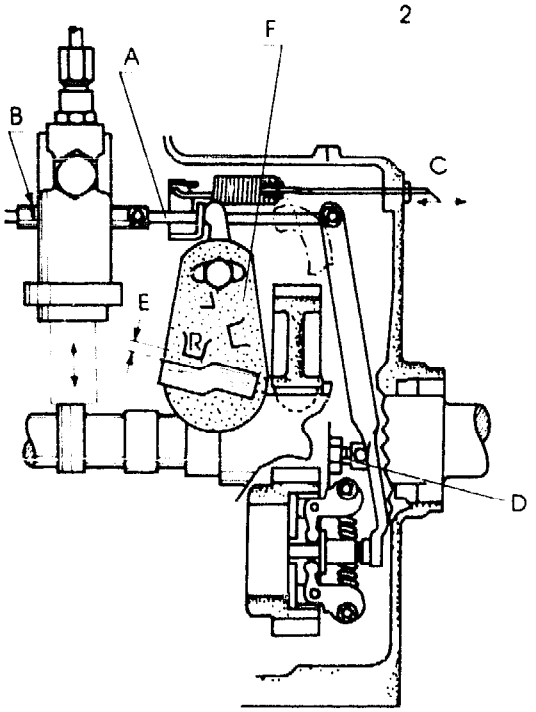

Adjust the governor lever fulcrum **2-D** so that, when the calibration mark **2-B** is against the outside of the fuel pump, the distance between the inside of the governor sleeve and the outside of the governor weight carrier complies with the manufacturer's technical data.

Set the clearance **2-E** to the correct figure for the application and speed of the engine; check these in the technical data. Maintain the correct clearance and rotate the locating plate **2-F** until the calibration mark **2-B** coincides with the side of the fuel pump. The full width of the calibration mark must be visible. When the marks coincide and the clearance is correct, secure the locating plate with the screw.
After making adjustments, check that the fuel pump rack and the linkage move freely.

Firing point

For an engine to operate efficiently the fuel must be injected into the cylinder combustion chamber at the correct time. This is known as the *firing point* and it occurs at a very precise time marked in degrees before TDC on the flywheel, see Fig. 1.
The firing point for each cylinder is usually marked as FP on the flywheel. The letters FP occur when this mark coincides with a fixed mark or pointer attached to the engine.

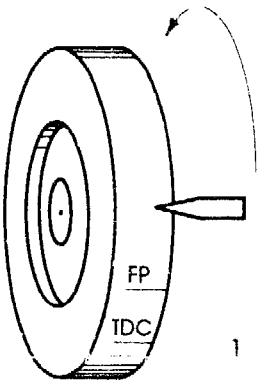

1

Timing the fuel injection pump
There are several methods of checking fuel pump timing, such as Spill Timing, Air Timing and Pump Drive Shaft Timing. Each manufacturer has developed his own fuel system and it is therefore essential to study the manufacturer's instructions and follow them precisely.

The timing is said to be *advanced* if the fuel is injected too early, see Fig. 2. The timing is said to be *retarded* if injection takes place after the flywheel has passed the fixed mark.
On single element pumps the firing point position can be adjusted by changing the vertical distance between the fuel pump and the camshaft, either by adding or removing thin metal shims under the pump body or by moving the pump vertically by a fixed adjuster. See Fig. 3-A.

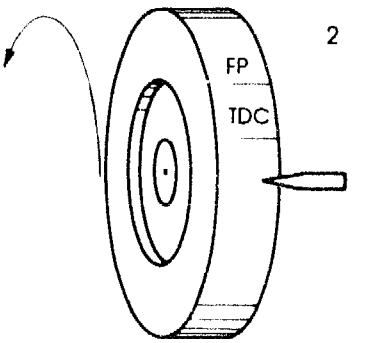

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In multi-cylinder pumps the fuel pump drive shaft is rotated after spill timing in line pumps. For rotary pumps a specially designed tool is used to show the angular degrees.

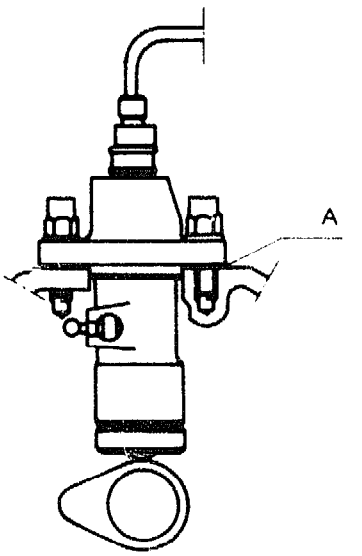

3

Fuel injection

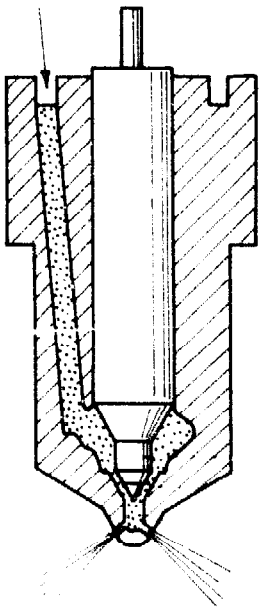

1

The way the fuel is injected into the air charge is very important, as you have seen before. There are two main methods of injection:
- Direct injection
- Indirect injection

Direct injection
When the piston rises during its compression stroke, a swirling motion of air is produced at the top of the stroke. This swirling motion takes the form of a ring of air revolving at high speed, like a ring of smoke blown from a pipe. It is into this rotating ring of air that the fuel charge is sprayed from many fine holes at the tip of the injector nozzle, see Fig. 1.

Direct injection by means of multi-hole injectors is widely used because, with this method of injection, the fuel is highly atomized before it mixes with the swirling air. But one disadvantage of direct injection is that, to produce a very fine spray, the fuel is injected through several very fine holes which may become blocked by carbon.

Indirect injection
Contrary to multi-hole injectors, the indirect injection nozzles have large holes through which the fuel is sprayed into the combustion chamber. Indirect injection nozzles are usually of the single or twin hole type with larger holes. So atomizing is not as satisfactory unless additional means are provided to ensure good mixing of the fuel and air, see Fig. 2.

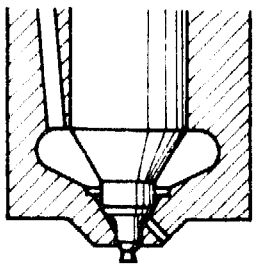

2

One way of improving this situation is to force the compression stroke air through a small orifice into a separate cell or combustion space, improving the swirling motion of the air.

Indirect combustion ensures good combustion over a wide range of load and speed conditions. In general the engine will be able to operate using poorer quality fuels with less risk of carbon formation.

Combustion chamber

In the previous lessons you have learned that the injection nozzle and its atomizing helps to mix the fuel and the air. The piston crown and the design of the cylinder head play an important role in improving the air and fuel mixture.

Turbulence chamber
Figure **1** shows a so-called open combustion chamber. In this chamber all fuel and air are confined to one area due to the concave shape of the piston crown, see Fig. 2. The piston comes close to the cylinder head and makes it easier for the fuel to be sprayed evenly into the chamber. The concave in the piston crown also sets up a turbulence of the compressed air. This speeds up the air and makes it easier to mix with the fuel.

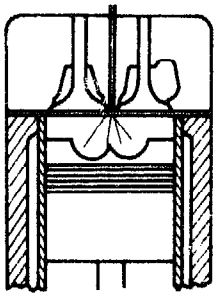

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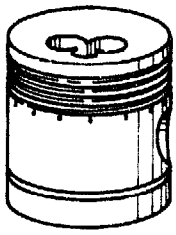

2

A turbulence chamber in the cylinder head is shown in Fig. **3**. As you see, the fuel is injected into a small chamber in the cylinder head and shaped in such a way that it produces a highly turbulent condition.
As the piston starts the compression stroke, the air is forced into the chamber and sets up the rotary motion. Near the top of the piston stroke the fuel is injected into the swirling air, which results in a good mixture of air and fuel.

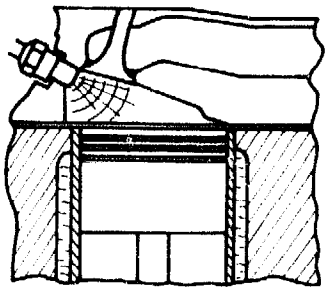

3

Pre-combustion chamber
This chamber is shown in Fig. **4-A** and is similar to the turbulence chamber except that only part of the air charge is forced into it. If the fuel starts to burn with an insufficient amount of air, it ignites, forcing the burning fuel into the cylinder **4-B**, where the fuel readily mixes with the remaining air during combustion.

Glow plug
Diesel engines are sometimes equipped with a glow plug to speed up the starting procedure by pre-heating the chamber. See Fig. **4-C**.

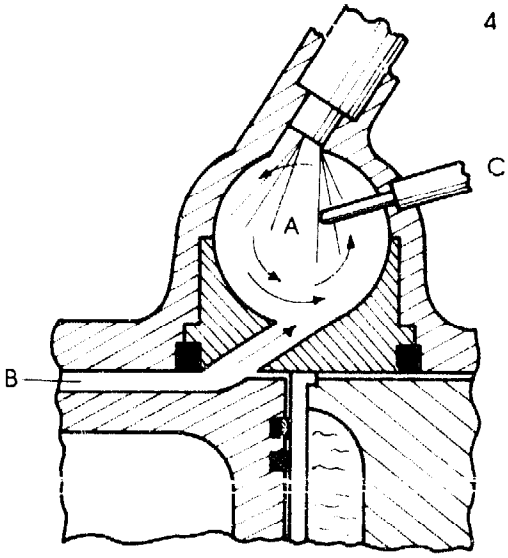

4

Injectors

1

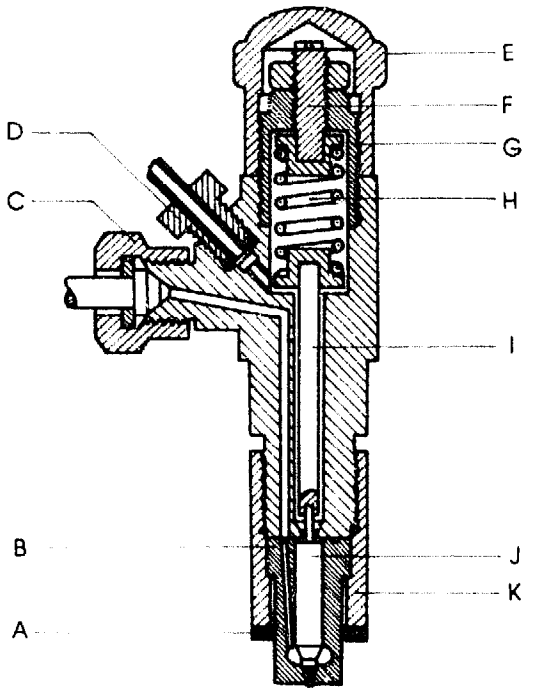

Injectors spray the fuel into the swirl chamber the moment the air in the swirl chamber has been compressed. Injectors consist of two principal parts:
- the *nozzle* with its *valve*,
- the *nozzle holder*.

A typical injector holder with nozzle is shown in Fig. **1**, where you will see:
- Copper washer **1-A**
- Nozzle body **1-B**
- Fuel inlet connection **1-C**
- Leak-off connection **1-D**
- Protective cap **1-E**
- Compression screw **1-F**
- Spring cap nut **1-G**
- Valve spring **1-H**
- Valve spindle **1-I**
- Nozzle valve **1-J**
- Nozzle cap nut **1-K**

When fixing the injector, you must make sure the nozzle cap nut is seated correctly and the copper washer **1-A** is of good quality, because there must be no pressure leaks.

Injection nozzles

Two typical *inward-openening* nozzles are shown in Figs. **2** and **3**. Both are of the *pintle type*.

2

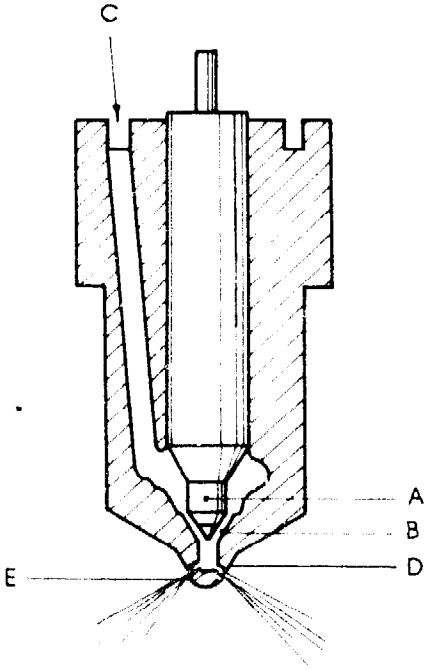

The multiple hole type nozzle in Fig. **2** uses a tapered valve **2-A** which seats in a single orifice **2-B** in the valve body. When fuel is pressed through the fuel inlet **2-C**, it pushes the valve upwards and allows fuel to pass towards the spray tip **2-D** and be sprayed through the nozzle holes **2-E**.

As soon as the fuel pressure drops, the valve resistance declines and the valve spring pushes the valve spindle and the nozzle valve down, thus closing off the fuel supply.

A closed pintle type nozzle is shown in Fig. **3**. This type of nozzle has auxiliary spray holes **3-A** to assist easy starting under cold conditions.

3

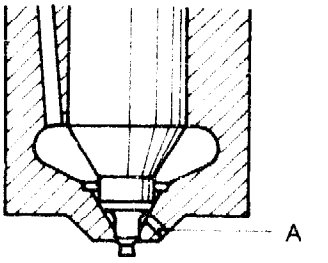

Faulty injectors

If you see excessive black or grey smoke coming from the exhaust of the engine, it is likely that one or more injectors are faulty. If the exhaust gives distinct puffs, probably one of the injectors must be serviced. White smoke shows that one or more cylinders have cut out. Uneven running or stalling under load are also symptoms of faulty injectors.

A good method of locating a faulty injector is to start the engine and let it warm up and then note the r.p.m. (revolutions per minute). Loosen one of the fuel lines. As the nut is loosened, the full pressure drops and injection stops at that particular injector. While doing this, keep your face and hands out of the way, because the fuel is under extreme pressure and may penetrate your skin. If the injector is good and working correctly, the engine slows down more than before and the sound of the engine changes. You understand that when the injector fuel inlet is loosened on a faulty injector, there will be no change in either sound or r.p.m.
Continue this test until all injectors have been checked. When you have identified the faulty injector remove it, service it or replace it with a new injector or nozzle.

Injector parts
- Valve cone **1-A**
- Valve stem **1-B**
- Valve seat **1-C**
- Pintle **1-D**
- Fuel inlet **1-F**
- Pressure face **1-E**
- Nozzle shoulder **1-G**
- Nozzle trunk **1-H**
- Fuel gallery **1-I**
- Valve seating **1-J**
- Pintle orifice **1-K**
- Nozzle retaining shoulder **1-L**

1

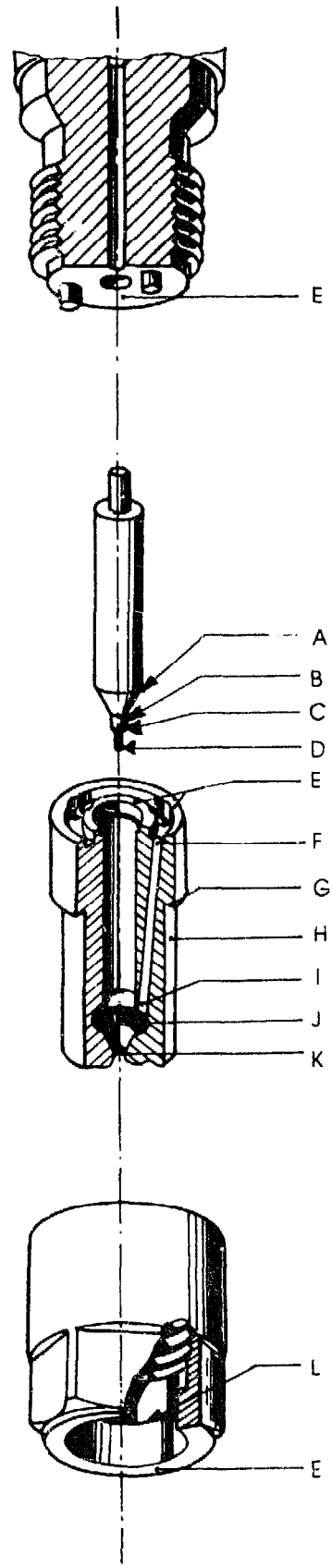

Servicing the nozzle

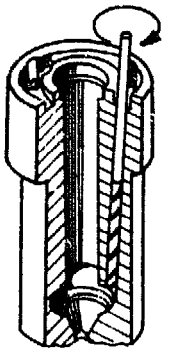
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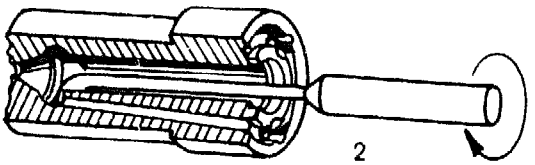
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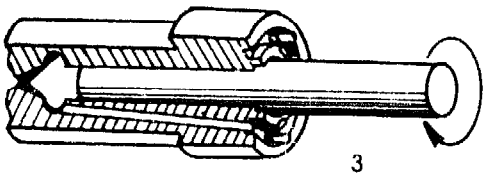
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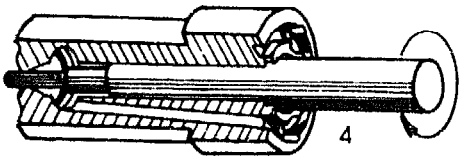
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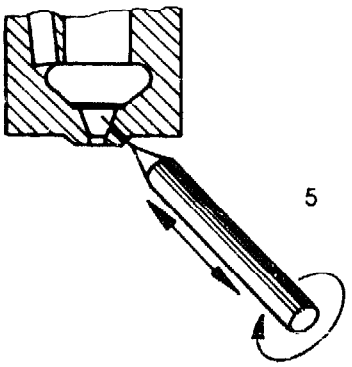
5

- If the nozzle is faulty, take it out of the nozzle body, examine it for carbon and check whether it lifts out freely.
- Examine the polished surfaces for scratches or dull patches.
- Examine the nozzle valve and the nozzle body for damage and blue parts, which are results from over-heating.
- Immerse the nozzle body and nozzle valve in clean diesel fuel to soak and soften the carbon.
- Brush all carbon from the outside of the nozzle body with a brass wire brush. *Never use a steel brush!*
- Clean the small fuel feed bore with a corresponding fine drill, see Fig. **1**.
- Insert a special groove scraper until the nose latches into the fuel gallery. Press hard against the side of the cavity and rotate the groove scraper to clear all carbon deposits from this area, see Fig. **2**.
- Clean all carbon from the valve seating with the correct valve seat scraper. Press the tool onto the seating and rotate it as shown in Fig. **3**.
- Select the right pintle orifice cleaning tool and insert it into the nozzle body until it passes through the pintle orifice. Then rotate the tool to clear off all carbon as shown in Fig. **4**.
- If there is an auxiliary spray hole, clean it with the relevant cleaning wire. It must be fixed into the tool chuck so that it protrudes about 2 to 3 mm, thus offering maximum resistance to bending. Extreme care must be taken to prevent the wire from breaking inside the hole, because such particles are almost impossible to remove.
- Put the wire into the hole and push and rotate it gently until the hole is clean, see Fig. **5**.
- Flush the nozzle body and the nozzle valve with clean diesel fuel. All remaining carbon particles can be removed carefully with a piece of hardwood soaked in diesel fuel. Then flush again.
- After cleaning, do not dry the nozzle valve, just put it in the nozzle body. Check its gliding capacity by pulling it half out of the body; it should sink slowly by its own weight.
- Pressure faces must be very clean.

Nozzle test bench

A nozzle test bench consists of the following components, see Fig. 1:
- Fuel container/filtering unit **1-A**
- Check valve **1-B**
- Air vent screw **1-C**
- Injection pump **1-D**
- Hand pump lever **1-E**
- Pressure gauge **1-F**
- Pressure feed pipe **1-G**
- Pressure adjusting screw **1-H**
- Locking nut (adjusting screw) **1-I**
- Protective shield (container) **1-J**

Testing the injectors and nozzles
An injector and a nozzle can be tested on a nozzle test bench as shown in Fig. 1.
- Fill the tank with clean diesel fuel.
- Bleed the system for a few seconds, using the air vent screw. Operate the pump several times until the fuel flows from the pressure supply pipe.
- Then connect the injector to the fuel feed pipe.
- Close the check valve so the pressure gauge is out of circuit. Operate the hand lever several times to expel all air from the test bench and injector.
- Open the check valve to bring the pressure gauge into circuit.
- Set the opening pressure of the nozzle on the required *bar*; see the handbook.
- Wipe the face of the nozzle dry and pump up to the required bar. Hold this pressure for ten seconds. First wipe your finger across the face of the nozzle and inspect for wetness.
- With the check valve still open, pump again to just below the opening pressure, release the hand lever and let it fall on its own weight.
- Time the drop of the gauge needle from ... bar to ... bar; see handbook.

Note: Carry out this test only when the valve seat is in good condition and if there is no leakage at the valve tip. During this test, make sure the protective shield is in the correct position.

Injector/nozzle test on engine
If no bench tester is available, a simple injector/nozzle test can be carried out on the engine itself.
- Take out the injectors and mark them correctly.
- Re-fit them upside down on the fuel pipes and tighten them correctly.
- Crank the engine until all air is expelled from the fuel system.
- Crank the engine again and note the atomizing of the fuel spray. Also compare the atomizing of all injectors at the same time; they must be the same.

Warning
It cannot be said too often that great care must be taken during these tests. On no account should your hands come into contact with the fuel spray. It has a very great penetration force and the spray easily passes through the skin.

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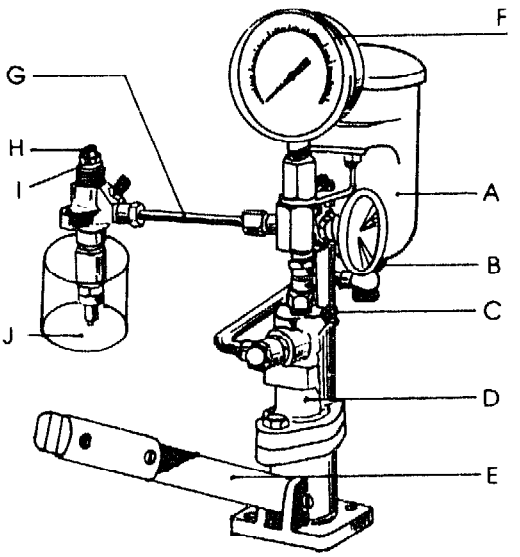

Injector testing

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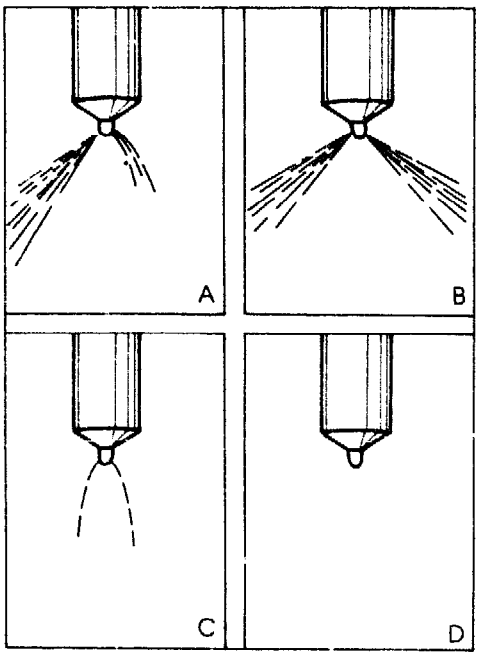

The primary function of a fuel injector nozzle is to atomize the liquid fuel so that it can be burned rapidly and efficiently in the cylinder of a diesel engine.
Atomizing the fuel is a purely mechanical process in which the fuel is forced through small orifices under high pressure and the multi-hole nozzle shown in Fig. **1** is used to help spread the fuel charge over the entire combustion chamber area.
Under high pressure the nozzle should spray from all the holes evenly, as shown in Fig. **1-B**. If one of the holes is blocked, the spray is not even, as shown in Fig. **1-A**.
For satisfactory operation of the injector nozzle, it is essential that the nozzle valve *snap-shuts* in the shortest possible time to avoid dribble, shown in Fig. **1-C**, which would rapidly cause excess carbon formation at the nozzle with blocking of the jets. For the valve to snap-shut, shown in Fig. **1-D**, the pressure in the fuel line must have some positive means of being reduced to 30 bar almost instantaneously, when the strong spring on the delivery valve itself will ensure that the valve closes as desired.

2

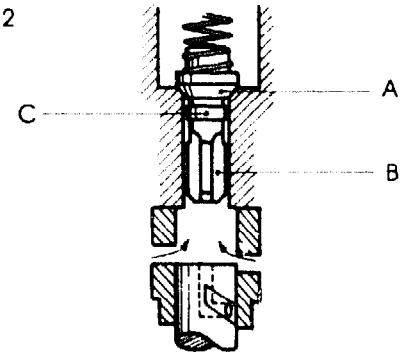

This pressure reduction is achieved by the construction of the mitre-faced delivery valve, see Fig. **2-A**, fitted at the top of the pump body and by the flutes **2-B** at the lower end of the valve. Just below the valve face there is a small plunger **2-C** which has a very accurate fit in the bore of the valve guide. While the pump is actually delivering fuel to the cylinder, this plunger is raised clear of the valve body and fuel flows round it into the delivery pipeline, see Fig. **3**.

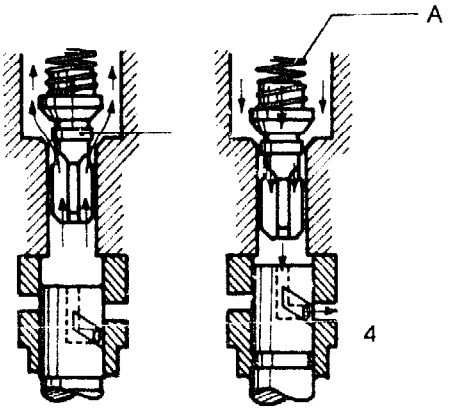

On a slight pressure drop in the pump, the delivery valve starts to return to its seat through the action of valve spring **4-A** in Fig. **4**, resulting immediately in location of the plunger in the bore of the valve guides. This forms a hydraulic seal so, at the moment under consideration, the pipe from the delivery valve to the injector nozzle can be regarded as being a separate system in which the fuel is still under considerable hydraulic pressure.
As the delivery valve moves fractionally towards its seat, the plunger displacement causes a small increase in volume of the fuel still under pressure, and the pressure is thus reduced immediately to zero, enabling the nozzle valve to snap-shut without sputtering or dribbling.

Fuel pipe fittings

Fuel filters, injectors, pumps and other units are connected by means of couplings or fittings. There are several types, such as:
- S.A.E. 45° flared
- Inverted flared
- Compression couplings
- Compression sleeve couplings

Each of these types consists of a male fitting, a seal and a female nut. To prevent damage to the seal when tightening or loosening a coupling, hold the fitting with one spanner while turning the nut with another. One of the most important rules for tightening tube fittings is:

Only tighten by hand lightly at first. Do not over-tighten.

If a fitting starts to break and seems to be loose, re-tighten it only up to the point where the leak stops.

S.A.E. 45° flared fitting
Figure 1 shows this type of coupling. The seal is achieved by compressing the flared tube between the tapered faces of the male and female connectors. One advantage of this connector is the locking action of the sleeve and the fact that the flared tube is not rotated during assembly.

Inverted flared fitting
This coupling is shown in Fig. 2. The seal produced by compressing the flared tube is the same way as the S.A.E. 45° fittings. In our opinion this connector gives the best seal.

Compression fitting
This coupling shown in Fig. 3 requires no flared tubing or sleeves. The seal results from the tubing being crimped by the male fitting when forced against the female nut. A disadvantage is that during tightening it tends to bind on the tubing, which may cause unequal sealing. The friction can also twist the tubing slightly.

Compression sleeve fitting
This type of fitting, see Fig. 4, uses a sleeve instead of flared tubing. The sleeve is placed on the tubing between the nut and the fitting. It crimps the end of the tube to seal it.

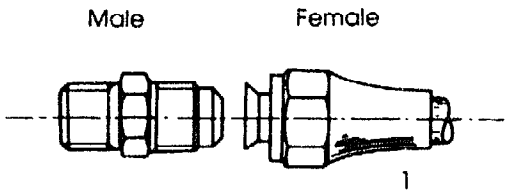

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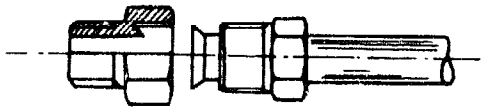
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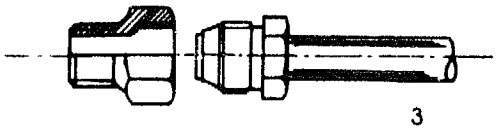
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4

Bleeding air from the fuel system

When the diesel fuel system has run dry or has been dismantled, a lot of air has entered the system. If this air is left in the system it may form an air lock which will prevent the fuel from reaching or passing through the injection pump and then to the injectors. The result may be that the engine does not start, misfires or loses power.

Bleeding the air from the diesel fuel system must be carried out in the correct sequence, otherwise the air lock remains inside the system. A correct method of bleeding the fuel system is explained below:

- Fill the fuel tank with clean fuel.
- Open the shut-off valve at the tank.
- Loosen the bleeding plug on the fuel filters and pump with the primer lever of the fuel pump until a continuous flow of fuel, free and air bubbles, flows from the opening in the bleed plugs.
- Tighten the plug. If there is more than one filter, bleed the next one. When bleeding is completed, make sure you leave the primer lever on the fuel pump at its lowest point of stroke.
- Loosen the injection line nuts one by one and crank the engine until fuel flows without foam around the couplings. Foam is mixed air and fuel.
- Tighten the pipe connections carefully and check for leaks.
- Make sure you loosen the connections by only one turn to avoid excessive spray, which may be harmful.

Engine trouble-shooting

Engine trouble-shooting

Every diesel engine is accompanied by a handbook in which you will find a trouble-shooting guide to the engine and its fuel injection system. If the engine fails to start, is difficult to start or misfires, the main problems may be:

- No fuel in the fuel tank. Clogged fuel supply or water in the fuel.
- Fuel transfer pump not operating.
- Air lock in injection pump.
- Governor linkage to pump is loose or broken.
- Fuel pump(s) or distribution pump not working correctly.
- Delivery valves are not seated correctly which may be due to broken springs or dirt.
- Pump(s) out of time.
- Nozzles not operating because the valves are stuck or the orifices plugged.

Wrong idling speed

If the engine does not idle smoothly it may be due to:

- Dirty fuel filters.
- Governor idling speed adjustment is not set correctly or the trottle linkage is worn.
- Pump rack or control may be stuck or is sticky.
- Fuel pump plunger sticks.
- Nozzle opening pressure may be wrong.
- Stuck nozzle valves.
- Fuel pump(s) are not correct -- loose control sleeves, pump timing incorrect or leaky delivery valves.

Engine smokes and knocks

- Fuel pump out of time.
- Dirty or wrong nozzles.
- Valve stuck open.
- Opening pressure too low.
- Fuel stop setting incorrect.
- Excessive fuel delivery.
- Causes such as: broken valves, scored pistons or dirty air cleaner.

Engine lacks power

Sometimes the engine lacks power, which may be due to:

- Retarded pump timing.
- Worn pump plungers.
- Worn distributor.
- Faulty nozzles.
- Governor out of adjustment.
- Dirty or plugged air or fuel filters.

Manufacturer's handbook

It must be understood that it is essential to read the manufacturer's instructions on the particular engine you service. All adjustments must be made according to the technical data provided.

Fault-finding guide for injection system

Symptom	Possible cause	Remedy
Engine is difficult to start	Incorrect fuel pump timing Defective fuel injection pump Defective or incorrect injectors	Check fuel pump timing Renew fuel injection pump Check the fuel pump
Engine will not start	Broken fuel injection pump drive	Check the fuel pump
Engine misfires	Incorrect fuel pump timing Defective or incorrect type of fuel injection pump Defective or incorrect injectors	Check the fuel pump timing Check the fuel injection pump Check the injectors
Lack of power	Incorrect fuel pump timing Defective or incorrect type of fuel injection pump Defective or incorrect injectors	Check the fuel pump timing Check the fuel injection pump Check the injectors
Excessive fuel pump consumption	Incorrect fuel pump timing Defective or incorrect type of fuel injection pump Defective or in correct injectors	Check the fuel pump timing Check the fuel injection pump Check the injectors
Black exhaust	Incorrect fuel pump timing Defective or incorrect injectors	Check the fuel pump Check the injectors
Blue exhaust	Oil consumption by the fuel injection pump	Renew leaking gaskets
Engine knocking	Incorrect fuel pump timing Defective or incorrect injectors	Check the fuel pump timing Check the injectors
Erratic running	Incorrect fuel pump timing Defective injectors	Check the fuel pump timing Service the injectors
Excessive oil consumption	Consumption by the fuel injectionpump	Check the fuel injection pump
Engine overheating	Defective or incorrect injectors	Check the injectors
Engine starts and stops	Sticking injectors	Service the injectors

Cooling systems

Cooling systems

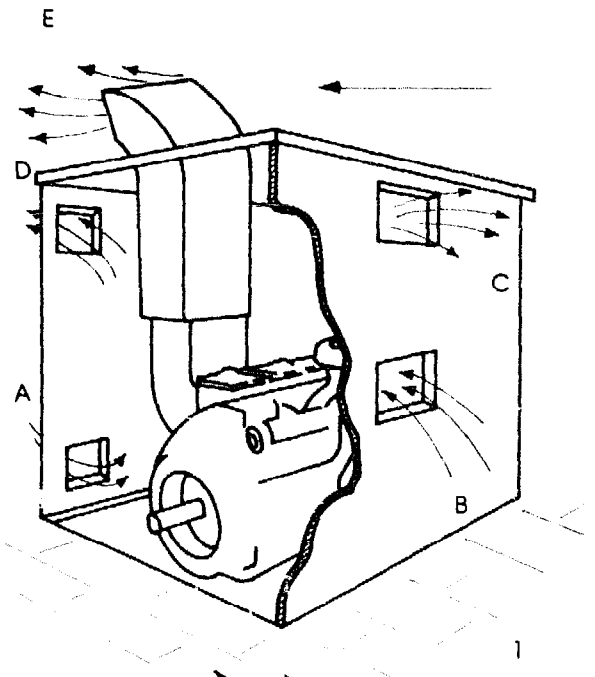

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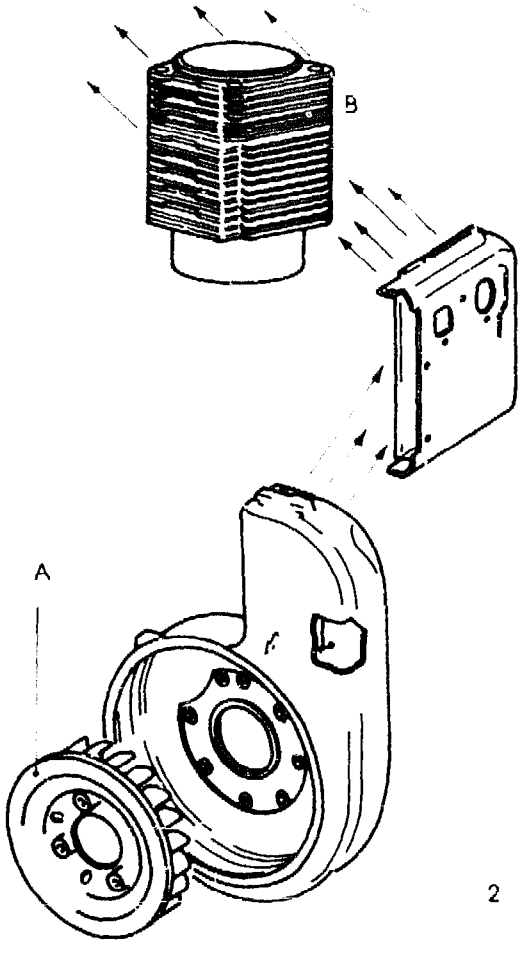

2

The operating temperature of a diesel engine is very critical to ensure maximum efficiency and to reduce wear on moving engine parts. If cooling is not adequate, the engine becomes over-heated causing possible:
- piston seizure,
- low engine performance,
- wear of movable parts,
- breakdown of lubricating parts,
- formation of carbon deposits.

Engine room design
Figure 1 shows an illustration of an engine room design. One of the cooling air intake holes must be near the bottom of the engine room to bring cool air in and also to strike along the engine sump to assist cooling of the lubrication oil, see **1-A**. Another air intake hole **1-B** must be opposite the air filter to ensure a good supply of cool combustion air. One or two cooling air holes must be near the top of the engine room to prevent an accumulation of hot air above the engine. Holes **1-C** and **1-D** allow hot air to leave the engine room. The exhaust leaves through the opening **1-E**.

Two systems of engine cooling
We will explain two cooling systems:
- *Air cooling*
- *Water cooling*

Air cooling system
Air cooling is used widely on smaller engines used for water pumps, small electric plants, compressors etc. See Fig. 2. It is a simple but reliable principle using a fan **2-A** secured to a flywheel which forces air through a system of deflector plates **2-B** over the finned cylinder barrel and sometimes over a finned section of a sump for oil cooling.

Air cooled diesel engines require approximately 35% less air than water cooled engines.
It must be understood that in tropical climates special attention must be paid to the supply of fresh air. Clean the finned section **2-A** regularly. The shroud or deflector plates must be taken off at regular intervals to make it possible to clean the fins of the cylinder barrel and thus ensure adequate cooling.

Water cooling systems

There are several systems to cool down an engine with cooling water. One such system is the *thermo-siphon* system, shown in Fig. **1**. A gravity feed is taken from a tank **1-A** located outside the engine room. This tank must be very well protected against the sun to ensure that the water used for cooling is not too hot. Water circulates through the engine cooling system **1-B** and is returned to the tank by the thermo-siphon action alone. The water circulates due to expansion of the heated water in the engine jacket, thus becoming less dense and rising as a result to the highest point of the system. Its return from the top of the engine system to the top of the cooling tank is ensured by a sloping pipe **1-C** which rises gradually to avoid possible air locks.

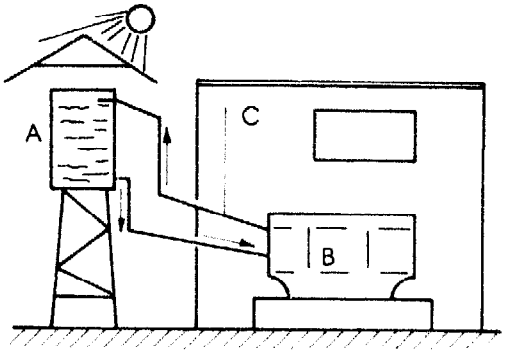

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Since this system cools the water slowly, a large tank is necessary. Some 250 liters of water are needed per brake horse-power (b.h.p.) for 22 hours running. In tropical countries it is advisable to double this amount to 500 liters per b.h.p.
To aid the thermo-siphon action a circulation pump is sometimes mounted on the engine, increasing the flow of water through the system. If such a pump is provided, the total amount of water needed for cooling may be 20% less than recommended above.

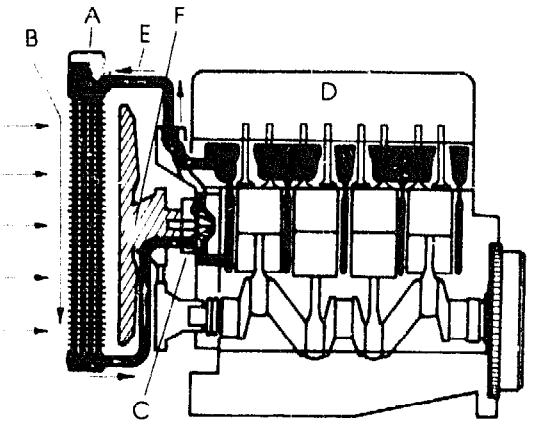

2

Another water cooling system is the *radiator cooling system*, as shown in Fig. **2**. Water flows from **2-A** through the radiator **2-B** via a flexible rubber hose to the waterpump **2-C**, where it is forced through the water jackets of the engine **2-D**. The heated water returns to the radiator via a rubber hose **2-E**. A cooling fan **2-F** is driven from a suitable extension shaft on the engine with one or more V-belts to draw cool air through the radiator and over the engine. This type of radiator is illustrated in Fig. **3**.

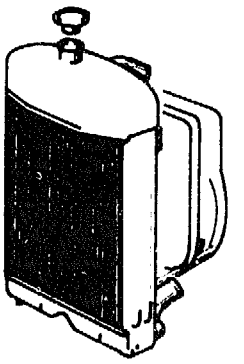

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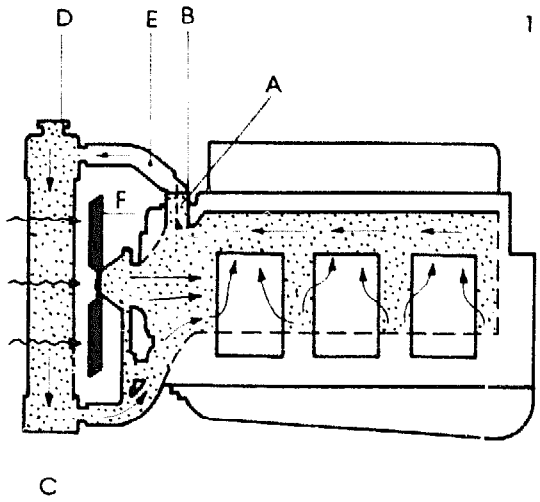

1

Water cooling system

A lay-out of a typical water cooling system is shown in Fig. 1.
The *water pump* **1-A** draws hot coolant from the engine block and forces it through the radiator **1-C** for cooling. The *thermostat* **1-B** controls the flow of coolant to the radiator to maintain the correct operating temperature of the engine.
The *radiator* **1-C** allows the coolant to cool before it re-enters the engine block. It also provides a reservoir for sufficient coolant for operation. The *radiator cap* **1-D** is also used to fill the reservoir of the radiator with coolant. In addition it allows operation of the engine at a higher temperature without boiling or loss of the coolant by evaporation.
Rubber hoses **1-E** make the connections between the rigid generator and the vibrating engine block.
The *blow* or *suction fan* **1-F** makes cool air flow through the radiator tubes or water passages. The fan may also suck cool air through the radiator tubes.

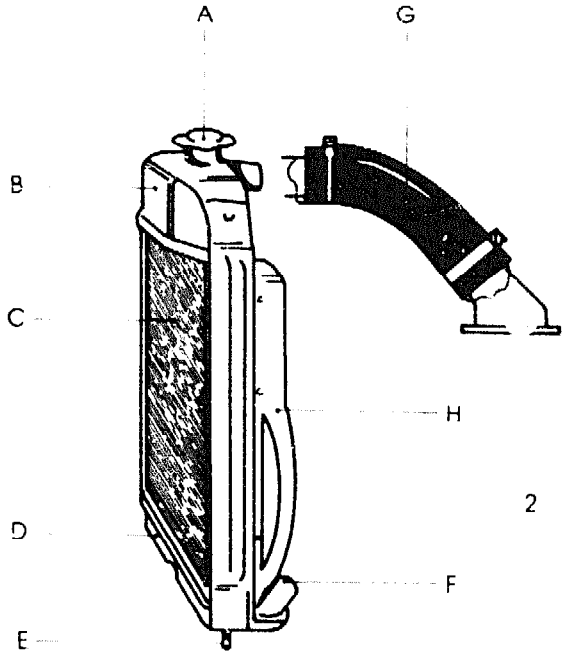

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Radiator

A typical diesel engine radiator is shown in Fig. 2. The different parts are:
- Radiator cap **2-A**
- Top reservoir radiator **2-B**
- Radiator water passages and fins **2-C**
- Bottom water reservoir **2-D**
- Drain plug for coolant **2-E**
- Bottom connection to engine block **2-F**
- Top inlet for coolant from engine block **2-G**
- Shroud to guide air flow **2-H**

Note how the rubber hoses are connected with hose clips between the radiator and the engine block.

Core type radiators

A section of a tube-fin type core radiator is shown in Fig. 3. This type of radiator is common in all types of engines. Water from the engine block enters the radiator via the top tank and then passes down through the tubes **3-A**. The fin **3-B** ensures maximum air flow for cooling.

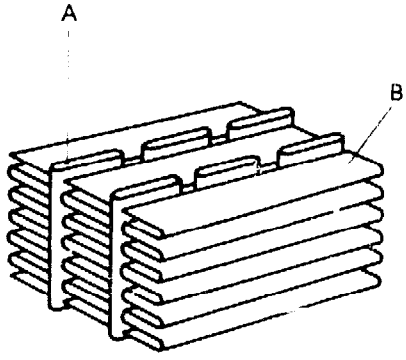

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Radiator cap

The radiator cap shown in Fig. **1** is of the pressure system type. It allows the engine to operate at a higher temperature without boiling

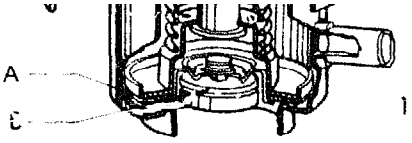

Figure **2** shows the radiator cap with its valve **2-A** closed completely. No coolant can escape via the overflow pipe **2-B**.

Figure 3 shows the same radiator cap with the pressure valve **3-A** completely opened. When in this position, the valve allows the coolant to escape under pressure and leave the radiator via the overflow pipe **3-B**.

The vacuum valve shown in Fig. **4** opens as relevant to prevent a vacuum in the cooling system. Valve **4-A** passes air via route **4-B**.

As there may be pressure in the radiator, you must be careful to remove the radiator cap slowly, so that any pressure can escape first.

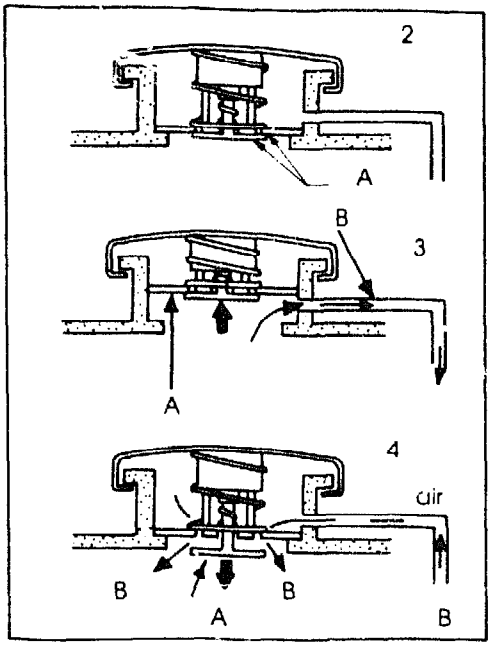

Thermostat
Figure **5** shows a part of the cooling system with the thermostat at **5-A** in a closed position. If the thermostat is open, the water can circulate through the radiator marked **5-B**. If the thermostat is closed, the coolant continues circulating through the pump in the engine block, see dotted area.

Figure **6** shows a typical bellows thermostat. The action of the thermostat valve **6-A** is controlled by the bellows, to which valve **6-B** is linked. In cold conditions the bellows are fully contacted and hold the valve tightly on the seat, so the coolant continues circulating from the cylinder head through the water pump and not through the radiator. This ensures a rapid rise in the coolant temperature. The thermostat in Fig. **6** is fully open, as you can see, so the coolant can circulate through the radiator, pump and engine block.
If the thermostat is not functioning correctly the engine may run too hot or too cold. Over-heating can damage the thermostat. As a result the valve does not function correctly and damages the engine. Rust caused by water in the system can also interfere with sound operation of the thermostat. Make sure you use a thermostat design recommended by the manufacturer.

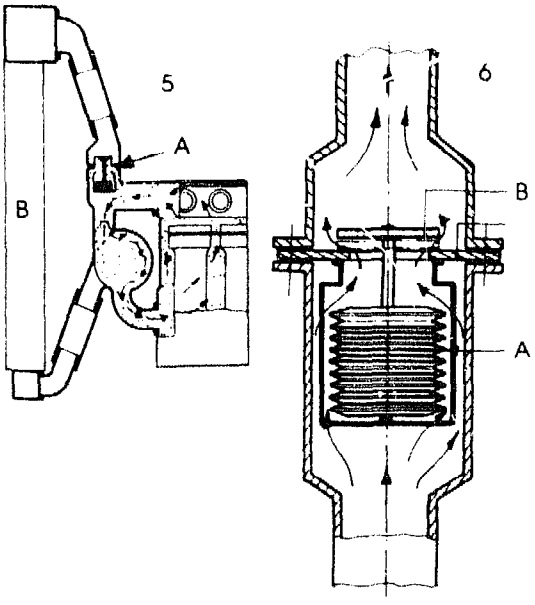

Water pump

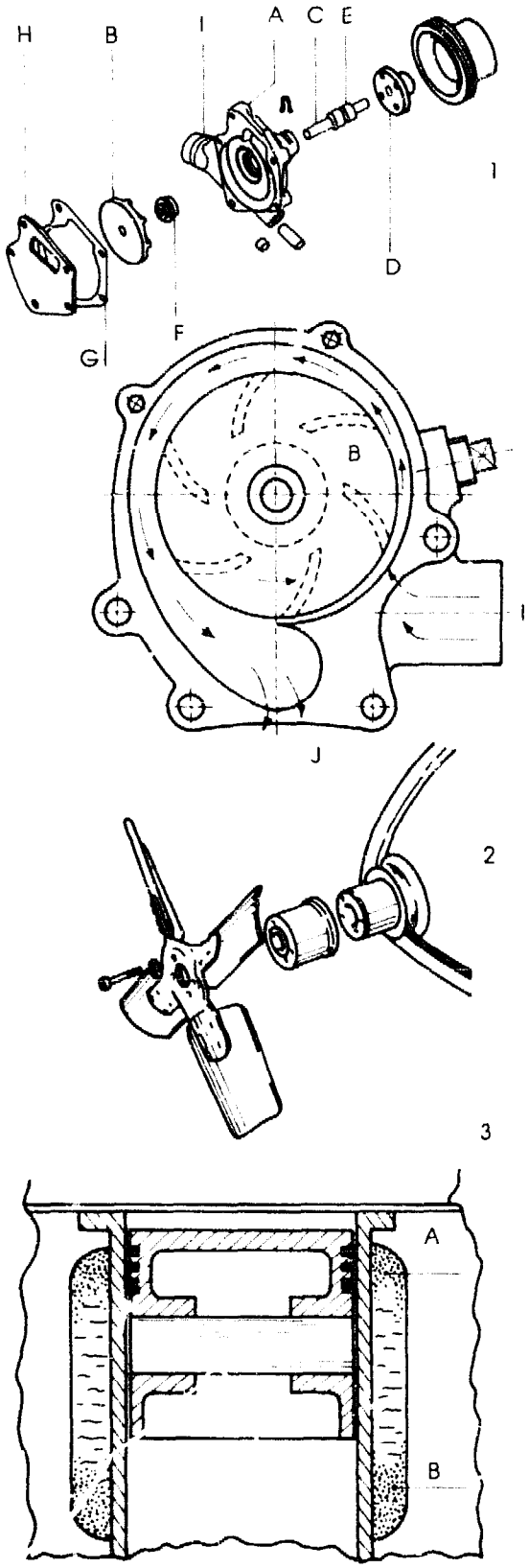

The water pump shown in an exploded view, Fig. **1**, is bolted at **1-A** to the engine block. The main part of the pump consists of an impeller **1-B** in the form of a disc with tapered blades on one side. The impeller is force fitted to one end of the drive shaft **1-C**. The hub **1-D** is fitted at the front of the shaft and the pulley and fan blade are bolted to it, see Fig. **2**. Two greased ball bearings **1-E** are fitted on the drive shaft. Between the impeller and the pump housing, a seal **1-F** is fitted to prevent leakage of the coolant. Between the pump housing and the engine block, a gasket **1-G** prevents the leaking of coolant. Between the pump housing and the engine block a gasket prevents leakage of the coolant, while a hole in the plate **1-H** allows the coolant to pass from the engine to the pump and then to the radiator. Coolant enters through **1-I** and leaves the pumps to the engine at **1-J**, see cross-section in Fig. **1**.

Cleaning the cooling system

During engine operation, clogging materials such as rust, lime, scale and grease may prevent maximum cooling of the engine. Rust accounts for some 90% of clogging which forms on the walls of the engine jacket, see Fig. **3-A**, and other metal parts. The coolant circulation may loosen the rust particles and carry them to the radiator, blocking the tubes. It is advisable to use clean rain water as a coolant to prevent lime deposits, due to so-called *hard* water forming a layer and thus blocking the circulation of the coolant. Lime may settle anywhere, while dirt settles at the bottom of the jacket **3-B** and the radiator tank.

Flushing the cooling system

Before flushing the cooling system, take out the thermostat to make sure the water can run freely through the system. Then fill the system with clean water. Run the engine for some time. Stop the engine and open all drain plugs and drain the system completely. Also clean the radiator tubes and remove all insects from the fins.

Check the thermostat, radiator pressure cap and the cap-seat for dirt and corrosion.

V-Belt construction

As already shown, a V-belt drives the water pump **1-C** in Fig. **1** and sometimes also the alternator **1-B** from a pulley attached to the crankshaft **1-A**. Sometimes a separate V-belt is used for large alternators. The advantage of using a V-belt instead of a gear or chain drive is that the V-belt is a simple construction, cheap and noiseless.
A cross-section of a V-belt is shown in Fig. **2**. V-belts are usually made of rubber incorporating steel wire and with cloth on the outside, see Fig. **3**.

Shape of pulley and V-belt
A section of a pulley is shown in Fig. **4**. The groove is shaped in such a way that it corresponds to the shape of the belt.
The force of the V-belt is transferred by friction between the V-belt shoulders and the pulley, see Fig. **4-A**. That, as you will understand, is why the V-belt must fit correctly to be able to transfer the force. A V-belt of the wrong size fails to meet its purpose.

Length of the V-belt
If you have to measure the length of a V-belt, mark the belt with a pencil, see Fig. **5-A**. Place the mark **5-A** at 0 on a ruler and roll the belt along the ruler until the mark indicates the length.

1

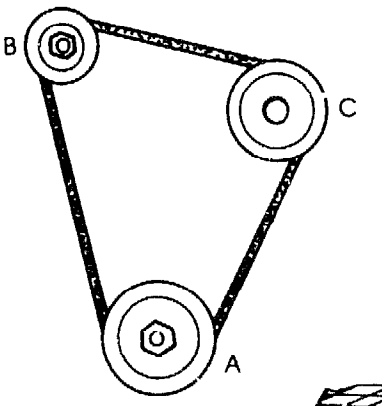

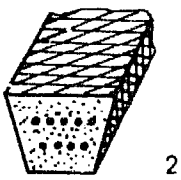

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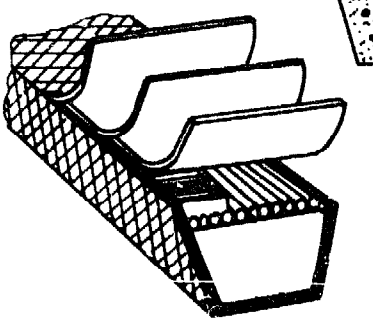

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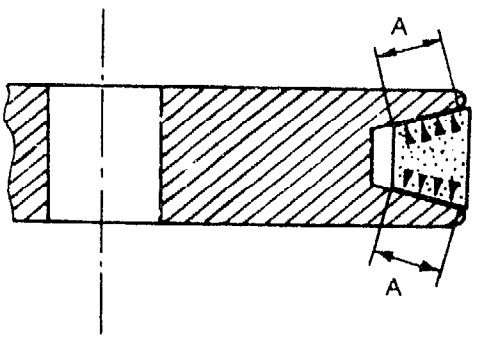

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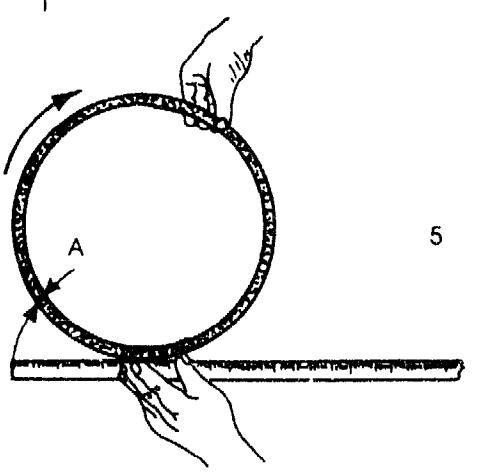

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Checking the V-belt condition

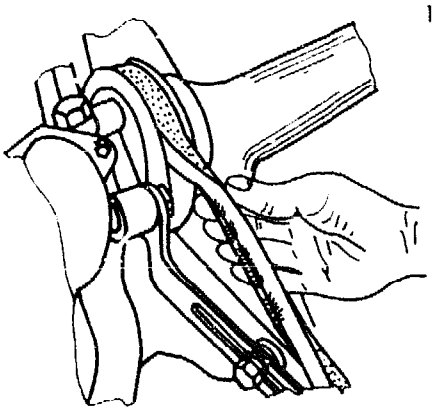

The demands made on the V-belt in connection with cooling the engine make it necessary to check the V-belt at regular intervals for signs of wear. The V-belt must be replaced if fibres along the sides become loose, see Fig. **1**.
Also roll the belt over to inspect the bottom and sides If the belt is glazed, many small cracks appear and you must install a new belt. Also change the belt if signs of oil soaking or any other damage is visible.
Check too whether the belt still runs correctly in its groove.
Figure **2-A** shows the correct position of the belt. Figure **2-B** shows a V-belt which is too wide, so grooves will soon appear at its sides. Such belts must not be used. Sections of worn belts are shown in Fig. **2-C**. These belts must be replaced to avoid over-heating through a slipping belt.

2

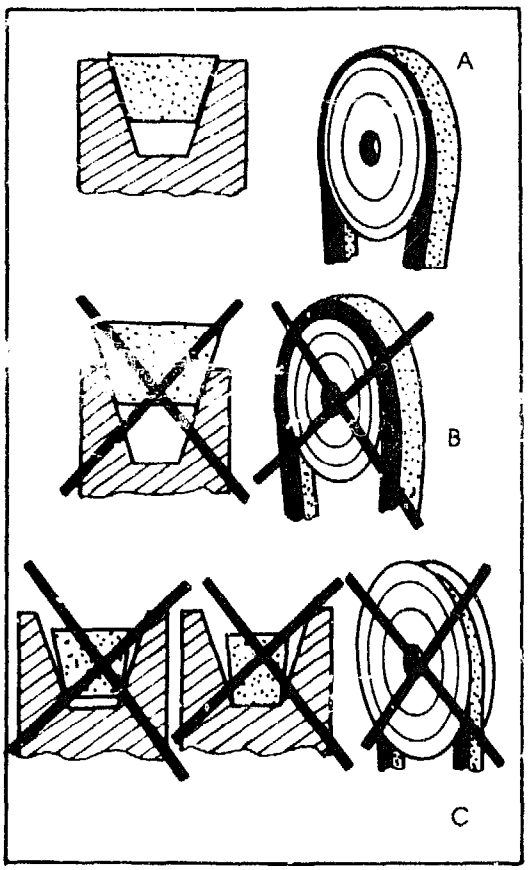

V-belt tension
Figure **3** shows a quick and good method of checking the tension of the V-belt. Place a straight edge over the pulleys and press the belt inwards in the centre between the two pulleys, using moderate pressure. Measure the deflection with a ruler. Deflection varies according to the length and size of the belt. The following can be taken as a general rule:
- Distance between the centres of the two pulleys is 1500 mm. The deflection may be 15 mm.
- Distance between the centres of the two pulleys is 2000 mm. The deflection may be 20 mm.

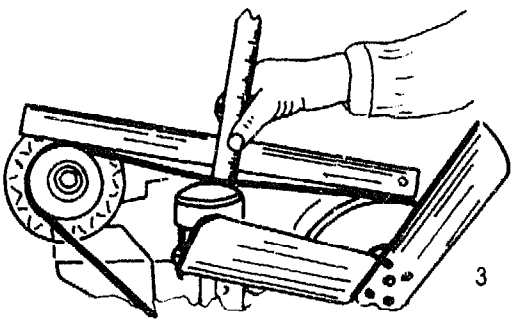

Lubrication system

Friction between metals

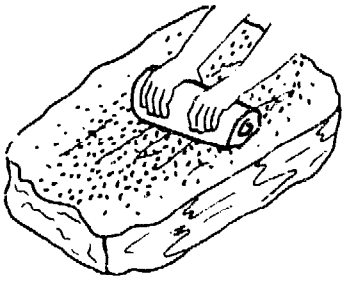

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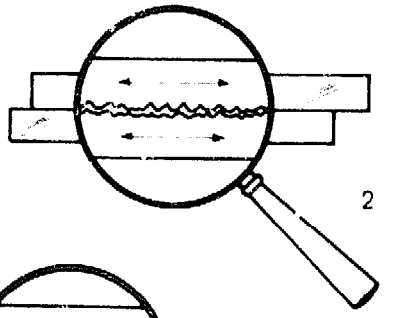

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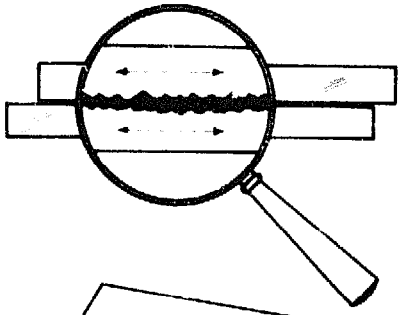

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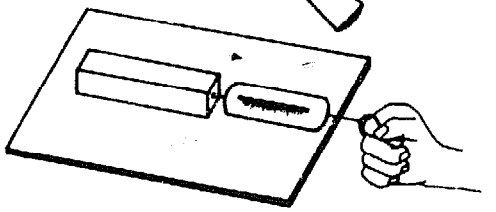

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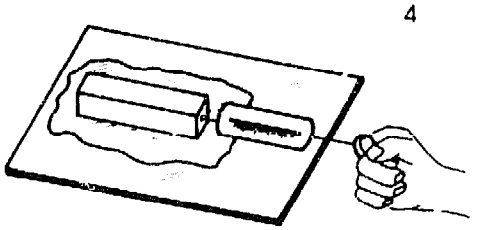

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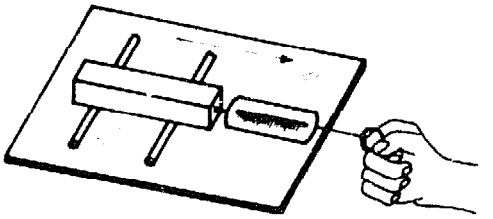

6

To understand the working of the lubrication system in an engine you must be aware of the effects of friction. You are already familiar with the properties of friction from your childhood. When you watched a woman grinding grain to make flour, you perhaps noticed at some stage that the small stone she used to grind the grain became hot after a while. If she had used the small stone without adding the grain, the stone would have become even hotter due to the friction between the large and the small stone. She reduced the friction by adding the grain, which acted as a lubricant, see Fig. 1.
For these lessons it is good to remember that two metal surfaces are made up of hills and valleys when they are seen under a microscope, see Fig. 2. These hills and valleys tend to interlock and grab each other when pushed in motion. Even highly polished surfaces are still made up of these valleys and hills, though to a lesser degree.
A stable oil film prevents this interlocking if the hills and valleys are not too big, see Fig. 3.

Sliding friction
To experiment with sliding friction, take a square polished steel bar and hook it onto a spring balance, see Fig. 4. Drag the bar over a polished steel surface and, while doing so, record on a piece of paper the reading on the spring balance.
After finishing the first experiment, cover the steel surface with a film of engine oil. Drag the square bar over the surface again and record the reading, see Fig. 5.
You will discover that dragging the bar over the oil-coated surface takes far less force. Even if water or any other kind of liquid is used, the friction is less, so less power is needed.

Rolling friction
Repeat the experiment described above but this time use two round pencils. Position the pencils between the flat plate and the square bar. Pull the bar as above and record the reading on the spring balance.
Less force is needed to overcome rolling friction, see Fig. 6.

Fluid friction

On the previous page you saw how a film of lubricant prevents contact between two solid materials. The same thing happens when a shaft rotates in a bushing or a bearing, see Fig. **1-A**. A film of oil under pressure ensures that the two metal surfaces slide over one another, see Fig. **1-B**. The only friction that occurs is in fact between the oil particles themselves.

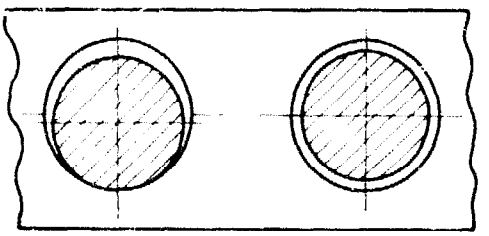

1

Mixed friction
Mixed friction is friction between two metals with a good film of lubricant between them, but this film is not thick enough to completely avoid any contact between the two metal surfaces.
Friction between cylinders and cylinder walls is an example of mixed friction. The metal of both parts touches for a short time, but just long enough to produce a lot of heat.
It must be noted that roller and ball bearings are also exposed to mixed friction, see Fig. **2**.

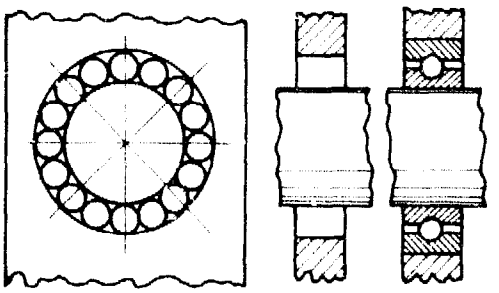

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Boundary friction
Boundary friction occurs between two materials with a little lubricant. Gear joints, hinges, linkage joints etc. are all subject to boundary friction, see Fig. **3**. A regular check must be made for lubrication in the form of oil or grease.

Dry friction
Examples of dry friction without any lubricant are between brake lining and brake drum (Fig. **4-A**), the clutch plate and flywheel (Fig. **4-B**) etc. A lot of heat is generated, so this friction must not be applied for too long at one time.

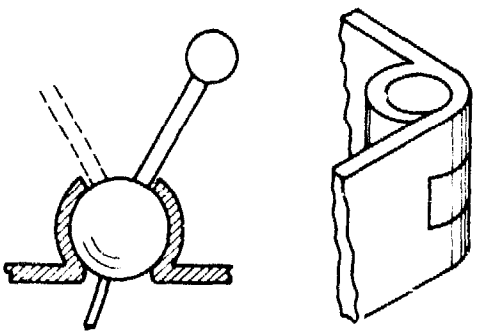

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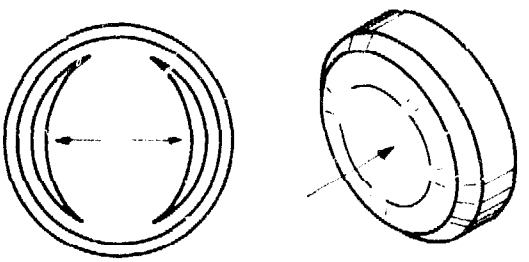

A 4 B

Classification of oils

In order to specify the different classes of engine oil, the American Petroleum Institute (API) has introduced a system of classification which is accepted all over the world.

The classification for petrol engine oil is made up of five classes, all starting with the letter S and followed by the letter A, B, C, D, or E. The letter S comes from Service, meaning that this type of oil is normally available from service centres. The letters A, B, C, D and E indicate the actual quality of the engine oil. For example: an oil with the letters SE indicates an oil of very high quality.
Oils used for diesel engines are marked with the letter C followed by the letter A, B, C or D. Diesel engine oil marked with the letters CA is of a low quality, while oil marked with the letters CD is of a high quality.

Sometimes oils are sold of a quality which can be used for both petrol and diesel engines. If this is the case, you will find both marks on the oil container – for example the letters SE-CC, see Fig. 1.

Technical data on engine oils
Oil for petrol engines is marked with the following letters:
SA = Is not used in modern engines.
SB = Used in engines running under very favourable conditions.
SC = This oil can be used in older types of petrol engines.
SD = Is the lowest quality oil which can be used in modern engines.
SE = This type of oil is top quality and can be used in all modern engines even under severe conditions.

Oil for diesel engines is marked with the letters:
CA = This oil can be used in engines running under favourable conditions.
CB = Suitable for diesel engines running under fairly difficult conditions using a low grade fuel.
CDC= This oil can be used in engines running under fairly difficult conditions using a good type of fuel.
CD = This oil is suitable for diesel engines with a high output. It is a top quality oil used in engines running under severe conditions.

Note: If an engine has been running on low quality engine oil and a change is to be made to a high quality oil, an extra oil change is recommended because the high quality oil has a high cleaning ability and after the first change combustion particles are washed out quickly, making the first oil dirty.

Always follow the manufacturer's recommendations regarding the quality and the grade of the engine oil to be used for that particular engine.

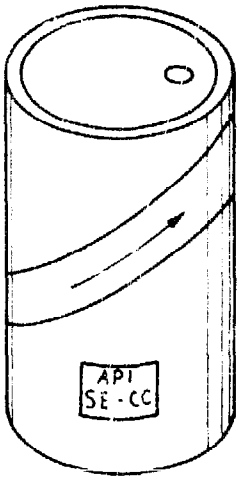

1

Engine oils

Crude oil found in several parts of the world is the raw material from which different products are made, such as petrol, kerosine, diesel fuels, gas and lubrication oils etc.
Engine oil is a high quality oil designed especially for the lubrication of particular engines under specific conditions. The basic function of engine oil is to ensure that all the moving parts in the engine function efficiently with a minimum of wear and friction. As noted above, engine oil has to provide a durable and protective film between the moving parts from the first to the last moment under both hot conditions and full load.

Oxidation occurs very fast at high temperatures and a good oil should also clean the internal parts of the engine, removing carbon and other deposits caused by combustion. Cylinder walls, bearings and other engine components must be protected against corrosion due to moisture and acids. This can be done with a good grade of engine oil.
A good grade of lubrication oil must form a correct sealing film between the pistons and cylinder walls so the high pressure needed for combustion is not lost due to leakage. A good engine oil should not form air bubbles when it is being splashed about, because this could prevent good lubrication.
Another function of engine oil is heat conduction, even when it becomes hot.

As you have now seen, engine oil has several functions to perform and the straight mineral oil is modified by various additives, such as:
- *Oxidation inhibitors* which reduce the tendency of the oil to absorb oxygen and so cause oxidation.
- *Rust inhibitors* which assist the oil in preventing corrosion of the engine parts.
- *Pressure agents* which reduce friction.
- *Detergents* which increase the cleaning efficiency of the oil.

Engine oil quality and viscosity

To guarantee all the requirements listed above it has been necessary to develop standards for the quality and viscosity of oils which are uniform and acceptable all over the world. When selecting oil for an engine it is important to choose the correct one. Two important factors which determine the choice of oil are:
- The oil must have the right thickness, which is called *viscosity*.
- The oil must meet the quality required by the manufacturer of the engine.

Viscosity
The term viscosity refers to the relative thickness of an engine oil. A thin free-flowing oil has low viscosity and a thick slow-flowing oil has high viscosity. The viscosity of oil changes as the temperature changes. At high temperatures the oil becomes thinner and at low temperatures it becomes thicker. That is why correct viscosity of the is essential to efficient running of the engine. If the oil is too thick it causes resistance and much more power is needed to turn the engine, which also makes it difficult to start the engine when it is cold. Thick oil does not circulate freely enough during the starting period, causing insufficient lubrication of the engine parts.

On the other hand, if oil is too thin the combination of high temperature and heavy load presents the risk of oil being pressed out from between the working surfaces of bearings of other engine parts. This causes the oil film to break down. Oil which is too thin does not provide an efficient seal between the cylinder wall and the piston rings.

Grades of engine oil
Engine oils are graded by the Society of Automotive Engineers (SAE) and numbered according to thickness.
The viscosity of oil grades SAE 5W, 10W, 15W and 20W is measured at a temperature of 18 °C. Oil grades SAE 20, 30, 40 and 50 are measured at an oil temperature of 100 °C, which is the normal oil temperature when the engine is running. Note that the lower the numbers, the thinner the oil.

The correct oil viscosity
Oils with a viscosity of SAE 5W to 20W are suitable for climates with a low temperature. Oils with a viscosity of SAE 20 and 30 are suitable for moderate to hot climates. Oils with a viscosity of SAE 40 and 50 are used in old engines or in badly worn engines with high oil consumption.

Multigrade oil
For practical reasons it is not possible to use a low viscosity oil for cold starting and then change to an oil with a higher viscosity when the engine is running and hot. That is why a multigrade oil has been developed which overcomes these difficulties.

Technical data on engine oils
A general technical specification for engine oils has been accepted;
- Single grade oil which covers one SAE grade, such as SAE 40.
- Double grade oil which covers two consecutive SAE grades, such as SAE 20/30W.
- Multigrade oil which covers three SAE grades, such as SAE 20/40W.
- Super multigrades which cover more than three SAE grades, such as 15/50W.

Lubrication system

1

A typical one cylinder diesel engine may have a lubrication system as shown in Figs. 1 and 2. The lubrication oil flows through:

- Sump **1-A**
- Strainer **1-B**
- Oil supply pump **1-C**
- Pressure valve **1-D**
- Main bearing **1-E**
- Drilling main bearing **1-F**
- Rocker arms **1-G**
- Dip stick **1-H**
- Lubrication oil level mark **1-J**
- Lubrication oil level **1-K**

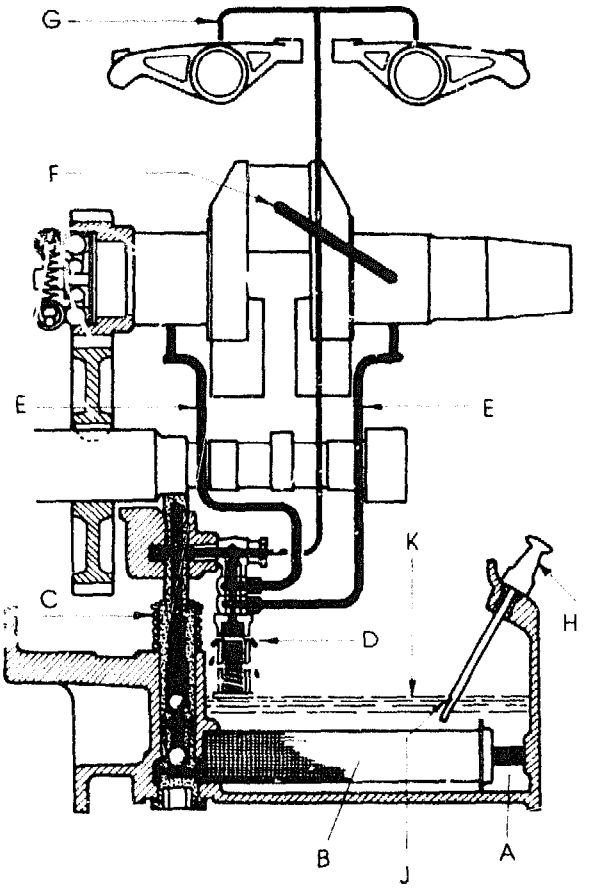

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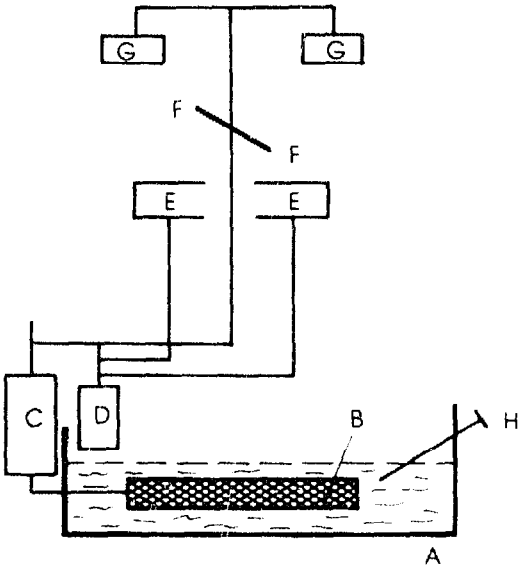

Lubrication system

1

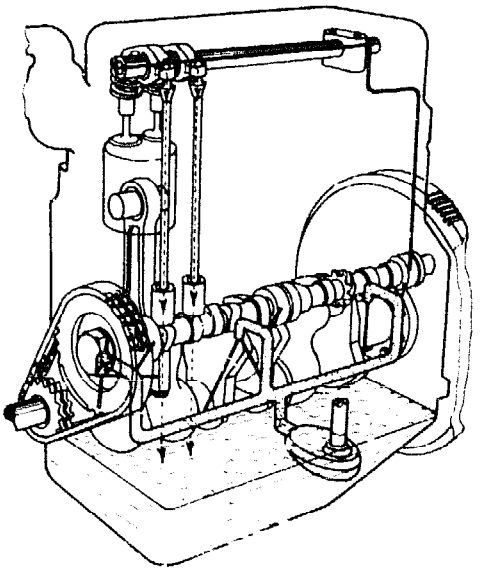

A typical 4-cylinder diesel engine may be equipped with a pressure feed lubrication system, see Fig. 1. A pump forces the oil to the various engine parts requiring lubrication. The oil is sucked from the sump through a primary gauze filter (strainer) and then pumped under pressure to the full flow oil filter. An adjustable pressure relief valve is fixed in the filter head. The pressurized oil then passes to the main oil gallery where the pressure gauge is fixed. Front, centre and rear main bearings are connected directly to the oil gallery, where a pressure gauge is fixed. Front, centre and rear main bearings are directly connected to the oil gallery by oil feed drillings. The big end bearings and camshaft bearings are lubricated from the cramshaft main bearings. The cylinder walls and the small end bearings are splash lubricated. The rear pedestal of the rocker arm shaft is supplied with oil from the rear crankshaft main bearing via the rear camshaft bearing. From there, oil passes through the hollow rocker shaft to each rocker and push rod. It then flows back to the sump. Lubrication oil is supplied by the front crankshaft bearing to the chain tensioner, the timing chain and, via the front camshaft bearing, to the fuel injection pump drive. See Fig. 2.

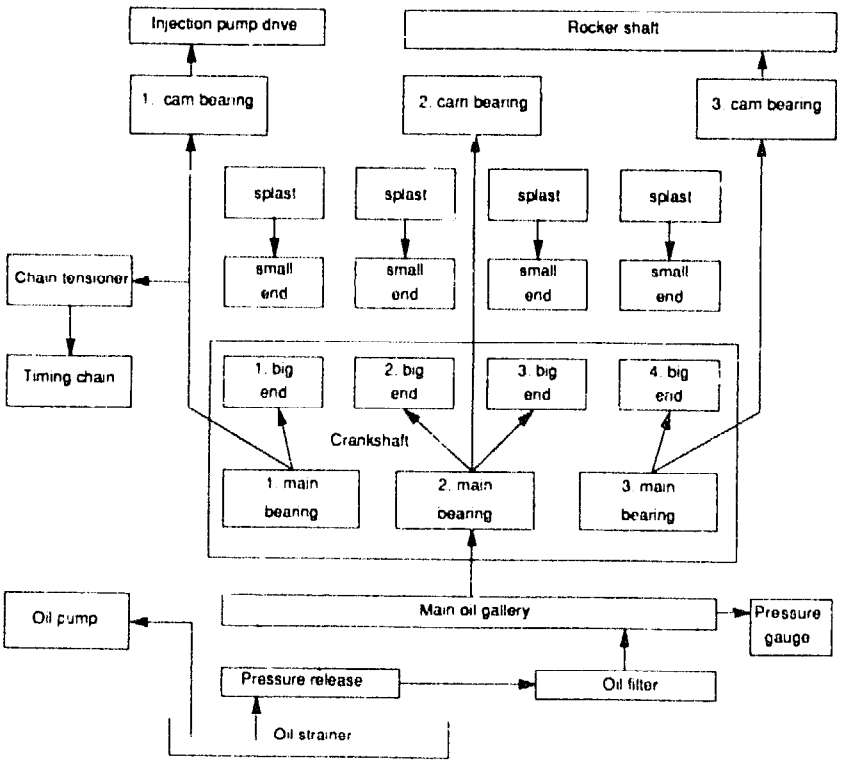

Pressurized lubrication oil system

The pressurized oil in the sump is pumped through a strainer and the oil pump to the oil filter and from there to the main oil gallery and oil passages which lead to the crankshaft and camshaft bearings, the rocker shaft and the rocker arms. Oil splashed from the crankshaft lubricates the piston and other internal moving parts of the engine.
After lubricating the moving parts the oil drips back into the sump.
In Fig. 1 the following components can be recognized:
- Oil pan/sump **1-A**
- Strainer **1-B**
- Oil pump **1-C**
- Relief valve **1-D**
- Main oil gallery **1-E**
- Oil pressure indicator **1-F**
- Oil filter **1-G**
- Dip stick **1-H**
- Filler cap **1-I**

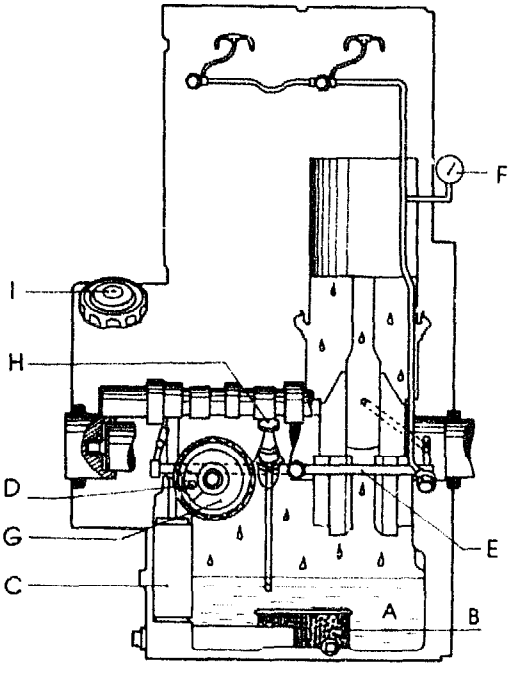

1

The working of lubrication oil
In the previous chapter we learned about the working of lubrication oil. Remember that, even when they appear to be smooth and polished, surfaces are in reality uneven, as shown in Fig. 2.

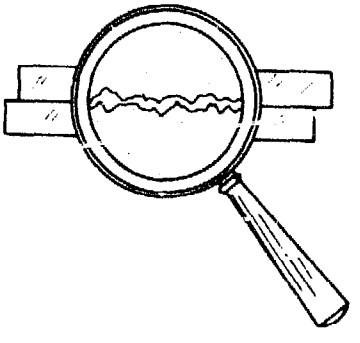
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Oil enters the bearing under pressure and a very small clearance is needed to allow the oil to form a film between the bearing and the shaft. The clearance data can be found in the manufacturer's manual.
What actually happens with the shaft and the oil film is shown in Fig. 3.
- When the shaft is not rotating it rests on the bearing and only a very thin film of oil separates the surfaces. This thin oil film is important because it is the only lubrication during the first revolutions of the shaft when the engine starts. See Fig. **3-A**.
- As soon as the engine starts and the revolutions increase, the oil pump starts to deliver oil and press it into the bearings. It forms a kind of wedge on which the shaft is raised from the bearing. See Fig. **3-B**.
- At full speed and with the right kind of oil and oil pressure, the shaft rotates freely in its bearing on the oil film. See Fig. **3-C**.

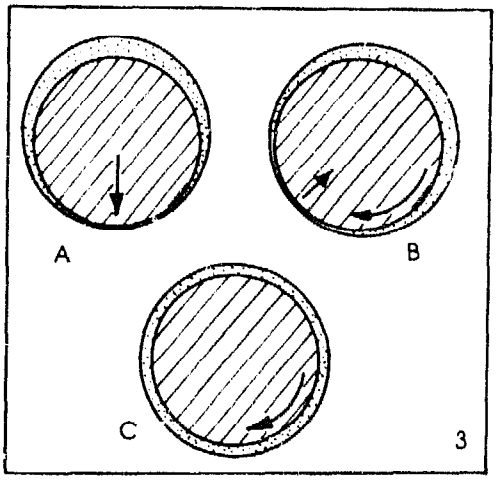

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Clearance

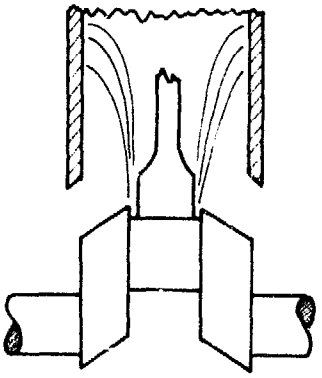

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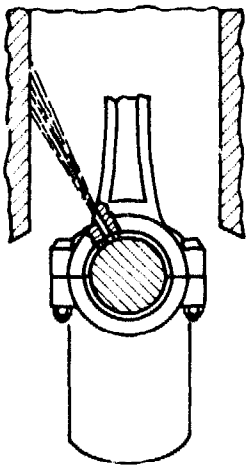

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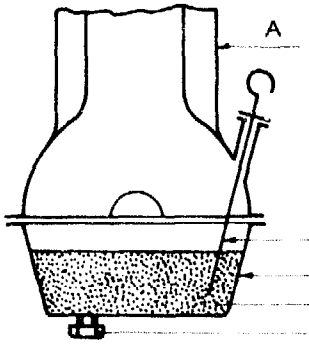

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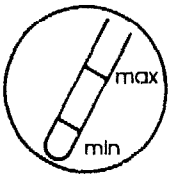

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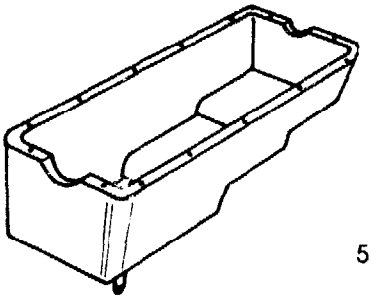

5

You realize it is very important that the bearings of an engine have the correct clearance. Too much clearance allows the oil to escape from the bearing without being able to create the required oil wedge. Too little clearance restricts the entry of the oil into the space between bearing and shaft, thus causing metal-to-metal contact. In both cases wear increases.
Figure **1** shows how the oil is pressed out from the bearings and splashed around, forming an oil mist which lubricates the inside cylinder wall and the piston.
Figure **2** shows that in some cases the connecting rod has a hole drilled from the side of the connecting rod into the bearing shell to spray oil onto the cylinder wall.

Oil pan
When you fill the engine with engine oil **3-D**, see Fig. **3**, it sinks through the engine **3-A** to the bottom where it is held in a reservoir **3-C**. This reservoir is either integral with the engine or sometimes it is attached to the engine block by bolts, in which case it is called the oil pan. One end of the oil pan shown in Fig. **5** is lower and forms a reservoir called the sump. A drain plug **3-E** is located at the bottom of the sump so that dirty oil can be drained off.
The oil level in the oil pan in Fig. **3** can be checked with a so-called dip stick **3-B** on which the minimum and maximum oil levels are marked, see Fig. **4**.

Typical oil pump

The oil pump in a diesel engine creates the pressure required to force the oil from the sump to the various lubrication points. Different pumps are used in different engines, such as a piston pump shown in Fig. **1**. This kind of oil pump is used in small diesel engines and the push rod is moved by a cam on the camshaft. Parts of this pump are:

- Push rod **1-A**
- Spring **1-B**
- Plunger **1-C**
- Valve spring **1-D**
- Ball valve **1-E**
- Valve holder **1-F**
- Pump housing **1-G**
- Valve holder **1-H**
- Plug **1-I**
- Strainer **1-J**

The oil pump pushes oil into the main gallery and from there to other parts of the engine. A relief valve is attached to the main oil pipe, see Fig. **2**.

Relief valve

When the engine speed increases the oil pump produces a higher oil pressure than required. This pressure can damage the oil pump. So a relief valve is used to take away some of the extra pressure and maintain it at a suitable level for the bearings.

The relief valve is connected either to the pump or to the main gallery and can be of any shape. All pumps consist mainly of a plunger, as shown in Fig. **3**, or a ball held in position by a spring.

When the oil pressure rises above the setting specified by the manufacturer the plunger **3-C** is pushed back against the spring **3-D** and opens the outlet to the sump via the oil pipe **3-B**. When the plunger is pushed back the pressure decreases and the rest of the oil **3-A** is forced under the correct pressure to the bearings via.

Figure **3** also shows the relief valve in a closed position; no oil returns through the oil pipe **3-B** to the sump.

Figure **4** shows a typical oil ball relief valve in the closed position. It works in the same way as the plunger relief valve.

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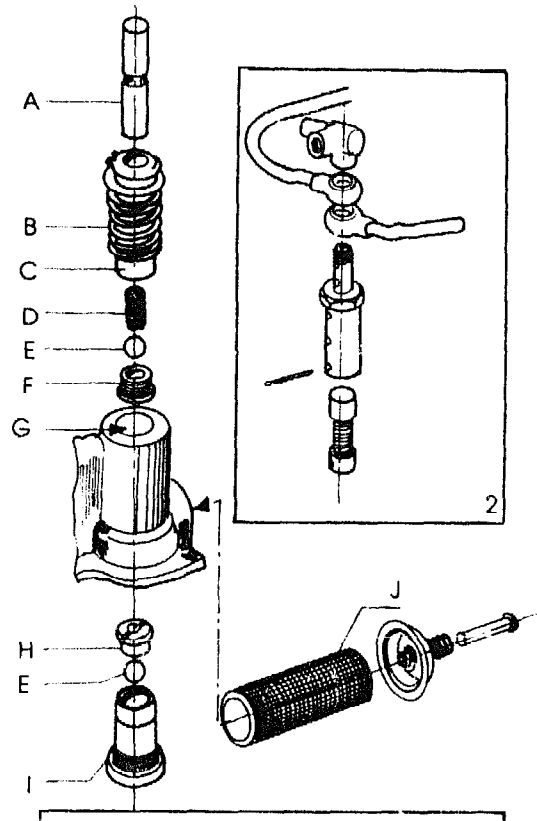

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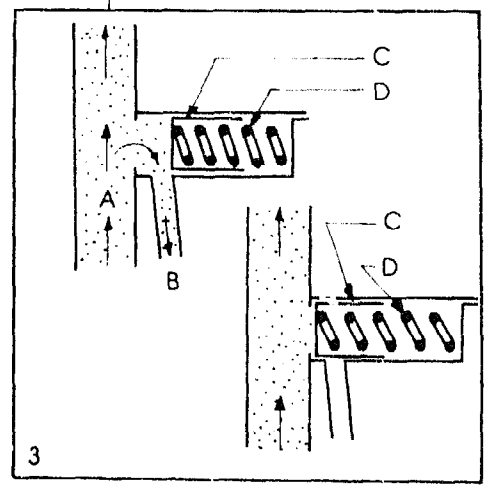

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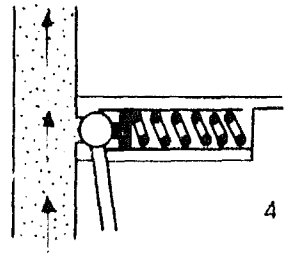

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Typical gear pump

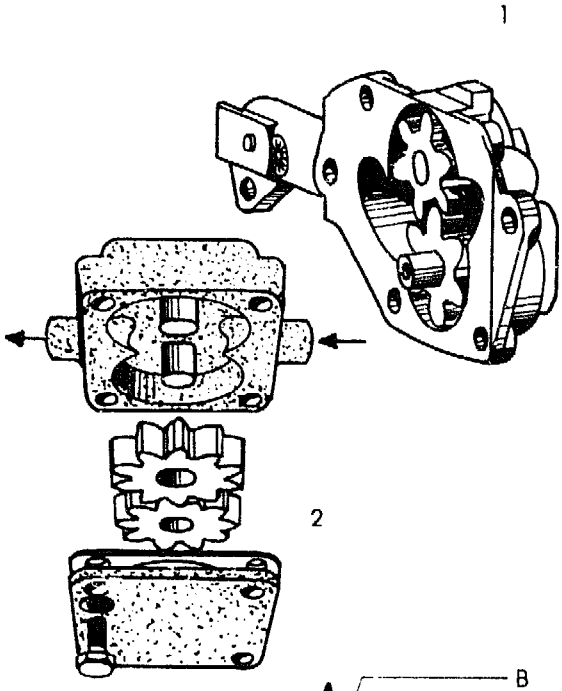

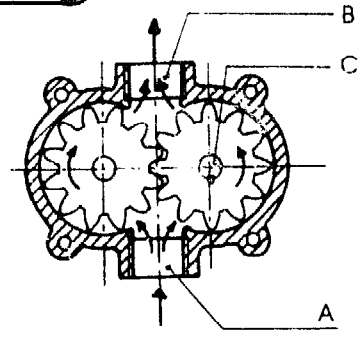

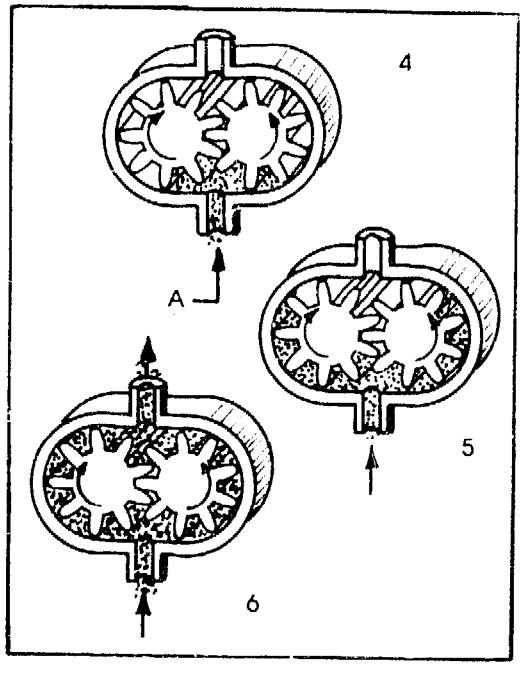

Gear pumps as shown in Figs. **1** and **2** are commonly used in diesel engines. They are either attached to the engine block as in the case of the pump in Fig. **1**, or they are closed with a cover as shown in Fig. **2**.
This pump consists of two gears as shown in Fig. **3**, one of which is driven by a helical gear **3-C** from the camshaft or an auxiliary shaft, depending on the type of engine and its manufacturer. Oil is sucked in at **3-A** and pressed into the system at **3-B**. The gears mesh with a minimum amount of clearance and they also only just clear the sides of the housing.
It is clear that the housing must be connected very tightly against the engine block or the cover must close very tightly.

Oil gear pump operation
The oil gear pump operates as follows;
- When the driven gear rotates, it turns the other gear as well. See Fig. **4**. When both gears are rotating, the oil enters through inlet port **4-A** into the space at the bottom of the pump.
- While rotating, the teeth of each gear catch the oil and carry it along the casing towards the other end of the pump housing, see Fig. **5**.
- The oil leaves the pump under pressure through outlet port, see Fig. **6** and enters the main oil gallery.

The rotary oil pump

Figure 1 shows a rotary pump consisting of the following components:
- Inner rotor **1-A**
- Outer rotor **1-B**
- Oil pump housing **1-C**

The inner rotor is driven from a gear **1-D** on the camshaft **1-E**.
Rotary pumps may differ in design but the principle is always the same.

Rotary pump design
Rotary pumps are designed in the form of a shaft **2-D** with four lobes **2-A**, see Fig. 2. It is fitted off-centre inside the outer rotor **2-B** with five recesses corresponding to the lobes. When the inner rotor turns, its lobes slide over the corresponding recesses in the outer rotor and turn it round in the pump housing **2-C**.

The working of the rotary oil pump
Figure 3 illustrates the working of the oil pump. Oil enters at **3-D** and leaves the pump at **3-E** through the inlet and outlet ports in the oil pump housing **3-C**.
As the inner rotor **3-A** turns (see arrow), the lobe **3-G** sliding inside the recess of the outer rotor **3-B** creates a space which, as it becomes larger or smaller, produces an alternating suction and pumping action.
When the space between the lobe **3-G** and the recess **3-F** increases, the oil is sucked into the pump through the inlet **3-D**. As the rotor turns further, the following lobe of the inner rotor closes the inlet port and the space reaches its maximum.
With further rotation of the rotor, the outlet port **3-E** opens, the space decreases and the oil is pushed out.

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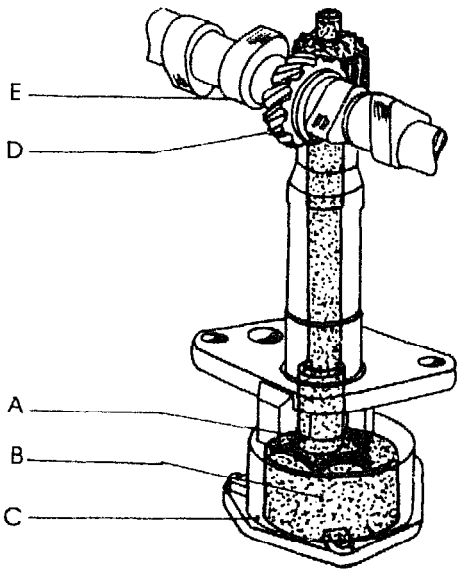

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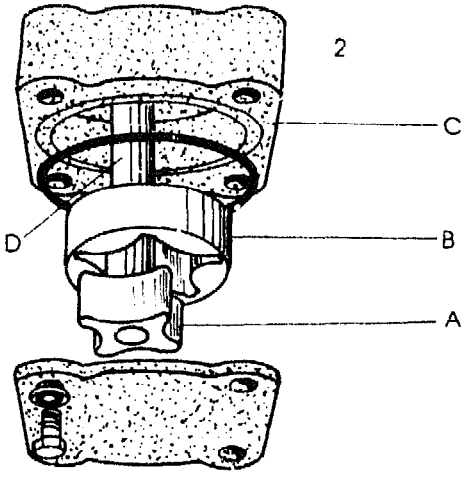

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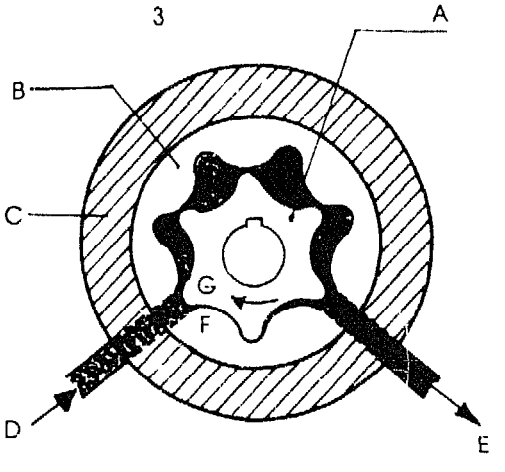

Servicing the oil gear pumps

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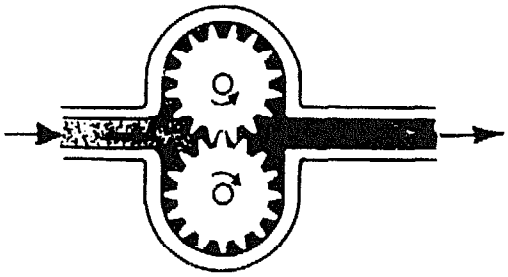

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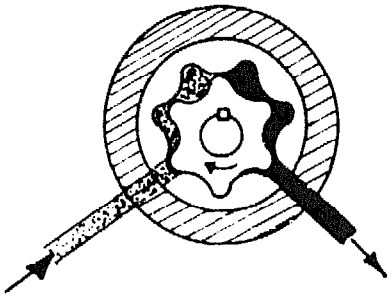

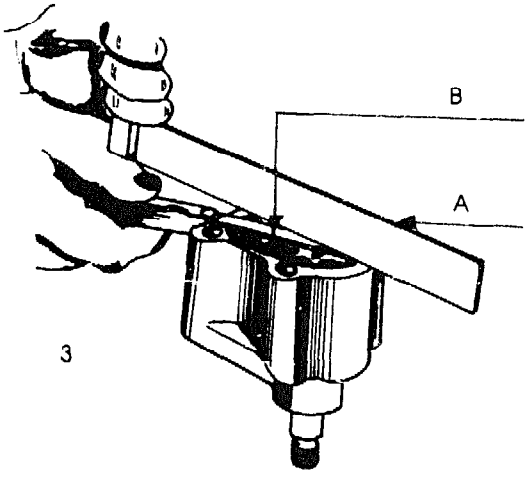

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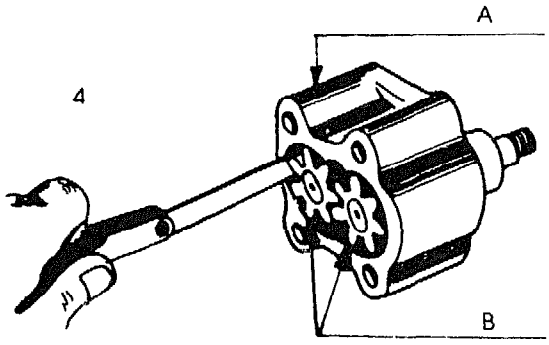

The oil pump must be checked for wear or damage during a general engine overhaul or when the oil pressure indicator shows the pressure is too low.
While loosening and handling the oil pump, be very careful not to damage the mounting surfaces, the housing or the cover.
Some pumps do not have a gasket, only the machined surfaces act as a seal.
In a gear pump, Fig. **1**, most wear develops between the teeth of the gears. In a rotary pump, Fig. **2**, wear develops mostly between the lobes on the rotor ring.

Measuring the clearance
Refer to Fig. **3**. With the gears mounted in the pump housing, place a straight edge **3-A** across the top of the pump housing to act as the cover and measure the clearance between the gears and the straight edge with a feeler gauge **3-B**. The number on the feeler gauge blade should comply with the manufacturer's recommendations.

Clearance between the teeth of the gears and the housing can be measured as shown in Fig. **4**. Place the correct feeler blade between the side of the housing **4-A** on top of the teeth **4-B** and measure the clearance while moving it backwards and forwards.

Almost all the pumps have a screen over the inlet to strain out dirt and foreign material. If possible, remove the screen and clean it. Also inspect all the bushings in the housing and replace them if necessary.

Engine oil filtration

When oil passes through the engine during operation it becomes contamined with metal particles, carbon, dust etc. As you realize, all these impurities cause engine parts to wear if they are left in the oil and that is why the oil system must be equipped with an oil filtering system.

Full flow filtration system
Nowadays all engines are equipped with a filtering system that filters all the engine oil before it reaches the lubrication system.
In this system of oil filtration, see Fig. **1**, all the oil is pumped from the sump **1-A** through the oil pump **1-B** to the oil filter **1-C**. In the filter the oil is pressed through a cleaning material and leaves the filter to pass to the main oil gallery and the engine parts. A relief valve **1-D** regulates the pressure in the system and the oil pressure gauge **1-E** indicates the actual pressure of the oil during operation.

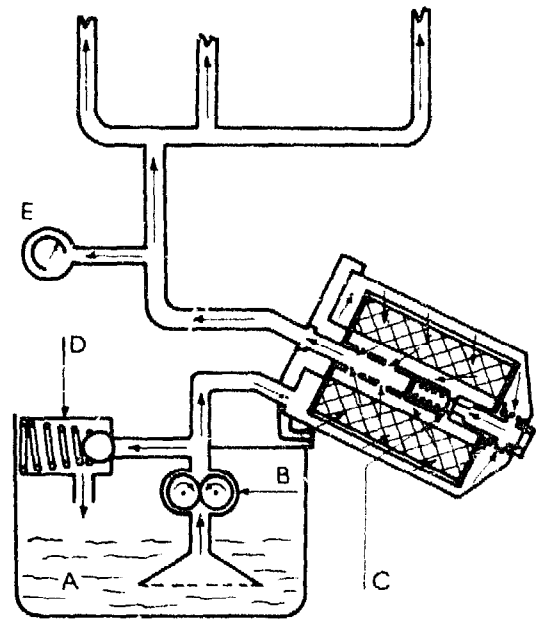

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Bypass filtration system
Sometimes a bypass filtration system is fixed on the engine, so only a portion of the oil passes through the filter. Figure **2** shows how the oil is pumped from the sump straight into the lubrication system. But some of the oil passes through a filter **2-A** and returns to the sump after filtration.
The volume of oil bypassed through this filter is controlled by a restriction in the filter outlet. If the filter is dirty or clogged, the volume of oil passing through the cylinder is reduced. Due to the two separate oil flows, oil pressure at the bearings is constant regardless of the condition of the filter, which is an advantage, but only checking can tell you whether the filter is dirty or clogged. That is why both filter and oil must be changed regularly to prevent loss of filtering.

Full flow/bypass filtration system
Some modern engines have both the full flow and the bypass filtration systems to ensure maximum cleaning of the oil during operation.

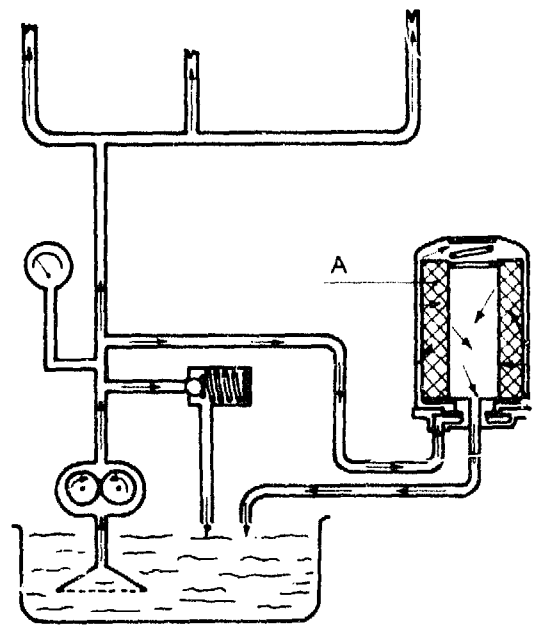

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Oil pressure regulating valves

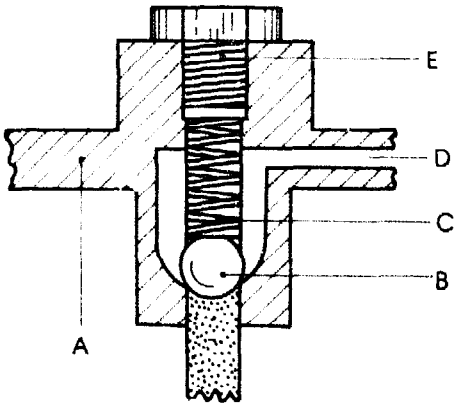

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As you have already learned, the oil pressure built up by the oil pump may exceed the valve setting. That is why the oil pressure regulating valves are designed in such a way that, in the event of over-pressure, the valve opens by itself and the excess oil returns to the oil sump. Regulating valves are usually connected to the main oil gallery through passages in the engine block, may be part of the oil pump and may be installed at bypass oil filters.
Figure **1** shows a typical oil pressure regulating valve installed in a bypass oil filter. It consists of a body **1-A** which is part of the oil filter assembly. A ball valve **1-B**, held in position by a spring **1-C**, closes off oil passage **1-D** by normal pressure. The pressure put on the ball by the spring can be increased by adding shims at **1-E**.

Another oil regulating valve is shown in Fig. **2**. At normal oil pressure the ball valve remains closed due to the pressure from the spring **2-A**. If the oil pressure builds up, the ball is pressed upwards, the oil passes the ball and returns to the sump, see Fig. **3**.
In this type of oil pressure regulating valve the pressure can be changed by loosening nut **2-B** and turning screw **2-C** in or outwards, depending on whether you want to increase or decrease the pressure. After adjusting the screw, tighten the nut properly to ensure the correct setting.

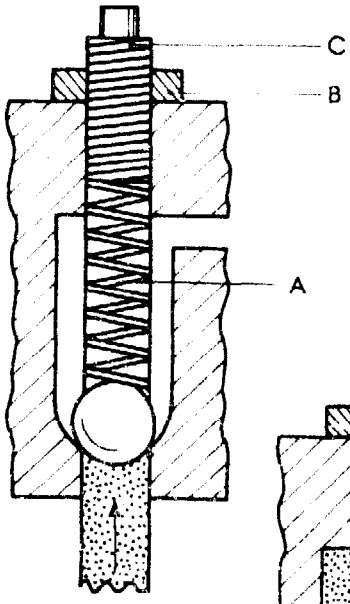

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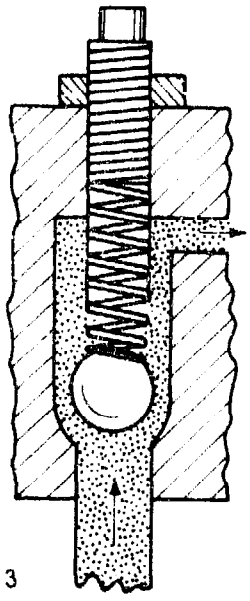

3

Oil filters

In different engines you may find different oil cleaning systems and filters. A good oil filter must be capable of stopping the flow of very small particles of dirt, carbon and metal without restricting the oil flow. Resin impregnated paper is the most commonly used material nowadays. This paper is folded and enclosed in perforated cylinders, one inner cylinder and one outer cylinder, as shown in Figs. 1 and 2.

When the oil passes through the paper the dirty particles accumulate on the surface of the paper. As shown in Fig. 2, the oil enters through the perforations at the outside of the cylinder, passes through the filter element and leaves the filter through the inner cylinder.

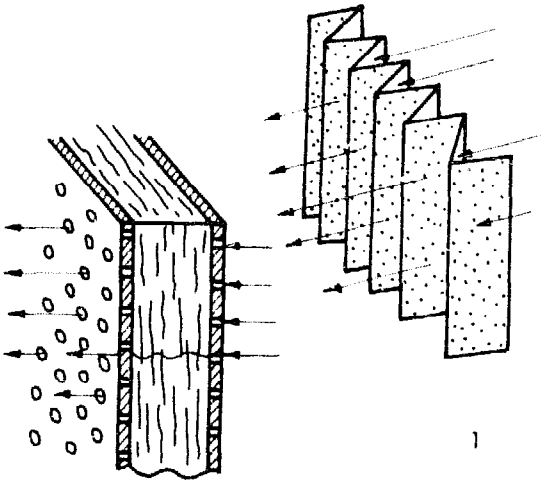

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Cartridge filter
Some filter elements are enclosed in metal containers, see Fig. 3, forming one unit. When the oil is changed, the whole cartridge has to be replaced.
Cartridges are removed with the special tool shown in Fig. 4. Do not use pliers to fasten the new cartridge because you will damage the metal container. Once the container is loosened, the element is simply changed out.

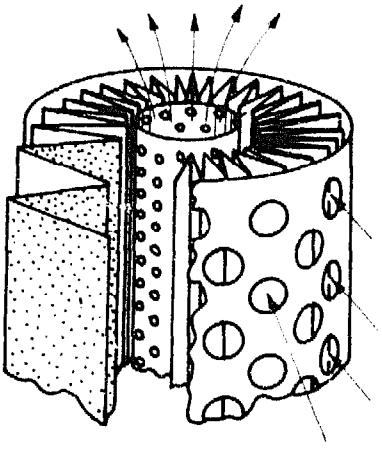

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Other types of filter
Other filter elements are used sometimes, such as the depth filter made from cotton waste. In this filter the oil moves in many directions before it finally enters the top of the lubrication system.
Manufacturers recommend the kind of filter to be used. It is advisable to follow their instructions.

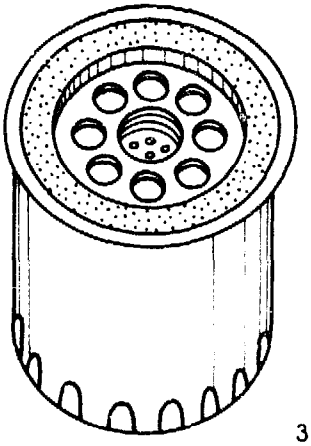

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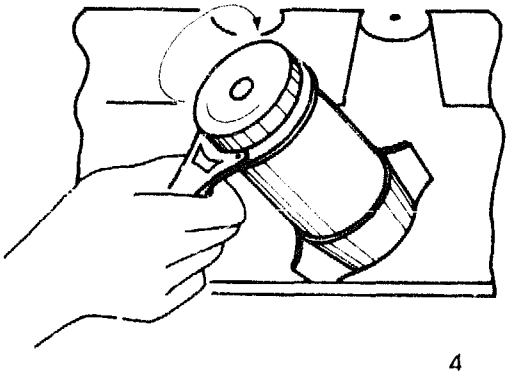

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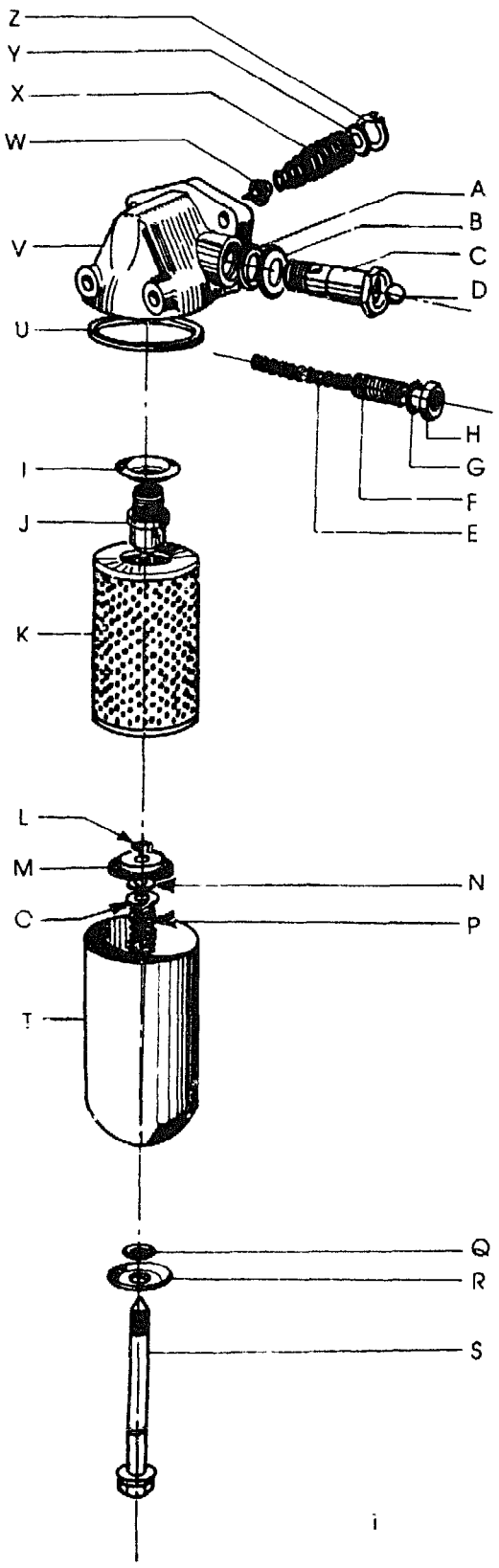

Typical oil filter parts

A typical oil filter assembly is shown in Fig. 1, in which the parts are:

- Relief valve seal **1-A**
- Relief valve washer **1-B**
- Valve body **1-C**
- Ball valve **1-D**
- Spring **1-E**
- Adjusting screw **1-F**
- Lead washer **1-G**
- Lock nut **1-H**
- Top guide element **1-I**
- Centre tube **1-J**
- Filter element **1-K**
- Circlip **1-L**
- Bottom guide element **1-M**
- Seal **1-N**
- Washer **1-O**
- Spring **1-P**
- Sump seal **1-Q**
- Reinforcing washer **1-R**
- Centre bolt **1-S**
- Sump assembly **1-T**
- Head seal **1-U**
- Head **1-V**
- Relief valve **1-W**
- Relief valve spring **1-X**
- Relief valve washer **1-Y**
- Relief valve circlip **1-Z**

Intake and exhaust

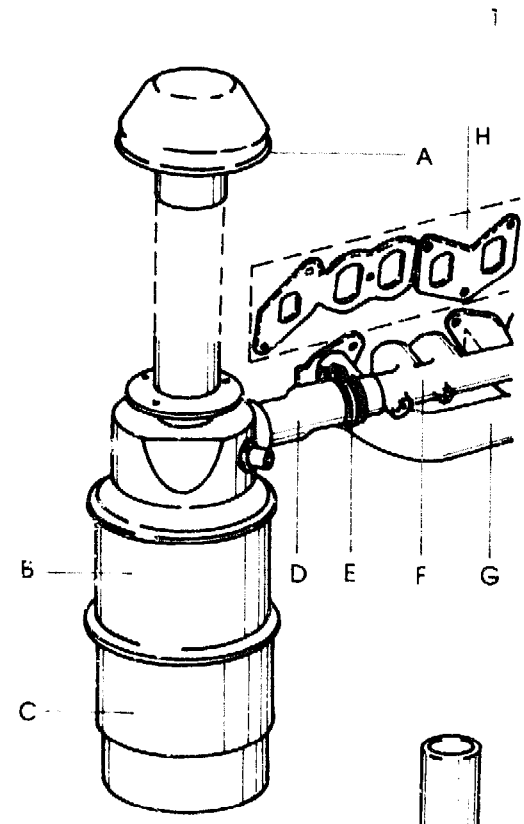

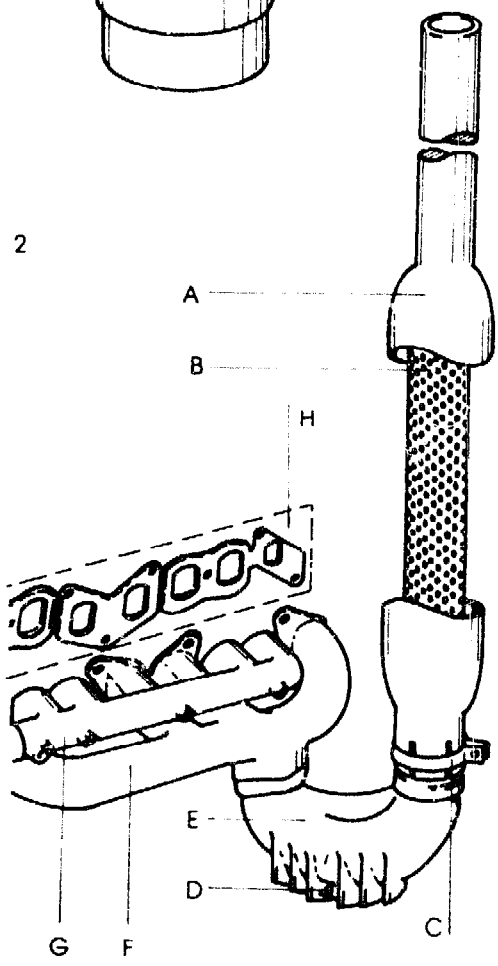

Intake system

The air needed for combustion enters the engine through an air filter, as shown in Fig. 1. The air filter **1-A-B-C** is attached to the intake manifold **1-D**. It may be a straight connection or via a rubber hose. The manifold is connected rigidly with bolts to the cylinder head of the diesel engine **1-H**. Figure 1 shows the inlet manifold near the exhaust manifold. But since diesel engines do not require heat, they may also be located on the other side of the cylinder head.

Intake system parts are:
- Air filter cover **1-A**
- Filter housing **1-B**
- Sump or oil pan **1-C**
- Rubber hose **1-D**
- Clamp **1-E**
- Inlet manifold **1-F**
- Exhaust manifold **1-G**
- Cylinder head, inlet valve **1-H**

Exhaust system

Figure 2 shows the exhaust system. It consists of the exhaust valve in the cylinder head, the exhaust manifold and the muffler. The exhaust valve seals the burning gases in the cylinder until the energy is spent, then opens so the burned gases can escape via the manifold, which brings them to the exhaust pipe. The muffler **2-B** reduces the engine noise during operation.

Exhaust system parts are:
- Exhaust pipe **2-A**
- Muffler **2-B**
- Clamp **2-C**
- Drain plug **2-D**
- Plug **2-E**
- Exhaust manifold **2-F**
- Inlet manifold **2-G**
- Cylinderhead, exhaust side **2-H**

Air cleaners

When air is sucked into the cylinder during its inlet stroke, dust or other material may enter as well. Dry wind during the harmattan or dust blown by storms are a potential danger because they can cause severe wear on cylinders and pistons, leading to loss of power, higher oil consumption and possible clogging of the lube oil system.
To prevent these particles entering the cylinder, air is passed through a filter. Types of air filters are:

- *Dry filters*, where air passes through a porous paper element.
- *Oil bath filters*, where air passes over an oil surface and through a filter of meshed wire.

Pre-cleaners
Figure 1 shows a cross-section of a pre-cleaner, in which air passes through a gauze-protected container and then through a glass bowl where, through whirling action, the dust settles at the bottom of the glass bowl.

Dry filter
Figure 2 shows a cross-section of a typical dry filter assembly. Air enters the filter at **2-A** and passes round the filter element. The air is then filtered through the element and leaves at **2-B**. Figure 3 shows a paper filter.

Dry element air cleaners
Dry element air cleaners are used in engines with a high demand for more air. Figure 4 shows a cross-section of an air cleaner assembly in which air is directed into the cleaner at a high speed so that it sets up a centrifugal rotation, see **4-A**, assisted by tilted fins attached to the end of the dry filter element. The air leaves the filter at **4-B** to the manifold. The centrifugal action continues until the air reaches the far end of the cleaner housing, where the dust collects in a dust cap **4-C** at the bottom of the housing.
Instead of a dust cap, a dust bowl can be installed as shown in Fig. 5. The bowl can be removed to take away the dust.

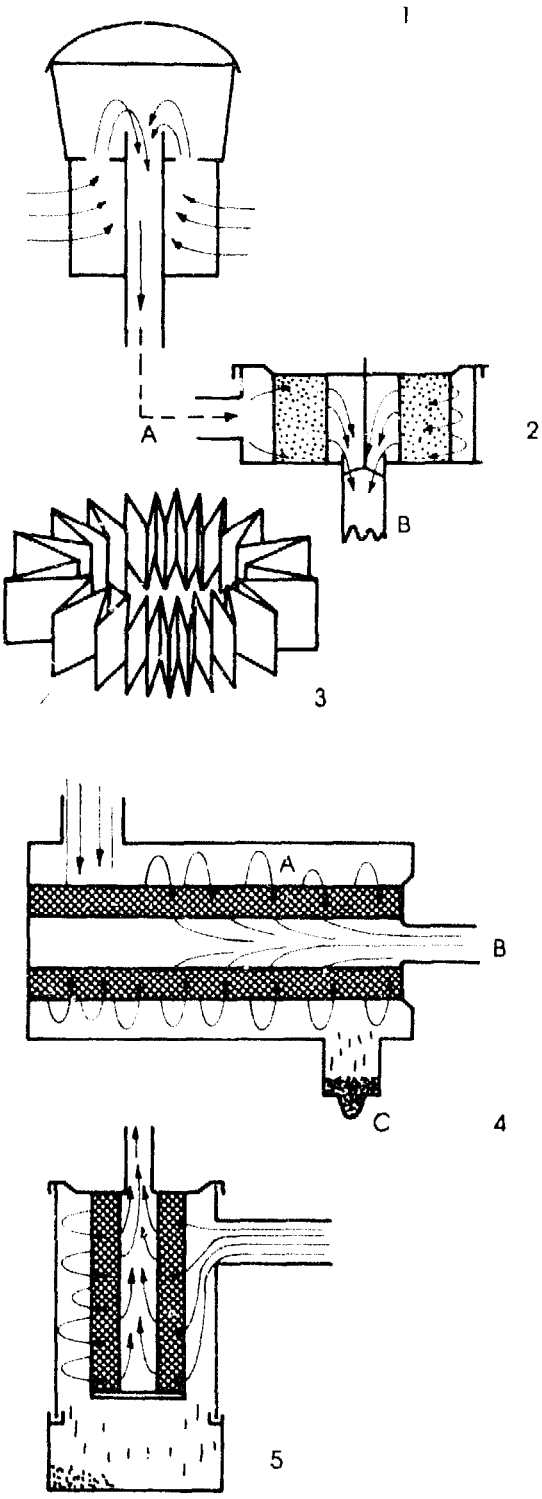

Light duty air cleaner

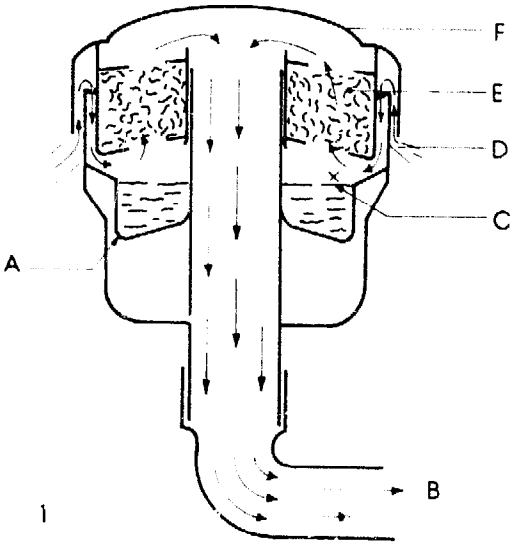

Figure 1 shows a cross-section of a light duty oil bath air cleaner. It consists of:
- Oil pan **1-A**
- Air outlet to engine **1-B**
- Oil bath **1-C**
- Air inlet **1-D**
- Meshed wire filter element **1-E**
- Air filter assembly cover **1-F**

The air cleaner may be loosened from the engine, after which the cover can be taken off and the filter element taken out. The oil sump has a level mark to which engine oil is filled. Air entering at **1-D** first passes over the oil before it is sucked through the actual filter. The filter element in this kind of filter can be cleaned in kerosine and dried, after which it is soaked in clean engine oil and lowered so the excess oil drips out. Before assembling, fill the oil sump with clean engine oil to the level mark **1-X**.

Heavy duty air cleaner

Figure 2 shows a partly opened heavy duty oil bath air cleaner. Air enters the filter through the tube **2-A** and passes over the oil surface **2-B**, from where it is sucked through a filter element **2-D** at the top of the sump **2-F**. From the filter element, the air is then sucked through a second filter in the top housing **2-C** and leaves the air cleaner through the tube **2-E**. This filter is not directly connected to the inlet manifold but connected with a rubber hose, so that it is not affected by vibration from the engine itself.

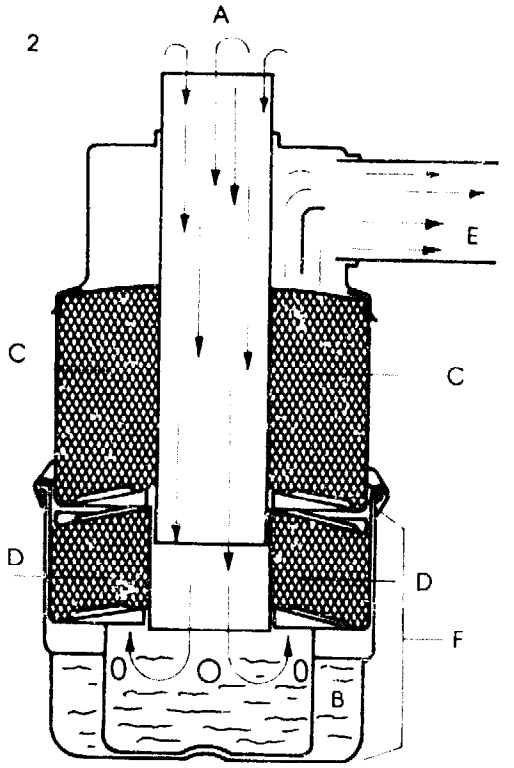

Miscellaneous

General safety precautions

- Keep a clean and well ventilated workshop.
- Keep all the tools in locked cupboards.
- Before working on an engine, check on all technical data in the workshop manual.
- Before dismantling an engine, make a clean space available in which all parts can be placed in correct sequence.
- Make the necessary notes about faults found in parts etc.
- Question the engine attendant before you attempt to work on the engine.
- After questioning, study the fault-finding chart for possible solutions.
- Ensure the engine is mounted securely.
- Ensure a general supply of air is available for the engine.
- Keep all safety guards in good condition.
- Keep hands and loose clothing away from air filters, shafts, belts, manifolds, fans and all other moving and hot parts.
- Do not smoke near starting batteries.
- Disconnect the battery before starting maintenance work (if installed).
- Do not allow the starting handle to rotate on the shaft.
- Keep all fuel and oil pipes free from chaffing.
- Do not allow rubber hoses to come into contact with the exhaust system.
- Never allow unprotected skin to come into contact with high pressure fuel oil – for example, when testing fuel injection equipment.
- Thoroughly remove any diesel fuel and lubricating oil from your skin as soon as practicable after contact.
- Rectify all fuel oil and water leaks as soon as practicable.
- Ensure the engine and surrounding area are kept clean.
- The lifting plates and eyes supplied on the engine are designed for carrying the engine and fitted accessories. They must not be used to lift complete assemblies such as a complete power unit.
- Check all fuel, oil and coolant levels before starting.
- When using a starting handle, hold the handle firmly with the thumb on top of the grip, not around it.
- When using a rope, do not wind the rope round your hand or wrist. Do not use a twisted or frayed rope or one that is contaminated with fuel or oil.

Guide to starting and running problems

1. Difficult starting

Fuel
- Overload trip/excess fuel device not operated
- Incorrect grade of fuel
- No fuel in tank
- Choked fuel filter
- Air lock in fuel system
- Injector nozzle valve stuck open
- Fuel pump delivery valve scored
- Sticking fuel pump rack
- Stop/start lever in wrong position
- Retarded injection

Compression
- Injector loose on seat
- Leaking valves
- Sticking piston rings
- Exhaust valve sticking
- Worn cylinder
- Choked air lifter
- Incorrect decompressor clearance

Cranking
- Unsuitable lube oil (too heavy)
- Load not disconnected
- Turning the crankshaft the wrong way

2. Knocking
- Valve, probably exhaust, sticking in guide and touching piston
- Worn connecting rod bush or bearing
- Worn gudgeon pin or small end bearing
- Insufficient clearance between piston and cylinder head
- Injection too early
- Flywheel coupling or pulley loose
- Too much crankshaft end float
- Excessive carbon deposit on piston
- Excessive clearance between piston and cylinder
- Engine loose on its mountings
- Wrong type of fuel

3. Excessive carbon deposits
- Choked air filter
- Choked exhaust system
- Unsuitable fuel oil
- Unsuitable lube oil
- Continuous idling
- Defective injector spraying
- Late injection of fuel
- Too much side clearance on valve rockers
- Low load running
- Low temperature running

4. Dark blue smoke
- Piston rings worn
- Cylinder bore worn

Faint blue smoke
- Light load

White smoke
- Water in the fuel supply
- Water in the cylinder combustion area

Black smoke
- Overload
- Choked air filter
- Inlet air temperature too high
- Defective injector spraying
- Unsuitable fuel oil or water in fuel

5. Engine stops
- Lack of fuel
- Choked air filter
- Inlet air temperature too high
- Defective injector spraying
- Excessive overload
- Over-heating
- Loss of compression
- Loss of oil

6. Loss of power
- Loss of compression
- Incorrect tappet clearance
- Choked air filter
- Choked exhaust filter
- Defective fuel pump or injector
- Choked fuel filter

7. Failure to attain normal speed
- Engine started at overload
- Fuel system not properly primed
- Insufficient fuel
- Injection retarded
- Governor out of adjustment
- Wrong type of governor weights etc. for speed expected

8. Loss of oil pressure
- Low oil level
- Strainer choked
- Fractured pipe or leaking joint
- Badly worn bearings
- Relief valve not seating
- Oil pump worn or drive failed
- Oil cooler choked
- Oil diluted with fuel
- Unsuitable lube oil (too thin)

Guide to starting and running problems (continued)

9. Overheating

Air cooled engines
- Cooling air being recirculated
- Fins of cylinder head or cylinder blocked with dirt
- Cooling air inlet obstructed
- Cooling air outlet obstructed
- Engine cooling air used to cool driven unit as well
- Overload
- Lube oil level too low
- Injection timing faulty

Water cooled engines
- Thermostat faulty
- Injection timing faulty
- Overload
- Cooling water level too low
- Lube oil level too low
- Water pump belt slipping
- Blockage in water cooling system

10. Low compression
- Injector loose on its seat
- Injector washer scored
- Piston ring caps in line
- Inlet or exhaust valve not seating
- Cylinder head gasket leaking

11. Hunting
- Tight spots on governor linkage
- Fuel pump rack not free
- Air in fuel system
- Faulty injector

12. High oil consumption
- Valve guides worn
- Piston rings worn
- Cylinder bore worn

13. Loss of crankcase vacuum
- Worn piston rings
- Worn cylinder barrel bore
- Worn oil seals
- Too much oil in the sump
- Oil filter cap not seating

14. Leaking oil seals
- Too much oil in the sump
- Loss of crankcase vacuum

Decarbonizing

Only a few engine manufacturers give a specific number of running hours after which decarbonizing should be carried out. The number of running hours depends on such factors as the type of fuel used, ambient temperature, period of low load running and others. Perhaps the best indication that carbonizing is due, is when the engine shows loss of compression or blow-by past the pistons. To decarbonize an engine thoroughly clean and examine for wear the following components, replacing any defective parts as necessary:

- Piston, piston rings and grooves and gudgeon pin
- The combustion chamber or cell
- Valves, valve springs, ports and seats
- Exhaust manifold, piping and silencer
- Inlet manifold and trunking
- Cylinder barrel, head and crankcase cooling fins
- Injector

Conversion factors

Length

	metre m	inch in	foot ft	yard yd
1 metre =	1	39.3701	3.2808	1.0936
1 inch =	0.0254	1	0.0833	0.0278
1 foot =	0.3048	12.00	1	0.3333
1 yard =	0.9144	36.00	3.00	1

Capacity

	UK pint pt	UK gallon gal	US pint pt	US gallon gal
1 UK pint =	1	0.1250	1.2009	0.1501
1 UK gallon =	8.00	1	9.6076	1.2009
1 US pint =	0.8327	0.1041	1	0.125
1 US gallon =	6.6614	0.8327	8.00	1

1 UK pint = 0.5683 litre
1 litre = 1.7598 UK pint

Volume

	cubic metre m^3	cubic decimetre dm^3	cubic inch in^3	cubic foot ft^3
1 m^3 =	1	1000.0	61023.8	35.3147
1 dm^3 =	0.001	1	61.0238	0.0353
1 in^3 =	1.6387×10^{-5}	0.0164	1	5.7870×10^{-4}
1 ft^3 =	0.0283	28.3168	1728.0	1

Linear velocity

	metre per second m/s	foot per second ft/s	foot per minute ft/m	inch per second in/s
1 m/s =	1	3.2808	196.85	39.3701
1 ft/s =	0.3048	1	60	12
1 ft/m =	0.0051	0.0167	1	0.2
1 in/s =	0.0254	0.0833	5	1

Rate of flow – mass

	kilogram per second kg/s	kilogram per hour kg/h	pound per second lb/s	pound per hour lb/h
1 kg/s =	1	3600	2.2046	7936.6
1 kg/h =	2.7777×10^{-4}	1	6.1239×10^{-4}	2.2046
1 lb/s =	0.4535	1632.9	1	3600
1 lb/h =	1.2599×10^{-4}	0.4535	2.7777×10^{-4}	1

Conversion factors

Rate of flow – volume

	cubic metre per second m^3/s	litre per second l/s	cubic foot per second ft^3/s	UK gallon per second gal/s
1 m^3/s =	1	1000	35.3147	219.969
1 l/s =	0.001	1	0.0353	0.22
1 ft^3/s =	0.0283	28.3168	1	6.2288
1 gal/s =	4.5460×10^{-3}	4.5461	0.1605	1

Pressure

	newton per square millimetre N/mm^2	kilogram-force per square centimetre kgf/cm^2	pound-force per square inch lbf/in^2	pound-force per square foot lbf/ft^2
1 N/mm^2 =	1	10.1972	145.038	20885.4
1 kgf/cm^2 =	9.8066×10^{-2}	1	14.2233	2048.16
1 lbf/in^2 =	6.8947×10^{-3}	0.0703	1	144
1 lbf/ft^2 =	4.788×10^{-5}	4.8824×10^{-4}	6.9444×10^{-3}	1

Pressure

	bar bar	atmosphere atm	kilogram-force per square centimetre kgf/cm^2	pound-force per square inch lbf/in^2
1 bar =	1	0.9869	1.0197	14.5038
1 atm =	1.0132	1	1.0332	14.6959
1 kgf/cm^2 =	0.9807	0.9678	1	14.2233
1 lbf/in^2 =	0.0689	0.068	0.0703	1

Pressure

	inch of water inH_2O	foot of water ftH_2O	millimetre of mercury mmHg	inch of mercury inHg
1 inH_2O =	1	0.0833	1.8683	0.0735
1 ftH_2O =	12	1	22.4198	0.8827
1 mmHg =	0.5352	0.0446	1	0.0394
1 inHg	13.5951	1.1329	25.4	1

Conversion factors

Torque (moment of force)

	newton-metre N m	kilogram-force metre kgf m	pound-force foot lbf ft	pound-force inch lbf in
1 N m =	1	0.102	0.7376	8.8507
1 kgf m =	9.8066	1	7.2330	86.7962
1 lbf ft =	1.3558	0.1382	1	12
1 lbf in =	0.1130	0.0115	0.0833	1

Energy

	kilowatt hour kWh	kilogram-force metre kgf m	foot pound-force fl lbf	horsepower hour hp h
1 kWh =	1	3.6709×10^{5}	2.6552×10^{6}	1.341
1kgf m =	2.7240×10^{-6}	1	7.233	3.6530×10^{-6}
1 ft lbf =	3.7661×10^{-7}	0.1382	1	5.0505
1 hp p =	0.7457	2.7375×10^{5}	1.98×10^{6}	1

Power

	kilowatt kW	metric horsepower CV	brake horsepower bhp	British thermal unit per hour Btu/h
1 kW =	1	1.3596	1.341	3412.14
1 CV =	0.7355	1	0.9863	2509.63
1 bhp =	0.7457	1.0139	1	2544.43
1 Btu/h =	0.00029	3.9846×10^{-4}	3.9301×10^{-4}	1

Temperature

The unit of temperature most commonly used in practice in many countries is the degree Celsius (°C), though the terms Centigrade (°C) and Fahrenheit (°F) are still in use. The Fahrenheit scale is not formally defined, but it is generally recognized that the temperature difference of 1 °F is equal to five ninths of the temperature difference of 1 °C.

$$°F = \frac{9}{5}\,°C + 32$$
$$°C = \frac{5}{9}\,(°F - 32)$$

Metric prefixes

Prefix	*Symbol*	*Factor by which the unit is multiplied*
tera	T	1 000 000 000 000
giga	G	1 000 000 000
mega	M	1 000 000
kilo	k	1 000
hecto	h	100
deca	da	10
deci	d	0.1
centi	c	0.01
milli	m	0.001
micro	μ	0.000 001
nano	n	0.000 000 001
pico	p	0.000 000 000 001
femto	f	0.000 000 000 000 001
atto	a	0.000 000 000 000 000 001

Tightening torques for nuts and bolts

The table gives the torque in Nm and lbf ft for unified and ISO metric nuts and bolts. The unified ones are to BS1768: 1963 Grade S for bolts and Grade 3 for nuts, whilst the ISO metric are to BS3692: 1967 Grade 8.8 for bolts and Grade 10 for nuts.

	Diameter of thread	*Threads per inch or mm pitch*		*Torque* *Nm*	*lbf ft*
UNF, UNC (fine and course)	1/4"	28/20	thds/"	11.5	8.5
	5/16"	24/18		20.3	15.0
	3/8"	24/16		43.4	32.0
	7/16"	20/14		67.8	50.0
	1/2"	20/13		92.2	68.0
	9/16"	18/12		135.6	100.0
	5/8"	18/11		203.4	150.0
	3/4"	16/10		271.3	200.0
	7/8"	14/9		440.7	325.0
	1"	12/8		678.2	500.0
ISO	4 mm	–/0.7	pitch	3.0	2.2
	6 mm	–/1.0		8.8	6.5
	8 mm	1.0/1.25		21.0	15.5
	10 mm	1.25/1.5		40.7	30.0
	12 mm	1.25/1.75		78.7	58.0
	16 mm	1.5/2.0		196.7	145.0
	18 mm	1.5/2.5		271.3	200.0
	20 mm	1.5/2.5		393.3	290.0
	24 mm	2.0/3.0		678.2	500.0

Standard bolt and nut torque specifications

Thread size	*260M bolt torque*	
	Nm	*(lb-ft)*
1/4 – 20	9 – 9	5 – 7
1/4 – 28	8 – 11	6 – 8
5/16 – 18	14 – 18	10 – 13
5/16 – 24	15 – 19	11 – 14
3/8 – 16	31 – 35	23 – 26
3/8 – 24	35 – 40	26 – 29
7/16 – 14	47 – 51	35 – 38
7/16 – 20	58 – 62	43 – 46
1/2 – 13	72 – 76	53 – 56
1/2 – 20	84 – 95	62 – 70
9/16 – 12	92 – 102	68 – 75
9/16 – 18	109 – 119	80 – 88
5/8 – 11	140 – 149	103 – 110
5/8 – 18	171 – 181	126 – 134
3/4 – 10	244 – 254	180 – 188
3/4 – 16	295 – 305	218 – 225
7/8 – 9	417 – 427	308 – 315
7/8 – 14	483 – 494	356 – 364
1 – 8	590 – 600	435 – 443
1 – 14	697 – 705	514 – 521

Thread size	*280M or better torque*	
	NM	*(lb-ft)*
1/4 – 20	10 – 12	7 – 9
1/4 – 28	11 – 14	8 – 10
5/16 – 18	18 – 23	13 – 17
5/16 – 24	20 – 26	15 – 19
3/8 – 16	41 – 47	30 – 35
3/8 – 24	47 – 53	35 – 39
7/16 – 14	62 – 68	46 – 50
7/16 – 20	77 – 83	57 – 61
1/2 – 13	96 – 102	71 – 75
1/2 – 20	113 – 126	83 – 93
9/16 – 12	122 – 136	90 – 100
9/16 – 18	146 – 159	107 – 117
5/8 – 11	186 – 200	137 – 147
5/8 – 18	228 – 242	168 – 178
3/4 – 10	325 – 339	240 – 250
3/4 – 16	393 – 407	290 – 300
7/8 – 9	556 – 569	410 – 420
7/8 – 14	644 – 657	475 – 485
1 – 8	786 – 800	580 – 590
1 – 14	928 – 942	685 – 695

Useful terminology

Abrasion: The wearing or rubbing away of a metal surface.

Air cleaner: Various types of device for removing particles of dust from air before it enters the engine.

Ambient temperature: The mean temperature of the combustion and cooling air entering the engine.

AP: The American Petroleum Institute.

Atmospheric pressure: The weight of air at sea level, this is usually taken as being 1 Bar or 14.7 lbs/in^2.

Backlash: The clearance or movement between the teeth of meshed gears.

Back pressure: A resistance to free flow, such as the restriction in an exhaust line.

Balancing fuel pumps: In multi-cylinder engines with single-element pumps the pump racks are adjusted to enable all pumps to deliver a similar amount of fuel.

Bearing: A precision finished surface that allows another part to turn or move against it.

B.h.p.: Brake horse-power is the measurement of the total power of the engine available at the flywheel.

Blow-by (past): The loss of compression past the piston rings.

Bore: The internal diameter of the cylinder barrel.

BS (I): British Standard (Institution).

Bypass: Usually used as an alternative route for oil when the filter is blocked.

Calibration marks: Marks on the fuel pump or pump rack to show when the pump is delivering optimum fuel.

Camshaft: The camshaft is timed to the crankshaft and cams operate the inlet and exhaust valves.

Celsius: Celsius has generally replaced centigrade, though the two are identical.

Cetane: The term used to show the pressure and temperature at which fuel ignites and burns.

Combustion: The process of burning.

Combustion chamber: The space between the underside of the cylinder head and the top of the piston when it is at the top of its stroke.

Compression: The reduction in volume of a gas by squeezing.

Compression ratio: The total volume of air in the cylinder compared to the volume in the combustion chamber, for example 16:1.

Connecting rod: The part which connects the piston to the crankshaft.

Constant speed: An engine with its governor adjusted to give one speed only.

Crankcase: The lower casting of the engine which contains the camshaft, bearings, crankshaft, oil etc.

Crankcase breather: A method used to maintain a crankcase vacuum.

Crankcase (sump) dilution: When fuel finds its way into the oil and dilutes it.

Crankcase pressure: Usually caused by combustion gases finding their way into the crankcase.

Crankcase vacuum: A slight vacuum in the sump is required to prevent oil seals and joints leaking oil. A vacuum is sometimes called negative pressure.

Crankshaft: The main drive shaft of the engine which transforms reciprocating motion into rotary motion.

Crankshaft counterweights: Either an integral part of or bolted onto the crankshaft to offset the weights of the piston and connecting rod.

CV: Cheval Vapeur (Metric Horse Power). Also known as CH in some countries.

Cyclic irregularity: Indicates the degree by which the flywheel varies from uniform rotary motion.

Cylinder: The component the piston is fitted into. Often called the barrel in air cooled engines and the block in water cooled engines.

Cylinder bore: The internal diameter of the cylinder.

Cylinder head: Fits onto the top of the cylinder and contains the valves, injector ansd manifold ports.

Decarbonize: Removal of the build-up of carbon from the piston and heads.

DEMA: American equivalent of BS.

De-rating: At certain site levels and temperatures the oxygen content of the air is less and the load must therefore be reduced to compensate.

Detergent: An additive used in lubricating oils to hold deposits of carbon in suspension and to help prevent frothing. The oil is usually referred to as having a mild or heavy duty detergent.

DIN: German equivalent of BS.

Diesel engine: This type of engine is called a compression ignition engine as the fuel is ignited by the heat of compression without the need of a spark.

Direction of rotation: Looking onto the flywheel, this is the way the engine is turning.

Dynamometer: Test equipment used to measure energy expended from an engine or mechanical force.

Exhaust: The waste producs of combustion.

Exhaust manifold: The component used to collect the exhaust gases to pass them to the silencer.

Exhaust valve: A spring-loaded valve operated from the camshaft to allow the exhaust gases in the cylinder to pass out at the correct time.

Excess fuel device: An automatic or manual method of moving the fuel pump rack to allow extra fuel to pass through the fuel pumps for starting.

Filter (oil, water, fuel): A device for removing particles of dirt from the fluids to protect the engine components concerned.

Flash point: The temperature at which a liquid or vapour will ignite when heated.

Flywheel: The flywheel is used mainly to provide the rotary motion for the driven unit; it also helps to reduce the variation in the speed of the crankshaft which is caused by the reciprocating motion of the cylinders.

Four-stroke cycle: The crankshaft turns twice but the cylinder fires only once.

1. Induction stroke
2. Compression stroke
3. Power stroke
4. Exhaust stroke

FP: Firing point, when fuel is sprayed into the combustion chamber.

Fuel consumption: The amount of fuel used by the engine to give a certain output rating.

Glazed bore (see also Polished bore): Used to describe the surface of a cylinder barrel bore when it has become extremely smooth and polished. Usually asssociated with using the wrong type of oil.

Governor: A device to control the speed of the engine by regulating the amount of fuel passing through the fuel pumps.

Gudgeon pin: Used to connect the piston to the connecting rod and held in position by two circlips.

Heat exchanger: Only used on water cooled engines to cool the water after it has circulated round the system. Works in a similar way to a radiator but uses colder water instead of the fan and air flows.

Hertz (Hz): Unit of frequency. The number of repetitions of a regular occurrence in one second.

Humidity: The measure of the percentage of water vapour held in suspension in the air.

Hunting: Often caused by a fuel pump rack or governor with tight spots resulting in the speed of the engine increasing and decreasing over a wide range.

Idling speed: The lowest speed setting on a variable speed engine.

Injection pump: A single-element or multi-cylinder pump used to meter and deliver fuel under pressure to the injector.

Injector: Used to inject atomized fuel into the combustion chamber at a very precise moment.

Injector leak off: A small diameter pipe allowing excess fuel from the injector to be fed back to the engine fuel tank.

Injector set pressure: The pressure at which the injector valve opens. This is adjustable and is controlled by an internal spring.

Inlet manifold: The casting which carries the combustion air from the air cleaner to the cylinder head.

Inlet valve: A spring-loaded valve operated from the camshaft to allow the combustion air to enter the cylinder barrel at the correct time.

Intercooler: A method of cooling the combustion air charge in some turbo-charged engines.

Internal combustion: The process of burning the air/fuel mixture in an enclosed chamber.

ISO: International Organization for Standardization.

Journal: The part of the crankshaft which runs in the main and connecting rod bearings.

Lapping: The process of rubbing two surfaces with an abrasive material until a seal is formed, as is performed with a valve and valve seat.

Lbf ft: Pounds-force feet.

Manometer: An open ended U-shaped tube partly filled with a liquid used to measure a vacuum.

Mechanical efficiency: The ratio between the indicated and the brake horse power of an engine.

Micrometer: An instrument to measure external or internal dimensions.

MIL.: American military standards as applied to lubricating oils.

Nm: Newton metres.

Overload: The amount of load given by the engine above its rated load.

Piston ring: A ring fitted into a piston ring groove to prevent gases or oil passing.

Polished bore (see also Glazed bore): A term used to describe the cylinder barrel bore when it has become smooth and polished, usually after the engine has run for a high number of hours.

P.s.i.: Pounds per square inch.

Pumping oil: A term describing the condition when an engine is using an excessive amount of lube oil.

Push rod: A metal rod operating from the camshaft to open and close the inlet and exhaust valves.

Rated load: The amount of power the engine is designed to deliver at a given speed.

Radiator: A series of enclosed pipes through which the engine water passes to enable air, which is fan driven across the pipes, to dissipate the heat.

Rotary motion: A circular movement such as the rotation of the crankshaft.

R.p.m., rev/min, r/min: Revolutions per minute.

SAE: Society of Automotive Engineers.

SI: System International.

Sludge: A composition of oxidised petroleum products and contaminants usually found in the crankcase oil sump or fuel tank.

Stroke: The distance the piston moves from its highest to lowest points.

Tachometer: An instrument for measuring the speed of an engine.

Tappet: The component which operates the fuel pump from the camshaft.

Tappet clearance: The clearance between the valve stem and the valve rocker arm.

TDC: Top Dead Centre.

Thermostat: A device used to regulate the flow of water from a cylinder block to the radiator or heat exchanger.

Throw: The distance between the centres of the crankshaft and connecting rod journals.

Thrust washer: A flat bearing surface fitted between a shaft and its housing to absorb any thrust.

Timing marks: Marks used to show the crankshaft and other driven gears are correctly aligned to ensure the valves and fuel pumps operating at the correct time. Marks on the flywheel show when the piston is at TDC or FP.

Torque: The effort of turning.

Torque wrench: An adjustable spanner or wrench to measure the applied turning force being put onto a bolt head or nut.

Turbo-charger: An engine-mounted device using the engine exhaust to drive a rotor and turbine to enable a larger combustion air charge to be delivered to the combustion chamber, resulting in a higher b.h.p. being obtained.

Vacuum: A term used to describe a pressure less than atmospheric pressure. Also known as negative pressure or, in case of an engine, crankcase depression.

Valve bounce: Occurs when the valve does not seat correctly and opens and closes fractionally.

Valve clearance: The distance between the valve stem and valve rocker when the engine is at TDC on the compression stroke.

Valve grinding: See lapping.

Valve guide: A bush through the cylinder head into which the valve fits.

Valve seat: The matched surface in the cylinder head onto which the valve seat mates.

Valve seat cutting. A process used to cut the untrue surface of the valve seat until it is correct to the profile of the valve head.

Variable speed engine: An engine designed to run at various speeds throughout a pre-determined range.

Viscosity: The resistance to flow of a liquid. The viscosity of oil is denoted by numbers, for example 10W, 20W, 30W etc.

Viscous damper: A device usually fitted to larger multi-cylinder engines to reduce the twisting or torsional vibration of the crankshaft.

Wrist pin: See gudgeon pin.

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Repelling Mosquitoes Naturally

by Deborah Taylor-Houg

With the advent of mosquito season, many people are feeling concern for more than just the annoying itchiness of a bite or two. Worries about West Nile Virus (and other mosquito-carried diseases) are leading many who would normally avoid excessive use of chemicals, to start spraying and slathering on insect repellents containing the chemical DEET (N,N-diethyl-m-toluamide).

But are there valid, healthier options when it comes to repelling our fine buzzing and biting friends? You bet! Some ideas for natural insect repellents fall into the category of folklore, myth and urban legends, but other natural remedies can be an effective means of protecting yourself and your loved ones from biting bugs and harsh chemicals.

Natural insect repellents tend to provide coverage for a shorter time, but their coverage is safer so you may find it worth the extra effort applying a bit more often. Most natural repellents only offer about one-tenth of the protection time found in DEET-containing products, so plan on reapplying every 30 minutes or so. Because of their shorter protection time, natural repellents are ideal for short evening outdoor activities like walking the dog, barbecuing, or watering the garden.

Don't spray or apply any insect repellents (natural or chemical) over cuts, scratches, rashes, or other open spots in the skin. Also, be sure to avoid the eye area when applying repellents.

Essential Oils as Natural Repellents

The most common (and most effective) natural insect repellents are various essential oils. Clove oil and citronella (rose geranium) are the most effective against mosquitoes, but be careful with clove oil and use it sparingly. It can be a skin irritant. Other fairly effective essential oils include lemon grass, eucalyptus, castor oil, peppermint, tea tree oil, lavender, and cedar. You can buy cedar oil in spray-on bottles at your local pet store.

It's important to remember when using essential oils that you shouldn't use them internally! They need to be used externally on your skin and garments. Be sure to test any oils on a small patch of skin before applying widely to your body to avoid allergic reactions or skin irritations.

You can make your own insect repellent sprays by combining rubbing alcohol (or witch hazel, vodka, or olive oil) with one of the listed essential oils (about 10-to-1, alcohol-to-oil ratio). Shake well before each use.

To make a lotion, use two ounces of distilled water, two ounces of olive oil, and about 120 drops essential oil. Put the water into a deep mixing bowl, and using a wire whip, begin beating quickly while slowly drizzling in the olive oil. After oil is mixed into the distilled water, stir in the essential oil of your choice (citronella is probably the most effective for insect repellent use).

You can also add a few drops of your choice of insect-repelling essential oils to your shampoo or liquid soap to help counteract the perfumes in these products.

Keep in mind that clothing rubbing on your skin, natural evaporation, your skin's natural ability to absorb anything applied to it, sweat or rain washing off the repellent, and a windy environment reduces the effectiveness of all insect repellents.

Some folks claim that garlic is an effective insect repellent, but I think it works best for repelling friends (and maybe a vampire or two).

HYBRID VILLAGE POWER SYSTEMS:

360 kWh/day Kahua, Hawaii

720 kWh/day Nabouwalu, Fiji

Luis A. VEGA, Ph.D.
Joseph B. CLARKSON

October 1998

Lessons Learned

- **Reliability** is paramount;
- **Reliability** based on: simplicity, capacity, redundancy and history;
- **Affordability** is another extremely important design consideration;
- **Installation** requirements must match in-country capabilities.

MUSTS:

- **involve** the in-country **stakeholders** in all aspects of the project, from resource evaluation to implementation,
- **train** operators,
- use **commercially available equipment**,
- **test** equipment, as part of a system, **before it can be deployed to remote locations**,
- establish appropriate **maintenance** schemes.

The Nabouwalu, Fiji System

- Eight Bergeys provide plenty of **redundancy** but they were difficult to fit into the site. Three or at most four larger turbines would have been better
- ASE Americas PV modules with high voltage cable connections built into the module, take much **less time** to wire (e.g., 40 kW in Fiji took 25% the time to wire 10 kW in Hawaii);
- One (of 144) module had its glass backing shatter from thermal effects, but it is still operational.

- The company chosen to provide the Fiji **inverter** had decades of experience in high power **UPS systems** and needed only minor modifications to turn one of its UPS consoles into a hybrid system inverter.
- The inverter is a hybrid rotary system: ABB **motor drive** powering an **induction motor**, which then turns a synchronous **generator**. The **capacity** of the inverter is such that it easily **supplies the load** and can start the entire load.
- The **efficiency is less** than the Hawaii static inverter, but the system has **been reliable** since installation.

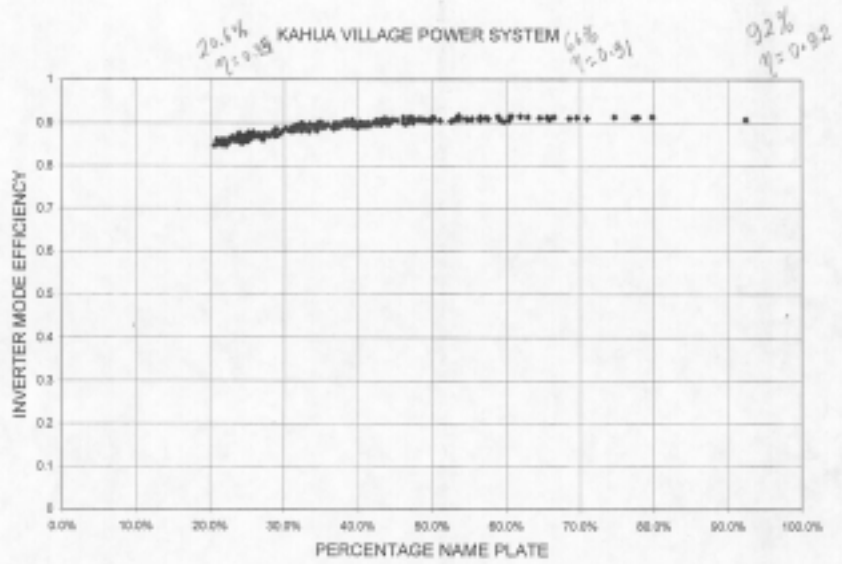

BIGINVERTER

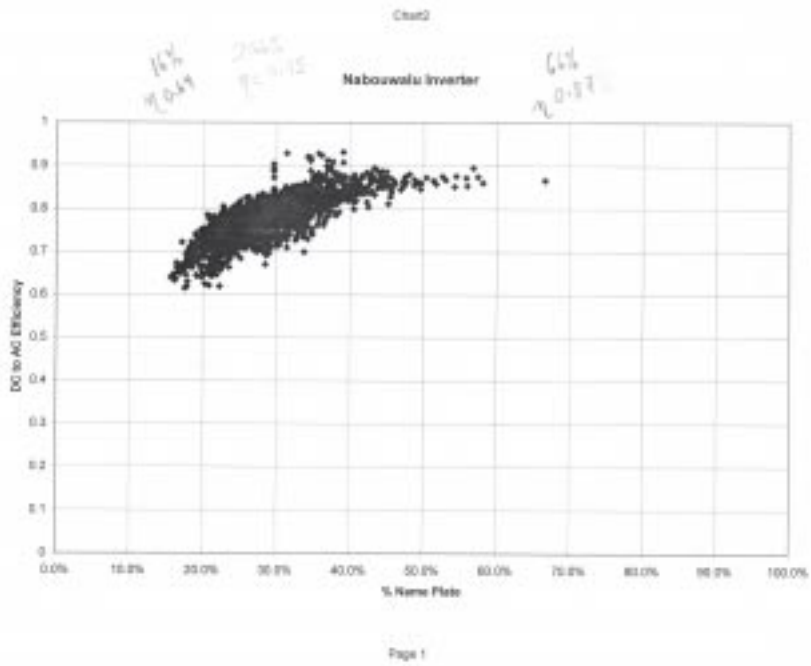

- To allow **easier installation** and better cooling of the cells The battery in Fiji has cell trays one half the size (six cells vs. twelve cells).

- Either genset can run the village, but neither can start the entire village so if diesel is used to bring the village on line, the load must be **segmented** and placed on the grid in sequence;

- The **major problems** with the system have involved the **gensets**. Only one has actually been placed into service, because of a breaker failure in unit 2. This means that when bad fuel caused problems with the lone operational diesel, the system could not supply load. Public Works is attempting to remedy the **fuel quality problem** and repair unit 2.

Summary

- Incremental increases in **simplicity**, **redundancy**, **capacity** and **operational history** have **increased** the **reliability** of the Fiji hybrid power system over the Hawaii system;

- Both are connected to existing mini-grids that were served by fossil fueled generation. Both grids have seen an **increase** in **power quality**; and, the Fiji grid has seen an increase in **availability**.

Demonstration and Training Facility in Hawaii

- Kahua Ranch Village on the Big Island of Hawaii. The village is the residential and operational center for a cattle and sheep ranch. Baseline (360 kWh/day) facility was **installed June 1996** and **reliable operations** were achieved in **August of 1997**.

- 3 x 8 kW_p Bergey Wind Turbine Generators

- 40 x 245 W_p ASE Americas PV Modules (Crystalline Silicon)

- 428 kWh, 240 VDC Trojan (flooded lead acid) Battery

- 30 kW Solid State (Static) Inverter by AES

- 36 kW Koehler Diesel Generator

SYSTEM PERFORMANCE

Design Conditions

- Annual averages of 5.25 sun-peak-hours/day (kWh/m^2-day) and 8.9 m/s;
- The **renewable energy** components were expected to meet **72%** od the demand, with the balance supplied by the genset;
- The COE was expected to be in the range of 0.32 to 0.36 $/kWh (15 years life; 3% to 5% loan; 5-year battery replacement)

Actual Performance (Since 8/97)

- The **PV array** is supplying **94 %** of the **design** value; and,
- The **WTGs** were only supplying **74 %** of the **design** value; however stator **modifications** should increase production to the design value*;
- The actual COE will be in the design range (≤ 0.36 $/kWh).

*once all stators are replaced.

KAHUA (HAWAII) REPAIR RECORD

	Date	REPAIRS	I&M
Wind Turbines	4/97	Repaired slip ring brush (unit 3), downtime: 1day	Monthly:
Installed 6/96	8/97	Replaced leading edge tape (all units), 1d	Visual inspection
	9/97	Tail damper shafts failure observed (all units). Apparently since 6/96.	Quarterly:
	9/97	Tail attachment failure (unit 3); downtime: 1 month	Lower & inspect turbines
	10/97	Replaced tail (unit 3); 1d	Yearly:
			Tighten all connections

	Date	REPAIRS	I&M
Wind Turbines	3/98	Test of Unit 2 with standard stator vs experimental: Production 1.4 x	See previous page
	5/98	Another tail attachment failure (unit 1); 1 day	
	9/98	New designed tail damper shafts & pins received from Bergey.	
	9/98	Stator for Unit 1replaced with standard design (higher production).	

	Date	REPAIRS	I&M
Inverter	4/96 to 3/97	Set point changes	Monthly:
Installed 4/96	9/96	New operating software	Visual inspection
		Replaced failed relay	Yearly:
		Installed diode across contactor	Tighten all connections
	10/96	Replaced burnt capacitors & new firmware	
	12/96	Replaced failed control battery (& 2/97); firmware, etc.	
	8/97	Grounding mods. & ferrite EMI filters to eliminate radiation	

	Date	REPAIRS	I&M
Inverter	8/98	After 1-year of reliable operation, inverter fails to control genset output. IC socket corrosion suspected. Repair of socket requires de-powering control board…another control program (firmware) lost on re-power of control board	See previous page
	9/98	Control board replaced (includes upgraded firmware); downtime: 6-weeks.	

Luis A. Vega, Ph.D.

Village Power 98

	Date	REPAIRS	I&M
Battery	6/97	Cleaned terminal corrosion	Biweekly: add 10 gallons of water
Installed 4/96	9/98	Cell 55 (of 120) very low voltage (0.82 V). Unable to charge. Cell jumpered across. Waiting for replacement.	Monthly: Visual Inspection. Yearly: tighten connections.

Luis A. Vega

70% Battery Discharge in 26 hours (Genset off)

hourly averages

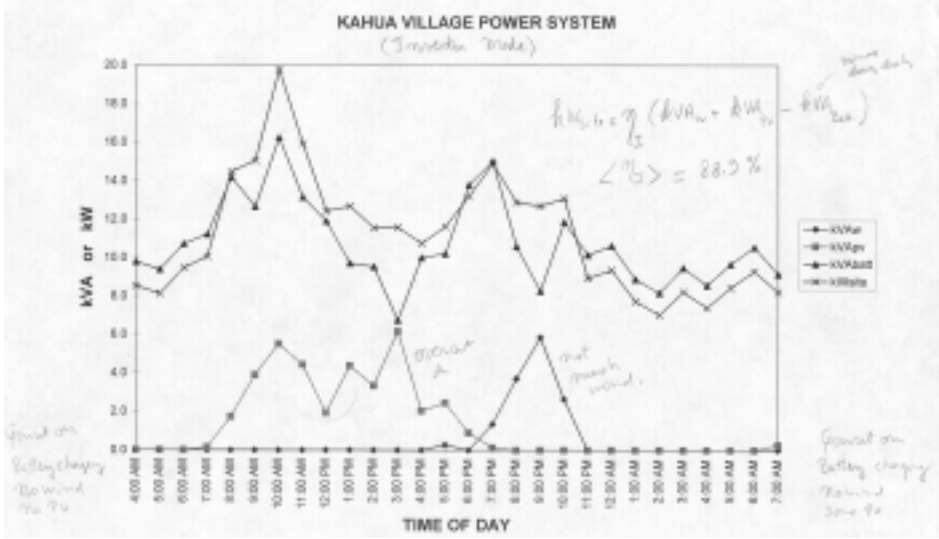

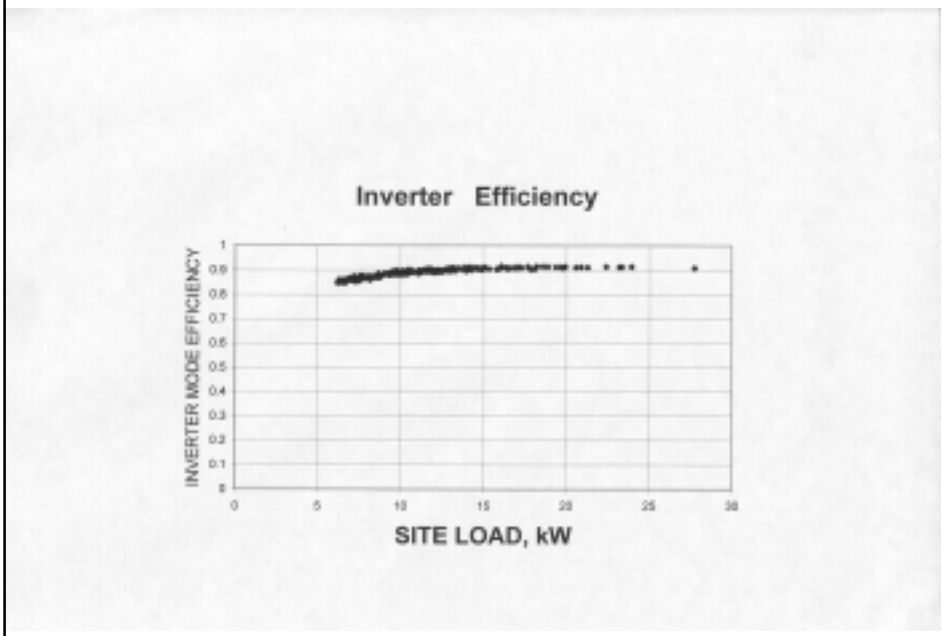
Inverter Efficiency
INVERTER MODE EFFICIENCY
SITE LOAD, kW

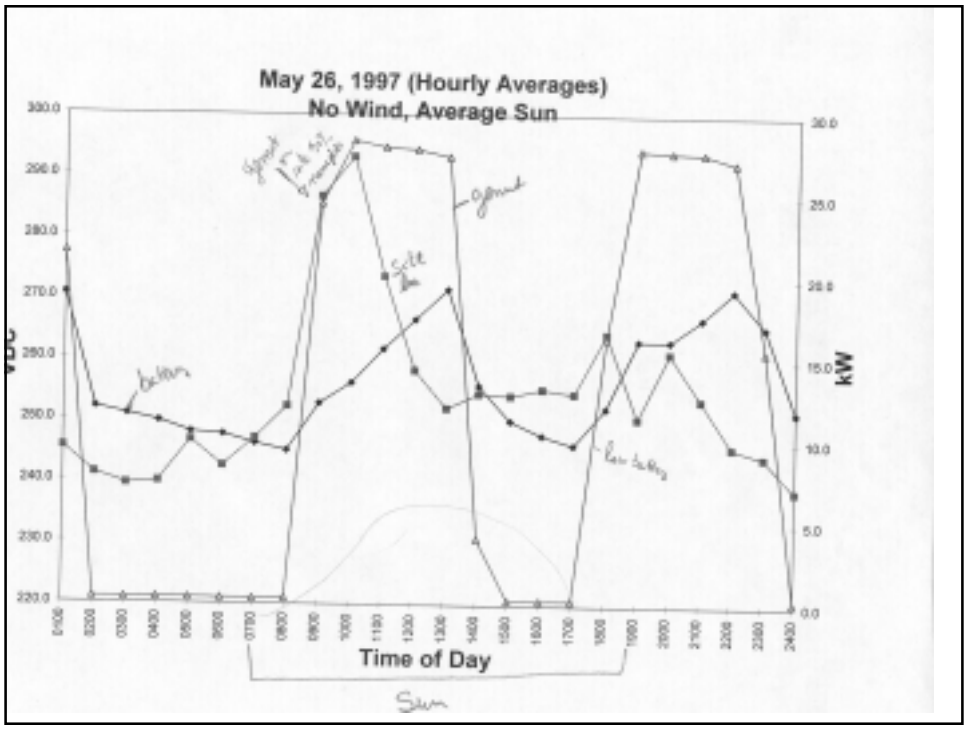
May 26, 1997 (Hourly Averages)
No Wind, Average Sun
kW
Time of Day
Sun

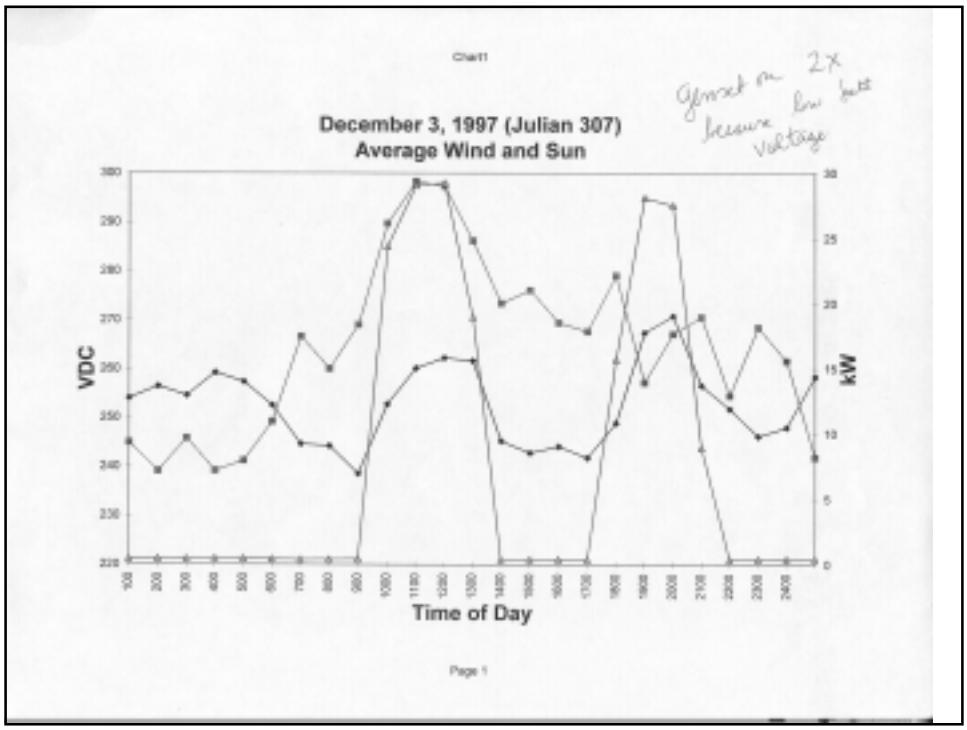

Luis A. Vega, Ph.D.

CONCLUSIONS Kahua (Hawaii)

- Testing has confirmed the importance of considering only **equipment with operational records** for applications in **remote locations**.
- Equipment must be tested as **part of a system** supplying electricity to actual users or to a load bank programmed to represent **realistic load profiles**.
- Preliminary **maintenance schedules** for all components have been developed.
- The **experience gained** was used to design a 720 kWh/day system for the village of Nabouwalu in Fiji.

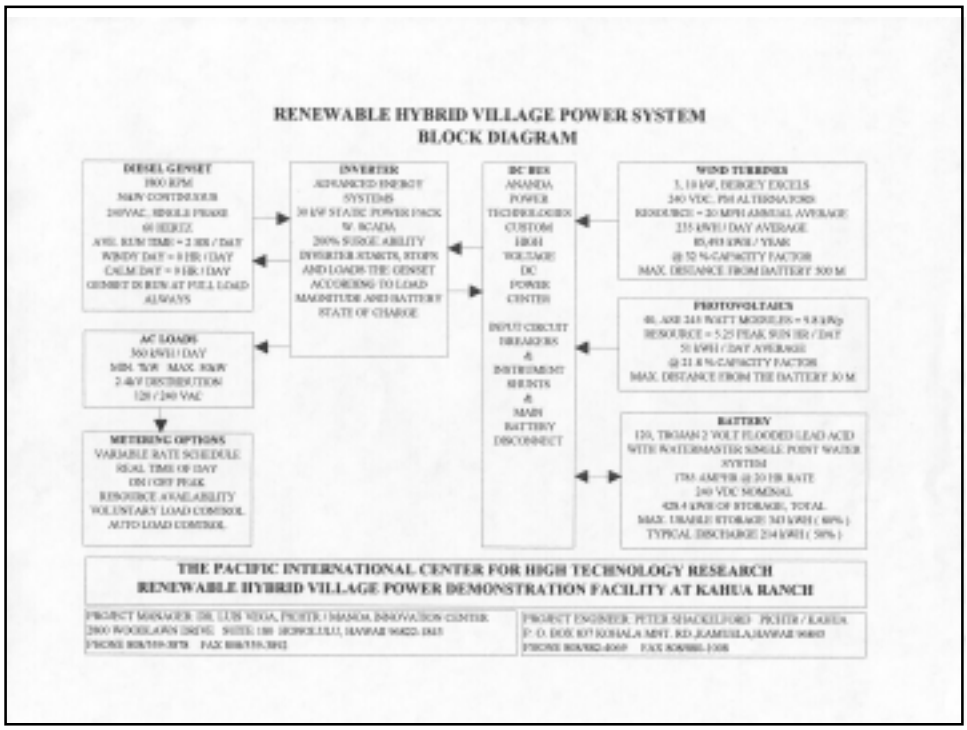

LOCATION	Kahua Training and Evaluation Center			
Village Power System		**Size**	**Cost**	
Diesel	0.4 $/W	**35 kW**	$14 k	
Battery	110 $/kWh	**420 kWh**	$47 k	
Inverter/Controller	1.4 $/W	**30 kW**	$42 k	
PhotoVoltaics	4.5 $/W	**9.8 kW**	$44 k	
Wind Turbine Generators	2.5 $/W	**30 kW**	$75 k	
Installation & Infrastructure			$34 k	
Shipping	Included above		$0 k	20' container OK
TOTAL			$256 k	
CURRENT DOLLAR LEVELIZATION (Constant Annual Cost)				
Site Average Consumption	**360 kWh/day**	Annual Average		
Renewables Average Production	288 kWh/day	Wind	6.9 m/s	32.0%
Installed Cost Renewables (CC)	$242 k	Sun	5.3 sunhours	21.9%
OM, Yearly O&M	$9 k	Includes Replacements		
I, Interest (current-dollar discount rate)	5.00%	AOS/WS<5%	Otherw 10%	
IR, Annual escalation (inflation) for entire period	2.00%			
N, System Life	15 years			
CAPITAL PAYMENT RENEWABLES				
CRF, Cap. Recov. Fac. or Invest. Level. Fac.f(I,N)	9.63%			
Levelized Invest. Cost, CC*CRF/Yearly Production	**0.22 $/kWh**	"Loan Amortization Payments"		
O&M (Replacement) COSTS RENEWABLES				
CRF, f(I,N)	9.63%			
Present Worth Factor with Inflation, f(I,N,IR)	11.99			
EUF, Expenses Levelizing Factor f(I,N,IR)	1.15			
Levelized Expen. Cost, OM*EUF/Yearly Production	**0.10 $/kWh**	To cover Battery Replacement (10 years)		
Total COE Production With Renew.	**0.33 $/kWh**			

Table 2 Levelized COE at Kahua Training and Evaluation Center

LOCATION	LONG TERM COST GOALS APPLIED TO KAHUA RESOURCE			
Village Power System		**Size**	**Cost**	
Diesel	0.4 $/W	**35 kW**	$14 k	Mature Price
Battery	110 $/kWh	**428 kWh**	$47 k	Mature Price/Double Life
Inverter/Controller	0.7 $/W	**30 kW**	$21 k	Price same as Home Inverter
PhotoVoltaics	3.5 $/W	**9.8 kW**	$34 k	Production Increase Price
Wind Turbine Generators	2.0 $/W	**30 kW**	$60 k	Competition Pricing
Installation & Infrastructure			$34 k	
Shipping	Included above		$0 k	20' container OK
TOTAL			$210 k	
CURRENT DOLLAR LEVELIZATION (Constant Annual Cost)				
Site Average Consumption	**360 kWh/day**	Annual Average		
Renewables Average Production	288 kWh/day	Wind 8.9 m/s		32.0%
Installed Cost Renewables (CC)	$196 k	Sun 5.3 sunhours		21.9%
OM, Yearly O&M	$5 k	Includes Replacements		
I, Interest (current-dollar discount rate)	3.00%	AOB/WB<5%	Otherw 10%	
ER, Annual escalation (inflation) for entire period	2.00%			
N, System Life	15 years			
CAPITAL PAYMENT RENEWABLES				
CRF, Cap. Recov. Fac. or Invest. Level. Fac.I(I,N)	8.38%			
Levelized Invest. Cost: CC*CRF/Yearly Production	**0.16 $/kWh**	"Loan Amortization Payments"		
O&M (Replacement) COSTS RENEWABLES				
CRF: I(I,N)	8.38%			
Present Worth Factor with Inflation: I(I,N,ER)	13.89			
SLF, Expenses Levelizing Factor I(I,N,ER)	1.15			
Levelized Expen. Cost: OM*CLF/Yearly Production	**0.05 $/kWh**	To cover Battery Replacement (10 years)		
Total COE Production With Renew.	**0.21 $/kWh**			

Table 3 Levelized COE for Long Term Cost Goals Applied to Kahua Resource

720 kWh/day Village Power System for Nabouwalu, Fiji

- Government station at Nabouwalu in Vanua Levu
- Wind and solar insolation monitoring station was set up, by FDoE, at a location selected after a field trip and in consultation with the residents
- With six-month environmental and electrical load data records (some correlated with twenty-year long records from a nearby meteorological station), the design was developed by PICHTR working with FDoE and PWD.

Design Configuration:

- 8 x 9 kW_p Bergey Wind Turbine Generators
- 144 x 260 W_p ASE Americas PV Modules
- 428 kWh, 240 VDC Trojan Battery
- 100 kVA Rotary-Hybrid Inverter by PS&C
- 2 x 100 kVA Diesel Generator and Mini-Grid in Nabouwalu

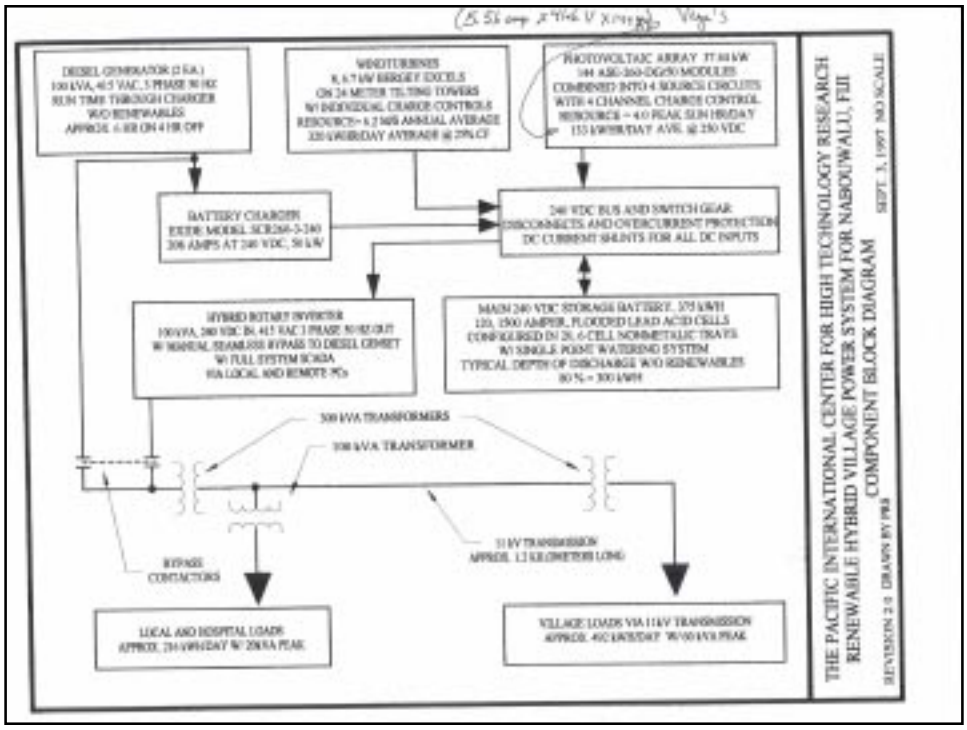

Energy Sources

Renewable sources are used to energize a DC bus, which supplies the energy to run a hybrid rotary inverter which in turn powers the load, the excess is stored in the battery

Wind Turbine Generators

- The WTGs turn permanent-magnet generators which produce three phase AC power of varying frequency …transmitted to the electrical/control room wherein the power is rectified and the voltage regulated
- With proper IM&R, the life of the wind turbines and towers should exceed 20 years.

PV Array

- DC electrical output of the fixed PV Array is regulated by a controller
- Minimal IM&R is required to attain life cycles of 30 years.

Genset

- The generators produce 50 Hz, three phase, 415 Volt output, to power the load directly and to charge the battery when required (set point 1.9 V/cell)

Energy Storage

- When the renewable resources are insufficient to support the load, the battery discharges to the DC bus.
- Fully charged, the battery can run the village ½ day.
- When the battery is charged (set point 2.4 V/cell), the WTGs and PV controllers limit the charge rate to prevent overcharging (i.e., regulate).
- With Proper IM&R the battery should last 5 to 10 years

DC to AC Conversion

- The hybrid rotary inverter consists of variable frequency motor drive (ABB) which converts the DC bus current to three phase, 50 hz, AC at ≈ 150 Volts RMS… to run an induction motor coupled to a synchronous generator which produces the 415 V, three phase, 50 Hz supply.
- The inverter requires no periodic maintenance other than inspection of the coupling between the motor and generator. The bearings in the motor and generator are sealed and cannot be greased. The expected life of these bearings in continuous service is 20 years.

SCADA

- Control of the inverter is shared between a microprocessor based control board and a GE Programmable Logic Controller (PLC-1).
- Another PLC (PLC-2), controls the operation of the diesel powered battery charger and collects data from various power monitoring and environmental sensors and transducers.
- Communication and collection of data from PLC-2 is through a personal computer running AIMAX software produced by T.A. Engineering.

EM 25

Reproduction in dairy cattle 1

What is important to know at the farm?

Bart Gietema

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Author: Bart Gietema

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NUGI: 835

Foreword

This guide on reproduction in dairy cattle is presented in two partner volumes:

Book I
Gives the basic facts of reproduction in dairy cattle. Facts which should be familiar to (modern) dairy farmers, dairy farm managers and extension workers dealing with dairy farming.

Book II
This part deals quite extensively with artificial insemination ‘at work level’ in a (sub)tropical environment.

It should be noted that in many places in the (sub)tropics ‘extensive’ dairy farming (as opposed to ‘modern’) may be the most common practice and in fact is the most economic way to keep cattle (see annex book I). The fact that this part pays so much attention to artificial insemination does not at all mean to say that it is a ‘must’ in dairy farming everywhere.

Acknowledgement
The text of both books has largely been adapted from texts originally prepared by Prof. Dr C.H.W. de Bois and Dr Uwland, formerly lecturers in the International Course on Dairy Cattle Husbandry of the International Agricultural Centre IAC in Wageningen, the Netherlands.

IJhorst, NL, April 2004
B.Gietema
compilation, editing & layout

Email: <b-n.gietema@hetnet.nl>

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1 Reproductive system and ovarian cycle

1.1 Introduction

Dairy cows are usually kept to produce milk and beef but the production of *offspring* is also important, because of its big influence on the milk and beef production on a farm.

After giving birth to a calf, a cow starts producing milk. The first weeks after calving milk production gradually increases. It reaches a peak one to two months after calving if all is well. After that milk production decreases. This goes on until the cow is dried off by the farmer or until the cow just stops producing. With low production cows, the latter can happen before the cow is 300 days in lactation; good cows, when not pregnant, can produce milk up till 400 or more days in lactation.

The *reproductive performance* is a measure of the number of offspring per cow per year; it has a great influence on the production of milk.
In this context, as a rule of thumb, a very good cow is a cow which produces **one calf every year.** A very good herd is a herd of which about 90% of the cows produce a calf every year. In the Netherlands such herds exist only where management is of high quality.

Unfortunately, in many places, too often reproduction is at a low level; this can be concluded from the long calving intervals and low conception rates.
Often, one of the major causes of low reproduction is poor herd management.

In the following sections and chapters, reproduction in cattle will be discussed, including aspects of artificial insemination, although the latter is the subject of Book II.

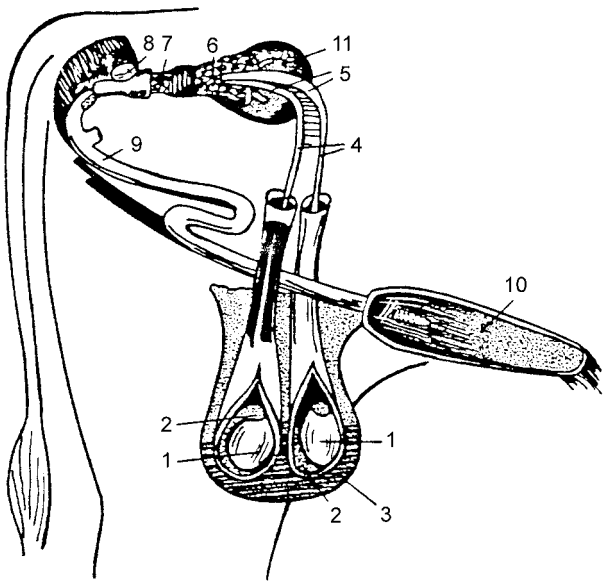

1 test (or testicle)
2 epididymus
3 scrotum
4 vas deferens
5 ampulla
6 seminal vesicle
7 prostate
8 Cowper's glands
9 penis
10 prepuce (or foreskin)
11 bladder

Figure 1: Reproductive tract of the bull

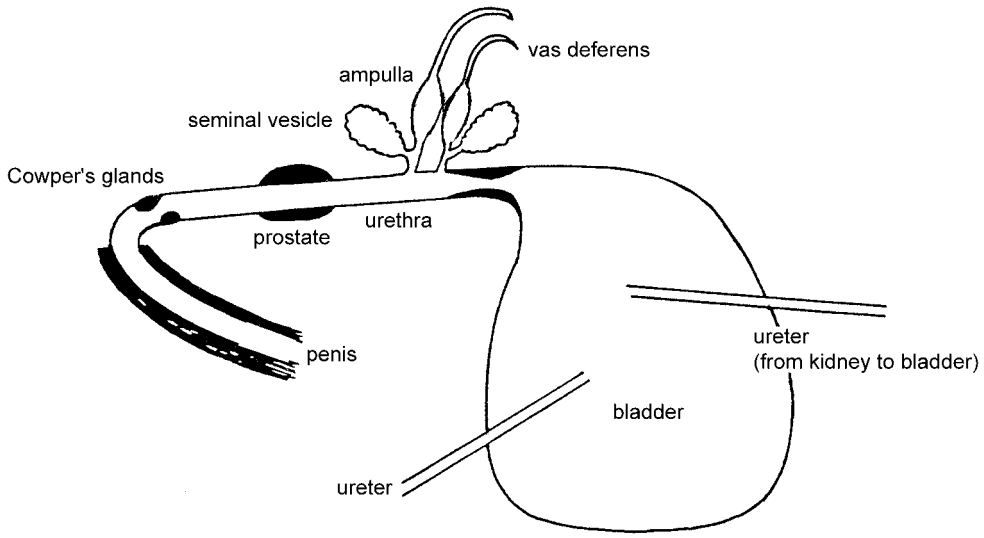

Figure 2: Reproductive tract of the bull

1.2 The reproductive tract of the bull

The male reproductive organs are the two testes (singular testis = testicle) and the epididymes (singular epididymis, meaning coil of conveying duct behind testicle); they are situated in the scrotum (bag enclosing the testicles). Furthermore the two vasa deferentia (singular vas deferens = spermatic duct), the seminal vesicles, the prostate gland, the Cowper's glands and the penis form part of the reproductive tract. The bladder, which collects and excretes the urine, is closely connected with the reproductive tract.

A *testicle* is made up of a semen producing part (more precisely spermatozoa = active fertilizing cells of male organism) and a hormone producing part. The semen producing part consists of a large number of small tubes that begin under the surface of the testicle and discharge into the epididymis. The total length of the small tubes is 400 to 500 metres. In these tubes the male cells are formed. A male cell consists of a more or less egg-shaped head, a short connecting piece and a long, mobile and wire-like tail.
The hormone producing part is situated between the semen producing tubes. With a microscope it is possible to detect clusters of cells, the so-called cells of Leydig, which produce the male sex hormones (testosterone). Hormones are a sort of messengers. They are produced in certain glands and transported by the bloodstream to their target organ. There they stimulate or inhibit certain processes. The hormones produced in the testicles have very important functions. They are of great influence on the development of the reproductive tract in young animals.

Later, when semen production starts, the hormones take care of the maturation of the male cells and bring about the sex drive (libido). Furthermore they are responsible for the development of the secondary sex characteristics. That is why a male animal has a different body conformation from a female animal. Bulls have greater muscle strength, bigger horns and show different behaviour than cows.

The testicles are situated in the *scrotum.* The main function of the scrotum is to assure the right temperature for male cell production. To produce viable male cells, the testicles must have a temperature that is 3 to 4 °C below body temperature. If the testicles get too cold, they are drawn closer against the body; the skin of the scrotum is wrinkled in this case. When it is very warm, the testicles hang further away from the body.
Scrotum temperature can also be controlled by the blood flow to the scrotum surface.

The *epididymes* are also situated in the scrotum. An epididymis forms a sort of coiled tube all along one side of a testicle. In these tubes the male cells are stored; at the same time there is a ripening process.
An epididymis can be divided into a head part, a body part and a tail part.

A *vas deferens* comes from the tail part of an epididymis and goes to the abdomen (belly). There it discharges into the urethra (duct through which urine is discharged from bladder). Just before the vasa deferentia discharge themselves into the urethra, they widen and form the so-called ampullae (singular ampulla).

The *ampullae* secrete a fluid that is mixed with the male cells when they leave the epididymes.

The *two seminal vesicles* are situated beyond the ampullae. These glands also secrete a fluid that is mixed with the semen.

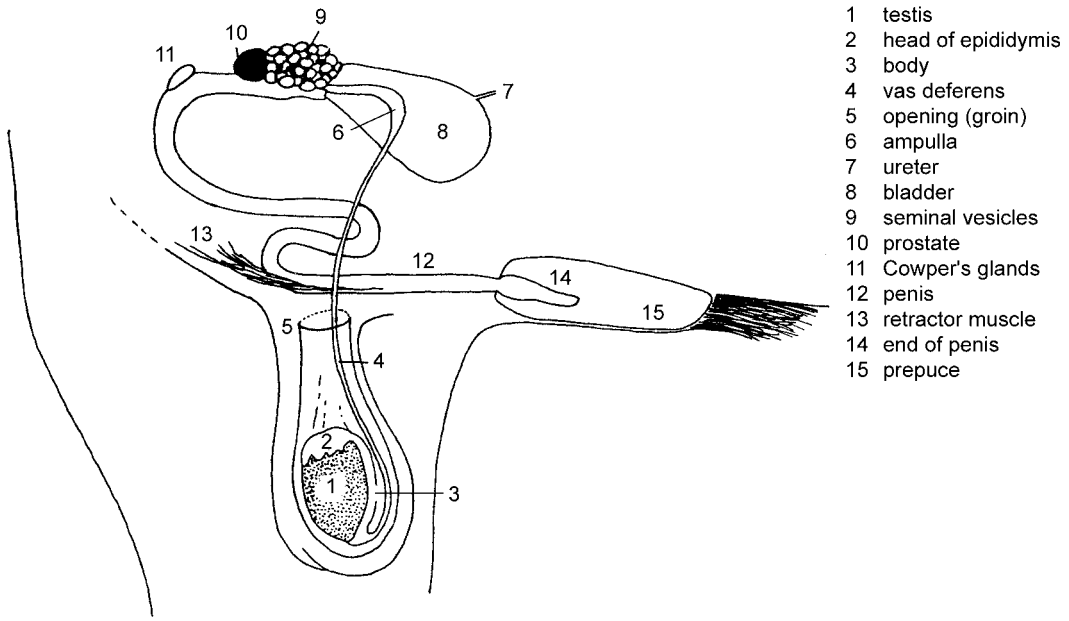

Figure 3: Again, the reproductive tract of the bull

In the urethra more fluid is added to the semen. This comes from glands, the *prostate gland and the Cowper's glands*.

When an animal ejaculates, the male cells pass from the epididymis through the vas deferens into the urethra. From there they pass into the *penis* and are excreted. On their way the male cells are mixed with fluids from the different glands.

The semen

Semen consists of male cells formed in the testicles and fluid from the so-called accessory male sex organs (ampullae, prostate, a.o.). About 5% is fluid with male cells from the epididymes.
The quantity of semen that is ejaculated by animals varies. A bull ejaculates 2 to 12 ml, a stallion 50 to 150 ml. In small ruminants such as the buck the amount of semen per ejaculation is 1 to 3 ml.
In semen of a bull and of small ruminants 500 million to 2000 million male cells per ml are found. The semen of stallions is less concentrated and contains 50 to 150 million male cells per ml.

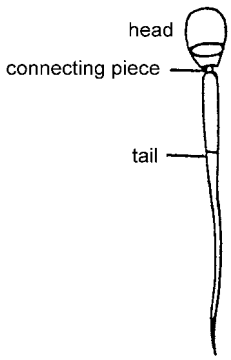

Male cells can move. This can be seen under a microscope. The motility of these cells gives an indication of the quality of the semen. A good motility is desired.

Figure 4: Male cell

Abnormalities in the male's reproductive tract

The absence of one or both testicles
Shortly before or after birth the testicles descend from the belly into the scrotum. Sometimes one or both testicles do not descend (horse; pig). If both testicles stay in the belly the animal will be completely sterile, except in cocks (birds) where this condition is normal. If only one testicle remains in the abdomen, the animal will be fertile. Such animals should not be used for breeding because this defect can be inherited by the offspring.

The absence of one or more accessory organs
This defect results in decreased fertility or total sterility.
Genetic factors are involved.

One or both testicles or one or more accessory organs is/are too small
This condition generally results in the production of semen of low quality.
It is also possible that there is hardly any semen production.

Insufficient erection of the bulls' penis
This is caused by mal-functioning of the retractor muscle. The S-formed curve in the penis is then not flattened completely, thus not making the penis come out enough.

Castration and sterilization

When the testicles of an animal are removed (= castration), the animal becomes sterile and also loses its sex drive, while the (secondary) sex characteristics disappear partly or completely.

A male animal can also be *sterilized*, by cutting through the vasa deferentia (= vasectomy). In this case the testicles are not removed and the blood circulation in the testicles will continue.
Male cell production will be inhibited this way, but the production of sex gland fluids and sex hormones can continue, and sex drive and secondary sex characteristics will not disappear.
Note that cutting through the vasa deferentia is in ordinary language often (wrongly) called 'castration'.

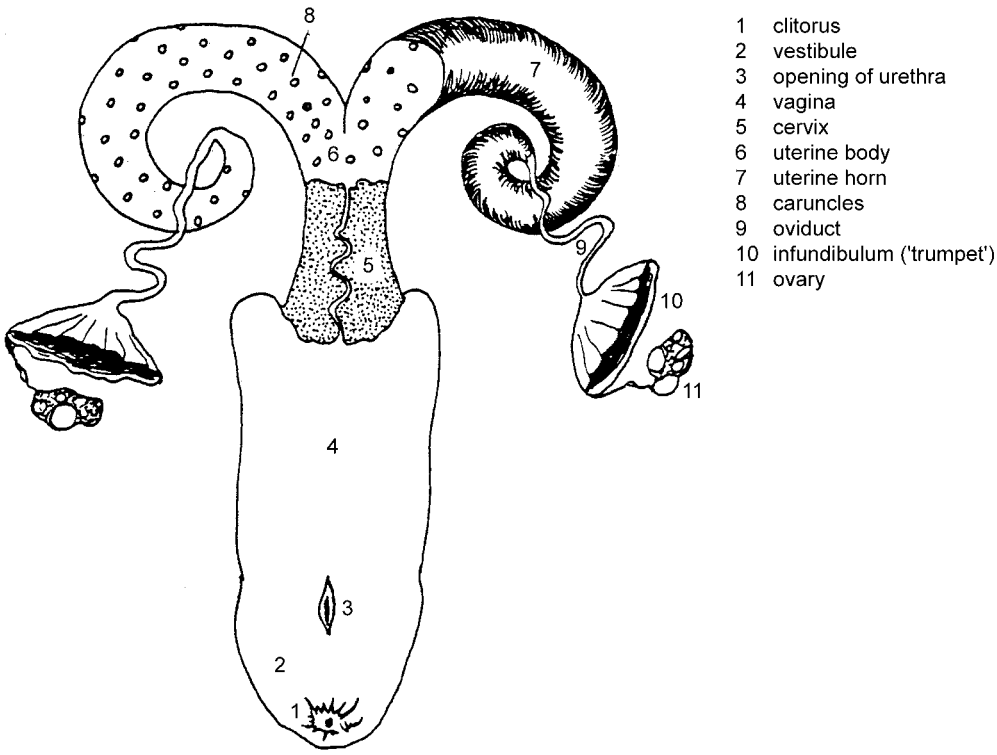

Figure 5: Reproductive tract of the cow seen from above

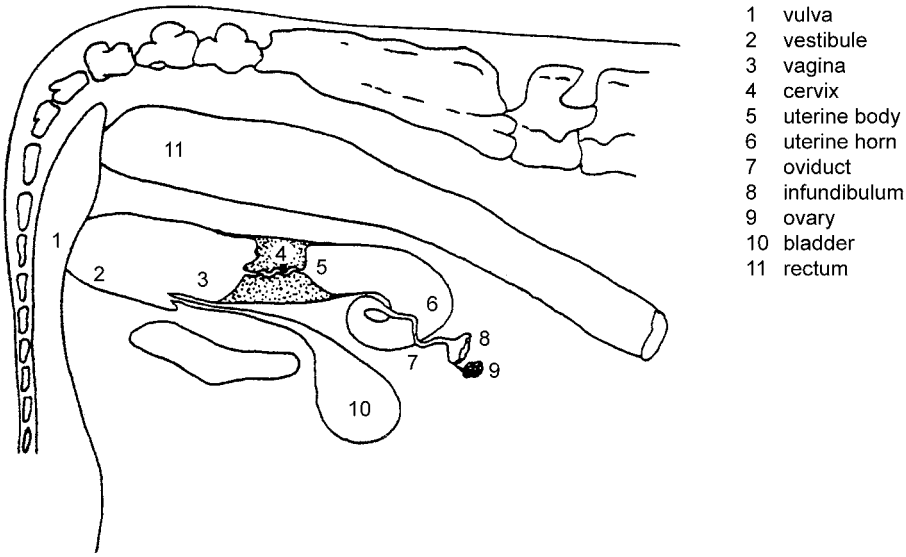

Figure 6: Reproductive tract of the cow seen from aside

1.3 The reproductive tract of the cow

The cow (in general: the female mammalian animal) not only provides the egg essential for the beginning of a new animal, but also the environment in which the new individual will be conceived and nourished during the early part of its life.
To carry out these functions, the cow has primary and secondary organs of reproduction.
The *primary organs of reproduction* are the ovaries which produce ova (plural of ovum = egg) and female hormones.
The *secondary organs of reproduction* are the oviducts, uterus, cervix, vagina and vulva. The mammary gland (the udder of the cow) is sometimes referred to as an accessory organ of reproduction.

An inseminator should be very familiar with both the structure and the function of the organs of reproduction of the cow.

The *reproductive tract of the cow* lies in the pelvic cavity and consists of the vulva, vagina,
cervix, uterus, the two oviducts and the ovaries plus supporting structures. The bladder discharges into the vagina.

The *vulva* is the external part of the reproductive tract and is the entrance to the vagina.
The vulva has two lips and a passage way of a few centimetres length. This passage is the *vestibule* of the vulva. In the ventral angle of the two lips is an organ of erectile tissue called the clitoris (which has no significance in artificial insemination).
Five to eight cm from the vulvar lips, on the floor of the vestibule, is the small opening of the *urethra* through which the urine from the bladder empties into the vulva.

Just beneath this opening is a small, blind pouch (suburethral diverticulum). The inseminator should be aware of these two openings because it is possible to direct the insemination pipette into one of these openings. To avoid this, the inseminator should direct the tip of the pipette upwards and forwards for the first centimetres.
In front of the urethral opening a slightly constricted area called the *hymen* may be present. This will not present any difficulty for the inseminator unless it is not perforated, a rare condition in cattle.

The *vagina* is continuous with the vulva and extends forward to the *cervix*. The vagina serves as passage for semen and urine; it is also the birth channel of the calf.
The vagina is a thin-walled, tough and elastic connective tissue organ. It is 20 to 30 cm long and tends to become longer with age and the number of calvings.
The vagina also functions as the copulatory organ; in natural mating the semen is deposited near the cervix.
The vagina is chemically acid because of lactic acid production by bacteria; this tens to prevent bacterial infections.
Urine (and air) may accumulate in the relatively large vaginal cavity if the walls are weak.

The *fornix* of the vagina is a blind pouch that encircles the projecting back part of the cervix in the cavity of the vagina.

This pouch may be troublesome for the inexperienced inseminator trying to introduce the pipette into the cervix. The pipette may bypass the external opening (os) of the cervix and be trapped in the fornix.

The *cervix* is a tough, muscular organ. It forms the connection between the vagina and the uterus. It is about 7 to 12 cm long and 2 to 5 cm wide, generally depending on age and number of calvings of the cow. The cervix is firmly closed. It opens only when the cow is calving and when the cow is on heat it opens a little.

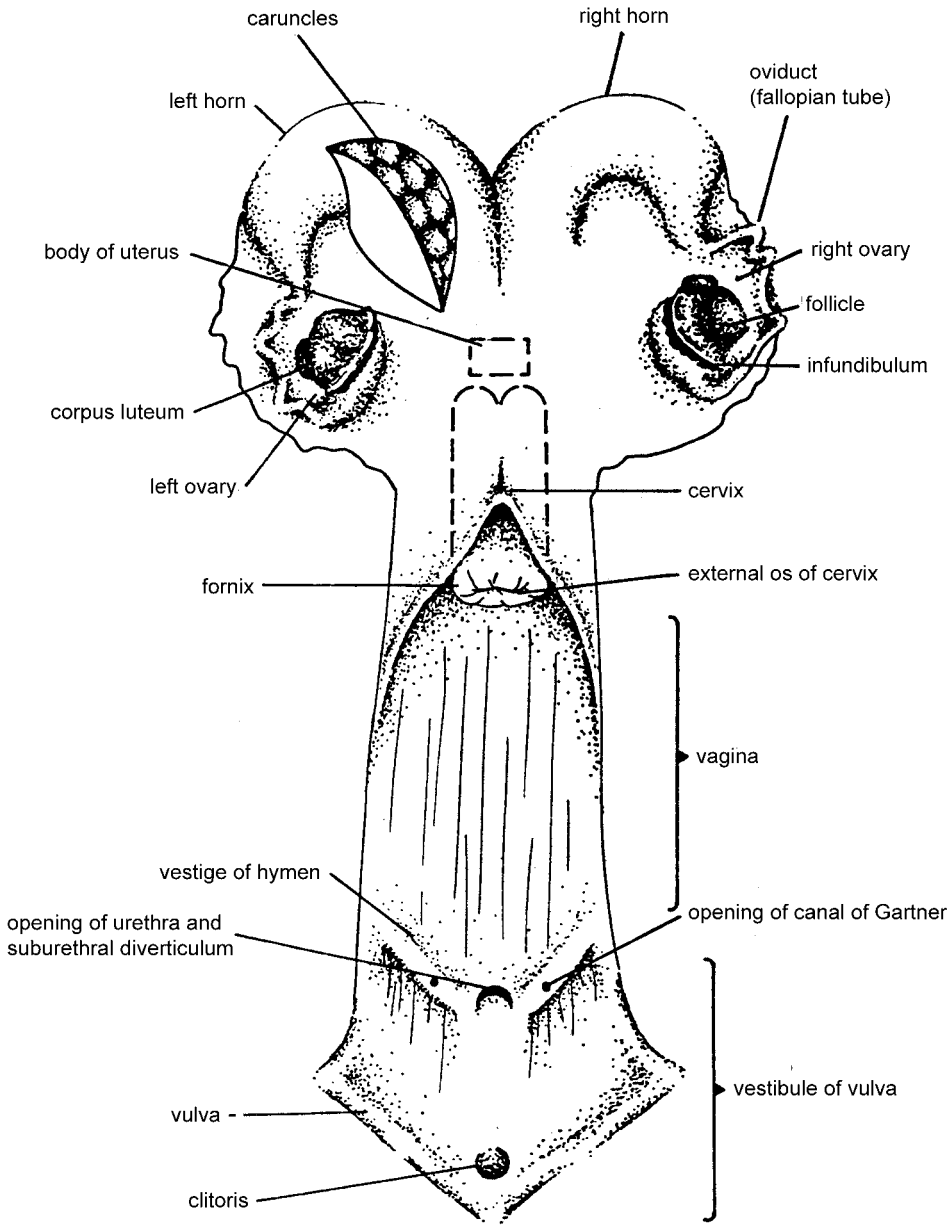

Figure 7:

The cervix observed through the vagina has a projected rosebud appearance, with an opening in the centre.

The cervix has several (three to five) thick folds or rings in its canal. Opposite folds overlap and form a narrow, spiral passage through the cervix. During oestrus (‘heat’) this passage is dilated and lubricated with mucus.
The inseminator, when trying to pass the pipette, may lodge it behind one of these annular rings and find the passage blocked. This problem occurs most often in virgin heifers with a small, underdeveloped cervix.
Fortunately the lining and walls of the cervix are thick and tough. This allows some manipulation or threading by the inseminator when the pipette is passed. However, any excessive pressure by the inseminator in forcing the pipette through the passage may cause haemorrhage (bleeding) and permanent damage to the cervix.

The *uterus* (womb) proper is composed of two parts, namely the uterine *body* and the uterine *horns.*

The *opening of the uterine body* is the target for semen deposition in artificial insemination. It is continuous with the anterior opening of the cervix and only about 2 cm in length.
The uterus has a thin, sensitive lining. If the insemination pipette is passed through the cervical canal and pressed too hard against the uterine wall, it may damage or perforate the wall and this will result in infection, sterility or even the death of the cow.

The uterine body divides into *two horns.*
The size of the horns depends on the age, the number of calvings and the length of time elapsed since the last calving. They are usually about 20 cm long in a virgin heifer and up to 40 cm long in older cows. The horns curve forward, downward, outward and then upward like the curled horns of a ram.
The horns are held in place by broad ligaments attached to the outside walls of the uterus.
The horns become quite firm and erect during oestrus and are then resistant to infection.

The uterine wall contains glands that secrete a substance called ‘uterine milk’ and a hormone.
The ‘milk’ nourishes the embryo between the time of conception and the time the foetal membranes begin to function. The hormone (a prostaglandin) causes regression of the corpus luteum if the cow does not become pregnant.
The wall of the uterus also has about 150 small, raised, button-like areas called *caruncles.*
These caruncles gradually develop after the egg has been fertilized. The foetal membranes are tightly attached to these caruncles; by means of these caruncles the cow passes nutrients on to the developing calf.

The two *oviducts* (so-called Fallopian tubes) are the tubular structures which carry the ovum from an ovary to the uterus. They are funnel-shaped at their ovarian end and tortuous; the distance from an ovary to the uterus is about 4 cm but an oviduct is about 20 cm long.
The funnel-shaped portion is the *infundibulum* of the oviduct which enfolds the ovary and traps the egg at the time of ovulation.
It takes about four days for an egg to traverse an oviduct so it is not present in the uterus until about four days after ovulation.

At the end of each of the two oviducts is an *ovary.* Their volume is about 8 to 10 cm^3. They can usually be located (palpation) near the uterine horns to which they are attached by the ovarian ligament and the oviduct. This ligament is part of the broad ligament in which much of the reproductive tract lies.

The ovaries are very important for reproduction because they produce eggs and oestrogens (female hormones).

A few days before oestrus *follicles* begin to develop on the ovaries.

Follicles are fluctuating, fluid-filled, blister-like structures each containing an egg
(egg follicles can be seen with the bare eye, in the slaughter house).
One of these follicles grows faster than the others and ruptures about 30 hours after the beginning of heat; this releases the egg into the infundibulum leaving an ovulation cavity.
Following the rupture of the follicle, a *corpus luteum* (CL or ‘yellow body’) forms in the ovulation cavity. This corpus luteum can be palpated by day-5 and it reaches its maximum size (20 to 30 mm) by day-13 of the oestrus cycle.
Most of the CL is embedded in the ovary but a small crown usually projects above the ovarian surface.
The CL produces the hormone *progesterone* which is essential for the maintenance of pregnancy.

Removal of the CL will cause abortion in the pregnant cow. This may be accompanied by bleeding and subsequent scarring which reduces the breeding potential of the cow.

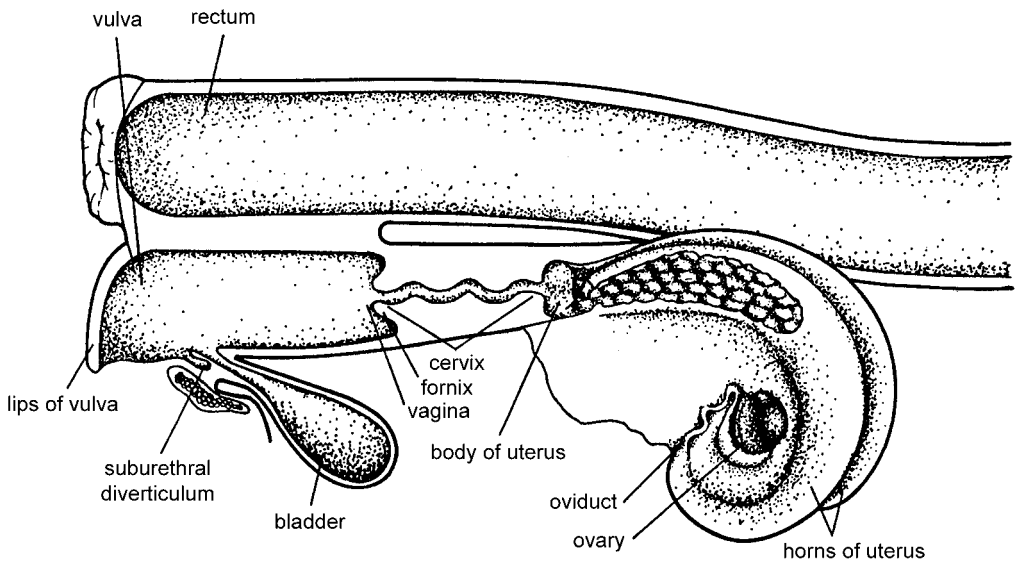

Figure 8:

1.4 The oestrus cycle of the cow

The **oestrus cycle** (also called ovarian cycle) is defined as the period from the beginning of one heat to the beginning of the next.
With the cow this period lasts on average **21** days.

At the beginning of this cycle the cow is unusually active and she is then sexually receptive; the cow is said to be 'in oestrus' or, more commonly, 'in heat'.

The time of first oestrus in the heifer varies from breed to breed and also depends on how well the heifer has been fed. Some well-fed dairy heifers may have their first oestrus when they are six months old. Some beef heifers may be eighteen months old before they come into heat, especially if they have not been fed properly.

The heat period lasts on average 18 hours with a range of 6 to 30 hours. About 90% of cows stay in heat from 10 to 24 hours. The most important part of the heat period is called the *standing heat period*. This is when the cow stands still when she is mounted by herd mates or a bull.

The ovaries of a cow contain numerous (many thousands) ova (= eggs), most of which are in resting stages. During each oestrus cycle several of these eggs become active. Fluid-filled cavities are formed, each containing an egg; they develop and enlarge and eventually form blister-like structures called follicles.
One of these follicles matures into a structure called *Graafian follicle.* The remaining follicles regress.
During heat the pituitary starts secreting LH (see below). Under the influence of LH, the Graafian follicle bursts open about 10 to 14 hours after the visible heat signs have disappeared and the egg is released.

The Graafian follicle has another, important function. The cells lining its wall produce 'female hormones' = oestrogens, which enter the blood and have profound effects on the behaviour and physiology of the female. In addition to heat inducement, the female hormones cause:

- growth and development of the female reproductive tract,
- growth of the muscle cells lining the uterus,
- increase of the blood supply throughout the tract (at the time of oestrus),
- contraction of uterine muscles (stimulation),
- production of mucus in the cervix and the vagina (stimulation),
- development and maintenance of secondary sex characteristics ('femininity').

Ovulation

The rupture of the Graafian follicle and the release of its egg is called *ovulation.* Ovulation takes place about 10-14 hours after the end of oestrus (= after the visible heat signs have disappeared). The egg is trapped in the funnel of the oviduct and carried into the canal of the oviduct. It is in this canal that fertilization takes place; in other words: where the egg meets the male cells.

Formation of corpus luteum (CL)

The cells which lined the cavity of the Graafian follicle continue to grow in size and to multiply in number until they fill the cavity; they now form the 'corpus luteum' CL (= 'yellow body'). The corpus luteum secretes *progesterone*, the 'pregnancy hormone'; the progesterone release starts 2 to 3 days after the end of the heat period. The preparation of the uterus for pregnancy, that was begun by oestrogen is continued by progesterone. If the cow conceives (becomes pregnant), the corpus luteum remains active and continues producing progesterone during the period of pregnancy. Progesterone has the following functions during pregnancy:

- it prevents the cow from coming on heat
- the function of the hormone oxytocin is blocked, thus preventing the start of labour
- it regulates the changes in the mucous membranes in the uterus
- it plays a role in the formation of udder tissue.

Oestrogens are produced by the placental membranes from about 3 to 4 months of pregnancy. These hormones are important for the growth of the foetus and for parturition.

If the cow has **not** become pregnant, the corpus luteum regresses (shrinks) and the uterus returns to its normal condition. At this time the pituitary starts releasing FSH again (see below)
and a few days later the cow comes on heat once more. The cow is a 'poly-oestrus' animal, like the sow; this in contrast to the sheep (ewe), for instance.

A schematic review of the oestrus cycle is given below:

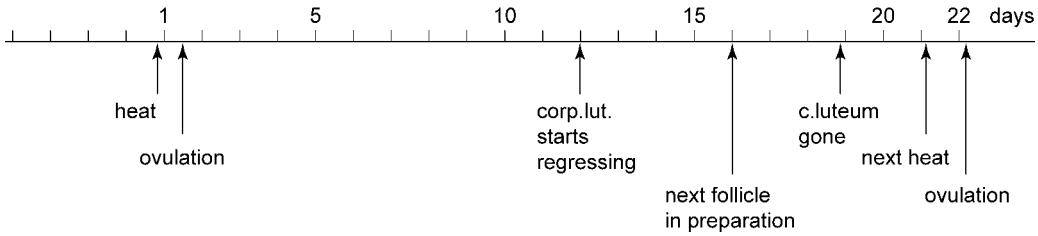

Figure 9: The oestrus cycle

Specific functions of progesterone are:

1 It stimulates growth and maintenance of the uterine mucosa and increases the blood supply to the uterus; this prepares the uterus for reception of the fertilized egg.
2 It causes secretion of 'uterine milk' by the uterine glands. Uterine milk supplies the nutrients for the fertilized egg until the placenta takes over this function (after about 45 days).
3 It inhibits contractions of uterine muscle and this makes it easier for the fertilized egg to attach itself to the lining of the uterus.

4 It causes the production of the cervical seal, a thick mucus ‘plug’ in the cervical canal which protects the embryo from infections.
5 It maintains pregnancy and prevents heat and ovulation in the cow.

Other organs involved in the oestrus cycle of the cow

Hypothalamus
The hypothalamus lies at the base of the brainstem. Among other things it monitors the levels of oestrogen and progesterone in the blood of the cow. As the levels of these hormones change, this causes the hypothalamus to produce either more or less of substances called *releasing factors*, which in their turn stimulate the master gland of the body which is the *pituitary gland.*

Pituitary
The pituitary gland is located in a pocket beneath the brain. It plays a vital role in the oestrus cycle by secreting hormones called *gonadotrophic hormones* which act on the ovary and cause puberty, ovulation, etc.

In the cow the hormones produced by the pituitary in the context of reproduction are:
- the ‘follicle stimulating hormone’ (FSH) which stimulates the growth of the follicle;
- the ‘luteinizing hormone’ (LH) which is involved in ovulation (i.e. rupture of the follicle, formation of the corpus luteum and secretion of progesterone by the corpus luteum) and in oestrogen production by the cells which line the follicle.

These pituitary hormones are in a delicate balance with the ovarian hormones and together they regulate the oestrus cycle.

The oestrus cycle of farm animals is still the subject of intensive research by scientists the world over; particularly its *regulation.*

The general picture of the *sequence of events* which takes place during the oestrus cycle of the cow is as follows:
1 ‘Releasing factors’ (FSHRF) are released from the hypothalamus and cause the release of FSH from the pituitary gland. The FSH reaches the ovary and causes the development of a follicle.
2 The follicle on the ovary produces oestrogen which brings the cow into heat.
3 The level of oestrogen in the blood rises and this causes the hypothalamus to stop producing releasing factors. Without the stimulus of releasing factor, the pituitary no longer releases FSH.
4 The high level of oestrogen in the blood causes the hypothalamus to produce LH releasing factors (LHRF). These act on the pituitary and cause the release of LH. The correct balance of FSH and LH causes the follicle to rupture. Under the stimulus of LH a corpus luteum is formed which produces progesterone. If pregnancy does **not** occur, the corpus luteum reaches its maximum size on about the 13th day after oestrus and then begins to regress as a result of the production of luteolytic substances (prostaglandins) in the uterus.
5 In this case the level of progesterone in the blood decreases, thus permitting the hypothalamus to produce FSHRF which causes the pituitary to release FSH: this starts a new cycle.
6 But if the cow has become pregnant, the corpus luteum remains and enlarges. It becomes the corpus luteum of pregnancy and continues to secrete progesterone until the birth of the calf.

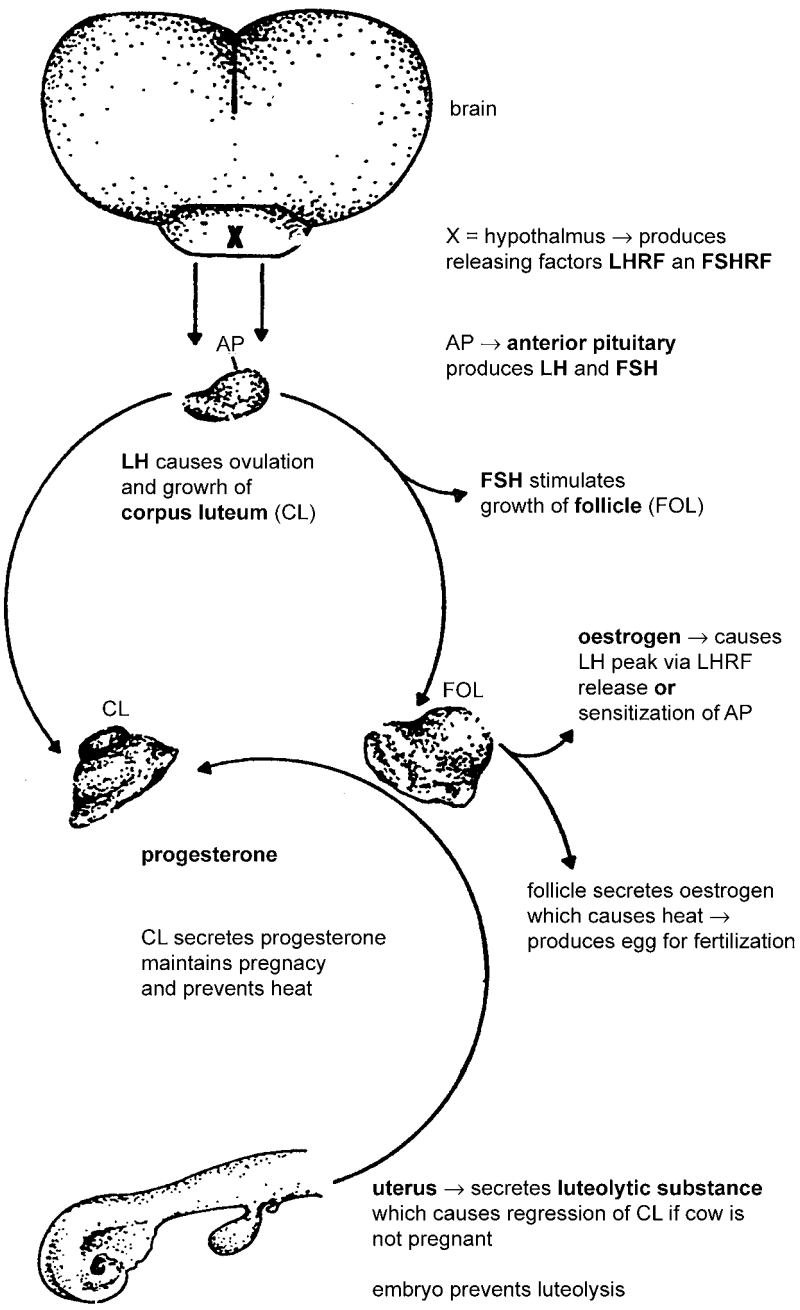

Figure 10:

Production of ova

A heifer is born with **all** the ova which she will have during her lifetime. Remember that in the bull male cells are formed *continually* (spermatogenesis).

During the lifetime of a cow approximately fifty ova are ovulated. At birth there are some 75,000 potential ova in each ovary of a calf. At one to three years of age there are about 21,000 ova remaining and later about 2,500 are still present.
This means that during the cow's lifetime many ova develop and then degenerate without ovulation; only a very few mature and then ovulate.
The maturation of the ovum involves many cell divisions (the same happens in male cell formation). However, one of the two cells resulting from each division of the ovum is relatively small and non-functional. Thus only **one** 'one-cellular organism' (the ovum) reaches maturity at each oestrus cycle.
One of the cell divisions reduces the number of chromosomes to one-half the normal number.

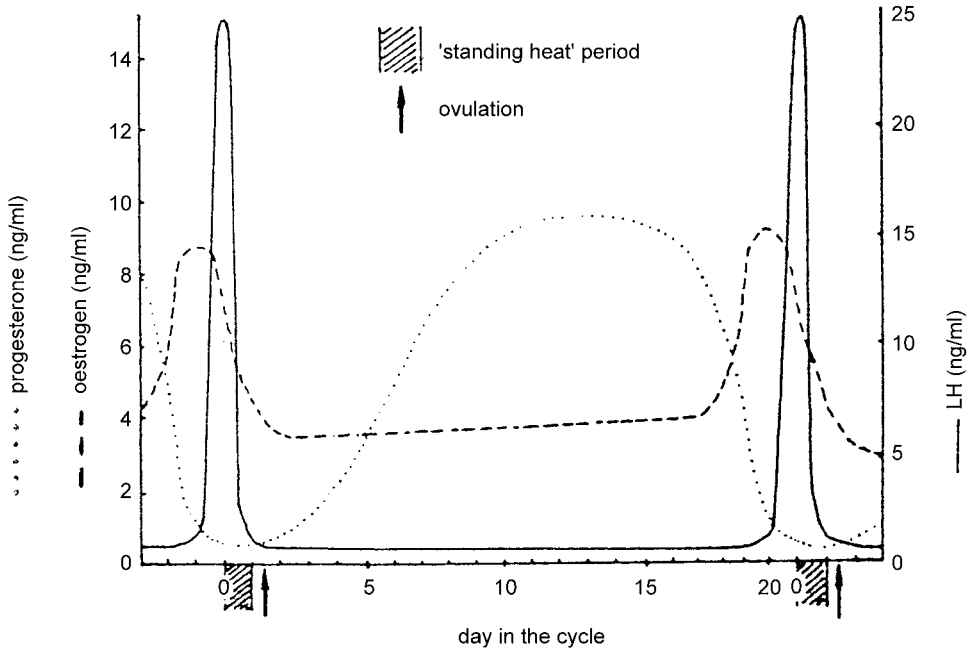

Figure 11: Hormone concentrations in the cow's blood during the oestrus cycle (no pregnancy)

Disturbances in the functioning of the ovaries:

- 'Silent heat'. The cow cycles normally and ovulation takes place but there are no heat signs. However, the cow is often blamed for the shortcomings of the herdsman who does not notice the (weak) heat signs!
- 'Cystic follicle'. The mature follicle does not burst open. In this case the production of oestrogen continues and in severe cases the cow is constantly on heat. A veterinarian can try to burst the follicle open.
- The corpus luteum does not regress although the cow is not pregnant. In this case the cow will not come on heat thus making the farmer believe that the cow is pregnant. A veterinarian can help.
- Pregnant cows are sometimes seen on heat. This is caused by insufficient progesterone production.
- Quite often embryos are lost during the early days of pregnancy or at about 25 days after conception ('early embryonic death').
- Abortion, because of infection of the placental membranes. For example, a brucellosis infection makes the placental membranes die off. In this case progesterone production stops and oxytocin is not blocked any more. This results in the expulsion of the foetus. Abortion can also have several other known or unknown causes.

For 'early embryonic death' and abortion, see Chapter 4.

2 Fertilization, gestation and birth

2.1 Fertilization

Fertilization means the *fusion (or union) of the ovum (egg) with a male cell.* The male cell actually penetrates the ovum. The fertilized ovum is the beginning of a new individual in which one-half of the chromosomes come from the sire (bull) and one-half from the dam (cow). The genetic material of the male cell and the egg have united to give the new individual the normal number of chromosomes needed for its development.
Fertilization normally takes place in the upper third of the oviduct.

When a bull serves a cow, millions of male cells are ejaculated in the vagina, close to the entrance of the cervix. Part of the cells move through the cervix into the uterus. Many cells have reached the oviduct within 6 to 7 hours after service.
In the uterus and oviduct, male cells can survive for about 20 hours.
Ovulation takes place 10 to 14 hours after the heat period. The mature egg can only survive for about 6 hours and therefore fertilization must take place within 6 hours after ovulation. Because of the limited time male cells can survive in the oviduct, service must not take place when the heat period starts. In this case it can be more than 24 hours later before ovulation takes place. An important rule is that *service or insemination should take place in the second half* of the heat period.

Male cells of some animal species must remain in the reproductive tract for a few hours before they are capable of fertilizing the egg. The changes that take place in the male cell during this time are termed *capacitation*. Although the need for capacitation has not been established for cattle, this may be another reason why semen needs to be inseminated a few hours before ovulation in order to obtain maximum fertility.

2.2 Gestation (pregnancy)

Early development; membranes

After fertilization, the fertilized egg splits into two cells. These two cells split up into four, these four into eight, etc. In the meantime the *embryo* is being moved through the oviduct into one of the uterine horns. In the cow, sheep and goat this process takes about 3 to 5 days, in the horse 8 to 10 days, after which the egg 'hatches' = attaches itself to the uterine wall for nutrition and further development. The cell division continues and after a few weeks the organs of the new animal are formed.
At four weeks the embryo in a cow has a size of about one cm. By the end of the second month it has developed into a complete miniature calf with a length of about eight cm. After three months it can be clearly recognized as a calf.

At about the 10th day after ovulation, the outer placental membrane (called *chorion*) begins to form and by the 17th day it extends throughout the length of the uterine horn. It is this membrane which is in close contact with the uterus of the cow and through which the embryo obtains its food.
By the 33rd to 35th day after ovulation the embryo is about 1 to 2 cm long and it is at this time that the embryo becomes attached to the wall of the uterus by means of the chorion. The attachment occurs by means of button-like structures which, on the chorion, have finger-like projections. These projections fit into grooves provided by button-like structures on the uterine wall. They are called *cotyledons* (caruncles). There are approximately 100 maternal cotyledons (on the wall of the uterus) which mesh with 100 foetal cotyledons (on the chorion).
As the foetus grows in the uterus the cotyledons become larger in order to provide for a greater flow of nutrients from the dam (the mother cow) to the foetus.

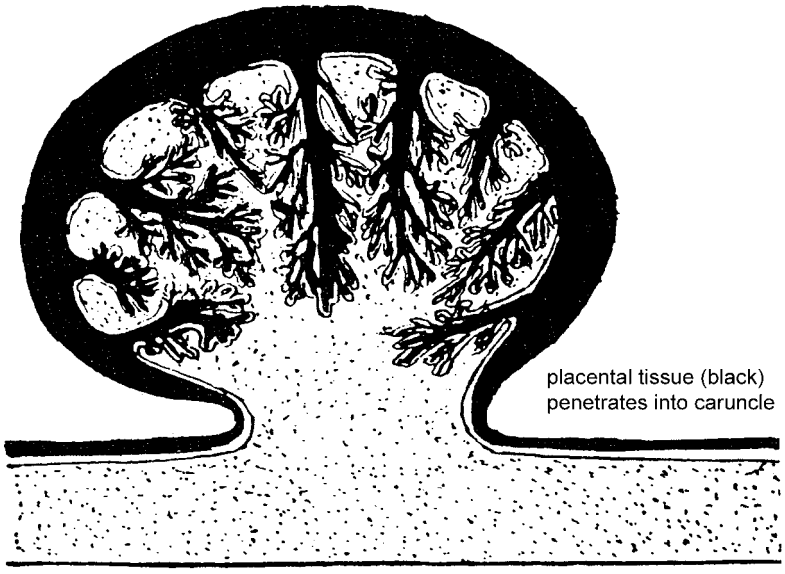

Figure 12: Caruncle on uterine wall

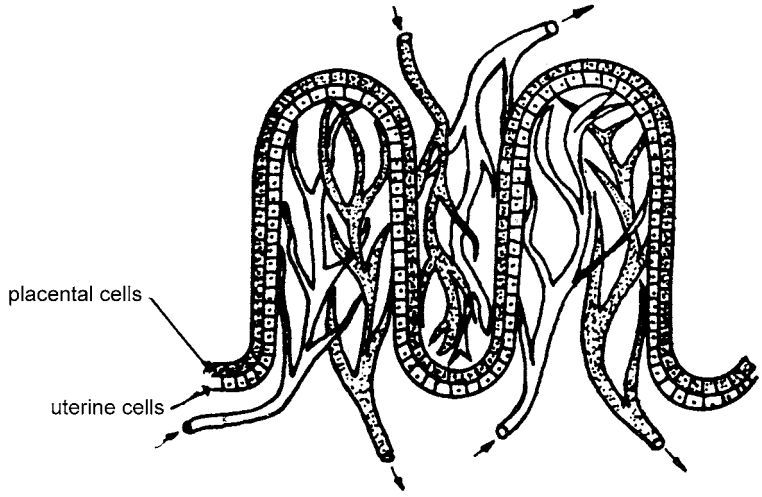

Figure 13: The blood vessels of mother and foetus are seperated by just two cell layers

On about the 17th day another membrane forms which encircles the embryo. This membrane is called the *amnion.* Between the amnion and the embryo is the *amniotic fluid.* The embryo 'floats freely' in this fluid-filled sac and is thus cushioned against blows or injuries which the cow might receive.
The amniotic sac is known by cattlemen as the 'water bag'.
Another membrane which develops from the growing foetus is the *allantois.* This membrane lies between the amnion and the chorion. It provides the means by which the foetus eliminates its waste products before it is born.

Thus the membranes have the following functions:
- protection of the foetus; also nutrition and the provision of oxygen,
- providing the connection between mother and foetus,
- excretion of metabolic wastes; secretion of oestrogen hormone,
- stretching of the birth channel during birth.

The membranes together make up the *placenta*. It is expelled soon after the calf is born. It is then commonly called ‘afterbirth’.

Location

In heifers and in most normal, non-pregnant cows the reproductive organs are found within the pelvic cavity.
In older cows which have had several pregnancies, the organs usually extend partly over the brim of the pelvis and into the abdominal cavity.

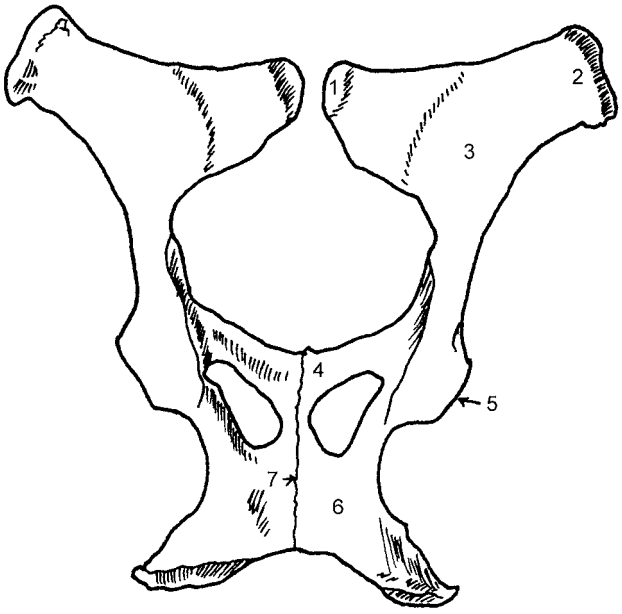

Figure 14: The pelvic bones with the (birth) channel

During the time of heat the reproductive organs are less relaxed than otherwise. In the heat period they take up less space in the pelvic cavity and the uterus is then quite firm when touched.
The broad ligaments of the uterus stretch as pregnancy advances and allow the uterus to go down into the abdominal cavity as the weight of the foetus increases.

Twins

Normally a cow has only one calf. Sometimes a twin is born. Twins may develop from one fertilized egg (identical or one-egg twins). In most cases, however, they develop from two fertilized eggs (fraternal or two-egg twins).
One-egg twins are genetically identical; therefore they have the same sex, appearance, characteristics and behaviour. Two-egg twins are not genetically identical. When they are of different sex, the female is almost always sterile (freemartin).

The duration of gestation is different for different animals:
- horse 48 weeks (11 months)
- cow 40 weeks (9 months and 9 days)
- sheep/goat 21 weeks (140 to 150 days)
- rabbit 30 - 31 days

Different breeds of cattle have a slightly different duration of gestation. The bull seems to have some influence as well.
Other factors that influence the duration of gestation are:
- sex and size of the foetus (males are carried longer than females),
- multiple pregnancy in a cow often causes an early birth,

- the age of the cow; first calving cows carry a few days shorter than older ones.

The development of the foetus is as follows:

Weight
When the cow is 4½ months pregnant, the foetus has about 10% of its birth weight.
At seven months, the foetus has reached about half of its birth weight. As from here onward its weight increases more rapidly.

Coat of hair
The foetus is viable when the body is completely covered with hair. This is the case when the cow is about 7½ months pregnant.

Length

7 weeks:	size of a mouse (about 5 cm)
around 3 months:	size of a rat (about 15 to 17 cm)
4 to 5 months:	foetus has about 10% of its birth weight
6 months:	the foetus has reached half the length of a newly born calf
7 months:	the foetus has reached half of its birth weight
7½ months:	the foetus is viable
9 months:	the foetus is ready to be born, its length is 80 to 90 cm, its weight 30 to 55 kg (Zebu 20 to 25 kg)

2.3 Symptoms of pregnancy

No heat
The first sign that a cow might be pregnant is that she is not seen on heat any more. However, this is no guarantee because heats may have passed unnoticed and eventually pregnant cows may mount other cows.

Belly size
When the cow is more than four months pregnant, its belly size increases. This can be seen when standing behind the cow. The rumen pushes the pregnant uterus to the right.

The udder
Milk production in pregnant cows decreases faster than in non-pregnant cows.
During the dry period, about four weeks before calving, the udder starts swelling because of udder tissue development and fluid formation. In heifers the increase in udder size starts earlier.

Movement of the foetus
After the sixth month a milker, who puts his/her head against the right flank during milking, may notice the foetus moving.

2.4 The birth of the calf

As calving time draws near, the ligaments around the tailhead and pelvis of the mother cow relax and sink. The vulva swells and mucus discharge can be observed. The udder becomes rapidly bigger (fuller).
Shortly before birth the uterus begins to contract, mildly at first. This may go on for as long as 24 hours (on average about 4 hours) during which time the cow becomes increasingly restless.
The calf is pushed against the cervix causing it to open. During this time the calf assumes its birth position, lying on its belly with the forelegs extended and the head resting on them.

Powerful contractions of the uterus begin and these are supported by voluntary contractions of the belly muscles.
The result is that the calf is pushed through the birth channel, normally within a few hours.
As the calf's head passes through the vulva, it bends downwards. This helps the rest of the calf pass trough the pelvis more easily.
In its normal birth position the calf assumes its smallest diameter. This is necessary to make the birth possible without too many difficulties.
As a rule the calf will be born within one hour after the forelegs begin to show in the vulva.
If the calf has not been born after an hour or two, an examination should be made.If the calf is in normal position, some assistance may be given by pulling with ropes that have been carefully attached to the forelegs.

Always pull downwards rather than straight out of the cow. Pull only when the cow strains and do it in a careful way.
Before giving assistance, clean water with a disinfectant should be used to wash the vulva and surrounding area. The person(s) giving the assistance should clean hands and arms thoroughly. Also the pulling ropes should be disinfected.

Abnormal dispositions of the calf occur sometimes. Veterinary assistance may then be needed.
Some abnormal dispositions are:
- only one front leg appears,
- the forelegs appear but without the head,
- the hindlegs appear first,
- the tail appears first.

In these cases the calf must usually be repositioned before it can be delivered.

Other abnormalities that can occur during calving include:
- the uterus contractions are not strong enough or cervix fails to dilate or area of bony pelvis is too small;
- the calf is too big for one reason or another; in this case surgery may finally be necessary to deliver the calf.

In normal delivery the foetal membranes rupture at about the time the forelegs pass the vulva.
Normally the calf is delivered free of the foetal membranes, which are still tightly attached to the placenta to assure a good oxygen supply to the calf during birth.
The umbilical cord (navel cord) usually breaks when the calf passes through the vulva. The calf must now start breathing since it can no longer obtain oxygen from the mother. Hence, after birth *oxygen* is the first requirement to make the calf survive. Make certain that the nostrils are free of membrane and fluids. Breathing can be stimulated by blowing air into the nose or by tickling the nasal cavity with a straw. This can make the calf sneeze which cleans the nostrils.

After birth the calf must receive *colostrum milk* as soon as possible (at least within two hours after birth).

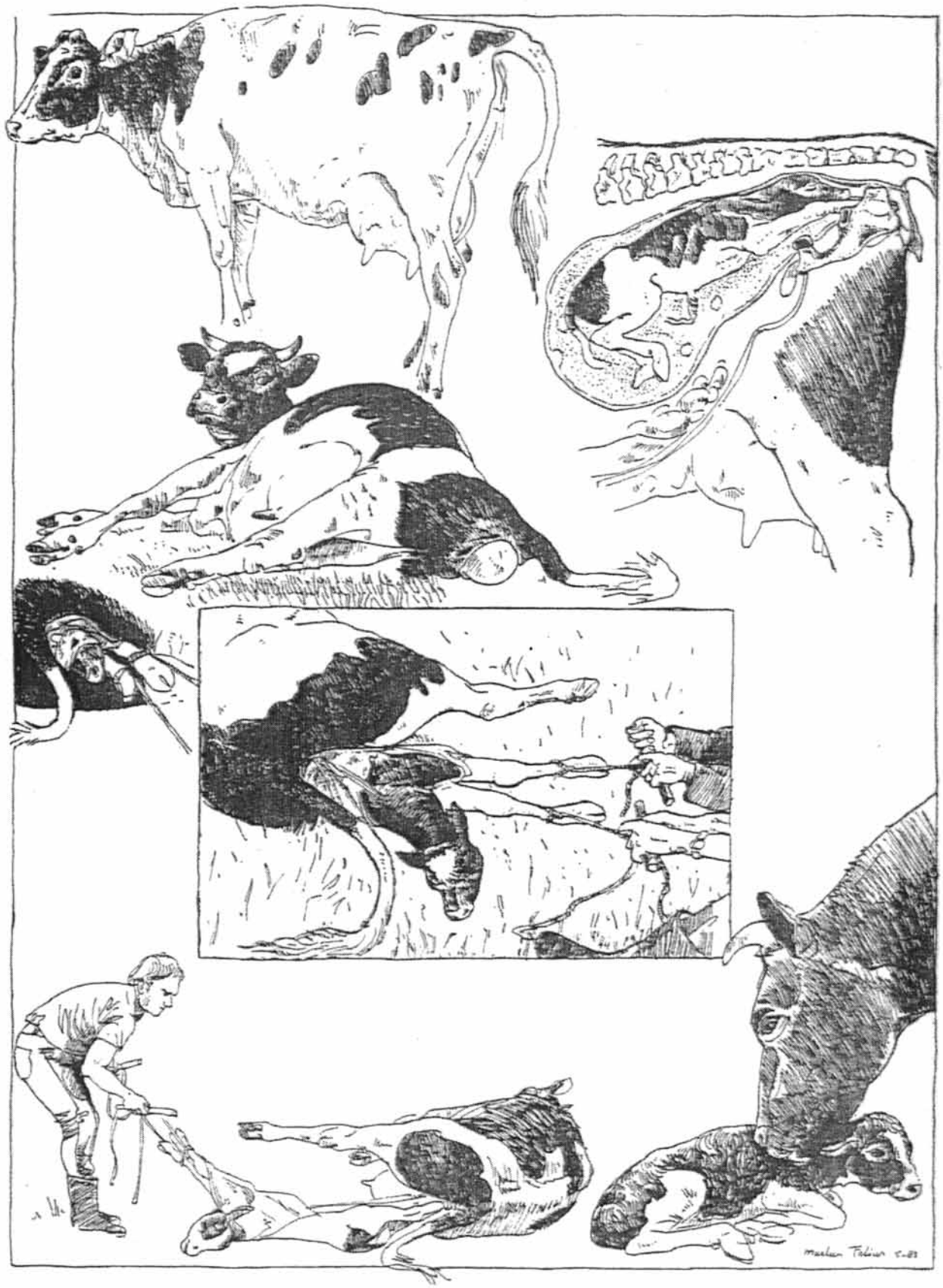

Figure 15: The birth of a calf (by Marleen Felius)

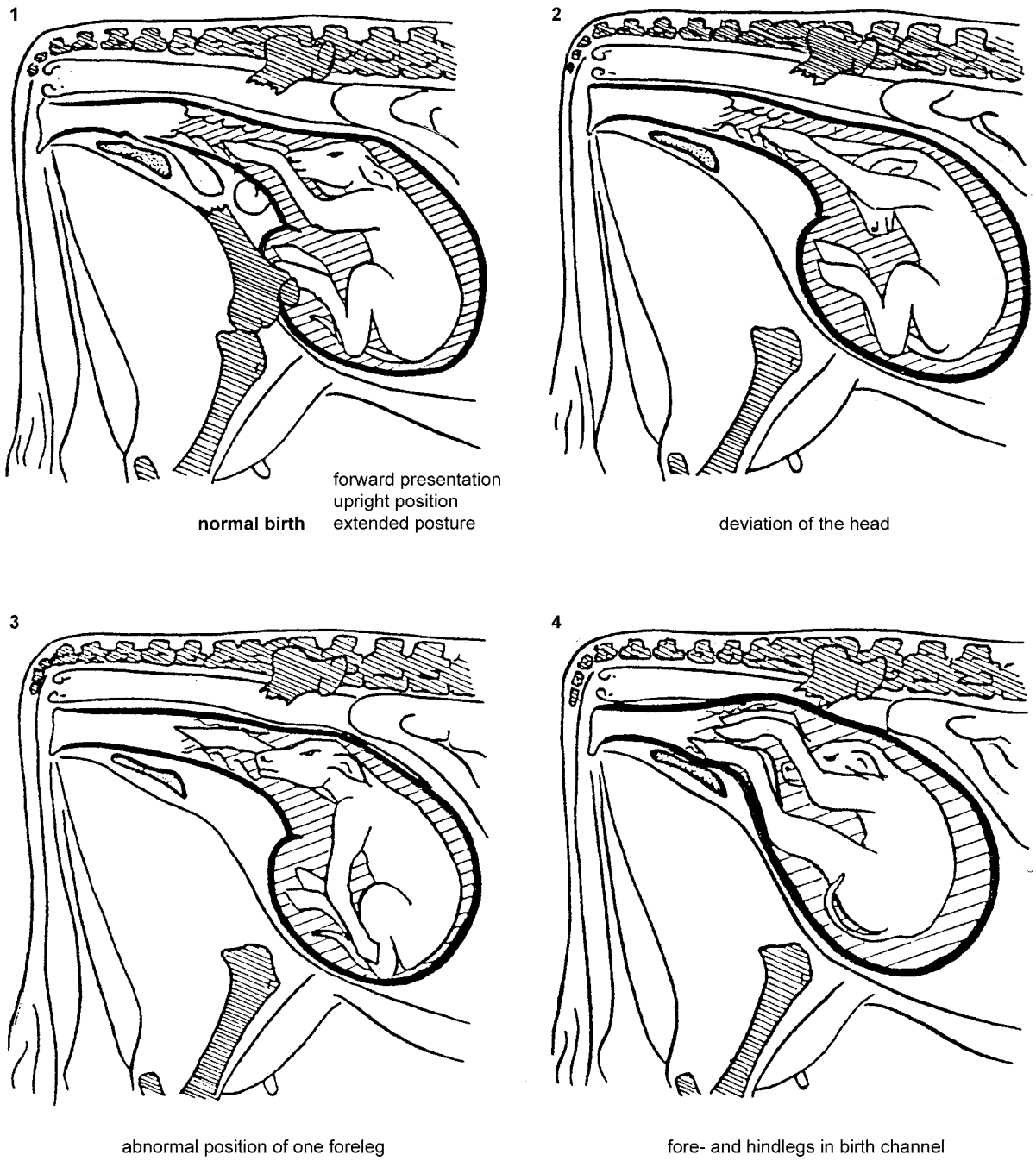

Figure 16: Abnormal positions of the calf in the uterus

After the calf is born, uterine contractions continue and they free the foetal membranes from the uterus and expel them. This is the *so-called afterbirth*. It should be disposed of as soon as it is expelled.

If the afterbirth is not expelled within 12 hours after parturition, it is considered *retained.*

When the afterbirth is retained and the cow sluggish, with a poor appetite, veterinary attention is needed.

It is bad practice to remove the afterbirth with force. The afterbirth is never removed completely in this case and the uterus may be seriously damaged resulting in sterility of the cow.

Some fluid, containing blood and bits of tissue is usually found in the uterus after calving. This fluid is normally expelled during the first days after calving. This does not necessarily mean that there is an infection.
However, infections do occur after calving. A good indication of the beginning of an infection is the odour of the discharge. The bloody discharge that occurs the first days after calving should not have a strong, foul smell. If there is a foul smell and pus, prompt attention is needed.

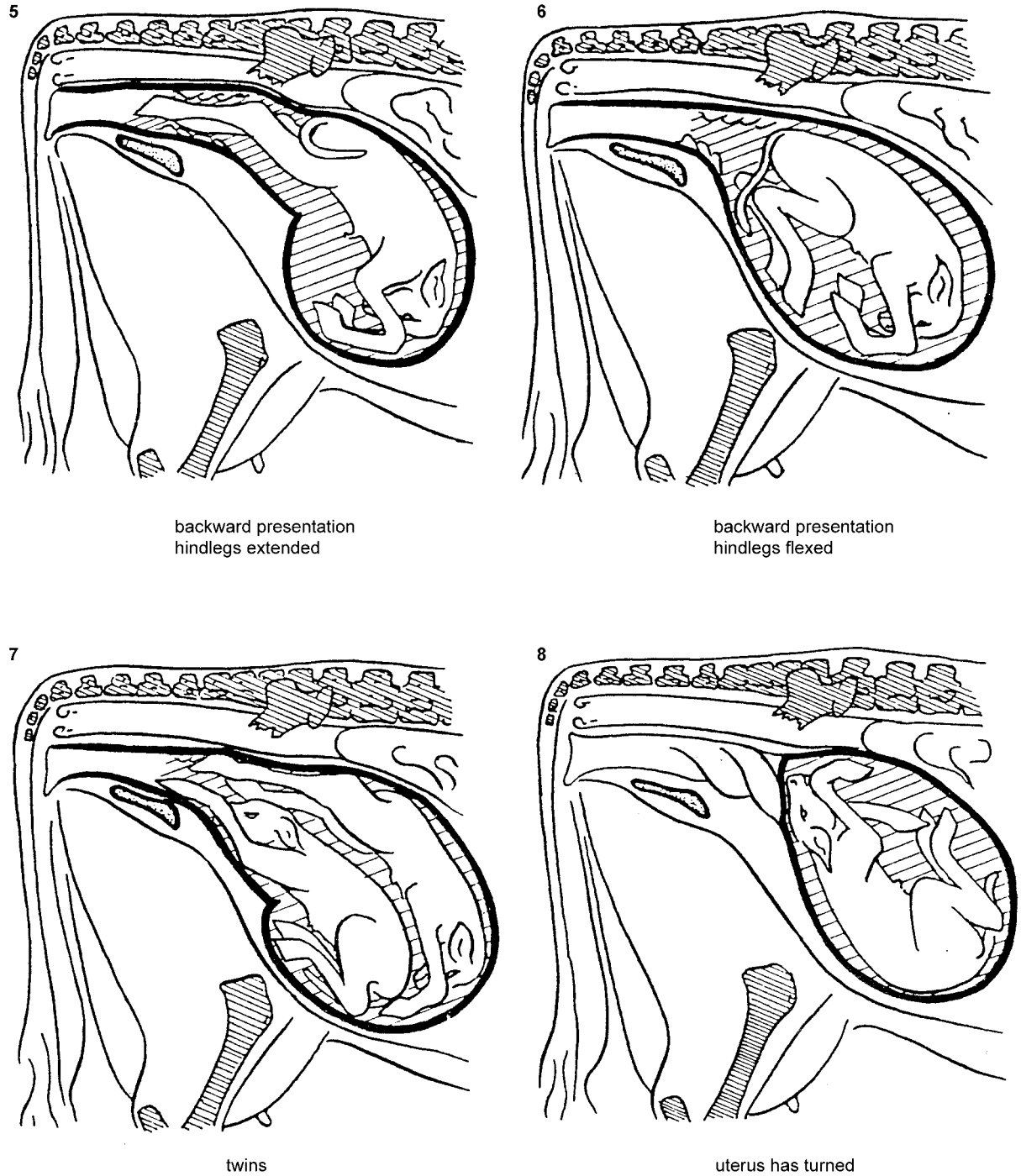

Figure 17: Continuation

3 The reproductive performance of a dairy herd

3.1 The calving interval

The calving interval is the *period between two successive calvings of a normal cow.* The following is a schematic review of the calving interval, first simplified and then more complete on the next page.

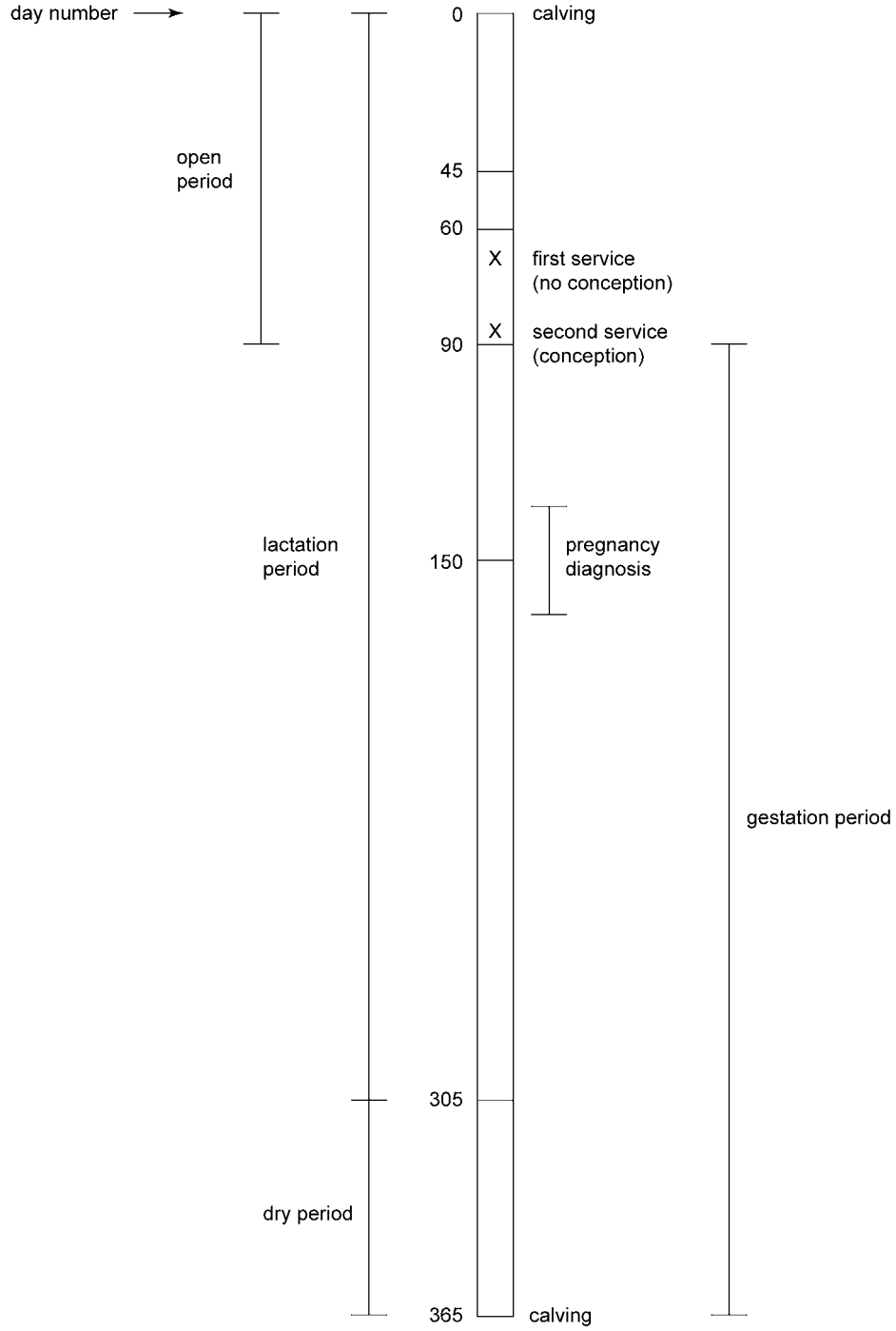

Figure 18:

Again, but more complete:

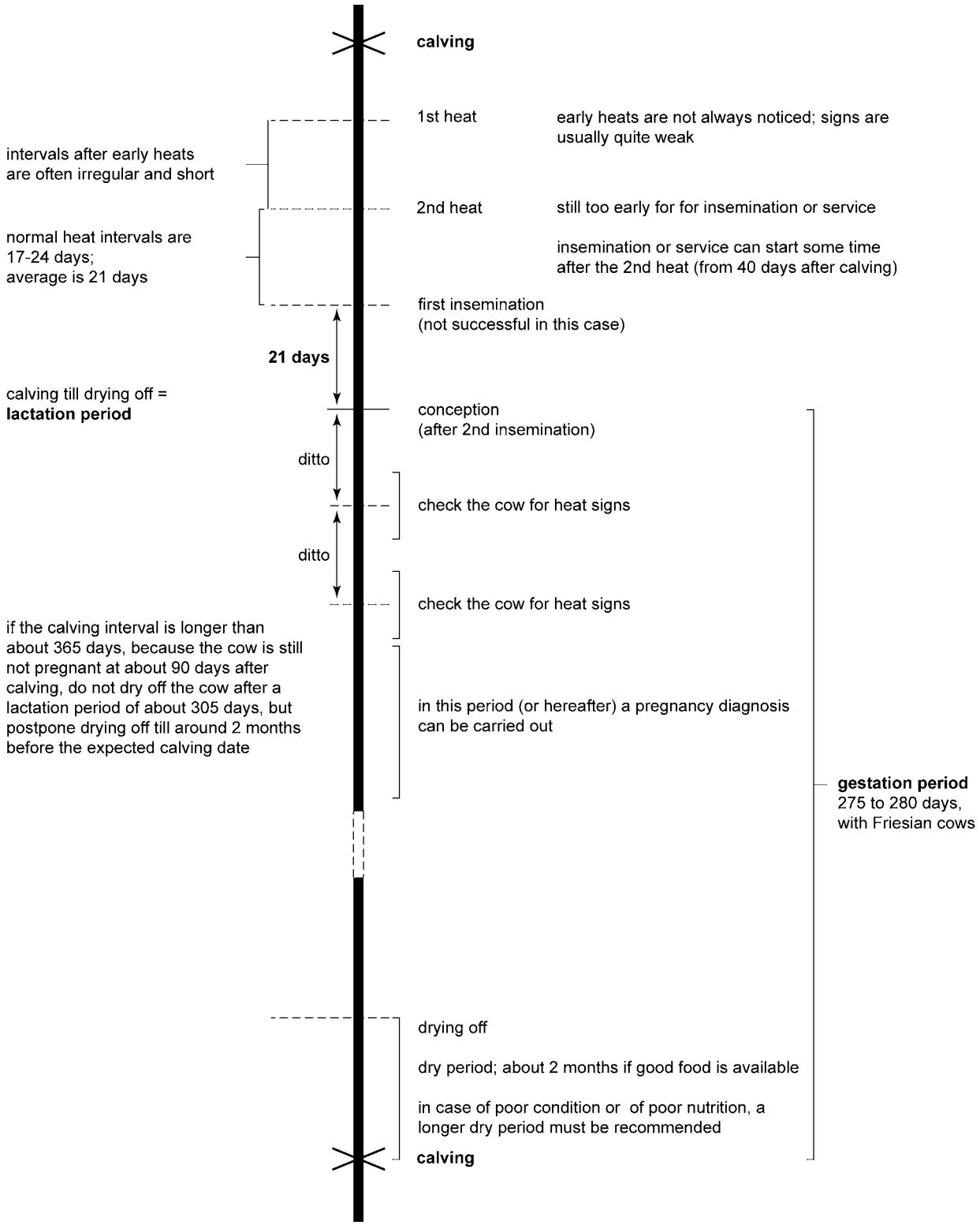

Figure 19:

3.2 The importance of good reproductive performance

A good reproductive performance means:
- higher average daily milk production,
- more calves per year,
- more opportunities for selection in the herd (better production).

The influence of the reproduction rate can be demonstrated with the following examples.

First example

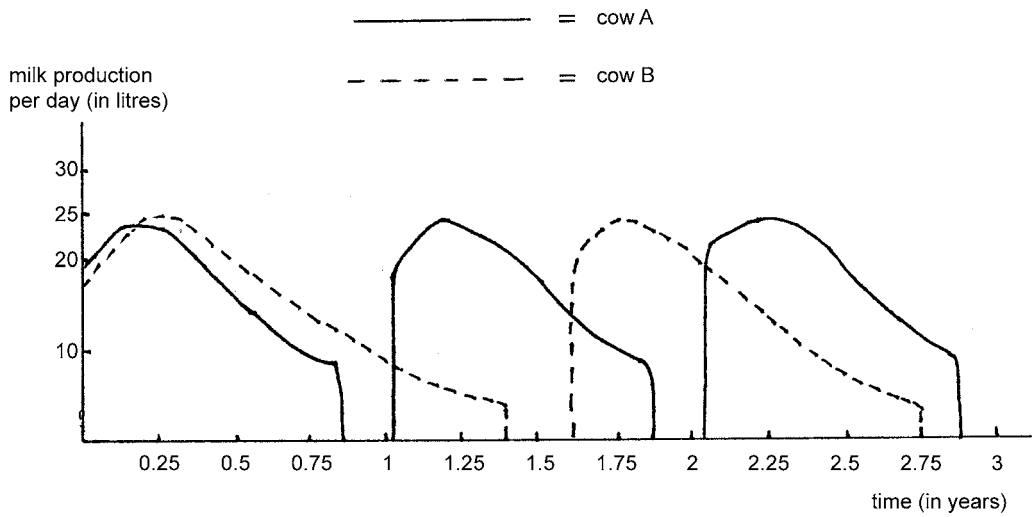

Figure 20: Influence of reproduction on milk production and on production of offspring

Cow A and cow B have the same genetic production potential. The only difference is their reproductive performance.

The illustration shows the lactation curves of both cows. In three years' time, cow A calves three times and cow B only twice.

The production per lactation of cow B is higher than that of cow A, but cow A has three lactations and cow B only two. The average milk production per day is highest for cow A.
Per lactation, cow A has a dry period of two months and cow B of three months. Besides producing more milk, cow A also produces one more calf.

In the Netherlands, optimum economic results are reached with calving intervals ranging from 350 to 390 days; for each farm the optimum interval can be calculated. When the calving interval becomes longer, the farmer's income decreases.

In the Netherlands, a prolongation of the calving interval by one day (beyond the optimum) means a loss of income of 1 to 2 US dollars. So, here a missed heat (a heat that is not noticed, while the cow could have been inseminated) costs 21 (days) x 1½ = about 30 US dollars.

Elsewhere losses will not be the same, as they depend on the price of milk, the value of a calf, feeding, housing and labour costs.
So, in other countries, under different circumstances, the *'optimum calving interval'* may not be the same as that of the Netherlands. But everywhere it is worthwhile to try to find out what the optimum calving interval is.
In general, the shortest possible calving interval is likely to be the most advantegeous.

Second example

Table 1: Influence of reproduction on production of offspring and replacement rate (selection)

	good reproduction & good calf rearing	**poor reproduction & poor calf rearing**
calving interval	1 year	1½ year
% of cows becoming pregnant	85%	65%
number of cows	1000	1000
calves born per year	85% of 1000 = 850	65% of 2/3 x 1000 = **433**
stillborn calves	2% = 17	5% = 22
calves born alive	850 - 17 = 833	433 - 22 = 411
calf mortality 0 - 24 months	8% = 67	20% = 82
animals of 24 months	766	329
females	50% = 383	50% = 165
sterile heifers	5% = 19	10% = 16
pregnant heifers	364	149

Note: assuming that the average cow 'lasts' five years, each year 20% of the cows must be 'normally' replaced

Both examples give a clear idea of the importance of good reproduction.

3.3 Measuring the level of reproduction on a farm

Milk production and growth rate of calves can easily be measured by weighing and calculation.

To measure *'reproduction'* on a farm is more difficult and **requires constant, reliable record keeping.** With these records it should be possible to follow individual cows and calculate 'indicators', which give an idea about the level of reproduction of the herd as a whole. Important indicators are described in the following (a., b., etc.).

Age at first calving (heifers)

As long as a (future) cow is not producing, it costs money because it needs feed and care. For that reason *heifers should calve as early as possible.*

The age at first calving is influenced by:
- good calf rearing,
- good feeding after the rearing period,
- parasite control,
- the breed (Zebu or Bos taurus).

First service of heifers can take place when the animals have reached about 60% of mature body weight. Age and condition are also important.
With good feeding and good management, Friesian heifers in the Netherlands can be inseminated from the 15th month. This will result in a first calving age of 24 months at the earliest.
In the (sub)tropics, where circumstances may be less favourable, first service with Friesian heifers should be possible from 20 months, or when the heifer reaches about 325 kg live weight. 'Weight' would seem to be the better criterion, but is admittedly less easy to establish than age.

Calving interval

This is a well-known indicator of reproductive performance.
The calving interval can be divided into two periods: period of *calving to conception* (the non-pregnant period; also called 'open period' or 'service period') and the *pregnancy period* (the gestation period). The pregnancy period has a fixed duration of 275 to 285 days or some more, depending on the breed.

The *average calving interval* of a herd can easily be calculated and gives an impression of the reproductive performance of a herd.

In the event of too long calving intervals, the problems always lie in the first period (calving to conception). The causes of a long calving interval can often be traced by further analysis of the interval.

The calculated average calving interval does not include the cows who do not come in calf at all. Therefore the herd's reproduction is always lower than the average calving interval indicates.

First heat after calving

Normal, healthy cows come on heat within 40 days after calving. First heat can occur at about 10 days after calving already. First heats are not always observed.

In all cows, clearly visible heats should be noticed every 21 days (average), from 40 days after calving. If a cow is not seen on heat before or around 60 days after calving, there can be several reasons for this:

- the cow has been on heat, but this has not been noticed by the person who is responsible (poor heat detection). In most cases this is the main reason;
- the cow is not normal, it can have endometritis or cystic follicles;
- poor nutrition, especially insufficient amounts of protein and minerals, can cause problems (the cow is not cycling).

Practical advice: when a cow is not seen on heat around 60 days after calving, and when heat detection and feeding is good, a veterinarian should examine the cow for possible disorders of uterus and ovaries.

First insemination (or service) after calving

In order to obtain an average calving interval of 365 days, insemination (or service) should start as soon as possible after calving.

Normal, healthy cows can be inseminated or serviced successfully from 40 days after calving.
With early inseminations or services, the conception rate is relatively low. However, this does not counteract what one gains in days of calving interval. Anyway, the first heat after 40 days from calving occurs around the 50th day on average; by that time the conception rate is already higher.

Practical advice: start inseminating normal cows from 40 days after calving. Low production cows may be inseminated earlier, high production may be inseminated a little later. The same applies to natural service. Be aware that insemination can only be successful in animals with a regular cycle (about 21 days).

Interval between two heats

The average interval between two heats lasts 21 days (17 to 24 days). So, when a cow does not conceive after insemination or service, 21 days later (on average) she comes on heat again.
Shortly after calving (up till about six weeks), heat intervals are shorter and rather irregular.

When heat intervals of six or nine weeks (2 or 3 x 21 days) are observed, this generally means that one or two heats have been missed. However, it is often said in these cases that the cow has had silent heats, but this is most probably **not** true. Silent heats are extremely rare. In most cases the heat is simply missed (not noticed) by the person who is responsible, because it was a short heat or a heat with weak signs.

In the case of long and irregular insemination intervals (30, 50 or 90 days), embryonic deaths may have occurred.

Conception rate

After insemination of 100 cows, it will be noticed that after three weeks a certain number of cows comes on heat again meaning that they have not conceived.
The percentage of cows conceiving at first insemination after calving is a measure for the reproductive performance of a herd; it is called *conception rate after first insemination or service*. In the tropics it seems to be very difficult to obtain a higher rate than 50. In the Netherlands a rate of 60-70% can be obtained.
When the conception rate after first insemination in a herd is lower than 50, this would mean that reproduction is not what it should be in that herd.

Low conception rates can have the following causes:
- the cows are not inseminated at the right moment
- there is endometritis (uterus inflammation) caused by poor hygienic conditions
- poor semen quality
- wrong insemination techniques are applied
- the cows are not in good condition

Number of inseminations necessary to obtain pregnancy

Since not all cows become pregnant after a first insemination, more inseminations are necessary than there are cows in the herd.
Normally two inseminations per cow are required (average).
When the average is higher, reproduction is not what it should be.
The reasons for the average number of inseminations per cow being too high, are the same as mentioned under the heading ‘conception rate’.

The average number of inseminations per cow on a farm can be influenced adversely by some poorly managed cows which only conceive after many inseminations.

Example: a herd with 100 cows (no bulling heifers)

100 first inseminations	→	50 cows conceive
50 second inseminations	→	20 cows conceive
30 third inseminations	→	10 cows conceive
20 fourth inseminations	→	6 cows conceive
14 fifth inseminations	→	4 cows conceive

Ten cows are still not pregnant after five inseminations.

conception rate after	1st	insemination is	50/100 × 100%	= 50%
,,	2nd	,,	20/50 × 100%	= 40%
,,	3rd	,,	10/30 × 100%	= 33%
,,	4th	,,	6/20 × 100%	= 30%
,,	5th	,,	4/14 × 100%	= 29%

In all, 90 cows become pregnant; so, the final conception rate (percentage of cows which do become pregnant) is **90%**.

In all 100 + 50 + 30 + 20 + 14 = 214 inseminations have taken place.
An average of 214/90 = 2.38 inseminations have been necessary per pregnant cow.

Ten cows did not conceive; they have had 10 x 5 = 50 inseminations.
The 90 cows which did conceive have had 214 - 50 = 164 inseminations, which corresponds with 1.82 inseminations per pregnant cow.

From this example it can be learned that the number of inseminations per pregnancy can be calculated in **two** ways:

- total number of inseminations divided by the number of pregnant cows
- total number of inseminations of the cows which did conceive, divided by their number

Hence, always mention what is meant.

Note: In a healthy herd it may happen that conception rates do not decrease with repeated inseminations. So, from 2nd, 3rd and 4th inseminations also 50% may conceive.

Percentage of cows producing a calf

Sometimes it may be difficult to keep good reproduction records. For example, with a beef herd where a bull (or more bulls) are running with the cows, there are quite often no records dealing with reproduction. With such herds, the level of reproduction can be indicated by the number of calves born in the herd.
When in a herd of 100 cows 80 calves are born in one year, it means that about
80% of the cows produced a calf that year. Hence, the calving percentage is used as a measure of reproductive efficiency.

Note:

In the above calculations we have 'worked' with herds of 100 or even 1000 cows.
This eased our calculations but has no other meaning.

The following page shows a table with reproduction data (from a dairy herd in North Africa).

Certain indicators have been calculated based on the data of the table.

In an instruction situation, the teacher should let the students calculate the indicators.
And, of course, calculating indicators of a herd known by techer and students is also very instructive.

Of a total of 25 cows, 23 cows became pregnant again.
The average calving interval is 9044/23 = 393 days.
First insemination is at 2331/25 = 93 days after calving.
Conception rate after first insemination is 11/25 x 100% = 44%.
Total number of inseminations divided by the number of pregnant cows is 55/23 = 2.4
Average number of inseminations of the cows which became pregnant is 46/23 = 2.0

Reproduction on this farm is low. What could be the causes?

No. of the cow	previous calving date	heats (dates)			insemination or services (dates)					(expected) next calving date	interval (days) between				number of inseminations	
		1st	2nd	3rd	1st	2nd	3rd	4th	5th		calving and 1st insemination	1st insemination and conception	calving and conception	calving interval		
1	11.10	20.10	30.10	20.11	11.12	-	-	-	-	11.9	61	-	61	335	1	
2	10.11	10.1	30.1	-	20.2	3.4	21.4	1.6	13.8	-	102	-	-	-	5	sold 20.8
3	18.11	13.12	3.1	-	5.3	14.4	5.5	-	-	5.2	107	61	168	444	3	
4	29.11	30.12	17.1	-	28.2	-	-	-	-	28.11	91	-	91	364	1	
5	5.12	30.12	18.1	-	8.2	28.2	-	-	-	28.11	65	20	85	358	2	
6	10.12	21.12	8.1	5.2	19.3	29.4	-	-	-	29.1	99	41	140	415	2	
7	16.12	-	-	-	22.3	-	-	-	-	22.12	96	-	96	371	1	
8	19.12	30.1	20.2	-	3.4	13.5	3.6	-	-	3.3	105	61	166	439	3	
9	21.12	22.2	-	-	4.4	-	-	-	-	4.1	104	-	104	379	1	
10	24.12	10.2	-	-	22.3	1.5	-	-	-	1.2	88	40	128	404	2	
11	28.12	30.1	20.2	-	1.4	-	-	-	-	1.1	94	-	94	369	1	
12	9.1	10.3	-	-	20.4	11.5	31.5	11.7	-	11.4	101	82	183	457	4	
13	9.1	21.2	-	-	2.4	-	-	-	-	2.1	83	-	83	358	1	
14	14.1	20.2	4.3	-	25.3	4.4	15.4	-	-	15.1	70	21	91	366	3	
15	17.1	20.3	-	-	1.5	15.6	-	-	-	15.3	104	45	149	422	2	
16	20.1	19.2	28.2	14.3	4.4	19.4	10.5	31.5	-	3.3	74	57	131	407	4	
17	22.1	-	-	-	20.4	-	-	-	-	20.1	87	-	87	363	1	
18	5.2	20.4	-	-	4.6	-	-	-	-	4.3	119	-	119	392	1	
19	7.2	15.4	-	-	4.5	25.5	17.6	29.7	18.8	-	86	-	-	-	5	sold 8.9
20	9.2	28.2	4.4	-	16.5	-	-	-	-	16.2	96	-	96	372	1	
21	15.2	20.4	-	-	31.5	10.7	-	-	-	10.4	105	40	145	419	2	
22	9.3	-	-	-	10.6	30.6	20.7	29.8	20.9	20.6	93	102	195	468	5	
23	20.3	15.4	30.4	-	11.6	-	-	-	-	11.3	83	-	83	356	1	
24	18.4	20.6	-	-	29.7	5.8	20.8	-	-	20.5	102	22	124	397	3	
25	20.5	14.7	-	-	13.9	-	-	-	-	13.6	116	-	116	389	1	
											2331			9044		

Figure 21: Example of a herd production record; calculation of reproduction data

3.4 Causes of low reproduction rates

Low reproduction rates on a farm can have several causes; often it is a combination of factors which cause reproduction to be poor.
The causes can be divided into the following groups.

Poor management

Poor management has a rather **disastrous** effect on reproduction:

- Heat detection is poor. Without good heat detection, many heats are missed and this causes longer calving intervals. From the records (if well kept!) it can be learned whether heat detection is good or not. Heat intervals, or intervals between two inseminations or services, of around 42 or 63 days indicate that heats have been missed.
- Inseminating the cow at the wrong time. A cow should be inseminated during the last part of the heat period, or within six to eight hours after the end of the heat. If inseminations take place in the beginning of the heat or too late after the end of the heat, conception rates decline.
- First inseminations take place too late after calving. With normal, healthy cows and with good nutrition, the first insemination can take place from 40 days after calving. After 90 days after calving conception rates tend to decline.
- Often cows have to walk far before and after insemination. This raises the body temperature which has a quite negative effect on conception. A good advice would be to keep the cows quiet till about three days after insemination.
- Poor herd administration can have many negative effects. One of the effects is that ‘problems’ like cows not coming on heat, are not discovered on time. Without good records one is simply handling the cows ‘like a blind man’.
- When there are reliable records they should also be used. Cows not coming on heat within 60 days after calving should be checked. If possible, six to eight weeks after the last insemination/service a pregnancy diagnosis should be carried out.

The environment

Good nutrition means sufficient energy, proteins, minerals and vitamins. Providing a balanced ration, according to the needs of the animal, does not only mean more milk, but also means a better reproductive performance. A better performance, by first calving at a younger age, by shorter calving intervals and by more cows coming in calf.
However, cows should not be over fed; then they become too fat and this has a negative effect on reproduction.

In many cases a mineral lick is advisable in addition to a normal ration, especially in the case of high production cows.

Lack of protein reduces reproduction (but too much protein causes diarrhoea and consequently also lowers fertility).

An important vitamin is vitamin A. Lack of vitamin A may be the cause when there is not enough green roughage (animals make vitamin A from carotene present in green roughage).
When there is lack of vitamin A, a premix with vitamin A should be used, or a lick which also contains vitamins.

Sometimes there are seasonal influences on reproduction when the cows mainly depend on grazing for their feeding.
Especially in the dry season there may be fertility problems because of low quality grazing.

Other seasonal influences may be *high temperatures and high humidity*. Heat detection may become very difficult. In case of high temperatures, heat detection should take place in the cooler periods of the day, with plenty of attention (see also following pages).

High temperatures and high humidity the year round (humid tropics!) : not so good for reproductive performance!

Diseases

Diseases affect (milk)production, but also fertility. Especially breeding diseases affect reproduction.
When artificial insemination is applied in a correct way, the majority of the breeding diseases can be prevented. Do not use bulls which have a breeding disease as discussed earlier.
Inflammation of the uterus (endometritis) also reduces reproduction. Endometritis can be largely prevented by taking hygienic measures around calving time as discussed before.

Hormonal disturbances

In individual cows hormonal disturbances can reduce fertility (problems with coming on heat or with conception).
Hormonal disturbances lead to inactive follicles or cystic follicles (corpus luteum persistence; the yellow body does not regress but continues producing progesterone). Or to follicles which do not rupture; in this case oestrogen is produced for a too long period.
Some of these problems can be dealt with by a veterinarian.

Hormonal disturbances are in most cases individual cow problems. Hormonal problems are generally **not** the cause of an overall low reproduction rate on a farm.

Other influences

A low reproduction rate can also be caused by:

- The bulls which are used.
  Some bulls produce semen that is not very fertile. This can be detected with the aid of a microscope. Only bulls with approved fertile semen should be used.
- Low quality semen.
  When semen is not correctly conserved, or when it is not correctly treated, many of the male cells die off. Not only the freezing procedure but also the *thawing procedure* by the inseminator is critical in this respect.
- Wrong insemination techniques.
  These can be overcome by better training of the inseminators. However, not every one can become a good inseminator by training only. The inseminator's attitude towards a cow and the way he approaches the animal are very important.
  Rough handling of cows before, during and after insemination can be a cause of a low reproduction rate.

Conclusion

Reproduction problems are mainly caused *by poor management and by poor nutrition.* Therefore a low reproduction level on a particular farm is most probably only for a small part caused by the cows themselves. The influence of the farm's management is much bigger.
Often the reproduction rate is a *measure for the quality* of the management on a farm.
Remember that the reproductive performance of a dairy herd is the most important single factor affecting its profitability!!

3.5 Measures to improve the reproductive performance of a herd

Identification of the cows

Especially on larger farms it is a **must** to have a possibility to identify all cows in an easy way.

Heat detection and insemination

A first basic necessity for a good reproductive performance is proper heat detection. When cows are not seen on heat, they are not inseminated.

Signs of heat:

- the cow becomes restless, sometimes separating herself from the rest of the herd, walking along fences to seek a bull,
- the cow moos in order to attract a bull (Bos taurus; the Zebu does not do this),
- the cow excites other cows and **stands** to allow them to mount her; **standing** is the only reliable practical test of heat,
- signs that the cow has been mounted by others, because she has mud on her flanks, bare patches of skin on the hock or the pin bones, ruffled hair on the back or a hollow back,
- the lips of the vulva turn red and are somewhat swollen,
- there is a discharge of clear, thin mucus hanging from the vulva or adhering to the tail.

These signs may not all occur or be noticed simultaneously, but usually some at least are noticed.
It is important to detect a heat because if undetected, the cow will (again) not be served/inseminated and the calving interval will be longer.
It is advisable to check the cows three times per day; at milking time (2x) and during the dark hours (1x), preferably at times when cows are normally resting, so just before milking.

The length of the heat period in tropical countries appears to be shorter than in Europe; on average it lasts about 11 hours in the tropics, against 21 hours in Europe.

One of the causes of a low conception rate is *a wrong insemination moment.*
Insemination should take place in the last half of the heat period or up till 6 to 8 hours after the end of the heat.
Signs of heat
Since there is variation in heat duration, it is important to know when the heat started.
To get an idea about the start, it is necessary to carry out regular and proper heat checks. When a cow is silent at ten o'clock in the evening and is seen active at five o'clock in the morning, the heat period started during the night. This cow can be inseminated successfully towards the end of the morning or early in the afternoon.

When a cow is silent around five o'clock in the morning and starts to come on heat around nine o'clock, it is not advisable to inseminate the cow early in the afternoon; it is better to wait till the end of the afternoon or the first part of the night.

Often the inseminator is not present to do inseminations at the most appropriate moment. The following is a piece of practical advice. The cows seen on heat up till or around six to seven o'clock in the morning, can be inseminated the same day, in the morning (this in case the inseminator is coming only in the morning). The cows seen on heat after seven o'clock in the morning, should then wait till the following morning.

For good results, it is absolutely necessary that the inseminator *can come any day*, or that the farmer can on any day go to a place where he can have his/her cow inseminated.
Waiting one day or more after the end of the heat, reduces the conception rate up to zero.

If the inseminator is not available every day, it may be advisable to keep a breeding bull (if possible). When the inseminator does not come, the bull can serve the cow that is on heat.

There is one important difference, however, between artificial insemination and natural service by a bull. Insemination can still be done after the end of the ‘standing heat’; natural service must be done during ‘standing heat’; after that period natural service is hardly possible.

Stress

Proper handling of the cow prior to, during and immediately after mating or insemination are important. Things that should avoided are : walking long distances, mishandling, shouting, sudden movements, non-routine events for cows and poor milking techniques.

In order to overcome the effect of heat stress on reproduction (in climates with a hot season), especially at the time of conception, seasonal breeding may be necessary; the cool season generally creates a better climatic environment for conception and implantation of the embryo.

Prevention of endometritis

Endometritis is an infectious inflammation of the uterus caused by bacteria (see page 49).
Endometritis often causes problems especially where there are (many) cows confined in small, (dirty) places for a long time. This is the case with zero grazing and permanent housing of dairy cows.
Normally a cow can only be infected during or shortly after calving. During calving and the first days thereafter, the cervix is open and bacteria can enter the uterus. Especially just after calving, the uterus is very vulnerable because there are many wounds in the uterine wall due to the rupture of the afterbirth (placenta) from the uterine wall.

Where cows are confined, *good endometritis prevention* can be achieved by providing a clean environment, especially during and after calving. This can be done in the following way.
Separate the cow from the herd a few days before calving and bring her to a special calving pen. This pen must be cleaned (and disinfected) before the cow is brought in.
Just before calving, the hind part of the cow (the area around the vulva and the tail) should be washed and disinfected. Also the hands (fingernails!) of the helpers and the pulling ropes should be cleaned and disinfected.
If possible, the cow should stay in this calving pen for two to three days at least or, in the case of a retained afterbirth, till the afterbirth has come out. After this the cow can go back to the herd.

Endometritis spreads by the discharge of infected animals. Cows which have endometritis, usually have a whitish, foul-smelling, dirty discharge from the vulva. This discharge is just pus, with a lot of bacteria in it. The discharge is dangerous for cows in late pregnancy and for newly calved cows.
It takes some weeks before infected cows start to produce ‘white discharge’.

Consequences of endometritis are:
- lower reproduction, because many infected cows do not come on heat; some infected cows do come on heat, but do not conceive;
- decline in milk production;
- loss of condition.

The disease can largely be *prevented* by very good hygiene, as described above.
A veterinarian can *treat* endometritis. As always, prevention is better than treatment.

In case of extensive grazing, metritis is seldom a problem. But where dairy herds are permanently housed (zero grazing), metritis can be a serious problem.

Good feeding

When cows do not get enough proteins or minerals, the provision of protein-rich concentrates or mineral licks can improve reproduction. This also applies to (bulling) heifers.
The energy in the ration should also be sufficient and meet the requirements of the animal.

Loss of condition due to an unbalanced ration or a high milk production also lowers reproduction. Such cows have weak heat signs or do not show heat signs at all.

Veterinary measures

With the aid of good records, problem cows in the herd can be traced. Such cows should then be examined by a veterinarian as soon as possible.
Cows to be checked by a veterinarian are:

- cows not seen on heat up till around 60 days after calving (endometritis? abnormal ovaries?);
- cows not conceiving after three or four matings/inseminations;
- cows not observed in heat eight weeks since the last mating/insemination (pregnancy diagnosis).

If most problem cows look normal and if the conception rate is low, wrong insemination timing, a wrong insemination technique or poor semen can be the cause.

When all cows on a farm have a low reproduction rate for no clear reason and when management is in order, specific mineral disorders may be the cause of the poor reproductive performance. A high frequency of retained afterbirth may also indicate mineral deficiencies.

When there are cows with irregular heat intervals, ovarian abnormalities may be the cause.

Culling

The cost of the farm buildings, the fences, etc., and the cost of maintenance feed is the same for high and low production cows. When two cows have the same genetic capacity for milk production, the cow with a poor reproductive performance has a lower production than the normal cow.
For these reasons it is not economic to keep cows with a poor reproductive performance when they can be replaced by normal, healthy animals. Unsatisfactory cows are, for instance, cows not yet pregnant six months after calving. Such cows will have a calving interval of at least one year and three months.
However, the exact definition of ‘poor reproduction’ within a given herd depends on the herd’s average performance.
If it is to be decided whether a cow should be culled for poor reproduction, milk production should also be considered. A low production cow (a cow with a low lactation yield) is culled sooner than a cow with a high lactation yield.

A cow that has been bought at a high price (perhaps an imported animal!) will not be culled soon either. Her calves are valuable.

Sometimes culling is impossible because the replacement rate is too low. In such a case other problems (management!) should be dealt with first of all.

Too often there is not enough culling on a farm; this may lead to overstocking and very low economic returns.

Final remarks

Cows which have conceived do not come on heat again before their next calving; so, not coming on heat three weeks after the last service or insemination may be an indication that the animal has conceived.
However, not coming on heat is no assurance for being pregnant. When one wants to be sure, a pregnancy diagnosis is necessary (from six to eight weeks after the last insemination or service).

It should not be concluded too soon that the bull or the insemination service is the cause of poor reproduction, unless there are clear indications.

When the bull is the problem, because its semen is not fertile, this problem can be solved by using another bull (if available). If the insemination service is the problem, it can be solved by improving the quality of this service or by using a bull on the farm.

4 Major diseases of reproduction

4.1 Endometritis

Endometritis is a uterine infection and is caused by various types of pus-producing micro-organisms. Normally the cervix is closed and prevents bacteria from entering the uterus. However, at calving time the cervix opens for the calf to pass through and bacteria can get into the uterus.

The major causes of uterine infections are:
- poor sanitation at calving time,
- difficult birth, unskilled personnel,
- dirty equipment has been used to assist in the delivery of the calf,
- a retained afterbirth.

Normally a cow discharges mucus with a bloody tinge for 10 to 14 days after calving. Danger signs that indicate an infection are pus in the mucus or a foul odour of the discharge.

Uterine infections delay the necessary healing of the lining of the uterus for the next pregnancy.
If the uterus remains infected for three to six weeks after calving, changes take place in the uterus lining that reduce fertility and that may even cause permanent sterility.
Often a cow with uterine infection does not produce well. Milk production increases after the infection is cured.

Sometimes the infection in the uterus is very mild and the mucus discharge (with flakes of pus) is only visible when the cow is on heat. Often mildly infected cows are repeat breeders.
It is very necessary to detect **early** the appearance of pus in the mucus discharge.

Under otherwise favourable conditions cows will often recover from uterus infection with time. Especially 'heat' has a healing influence. Antibiotics may be infused into the uterus to stimulate the natural healing process. Stubborn cases may require more than one treatment. Strict sanitary procedures should be followed when infusing the uterus.
In addition, antibiotics may also be given intramuscularly to treat severe cases of endometritis.

Remember that milk from a cow treated with antibiotics must be withheld from the market for a prescribed period of time.

Many uterine infections can be prevented if good sanitary practices are applied at calving time.

Infected cows should be kept isolated because the disease can spread to healthy cows that come into contact with the infected discharge (pus).

Especially when cattle are permanently housed (zero grazing), endometritis can be a serious problem.

4.2 Abortion in cattle

Generalities

'Early embryonic death' occurs between day-8 and day-20 after fertilization, before the fertilized egg hatches in the uterus. This is a very sensitive period for the embryo.
Early embryonic death happens quite often. If the embryo dies before day-18, the cow will come on heat normally; if the embryo dies after day-18, heat may be delayed somewhat.

'Late embryonic death' is death between day-20 and day-45.

Embryonic death before day-45 usually goes unnoticed; the embryo is broken down by enzymes and is then absorbed by the bloodstream.
Around day-45 all organs are present in principle and the calf has its definite form.

Abnormalities in respect of the chromosomes is probably the most common cause of embryonic death. Insemination carried out too early or too late may also be the cause of embryonic death, just as improper feeding or stress.
Infections and diseases may also cause embryonic death.
Hence, embryonic death is a multi-factor problem. Correct insemination timing, hygiene, prevention of stress and proper feeding (no sudden changes) help.

In cattle the length of the gestation period is about 40 weeks (280 days).

When considering the birth of calves we distinguish:
- normal calving
- partes praematurus (early birth)
  after a pregnancy of at least **32** weeks; by this time the body of the calf is fully covered with hair and the calf is viable generally
- partes immaturus (birth of an unfinished organism) or *abortion*
  after a pregnancy of **less** than 32 weeks and more than two months; at this stage the foetus is not yet viable.

In other words, 'abortion' is the untimely birth of a non-viable but fully developed foetus.
In principle there are two direct causes of abortion:
1 The corpus luteum stops functioning and the foetus is expelled. The corpus luteum is very sensitive to high body temperature (fever). Hence all diseases with fever may lead to abortion. Characteristically the expelled foetus looks 'fresh' just like the afterbirth if normally expelled.
2 Pathogenic germs attack the foetus and/or the placenta. The foetus and its placenta become diseased and die. Often the foetus swells (oedema) particularly its belly. Because of these changes the afterbirth is often retained.

Sometimes the foetus is not immediately expelled after its death in the womb. The foetus may dry up in the womb; this happens in particular before the 5th month of pregnancy. The foetus is 'mummified'. Between death and mummification is a period during which the foetus is partly more or less 'fluid' and especially (pieces of) bones may be expelled.
A 'mummy' may stay in the womb for a very long time. Nine months may pass and nothing happens. A good herdsman (farmer) will have noticed beforehand that something is wrong and will call for a veterinarian. A treatment with hormones will usually lead to the 'birth' of the mummy.

In *cattle* abortion is *more common* than in the horse and in smaller ruminants; in the pig its frequency is lowest.

The external signs of an approaching abortion are the same as in normal calving but *less obvious*:
- swelling of udder and teats,
- loosening of the ligaments connecting the tail head with the pelvis,
- greyish bloody discharge from the vulva,
- the cow may be a little restless and strain every now and then.

Note that especially in the first half of the gestation period an approaching abortion may hardly be noticeable.

During an abortion the activities of the female tract are more or less the same as in normal calving, but everything goes in ‘slow motion’. This may lead to complications.
For example, relaxation of the cervix may take several days; during this time bacteria of all kinds can penetrate the uterus (from the vulva) and cause (secondary) infections.

Any case of abortion may lead to large-scale **dissemination of pathogenic germs!** Therefore it is absolutely necessary

- to recognize the first signs of an approaching abortion and to report it immediately,
- to separate the cow from the herd and to bring it to a calving pen or box before the foetal membranes rupture (a place reserved specially for abnormal situations),
- to prevent the dissemination of germs with the amniotic fluid, the aborted foetus and the afterbirth; the attendant must wear special clothing, rubber boots and gloves and use disinfectants abundantly (this is also for his/her own protection!),
- to send certain parts of the foetus and afterbirth to a laboratory for diagnostic purposes (if possible and desirable); the remaining parts must be incinerated or at least be buried deep and covered by a layer of quick lime,
- to disinfect the pen itself after its use (no germs should be carried away from the pen); disinfect also the cow, boots and clothing, tools, buckets and straw and maintain these precautions for several weeks (in the case of Brucellosis),
- to send blood samples from the cow for a series of serological tests (if desirable and if possible).

For diagnostic purposes, the abomasum (true stomach) of the foetus together with its contents, the caecum of the foetus and the mushroom-like cotyledons of the afterbirth are particularly important.

Especially when the cows live close together, everything should be done to prevent the spread of the pathogenic germs involved in abortion.

What causes abortion

Infections are normally the most important cause of abortion. For this reason abortion is usually **contagious**. When several cows in a herd abort within a relatively short time, one should suspect contagious abortion.
In countries where the bacterium Brucella abortus exists, this bacterium is usually the most important cause of abortion. Brucellosis is often called ‘contagious abortion’.

However, there are many other causes of (contagious) abortion and for that reason it is often difficult to establish the exact cause of abortion.

The following is an overview likely to cover abortion everywhere:

- The cause may be in the cow herself: more abortions in older animals, breed and family, liver not functioning properly, cow over-sensitive to certain medicines or other products including feedstuffs.
- Feeding may play a role: malnutrition, lack of minerals etc., sudden feed changes, large amounts of cold water or cold feedstuffs, a.o.
- The care of the cows: transport, fear, accidents; insemination of a pregnant cow; medicines are toxic sometimes and may cause abortion, especially hormone treatments.
- Diseases; any disease may cause abortion. Diseases generally weaken the body and as such may lead to abortion. Fever has a negative effect on the corpus luteum. Especially parasitic infections stimulate abortion.
- Many different kinds of pathogens can cause abortion in cattle. We mention:

  viruses:
  IBR/IPV (Infectious Bovine Rhinotracheitis; Infectious Pustular Vaginitis),
  BVD (Bovine Viral Diarrhoea)

and other viruses

bacteria:
Brucella abortus (→ brucellosis, abortus Bang, Bang's disease)
Campylobacter foetus
Leptospira (→ leptospirosis)
Chlamydia
Salmonella
Listeria (→ listeriosis)
and other bacteria

protozoa: Trichomonas foetus
fungi: Aspergillus (in feedstuffs)

4.3 Some specific infections

Brucellosis (Bang's disease)

Summary
Brucellosis is a bacterial disease most often spread by:
- an aborted foetus, afterbirth or placental fluids,
- feed or water infected with vaginal mucus from an infected cow,
- direct contact with an infected cow or bull.

The disease is sometimes called *contagious abortion* because it is so easily transmitted from one cow to another.

Man may contract *undulant fever* by drinking unpasteurized milk from infected cows. Most cases of undulant fever result from direct contact with vaginal discharge.

After the infected cow becomes pregnant, the brucellosis bacteria destroy the delicate transfer of nutrients from the mother to the foetus. As a result the foetus may be aborted any time but usually abortion occurs after the fifth month of pregnancy.
After abortion occurs, retained afterbirth, infection of the uterus and sterility are common. However, other causal agents may also be involved in this. Therefore a blood test is required for a precise diagnosis.

There is *no cure* for brucellosis, although some cows develop an immunity and subsequently carry a calf full term.
Such cows usually continue to give a positive blood test for life and may spread the disease for long periods of time.
Slaughter of infected animals is the only effective way to eliminate the disease.

Brucellosis can be *prevented* by routine vaccination of all female calves between three and eight months of age (preferably between three and five months).
Once a country is free from brucellosis, the vaccination programme may be stopped.

Artificial insemination with semen from brucellosis-free bulls is an important weapon in preventing the spread of brucellosis at breeding.
AI stations routinely test their bulls for brucellosis and only use brucellosis-free bulls. They also add anti-bacterial agents to the semen as a precaution.

Dairy cattle exported from Western Europe are free from tuberculosis and brucellosis. But such cattle will be susceptible to infection when imported in countries where these two diseases are normally present in the local livestock population.
Care must be taken to ensure that the susceptible imported animals do not come into contact with any local cattle that might be infected.
Strict hygienic precautions should also be taken to avoid infection being transmitted in any other way.

More details
In countries where the bacterium Brucella abortus exists, it is likely to be the most common cause of infectious abortion in cattle.
Other domestic animals such as sheep, pigs and dogs may become infected as well. Occasionally it occurs in the horse.

Men are highly susceptible too.
The germs penetrate through the mucous membrane of the eye (of the milker) and the mouth (of the drinker of raw infected milk) and through lesions in the skin of persons who assist at abortive calving; meat may also be a vector.
Stockmen working with infected livestock are particularly at risk; the same applies to vets.
Symptoms of the disease in men are: general weakness, sweating, painful muscles and joints, headache and *undulant fever.*
As long as the infection has not become chronic, treatment with antibiotics may be successful.

Brucellosis **in cattle** is characterised by inflammatory changes in the uterine mucosa and foetal membranes which lead to *premature expulsion* of the foetus.

The disease exists in many countries outside the 'Western world'.

Where Brucella abortus exists, under conditions of extensive range management (for example, nomadic cattle husbandry) brucellosis is not spectacular. But as soon as herds are confined to restricted areas, abortions may occur and weak calves and cases of endometritis and infertility may become significant.
Susceptible exotic cattle introduced to such an environment may suffer from an *acute outbreak of abortion.*

The economic significance of brucellosis:
- loss of calves needed by the farmer for replacing stock or for other purposes,
- reduced milk yield of the cows which are affected,
- losses due to a longer calving interval; repeated matings/inseminations are required before such cows become pregnant again (troublesome and costly!).

Transmission and course
Young calves are relatively insusceptible to infection but they become more susceptible as puberty approaches. *Pregnant females are highly susceptible.* In males the percentage of infected animals is generally lower than in females.

The Brucellosis bacteria are disseminated with the aborted foetuses, the foetal membranes and fluids and the vaginal discharge of infected cows (which may persist for several weeks); the dam's colostrum, milk and faeces may also be infectious.
Consequently pastures, litter, dry roughage and water supplies may become contaminated.
Carrion birds, dogs and other animals may carry the aborted foetuses long distances.

Cattle may ingest contaminated feed or water or lick the genitals of herd mates which have recently aborted or even the aborted foetuses themselves.

Infected bulls may spread the germs with their semen, especially when artificial insemination is applied.
Blood sucking insects, ticks and mites may also transmit the germs.

The Brucellosis bacteria penetrate the body of their next victim through the mucous membrane of the alimentary tract, the respiratory tract or through the eye lids.

Once they have entered the body, the germs lodge and multiply in lymph nodes, the udder, the uterus, joints, etc.
They will quite soon disappear from both the underdeveloped udders of young stock and the 'empty' uteri of non-pregnant cows and heifers.
However, in the well-developed udder of adult animals they will persist for a long time, waiting for the host to become pregnant again; when that happens the germs will move into the uterus. There they cause inflammatory processes which lead to diminishing nutrition of the foetus, to its putrefaction and finally its mortification.

Bovine brucellosis is a **chronic infection** that remains indefinitely in a herd. Young heifers will pick up the infection and may abort the first calf. Usually, each animal will only abort once and more than two abortions are uncommon. A certain degree of immunity develops. So, in the *individual* animal brucellosis is a self-limiting disease.

Diagnosis
Abortion usually occurs some time after the death of the foetus but sometimes the aborted foetus is still alive. In many cases abortion is accompanied by retained placenta ('afterbirth').

Usually there is no severe effect on the general health of the cow which aborts, but its milk yield is often reduced.

In the bull there may be inflammation of the testicles; they become swollen and painful and produce contaminated semen. Appetite and sex drive are reduced.

It is possible to isolate bacteria from foetal stomach contents and from spleen, liver and lung tissues, but it requires a great deal of skill and fresh, clean animal material. Moreover, it is difficult to apply on a large scale.

It is better to recognize an animal carrying the pathogenic germs well before it may infect its herd mates. To this end several tests have been developed; no one test is entirely reliable but a combination of two or more is likely to be effective:

1 Blood serum agglutination tests are practical and quite reliable methods of diagnosing bovine brucellosis
   - the serum from an infected animal contains antibodies which will clump the bacteria of the antigen made from a culture of the organism,
   - a deposit of bacteria at the bottom of a test tube means a positive reaction (ie. the animal is infected).

   Animals which have been vaccinated previously also tend to show a positive reaction to this test. This is inconvenient; therefore another serological test has been developed, namely the
2 Complement fixation test; it is more elaborate but it distinguishes between reactions due to natural infection and those resulting from vaccination.
3 The Abortus Bang Ring Test (ABR) is an agglutination test on **milk;** it is a very sensitive test and is used by dairy plants as a screening test

- the antigen is a coloured suspension of Brucella abortus; it produces a definite ring at the cream line when incubated with a small quantity of milk from an infected animal,
- in negative reactions the milk remains bluish and is capped by an uncoloured layer of fat

and other tests.

Control
There is no practical and effective treatment for brucellosis.

Therefore all efforts should be directed towards *control and prevention.* The eventual *eradication* of the disease requires the elimination of all (newly) infected animals.

The following measures should be taken in an anti-brucellosis campaign:
1 Apply the ABR test ('milk ring test') to every dairy herd in the region, at three to four months' intervals; in this way the brucellosis status of individual dairy herds can be determined. Milk samples are collected and tested at the milk plant, taking each separate herd *as a whole.*
2 **All** animals in a 'positive' herd are then submitted to **individual** blood serum tests; those showing a positive reaction are slaughtered.
3 'Clean' herds must be *protected from reinfection.* The greatest danger comes from purchased replacements.

Where possible, new additions should be vaccinated calves or non-pregnant heifers.
If pregnant or fresh cows must be bought, they should originate from brucellosis-free herds (this means at least three negative quarterly ABR tests in succession) and be negative to the blood serum agglutination test individually.
It is advisable to keep such replacements separated from the herd for at least 30 days and to retest them before permitting them to mix with the main herd.

Note: it is clear that such a campaign can only be held in regions with a certain infrastructure of milk collection and animal health.

Vaccination
The first vaccine which was successful against bovine brucellosis was that prepared from the 'strain 19' organism. Strain 19 vaccination can be applied at all ages but in the adult animal it gives a positive reaction to diagnostic tests for some years afterwards.
In calves, however, a good degree of brucellosis resistance is obtained, while the animals cease to show a positive reaction by the time of first calving.
In the Netherlands (Western Europe in general), vaccination against bovine brucellosis was stopped many years ago. The country is free of the disease and, moreover, a number of countries to which breeding stock is sold do not accept cattle from countries where such vaccinations are used.

Another strain of brucellosis bacteria, number 45/20, is sometimes used as a supplementary vaccine. This dead vaccine induces resistance for a short time at any age of the animal, while positive reactions to diagnostic tests fade away soon after its application.
Disadvantages are that two doses (at specified intervals), and on top of that annual booster injections, are required to develop a satisfactory immune response; this is laborious and costly. Occasionally local and febrile reactions to the injection occur.

As a temporary aid to control of brucellosis, both vaccines have their applications, particularly in situations where initial infection is widespread and speedy action is required.

It must be borne in mind that in areas where the disease is widespread eradication is **not** possible on a purely voluntary basis.

The brucellosis germs spread too easily, for instance by direct contact across poorly fenced boundaries, on premises where animals have aborted, through vehicles, and so on. Sanitary regulations are indispensable (and must be enforced).

Leptospirosis (Lepto)

Cows most often contract lepto from the urine of infected cows or other infected animals. Natural mating can also be a route of infection.
Milkers may also contract the disease.

High fever and poor appetite are usually the first symptoms. Pregnant cows may abort as a result of the disease, regardless of the stage of gestation.
Abortions are most frequent in the last three months of pregnancy, however.

The kidneys and blood cells may also be affected by the organisms. As a result, bloody urine and anaemia are primary symptoms. Symptoms resembling mastitis are also common. The milk contains yellow, ropy masses.

For positive diagnosis blood and/or urine are usually tested to isolate the infecting organism.
Not everything is known about prevention and control of leptospirosis. The animals can be tested yearly to help prevent spreading of a lepto infection in a herd.
Artificial insemination with semen from non-infected bulls is also helpful. Vaccination is recommended if the herd is in an area where lepto is common.
Good protection against lepto is possible if the correct lepto vaccine is used. Vaccines must be administered every 6 to 12 months for good protection.

Campylobacter foetus

Summary

Campylobacter foetus is a bacterium transmitted by natural mating. The infected bull may not show any external symptoms. Less frequently, cows may contract this disease by direct contact with infected cows.

Repeat breeding problems or abortions between the fourth and seventh month of pregnancy are the first indications of this infection. Most infected cows in the herd may require several services before they settle. Heat periods are irregular and many cows will have uterine discharge. The reproductive performance is very poor.

For positive diagnosis a trained technician should culture the vaginal mucus from the cow or fluids from a freshly aborted foetus to identify the micro organisms.
Of the bull, mucus collected from the prepuce should be cultured.

Cows develop an immunity a few months after infection with this bacterium.
New animals added to the breeding herd will often become infected by the bull.
Following an infection, which may or may not cause abortion, some cows remain less fertile or sometimes totally sterile.

There is a vaccine available to protect cows against Campylobacter foetus. Two vaccinations given three weeks apart are required the first year, followed by one yearly vaccination afterwards.

Campylobacter foetus can also be prevented by using artificial insemination. In countries where the disease is prevalent, most AI stations test their bulls for this disease and use only negative (non-infected) bulls.
In this way the spread of the disease from the bull to the cow can be completely prevented.

As a precaution, on many AI stations anti-bacterial agents are added to the semen as well.

More details

In cattle, Campylobacter foetus (campylobacteriosis or vibriosis as it was and is still called) is a venereal disease. In sheep, however, it is assumed that the transmission of the bacteria occurs when the sheep ingest contaminated feed and water.

Campylobacteriosis should be suspected to be present when the majority of the cows and heifers in a herd are returning to service, either regularly or irregularly, especially if this coincides with the introduction of a new bull.

The bull may harbour the organism for long periods on the surface of the penis and the inner wall of the prepuce without showing any lesions.
In the female, the infection is temporary and immunity is established in about three months.

Course of the disease and its diagnosis

The primary effect of campylobacteriosis is *temporary infertility;* abortion is of secondary importance.

An irregular oestrus cycle is a prominent sign. In fact the cow has conceived but the embedding of the fertilized egg in the uterus is interrupted. This interruption must be seen as a defensive reaction of the mucous membrane of the uterus to the presence of the bacteria.

Early embryonic death is the result; normally the embryo is absorbed and a new cycle starts.
If the embryo is expelled, it is often so small that it goes unnoticed.
Some of the cows served by an infected bull may carry their calves to full term.
If not, reinfection takes place with continued service by the (same) infected bull. But gradually immunity is built up and early embryonic death does not occur any more.
However, in such cases the foetal membranes and the cotyledons may still be damaged in such a way that the foetus is aborted (4th to 7th month of pregnancy); this abortion is usually accompanied by retained afterbirth.

Foetal stomach fluid is the best source of pure cultures of the bacterium, but its application is limited:
- only about 10% of infected cows abort sizable foetuses and
- abortion is a relatively late manifestation of bovine campylobacterial infertility.

It is also possible to isolate the bacterium from oestrus samples of vaginal or cervical mucus; positive results may be expected about four weeks after exposure to infection.

It is difficult to isolate the bacteria from the semen or from material sampled from the prepuce of the bull.
However, if a female served by the herd bull is found to be infected, it is most likely that the bull is infected as well.

Blood serum agglutination tests are not reliable with this particular disease.
The antibodies accumulate locally in the female genital tract and therefore vaginal mucus is used. Agglutinating antibodies have been found 60 days after experimental venereal infection and they persist for about seven months.
The test should be applied on a herd basis. **All** non-pregnant cows that were first exposed to service more than two months previously should be included (a single animal might show a false reaction, either positive or negative).

Freedom from campylobacteriosis is essential for AI bulls. This can be ascertained by test-mating a new bull to two virgin heifers. The heifers act as natural incubators. If the bull is infected, the bacteria may be recovered from vaginal mucus samples about four weeks after service and/or a positive agglutination test of the vaginal mucus will be obtained about sixty days after service.

Control

An infected bull transmits the bacteria not only by natural mating but also with its semen if this is used for artificial insemination. Treating the semen with antibiotics reduces the risk of the latter.

It may be possible to treat infected bulls but so far no practical method has been developed.

Infected cows become immune within a period of three to six months after they have been exposed to service by an infected bull (it is recommended to give them sexual rest until they have completed this period).

Artificial insemination is the best method of controlling this disease, provided that:

- the AI bulls have never been used for natural mating,
- they are not infected by contact of the penis with contaminated instruments or with the rump of the dummy cow when the semen is collected,
- the inseminations are performed under strict hygienic conditions (the equipment that is used; the hands of the inseminator).

If natural mating has to be continued, the unexposed females should be kept isolated from the exposed cows; only non-infected bulls should be used on this clean herd.
The separation must be strictly maintained.

By means of *vaccination* satisfactory protection of susceptible stock has been achieved, especially in beef herds under range conditions. Usually the females are vaccinated at least two weeks before breeding and the procedure is repeated annually.

Vaccination of the bull was never very successful until the 'Belgian vaccine' was introduced. The systematic application of this vaccine has been reported to reduce the percentage of affected bulls spectacularly.

Trichomonas foetus

Summary

Trichomoniasis is also a breeding disease. Trichomonas is a protozoan (singular cell, microscopic) transmitted by natural mating. Even though bulls never show external symptoms of the disease, they are usually the source of infection in a herd.

As a result of infection, abortions occur during the first four months of pregnancy.
Large quantities of greyish, abnormal fluid may be discharged during the first half of pregnancy as a result of uterine infection caused by trichomoniasis.
In open cows, heat periods are irregular and often many services are required to settle the cow.

For a positive diagnosis the organisms which cause the disease must be identified microscopically in the fluids from the aborted foetus, the vagina of the cow, the prepuce of the bull or in the semen.
There is no reliable treatment. Cows which have aborted usually develop an immunity.
The anti-bacterial agents commonly used in semen by AI centres may not be as effective in controlling this disease as they are for Campylobacter foetus.

The best method of preventing trichomoniasis is using semen from non-infected bulls.

In countries where the disease is prevalent, AI centres test their bulls regularly to guard against this disease.

More details
Bovine trichomoniasis is a venereal disease spread all over the world.
Like campylobacteriosis, it is an insidious disease; that is to say that it may have been present in a herd for months before it is recognized.

When it first affects the herd the infection rate is high. Nevertheless, as females develop resistance, fertility may (again) reach such a level that the owner never becomes aware of the presence of the disease.

The organism which causes the disease is a flagellate protozoan, which is found only in the genital tract of male or female cattle. At the AI centre the organism may spread from one bull to another by indirect contact (via the rump of the teaser or the dummy or via contaminated equipment and hands). Between bull and cow, transmission generally only occurs during mating.

A number of cows and heifers served by infected bulls conceive and either carry to term (without any signs of infection) or abort within two to four months. Others return to multiple services and may not show clinical symptoms.

Note:
- early abortion (first third of pregnancy period) is usually associated with trichomoniasis,
- abortion during the middle third of the pregnancy period is usually due to campylobacteriosis,
- late abortion (last third of the pregnancy period) suggest brucellosis.

The death of the foetus is often accompanied by its maceration and the accumulation of pus or fluid in the uterus. In such cases manipulation of the uterus often provokes a discharge from the vulva in which motile trichomonads can generally be demonstrated.

In Europe the widespread use of artificial insemination since about 1950 has made it possible to control the disease. In this respect, the main advantage of artificial insemination is that it prevents infection of the bull.
Although transmission by artificial insemination is reduced by the usual dilution methods of semen, it can still occur.

Diagnosis
In the female, infection is characterised by:
- a low conception rate (repeat breeding);
  one must become suspicious when several females fail to conceive to a bull of which the semen is found to be of good quality (number and motility of male cells),
- a profuse mucoflocculent discharge from the vulva,
- early abortion (2nd to 4th month of pregnancy); often a foetus of no more than 6 to 7 cm body length,
- pyometra, which means accumulation of pus in the uterus; the corpus luteum persists and hence oestrus does not occur.

The tentative diagnosis is confirmed when one finds the organism in at least one animal of the herd. Microscopic examination of mucus obtained from the vagina shows the motile trichomonads.

In the bull, the trichomonads are present in the prepuce, especially in the fornix and on the glans penis.

Treatment and control
In the female, the disease is self-limiting and infection induces a relative degree of temporary resistance.
On the other hand the bull remains permanently infected unless properly treated.

As soon as the presence of the disease in a herd is established, the unexposed females should be separated and artificially inseminated.

Exposed females showing pyometra or other severe genital abnormalities can better be eliminated from the herd.
Less severe cases must be treated properly and none of the healthy-looking animals of the exposed group should be used for breeding before their third **regular** heat period.

IBR/IPV (Infectious Bovine Rhino-tracheitis & Pustular Vaginitis)
IBR/IPV is a disease caused by a virus. In Holland it is commonly called ‘cow flu’.
Several forms of the disease are recognized, for instance pink eye, pneumonia and vaginitis.
The disease may cause severe economic losses: less production and the cows may even die; embryonic deaths, abortions and stillbirths occur.
It is a very contagious disease.

Vaccination is possible, as a preventive measure.

Appendix

Article: Optimizing and modernizing extensive cattle farming

Editor: *the text of the following article is from Katrien van 't Hooft and Vivienne Lewis, both veterinarians, and written after several years' experience with dairy farming in a Central American country.*
Conditions may be different elsewhere but it is interesting to note that genetic improvement of the cattle (not to mention artificial insemination) only appears late in the article!

Many people see the use of purebred dairy cows, artificial insemination and, most of all, producing irrigated fodder crops for feeding in the dry season as intrinsic to modern dairy farming. In the following text we adhere to these principles, but also recognize that in many situations extensive cattle farming may be the most common practice.

How can extensive cattle farming be characterized?

In extensive cattle farming the cattle graze all the year round on low quality pastures, are hand-milked with the calves allowed to suckle before and after milking. The bulls usually run permanently with the female cattle. Production is low due to severe feeding constraints in the dry season, combined with the adverse effects of infectious and parasitic diseases.
The cattle are mainly dual-purpose, producing milk and beef, as well as herd replacements and draft animals. Usually tropical cattle breeds are utilised, as they survive long periods of food shortages better than non-tropical breeds, and have a greater resistance to common diseases. Often tropical breeds are crossbred with european dairy cattle breeds, giving good results as longs as the resultant cattle do not have too much pure dairy blood.

Extensive cattle rearing is often seen as synonymous with 'backwardness' and underdevelopment, because of the perceived low productivity of the cattle. However, for many farmers in tropical regions it is often more important to produce milk and meat at minimal costs rather than concentrating on the total amount produced. Thus, extensive cattle rearing is often the most economic way to keep cattle.

More intensive dairy farming

In areas near towns and cities the situation is different for dairy farmers. Milk prices may be higher whilst transport costs are reduced. This should give the producer the incentive to improve milk yields per cow, changing from an extensive to a more intensive dairy farming enterprise.

Technical strategy to optimise or intensify extensive cattle rearing

The following strategy can be applied to all levels of cattle management, adapting it to the specific reality of each farm. It is based on improving essential cattle management factors that are possible and economically feasible for the farmers involved. It is derived from the present-day cattle management systems used by farmers in Nicaragua, Central America, and should be adapted to local circumstances when used in other countries.
The strategy recommends step-wise modifications and is divided into **three phases:**
Phase 1 - Basic phase for all cattle farmers
Phase 2 - Extra attention given to cattle feeding
Phase 3 - Phase of long-term, larger investments

Farmers who rear their cattle in extensive systems will be able to optimise their enterprises by applying phase 1. They may also be able to apply parts of phase 2 depending on their circumstances. Farmers who intend to intensify extensive cattle enterprises, will need to apply all 3 phases.

Improving cattle management and productivity is a long-term process, which requires not only extensive technical knowledge and experience but also organizational and problem-solving skills.

Phase 1: Basic phase for all cattle farmers

The purpose of this first phase is by using very low-cost interventions, cattle mortality can be reduced and production can be slightly increased, encouraging greater farmer-interest. This is achieved **by guaranteeing 8 minimum requirements,** as well as some basic management and organizational factors. Cattle improvement will be noticed within a few months, especially decreased mortality and better physical condition, motivating the farmer to carry on with his/her endeavour.

The small investment necessary to provide this basic phase can be obtained by selling one or two poor quality animals.

1 The **8 minimum requirements** for extensive cattle rearing.
   The relative importance of each requirement depends on the individual charac- teristics of each farm, the type of cattle and production goals of the farmer
   - Sufficient clean drinking water (twice a day at least).
   - Strategic supplementary feeding during the last 3 months of the dry season for cows-in-milk, small and recently weaned calves and sick or weak animals. This feeding aimed at survival, can be based on traditional feeds like cattle sorghum, or on crop residues, hay and other cheap and easy to obtain products such as fruits and seeds of mainly leguminous trees.
   - Give sufficient common salt.
   - Adequate grassland management; rotational use of fields and the prevention of overgrazing and weed infestation.
   - Vaccinate twice a year against Anthrax and Blackleg.
   - Deworming of young cattle, plus preventive measures to reduce high worm burdens.
   - Regular dipping / spraying (ticks and hypoderma).
   - Good general care of all stock, especially cows at calving time, new-born calves and weak or sick animals.
2 **Essential organisational factors** (eg. for cooperative farms).
   - Appoint the most suitable person to be in charge of the cattle.
   - Guarantee the stability of the people working with the cattle.
   - Improve planning of basic management activities, on the basis of evalua tion of past performance.
3 **Essential cattle management factors.**
   - Castrate all male cattle over 1 year old that run with the female cattle, with the exception of the bulls used for reproduction.
   - Sell/exchange bulls used for reproduction that have been working on the farm for 4 years or more.
   - Separate young heifers from the bulls (if possible).
   - Sell animals in case of overgrazing.
   - Revise and possibly reduce the time the milking cows stay in the corral with their calves after milking.
   - Improve hygiene and milking techniques.
   - Start a small veterinary kit, including the most essential medicines in case of an emergency.
   - Enumerate all female animals, preferably indicating year of birth.
   - Start keeping records: costs and income from cattle enter prises, recording of births, deaths, sales and bought-in animals, and total numbers by category.

Phase 2: Extra attention given to cattle feeding

Maintain the standards that have been set during phase 1. This may not be so easy as it seems and requires continual analysis and evaluation!

Some of the increased farm income due to decreased mortality and increased production can now be invested in improving supplementary feed for the dry season. This could include:

- The construction of simple feed troughs.
- Supplying mineral salts or bone meal in combination with common salt.
- Supplementary feeding during 5 months of the dry season instead of 3 months.
- Sowing legumes.
- Growing forage crops e.g. sugar cane or elephant grass.
- Buying and installing a simple chopping machine.
- Adding molasses and urea to the forage.
- Mixing home-made concentrates.
- Making silage.

(editor: see AGROMISA publication 'Modern Dairy Farming in Warm Climate Zones, Book I, for details)

Which of these interventions to introduce and how to introduce them, depends on local conditions and circumstances, the preferences of the farmer and the prices of meat, milk and other dairy products as well as input prices.
Other important points at this stage are:

Genetic improvement of the cattle; e.g. the acquisition of a superior quality bull, or better selection of female cattle, which is now possible due to lower mortality rates.
Further grassland improvements; these may take several years.
Provide several fields for young calves. Improve methods of grazing. See earlier chapters for details.
Control of vampire bats.
Brucellosis control.
Extend record keeping.

Phase 3: Phase of long-term, larger investments
Depending on the cattle enterprise, the goals and interest of the farmer and the current government agricultural policy (input/output prices, subsidies, markets etc.), it may be rational to make *some larger investments that give long-term results.* However, it must be stressed that making large-scale investments without routinely maintaining the improvements realized in phases 1 and 2, will **not** increase cattle production or profitability.
Long-term investments that could be considered are:
1 More field divisions, to facilitate improved grassland and cattle management.
2 Construct water tanks and reservoirs in farms where water supply is a pro blem in the dry season.
3 Buy-in more cattle in cases of low stocking rates and general under-producti vity. Ensuring appropriate stocking rates will assist a grassland improvement programme.
4 Further selection and genetic improvement, by establishing a rational breeding programme. However, it is not recommended to breed cattle with more than 75% of pure dairy blood.
5 Supplementary feeding of the in-calf cows and heifers during the dry season. These animals do not usually receive any extra feeding but as part of a more intensive cattle management programme it should be possible to offer supple mentary feeding to all cattle on the farm.

However, many farmers practising small-scale extensive cattle farming, will **not** find it profitable to make these large-scale investments.

End of article.

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Reproduction in dairy cattle II

Bart Gietema

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Foreword

This guide on reproduction in dairy cattle is presented in two partner volumes:

Book I
Gives the basic facts of reproduction in dairy cattle. Facts which should be familiar to (modern) dairy farmers, dairy farm managers and extension workers dealing with dairy farming.

Book II
This part deals quite extensively with artificial insemination 'at work level' in a (sub)tropical environment.

It should be noted that in many places in the (sub)tropics 'extensive' dairy farming (as opposed to 'modern') may be the most common practice and in fact is the most economic way to keep cattle (see annex book I). The fact that this part pays so much attention to artificial insemination does not at all mean to say that it is a 'must' in dairy farming everywhere.

Acknowledgement
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B.Gietema
compilation, editing & layout

Email: <b-n.gietema@hetnet.nl>

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1 Introduction to artificial insemination (AI)

Artificial insemination (AI) in cattle is a breeding method which is practised worldwide. In some countries (almost) 100% of the dairy cows are bred by AI.

1.1 Possibilities and advantages of AI

- With AI the direct contact between males and females is avoided. For that reason AI can be used as a means to *combat venereal diseases* in cattle such as trichomoniasis and campylobacteriosis (see Book 1). In fact an important reason why AI in cattle was introduced in most European countries was to combat venereal diseases.
- Application of AI *extends the use of good sires*.
  A bull used for natural service breeds considerably fewer females than a bull used for AI. In natural service one ejaculate is used to breed only one female whereas in AI each ejaculate can be diluted, stored, and used to breed many females. With AI one bull can breed from 20 000 up to 100 000 or even more cows per year depending on semen quality, processing of the semen and on insemination techniques.
  Thus artificial insemination provides the means by which a sufficient number of offspring can be bred from a bull in a relatively short time in order to record the performance of this bull.
  Once the bull has been genetically proven, then AI alone can assure the fullest use of this bull.
  Hence AI is a method by which bulls can be genetically tested and by which the most prominent proven bulls can be used intensively for the production of the next generation. The cattle population can thus be rapidly improved provided that sound selection methods are applied. This is in fact by far the most important reason for the widespread application of artificial insemination in cattle.
- Artificial insemination permits the *use of different bulls* and even bulls of different breeds within one herd.
  This enables herd owners to breed individual cows to selected sires according to the breeding goal and the genetic make-up of dams and sires.
- In dairy herds where income derived from milk production largely exceeds income from beef production, the application of *AI can be cheaper* than keeping a bull oneself.
  The costs of feeding and of depreciation of even inferior bulls can be higher than the fees for the insemination service, apart from the fact that AI provides the farmer the use of genetically better bulls.
- In the (sub)tropics especially *dairy smallholders* can take advantage of AI since it permits them to keep dairy crossbred animals and to apply criss-crossing with, for instance, Sahiwal and Friesians.

1.2 Limitations and negative aspects of AI

- Even under the most favourable conditions the *conception rates of AI are considerably lower* than those of natural service from bulls allowed to run free with the herd, and slightly lower than those of natural service by 'hand mating'.
  Under less favourable conditions the conception rates of AI easily become so low as to cause serious economic losses to herd owners.
  Conception rates of AI largely depend on the fertility of the bulls in use, the semen collection method which is applied and on insemination techniques. Acceptable conception rates of AI can only be achieved by continuous monitoring of results and by continuous supervision of methods and techniques by skilled and knowledgeable persons.
- The success of an AI service also depends very much on *the management of the herds* which are served.
  The owners of these herds or their personnel must *be able to detect heats accurately* and in fact do so, as nobody else can do this for them.

Artificial insemination is therefore **not** applicable where cattle cannot be kept under close supervision or where basic knowledge amongst farmers about heat detection does not exist.

- Experience in many countries has shown the *serious risks of AI* with semen from bulls which are not *thoroughly tested for the absence of undesirable genes* (traits).
  The widespread use of bulls which are not properly tested under local environmental conditions (or conditions similar to those prevailing locally), can easily lead to the introduction of undesirable genes in the population.
  Therefore the application of AI is only warranted in situations where the bulls used for AI are properly selected under **local** environmental conditions.
  This is very important in cases where AI is used to cross an existing local cattle population with bulls of exotic dairy breeds in order to increase the milk production ability of the cows.
  Outcrossing an existing cattle population with foreign breeds not only leads to the introduction of the genes from the foreign breed; it also causes a loss of valuable adaptive genes in the local population.Genes which enabled the local cows to survive and to reproduce under local conditions.
  Foreign breeds, by natural and human selection, have been adapted to the environmental conditions prevailing in their country of origin. But they do not necessarily possess the genetic make-up which allows them to thrive under completely different conditions of climate, feeding and management.
  Although under optimum management conditions European dairy breeds like Friesians and Jerseys do reasonably well under a variety of climatic conditions, the unlimited use of foreign dairy breeds in tropical areas will almost certainly cause an introduction of undesirable genes and a loss of desirable genes. This could, for instance, result in cows which are more susceptible to heat stress and tropical diseases.
  Unless the bulls used for widespread use of AI are carefully selected under local environmental conditions, the resulting progeny may in fact become less productive on a lifetime basis than the indigenous cows.
- Proper application of AI will lead to improved animals capable of producing more milk than the original cows. However, such animals are usually more susceptible to stress and *they require improved feeding and management methods*. Therefore the introduction of AI will only lead to the expected results in situations where animal health care, feeding and management do not constitute limiting factors in the drive towards increased productivity.
  So, parallel efforts are required to strengthen the existing animal health service and to improve feeding and management of the new stock.
- *Skilled inseminators are required* for optimum conception rates.
  A minimum number of at least 1000 inseminations per year is necessary for inseminators to retain their skills. This restricts the application of cattle AI to areas with a sufficiently dense cattle population or to very large isolated herds.
  A network of roads throughout the area of operation is also essential, in order to make full use of the inseminators' time and to permit the distribution of semen supplies to the various insemination (sub)centres.
- Unless appropriate measures are taken, AI can be a means of *spreading infectious diseases.*
  The bulls in the AI stud should be free from infectious diseases.
  All AI activities should be under continuous veterinary supervision to prevent diseases from being spread through artificial insemination.

1.3 What is necessary for a successful AI programme?

The basic goal of any AI programme should be *genetic improvement.*
Improved cattle, however, require high standards of nutrition, health care and management for survival, production and reproduction. In many cases this requires the development of plans for increasing and improving the production of roughage and concentrates needed to realize the increased production capacity.

In areas with small (dairy) farms and traditional cattle management, the establishment of an *appropriate dairy extension service* is required to supply knowledge to the farmers about improved dairy management (housing, nutrition, fodder production and conservation, handling and milking, disease prevention, breeding, a.o.). Without improved dairy management genetic improvement makes very little sense.
The value of textbooks like the Modern Dairy Farming series, and the underlying text about reproduction in dairy cattle, is limited. However, lots of errors can be avoided by reading through these texts; at (almost) no cost (!) compared to the amount of money involved in the importation of just one exotic dairy heifer or the costs of sending just one person abroad to attend a dairy farming training course.

Also an appropriate *animal health service network* is required because genetically improved cows tend to show an increased susceptibility to diseases.
Major infectious diseases should be controlled or eradicated before the introduction of exotic susceptible breeds into the area.

Careful planning of a breeding programme is another prerequisite before the start of an AI programme.
Before any genetic improvement programme is embarked upon it is essential that its planners establish the ultimate goal of the programme. This may differ greatly from region to region, depending on local environment, the role played by cattle in the economy and ecology and limiting factors such as labour, land or feed.

An important limiting factor in determining objectives for breeding plans is *the climate.* Improved dairy breeds thrive in moderate climates but subtropical and tropical areas certainly have special problems when it comes to cattle breeding, maintenance and health.

European dairy breeds can survive, reproduce and produce in hot, dry areas, provided that they are protected against environmental hazards by the provision of shade, regular spraying or dipping, a supply of cool drinking water, being fed optimally adapted diets, reliable heat detection, overall good hygiene and management and an intensified veterinary care.

In *permanently hot and humid areas,* however, pure breeds of European cattle do not thrive. They may not even survive.
Especially affected is the fertility of the cows and the viability of the calves.
Under such conditions experience has shown that *crossbreeding* with local cattle to meet local conditions is normally the most practical course of action. Generally the resulting crossbreeds are superior to both purebred parent populations.

In such a programme AI bulls are bred as crossbreeds *in nucleus herds* by crossing carefully selected dams of indigenous breeds with semen from selected bulls of exotic breeds. The resulting male offspring is used to perform inseminations in the field.
Gradually, after thorough experience with the resulting offspring under field conditions, the proportion of exotic genes can be increased up to 3/4 or even 7/8 but upgrading should proceed with caution up to the optimum genetic level under the prevailing conditions.

However, it is extremely difficult to accomplish a controlled crossbreeding programme with AI.
In many cases the introduction of exotic breeds through AI has resulted in an uncontrolled and unlimited outbreeding of the indigenous population and consequently in disappointing results in the long run.

Finally, an increase in milk production requires an *appropriate milk marketing system* including milk collection, processing and distribution facilities.

Without possibility to sell the increased milk production at reasonable prices, farmers will have no incentive to increase the milk production of their cows and thus AI will fail to acquire broad acceptance amongst farmers.

Many AI programmes throughout the world were started without planned breeding programmes or without the necessary infrastructure having been set up first and consequently did not result in a considerable increase in production.
Such programmes invariably lead to a waste of money and effort because AI programmes, whether successful or not, are always expensive and labour-intensive.

AI can only give a considerable return on investments in situations where the prerequisites as summed up in this chapter have been taken into account.

2 Incorporation of artificial insemination in genetic improvement programmes

Selection of bulls

The introduction of AI requires careful planning of breeding goals adapted to local circumstances and careful establishment of a breeding programme to achieve these goals.
Therefore any AI organisation should be integrated in a genetic improvement programme.
Cattle geneticians should decide on the choice and selection of the bulls.

The selection of the bulls to be used for AI should always be based on their breeding values in relation to the overall breeding goal of the AI programme.

Basic principles of the assessment of breeding values of individual bulls can be found in PRINCIPLES OF DAIRY SCIENCE, by G.H.Schmidt, L.D.Van Vleck and M.F.Hutjens (Prentice-Hall Inc., New Jersey, USA).

Importation of semen

Quite often AI in many developing countries started with the use of imported semen.
Frozen semen from high quality dairy bulls of 'Western' countries was and still is donated to developing countries under the FAO Bull Semen Donation Scheme (IBSDS). This programme, introduced as long ago as in 1971, initially aroused great interest and several semen-donation projects have been implemented since then.
However, the overall results of these projects were discouraging. In semen importation it is assumed that the best bull in the exporting country will also be the best bull under the local conditions in the importing country. Quite often this is **not** the case, especially when semen is imported from countries where bulls are selected under quite different climatic and environmental conditions.

Large-scale importation of semen is only a realistic approach when preliminary trials have shown that the exotic gene pool does well under the local environmental conditions and management. Furthermore, the breeding goals of both the exporting and importing country must be similar. And sufficient foreign currency must be available to guarantee a regular and uninterrupted importation of semen.

Nucleus herds

A far better approach is to establish 'nucleus herds' locally and to breed AI bulls from these herds.
In these herds the animals can be selected for their adaptation to the local environment even though their number might be too small to permit the immediate start of bull progeny testing programmes.
Whether the females in these herds should be carefully selected outstanding cows of indigenous breeds, **or** imported cattle from exotic breeds, should depend largely on the quality of tbe existing indigenous breeds, the breeding goals and the prevailing climate, and on ecological and economical conditions.

Especially in hot, humid climates and in areas with primitive dairy management, bulls bred by crossbreeding Bos indicus with Bos taurus breeds will often be better suited for widespread use through AI than purebred European dairy bulls.

By the production of crossbred AI bulls, the unlimited and uncontrolled spread of exotic genes throughout the cattle population can be prevented. The same applies to the undesirable disappearance of valuable adaptive genes in the indigenous stock.
However, it requires careful breeding plans in the nucleus herds, geared to preserve a purebred stock of selected indigenous cattle.

Nucleus herds for the production of AI bulls should be sufficiently large to permit a reliable selection of bull dams in the herd.

In the nucleus herds the animals should be kept under optimum conditions of feeding, housing, care and management so that the cows can produce as near as possible up to their genetic capacity. Under such circumstances the performance and the production of the individual animals in the herd will reflect their individual genetic merit. Thus the individual animals can be ranked on the basis of production, conformation and disposition, making a selection of individual animals within a herd possible.

Selection of individual outstanding animals within the nucleus herd under optimum management conditions is only possible when there is *a reliable registration of each individual animal in the herd.* The registration of each animal should include pedigree, growth and performance, fertility and diseases, dairy disposition and character, conformation and, most important, an *individual production record* of milk and butterfat produced by the animal. Only in this way can a reliable selection based on production, conformation and dairy disposition (ie. ease of milking, character) of individual animals be carried out.

The most outstanding animals in the nucleus herd are used as bull dams.
For every bull needed in AI, three or four bull dams have to be selected as one cannot expect each bull dam to produce a live and sexually normal bull calf.
The bull dams should be inseminated with semen from the most outstanding progeny tested AI bulls available.
The male offspring will then have the highest possible genetic capacity to produce offspring with a high level capacity for production and performance.
They can be selected on growth rate and conformation in a *bull calf rearing unit* up to sexual maturity and the best ones can be taken into use as AI bulls for the upgrading of the local cattle population.
In nucleus herds destined for the production of bull calves in programmes for outcrossing or breed replacement, the female offspring of the bull dam is kept in the herds for replacements.
However, in nucleus herds destined for the production of bull calves for upgrading purposes, the female offspring of bull dams has either to be sold to other farms (replacement of the female stock in the herds by acquisition of purebred stock from elsewhere) **or** they should be inseminated with semen from crossbred bulls in order to maintain the optimum degree of upgrading.

Progeny testing schemes

Progeny testing of AI requires well organised systems for pedigree registration and individual milk recording.
The use of rather sophisticated electronic data processing equipment for the calculation of breeding values is recommended, although judging based on average yields of daughter groups can provide sufficient information.

Systems for progeny testing AI bulls are described in PRINCIPLES OF DAIRY SCIENCE mentioned before.

If such an approach is decided upon, the first step is to institute *a milk recording system* and a *breeding results recording system.*
These systems should include a large proportion of the cattle population in the area covered by AI as the size of the registered and production recorded population is a controlling factor.
For example, to test ten bulls a year requires about 5,000 cows in registered and controlled herds. Assuming that half of the cows are mated to proven sires, the total population of recorded and inseminated cattle should be at least 10,000.

In areas where a sufficiently large cattle population is registered and milkrecorded, planned mating systems for the production of future AI bulls can be introduced to replace the system of nucleus herds.
By intra-herd comparison based on genetic principles, the most outstanding dams from the entire milk-recorded population can be selected as bull dams and mated to the most outstanding progeny-tested sires to breed the future generation of AI bulls.
So, the introduction of a milk recording system not only permits the institution of a progeny testing system for AI bulls, but also an improved system for the acquisition of future AI bulls by selection of bull dams in a larger population.

However, in areas with a *very low average herd size,* or with primitive dairy herd management, the introduction of a milk recording system is not a good proposition:

- usually there is a lack of interest on the side of the farmers (and what incentives can be offered?);
- in the majority of smallholders' herds poor management, low feeding levels, sucking of calves, shortened lactation periods and other things will often cause a too low heritability of milk production as measured by milk recording; so, milk recording under these conditions has no value at all for genetic selection.

Therefore, for genetic improvement one should here rely on careful selection of AI bulls *based on their pedigrees.*

3 Organisation of an artificial insemination service

3.1 General considerations

Acceptance of AI by herd owners and good conception rates both depend largely on a *regular, daily* availability of the AI services. Farmers demand an AI service that operates every day of the year.
There are many ways to organise an AI field service so that farmers' demands will be met. The important principle is that the organisation must be carefully adapted to local conditions and that sufficient reserves are built in to guarantee a *reliable service* and *acceptable conception rates.*

For the continuity of the services it is of vital importance that all necessary requirements, such as finances, materials, facilities and skilled personnel are continuously available. An uninterrupted, optimum field service must be guaranteed.

In the past too many AI programmes have failed simply because of inadequate planning.
Failures of first attempts discourage everybody concerned from trying again even when conditions are made much more favourable.

Choice of area to be covered

Areas with the best potential for production improvements must be given priority for AI development.
Facilities for disease control and for collection and processing of milk must be available in principle, in areas selected for AI establishment.

The basic rule is to maintain adequate financial and personnel reserves and not to stretch resources too far, even when pressure is applied to do so. Maintaining *continuity of operation* should be the primary consideration, even at the expense of complete coverage of the area selected.

A successful AI operation means enthusiastic cooperation on the part of the farmers. An area in which a majority of farmers is eager to improve their herds by application of AI is to be preferred over a larger area in which only a minority of farmers is willing to participate.
Experience has shown that seducing or even forcing farmers to apply improved breeding methods always leads to mistrust of the farmers involved and thus to negative results.

In areas where bulls are allowed to run free with the herds or have free access to the females, AI is **not** applicable because of lack of knowledge amongst farmers on how to detect heat in cattle.
Also in areas with very primitive farm management systems or in areas where farmers stick to tradition (reluctance to accept new ideas), the introduction of AI will most likely prove to be very disappointing. In such areas an overall change in farmers'attitudes and management practices is required before AI can be successfully introduced.

Combining AI with other services

Many attempts have been made in the past to combine AI with other services, in situations where inseminators were not fully occupied with their proper tasks.

An obvious combination is AI and animal health. However, if the inseminator must also participate in ordinary veterinary services, these services can take precedence and this may result in a slow-growing or stagnating AI service.
Moreover, this combination easily leads to confusion amongst farmers. They may consider AI as a gynaecological rather than as a genetic measure.
AI is by no means a gynaecological treatment as conception rates of AI are generally lower than those of natural matings.

Optimum conception rates of AI require that only gynaecologically healthy cows are presented for insemination, and not those that have failed to conceive after natural mating. Therefore it is important that a clear distinction is made between gynaecology and AI.
Veterinarians and animal health workers should not inseminate cows; inseminators should not perform gynaecological treatments. When inseminators detect abnormalities, they should advise farmers to consult a veterinarian for proper treatment prior to insemination.

Combining AI work with general animal husbandry advisory work is another possibility. However, this combination can also lead to delays and interruptions in regular daily AI services.

The recommended procedure is to use *full-time, specialised* inseminators. This makes it possible to perform a maximum number of inseminations per day. It also helps the inseminator to maintain his manual skills.

3.2 Organisation of field services

Locally stationed inseminators

The inseminators are stationed individually and the farmers bring their cows to the insemination point.
At first sight this seems to be an easy and cheap arrangement but there are many obvious disadvantages:

- it requires a large number of inseminators and insemination centres as one cannot expect farmers to walk long distances with their cows in heat;
- the number of inseminations per day may be very low and therefore inseminators may loose their skill (one thousand inseminations per year are considered a minimum);
- a dense network of individually stationed inseminators is difficult to supervise and difficult and expensive to supply with semen and requisites;
- losses of semen (when fresh semen is used) or of liquid nitrogen may be high.

In general, individually stationed inseminators *are only recommended in situations* where they are employed directly by a local group of farmers in an area with a dense cattle population or where they are working with one or more large-scale farms.

Travelling on request

The inseminator goes to a farm whenever a cow is found to be in heat.
Here travelling tends to be uneconomic since it cannot be planned ahead of time.
Moreover, a single insemination may take several hours and because of this other farmers may have to wait.
Conception rates are generally low (inseminators do not get enough practice).
Experience with this system has generally been discouraging.

Roadside crush system

An obvious variation on ‘travelling on request’ is *to have the inseminator move along a scheduled circuit within his area every day.*
Farmers are informed of the period of time the inseminator will remain at each ‘insemination point’ which may be a roadside crush.
Roadside crushes are simple wooden constructions with two lattice frames between which the cow is kept in a fixed position during insemination.
The crushes can be constructed by the farmers themselves, and located a few kilometres apart.
The inseminator travels daily along the road, following a predetermined schedule and visiting each crush at a predetermined time.
This roadside crush system can even be used in difficult or densely populated cattle areas, where the inseminators have to travel by bicycle or even on foot.

Naturally the *means of transport* must be carefully adapted to local weather and road conditions.
Motor transport is much more expensive than travelling by bicycle, by ox cart or on foot. However, coverage and efficiency are better. The possibility of breakdowns must be weighed carefully against the improved efficiency of motor transport.

Ordinary motor cars may not be able to pass in the rainy season and here four-wheel drive vehicles are required to ensure a regular daily service.

A rough indication (that is all!) of output per day:

Table 1:

	coverage	number of crushes	number of inseminations
car	up to 150 km	30 - 70	10-25 per carround (up to over 60 has been proved possible)
motorcycle	80 km	10-40	
bicycle	40 km	5-20	

To compensate for breakdowns, maintenance and minor repairs, about 1.3 car or 1.5 motorcycles or 1.1 bicycles should be available per daily round.

Farm-visit programme
A farm-visit programme is an expansion of the roadside crush system. This programme is mainly suited to large-scale dairy farming areas with good roads. Farmers can contact inseminators by telephone, if available, or by flags or signs displayed along the road.
Where telephone connections are available, the planning of the inseminator's rounds can be flexible; where the flag system is used, fixed daily rounds have to be planned as in the roadside crush system.

As to the **choice of system,** both the roadside crush system and the farm-visit system are more appropriate and efficient than any other system. They ensure maximum employment of inseminators and reduce investments in materials and equipment. They avoid wastage of semen where fresh semen is used and also avoid wastage of liquid nitrogen where frozen semen is applied.

Moreover, these systems allow the establishment of *subcentres,* from which up to fifteen inseminators operate covering a large area.
This greatly facilitates supervision and the supply with semen and liquid nitrogen.

3.3 Main centre and subcentres

The most successful organisational structure for an AI operation is the establishment of a main centre with several subcentres situated at strategic positions throughout the area of operation.

The *main centre* serves as the central semen distribution centre.
It supervises the activities of the subcentres, assesses the quality of the semen issued and acts as the administrative centre.
In most cases it also serves as a bull semen production centre.

The *subcentres are regularly visited by AI supervisors* who report to the main centre. They should visit each subcentre for a few days each month. On these visits the supervisors should spend much of their time on examining AI records and considering financial aspects including transport costs and liquid nitrogen use.
They should also follow up individual inseminator performance in the field, by checking on time schedules, care and correctness of AI records, insemination techniques, handling of AI equipment, use of vehicles and even the attitude of inseminators towards farmers.

Moreover, they should check on stores, use of transport facilities, supplies of semen, recording of AI fees, transport management, the balancing of the number of semen doses in relation to inseminations performed, and so on.

AI supervisors should be recruited from those persons who have established a particularly good field performance record.

Close cooperation between supervisors and inseminators is extremely important.
The attitude of supervisors should basically be that of advisors, staff trainers and promoters of AI service, rather than of superior controlling officers.

Subcentres
The actual inseminations are performed through the subcentres.

It is advantageous to keep the number of subcentres as low as possible. Each subcentre should perform a sufficient number of inseminations to keep the inseminators fully occupied.

Each subcentre is managed by a *field officer.*
Field officers hold the key positions in any AI field service. They are responsible for the daily activities in the subcentre's area and report to the AI supervisor.

Field officers should undergo basic AI training of the type given to inseminators, plus at least one six-weeks course in organisation and management of AI schemes.
It is advisable to set up regular in-service seminars and meetings for field officers.

Generally, field officers should be recruited from those inseminators showing high conception rates and exceptional dedication to their job.

The number of inseminators required per subcentre should be about 60% above the number of daily rounds. This is based on a 240-days working year, with reserve for in-service training, sick leave and other contingencies.
One field officer and one clerk will usually be needed in addition.

Experience has shown that granting financial incentives based on quantity and quality of the inseminations performed can have beneficial effects on the expansion of the AI service and on conception rates obtained by the inseminators. Incentives could, for instance, be based on the number of calves produced per inseminator.
The housing of field staff should be considered carefully. The local centre is often located in a rural area where housing may be hard to find. Staff motivation is vitally important, however.

3.4 Financing AI services

In most Western countries AI organisations are self-supporting and financially independent. They operate without government subsidies as farmers' cooperatives or as private enterprises.
The running costs are met by charging the users of the service realistic insemination fees.

Provided proper breeding plans are applied, the real costs of any AI service are always lower than the benefits from increased productivity through the use of selected high-quality bulls.

Most AI organisations in Western countries charge dairy cattle owners *an insemination fee for each first insemination.*
Followed, if necessary, by a restricted or even unlimited number of **free** repeat inseminations (in case the cow fails to conceive).

Repeat inseminations at more than six months after a preceding insemination are generally considered as being first inseminations.
Often, within one AI organisation, different insemination fees are applied, depending on the quality of the bull used. Or a distinction is made between the price of the semen used and the actual insemination costs.

In many countries elsewhere, however, the situation is different.
For one reason or another AI organisations are usually government services or organisations heavily subsidised from public funds.
The farmers are usually insufficiently organised or have insufficient capital to set up their own AI organisation.

Yet it is strongly recommended to charge the users of any AI service *at least a small insemination fee.* Demanding of even a small insemination fee will prevent farmers from presenting cows that are not likely to conceive and this will help to obtain good conception rates.

The simplest and cheapest way to collect insemination fees is to have them collected by the inseminators ie. to ask the farmer to pay the inseminator in cash for every first insemination.
Collecting the insemination fees by sending the farmers invoices requires a more complicated accounting system and is more expensive.

The *ultimate goal of any AI organisation should be self-sufficiency,* which it can best realize by charging farmers realistic insemination fees, as only this approach will force the AI service to provide the best possible service at the lowest possible cost.
There is another important reason for charging the farmers an insemination fee per first insemination: it is an indispensable measure to obtain reliable conception rates. Only where farmers have to pay for a first service, with repeat services free of charge, one can expect that the majority of animals that failed to conceive will be presented for a (free) repeat service.

Where ‘bribing’ of inseminators occurs, this usually indicates that insemination fees are too low and that the service is poorly organised.
Much can be done by raising the insemination fees, by improving the service and by paying the inseminators higher wages, preferably performance-related.

4 The semen production unit

Where fresh semen is used, an AI organisation needs at least one bull per thousand cows to be inseminated; this allows for temporary cessation of the semen production of individual bulls.

With frozen semen fewer bulls are needed, but at least one bull per three thousand cows is recommended.

When there is no bull progeny registration and testing system, it is strongly recommended to replace the AI bulls frequently in order to avoid the risk of inbreeding and to restrict the spread of possible undesirable genes throughout the local cattle population (this may not be noticeable). For the same reasons the bulls in the AI centre should not be interrelated.

Even in the smallest AI operation there should be four bulls at least; with a smaller number one risks not to have bull semen available continuously.

Housing

Bull pens should measure at least 4 × 4 m and give free access to an exercise lot in the open air of approximately 4 × 8 m.
Both the floor of the pen and the exercise lot should be made of concrete to enable regular cleaning.
In one of the corners of the pen the construction of a resting place with a surface of at least 1.20 × 2.00 m is recommended.
This resting place with clean straw bedding will keep the bull clean.

However, there is ample evidence that bulls remain in good health and maintain a satisfactory level of semen production and fertility when allowed only the freedom of their pens provided that these pens are sufficiently large.

Tying of the bulls in *stalls* can also be satisfactory provided that sufficient attention is paid to size and construction of the stalls.
Keeping the bulls tied in stalls saves considerably in building and labour costs. But it requires regular hoof care (trimming). And the stalls should always have a thick, clean straw bedding to prevent damage to skin and joints.
Stall housing is better than housing the bulls in loose pens which are too small.

Special attention should be paid to *ventilation.* Bull houses must be kept as cool as possible.
When constructing bull houses one should realize that both libido and semen production capacity of bulls are adversely affected by high temperatures.
Even in temperate climates some AI centres have airconditioned bull houses (temperature below 15 °C) for optimum housing of their valuable bulls.

Feeding AI bulls

Young bull calves should be fed a liberal, well-balanced ration in order to obtain maximum growth.
Excess feeding of high-fibre rations should be avoided as this retards growth and causes paunchiness.
Cool, clean water should always be available to the calves. Supply of water by automatic drinking bowls is recommended.

Properly fed bull calves should reach sexual maturity at 12 to 15 months of age.

After the bull has reached the age of 16 to 20 months feeding should become less liberal. At this age the growth rate decreases considerably; the only aim of feeding should now be to keep the bull in good breeding condition.

A breeding sire should never become fat because this has a negative effect on semen production and fertility.

Excess roughage in the ration should be avoided because it leads to paunchiness which adversely affects the sex drive. The ration should be well-balanced and adjusted to the weight of the bull.
Minerals and vitamins in the ration should be properly balanced. Special attention must be paid to carotene in the rations; lack of carotene has proved to affect fertility adversely.
Young, green feedstuffs normally contain enough carotene (vitamin A).

Sudden changes in the composition of the ration should be avoided as they can affect the quality of the semen adversely.
Semen quality changes caused by sudden fodder changes are often not immediately noticed because their effects become apparent after 4-6 weeks only, due to the fact that ripening and maturation of male cells inside the male genital tract takes several weeks.

AI bulls should continuously have free access to cool and clean drinking water.
In hot climates mature bulls can drink up to 70 litres of water per day. Installation of automatic drinking bowls is recommended.

Care and handling of the bulls

Bulls should be kept clipped and groomed and their pens should be kept clean and well-bedded.
The long hairs at the sheath should be clipped regularly and especially the underside of the belly should be kept clean in view of hygienic semen collection procedures.
However, washing the bulls immediately before semen collection is not recommended; for hygienic reasons bulls should be dry during semen collection.

Special attention should be paid to *regular hoof trimming.*
Negligence affects the sex drive and thus decreases semen production.

For safety reasons AI *bulls should be provided with nose rings.* Ringing is best done at an age of 6-8 months.
Many AI centres also dehorn the bulls in the stud for safety reasons.
As bulls are always dangerous in principle they should be handled with care. At least two persons (bull attendants) should always be present when bulls have to be moved or handled, so that one can assist the other in dangerous situations.

Health tests and disease control

The secondary aim of artificial insemination is disease control.
So, AI centres must ensure that bulls are free from infectious diseases prior to their introduction in the centre.

Particular attention must be paid to those diseases that can be transmitted through semen, such as tuberculosis, brucellosis, IBR/IPV, leucosis, leptospirosis, campylobacteriosis and trichomonasis.

Before bulls enter the stud, they should be checked for the presence of the above diseases. Only bulls that are free from these diseases should be accepted.
Moreover, regular health checks (at least twice yearly) are necessary to ensure the maintenance of the disease-free status of the bulls of the centre. Any bull stud should be under continuous veterinary supervision.

Without sanitary precautions AI can rapidly spread contagious venereal diseases rather than being a means for *combating* such diseases.

5 Semen collection and processing

Semen collection methods are described in FERTILITY AND INFERTILITY IN DOMESTIC ANIMALS edited by J.A.Laing, Baillière Tindall - London, and in PRINCIPLES OF DAIRY SCIENCE mentioned in Chapter 2.

Semen collection should take place in a special area. This 'arena' should be large enough to permit safe handling of several bulls at a time.
It should have a roof (protection from rain and sunshine) and it should be in the direct vicinity of the semen processing room to avoid unnecessary delay between semen collection and semen processing.
The floor of the semen collection area should be paved. Semen collection on a dusty or muddy floor will invariably result in contamination of the collected semen.
The floor should not be slippery.

Other bulls or bullocks can be quite satisfactorily used in semen collection (as teaser animals).

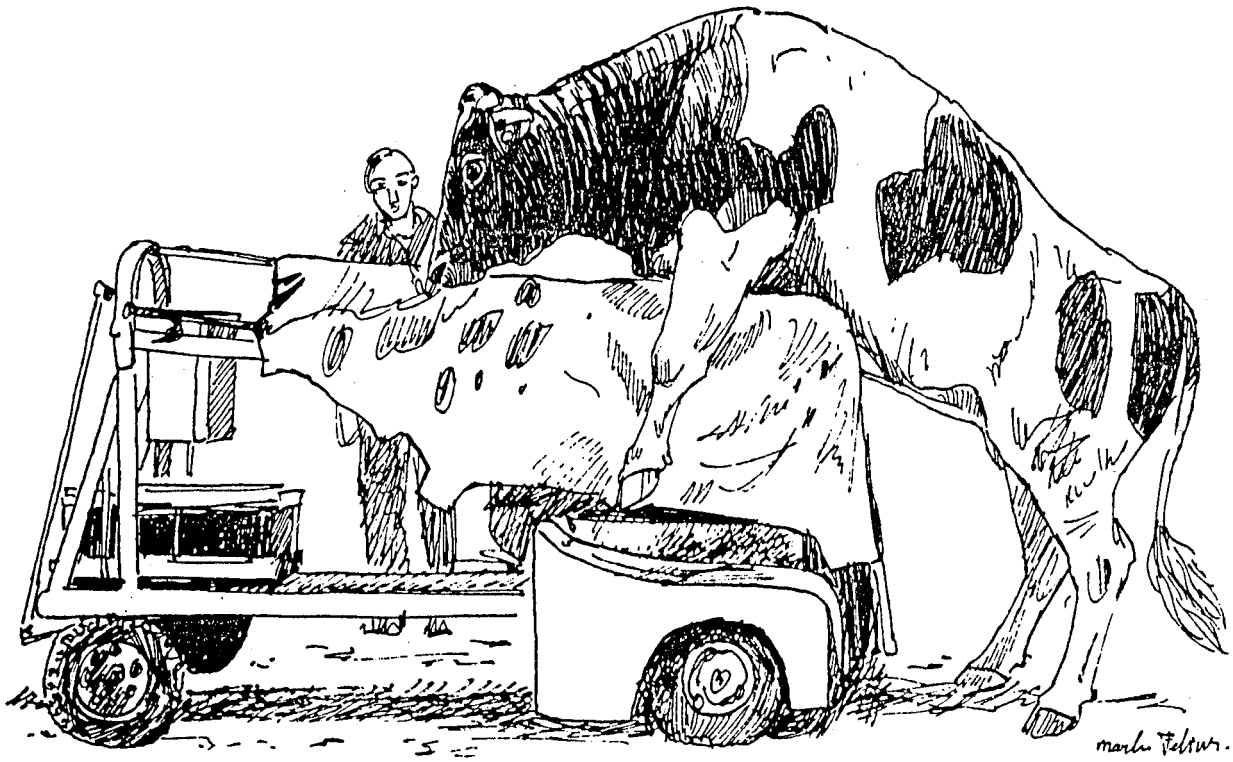

Figure 1: Bull mounts riding dummy cow

The use of dummy cows with a built-in seat for semen collection has the advantage that bending of the penis is no longer necessary. This intensifies thrust and ejaculation which has a favourable effect on the quantity and quality of the semen which is collected.

Artificial vaginas can be recommended for general use in AI centres.

This cannot be said of electro-ejaculation because it is rather dangerous for bulls as well as for bull attendants as there may be muscular spasms.
Moreover, the quality of the collected semen is generally very poor due to the presence of urine and smegma (ie. secretion in folds of the prepuce) and of an increased amount of fluid from the accessory glands.
And experience has shown that electro-ejaculation shortens the productive lifespan of bulls.

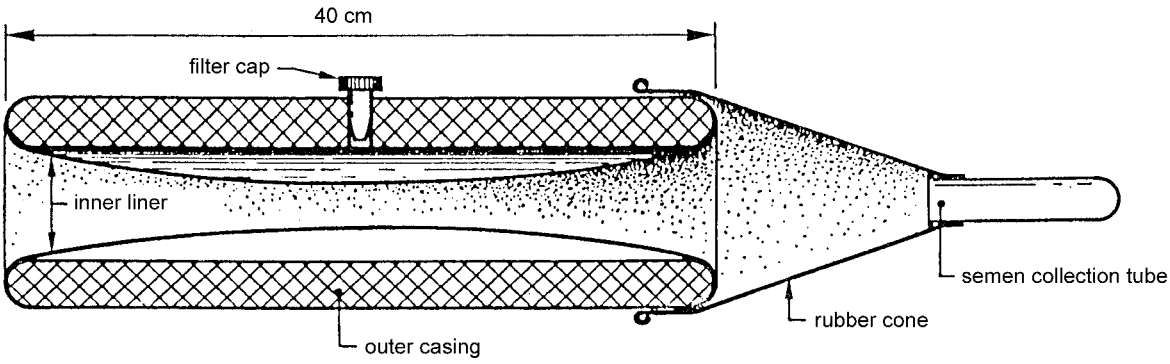

Figure 2: Artificial vagina for the collection of semen of AI bulls

Artificial vaginas should be *properly sterilised* in order to prevent any possible spread of infections between bulls within a centre and to avoid contamination of the semen.
This means that after each use they should be thoroughly cleaned and sterilised in boiling water. Then they should be stored in a clean, dust-free place.
The use of a specially temperature-controlled cabinet for the storage of artificial vaginas can be recommended.

Collection frequency and pre-collection stimulation

It is generally agreed that, when proper semen collection techniques are applied, the average sexually mature bull can be expected to ejaculate at least four times a week without appreciable negative effects.
More ejaculations do considerably increase the amount of semen produced by the bull but require very good collection and stimulation procedures because the bulls's sex drive tends to decrease with this.

Pre-collection stimulation is recommended; this increases both the quality and the quantity of the ejaculated semen.
A commonly applied practice is to allow the bull to perform two false mounts, followed by 1-2 minutes of active restraint, and again one false mount, before semen is finally collected. However, since bulls show great variations in behaviour and temperament, one cannot expect one rigid system to be equally satisfactory for all bulls.
The main aim should be to accustom the bull to a set routine for semen collection. At collection time the important thing is to stimulate the bull to mount the teaser and to ejaculate, in the manner which has been found to initiate the copulatory reflex of the bull in question.

What should be avoided in all cases:
- rough treatment
- sudden moves or loud talking
- artificial vaginas which are either too cold or too hot; their temperature should be 40 to 45 °C

Incorrect temperatures of the vagina will in the long run make the bull refuse to mount and to ejaculate.

Semen evaluation

Semen evaluation methods are described in FERTILITY AND INFERTILITY IN DOMESTIC ANIMALS mentioned above.
There would seem to be a significant correlation between fertility and the following semen characteristics:
- semen morphology (the form of the male cells)

- heat-resistance of semen
- percentage of male cells with intact acrosomes (tips)
- number of motile male cells which are inseminated (ie. cells capable of motion)

Before semen is diluted and processed the following characteristics should be examined at least:

- volume → ejaculates with a volume of less than 1 ml should be rejected (not be kept)
- colour → ejaculates with abnormal colour should be rejected
- consistency → ejaculates with abnormal consistency should be rejected
- concentration → ejaculates with less than 500 million male cells per ml should be rejected
- mass motility → ejaculates without any wave motion should be rejected
- individual → ejaculates with less than 60% motile cells should be rejected motility

Semen morphology:

- where semen morphology is assessed with a phase-contrast microscope, a gross examination of the morphology can be performed during the assessment of individual motility; samples showing abnormal morphology should be morphologically examined;
- where no phase-contrast microscope is available, all semen samples should be morphologically examined prior to processing; ejaculations with more than 20% abnormal cells should be rejected.

After processing and before it is issued for insemination, semen should at least be tested on the following:

- *survival rate* — semen samples in which less than 40% of the cells survive after processing and storage, should be rejected;
- *number of living cells* — samples with less than 6 million motile cells per insemination doses should be rejected;
  the minimum number of motile cells per insemination depends largely on the insemination techniques which are applied; so, in AI organisations with insufficiently trained inseminators the minimum number of living cells should be much higher than 6 million;
- *heat resistance* — semen samples in which less than 25% of the initially living cells survive after four hours storage in a waterbath at 37 °C should be rejected.

Semen processing

Semen processing for the production of liquid semen and handling, storage and distribution of liquid semen are extensively described in FERTILITY AND INFERTILITY OF DOMESTIC ANIMALS mentioned above.
Basic principles for the production of frozen bull semen can be found in the same book.

In recent years the techniques for freezing semen in plastic straws have replaced almost completely all other semen techniques.
Standardised processing techniques for the production of bull semen in straws have been worked out.
On request, the manufacturers or suppliers of equipment for freezing in straws can organise practical, on-the-spot demonstrations to familiarise the laboratory workers with the techniques involved.
It is strongly recommended that in the production of semen frozen in straws, the prescriptions of the straw and equipment suppliers are meticulously followed.

The production of frozen semen requires *much higher investments* in laboratory equipment than the production of liquid semen.
Moreover, machinery and instruments necessary for the production of frozen semen can break down.
Skilled craftsmen for the repair of the rather complicated machinery and equipment must be readily available before the decision is made to switch from liquid semen to frozen semen production programmes. There must also be an ample stock of spare parts.
Refer to following chapter for more details.

6 Fresh semen or frozen semen

The use of frozen semen has the following *advantages:*

- It can be stored for long (indefinite) periods without losing its fertilising capacity and it can be transported over unlimited distances.
  In contrast, fresh semen, even under optimum conditions of buffering and storage, deteriorates rather rapidly and can be used for a maximum period of four days only.
  Thus, with frozen semen wastage is avoided and consequently bulls can be used more efficiently.
- Frozen semen can be distributed to subcentres at intervals of several weeks or even months rather than the three-day-period required by fresh semen; this reduces transportation costs considerably.
- The use of frozen semen also reduces the number of bull semen production units required to cover a given area because frozen semen can be transported in bulk over unlimited distances.
- The use of frozen semen provides increased versatility in breeding plans because a variety of bulls can be made available.

But there are *negative aspects* as well:

- High investments and high running costs are involved in keeping the product (the semen) *continuously* at a very low temperature.
  Keep in mind that an exposure for just a few seconds to temperatures higher than minus 120 °C can already damage frozen semen!
- The constant need for cooling of frozen semen requires a *reliable* liquid nitrogen (LN_2) supply, in sufficient quantities.
  A breakdown in the nitrogen supply can have disastrous effects in AI organisations working with frozen semen.
  Careful planning of liquid nitrogen acquisition and distribution along with ample reserves to overcome temporary breakdowns are essential in a frozen semen operation.
- Frozen semen requires *more skill and accuracy* both from laboratory workers and from inseminators.
  It is easier to obtain acceptable fertility results with fresh semen than with frozen semen.
  Laboratory workers as well as inseminators must therefore be re-trained when an AI programme switches from fresh semen to frozen semen.
  Special attention must be paid to inseminators' techniques because the successful use of frozen semen depends largely on correct thawing and insemination procedures.
  However, experience has shown that it is possible to obtain fertility rates which are quite comparable with those obtained from fresh semen provided that inseminators and laboratory personnel are properly (re-)trained and informed.

Acquisition and distribution of liquid nitrogen

In technically advanced countries and in areas around industrial centres in less advanced countries, liquid nitrogen can often be acquired through bulk suppliers or directly from gas producing plants.
Where this way of liquid nitrogen acquisition is adopted, a *continuous* operation of the gas producing and delivering plant must be guaranteed and road or rail transport must always be available.
However, sufficient quantities of liquid nitrogen should still be kept in store at the semen production unit as a reserve in order to overcome possible breakdowns in the delivery system.

Where outside supplies are not absolutely guaranteed or not available at all, on-site production of liquid nitrogen is recommended.
Compact, self-contained liquid nitrogen producing plants are available on the market, with production capacities ranging from about 1000 to 3500 litres per week.
These plants can be installed at any site where reliable electrical power is available.
But also in this case precautions should be taken to ensure a *continuous availability* of liquid nitrogen:

- the plant must be installed and operated by trained and knowledgeable personnel, strictly according to the instructions of the manufacturer;
- it must be serviced and checked for proper functioning at regular intervals by specially trained craftsmen, preferably under a service contract;
- it is strongly recommended to install a diesel-engined power generator of sufficient capacity and with an automatic starting device, in order to overcome possible breakdowns in the electric power supply;
- it is recommended to store sufficient quantities of liquid nitrogen at all times to overcome possible breakdowns of the nitrogen producing plant itself.

Liquid nitrogen containers

Liquid nitrogen containers differ in evaporation losses, depending on size, construction and quality of the insulation.
The best containers are made of stainless steel or aluminium; they have high-vacuum insulated double walls and are provided with highly efficient insulation materials.

Static holding times of frozen semen storage containers vary between 20 and 100 days, with evaporation rates of 5% down to 1% per day.
Containers with longer static holding are generally larger and not suitable for use in the field.

Small containers designed for field use need liquid nitrogen refills at regular intervals varying from 3 to 40 days depending on size and quality of the container in question.
Liquid nitrogen containers are complicated in construction. They are therefore liable to irreparable damage and should be handled with care.

The insulation capacity of containers diminishes with time, mainly due to loss of vacuum.

It is advisable to have some spare containers available for the immediate transfer of frozen semen in case of a sudden breakdown.

7 Heat detection & timing of insemination

7.1 Heat detection

Once more the topic 'heat detection in cattle', to underline the importance of this topic (see Book I); here specifically in the context of artificial insemination.

As inseminators have to rely on the observations of the farmer or his stockmen, the latter must be encouraged to obtain the highest possible degree of efficiency in heat detection.

Heat symptoms are:

1 *Pre-heat,* lasting 6 to 18 hours
- the cow is restless, alert, her ears are standing up, the eyes are bright and she sniffs the air,
- she licks and approaches other cows; sometimes she moos,
- the vulva is swollen and reddened.

However, not all cows show pre-heat symptoms and not all symptoms may be equally apparent.

2 *Standing heat,* lasting approximately 18 hours or less
- symptoms as mentioned above but more clearly noticeable,
- transparent mucus discharge from the vulva may be observed, mainly in the second part of the standing heat period; however, mucus discharge is a rather poor heat symptom as it can also sometimes be noticed in the midst of the sexual cycle and even in pregnant cows,
- there may be a drop in milk production
- but the MOST IMPORTANT and reliable sign of standing heat is that the cow invites and allows other cows to mount her.

3 *Post-heat,* lasting approximately 10 hours
- all the above heat signs become less apparent and disappear gradually,
- the cow does not allow other cows to mount her any more,
- in many cases some 12 to 48 hours after cessation of the standing heat period, a bloody discharge from the vulva can be noticed (ie. discharge 'with a bloody tinge').

Keep in mind that heat signs are not shown continuously.
During feeding and milking and during the hot periods of the day most cows do not show any heat symptoms at all.
Therefore the best time to observe heat symptoms is during the cooler periods of the day and when the animals are allowed to run free.

Cows which are expected to come into heat or could come into heat (cow calendar! refer to Chapter 11.3) should be observed closely, at least *three times a day,* during which especially the changes in behaviour should be watched.

So, a reliable heat detection is only possible in free running cattle. In permanently housed cattle the symptoms of standing heat cannot be detected at all. In such cases it is advisable to allow the cows to run free in a paddock or in a grazing pasture at least twice daily, under close observation. And this in the cooler periods of the day when the climate is hot (early in the morning and late in the afternoon).
Allowing cattle to run free during the night could be most helpful for a better expression of heat symptoms; but of course at night a herd is difficult to observe properly.

Bos taurus versus Zebu breeds

Normally it is not difficult to detect heat symptoms of Bos taurus cattle in temperate climates.
In the tropics such cattle tend to show slightly shortened and less intense heat symptoms. Moreover, the symptoms are mainly expressed in the period between sunset and sunrise.

But with appropriate measures heat detection of these breeds in the tropics should not be too difficult. Missed heats are generally the result of *negligence* or *lack of knowledge* about heat symptoms and it is usually not the cow which is at fault.
Therefore herdsmen should be instructed how to detect heat symptoms *and* should be motivated to apply proper heat detection methods. In large dairy herds experience has shown that a bonus for any cow seen in heat improved the motivation of herdsmen to watch their cows closely and to record any animal seen in heat.

Many Zebu breeds, however, show heat symptoms less clearly and in most Zebu breeds the true standing heat period appears to be of much shorter duration than in Bos taurus breeds.

The use of vasectomized bulls in Zebu herds is often recommended in order to obtain accurate heat detection.
A cow coming on or going off heat can thus be spotted, because the bull is following her and attempts to mount her, particularly at the onset of true heat. But the cow will not stand for service unless she is actually in heat.
Vasectomized bulls are quite suitable for large herds but not for the peasant herd owner. However, heat detection is mainly a problem in larger herds; in smaller herds the cows are generally under closer observation.

In (large) herds any observed heat should be *recorded immediately,* in an appropriate administrative system.
Such a system makes it possible to predict the date of the next expected heat and this is of great help for proper heat detection. Moreover, it provides the necessary information for the veterinarian in case of breeding problems.

7.2 Timing of insemination

The best conception rates are obtained with inseminations done between 4 to 24 hours after the onset of heat. So, inseminations should be performed in the middle or latter half of the heat period or within 8 hours after cessation of the standing heat symptoms.

Inseminations performed within 4 hours after the onset of the standing heat period result in lowered conception rates.
Inseminations more than 8 hours after cessation of the standing heat symptoms also result in lower fertility; moreover, the risk of causing injury to the genital organs has increased (the uterus is more susceptible to inflammation and the cervix has usually tightly closed again by this time).
Bull semen cells are not capable of fertilisation immediately after insemination. It takes several hours in the cow's genital tract before semen cells are capable of fertilising an egg (ovum).
In normal cows ovulation (ie. the release of an ovum) takes place some 10 hours after cessation of the standing heat symptoms. Unfertilised eggs can survive in the cow's oviduct for a few hours only. Therefore inseminations at too short a time before ovulation result in lowered conception rates as the ovum can be dead already before the semen cells are capable of fertilisation.

On the other hand bull semen can not survive in the cow's sexual organs for a period longer than approximately 24 hours. Therefore too early inseminations will result in the semen cells being dead before ovulation has taken place.

As a general rule it can be recommended that cows seen in heat early in the morning up to 8 a.m. should be inseminated on the same day .....
whilst cows coming in heat later on (that day) should be inseminated the following morning.

In practice, in view of the inevitable delay between the cow being seen in heat and the inseminator arriving at the farm, there is little chance of the insemination being done too early in the heat.
But this risk exists where inseminations are performed by herd owners themselves; here the tendency is to inseminate as soon as heat symptoms are detected.

Suspending inseminations for one day per week reduces the chances of conception in cows in heat on that particular day (and held over to the next day).

Optimum time for insemination after calving

The uterus of a healthy, normal cow has returned to its normal size by about the 28th day after calving.
However, for optimum fertility a much longer interval between calving and insemination is necessary.
Fertility increases with time, up to 90 days after calving and levels out thereafter.

It is generally agreed that a minimum of *60 days* after calving is required to obtain acceptable conception rates, in the case of normal, healthy cows.
A diseased uterus presents a quite different picture in this respect (ie. the interval becomes much longer).

8 Insemination techniques

Insemination must be done properly and this is essential for any AI operation.
Inseminators must be trained in applying the correct techniques and thereafter they must be regularly checked by experienced supervisors on the correct application of these techniques.

Insemination with the use of a speculum is a method that has been widely applied but that has now been largely replaced by the *recto-vaginal technique.* The speculum method found favour because little experience was needed.
However, there were certain drawbacks. One of these was the need for cleaning and sterilizing the speculum after each insemination. Conception rates were not as good as they are with the recto-vaginal technique.
The recto-vaginal technique on the other hand requires considerable practice before proficiency is reached.
See Chapter 12, 'artificial insemination and rectal palpation'.

Proper insemination techniques involve:
- proper identification of the cow before insemination,
- interrogating the farmer in order to obtain a clear picture about the 'history' of the cow,
- careful approach and handling of the cow prior to and during insemination,
- external examination of the cow to be inseminated,
- proper selection of the semen which is required,
- application of correct thawing techniques where frozen semen is used,
- proper preparation of the insemination syringe,
- hygienic handling of syringe and cow,
- thorough rectal examination of vagina, cervix and uterus before actual insemination,
- proper introduction of the syringe into the cervix,
- deposition of the semen at the right spot in the genital tract of the cow,
- correct and legible filling in of the insemination documents after insemination,
- proper cleaning and handling of all materials and equipment,
- correct attitude of the inseminator towards the farmers or their personnel.

These points are elaborated below.

Identification
Before insemination, the cow to be inseminated should be properly identified by checking her against the individual cow card which is presented by the farmer.

For every new cow to be inseminated, the inseminator has to hand over a cow card to the owner.

The cow card remains with the cow (ie. the owner).

COW CARD

OWNER	Farm Number: Name:											
	Address:											
COW	Ear Notch Number: Breed:											
YEAR	1st insemination			2nd insemination			3rd insemination			4th insemination		
	date	number	bull	date	number	bull	date	number	bull	date	number	bull

Figure 3: Cow card

Before the cow is inseminated, the inseminator must ask for the cow card, in order to
- identify the cow to be inseminated
- find out whether it is a first or a repeat insemination
- find out whether the cow could be pregnant or not
- know the data of the previous insemination

For new cows to be inseminated the inseminator should make up an individual cow card prior to insemination.
This cow must show the required identification marks.
With spotted cows identification can be based on colour markings, but in evenly coloured cows tattooing, ear marks or ear notching is required for proper identification.
Marking of cows is easiest done with ear marking pliers. Where this system is adopted, every inseminator should be thoroughly familiar with the international ear notch code (see following page).

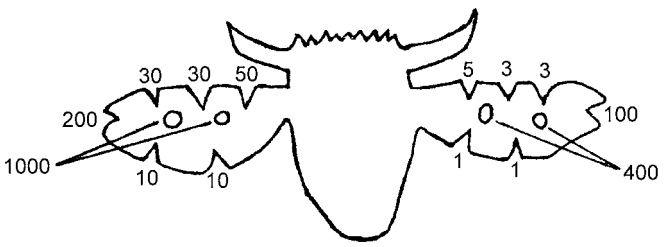

Figure 4: The international ear notch code

The individual cow card should be left with the cow and at every following insemination this cow card should be shown by the person who presents the cow.
The cow card provides valuable information:
- is it a first or a repeat insemination?
- in case of a repeat insemination, the length of the preceding sexual cycle;
- the number of previous calvings;
- the age of the cow;
- and possibly other information.

The 'history' of the cow

Before starting with the actual insemination, the person presenting the cow (possibly the owner) should be asked about when the cow calved and whether any abnormal discharge or abnormal behaviour was noticed.
Cows should not be inseminated within 60 days after normal calving and not within 90 days in case of an abnormal calving or in case of abnormalities after calving.
Cows which have shown abnormal discharge from the vulva in the three-weeks period prior to present insemination should also be refused.

External examination

The next thing to do is the external examination of the cow:
- the tail, the vulva and adjacent parts should be carefully checked for the presence of mucus or purulent discharge;
- are there signs of standing heat on the rump or the tailhead - a cow that has been mounted is likely to show mud or scars on these areas;
- open the lips of the vulva with the fingers and check the clitoris and the mucous membranes; in case of abnormal discharge, flocks of pus are likely to be detected on the clitoris;
- cows which show abnormalities in external examination should be refused for insemination and the farmer should be advised to consult a veterinarian.

Selection of the semen

Semen containers should be opened only after the cow to be inseminated has been properly identified and examined.
In selecting the required semen in the container, take care not to warm up the semen in the container.

Liquid semen can be used immediately, but frozen semen must be thawed prior to insemination.

Thawing of frozen semen

Ampoules and straws require thawing water of 35 °C. It is strongly recommended to use a thermos flask for carrying thawing water of correct temperature. The temperature of the thawing water should be carefully checked with a thermometer. If necessary, the temperature should be adjusted by adding either hot or cold water until the correct thawing temperature is reached.

Pellets are thawed in 1 ml of a special thawing solution at a temperature of 35 °C. The thawing solution should be packed in ampoules of 1 ml and carried in a thermos flask with water of exactly 35 °C.

A metal tweezer should be used to take a dose of frozen semen out of the liquid nitrogen container; the points should be cooled down in the liquid nitrogen for a few seconds before the semen dose is touched.
After the semen dose has been taken out of the container, it should be thawed immediately, as rapidly as possible.

Pellets are immediately transferred into 1 ml of the special thawing solution at 35 °C for at least 35 seconds; in this way optimum survival rates will be obtained.

Thawed semen must be used for insemination as soon as possible and in any case within one hour after thawing.
Once thawed, semen should never again be put back in liquid nitrogen as this will destroy the semen immediately.

Preparing the syringe (also called 'pipette' or 'pistolet')

The syringe should have about the same temperature as the thawed semen. Syringes which are too cold or too hot can damage the semen.
If necessary, the temperature of a syringe can be raised by rubbing it with a clean piece of paper; or lowered by moving it in the air.
Sterile, disposable plastic syringes should be used for liquid semen, ampoules and pellets.
Special metal syringes are required for insemination of semen packed in straws; they are covered with a sterile, disposable plastic sheet prior to insemination.
The sterility of the syringe should be preserved throughout the whole operation; syringes should only be handled at the rear end to avoid contamination.
It is recommended to hold the loaded syringe between the teeth while the cow which must be inseminated is approached.

Rectal examination of the cow

- One hand is gloved and the glove is lubricated with a special, non-irritating lubricant;
- approach the cow with the syringe kept in the mouth. Insert the gloved hand in the rectum with gentle movements (bending of the tail should be avoided as this might upset the cow);
- if necessary, remove the dung from the rectum with gentle hand movements;
- carefully palpate the cervix and the two uterine horns. If the cervix is soft and pliable and if the uterine horns are rigid and contract on palpation, the cow is likely to be in heat;
- however, if the cervix is hard and rigid and the uterine horns soft and flappy, it is unlikely that the cow is in heat;
- the two uterine horns should be carefully checked for endometritis, pregnancy or abnormalities;
- cows with abnormalities or without obvious heat signs should **never** be inseminated;
- *avoid touching the ovaries* during rectal palpation. Palpation of the ovaries of cows in heat can provoke rupture of the follicle and then the cow will no longer be able to conceive.

Introduction of the syringe (after everything has been found to be in order)

- After the genital tract has been examined by rectal palpation, the arm in the rectum is withdrawn until only the hand remains in the rectum;
- clean the vulva with the free hand, with a dot of cotton wool, a towel or a piece of toilet paper. An inseminator should always carry cleaning material in his trouser pocket, at the side of his free, ungloved hand;
- after the vulva has been cleaned, apply gentle pressure with the palm of the hand which is in the rectum, in order to push down the vulva somewhat. This will open the vulva;

- only at this moment is the syringe taken out of the mouth. Insert the tip of the syringe into the vulva and in doing this avoid touching the gloved arm or the cow herself;
- push the gloved hand toward the cervix. At the same time gently force the tip of the syringe to follow this movement alongside the roof of the vagina;
- next the gloved hand takes hold of the cervix, closes the fornix with the fingers and gently massages the cervix over the tip of the syringe. This action is *difficult to perform* and requires a lot of experience.

Note that the syringe should *never be pushed into the cervix* as the cow could be badly damaged when this is done.
The syringe should always be kept parallel with the gloved arm in the rectum. The hand in the rectum is supposed to do the job.

Deposition of the semen

In case of a *first* insemination the semen should be deposited just in front of the internal opening of the cervical canal in the uterus. The syringe should **not** enter the uterus itself as this can cause serious injury to the uterine wall.
In case of *repeat* insemination there is the possibility that the cow is actually pregnant. Therefore it is recommended to deposit the semen in repeat inseminations between the third and the fourth cervical ring (or fold) and **not** to pass the cervix completely.

All the semen should be deposited at the same site. Withdrawal of the syringe during the emptying should be avoided.

Checks after insemination

- After insemination, withdraw the gloved hand from the rectum. With the same movement withdraw the syringe from the genital tract;
- then carefully check the tip of the syringe for the presence of pus or blood. If **pus** is detected at the tip of the syringe, there must be a purulent inflammation of the cervix or the uterus:
  - the farmer should be advised to consult a veterinarian
  - the inseminator himself/herself should improve his insemination techniques as referred to earlier, because this condition should have been discovered before performing the actual insemination

    If *blood* is detected at the tip of the syringe, this was caused by damage due to poor introduction techniques and the inseminator must improve his/her techniques.

Gentle handling of the cow

In order to obtain good conception rates cows should be handled gently and in a friendly way. Cows must find the insemination pleasant; otherwise the semen will not be transported to the right place after insemination. The following helps in this respect:
- apply sufficient lubricant;
- avoid bending or touching the tail;
- nails should be clipped short, to avoid damage to the rectal wall;
- all movements in the rectum should be executed gently and carefully;
- do not apply force when inserting the syringe and when passing the cervical canal.

Cleaning

After insemination, hands, boots and equipment should be cleaned carefully.

All insemination equipment should always be *impeccably clean* and stored in clean bags or boxes.

Recording

After insemination fill in:

- the cow card;
- the insemination ticket (or insemination certificate); refer to following page.
- To be bound in booklets of 200 sheets, prenumbered in duplicate, and perforated at the top side.
- To be filled up with a sheet of carbon paper between the two sheets of a set.
- The first ticket to be handed over to the farmer, the copy ticket to be handed in at the main centre at least once a week.
- Every inseminator uses his own ticket book, so that the insemination number can be linked to the person who performed the insemination.

INSEMINATION TICKET

---------- (perforation) ----------

ARTIFICIAL INSEMINATION TICKET

Name inseminator: .....
code number : .....

FARM	Farm Number:	Name:
	Address:	
COW	Ear Notch Number:	Breed:
INSEMINATION	Date (year/month/day):	Bull:
PREVIOUS INSEMINATION	Date (year/month/day):	Insemination Number:

RECEIPT I hereby declare that I have received the amount of M .....
for the insemination of the above-mentioned cow.

....

(date) (signature)

Figure 5: Insemination ticket

9 Record keeping in an AI operation

An AI organisation must have an efficient record keeping system. The office of the main centre must have all the attributes of any medium-size thriving business concern.
It is not an exaggeration to say that *without efficient record keeping any AI programme is doomed to failure.*

One should not underestimate the amount of work involved in an efficient record keeping system.
Thousands of inseminations should be related to the end result, entered on farm record cards and used for the compilation of monthly statistics per area, per bull and per inseminator.
Non-return rates have to be calculated monthly, per bull and per inseminator.
The bull semen production unit must keep records of each semen collection, its quality, dilution rate, storage time, etc.
Lastly, financial records on money received, cash disbursements, etc.,require standard bookkeeping systems.

As a programme grows, it is wise to consider the use of **electronic data processing** for statistical compilation and analysis.
Although the initial investment may appear to be high, considerable time savings are possible and financial management is greatly simplified.
Modern data processing systems provide high processing power at moderate cost and may even be leased on a monthly or yearly basis.

In the following a simple record system is presented; it is designed for *hand operation.*
Its application can be recommended in small or medium-sized AI operations.
It is based on a system of **one** paid insemination followed by up to three repeat inseminations **and** on collection of insemination fees by the inseminators, but it can be adapted to even any other insemination system.

9.1 Example of a simple record keeping system

The inseminator must fill in **two** documents for each insemination namely the *insemination ticket* in duplicate and the *cow card.*
Moreover, he must cash the insemination fee which is due.

The insemination ticket

The inseminator must fill in an insemination ticket for **every** insemination.
An example of an insemination ticket is presented on page 42.
The insemination tickets are pre-numbered in duplicate:

- one copy is handed over to the farmer and serves as a receipt
- the other copy is handed in to the main centre; this is done at least once a week

The total number of straws used by the inseminator should be the same as the number of tickets handed in at the main centre.

In case a mistake is made in filling in the ticket, the inseminator must cross the ticket and must hand in **both** copies to the main centre.

Sometimes straws are thawed without being used for an insemination. Such straws must be kept and handed in to the main centre as so-called ‘unused straws’.

It is important that every inseminator uses his own pre-numbered ticket book and that for every inseminator the ticket numbers are different. Thus every insemination can be traced back to the inseminator who performed it, by its insemination number.

In case an insemination is performed in a new herd, the number of the farm is not known. In that case the inseminator leaves the space after 'Farm Number' open and he writes on the ticket 'New Farm'. Upon receipt of such a ticket in the main centre this farm can be given a number.

The cow card

The inseminator always carries a sufficient number of cow cards with him. For every new, not previously inseminated cow, a cow card is filled in; if necessary, the cow concerned is identified by ear notching, by the inseminator.
An example of a cow card is given on page 36.
The cow card remains with the cow and must be presented by the farmer to the inseminator.
The inseminator must check the cow card before inseminating the animal; it gives important information to the inseminator:

- is it a first or a repeat insemination
- the length of the preceding sexual cycle (in case of a repeat insemination)
- the age of the cow
- the number of previous calvings

Moreover, the cow card is the only means to identify the cow properly before insemination.

Remember: no insemination without prior identification!

Transfer to the main centre

At least once a week all subcentres must hand in

- the insemination tickets
- the insemination fees which have been collected
- the 'unused straws'

The main centre issues receipts to the subcentres. Each receipt must be countersigned by the senior inseminator of the subcentre concerned.
A duplicate of the receipt is given on page 50.

Semen stock inventory

The main centre keeps a semen inventory book (on page 51).

The number of insemination tickets received plus the number of 'unused straws' from a subcentre must be the same as the number of straws issued to this subcentre minus the semen stock in the subcentre.

The semen stock in a subcentre should regularly be checked by the main centre.

It is advisable to keep the semen stock in the subcentres as small as possible in order to facilitate the administration.

The amount of 'unused straws' should be kept as low as possible.
Inseminators who spoil relative large amounts of straws must be warned. They should thaw the straws more carefully and should more consciously select and identify the cows **before** insemination.

Membership registration

The main centre keeps a register of membership.

All farms that make use of AI are provided with a farm number.
Make an entry in the register every time when a ticket is received with the mention 'new farm'; for this farm a new number should be issued.

It is advisable to coordinate the register of membership with that of other dairy organisations (if existing) so that all organisations work with the same farm number for the same farm.

A copy of the register of membership must be available at each subcentre and these copies must be kept up to date.

Financial administration

The total amount of insemination fees to be received from the subcentres can be calculated from the insemination tickets received.

Fees are cashed by the main centre against issue of a receipt countersigned by the subcentre concerned.
This receipt is made up in duplicate; one copy is issued to the subcentre and the other is kept at the main office.

The main centre keeps book on all incomes per bull and per inseminator.

Bull and inseminator statistics

The main office keeps
- one bull book for every bull in use
- one inseminator book for every inseminator employed

Examples are given on pages 51 and 52.
The directions for use of these books are as follows.

Upon receipt of the insemination tickets, these are first assorted according to insemination number.
Thereafter all insemination tickets are entered in the respective inseminator books.
One line is used for each insemination.

In case of a **repeat** insemination, the number of the preceding insemination is **underlined**.

After that the tickets are assorted per bull and within bulls in numerical sequence.
Now the information of the tickets can be entered in the respective bull books.
Here again, for each repeat insemination the number of the preceding insemination should be **underlined**.

In case this preceding insemination was a first insemination, in the column under 'number' a **2** is entered. A **3** is entered in the column under 'number' where the preceding insemination was a second insemination and so on.
This is a check on the correct cashing of insemination fees by the inseminators.
Where a **4th** insemination is registered, the inseminator must have cashed and handed over an insemination fee.

Information about the results of P.D.'s (pregnancy diagnoses) must also be entered (in the bull book as well as in the inseminator book), as soon as it becomes available.

One page must be used (if necessary one double page) for each month. This holds for the inseminator books as well as for the bull books.

Farm record cards

Finally the insemination tickets are assorted according to farm number and entered on farm record cards.
An example of a farm record card is given on page 54.

These cards are useful; for instance when a farmer reports too many repeat inseminations (or other problems), or when incorrectly completed AI certificates must be adjusted.

They can also help veterinarians making pregnancy diagnoses or investigating fertility problems.
In areas where milk recording systems exist, copies of the farm records should be sent to the milk recording office at least twice yearly, for pedigree registration of newborn calves.

10 Calculation of fertility rates

Calculation of fertility rates IS A MUST. It is done in order
- to check and to supervise the quality of the work done by the individual inseminator
- to check the semen quality of the individual bull

The *only absolute way* in which fertility from artificial insemination can be assessed is from the number of calves born. But even this does not give a true measurement of conception unless it takes into account the number of calves which are aborted.

Making enquiries at about the expected date of calving (some 280 to 300 days after the last insemination) can give valuable information about the productivity of the AI service in terms of number of calves produced.
It also provides very useful information about the average gestation period, the average birth weight, the occurrence of calving difficulties, the number of stillborn calves and inborn defects at birth; this can be related to the bulls which have been used.

However, the above method cannot be used to monitor the conception rates of sires and inseminators (so to speak), because the interval between insemination and calculation of fertility rates is over nine months ..... much too long to take adequate action in case of low fertility rates!!

Therefore methods of making earlier estimations of fertility rates have been developed.
One obvious method would be *pregnancy diagnosing* all inseminated cows some six to twelve weeks after the last insemination. But this is expensive and time-consuming and experience has shown that it is often difficult to get full cooperation of all farmers needed to check all inseminated cows on pregnancy.

Hence most AI organisations calculate conception rates as *non-return rates from first insemination:*
- the 30-60 days non-return percentage (so-called % 30-60 NR) is the percentage of cows and heifers inseminated for the first time that were **not** reported as requiring a repeat insemination at the end of the month following that in which they were inseminated;
- the 60-90 days non-return percentage is the percentage of cows **not** reported in heat at the end of the **second** month following that in which the first insemination was performed.

Note that calculation of non-return rates is **not** an exact measure of fertility; other factors may be involved such as the failure of the farmer to request a repeat insemination if the first insemination was not successful.

The average difference between the % 30-60 NR and actual pregnancy rate is approximately 20%; that between 60-90 NR and actual pregnancy rate 10%.

Actual calculation

At the end of each month, as soon as all inseminations of the month in question have been entered, in the inseminator books as well as in the bull books, calculate the fertility rates *before entering new tickets* from inseminations performed in the next month.
As follows.

1 Count *all* inseminations performed during the month, in the bull book as well as in the inseminator books
   - the number calculated from the combined bull books should be the same as the number calculated from the combined inseminator books (a check).

2 Count all *first* inseminations performed during the month, in the bull books as well as in the inseminator books
   - the number obtained by summing up the countings of the inseminator books should be the same as the number obtained by summing up the countings of the bull books.
3 Count in each book *all underlined first* insemination numbers in the *preceding* month. So, for instance at the end of July, count all underlined first insemination numbers from June
   - the difference between the number of *all* first inseminations performed in one month and the number of *underlined* first inseminations in the same month provides (when calculated) at the end of the next month the number of 30-60 days non-returns
   - the % 30-60 NR can then be calculated by dividing this number of non-returns by the number of first inseminations in the same month and multiplying the quotient by 100.
4 Count in each book all *underlined first* inseminations from two months ago. So, for instance at the end of July, count all underlined first inseminations from May
   - the difference between the number of **all** first inseminations performed in one month and the number of *underlined* first inseminations in the same month provides (when calculated) at the end of the second following month the number of 60-90 days non- returns
   - the % 60-90 NR is calculated by dividing this number of non-returns by the number of first inseminations in the same month and multiplying it by 100.
5 Count in each book the number of P.D.'s after *first inseminations* performed in the month in question **and** the number of cows confirmed to be pregnant after P.D.
   - the number of pregnancies *after first inseminations* divided by the number of P.D.'s *after first inseminations* and multiplied by 100 provides the *conception rate.*

Keep in mind: fertility rates as well as conception rates are only calculated from **first** inseminations.

Monthly statistics

At the end of each month a report should be made on each bull and on each inseminator.
Examples of such monthly reports are given on pages 55 and 56.

The figures on the bottom line of the monthly bull report (the overall total) should be the same as those of the monthly inseminator report.

A copy of the monthly bull report should be sent to the producers of the bull semen.
In case one of the AI used bulls shows fertility rates that are significantly lower than the mean fertility rate of the month in question, the head of the bull semen production centre should be contacted. He should take measures either to improve the semen quality of the bull under question or to replace it by semen from a more fertile bull.

Poor fertility rates of inseminators **can** be due to the fact that the semen used is from bulls which are not very fertile.
If this can be ruled out (because colleagues obtained good results) measures should be taken to improve insemination techniques of these inseminators.

Finally, **overall monthly statistics** are prepared (see page 57). They serve for management appraisal and improvement.

The management of an AI operation should aim at:
- an increase of the number of first inseminations
- an increase of the % 60-90 NR
- a decrease of the LN_2 consumption per insemination
- a decrease of the distance covered per insemination (kms)
- an increase in income from insemination fees
- a decrease of the number of straws used per first insemination

- To be made up in duplicate.
- One copy to be handed over to the inseminator at presentation of his tickets and unused straws, the other copy to be held in stock.

TO SUM UP:
THE BEST POSSIBLE SERVICE
AT THE LOWEST POSSIBLE COST !!!

RECEIPT FOR TICKETS AND FEES

RECEIPT

Received from inseminator ....
(Number) (Name)

..... tickets, from No. ..... to No....., all included
(number)

and..... unused straws
(number)

SPECIFICATION

.....	tickets 1st at	.... = ...	.... straws bull ....
.....	tickets 1st at	.... = ...	.... straws bull ....
.....	tickets repeat at	.... = ...	.... straws bull ....
.....	tickets repeat no fee		——— +
.....	tickets fault		..... straws unused
——— +		——— +	
.....	tickets	..... (money)	

DATE: ..... Signature: .....

COUNTERSIGN INSEMINATOR: .....

---

* To be made up in duplicate.

* One copy to be handed over to the inseminator at presentation of his tickets and unused straws, the other copy to be held in stock.

Figure 6: Receipt for tickets and fees

SEMEN INVENTORY BOOK

BULL:

DATE	NUMBER OF STRAWS				
	RECEIVED	FROM	ISSUED	TO	BALANCE IN STOCK

Figure 7: Semen inventory book

BULL BOOK

Note: - one book per bull
- one (double) page per month

BULL: MONTH:

DATE	Ins.No.			P.D.		DATE	Ins.No.			P.D.		DATE	Ins.No.			P.D.	
	1st	repeat	No.	date	+/-		1st	repeat	No.	date	+/-		1st	repeat	No.	date	+/-

Ins.No. = insemination number
P.D. = pregnancy diagnosis

Figure 8: Bull book

INSEMINATOR BOOK

Note: - one book per inseminator
- one (double) page per month

INSEMINATOR NAME: MONTH:
No. :

DATE	Ins.No. 1st	Ins.No. repeat	BULL	P.D. date	P.D. +/-	DATE	Ins.No. 1st	Ins.No. repeat	BULL	P.D. date	P.D. +/-	DATE	Ins.No. 1st	Ins.No. repeat	BULL	P.D. date

Figure 9: Inseminator book

FARM RECORD CARD

THE _____ ARTIFICIAL BREEDING ASSOCIATION

MEMS. PAID	ASS 'T. FWD

REGISTRATION AND EAR TAG NUMBER OF COW	DATE BRED	BULL	DATE RE-BRED	BULL	DATE RE-BRED	BULL	DATE RE-BRED	BULL	REMARKS	SERVICE 1st	SERVICE 4th

DATE JOINED		BREED	D.H.I.A.	SIZE OF HERD FEMALES OVER 6 MO.	STERILITY DISEASE?
LOCATION		PHONE			
OWNERS NAME		ADDRESS			

FOR THE FISCAL YEAR ENDING _____ 19 ____

Figure 10: Farm record card

MONTHLY REPORT PER BULL MONTH:

BREED	BULL	NO. OF IN-SEMINATIONS IN MONTH	NO. OF FIRST IN-SEMINATIONS IN MONTH	FERTILITY RATES		CONCEPTION RATE		SEMEN STOCK FLOW			MONEY CASHED
				% 30-60 d. N.R. 1 MONTH AGO	% 60-90 d. N.R. 2 MONTHS AGO	NO. OF P.D.'s AFTER FIRST INS.	% OF POSITIVE P.D.'s AFTER 1st INS.	RECEIVED IN MONTH	ISSUED IN MONTH	SEMEN STOCK PER END OF MONTH	
BREED SUBTOTAL											
BREED SUBTOTAL											
OVERALL TOTAL											

Figure 11: Monthly report per bull

Figure 12: Monthly report per inseminator

MONTHLY REPORT PER INSEMINATOR

MONTH: .....

DISTRICT	INSEMI-NATOR NO.	NUMBER OF INSEMINATIONS PERFORMED IN MONTH:						FERTILITY RATES		CONCEPTION RATES		MONEY CASHED	KMS COVERED
		1st	2nd	3rd	4th	4th	total	% 30-60 d. N.R. 1 month ago	% 60-90 d. N.R. 2 months ago	No. of P.D.'s after 1st ins.	% of posi-tive P.D.'s after 1st ins.		
DISTRICT SUBTOTAL													
DISTRICT SUBTOTAL													
OVERALL TOTAL													

MONTHLY STATISTICS

MONTH: .....

A. PER DISTRICT

DISTRICT						**TOTAL**
Number of inseminations						
Number of 1st inseminations						
% of total						
% 60-90 days NR						
Litres LN_2 per insemination						
Kilometres per insemination						
Total amount cashed						
Number of straws per 1st insemination						

B. PER BREED

BREED						**TOTAL**
Number of bulls						
Number of inseminations						
Number of 1st inseminations						
% of total						
% 60-90 days NR						
Number of doses received						
Number of doses issued						
Semen stock						
Number of doses used per 1st insemination						

Figure 13: Monthly statistics

11 Miscellaneous

11.1 Training of inseminators

It is very important that inseminators receive a thorough theoretical and practical training before they are allowed to inseminate cows in the field.
In many countries there are special training facilities for inseminators.

The practical work should be organised and supervised by qualified and experienced instructors.
A sufficient number of cows of different breeds (if possible) and of different age should be readily available so that the trainee-inseminators have every opportunity to practise the skills which must be acquired during the training course.

Practical training is best done in *slaughterhouses:*

- unexperienced trainee-inseminators can cause serious damage to the genital organs of cows in trying to inseminate these cows;
- slaughterhouses provide the possibility to examine cows after slaughtering for internal damage caused by insemination;
- if colour dyes have been used for insemination, it is possible to check whether the 'semen' has been deposited in the right spot in the genital tract of the cow.

Methylene-blue solution in agar is widely used for this purpose.
The use of a specially designed battery-operated searing syringe has the advantage that even in cows slaughtered up to 48 hours after insemination the site of deposition of the 'semen' can still be detected.
When only a colour dye is used, the cows must be slaughtered as soon as possible because the dye tends to spread throughout the cervix and uterus rather rapidly.

Only **thoroughly trained** inseminators, capable of depositing the semen at the right spot without damaging the cow should be allowed to perform inseminations in the field.

The practical training (in the slaughterhouse) should be accompanied by theory lessons on reproductive anatomy and physiology, semen handling techniques, hygiene and disease prevention, with demonstrations and exercises wherever necessary.
Moreover, the trainees should learn the basic facts about dairy farm management, cattle genetics and breeding.

Although not strictly necessary it can be recommended that trainees learn to detect gross abnormalities of the sexual organs of the cow and to carry out pregnancy diagnoses.

The work done by inseminators in the field MUST BE MONITORED CONTINUOUSLY and INDIVIDUALLY (how is his/her 'conception rate'?). Those showing poor results must either be retrained or replaced.

Many AI organisations provide regular practical and theoretical refresher courses for their inseminators. This is a very good way to ensure optimum conception rates.

11.2 Artificial insemination in buffaloes

The domestic buffalo (Bos bubalis) is an important dairy animal in many parts of Asia (apart from being a draught animal). Also in the Middle East (especially Egypt, Iraq and Turkey) buffaloes contribute significantly to dairy production.

What are the differences as far as reproduction and artificial insemination are concerned:

1 The fertility of buffaloes is definitely lower than that of cattle.
  Buffaloes reach sexual maturity at least six months later than cattle and also the calving interval of buffaloes is significantly longer than that of cows.
2 The male buffalo is more easily trained for artificial insemination than the bull.
  Many buffaloes will ejaculate into the artificial vagina at the first attempt.
  The buffalo is also less discriminating with respect to a teaser and does not require as much pre-collection stimulation.
  The thrust given by a male buffalo at the time of service is much less forceful than that of the bull.
  Artificial vaginas for buffaloes should have a lower temperature than those used for bulls; the optimum temperature is 39 to 41 °C.
3 The volume and concentration of the semen obtained from male buffaloes is less than that obtained from bulls and there is relatively much seasonal variation.
4 Buffalo male cells can readily be distinguished from bull cells by the shape of the heads of the cells. Buffalo male cells rather look like those of the ram (male sheep) in outline, but buffalo cells are shorter and narrower.
5 Nonetheless buffalo semen can be processed in exactly the same way as bull semen.
6 Insemination of the female buffalo can be done by the recto-vaginal technique as in the cow. However, manipulations through the rectal wall must be carried out more gently and more carefully than in the cow because the capillaries in the rectal wall of the buffalo appear to be more fragile and they tend to bleed readily.
7 The heat tolerance of the buffalo bulls is lower; therefore particular attention must be given to shelter requirements of buffalo bulls kept in studs.
  During hot summer months the bulls should have free access to clean wallows or, if that is not possible, should be given cool showers or splashed with cool water daily.
8 Special care must be taken to prevent fighting between buffalo bulls; they are inclined to be more aggressive than cattle.
  Dehorning of buffalo bulls is seldom practised because the horn is greatly valued as a breed characteristic.

11.3 Aids to heat detection

An **effective recording system** is the most important aid to heat detection.
It may begin with a small notebook carried ‘in the field’, to make notes of cows seen in heat.
Every heat should be noted down, even if the cow in question is not due to be served or inseminated. In this way it is possible to predict the date of the next heat so that the cow can be watched carefully at that time. Conversely, if a cow is suspected to be in heat, if there is a record of the previous heat (about 21 days ago), this will help to establish the fact that the cow is in heat.
This ‘basic field notebook’ necessary with larger dairy herds must be followed up by a proper recording system at home or in a suitable place at the farm.

A simple and effective aid is a so-called *21-day-calendar,* as shown below. For the year 1999, 25,26 and 27 January 66 21 days later is 15, 16 and 17 February 66 21 days later is 8,9 and 10 March, and so on.

January	February	March	and so on.
.....	.....	.....	
.....	.....	.....	
25	15	8	
26 **X**	16 **X**	9	
27	17	10	
.....	.....	.....	
.....	.....	.....	

This calendar shows at a glance that cow X recorded in heat on 26th January, is due again on 16th February.

A more sophisticated aid is the **disk model cow calendar.** It is also called 'breeding wheel'.
It can be bought internationally; there are various models. It can also be home-made, in a carpenter's shop. It should be installed near the cows: farm office, dairy room, a store or any other convenient place. For a picture, see page 10 of the STOAS publication **'Guide to Effective Teaching'.**

The following is a description of a disk model cow calendar with a revolving disk and fixed indicators.
See illustration on page 63.

The disk is divided into 12 sections. Each section represents one month and is sub-divided into days.

The fixed indicators indicate successively:
- the insemination date (or date of natural service),
- the date on which pregnancy has to be checked (21 days after the insemination date),
- the date of drying off (seven months after the insemination date),
- the (expected) calving date (nine months after the insemination date),
- sometimes a second pregnancy check indicator is used (six weeks after the insemination date). The disk is further divided into four or five circles, from its centre. These circles serve to indicate first, second, third, etc., insemination/natural service.

Normally the *insemination date is the starting date.* Every day the disk is turned by one day.

The cows are represented by their names or by their numbers, which can be moved and stuck on the disk, one way or another.

How to proceed

Insemination
Today is April 21st (assumption). The cow which is on heat today is inseminated and its number is placed under the insemination indicator, in the outer circle.
Three weeks later (May 12th), the number of this cow has come under the (first) pregnancy check indicator.
If the cow comes on heat again, she is again inseminated and her number is again placed under the insemination indicator (May 12th). The number is now placed on the second circle, to indicate that it is a second insemination.
Some cows come back after six weeks, hence the second pregnancy check indicator.

Drying off
The cow which has been inseminated on April 21st, arrives under the drying off indicator on November 21st. The cow should then be dried off.

Calving
Two months after drying off the cow arrives under the calving indicator. In case actual calving takes place before or after the expected calving date, on the actual calving date the number is placed under the calving indicator.

After calving
When the cow comes on heat for the first time after calving, it is usually too early to inseminate. Depending on the date and the desired calving interval, the number is placed 1, 2 or 3 periods of three weeks before the insemination indicator.

Daily use
One glance at the calendar will give the farmer (or the person who is responsible) sufficient information. Only cows whose numbers are under (or near) an indicator, need attention as far as insemination, pregnancy checking, drying off and calving is concerned.

Finally, the disk model cow calendar is a relatively sophisticated tool. Quite often, especially on the smaller dairy farms, a *simple card system,* with a card for every individual cow, will be more appropriate.

The next page shows an illustration of the disk model cow calendar.

Other aids to heat detection in dairy herds are:
1 heat mount detector
2 closed circuit television
3 a teaser bull (vasectomized; see page 32)
4 movement detector
5 temperature measurement

The above aids to heat detection (with the exeception of **3**) are associated with technically advanced ('computerized') dairy enterprises.

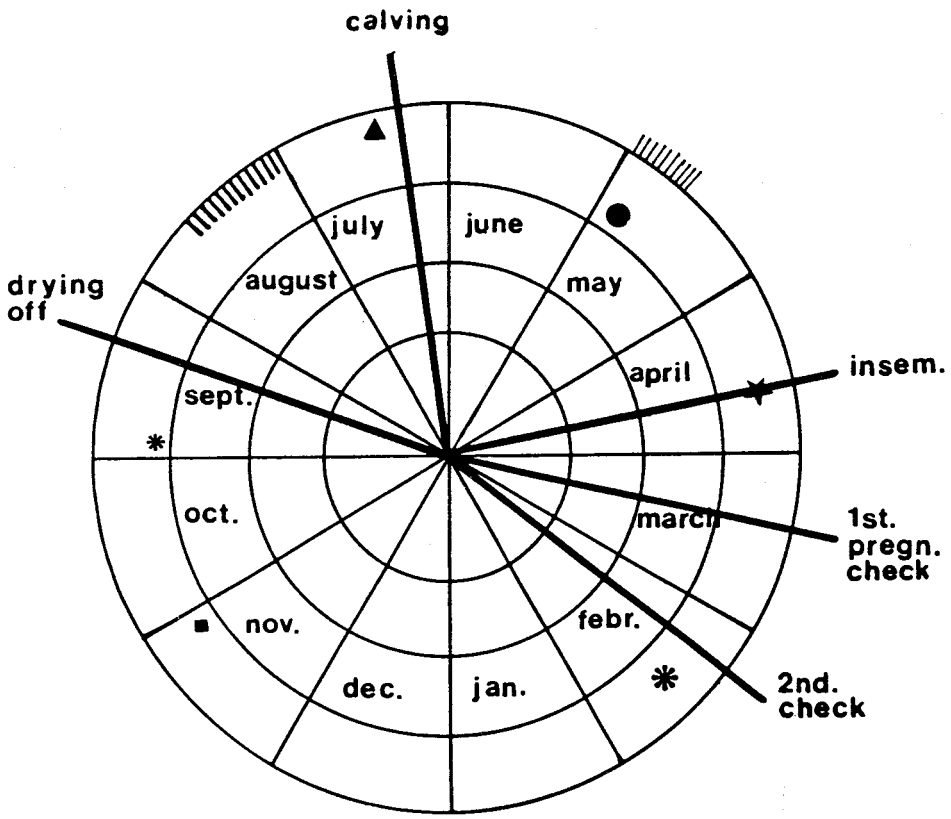

Figure 14: Disk model cow calendar

12 Artificial insemination & rectal palpation

Also refer to Chapter 8 of this book.

To enter the rectum, the fingers of the hand must be formed into a cone. Then the hand must gently but firmly be passed through the anus of the cow.
The entry usually elicits a defecation reflex; in any case the rectum must be emptied before the examination can proceed. Do not forcefully manipulate against the peristaltic waves or against a rectum ballooned with air, as this usually results in trauma as well as inadequate examination.

Should the rectum fill with air, reach forward and gently grasp the first contracted ring of rectal mucosa, then slowly pull backwards. This will usually stimulate a peristaltic wave which will evacuate the rectum.

The 'landmarks' of greatest value in rectal examination are the *cervix,* the shaft of the *ilium* (hipbone) and the *pubis* (pelvic brim).
The first thing to do is to locate the pelvic brim; if one then sweeps the cupped hand along the brim, the cervix may be located as a firm, cylindrical structure in the midline or just over the pelvic brim.

To pass the insemination pipette (other names are syringe or pistolet) successfully, one must be able to immobilise and control the cervix and guide the tip of the pipette with the hand which is in the rectum.

In addition, *strict sanitary precautions* must be observed; the introduction of faecal bacteria into the uterus must be avoided at all cost!!

Proceed as follows:
Insert the hand into the rectum. Clean the lips of the vulva with paper tissue.
In order not to contaminate the insemination pipette, the vulvar lips must be parted; this can be achieved by *one* of the following methods:

- place the arm in the rectum and lift the arm up sideways; this separates and opens the lips of the vulva,
- place the hand just inside the rectum with the thumb down; by spreading the thumb and then retracting the hand with thumb pressure against the rectum and upper cleft of the vulva, the vulvar lips will part,
- if the above methods fail, a wad of tissue can be worked between the lips of the vulva and be left in the ventral cleft.

Then pass the pipette into the vulva for about 5 to 7 cm, first upwards at a 60 °angle, then tilted to the horizontal.
Grasp the cervix at its vaginal end and push it forward. This manipulation prevents folds of the vagina from interfering with the passage of the pipette through the vagina to the external cervical os.

Loosely grasp the cervix and immobilise it against the floor or side of the pelvis. While holding the cervix in position with the thumb and forefinger, guide the pipette into the external os with the little finger.

The entry into the cervix can be checked by encompassing the cervix with the hand; if the pipette cannot be felt in the fornix one can be sure that it has penetrated into the cervix. Passage is then completed by manipulating the cervix in the horizontal and vertical planes while exerting **gentle** pressure on the pipette.

One can be certain that the pipette has passed through the internal os when its tip can be felt through the uterine wall.

In *no case* should the pipette be passed more than two cm beyond the internal os!!

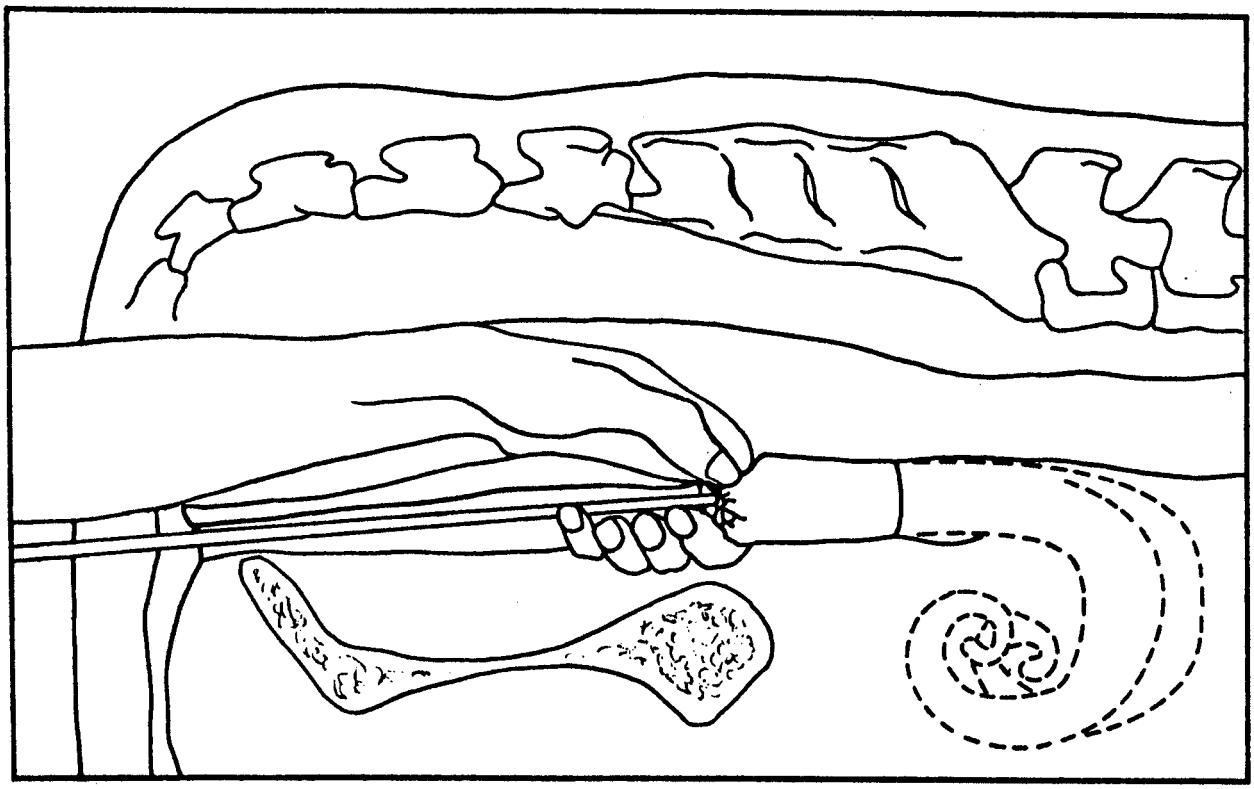

Figure 15: Manipulating insemination pipette into cervix (adapted from M.H. Bartlett)

Points to remember:

- Do not pull the pipette out of the vagina and then reinsert it; this will only carry contamination further up in the vagina.
- The pipette must not be withdrawn if the cow urinates or defaecates with the pipette well inserted into the vagina. In this case attempt to minimise faecal contamination by moving the pipette to one side, to allow the faeces to fall to the ground without contacting the pipette.
- Do not attempt to guide the pipette by violent manipulation of the end which is outside the cow.
- Do not force the pipette through the cervix as this can produce a cervical abscess or perforation of the uterus.
- The uterus is a bacteriologically sterile organ: do not allow the pipette to contaminate it!

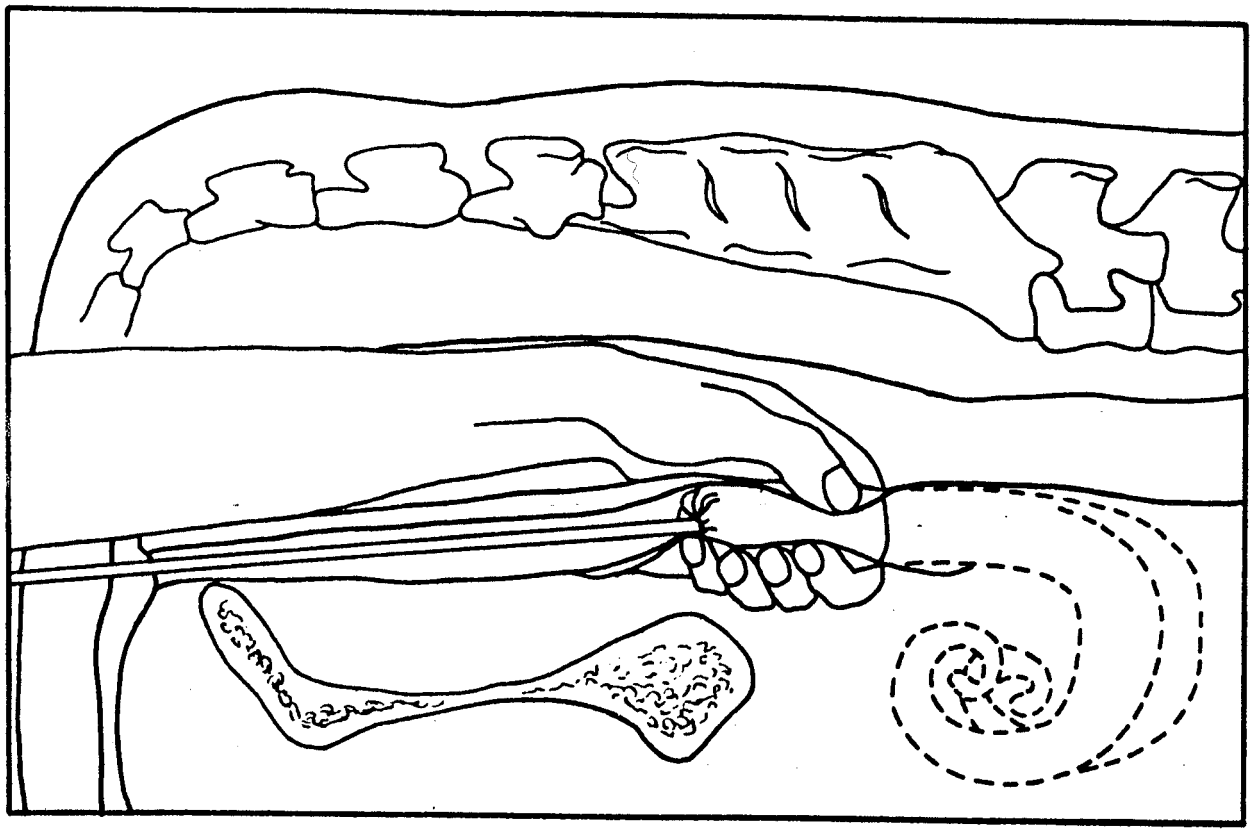

Figure 16: Improper manipulation of cervix to introduce pipette

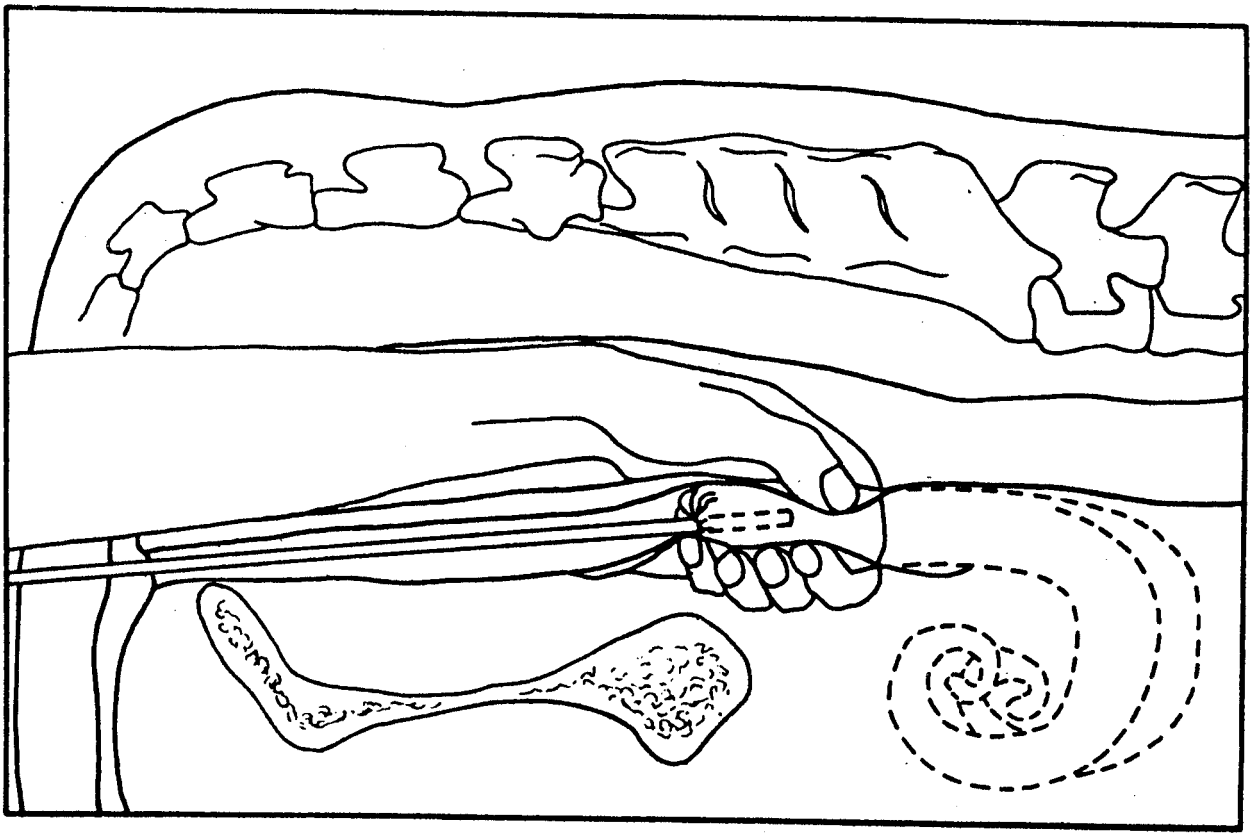

Figure 17: Manipulation of pipette through the cervix

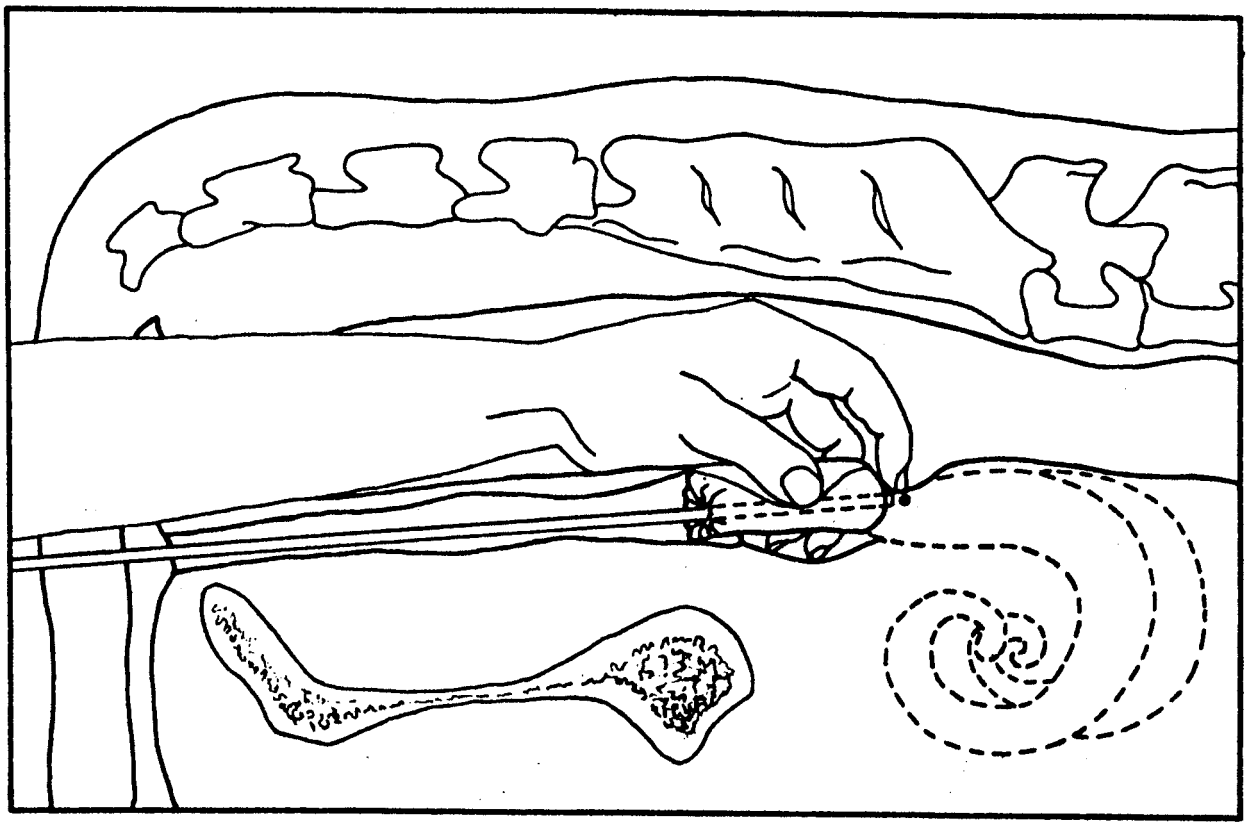

Figure 18: Proper site for semen deposition

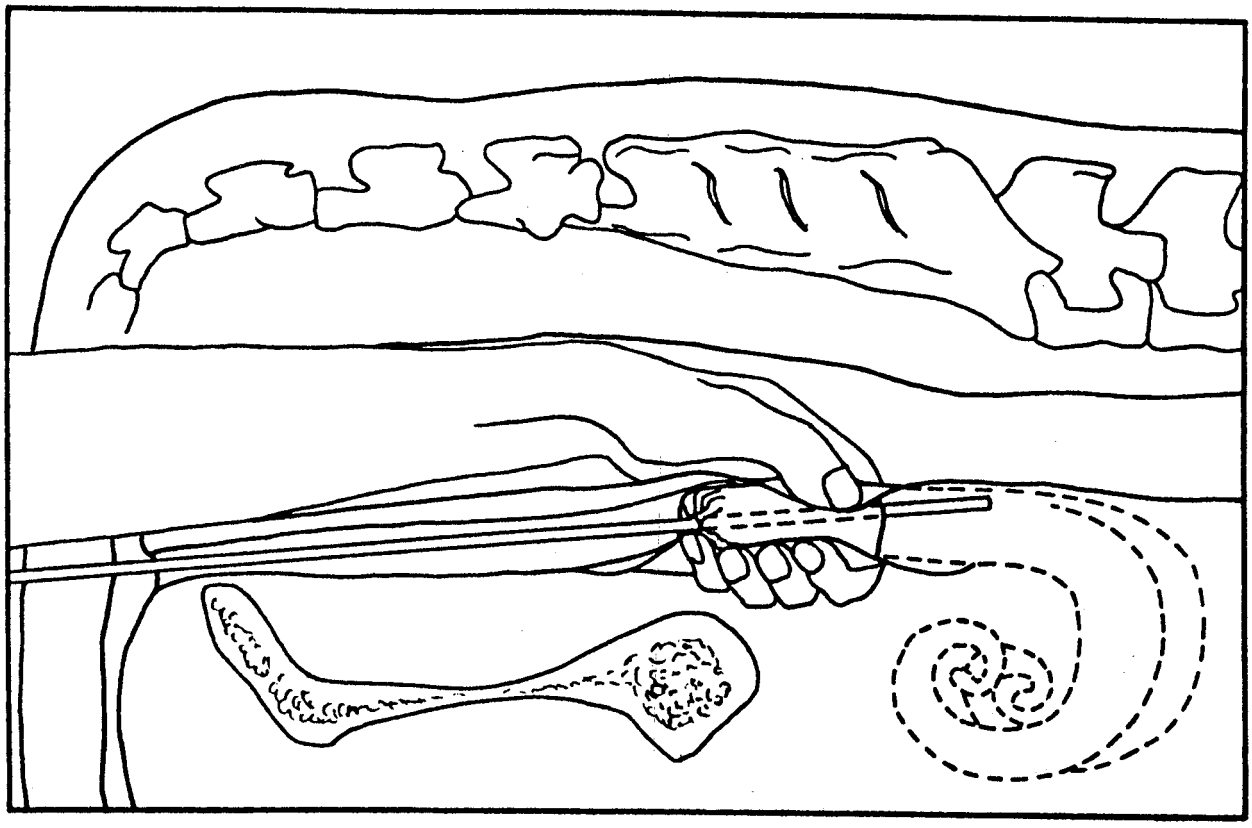

Figure 19: Insemination pipette too deep in uterus

13 Pregnancy diagnosis

Pregnancy diagnosis is also called ‘pregnancy determination’. It is usually shortened as PD.

There are three reasons why PD is important:
1 With PD we can identify and combat fertility problems in herds or individual cows at as early a stage as possible.
2 With PD we can identify non-pregnant cows and they can then be culled if desirable. In this way PD assists economy and efficiency.
3 With PD we can certify that a cow is pregnant; this is important where cows are bought or sold.

In a laboratory it is possible to measure the progesterone level in the milk of a cow in order to determine pregnancy at an early stage, say 21 to 24 days after service. Progesterone levels in milk (or blood) are indicators of corpus luteum function. A low progesterone level means that the cow is not pregnant.
This way of doing a PD requires a suitable laboratory and high quality management on the farm to ensure that samples are taken at the right time and are properly conserved and labelled.
Measuring the progesterone level in milk is not the only laboratory method that is available for PD.

In this guide we will only describe PD by means of the *rectal palpation* method. This remains the method of choice for pregnancy diagnosis in cows and can be applied anywhere.

PD by means of rectal palpation is an art. Like any art, it requires considerable guidance before it is mastered and then more or less *constant practice* in order to maintain proficiency.

Other requirements:
1 every effort must be made to avoid spreading infectious diseases from cow to cow or from farm to farm; suitable protective clothing , including plastic or rubber arm-length gloves, must be worn and kept scrupulously clean,
2 good oestrus detection after service (by the livestock owner) should identify non-pregnant cows before any examination is carried out,
3 the operator of PD should never guess and should only give a diagnosis if he or she is completely satisfied that it is correct; it is better to re-examine a cow than to give a wrong verdict.

Pregnancy diagnosis is unreliable and slow when unskilled or semi-skilled persons attempt to do it. At the same time it is costly under such conditions. For these reasons it is usually more economical to hire a skilled and reputable person to do PD than to attempt to do it otherwise.
An additional advantage is (when a professional does the job) that veterinary service is available when it is needed.

As stated before (page 65), the ‘landmarks’ of greatest value in rectal examination are the cervix, the shaft of the ilium (hipbone) and the pubis (pelvic brim).

For quick and accurate genital examination, retraction (drawing back or in) of the open or early gravid (pregnant) uterus into the pelvic inlet is essential. Retraction is relatively easy in open (non-pregnant) cows and in cows which are not more than 90 days pregnant. Beyond 90 days it becomes more difficult.
Methods for retraction vary.
The following method is suggested as a guide to help students establish satisfactory procedures of their own.
For purposes of description left handed palpation is assumed.

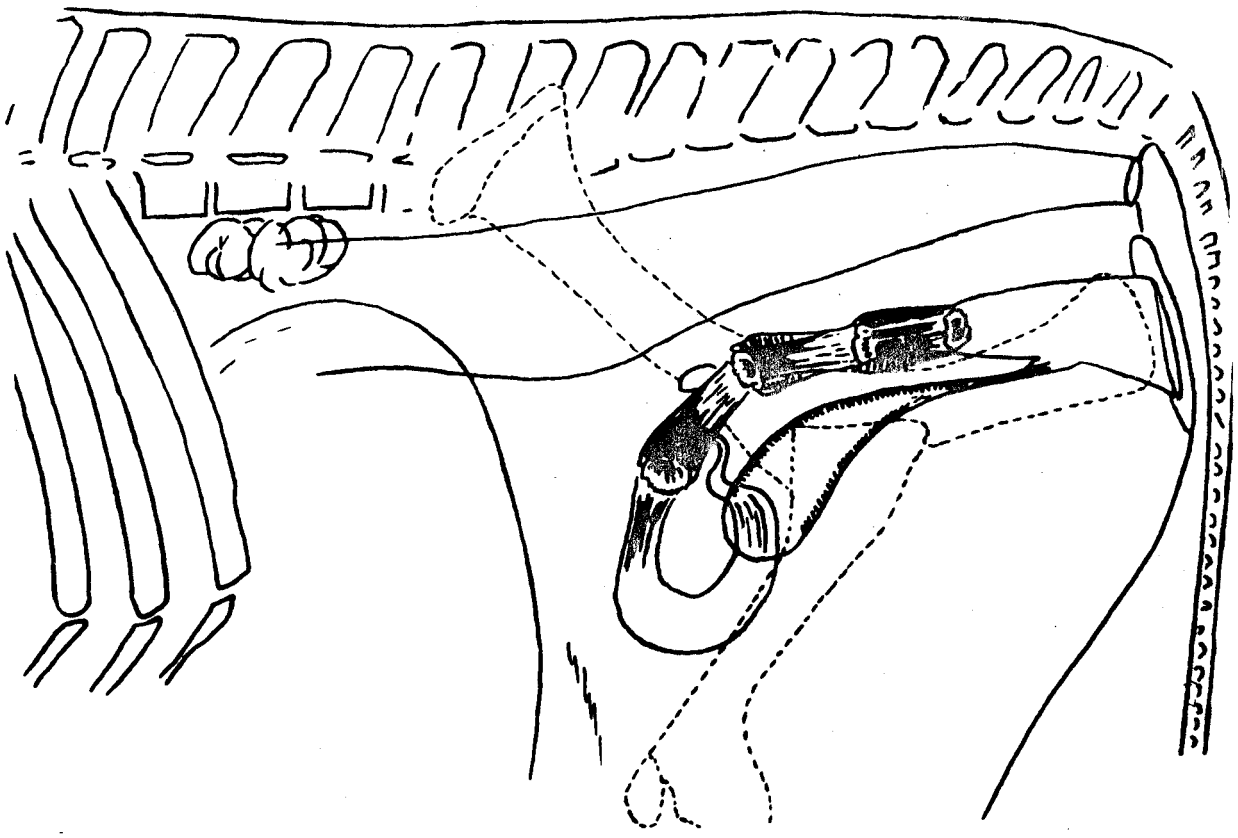

Figure 20: Normal variations in the position of the cervix in the normal open cow

The cervix may be found on the midline near the pelvic brim. It is a firm, cylindrical structure about eight cm long. It is located by sweeping the pelvic inlet with the edge of the open palpating hand. Do not use finger tips as they may damage the rectal mucosa. Normally the cervix will be found in this way.
If not, it is lying either over the brim of the pelvis or entirely within the pelvis. In that case repeat the procedure at various depths until the cervix is located.

Then elevate the cervix against the side of the pelvic inlet and insert the thumb **beneath** it. Rotate the hand so that the cervix is fixed between the ilium and the angle formed by the thumb and forefinger. At this time position the fingers dorsal to the cervix.
Flex the thumb and slide it forward along the cervix and the body of the uterus whilst keeping these organs slightly elevated and pressed between the thumb-forefinger angle and the pelvis. By sweeping the fingers laterally at this time, it is usually possible to grasp the left broad ligament. The broad ligament is felt as a band across the inside of the flexed fingers as the hand is retracted.

The thumb can now be placed in the angle of attachment of the broad ligament and the uterus; retraction can be maintained as the fingers sweep medially to grasp the left uterine horn. In some instances it is easy to cup the uterus in the hand at this time.
Retraction is completed by hooking a finger beneath the ventral intercornual ligament and tipping the genital tract back into the pelvis.

In some instances the intercornual ligament can be grasped by going directly to it and hooking it with the fingers. However, this technique is usually not successful.

In some pregnant cows the hand can be inserted over the brim of the pelvis and down beneath the uterus which is then cupped in an angle formed by the arm and the hand. It can then be retracted by gently moving it up and over the brim of the pelvis. Or, possibly, the membranes may be able to be slipped without retraction.

Actual pregnancy diagnosis

If possible, the two uterine horns should be palpated throughout their entire length to determine their consistency. If the horns are empty they will have a meat-like consistency. If there is a pregnancy, fluids will be present in one or both horns.

A common mistake made by beginners is that of attempting to slip foetal membranes without determining the uterine contents. Sometimes a false slip is obtained and an open cow is called pregnant.

Four criteria can be applied to declare a cow pregnant:
1 palpation of the amniotic fluid
2 slip of foetal membranes
3 palpation of the foetus
4 palpation of placentomes (caruncles)

In addition, in advanced pregnancy the size and fremitus (which is the buzzing sensation resulting from turbulence produced by hypertrophy of the artery) of middle uterine arteries also give positive evidence of pregnancy.

Palpation of the *amniotic fluid* is possible from about day-30 to day-70 of gestation.
Before day-30 the amniotic vesicle is too small and after day-70 it becomes too large and too soft for palpation. Palpation of the amnion should not be done as a routine to determine pregnancy because of the risk of rupturing either the amniotic vesicle or the foetal heart sac; rupture will result in abortion. After 50 days the risk increases.

The *chorio-allantoic membranes* can be slipped in the interplacental areas because there are no normal uterine-foetal attachments in these areas.

Gently grasp a portion of the fluid-filled part of the uterine wall (in early pregnancy, the entire cross section of a horn) between thumb and forefinger and then release it gradually. The chorio-allantois and the uterine wall will slip between the thumb and forefinger in turn and this gives a typical ‘slipping’ sensation if the cow is pregnant.

As pregnancy advances the membranes fill progressively both uterine horns and the gravid horn becomes quite turgid. At ten weeks it is often easier to detect pregnancy by slip of membranes in the non-gravid horn because it is less tense.

The size and position of the uterus may be helpful indicators and may suggest pregnancy, but one should not call a cow pregnant unless a **positive sign of pregnancy is detected.**

Small *placentomes* can be palpated from 75 to 80 days. They become a more important diagnostic criterion in advanced pregnancy. Then relatively the amount of fluid has decreased and this makes them more evident.
Beginners who fail to orient themselves in the genital tract frequently make the error of palpating a caruncle, calling it an ova, and declaring a cow open when in fact she is in advanced pregnancy.

The *foetus* cannot be palpated until the amnion has become flaccid enough to allow manipulation. This is usually the case at about 75 days.

From then onwards palpation of the foetus is valuable for diagnosis and for estimating the duration of pregnancy.
In many cows the foetus is out of reach between about five and seven months.

Hypertrophy of the middle uterine artery can be palpated on the gravid side as early as 85 to 90 days after conception.
This structure is felt as a freely movable vessel which lies in the region of the shaft of the ilium. Make sure to distinguish it from the external iliac artery which is attached to the ilium.
The middle uterine artery can be felt as a cord four to five mm thick on the gravid side in early pregnancy; it progressively enlarges thereafter.
Fremitus may be distinguished as early as 90 to 120 days after conception, by holding the artery loosely between the fingers.
Too much digital pressure can produce a false fremitus.

Ovaries

The *ovaries* are located just lateral and caudal to the tips of the horns. They are easily located by tracing the horn with the hand until the tip is reached and then grasping outwards and slightly caudally.

As an alternative one can attempt to follow the mesovarium to the ovary, but this is more difficult.

The ovaries are flattened, almond-shaped organs approximately 3 × 2 × 1 cm. This shape can be distorted by the following functional structures:

1 The *follicle* is palpated as a smooth, rounded structure 1 to 2½ cm in diameter, which blends smoothly with the ovarian tissue. The texture varies with the stage of development.
  Smaller, early follicles are deeply embedded in ovarian stroma and feel quite hard.
  With advancing maturity, follicles may become fluctuating and blister-like.
2 The *corpus haemorrhagicum* is the structure which first develops after ovulation and it lasts until day-6 (5 days post ovulation).
  Following ovulation the ovulation depression (OVD) fills with blood.
  Surrounding luteal cells proliferate and hypertrophy to form the corpus haemorrhagicum which develops into the corpus luteum.
  In its early stages of growth the corpus haemorrhagicum is difficult to palpate. Later it is a soft structure with a smaller, softer crown than a developed corpus luteum.
3 The *corpus luteum (CL)* is palpable at about five days post ovulation. It frequently has a distinct crown about ½ cm in diameter and about ½ cm high; this crown projects from the surface of the ovary. The corpus luteum enlarges progressively to two to three cm by day-8 or 9 and has a liver-like consistency.
  After this, when there is no pregnancy, it regresses rapidly and becomes firmer and smaller.
  At the time of heat it can usually be palpated as a small, hard structure on one of the ovaries.
  The corpus luteum of pregnancy, however, becomes smooth, rounded and covered with epithelial cells after a month or two.

14 A brief description of the bovine embryotransfer technique

Principle of embryo transfer

Embryo transfer (ET) is used to obtain *more calves* from *genetically highly valuable cows.*
These so-called donor cows are stimulated with hormones to release several eggs at one time ('superovulation'); normally only one egg is released at ovulation.
Some days after fertilization the embryos are flushed out and transferred into recipient cows.
The oestrus cycle of the recipient cow should be synchronus with the oestrus cycle of the donor cow; this can be achieved by applying oestrus-synchronizing treatments.
Collection of embryos can be repeated quite successfully on the same cow.

With a diagram:

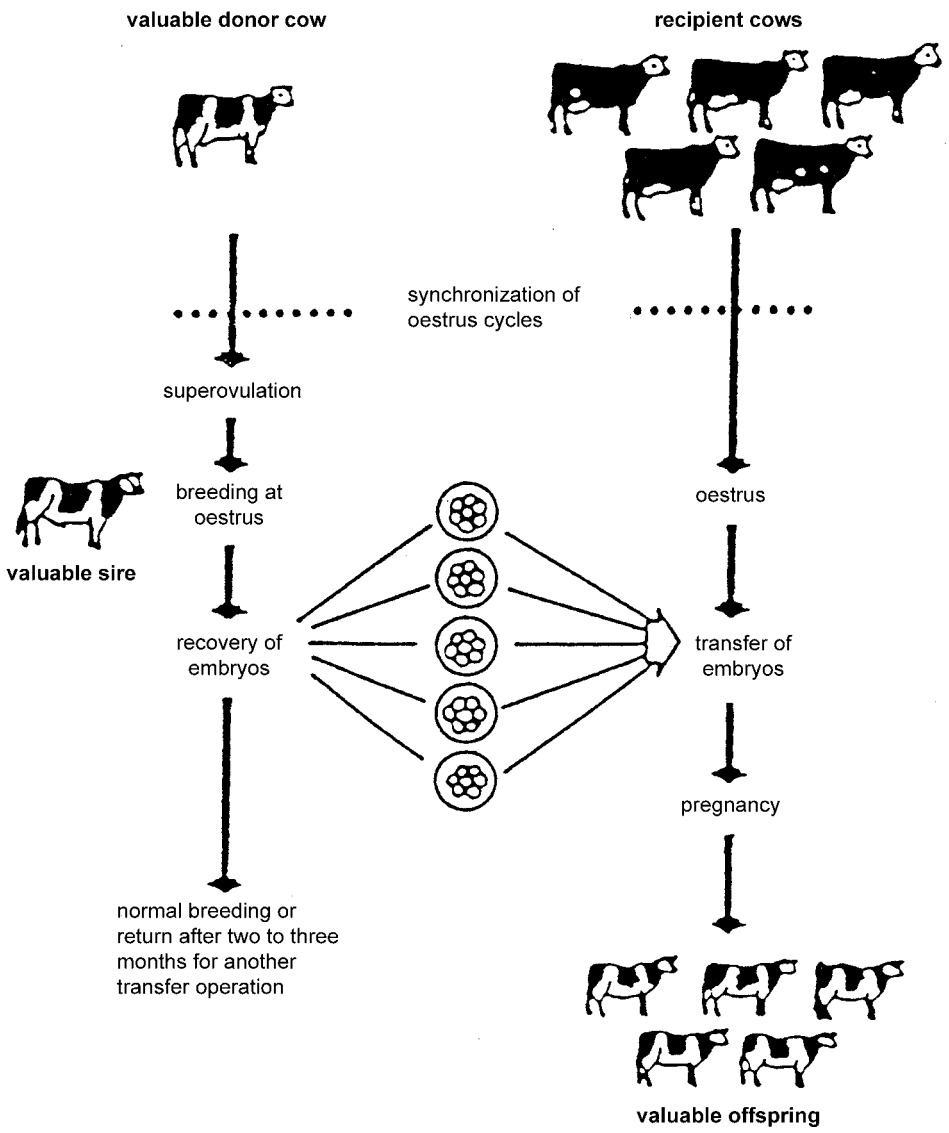

Figure 21:

Superovulation

Superovulation can be induced by injecting FSH (follicle-stimulating hormone). FSH will stimulate follicles on the ovaries to mature.
Normally FSH from swine or sheep, or PMSG (pregnant mare serum gonadotrophin) is used.

Because of its relatively long-lasting effect, one PMSG injection is sufficient.
On the other hand, FSH has to be injected twice daily for 4 to 5 days (more effort is required).
A frequently used dosage is 3000 IU ('international units') PMSG or 2 × 7.5, 5.0, 5.0, 2.5 (2.5) mg FSH on four (or five) consecutive days.
The treatment is started between days-9 and 14 of the cow's cycle (day-0 = day of oestrus).

About 48 hours after the PMSG injection (or after the first FSH injection), a normal dosage of prostaglandin $F_{2\alpha}$ (or an analogue) is given in order to induce oestrus in the donor animal.
If PMSG is used, anti-PMSG has to be given in order to stop the long-lasting activity of PMSG.

The donor cow is usually served about 12 hours after the start of the standing heat period. Service has to be repeated 12 hours later if oestrus has not stopped by then.
The cycle of the recipient cows *must be synchronous with* that of the donor cow, in order to obtain good results (this is of the utmost importance!).
In most cases this means synchronizing recipient cows artificially. This can be done with one injection of prostaglandin $F_{2\alpha}$ about 12 hours before the donor cow is to be injected for oestrus induction.
It is also possible to synchronize the cycles with an artificial corpus luteum (a progesterone-releasing intravaginal device or an ear implant) for about ten days.

Embryo collection

Embryos are collected non-surgically, **after** day-5 (arrival of embryo in uterine horn) and before day-8 (hatching from the zona pellucida).

Just after hatching the embryo is difficult to find, but between days-11 and 14 embryo collection is again possible.

In the first case embryos can be preserved for a long period by deepfreezing. And they can also be split into halves, triplets or quadruplets. Embryos collected between days-11 and 14 cannot successfully undergo these treatments.

But between days-11 and 14 it is very easy to find the embryos because of their relatively large size and this is a considerable advantage.
Before hatching the size of an embryo is about 0.15 µm, at day-12 about 5 µm and at day-14 from 50 to 100 µm (1 µm = 1/1000 mm).

Before starting the collection of embryos, the donor cow is checked for the number of corpora lutea and/or follicles. The rectum is emptied and a local aneasthetic is injected around the spinal cord on the tail head. This prevents strain during the flushing of the uterine horns.
Finally the vulval area is cleaned.

Then the embryos are collected by flushing the uterine horns one by one, with a Foley three-channel catheter held in position by the inflated collar at the tip of the catheter.
The catheter is connected with a tubing system or with a syringe filled to 100 ml.

The uterine horn is flushed several times with 25 to 100 ml fluid each time, depending on the size of the uterus.
The fluid used for flushing is usually a phosphate-buffered saline solution according to the formula of Dulbecco (PBS), supplemented with 1% heat-treated foetal calf serum (56 °C, for 30 minutes).
When both horns have been flushed, the collected fluid is examined for the presence of embryos. This is done by filtering the fluid through a filter system (φ 0.05 mm). The last 20 ml (with the embryos!) is flushed from the filter into a petri dish.

It is also possible to let the fluid collected from the donor cow stand for 30 minutes at least. This allows the embryos to settle and they can then be sucked up from the bottom by means of a 25 ml pipette; they can also be collected by removing the fluid that stands above the embryos.

The (remaining) fluid with the embryos is placed in a petri dish (φ about 10 cm).
This fluid is then examined with a dissecting microscope (magnification 20 x).

The embryos which one finds in the fluid must be checked for quality (magnification 50 x).
A normal embryo is in the right development stage and does not show signs of cellular degeneration (no loose cells, no dark spots).

Embryos which are found to be transferable are washed several times and then stored in fresh PBS, with 10-20% heat-treated serum.

Embryo transfer

Embryos are sucked into a semen straw or into a special embryo transfer straw, depending on the transfer method that is applied (one embryo per straw).

The semen straws are used with an enlarged AI gun (length 50 cm), together with special, enlarged sheaths.
The embryo transfer straws have to be used with a special transfer apparatus.

With both methods, after the transfer gun has been loaded, a small plastic bag is placed around the transfer gun in order to prevent contamination in the vagina of the recipient cow.
When the tip of the transfer gun has reached the cervix (check by rectal palpation), the plastic bag is ruptured and the tip of the (still sterile) transfer gun is passed through the cervix into the uterine horn at the side of the corpus luteum containing ovary.
The embryo is placed as deeply as possible into the uterus, without damage to the uterine lining.

Preservation of embryos

When there are more fresh embryos than recipient cows, the embryos can be preserved for later use.
Embryos can be preserved by cooling them down to temperatures lower than minus 130 °C.
Only good quality embryos should be deepfrozen; the freezing of low-quality embryos leads to poor results later on.

A cryoprotectant must be added before the freezing process is started; usually 1.4 M glycerol in PBS with 20% serum is added at 20 °C, in three steps.

The embryos are packed in straws or ampoules (plastic or glass) and are placed in a freezing chamber at minus 6 °C. Ten minutes later the cristallization is induced by touching the ampoules or straws with a very cold forceps; the medium freezes where they are touched (‘seeding’). Then the cristallization spreads throughout the ampoule or straw.
When the cristallization is complete, the cooling must be resumed until the temperature reaches minus 35 °C. The cooling rate must be about 0.3 °C/minute.

The material is stored in liquid nitrogen at minus 196 °C.

When the embryos are needed, they must be thawed in a water bath of 35 °C. The glycerol has to be removed; this can be done by bringing the embryos in 4 to 6 steps into a phosphate-buffered saline solution (+ 20% serum), each time with a lower glycerol concentration.
However, instead of using different glycerol concentrations to remove the glycerol, one can also use one sucrose solution (about 0.8 M). In fact sucrose solutions are used more and more.

Splitting

To increase the number of calves per donor cow it is possible to split the embryos into halves, triplets or quadruplets.

The easiest way is to cut a morula (this is a 6 to 7 days old embryo) into two halves through the zona pellucida. Each half can lead to a normal pregnancy, with a normal pregnancy rate. So there will be twice as many pregnancies.
Some identical twins will be produced.

Results

After superovulation one finds on average six normal, transferable embryos. With an average pregnancy rate of 55% this results in about three calves. With frozen (excellent quality) embryos a pregnancy rate of about 40% only can be expected.
With splitting embryos into halves one may expect a pregnancy rate of 110% (for instance, 10 non-cut embryos give 11 calves).
Splitting embryos into more than two parts will lower the pregnancy rate.

If embryo collection is done in a correct way, the donor cow is not damaged at all.
It is possible to repeat the process several times, at intervals of about two months.
To prevent pregnancy of the donor cow, her uterine horns are flushed with an embryo-toxic agent or the donor cow is given prostaglandin $F_{2\alpha}$.

The cost of embryo transfer is relatively high. In the Netherlands an ET calf costs about 200 US dollars as far as treatments are concerned. This means that the donor cows must be very valuable indeed!
In the Netherlands all treatments involved are carried out on the farm, by personnel employed by AI organisations.

The whole process of embryo transfer requires *specialized veterinary knowledge and experience*, as well as an *advanced breeding infrastructure.*

For many countries ET will as yet prove to be *too difficult and too costly* to implement on a regular basis.
The importation of frozen embryos, for instance to establish nucleus herds, seems more appropriate but whether it will justify the costs involved has to be studied in each individual case.

Concluding remarks

The ideal recipient cow is a disease-free cow or heifer, cycling regularly, which can be of any breed.
The recipient cow should be in a well-nourished condition and be able to give birth to a calf the size of the implanted breed.

Successful embryo transfer activities require a *highly motivated and experienced staff* and *high capital investment* for facilities, equipment, drugs and experimental animals.

Possibilities of ET:
- ET can accelerate genetic progress in cattle breeding programmes,
- ET is an important research tool in studying genetic defects,
- ET can be used in research in general: reproduction physiology, fertilization, embryo implantation and pregnancy diagnosis,
- ET offers advantages over traditional transport of livestock between countries,
- the danger of disease transmission is reduced; for instance, BLV (bovine leukaemia virus), BTV (blue tongue virus) and FMDV (foot and mouth disease virus), provided that proper ET methods are used.

At present it is considered that AI still constitutes a more effective method of obtaining large-scale genetic gain. This is specifically true for those countries in which AI is still in its infancy and where milk recording and progeny-testing schemes are not yet established.

Bio-technology related to embryo transfer technology:
- in-vitro production of embryos (IVP)
- sex determination
- embryo splitting and cloning
- 'genetic engineering'

The text of this chapter has been prepared in cooperation with the late Dr H.Hoogenkamp
of the Department of Herd Health and Reproduction
Faculty of Veterinary Medicine, Utrecht University
P.O.Box 80.151
3508 TD Utrecht, NL

Further reading

Relevant to dairy farming in warm climate zones, at farm level
AGROMISA Educational Materials:

- Basic calculations in agriculture and animal production.
  Instruction followed by exercises (with answers) at lower secondary level, for use in groups or for self-tuition. 80 pages, with illustrations in the text.
  Latest edition 1998.
- The farm as a commercial enterprise in a market economy.
  Elementary instruction followed by universally applicable exercises with answers, so that users gain a working knowledge of the subject. Latest revised edition 2003; 110 pages.
- Farm accounting. 50 pages, latest revised edition 2003.
- Modern dairy farming in warm climate zones (in three partner volumes). In total over 300 pages; latest version 2002.
- Tropical grasslands.
  Lecture notes made by the Department of Agronomy of the Wageningen Agricultural University and published by STOAS (latest version 1999).
- Video production on hand milking of dairy cows.
- Video production on embryo transfer in cattle.
- Foot care in cattle
  A guide complemented by a video production.

Reproductive system

From Wikipedia, the free encyclopedia

The **reproductive system** or **genital system** is a system of sex organs within an organism which work together for the purpose of sexual reproduction. Many non-living substances such as fluids, hormones, and pheromones are also important accessories to the reproductive system.[1] Unlike most organ systems, the sexes of differentiated species often have significant differences. These differences allow for a combination of genetic material between two individuals, which allows for the possibility of greater genetic fitness of the offspring.[2]

Reproductive system

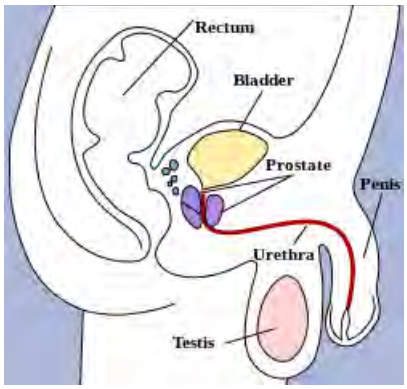

Human male reproductive system.

Details

Identifiers

Latin	*systema reproductionis*
TA	A09.0.00.000 (http://www.unifr.ch/ifaa/Public/EntryPage/TA98%20Tree/Entity%20TA98%20EN/09.0.00.000%20Entity%20TA98%20EN.htm)
FMA	7160 75572, 7160 (http://xiphoid.biostr.washington.edu/fma/fmabrowser-hierarchy.html?fmaid=75572,)

Anatomical terminology

[edit on Wikidata]

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Animals

In mammals, the major organs of the reproductive system include the external genitalia (penis and vulva) as well as a number of internal organs including the gamete producing gonads (testicles and ovaries). Diseases of the human reproductive system are very common and widespread, particularly communicable sexually transmitted diseases.[3]

Most other vertebrate animals have generally similar reproductive systems consisting of gonads, ducts, and openings. However, there is a great diversity of physical adaptations as well as reproductive strategies in every group of vertebrates.

Vertebrates

Vertebrate animals all share key elements of their reproductive systems. They all have gamete-producing organs or gonads. In females, these gonads are then connected by oviducts to an opening to the outside of the body, typically the cloaca, but sometimes to a unique pore such as a vagina or intromittent organ.

Humans

The human reproductive system usually involves internal fertilization by sexual intercourse. During this process, the male inserts his erect penis into the female's vagina and ejaculates semen, which contains sperm. The sperm then travels through the vagina and cervix into the uterus or fallopian tubes for fertilization of the ovum. Upon successful fertilization and implantation, gestation of the fetus then occurs within the female's uterus for approximately nine months, this process is known as pregnancy in humans. Gestation ends with birth, the process of birth is known as labor. Labor consists of the muscles of the uterus contracting, the cervix dilating, and the baby passing out the vagina (the female genital organ). Human's babies and children are nearly helpless and require high levels of parental care for many years. One important type of parental care is the use of the mammary glands in the female breasts to nurse the baby.[4]

The female reproductive system has two functions: The first is to produce egg cells, and the second is to protect and nourish the offspring until birth. The male reproductive system has one function, and it is to produce and deposit sperm. Humans have a high level of sexual differentiation. In addition to differences in nearly every reproductive organ, numerous differences typically occur in secondary sexual characteristics.

Male

The male reproductive system is a series of organs located outside of the body and around the pelvis region of a male that contribute towards the reproduction process. The primary direct function of the male reproductive system is to provide the male sperm for fertilization of the ovum.

The major reproductive organs of the male can be grouped into three categories. The first category is sperm production and storage. Production takes place in the testes which are housed in the temperature regulating scrotum, immature sperm then travel to the epididymis for development and storage. The second category are the ejaculatory fluid producing glands which include the seminal vesicles, prostate, and the vas deferens. The final category are those used for copulation, and deposition of the spermatozoa (sperm) within the male, these include the penis, urethra, vas deferens, and Cowper's gland.

Major secondary sexual characteristics includes: larger, more muscular stature, deepened voice, facial and body hair, broad shoulders, and development of an adam's apple. An important sexual hormone of males is androgen, and particularly testosterone.

The testes release a hormone that controls the development of sperm. This hormone is also responsible for the development of physical characteristics in men such as facial hair and a deep voice.

Female

The human female reproductive system is a series of organs primarily located inside of the body and around the pelvic region of a female that contribute towards the reproductive process. The human female reproductive system contains three main parts: the vagina, which leads from the vulva, the vaginal opening, to the uterus; the uterus, which holds the developing fetus; and the ovaries, which produce the female's ova. The breasts are involved during the parenting stage of reproduction, but in most classifications they are not considered to be part of the female reproductive system.

The vagina meets the outside at the vulva, which also includes the labia, clitoris and urethra; during intercourse this area is lubricated by mucus secreted by the Bartholin's glands. The vagina is attached to the uterus through the cervix, while the uterus is attached to the ovaries via the fallopian tubes. Each ovary contains hundreds of egg cells or ova (singular *ovum*).

Approximately every 28 days, the pituitary gland releases a hormone that stimulates some of the ova to develop and grow. One ovum is released and it passes through the fallopian tube into the uterus. Hormones produced by the ovaries prepare the uterus to receive the ovum. The lining of the uterus, called the endometrium, and unfertilized ova are shed each cycle through the process of menstruation. If the ovum is fertilized by sperm, it attaches to the endometrium and the fetus develops.

Other mammals

Most mammal reproductive systems are similar, however, there are some notable differences between the non-human mammals and humans. For instance, most male mammals have a penis which is stored internally until erect, and most have a penis bone or baculum. Additionally, males of most species do not remain continually sexually fertile as humans do. Like humans, most groups of mammals have descended testicles found within a scrotum, however, others have descended testicles that rest on the ventral body wall, and a few groups of mammals, such as elephants, have undescended testicles found deep within their body cavities near their kidneys.[5]

The reproductive system of marsupials is unique in that the female has two vaginae, both of which open externally through one orifice but lead to different compartments within the uterus; males usually have a two-pronged penis which corresponds to the females' two vaginae. Marsupials typically develop their offspring in an external pouch containing teats to which their newborn young (joeys) attach themselves for post uterine development. Also, marsupials have a unique prepenial scrotum.[6] The 15mm (5/8 in) long newborn joey instinctively crawls and wriggles the several inches (15 cm), while clinging to fur, on the way to its mother's pouch.

A newborn joey suckles from a teat found within its mother's pouch

The uterus and vagina are unique to mammals with no homologue in birds, reptiles, amphibians, or fish. In place of the uterus the other vertebrate groups have an unmodified oviduct leading directly to a cloaca, which is a shared exit-hole for gametes, urine, and feces. Monotremes (i.e. platypus and echidnas), a group of egg-laying mammals, also lack a uterus and vagina, and in that respect have a reproductive system resembling that of a reptile.

Dogs

In domestic canines, sexual maturity (puberty) occurs between the ages of 6 to 12 months for both males and females, although this can be delayed until up to two years of age for some large breeds.

Horses

The mare's reproductive system is responsible for controlling gestation, birth, and lactation, as well as her estrous cycle and mating behavior. The stallion's reproductive system is responsible for his sexual behavior and secondary sex characteristics (such as a large crest).

Birds

Male and female birds have a cloaca, an opening through which eggs, sperm, and wastes pass. Intercourse is performed by pressing the lips of the cloacae together, which is sometimes known as intromittent organ which is known as a phallus that is analogous to the mammals' penis. The female lays amniotic eggs in which the young fetus continues to develop after it leaves the female's body. Unlike most vertebrates female birds typically have only one functional ovary and oviduct.[7] As a group, birds, like mammals, are noted for their high level of parental care.

Reptiles

Reptiles are almost all sexually dimorphic, and exhibit internal fertilization through the cloaca. Some reptiles lay eggs while others are viviparous (animals that deliver live young). Reproductive organs are found within the cloaca of reptiles. Most male reptiles have copulatory organs, which are usually retracted or inverted and stored inside the body. In turtles and crocodilians, the male has a single median penis-like organ, while male snakes and lizards each possess a pair of penis-like organs.

Amphibians

Most amphibians exhibit external fertilization of eggs, typically within the water, though some amphibians such as caecilians have internal fertilization.[8] All have paired, internal gonads, connected by ducts to the cloaca.

A male common frog in nuptial colors waiting for more females to come in a mass of spawn

Fish

Fish exhibit a wide range of different reproductive strategies. Most fish however are oviparous and exhibit external fertilization. In this process, females use their cloaca to release large quantities of their gametes, called spawn into the water and one or more males release "milt", a white fluid containing many sperm over the unfertilized eggs. Other species of fish are oviparous and have internal fertilization aided by pelvic or anal fins that are modified into an intromittent organ analogous to the human penis.[9] A small portion of fish species are either viviparous or ovoviviparous, and are collectively known as livebearers.[10]

Fish gonads are typically pairs of either ovaries or testes. Most fish are sexually dimorphic but some species are hermaphroditic or unisexual.[11]

Invertebrates

Invertebrates have an extremely diverse array of reproductive systems, the only commonality may be that they all lay eggs. Also, aside from cephalopods, and arthropods, nearly all other invertebrates are hermaphroditic and exhibit external fertilization.

Cephalopods

All cephalopods are sexually dimorphic and reproduce by laying eggs. Most cephalopods have semi-internal fertilization, in which the male places his gametes inside the female's mantle cavity or pallial cavity to fertilize the ova found in the female's single ovary.[12] Likewise, male cephalopods have only a single testicle. In the female of most cephalopods the nidamental glands aid in development of the egg.

The "penis" in most unshelled male cephalopods (Coleoidea) is a long and muscular end of the gonoduct used to transfer spermatophores to a modified arm called a hectocotylus. That in turn is used to transfer the spermatophores to the female. In species where the hectocotylus is missing, the "penis" is long and able to extend beyond the mantle cavity and transfer the spermatophores directly to the female.

Insects

Most insects reproduce oviparously, i.e. by laying eggs. The eggs are produced by the female in a pair of ovaries. Sperm, produced by the male in one testis or more commonly two, is transmitted to the female during mating by means of external genitalia. The sperm is stored within the female in one or more spermathecae. At the time of fertilization, the eggs travel along oviducts to be fertilized by the sperm and are then expelled from the body ("laid"), in most cases via an ovipositor.

Arachnids

Arachnids may have one or two gonads, which are located in the abdomen. The genital opening is usually located on the underside of the second abdominal segment. In most species, the male transfers sperm to the female in a package, or spermatophore. Complex courtship rituals have evolved in many arachnids to ensure the safe delivery of the sperm to the female.[13]

Arachnids usually lay yolky eggs, which hatch into immatures that resemble adults. Scorpions, however, are either ovoviviparous or viviparous, depending on species, and bear live young.

Plants

Among all living organisms, flowers, which are the reproductive structures of angiosperms, are the most varied physically and show a correspondingly great diversity in methods of reproduction.[14] Plants that are not flowering plants (green algae, mosses, liverworts, hornworts, ferns and gymnosperms such as conifers) also have complex interplays between morphological adaptation and environmental factors in their sexual reproduction. The breeding system, or how the sperm from one plant fertilizes the ovum of another, depends on the reproductive morphology, and is the single most important determinant of the genetic structure of nonclonal plant populations. Christian Konrad Sprengel (1793) studied the reproduction of flowering plants and for the first time it was understood that the pollination process involved both biotic and abiotic interactions.

Fungi

Fungal reproduction is complex, reflecting the differences in lifestyles and genetic makeup within this diverse kingdom of organisms.[15] It is estimated that a third of all fungi reproduce using more than one method of propagation; for example, reproduction may occur in two well-differentiated stages within the life cycle of a species, the teleomorph and the anamorph.[16] Environmental conditions trigger genetically determined developmental states that lead to the creation of specialized structures for sexual or asexual reproduction. These structures aid reproduction by efficiently dispersing spores or spore-containing propagules.

See also

- Major systems of the human body
- Reproductive system disease
- Human sexuality
- Human sexual behavior
- Plant sexuality
- Meiosis

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External links

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Categories: Reproductive system | Fertility | Endocrine system

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The Wikibook *Human Physiology* has a page on the topic of: ***The male reproductive system***

The Wikibook *Human Physiology* has a page on the topic of: ***The female reproductive system***

The Wikibook *Anatomy and Physiology of Animals* has a page on the topic of: ***Reproductive System***

Repulsion motor

From Wikipedia, the free encyclopedia

A **repulsion motor** is a type of electric motor for using on alternating current (AC). It was formerly used as a traction motor for electric trains (e.g. SR Class CP and SR Class SL electric multiple units) but has been superseded by other types of motors. Repulsion motors are classified under single phase motors. In repulsion motors the stator windings are connected directly to the AC power supply and the rotor is connected to a commutator and brush assembly, similar to that of a direct current (DC) motor.[1]

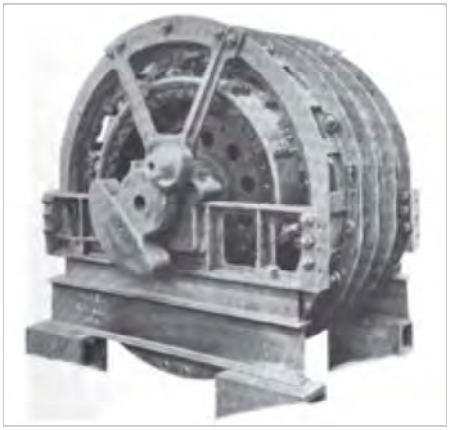

700 horsepower Brown-Boveri-Déri repulsion motor with 10 poles to be used with 16 2/3 Hz single phase current. Two of these motors were used in the French electric locomotive Midi E3301

Contents

- 1 Construction
- 2 Voltage
- 3 Principle
  - 3.1 Stop positions
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- 4 Types of repulsion motor
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  - 4.2 Deri
  - 4.3 Latour-Winter-Eichberg
  - 4.4 Atkinson
  - 4.5 Repulsion-start induction-run
- 5 Applications
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Construction

The motor has a stator and a rotor but there is no electrical connection between the two and the rotor current is generated by induction. The rotor winding is connected to a commutator which is in contact with a pair of short-circuited brushes which can be moved to change their angular position relative to an imaginary line drawn through the axis of the stator. The motor can be started, stopped and reversed, and the speed can be varied, simply by changing the angular position of the brushes.

Voltage

Most commutator motors are limited to about 1,500 volts because higher voltages give rise to a risk of arcing across the commutator. Repulsion motors can be used at higher voltages because the rotor circuit is not electrically connected to the supply.

Principle

Idle	Short-circuit	Position for clockwise operation	Position for counterclockwise operation
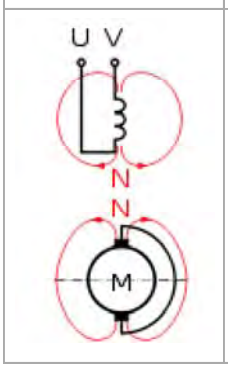	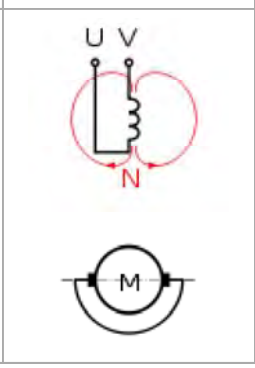	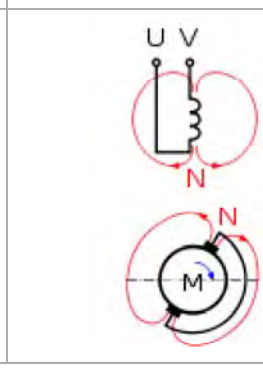	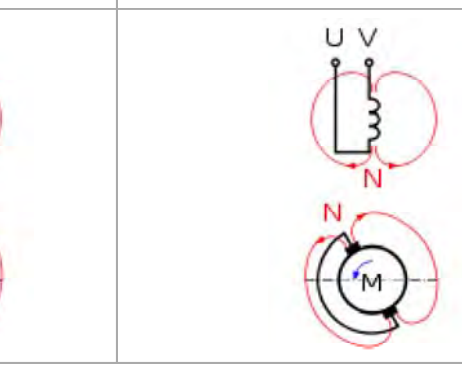

Repulsion motors are based on the principle of repulsion between two magnetic fields. Consider a 2-pole salient pole motor with a vertical magnetic axis. The armature is connected to a commutator and brushes. The brushes are short circuited using a low-resistance jumper. When alternating current is supplied to the field (stator) winding, it induces an electromotive force (emf) in the armature. The direction of alternating current is such that it creates a north pole at the top and a south pole at the bottom. The direction of induced emf is given by Lenz's law, according to which the direction of induced emf opposes the cause producing it. The induced emf induces current in the armature conductors and the direction of the induced current depends on the position of the brushes.

Stop positions

Brush axis parallel to field

If the brush axis is along the direction of the magnetic field, the armature behaves like an electromagnet and a N-pole is formed directly below the N-pole of the stator and a S-pole is formed directly above the S-pole of the stator. The net torque in this condition is zero. Both the N-poles repel each other and both the S-poles repel each other. The two repulsion forces are in direct opposition to each other and hence no torque will be developed. This is very fast process in this repulsion motor.

Brush axis at right angles to field

If the brushes are shifted through 90 degrees, so that the magnetic axis is perpendicular to the brush axis, the coils undergoing short circuit change. Apart from the coils undergoing short circuit, the voltage induced in the other coils between the brush terminals is neutralized and the net voltage is zero. Since there is no induced emf, there is no current in the circuit and the net torque developed is, again, zero.

Run positions

If the brush axis is displaced at an angle to the magnetic axis, a net voltage is induced at the brush terminals which will produce current in the armature. The current in the armature circuit will produce its own magnetic field, with North and South poles, but in this condition, the North Pole is not directly under the North pole of the magnetic axis and the South Pole is not directly above the South Pole of the magnetic axis. The poles of the armature are slightly displaced from those of the stator. In this condition, the N-pole of the stator field will repel the N-pole of the rotor field and the S-pole of stator field will repel the S-pole of the rotor field, so the rotor starts rotating.

Direction of rotation

The direction of rotation is determined by the position of the brushes with respect to the magnetic field of the stator. If the brushes are shifted clockwise from the main magnetic axis, the motor will rotate in a clockwise direction. If the brushes are shifted counter-clockwise from the main magnetic axis, the motor will rotate in a counter-clockwise direction.

Torque and speed control

The starting torque of a repulsion motor is determined by the angle of brush shift from the main magnetic axis. The maximum torque is obtained from a brush shift of 45 degrees. Brush shift can also be used to control the speed of a repulsion motor.

Types of repulsion motor

Types of repulsion motor are listed below. It is likely that the different types were developed to match the torque/speed characteristics of the motor as closely as possible to the service it was required to provide.

Elihu Thomson

The Elihu Thomson motor is the original repulsion motor and is described in "Construction" above.

Deri

The Deri motor is similar to the Elihu Thomson type but has two pairs of short-circuited brushes—one fixed and one moveable. This allows very fine control of speed.

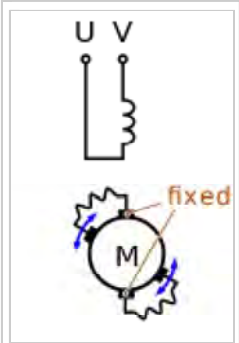

Two pole Deri motor

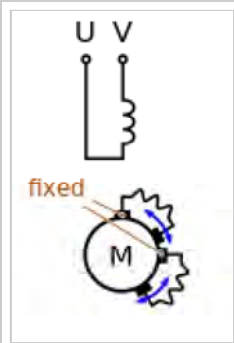

Four pole Deri motor

Latour-Winter-Eichberg

This is the "compensated" repulsion motor devised independently by **Latour** and by **Winter-Eichberg**. There are, again, two pairs of brushes but they are fixed at right angles to each other. One pair is short-circuited while the other pair is fed with variable-voltage alternating current from tappings on the secondary winding of a small transformer. The primary winding of the transformer is in series with the stator winding of the motor. This motor has the same torque/speed characteristics as an ordinary series-wound motor.

Atkinson

The **Atkinson** motor has two stator coils at right angles to each other. Speed control (by brush-shifting) is possible from 75% below synchronous speed to 10% above. Starting torque is about 2.5 times full-load torque with twice full-load current.

Repulsion-start induction-run

These were used where high starting torque was required. They started as repulsion motors, but once they were running at a sizable fraction of full speed, the brushes were lifted mechanically and all commutator bars were short-circuited together to create the equivalent of a squirrel-cage induction motor.

Applications

Repulsion motor applications included:

- High speed lifts
- Fans and pumps
- Printing presses
- Textile machines
- Film winding machines (smooth manual speed and direction adjustment could be achieved without complicated circuitry)

See also

- AC motor
- Electric motor
- Universal motor

References

1. *The Electrical Year Book 1937,* published by Emmott and Company Limited, Manchester, England, pp 79–82

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Categories: Electric motors | Electric power | Electrical engineering | Energy conversion

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Power for Water Pumping

The power required to pump water is proportional to the flow rate and to the pressure against which the pump is working. This pressure is usually expressed in terms of the "head," which has two contributions: (1) the height that the water must be pumped from groundwater level, and (2) an extra contribution, called the "friction head," due to friction in the pipes retarding the flow of water. A fairly accurate value for the power required can be calculated using the formula:

$$\text{Power} = 0.00025 \times \frac{G}{E_p} \times (WH + FH),$$

where

G = *water flow rate in gallons per minute;*
E_p = *mechanical efficiency of the water pump;*
WH = *water head—the vertical height in feet from groundwater level to tank inlet; and*
FH = *friction head in feet.*

This formula gives you the power in units of horsepower; to get the answer in watts, multiply by 746.

This equation is meant to work with the average flow rate and to give you the average power required by the pump. One simple way to establish an average flow rate is to estimate your need for water, expressed in gallons, and divide this need by the number of hours you expect the wind to produce usable power during the same time period. Do this on a daily, weekly or monthly basis—depending on the results of your wind survey. To get the flow rate in gallons per minute, then, use the formula:

$$G = \frac{\text{Gallons Needed}}{60 \times \text{hours of wind}}.$$

Friction losses depend on the pipe length L (in feet), the pipe diameter D (in inches), the number N of pipe joints and corners, and the flow rate G. The formula for friction head FH is:

$$FH = \frac{L \times G^2}{1000 \times D^5} + 2.3 \times N.$$

The pipe length L includes all pipes down in the well, across the pasture, and up the hill or into the tank. If pipe diameter changes along the way, as it usually does, this formula must be used separately for each different length of pipe, and the results added together to get the total friction head.

Example: *Suppose the depth of water in a well is 100 feet below the ground level. A 3-inch pipe brings this water to the surface. The water passes through one elbow joint and into a 1-inch diameter pipe running 200 feet along the ground, then through a second elbow joint and up 14 feet before passing through a third elbow and into the tank. Suppose the farmer needs 2700 gallons of water per day and there are an average of 6 hours of usable wind per day. How many watts of wind power must be supplied to a water pump with 75 percent efficiency?*

Solution: *The average flow rate needed is*

$$G = \frac{2700}{60 \times 6} = 7.5 \text{ gallons/min}.$$

The friction head in the 3-inch pipe is

$$FH = \frac{100 \times 7.5^2}{1000 \times 3^5} + (2.3 \times 1)$$

$$= 2.3 \text{ feet}.$$

The friction head in the 1-inch pipe is

$$FH = \frac{214 \times 7.5^2}{1000 \times 1^5} + (2.3 \times 2)$$

$$= 16.6 \text{ feet}.$$

The total friction head is the sum of these two contributions or FH = 18.9 feet. Then the pump power required is

$$\text{Power} = 0.00025 \times \frac{7.5}{0.75} \times (114 + 18.9)$$

$$= 0.33 \text{ hp}.$$

To get the answer, you just multiply by 746, so the power requirement is 246 watts.

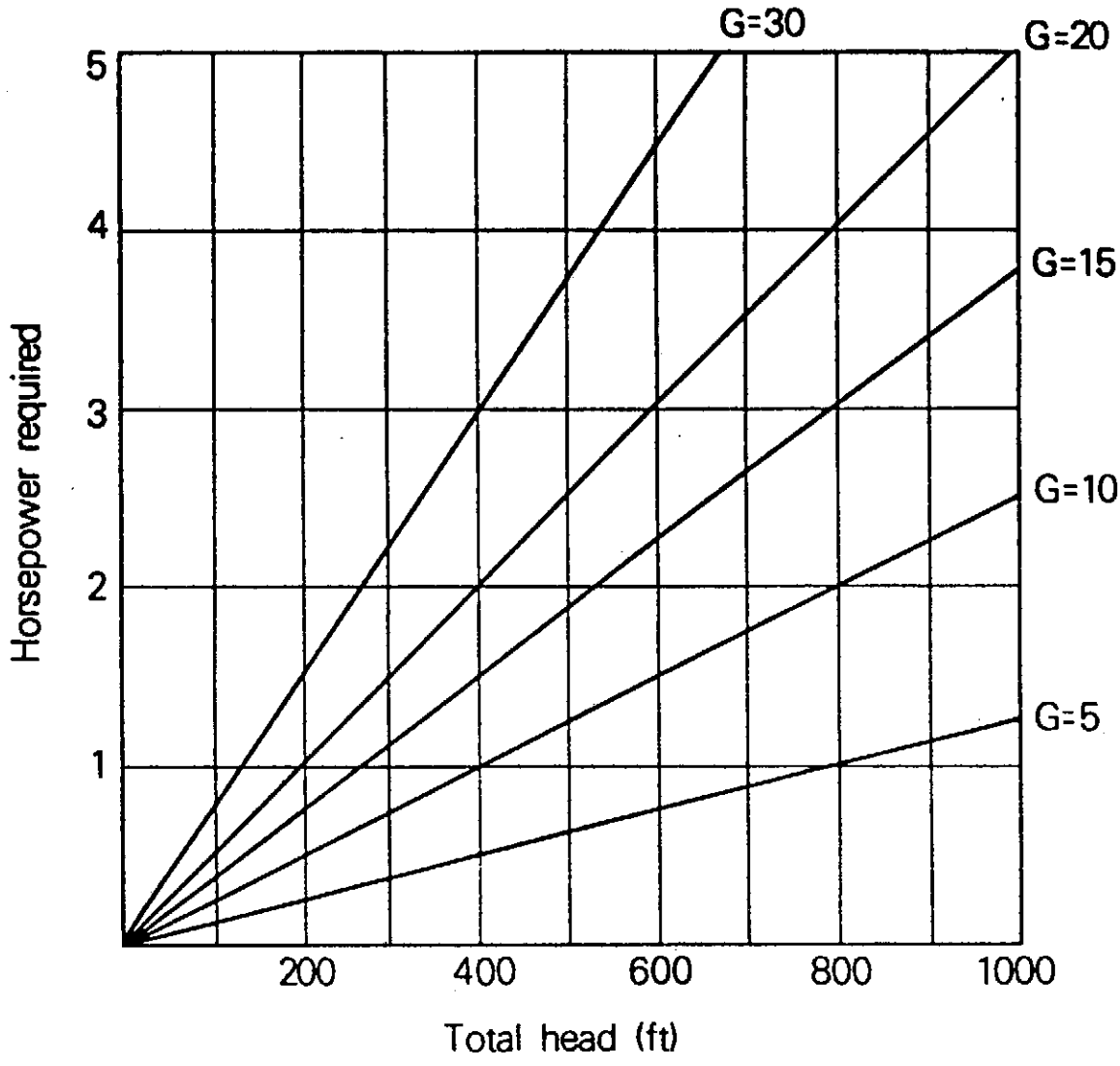

Pump power needed to lift water at a flow rate G, in gallons per minute. To get the wind power needed to drive the pump, divide by the pump efficiency—about 70 percent.

Rescue

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Rescue comprises responsive operations that usually involve the saving of life, or prevention of injury during an incident or dangerous situation.

Tools used might include search and rescue dogs, mounted search and rescue horses, helicopters, the "jaws of life", and other hydraulic cutting and spreading tools used to extricate individuals from wrecked vehicles. Rescue operations are sometimes supported by special vehicles such as fire department's or EMS heavy rescue vehicle.

Look up ***rescue*** in Wiktionary, the free dictionary.

Rescue team in Dresden, Germany, in 2006

Helicopter rescue

Real Helicopter rescue in Malta in 2007

Contents

- 1 Overview
- 2 Old meanings
- 3 See also
- 4 External links

Overview

Ropes and special devices can reach and remove individuals and animals from difficult locations including:

- Air-sea rescue
- Cave rescue
- Combat search and rescue
- Confined space rescue
- Helicopter rescue basket
- Mine rescue
- Rope rescue
- Search and rescue
- Ski patrol
- Surface water rescue
- Swiftwater rescue
- Urban search and rescue
- Vehicle extrication
- Wilderness

Rescue operations require a high degree of training and are performed by rescue squads, either independent or part of larger organizations such as fire, police, military, first aid, or ambulance services. In the U.S., they are usually staffed by medically trained personnel as NFPA regulations require it.

Patient in mountain rescue stretcher in Germany.

Old meanings

In former centuries the word "rescue" had other meanings: for example, there is an old record of a countryman living where Wythenshawe is now, being prosecuted in a local court for "making rescue" of a pig which had been seized as a distress for non-payment of money owed.

See also

- Animal rescue
- Civil defense
- Diver rescue
- Emergency management
- Extraction (military)
- International Rescue Corps
- Lifeboat (rescue)
- Rescue robot
- Technical rescue
- Vehicle extrication

External links

The dictionary definition of rescue at Wiktionary Media related to Rescue at Wikimedia Commons

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Categories: Rescue

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Residential and Non-Residential Drinking Water Installations and Drainage Requirements in Nepal

By: Andreas Bachmann & Heinz Waldvogel

Published by: The Mechanical Training Centre (MTC)
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DRINKING WATER INSTALLATIONS AND DRAINAGE REQUIREMENTS IN NEPAL

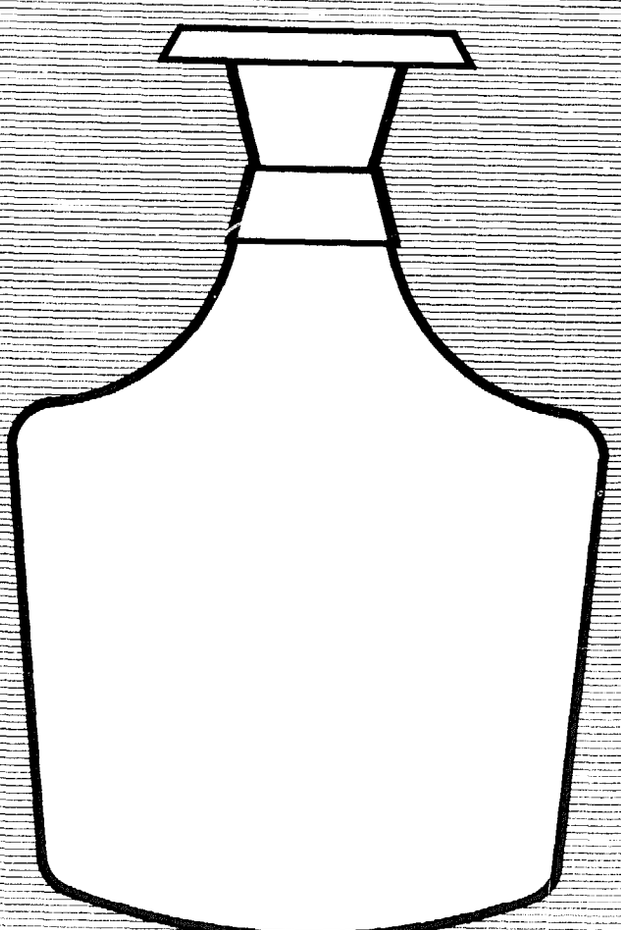

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MECHANICAL TRAINING CENTRE BALAJU

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DRINKING WATER INSTALLATIONS AND DRAINAGE REQUIREMENTS IN NEPAL

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The Mechanical Training Centre (MTC) is a vocational training centre run jointly by His Majesty's Government of Nepal and the Government of Switzerland through the Directorate for Technical and Vocational Education (Nepal) and Helvetas Nepal.

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INTRODUCTION

Urbanization is profoundly changing the face of many nations. Rapidly growing cities bring new possibilities, but also new challenges. One of the most vital of these challenges is the provision of piped water and of efficient sanitation for an ever-growing urban population.

In Nepal, as in many other countries, sanitary installation represents a new trade. It was with the intention of giving useful hints and guidelines to the practitioners of this trade that the first edition of this book was published.

This fourth edition is the result of a steady demand for the book in many countries. The opportunity has been taken to review and improve the entire text. Drawings have been redone and the section on drainage has been considerably enlarged. As in earlier editions, more than one solution is given for certain problems because some norms differ from country to country. In all cases, however, care was taken to use standard terminology.

In preparation of this edition, special thanks are due to Mr. Laxmi Bahadur Manandhar, Principal of M.T.C. and Mr. A. Wiederkehr of Helvetas, Zurich. Thanks are also due to Mr. Ram Prasad Shah, Draftman; Mr. Ram Kumar Thapa, Office Asst.; Mr. Purna Man Shrestha, Office Incharge. Grateful acknowledgement is owed to SSIV (Schweiz. Spenglermeister und Installateur Verband) for much additional information on soil and waste water drainage. The English language was checked and corrected by Mr. Nick Gregory.

This book is intended to be used as manual and reference work by practising sanitary engineers. We hope that it will continue to be a valuable and trusted companion to many planners and practitioners in Nepal and abroad.

Ben Dolf / Programme Director
Helvetas Nepal

Patrick Leu / Co-Principal
MTC, Balaju

FOREWORD

These guidelines were prepared in accordance with international and regional standards. Much attention was also given to the local conditions to ensure acceptable and troublefree installations.

This is the fourth edition, and has a wider coverage on drainage requirements in buildings. In this we have tried to give a proper blend of different types of modern installation technologies, suitable for actual needs. The manual includes essential details of technologies of different countries. Expressions vary from one region and language to another and this book aims to use internationally acceptable expressions without creating new words or definations.

As the Mechanical Training Center has a Sanitary Section, updated schooling materials were required. These guidelines were collected to give essential knowledge on sanitary installations in buildings in Nepal. Although the guidelines are quite complete they are not intended for self-teaching. This manual cannot and shall not be used in place of methodologically introduced teaching materials nor should it be used in place of school lessons.

We are grateful to the concerned authorities in Nepal and to Helvetas for having supported this new edition. Thanks also to Mr. R.P. Shah, Draftsman at MTC, for his many drawings included in this book.

Andreas Bachmann & Heinz Waldvogel

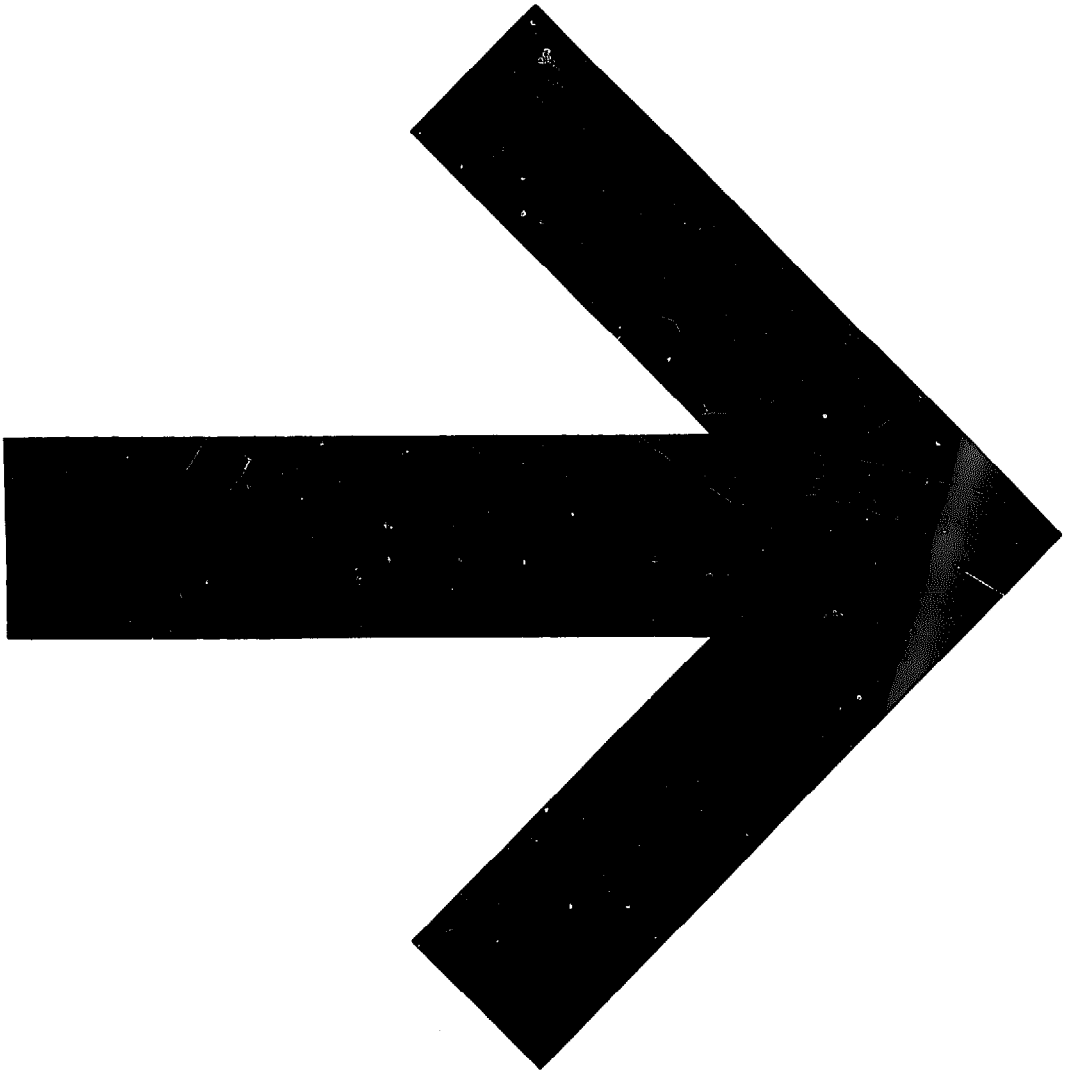

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DRINKING WATER INSTALLATIONS AND DRAINAGE REQUIREMENTS IN NEPAL

PART 1
DRINKING WATER INSTALLATIONS

DRINKING WATER INSTALLATIONS

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1. OBJECTIVES

This manual explains how to supply and distribute pure water, free of impurities and in sufficient quantity to the consumers. All connections to the main pipelines must be technically sound, so that the water will remain uncontaminated.

2. FIELD OF APPLICATION

This manual deals with drinking water installations from the town main supply to the tapping places, including the connected apparatus, as follows:

- communication and service pipes
- domestic installations (house installations)
- cold and hot water supply

2.100 REQUIREMENTS

Installations between the distribution pipes and the water consumer must fulfill the following requirements in order to maintain a pure and high quality water supply.

2.110 **Hygienic requirements** - The water must stay free of pollution or anything else harmful to health. Examples:

- Absorbing dirty substances,
- re-infections (through bad or wrong installation)

Also to be avoided are:

- the heating of water from the pipes (sun, fire, etc.)
- noise transfers.

2.120 **Technical requirements** - The installation and all connected apparatus must be adapted to the existing mains and flow pressure (from the distribution pipes) to guarantee an adequate quantity of water.

3. TERMS AND DEFINITIONS

3.101 **Main** - means a pipe laid by the water authority for the purpose of giving a general supply of water but does not include a communication or service pipe.

3.102 **Communication pipe** - means that part of a service pipe which lies between the main and the boundary of the street in which the main is laid.

3.103 **Consumer** - means a person supplied with water by the water authority.

3.104 **Meter** - includes an appliance or device used to measure or ascertain amounts of water taken or used from the water authority's waterworks.

3.105 **Service pipe** - means any portion of any pipe or any fittings from the water authority's mains to any premises which conveys or is capable of conveying water under pressure.

3.106 **Supply pipe** - means any portion of any pipe which is not a communication pipe.

3.107 **Storage tank** - means any tank for containing water supplied by the water authority or by the consumer, other than a flushing tank or hot water tank.

3.108 **Flushing tank**- means a tank with a discharging apparatus for flushing a water closet, sink, urinal or drain.

3.109 **Cylinder**- means a cylindrical closed vessel capable of holding water under pressure.

3.110 **Water fittings**- includes pipes and parts to change direction, branches, etc., (other than mains) taps, cocks, valves, etc.

3.111 **Apparatus**- includes water closets, wash basins, bath tubs, kitchen sinks, machines, tanks and other similar devices. Usually they have a drain for connection to the waste water system.

3.112 **Stop cock** - includes stop tap, stop valve, angle valve and any other device for stopping the flow of water in a line of pipes.

3.113 **Ball cock** - means flow operated valve for controlling the inflow of water to a tank.

3.114 **Overflow pipe** - means a pipe so fixed that the discharge of water may readily be seen.

3.115 **Waterworks**- includes all catchment areas, reservoirs, wells, boreholes, dams, weirs, tanks, cisterns, tunnels, filter beds, conduits, aqueducts, fountains, standposts, sluices, valves, hydrants, pumps, prime movers and all other structures or appliances used or constructed for the collection, storage, conveyance, supply, measurement or regulation of water, and which have been constructed by or on behalf of the water authority and are the property thereof or which shall hereafter be used or constructed by the water suthority.

3.116 **Premises** - includes dwellings, buildings, lands and leasements whether open or enclosed, and whether public or private.

3.117 **Catchment area** - means any surface of land or other area which collects rainfall for the purpose of the waterworks.

4. PRINCIPLES OF INSTALLATIONS

4.100 FUNDAMENTAL RULES

4.101 **Continuous supply from the mains** - the water authority will endeavour to maintain continous supply of potable water to consumers but will not be liable for compensation in respect of loss or damage caused by or attributable to any failure or disruption or supply.

4.102 **Security** - The quality of the water supplied must remain uncontaminated. And the installations made by the plumber must be carried out with greatest care, according to this manual.

4.103 **Skill and supervision** - Practical work should be done only by specially trained persons. To attain this manual's standard, the installation should be supervised during construction and in operating conditions.

4.104 **Materials** - all materials installed should be of good quality to guarantee proper, trouble-free function and long life for the installation.

4.105 **Apparatus** - The sanitary apparatus supplied must be of standard make and connected with the septic or sewer systems. Protection against the exit of the poisonous and bad smelling gases must be ensured by means of siphon or trap.

4.106 **Existing installations** - Should also conform to the rules of this manual. If safety is not guaranteed, repairs should be done immediately.

4.200 PROTECTION FROM DAMAGE FROM FROST

Every water fitting, whether inside or outside a building, should be placed so as to

reduce the risk of damage by frost.

4.300 **SUPPORT OF PIPES**

Every pipe shall be properly supported and so arranged as to avoid air locks or reverberation.

4.400 **PROTECTION AGAINST WATER HAMMER**

Both in choice of apparatus and design of the installation, consideration should be given to the avoidance of water hammer.

4.410 **Plug valves** - should not be used, except for draining purposes.

4.420 **Spring loaded flushing systems** - (as for closets, urinals) should be avoided, instead cisterns should be utilized. If a spring loaded flushing system is necessary then it should be installed so that there is **no possibility of a cross connection between the drinking water and the waste water system.**

4.500 **PROTECTION FROM DAMAGE FROM OTHER CAUSES**

Every water fitting should be so placed as to be readily accessible for purposes of examination and repair.

4.510 **Dissimilar metals** - water fittings of unlike metals should not be used unless effective measures are taken to prevent deterioration.

4.600 **DIRECT CONNECTION OF TOWN SUPPLY**

With pipes from private water supplies is not allowed.

4.700 **PREVENTION OF WATER POLLUTION**

4.710 Principles

4.720 The entire installation has to be assembled so that there is no possibility of **back siphonage** or back-flow of foul water or sewage or any form of pollution to the installed water system.

4.730 **Pipes are not to be laid through sewers,** - etc: No pipe shall pass into or through any ashpit, manure pit, sewer drain, cesspool, trash chute or through any manhole.

4.740 **Cross connections** - from the drinking water with the waste water system are prohibited.

4.750 **Waterworks have to be kept clean**. It is not permissible to deposit any earth, material, liquid or any dead creature in such manner or place that it may be washed, fall or be carried into the waterworks. However, nothing in this section shall be analysed as prohibiting or restricting:

a) any method of cultivation of land which is in accordance with the principle of good husbandry; or

b) the reasonable use of oil or tar on any highway maintainable at the public expense, so long as all reasonable steps are taken for preventing the pollution of any part or any water of the waterworks.

4.800 **APPROVED MANUFACTURE**

All pipes and fittings which carry water supplied by the water authority must comply with their regulations and be of approved manufacture.

4.810 **Costs of replacement** - All water installations have to be of good quality. It is required that water is kept clean and is not contaminated in any way, also including through defective installation. Consumption has to be within reasonable limits and must be measured properly. Although water is supplied by the water authority, alteration or renewal of pipelines and fittings may be charged to the consumer.

4.820 **Entry into premises** - The water authority may enter into premises into which pipes have been laid for the supply of water:

a) to inspect any supply pipe
b) to regulate and repair any supply pipe or meter as circumstances may require
c) to ascertain consumption
d) to disconnect the supply pipe to any premises or to suspend, stop. turn off or divert the supply of water to any premises or to suspend, stop, turn off or divert the supply of water to any premises.

4.900 **DISTRIBUTION OF WATER FROM OTHER SOURCES**

The concerned person should apply to the water authority for a licence if the water has to be supplied from under ground or from a river, lake or pond lying within the distribution area of the water authority.

However, a license may not be required for the under mentioned conditions which should be checked for approval with the concerned water authority:

a) If somebody wishes to take water supply of up to 5,000 liters (or the proper quantity approved by the water authority) for household purposes.

b) If some land owner wishes to take the water supply for cultivation of his own land from the nearest source attached to his land.

4.910 **Responsibilities of waterworks** - Waterworks are under the responsibility of the water authority for the following:

a) operation of waterworks
b) maintain the quality of water supply
c) grant permission to draw off, divert or take water from any stream or waters by which the waterworks are supplied, or
d) arrange to open or shut any valve, hydrant or stopcock belonging to the water authority
e) arrange for measurement of water consumption.

5. PARTS OF PIPELINES

5.100 **COMMUNICATION AND SERVICE PIPES (water authority)**

All communication pipes at present existing or here-after constructed should vest in the water authority and the water authority should at it's own expense, carry out any necessary works of maintenance, repair or renewal of such pipes.

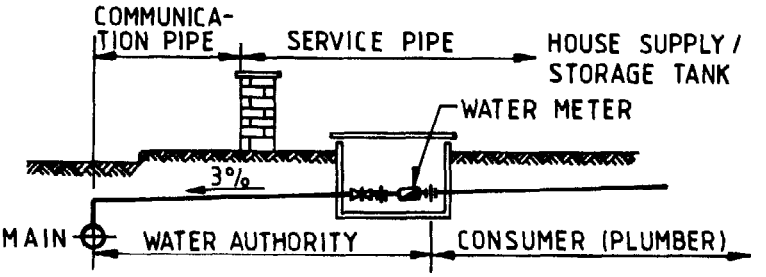

5.110 **Provision and maintenance of fittings** - The water authority may provide and sell or hire any water fittings and may install, repair or alter any water fitting, whether supplied by it or not and may provide any materials and do any work required in connection with the installation, repair or alteration of water fittings, making reasonable charge therefore.

5.120 **Stopcocks on pipe lines** - every pipe supplying water to a building shall be fitted with a stopcock adjacent to the water meter; near to the ground tank; or inside and as near as possible to the point where it enters the building.

5.130 Water authority regulations prohibit the installation of a suction pump directly into the main supply pipe lines.

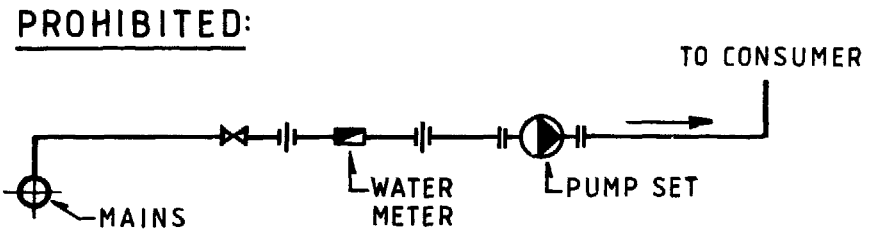

5.200 **SERVICE AND SUPPLY PIPES (Consumer)**

5.210 **Costs relating to supply pipes** - The cost of constructing, altering or repairing all supply pipes shall be borne by the consumer.

5.220 **Stand posts** - No person should erect a standpost for conveying water (supplied by the water authority) for the occupants of more than one building or of separately occupied parts of a building unless the pipe is provided with a non-concussive self-closing tap.

5.230 **Drinking troughs** - Every pipe supplying water to a drinking trough or drinking bowl for animals and poultry should be fitted with an approved ball cock for controlling the inflow of water so as to prevent overflow.

5.240 **Tap and stop cock pressure requirements** - Every draw-off tap and every stop cock not of the ordinary screwdown pattern shall be capable of withstanding a hydraulic test pressure of at least 20 kgs/cm2 and shall be of approved manufacture.

5.250 **Location of stop cock** - every stop cock should be so placed that it can be readily operated by the means by which it is designed to be operated.

6. WATER METER

6.100 **PRINCIPLES**

The provision, size and the placement of all water meters, both for domestic and industrial premises should be approved by the water authority.

6.200 **POSITION**

A water meter should, in general, be installed inside the consumer's boundry wall in a secure and readily accessible position.

6.300 **INSTALLATION**

Water meters, in general, are to be supplied by the water authority. A stop cock should be fitted on the supply side of the meter and the meter itself should be

fitted between unions or flanges for easy replacement.

6.400 **ACCURACY OF METERS**

The accuracy of water meters has always to be maintained. No person is permitted to:

a) alter or cause or permit to be altered any supply pipe with intent to avoid the accurate measurement of water;
b) willfully or negligently interfer with or injure any meter;
c) dishonestly alter the index of any meter used by the water authority; or
d) dishonestly prevent any meter used by the water authority from registering correctly the quantity of water supplied.

Handling of water meters, including repairs and replacements, are under the rules and regulations of the water authority.

7. STORAGE TANKS

7.100 **PRINCIPLES**

7.110 **Materials for storage tanks** - Every storage tank should be watertight and of adequate strength and should be constructed of galvanized iron or steel, copper, ferro-cement, concrete or other approved materials, and should be provided with a cover of an approved pattern.

7.120 **Protection from corrosion of storage tank** - Every tank should be suitably protected from corrosion.

7.130 **Capacity of storage tanks**- Every storage tank should have a capacity of not less than 100 liters and if used for hot water systems of not less than 200 liters.

7.140 **Placing of storage tanks** - Every storage tank should be so placed and equipped that it can be readily inspected and cleansed, and not be liable to any contamination.

7.150 **Storage tank support** - Every storage tank should be adequately supported and suitably covered.

7.160 **Every storage tank should be provided with a:**

a) **Manhole,** having a diameter of at least 50 cm, the edge of which is at least 20 cm above the tank top. The manhole should be provided with a cover which can be securely fastened;
b) Device, for the **control of the inflow** of water, so designed as to prevent overflow (e.g. ball cock or electrical pump-switch);
c) **Overflow,** which should be of a larger diameter than the inlet pipe and be at least 2 cm below the inlet level;
d) **Ventilation pipe;**
e) **Drain valve,**if possible
f) **Stopcock,** to be fitted to each draw-off pipe, as near to the storage tank as possible (on tanks exceeding [illegible] liters capacity).

7.170 **Ball cocks**

7.171 Every ball cock shall be **securely and rigidly fixed** to the tank it serves.

7.172 The ball cock should be fitted in such a **position** that:
a) It discharges at a level higher than the level of the overflow;
b) can easily be checked and repaired from the top, and without necessarily draining the water tank.

7.173 Every ball cock should be of **approved manufacture** and comply with the following requirements:

a) Working pressure of 15 kg/cm2 with every medium pressure valve of 10 kg/cm2 and every low pressure valve of 5 kg/cm2.
b) Every ball cock of the piston type should have a suitable washer of approved materials.

7.200 **LOW LEVEL STORAGE TANKS**

7.210 Principles

No storage tank should be buried or sunk in the ground unless there is sufficient space around for the purposes of maintenance and the detection of leaks. This shall not apply to a concrete tank designed and constructed to an approved standard.

When possible, tanks should be installed above ground level.

In the case of sunken tanks special precautions should be taken to avoid flooding. In particular, the manhole should be above any possible flood level.

Low level tanks should be secured with fastened manholes, having inlets with a control device (ball cock) and an overflow. Where possible, a drain-out system should be fitted which should include a drain cock or plug.

7.300 **ROOF TANKS**

7.310 **Placement** - Roof tanks shall be securely placed on top of the house installation, taking into account the structural requirements to carry the heavy weight. Tanks have to remain easily accessible for inspection and maintenance. They shall be placed on adequate battens, leaving gaps for air circulation beneath.

7.320 **Tanks inside the building** - roof tanks inside the building require a safety tray made of watertight design, having side walls of not less than 10 cm in height. Such trays need to be of greater surface area in order to securely collect overflowing water from the tank. A separate drain is required for the safety tray. Such tanks also require to be on battens leaving gaps for air circulation and prevention of condensed water accumulation.

7.330 The inlet requires a **control device**

a) A ball cock when connected directly to a pressurized system (town supply).
b) A cut-out switch at low level to be provided for the pump, arranged to operate when the tank is completely filled. Alternatively the tank should be fitted with a water level indicator.

7.340 The **supply outlet** should be positioned 5 to 10 cm above the bottom of the tank.

7.350 A **drain out** should be provided and arranged so that there is no direct connection with the waste water system.

7.360 Roof tanks require an **overflow,** the diameter to be larger than that of the inflow. The level of the overflow to be at least 2 cm below the level of inlet.

7.400 **PUMPS**

7.410 For installations in buildings **pumps** are normally used to move the drinking water from the ground tank to the roof tank, i.e., where the pressure from the mains is insufficient.

7.420 Alternatively **pressure boosters,** with cylinder and pump could be used, where there is continuous electricity supply.

7.430 The most common type of centrifugal pump used in such small installations is of the "**monobloc**" type, powered by electricity.

7.440 **Pumps and motors should be securely mounted** on concrete blocks, preferably higher than the surrounding floor or ground level. Pumps should also be provided with a roofing, in order to protect the electric motor and it's connection from rain water.

7.450 Pumps, as other devices fitted to the pipeworks, should always **remain easily accessible** for maintenance, and always be fitted with flanges or unions for easy removal.

7.460 **Pump connections.** These can be divided in two groups:

a) Suction or inlet pipework
b) Delivery or discharge pipework

Further there are differences in:

c) Gravity-fed installation (= efficient and trouble-free) (Ref: table no 1/11)
d) Suction-fed installation (Ref: table No 1/12)

7.470 **Suction pipe** - This pipework should be kept as short as possible and have a gradual rise towards the pump (to avoid air locks in the suction line). Diameters of such suction pipework should be the same as of the pump inlet connection or preferably be of the next larger diameter.

It is suggested to install a tee-piece near to the entrance of the pump, fitted with a valve and a funnel to enable initial priming, when required.

7.471 **Foot valve, strainer** - Suction pipes require a foot valve. It maintains water in the suction line on completion of pumping, reducing the need to prime the pump when pumping is recommenced. A swing type valve is recommended. A strainer is often incorporated in this type of foot valve.

7.480 **Delivery pipework.** The diameter of such pipes should be the same as of the pump exit connection. The pipes should be fitted in a straight line and where bends are required use those with a long radius to minimize frictional losses.

Pipes should be arranged so that there is a **gradual rise** from the pumps towards to the roof tank to enable automatic air release at the highest point, i.e. at the tank inlet.

7.490 Adjacent to the pump a **non-return valve** is to be fitted. This valve prevents the water of the delivery pipe from draining back through the pump casing when the pump is turned off.

Non-return valves: A swing type valve is the most suitable, since it offers less restriction to the flow as compared to the under-and-over type.

7.500 **DOUBLE-PUMP INSTALLATION**

For larger buildings at least two pumps should be fitted, having the necessary bypass pipeworks and valves. These pumps should be run alternately, giving security for continuous water supply.

8. PROTECTION AGAINST CORROSION

8.100 PRINCIPLES

The pipelines (pipes and connections) should be protected against corrosion.

8.200 PIPES IN THE GROUND/SOIL

Pipes, fittings and valves should be protected with an inert insulation.

Before the corrosion protector is applied to the pipes, all rust, tinder, dirt and all other impurities have to be removed.

The protection of pipes should be ensured by providing a suitable pipe cover.

Possibilities:

a) **Steel pipes, galvanized pipes** - galvanization is not sufficient as outer protection, it tends to be damaged during installation. Bitumen paint and a layer of hessian can protect the pipes.

b) **Cast-Iron** - in a very aggressive soil even cast-iron pipes have to be protected against corrosion. (clay soil, pipes in refill of building rubbish).

c) **Plastic pipes** need no protection against corrosion, but they should be well protected against mechanical destruction and if necessary should be laid in sand. No stone or rock should be used in the first stage of refilling.

8.300 PIPES IN BUILDINGS:

If the pipes are visible, galvanized pipes will be used. Copper and stainless steel need no additional protection.

8.310 **Pipes in the walls** (under plaster): galvanized steel pipes must be protected with an anti-rust paint and with a wrapping or bandage, which must remain completely dry.

9. MATERIALS AND CONNECTIONS OF PIPELINES

9.100 MATERIALS

9.110 a) Laying in soils:

- welded or seamless steelpipes, galvanized, (called G.I. pipes)
- jointless steelpipes, internally coated
- cast-iron pipes (called G.I. pipes)
- H.D.Pe (only best quality and made specially for water pressure pipelines to be used).
- Ductile iron pipes

Prohibited:

- Plastic pipes as used in conduits for electrical installations.
- the use of lead pipes (poisonous)

9.120 b) Installation in buildings:

- welded or seamless steel pipes, galvanized (G.I. pipes)
- copper

Prohibited: lead pipes

9.200 PIPE CONNECTIONS

9.210 **The pipe connections** should be made in such a way that the strength of the pipe material should not be weakened connections as follows:

- Thread connections, welding connections
- hard soldering, compression joints
- screw socket connections
- connections with flanges and gaskets
- connections with sockets and lead.

9.220 **Thread connections** - fittings of good quality are necessary for thread connections with steel pipes (G.I. pipes).

9.230 **The fittings have to be leak-proof.** The thread must be cut exactly at right angles to all branch directions. They must also have full threads without much space. After cutting the pipes, the inside burr (spin) must be removed.

9.240 **Thread cutting** - lubrication oil of acceptable quality shall be used for thread cutters (No old mobil oil!)

9.250 **Thread joint** - non-poisonous materials shall be used, such as hemp and joining paste (compound) or teflon tape. No putty: **the use of putty is prohibited.**

Cautions: Red and white lead jointing compounds should not be used in pipe joints for health reasons (white lead was very often used, but it is a health risk).

Connections with flanges - Flange connections shall be used for pipes of 2" diameter and above. Flanges are often also used on pumps and other machines. The flange surface shall be parallel.

Other pipe connections - Caulked socket connections (lead joints). Lead joints should contain, after finishing the connection, jute rope in 2/3 of the socket, and lead in 1/3 of the socket.

Before caulking the rope inside the sockets, ensure that the pipes are well pushed together into the sockets, so that the rope does not enter into the pipes. Also check that the ring-type joint has been properly centered (centric-placement).

The joint should be poured in one casting as fast as possible.

Characteristics of G.I. pipes

Nominal	Diameter i.d.*	Diameter o.d.	Approx. weight' per meter in kg	Useful length of thread in mm
1/2	16	21.3	1.2	13
3/4	21.6	26.9	1.5	15
1"	27.2	33.7	2.4	17
1 1/4"	35.9	42.4	3.1	19
1 1/2"	41.8	48.3	3.6	19
2"	53.0	60.3	5.0	24
2 1/2"	68.8	76.1	6.5	27
3"	80.8	88.9	8.4	30

* i.d. = nominal width, as of ISO standards

10. POSITIONING OF PIPELINES

10.100 LAYING IN SOILS

Pipelines must be placed as deep in the ground as possible so that they do not get damaged through mechanical forces, e.g. traffic. The covering should be, if possible, at least 1 meter deep.

Pipelines underground should be installed on a rising alignment so that the pipeline can be drained and air be released from the water system.

If the soil is yielding, the pipes must be protected, e.g. cast iron pipes break easily through settlement of poorly consolidated soil.

Water pipelines must be at a higher level than the sewerage systems (waste water lines), so that **leakage from foul water may never enter the drinking water system.**

Cast iron pipes are vulnerable to any movement and must be protected by being surrounded with an elastic substance when passing through walls.

If there are valves outside the building, they must be protected, have a waterproof signboard, and be indicated with marker plates.

For pipelines laid in the ground: bends should be used in preference to elbows.

10.200 PIPELINES INSIDE THE BUILDING

10.210 **Layout** - The pipelines should be laid as straight as possible, and change of direction made by means of elbows with a small radius.

10.220 **No bending** - G.I. pipes must not be bent (by bending the galvanization may split off and cause corrosion).

10.230 **Drainage** - A drain valve must be installed at the lowest point of the whole installation.

10.240 **Pipe closure** - Pipe covers have to be made of pressure resistant and watertight materials, such as: metal, plastic or other suitable materials. A cover can be a plug, cap, blind flange, etc., however, other stoppings (as for example wooden plugs) are not permissible. Completed installations, but not connected inside pipelines, must be closed with such covers.

10.250 **Building strength** - The building must not be weakened through the installation of pipelines and other sanitary requirements, (slits, openings, cutting of reinforcement iron, etc.). Therefore, care must be taken to avoid weakening the structure when breaking holes. Particular care must be taken not to cut reinforcing material.

10.260 **Exposed pipelines**

10.261 Water pipelines must be installed **beneath the electric** installations, where possible. (Condensed water may cause danger to the electric installations).

10.262 Pipelines passing **through floors** exposed to high moisture (kitchens, bathrooms) must be protected by waterproofing fitted closely to the pipe (Ref: Table 1/8)

10.263 **Pipes should be firmly fixed with clamps,** pipe carriers or suspension fixtures. In general these should be spaced at 1.5 m intervals, but account should be taken of the diameter and weight of the pipe.

10.270 **Concealed pipelines** (under plaster)

10.271 G.I. pipe and fittings (in protective wrapping) may only be covered with **non-corrosive material** such as cement plaster.

10.272 Any water connection liable to leakage (e.g. union, flange connection, valve) should not be concealed.

10.273 Hot water pipes require special attention for reasons of expansion and contraction, and also for reduction of heat losses (insulation).

11. INSTALLATIONS IN BUILDINGS

11.100 COLD WATER

110 **Distribution lines:** Each house should have at least two separate lines, each having a gate valve. They should be connected near to the water meter or adjacent to the roof tank. One line to be for the kitchens and the other for the bathrooms, so as to allow separate sections to be cut off without interrupting the supply to the other section.

Example: Distribution lines

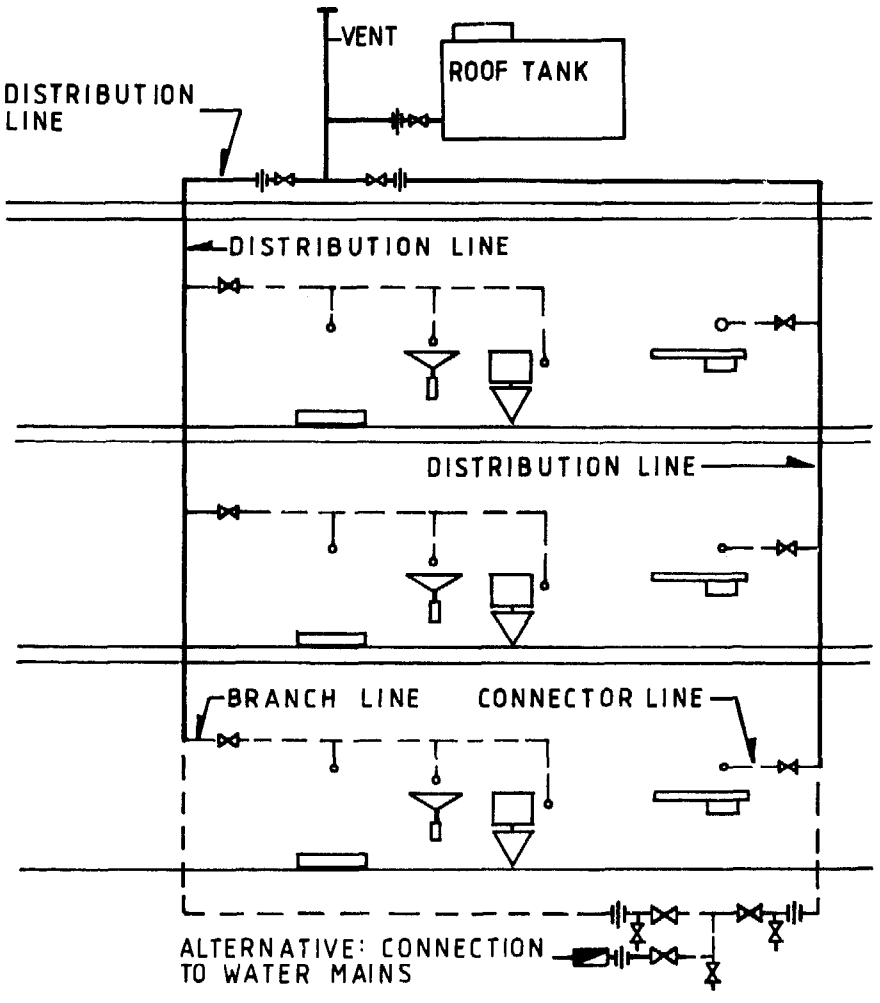

11.111 Additionally, in low pressure systems, there may be another separate distribution line with a valve for the **hot water system.** Fitted also near to the roof tank or adjacent to the water meter.

11.120 **Branch lines** - Houses designed for more than one family, and apartments, as well as hotels, hospitals, laboratories, etc., require a separate service valve for each unit (e.g. per one bathroom in a hotel), so as to allow convenient repairs, without interrupting the others' water supply.

Example: Branch lines (in a hotel)

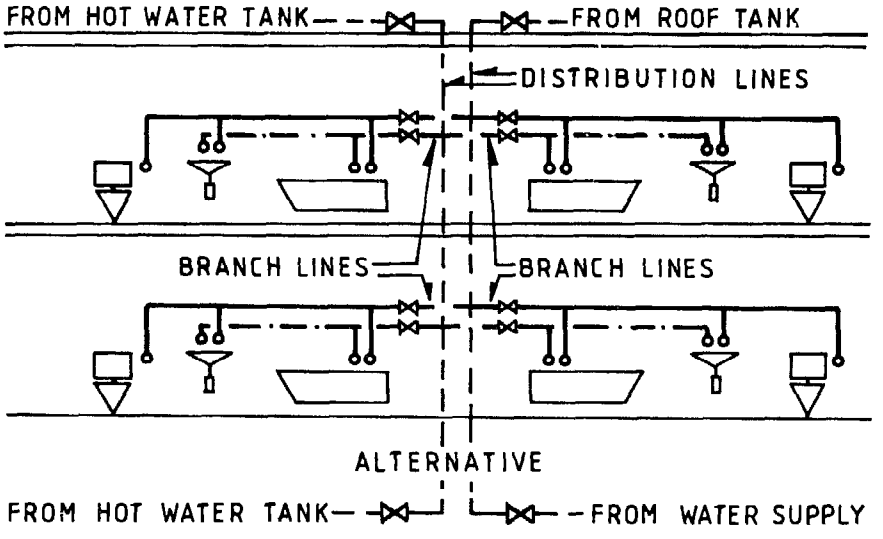

11.200 **HOT WATER SYSTEMS**

11.210 Hot water systems, in general, should be installed in the same way as cold water systems. However, more attention is required to the change of length through temperature variation (expansion, contraction), as well as for proper insulation.

11.211 Hot water systems are **more liable to corrosion** than cold water systems.

11.212 **Hot water heaters should operate at temperatures** of approx. 60° Centigrade, but not exceeding 70° C.

11.230 **Domestic installations:** The water is heated in water heaters (by electricity, gas, solar, etc.). They should be centrally positioned, so that the hot water is quickly available at the users' taps. These direct systems supply bath, kitchen sink, wash basin, etc. This system is commonly used in Nepal for domestic requirements and in hotels, hospitals, etc.

11.240 **Centralized systems:** Water is heated and stored centrally and distributed throughout the building by means of pipework with good insulation. In order to quickly receive hot water at the users' places these systems require constant circulation by means of a circulation pump, (or probably through thermosyphon, provided the hot tank is placed in the ground floor). These systems require much attention to good insulation to reduce heavy heat losses in the pipelines.

11.250 **Hot water tanks should be positioned so that:**

- the hot water reaches the taps within 20 to 30 seconds;
- they remain easily accessible for maintenance and repairs;
- heat loss is reduced, therefore tanks are fitted inside the building only.

11.260 Hot water taps should always be fitted in **mixing arrangements,** i.e. to have one spout outlet for both, cold and hot water. Such mixing taps require attention to guarantee proper function and safety to the house installation:

a) Hot water connections to mixing taps should always be on the left side (and with vertical mixers the hot tap below).

b) Mixing taps must always have one open outlet in order to avoid internal hot water circulation into the cold water line, i.e. without intervening valve between the mixing valve and the outlet.

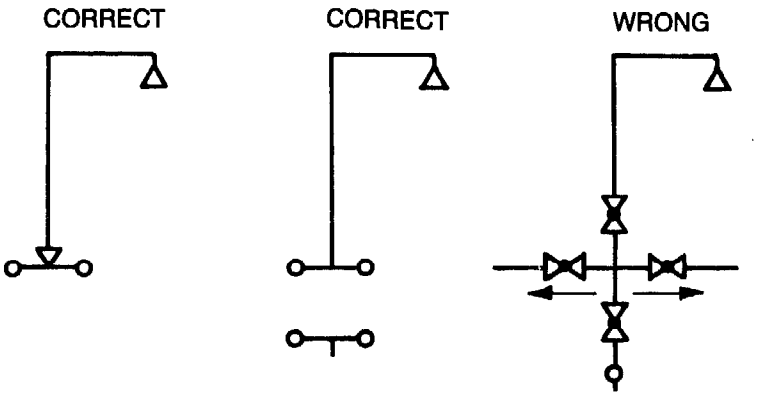

OPEN OUTLETS PREVENT INTERCONNECTIONS

TAPS ON OUTLETS ENABLE INTERCONNECTION OF HOT INTO COLDLINE

c) For successful shower installations it is required that the **pressure must be adequate.** Note that telephonic showers have large losses in pressure and should be installed only where pressure is above 5 meters head, otherwise a metal pipe should be fitted.

LOW PRESSURE INSTALLATION:

TELEPHONIC SHOWER

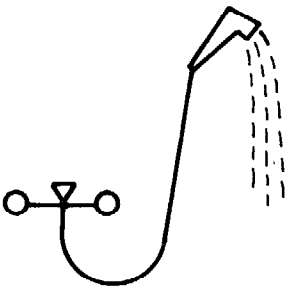

(INSUFFICIENT FLOW)

METAL PIPE INSTALLATION

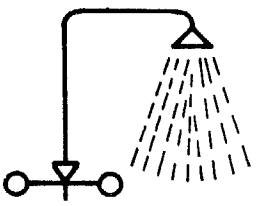

(SATISFACTORY FLOW)

11.300 **HOT WATER TANK CONNECTIONS**

11.310 Hot water tanks may be connected to the supply lines **only if adequate security measures** are taken into consideration (non-return valve, safety valve, pressure reducer, etc.). The source of energy (electricity, solar, gas, etc.), makes no difference for the above requirements.

11.320 A hot water tank must **always remain filled with water;** i.e. not to be drained when cold water pipelines are without water.

11.330 Pressure of supply line and **limits of tank operation** pressure are to be checked prior to installation. Where the pressure in the cold water line exceeds 30 kg/cm2, and where the heater is not designed to operate at high pressure, a pressure reducing valve or a separate feed tank (with ball valve) has to be fitted in the cold water system.

11.340 A **stop valve** must be fitted in the cold water line adjacent to the heater to allow it to be removed for repair without draining the entire line.

11.350 **Inlet and supply connections** to heaters must be fitted with unions, and the cold water inlet must lead to the bottom of the heater.

11.360 **A drain branch** should be fitted between the stop valve and the apparatus (or the non-return valve, if such is installed), which should be provided with a drain cock operated with an open-end spanner or a stop valve or plug.
Note: drain outlets may not be connected directly to the waste water system.

11.370 **Non return valve** - A non-return valve is to be fitted in the cold water line, adjacent to the stop cock valve.

11.380 A **safety valve** is to be fitted between the non-return valve and the heater (and not having under any circumstances any stop valve fitted between!)

11.381 **Safety valves** should be provided with a **drain outlet,** which must not be connected directly to the waste water system.
Safety valves should release pressure if there is an increase in pressure of 0.5 to 1 kg/cm2 above normal working pressure in the line.

11.390 For smaller heaters up to 7 kW/hr one safety valve of 1/2" diameter is sufficient. Larger capacity heaters require larger safety valves (note: lever-arm safety devices are not permissible).

11.400 HOT WATER TANK CONNECTIONS TO ROOF TANKS

11.410 It is recommended to have **separate cold water lines** from the roof tank to each water heater. This system does not require a non-return valve (which often leaks and/or reduces an easy flow of water). The hot water tank will remain filled with water, even when the roof tank is empty (safety of electric heating element). A separate stop cock is required, adjacent to roof tank.

11.420 **Over-pressure** is to be released by means of a **safety valve.** Instead of a safety valve, a vent pipe can be fitted to allow excess pressure to escape. A vent pipe also acts as a anti-vacuum and so ensures an easy flow of hot water. This has its importance, especially in low pressure systems.

11.430 In buildings having more than two storeys or where it is not practical to provide separate water supply piping from the roof tank to each hot water tank, there must be fitted between the stop valve and the heater in a readily accessible position: **a non-return** valve and a safety valve between the non-return valve and the heater.

11.440 Hot water tanks must be **fitted with unions,** and have a **drain branch** in the cold water inlet pipeline. Drain outlets **must never be connected directly to the waste water systems!**

11.500 ECONOMICAL HOT WATER INSTALLATIONS

11.510 In order to achieve **economical utilization** of hot water systems great care is required at the planning phase. It is essential to reduce heat losses to the minimum. When installing hot water tanks and pipe-lines the following points should therefore be observed:

a) Use **well-insulated** hot water tanks only, having a minimum of 50 mm thickness (or preferably 75 mm) of good quality insulating material.

b) Where possible, keep the **hot water tank inside the building,** especially in areas where freezing can happen.

c) Keep the **hot water supply pipes as short** as possible, especially to the kitchen sink. The sink is used more frequently than other apparatus and a near-by water heater is therefore an energy-saving and economical solution.

When having a **solar water heater system** at a distance from the kitchen sink, an additional small water heater fitted near the sink could prove economical by using preheated water from the solar system.

d) Instead of using one pipeline of larger diameter it **might be better to have several lines** of smaller diameters, leading from the hot water tank to the various hot water taps.

e) **Insulation** of hot water pipes is required especially where the exit is directly from the top of the hot water tank. To reduce the heat losses at least the first vertical pipe and part of the horizontal pipe require an insulating cover (This situation often occurs with solar water heater installations).

11.600 **SAFETY**

11.610 **Electric hot water tanks** must be fitted properly to guarantee complete safety.

a) Installation away from direct water sprinkling: shower, bath tubs, rain, etc.

b) Electric connections (earth, fuse, switch, etc.) as per rules and regulations through specialized persons only.

c) Water heater not to be damaged when pipe system is without water supply. (Water tank always to remain filled with water - and draining possible only by opening of special valves).

Guiding principles for hot water requirements

Purpose	medium consumption / day Liter / person at 60-65 °C	maximum consumption / day Liter / person at 60-65 °C
modest domestic	20 - 40	30 - 60
comfortable standard	40 - 60	60 - 90
high standard	60 - 120	90 - 180
children hostel	40 - 60	60 - 80
hospital (town)	70 - 100	100 - 150
hostel (luxery)	upto 200	upto 300

Consumption	Quantity in ltrs.	Temperature °C
bathtub	150 - 200	40
shower (ca. 5-6 min.)	40 - 60 (20 - 30)	40
bidet (for 1 filling)	25	40
washbasin (1 filling)	6 - 8	40
kitchen (1 filling)	25 - 30	50 - 60
dish washing machine	15 - 25	55

12 APPARATUS AND VALVES

12.110 Each individual piece of apparatus in the installation must be controlled **by it's own stop valve** (angle valve, etc.). The connection between the stop valve and the apparatus should enable easy repair of the apparatus and valves, or easy removal for replacement.

12.120 Every draw off point (wash basin, closet, floor drain, etc.) **must be connected to the waste water** system with trapped outlets.

12.130 **Open containers** with direct connection to the drinking water system and without automatic inflow regulation must have the lower edge of the drinking water outlet to be at least 2 cm higher that the overflow, (Ref: Table: 1/7). If the inlet must be introduced under water level (fishbasin, swimming pool, etc.) a special interruption system must be introduced to obtain 2 cm space **in order to prevent back-siphoning.**

12.140 **Closet / Urinal Flushing** in principle, water closets and urinals shall be flushed by means of cisterns only. Where in special cases valves for direct flushing are fitted, it is absolutely essential that a back-flow prevention is included in the flushing pipe (e.g. vacuum breaker), to make any siphoning from the pan into the drinking water pipelines impossible. Note that such a flushing system requires pipes with large diameter, and could be troublesome when flushing in low-pressure systems.

12.150 **No pipe other than flushing pipe** leading from a flushing tank shall be connected so that it can deliver water to any water closet pan or urinal.

12.160 **Volume of flush** no flushing tank or other flushing apparatus serving a water closet pan shall give a flush of more than 10 liters (or of more than 5 liters per stall of a urinal).

12.170 **Fixing of non-return valves** these valves are fitted to prevent return flow of drinking water (i.e. opposite direction of supply). They are required with: hot water systems, pumps, foot valves, machines, thermo-regulated valves, pressure boosters, water treatment plants, etc.
Note: direct connections with other mediums than drinking water are prohibited by any means. Direct connections are not permitted by use of non-return valves!

12.180 **Connections of machines** are to be made of high-pressure resitant flexible tubes, and preferably in rooms only having a floor drain (for prevention of damage by water flooding). A stop cock must be fitted before such a flexible tube.

12.190 **Concealed fixtures** - valves shall preferably be fitted in the open, and remain accessible for repair and easy replacement. Where concealed installations are required only specially designed valves for these purposes shall be utilized.

13 FIRE HYDRANT LINES

13.110 **FIRE HYDRANTS SHOULD BE SITED IN A BUILDING ON ADVICE OF THE FIRE AUTHORITY**

13.120 Installations of fire hydrant pipelines require **separate distribution lines,** to ensure an adequate supply of water for the fire hydrants. In case of low pressure systems adequate roof tank capacity and pipelines of larger diameters must be provided.

13.130 **A connection from the fire hydrant** to regularly used sanitary apparatus (water closet) should be made in order to provide for water renewal. For pressure lines this should be at the highest point of the building and for low pressure systems at the lowest point.

13.140 **A minimum of 3" diameter pipe** should be installed for fire hydrants.

13.150 **The fire hose** (e.g canvas) has to be long enough to be able to cover the entire area with water.

13.160 **The hydrant locations have to be near doors** and stairs. in order to secure operation and escape.

13.170 **The hydrants must be accessable to all people** in the building (for 24 hours a day): no locks on cabinets. The fire hydrants need a large "F" sign on doors of cabinets.

14. FREEZING PROTECTION

14.100 To secure regular water supply and avoid damage, pipelines fitted in places with sub-zero temperatures **require special attention.** Security can partly be achieved by proper installation, however, when systems inside the buildings are left without room heating they need to be drained.

The following should be observed:

a) Feed line from mains to be underground (1 meter deep) Pipelines have **to be inside the building** as much as possible.

b) **Main valve to be inside the house,** having a drain valve at the lowest point. The drain valve has to be operated before freezing conditions occur, and must be left open until system is refilled.

c) All pipes to be fitted with **constant slope** towards either the taps or the lowest drain point. A proper **ventilation** is also required to guarantee a through drainage (top-most valve or ventilation pipe).

d) Pipelines **not to be concealed** in outer walls.

e) Consider whether pipes could be fitted on **walls or in ducts** - keeping distance from walls by means of clamps - and insulation added where required.

f) Pipelines **not to pass through shafts, chimneys,** etc., and to remain accessible as much as possible.

g) **Hot water tanks to be fitted inside the house,** with easy draining facility.

h) Pipelines and valves **exposed to outside temperatures** (pump line, pipeline in roof, vent pipe) probably **require good pipe insulation.**

i) **The use of G.I. pipes in the house is recommended,** they could be thawed by flame heat. (HDPe pipes have the advantages as they will not crack in normal circumstances, but if they freeze they cannot be thawed by flame heat).

k) **Water storage tanks and pipelines** may require lagging to prevent freezing of the water, especially when fitted in cold roofs. The insulation shall be of inorganic materials.

15. DIMENSIONING

15.100 Proper dimensioning is essential to guarantee a trouble-free supply of water, in sufficient quantity and with sound controls.

15.200 **THE DIMENSIONS CAN BE CALCULATED IN TWO WAYS:**

1) With tables (see table 15.460) for procedure for normal house installations,

2) Through calculation.

15.300 **FOR NORMAL INSTALLATIONS THE FOLLOWING LOSSES OF HEAD CAN BE ACCEPTED:**

- The flow-pressure (dynamic pressure) may **not** be less than approx. 0.5 kg/cm2 (7 lb/in2) and the total loss of head in the entire installation may not be more than 1 kg/cm2 (14 lb/in2).

- For pressure over 5 kg/cm2 (70 lb/in2), the pressure loss on the longest distance may not be more than max. 20 percent.

15.400 **NORMAL HOUSE INSTALLATIONS**

15.410

Loading values of taps and aparatus		
Utility	valve diameter	units
Washbasin, hand washbasin, bidet, flushing cistern, single tap	1/2"	0.5
Kitchen sink, service sink, dish washing machine, laundry trough, wash sink	1/2"	1.0
Bath mixer, shower mixer, wash fountain, washing machine (up to 6 kg)	1/2"	2.0

15.420 **Hot and cold water connections** must be taken into account separately for calculating the connection value even though they may be at a joint mixer.
For example: 1 washbasin 1/2"

Coldwater	**0.5 U**
Warmwater	**0.5 U**
Total Units	**1.0 U**

15.430 **Water heater connection-dimensions** will be according to the loading unit of the apparatus, i.e. the total of all units connected to the hot water system.
For example: 4.0. U = 3/4", or 8.0. U = 1"

15.440 **One loading unit (1.0.U)** corresponds to a medium water consumption of 10 liters/minute. In respect to quantities of 5 liters/minute, or less, the unit is taken as 0.5 U.

15.450 For installations with high **simultaneous draw-off** (schools, canteens, hotels, etc.), a higher consumption must be considered, e.g. by doubling the value of the units.

15.460 TABLE FOR DIMENSIONING WITH UNITS

15.461 A) For systems with roof tanks
(Head less than 40 meters)

LOADING VALUES AND DIAMETERS (G.I. PIPES)	
PIPE DIAMETER IN INCHES	MAX. LOADING IN UNITS
1/2	0.5 - 2.0
3/4	2.5 - 4.0
1	4.5 - 10.0
$1^1/_4$	10.5 - 20.0
$1^1/_2$	20.5 - 40.0
2	40.5 - 100.0

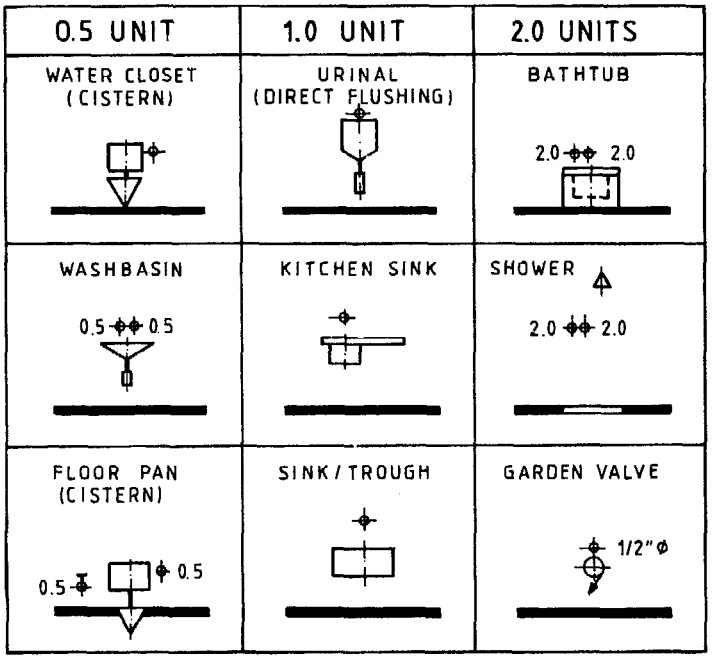

15.462 B) For systems with pressure
(Head above 40 meters)

LOADING VALUES AND DIAMETERS (G.I. PIPES)	
PIPE DIAMETER IN INCHES	MAX. LOADING IN UNITS
1/2	0.5 - 2.5
3/4	3.0 - 5.0
1	5.5 - 12.0
$1^1/_4$	12.5 - 25.0
$1^1/_2$	25.5 - 50.0
2	50.5 - 125.0

15.500 **CALCULATION OF DIMENSIONS**

For special conditions and in doubtful situations it is necessary to calculate the pipeline-diameters. For example:

- pipelines longer than 30 meters in length (measured from the tap farthest away from the tank)
- where there is simultaneous demand on the installations
- industrial districts
- fire hydrant lines

15.510 **Basis for the exact calculations are:**
- the acceptable loss of head
- the connected load of apparatus (unit) considering also the likelihood of the simultaneous use of the installations (Ref: table 1/39)
- the length and diameter of the pipes considering the loss due to friction (Ref: table 1/37)

15.520 **Procedure for calculation**

- Fixing of the acceptable loss of head
- Assessing the simultaneous demand of the installation according to the table.
- For industries, schools, etc., the fact that most of the taps might be used simultaneously must be taken into consideration.
- Working out the dimensioning, considering the probability of **simultaneous use** and the disposal loss of head.
- **Comparing calculated loss of head,** and acceptable loss of head. The results of both values should be about the same.
- If there is a big difference between the acceptable and the calculated loss of head, a **new assessment must be worked out.** The calculated loss of head has to be checked again as before using different pipe dimensions.

16. TESTING OF A NEW INSTALLATION

16.100 **A TEST MUST BE CARRIED OUT ON ALL PIPELINES PRIOR TO THEIR BEING COVERED.**

The procedure for the test should be as follows:

a) Pipelines should be closed off from all apparatus such as basins, water closets, hot water storage tanks, etc.

b) The system should be filled with water and be thoroughly ventilated to secure the release of all trapped air.

c) The system should be closed, and a pressure of 1 1/2 times the working pressure applied by means of a hand pump.

d) The system should remain under pressure for at least one hour. During this testing period the loss of pressure should not be more than 0.1 kg/cm2.

16.110 **After the pressure test** is completed satisfactorily all apparatus should be connected and the system refilled and checked for leaks.

16.120 **Before handover the system** should be filled and drained at least 2 times to ensure that it is properly cleansed of sand, cutting oil, or other material.

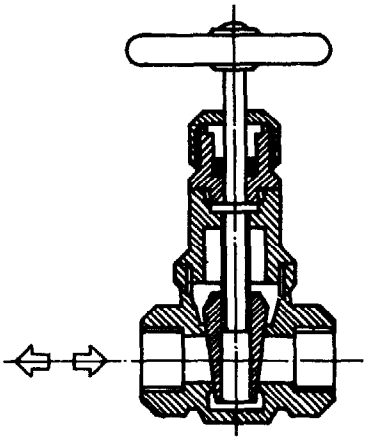

GATE VALVE (STOP VALVE)

The seat openings are usually of the same diameter as the inside of the pipes. They have very little loss of head, when the valve is completely opened.

Application: In main pipelines, before the taps. Where watertightness is not so important.
Don't use: As out-flush valve (too high speed in the pipeline, and not really watertight) instead, use a suitable tap.

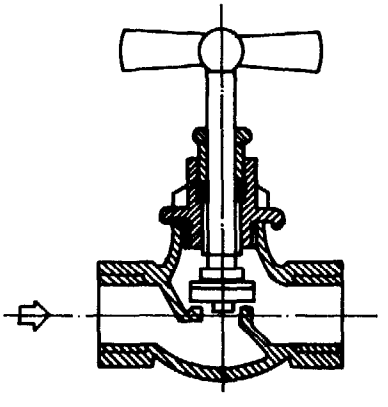

GLOBE VALVE (STOP COCK)

This valve has to be installed with the water pressure under the valve seat.
A globe valve can be repaired and is watertight, however, it has a quite high loss of head.

Application: for smaller diameters.
Don't use: as outflush (drain valve at water reservoirs).

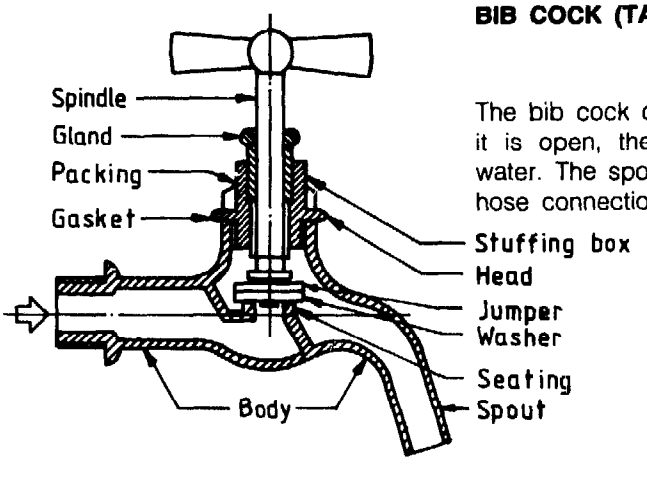

BIB COCK (TAP; FAUCET)

The bib cock closes against water pressure. When it is open, the passage is relatively free for the water. The spout may or may not be threaded (for hose connection).

C.P. VALVES, EXAMPLES

TABLE 1/2

BIB COCK

(Tap. faucet)

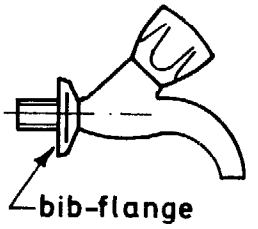

BIB COCK WITH HOSE CONNECTION

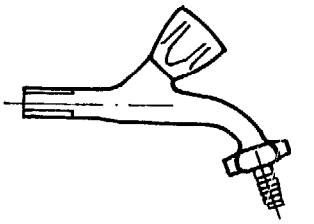

PILLAR COCK

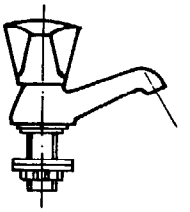

PILLAR COCK SWIVEL

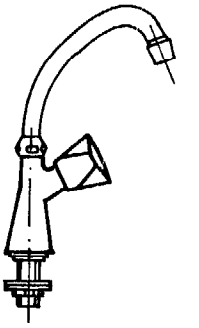

ANGLE STOP COCK

(Angle valve)

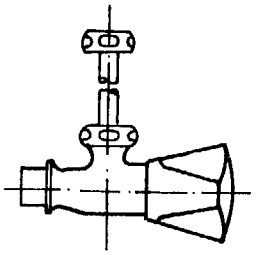

GLOBE VALVE

(Stop cock, female)

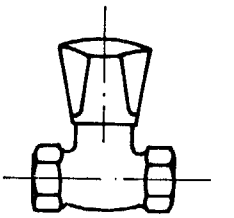

UP-VALVE (Under plaster)
(Concealed stop cock)

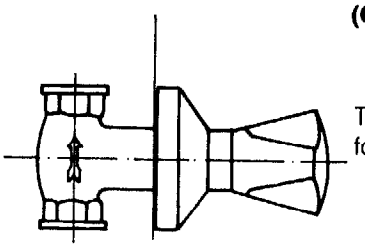

This is the only stop cock type which may be fixed for concealed pipes (under plaster).

C.P. = CHROME PLATED

C.P. VALVES, EXAMPLES

TABLE 1/3

BASIN, ONE HOLE MIXER

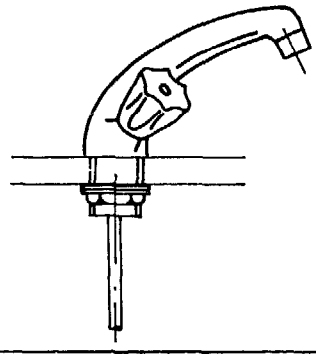

BASIN, THREE HOLE MIXER

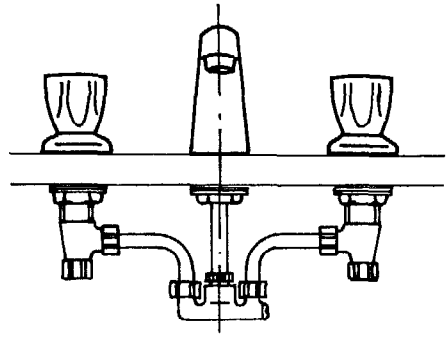

BASIN / SINK

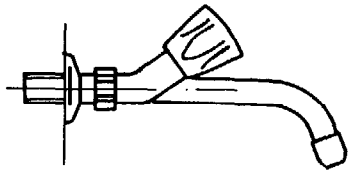

SIDE

WALL MIXER

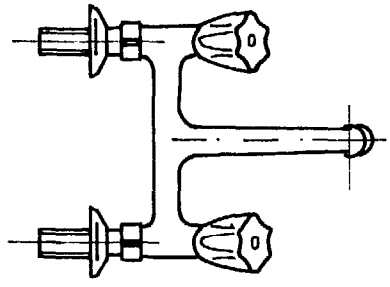

TOP

BATH WALL MIXER

With eg. telephonic shower
(Waterhead min. 5m)

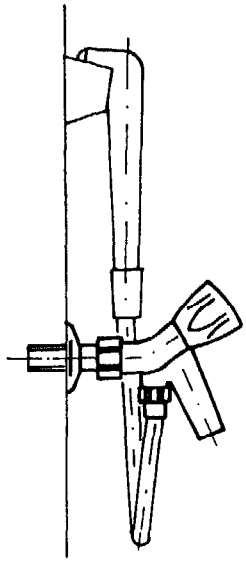

SIDE

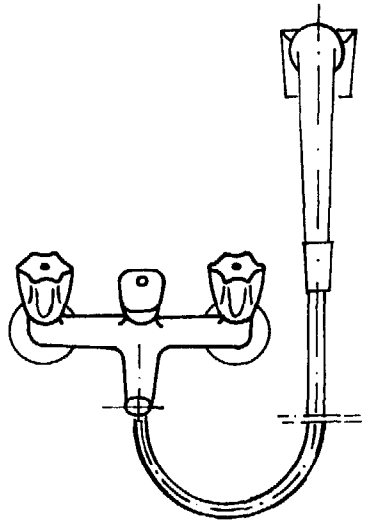

FRONT

C.P. = CHROME PLATED

VALVES, EXAMPLES

TABLE 1/4

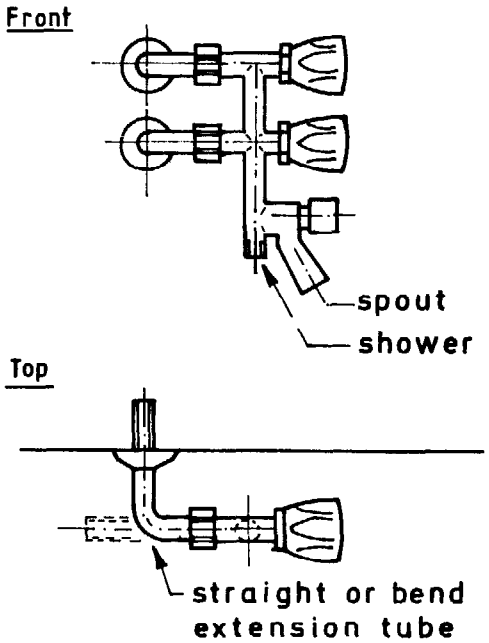

VERTICAL BATH MIXER

In many situations this rather unusual mixer might be the adequate solution, eg. if bathtub or. shower is in a niche or corner. In addition it can be the more economical installation. (Soma Plumbing Fixtures Ltd, India Similor, Switzerland).

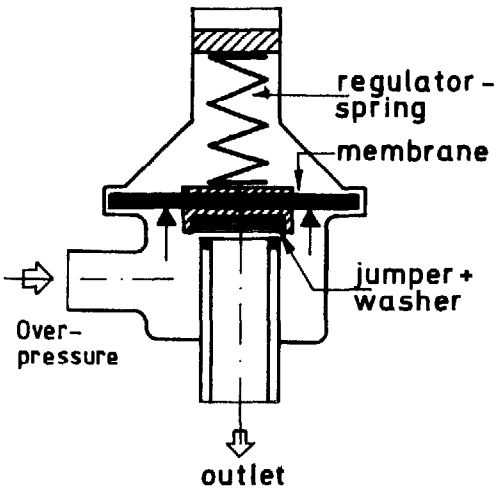

SAFETY VALVE (PRESSURE RELEASE)

Application: Must be fitted in pressure systems with hot water tanks (low pressure vent pipe will also do).

Caution: Verify the flush direction of the water.

Danger: Never install any valve between the hot water tank and the non return or any other valve !

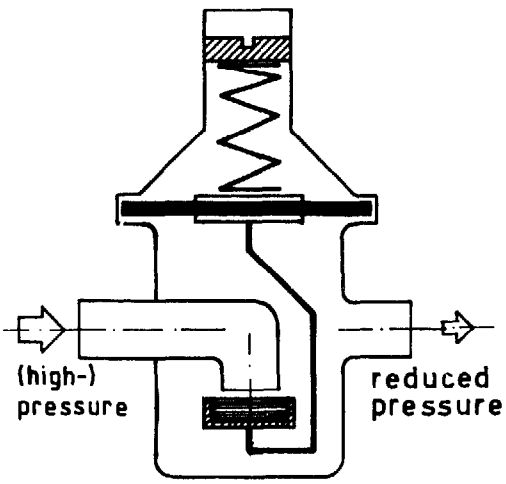

PRESSURE REDUCER VALVE

This valve is applied where a lower pressure is required.
Pipelines for domestic use should not be over a pressure of 4 kg/cm2 (= 40 m Head).

Note: Hot water tanks are normally built to resist a maximum head of 30 m. Where the water supply has more pressure a reducing device (pressure reducer valve, cistern) is required.

VALVES, EXAMPLES

TABLE 1/5

FOOT VALVES

Application: On inlets of suctions pipes in pumped systems

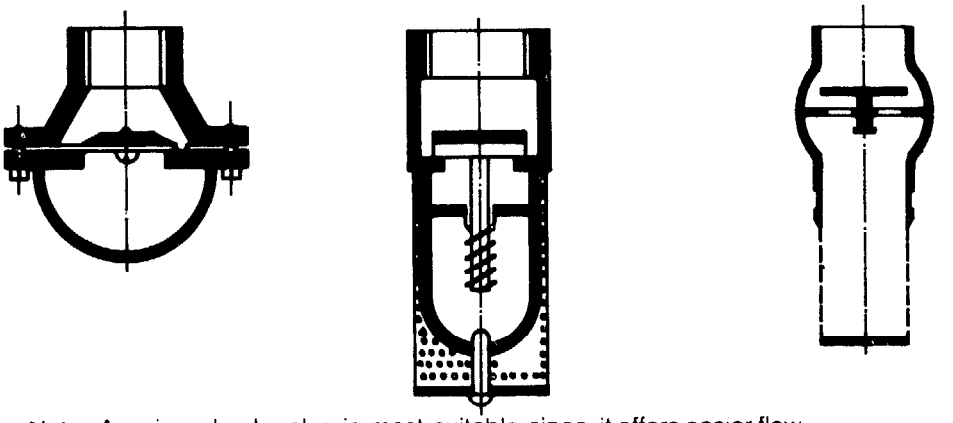

Note: A swing check valve is most suitable since it offers easier flow

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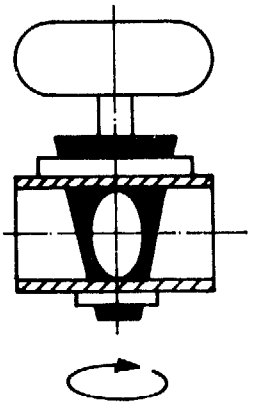

TAPERING PLUG (GAS COCK)

Applications: for gas installations and drain valves only.

Note: these valves are made for low pressure application only: since the water flow would be stopped to fast in pressure systems they would produce water hammers and damage the pipeline.

NON-RETURN VALVES

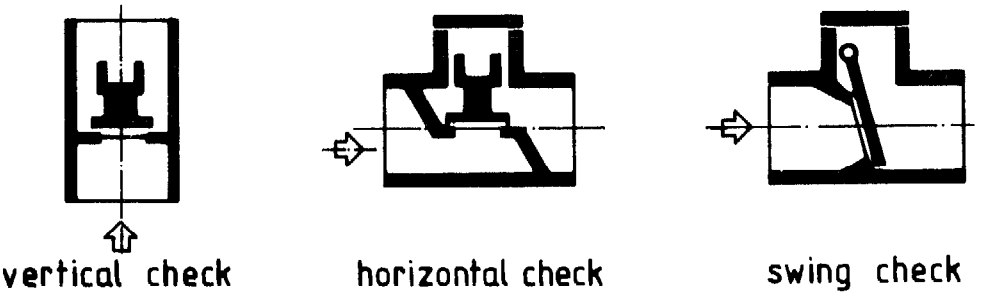

Non return valves are fitted in pipe systems to secure the flow direction and to prevent any flow back.
For application in systems with hot water tanks, solar water heaters, pumps, pressure boosters, washing machines, etc.
Swing checks are recommended (flap type), since there is full passage and less friction loss.
Caution: Attention has to be given to the flow direction. Non return valves have to be fitted in that way that the water pressure (incoming) remains under the valve seat.

G.I. FITTINGS

TABLE 1/6

EXAMPLE

BEND 90° (made out of steel tubes) 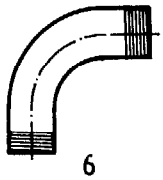 6	BEND 45° (made out of steel tubes) 8	ELBOW 90° female equal + reducing 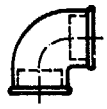 90	ELBOW 90° male + female equal + reducing 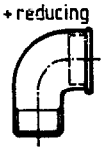 92
TEE female 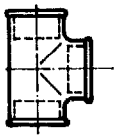 130	CROSS female 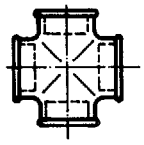 180	SIDE OUTLET ELBOW female 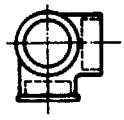 221	SIDE OUTLET TEE female 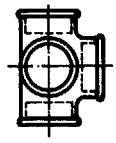 223
REDUCING SOCKET female 240	REDUCING BUSH female + male 241	RED. HEXAGON male 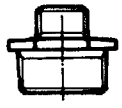 245	RED. SOCKET male + female 246
SOCKET 270	PLUG 291	BACKNUT 310	CAP 300
FLANGE 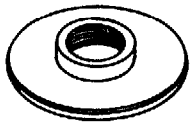 321	UNION flat sheet female 330	NIPPLE 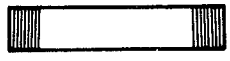 530	

WATER SUPPLY TO BATHTUBS AND BASINS

TABLE 1/7

PREVENTION OF BACK - SIPHONING

Bathtub, mixing - tap

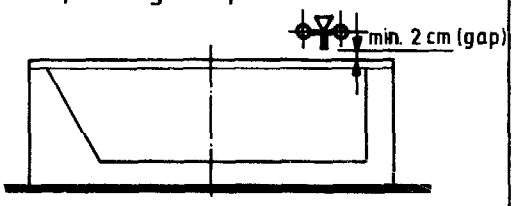

Safety valve

means of safe drainage

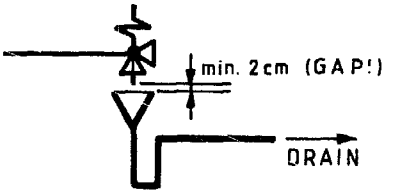

Correct

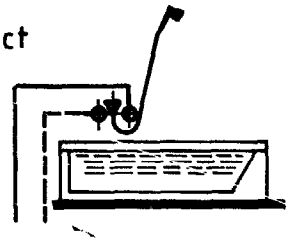

Keep telephonic showers out of bath tubs

Wrong

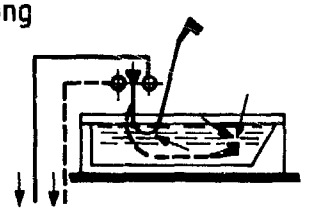

It is dangerous to have telephonic showers in used water : with empty feed lines, the water can be sucked into the drinking water.

DIRECT WATER SUPPLIES FOR BASINS

Basin / Inlet above water level

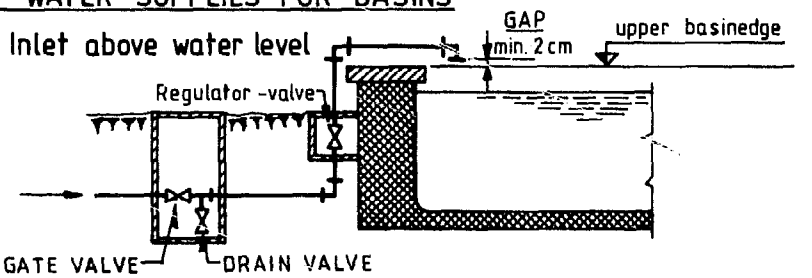

Inlet under water level

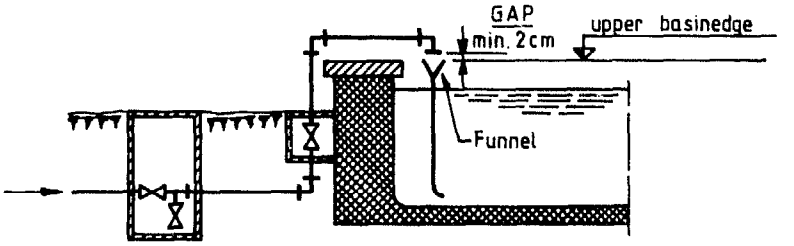

Wrong

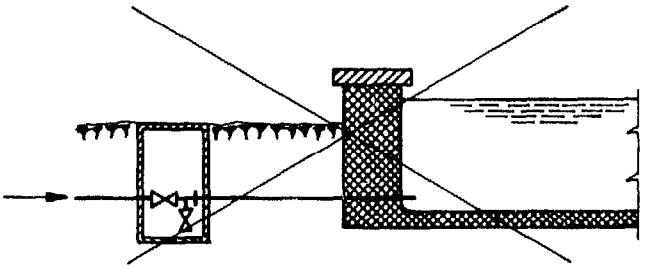

PASSAGES OF PIPES **TABLE 1/8**

THROUGH WALLS AND CEILINGS

Galvanized pipe through the outside-wall

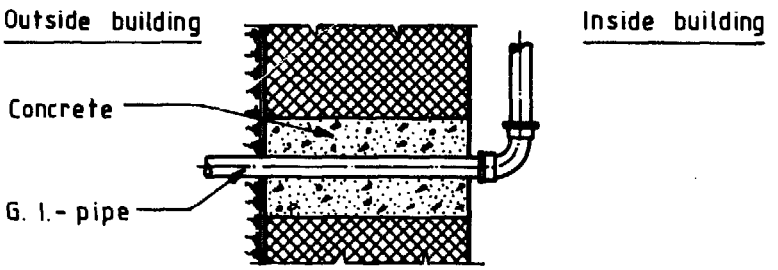

Cast iron pipe through the outside-wall

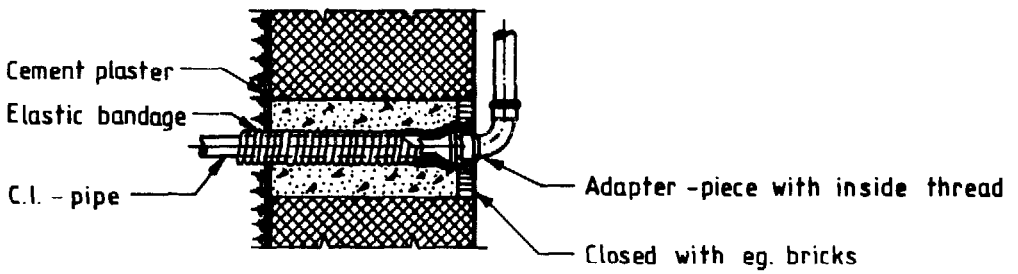

Galvanized pipe through 2 walls with expansion joint

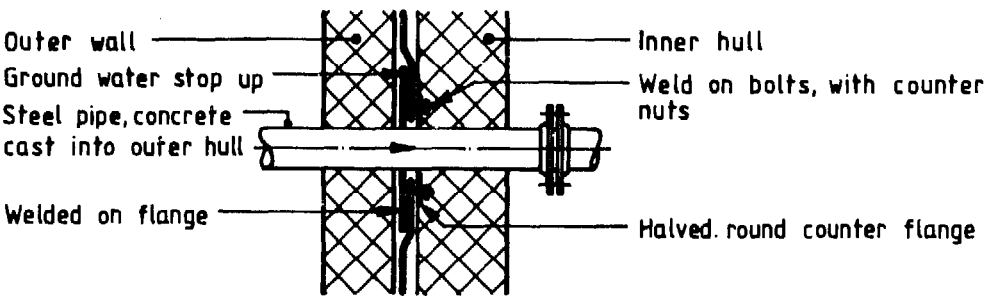

Pipe passage through ceiling (for rooms with high moisture)

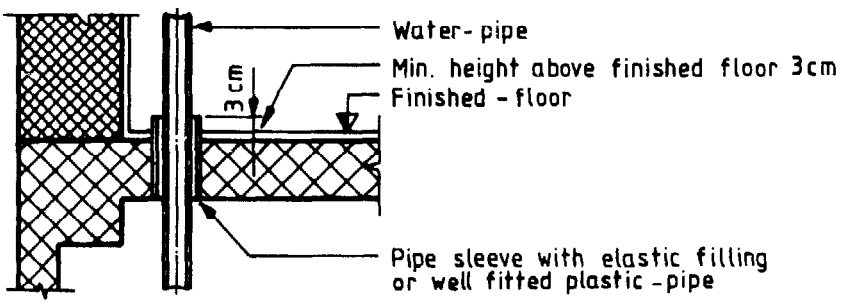

ROOF TANK PRINCIPLE REQUIREMENTS TABLE 1/9

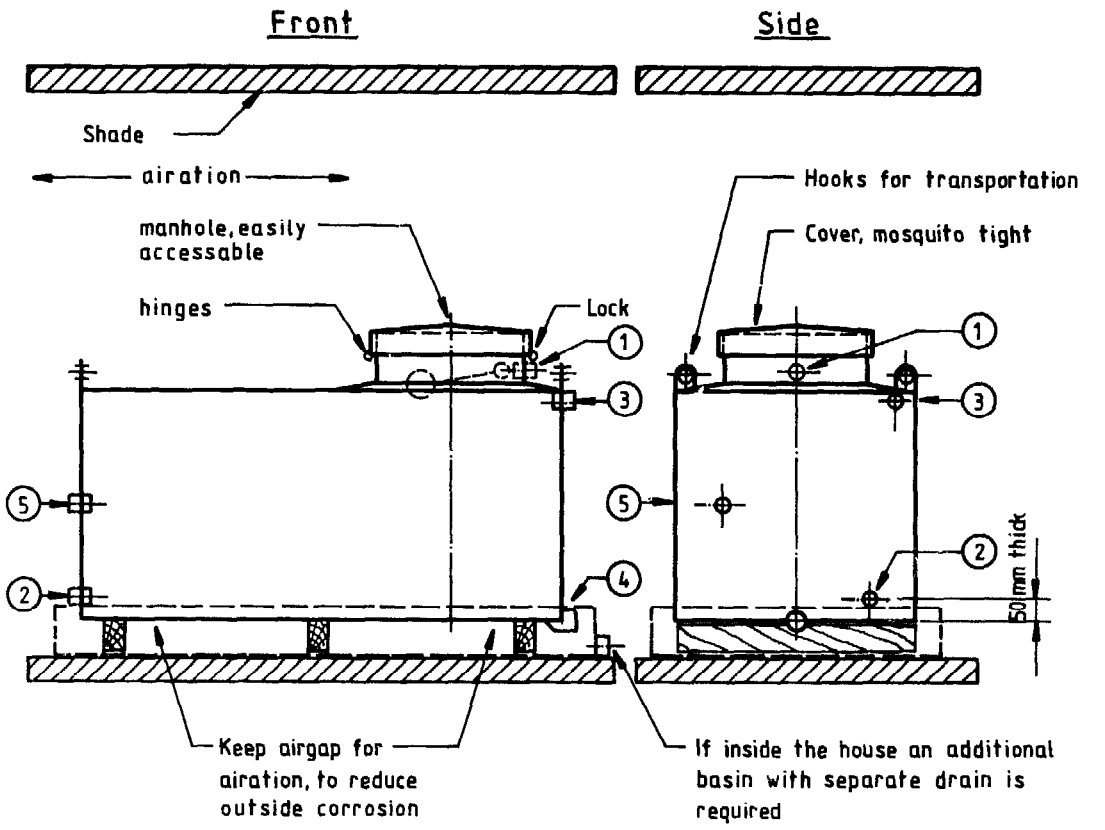

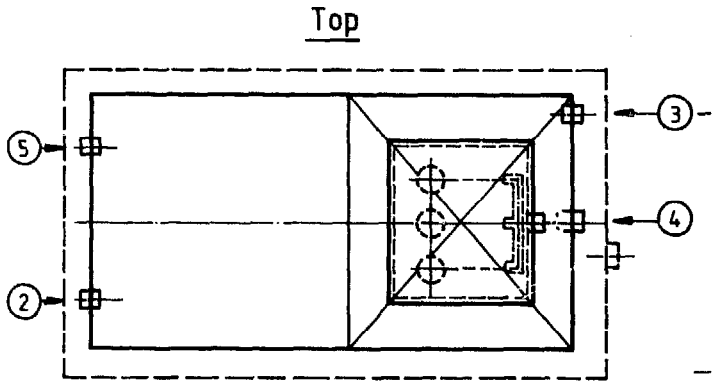

Materials :

- M.S. sheet, min. 2 mm thick corners welded
  Paintings:
  inside : red oxide + special non-poisenous bitumen
  outside : red oxide + aluminium paint
- galv. sheet, corners folded seams soldered (no putty, no rivets)
- cement

1 Inlet, with one or more ball valves, or open inlet, when filled with pump or with electric automatic control system.
2 Outlet, min. 5/4" Ø G.I. socket, and after fixing of main gate valve.
3 Overflow, min. 5/4" Ø G.I. socket.
4 Drain, min. 2" Ø G.I. socket with plug.
5 Interconnection, min. 5/4" Ø G.I. socket for possible extensions.

Note: A water level indicator is useful (clear plastic pipe) size of tank: Water consumption
per one person approx. 165 l/day, suggested minimal size: 1000 liters.

PARTS OF WATER INSTALLATIONS — TABLE 1/10

1 WATER MAIN
2 MAIN CONNECTION (FERRULE OR CONTROL VALVE)
3 COMMUNICATION PIPE
4 METER CONTROL VALVE
5 WATER METER
6 SERVICE PIPE
7 SUCTION PIPE WITH FOOT VALVE
8 PUMP
9 CHECK VALVE (NON RETURN)
10 DELIVERY PIPE (PUMP LINE; DISCHARGE)
11 OVERFLOW
12 DISTRIBUTION LINE
13 BRANCH LINE
14 APPARATUS CONNECTOR
15 TAP
16 WATER HEATER
17 HOT WATER SUPPLY LINE

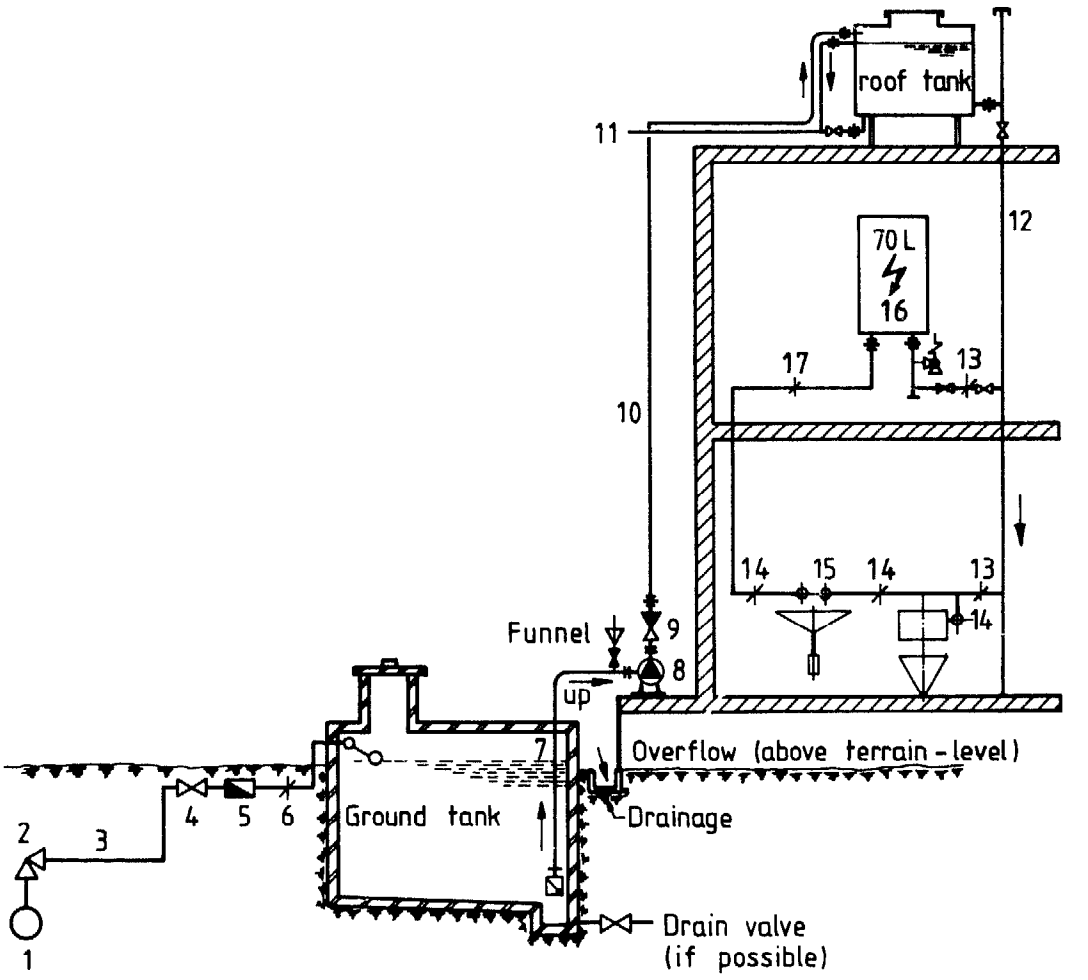

ROOF TANK CONNECTION, EXAMPLE

TABLE 1/11

1 MAIN VALVE
2 WATER METER
3 BALL VALVE
4 OVERFLOW
5 DRAIN-OUT
6 PUMP
7 NON-RETURN VALVE
8 ELECTRIC-PUMP SWITCH-OUT
9 WATER TO THE APPARATUS

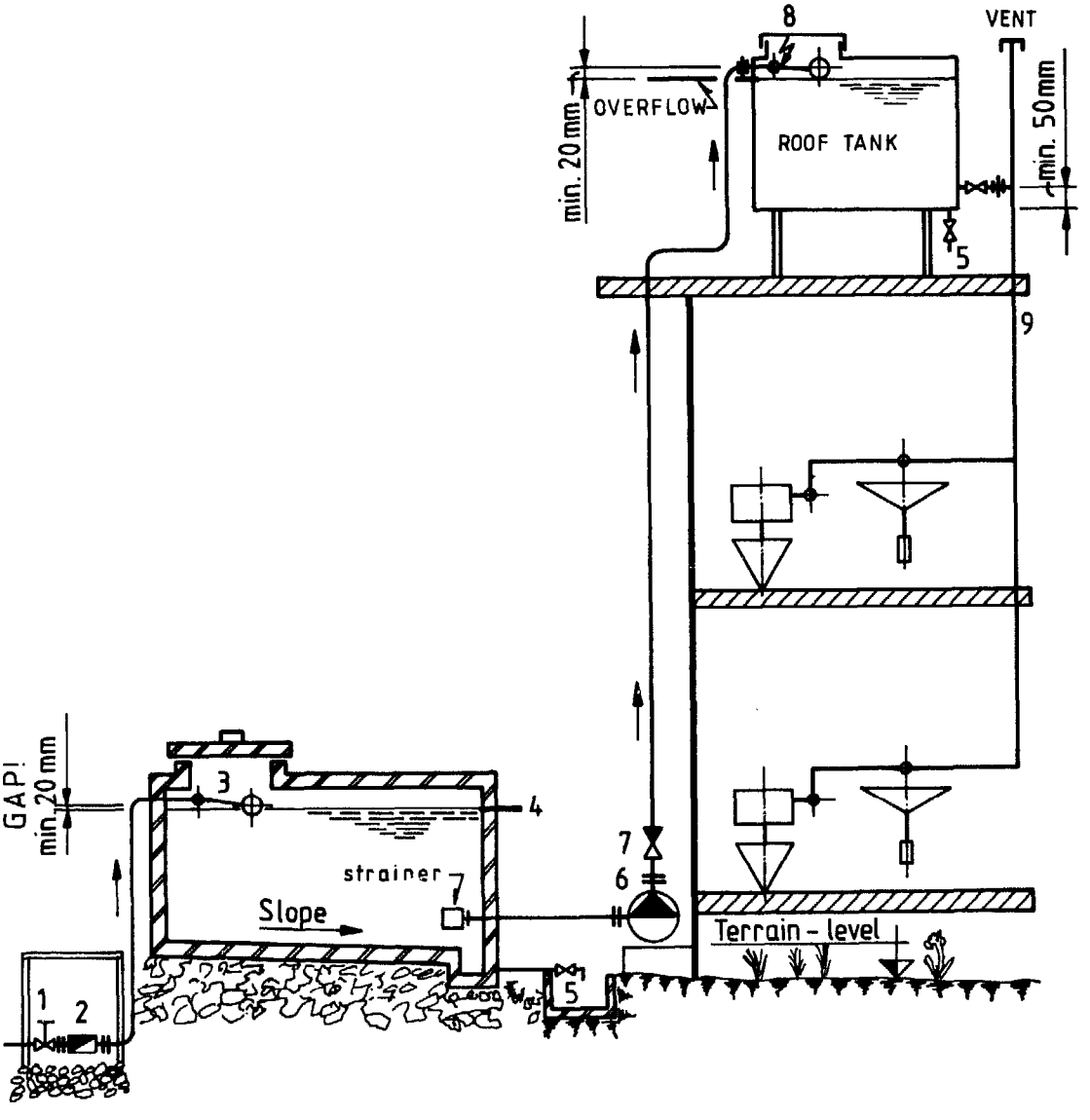

ROOF TANK CONNECTION, EXAMPLE **TABLE 1/12**

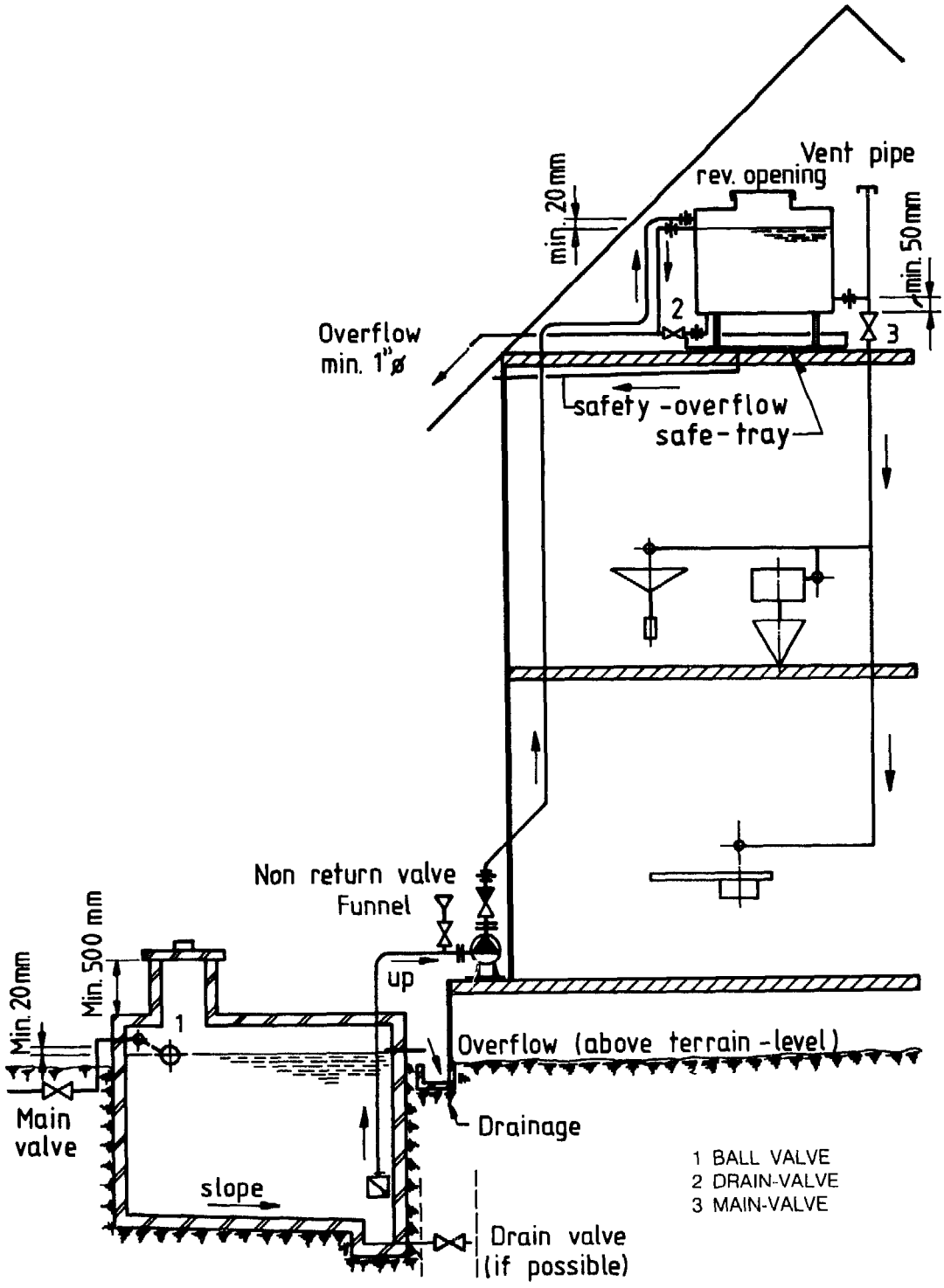

Note: Drinking water tanks should be above the ground

FIRE HYDRANT CONNECTIONS TO ROOF TANKS TABLE 1/13

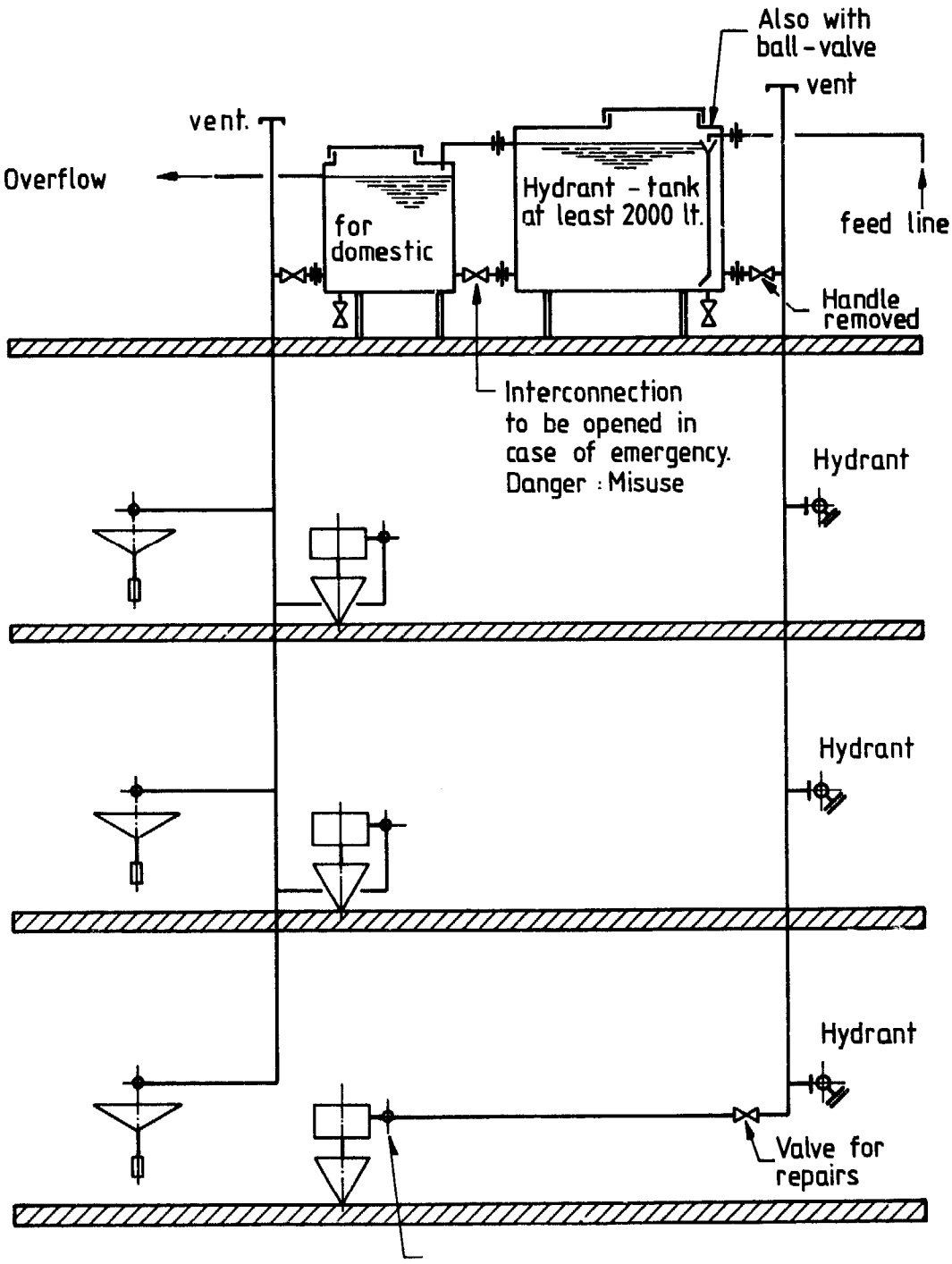

Note: Regular replacement of water in pipes and roof tank is maintained by having a cistern connected, at furtherst distance from tank, i.e. at lowest point.

PRESSURE INCREASE WITH BOOSTER

TABLE 1/14

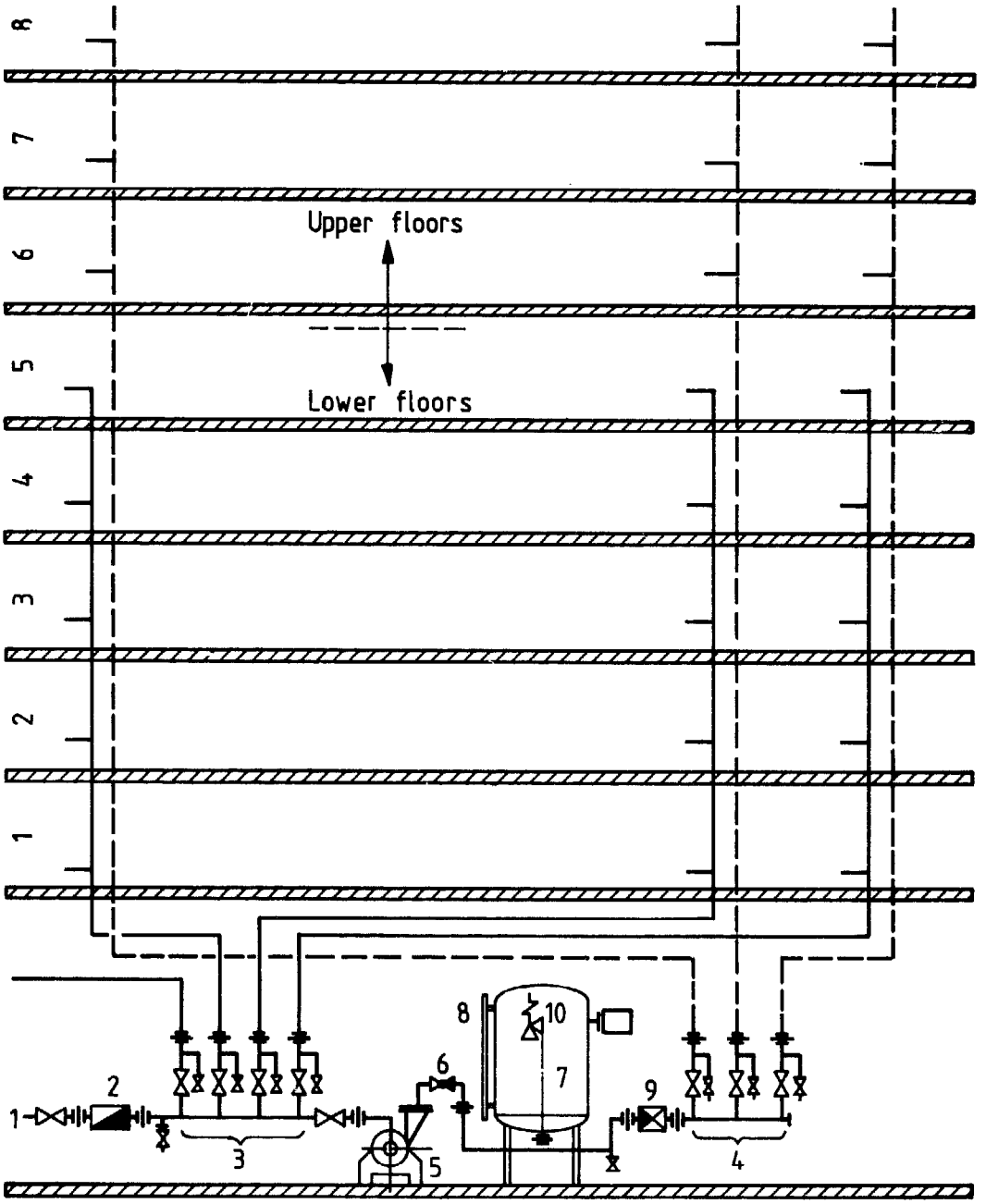

1 TOWN SUPPLY LINE
2 WATER SUPPLY LINE
3 DISTRIBUTION, LOWER FLOORS
4 DISTRIBUTION, UPPER FLOORS
5 PUMP FOR PRESSURE-INCREASE
6 NON RETURN VALVE
7 PRESSURE-BOOSTER
8 WATER LEVEL INDICATION
9 PRESSURE-RSEDUCER VALVE
10 SAFETY-VALVE

HOUSE INSTALLATION IN FREEZING CLIMATE TABLE 1/15

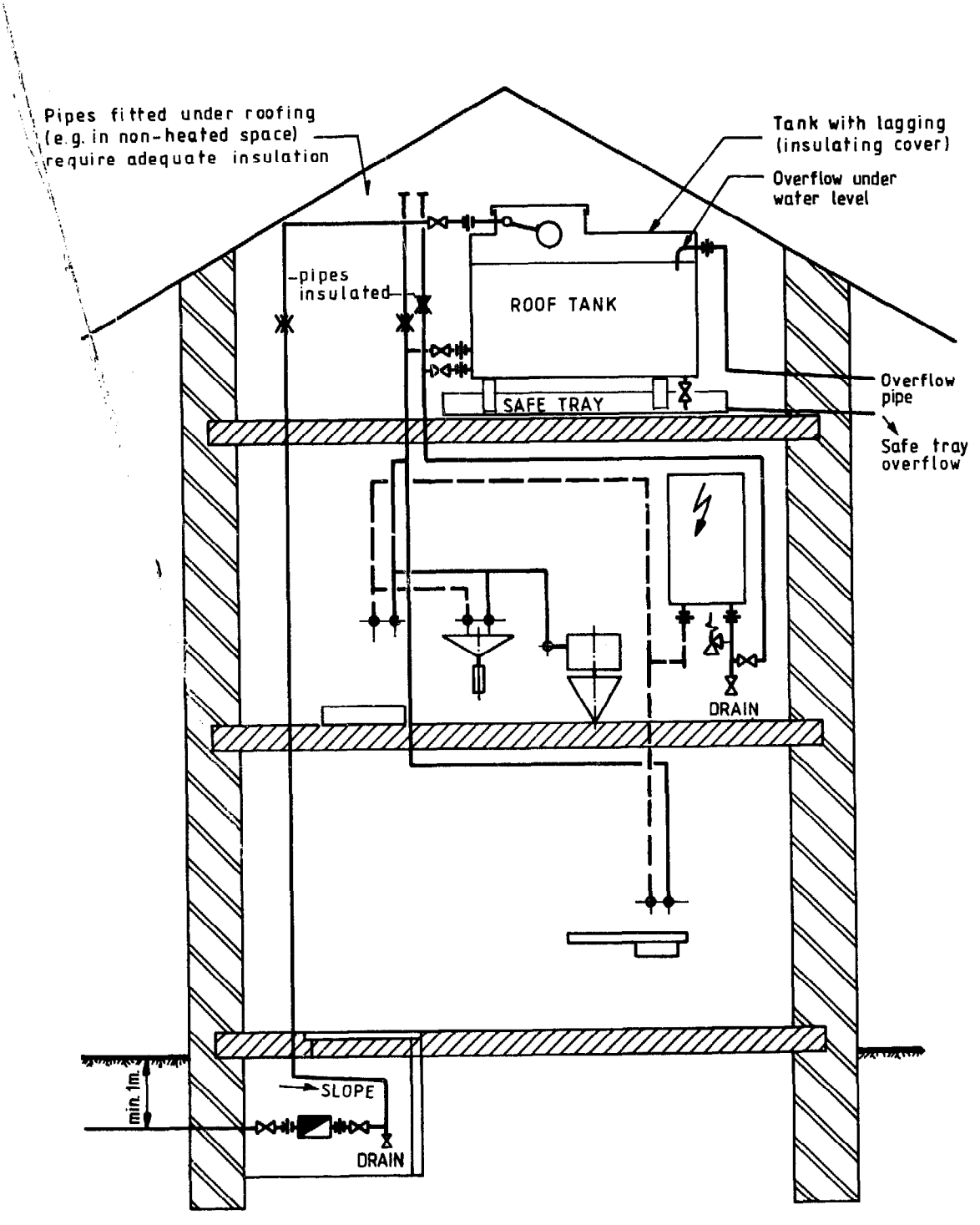

Notes: Pipes not to be fitted into outside walls pipes to fitted with slopes (no siphons!) to enable thorough drainage.

WATER HEATER CONNECTION — TABLE 1/16

Note: All installed water heaters must have a pressure-release possibility: by safety valve or by an air pipe.

Caution: The maximum head for water heaters is given by the factory and is indicated on the water heaters. (Normally for max. 30 m head = 3kg/cm²).

LOW-PRESSURE CONNECTION

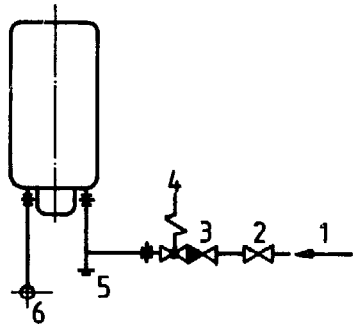

PRESSURE CONNECTION with pressure reducer valve

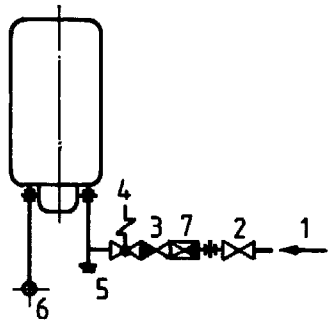

LOW-PRESSURE CONNECTION with air-pipe

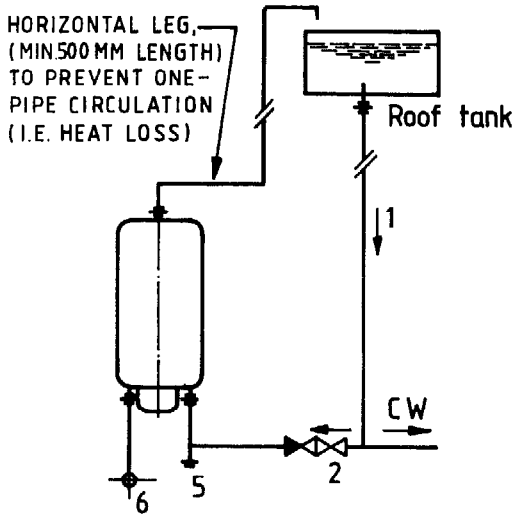

PRESSURE CONNECTION with cistern for pressure reducing (or via roof tank) HIGHLY RECOMMENDED

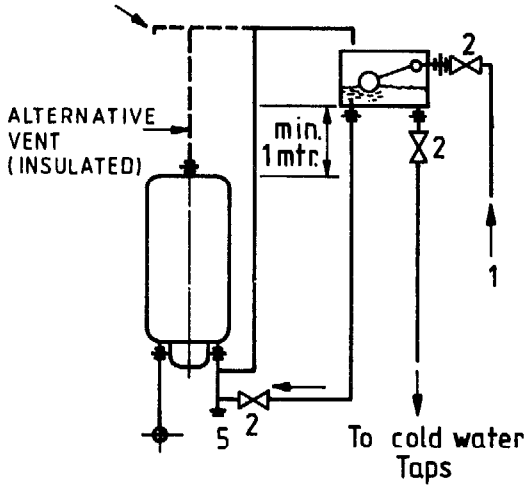

1 FEED PIPE
2 MAIN VALVE
3 NON RETURN VALVE
4 SAFETY VALVE
5 DRAIN (PLUG OR VALVE)
6 HOT WATER TAP
7 PRESSURE REDUCER VALVE

HOT WATER SUPPLY SYSTEMS **TABLE 1/17**

Serie - connection

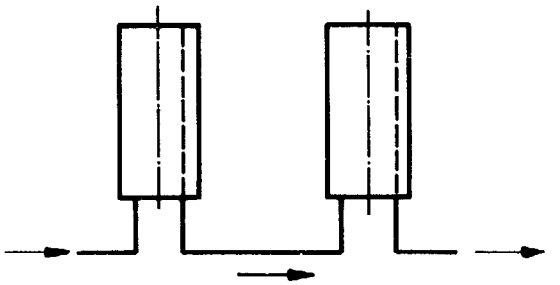

Parallel - connection

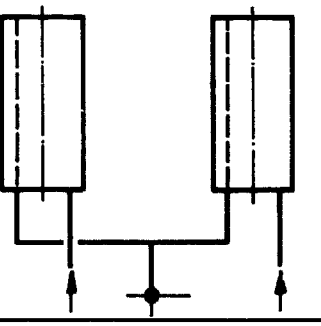

Single - supply

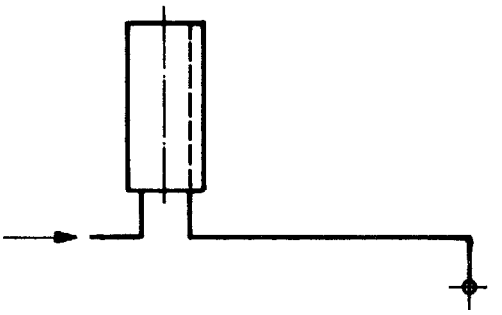

Group - supply (for nearby taps)

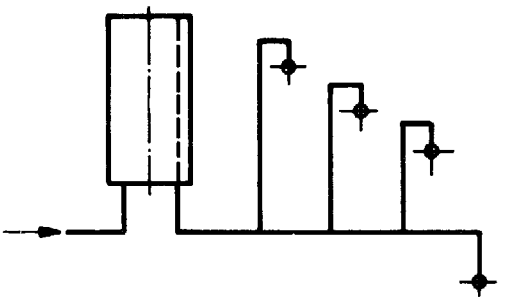

Single - tap system (effective and economical; fast hot water availability)

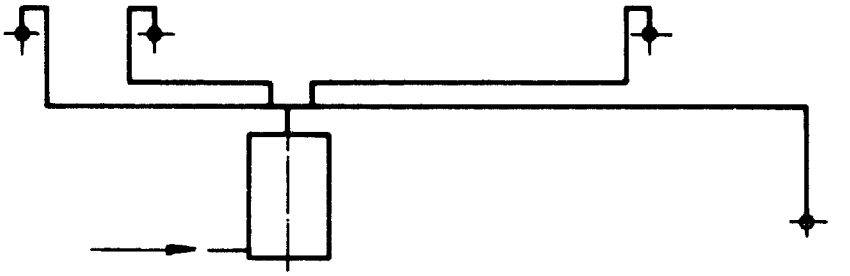

Distribution line with circulation

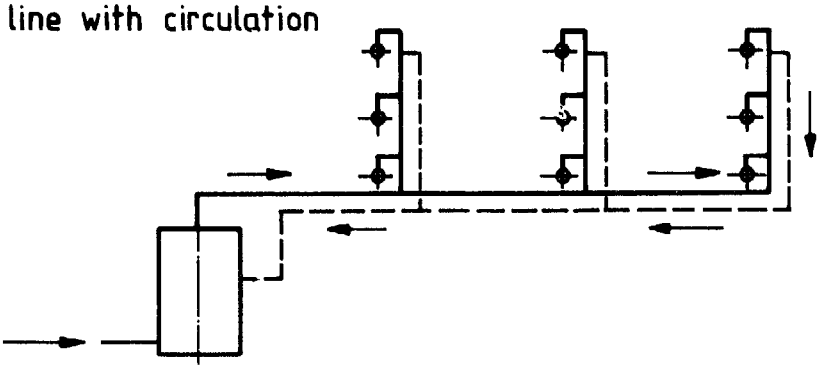

HOTWATER SUPPLY **TABLE 1/18**

EXAMPLE No 1: ONE FAMILY HOUSE
SEPARATE FEED LINE TO HOT WATER TANK (=NO NON-RETURN VALVE)
HOT WATER TANK LOWER THAN TAPS

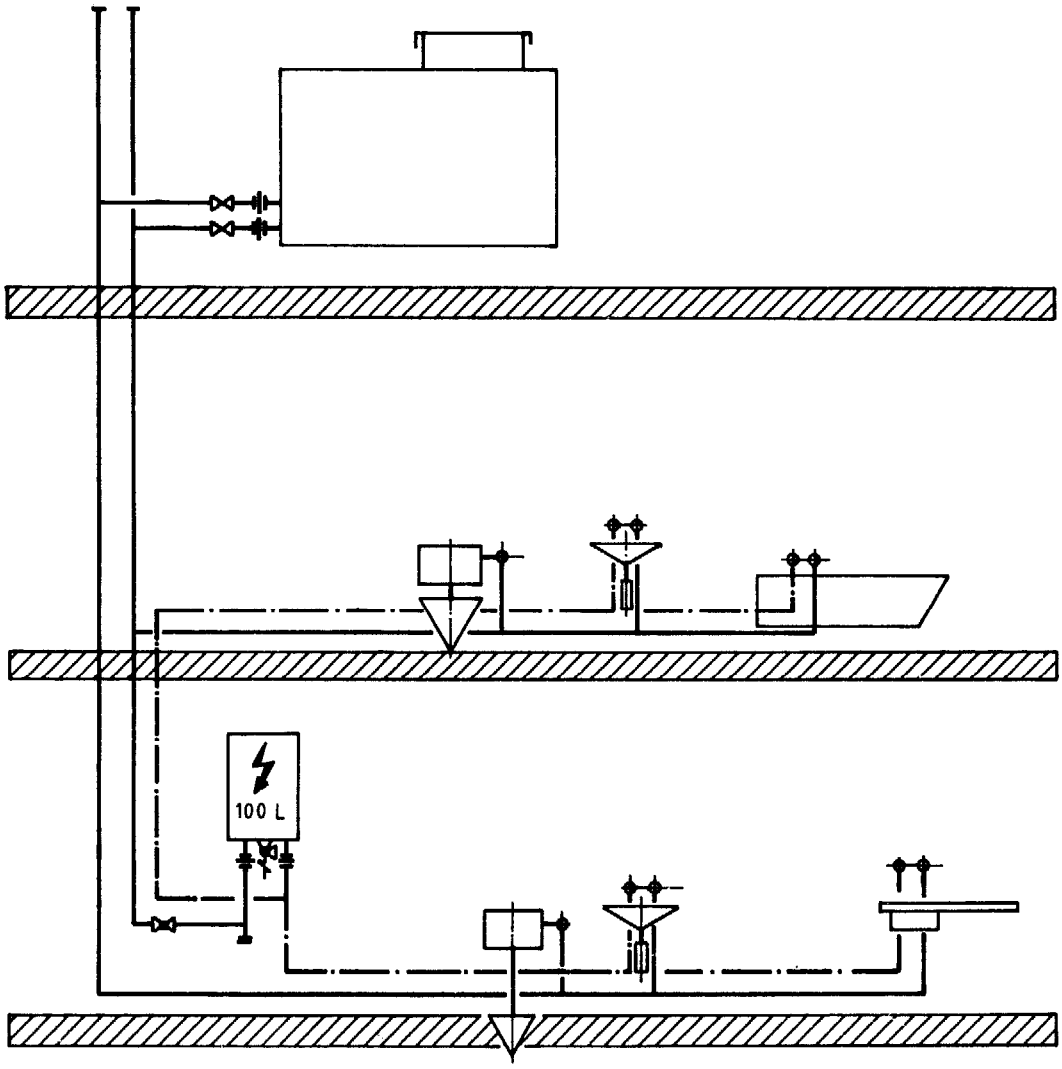

HOTWATER SUPPLY

TABLE 1/19

EXAMPLE No. 2: LARGE ONE FAMILY HOUSE
SEPARATE FEED LINE TO HOT WATER TANK
(= NO NON-RETURN VALVE)
DIVIDED CONNECTIONS FROM HOTWATER TANK TO TAPS
FOR SPEEDY AND ECONOMICAL HOTWATER SUPPLY.

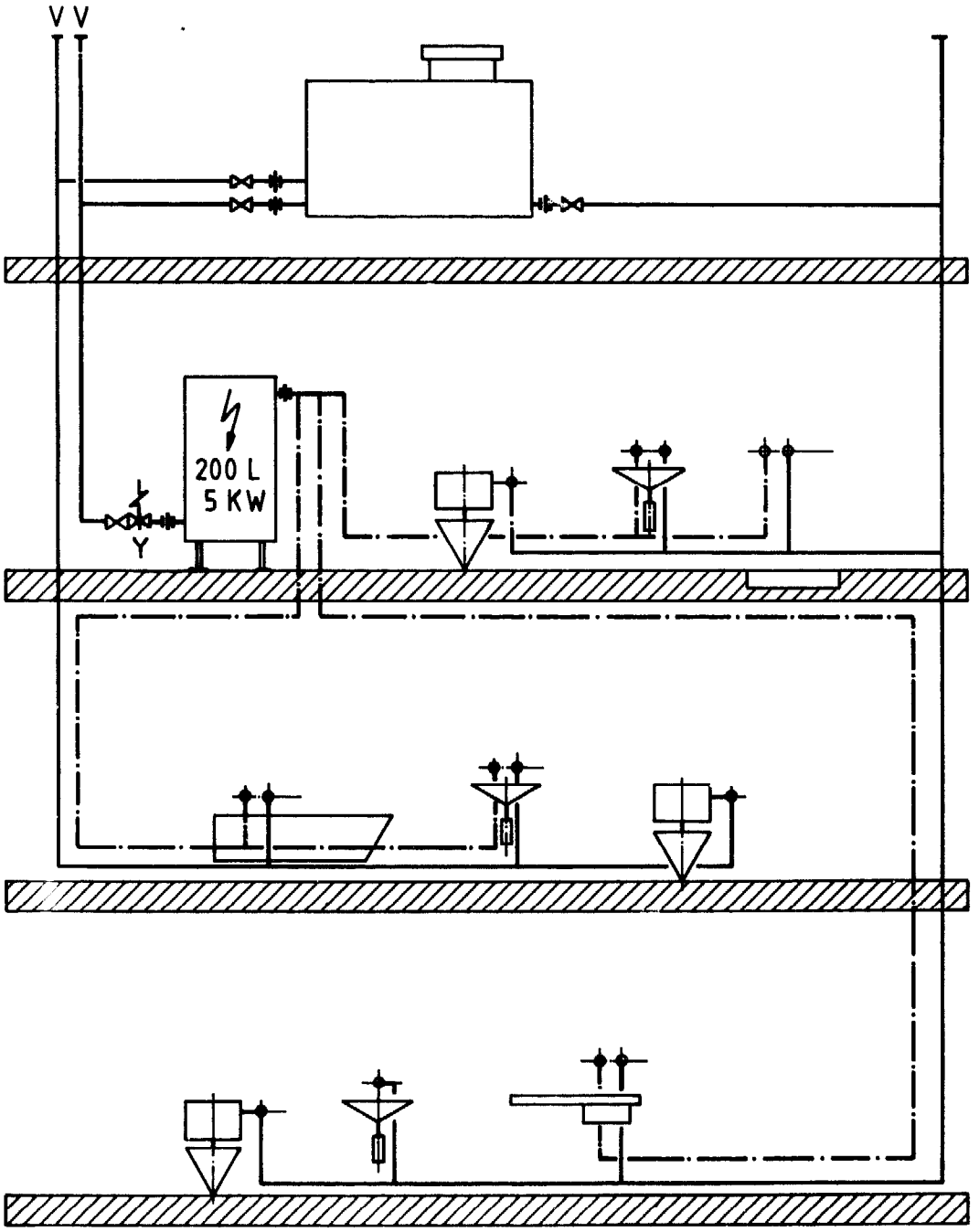

EXAMPLE No 3: TWO FLAT HOUSE, WITH SEPARATE HOTWATER TANK
WITH SEPARATE FEED LINES TO HOT TANK (= NO NON-RETURN VALVE)

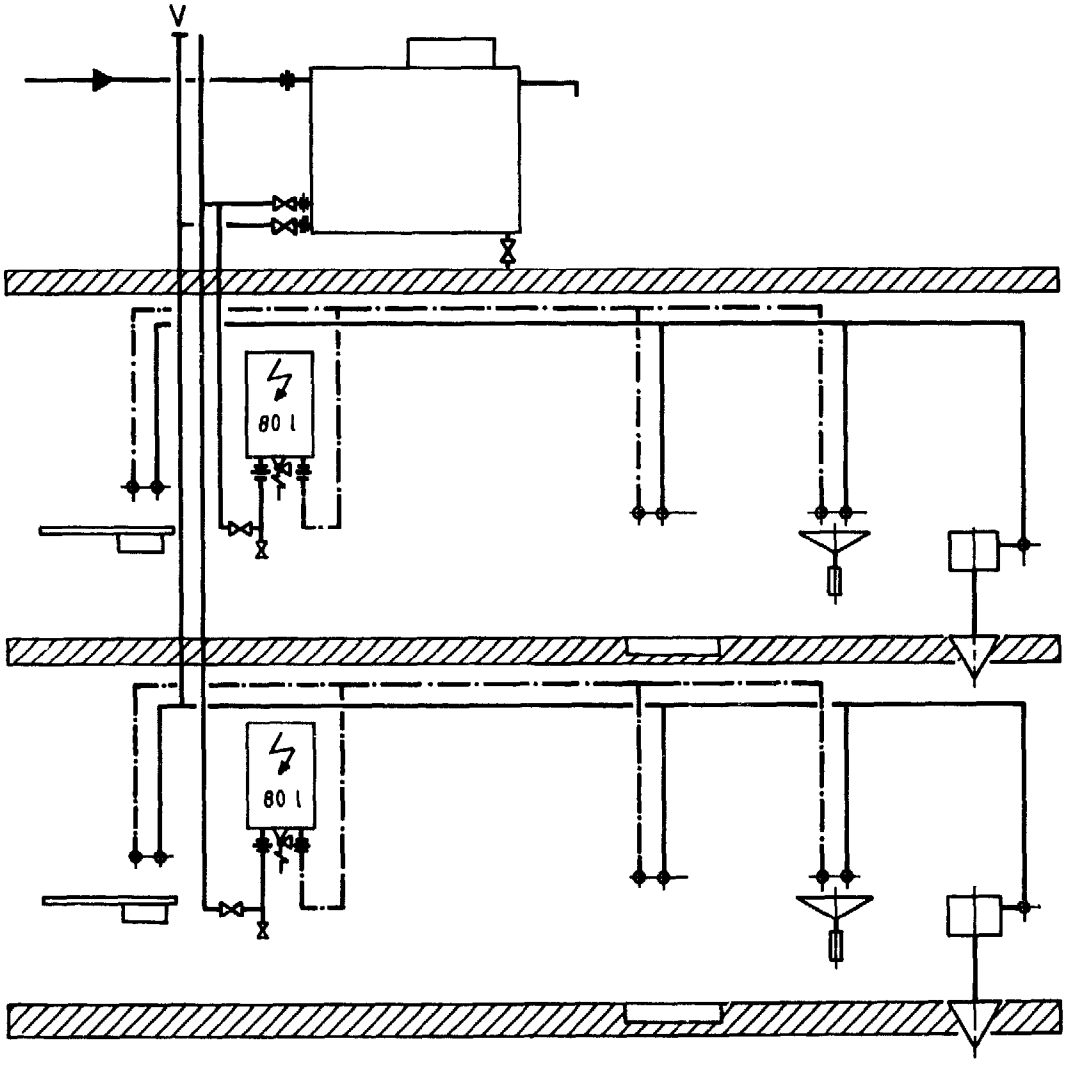

HOTWATER SUPPLY

TABLE 1/21

EXAMPLE No 4: MULTISTORY BUILDING
WITH SEPARATE FEED LINES TO HOTWATER TANKS
EACH HOTWATER TANK HAVING 1 VALVE, 1 NON-RETURN VALVE
AND 1 SAFETY VALVE.

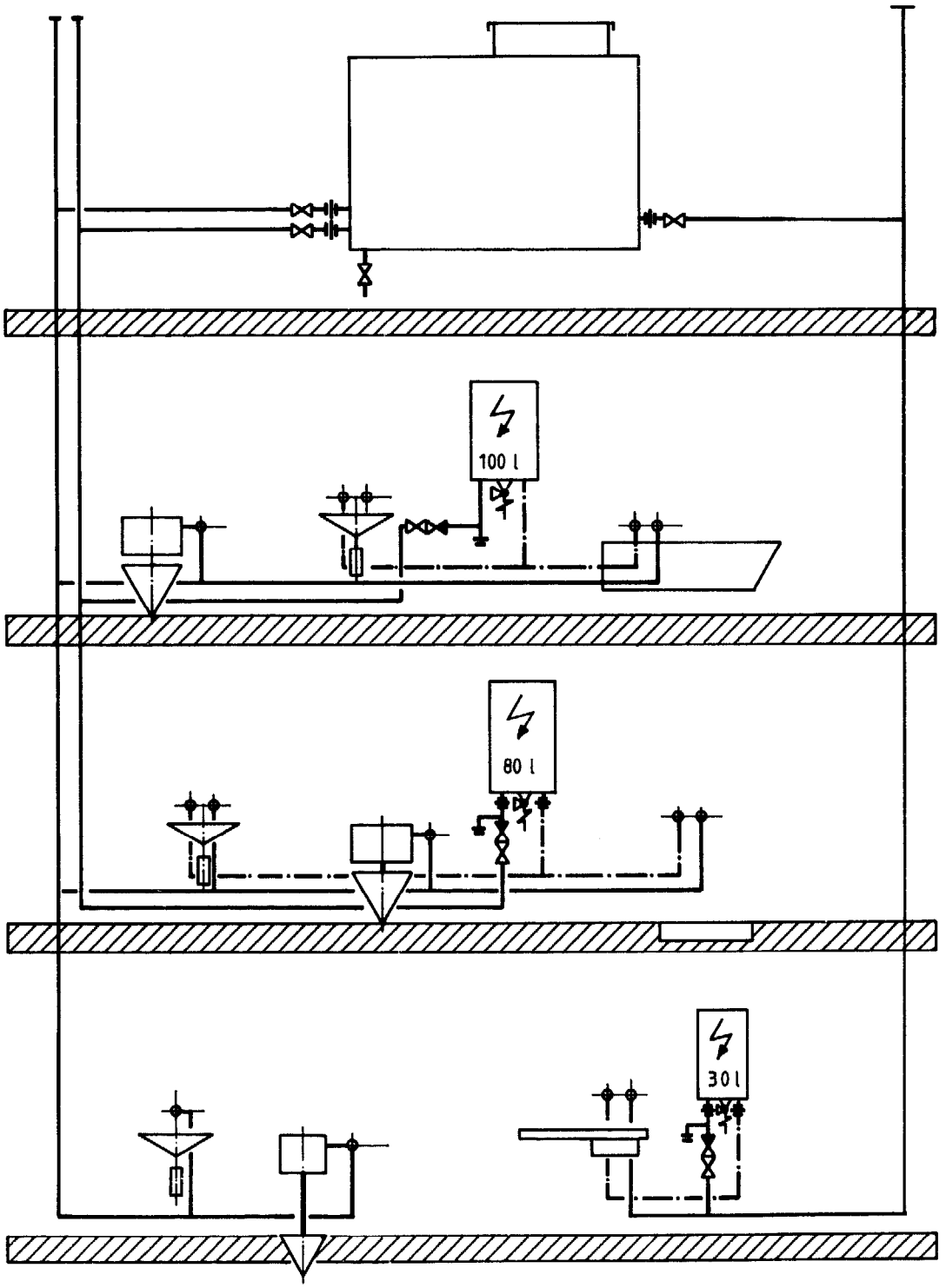

HOTWATER SUPPLY

TABLE 1/22

EXAMPLE No 5: REDUCTION OF HIGH PRESSURE SUPPLY BY MEANS OF A BALL-VALVE OPERATED CISTERN.

Note:
1) Hot water and cold water should have the same pressure, therefore cold water is also supplied from the cistern.
2) Due to low pressure the vent pipe fitted on top of hot water may be required to release eventual
3) Obviously the cistern has always to be the top-most placed item, in order to supply water to the hot water tank and to the taps.

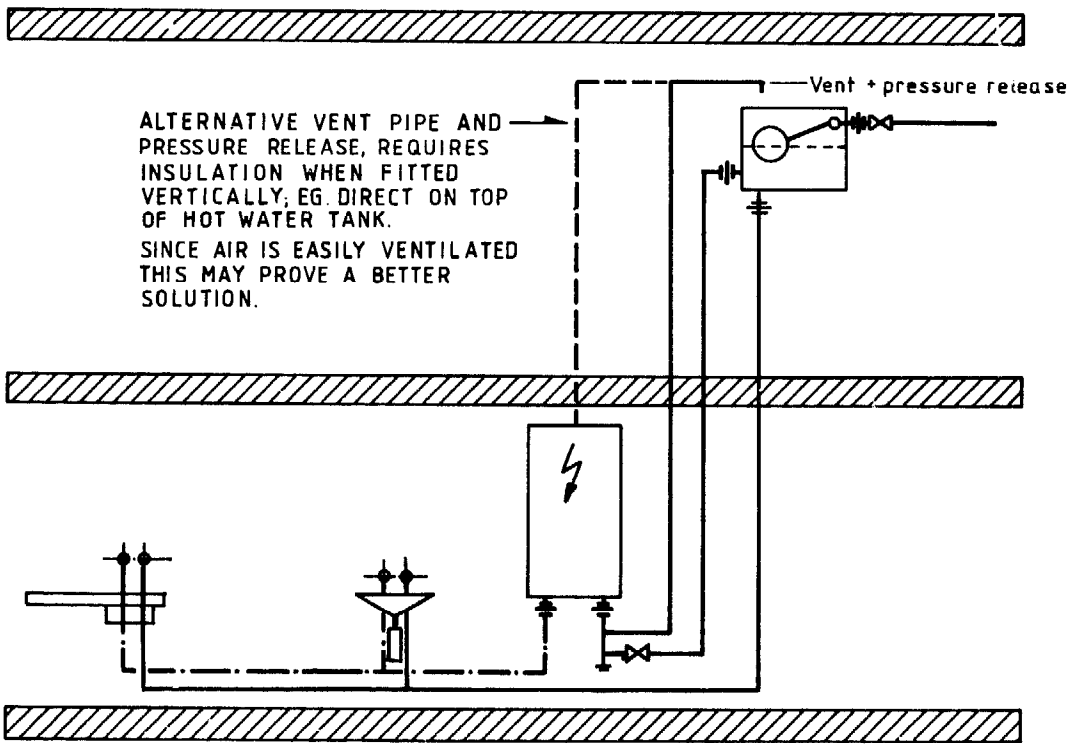

SOLAR WATER HEATER INSTALLATION — TABLE 1/23

INSTALLATION EXAMPLE No 1: ROOF TANK, WITH SEPARATE COLDWATER PIPELINE TO THE SWH-SYSTEM, WITHOUT REQUIREMENT OF SPECIAL VALVES

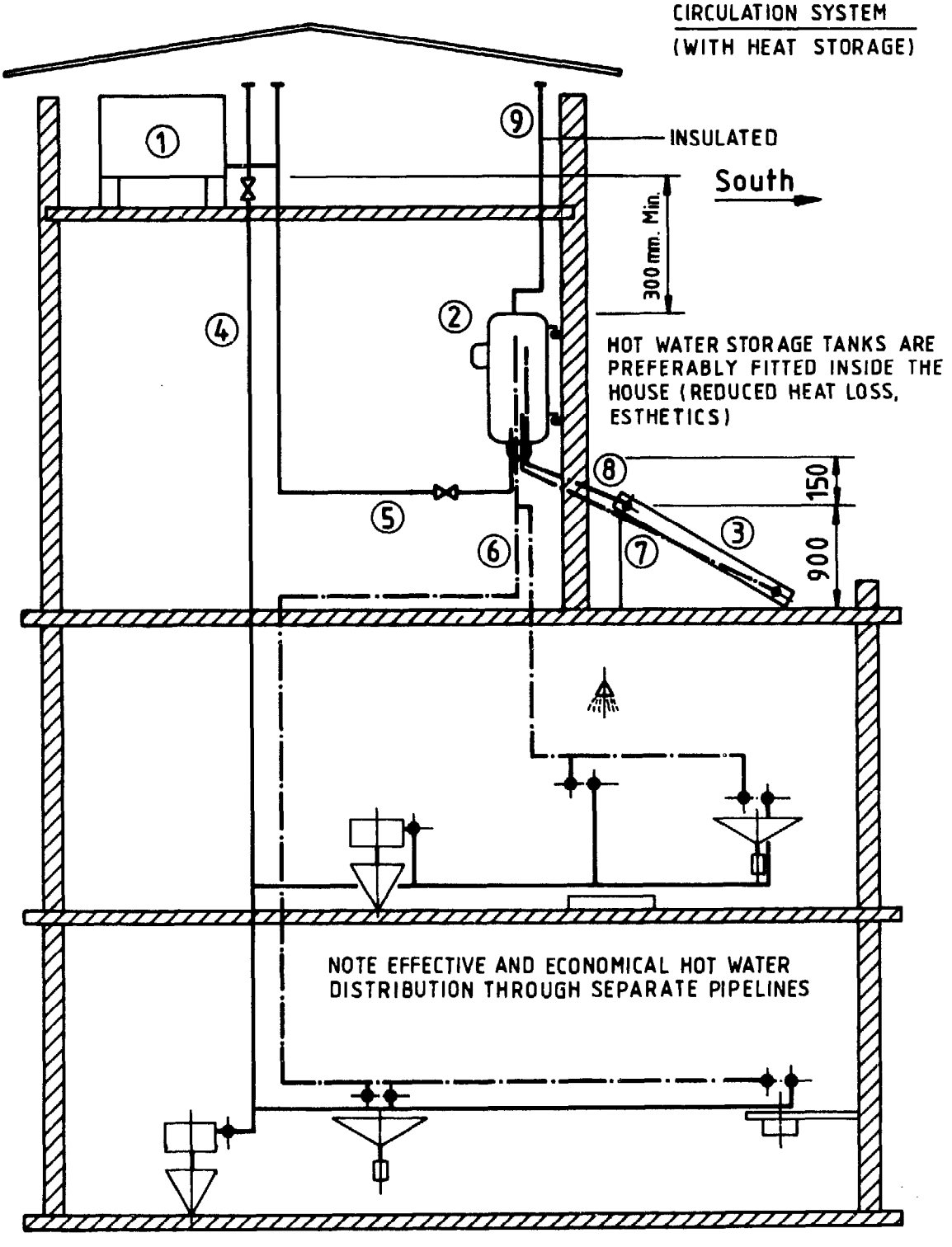

1 COLDWATER STORAGE TANK
2 HOTWATER STORAGE TANK
3 COLLECTOR
4 COLDWATER PIPELINE
5 COLDWATER TO HOT TANK
6 HOTWATER TO THE TAPS
7 CIRCULATION PIPE TO COLLECTOR
8 CIRCULATION PIPE TO HOT TANK
9 VENT PIPE

SOLAR WATER HEATER INSTALLATION — TABLE 1/24

INSTALLATION EXAMPLE No 2: ROOF TANK WITH BRANCH IN MAIN COLDWATER PIPELINE CONNECTING THE SWH-SYSTEM
REQUIRES: 1 NON-RETURN VALVE

CIRCULATION SYSTEM
(WITH HEAT STORAGE)

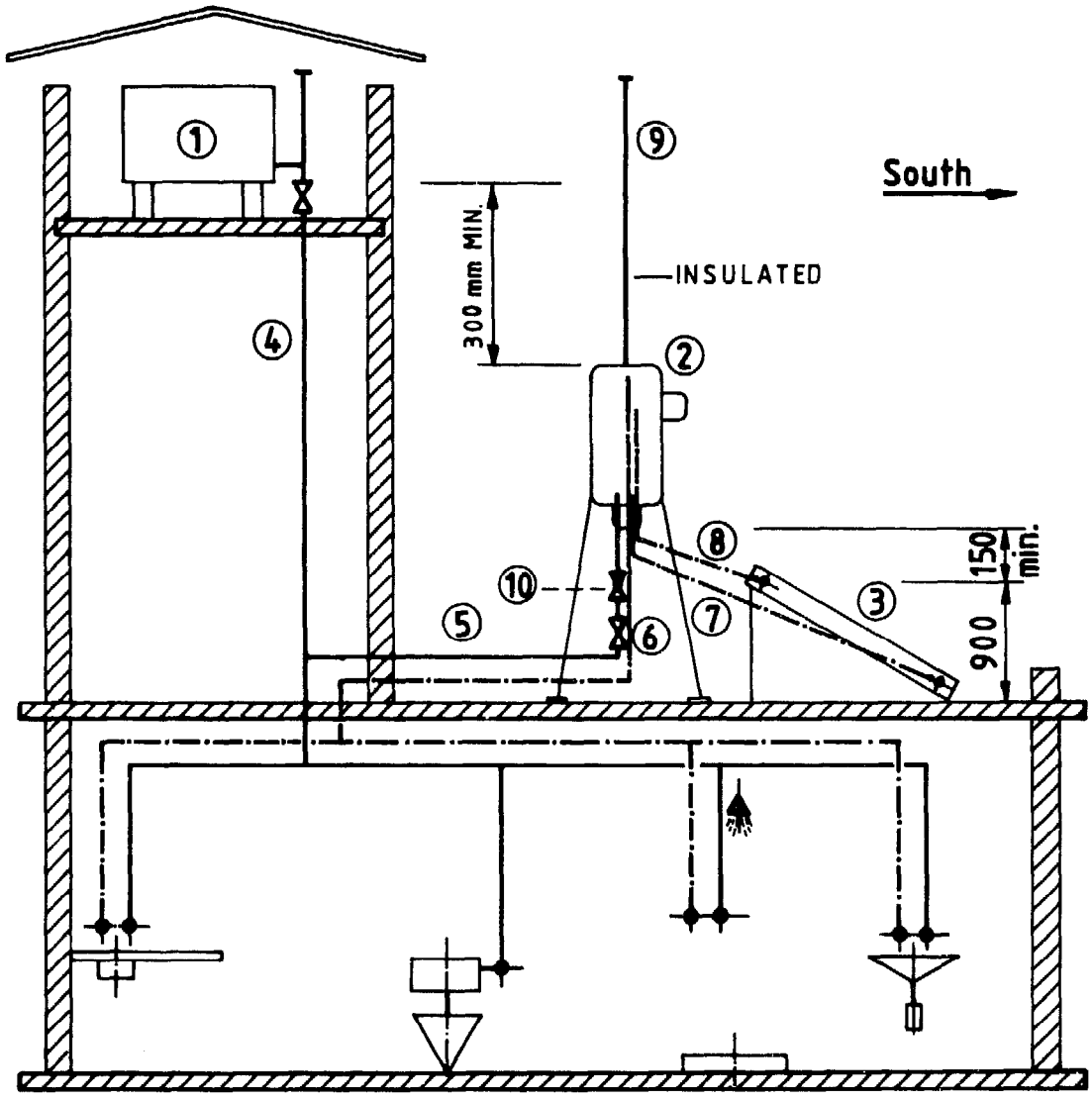

1 COLDWATER STORAGE TANK
2 HOTWATER STORAGE TANK
3 COLLECTOR
4 COLDWATER PIPELINE
5 COLDWATER TO HOT TANK
6 HOTWATER TO THE TAPS
7 CIRCULATION PIPE TO COLLECTOR
8 CIRCULATION PIPE TO HOT TANK
9 VENT PIPE, INSULATED
10 CHECK (NON RETURN VALVE)

Note: A book "solar water heaters in Nepal-manufacturing and installation" with relevant information, was prepared through the same publishers.

SOLAR WATER HEATER INSTALLATION

TABLE 1/25

INSTALLATION EXAMPLE NO 3: TOWN SUPPLY (24 HOURS/DAY) WITH LOW-PRESSURE CONDITION
REQUIRES:1 NON-RETURN AND 1 SAFETY VALVE

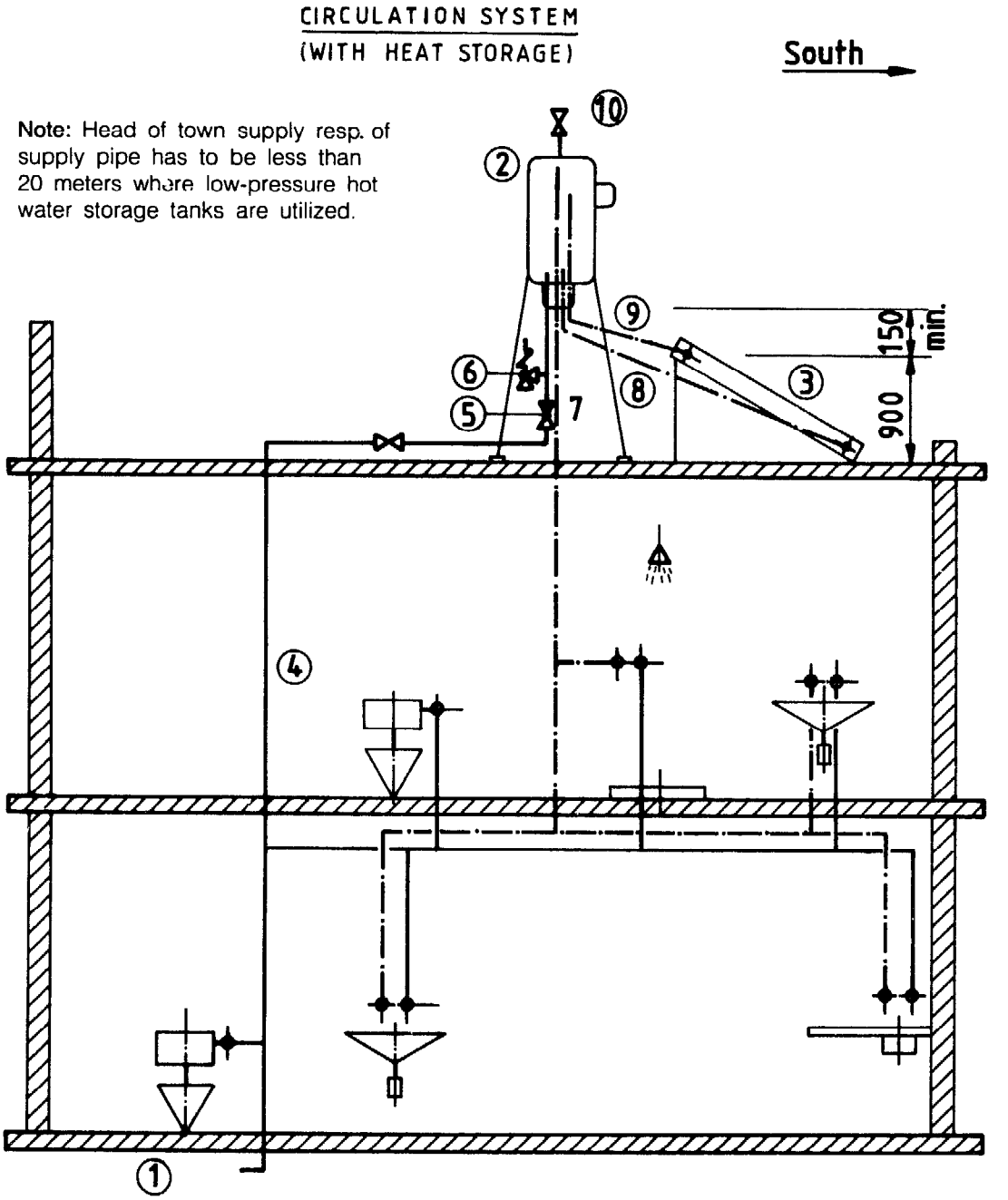

1 COLDWATER, TOWNSUPPLY
2 HOTWATER STORAGE TANK
3 COLLECTOR
4 COLDWATER TO HOT TANK
5 CHECK (NON-RETURN VALVE)
6 SAFETY VALVE
7 HOTWATER TO THE TAPS
8 CIRCULATION PIPE TO COLLECTOR
9 CIRCULATION PIPE TO HOT TANK
10 AIR VALVE

SOLAR WATER HEATER INSTALLATION TABLE 1/26

INSTALLATION EXAMPLE NO 4: OPEN HOTWATER OUTLET SIMPLE AND LOW-COST INSTALLATION, BUT FOR ONE (OR TWO) HOTWATER OUTLETS ONLY.

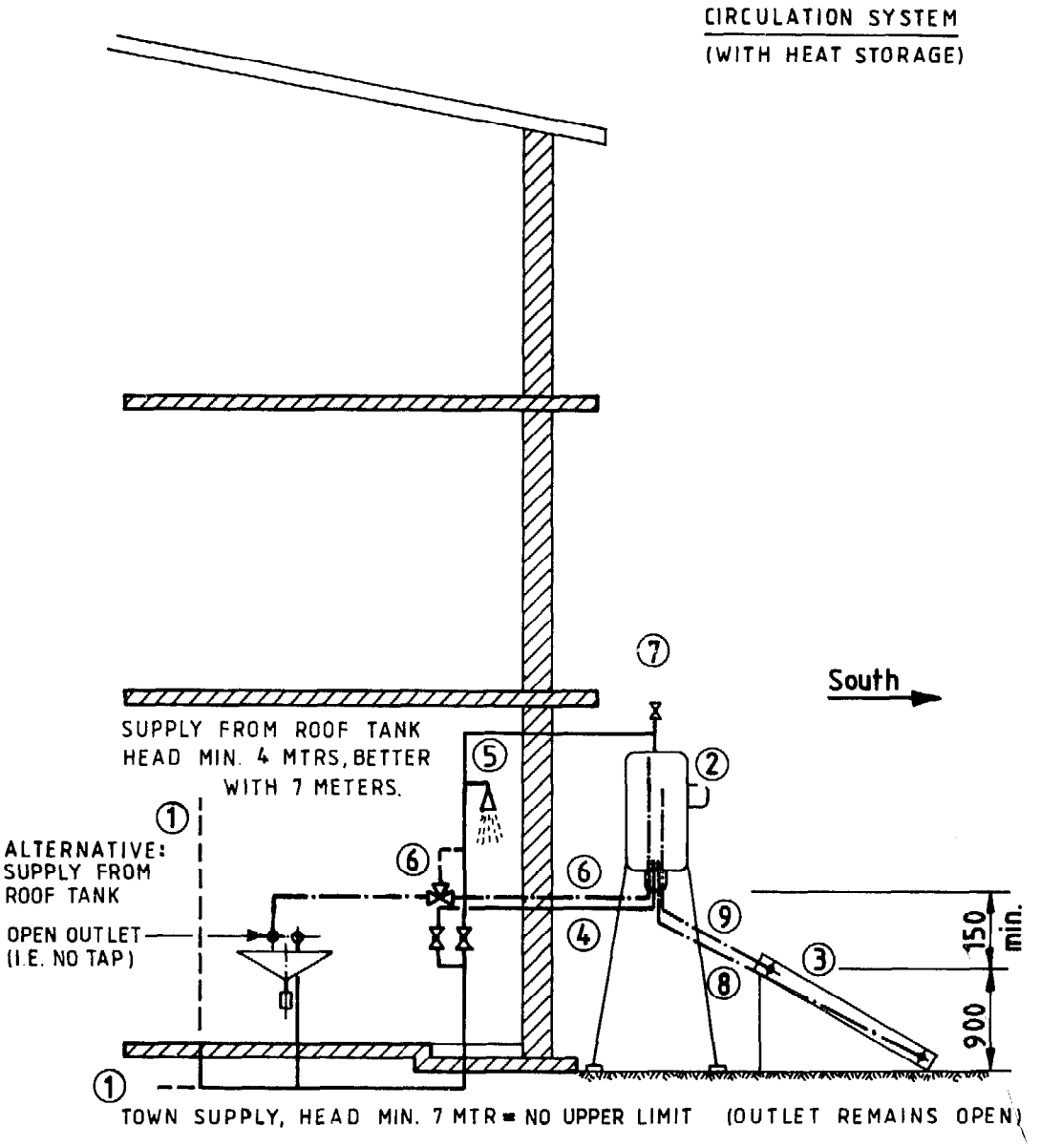

1 COLDWATER SUPPLY
2 HOTWATER STORAGE TANK
3 COLLECTOR
4 COLDWATER TO HOT TANK
5 HOTWATER TO SHOWER
6 TWO-WAY VALVE, IF FOR TWO OTWATER OUTLETS
7 EVENTUALLY: AIR VALVE
8 CIRCULATION PIPE TO COLLECTOR
9 CIRCULATION PIPE TO HOT TANK

Note: For hotwater on shower only: Install pipe No 5, but not pipe No 6 and without a 2-way valve/for double use, i.e. shower or washbasin install pipe No 6 incl. 2-way valve, but not pipe No 5.

SOLAR WATER HEATER INSTALLATION TABLE 1/27

INSTALLATION EXAMPLE NO 5: ROOF TANK, WITH SEPARATE COLDWATER PIPE TO THE FLAT TANK COLLECTOR,
REQUIRES NO SPECIAL VALVES.

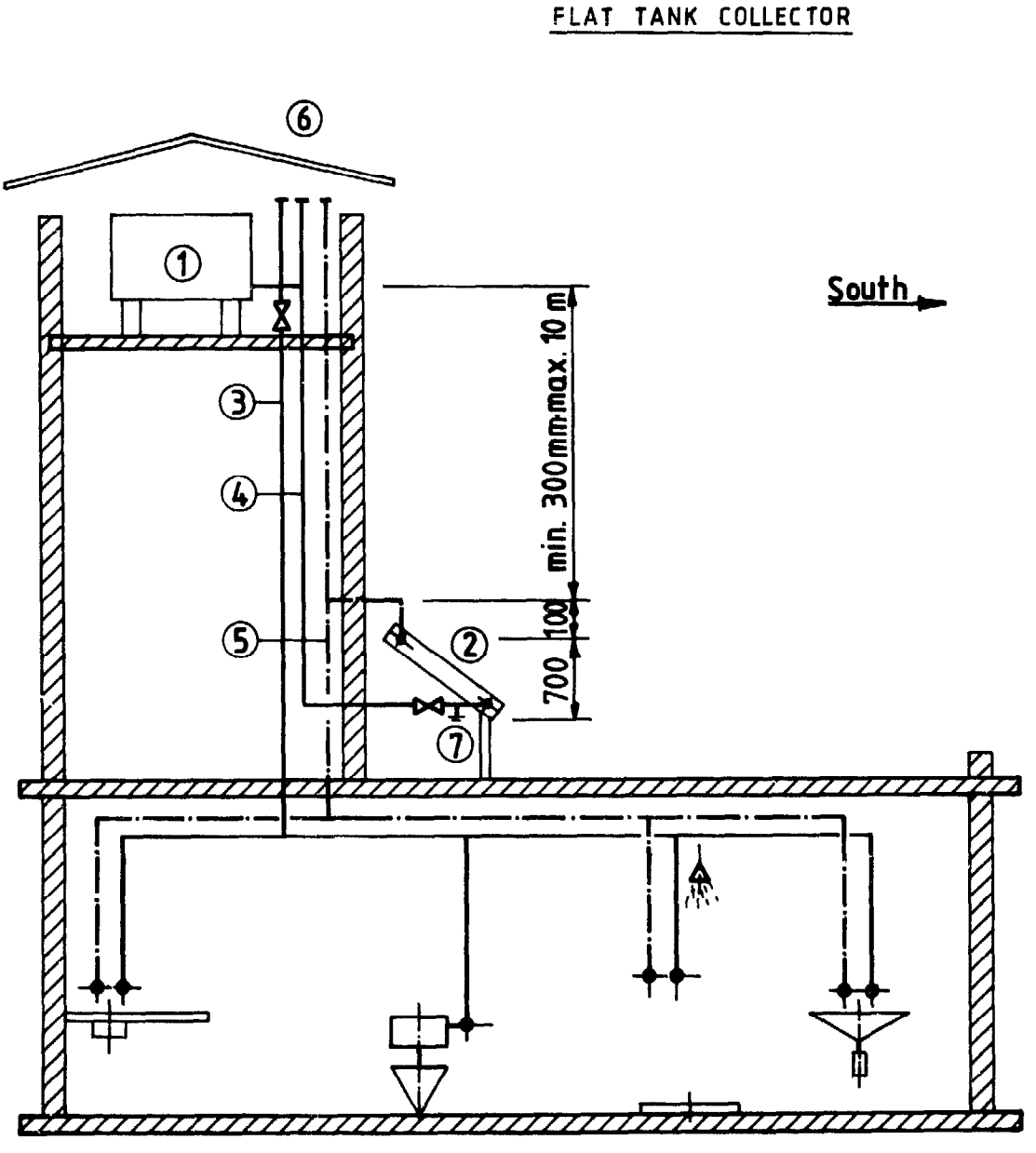

1 COLDWATER STORAGE TANK
2 FLAT TANK COLLECTOR
3 COLDWATER PIPELINE
4 COLDWATER TO FLAT TANK COLLECTOR
5 HOTWATER TO THE TAPS
6 VENT PIPE
7 DRAIN (TEE WITH PLUG OR VALVE)

SOLAR WATER HEATER INSTALLATION TABLE 1/28

INSTALLATION EXAMPLE NO 6: ROOF TANK WITH BRANCH IN THE MAIN COLDWATER PIPE TO THE FLAT TANK COLLECTOR
REQUIRES: 1 NON-RETURN VALVE

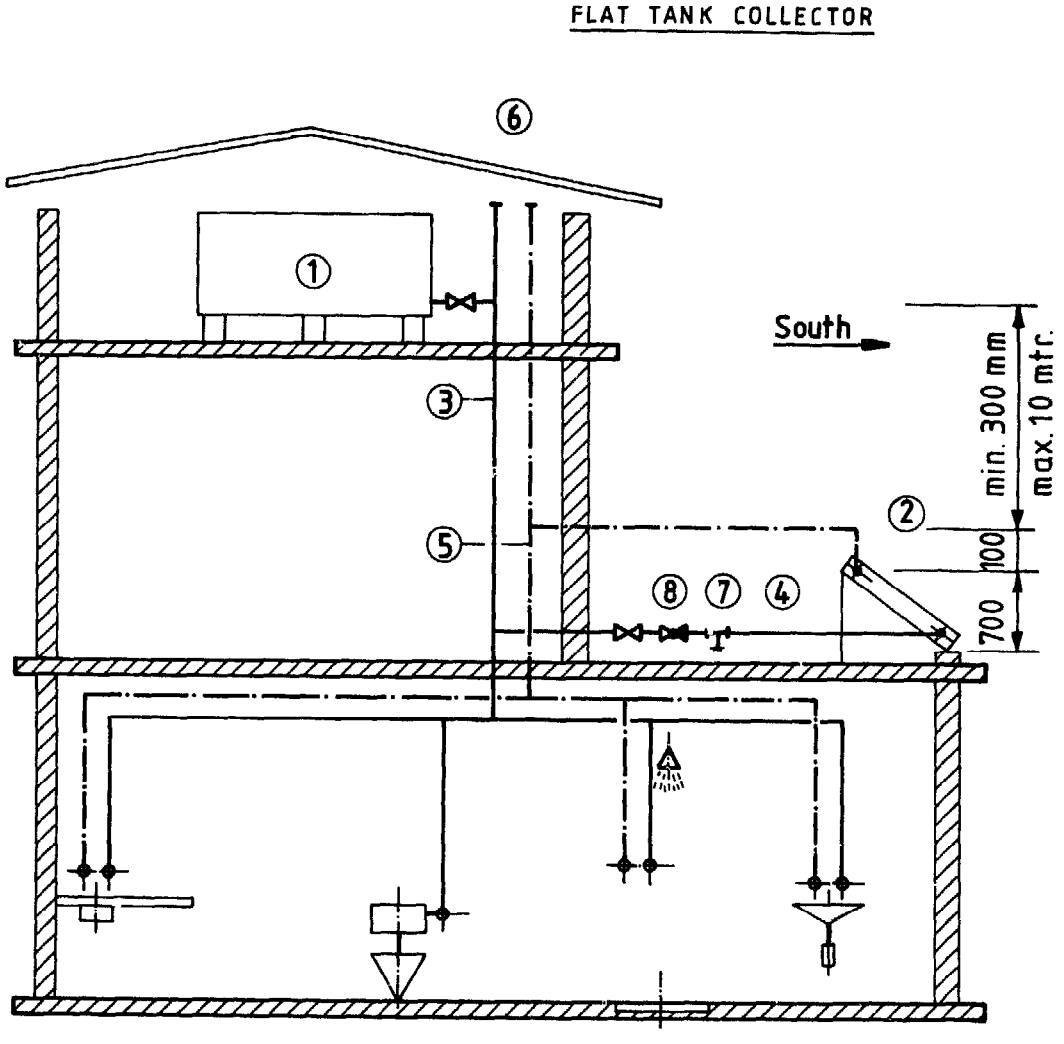

1 COLDWATER STORAGE TANK
2 FLAT TANK COLLECTOR
3 COLDWATER PIPE
4 COLDWATER TO FLAT TANK
5 HOTWATER TO THE TAPS
6 VENT PIPES
7 DRAIN TEE WITH PLUG OR VALVE
8 CHECK (NON-RETURN VALVE)

SOLAR WATER HEATER INSTALLATION

TABLE 1/29

INSTALLATION EXAMPLE NO 7: PREHEATER TO ELECTRIC HOT WATER TANK, INCREASES THE HOTWATER CAPACITY, REDUCES ELECTRICITY CONSUMPTION

FLAT TANK COLLECTOR

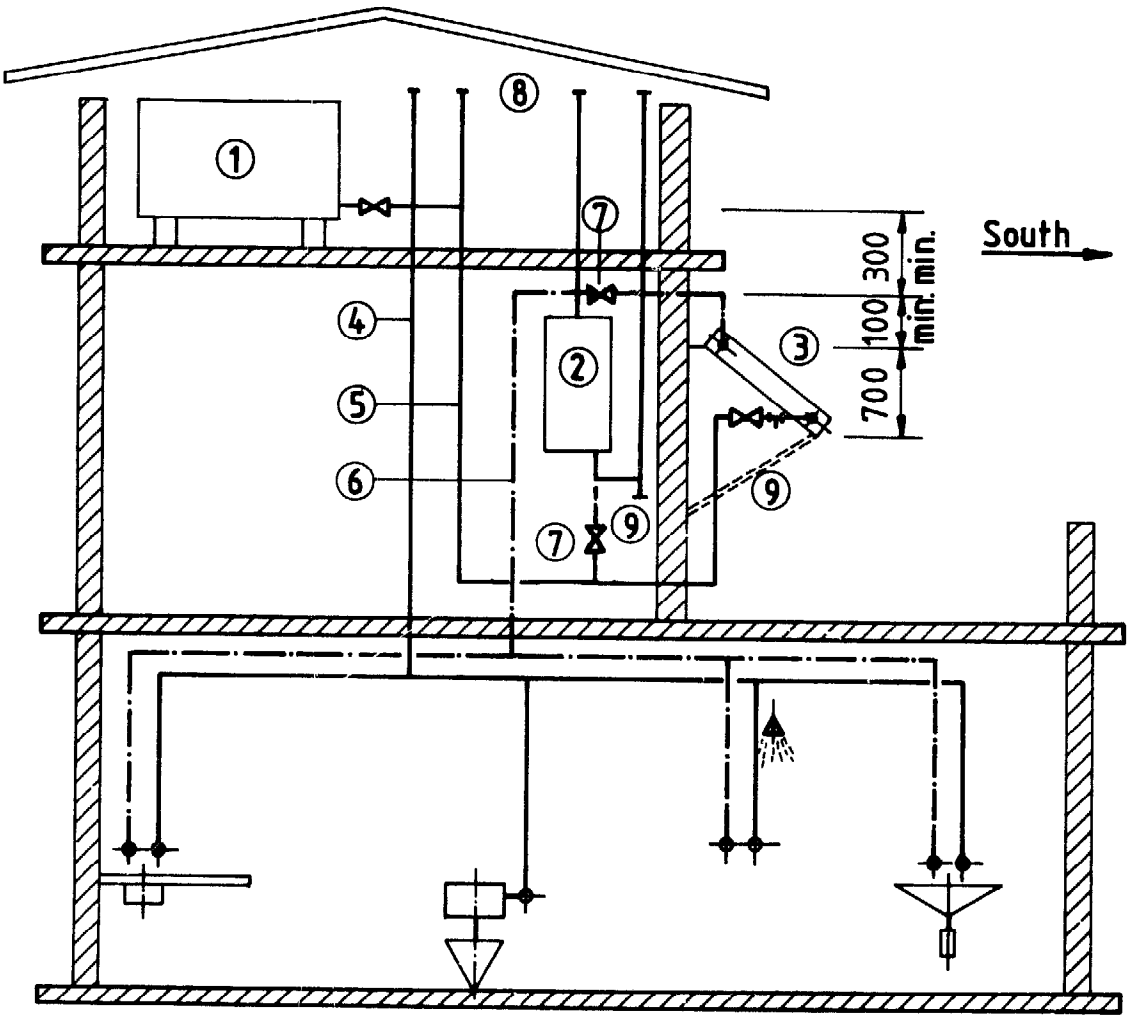

1 COLDWATER STORAGE TANK
2 ELECTRO-OR GAS HOT TANK
3 FLAT TANK COLLECTOR
4 COLDWATER PIPE
5 COLDWATER PIPE TO FLAT TANK COLLECTOR (AND TO ELECTRO-OR GAS HOT TANK)
6 HOTWATER TO THE TAPS
7 BYPASSES (TO ENABLE DIRECT USE OF ELECTRO HOT TANK ONLY)
8 VENT PIPES
9 DRAIN (TEE WITH PLUG OR VALVE)

DIMENSIONING, EXAMPLES

TABLE 1/30

LOW PRESSURE (ROOF TANK)

DIMENSIONS ACCORDING UNITS, TABLE A

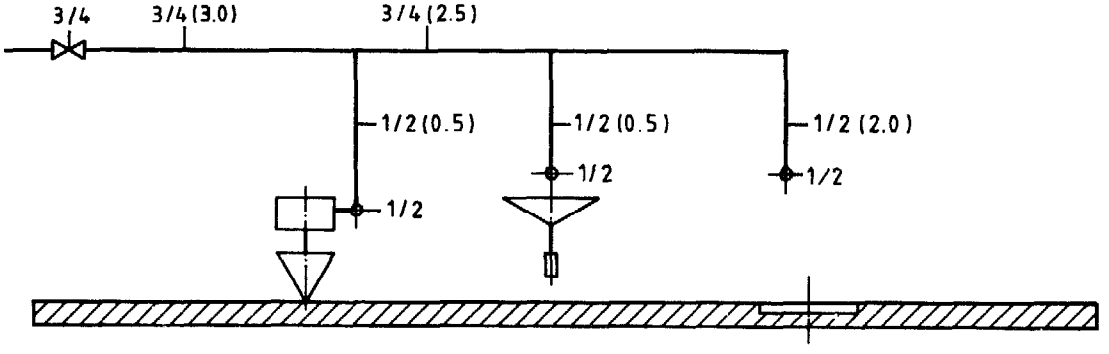

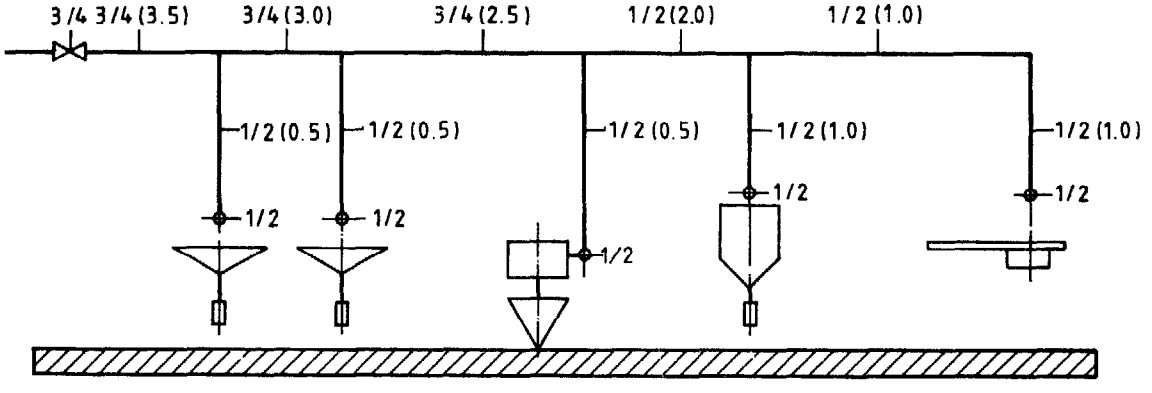

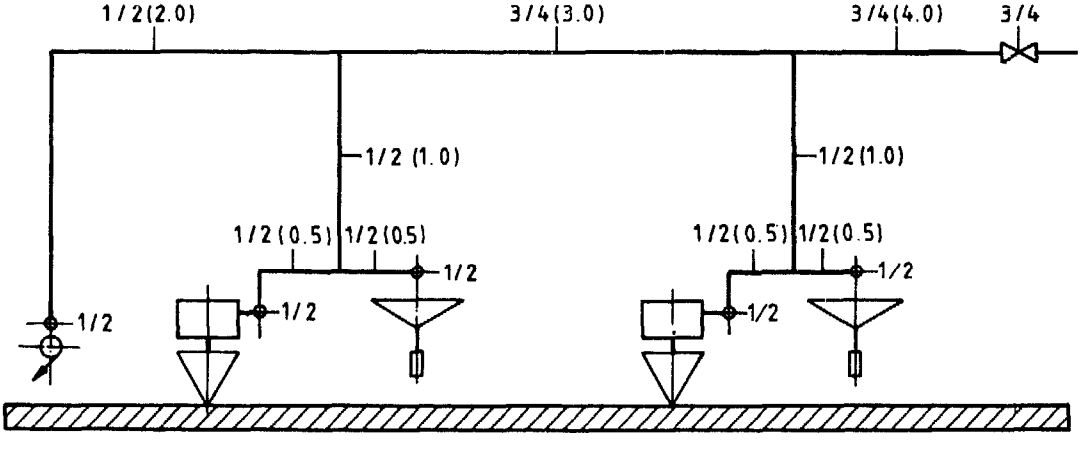

DIMENSIONING, EXAMPLE

TABLE 1/31

LOW PRESSURE (ROOF TANK)

DIMENSIONING ACCORDING UNITS, TABLE A

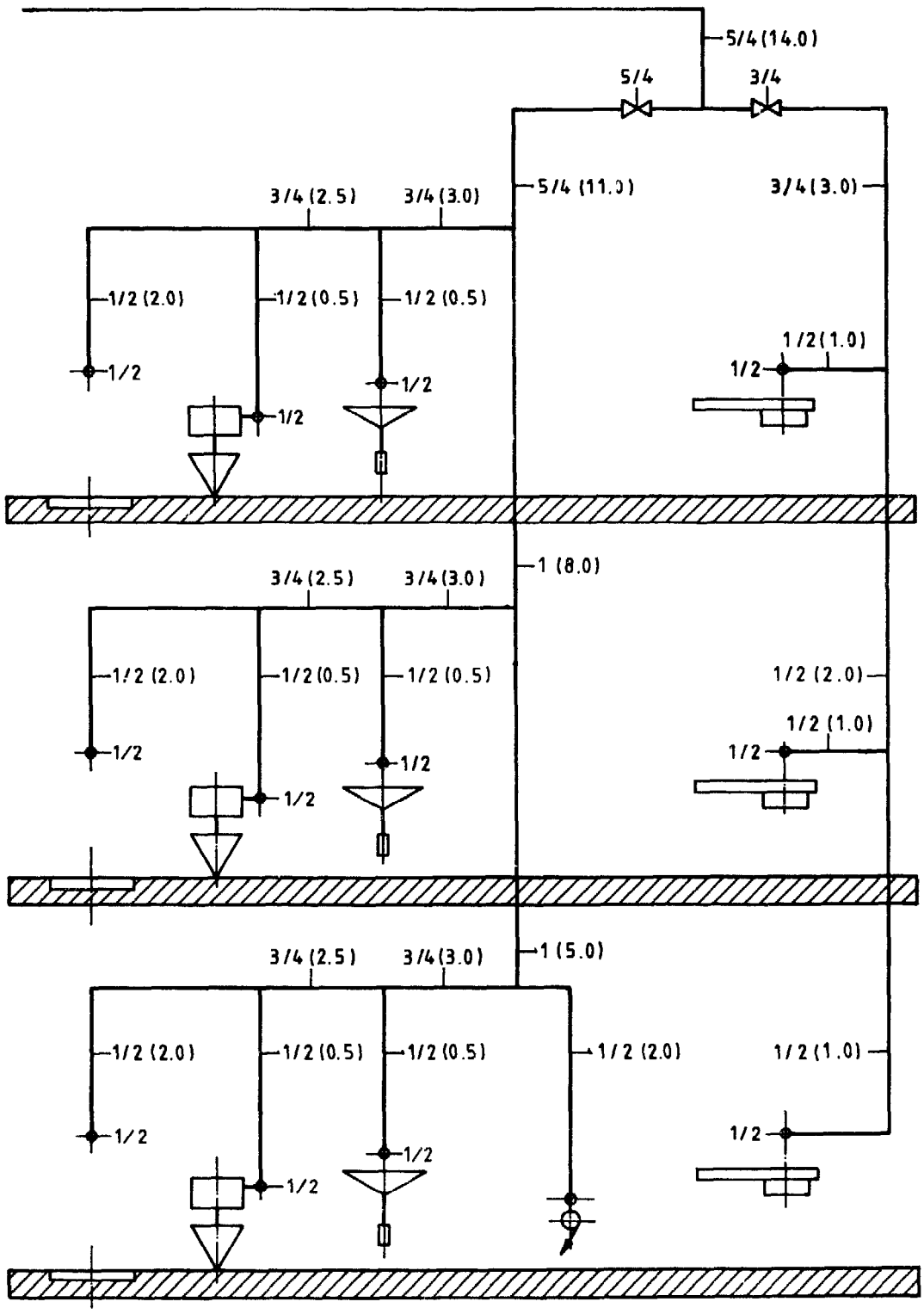

DIMENSIONING, EXAMPLES

TABLE 1/32

LOW PRESSURE (ROOF TANK)

DIMENSIONS ACCORDING UNITS, TABLE A

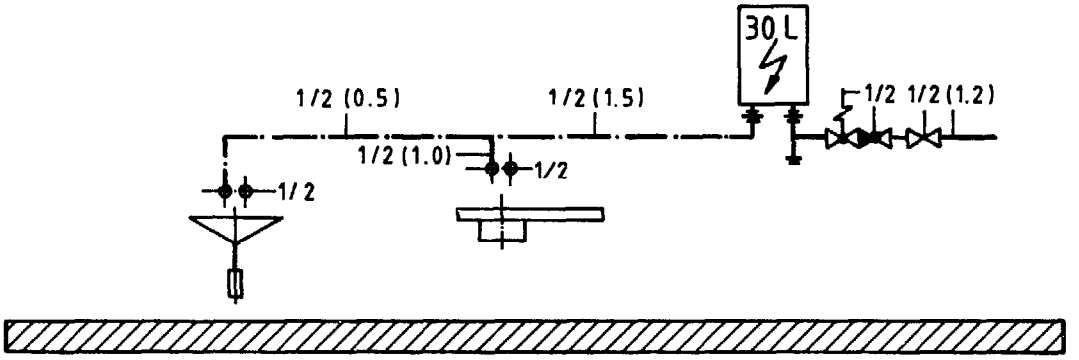

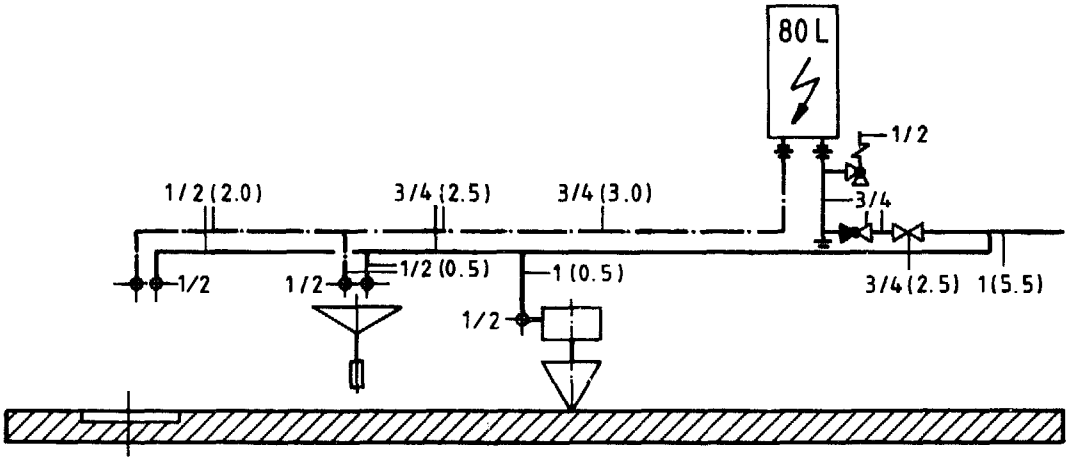

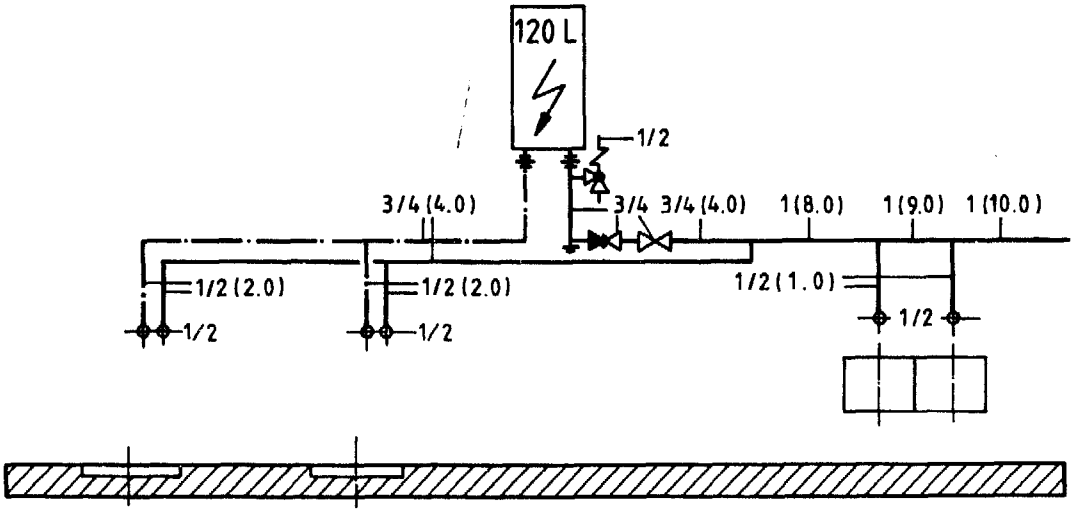

DIMENSIONING, EXAMPLE

TABLE 1/33

PRESSURE, TOWNSUPPLY

DIMENSIONS ACCORDING UNITS/TABLE B

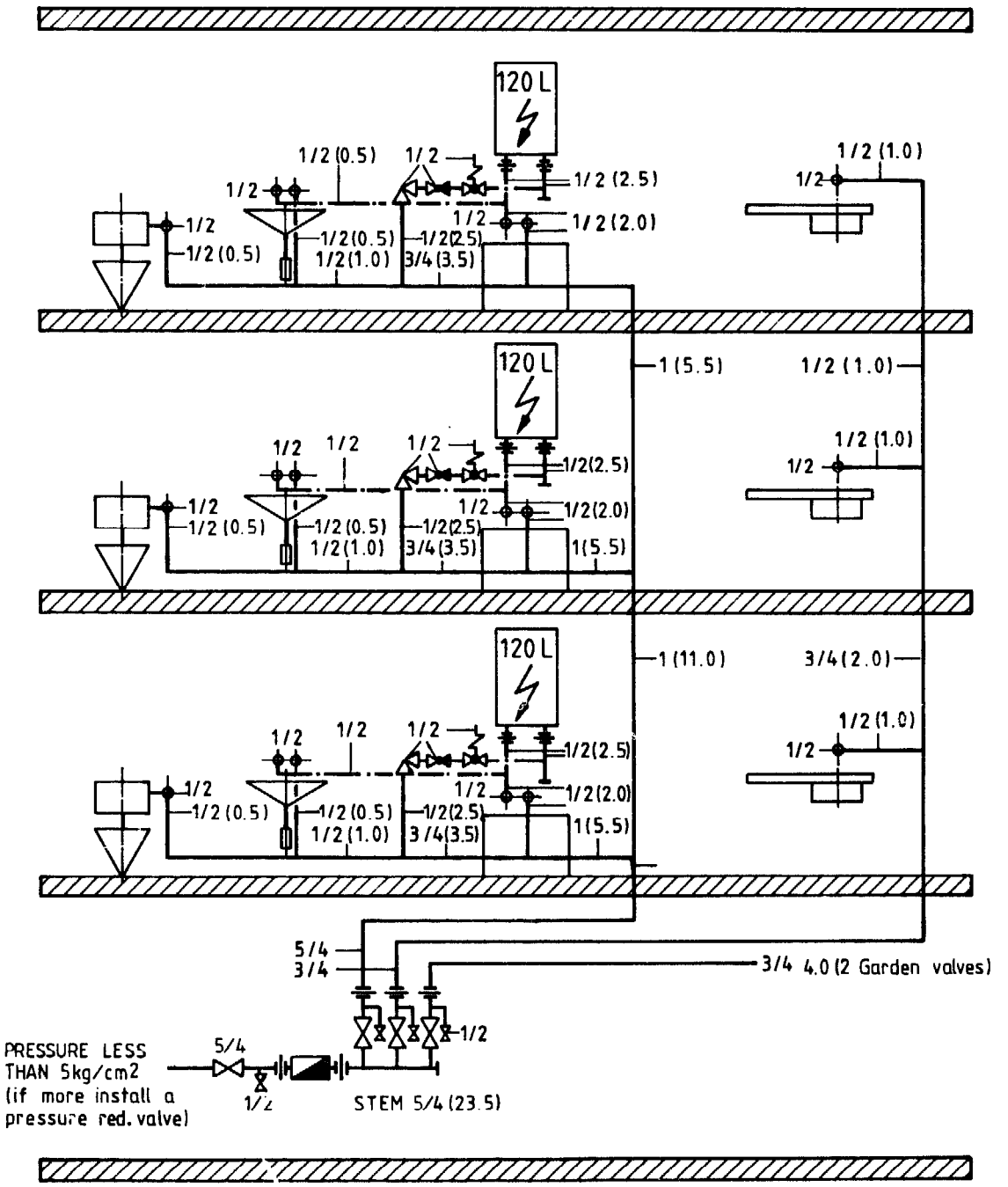

DIMENSIONING, EXAMPLE **TABLE 1/34**

PRESSURE, TOWNSUPPLY, ACCORDING UNITS/TABLE B

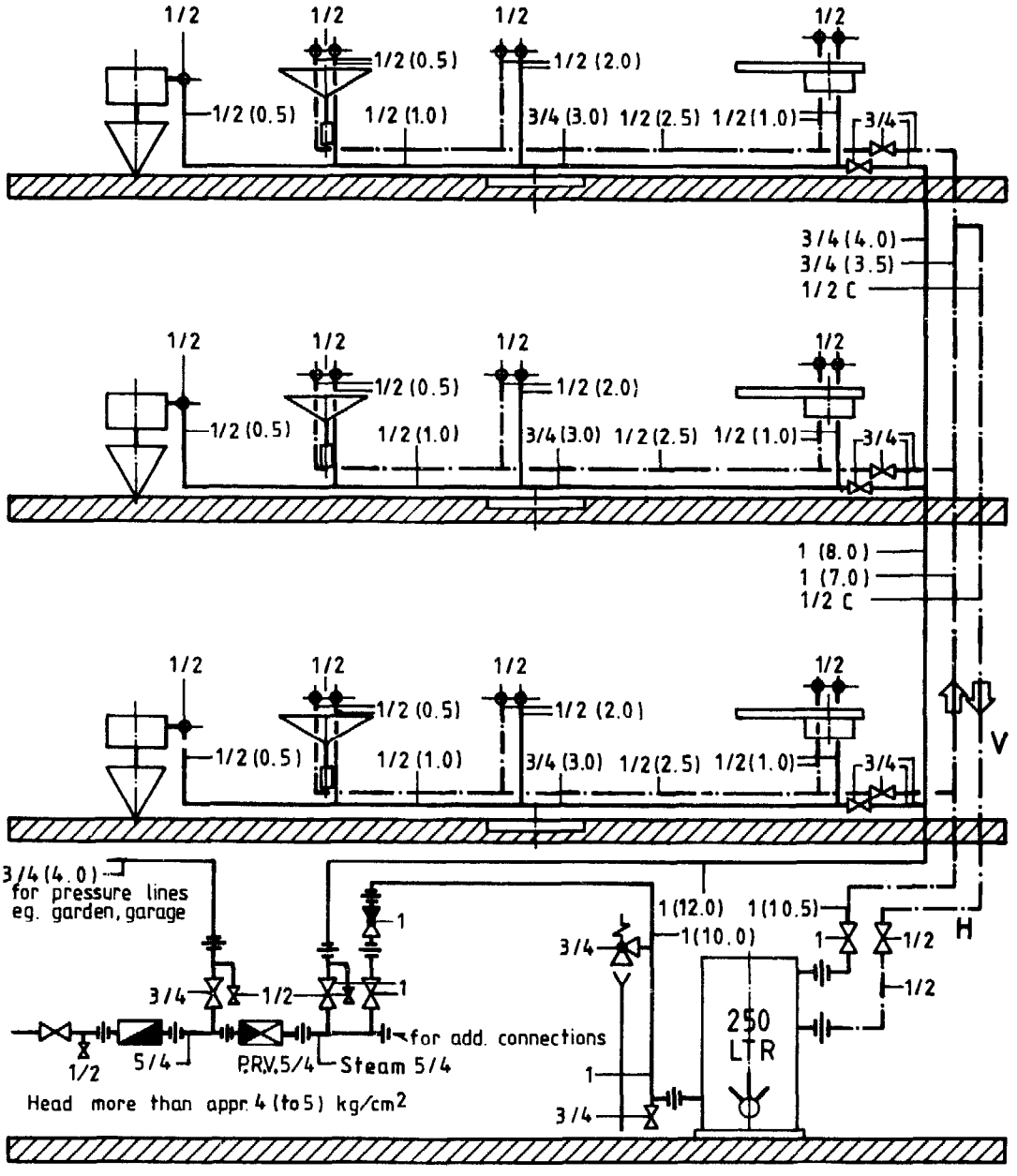

Note: All circulation pipes have to be insulated !

Gravity circulation system (without pump) rule of thumb: The horizontal (H) may not be longer than the vertical length (V). The diameter of the circulation (backflow) pipe to be appr. two dimensions smaller than the forward pipe (but at least 1/2" ∅).

DIMENSION-CALCULATION EXAMPLE

TABLE 1/35

PIPELINE - SCHEME

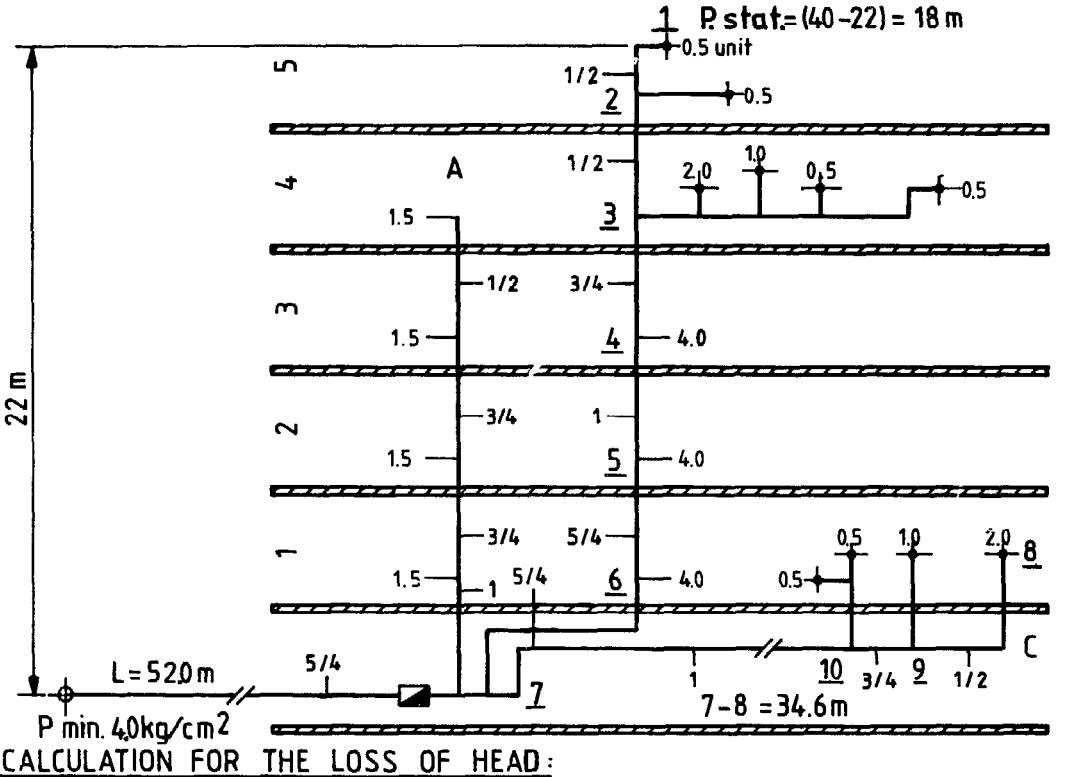

CALCULATION FOR THE LOSS OF HEAD:

pipe	section	units	max. load ltrs/min.	ø inches	length meter	addition %	total length m.	loss of head mm/m	loss of head total mm
B	1 - 2	0.5	5	1/2	1.80	100	3.60	25	90
	2 - 3	1.0	10	1/2	3.20	100	6.40	85	544
	3 - 4	5.0	30	3/4	3.00	100	6.00	170	1020
	4 - 5	9.0	38	1"	3.00	100	6.00	80	480
	5 - 6	13.0	44	5/4	3.00	100	6.00	28	168
	6 - 7	17.0	48	5/4	6.80	100	13.60	33	448
	1 - 7				20.80				2750
	Water meter	27.0	60	1"	-	-	-	-	2650
	connection	27.0	60	5/4	52.00	50	73.00	50	3650
									9050mm
									(9.05 m)
C	8 - 9	2.0	20	1/2	2.70	100	5.40	290	1566
	9 - 10	3.0	24	3/4	3.50	100	7.00	120	840
	7 - 10	4.0	27	1"	28.40	70	48.30	47	2270
	7 - 8				34.60				4676
	Water meter	27.0	60	1"	-	-	-	-	2650
	connection	27.0	60	5/4	52.00	50	73.00	50	3650
									10976mm
									(10.976 m)

DIMENSION-CALCULATION EXAMPLE

Explanations to the example table 1/35

In most cases it will be sufficient to check the dimensions after using the simplified method (unit, dimensioning table)

The calculation-bases are the following:

a) Lowest dynamic pressure of 0.5 kg/cm² on the highest fixed tap. This pressure is absolutely necessary to guarantee a normal water-flow and to prevent any re-suction from waste-water into the drinking water pipeline.

b) Highest loss of head of 1.0 kg/cm² in the whole installation (including the feeding-pipeline and the water meter).

c) Consumption of water according to the probable maximum load in domestic and office buildings (according to table). For industries, fire-hydrants etc. the highest load has to be calculated according to the actual consumption in L/S.

d) Effective length of the pipelines has to be measured at the building sites or from the plans. The effective length must be increased to include also the losses of head in the fittings.

feeding - lines + appr.	50% (to the effective length).
house-installations appr.	100% (to the effective length).

Example for the control of the measurements from an installation

indications:

- Lowest pressure on the connection	40	m	watercolumn
- Height-difference between the connection and the highest-placed tap	22	m	WC
- Static-pressure on the highest tap	18	m	WC
- Length of the connection line	52	m	
- Inside-pipeline according to the scheme			

Calculation of the pipeline 'B'

Make provisional statement of the consumer units and diameter according to the pressure table.

Calculate the loss of head in the separate pipeline-sections 'B', beginning from the water meter and from the connection.

DIMENSION-CALCULATION EXAMPLE

Total loss of head of the installation 9.76 m water-column, that is less than 10 m.

Dynamic-pressure on the highest placed tap 3.24 m, that means more than 5 m.

Final Conclusion: The dimensions according to the easy method are sufficient (unit, dimensioning table).

Calculation of the pipeline 'C'

Length, beginning from the water-meter 34.6 m
To consider this pipe length, there is the adjustment from the section 7-10: The diameter is changed into 1" Ø (instead 3/4"Ø for 4 units).

Calculation for the loss of head in the pipeline 'B'

Total loss of head: 11.99 m, that means 20% more than the admissible loss of head from 10 m. But this difference is tolerable, because the connection is for adjoining rooms, and because pipeline has little influence on the feeding of the main-building.

Water Meter

The produced loss of head in a water meter may determined with diagrams or with a calculation. Therefore take the waterflow with a loss of head 10 m.

Water meter 25 mm Ø = 7 m^3 h with a loss of head of 10 m. For the waterflow of 60 litre/minute, that means 3.6 m^3 h, result in a loss of head in the water meter of:

$$\frac{10 \times 3.6 \times 3.6}{7 \times 7} = 2.65 \text{ m}$$

Connection

For the calculation of the loss of head in the connection pipeline, it may be assumed to take 10% of the net (town-line). An additional charge of 50% on the length of the pipeline will be sufficient, to consider the armatures and other special pieces. That is because they will be less numerous than the inside installations.

Assumable loss of head 10/%	=	4 m
Calculated loss of head	=	3.65 m

Also in this case the easy method is sufficient to determine the diameter, even when the connection-line is longer than 30 m.

GUIDING PRINCIPLES FOR WATER REQUIREMENTS TABLE 1/36

Purpose	Unit	Requirement		
	Consumer/Time	Min.	Medium	max.
Domestic Purposes:				
drinking, cooking, cleaning	person day	50	80	120
laundry (washing)	person day	10	20	40
bathing, douche	person day	50	100	180
WC-cistern, flush	person day	40	50	60
cleaning of a car	car	150	250	400
Domestic Buildings:				
modest conditions	inhabitant day	100	150	200
medium comfort	inhabitant day	150	200	300
higher standard	inhabitant day	250	400	600
Public:				
schools	student day	10	12	15
hospitals	patient day	300	450	600
bathing establishment	500 - 600 bath	500	550	600
restaurants (for meals)	guest day	60	100	150
barracks (army)	man day	50	100	150
covered market	m^2 day	3	4	5
slaughter houses	cattle/big	400	450	500
slaughter houses	livestock, small	300	350	400
wash institution	kg (dry wash)	50	60	70
open yard(grass field)	m^2 surface	1	1.5	2
road sprinklers	m^2 surface	1	1.25	1.5
car workshop	employee day	30	40	50
backery (bread)	employee day	120	130	140
hair-dresser	employee day	160	170	180
photo-studio	employee day	280	300	320
administration-building	employee day	30	40	50
Industries:				
brewery (without cooling)	100 ltr. beer	600	700	800
(with cooling)	100 ltr. beer	1400	1700	2000
dairy	100 ltr. milk	400	500	600
paper factory	kg, fine paper	1500	2200	3000
Farming Purposes:				
horses	1 pc. day	60	70	80
cows	1 pc. day	60	65	70
young cattle	1 pc. day	40	45	50
pig	1 pc. day	15	20	25
sheep goats	1 pc. day	5	6	7

* According international standards

LOSS OF HEAD-CHART / G.I. PIPES

TABLE 1/37

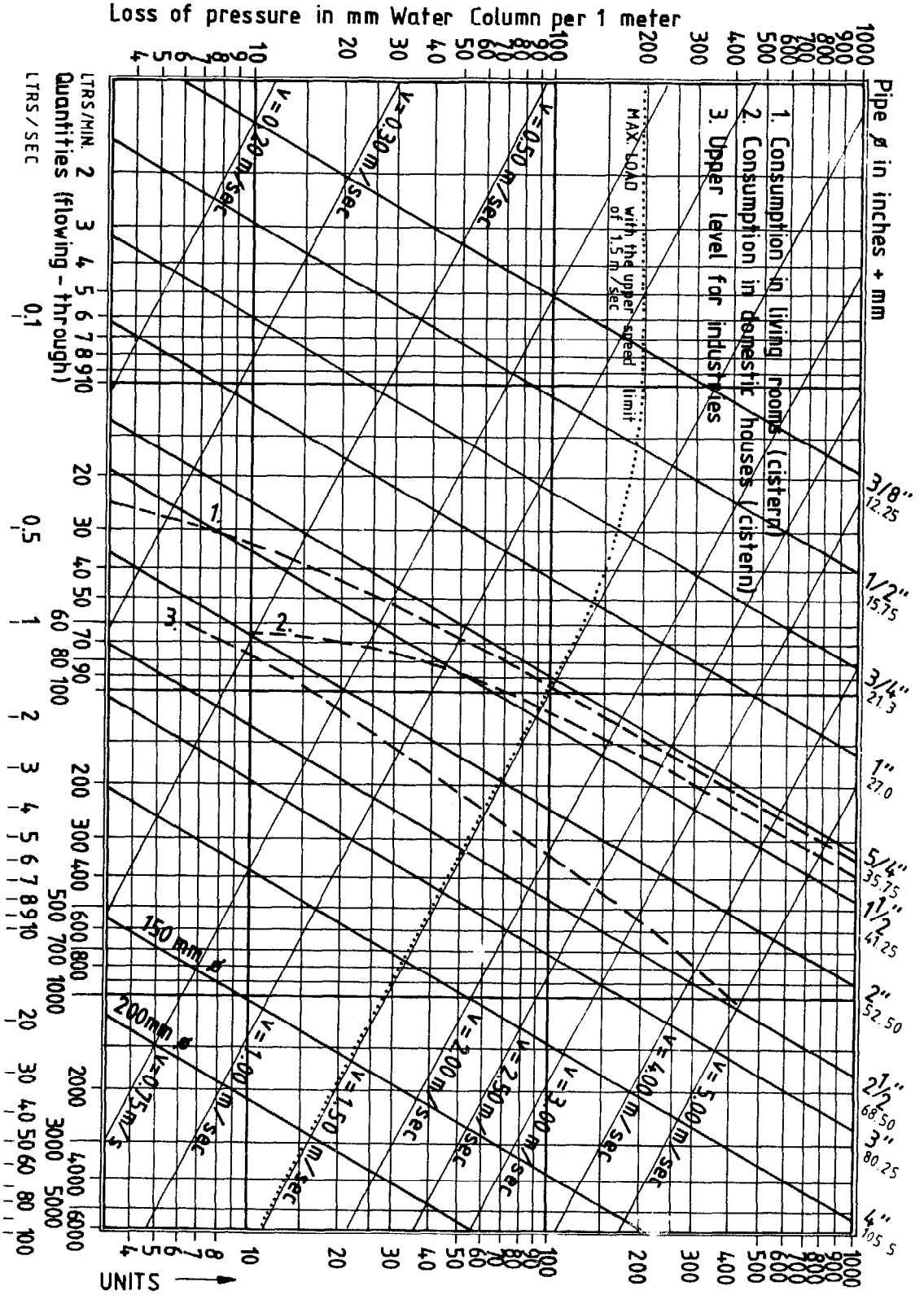

LOSS OF HEAD - CHART

TABLE 1/38

LOSS OF HEAD IN POLYETHYLENE PIPES (WATER AT 10°C)

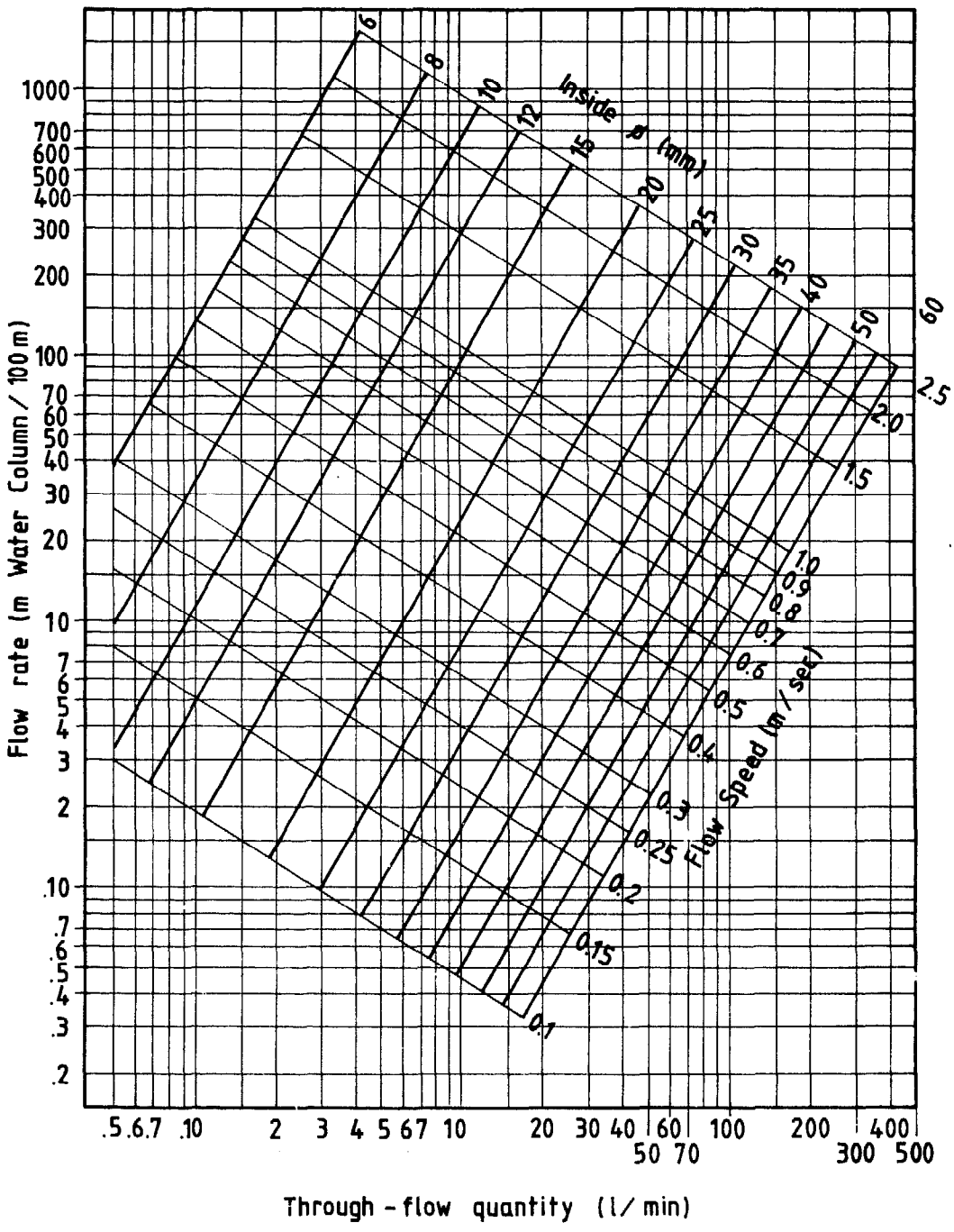

MAXIMUM LOAD CHART - UNITS INTO LTR/MIN **TABLE 1/39**

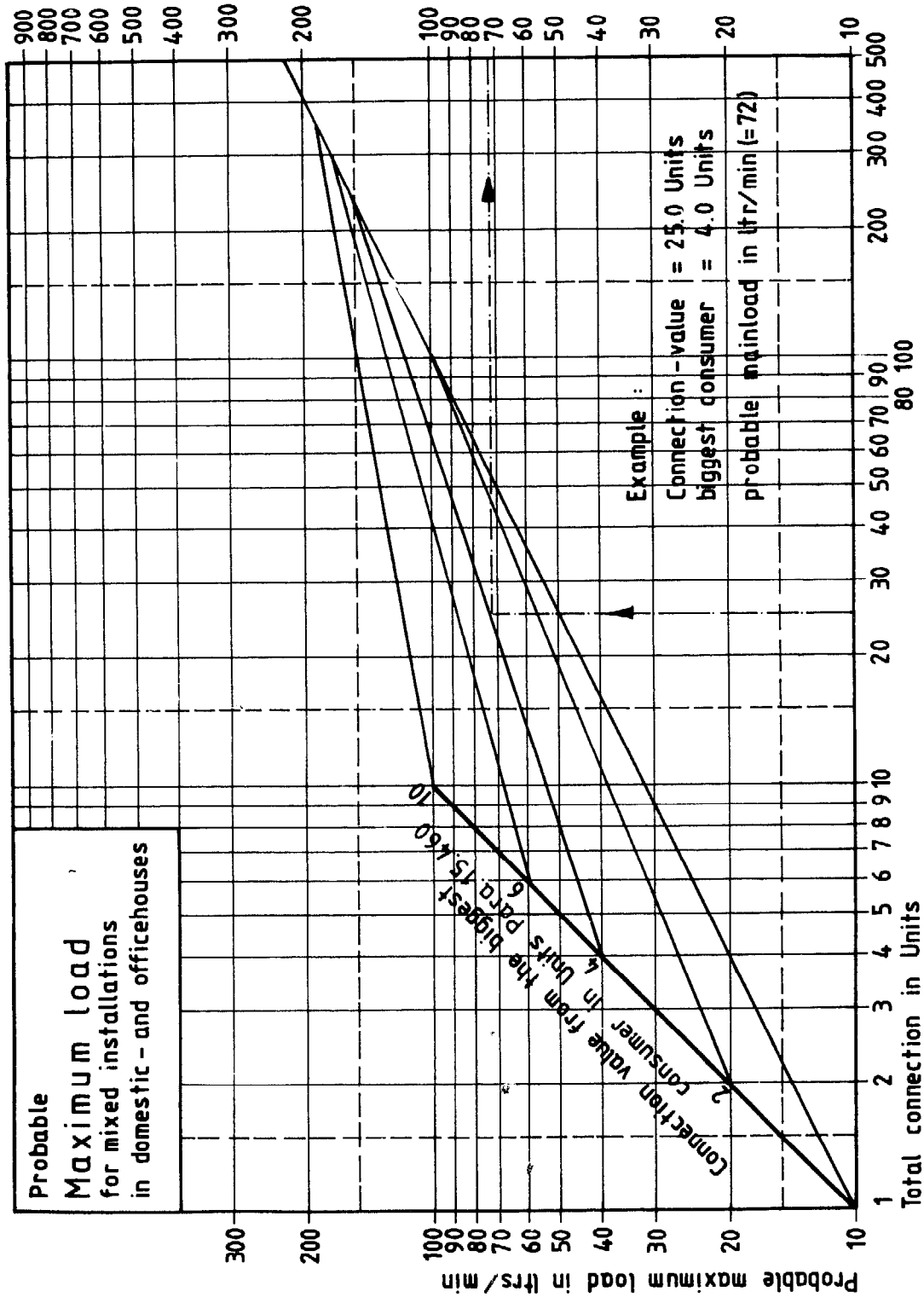

G.I. MATERIAL LIST

TABLE 1/40

BUILDING SITE: _____ SECTION: _____

SUBJECT: COLD- OR HOTWATER DATE:

SIG.	ARTICLE	Nº	3/8	1/2	3/4	1"	5/4	1½	2"	3"	4"
	PIPES GALV. G.I.										
	PIPES TOTAL										
	PIPES GALV.										
	WITH PAINT										
	WITH BANDAGE										
	PIPES PROTECTED										
	SOCKET	270									
	ELBOW	90									
	BEND 90°	3									
	BEND 45°	8									
	CROSS TEE	180									
	REDUCER SOCKET	240									
	TEE	130									
	FLANGE	329									
	UNION	330									
	PLUG	290									
	CAP	301									
	NIPPLE	530									
	CLAMP										
	SADDLE CLAMP										
	SCREW / DOWEL										
	GATE VALVE										
	TAP (BIB COCK)										
	GLOBE VALVE (CHROM)										

Residential and Non - Residential

DRINKING WATER INSTALLATIONS AND DRAINAGE REQUIREMENTS IN NEPAL

PART 2
DRAINAGE REQUIREMENTS

DRAINAGE REQUIREMENTS

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1 SCOPE

This section deals with the design and installation of soil, waste and ventilating pipes where they occur above ground both inside and outside the building.

The establishment of unobjectionable sewerage system and the safety of the community have been taken into account.

2 FIELD OF APPLICATION

These guidelines are applicable for:

- Domestic house drainage systems (soil and waste waters)
- Partly covered: Rain water pipes

2.100 PRINCIPLES

This manual covers modern methods of plumbing, namely, the single stack system, the divided stack system and the one-pipe system. However, in view of the simplicity and economy of the single stack system, it is recommended that for all new construction this system may be adopted in preference to other systems.

2.200 DESIGN CONSIDERATIONS

The system to be adopted will depend on the type and design of the building in which it is to be installed and will be one of the following:

a) Single stack system
b) Divided stack system
c) One-pipe system

2.300 STACK SYSTEMS

This is the name given to a simplified system, wherein all separate ventilation pipes are omitted. The stack itself is made to cater (or provide) for all vent requirements by restricting the flow into the stack to certain predetermined limits.

A stack is a pipeline for main vertical discharge, extending more than one storey in height, and where all fixtures connected to it require a trap.

Note: rain water pipes are not to be fitted to stacks for soil and/or waste water pipelines. Usually they are not connected to the ground pipelines but drained through separate systems.

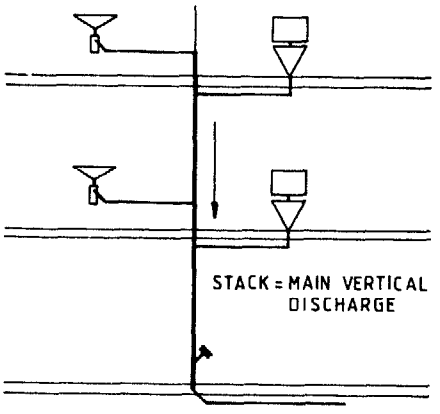

2.310 **Single Stack System (Standard Installation)** -In this mixed system, the pipe conveys discharges from all waste water appliances (e.g. soil and waste appliances) such as water closets, urinals, bath tubs, wash basins, kitchen sinks, etc.).

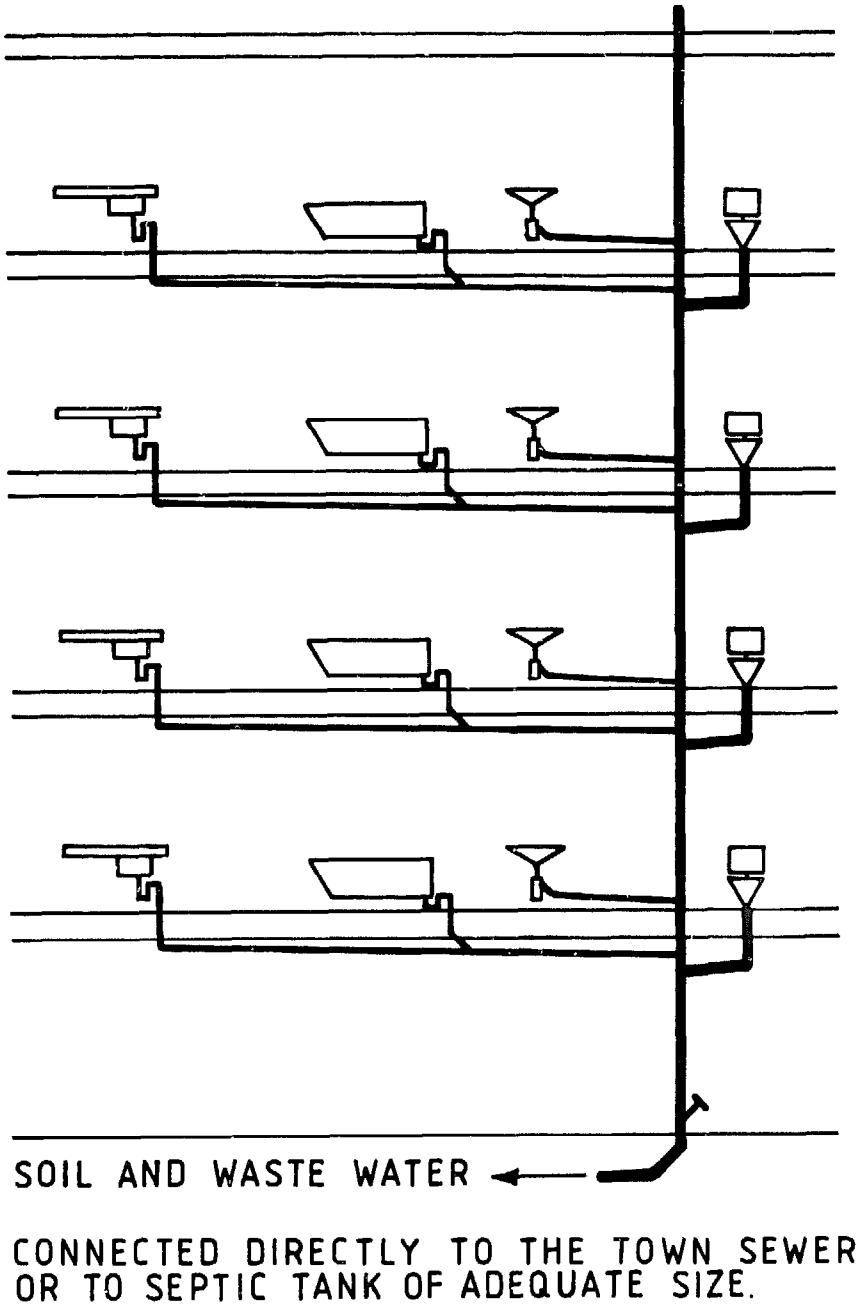

These pipelines convey waste water directly to the canalization main pipelines or into individual septic tanks of adequate size.

2.320 **Divided Stack System** (Individual Installation) - In this divided system there are two (or more) separate separate stacks:

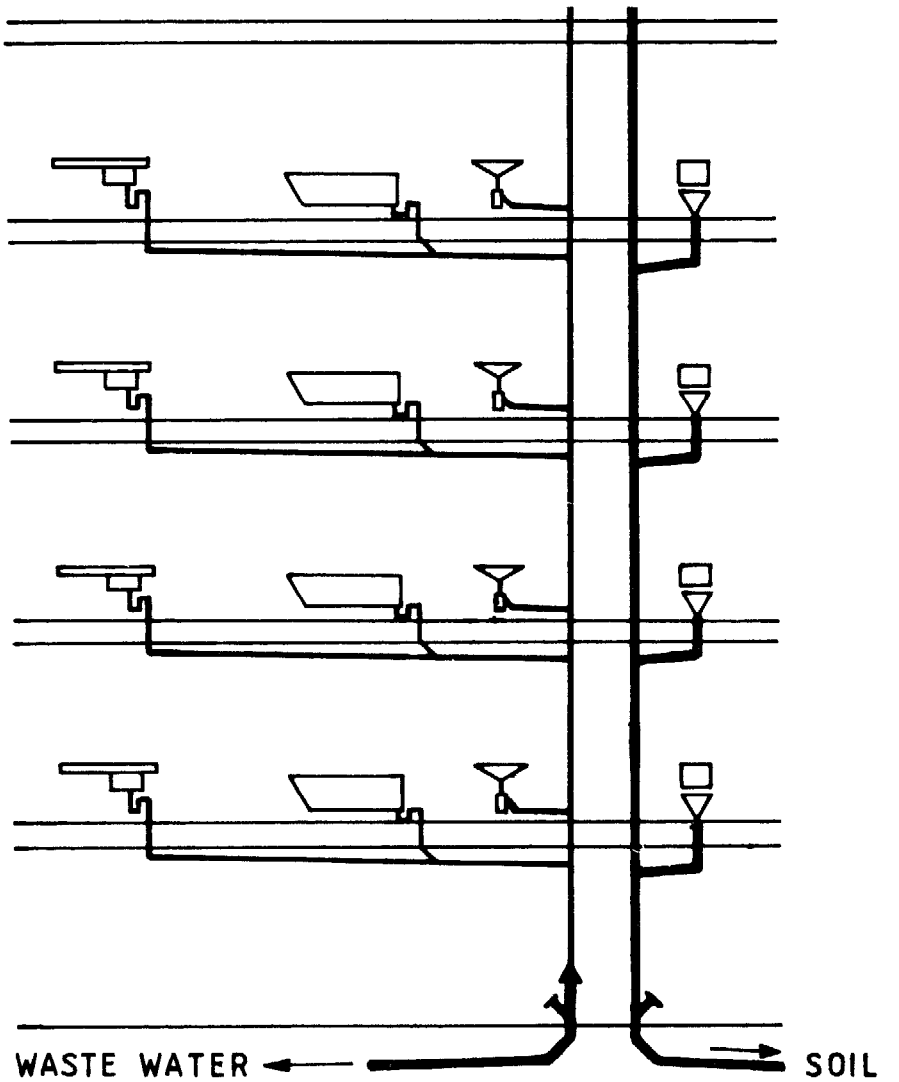

CONNECTED SEPARATELY TO SEPTIC TANKS

i) The soil stack conveys discharges from water closets, urinals and similar soil appliances directly to the septic tank.

ii) The waste stack conveys wastes from ablutionary (washing, washing-off) and culinary appliances (food), such as wash basins, bath tubs, kitchen sinks, shower trays, etc., either to a separate septic tank, or to the last chamber of the septic tank.

Divided stacks are to be ventilated above roof level in the same way as single stacks. If required, a waste stack ventilation, instead of being led straight through the roofing, could be joined to a nearby soil stack ventilation by use of 88° to 45° bends, with the branch at least 0.5 m above the upper level of the top-most apparatus.

Note: Divided stack systems might be useful in places with individual, small septic tanks. It is not required for mixed systems, e.g. when led into the town mains, or where septic tanks of sufficient capacity are provided.

2.340 Note: Previously a **"Two-Pipe System"** was applied in building installations. In this separate pipelines conveyed discharges:

- The soil pipes from water closets, urinals and similar appliances discharged directly to the drainage system (e.g. septic tank). Thorough ventilation was maintained by an extensive pipe-work of additional branch and main ventilation pipes.

- The waste pipes from ablutionary and culinary appliances were conveyed to the drainage systems directly or through a trapped gully, where desired. In these pipelines also the ventilation was maintained by an extensive pipework of additional branch and main ventilation pipes.

As mentioned earlier, in view of modernization and consideration of economy this "Two-Pipe System" is not now applied in new buildings.

DIAGRAM OF TWO-PIPE SYSTEM

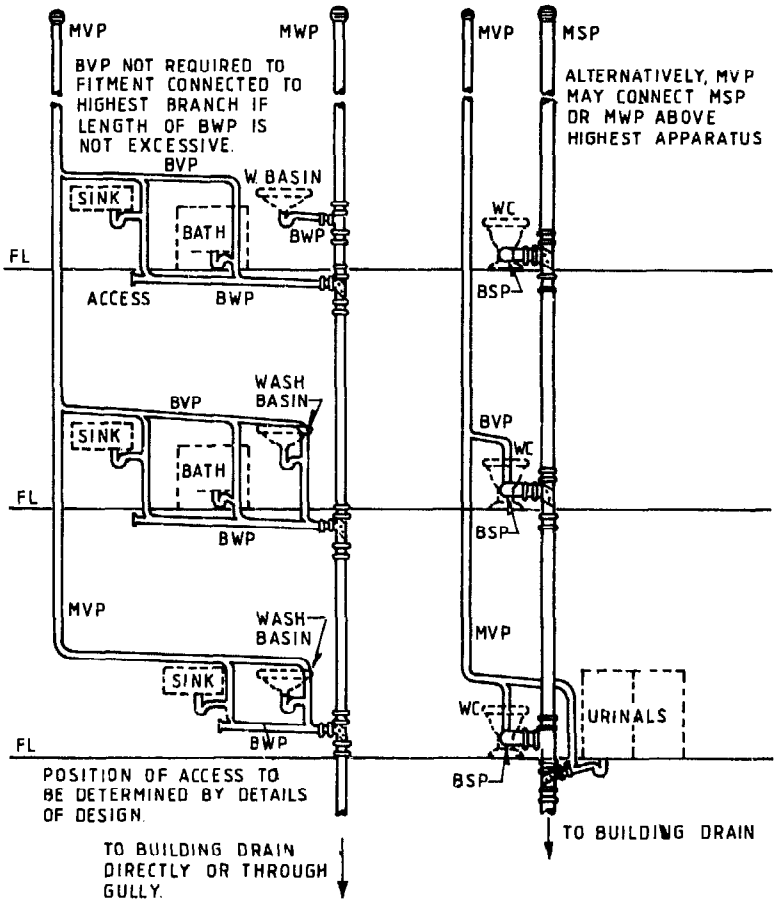

Main Soil Pipe (M.S.P.): A pipe connecting one or more branch soil pipes to the drain.
Main Waste Pipe (M.W.P.): A pipe connecting one or more branch waste pipes to the drain.
Main Soil Waste Pipe (M.S.W.P.): A pipe connecting one or more branch soil waste pipes to the drain.
Branch Soil Pipe (B.S.P.): A pipe connecting waste appliances to the main soil pipe, (stack).
Branch Waste Pipe (B.W.P.): A pipe connecting waste appliances to the main waste pipe, (stack)
Branch Soil Waste Pipe (B.S.W.P.): A pipe connecting soil and/or waste appliances to the main soil waste pipe (stack).

2.400 DRAINAGE REQUIREMENTS FOR BUILDINGS

Principles of system

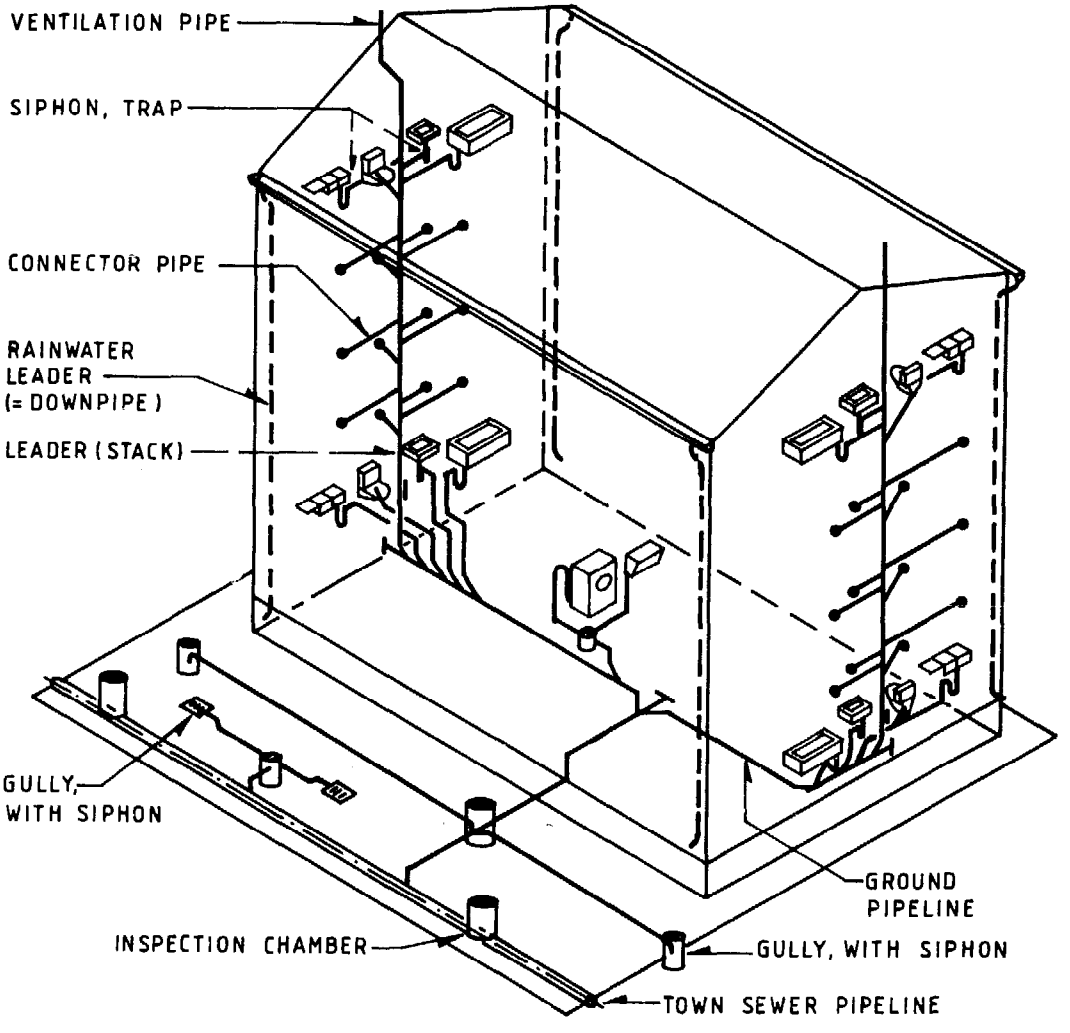

Notes:

- Rain water drains may only be connected to combined or single sewer systems in which the sewer pipe is designed to take both sewage and rain water.
- Rain water drains must be properly trapped before entry into soil drainage system (town sewer).
- Written permission must first be obtained from the concerned government authorities befor rainwater drains can be connected to the sewerage systems.

3 TERMS AND DEFINITIONS

3.100 WASTE WATER

(WA) - General term for all types of waste water.

3.110 **Waste Water Clear** (WAC) - Waste water that can be led directly to the outfall ditch, e.g. led without any treatment to an open drain (river, lake, etc.) WAC includes:

- Storm drain (WAC-R) (=Rainwater)
- Water from cooling tower (WAC-C)
- Waste water approved by the water and sewerage authority (WAC-A)
- Ground water approved by the water and sewerage authority (WAC-G)
- Treated waste water (WAC-T)
- Drainage water (WAC-D)

3.120 **Soil Water** - Contaminated waste water which requires treatment, such as:

- Domestic waste water (Soil waste water = WAS-H)
- Heavily contaminated rain water (WAS-R)
- Pretreated industrial waste water (WAS-I)

3.130 **Industrial Drain** - Water which needs treatment by specialized plants before being led into the main sewerage line.

3.140 **Drain** - Any pipe which conveys discharges from sanitary appliances into a drainage system.

3.141 **Building Drain** - The building (house) drain is that part of the lowest horizontal piping of a drainage system which receives the discharge from soil, waste and other drainage pipes inside the walls of the building and conveys it to the building (house) sewer beginning outside the building wall.

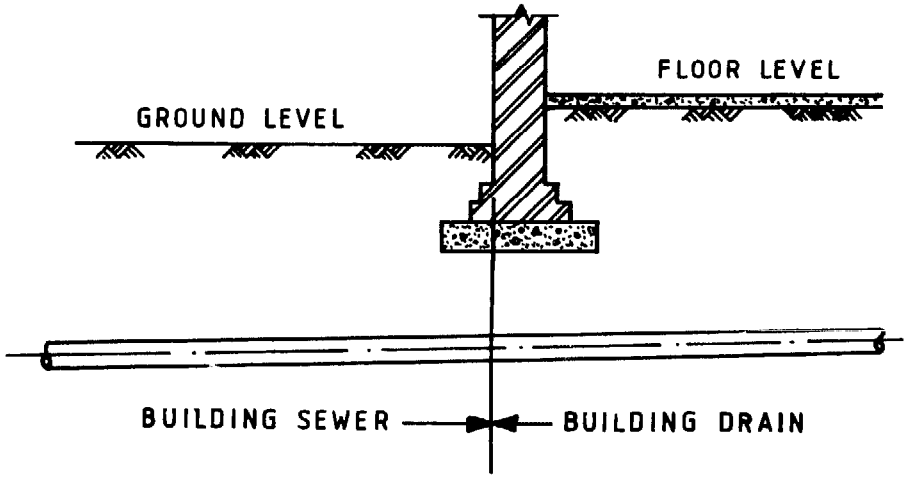

3.142 **Building Sewer** - The building (house) sewer is that part of the horizontal piping of a drainage system which extends from the end of the building drain and which receives the discharge of the building drain and conveys it to a public sewer, private sewer, individual sewage-disposal system, or other point of disposal.

3.143 **Soil Connections** - Connections to the drainage system of water closets, urinals and similar appliances (which contains human or animal excreta, but not water with soap).

3.144 **Waste Connections** - Connections to the drainage system of wash basins, bath tubs, shower trays, bidets, kitchen sinks and similar appliances (which does not contain excreta, but probably contains soapy water).

3.145 **Soil and Waste Water Pipelines (Combination Drain)** - A pipe which conveys to a drain the discharges from a water closet or urinal as well as the discharges from baths, wash basins, sinks and similar appliances.

3.146 **Divided Drains** - Pipes which convey discharges in separate pipes to the drainage systems: one system for the soil connections and the other system for the waste connections.

3.150 **Soil and/or Waste Water Accumulation** - Discharge of water quantity.

3.151 **S-Value** (Soil and Waste Water Flow Value - SV, also called fixture unit) - Calculated value of nominal soil and/or waste water flow rate of any drainage appliance per unit time through proper waste outlet. The basic outlet unit 1 SV corresponds with the discharge in time unit of 1 liter/sec.

3.152 **Volume flow rate** (loading) - Soil and/or waste water accumulation per unit time:
- Vs (Volume flow) of several drainage appliances
- Vr Flow rate per unit time of rain water.
- Vm Flow rate per unit time of mixed soil and/or waste water with rain water (inground pipes only).

3.153 **Loading Capacity** - Permissible load in (l/s) of a pipelines, drainage appliance or drainage system.

3.154 **Inside Diameter** (i.d.) - Inside diameter of round pipes.

3.155 **Width of pipe** - Nominal inside (light) diameter of round pipes, i.e. bore.

3.156 **Soffit** - The highest portion of the interior of a sewer pipe at any cross section.

3.157 **Invert** - The lowest point of the interior of a sewer or rain pipe at any cross section. In a manhole chamber, the channel in the floor of the chamber which carries the flow of sewage through the manhole.

3.160 **Ground pipeline** - Horizontal installed pipeline for intake of a soil and waste water (building drain) below floor level or below basement.

3.161 **Collector pipe** - Horizontal, openly installed pipeline for intake of soil and/or waste water from leaders, branch and connector pipelines.

3.162 **Leader** - Vertical pipeline (eventually with loop), leading through one or several storeys, ventilated over roofing and led into a ground pipeline or into a collector pipeline.

3.163 **Stack** - A main vertical discharge or ventilating pipe, extending more than one storey in height, and where all fixtures connected to it require a siphon.

3.164 **Connector pipe** - Pipeline from an apparatus connector joint of a drainage appliance to a branch, leader (stack), collector or ground pipeline.

3.165 **Branch Pipeline** - Joining pipeline of several connector pipelines to the leader, collector or ground pipeline.

3.170 **Fall line**- Part of vertical distance of a connector or branch pipeline above 0.2 m.

3.171 **Tilt line** - Part of distance of a connector or branch pipeline having more than 10 percent slope and above o.2 m height.

3.172 **Offset** - Installed vertical pipeline having a shifted axis, made of one fitting or of two bends up to 45°, which does not require any technical drainage measures.

3.173 **Loop** - Horizontal connection of two parts of a leader up to max. 10 m length.

3.174 **Bypass** - Side pipeline to the leader in the range of a loop with connection of drainage appliances which are connected below or above this leader.

3.175 **Special Fitting** - Fitting which reduces the over-pressure or vacuum in a leader (required at extended heights).

3.200 **DRAINAGE APPLIANCES**

Collective term for all drainage places, i.e: Appliances which serve as containers for the intake of water after its use in domestic ranges, enterprises or industries and disposes this water as soil and/or waste water, (e.g: water closet, bath tub, inlet funnel, etc.).

3.210 **Sanitary Apparatus** (Fixture), such as - Bath tubs, shower trays, wash basins, bidets, water closets, urinals, service sinks, sinks, kitchen sinks, domestic kitchen and wash-kitchen apparatus, etc.

3.220 **Special Sanitary Apparatus** (Special Fixture), such as-commercial kitchen and washing-kitchen apparatus, laboratory and hydrotheraphy, etc.

3.230 **Drain funnels** - Open conical inlet with drain outlet.

3.240 **Floor Drain Inlets** - Appliances with drain outlets, without siphon, for collecting and draining of floor water.

3.250 **Rain Water Inlet** - Appliances with drain outlet, without siphon, for collecting and draining of rain water.

3.260 **Floor Drains** - Appliances with drain outlet and siphon for the collection and drainage of waste water inside buildings.

3.270 **Manhole (Inspection Chamber)** - Any chamber constructed on a sewer pipe, with access for inspection, maintenance and clearance of obstruction. Used for both soil and waste waters. They are placed on branches to the main sewer pipe, at a change in grade, diameter, direction and in straight length at appropriate intervals. They are so located to provide access.
Note: Manholes inside buildings are to be fitted with an airtight and removable cover.

3.280 **Siphon (Trap)** - A fitting or part of an appliance or pipe which contains water to prevent the passage of air. An integral trap is one formed in an appliance during manufacture. An "**attached siphon**" is a separate fitting which is connected to the waste outlet of the appliance.

3.281 **Water Seal** - The depth of water which should be removed from a fully charged siphon before air can pass through the siphon.

3.282 **Self-Siphonage**- It is the action by which the wastes from individual appliances suck out their own seals at the end of their discharge.

3.283 **Induced Siphonage** - The siphonage of a siphon due to the discharge of other appliances in the system.

3.284 **Back Pressure** - Air or waste water from pipes being forced up through siphons.

3.285 **Back-Siphoning** - Suction of used waters (e.g. from filled bath tubs) into the drinking water pipes. A situation which must absolutely be prevented through professional installations!

3.300 **SPECIAL ARRANGEMENTS**

3.310 **Floor Trap** - Small container with siphon (dive bend), with a inlet for waste water and the exit connected to the drainage pipe, by which heavy particals remain in the trap.

3.320 **Sludge Trap** - Appliance with a cover perforated with holes (above 150 cm2 with slots) and having a sludge sack, which receives incoming waste water, separates the heavy particals and solid matter, then leads the waste water into the drainage pipes. As of local regulations it requires a dive bend (or a dividing wall), which can be removed for cleaning purposes.

3.330 **Silt Trap** - Container or appliance without siphon, which receives incoming waste water. Heavy particals, (sand, gravel, etc.) are retained and waste water is led to an arrestor (separator).

3.340 **Arrestor** (Separator) - Appliance with siphon (dive bend, dividing wall), which separates and retains from waste waters matters such as mineral oils, greases, per-chloride-ethylene, etc.

3.350 **Drainage Pump** (for Sewer) - Arrangement for lifting of waste water.

3.360 **Back-flow Prevention** - Arrangement which should prevent a possible back-flow from the canalization into rooms.

3.400 **VENTILATION PIPES**

3.410 **Vent Pipes** - Pipelines which serve for the circulation of air, but do not dispose of any waste water.

3.420 **Stack Vent** (Main Ventilating Pipe) - Continuation of a leader, without reduction of the inner diameter. It is the primary vent, beginning from the top-most inlet and passing above roof level.

3.430 **Connector Vent** - Ventilation of a connector pipeline.

3.440 **Branch Vent** - Ventilation of a branch pipeline.

3.450 **Pit Vent** - (Drain Ventilating Pipe - D.V.P.) A pipe installed to provide flow of air to or from a pit (e.g: pump sump, arrestor, etc.) which is extended to above roof level or fitted into a leader.

3.460 **End Vent** - Ventilation of a ground or collector pipeline above roof level or into a leader.

3.470 **Collector Vent** - Collector pipeline of two or several vertical pipe vents or side (branch) vents.

3.500 VENTILATION SYSTEMS

3.510 **Stack Vent** (Leader Vent) - Is the main vent system, having the same diameter as the stack.

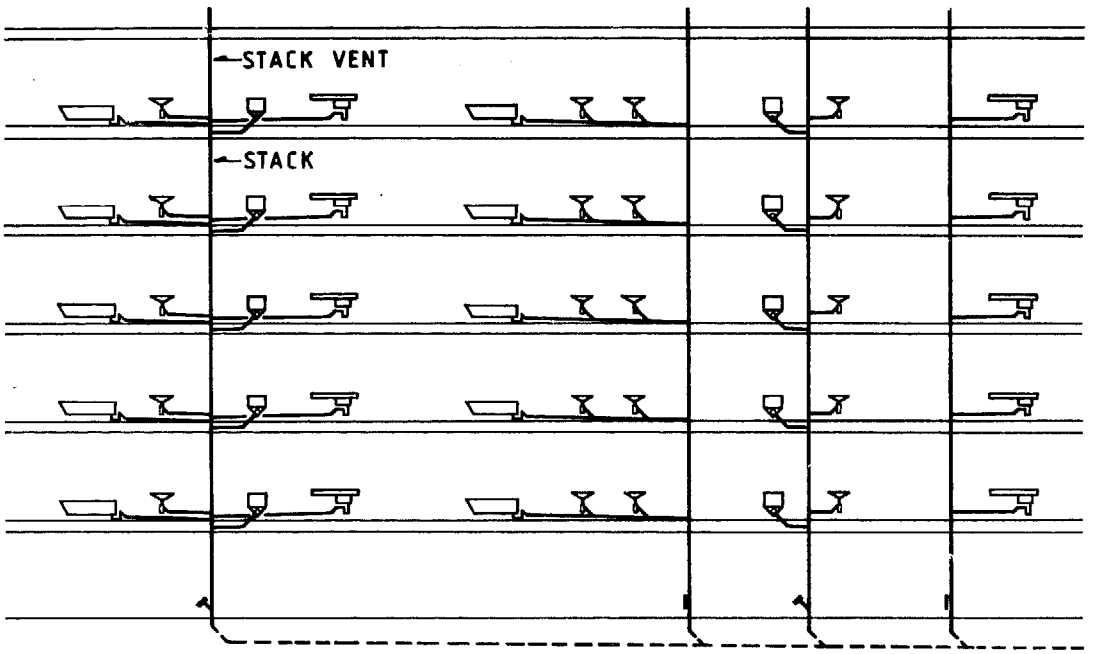

3.520 **Direct Side Vent System** - Parallel to the stack (leader) lead vent pipe, which is connected on each floor with the stack.

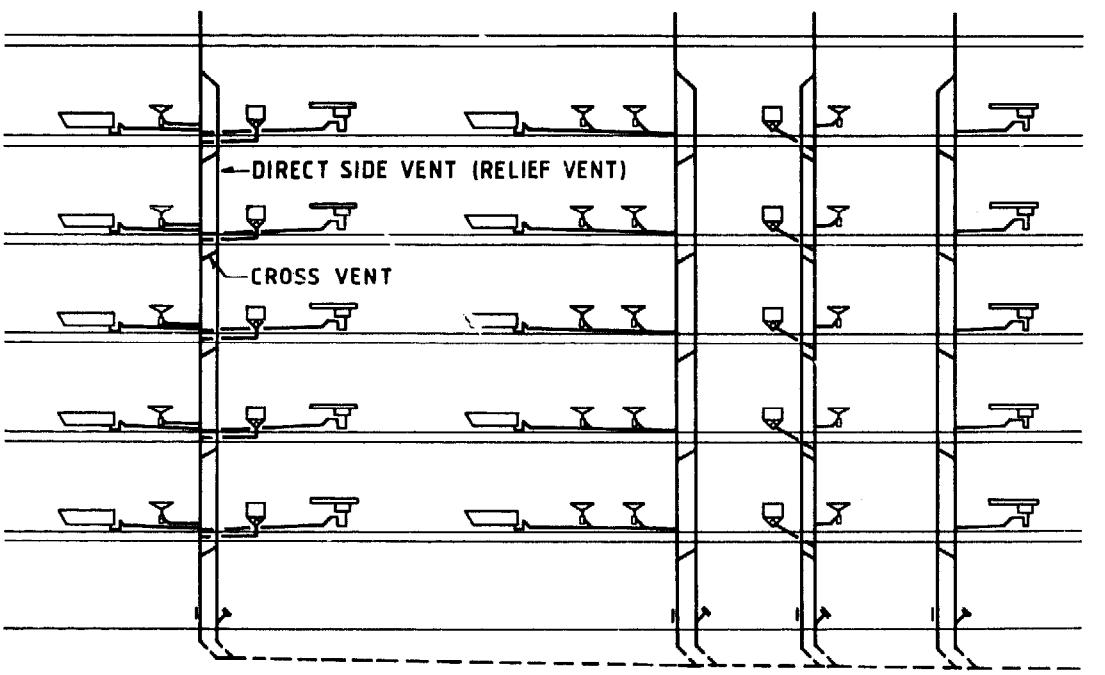

3.530 **Indirect Side Vent System** - Parallel to the leader (stack) lead vent pipe, which in each floor is connected with a branch pipeline to the leader.

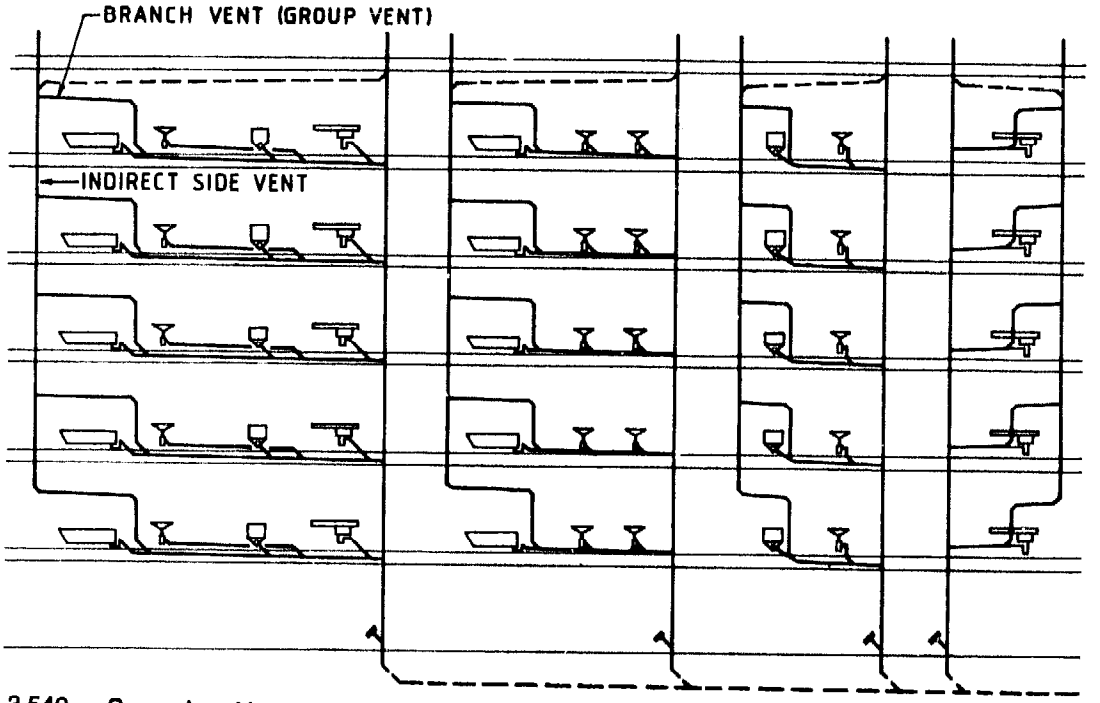

3.540 **Secondary Vent System** (modified One-Pipe System) - Ventilation of single connector pipelines with a side vent leading above the roof or connected to a leader at a minimum of 0.1 m above top-most apparatus.

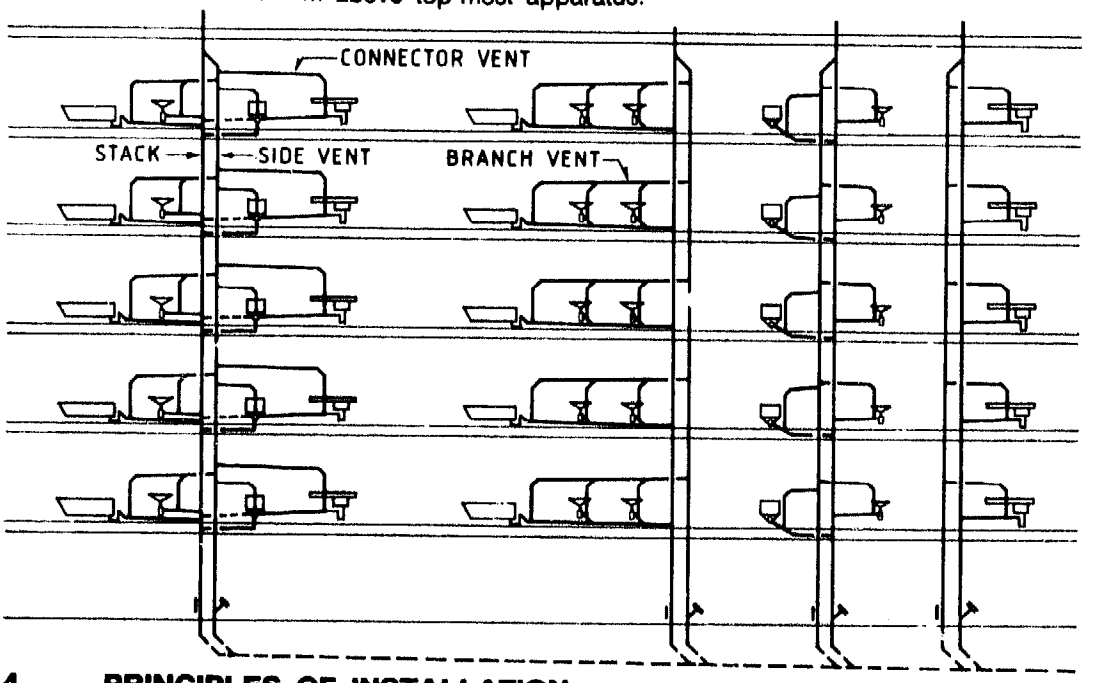

4. PRINCIPLES OF INSTALLATION

4.100 HYGIENE AND FUNCTION

The buildings are to be fitted with drainage installations which should follow these guidelines in view of hygiene and function.

The waste waters have to flow as fast as possible into the plot's sewerage system without leaving sediments in the pipelines (i.e. to be self-cleaning).

4.200 SAFETY

The drainage system has to be planned and to be installed so that the following conditions are fulfilled:

- Resistant to domestic soil and waste waters and gases
- To absorb the soil waste waters

Protection provided against:

- Exit of any soil and waste waters and gases
- Mechanical influences of all kinds
- Outside influences of temperatures
- Back-flow
- Corrosion and erosion

4.300 NOISE CONTROL

Drainage installations are to be collected and reasonably fitted in those rooms where normally no noise control is required. (e.g: bathrooms, kitchens, etc.).

4.400 PROHIBITION OF DIRECT CONNECTION WITH THE WASTE WATER PIPELINE

Drinking water (and overflows and drainages of containers and appliances, which are fed from a drinking water pipeline) must never be connected directly to the drainage pipes, (prevention of back-siphoning)!

4.500 SEPARATION OF RAIN WATER AND WASTE WATERS

Rainwater and soil/or waste waters have to be drained separately, and **(if permitted)** may only be joined outside the building into the ground pipeline.

4.600 CHEMICALLY LOADED WASTE WATER

Chemically loaded waste waters are to be led separately to a pre-processing plant.

Waste waters require a special pre-processing plant, especially when they contain:
a) Floating matter and heavy sediments;
b) Oils and greases in large quantities or on demand of the concerned authorities;
c) Strong poisons;
d) Acids
e) Strong alkalinous reacting substances
f) Radiation exposure

The damaging effects of these substances are opposed by means of:

a) Silt traps, filters or sieve plants
b) Oil or grease arrestors
c) Detoxication
d & e) Neutralization
f) Decontamination plants

- Processing plants are to be established and to be operated according to the Government's laws.

- The achievement of determined limiting values by means of dilution is prohibited.

4.700 SECURING OF AERATION AND VENTILATION

Sewerage plants are to be constructed so that the air can circulate, also during the drainage of waste waters.

4.800 **MAINTAINING OF FLOW SECTION**

Soil and/or waste water pipes are not to be reduced in their sections in the direction of drainage.

4.900 **CLEANING**

The cleaning of drainage systems is to be secured by means of relevant cleaning openings (clean out, cleaning eye, manhole, etc.)

4.910 **Siphon** (Traps) - The entry of foul air to the building should be prevented by suitable siphons, properly sited. Each drainage appliance is to be fitted with such a siphon, which needs to be installed at the place of the outflow of water, e.g. waste coupling. Out of use drainage appliances are to be removed and the apparatus connector pipeline must be closed tightly by professional skills.

4.920 **Back-flow** - Where a back-flow from the public canalization is to be expected, an overflowing of endangered basement rooms is to be avoided by means of a suitable precaution (e.g. pump). The level of the back-flow is to be asked from the concerned authorities.

4.930 **Gravity flow** - All drainage appliances situated above the back-flow level are to be drained directly through gravity flow.

4.940 **Drainage of rainwater** (storm water) - Roofs, balconies and other building annexes are to be drained by means of rain gutters, roof drains and through leaders, provided they are projecting over accessible surfaces (walk ways, forward squares, side walks, etc.).

5 PRINCIPAL REQUIREMENTS FOR PARTS OF PIPELINE

5.100 **PIPES, FITTINGS AND CONNECTOR PIECES**

5.110 **Choice of material** - The choice of suitable materials (e.g. reinforced cement, cast-iron or plastic pipes and steel with corrosion protection), is dependent on the range of application, the local conditions and the loading factors.

5.120 **Tightness** - All pipes and joints in pipework and connector pieces to appliances should be made in such a manner as to be air-tight and water-tight and to remain so during use. Care should be taken to ensure that no jointing material may enter the pipe. Some flexibility is desirable where there is a possibility of movement between the pipes or between the pipes and the appliances.

They have to withstand the following pressures within the surrounding temperatures:

- Accessible, open fitted connections of waste water appliances and apparatus connectors 0 up to 0.1 bar (0 up to 1 m water column).

- All other connections and soil and waste water pipelines 0 up to 3 bar (0 up to 30 m water column).

5.130 **Mechanical stress and resistance** - All soil and waste water pipelines and their parts have to be of proven quality in order to remain stable, hit proof, shock resistant, abrasive and scratch resistant and corrosion resistant.

The surface condition of the pipes, fittings and connectors must not favour blockages.

5.140 **Cleaning devices** - All apparatus and pipelines shall be easily cleaned and shall resist normal commercially used cleaning devices.

5.150 **Temperature resistance** - Waste water pipelines and their parts have to resist changes of temperature. Appropriate measures are to be taken, where required, to safeguard stability (e.g. expansion joints, halved shells under horizontally placed plastic pipes).

5.170 **Installation** - The connection of pipes and fittings, and all appliances (apparatus) must be easily made and be safe.

5.180 **Colour** - Non-transparent materials are to be utilized. Non-compatibility with specific coatings (paints) have to be indicated.

5.200 **Water proofing compound for connections**

5.210 **Requirements for compounds** - Materials for connections of pipes, fittings and apparatus must correspond, with regard to mechanical, chemical and thermal resistance, to the same requirements as for the materials of pipes.

They must not endanger the functioning of the connections.

6 PRINCIPAL REQUIREMENTS FOR DRAINAGE APPLIANCES

6.100 PRINCIPLE

To each water tap in buildings there belongs a drainage appliance (Exception: fire fighting equipment).

6.200 DISCHARGE VALUE

The discharge value of soil and/or waste water of any drainage appliance depends on its function.

6.300 OVERFLOW

Drainage appliances having outlets with stoppers (e.g. washbasins, kitchen sinks, bath tubs, etc.) require an overflow.

6.400 BACK FLOW PREVENTION

Drainage appliances have to be above the level of back-flow or are to be secured against exit of waste water by means of appropriate measures.

6.500 PREVENTION OF EXIT OF GASES

6.510 **Siphon drainage appliance** - Each drainage appliance (with exception of inlets, e.g. drain inlets) has to be fitted with a siphon to prevent the exit of gases. This siphon can be an integral part of an appliance or be directly attached to the outlet of the appliance. The pipe bore should be uniform througout and have a smooth surface.

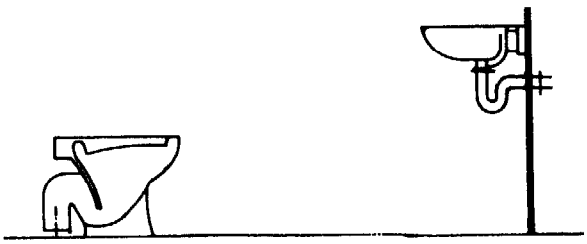

6.520 **Siphon rainwater** - Rainwater pipelines, from which disturbing odours may occur, are to be fitted with a siphon, fitted in a frost-secured place.

6.600 REQUIREMENTS OF SIPHONS (traps)

6.610 **Water Seal** - The siphon prevents the exit of gases by means of it's water seal.

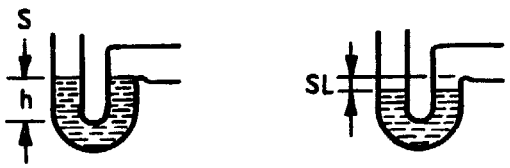

h = height of water seal (odour lockage)
for water closets, min.50 mm
for all other siphons, min. 70 mm
S = level of water seal
SL = (partial) loss of water seal (e.g. trough siphonage)

6.620 **Self-cleansing** - Siphons should always be of a self-cleansing pattern, by means of the discharged waste and/or soil water.

Anyhow, a cleaning opening must be provided.

6.630 **Placement of siphon** - Siphons for use in domestic waste installations and all other siphons should be accessible. A siphon has to be directly attached to the outlet of the appliance, or to be an integral part of the appliance (e.g. water closets).

6.640 **Removable connection** - Where openly fitted, such a siphon has to be easily fitted and removed.

6.650 **Concealed siphons** - The construction and fitting of siphons must guarantee an easy removal of parts of the siphon and therefore enable easy access to the connector pipeline.

Where the siphon is an integral part of the appliance, the connector pipeline has to be accessible through either easy removal of the drainage apppliance (closet, urinal, etc.), or by means of reasonably placed cleaning openings. The cleaning opening has to be adjacent to the siphon or be directly part of it (e.g. floor drain with siphon).

Where the siphon is concealed in the building construction, with the exception of shower tray and bathtub, the possibility for cleaning is to be secured by means of a manhole or a cleaning opening.

6.660 **Guarantee of water level** - To maintain the minimal required water level at each siphon, a permanent guarantee has to be provided by appropriate means.

6.670 **Water replacement** - Closets and urinals with self-siphoning flushing systems have to be fitted with a device which replaces the water in the siphon automatically after each flushing.

6.680 **Mechanical odour barriers and aeration valves** - both are prohibited for installation in domestic waste systems.

6.700 **Prohibition of direct connection with soil and/or waste** water pipelines - Appliances, refrigerators, refrigerator plants, fish cabinets, food cabinets and other containers for food may only be connected to the soil and/or waste water pipeline by means of a inlet funnel. This same is also valid for drains of safety valves and other devices of the drinking water system.

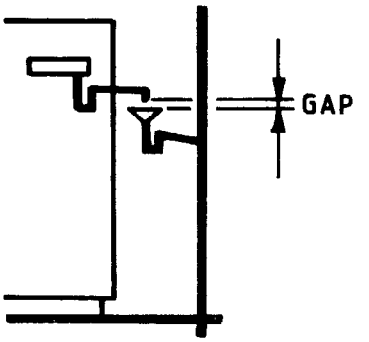

gap to be of min. 2 cm, or of same diameter as inlet.

6.800 **PROTECTION AGAINST POLLUTION OF PIPELINES**

6.810 **Protection from solid matter** - no solid matter, such as sand, garbage, textiles, vegetable wastes, etc., may be fed into a drainage system.

6.820 **Protection from gross pollution** - The outlet of a drainage appliance has to be constructed in such a way that no blocking solid matter may reach the siphon. The fitting of a kitchen waste chopper is prohibited.

6.830 **Closet arrangements** - They have to be fitted with flushing cisterns, in order to guarantee the self-cleansing of the soil water system.

7 PRINCIPLES FOR THE PLANNING AND FITTING OF DRAINAGE PIPES

7.100 PRINCIPLES FOR PLANNING

For planning and execution of building drains (domestic house drainage system) the following marginal requirements are valid. The drainage of premises is as of separate, governmental rule.

7.110 **Method of connection** - Each plot shall be drained separately and led into the canalization by the shortest way and without using the neighbour's plot.

Where the above is not feasible or not appropriate the drainage of several buildings can be realized by means of a collecting or ground pipe, provided the approval of the concerned government authority has been given.

Where the approval of the authority has been given for such cases of joint sewerage pipes it is suggested that the legality be secured by entering the agreement into the land regisstery.

7.120 **Later extension** - Where plots are only partially covered with buildings, attention is required that at extension stages the sewer can also be drained by gravity flow.

7.130 **Direct drainage in public waters** - where premises are situated near public waters the tendency should be for their direct connection to these waters, provided the authorities give their require approval.

7.140 **Seepage water** - Seepage water shall, if possible, be led to the outfall ditch or in any possible way to the ground water.

7.150 **Slope or ground water** - Slope or ground water may only be connected into the canalization where permission of the concerned authorities has been granted.

7.160 **Seepage of stormwater** - where soil conditions are acceptable, a seepage of rainwater can be led directly to the underground, provided permission has been given.

7.200 **PRINCIPLES FOR THE LAYING OF PIPES**

7.210 **Change of direction** - Pipe connections may not be utilized for change of direction.

7.220 **Reducer fittings** - Centric reducers are permissible for connector pipes and branch pipelines, as well as for vertical pipelines (e.g. stacks).

For collector and ground pipelines, as well as in loops, the various diameters may preferably be connected by means of excentric reducers and at parting alignment.

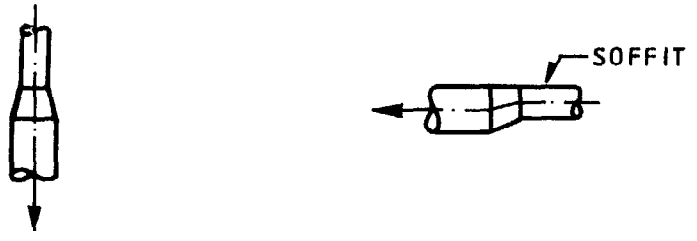

VERTICAL (CENTRIC REDUCER) HORIZONTAL (EXCENTRIC REDUCER)

7.230 **Manhole / Inspection Chamber** - At each exit of pipes from the house to the pipeline fixed in the ground, there should be a inspection opening, preferably a manhole or a clean out (i.e. branch with tight cover).

On collecting pipes accessible clean outs are required at:
- exit of buildings
- at straight lines after each 40 meters length
- change of direction

CO = CLEAN OUT

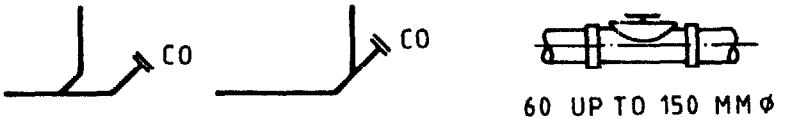

60 UP TO 150 MM Φ

7.300 **BUILDING SEWER** - as of special governmental rules.

7.400 **HORIZONTAL PIPELINES** (Ground pipelines).

7.410 **Principles** - All drains and private sewers have to be of sufficient strength and must be bedded and supported so as not to be damaged by the maximum loads to which they may be subjected. They must be constructed of materials of adequate durability in relation to matter being carried by the drain in relation to the ground and subsoil water outside. Joints must be formed in materials appropriate to the drain itself and in such a way that they remain watertight in all working conditions, including any differential movement that may occur between the pipe and the ground or the structure under which it passes. Joints must not form any obstruction in the interior of the drain.

7.420 **Design of pipelines** - Drains must be laid in a straight line between points where changes of direction occur. Horizontal pipelines shall be fitted in parallel to the walls of the buildings. The drains have to be of such size and gradient (slope) as to ensure that they are self cleaning and can carry the maximum volume of matter which can be discharged.

7.430 **Sizes** - The size and method of construction for pipes which carry soil and waste water, including their ventilation system, must be appropriate to their function. In the direction of flow, pipes are to be of the same or larger diameters, and must not be reduced.

7.431 **Minimal diameter** - For ground pipelines the internal diameter at any point must not be less than the outlet diameter of any appliance, pipe or drain discharging its contents through it, and in any case should never be less than 100 mm i.d.

7.440 **Water seals** - Provision has to be made in the system to ensure that in normal working conditions the water seal in any siphon (trap) in the system is maintained.

7.450 **Ventilation** - Each house connected to a drainage system requires at least one main ventilation of not less than 100 mm Ø (whether connected to a septic tank or to the canalization mains).

7.460 **Means of access** - All drains and private sewers shall have such means of access as may be necessary for inspection and cleaning, as indicated below. Inspection chambers etc., may be of brickwork, concrete or other suitable materials so as to properly sustain any loads imposed, to exclude subsoil water, and to remain water tight.

MEANS OF ACCESS

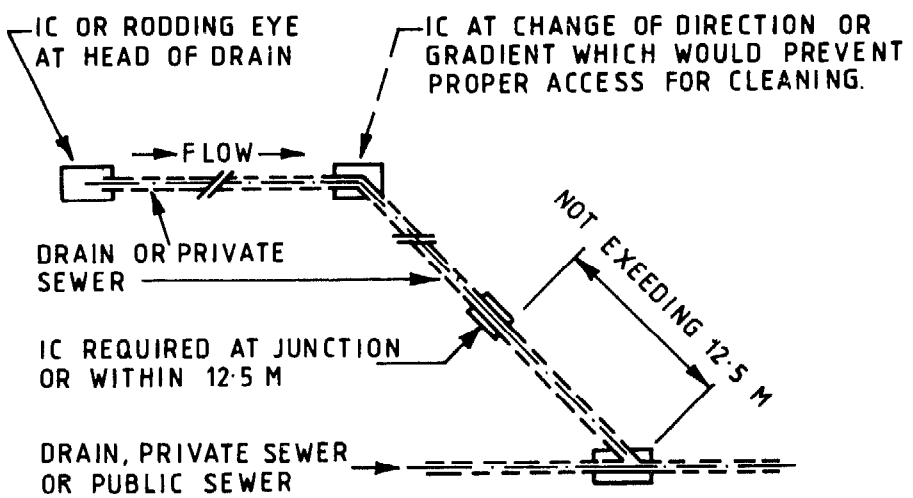

MAXIMUM SPACING OF INSPECTION CHAMBERS ON STRAIGHT RUNS

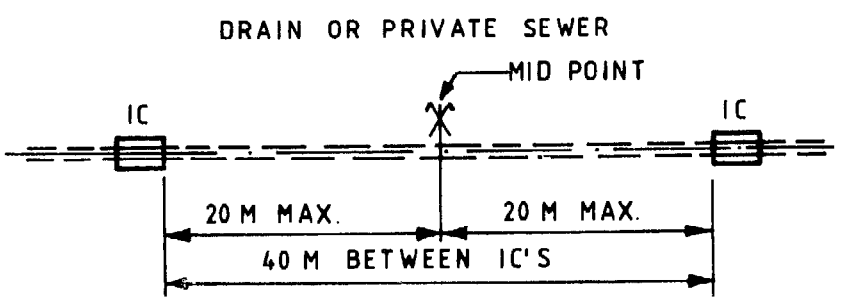

(FOR DIAMETERS UP TO 300 MMØ)

7.470 **Manholes/outside buildings** - at every change of alignment, gradient or diameter of drain, there shall be a manhole or inspection chamber. Bends and junctions in the drains shall be grouped together in manholes as far as possible. The maximum spacing of manholes in any ground pipelines, for diameters up to 300 mm, may not exceed 40 m.

7.471 **Sizes of manholes** - Chambers shall be of such size as will allow necessary examination or clearance of drains. Size of manholes shall be adjusted to take into account any increase in the number of entries to the manhole. The minimal internal sizes of chambers (between brick faces) shall be as follows:

a) for depth of 1 m or less 0.8 × 0.8 m
b) for depths between 1 m and 1.5 m 1.2 × 0.9 m

In adopting the above sizes of chambers, it should be ensured that these sizes accord with full or half bricks and with standard thickness of mortar joints so as to avoid wasteful cutting of bricks.

7.473 **Manholes/Inside buildings** - Inspection chambers on drains (= manhole on sewers) inside buildings are to comply with the following construction requirements:

a) to be fitted with cover having an airtight seal, fixed down with bolts of non-corrodible material. The chamber is to be watertight under the maximum pressure which could be created by a blockage at a point below the chamber, or

b) contain a drain equipped with fittings having water-tight inspection covers.

7.474 **Sample of a manhole,** inside building:

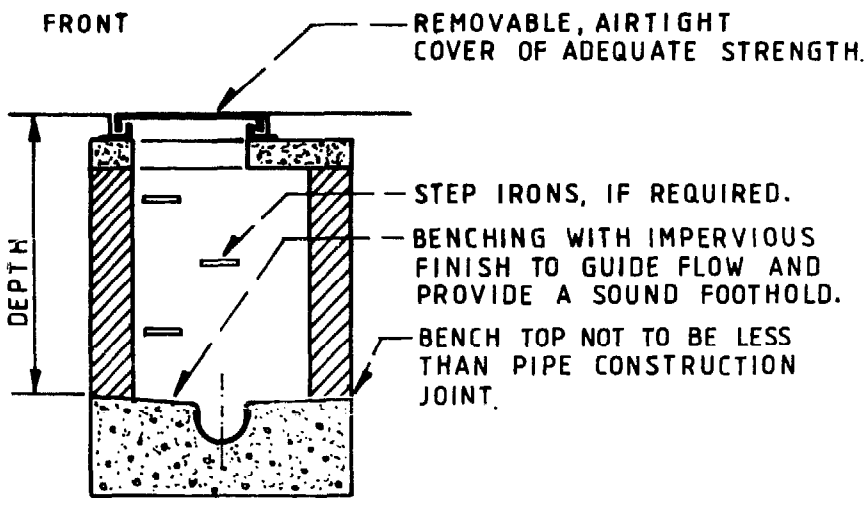

NOTE THAT CHAMBER SHOULD BE OF ADEQUATE SIZE TO PERMIT READY ACCESS TO DRAINS FOR CLEANING AND RODDING.

COVERSIZE	DEPTH
60 x 60 CM	60 CM
80 x 80 CM	80 CM
80 x 80 CM OR 100 x 100	100 CM

7.475 **Separate Manholes** - For drainages with divided systems joint manholes for any kind of waste waters are not permissible, except where passages are fully enclosed and incorporate approved cleaning openings.

7.510 **Slopes of pipelines** - Horizontal pipelines shall be fitted with an even slope gradient. The optimal slope for soil and/or waste water pipes is 3%. The acceptable minimal slopes are shown in the following table.

Minimal slope	in %
Storm sewer	1
Soil / waste water drainage Ground pipelines and collecting pipes - up to i.d. 200 mm Ø - above i.d. 250 mm Ø Branch- and connecting pipelines	 2 1.5 2
Vent pipes	1

7.520 **Connections to collection and ground pipelines**

- Connections to the collecting pipes have to be made with a fitting of up to 60° (e.g. open installation on ceilings).
- Connections to the ground pipeline have to be made with a fitting of up to 45°.
- As a rule the connection in ground pipelines and collector pipes must be made in the upper half of the pipe (e.g. above horizontal axis).

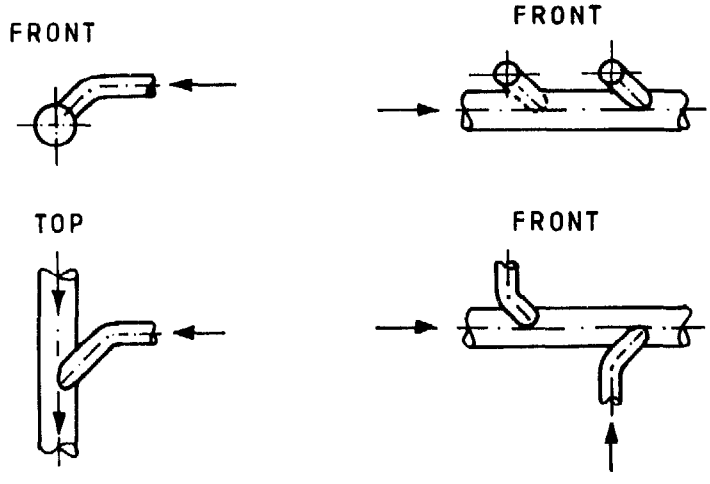

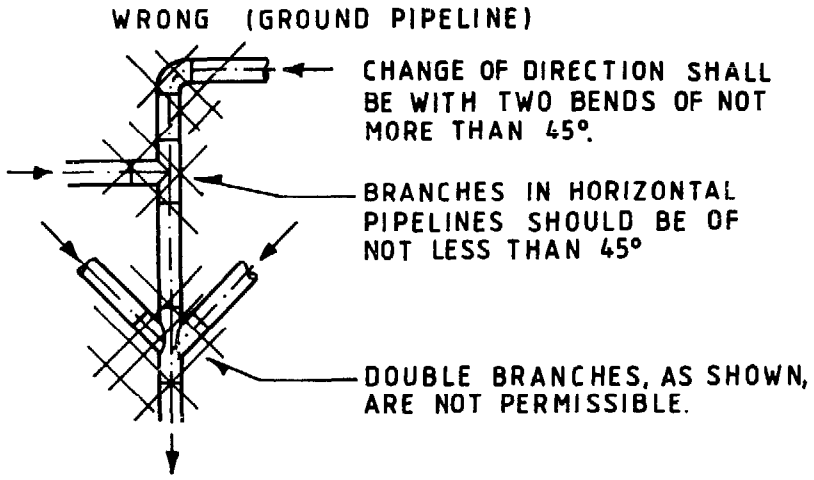

7.521 **Change of direction** - Ground pipelines and collecting pipes shall be fitted with bends up to 45°.

7.522 **Example of 90 degree change of direction**

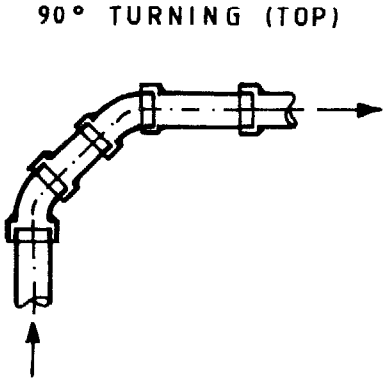

7.530 **Trenches for drains** - Where trenches for drains are constructed adjacent to the foundations of a building, precautions must be taken to ensure that the drainage trench in no way impairs the stability of the building. Therefore sufficient distance from the building foundation to the sewer pipes and trenches is required.

7.531 **Trenches for drains near a building**

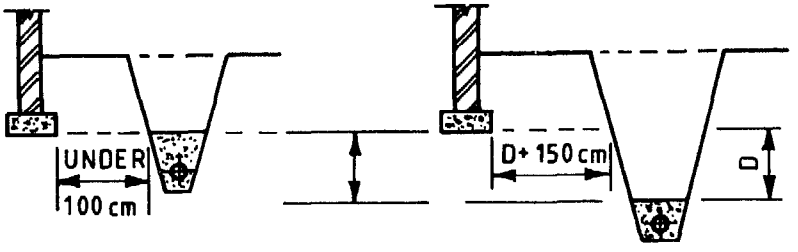

trenches filled with concrete to levels shown, expansion joints at spacing not excedding 9 m centres along trench.

7.540 **Drains passing through outer walls** - Where a drain passes through a wall (including the wall of an inspection chamber or septic tank) precautions must be taken to prevent damage or loss of watertightness by differential movement. This also applies if a drain passes under any other structure which may exert stress. Note: Where within the range of the ground-water table, a watertight passage is indispensible.

7.550 **Inlets to drain** - Inlets to ground pipelines and collector lines are to be made as indicated below.

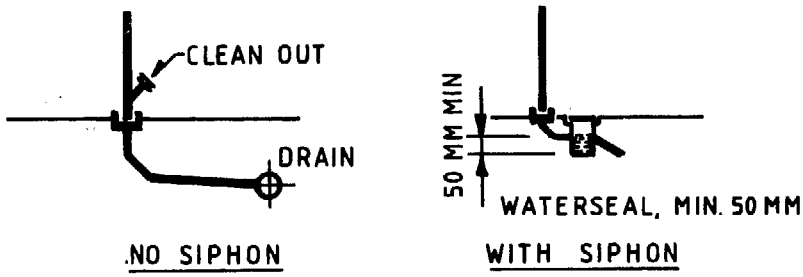

7.560 **Series of rainwater pipes** - Collected, with siphon and with connection to sewer, as indicated below.

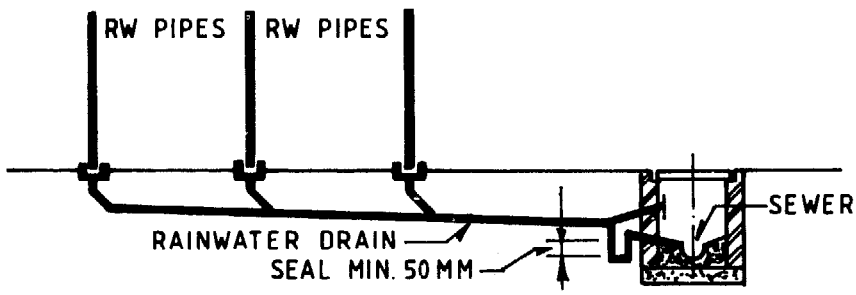

7.570 **Waste connection to gully** - In divided drainage systems, where waste waters are discharged separately from soil waters, there exists the possiblity of joined drainages by use of a gully.

Such waste water pipes in a building can be taken through an external wall of the building by the shortest practicable line, and shall discharge below the grating or surface box of the chamber but above the grating of a properly trapped gully.

The waste pipes shall be brought to the gulley without any reduction in diameter. A straight pipeline with few bends is preferable.

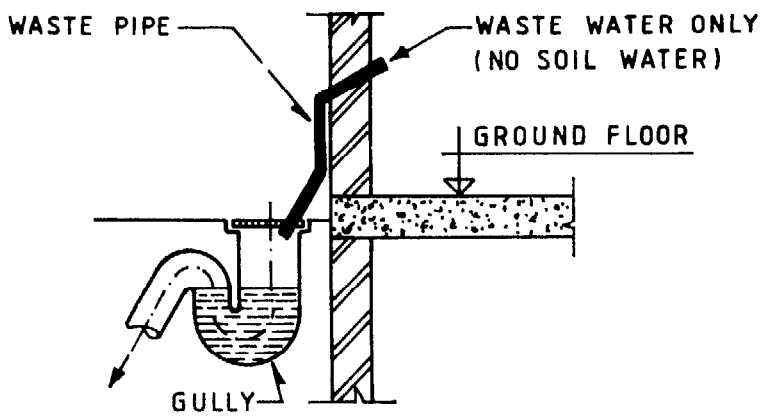

Note: The outlet of a gulley (floor drain with siphon) may be led into a soil and/or waste water sewer system.

7.580 **Connections of appliances into horizontal pipelines near to (vertical) stacks** - Where stacks are over 10 m in height, connections of appliances for drainage are to be inserted into collector or ground pipeline no closer than 1.5 m from the vertical stack.

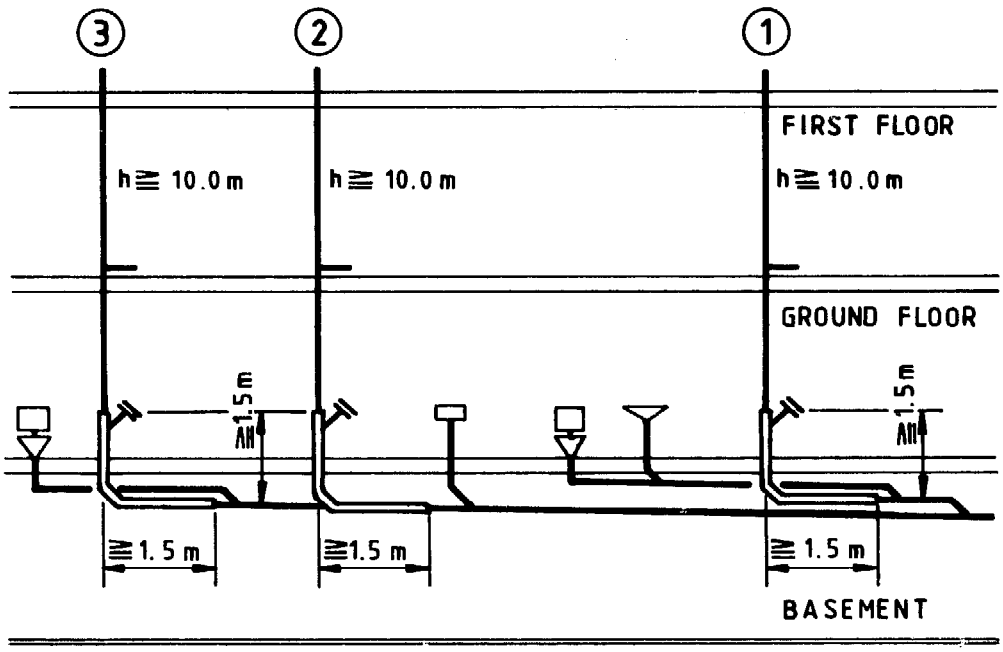

7.590 **Septic Tank design** - The principal factors to be considered in deciding on the capacity of a septic tank are the average daily flow of sewage, the rentention period and adequate sludge storage to suit the frequency of cleaning (desludging).

7.591 It is important that the tank capacity be sufficient to permit reasonably long periods of trouble-free service and prevent frequent progressive damage to the effluent absorbtion systems due to discharge of sludge by overloaded tanks.

7.592 Depending on local circumstances preferred methods of disposal of septic tank effluent are:

a) by dilution, if there is adequate flow in the receiving watercourse,
b) by a soakpit, if the ground is sufficiently porous and the water table is sufficient low,
c) by sub-surface irrigation where the ground is less porous,
d) by surface irrigation over a grass plot where ground conditions are unsuitable for sub-soil irrigation. An area of about 1 m2 per person is required, or
e) by evapo-transpiration up to 100 m2 per person may be required where the ground is of heavy clay.

In connection with (c) above, the WHO publication "Excreta Disposal for Rural Areas and Small Communities" sets out the percolation test procedure and, based on the results, the size and minimum spacing requirements for disposal trenches.

7.593 Note: In principle septic tank designs are to be provided by civil engineers/ architects, as they are not part of sanitary building installations.

7.594 **Example of a septic tank design**

Basic design for a septic tank and the basic dimensions for tanks to serve various sized populations

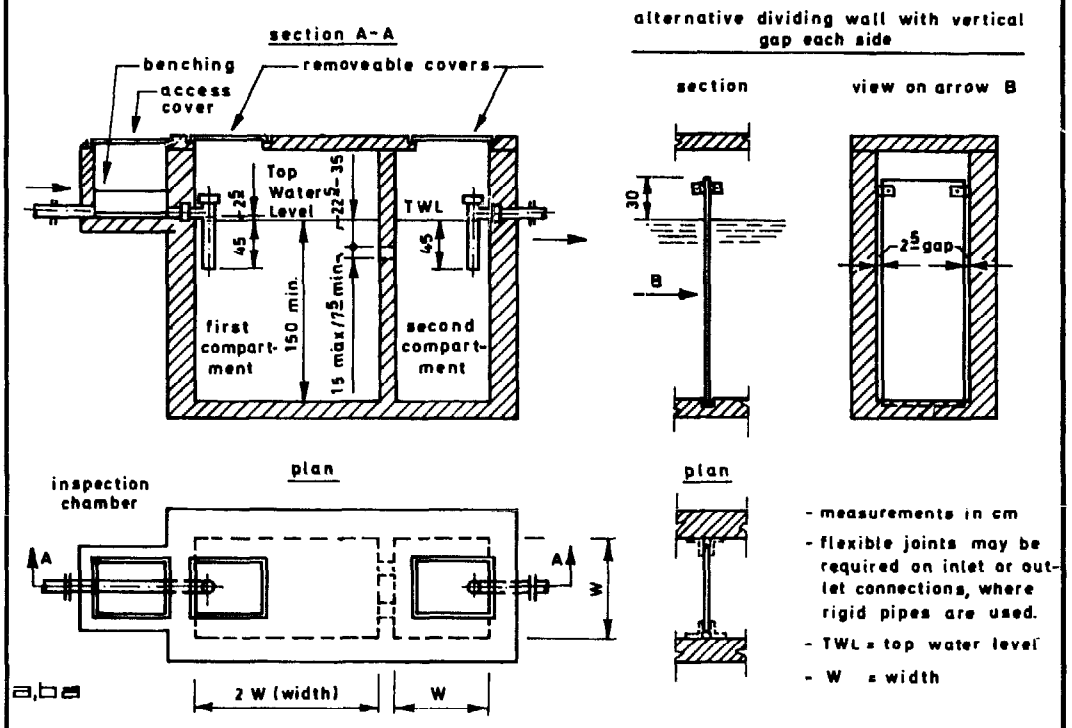

population served	capacity litres	depth below TWL	width
6	3 200	150 cm	70 cm
12	4 500	150	80
20	6 000	150	93
50	11 700	150	130

7.595 **Kitchen connections** - In certain cases it might be advisable to have a simple grease arrestor fitted near to the kitchen sink (e.g. covered gully). This helps to avoid blockages in the drainage pipe, leading from the house to the mains or to the septic tank.

7.600 **LEADERS (Stacks)**

7.610 **Principles** - drainage pipes, such as leaders, branch and connector pipelines, etc., shall be situated inside the building. If this is not possible then they can be situated outside the building, provided easy access is maintained after completion of construction works.

7.611 **Leaders** (Stacks) - shall have the approved diameter and be continued upwards without any reduction in diameter, without any bends or angle being formed (except where this is unavoidable), to such a height and position as to afford by means of the open end a safe outlet for foul air.

7.612 **Layout of pipes** - Pipe work and appliances should be so arranged as to allow close grouping of connections preferably with the water closet near to the leader.

7.613 **Siphon** - All appliances directly connected to leaders (stacks) are to be fitted with a siphon.

7.614 **Placing of pipes** - Pipes should be placed, fixed and jointed so as to avoid risk of damage through variations in temperature. Unless suitable precautions are taken, the jointing of pipes exposed to unduly high temperatures may become unsatisfactory. Small drainage pipes are particularly liable to damage caused by the freezing of water from a leaking tap in places where freezing normally occurs.

7.615 **Access** - Sufficient provision should be made for access to all pipework. The embedding of joints in walls should be avoided as far as possible. Pipes should remain readily accessible for the complete height of the building both during erection and after completion for maintenance works. Where fitted inside the house and in shafts access must be possible from each floor. Where fitted on to the outside wall, permanent platforms are to be provided for access.

LEADER (STACK) FITTED INSIDE HOUSE CONSTRUCTION.

LEADER (STACK) FITTED OUTSIDE THE WALL CONSTRUCTION.

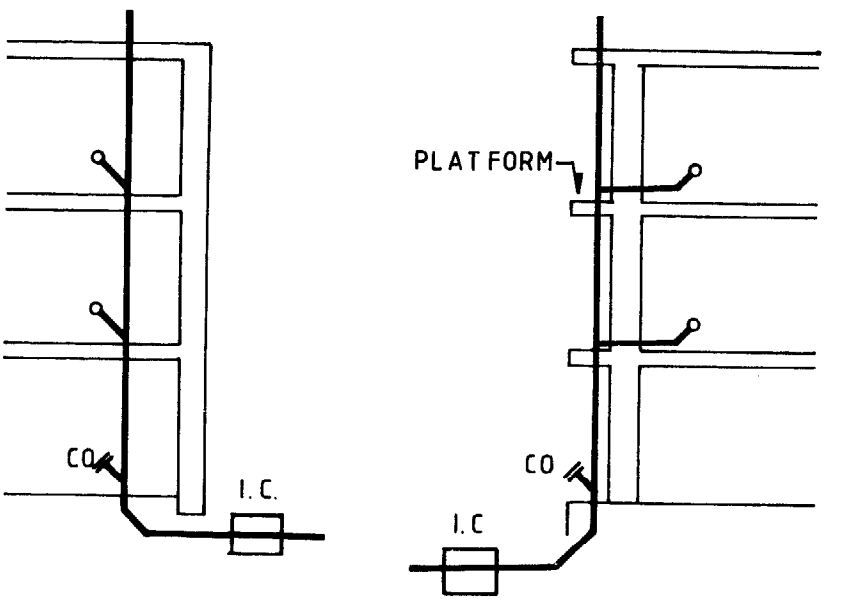

IC = INSPECTION CHAMBER

CO = CLEAN OUT

It is recommended that leaders and branch and connector pipelines remain accessible, where possible, and are not concealed in masonry (to be fitted in shafts, ducts, etc.).

7.616 **Clean out** - At the footing of each leader and at easily accessible sites, installation of lockable, airtight gastight "clean outs" is required. This is in order to secure cleaning of these pipelines. However, they may not be situated in living rooms, and if possible also not in workshops.

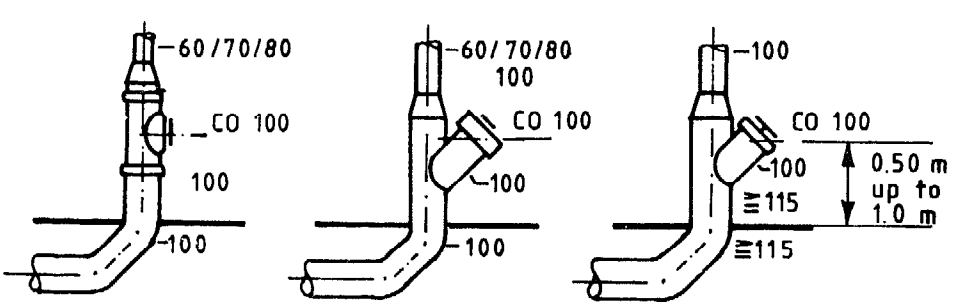

Note: clean-out's to be the same dimension as the horizontal ground pipeline (min. 100 mm i.d.): reduction only above the clean out.

7.617 **Change of direction** - The transition of the leaders into the horizontal pipeline or into a loop, and the transition of the horizontal pipeline into the leader is to be made with two bends of between 30° and 60° (max.) and with a straight piece of pipe between (M $\geq$ 2d).

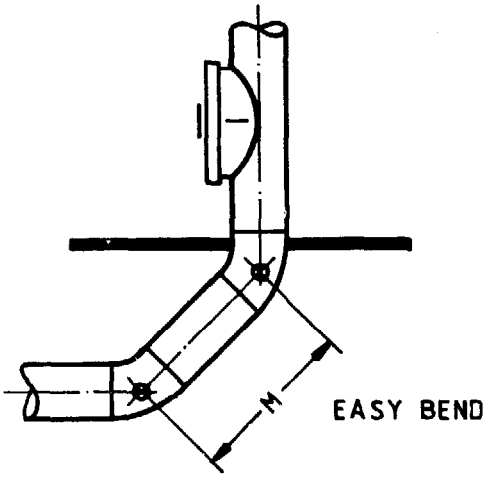

7.618 **Offset** - To shift the fall line of leaders up to 1 m distance offset bends with pointed edges from 15° up to 45° shall be utilized.

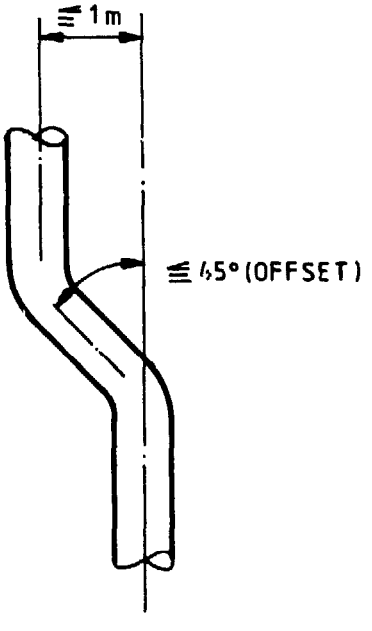

7.620 **Loops** - Where loops of leaders are unavoidable the influence on the drainage function shall be compensated by appropriate measures.

7.621 **Loop with bypass** - Where the leaders have a height of over 10 m the drainage appliances in the storey above the loop have to be connected to a bypass. Where there are no drainage appliances in the storey above the loop, a vent pipe shall be made.

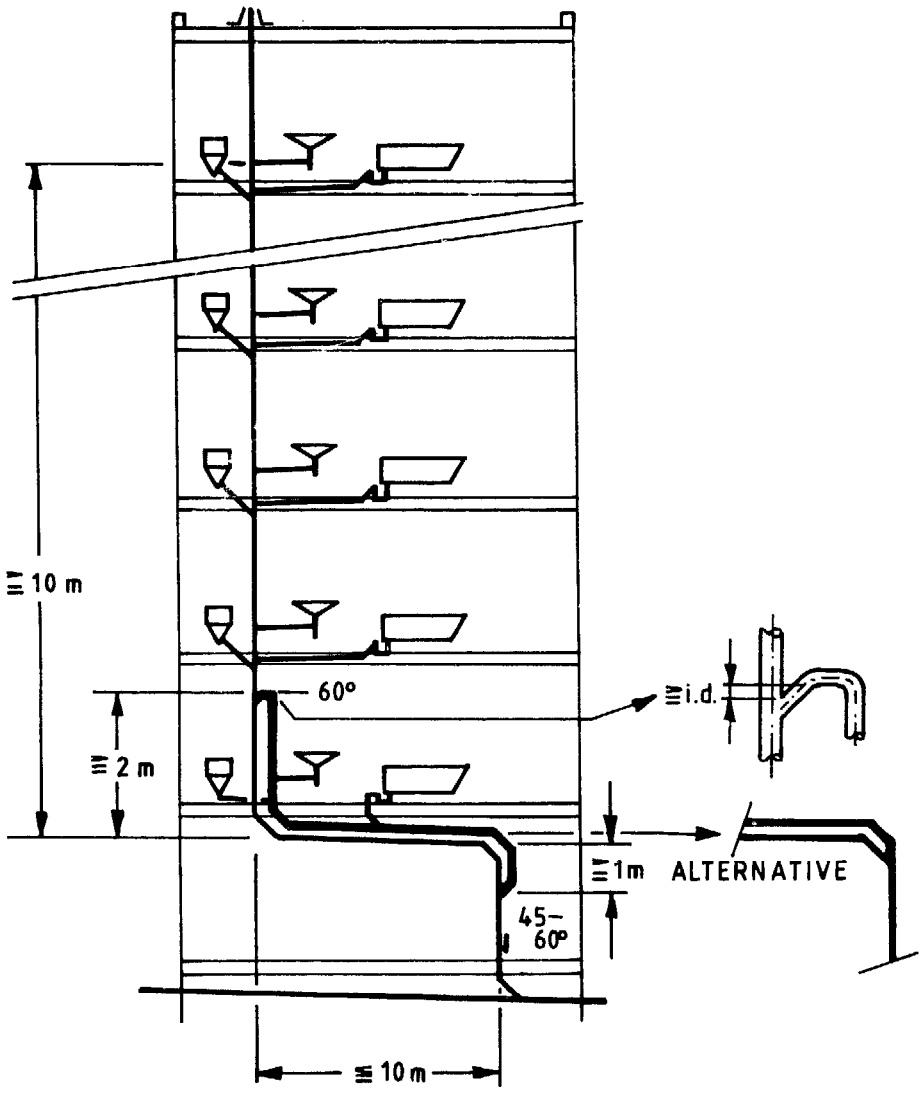

7.622 **Connections of bypass loop to stack** - The connections to the stack must be made at least 2 m above and 1 m below the stack loop. Connections must be made using fittings having angles of between 45° (min.). and 60° (max.), as shown above.

7.623 **Dimensioning of loop pipes** - The diameter has at least to correspond to the connected S-values. The loop can be made one dimension smaller than the corresponding leader.

7.624 **Loop without bypass** - No stalk bypass is required where the height of the leader between the top-most inlet and loop is less than 10 m. In such a case there may be no insertion of a connector or branch line into the leader within 1 m either side of the loop bend.

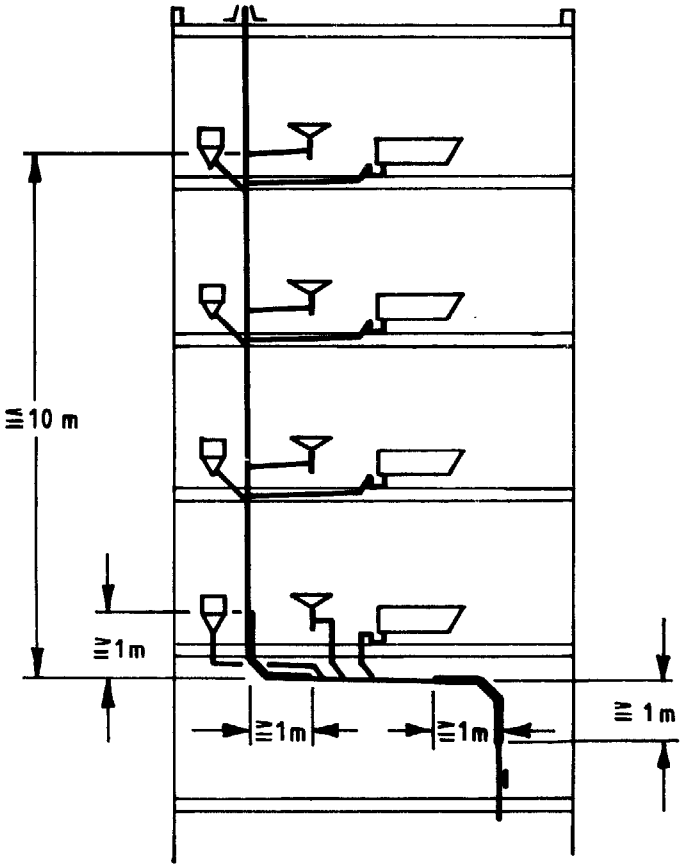

7.630 **Connection of appliances into horizontal pipelines near to vertical stacks** - Where leaders are less than 10 m in height (Height between the top-most inlet and the collection pipe or ground pipeline) no apparatus may be connected within 1 m either side of the easy bend (as shown above)

7.640 **Pipe fixings** - All drainage pipes need to be securly fasted to the building structure in order to remain in their proper place and not to change shape or direction (e.g. plastic pipes). A proper, open installation has pipes fixed approx. 5 cm clear of the finsihed surface of the wall by means of suitable clamps.

7.641 **Brackets/Clamps** - Pipe clamps are to be appropriately designed so as to withstand applied loads. They are to be coated to resist corrosion.

Note that branches from leaders are not to be regarded as fixings, since such "clamping" could harm the branch fittings (especially on plastic pipes) and therefore clamps are still required. There are principally two types of brackets:

a) Guide bracket and hangers: they serve as pipe guides and enable contraction and expansion in the desired directions.
b) Anchor bracket: A strong bracket fitted firmly to the building structure and the pipe. It serves to hold the pipes and to resist possible movement of pipes (i.e. fixpoint). All sockets normally should be secured with such a strong bracket.

7.642 **Number of brackets** - Leaders shall be secured with a minimum of two brackets in each floor. One anchor bracket just below the socket, and one guide bracket at the middle point.

7.700 **BRANCH AND CONNECTOR PIPELINES**

7.710 **Principles** - The pipework in branch and connector pipes should always be arranged to allow free drainage of the system. Connections to main or branch pipes should be so arranged as to prevent cross flow from one appliance to another.

Self-siphonage of traps through drainage in the branch and/or connector pipeline shall be avoided by means of the following installation technologies.

7.720 **Horizontal Connection** - The appliances should be grouped as closely as possible round the main stack so as to keep the branch and/or connector pipes short and reduce noise.

7.721 **Gradual slope** - Pipes should have a gradual and continuous slope in the direction of flow.

7.722 **Minimal distance** - In order to prevent siphonage, the distance of the leader's fall line and the angle of the next 88.5° bend may not be less than 0.25 m.

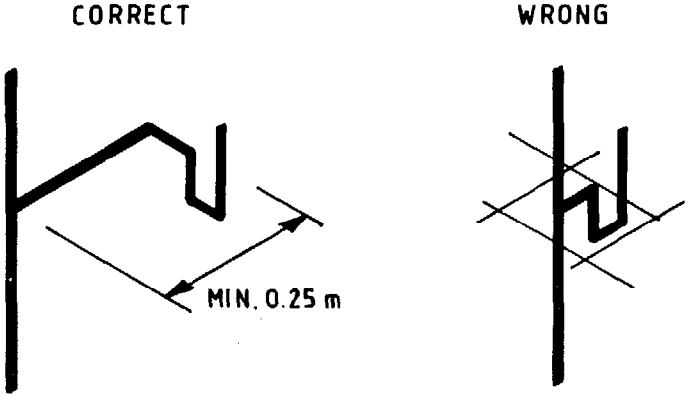

Note: A direct horizontal connection between the siphon exit and leader is prohibited.

7.723 **Minimal slope of connector- and branch pipelines** - The minimal slope has to be equal to the measurement of the internal diameter of the connector or branch pipeline, as shown below.

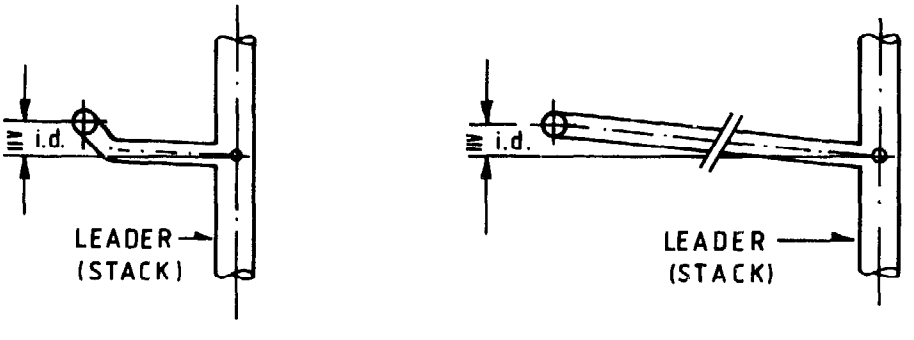

7.730 **Branches from the leader** - The branch of a horizontal connector pipeline from the leader has to be made at an angle of between 87° and 88.5°. In the case of a connector pipeline with secondary ventilation the connection to a leader can be between 45° and 88.5°.

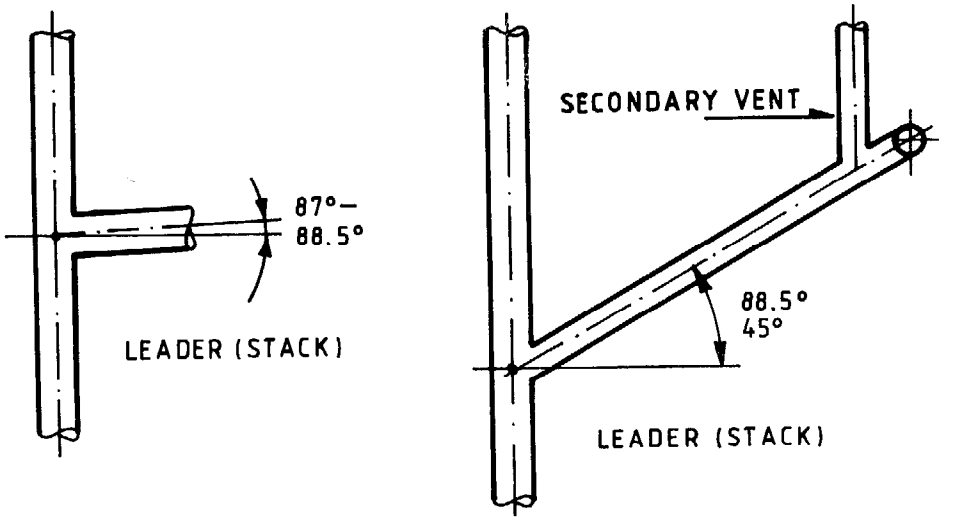

7.731 **Connector tilt-line** - Single devices for drainage can be connected to a leader with a straight tilt-line of between 45° and 60° (max.).

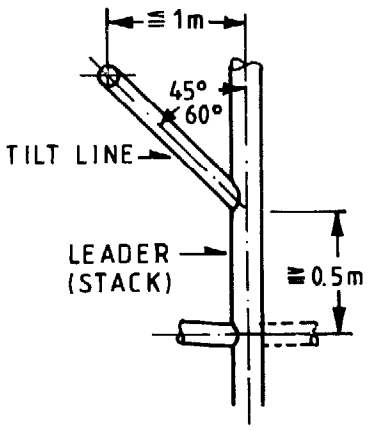

7.732 **Adapters and connections** - The adapter to a connector on to a branch pipeline or collector pipe, has to be made with a fitting of up to 60°.

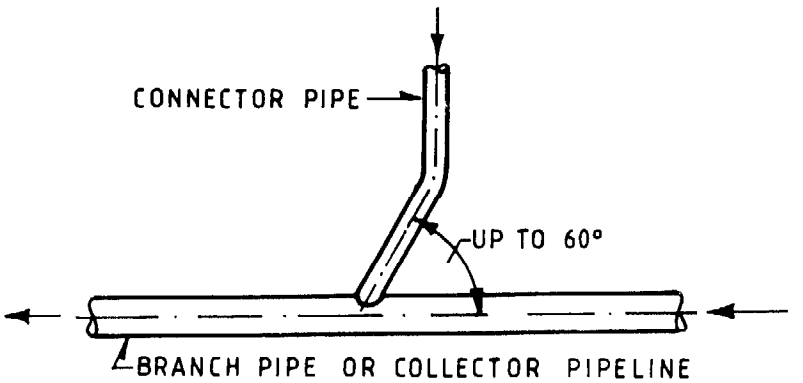

7.740 **Cross flow** - The insertion of a connector pipeline into a leader has to be made so that no disturbing cross-flow may occur into another connector pipeline. The following shows some examples of this.

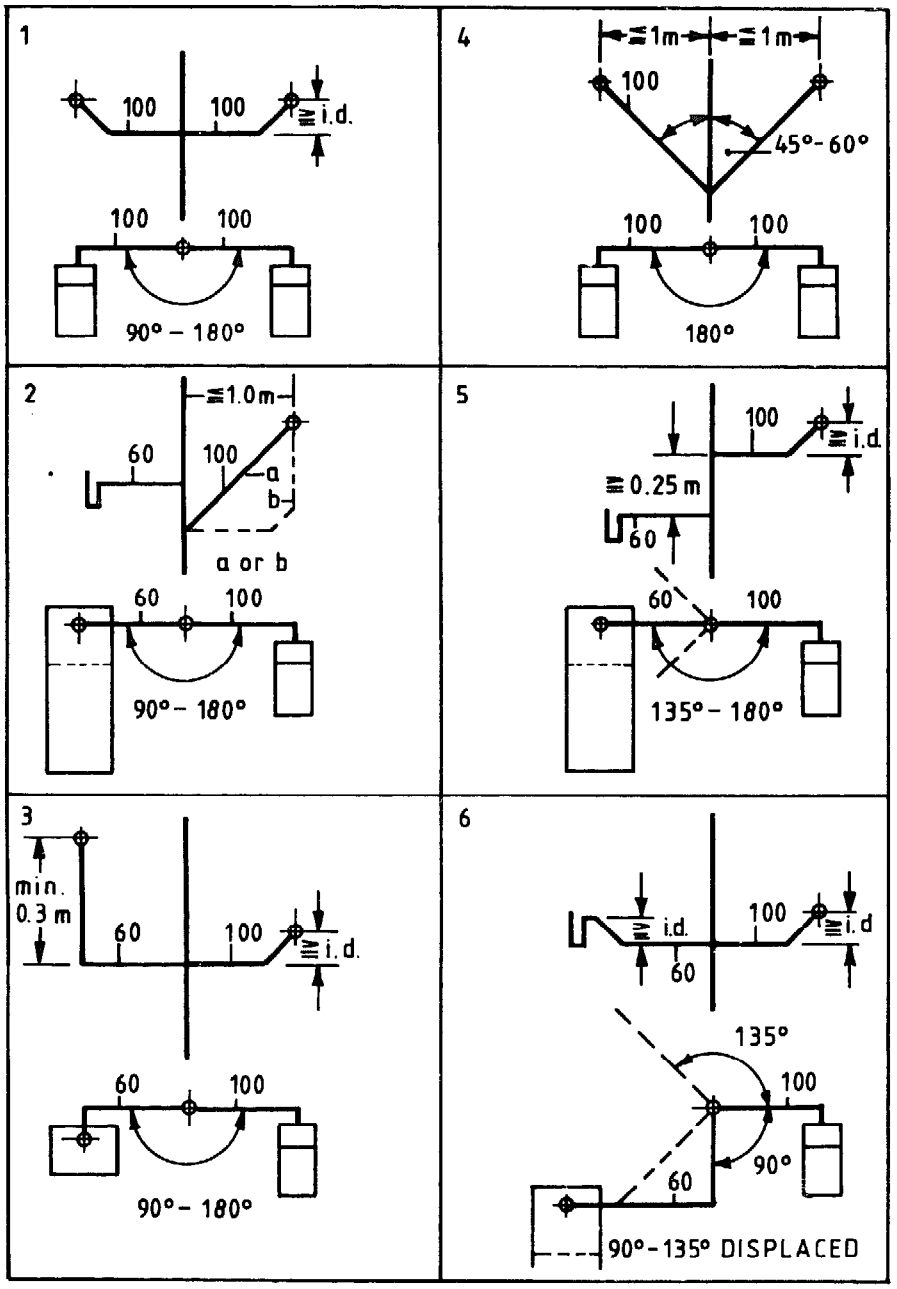

7.741 **Opposite drainage appliances** - Connector pipelines of opposite, equally loaded drainage appliances may be joined by the use of permitted special fittings, provided they are located in the same appartment or where it is possible to have a round-the-clock access to the drainage appliances (e.g. in hotels, schools, etc.). Opposite WC-arrangements are to be connected vertically.

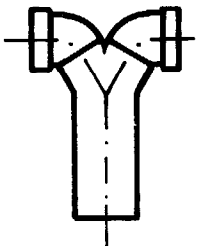

7.742 **Dimensioning** - Branch and connector pipelines of max. 4 m effective length, having max. 1 fall line or tilt line in a branch pipeline of max. 1.5 m in height are to be dimensioned according the table: "**Branch and connector pipelines without vent.**" (Fig. 13.420)

7.743 **Increased loadings with secondary vent** - Where the above conditions may not be realized, a branch- or connector pipeline can be ventilated at it's end. Such pipes with secondary vent. pipes may have increased loadings, as of table: "**Branch and connector pipelines with ventilation.**" (Fig. 13.430)

7.760 **Principle of installation for connector and branch pipelines** - Variant 1: The connector pipeline with an effective length of up to 4 meters, may have only **one** tilt-line or fall line up to max 1.5 m measured after the elbow of the apparatus connector. The dimensioning follows the table: "**SV-values**" (13.300)

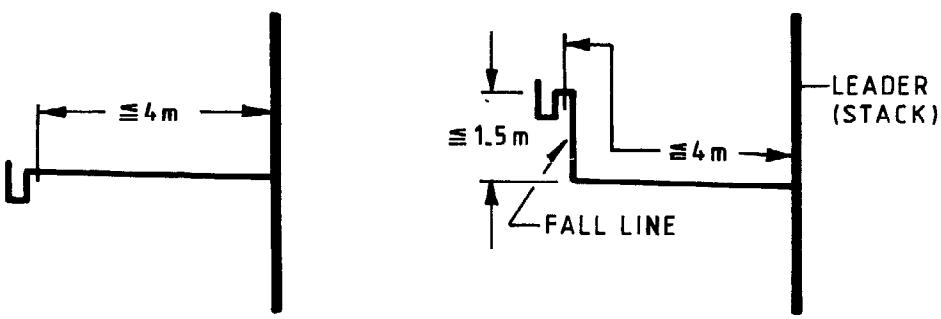

Variant 2: The connector or branch pipeline of the SV-groups o.5 and 1.0, with an effective length of between 4 and 8 meters, may have only one fall line or one tilt-line of up to 1.5 m if adjacent to the elbow of the apparatus connector, provided the diameter of the pipeline is made larger by one dimension as in table: "**SV-values**", Fig. 13.300 (i.e. to increase indicated SV-values by one dimension).

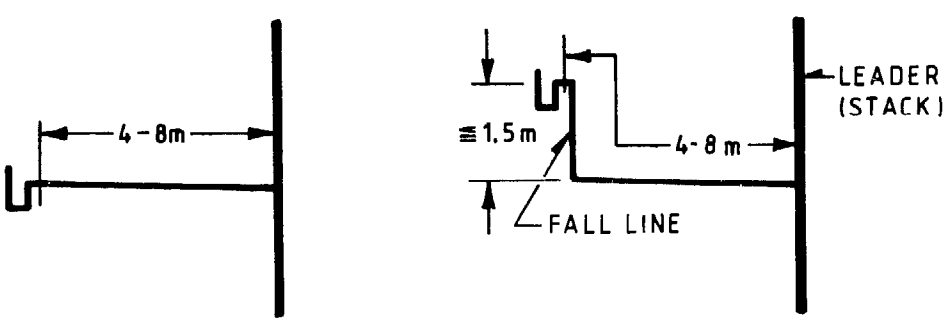

Variant 3: The connector or branch pipeline, with an effective length of up to 4 meters and with one or several tilt-lines or fall lines within 4 meters, has to be made one dimension larger as indicated in table: **SV-value** (= increase indicated diameter of table by one dimension), except for WC

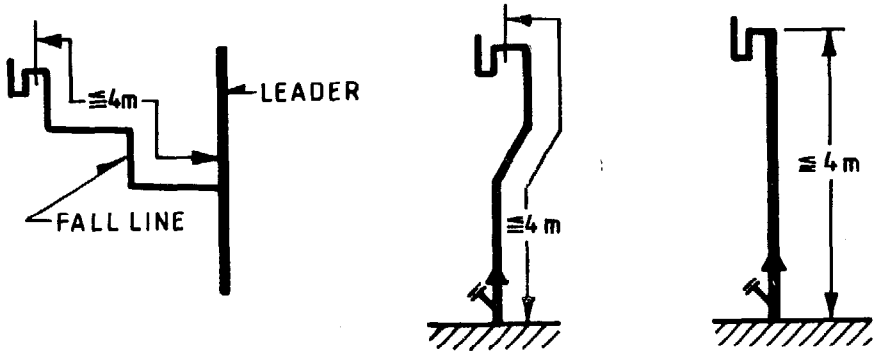

Variant 4: All other connector or branch pipelines are to be made with a connector or branch vent, as mentioned in table: **SV-values.**

7.770 **Branch pipeline with ventilation** - Stacks normally require a ventilation pipe to be of the same dimension as the stack. Provided there is at least one ventilation pipe of 100 mm Ø within the house installation, the following exception for reduced ventilation is applicable.

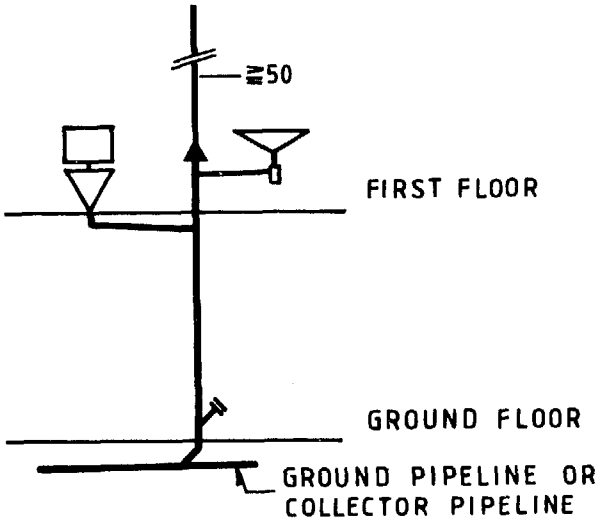

Both of the drainage appliances closet and service sink or wash basin fitted in the first floor may be connected as a joint pipeline to a ventilated collector pipeline or ground pipeline. The dimension of the corresponding vent pipe above roof level may be reduced to i.d. 50 mm.

8. SANITARY APPARATUS (Fixture, Appliance)

8.100 PRINCIPLE

All apparatus must be fixed securly to the building structure. They have to withstand the loads of the apoliance itself as well as additional load (e.g. wall water closets and person; washbasin with children on it, etc.) Ceramic items are to be fitted on finished walls or finished floors, with screws, in order to enable easy removal and replacement when required.

8.110 **Apparatus connections**- All connected apparatus shall always be easy removeable and accessible for maintenance. This can be through the fixing with back-nuts (raccords), for water closets, resp. ceramic connections with a rubber-ring seal or ropes with putty (mastic). No cement shall be used, as the whole apparatus might be damaged if it has to be removed at later stage.

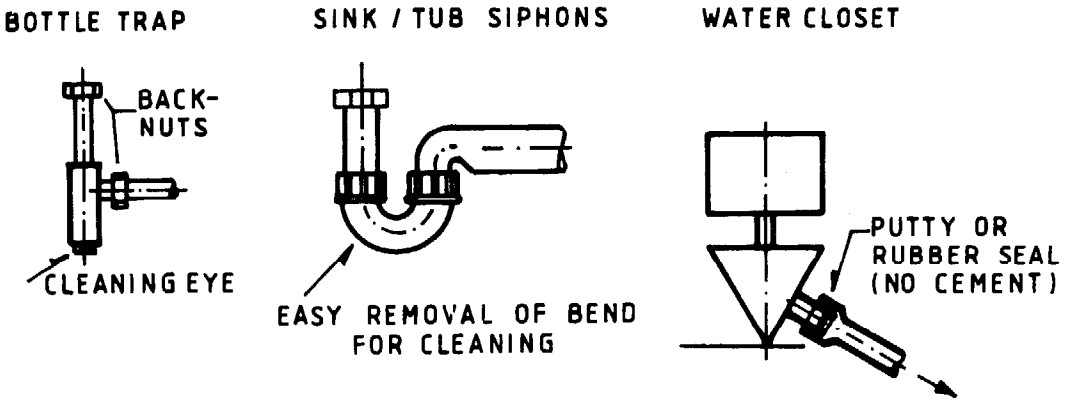

8.200 **WASTE COUPLING AND SIPHON**

The waste outlet and siphon of a sanitary apparatus can consist of the following parts:

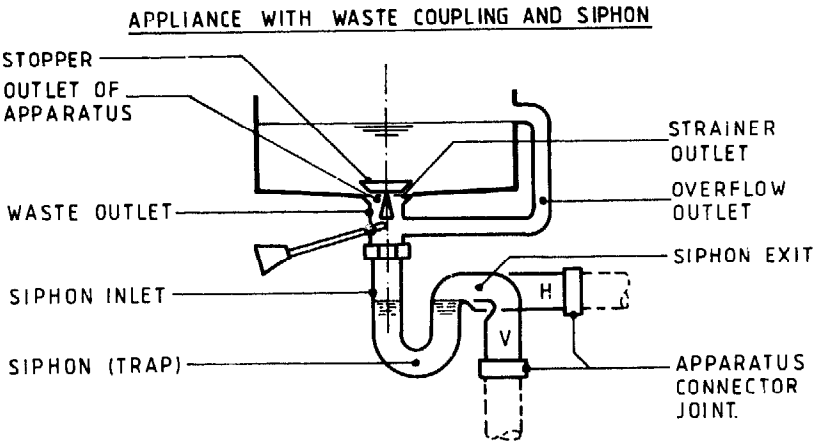

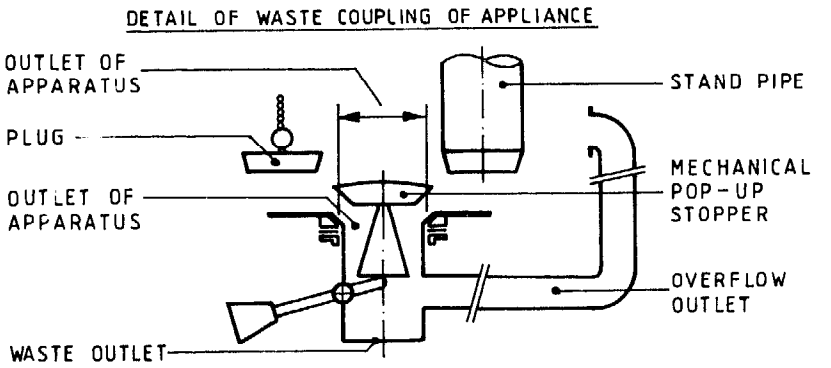

8.210 **Outlet of apparatus** - Removeable or fixed connection on outlet for the connection of the drainage appliance with the siphon or with the connector line respectively.

8.211 **Waste coupling** - Removable (flanged) or fixed projection at outlet for the connection of the drainage appliance with the siphon or the connector pipeline respectively.

8.212 **Stopper** - for the watertight closing of the waste outlet, such as:

a) Standpipe (for kitchen sinks)
b) plug (rubber, with chain)
c) mechanical pop-up stopper (washbasin)

8.220 **Overflow outlet** - Device which when outlet closed, prevents an overflowing of the drainage appliance up to the maximal permitted inlet volume.

8.230 **Siphon (Traps)** - A siphon is a device which prevents the exit of gases from soil and/or waste water pipelines, canals and of septic tanks.

8.231 **Siphon inlet** - Connector piece between outlet of drainage appliance and of siphon.

8.232 **Siphon exit** - Connector piece from siphon to connector pipeline.

8.233 **Apparatus Connector Joint**- Connector between siphon exit and connector pipeline with collar, ring seal socket, H-nipple, siphon, joint socket, etc.

8.234 **Cleaning of siphons** - Siphons should always be of a self-cleansing pattern. They are to be situated so as to be conveniently accessible and provided with cleaning eyes, or other easy means of cleaning, e.g. removal of entire siphon.

8.235 **Placement of siphons** - Close to each appliance there must always be a siphon of adequate diameter and appropriate seal. A siphon which is not an integral part of an appliance should be directly attached to its outlet, and the pipe bore should be uniform throughout and have a smooth surface.

Note: In any situation (including where the appliance itself has a siphon) more than one siphon in the pipeline is not permissible.

8.236 **Single siphons** - In certain conditions ranges of appliances need not have a separate siphon for each apparatus, for example:

a) Single trap for range of basins

RANGE OF LAVATORY BASINS OR BATHS

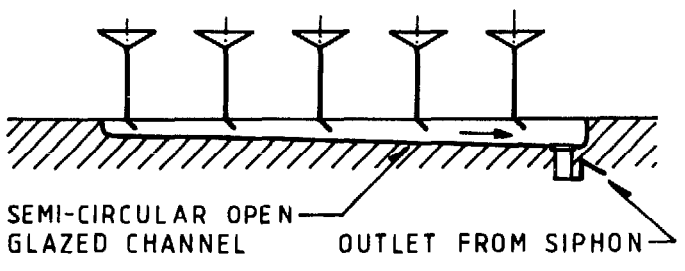

b) Range of lavatory basins or showers

RANGE OF LAVATORY BASINS OR SHOWERS

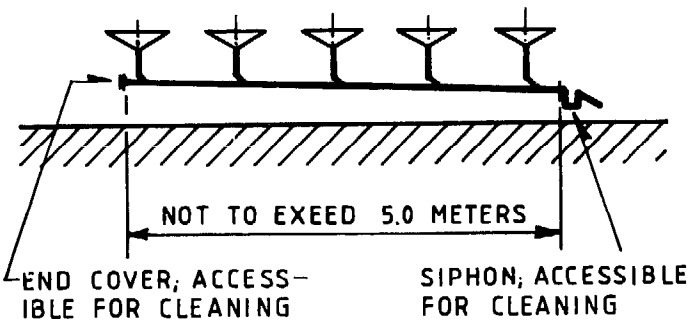

9. VENTILATION

9.100 PRINCIPLES

The main purposes of a drain-ventilating pipe are to prevent undue concentrations of foul air and to provide sufficient ventilation. Ventilation is required to avoid loss of water in a siphon seal caused by siphoning and to prevent admission of foul air to the building caused by back-pressure. Ventilation pipes have to be so installed that water cannot be retained in them. They should be fixed vertically, and whenever possible horizontal runs should be avoided.

9.200 CORROSION RESISTANCE

In principle the same requirements apply as for drainage pipes, however, more attention is required to corrosion resistance. Note: galv. sheet metal pipes are not permissible.

9.300 MINIMAL REQUIREMENT

A building requires at least one ventilation pipe, with a diameter of not less than 100 mm i.d.

9.310 **Leader/Stack vent** - The upper end of a leader or stack is to be continued (with a pipe having the same diameter as the drainage pipe), to the open air above roof level.

9.320 **Branch and connector pipes** - Normally sufficient ventilation is provided from the leader, However, where the installation is not within the range of the leader's ventilation, additional vent pipes (e.g. secondary vents) are to be installed to secure sufficient air flow.

9.400 TERMINATION OF VENT PIPES

The ventilation pipe has always to be taken above the level of the flat roof or of the eaves or terrace parapet, whichever is higher, or the top of any window.

9.410 **Flat roofs** - Vents of leaders are to be fitted separately to a leader and to be of the same diameter as the leader, to a height of 0.3 m above roof level. In regions with heavy snowfalls the vent should be correspondingly higher.

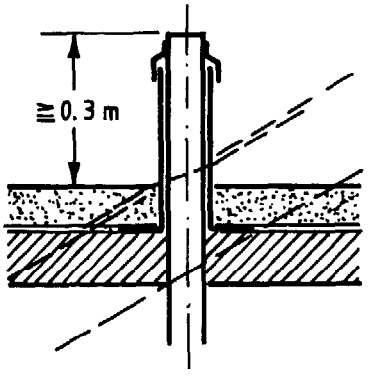

9.420 **End of vent pipes** - Caps on vent pipes (vapour pipe) and end pieces with cross-sectional narrowing of diameter should not be fitted, since they may endanger the proper functioning of the drainage system.

9.430 **Layout** - The vent pipes led to the outside and above the building have to be so arranged that there may be no occurance of odour annoyance. (Facades, windows, terraces, air conditioning plants, ventilations, etc.)

9.500 **DISTANCES**

Vent pipes having an exit nearer than 2 m to a window of inhabited rooms, have to be led to a minimum of 0.1 m above the lintel.

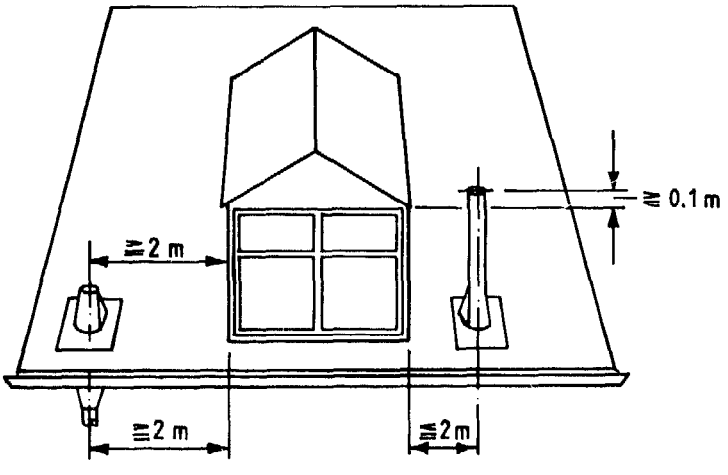

In districts with mixed drainage systems, storm drains having inlets without siphons, require to have a distance of 2 m from windows of inhabited rooms.

9.600 **VENT LOOPS**

Vent pipes require a minimum slope of 1%, for the drainage of the expected condensed water.

10 RAIN WATER

10.100 PRINCIPLES

The drainage of rainwater from roofs, terraces, etc., has to be according to the climatic conditions and must follow the rules of the building inspectorate. Spouts are to be applied only beyond walkways. Rain water drainage requires separate pipe-work for the entire building installation. Any possible joining with a drainage system are to be made **outside the building only!**

10.200 LEADERS

The rain water leader shall be situated outside the building, where possible, and shall be continued upwards without diminution of it's diameter to the roof outlet. Pipes are preferably to be in a vertical line, and except where it is unavoidable bends should be utilized. Changes of directions to be made with bends having larger radius, and approx. 15° up to 45° (no elbows!)

10.300 TERRACES

Where terraces are connected to the drainage system, this must be made with a separate leader and with a siphoned device and situated in a frost-protected place.

10.400 ACCESSIBLE ROOFS

On accessible roofs (as for example Penthouses) the rain waterleader requires a siphon or mud trap (with siphon). Exception: Divided systems, i.e. rainwater drainage led into an outfall ditch.

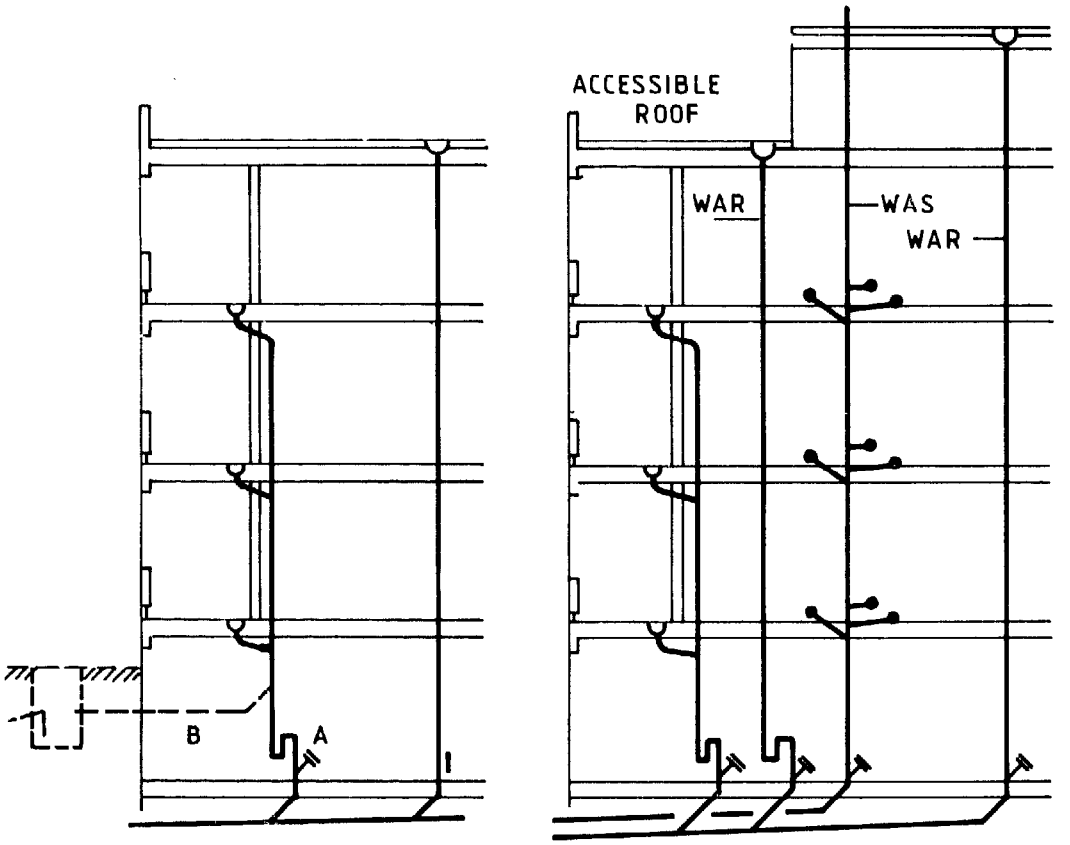

10.500 ROOF SURFACES AT DIFFERENT LEVELS

On buildings with roof surfaces at different levels it is suggested to design separate rain water leaders. Where this suggestion is not followed, the installation has to be made in such a way that no damage may occur due to back-flow.

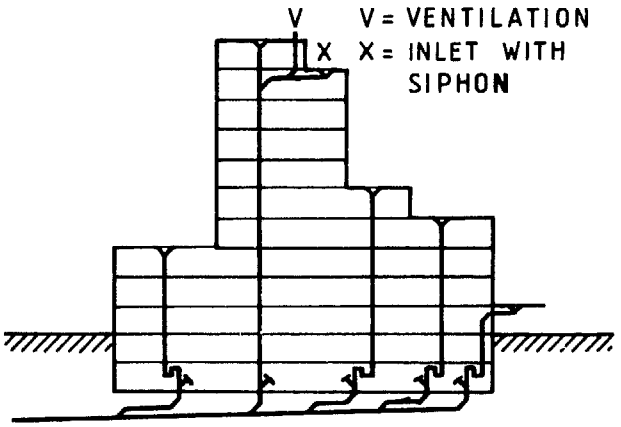

10.600 OUTSIDE RAIN WATER LEADERS (=DOWNPIPES)

Are to be made of mechanical resistant (impact-strengthened) material up to a height of min. 1m, measured from above terrain level, and to have a sliding piece (for easy removal of downpipe when required).

10.700 PROTECTION OF RAINWATER PIPES AT ROAD SIDES

Rain pipes adjoining public pavements or roads should be recessed up to a height of 3 m into the building facade.

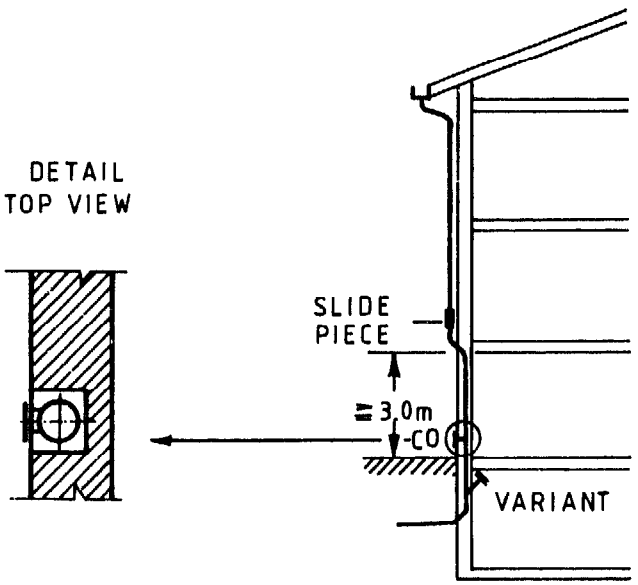

10.800 **RAINWATER OUTLETS**

The funnel and gutter outlets have to be conical, in order to ensure proper swallowing of rain water.

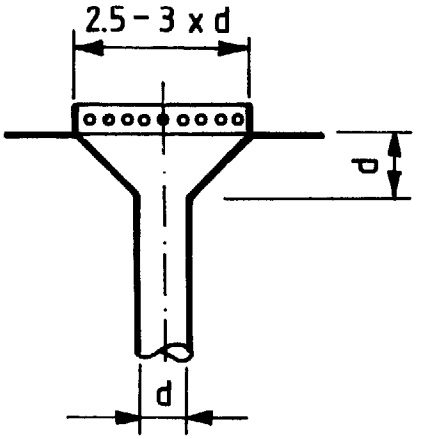

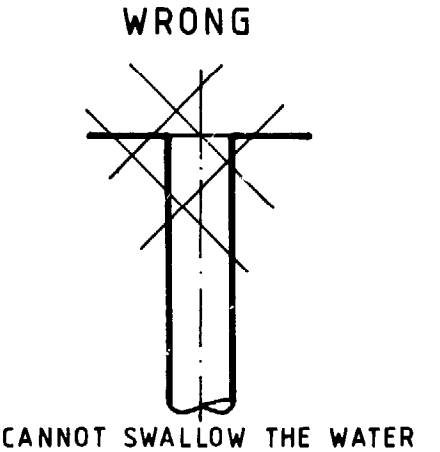

10.900 **SAFETY OVERFLOW**

Flat roofs are to be provided with a safety overflow!

11 MATERIALS

11.100 **PLASTIC PIPES, PRINCIPLES** - Plastic pipes require special attention:

- Contraction/expansion to be taken care of by including special sockets, and by clamps which provide longitudinal movement.
- Horizontal pipelines to be fitted with galv. M.S. half-shells, or additional number of clamps, in order to provide required strength.

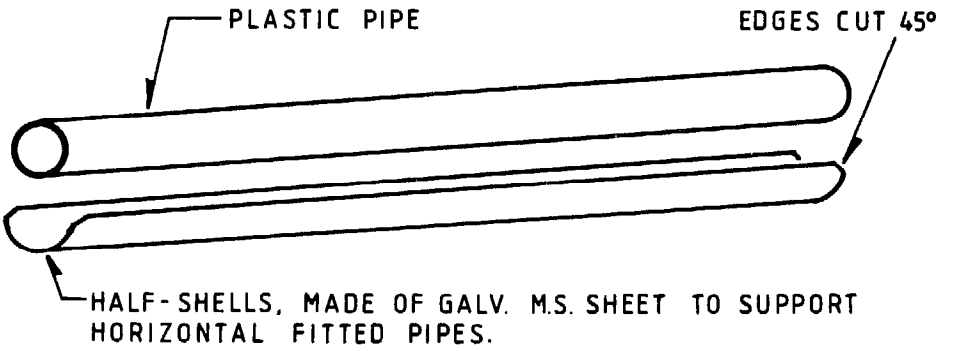

11.200 **FIXED JOINTS**

Fixed joints of plastic pipes are achieved by welding (e.g. butt welding with a hot plate for HDPe, or by solvent weld joint using solvent cement on to uPVC pipes).

11.130 **Ring seal sockets** - Are joints having a neoprene ring seal and allow easy fitting on site. They have a limited capability to absorb little changes in length. Protection of sensitive sealing parts from any ingress of dirt is to be maintained, especially at the building site (wrapping of joints with pieces of cloth and securing it with adhesive tape).

11.140 **Preparation of pipe ends** - The end to be inserted should be bevelled all around to an even angle of approx. 15°

Before joining: sockets and spigot ends are to be cleaned from any impurities.

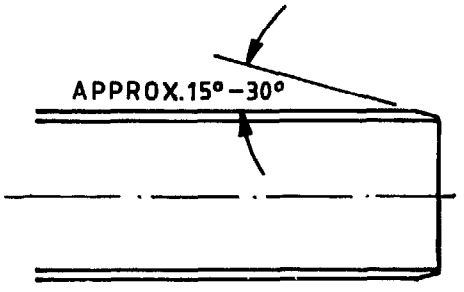

11.150 **Insertion depth** - It is required to mark the depth of insertion on the spigot end, prior to joining. When using flexible joints (e.g. ring seal sockets), in winter at lower temperature, insert to approx. 5 mm less than entire insertion length.

Summer = full depth

Winter = minus 5 mm of full depth

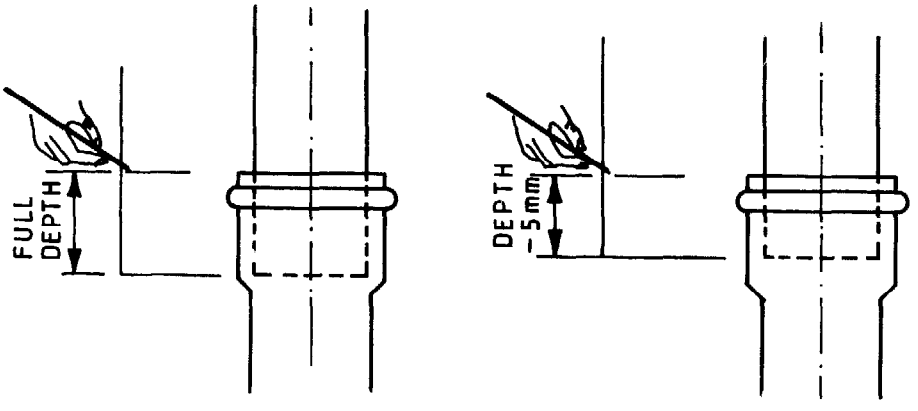

11.160 **Fixation of horizontal pipelines** - Exposed lay-outs' require attention to physical strength and changes in length. Satisfactory fixings can be achieved partly by using appropriate sealing sockets, and with a pipe lay-out allowing flexibility for limited movement. (Prevention of movement is possible when having a fixed lay-out by embedding the pipe in concrete or by having strongly fixed pipes).

It is recommended to have horizontal pipelines fitted with half-shells, as follows:

WITH SUPPORT SHELL

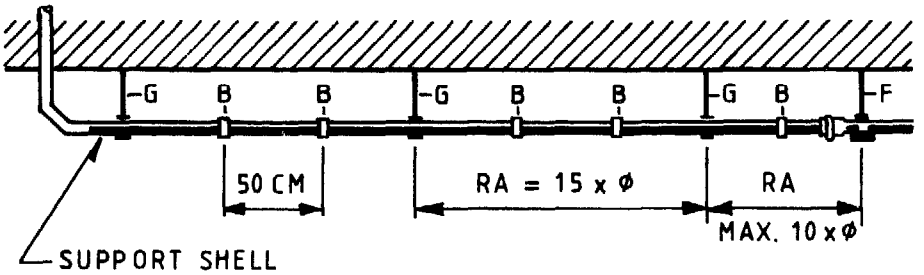

SUPPORT SHELL
B = PIPE BAND
F = ANCHOR HANGER
G = GUIDE HANGER
RA= SPACING OF HANGERS

Alternatively, instead of having half-shells, one could provide a greater number of appropriate clamps.

WITHOUT SUPPORT SHELL

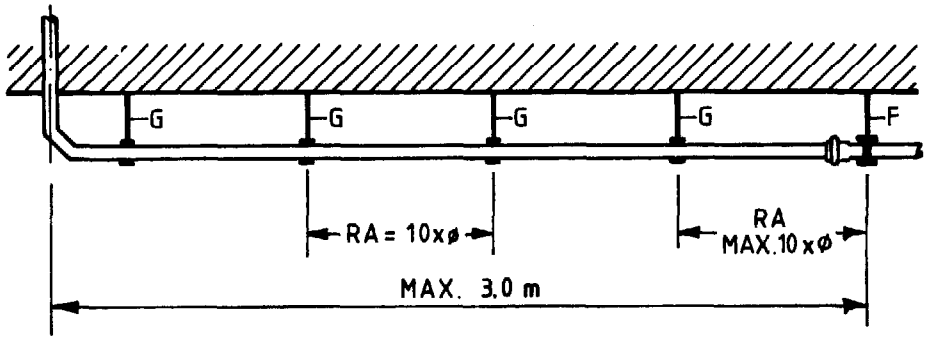

11.200 **CAST-IRON PIPES, PRINCIPLES**

C.I. pipes can be used for soil and/or waste waters and also for ventilation pipes.

11.210 **Quality** - C.I. pipes shall be sand cast iron or centrifugally cast (spun) iron pipes as per accepted standards.

11.220 **Application** - C.I. pipes can be used:

a) in unstable ground where limited soil movement is expected;
b) in made-up or tipped ground;
c) To provide for increased strength where a sewer is laid at insufficient depth, where it is exposed or where it has to be carried on piers or above ground;
d) under buildings and where pipes are suspended in basements and similar situations;
e) In reaches where the velocity is more than 2.4 m/s;
f) For crossing of watercourses.

11.230 **Corrosion of C.I. pipes** - It shall be noted that cast iron pipes even when given a protective paint are liable to severe external corrosion in certain soils. Among such soils are:

- soils affected by peaty waters, and
- soils in which the subsoil contains appreciable concentrations of sulphates.

11.300 **REINFORCED CEMENT PIPES**

Are commonly used for house drainage systems and they shall conform to accepted standards. They are not recommended for underground situations. If used underground the life of reinforced cement pipes may be increased by lining the inside of the pipes with suitable coatings like epoxy/polyester resins, etc.

11.400 **SALT GLAZED STONEWARE PIPES**

For all sewers and drains in all soils, except where supports are required as in made-up ground, glazed stoneware pipes may be used. They are suitable particularly where acid effluents or acid subsoil conditions are likely to be encountered. Salt glazed stoneware pipes shall conform to accepted standards.

12 PRINCIPLES OF CALCULATION

12.100 GENERAL PRINCIPLES

The dimensioning of a drainage system is based on the following factors:

12.110 **Sewer Value (SV)** - Sewer accumulation per time unit in l/s of the drainage appliance.

12.120 **Duration of drainage** - Duration of discharge in seconds (s) of the drainage appliance.

12.130 **Probable maximum load** - Maximum expected discharge of soil and/or waste water per time unit in simultaneous use of sanitary drainage appliances.

12.140 **Loading Capacity** - For those under section: "**Dimensioning**" fixed and permissible loadings are based on following preconditions:

- trouble-free drainage of the waste waters
- warranty of ventilation of the drainage systems and of the ventilation system respectively
- water seal (of siphon) may neither break through by vacuum, nor be pushed out of the siphon due to over-pressure

Note: Larger inner diameters than indicated are not to be used.

12.150 **Classification of groups for drainage appliances**- All places of discharges of soil and/or waste water (from drainage appliances) are classified in four SV-groups, ref. table: "**Nominal sewerage values.**" (13.300) The smallest SV is 0.5.

12.160 **Soil and/or waste discharges over 2.5 l/s** - Drainage appliances with an S-Value larger than 2.5 l/s, as well as continuous discharges (pumped soil and/or waste water plants) are to be treated as special arrangements and their effective drainage capacity to be added to the findings of maximum loading under diagram 1.

12.170 **Dish washing machine** - The S-value of domestic dish washing machines connected to a siphon of a single or double sink is not to be considered.

12.180 **Duration of the discharges of drainage devices** - When determining the possible maximum-loading and the dimensioning of drainage arrangements, the following are to be differentiated:

a) short term drainage as for closets, washbasins, etc., which are marked for residential buildings.

b) long term drainage, as for example in industries, trades and in laboratories.

12.200 PRINCIPLES OF DIMENSIONING

12.210 **Determination of the possible maximum loading** - for the determination of the possible maxium loading serves, above 60 SV, the approximation formula is used:

$$Vs\ max. = \sqrt{0.5 \times \Sigma SV}\ (L/s)$$

this takes into consideration the differentiation of connected drainage appliances of a domestic system.

Below 60 SV the maximum loading is not to be calculated, but determined according to the dimensioning tables.

12.220 **Filling ratio** : The ratio for filling for ground pipelines or collector pipelines will be assumed, as follows:

Sewer, rain and mixed waste water $\frac{h}{di} = 0.8$

12.230 **Simultaneous Discharges:-** When dimensioning leaders (stacks, collector and ground pipelines), the possibility of simultaneous discharge must be considered. Maximum loading is determined by adding connected discharges in l/s of connecting pipes, as of diagram 1.

12.300 **DIMENSIONING**

12.310 **Connector - and branch pipelines -** The dimensioning of the connector line results from table: "Nominal Sewerage values" (Fig. 13.300). The following tables serve for the dimensioning of branch and connector pipelines.

Up to 60 SV determination of the expected probable maximum load is not required.

12.320 **Diagram 1 -** This diagram serves to determine the expected maximal loadings of a soil and waste water system in a domestic building. The graph converts total S-Values into liters per seconds.

For the calculation of the probablemaximum loading with connecting values above 60 SV, the following equation is valid:

$$Vs \text{ max. } 0.5 \times \sqrt{\Sigma SV} \quad (l/s)$$

(Vs max. = Volume flow of all drainage appliances)

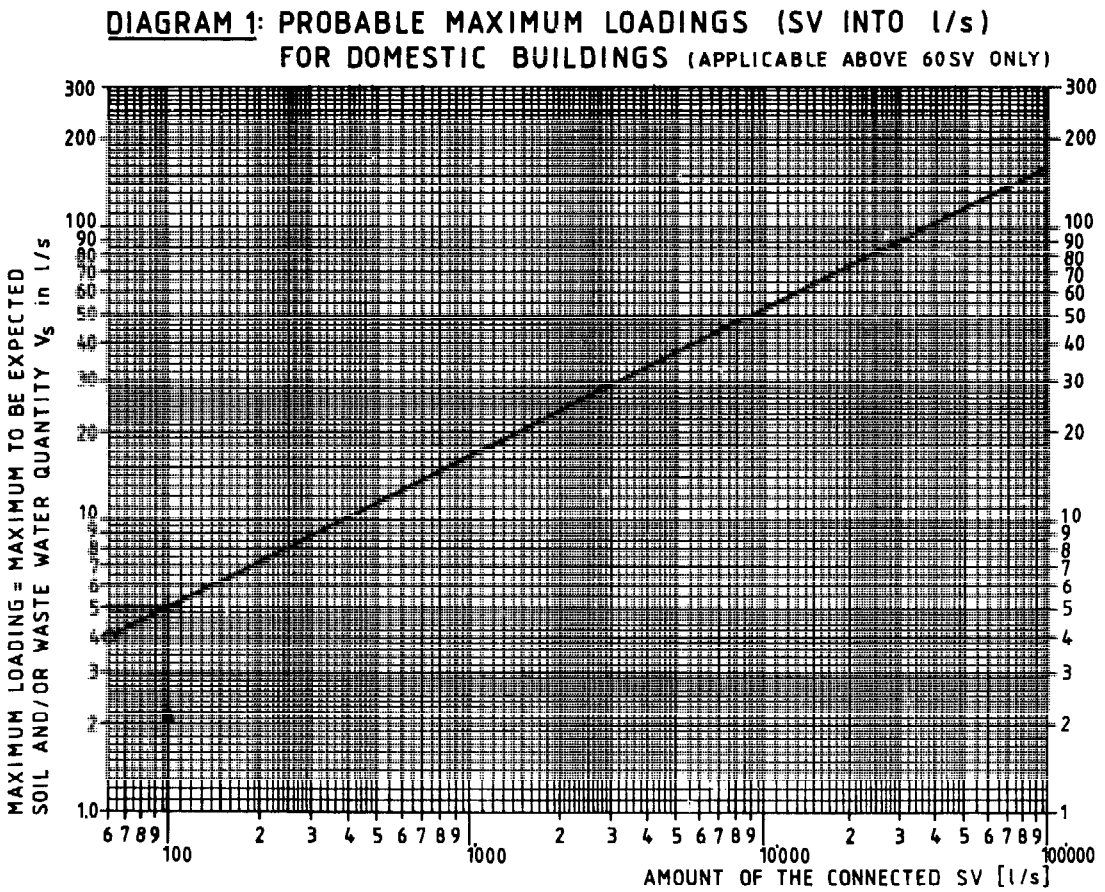

Reading example: known: 20 flats at 5 SV = 100 SV
wanted: Probable Maximum Load
solution: $Vs = 0.5 \times \sqrt{100\ (l/s)} = 5\ l/s$

12.330 **Leaders** - The permissible loading (Vs) of the leader is variable depending of the ventilation system and assessed in the tables: "**dimensioning of leaders**" (Fig. 13.500)

12.340 **Ground pipelines and collector pipes** - Relevant for the determination of the inner diameter (i.d.) for ground pipelines and collector pipes is the maximum expected loading, Vs max. in l/s.

- For soil and/or waste water pipelines the i.d. is determined based on the maximum expected loading (Vs max.), under consideration of the total simultaneous amount of the SV before this point, according to diagram 1.
- For rain water the effective loading of rain water, Vr, is decisive for the determination of the i.d.

- Roof surfaces - The horizontal projection is the base for the calculation of roof surfaces (A in m2)

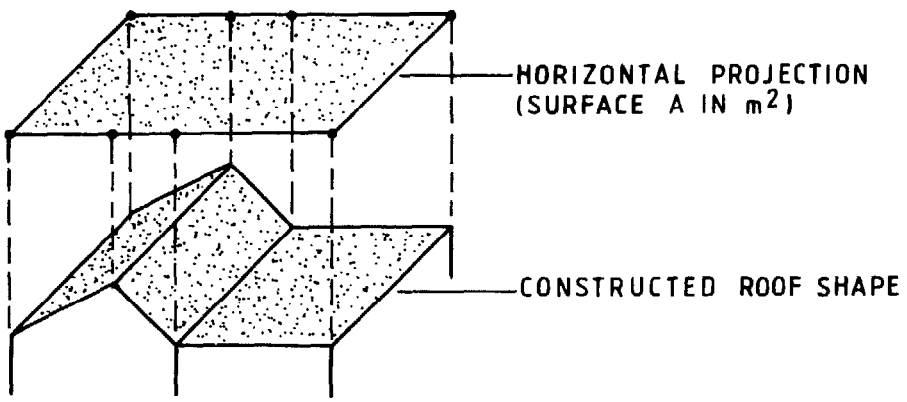

- For ground pipelines in mixed systems the maximum expected loading, Vm, results from the amount of Vs max. + Vr.

- Vs = Volume flow of several drainage appliances
- Vr = Flow rate per unit time of rain water
- Vm = Flow rate per unit time of mixed soil, waste water and rain water (in ground pipelines only).

13 DIMENSIONING

13.100 PRINCIPLES

Decisive for the dimensioning of parts of arrangements and systems are the principles explained in the chapter: "Principles of Calculation",

13.200 ARRANGEMENTS OF PARTS AND SYSTEMS

Systems and arrangements of parts are separately treated according to their dimensions as follows:

- connector pipes
- branch pipes
- leader with leader vent (stack with stack vent)
- leader with leader vent and indirect side vent
- leader with secondary vent
- vent pipe
- ground pipelines and collector pipelines

13.300 NOMINAL SEWERAGE VALUE (SV).

Of drainage appliances and for the dimensioning of their connector pipes.

SV		Minimal inner diameter in mm		
	Drainage device with relevant siphon	Connector pipe 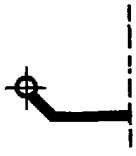	Connector and branch pipe, 2) 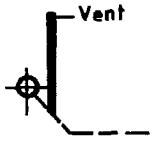	Siphon exit & connection (excl. self-siphonage apparatus)
0.5	Handwashbasin i.d. 44 Washbasin Bidet	44		
	Service sink, at schools Washsink, up to 3 taps Domestic centrifuge Shower tray, without stopper	57	44 or 50	32 outside 40
1.0	Bathtub Combitub Feet sink, up to 5 taps Shower tray, with stopper Washsink, 4 to 10 taps Urinals (connector 40/45 mm) Kitchen sink (cement, metal) Double kitchen sink (cement, metal) Dish washing machine Wash fountain, 6 - 10 taps Laundry sink Washing machine, up to 6 kg Floor drain, i.d. 60 mm	57	44 or 50	50 57
105	Large-sized bathtub Laboratory tub Washing machine, 7 - 12 kg Dish washing machine for commercial use, 1) Floor drain, i.d. 70 mm	69	50	57
2.5	Water closets, all types Service sink / wall types (faeces, scrub/floor water) Service sink / standing type (faeces, scrub/floor water) Floor drain, i.d. 80 to 100 mm Washing machine, 13 to 40 kg Bed pan cleaning device (hospital)	100	50	80

1) For the definative decision of the S-value the effective pump drainage accumulation respectively, is decisive.
2) The vertical pipelines of collected connector vent pipelines and branch vent pipelines are dimensioned as of table: "side vent".
3) Exceptions are siphons of ceramic make.
4) Horizontal connector pipelines, i.d. 44 up to max. 2 meters, with maximum one change in direction up to 45°, excl. apparatus connector elbow.

13.400 **Dimensioning tables for soil and/or waste water system**

13.410 **Leaders (stacks),** Main vent system.

stack	max. permitted numbers				permitted loading
	SV		WC		
i.d. in mm	Total	largest single SV	Total	per storey	Vs (1/s)
57	3 -1)	1.0	--	--	1.3
69	7	1.0	--	--	2.0
80	20	1.5	--	--	3.0
100	70	2.5	14	6	4.2
118	100	2.5	20	7	5.0
125	150	-	30	10	6.1
150	400	-	80	22	10.0

1) max. 2 apparatus at 1 SV.

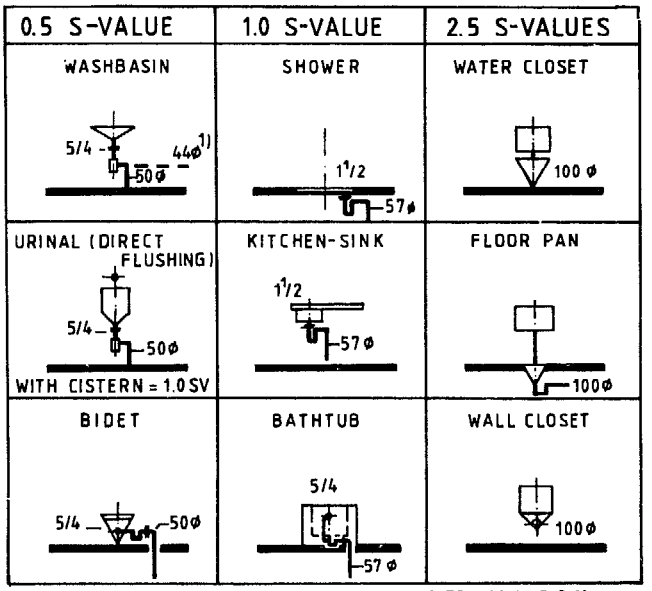

1) HORIZONTAL CONNECTOR PIPE, I.D 44ø UP TO MAX. 2.0 M

13.420 **Branch- and connector pipes,** without secondary vent.

i.d. in mm	max. permitted numbers SV	largest single SV
50	1	0.5
57	2	1.0
69	3 -1)	1.5
80	6	1.5
100	15	2.5

1) max. 1 apparatus at 1.5 SV.

13.430 **Branch- and connector pipes,** with secondary vent.

i.d. in mm	max. permitted numbers SV	largest single SV	vent pipe in mm
50	2	0.5	44 or 50
57	3 -1)	1.0	44 or 50
69	4. 5	1.5	50
80	9	1.5	50
100	25	2.5	50

1) max. 2 apparatus at 1 SV.

13.500 **Soil and/or waste water leaders (stacks)** with direct and indirect side vent system.

i.d. in mm	max. permitted numbers			Vs -1) permitted [1/s]	side vent i.d. in mm
	Total	WC Total	WC per storey		
80	64	---	---	4.2	57
100	150	30	6	5.9	80
118	200	40	7	7.0	80
125	300	60	10	8.5	80
150	800	160	20	14.0	100

1) Vs permissible values as compared to 13.410 increased by 80%
2) The connection of the side vent with the stack is to be made of the same dimension as the side vent.

13.600 **Soil and/or waste water leaders (stacks)** having secondary vents connected.

i.d. in mm	max. permitted numbers SV Total	WC Total	per storey	Vs -1) permitted [1/s]	side vent i.d. in mm
80	100	--	--	5.4	57
100	240	50	8	7.6	80
118	300	75	10	9.0	80
125	500	100	15	11.0	80
150	1200	260	30	18.0	100

1) Vs permissible values as compared 13.410 increased by 80%

13.700 **Collector pipeline and ground pipeline**

V permitted in l/s (as of Prandtl-Colebrook) -1)							
i.d. in mm	slope in % -3) 1	1.5	2	3	4	5	i.d. in mm
80	2.8	3.4	4.0	4.9	5.6	6.3	80
100 -2)	5.0	6.2	7.2	8.9	10.2	11.5	100 -2)
118 -2)	8.0	9.8	11.3	13.9	16.0	17.9	118 -2)
125	9.2	11.3	13.1	16.0	18.6	20.8	125
150	15.0	18.4	21.3	26.1	30.2	33.8	150
187	27.0	33.1	38.1	47.0	54.3	60.8	187
200	32.3	39.7	45.8	56.2	64.9	72.6	200
250	58.4	71.7	82.8	101.6	117.3	131.2	250
300	94.7	116.2	134.2	164.6	190.6	212.6	300

1) For all pipe materials; after Prandt1-Colebrook:
   Operation roughness kb = 1.0 mm
   Kinetic velocity γ (ny) = 1.3×10^6 m²/s
   Filling relation h/di = 0.8
2) Minimal inner diameter of ground pipelines = 100 mm Ø
   Where WC are connected, suggested to be min. = 118 mm Ø
3) Optimal slope is 3% - to be maintained where possible.

13.800 **DIMENSIONING OF VENT PIPES**

13.810 **Maximum length** - Maximum effective length of a loop pipe from the axis of the first bend over the top-most apparatus connector: 100 times i.d.

Deductions for:
- Bends 15° - 60° 5 times i.d.
- Bends 75° - 88.5° & branches 10 times i.d.

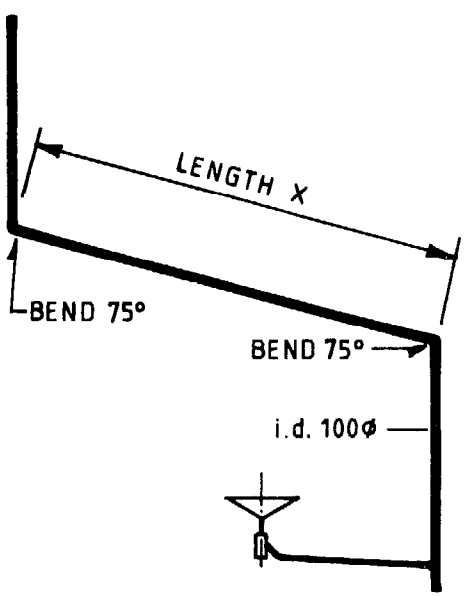

LENGTH X:

MAX. LENGTH (100 x i.d) = 10.0 m
DEDUCTIONS FOR 2Nº
BENDS 75°,
2 x (10 x i.d.) 1.0 m = -2.0 m

MAX. LENGTH X = 8.0 m

13.820 **Collector vent pipes** - Where for compelling reasons a collector vent pipe cannot be avoided, it will be equally dimensioned as leaders with relevant total loadings (table 13.410), and with the reservations mentioned in fig. 13.810.

13.830 **Connection of pumped pressure pipelines** - When connecting pumped pressure pipelines to collector pipelines or to ground pipelines, the following regulations apply:
The dimension of the collector or ground pipelines will be determined by calculating the total of Vs + Vp, after the table 13.700.

Vs = Volume flow of several drainage appliances
Vp = Volume of pumped water

The inlet of a pumped pressure pipeline normally requires an enlargement of the collector or ground pipeline by one dimension up to max. i.d. 150 mm.

14 INSPECTION AND TESTING

14.100 INSPECTION

Work should be inspected during installation and tests applied on completion, care being taken that all work to be encased or concealed is tested before it is finally enclosed.

14.110 **Range of inspection** - Pipe systems should be tested for tightness and for hydraulic performance. Inspection should be carried out to ensure the following:

a) Work accords with the drawings and specifications;
b) All pipe brackets, clips, etc., are securely fixed;
c) Fixings are correctly spaced;
d) Pipe is protected where necessary by insulation;
e) Embedded pipework is properly protected before sealing-in;
f) All access covers, caps or plugs:
   - are accessible,
   - are so made that the internal faces truly complete the internal bore,
   - cause no obstruction in the pipe bore, and
   - are well jointed.

14.200 TESTING OF THE SYSTEM

The water test must be applied before the appliances are connected and prior to concealing of pipes.

14.210 **Hydraulic performance** - Discharge tests should be made from all the appliances, singly and collectively. Obstruction in any of the pipelines should be traced and the whole system examined for proper hydraulic performance, including the retention of an adequate water seal in each trap.

14.230 **Defects** - Any defects revealed by the tests should be repaired, and the tests repeated until a satisfactory result is obtained.

14.300 **Efficiency** - When testing the efficiency of the design of soil and waste water pipe systems they should withstand any condition of discharge of appliances which may occur in practice. The discharge from one appliance must not be forced up into another, and every siphon should retain at least 25 mm of its seal under these conditions. The tests should be designed to make full allowance for the maximum suction and pressure effects which may occur as given below:

a) in small installations when all the appliances are discharged together, and
b) in large installations when sufficient appliances are simultaneously discharged to simulate peak conditions.

14.310 **Testing of siphons** - When testing the seals of siphons fitted to appliances, they should be filled to overflow level (where applicable, e.g. wash basins, kitchen sinks, etc., and allowed to discharge in the normal way.

14.320 **Similar tests** - Tests similar to the above should also be carried out by discharging some appliances, while others are empty with plugs out.

PARTS OF SOIL AND WASTE WATER SYSTEMS

TABLE 2/1

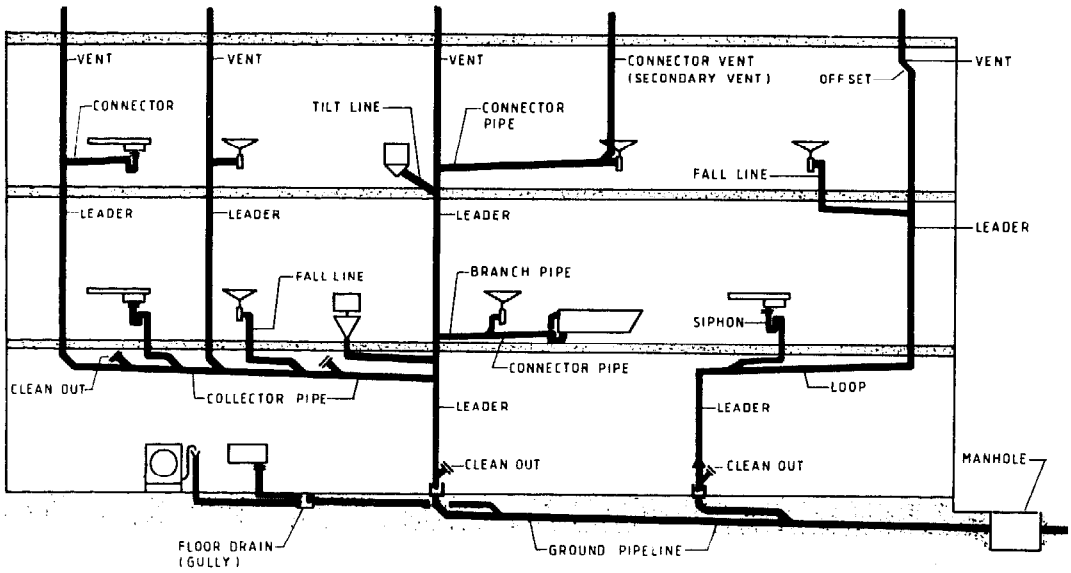

PARTS OF SINGLE STACK SYSTEM

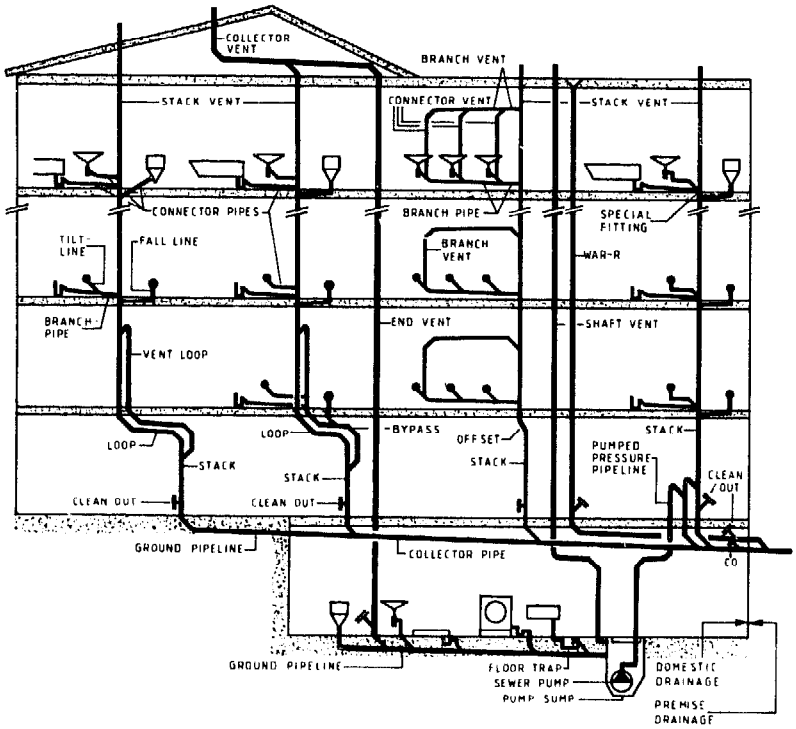

PRINCIPAL REQUIREMENTS ON STACK SYSTEMS — TABLE 2/2

ALL APPARATUS (INCLUDING FLOOR DRAINS, FUNNEL OF SAFETY VALVE, ETC) CONNECTED TO A STACK DRAINAGE SYSTEM MUST HAVE A SIPHON.

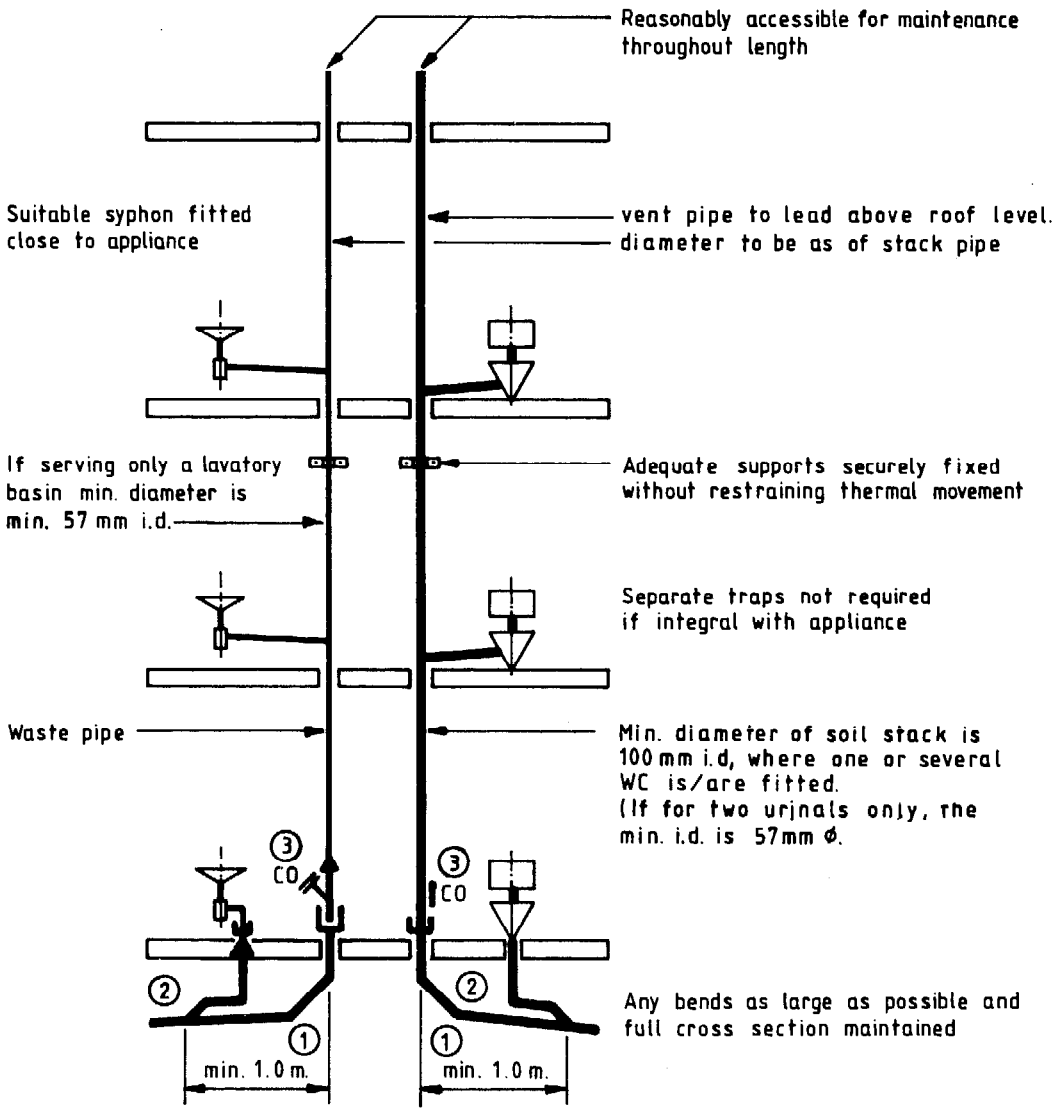

Note:

1 For a height up to 10m, a min. distance of 1.0m is required for buildings above 10.0m a min. distance of 1.5m is necessary.

2 Ground pipelines to be of min. 100 mm i.d.

3 Diameters of clean-outs to be of min. 100 mm Ø

GROUNDFLOOR CONNECTION OF APPARATUS

TABLE 2/3

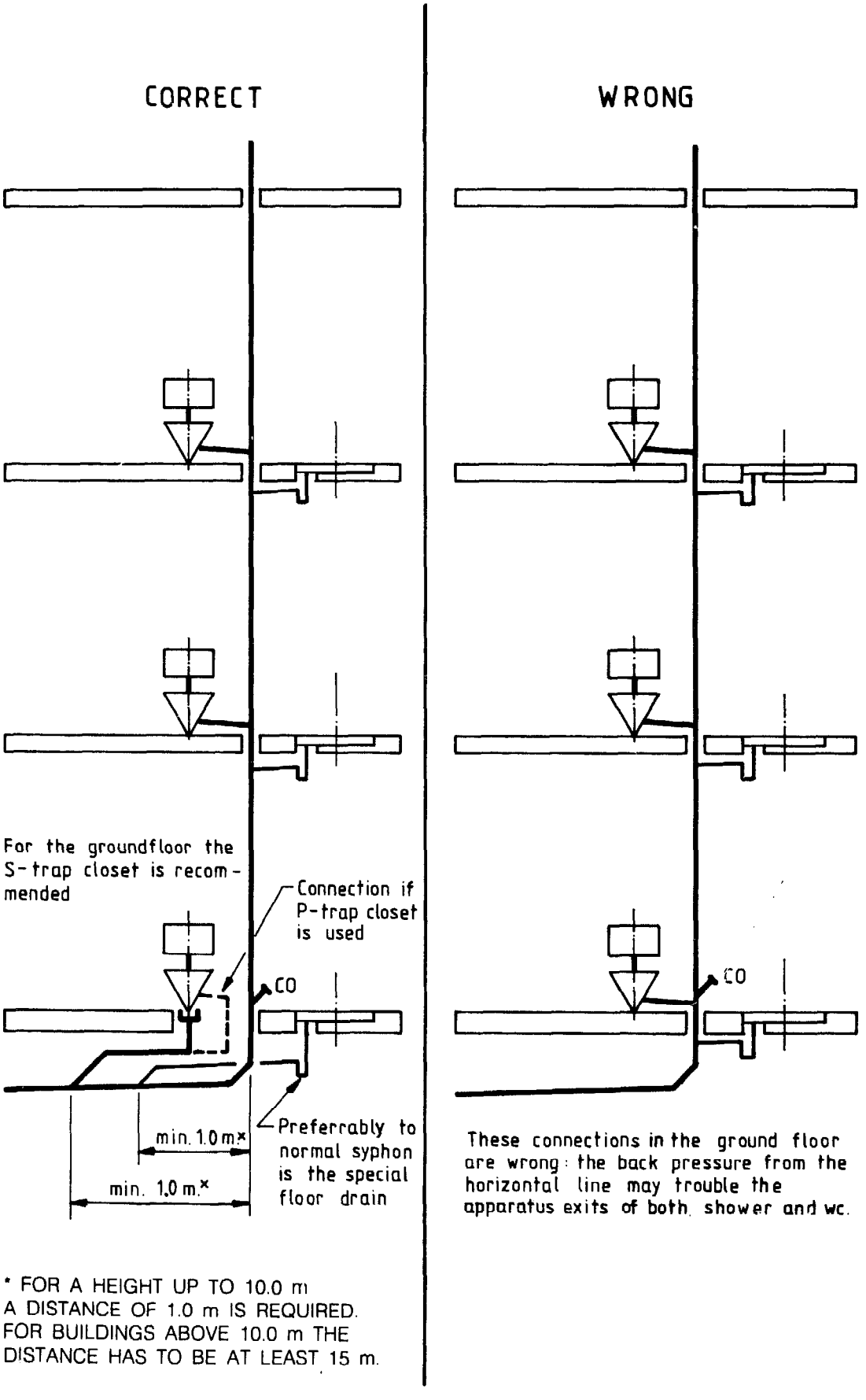

* FOR A HEIGHT UP TO 10.0 m
A DISTANCE OF 1.0 m IS REQUIRED.
FOR BUILDINGS ABOVE 10.0 m THE
DISTANCE HAS TO BE AT LEAST 15 m.

DIMENSIONING EXAMPLE

TABLE 2/4

SINGLE STACK SYSTEM: SOIL AND WASTE WATER DRAINAGE

VENT PIPE ABOVE ROOF LEVEL: EACH HOUSE MUST HAVE AT LEAST ONE VENT PIPE OF 100 mm iØ. WHETHER FOR SINGLE OR MULTISTORY BUILDINGS

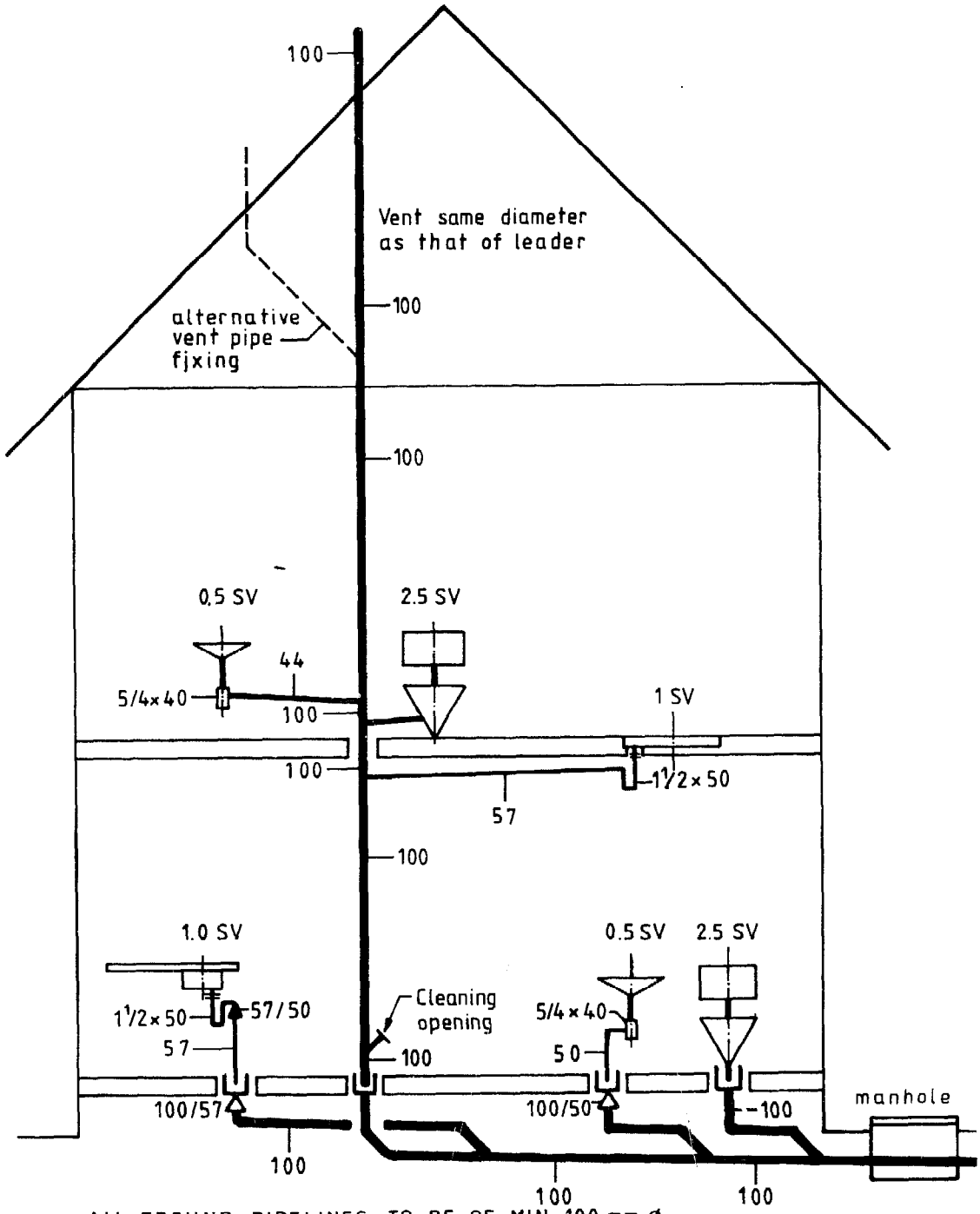

ALL GROUND PIPELINES TO BE OF MIN. 100 mm Ø

STACK DIMENSIONING:			
	1 SHOWER	1 SV	
	1 WASHBASIN	0.5 SV	
	1 WC	2.5 SV	(= MIN Ø 100 mm)
	TOTAL	3.5 SV	= 100 mm Ø

DIMENSIONING EXAMPLE — TABLE 2/5

SINGLE STACK SYSTEM: SOIL AND WASTE WATER DRAINAGE

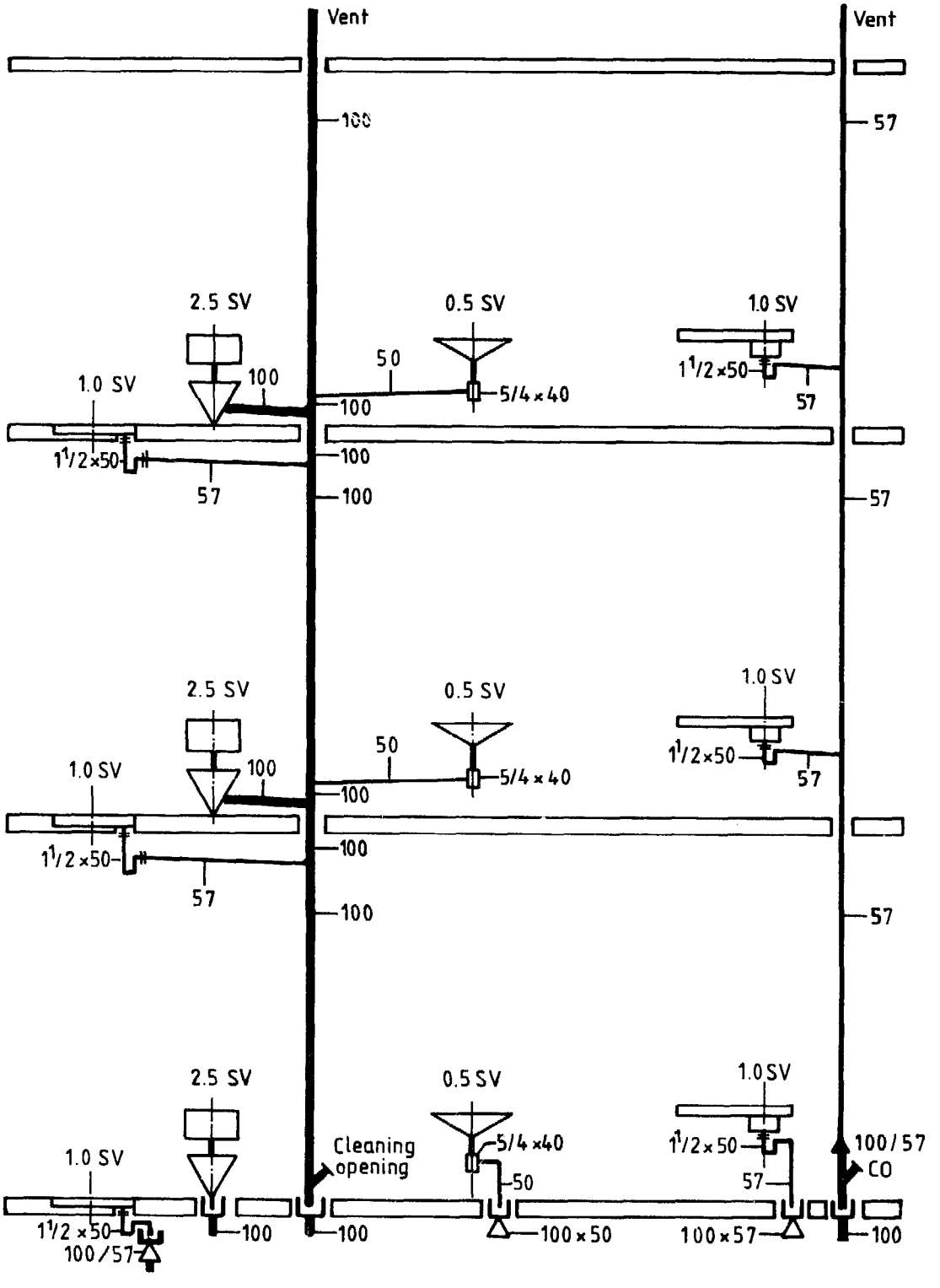

STACK №1: 2 Washbasin a 0.5 SV = 1 SV
2 Shower a 1.0 SV = 2 SV
2 WC a 2.5 SV = 5 SV
Total for leader pipe 8 SV=100 ϕ

STACK № 2: 2 kitchen at 1.0 SV =
Total 2 SV = 57 mm i.d.

DIMENSIONING EXAMPLE — TABLE 2/6

Dimensions of leader pipes depends on the numbers of connected apparatus resp. their S-values, but at least 57 mm Ø (when without WC)
When with WC diameter is at least 100 mm 0 (upto max. 14 WC and/or max. 70 SV) (Single stack system)

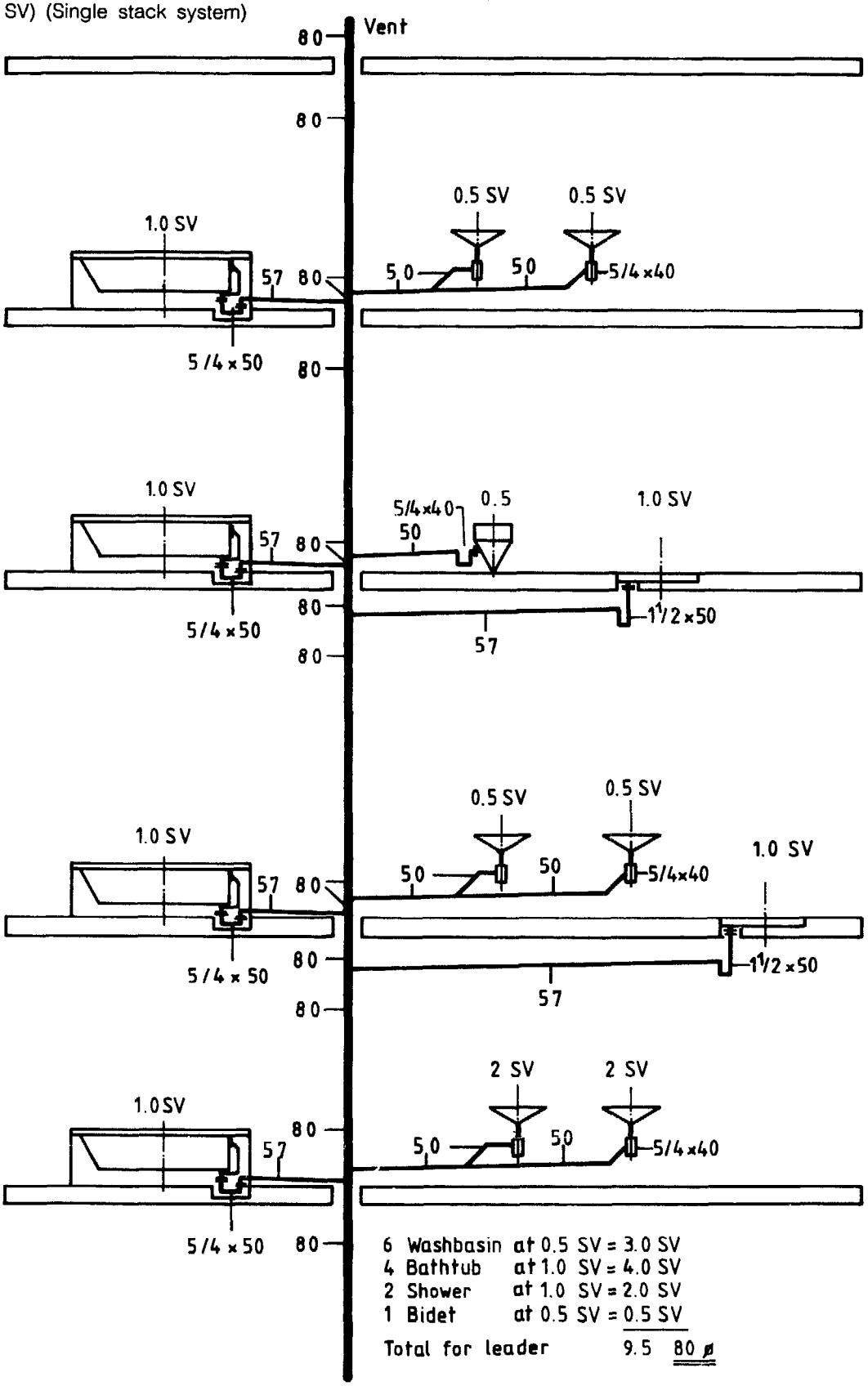

6	Washbasin	at 0.5 SV =	3.0 SV
4	Bathtub	at 1.0 SV =	4.0 SV
2	Shower	at 1.0 SV =	2.0 SV
1	Bidet	at 0.5 SV =	0.5 SV
Total for leader			9.5 80 ø

PRINCIPLES ON STACK VENTILATION **TABLE 2/7**

SINGLE STACK SYSTEM: SOIL AND WASTE WATER DRAINAGE

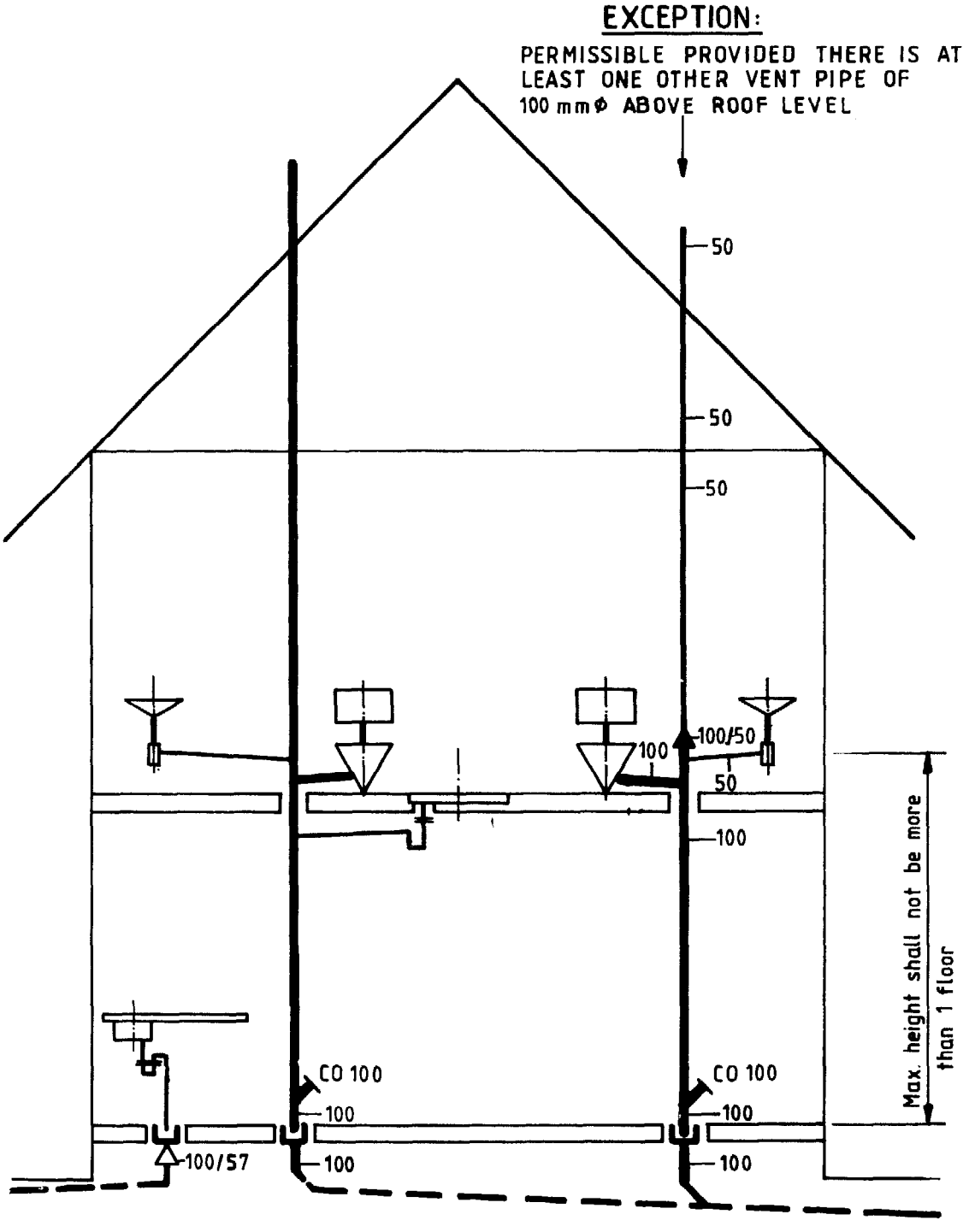

Each house shall have at least one main vent of 100mm Ø. However additional single connections may be used for example:

Watercloset and washbasin can be fixed to an existing sewerage system and there dimension of the vent pipe can in this case be (not less than) 50 mm Ø

DIMENSIONING EXAMPLE

TABLE 2/8

Divided Stack System:

a) Soil Stack: The water closet is led to the septic tank

b) Waste Stack: Other apparatus, free from human faeces, are led into a separate septic tank

Note:
- It might be advisable to incorporate a grease arrestor, in order to retain the kitchen wastes from the drainage pipes.
- Ventilation: each house requires at least one ventilation pipe (100 ∅)
- All ground pipelines to be of min. 100 mm inner diameter

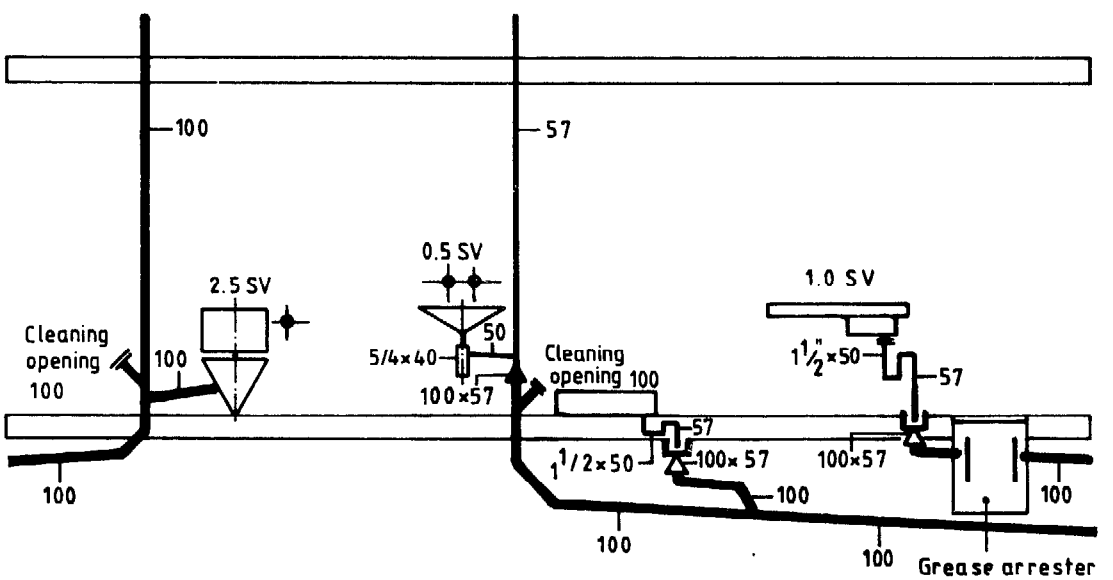

DIMENSIONING EXAMPLE — TABLE 2/9

Divided Stack Drainage System:

a) Soil Stack: Pipe line to which water closets are fitted and led to the septic tank with straight ventilation above roof

b) Waste Stack: Washbasin, bathtub and kitchen, having a separate stack, which is led to a separate septic tank it requires a vent pipe above roof level.

Note: This system is optional e.g. where houseowner asks for the same - however, single stack systems are similor in function.

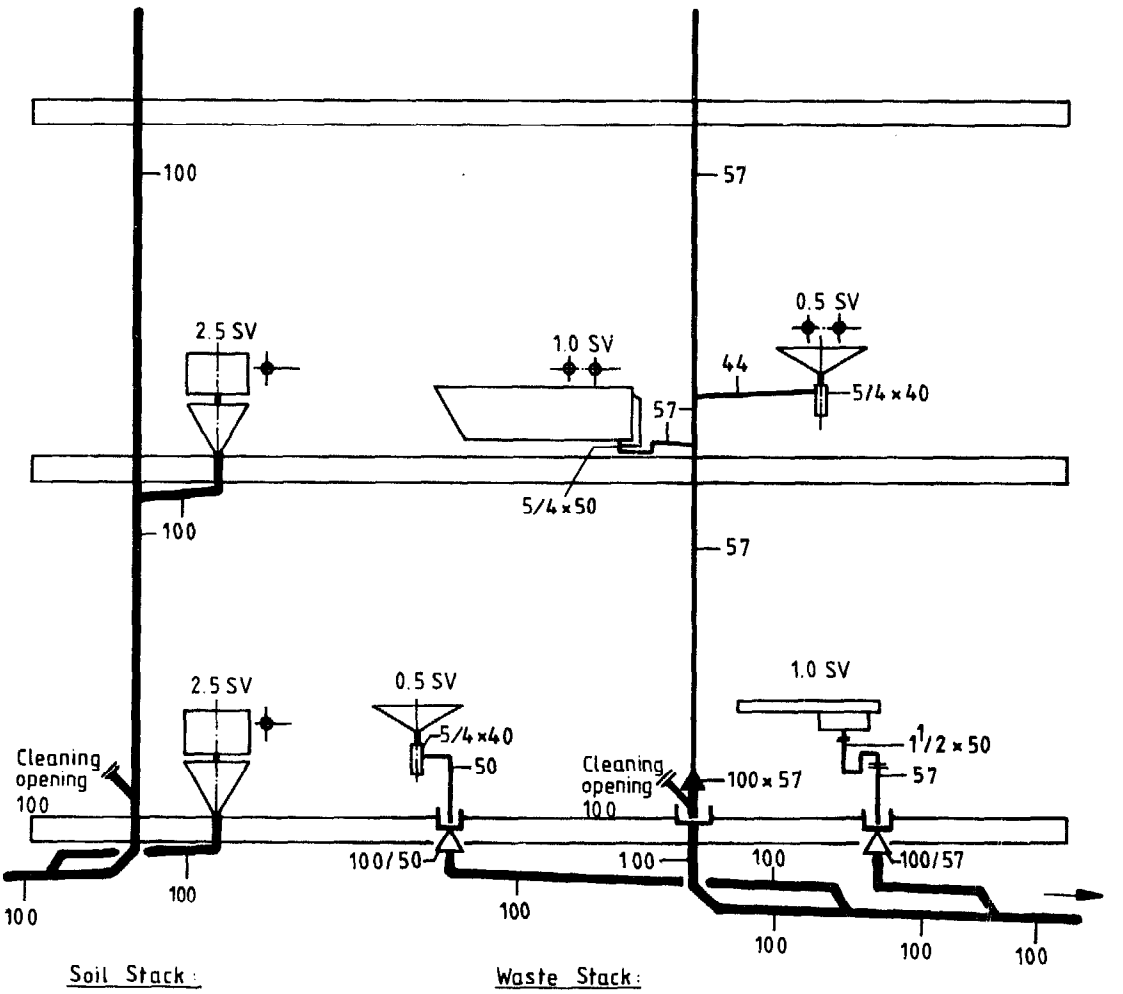

Soil Stack:
1 WC at 2.5 = 100 mm ø

Waste Stack:

1 WASHBASIN	0.5 SV
1 BATH TUB	1.0 SV
TOTAL	1.5 SV = 57 mm ø

ALL GROUND PIPELINES TO BE OF MIN. 100 mm INNER DIAMETER

DIMENSIONING EXAMPLE — TABLE 2/10

Divided Stack Drainage System:

a) Soil Stack: all water closets, to be lead into septic tank

b) Waste stack: washbasins and bathtubs into waste stack, to be lead into separate septic tank

alternatively vent pipe could lead into soil stack

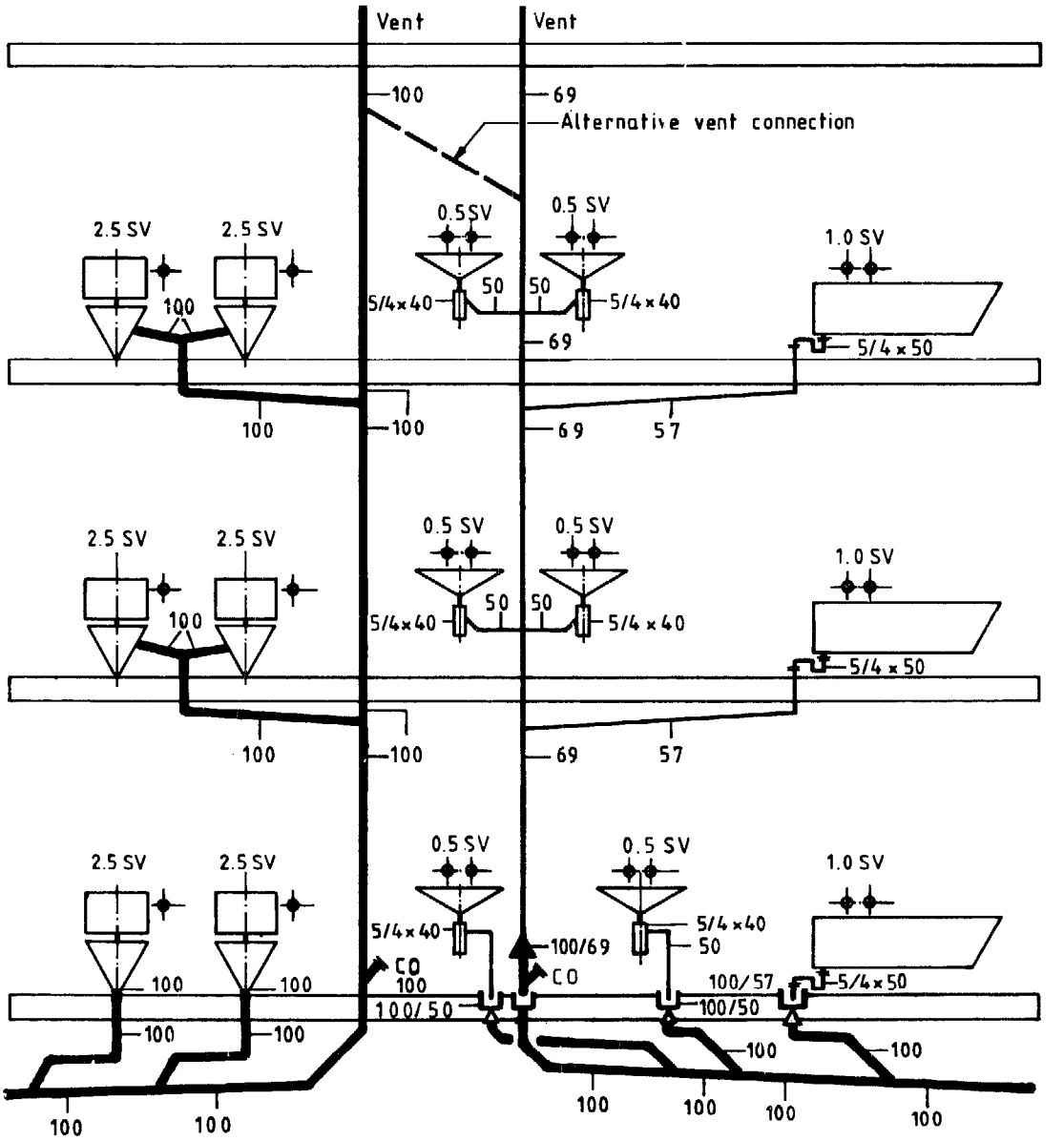

Soil stack

4 WC at 2.5 SV = 10 SV = 100 ø

Waste stack:

4 Washbasin at 0.5 = 2 SV

2 Bathtub at 1.0 = 2 SV

4 SV = 69 ø

MANHOLE EXAMPLE (EXTERIOR) TABLE 2/11

SECTION XX

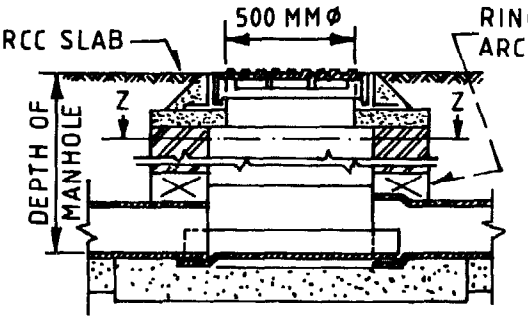

SECTION YY

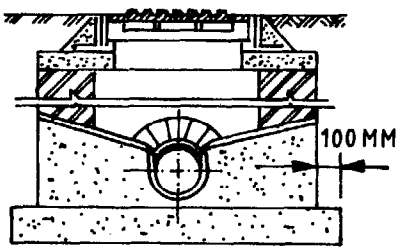

SECTIONAL PLAN AT Z-Z

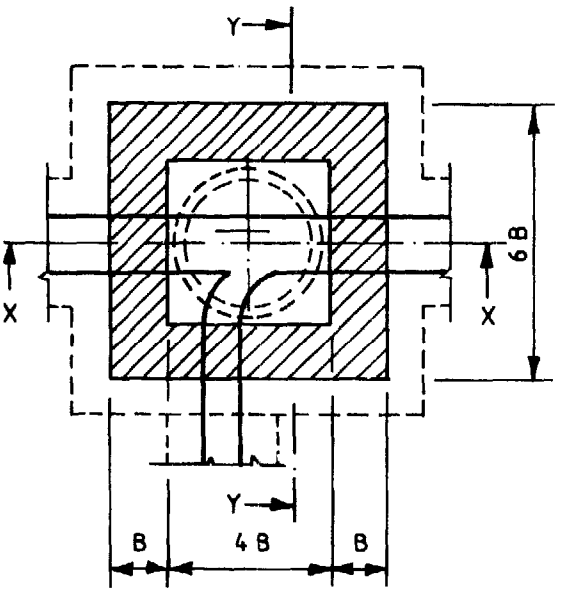

DETAIL OF BENCHING

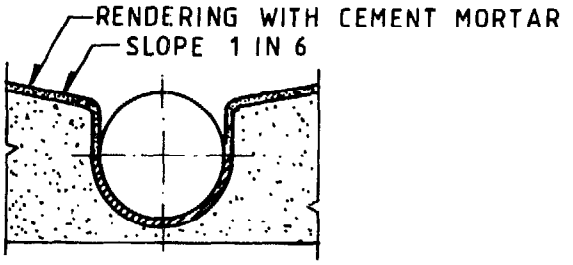

Note: Wall thickness have been indicated in brick lengths to provide for use of modular bricks or traditional bricks in the figure, B = one brick length, 6 B = six bricks

H.D.P.E. PIPES MATERIAL LIST

TABLE 2/12

BUILDING SITE: _____

SECTION: DATE:

SIG.	ARTICLE	i.d. 44Ø 44/50	57Ø 57/63	83Ø 83/90	100Ø 100/110
	PIPES HDPE				
	PIPES TOTAL				
	BRANCH 90°				
	BRANCH 60°				
	BRANCH 45°				
	BRANCH 90° RED 100Ø –	100/44	100/57	100/83	
	BRANCH 90° RED. 83Ø –	83/44	83/57		
	BRANCH 90° RED 57-44Ø	57/44			
	BEND 90°				
	BEND 45°				
	BEND RED. 90°	57-44			
	Y-TEE				
	REDUCER 100Ø –	100/44	100/57	100/83	
	REDUCER 83Ø –	83/44	83/57		
	REDUCER 57/44	57/44			
	HDPE WASTE COUPLING	44 x 5/4"	44 x 1 1/2"		
	WASHBASIN SIPHON SOCKET	44			
	WC SOCKET W. RUBBER SEAL				
	RING SEAL SOCKET				
	SCREW-THREADED SOCKETS				
	CLAMPS				
	CEMENT FIXATION				
	SADDLE CLAMP				
	SCREW / DOWEL				

Residential and Non - Residential

DRINKING WATER INSTALLATIONS AND DRAINAGE REQUIREMENTS IN NEPAL

PART 3
DRAWINGS / DESIGN

APPARATUS REQUIREMENTS **TABLE 3/1**

GUIDELINES FOR THE DETERMINATION OF REQUIRED APPARATUS IN BUILDINGS

Object	unit	take graph for				
		WC (commode)		urinals	showers	
		ladies	gents	gents	ladies	gents
1. schools	students	3 - 4	4 - 5	3 - 4	2 - 3	2 - 3
2 offices	employees	2 - 3	3 - 4	2 - 3	-	-
3 industries	employees	2 - 3	3 -	2 - 3	6 - 7	6 - 7
4 hotel / rest.	seats	3 - 4	4 - 5	3 - 4	-	-
5 restaurants	seats	4 - 5	5 - 6	4 - 5	-	-
6 swimmingpool	locked boxes	5 - 6	6 -	6 -	5 - 6	5 - 6
7 theatres	visitors	6	6 - 7	5 - 6	-	-
8 barracks	persons	5	3 - 4	3 - 4	5 - 6	5 - 6

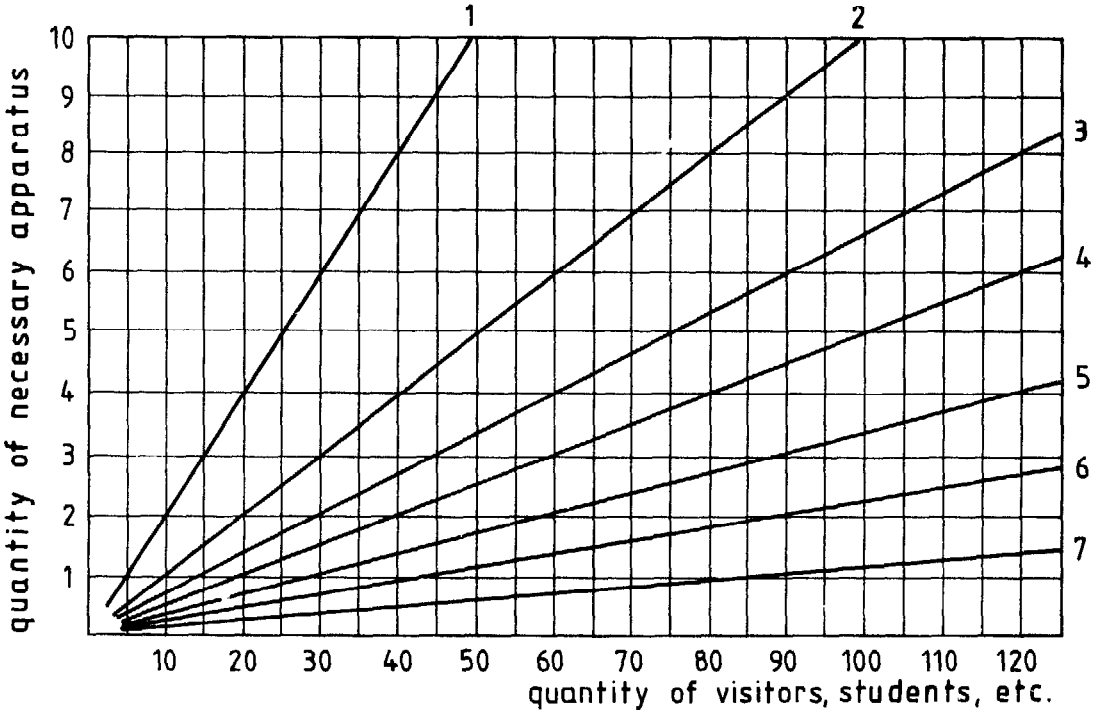

The above indications are in accordance with international directions.

WATER CLOSET (COMMODE) **TABLE 3/2**

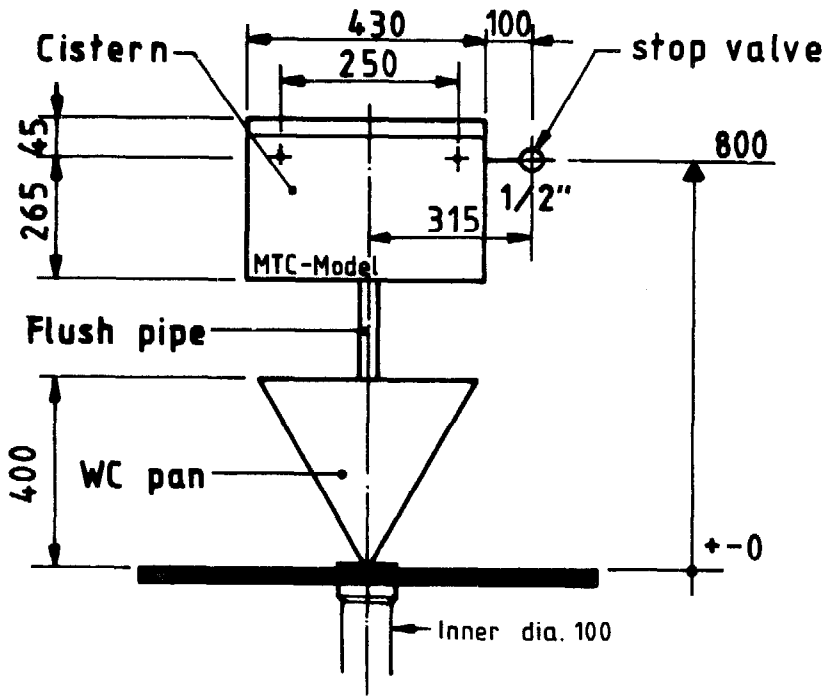

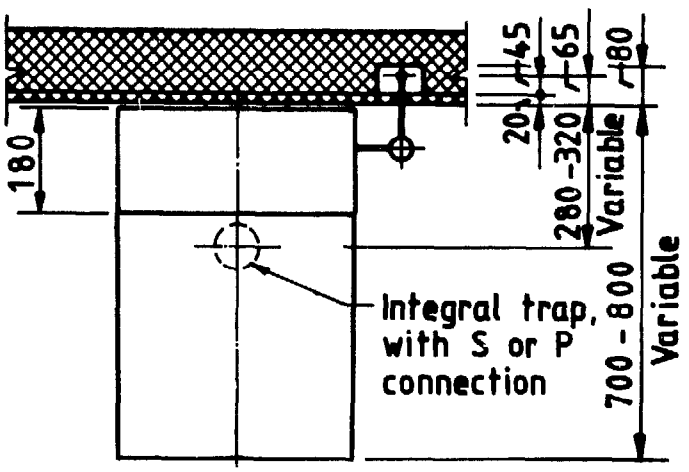

Example of Apparatus. Note: There are many different types and designs available on the market. The indications above are proposals. Actual dimensions of the apparatus and appliances (height, diameters, connecting accessories, etc.) have to be measured from the very apparatus to be fixed at the site, prior to fixing of pipes into the walls or floors.

WC FLOOR PAN **TABLE 3/3**

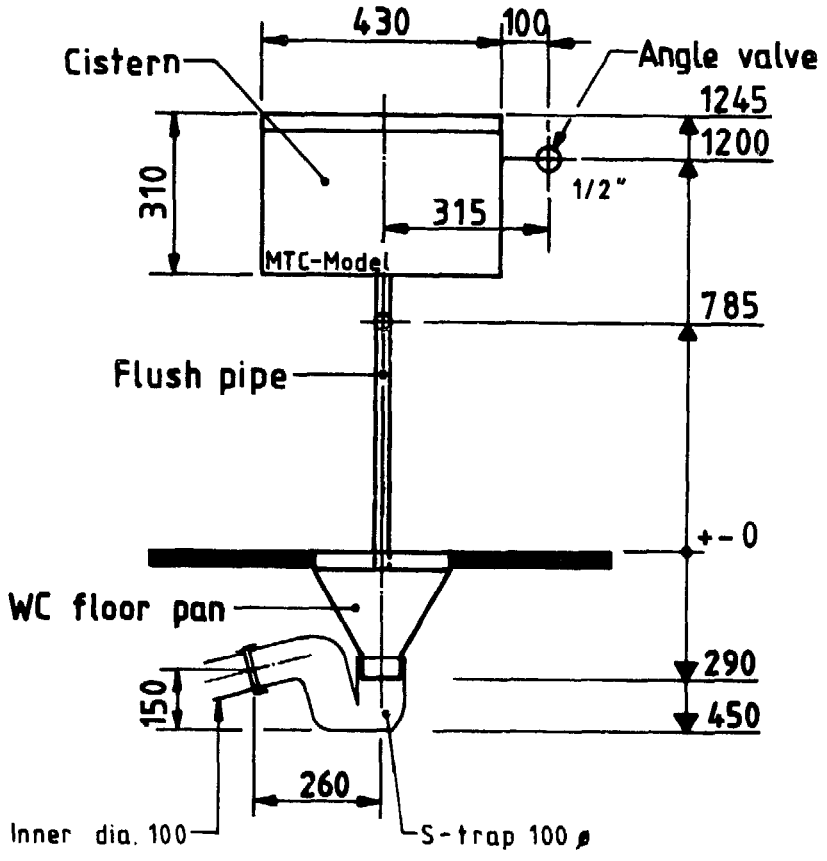

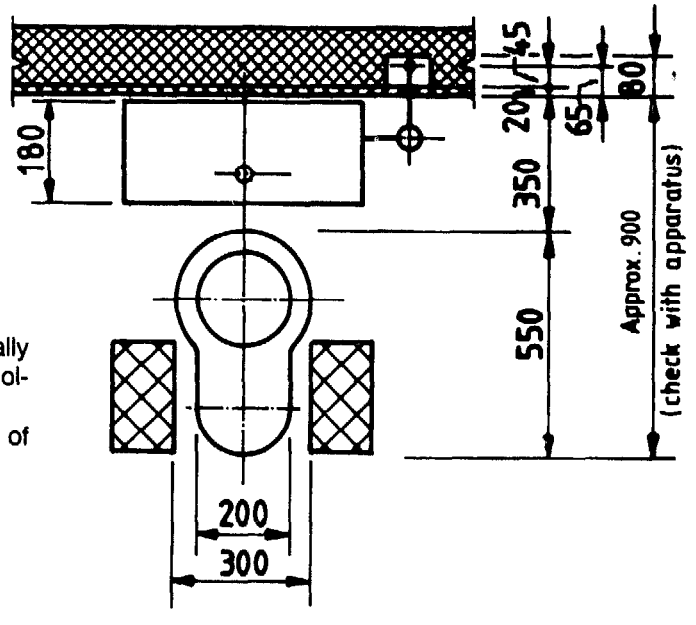

Note: This type of WC usually requires one additional cold-water tap (1/2") fitted nearby at a height of approx. 400 mm.

Example of Apparatus. Note: There are many different types and designs available on the market. The indications above are proposals. Actual dimensions of the apparatus and appliances (height, diameters, connecting accessories, etc.) have to be measured from the very apparatus to be fixed at the site, prior to fixing of pipes into the walls or floors.

WASHBASIN (LAVATORY) **TABLE 3/4**

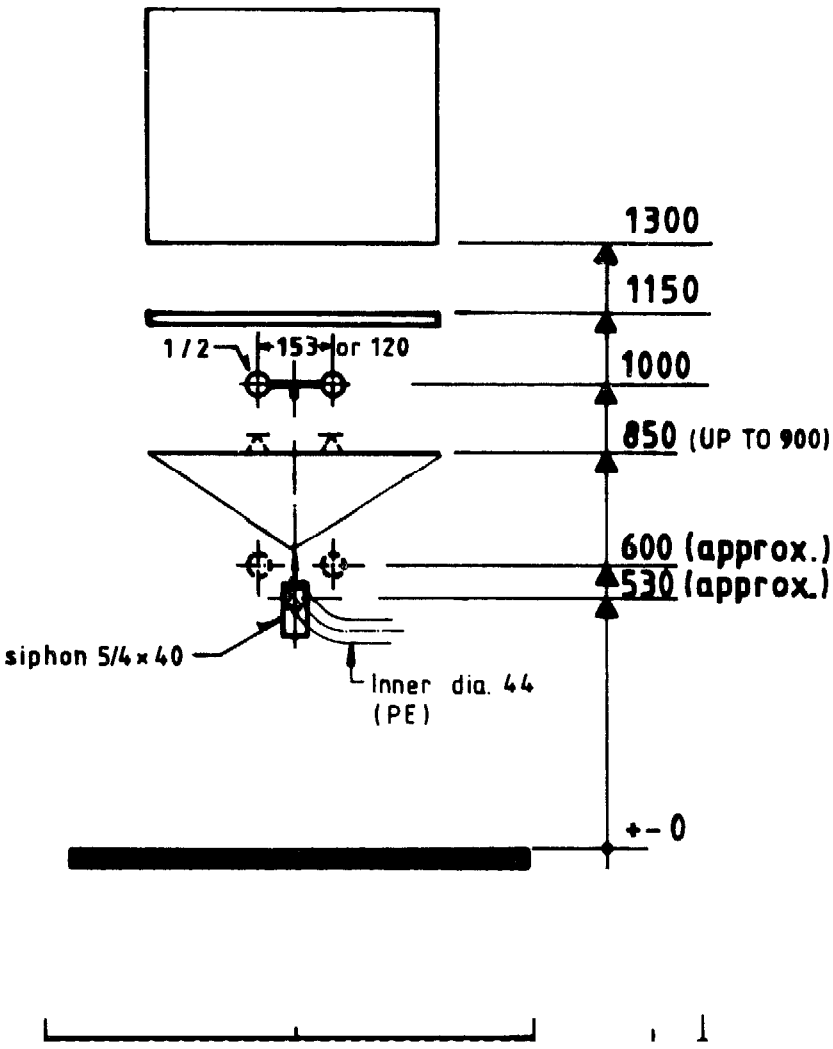

BATHTUB **TABLE 3/5**

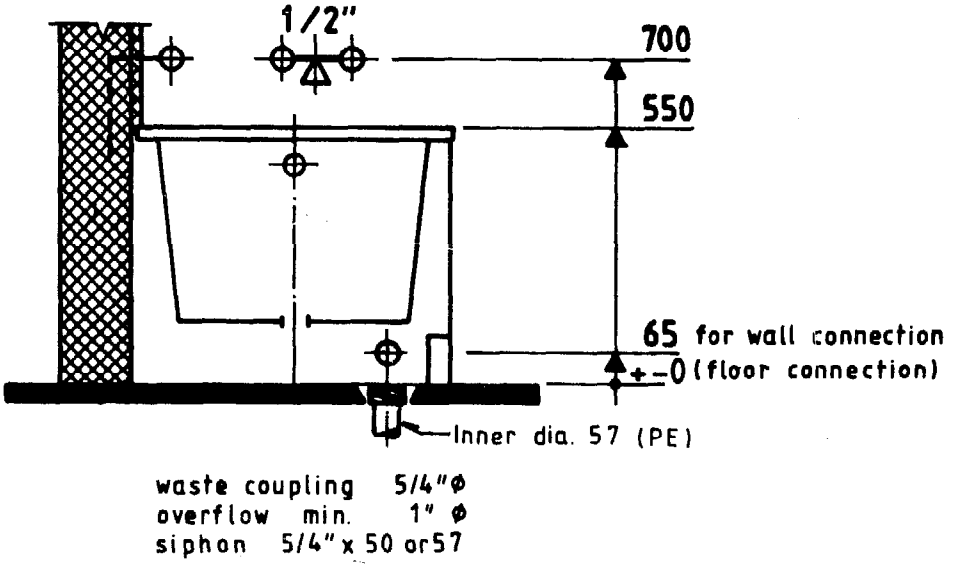

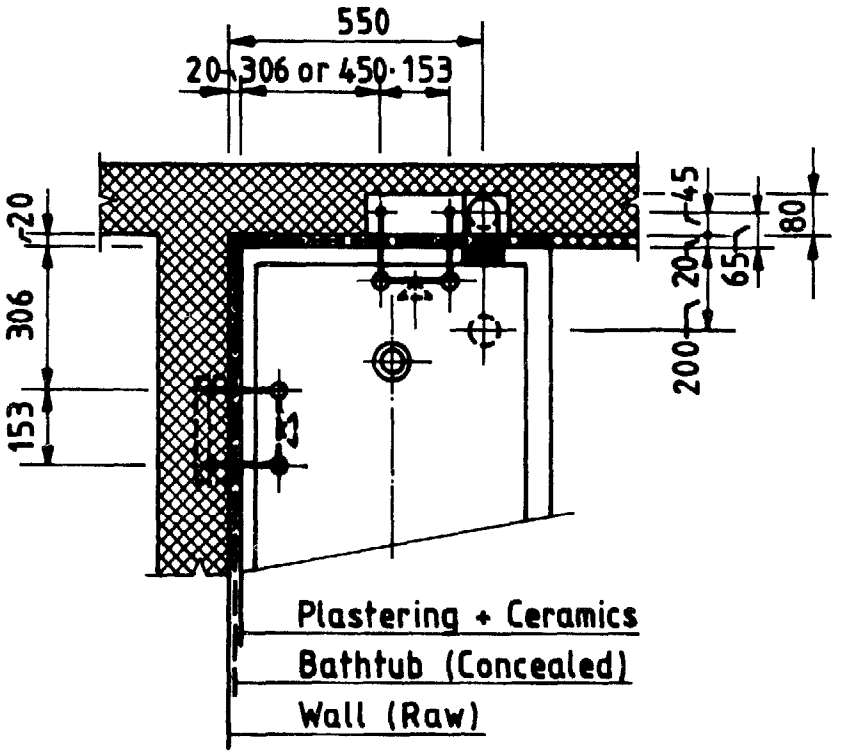

Example of Apparatus. Note: There are many different types and designs available on the market. The indications above are proposals. Actual dimensions of the apparatus and appliances (height, diameters, connecting accessories, etc.) have to be measured from the very apparatus to be fixed at the site, prior to fixing of pipes into the walls or floors.

URINAL **TABLE 3/6**

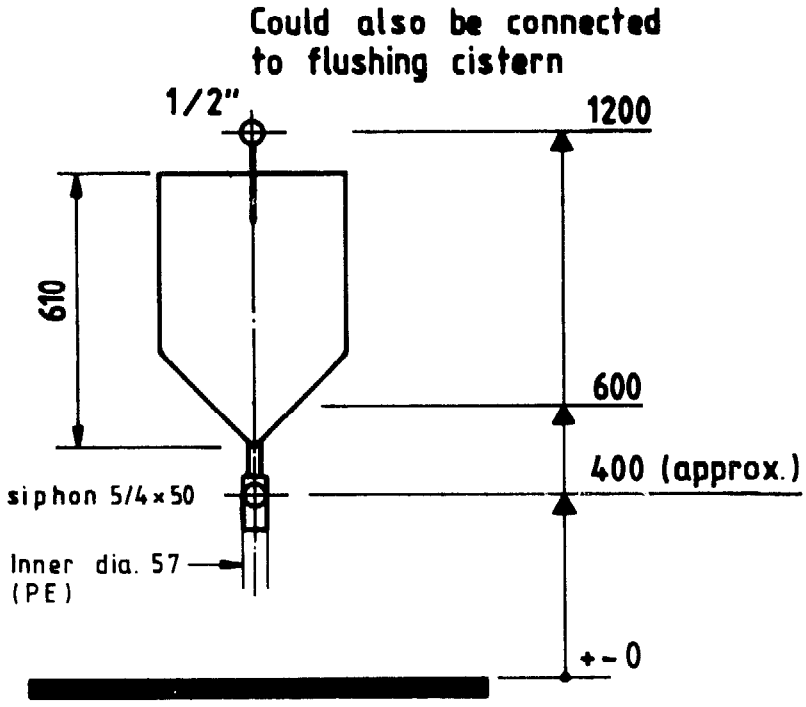

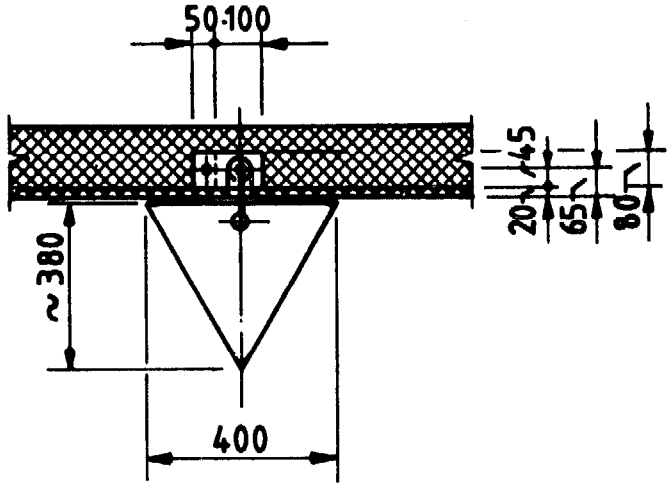

Example of Apparatus. Note: There are many different types and designs available on the market. The indications above are proposals. Actual dimensions of the apparatus and appliances (height, diameters, connecting accessories, etc.) have to be measured from the very apparatus to be fixed at the site, prior to fixing of pipes into the walls or floors.

URINAL (SMALL TYPE) **TABLE 3/7**

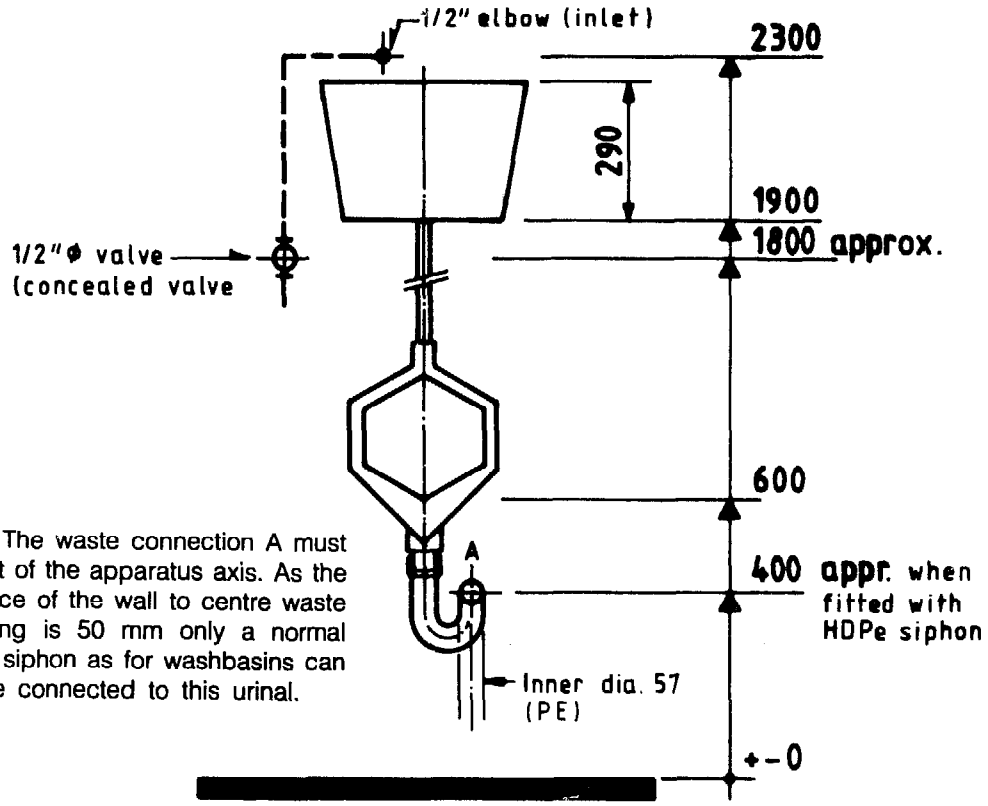

Note: The waste connection A must be out of the apparatus axis. As the distance of the wall to centre waste coupling is 50 mm only a normal bottle siphon as for washbasins can not be connected to this urinal.

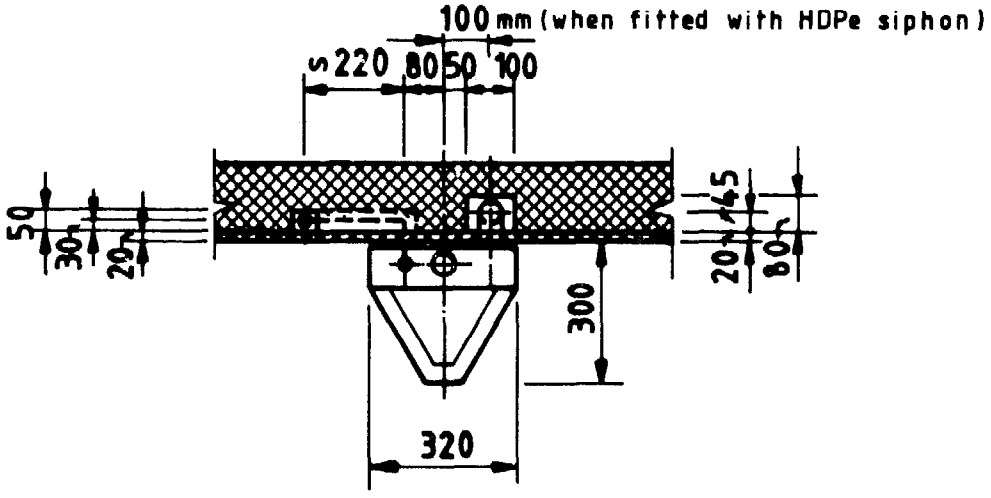

Example of Apparatus. Note: There are many different types and designs available on the market. The indications above are proposals. Actual dimensions of the apparatus and appliances (height, diameters, connecting accessories, etc.) have to be measured from the very apparatus to be fixed at the site, prior to fixing of pipes into the walls or floors.

KITCHEN SINK **TABLE 3/8**

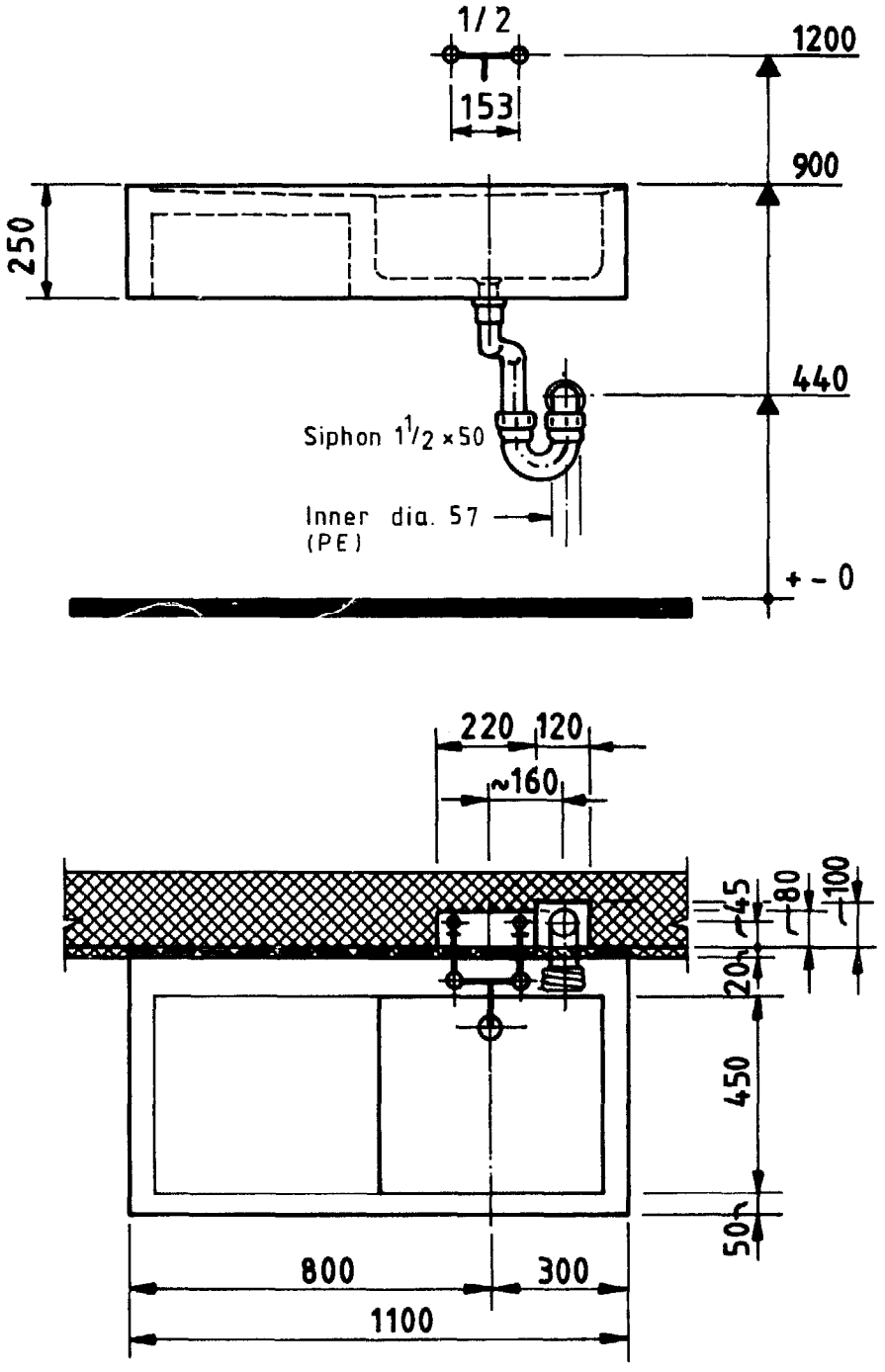

Example of Apparatus. Note: There are many different types and designs available on the market. The indications above are proposals. Actual dimensions of the apparatus and appliances (height, diameters, connecting accessories, etc.) have to be measured from the very apparatus to be fixed at the site, prior to fixing of pipes into the walls or floors

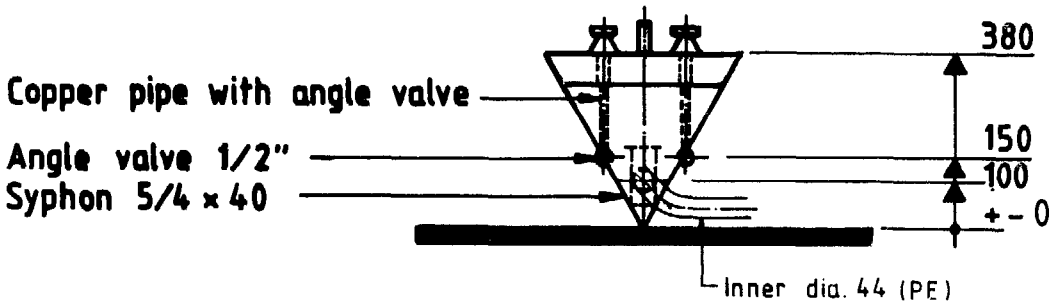

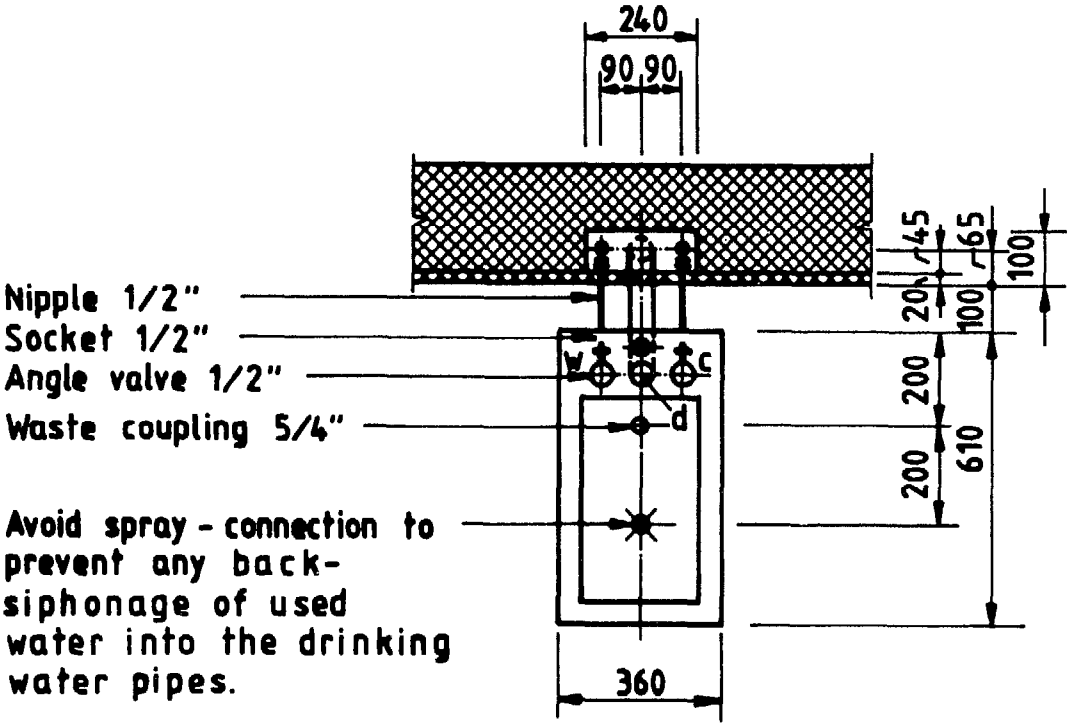

w = warmwater
d = directing valve to rim
c = coldwater

Example of Apparatus. Note: There are many different types and designs available on the market. The indications above are proposals. Actual dimensions of the apparatus and appliances (height, diameters, connecting accessories, etc.) have to be measured from the very apparatus to be fixed at the site, prior to fixing of pipes into the walls or floors.

SHOWER **TABLE 3/10**

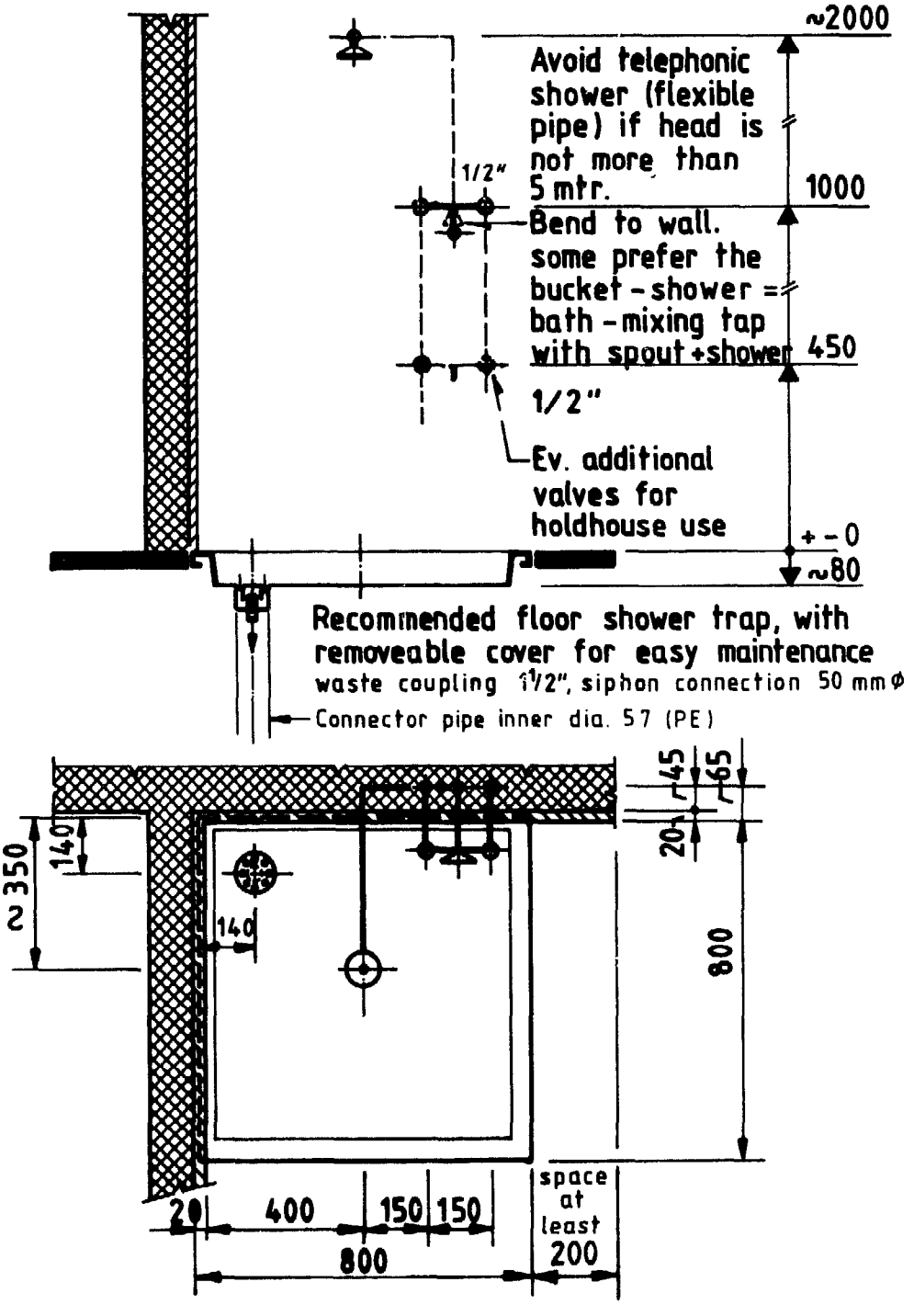

Example of Apparatus. Note: There are many different types and designs available on the market. The indications above are proposals. Actual dimensions of the apparatus and appliances (height, diameters, connecting accessories, etc.) have to be measured from the very apparatus to be fixed at the site, prior to fixing of pipes into the walls or floors.

ROOM MEASUREMENTS

TABLE 3/11

MINIMAL SPACE REQUIREMENTS FOR APPARATUS AND PERSON

1 Washbasin

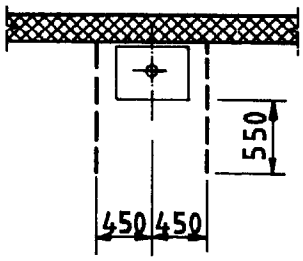

2 Hand-Washbasin

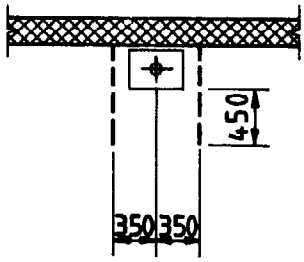

3 Urinal

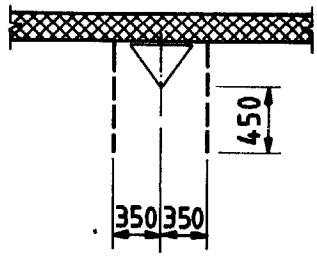

4 Bathtub

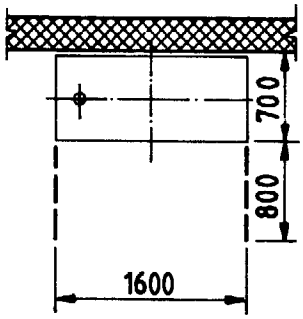

5 Showertray

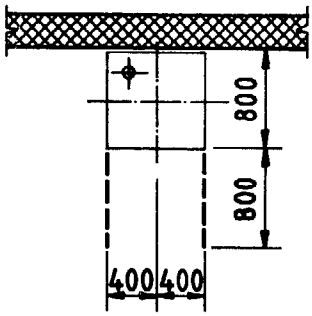

6 Bidet

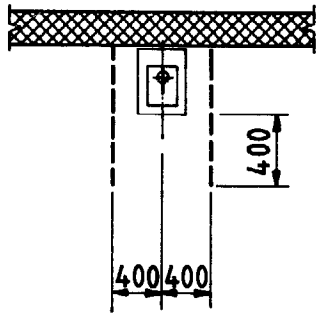

7 Water-Closet

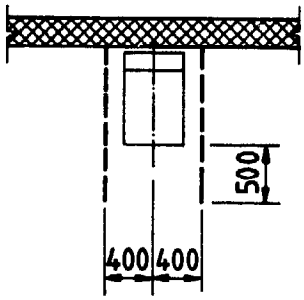

8 Water-Closet with Tank

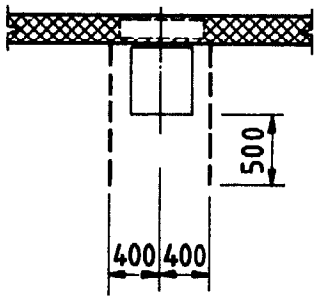

9 Floor-Pan

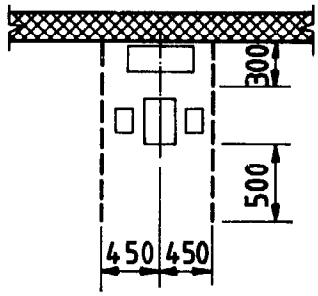

ROOM MEASUREMENTS

TABLE 3/12

MINIMAL SPACE REQUIREMENTS FOR APPARATUS AND PERSON

1 WC + Handwashbasin

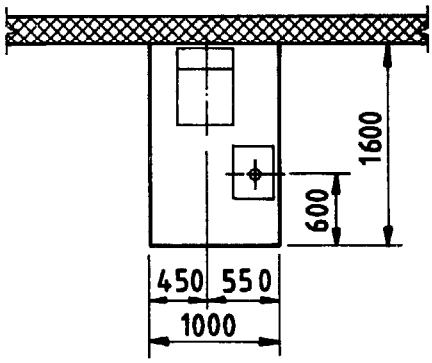

2 WC + Washbasin

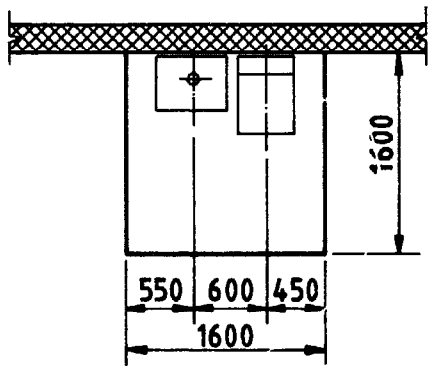

3 Floor -Pan + Handwashbasin

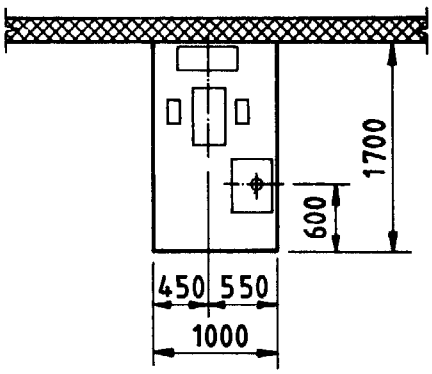

4 Floor -Pan + Washbasin

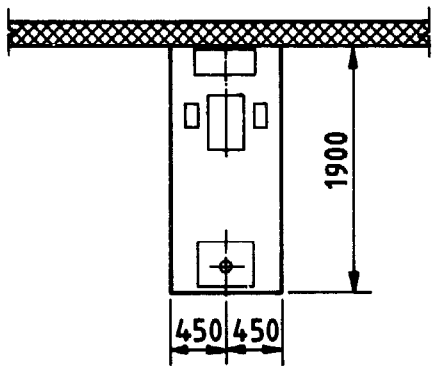

5 Shower + Washbasin

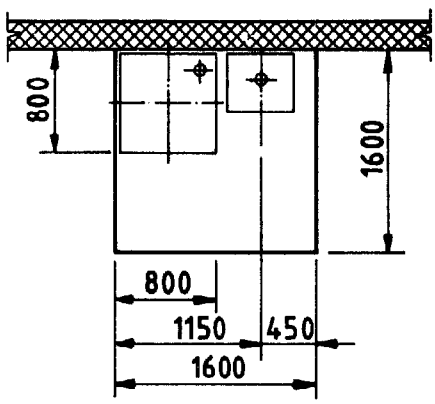

6 Shower, Washbasin + WC

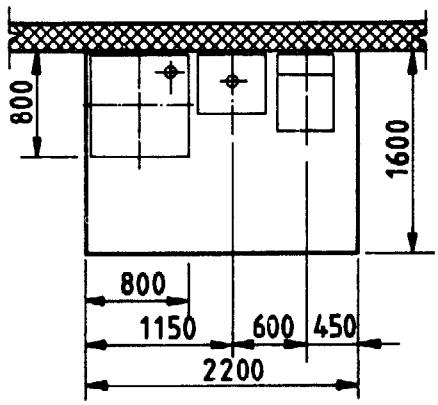

ROOM MEASUREMENTS TABLE 3/13

MINIMAL SPACE REQUIREMENTS FOR APPARATUS AND PERSON

1 Bathroom with 2 apparatus

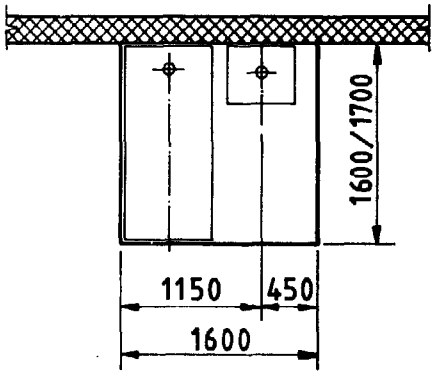

2 Bathroom with 3 apparatus

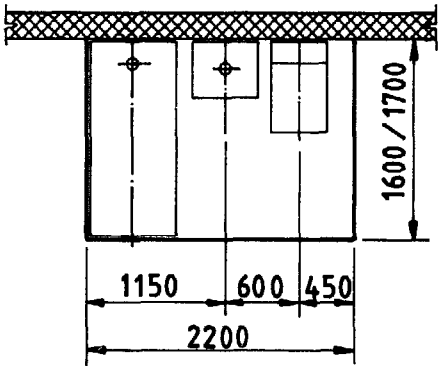

3 Bathroom with 3 apparatus

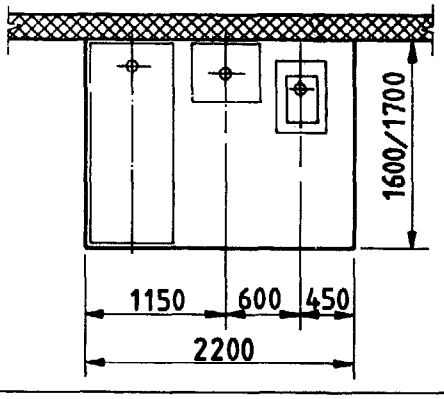

4 Bathroom with 3 apparatus

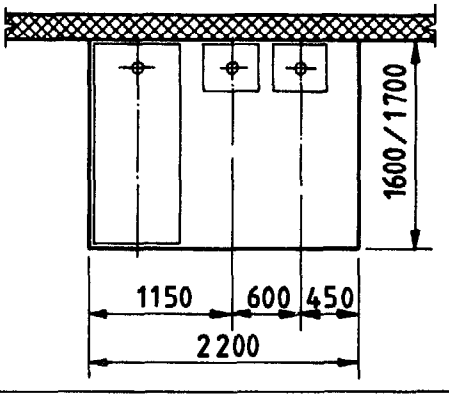

5 Bathroom with 4 apparatus

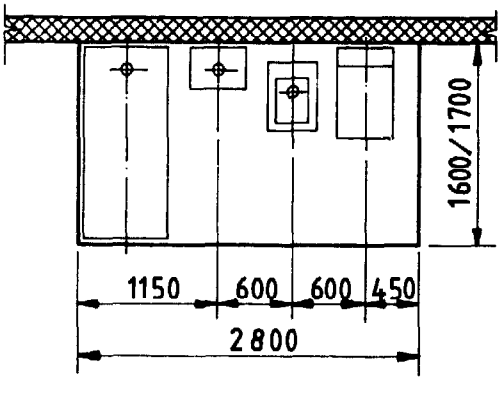

6 Bathroom with 4 apparatus

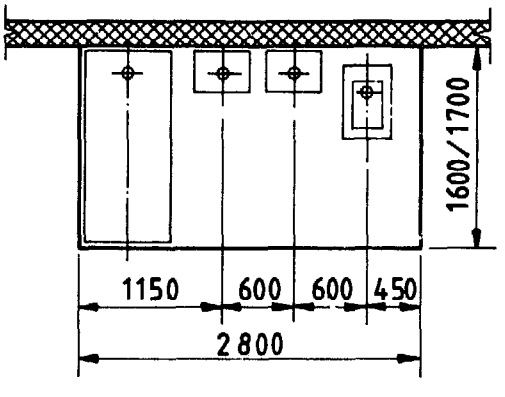

INSTALLATION SHAFTS

TABLE 3/14

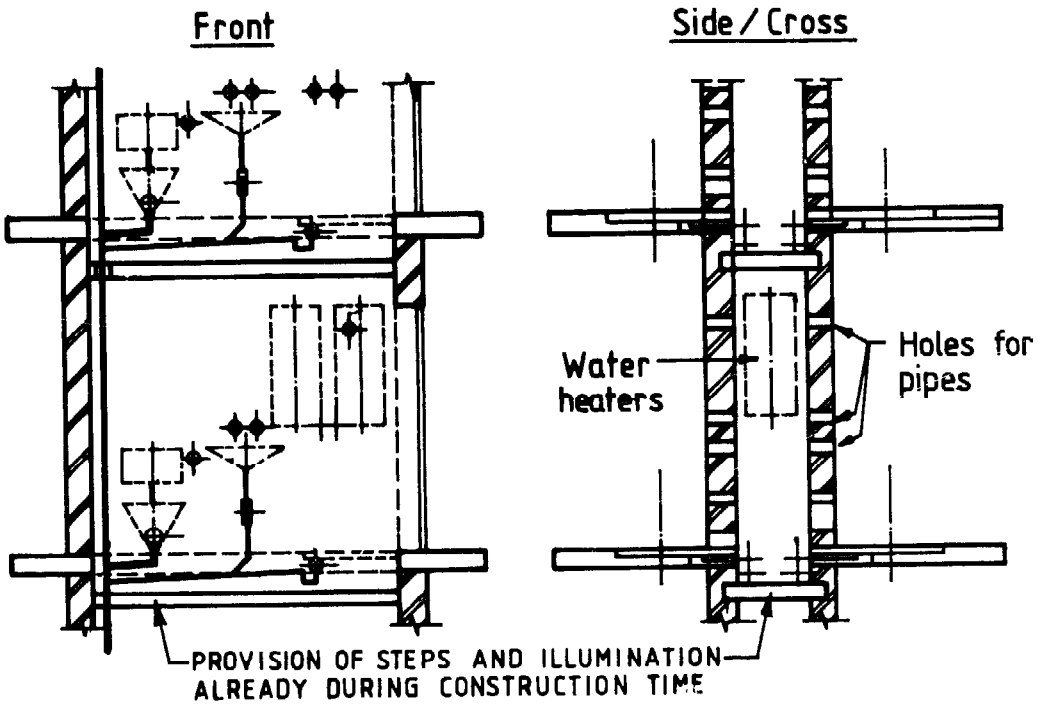

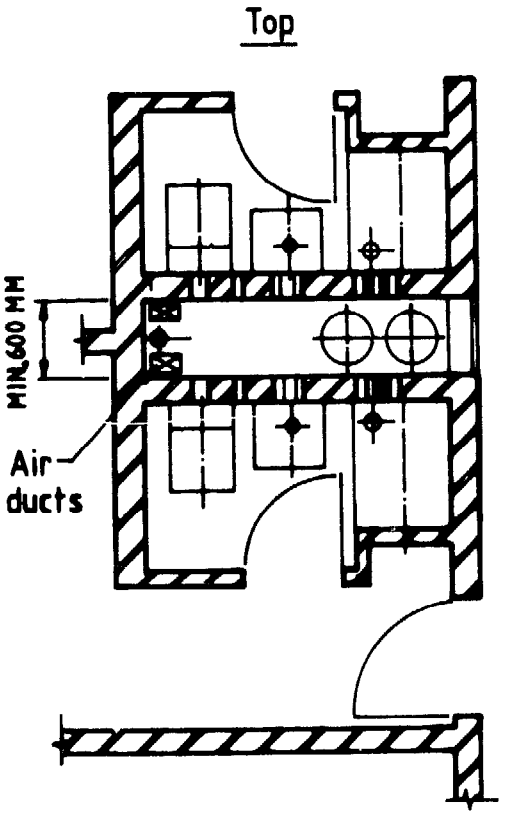

Principle Requirements to Shafts

1. To remain always easy accessible
2. Sufficient in width, min. 600 mm
3. Light provision (at least one socket)
4. Strong walls, so that water heaters can also be fixed.
5. Keeping all openings, until the pipes are fixed.
6. Apparatus to be fixed with its back towards the walls of the shaft (easy and economical pipe fixing).
7. If possible, keep floor level approx. one step lower; this facilitates the installations and accessability of siphons of shower trays and bath tubs.
8. Each room must have sufficient hot water, either by having it's own electric water tank, or through a central hot water system.

Caution
All openings in the floors have also to be sealed after completion of the installation works, for reasons of fire safety !

LAYOUT, EXAMPLE

TABLE 3/15

LAYOUT AS REALIZED IN A HOTEL. INSTALLATION IN SHAFTS FACILITATES WORKS AND MAINTAINS EASY ACCESS FOR REPAIRS.

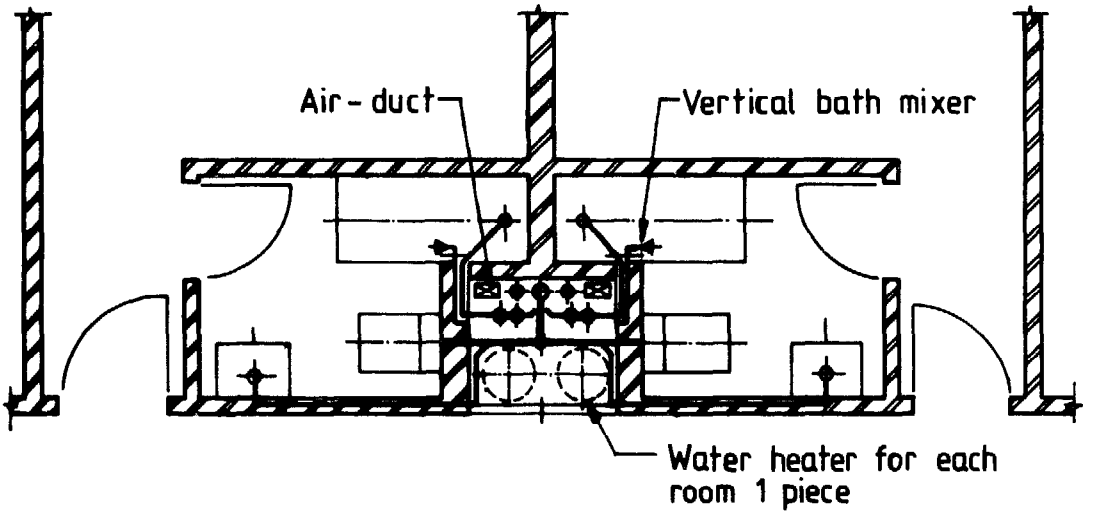

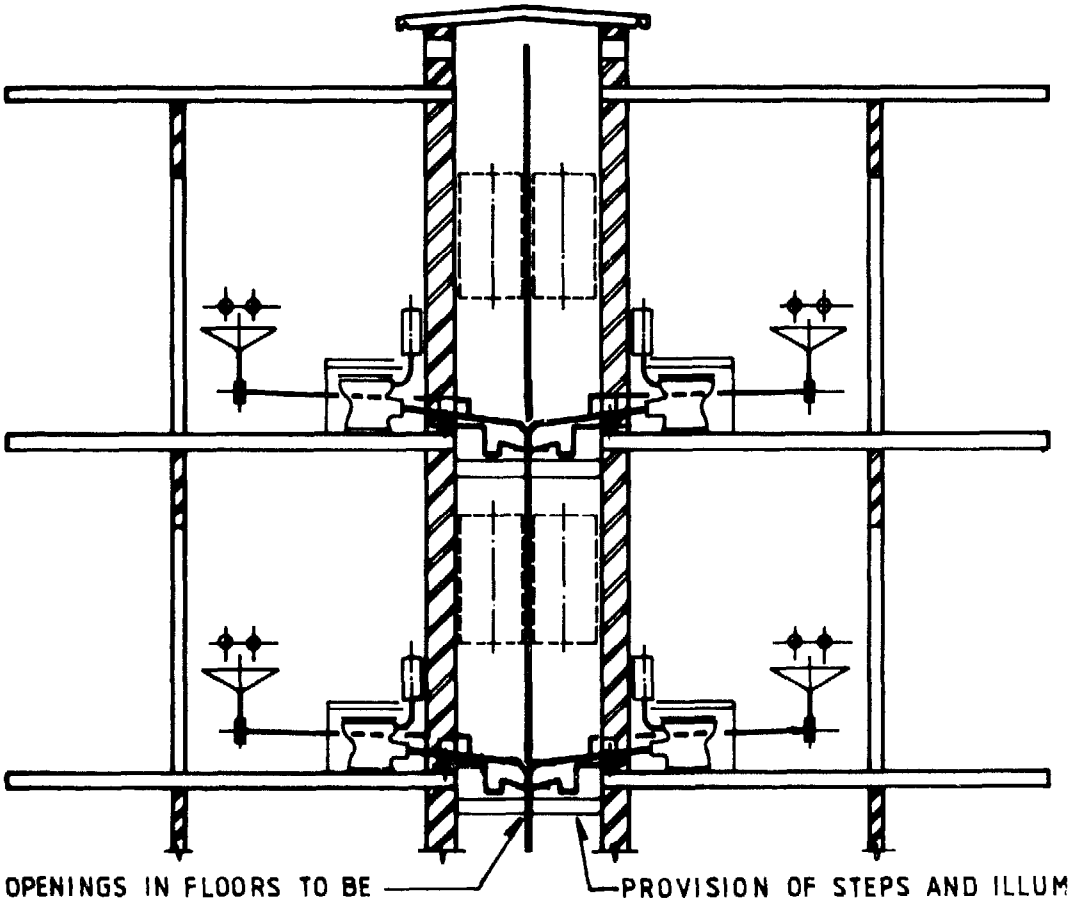

OPENINGS IN FLOORS TO BE SEALED AFTER COMPLETION FOR REASONS OF FIRE SAFETY

PROVISION OF STEPS AND ILLUMINATION ALREADY DURING CONSTRUCTION TIME.

LAYOUT, EXAMPLE

TABLE 3/16

TYPICAL BATHROOM REQUIREMENTS IN A HOTEL PIPELINES ARE FITTED IN A SHAFT AND REMAIN EASILY ACCESSABLE FOR REPAIRS AND MAINTENANCE.

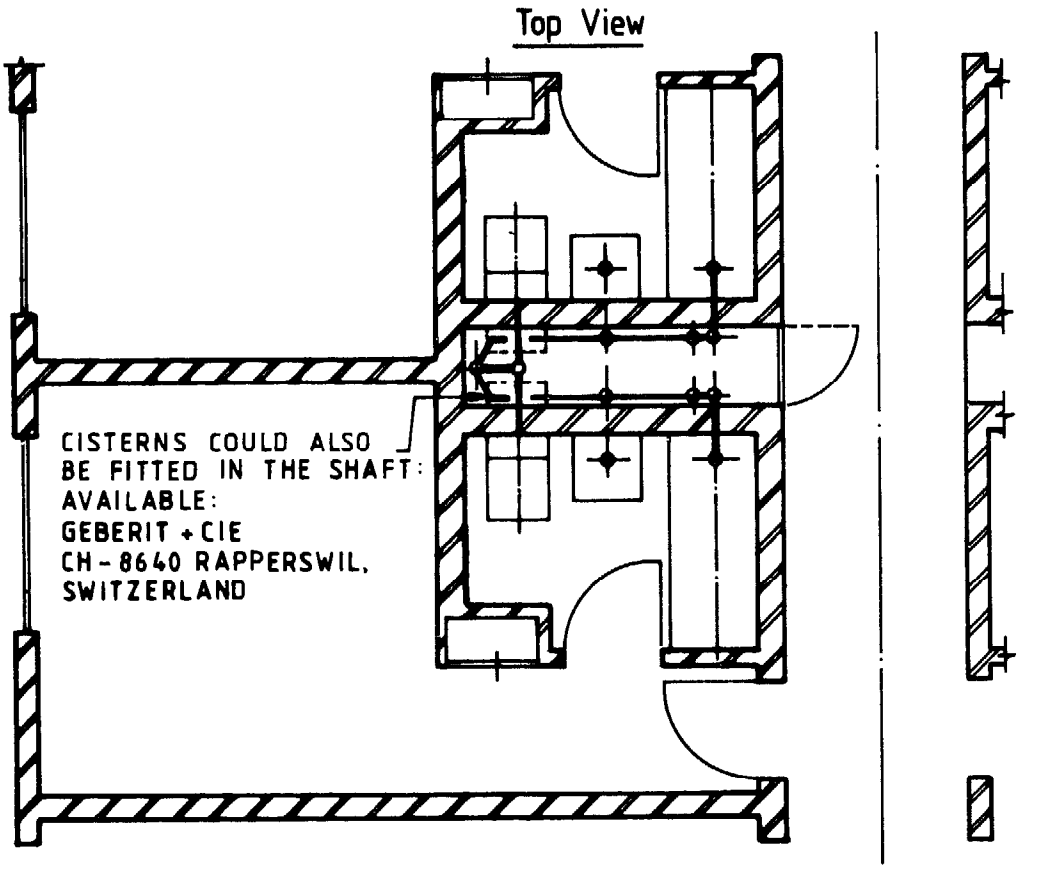

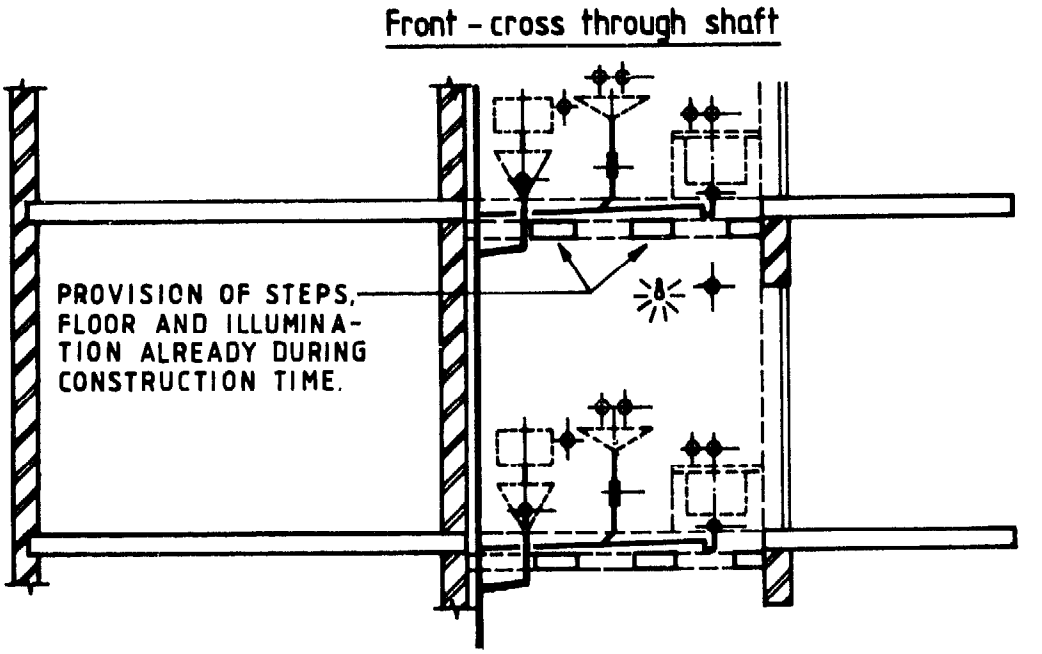

SYMBOLS **TABLE 3/17**

FOR MECHANICAL INSTALLATIONS IN BUILDINGS

Scope: These symbols are valid for the following installations in buildings:
- Plumbing
- Heating
- Ventilating
- Air conditioning
- Refrigeration

SYMBOLS ARE DETERMINED ON THE BASE OF **I S O STANDARDS**. FOR UNIFORM PRESENTATION OF DRAWINGS OF INSTALLATIONS IN BUILDINGS.

1 BASIC + GENERAL SYMBOLS					
1 1 Basic Symbols					
1 11		Pipes	1 12		Direction of flow of pipe content (arrow)
1 13		Control valves Stop valves (i.e. gate valves, butterfly valves)	1 14		Apparatus (without rotating parts)
1 15		Apparatus (without rotating parts)	1 16		Indicating and recording instruments
1 2 General Symbols					
1 201 Pipes					
1		Pipe	2	XX XX	Contents of pipe : Method A : Designation by printing the nature of contents above or in the line
3		Contents of pipe : Method B : Designation by different lines (example on the left)	4	*	Contents of pipe : Method C : Designation by coloured * lines according to the colour code used in the industries
5		Direction of flow of pipe content (arrow)	6		Duct
7		Crossing of two pipes without connection	8		Crossing of two pipes with connection

1 201		Continuation (General symbols)			
9		Branching pipe (Tee)	10		Pipe with slope
11		Flexible pipe	12		Insulated pipe
13		Heated pipe	14		Pipe with heating or cooling jacket
1 202		Pipe shown in plan			
1		Change of level in the same level	2		Pipe going through
3		Pipe going down	4		Pipe going up
5		Indication of levels / = highest level			
1 203		Pipe connections			
1		Pipe socket	2		Flanged connection
3		Screwed connection union	4		Pipe coupling
5		Centric reduction	6		Excentric reduction (above)
7		Excentric reduction (below)			
1 204		Expansion joints			
1		Expansion joint (general)	2		U - bend

1 204		Continuation (Expansion joints)			
3		Slip joint	4		Bellow expansion joint (axial)
5		Bellow expansion joint (lateral)			
1 205		Supports			
1		Anchor point	2		Sliding support
3		Pipe support	4		Pipe hanger
5		Pipe hanger with spring	6		Sliding pipe hanger
7		Sliding pipe, hanger with guides	8		Rolling pipe support
1 206		Stop valves			
1		Valve (general)	2		Angle valve
3		3 Way valve	4		4 Way valve
5		Valve	6		Gate valve
7		Stop cock	8		Pressure reducing valve
9		Non return valve (check valve)	10		Spring operated safety valve
11		Weight operated safety valve	12		Butterfly safety valve

1 206		Continuation (Stop valves)			
13		Butterfly stop valve	14		Butterfly check valve
15		Butterfly throttling valve	16		Pipe vent
17		Funnel	18		Sight glass
19		Steam trap	20		Strainer
21		Water meter			
1 207		**Apparatus**			
1		Apparatus without rotating parts (with exact description)	2		Apparatus with rotating parts (with exact description)
3		Pump	4		Fan
5		Compressor	6	M	Motor
1 208		**Measuring and sensing element**			
1		Measuring point	2		Temperature sensing element
3		Pressure sensing element	4		Flow sensing element
5		Humidity sensing element	6		Level sensing element
7		Built - in measuring device	8		Measuring orifice (measuring nozzle)

1 208		Continuation (Measuring and sensing element)			
9		Flow limiting device	10		Indicating device
11		Recorder			
1 209		Transmitters and controllers			
1		Transmitter	2		Controller
1 210		Drives			
1		Manual drive	2		Automatic drive (with auxiliary energy)
3		Direct drive	4		Weight operated drive
5		Float operated drive	6		Spring drive - operated
7		Piston drive operated	8		Diaphragm drive operated
9		Solenoid drive operated	10		Motor drive
1 211		Sources of energy			
1		Solid fuel	2		Liquid fuel
3		Gaseous fuel	4		Electric power
1 212		Heat meter			
1		Mechanical heat meter			Heat meter with electronic integration

2 PLUMBING SYMBOLS 2.1 Sanitary Fixtures	Connecting Values			
	Soil+waste water		Drinking water	
	Siphon	S- value	Valve	Units
1 Bath tub 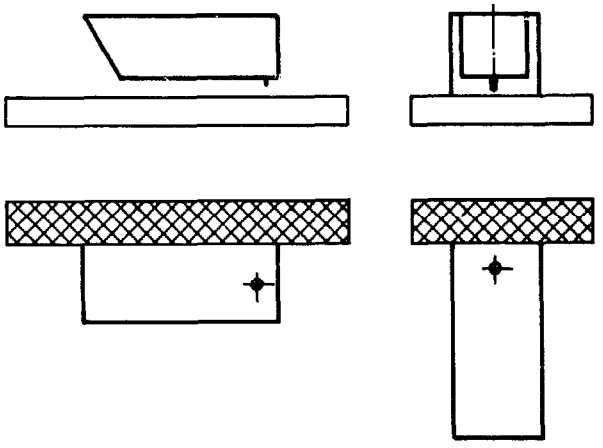	5/4 × 50 (or 57)	1	1/2"	2.0
2 Shower 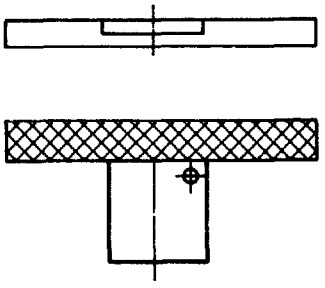	$1\frac{1}{2}$" × 50 (or 57)	1	1/2	2.0
3 Lavatory (wash basin) 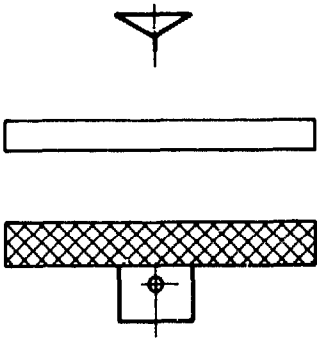	5/4 × 40 (or 32)	0.5	1/2	0.5

2 PLUMBING SYMBOLS (CONTINUED) 2.1 Sanitary Fixtures	Connecting Values			
	Soil+waste water		Drinking water	
	Siphon	S- value	Valve	Units
4 Bidet	5/4 x 40 (or 32)	0.5	1/2	0.5
5 Water closet, low tank	100mm	2.5	1/2	0.5
6 Water closet, high tank	100mm	2.5	1/2	0.5

2 PLUMBING SYMBOLS 2.1 Sanitary Fixtures	Connecting Values			
	Soil + waste water		Drinking water	
	Siphon	S - value	Valve	Units
6a Water closet floor pan 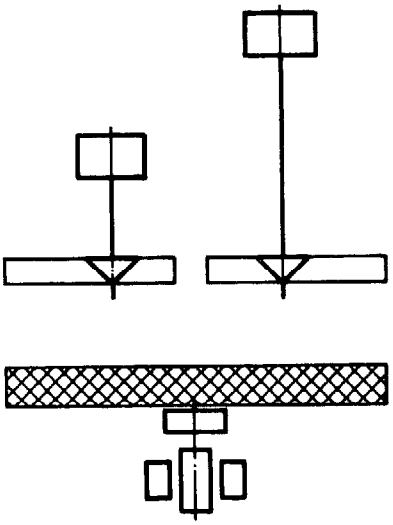	100 mm	2.5	1/2 Cleaning tap: 1/2	0.5 0.5
7 Water closet with tank built into wall 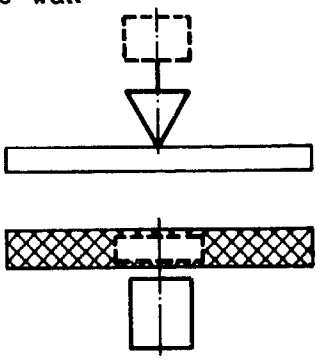	100 mm	2.5	1/2	0.5
8 Automatic water closet 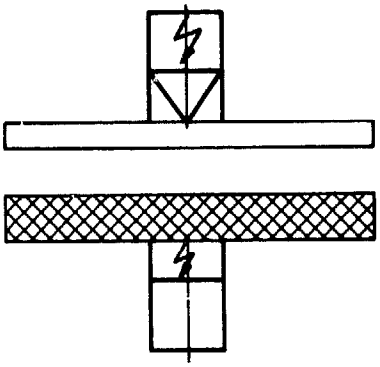	100 mm	2.5	1/2	0.5

2 PLUMBING SYMBOLS 2.1 Sanitary Fixtures	Connecting Values			
	Soil + waste water		Drinking water	
	Siphon	S-value	Valve	Units
9 Urinal, wall type 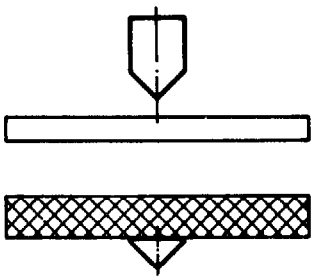	5/4 × 50 (or 57)	1.0	1/2	1.0
10 Service sink 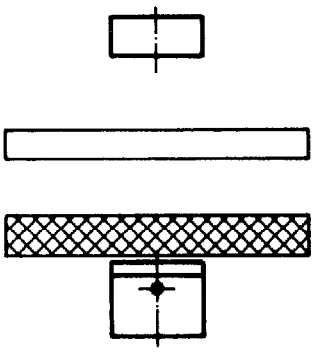	1½ × 50 (or 57)	1.0	1/2	1.0
11 Laundry trough 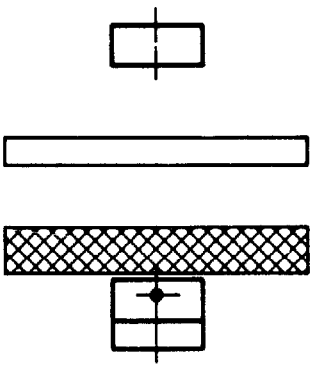	1½ × 50 (or 57)	1.0	1/2	1.0

2 PLUMBING SYMBOLS (CONTINUED) 2.1 Sanitary Fixtures	Connecting Values			
	Soil+waste water		Drinking water	
	Siphon	S-value	Valve	Units
12 Wash sink 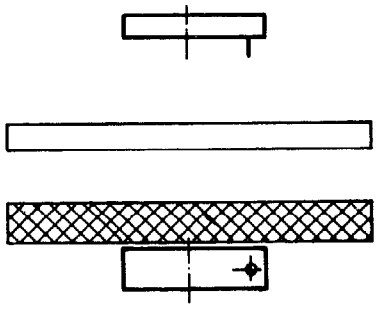	$1\frac{1}{2}$ × 50 (or 57)	1.0	1/2	1.0
13 Wash fountain 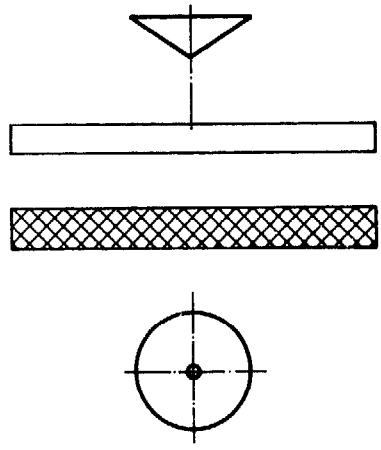	$1\frac{1}{2}$ × 50 (or 57)	1.0	1/2	1.0
14 Single kitchen sink with drain board 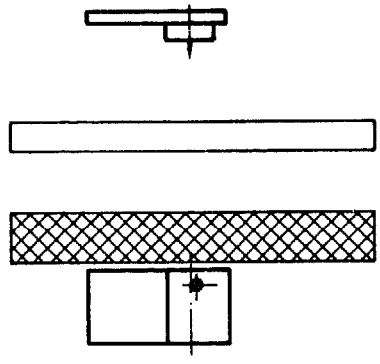	$1\frac{1}{2}$ × 50 (or 57)	1.0	1/2	1.0

2 PLUMBING SYMBOLS (CONTINUED) 2.1 Sanitary Fixtures	Connecting Values			
	Soil + waste water		Drinking water	
	S phon	S-value	Valve	Units
15 Double kitchen sink with drain board 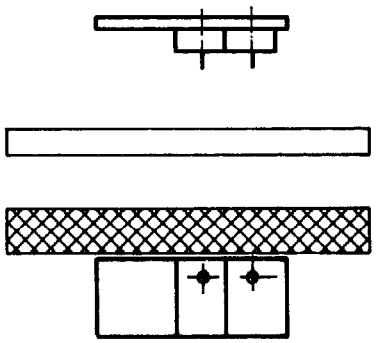	$1\frac{1}{2}$ × 50 (or 57)	1.0	1/2	1.0
16 Washing machine 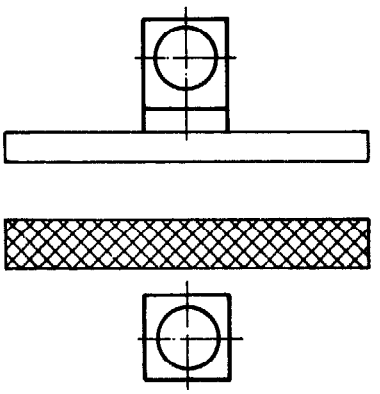	$1\frac{1}{2}$ × 50 (or 57)	1.0 up to 6kg	1/2	2.0
17 Clothes dryer (tumbler) 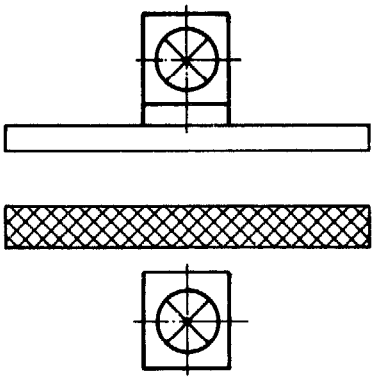	N. A	N. A.	N. A.	N. A.

2 PLUMBING SYMBOLS (CONTINUED) 2.1 Sanitary Fixtures	Connecting Values			
	Soil+waste water		Drinking water	
	Siphon	S-value	Valve	Units
18 Centrifugal dryer (electric)	5/4 × 40 (or 32)	0.5		
19 Water heater	Probably safety valve drainage	nil	As per total connected units of hot water taps	
20 Gas water heater	N.A.	N.A.	Gas: Valve / m³/h As of indications on apparatus.	

2 PLUMBING SYMBOLS (CONTINUED)	Connecting Values			
	Soil+waste water		Gas	
2.1 Sanitary Fixtures	Siphon	S-value	Valve	m^3/h
21 Gas cooker 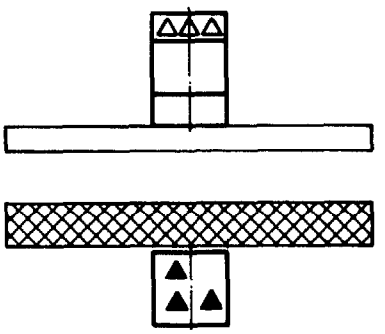	N.A.	N.A.	1/2	as of indication on apparat.
22 Automatic dish washer 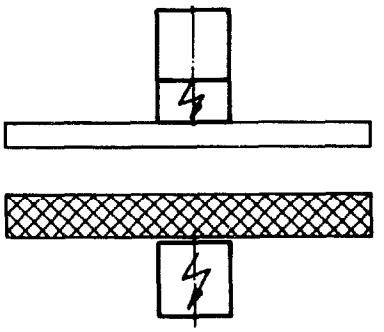	by hose pipe into kitchen sink siphon	not to be counted for, if fitted into sink siphon		
	otherwise:			
	$1^1/2 \times 50$ (or 57)	1.0		

Drinking water	
Valve	Units
1/2	1.0

2 2		Valves			
1		Bib cock	2		Mixing valve
3		Compact mixing valve	4		Mixing valve with regulator
5		Hose bib	6		Bib cock with bypass and hose connection
7		Twin regulator valve	8		Mixing valve with bypass
9		Pillar tap	10		Mechanical mixer
11		Thermostatic mixer	12		Mechanical mixer with manual valves
13		Thermostatic mixer with manual valves	14		Mechanical mixer with regulator and manual valves
15		Thermostatic mixer with regulator and manual valves	16		Mechanical mixer with bypass
17		Thermostatic mixer with bypass	18		Shower

2 3	Drainage elements		
2 31	Pipes		
	Plan	Elevation	
1	—WAR—		Clear waste water
2	—WAR-R—		Storm sewer

SYMBOLS **TABLE 3/31**

2 31			Continuation (Pipes)
	Plan	Elevation	
3	—WAS—		Sanitary sewer
4	—WAI—		Industrial sewer
5	—V—		Vent pipe
2 32			**Pipe fittings**
1			Pipe socket Pipe coupling
2			Pipe end with clean out
3			Clean out
4	125 100	100 125	Reduction ; centric
5	125 100	125 100	Reduction ; excentric
7			S - Trap
8			Bottle trap
9			Horizontal trap

2 32			Continuation (Pipe fittings)
	Plan	Elevation	
10			Floor sink without bottle trap
11			Floor sink with bottle trap
2 33			**Collector, separators, wells, pumps**
1	S		Collector (sludge separator)
2	F		Grease trap
3	A		Mineral oil separator
4	SP		Fuel oil lock
5			Double non - return lock
6			Control well (open system)
7			Control well (closed system)
8			Sump pump (not for raw sewage)
9			Pump for sanitary waste. vented

SYMBOLS FOR HEATING INSTALLATIONS

3 1 Boilers

1		Boiler for solid fuel	2		Boiler for liquied fuel
3		Boiler with fan assisted gas burner	4		Gas fuelled flow - heater with atmospheric burner
5	120	Dual fuel boiler vertical hot water storarage tank mounted on top (capacity e. g. 120 litres)	6	100	Oil fired boiler with hot water storage tank (horizontal) mounted on top (capacity e.g. 100 litres)
7	200	Gas fired boiler with hot water storage tank (vertical) mounted on side (capacity e.g. 200 litres)	8		Dual fuel boiler with hot water flow - heater

3 2 Storage heaters and heat exchangers

1	50 kw	Electric storage heater with ceramic core power : e. g. 50 kw	2	500 l 10 kw	Electric storage heater for water capacity : e.g. 500 litres power : e.g. 10 kw
3		Electrically heated flow type water hearer power : e.g. 5 kw	4		Horizontal water to water heat exchanger
5		Heat exchanger cooling the secondary circuit	6		Heat exchanger with co - axial tubes

3 2	Continuation (Storage heater and heat exchangers)				
7	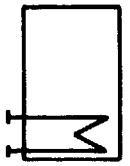	Vertical hot water tank with fixed heating coil at bottom	8	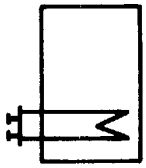	Vertical hot water tank with removable heating coil
9	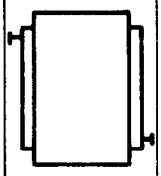	Vertical hot water tank with double jacket	10	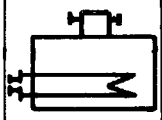	Horizontal water heated steam generator with removable heating coil
11	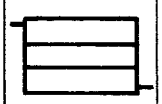	Water heater in several segments			

BASIC PRINCIPLES OF PLANNING AND DESIGN

The following rules are general guidelines which may be altered when necessary to suit particular circumstances.

Additional basic principles will arise out of practical experience.

1. For representation in the drawings use only official and common symbols.

2. Consider always that lines in a drawing represent pipe lines and that the space required for pipes must be allowed for.

3. The sanitary installations of a building are a complete functional unit made up of supply and waste disposal pipe lines (water, waste water etc.). For correct installation, pipelines and apparatus must be shown in their proper relationship to each other in all drawings (top view, schemata and detail drawing).

4. Drawings should be complete, containing sufficient information for making the material list and for execution on the site. There should be no need for further inquiry at the design office.

TOP VIEW DRAWING

1. The scale for top view drawings, is normally 1:50.

2. The dividing line of storys (floors) for drawing in pipelines is top of floor level up to top of ceiling level.

DIVIDING LINE OF STORYS

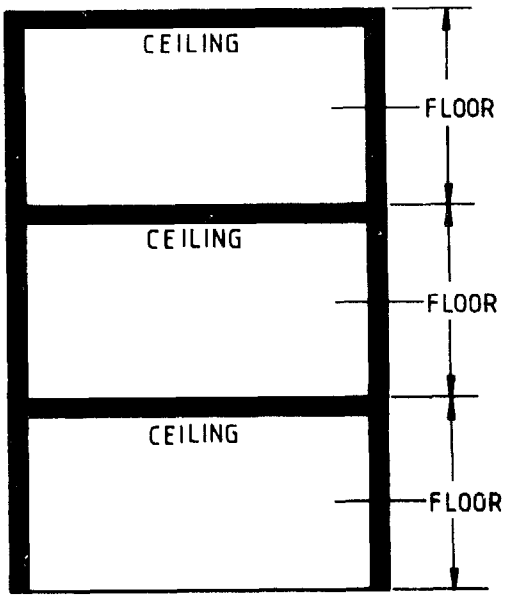

3. Before starting to draw in pipelines, study carefully all top view plans and all building cross section drawings. A better knowledge of the building and of all its constructional details results in a faster execution and conformation of the pipe layout.

4. Preferably start the design from top to bottom (top floor to basement) and prepare a separate layout for each different apparatus group.

5. After the draft is completed the final design of the pipelines should be made in coordination with other installations (e.g. electrical, air condition etc.).

TOP VIEW

EXAMPLE 1

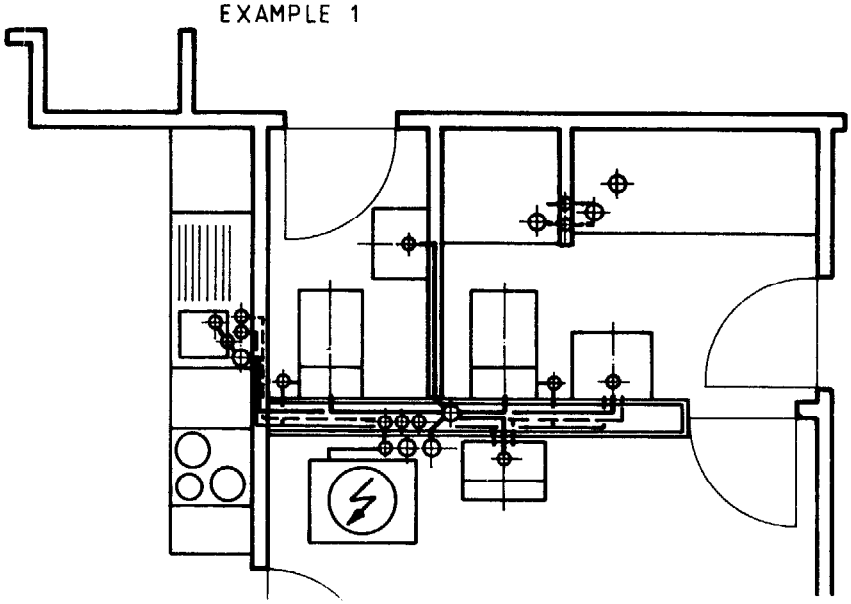

EXAMPLE 2

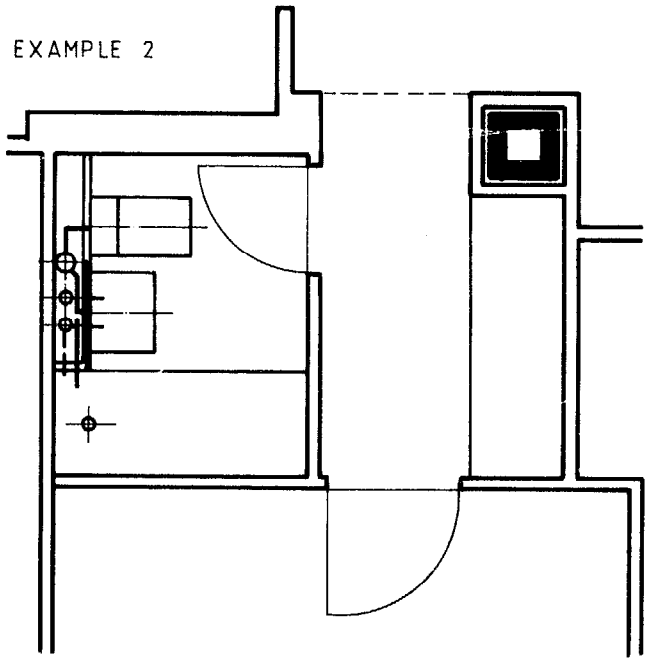

SCHEMATIC DRAWING

1. A representation of all installation parts in a three dimensional room is no: possible on a 2-dimensional drawing therefore the best possible solution should be chosen.

2. A schematical drawing is made primarily to show the pipelines. Items of apparatus are of secondary importance and show for what purpose at which height, and how the pipes are connected to them.

3. The representation of the total pipe system should whenever possible be drawn acc. to the top view drawings of the architects. For example, where installation parts in the top view drawing are on the left side they should also be shown on the left side of the schematic drawing.

   When items of apparatus in the plan view drawing are on top of each other (e.g. first floor, second floor) they should be drawn in same way in the scheme.

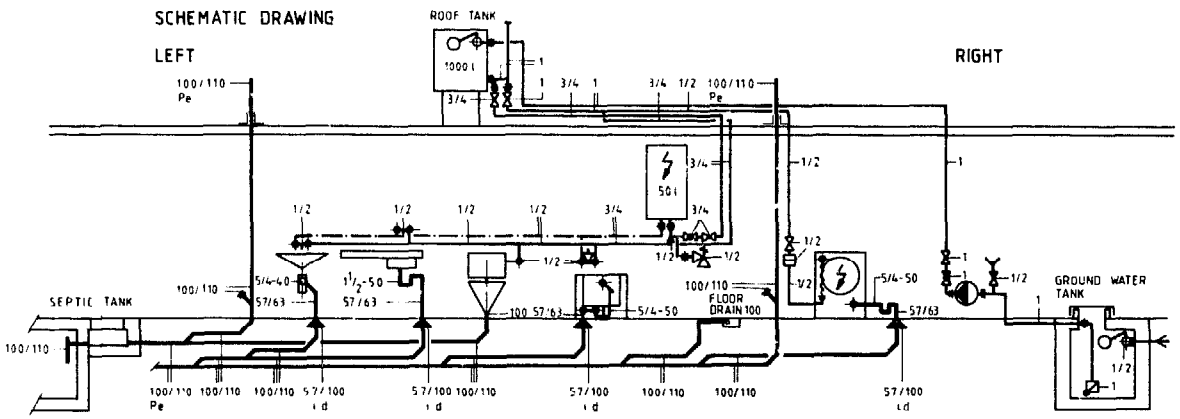

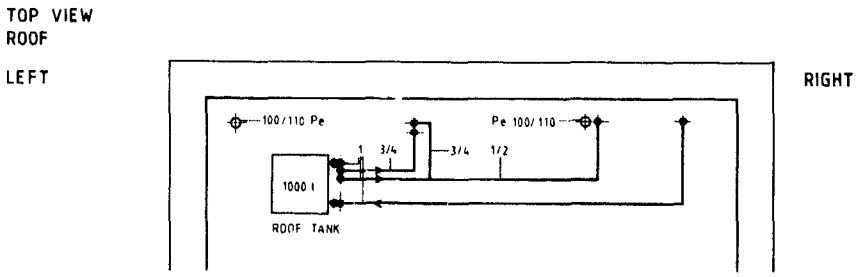

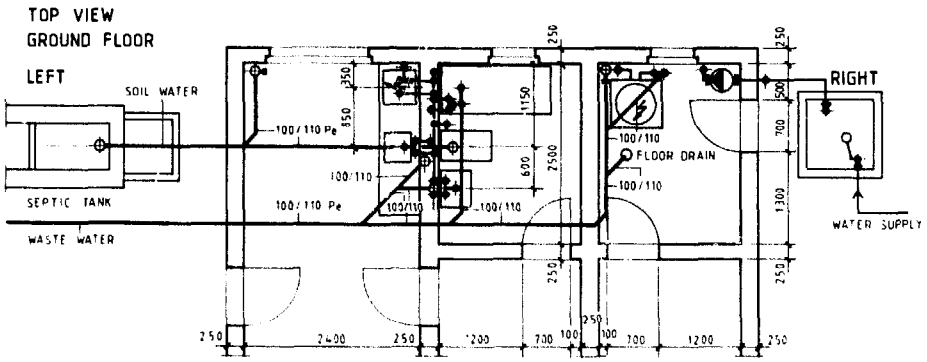

4. In all drawings pipelines should be represented in the same way as they later will be installed on the site. This applies for individual rooms as well as for the branches and tees.

5. In cases where apparatus is fitted on both sides of a wall, the development of the schematic drawing starts from the point where the pipes will be fitted. The view should, therefore, be from the wall on which the pipes are fitted (regardless of which wall has most apparatus).

6. The items of apparatus must be shown in order of their pipe connections (as they will be fitted at the building site). Apparatus fitted on the back of the wall will be drawn as it would be seen from the front. The same applies to the water connection pipelines. For mixing taps the cold water connection shall always be drawn on the right side, and the warm water connection on the left side.

SCHEMATIC DRAWING

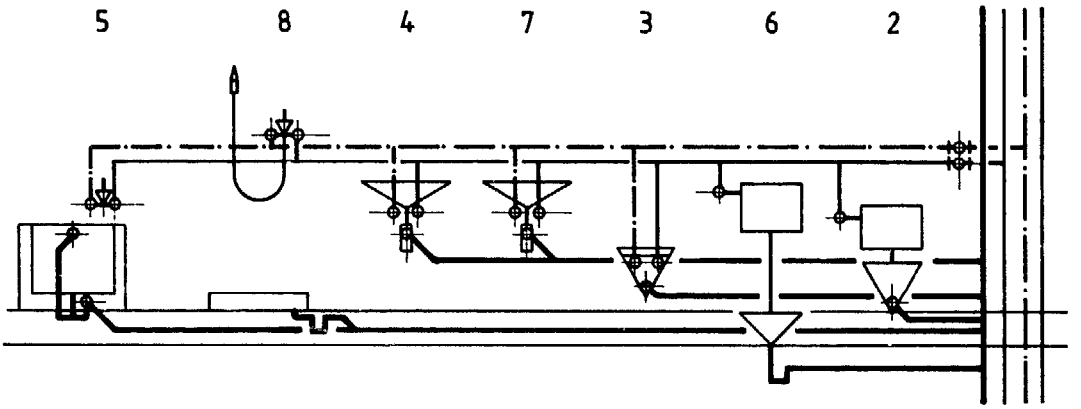

TOP VIEW

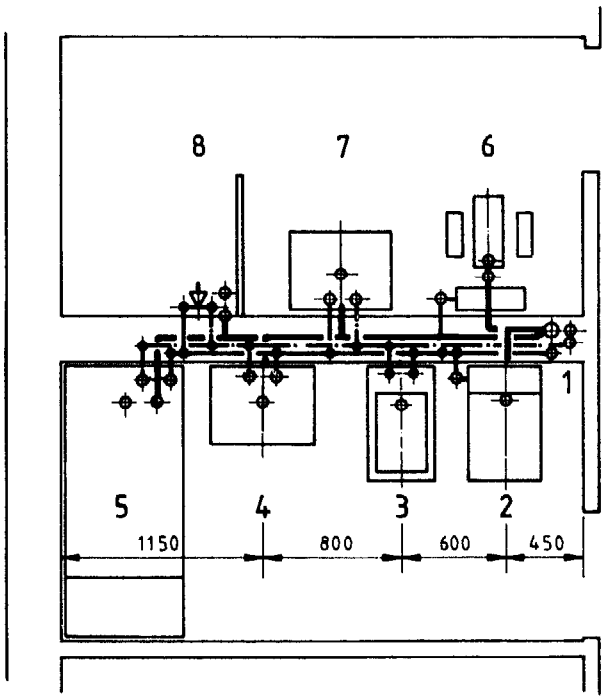

7. The order of branches (waste water) and of tees (cold-, hot water), in the schematic drawing has to correspond with the order shown in the top view.

8. The height for fixing of apparatus, valves (armatures) and connecting places shall be to scale 1:50. The drawing of increased heights of storys should be avoided if possible (especially in cases where a greater concentration of pipes in basements may occur).

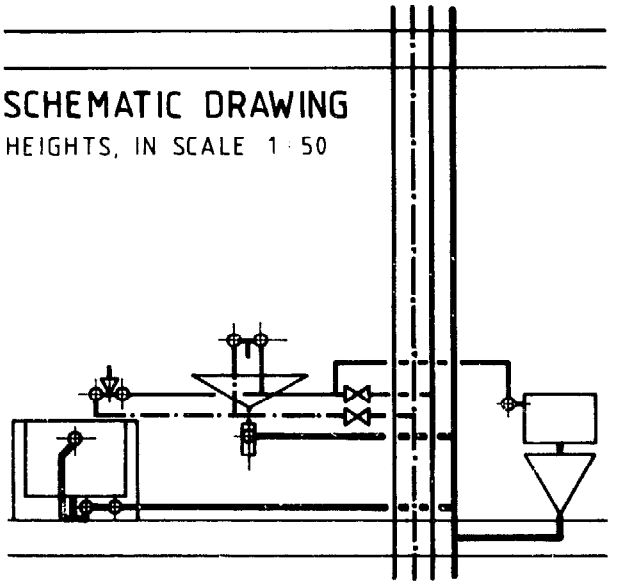

9. The sizes of all parts of valves and parts of water and gas pipelines must be given. When the connector pipe for the tap has the same dimension as the tap itself, it is not necessary to mention separately the dimension of this pipe.

   Indications of dimensions shall be made in letters of sufficient height. Lines of reference to pipes should be of short distance.

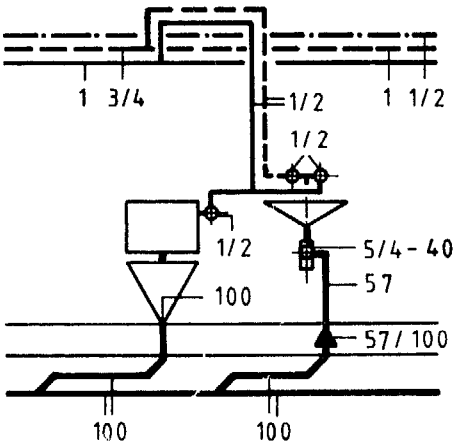

For soil and waste water pipelines sizes must be given for :-

- all pieces of pipe between each branch,
- apparatus connectors, siphons, cleaning openings, reducers and connections to the ground pipeline.

The minimal inside diameter in mm (e.g. 100, 57, 44) or both inside/outside dia. (e.g. 100/110, 57/63, 44/50) should be indicated in letters of sufficient height.

Shifting of the axis (offsets) of leaders must be shown in the schematic drawing.

SCHEMATIC DRAWING

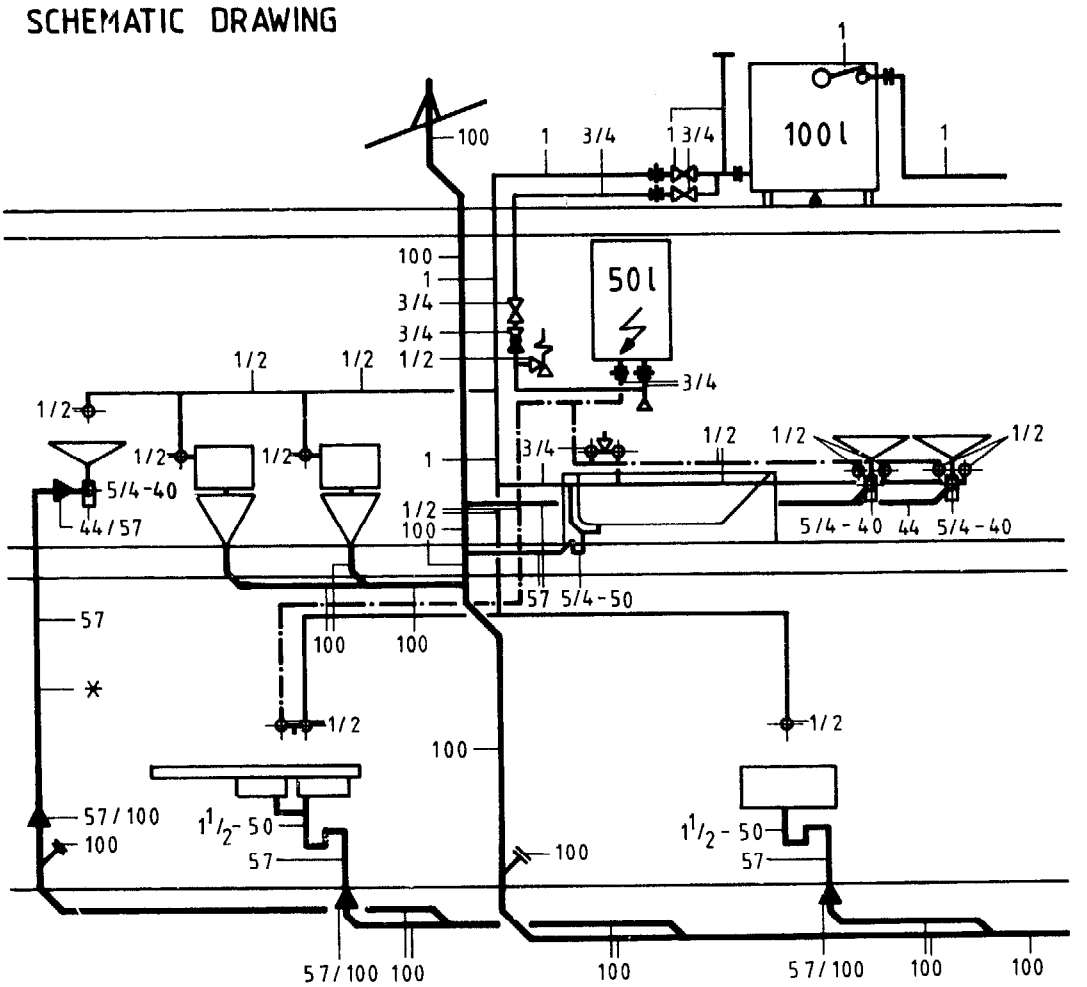

LEGEND:

COLD WATER

HOT WATER

SOIL / WASTE WATER

* SEE PARA 7.760 VAR 3

DIMENSION OF WASTE WATER PIPES = MINIMAL INSIDE DIA.

DETAIL DRAWING

There are many different stages of planning, from the very first thoughts up to the execution of an installation. One part of the planning is the detailed drawing which itself can have also different levels of detail.

A bathroom drawing can refer to :

Level 1: Roomsize, items of apparatus and their center to center distance.

Level 2: As above plus front view with the heights of the apparatus and the connections to the water and waste water system. The minimal space requirements of each individual item of apparatus may also be shown.

Level 3: Top and front view of a bathroom in scale 1:10, using symbolic design for the apparatus and pipelines. The pipelines should be drawn in a single pencil or ink line with all necessary information about material and dimensions of the pipes. Further it should include the center to center dimensions and (in the elevation) all measurements of the different levels (heights of the apparatus, pipes, etc.). (N.B. one measurement line only for one apparatus)

Only absolutely necessary measurements should be shown in the drawing. With all this information, it should be possible to prepare a pre-assembly drawing and a detailed material list.

1. All dimensions (measurements) of the pipelines and apparatus in the top view drawing should be given from one side only and never from both sides of the walls.

2. All measurements, including the center to center distance of the apparatus and the stack (vertical waste water pipe) take their reference measurement from the same wall (as do all others risers and connections to the apparatus).

DETAIL DRAWING

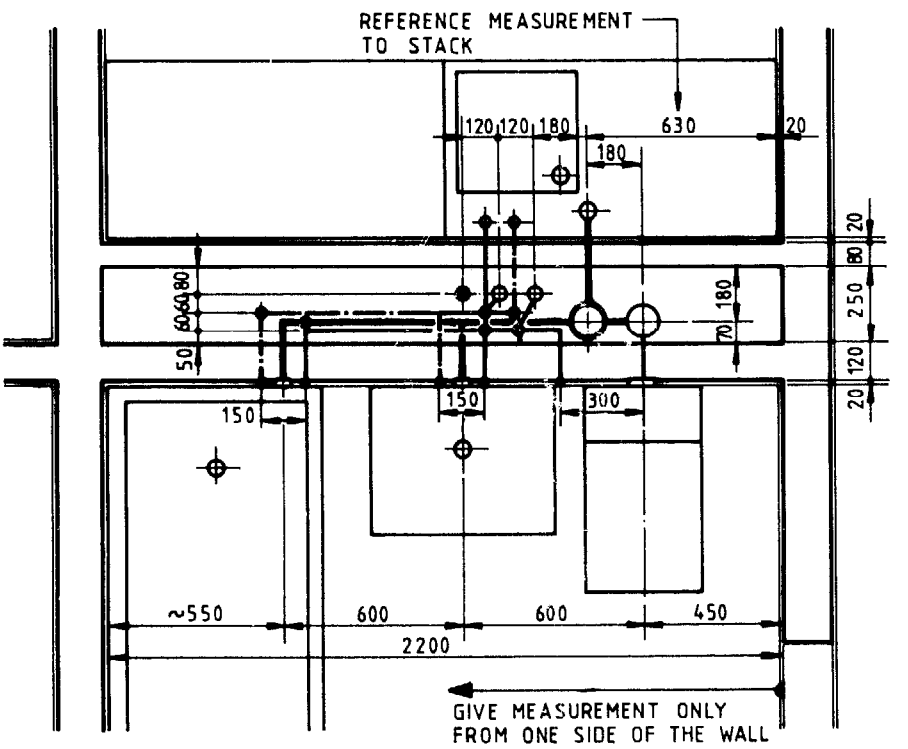

3. Consider when working out the disposition of the pipelines, that the execution at site must be possible with standard available fittings.

4. For the center to center distance of apparatus and for pipe connections use only standard measurements with consideration for minimal space requirements (see Table 3/11 - 3/13).

DETAIL DRAWING

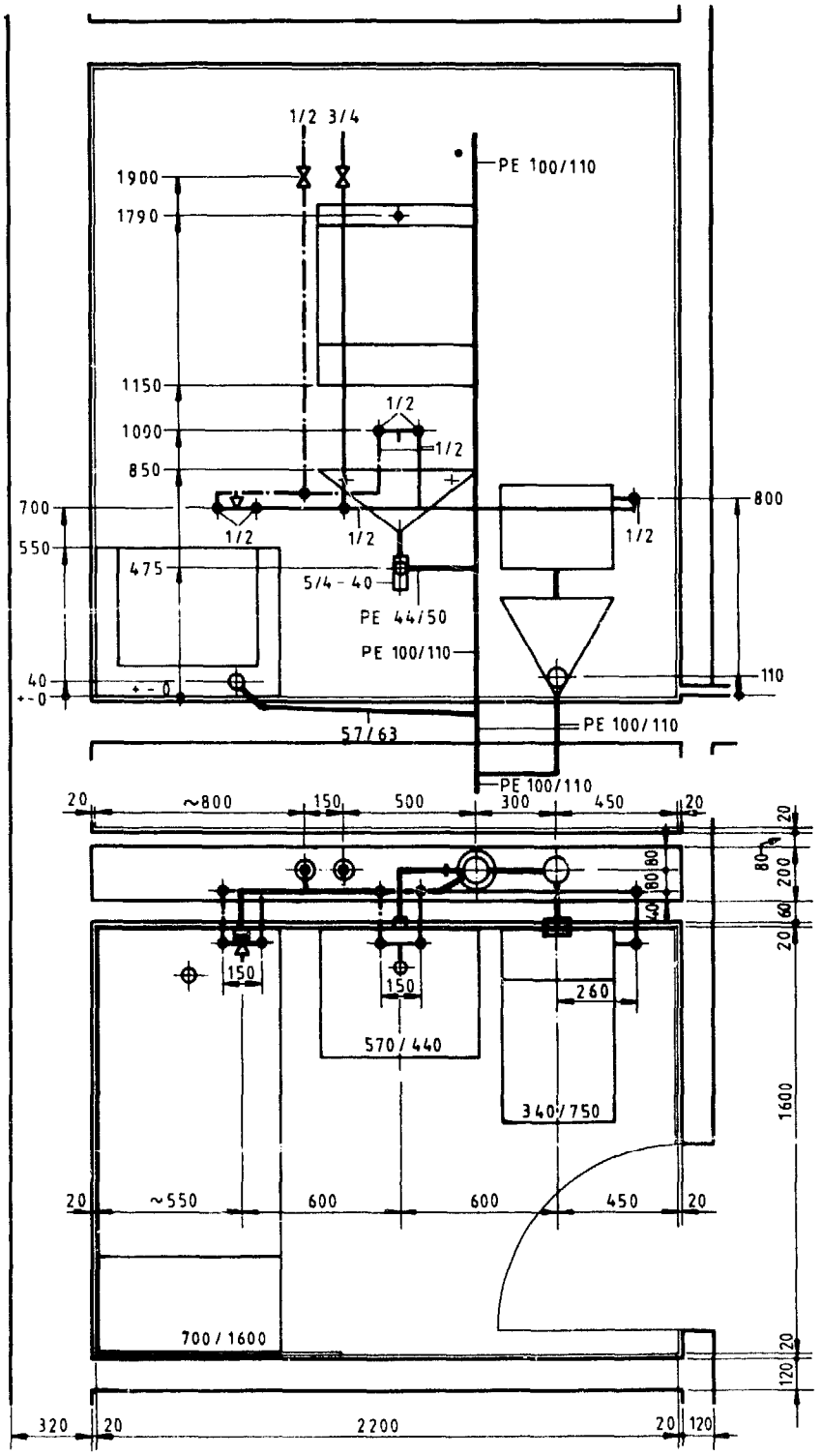

FIXATION OF PIPES EXAMPLES

All pipelines have to be fixed with adequate clamps, to hold the weights very well, (also when waste - lines are filled with water)
Materials: mild steel 2 - 3mm thick, galv or painted

Clamp, cement fixation

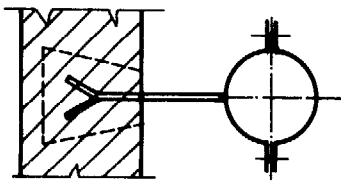

Clamp, fixation with dowel

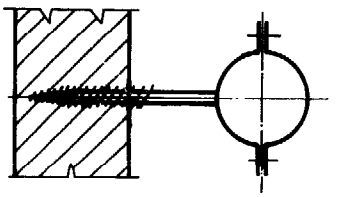

Clamp, with M. S. plate

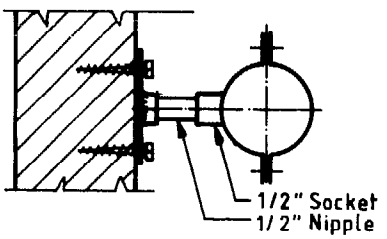

Carrier

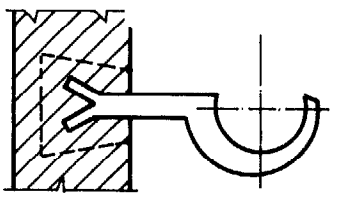

Bracket not recommended, there is no distance to the wall.

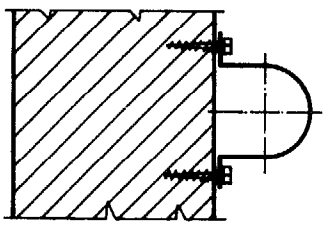

Hanger

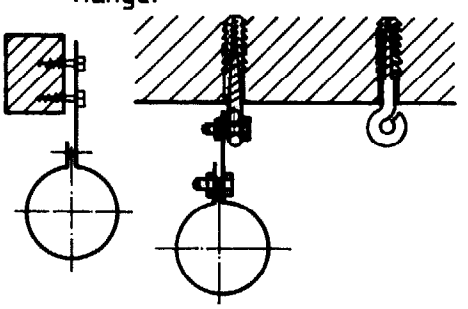

Front

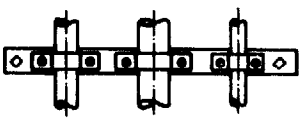

Top

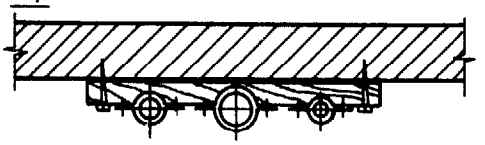

Combined system

might be usefull in installation shafts, but only where not exposed to outside conditions.

ABBREVIATIONS

i.d.	inner diameter
Ø	diameter
N.D.	Nominal diameter
mm	millimeter
cm	centimeter
m	meter
1	length
h	height
××2	square
××3	cubic
A	surface
"	inch
'	foot
I.S.	Indian Standard
I.S.O.	Intl. Standard Org.
C.O.	Clean out
C.P.	chrome plated
WC	Water closet
Vent	Ventilation
U	Unit/used for dimensioning of drinking water
SV	S-Value (Sewer value) used for dimensioning of soil and waste water
1/s	liters per seconds
N.A.	Not applicable
>	larger than
<	smaller than
≥	larger or same
≤	smaller or same
Σ	sum, total

Conversion table sheet metal

Thickness in I.S.W.G.	Thickness in mm
30	0.314
29	0.345
28	0.376
27	0.416
26	0.457
25	0.507
24	0.558
23	0.609
22	0.711
21	0.812
20	0.914
19	1.015
18	1.218
17	1.422
16	1.625
15	1.828
14	2.040
13	2.337
12	2.641
11	2.946
10	3.250

I.S.W.G = Imperial Standard Wire Gauge

DRINKING WATER DIMENSIONING

Table for dimensioning with units

A) For systems with roof tanks
(Head less than 40 meters)

LOADING VALUES AND DIAMETERS (G.I. PIPES)	
PIPE DIAMETER IN INCHES	MAX. LOADING IN UNITS
1/2	0.5 - 2.0
3/4	2.5 - 4.0
1	4.5 - 10.0
$1^1/_4$	10.5 - 20.0
$1^1/_2$	20.5 - 40.0
2	40.5 - 100.0

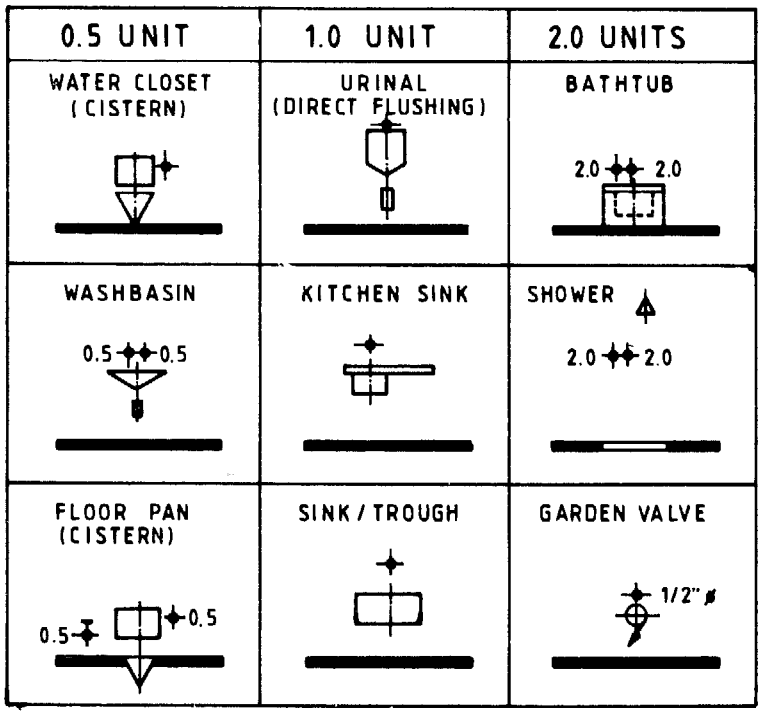

B) For systems with pressure
(Head above 40 meters)

LOADING VALUES AND DIAMETERS (G.I. PIPES)	
PIPE DIAMETER IN INCHES	MAX. LOADING IN UNITS
1/2	0.5 - 2.5
3/4	3.0 - 5.0
1	5.5 - 12.0
$1^1/_4$	12.5 - 25.0
$1^1/_2$	25.5 - 50.0
2	50.5 - 125.0

SOIL AND WASTE WATER DIMENSIONING

Leaders (stacks), Main vent system

stack	max. permitted numbers				permitted loading
	SV		WC		
i.d. in mm	Total	largest single SV	Total	per storey	Vs (1/s)
57	3 -1)	1.0	--	--	1.3
69	7	1.0	--	--	2.0
80	20	1.5	--	--	3.0
100	70	2.5	14	6	4.2
118	100	2.5	20	7	5.0
125	150	-	30	10	6.1
150	400	-	80	22	10.0

1) max. 2 apparatus at 1 SV.

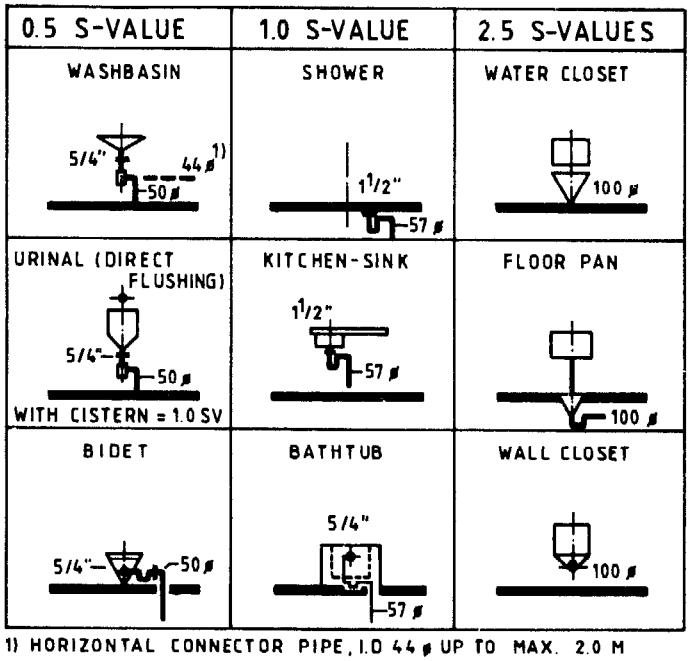

1) HORIZONTAL CONNECTOR PIPE, I.D 44 ø UP TO MAX. 2.0 M

Branch- and connector pipes, without secondary vent.

i.d. in mm	max. permitted numbers SV	largest single SV
50	1	0.5
57	2	1.0
69	3 -1)	1.5
80	6	1.5
100	15	2.5

1) max. 1 apparatus at 1.5 SV

FURTHER READINGS

1) **Code of practice for Plumbing**

Royal Government of Bhutan (NUDC/004/1984) issued under the authority of Chairman, National Urban Development Coproration, Thimphu, Bhutan (78 pages)

2) **Code of Practice for sanitary pipe work above ground for buildings.** (Indian Standard, 15:5329-1969)

Indian Standards Institution, Manak Bhava, 9 Bahadur Shah Zafar Marg, New Delhi -110 002

3) **"Plumbing"** - Periodical
The Institute of Plumbing,
64 Station Lane, Hornchruch / Essex RM12 1BR, U.K.

4) **Symbols for mechanical installations in buildings**
(German, French, Italian, English)
Schweiz. Ing.- und Architekten-Verein
Postfach, 8039 Zurich, Switzerland

5) **Water Installation and Drainage System**
by F. Hall, 1978
The Construction Press (Longman Group)
Lancaster, England

6) **Solar Water Heaters in Nepal / Manufacturing and Installations**
by A. Bachmann and H. Waldvogel
a publication by MTC/Nepal and SKAT/Switzerland
SKAT, Varnbuelstrasse 14, CH- 9000 St. Gallen, Switzerland

7) **PLUMBING SERVICES:**

Volume I	1982	Basic Skills, Water Supply
Volume II	1982	Waste Disposal, Roof Plumbing
Volume III	1986	Gasfitting
Volume IV	1986	Mechanical Services. Air Conditioning

by: R.J. Puffet and L.J. Hossack
McGraw-Hill Book company, Sidney
4 Barcoo Street, Roseville, NSW 2069, Australia

8) **MATHEMATICS - PLUMBERS AND PIPEFITTERS**
by: Bartholomew D'Arcangelo, et al.
DELMAR PUBLISHERS INC., USA, 1968
(Library of congress Catalog Card No: 68-29997)

9) **PLUMBING AND HEATING**
by: F. Hall (reprinted 1981)
The Macmillan Press, Ltd, London and Basingstoke

10) **HOME PLUMBING**
by: F. Hall (reprinted 1983)
David and Charles (Publishers) Newton Abbot, London

11) **PLUMBING - HOT WATER SUPPLY AND HEATING SYSTEMS**
by: F. Hall
Longman Scientific & Technical, Longman House, Burnt Mill, Harlow, Essex CM20 2JE, England

FURTHER PUBLICATIONS ON THIS SUBJECT IN SKAT'S BOOKSHOP

ENVIRONMENTAL HEALTH ENGINEERING IN THE TROPICS: AN INTRODUCTORY TEXT, S. Cairncross and R. Feacham
1983, 283 pp., SFr. 49.- (Bookshop 36048e)
Handbook dealing extensively with a large number of infectuous diseases which can be controlled by environmental intervention. Covers: health and pollution; water supply; excreta treatment etc.

A HANDBOOK OF GRAVITY-FLOW WATER SYSTEMS, T.D. Jordan JR.
1984, 250 pp., SFr. 18.- (Bookshop 34008e)
Originally written for systems in Nepal, most principles presented are applicable in locations all around the world. The materir' is organized for quick reference.

DRINKING WATER SUPPLY - TECHNICAL ASPECTS, K. Wehrle
1985, 177 pp., SFr. 20.- (Bookshop 34030e)
Description of all technical aspects of drinking water supply and sanitation projects.

VILLAGE WATER SUPPLY IN THE DECADE, LESSONS FROM FIELD EXPERIENCE, C. Glennie,
1983, 152 pp., SFr. 43.- (Bookshop 34031 e)
Gives a detailed account of a successful rural water supply programme in East Africa over a period of 10 years. Emphazises the role of management, organization and community participation.

GUIDELINES FOR DRINKING-WATER QUALITY, VOLUME I: RECOMMENDATIONS, WHO
1984, 130 pp., SFr. 38.- (Bookshop 32010e)
Provides a basis for the development of standards. May also be of assistance in developing alternative control, procedures where the implementation of drinking water supply is not feasible (also available VOLUME II: Health Criteria and other supporting information and VOLUME III: Drinking Water Quality Control in Small Community)

SIMPLE METHODS FOR THE TREATMENT OF DRINKING WATER, GATE
1985, 78 pp., SFr. 18.50 (Bookshop 36046e)
Manual with basic technical information on equipment, procedures and hints for planning and implementing water treatment projects.

HAND DUG WELLS AND THEIR CONSTRUCTION, S. Watt and W. Wood
1977, 253 pp., SFr. 15.- (Bookshop 32001e)
Provides practical step-by-step guidance in the techniques of digging and constructing a well: principles of groundwater storage, the actual construction, the materials required and details on additional sources of information.

GUIDELINES FOR PLANNING COMMUNITY PARTICIPATION IN WATER SUPPLY AND SANITATION, A. Whyte
1983, 60 pp., SFr. 5.- (Bookshop 34022)
Guidelines for planners on how to establish community participation in projects concerned with water supply and sanitation.

MANUAL FOR RURAL WATER SUPPLY, HELVETAS
1985, 175 pp., SFr. 34.- (Bookshop 34003e)
A guide on how to identify, plan, organise, and execute drinking water projects. With many elaborate scale drawings. Specially written for engineers and construction supervisors but serves also as a comprehensive introduction for non-technical readers (also available in french and spanish).

SLOW SAND FILTRATION FOR COMMUNITY WATER SUPPLY PLANNING, DESIGN, CONSTRUCTION, OPERATION AND MAINTENANCE, J.T. Visscher et al
1987, 149 pp, SFr. 20.-
Describes the principles and applicability of slow-sand filtration. Provides guidelines resulting from demonstration projects in developing countries.

HORIZONTAL-FLOW ROUGHING FILTRATION (HRF), A DESIGN, CONSTRUCTION AND OPERATION MANUAL, M. Wegelin
1986, 142 pp., SFr. 15 (Bookshop 35007e)
Technical manual addressed primarily to design engineers. Covers design, construction, operation and maintenance aspects. The content is based on laboratory tests and field experiences.

COMMUNITY WATER SUPPLY, THE HANDPUMP OPTION, S. Arlosoroff et al
1987, 202 pp, SFr. 26.40 (Bookshop 34034e)
Reference manual for policy makers and professionals. The critical elements of a handpump-based community water supply systems are discussed and analysed.

If you are interested in further publications on water supply or on appropriate technology please ask for our free bookshop catalogue; it lists all our titles for sale. Our Address: ***SKAT****, Varnbüelstr. 14, CH-9000 St. Gallen, Switzerland*

How to "remove ozone" from water

Summary:

- In municipal drinking water applications, removal of residual ozone in a contact system can be accomplished with the addition of hydrogen peroxide (H202). Known as ozone quenching,

- Aeration by cascade, packed column or air diffusion. This method strips off the ozone to the atmosphere, so proper controls and monitoring must be employed for safety and environmental reasons.

----

residual ozone destruction

http://www.ozonia.com/tips/residual_destruction.html

Ozone, when properly applied and dissolved at the required residual concentration in water, is a very powerful and effective oxidizing and disinfecting agent. Its properties destroy microbiological organisms and degrade many organic contaminants present in the water.

Ozone is preferred over conventional chemical agents because it is generated on site with limited storage or handling concerns. Additionally, residual dissolved ozone ultimately decomposes into oxygen, making it both process and environmentally friendly.

Ozonation is typically only one step in a chain of treatment processes. As such, it is often removed prior to subsequent unit processes for a variety of reasons.

Unlike bottled water, where a dissolved ozone residual reaching the bottle is desired (or even mandated), production of other beverages may require removal of dissolved ozone to prevent reactions with sweeteners, concentrates or other ingredients.

Similarly, in ultrapure water (UPW) applications, dissolved ozone is removed the majority of the time to prevent contact with ingredients and is periodically allowed to flow through process loops for CIP sanitization.

Municipal water treatment plants use ozone for a variety of reasons, such as, THM precursor control, *cryptosporidium* and *giardia* removal, taste, odor and color removal, general disinfection, etc. However, even here the dissolved ozone must be removed prior to the addition of chlorine used for water protection in the distribution system.

Destruction of residual ozone is therefore essential in these and other applications before the ozonated water can be utilized or continue in the treatment process.

The following are some of the ways ozone destruction can be effectively accomplished:

- In purified water systems (UPW for example), strategic placement of properly designed and sized medium pressure ultraviolet (UV) ozone destruction equipment

simply and effectively reduces residual ozone to below detectable levels with the additional benefit of TOC destruction. Positioning a UV ozone destruction unit directly before the water treatment components requiring protection from ozone (i.e. DI polishing) maximizes the sanitizing benefits provided by residual ozone up to that point. When loop sanitizing is desired, the UV is simply turned off and any sensitive process step is bypassed for a brief period of time. Medium pressure UV systems in UPW also offer the added benefits of TOC destruction and act as "back-up sanitizers" to ozone.

- In municipal drinking water applications, removal of residual ozone in a contact system can be accomplished with the addition of hydrogen peroxide (H202). Known as ozone quenching, this step is important during plant start-up, performance testing or in general when ozone equipment has to be operated to meet CT criteria and then followed by addition of chlorine or other chemicals.

Other methods used to remove ozone from water include:

- Aeration by cascade, packed column or air diffusion. This method strips off the ozone to the atmosphere, so proper controls and monitoring must be employed for safety and environmental reasons.
- Filtering to water through activated carbon adsorbs the dissolved ozone on the carbon and adds the removal benefit of carbon in general. This technique can be employed where water quality is less than ultrapure and the carbon can actually contaminate the water.

For more information on this or other ozone and UV related topics, contact your nearest Ozonia office.

http://www.nesc.wvu.edu/ndwc/pdf/OT/TB/TB12_ozone.pdf

mutagenicity

ozone water "carbon filter" reaction

http://www.water-research.net/ozone.htm

15 watt water ozinator for 150$
http://www.maxximastyle.com/Merchant2/merchant.mvc?Screen=PROD&Product_Code=Ozonator&Category_Code=&gclid=CLKV5Z6lwY4CFRnwYAodsVxigQ

http://www.wwdmag.com/Ozone-Treatment-for-Residential-Well-Water-article4119

Ozone Treatment for Residential Well Water

Terms & Conditions of Use

Tech Update

Your customers not only are expecting to have enough water supplied from their water source, but they also demand that it is of superior quality. Ozone's technology coupled with such treatment as filters or softeners can fulfill this expectation. Ozone does not need to be complicated in order to treat small water systems.

- Myrle Melligan, Triple O Systems, Inc.

Ozone does not need to be complicated in order to treat small water systems. A small water system consists of one or multiple households on well, spring or rooftop water. Treatment means removal of iron, manganese and hydrogen sulfide to below the U.S. Environmental Protection Agency (EPA) acceptable levels including bacterial control.

Ozone consists of three atoms of oxygen (O3) and is a powerful oxidizer and disinfectant. It must be generated on site since it reverts to oxygen (O2) within minutes. Ozone, which works faster and is more powerful than chlorine, adds nothing to the water except pure oxygen. Chlorine, on the other hand, can produce a carcinogenic byproduct called trihalomethanes (THMs) when combined with organic matter found mostly in surface waters. Its objectionable odor is another disadvantage to those who expect their well or spring water to taste and smell sweet and natural.

In traditional applications, ozone is produced by the corona or high voltage spark method. In order to be effective, the corona-type ozone requires a dry filtered air. Its longevity depends on this because moisture creates nitric acid, thus decreasing ozone output and corroding the equipment. If the air dryer fails, so will the entire system. A corona ozone injection system uses lots of electricity, is complex and, therefore, not very reliable for the average homeowner or small system operator. In addition, applications of corona ozone must be done carefully as high concentrations of ozone literally can destroy common holding tanks and distribution systems. When using corona ozone, stainless steel tanks are recommended as well as an activated carbon filter to remove the excess ozone before the water enters the distribution system. This complicated corona method produces large amounts of ozone and uses a relatively short contact time with the water. For these reasons, corona ozone use is recommended for large commercial applications where it can be monitored on a consistent basis.

An alternative technology has been developed using small, safe levels of ozone produced by the ultraviolet (UV) light method. With this technology, low levels of ozone are continuously introduced into an atmospheric holding tank. If the approach to water treatment would be by injection or single pass, this method would be insufficient to perform its oxidation and disinfection tasks. Since this system bubbles ozone into the tank water 24 hours per day, it not only is extremely efficient but also cost effective due to its low energy consumption of 55 watts, lack of an air dryer and compatibility with tank materials.

Unique to this system is a filter module that is suspended on a stainless steel chain and actually filters the entire contents of the holding tank. The water moves through the 100-square-foot filter at 10 gallons per minute or 14,000 gallons per day, thus removing all of the oxidized particulates and preventing debris from accumulating on the bottom of the tank. When the filter becomes loaded, it is washed off and returned to the tank, eliminating the need for costly filter replacements. This unique in-tank filtration also eliminates filter backwashing and its associated water loss.

An optional piece of equipment used with this system is a mixer/injector that diverts the ozone from the tank and injects it into the incoming water. This injection takes place only

when the pump is in operation and the tank is being refilled with the raw water, thereby pretreating the water before its introduction into the tank.

This type of system is capable of removing all objectionable levels of iron, manganese and hydrogen sulfide. In severe cases, it may be necessary to use two tanks in series and to treat each tank individually. For instance, in a water supply containing 60 ppm of iron, the iron was successfully removed using this dual tank set-up. Generally speaking, tanks need to be sized at four times the daily water usage. An average family of four uses approximately 350 gallons of water per day, so the minimum tank size should be about 1,500 gallons or larger. If possible, take irrigation water off the wellhead before the tank and use the tank water for household use only. Use one system per each 10,000 gallons to be treated. Multiple systems can be used in larger tanks.

When considering this technology for contaminant removal, it is important to know the volume of water used per day as well as the contaminant levels. Contaminant levels are best shown by a water analysis performed by an independent laboratory. Ozone readily oxidizes both iron and manganese but will oxidize all the iron before attacking the manganese. This is a phenomenon that will affect the prescribed dosage and contact times and is another reason to have a thorough knowledge of the water that will be treated. Also, water with a high organic content such a tannin will adversely affect the ozone's ability to act on inorganic material, further affecting dosages and contact times.

An additional benefit of this technology is the aeration process. A system such as this is able to remove undesirable gasses and their effects from the water because it uses ozone in combination with aeration. For instance, when low pH is attributed to carbon dioxide gasses, which are removed in the aeration process, the pH levels then are elevated. Due to the aeration process, this system acts on all dissolved gasses contained in the water including radon and methane. Another benefit applies when a customer has an existing holding tank with no particular water problem. This system can be used to prevent stagnation, algae growth and bacterial contamination.

This technology also is appropriate for use in surface water and/or rooftop catchment systems. Under surface water conditions, a sand filter is suggested to remove turbidity (dirt) and debris before the water enters the tank. The ozone then is able to expend all of its energy on killing bacteria. When treating surface water, it is advised that a secondary method of disinfection should be added as back-up protection, since you are dealing with water subject to fecal coliform and other primary health contaminants. If Giardia or Cryptosporidium (protozoa) are of concern, do not rely on ozone technology. Instead, use a 1 micron absolute filter for removal after the tank treatment. When treating other contaminants in well water such as total dissolved solids, use the in-tank ozone system before both water softeners and reverse osmosis units to keep resins and membranes clean.

Maintenance is a major consideration in any type of water treatment equipment. Maintenance required for this system is minimal. It consists of cleaning the filter approximately every three to six months by pulling it from the tank and hosing off the

accumulated debris. The ozone diffuser also is cleaned at the time by dipping it into muriatic acid. The ozone-producing UV light needs to be changed every 18 to 24 months if treating secondary contaminants or every 12 months if used for bacterial control.

Installation is another important consideration when dealing with water treatment equipment. This ozone system normally will take less than two hours to install, and its installation is relatively simple. The ozone generator is mounted beside or up to 200 feet from the holding tank. Tubing that carries the ozone gas runs from the generator, up the side of the tank and down inside the tank where it connects to the filter module. The filter module is suspended from the tank top on a stainless steel chain and contains the diffuser that bubbles ozone up through the tank water. The mixer/injector is mounted into the inlet pipe to the tank.

Using atmospheric vented holding tanks/cisterns to apply ozone is a simple, viable, cost-effective and reliable method of water treatment for problem well water. Water treatment professionals worldwide have used this technology successfully since its development in 1990.

Your customers not only are expecting to have enough water supplied from their water source, but they also demand that it is of superior quality. Ozone's technology coupled with such treatment as filters or softeners can fulfill this expectation.

Myrle Melligan is sales manager and tech support for Triple O Systems, Inc., Campbell, Calif. She can be reached by e-mail at sales@tripleo.com.

Source: *Water Quality Products* June 2003 Volume: 8 Number: 6
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Carbon Filter Regeneration.

The best way of removing harmful VOC's, chemicals, and gases from the air in our opinion is via a good HEPA machine with 15 lbs or more of activated carbon or utilizing a carbon furnace filter. Activated carbon and or Zeolite will absorb harmful gases and chemicals in the air. The only problem is that once the carbon granules are full, they can no longer do their job. We have a solution. Rejuvenate your carbon filters with ozone! The Ozone will be absorbed by the carbon and oxidize the harmful substances collected by inside the carbon pores. Depending on the amount of VOC's and harmful substances in your indoor air, you only need to run your ozone generator 10 minutes a day to both enhance the effectiveness of your carbon filter and to prolong the life of your carbon filter. (A saving of hundreds a year) You won't smell any ozone whatsoever; it will all be absorbed by your carbon filter where ozone can fulfill the measure of it's creation and assist carbon in fulfill it's mission as well.

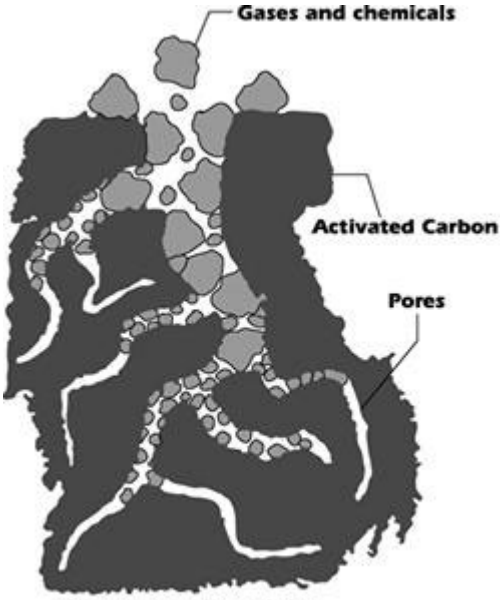

Activated Carbon adsorbs gases and chemicals

Applied Ozone Systems Corona Discharge Ozone Generators Ozonators
http://www.appliedozone.com/ozone_generators_ozonators.html

Resin worker

From Wikipedia, the free encyclopedia

Resin workers were people whose work involved the extraction or working of resin. Resin work was an occupation that largely died out in the 19th and 20th centuries, but it was sometimes a primary occupation as well as a secondary source of income. Resin was needed as a raw material in the manufacture of pitch, tar and terpentine.

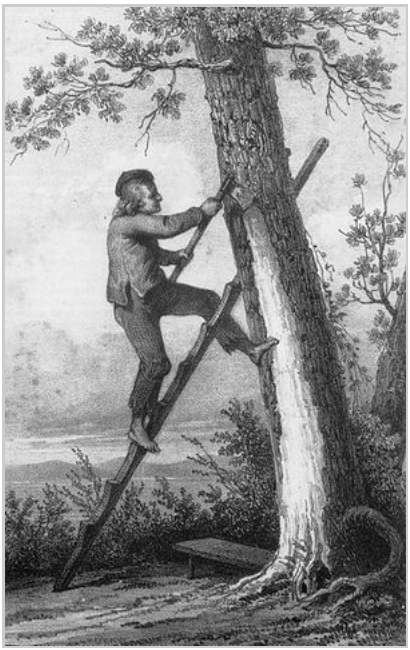

French resin burner

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Terminology

As well as the general term "resin worker", the terms **resin burner** and **resin picker** are also used in the literature.

Live resin in Poland

France

In France, where the occupation was common, a resin picker was a *gemmeur*, whilst a resin worker was a *résinier*.

Germany

In German-speaking lands, the general term was *Harzer*. Other names were *Harzbrenner* ("resin burner")[1] in the Palatinate region and *Pecher* ("pitcher") in Lower Austria, or *Pechler*, *Pechsieder*, *Harzeinsammler* ("resin picker") and *Harzscharrer* ("resin scraper").[2]

Resin worker's craft

From ancient times resin was gathered from pines in the form of "living resin" (*Lebendharzung*). By removing bark from the tree trunk and cutting into the underlying wood, the tree was injured in order to tap into the resin that was exuded; it was then gathered and processed. Through this cutting and "bleeding", the wood of the tree became generally unusable for construction or other purposes. That was a reason why enmity existed between resin workers and foresters.

To increase the yield, carbonizing ovens (*Schwelöfen*), known in the Palatine Forest as "resin ovens"

(*Harzöfen*), were used. Using wood as a raw material, resinous pine wood (*Kienholz*) was turned into resin and pitch through a burning process. The burning of resin was sometimes strictly regulated in order to prevent the wanton damage of the forest.

In the 19th century, larger and larger facilities were built to extract resin. In the Palatinate area of Germany, street and place names witness to the industry that went into decline in the 20th century e.g. *Harzofen* in Kaiserslautern and near Elmstein).

Resin was gathered in this way in East Germany until the Wende in 1990.

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See also

- de:Pecherei in Lower Austria
- Gemmage (French)

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Resin

From Wikipedia, the free encyclopedia

In polymer chemistry and materials science, **resin** is a "solid or highly viscous substance," which is typically convertible into polymers.[1] Such viscous substances can be plant-derived or synthetic in origin. They are often mixtures of organic compounds. Many plants, particularly woody plants produce resin in response to injury. The resin acts as a bandage protecting the plant from invading insects and pathogens.[2]

Cedar of Lebanon cone showing flecks of resin as used in the mummification of Egyptian Pharaohs.

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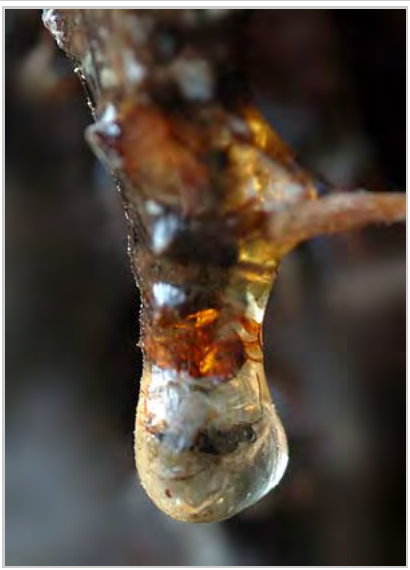

Insect trapped in resin

Examples of natural resins and related materials

Plants secrete resins and rosins for their protective benefits. They confound a wide range of herbivores, insects, and pathogens; while the volatile phenolic compounds may attract benefactors such as parasitoids or predators of the herbivores that attack the plant.[3]

Resins

The resin produced by most plants is composed mainly of terpenes and derivatives. The most common terpenes in resin are the bicyclic terpenes alpha-pinene, beta-pinene, delta-3 carene, and sabinene, the monocyclic terpenes limonene and terpinolene, and smaller amounts of the tricyclic sesquiterpenes, longifolene, caryophyllene and delta-cadinene. Some resins also contain a high proportion of resin acids. The individual components of resin can be separated by fractional distillation. Rosins on the other hand are less volatile and consist, inter alia, of diterpenes.

Notable examples of plant resins include amber, Balm of Gilead, balsam, Canada balsam, Boswellia, copal from trees of *Protium copal* and *Hymenaea courbaril*, dammar gum from trees of the family Dipterocarpaceae, Dragon's blood from the dragon trees (*Dracaena* species), elemi, frankincense from *Boswellia sacra*, galbanum from *Ferula gummosa*, gum guaiacum from the lignum vitae trees of the genus *Guaiacum*, kauri gum from trees of *Agathis australis*, hashish (Cannabis resin) from *Cannabis indica*, labdanum from mediterranean species of *Cistus*, mastic (plant resin) from the mastic tree *Pistacia lentiscus*, myrrh from shrubs of *Commiphora*, sandarac resin from *Tetraclinis articulata*, the national tree of Malta, styrax (a Benzoin resin from various *Styrax* species), Spinifex resin from Australian *Spinifex* grasses, and turpentine, distilled from pine resin. Amber is fossil resin (also called resinite) from coniferous and other tree species. Copal, kauri gum, dammar and other resins may also be found as subfossil deposits. Subfossil copal can be distinguished from genuine fossil amber because it becomes tacky when a drop of a solvent such as acetone or chloroform is placed on it.[4]

Fossil resins

Certain resins are obtained in a fossilized condition, amber being the most notable instance of this class. African copal and the kauri gum of New Zealand are also procured in a semi-fossil condition.

Rosin

Solidified resin from which the volatile terpene components have been removed by distillation is known as rosin. Typical rosin is a transparent or translucent mass, with a vitreous fracture and a faintly yellow or brown colour, non-odorous or having only a slight turpentine odor and taste. Rosin is insoluble in water, mostly soluble in alcohol, essential oils, ether and hot fatty oils, and softens and melts under the influence of heat, and burns with a bright but smoky flame.

Extremely viscous resin extruding from the trunk of a mature *Araucaria columnaris*.

Rosin consists of a complex mixture of different substances including organic acids named the resin acids. These are closely related to the terpenes, and derive from them through partial oxidation. Resin acids can be dissolved in alkalis to form resin soaps, from which the purified resin acids are regenerated by treatment with acids. Examples of resin acids are abietic acid (sylvic acid), $C_{20}H_{30}O_2$, plicatic acid contained in cedar, and pimaric acid, $C_{20}H_{30}O_2$, a constituent of galipot resin. Abietic acid can also be extracted from rosin by means of hot alcohol; it crystallizes in leaflets, and on oxidation yields trimellitic acid, isophthalic acid and terebic acid. Pimaric acid closely resembles abietic acid into which it passes when distilled in a vacuum; it has been supposed to consist of three isomers.

Rosin is obtained from pines and some other plants, mostly conifers.[5] Plant resins are generally produced as stem secretions, but in some Central and South American species such as *Euphorbia dalechampia* and *Clusia* species they are produced as pollination rewards, and used by some stingless bee species to construct their nests.[6][7] Propolis, consisting largely of resins collected from plants such as poplars and conifers, is used by honey bees to seal gaps in their hives.[8]

Petroleum- and insect-derived resins

Shellac and lacquer are examples of insect-derived resins.

Asphaltite and Utah resin are petroleum bitumens, not a product secreted by plants, although it was ultimately derived from plants.

History and etymology

Plant resins have a very long history that was documented in ancient Greece by Theophrastus, in ancient Rome by Pliny the Elder, and especially in the resins known as frankincense and myrrh, prized in ancient Egypt.[9] These were highly prized substances, and required as incense in some religious rites.

The word *resin* comes from French *resine*, from Latin *resina* "resin", which either derives from or is a cognate of the Greek ῥητίνη *rhētinē* "resin of the pine", of unknown earlier origin, though probably non-Indo-European.[10][11]

The word "resin" has been applied in the modern world to nearly any component of a liquid that will set into a hard lacquer or enamel-like finish. An example is nail polish. Certain "casting resins" and synthetic resins (such as epoxy resin) have also been given the name "resin."

Some resins when soft are known as 'oleoresins', and when containing benzoic acid or cinnamic acid they are called balsams. Oleoresins are naturally occurring mixtures of an oil and a resin; they can be extracted from various plants. Other resinous products in their natural condition are a mix with gum or mucilaginous substances and known as gum resins. Several natural resins are used as ingredients in perfumes, e.g., balsams of Peru and tolu, elemi, styrax, and certain turpentines.[5]

Non-resinous exudates

Other liquid compounds found inside plants or exuded by plants, such as sap, latex, or mucilage, are sometimes confused with resin, but are not the same. Saps, in particular, serve a nutritive function that resins do not.

Uses

Resin of a pine

Plant resins

Plant resins are valued for the production of varnishes, adhesives, and food glazing agents. They are also prized as raw materials for the synthesis of other organic compounds and provide constituents of incense and perfume.

The hard transparent resins, such as the copals, dammars, mastic, and sandarac, are principally used for varnishes and adhesives, while the softer odoriferous oleo-resins (frankincense, elemi, turpentine, copaiba), and gum resins containing essential oils (ammoniacum, asafoetida, gamboge, myrrh, and scammony) are more used for therapeutic purposes and incense. The resin of the Aleppo Pine is used to flavour retsina, a Greek resinated wine.[12]

Synthetic resins

Many materials are produced via the conversion of synthetic resins to solids. Important examples are bisphenol A diglycidyl ether, which is a resin converted to epoxy glue upon the

addition of a hardnener. Silicones are often prepared from silicone resins via room temperature vulcanization.

Lumps of dried frankincense resin

See also

- Resin extraction – method of harvesting resin from trees
- Balsam of Peru – a balsam used in food and drink for flavoring, in perfumes and toiletries for fragrance, and in medicine and pharmaceutical items.
- Mastic (plant resin) – resin from the Pistacia lentiscus tree
- Pitch (resin)
- Kino (gum) – a plant gum similar to resin
- Biodegradable – plant resins are naturally biodegradable in many circumstances.
- Resin casting – casting with a resin, usually using a synthetic not a natural resin.
- Polyresin – a hard, synthetic resin for casting in molds

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External links

- The dictionary definition of resin at Wiktionary
- Media related to Resin at Wikimedia Commons

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Categories: Resins | Non-timber forest products | Papermaking | Tree tapping

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Resist dyeing

From Wikipedia, the free encyclopedia

Resist dyeing (**resist-dyeing**) is a term for a number of traditional methods of dyeing textiles with patterns. Methods are used to "resist" or prevent the dye from reaching all the cloth, thereby creating a pattern and ground. The most common forms use wax, some type of paste made from starch or mud,[1] or a mechanical resist that manipulates the cloth such as tying or stitching. Another form of resist involves using a chemical agent in a specific type of dye that will repel another type of dye printed over the top. The best-known varieties today include tie-dye and batik.

Indonesian batik fabric

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- 2 History
- 3 Traditions using wax or paste
- 4 Traditions using tying or stitching
- 5 Traditions using printing
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Basic methods

Wax or paste: melted wax or some form of paste is applied to cloth before being dipped in dye. Wherever the wax has seeped through the fabric, the dye will not penetrate. Sometimes several colors are used, with a series of dyeing, drying and waxing steps. The wax may also be applied to another piece of cloth to make a stencil, which is then placed over the cloth, and dye applied to the assembly; this is known as **resist printing**.

Paper stencils may also be used; another type of resist printing. The same method is used in art in printmaking, in one form of screenprinting.

Mechanical: the cloth is tied,stitched, or clamped using clothespegs or wooden blocks to shield areas of the fabric.

Chemical: a modern textile printing method, commonly achieved using two different classes of fiber reactive dyes, one of which must be of the vinyl sulfone type. A chemical-resisting agent is combined with dye Type A, and printed using the screenprint method and allowed to dry. A second dye, Type B, is then printed overtop. The resist agent in Type A chemically prevents Type B from reacting with the fabric, resulting in a crisp pattern/ground relationship.[2]

History

Resist dyeing has been very widely used in Eurasia and Africa since ancient times. The first discoveries of pieces of linen was from Egypt and date from the fourth century. Cloth, used for mummy wrappings, was coated with wax, scratched with a sharp stylus, and dyed with a mixture of blood and ashes. After dyeing the cloth was washed in hot water to remove the wax. In Asia, this technique was practiced in China during the T'ang dynasty (618-907), in India and Japan in the Nara period (645-794). In Africa it was originally practiced by the Yoruba tribe in Nigeria, Soninke and Wolof in Senegal.[1]

Traditions using wax or paste

- Guizhou Province of China had a strong tradition of wax dyeing
- Indonesia, Malaysia and India - Batik with wax
- Japan - Rōketsuzome with wax, Katazome, Yūzen and Tsutsugaki with rice-paste
- Africa - Yoruba people of Nigeria uses cassava paste as a resist while the people of Senegal use rice paste. Among other terms, Madiba.[1]

Rōketsuzome printing wheels at Roketsuzome Yamamoto, Kyoto.

Traditions using tying or stitching

- Indonesia and Malaysia - Ikat, where only the warp or weft is dyed (article covers similar techniques elsewhere).
- India
- Africa - Adire
- Modern West - Tie-dye
- Japan - Shibori

Traditions using printing

- Japan- Katagami and Bingata with stencils
- China - about 500 AD the *jia xie* method for dyeing (usually silk) using wood blocks was invented. An upper and a lower block is made, with carved out compartments opening to the back, fitted with plugs. The cloth, usually folded a number of times, is inserted and clamped between the two blocks. By unplugging the different compartments and filling them with dyes of different colours, a multi-coloured pattern can be printed over quite a large area of folded cloth.[3]

Other traditions

- Ukraine, Russia and Poland - Pysanka, with wax for eggs at Easter

A mix of modern and traditional Ukrainian pysanky

See also

- Woodblock printing
- Byzantine dress

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Resistor Color Code

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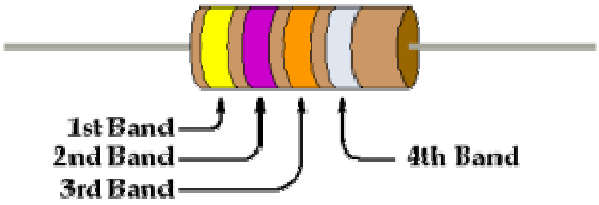

Color	1st Band	2nd Band	3rd Band (Multiplier)	4th Band (Tolerance)
Silver			0.01	None (±20%) Silver (±10%) Gold (±5%)
Gold			0.1	None (±20%) Silver (±10%) Gold (±5%)
Black	0	0	1	None (±20%) Silver (±10%) Gold (±5%)
Brown	1	1	10	None (±20%) Silver (±10%) Gold (±5%)
Red	2	2	100	None (±20%) Silver (±10%) Gold (±5%)
Orange	3	3	1000	None (±20%) Silver (±10%) Gold (±5%)
Yellow	4	4	10000	None (±20%) Silver (±10%) Gold (±5%)
Green	5	5	100000	None (±20%) Silver (±10%) Gold (±5%)
Blue	6	6	1000000	None (±20%) Silver (±10%) Gold (±5%)
Violet	7	7	10000000	None (±20%)

				Silver (±10%) Gold (±5%)
Gray	8	8	100000000	None (±20%) Silver (±10%) Gold (±5%)
White	9	9	1000000000	None (±20%) Silver (±10%) Gold (±5%)

Mnemonic to remember the color order:

- **B**rave **B**oys **R**ace **O**ur **Y**oung **G**irls **B**ut **V**iolet **G**enerally ins

How to decipher the code:

1. Take the first color and find its integer equivalent (e.g., Yellow = 4)
2. Take the second color and find its integer equivalent (e.g., Violet = 7)
3. Take the third color and find its multiplier equivalent (e.g., Orange = 1000)
4. Take the third color and find its tolerance equivalent (e.g., Silver = ±10%)

Putting them all together: 47 * 1000 = 47000 Ω = **47 KΩ ±10%**

http://www.aqeds.com/support/rot/rot_resistor.asp

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http://www.tscm.com/elecform.pdf
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http://www.coasteltools.com/tech_electronic-formulas.htm

Ohm's Law Formulas for D-C Circuits.

$$E = IR = \frac{P}{I} = \sqrt{PR} \qquad P = I^2R = EI = \frac{E^2}{R}$$

Ohm's Law Formulas for A-C Circuits.

In these formulas θ is the angle of lead or lag between current and voltage and cos θ = P/EI = power factor.

$$E = IZ = \frac{P}{I\cos\theta} = \sqrt{\frac{PZ}{\cos\theta}} \qquad P = I^2 Z\cos\theta = IE\cos\theta = \frac{E^2\cos\theta}{Z}$$

Resistors in Series

$R_{total} = R_1 + R_2 + R_3 + \ldots$

Two Resistors in Parallel

$$R_t = \frac{R_1 R_2}{R_1 + R_2}$$

Resistors in Parallel, General Formula

$$R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots}$$

Sinusoidal Voltages and Currents

Effective value	=	0.707 x peak value
[Also known as Root-Mean Square (RMS) value]		
Half Cycle Average value	=	0.637 x peak value
Peak value	=	1.414 x effective value
Effective value	=	1.11 x average value

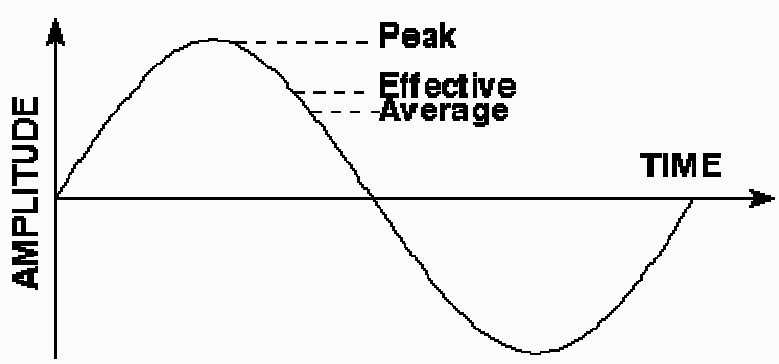

Resonant Frequency Formulas:

*Where in the second formula f is in kHz and L and C are in micro units.

$$f = \frac{1}{2\pi\sqrt{LC}} \quad or \quad f = \frac{159.2*}{\sqrt{LC}}$$

$$L = \frac{1}{4\pi^2 f^2 C} \quad or \quad L = \frac{25,330*}{f^2 C}$$

$$C = \frac{1}{4\pi^2 f^2 L} \quad or \quad C = \frac{25,330*}{f^2 L}$$

Conductance

$$G = \frac{1}{R} \quad (for\ D\text{-}C\ circuits) \qquad G = \frac{R}{R^2 + X^2} \quad (for\ A\text{-}C\ circuits)$$

Reactance Formulas

$$X_c = \frac{1}{2\pi fC} \qquad C = \frac{1}{2\pi f X_c} \qquad X_L = 2\pi fL \qquad L = \frac{X_L}{2\pi f}$$

Impedance Formulas

For series circuits

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

For R and X in parallel

$$Z = \frac{RX}{\sqrt{R^2 + X^2}}$$

Q or Figure of Merit

$$Q = \frac{X_L}{R} \quad or \quad \frac{X_c}{R}$$

Power Factor

pf = cos θ, where θ is the angle of lead or lag

Note: Active power is the "resistive" power
and equals the equivalent heating effect on water.

$$pf = \frac{\text{Active power (in watts)}}{\text{Apparent power (in volt-amps)}} = \frac{P}{EI} \qquad pf = \frac{R}{Z}$$

Three-phase AC Configurations (120 deg phase difference between each voltage)

If the connection to a three phase AC configuration is miswired, switching any two of the phases will put it back in the proper sequence. Electric power for ships commonly uses the delta configuration, while commercial electronic and aircraft applications commonly use the wye configuration.

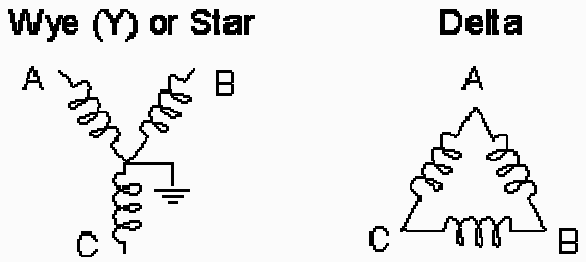

Voltage/Current Phase Rule of Thumb: Remember "ELI the ICE man"

ELI: Voltage (E) comes before (leads) current (I) in an inductor (L)

ICE: Current (I) comes before (leads) Voltage (E) in a capacitor (C)

Color Code for Resistors

First and second band: (and third band # of zeros if not gold/silver)				Third band Multiplier		Fourth band Tolerance	
0	0 BLACK	5	5 GREEN	0.1	GOLD	5%	GOLD
1	1 BROWN	6	6 BLUE	0.01	SILVER	10%	SILVER
2	2 RED	7	7 VIOLET			20%	NO COLOR
3	3 ORANGE	8	8 GRAY				
4	4 YELLOW	9	9 WHITE				

The third color band indicates number of zeros to be added after figures given by first two color bands. But if third color band is gold, multiply by 0.1 and if silver multiply by 0.01. Do not confuse with fourth color-band that indicates tolerance. Thus, a resistor marked blue-red-gold-gold has a resistance of 6.2 ohms and a 5% tolerance.

Color Code for House Wiring

Color Code	Purpose	Color Code for Chassis Wiring:
Black or **red**	**HOT**	**Red**
White	NEUTRAL (Return)	White
Green or bare	GROUND	Black

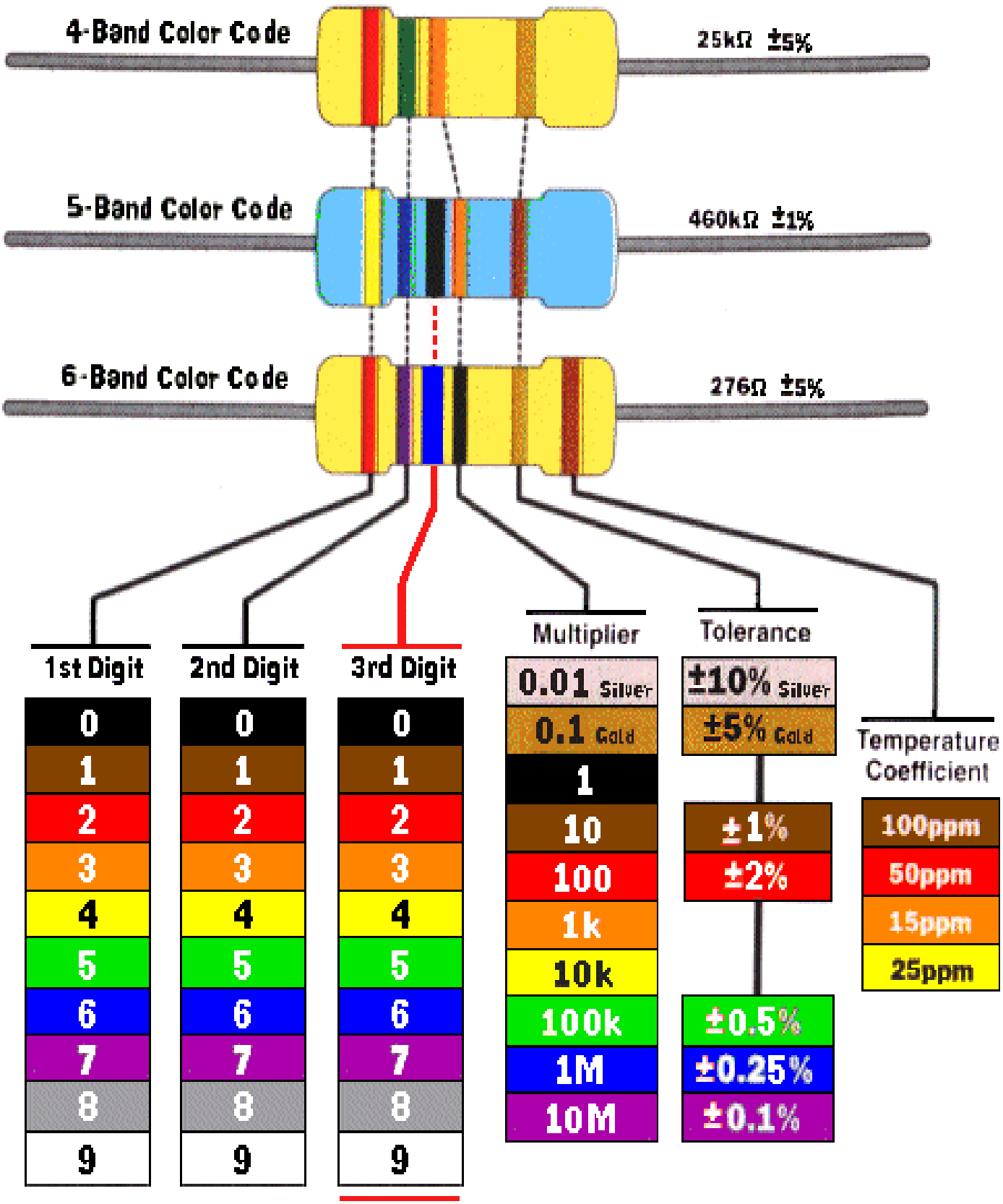
4-Band Color Code
25kΩ ±5%
5-Band Color Code
460kΩ ±1%
6-Band Color Code
276Ω ±5%
1st Digit
2nd Digit
3rd Digit
Multiplier
Tolerance
Temperature Coefficient
0
1
2
3
4
5
6
7
8
9
0.01 Silver
0.1 Gold
1
10
100
1k
10k
100k
1M
10M
±10% Silver
±5% Gold
±1%
±2%
±0.5%
±0.25%
±0.1%
100ppm
50ppm
15ppm
25ppm

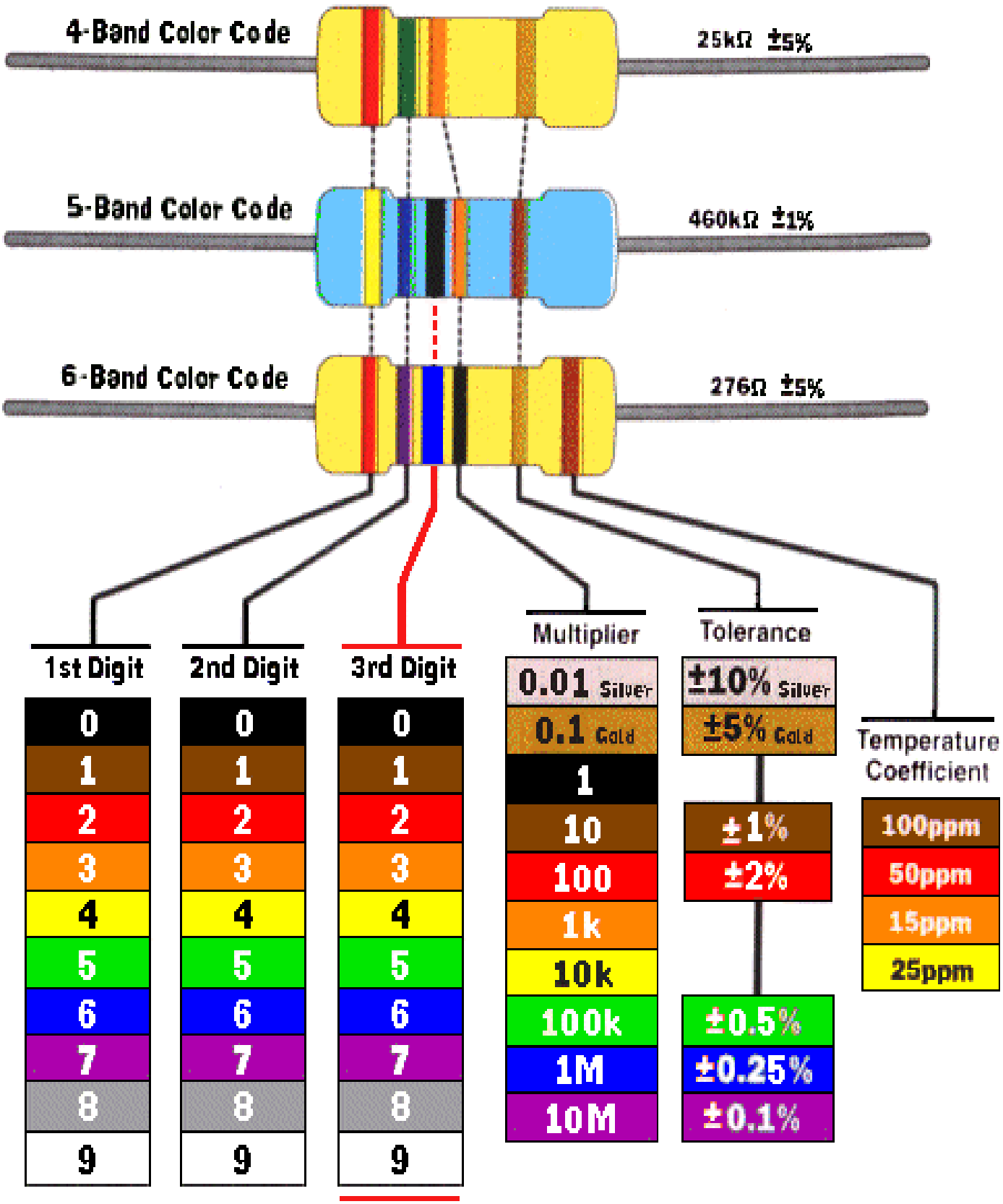
4-Band Color Code
25kΩ ±5%
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460kΩ ±1%
6-Band Color Code
276Ω ±5%
1st Digit
2nd Digit
3rd Digit
Multiplier
Tolerance
Temperature Coefficient
0
1
2
3
4
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8
9
0.01 Silver
0.1 Gold
1
10
100
1k
10k
100k
1M
10M
±10% Silver
±5% Gold
±1%
±2%
±0.5%
±0.25%
±0.1%
100ppm
50ppm
15ppm
25ppm

Resistor Color Code Calculator

Band 1	Band 2	Band 3	Multiplier	Tolerance
0-Black	0-Black	0-Black	1-Black	
1-Brown	1-Brown	1-Brown	10-Brown	+/- 1%
2-Red	2-Red	2-Red	100-Red	+/- 2%
3-Orange	3-Orange	3-Orange	1000-Orange	
4-Yellow	4-Yellow	4-Yellow	10000-Yellow	
5-Green	5-Green	5-Green	100000-Green	+/- 0.5%
6-Blue	6-Blue	6-Blue	1000000-Blue	+/- 0.25%
7-Violet	7-Violet	7-Violet	10000000-Violet	+/- 0.10%
8-Gray	8-Gray	8-Gray	100000000-Gray	+/- 0.05%
9-White	9-White	9-White	1000000000-White	
			0.1-Gold	+/- 5%
			0.01-Silver	+/- 10%
				+/- 20% (none)

Calculate

Resistance: 24300

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How to read Resistor Color Codes

First the code

Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
0	1	2	3	4	5	6	7	8	9

The mnemonic

Bad Boys Ravage Only Young Girls But Violet Gives Willingly

Black is also easy to remember as zero because of the nothingness common to both.

How to read the code

First find the tolerance band, it will typically be gold (5%) and sometimes silver (10%).

Starting from the other end, identify the first band - write down the number associated with that color; in this case Blue is 6.

Now 'read' the next color, here it is red so write down a '2' next to the six. (you should have '62' so far.)

Now read the third or 'multiplier' band and write down that number of zeros.

In this example it is two so we get '6200' or '6,200'. If the 'multiplier' band is Black (for zero) don't write any zeros down.

If the 'multiplier' band is Gold move the decimal point one to the left. If the 'multiplier' band is Silver move the decimal point two places to the left. If the resistor has one more band past the tolerance band it is a quality band.

Read the number as the '% Failure rate per 1000 hour' This is rated assuming full wattage being applied to the resistors. (To get better failure rates, resistors are typically specified to have twice the needed wattage dissipation that the circuit produces) 1% resistors have three bands to read digits to the left of the multiplier. They have a different temperature coefficient in order to provide the 1% tolerance.

We now have a program that calculates the minimum error on resistor dividers of up to 4 values. See Resistor for details.

See our Capacitor Wizard
How to read Capacitor codes
Learn about Capacitors and ESR
Soldering Stations

Test Equipment Index

Was this Information Useful?

If you found this information useful - all I ask is to look at our home page and see if we have any products that might be of use to you or a colleague. Link to us if you have a web page. If you have some thing to add to this page please send it to the e-mail below.

Answers to E-mail Questions:

Dear Transtronics

What are the standard 5% Resistor values for one decade?

John

Dear John,

The values are as follows.

10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91,

Here is a very low cost resistor picking program that will help you pick the correct values to form an optimized resistor divider for up to 4 output taps.

Exact values will print only the resistor pairs that provides an exact output of the divider.

EIN is the voltage going into the top of the divider

Eout is the Voltage you want to come out of the divider.

% tolerance will let you chose to work with 5% or 1% resistor values.

Installing

Just dump it in a folder and it should run - needs LPT1 for output.

Dear Transtronics,

Hello, I would like to know something about resisters- do they need to be put in a circuit in a certain way (positive, negative)? if so, how do I tell what end from the other?

Dylan

Dear Dylan,

Resistors Have no polarity; they can be installed either way, but often it is best to put them in all facing the same way so as to make reading them easier.

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How to read Resistor Color Codes

First the code

	Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
	0	1	2	3	4	5	6	7	8	9
Multiplier	1	10	100	1,000	10,000	100,000	1,000,000	10,000,000	100,000,000	...

How to read the code

Resistors are color coded for easy reading. Imagine how many blind technicians there would be otherwise.

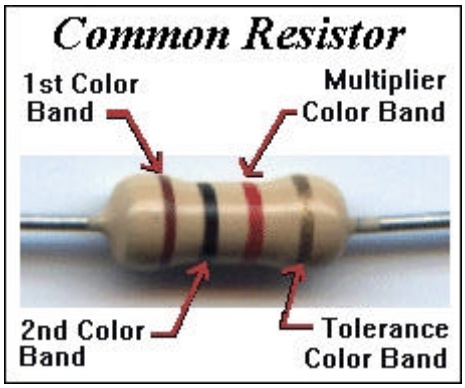

To determine the value of a given resistor look for the gold or silver tolerance band and rotate the resistor as in the photo on the left. (Tolerance band to the right-- refer to the tolerance chart below for exact values.). Look at the 1st color band and determine its color. This maybe difficult on small or oddly colored resistors. Now look at the chart and match the "1st & 2nd color band" color to the "Digit it represents". Write this number down.

Now look at the 2nd color band and match that color to the same chart. Write this number next to the 1st Digit.

The last color band is the number you will multiply the result by. Match the 3rd color band with the chart under multiplier. This is the number you will multiply the other 2 numbers by. Write it next to the other 2 numbers with a multiplication sign before it. Example : 2 2 x 1,000.

To pull it all together now, simply multiply the first 2 numbers (1st number in the tens column and 2nd in the ones column) by the Multiplier.

Read the number as the '% Failure rate per 1000 hour' This is rated assuming full wattage being applied to the resistors. (To get better failure rates, resistors are typically specified to have twice the needed wattage dissipation that the circuit produces) 1% resistors have three bands to read digits to the left of the multiplier. They have a different temperature coefficient in order to provide the 1% tolerance.

Tolerance Explained

Resistors are never the exact value that the color codes indicate. Therefore manufacturers place a tolerance color band on the resistor to tell you just how accurate this resistor is made. It is simply a measurement of the imperfections.

Tolerance Rating	Red = 2%	Gold = 5%	Silver = 10%	No band = 20%

As the chart indicates, Red means the resistor is within 2%; Gold means the resistor is within 5% of being dead-on accurate. Silver being within 10% and no color band being within 20%. To determine the exact range that the resistor may be, take the value of the resistor and multiply it by 5,10, 0r 20%. That is the number that the resistor may go either way.

A couple of examples:
Example: A 1,000 Ohm resistor with a gold band maybe any value between 950 to 1050 Ohms.

Example: A 22,000 Ohm resistor with a silver band maybe any value between 19,800 and 24,200 Ohms.

Resistor FAQ's

Just a few common questions to help you out.

1) **Which side of the resistor do I read from?**

The Gold or Silver band is always set to the right, then you read from left to right. Sometimes there will be no tolerance band -- Simply find the side that has a band closest to a lead and make that the first band.

2) **Sometimes the colors are hard to make out. How do I make certain what the value of the resistor really is?**

Occasionally the colors are jumbled or burnt off. The only way to read it then is with a multi-meter across the leads

3) **How do I remember this sequence of colors?**

Remember the color codes with this sentence: **B**ig **B**rown **R**abbits **O**ften **Y**ield **G**reat **B**ig **V**ocal **G**roans **W**hen **G**ingerly **S**lapped.

Back

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5% Carbon Film Resistors

Table of Values in Ohms

1.0	5.6	33	160	820	3.9K	20K	100K	510K	2.7M
1.1	6.2	36	180	910	4.3K	22K	110K	560K	3M
1.2	6.8	39	200	1K	4.7K	24K	120K	620K	3.3M
1.3	7.5	43	220	1.1K	5.1K	27K	130K	680K	3.6M
1.5	8.2	47	240	1.2K	5.6K	30K	150K	750K	3.9M
1.6	9.1	51	270	1.3K	6.2K	33K	160K	820K	4.3M
1.8	10	56	300	1.5K	6.6K	36K	180K	910K	4.7M
2.0	11	62	330	1.6K	7.5K	39K	200K	1M	5.1M
2.2	12	68	360	1.8K	8.2K	43K	220K	1.1M	5.6M
2.4	13	75	390	2K	9.1K	47K	240K	1.2M	6.2M
2.7	15	82	430	2.2K	10K	51K	270K	1.3M	6.8M
3.0	16	91	470	2.4K	11K	56K	300K	1.5M	7.5M
3.3	18	100	510	2.7K	12K	62K	330K	1.6M	8.2M
3.6	20	110	560	3K	13K	68K	360K	1.8M	9.1M
3.9	22	120	620	3.2K	15K	75K	390K	2M	10M
4.3	24	130	680	3.3K	16K	82K	430K	2.2M	15M
4.7	27	150	750	3.6K	18K	91K	470K	2.4M	22M
5.1	30								

1% Metal Film Resistors

Table of Values in Ohms

10	33	100	332	1K	3.32K	10.5K	34K	107K	357K
10.2	33.2	102	340	1.02K	3.4K	10.7K	34.8K	110K	360K
10.5	34	105	348	1.05K	3.48K	11K	35.7K	113K	365K
10.7	34.8	107	350	1.07K	3.57K	11.3K	36K	115K	374K
11	35.7	110	357	1.1K	3.6K	11.5K	36.5K	118K	383K
11.3	36	113	360	1.13K	3.65K	11.8K	37.4K	120K	390K
11.5	36.5	115	365	1.15K	3.74K	12K	38.3K	121K	392K
11.8	37.4	118	374	1.18K	3.83K	12.1K	39K	124K	402K

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12	38.3	120	383	1.2K	3.9K	12.4K	39.2K	127K	412K
12.1	39	121	390	1.21K	3.92K	12.7K	40.2K	130K	422K
12.4	39.2	124	392	1.24K	4.02K	13K	41.2K	133K	430K
12.7	40.2	127	402	1.27K	4.12K	13.3K	42.2K	137K	432K
13	41.2	130	412	1.3K	4.22K	13.7K	43K	140K	442K
13.3	42.2	133	422	1.33K	4.32K	14K	43.2K	143K	453K
13.7	43	137	430	1.37K	4.42K	14.3K	44.2K	147K	464K
14	43.2	140	432	1.4K	4.53K	14.7K	45.3K	150K	470K
14.3	44.2	143	442	1.43K	4.64K	15K	46.4K	154K	475K
14.7	45.3	147	453	1.47K	4.7K	15.4K	47K	158K	487K
15	46.4	150	464	1.5K	4.75K	15.8K	47.5K	160K	499K
15.4	47	154	470	1.54K	4.87K	16K	48.7K	162K	511K
15.8	47.5	158	475	1.58K	4.99K	16.2K	49.9K	165K	523K
16	48.7	160	487	1.6K	5.1K	16.5K	51K	169K	536K
16.2	49.9	162	499	1.62K	5.11K	16.9K	51.1K	174K	549K
16.5	51	165	510	1.65K	5.23K	17.4K	52.3K	178K	560K
16.9	51.1	169	511	1.69K	5.36K	17.8K	53.6K	180K	562K
17.4	52.3	174	523	1.74K	5.49K	18K	54.9K	182K	576K
17.8	53.6	178	536	1.78K	5.6K	18.2K	56K	187K	590K
18	54.9	180	549	1.8K	5.62K	18.7K	56.2K	191K	604K
18.2	56	182	560	1.82K	5.76K	19.1K	57.6K	196K	619K
18.7	56.2	187	562	1.87K	5.9K	19.6K	59K	200K	620K
19.1	57.6	191	565	1.91K	6.04K	20K	60.4K	205K	634K
19.6	59	196	578	1.96K	6.19K	20.5K	61.9K	210K	649K
20	60.4	200	590	2K	6.2K	21K	62K	215K	665K
20.5	61.9	205	604	2.05K	6.34K	21.5K	63.4K	220K	680K
21	62	210	619	2.1K	6.49K	22K	64.9K	221K	681K
21.5	63.4	215	620	2.15K	6.65K	22.1K	66.5K	226K	698K
22	64.9	220	634	2.2K	6.8K	22.6K	68K	232K	715K
22.1	66.5	221	649	2.21K	6.81K	23.2K	68.1K	237K	732K
22.6	68	226	665	2.26K	6.98K	23.7K	69.8K	240K	750K
23.2	68.1	232	680	2.32K	7.15K	24K	71.5K	243K	768K
23.7	69.8	237	681	2.37	7.32K	24.3K	73.2K	249K	787K
24	71.5	240	698	2.4K	7.5K	24.9K	75K	255K	806K
24.3	73.2	243	715	2.43K	7.68K	25.5K	76.8K	261K	820K
24.7	75	249	732	2.49K	7.87K	26.1K	78.7K	267K	825K
24.9	75.5	255	750	2.55K	8.06K	26.7K	80.6K	270K	845K
25.5	76.8	261	768	2.61K	8.2K	27K	82K	274K	866K
26.1	78.7	267	787	2.67K	8.25K	27.4K	82.5K	280K	887K
26.7	80.6	270	806	2.7K	8.45K	28K	84.5K	287K	909K
27	82	274	820	2.74K	8.66K	28.7K	86.6K	294K	910K
27.4	82.5	280	825	2.8K	8.8K	29.4K	88.7K	300K	931K
28	84.5	287	845	2.87K	8.87K	30K	90.9K	301K	953K
28.7	86.6	294	866	2.94K	9.09K	30.1K	91K	309K	976K
29.4	88.7	300	887	3.0K	9.1K	30.9K	93.1K	316K	1.0M
30	90.9	301	909	3.01K	9.31K	31.6K	95.3K	324K	1.5M

30.1	91	309	910	3.09K	9.53K	32.4K	97.6K	330K	2.2M
30.9	93.1	316	931	3.16K	9.76K	33K	100K	332K	
31.6	95.3	324	953	3.24K	10K	33.2K	102K	340K	
32.4	97.6	330	976	3.3K	10.2K	33.6K	105K	348K	

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CYLINDRICAL CELL - STANDARD PRODUCTS																		
MN1300	D	1.5	15000	0.8	10	115	34.20	1.346	61.50	2.421	-	-	138.0	4.86	56.4	3.44	13A	LR20
MN1400	C	1.5	7800	0.8	20	60	26.20	1.031	50.00	1.969	-	-	65.0	2.29	26.9	1.64	14A	LR14
MN1500	AA	1.5	2850	0.8	43	28	14.50	0.571	50.50	1.988	-	-	23.6	0.83	8.4	0.51	15A	LR6
MN2400	AAA	1.5	1150	0.8	75	15	10.50	0.413	44.50	1.752	-	-	11.0	0.39	3.8	0.23	24A	LR03
MN9100	N	1.5	800	0.8	100	12	12.00	0.472	30.20	1.189	-	-	9.6	0.34	3.4	0.21	910A	LR1
OTHER SELECTED MULTICELL BATTERIES - STANDARD PRODUCTS							**LENGTH**		**HEIGHT**		**WIDTH**							
MN1203	-	4.5	4400	2.4	20	175	62.00	2.441	67.00	2.638	22.00	0.866	154.0	5.43	91.4	5.58	706A	3LR12
7K67	J	6.0	580	3.2	340	14	35.60	1.402	48.50	1.909	9.14	0.360	34.0	1.20	15.7	0.96	1412AP	4LR61
MN908	LANTERN	6.0	11500	3.2	15	290	68.20	2.685	115.00	4.528	68.20	2.685	612.0	21.60	501.8	30.62	908A	-
MN918	LANTERN	6.0	24000	3.2	9	490	136.50	5.370	127.00	5.000	73.00	2.874	1270.0	44.80	1243.5	75.88	918A	-
MN1604	9-VOLT	9.0	580	4.8	620	12	26.50	1.043	48.50	1.909	17.50	0.689	45.9	1.62	22.8	1.39	1604A	6LR61
MN21	CYLINDRICAL	12.0	34	6.0	20K	0.50	10.32	0.406	28.50	1.122	-	-	7.4	0.26	2.3	0.14	1811A	-

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American Wire Gauge (AWG)

AWG	Inches	mm	AWG	Inches	mm
40	0.0031	0.079	24	0.0201	0.511
39	0.0035	0.089	23	0.0226	0.574
38	0.004	0.102	22	0.0253	0.643
37	0.0045	0.114	21	0.0285	0.724
36	0.005	0.127	20	0.032	0.813
35	0.0056	0.142	19	0.0359	0.912
34	0.0063	0.16	18	0.0403	1.02
33	0.0071	0.18	17	0.0453	1.15
32	0.008	0.203	16	0.0508	1.29
31	0.0089	0.226	15	0.0571	1.45
30	0.01	0.254	14	0.0641	1.63
29	0.0113	0.287	13	0.072	1.83
28	0.0126	0.32	12	0.0808	2.05
27	0.0142	0.361	11	0.0907	2.3
26	0.0159	0.404	10	0.1019	2.6
25	0.0179	0.455			

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The Complete Smith Chart

Black Magic Design

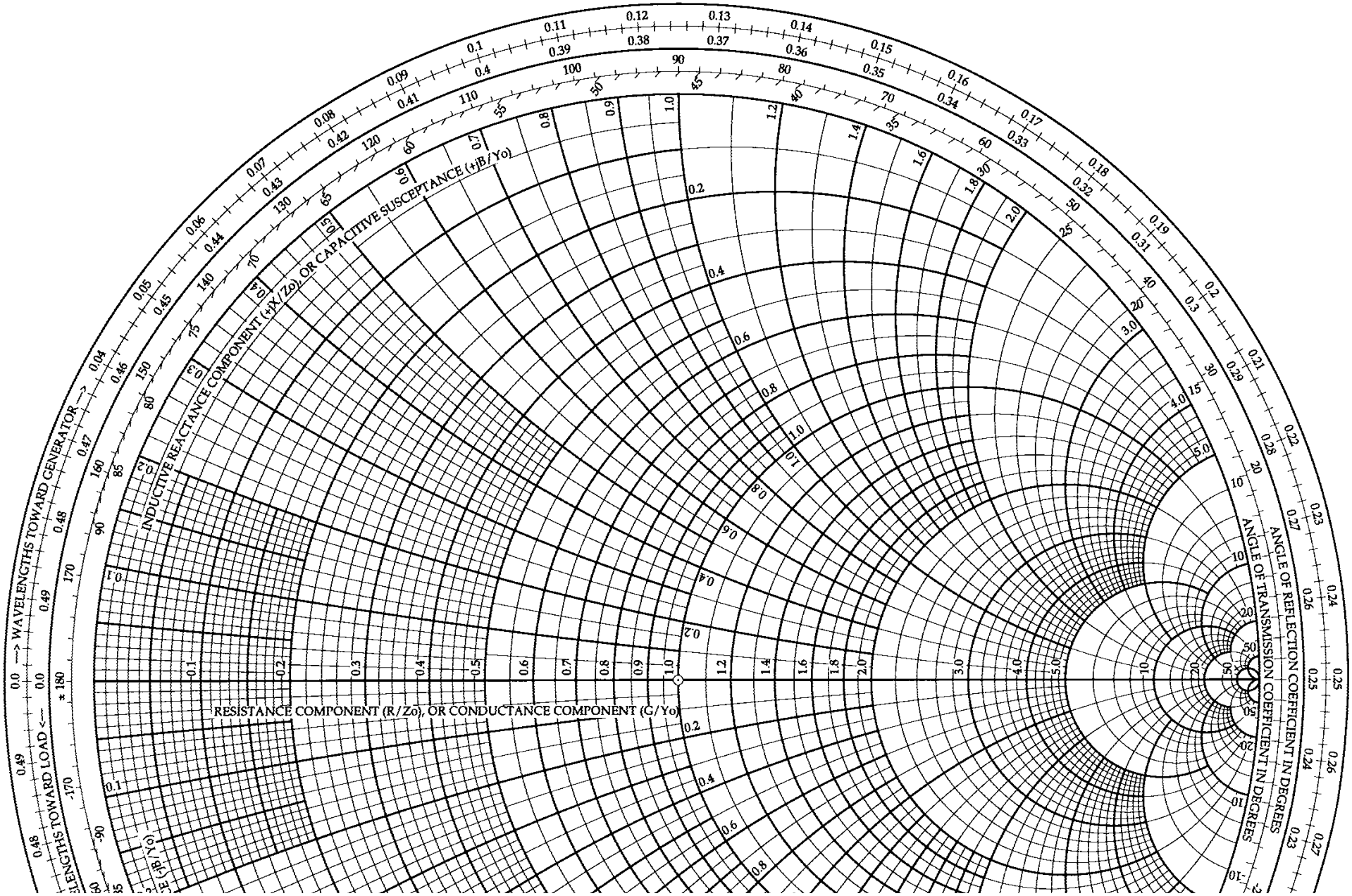

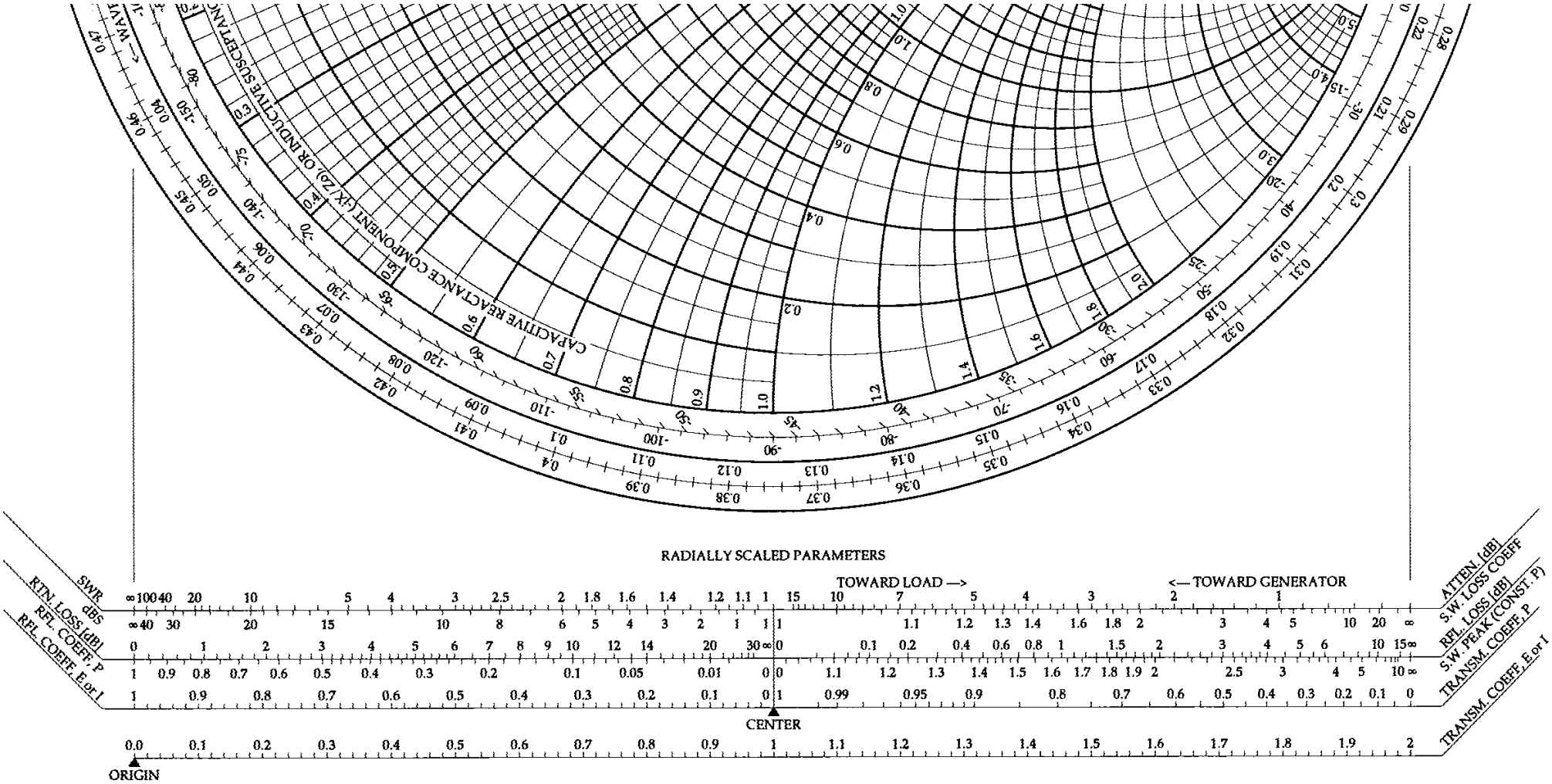
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RFL. COEFF, E or I
ATTEN. [dB]
S.W. LOSS COEFF
RFL. LOSS [dB]
S.W. PEAK (CONST. P)
TRANSM. COEFF, P
TRANSM. COEFF, E or I
CENTER
ORIGIN

Resonance

From Wikipedia, the free encyclopedia

In physics, **resonance** is a phenomenon in which a vibrating system or external force drives another system to oscillate with greater amplitude at a specific preferential frequency.

Frequencies at which the response amplitude is a relative maximum are known as the system's **resonant frequencies** or **resonance frequencies**. At resonant frequencies, small periodic driving forces have the ability to produce large amplitude oscillations, due to the storage of vibrational energy.

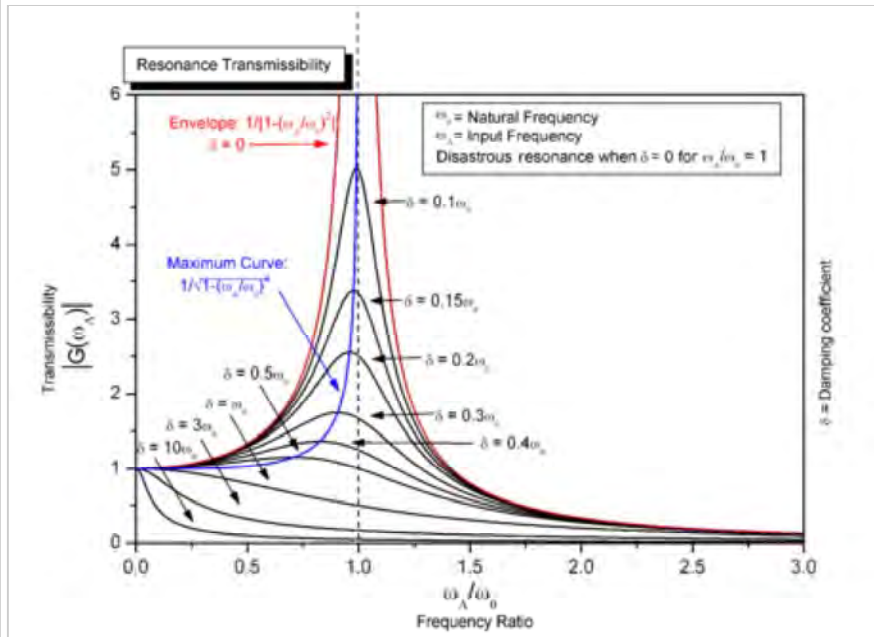

Increase of amplitude as damping decreases and frequency approaches resonant frequency of a driven damped simple harmonic oscillator.[1][2]

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Overview

Resonance occurs when a system is able to store and easily transfer energy between two or more different storage modes (such as kinetic energy and potential energy in the case of a pendulum). However, there are some losses from cycle to cycle, called damping. When damping is small, the resonant frequency is approximately equal to the natural frequency of the system, which is a frequency of unforced vibrations. Some systems have multiple, distinct, resonant frequencies.

Resonance phenomena occur with all types of vibrations or waves: there is mechanical resonance, acoustic resonance, electromagnetic resonance, nuclear magnetic resonance (NMR), electron spin resonance (ESR) and resonance of quantum wave functions. Resonant systems can be used to generate vibrations of a specific frequency (e.g., musical instruments), or pick out specific frequencies from a complex vibration containing many frequencies (e.g., filters).

The term *resonance* (from Latin *resonantia*, 'echo', from *resonare*, 'resound') originates from the field of acoustics, particularly observed in musical instruments, e.g., when strings started to vibrate and to produce sound without direct excitation by the player.

Resonance occurs widely in nature, and is exploited in many manmade devices. It is the mechanism by which virtually all sinusoidal waves and vibrations are generated. Many sounds we hear, such as when hard objects of metal, glass, or wood are struck, are caused by brief resonant vibrations in the object. Light and other short wavelength electromagnetic radiation is produced by resonance on an atomic scale, such as electrons in atoms.

Examples

Mechanical and acoustic resonance

Mechanical resonance is the tendency of a mechanical system to absorb more energy when the frequency of its oscillations matches the system's natural frequency of vibration than it does at other frequencies. It may cause violent swaying motions and even catastrophic failure in improperly constructed structures including bridges, buildings, trains, and aircraft. When designing objects, engineers must ensure the mechanical resonance frequencies of the component parts do not match driving vibrational frequencies of motors or other oscillating parts, a phenomenon known as resonance disaster.

Avoiding resonance disasters is a major concern in every building, tower, and bridge construction project. As a countermeasure, shock mounts can be installed to absorb resonant frequencies and thus dissipate the absorbed energy. The Taipei 101 building relies on a 660-tonne pendulum (730-short-ton)—a tuned mass damper—to cancel resonance. Furthermore, the structure is designed to resonate at a frequency that does not typically occur. Buildings in seismic zones are often constructed to take into account the oscillating frequencies of expected ground motion. In addition, engineers designing objects having engines must ensure that the mechanical resonant frequencies of the component parts do not match driving vibrational frequencies of the motors or other strongly oscillating parts.

Clocks keep time by mechanical resonance in a balance wheel, pendulum, or quartz crystal.

The cadence of runners has been hypothesized to be energetically favorable due to resonance between the elastic energy stored in the lower limb and the mass of the runner.[3]

Acoustic resonance is a branch of mechanical resonance that is concerned with the mechanical vibrations across the frequency range of human hearing, in other words sound. For humans, hearing is normally limited to frequencies between about 20 Hz and 20,000 Hz (20 kHz),[4]

Acoustic resonance is an important consideration for instrument builders, as most acoustic instruments use resonators, such as the strings and body of a violin, the length of tube in a flute, and the shape of, and tension on, a drum membrane.

Like mechanical resonance, acoustic resonance can result in catastrophic failure of the object at resonance. The classic example of this is breaking a wine glass with sound at the precise resonant frequency of the glass, although this is difficult in practice.[5]

Swing

A familiar example is a playground swing, which acts as a pendulum. Pushing a person in a swing in time with the natural interval of the swing (its resonant frequency) makes the swing go higher and higher (maximum amplitude), while attempts to push the swing at a faster or slower tempo produce smaller arcs. This is because the energy the swing absorbs is maximized when the pushes are "in phase" with the swing's natural oscillations, while some of the swing's energy is actually extracted by the opposing force of the pushes when they are not.

Pushing a person in a swing is a common example of resonance. The loaded swing, a pendulum, has a natural frequency of oscillation, its resonant frequency, and resists being pushed at a faster or slower rate.

Tacoma Narrows Bridge

The dramatically visible, rhythmic twisting that resulted in the 1940 collapse of "Galloping Gertie", the original Tacoma Narrows Bridge, is misleadingly characterized as an example of resonance phenomenon in certain textbooks. The catastrophic vibrations that destroyed the bridge were not due to simple mechanical resonance, but to a more complicated interaction between the bridge and the winds passing through it—a phenomenon known as aeroelastic flutter, which is a kind of "self-sustaining vibration" as referred to in the nonlinear theory of vibrations. Robert H. Scanlan, father of bridge aerodynamics, has written an article about this misunderstanding.[6]

Electrical resonance

Electrical resonance occurs in an electric circuit at a particular *resonant frequency* when the impedance of the circuit is at a minimum in a series circuit or at maximum in a parallel circuit (or when the transfer function is at a maximum).

Optical resonance

An optical cavity, also called an *optical resonator*, is an arrangement of mirrors that forms a standing wave cavity resonator for light waves. Optical cavities are a major component of lasers, surrounding the gain medium and providing feedback of the laser light. They are also used in optical parametric oscillators and some interferometers. Light confined in the cavity reflects multiple times producing standing waves for certain resonant frequencies. The standing wave patterns produced are called "modes". Longitudinal modes differ only in frequency while transverse modes differ for different frequencies and have different intensity patterns across the cross-section of the beam. Ring resonators and whispering galleries are examples of optical resonators that do not form standing waves.

Different resonator types are distinguished by the focal lengths of the two mirrors and the distance between them; flat mirrors are not often used because of the difficulty of aligning them precisely. The geometry (resonator type) must be chosen so the beam remains stable, i.e., the beam size does not continue to grow with each reflection. Resonator types are also designed to meet other criteria such as minimum beam waist or having no focal point (and therefore intense light at that point) inside the cavity.

Optical cavities are designed to have a very large Q factor.[7] A beam reflects a large number of times with little attenuation—therefore the frequency line width of the beam is small compared to the frequency of the laser.

Additional optical resonances are guided-mode resonances and surface plasmon resonance, which result in anomalous reflection and high evanescent fields at resonance. In this case, the resonant modes are guided modes of a waveguide or surface plasmon modes of a dielectric-metallic interface. These modes are usually excited by a subwavelength grating.

Orbital resonance

In celestial mechanics, an orbital resonance occurs when two orbiting bodies exert a regular, periodic gravitational influence on each other, usually due to their orbital periods being related by a ratio of two small integers. Orbital resonances greatly enhance the mutual gravitational influence of the bodies. In most cases, this results in an *unstable* interaction, in which the bodies exchange momentum and shift orbits until the resonance no longer exists. Under some circumstances, a resonant system can be stable and self-correcting, so that the bodies remain in resonance. Examples are the 1:2:4 resonance of Jupiter's moons Ganymede, Europa, and Io, and the 2:3 resonance between Pluto and Neptune. Unstable resonances with Saturn's inner moons give rise to gaps in the rings of Saturn. The special case of 1:1 resonance (between bodies with similar orbital radii) causes large Solar System bodies to clear the neighborhood around their orbits by ejecting nearly everything else around them; this effect is used in the current definition of a planet.

Atomic, particle, and molecular resonance

Nuclear magnetic resonance (NMR) is the name given to a physical resonance phenomenon involving the observation of specific quantum mechanical magnetic properties of an atomic nucleus in the presence of an applied, external magnetic field. Many scientific techniques exploit NMR phenomena to study molecular physics, crystals, and non-crystalline materials through NMR spectroscopy. NMR is also routinely used in advanced medical imaging techniques, such as in magnetic resonance imaging (MRI).

All nuclei containing odd numbers of nucleons have an intrinsic magnetic moment and angular momentum. A key feature of NMR is that the resonant frequency of a particular substance is directly proportional to the strength of the applied magnetic field. It is this feature that is exploited in imaging techniques; if a sample is placed in a non-uniform magnetic field then the resonant frequencies of the sample's nuclei depend on where in the field they are located. Therefore, the particle can be located quite precisely by its resonant frequency.

Electron paramagnetic resonance, otherwise known as *Electron Spin Resonance* (ESR) is a spectroscopic technique similar to NMR, but uses unpaired electrons instead. Materials for which this can be applied are much more limited since the material needs to both have an unpaired spin and be paramagnetic.

The Mössbauer effect is the resonant and recoil-free emission and absorption of gamma ray photons by atoms bound in a solid form.

Resonance in particle physics appears in similar circumstances to classical physics at the level of quantum mechanics and quantum field theory. However, they can also be thought of as unstable particles, with the formula above valid if Γ is the decay rate and Ω replaced by the particle's mass M. In that case, the formula comes from the particle's propagator, with its mass replaced by the complex number $M + i\Gamma$. The formula is further related to the particle's decay rate by the optical theorem.

NMR Magnet at HWB-NMR, Birmingham, UK. In its strong 21.2-tesla field, the proton resonance is at 900 MHz.

International Space Station

The rocket engines for the International Space Station (ISS) are controlled by an autopilot. Ordinarily, uploaded parameters for controlling the engine control system for the Zvezda module make the rocket engines boost the International Space Station to a higher orbit. The rocket engines are hinge-mounted, and ordinarily the crew doesn't notice the operation. On January 14, 2009, however, the uploaded parameters made the autopilot swing the rocket engines in larger and larger oscillations, at a frequency of 0.5 Hz. These oscillations were captured on video, and lasted for 142 seconds.[8]

Other examples

- Timekeeping mechanisms of modern clocks and watches, e.g., the balance wheel in a mechanical watch and the quartz crystal in a quartz watch
- Tidal resonance of the Bay of Fundy
- Acoustic resonances of musical instruments and the human vocal tract
- Shattering of a crystal wineglass when exposed to a musical tone of the right pitch (its resonant frequency)
- Friction idiophones, such as making a glass object (glass, bottle, vase) vibrate by rubbing around its rim with a fingertip
- Electrical resonance of tuned circuits in radios and TVs that allow radio frequencies to be selectively received
- Creation of coherent light by optical resonance in a laser cavity
- Orbital resonance as exemplified by some moons of the solar system's gas giants
- Material resonances in atomic scale are the basis of several spectroscopic techniques that are used in condensed matter physics
    - Electron spin resonance
    - Mössbauer effect
    - Nuclear magnetic resonance

Theory

The exact response of a resonance, especially for frequencies far from the resonant frequency, depends on the details of the physical system, and is usually not exactly symmetric about the resonant frequency, as illustrated for the simple harmonic oscillator above. For a lightly damped linear oscillator with a resonance frequency Ω, the *intensity* of oscillations I when the system is driven with a driving frequency ω is typically approximated by a formula that is symmetric about the resonance frequency:[9]

$$I(\omega) \propto \frac{\left(\frac{\Gamma}{2}\right)^2}{(\omega - \Omega)^2 + \left(\frac{\Gamma}{2}\right)^2}.$$

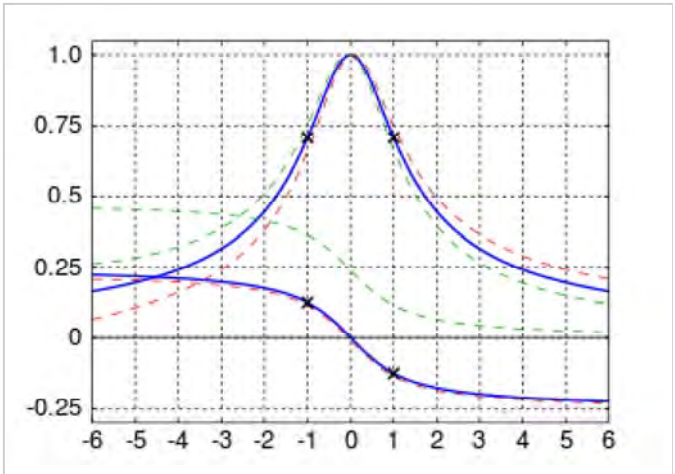

"Universal Resonance Curve", a symmetric approximation to the normalized response of a resonant circuit; abscissa values are deviation from center frequency, in units of center frequency divided by 2Q; ordinate is relative amplitude, and phase in cycles; dashed curves compare the range of responses of real two-pole circuits for a Q value of 5; for higher Q values, there is less deviation from the universal curve. Crosses mark the edges of the 3 dB bandwidth (gain 0.707, phase shift 45° or 0.125 cycle).

The intensity is defined as the square of the amplitude of the oscillations. This is a Lorentzian function, or Cauchy distribution, and this response is found in many physical situations involving resonant systems. Γ is a parameter dependent on the damping of the oscillator, and is known as the *linewidth* of the resonance. Heavily damped oscillators tend to have broad linewidths, and respond to a wider range of driving frequencies around the resonant frequency. The linewidth is inversely proportional to the Q factor, which is a measure of the sharpness of the resonance.

In electrical engineering, this approximate symmetric response is known as the *universal resonance curve*, a concept introduced by Frederick E. Terman in 1932 to simplify the approximate analysis of radio circuits with a range of center frequencies and Q values.[10][11]

Resonators

A physical system can have as many resonant frequencies as it has degrees of freedom; each degree of freedom can vibrate as a harmonic oscillator. Systems with one degree of freedom, such as a mass on a spring, pendulums, balance wheels, and LC tuned circuits have one resonant frequency. Systems with two degrees of freedom, such as coupled pendulums and resonant transformers can have two resonant frequencies. As the number of coupled harmonic oscillators grows, the time it takes to transfer energy from one to the next becomes significant. The vibrations in them begin to travel through the coupled harmonic oscillators in waves, from one oscillator to the next.

Extended objects that can experience resonance due to vibrations inside them are called resonators, such as organ pipes, vibrating strings, quartz crystals, microwave and laser cavities. Since these can be viewed as being made of millions of coupled moving parts (such as atoms), they can have millions of resonant frequencies. The vibrations inside them travel as waves, at an approximately constant velocity, bouncing back

and forth between the sides of the resonator. If the distance between the sides is d, the length of a roundtrip is $2d$. To cause resonance, the phase of a sinusoidal wave after a roundtrip must be equal to the initial phase, so the waves reinforce the oscillation. So the condition for resonance in a resonator is that the roundtrip distance, $2d$, be equal to an integer number of wavelengths λ of the wave:

$$2d = N\lambda, \qquad N \in \{1, 2, 3, \ldots\}$$

If the velocity of a wave is v, the frequency is $f = \frac{v}{\lambda}$ so the resonant frequencies are:

$$f = \frac{Nv}{2d} \qquad N \in \{1, 2, 3, \ldots\}$$

So the resonant frequencies of resonators, called normal modes, are equally spaced multiples of a lowest frequency called the fundamental frequency. The multiples are often called overtones. There may be several such series of resonant frequencies, corresponding to different modes of oscillation.

Q factor

The Q factor or *quality factor* is a dimensionless parameter that describes how under-damped an oscillator or resonator is,[12] or equivalently, characterizes a resonator's bandwidth relative to its center frequency.[13] Higher Q indicates a lower rate of energy loss relative to the stored energy of the oscillator, i.e., the oscillations die out more slowly. A pendulum suspended from a high-quality bearing, oscillating in air, has a high Q, while a pendulum immersed in oil has a low Q. To sustain a system in resonance in constant amplitude by providing power externally, the energy provided in each cycle must be less than the energy stored in the system (i.e., the sum of the potential and kinetic) by a factor of $\frac{Q}{2\pi}$. Oscillators with high-quality factors have low damping, which tends to make them ring longer.

Sinusoidally driven resonators having higher Q factors resonate with greater amplitudes (at the resonant frequency) but have a smaller range of frequencies around the frequency at which they resonate. The range of frequencies at which the oscillator resonates is called the bandwidth. Thus, a high-Q tuned circuit in a radio receiver would be more difficult to tune, but would have greater selectivity, it would do a better job of filtering out signals from other stations that lie nearby on the spectrum. High Q oscillators operate over a smaller range of frequencies and are more stable. (See oscillator phase noise.)

The quality factor of oscillators varies substantially from system to system. Systems for which damping is important (such as dampers keeping a door from slamming shut) have $Q = \frac{1}{2}$. Clocks, lasers, and other systems that need either strong resonance or high frequency stability need high-quality factors. Tuning forks have quality factors around $Q = 1000$. The quality factor of atomic clocks and some high-Q lasers can reach as high as 10^{11}[14] and higher.[15]

There are many alternate quantities used by physicists and engineers to describe how damped an oscillator is that are closely related to its quality factor. Important examples include: the damping ratio, relative bandwidth, linewidth, and bandwidth measured in octaves.

See also

- Acoustic resonance
- Antiresonance

- Center frequency
- Cymatics
- Damping
- Driven harmonic motion
- Earthquake engineering
- Electrical resonance
- Electric dipole spin resonance
- Formant
- Harmonic oscillator
- Impedance
- Limbic resonance
- Nonlinear resonance
- Positive feedback
- Q factor
- Resonance disaster
- Resonator
- Schumann resonance
- Simple harmonic motion
- Stochastic resonance
- Sympathetic string
- Tuned circuit
- Vibration

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15. Time and Frequency from A to Z: Q to Ra (http://tf.nist.gov/general/enc-q.htm)

External links

- Definition of Resonance (http://www.answers.com/topic/resonance) - "The increase in amplitude of oscillation of an electric or mechanical system exposed to a periodic force whose frequency is equal or very close to the natural undamped frequency of the system."
- Resonance (http://www.lightandmatter.com/html_books/lm/ch18/ch18.html) - a chapter from an online textbook
- Greene, Brian, "*Resonance in strings (http://www.pbs.org/wgbh/nova/elegant/resonance.html)*". The Elegant Universe, NOVA (PBS)
- Hyperphysics section on resonance concepts (http://hyperphysics.phy-astr.gsu.edu/hbase/sound/rescon.html#c1)
- Resonance versus resonant (http://users.ece.gatech.edu/~mleach/misc/resonance.html) (usage of terms)

- Wood and Air Resonance in a Harpsichord (http://www.johnsankey.ca/bottom.html)
- Java applet (http://www.phy.hk/wiki/englishhtm/StatWave.htm) demonstrating resonances on a string when the frequency of the driving force is varied
- Java applet (http://phy.hk/wiki/englishhtm/Resonance.htm) demonstrating the occurrence of resonance when the driving frequency matches with the natural frequency of an oscillator
- Breaking glass with sound (http://www.acoustics.salford.ac.uk/acoustics_info/glass), including high-speed footage of glass breaking

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Categories: Antennas (radio) | Control theory | Scattering | Waves

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Respirator assigned protection factors

From Wikipedia, the free encyclopedia

The respiratory protective devices (RPD) can protect workers only if their protective properties are adequate to the conditions in the workplace. Therefore, specialists have developed criteria for the selection of proper, adequate respirators, including the **Assigned Protection Factors** (APF) - the decrease of the concentration of harmful substances in the inhaled air, which (is expected) to be provided with timely and proper use of a certified respirator of certain types (*design*) by taught and trained workers (after individual selection with a tight-fitting mask and fit testing), when the employer performs an effective respiratory protective device programme.

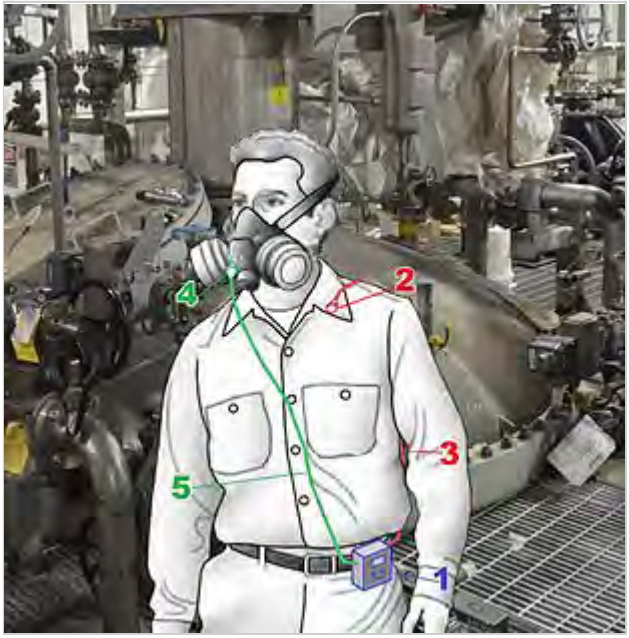

Example of measurement of efficiency of the respirator (in the workplace). Description: (1) Personal sampling pump, (2) The cassette and the filter for determining the concentration (in the breathing zone), (3) The cassette and the filter to determine the concentration (under a mask), (4) The sampling line (from the breathing zone), and (5) The sampling line (from the mask).

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- 5 The use of the APFs when selecting respirators for known workplace conditions
- 6 International standard for RPD selection and usage
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Background

The different methods of protection from air pollution and their effectiveness

The imperfection of technological processes, machines and other equipment can lead to air contamination with harmful substances in the workplace. Protecting of the workers' health in this situation may be achieved with different ways, listed below in order of decreasing of their effectiveness:

Hierarchy of hazard control[1][2]	
1.	The use of alternative substances which are less hazardous.
2.	The substitution of a given substance in a form that is less hazardous, e.g. replacing a fine powder by a coarser powder, pellets, or by a solution
3.	The substitution of a process by an alternative process likely to generate lower airborne concentrations of substances
4.	Total or partially enclosed process and handling systems
5.	Partial enclosure with local exhaust ventilation
6.	Local exhaust ventilation
7.	General ventilation
8.	Reducing period of exposure
9.	The introduction of appropriate working practices and systems of work, e.g. to close and store containers securely when not in use
10.	Use of monitors and warning devices to give a clear indication when unsafe airborne concentrations are present
11.	Good housekeeping
12.	Provision of a respiratory protective device programme

Self Containing Breathing Apparatus (SCBA) with pressure-demand air supply mode into the full face mask. This is the most reliable RPD type, its APF = 10 000

If the use of these methods is impossible, or if their use did not reduce the concentration of harmful substances to a safe value, workers must use respirators. These respirators must be sufficiently effective, and they should correspond to known or expected conditions at the workplace. However, it is the least effective method of protection; and the reasons for the decrease of

their efficiency often are: non-usage of the respirators in the contaminated atmosphere; leakage of unfiltered air through the gaps between the mask and face; and delayed replacement of gas cartridges.

Supplied Air Respirator (SAR) with auxiliary breathing apparatus (for evacuation in case of possible supply disruptions of air through the hose) with pressure-demand air supply mode into the full face mask. This is one of the most reliable RPD type, its APF = 1000

The effectiveness of respirators with different designs

Different terms may be used to describe the protective properties of respirators:

- **Penetration** = (the concentration of harmful substances under mask) / (concentration outside the mask);
- **Efficiency** = **(** (concentration outside the mask) - (the concentration of harmful substances under mask) **)** / (concentration outside the mask) = 1 - Penetration;
- **Protection Factor** (PF) = (the concentration of harmful substances on the outside of the mask) / (concentration under mask) = 1 / Penetration.

The term "Protection Factor PF" has been used in the U.S., and the term "Penetration" was used in the soviet literature from the 1960s.

In the first half of the 20th century, experts carried out measurements protective properties of respirators in the laboratories. They used different control substances (argon,[3] halogenated hydrocarbon vapour,[4] aerosols of sodium chloride and oil mist,[5] fluorophores,[6] dioctyl phthalate,[7][8] and others, and they measured their concentrations under the mask, and outside masks (simultaneously). The ratio of the measured concentrations is an indicator of the protective properties of different types of respirators. These

measurements showed that if the efficiency of filters is enough high, then the gaps between the mask and the face become the main way of penetration of air contaminations under the mask.

The shape and size of these gaps is not constant, and depends on many factors (the degree of fit the mask to the face - by shape and size; the correct donning the mask; the mask slippage on the face during the work due to execution of different movements; the design of the mask). The respirator's PF may change dozens of times during of several minutes; and the two average PF (*that were measured for the same worker in one day; for example - before and after the lunch break*) can differ by more than 12 000 times.[10]

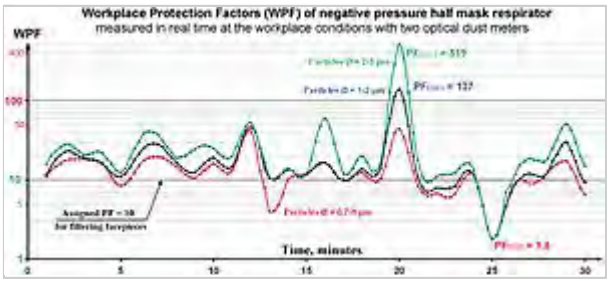

Workplace PF of filtering facepiece, measured in real time with two optical dust meters. In-facepiece dust concentration is changed dozens of times in a matter of minutes due to changes of the size of the gaps between the mask and face. Source[9]

Experts believed that the measurement of protection factors in the laboratory allows them to correctly evaluate, predict the RPD efficiency in the workplace conditions. But after the detection of cases of excessive harmful exposure on employees who used high quality respirators with HEPA particle filters in the nuclear industry of the USA, the experts changed their opinion.[11] Studies have been carried out to measure the protection factors for the various types of respirators - not only in the laboratories, but also at the workplaces.[12] Dozens of such field studies have shown that the performance of serviceable respiratory protective equipment at the workplaces may be significantly less than in laboratory conditions. Therefore, the usage of laboratory results to assess the real efficiency is incorrect; and can lead to a wrong choice of such respirators that can not reliably protect workers.

Terminology to describe the different PF, and methods for APF development

The experts used the results of measurements at the laboratories and at the workplaces to develop more completely terminology for description of the respirators' performance;[13][14][15][16] and this terminology has been applied officially,[17] and in the preparation of research results for publication.[18] Specialists began to use different terms to describe the protection factors, which were measured at workplaces with continuous use of respirators; and measured in the workplace when the workers used of respirators intermittently; measured not in the workplace while fit testing; measured in the laboratories under the simulation workplace's conditions; and for the protection factors, that can be expected (*in most cases*) when the workers properly used the respirators at the workplace.

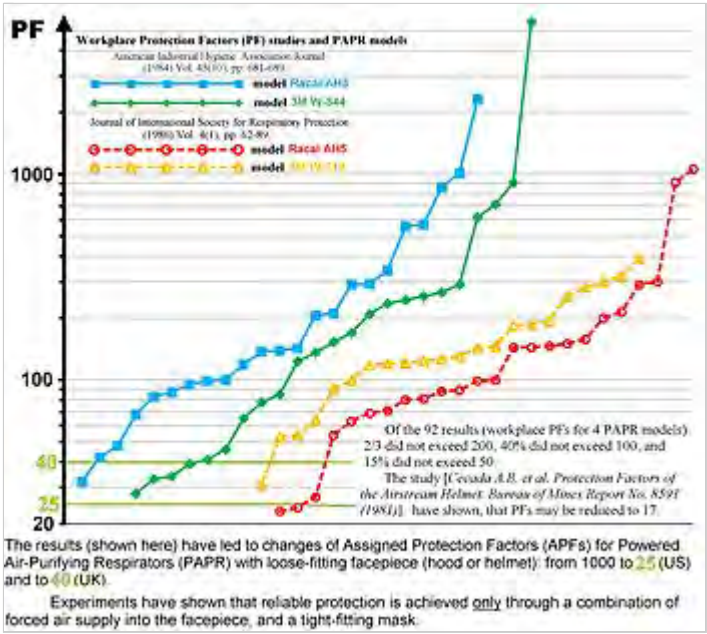

The diagram show 92 values of the Workplace PFs of PAPRs with loose-fitting facepieces (hood or helmet). After them, the Assigned Protection Factors of such PAPRs were reduced from 1000 to 25 (US) and to 40 (UK)

The modern terminology for RPD performance description (pp. 22–26 [17])	
Protection Factor	**A description of the term**
Assigned Protection Factor (APF)	The minimum anticipated protection provided by a properly functioning respirator or class of respirators to a given percentage of properly fitted and trained users.
Fit Factor	A quantitative measure of the fit of a specific respirator facepiece to a particular individual *(FF are measured during fit test)*.
Simulated Workplace Protection Factor (SWPF)	A surrogate measure of the workplace protection provided by a respirator (SWPF are measured in laboratory conditions, that imitate real workplace conditions during "work")
Workplace Protection Factor (WPF)	A measure of the protection provided in the workplace only while the respirator was properly worn and used during normal work activities *(WPF are measured at the workplaces, after fit testing; and without mask doffing during measurement)*.

A significant difference between respirator performance in the laboratories compared to the efficiency at the workplaces not allowed to use the laboratory results to predict the degree of protection offered in practice. And instability of respirators' protective properties (for the same RPD design, and in the same usage conditions) prevented evaluate their efficiency. For solving these problems, scientists Donald Campbell and Steven Lenhart suggested to use the results of measurements of Workplace PF values for development of Assigned (*expected in practice*) PF values (APF) - as the **lower** 95% confidence interval of WPF values.[19] The results of measurements of WPF has been used in the development of APF by ANSI (for the recommended standard, that is not mandatory).[20] The same was made during the development of the APF[21] by OSHA (in the development of the standard,[22] that is mandatory for the employer).

Development of APF values for the various respirator types

Results of measurements of WPF in the US and the UK became the basis for the development of APF for UK standard[1] and for English version of EU standard.[2] In some cases, there was no information on the effectiveness for respirators of specific design (type) in the workplace. This is due to the fact that the measurement of workplace PF is very difficult, time consuming, and expensive work, which was carried out not very often. For these types of respirators experts used the results of WPF measurements of other types of respirators, which are similar. For example, the effectiveness of the Supplied Air Respirators (SARs, with hose) was considered similar to the efficiency of Powered Air Purifying Respirators (PAPRs), if they have the same facepieces and the same air supply mode. Finally, in the absence of this information, specialists could use the results of Simulated WPF measurements; or estimates of competent experts.[20]

Correction of Assigned PF values

Measurement of workplace protection factors surprisingly revealed the low efficiency of some designs of respirators, and that results have led to a sharp tightening of the requirements for application limits for respirators of such designs.

- PAPR with helmets or hoods

Measuring WPF of Powered Air Purifying Respirators (PAPR) with helmets (that is not tight-fitted to the face) showed that the ingress of harmful substances in the inhaled air can be very high[23] (PF = 28 and 42 for two models). It was a surprise, since earlier studies in the laboratory showed that the flow of clean filtered air from the inside to the outside of the helmet prevents ingress of harmful substances under the helmet (PF > 1000). Additional studies[24] have confirmed the result of the first study: the

minimum values of the workplace protection factors of 2 models of respirators were 31 and 23; and leakage of unfiltered air achieved 16% in some cases in wind tunnel at 2 m/s air velocity[25]

PAPR with hood. APF decreased from 1000 to 25 after PF studies in the workplaces

Therefore, the use of such RPD types was limited 25 PEL in the U.S.,[22] and 40 OEL in the UK.[1][2]

- Negative pressure full face masks

Measurement of protection factors of negative pressure full face masks with high-efficiency filters in the laboratory revealed a risk of decrease in protective properties to a small values.[27] Therefore, the use of such respirators has been limited to the values 50 or 100 PEL in the United States. However, the experts in the UK believed that the quality of their masks is higher than American masks, and were allowed to use up to 900 OEL. But the study[26] showed that the value of the protection factor of > 900 has been achieved in practice infrequently. Minimum protection factors of 3 different models of full facepiece respirators were 11, 18 and 26. So, the new standards[1][2] limit usage of these respirators up to 40 OEL in UK (after this study).

Results of respirator Workplace Protection Factors (WPF) measurement. Source[26]

Negative pressure full face mask. APF decreased from 900 to 40 after PF studies in the workplace

- Negative pressure half mask respirators (after fit testing)

Fit testing of tight-fitting masks of negative-pressure respirators became widely used in US industry in 1980-s. At the beginning, it was thought that the half-mask fit quite well to the worker's face, if during a fit test the protection factor (fit factor) is not less than 10

Negative pressure full face masks, possible APF decreased from 100 to 10

(later, experts began to use "safety factor" = 10 during the fit test; threshold fit factor become 10 × 10 = 100). The widespread use of fit testing in the industry gives professionals optimism, and they allowed to the employers restrict the use of half mask respirators in accordance with the values of worker's personal fit factor (the maximum concentration of pollutants = personal Fit Factor × PEL), but not more than 100 × PEL. However, scientific studies have shown that although such test increases the effectiveness of protection, the risk of leakage of large amounts of unfiltered air is maintained. Furthermore, the studies have shown that non-filtered air under the mask is not uniformly mixed with the filtered air, which leads to large errors in the measurement of the in-facepiece concentration of contaminants, and subsequent calculations of fit factors - the latter is often much smaller than the "measured" value. So, specialists recommend not allowed usage negative pressure half mask respirators then harmful substances' concentrations exceeds 10 PEL.[28] Therefore, OSHA standards require to restrict using of half-mask negative-pressure respirators up to 10 PEL after obtaining fit factor greater than or equal to 100 during the mask selection for the worker (they used a safety factor = 10).

Comparison of APF in the US and the UK

The table lists the APF values for the most common respirator types (for US and UK).

The Assigned Protection Factors for some main (*equivalent*) RPD types *(developed on the basis of results of Workplace Protection Factors studies)*			
RPD type in US	**APF in US** [22]	**RPD type in UK**	**APF in UK** [1][2]
N95 negative pressure air-purifying half mask respirators (filtering facepieces or elastomeric)	10	FFP2 filtering facepieces or elastomeric half masks with P2 filters	10
N99 or N100 negative pressure air-purifying half mask respirators (filtering facepieces or elastomeric)	10	FFP3 filtering facepieces or elastomeric half masks with P3 filters	20
Negative pressure air-purifying respirators with full facepieces with P100 filters	50	Negative pressure air-purifying respirators with full facepieces with P3 filters	40
Powered Air-Purifying Respirators (PAPRs) with loose-fitting hood or helmet, and P100 filters	25	PAPRs with loose-fitting hood or helmet, and P3 filters	40
Supplied Air Respirators (SARs) or Self Contained Breathing Apparatus (SCBA) with full mask and air supply on demand	50	SARs or SCBAs with full face mask and negative pressure demand air supply	40
SARs with full mask and pressure demand air supply	1 000	SARs with full face mask and positive pressure demand air supply	2 000
			2 000

SCBAs with full mask and pressure demand air supply	10 000	SCBAs with full face mask and positive pressure demand air supply	

US particle filters N95 are similar to P2; and P100 (HEPA) are similar to P3; filtering materials in US N95 filtering facepieces are similar to FFP2.

The difference of the APF for air purifying negative pressure full-facepiece masks are not large. The difference between PAPR with helmets a few more. But measurements showed that the real effectiveness of RPD (at the workplace conditions) is strongly dependent on the conditions of their use, not only from the design, and this partly explains the difference in APF values. The APF for negative pressure half mask respirators are twofold. But this difference cannot be considered separately from recommendations for use of respirators. The use of half-face masks in the US is limited to 10 PEL for the "worst case" - work in the polluted atmosphere of 8 hours per day, 40 hours a week. But British experts took into account large experience of the use of negative pressure air purifying RPDs, and they concluded that to achieve continuous wear respirator 8 hours a day is impossible (because of the negative impact on the health of workers). For this reason, they recommend to the employer to give the job to the workers so that they work in the polluted atmosphere not during entire shift, but only a part of the shift. The remaining time the employee needs to work in a non-polluted atmosphere (without the respirator). The fact that the employee is in a non-polluted atmosphere some part of working time provide additional protection of his health, and therefore, the requirements to the efficiency of the respirator may be less stringent.

The development of the Assigned PF in the United States and Britain were based on measurements of the effectiveness of respirators in the workplace (after statistical processing). Also used opinions of experts, based on the similarity of the respirators with different designs (for example, powered air purifying filtering respirators (PAPR), and a similar supplied air respirators SAR) - provided that the mode and the quantity of air supply, and the facepieces (masks) were the same. Experts in the two countries often used the results of the same studies of WPF (because of their limited number). For

example, British standard[1] had been developed with usage of results of 1897 WPF measurements during 31 studies; and 23 of this 31 studies had been conducted in United States.

Therefore, the values of the assigned PF in the US and in the UK are evidence-based; and they are very similar to each other.

The values of the APF in EU and other countries

Studies of respirator's performance was carried out not very often, and almost all of these studies were conducted in USA (and UK). It is possible that the lack of information about the RPD efficiency in the workplaces, was the reason behind developing these assigned PF in several European countries, whose values differ significantly from the evidence-based values of APFs in the US and UK.

The Assigned Protection Factors for some main RPD types, developed in several EU countries[2]				
RPD type	**APF in several EU countries**			
	Finland	**Germany**	**Italy**	**Sweden**
FFP2 filtering facepices	10	10	10	10
Elastomeric half masks with P2 filters	10	10	10	10
FFP3 filtering facepices	20	30	30	20
Elastomeric half masks with P3 filters	-	30	30	-
Negative pressure air-purifying respirators with full face mask and P2 filters	15	15	15	15
Negative pressure air-purifying respirators with full face mask and P3 filters	500	400	400	500
Powered Air-Purifying Respirators (PAPRs) with loose-fitting hood or helmet, and THP3 filters	200	100	200	200
PAPRs with full face mask, and TMP3 filters	1000	500	400	1000
SARs with full facepiece and negative pressure demand air supply	500	1000	400	500
Supplied Air Respirators (SARs) with full facepiece and positive pressure demand air supply	1000	1000	400	1000
SCBAs with full facepiece and positive pressure demand air supply	-	≥ 1000	1000	-

Most European countries (except UK) did not conduct very complex and expensive studies on the effectiveness of respirators in the workplaces, or spent very little of such research. Therefore, it may be that some countries do not take full account of results of foreign researches (that showed a significant

difference between the effectiveness of respirators in a laboratory environment; and in applying them in the workplaces). For example, after the study[26] in 1990, the APF value of negative pressure full face masks was reduced from 900 to 40 (1997)[1] in UK. But in other countries, similar research was not carried out; and a similar decrease did not occur.

The study[26] showed that the three models of full face masks had a significant leakage of unfiltered air through the gaps between the mask and the face. The minimum values of the workplace protection factors (WPF) of each of the three negative pressure full face mask models were 11, 17 and 26. The maximum value of the WPF from one of the models did not exceed 500 no times at all. And for all results together, the WPF was not more than 100 in ~ 30% of the measurements. So, for this reason, the values of the APFs for this RPD type in Germany (400), Finland (500), Italy (400), and Sweden (500), may not fully take into account the lower this type respirators' performance at the workplace compared to the performance in the laboratory (during certification). The same was true for other RPD types and their APF.

State standard in India[29] points to the need to use the workplace protection factors for restricting the permissible use of respirators, but does not set any values of the APFs. The standard also recommends the use of those PFs, which are obtained during the certification (in the laboratories, but not at workplaces). These values greatly exceed the values used in the USA and in the UK.

The Ukrainian version of the EU standard EN 529 does not set any values of the APFs for the selection of respirator in this country.[30] This document only listed the values of APFs in several European countries (for reference); and declares the inadmissibility of the use of laboratory efficiency for predicting the protective properties at the workplace.

The APFs are not developed in RF,[31] in South Korea, as well as in many other countries, and selection of respirators is not regulated by its national legislation. This contributes to errors, and the usage of such respirator's types, which are not able to reliably protect the workers due to its design (even at high quality of specific certified models).

The use of the APFs when selecting respirators for known workplace conditions

US law obliges the employer to accurately measure air pollution at workplaces. The results of such measurements are used to assess whether short-term inhalation of harmful substances lead to the death of the person, or irreversible and significant deterioration of his health (IDLH concentrations). If concentrations exceed the IDLH, the standard allows the use of only the most reliable respirators - SAR or self-contained breathing apparatus: with pressure-demand air supply in the full facepiece mask (§(d)(2)[22]).

If the concentration of harmful substance is less than IDLH, when one must determine the coefficient of air pollution for harmful substance (Hazard Factor), which is equal to the ratio of this concentration to the PEL (TLV, OEL) for the harmful substance. APF of selected respirator type must be equal or exceed the Hazard Factor .[17][32]

If there are several harmful substances in the workplace air, then the selected respirator must run the following requirement:[17]

$$C_1/(APF \times PEL_1) + C_2/(APF \times PEL_2) + C_3/(APF \times PEL_3) + ... + Cn/(APF \times PELn) \leq 1$$

where C_1, C_2 ... and Cn - concentrations of harmful substances number 1, 2 ... n; and PEL is the maximum allowable concentration for corresponding harmful substances in the breathing zone.

If this requirement is not met, the employer needs to choose a different type of respirator, which has a greater APF value.

In all cases, if employer select respirator with tight-fitting facepiece (full face mask, elastomeric half-mask or quarter-mask, or filtering facepiece respirator), all employee must be fit tested (*to prevent leakage unfiltered polluted air through gaps between their faces and the tight-fitting masks, which may not match to their faces*). Appendix A[22] provides a detailed description of this testing.

Values of IDLH concentrations and detailed recommendations for the selection of respirators (and self-rescuers) are available in the NIOSH directory.[33]

International standard for RPD selection and usage

ISO is developing two international standard types, that governing the certification of respirators;[34] and their selection and application[35][36]

The standards governing the selection of respirators, uses the values of APF. But HSE spesialist criticue this documents.[37] These standards are set those values of Assigned Protection Factors that differ from those established in the US and the UK (evidence-based); and these values are set not for specific RPD type, but for any RPD, that met approval requirements:

New ISO RPD classification and APF		
ISO RPD type	**ISO requirements for approval**[38]	**Protection level**
PC6	TIL < 0.001%	10 000
PC5	TIL < 0.01%	2000
PC4	TIL < 0.1%	250
PC3	TIL < 1%	30
PC2	TIL < 5%	10
PC1	TIL < 20%	4

The report concluded - new ISO standards are used insufficiently substantiated APF values, and M. Clayton made recommendation: do not use these values in practice, and to continue work on APF justification for the different types of respirators.

See also

- Immediately dangerous to life or health
- Respirators testing in the workplaces

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Categories: Gas masks | Protective gear | Safety equipment

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Respirator

From Wikipedia, the free encyclopedia

A **respirator** is a device designed to protect the wearer from inhaling harmful dusts, fumes, vapors, or gases. Respirators come in a wide range of types and sizes used by the military, private industry, and the public. Respirators range from relatively inexpensive single-use, disposable masks to more robust reusable models with replaceable cartridges.

A half face particulate (air-purifying) mask is generally worn to protect the wearer from dust and paint fumes.

There are two main categories: the *air-purifying respirator* which forces contaminated air through a filtering element, and the *air-supplied respirator* in which an alternate supply of fresh air is delivered. Within each category, different techniques are employed to reduce or eliminate noxious airborne contaminants.

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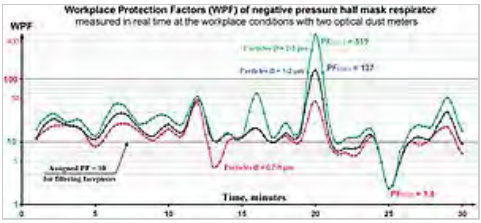

Workplace PF of filtering facepiece, measured in real time with two optical dust meters. In-facepiece dust concentration is changed dozens of times in a matter of minutes due to changes of the size of the gaps between the mask and face. Source[1]

Early development of respirators

The history of protective respiratory equipment can be traced back as far as the first century, when Pliny the Elder (circa A.D. 23-79) described using animal bladder skins to protect workers in Roman mines from red lead oxide dust.[2] In the 16th century, Leonardo da Vinci suggested that a finely woven cloth dipped in water could protect sailors from a toxic weapon made of powder that he had designed.[3] Alexander von Humboldt introduced a primitive respirator in 1799 when he was working in Prussia as a mining engineer.

Practically all the early respirators consisted of a bag placed completely over the head, fastened around the throat with windows through which the wearer could see. Some were rubber, some were made of rubberized fabric, and still others of impregnated fabric, but in most cases a tank of compressed air or a reservoir of air under slight pressure was carried by the wearer to supply the necessary breathing air. In some devices certain means were provided for the adsorption of carbon dioxide in exhaled air and the rebreathing of the same air many times; in other cases valves were provided for exhalation of used air.

The first US patent for an air purifying respirator was granted to Lewis P. Haslett in 1848[4] for his 'Haslett's Lung Protector,' which filtered dust from the air using one-way clapper valves and a filter made of moistened wool or a similar porous substance. Following Haslett, a long string of patents were issued for air purifying devices, including patents for the use of cotton fibers as a filtering medium, for charcoal and lime absorption of poisonous vapors, and for improvements on the eyepiece and eyepiece assembly. Hutson Hurd patented a cup-shaped mask in 1879 that became widespread in industrial use, and Hurd's H.S. Cover Company was still in business in the 1970s.

Inventors were also developing air purifying devices in Europe. John Stenhouse, a Scottish chemist, was investigating the power of charcoal, in its various forms, to capture and hold large volumes of gas. He put his science to work in building one of the first respirators able to remove toxic gases from the air, paving the way for activated charcoal to become the most widely used filter for respirators. British physicist John Tyndall took Stenhouse's mask, added a filter of cotton wool saturated with lime, glycerin, and

charcoal, and invented a 'fireman's respirator,' a hood that filtered smoke and gas from air, in 1871; Tyndall exhibited this respirator at a meeting of the Royal Society in London in 1874. Also in 1874, Samuel Barton patented a device that 'permitted respiration in places where the atmosphere is charged with noxious gases, or vapors, smoke, or other impurities.' German Bernhard Loeb patented several inventions to 'purify foul or vitiated air,' and counted among his customers the Brooklyn Fire Department.

Woodcut of Stenhouse's mask

Chemical warfare

The Second Battle of Ypres was the first time Germany used chemical weapons on a large scale on the Western Front in World War I. 168 tons of chlorine gas was released on 22 April over a four-mile (6 km) front. Around 6,000 troops died within ten minutes from asphyxiation. The gas affects the lungs and the eyes causing respiration problems and blindness. Being denser than air it flowed downwards forcing the troops to climb out of trenches.

Eventually reserve Canadian troops held the front, being away from the attack, using urine-soaked cloths as primitive respirators. A Canadian soldier realized that the ammonia in urine would react with the chlorine, neutralizing it, and that the water would dissolve the chlorine, allowing the soldiers to breathe through the gas. This is the first recorded response and defense against chemical attacks using respirators.

Modern respirator technology

Cross-section of a disposable NIOSH P95 filter pad used in metalworking operations. Even "clean" industrial processes often generate large amounts of harmful particulate matter and require breathing protection.

All respirators have some type of facepiece held to the wearer's head with straps, a cloth harness, or some other method. The facepiece of the respirator covers either the entire face or the bottom half of the face including the nose and mouth. Half-face respirators can only be worn in environments where the contaminants are not toxic to the eyes or facial area. For example, someone who is painting an object with spray paint could wear a half-face respirator, but someone who works with chlorine gas would have to wear a full-face respirator. Facepieces come in many different styles and sizes, to accommodate all types of face shapes, and there are many books and references available for determining which kind of hazard requires what type of respirator.

Fit testing respirators

All respirators function by forming a seal on the users face with the respirator itself. This is essential, as respirators are designed to come in contact with all air flowing through them, which is then delivered to the user. Fit testing uses simple equipment that places the users face and head into a hood, into which flavored mist is sprayed. Usually either bitter or sweet in flavor, with bitter flavors being favored for the almost involuntary reaction of users. Following a standard procedure, the user then breathes through the chosen respirator, and indicates whether they can detect the mist. If they cannot, the filter has passed the basic requirement of a face seal and the user also understands how to fit the mask.

While the user may not detect the sweet or bitter indicator, which indicates a proper fit, this test does not provide any indication as to whether the equipment is appropriate for the hazard.

Air-purifying respirators

Air-purifying respirators are used against particulates (such as smoke or fumes), gases, and vapors that are at atmospheric concentrations less than immediately dangerous to life and health. The air-purifying respirator class includes:

- negative-pressure respirators, using mechanical filters and chemical media
- positive-pressure units such as powered air-purifying respirators (PAPRs)
- Escape Only respirators or hoods such as Air-Purifying Escape Respirators (APER) for use by the general public for chemical, biological, radiological, and nuclear (CBRN) terrorism incidents.

Protective filter mask worn by NYPD officer

Full hood, half- or full-facepiece designs of this type are marketed in many varieties depending on the hazard of concern. They use a filter which acts passively on air inhaled by the wearer. Some common examples of this type of respirator are single-use escape hoods and filter masks. The latter are typically simple, light, single-piece, half-face masks and employ the first three mechanical mechanisms in the list below to remove particulates from the air stream. The most common of these is the disposable white N95 variety. The entire unit is discarded after some extended period or a single use, depending on the contaminant. Filter masks also come in replaceable-cartridge, multiple-use models. Typically one or two cartridges attach securely to a mask which has built into it a corresponding number of valves for inhalation and one for exhalation.

The American National Standard for Air-Purifying Respiratory Protective Smoke Escape Devices was established to define both test criteria and approval methods for fire/smoke escape hoods. ANSI/ISEA 110 provides design guidance to Respiratory Protective Smoke Escape Devices (RPED) manufacturers in the form of a detailed set of performance requirements and testing procedures. Key sections of the standard cover certification, labeling, design, performance, conditioning and testing requirements.

ANSI/ISEA 110 was prepared by members of the ISEA RPED Group, in consultation with testing laboratories and was reviewed by a consensus panel representing users, health and safety professionals and government representatives.

ANSI/ISEA Standard 110[5] contains general requirements for certification – including ISO registration for the manufacturer, independent process and quality control audits and follow-up inspection programs – and a comprehensive schedule of performance requirements and associated test methods.

The U.S. Consumer Product Safety Commission is using ANSI/ISEA 110 as the benchmark in their testing of fire escape masks, stating on their website, “Emergency escape masks have the potential to reduce consumer-related deaths and injuries by assisting in egress from fires, provided they perform effectively and reliably."

The Safety Equipment Institute (SEI) is a private, non-profit organization that administers a non-governmental, third-party certification program and tests and certifies a broad range of safety and protective products used occupationally and recreationally. SEI certification programs are voluntary and available to any manufacturer of safety and protective equipment seeking to have product models certified by SEI.

Mechanical filter respirators

Mechanical filter respirators retain particulate matter when contaminated air is passed through the filter material. This was the method used by early inventors such as Haslett and Tyndall. Wool is still used today as a filter, along with other substances such as plastic, glass, cellulose, and combinations of two or more of these materials. Since the filters cannot be cleaned and reused and therefore have a limited lifespan, cost and disposability are key factors. Single-use, disposable as well as replaceable cartridge models are common.

Mechanical filters remove contaminants from air in the following ways:

1. by particles which are following a line of flow in the airstream coming within one radius of a fiber and adhering to it, called *interception*;
2. by larger particles unable to follow the curving contours of the airstream being forced to embed in one of the fibers directly, called *impaction*; this increases with diminishing fiber separation and higher air flow velocity
3. by an enhancing mechanism called *diffusion*, which is a result of the collision with gas molecules by the smallest particles, especially those below 100 nm in diameter, which are thereby impeded and delayed in their path through the filter; this effect is similar to Brownian motion and increases the probability that particles will be stopped by either of the two mechanisms above; it becomes dominant at lower air flow velocities
4. by using certain resins, waxes, and plastics as coatings on the filter material to attract particles with an electrostatic charge that holds them on the surface of the filter material;
5. by using gravity and allowing particles to settle into the filter material (this effect is typically negligible); and
6. by using the particles themselves, after the filter has been used, to act as a filter medium for other particles.

Considering only particulates carried on an air stream and a fiber mesh filter, diffusion predominates below the 0.1 µm diameter particle size. Impaction and interception predominate above 0.4 µm. In between, near the 0.3 µm most penetrating particle size (MPPS), diffusion and interception predominate.

Filtering half mask with exhalation valve (class: FFP3)

For maximum efficiency of particle removal and to decrease resistance to airflow through the filter, particulate filters are designed to keep the velocity of air passing through the filter medium as low as possible. This is achieved by manipulating the slope and shape of the filter to provide larger surface area.

A substantial advance in mechanical filter technology was the HEPA filter. A HEPA filter can remove as much as 99.97% of all airborne particulates with aerodynamic diameter of 0.3 micrometres or greater.

The National Institute for Occupational Safety and Health in the United States defines the following categories of particulate filters:[6]

Oil resistance	Rating	Description
Not oil resistant	N95	Filters at least 95% of airborne particles
	N99	Filters at least 99% of airborne particles
	N100	Filters at least 99.97% of airborne particles
Oil Resistant	R95	Filters at least 95% of airborne particles
	R99	Filters at least 99% of airborne particles
	R100	Filters at least 99.97% of airborne particles
Oil Proof	P95	Filters at least 95% of airborne particles
	P99	Filters at least 99% of airborne particles
	P100	Filters at least 99.97% of airborne particles

A video describing N95 certification testing

European standard EN 143 defines the following classes of particle filters that can be attached to a face mask:

Class	Filter penetration limit (at 95 L/min air flow)
P1	Filters at least 80% of airborne particles
P2	Filters at least 94% of airborne particles
P3	Filters at least 99.95% of airborne particles

European standard EN 149 defines the following classes of "filtering half masks" (also called "filtering face pieces"), that is respirators that are entirely or substantially constructed of filtering material:

Class	Filter penetration limit (at 95 L/min air flow)	Inward leakage
FFP1	Filters at least 80% of airborne particles	<22%
FFP2	Filters at least 94% of airborne particles	<8%
FFP3	Filters at least 99% of airborne particles	<2%

Both European standards test filter penetration with both dry sodium chloride and paraffin oil aerosols, after storing the filters at 70 °C and −30 °C for 24 h each. The standards also include tests on mechanical strength, breathing resistance and clogging. EN 149 also tests the inward leakage between the mask and face (ten human subjects perform five exercises each and for eight of these individuals the average measured inward leakage listed above must not be exceeded).

Chemical cartridge respirators

Chemical cartridge respirators use a cartridge to remove gases, volatile organic compounds (VOCs), and other vapors from breathing air by adsorption, absorption, or chemisorption. A typical organic vapor respirator cartridge is a metal or plastic case containing from 25 to 40 grams of sorption media such as activated charcoal or certain resins. The service life of the cartridge varies

based, among other variables, on the carbon weight and molecular weight of the vapor and the cartridge media, the concentration of vapor in the atmosphere, the relative humidity of the atmosphere, and the breathing rate of the respirator wearer. When filter cartridges become saturated or particulate accumulation within them begins to restrict air flow, they must be changed.[7]

If the concentration of harmful gases is immediately dangerous to life or health, a US law[8] and NIOSH[9] prohibits the use of any air-purifying respirators.

Combined gas and particulate respirator filter for protection against acid gases, the type of BKF (БКФ). It has transparent body and special sorbent that changes color after the saturation. This color change may be used for timely replacement of respirators' filters (like End of Service Life Indicator ESLI).

Powered air-purifying respirators (PAPRs)

The purpose of a PAPR is to take air that is contaminated with one or more types of pollutants, remove a sufficient quantity of those pollutants and then supply the air to the user. There are different units for different environments. The units consist of a powered fan which forces incoming air through one or more filters for delivery to the user for breathing. The fan and filters may be carried by the user or with some units the air is fed to the user via tubing while the fan and filters are remotely mounted.

The type of filtering must be matched to the contaminants that need to be removed. Some respirators are designed to remove fine particulate matter such as the dust created during various woodworking processes. When used in combination with the correct filters they are suitable for working with volatile organic compounds such as those used in many spray paints. At the same time filters that are suitable for volatile substances must typically have their filter elements replaced more often than a particulate filter. In addition there is some confusion over terminology. Some literature and users will refer to a particulate filtering unit as a dust mask or filter and then use the term respirator to mean a unit that can handle organic solvents.

Self-contained breathing apparatus (SCBA)

An SCBA typically has three main components: a high-pressure tank (e.g., 2200 psi to 4500 psi), a pressure regulator, and an inhalation connection (mouthpiece, mouth mask or face mask), connected together and mounted to a carrying frame. There are two kinds of SCBA: open circuit and closed circuit.

Open-circuit industrial breathing sets are filled with filtered, compressed air, the same air we breathe normally. The compressed air passes through a regulator, is inhaled by the user, then exhaled out of the system, quickly depleting the supply of air. Most modern SCBAs are open-circuit. An open-circuit SCBA has a full-face mask, regulator, air cylinder, cylinder pressure gauge, and a harness with adjustable shoulder straps and belt which lets it be worn on the back. Air cylinders are made of aluminum, steel, or of a composite construction (usually fiberglass-wrapped aluminum.) Commonly an SCBA will be of the "positive pressure" type, which supplies a slight steady stream of air to stop toxic fumes or smoke from leaking into the mask. Not all SCBAs are positive pressure; others are of the "demand" type, which only supply air on demand (i.e., when the regulator senses the user inhaling). All fire departments and those working in toxic environments need to use the positive pressure SCBA for safety reasons.

The closed-circuit type filters, supplements, and recirculates exhaled gas: see rebreather for more information. It is used when a longer-duration supply of breathing gas is needed, such as in mine rescue and in long tunnels, and going through passages too narrow for a large open-circuit air cylinder.

Educational textbook

There are different respirators designs, and their design differences have a significant impact on the resulting degree of protection. So, the use of high quality and certified (approved) respirator under conditions, for which its design is not intended, may not preserve the health of workers. Therefore, the industrialized countries have requirements for employer containing specific instructions for selection and use of RPD, enshrined in national legislation. And in accordance with these requirements of the law were developed tutorials with information on how to meet these requirements:

- *Nancy Bollinger, Robert Schutz et al.* NIOSH Guide to Industrial Respiratory Protection. (http://www.cdc.gov/niosh/docs/87-116/pdfs/87-116.pdf) — NIOSH. — Cincinnati, Ohio: DHHS (NIOSH) Publication No. 87-116, 1987. — 305 p.

- *Linda Rosenstock et al.* TB Respiratory Protection Program In Health Care Facilities. Administrator's Guide. (http://www.cdc.gov/niosh/docs/99-143/pdfs/99-143.pdf) — DHHS (NIOSH) Publication No. 99-143. — Cincinnati, Ohio, 1999. — 120 p.
- *Nancy Bollinger et al.* NIOSH Respirator Selection Logic. (http://www.cdc.gov/niosh/docs/2005-100/pdfs/2005-100.pdf) — DHHS (NIOSH) Publication No. 2005-100. — Cincinnati, Ohio, 2004. — 39 p
- Respiratory protective equipment at work. A practical guide. 4 ed. (http://www.hse.gov.uk/pubns/priced/HSG53.pdf) — HSE (UK). — Norwich: Crown, 2013. — 59 p. — ISBN 978 0 7176 6454 2.
- BGR/GUV-R 190 Benutzung von Atemschutzgeraten. (http://publikationen.dguv.de/dguv/pdf/10002/R-190.pdf) — Deutsche Gesetzliche Unfallversicherung e.V. (DGUV), Medienproduktion. — Berlin (BRD), 2011. — 174 p.
- *Jaime Lara, Mireille Vennes*. Guide pratique de protection respiratoire. (http://www.irsst.qc.ca/media/documents/PubIRSST/R-319.pdf) — Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST). — Montréal (Canada), 2002. — 56 p. — ISBN 2-550-37465-7
- Occupational Safety & Health Administration, Respiratory Protection Training Video (https://www.osha.gov/SLTC/respiratoryprotection/training_videos.html#video)

See also

- Air filter
- Gas mask
- HEPA
- Pocket mask
- Poison gas in World War I
- Atmospheric particulate matter
- Cartridges and canisters of air-purifying respirators
- Surgical mask
- Smoke hood
- Respirator Assigned Protection Factors
- Respirators testing in the workplaces

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2. "OSHA Technical Manual (OTM) Section VIII: Chapter 2, Respiratory Protection". United States Department of Labor Occupational Safety and Health Administration. 1999-01-20. Retrieved 2013-09-13.
3. "Women in the US Military – History of Gas Masks". Chnm.gmu.edu. 2001-09-11. Retrieved 2010-04-18.
4. Christianson, Scott (2010). *Fatal Airs: The Deadly History and Apocalyptic Future of Lethal Gases that Threaten Our World*. ABC-CLIO. ISBN 9780313385520.
5. "International Safety Equipment Association". Safetyequipment.org. Retrieved 2010-04-18.
6. Metzler, R; Szalajda, J (2011). "NIOSH Fact Sheet: NIOSH Approval Labels - Key Information to Protect Yourself" (PDF). *DHHS (NIOSH) Publication No. 2011-179*. Centers for Disease Control and Prevention. ISSN 0343-6993.
7. The document describes the methods used previously and currently used to perform the timely replacement of cartridges in air purifying respirators.
8. OSHA standard 29 CFR 1910.134 (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=12716) "Respiratory Protection"
9. Bollinger, Nancy; et al. (1987). *NIOSH Respirator Selecion Logic*. DHHS (NIOSH) Publication No. 87-108. Cincinnati, Ohio: National Institute for Occupational Safety and Health. p. 32.

Further reading

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- Palazzo, Albert (2000). *Seeking Victory on the Western Front: The British Army and Chemical Warfare in World War I*. University of Nebraska Press. ISBN 0-8032-8774-7.
- Cheremisinoff, Nicholas (1999). *Handbook of Industrial Toxicology and Hazardous Materials*. Marcel Dekker. ISBN 0-8247-1935-2.
- NIOSH respirators main page (http://www.cdc.gov/niosh/topics/respirators/)
- NIOSH respirator fact sheet (http://www.cdc.gov/niosh/npptl/topics/respirators/factsheets/respfact.html)
- What's Special about Chemical, Biological, Radiological, and Nuclear (CBRN) Air-Purifying Respirators (APR)? (http://purl.fdlp.gov/GPO/gpo41712) NIOSH Fact Sheet

- NIOSH-Approved Disposable Particulate Respirators (Filtering Facepieces) (http://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/)
- TSI Application note ITI-041: Mechanisms of Filtration for High Efficiency Fibrous Filters (http://www.tsi.com/uploadedFiles/Product_Information/Literature/Application_Notes/ITI-041.pdf)
- British Standard BS EN 143:2000: Respiratory protective devices – Particle filters – Requirements, testing, marking
- British Standard BS EN 149:2001: Respiratory protective devices – Filtering half masks to protect against particles – Requirements, testing, marking

External links

- 3M Safety Respirator Classification Guide (http://solutions.3m.com/wps/portal/3M/en_US/PPESafetySolutions/PPESafety/Personal_Protective_Equipment/Respirators/)
- Mine Safety Appliance Company (MSA) Respirator Classification Guide (http://webapps.msanet.com/ResponseGuide)
- The Invention of the Gas Mask (http://www33.brinkster.com/iiiii/gasmask/page.html)
- CDC Protective Masks Fact Sheet (http://www.cdc.gov/niosh/npptl/topics/respirators/factsheets/respfact.html)
- Canadian Centre for Occupational Health and Safety (CCOHS)> Respirator Selection (http://www.ccohs.ca/oshanswers/prevention/ppe/respslct.html)
- For CBRN defense responders: The following links are ideal respirator selection logic and competitive bid research information pages for use by all end-users, especially respiratory protection program managers, safety officers, industrial hygienists, CBRN defense specialists, and grant writers seeking funding from the United States Department of Homeland Security (DHS) or other public safety sources:
  - APR (http://www.cdc.gov/niosh/npptl/topics/respirators/cbrnapproved/apr/): Respirator manufacturer approvals for NIOSH-certified air-purifying respirator with CBRN Protections (CBRN APR). This link covers APR and Air-Purifying Escape Respirators (APER) certified by the NIOSH's National Personal Protective Technology Laboratory (NPPTL), Pittsburgh, PA, to Chemical, Biological, Radiological, and Nuclear (CBRN) protection NIOSH standards. CBRN APR are tight-fitting, full-face respirators with approved accessories and protect the user breathing zone by relying on user negative pressure, fit testing and user seal checks to filter less than Immediately Dangerous to Life and Health (IDLH) concentrations of hazardous respiratory compounds and particulates through NIOSH CBRN Cap 1, Cap 2 or Cap 3 canisters for CBRN APR- or CBRN 15- or CBRN 30-rated APER.
  - PAPR (http://www.cdc.gov/niosh/npptl/topics/respirators/cbrnapproved/papr/default.html): Respirator manufacturer approvals for NIOSH-certified powered air-purifying respirator with CBRN Protections (CBRN PAPR-loose fitting or tight fitting)
- OSHA videos on respiratory protection (http://www.osha.gov/video/respiratory_protection/index.html)

Wikimedia Commons has media related to ***Respirators***.

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Categories: Filters | Masks | Protective gear

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Restoring a hydro unit

The alternator is the mainstay of wind and water power systems and homebuilt standby generators

[This is the second in a series of articles on hydropower. Last issue, in *Do-it-Yourself Hydro Survey* (Jan/Feb 2001), I detailed how to evaluate the potential to generate power from the runoff or the seasonal or annual flow of water across one's land. This article details alternator rebuilding and simple, practical control circuits for these systems, including homebuilt ones. The hydro unit restored in this article is part of an installation in progress and will be the subject of an article in a future issue.}

By Michael Hackleman

The alternator has replaced the generator as the preferred way to produce low-voltage dc for recharging the battery and powering lights, wipers, and other big loads in today's automobiles. The alternator has found further application in producing electricity in wind and water energy systems and standby generators, and is a favorite with manufacturers and hobbyists alike. I was recently asked to check out a used hydro-electric unit as part of a planned water power installation. As most of the effort focused on restoring the alternator in this unit, I felt it was a good opportunity to share the process with those interested in adapting or using such a universal electricity-producing device in their own projects.

Donna D'Terra wanted to supplement the energy produced by her solar-electric modules at Motherland, her homesite and retreat center located in the mountains outside Willits, California. More specifically, she wanted to cut back on the cost and noise of a standby generator in the winter when the waning sunlight reduced panel output.

A site survey established that she could take advantage of the energy of several streams that flow seasonally. As well, I was able to confirm that a used, Pelton-type hydro unit she had traded for work several years previously would operate in this application.

Using the hose-and-pressure gauge method of establishing head (see *Do-it-Yourself Hydro Survey*, Jan/Feb 2001) and the pipe-and-bucket method of finding seasonal flow, I designed the system around a static head of 100 feet and a flow of 24 gpm. I identified the hydro unit as a Burkhardt turbine which was produced locally here in Mendocino County. This unit was reported to be operational when removed from service. I was asked to check it out. A control box (missing) would need to be purchased or fabricated.

The hydro unit

The Burkhardt turbine consists of a Delco alternator, a Pelton-type impeller, an input nozzle assembly, two aluminum spray shields, and a support framework for bolting the unit down.

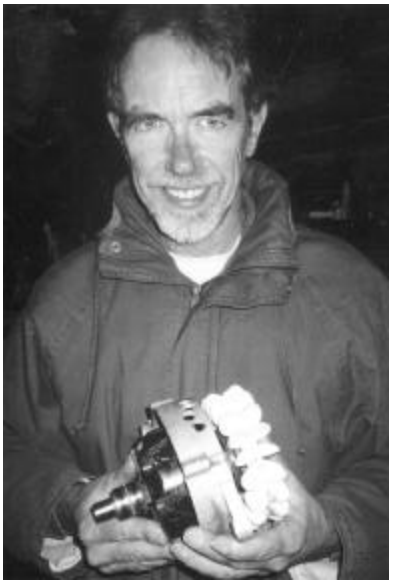

Michael Hackleman holds refurbished alternator parts.

The hydro unit appeared to be in good shape. I reached in with my hand to discover that the Pelton impeller was both intact and virtually unworn. The impeller has twin rows of tiny, spoon-shaped buckets distributed equally around the rim of a center-punched disk. The all-plastic part has 17 buckets to a row, or 34 buckets total. The resulting impeller is 5 inches in diameter and 1¾ inches thick at its widest part.

There was some resistance when I attempted to spin the impeller, so I knew that I would need to check the alternator's bearings. Further inspection revealed that the impeller would have to be removed for the alternator to pull through the back of the salad-bowl housing. A complete disassembly of the unit was called for. This was okay. While I had no idea as to how long the unit had been in service, I *did* know that it would be used in its new application for six months at a time, 24 hours a day. Every component needed to be in top condition for this extreme duty cycle.

The spray shield housing functions as spray guard and drain guide. The spray from a jet of water hitting an

impeller at high rpm is intense, so the spray guard helps keep the surroundings dry. The two halves of this housing are aluminum salad bowls that were adapted to this application. As such, the outermost bowl is cut away about 1½ inches wide along its rim for about a third of its circumference to help route waste water out of the bottom of the unit.

I removed the bolts that held the two bowls together around the rim and separated the two halves. I took a moment to examine the nozzle assembly. This consists of a casting that bolts to the inner spray shield and has a threaded jet in one end (inside) and a threaded receptacle for the 2-inch pipe at the other end (outside). The size of the jet is critical in matching the head and rate of water flow with the turbine for best efficiency. Selecting the correct size of jet (orifice) is part of the "tuning" process once the hydro unit is in place and has water flowing to it. (This will be covered in greater detail in the installation article next issue.)

With the spray shield halves separated, the nut that holds the impeller onto the alternator shaft is exposed. The shaft has a hex-shaped hole machined into its end so that a large Allen wrench can grip the shaft for removing the nut. I didn't have this size of wrench handy so I contemplated my options.

Rather than risk breaking the impeller (a $100 item) by trying to hang onto it to remove the nut, I elected to open the alternator casing to get at the shaft. After scratching a line across the casing halves (for correct alignment during reassembly), I removed the four small bolts that held the alternator case together and pulled off the rear alternator casing. This exposed the alternator shaft with its field coils. I was able to lock some vise-grips onto one of the solid iron jaws surrounding the field coils and, with a medium-sized crescent wrench, was able to twist free the impeller nut at the other end of the shaft.

To complete the disassembly, I removed the four bolts holding the framework and the rear bowl housing to the alternator's front casing and this separated all the parts of the unit. Incidentally, the hydro unit weighs 17 pounds, with the bulk taken by the alternator (10 lbs).

The alternator

Opening up an alternator may seem daunting the first time you do it, but it's really no big thing. In pulling the alternator's rear casing off the rotor,

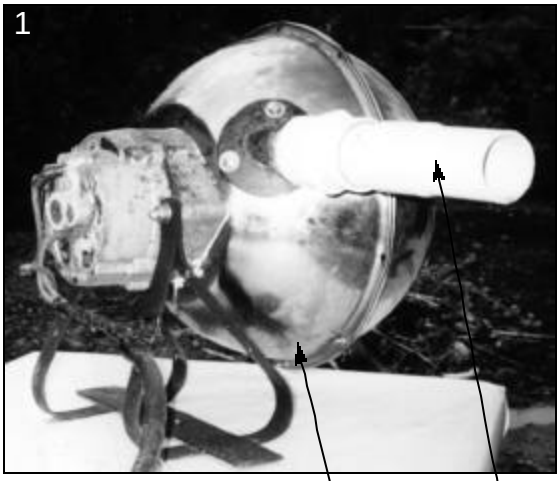

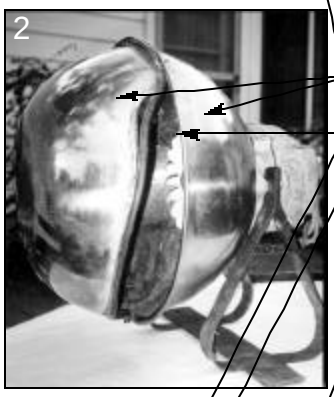

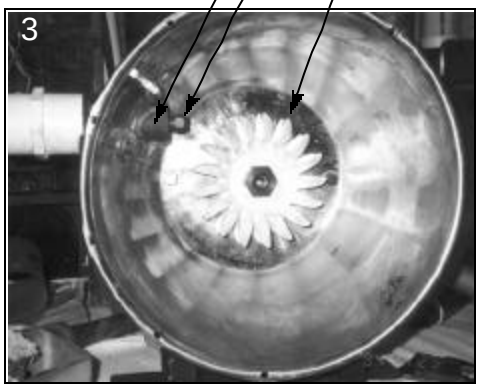

Inlet pipe
Spray shield(s)
Nozzle Assembly
Nozzle Jet
Crescent wrench
Vicegrips
Impeller

Burkhardt Turbine

1. The Burkhardt turbine with inlet pipe and framework

2. Water exits the turbine through a slot in the outer bowl.

3. Removing the spray shield reveals the impeller and nozzle jet. The impeller nut can be loosened with a crescent wrench on the nut and an Allen wrench on the shaft ...

4. ... or by grasping the field rotor with vicegrips.

5. Case halves, field rotor, and impeller

two brushes leap from their sockets. At this point, you may wonder how will you hold them in their guides until you push the rotor back and the brushes are once again held against the rotor's sliprings? If you look carefully, you'll see that the manufacturer solved this by providing a hole in the rear housing. Professionals insert a paper clip through it to temporarily hold the spring-tensioned brushes in their guides. Alternately, a thin wire may be routed over the brushes and out another opening and twisted together. Once the rotor is back in place, the clip or wire is pulled out and the brushes will seat against the sliprings.

Whenever opening something for the first time, it's important to position the parts on the bench and simply look at them. Troubleshooting starts with careful observation. What was I looking for? Signs of arcing or burning or open-ended (disconnected) wires are not good. If the unit shows evidence of this kind of damage, deal with it first. Alternators are not that expensive, new or re-manufactured, so anything beyond your ability to rectify easily or inexpensively is not worth it. As well, alternator shops can do everything I did to this unit and have the tools, parts, and experience to handle all alternator brands.

This unit passed the initial visual inspection. The brushes (rear casing) and sliprings (rotor shaft) drew my attention next. The brushes transfer power to the field coils in the rotor through the sliprings. Since the field coil in a standard alternator only draws about 3 amps at 12 volts, these are small brushes and they don't work very hard. The sliprings had a nice chocolate brown look to them, which is good. The brushes still had plenty of length (which decreases with wear), a smooth curvature to fit the sliprings themselves, and were not gouged, burned, or pitted. The brush leads were neither frayed nor corroded. Brushes are not expensive but *new* brushes must be "arced" to the slipring curvature. This work is unwarranted unless the brushes *must* be replaced for one of the aforementioned reasons.

I used a multimeter to test the field winding's resistance. With a test lead held against each of the copper sliprings on the rotor, I observed a 4.2 ohm reading. I did the math. Volts equals amps times ohms. Therefore, amps equals volts divided by ohms. 12V divided by 4.2 ohms equals 2.85 amps. That's close to the approximately 3 amps I knew the field would draw.

The front and rear bearings were my next focus. The front one was a standard ball bearing. The rear one was a much smaller, needle-roller type. Both turned smoothly but slowly. I pealed the plastic side off the front "sealed" bearing. The lubricant inside was dried and crusty. I felt tempted to soak out the old lubricant and repack the bearings with good grease. However, with no knowledge of the history of this unit, I opted for new bearings. Toward this end, I removed both bearings, using a socket and shaft extension like a punch to drive them out. The local bearing distributor was able to upgrade these Chinese and Hungarian bearings to higher quality ones for a cost of $17.

Checking the diodes

It was time to check the diodes. The diodes in an alternator can be checked with a standard multimeter but the process is somewhat involved for the novice (Sidebar A).

My measurements resulted in some distinctly different readings between some diodes, so I opted to take the casing to a local alternator shop. Their test equipment, designed specifically for testing diodes, confirmed the same borderline readings. Since these values can be influenced by a high-resistance path across the diode surfaces (usually a result of corrosion), a shop worker bead-blasted the entire rear casing and retested. Everything checked good. In a split second, the technician even popped in a rear bearing. (Darn if it wasn't the same one I'd just bought.). Since I had brought the alternator in disassembled, I was only charged $5 for the 5 minutes of time this entire process took.

Assembling the unit

I was now ready to reassemble the hydro unit. I relied on photographs I had taken of the unit *before* disassembly to help orient everything correctly.

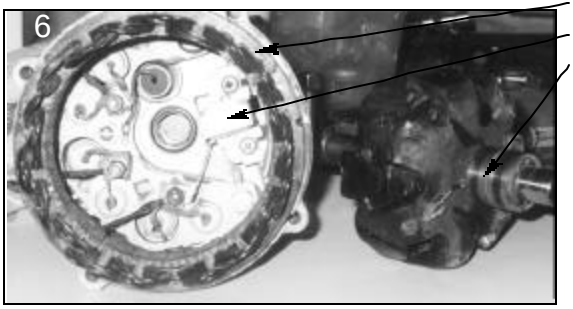

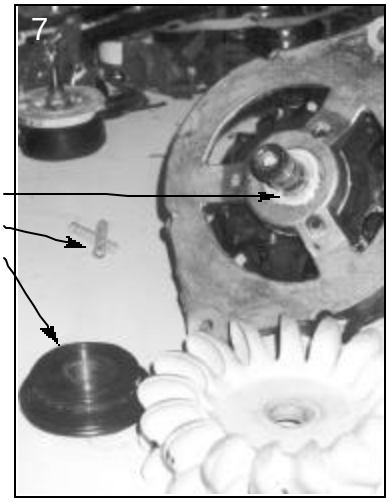

6. The rear alternator casing and field rotor.

7. The front bearing is packed with grease. The backing plate and impeller are ready to install on the rotor shaft.

Since I would need the grip on the rotor to re-install the impeller nut, I began by installing the new sealed ball bearing and its retaining plate in the front alternator casing. Since this bearing is within an inch of the water-driven impeller, I packed plenty of Lubriplate on either side of the bearing to help keep out water. Next, I slid the bushing onto the shaft of the alternator rotor and inserted the shaft through the front bearing in the alternator casing. I squeezed out a thin coating of Form-a-Gasket (non-hardening type) onto the front of the alternator casing and mated it against the inner spray shield to further waterproof the unit.

Alternators have two mounting holes, one larger than the other. The hole for the smaller bolt is threaded, so its bolt is inserted from the inside of the bowl and is simply tightened down. The larger bolt slips through

Sidebar A: Alternator diodes

Alternators have rotating fields and stationary stator windings. As the name implies, the field coils on the rotating core generate an electromagnetic field. The stator (power) windings are stationary and produce electricity up to 35-45 amps at 12V as a result of rotation through the field. The field coils receive power from B+, or the alternator's output through graphite brushes in contact with sliprings on the rotor. The stators are wound to produce 3-phase ac electricity which is converted into DC with diodes. Each phase needs two diodes, each one of which are ganged together at B+ or ground.

So, there are six diodes mounted in the alternator—three in the rear casing and three in a metal plate that is electrically-isolated from the casing. Unless there is reported trouble with the alternator's output, the diodes are generally assumed to be good and are left alone. A diode in your hand is easy to test with an ohmmeter or a continuity tester (both functions are found on inexpensive multimeters) to find out if it's shorted or open. However, alternator diodes are pressed into tight holes and are difficult to remove. To test them in place, a diode lead must be disconnected so that each diode is essentially "out of the circuit" and not influenced by other wiring or diodes.

The process of checking the diodes begins by locating the stator windings. These are wound in a frame that fits the inside curvature of the casing and they handle all the power generated in the alternator. Three wires from this array terminate on three separate posts on the rear plate, each wire representing 1 phase of the generated 3-phase output. The leads from two diodes also attach at each post. So, three windings (phases) = three posts = six diode leads.

A few words of caution before you tackle this. First, it's a small space and the stator wires are stiff. Be gentle and don't move anything more than you have to. Second, make a drawing. At least, it's a good place to write down the readings. It's also a great guide during assembly when you can no longer, perhaps a few days later, remember which of several possible ways something might go back together.

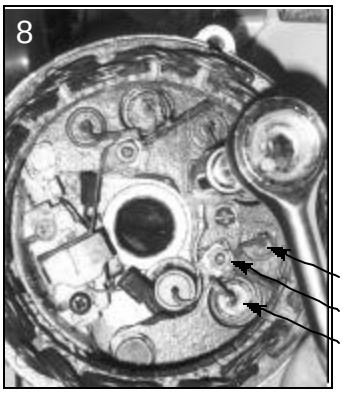

8. The nut is removed from a stator terminal to free two diode leads.

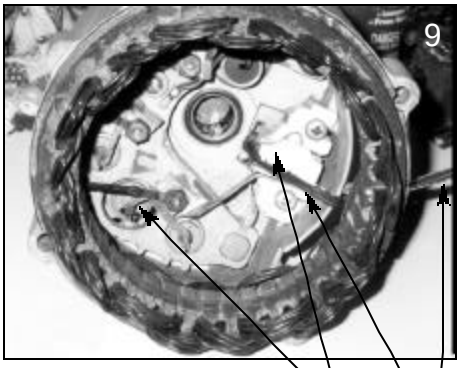

9. A grocery tie holds the brushes in place before the rotor is re-inserted in the casing.

Third, pay attention to detail. This ensures proper reassembly, particularly in that nothing shorts out or drags against the rotating parts. Finally, alternators are not all the same. Adapt my procedure to fit your alternator.

I used a small nut driver to remove the nut from one of the posts where the stator windings meet the diode leads. I used needlenose pliers to gently lift the diode connectors off the post, removing other leads only if necessary to get at the diode leads. I figured that working with one terminal post at a time would prevent any crossed wires.

I touched one lead of the multimeter to the diode lead I had just freed and the other to the metal case (or standoff plate) in which the diode is embedded. A continuity tester will show current flow in one direction only, so reverse the multimeter leads, finding first continuity, then no continuity. This tells you if the diode is good or bad. I also tested these diodes with the ohm function of the multimeter, providing me with actual values of ohms (a measure of resistance) in each direction for each diode.

the bowl and the alternator flange. At this point, I slipped the support frame for the hydro unit over the exposed threads and added nuts to each.

The impeller is held to the alternator shaft by a big brass nut and a large, thick brass backing plate. I slid the plate onto the alternator shaft, pushed the impeller into place—ensuring that its buckets are correctly oriented to the nozzle—and added the nut. As with disassembly, the vice grips held the alternator rotor while I tightened the nut against the impeller, being careful not to over-tighten it.

I was ready to install the field brushes. This job requires some dexterity. I set the rear alternator casing onto a towel on my workbench so that I had both hands free. I inserted a spring into the rear brush holder and held it in place with a screwdriver. With my free hand, I grabbed the brush with needlenose pliers and oriented it over the spring, slipping out the screwdriver as I pressed the brush into place. I inserted a grocery tie (used for holding market vegetables together) through the hole in the rear casing and across this brush to hold it in place. I repeated this process for the front brush, then routed the grocery tie out another hole so that I could twist the two ends together outside the casing. This process is tedious because the brush leads are short and already anchored to their terminals. Be patient or you'll be starting over a lot.

Since the rear needle-type bearing was already installed in the rear alternator casing, I was ready to join the alternator halves. I slipped the rear casing over the rear of the rotor and aligned the scratch marks I'd made (before disassembly) with those of the front casing. I inserted and tightened the four case bolts.

Once the alternator was assembled, I untwisted the grocery tie holding the brushes in place and pulled it out. I again checked the field coil resistance with my multimeter, placing one test lead on the F+ (Field positive) post and the other at the B- (Battery minus, which is also F-) post. The reading was the same as before: 4.2 ohms. This one test confirmed a good electrical contact through the terminals, brushes, sliprings, and field coils.

The control box

The control box for the Burkhardt turbine was missing in this application. The circuitry requirements for an alternator in a hydro unit are nearly identical to those used in a windplant or a standby generator—an ammeter, a diode, a rheostat, a fuse, a terminal junction, and an enclosure (Fig. 10). The ammeter displays alternator output (current) in amps. The diode blocks battery voltage from powering the field coils, which rely instead on the residual magnetism in the rotor's iron for excitation. The rheostat (another name for a potentimeter or variable resistor) manually adjusts field current, replacing the function of the voltage regulator used in automobiles. The fuse protects the field from too much electric current. The terminal strip helps with electrical connections between the unit and the alternator and battery pack. Finally, the enclosure protects these components from the environment.

Since I had the tools and experience to assemble such a simple circuit, I opted to fabricate a control box from scratch, mostly copying the original design.

I strayed from the original design of the control box in two ways: how the field coils are energized and where the external shunt is located (Sidebar B and Fig. 11). The first one simplifies the circuitry and reduces the amount of the output power that is taxed to energize the field coils. The second increases the accuracy of monitoring power output from the system and avoids running large wires through the control box.

I obtained a rheostat—rated at 28 ohms (resistance) and 50 watts (heat dissipation ability)—directly from John Takes, who owned and operated Burkhardt Turbines for many years. For a 12-volt system, a 12-ohm rheostat is generally more appropriate, but I will try the 28-ohm one first. (This will be tested when the hydro unit is installed and water is available to it.) I purchased the fuse holder and fuse, a pushbutton switch, terminal strip, and enclosure from a local Radio Shack for this circuit. I used terminals for multimeter test leads from my own parts' stock.

Construction tips

After a careful inspection of the system schematic, I recognized that the control unit was basically handling field current circuitry and a small bit of metering. Its container would mount the rheostat, pushbutton switch, two meter terminals, a fuse, a terminal strip, and interconnecting wires.

Accordingly, I selected a 5-inch long, 3-inch wide, and 2-inch deep plastic box for the control unit. (It was a tight fit; a novice might want to pick something larger.) Since the control unit is attached to (or near) the hydro unit itself, it is

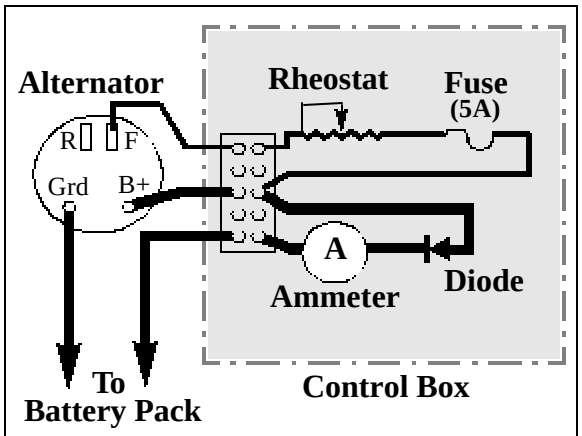

Fig. 10: A basic control circuit for an alternator

exposed to a water environment and must be fairly waterproof. I initially considered using a Tupperware container for this application because it provides great access and seals so well. I rejected this idea only because I thought the sunlight might eventually embrittle it. I also rejected the use of a steel box, since it would require a grounding rod at the hydro site.

The rheostat is large and takes up most of the room, so I positioned this at one end of the box. The only other holes in this face of the box are the pushbutton switch and the two meter terminals. Other considerations in layout? Components should not interfere with each other. Wires take up space, so allow for them. Finally, position the exit hole in the end face of the box to permit easy hookup of a built-in shunt. While this is nicely packaged, this type of meter offers poor resolution for anything except mid-scale readings, must be waterproofed, and limits output readings to the immediate vicinity of the hydro unit.

I elected instead to use a standard meter shunt. This calibrated gizmo offers accurate readings to within 1/10th of an amp of current across the range of amperage measured when used in conjunction with even a cheap ($20) digital multimeter. The advantage of the shunt is that it may be mounted anywhere in the line between the control box and its connection with the battery pack. Small-gage wires may then be run to meters **or** terminals that accept the test leads from a multimeter. In this application, I wanted to mount the shunt near the battery pack where it would pull double duty, monitoring the output of the existing solar modules. From there, I could run small wires to test points in the control box at the hydro site.

A side benefit of this arrangement was that I did not need to mount the shunt inside the control unit, thereby avoiding having to route large-gage (power) wires *through* the control box itself.

Sidebar B: Control box

The control box I built uses a field circuit modified from the standard field circuit and measures output current differently.

1. Field connection. While the diode (as shown in Fig. 10) provides a way to supply field current to the alternator, it also assesses its own tax for this effort. Common diodes dissipate (as heat) as much as one watt per amp—a whopping 35 watts for a 35-amp output—due to their own internal resistance. If you choose to use this circuit, use a Schottky diode. While more expensive, it will reduce this loss by half.

However, there is a way to avoid the use of a diode altogether which works especially well with hydro-electric units and standby generators. (Sorry, it won't work well with homebuilt windplants.) This method relies on the use of the **R** (rotor) terminal on Delco alternators (or the similar spade terminal of other alternator brands) to supply field current. The **R** terminal actually taps *one* rotor phase in the alternator while the output leg (**B+**) represents *three* phases. The difference? The **R** terminal is connected to one stator and produces ac (not dc) with about half the voltage (and, therefore half the current) normally available at the **B+** terminal.

The control circuit that takes advantage of the **R** terminal (Fig. 11) is radically different than the one using a diode (Fig. 10). A critical component in this setup is the momentary-contact, pushbutton switch. Without it, the field coils might not self-energize because of the lower voltage available from the **R** terminal. Fortunately, hydro-electric units that employ the Pelton-wheel are "tuned" for a specific head and flow of water. As such, the reduced current to the field coils is part of this tuning process. Once adjusted, the hydro unit may be energized by the owner via the pushbutton switch and, thereafter, left unattended.

Two cautions. First, momentary means *momentary*, i.e. *less* than a second. Any longer and there is risk of blowing a diode or the fuse. Second, don't miswire the circuit, or you can add heat and fire to the symptoms listed above. If you can't get it to work, go back to the circuit shown in Fig. 10.

2. Meter shunt. The original design of control box used a stock ammeter with

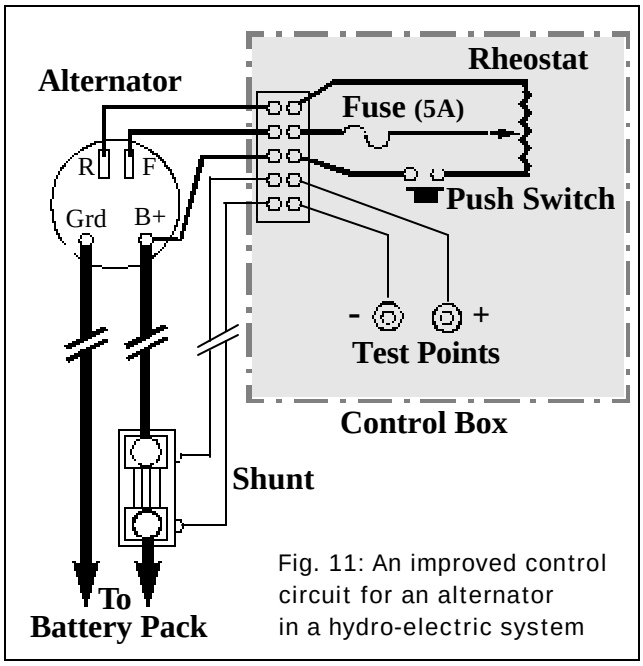

Fig. 11: An improved control circuit for an alternator in a hydro-electric system

Fig. 12: Components for the control box are based on the circuit illustrated in Fig. 11.

Fig. 13: Draw a wiring diagram and check it against the schematic before you start construction.

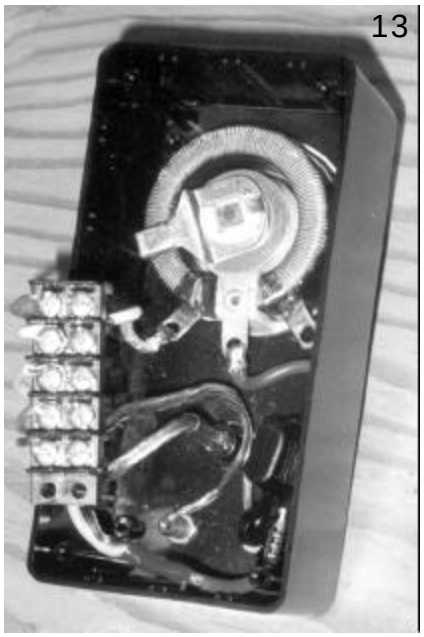

the external wires to the terminal strip.

If you're fabricating something yourself, a wiring diagram is important, so make one. At least, it minimizes confusion, which usually leads to mistakes. Better yet, it helps you figure out the best way to hook something up. The easiest way is not always the best way. For example, it would have been easier to avoid using a terminal strip. I could much more easily route all of the wires straight out of the box directly from their connections with the components.

I used the terminal strip for three reasons. First, it makes it easy to disconnect and remove the control unit from the hydro system and, then, reinstall it *without* disturbing the bulk of the internal wiring. Second, the wires can't be easily ripped from the unit since the terminal strip won't fit through the exit hole for the wires. Finally, a terminal strip makes for easier troubleshooting by minimizing the possibility of inadvertent shorts when probing through wiring to reach test points. I believe that anything I can do to help anyone who might later work on the unit is worth the extra effort it takes.

The components inside this control box are interconnected with wires. The layout will help you decide their length. While the shortest distance between two points is a straight line, it's not always practical. My work with communications and radar equipment when I served in the U.S. Navy taught me the virtue of routing wires in a neat and orderly fashion. Basically, you want them out of the way. More importantly, you want to be able to remove components later without having to undo wires just to get at or extract them.

What about wire size and color? It's a good rule of thumb not to use wires any smaller *or* larger than they need to be. Too small, they may heat up, catch fire, and melt. Too large and they are harder to work with. From the schematic, I readily knew that the control unit is only handling field current (3 amps) and a metering circuit (0.1 amps). Stranded #12 wire is more than adequate for the field current and stranded #18 (or smaller gage) wire works for the meter circuit. (Stranded wires conduct dc current better than a similar gage of solid wire, like that used in Romex for ac wiring in homes.)

Wires of different color help you keep things straight as you hook things up. More significantly, they will aid the eye in tracing *one* wire through the maze of other wires. While this is very helpful in troubleshooting, it has a more immediate benefit: checking your work *before* you hook it up and apply power to it for the first time.

In ac circuits, black is power, white is common, and green is ground. In dc circuits, red is positive (power) and black is negative (common). Since I was limited in the color wire available to me in this construction *and* the circuits weren't really power circuits, I followed *neither* of these conventions. However, I did maintain the same color on each side of the terminal strip, so that the colors of the external wires had a corresponding

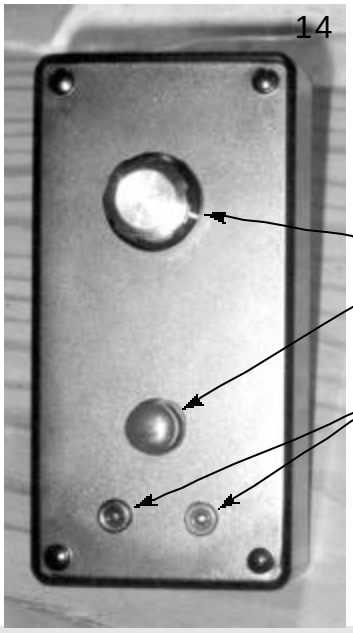

Fig. 14: The completed hydro unit's control box

color match in wires from the internal components.

One tricky job is wiring up the rheostat correctly. Most military, industrial, and commercial electric and electronics devices are built with a common understanding that clockwise rotation increases something, i.e., more volume on a stereo, brighter light with a dimmer, etc. Since the rheostat's job is to limit current to the field, it was wired so that turning the knob clockwise (cw) increases the field current by decreasing the in-line resistance. Thus, counterclockwise (ccw) limits the field current by increasing resistance. Since the rheostat is wired from the back side, it's easy to get confused and wire it backward. Doublecheck it. Did you do it backward? Simply swap the wire from the outside terminal on one side of the rheostat to the other side to reverse it.

There's a protocol to getting good electrical connections. The first rule of a good connection is to make it physically strong, such as a wire under a bolt, a wire lug under a bolt, etc. The second rule is maximum surface area of contact, best accomplished by soldering. Over time, the *weak* link in wiring between components is usually a connector, i.e., a plug, a receptacle, or a joint. I resist using spade (slide-on) connectors for this reason. Consequently, I soldered wires to a number of components in this box. If your skills are less developed, purchase these spade connectors from a local hardware or Radio Shack. Also purchase the special crimping tool for these connectors and learn to use it correctly. (Crimping is the process of squeezing the soft metal of the connector around an exposed end of a copper or aluminum wire.) Using crimpers avoids the bad crimps that result from *mis*applying needlenose or regular pliers or diagonal cutters for the job.

There is wisdom in the notion of minimizing the number of exposed connections in electrical circuits, so I purchased a bag of heat-shrink tubing of mixed sizes. When exposed to the heat from the tip of the soldering gun, a match, or a butane lighter, this stuff will shrink to about 60% of its original size, forming a snug fit over the joint. As needed, I selected the correct size (50% bigger than the wire itself) of tubing, cut it to a length that would overlap the joint, and slipped it over the wire before I physically secured the wire to the terminal with needlenose pliers. Adding a little flux, I was ready to solder the connection. If you're holding any part of the joint (i.e., the wire itself), hold it still for a full three seconds after removing the heat of the soldering iron or gun. Otherwise, the molten joint may not set, resulting in a cold-solder joint and a weak electrical connection. After waiting 15 seconds for the soldered joint to cool, I slipped the shrink-tubing over the joint. Just the radiant heat from a soldering gun will shrink the tubing. With practice, the result has a professional look to it.

Once the control box was wired internally, I performed a visual check, tracing the wires to their respective terminals and components. I followed this up with an electrical check, using my multimeter. Most of this is a simple continuity check—does this connect with that?—but I used the ohms scale on the multimeter to confirm the full resistance of the rheostat (28 ohms) and to confirm that this value decreased as I turned it clockwise.

The next job was to drill the exit hole for the wires that run to the alternator terminals and meter shunt. I figured to size this hole just large enough for the wires—two #12 wires (rotor and field), a #14 wire (B+), and two #22 wires (+ and -, meter shunt)—and use silicone sealant to weatherproof the exit. Accordingly, I drilled a ¼-inch hole and fed through the first three wires. Their ends were stripped, shaped, and tightened under screws on the terminal strip. I cut these wires to equal lengths, about 18 inches long, which should easily reach the end of the alternator from the mounting position on the framework. I soldered a ring-connector to the wire that goes to B+, and added push-on connectors to the ends of the other two, for connection to the F+ and R terminals on the alternator. Once the control box is installed on the hydro unit, the two wires from the remote meter shunt will be fed into it, and also connected to the terminal strip. Afterwards, I will use silicon sealant on the inside and outside of the exit hole to effectively seal this opening against the elements and insect life.

I like to add schematics and/or wiring diagrams to black boxes, so I embarked on this final task. The resulting diagram is a mix of a schematic and wiring diagram, with particular emphasis on the terminal strip and the colors of the different wires. I reduced this image to a size smaller than the back plastic cover. Once positioned, I used fiberglass tape in overlapping strips to secure and seal this artwork against the cover inside this cover, and used the four screws to secure the cover to the control box. Once the hydro system is installed, I will add a tiny bead of Lubriplate or similar compound around the perimeter of the cover plate (before screwing it on) to further seal it against weather.

(Michael Hackleman, P.O. Box 327, Willits, CA 95490. E-mail: mhackleman @saber.net]) D

To read more of Michael Hackleman's energy articles, visit *BHM's* webside at www.backwoodshome.com.

Retreat (survivalism)

From Wikipedia, the free encyclopedia

A **retreat** is a place of refuge for those in the survivalist subculture or movement. A retreat is also sometimes called a **bug-out location** (**BOL**). Survivalist retreats are intended to be self-sufficient and easily defended, and are generally located in sparsely populated rural areas.

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  - 1.2 1970s
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History

While fallout shelters have been advocated since the 1950s, dedicated self-sufficient survivalist retreats have been advocated only since the mid-1970s. The survival retreat concept has been touted by a number of influential survivalist writers including Ragnar Benson, Barton Biggs, Bruce D. Clayton, Jeff Cooper, Cresson Kearny, James Wesley Rawles, Howard Ruff, Kurt Saxon, Joel Skousen, Don Stephens, Mel Tappan, and Nancy Tappan.

1960s

With the increasing inflation of the 1960s, the impending US monetary devaluation, the continuing concern with possible nuclear exchanges between the US and the Soviet Union, and the increasing vulnerability of urban centers to supply shortages and other systems failures, a number of primarily conservative and libertarian thinkers began suggesting that individual preparations would be wise. Harry Browne began offering seminars in 1967 on how to survive a monetary collapse. He worked with Don Stephens, an architect, survival bookseller, and author, who provided input on how to build and equip a remote survival retreat. He provided a

copy of his original *Retreater's Bibliography* (1967) for each seminar participant.

Articles on the subject appeared in such small-distribution libertarian publications as *The Innovator* and *Atlantis Quarterly*. It was also from this period that Robert D. Kephart began publishing *Inflation Survival Letter*[1] (later renamed *Personal Finance*). The newsletter included a continuing section on personal preparedness by Stephens for several years. It promoted expensive seminars around the US on the same cautionary topics. Stephens participated, along with James McKeever and other defensive investing, hard currency advocates.

1970s

In 1975, Kurt Saxon began publishing a newsletter called *The Survivor*, which advocated moving to lightly populated regions to "lie low" during a socio-economic collapse, and setting up fortified enclaves for defense against what he termed "killer caravans"[2][3] of looters from urban areas.

In 1976, Don Stephens popularized the term "retreater" and advocated relocating to a rural retreat when society breaks down.

Writers such as Howard Ruff warned about socio-economic collapse and recommended moving to lightly populated farming regions, most notably in his 1979 book *How to Prosper During the Coming Bad Years*, a best-seller in 1979.

For a time in the 1970s, the terms "survivalist" and "retreater" were used interchangeably. The term "retreater" eventually fell out of favor.[4]

One of the most important newsletters on survivalism and survivalist retreats in the 1970s was the *Personal Survival ("P.S.") Letter* (circa 1977-1982) published by Mel Tappan, who also authored the books *Survival Guns* and *Tappan on Survival*. The newsletter included columns from Tappan himself, as well from Jeff Cooper, Al J. Venter, Bill Pier, Bruce D. Clayton, Rick Fines, Nancy Mack Tappan, J.B. Wood, Dr. Carl Kirsch, Charles Avery, Karl Hess, Eugene A. Barron, Janet Groene, Dean Ing, Bob Taylor, Reginald Bretnor, C.G. Cobb, and several other writers, some under pen names. The majority of this newsletter revolved around selecting, constructing and logistically equipping survival retreats.[5] Following Tappan's death in 1980, Karl Hess took over publishing the newsletter, eventually renaming it *Survival Tomorrow*.

1980s

Survivalist retreat books of the 1980s were typified by the 1980 book *Life After Doomsday*[6] by Bruce D. Clayton, advocating survival retreats in locales that would minimize fallout, as well as specially constructing blast shelters and/or fallout shelters that would provide protection in the event of a nuclear war.

1990s

Several books published in the 1990s offered advice on survival retreats and relocation. Some influential in survivalist circles are *Survival Retreat: A Total Plan For Retreat Defense* by Ragnar Benson, *Strategic Relocation—North American Guide to Safe Places* by Joel Skousen, and *The Secure Home*, (also by Skousen).

2000 to present

In recent years, advocacy of survivalist retreats has had a strong resurgence after the terrorist attacks on the

World Trade Center in New York City in 2001, the 2002 attacks and 2005 attacks in Bali, the 2004 Madrid train bombings in Spain, and the 2005 public transportation bombings in London.

Several books published since 2000 advocate survival retreats and relocation. Some that have been particularly influential in survivalist circles are *How to Implement a High Security Shelter in the Home* by Joel Skousen, *Rawles on Retreats and Relocation* by James Wesley Rawles, and *Life After Terrorism: What You Need to Know to Survive in Today's World* by Bruce D. Clayton.[7]

Online survival websites, forums, and blogs (such as SurvivalBlog) discuss the best locales for survival retreats, how to build, fortify, and equip them, and how to form survivalist retreat groups.[8]

Economic troubles emerging from the credit collapse triggered by the 2007 US subprime mortgage crisis have prompted a wider cross-section of the populace to modify their homes as well as establish dedicated survival retreats.[9] James Wesley Rawles, the editor of SurvivalBlog was quoted by the *New York Times* in April 2008 that "interest in the survivalist movement 'is experiencing its largest growth since the late 1970s'". He also stated that his blog's conservative core readership has been supplemented with "an increasing number of stridently green and left-of-center readers."[9]

Necessity of retreats

Mel Tappan was quoted in 1981 by then AP correspondent Peter Arnett that: "The concept most fundamental to long term disaster preparedness, in retreating, is having a safe place to go to avoid the concentrated violence destined to erupt in the cities." [10]

Common retreat locale parameters

Common retreat locale selection parameters include light population density, plentiful water, arable land, good solar exposure for gardening and photovoltaics, situation above any flood plains, and a diverse and healthy local economy.[11] Fearing rioting, looting and other unrest, many survivalists advocate selecting retreat locales that are more than one tank of gasoline away from any major metropolitan region. Properties that are not in "channelized areas" or on anticipated "refugee lines of drift" are also touted.[12]

One of the key goals of retreats is to be self-sufficient for the duration of societal collapse. To that end, plentiful water and arable soil are paramount considerations. Beyond that, a priority is situation on isolated, defensible terrain. Typically, retreats do not want their habitations or structures jeopardized by being within line of sight of any major highway.

Because of its low population density and diverse economy, James Wesley Rawles [13] and Joel Skousen [14] both recommend the Intermountain West region of the United States as a preferred region for relocation and setting up retreats. Although it has higher population density, Mel Tappan recommended southwestern Oregon, where he lived,[15] primarily because it is not downwind of any envisioned nuclear targets in the United States.

Mel Tappan was disappointed by the demographics of southwestern Oregon after the survivalist influx of the late 1970s. "Too many doctors and lawyers" relocated to Oregon, and "not enough plumbers, electricians, or carpenters."[15]

Evacuation to a retreat

While some survivalists recommend living at a rural retreat year-round,[16] most survivalists cannot afford to do so. Therefore, they rely on keeping a well-stocked retreat, and plan to go there "at the 11th hour", as necessary. They keep a bug-out bag handy, and may have a dedicated **bug-out vehicle** (BOV). This is a vehicle that the owner keeps prepared in the event of the need for an emergency evacuation. Typically a BOV is equipped with a variation on the bug-out bag that includes additional automotive supplies, clothing, food and water. Survivalists tend to favor four wheel drive trucks and SUVs due to their greater off-road abilities. In the event of a nuclear catastrophe, survivalists may opt into maintaining an older vehicle since it most likely lacks critical electronic components that would otherwise be damaged by the electromagnetic pulse that accompanies a nuclear explosion.

Retreat organization

Most survivalist retreats are created by individuals and their families, but larger "group retreats" or "covenant communities" are formed along the lines of an intentional community.

Retreat architecture and security

Jeff Cooper popularized the concept of hardening retreats against small arms fire. In an article titled "Notes on Tactical Residential Architecture" in Issue #30 of P.S. Letter (April, 1982), Cooper suggested using the "Vauban Principle", whereby projecting bastion corners would prevent miscreants from being able to approach a retreat's exterior walls in any blind spots. Corners with this simplified implementation of a Vauban Star are now called "Cooper Corners" by James Wesley Rawles, in honor of Jeff Cooper.[17] Depending on the size of the group needing shelter, design elements of traditional European castle architecture, as well as Chinese Fujian Tulou and Mexican walled courtyard houses have been suggested for survival retreats.

In both his book *Rawles on Retreats and Relocation* and in his survivalist novel, *Patriots: A Novel of Survival in the Coming Collapse*, Rawles describes in great detail retreat groups "upgrading" brick or other masonry houses with steel reinforced window shutters and doors, excavating anti-vehicular ditches, installing warded gate locks, constructing concertina wire obstacles and fougasses, and setting up listening post/observation posts (LP/OPs.) Rawles is a proponent of including a mantrap foyer at survival retreats, an architectural element that he calls a "crushroom".[18]

Bruce D. Clayton and Joel Skousen have both written extensively on integrating fallout shelters into retreat homes, but they put less emphasis on ballistic protection and exterior perimeter security than Cooper and Rawles.

Retreat logistics

Anticipating long periods of time without commerce in the future, as well as observing documented history, retreat groups typically place a strong emphasis on logistics. They amass stockpiles of supplies for their own use, for charity, and for barter. Frequently cited key logistics for a retreat include long term storage food, common caliber ammunition, medical supplies, tools, gardening seed, and fuel. In an article titled "Ballistic Wampum" in Issue #6 of P.S. Letter (1979) Jeff Cooper wrote about stockpiling ammunition far in excess of his own needs, keeping the extra available to use for bartering.

In their books, Joel Skousen, Mel Tappan and Howard Ruff all emphasize the need to have a one-year supply of storage food.

Mainstream economist and financial adviser Barton Biggs is a proponent of well-stocked retreats. In his 2008 book *Wealth, War and Wisdom*, Biggs has a gloomy outlook for the economic future, and suggests that investors take survivalist measures. In the book, Biggs recommends that his readers should “assume the possibility of a breakdown of the civilized infrastructure.” He goes so far as to recommend setting up survival retreats: “Your safe haven must be self-sufficient and capable of growing some kind of food,” Mr. Biggs writes. “It should be well-stocked with seed, fertilizer, canned food, wine, medicine, clothes, etc. Think Swiss Family Robinson. Even in America and Europe there could be moments of riot and rebellion when law and order temporarily breaks down.”[9]

Survivalist retreats worldwide

Survivalist retreats, both formal and informal exist worldwide, most visibly in Australia,[19] Belgium, Canada,[20] France,[21] Germany[22] (often organized under the guise of "adventuresport" clubs),[23] New Zealand,[24] Norway,[25] Russia,[26] Sweden,[27] the United Kingdom[28] and the United States.[9]

Government operated retreats

Construction of government-built retreats and underground shelters—roughly analogous to survivalist retreats—has been done extensively since the advent of the Cold War, especially of public nuclear fallout shelters in many nations. The United States government has created Continuity of Government (COG) shelters built by the Department of Defense and Federal Emergency Management Agency ("FEMA"). These include the massive shelter built under the Greenbrier hotel (aka Project Greek Island), military facilities like Cheyenne Mountain Complex, and the Raven Rock Mountain Complex and Mount Weather sites. Other nations' facilities include the Swiss redoubt fortress system and its dual use facilities like the Sonnenberg Tunnel and Norway's Sentralanlegget bunker in Buskerud County.

In fiction

Robert A. Heinlein featured survivalist retreats in some of his science fiction. *Farnham's Freehold* (1964) begins as a story of a small group in a survivalist retreat during a nuclear war. Heinlein also wrote essays such as *How to be a Survivor*[29] which provide advice on preparing for and surviving a nuclear war, including stocking a fallout shelter and retreat.

Malevil by French writer Robert Merle (1972) describes refurbishing a medieval castle and its use as a survivalist stronghold in the aftermath of a full-scale nuclear war. The novel was adapted into a 1981 film directed by Christian de Chalonge and starring Michel Serrault, Jacques Dutronc, Jacques Villeret and Jean-Louis Trintignant.[30]

Lucifer's Hammer by Jerry Pournelle and Larry Niven (1977) is about a cataclysmic comet hitting the Earth, and a group of people struggling to survive the aftermath.

Patriots: A Novel of Survival in the Coming Collapse by James Wesley Rawles (2009) describes how the lead characters establish a self-sufficient survival retreat in north-central Idaho.

Jericho (2006) is a TV series that portrays a small town in Kansas after a series of nuclear explosions across the United States. In the series, the character Robert Hawkins uses his prior planning and survival skills in preparation of the attacks. Although it is not fortified, the town effectively becomes a large scale retreat, for its

residents.

Further reading

The text of some books discussing survivalist retreats can be found online:

- *Fallout Protection* (1961)[31]
- *Nuclear War Survival Skills* by Cresson Kearny (1979, updated 1987 version) ISBN 0-942487-01-X
- *Survival Under Atomic Attack* (1950)[32]
- *Tappan on Survival* by Mel Tappan (1981) ISBN 0-916172-04-X [33]
- Textfiles.com archive of articles that circulated online during the BBS era, includes several Kurt Saxon articles from his old newsletter: Article archives (http://www.textfiles.com/survival/)

See also

- Blast shelter
- Bug-out bag
- Fallout shelter
- Intentional community
- Survival kit
- Survivalism
- Tsunami house

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Categories: Survivalism | Social movements | Survival skills

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REUSABLE ALKALINE™ BATTERY SYSTEM FROM RAYOVAC (RENEWAL®)

U. Sengupta, S. Megahed, A. Homa, S. Ruth
Rayovac Corporation
601 Rayovac Drive
Madison WI 53711

■ ABSTRACT

The Rayovac Corporation successfully introduced the Rechargeable Alkaline Manganese-Zinc (RAM) System for consumer applications in the fall of 1993 in four conventional cell sizes (AA, AAA, C, D). The RAM battery is being consumer marketed as a reusable alkaline battery system under the trademark Renewal®. It is being targeted toward all types of applications where primary alkaline are presently used. In addition to consumer replaceability of the Renewal battery, several questions were raised by designers of portable battery-operated equipment regarding battery-charger characteristics for future design-in of this new chemistry. This paper will address these questions and will point the major advantages and disadvantages of the Renewal batteries as compared to nickel-based batteries (e.g., Nickel/Cadmium, Nickel/Metal Hydride).

■ INTRODUCTION

The *RENEWAL*® Reusable Alkaline™ Battery System represents a new alternative for the designer of portable battery-operated equipment. Prior to the introduction of the Renewal product family, most portable equipment was constrained to use either single-use disposable Alkaline batteries or rechargeable battery systems such as Nickel-Cadmium (NiCd) or Nickel-Metal Hydride (NiMH). Renewal can be thought of as "bridging the gap" between the single-use primary alkaline and the traditional choices in rechargeable battery systems. It combines many of the benefits of both conventional alkaline and rechargeable Nickel-based systems.

Renewal can provide an excellent solution for many battery-operated products when one considers all of the various design trade-offs such as cost, battery run-time, storage characteristics and environmental impact. However, the electronic system designer should understand that the Renewal battery may not be the best choice for all applications. For this reason, the following selection criteria, electrical performance and charging method will explain those applications where the Renewal battery is best utilized.

■ BATTERY SELECTION CRITERIA

Primary alkaline batteries are designed for a single discharge only. They have very good energy density when operated at moderate to low discharge rates (typically less than a few hundred milliamperes to one ampere drain rates) and have excellent charge retention during storage. Attempting to recharge these batteries may result in internal short-circuits between the anode and cathode, internal gas generation and probable leakage. Both primary and reusable Alkaline batteries can be safely disposed of in landfills with no toxic material concerns.

NiCd and NiMH batteries can be recharged and reused many times. They have a very low internal resistance, allowing them to be used for high drain rate discharges up to several amps. They are generally the battery system of choice for relatively high-power portable devices such as power tools, notebook computers, etc. However, their capacity for a single discharge cycle at low to moderate rates in products such as portable audio equipment, palmtop computers, electronic games and toys, or other handheld equipment can be substantially less than that of primary alkalines. Additionally, they tend to have poor shelf life and require recharging before each use if the time between uses is long (days or months, depending on storage conditions).

Finally, NiCd batteries contain Cadmium and require special handling for disposal or recycling. NiMH batteries are perhaps less objectionable environmentally than the NiCd cells but may still be subject to local environmental regulations in some areas. NiMH batteries also have a noticeably higher self-discharge characteristic and are more expensive than NiCd batteries.

Renewal Reusable Alkaline batteries combine some of the characteristics of conventional Alkaline and rechargeable Nickel-based battery products. They have a higher initial capacity than NiCd/NiMH cells, but not as high as primary alkaline. Unlike primary alkaline, they can be recharged and reused, but not for as many cycles as NiCd/NiMH.

The reason for increased capacity, but not drain rate, of primary alkaline and the Renewal battery as compared to NiCd/NiMH is attributed to electrode design. Primary alkaline and Renewal electrodes (bobbin-type) have higher packing density but lower surface area than those of NiCd/NiMH (spiral-wound). The former also is lower in manufacturing cost than the latter due to a simpler and more efficient manufacturing method.

a) Renewal versus Primary Alkaline

Renewal Reusable Alkalines are generally interchangeable with primary alkaline batteries. However, they do have a slightly higher internal resistance characteristic than primary alkaline batteries. Because of

this, Renewal batteries may exhibit lower performance when compared to primary alkalines in applications that require high continuous or pulse current loads.

At low and moderate drain rates (where the effect of the internal resistance in the Renewal battery is less significant), the performance of Renewal can be close to that of primary alkalines. The general operation, discharge curve shape, and storage (charge retention) characteristics of Renewal and primary alkaline batteries are very similar.

The advantage of Renewal batteries over primary alkalines is the reusability of the Renewal system. Renewal batteries can be recharged because they have different internal construction and chemical composition than conventional alkalines.

While the performance of a Renewal cell on a single discharge cycle may be less than that of a primary alkaline, the rechargeability of the Renewal system allows a single cell to provide a cumulative capacity equivalent to dozens of single-use cells.

Over a period of several charge/discharge cycles Renewal batteries can represent a significant cost savings to the end user over single-use disposable alkaline batteries. Renewal also presents a more environmentally responsible alternative to the large number of primary alkaline batteries that would require disposal over time when used throughout the lifetime of a given electronic product.

b) Renewal versus NiCd and NiMH

NiCd and NiMH batteries generally provide a good solution for applications requiring high rate discharge or very frequent charge / discharge cycles. However, these batteries are relatively expensive and have very poor shelf life characteristics. Additionally, they have relatively low energy density in comparison with alkalines at low or moderate drain rates, a lower terminal voltage (which may be relevant for low-power single-cell or two-cell applications that have very little margin or voltage range to work with) and are subject to environmental restrictions regarding collection and recycling at end of life.

Renewal provides an alternative which may have both lower cost and better performance for products with low or moderate drain levels or intermittent usage patterns. The advantages of Renewal compared to the Nickel-based systems are summarized below.

- Battery operated equipment can run longer between recharges due to higher capacity of the Renewal batteries
- Renewal batteries come in standard sizes and can be used in multiple devices (unlike custom-designed battery packs which are unique to a specific product)
- Renewal eliminates the need for the user to manage battery usage patterns... it does not require full discharge before recharge, has no memory effect, negligible self-discharge, etc.
- Easily and inexpensively replaced by consumers when new batteries are needed
- Environmentally responsible
- Substantially better shelf life (5+ years in storage)
- Lower initial cost of cells results in lower product cost
- Low-battery warning circuitry can be simpler due to shape of Alkaline cell discharge curve

Table 1 compares Renewal with NiCd and NiMH at nominal loads (approximately 150 mA) and temperature (approximately 20°C) using the AA-cell size as a test vehicle. The table shows the capacity and cost advantages of Renewal over nickel-based systems.

TABLE 1: COMPARISON OF RENEWAL WITH NiCd AND NiMH EXAMPLE: AA-CELL (APPROXIMATE VALUES)

	RENEWAL	NiCd*	NiMH*
Nominal Capacity, mAh (varies with load)	1400 initial, 700 after 25 cycles	750	1100
Usable Cycles (varies with discharge level)	25+	200+	300+
Nominal Voltage Range (under load)	0.9 to 1.4	1.0 to 1.3	1.0 to 1.3
Weight	22g	22g	26g
Gravimetric Energy Density (watt-hr/kg)	80 (initial)	41	51
Volumetric Energy Density (watt-hr/liter)	220 (initial)	115	170
Continuous Output Current (max. recommended)	400 mA	>5A	>4A
Peak Output Current	1A	>10A	>10A
Fast Charge Time	2-3 Hrs	1 Hr	1 Hr
Self-Discharge Rate (room temperature)	0.01% per day	1% per day	4% per day
Typical OEM Cost Per Cell	$0.50	$1.25	$3
Typical Retail Replacement Cost (4-cell pack)	$5	$10-$30	$60+
Safely Disposable	Yes	No	???

**NiCd/NiMH capacity and weight data was taken from Energizer Ultramax and Hydritech Data Sheets. Other parameters are estimates or calculations based on typical values and may not be exact.*

■ ELECTRICAL PERFORMANCE DATA (AA-SIZE)

Data on operating voltage, cycle life and recharge time for the AA Renewal cell is presented below. Similar data on other sizes (AAA, C, D) are available upon request from Rayovac.

a) Operating Voltage/Capacity

Figures 1.a. and 1.b. show the voltage profile for constant current discharge (20-400 mA/cell) of AA Renewal cell to a cut-off voltage of 0.9 volt. Increasing the discharge current resulted in lower capacity and efficiency due to cell polarization - a phenomenon common to all batteries. Cell capacity and discharge efficiency is shown in Table 2.

Current Load (mA)	Discharge Time (Hrs)	AA Capacity (mAh/Cell)	Efficiency
20	90.0	1800	100%
50	36.0	1800	100%
100	16.0	1600	89%
200	6.15	1230	68%
300	3.45	1035	58%
400	2.25	900	50%

Table 2.

The taper discharge curves in Figure 1.a. and 1.b. represent initial cell capacity (that is, the capacity for a new cell on its first discharge cycle). Figures 2.a, 2.b. and 2.c. show the effect of charge/discharge cycle on cell capacity at specific discharge rates. In each graph, the voltage profiles show the results obtained from the same cell for different discharge cycles at the specified drain rate. Each discharge was terminated when the cell voltage dropped to 0.90 volt.

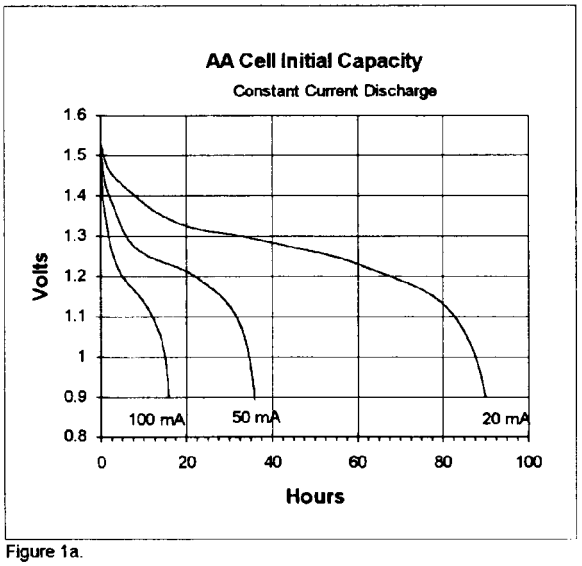

Figure 1a.

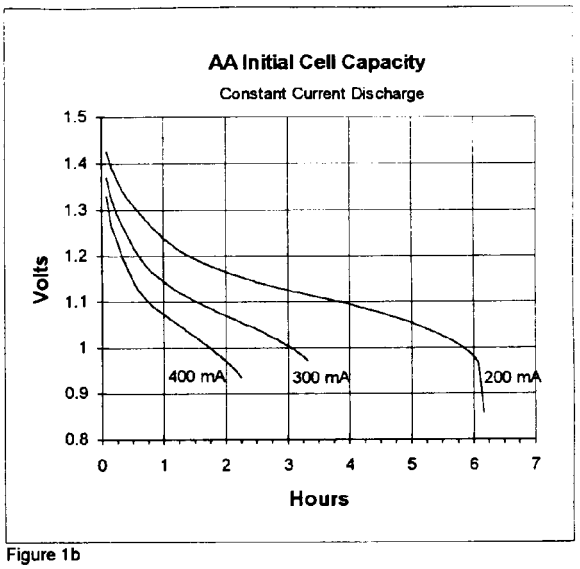

Figure 1b

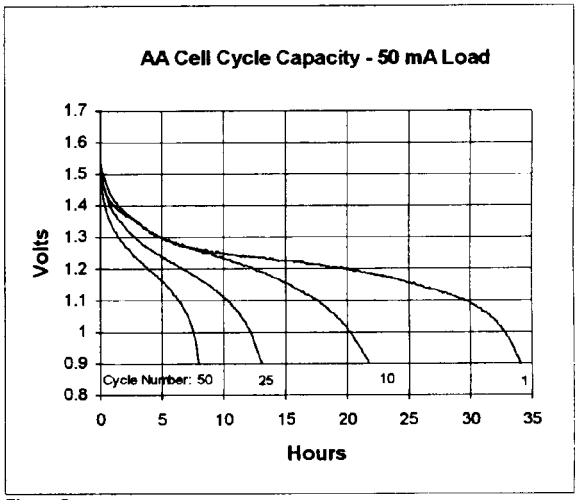

Figure 2a.

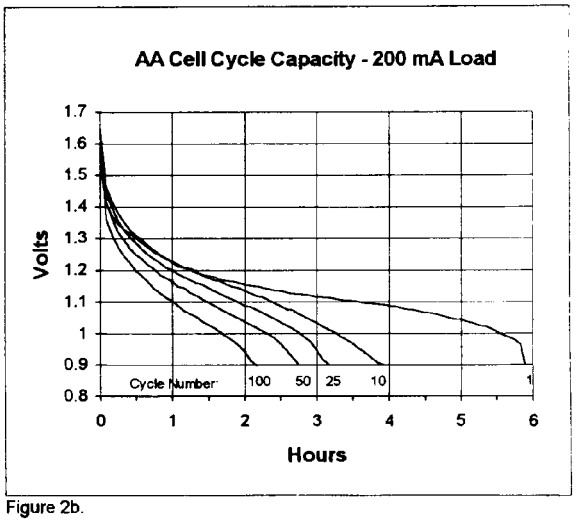

Figure 2b.

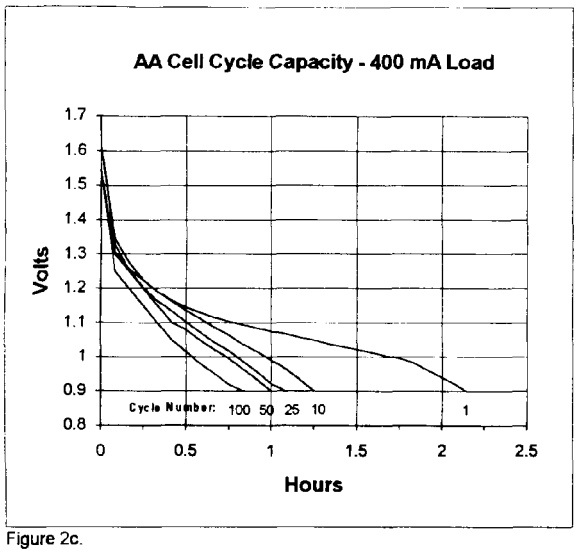

Figure 2c.

b) Cycle Life/Capacity Fade

On each successive discharge cycle, the performance of the Renewal cell will be lower in comparison to the previous cycle. Figure 3 illustrates the loss in capacity from the initial to the 25th discharge cycle at different discharge rates. The batteries can continue to be charged and discharged for additional cycles if desired; the cell performance will continue to diminish accordingly.

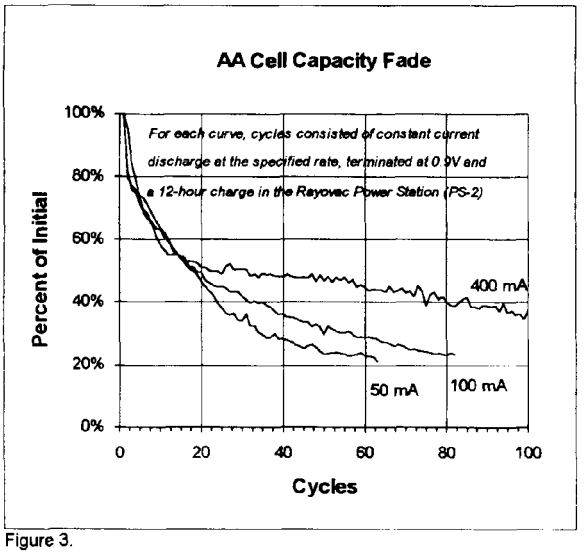

Figure 3.

The degree of this deterioration will not be the same in all applications. It depends on factors such as rate of discharge and the endpoint voltage at which the discharge is terminated. These relate to the "depth of discharge," or the amount of energy withdrawn from the battery prior to recharge for each cycle.

The *depth* of discharge is not the same as the *rate* of discharge. Depth of discharge refers to the total amount of capacity withdrawn from the battery, while rate of discharge is the level of current being drawn from the cell at a given time.

Figure 4 shows the cumulative capacity obtained over the first 25 cycles at specific discharge rates with each discharge terminated at a cell voltage of 0.9 Volts. While the low rate discharge curves in Figure 3 showed a higher degree of capacity fade than at high rates, it can be seen from Figure 4 that the total capacity delivered is still higher when the cell is discharged at low drain rates to the same endpoint voltage.

The curves in Figure 4 have a decreasing slope as the cycle count increases, which is indicative of diminishing discharge capacity with each successive cycle. However, it can be seen from the positive slope at the end of the graph that there are usable cycles left in the cells. If a battery was at the absolute end-of-life, recharging it would not restore any significant amount of discharge capacity and thus the cumulative capacity would no longer increase with successive cycles. The number of usable cycles in a given application will depend on the point at which the operating time for the batteries in the device falls below a minimum acceptable level.

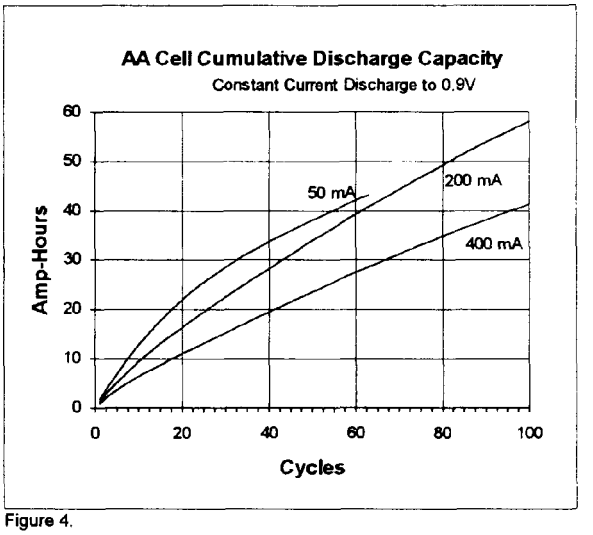

Figure 4.

In summary, applications which a have higher depth of discharge between recharge cycles will see the most pronounced capacity fade. Applications with a very shallow discharge will be able to obtain a greater number of discharge / recharge cycles from Renewal cells because of the reduced level of capacity fade. The standard claim of 25 cycles for Renewal batteries is based on typical or average use in consumer products. For certain applications with shallow discharges and frequent recharges, it is possible to obtain hundreds of usable cycles

c) Recharge Time

Figure 5 shows the time required to restore the AA cell to

a given state of charge after various discharge conditions. The cells were recharged in the PS-2 Power Station after being discharged at different rates to the same endpoint voltage (a more detailed description of the charge method used in the Renewal Power Station is given in the following section).

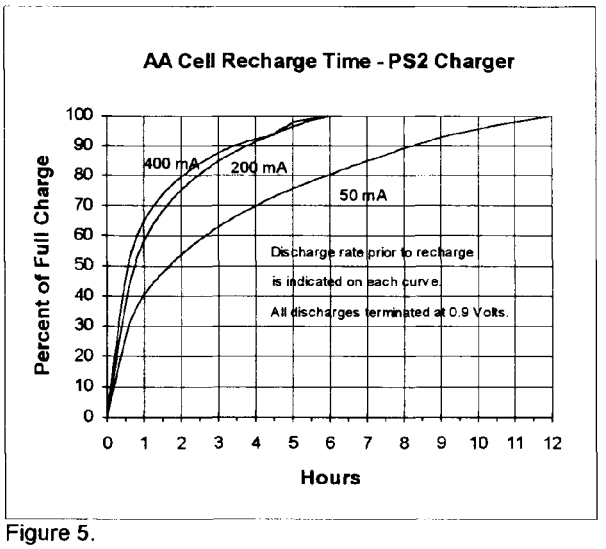

Figure 5.

The illustration shows that if the same peak charge rate is used, the length of time required to reach full charge is higher for the lower-rate discharge case when the endpoint voltage of the discharge is the same. This is because the low-rate cell had a significantly greater depth of discharge (as described in the earlier section on cycle life and capacity fade). Since the cells were all recharged at the same rate, the cells which had been more fully drained required a longer time to be restored to a full state of charge.

For purposes of this illustration, "full charge" is defined as the point when the average charge current delivered to the cell had tapered to a negligibly low value (a few milliamps or less). This means that the amount of capacity being added to the battery by the charger was asymptotically approaching zero. The LED-out point generally corresponds to a state of 80 to 85% of this level, depending on the discharge condition of the cell.

Recharge times are fairly consistent over the cycle life of the battery as long as the discharge rate and endpoint voltage are kept consistent for each discharge. The data is shown for cycle 10 only as a representative indication.

■ CHARGING METHOD

The Renewal Power Stations implement a special charge method as described below. The present chargers perform the recharge on each cell individually. The characteristics of the Reusable Alkaline system require that the charging of the cells be done on an individual cell basis and not on a series connection of cells.

Many of the standard techniques used with NiCd/NiMH fast chargers such as $-\Delta V/\Delta t$ slope detection, absolute temperature cutoff, or $+\Delta T/\Delta t$ termination are not compatible with Reusable Alkaline batteries. Continuous trickle charging and overcharging as used in many low-cost NiCd chargers is also not acceptable.

Renewal batteries are charged using a pulse charge method. Fixed amplitude, variable duty cycle pulses are applied to the battery during charge. The pulses are limited in amplitude by current-limiting resistors. The duty cycle is modulated by a control chip.

This device is and Application Specific Integrated Circuit, (ASIC) specifically designed for use in the Renewal Power Stations. The average value of the charging current applied to the batteries is gradually reduced as the open-circuit voltage of the battery increases during the charge. The charging mechanism compensates for the internal resistance of the cell by taking the voltage measurement of the cell during the off-time of the charging pulse.

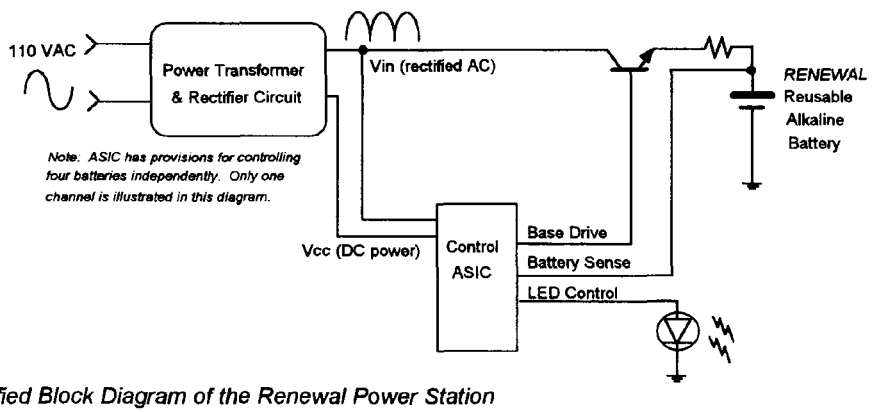

Figure 6. Simplified Block Diagram of the Renewal Power Station

As illustrated in Figure 6, the transformer in the charger has two outputs. The signal labeled "Vin" is a rectified (but not filtered) sine wave which provides 120Hz pulses at an amplitude of approximately 4 volts peak; the other (designated as Vcc) is a filtered output that provides approximately 8V DC to operate the ASIC and also

provide a positive bias to turn on the NPN pass transistors (via the chip's DRIVE signal). The voltages are taken off the secondary side of a 60Hz transformer and are unregulated, so they will vary somewhat over line and load changes.

The Vin pulses are used for charging the battery. The ASIC monitors the battery voltage during the time when the pulse amplitude is low to get an accurate *open circuit voltage* (OCV) measurement. Monitoring the battery during charge (i.e., when the pulse amplitude is higher than the battery's OCV) will give a higher voltage reading due to the voltage drop across the battery's internal resistance. This is caused by the charge current flowing into the cell.

As the ASIC senses the battery's OCV, it determines how much charge the battery receives by modulating the duty cycle of the base drive signal to the NPN pass transistor. As the OCV of the battery increases, the duty cycle of the DRIVE signal is reduced accordingly, resulting in a tapering average charge current profile towards the end-of-charge. The LED is deactivated when three consecutive charge pulses are disabled (the battery has stayed above the 1.65V reference value for this period of time).

As the battery reaches full charge, the duty cycle of the pulse train continues to decrease (a greater number of consecutive pulses are blocked) causing the average current applied to the battery to taper towards zero.
The recharge process is inhibited if the charge control ASIC senses that a battery is in a condition that should not allow recharging, such as an excessively drained battery (below undervoltage limit) or a high-impedance battery (above overvoltage limit when charge current is applied).A typical cell voltage/current profile during the recharge process is shown below in Figure 7.

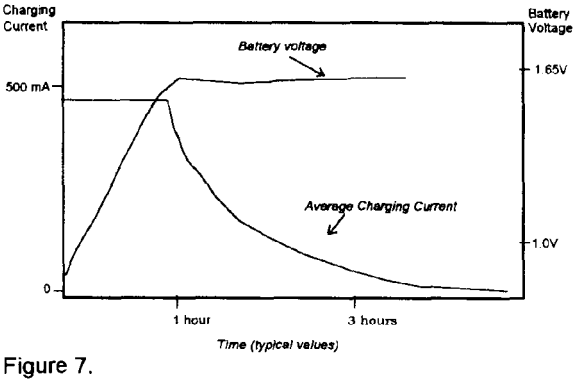

Figure 7.

■ SYSTEM DESIGN CONSIDERATIONS

The performance of Renewal batteries in a given electronic system can be optimized if the system contains circuitry to manage the use of the batteries.

a) Discharge Monitoring

The cycle life of the cells is optimized if they are not excessively discharged. A cutoff voltage of no less than 0.8V per cell is recommended. In particular, cell reversal should be avoided. If multiple cells are connected in series, some cells may be drained more rapidly than others due to mismatches in internal resistance or initial voltage between the cells.

In NiCd/NiMH based systems with cells connected in series, the total voltage of the series string is generally used to indicate a low battery or cutoff condition. In the case of Renewal, the low battery cutoff should occur when any one of the individual cells in the series connection reaches the low-voltage threshold. While this may reduce the operating time for a given discharge cycle (because the operation is effectively terminated when the weakest of all the cells is drained), it will avoid the overdischarge or reversal that may occur if only the overall voltage of the series connection is monitored.

The low-battery warning can be made by a voltage measurement only (it is generally not necessary to attempt to detect the "knee" of discharge by monitoring dV/dt as is often done in NiCd/NiMH systems due to their flat discharge curve). If a prediction of residual capacity is required at a certain voltage point, the circuit should be calibrated for the current level at which that the device is operating as the in-circuit voltage of the batteries will depend on the load current. The threshold for cutoff can be set to a level appropriate for the application based on run-time, load rate, and cycle life requirements.

b) Pulse/Transient Loads

As is observable from the discharge curves in Figures 1 and 2, a cell loaded at 200 mA will last more than twice as long as a cell loaded at 400 mA. Thus, a constant 200 mA load will last longer than a 400 mA load at 50% pulsed duty cycle (even though both load conditions have the same average value).

For example, switch-mode power supplies used for DC/DC conversion in portable products will typically place a discontinuous load on the power source. It is desirable to minimize the input ripple current by using low-ESR, high value input bypass capacitors. This will average the load transients that are applied to the cells and increase the operating time available.

c) Charging System Implementation

OEM developers considering RENEWAL have various options as to the recharging system that they can use. For applications which allow for charging of the batteries outside of the device that uses them, the Rayovac PS-1 and/or PS-2 Power Stations can be used. Alternatively, developers may implement the Renewal charging algorithm into their own equipment either via a charge-control IC as specified by Rayovac from an approved source, or by their own microprocessor-based control device with incorporating the Renewal charge algorithm into the code, or by a hardware implementation providing

the equivalent functionality.

Rayovac can provide circuit diagrams, parts lists, and sources for the unique components in the Rayovac Power Stations to OEMs who wish to incorporate the charging circuitry into their own products. Rayovac may request that OEM developers who wish to implement their own charging system agree to a contract of mutual non-disclosure prior to receiving this information.

d) Storage and Replacement

The storage characteristics of Renewal are generally comparable to primary alkaline batteries. High temperature storage conditions will reduce the shelf life of the batteries and should therefore be avoided if possible. The Renewal cells will retain their capacity best if left in a fully charged state prior to storage.
Circuitry connected to the batteries should not place a continuous load on the cells during periods of storage. This could possibly overdischarge them (this is referred to as a "loaded storage" condition that is considered undesirable for any rechargeable battery system). For example, a resistance placed across the battery terminals as part of a battery monitoring circuit should be disconnected when the device is not in use.
Otherwise, it could eventually discharge the cells below the undervoltage limit of the charger. This will reduce the rechargeability of the cells.

As with any battery system, when cells are replaced at the end of their useful cycle life, all cells in the device should be replaced simultaneously.

■ SUMMARY

The Renewal Reusable Alkaline Battery System from Rayovac gives the designers of portable battery-operated equipment an excellent opportunity to maximize the benefits of an optimum design. Reviewing the selection criteria, electrical performance and charging method at the beginning of the design cycle will permit the designer to capitalize o the benefits of the Renewal battery (e.g., low cost, environmental responsibility, excellent shelf, etc.). Further assistance can be provided by Rayovac regarding discharge monitoring, pulse/transient loads and charging system implementation. The Renewal system can be thought of as "bridging the gap" between the single-use primary alkaline and the traditional nickel-based systems. This gap can now be properly filled with this new innovation.

Any circuitry associated with the charging of Renewal batteries should be reviewed and approved by Rayovac prior to product release.

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REVERSE OSMOSIS MEMBRANE SENSITIVITY TO OZONE AND HALOGEN DISINFECTANTS

J. GLATER, M.R. ZACHARIAH, S.B. McCRAY AND J.W. McCUTCHAN

Chemical, Nuclear and Thermal Engineering Department, University of California, Los Angeles, CA 90024 (USA)

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SUMMARY

The sensitivity of commercial reverse osmosis (RO) membranes toward halogen and ozone disinfectants has been measured at carefully controlled concentration and pH levels. Membrane sensitivity varies with polymer type, disinfectant chemical, and solution pH. Aromatic polyamide membranes are damaged by halogen addition to aromatic rings within the polymer. This process follows predictable reaction kinetics. Polymer viscosity changes with increasing membrane damage have also been followed. Results of this study will be useful in planning disinfection strategies for RO units in the field.

INTRODUCTION

Natural water RO systems require feedwater disinfection to prevent slime formation and potential microbiological degradation of membrane polymers. Chlorine, the most common water disinfectant, came under careful scrutiny during the early 1970s because of the appearance of tri-halo methanes in certain municipal drinking water supplies [1]. This discovery motivated the search for alternative disinfection strategies. These included ozone, chlorine dioxide and other halogen agents. This work, sponsored by OWRT, was initiated because of the lack of detailed information on membrane-chemical interactions.

Certain papers on membrane sensitivity to chlorine have been published by Spatz and Friedlander [2], Vos et al. [3] and Fluid Systems Division of UOP [4]. Brief reports on chlorine dioxide and iodine were also presented by Vos et al. [5] and Turby and Watkins [6] respectively. Prior to the onset of our work at UCLA, membrane responses to ozone, bromine, or bromine chloride had not been observed.

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Comprehensive studies of membrane-halogen interactions have recently been published by Glater et al. [7], Glater et al. [8] and McCray et al. [9]. These papers represent a summary of work conducted with five different types of commercial RO membranes. Experiments were carried out with Cl_2, Br_2, I_2, ClO_2, and BrCl under carefully controlled conditions of pH and halogen concentration. Membrane damage was evaluated by performance testing in a two inch flat plate laboratory RO unit. The product flux and percent rejection of a 5,000 ppm sodium chloride solution were compared to baseline performance of unexposed membrane.

In the present study we have continued this series of experiments which include membrane exposure to ozone. We will also report on some additional techniques designed to provide further insights into the nature of membrane-chemical interaction. Additionally these studies include rate studies of membrane deterioration in certain chemical environments.

EXPERIMENTAL

Techniques of soak testing, chemical monitoring, pH regulation, and performance assessment with halogen based disinfectants have been previously presented by Glater et al. [7]. As reported in earlier work, all soak testing was conducted in buffer solutions adjusted to pH levels of 3.0, 5.8, and 8.6. Membrane samples were exposed to ozone by sparging ozone-oxygen gas mixtures into buffered solutions. Ozone was generated by passing pure oxygen gas through an ultraviolet type ozonator. The configuration shown in Fig. 1 was capable of maintaining a maximum concentration of 0.9 ppm O_3 in a 28 liter exposure chamber. Note the elevated position of the gas diffusers. With this arrangement, direct contact between gas bubbles and membrane samples could be avoided.

Because of ozone instability, gas injection must be carried out continuously. A six hour pre-injection period was required to build up steady state levels of dissolved ozone. Ozone levels in the system were periodically monitored by removing bath samples for analysis. These samples were analyzed by iodine release and subsequent titration with sodium thiosulfate according to standard methods.

Certain halogen treated membrane samples were analyzed for halogen uptake following exposure. Membranes were rinsed thoroughly with distilled water, oven dried at 110°C and sent out to Global Geochemical Corp., Los Angeles, CA, a commercial laboratory. The samples were first degraded by sodium fusion, eluted with water, and the resulting solution analyzed by ion chromatography. Halogen incorporated into the membrane was reported as percent by weight of dry sample.

The viscosity of certain membrane samples was measured in an attempt to study possible membrane depolymerization following halogenation. Measure-

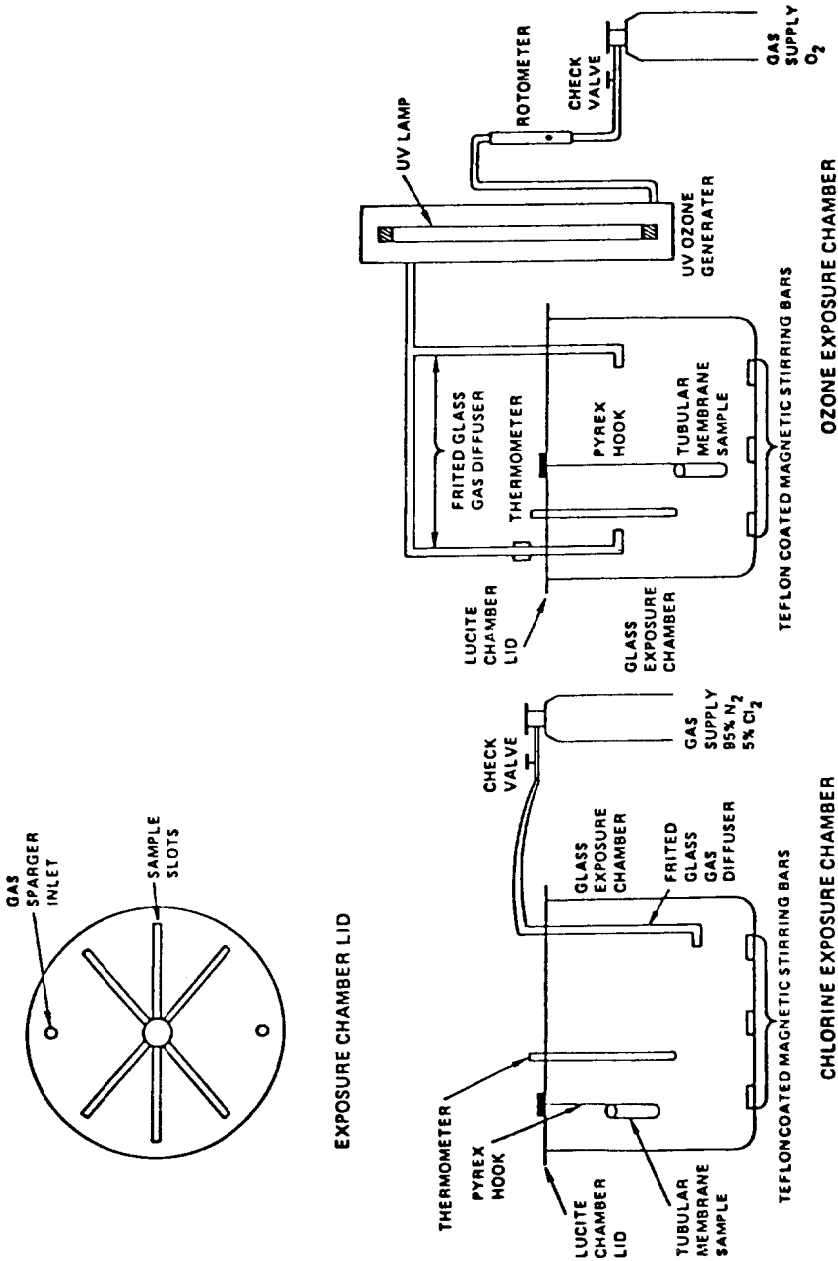

Fig. 1. Experimental apparatus for membrane soak tests with chlorine and ozone.

ments were carried out with a Ubbhelode capillary type viscometer at constant water bath temperature of 25 ± 0.1°C. The experimental procedure, taken from Billingham [10] gives the following equation for solution viscosity.

$$\gamma = A \rho t \tag{1}$$

The viscosity γ is a linear function of solution density ρ and time t in seconds. The constant A is a calibration constant unique to each viscometer.

All viscosity measurements were carried out with B-9 membrane in dimethyl sulfoxide solvent at 1.0% by weight concentration. No accurate assessment of viscosity could be determined since A was not calibrated and values of ρ were not constant because of changes during membrane halogenation. As a result, we simply used time as a rough measure of viscosity changes. It should also be noted that no attempt was made to relate viscosity to molecular weight.

All performance data reported in this paper is compared with baseline data for each membrane. Assessment of membrane damage is based on difference in product flux and percent rejection between exposed and unexposed membranes. A list of commercial membranes used in this work and corresponding baseline data is given in Table I. All performance testing was conducted in a small two inch flat plate laboratory RO unit using 5,000 ppm sodium chloride feed at an operating pressure of 600 psig.

TABLE I

COMMERCIAL MEMBRANE DESIGNATIONS AND BASELINE PERFORMANCE DATA

Manufacturer	Mfg. code	Polymer type	Product flux* (GFD)	Salt rejection (percent)
Fluid Systems	TFC-RC-100	Poly(ether/urea) (thin film composite)	13.8	99.8
Envirogenics	CA blend 72°C cure	CA-CTA blend (homogeneous)	29.5	96.7
Hydranautics	γ	Homogeneous CA (coated with vinyl acetate)	20.2	97.7
DuPont	Aramid B-9	Homogeneous aromatic polyamide	15.7	97.3
FilmTec	FT-30	Composition unknown (thin film composite)	25.8	98.5

*Tested at 600 psig, 5,000 ppm NaCl feedwater at 25 ± 1°C.

MEMBRANE RESPONSE TO HALOGENS

Polyamide type membranes have, in general, been considered sensitive to chlorine as reported in previous work [7, 8, 9]. In light of our recent experimental data, however, this conclusion must be qualified. Considerable work with FT-30 and B-9 have shown these membranes to withstand chlorine attack provided the pH is carefully regulated. Fig. 2 illustrates a prolonged exposure of FT-30 to 30 ppm chlorine. Note the sustained salt rejection capability and reasonably constant product flux at pH 3.0 and 5.8. Note that performance remains fairly constant at pH levels below 5.8. At pH 8.6, however, severe degradation in performance is observed over a 328 hour period.

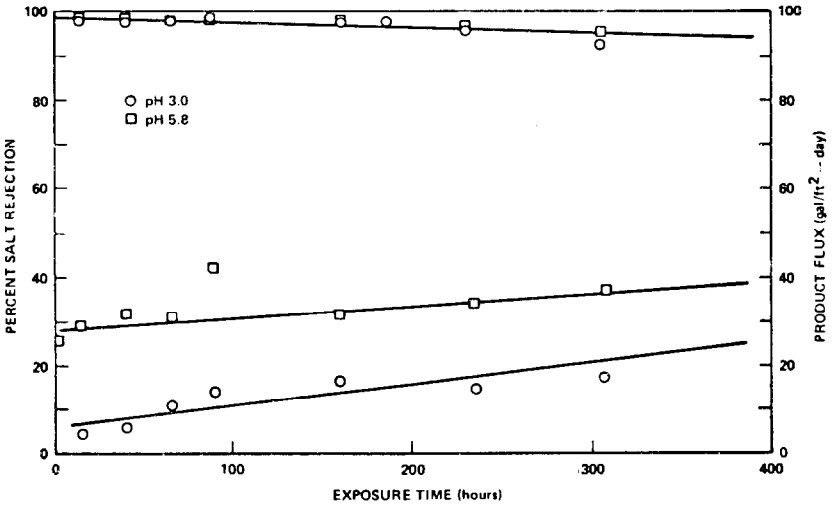

Fig. 2. Change in performance of FT-30 membrane on continuous exposure to 30 ppm chlorine at pH 3.0 and 5.8.

Similar chlorine resistance is demonstrated by B-9 membrane as shown in Fig. 3. Note the similar flat performance profiles at pH levels above 5.8. In this case severe damage occurs at pH 3.0 within 72 hours of exposure. It is interesting to note the opposite pH sensitivity of these polymers. Both membrane types are unresponsive to iodine on prolonged exposure at high concentration but show different performance profiles with bromine. FT-30 displays approximately the same sensitivity to bromine and chlorine. On the other hand, B-9 is severely damaged by bromine over the pH range used in these experiments.

Obviously the chemical structure of FT-30 differs from that of B-9. At this time we are unable to explain the difference in pH response of these

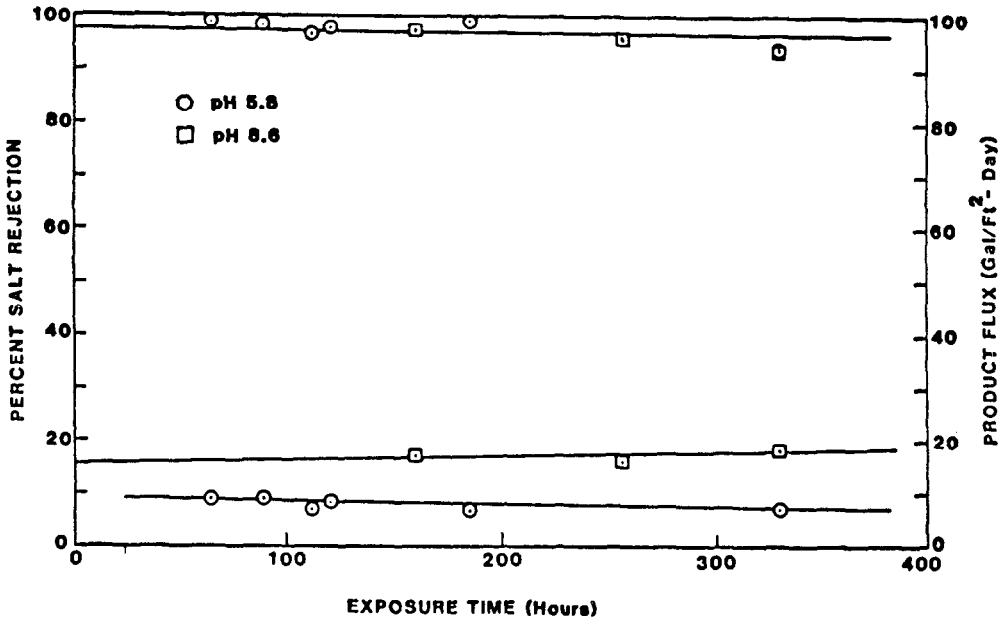

Fig. 3. Change in performance of B-9 membrane on continuous exposure to 30 ppm chlorine at pH 5.8 and 8.6.

membranes to chlorine and the overall difference in sensitivity to bromine. Details on polymer structure may provide further insights into this difference in chemical and pH sensitivity. In order to better understand the nature of halogen-membrane interaction, three different lines of investigation have been followed. The first involves elemental analysis of exposed membrane samples for halogen uptake, the second is a measurement of viscosity of exposed polymer solutions, and the third involves a study of these samples by infrared and NMR techniques. The following discussion will focus on results derived from elemental analysis and viscosity measurements. A report of our instrumental studies will appear in a subsequent paper.

All work on elemental analysis was conducted with DuPont B-9 membrane because of its halogen sensitivity at low pH. Also, this membrane is a homogeneous film of considerable thickness as compared with TFC types. Because of these properties, measurable quantities of halogen could be detected in small membrane samples.

Membranes were exposed at fixed halogen concentration in buffer solutions of constant pH. Following exposure, samples were washed thoroughly in distilled water, oven dried at 110°C, and submitted for halogen analysis. The analytical procedure first involved sodium fusion requried to convert organo-halogen compounds to halide ion. The resulting sample was then eluted with water and halide ion determined by ion chromatography.

Experiments were carried out with chlorine, bromine and chlorine dioxide for varying periods of time at different pH and concentration levels. Experimental data is summarized in Table II. Results are expressed as percent by weight of dry exposed membrane. A blank determination on unexposed membrane showed less than 0.1% halogen and was considered insignificant.

The experimental data in Table II enables us to estimate the level of halogen-polymer addition on a mole-mole basis. As a model for this calculation, we assume that aromatic halogen substitution takes place on one or both rings of the following repeating polymer unit (Fig. 4). This assumption is supported by data from our study of infrared spectra. The proposed unit was

TABLE II

HALOGEN INTAKE OF EXPOSED B-9 MEMBRANE

Disinfectant chemical	Concentration (ppm)	pH	Exposure time (h)	Polymer halogen content (% by wt.)
Cl_2	30	3.0	8	13.4
	30	3.0	24	17.0
	30	3.0	40	17.7
	30	3.0	100	22.1
	30	8.6	112	0.1
Br_2	70	3.0	40	22.2
	70	5.8	40	29.5
	70	8.6	40	19.1
ClO_2	30	3.0	100	0.5
	30	8.6	48	0.3

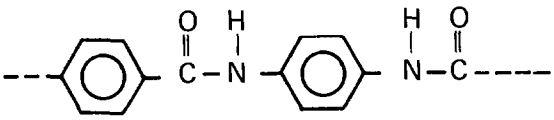

Fig. 4. Repeating polymer unit of B-9 membrane.

suggested by DuPont [11] showing B-9 membrane to consist essentially of a linear aromatic polyamide. The peptide linkages

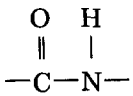

are arranged so that alternate rings are bonded in the meta position on each side either by

$$\begin{array}{c} H \\ | \\ -N- \end{array} \text{ or by } \begin{array}{c} O \\ \| \\ -C- \end{array}.$$

This structure has also been suggested by infrared spectra.

The DuPont patent disclosure for B-9 membrane [12] also shows some of the aromatic rings to contain substituted sulfonic acid groups ($-SO_3H$). This functional group is said to be present on approximately 10% of the aromatic rings. The formula weight of the repeating polymer unit equals 238. If we now consider the addition of one sulfonic acid group to every five repeating units, the formula weight is increased by $-SO_3H/5 = 81/5 \approx 16$ atomic weight units. This gives a corrected formula weight of the repeating unit of approximately 254. By using this figure we can calculate theoretical percentage halogen uptake based on one or two halogen atoms substituted. These calculations are presented in Table III.

TABLE III

THEORETICAL PERCENTAGE HALOGEN IN MONO- AND DI-SUBSTITUTED POLYMER

Substitution pattern	Theoretical % halogen (calculated)
1 Cl per formula unit	12.25
2 Cl per formula unit	21.85
1 Br per formula unit	23.95
2 Br per formula unit	38.64

The chlorine uptake data clearly indicates halogen addition to be initially very rapid. With continued exposure, the rate slows down as shown in Fig. 5. This is easily explained by increased polymer saturation, but, in addition, it is evidently more difficult to substitute a second chlorine atom on mono-substituted aromatic rings. It should be noted that alternate rings are either activated or de-activated by

$$\begin{array}{c} H \\ | \\ -N- \end{array} \text{ or } \begin{array}{c} O \\ \| \\ -C- \end{array}$$

substituents respectively. Substitution on the de-activated ring would thus

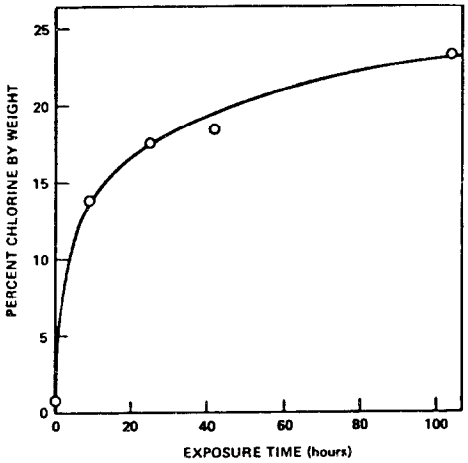

Fig. 5. Chlorine uptake by B-9 membrane on continuous exposure to 30 ppm chlorine at pH 3.0.

proceed at a slower rate. In addition, only one site in the meta position is available.

Note also that mono-substitution is completed in less than eight hours when the chlorine content reaches 13.4%. Two chlorine atoms give a theoretical value of 21.85% chlorine which agrees well with the 22.1% measured after a 100 hour exposure period. We are not certain whether a third chlorine could be substituted on continued exposure.

The effect of pH on chlorine substitution is also clearly illustrated by the data. At pH 8.6 there is no chlorine uptake. Experiments were not conducted at pH 5.8 but we would anticipate results similar to the pH 3.0 data. It is evident that HOCl, which predominates below pH 5.8 is an effective halogenating agent. The species OCl^- which exists in solution at pH 8.6 shows no activity in ring halogenation.

A kinetic analysis of the chlorine data from Table II and Fig. 5 leads to some interesting interpretations. It is assumed that mono-halogenation is a very fast reaction followed by a much slower addition of the second halogen atom. It is also assumed that the di-halogen derivative represents maximum substitution. Thus, the following reaction describes the rate determining step in which MX represents mono-halogenated polymer and K_2 is the rate constant.

$$MX + X \xrightarrow[K_2]{\text{slow}} MX_2 \tag{2}$$

The overall reaction rate may be described by the following equation

assuming that MX is formed instantaneously from M and that both reactions are irreversible.

$$\text{rate} = -\frac{d[M]}{dt} = -\frac{d[MX]}{dt} = K_2\ [MX]\ [X] \tag{3}$$

Since the halogen concentration is kept constant over the duration of the reaction, a pseudo-first order rate constant K'_2 may be defined as:

$$K'_2 = K_2\ [X]$$

From classical kinetic theory the following integrated form of the rate equation can be derived in which $[MX] = [M]$ and represents the relative concentration of mono-halogenated polymer at time 0 and $[MX_2]$ is the relative concentration of di-halogenated polymer at any time during the reaction. Time in hours is given by t.

$$\ln\ 1 - \frac{[MX_2]}{[MX]_0} = -K'_2\ t \tag{4}$$

The above linear pseudo-first order equation, based on chlorine data from Table II is plotted in Fig. 6. The resulting straight line with a slope of 0.0231 hrs^{-1} is equal to the rate constant K'_2.

This type of analysis may be useful in projecting the life expectancy of RO membranes under field conditions. The methodology is applicable to different membrane types and pretreatment conditions.

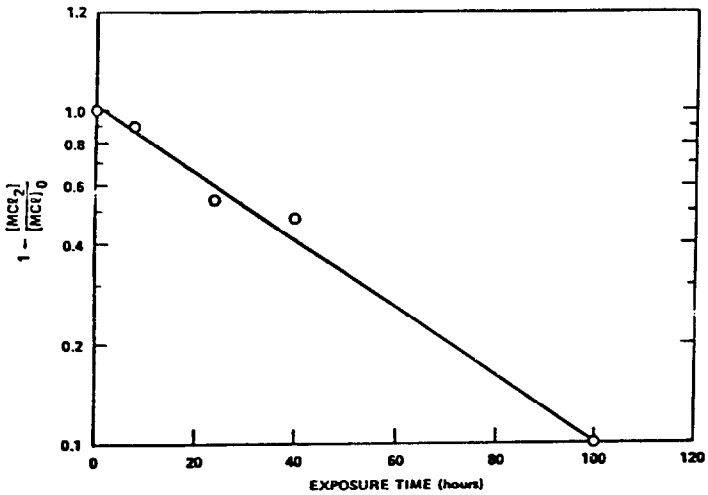

Fig. 6. Rate of chlorine uptake by B-9 membrane showing pseudo first order reaction kinetics.

A series of experiments have also been conducted in an effort to relate performance decline and halogen uptake with membrane degradation. Viscosity measurements of polymer solutions were conducted in an effort to reveal depolymerization or other morphological changes.

Fig. 7 shows changes in viscosity of chlorinated B-9 membrane samples dissolved in dimethyl sulfoxide. Samples were exposed to 30 ppm chlorine at pH 3.0 for time intervals up to 100 hours. All membrane solutions were made up of 1% dry polymer by weight. Superimposed on this figure is the chlorine uptake data also shown in Fig. 5. Note the continually decreasing viscosity as the membrane chlorine content increases. Also note the viscosity increase during the first 10 hours of exposure.

This data suggests a plausible mechanism for membrane deterioration. The initial short rise in the curve is evidently due to chlorine addition accompanied by a corresponding increase in polymer mass and viscosity. Continued exposure possibly results in bond cleavage accompanied by chlorine uptake. The chlorinated polymer fragments are now of significantly lower molecular weight. This sequence of events would appear to follow the initial

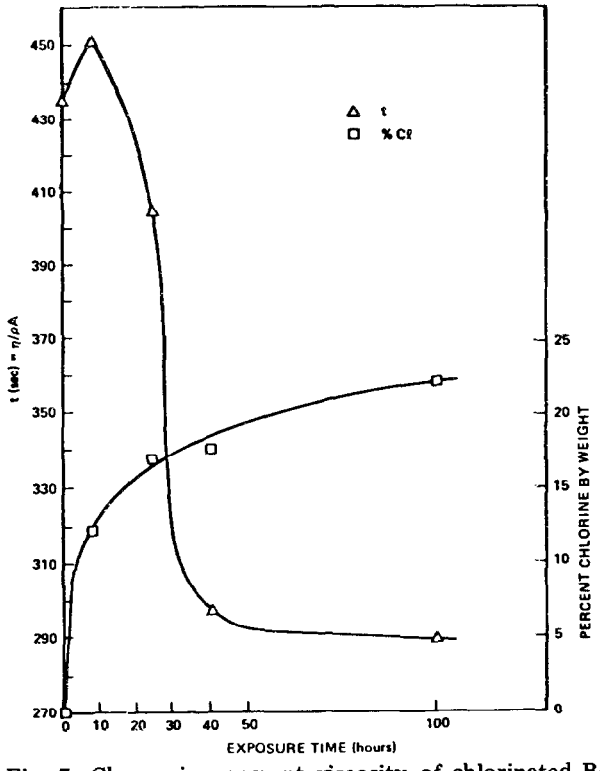

Fig. 7. Change in apparent viscosity of chlorinated B-9 membrane samples dissolved in DMSO plotted with chlorine uptake data.

membrane tightening and subsequent performance decline observed in earlier experiments [8, 9]. At this point we are not sure of the mechanism of viscosity decline which may also result from changes in hydrogen bonding or cross linkage within the halogenated polymer.

The bromine data also indicated pH specificity of polymer halogenation as illustrated in Fig. 8. Bromine is clearly most aggressive at pH 5.8 when the solution is nearly 100% HOBr. At pH 3.0 the approximate species distribution is 11% HOBr and 89% Br_2, and at pH 8.6 it is 56% HOBr and 44% OBr^-. The slightly greater bromine uptake at pH 3.0 compared with pH 8.6 is probably due to concerted attack of HOBr and Br_2. Earlier work has shown OBr^- to be unreactive. From this data we may arrange the overall activity of bromine species in the order HOBr > Br_2 > OBr^-.

The extent of bromine substitution is similar to chlorine, showing approximately one bromine atom per polymer unit after a 40 hour exposure. The data also suggests that HOCl at pH 3.0 is somewhat more active than HOBr at pH 5.8.

B-9 membrane exposure to chlorine dioxide (Table II) shows virtually no chlorine uptake. This finding is in agreement with literature reports indi-

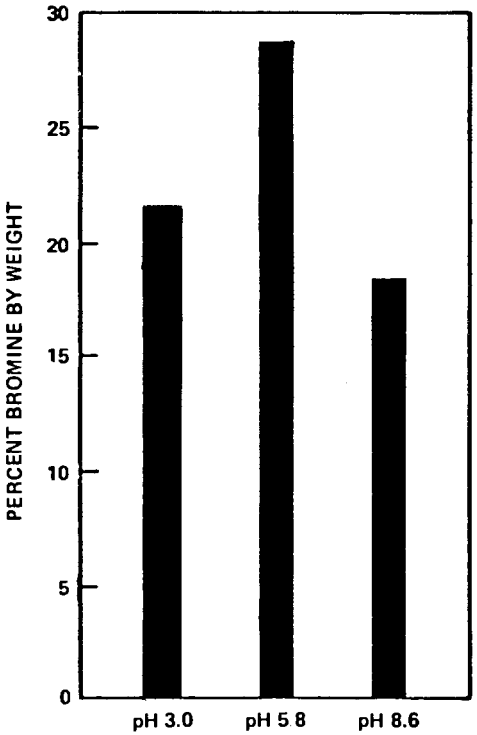

Fig. 8. Bromine uptake of B-9 membrane exposed to 70 ppm bromine for 40 hours at various pH levels.

cating that ClO_2 reacts with organic compounds by oxidation rather than halogenation [13]. The very low measured levels are probably due to traces of chlorine in the ClO_2 solutions.

The response of FT-30 and B-9 membranes to chlorine dioxide has been documented in earlier reports [8, 9]. Both membranes show good resistance at near neutral pH but are severely damaged at pH 8.6. Chemical attack evidently occurs by a mechanism different from chlorination, however, since chlorine is not incorporated into the membrane polymer.

MEMBRANE RESPONSE TO OZONE

Membrane exposure to ozone was carried out by continuous gas injection into the exposure chamber. Steady-state levels of 0.3 ppm were maintained in all experiments. This concentration is approximately six times the average residual used in water treatment applications. As in the case of halogens, experimental conditions represent "accelerated testing".

Ozone was the most aggressive chemical disinfectant tested. All membranes used in this program were damaged during the maximum test period of 90 hours. Even cellulose acetate films which are quite halogen resistant, show a marked sensitivity to ozone within the same exposure period.

All polyamide type membranes tested are very sensitive to ozone. B-9 membrane, for example, shows a marked performance decline within the first few hours of exposure. Complete membrane failure occurs after 15 hours as displayed in Fig. 9. Note that salt rejection drops to less than 10% over the experimental range of pH. Similar results were observed on exposure of RC-100 and FT-30 to ozone.

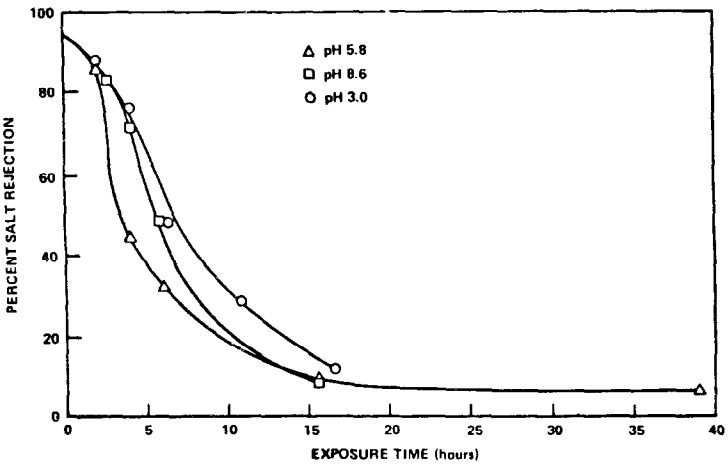

Fig. 9. Change in salt rejection of B-9 membrane on continuous exposure to 0.3 ppm ozone at various pH levels.

The effect of ozone on performance of Envirogenics blended cellulose acetate membrane is displayed in Fig. 10. This membrane is very sensitive at pH 8.6 but sustains only modest performance changes at pH levels below 5.8. It appears that trace ozone concentrations would have minimum effect on membrane life, especially for short exposure periods.

Despite the very aggressive nature of ozone, it seems premature to rule out the use of this disinfectant in RO systems containing cellulose acetate membranes. Following disinfection, deozonation systems based on degasing or chemical treatment could be developed. Even if slight ozone residuals were to remain, it appears that cellulose acetate will resist attack at near-neutral pH. This strategy is not, however, recommended for polyamide containing systems. In this case, the risk of severe membrane damage is too great.

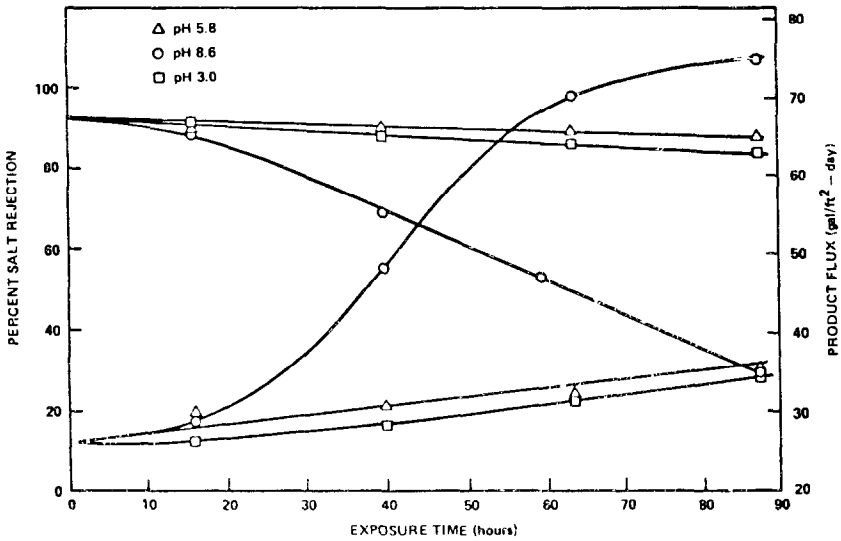

Fig. 10. Change in performance of blended cellulose acetate membrane on continuous exposure to 0.3 ppm ozone at various pH levels.

CONCLUSIONS

Work described in this paper should be useful in planning reasonable disinfection strategies for RO units in the field. Additionally, this research approach may provide techniques for estimation of membrane life expectancy. A better understanding of the nature of membrane-halogen interactions will also aid manufacturers in development of more chemically resistant membranes. Following are the most significant conclusions resulting from this work.

1) Cellulose acetate membranes are generally resistant to halogens and halogen derivatives.

2) Polyamide type membranes are sensitive to chlorine and bromine but show reasonable resistance with appropriate pH control.

3) Ozone will damage any membrane tested, however, cellulose acetate shows some resistance at low pH levels. This type membrane may resist low concentrations in systems designed for ozone disinfection.

4) All membranes are generallly resistant to iodine.

5) Polyamide type membranes are generally resistant to chlorine dioxide at near-neutral pH. This chemical evidently attacks membranes at high pH by oxidation since no halogen uptake is observed.

6) DuPont B-9 membrane chemically combines with chlorine during exposure. This process is accompanied by decreasing viscosity of polymer solutions in dimethyl sulfoxide.

7) Chlorine uptake data follows pseudo-first order reaction kinetics.

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Reverse osmosis

From Wikipedia, the free encyclopedia

Reverse osmosis (**RO**) is a water purification technology that uses a semipermeable membrane to remove ions, molecules, and larger particles from drinking water. In reverse osmosis, an applied pressure is used to overcome osmotic pressure, a colligative property, that is driven by chemical potential differences of the solvent, a thermodynamic parameter. Reverse osmosis can remove many types of dissolved and suspended species from water, including bacteria, and is used in both industrial processes and the production of potable water. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side. To be "selective", this membrane should not allow large molecules or ions through the pores (holes), but should allow smaller components of the solution (such as solvent molecules) to pass freely.

In the normal osmosis process, the solvent naturally moves from an area of low solute concentration (high water potential), through a membrane, to an area of high solute concentration (low water potential). The driving force for the movement of the solvent is the reduction in the free energy of the system when the difference in solvent concentration on either side of a membrane is reduced, generating osmotic pressure due to the solvent moving into the more concentrated solution. Applying an external pressure to reverse the natural flow of pure solvent, thus, is reverse osmosis. The process is similar to other membrane technology applications. However, key differences are found between reverse osmosis and filtration. The predominant removal mechanism in membrane filtration is straining, or size exclusion, so the process can theoretically achieve perfect efficiency regardless of parameters such as the solution's pressure and concentration. Reverse osmosis also involves diffusion, making the process dependent on pressure, flow rate, and other conditions.[1] Reverse osmosis is most commonly known for its use in drinking water purification from seawater, removing the salt and other effluent materials from the water molecules.

Water desalination

Methods

- Distillation
  - Multi-stage flash distillation (MSF)
  - Multiple-effect distillation (MED|ME)
  - Vapor-compression (VC)
- Ion exchange
- Membrane processes
  - Electrodialysis reversal (EDR)
  - **Reverse osmosis** (RO)
  - Nanofiltration (NF)
  - Membrane distillation (MD)
  - Forward osmosis (FO)
- Freezing desalination
- Geothermal desalination
- Solar desalination
  - Solar humidification–dehumidification (HDH)
  - Multiple-effect humidification (MEH)
- Methane hydrate crystallization
- High grade water recycling
- Seawater greenhouse

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History

The process of osmosis through semipermeable membranes was first observed in 1748 by Jean-Antoine Nollet. For the following 200 years, osmosis was only a phenomenon observed in the laboratory. In 1950, the University of California at Los Angeles first investigated desalination of seawater using semipermeable membranes. Researchers from both University of California at Los Angeles and the University of Florida successfully produced fresh water from seawater in the mid-1950s, but the flux was too low to be commercially viable[2] until the discovery at University of California at Los Angeles by Sidney Loeb[3] and Srinivasa Sourirajan at the National Research Council of Canada, Ottawa, of techniques for making asymmetric membranes characterized by an effectively thin "skin" layer supported atop a highly porous and much thicker substrate region of the membrane. John Cadotte, of FilmTec Corporation, discovered that membranes with particularly high flux and low salt passage could be made by interfacial polymerization of *m*-phenylene diamine and trimesoyl chloride. Cadotte's patent on this process[4] was the subject of litigation and has since expired. Almost all commercial reverse osmosis membrane is now made by this method. By the end of 2001, about 15,200 desalination plants were in operation or in the planning stages, worldwide.[1]

In 1977 Cape Coral, Florida became the first municipality in the United States to use the RO process on a large scale with an initial operating capacity of 3 million gallons (11350 m^3) per day. By 1985, due to the rapid growth in population of Cape Coral, the city had the largest low pressure reverse osmosis plant in the world, capable of producing 15 million gallons per day (MGD) (56800 m^3/d).[5]

Process

Osmosis is a natural process. When two solutions with different concentrations of a solute are separated by a

semipermeable membrane, the solvent has a tendency to move from low to high solute concentrations for chemical potential equilibration.

Reverse osmosis production train, North Cape Coral Reverse Osmosis Plant

Formally, reverse osmosis is the process of forcing a solvent from a region of high solute concentration through a semipermeable membrane to a region of low solute concentration by applying a pressure in excess of the osmotic pressure. The largest and most important application of reverse osmosis is the separation of pure water from seawater and brackish waters; seawater or brackish water is pressurized against one surface of the membrane, causing transport of salt-depleted water across the membrane and emergence of potable drinking water from the low-pressure side.

A semipermeable membrane coil used in desalination

The membranes used for reverse osmosis have a dense layer in the polymer matrix—either the skin of an asymmetric membrane or an interfacially polymerized layer within a thin-film-composite membrane—where the separation occurs. In most cases, the membrane is designed to allow only water to pass through this dense layer, while preventing the passage of solutes (such as salt ions). This process requires that a high pressure be exerted on the high concentration side of the membrane, usually 2–17 bar (30–250 psi) for fresh and brackish water, and 40–82 bar (600–1200 psi) for seawater, which has around 27 bar (390 psi)[6] natural osmotic pressure that must be overcome. This process is best known for its use in desalination (removing the salt and other minerals from sea water to get fresh water), but since the early 1970s, it has also been used to purify fresh water for medical, industrial, and domestic applications.

Fresh water applications

Drinking water purification

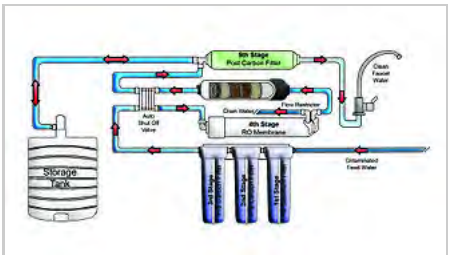

The reverse osmosis water filter process

Around the world, household drinking water purification systems, including a reverse osmosis step, are commonly used for improving water for drinking and cooking.

Such systems typically include a number of steps:

- a sediment filter to trap particles, including rust and calcium carbonate
- optionally, a second sediment filter with smaller pores
- an activated carbon filter to trap organic chemicals and chlorine, which will attack and degrade thin film composite membrane reverse osmosis membranes
- a reverse osmosis filter, which is a thin film composite membrane
- optionally, a second carbon filter to capture those chemicals not removed by the reverse osmosis membrane
- optionally an ultraviolet lamp for sterilizing any microbes that may escape filtering by the reverse osmosis membrane

- latest developments in the sphere include nano materials and membranes

In some systems, the carbon prefilter is omitted, and cellulose triacetate membrane is used. CTA (Cellulose Triacetate) membrane is a paper by-product membrane bonded to a synthetic layer and are made to allow contact with chlorine in the water. These require a small amount of chlorine in the water source to prevent bacteria from forming on it. The typical rejection rate for CTA membranes is 85–95%.

The cellulose triacetate membrane is prone to rotting unless protected by chlorinated water, while the thin film composite membrane is prone to breaking down under the influence of chlorine. A thin film composite (TFC) membranes are made of synthetic material, and require chlorine to be removed before the water enters the membrane. To protect the TFC membrane elements from chlorine damage, carbon filters are used as pre-treatment in all residential reverse osmosis systems. TFC membranes have a higher rejection rate of 95–98% and a longer life than CTA membranes.

Portable reverse osmosis water processors are sold for personal water purification in various locations. To work effectively, the water feeding to these units should be under some pressure (40 pounds per square inch (280 kPa) or greater is the norm).[7] Portable reverse osmosis water processors can be used by people who live in rural areas without clean water, far away from the city's water pipes. Rural people filter river or ocean water themselves, as the device is easy to use (saline water may need special membranes). Some travelers on long boating, fishing, or island camping trips, or in countries where the local water supply is polluted or substandard, use reverse osmosis water processors coupled with one or more ultraviolet sterilizers.

In the **production of bottled mineral water**, the water passes through a reverse osmosis water processor to remove pollutants and microorganisms. In European countries, though, such processing of natural mineral water (as defined by a European Directive[8]) is not allowed under European law. In practice, a fraction of the living bacteria can and do pass through reverse osmosis membranes through minor imperfections, or bypass the membrane entirely through tiny leaks in surrounding seals. Thus, complete reverse osmosis systems may include additional water treatment stages that use ultraviolet light or ozone to prevent microbiological contamination.

Membrane pore sizes can vary from 0.1 to 5,000 nm (4×10^{-9} to 2×10^{-4} in) depending on filter type. Particle filtration removes particles of 1 µm (3.9×10^{-5} in) or larger. Microfiltration removes particles of 50 nm or larger. Ultrafiltration removes particles of roughly 3 nm or larger. Nanofiltration removes particles of 1 nm or larger. Reverse osmosis is in the final category of membrane filtration, hyperfiltration, and removes particles larger than 0.1 nm.

Military use: the reverse osmosis water purification unit

A reverse osmosis water purification unit (ROWPU) is a portable, self-contained water treatment plant. Designed for military use, it can provide potable water from nearly any water source. There are many models in use by the United States armed forces and the Canadian Forces. Some models are containerized, some are trailers, and some are vehicles unto themselves.

Each branch of the United States armed forces has their own series of reverse osmosis water purification unit models, but they are all similar. The water is pumped from its raw source into the reverse osmosis water purification unit module, where it is treated with a polymer to initiate coagulation. Next, it is run through a multi-media filter where it undergoes primary treatment by removing turbidity. It is then pumped through a cartridge filter which is usually spiral-wound cotton. This process clarifies the water of any particles larger than 5 micrometres (0.00020 in) and eliminates almost all turbidity.

The clarified water is then fed through a high-pressure piston pump into a series of vessels where it is subject to reverse osmosis. The product water is free of 90.00–99.98% of the raw water's total dissolved solids and by military standards, should have no more than 1000–1500 parts per million by measure of electrical conductivity. It is then disinfected with chlorine and stored for later use.

United States Marines from Combat Logistics Battalion 31 operate reverse osmosis water purification units for relief efforts after the 2006 Southern Leyte mudslide

Within the United States Marine Corps, the reverse osmosis water purification unit has been replaced by both the Lightweight Water Purification System and Tactical Water Purification Systems.[9] The Lightweight Water Purification Systems can be transported by Humvee and filters 125 US gallons (470 l) per hour. The Tactical Water Purification Systems can be carried on a Medium Tactical Vehicle Replacement truck, and can filter 1,200 to 1,500 US gallons (4,500 to 5,700 l) per hour.

Water and wastewater purification

Rain water collected from storm drains is purified with reverse osmosis water processors and used for landscape irrigation and industrial cooling in Los Angeles and other cities, as a solution to the problem of water shortages.

In industry, reverse osmosis removes minerals from boiler water at power plants.[10] The water is distilled multiple times. It must be as pure as possible so it does not leave deposits on the machinery or cause corrosion. The deposits inside or outside the boiler tubes may result in underperformance of the boiler, bringing down its efficiency and resulting in poor steam production, hence poor power production at the turbine.

It is also used to clean effluent and brackish groundwater. The effluent in larger volumes (more than 500 m^3/d) should be treated in an effluent treatment plant first, and then the clear effluent is subjected to reverse osmosis system. Treatment cost is reduced significantly and membrane life of the reverse osmosis system is increased.

The process of reverse osmosis can be used for the production of deionized water.[11]

Reverse osmosis process for water purification does not require thermal energy. Flow-through reverse osmosis systems can be regulated by high-pressure pumps. The recovery of purified water depends upon various factors, including membrane sizes, membrane pore size, temperature, operating pressure, and membrane surface area.

In 2002, Singapore announced that a process named NEWater would be a significant part of its future water plans.[12] It involves using reverse osmosis to treat domestic wastewater before discharging the NEWater back into the reservoirs.

Food industry

In addition to desalination, reverse osmosis is a more economical operation for concentrating food liquids (such as fruit juices) than conventional heat-treatment processes. Research has been done on concentration of orange juice and tomato juice. Its advantages include a lower operating cost and the ability to avoid heat-treatment processes, which makes it suitable for heat-sensitive substances such as the protein and enzymes found in most food products.

Reverse osmosis is extensively used in the dairy industry for the production of whey protein powders and for the concentration of milk to reduce shipping costs. In whey applications, the whey (liquid remaining after cheese manufacture) is concentrated with reverse osmosis from 6% total solids to 10–20% total solids before ultrafiltration processing. The ultrafiltration retentate can then be used to make various whey powders, including whey protein isolate. Additionally, the ultrafiltration permeate, which contains lactose, is concentrated by reverse osmosis from 5% total solids to 18–22% total solids to reduce crystallization and drying costs of the lactose powder.

Although use of the process was once avoided in the wine industry, it is now widely understood and used. An estimated 60 reverse osmosis machines were in use in Bordeaux, France, in 2002. Known users include many of the elite classed growths (Kramer) such as Château Léoville-Las Cases in Bordeaux.[13]

Maple syrup production

In 1946, some maple syrup producers started using reverse osmosis to remove water from sap before the sap is boiled down to syrup. The use of reverse osmosis allows about 75–90% of the water to be removed from the sap, reducing energy consumption and exposure of the syrup to high temperatures. Microbial contamination and degradation of the membranes must be monitored.

Hydrogen production

For small-scale hydrogen production, reverse osmosis is sometimes used to prevent formation of minerals on the surface of electrodes.

Reef aquariums

Many reef aquarium keepers use reverse osmosis systems for their artificial mixture of seawater. Ordinary tap water can contain excessive chlorine, chloramines, copper, nitrates, nitrites, phosphates, silicates, or many other chemicals detrimental to the sensitive organisms in a reef environment. Contaminants such as nitrogen compounds and phosphates can lead to excessive and unwanted algae growth. An effective combination of both reverse osmosis and deionization is the most popular among reef aquarium keepers, and is preferred above other water purification processes due to the low cost of ownership and minimal operating costs. Where chlorine and chloramines are found in the water, carbon filtration is needed before the membrane, as the common residential membrane used by reef keepers does not cope with these compounds.

Window cleaning

An increasingly popular method of cleaning windows is the so-called "water-fed pole" system. Instead of washing the windows with detergent in the conventional way, they are scrubbed with highly purified water, typically containing less than 10 ppm dissolved solids, using a brush on the end of a long pole which is wielded from ground level. Reverse osmosis is commonly used to purify the water.[14]

Landfill leachate purification

Treatment with reverse osmosis is limited, resulting in low recoveries on high concentration (measured with electrical conductivity) and fouling of the RO membranes. Reverse osmosis applicability is limited by conductivity, organics, and scaling inorganic elements such as CaSO4, Si, Fe and Ba. Low organic scaling can be used two different technology, one is using spiral wound membrane type of module, and for high organic

scaling, high conductivity and higher pressure (up to 90 bars) can be used disc tube module with reverse osmosis membranes. Disc tube modules was redesigned for landfill leachate purification, what usually is contaminated with high organics. Due to the cross-flow with high velocity is given by a flow booster pump, what is recirculating the flow over the same membrane surface between 1,5 and 3 times before is released as a concentrate. High velocity is also good against membrane scaling and allows successful membrane cleanings.

Power consumption for a disc tube module system

energy consumption per m³ leachate			
name of module	1-stage up to 75 bar	2-stage up to 75 bar	3-stage up to 120 bar
disc tube module	6.1 – 8.1 kWh/m³	8.1 – 9.8 kWh/m³	11.2 – 14.3 kWh/m³

Disc tube module with RO membrane cushion and Spiral wound module with RO membrane

Desalination

Areas that have either no or limited surface water or groundwater may choose to desalinate. Reverse osmosis is an increasingly common method of desalination, because of its relatively low energy consumption. In recent years, energy consumption has dropped to around 3 kWh/m^3, with the development of more efficient energy recovery devices and improved membrane materials. According to the International Desalination Association, for 2011, reverse osmosis was used in 66% of installed desalination capacity (44.5 of 67.4 Mm^3/day), and nearly all new plants.[15] Other plants mainly use thermal distillation methods: multiple-effect distillation and multi-stage flash.

Sea water reverse osmosis (SWRO) desalination, a membrane process, has been commercially used since the early 1970s. Its first practical use was demonstrated by Sidney Loeb from University of California at Los Angeles in Coalinga, California, and Srinivasa Sourirajan of National Research council, Canada. Because no heating or phase changes are needed, energy requirements are low, around 3 kWh/m^3, in comparison to other processes of desalination, but are still much higher than those required for other forms of water supply, including reverse osmosis treatment of wastewater, at 0.1 to 1 kWh/m^3. Up to 50% of the seawater input can be recovered as fresh water, though lower recoveries may reduce membrane fouling and energy consumption.

Brackish water reverse osmosis refers to desalination of water with a lower salt content than sea water, usually from river estuaries or saline wells. The process is substantially the same as sea water reverse osmosis, but requires lower pressures and therefore less energy. Up to 80% of the feed water input can be recovered as fresh water, depending on feed salinity.

The Ashkelon sea water reverse osmosis desalination plant in Israel is the largest in the world.[16][17] The project was developed as a build-operate-transfer by a consortium of three international companies: Veolia water, IDE Technologies, and Elran.[18]

The typical single-pass sea water reverse osmosis system consists of:

- Intake
- Pretreatment
- High pressure pump (if not combined with energy recovery)
- Membrane assembly

- Energy recovery (if used)
- Remineralisation and pH adjustment
- Disinfection
- Alarm/control panel

Pretreatment

Pretreatment is important when working with reverse osmosis and nanofiltration membranes due to the nature of their spiral-wound design. The material is engineered in such a fashion as to allow only one-way flow through the system. As such, the spiral-wound design does not allow for backpulsing with water or air agitation to scour its surface and remove solids. Since accumulated material cannot be removed from the membrane surface systems, they are highly susceptible to fouling (loss of production capacity). Therefore, pretreatment is a necessity for any reverse osmosis or nanofiltration system. Pretreatment in sea water reverse osmosis systems has four major components:

- Screening of solids: Solids within the water must be removed and the water treated to prevent fouling of the membranes by fine particle or biological growth, and reduce the risk of damage to high-pressure pump components.
- Cartridge filtration: Generally, string-wound polypropylene filters are used to remove particles of 1–5 µm diameter.
- Dosing: Oxidizing biocides, such as chlorine, are added to kill bacteria, followed by bisulfite dosing to deactivate the chlorine, which can destroy a thin-film composite membrane. There are also biofouling inhibitors, which do not kill bacteria, but simply prevent them from growing slime on the membrane surface and plant walls.
- Prefiltration pH adjustment: If the pH, hardness and the alkalinity in the feedwater result in a scaling tendency when they are concentrated in the reject stream, acid is dosed to maintain carbonates in their soluble carbonic acid form.

  $CO_3^{2-} + H_3O^+ = HCO_3^- + H_2O$

  $HCO_3^- + H_3O^+ = H_2CO_3 + H_2O$

- Carbonic acid cannot combine with calcium to form calcium carbonate scale. Calcium carbonate scaling tendency is estimated using the Langelier saturation index. Adding too much sulfuric acid to control carbonate scales may result in calcium sulfate, barium sulfate, or strontium sulfate scale formation on the reverse osmosis membrane.
- Prefiltration antiscalants: Scale inhibitors (also known as antiscalants) prevent formation of all scales compared to acid, which can only prevent formation of calcium carbonate and calcium phosphate scales. In addition to inhibiting carbonate and phosphate scales, antiscalants inhibit sulfate and fluoride scales and disperse colloids and metal oxides. Despite claims that antiscalants can inhibit silica formation, no concrete evidence proves that silica polymerization can be inhibited by antiscalants. Antiscalants can control acid-soluble scales at a fraction of the dosage required to control the same scale using sulfuric acid.[19]
- Some small scale desalination units use 'beach wells'; they are usually drilled on the seashore in close vicinity to the ocean. These intake facilities are relatively simple to build and the seawater they collect is pretreated via slow filtration through the subsurface sand/seabed formations in the area of source water extraction. Raw seawater collected using beach wells is often of better quality in terms of solids, silt, oil and grease, natural organic contamination and aquatic microorganisms, compared to open seawater intakes. Sometimes, beach intakes may also yield source water of lower salinity.

High pressure pump

The high pressure pump supplies the pressure needed to push water through the membrane, even as the membrane rejects the passage of salt through it. Typical pressures for brackish water range from 225 to 376 psi (15.5 to 26 bar, or 1.6 to 2.6 MPa). In the case of seawater, they range from 800 to 1,180 psi (55 to 81.5 bar or 6 to 8 MPa). This requires a large amount of energy. Where energy recovery is used, part of the high pressure pump's work is done by the energy recovery device, reducing the system energy inputs.

Membrane assembly

The membrane assembly consists of a pressure vessel with a membrane that allows feedwater to be pressed against it. The membrane must be strong enough to withstand whatever pressure is applied against it. Reverse osmosis membranes are made in a variety of configurations, with the two most common configurations being spiral-wound and hollow-fiber.

The layers of a membrane

Only a part of the saline feed water pumped into the membrane assembly passes through the membrane with the salt removed. The remaining "concentrate" flow passes along the saline side of the membrane to flush away the concentrated salt solution. The percentage of desalinated water produced versus the saline water feed flow is known as the "recovery ratio". This varies with the salinity of the feed water and the system design parameters: typically 20% for small seawater systems, 40% – 50% for larger seawater systems, and 80% – 85% for brackish water. The concentrate flow is at typically only 3 bar / 50 psi less than the feed pressure, and thus still carries much of the high pressure pump input energy.

The desalinated water purity is a function of the feed water salinity, membrane selection and recovery ratio. To achieve higher purity a second pass can be added which generally requires re-pumping. Purity expressed as total dissolved solids typically varies from 100 to 400 parts per million (ppm or milligram/litre)on a seawater feed. A level of 500 ppm is generally accepted as the upper limit for drinking water, while the US Food and Drug Administration classifies mineral water as water containing at least 250 ppm.

Energy recovery

Energy recovery can reduce energy consumption by 50% or more. Much of the high pressure pump input energy can be recovered from the concentrate flow, and the increasing efficiency of energy recovery devices has greatly reduced the energy needs of reverse osmosis desalination. Devices used, in order of invention, are:

- Turbine or Pelton wheel: a water turbine driven by the concentrate flow, connected to the high pressure pump drive shaft to provide part of its input power. Positive displacement axial piston motors have also been used in place of turbines on smaller systems.
- Turbocharger: a water turbine driven by the concentrate flow, directly connected to a centrifugal pump which boosts the high pressure pump output pressure, reducing the pressure needed from the high pressure pump and thereby its energy input, similar in construction principle to car engine turbochargers.
- Pressure exchanger: using the pressurized concentrate flow, in direct contact or via a piston, to pressurize part of the membrane feed flow to near concentrate flow pressure. A boost pump then raises this pressure by typically 3 bar / 50 psi to the membrane feed pressure. This reduces flow needed from the

high-pressure pump by an amount equal to the concentrate flow, typically 60%, and thereby its energy input. These are widely used on larger low-energy systems. They are capable of 3 kWh/m^3 or less energy consumption.

- Energy recovery pump: a reciprocating piston pump having the pressurized concentrate flow applied to one side of each piston to help drive the membrane feed flow from the opposite side. These are the simplest energy recovery devices to apply, combining the high pressure pump and energy recovery in a single self-regulating unit. These are widely used on smaller low-energy systems. They are capable of 3 kWh/m^3 or less energy consumption.

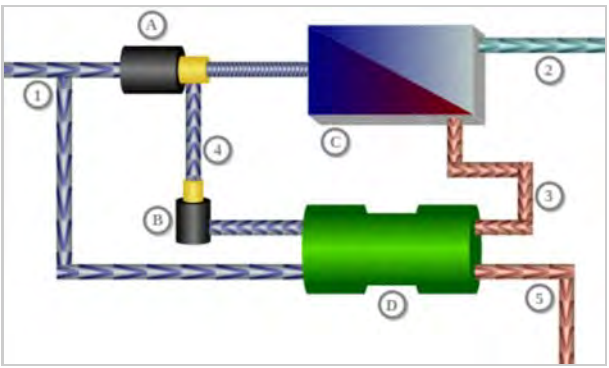

Schematics of a reverse osmosis desalination system using a pressure exchanger.
1: Sea water inflow,
2: Fresh water flow (40%),
3: Concentrate flow (60%),
4: Sea water flow (60%),
5: Concentrate (drain),
A: Pump flow (40%),
B*: Circulation pump,*
C*: Osmosis unit with membrane,*
D*: Pressure exchanger*

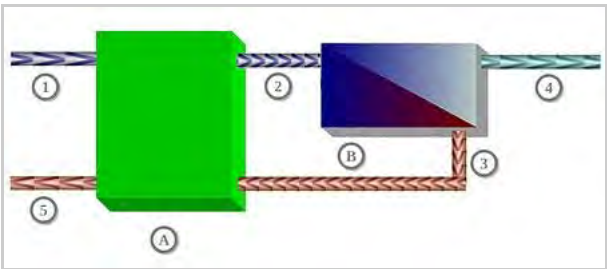

Schematic of a reverse osmosis desalination system using an energy recovery pump.
1: Sea water inflow (100%, 1 bar),
2: Sea water flow (100%, 50 bar),
3: Concentrate flow (60%, 48 bar),
4: Fresh water flow (40%, 1 bar),
5: Concentrate to drain (60%,1 bar),
A: Pressure recovery pump,
B*: Osmosis unit with membrane*

Remineralisation and pH adjustment

The desalinated water is "stabilized" to protect downstream pipelines and storage, usually by adding lime or caustic soda to prevent corrosion of concrete-lined surfaces. Liming material is used to adjust pH between 6.8 and 8.1 to meet the potable water specifications, primarily for effective disinfection and for corrosion control. Remineralisation may be needed to replace minerals removed from the water by desalination. Although this process has proved to be costly and not very convenient if it is intended to meet mineral demand by humans and plants. The very same mineral demand that freshwater sources provided previously. For instance water from Israel's national water carrier typically contains dissolved magnesium levels of 20 to 25 mg/liter, while water from the Ashkelon plant has no magnesium. After farmers used this water, magnesium deficiency symptoms appeared in crops, including tomatoes, basil, and flowers, and had to be remedied by fertilization. Current Israeli drinking water standards set a minimum calcium level of 20 mg/liter. The postdesalination treatment in the Ashkelon plant uses sulfuric acid to dissolve calcite (limestone), resulting in calcium concentration of 40 to 46 mg/liter. This is still lower than the 45 to 60 mg/liter found in typical Israeli freshwaters.[20]

Disinfection

Post-treatment consists of preparing the water for distribution after filtration. Reverse osmosis is an effective barrier to pathogens, but post-treatment provides secondary protection against compromised membranes and downstream problems. Disinfection by means of ultra violet (UV) lamps (sometimes called germicidal or

bactericidal) may be employed to sterilize pathogens which bypassed the reverse osmosis process. Chlorination or chloramination (chlorine and ammonia) protects against pathogens which may have lodged in the distribution system downstream, such as from new construction, backwash, compromised pipes, etc.[21]

Disadvantages

Household reverse osmosis units use a lot of water because they have low back pressure. As a result, they recover only 5 to 15% of the water entering the system. The remainder is discharged as waste water. Because waste water carries with it the rejected contaminants, methods to recover this water are not practical for household systems. Wastewater is typically connected to the house drains and will add to the load on the household septic system. A reverse osmosis unit delivering five gallons (19 L) of treated water per day may discharge between 20 and 90 gallons (75–340 L) of waste water per day.[22]

Large-scale industrial/municipal systems recover typically 75% to 80% of the feed water, or as high as 90%, because they can generate the high pressure needed for higher recovery reverse osmosis filtration. On the other hand, as recovery of wastewater increases in commercial operations, effective contaminant removal rates tend to become reduced, as evidenced by product water total dissolved solids levels.

Due to its fine membrane construction, reverse osmosis not only removes harmful contaminants present in the water, but it also may remove many of the desirable minerals from the water. A number of peer-reviewed studies have looked at the long-term health effects of drinking demineralized water.[23]

Waste stream considerations

Depending upon the desired product, either the solvent or solute stream of reverse osmosis will be waste. For food concentration applications, the concentrated solute stream is the product and the solvent stream is waste. For water treatment applications, the solvent stream is purified water and the solute stream is concentrated waste.[24] The solvent waste stream from food processing may be used as reclaimed water, but there may be fewer options for disposal of a concentrated waste solute stream. Ships may use marine dumping and coastal desalination plants typically use marine outfalls. Landlocked reverse osmosis plants may require evaporation ponds or injection wells to avoid polluting groundwater or surface runoff.[25]

New developments

Since the 1970s, prefiltration of high-fouling waters with another larger-pore membrane, with less hydraulic energy requirement, has been evaluated and sometimes used. However, this means that the water passes through two membranes and is often repressurized, which requires more energy to be put into the system, and thus increases the cost.

Other recent developmental work has focused on integrating reverse osmosis with electrodialysis to improve recovery of valuable deionized products, or to minimize the volume of concentrate requiring discharge or disposal.

In the production of drinking water, the latest developments include nanoscale and graphene membranes.[26]

The world's largest RO desalination plant was built in Sorek, Israel in 2013. It has an output of 624,000 m^3/day.[27] It is also the cheapest and will sell water to the authorities for US$0.58/$m^3$.[28]

See also

- Electrodeionization
- ERDLator
- Forward osmosis
- Microfiltration
- Reverse osmosis plant
- Silt density index
- Salinity gradient
- Milli-Q water
- Water pollution
- Water quality

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Review of applications of gases from biomass gasification

H. Boerrigter

R. Rauch[*)]

[*)] *Vienna, University of Technology, Institute of Chemical Engineering*

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The main body of this report was previously published as Chapter 10 (pp. 211-230), titled: "*Syngas production and utilisation*" in the *Handbook Biomass Gasification*, edited by H.A.M. Knoef and published by the Biomass Technology Group (BTG), The Netherlands in 2005.

In addition to the Handbook version, some sections have been included on gasification processes to make underlying report independently readable. Furthermore, the discussion on the utilisation of the different gases is more elaborated.

Abstract

Biomass will play an important role in the future global energy infrastructure for the generation of power and heat, but also for the production of chemicals and fuels. The dominant biomass conversion technology will be gasification, as the gases from biomass gasification are intermediates in the high-efficient power production or the synthesis from chemicals and fuels. In the discussion on the utilisation of gases from biomass gasification it is important to understand that the composition of the gasification gas is very dependent on the type of gasification process and especially the gasification temperature. In this report the two main types of gasification gas and their typical applications and specifications were discussed, *i.e.* **biosyngas** and **product gas**.

Keywords

Biomass, gasification, syngas, biosyngas, product gas, gas markets, gas cleaning, gas conditioning, synthetic natural gas (SNG), Fischer-Tropsch (FT), methanol, hydrogen, ammonia, power.

Contact

For more information, please contact:
Dr. Ir. Harold Boerrigter
Energy research Centre of the Netherlands (ECN)
ECN Biomass, Coal & Environmental research
P.O. Box 1
1755 ZG Petten
The Netherlands
Phone: +31-224-564591
Fax: +31-224-568487
Email: boerrigter@ecn.nl
Web: www.ecn.nl/biomass *(non-confidential ECN reports can be downloaded from this site)*

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Summary

At present, syngas is mainly produced from fossil fuels, with the main applications being the production of ammonia, hydrogen for refineries, methanol, Fischer-Tropsch products, and electricity. In the view of decreasing reserves of fossil fuels and also because of the aim of the EC to reduce the dependency from imported fossil fuels, there is a growing interest in producing syngas from the renewable source biomass, *i.e.* "biosyngas". Biomass will play an important role in the future global energy infrastructure for the generation of power and heat, but mainly for the production of chemicals and fuels. The predicted 2004 world biosyngas market is approx. 10% of the total energy consumption, with main application for biomass-to-liquid processes.

The dominant biomass conversion technology will be gasification, as the gases from biomass gasification are intermediates in the high-efficient power production or the synthesis from chemicals and fuels. Oxygen-blown or indirect gasification is required to produce a gas with low inert content (*e.g.* nitrogen).

In the utilisation of gases from biomass gasification it is important to understand that depending on the gasification temperature a ***biosyngas*** (>1200°C) or a ***product gas*** (<1000°C) is generated, of which the latter can be converted into biosyngas by catalytic or thermal cracking. Slagging entrained flow gasification is the most suitable technology for high temperature gasification. Product gas is preferred for utilisation for power generation and synthetic natural gas synthesis. Biosyngas is the feedstock for the more advanced applications like Fischer-Tropsch synthesis, ammonia and hydrogen production, and in processes like olefin hydroformylation and mixed alcohol synthesis.

The removal of inorganic impurities that are catalyst poisons (*e.g.* Na, K, P, S, and Cl) is the main challenge is gas cleaning of biosyngas, however, the existing natural gas based processes offer potential solutions. The same applies for application of the gas conditioning processes (*i.e.* water-gas-shift and CO_2 removal).

1 Introduction

1.1 Biomass

Biomass is a general term to describe all organic carbon-containing material produced by photosynthesis in plants. Biomass is available in many forms, comprising products as well as residues from agriculture, forestry, and the agro-industry. Although biomass is the oldest energy source known to mankind, its current contribution to the primary energy consumption in the Western world is small. Biomass was gradually substituted after the discovery of huge amounts of cheap fossil fuels. Coal, crude oil, and natural gas were not only cheaper, but also more convenient to use. Furthermore, the 'new' fuels allowed applications that were not possible with biomass: liquid transportation fuels from crude oil and gas for cooking. Biomass appeared to have no future as energy source.

The insight that the fossil fuel reserves are limited, together with concerns over security of supply (*i.e.* the oil crises), initiated the first upraise of interest in biomass (and all other renewable energy forms) in the 1970s. However, continuously low fossil energy prices and the discovery of new fossil fuel reserves impeded the development of biomass technologies. In the 1980s the concern grew that global warming and the resulting climate change were enhanced (if not caused) by CO_2 emissions resulting from fossil fuel consumption. This concern resulted in the Kyoto protocol in which objectives to reduce the anthropogenic CO_2 emissions are documented. To achieve the Kyoto objectives, the share of renewable energy in the primary energy consumption has to increase significantly. The interest in biomass was renewed, as biomass is considered to be one of the most important renewable energy sources for this century [1,2].

1.2 Energy, fuels, and products from biomass

By definition, biomass is a renewable material, as during growth of the plants, crops, and trees, CO_2 is withdrawn from the atmosphere (the carbon source) and stored in the biomass as chemical energy. The CO_2 cycle is closed again when the CO_2 is released during conversion of the biomass and the use of derived products. The renewable and CO_2-neutral nature of biomass is the major motivation to use the material for the energy generation (*e.g.* green electricity and heat).

The same consideration applies for the use of biomass for the production of fuels and products. To date, nearly all transportation fuels and most materials and chemicals are produced from crude oil or natural gas. At a certain moment in the future, the decreasing reserves of these fossil materials will give rise to increasing prices. Therefore, an additional motivation is that to maintain the same production levels, an alternative carbon source is required and biomass is the only carbon source that is renewable. Biomass will be the future feedstock for the production of transportation fuels and chemicals.

1.3 Gases from biomass gasification

Gasification is the key conversion technology in all processes for the production of energy, fuels, and/or products from biomass. In electricity production biomass is thermally converted by gasification into a combustible gas that can be used in a gas engine or turbine with electricity as well as heat as products. The advantage of the gasification route is the higher overall electric efficiency compared to the alternative of direct biomass combustion. In the production of fuels

and chemicals the combustible gasification gas is used in a catalytic process to synthesise the desired product.

In the discussion on the utilisation of gases from biomass gasification it is important to understand that gas specifications are different for the various gas applications. Furthermore, the composition of the gasification gas is very dependent on the type of gasification process, gasification agent and the gasification temperature. Based on the general composition and the typical applications, two main types of gasification gas can be distinguished, *i.e.* 'biosyngas' and 'product gas' (Figure 1):

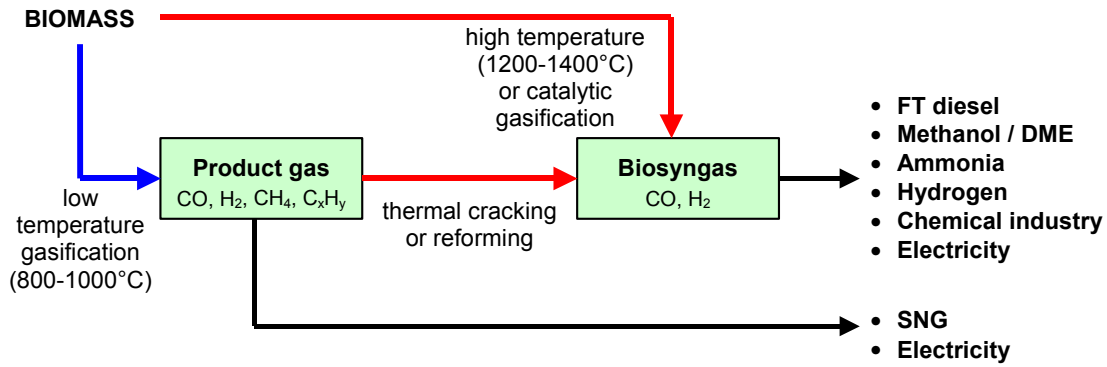

***Figure 1**. Difference between 'biosyngas' and 'product gas' and their typical applications.*

- **Product gas**; produced by low temperature gasification (below 1000°C) and containing CO, H_2, CH_4, C_xH_y aliphatic hydrocarbons, benzene, toluene, and tars (besides CO_2 and H_2O). The syngas components H_2 and CO typically contain only ~50% of the energy in the gas, while the remainder is contained in CH_4 and higher (aromatic) hydrocarbons.
- **Biosyngas**; produced by high temperature (above 1200°C) or catalytic gasification. Under these conditions the biomass is completely converted into H_2 and CO (besides CO_2 and H_2O). Biosyngas is chemically similar to syngas derived from fossil sources and can replace its fossil equivalent in all applications. Biosyngas can also be made from product gas by heating the thermal cracking or catalytic reforming.

Both gases need additional gas cleaning and conditioning to afford a gas with the correct composition and specifications for the final application, *e.g.* synthesis. In this report the major utilisations of both types of gases will be assessed, *i.e.* product gas and biosyngas. However, the focus will be on biosyngas applications, as biosyngas utilisation is expected to be dominant on the long term. Whereas for electricity production other renewable options exist (*i.e.* solar PV and wind turbines), biomass is the only renewable carbon-source.

2 Gas Markets

2.1 Product gas

The major application of product gas will be the direct use for the generation of power (and heat). This can be either in stand-alone combined heat and power (CHP) plants or by co-firing of the product gas in large-scale power plants. The installed power production capacity in the EU-25 countries is approx. 700 GWe (2004) [3], which is expected to increase to 1040 GWe in 2020 (based on an assumed growth rate of the power consumption of 2% per year). A target can be set to implement 10% of the growth of power production in the period between 2000 and 2020 with biomass-gasification plants, i.e. 34 GWe or 1,000 PJ. The second major application of product gas is the production of synthetic natural gas (SNG). The volume of the European market for SNG is more difficult to predict.

2.2 Biosyngas

Syngas is a versatile building block in chemical industry [4,5]. The total global annual use of fossil-derived syngas is approximately 6,000 PJ_{th}, which corresponds to 2% of the total primary energy consumption. The largest part of the syngas is used for the synthesis of ammonia for fertiliser production (~55%), the second largest share is the amount of hydrogen from syngas consumed in oil refining processes (~24%), and smaller amounts are used for methanol production (12%). Figure 2 shows the present syngas market distribution [6]. Today's, global use of syngas for the production of transportation fuels in the so-called "gas-to-liquids" processes (GTL) correspond to approx. 500 PJ per year, *i.e.* from the Fischer-Tropsch processes of Sasol in South Africa and of Shell in Bintulu, Malaysia.

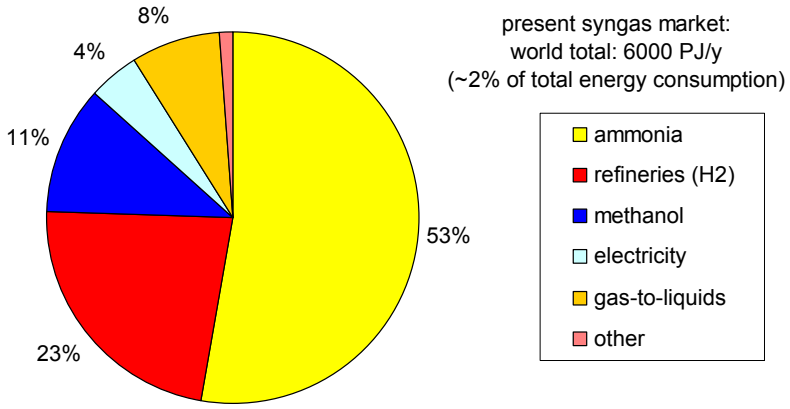

***Figure 2**. Present world syngas market.*

In the future, syngas will become increasingly important for the production of cleaner fuels to comply with the stringent emission standards, *e.g.* methanol/DME, ethanol, and/or Fischer-Tropsch diesel. Also the future bio-fuels will be ultra-clean designer fuels from GTL processes; transportation fuels directly produced from biomass (*e.g.* biodiesel, pyrolysis oils are expected to have only very limited application, as was the conclusion from the Wolfsburg (Germany) *Congress on Synthetic Biofuels - Technologies, Potentials, Prospect*s that was held from 3-4 November 2004.

The huge potential market for syngas is illustrated by the fact that approximately 30% of the world primary energy consumption is for the transportation fuels and chemicals [7]. With biomass being the only sustainable carbon-containing source, it is expected that biosyngas will be the key-intermediate in the future production of renewable fuels and chemicals. When an average of 30% substitution of fossil fuels by biosyngas is assumed, based on extrapolation of current EU Directives, and this is translated to the world energy consumption, the total annual syngas market will be increased to approx. 50,000 PJ in 2040. The world (bio) syngas market will then look as shown in Figure 3 (assuming no changes for the other applications). The major share of the syngas will be used for production of fuels (biomass-to-liquids; BTL) and another major part for the production of renewable chemicals (biomass-to-chemicals) [6].

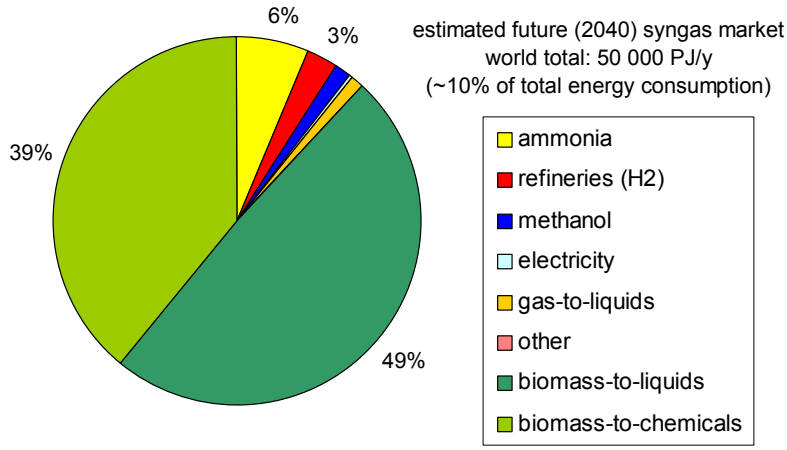

***Figure 3**. Predicted world syngas market in 2040.*

The future biosyngas demand exceeds the present syngas consumption by a factor of eight. Therefore, it is clear that large biosyngas production capacities are needed to meet the European and national renewable energy and CO_2-emission reduction targets. Not only are large installed capacities necessary, also the individual plants, compared to typical biomass plants, have to be large considering the typical plant scales for the two main applications, *i.e.*:

- Transportation fuels in BTL plants: few 100 MW to several 1,000 MW;
- Chemical sector: 50-200 MW.

Syngas demands for liquid fuel synthesis will typically be >1,000 MW for plants, where the whole chain from biomass to the final product is realised (to benefit from economy of scale, which is necessary to reduce costs). For illustration, the Shell GTL plant in Malaysia of 12,500 bbpd (*i.e.* ~1,000 MW) is considered as a demonstration plant, while the new plant in Qatar will have a six times higher capacity (75,000 bbpd or ~6,000 MW). Another possibility is, that there are several smaller plants in the size of ~500 MW, which produce only intermediate products, *e.g.* raw liquid products, where the final work-up is done in a central facility.

The typical syngas demands for chemical processes correspond to 50-200 MW_{th}. Even though the scale of an individual biosyngas plant may be relatively small, in most cases the plant will be part of a larger centralised chemical infrastructure with several other processes and plants to optimise energy and product integration (*i.e.* the syngas consumer). There is only a limited market for stand-alone small-scale biosyngas production for distributed chemical plants (although there will always be exceptions).

To ensure cost-effective biomass supply (*i.e.* avoid land transport) biosyngas production plants will be constructed close to ports or larger waterways. For the selection of the location the same

considerations apply as for current coal-fired power plants and their coal logistics. Also the main large concentrations of chemical industry are located on locations easy accessible from water, *e.g*. the Dutch Maasvlakte near Rotterdam and the German Ruhrgebiet.

3 Gasification processes

Gasification is the complete thermal breakdown of biomass into a combustible gas, volatiles, char, and ash in an enclosed reactor or gasifier. Gasification is a two-step, endothermic (*i.e.* heat absorbing) process. In the first reaction, pyrolysis, the volatile components of the fuel are vaporized at temperatures below 600°C by a set of complex reactions. Included in the volatile vapours are hydrocarbon gases, hydrogen, carbon monoxide, carbon dioxide, tar, and water vapour. As biomass fuels tend to have more volatile components (70-86% on a dry basis) than coal (30%), pyrolysis plays a larger role in biomass gasification than in coal gasification. Char (fixed carbon) and ash are the pyrolysis by-products, which are not vaporized. In the second step, the char is gasified through reactions with oxygen, steam, carbon monoxide and hydrogen. The heat needed for the endothermic gasification reactions is generated by combustion of part of the fuel, char, or gases, depending on the reactor technology.

Depending on the temperature of the second and actual gasification step, the process yields a biosyngas or a product gas (*cf.* Figure 1). The choice for air or oxygen as gasification medium determines whether the product gas or biosyngas contains nitrogen. There is a large number of gasification processes in development. Within the scope of this report some main types are briefly discussed with the focus on the gas generation.

3.1 Product gas production

Product gas is generated by low-temperature (<1000°C) gasification. Gasification processes can be differentiated in direct (autothermal) and indirect (or allothermal) processes. For biomass applications the direct processes are typically operated with air as gasification medium. The main direct and indirect processes are:

- Fixed-bed updraft;
- Fixed-bed downdraft;
- Fluidised bed (bubbling and circulating, *i.e.* BFB and CFB); and
- Indirect fluidised bed (steam-blown).

In most biomass applications the gasifiers are operated with air as gasification medium affording a product gas diluted with nitrogen. For the more advanced applications, a nitrogen-free product gas is required (*cf.* Chapter 6). A nitrogen-free product gas can be produced by oxygen-blown gasification or alternative by indirect processes. The indirect gasification process is very attractive for N_2-free product gas generation as no oxygen is required for the gasification. Furthermore, the conversion is generally complete, whereas, direct gasification processes afford carbon-containing ashes due to incomplete conversion (*i.e.* typically 90-95%). Indirect processes can be divided into two groups:

- Transport of heat by inert material
- Transport of heat by heat exchangers

Examples of indirect gasification processes, where the heat is transported by inert material, are the Fast Internal Circulation Fluidised Bed (FICFB) process developed by the Vienna University of Technology (TUV) [8], the SilvaGas process based on the Batelle development [9], and the MILENA gasifier developed at the Energy research Centre of the Netherlands (ECN) [10]. Typical gas compositions for these three processes are summarised in Table 1

***Table 1**. Typical gas compositions of three indirect gasification processes (wood as fuel).*

Gas component, dry basis		FICFB (Güssing)	SilvaGas	MILENA (ECN)
Hydrogen	vol%	30-45	20-22	15-20
Carbon monoxide	vol%	20-30	41-44	40-43
Carbon dioxide	vol%	15-25	11-14	10-12
Methane	vol%	8-12	12-16	15-17
C_2+ hydrocarbons	vol%	1-3	4-6	5-6
Benzene	vol%		1	1
Nitrogen	vol%	1-3	2-10	1-4
Ammonia	ppmV	500-1000		500-1000
H_2S	ppmV	50-120		40-100
Tar	g/m_n^3	0.5-1.5	40	40
Particles	g/m_n^3	10-20		~

The principle of an indirect gasifier is discussed from the FICFB concept (Figure 4). The reactor consists of two zones, a gasification zone and a combustion zone. Inert, heat carrying bed material is circulated between these two zones to transfer heat from the combustion zone to the gasification zone, while separating the flue gases in the combustion zone from the product gas produced in the gasification zone. Biomass is fed into the gasification zone and gasified with steam at 850-900°C and the thermal energy provided by the circulating solids. As a result the gas produced in this zone is nearly free of nitrogen. The bed material, together with the char left over from steam gasification, is circulated to the combustion zone. This zone is fluidised with air to burn the char and any carryover product gas.

Following the initial development of the FICFB Process in a laboratory test unit at Technical University of Vienna (TUV), a demonstration plant was erected. This plant is an 8MWth feed capacity plant situated in Güssing (Austria) with an electric output of 2 MW. The plant went into operation in autumn 2001.

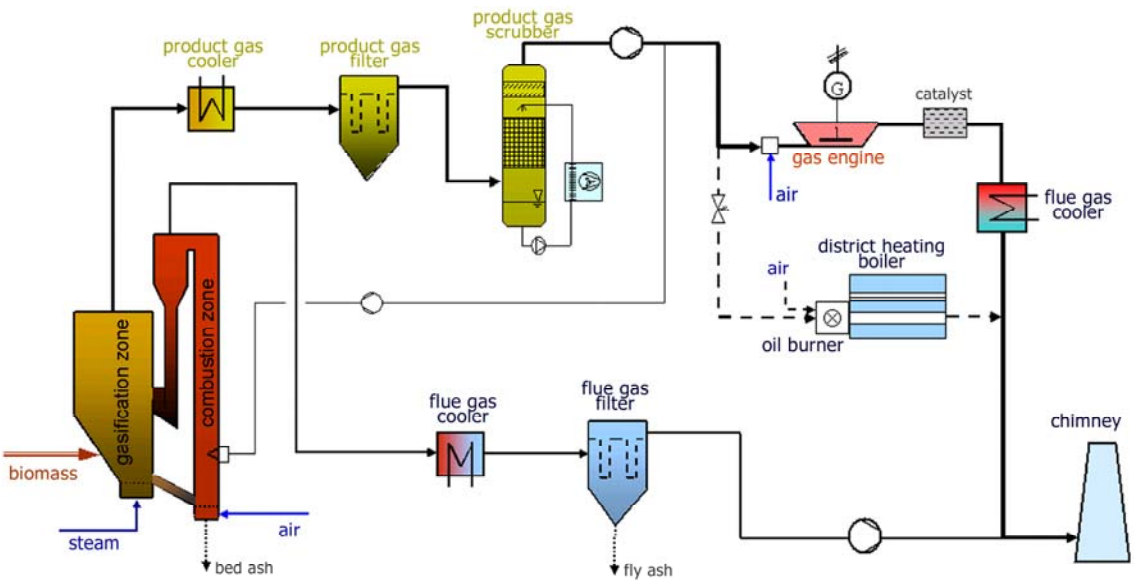

***Figure 4**. FICFB gasification process.*

3.2 Biosyngas production

Biosyngas is produced by high-temperature (>1200°C) gasification. In principal, the (oxygen-blown) downdraft and the entrained flow gasification processes are suitable for this. However, downdraft fixed-bed gasifiers are limited in scale and require a well-defined fuel, making them not fuel-flexible. Therefore, the preferred process to produce biosyngas is entrained flow gasification [11]. There are two different types of EF:

- Slagging, for ash containing feedstock (*e.g.* biomass);
- Non-slagging, for essentially ash-free feedstock.

Entrained flow (EF) gasifiers typically operate at high temperatures (1200-1500°C) at which the feed is completely converted into syngas, even at the short residence time of only a few seconds. In a slagging gasifier, the ash forming components melt in the gasifier. The molten particles condense on the relatively cold walls and ultimately form a layer being solid close to the wall and liquid on the inner side. This slag layer serves as a protective layer for the wall. The liquid slag is removed from the bottom of the gasifier. In order to generate a liquid slag with the right viscosity at the given temperature, generally so-called fluxing material must be added. For coal-fired plants, this often is limestone or another Ca-rich material. Slagging entrained flow gasifier manufacturers are Shell, Texaco, Krupp-Uhde, Future-Energy (formerly: Noell and Babcock Borsig Power), E-gas (formerly Destec and Dow), MHI (Mitsubishi Heavy Industries), Hitachi and Choren (formerly UET).

In Table 2 typical biosyngas compositions are shown that are produced by slagging EF gasification. For comparison, also product gas compositions are included from the most common type direct gasifier (*i.e.* the circulating fluidised bed gasifier). The effect of the higher gasification temperatures on the yield of the syngas components hydrogen and carbon monoxide is evident.

Table 2. *Typical biosyngas compositions of entrained flow (EF) gasification of woody biomass (7% moisture) compared to product gas compositions from a direct circulating fluidised bed (CFB) gasifier at 850°C and various conditions [12].*

Gasification process:		**CFB**	**CFB**	**CFB**	**EF**	**EF**
Pressure [bar]:		1	1	20	1	20
Gasification medium:		air	O_2/steam	O_2/steam	oxygen	oxygen
Hydrogen	vol%	14	32	19	33	27
Carbon monoxide	vol%	21	27	20	53	53
Carbon dioxide	vol%	14	29	40[a]	13	19[a]
Methane	vol%	5	8	15	0	0
C_2+ hydrocarbons	vol%	2	3	5	0	0
Benzene (*i.e.* C_6H_y)	vol%	0.4	1	1	0	0
Nitrogen	vol%	44	0	0	0	0
Tar (wet gas)	g/m_n^3	8	8	11	0	0
H_2O	$vol\%_{wet}$	11	28	30	19	22
LHV (dry gas)	MJ/m_n^3	7.7	12.4	14.9	10.3	9.6

a. In pressurised gasification carbon dioxide is used for inertisation of the feed to prevent nitrogen dilution of the gas.

In most cases, EF gasifiers are operated under pressure (typically 20-50 bar) and with pure oxygen and with capacities in the order of several hundreds of MW_{th}. Biosyngas production based on slagging entrained flow gasification has the following technical advantages [11]:

- **Large-scale high-efficiency biosyngas production**. Several commercial EF gasifiers exist and have proven availability at large-scale (700 MW_{th}). EF gasifiers are operated at sufficient high temperatures (1200-1500°C) to ensure complete conversion of the biomass is completely (>99.5% carbon conversion) and has a high biomass-to-biosyngas efficiency.
- **Fuel-flexibility**. The slagging entrained-flow gasifier can convert all type biomass materials and the fuel-flexibility is extended as well to the fossil fuels coal and oil residues. EF is suitable for wood, alkaline rich biomass like straw and grasses, high ash streams like sludges and manure, wastes like RDF and plastics, as well as the back-up option to use coal.
- **Simple gas cleaning**. Due to the high temperature in the gasifier, the biosyngas is absolutely free of organic impurities (*i.e.* tars) and can easily be cleaned from small traces of inorganic impurities with conventional proven technologies.
- **Minimum waste & mineral recycling**. The minerals from the biomass are recovered in the slag and the fly ash. The slag can be used as construction material; this in contrast to other (low temperature gasification) processes that yield a carbon-containing ash that has to be disposed of as chemical waste. The carbon-free fly ash can be used for mineral recycling and fertilisation of biomass production areas.

One example of a large-scale entrained flow gasifier is the 600 MW_{th} coal-fired Shell gasifier in Buggenum, the Netherlands [13]. It is owned by the utility company NUON and produces electricity with a net efficiency of 43%. Tests have been performed with different kinds of biomass like wood, sewage sludge and chicken manure up to approximately 10% on energy basis (corresponding to 18% on weight basis). It is planned to co-fire 25% biomass on energy basis in 2005 [14]. Shell has signed several contracts to make similar coal gasifiers for fertilizer industries in China. Another example is a 130 MW_{th} gasifier (25 bar) made by Future Energy, operating on waste oil and sludges on the premises of the Schwarze Pumpe in Germany [15]. As example, Figure 5 shows the Future Energy gasifier.

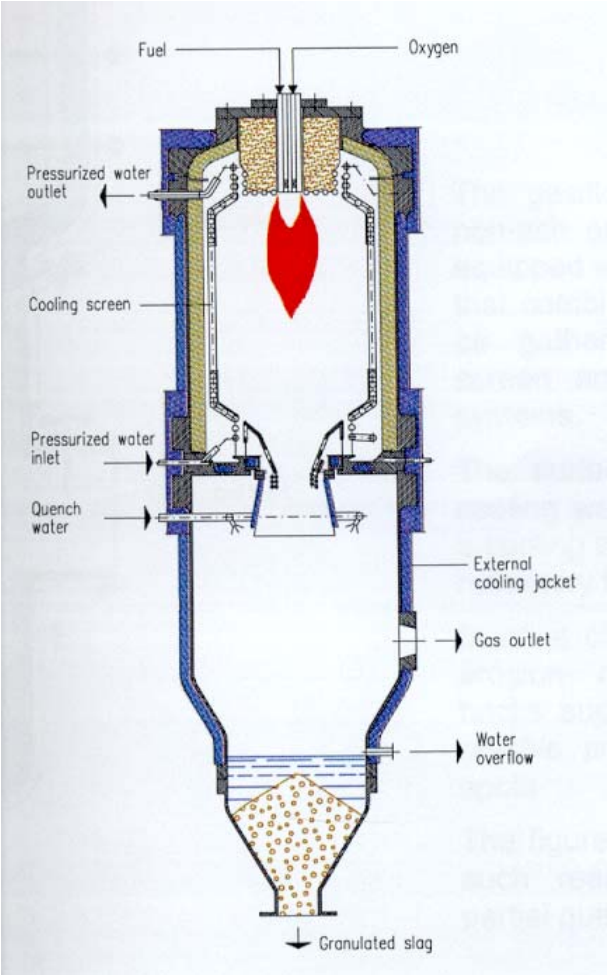

Figure 5. *Schematic representation of the entrained flow reactor of Future Energy [15].*

4 Utilisation of Product gas

The main application at presence of product gas from gasification is found in direct or indirect combustion to generate power with co-production of heat. Due to the typical complex composition of product gases (*cf.* Table 1), more advanced applications are not first choice, as the syngas components H_2 and CO represent only approx. 50% of the energetic value of a product gas. The only exception is the production of synthetic natural gas (SNG), as in that case the presence of (as much as possible) CH_4 is beneficial to achieve high overall yields (see Section 4.2). Therefore, in the context of SNG production, product gas is sometimes referred to as "methane-rich synthesis gas".

4.1 Power generation

4.1.1 Co-firing

The most straightforward application of product gas is co-firing in existing coal power plants by injecting the product gas in the combustion zone of the coal boiler. Co-firing percentages up to 10% (on energy basis) are feasible without the need for substantial modifications of the coal boiler. Critical issue in co-firing is the impact of the biomass ash on the quality of the boiler fly and bottom ash. The application of the fly and bottom ash in construction and cement production often sets the specifications for the amount and type of biomass that can be co-fired. Examples of biomass co-firing plants are the AMER 85 MW_{th} circulating fluidised bed (CFB) gasifier in the Essent power plant in Geertruidenberg (the Netherlands) and the Foster Wheeler CFB gasifiers in Lahti (Finland) and Ruien (Electrabel power plant, Belgium).

4.1.2 Combined heat and power (CHP)

In combined heat and power (CHP) plants the product gas is fired on a gas engine. Modified gas engines can run without problems on most product gases even those from air-blown gasification that have calorific values of approx. 5-6 MJ/m_n^3. Typically, the energetic output is one-third electricity and two-third heat. The main technical challenge in the implementation of integrated biomass gasification CHP plants has been, and still is, the removal of "tar" from the product gas. Regarding the presence of tar in product gas, it may be stated that "tar" is equivalent to a major economic penalty in biomass gasification. Tar aerosols and deposits lead to more frequent maintenance and repair of especially gas cleaning equipment and resultantly lower plant capacity factors. This leads to a decrease of revenues or to higher investments, as some equipment will be installed in duplicate to overcome standstills. Furthermore, removal of tar components from the process wastewater requires considerable investments that can even be dramatic as some tar components show poisoning behaviour in biologic wastewater treatment systems (*e.g.* phenol) [16]. The few technological successful biomass gasification plants, *e.g.* the plants in Güssing (Austria; see also Section 3.1 and Figure 4) [17] and Harboøre (Denmark) [18], have in common that they result from long development trajectories and that the technologies are neither simple nor cheap.

4.1.3 Integrated gasification combined cycle (IGCC)

In practice, the scale of integrated biomass gasification CHP plants will be limited by the local heat demand (*i.e.* up to approx. 20 MW_{th}). For electricity production on larger scales, integrated gasification combined cycles (IGCC) are preferred in which the gas is fired on a gas turbine. As a gas turbine requires a pressurised feed gas the biomass gasification should be carried out at the

pressure of the turbine (typically 5-20 bar) or the atmospherically generated product gas must be pressurised. The first route is preferred as in that case only dedusting of the gas and cooling to the turbine inlet temperature (400-500°C) is required, whereas in the alternative route the product gas must be completely cleaned and cooled down to allow compression. The first route has been demonstrated in the Värnamo (Sweden) plant, *i.e.* an 8 MW_{th} pressurised air-blown circulating fluidised bed biomass gasifier [19]. However, in general the operational costs related to the inert gas consumption and electricity consumption for pressurisation of the inert gas for solids feeding and the gasification air are a major drawback for pressurised gasification.

4.1.4 Fuel cells

The application of product gas in fuel cells for the production of electricity is still in its early development. In theory, fuel cells have the potential to achieve higher electrical efficiencies compared to simple combustion systems and gas engines [20]. However, in practice this is only relevant on small-scale where combustion/steam-cycles suffer from relatively high losses. A combination that is often mentioned for its extremely high electric efficiency, is the fuel cell downstream a gasifier functioning as the combustion chamber for a (micro) gas turbine. This implies that the fuel cell must operate under pressure. In a simpler system, the fuel cell can be connected to a gasifier to both have a high electric efficiency and a high overall efficiency in a CHP (combined heat and power) system.

A fuel cell burns H_2 and produces electricity directly through electrochemical reactions. Depending on the type of fuel cell, also CO, CH_4 and other fuels can be converted. An SOFC can handle all these molecules and therefore is generally considered a good match with product gases from low temperature biomass gasification. Furthermore, methane (and other hydrocarbons) in *product gas* can increase the performance of an SOFC because it is reformed into H_2 in the anode of the fuel cell. Since reforming is an endothermal reaction, it provides effective cooling of the fuel cell, which should otherwise be done in a way that generally increases complexity and costs and decreases overall efficiency.

4.2 Synthetic Natural Gas (SNG)

Whereas high-temperature gasification processes yield *biosyngases* with high concentrations of carbon monoxide and little methane, interest in Synthetic Natural Gas (SNG) production is concentrated on gasification processes that yield *product gases* with high methane contents. SNG is a gas with similar properties as natural gas but produced by methanation of H_2 and CO in gasification product gas. Methanation is the catalytic reaction of carbon monoxide and/or carbon dioxide with hydrogen, forming methane and water:

$$CO + 3H_2 \Rightarrow CH_4 + H_2O \qquad (1)$$

Consecutive and side reactions (shift conversion, Boudouard equilibrium, hydrogenation of carbon) make the calculation of equilibrium conditions very complex. The methanation reactions of both carbon monoxide and carbon dioxide are highly exothermic. Such high heat releases strongly affect the process design of the methanation plant since it is necessary to prevent excessively high temperatures in order to avoid catalyst deactivation and carbon deposition. The highly exothermic reaction generally creates a problem for the design of methane synthesis plants: either the temperature increase must be limited by recycling of reacted gas or steam dilution, or special techniques such as isothermal reactors or fluidised beds, each with indirect cooling by evaporating water, must be used.

The methanation process is a very well known and technically important as a catalytic purification step for the removal of trace carbon monoxide (typically below a few vol%) from process gases, especially for hydrogen production. Methanation of gases with a high CO

content, like gasification product gas is not well established and there are no commercial catalysts available (*i.e*. the Dakota coal-to-SNG plant uses a non-commercial catalyst).

For the removal of carbon monoxide from synthesis gases, catalysts with usually <15 wt% nickel are used predominantly. For SNG production, catalysts with high nickel content are preferred, similar to those used in reforming naphtha to a methane-rich gas. Catalysts based on ruthenium have been tried repeatedly for methanation but have not found the broad application of nickel-based catalysts. Catalytic activity is affected seriously even by very low concentrations of catalyst poisons in gases to be reformed. Such catalyst poisons are sulphur, arsenic, copper, vanadium, lead, and chlorine or halogens in general. Precaution must be taken with nickel-containing catalysts to prevent formation of highly poisonous nickel carbonyl [$Ni(CO)_4$]. In practical operation of methanation plants, temperatures below 200°C at the nickel catalyst must be avoided.

5 Utilisation of Biosyngas

5.1 Power generation

Biosyngas is a combustible gas and can be used for the production of electricity in all prime movers from steam cycles, to gas engines, turbines (combined cycle), as well as fuel cells. Based on energetic considerations, however, this is not an attractive utilisation of the syngas. It is more sensible to use ***product gas*** instead of ***biosyngas*** for power production. This originates in the lower net energetic efficiency of biosyngas compared to product gas production due to the higher gasification temperature and electricity consumption for oxygen production. Therefore, a general statement can be made that for gas utilisations, in which both biosyngas and product gas can be applied the latter is preferred.

A motivation, however, to operate a gas turbine with a combined cycle on biosyngas would be the possibility to use large-scale technologies that are available from coal gasification. In this way it is possible to reach relatively large-scale implementation of biomass-based electricity production without the requirement to go through the complete development of the existing small-scale biomass gasification technologies. For example, in the Buggenum (the Netherlands) 253 MW_e coal-fired entrained flow IGCC already today up to 18 wt% biomass is co-fired. The basic technology is also suitable for dedicated biomass firing. By converting a coal plant into a biomass plant on relatively short term a large green electricity production capacity can be realised. Considering the ambitious green energy targets of the EU and national governments, the possibility for short term implementation may be more important today than smaller production capacities but with higher energetic efficiencies [21].

5.2 Transportation fuels

In the future, biosyngas will become increasingly important for the production of ultra-clean designer fuels from GTL processes, with the main examples being Fischer-Tropsch diesel and methanol/DME.

5.2.1 Fischer-Tropsch synthesis

In the non-selective catalytic Fischer-Tropsch (FT) synthesis one mole of CO reacts with two moles of H_2 to form mainly paraffin straight-chain hydrocarbons (C_xH_{2x}) with minor amounts of branched and unsaturated hydrocarbons (*i.e.* 2-methyl paraffins and α-olefins), and primary alcohols. Undesirable side reactions include methanation, the Boudouard reaction, coke deposition, oxidation of the catalyst, or carbide formation. Typical operation conditions for FT synthesis are temperatures of 200-350°C and pressures between 25 and 60 bar [22]. In the exothermic FT reaction about 20% of the chemical energy is released as heat:

$$CO + 2H_2 \Rightarrow -(CH_2)- + H_2O \qquad (2)$$

Fischer-Tropsch processes can be used to produce either a light synthetic crude oil (syncrude) and light olefins or heavy waxy hydrocarbons. The syncrude can be refined to a high quality sulphur and aromatic liquid product and specialty waxes or, if hydrocracked and/or isomerised, to produce excellent diesel fuel, lube oils, and naphtha, which is an ideal feedstock for cracking to olefins. For direct production of gasoline and light olefins, the FT process is operated at high temperature (330–350°C), for production of waxes and/or diesel fuel, at low temperatures (220–250°C), *cf.* Table 3.

Table 3. Process conditions for Fischer–Tropsch synthesis.

Parameter	Low-temperature FT	High-temperature FT
Products	Waxes and/or diesel fuels	Gasoline, light olefins
Temperature [°C]	220 - 250	330 - 350
Pressure [bar]	25 - 60	25
$CO + H_2$ conversion [%]	60 - 93	85

Several types of catalysts can be used for the Fischer-Tropsch synthesis - the most important are based on iron (Fe) or cobalt (Co). Cobalt catalysts have the advantage of a higher conversion rate and a longer life (over five years). The Co catalysts are in general more reactive for hydrogenation and produce therefore less unsaturated hydrocarbons (olefins) and alcohols compared to iron catalysts. Iron catalysts have a higher tolerance for sulphur, are cheaper, and produce more olefin products and alcohols. The lifetime of the Fe catalysts is short and in commercial installations generally limited to eight weeks [23].

Catalysts for Fischer-Tropsch synthesis can be damaged with impurities as NH_3, HCN, H_2S, and COS. These impurities poison the catalysts. HCl causes corrosion of catalysts. Alkaline metals are deposited on the catalyst. Tars are deposited, cause poisoning of catalyst and contaminate the products. And particles (dust, soot, ash) cause fouling of the reactor. The removal limit is based on an economic optimum determined by catalyst stand-time and investment in gas cleaning. But generally, all these impurities should be removed to a concentration below 1 ppmV [24].

5.2.2 Methanol

Methanol can be produced by means of the catalytic reaction of carbon monoxide and some carbon dioxide with hydrogen. The presence of a certain amount of carbon dioxide in the percentage range is necessary to optimise the reaction. Both reactions are exothermic and proceed with volume contraction; a low temperature and high pressure consequently favours them [25]:

$$CO + 2H_2 \Rightarrow CH_3OH \tag{3}$$

$$CO_2 + 3H_2 \Rightarrow CH_3OH + H_2O \tag{4}$$

Side reactions, also strongly exothermic, can lead to formation of by-products such as methane, higher alcohols, or dimethyl ether (DME). The oldest process for the industrial production of methanol is the dry distillation of wood. Methanol is currently produced on an industrial scale exclusively by catalytic conversion of synthesis gas. Processes are classified according to the pressure used:

1. High-pressure process: 250-300 bar;
2. Medium-pressure process: 100-250 bar;
3. Low-pressure process: 50–100 bar.

Both high- and low-pressure processes are available to hydrogenate carbon monoxide. The high-pressure method was commercialised by BASF. These processes used zinc-chromium oxide catalysts at or above 340°C and required a pressure of 300-500 bar to obtain methanol concentrations of about 5-6 vol% in the effluent gases from the reactor, together with significant amounts of methane, dimethyl ether (DME), ethanol, and higher alcohols. In 1966 ICI introduced a low-pressure methanol synthesis that used a copper-zinc-chromium catalyst at 50 bar. The low-pressure processes differ primarily in operating pressure, catalyst, and reactor design, especially with respect to heat recovery and temperature control. The low-pressure processes are dominant currently and their main advantages are lower investment and

production costs, improved operational reliability, and greater flexibility in the choice of plant size [25].

5.3 Chemical synthesis

5.3.1 Ammonia for fertiliser production

The major share (*i.e.* 85%) of the ammonia is used for the production of fertilisers [25], while the other 15% is used for a broad variety of applications. Each nitrogen atom in industrially produced chemicals is directly or indirectly derived from ammonia (or its derivative nitric acid), *e.g.* it is used for the production of plastics and fibres like polyurethane, polyamides, and polyacronitril. Furthermore, ammonia is used for the production of explosives and animal feed. The ammonia synthesis is a catalytic reaction carried out at pressures between 100 and 250 bar and temperatures of 350-550°C, according the reaction:

$$N_2 + 3H_2 \Rightarrow 2NH_3 \tag{5}$$

Typically, iron-based catalysts are used for the ammonia synthesis. The reaction is thermodynamically limited and the conversion per cycle is limited to approx. 20-30%. To achieve higher conversions the unconverted gas is partly circulated, while the other part is bleed to prevent accumulation of inert gases and impurities. The ammonia is recovered from the gas as a liquid by cooling and condensation. In comparison with other syngas-based processes, the ammonia synthesis has two significant characteristics. Firstly, a high concentration of the inert gas nitrogen is acceptable and even required. Secondly, the specifications for oxygen-containing gases (*e.g.* CO_2, and CO) that typically are present in syngas are very strict, *i.e.* the sum of the concentrations should be lower than 20 ppmV [25].

5.3.2 Hydroformylation of olefins

Olefins react with synthesis gas (carbon monoxide and hydrogen) in the presence of homogeneous catalysts to form aldehydes containing an additional carbon atom. This hydroformylation, also called oxo-synthesis or Roelen reaction, is a commercial-scale process for the production of aldehydes. By catalytic addition of hydrogen and carbon monoxide to an olefin an aldehyde is obtained under chain elongation:

$$R-CH=CH_2 + CO + H_2 \Rightarrow R-CH_2-CH_2-CHO + R-CH(CH_3)-CHO \tag{6}$$

Hydroformylation is generally an exothermic, homogeneously catalysed liquid-phase reaction of the olefin with hydrogen and carbon monoxide. The hydroformylation reaction is used on an industrial scale to produce aldehydes and alcohols. The most important oxo products are in the range C_3-C_{19}; with a share of roughly 75 %, butanal is by far the most significant. Propene is the olefin mostly used. The oxo-products are converted to alcohols, carboxylic acids, aldol-condensation products, and primary amines. About 20 commercial processes are state-of-the-art [25].

Up until the mid 1970s only the cobalt-based catalysts were important industrially. The situation changed when Union Carbide and Celanese, independently of one another, introduced rhodium-based catalysts on an industrial scale. Since then, cobalt catalysts for the hydroformylation of propene have been replaced in nearly all major plants by the more advantageous rhodium catalysts despite the higher price of the noble metal. The catalyst lifetime can be severely diminished by "extrinsic poisons" such as strong acids, hydrogen cyanide, sulphur, hydrogen sulphide, COS, oxygen, and dienes. The feedstock must therefore be very pure. Next to the efficiency, activity, and selectivity of the catalyst, the catalyst lifetime is the most industrially important reaction parameter.

5.3.3 Hydrogen in refineries

Syngas is one of the main sources for hydrogen used in refineries. The syngas is generally produced by steam reforming of natural gas or in some cases by gasification of heavy oil fractions ("bottom-of-the-barrel"). In refineries, hydrogen is used for the hydro-treating and hydro-processing operations. Hydro treating is used to remove impurities (desulphurisation and nitrogen) and for the hydrogenation of olefins. In each refinery several hydro-treating units are present to treat the various product fractions (*i.e.* gasoline, kerosene, diesel, and heating oil). Furthermore, the process is used to pretreat the feedstock of catalytic cracking processes. Hydro processing is used to upgrade the heavy oil fractions to lighter products that can be used for the production of transportation fuels. The specifications for hydrogen in the process industry are relatively mild, typical demands for a hydro-cracker are [25]: H_2 content ≥98 vol%, sum CO and CO_2 ≤10-50 ppmV, O_2 ≤100 ppmV, and inert gases (*i.e.* N_2, Ar, and CH_4) below 2 vol%.

5.3.4 Synthetic Natural Gas (SNG)

In Section 4.2 the production of SNG from product gas was discussed. SNG can also be produced from syngas, however, in that case the biomass to SNG yield is significantly lower, as no advantage is taken from already present amounts of methane [26].

5.3.5 Other applications

Other applications of syngas have a relatively small market or the processes are still in development phase. Some examples are:

Mixed alcohols

Similar to Fischer-Tropsch synthesis in which a mixture of straight chain hydrocarbons is produced with varying chain lengths, a similar mixture of alcohols can be produced in a catalytic syngas process. Various activities on this subject have not yet resulted in industrial developments. However, probably resulting from the large interest in bio-ethanol, the mixed-alcohol synthesis has received renewed attention in the United States. Power Energy Fuels, Inc. in Denver, Colorado plans to commercialise a process that produces mixed alcohols. Their product with the trade name Ecalene™ consists of a mixture of 75 wt% ethanol and the remainder being higher alcohols [27].

Carbon monoxide

The production volume of carbon monoxide (CO) from syngas is very small compared to other syngas applications. The main consumers of CO are acetic acid and phosgene production processes. With the increasing demand of alternative carbon sources (other than crude oil) it is expected that the demand of CO will increase in the future, *i.e.* the so-called C1-chemistry.

Olefins and aromatics

To date, the most important classes of base chemicals are olefins and aromatics. Already for several decennia research is ongoing to produce these compounds directly from syngas [28]. So far, these attempts have not been successful; processes in which the chemicals are produced from methanol, *i.e.* a syngas product, are more promising. Mobil has developed several processes in which methanol is converted using zeolite catalysts. In the methanol-to-gasoline (MTG) process gasoline is produced from methanol. The product contains approx. 15 wt% of aromatics. By applying conventional separation techniques, the aromatics can be recovered and in this way aromatics can be produced from biomass (when the methanol was produced from biosyngas). In a variant of the MTG process, the methanol-to-olefines (MTO) process, olefins are produced from methanol. The processes have been in operation on 14,500 and 100 bbl/day for the MTG and MTO processes, respectively [29].

6 Gas Specifications

Specifications for biosyngas and product gas are defined by the final gas application and comprise acceptable levels for the concentration of impurities and the required main gas composition. In addition, for certain applications specifically a (cleaned) biosyngas and product gas feed is preferred or required, *e.g.*:

Heat	:	product gas
Power - Combined cycle	:	product gas
Power - CHP gas engine	:	product gas, low tar content
Power - CHP fuel cell (SOFC)	:	product gas, low hydrocarbon & organic content
SNG	:	product gas, nitrogen-free, high methane content
Liquid fuel synthesis	:	biosyngas, nitrogen-free
Chemical synthesis	:	biosyngas, nitrogen-free
Hydrogen production	:	biosyngas, nitrogen-free
Ammonia production	:	biosyngas, containing nitrogen

For the heat and power applications also a biosyngas can be used, however, a product gas is preferred because the energy efficiency from biomass to product gas is higher than the efficiency to biosyngas. In the next two sections the general specifications for biosyngas and product gas are discussed.

6.1 Product gas

The applications of product gas are found in the production of power and/or heat and the synthesis of SNG. The utilisation of biomass-based product gas is not (yet) completely established and for the more advanced applications the technologies are still in development. Resultantly, also the *technical* gas specifications have not yet been defined. More important for heat and power production, however, are the applicable emission regulations that in most cases will results in more stringent gas specifications than required for technical reasons. Typical limits standards apply for emissions of dust, CO and/or CH_4 (indicators for incomplete conversion), NO_x (from fuel-NH_3 and thermal NO_x), SO_2 (from fuel-S), volatile metals, and dioxins.

6.1.1 Heat

For heat production by direct firing of the gas there are in principle no technical specifications for the main gas composition and the impurities (for corrosion reasons the chloride content should not be too high, which for biomass is hardly ever an issue). The product gas must be combustible, *i.e.* a lower heating value of >5 MJ/m_n^3. Limitations for the dust content of the gas may apply depending on the type of boiler and the burner. Emission limits can be met with standard and commercially available flue gas cleaning. Gasification gives the advantage of separating the noxious substances from the fuel gas prior to combustion, therefore, alternatively product gas cleaning might be applied. The choice of either approach will be made case-specific and in most cases based on economic considerations.

6.1.2 Power

For power production in a combined cycle (CC) there is only the requirement of a gas free of dust and volatile metals (*i.e.* potassium and sodium). A pressurised feed gas is required,

therefore, the product gas must be generated by pressurised gasification. In case of atmospheric gasification, intermediate product gas compression is an option, however, to allow compression to typical CC pressures (15-40 bar) the gas must be completely clean, making this route much less attractive.

Firing of the product gas in a gas engine requires a dust-free gas with a tar dewpoint below the engine inlet temperature (or even lower in case of a turbo-charged engine) to prevent tar condensation and fouling, *i.e.* typically, up to 2 g/m_n^3 of tars and a few vol% of benzene and toluene may be present in the gas. Similar to the heat production case, it is an economic consideration to choose either product gas or flue gas cleaning to meet the emission regulations. The use of fuel cells for power is in theory an attractive alternative for the use of gas engines due to the potential higher electrical efficiencies. As a fuel cell (SOFC) is in principal catalytic process, the gas specifications are much stricter. Sulphur must be completely removed, as it is a poison to the fuel cell, while the content of aliphatic and aromatic hydrocarbons and tars must be not too high to prevent soot formation and coking (*i.e.* quantitative specifications are not yet available from experimental work). A nitrogen-free gas is not required.

6.1.3 Synthetic Natural Gas (SNG)

The production of methane from product gas is a catalytic synthesis for which several processes and catalysts are in development. For all processes sulphur is a serious catalyst poison. Evidently, the use of product gases with high methane concentrations is preferred, while the product gas must be essentially nitrogen-free to be able to meet the final SNG specifications.

6.2 Biosyngas

6.2.1 Impurities

The main application of biosyngas is found in catalytic synthesis processes and catalysts are intrinsically very sensitive to small amounts of impurities. In general, the required gas purity specifications depend on economic considerations, *i.e.* additional investments in gas cleaning versus accepting decreasing production due to poisoning of catalysts or higher maintenance intervals due to fouling of the system. Therefore, there are no “hard” data on maximum levels for impurities in gas. For each plant the acceptable levels may be different. However, rule-of-thumb levels may be used for indication based on data derived for Fischer-Tropsch synthesis [23].

A maximum value of less than 1 ppmV is defined for both the sum of the nitrogen-containing and sulphur-containing compounds. Although for low-pressure methanol process a level as low as 0.1 ppmV of total sulphur is required. For the halides and alkaline metals a lower level of less than 10 ppbV is assumed (see Table 4). Solids must be removed essentially completely, as they foul the system and may obstruct fixed-bed reactors. A number of other possible impurities, such as organic acids (*e.g.* formic and acetic acid) and unsaturated and higher boiling hydrocarbons, are normally not included in purity specifications for synthesis processes because they are already undesirable in upstream process stages of biosyngas production (*e.g.* compression steps). However, organic compounds present must be below their dewpoint at pressure of the gas application to prevent condensation and fouling in the system [23,30]. For organic compounds with S or N hetero atoms (*e.g.* thiophene and pyridine) the additional specification applies that they need to be removed below ppmV level, as they are intrinsically poisonous for the catalyst.

Table 4. *Purification level of main biosyngas impurities [23].*

Impurity	Removal level
Sum of sulphur compounds (H_2S + COS + CS_2)	< 1 ppmV
Sum of nitrogen compounds (NH_3 + HCN)	< 1 ppmV
HCl + HBr + HF	< 10 ppbV
Alkaline metals	< 10 ppbV
Solids (soot, dust, ash)	essentially completely
Organic compounds (hydrocarbons, tars)	below dewpoint

6.2.2 Main gas compositions

When gasification is followed by downstream synthesis the stoichiometry of that synthesis reaction requires in most cases a very specific gas composition. In addition, economic aspects must be considered concerning the inerts contained in the gas, which unnecessarily reduce the partial pressure of reactants and tend to concentrate in recycle processes so that a considerable amount of purge gas must be branched off [25]. In Table 5 an overview is presented of main gas specifications for the major biosyngas applications.

Table 5. *Overview of main gas composition specifications for selected applications [12].*

Synthesis	H_2 for refinery	Ammonia	Methanol	Fischer-Tropsch	Oxo alochols
H_2	>98%	75%	71	60	60
CO	<10-50 ppmv	CO+CO_2	19	30	40
CO_2	<10-50 ppmv	<20 ppmv	4-8%		
N_2		25%			
Inert	N_2, Ar, CH_4 Balance	Ar, CH_4 as low as possible	N_2, Ar, CH_4 as low as possible	CO_2, N_2, Ar, CH_4 low	
H_2/N_2		~3			
H_2/CO				0.6-2	1-1.5
$H_2/(2*CO+3*CO_2)$			1.3-1.4		
Process temperature		350-550°C	300-400°C	200-350°C	85-200°C
Process pressure	>50 bar	100-250 bar	50-300 bar	25-60 bar	15-350 bar

Each application has its own specifications, therefore, it is not possible to define one set of biosyngas specifications. However, a general specification is a hydrogen content of >60%. In methanol and Fischer-Tropsch synthesis 19 and 30% of CO is required, respectively, while for hydrogen production and ammonia synthesis the CO must be completely removed. The total content of inerts (*e.g.* N_2, Ar, and CH_4), which in most cases are not dangerous to synthesis but undesirable for economic reasons, must often be <2% (*i.e.* as low as possible). The exception is ammonia synthesis, in which 25% of nitrogen is required. In general the required ratio of hydrogen to carbon monoxide offers a simple characterization as the main biosyngas characteristic.

7 Gas treatment

Each synthesis gas production plant requires gas treatment facilities to purify product gases and also, in many cases, to condition them. Whereas the gas purification system eliminates the components that would affect downstream processing or utilization of these gases, the purpose of a conditioning system is to remove undesired main gas compounds and to adjust gas components to the appropriate ratio. Especially, the ratio of hydrogen to carbon monoxide must be matched to the requirements of downstream synthesis units or gas consumers [25]. Depending on the type and composition of feedstock and the type of gasification process used, the gas purification and conditioning must handle the following impurities and undesired compounds:

- Particulates.
- Sulphur compounds, *e.g*. hydrogen sulphide, carbonyl sulphide, organic sulphur.
- Nitrogen compounds, *i.e*. mainly ammonia.
- Halogens, *e.g*. chloride.
- Volatile metals, *e.g*. alkali and earth alkali compounds.
- Tars.
- Hydrocarbons (if removal is necessary for usage), *e.g*. CH_4, C_2+ aliphatic hydrocarbons and aromatics like benzene and toluene.
- Carbon dioxide (if removal is necessary for usage).

For discussion the gas treatment is divided in removal of particulates, organic impurities (*i.e*. tars and hydrocarbons), and inorganic impurities (*i.e*. metals, halides, and nitrogen and sulphur containing compounds), and gas conditioning. A good overview about gas cleaning is given in reference 31, therefore, no detailed description of gas treatment system to remove particulates is given here.

7.1 Particulates

Particulate removal is required for both product gas and biosyngas. Particulates originate from the ash of the feedstock, dust, unconverted carbon (in product gas from low temperature gasification, soot (typically for high temperature oxygen-blown gasification), and carry-over bed material in the case of fluidised bed gasifiers. There are many different technologies to remove particulates from gases that can be applied to both biosyngas and product gas. To remove particulates from the synthesis gas the following systems can be used: cyclones, barrier filters, electrostatic filters (ESP), and solvent scrubbers.

7.2 Organic impurities

Organic compounds can only be present in product gas generated in gasification processes operated at temperatures below 1000°C, such as the indirect and CFB gasification processes. The main organic compound is methane. Other organic compounds are the aliphatic C_2+ hydrocarbon higher than methane, with the most important representative being ethylene (C_2H_4), the mono aromatic compounds benzene and toluene, and “tars”. At the high temperatures of entrained flow gasification all organic material is completely destructed and converted into H_2 and CO (with CO_2 and H_2). Therefore, removal of organic impurities, especially the tars, is only of importance for product gas applications.

The C_2+ hydrocarbons and benzene are not considered as impurities in most product gas applications (*cf.* Chapter 4). Complete removal of the tars or at least the larger part of them, however, is necessary. A lot of research and development is ongoing on tar removal and a good overview is given in reference 31, therefore, only the main concepts are discussed here:

- High temperature destruction. Upon increasing the temperature of the raw product gas by oxygen injection all organic compounds are 'cracked' and destructed. The effect is similar to direct gasification at a high temperature (*i.e.* an entrained flow gasifier can be used as tar cracker). As the methane, C_2+ hydrocarbons, and benzene are destructed, which is unnecessary or even undesired, this approach is not preferred.
- Catalytic destruction. Catalytic tar reduction is typically performed in the raw gas after the gasifier at elevated temperatures (400-850°C) in most cases with nickel-based catalysts. With this method a large part of the tars can be destructed, while the methane and benzene remain intact for the major part. Major disadvantage of this concept is the sensitivity of the catalysts for (inorganic) impurities in the raw product gas.
- Physical removal. The most promising tar removal concepts are based on physical removal with organic washing liquids. In the FICFB plant in Güssing biodiesel is used to clean the product gas to meet gas engine specifications (tar dewpoint of ~40°C) [8]. ECN has developed the OLGA process that is capable of removing all aromatic organic components to very low levels (*i.e.* tar dewpoints below -15°C). Additional advantage of the OLGA process is that the tars are removed prior to water condensation to prevent pollution of process water and related costs for wastewater treatment [32].

7.3 Inorganic impurities

Removal of inorganic impurities is required for both product gas and biosyngas applications. In this section a general cleaning approach is discussed that is applicable to all types of gases (assuming all possible organic impurities in a product gas have been removed upstream). The cleaning of the raw syngas, produced from fossil fuels, is a well-known and commercially available process (Figure 6), *i.e.* reference is made to processes applied for fossil syngas [33].

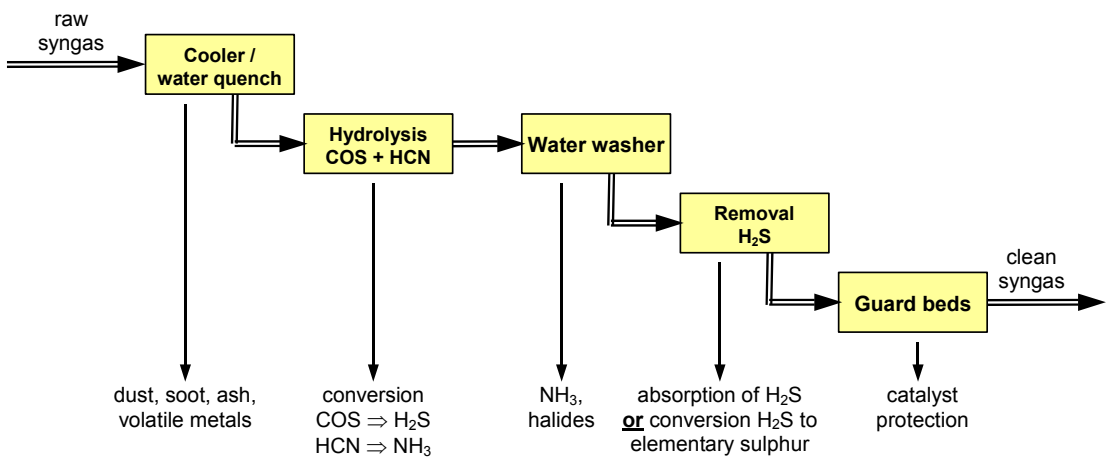

***Figure 6**. Schematic representation of general industrial approach towards cleaning of syngas from partial oxidation of natural gas based on commercially available technologies [33].*

The general approach is to quench the raw hot syngas with water to cool the gas and remove solid particles (*viz.* dust, soot, and ash) and the volatile alkaline metals. Upon syngas production, H_2S, NH_3, COS (and CS_2), and HCN are formed from sulphur and nitrogen in the fuel. The NH_3 is removed downstream together with the halides (*viz.* HCl, HBr, and HF) with a

water washer and H_2S is removed either by absorption or after conversion to elementary sulphur (*i.e.* the Claus process) - the adsorption removal is preferred (cheaper) when relatively small amounts of H_2S are present. Similar is valid for the presence of COS and HCN. These impurities are hardly removed in the gas cleaning and are captured in the guard beds. When a syngas contains higher loads of these compounds it is economically more attractive to install a hydrolysis step to convert the compounds to H_2S and NH_3, respectively, that are readily removed in the gas cleaning. With this cleaning process the syngas specifications are met (*cf.* Section 6.2.1) [24].

7.4 Gas conditioning

Gas conditioning comprises all gas treatment steps to adjust the main gas composition of the biosyngas (or product gas) to meet the specifications of the gas application (*cf.* Table 5). The main issues in gas conditioning are adjustment of the H_2/CO ratio and CO_2 removal. Typically, processes for the manufacturing of syngas from hydrocarbon feedstocks produce mixtures of hydrogen, carbon dioxide, methane, and varying amounts of carbon monoxide. For the majority of industrial processes, the carbon monoxide content is higher than that required for synthesis. The presence of CO_2 is undesired in most processes and this compound should be removed.

7.4.1 Water-gas-shift

To increase the H_2/CO ratio or to (essentially completely) convert CO (and H_2O) into H_2 (and CO_2) the water-gas-shift reaction is used:

$$CO + H_2O \Rightarrow CO_2 + H_2 \tag{7}$$

The water gas shift equilibrium among carbon monoxide, carbon dioxide, hydrogen, and steam depends on temperature but is almost independent of pressure in the industrial range (elevated pressures up to 70 bar). Above 950-1000°C, the equilibrium is established rapidly enough without a catalyst, but typically the shift is carried out at lower temperatures with a catalyst. Temperature ranges used in commercial carbon monoxide shift conversions are:

1. High-temperature shift (HTS) at about 300 to 510°C with copper-promoted catalysts
2. Low-temperature shift (LTS) at about 180 to 270°C with copper-zinc-aluminium oxide-based catalysts.

Depending on the required H_2/CO ratio the shift is carried out in two steps. In the first high temperature (HTS) step the bulk of the CO is converted; the remaining CO concentration is minimum 1-2 vol%. If hydrogen production is aimed at, a second shift LTS step is carried out to reduce the CO content to 0.2-0.5 vol%.

7.4.2 CO_2 removal

Carbon dioxide can be removed from syngas by chemical and physical absorption with a washing liquid or by adsorption with solid absorbentia. The choice for chemical or physical absorption (or a combination of both) depends on the partial pressure in the gas. For chemical absorption in commercial processes substituted amines are used, while solvents like methanol, polyethylene glycol, and dimethyl ether are used for physical absorption. The CO_2 concentration can be removed to approx. 0.1 vol% by these processes. When the syngas contains significant concentrations of other gases besides H_2 and CO_2, adsorption on solid absorbentia is preferred. Examples of these materials comprise silica gel, active carbon, zeolites, and molecular sieves. The adsorption takes place at low temperatures and high pressures and the regeneration takes place either by higher temperature (TSA; Thermal Swing Adsorption) or lower pressure (PSA; Pressure Swing Adsorption).

8 Concluding Remarks

Biomass will play an important role in the future global energy infrastructure for the generation of power and heat, but also for the production of chemicals and fuels. The dominant biomass conversion technology will be gasification, as the gases from biomass gasification are intermediates in the high-efficient power production or the synthesis from chemicals and fuels. In the discussion on the utilisation of gases from biomass gasification it is important to understand that the composition of the gasification gas is very dependent on the type of gasification process and especially the gasification temperature. In this report the two main types of gasification gas and their typical applications and specifications were discussed, *i.e.* **biosyngas** and **product gas**.

In the past several definitions for gasification gases were used without making this distinction. However, clear understanding of the relation between gasification technologies, the generated gas, its typical applications, and the corresponding specifications is crucial in today's decision-making processes. Incorrect perceptions resulting from confusing terminologies may result in delayed developments, too high expectations, disappointments, and in the worst-case into loss of support because promises are not made true.

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REVIEW OF SOLAR COOKER DESIGNS

Ashok Kundapur

MGM College, Udupi – 576 102, INDIA

This is a HTML version of the article which appeared in TIDE, Vol 8, No. 1, March 1998 Page 1-37. This paper is now presented here in 16 parts.

This site helps you to find out if your design of solar cooker works or not. (The cartoon is from Prof Bernard's little book on Solar Cookers " La cuisson Solari Facile") Published by Jouyence Silence. France, reproduced here with his and publisher's permission)

Abstract

This review presents about **60 major designs** , 69 variations and 80 drawings of solar cookers. Test data published by other researcher is compiled and a new set of parameters is suggested for testing solar cookers, reflectors, and insulating material. This compilation recommends do – it-yourself box-type solar cookers incorporated in the house for the rural areas (type BDM 2, concept IX). For urban areas, the best suited design would be Prof. Bowman's design with slight modifications (Type MP 3a, Concept IV). Another design for small towns, where smaller houses are more in number, is the roof-top water lens whose focus is suitably deflected to the bottom of the cooking vessel (Type LCA 3a, Concept VI).Of other viable designs Bernards 'COOKIT' appears to be the best suited, other designs are also discussed. (**Update** 6 more new designs have been added since this site was launched in June 1999, for details see at the end of this part and also in the respective sections)

PLEASE NOTE:

- **The designs designated here as CONCEPTS I to XII were conceived during '80ies, but I do not claim any right over the same, these designs can be tried out without any prior permission from me. However I appreciate if I get a detailed report of the performance.**
- **This is an ACTIVE SITE, a researcher or an Inventor may advertise/contribute his/her design through this pages.**
- **All the new entries made after 6th June 1999 will be entered in parenthesis under the title of UPDATE.**

CONTRIBUTORS TO THIS SITE

- **BRETT WHITE of Australia, was the first contributor to this SITE. He has updated the folding type Parabolic cookers listed here under PC 8.**
- **DERIS JEANNETTE from USA is the second contributor. She has evolved 'CLEAR DOME SOLAR COOKERS' classified here under LCA 7. She also presents several other interesting variations, some of which are for sale.**
- **DAVID DELANEY of Canada, turns out to be the first critic of the site, and as per his advice, I have renamed the web page as my Homesite. He is concentrating on improving the transparent insulating cover, first suggested by Prof. Bernard and then modified by Prof. Barbara Kerr, more effective. His site should visited for more detailed information which is a must if the solar cooking has to be effective.**
- **QUINSTONE STOWELL from UK, is the fourth contributor to the site. He had detailed his project work undertaken at Peru and presents several guidelines for easier construction of parabolic solar Cookers.**
- **I am delighted to receive very nice words and a beautiful book from Prof. BERNARD, (off France), designer of 'COOKIT". The book is in French but fortunately details of his designs are presented by Solar Cooker International.**
- **Stoven has presented an interesting design called FUNNEL COOKERS, I would place it close to ' Cookit', and designate it as LCA 8.**
- **Prof. Paul Funk's SEAE Standards on testing Solar Cookers has been added just this month that is, October 2001.**

Active researchers who have tested the solar cookers using this method could please send me the details.

Acknowledgements

The author acknowledges the help and encouragement extended by the late Prof. P.S. Shivram, Head, Department of Printing Technology and Energy Centre, MIT, Manipal , who was solely responsible for the publication of the earlier review in 1995. In fact the work on Solar Cookers was launched here at Udupi way back in 1975 and it was Ms Janet Alarcon of **VITA** and Sri. G K Gopalakrishnan, Chief Documentation officer, TERI , (then located at Mumbai) who not only enthused me forther but helped me by sending tons of information. And now, especially to Dr. M C Shukla of TERI, New Delhi, for having recognized this work and encourage compilation of this abridged and updated version, and getting it published in TIDE. I am also grateful to Ms. Bev Blum, Vice President, **Solar Cooker International**, USA. for encouraging me to put this paper on WEB. I am also grateful to Prof. Sureshramana Mayya, Department of Commerce, at our College for taking special interest in converting this paper into HTML format. (for other links see at the end of References)

PROLOGUE

(Read this before you go further)

This site was launched in June 1999, since then over 1400 interested persons have visited the site, and many of them have spoken very high of it and some have also suggested changes which have been incorporated. New designs and works too have been added. But before one continues further I request them to read this prologue.

Many of the Solar Cooker Enthusiasts are still keen on fabricating perfect Parabolic reflectors! But this aspect has been dealt in detail under the section. Many of the Stalwarts like Prof. T. E. Bowman of Florida Institute of Technology, and also Prof. Roger Bernard of France have suggested using Plane mirrors in sted. I guess it would be much easier to do so.

Remember the insulated Box of Box type Gosh Solar Cooker. Prof. Barbera Kerr and several others had suggested using paper balls, straw and a wide variety of materials for making the box and the insulation to go in-between. Inventors like Patel (1981, Ref. 74,) had in fact suggested inverted Glass Jar in sted of a very heavy and combersome insulated Box. Later Prof. Bernard had suggested the use of such a Jar for his 'COOKIT' design. Glass Jars are costly and are prone for breakage so Prof. Barbera Kerr used clear plastic bags to cover the cooking pots very successfully. Prof. Bowman too had realised the importance of the insulation of Cooking vessel and he had suggested FOAM GLASS boxes around cooking pots for the FIT designs. Recently Deris uses two such clear jars (Glass or heat resistant Polycarbonate jars), inverted over the cooking pots where the light is concentrated by a circle of ordinary mirrors! I guess the solar Cooking can not be made simpler than this.

At this juncture I wish to introduce the work being pursued by Prof. David Delaney of Canada. Taking the cue from Prof. Bernard, and Barbera Kerr he is attempting to improve this Glass Jar concept. Covering the Cooking pot with a Glass jar has two problems, handling the cooking pot and its contents become difficult, and condensation of moisture inside the glass container affects the transmission of solar light to the pot. So he suggests use of a upright jar of not more than 2 inches in diameter of the cooking pot. Use of a suitable collar of card board or more stable material for placing the pot into the jar, and also a cooking pot with a clear glass 'insulated' lid. I feel that these suggestions are very apt, but at the sametime find that the Glass jars of that type are rather costly upto Rs. 400 ($ 10) especially because Gosh type Solar Cookers of 2' x 2' were being sold in our country at Rs. 450 to 650! ($ 12 to 16 only). I do not suggest that the Box type of Cookers are better, but an attempt is needed to find a suitable material to cover the cooking pot.

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Introduction

Solar energy is the primary source of energy for our planet. Increased utilization of the same would result in an all-round benefit, both in terms of cleaner environment and monetary gain, for the individual users as well as the nation. Use of solar energy would save a lot of time and money for the user and this could be effectively diverted for increased productive activities and monetary gains which means better living standards and overall prosperity. The Gujarat Energy Development Agency (GEDA 1979) calculates that the use of solar cookers by about 2000 families for 10 years would mean a saving of Rs 3.6 million in terms of reduced firewood consumption, or Rs. 100 million worth coal or Rs. 8.55 million worth kerosene (as per 1979 prices).

History

The history of solar cooking goes back to dim recess of antiquity. The use of solar power to ignite altar fires has been mentioned (Meinel, Meinel 1997). References indicate the use of sun rays to melt chemicals and metals. The very first solar furnace was fabricated in France by the famed naturalist George Louis Leclere Buffon (1707 – 1788). However, the first reference relating to solar cooking was that of Nicholas-de-Saussure (1740 – 1799). There are over 50 major designs of solar cookers, some of which are patented, and more than 100 variations. Of these, this review covers about 59 of the most important variations. The main purpose of this compilation is to present all possible major designs and their variations so as to prevent the solar cooker designer from wasting time on a design which has already been under the Sun. An attempt is made to cover most of the designs, but if there are any omissions then the designers may please send the details (Kundapur 1995). Though the description of the cooker is brief, accompanying diagrams would fill the void. As regards dimensions, adequate guidelines are given in the respective sections, but for concentrating type the area should preferably be more than 1.5 sq. m, and in the case of box type, it should be around 0.6 sq. m.

The solar cookers presented in the review are classified under THREE categories:

- **Concentrator Type**
- **Box-type designs**
- **Indirect Types**

The Concentrator type, concentrate the sun's rays either on to the top or at the bottom of the cooking pot, was the pioneering design. Naturally maximum variations are found under this category and 28 designs are discussed here. The Box type design was one of the first solar cookers to appear under the sun, and is one of the popular designs now. Eleven major designs of this type are described here. The Indirect type solar cookers are those that have collectors outside and the cooking area or plate is inside the house. Some exotic designs are covered here and 11 major designs find place in this review (Chart I).

TABLE I - SOALR COOKERS		
Concentrator Type **LIGHT FROM ABOVE** LIGHT FROM BELOW ▪ Spherical ▪ Fresnel ▪ Cylindro parabolic ▪ Mirror plane ▪ PARABOLIC • Collapsible • Rigid ❍ Asymmetrical ❍ Shallow ❍ Deep	**Box-type designs** • Without Mirrors • With Mirrors ❍ Single Mirror ❍ Double Mirrors ❍ Three Mirrors ❍ Four Mirrors ❍ Four plus Four	**Indirect Types** ❍ IDT 1 Whiller type ❍ 1a Stam Cooker ❍ 1b Bowman type ❍ 1c Venugopal type ❍ IDT 2 Chinese type ❍ 2a Nijaguna type ❍ IDT 3 Stam type ❍ IDT 4 Swet type ❍ IDT 5 Fraber type ❍ IDT 6 Winston CPC tpye ❍ IDT 7 Concept XII ❍ IDT 8 Chemical types ❍ IDT 9 Biogas ❍ IDT 10 Solar Hydrogen ❍ IDT 11 Solar Water Heater
(for details See Chart Ia)	(for details See Chart Ib)	

(**UPDATE** : Medved et.al., 'SOLAR BALL' under Spherical Concentrators S-2

Amith Kumar's Circular Box with Contored Mirror under BSM 2, Prof Sayiah Type under BSM 3, Prof. El Sebiis type under BSM 4, Fatangares type under BWM 7, Double Parabola under PRS 2,

Prof. Bernard's 'NEPLA' in under MP 3 are 7 new designs considerded in this first ed. of the web page)

Source:- TIDE., March 1998, 8-1, pp 1-37, For Comments, suggestions,contributions contact < ashok_kundapur@yahoo.com>

PREVIOUS PART To Home page		**NEXT PART** CLASSIFICATION CHART

For easy NAVIGATION use this chart.

OTHER LINKS are found under References S to W

INRTODUCTION	CLASSIFICATION CHART	TABLE 1a & 1b
Collapsible Parabola	Parabolic Concentrators	light from above
Box type designs	Box with 2 reflectors	Indirect types
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click here for comments received

For details regarding testing of solar cookers (International Standards) please click here

For Comments, suggestions,contributions contact < ashokk12@rediffmail.com>

Medicinal Seed Information

Common Name	Baical Scullcap
Botanical Name	Scutellaria baicalensis
Climate	Arctic
Planting Instructions	Grows easily from seed and is generally sown in the spring directly outdoors or started in the greenhouse and transplanted outdoors. It tends to prefer soils that retain moisture (contain moderate amounts of compost or organic matter) and can withstand colder temperatures. Skullcap prefers a moderate amount of spacing between plants.
Light	Full sun/partial shade
Water	Grows well in any well-drained soil and is also drought hardy
Germination Rate	24 days
Days to Maturity	Flowers in the summer or fall of the first season when planted in the spring.
Special Instructions	Harvest the root when it is 3-4 years old in the fall or spring. Likewise, harvest the leaves and stems before flowering during the summer.
Part of Plant used Medicinally	whole plant
Spiritual Needs	Baical scullcap is a feminine plant that promotes peace, love and spirituality. It is soothing and relaxing.
Medicinal Uses	Used to relieve allergies, reduce water retention, high blood pressure, anxiety and fever. Its anti-bacterial and anti-viral properties is useful for dysentery, diarrhea and other infections. It is used for hot and thirsty conditions, reduces inflammation especially in the lungs and liver (hepatitis), stops bleeding, aids in decreasing cough and detoxifies. It has a tranquilizing effect and aids in preventing abortion. It is soothing to a fetus. Baical scullcap is also a sedative, nervine (tones the nerves) and anti-spasmodic.
Description	Herbaceous Perennial with purple flowers. Grows to 12 inches tall
Other	
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Bittersweet
Botanical Name	Solanum dulcamara
Climate	Temperate
Planting Instructions	Easily grown from seed. Sow directly in garden in Spring or start early in the greenhouse and transplant outdoors. Prefers a lot of space between plants.
Light	Partial shade to full sun
Water	Prefers moist soil
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	Will mature in the late fall or at least be well established before winter if sown in the spring.
Special Instructions	Harvest twigs and bark after foliage has fallen. Harvest the stems when they are young and green up to when they are an older, wooden bark.
Part of Plant used Medicinally	Stems, good for at least 2 years if left whole; bark of the root and twigs .
Spiritual Needs	This herb is a member of the Nightshade family and it can be poisonous if used inappropriately, as such, it must be treated with extreme caution. It is a very potent herb and must be used with care. Bittersweet is a masculine plant. It offers spiritual powers, visions, protection and healing for emotional traumas when worn.
Medicinal Uses	Low dosage of the tincture, tea or homeopathic remedy is used internally as a narcotic, to treat a sluggish liver, jaundice, obesity, skin disharmonies due to poor assimilation of fats such as eczema and warts, gallbladder and spleen disturbances, rheumatic conditions, gout, asthma, chronic bronchitis and whooping cough. It also heals all internal wounds, bruises and ruptures, dissolves congealed blood and is valuable as a remedy for fever, muscle spasms and inflammation. Topically, a poultice can be used for gout and herpes. It has an affinity with the liver, lung and stomach organs and meridians.
Description	Woody perennial drooping bush. Red berries. Grows to 4 ft. tall, with many nodding purple and yellow flowers
Other	Berries are toxic. Leaves are toxic in excess, use with caution. Contains alkaloids.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Burdock, Gobo
Botanical Name	Arctium lappa
Climate	Temperate
Planting Instructions	Burdock grows easily from seed and is an extremely versatile plant, withstanding extremely cold and hot temperatures, though it tends to grow best at about 20 - 30 F. Direct seed in the garden in the spring once soil is warm, or start earlier in the greenhouse and transplant outdoors. Prefers a neutral pH and varies in its need for space, so ask the plant how far apart it woud like to be planted. Roots grow deeply, therefore transplanting is too hard on the plant once it is well established. Grows in many soil types but tends to prefer a loose, easily crumbled soil that is deeply dug. Can be grown on mounds of soft soil or planted with wood chips and sawdust to make digging up the root easier.
Light	Full sun
Water	Keep seeds wet until seedlings sprout, do not saturate soil once seedlings become established. Prefers moist and well drained soil.
Germination Rate	10-14 days. Some can remain dormant until following fall.
Days to Maturity	Will at least be well established by winter if sown in the spring.
Special Instructions	Harvest the root during the first growing season or at the latest, in the dormant period after first season of growth. Harvest seeds in summer, the whole plant in mid-summer. Seeds are produced during the second year.
Part of Plant used Medicinally	Root. Seeds , leaves
Spiritual Needs	Burdock is a feminine plant. It offers protection and healing. When casted around the home, it wards off negativity.
Medicinal Uses	Burdock is high in minerals and vitamins found in the soil. Its root improves liver and spleen function, eliminates heavy metals, improves skin conditions such as psoriasis and acne (through improvement of liver and spleen), reduces inflammatory conditions such as gout and fever, can be used for hypoglycemia, diabetes, chronic indigestion, as an antibacterial and antifungal, for lymphatic congestion, for growths and can be used to dissolve kidney stones. The tea made from its leafy branches is used to treat gonorrhea, vertigo, rheumatism, and measles. A poultice from the leaves is useful for burns, ulcers bruises and sores; a tea/tincture made of the seeds are used to reduce water retention, to clear abscesses, insect and snake bites, flu and constipation. This preparation can also be used as a wash for hives and eczema. Burdock should be used under supervision of a healer during pregnancy. It has an affinity to the lungs, stomach, kidney and liver organs and meridians.
Description	Biennial. Will self seed if seeds are not removed and may take over surrounding area. Flowers to 7 ft. tall in the second year. Stout, multibranched; clumps of purplish, red flowers, egg-shaped leaves; after flowering. When grown in a climate with a short growing season it tends to always flower during its second year.
Other	The leaves of burdock can be used to help cure gout when placed to the soles of the feet.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Clover, Red
Botanical Name	Trifolium pratense
Climate	Temperate
Planting Instructions	Red clover can be broadcasted on a newly tilled field in the spring, summer or fall or planted directly in the garden with a small amount of space between the plants. It can also be started in the greenhouse early in the season and transplanted outdoors.
Light	Full sun
Water	Thrives in a variety of moist, well drained soils, but does not grow well in sand or gravel.
Germination Rate	3 days
Days to Maturity	Will flower or at least be well established before winter if sown in the spring.
Special Instructions	Harvest ripe blossoms and stems when flowers are in full bloom. Treat seed with rhizobium inoculant (available through Horizon Herbs).
Part of Plant used Medicinally	Dried blossoms and upper leaves. Stems.
Spiritual Needs	Red clover is a masculine plants that offers purification, raises spiritual vibrations and strengthens psychic powers.
Medicinal Uses	Red clover contains coumadin, which thins the blood. It improves liver and spleen function; thus cleansing toxins from the blood. Red clover is excellent for treating growths, chronic skin infections (eczema, psoriasis) bronchial and whooping cough, mucous congestion and is antispasmodic (especially for the respiratory tract). Red Clover helps the body assimilate nutrients and eliminate cellular waste, stabilize female hormones, treat infections and enhance the immune system. Body system affinity - liver, skin, immune and musculoskeletal systems, smooth muscle and respiratory tract.
Description	Perennial cover crop. One oz. of seeds covers 125 sq. ft. Fixes approx. 140 lb. of pure nitrogen per acre. Cleansing and fortifying to the soil
Other	Flowers yield a yellow dye. Grown or scattered, it helps keep snakes away. Use care with Red Clover, as it also cleans disturbed soil. To use medicinally, ensure the soil it is growing in is not contaminated. Red Clover adds nitrogen to the soil and its deep roots help break up compacted soil.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Dandelion, Wild
Botanical Name	Taraxacum officinale
Climate	Temperate
Planting Instructions	Dandelion is easily grown from seed and can be seeded directly in the garden in the spring or started earlier in the greenhouse and transplanted outdoors. It tends to prefer loose, nitrogen rich soil with plenty of compost in it, but grows well in any soil, and prefers a moderate amount of space between plants. The tap roots left in the ground will sprout again. Soil lightened with sawdust or wood chips make harvesting easier.
Light	Full sun to partial shade .
Water	Keep well watered. Keep well drained.
Germination Rate	3 days.
Days to Maturity	Blooms in April-May when planted the previous spring.
Special Instructions	Harvest the young leaves as they develop. Harvest root an the end of the second growing season in the late summer or fall, however, roots left in the ground will sprout again. Harvest stems (containing sap) and flowers as the flowers bloom.
Part of Plant used Medicinally	Roots, leaves, white sap and flowers
Spiritual Needs	Dandelion is a masculine plant. It promotes psychic powers, divination, and the calling of the spirits. When Dandelion is buried on the NorthWest corner of the house, it brings favorable winds.
Medicinal Uses	Leaves gently tone the liver, cleanse toxins out of tissues and reduce water retention as well as replenish the body with its high potassium content, and dissolves gall bladder and urinary stones. they are also used for lymphatic swellings, nerve inflammations, urinary tract infections, anemia, acidic urine, high blood pressure, congestive heart failure, tooth cavities, lactation, colds and bronchitis. Fresh root tincture reduces inflammation of the skin and joints such as in hives, arthritis or allergic reactions. It also stimulates bile flow and acts as a laxative; The dried root tea and tincture is indicated for hepatitis, anemia, jaundice, cirrhosis low blood sugar and gallstones. The fresh juice of root is used for diabetes and liver disharmonies and snake bites. The dried roots are rich in minerals used to build blood. The sap (milk) is used to remove warts and dried leaves and flowers can be added to a bath or sitz bath for vaginal yeast infections. Body system affinity - liver, spleen, stomach, musculoskeletal, kidney, bladder.
Description	Herbaceous perennial. Flowers sunny yellow to 1 ft.
Other	Use care in using Dandelion, as it also cleans disturbed soil. To use medicinally, ensure the soil it is growing in is not contaminated.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Devil's Club
Botanical Name	Oplopanax horridum
Climate	Temperate to Arctic
Planting Instructions	Before sowing seeds, break paired seeds apart into singles. Sow seeds in the fall, midwinter or early spring in the greenhouse, transplant seedlings to a pot, and grow out for a year or more before planting. Plants need a lot of space between them.
Light	Cool, shady
Water	Prefers moist, well drained soil and does well if planted adjacent to running water.
Germination Rate	Germinates in cold soils.
Days to Maturity	Plants sown in the spring will generally mature in late fall or at least be well established before the winter
Special Instructions	Harvest roots in the spring when leaf shoots appear
Part of Plant used Medicinally	Roots and greenish inner bark
Spiritual Needs	Devil's club is a masculine plant. This herb has been traditionally used in rituals, lodges and vision quests by different native people. It wards of evil, and offers protection and love.
Medicinal Uses	General adaptogen (allows body to return to balance after experiencing stress by strengthening the hypothalamus and pituitary). Devil's club is also useful as an expectorant and respiratory stimulant; A cold infusion (roots steeped in cold water) is used to treat rheumatoid arthritis, adult onset insulin-resistant diabetes and ulcers. The tea of the root and bark is used for tuberculosis, to regulate menses and after childbirth as well as for balancing and strengthening the entire body. A tea of stems and branches is used to reduce fever. The chewed stalk can be applied into open wounds for emergency pain relief. Bark strips reduce pain and swelling from fracture.
Description	Perennial creeping shrub. Green flowers, grows up to 10 ft. tall. Large umbrella leaves, thick spiny stem, sweetly aromatic .
Other	This plant must be used with caution both spiritually and physically, as it can be poisonous if used inappropriately. Wood can be used for fishing lures. Fruit is inedible.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Dong-quai
Botanical Name	Angelica sinensis
Climate	Temperate
Planting Instructions	The best way to grow Dong-Quai is by direct seeding into the garden. Fresh seeds can be sown in the spring or summer or started earlier in the greenhouse and transplanted outdoors. Older seeds can be sown in the fall. The seeds need light, cold soil for germination. It is recommended to sow seeds 1/2 inch deep in deeply dug, slightly acidic (compost-rich) soil. Give a moderate amount of space between plants.
Light	Full sun/partial shade
Water	Prefers well-drained, moist soil.
Germination Rate	4 months. Keep seeds very damp.
Days to Maturity	Flowering and seed production usually occur in the second or third year. Once it flowers and seeds, Dong-Quai dies. By cutting flower stalks every year before the seeds form, the plant will grow for many years.
Special Instructions	Harvest leaves for fresh use from spring onward. Harvest and dry roots in the fall of the second year.
Part of Plant used Medicinally	Root, leaves.
Spiritual Needs	Dong Quai is a feminine plant that offers balance and harmony.
Medicinal Uses	Dong Quai balances female hormones and strengthens the quality of the blood. Tea of root is used for colds and bronchial conditions; using the entire plant strengthens the liver, decreases blood cholesterol, dilates blood vessels, stabilizes heat, regulates the immune system, sedates the nervous system, is antibacterial and clears "damp wind" conditions.
Description	Biennial. Grows to 6ft
Other	Must be distinguished from highly poisonous water hemlock. Unique characteristics: tan-colored seeds have winged appearance. Leaves differ from water hemlock in that veins on extend to the tips of serrated edges.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Goldenrod Official
Botanical Name	Solidago canadensis gigantea
Climate	Temperate
Planting Instructions	Goldenrod is easily grown from seed in the spring, direct seeded in the garden or started earlier in the greenhouse and transplanted outdoors. It prefers poor soil and withstands temperatures down to -30 F.
Light	Prefers full sun
Water	Prefers moisture and well drained soil.
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	Generally flowers in the late summer to fall if sown in the spring.
Special Instructions	Harvest leaves in the spring and the whole plant in the summer while in flower.
Part of Plant used Medicinally	Leaves and flowers.
Spiritual Needs	Goldenrod is a feminine plant that offers psychic powers, divination and visions.
Medicinal Uses	Soothes irritated urinary tract, bleeding and inflammation of the kidneys, reduces inflammation in the urinary tract, flushes kidney and bladder stones, increases urine output and can also be taken for sore throats, yeast infections, oral thrush, chronic nasal congestion, diarrhea and for inflammation of the GI tract in children.
Description	Perennial. Grows to 6 ft.
Other	This plant must be used with extreme caution both spiritually and physically as it can be poisonous if used inappropriately. Tannin-rich plant.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Goldenseal
Botanical Name	Hydrastis canadensis
Climate	Temperate
Planting Instructions	Goldenseal is a sensitive plant and therefore, one method of planting is to mix the seeds with fine, clean, damp sand and put the mixture in a screen pouch or wooden box with fine screen on the top and bottm. The box or pouch is then buried in a shaded, well-drained area exposed to rain in the fall or early spring. It is recommended to allow the seedlings to grow closely together for 2 years before transplanting in the fall with a small amount of space between them. Once established, the plants' rhyzomes, pieces and root cuttings can be planted as well, for future growing. If direct seeding into the garden without a pouch or wooded box, sow seeds in closely placed rows 1/2 inch deep and cover lightly with mulch (leaves, hay etc.) to prevent the soil from drying. Sow in beds in the woods in the fall or very early spring with a little space between them.
Light	Sow in forest or shady beds; prefers open hardwood forest or shade garden.
Water	Prefers moisture and well drained soil.
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	5 years
Special Instructions	Seed collection: harvest fully ripe fruit and knead it, being careful not to damage the seed. Ferment in water until flesh and seed can be separated easily (can take several days). Add water, pour gently into another container and rinse until water and seed are clean. Spread seeds on fine mesh screen and rinse with high pressure spray. Dry seed for storage. Harvest root in the fall after 3-5 years after the seeds ripen. Wash roots with a hose on mesh screen. Remove all dirt off the smaller roots. Dry in a well ventilated area in the shade at low temperatures (95-100 F) with good air flow . Harvest rhizome in late fall after top growth is killed by frost. Harvest leaves in the late summer.
Part of Plant used Medicinally	Rhizome, roots, leaves.
Spiritual Needs	This plant is masculine. It is used in healing rituals of the spirit and is a shamanic plant.
Medicinal Uses	Goldenseal is an astringent and tones the mucous membranes and circulatory system. It is used for sinusitis, conjunctivitis, ulcers, dyspepsia (indigestion), diphtheria, scarlet fever, smallpox , staph, shigella, E. Coli, and Candida Albicans infections, snake bites, whooping cough. Externally it is used as an eye wash, for gingivitis, hemorrhoids, rectal fissures, eczema, boils and wounds. As a powder it can be placed on a newborn's belly button until cord falls off. Internally it is used for tonsillitis, uterine problems, to aid digestion, to tone uterus after giving birth and hemorrhoids. Homeopathically, it is used for alcoholism, asthma, indigestion, growths, hemorrhoids and liver ailments. Body system affinity - liver, spleen, immune system, skin, mucous membranes.
Description	Woodland herbaceous perennial. Greenish-white flower, orange, red berries 6-12 inches, yellow root stalk .
Other	This plant must be used with extreme caution both spiritually and physically as it can be poisonous if used inappropriately. Goldenseal is best used for acute situations on a short-term basis, as it can irritate mucous membranes after prolonged use and reduces the gut's capacity to absorb nutrients, especially B vitamins. Contains alkaloids.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Lemongrass
Botanical Name	Cymbopogon flexuosus
Climate	Tropical perennial/Temperate annual
Planting Instructions	Easily grown from seed in the summer in warm soil. Prefers compost-rich soil. Start seeds in containers inside or in a sunny location when the ground is warm. Bring them inside in the winter if planted in pots.
Light	Keep plants indoors or in the garden in a sunny place
Water	Plants prefer moisture
Germination Rate	12 days. Needs light to germinate.
Days to Maturity	Roots will be established by winter.
Special Instructions	Cut outer leaves at the base as needed. Store in an airtight container to preserve volatile oils.
Part of Plant used Medicinally	Leaves, essential oils
Spiritual Needs	Lemongrass is a masculine plant. It can be used as an aid in the development of psychic powers and for protection when worn or cast around the home.
Medicinal Uses	Lemon grass reduces inflammation in the gastrointestinal system, aids in digestion and is used to treat cholera and rheumatism as well as fever with significant congestion. Applied externally as a poultice or as an essential oil, it eases pain and arthritis. The paste of the leaves can be smeared to patches of ringworm.
Description	Tropical perennial/ temperate annual. Aromatic
Other	
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Maca
Botanical Name	Lepidium peruvianum
Climate	Tropical
Planting Instructions	Easy germination in cold or warm soils. Recommend direct seeding into garden. Sow seeds thickly in early spring. Prefers cold, poor or clayey soils.
Light	Prefers full sun
Water	Thrives on very little water
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Root
Spiritual Needs	Maca is a masculine plant. It increases mental and psychic powers.
Medicinal Uses	Nutritive - high in protein, iron, iodine amino acids and trace minerals. Roots strengthen and balance the endocrine and reproductive system. It has a reducing effect on diastolic arterial pressure, and promotes the use of glucose in the bloodstream for energy rather than it being processed into fat storage. It is also used to increase energy, vitality and to promote mental clarity. Maca is helpful in encouraging fertility in both men and women. Maca has helped diminish symptoms of menopause such as hot flashes and mood swings.
Description	Matting Perennial. Creeping rosette. Flowers off-white and grows about 3 in. tall. In high elevations, attains only height of 1 in., although rosettes spread substantially.
Other	High elevation plant adapted to summer cultivation at elevation in the equatorial regions, Rockies or coast ranges or in the far north. Developing plants may burn up in hot weather. In temperate gardens in Midwest and East, plant is best grown as a spring herb, direct seeded as soon as the ground is workable and harvested before summer heat. However, the roots are small. In coastal temperate areas, it is grown as a winter herb, seeding in the autumn when soils begin to cool. The plant flowers in the early spring after overwintering.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Ma-Huang
Botanical Name	Ephedra sinica
Climate	Temperate
Planting Instructions	Easily grown from seed. Sow in spring in dry, sandy soils or start early in the greenhouse and transplant outdoors.
Light	Prefers full sun.
Water	Prefers dry soil
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	Grows slowly, flowers in early summer.
Special Instructions	Stems can be collected in any season.
Part of Plant used Medicinally	Stem
Spiritual Needs	Ma-Huang is a masculine plant. It strengthens the spirit and raises vibrations.
Medicinal Uses	Ephedra stimulates the sympathetic nervous system - it increases blood pressure, dilates the bronchioles, stimulates circulation, increases breathing rate, increases urination and elevates blood sugar levels. This herb is used to reduce inflammation, for asthma (reduces asthma attacks), hay fever, acute onset of colds and flu, raises blood pressure (good for shock), cools fevers and alleviates symptoms of rheumatism.
Description	Perennial, primitive shrub
Other	Use this herb with caution as it can over-stimulate the body, suppress the immune system and deplete the adrenals.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Oregon Grape
Botanical Name	Berberis aquifolium
Climate	Temperate
Planting Instructions	Sow outdoors in fall or early spring or start earlier in the greenhouse. Allow seedlings to grow for a year or more in nursery beds or in pots, then transplant to a permanent location with a lot of distance between plants.
Light	Prefers semi-shade or no shade
Water	Dry or moist soil
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	Harvest roots and lower yellow stems from mid-summer to winter. Harvest the leaves from May through mid-fall. Wash roots and stems while still fresh. Do not use bark or stems with little or no color. Dried leaves if stored out of the light will last up to a year, dried roots and stems will last for several years.
Part of Plant used Medicinally	The root is the primary part used of this plant. "Grapes" are edible.
Spiritual Needs	Oregon Grape is a feminine plant. It is earthy and grounding.
Medicinal Uses	Gently stimulates liver function and regulates secretions of the mucous membranes. It is used to regulate the digestive system, detoxifies the blood, enhances the immune system and can be used to prevent or treat infections, internally and externally. Mildly stimulating to the thyroid, releases stored iron into the blood stream. Externally it can be used as an eye wash. It is used for gastritis, digestive weakness, Crohn's disease, hepatitis, cirrhosis, anemia, indigestion, gastrointestinal ulcers, anorexia, fungal and bacterial infections, allergies, congestion problems (mainly in the gut) and chronic skin conditions. Oregon Grape has special affinity for the liver, gallbladder, spleen and mucous membranes.
Description	Perennial evergreen shrub. Bright yellow flowers. Grows to 6 ft.
Other	As with Goldenseal, Oregon Grape root is to be used with care and not on a long-term basis, though it is less irritating than Goldenseal. Roots yield a golden dye. Contains alkaloids. Do not take during pregnancy.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Phyllanthus
Botanical Name	Phyllanthus niruri
Climate	Tropical
Planting Instructions	Easy cultivation. Press into soil surface and keep moist. Prefers moderate spacing. Prefers alkaline (dolomite, egg shells, limestone, wood ash) soil.
Light	Full sun to light shade
Water	Moist soil
Germination Rate	Slow to germinate
Days to Maturity	Fowers and fruits from January to October.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Entire plant.
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Tones the stomach, stimulates menses, cools fevers, treats viral hepatitis A, B and C, treats fevers, is antiviral, antibacterial and anti-inflammatory, is a laxative, treats hypoglycemia and low blood pressure, genito-urinary infections. Treats kidney and gallstone problems.
Description	Annual, shrubby herb with bell-like, dangling flowers. Grows 2 ft. tall.
Other	
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Poison Hemlock
Botanical Name	Conium maculatum
Climate	Temperate
Planting Instructions	Easily grown from seed. Sow seed in early spring directly in the garden. Barely cover, tamp down and keep moist until germination. Can grow in a variety of soil types and pH. Sow fresh seed in summer as soon as it ripens.
Light	Full sun or partial shade.
Water	Requires moist soil.
Germination Rate	Fresh seed sown in summer will germinate in the fall.
Days to Maturity	Fresh seed sown in summer will take root before winter.
Special Instructions	The leaves and stems should be harvested when the first fruits are forming, since they are then at their most active medicinally. The fruits are gathered either when fully ripe, or before they turn from green to yellow, and are then dried.
Part of Plant used Medicinally	Dried seeds, roots or leaves.
Spiritual Needs	Poison Hemlock is a feminine plant used in astral projection, meditations, visions. It is a protective herb.
Medicinal Uses	Minute dosages of the freshly-prepared tincture or fresh plant succus is used for calming nervous excitation and restlessness and for relieving neuralgic or rheumatic pain as a sedative and analgesic. In the past, it was prescribed for treatment of epilepsy, chorea and Parkinson's disease. Homeopathically it is also used for paralysis, growth of tumors, weakness of body and mind, headaches that dull the senses, dry coughs and extreme sensitivity to light.
Description	Grows from 3 to 15ft. Tall.
Other	This plant must be used with extreme caution both spiritually and physically as it can be poisonous if used inappropriately. - do not handle with bare hands, use only in very low doses- a homeopathic preparation is recommended. An overdose will paralyze breathing and cause death. High in alkaloids.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Poppy, Breadseed (opium poppy)
Botanical Name	Papaver somniferum
Climate	Temperate
Planting Instructions	The plant does well in a variety of soils and tolerates acidic neutral or basic soils. Sow in the spring or autumn. Self sows if seeds are not harvested.
Light	Full sun
Water	Well drained, moist soil.
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	During the summer, the seed capsules are cut and the white latex that exudes is gathered the next day and dried.
Part of Plant used Medicinally	latex (milk from stalks and leaves), leaves and flower heads.
Spiritual Needs	Opium poppy is a feminine plant used in dreamtime, for invisibility and for the healing of heart.
Medicinal Uses	Sedates and relieves pain. A decoction of leaves and flowerheads induce sleep. Mashed flowerheads mixed with flour to make a plaster treats inflammations and St. Anthony's fire (erysipelas, a bacterial infection of the skin). Reduces and suppresses nervous activity, pain and coughs. Also a remedy for acute diarrhea.
Description	Annual or overwintering annual. Lavender flowers, dark basal spot, giant pods. Flowers grow 3 to 4 ft. tall
Other	This plant must be used with extreme caution both spiritually and physically as it can be poisonous if used inappropriately. Alkaloid-rich herb - alkaloids are chemical compounds that can be toxic in high doses. Do not mix with herbs high in tannin content (oak, spruce, agrimony, cinnamon, witchhazel)
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Purslane
Botanical Name	Portulaca oleracea
Climate	Temperate
Planting Instructions	Seeds germinate readily in warm soils. Prefers lighr or compost rich soils. Prefers a moderate amount of space between plants. Sow seeds directly outdoors in the late spring to early summer or start earlier in the greenhouse and transplant outdoors.
Light	Full sun to partial shade
Water	Prefers rich soils where water puddles up then drains. Likes deep watering several times a week.
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	Will be established by winter
Special Instructions	Harvest greens and flowers in the spring to summer. Harvest taproots in the fall and spring.
Part of Plant used Medicinally	Entire plant.
Spiritual Needs	Purslane is a feminine plant used for protection in dreamtime, for spiritual and physical protection.
Medicinal Uses	This is a highly nutritive herb. It is one of the only sources of omega-3 fatty acids in plants. It contains much calcium, iron, vitamin A and C as well as potassium salts and amino acids. Prevents scurvy and is used to treat headaches, stomach ache, dysentery, diarrhea, intestinal worms, appendicitis, difficulty in urination and as an antidote to wasp stings and snake bites. As an external wash, the juice or decoction relieves skin ailments such as boils and carbuncles and helps reduce fever (internally).
Description	Creeping annual. Grows to 6 inches
Other	
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Shiso, Red Leaf
Botanical Name	Perilla frutescens
Climate	Tropical
Planting Instructions	Sow seed directly in the greenhouse in mid-spring and cover lightly with soil. Prefers sandy or compost rich soils. Transplant in early summer. Can tolerate any pH. Prefers a moderate amount of space. Prefers acidic (compost rich) soil. Not frost hardy. Seed should be used within 1 year.
Light	Plant prefers partial shade to full sun.
Water	Prefers regular watering
Germination Rate	11 days and grows rapidly.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Leaves, stems and seeds
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	The entire plant is very nutritious, with numerous vitamins, flavonoids and minerals. An infusion of the plant is useful in the treatment of asthma, colds, cough and lung afflictions, influenza prevention, nausea, vomiting, abdominal pain, constipation, food poisoning and allergic reactions (especially from seafood), and to restore health and balance. The stems are a traditional Chinese remedy for morning sickness and restless fetus in pregnancy, though some say the herb should be avoided by pregnant women.
Description	Annual. Grows to 3 ft.
Other	Perilla seed oil has been used for protective waterproof coatings on cloth. The crushed plant also makes an effective insecticide.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Skullcap, Official
Botanical Name	Scutellaria lateriflora
Climate	Temperate
Planting Instructions	Prefers compost rich soil. Grows easily from seed and is generally sown in the spring directly outdoors or started in the greenhouse and transplanted outdoors. It tends to prefer soils that retain moisture (contain moderate amounts of compost or organic matter) and can withstand colder temperatures. Skullcap prefers a moderate amount of spacing between plants.
Light	Prefers partial shade or full sun
Water	Prefers plenty of water.
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	Will flower or at least be well established by winter if sown in the spring.
Special Instructions	Gather flowers and stems while in flower. Harvest leaves in late spring and early summer when in flower.
Part of Plant used Medicinally	Flowers, leaves and stems
Spiritual Needs	Scullcap is a feminine herb, it is use for meditation, peace and love.
Medicinal Uses	Scullcap tones the nerves, it is calming to the central nervous system and the musculoskeletal system. It is used for insomnia, anxiety and muscle spasms, epilepsy and chorea (muscle twitching), muscular pain and inflammation. It is effective to lessen withdrawal symptoms from alcohol or drug use due to its detoxification effects. It is also used to induce perspiration and reduce temperature in feverish children.
Description	Creeping herbaceous perennial. Blue flowers, grows 2 to 4 ft. tall.
Other	Rich in minerals.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Spilanthes, Brede Mafane
Botanical Name	Spilanthes acmella
Climate	Tropical perennial/temperate annual
Planting Instructions	Sow in spring pots in a sunny window, directly in the garden, or in the greenhouse to be transplanted into garden. Prefers compost rich soil. Plant 2 feet apart.
Light	Prefers plenty of sun
Water	Prefers plenty of water.
Germination Rate	10 days
Days to Maturity	Matures in late fall or is at least well established by winter if sown in the spring.
Special Instructions	Harvest leaves, stems and buds on an ongoing basis.
Part of Plant used Medicinally	Leaves, stems and buds
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Treats malaria and thrush. It is also used for enhancing the immune system's resistance to infections. It is known to protect against colds and flu and decrease allergic symptoms, indicated in swollen glands and in all types of acute viral, bacterial or fungal infections.
Description	Bright yellow flowers. Grows 12 inches tall.
Other	
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Spilanthes, Official
Botanical Name	Spilanthes acmella
Climate	Tropical perennial/temperate annual
Planting Instructions	Sow in spring pots in a sunny window, directly in the garden, or in the greenhouse to be transplanted into garden. Prefers compost rich soil. Plant 2 feet apart.
Light	Prefers plenty of sun
Water	Prefers plenty of water.
Germination Rate	10 days
Days to Maturity	Matures in late fall or is at least well established by winter if sown in the spring.
Special Instructions	Harvest leaves, stems and buds on an ongoing basis.
Part of Plant used Medicinally	Leaves, stems and buds
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Treats malaria and thrush. It is also used for enhancing the immune system's resistance to infections. It is known to protect against colds and flu and decrease allergic symptoms, indicated in swollen glands and in all types of acute viral, bacterial or fungal infections.
Description	Striking golden, bud-shaped flowers with deep red eyes on glossy green spreading plants.
Other	
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Spilanthes, Velvet
Botanical Name	Spilanthes oleracea
Climate	Tropical perennial/temperate annual
Planting Instructions	Sow in spring pots in a sunny window, directly in the garden, or in the greenhouse. Transplant into garden once plants are well established. Prefers rich soil. Plant 2 feet apart.
Light	Prefers plenty of sun
Water	Prefers plenty of water.
Germination Rate	10 days
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	Harvest leaves and buds on an ongoing basis. Harvest the root at the end of the growing season just before leaves start turning brown.
Part of Plant used Medicinally	root
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	It is used for gout, scurvy, asthma, bladder infections and rheumatism.
Description	Large-leafed, purpled-hued creeper makes barrel-shaped flowers with velvety-red centers.
Other	insecticide,
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	St. John's Wort, Topaz
Botanical Name	Hypericum perforatum
Climate	Temperate
Planting Instructions	St. John's Wort prefers a very sandy soil mix for sowing directly in the ground in the fall. However, once established, it will grow in almost any soil type or elevation. It tolerates temperatures down to -10 F, and will spread readily, once established. It is short lived, so needs to be replanted every few years.
Light	full sun to partial shade
Water	Once established, is drought tolerant
Germination Rate	5 days. Light-dependent germinator
Days to Maturity	Blooms in July - August of the following year if planted in the fall.
Special Instructions	Harvest leaves and tops during midsummer
Part of Plant used Medicinally:	leaves and buds
Spiritual Needs	St. John's Wort is a masculine plant, it enhances dreamtime, visions and purification.
Medicinal Uses	Deep-seated nervine effect, helps restore damaged nerve tissue and deadens pain. Strengthens the urinary organs. An oil sun infusion of the buds is used to treat nerve injuries/trauma topically, it is antiseptic and can also be used to relieve cramp and nerve pain as well as wounds and burns. The oil can be taken internally for peptic ulcers and gastric inflammation. Internally, it is used as a nervine tonic for insomnia, tension, anxiety and depression, especially when associated with menopause. Tones the liver and gall bladder. It is antiviral, anti-inflammatory with both internal and external application.
Description	Herbaceous perennial. Flowers are 3 to 4 ft. tall.
Other	This plant must be used with extreme caution both spiritually and physically as it can be poisonous if used inappropriately.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Golden Root
Botanical Name	Rhodiola rosea
Climate	Temperate
Planting Instructions	Golden Root is easily grown from seeds in the spring or started early in the greenhouse. Sow the tiny seed on the surface of the soil and keep it moist until it germinates. Grow out in pots or in flats and transplant. Prefers a limey soil or rock garden. Self sows if seeds are not collected.
Light	Prefer full sun
Water	Prefer moderate water
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	Flowers in the second year if grown in the spring.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Root
Spiritual Needs	Golden Root is a feminine plant used in divination, visions and healing with the fourth chakra.
Medicinal Uses	Dried roots are high in compounds that stimulate the immune system. Roots tone and strengthen the endocrine system, allowing the body to recuperate from stress. It is similar to Siberian Ginseng. It is also used to improve learning and memory. It may also have anti-cancer properties and the effect of protecting the liver.
Description	Rare. Grows to 10 in. tall. Edible. Dried roots are rose scented.
Other	This plant must be used with extreme caution both spiritually and physically as it can be harmful if used inappropriately.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Hen-and-Chickens
Botanical Name	Sempervivium tectorum
Climate	Temperate
Planting Instructions	Prefers limey soil or rock garden. Flowers in second year. Easy cultivation. Sow very tiny seed on surface of soil in spring and keep moist until germination. Grow out in pots or in flats and transplant, or direct seed with care. Tolerates a wide range of soil types.
Light	Prefer full sun
Water	Prefer moderate water, can tolerate drought.
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	Leaves are harvested as required and used fresh
Part of Plant used Medicinally	Leaves
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	The turgid, tart leaves are chewed fresh to relieve toothache pain. Masticated leaves are also used to make a poultice for bee stings, burns, wounds, boils and corns. Juice can be sniffed to stop nosebleed. Internal use induces vomiting.
Description	Makes a central, rose-hued rosette which produces numerous offshoots. Pink, star-shaped flowers, clustered on a truck rising 1 to 2 ft. tall.
Other	Traditionally planted on sod roofs to protect from lightning strikes. Edible. Contains tannins.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Stonecrop, Goldmoss
Botanical Name	Sedum acre
Climate	Temperate
Planting Instructions	Flowers in the second year. Easily grown from seed. Sow very tiny seed on surface of soil in spring and keep moist until germination. Grow out in pots or early in the greenhouse and transplant outdoors. Prefers limey soil or rock garden but will tolerate a wide range of soil types.
Light	Prefers full sun
Water	Prefers moderate water. They thrive in sweltering tropical jungles, blustery arctic shores and rock gardens.
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	Harvest leaves in spring before flowering.
Part of Plant used Medicinally	Stem and leaves
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Fresh herb is laxative. The leaves are high in vitamin A and C. leaves can be used in the same manner as aloe Vera for burns and skin eruptions. Leaf infusions and root decoctions are used for colds, gargles and as an eye wash for irritated eyes.
Description	Flowers to 2 in. tall, forms a low-lying mat, giving rise to a complete cover of bright yellow flowers.
Other	Edible.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Vernal, Sweet (False Hellebore)
Botanical Name	Adonis vernalis
Climate	Temperate
Planting Instructions	Sow in the fall, midwinter or early spring. Winter hardy. Use regular garden soil. Prefers a moderate amount of space. Best planted in profusion. May take over other nearby plants.
Light	Prefers full sun.
Water	Prefers moisture.
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	The leaves, stems and flowers are harvested every third year as they come into flower
Part of Plant used Medicinally	Leaves, stems and flowers
Spiritual Needs	Sweet vernal is a feminine plant used for invisibility and astral projection.
Medicinal Uses	Cardiac sedative, used mainly for the treatment of tachycardia, extrasystole and arterial hypotension. Also counters water retention due to poor circulatory function. Homeopathically, it is used to treat angina.
Description	Perennial. Makes large, bright-golden blossoms on finely cut foliage. Flowers to 1 ft. tall.
Other	This plant must be used with extreme caution both spiritually and physically as it can be harmful if used inappropriately. Use in low dosages.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Thistle, Globe Artichoke
Botanical Name	Cynara scolymus
Climate	Temperate
Planting Instructions	Easy cultivation. Sow in spring, directly in the garden or in gallon pots. Thin or transplant to 2 ft. apart. Prefers rich and composty soil. Hardy to 20 degrees F. Add more compost around plant throughout growing season. Add more compost around plant throughout growing season.
Light	Prefers full sun.
Water	Prefers moisture.
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	Matures in late fall or is at least well established by winter
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Leaf
Spiritual Needs	Artichoke is a masculine plant. It aids in the strength of spirit, it is used for protection and purification.
Medicinal Uses	Leaf is used as a digestive tea to treat indigestion, liver disharmony, arteriosclerosis, gallstones and obesity. It is also used to repair the integrity of the gastrointestinal tract. Also used in the early stages of late-onset diabetes, as it lowers blood sugar levels, stimulates urine production and is a liver and gallbladder tonic. Used for nausea, indigestion and bloating.
Description	Perennial. Produces giant, edible globes in one season. Flowering purple to 5 ft. tall.
Other	
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Thistle, Blessed
Botanical Name	Cnicus benedictus
Climate	Tropical
Planting Instructions	Direct seed any time from fall to late spring or start earlier in the greenhouse and transplant outdoors. Prefers a moderate amount of space. Prefers well manuered soil.
Light	Full sun
Water	Dry soil
Germination Rate	2-6 weeks
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	The entire plant is harvested in early flower and shade dried.
Part of Plant used Medicinally	Entire plant
Spiritual Needs	Blessed thistle is a masculine plant used for protection and purification.
Medicinal Uses	Tea stimulates appetite, aids digestion and diminishes pain of migraine. It improves liver function and regulates female hormones. It promotes sweating, good for all malignant and pestilential fevers, destroys worms in t the stomach and good against all sorts of poison.
Description	Annual or overwintering annual. Grows up to 2 ft. covered with down, barely prickly at leaf tips. Flowers yellow to 1 ft. tall.
Other	
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Thistle, Carline
Botanical Name	Carlina acaulis
Climate	Temperate
Planting Instructions	Sow in spring or early summer. Prefers a moderate amount of space. Grows well in any pH soil and thrives well in very alkaline soil. Prefers poor soil.
Light	Full sun
Water	Dry or moist soils. Once established, is drought tolerant.
Germination Rate	4 weeks
Days to Maturity	Matures in the fall or is at least well established by winter when sown in the spring.
Special Instructions	The root is harvested in the autumn and dried for later use.
Part of Plant used Medicinally	Roots
Spiritual Needs	Carline thistle is a masculine plant used for purification, healing and to see rightfully.
Medicinal Uses	Powerfully antiseptic, used similarly to Elecampane for coughs and bronchial irritation. It is also used as a purgative. Treats spasms of the digestive tract, gall bladder and liver disorders, dropsy, urine retention, skin complaints such as acne and eczema. A decoction of the root can be used externally to cleanse wounds or as an antiseptic gargle. It is also antibiotic and treats fevers, aids in digestion, increases perspiration.
Description	Biennial. Flowers large and silvery to 2 ft. tall.
Other	Legendary thistle used to cure pestilence.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Thistle, Musk
Botanical Name	Carduus nutans
Climate	Tropical
Planting Instructions	Sow in fall or early spring, in garden or cold greenhouse. Plant prefers soils with alkaline pH (limestone, dolomite, egg shells, wood ash). Plant prefers a lot of space.
Light	Plant prefers full sun.
Water	Plant prefers dry or sandy soils.
Germination Rate	Will germinate after several seasonal cycles.
Days to Maturity	July to August if sown during the spring
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Flowers, oil from seed
Spiritual Needs	Musk thistle is a masculine plant used in divination, invisibility and justice. It revives consciousness and powers.
Medicinal Uses	Blood Purifier and good for fever. The oil contains linoleic acid which aids in the prevention of atherosclerosis. As part of the thistle family, Musk thistle is healing towards the spleen and liver, as are all thitles. The musk aspect of this thistle makes it cleansing and nutritive to these organs. As we have never grown this particular plant, we will be working with it spiritually to understand its healing properties and will pass on all information to you as we learn.
Description	Biennial, flowering from May to August
Other	This plant must be used with extreme caution both spiritually and physically as it can be harmful if used inappropriately. Pithy stem is excellent as a cooked vegetable. The down may be used as a material in making paper. Attracts bees and butterflies.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Thistle, Noble
Botanical Name	Eryngium planum
Climate	Tropical
Planting Instructions	Easily grown from seed. Sow in fall, spring or summer directly in the garden or early in the greenhouse and transplanted outdoors. Plant prefers dry, calcareous soil. Can grow in nutritionally poor soil. Cold hardy. Prefers a moderate amount of space between plants. Self seeding if seeds are not removed.
Light	Plant prefers full sun.
Water	Requires dry or moist well drained soil. Drought tolerant.
Germination Rate	10 to 90 days
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Spiritual Needs	Noble thistle is a masculine plant used for movement of spirit.
Medicinal Uses	Treats dropsy, reduces water retention. Treats whooping cough.
Description	Herbaceous perennial. Flowers blue to 2 ft. tall.
Other	Attracts bees
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Vaccaria
Botanical Name	Vaccaria pyramidata
Climate	Temperate
Planting Instructions	Easily grown from seed. Direct seed in the garden in the spring or start early in the greenhouse and transplant outdoors. Prefers compost-rich soil. Needs little space. Fast growing.
Light	Prefers sun or partial shade
Water	Prefers moisture.
Germination Rate	7 days
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Seed
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Reduces water retention, increases milk flow and brings oxygen and nutrients to the blood. It is also used against kidney stones and tumors of the breast.
Description	Flowers pink to 2 ft. tall. Lush vegetation gives way to flowers and then seed pods.
Other	
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Lettuce, Wild
Botanical Name	Lactuca virosa
Climate	Temperate
Planting Instructions	Easily grown from seed in the spring or fall directly into the soil and only just covered with soil or start early in the greenhouse and transplant outdoors. Prefers sandy and compost rich soil. Frost hardy.
Light	Full sun
Water	Moist soil
Germination Rate	Quick germination
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	Gently take off the flowering head and allow the medicinal milk to harden and dry in the sun.
Part of Plant used Medicinally	latex (milk from stalks and leaves)
Spiritual Needs	Wild lettuce is a feminine plant used for freedom of expression, for the purification of spirit and for dreamtime.
Medicinal Uses	Contains the highest concentration of the bitter sap, which when milked from the plant and dried is known as lactucarium. The latex is mildly sedative, calms coughs, relieves spasms, especially of the respiratory tract and helps relieve pain.
Description	flowers yellow to 6 ft.
Other	This plant must be used with extreme caution both spiritually and physically as it can be harmful if used inappropriately. Contains some alkaloids - overdose may cause poisoning.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Woad
Botanical Name	Isatis tinctoria
Climate	Temperate
Planting Instructions	Easy grown from seed. Sow seed directly in garden in the spring and thin seedlings the following spring. Prefers average to poor soils. It needs a moderate amount of space between plants. Once established, Woad will self sow freely each year. If planted well away from related crops, Woad will have fewer pest problems.
Light	Prefers full sun
Water	Prefers well drained soil.
Germination Rate	10 days
Days to Maturity	Flowers early in the second year.
Special Instructions	Leaves are harvested in the summer
Part of Plant used Medicinally	leaves, roots
Spiritual Needs	Woad is a feminine plant use for the purification of judgements.
Medicinal Uses	This herb is used externally as a poultice or wash as an antiseptic gargle. An ointment of the leaves staunches bleeding, for moist ulcers and cools inflammations. A plaster relieves inflammation of the liver and spleen applied directly to that area.
Description	Flowers yellow to 4 ft.
Other	Natural blue dye.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Yerba del Lobo
Botanical Name	Helenium hoopesii
Climate	Temperate
Planting Instructions	Seed - sow spring in a greenhouse. Transplant into individual pots and grow them on in the greenhouse for their first winter. Plant them out into their permanent positions in late spring or early summer, after the last expected frosts.
Light	Semi-shade or no shade
Water	Likes plenty of water
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant's needs.
Special Instructions	We know that generally, leaves are ready for harvest before the plant starts to flower. We will watch this plant and work with it spiritually, to determine when it prefers to be harvested and will pass on all the information to you as we gain in understanding of this plant's needs.
Part of Plant used Medicinally	Leaves
Spiritual Needs	Yerba del Lobo is a feminine plant used for beauty, healing and psychic powers.
Medicinal Uses	Applied externally as a liniment, this herb helps resolve bruises (similar to Arnica), relieves inflammation from injuries and sprains and reduces varicosities.
Description	Flowers yellow to 3 ft.
Other	Good bee and butterfly plant.
Purchased From	Horizon Herbs

Medicinal Seed Information

Common Name	Agrimony
Botanical Name	Agrimonia eupatoria
Climate	Temperate
Planting Instructions	Easily started from seed and will self seed once it is established. Sow in the Fall or early spring. Seedlings have varying preferences for spacing and must be asked as to how close they want to be planted. Very tolerant to varying soil pH. Cold hardy to temperatures of -30 to -40 F.
Light	Prefers partial to full sun.
Water	Prefers average to dry soil.
Germination Rate	Slow to germinate: 5-14 weeks
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	Gently take the whole plant, leaving only the roots, when flowers are just blooming. Dry in the shade.
Part of Plant used	flowers, leaves and stems
Spiritual Needs	Agrimony is a masculine plant used for protection and dreamtime.
Medicinal Uses	Used to heal wounds, staunches bleeding and encourages clot formation. It is astringent and mildly bitter, is a gentle tonic for digestion and has been used for kidney stones, sore throats, rheumatism, arthritis and urinary incontinence. Tea also soothes inflammation of the urinary tract.
Description	hardy perennial with small yellow flowers. Ornamental and fragrant flowers to 3 to 5 feet.
Other	Yellow dye, high in tannins - do not mix with herbs high in alkaloids (e.g. opium poppy, California poppy)
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Aloe
Botanical Name	Aloe melanacantha
Climate	Dry, desert regions
Planting Instructions	Requires a minimum of 41 F to survive and grows well if grown in a container and brought indoors in the winter or kept indoors year-round. Prefers soil containing limestone, but will prosper in soil low in nutrients. Will thrive for years in the same pot if it has good soil. It seems to grow best when the roots are fairly crowded, so avoid repotting.
Light	Prefers full sun but will tolerate some shade.
Water	Aloe does not require frequent watering, however plants that are fully exposed to the sun require a little more water than those in partial shade or they will become stunted and thin. During the spring and summer, water when the soil is moderately dry. In the winter, allow the soil to dry completely between waterings. Drainage is very important, so the soil should not contain large quantities of organic matter.
Germination Rate	2 weeks
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	Easily propagated from offshoots that grow around the base of the plant. They can be removed gently by taking the plant out of the soil, gently separating the offshoots and repotting them and returning the mother plant to its pot. When you harvest, gently take the outermost leaves first as the plant produces new leaves from its center. Peel away the waxy skin to expose the gel and juice.
Part of Plant used	Juice
Spiritual Needs	Aloe is a feminine plant used in cleansing and protection.
Medicinal Uses	Dried juice is used as a purgative. Fresh application of juice is used to heal wounds and burns, including X-ray and radiation burns, promoting cell growth and speeding the healing process.
Description	Perennial succulents with rosettes of spiny-toothed sword-shaped leaves and showy tubular flowers. Short-stemmed, foot-wide rosettes of triangular bronzy leaves with stout black and white thorns on the edges and backs. Scarlet flowers turning yellow, three feet high
Other	
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	American Spikenard
Botanical Name	Aralia racemosa
Climate	Temperate
Planting Instructions	Sow in the fall to produce seedlings over the next two years. Outdoor treatment is best. Grows well in the woods. Seeds often have double dormancy, and need scarification and cold treatment or warm then cold treatment.
Light	Full or semi-shade
Water	Moist soil
Germination Rate	1-4 months
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	Harvest rootstalk and root in the summer
Part of Plant used	Root and rootstalk
Spiritual Needs	American Spikenard is used in cleansing, purification and for balance.
Medicinal Uses	Spinkenard is used for backache, rheumatism, asthma, coughs, flatulence, breast pain, blood poisoning, eczema (topically as a poultice) and urinary troubles. It encourages sweating, stimulates the body and detoxifies the body.
Description	Deciduous tree, grows to 6 feet tall with large leaves, small flowers and blue berries.
Other	Grown for food or medicinal use
Purchased from	J.L. Hudson

Medicinal Seed Information

Common Name	Ashwagandha
Botanical Name	Withania somnifera
Climate	Tropical/ (perennial), Temperate (annual)
Planting Instructions	Easily grown from seed. Broadcast seeds in early spring in deeply dug soil after heavy rainfall and cover lightly with soil or start early in the greenhouse and transplant outdoors. Not winter hardy. Prefers to be planted about a foot apart.
Light	Full sun, cannot grow in the shade.
Water	Requires very little water and well drained soil.
Germination Rate	15 days - light dependent 50%-100% germination
Days to Maturity	160-190 days
Special Instructions	Harvest root when red flowers boom and leaves start dying.
Part of Plant used Medicinally	Leaves, seeds and roots
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Improves memory, is antibiotic, anti-viral and insecticidal, tonic and hypnotic. This herb also regulates and nourishes the endocrine system and treats anemia due to its high iron content. It reduces water retention and inflammation in rheumatism, fevers, sores and asthma; dried root is a Ginseng-like tonic of the Ayurvedics. Stimulates activation of immune system cell and is used to treat growths.
Description	Perennial or annual. Ornamental woolly or hoary shrubs with clustered flowers and Chinese-lantern-like fruits. Small whitish to yellow flowers followed by attractive scarlet berries. 1 to 7 feet tall with downy leaves.
Other	Berries are used as soap
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Astragalus
Botanical Name	Astragalus membranaceus
Climate	Dry temperate
Planting Instructions	Easy cultivation. Scarify or nick seed lightly, and use rhizobium inoculant (available through Horizon Herbs). Direct seed in early spring. Prefers to be planted close together. Prefers average soil or sandy, slightly alkaline soil.
Light	Prefers full sun
Water	Prefers good drainage. Prefers to be bottom watered while small.
Germination Rate	1-2 weeks without nicking. Good cold soil germinator.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Long, flexible roots
Spiritual Needs	Astragalus is a feminine plant used in purification, cleansing and balance.
Medicinal Uses	Astragalus is an energy tonic, helps the body to adapt to external influences, especially to cold. Encourages blood flow to the surface, used for night sweats, relieves fluid retention, reduces thirstiness, increases appetite, stimulates the immune system and treats prolapsed organs, especially the uterus and is beneficial for uterine bleeding. Also useful to discharge pus and to promote healing of ulcers, for poor circulation and lassitude. This herb is usually used on younger people instead of Ginseng. Astragalus also strengthens digestion, raises the metabolism and treats chronic weakness of the lungs. It is very effective in cases of nephritis (6-15 gms).
Description	Light yellow flowers to 4 ft. tall, in spikes, followed by semi-transparent pods. Hardy perennial to 2 ft. with long, flexible roots.
Other	Soil builder and mineral indicator. Provides food, forage and medicinals.
Purchased From	Horizon

Medicinal Seed Information

Common Name	Bilberry
Botanical Name	Vaccinium myrtillus
Climate	Temperate
Planting Instructions	Best sown on the surface of the soil in the late summer or fall in with a lot of light. Prefers acidic soil (compost rich). Prefers a small amount of space between plants.
Light	Give partial shade to developing seedlings
Water	Prefers moist soil
Germination Rate	3-4 weeks. 75%-100%. Slow to germinate; ongoing germination.
Days to Maturity	Will take root by winter
Special Instructions	Fruit and leaves are collected in the summer.
Part of Plant used Medicinally	leaves and berries
Spiritual Needs	Billberry is a feminine plant used to see rightly, for purification and for cleansing.
Medicinal Uses	Used medicinally like Uva ursi, for cystitis and other urinary tract problems. Ripe fruit is mildly laxative due to high sugar content. Dry fruit is constipating and has antibacterial action. A decoction of dried fruit is useful for diarrhea. Leaves and berries are used to treat varicose veins, hemorrhoids, capillary fragility, to improve eyesight and are used to prevent and improve degeneration of the retina. Leaves may be helpful in pre-diabetic states as well. Tannin and anthocyanidin-rich berries are astringent, antioxidant and antibacterial.
Description	Perennial woody shrub. Bell shaped flowers. Tiny shrub rarely over 2 ft with leathery myrtle-like leaves. White or pink flowers. Black berries.
Other	Edible berries. Indelible purple dye. Rick in tannings, do not use with alkaloid-containing herbs. Do not use for longer than 3 weeks at a time.
Purchased From	Horizon

Medicinal Seed Information

Common Name	Bitter Melon (Ceracee)
Botanical Name	Momordica charantia
Climate	Tropical
Planting Instructions	Quick growing, preferring warm soil and a long season. Start early indoors in the north and treat like cucumbers or sow directly into the garden in warmer climates. Plant seeds about 1/2 inch deep. Provide compost rich soil and a trellis. Prefers a moderate amount of space between plants. Frost can kill the plants.
Light	Requires plenty of sun.
Water	Prefers moist soil. Water frequently.
Germination Rate	1-3 weeks at warm temperatures - 50%-75% germination. Seed viable for 3-4 years.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	Harvest fruits 8-10 days after flowers open.
Part of Plant used Medicinally	Leaves , seed oil, fruit. Seed may be tinctured fresh.
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Ripe fruits are soaked in alcohol and used externally as a rub for skin diseases, muscle and head aches. The ripe fruit is a stomach tonic and induces menstruation, also used to treat ulcers, lowers blood sugar levels, expels worms, urinary stones and is used to treat fever. The juice of the fruit is used as a purgative, for colic and gas. A decoction of the leaves is taken for liver problems and colitis. The seed oil is used on wounds.
Description	Perennial vine, grows as an annual in temperate climates. Tendril climbing vines. Yellow inch wide flowers followed by odd attractive 4-9" fruits which turn orange when ripe and split to expose seeds which are enclosed in a mucilaginous, dark red jelly-like arils. Grows up to 30 ft with deeply lobed leaves. Vines to about 6 ft.
Other	Fruits are boiled before eating to remove bitterness. Bitter parts eaten in excess may be toxic. Bright red aril and seed may also be eaten. Use in low dosage. Do not take longer than 4 weeks or if prone to low blood sugar levels.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Black Cohosh
Botanical Name	Cimicifuga racemosa
Climate	Temperate
Planting Instructions	Sow in the spring, summer or fall to germinate the following spring, or give cold treatment for 2 weeks, then warm for 2 weeks, then expect germination as the ground warms again. Grows best in compost rich soil. If growing in the greenhouse keep seedlings in pots for a full growing season and transplant in the fall. Prefers rich soil of forest or shade garden. Prefers a lot of spacing between plants.
Light	Prefers shade
Water	Prefers plenty of moisture
Germination Rate	1-6 months - see planting instructions. 75%-100% germination.
Days to Maturity	Approx. 1 year
Special Instructions	Harvest roots in the fall after the fruits have ripened.
Part of Plant used Medicinally	Root
Spiritual Needs	Black cohosh is a masculine plant used for courage, protection and to drive away evil.
Medicinal Uses	Black cohosh is an astringent, encourages menstrual flow, decreases water retention, antidotes poisons such as those from a snakebite, stops violent coughing, elevates mood, relieves pain (especially nerve pain), dilates the peripheral blood vessels, reduces muscle spasms (especially smooth muscle in the uterus and respiratory tract), relieves inflammation, ringing in the ears and helps control hot flashes during menopause. During delivery, it regulates uterine contractions. Black Cohosh decreases production of progesterone and increases estrogen production.
Description	Tall, herbaceous perennial. Grows to 8 ft. White flowers in long wands, with clumps of shiny dark leaves
Other	Avoid during pregnancy. An overdose can result in intense headache, dizziness, visual disturbances, slow pulse rate, nausea and vomiting.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Blushing Glory-Bind
Botanical Name	Convolvulus erubescens
Climate	Tropical
Planting Instructions	Easily grown in most soils with little care. Soak seed, nick if unswollen. Sow in early spring 1/4" deep. In cold climates it cal be grown as an annual if started early, or the carried over indoors. Long bloom period.
Light	Prefers full sun
Water	Moist soil
Germination Rate	1-3 days at 60-65 F. 75%-100% germination. Seeds have grown well after being stored up to 26 years.
Days to Maturity	Will be established by winter if sown in the spring.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Spiritual Needs	Do not know, will have to work with it.
Medicinal Uses	Digestive problems.
Description	Hardy perennial. Twining vines ore upright herbs with funnel-shaped morning-glory-like flowers. Vigorous growers, only a few are invasive or weedy. Small pink or white 1/2" flowers, slightly five-pointed. Half hardy twining or trailing perennial to 3-6 ft. from a thick rootstock. Odd, often silvery foliage, the leaves ranging from narrow spear-shaped to palmately divided.
Other	
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Calendula, Field Marigold
Botanical Name	Calendula officinalis
Climate	Temperate
Planting Instructions	Sow seed directly into garden in warm soils in April or May or start early in the greenhouse and transplant outdoors. Plant 1/4 inch deep as it needs to germinate in the dark. Prefers a small amount of space between plants. Survives frost and early snow. Seed is not ripe for 6 months, therefore, newly harvested seed will not germinate well until the following spring. Seeds last for only a year, so using fresh ripened seed is essential. Thrives in the poorest soils and harsh conditions. Will self sow if seeds are not removed and adapts well to new environments.
Light	Full sun
Water	Well drained soil.
Germination Rate	About half dormant. Four weeks cold helps. Germinates in 1-5 weeks. 75%-100% germination.
Days to Maturity	40-50 days. Blooms late summer or early fall if sown in the spring.
Special Instructions	Harvest petals in full bloom and dry on white cloth if possible.
Part of Plant used Medicinally	Petals
Spiritual Needs	Calendula is a feminine plant used in nurturing, honoring and expansive. Petals comfort the heart and spirits.
Medicinal Uses	Flowers have highly antiseptic and healing properties for the skin when applied as a salve, succus (fresh plant juice), tincture or simply masticated to an injury. Prevents inflammation, promotes formation of granulation tissue in wounds (prevents scarring), prevents hemorrhaging, relieves muscle spasms and is astringent. Calendula succus is also used as a wash externally to heal and cleanse the peritoneal area after giving birth. Calendula flowers aid in digestion as a bitter, increasing gastric juices. It is used for wounds, cut, scrapes, burns, fungal conditions, diaper rash, peptic ulcers, measles, conjunctivitis (as a wash), earaches, inflammation of the intestines and cleanse the liver and gallbladder.
Description	Hardy annual to 1-2ft. Flowers to 18 inches tall. Large yellow and orange daisies.
Other	Flowers, when boiled, yield a bright yellow-orange dye.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Calendula, Pacific Beauty
Botanical Name	Calendula officinalis
Climate	Temperate
Planting Instructions	Sow seed directly into garden in warm soils in April or May or start early in the greenhouse and transplant outdoors. Plant 1/4 inch deep as it needs to germinate in the dark. Prefers a small amount of space between plants. Survives frost and early snow. Seed is not ripe for 6 months, therefore, newly harvested seed will not germinate well until the following spring. Seeds last for only a year, so using fresh ripened seed is essential. Thrives in the poorest soils and harsh conditions. Will self sow if seeds are not removed and adapts well to new environments.
Light	Full sun
Water	Well drained soil.
Germination Rate	About half dormant. Four weeks cold helps. 1-3 weeks. 75%-100% germination.
Days to Maturity	40-50 days. Blooms late summer or early fall if sown in the spring.
Special Instructions	Harvest petals in full bloom and dry on white cloth if possible.
Part of Plant used Medicinally	Petals
Spiritual Needs	Pacific Beauty Calendula is a feminine plant used in nurturing, grounding and for inner work.
Medicinal Uses	Flowers have highly antiseptic and healing properties for the skin when applied as a salve, succus (fresh plant juice), tincture or simply masticated to an injury. Prevents inflammation, promotes formation of granulation tissue in wounds (prevents scarring), prevents hemorrhaging, relieves muscle spasms and is astringent. Calendula succus is also used as a wash externally to heal and cleanse the peritoneal area after giving birth. Calendula flowers aid in digestion as a bitter, increasing gastric juices. It is used for wounds, cut, scraped, burns, fungal conditions, diaper rash, peptic ulcers, inflammation of the intestines and cleanses the liver and gallbladder.
Description	Hardy annual to 1-2ft. Flowers to 18 inches tall.
Other	Flowers, when boiled, yield a bright yellow-orange dye.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	California Poppy
Botanical Name	Eszcholzia californica
Climate	Temperate
Planting Instructions	Direct seed into cold, compost-rich soils in the fall or early spring, pressing hard into the surface. It is not recommended to transplant poppy. Grows rapidly in rich, sandy soils, but does well in poor dry soils. Sow where they are to stand, at intervals through March and April. Self sows when not crowded by weeds. Does not like growing next to Pineapple Weed. It is best to grow it on its own bed.
Light	Prefers sunny places and hot, dry conditions.
Water	Prefers well drained places and moist soil
Germination Rate	75%-100% germination rate. Short lived seed--sow within 2 years of receipt.
Days to Maturity	Blooms in late summer or fall of the first year
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Entire herb, especially root and seed capsule
Spiritual Needs	California Poppy is a feminine plant used for invisibility and is curative to the spirit.
Medicinal Uses	Tincture of fresh herb is used to relieve anxiety, insomnia, bedwetting and other nervous disorders. Blends well with Skullcap. This herb is not a narcotic, it normalizes psychological function and has gentle sedative, pain relieving and anti-spasmodic effects.
Description	Perennial, grown as annuals in cold areas. Bright orange flowers up to 18 inches. Very resilient and tough flowers.
Other	Use with extreme caution both physically and spiritually. This plant can be poisonous if used inappropriately.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Catnip, Japanese (Jing Jie)
Botanical Name	Schizonepeta tenuifolia
Climate	Temperate
Planting Instructions	Does best in dry soils. Grows easily from seed. Direct seed in early spring or summer or start in greenhouse and transplant outdoors in average, sandy, slightly alkaline (limestone, wood ashes, dolomite, egg shells) soil. Thin or transplant, giving generous spacing. Tolerates temperatures down to -40 F.
Light	Does best in full sun or partial shade
Water	Prefers well drained soil. Dry soil increases aromatic properties.
Germination Rate	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Days to Maturity	Matures in late summer or fall if sown in the spring
Special Instructions	Harvest leaves and flower tops in the late summer when in bloom.
Part of Plant used Medicinally	Dry and strip leaves and flowers from stems for tea or tincture
Spiritual Needs	Japanese catnip is a feminine plant used for harmony, beauty and truth and for shamanic purposes.
Medicinal Uses	This herb increases circulation to the surface of the skin, encourages perspiration, sedates the nervous system, mildly astringent. Has been used to stop internal bleeding, to detoxify the skin, for fever, as a remedy for measles and anxiety.
Description	Annual. Aromatic. Three-parted leaves with long spikes of flowers.
Other	Use with extreme caution both physically and spiritually. This plant can be harmful if used inappropropriately.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Chamomile, German
Botanical Name	Matricaria, chamomilla
Climate	Temperate
Planting Instructions	Chamomile seeds are short lived and must therefore be used readily. Sow in the fall, mid-winter or very early spring directly in weed-free garden bed or start early in the greenhouse and transplant outdoors. Scatter in well dug soil and tamp down. Prefers sandy soil, but is easily grown in almost any soil. Prefers not to be covered or transplanted. Does not require a lot of space between plants. Self sowing if seeds are not removed.
Light	Prefers full sun to partial shade
Water	Light watering, likes well drained, evenly moist soil.
Germination Rate	1-2 weeks. 75%-100% germination. Seed viable for 2-3 years
Days to Maturity	Blooms about 16 weeks from seed
Special Instructions	Harvest flower heads when in full bloom and store in airtight container to preserve volatile oils.
Part of Plant used Medicinally	Flowers, volatile oil
Spiritual Needs	Chamomile is a masculine plant used for divination and balancing.
Medicinal Uses	Chamomile has an affinity for the digestive tract and the nervous system. Aids in digestion, relieves gas, colic (especially in babies), menstrual cramps, nervousness and insomnia. Some individuals may experience allergic reactions to chamomile if they are prone to hayfever due to its high pollen content. The volatile oils have antibacterial properties. Chamomile tea can be used externally as an eyewash as well as a wash for wounds and scrapes.
Description	White inch-wide daisies with yellow disks. Hardy sweet-scented annual to 2 1/2 ft with finely divided ferny foliage.
Other	Chamomile is a very gentle herb when used medicinally and is therefore excellent for children.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Chaste Tree
Botanical Name	Vitex agnus-castus
Climate	Tropical
Planting Instructions	Grown in almost any soil from seed in spring or start early in pots in the greenhouse and Grow out for a year then transplant outdoors. Applying up to 90 days cold may help germination. Prefers a lot of spacing between trees.
Light	Prefers full sun
Water	Prefers dry exposure
Germination Rate	8-10 weeks. 18 days. 75%-100% germination.
Days to Maturity	1 year
Special Instructions	Pick berries when ripe in the fall and dry in the shade.
Part of Plant used Medicinally	fruit
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Fruits regulate the menstrual cycle, particularly progesterone levels. Alleviates hot flashes, insomnia and irritability. Chaste berries stimulates the pituitary to increase luteinizing hormone, which then stimulates progesterone production and induces menstruation.
Description	Perennial deciduous shrub or small tree. Aromatic lilac flowers in dense 5-7 inch spikes at the branch tips, from July to Sept. Strongly aromatic shrub or small tree to 10-25 ft., with divided leaves, dark green above and grayish below.
Other	Branches used in basket work.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Chia
Botanical Name	Salvia hispanica
Climate	Temperate to Tropical
Planting Instructions	Easy to grow from seed. Dirct seed in the spring or start early in the greenhouse to give long growing season. Excess nitrogen may delay flowering. Prefers moderate spacing between plants.
Light	Prefers full sun
Water	Prefers regular watering.
Germination Rate	1-3 weeks. 4-8 days. 75%-100% germination rate.
Days to Maturity	Blooms late summer or early fall if sown in the spring.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	seeds
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Highly nutritive and high in soluble fiber and oil - it is roasted, ground and added to water, which forms a gel. One tablespoon is sufficient to sustain a person for 24 hours on a forced march. Whole seed can be placed in water or juice. Soaking swells the seed covering up into a clear gel that looks like frog eggs. Drinking chia seeds in this manner will alleviate diarrhea. Chia seeds also regulate blood sugar, alleviate constipation and protect damaged or inflamed tissues.
Description	Annual. Succulent, bright green, bushy plants up to 4 ft. tall
Other	
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Coriander
Botanical Name	Coriandrum sativum
Climate	Tropical
Planting Instructions	Sow in the fall in the south, early spring in the north. Sow after danger of frost has past. Place seeds 1/4 to 1/2 inch deep and sow where they are to grow. Plant will bolt very quickly if kept in pots. Prefers to be closely spaced. Weed or mulch (with stray, leaves etc.) early in the season. Prefers slightly alkaline (limestone, wood ashes, egg shells, dolomite), moderately compost-rich, light soil.
Light	Full sun to partial shade
Water	Well drained soil.
Germination Rate	1-2 weeks. 13 days 75%-100% germination. Seed viable 6-8 years
Days to Maturity	40-50 days - mature in the fall if sown in the spring.
Special Instructions	Harvest the shining , smooth leaves before the plant flowers for tincturing. Harvest seed clusters when they begin to turn brown. Cut whole plant and hang upside down. Gather seeds as they fall. Seeds viable 6-8 years.
Part of Plant used Medicinally	Leaves and seeds
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Herb is used to bind mercury and other heavy metals. Seeds aid in digestion and decrease flatulence.
Description	Aromatic annual 1-3 ft tall with divided leaves and small white or pinkish flowers in umbels, followed by clusters of round aromatic seed.
Other	Grow with care. Coriander plants will bind mercury and other heavy metals in the soil. Do not use plants medicinally if soil is contaminated with heavy metals.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Dwarf Nettle
Botanical Name	Urtica urens
Climate	Temperate
Planting Instructions	Sow in fall or the very early spring for germination in following spring. Transplant seedlings with a small amount of space between plants. Easily grown from seed in any soil.
Light	Transplant to an area of dappled shade
Water	Transplant to an area near running water. Grows best with abundant water and well-drained soil.
Germination Rate	75%-100% germination
Days to Maturity	40-50 days; late summer to fall if sown in the spring.
Special Instructions	Harvest leaves before flowering in the late spring or early summer
Part of Plant used Medicinally	Leaves and roots
Spiritual Needs	Dwarf Nettle is a masculine plant used in protection, purification and for visions.
Medicinal Uses	Nettles are high in minerals, stimulate milk production, anemia, relieve hayfever and other allergies, strengthens capillaries and is an antibiotic against tuberculosis. It is an excellent spring tonic for the entire body. Nettles help the body assimilate nutrients and eliminate waste products of metabolism, increase the flow of urine and help dissolve urinary stones and gravel. It also stops bleeding (especially with blood in the urine, hemorrhoids and excessive menstrual flow), helps clear up rheumatic problems and chronic skin conditions.
Description	Hardy annual, usually under 1 ft. tall. Deeply toothed leaves. Has stinging hairs. Grows to 4 ft.
Other	Use with extreme caution both spiritually and physically. This plant can be harmful if used inappropriately. The stalks can be used to make cord and rope.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Elecampane
Botanical Name	Inula helenium
Climate	Temperate
Planting Instructions	Sow seed in greenhouse in early spring and transplant outdoors or sow directly in garden. Prefers a lot of space between plants. Use slightly acidic (compost rich) soil with clay in it. Once plant is established, it is best propagated from 2 inch root cuttings taken in the fall from buds of 2 year old roots. Cover cuttings with moist, sandy soil and store for the winter in a cool indoor room. Plant far apart after the frost.
Light	Grows in full sun or partial shade
Water	Moist soil
Germination Rate	1-4 weeks. 12 days. 75%-100% germination rate. Light dependent germinator.
Days to Maturity	Will flower in fall or at least be well established by winter if sown in the spring.
Special Instructions	Harvest roots in the fall of the second season after two hard frosts.
Part of Plant used Medicinally	root
Spiritual Needs	Elecampane is a masculine plant used to develop psychic powers, visions and in dreamtime.
Medicinal Uses	Rich in inulin - a starch that stimulates the immune system. Elecampane is used as a cough and lung remedy, especially for wet coughs. It contains volatile oils that act as antiseptic in respiratory tract infections. It is also used for diseases of the breast, malignant fevers, sluggish liver, indigestion and tuberculosis. Elecampane strengthens, cleanses and tones the pulmonary and gastric membranes, balances the metabolism and assists pancreatic function. It has been used to expel worms and reduce the retention of water, to lessen tooth decay and to firm the gums. A poultice or a strong tea is made and used for itching, skin rash and wounds externally.
Description	Large yellow 4inch wide flowers on a robust hardy perennial to 6 ft. with leaves up to 2 ft. long.
Other	Use this herb with extreme caution both spiritually and physically. This plant can be harmful if used inappropriately. Yields blue dye
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Elephant Heads
Botanical Name	Pedicularis groenlandica
Climate	Temperate
Planting Instructions	Grown easily from seed in most soils. Needs cold treatment for germination.
Light	Prefers partial shade
Water	Prefers moist soil
Germination Rate	May take 6-7 weeks to germinate at cool temperatures
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Leaves
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	This herb is noted for its sedative effects. It is a mild relaxant for skeletal muscles and brain, quieting anxieties and tension. The powdered plants have been used to repel lice.
Description	Hardy perennial to 2 ft. tall with feathery divided 6inch leaves. Red, pink and white fragrant 3/4inch flowers in spikes with finely divided leaves.
Other	
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Fenugreek
Botanical Name	Trigonella foenum-graecum
Climate	Tropical
Planting Instructions	Easily grown from seed in any alkaline (limestone, egg shells, dolomite, wood ash) soil. Sow where they are to stand in the fall in warm areas or direct seed in the late summer to early spring after the ground has warmed in cooler regions. Fenugreek breaks up heavy clay soils and contributes nitrogen and organic matter to the soil.
Light	Full sun
Water	Well drained soil
Germination Rate	1 week. 75%-100% germination. Seed viable for 4 years or more. Germinates in cold soils. Use rhizome inoculant if possible to increase germination rate. (available through Horizon Herbs)
Days to Maturity	3 weeks
Special Instructions	Harvest pods when fully formed before cracking. Remove the sand and dry in the sun. Pick young leaves as needed
Part of Plant used Medicinally	seeds, leaves
Spiritual Needs	Fenugreek is a masculine herb. It is expansive, for justice and ethical doing.
Medicinal Uses	Bitter young leaves are rich in vitamin C. Seeds are rich in calcium as well. Seeds increases milk flow and contain diosgenin which can be used to regulate reproductive hormones. Fenugreek seeds also contain a steroidal cardiotonic, an anti-viral, a hypoglycemic and an antihypertensive compound. Seed is warming to the digestive tract, absorbs toxins, lowers cholesterol levels and regulates blood sugar. Fenugreek is used to improve heart function, decrease blood pressure, regulate diabetes/ high blood sugar levels, soothe bronchitis and in viral infections. There have been some studies that report Fenugreek as useful for epileptic seizures. As a poultice, it is used to draw toxins out and to relieve rheumatic pains or boils.
Description	White 1/2 inch. flowers with distinctive blue markings on a clover-like annual to 1-2 ft. 3-6 inch beaked pods. Aromatic foliage.
Other	Edible seed. Contains alkaloids, do not mix with herbs containing tannins. Do not use during pregnancy, as it stimulates the uterus and may induce abortion.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Feverfew
Botanical Name	Chrysanthemum parthenium Roya
Climate	Temperate
Planting Instructions	Sow in flats or pots in February or March 2 weeks before frost danger has passed or direct seed in spring or summer 1/8 to 1/4 inch deep in milder areas. Prefers warm days and cool nights. Transplant with a moderate amount of space between plants. Prefers slightly alkaline (limestone, egg shells, dolomite rich) soil. Gently pinching back the buds increases growth. Do not plant near other plants that require bees for pollination as bees dislike the smell of Feverfew.
Light	Prefer full sun or shade
Water	Keep seedlings moist. Plant prefers a well-drained soil
Germination Rate	Light dependent germinator. 13 days. 1-2 weeks. 50%-75% germination. Seeds viable 1-10 years.
Days to Maturity	Blooms in fall or is at least well established before winter if planted in the spring.
Special Instructions	Harvest leaves and flowers at any time.
Part of Plant used Medicinally	Leaf, flower or seed may be made into tea or tincture
Spiritual Needs	Feverfew is a masculine plant for protection against negative intrusion, it is healing to the mind and can be used for dreamtime.
Medicinal Uses	Tonic for prevention of migraine, fevers, headaches, nervousness, depression, coughs, to induce menstruation, to help arthritic and rheumatic pain and insect bites. Feverfew also allays nausea and vomiting, promotes restful sleep, improves digestion and relieves asthma attacks.
Description	Herbaceous perennial. Single, white and yellow, daisy-like flowers grow densely on upright bushes. Grows to 3 ft.
Other	Do not use during pregnancy as it may induce abortion. Prolonged use may cause mouth ulcers.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Fireweed
Botanical Name	Epilobium angustifolium
Climate	Temperate to arctic
Planting Instructions	Easy to grow from seed. Sow on the surface to germinate in 1-2 weeks. Mix very small seed with sand and press into surface of flat, or bury shallowly and use fire treatment. Plants prefer a moderate amount of distance between plants.
Light	Full sun to partial shade
Water	At their best in moist places or at the waters edge
Germination Rate	Light dependent germinator. 75%-100% germination rate
Days to Maturity	30-40 days
Special Instructions	Harvest shoots in the early spring, leaves in the late spring, buds and flowers in the summer, and the downy mature Pod and rootstalk coverings in the fall.
Part of Plant used Medicinally	Shoots, leaves
Spiritual Needs	Fireweed is a feminine plant, used by Native Americans for shamanic purposes, vision quests and right seeing.
Medicinal Uses	Young leaves are high in vitamins A and C. Tea is used to relieve stomach ache, but said to be dull the senses and cause diarrhea when drunk in excess. Oil made from a leaf infusion in a salve reduces swelling of hemorrhoids. An infusion relieves constipation. A cooled decoction of the whole herb is used as antispasmodic to relieve whooping cough and asthma, sipped in small quantities until spasms pass. The mashed fresh root is good to draw out boils.
Description	Hardy perennials with willow-like leaves and large spikes of purple to rose 1 1/4 inch flowers. Grows 3-8 ft. with 6inch willow-like leaves
Other	Use this herb with extreme caution both spiritually and physically. It can be harmful if used inappropriately. Young shoots can be eaten like asparagus. Pith of stems can be eaten and the fiber from the stem can be made into rope/cord. Rubbing fireweed flowers on rawhide can be used for waterproofing. The inner pith from stems are dried and powdered and used as talk to prevent chapping. Shoots are edible, high in vitamin A and C.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Foxglove, Grecian
Botanical Name	Digitalis lanata
Climate	Temperate
Planting Instructions	Sow in the late spring or early summer directly into the garden to survive the winter or start early in the greenhouse and transplant outdoors. Cover lightly with soil to keep moist. Plant prefers a lot of space between. Tolerates a wide range of soil types as well as freezing temperatures, however it needs some protection from the cold and snow. Does well in dry soils and prefers a slightly acidic (compost-rich) soil.
Light	Full sun to partial shade
Water	Needs good drainage or the root will rot.
Germination Rate	2-3 weeks. 75%-100% germination.
Days to Maturity	Will flower by late fall or at least be well established by winter.
Special Instructions	Leaves are harvested in the summer.
Part of Plant used Medicinally	leaves
Spiritual Needs	Foxglove is a feminine plant used in cleansing, purifying, protection and visions.
Medicinal Uses	This herb is best used internally in very low doses, as it contains a potent heart stimulator, digitoxin. It enables the heart to beat more strongly, slowly and regularly without requiring more oxygen. It simulates urine production, which lowers blood volume. This herb is also used as a poultice on fresh wounds, its juice is also used in old sores to cleanse, dry and heal them.
Description	Hardy perennial or biennial to 3 ft. Creamy yellow to gray inch-long flowers.
Other	Use this plant with extreme caution both spiritually and physically. It can be poisonous if used inappropriately. Can be toxic and fatal when taken internally in large doses.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Holy Basil
Botanical Name	Ocimum sanctum
Climate	Temperate
Planting Instructions	Grown easily from seed after frost has past. Plant in warm soil 1/8 inch deep in mid summer if sowing directly into garden in manure or compost rich soil with an overall balance of clay, sand and silt. After established, mulch around the plant. Pinch flowering tops to increase growth. If starting in the greenhouse, sow in the spring 6-8 weeks before last frost. Frost hardy once established. Prefers small spacing between plants.
Light	Prefer full sun
Water	Prefers plenty of water
Germination Rate	14 days 1-4 weeks. 75%-100% germination rate. Seeds viable 8-10 years
Days to Maturity	40-50 days. Mid to late summer if planted in the spring.
Special Instructions	Harvest leaves before blooming when the sun is at its hottest. Do not water the day of harvesting to allow volatile oils to concentrate in the leaves. For drying, cut sprigs just before it reaches full bloom.
Part of Plant used Medicinally	leaves
Spiritual Needs	Holy Basil is a feminine plant, it is balancing, harmonizing and cleansing.
Medicinal Uses	Highly aromatic, antifungal, antibiotic and antibacterial. Used to treat fevers, ringworm, malaria and dysentery. Smelling the herb soothes nervous headaches. Tea calms an upset stomach and helps the body adapt to stress. Holy Basil has an affinity for the heart, protects it from stress, lowers blood pressure and cholesterol level. Stabilizes blood sugar levels, useful in treating diabetes. It is also valuable for respiratory infections such as colds, coughs, bronchitis and pleurisy as well as asthma. The juice is extracted and applied to insect stings, ringworm, canker sores and skin diseases, also used as eardrops for ear infections.
Description	Tender annuals. Edible leaves. Bushy, grows 1-3 ft. Profuse purple or white bloom
Other	
Purchased From	J.L. Hudson
Common Name	Hops, Nugget
Botanical Name	Humulus lupulus
Climate	Temperate
Planting Instructions	Start in early spring in a cold greenhouse and transplant outdoors in the summer or following spring. Hops grows well in either sandy, compost-rich or clayey soils. It also grows well in acidic (compost-rich), neutral, alkaline (limestone, dolomite, egg shell, wood ash) soils.
Light	Semi-shade/full sun
Water	It grows well in dry or moist soil and can tolerate drought.
Germination Rate	Give 3-6 weeks of cold treatment to germinate in 1-2 weeks.
Days to Maturity	Early fall

Medicinal Seed Information

Special Instructions	The female flowering heads are harvested in the fall and can be used fresh or dried.
Part of Plant used Medicinally	Female fruiting body, flowering heads
Spiritual Needs	
Medicinal Uses	Hops is used to calm the nerves, to relieve pain, increase digestion and bile flow and depress the central nervous system. It is indicated for nervous irritability, insomnia and acid reflux. Hops contains estrogen-like compounds, which cancels the effects of male hormones. A decoction of hops cleanses the blood, thus, it is indicated for itch, ringworm, spreading sores and skin discolorations. Hops tones the liver, acts as a mild laxative and increases the flow of urine.
Description	Hops have rough, very long stems that twist around any support. Leaves are in pair, stalked, saw toothed and heart-shaped. The flowers are 3-5 lobed that have yellowish green scales and have a strong smell.
Other	Some people develop headache and nausea with hops, avoid if a person strongly dislikes the smell of hops.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Indian Hemp
Botanical Name	Apocynum cannabinum
Climate	Temperate
Planting Instructions	Grows well in any soil and pH. Sow in Early spring, giving cold treatment before sowing.
Light	Full sun to partial shade
Water	Prefers dryish to moist soil.
Germination Rate	1-3 weeks. 75%-100%
Days to Maturity	well be well established by winter.
Special Instructions	Harvest and dry root in the fall.
Part of Plant used Medicinally	Fresh Root
Spiritual Needs	Indian Hemp is a feminine plant used in mediation, for visions - it is expansive and healing to the heart.
Medicinal Uses	In low doses, it aids in digestion and is useful in fever and the treatment of syphilis. The root steeped in water is used to expel worms. It also expels excess fluid from the body, it induces sweating and is a powerful purging agent. It stimulates and tones the heart. It relieves pain, is antispasmodic and can induce a hypnotic state. In large doses, it induces vomiting. Can be used in acute alcoholism - 1/8 of an ounce of a decoction in 4 ounces of water. Milky sap is used for venereal warts.
Description	Hardy perennial with caustic milky juice. Small white or pink flowers. Grows to 4 ft. tall with ovate 2-6 inch leaves and slender paired pods.
Other	Makes strong fiber from stems to make linen cloth, nets, rope. A decoction yields a permanent dye - black or brown depending on the mordant used.
Purchased From	Horizon

Medicinal Seed Information

Common Name	Lemon Balm
Botanical Name	Melissa officinalis
Climate	Temperate
Planting Instructions	Grows easily from seed outdoors in the spring, summer or fall or start early in the greenhouse and transplant outdoors. Providing 2 weeks of cold treatment can help with germination, as well as keeping the seeds moist but uncovered when direct seeding. Prefers normal garden soil and a slightly alkaline pH (add dolomite, wood ash, egg shells or limestone). It can withstand temperatures as low as -30 F. Sow after all danger of frost has past. Prefers a moderate amount of space between plants.
Light	Prefers full sun or shade
Water	Needs minimal water and well drained soil
Germination Rate	1-5 weeks. 75%-100% germination. Light-dependent germinator.
Days to Maturity	Blooms in mid to late summer if planted in the spring.
Special Instructions	Harvest before flowering. Should get 3 cuttings per season. Cut off entire plant 2 inches above ground and gently strip off leaves. Store in an airtight container to preserve volatile oils.
Part of Plant used Medicinally	volatile oil, leaves.
Spiritual Needs	Lemon Balm is a feminine plant. It's energy is infinite, of purification and love.
Medicinal Uses	Regulates high blood pressure, alleviates migraines, hysteria, melancholia, goiter and hyperthyroidism . Lemon balm is a highly nutritive herb. It is very soothing to the central nervous system as well as to the digestive system, also relieving allergies due to its antihistamine effect. Lemon balm also promotes menses and eases menstrual cramps, is used to promote sweating to treat colds, flu, mumps, cold sores and other viruses. It has also been found to be anti-viral.
Description	Perennial, 2-3 ft. tall, forming large bushes . Flowers yellow to 2ft. Tall.
Other	Good bee attractant
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Licorice, Official
Botanical Name	Glycyrrhiza glabra
Climate	Tropical
Planting Instructions	Licorice is best grown from root cuttings, but can be grown directly in the ground in late summer from seed or started earlier in the greenhouse and transplanted outdoors. Prefers deeply dug, compost rich soil with water during the growing season and hot, dry weather in late summer. Seeds may need to be scarified before sowing. Licorice prefers a lot of space between plants and a neutral pH. Hard freezes will kill licorce.
Light	Prefers full sun
Water	Prefers dryish soil
Germination Rate	1-6 weeks. 25%-50% germination.
Days to Maturity	Will take root before winter
Special Instructions	Harvest roots the second or third season.
Part of Plant used Medicinally	Root
Spiritual Needs	Licorice is a feminine plant, cleansing to the spirit and used for love and growth.
Medicinal Uses	Licorice nourishes the endocrine system (pituitary, adrenals and thyroid), particularly the adrenal cortex. It aids in recuperating after exhausting diseases, stimulates the immune system, protects the body against the side effects of chemotherapy, increases stamina and endurance, is anti-inflammatory, helps regulate blood sugar and reproductive hormones (it contains estrogen-like compounds). it is also a gentle laxative, relieves heartburn, eases large intestine spasms, neutralizes toxins (such as diphtheria and tetanus), lowers blood cholesterol level, reduces iirtation in the throat and increases expectoration. It is used for viral infections, coughs, chronic skin ailments (eczema, psoriasis), gastric ulcers and to dilate the blood vessels. Licorice sticks are useful to chew on when quitting smoking. Long-term use may be problematic for certain individuals, especially those with high blood pressure, kidney disease or are pregnant, as it may cause fluid retention.
Description	Perennials with feathery pinnate leaves and spikes of pale blue 1/2inch flowers in summer to 3-4ft. Once established, the plants shoot up like a young Willow thicket.
Other	Root contains glycyrrhizin, a compound that is 50 times sweeter than sucrose. Helps relieve symptoms of Poke root overdose.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Lobelia, red
Botanical Name	Lobelia cardinalis
Climate	Temperate
Planting Instructions	Can be direct seeded into the garden in the spring or fall in compost rich soil. Mix the seed with a teaspoon of dry sand to keep seedlings separate from eachother. Prefers a moderate amount of space between plants. If central flower is picked after blooming, the side shoots will bloom till autumn. Mixing seed with about a teaspoon of dry sand prior to sowing is recommended. This will assist in keeping seedlings separate from each other.
Light	Part shade to full sun.
Water	Prefers moist areas. Water seedlings very gently or you will upset them. Likes much watering.
Germination Rate	Light-dependent germinator. 1-3 weeks in warm soils. 2-3 weeks with GA-3. Short lived seed.
Days to Maturity	Flowers late in the fall or is at least well established by winter if planted in the spring or previous fall.
Special Instructions	Harvest entire plant above ground at the end of the flowering time.
Part of Plant used Medicinally	Entire plant
Spiritual Needs	Lobelia is a feminine plant, used for calming storms, visions and dreamtime.
Medicinal Uses	In lower doses, Lobelia stimulates the nervous system, in larger doses, it depresses the nervous system. Lobelia is used to relieve coughs, asthma, bronchitis and muscle spasms. As an infusion, it can be used to stop bleeding. Excessive internal dosage may prove nauseating or promote vomiting. Lobelia plasters are used to treat sprains, muscle spasms and bruises due to its relaxing and stimulating effect. It is good for insect bites and ringworm.
Description	Perennial. Flowers 1 1/2 inch, long lived, 3-4 ft. tall. Grows to 18inch.
Other	Use this herb with extreme caution. It can be harmful if used inappropriately. Can be toxic used in large dosage. Attracts hummingbirds. Has been used to wean off tobacco as a tobacco substitute.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Lovage
Botanical Name	Levisticum officinale
Climate	Temperate
Planting Instructions	Prefers compost rich soil and can be sown directly into the garden in the spring, late summer or fall, or started early in the greenhouse and transplanted into the garden. Prefers a lot of space between plants. Can withstand extremely cold temperatures and prefers a neutral pH soil.
Light	Best in full sun to partial shade
Water	Best in moist, well drained soil
Germination Rate	2-3 weeks to germinate in warm soil. 75%-100% germination. Seed viable for 3 years.
Days to Maturity	Growth tapers off after 4 years and maintains the same size.
Special Instructions	Leaves, roots and stems can be harvested as needed, once plant is established.
Part of Plant used Medicinally	Root, volatile oil
Spiritual Needs	Lovage is a masculine plant used in ceremonies as an offering to the spirits, for spirit dreams.
Medicinal Uses	Lovage is a stimulant and warming digestive tonic. Eases indigestion, induces sweating, decreases water retention, promotes onset of menstruation, relieves menstrual cramps and it can be substituted for Dong Quai for its estrogenic qualities. It promotes the production of estrogen and regulates menses.
Description	Tall perennial with shiny dark green leaves in mounds 2-3 ft. 6 ft flower stalks topped with small yellow flowers followed by strongly aromatic seeds. Flowers to 12 ft. in the second year.
Other	Do not use during pregnancy or kidney disease as it may induce abortion and irritates the kidneys.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Marshmallow
Botanical Name	Althea officinalis
Climate	Temperate
Planting Instructions	Can be grown in a variety of soil types ranging from dry to moist. Sow seeds 1/4 inch deep in the late spring to summer in warm, compost rich soil or start earlier in the greenhouse and transplant. Prefers an alkaline (limestone, egg shells, dolomit) soil that is light. Prefers a lot of space between plants.
Light	Prefers full sun or shade
Water	Prefers well drained soil
Germination Rate	9-30 days. 50%-75% germination
Days to Maturity	Should flower or at least be well established by winter if sown in the spring.
Special Instructions	Harvest long tap root after 2 years. Dig root in the fall after top growth has died off. Leaves should be collected in summer after flowering.
Part of Plant used Medicinally	Entire plant contains mucilage; roots, leaves and flowers are dried for tea.
Spiritual Needs	Marshmallow is a masculine plant for purifying and is other-realm inducing.
Medicinal Uses	Contains high-grade mucilage which stimulates white blood cells to digest foreign material. Mucilage is best extracted by a cold infusion and used to soothe irritated mucus membranes - throat, lungs, digestive and urinary tract. Used to soothe dry, tight coughs, sore throats, gastric and duodenal ulcers and in urinary tract infections. The dried roots can be used as a healing and drawing poultice when applied warm.
Description	Overwintering annual or Perennial. Soft-leafed plants with large, white flowers on multiple stalks to 4 ft. high.
Other	Roots are highly nutritive and may be used as food as well
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Milk Thistle
Botanical Name	Silybum marianum
Climate	Tropical
Planting Instructions	Sow in fall, early spring or late summer where they are to grow and thin to a generous spacing. Seed demonstrates partial dormancy, with some emerging immediately and others emerging over the space of 2 years.
Light	Full sun
Water	Likes plenty of water, well-drained soil.
Germination Rate	Sprouts in 1-3 weeks. Fresh seed will only sprout at cool temps, but after 5 months of dry storage, they will germinate well at warm temperatures. 50%-100% germination rate.
Days to Maturity	2 years
Special Instructions	Gather ripe seeds in summer to early fall.
Part of Plant used Medicinally	seeds
Spiritual Needs	Milk Thistle is a masculine plant. It strengthens, protects and heals, used for right judgment.
Medicinal Uses	Increases milk production in nursing women. Ground seeds are used to help the liver detoxify toxins by increasing production of glutathione in the liver, regenerates liver cells and protects against the death cap mushroom. It effectively treats cirrhosis, hepatitis A and B, and lowers fat deposits in the liver.
Description	Bold and striking rosettes of large glossy, dark green, spiny leaves streaked and marbled with white, followed by 2inch wide rose-purple, faintly scented flower-heads on 4-6 ft. stalks.
Other	Flowers much visited by bees, birds love the seeds. Loosens hard, compacted soil. Can boil young leaves or eat in salads, eat peeled stalks, eat roots like salsify, or eat young heads like artichokes. Prevents death in dogs from fatal doses of Destroying-Angel mushroom toxins.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Motherwort Official
Botanical Name	Leonurus cardiaca
Climate	Temperate
Planting Instructions	Easily grown from seed. Sow in the fall or early spring directly in the garden, or start early in the greenhouse and transplant outdoors. Likes regular garden soil. Motherwort likes to grow by itself without other plants near it.
Light	Likes partial or full sun
Water	Prefers well drained soil, but tolerates dry soil.
Germination Rate	1-3 weeks. 75%-100% germination.
Days to Maturity	40-50 days. Flowers usually in the first year.
Special Instructions	Harvest leaves before plant flowers. Harvest and dry flowering tops before they become prickly.
Part of Plant used Medicinally	leaves
Spiritual Needs	Motherwort is a feminine plant. She is very powerful plant. Used for wisdom, nurturing and truth.
Medicinal Uses	Motherwort is used to balance female hormones, suppressed menstruation, relieve tachycardia (rapid heart beat), palpitations and emotional irritability, to increase blood circulation, for nervousness, insomnia. It is also used to treat sciatica, thyroid disharmonies and hypoglycemia. Promotes fertility and lactation in menstruating women.
Description	White, woolly flowers on a hardy perennial to 5 ft. With palmately divided lower leaves. Flowers 4-6 ft.
Other	Good bee attractant. Dark green dye
Purchased From	Horizon

Medicinal Seed Information

Common Name	Mugwort
Botanical Name	Artemisia vulgaris
Climate	Temperate
Planting Instructions	Easily grown in poor soil. Sow in the spring or start early in the greenhouse. Because seeds are small, it may be easier to mix seeds with sand before planting. Sow on the surface. Prefers a lot of space between plants. Does not like growing in very clayey soil. Cold hardy to -40 F.
Light	Full sun
Water	Easily grown in dry soil - many thrive in arid regions
Germination Rate	1-3 weeks in warm temps. 75%-100% germination rate, seeds viable 3-9 years
Days to Maturity	Will flower in summer or fall or at least be established by winter if planted in the spring.
Special Instructions	Cut to 4 inches above ground just as it blooms in the summer, and gently strip off leaves.
Part of Plant used Medicinally	Leaves, volatile oils
Spiritual Needs	Mugwort is a feminine plant. It can be used in dreamtime, for strength, psychic dreams, prophetic dreams, protection, healing and astral travel.
Medicinal Uses	Bitter leaves are used as tonic nervine and to encourage menstrual flow, for menstrual cramps, to hasten delivery, helps expel the placenta, for sciatica, to ease uncontrollable shaking, nervousness and insomnia, It is also used to treat liver and stomach disorders, for colds, flu, bronchitis, fevers. Tea is good to treat parasitic infections. The juice can be taken to relieve over-dose of opium.
Description	Very hardy woody perennial to 2-3 ft, with dark green divided leaves and tall, pyramidal clusters of small yellowish flowers to 5 ft. tall
Other	Use with extreme caution both spiritually and physically. This plant can be harmful if used inappropriately.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Ox-Knee
Botanical Name	Achyranthes bidentata
Climate	Temperate
Planting Instructions	Easily grown from seed. Sow in spring directly in the garden or start early in the greenhouse and transplant outdoors. Plant prefers fertile and acid soul, compost.
Light	Plant prefers full sun
Water	Plant prefers good drainage and deep, regular watering.
Germination Rate	1-2 weeks. 75%-100%
Days to Maturity	will be well established by winter if planted in the spring.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Entire herb
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Nourishing to the blood, kidney and liver; strengthens bones and sinews, used during labor and to treat sores of mouth and tongue. Also used to stimulate menstruation, ease menstrual pain, relieve lower back pain, hypertension, canker sores, toothache, bleeding gums and for nosebleeds.
Description	Perennial, making dense bushes, columnar or ovate in outline, composed of succulent green stalks with red highlights. Slender spikes of small flowers and broad oval leaves and large greenish-purple stems with joints resembling an ox's knee. Flowers greenish to 2-3 ft. tall.
Other	
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Peppermint
Botanical Name	Mentha piperita
Climate	Temperate
Planting Instructions	Sow early in greenhouse and transplant outdoors or sow directly outside in the spring. Prefers small spacing. Prefers cool conditions and slightly alkaline (limestone, dolomite, egg shells, wood ash) compost rich soil. Plants grow profusely and will get woody after several years.
Light	Prefers partial sun
Water	Prefers moist, well drained soil
Germination Rate	Light-dependent germinator. 7-14 days. 1-3 weeks in warm soil. 50%-75% germination.
Days to Maturity	Will flower in summer or fall or at least be established by winter if planted in the spring.
Special Instructions	Cut stems during early to midflowering; bundle, hand and dry, then roll on clean table and remove stems. Keep leaves in an airtight container to preserve volatile oils.
Part of Plant used Medicinally	Volatile oil, leaves
Spiritual Needs	Mint is a masculine plant used to induce dreamtime, psychic dreams and purification.
Medicinal Uses	Stimulating and digestive tea. For nausea, fever, colds, ringworm, rheumatism, ulcers, menstrual cramps, headaches (applied to temples), colic. Relaxes the central nervous system. Stimulates the liver and gallbladder and decreases inflammation, topically, it increases blood-flow to the area applied. It is cooling and pain relieving when applied externally. Inhalations of the herb are useful to increase concentration and reduce excessive respiratory mucus.
Description	Hybridize freely. Purple flowers with purple tinged leaves to 2-3 ft.
Other	Do not use for babies due to its highly cooling effects.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Pleurisy Root
Botanical Name	Asclepias tuberosa
Climate	Temperate
Planting Instructions	Very easy to grow. Sow the seeds in early spring directly into garden or give 2 weeks cold conditioning or start early in the greenhouse and transplant outdoors. Plants are tap rooted, so early transplant gives best results. Does well in regular garden soil or poor soils. Prefers a moderate distance between plants.
Light	Prefer full sun
Water	Stands drought and dry soil.
Germination Rate	3 weeks in warm temperatures. 75%-100% germination rate.
Days to Maturity	will be well established by winter if planted in the spring.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Root
Spiritual Needs	Pleurisy root is a feminine plant used in purification, cleansing, as a restorative and healing to spiritual assault.
Medicinal Uses	Treats inflammation of serous membranes of the lungs as in pleurisy, bronchitis, pneumonia and coughs. It is used to induce sweat, for colds, flu and respiratory problems, allows expelling of phlegm/mucus.
Description	Hardy perennials. Orange flowers in large clusters. Grow to 3 ft. from long horizontal roots.
Other	Shoots and pods are edible. Flowers attract butterflies. Rare
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Poke Root
Botanical Name	Phytolacca americana
Climate	Temperate
Planting Instructions	Easily grown in most soils but prefers rich, moist soil. Sow in mid-summer. Cold hardy once established. Prefers a lot of space between plants.
Light	Full sun to partial shade
Water	Prefers moist soil
Germination Rate	Heat dependent germinator. Give seeds 3 months cold treatment to germinate in 1-2 weeks. Long lived seed (40+years)
Days to Maturity	Attains a harvestable size after overwintering and growing through another summer.
Special Instructions	Unearth root in late fall or spring. Clean and split lengthwise before drying. Collect berries when ripe
Part of Plant used Medicinally	root, berries
Spiritual Needs	Poke is a masculine plant for courage, strength and far-seeing.
Medicinal Uses	Incredible lymphatic stimulant for resolving lymphatic blockage, but must be taken in carefully measured small doses. Used for tonsillitis, swollen glands, mumps, rheumatism. Large doses will induce vomiting and produce a laxative effect. Infused oil of root is used externally for treating mastitis, growths and breast cancer. Kills snails that carry bilharzia - a trematode worm that causes human and animal blood fluke disease.
Description	Hardy perennial to 12 ft. Bears grape-like clusters of purplish-black berries filled with crimson juice, used as a source of red ink. Small white or purplish flowers in 6inch spikes. Young shoots are a succulent vegetable. Berries are toxic to eat, but great for birds.
Other	Potentially toxic in large doses. Overdoses can be fatal.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Purple Coneflower
Botanical Name	Echinacea Purpurea
Climate	Temperate
Planting Instructions	Sow seed in early spring in flats outdoors or in the greenhouse, and transplant in mid-spring after soil is warm. Prefers a lot of space between plants. Alternatively, sow dry seed directly in the garden or field in the fall or early spring. Barely cover the seed and tamp in. Do not cover seeds. Keep weeded and thin to desired spacing. Does well in either limey soil or slightly acidic soils. Mulch in the winter to keep warm.
Light	Prefers full sun. Tolerates hot temperatures.
Water	Prefers regular watering. Tolerates humid temperatures.
Germination Rate	2-3 weeks. 75%-100% germination.
Days to Maturity	Will be well established by winter if planted in the spring.
Special Instructions	Unearth root in fall after it goes to seed and has endured several hard frosts. Harvest leaves anytime and flowers in the spring and summer while flowers are in bloom.
Part of Plant used Medicinally	Root and flowering tops
Spiritual Needs	Purple coneflower is a masculine/feminine plant, used as a spiritual tonic, balancing and truth-seeing. It is used in North American Indian ceremonies to strengthen and ensure visions.
Medicinal Uses	Immune system stimulant, effective against bacterial and viral infections. It has been used for snakebites and for healing wounds with pus (suppurating, reducing putrefaction and pain of a wound externally. It cleanses the blood by stimulating liver and spleen function. Internally, it is used for tonsillitis, inflamed gums, mucus in the nose, sinuses, lungs and digestive tract, to fight infections (bacterial and viral) and allergies.
Description	Large daisy-like flowers and thick, medicinal roots. Flowers purple 4inch wide. 3-4 ft. tall. Perennial.
Other	Use with extreme caution both spiritually and physically. This plant can be harmful if used inappropriately.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Red Trumpet Vine
Botanical Name	Campsis radicans
Climate	Temperate
Planting Instructions	Prefers compost rich soil. Sow outdoors in early spring or early in the greenhouse and transplant outdoors. Very cold hardy. Will spread by means of multiple suckers.
Light	Prefers sunny places
Water	Average water, moist soil.
Germination Rate	60 days cold treatment to germinate in 15-30 days. 75%-100% germination rate.
Days to Maturity	will be well established by winter if planted in the spring.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Root.
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Dried herb is antifungal, used as a douche for treating Candida or as an external wash for treating fungal skin infections.
Description	Hardy deciduous vining shrubs to 30 ft. Tall. Clusters of orange flowers 3 inch wide. Dark green pinnate foliage.
Other	Good erosion control and wildlife food. Some are roots are hardy to -30 degrees F.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Rue, Official
Botanical Name	Ruta graveolens
Climate	Tropical
Planting Instructions	Grows easily. Sow in spring or start early in the greenhouse and transplant outdoors. Prefers clayey compost rich soil, slightly alkaline (dolomite, egg shells, wood ash, limestone). Prefers a lot of space between plants.
Light	Prefers full sun/ partial shade
Water	Prefers well-drained, moist soil.
Germination Rate	1-3 weeks. 75%-100% germination. Seed viable for 2 years.
Days to Maturity	Will be well established by winter if planted in the spring.
Special Instructions	Harvest several times a year. Apply compost after first harvest. Harvest leaves before flowers form.
Part of Plant used Medicinally	Leaves, stems and flowers
Spiritual Needs	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Medicinal Uses	Rue is used in low doses or as a homeopathic remedy. It is used for absent menses, strained eyes and headaches caused by eyestrain, nervous headaches, heart palpitations, nervous indigestion and colic. The tea expels worms, stimulates the uterus to promote menstruation, strengthens fragile blood vessels and varicose veins. It is good as an ointment for gouty, rheumatic pains, sprained or bruised tendons and chilblains, snake and insect bites. It has been used to ward off fleas and contagion.
Description	Hardy, woody perennial to 2-3ft. With finely divided blue-green foliage. Aromatic, yellow four petaled flowers to 3 ft.
Other	Pungent aroma repels pests. May cause rash in sensitive people
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Sage, Garden
Botanical Name	Salvia officinalis
Climate	Tropical
Planting Instructions	Easily grown from seed. Sow from early spring to early summer directly in the garden or start early in the greenhouse and transplant outdoors. Seeds may need some scarification. Transplant seedlings to garden after soil has thoroughly warmed up. Grows well in almost any soil, but prefers slightly alkaline (dolomite, egg shells, wood ash, limestone) soil. Mulch in the winter if temperature falls below 0 F.
Light	Prefers partial shade to full sun
Water	Seedlings require plenty of moisture to get started, but develop drought tolerance and prefer dryish soils as they mature.
Germination Rate	10 days. A period of cold, moist conditioning may improve germination. 1-3 weeks. 75%-100% germination rate.
Days to Maturity	Will be well established by winter if planted in the spring.
Special Instructions	Harvest leaves in midsummer before flowers open by cutting the plant to 4 inches above the ground and gently removing the leaves. Store in an airtight container to preserve volatile oils.
Part of Plant used Medicinally	leaves, volatile oils
Spiritual Needs	Sage is a masculine plant used in cleansing, purifying, for wisdom and protection. It is used to call spirits and for the divination of truth.
Medicinal Uses	Antibacterial, gargle for sore throats, mouth ulcers, inflammation of the tonsils. As a tea, it can be used for colds and flu, indigestion, hot flushes (prevents sweating), lack of menses and painful periods (due to estrogenic properties). Also reduces or stops the flow of milk in nursing women. Sage is strongly antiseptic, strengthens the nervous system and stimulates digestion. Can be used as a steam inhalation for congested sinuses and sinusitis.
Description	Woody perennial with blue 1 1/4 inch flowers in spikes. Grows to 2 ft. tall with gray leaves and white woolly stems.
Other	Tea should only be taken a week or two at a time due to high content of potentially toxic essential oil, thujone.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Scarlet Pimpernel
Botanical Name	Anagallis arvensis
Climate	Temperate
Planting Instructions	Sow in March indoors or in April outdoors. Prefers a moderate amount of space. Self sowing if seeds are not collected. Succeds in dry, sandy soils or clayey soils at any pH. Frost tolerant.
Light	Full sun
Water	Prefers moist soil
Germination Rate	1-6 weeks at cool to warm temps. 75%-100% germination rate.
Days to Maturity	Mid-summer
Special Instructions	Harvest leaves and stems in June
Part of Plant used Medicinally	Leaves and stems tinctured fresh
Spiritual Needs	Scarlet Pimpernel is a masculine plant used for truth, wisdom, clarity and strength of purpose.
Medicinal Uses	Tincture of leaves used in low dosages to alleviate water retention and to soothe the urinary tract. Used for obstructions of the liver and spleen, melancholy and associated mental disease, fear of water, epilepsy, urinary irritability, pulmonary consumption (in its early stages) and rheumatism.
Description	Creeping annual. Salmon-red, 5-petaled flowers produced abundantly on a low, trailing plant to 8inches. Stamens are covered with delicate violet hairs. Flowers close if rain threatens. Flowers to 4 inches.
Other	Leaves can be added sparingly to greens.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Squirting Cucumber/ Wild Cucumber
Botanical Name	Ecballium elaterium
Climate	Tropical perennial; Arctic annual
Planting Instructions	Easily grown from seed. Start in pots or in hills in the garden or greenhouse in early spring. Likes rich soil.
Light	Likes full sun
Water	Likes plenty of water
Germination Rate	2-4 weeks in warm soil. 50%-75% germination rate.
Days to Maturity	Fruits the first year from seed.
Special Instructions	The fully grown but unripe fruits are harvested during the summer, they are left in containers until the contents are expelled and the juice is then dried for later use
Part of Plant used Medicinally	Seeds (Elatarin), juice, root
Spiritual Needs	Do not know, will have to work with it.
Medicinal Uses	Laxative, also for pulmonary edema - it is a potent hydragogue- releases water from the lungs. May be debilitating if used after a weakening illness. DOSE: Start with 1 drop of tincture, increase gradually up to 10 drops.
Description	Perennial vine with grayish triangular 4" leaves. Bears oblong green 2" cucumber-like fruits which fall and explosively squirt seeds and mucilaginous juice when ripe.
Other	
Purchased From	Horizon

Medicinal Seed Information

Common Name	Swamp Milkweed
Botanical Name	Asclepias incarnata
Climate	Temperate
Planting Instructions	Prefers a light compost -rich soil with cocopeat. Succeeds on dry soils and on all soil types. Self sows if seeds are not collected. Cold hardy. Sow seed in the greenhouse in early spring and transplant into larger pots. Keep in the greenhouse the first winter and transplant the following late spring or early summer.
Light	Full sun
Water	Likes plenty of water, well drained soil. Does well by water.
Germination Rate	Germinates easily at warm temperatures. Seed might need 2 - 3 weeks cold treatment. Germinates in 1 to 3 months with stragglers up to 1 year. 75%-100% germination.
Days to Maturity	approx. 1 year
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Root
Spiritual Needs	Swamp Milkweed is a masculine plant used in cleansing and purification.
Medicinal Uses	Swamp Milkweed can cause vomiting and is used as a laxative in large doses, also used in smaller doses for dropsy, asthma and dysentery. Tones the urinary tract, reduces flatulence and dispels tapeworms.
Description	Hardy perennial. Rose pink to red flowers to 4 feet with fibrous roots. Flowers 3 to 4 feet tall.
Other	Attracts butterflies. Buds can be eaten in soup or corn meal mush. Cord made from dried stems for tooth extraction, fish nets and burden straps.
Purchased From	Horizon

Medicinal Seed Information

Common Name	Sweetgrass
Botanical Name	Hierachloe odorata
Climate	Temperate
Planting Instructions	Easily grown in moist places. Sow on surface and press in. Regular garden soil. Cold hardy. We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Light	Plant prefers full sun
Water	Keep moist until germination
Germination Rate	2 weeks to 6 months, but is speeded to 2-4 weeks by soaking in 2000ppm KNO3 (Potassium Nitrate) or GA-3. 75%-100% germination rate. Rubbing tiny seed out of husk will give much better germination.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Essential oils (coumarin rich), leaves
Spiritual Needs	Sweetgrass is a feminine plant. It is used as sacred smudging braids for purification and sending offerings and blessings, for visions, purification, understanding and for calling of the spirits.
Medicinal Uses	Leaves are chewed to give strength during fasting; tea is used to treat vomiting, coughing, sore throats and bleeding. Externally, used for treating sore eyes and saddle sores.
Description	Perennial grass to 1-2 feet with graceful brownish panicles. Spreads easily. Flowers golden to 2 feet.
Other	
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Valerian
Botanical Name	Valeriana officinalis
Climate	Temperate
Planting Instructions	Sow in the spring or start early in the greenhouse and transplant outdoors. Prefers compost rich soil and a moderate amount of space between plants. Self sows if seeds are not removed.
Light	Prefers full sun to partial shade
Water	Best in damp areas. Keep seed continuously moist
Germination Rate	1-4 weeks, may be irregular. GA-3 helps. 25%-50% germination rate. Light dependent germinator. Short lived seed. Plant within one year of receipt.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	Harvest rhizomes in the fall of the second year.
Part of Plant used Medicinally	Rhizomes
Spiritual Needs	Valerian is a feminine plant, used for purification, protection of dreams and journeys and for understanding.
Medicinal Uses	Strongest cerebral sedative, a sedative and anti-anxiety remedy. Used for insomnia, anxiety, headaches and nervous tension. Serves to put one to sleep, and as long as the dosage is correct, also allows one to awaken refreshed, willing and able to get on with the day. It is also a strong muscle relaxant, useful in stomach cramps, spastic or irritable bowel, menstrual cramps and nervous indigestion. In some individuals, Valerian may stimulate the nervous system. Valerian will sedate agitated individuals and stimulates someone who suffers from fatigue. Valerian also strengthens the heart and lowers blood pressure.
Description	Creeping perennials. Large clusters of tiny white flowers with a spicy scent to 3-5 feet, with pinnate foliage. Forms nice colonies with age.
Other	
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Wool Mullein
Botanical Name	Verbascum thapsiforme
Climate	Temperate
Planting Instructions	Sow in the spring or start early in the greenhouse and transplant outdoors. Prefers a moderate amount of space between plants. Sow on surface and compact down hard. Seedlings transplant well and require little care past occasional watering when they are young. They discourage other plants from growing near them. Tolerate poor, gravelly soil. Fertile soils produce monumental plants.
Light	Likes sun. Tolerates fierce sun.
Water	Likes dry soil. Occasional watering produces monumental plants.
Germination Rate	Light-dependent germinator. 75%-100% germination.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Part of Plant used Medicinally	Leaves and flowers
Spiritual Needs	Wool Mullein is a feminine plant used in cleansing, courage, protection and divination.
Medicinal Uses	Moistens mucous membranes, a great soothing agent for the throat and lungs. Can be irritating after prolonged use. Used for dry coughs, bronchitis, asthma and whooping cough as well as cystitis and urethritis. Mullein has also been used as a sedative for insomnia. As on oil infusion, mullein can be used for earache as eardrops and rubbed into rheumatic joints to ease the pain. Mullein leaves are excellent for poultices for boils and sores. Do not use for wet coughs, as it may worsen the condition by increasing lung secretions.
Description	Tall, hardy. Large, bright yellow 2" wide flowers in long branched spikes up to 8-10 feet tall, above a rosette of leaves. Whole plant is covered with dense, yellow down.
Other	Bee plant, can be used as a smoking herb.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Wormwood
Botanical Name	Artemisia absinthium
Climate	Temperate
Planting Instructions	Easily grown in poor soil. Sow in fall or early spring or start early in the greenhouse and transplant outdoors. Mix very tiny seed with sand before sprinkling on surface and tamping in, so that the seedlings do not emerge too closely together. Discourages other plants from growing near them. Plant prefers a lot of space.
Light	Prefers full sun to partial shade
Water	Easily grown in dry soil.
Germination Rate	1-3 weeks. Light-dependent germinator. 75%-100% germination.
Days to Maturity	We will be working with this plant, spiritually, to know its needs and its characteristics and will pass on all information to you as we gain in understanding of this plant.
Special Instructions	Hang to dry, then strip the leaves from stems and use for tea or tincture.
Part of Plant used Medicinally	Leaves
Spiritual Needs	Wormwood is a masculine plant used for psychic powers, calling of the spirits and for protection.
Medicinal Uses	Dispels worms, tones the mucous membranes, stimulates digestion, movement of the bowels, liver and gallbladder. It also is used to reduce fever and as an anti-inflammatory. When used over a period of two weeks, a tea of the leaves will rid the GI tract of parasites.
Description	Woody hardy perennial to 2-5 feet with grayish, silky, divided foliage and leafy spikes of little nodding flowers.
Other	Use with caution both spiritually and physically. Can be harmful if used inappropriately. Potentially toxic if used in large doses - has been known to cause nervous system damage.
Purchased From	J.L. Hudson

Medicinal Seed Information

Common Name	Yarrow
Botanical Name	Achillea millefolium
Climate	Temperate
Planting Instructions	Easy cultivation in any soil and grows longer in poor soils. Sow early spring or fall directly outdoors or early in the greenhouse and transplant outdoors. Prefers a lot of space plants between plants. Cold hardy.
Light	Full sun.
Water	Prefers very little water, well drained soil.
Germination Rate	Germinate best at 70 degrees, 5-15 days. 75%-100% germination.
Days to Maturity	Flowers from June to August.
Special Instructions	Harvest entire plant when in flower, cutting it just above ground.
Part of Plant used Medicinally	flowering tops, essential oils
Spiritual Needs	Yarrow is a feminine plant used for courage, psychic powers of truth and divination.
Medicinal Uses	Used to stop bleeding (external and internal) and as a tea for colds and fever, expels toxins, encourages blood flow to the skin, lowers blood pressure, clears blood clots, it is used as a poultice for healing wounds and induces menses. Antiseptic, anti-inflammatory.
Description	Hardy perennial to 3 feet with feathery leaves and flat clusters of white flowers. Spreads by roots and seeds. Spreads easily
Other	Taking yarrow orally may cause sensitivity to sunlight in some individuals. High in tannins, which can be used to clean (as an alternative to soap).
Purchased From	J.L. Hudson

By Wes Hayward, W7ZOI, and Terry White, K7TAU

A Spectrum Analyzer for the Radio Amateur

Good tools are priceless when you need them. Here's a piece of test equipment you've always wanted for your workbench. Now you can have it—without spending a fortune.

Among the many measurement tools sought by the amateur experimenter, the most desired—but generally considered the least accessible—is the *radio-frequency spectrum analyzer* or SA. This need not be. Simple and easily duplicated, this home-built analyzer is capable of useful measurements in the 50 kHz to 70 MHz region. The design can be extended easily into the VHF and UHF region with methods outlined later. The instrument is configured to be self-calibrating, or capable of calibration with simple home-built test gear.[1]

[1]Notes appear on page 43.

We often read and hear about "simple designs." Simplicity implies that something is eliminated to make the equipment easier to build, use or afford. Unlike designs that sacrifice performance for cost and simplicity, this one sacrifices only convenience, while retaining the capabilities needed for accurate measurements.

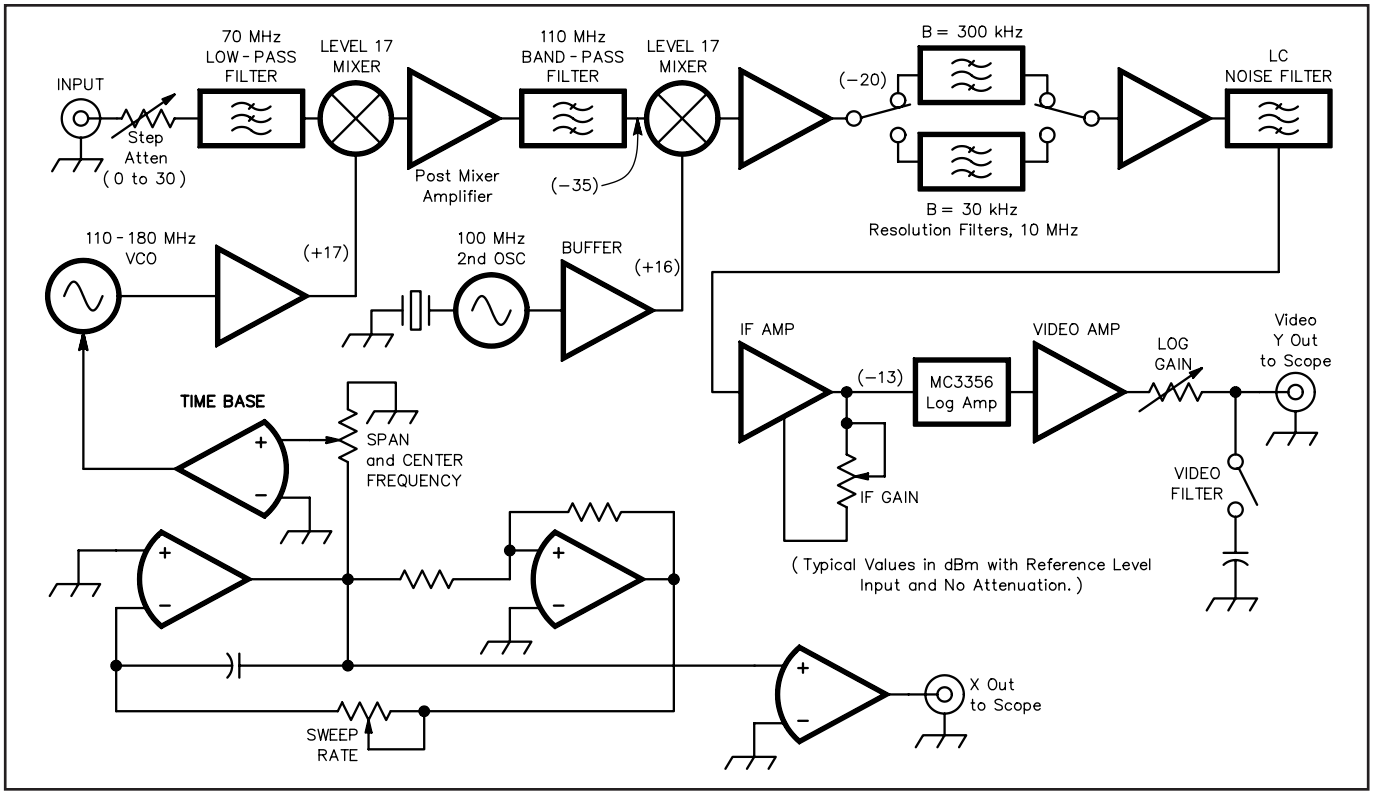

Figure 1—Block diagram of the spectrum analyzer. The circuit is a double-conversion superheterodyne design with intermediate frequencies of 110 and 10 MHz.

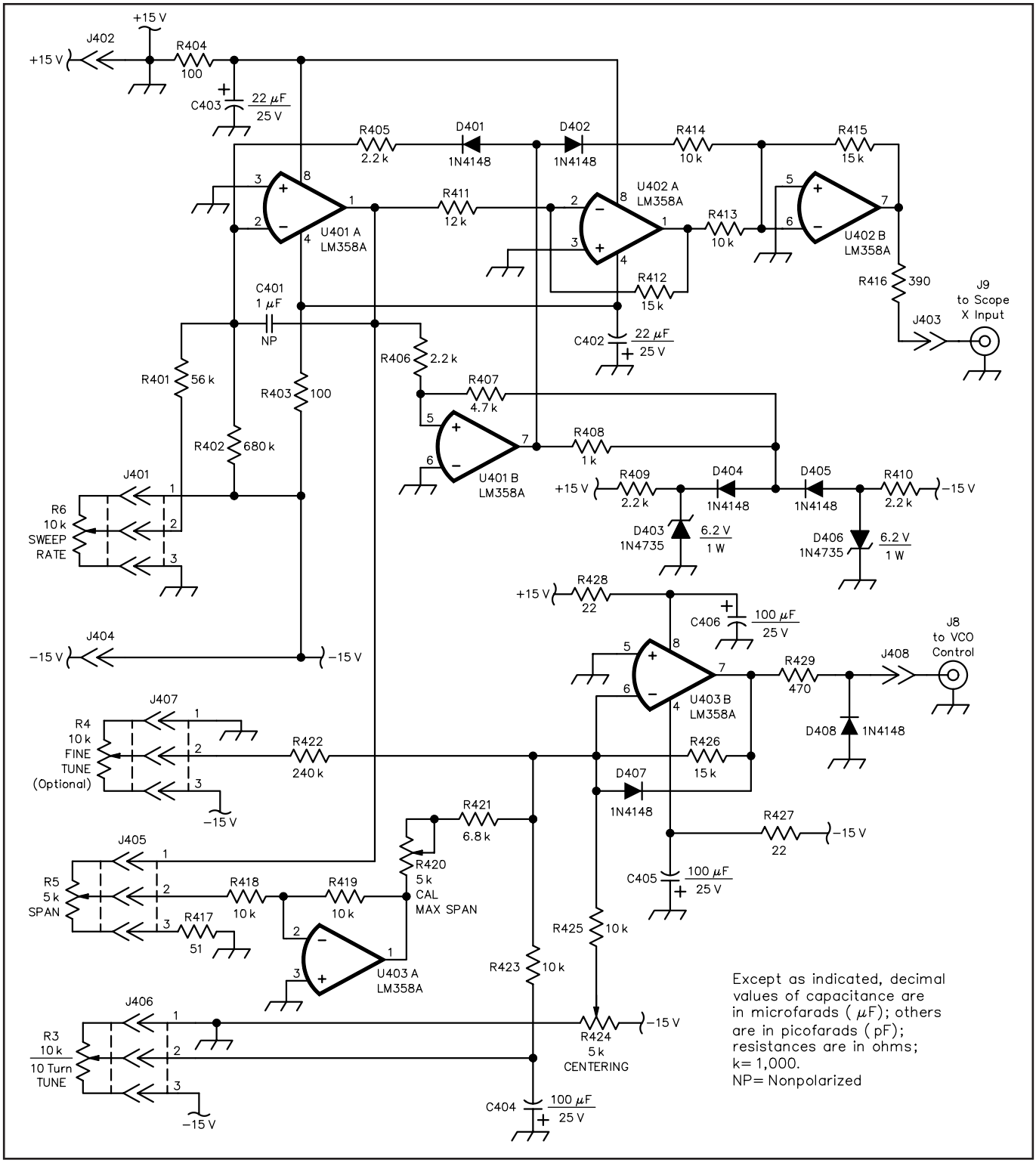

Figure 2—Time base for the spectrum analyzer. Refer to the text for a discussion of the various circuit functions. Front-panel controls include **SWEEP RATE, SPAN** and **TUNE**. Unless otherwise specified, resistors are 1/4 W, 5% tolerance carbon-composition or film units. Equivalent parts can be substituted.

U401, U402, U403—LM358 op amp
D403, D406—6.2 V Zener diodes, 1 W
C401—Metal film or Mylar, 1.0 µF capacitor
R420, R423—PC-mount trim pots, 5 kΩ or 10 kΩ suitable
R3, R4, R5, R6—Panel-mounted linear control, 5 kΩ or 10 kΩ suitable. If a 10 turn pot is used for R3, R4 is not needed.

Modern technology eases the construction of this spectrum analyzer. The logarithmic amplifier uses an IF amplifier IC found in cellular telephones and includes a *received signal strength indicator* (RSSI) function. Hybrid and monolithic IC building blocks are employed extensively. These include mixers, amplifiers and VCOs—all vital elements in an analyzer. Finally, it is a rare devoted experimenter today who does not own an oscilloscope. With good basic 'scopes available for about the price of a hand-held FM transceiver, every experimenter should have one. Our spectrum analyzer uses a 'scope as the display. There

are no special requirements for 'scope performance other than an X-Y mode with dc coupling in the X and Y axes.

Some Spectrum-Analysis Basics

The RF spectrum analyzer is essentially a swept receiver with a visual display. The display shows the strength of all signals within a user-defined frequency span. Each signal is represented by a line or blip that rises out of a background noise, much like the action of an S meter. Commercial analyzers are calibrated for signal power, with all signals referred to a reference level at the top of the screen. Our analyzer is designed for a basic reference level of –30 dBm, a common value in commercial analyzers.[2]

Signal levels are read from the display by noting that power drops by 10 dB for each major division on the 'scope. You can change the reference level. Adding gain to the analyzer moves the reference to lower levels; introducing attenuation ahead of the instrument moves the reference to higher power levels.

Circuit Overview

Figure 1 is a block diagram of our spectrum analyzer. A double-conversion superheterodyne, it begins with a step attenuator, followed by a low-pass filter and the first mixer, where incoming signals are upconverted to a 110 MHz first IF. After some gain and band-pass filtering, a second conversion moves the signals to a 10 MHz IF. The resolution bandwidths available are 30 kHz and 300 kHz. A video filter smooths or averages noise. The available frequency spans range from a per-division maximum of 7 MHz to about 50 kHz. The center frequency can be adjusted over the entire 70 MHz range. An uncalibrated **SPAN** control allows expansion of the display about the screen center. An uncalibrated **SWEEP RATE** control allows the sweep to be controlled and matched to a given span while avoiding excessively fast scans that could introduce errors.

Ideally, a receiver's first IF should be greater than twice the highest input frequency, a design rule that we bend in this application. The input tuning range includes all HF amateur bands and 6 meters. (We'll discuss higher tuning ranges later.) We picked the 10 MHz second IF because surplus-crystal filters and LC filters for this frequency are easily built. You can easily adapt the design's IF to 10.7 MHz, or other close, convenient values.

The swept LO tunes from 110 to 180 MHz with a commercial VCO module. The VCO output is amplified to drive a high-level-input mixer. The commercial VCO is a recent modification to a design that started with a homebrew oscillator.[3]

Amplifiers are included at the 10 and 110 MHz IFs. These establish signal levels that properly match the log-amplifier window, while preserving system dynamic range. The proper distribution of gain, selectivity and signal-handling capability (intercepts) of the amplifiers and mixers is vital to achieving good performance in a spectrum analyzer, and indeed, any receiver. A proper design will have the same number of stages as a poor one, but will probably use different components and consume more current.

The analyzer uses a ±15 V power supply. The positive supply delivers about 0.5 A. The negative supply current drain is under 50 mA.

Following sections present the circuit blocks in greater detail, in the order that they should be built. The partial but growing system can then be used to test the other sections as they are built, turned on and integrated. We *strongly discourage* building the entire analyzer before testing specific sections. Such an approach may work for casual kits, but is *not suitable* when careful control of signal levels is required. That approach also robs you (the builder) of the excitement of the process: the learning that comes from detailed examination.

Before jumping into the circuit details, we reemphasize that this analyzer—although simple—is intended for *serious* measurements. This means that a normal maximum span display contains no spurious signals. When clean (well-filtered, harmonic-free) signals are applied to the analyzer, there should be *no* extra products as long as the signal level is kept on screen. This performance goal applies for a single tone, or for two equal signals at the top of the screen.

Time Base

Figure 2 shows the analyzer time base, designed for basic functionality without frills; the result is a circuit using only a handful of op amps.[4] U401A and U401B form a free-running sawtooth generator, a circuit commonly found in function generators. U401A operates as an integrator; current is pulled from the inverting input through a 56-kΩ resistor connected to the **SWEEP RATE** control. This current must flow through the capacitor (C401), creating a linearly changing op-amp output voltage. This ramp is applied to U401B, a regenerative comparator, which provides a reset signal to the integrator. The sawtooth waveform (pin 1 of U401A) is asymmetrical: The positive-going ramp grows with a slope determined by the front-panel-mounted **SWEEP RATE** pot, while the negative-going, faster reset ramp is determined by fixed-value components.

The U401 ramp is used twice. U402A and B process the ramp to generate a signal that drives the 'scope's X axis. The signal has a 0 V-centered range with just over a 10 V total swing. Some of the "square wave" from the basic time base (U401B, pin 7) is added to the input of U402B to cause the sweep to reset quickly, even though the return sweep for the VCO occurs in a more stable, smooth way. A slight overscan is generated for the X axis, serving to hide an aberration occurring near the sweep beginning.

The sweep also generates the signal that controls the VCO. The sweep signal (U401A pin 1) is applied to a **SPAN** control. When the analyzer is set for maximum span, the VCO voltage (about 2 to 10 V) generates a sweep from 110 to 180 MHz. The VCO uses only positive sweep voltages, so the output of U403B is diode-clamped to prevent negative output. The center frequency **TUNE**, **FINE TUNE** and a **MAX SPAN** calibration pot set up the proper sweep for maximum span. As the span is reduced with the **SPAN** control, the sweep expands on (or zeroes in on) whatever appears at the center of the screen, determined by the tuning. The center frequency must be set for 35 MHz at maximum span, which coincides with having the zero signal, or

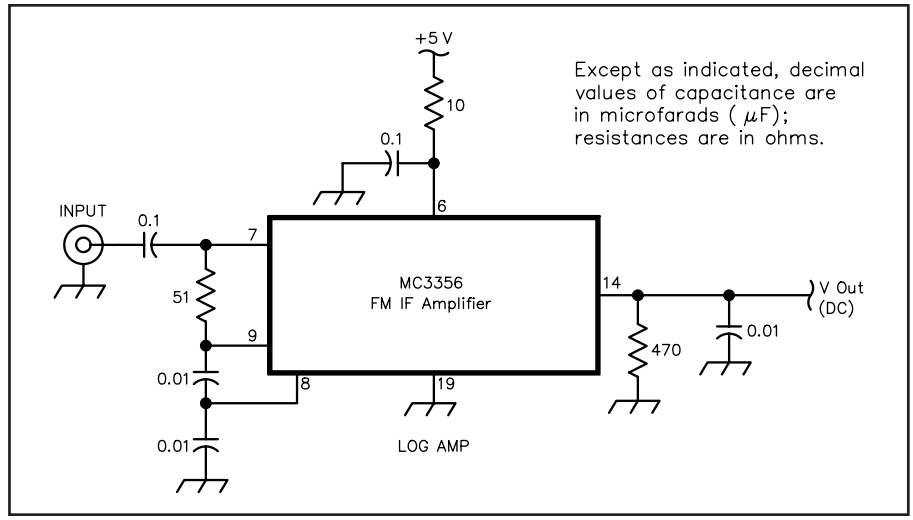

Figure 3—An experimental logarithmic amplifier breadboarded to evaluate performance prior to analyzer construction. You may want to duplicate this circuit and analyze its performance if you decide to use other log-amp ICs.

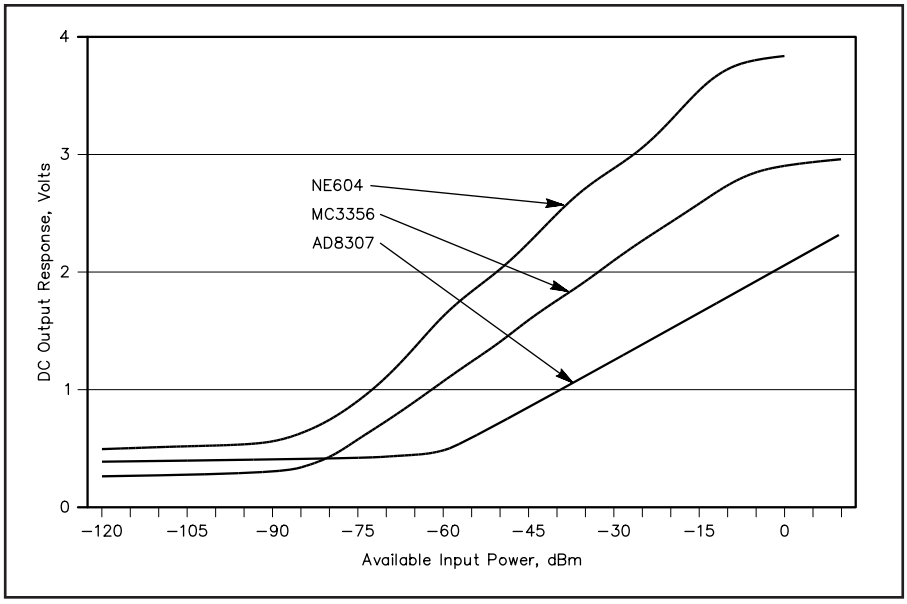

Figure 4—Transfer characteristics for three different logarithmic amplifier ICs. Although the MC3356 is used in our analyzers, use of the AD8307, shown in the lower curve, is recommended. Some curves have been linearly scaled to ease comparison.

"zero spur" at the left edge of the screen.

Setting up the time-base function is generally straightforward. The 'scope can be used to debug, check and study the circuits. The X-axis signal is a ramp ranging from –6 to +6 V with a reset to –15 V during the retrace. A similar ramp appears (without a reset pulse) at the VCO output, but with an amplitude dependent on the **SPAN** control setting.

Although the op amps are carefully bypassed, and the signal that tunes the VCO is shielded, most circuits are noncritical. Normal op-amp circuit precautions are taken with resistors injecting signals into inverting inputs positioned close to the op-amps.[5]

A 10-turn front-panel-mounted pot is used for the **TUNE** control (any value from 5 kΩ to 50 kΩ is suitable). A single-turn pot can be substituted if a 10-turn pot is not available. A fine-tuning function is included in this design, but may be omitted if a 10-turn pot is used for the main tuning.

Log Amplifier and Detector

Central to any spectrum analyzer is a *logarithmic amplifier*. The need for logarithmic processing becomes clear if we consider the range of signals we want to measure: At the low end, we may want to look at submicrovolt levels: under –107 dBm in a 50-Ω system. At the other extreme, we may want to measure the output of small transmitters, perhaps up to a power of 1 W, or +30 dBm. The difference between the two levels is 137 dB. The human ear is capable of handling linear ranges well over 60 dB.[6] This is a wide dynamic range world and linear displays, such as our screen, are inadequate unless some form of data compression or logarithmic processing is used.

The circuit element we use for this processing is the log amplifier.[7] The term is a misnomer, for the usual log-amp IC is both a logarithmic processor (amplifier) and a detector. The chips provide a dc output voltage that increases in proportion to the logarithm of the input amplitude. The central sensitivity specification for a log amp is a voltage slope that is equal to the voltage change (per decade or per decibel) of input-voltage-amplitude change.

An experimental log amp is shown in Figure 3. We breadboarded and tested this circuit to evaluate the log IC. To produce the MC3356 curve shown in Figure 4, the 10 MHz output of an HP-8654 signal generator was applied through HP-355 step attenuators. Exact dc output levels are insignificant, for they can be adjusted with dc voltage gain in a following amplifier. The salient detail that we observe is the dynamic input window. The MC3356, with a 50-Ω input termination, produces a nearly straight-line output voltage versus input power for inputs in the –80 to –10 dBm range. Hence, the analyzer log amp should operate with an input signal of –10 dBm for signals at the top of the screen.

We evaluated two other ICs. One, the commonly available NE/SA604, shows considerable ripple. The best performance offered came from a recently introduced chip from Analog Devices: the AD8307. This IC is designed specifically for measurement applications and offers outstanding logarithmic accuracy, a dynamic range exceeding 90 dB and better temperature stability than found with the usual cellular-receiver chips. The AD8307 requires a high drive level, so it must be preceded with higher-power amplifiers or impedance-transforming networks. The bandwidth of the AD8307 is about 500 MHz, so care is required in its use.

Our analyzer uses the inexpensive and readily available MC3356 log amp shown in Figure 5.[8] An op amp, U303, used to increase the signal output to 0.5 V per division, follows the log chip, U301. The 0 V level corresponds to the bottom of the screen; a signal of 4 V brings the response to the top of the screen. The op-amp output is slightly higher than this, but is then attenuated with a **LOG AMP CAL** control, R2. This pot should be accessible from the outside of the instrument.

The log amp is preceded by an IF amplifier, Q301 through Q303. These stages are biased for relatively high-current operation to preserve linearity. Gain is controlled through variable emitter degeneration in the form of a PIN diode, D301. Most common 1N4000-series power rectifiers work well for gain control. The **IF GAIN ADJ** control (R1) should be available from the exterior of the RF-tight amplifier box. We have placed it on the front panel of our analyzers.

Calibration of the IF and log amplifier is straightforward. First, set the 'scope's Y axis to 0.5 V/division and short it. Set the now-working time base to drive the X axis and adjust the 'scope's vertical position control to place the horizontal line at the bottom of the screen. Inject a –10 dBm signal from a signal generator into the log amplifier input, remove the short circuit and adjust R2, **LOG AMP CAL**, for a full-screen (reference level) response. The input level is next reduced in 10 dB steps. The horizontal sweep line should drop down one major division for each 10 dB reduction over a 60 dB range. If this does not happen, repeat the procedure with a slightly different drive level. In our analyzers, a typical drive level of –13 dBm produced good accuracy.

Now, attach the IF amplifier to the log amplifier and drive them with an input level of –23 dBm. Peak the IF output filter for maximum response and set R1, **IF GAIN ADJ**, for a full-screen response. A true filter peak can be confirmed by varying the generator frequency. There is considerable extra range in the **IF GAIN ADJ**, providing extra flexibility during use.

Resolution Filters

Continuing the backward progression through the system, we encounter the resolution-bandwidth-determining filters. Our analyzer uses bandwidths of 30 and 300 kHz, provided by crystal and LC filters, respectively. The 300 kHz LC filter, the crystal filter and the relay circuitry for bandwidth switching are shown in Figure 6. Although shown as individual modules, they can be incorporated into one. The PC board for the filter includes the LC filter and switching relays with room for a user-selected crystal filter. Builders may want to implement their own scheme here. We

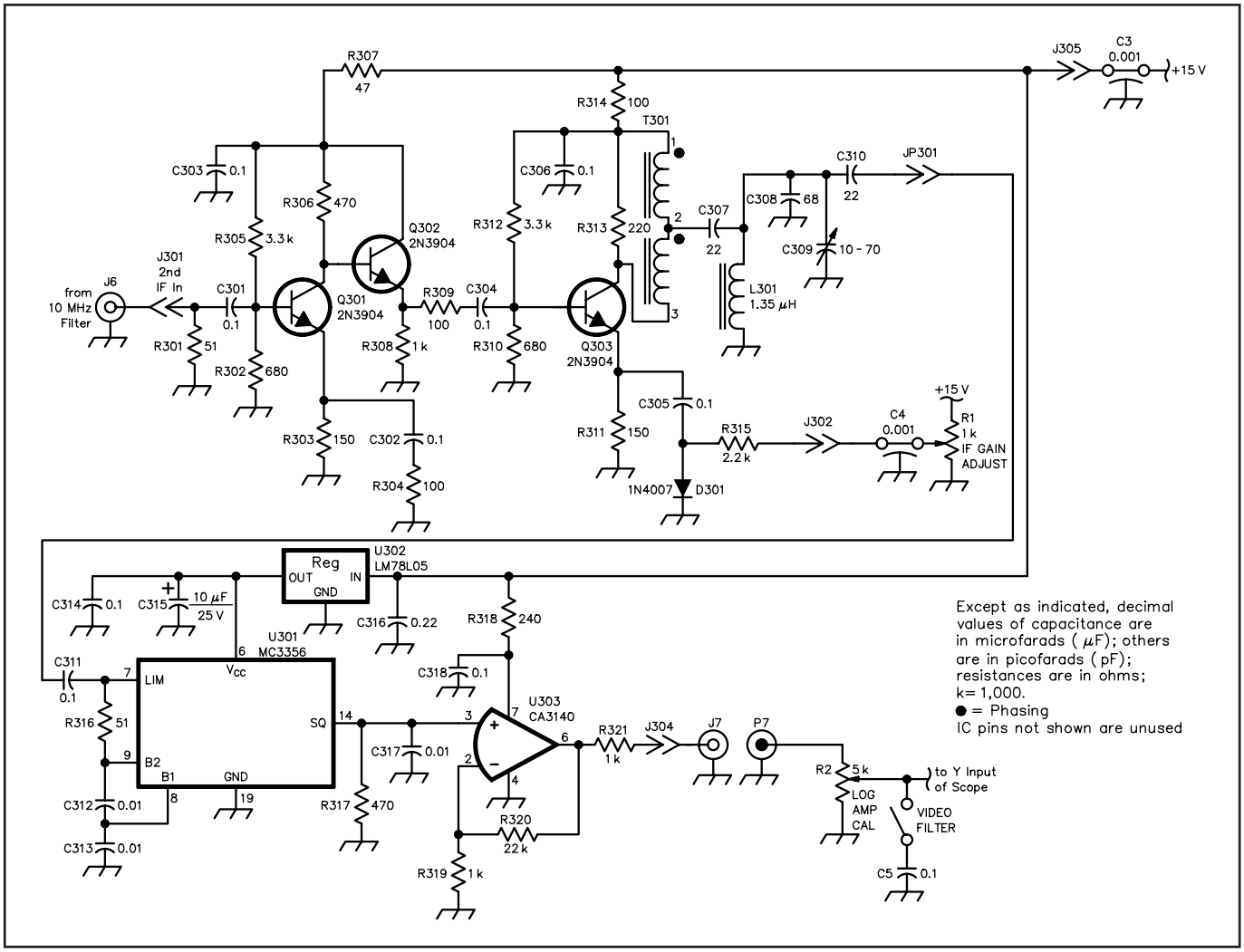

Figure 5—The 10 MHz IF amplifier and log amplifier used in the analyzer. Refer to the text for adjustment details. Unless otherwise specified, resistors are 1/4 W, 5% tolerance carbon-composition or film units. Equivalent parts can be substituted.

C309—Plastic dielectric trim cap (Sprague-Goodman GYD65000)
C307, C308, C310—Silver mica or NP0 ceramic capacitors, 10% tolerance
C316—0.22 µF ceramic
D301—PIN diode; 1N4007 used
L301—1.35 uH, 18 turns #24 enameled wire on T-44-6 core, Q >150
Q301, Q302, Q303—2N3904
R1—Panel-mount, 1 kΩ linear
R2—Panel-mount, 5 kΩ linear
U301—Motorola MC3356
U302—78L05 +5 V regulator
U303—CA3140 op amp

reasoned that builders would want to implement their own ideas. Maintain reasonable shielding for this part of the system. Additional attenuator pads can be inserted in line with one filter or the other to approximately equalize filter loss in the two paths.

You may want to build crystal filters for your analyzer.[9] The VCO stability in this analyzer will support resolution bandwidths as narrow as 3 to 5 kHz. For a simplified beginning, a very practical analyzer can be built with only one resolution bandwidth of 300 kHz.

Second Mixer and Second Local Oscillator

Figure 7 shows the second mixer and related LO. The heart of this module—and to some extent that of the entire analyzer—is U202, a high-level second mixer. This mixer is bombarded by large signals that are as strong or stronger than those at the front end. Accordingly, the second mixer should have an intercept similar to that of the first mixer. This is the usual weak point in all too many homebrew spectrum analyzers—as well as more than a few receivers! The second mixer, U202, uses a +17 dBm level Mini-Circuits TUF-1H. This is *not* the place for a current-starved telephone component! The second mixer is terminated in a high-pass/low-pass diplexer followed by an IF amplifier (Q202) biased at 50 mA. This is a critical stage for dynamic range: Don't replace it with a monolithic substitute of reduced gain or intercept.

The second LO begins with a 100 MHz, fifth-overtone crystal oscillator (Q201), followed by a pad and a power amplifier. The oscillator inductor, L201, in Q201's collector is made of five turns of #22 wire wound on a 6-32 machine screw. (Remove the screw before installing the coil.) Here's an excellent way to align the oscillator: Temporarily replace the crystal, Y201, with a 51 Ω resistor. Adjust the tuned circuit until oscillation occurs at the desired 100 MHz frequency. Then, replace the 51 Ω resistor with the 100 MHz crystal; no further tuning is required. Measure the oscillator's output with a power meter before applying it to U202. Adjust the pad attenuation (R205, R206, R207) to realize the specified LO drive level.

After the second LO is operating, attach it to the second mixer and the rest of the analyzer. With a second mixer input of –35 dBm at 110 MHz, you should obtain a reference-level response.

Voltage-Controlled Local Oscillator and First Mixer

Figure 8 shows the analyzer's swept LO. The foundation for this module is a Mini-Circuits POS-200 VCO module, U101. Similar VCOs are available from many

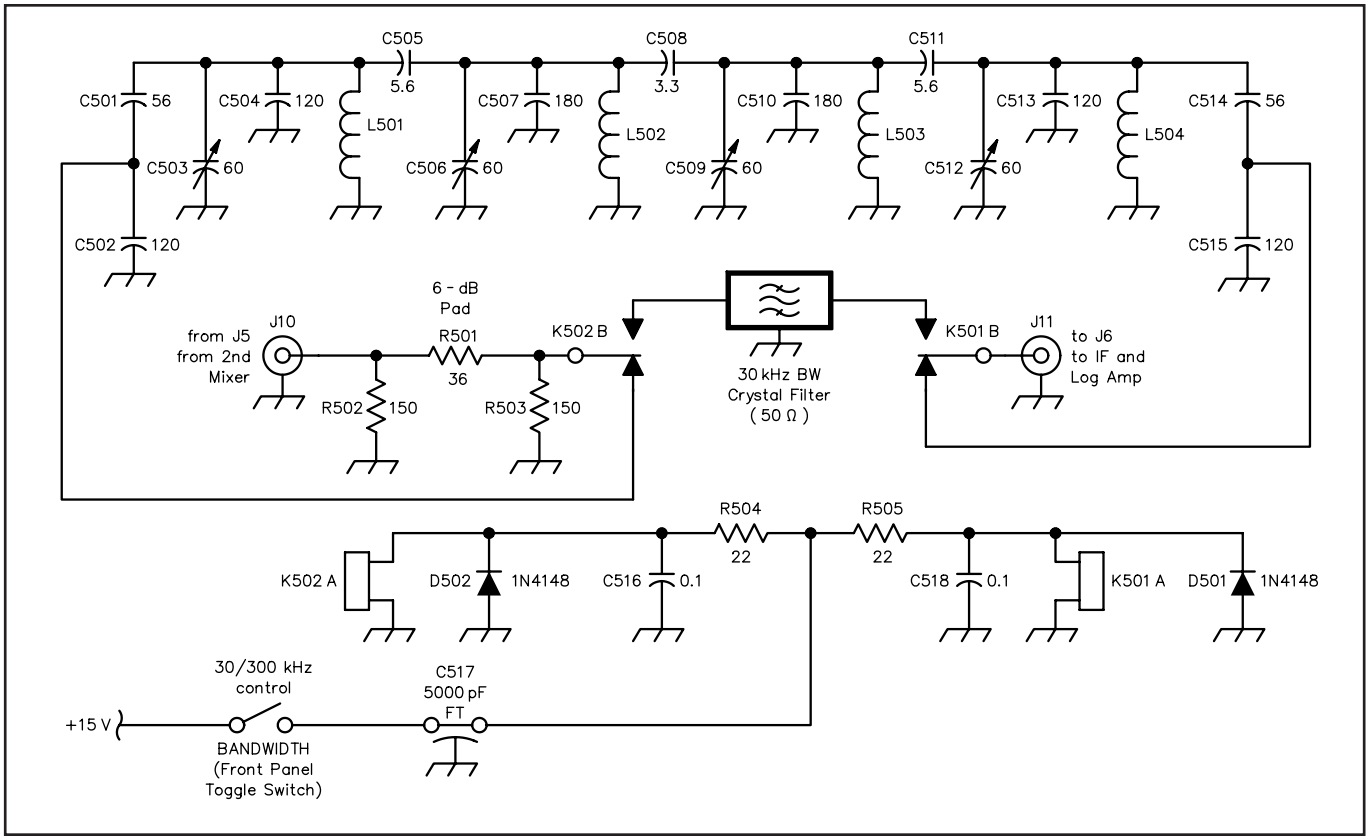

Figure 6—Resolution filters: The upper schematic shows the 300 kHz bandwidth 10 MHz LC filter. If desired, that circuit can be realigned at 10.7 MHz without other design changes. The LC filter is shown as a separate unit connected to the rest of the analyzer with coaxial cable. However, the filter can be constructed on the board with the crystal filter and relays. Unless otherwise specified, resistors are 1/4 W, 5% tolerance carbon-composition or film units. Equivalent parts can be substituted.

C501, C502, C504, C505, C507, C508, C510, C511, C513, C514, C515—Silver mica or NP0 ceramic, 5%
C503, C506, C509, C512—65 pF plastic dielectric trim cap (Sprague-Goodman GYD65000)
K501, K502—SPDT relay; Aromat TF2-12V used here (one contact set unused); values of associated dropping resistors may need adjustment.
L501-L504—17 turns of #22 enameled wire on a T-50-6 toroid (1.15 µH), Q > 250

vendors.[10] The VCO output is about +10 dBm, too low a level for the high-level mixer. A MAV-11 amplifier, U102, preceded by a pad to provide level adjustment, increases the signal level. Confirm the output power level before applying it to the mixer, U103.

Once the VCO output level is adjusted and confirmed, calibrate its frequency against the VCO control voltage. If a VHF counter is not available, you can obtain a few points by tuning the VCO to hit local FM broadcast signals of known frequency. Calibrating the VCO is useful if the module is used later as a signal source for alignment of the 110 MHz band-pass filter.

Figure 8 also shows the input mixer, U103, another Mini-Circuits TUF-1H, terminated in a 6 dB pad. Although the pad degrades the noise figure, it presents a solid output termination for the mixer. This termination is reflected, helping to provide a good mixer-input impedance match, important in a measurement instrument. The pad is followed by a Mini-Circuits MAV-11 IF amplifier (U104) that restores the gain lost in the mixer and pad.

The mixer application differs from a normal diode ring: The RF input is now attached to the dc-coupled port. This allows input frequencies as low as 50 kHz to be converted to the first IF. The low-frequency end is limited by mixer LO to RF isolation, which determines the LO energy that reaches the first IF. The related on-screen response is often termed the *zero spur*, a familiar "feature" in most RF spectrum analyzers.

This module (VCO and first mixer) is contained in a shielded enclosure with coaxial inputs and outputs, including coaxial routing of the VCO control voltage. The front end is susceptible to any VHF and UHF signals reaching it, making shielding and decoupling especially important.

The 110-MHz IF Band-Pass Filter

One of the more-critical blocks in the analyzer is the filter that establishes the bandwidth of the VHF IF. The bandwidth must be at least as wide as the widest 10 MHz filter, but must be narrow enough to reject the 90 MHz second-conversion images by 80 dB or more. This performance is only available with a three-pole or higher-order filter. The best double-tuned circuits we built (or computer simulated) came close, but just didn't cut it.

We described double-tuned circuits in detail in a 1991 *QST* tutorial paper.[11] Those methods have recently been extended to three-resonator filters.[12] One of the methods presented in the later paper is a sequential approach that begins with a double-tuned circuit (DTC). First, a DTC is built for the desired 3 dB bandwidth and has its performance confirmed with a wideband sweep (a vital requirement!) Then, a third resonator is inserted between the original two. Coupling elements similar to the one that produced the required DTC bandwidth are repeated in the triple-tuned circuit, but end-section loading is not changed. The center frequency of the three resonators is aligned to complete the filter.

The schematic for the 110 MHz triple-tuned circuit is shown in Figure 9. The inductors,100 nH, are made by winding 5 turns of #18 wire on the shank of a 1/4-inch drill bit. These inductors typically have an unloaded Q of just over 200 at 110 MHz. Larger-diameter inductors would have produced higher unloaded Q with the attendant lower insertion loss. However, the

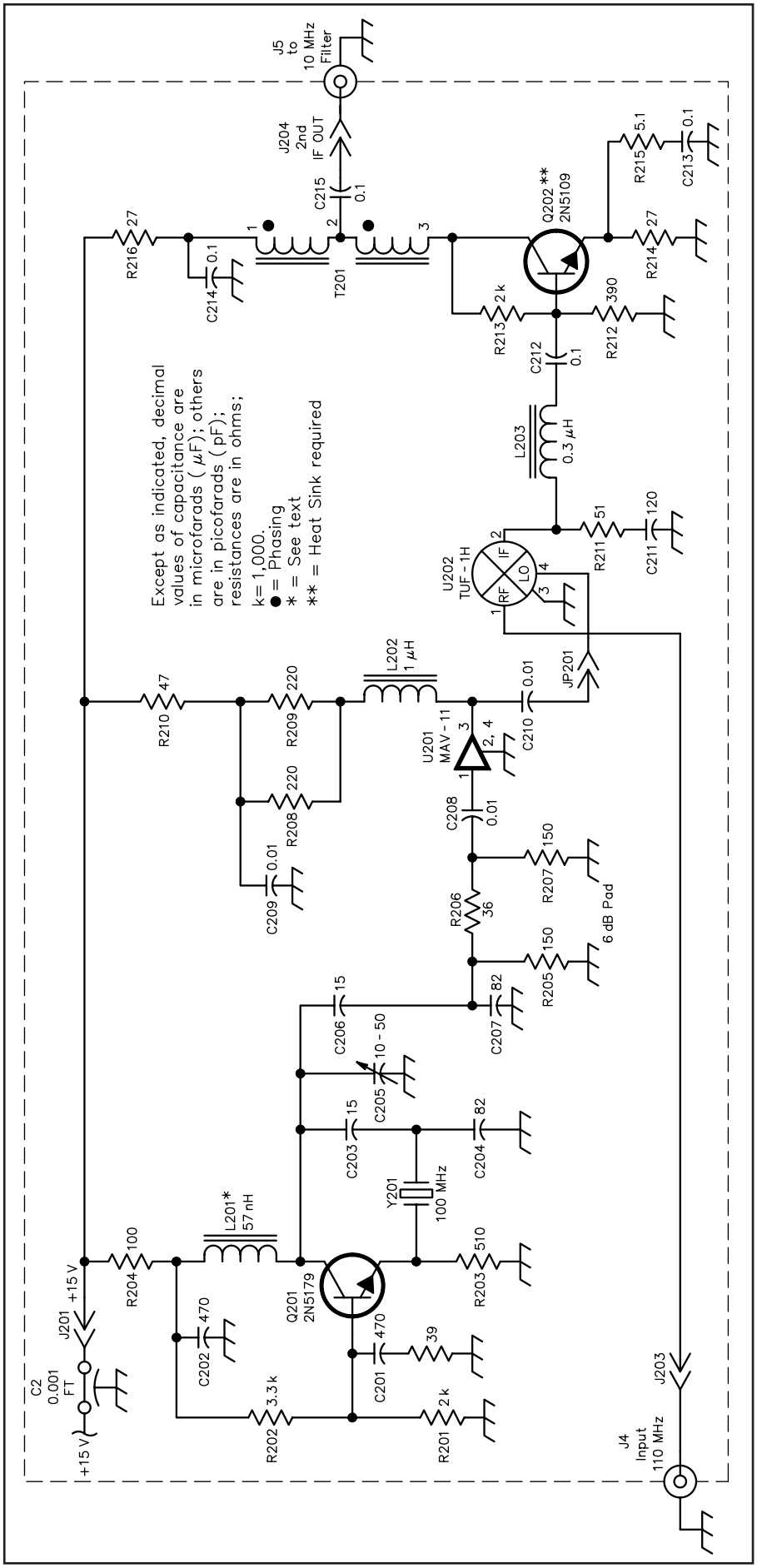

Figure 7—Second mixer and second LO. L203 in the output of U202 consists of 17 turns of #28 enameled wire on a T-30-6 toroid. The actual value is not critical and a molded RF choke can be used in place of the toroid. Unless otherwise specified, resistors are 1/4 W, 5% tolerance carbon-composition or film units. Equivalent parts can be substituted.

C201, C202—470 pF ceramic
C203, C206—15 pF NP0 ceramic or silver mica
C204, C207—82 pF NP0 ceramic or silver mica
C205—65 pF plastic dielectric trim cap (Sprague-Goodman GYD65000)
C211—120 pF, silver mica or NP0 ceramic
L201—57 nH; 5 turns of #22 wire wound on a 6-32 machine screw. Remove the screw before installing the coil.
L202—1 µH molded RFC; any value from 100 nH to 2.7 µH is okay
L203—0.3 µH; 9 turns #24 enameled wire on a T-30-6 core
Q201—2N5179
Q202—2N5109, 2N3866, 2SC1252, etc
U201—Mini-Circuits MAV-11
U202—Mini-Circuits TUF-1H mixer
T201—10 bifilar turns #28 on FT-37-43 ferrite toroid

stray coupling between coils would have increased, which would have necessitated shields between filter sections. The smaller (10 nH) end-matching inductors are one-inch lengths of #18 wire. The triple-tuned filter, and its parent DTC, have bandwidths of 2 to 3 MHz.

The filter alignment and experimentation is usually done with a sensitive power meter,[13] a step attenuator and a signal source. As mentioned earlier, the VCO can serve the role of signal generator, if one is not available.

The second-conversion image rejection is easily measured with a finished analyzer. Apply a 40 MHz signal to the analyzer and adjust it for a reference-level response. Don't touch the analyzer tuning, but move the signal generator to 60 MHz. An image signal may appear at the same point on screen as the original 40 MHz signal. The rejection was only 66 dB with a DTC used for some experiments. The triple-tuned filter produced 90-dB rejection. The slight extra effort of the triple-tuned circuit is easily justified. No PC board is available for the IF filter.

Input Low-Pass Filter

A 70 MHz low-pass filter is shown in Figure 10. This circuit and a step attenuator are housed in separate shielded enclosures in one of our analyzers. In the other, the filter and the attenuator remain outboard elements. Integral components are more convenient for routine analyzer applications, but incorporation removes them from the equipment pool available for other experiments. Also, operation without an outboard low-pass filter allows the instrument to be

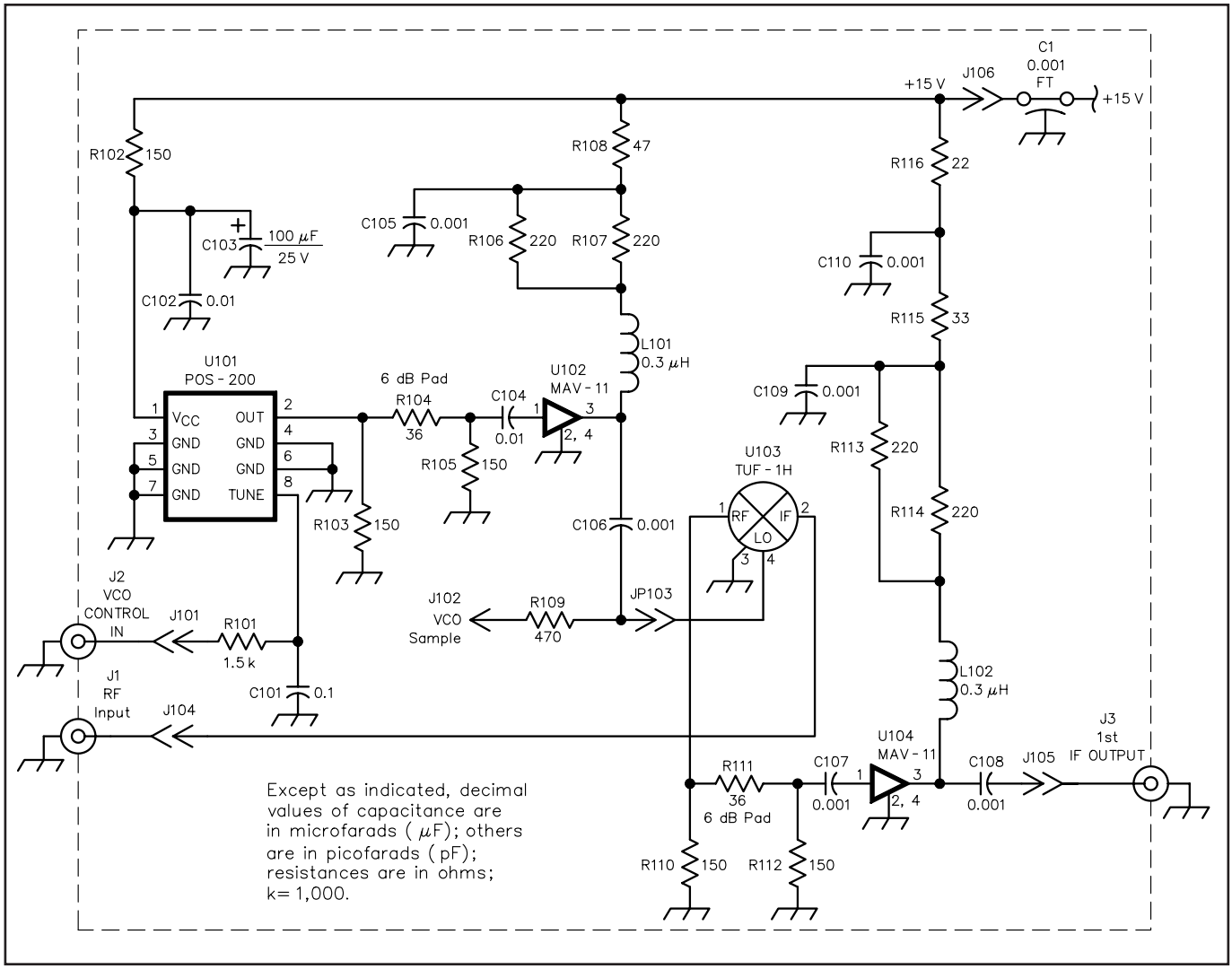

Figure 8—Front-end for the spectrum analyzer. The LO drive level is set to between +16 and +18 dBm by trimming the pad attenuation. The 1 µH inductors used in the MAV-11 outputs can be molded RF chokes or made of 17 turns of #28 enameled wire wound on T-30-6 toroids. Unless otherwise specified, resistors are 1/4 W, 5% tolerance carbon-composition or film units. Equivalent parts can be substituted.

L101, L102—1 µH molded RFC; any value between 100 nH to 2.7 µH suitable

U101—Mini-Circuits POS-200 VCO
U102, U104—Mini-Circuits MAV-11

U103—Mini-Circuits TUF-1H

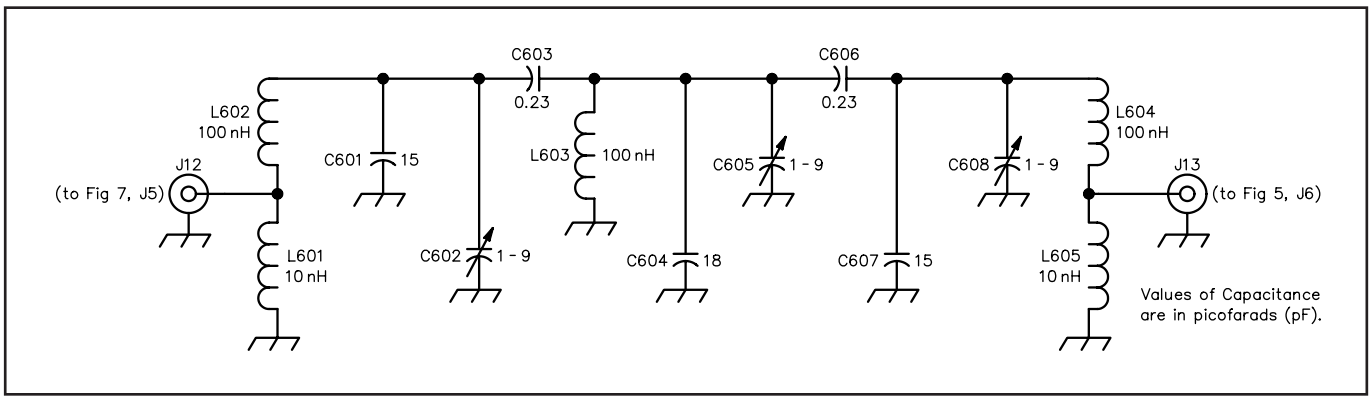

Figure 9—VHF band-pass filter used in the 110 MHz IF.

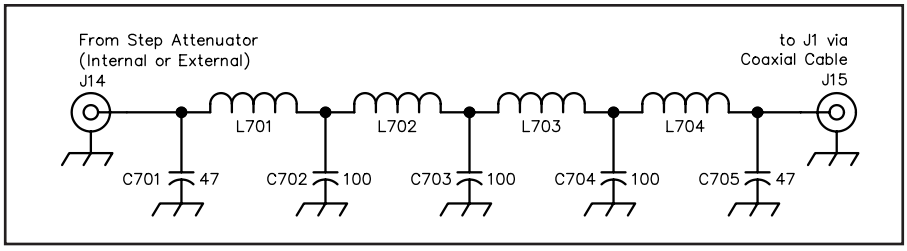

Figure 10—Input 70 MHz low-pass filter. The filter started as a ninth-order Chebyshev design, but was modified through computer manipulation to use equal-value inductors and standard-value capacitors. The inductors each consist of 8 turns of #22 wire. The wire is wound on the threads a 1/4-20 bolt as a form; remove the bolt after winding the inductor. See text.

C701-C705—NP0 ceramic, 5% tolerance.

L701-L704—8 turns #22 bare wire wound in 1/4-20 bolt threads; see text.

used well into the low UHF area by operating the mixer with VCO harmonics. (No circuit boards are available for this filter.)

Construction and Adjustment Hints

The spectrum analyzer can be built using a number of RF techniques. Our analyzers are collections of small boxes using coaxial-cable interconnections. Power supplies reach the interior of RF modules through feedthrough capacitors. The only open boards in the system are the time base and (in one instrument) the log amp, both constrained to low frequencies. The 110 MHz IF filter and all RF circuit boards are designed to fit in Hammond 1590B diecast aluminum alloy boxes.

The sensitivity of such RF measurement equipment justifies the extensive shielding. Spurious responses are readily seen on the display. While a few can be tolerated, they seriously detract from a measurement when, for example, spurious transmitter products are being examined.

Most of the adjustment has already been discussed. Indeed, by the time the analyzer is finished, there is little alignment left! The block diagram (Figure 1) has typical signal levels shown in parentheses.

The finished analyzer is set up with a –30 dBm signal from a stable-impedance source. Adjust the IF gain to establish the reference level. If the 10 dB per division tracking is not quite correct, change the log amp gain, followed by a readjustment of the IF gain until tracking is correct. IF gain is adjusted to the reference level whenever the analyzer is used.

Next month, we'll present methods to extend the analyzer to higher frequencies. We'll discuss simple test equipment that can be used in alignment and present some typical examples of spectrum-analyzer use.

Notes

[1]Homebrew analyzers described in amateur literature in recent years have often used TV tuners as the front end. See, for example, Al Helfrick, K2BLA, "An Inexpensive Spectrum Analyzer for the Radio Amateur," *QST*, Nov 1985, pp 23-29. A more recent example is Fred Brown, W6HPH, "Build a 5- to 850-MHz Spectrum Analyzer," *Communications Quarterly*, Winter, 1997, pp 91-96.

[2]The usual unit for power measurement with a spectrum analyzer is dBm. This is an absolute, impedance invariant unit, signifying power compared with 1 mW. Hence, –30 dBm is 30 dB below a milliwatt, or a microwatt. The dBm unit is especially useful in spectrum analysis where two levels are often compared. The difference between two powers in dBm is a power ratio in dB. (See Jay Craswell, WBØVNE, "Converting Between dBm, Milliwatts and Watts," Technical Correspondence, *QST*, Jul 1998, p 70.—*Ed.*)

[3]Excellent homebrew VCOs can be built using the work of Allan Victor, WA4MGX, "Wideband VCO Design," *Ham Radio Magazine*, Jul, 1984, pp 49-58. See also the recent work of Colin Horrabin, G3SBI, as reprinted in "Tech Notes," *Communications Quarterly*, Winter, 1996, pp 94-104.

[4]Many amateurs are uncomfortable with op-amp circuits, a situation easily remedied by a study of the excellent text by Horowitz and Hill, "The Art of Electronics," 2nd Edition, Cambridge University Press, 1989. See the golden rules presented on page 177. An op-amp integrator is presented on page 222. The information on sawtooth oscillators beginning on page 288 is also useful.

[5]PC boards for several of the analyzer circuits are available from Kanga USA. Details are available at the Kanga Web site, **http://www.bright.net/~kanga/kanga/**, or from Kanga USA, 3521 Spring Lake Dr, Findlay, OH 45840.

[6]The best digital audio recording and playback systems have a dynamic range around 90 dB.

[7]An outstanding fundamental treatment of log amps is given in applications data from Analog Devices. See, for example, the data sheet for the AD8307, Analog Devices, Norwood, MA, 1997, **http://www.analog.com/product/Product_Center.html**.

[8]The log/IF board available from Kanga (see Note 5) is configured for the MC3356. Most of the 20 pins allotted to the IC are not used and their locations can be employed to breadboard and retrofit the AD8307 (8 pin DIP) into the system, if desired.

[9]If crystal filters are built especially for this project, we recommend a peaked response shape (such as Gaussian-to-6 dB). We have investigated wider bandwidth crystal filters as presented in Wes Hayward, W7ZOI, "Refinements in Crystal Ladder Filter Design," *QEX*, Jun, 1995, pp 16-21. See also the careful work of Bill Carver, "High Performance Crystal Filter Design," *Communications Quarterly*, Winter, 1993, pp 11-18, and that of Jacob Makhinson, N6NWP, "Designing and Building High Performance Crystal Ladder Filters," *QEX*, Jan 1995, pp 3-17.

[10]See the Mini-Circuits catalogs and applications manuals. A family of viable VCOs are also available from Synergy Microwave. These units are more expensive, but offer lower phase noise, which would be significant for more-stringent applications.

[11]Wes Hayward, W7ZOI, "The Double Tuned Circuit: An Experimenter's Tutorial," *QST*, Dec 91, pp 29-34.

[12]Wes Hayward, W7ZOI, "Extending the Double-Tuned Circuit to Three Resonators," *QEX*, March-April, 1998, pp 41-46.

[13]Denton Bramwell, K7OWJ, "The Microwatter," *QST*, Jun 1997, pp 33-35. Also, see the sidebar in the referent of Note 11.

Wes Hayward, W7ZOI, and Terry White, K7TAU, are not strangers to QST. *This is also not the first* QST *project on which they've worked together. The first, "The Mountaineer—An Ultraportable CW Station," described a QRP transceiver and appeared in the August 1972 issue. At the time this spectrum-analyzer project evolved, the authors worked together in the Advanced Circuits section of the Receiver Group at TriQuint Semiconductor in Hillsboro, Oregon. Over the years, Wes has provided readers of* QST, The Handbook *and other ARRL publications with a wealth of projects and technological know-how. You can contact Wes at 7700 SW Danielle Ave, Beaverton, OR 97008; e-mail* **w7zoi@teleport.com**. *Terry can be reached at 9480 S Gribble Rd, Canby, OR 97013; e-mail* **twhite@tqs.com**.

New Products

ATV TRANSMITTER FROM PC ELECTRONICS

◊ The TX70-10 ATV transmitter from PC electronics is aimed at operators who use cable-ready TVs (tuned to channels 57-60) to receive amateur television signals in the 70-cm ham band. The continuous-duty transmitter puts out 10 W AM (color or black-and-white, just like broadcast TV stations) and features a built-in T/R relay, variable power output, front-panel RCA jacks for video and audio (with line and mic inputs), a video monitor circuit and a PTL jack (push-to-look) in parallel with the unit's T/R switch.

The TX70-10 is housed in a die cast aluminum box measuring about 7×5×3 inches and is powered by 13.8 V dc at 3 A. The unit comes with one user-specified crystal in the 440-MHz range. An optional second front-panel-selected crystal is available for $20. A repeater version, the RTX70-10, is also available.

Price: $439 shipped to the lower 48 states. For more information, contact PC Electronics, 2522 Paxson Ln, Arcadia, CA 91007; tel 626-447-4565; **tomsmb@aol.com**.

By Wes Hayward, W7ZOI, and Terry White, K7TAU

A Spectrum Analyzer for the Radio Amateur—*Part 2*

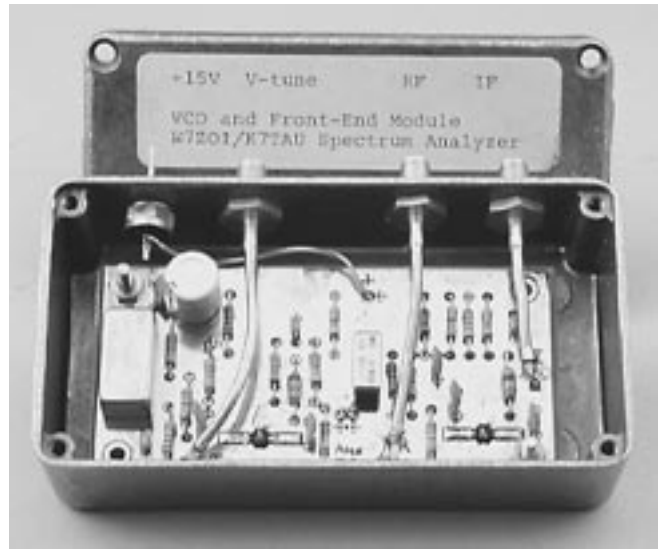

Here are some examples of procedures you can use to become familiar with your new spectrum analyzer.

In Part 1,[14] we described the design and construction of a simple, yet useful spectrum analyzer. This installment presents some applications and methods that extend the underlying concepts.

Amplifier Gain Evaluation

One use for a spectrum analyzer is amplifier evaluation. We can illustrate this with a small amplifier from the test-equipment drawer—an old module that has been pressed into service for a variety of experiments. This circuit, shown in Figure 11, is used for illustration only and is not presented as an optimum design. It's a project that grew from available parts and may be familiar to some readers. The circuit uses four identical 2N5179 amplifier stages. A combination of emitter degeneration and parallel feedback provides the negative feedback needed to stabilize gain and impedance. (Ideally, construction and measurement of a *single* stage should precede construction of the complete amplifier.)

We began the experiment by setting the signal generator at a known power level, –20 dBm. (If a good signal generator is unavailable, you can easily build a suitable substitute.[15] We used a surplus HP8654A for most of these experiments.) With the generator and spectrum analyzer connected to each other through 50-Ω coax cable, we set the generator to 14 MHz with 10-dB attenuation ahead of the analyzer. The amplifier was not yet connected. We adjusted the analyzer's **IF GAIN** control for a response at the top of the screen. Using a resolution bandwidth of 300 kHz allows for a fast sweep without distortion. In our case, the second harmonic was only 26 dB below the peak response. However, when we added a 15 MHz low-pass filter, the second harmonic dropped to –57 dBc.[16] The third harmonic is well into the noise. (It is not unusual for a signal generator to be moderately rich in harmonics.)

Next, we inserted the amplifier between the signal generator and the analyzer, keeping the low-pass filter in the generator output. The on-screen signal went well above the top as soon as the amplifier was turned on. Decreasing the signal generator output to –51 dBm produced the same –20 dBm analyzer signal that we saw before the amplifier was inserted. The gain measured 31 dB.[17] Increasing the analyzer attenuation by 10 dB (for a reference level of –10 dBm) and increasing the generator output to –41 dBm produced the same gain, but a growing harmonic output. The second-harmonic response was now at –43 dBc and a third harmonic appeared out of the noise at –60 dBc.

We continued the process—moving both step attenuators produced an amplifier output of 0 dBm with second and third harmonics at –28 and –36 dBc, respectively. The next 10-dB step, however, didn't work as well, producing gain compression. With a drive of –21 dBm, the output was only +4 dBm, a gain of only 25 dB instead of the small-signal value of 31 dB.

Amplifier Intermodulation Distortion

Next, we measured intermodulation distortion (IMD). The setup for these experiments is shown in Figure 12. Two crystal-controlled sources[18] at 14.04 and 14.32 MHz are combined in a 6 dB hybrid combiner (return-loss bridge),[19] applied to the 15 MHz low-pass filter and a step attenuator having 1 dB steps. This composite signal drove the amplifier, with its output routed to the spectrum analyzer. For this measurement, we dropped the resolution bandwidth to 30 kHz. (The video filter was turned on and the sweep rate reduced until the signal amplitude was stable.) The analyzer's attenuator, set for a reference level of –10 dBm at the top of the screen, was confirmed with a calibration signal from the signal generator. We adjusted the **IF GAIN** to compensate for changes in analyzer bandwidth and for log-amplifier drift.

The output of the two-tone generator system was adjusted to produce a spectrum analyzer response of –10 dBm per tone. The IMD responses were readily seen, now 47 dB below the desired output tones. The output intercept is given by

$$IP3_{out} = P_{out} + \frac{IMDR}{2}$$

where P_{out} is the output power of each desired tone (–10 dBm) and IMDR is the intermodulation distortion ratio, here 47 dB. The output intercept for this amplifier measured +13.5 dBm. This is well in line with expectations for such a design.

When performing IMD measurements, it's a good idea to change the signal level while noting the resultant performance. Dropping the drive power by 2 dB should cause a –2 dB response in the desired tones, accompanied by a 6 dB drop in distortion-product tones. The output intercept

[14]Notes appear on page 40.

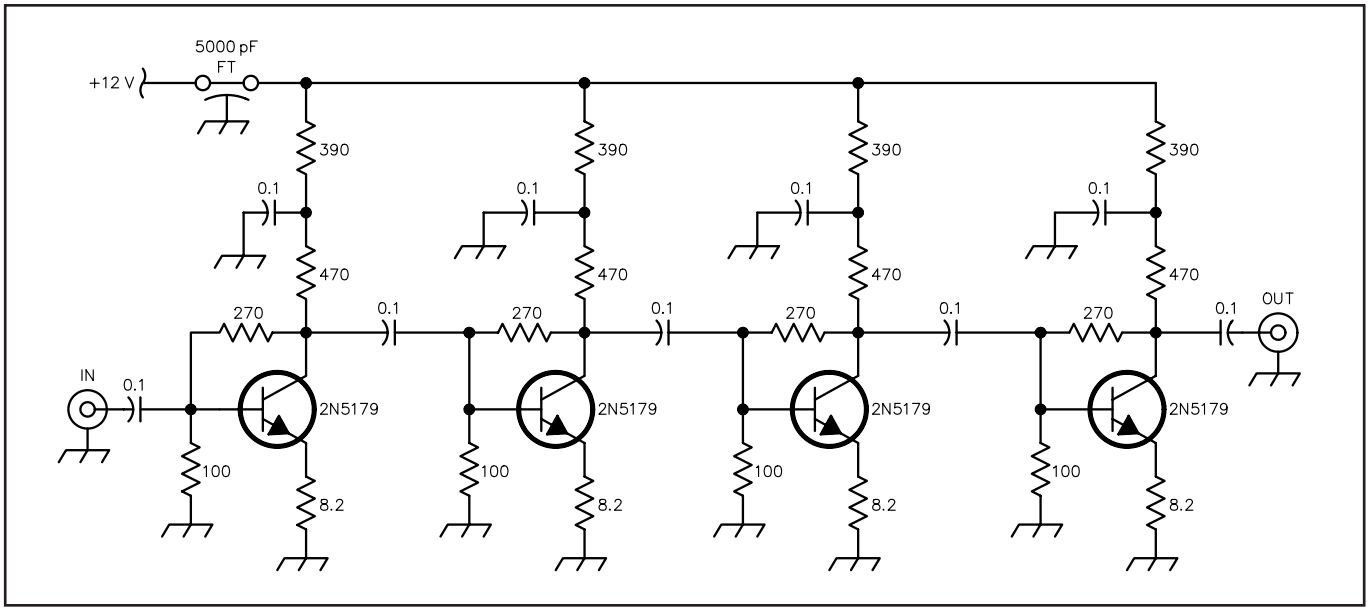

Figure 11—Sample wideband amplifier used to illustrate amplifier measurements.

should remain unchanged.

The IMD in the preceding example was 47 dB below the desired output tones, a value that we obtained by simply reading it from the face of the 'scope, possible because we use a log amplifier that has moderate log fidelity. If the log amplifier was not as accurate as it is, we could still get good measurements. In this example, you would note the location of the distortion products on the display. Then, using the step attenuator, decrease the desired tones until they are at the noted level. The result would be –47 dBc for the distortion level, a measurement that depends solely on the accuracy of the attenuator. This illustrates the profound utility of a *good* step attenuator, an instrument that can be the cornerstone of an excellent basement RF laboratory.

During the third-order output-intercept determination just described, we assumed that the distortion was a characteristic of the amplifier under test. This may not be true. It is important to determine the IMD characteristics of the spectrum analyzer used for the measurements before the amplifier measurements are fully validated. Specifically, for results to be valid, the input intercept of the analyzer should be much greater than the output intercept of the amplifier under test.

The spectrum analyzer input intercept is easily measured with the same equipment used to evaluate the amplifier. The two tones are applied to the analyzer input with no attenuation present at the analyzer front end. Then, the input tones are adjusted for a full-screen response. In this condition, there should be no trace of distortion. Although this is generally an adequate test, it *does not* establish a value for the input intercept. To do that, we must overdrive the analyzer, using signals that exceed the top of the screen.

The following steps were used to measure the analyzer input intercept:

• We calibrated the analyzer for a reference level of –30 dBm with a 30-kHz resolution.

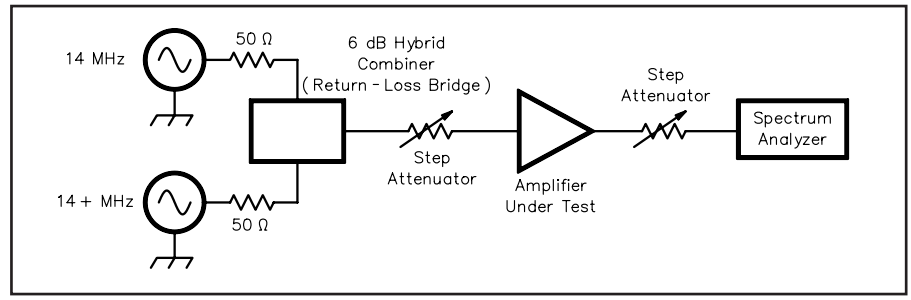

Figure 12—Equipment setup for evaluation of amplifier intermodulation distortion.

• Confirmed the lack of on-screen distortion with two tones at the reference level.

• Increased the drive of each tone by 10 dB to provide a pair of –20 dBm tones to the analyzer. This higher-than-reference-level input produced distortion products 66 dB below the reference level, or –96 dBm. The input signals producing this were each –20 dBm, so the IMD ratio is (–20) – (–96) = 76 dB. Following the earlier equation, the input intercept was +18 dBm.

• A 2-dB drive increase produced the expected 6-dB distortion increase. If this had not occurred, distortion measurements under overdrive would be suspect. The +18-dBm value seems to be a good number. This analyzer generally seems happy with signals 20 dB above the top of the screen, but not much more.

The intercept for the analyzer with attenuation in place is the measured value with no pad plus the attenuation. Hence, with 20 dB of attenuation, the input intercept will be +38 dBm, and so forth.

Return-Loss Measurements

The next amplifier characteristic that we measured was the input impedance match, or return loss, performed with the setup shown in Figure 13. With the signal generator set for a 14-MHz output of about –30 dBm, we set

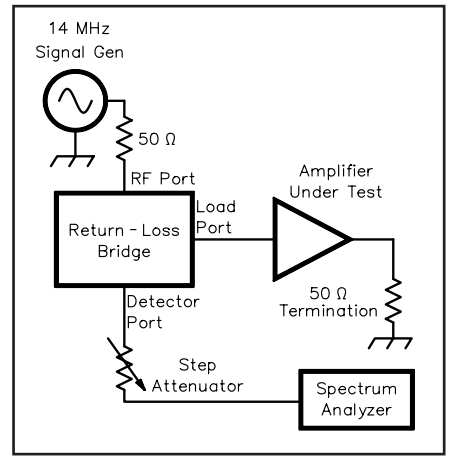

Figure 13—Test setup for impedance-match measurements with return-loss bridge.

the analyzer for full-scale response with the **LOAD** port of the return-loss bridge open circuited. Placing a 50-Ω termination momentarily on the **LOAD** port, produced a 38-dB signal drop. This is a measure of the bridge directivity. A 38-dB directivity is more than adequate for casual measurements.

Then, we removed the termination from

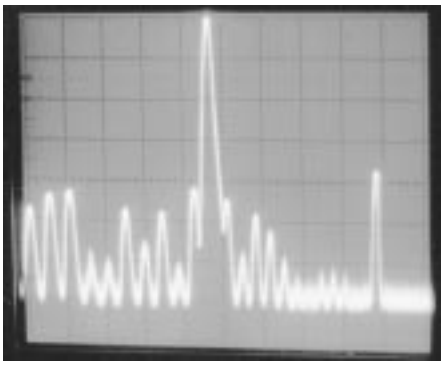

Figure 14—Output of a typical QRP transceiver kit. The 1-W plus output at 7 MHz is the dominant signal; all others are spurious outputs more than 40 dB down, currently meeting FCC specifications.

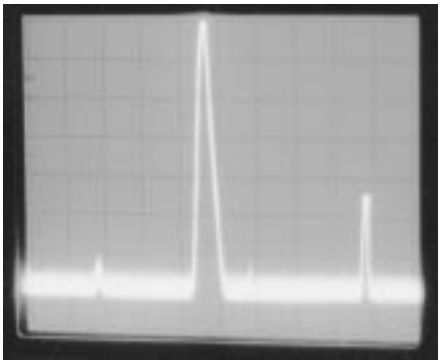

Figure 15—Output of a simple homemade QRP rig. The desired signal is the large pip at the center of the trace. Two measurable spurious responses exist, one to the left and one to the right of the main signal. The response to the left is 3.5 MHz feedthrough from the VFO at –64 dBc; the response to the right of the desired signal is a second harmonic at –44 dBc.

the bridge and placed it on the amplifier output. A short length of cable connected the bridge load port to the amplifier input with power applied to the amplifier. The result was a response 20 dB below the top of the display; 20 dB is the return loss for the amplifier input, an excellent match for a general-purpose amplifier.[20] The match improved slightly when the output load was removed, an unusual situation.

The next variation measured the output match for the amplifier. The load was transferred to the amplifier input and the cable from the bridge **LOAD** port was moved to the amplifier output, producing a reading 15 dB below the screen top. This match was virtually unchanged when the input termination was removed. The weak dependence of both amplifier return losses is the result of a four-stage design. A single-stage feedback amplifier will have port impedances that depend strongly on the termination at the opposite port.

The –30 dBm drive from the generator provides an available power of –36 dBm from the bridge **LOAD** port. This is low enough that the amplifier is not over-driven. The match measurements should be done at a level low enough that the amplifier remains linear. In this case, we saw no difference in the results with drive that was 10 dB higher.

When performing return-loss measurements—and indeed, most spectrum-analyzer measurements—it is wise to place at least 10 dB of attenuation ahead of the spectrum-analyzer mixer. When this attenuation is switched in, the reference level changes from the top of the screen to a point down screen a bit. Return loss is then measured as a decibel difference with regard to the new reference.

Antenna Measurements

It is interesting to look at some other impedance values while the return-loss bridge is attached to the signal generator and spectrum analyzer. The obvious choice is the station antenna system, especially if it is connected through a Transmatch. Playing with the tuning will readily demonstrate that the return-loss bridge and sensitive detection system will allow adjustments to accuracy unheard of with traditional diode detector systems. Although such tuning accuracy is not needed in a normal antenna installation, it is interesting to see what *can* be measured when the need does arise.

Transmitter Evaluation

Another obvious application for a spectrum analyzer is in transmitter evaluation. Figure 14 shows the output of a typical QRP transceiver kit. The 1-W plus output at 7 MHz is the dominant signal, with all others being transmitter spurious outputs. All spurs are more than 40 dB down, which meets current FCC specifications. On the other hand, significantly better performance is easily obtained, especially if the builder has the facilities to measure them. Figure 15 is a photograph of a simpler QRP rig with two measurable spurious responses. One is the 3.5-MHz feedthrough from the VFO at –64 dBc; the second is a harmonic at –44 dBc.

The output available from a typical QRP rig (and certainly higher power rigs) is enough to damage the spectrum-analyzer input circuits. Attenuators that we generally build are capable of handling 0.5 to 1 W input without damage, while commercial attenuators are rated at from 0.5 to 2 W input. The mixers used in this analyzer can be damaged with as little as 50 to 100 mW signals. Two methods can be employed to view the output of a high-power transmitter without causing damage to the spectrum analyzer. In one, the transmitter output is run through a directional coupler with weak coupling to the sampling port—perhaps –20 to –30 dB. The majority of the output is dissipated in a dummy load. The second method uses a fixed, high-power attenuator. Figure 16 shows an attenuator that will handle about 20 W while providing 20-dB attenuation. The design is not symmetrical.

Spectrum Analysis at Higher Frequencies

Although the 70-MHz spectrum analyzer is extremely useful, we constantly wish that it covered higher frequencies. Not only do we want to experiment on the VHF and UHF bands, but we need to examine higher-order harmonics of HF gear. One method we can use with a regular receiver is a converter, usually crystal controlled. The same can be done with a spectrum analyzer, although crystal control is not needed. We can build a simple block converter, consisting of nothing more than a 100 to 200 MHz VCO (just like that used in the analyzer) and a diode ring mixer. A Mini-Circuits POS-200 VCO with a 3 dB pad will directly drive a Mini-Circuits SBL-1 or TUF-1 mixer to produce a block converter with a nominal loss of 10 dB. (One of the spectrum analyzer front-end boards could be used, with slight modification, for the block converter.)

This block converter allows analysis of much of the VHF spectrum. With the converter VCO set at 100 MHz, frequencies from 100 to 170 MHz are easily studied. The 70 to 100-MHz image is also available—it can also lead to confusion, as a few minutes with a signal generator will demonstrate. With the converter VCO up at 200 MHz, the 200 to 270 MHz spectrum is also available. Clearly, there is nothing special about the particular VCO used in the converter. All that is required to convert other portions of the low UHF spectrum to the analyzer range is a different VCO, and perhaps, a higher-frequency mixer. We will soon build similar block converters to allow analysis of the 432-MHz area. One of the popular little UHF frequency counters is quite useful with these converters. The block converters should be well shielded and decoupled from the power supply.

Even without the analyzer, the block converter is a useful tool. For example, it can be used with a 10 MHz LC band-pass filter and an amplifier to directly drive a 50-Ω-terminated oscilloscope. This can serve as a sensitive detector for the alignment of a 110-MHz filter.

As useful as the block downconverter is, it has image-response problems that can greatly confuse the results. The preferred way to get to the higher frequencies is with a spectrum analyzer—just like the one we have described—but having higher-frequency oscillators and front-end filters. If you're careful, you can build helical resonator filters for the 500-MHz region, or higher, with sufficiently narrow selectivity to allow a second conversion to 10 MHz. A more practical route uses a third IF. Such a triple-conversion analyzer is shown in Figure 17, where a 1 to 1.8 GHz VCO moves signals in the 0 to 800-MHz spectrum to a 1 GHz IF. This signal is still easily amplified with available monolithic amplifiers. Building a 1 GHz filter should not be too difficult, for a narrow bandwidth is not required. A bandwidth of 20 or 30 MHz with a three-resonator filter would be adequate. The resulting signal is then heterodyned to a VHF IF (such as 110 MHz) where the remaining circuitry is now familiar.

Clearly, there are several ways to attack the project. Recent technology offers some help in the way of interesting band-pass filter structures, as well as high-performance, low-noise VCOs. Time spent with some cata-

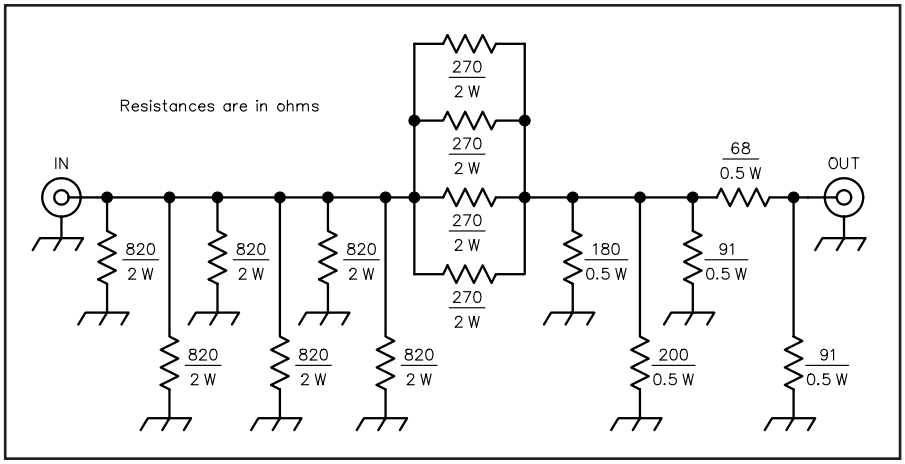

Figure 16—A 20-W, 20-dB attenuator for transmitter measurements.

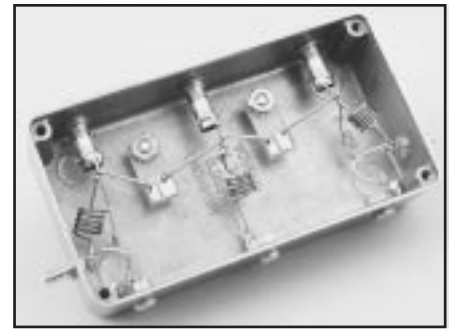

An inside view of a prototype VHF band-pass filter. See Figure 7.

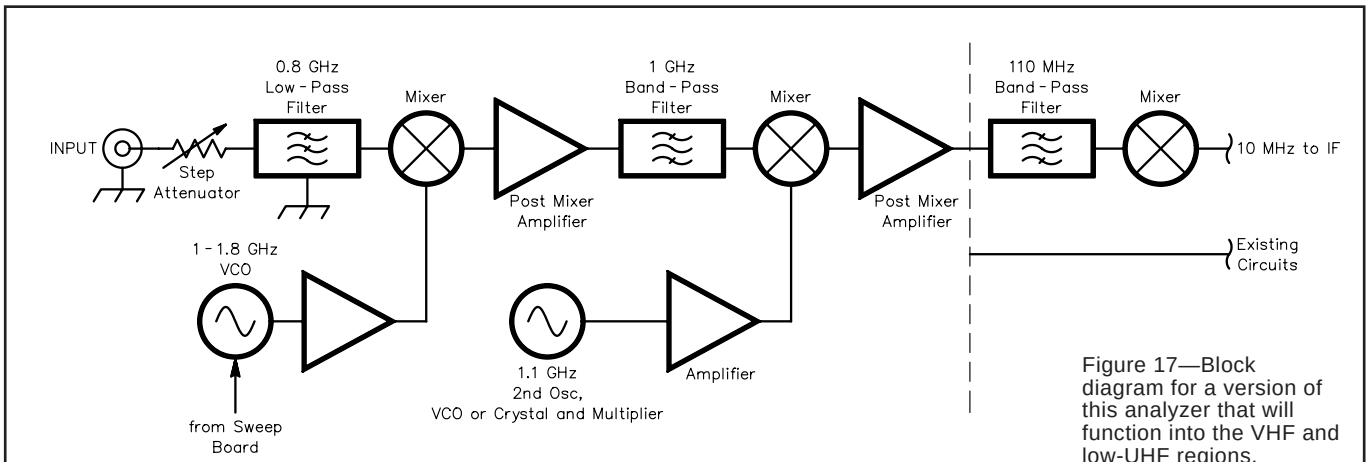

Figure 17—Block diagram for a version of this analyzer that will function into the VHF and low-UHF regions.

logs and a Web browser could be very productive in this regard. Just as important is the experience that the lower-frequency analyzer will provide. Not only is it the tool (perhaps supplemented with block converters) that is needed to build a higher-frequency spectrum analyzer, but it is the vehicle to provide *the confidence* needed to tackle such a chore.

Summary

This analyzer has been a useful tool for over 10 years now. It was a wonderful experience and fun to build HF and VHF CW and SSB gear with the "right" test equipment available. We have built special, narrow-tuning-range analyzers to examine transmitter sideband suppression and distortion. The equipment uses the same concepts presented.

There are many ways that this instrument can grow. One builder has already breadboarded a tracking generator. (Let's see that in *QST*!—*Ed.*) Many builders will want to interface the analyzer with a computer instead of an oscilloscope. A recent *QST* network analyzer paper suggests circuits that may provide such a solution.[21]

A recent *QST* summary of WRC97[22] outlines new specifications regarding spurious emissions from amateur transmitters. Generally, the casual specifications that we have enjoyed for many years are being replaced by new ones that are more stringent—and more realistic in safeguarding the spectral environment and reflecting the sound designs that we all strive to achieve. Equipment such as the spectrum analyzer described here can provide the basic tool needed to meet this new challenge.

Acknowledgments

Many experimenters had a hand in this project and we owe them our gratitude. Jeff Damm, WA7MLH, and Kurt Knoblock, WK7Q, built versions of the analyzer and have garnered several years of use with them. Their experiences have been of great value in our efforts. Barrie Gilbert of Analog Devices Northwest Labs suggested the AD8307 log amplifier and provided samples and early data needed for evaluation measurements. Many of our colleagues within the Wireless Communications Division at TriQuint Semiconductor have helped us with filter measurements: Thanks go to George Steen and to Don Knotts, W7HJS. Finally, special thanks go to our colleague in the receiver group at TriQuint, Rick Campbell, KK7B, who provided numerous enlightening discussions and suggestions regarding the preparation of the paper and the role of measurements in amateur experiments.

Notes

[14]Wes Hayward, W7ZOI, and Terry White, K7TAU, "A Spectrum Analyzer for the Radio Amateur," *Part 1*, *QST*, Aug 1998, pp 35-43.

[15]The wide-range oscillator presented in Fig 68, Chapter 7 of *Solid-State Design for the Radio Amateur* (Newington: ARRL, 1997) is still intact and still often used.

[16]The term dBc refers to dB attenuation with respect to a specific *carrier*.

[17]Formally, this is the transducer gain, or 50-Ω insertion gain. There are many different parameters that are called "gain."

[18]The signal sources used are updated versions of the circuits shown in Fig 66, p 168, in the Note 15 referent.

[19]See page 154, *Solid-State Design for the Radio Amateur*.

[20]A 20-dB return loss corresponds to a voltage reflection coefficient of 0.1, or an SWR of 1.222. See Wes Hayward, W7ZOI, *Introduction to RF Design* (Newington: ARRL, 1994), p 120.

[21]See, for example, Steven Hageman, "Build Your Own Network Analyzer," *QST*, Jan 1998, pp 39-45; *Part 2*, Feb 1998, pp 35-39.

[22]Larry Price, W4RA, and Paul Rinaldo, W4RI, "WRC97, An Amateur Radio Perspective," *QST*, Feb 1998, pp 31-34. See also Rick Campbell, KK7B, "Unwanted Emissions Comments," Technical Correspondence, *QST*, Jun 1998, pp 61-62.

◊ Please refer to Wes Hayward, W7ZOI, and Terry White, K7TAU, "A Spectrum Analyzer for the Radio Amateur—*Part 2*, *QST*, Sep 1998, p 40, Fig 16. The six 2-W input resistors for the 20-dB pad should be 620 Ω units, not 820 Ω as originally specified.—*Wes Hayward, W7ZOI (tnx EA2SN)*

Rice cooker

From Wikipedia, the free encyclopedia

A **rice cooker** or **rice steamer** is an automated kitchen appliance designed to boil or steam rice. It consists of a heat source, a cooking bowl, and a thermostat. The thermostat measures the temperature of the cooking bowl and controls the heat. Complex rice cookers may have many more sensors and other components, and may be multipurpose.

Electric rice cooker, including scoop, containing uncooked rice

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Naming

The term **rice cooker** formerly applied to non-automated dedicated rice-cooking utensils, which have an ancient history (a ceramic rice steamer dated to 1250 BC is on display in the British Museum). It now applies mostly to automated cookers. Electric rice cookers were developed in Japan, where they are known as pressure cookers *suihanki* (炊飯器).

Principle of operation (basic rice cooker models)

The cooking bowl is filled with rice and water. During cooking, the rice/water mixture is heated at full power. The water reaches a temperature of 100 °C (212 °F); it cannot get hotter than its boiling point (all the energy goes into vapourizing the water). At the end of cooking there will be no free water left; most

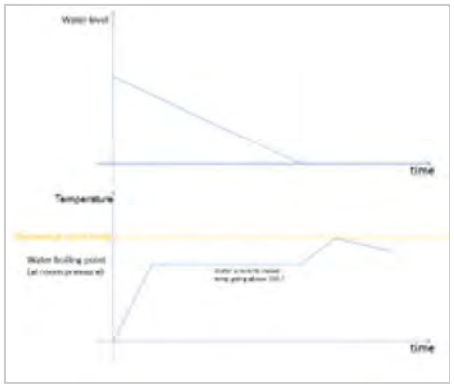

Basic principle of electric rice cooker operation

will have been absorbed by the rice, and some boiled off. As heating continues, the temperature can now rise above boiling point; this makes the thermostat trip. Some cookers switch to low-power "warming" mode, keeping the rice at a safe temperature of approximately 65 °C (150 °F); simpler models switch off.

This means that if more water is added, the rice will cook for longer.

Purpose

Cooking rice has traditionally required constant attention to ensure the rice was cooked properly, and not burnt. Electric rice cookers automate the process by mechanically or electronically controlling heat and timing, thus freeing up a heating element on the cooking range that had to be otherwise occupied for rice cooking. Although the rice cooker does not necessarily speed up the cooking process, with an electric rice cooker the cook's involvement in cooking rice is reduced to simply measuring the rice, preparing the rice properly and using the correct amount of water. Once the rice cooker is set to cook, the rice will be cooked with no further attention.

Some types of rice dishes require special ways of preparation and are not suited to the mode of cooking used by electric/gas rice cookers. These recipes include, e.g., risotto, paella, and stuffed peppers (*capsicums*). They must be cooked by hand.

Cooking rice with an electric rice cooker

Inexpensive electric rice cooker containing cooked rice

The rice is measured and added to the inner bowl or washed in a separate bowl (it is not recommended to wash rice in the inner bowl itself) in order to remove loosened starch and residual bran. Strainers are often used in the washing and draining process. For better texture and taste, some types of rice, e.g., Japanese rice or Calrose rice which is suited for absorption method, require pre-cooking water absorption. The water absorption step typically involves letting the rice stand for at least 5 min after draining water from the washing step and soaking the rice in the measured water for at least 15 min (or some claim it to be 1 hour) before cooking. The water draining step is colloquially believed to make the water measurement more accurate, if the water is measured and added after the initial water absorption that takes place in the washing step. Some people prefer to achieve the water absorption by simply leaving the rice soaking in the rice cooker overnight before starting cooking in the morning. Some other types of rice, e.g., long-grain rice or scented rice such as jasmine rice, do not require washing or the water absorption step. The water for cooking is added to the inner bowl by using measuring cups or simply filling up to the appropriate graduated mark in the inner bowl. Although cold water is normally added, boiling water is used for cooking sushi rice.

Different kinds of rice require different amounts of water. Usually, there are graduated marks for the right amount of water only for white rice, but sometimes there are separate scales for brown rice (as more water is required) or for cooking other food in the appliance.

Once the lid is closed and the cooking cycle has been activated, the rice cooker does the rest. Most models give a countdown in minutes to the "ready time," or beep when done. After cooking cycle is completed, it is recommended that the rice is to "rest" for 5 minute for post-absorption and then to be stirred to prevent the grains from clinging to each other too hard. Some rice, e.g., long-grain or scented rice, do not seem to require this post-absorption step.

Some higher-end models automatically time the soaking (pre-cooking water absorption) and the resting periods, therefore, there is no need to manually manage the water absorption or time these steps.

Time

It takes about 30 minutes to 1 hour for most electric rice cookers to complete cooking. Some advanced models can back-calculate the cooking start time from given finish time. The time required for cooking rice depends on the amount of rice, the power of the heating elements, and atmospheric pressure, thus it is not constant. Pressure-cooker models are not influenced by atmospheric pressure. The special features distinguish high-end models from lower-cost, simpler models.

Appliance type

Automatic rice cookers may be either gas or electrical appliances. Most dedicated home rice cookers are of the electric type. In commercial or industrial use, there are many varieties, such as large gas or electric rice cookers, a large-scale rice cooker that is called a "rice boiler", and fully automatic versions which handle the whole process of rice cooking from washing rice to the end of the cooking cycle.

Many modern cookers have a heat-insulating casing and a warming mechanism. When the rice is determined to be fully cooked, the unit will automatically switch to the "keep warm" cycle, thus preventing the rice from being overcooked and keeping the rice warm until it is ready to be served. The degree of insulation provided by the casing can also be used to keep cold solids cold.

Electric rice cookers

Features and specifications

For modern home rice cookers, the smallest single-person model cooks 1 rice cup (180 ml), whereas large

models can cook 10 cups. Commercial models can cook 20 or more cups. As a possible source of confusion, model specifications and names may list either cooked or uncooked capacity. Rice roughly doubles in cups of cooked rice country of origin.

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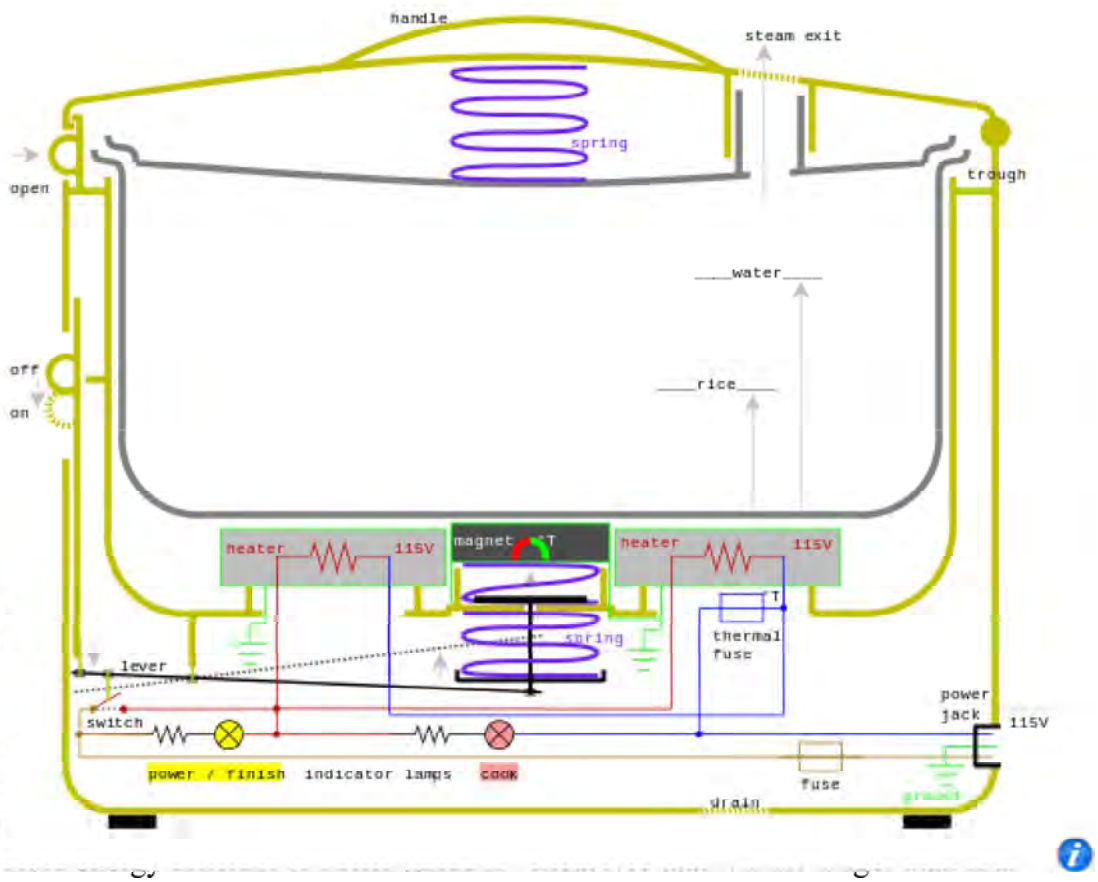

Some rice cookers use induction heating, with one or more induction heaters directly warming the pot. This can improve energy efficiency.

Most modern rice cookers use aluminium for the inner cooking bowl. There are some models that use stainless steel instead of aluminium. Various other materials, such as copper, pure carbon, ceramic, and diamond powder coating, may be used for higher heat conductivity or better taste.

The pressure-cooking models can raise the water's boiling point higher, e.g., from 100 °C at 1.0 atm up to about 110 °C at 1.4 atm, which speeds cooking. The pressure-cooking models can also be used in high altitude areas, where the boiling temperature is below 100 Celsius. Pressure cookers are also suitable for cooking brown rice (which contains oils and bran fiber that cook differently from pure white rice starch). Some pressure rice cookers have a varying pressure control mechanism (named the "dual-pressure" method) that creates repeated pressure/release cycles during the cooking.

There also exist mechanisms to collect and return the boiled over liquid to the inner rice bowl.

Many cookers now have microprocessor-controlled cooking cycles, which are often used to adjust for rice and cooking type.

Rice types and rice cookers

Rice cookers are typically used for the preparation of plain or lightly seasoned rice. Each rice cooker model may be optimized to cook a certain type of rice best. For example, most Japanese rice cookers are optimized for cooking Japanese rice and may not be the best for other types of rice, although cooking time can be lengthened simply by more water.

The typical method of cooking long grain rice is boil-and-strain and/or steaming method. The absorption method used in Japanese rice cookers will produce slightly different texture and taste, usually stickier rice.

Brown rice generally needs longer cooking times than white rice, unless it is broken or flourblasted (which perforates the bran).[1]

Different varieties of rice need different cooking times, depending on their grain size, grain shape, and grain composition. There are three main types of Asian rice: *Oryza sativa* subsp. indica, i.e., Indian rice (long grain rice, e.g., basmati rice and Thai jasmine rice), *O. sativa subsp. javanica*, i.e., Java rice (large grain rice) and *O. sativa subsp. japonica*, i.e., Japanese rice (medium grain rice, e.g., Calrose rice, short grain rice, e.g., most Japanese rice and risotto rice).

African rice, *Oryza glaberrima*, is an entirely separate species, but can be cooked in the same way. Zizania is not even in the same genus, although it is often called a rice (or "water oats"); it, too, can also be cooked in a rice cooker.

A rice cooker can be used to cook many boiled or steamed granular foods, such as pot barley, bulgar wheat, and dal. Provided the ingredients have similar cooking times, a rice cooker can cook mixtures such as khichdi. Some rice cookers can be used as automated couscoussiers, cooking couscous and a stew simultaneously.

Extended uses

Some rice cookers have settings for congee, a type of rice porridge called *okayu* in Japanese, juk in Korea, and *zhou* in Chinese.

Many models feature an ability to cook sticky rice or porridge as an added value. Most can be used as steamers. Some can be used as slow cookers. Some other models can bake bread or in some cases have an added function to maintain temperatures suitable for fermentation of bread dough or yogurt.

More elaborate recipes are possible using a rice cooker, and there are cookbooks devoted entirely to dishes prepared using a rice cooker. It is possible to cook soups, stews or sponge cakes in electric rice cookers. By simply adding ingredients and setting it to "warm", a rice cooker cooks the contents at about 65 °C (150 °F). In a few hours, the stew is fully cooked and ready to eat.

Some rice cookers are designed to accommodate a basket to steam vegetables, dumplings, buns, and so on in the steam coming off the rice. If the rice cooker is not suited for such uses, there is a chance that it will damage the appliance. In particular, it is quite possible that the Teflon coating becomes scarred by the rough bottom of ceramic wares placed inside the inner cooking bowl. If such cooking was outside indicated usage of the appliance, it typically invalidates the warranty. In some countries, electric rice cookers, including Japanese models, are regarded as automated universal electric cooking pots, and their use in the preparation of a variety of foods is rather standard.

Gas rice cookers

Gas rice cookers have a significantly larger capacity than home rice cookers (5 to 10 liters) and are more commonly used for commercial purposes. They must be connected directly to a fuel source (either a natural gas line or a portable propane source) and do not require an electrical power supply.

When cooking in a commercial setting, where quality, quantity, and speed are important factors, gas powered rice cookers offer several benefits. The gas powered flame source heats the cooking pot much more quickly than electrical power sources. Cooking at higher temperatures allows the rice to absorb water faster and cook more quickly, yielding a sweeter and more firm final product. Due to the amount of rice being cooked at one time, electrical powered cookers are not able to heat the cooking pot fast enough. This usually results in uneven cooking of the overall batch of rice-often leading to mushy or burnt rice on the bottom of the pot and sometimes under-cooked rice at the middle and top of the cooking pot. Finally, being able to heat the cooking pot to a higher temperature relatively quickly allows the rice to cook faster and steam properly, resulting in a better quality batch of rice.

Most, if not all, gas rice cookers use an heat based automatic shut-off system. The basic principle of these systems is such that gas flow into the burner is halted once a specific temperature is reached, resulting in the burner flame to go out.

A relatively new concept is the commercial gas pressure cooker. These cookers use pressure cooking to produce a uniformly cooked batch of rice. Cooking rice in a pressure cooker allows the rice to cook under more optimal conditions.

Ideal cooking for rice employs a method of a fast heating source along with a uniform delivery of that heat. A gas powered pressure cooking system is able to use a flame heat source to heat the cooking vessel quickly and the pressure cooker is able to heat the internal cooking environment to higher than the boiling point of water in a uniform manner.

History

In 1937 the Imperial Japanese Army sanctioned a Type 97 automobile-kitchen equipped with a primitive rice cooker. The rice cooker was a rectangular wooden box with two electrodes attached to opposite ends. To cook the rice, the box was filled with washed rice and water, and then a current was applied. This caused the water to boil. When the rice was cooked, the reduction of the water caused an increase in resistance and reduced the heat, then it automatically became a stay-warm state. This method, however, was not suitable for different water qualities or degrees of rice washing and as such varied the amount of heat produced and the end results. It also presented a high risk of electrocution, thus it was not suitable for home cooking.

In 1945, the Japanese Mitsubishi Electric Corporation was the first company to produce an electric commercial rice cooker. The Mitsubishi product was an aluminium pot with a heating coil inside. It had no automatic turn-off facility, and it required constant monitoring during cooking.

In the early development phase, electric home rice cookers used the simple concept of simply heating the rice to cook and turning off the heater when the temperature rose to a certain point. This method, however, is influenced too greatly with seasonal changes in room temperature and often produced

under-cooked rice. Many makers continued to experience failures in their ongoing trial-and-error approaches. At this stage, there was even a trial model which embedded the heating element in a traditional wooden rice container.

The first practical electric rice cooker was invented by Yoshitada Minami,[2][3] who had an association with Toshiba Electric Corporation. It became possible to cook rice practically by employing the triple-chamber rice cooker (that provided heat insulation by air layers).

In December 1956, the Toshiba Corporation placed the first commercially successful automated electric rice cookers on the market.[4] It used a double-chamber indirect rice cooking method. Rice was placed into the rice pot, and water into a surrounding container. When the water in the outer pot boiled off, the temperature of the pot rose rapidly. A bimetallic thermostat then activated, and automatically turned off the cooker to prevent burning of the cooked rice. Soon, Toshiba was producing 200,000 rice cookers per month for the Japanese market. Four years later, rice cookers could be found in half of Japanese homes.

The double-chamber indirect cooking model took more time to complete cooking and also consumed more electricity. This model was gradually phased out in the 1960s, but there are some companies, such as Tatung, that still manufacture them. Today, electric rice cookers utilize an insulated outer container and an inner removable bowl, often coated with a non-stick surface, and stamped with water-level graduations marked in cups of rice used. The rice cup measure is normally based on the traditional Japanese measurement system 1 *gō* (合), which has its origin in China (Chinese: 合; pinyin: *gě*). One *gō* (合) is 180 *ml*, or approximately 25% smaller than the American measuring cup of 8 (US) fluid ounces/240 ml, and is regarded as producing enough cooked rice for a single meal for one person.

Initial models did not have a keep-warm feature and the cooked rice cooled down too quickly, thus it was often necessary to move the cooked rice to heat-insulated serving containers. In 1965, Zojirushi Thermos company started selling electric rice cookers with a stay-warm function, using a semi-conductor heat regulator. The product sold 2,000,000 units per year. Other makers soon followed suit. The stay-warm function can typically keep rice warm for up to 24 hours at a temperature high enough to suppress growth of *Bacillus cereus*, a cause of food poisoning. Another notable improvement was the use of electric timers.

In simple models, a mechanical thermostat is used to turn off the cooker when the rice is ready. Since the 1980s, higher-end electric rice cookers have used microprocessors to control the cooking process, often incorporating a memory and electronic timer that can be used to set the desired "ready time". Since the 1990s, many models allow users to select desired cooking results for rice (e.g., soft, medium, firm, etc.), different types of rice, or ingredients other than rice. Some models can be used as steamers.

In the late 1980s, some higher-end electric rice cookers started using induction heating. This type aims to produce tastier cooked rice by controlling the heating process more precisely. Some other pressure-cooking models use 1.2 *atm* to 1.7 *atm* (not over 1.4 *atm* for home appliances) to raise the cooking temperature over 100 °C. Expensive models often provide a steam-heating function.

In the 1990s, China started-mass-producing economical electrical rice cookers with limited functions and exporting them to many countries. Japanese makers have been attempting to compete by seeking a niche in models with added values by increasing the number of features of their products.

Electric Rice Cooker made by Philips in an Indian appliance Showroom

In the 2000s, more deluxe models appeared on the market and attracted much attention. These models are characterized by non-metallic materials for inner cooking bowls to employ thermal far-infrared radiation in order to improve the taste of cooked rice. In 2006 Japanese Mitsubishi Electric corporation produced an expensive cooker which used an inner cooking bowl called *honsumigama* (本炭釜) made of hand-carved pure carbon, with a better heat-generating profile with induction cooking. Despite the high price (¥115,500, about US$1,400 at the time), it sold 10,000 units within six months after it was introduced. It was a huge success and it set the trend of extremely high-end models in the market. There is also a product which uses pottery, e.g., Arita-yaki, for the inner cooking bowl. There have been pottery-based electric cooking appliances in China since the 1980s, and in recent years rice cookers have been also produced. Some other materials used for luxurious rice bowls are pure copper, ceramic-iron layers, and diamond coating. These rice cooker makers research what the best cooked rice means (in taste and texture) and attempt to realize "the best cooked rice" in electric rice cookers by using various inventions. Most regard rice cooked either in a traditional rice cooker used in hearth or in a gas pressure cooker as references, and attempt to achieve or exceed the same.

Restaurants that serve a lot of rice, particularly those specializing in Asian cuisine, often use industrial-sized rice cookers (often they are gas pressure cookers, but there are electric models) that quickly and cheaply produce large quantities of cooked rice. A rice cooker is a standard appliance in kitchens in many Asian countries and households.

Production

There were approximately 85 million rice cookers made in 2005. Most of the rice cookers were made in China, South Korea and Japan, with 70% of the production in China. Most of Chinese production was from Zhanjiang City and Lianjiang City in Guangdong Province.

Japanese rice cookers used overseas

Since the 1980s, electric rice cookers were manufactured in China and Korea, who focused on simple feature models because of the market trend which regarded the price competition to be more important than rich features.

Some visitors to Japan desired to buy Japanese domestic models as souvenirs, due to their ability to produce better tasting cooked rice and the multiple features. Since the Japanese domestic models use 100 volts only, they cannot be used in most other countries without adapters and power converters. In Akihabara Electric Town, various models that are modified to be able to operate under 110 V/220 V-240 V are sold in boxes that are labeled with English. A few rice cooker makers produce export models for use abroad.

See also

- Rice polisher

- Slow cooker
- Remoska
- Vacuum flask
- Hot water dispenser
- Zojirushi Corporation
- Tiger Corporation
- List of cooking appliances
- List of Japanese cooking utensils

Wikimedia Commons has media related to ***Rice Cookers***.

Wikibooks Cookbook has a recipe/module on ***Rice Cooker***

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Categories: Rice | Cooking appliances | Cookware and bakeware

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Rice cooker

From Wikipedia, the free encyclopedia

A **rice cooker** or **rice steamer** is an automated kitchen appliance designed to boil or steam rice. It consists of a heat source, a cooking bowl, and a thermostat. The thermostat measures the temperature of the cooking bowl and controls the heat. Complex rice cookers may have many more sensors and other components, and may be multipurpose.

Electric rice cooker, including scoop, containing uncooked rice

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Naming

The term **rice cooker** formerly applied to non-automated dedicated rice-cooking utensils, which have an ancient history (a ceramic rice steamer dated to 1250 BC is on display in the British Museum). It now applies mostly to automated cookers. Electric rice cookers were developed in Japan, where they are known as pressure cookers *suihanki* (炊飯器).

Principle of operation (basic rice cooker models)

The cooking bowl is filled with rice and water. During cooking, the rice/water mixture is heated at full power. The water reaches a temperature of 100 °C (212 °F); it cannot get hotter than its boiling point (all the energy goes into vapourizing the water). At the end of cooking there will be no free water left; most will have been absorbed by the rice, and some boiled off. As heating continues, the temperature can now rise above boiling point; this makes the thermostat trip. Some cookers switch to low-power "warming" mode, keeping the rice at a safe temperature of approximately 65 °C (150 °F); simpler models switch off.

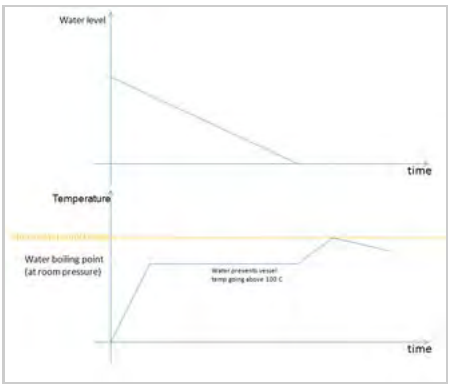

Basic principle of electric rice cooker operation

This means that if more water is added, the rice will cook for longer.

Purpose

Cooking rice has traditionally required constant attention to ensure the rice was cooked properly, and not burnt. Electric rice cookers automate the process by mechanically or electronically controlling heat and timing, thus freeing up a heating element on the cooking range that had to be otherwise occupied for rice cooking. Although the rice cooker does not necessarily speed up the cooking process, with an electric rice cooker the cook's involvement in cooking rice is reduced to simply measuring the rice, preparing the rice properly and using the correct amount of water. Once the rice cooker is set to cook, the rice will be cooked with no further attention.

Some types of rice dishes require special ways of preparation and are not suited to the mode of cooking used by electric/gas rice cookers. These recipes include, e.g., risotto, paella, and stuffed peppers (*capsicums*). They must be cooked by hand.

Cooking rice with an electric rice cooker

Inexpensive electric rice cooker containing cooked rice

The rice is measured and added to the inner bowl or washed in a separate bowl (it is not recommended to wash rice in the inner bowl itself) in order to remove loosened starch and residual bran. Strainers are often used in the washing and draining process. For better texture and taste, some types of rice, e.g., Japanese rice or Calrose rice which is suited for absorption method, require pre-cooking water absorption. The water absorption step typically involves letting the rice stand for at least 5 min after draining water from the washing step and soaking the rice in the measured water for at least 15 min (or some claim it to be 1 hour) before cooking. The water draining step is colloquially believed to make the water measurement more accurate, if the water is measured and added after the initial water absorption that takes place in the washing step. Some people prefer to achieve the water absorption by simply leaving the rice soaking in the rice cooker overnight before starting cooking in the morning. Some other types of rice, e.g., long-grain rice or scented rice such as jasmine rice, do not require washing or the water absorption step. The water for cooking is added to the inner bowl by using measuring cups or simply filling up to the appropriate graduated mark in the inner bowl. Although cold water is normally added, boiling water is used for cooking sushi rice.

Different kinds of rice require different amounts of water. Usually, there are graduated marks for the right amount of water only for white rice, but sometimes there are separate scales for brown rice (as more water is required) or for cooking other food in the appliance.

Once the lid is closed and the cooking cycle has been activated, the rice cooker does the rest. Most models give a countdown in minutes to the "ready time," or beep when done. After cooking cycle is completed, it is recommended that the rice is to "rest" for 5 minute for post-absorption and then to be stirred to prevent the grains from clinging to each other too hard. Some rice, e.g., long-grain or scented rice, do not seem to require this post-absorption step.

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Many modern cookers have a heat-insulating casing and a warming mechanism. When the rice is determined to be fully cooked, the unit will automatically switch to the "keep warm" cycle, thus preventing the rice from being overcooked and keeping the rice warm until it is ready to be served. The degree of insulation provided by the casing can also be used to keep cold solids cold.

Electric rice cookers

Features and specifications

For modern home rice cookers, the smallest single-person model cooks 1 rice cup (180 ml), whereas large models can cook 10 cups. Commercial models can cook 20 or more cups. As a possible source of confusion, model specifications and names may list either cooked or uncooked capacity. Rice roughly doubles in size during cooking; therefore, a 10 cup (uncooked) rice cooker can produce up to 20 cups of cooked rice. The prices vary greatly, depending on the capacity, features, materials used, and the country of origin.

The majority of modern electric rice cookers are equipped with a stay-warm or keep-warm feature, which keeps the rice at an optimal temperature for serving without over-cooking it. Some gas cookers also have electric stay-warm mechanism. However, the usefulness of this feature degrades over time, a microwave may be more energy efficient or better suited to reheat rice that will sit longer than four hours.

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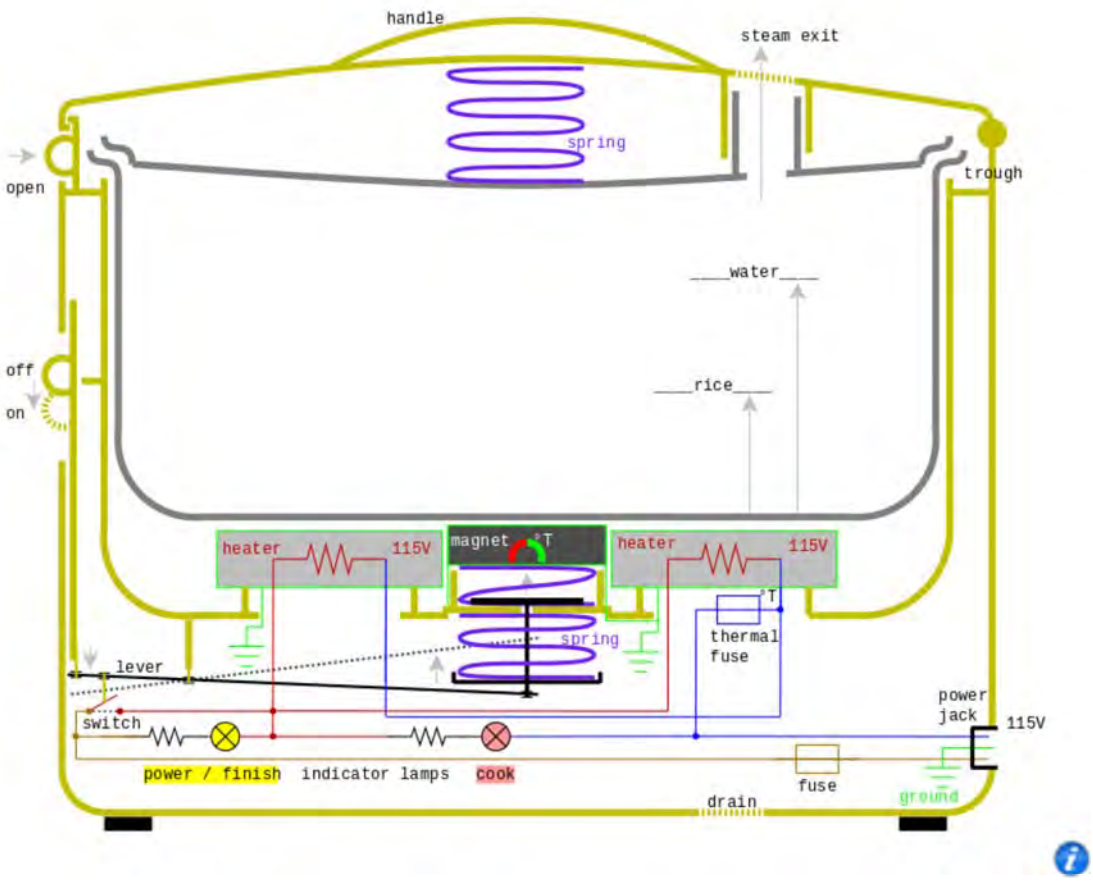

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Gas rice cookers have a significantly larger capacity than home rice cookers (5 to 10 liters) and are more commonly used for commercial purposes. They must be connected directly to a fuel source (either a natural gas line or a portable propane source) and do not require an electrical power supply.

A typical commercial gas cooker. To use it, the left lever is depressed to ignite the pilot burner for stand-by and keep-warm purposes. To start cooking, the right lever is pushed to operate the main burner, whose flames are ignited by the pilot burner. Like its electric counterpart, the cook lever releases automatically once the rice is fully cooked.

When cooking in a commercial setting, where quality, quantity, and speed are important factors, gas powered rice cookers offer several benefits. The gas powered flame source heats the cooking pot much more quickly than electrical power sources. Cooking at higher temperatures allows the rice to absorb water faster and cook more quickly, yielding a sweeter and more firm final product. Due to the amount of rice being cooked at one time, electrical powered cookers are not able to heat the cooking pot fast enough. This usually results in uneven cooking of the overall batch of rice-often leading to mushy or burnt rice on the bottom of the pot and sometimes under-cooked rice at the middle and top of the cooking pot. Finally, being able to heat the cooking pot to a higher temperature relatively quickly allows the rice to cook faster and steam properly, resulting in a better quality batch of rice.

Most, if not all, gas rice cookers use an heat based automatic shut-off system. The basic principle of these systems is such that gas flow into the burner is halted once a specific temperature is reached, resulting in the burner flame to go out.

A relatively new concept is the commercial gas pressure cooker. These cookers use pressure cooking to produce a uniformly cooked batch of rice. Cooking rice in a pressure cooker allows the rice to cook under more optimal conditions.

Ideal cooking for rice employs a method of a fast heating source along with a uniform delivery of that heat. A gas powered pressure cooking system is able to use a flame heat source to heat the cooking vessel quickly and the pressure cooker is able to heat the internal cooking environment to higher than the boiling point of water in a uniform manner.

History

In 1937 the Imperial Japanese Army sanctioned a Type 97 automobile-kitchen equipped with a primitive rice cooker. The rice cooker was a rectangular wooden box with two electrodes attached to opposite ends. To cook the rice, the box was filled with washed rice and water, and then a current was applied. This caused the water to boil. When the rice was cooked, the reduction of the water caused an increase in resistance and reduced the heat, then it automatically became a stay-warm state. This method, however, was not suitable for different water qualities or degrees of rice washing and as such varied the amount of heat produced and the end results. It also presented a high risk of electrocution, thus it was not suitable for home cooking.

In 1945, the Japanese Mitsubishi Electric Corporation was the first company to produce an electric commercial rice cooker. The Mitsubishi product was an aluminium pot with a heating coil inside. It had no automatic turn-off facility, and it required constant monitoring during cooking.

In the early development phase, electric home rice cookers used the simple concept of simply heating the rice to cook and turning off the heater when the temperature rose to a certain point. This method, however, is influenced too greatly with seasonal changes in room temperature and often produced under-cooked rice. Many makers continued to experience failures in their ongoing trial-and-error approaches. At this stage, there was even a trial model which embedded the heating element in a traditional wooden rice container.

The first practical electric rice cooker was invented by Yoshitada Minami,[2][3] who had an association with Toshiba Electric Corporation. It became possible to cook rice practically by employing the triple-chamber rice cooker (that provided heat insulation by air layers).

In December 1956, the Toshiba Corporation placed the first commercially successful automated electric rice cookers on the market.[4] It used a double-chamber indirect rice cooking method. Rice was placed into the rice pot, and water into a surrounding container. When the water in the outer pot boiled off, the temperature of the pot rose rapidly. A bimetallic thermostat then activated, and automatically turned off the cooker to prevent burning of the cooked rice. Soon, Toshiba was producing 200,000 rice cookers per month for the Japanese market. Four years later, rice cookers could be found in half of Japanese homes.

The double-chamber indirect cooking model took more time to complete cooking and also consumed more electricity. This model was gradually phased out in the 1960s, but there are some companies, such as Tatung, that still manufacture them. Today, electric rice cookers utilize an insulated outer container and an inner removable bowl, often coated with a non-stick surface, and stamped with water-level graduations marked in cups of rice used. The rice cup measure is normally based on the traditional Japanese measurement system 1 *gō* (合), which has its origin in China (Chinese: 合; pinyin: *gě*). One *gō* (合) is 180 *ml*, or approximately 25% smaller than the American measuring cup of 8 (US) fluid ounces/240 ml, and is regarded as producing enough cooked rice for a single meal for one person.

Initial models did not have a keep-warm feature and the cooked rice cooled down too quickly, thus it was often

necessary to move the cooked rice to heat-insulated serving containers. In 1965, Zojirushi Thermos company started selling electric rice cookers with a stay-warm function, using a semi-conductor heat regulator. The product sold 2,000,000 units per year. Other makers soon followed suit. The stay-warm function can typically keep rice warm for up to 24 hours at a temperature high enough to suppress growth of *Bacillus cereus*, a cause of food poisoning. Another notable improvement was the use of electric timers.

In simple models, a mechanical thermostat is used to turn off the cooker when the rice is ready. Since the 1980s, higher-end electric rice cookers have used microprocessors to control the cooking process, often incorporating a memory and electronic timer that can be used to set the desired "ready time". Since the 1990s, many models allow users to select desired cooking results for rice (e.g., soft, medium, firm, etc.), different types of rice, or ingredients other than rice. Some models can be used as steamers.

In the late 1980s, some higher-end electric rice cookers started using induction heating. This type aims to produce tastier cooked rice by controlling the heating process more precisely. Some other pressure-cooking models use 1.2 *atm* to 1.7 *atm* (not over 1.4 *atm* for home appliances) to raise the cooking temperature over 100 °C. Expensive models often provide a steam-heating function.

Electric Rice Cooker made by Philips in an Indian appliance Showroom

In the 1990s, China started-mass-producing economical electrical rice cookers with limited functions and exporting them to many countries. Japanese makers have been attempting to compete by seeking a niche in models with added values by increasing the number of features of their products.

In the 2000s, more deluxe models appeared on the market and attracted much attention. These models are characterized by non-metallic materials for inner cooking bowls to employ thermal far-infrared radiation in order to improve the taste of cooked rice. In 2006 Japanese Mitsubishi Electric corporation produced an expensive cooker which used an inner cooking bowl called *honsumigama* (本炭釜) made of hand-carved pure carbon, with a better heat-generating profile with induction cooking. Despite the high price (¥115,500, about US$1,400 at the time), it sold 10,000 units within six months after it was introduced. It was a huge success and it set the trend of extremely high-end models in the market. There is also a product which uses pottery, e.g., Arita-yaki, for the inner cooking bowl. There have been pottery-based electric cooking appliances in China since the 1980s, and in recent years rice cookers have been also produced. Some other materials used for luxurious rice bowls are pure copper, ceramic-iron layers, and diamond coating. These rice cooker makers research what the best cooked rice means (in taste and texture) and attempt to realize "the best cooked rice" in electric rice cookers by using various inventions. Most regard rice cooked either in a traditional rice cooker used in hearth or in a gas pressure cooker as references, and attempt to achieve or exceed the same.

Restaurants that serve a lot of rice, particularly those specializing in Asian cuisine, often use industrial-sized rice cookers (often they are gas pressure cookers, but there are electric models) that quickly and cheaply produce large quantities of cooked rice. A rice cooker is a standard appliance in kitchens in many Asian countries and households.

Production

There were approximately 85 million rice cookers made in 2005. Most of the rice cookers were made in China, South Korea and Japan, with 70% of the production in China. Most of Chinese production was from Zhanjiang City and Lianjiang City in Guangdong Province.

Japanese rice cookers used overseas

Since the 1980s, electric rice cookers were manufactured in China and Korea, who focused on simple feature models because of the market trend which regarded the price competition to be more important than rich features.

Some visitors to Japan desired to buy Japanese domestic models as souvenirs, due to their ability to produce better tasting cooked rice and the multiple features. Since the Japanese domestic models use 100 volts only, they cannot be used in most other countries without adapters and power converters. In Akihabara Electric Town, various models that are modified to be able to operate under 110 V/220 V-240 V are sold in boxes that are labeled with English. A few rice cooker makers produce export models for use abroad.

See also

- Rice polisher
- Slow cooker
- Remoska
- Vacuum flask
- Hot water dispenser
- Zojirushi Corporation
- Tiger Corporation
- List of cooking appliances
- List of Japanese cooking utensils

Wikimedia Commons has media related to ***Rice Cookers***.

Wikibooks Cookbook has a recipe/module on ***Rice Cooker***

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Categories: Rice | Cooking appliances | Cookware and bakeware

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A project of Volunteers in Asia

Rice Husk Ash Cement

by Ray Smith

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RICE HUSK ASH CEMENT

Progress in development and application

Ray Smith

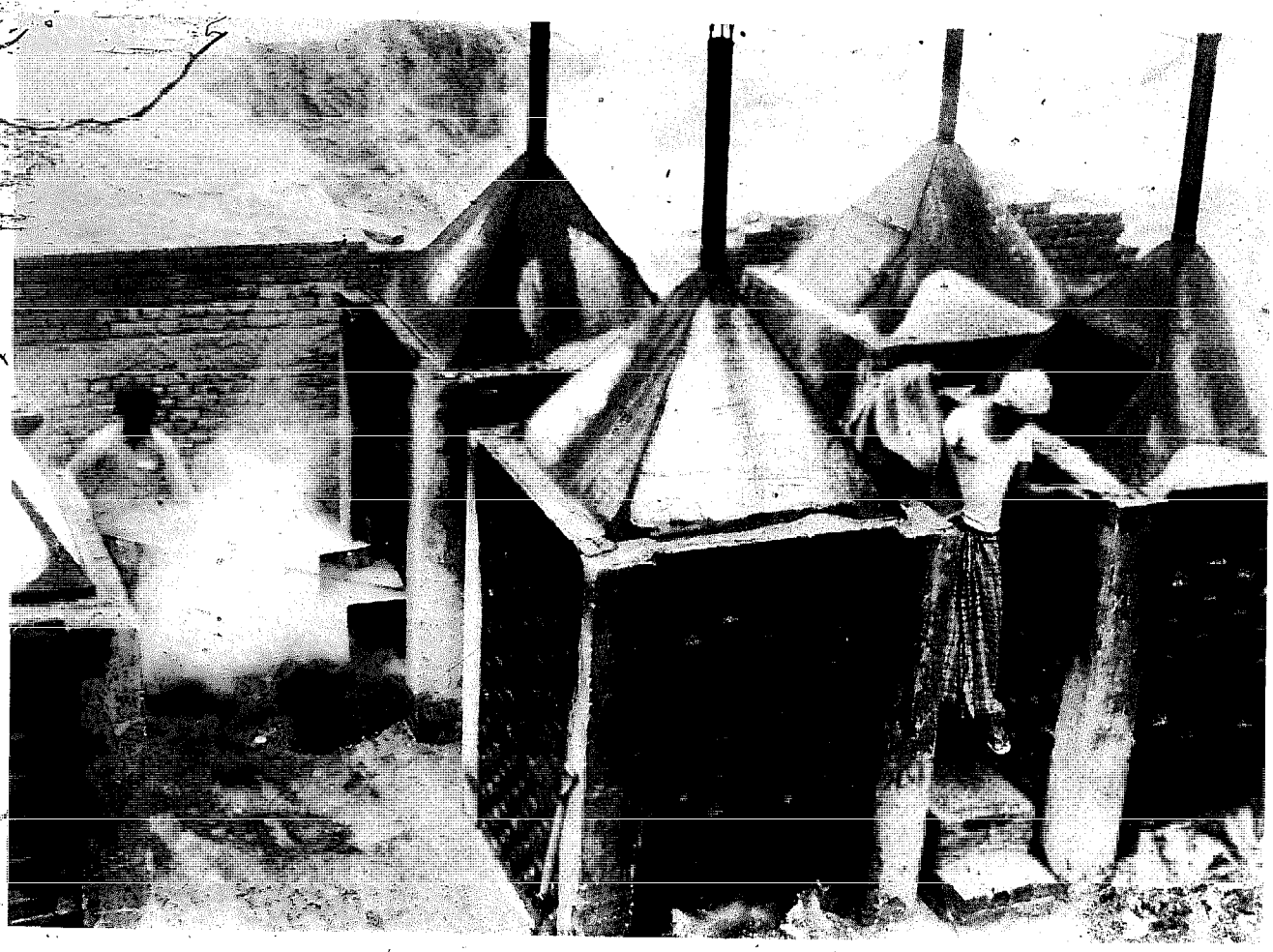

RICE HUSK ASH CEMENT

Progress in Development and Application

A report on site visits to

India, Nepal and Pakistan

by R. G. Smith
Building Research
Establishment
Watford.

Intermediate Technology Development Group Limited
9 King Street
London
WC2E 8HN

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PREFACE

The use of the ash resulting from burning rice husk as a cementitious binder in conjunction with lime has been receiving increasing attention over recent years. It would appear to offer the attractive prospect of providing a low-cost alternative cement by simple, village-scale technology using a readily available agricultural waste material. The need for such materials is clear, as the conventional binder, Portland cement, is commonly unavailable or expensive particularly in rural communities where, indeed, its high-strength, rapid-setting properties are not of primary importance to the low-rise building or simple civil engineering work typically undertaken in these areas.

The basic research and development work into rice husk ash (RHA) cement technology has been undertaken by a variety of institutions and individuals, principally in the Indian sub-continent, and several attempts have been made to commercialise and disseminate the technology. Reports on this work are sparse, and in particular there has been a lack of independent comparative data on the various approaches used; these, it will be seen from this report, contain significant differences in terms of the final product and the production process used. These differing approaches were adopted for good reason and, as in all appropriate technologies, it is unlikely that a single process will emerge as being the unique solution for all situations. This report is not, therefore, intended to be a guide to the "best buy" in RHA cement technology but is an attempt to bring together comparative data on the various initiatives for the benefit of those contemplating the use of such a material in their own region.

The report must be read with all the usual cautions; in particular the laboratory tests were performed on 'grab' samples and should not be seen as definitive or statistically significant.

Our thanks are due to those people and institutions visited who gave their time and shared their experiences freely with the compilers of this report.

F. R. Almond, Intermediate Technology Industrial Services, February 1984.

SUMMARY

The purpose of the four-week visit was to conduct a 'state-of-the-art' review of rice husk ash cement technology and production in the Indian sub-continent. Twelve specific locations were visited to discuss research and development. Visits to pilot and commercial production plants were included, and samples were collected for later analysis in the UK.

Some of the completed research still awaited application but some was being applied. Commercial production was often held up through non-delivery of raw material, failure of power supplies or mechanical breakdown, but some rice husk ash cement was being made, sold and used.

Research workers had found that it was necessary to limit the temperature of the burning husks to no more than 700°C to obtain an amorphous ash which would be reactive with lime, although in some production processes this temperature was exceeded.

It had been found that the ash needed several hours of grinding to produce a sufficiently fine powder. The period in practice using ball mills varied between 1.5 and 5 hours.

In most cases the cement was made by mixing one part of lime with two parts of rice husk ash (by weight). Sometimes ordinary Portland cement was used in place of lime. It was commonly recommended that for building use, one part of rice husk ash cement should be mixed with 3 parts sand (by volume).

The rice husk ash cement is much cheaper than ordinary Portland cement for a given weight and in spite of richer mixes being used in practice it is still cheaper to make mortars from the rice husk ash cement. Capital investment of some £12,000 may be required for a complete plant.

Results of tests in UK laboratories are given and are compared with manufacturers' claims and with requirements in the most relevant Indian and British Standard Specifications.

The rice husk ash cements often exceeded the requirements of the Indian Standard for Lime-Pozzolana Mixture. In general they should be suitable for use in making mortars, renderings for walls, and some lower strength requirement concrete.

It is recommended that the technology be applied in other rice-growing countries of the world.

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KEY TO INSTITUTES

INDIA

A Cement Research Institute of India, New Delhi
B Indian Institute of Technology, Kanpur
C Birla Institute of Scientific Research, Ranchi
D Central Building Research Institute, Roorkee

NEPAL

E Research Centre for Applied Science and Technology, Kathmandu

PAKISTAN

F Pakistan Council for Scientific and Industrial Research, Karachi

1. INTRODUCTION

Throughout the world eighty million tonnes of husk become available each year during the processing of rice. Some is used as packaging or fuel, but the greatest proportion is dumped as a waste by-product.

Several institutes have investigated the properties of the ash of the burnt husk, which contains a high proportion of silica, and there has been some commercial exploitation of its pozzolanic reaction with lime to form a cementitious material of potential use in the building and construction industry. Research was carried out in the United States by P. K. Mehta, and later the first meeting of the United Nations (ESCAP) National Focal Points for Regional Centre for Technology Transfer (Bangalore, India), in 1978 decided that RCTT should promote rice husk ash (RHA) cement technology. In consequence, three international RHA cement workshops have taken place; at Peshawar (Pakistan 1979), Alor Setar (Malaysia 1979) and Delhi (India 1981), where information was presented and discussed. Training centres, compilation of a Standard Specification, study of use in building and preparation of a manual on manufacture were recommended. An information centre has been established at Bangalore.

The Intermediate Technology Industrial Services (ITIS) unit of the Intermediate Technology Development Group requested a review of the current state of this art of producing a cementitious material from rice husks in the Indian sub-continent. It was already known that development work had been done there by several organisations. Various claims, reports and publications gave a confusing picture of the situation and there was no overall comparative review of the subject. ITIS recognised the potential benefits of making these materials in India and also in other rice growing areas of developing countries to increase the supply of building materials, especially where ordinary Portland cement was expensive or scarce. Such use would also effectively dispose of and utilise, an agricultural waste, improve rural economy and generate employment, with low capital costs. ITIS wished to be in a position to make recommendations so, in 1982 the author, a member of the staff of the Overseas Division, BRE, visited India, Nepal and Pakistan to gain first-hand information.

Professor D. J. Cook, Associate Professor in the Department of Civil Engineering at the University of New South Wales, accompanied the author for part of the visit.

2. SITE VISITS

Discussions on research into the various processes were held at six institutes and visits were made to inspect the commercial enterprises utilising the process of each institute. The map (Figure 1) shows the location of places visited and other centres of information. This section of the report describes discussions and site visits but a more detailed comparison of methods, properties of the products and economics is made in later sections.

Conversion of local currencies into Sterling is based upon rates operating at the time of the visit namely: £1 equivalent to Indian Rs. 16, Nepalese Rs. 24, Pakistani Rs. 19.

2.1 INDIA

Research Institute A

Small experimental units for burning husk had been built and operated and 'know how' and services had been sold to entrepreneurs. It was claimed that a consistently good product was best obtained by controlling the burning temperature of husks to less than about 600 to 650 °C in order to produce active amorphous ash. Higher temperatures were said to result in a crystalline less-reactive ash.

Ready-burnt ash such as that obtained from parboiling of rice had been found unsatisfactory, being up to 95% crystalline. Early laboratory experiments with a round brick-built incinerator with little ventilation (Figure 2) did not produce good ash. A small square incinerator (Figure 3) of open brickwork with metal mosquito netting to retain husks and ash had the advantages of less thermal mass, and greater access for air. A satisfactory reactive ash was claimed to be produced. The fairly high carbon content of the ash produced did not prevent it from being acceptable. Different sources of husk had shown variations in ash residue after burning, from 20 to 28% by weight of husk, and silica content of the ash was from 82 to 96%, although all these could be used satisfactorily. In order to

obtain the desired high standard it was recommended that, for commercial manufacture, the lime be produced at the same location, limestone being brought in and burnt in kilns under the same careful supervision as used in burning husks, rather than purchasing ready-made lime from the existing market. Hydraulic lime, which can produce some calcium silicate itself, was found satisfactory. Too high a proportion of lime in admixture with ash was said to delay the development of strength of the product in use, and a weight ratio of 1:2 lime:ash was used.

To obtain sufficiently fast reaction rates between ash and lime it was necessary to grind the ash in a ball mill for one hour, then add lime, and continue milling for a further half hour to mix the components. Entrepreneurs were encouraged to mill the ash for 1.5 hours to be more certain of attaining the necessary fineness. They were also advised to obtain a ball mill of slightly larger capacity than that required for continuous use, to allow for breakdowns and the inevitable interruptions in electric power supply. Such a mill is available in India ready-made, its size being 1.5 x 1.5 m with a 15kW motor.

A two tonne per day output, which may be suitable for rural use adjacent to a rice mill, was reckoned to be the minimum economic size. Such a plant would be run by nine people (one supervisor, one lime kiln operator and 7 unskilled labourers). The Institute listed items of capital expenditure, of which the ball mill complete with ball charge was the most expensive at £5,000, followed by an allocation of nearly £4,000 for civil works which included boundary walls, storage and equipment accommodation, and the cost of 1000m^2 of land at £1,200. A lime kiln and husk incinerator (scaled up from the earlier experimental design) were each priced at £500. Other items brought the total of fixed capital to £12,000.

The annual costs of running the plant for 330 days per year at 90% capacity were also indicated. Raw materials were a small part of the whole: cost for rice husk was taken as charges for transportation only, so the 1950 tonnes required per annum would cost £1,180. 300 tonnes of limestone plus transport would cost £1,800. Cinder for burning the limestone would cost £1,300; electricity, chiefly for the ball mill, was calculated at £220 but this seems to be an underestimate. Depreciation of equipment would

be anticipated at £750, largely due to wear of the ball mill shell, which might last only three years. Salaries of £2,250, and similar amounts for interest on loans and for packaging plus a number of smaller items would give a total annual cost of £12,000 or £19 per tonne. With an estimated selling price of £27 per tonne this would yield a return on investment of 32%.

The above selling price was much lower than the lowest price for ordinary Portland cement (OPC) of at least £40 per tonne. One third of the OPC production in India must now be sold on the open market (since February 1982), and it commands an even higher price, up to about £95 per tonne. RHA cement therefore appears very attractive economically.

Agreements had been signed with entrepreneurs in four States for plants with 4, 4, 3 and 10 tonnes per day capacities respectively. Agreements are made with a payment by entrepreneurs for plant commissioning, routine testing, examination of samples for the first month or so, and occasional testing and advice later. Laboratory tests were to ASTM, for water retention, water demand, fineness, compressive strength, slump (on flow table), and lime reactivity of ash (at 50 ^{o}C). No specific standard for RHA cement existed but the products were generally assessed by the requirements of IS 4098. Specification for Lime - Pozzolana Mixture. There was little feedback of detailed information from plants at the time of the visit, except from one which was visited later, as part of the review. The larger plant which had two mills, each 1.8 x 1.8 m, was reported to be not working, due to some mechanical failure.

Six more parties were about to sign agreements and a further 400 enquiries had been received.

It was envisaged that in rural communities village people would bring their rice to a local mill, and could purchase RHA cement from the adjacent plant, taking it to their villages using the same transport as for the rice.

Experiments carried out by the Institute demonstrated the fairly successful use of RHA cement:sand mixes for renderings (1:3 by volume). Although cracks had appeared in some elevations, the renderings seemed well attached to the brickwork. Fair-faced brickwork built with RHA

cement:sand mortar (1:6 by volume) (Figure 4) showed satisfactory performance as a mortar. RHA cement was not recommended for reinforced concrete work.

Production Plant A1 (using technology of Institute A)

Approximately eight workers were seen to be busily engaged. Eight incinerators were being operated, in spite of rain and wind at the time of the visit, which made working conditions difficult (Figure 5). It was observed that unburnt husk was in and around the bottom area of some incinerators, yet fortunately the workers managed to avoid collecting unburnt material with the ash. It was said that a thermocouple enabled burning temperatures to be monitored and controlled, but there was some difficulty in obtaining a meaningful reading with the instrument when placed in a pile of hot ash lying in a storage shed.

Two brick-built lime kilns were at the site. One was to the design of the Khadi and Village Industries Commission, but was not used, since the workers preferred the other which was built to their own traditional design. It was 3.25m high, approximately 2 m diameter internally at the top, tapering to 1.5 m at the base. No lime burning was possible at the time of the visit because limestone deliveries from the quarries had been disrupted by landslides which had dislocated road transport. A simple flat area was available for slaking quicklime with water.

The ball mill (Figure 6) was apparently in working order, though unfortunately the electricity supply had been temporarily interrupted. Consequently no product was being made at the time of the visit, though a sample was obtained, and a representative sample of ash was taken from the storage shed.

When the product was being made it was sold and used locally, though some was transported to the nearest city. Its performance was said to be satisfactory and when inspected, it did appear so. It had been used for construction both in the plant and in the adjoining rice mill for mortars, renderings and for construction of a flight of steps.

Research Institute B

An amorphous ash, obtained by burning husks at less than 750°C, was claimed to be desirable, but use of any type of ash which might become available was considered. This was because rice husk was being increasingly used as a fuel, so that it might not be cheaply available in a few years' time for burning in special incinerators. Consequently a technique which could be modified according to prevailing conditions was advocated. Although 2 hours grinding was adequate for amorphous ash, longer periods of grinding, of 6 hours or so, could be effective in increasing the strength of cements made from more crystalline ash. To conserve energy and improve efficiency of production, appropriate minimum grinding times should be used for each particular ash. Up to 10% carbon had not proved deleterious.

Where husk was available, controlled burning at a sufficiently low temperature would give a highly reactive ash which needed little grinding in order to obtain adequate cement strengths. A cylindrical metal wire mesh basket, 1.2 m high and 0.6 m in diameter, lined with a finer wire netting to retain husks, set in a mild steel frame on legs, and with a perforated metal chimney up the centre had proved successful as an incinerator (Figure 7). To operate, a fire was kindled at the base between the legs. A damper was provided at the chimney base so that with it open, air could flow in at the base or with it closed, air would be drawn in through the husks in the basket. The fire was allowed to burn up through the husks, volatile matter from them entering the chimney and shooting out of the top in a large flame. As husk burnt the top level fell, and was topped up with more husk. The whole lot was burnt out in less than two hours. In theory the volatiles could be taken off from the chimney for combustion elsewhere, though ducting would diminish the draught through the fire. However this might be the basis of utilising the fuel value of the husks. Alternatively, rows of such incinerators might be operated under some device which needed heating (e.g. in the drying of food crops). There was no convenient method of removing ash and the incinerators had to be tipped over by hand.

The BET method for determining specific surface area of husk burnt in a laboratory furnace had shown a decrease in area with increasing burning temperature. After determining the surface area of the ash, it was inferred from this relationship that temperatures had been approximately 400°C, but no direct temperature readings seem to have been taken from the incinerator.

Ash was used for two different products. One was produced by grinding ash and mixing with ordinary Portland cement (OPC). The other was made by grinding ash and hydrated lime together. OPC and lime were bought as available on the market.

The suggested size of ball mill for both products was 1.5 x 1.5 m, with a 25kW motor, capable of producing at least 1.7 tonnes per day, or more for a soft ash. A grinding medium of 3 tonnes of cast iron or steel balls, 20-25 mm in diameter was used, but no special mill lining was specified.

The lime-ash material was said to be the slower setting of the two products, but accelerators, other than up to 10% OPC, were not recommended as they would be an added complication and expense.

Proportions of lime and ash varied; for every part by weight of lime, from 1 to 2.5 of ash might be added depending upon requirements in use. It was satisfactory for masonry and foundations or general concreting work, but never for reinforced concrete. Proportions of OPC to ash could be one part by weight OPC with from 0.5 to 1.5 parts ash, depending whether high or ordinary strength was required. Instead of OPC, Portland pozzolana cement (PPC) may be used. PPC is OPC containing brick dust or other pozzolanic material, and one part would be mixed with from one to two parts ash by weight, depending upon whether strong or normal properties were needed.

For practical use as mortars, the lime-ash material would be mixed with sand in volume ratios from 1:1.5 to 4 and the OPC-ash material from 1:2 to 5 depending upon properties required.

It was emphasised that in practical use it should be remembered that although these cementing materials are sold by weight they are less dense than OPC. The lime-ash material in particular has a bulk density approximately half that of OPC. So there will be have to be nearly twice the volume

to obtain the same weight ratio to sand and aggregate. Cubes had been cast and tested to ascertain the properties obtained when used in construction. Strength after 28 days was fairly high, a 1:3 mix of the OPC-ash material to sand being stronger than 1:3 lime-ash to sand. Pieces remaining from the test were inspected and appeared to be of good quality.

It cost approximately £30 to produce a tonne of either product which might be sold at £50. Actual and comparative costs with OPC were difficult to make at the time of the visit due to the recent change in marketing policy of the OPC as mentioned previously, but as OPC prices on the free market were rising at the time, RHA cements apparently gained an advantage.

The suggested production plant was similar in capacity to the plant A. The following costs presented here had not been updated for a few years so will be low. However, of the fixed capital required the ball mill cost at £4,500 and land at £1,200 were similar to the figures provided for Institute A. Allocation for buidings etc at £1200 was not directly comparable with A as boundary walls etc., were not mentioned. Total fixed capital was therefore approximately £7,000.

Estimates of annual costs of running the plant for 300 days per year, on three shifts per day for three workers per shift (less workers than A as ash is bought ready-burnt) plus materials, power and packing were difficult to assess with varying raw material prices, but may be between £8,000 and £14,000. Higher cement-content products will increase cost.

Indian patent no: 142966 existed on the process. Many enquiries about the process were reported and a number of entrepreneurs had commenced or were planning to commence manufacture in various places, within four separate States.

Of these only two were stated to be in production and there was some doubt about the others. Production of these plants was generally the lime-ash material.

In addition there were two other plants in operating condition and it was intended that they should both become not only production plants, but also demonstration and training centres for further developments.

Numerous enquiries had been received from India and from overseas. The following criteria were suggested before considering development.

1. Is there the ability to absorb the technology?
2. Does the necessary infrastructure exist?
3. Does sufficient need for the product exist?

Production Plant B1 (using technology of Institute B)

The plant had three entrepreneurs who engaged eight workers.

At the time of the visit husks were being burnt (Figure 8) in a large open pile 2.5 m high, partly contained by a circular brick wall 16 m in diameter. The consultant from Institute B claimed to have advised against this procedure which he forecast would give ash with low reactivity. A quarter of the contents in the whole enclosed area was removed each day and replaced with new husk, though the extreme bottom of the pile was never cleared out. The fire was thus allowed to move round the area from one quarter to the next. It was said that wind direction had no effect.

Some ready-burnt boiler ash was sometimes brought in to supplement the supply, but was further burnt by laying it on top of the already burning husks in the incineration area.

The proprietors said they were planning to construct a large brick built type of incinerator.

The ash was normally ground by ball milling for five hours, then mixed with lime or cement and milled again, but prior to the visit the mill had broken down and had been removed elsewhere for repair. Two new smaller mills, each 1.2 x 1.2 m were seen being installed (Figure 9), but as they were not yet operational, no actual product was being made for sale at the time of the visit.

When in production 1 part of lime was mixed with 1.5 parts of ash by weight, and setting accelerated by the addition of secret additives. These were probably common salts, but no statement was made by the proprietors. OPC was used instead of lime, in the same proportion, for an alternative product. An 'Instructions for Use' leaflet in English and Hindi was included with

every bag. Due to difficulties in obtaining OPC, some product was made using 1 part of PPC, with 1 part ash.

Current prices were said to be £40 and £52 per tonne for the two types respectively. No detailed information was obtained on economics of the plant, but it was said to be profitable, and the partners were planning to increase production.

Mix proportions for mortar and concrete were clearly stated - by weight 1:4 cement:sand and 1:2:4 cement:sand:coarse aggregate and by volume 1.75:4 and 1.75:2:4 respectively. 50% less mixing water than required for OPC was indicated.

The products from the works were said to be much in demand.

Research Institute C

In the process developed during the preceding 5 years, ready-burnt husk ash was bought usually from rice mills where it had been burnt in 1 metre high piles. Alternatively ash from husks burnt for parboiling of rice might be used. Two parts by weight of ash were mixed with one part lime and one part waste from a local industry. This waste gave higher strengths to the finished product, possibly due to the contribution of aluminates in the waste. Lime was bought in for pilot scale work at the Institute. The constituents were ground together for 3 hours in a 0.5 x 0.5 m rod mill, capable of giving 0.5 tonne per day.

Research into the strength of concrete specimens made with this product had led to the conclusion that 500°C was a suitable ignition temperature for the husks though 700°C was acceptable. Furthermore up to 20% of carbon in the ash seemed to be acceptable. Test results also indicated that concretes of 1:2:4 RHA cement:lime:sand, although weaker at 7 days, were stronger at 28 days than if OPC were used.

Some reinforced concrete samples had been kept in water for up to two years soaking but not enough was known at the time to make any recommendations.

The rice husk cement had been used successfully for making the rendering on the small building which housed the rod mill (Figure 10).

The cost of production on a commercial scale of 16 tonnes per day was said to be £28 per tonne, and the selling price was £36 per tonne. Eight people would be required and the cost of setting up such a plant, complete with lime kiln, was said to be £30,000 plus £12,000 for land and buildings.

Entrepreneurs were required to pay £300 for the "know-how", then 1% of the sales for the first 5 years. For this payment entrepreneurs received a one-week training course, and a written document describing the process, detailing procedures for various chemical and other tests, and giving a sample economic feasibility report. The report indicated that a plant of 16 tonnes per day capacity, operating 24 hours a day, 300 days a year, would require 2 ball mills, costing a total of £18,000, other machinery and fittings £3,000, pre-operative expenses of £4,000, contingencies £4,000, working capital for salaries and materials for one month's production, stock, stores etc., £21,000. The cost of a lime kiln was not mentioned in these data.

Entrepreneurs who had gained knowledge and experience by working at the Institute were building production plants at two locations. At one, accommodation buildings were still under construction. However, adjacent to the Institute construction had been finished and equipment installed, and this latter plant was visited. Three more parties had the know-how and had been trained. They planned to set up plants so there would be production in three States.

Production Plant C1 (using technology of Institute C)

To enable ex-students from Institute C to obtain practical industrial experience in management and manufacturing, a division of the Institute has set up 30 small factory buildings, complete with services, on an adjacent site. One of the units is for the production of rice husk ash cement. Equipment and materials (Figure 11) had been assembled ready for commissioning a few days before the visit, but unfortunately the 1.8 x 1.8 ball mill was found to have misaligned bearings when it was first run, so it was being dismantled at the time of the visit. Such a mill was too heavy to man-handle, so shear legs with lifting tackle had to be brought into lift it. The mill was to take a charge of 2 tonnes, plus the weight

of the balls. Husk ash was to be bought in ready-burnt, but two lime kilns had been constructed just outside the factory building. Other additives were seen piled against the factory wall. Proportions were to be measured out with gauge boxes, and a heavy steel truck was installed for removing the charge after milling. It was planned to automate parts of the process later. The whole process plant seemed well laid out, and the entrepreneur was enthusiastic, well-trained, and in a convenient position to call on the advice of the Institute's staff.

(This plant was reported to be working now.)

Research Institute D.

The process utilised not only rice husk, but also lime sludge waste from the sugar industry. The lime sludge was a gel, which had to be dried first, mixed with an equal weight of husk, rewetted, then rolled by hand into 80 mm diameter balls. These were allowed to dry in the sun (Figure 12), then laid in a long trench. A fire was started at one end and allowed to burn right through to the other. The cooled balls were then ground for one hour to give a product which would be marketed as a lime-pozzolana.

Approximately 700°C was reckoned to be a critical temperature for burning the husk. Below that temperature amorphous ash was produced, regardless of time of heating. Above, time of heating was important, so that more than 3 hours at 800°C or more than 1.5 hours at 900°C would give crystalline ash. However, one member of the staff reckoned the ash was 50% crystalline at 700°C and 750°C was the absolute maximum permissible. To convert the lime in the lime sludge into quicklime, a temperature of over 800°C was necessary. The crude trench burning method was claimed to give sufficient temperature, though actual measurements showed only 700°C. The trench method allowed excess air, which helped to burn off carbon from the husk, and to remove carbon dioxide from the decomposing lime. 12% residual carbon gave maximum reactivity. Burning time is adjusted to give a reasonably white ash.

Setting times of 0.5 hour initial and 10 hours final were reported. Concrete made from the RHA cements (1:2:4 RHA cement:sand:coarse aggregate) was less strong than when ordinary Portland cement was used. Where no fired clay bricks were

available, RHA cement was suggested as a basis for concrete block manufacture.

Estimates for production cost had been made prior to commercial application. Land, buildings, machinery etc., contributed to a capital cost of £10,000 and a similar amount might be required to meet annual costs.

The rendering (1:3 RHA cement:sand) on a brick wall, fully exposed to the weather for six years was inspected and found to be in good condition.

Some entrepreneurs were reported to have done experiments, and it was hoped that one would commence production within a few months but at the time of the visit there had been no commercial exploitation of the process.

2.2 NEPAL

Research Institute E

The method used involved collection of ash (from parboiling of rice etc.,) grinding in a ball mill, then further intergrinding for a total time of two hours with one third by weight of bought-in lime. Addition of 5-20% by weight of burnt clay had been found to give a more workable mix, but much grinding was required. A small proportion of ordinary Portland cement was added sometimes.

The product was not recommended for reinforced concrete construction.

Mortar could be made by mixing the product with three parts sand. However it was said that an equivalent low strength mortar could be made with OPC, using eight parts of sand, so to compete, the price of RHA cement must be much lower than that of OPC. In Kathmandu RHA cement sold at £55 per tonne while OPC was £90/tonne. It was claimed that Government contracts specified OPC and never RHA cement, so reducing the chances of the use of the latter. However, the current demand for cement in Nepal was said to be 300,000 tonnes per year; only 40,000 tonnes was produced locally. Demand should not fall since the Government's five year plan for 1985-90 was to concentrate on house building. Bringing in imported cement, over the difficult terrain resulted in high prices. These would be even higher in more remote parts, so there was considerable scope for small-scale RHA cement production to make up the deficit. A new

OPC plant of 120,000 tonnes per year was to be built in the south of the country, but even so there would be a shortfall in production, compared with demand.

The Institute had basic laboratory facilities and some RHA cement test results were reported, indicating reasonably good properties.

Twenty applications for details of the production process were said to have been received from entrepreneurs. Two were already said to be operating within Kathmandu, and three others were reported. The product was said to be selling well. The Institute reckoned it would cost £10,000 to set up a commercial plant.

Production Plant E1 (using technology of Institute E)

Rice grains for human consumption were being roasted on small husk-fire ovens. The husk ash was raked into piles out-of-doors (Figure 13), from where it was taken, while still hot, in wheelbarrows to the RHA cement production plant.

Ash was stored for two days and changed from dark grey to white. A small ball mill (0.7 x 0.7m) (Figure 14) was used to first grind the ash, then to intermix with lime, for a total time of two hours. The resulting fine powder was weighed into any available bags for sale (Figure 15) at £55 per tonne. Recommended mix for use was 1:3 RHA cement:sand.

Setting times of 1.5 hours initial and 3.5 hours final were claimed. A water requirement of 40% was quoted. Only about half a tonne could be produced per day, but it sold well.

Production Plant E2

An entrepreneur commenced production of RHA cement three years previously and had spent over £6,000 to date. He had bought 'know-how' of an early method that Institute E had apparently offered. The method consisted of making balls from rice husks and lime sludge, so was similar to that seen at Institute D, but the entrepreneur had no success with the method so changed to another. He built two large circular brick and concrete domed kilns, 3m high and 6m in diameter (Figure 16). The ash was mauve in colour, and the only way it could be removed was by someone entering the

dusty inside of the kilns. The ash was ground in three locally-made ball mills of each 0.9m long and 0.6m in diameter (Figure 17). Ball mill life was said to be two years. Lime and ash were mixed and put in gunny bags for sale. Maximum production rate was 0.75 tonne per day. A stock of some 9 tonnes was seen, which might deteriorate with long periods of storage.

The RHA cement had been sold at £60 per tonne, somewhat cheaper than ordinary Portland cement, quoted as costing £90 per tonne.

For use, a 1:3 by volume RHA cement:sand mix was usually suggested. The cement could be used for a mortar, render and flooring, but not for reinforced concrete work.

Since the properties were poor, and it was likely that ash temperatures were too high, it was suggested that husks be burnt in much smaller quantities, in the first instance by dividing an existing kiln into several compartments. Temperatures might be monitored with a thermocouple.

2.3 PAKISTAN

Research Institute F

Rice husk was being used increasingly as a fuel, for example half of the existing brick kilns were said to use it, so it was becoming less abundant and more expensive. Three new OPC plants were planned so that eventually there would be a surplus for export.

Nonetheless, there was a case for production of RHA cement. Firstly it could have specific properties, such as better chemical resistance than OPC, so it could be of particular use, for example for floors in the food industry where acid resistance would be a benefit. It was said that in big towns businessmen were not interested in small investments, but for special-purpose cement making, larger plants might be considered. Secondly, in remote rural areas there was a need for cementitious materials, but there were increased transport difficulties and costs. However, rural people had a fondness for locally made things, so small scale RHA cement may be very acceptable in that situation. Research had been undertaken at laboratories and put into full scale practice by an Agricultural Corporation (see

below), but it was hoped that the method could be tried out in a model village to build confidence with the people, then presented to others as a proven package. The estimated cost of setting up was only £1,600, and might be taken up by cooperatives in the rural areas. It was thought that RHA cement would be made for £10 per tonne, which was much less than the current selling price of OPC at £100 per tonne, giving a good margin for error and profit.

Husks were burnt in special incinerators made from oil drums, or in large heaps, but in either case the temperatures were said to be limited to 600 to 700°C. After grinding, the ash was mixed with lime.

The Institute's extensive laboratory facilities were visited. Fast burning was found to give black ash, which became white on standing. It was claimed that more than 4% carbon in the ash resulted in a loss of strength in use, though workers elsewhere have found that even 15% is acceptable. It had been found that an addition of 10% of OPC gave better workability.

Adjacent to the laboratories were well-equipped workshops. Two ball mills were in the course of manufacture, each 1.3 x 1.3m, which might be used for work on RHA cement (Figure 18).

Production Plant F1 (using technology of Institute F)

The Agriculture Corporation had been producing a large quantity of rice husk and sought a useful method of disposal. Consequently they set up a plant which was said to cost £1,600 and could produce 3 tonnes per day of rice husk ash cement. This was for use in their own construction programme.

The husk had been burnt in a heap 2.5m high, at 600°C (checked with a thermocouple). Ash was ground in two ball mills each 0.9 x 0.8m for 5 to 6 hours, using hard steel balls as the grinding medium, then 30% by weight of lime was added. The resulting RHA cement was used in the proportions of 1:3 RHA cement:sand.

However, the demand for husks as fuel increased and it was found to be economic to sell the husks rather than make RHA cement, so the plant ceased operation after only one year, during which time only 100 tonnes was produced. Consequently the plant was not visited.

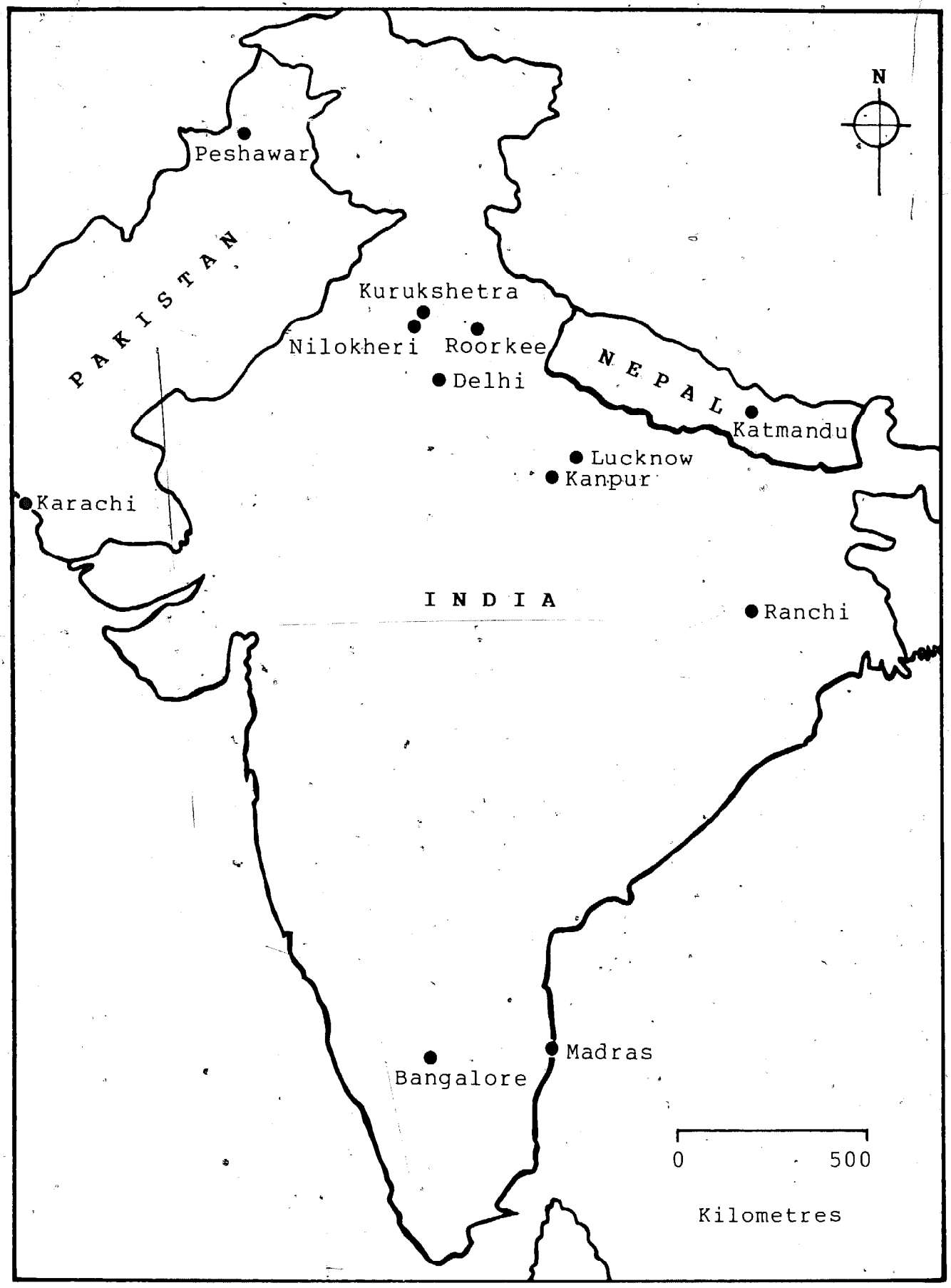

Figure 1. Some Centres of Rice Husk Ash Cement Information, Research and Development in the Indian Sub-Continent

Figure 2. CRI small experimental incinerators at Ballabgah.
Left – unsuccessful design. Right – successful design.
Dr. S.C. Ahluwalia (CRI), Prof. D.J. Cook (Univ. NSW)

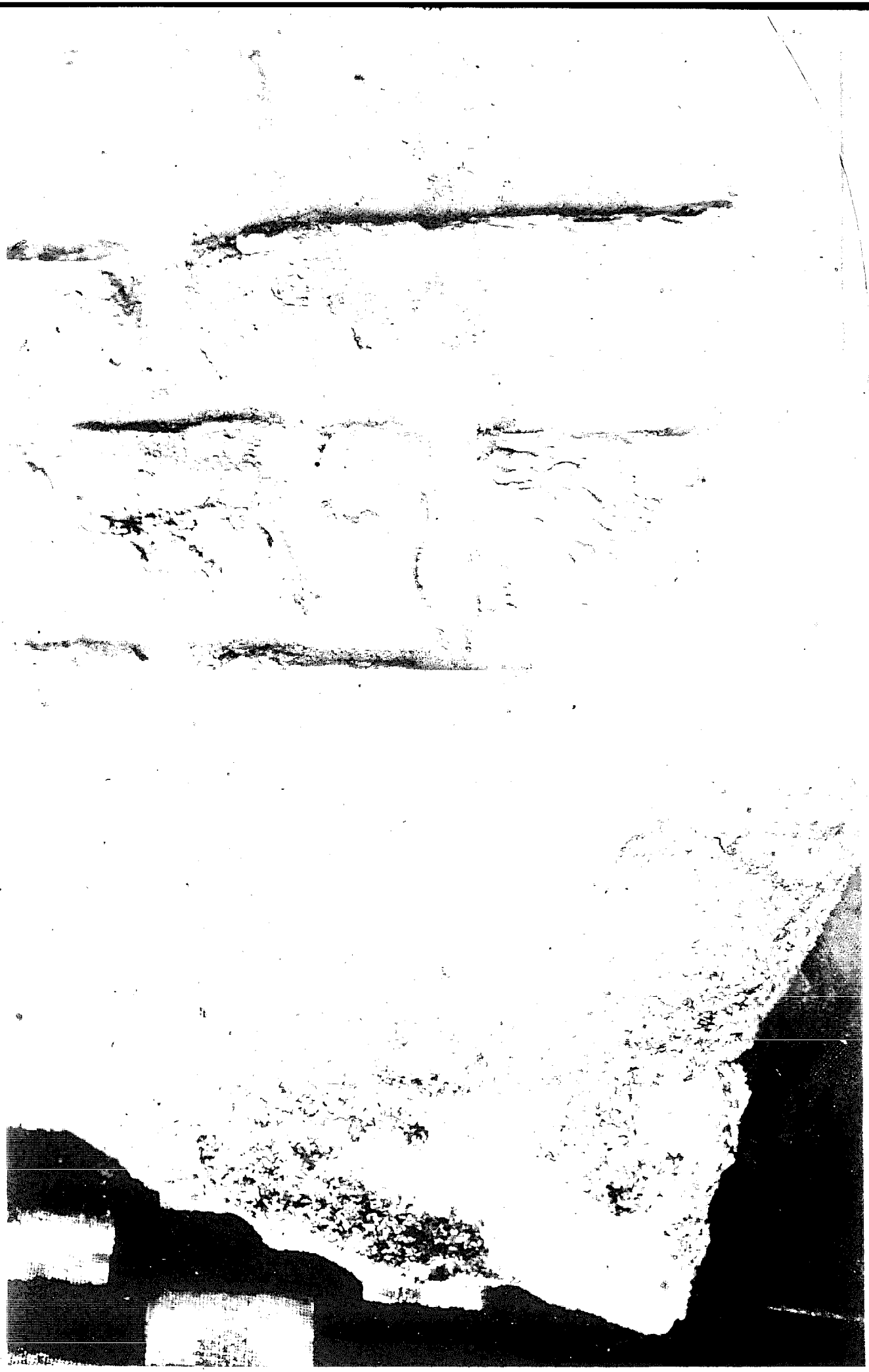

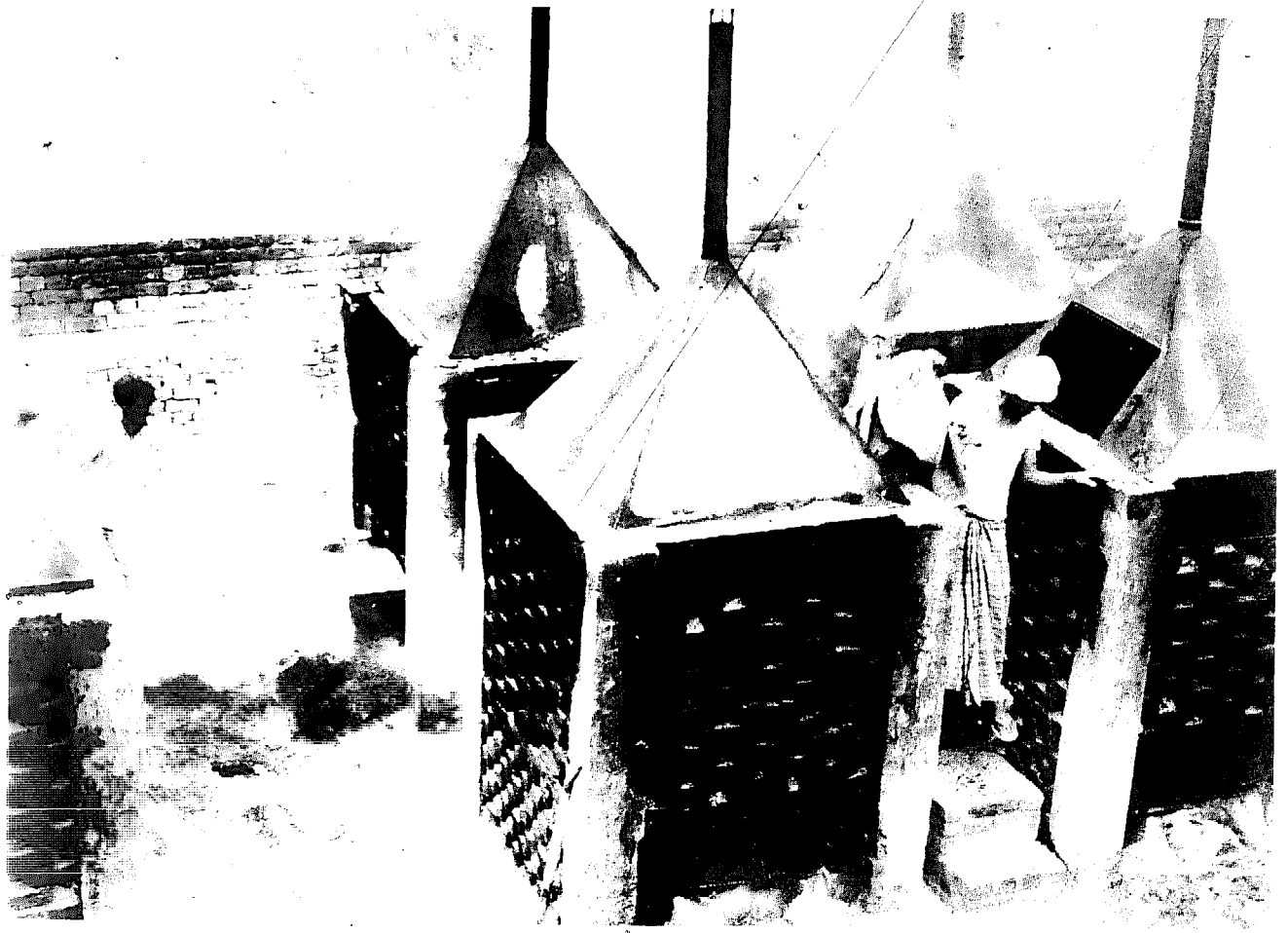

Figure 5. Rice husk incinerators at Nilokheri

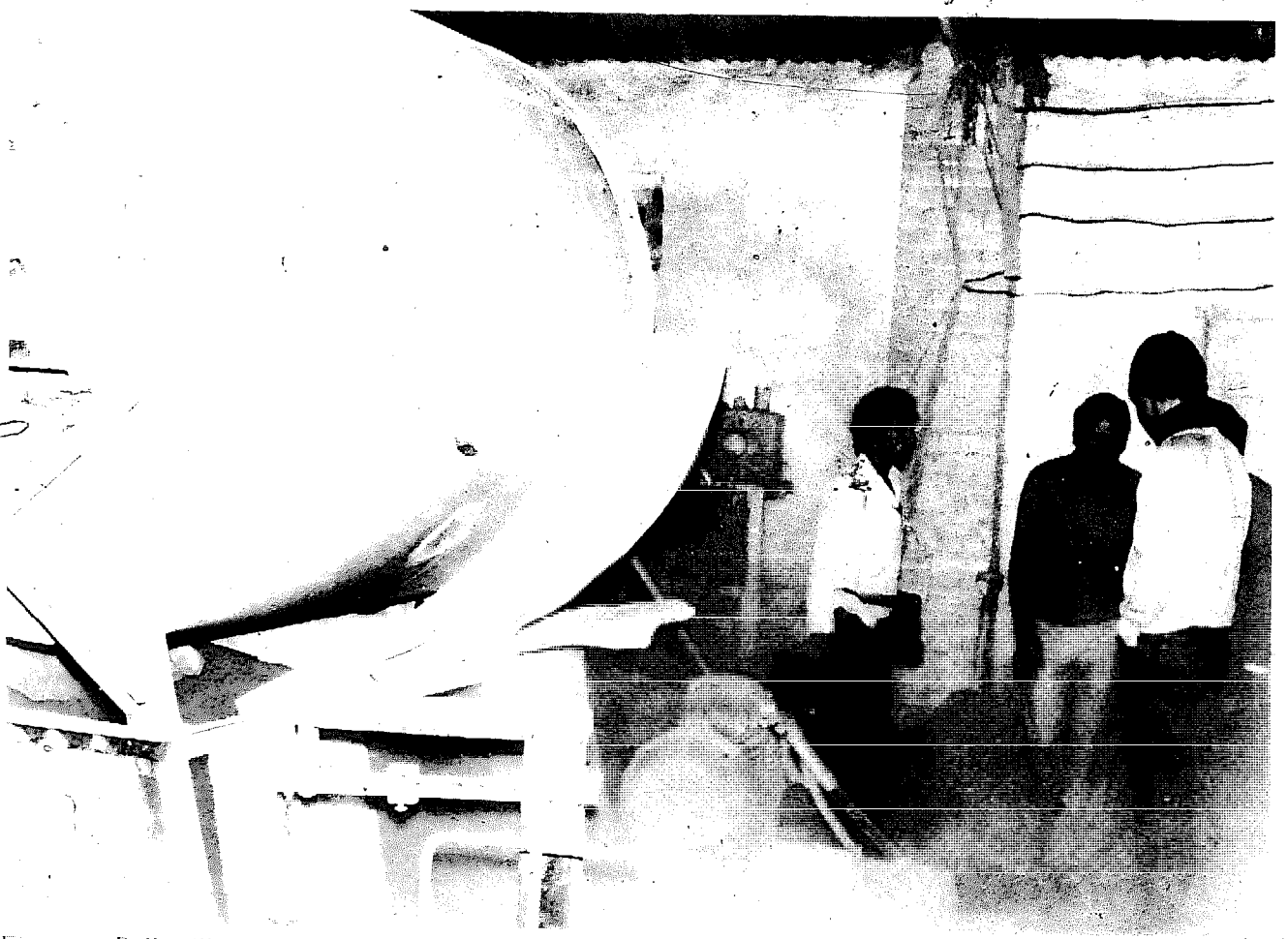

Figure 6. Ball mill at Nilokheri

Figure 7. Prof. P.C. Kapur with LaBrunneration at Kanpur

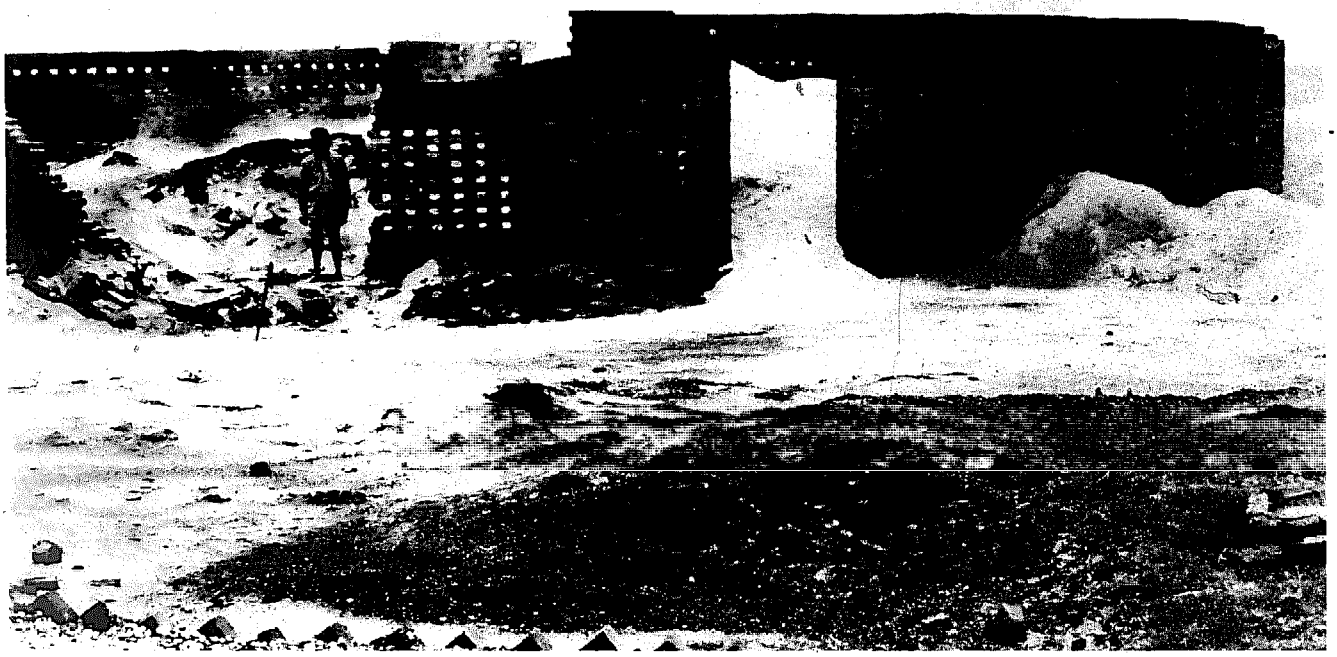

Figure 8. Heap burning of rice husk at Kurukshetra

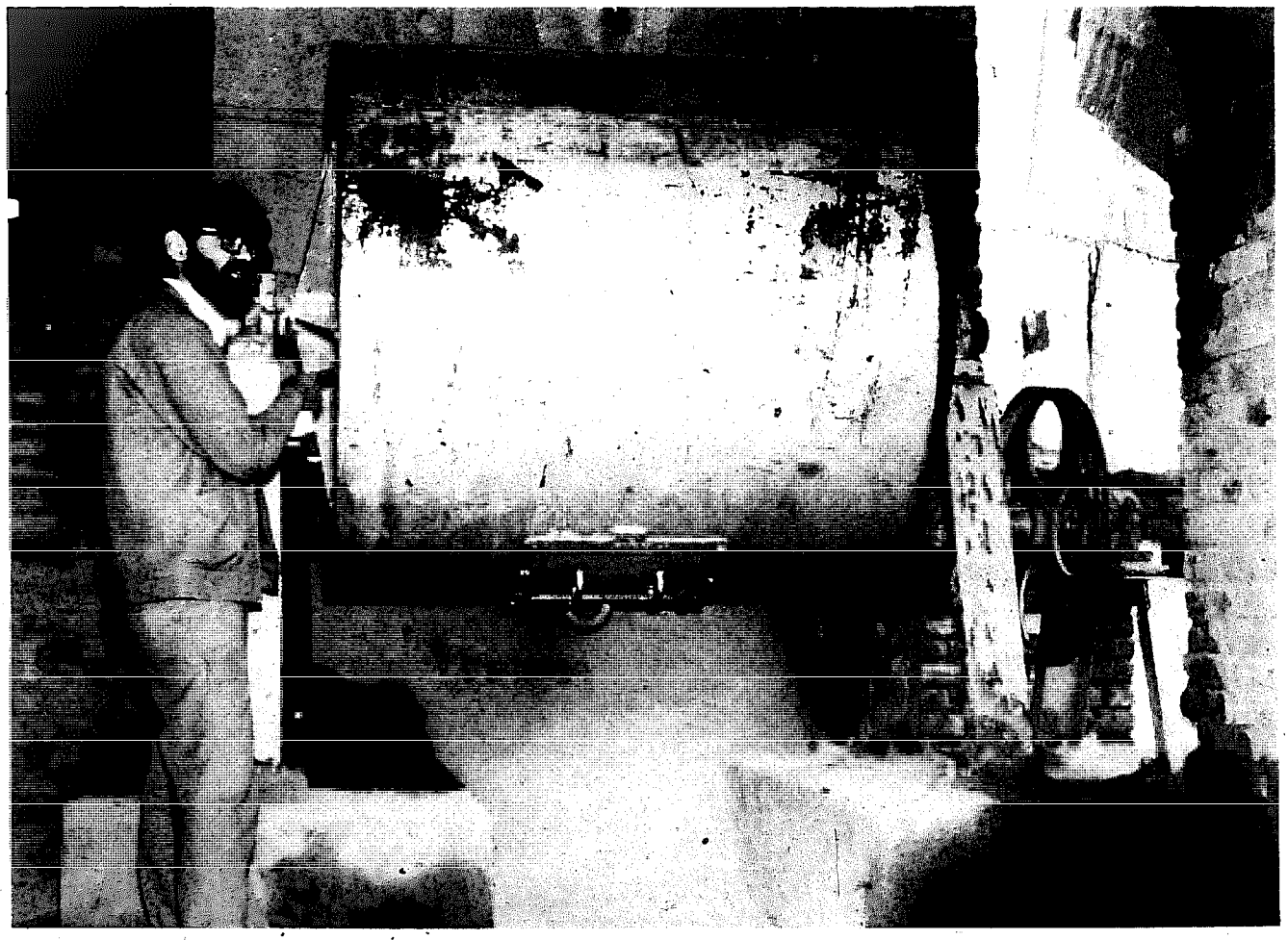

Figure 9. Mr. Lalit with new ball mill at Kurukshetra

Figure 10. Rice husk ash cement rendering at Institute C

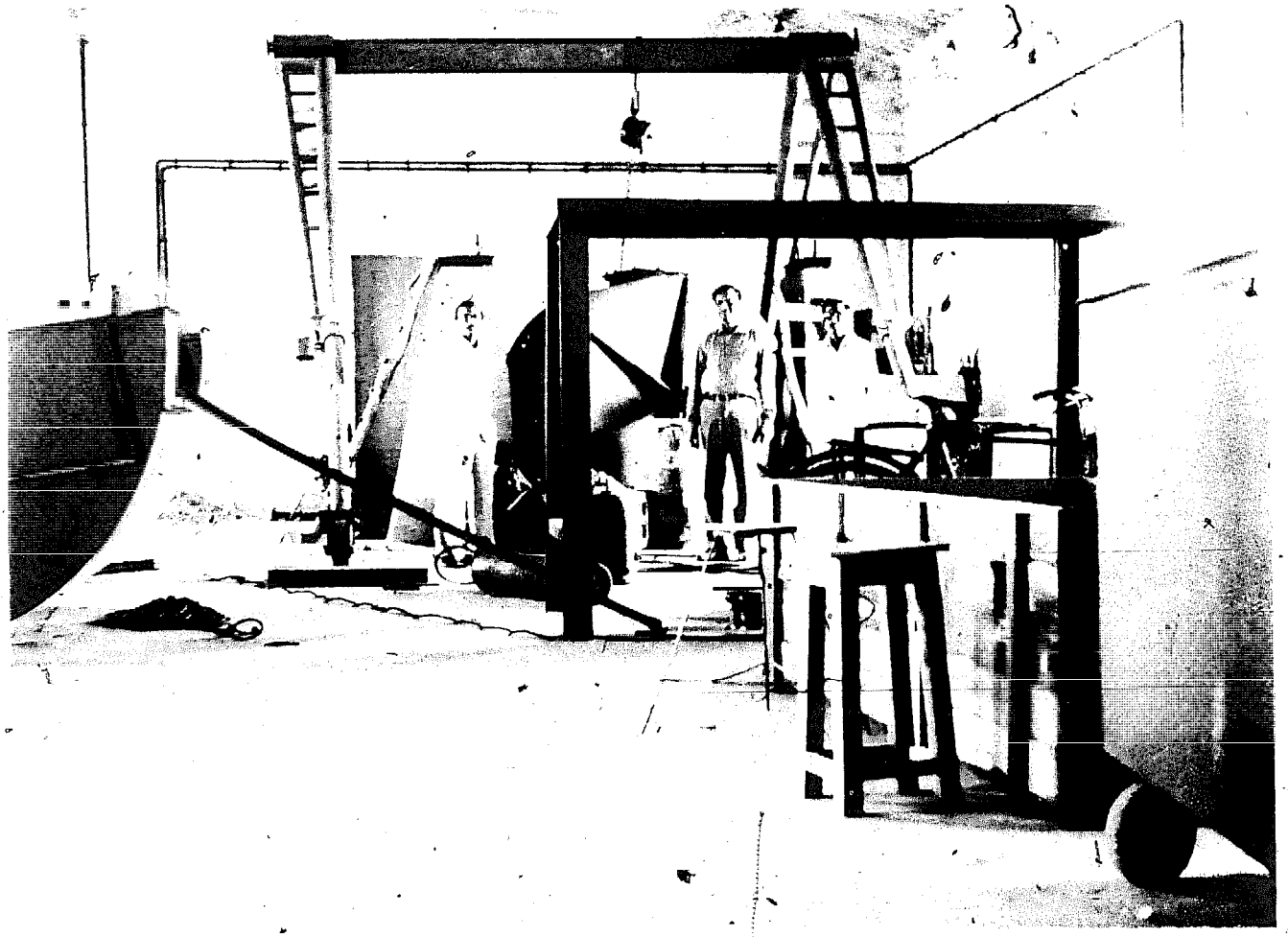

Figure 11. Nearly-complete production unit at Plant C1

Figure 12. Dr. A. Dass at CBRI shows lime, sludge, rice husk balls laid out to dry

Figure 13. Rice husk ash is raked out from small oven in Kathmandu

Figure 14. Ball mill etc., Kathmandu

Figure.15. Author and Mr. R.D. Shrestha with bagged cement for sale at street-side

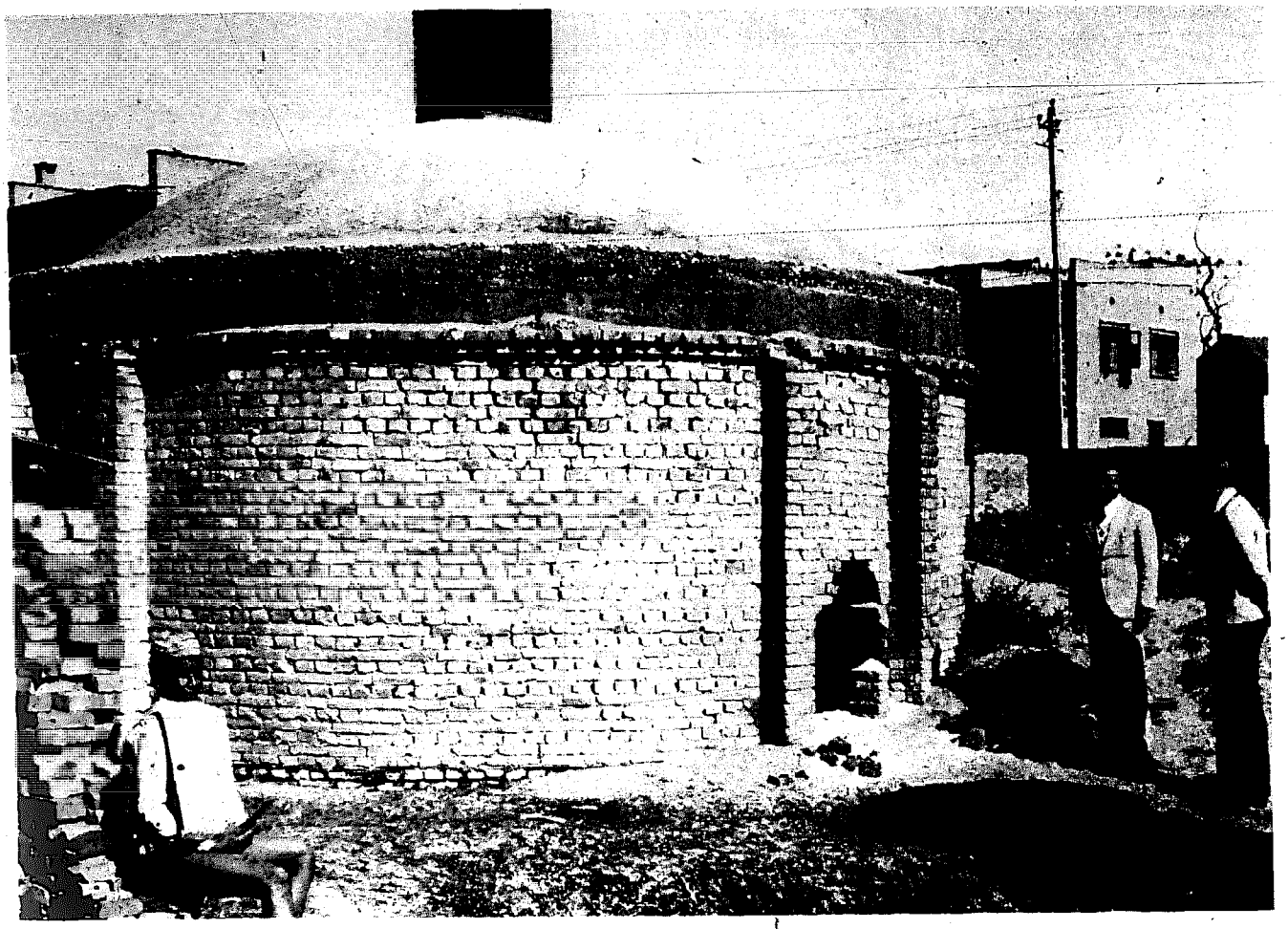

Figure 16. Large incinerator at Patan

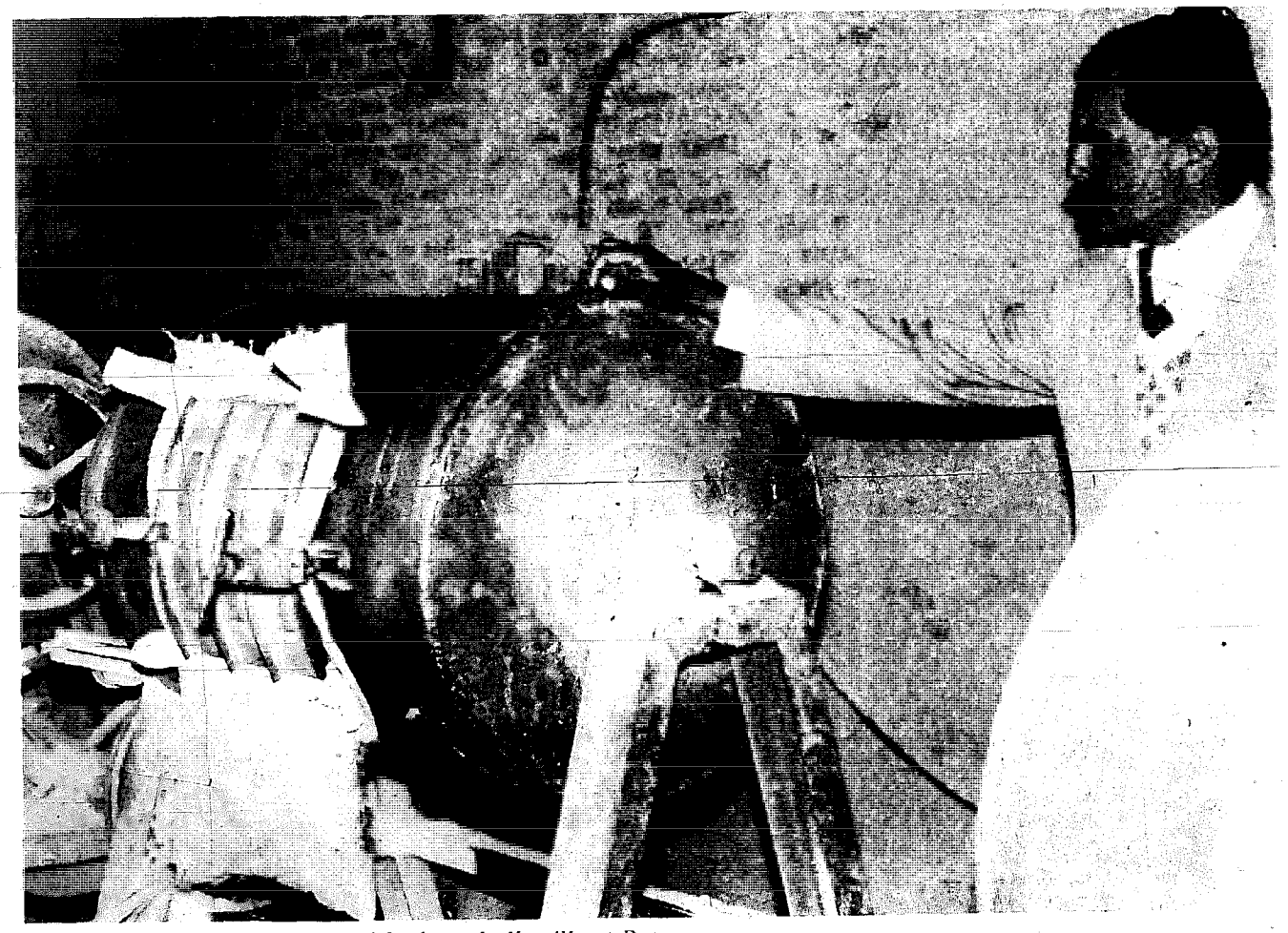

Figure 17. Mr. M.P. Dabadi with three ball mills at Patan

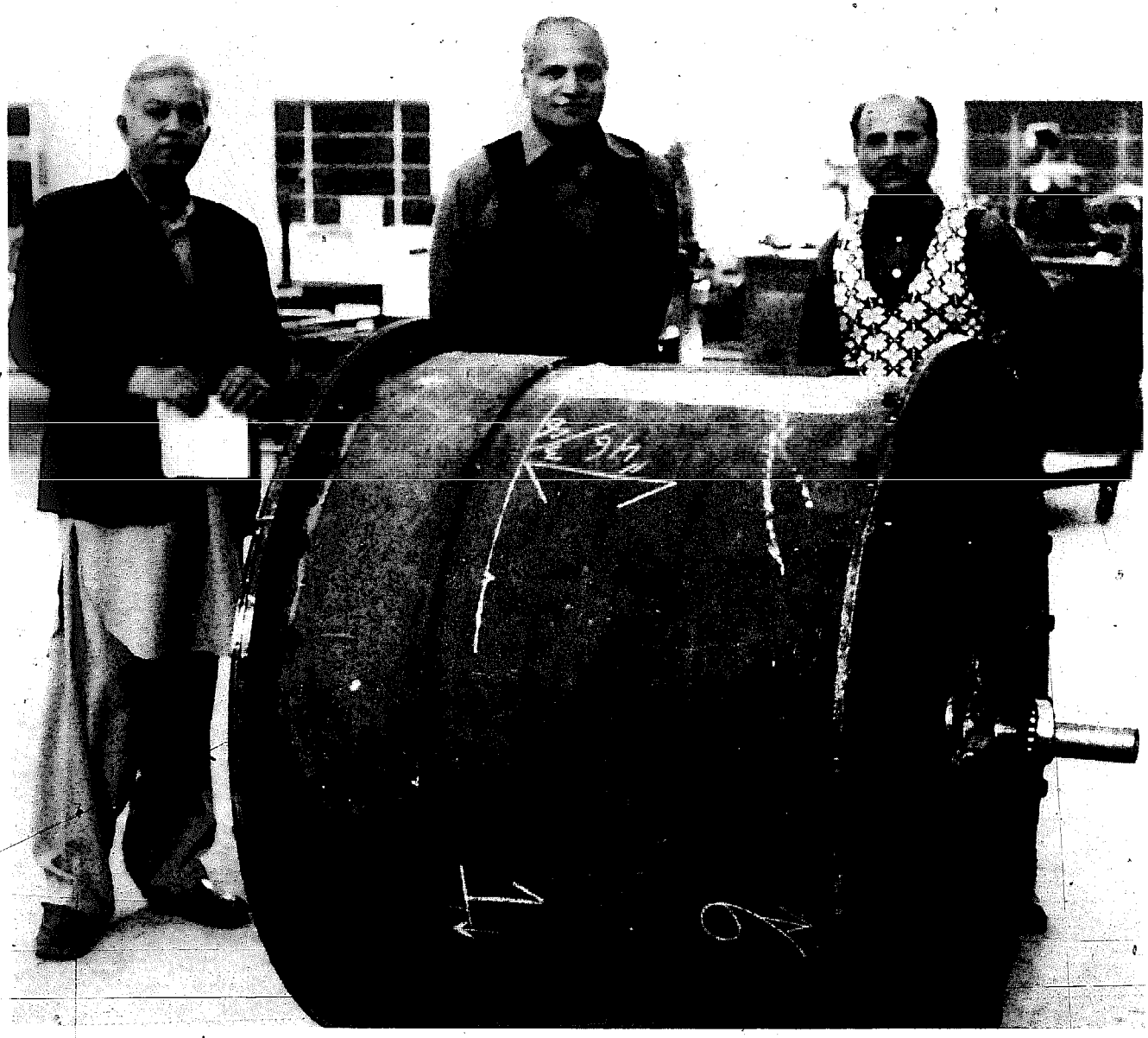

Figure 18. Dr. R.A. Shah (centre) with part finished ball mill at Karachi

3. COMPARISON OF PRODUCTION METHODS AND RECOMMENDATIONS FOR USE

To facilitate a simple comparison of the methods, Table 1 shows the size of plants, usual sources of the basic raw materials, grinding time in the ball mill, and number of employees. Data can only be regarded as approximate in most cases. The wide variation in grinding time at Institute B is by design: soft ash required shorter time than hard ash. Many plants were not completely operational at the time of the visit, though methods were discussed and some equipment and materials inspected, as detailed above.

Plant capacity was very small in all cases, averaging approximately 4 tonnes per day.

Methods were nearly equally divided between those burning husk in special incinerators and those buying in ready-burnt material, but most operators bought ready-burnt lime. OPC and aluminates were always bought ready made.

Grinding time varied by several hours about a mean of 3.5 hours.

The numbers of employees was difficult to assess in some cases, but averaged approximately seven per plant.

The success of the operations seemed to vary immensely. Some were well run profitable businesses, while others were losing money. Research carried out in some institutes had been applied by entrepreneurs, in other cases entrepreneurs had installed equipment and were ready to commence production. Some research had not yet got beyond a basic agreement with an entrepreneur, as detailed above.

Mix proportions used in manufacturing RHA cements and for their use in mortars are summarised in Table 2. In general one part of lime has been mixed with two of RHA by weight, but with OPC and aluminates one part has been mixed with only 1.5 of RHA. For use as mortar the recommended mix is in the proportions of one part RHA cement to three parts of sand by volume generally, but this varies depending upon RHA cement quality and mortar quality required.

4. TESTING SAMPLES IN UK

Samples of ashes and RHA cements were collected where possible, and brought back to England for test under standard conditions. Ashes were examined by X-ray diffraction techniques to determine whether they were amorphous or crystalline. Ashes were mixed with half their weight of fresh hydrated lime and then tested in the same way as the ready-made RHA cements. Methods were based on those specified in the British Standard Specification for Cement, BS 12:1978. Soundness of the materials was done by the Le Chatelier method, initial and final setting times with the Vicat apparatus, using pastes, when sufficient material was available.

For compressive strength tests, cements were mixed with three times their volume of graded sand (BS 4451) and cast into 25mm cubes (smaller than BS 12). The quantity of water in each mix was that necessary to give a standard workability. In addition to testing after 7 and 28 days storage at ambient temperature (20°C), an accelerated test was carried out using an elevated temperature (50°C).

Table 3 identifies the nature of the samples taken at the various places visited. It is not possible to say how representative the samples were of production over a long period.

5. RESULTS OF UK LABORATORY TESTS

Results of tests are divided into three separate groups. First the samples of 'as-sold' RHA cement made using local lime and ash, then those 'as-sold' using OPC etc., and ash, and finally the mixture of a standard UK lime with the ash. Results are given in Table 4.

5.1 Compressive strength

In accordance with common practice, 1:3 cement:sand mortar was made but because of small quantities of material available 25mm cubes were cast and cured at 20°C then tested at 7 and 28 days. In addition an accelerated test was carried out by keeping some cubes at an elevated temperature of 50°C from day 4 to day 7, cooling for one hour, then testing. At least three cubes were used for each test, and results showed very good reproducibility.

Of the 'as-sold' RHA cements, the lime/ash were not as strong as the OPC/ash in 7, 28 and 7 (accelerated) day tests. The apparent exception, lime/ash B probably owes its higher strength to the incorporation of a small proportion of OPC. The lime/ash 'as-sold' cements were not as strong as the mixtures of ashes with UK lime, in general, perhaps due to the relative freshness of the UK lime.

Inspection of data in Table 4 shows that 7-day accelerated test results give an approximate indication of 28-day strength under ambient test conditions.

Overall, the materials gain approximately three times their 7 day strength by 28 days. This ratio does not differ significantly between lime and aluminates, though where OPC is used in the mix there is slightly faster development of early strength.

5.2 Soundness

Le Chatelier's method, with a split ring mould and pointed indicators to amplify any movement, was used. No significant expansions were found in any of the samples tested.

5.3 Setting Time

The Vicat apparatus, with its penetrating needle and attachments was used. Initial setting times varied widely from 3 to 30 hours, and final setting times from 10 to 36 hours.

Within each of the two groups of 'as-sold' cements (i.e. the lime/ash and the OPC or aluminates/ash) the higher the compressive strength the faster were the initial and final sets.

5.4 Crystallinity

X-ray diffraction analysis of each ash sample showed that three were mainly amorphous while the others were crystalline. Results are detailed in Table 5.

6. COMPARISON OF PRODUCERS' DATA WITH UK RESULTS

The properties of RHA cements which were claimed for the various 'as-sold' products during the visit are listed in Table 6, which is in the same format as Table 4 for ease of comparison.

Compressive strengths claimed were up to about three times greater than those found in the UK tests in spite of the fact that smaller cubes used in the UK would give greater strength. An exception was the Institute C samples, at 28 days. Possibly the claimed higher values were partly due to materials being more fresh.

Soundness data reported by producers showed slightly greater expansions.

Setting times claimed were faster than UK results show. Again this could be due to material being more fresh. The E2 sample was an exception.

Some data was collected on fineness.

7. COMPARISON OF EXPERIMENTAL DATA WITH STANDARD REQUIREMENTS

There is no existing standard specification entirely relevant for rice husk ash cements. Table 7 shows the requirements of standards for materials intended for a similar use. The most relevant is IS 4098-1967, the Indian Standard for Lime-Pozzolana Mixture.

Producers' data for 'as-sold' lime/ash products meet the highest requirements of IS 4098 (LP 40), but UK tests on the same materials show some of them only satisfy the minimum requirement (LP 7). UK lime/ash mixes meet the highest requirement. Mixes containing OPC, being stronger, exceed the highest requirements of IS 4098, and some even exceed requirements for OPC. It is difficult to be certain of the exact composition of the samples, and as noted above in the accounts of site visits, it is known that aluminates, OPC and PPC are always used in some products, but they may be incorporated sometimes in others.

Initial setting times claimed by producers are near the requirement of IS 4098. UK tests show longer initial setting times, but this is allowable in the standard.

Final setting times claimed are quite fast, within the fastest limit of IS 4098. All UK tests are within the slowest rate of that standard.

Fineness of the RHA cements quoted by some manufacturers is finer than required for OPCs. IS 4098 requires 10% (maximum) retained on a 150-micron sieve, so available data cannot be compared directly with this.

8. ECONOMICS

The economics of the various production methods were difficult to compare, due to the different amounts of information, and the possible inaccuracy of information obtained. For example, the Institute A provided detailed costings, which applied to the commercial production unit A1, and although Institute B gave figures, the plant B1 was so different from the general model that the figures might be considered inapplicable and no data other than selling price was revealed by the entrepreneurs at B1. Costs of raw materials vary continually, and the numbers of workers is difficult to define accurately.

The price of OPC in India had been Government controlled, and kept uniform throughout the country until one month before the visit. A third of production was then released on to the free market, and its price escalated rapidly from £50 per tonne (controlled) to approximately £95 per tonne (free). This would appear to increase the selling price advantage of RHA cement, though it would increase production cost of those RHA cements containing OPC. Thus prices were in a state of flux at the time of the visit to India.

Nevertheless some comparative data is presented in Table 8. The cost of ash is generally low. In some cases it is only the cost of transportation of husk from the rice mill to incinerator. Some expenditure is inevitable in the burning process, but is not necessarily included in the figures obtained and quoted in the table.

Cost of lime must be important but would vary. For example at Plant E2 in Nepal the entrepreneur spoke of preferring Indian lime which was more expensive than local lime, so the higher figure is quoted on the table.

The cost of making RHA cement could not always be obtained. Where it is high, selling price is high.

Selling price of RHA cement varied from £27 to £60, with the exception of the Institute D price which was hypothetical, as it was not actually in commercial production. The plant in Pakistan only made RHA cement for use by the owning organisation, not for sale, so no selling price could be quoted.

Prices for OPC were obtained in all three countries, though not at every location visited. Overall, the selling price of RHA cement was approximately 45% of the price of OPC. However there are two conflicting factors which should be considered as they affect the extent of this apparent price difference in its effect on the user of the product. Firstly the bulk density of RHA cement may be only two thirds that of OPC, so for a mix specified by volume (as is common) less weight of RHA cement will be required than for OPC. The cost advantage of RHA cement would be improved therefore to 2/3 of 45% or 30% of OPC cost. Secondly, on the other hand, the strength of the normally suggested 1:3 mix of RHA cement:sand for mortars (see above) could be equalled by a less rich (say 1:7) OPC:sand mix. Thus 2.3 times as much RHA cement may be required for an equivalent mix, bringing the cost advantage to the user of RHA cement to 2.3 times 30% or 70% of OPC cost.

Capital cost for setting up plant was obtained from most places visited. There was no way of checking the details in some instances. The relatively low cost quoted for the Pakistan plant is surprising, but may exclude some items of cost included in the other figures. Cost in Nepal at E2 includes cost of abortive experimental production. Since plants are of different size outputs, direct comparison of capital cost has little meaning, so these figures may be divided by the plant capacity, giving for India a capital cost per tonne per day of between £3,000 and £4,000.

Net annual cost figures were obtained from some places and found to be of the same order as the capital cost. For comparison these net annual cost figures may be divided by the annual tonnage produced, when it is seen that net annual cost is

approximately £20 per tonne; individual figures agree with the cost of making one tonne quoted in the same table.

More detailed calculations by two of the Institutes lead to calculated returns on investments of 32% and 20%.

9. CONCLUSIONS

1. It has been amply demonstrated that RHA cement can be made using simple technology not only on laboratory or pilot scale, but also as a commercial venture producing several tonnes of product per day.

2. To maintain production, supplies of raw materials must be continuously available or stock-piled. Power must be available especially for ball mills, with no more than infrequent short interruptions, or ball mills must be over-size capacity to allow for these interruptions.

3. To maintain sales of the product, especially when alternative materials are available, the RHA cement must be of a consistently high quality. It is best to burn husk at no more than 700°C.

4. Several variations of the basic process are available. Ash and lime alone, which constitute a type of lime-pozzolana mixture, can give a useful cementing material. When particular local conditions permit, the basic mixture of ash and lime may be modified with advantage.

5. Controlled burning of husk in specially made incinerators though desirable, is not essential to producing a good RHA cement. However it is probably desirable in order to get a cement of consistent properties. Chemical analysis and fineness determinations might have been done on these samples with advantage in helping to understand their behaviour.

6. Husk burnt in large quantities is likely to be crystalline. Amorphous ash is produced when smaller quantities are burnt with plenty of air. 10 to 20% of carbon in the ash may be acceptable.

7. If ash of various qualities is to be accepted, it may be necessary to adjust grinding times in order to develop sufficient strength in mixes with time.

8. The ash from plant A1, though amorphous and said to be ground very fine, produced surprisingly low strength mortars. The crystalline ash from B1 produced surprisingly high strength mortars.

9. The RHA cement has properties which make it suitable for mortars and rendering, that is to say for use as a masonry cement. Some of the products tested meet performance requirements of BS 5224:1976. Some meet IS4098:1967. Concrete for general work could be made, though strength may not be as high as with OPC. There is no evidence that RHA cement concrete allows corrosion of embedded steel but at the present time it is not recommended for reinforced concrete work.

10. RHA cement may cost only 45% of the cost of OPC in the market. Mortar made with RHA cement may cost only 70% of equivalent OPC mortars.

11. There may be additional technical advantages in some possible areas of use of RHA cements. Heat generated during hydration may be less than that of OPC, so lower thermal stresses would result if RHA cements were used in massive concrete structures. Where concrete aggregates may be reactive with lime released during setting of OPC, which in some instances has lead to disruptive stresses being set up, RHA cements may possibly show less reaction with those aggregates. Chemical resistance, to acids and sulphates, may be enhanced if RHA cements are used instead of OPC.

12. Guidelines for design of 4-tonne per day small-scale plant burning its own limestone and husk to make RHA cement:

Capital investment	£12,000
Net annual cost	£12,000
Workforce	8 people
Materials	12 tonnes rice husk per day 2 tonnes limestone per day
Equipment to include	small incinerators with open-work sides, lime kiln ball-mill, operating for 3 hours per batch
Selling price	£40 per tonne
Mix proportions	RHA cement may consist of 1 part lime - 2 parts ash by weight, mortars may be made from 1 part RHA cement - 3 parts sand by volume.

Detail will vary considerably, depending upon local circumstances.

10. RECOMMENDATIONS

1. Incinerators for burning husk should allow plenty of cooling air which will also help to keep carbon content low. This is more easily achieved in small incinerators than in large heap burning. The temperature should be limited to 700°C maximum to avoid formation of crystalline ash.

2. Heat generated by combustion of ash should be usefully employed, for example for drying foodstuffs.

3. The period of grinding in the ball mill should be adjusted to the minimum necessary to produce the required properties in the RHA cement. Specially burnt ash should be soft and require less grinding, but if ash is bought in ready burnt, having already contributed its heating value in some process, longer grinding may be necessary in order to produce a satisfatory RHA cement.

4. Inhalation of dust should be avoided as far as possible, since the extent of the health risk is not fully understood at present.

5. At present it would be advisable to market the material as a cement for masonry. Packaging should be clearly marked to differentiate RHA cement from other types of cement.

6. Liaison should continue with the institutes and entrepreneurs already visited. Institutes will be in possession of new information. Some entrepreneurs had only just commenced production, others had not started, and one was recommended to make changes, at the time of the visit, so subsequent production results would be of interest. Further advice might be welcomed by entrepreneurs.

7. Information should be sought on the unformity of product quality from various plants over a long period. Quality should be recorded and producing countries should compile standard specifications.

8. New areas for application of this technology should be found in other rice growing countries where there is a shortage of cementitious materials.

TABLE 1 COMPARISON OF PRODUCTION METHODS INVESTIGATED

Country	Location	Scale of production	Plant capacity (tonnes) per day	Raw Materials and sources			Grinding Period in ball mill (hours)		Number of employees	Notes (at time of visit)
				Ash	Lime	OPC etc	Ash only	Total		
India	A1	Commercial	2	S	S	-	1.5	2	8	Production stopped temporarily
	B	Pilot	1.5	S	B	B	-	2 - 6	-	Not being used
	B1	Commercial	8	S*	B	B	5	5.5	8	Production delayed temporarily
	C	Pilot	0.5	B	B	B	-	3	-	Not running
	C1	Commercial	16	B	S	B	-	3	8	Not yet in production
	D	Pilot	5	S	B dried sludge	-	-	1	15	No longer in production
Nepal	E1	Very Small Commercial	0.5	b	B	-	1.5	2-3.5	2	Working
	E2	Commercial	0.75	B	B	-	-	probably 6	3	Working but product not selling
Pakistan	F1	Commercial	3	B	B	-	-	5 - 6	-	No longer in production

B = Bought-in ready-burnt from large scale burning elsewhere.
b = Bought-in ready-burnt from small scale burning elsewhere.
S = Specially burnt in purpose-built incinerator or kiln at RHA cement plant. * Some B

TABLE 2 MIX PROPORTIONS USED IN MANUFACTURING RHA CEMENT AND IN USE AS MORTARS

Country	Location	Proportions of constituents in RHA cement (by weight)		Proportions of mortar (by volume)
		Lime:ash	OPC:ash	rha cement: sand
India	A1	1 : 2*		1 : 4
	B	1 : 2.5		1 : 1.5 to 4
			1 : 0.5 to 1.5	1 : 2 to 5
	B1	1 : 1.5 plus additives		
			1 : 1.5	1 : 2.25
	C		1*: 1	1 : 3.5 to 4.5
	D	1(lime sludge) : 1		1 : 3
Nepal	E1	1 : 3		1 : 3
	E2			1 : 3
Pakistan	F1	1 : 2.25		1 : 3

* Not OPC, but equal weights of lime and an aluminate waste.

TABLE 3 RICE HUSK ASH MATERIALS SAMPLED

Country	Location	Type of sample with sample reference number		
		Ash	Lime/Ash cement	OPC or aluminate/ Ash cement
India	A1	2	1	-
	B	12	11	10
	B1	13	-	3
	C	-	-	15,16
Nepal	E1	7	6	-
			4(with brick dust)	-
	E2	8	9	-

TABLE 4 PROPERTIES OF RHA CEMENTS, DETERMINED IN UK LABORATORIES

Type and source of sample	Sample No.	Compressive Strength (MN/m^2) 25 mm mortar cubes			Soundness Le Chatelier Expansion (mm)	Setting time (hours) Vicat	
		7 day 20°C	28 day 20°C	7 day 50°C		Initial	Final
1) Lime/ash products, as sold							
India A1 (a)	1	0.5	2.2	1.6	-	30	40
B	11	5.7	14.5	14.7	-	-	-
Nepal E1	6	1.5	6.2	3.2	0.5	12	20
E1 (20% brick dust)	4	0.9	4.3	3.5	1	10	24
E2	9	0.34	3.8	1.7	1	10	24
2) OPC or aluminates/ash products as sold							
India B	10	10.0	16.6	16.5	-	-	-
B1 (with PPC)	3	10.3	15.6	15.2	-	3	10
C - slow set	15	3.6	10.7	8.9	0.5	28	36
C - normal set	16	4.4	14.5	10.4	0.5	3	24
3) UK lime/ash							
India A1	2	2.1	4.6	3.9	-	-	-
B (specially burnt ash)	12	8.0	10.5	9.1	-	-	-
B1	13	3.4	7.2	6.2	1	16	24
Nepal E1	7	6.4	10.6	9.5	-	-	-
E2	8	0.07(b)	0.41	0.96	-	-	-

(a) may include 10% OPC
(b) not all cubes tested successfully

TABLE 5 RESULTS OF X-RAY DIFFRACTION ANALYSIS OF RICE HUSK ASHES

Country	Location	Sample No.	State and Minerals identified in Ash
INDIA	A1	2	Mainly AMORPHOUS plus minor crystalline quartz
	B	12	Mainly AMORPHOUS plus minor crystalline quartz
	B1	13	CRYSTALLINE
NEPAL	E1	7	Mainly AMORPHOUS plus minor crystalline quartz
	E2	8	Mainly CRYSTALLINE tridymite (SiO_2 polymorph)

TABLE 6 PROPERTIES CLAIMED BY PRODUCERS

Type of Cement and Producer	Compressive Strength (MN/m) 50 mm mortar cubes		Soundness Le Chatelier Expansion (mm)	Setting Time (Hours) Vicat		Fineness Blaine (m^2/kg)
	7 day	28 day		Initial	Final	
1. Lime/RHA cement product						
INDIA A1 (1)	-	4	-	2 to 4	-	1000
B	15	25	-	1.5	6	-
D	6	11	2.5	0.5 to 1.5	8 to 10	500
NEPAL E1	6	15	1	1.5	3.5	-
E2	-	8 (2)	-	-	48	-
PAKISTAN F1	16	19	0	3	4	400
2. OPC or Aluminate/RHA cement product						
INDIA B (PPC)	27	42	-	0.5	3.5	-
C	4	6	3	21	23	-
C (different composition)	6	10	1.5	2	3	-

1. May contain 10% OPC
2. 3 weeks, 1:2:4 concrete mix.

TABLE 7 REQUIREMENTS OF STANDARD SPECIFICATIONS

INDIAN STANDARDS (IS) AND BRITISH STANDARD (BS)

Standard	Compressive strength Mortar cubes (MN/m^2 minimum)			Soundness Le Chatelier Expansion (mm maximum)	Setting Time Vicat		Fineness Blaine (m^2/kg minimum)
	7 day	14 day	28 day		Initial (hrs minimum)	Final (hrs maximum)	
IS 4098-1967 Type LP 40	2	-	4	Firm no cracking	2	24	-
Lime-pozzolana mixture							
Type LP 20	1	-	2		2	36	-
Type LP 7	0.3	-	0.7		2	48	-
IS 1489-1967 Portland-Pozzolana Cement	17.5	25	-	10	0.5	10	300
IS 269-1967 Ordinary Portland Cement	22	-	-	10	0.5	10	225
BS 12:1971	23	-	-	-	-	-	-
:1978 Ordinary Portland Cement	-	-	41	10	0.75	10	225

TABLE 8 ECONOMICS - COMPARISON OF VARIOUS PRODUCTION METHODS

Country	Location	Cost of ash £ per tonne	Cost of lime £ per tonne	Cost of making RHA cement £ per tonne	Selling price of RHA cement £ per tonne	Local Selling price of OPC £ per tonne	Capital Cost £	Capital Cost per tonne per per day £	Net annual cost £	Net annual cost per tonne £	Retur on Inves ment
India	A1	1	8	19	27	95	12,000	6,000	12,000	18	32%
	B			30	50	higher than the cement	7,000	5,000	8,000 to 14,000	15 to 30	
	B1				40 to 52						
	C	3		28	36		42,000	2,500			
	D			10	13		10,000	2,000	10,000	10	20%
Nepal	E1				55	90	10,000				
	E2	10	40		60	90	6,000	8,000			
Pakistan	F1	2	15	10	not sold	100	1,600	500			

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Rice Husks as a Fuel

Sekam Padi sebagai Bahan Bakar

Craig Thorburn

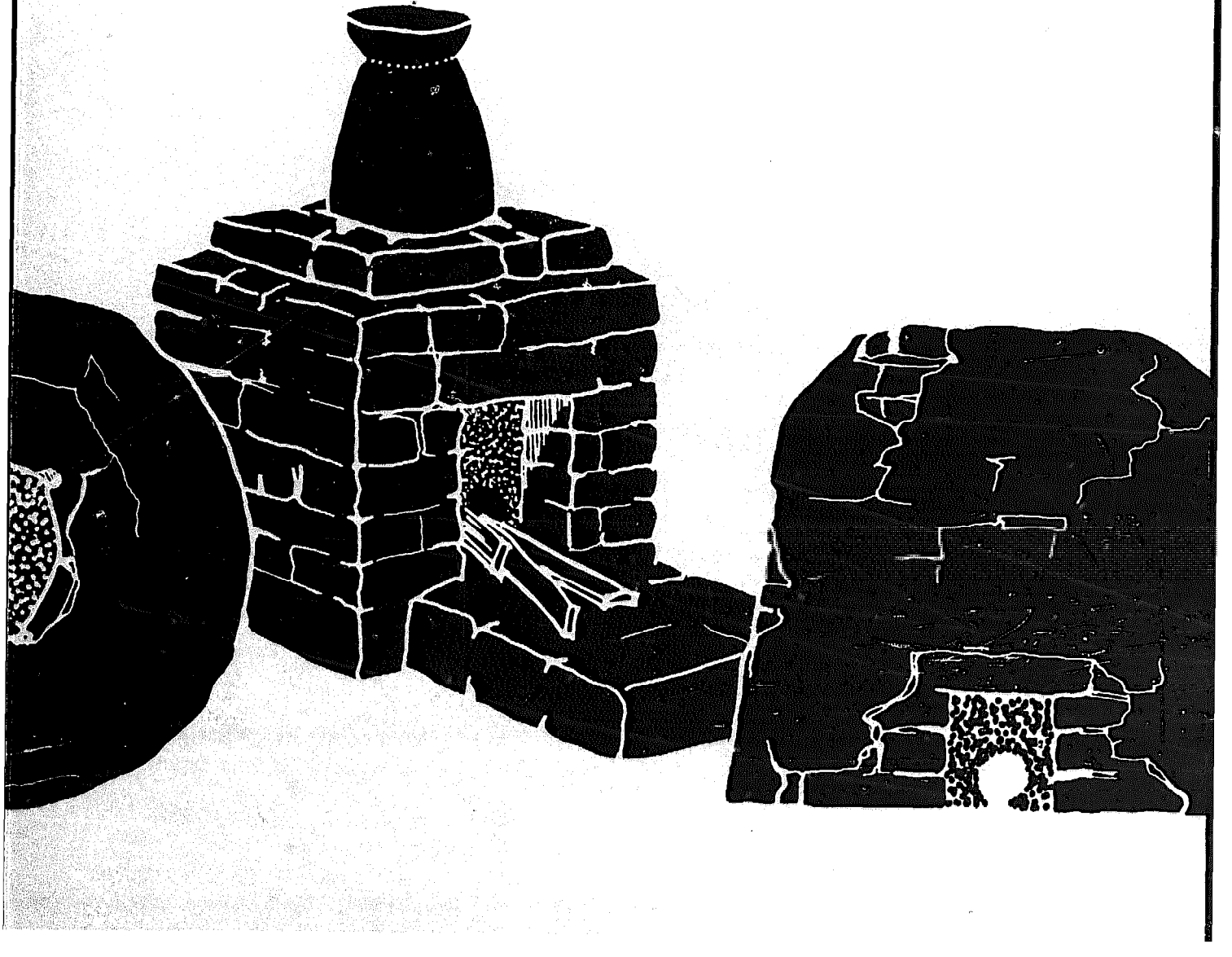

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Based on research by
Ir. Filino Harahap Ph. D., Ir. Saswinardi Ph. D.
Dr. Muchidin Apandi M.Sc., Craig Thorburn

Development Technology Center,
Bandung Institute of Technology (DTC-ITB)

Berdasarkan penelitian oleh
Ir. Filino Harahap Ph. D., Ir. Saswinardi Ph. D.
Dr. Muchidin Apandi M.Sc., Craig Thorburn

Pusat Teknologi Pembangunan,
Institut Teknologi Bandung (PTB-ITB)

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PREFACE

As government and private agencies begin to examine possible roles for simple appropriate technologies in their community development programs, discussions frequently center upon "transfer of technology"; the adoption or adaption of "modern" technologies from industrial nations for use in developing communities. While it is true that many technologies originating from industrialized nations certainly have vital roles to play in the progress of developing nations, often little or no attention is paid to the wealth of indigenous technologies developed and used by the intended beneficiaries of the programs. Every society has a technological tradition and new technologies must grow out of this tradition.

Indonesian villagers have been subsisting

PENDAHULUAN

Dewasa ini pihak pemerintah dan swasta sedang menyelidiki kemungkinan peranan penggunaan teknologi yang sederhana untuk program-program pengembangan masyarakat. Sehubungan dengan itu, banyak dibicarakan mengenai "Pengalihan Teknologi" - yaitu penerapan dan pengadaptasian teknologi modern dari negara-negara industri demi pembangunan masyarakat. Walaupun banyak teknologi yang berasal dari negara-negara industri memegang peranan penting dalam memajukan negara-negara berkembang, namun hanya sedikit saja yang menyadari potensi kekayaan teknologi yang khas berasal dari daerah setempat, yang dapat dimanfaatkan untuk program-program pembangunan. Setiap kelompok masyarakat mempunyai tradisi teknologinya sendiri dan teknologi mutakhir harus tumbuh dari tradisi ini.

Penduduk desa di Indonesia mempunyai kebiasaan yang telah berabad-abad usianya, yaitu menggunakan pelbagai alat dan proses yang dikembangkan dan diproduksi sendiri. Bukanlah suatu hal yang kuno atau tidak logis seperti dibayangkan orang, tetapi teknologi

for centuries, using a wide variety of tools and processes that they developed and manufacture themselves. Far from being backward or illogical as is often supposed, most of these traditional technologies do in fact have an underlying rationale which has developed in response to local conditions, needs, and materials. They reflect the people's accumulated expertise evolved over thousands of years. Often these technologies represent appropriate solutions to needs in specific geographic, social, and economic environments.

Countless cases of villages in close proximity possessing similar or identical problems, one of which has developed a solution which remains unknown to the other community, point out the need for more efforts to document and disseminate existing village technologies and ongoing innovations. This book represents one such effort. Besides attempting to illustrate the elegant simplicity of a few village developed stoves and firing techniques, it is intended to illustrate these tools and processes in sufficient detail that they can be copied or altered to meet local conditions and needs. It is our hope that this book will reach the hands of people living in areas where rice husks or sawdust are still being wasted, and will assist them in utilizing this cheap and abundant fuel.

tradisional ini sungguh mempunyai dasar kuat yang telah berkembang dengan sendirinya sesuai dengan kondisi, kebutuhan dan bahan-bahan setempat. Hal-hal ini mencerminkan ketrampilan yang telah berkembang sejak ribuan tahun. Teknologi mereka bahkan sering berhasil memberi pemecahan yang cocok bagi kebutuhan-kebutuhan khusus sesuai dengan letak geografis, keadaan sosial dan ekonomi setempat.

Berpuluh desa mempunyai masalah yang mirip atau sama, dan bila sebuah desa mempunyai pemecahannya maka desa-desa lainnya tidak mendapat kesempatan untuk mengetahuinya. Hal ini menunjukkan adanya kebutuhan untuk mencatat dan menyebarkan teknologi yang sudah ada di suatu daerah dan memperbaharuinya.

Buku ini berusaha untuk memenuhi harapan tersebut. Di samping mencoba untuk menggambarkan kesederhanaan tungku-tungku dan teknik pembakaran yang telah dikembangkan di beberapa desa, buku ini bermaksud pula melukiskan alat-alat yang dibutuhkan serta prosesnya melalui detail yang cukup banyak agar dapat dicontoh atau disesuaikan dengan kebutuhan dan kondisi setempat. Kami berharap agar buku ini dapat sampai ke tangan mereka yang tinggal di kawasan di mana gabah dan serbuk gergaji masih terbuang sia-sia. Mudah-mudahan buku ini dapat membantu mereka memanfaatkan bahan bakar yang murah dan berkelimpahan ini.

RICE HUSKS AS A FUEL

Most irrigated paddy growing areas in tropical countries are densely populated, with nearly all arable land already under cultivation. Remaining forest reserves in these areas are seldom sufficien[illegible]ge or well managed to meet the growin[illegible]ewood needs of the population. Further logging can result in serious erosion and depletion of ground water reservoirs. Fast-growing bamboo is not a good fuel as it burns intensely then leaves no coals. Fossil fuels are unavailable or expensive in many of these areas, and importing fuel wood from other areas is a costly and impractical solution to this problem.

Rice husks, usually regarded as a waste product of rice processing, can easily be used as a fuel for cooking or firing bricks, tiles, and earthenware vessels. Burning unaided, rice

SEKAM PADI SEBAGAI BAHAN BAKAR

Kebanyakan daerah persawahan di negara-negara tropis berpenduduk padat, dan hampir seluruh tanah yang dapat dipakai bertani di daerah-daerah tersebut telah digarap. Cadangan hutan di daerah-daerah ini jarang dikelola dengan cukup baik untuk dapat mencukupi kebutuhan penduduknya akan kayu bakar yang kian meningkat. Penebangan hutan yang lebih lanjut dapat berakibat terjadinya erosi yang cukup parah serta habisnya cadangan air tanah. Bambu, yang tumbuh cepat, bukanlah merupakan bahan bakar yang baik karena menyala dengan hebat untuk waktu yang singkat serta tidak meninggalkan arang yang membara. Bahan bakar yang berasal dari fosil tidak tersedia atau sangat mahal di kebanyakan daerah ini, dan mendatangkan kayu bakar dari daerah lain merupakan pemecahan masalah yang mahal dan tidak praktis.

Sekam padi, yang biasanya dianggap hasil sampingan pengolahan padi yang tidak bermanfaat, dengan mudah dapat dipergunakan sebagai bahan bakar untuk memasak atau membakar batu bata, genteng atau tembikar Jika dibakar tanpa dibantu, sekam padi akan

husks smolder slowly, producing thick acrid smoke. In certain areas of Indonesia, Thailand, and the Philippines, people have designed simple stoves which overcome these characteristics in order to take advantage of this plentiful and inexpensive fuel. Nearly all of these rice husks stoves can also burn sawdust if it is available in sufficient quantities. In order to obtain a clean hot flame, the stoves are built in such a manner that a natural draft is created, increasing the flow of oxygen past the burning fuel. Some of the simpler designs employ small amounts of wood or trash to assist the flame.

The techniques used to burn rice husks or sawdust as a fuel can be divided into three catagories :

A. Packed stoves with a channel molded into the fuel mass through which the flame passes. These stoves require the addition of small amounts of another fuel in order to burn efficiently.
B. Natural draft stoves employing a hopper, grate, and chimney.
C. Smoldering.

The following text provides explanations of these three different techniques and gives several examples of each.

membara pelan-pelan sambil menghasilkan asap tebal yang terasa pedih di mata. Di beberapa daerah tertentu di Indonesia, Muangthai dan Filipina, orang telah membuat tungku-tungku sederhana yang mengatasi sifat-sifat tersebut untuk memanfaatkan bahan bakar yang murah dan tersedia dalam jumlah banyak ini. Untuk dapat menghasilkan nyala yang bersih dan panas, tungku-tungku itu dibuat sedemikian rupa sehingga tercipta suatu aliran udara secara alamiah, yang meningkatkan jumlah aliran zat asam melewati bahan bakar yang menyala. Beberapa bentuk tungku yang lebih sederhana menggunakan sejumlah kecil kayu atau sampah untuk membantu nyala api.

Teknik-teknik yang digunakan untuk membakar sekam padi atau serbuk gergaji sebagai bahan bakar dapat dibagi dalam tiga golongan :

A. Tungku-tungku yang mempergunakan bahan bakar yang dipadatkan dengan suatu saluran udara yang dibentuk dalam massa bahan bakarnya agar nyala api dapat melaluinya. Agar dapat menyala dengan baik tungku-tungku jenis ini memerlukan sejumlah kecil tambahan bahan bakar yang lain.
B. Tungku-tungku yang di dalamnya tercipta aliran udara secara alamiah. Tungku-tungku ini mempergunakan sebuah pintu atau kotak pemasukan bahan bakar, sebuah garangan atau rangka bakar, serta sebuah cerobong.
C. Membarakannya.

Uraian berikut memberikan penjelasan mengenai ketiga teknik yang saling berbeda ini dan disertai beberapa contoh untuk masing-masing teknik.

PACKED STOVES

These stoves are simple hollow vessels made of bricks and mud, fired clay, or sheet metal. The rice husks are packed tightly into the stove leaving empty channels through the fuel mass for the air, smoke, flames, and hot gases to pass. There are one to three doors at the base of the stove, and cookpots are placed on an opening at the top.

When in operation, these stoves draw air for combustion in through the doors at the base. Smoke and gases rising through the vertical channel in the center of the fuel mass create a natural draft, sucking more air into the stove. The hulls are tightly packed, and the air and flame is drawn past the burning edge of the fuel mass. This configuration reduces the burning surface and prevents oxygen from penetrating very deeply into the fuel mass, hence the addition of small

TUNGKU SEKAM PADAT

Tungku-tungku jenis ini berupa bejana-bejana kosong yang sederhana, terbuat dari batu bata dan lempung, tanah liat yang dibakar atau dari lempengan logam. Sekam padi dipadatkan dalam tungku dengan beberapa saluran melalui massa bahan bakar yang dibiarkan tetap terbuka agar udara, asap, nyala api, serta gas-gas panas dapat melaluinya. Terdapatlah satu sampai tiga buah pintu di kaki tungku, dan lubang untuk memasak terdapat di bagian atas tungku.

Dalam penggunaannya, tungku-tungku ini mendapatkan udara untuk pembakaran melalui pintu-pintu di kaki tungku. Asap dan gas-gas yang naik melalui saluran tegak di pusat massa bahan bakar akan menciptakan suatu aliran udara secara alamiah, dan dengan demikian menghisap lebih banyak udara ke dalam tungku. Sekam padi dalam tungku dipadatkan, dan udara serta nyala api terhisap melalui sisi massa bahan bakar yang menyala. Susunan seperti ini mengurangi luas permukaan yang menyala serta mencegah zat asam untuk masuk terlampau dalam ke dalam massa bahan bakar. Karena demikian penambahan sejumlah kecil bahan

amounts of supplemental fuel such as sticks or trash is required in order to burn well.

The pothole at the top of the stove must provide sufficient space for the unhindered passage of smoke and hot gases around the base of the cookpot. This is achieved by either making flanges or brackets, a square hole for a round pot, or perforations around the top of the stove. If these vents are too small and air passage is constricted, the stove will not burn well.

Because the vertical channel molded into the center of the packed fuel mass acts as a chimney; the taller the stove, the stronger the draft created, and the more efficiently it will burn. The fire can be adjusted by partially covering or opening the doors at the base of the stove to control the air flow, also by adding or subtracting supplementary fuel.

These stoves are somewhat of a nuisance to load and empty. They cannot be turned off between meals, but rather continue to smolder until all of the fuel is consumed. Thin metal cookpots used on these stoves wear out quickly because the flame always strikes them on the same spot. And they have no chimney to draw the smoke out of the kitchen. But because of the low price and abundance of the fuel, and simplicity and low cost of stove construction, many families consider these packed stoves to be the most appropriate choice.

bakar tambahan seperti ranting-ranting kayu atau sampah tetap diperlukan untuk mendapatkan nyala api yang baik. Lubang untuk alat masak di bagian atas tungku harus cukup besar, agar asap dan gas-gas panas dapat melalui celah-celah di sekitar dasar panci tanpa terhalang. Hal ini dicapai dengan membuat tonjolan-tonjolan, atau suatu lubang segi empat untuk panci yang bundar, atau lubang-lubang di bagian atas tungku. Jika celah-celah atau lubang-lubang udara ini terlalu sempit dan aliran udara terhambat, tungku akan menyala dengan kurang baik.

Karena saluran udara tegak yang dibuat di pusat massa bahan bakar berfungsi sebagai cerobong udara, maka makin tinggi tungkunya, makin kuat pula aliran udara yang terjadi, dan nyala api yang dihasilkan makin berdaya guna pula. Nyala api tersebut dapat disesuaikan dengan besar kecilnya kebutuhan dengan cara menutup atau membuka sebagian pintu-pintu di kaki tungku untuk mengendalikan jumlah aliran udara, dan juga dengan cara menambah atau mengurangi jumlah bahan bakar tambahan.

Tungku-tungku jenis ini agak merepotkan dalam pengisian dan pengosongannya. Api tungku-tungku jenis ini juga tidak dapat dimatikan pada waktu-waktu memasak, bahkan sebaliknya, api tungku akan terus saja membara sampai seluruh bahan bakarnya habis terbakar. Panci-panci yang terbuat dari logam yang tipis akan cepat usang jika dipakai memasak di atas tungku-tungku jenis ini karena nyala api akan mengenai panci itu selalu pada tempat yang sama. Tungku-tungku jenis ini juga tidak mempunyai cerobong untuk mengeluarkan asap dari dapur. Namun karena harganya yang murah, dan karena bahan bakarnya yang tersedia dalam jumlah yang melimpah, banyak keluarga menganggap tungku yang mempergunakan bahan bakar yang dipadatkan ini sebagai pilihan yang paling tepat.

Mud and brick stove: Java & Bali

This is a small mud and brick stove commonly used in Java and Bali. It holds about 1½ kg of rice husks and burns for about 6 hours per load of fuel, also consuming a small amount (¼ to ½ kg) of kindling during that time to keep the fire burning well. Filling the stove with rice husks is a nuisance, and emptying the ashes afterwards is a very messy task. When rice husks are not available, this type of stove can be used without any alterations to burn wood.

Tungku bata dan tanah : Jawa & Bali

Gambar ini menunjukkan sebuah tungku kecil, terbuat dari tanah lempung dan batu bata, yang umum dipergunakan di Jawa dan Bali. Tungku seperti ini memuat kurang lebih 1½ kg sekam padi serta dapat menyala kira-kira 6 jam setiap kali diisi, serta pada saat yang sama menghabiskan juga sejumlah kecil (¼ sampai ½ kg) ranting kayu untuk membantu api agar menyala dengan baik. Mengisi tungku ini dengan sekam padi merupakan pekerjaan yang merepotkan, dan mengeluarkan abu sisa pembakarannya kemudian merupakan pekerjaan yang pasti mengotorkan tangan. Jika tidak tersedia sekam padi, tungku ini dapat dipergunakan untuk membakar dengan kayu tanpa perubahan apapun.

Measurement / Ukuran : cm

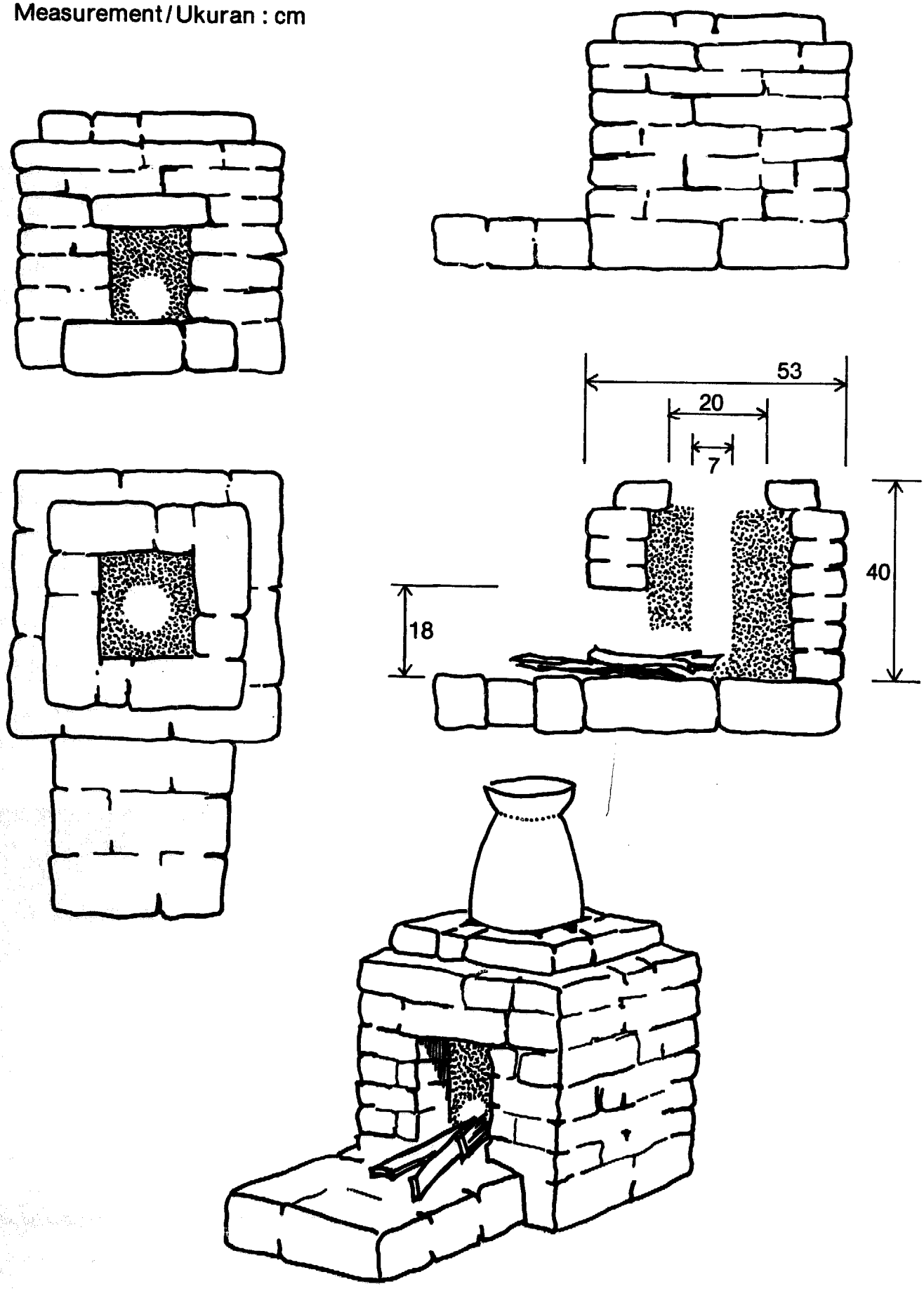

Mud and brick stove: Bali

This stove, also from Bali, differs from the stove depicted on page 11 only in shape. Because the fuel chamber has no corners to trap unburned hulls, this stove burns the husks more completely than the square one and is therefore easier to clean out after use.

Tungku bata dan tanah : Bali

Tungku ini, yang juga berasal dari Bali, berbeda dengan tungku yang ditunjukkan di halaman 11 hanya dalam bentuknya. Karena ruangan bahan bakarnya tidak mempunyai sudut-sudut di mana sekam padi yang belum terbakar dapat terjebak, tungku ini dapat membakar sekam padi yang menjadi bahan bakarnya dengan lebih sempurna dari pada tungku berbentuk persegi dan karenanya lebih mudah untuk dibersihkan setelah pemakaiannya.

Measurement / Ukuran : cm

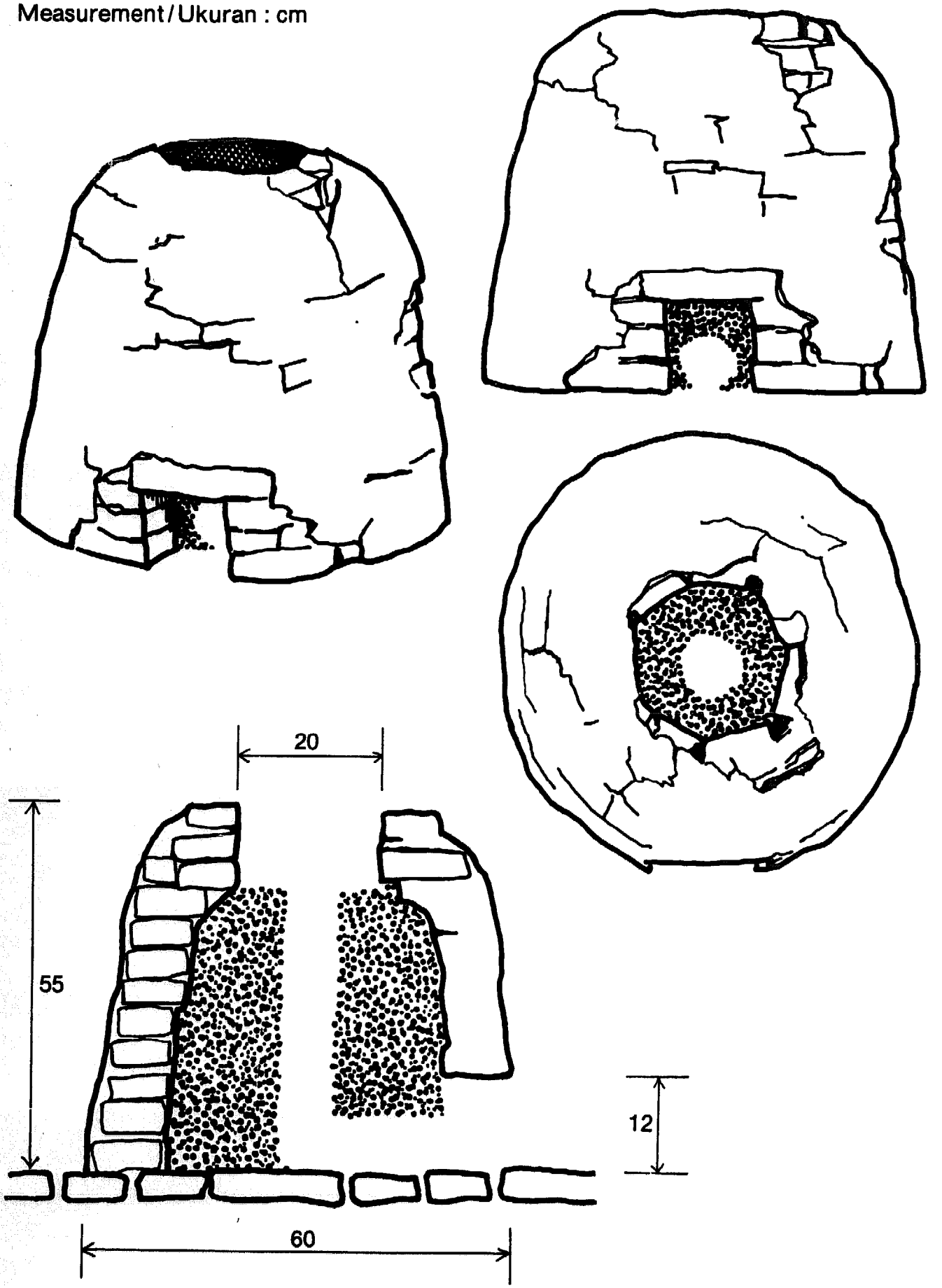

Multiple burner stove

This is actually three separate stoves built together for the busy homemaker or for small sugar or fish processing operations. The three stoves can be loaded and burned separately.

Tungku gandeng

Tungku ini sebenarnya merupakan tiga buah tungku yang dibangun menjadi satu guna kepentingan ibu rumah tangga yang sibuk atau untuk kegiatan pengolahan ikan atau gula dalam jumlah kecil. Ketiga tungku itu masing-masing dapat diisi dan dinyalakan secara terpisah.

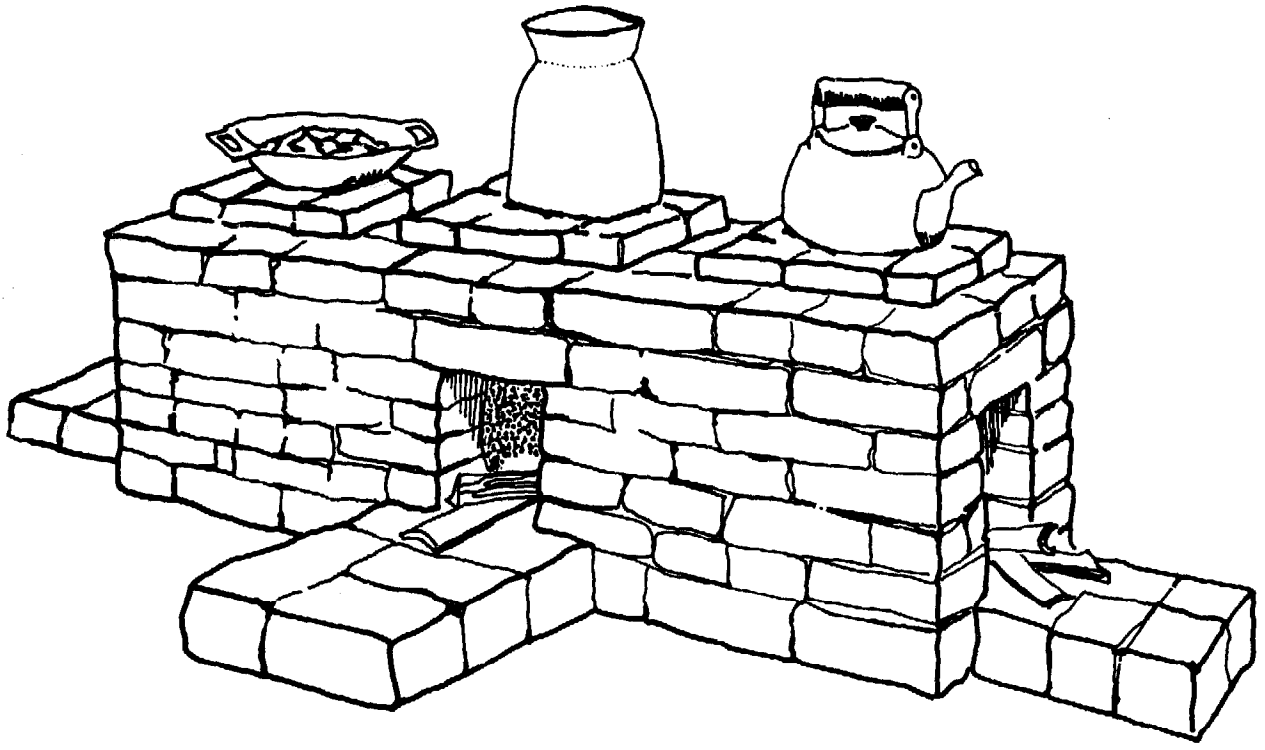

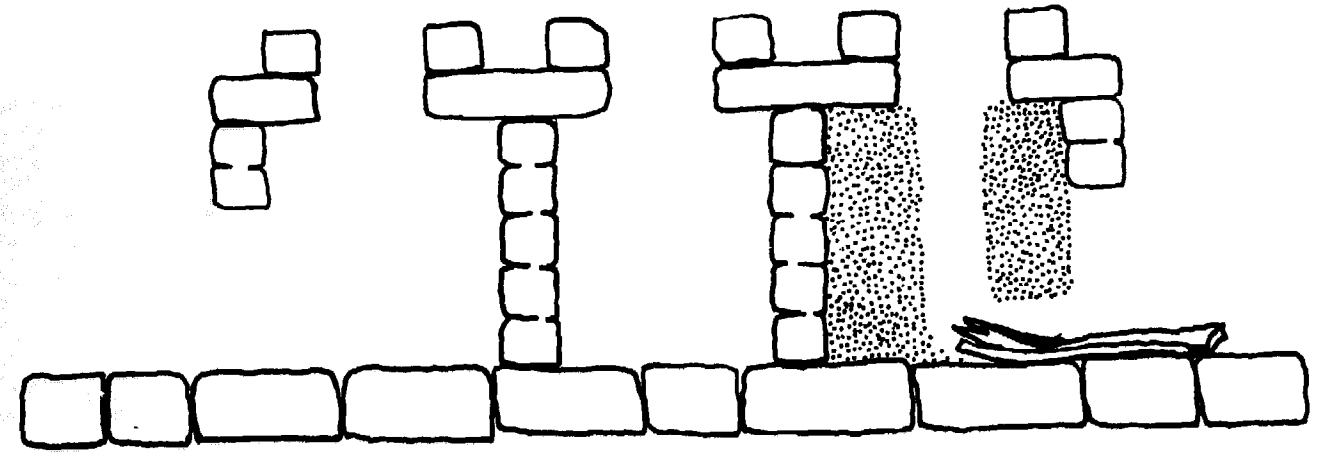

Sheet metal stove

The stove depicted here is an adaptation of the previous designs using sheet metal from old oil or asphalt drums. The conical shape imitates the configuration in which the husks burning in packed stoves are consumed, guaranteeing that none will be left unburned. This stove has the advantage of portability; it can be loaded, lit, and emptied outside of the kitchen. However it costs more and does not last as long as the other designs, and radiates more heat into the kitchen while in use.

Tungku besi plat

Tungku yang diperlihatkan dalam gambar ini merupakan suatu penyesuaian yang dikembangkan dari rancangan-rancangan yang telah dibicarakan sebelumnya. Tungku jenis ini dibuat dari lempengan logam yang berasal dari bekas drum minyak atau aspal. Bentuk kerucutnya meniru susunan pembakaran sekam pada tungku yang mempergunakan bahan bakar yang dipadatkan. Susunan ini menjamin bahwa tidak ada sekam yang tidak habis terbakar. Keuntungan tungku ini ialah bahwa tungku ini dapat diangkat, diisi, dinyalakan, dan dikosongkan di luar dapur. Namun demikian harganya lebih mahal dan tidak seawet rancangan-rancangan tungku yang lain. Lagi pula dalam pemakaiannya tungku ini memancarkan lebih banyak panas ke dapur.

Measurement / Ukuran : cm

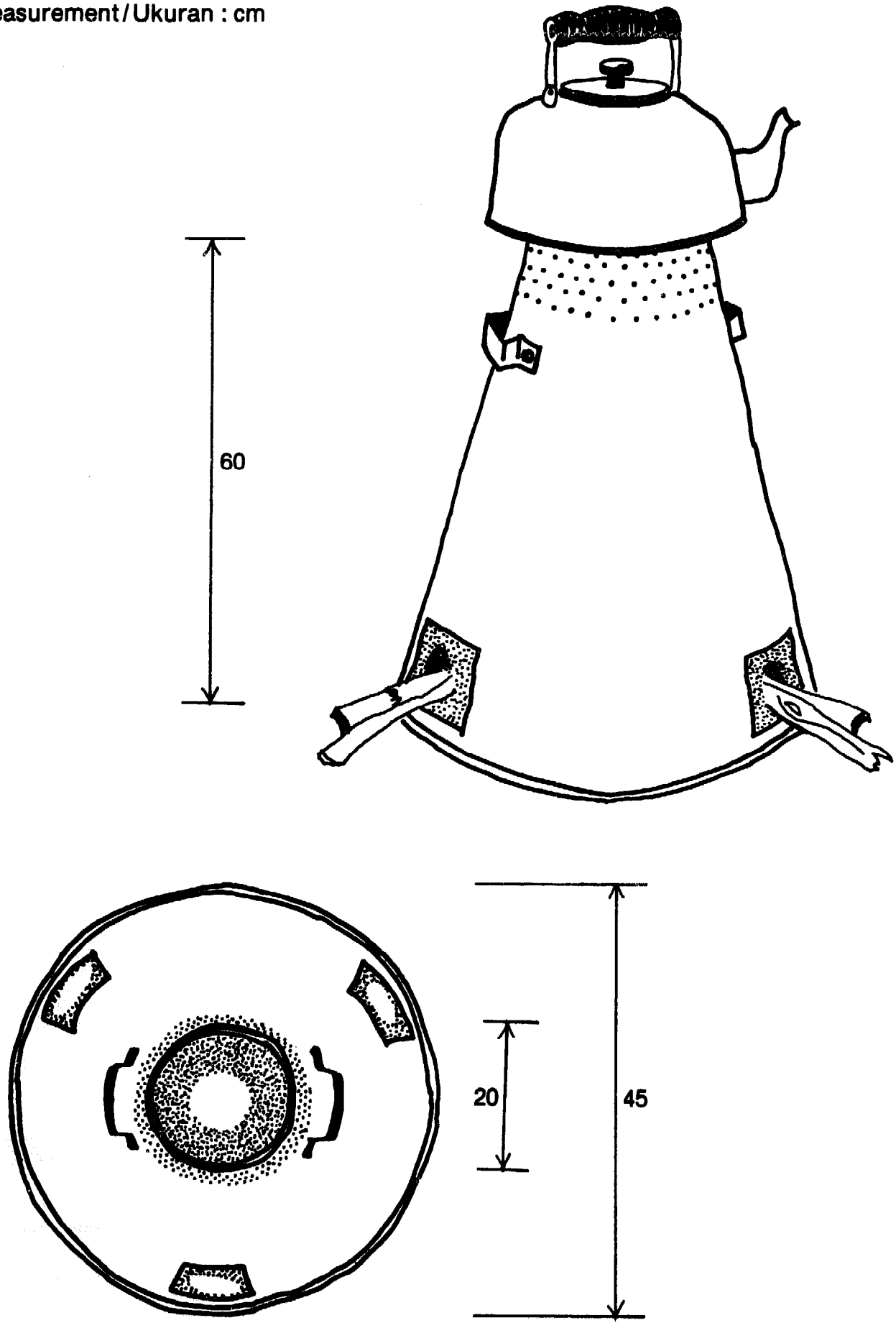

Earthenware stove: Java

This is a small earthenware stove which has been used in Central Java for several decades. It holds about ½ kg of rice husks or sawdust and burns for almost 2 hours per filling. Similar stoves have been made in Thailand using discarded paint cans.

Pawan anglo krajen : Jawa

Gambar ini menunjukkan tungku kecil terbuat dari tanah liat yang selama puluhan tahun telah dipergunakan di Jawa Tengah. Tungku ini memuat kurang lebih ½ kg sekam padi atau serbuk gergaji dan dapat menyala selama kira-kira 2 jam setiap kali diisi. Tungku-tungku yang mirip dengan tungku jenis ini telah dibuat pula di Muangthai dari kaleng-kaleng cat bekas.

Measurement / Ukuran : cm

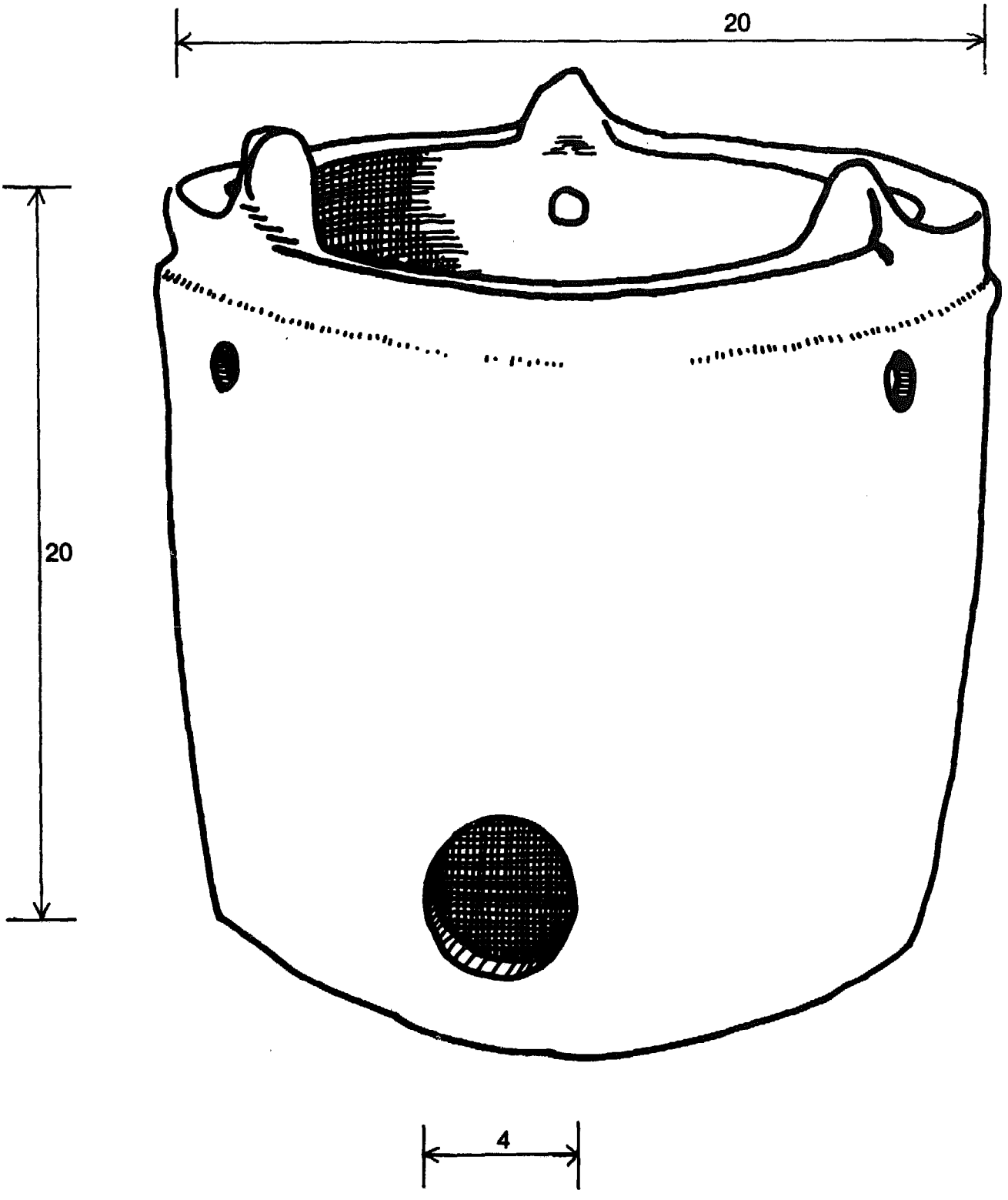

Loading and firing

It is important when lighting these packed stoves that the mass of rice husks is packed tightly enough that it will not collapse as its core is consumed by the fire, and that the passage for air, flame, smoke, and hot gases is clear and big enough that air flow is not constricted.

Step 1: A smooth wooden cylinder, length of pipe, or bottle with a diameter of about 7 cm is placed vertically in the center of the stove, protruding through the top hole. Similarly cylindrical objects are positioned horizontally, radiating from the base of the vertical piece and protruding through the doors.

Step 2: The stove is then filled until more than half full with rice husks and/or sawdust.

Step 3: These husks are then tamped with a stick of wood or bamboo until they form a dense mass. More husks are added and then tamped again.

Pengisian dan pembakaran

Yang penting dalam menyalakan tungku-tungku yang mempergunakan bahan bakar yang dipadatkan ini ialah bahwa massa sekam padi cukup dipadatkan sehingga tidak akan runtuh apabila intinya habis dimakan api. Juga bahwa saluran untuk udara, nyala api, dan gas-gas panas cukup besar serta tidak terhambat, sehingga aliran udara dapat mengalir dengan lancar.

Langkah 1 : Suatu silinder kayu, sepotong pipa, atau sebuah botol dengan garis tengah kira-kira 7 cm dipasang secara tegak lurus di pusat tungku, menyembul sebagian melalui lubang di bagian atas tungku. Benda berbentuk silinder yang sejenis ditempatkan secara mendatar, mengikuti jari-jari tungku, mulai dari pangkal silinder yang tegak dan menyembul dari pintu tungku.

Langkah 2 : Tungku kemudian diisi sedikit lebih dari separuhnya dengan sekam padi dan/atau serbuk gergaji.

Langkah 3 : Sekam padi ini kemudian ditumbuk dengan sebatang kayu atau bambu sampai padat. Kemudian sekam baru ditambahkan lagi dan dipadatkan lagi.

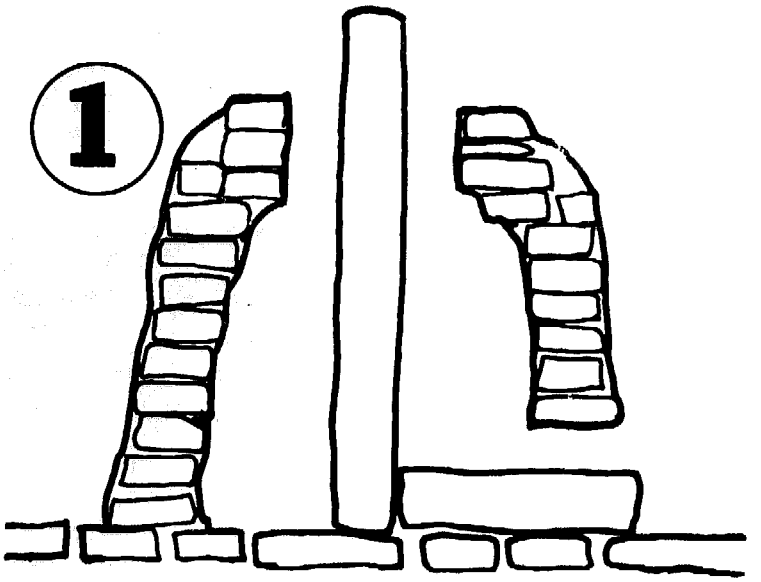
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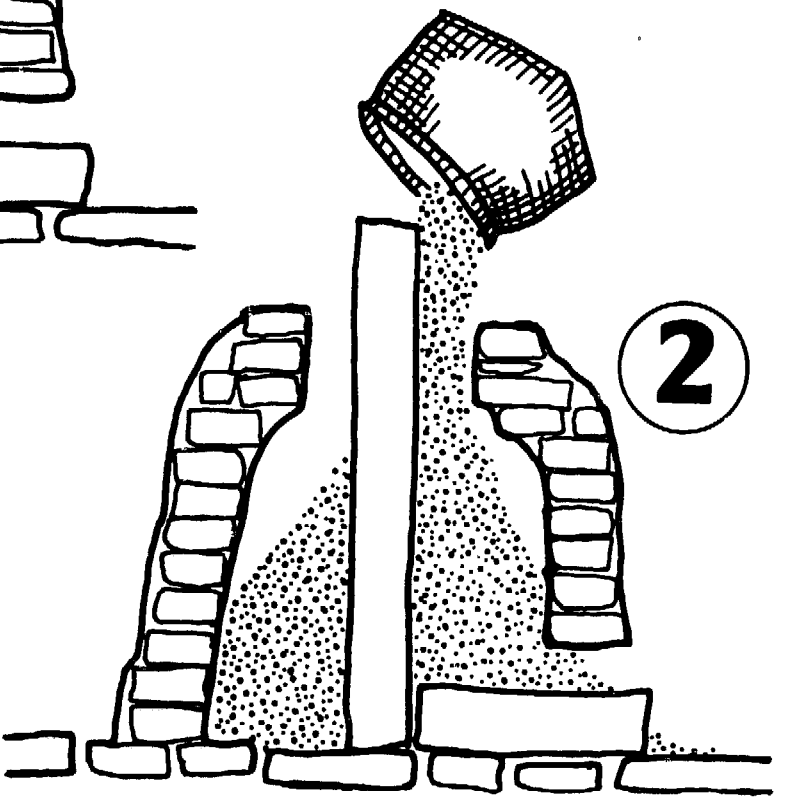
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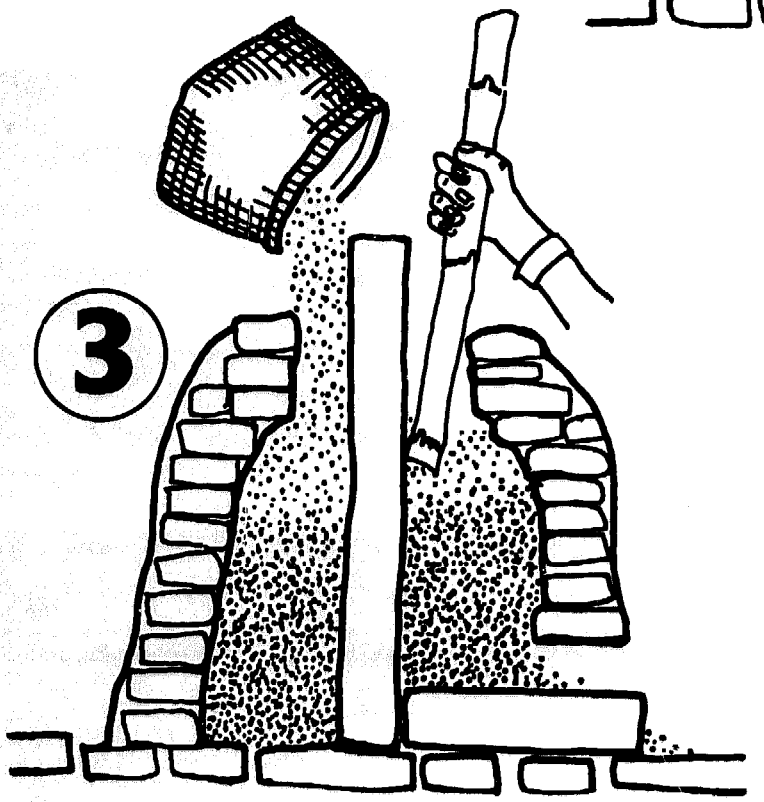
3

Step 4: This process is repeated until the stove is nearly full of tightly packed husks.

Step 5: The cylinders are then carefully pulled out, leaving in their place a hollow passage running from the doors to the top opening.

Step 6: To light the stove, two or three burning sticks are placed in the doors. Sometimes the stove is difficult to light and several tries may be required. It may be necessary to loosen some of the husks around the door before it will catch. Initially the fire will produce lots of smoke which decreases as the husks begin to burn well. The sticks are pushed in as the ends burn off and replaced when they are finished. Without the addition of a few sticks or twigs, the flame soon dies and the husks smolder slowly. The heat of the fire is controlled by adding more sticks or by partially covering the doors.

Note: The growing popularity of the small rice milling units which use rubber rollers has complicated the use of this stove. The old type huller produced small broken pieces of rice husks which packed very well into a cohesive mass. But the new machines split the husks neatly in half, producing a product which does not compress tightly or hold its shape. This can be overcome by mixing some rice polishings in with the husks in a ratio of about 1 to 2. This produces a denser and more cohesive mass.

Langkah 4 : Proses ini dilakukan berulang kali sampai tungku hampir penuh seluruhnya dengan sekam padi yang dipadatkan.

Langkah 5 : Setelah itu kedua silinder dicabut dengan hati-hati sehingga kini terdapat suatu ruangan kosong yang merupakan sebuah saluran dari pintu tungku menuju ke lubang bagian atas tungku.

Langkah 6 : Untuk menyalakan tungku, dua atau tiga ranting kayu yang menyala ditempatkan di pintu tungku. Kadang-kadang tungku memang sukar dinyalakan dan kita mungkin harus mencobanya beberapa kali sebelum berhasil. Mungkin pula kita perlu melonggarkan sejumlah sekam padi di sekitar pintu perapian agar api mulai menyala. Pada mulanya api dalam tungku akan mengeluarkan banyak asap, namun asap ini akan berkurang jumlahnya apabila sekam telah mulai menyala dengan baik. Ranting-ranting kayu yang menyala tersebut didorong masuk ke dalam tungku jika ujungnya telah habis terbakar, dan diganti dengan yang baru jika telah habis. Tanpa penambahan ranting-ranting kayu ini, bunga api akan mati dan sekamnya akan membara perlahan-lahan. Panas apinya dapat diatur dengan menambah atau mengurangi jumlah ranting-ranting kayu, atau dengan membuka atau menutup sebagian pintu tungku.

Catatan : Bertambah luasnya pemakaian mesin-mesin penggiling padi kecil yang mempergunakan gelondongan penggiling yang terbuat dari karet telah mempersukar pemakaian tungku-tungku jenis ini. Mesin-mesin penggiling padi yang lama menghasilkan sekam padi yang berbentuk kepingan patah-patah yang kecil yang mudah dipadatkan. Tetapi mesin-mesin penggiling padi jenis baru membelah sekam menjadi dua bagian dengan rapi, sehingga tidak mudah dipadatkan dan dipertahankan bentuknya. Hal ini dapat diatasi dengan mencampurkannya dengan dedak, dengan perbandingan 1 : 2. Dengan cara ini akan dihasilkan suatu bahan yang lebih mudah dipadatkan dan dibentuk.

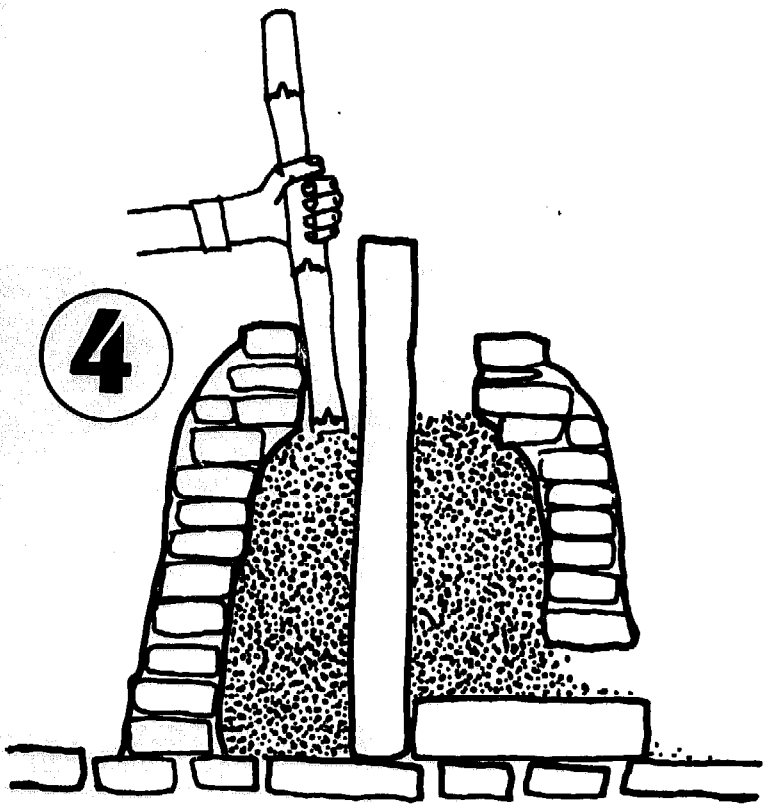
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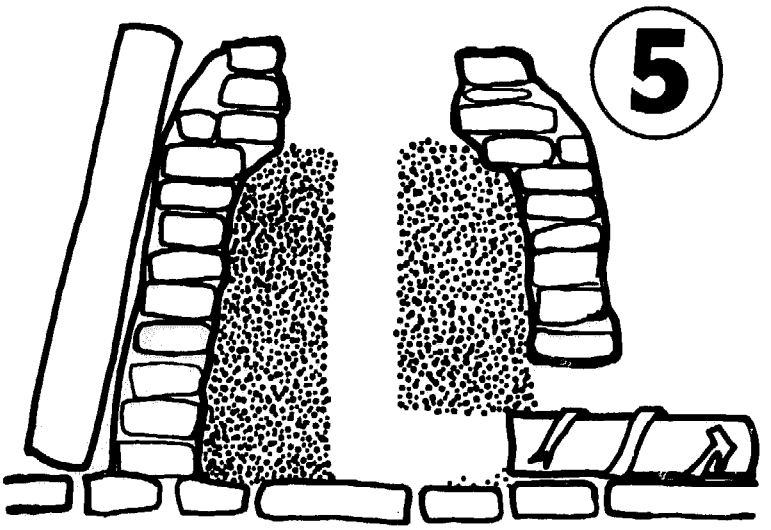
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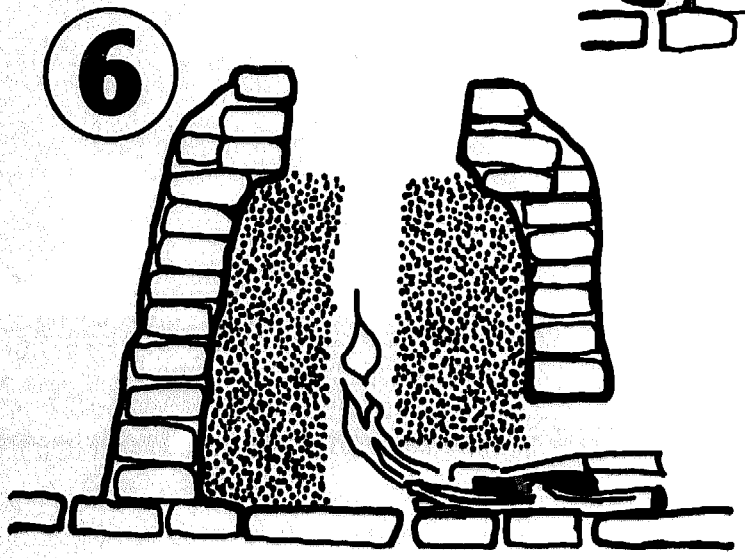
6

NATURAL DRAFT STOVES

In the natural draft stoves, smoke and hot gases rising through a chimney create a strong suction drawing air through the burning mass of rice husks. The husks are fed into the stove above the fire and fall down a slanted grate as they burn. The air intake is located under this grate, forcing all air drawn into the stove to pass through the burning fuel. The ashes are raked out from below the grate.

Natural draft stoves produce a clean hot flame. Air drawn into the stove must pass through the burning husks in order for the stove to burn properly. This means that the bases of the cookpots must fit snugly into their holes in the top of the stove, and that tight-fitting covers must be made to close the holes not in use. In most of the stove designs used in commercial food processing

TUNGKU YANG MEMANFAATKAN ALIRAN UDARA

Pada tungku-tungku jenis ini, asap dan gas-gas panas yang naik melalui cerobong menghasilkan gaya hisap yang kuat yang menarik udara agar mengalir melalui massa sekam yang sedang menyala. Sekam padi dimasukkan ke dalam tungku di atas api dan akan jatuh pada suatu garangan yang ditempatkan miring pada waktu menyala. Lubang pemasukan udara ditempatkan di bawah garangan ini, dan dengan demikian memaksa semua udara yang terhisap ke dalam tungku untuk mengalir melalui bahan bakar yang sedang menyala. Abu dan sisa-sisa pembakaran lainnya dikeluarkan dari tungku di bawah garangan tersebut.

Tungku-tungku yang secara alamiah di dalamnya terjadi aliran udara seperti ini menghasilkan nyala api yang bersih dan panas. Agar api tungku dapat menyala dengan baik, udara yang masuk ke dalam tungku harus melalui sekam padi yang sedang menyala. Ini berarti bahwa dasar panci yang dipakai untuk memasak harus dapat masuk dengan tepat dan benar dalam lubang di atas tungku. Juga harus dibuat penutup lubang yang dapat masuk dengan tepat dan benar

operations, the large cookpots are cemented into the tops of the stoves. The rice husk feeding ports must also be closed while the stove is in operation. This is done by keeping the feed port or hopper full of husks ready to drop down onto the grate as the ones below them are consumed by the fire.

The grate employed in the various designs differ in shape, configuration, and materials used. Some are nearly vertical, others descend at nearly a 45 degree angle. Most are about 30 degrees from vertical. Some grates are made of cast iron, some are fabricated from strap iron, others are made of small diameter iron rods hung diagonally, and still others are of perforated iron sheet. The cast iron grates last longest, while the diagonal rod or perforated sheet grates are the easiest to remove and replace.

The chimneys are made of bricks, clay pipe, or cast iron pipe. They range in length from 1½ to 7 meters. The ratio of stove length to chimney height ranges from 1 : 1 to 1 : 4. One novel design from the Philippines does not employ a chimney.

Though there are many variations in the shape, size, and function of these stoves, there are certain design criteria common to all of them :

1. The grate must be steeper than 45 degrees
2. The wider the grate, the hotter the fire.
3. The taller the chimney, the stronger the draft, meaning a longer flame and greater fuel consumption.
4. In long stoves employing more than one cookpot arranged in a row, the pots near the fire are hotter than those near the chimney end. The base of the stoves

pula untuk menutup lubang-lubang tungku yang sedang tidak dipergunakan. Pada kebanyakan rancangan tungku yang digunakan dalam kegiatan pengolahan pangan secara komersial, panci-panci besar yang dipergunakan disemen dalam lubang-lubang di bagian atas tungku tersebut. Pintu tungku untuk memasukkan sekam padi harus ditutup bila tungku sedang dipergunakan. Hal ini dilakukan dengan menjaga agar pintu atau kotak pemasukan bahan bakar selalu penuh dengan sekam padi yang siap untuk dijatuhkan pada garangan begitu sekam padi di bawahnya habis dimakan api.

Garangan yang dipergunakan dalam berbagai rancangan tungku saling berbeda dalam hal ukuran, susunan, bentuk dan bahannya. Beberapa di antaranya hampir tegak lurus, yang lain miring dengan sudut yang mendekati 45 derajat. Namun kebanyakan ditempatkan dengan sudut sebesar kira-kira 30 derajat dari arah tegak lurus. Beberapa garangan terbuat dari besi tuang, beberapa buah dari besi plat, yang lain terbuat dari batang-batang besi bergaris tengah kecil yang dipasang secara diagonal, dan yang lain lagi terbuat dari lembaran seng yang dilubangi. Garangan yang terbuat dari besi tuang akan berumur paling lama, sedangkan yang terbuat dari batangan besi yang dipasang secara diagonal dan yang terbuat dari seng yang dilubangi akan mudah diganti jika rusak.

Cerobong tungku-tungku ini dibuat dari batu bata, pipa tanah liat (hong), atau pipa besi tuang. Tinggi cerobong-cerobong ini berkisar antara 1½ dan 7 meter. Sedangkan perbandingan antara panjang tungku dan tinggi cerobongnya berkisar antara 1 : 1 dan 1 : 4. Salah satu rancangan baru yang berasal dari Filipina tidak mempergunakan cerobong.

Meskipun terdapat keaneka-ragaman dalam bentuk, ukuran, serta kegunaan, tetapi ada beberapa kriteria rancangan yang umum bagi semua rancangan tersebut :

1. Kemiringan garangan harus lebih besar dari 45 derajat.
2. Makin luas permukaan garangan makin panas pula nyala apinya.
3. Makin tinggi cerobongnya, makin kuat pula aliran udara yang terjadi. Hal ini berarti nyala api yang lebih besar dan pema-

should be higher at the chimney than at the grate. This is achieved either by slanting the base or building in one or two steps.

The stoves depicted in the following section are designed and built for a variety of functions. Design and construction also differ in accordance with the skills and materials available in their area of origin.

kaian bahan bakar yang lebih banyak.

4. Pada tungku-tungku yang panjang, yang mempunyai lebih dari satu lubang untuk memasak yang disusun berjajar, panci yang lebih dekat dengan api akan lebih panas dari pada yang dekat dengan cerobong. Karenanya dasar dari tungku-tungku ini harus lebih tinggi dekat ke cerobong dari pada dekat ke garangan. Hal ini dicapai dengan membuat dasar tersebut miring ke arah cerobong atau membangunnya dengan bertangga.

Tungku-tungku yang digambarkan dalam bagian berikut dirancang dan dibangun untuk berbagai kegunaan. Rancangan dan konstruksinya juga berbeda menurut ketrampilan dan bahan-bahan yang terdapat di daerah asal tungku tersebut.

Loading and firing

To light these stoves, husks are poured onto the grate until it is covered with about 5 to 8 cm of fuel. Trash or small sticks are then placed below the grate and lit. Soon a draft is created and the husks catch fire. The fuel inlet port or hopper should be kept full of husks which fall down onto the grate as the burning fuel is consumed. Occasionally the contents of the hopper or inlet port must be poked or stirred to assure their continued flow onto the grate. As ashes pile up at the bottom of the grate, they must be raked out the front of the stove and thrown away or stored to be used as a fertilizer or building material.

Pengisian dan pembakaran

Untuk menyalakan tungku-tungku ini, sekam padi ditaburkan di atas garangan sampai seluruh garangan tertutup oleh lapisan sekam setebal kira-kira 5 sampai 8 cm. Sampah atau ranting-ranting kemudian ditempatkan di bawah garangan, lalu dinyalakan. Dalam waktu singkat akan tercipta suatu aliran udara dan sekam-sekam padi itu akan mulai menyala. Pintu atau kotak pemasukan bahan bakar harus dijaga agar selalu penuh dengan sekam padi yang akan jatuh di atas garangan setelah bahan bakar yang menyala habis dimakan api. Sekali-kali isi pintu atau kotak pemasukan bahan bakar tersebut harus ditusuk-tusuk atau diaduk untuk menjamin adanya aliran bahan bakar yang terus menerus ke atas garangan. Abu yang akan bertumpuk di bawah garangan harus dikeluarkan dari bagian depan tungku kemudian dibuang atau disimpan untuk kemudian dipergunakan sebagai pupuk atau sebagai bahan bangunan.

Natural draft stove: Thailand

Farmers in Thailand make stoves like this out of sandy clay or bricks with clay mortar. Recently some companies have started manufacturing them out of cement. The two pot holes have tapered sides so that a variety of cookpots can fit in them. The hole closer to the fire is hotter, hence it is used for cooking while the back hole is used for warming. Cement covers with iron handles fit snugly into these holes to close them when only one is being used.

This stove features a unique grate. 3 or 4 mm diameter iron rods hooked at one end and bent 90 degrees on the other are hung diagonally across two 10 mm iron rods built into the stove body. The small rods have a gap of 3 to 5 mm, about the size of rice husks, between them. These rods are not fixed to the support bars, so they are easily removed and replaced. The 2 to 3 meter chimney is made of 10 cm clay or cast iron pipe.

Tungku semen : Muangthai

Petani-petani di Muangthai membuat tungku-tungku seperti ini dari tanah liat berpasir atau dari batu bata dengan tanah liat sebagai semennya. Akhir-akhir ini ada beberapa perusahaan yang mulai membuat tungku-tungku ini dari semen. Kedua lubang untuk memasak mempunyai sisi-sisi miring sehingga panci-panci dari berbagai ukuran yang berbeda dapat dipasang pada lubang-lubang untuk memasak tersebut. Lubang yang lebih dekat pada api akan lebih panas, karenanya lubang itu dipakai untuk memasak, sedangkan lubang yang belakang dipakai untuk menghangatkan. Tutup semen dengan pegangan dari besi yang dapat menutup lubang itu dengan rapat dipakai untuk menutup salah satu lubang jika hanya satu lubang yang dipakai.

Tungku ini mempunyai garangan yang khas. Batang-batang besi bergaris tengah 3 atau 4 mm yang berkait pada satu ujung dan dibengkokkan 90 derajat pada ujung yang lain dipasang secara diagonal melintang pada dua batang besi bergaris tengah 10 mm yang dipasang secara tetap dalam tubuh tungku itu. Batang-batang besi yang kecil mempunyai jarak antara 3 sampai 5 mm, yang merupakan ukuran yang kira-kira sesuai dengan ukuran sekam padi. Batang-batang besi yang kecil ini tidak dipatri atau dilas secara tetap pada batangan besi penyanggahnya sehingga batang-batangan besi kecil itu mudah dilepaskan dan diganti. Cerobongnya, yang tingginya antara 2 sampai 3 meter, terbuat dari pipa tanah liat (hong) atau pipa besi yang bergaris tengah 10 cm.

Measurement / Ukuran : cm

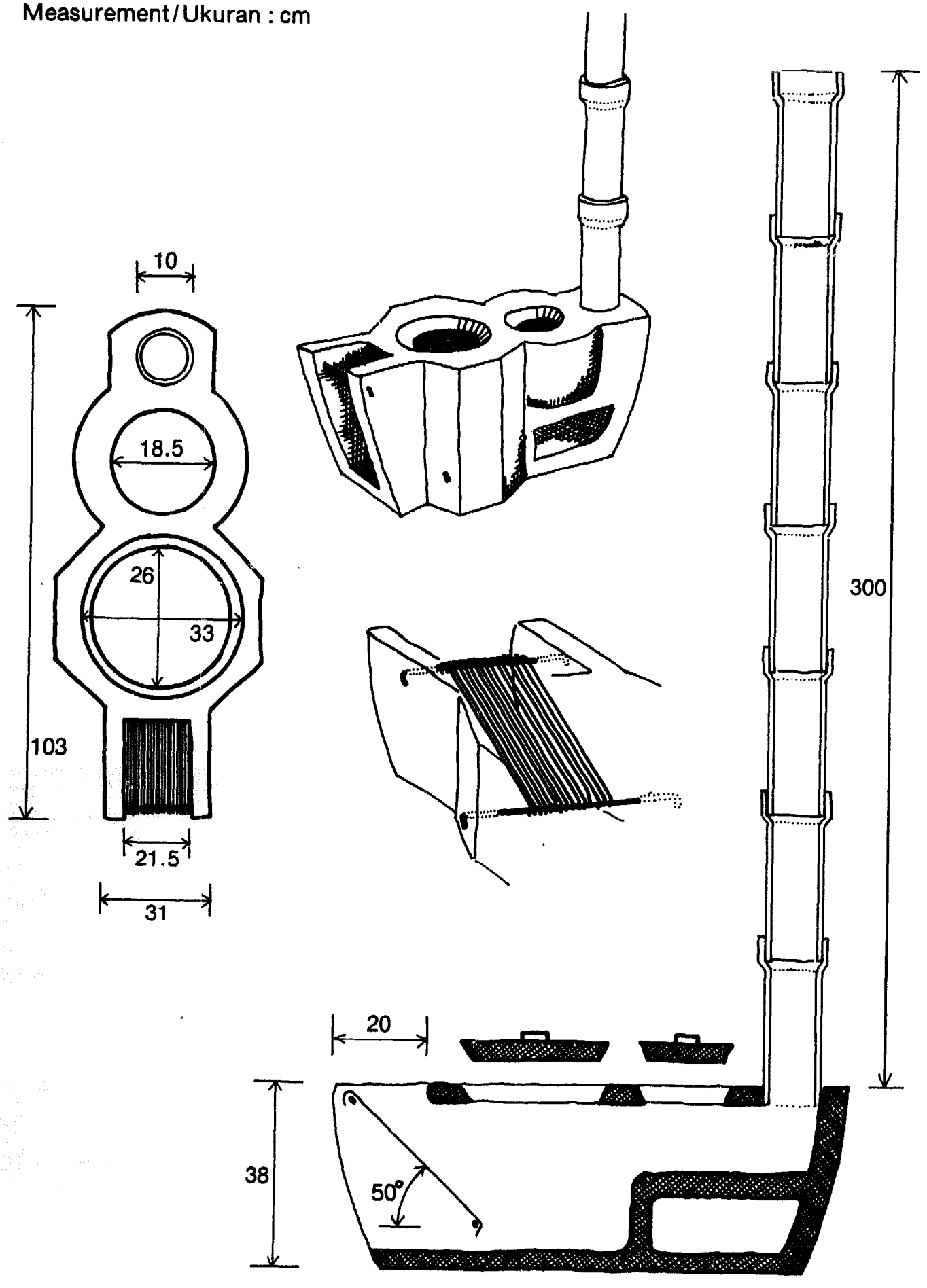

Palm sugar production stove: Java

This is a simple stove used by palm sugar producers in East Java. It can also be adapted for household use. The stove is made of bricks with a mortar of clay, sand, and rice husk ash. The pot holes are shaped exactly to the bottoms of the pots used. If any leaks develop around the pots, they are simply patched with a mixture of mud and rice husk ash.

Tungku pembuatan gula Jawa : Jawa

Gambar ini menunjukan suatu tungku sederhana yang dipergunakan oleh para pembuat gula aren di Jawa Timur. Tungku ini dapat pula disesuaikan untuk keperluan rumah tangga. Tungku ini dibuat dari batu bata dengan campuran tanah liat, pasir dan abu sekam padi sebagai semennya. Lubang-lubang untuk memasak dibentuk tepat menurut bentuk dasar panci yang dipergunakan. Jika terjadi kebocoran di sekitar dasar panci, dengan mudah kebocoran itu ditambal dengan campuran lumpur dengan abu sekam padi.

Measurement / Ukuran : cm

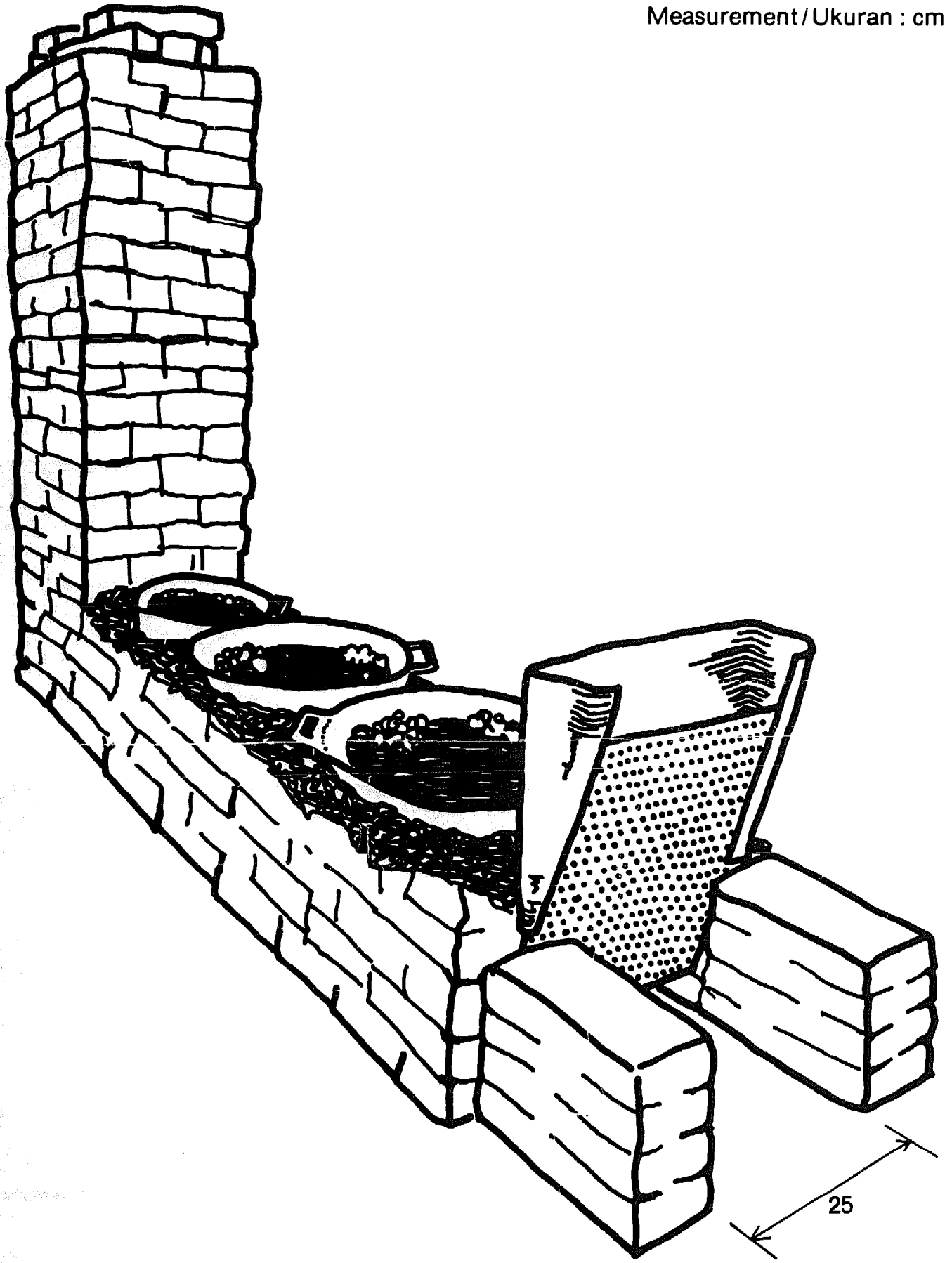

The nearly vertical grate of the Javanese stove is made of perforated 1 or 2 mm sheet iron, and is held in place by a piece of oil drum shaped to act also as a fuel hopper. The base of the stove slants upward toward the chimney end of the stove, rising 25 cm over its 1½ meter length. The 1½ meter chimney is also made of bricks and mud. Opening or partially closing the top of the chimney with loose bricks adjusts the heat of the fire and length of the flame.

Garangan yang hampir tegak lurus pada tungku Jawa terbuat dari seng 1 atau 2 mm yang dilubangi, dan ditahan pada tempatnya oleh sebagian dari drum yang dibentuk sedemikian rupa sehingga dapat pula berfungsi sebagai kotak bahan bakar. Dasar tungku ini miring menaik ke arah cerobong sebesar 25 cm sepanjang 1½ meter panjangnya tungku. Cerobong tungku yang tingginya 1½ meter itu juga terbuat dari batu bata dan lumpur. Panasnya api dan tingginya nyala api diatur dengan cara membuka atau menutup sebagian bagian atas cerobong dengan batu-batu bata yang lepas.

Measurement / Ukuran : cm

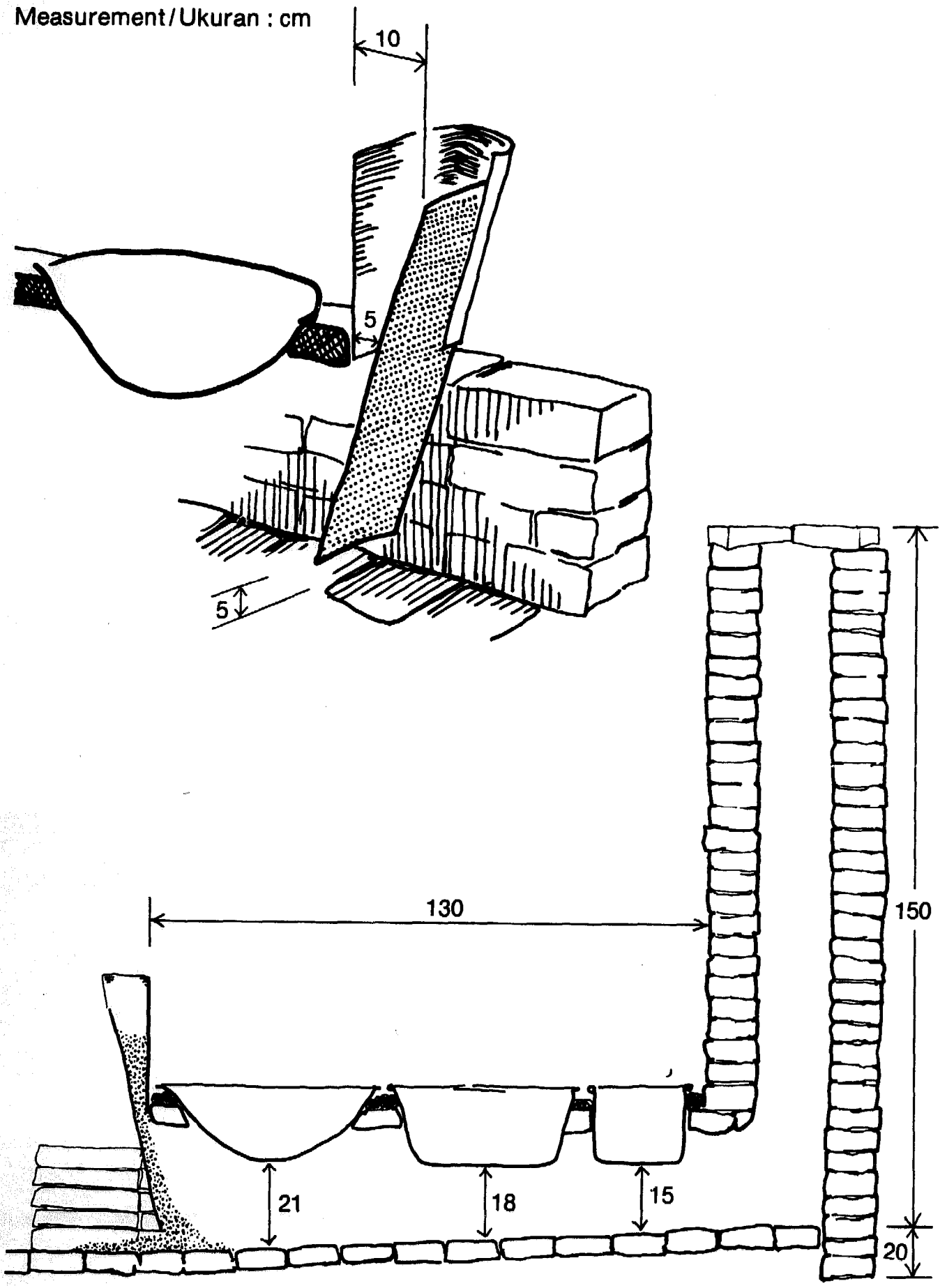

Household and restaurant stove: Philippines

The Philippines has several very convenient rice husk burning stove models for households and restaurants. The cast iron stove tops, grates, and stovepipes are manufactured by local smelters, and along with the prefabricated galvanized iron fuel hoppers are sold in hardware stores in many areas of the country.

Tungku rumah tangga dan restoran : Filipina

Di Filipina terdapat beberapa bentuk tungku pembakar sekam padi yang sangat praktis untuk rumah tangga dan rumah-rumah makan. Bagian atas tungku terbuat dari besi tuang. Garangan dan pipa-pipa untuk cerobongnya dibuat oleh pabrik besi tuang. Kotak pemasukan bahan bakar terbuat dari besi plat yang digalvanisir. Semua telah dibuat sedemikian rupa sehingga tinggal dirakit saja dan dijual di toko besi di banyak daerah.

Measurement / Ukuran : cm

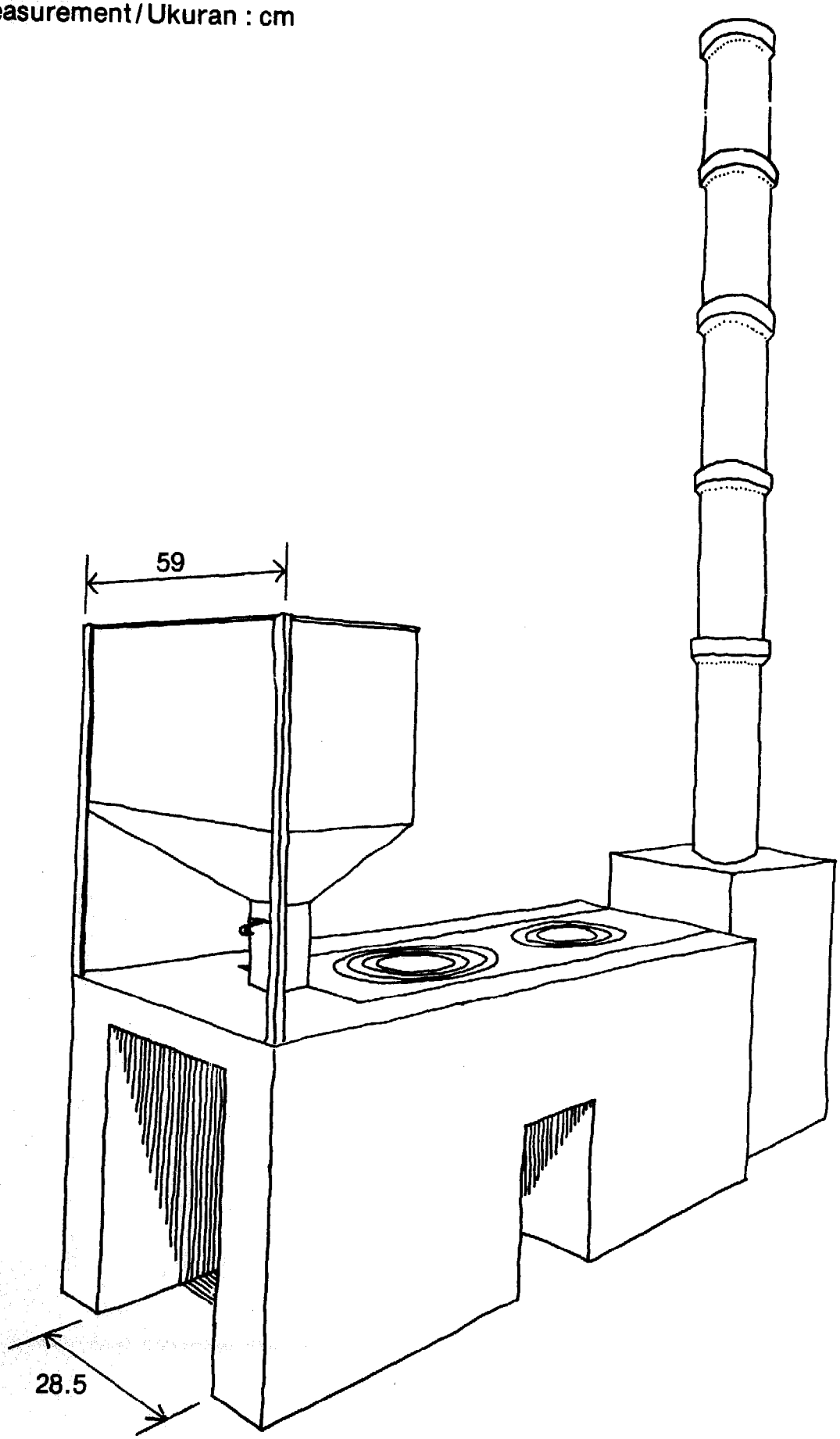

The body of the Philippine stove is made of bricks with regular cement mortar. The flame passage narrows towards the chimney end of the stove, improving draft and assuring more even distribution of heat. The fuel hopper has a sliding gate to control the flow of husks into the fire.

Badan tungku dari Filipina ini terbuat dari batu bata dengan semen biasa. Ruang pembakarannya menyempit ke arah cerobongnya. Hal ini memperlancar aliran udara yang terjadi sehingga didapatkan penyebaran panas yang lebih merata. Kotak pemasukan bahan bakar mempunyai suatu pintu yang dapat bergeser untuk mengatur aliran sekam ke dalam api.

Measurement/Ukuran : cm

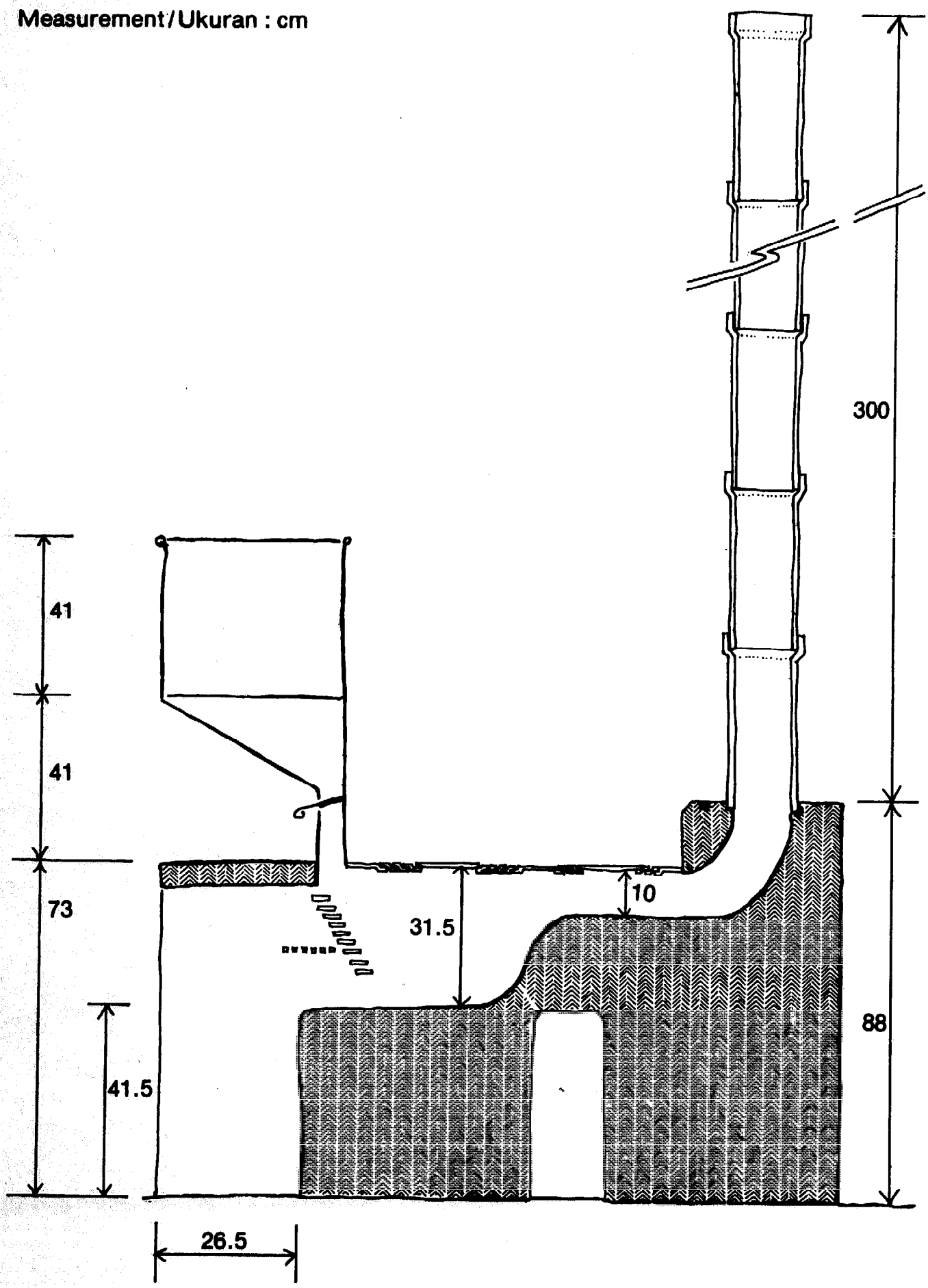

The pot holes feature concentric rings made of cast iron so that their diameter can be adjusted to fit many different sized pots. The grate has a horizontal rack under it to hold the trash or sticks used to light the stove.

Lubang-lubang untuk memasak terdiri dari beberapa cincin dari besi tuang dengan titik tengah yang sama sehingga garis tengah lubang memasak tersebut dapat diatur agar sesuai dengan panci berbagai ukuran. Di bawah garangan terdapat suatu kerangka mendatar untuk menempatkan ranting-ranting atau bahan-bahan lain yang dipergunakan untuk menyalakan apinya.

Measurement / Ukuran : cm

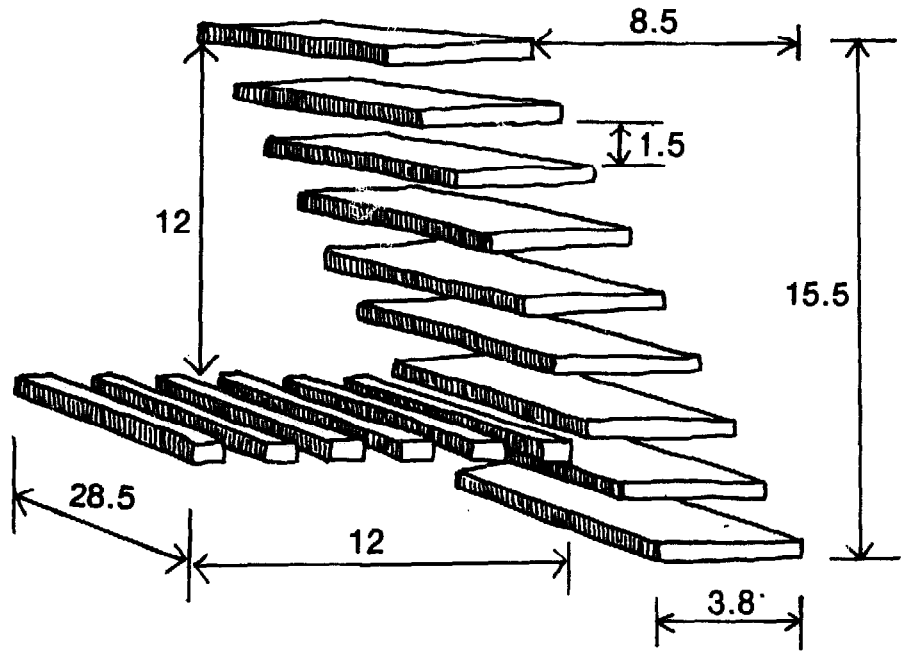

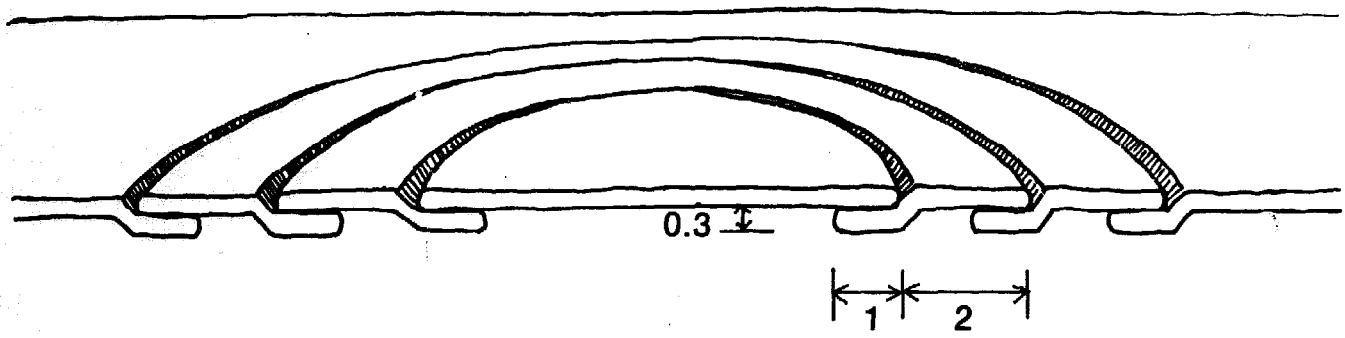

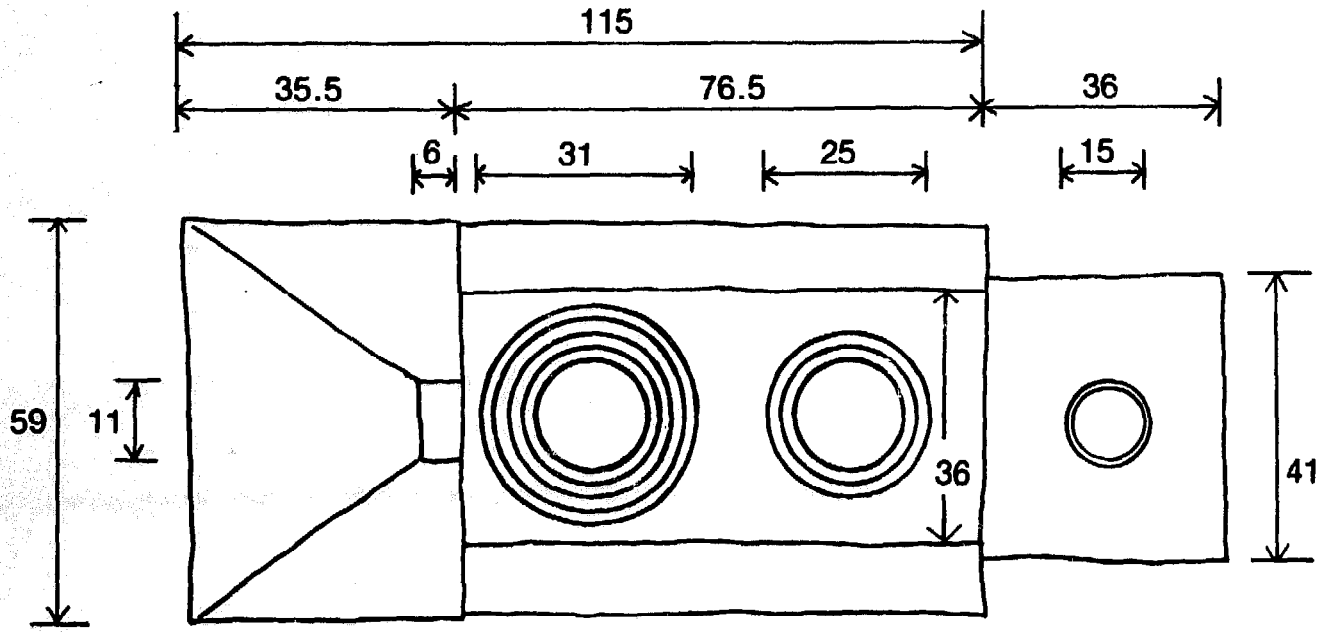

Household and restaurant stove: Philippines

This is a larger Philippines stove, with three pot holes instead of two. Materials and construction are identical to the previous example.

Tungku rumah tangga dan restoran : Filipina

Gambar ini memperlihatkan tungku dari Filipina yang bentuknya sama, hanya lebih besar. Tungku ini mempunyai tiga lubang untuk memasak. Bahan-bahan serta konstruksinya sama dengan contoh terdahulu.

Measurement / Ukuran : cm

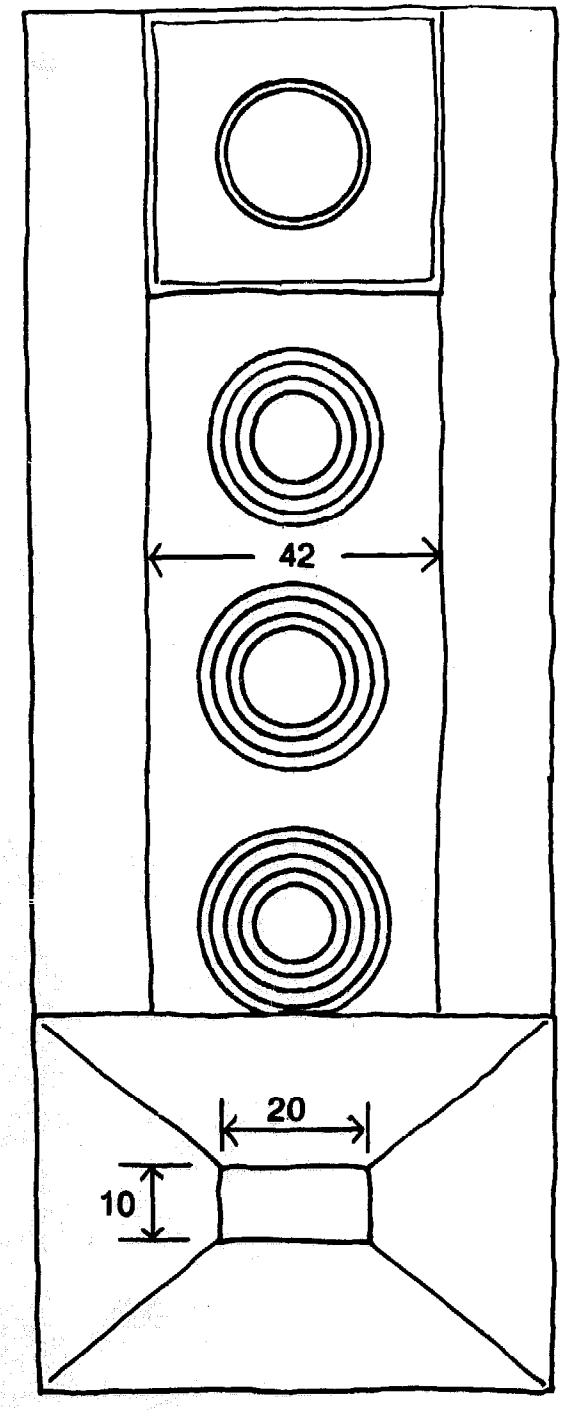

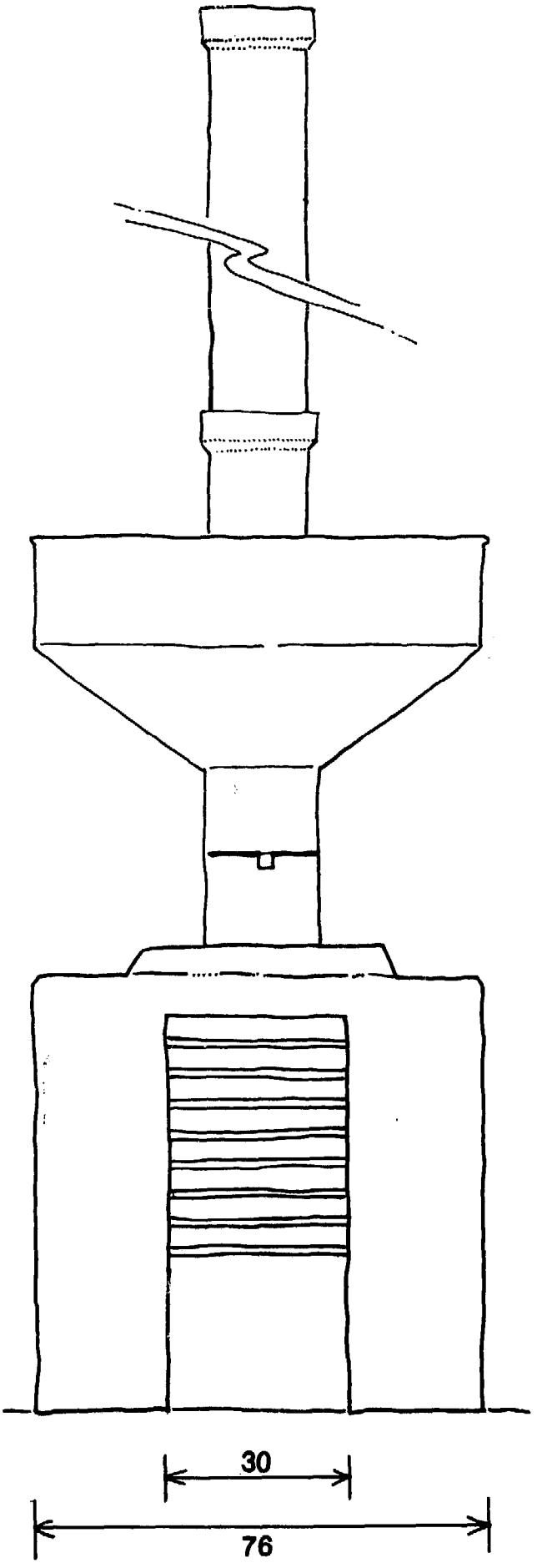

Cross-sectional view of the three pot hole Philippine stove. The base of the flame chamber rises in three steps, corresponding to the three pot holes in the cast iron stove top.

Di sini ditunjukkan gambar potongan melintang dari tungku Filipina yang mempunyai tiga lubang untuk memasak. Dasar ruang pembakaran menaik dalam tiga tingkat, setiap tingkat merupakan anak tangga yang disesuaikan dengan lubang-lubang untuk memasak yang terdapat di atasnya.

Measurement / Ukuran : cm

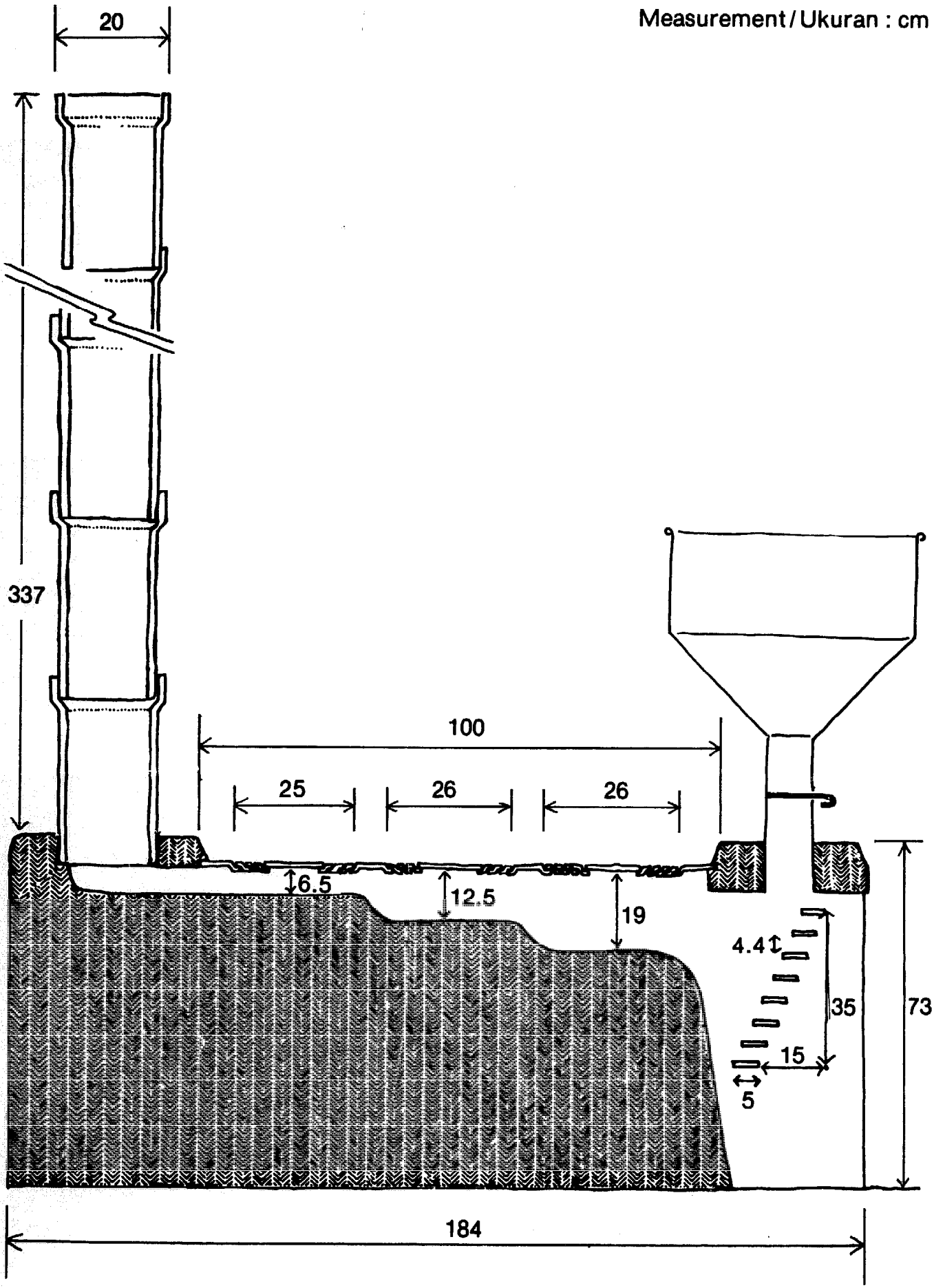

Drum stove: Philippines

This unusual stove is also from the Philippines. It is made from a 40 liter drum, cut and lined with clay which contains a high percentage of sand, brick dust, and ash, to prevent shrinkage as it dries and is fired. This clay lining is fired as the stove is used. The combination hopper and grate is made from sheet iron cut from an oil drum. Because the stove has no chimney, a secondary air inlet is cut opposite the grate to increase the flow of air reaching the burning husks. These stoves burn well, and last about a year before the sheet metal grate disintegrates.

Tungku drum : Filipina

Tungku yang bentuknya luar biasa ini juga berasal dari Filipina. Tungku ini terbuat dari sebuah drum 40 liter yang dipotong dan dilapisi dengan tanah liat yang mengandung pasir, serbuk batu bata dan abu dalam kadar yang tinggi untuk mencegah terjadinya penyusutan pada waktu tanah liat itu mengering dan dibakar. Lapisan tanah liat tersebut dibakar pada saat tungku itu dipergunakan. Garangannya terbuat dari lembaran besi yang diambil dari sebuah drum minyak. Karena tungku ini tidak mempunyai cerobong maka dibuatlah sebuah lubang pemasukan udara kedua yang berhadapan dengan garangan untuk memperbesar aliran udara yang mencapai sekam padi yang sedang menyala. Tungku-tungku seperti ini menyala dengan baik, dan dapat dipakai selama kurang lebih setahun sebelum garangan yang terbuat dari lembaran logam itu hancur.

Measurement / Ukuran : cm

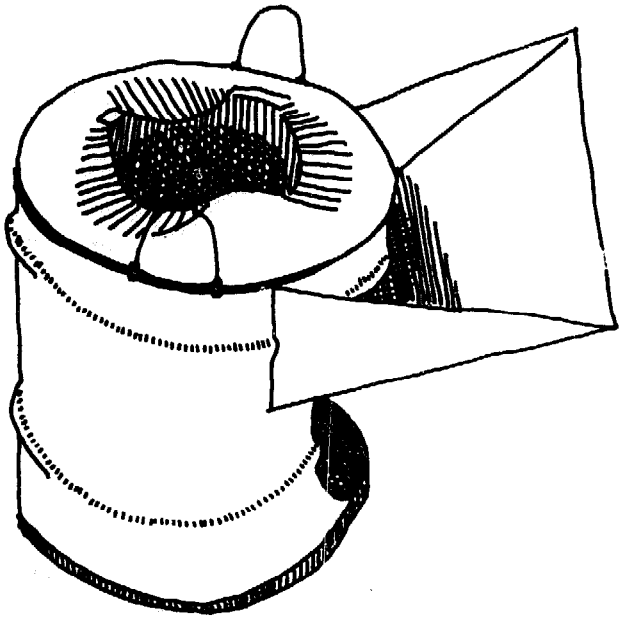

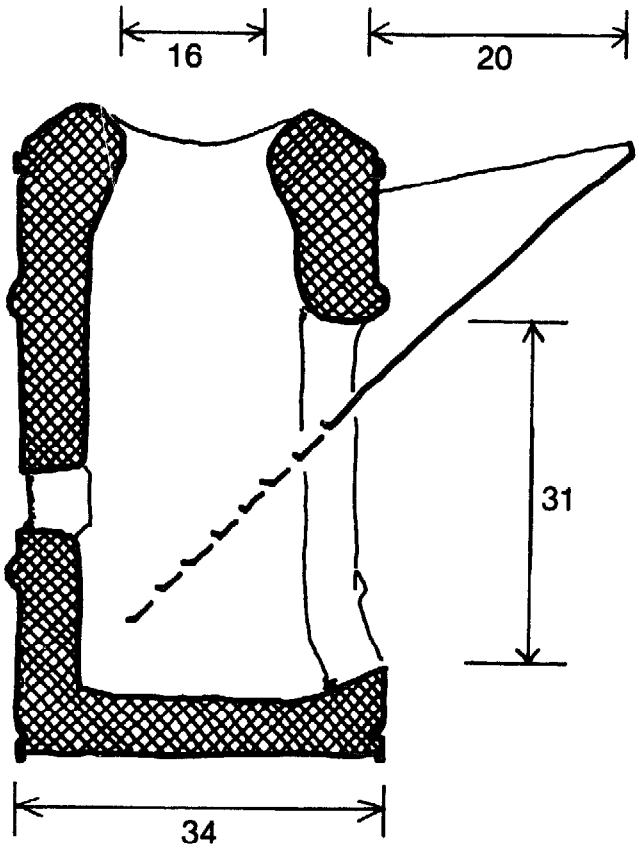

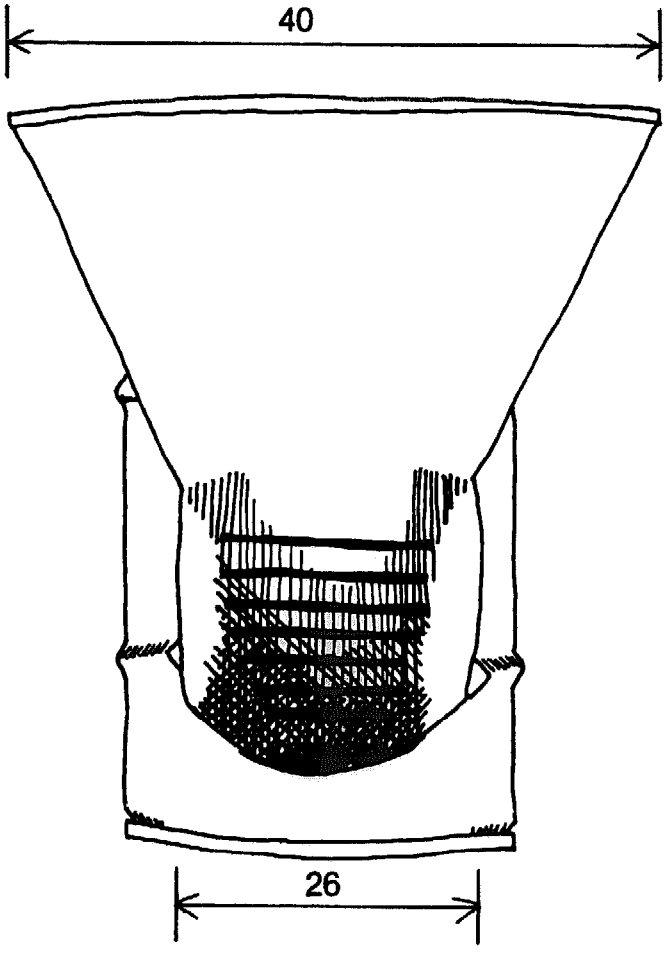

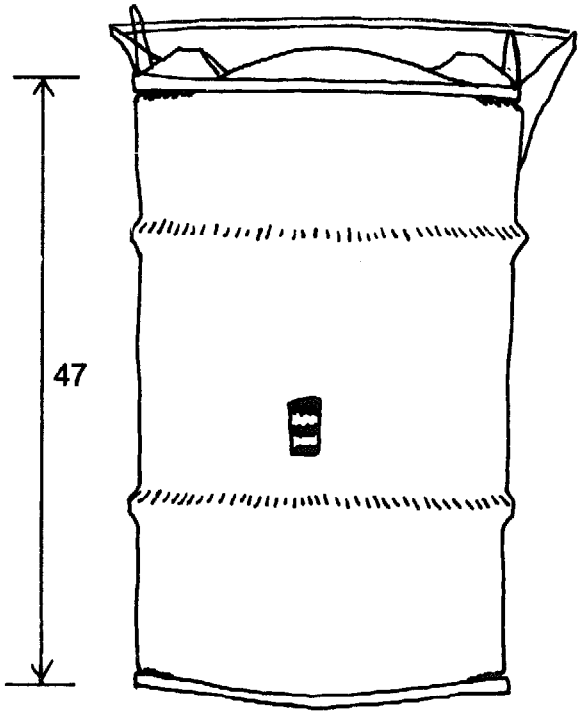

Tofu production stove: Java

This stove is used by Javanese soy bean cake (tahu) manufacturers to boil soy milk. It can boil six to ten 150 liter batches per day, using about 125 kg of rice husks.

Tungku pembuatan tahu: Jawa

Tungku seperti ini dipergunakan oleh para pembuat tahu di Jawa untuk memasak sari kedele. Tungku ini dapat memasak enam sampai sepuluh kali 150 liter setiap harinya, menghabiskan kira-kira 125 kg sekam padi.

Measurement / Ukuran : cm

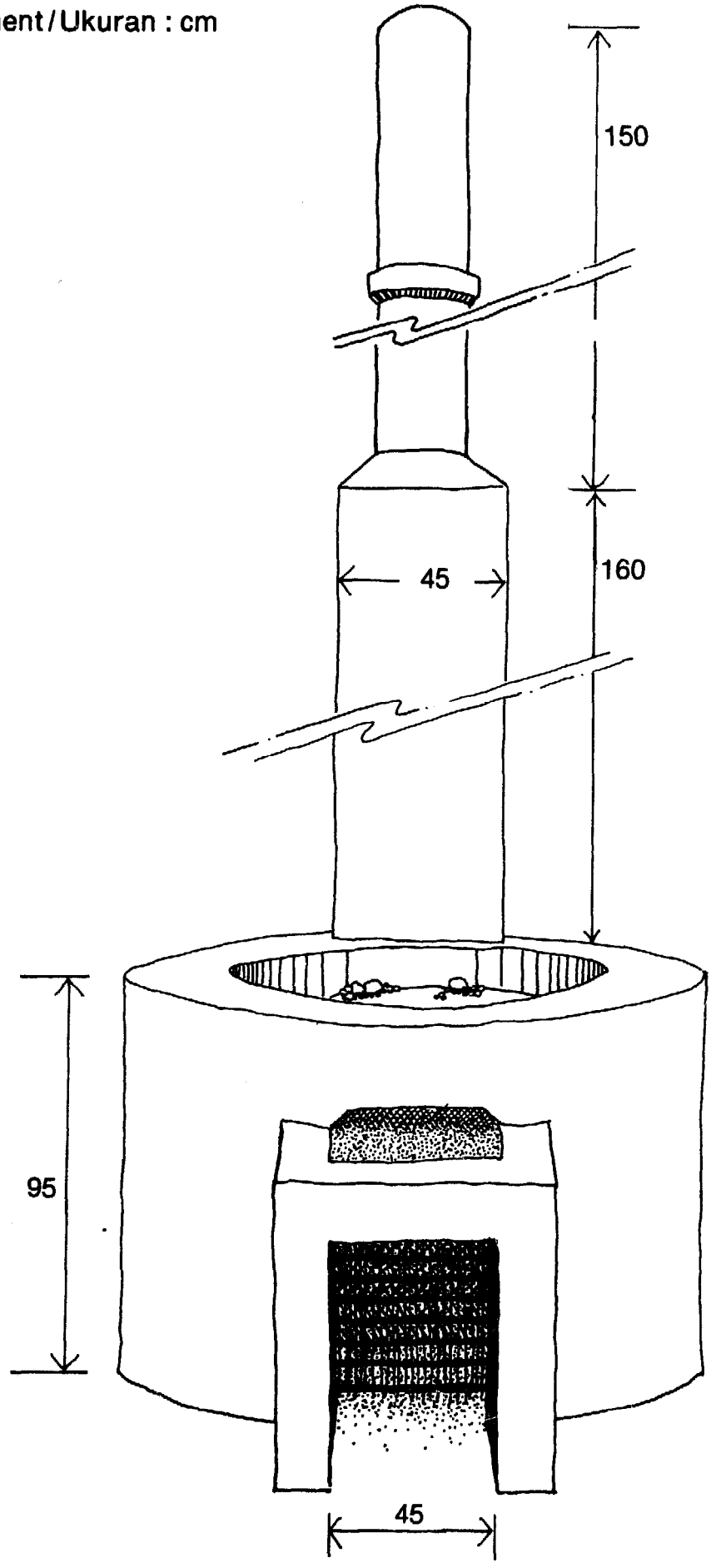

The Javanese soy milk stove is made of bricks with a cement and sand mortar. The cast iron pot is cemented into the body of the stove. The grate is fabricated from 5 cm strap iron spaced 4½ cm apart and descending at an angle of 60 degrees. This grate has to be replaced after 3 to 5 years of constant use. The top half of the chimney is made of 20 cm clay pipe.

Tungku untuk memasak sari kedele yang dipergunakan di Jawa itu terbuat dari batu bata dengan adukan semen dan pasir. Panci atau wajan yang terbuat dari besi tuang disemen dalam badan tungku. Garangannya terbuat dari besi strip yang lebarnya 5 cm, dengan jarak antara 4½ cm, dan menurun dengan sudut 60 derajat. Garangan ini harus diganti setelah 3 sampai 5 tahun dipergunakan secara terus menerus. Bagian atas cerobong terbuat dari pipa tanah liat (hong) bergaris tengah 20 cm.

Measurement / Ukuran : cm

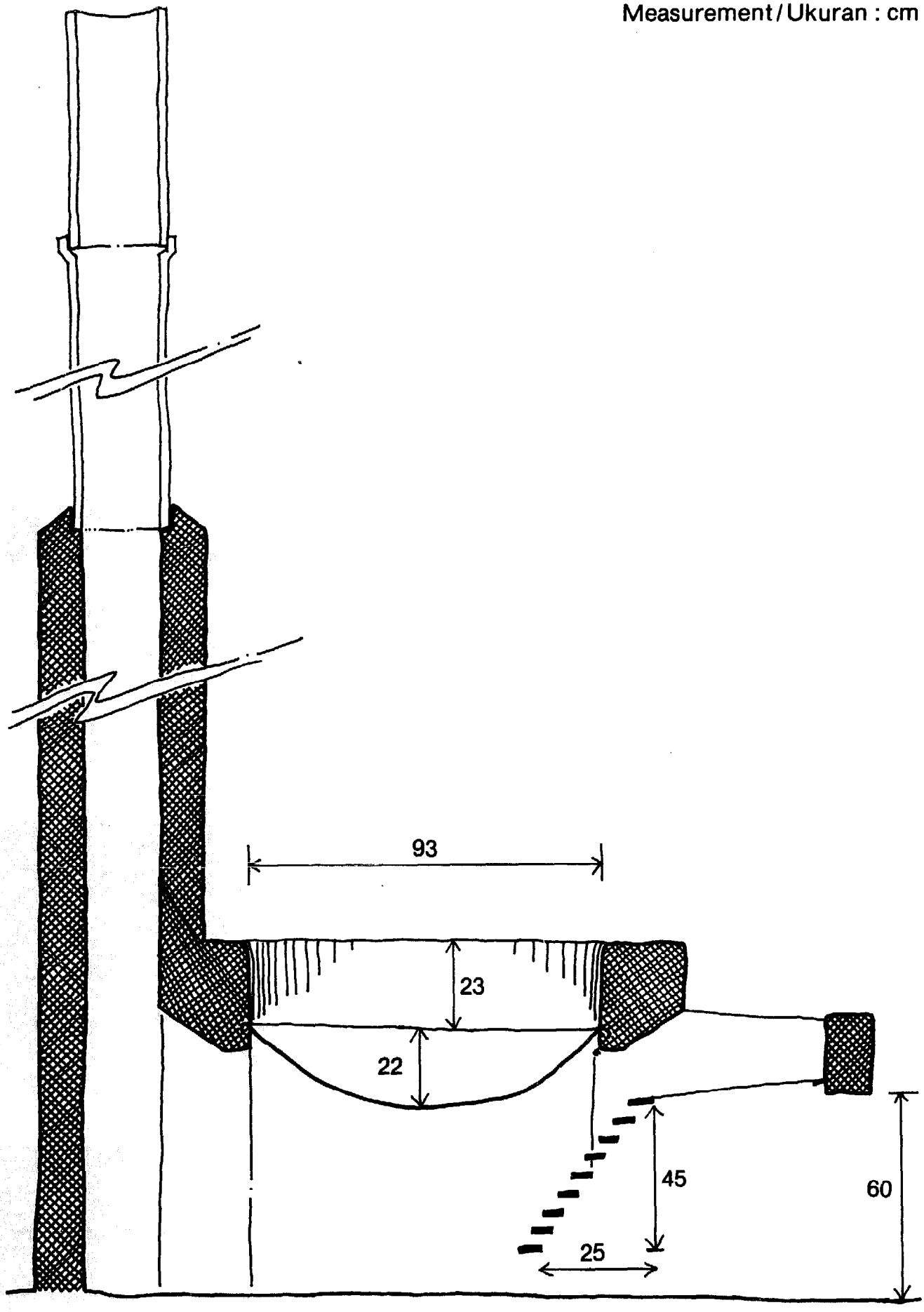

Krupuk cracker production stove: Java

The large stove depicted here is used in the manufacture of "krupuk" manioc paste crackers in Java. Pressed cracker dough is steamed in bamboo racks stacked 1½ meter above each of the four pots of boiling water.

The floor of the stove rises 30 cm between the ash pit below the grate and the base of the chimney, and the pots are positioned so that the base of each one is 2 cm lower than the preceeding one as they approach the cooler chimney end of the stove. This is to attain more even temperatures in all of the pots. The grate is 55 cm wide and made of 1 × 6 cm strap iron. This stove needs a small door at the base of the chimney to remove fly ash which becomes caught in the chimney and falls back into the stove.

Tungku pembuatan krupuk : Jawa

Tungku besar yang digambarkan di sini dipergunakan di Jawa untuk pembuatan krupuk. Adonan krupuk yang telah dicetak dikukus dalam rak-rak bambu yang ditempatkan 1½ meter di atas setiap wajan yang berisi air mendidih.

Dari lubang abu di bawah garangan sampai kaki cerobong dasar tungku miring setinggi 30 cm, dan panci-panci atau wajan ditempatkan sedemikian rupa sehingga dasar setiap panci yang lebih dekat pada ujung tungku yang lebih dingin, yakni ke arah cerobong, letaknya lebih rendah 2 cm dari panci atau wajan sebelumnya. Hal ini dilakukan untuk mendapatkan suhu yang lebih merata antara semua panci tersebut. Lebar garangannya 55 cm dan garangan itu terbuat dari besi strip berukuran 1 × 6 cm. Pada tungku ini perlu dibuat sebuah pintu kecil di kaki cerobong untuk mengeluarkan abu halus yang terkumpul dalam cerobong asap dan jatuh kembali ke dalam tungku.

Measurement / Ukuran : cm

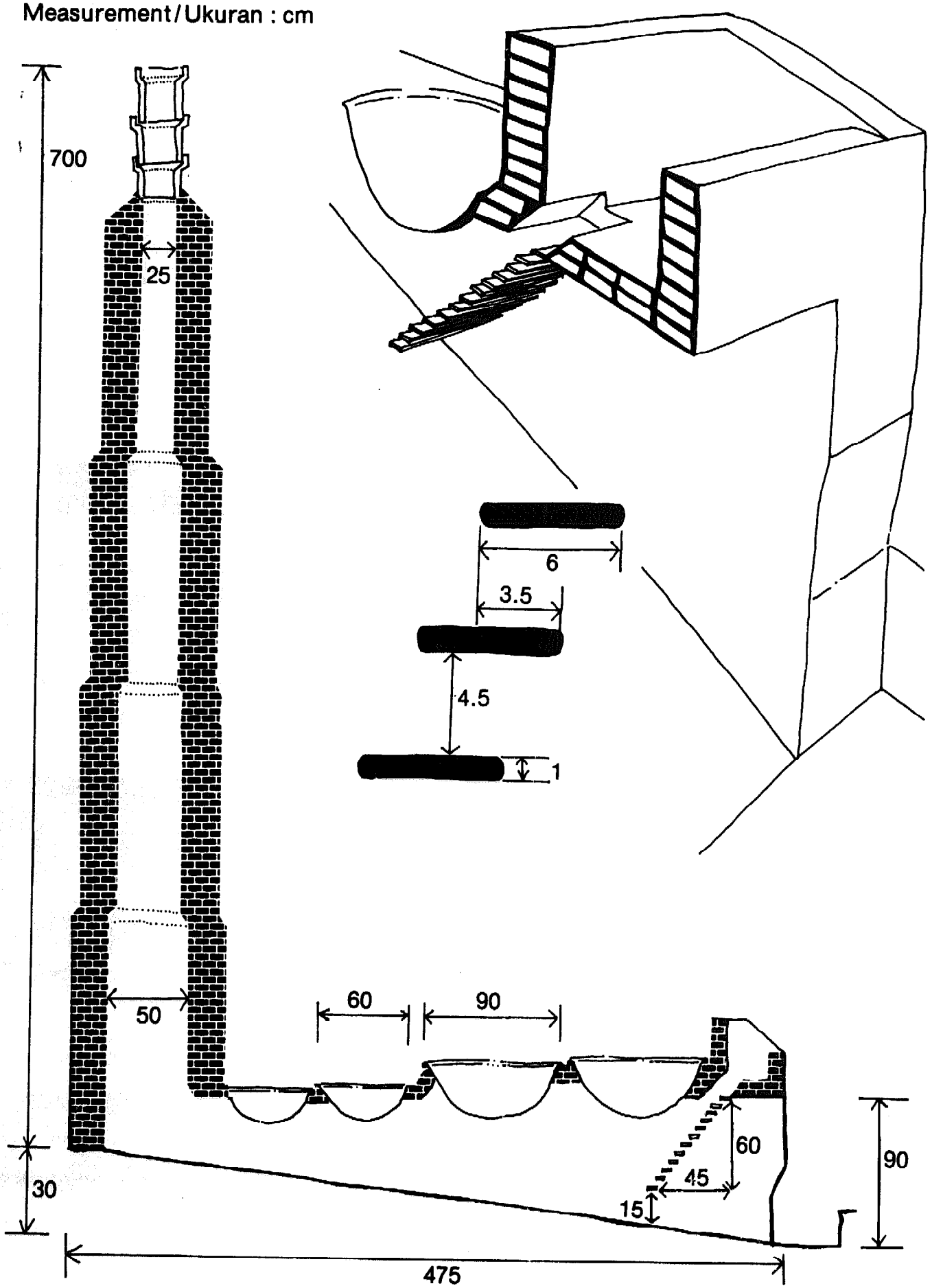

SMOLDERING

The slow even fire produced by a smoldering pile of dry rice husks can be used to fire bricks, roof tiles, and other earthenware products which mature at a relatively low temperature. The practice of firing bricks with rice husks is found in many areas of Indonesia. Quality of the bricks produced by this method is similar to that of wood-fired bricks made from the same clay. However with rice husks a higher percentage of the bricks do not reach maturity and must be fired again. This is caused by the accumulation of ash as the firing proceeds, preventing the fire from reaching the bricks at the bottom of the pile.

Most brickworks using rice husks employ no permanent kiln but rather stack the unfired bricks in several rows with spaces between them for the smoldering fuel.

PEMBARAAN SEKAM

Api yang menyala pelan-pelan dan merata seperti yang dihasilkan oleh setumpuk sekam padi kering yang membara, dapat dipakai untuk membakar batu bata, genteng serta barang-barang tembikar yang dapat menjadi matang pada suhu pembakaran yang relatif rendah. Cara membakar batu bata dengan sekam padi seperti ini dapat ditemukan di banyak daerah di Indonesia. Mutu batu bata yang dihasilkan dengan pembakaran seperti ini sama dengan mutu batu bata dari jenis tanah liat yang sama yang dibakar dengan kayu. Namun demikian pada pembakaran yang mempergunakan sekam padi, persentase batu bata yang tidak matang dan harus dibakar lagi akan lebih besar. Hal ini terjadi karena abu yang bertumpuk selama pembakaran berlangsung akan mencegah api untuk sampai pada batu-batu bata di bagian bawah tumpukan.

Kebanyakan pembakaran batu bata yang mempergunakan sekam padi tidak menggunakan bangunan (dapur) yang tetap, tetapi beberapa tumpukan batu bata yang disusun berjejer dengan ruang antara untuk bahan bakar yang membara. Sebuah dinding pelin-

A retaining wall of bricks or stone blocks is built around these rows before the firing begins. The stacks of bricks are then covered with loosely packed rice husks which are ignited from the bottom and allowed to smolder. As they burn away, more husks are piled on top. The firings continue for 4 to 7 days, until the entire stack is covered with powdery white ash, and the bricks are done. If the weather is dry on the day that the firing begins, the bricks can be fired in the open even if it rains lightly for the remainder of the firing.

It is important to have enough fuel on hand before the firing begins. Achieving maturation temperature is a cumulative process, and if the firing is interrupted before the bricks mature, the ashes have to be cleared away and the firing begun again.

Brickmakers in Indonesia try to have a stock of at least 15 to 20 gunny sacks of rice husks ready per 1000 bricks being fired before commencing with the firing.

dung dari batu bata atau batu padas dibangun sekeliling tumpukan-tumpukan batu bata yang disusun berjejer ini sebelum pembakaran dimulai. Tumpukan-tumpukan batu bata itu kemudian ditutup dengan sekam padi yang tidak terlalu dipadatkan. Sekam padi itu kemudian dibakar mulai dari bawah dan dibiarkan membara, sementara sekam padi mulai habis dimakan api, sekam padi baru sudah mulai ditumpuk di atasnya. Pembakaran ini berlangsung selama 4 sampai 7 hari, sampai seluruh tumpukan tertutup dengan abu yang berupa serbuk putih, dan batu-batu bata tersebut matang. Jika cuaca pada hari dimulainya pembakaran baik, pembakaran dapat dilakukan di alam terbuka, meskipun pada saat pembakaran selanjutnya turun hujan gerimis.

Yang penting pula adalah tersedianya bahan bakar dalam jumlah yang cukup sebelum pembakaran dimulai. Dicapainya suhu yang dibutuhkan agar batu bata dapat menjadi matang merupakan suatu proses yang kumulatif, dan jika pembakarannya terhenti sebelum batu-batu bata itu matang, semua abu sisa pembakaran harus dikeluarkan dari antara tumpukan batu bata itu dan pembakaran harus dimulai lagi dari awal. Sebelum memulai pembakaran, para pembuat batu bata di Indonesia berusaha agar sekurang-kurangnya tersedia 15 sampai 20 karung sekam padi untuk setiap 1000 batu bata yang akan dibakar.

Brick firing: Bali

This is a stacking method used by small brick producers in Bali, used to fire about 1000 bricks at a time. The bricks are stacked in four rows, slightly more than a meter high and 2 to 3 meters long. 2 to 4 cm gaps are left between the faces of the bricks to assure good heat penetration.

Pembakaran bata : Bali

Gambar ini menunjukan cara penumpukan batu bata yang dipergunakan oleh para pembuat batu bata kecil di Bali, yang dipergunakan untuk membakar kira-kira 1000 batu bata sekali pembakaran. Batu bata tersebut ditumpuk dalam empat jejeran yang sedikit lebih tinggi dari satu meter dan panjangnya antara 2 sampai 3 meter. Antara tiap batu bata dibiarkan suatu celah yang lebarnya antara 2 sampai 4 cm untuk menjamin adanya perembesan panas yang baik.

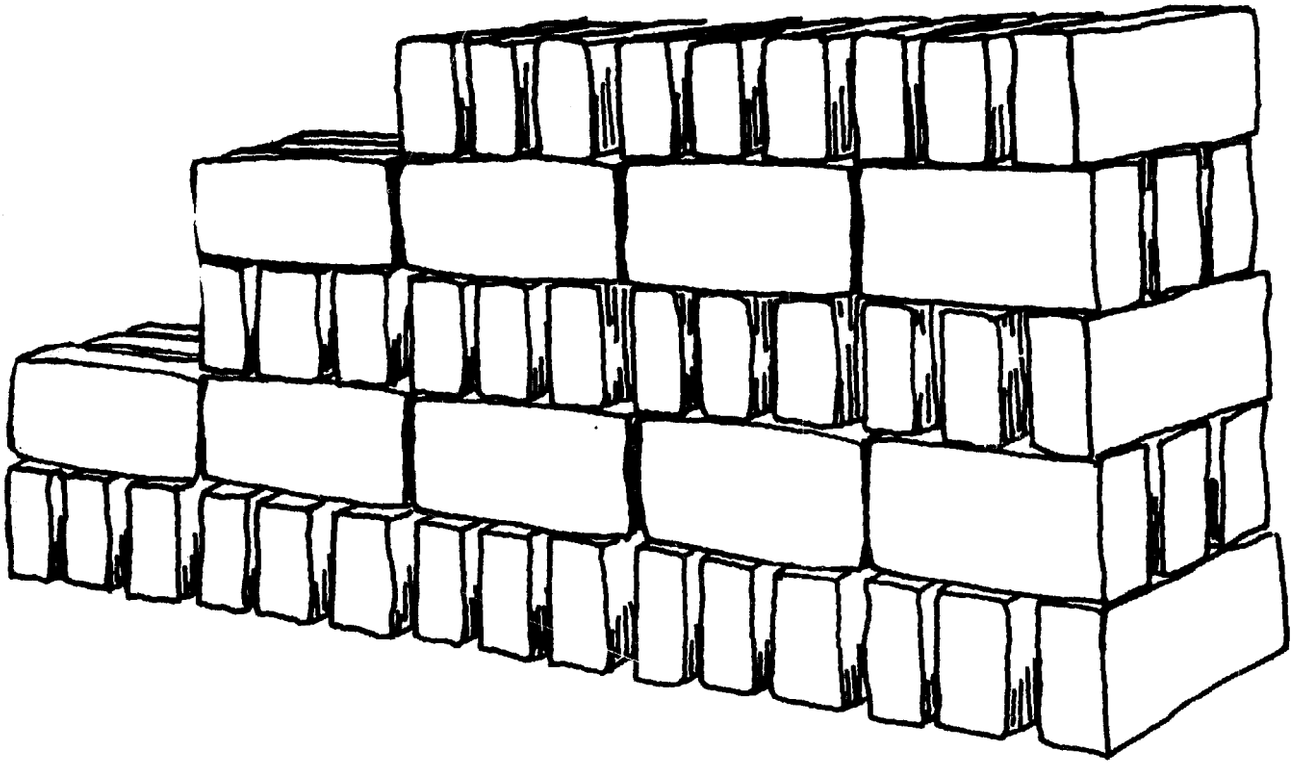

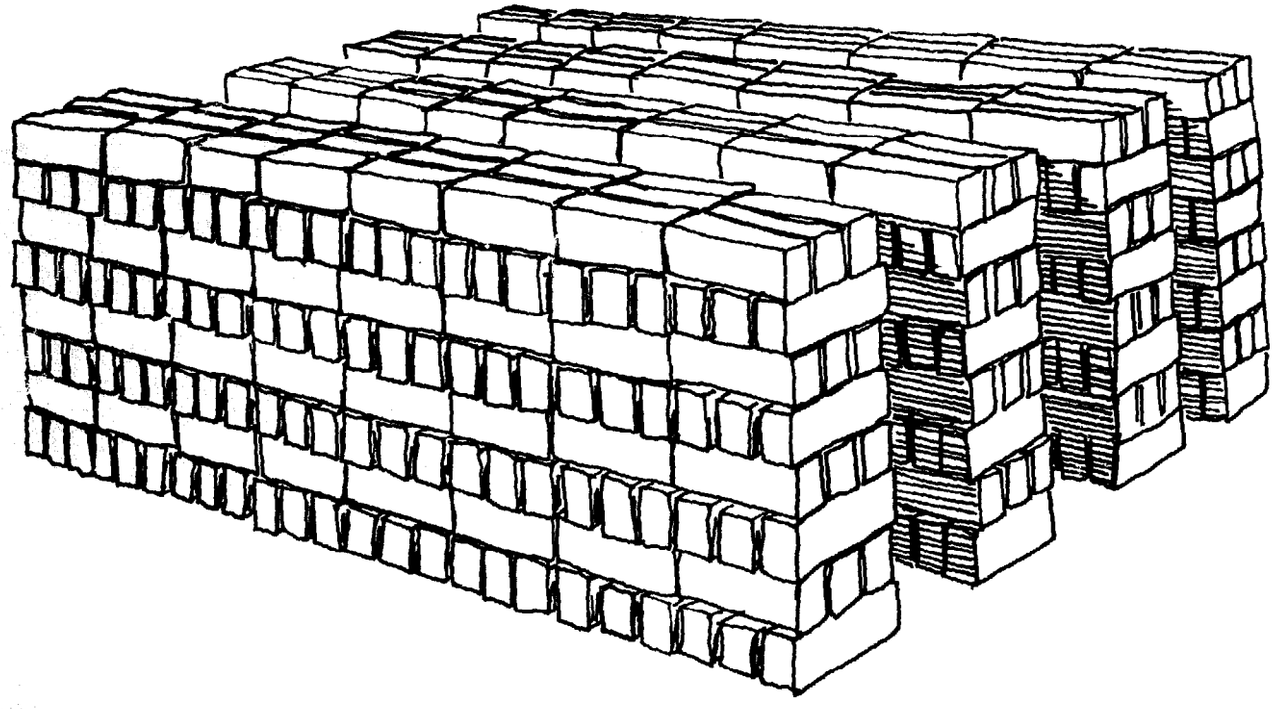

After the bricks are stacked, a retaining wall is built around them using large sandstone blocks. Four holes are left at the base of the wall through which the husks are lit and some air for combustion is drawn. The bricks are then completely covered with husks and firing begins. Firing takes 6 days, using about 15 to 20 gunny sacks of rice husks per day.

Setelah tumpukan batu bata disusun, suatu dinding pelindung dari bongkahan batu padas yang besar dibangun di sekililingnya. Empat buah lubang di dasar dinding tersebut dibiarkan terbuka. Lubang-lubang ini dipergunakan untuk menyalakan sekam padi dan untuk aliran udara yang diperlukan untuk pembakaran. Tumpukan batu bata itu kemudian ditutup seluruhnya dengan sekam padi dan pembakaran dimulai. Pembakaran itu berlangsung selama 6 hari, serta menghabiskan sekitar 15 sampai 20 karung sekam padi setiap harinya.

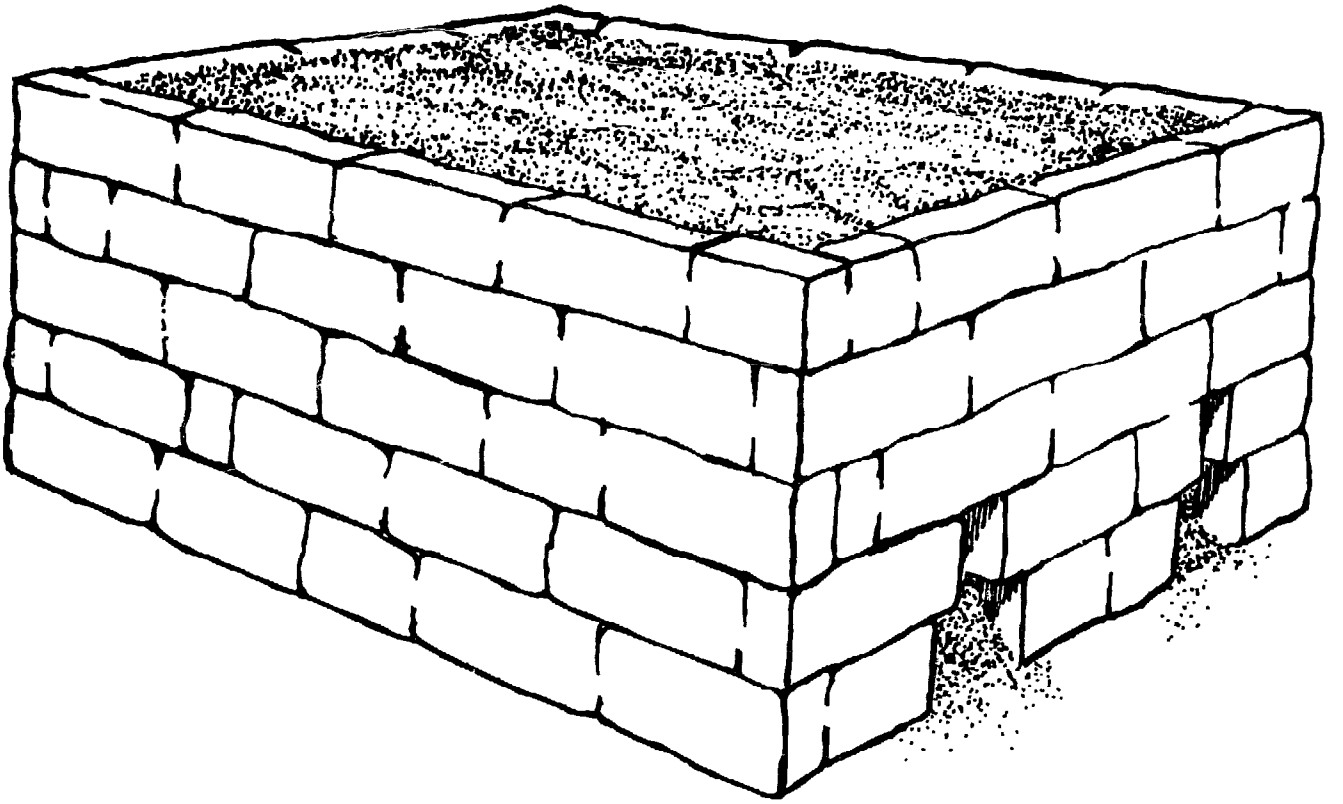

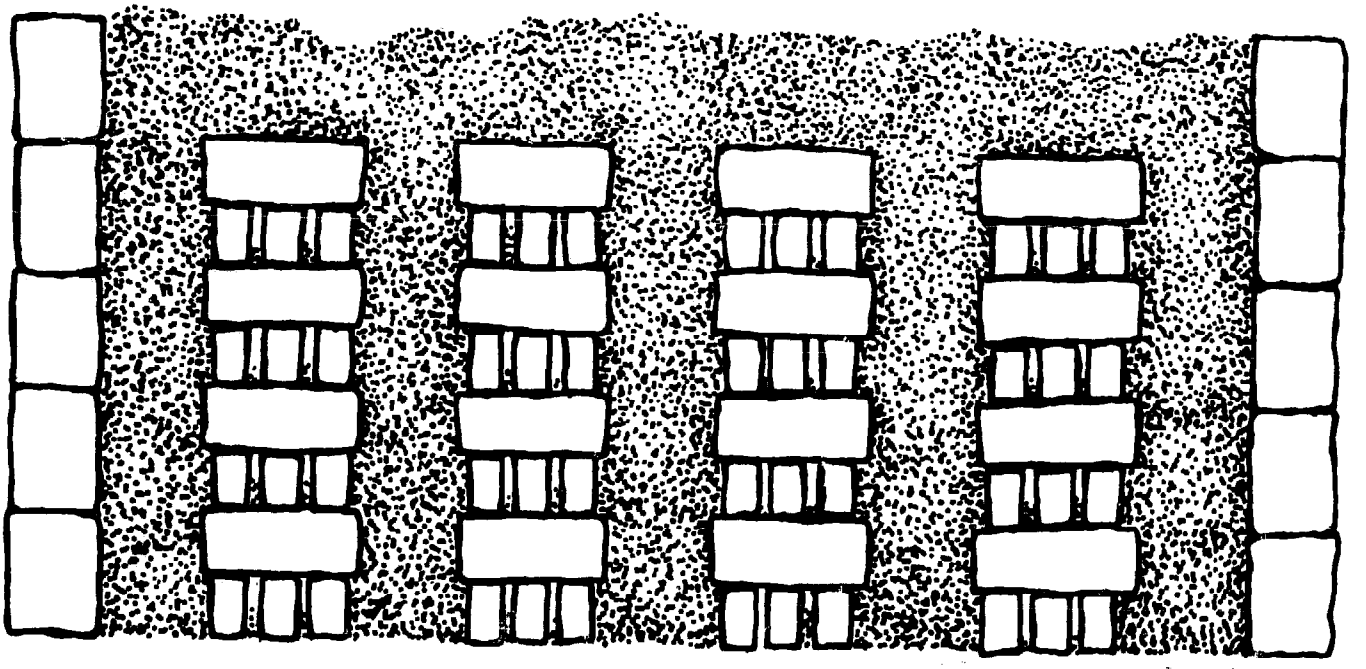

Brick firing: Java

This East Javanese stacking method, similar to the previous example from Bali, is used to fire between 5,000 to 15,000 bricks at a time. For larger firing, the rows of bricks are made longer and more rows are added, but the bricks are not stacked any higher than depicted here. The retaining walls and the bottom layer of each row are built hollow to decrease the number of bricks which do not reach maturity and must be refired. To begin a firing, a small amount of husks is spread between the bottom of the rows and ignited, then husks are piled on until the rows are covered. Unlike the Balinese design, these retaining walls have no holes at their base. The Javanese brickmakers claim that having holes would create hot and cold spots, resulting in an uneven firing.

Pembakaran bata : Jawa

Cara penumpukan batu bata dari Jawa Timur ini mirip dengan contoh dari Bali yang diberikan sebelumnya. Ia dipergunakan untuk membakar antara 5.000 sampai 15.000 buah batu bata dalam satu kali pembakaran. Untuk pembakaran batu bata dalam jumlah yang lebih besar, jejeran-jejeran batu bata dibuat lebih panjang dan jumlah tumpukan ditambah, namun tumpukan-tumpukan itu tidak dibuat lebih tinggi dari pada yang diperlihatkan di sini. Dinding pelindung dan lapisan batu bata yang paling bawah pada setiap tumpukan disusun sedemikian rupa sehingga di dalamnya terdapat suatu rongga. Hal ini dilakukan untuk mengurangi jumlah batu bata yang tidak matang dan harus dibakar ulang. Untuk memulai pembakaran, sela-sela di antara jejeran batu bata tersebut diisi dengan lapisan tipis sekam padi yang lalu dinyalakan. Setelah menyala ditambahkan lagi sekam padi sampai bagian atas susunan batu bata tertutup seluruhnya. Berbeda dengan rancangan dari Bali, dinding-dinding pelindung pada rancangan ini tidak mempunyai lubang-lubang di bagian bawahnya. Para pembuat batu bata di Jawa berpendapat bahwa adanya lubang-lubang seperti itu akan menyebabkan terjadinya tempat-tempat yang panas dan dingin sehingga pembakarannya tidak akan merata.

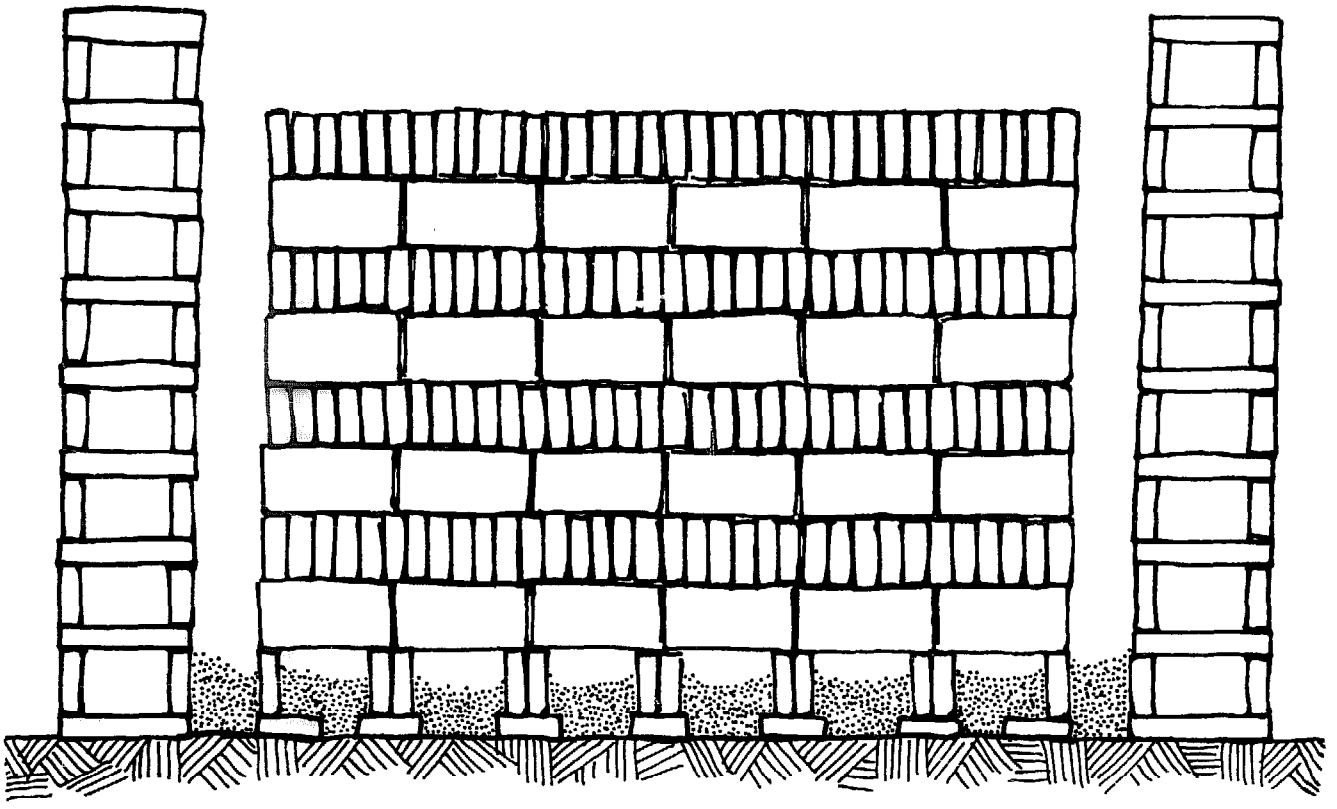

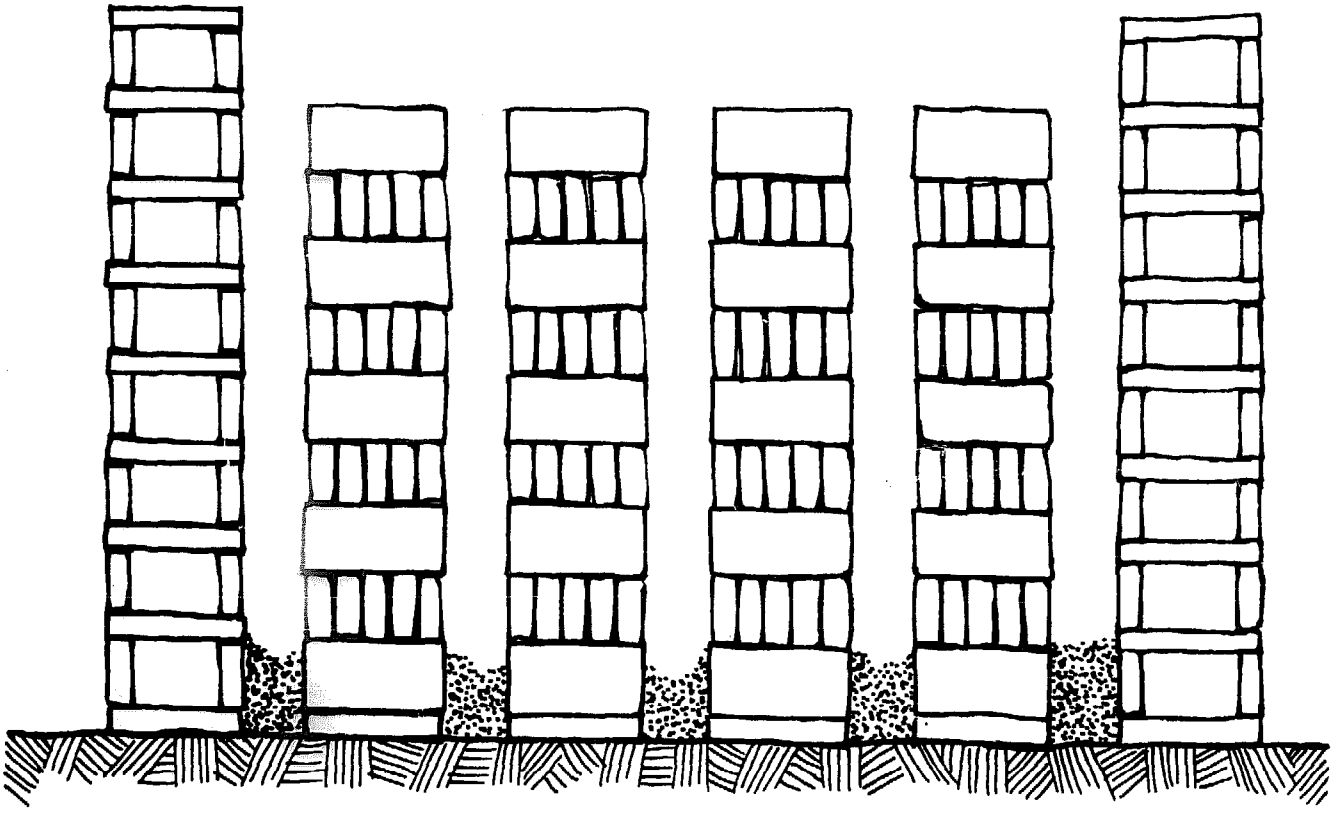

Brick firing: Java

This Central Javanese stacking method produces very high quality bricks, with a low percentage of unmatured bricks which have to be refired. About 15,000 bricks are fired at a time.

Pembakaran bata : Jawa

Cara penumpukan dari Jawa Tengah ini menghasilkan batu bata yang bermutu sangat tinggi, dengan persentase yang rendah dari batu bata yang tidak matang dan harus dibakar lagi. Pada satu kali pembakaran kurang lebih 15.000 buah batu bata dapat dibakar.

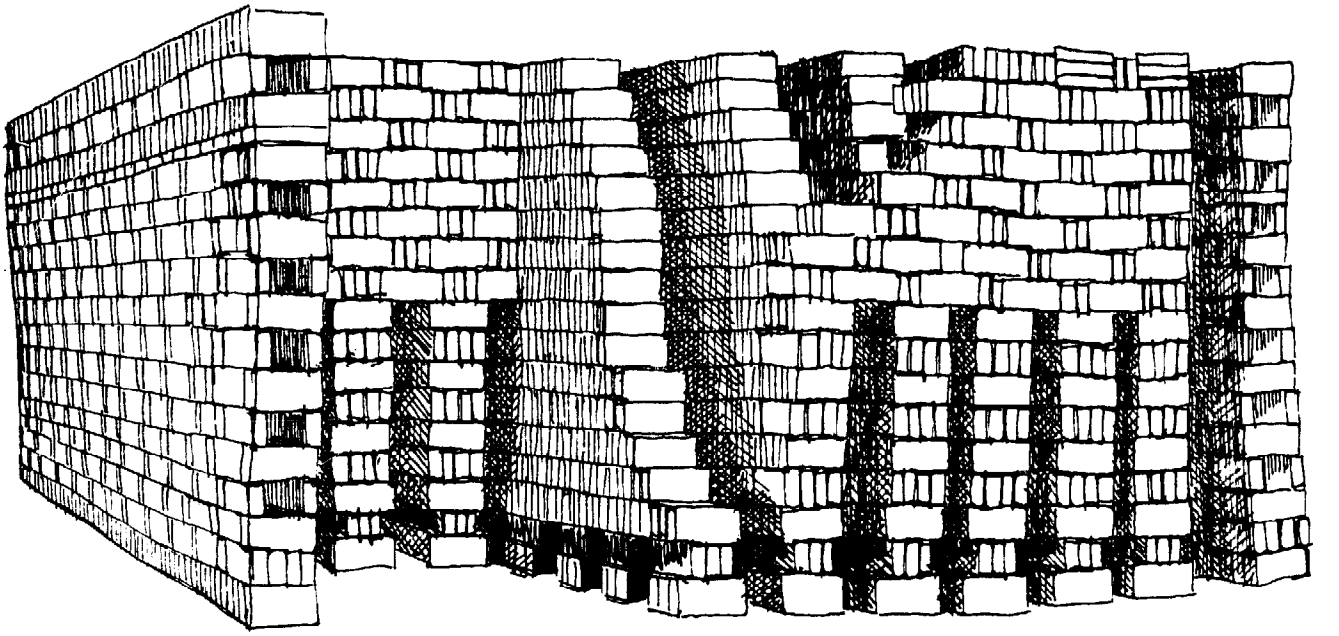

This plan view of the Central Javanese method shows that the ends of the rows of stacked bricks are bridged together to prevent their collapse or tilting during firing. Sometimes, such ties are also employed in the middle of the rows to further increase stability.

Bagan rancangan metoda Jawa Tengah ini memperlihatkan bahwa ujung-ujung tumpukan batu bata yang disusun berjejer saling dihubungkan untuk mencegah runtuh atau condongnya tumpukan-tumpukan batu bata itu selama pembakaran. Kadang-kadang hubungan seperti itu dibuat pula di bagian tengah jejeran-jejeran batu bata untuk memperkokoh lebih lanjut tumpukan-tumpukan tersebut.

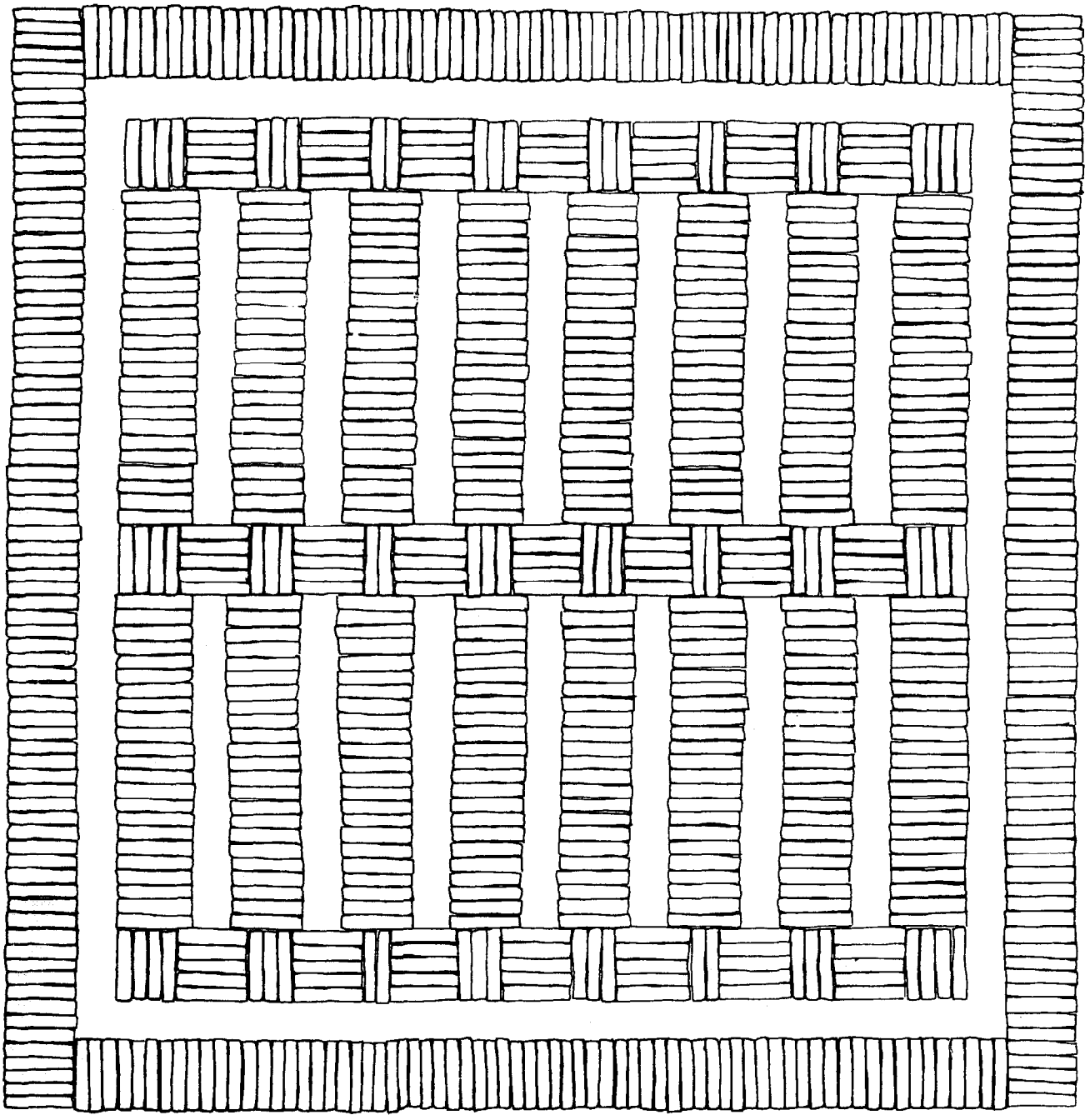

Cross-section A—B: An individual row, viewed from the side, looks like this. With the exception of (1) the bricks tying the ends of the stack on, (2) those bridging the empty spaces at the base of the stack, and (3) the second row of bricks, which are all stacked parallel to the direction of the row, all of the bricks are stacked perpendicular to the line of the row. This allows better penetration of heat into the center of each row, thus resulting in a complete and even firing.

Potongan A—B: Satu jejer tersendiri, dilihat dari samping akan tampak seperti ini. Dengan perkecualian (1) yakni batu-batu bata yang menghubungkan ujung-ujung jejeran batu bata, (2) yakni batu bata yang menjembatani ruang kosong di dasar tumpukan, dan (3) yakni jejeran kedua, yang kesemuanya disusun sejajar dengan arah jejeran, semua batu bata yang lain ditumpuk melintang tegak lurus terhadap arah jejeran. Hal ini memungkinkan perembesan panas yang lebih baik ke pusat tiap jejeran, dan dengan demikian menghasilkan pembakaran yang lebih sempurna dan lebih merata.

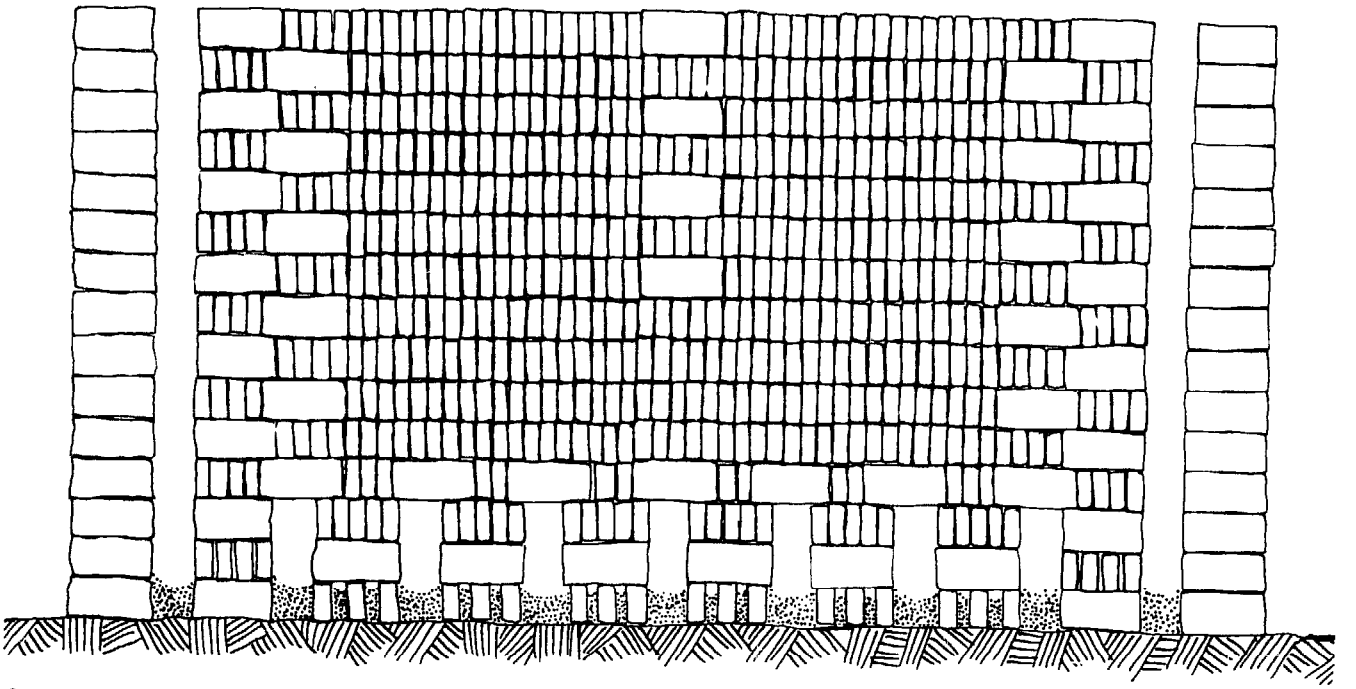

Cross-section / Potongan A - B

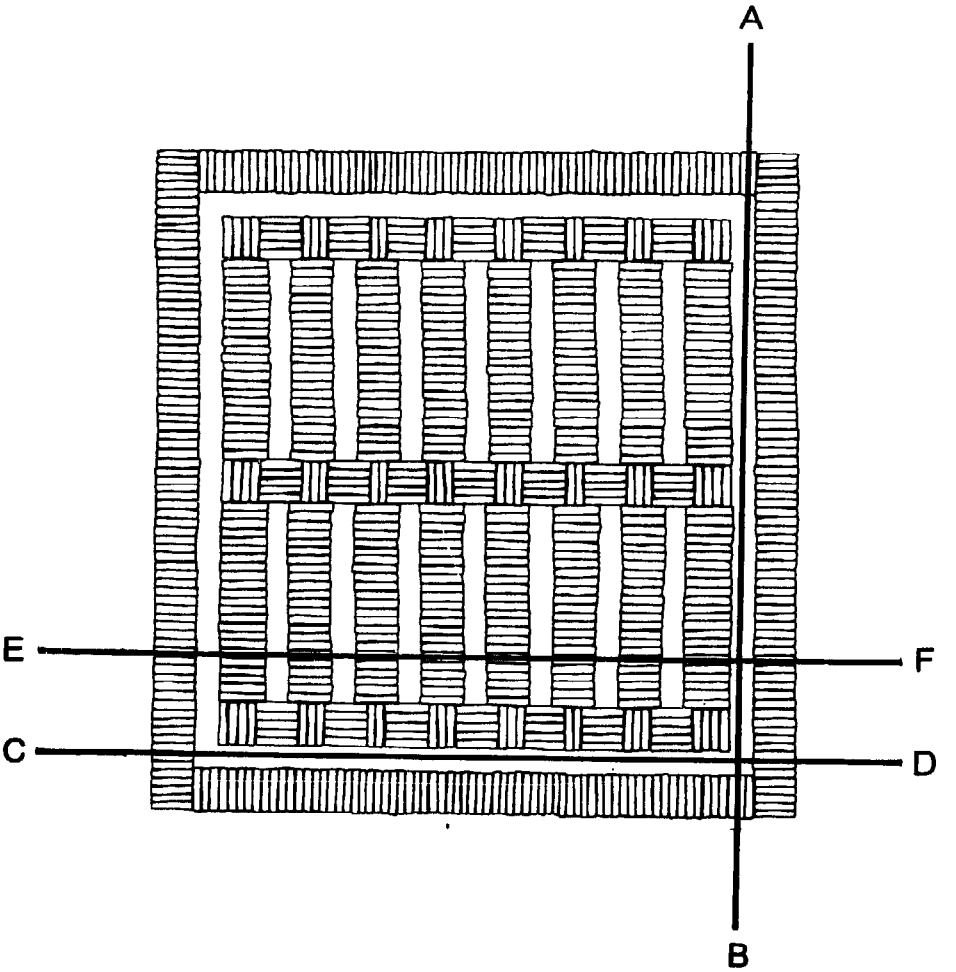

Cross-section C—D: Viewed from the end of the rows, the stacks look like this. Beginning at the ninth layer, bricks are placed across the gaps between the rows, forming bridges to stabilize the tall stacks and keep them from tilting or collapsing.

Cross-section E—F: A cross-sectional view taken from the center of the rows once again reveals that nearly all of the bricks are stacked on their edges, facing perpendicular to the line of the rows. The second layer of bricks is stacked parallel to the row, with small gaps between the four bricks. The fourth row, forming a bridge across the open gaps in the base of the rows, is five tightly stacked bricks, strong enough to bear the weight of the eleven rows of bricks stacked upon it.

Potongan C—D : Dilihat dari ujung jejeran, tumpukan batu bata akan tampak seperti ini. Mulai dari lapisan batu bata yang ke-sembilan, batu-batu bata ditempatkan melintang menjembatani celah-celah antara jejeran-jejeran batu bata untuk memperkokoh susunan batu bata yang tinggi itu dan mencegahnya condong atau roboh.

Potongan E—F : Suatu potongan melintang di pusat jejeran sekali lagi memperlihatkan bahwa hampir semua batu bata dipasang pada sisinya, tegak lurus pada arah jejeran. Lapisan batu bata yang kedua disusun sejajar dengan arah jejeran, dengan celah-celah sempit di antara keempat batu bata yang ber-sangkutan. Jejeran keempat, yang mem-bentuk suatu jembatan yang merentangi celah-celah terbuka di dasar jejeran-jejeran, terdiri dari lima buah batu bata yang disusun dengan rapat, serta cukup kuat untuk men-dukung beban sebelas jejeran batu bata yang ditumpuk di atasnya.

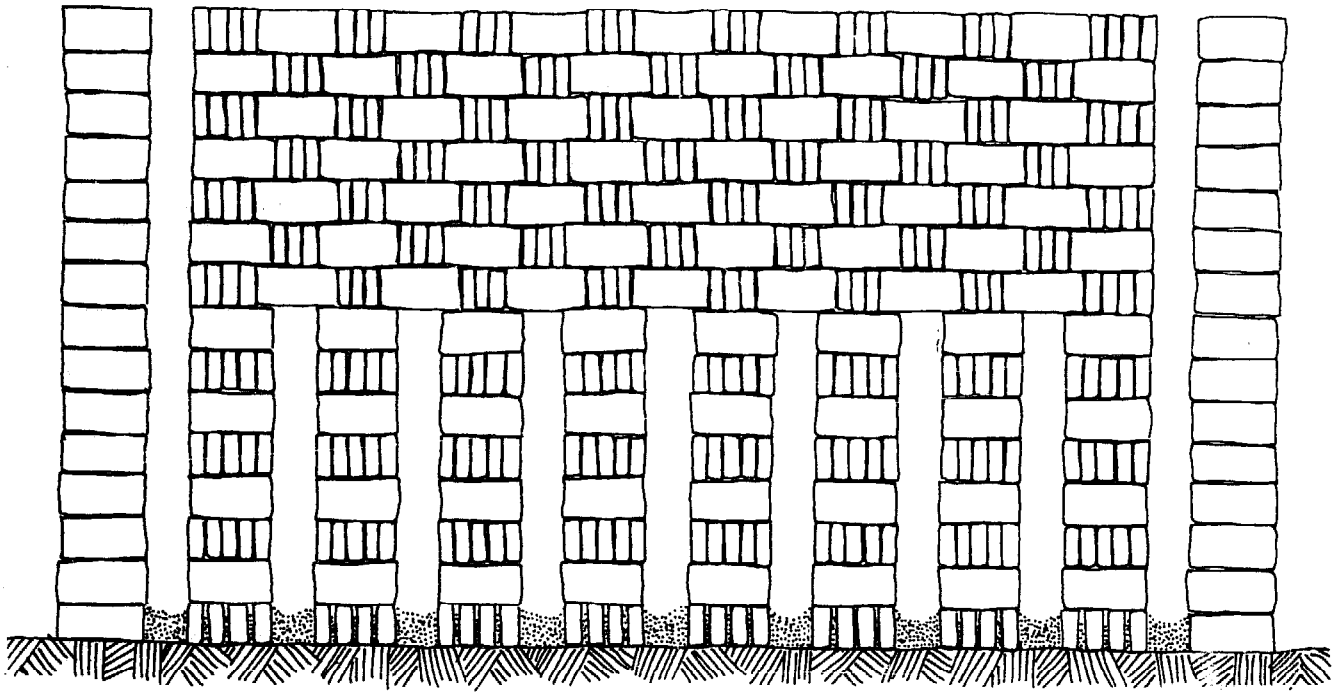

Cross-section / Potongan C - D

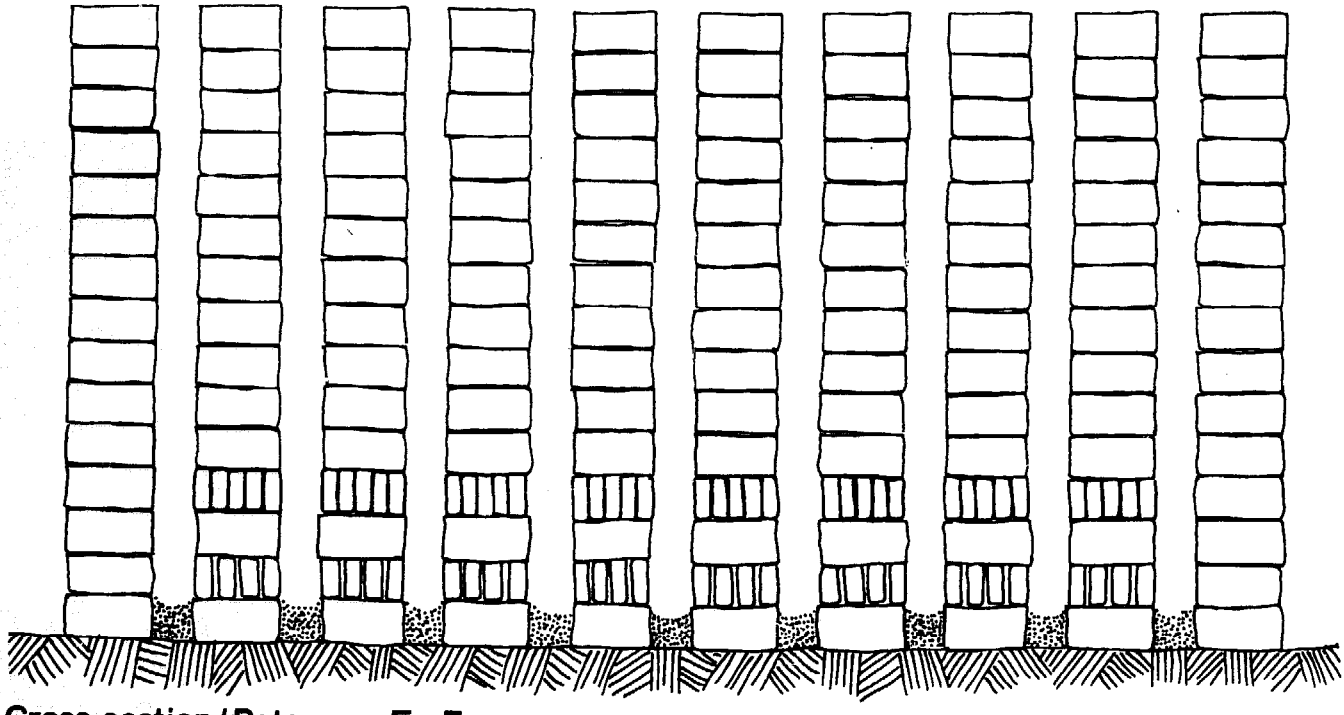

Cross-section / Potongan E - F

Roof tile kiln: Java

This is a small kiln used to fire roof tiles in Central Java, using rice husks, straw, and trash as fuel. The kiln is made of stones and mud, and has two open channels running through the base of the structure. Once the kiln is loaded, these channels are filled with trash and straw which is ignited from both ends. As this burns, the coals and ashes are raked out and piled on top of the tiles, and the channels are refilled. This process is repeated for about 8 hours, until the tiles have achieved a deep red color.

Dapur pembakaran genteng : Jawa

Ini adalah suatu dapur kecil yang di Jawa Tengah dipergunakan untuk membakar genteng dengan bahan bakar sekam padi, jerami dan sampah. Dinding dapur itu terbuat dari batu dan lumpur, mempunyai dua buah saluran terbuka di sepanjang dasarnya. Jika dapur tersebut telah diisi, saluran-saluran ini diisi dengan jerami dan sampah yang kemudian dinyalakan dari kedua ujung saluran itu. Jika bahan-bahan ini telah dimakan api, arang dan abu dikeluarkan dan ditumpuk di atas susunan genteng dan saluran-saluran itu diisi kembali. Proses ini diulang selama kira-kira 8 jam, sampai genteng-genteng yang sedang dibakar mendapatkan warna merah tua.

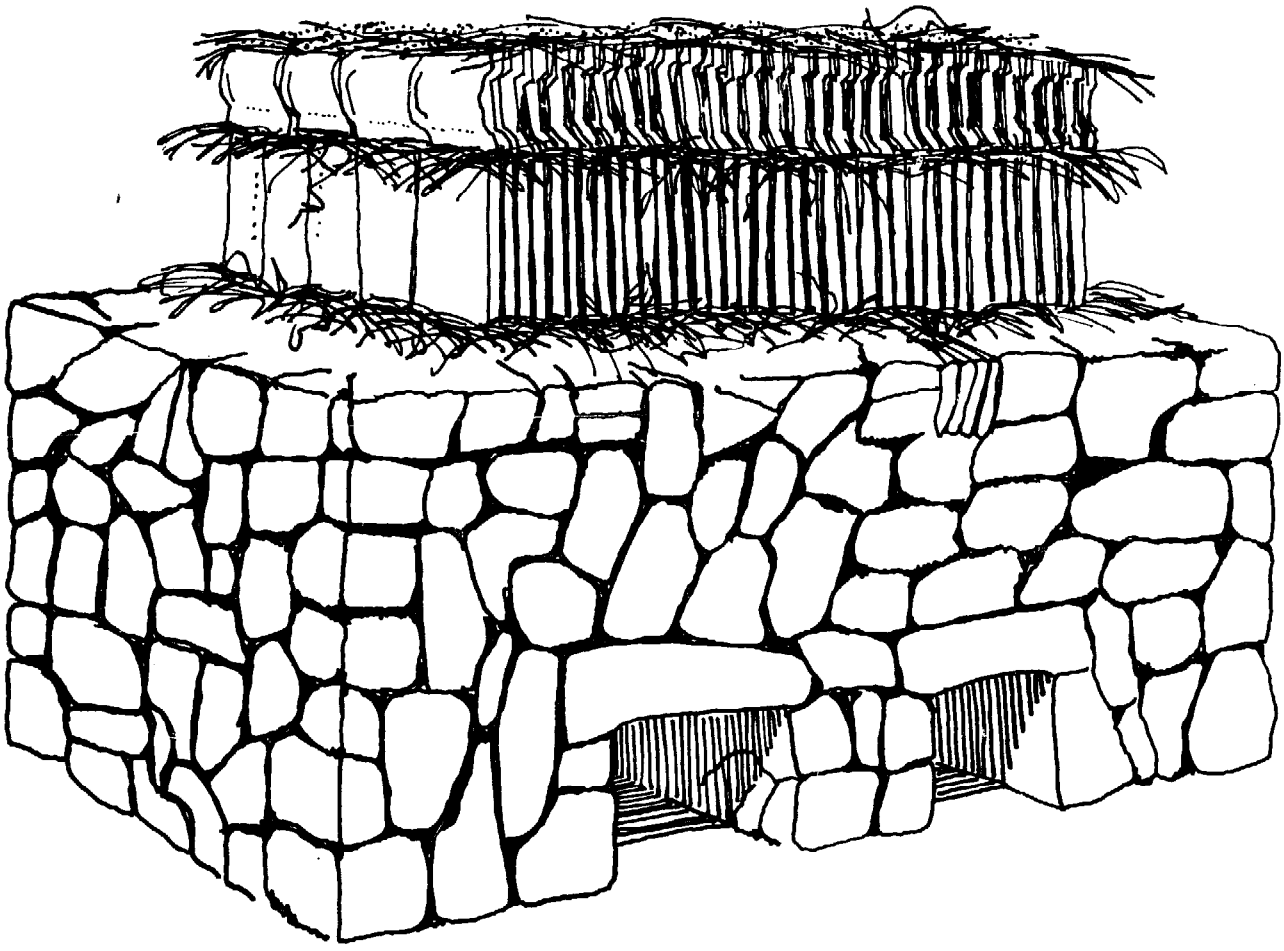

This cross-sectional view of the loaded kiln shows the stacking of the tiles standing on end packed very tightly. All gaps are filled with rice husks and straw, and a layer of these materials is spread over the top of each layer before the following layer is added. One loading fires about 1500 tiles.

Pandangan potongan melintang dari dapur yang telah diisi ini memperlihatkan bahwa genteng disusun secara tegak dengan sangat rapat. Semua celah diisi dengan sekam padi dan jerami, dan selapisan bahan-bahan ini ditebarkan di atas setiap lapisan genteng sebelum lapisan genteng yang berikutnya disusun lagi di atasnya. Dalam satu kali pembakaran dapat dibakar kira-kira 1500 buah genteng.

Measurement / Ukuran : cm

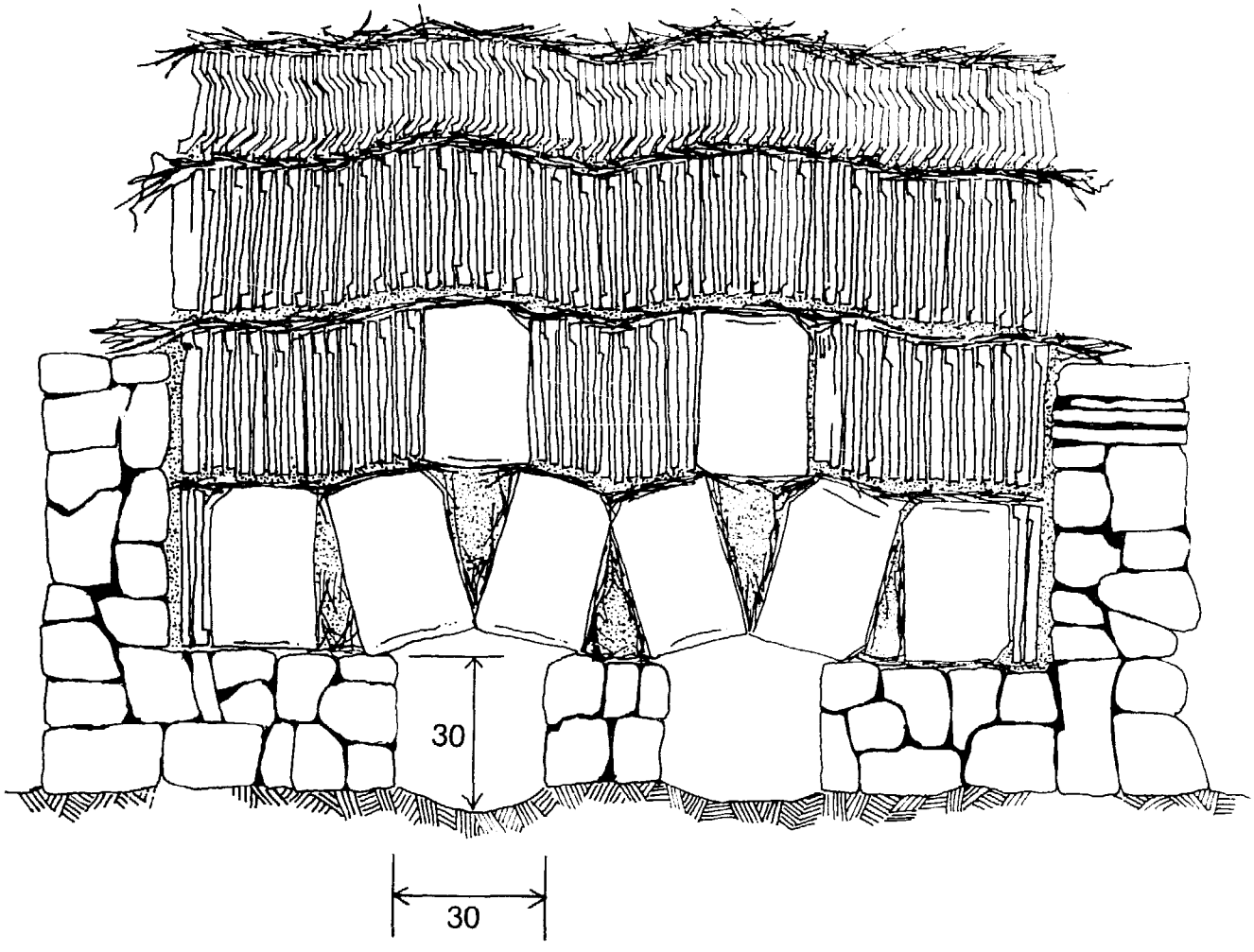

Banana ripening: Bali

In Bali, smoldering rice husks are also used to ripen bananas. Bananas must be picked while still green in order to avoid damage during transport and storing. When Balinese villagers want to eat the bananas, they hang them inside a drum or large pot closed with a tight-fitting lid and sealed with a paste made of rice husk ash and water. A perforated bucket of rice husks is kept smoldering on top of this container for 3 days, until the bananas are ripe. The Balinese claim that this method produces sweeter tasting bananas than the carbide gas treatment usually used.

Pematangan pisang: Bali

Di Bali, sekam padi yang membara dipergunakan pula untuk membuat pisang menjadi masak. Untuk mencegah kerusakan selama pengangkutan dan penyimpanan, pisang harus dipetik waktu masih hijau. Bila pisang itu ingin dimakan, penduduk di Bali menggantungkan pisang tersebut di dalam sebuah drum atau suatu gentong yang besar yang dapat ditutup dengan rapat dan disekat dengan suatu adonan dari abu sekam padi dan air. Sebuah ember yang diberi lubang diisi dengan sekam padi yang membara; dibiarkan di atas wadah tersebut selama tiga hari, sampai pisangnya masak. Orang-orang di Bali berpendapat bahwa cara ini menghasilkan pisang yang lebih manis rasanya daripada pisang yang di-"karbit" seperti yang dilakukan di daerah lain.

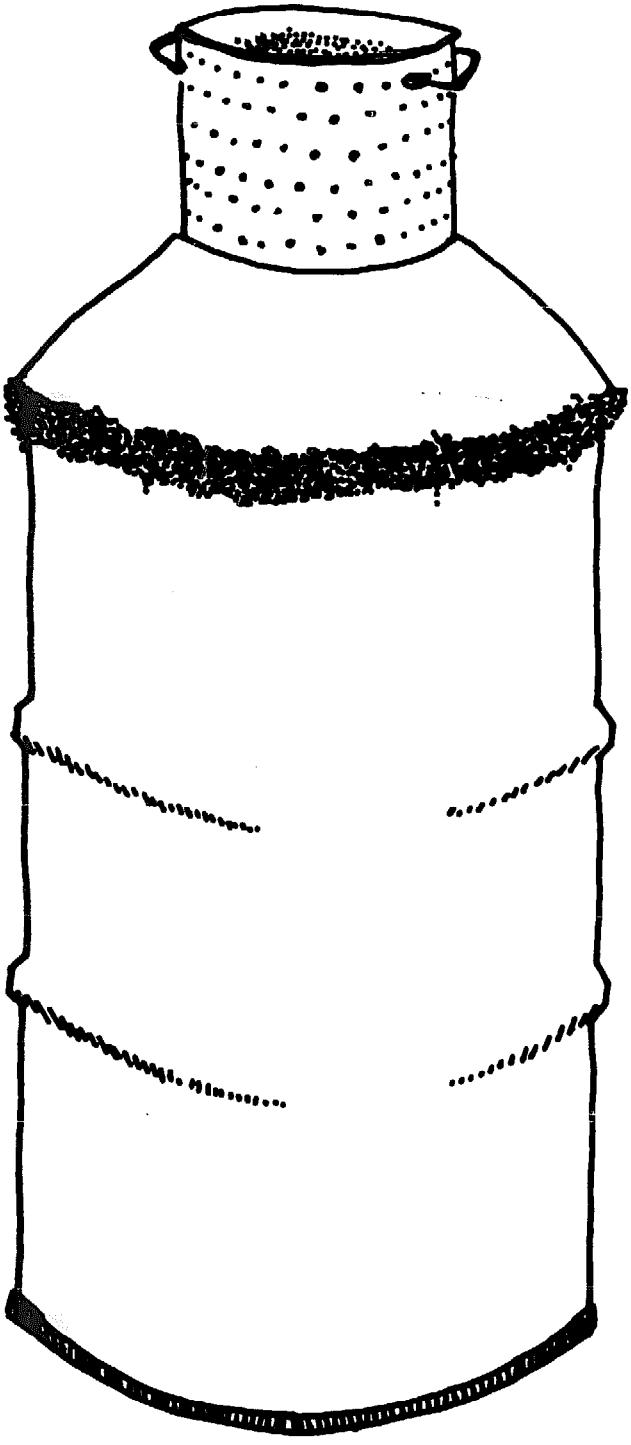

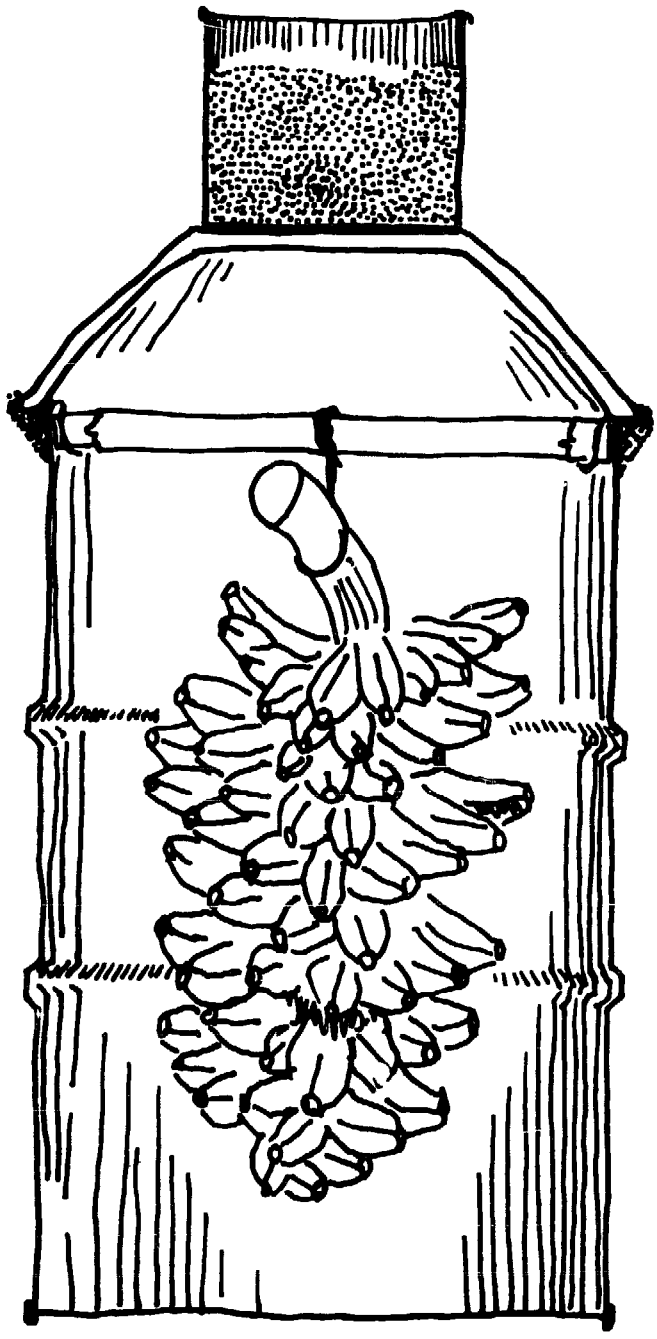

CONCLUDING REMARKS

People have been using rice husks and sawdust as fuel for decades. The examples shown in this book are a sample of the many types of stoves and techniques currently in use. Their existence and ongoing utilization attest to the viability of this energy source. Still, rice husks are viewed by many as a useless waste product of rice processing, and a nuisance to dispose of. In many of the areas where rice mills all have huge heaps of smoldering husks creating nothing more useful than smoke and powdery white ash, deforestation already threatens the supply of water necessary to grow the rice.

It is true that rice husks do have certain shortcomings as a fuel source. They are bulky, messy, and produce large quantities of ash. But they are plentiful, cheap, and in some cases practically the only fuel available.

KATA PENUTUP

Sudah berpuluh tahun orang mempergunakan sekam padi dan serbuk gergaji sebagai bahan bakar. Contoh-contoh yang diberikan dalam buku ini hanyalah merupakan sebagian dari berbagai jenis tungku dan berbagai teknik yang dewasa ini telah dipergunakan. Adanya serta penggunaan tungku-tungku dan teknik-teknik tersebut selama ini cukup membuktikan bahwa sumber energi ini memang berfaedah. Namun demikian masih banyak orang menganggap sekam padi hanya sebagai hasil sampingan pengolahan padi yang berguna, sebagai sampah yang merepotkan dan perlu dibuang. Di banyak daerah di mana dekat setiap penggilingan beras terdapat tumpukan-tumpukan besar sekam padi yang membara yang hanya menghasilkan asap tebal dan abu berupa serbuk putih yang tidak bermanfaat untuk apapun, penggundulan hutan telah mengancam kelangsungan persediaan air yang dibutuhkan untuk menanam padi.

Memang benar bahwa sebagai bahan bakar, sekam padi mempunyai banyak kekurangan. Sekam padi banyak mengambil tempat, kotor dan menghasilkan sejumlah

It is our hope in producing this book that people in areas where this fuel is being wasted can adapt some of these designs or create their own specifically suited to their own needs, skills, and materials. It is also our hope that this publication will prompt people in areas where rice husks are being used to share their designs, ideas, and innovations.

We would greatly appreciate receiving any designs or ideas related to the utilization of rice husks and sawdust, and any suggestions as to how our next publications on the subject can be improved. We view this book as the first step in establishing a better collection and communication of information and ideas which will contribute to the broader and more effective utilization of a valuable energy source.

Designs, ideas, and suggestions should be sent to :

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or

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besar abu. Namun sekam padi juga murah, tersedia dalam jumlah yang banyak, dan dalam keadaan-keadaan tertentu merupakan satu-satunya jenis bahan bakar yang tersedia. Harapan kami dengan menerbitkan buku ini adalah bahwa penduduk di daerah-daerah di mana bahan bakar ini sampai sekarang masih disia-siakan, dapat menerapkan atau menyesuaikan beberapa di antara rancangan-rancangan ini atau menciptakan rancangan-nya sendiri, sesuai dengan kebutuhan, ke-trampilan dan bahan-bahan yang dimilikinya sendiri. Kami juga mengharapkan bahwa penerbitan ini merangsang penduduk di daerah di mana bahan bakar ini telah diper-gunakan untuk saling bertukar rancangan, gagasan, penemuan-penemuan baru dan pengalaman dalam hal penggunaan bahan bakar ini.

Kami akan sangat menghargai kesediaan Anda untuk menyampaikan kepada kami setiap rancangan atau gagasan yang ber-hubungan dengan pendayagunaan sekam padi dan serbuk gergaji, serta setiap saran mengenai bagaimana penerbitan kami me-ngenai pokok masalah ini selanjutnya dapat ditingkatkan. Kami sendiri memandang buku ini sebagai langkah pertama ke arah pengadaan suatu himpunan dan pertukaran informasi dan gagasan-gagasan yang lebih baik yang akan merupakan suatu sumbangan bagi pendayagunaan yang lebih luas dan lebih berdayahasil dari suatu sumber energi yang bernilai. Rancangan, gagasan serta saran Anda dapat disampaikan kepada :

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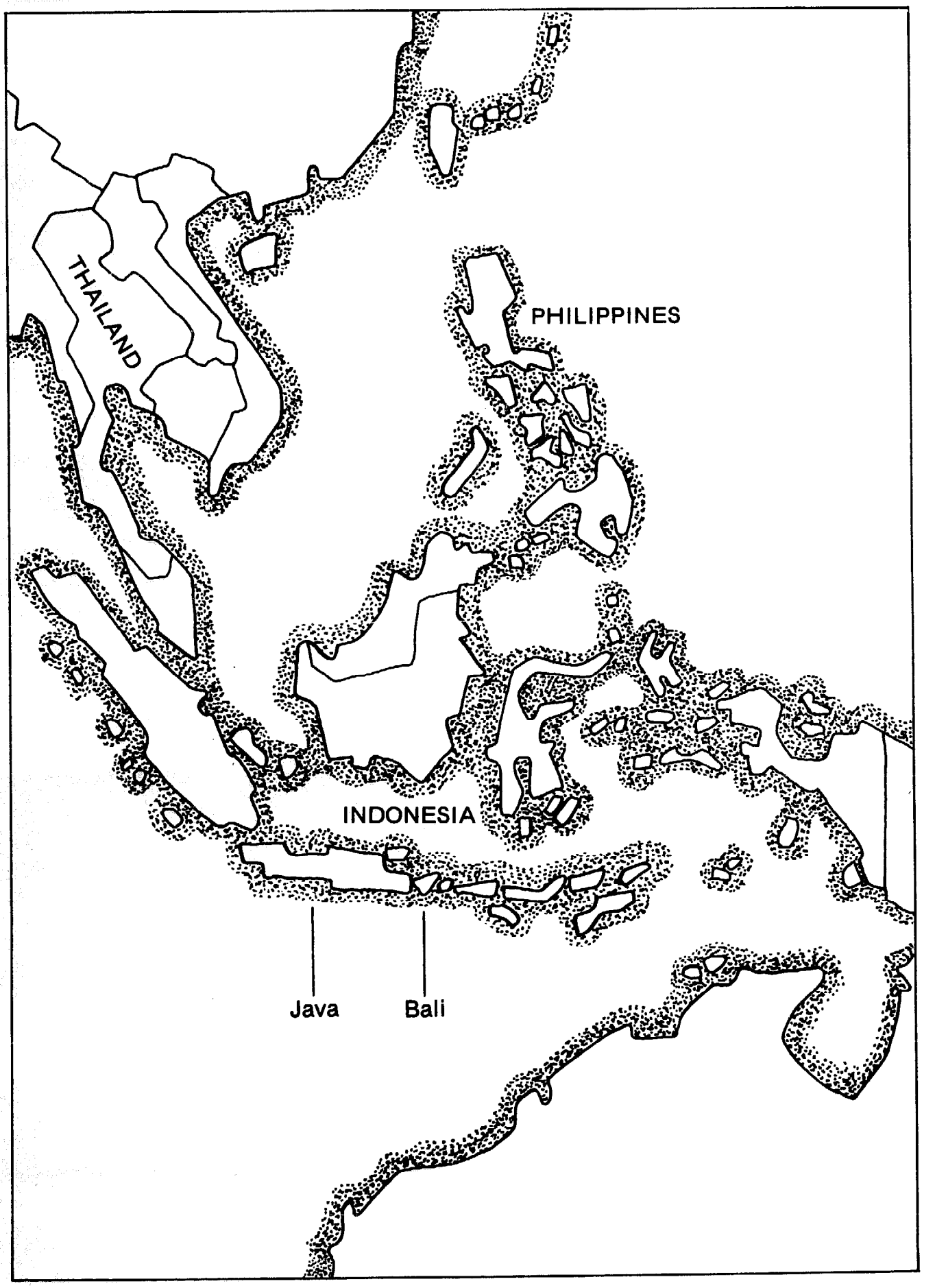
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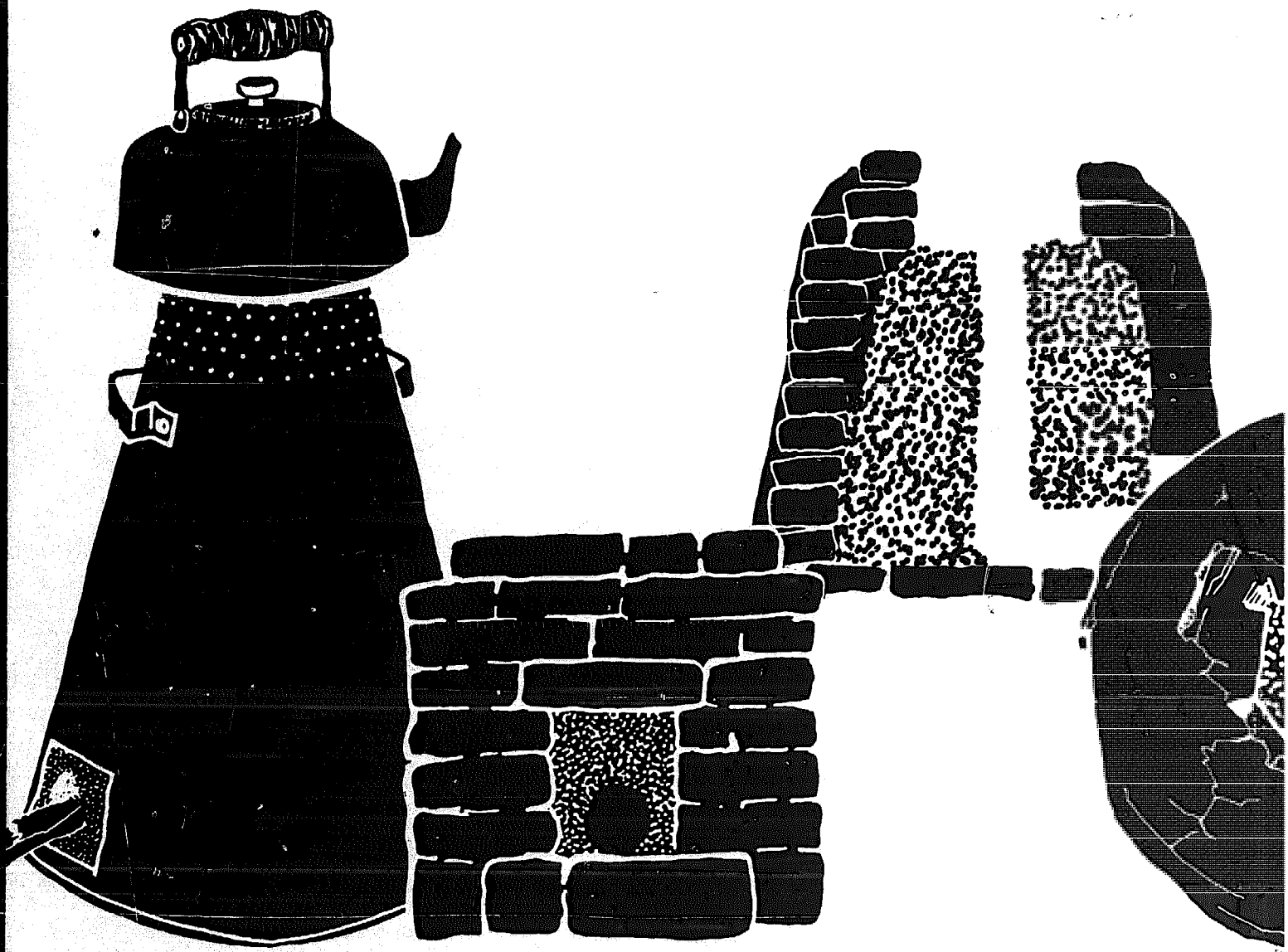

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Rice: Postharvest Technology

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RICE
postharvest technology

Editors: E. V. Araullo, D. B. de Padua, and Michael Graham

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RICE
Postharvest Technology

Edited by E. V. ARAULLO
International Development Research Centre
Singapore

D. B. DE PADUA
University of the Philippines at Los Baños

MICHAEL GRAHAM
International Development Research Centre
Ottawa

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Foreword

The contents of this publication represent an immense amount of thoughtful and valuable work. It is indeed encouraging to observe how much attention and investment is being devoted to increasing the yield potential of the rice plant and to the development and demonstration of improved systems of rice production in South and Southeast Asia. On the other hand much less effort has been devoted to the postharvest rice system: the continuum of activities that begins with the harvest and ends when the rice grain is eaten and its by-products are efficiently used.

This training manual, which is the outcome of a regional training course presented at the University of the Philippines at Los Baños, provides a wealth of useful information and advice to all who are directly concerned with rice production, protection, processing, marketing, distribution, and use. The contributors, together with all those who took part in organizing and presenting the course, and in the design, compilation, and editing of this publication are to be warmly congratulated upon the service they have rendered to international food and agricultural development.

JOSEPH H. HULSE
Program Director
Agriculture, Food and Nutrition Sciences
International Development Research Centre
Ottawa, Canada

Contributors

John Rawnsley Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines

Bienvenido O. Juliano Department of Agricultural Chemistry, International Rice Research Institute, Los Baños, Laguna, Philippines

Noel G. Mamicipic Department of Agronomy, University of the Philippines at Los Baños, College, Laguna, Philippines

U Thet Zin Food and Agriculture Organization of the United Nations, Regional Office, Bangkok, Thailand

Harry van Ruiten Department of Agricultural Engineering, University of the Philippines at Los Baños, College, Laguna, Philippines

M. B. de Ramos College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines

Amir U. Khan Department of Agricultural Engineering, International Rice Research Institute, Los Baños, Laguna, Philippines

James M. Beck Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines

D. B. de Padua Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines

Florendo C. Quebral Department of Plant Pathology, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines

Nawab Ali Agricultural Engineering Department, Indian Institute of Technology, Kharagpur-721302 W.B., India

T. P. Ojha Agricultural Engineering Department, Indian Institute of Technology, Kharagpur-721302 W.B., India

James Wimberly IRRI – Ford Foundation Sri Lanka, Rice Processing Project, Colombo, Sri Lanka

Nora C. Quebral Department of Development Communications, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines

Bart Duff Department of Agricultural Engineering, International Rice Research Institute, Los Baños, Laguna, Philippines

Ida Estioko Department of Agricultural Engineering, International Rice Research Institute, Los Baños, Laguna, Philippines

J. D. Drilon Southeast Asian Regional Centre for Graduate Study and Research in Agriculture, College, Laguna, Philippines

Vicente U. Quintana Agricultural Credit and Cooperative Institute, University of the Philippines at Los Baños, College, Laguna, Philippines

Manuel B. Villar, Jr. University of the Philippines at Los Baños, College, Laguna, Philippines

Jose C. Lapus University of the Philippines at Los Baños, College, Laguna, Philippines

R. Chandrasekaran Paddy Processing Research Centre, M. R. Mill, Tiruvarur, S. India

P. Pillaiyar Paddy Processing Research Centre, M. R. Mill, Tiruvarur, S. India

Sjuhinar Bustami Ricc Mill "Sinar Kongsi," 58 Diponegoro, Padang, W. Sumatra, Indonesia

Kong Samol Agriculture Department, Phnom Penh, Khmer Republic

Chhieu Nam Agriculture Department, Phnom Penh, Khmer Republic

Thao Sommai Department of Agriculture, Vientiane Province, Laos

Luang Baccam Department of Agriculture, Vientiane Province, Laos

Ahmad Annuar bin Mohd. Ibrahim National Padi and Rice Board, Tingkat 20-21, Bangunan UMBC, 4 Jalan Sulaiman, Kuala Lumpur, Malaysia

Abdul Rahman bin Mohd. Dalib National Padi and Rice Board, Tingkat 20-21, Bangunan UMBC, 4 Jalan Sulaiman, Kuala Lumpur, Malaysia

Salim bin Abdul Hamid National Padi and Rice Board, Tingkat 20-21, Bangunan UMBC, 4 Jalan Sulaiman, Kuala Lumpur, Malaysia

T. B. Karki Ministry of Food, Agriculture, and Irrigation, Department of Food, Agriculture, and Marketing Services, Shri Mahal, Kathmandu, Nepal

Ernesto Tubon Technical Research and Services Division, National Grains Authority, Quezon Boulevard Extension, Quezon City, Philippines

Javier Lozada, Jr. Technical Research and Services Division, National Grains Authority, Quezon Boulevard Extension, Quezon City, Philippines

B. D. E. M. Pereira Paddy Marketing Board, P.O. Box 205, Colombo 5, Sri Lanka

F. S. Y. Samuel Paddy Marketing Board, P.O. Box 205, Colombo 5, Sri Lanka

Chaw Suvansatit 516/19 Larnluang Road, Bangkok, Thailand

Prayoon Sawangsak College of Agriculture, Kasetsart University, Bangkok 9, Thailand

C. L. Intong, Jr. Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines

RICE
Postharvest Technology

FOREWORD

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Introduction

A cooperative research program in postharvest rice technology was initiated by a working group of food scientists and technologists from Asia that met first in Singapore in March 1972. One of the priorities identified by this group was the need for short courses, training sessions, and seminars dealing with postharvest systems. Training sessions were specifically needed to provide intensive training for development managers, technicians, and engineers so that they could return to their countries to rehabilitate old facilities, to manage and operate new and existing complexes, and to serve as extension engineers.

This manual is derived from material prepared for one such training course in postharvest technology that took place at the University of the Philippines in April 1973 and was sponsored, in response to the working group's recommendation, by the IDRC and the Canada Plus One Project in cooperation with the Southeast Asian Centre for Agriculture and the United Nations Development Program Grain Industries Project (RP/UNDP SF/PHI-70 534).

The introductory sections describe some of the anatomical and biochemical properties of the rice grain in relation to postharvest processing problems. By examining the mechanical and thermal stresses that are applied during processing operations in conjunction with the anatomy of the rice grain, insight is obtained into the causes of breakage during various processing operations. Biochemical studies are correlated to variations in milling and cooking quality to identify the critical factors for consumer preference and to examine the effect of grain hardness on milling quality.

The importance of the seed to the viability of the whole grain industry is stressed in Standards, and two methods of maintaining seed quality, the limited generation system of seed multiplication and seed certification, are presented. In order to establish quality standards it is essential that grain should be graded. The advantages and disadvantages of various grading machines and their operational principles are examined. However, to ensure the accuracy of both grading and laboratory analyses, it is essential that proper experimental design and sampling techniques be used. These subjects are reviewed and a model grading system and the Philippine rice grading specifications are included as practical examples.

Suitable harvesting and threshing methods are required to achieve the optimum benefit from improved production techniques. Harvesting and Threshing covers the gradual changeover, from labour-intensive manual operations to mechanization, that is occurring in the tropical regions of the world. The constraints affecting farmers, farms, crops, and equipment are stressed,

and the methods for harvesting and threshing and their influence on grain yield and quality are reviewed.

A review of the principles of psychrometry and some examples of the practical application of the psychrometric chart are included in Drying since a knowledge of the properties of air is essential for an understanding of the processes involved in grain drying and storage. The significance, representation, and determination of the moisture content of the grain are stressed since moisture content is one of the most important indices for timing the harvest and for ensuring safe storage and maximum milling recovery. Because the rice grain is a living, respiring biological product, its respiration rate must be reduced for safe storage by decreasing its moisture content to 14% or less on a dry weight basis. The principles and practices used for reducing the moisture content are outlined and several systems are described.

The climatic conditions of Southeast Asia are very favourable to rapid insect and microbial growth, and in general create unique problems for grain storage. Therefore, careful consideration must be given to the methods of construction of storage facilities. In Storage the biological and physical constraints governing safe storage and the problems associated with infestations of moulds, insects, and other storage pests are discussed. Recommendations are given for the prevention of infestations and for other design parameters of storage facilities, such as methods of temperature and relative humidity control especially suited to the tropics.

Many premilling techniques have been devised to increase the milling, nutritional, cooking, and eating quality of rice. The latest and most widely used of these treatments is parboiling. Parboiling technology has evolved from simple methods to complex industrial ones, and several methods and their advantages and disadvantages are described. The basic principles of parboiling and their effect on chemical, biological, and eating quality are outlined. Costs analyses of both a traditional and a modern parboiling plant are presented to point out differences in the cost of parboiling and drying one tonne of paddy.

Regardless of whether or not the rice is parboiled, it must be hulled and milled efficiently. However, maximum efficiency and yield can only be ensured by correct adjustment and operation of the milling machinery. The machines are described in great detail in Milling, affording insight into their operation, and providing a firm basis for an understanding of the principles of their operation. By combining the description of their operation with the preceding information on the characteristics of the rice grain, precautions and recommendations for precleaning, hulling, husk and paddy separation, whitening, polishing, and glazing are obtained. The comparative performance of different rice mills is also illustrated.

The methods and systems of moving both bulk and sacked grain are discussed in Handling and Conveying. Several conveying systems are shown and the uses and advantages of each system are discussed.

The section on Implementation is devoted to the software necessary for the successful development of the grain industries. The importance of effective communication of the improvements in processing technology are outlined, and the necessity of establishing design criteria that meet the needs of developing countries are explained. Agribusiness management concepts and cooperatives are reviewed to furnish ideas for effective organization and col-

laboration for the benefit of both the individual farmer and the whole processing industry. In addition, two case studies are presented.

In Processing Methods the practices and special problems related to the rice processing industries in various Southeast Asian countries are examined, and suggestions for improvements and modifications to increase the efficiency of individual systems are explained.

An Appendix includes the results of drying and milling tests and the labour and power requirements for various harvesting and processing operations and provides a basis for some general comparisons between different systems and procedures. In addition, biological and physical properties of both the rice plant and the grain are given.

By virtue of its broad coverage, the manual is designed to be both a teaching aid for future training sessions and a convenient referenee for those engaged in improved methods of rice teehnology.

To all those people who contributed directly or indirectly to the success of the training course that formed the basis for this manual, and in particular to the staff of the University of the Philippines at Los Baños, I wish to express my sincere thanks.

E. V. Araullo
Senior Program Officer
Agriculture, Food and Nutrition Sciences
International Development Research Centre
Asia Regional Office
Singapore

BIOLOGY

Anatomical Studies

An understanding of the gross anatomy of the rice grain will: (1) clarify the reason rice kernels break so easily on mechanical impact during the physical operations of threshing and milling and under thermal stress during drying; (2) give a fairly precise visual determination of the degree of milling and, consequently, the period of whitening that will produce a particular combination of the required recovery, nutrition, and palatability; (3) indicate a means of visually examining the effects of different hulling methods on the surface tissue of the grain kernel and the importance of this in storage; (4) demonstrate the importance of the correct adjustment of hulling machines to take advantage of the structure of the grain in preventing breakage; and (5) present the possibilities in certain circumstances of benefitting from the much greater bulk density of brown rice compared with paddy and, therefore, economizing on storage volume.

Anatomy of the Rice Grain

The outermost tissue of the grain is commonly known as the husk and is formed from two specialized leaves, the lemma covering the dorsal part of the seed and the palea covering the ventral portion. The palea and lemma are very loosely joined together longitudinally by means of an interlocking fold on each side of the seed, and they are consequently very easily separated. The husk is formed mostly of cellulosic and fibrous tissue and is covered with very hard glass-like spines. In the dry seed there is a distinct space between the husk and the caryopsis (kernel).

The outermost layer of tissue of the caryopsis is a thin sheet of fibrous cells, the pericarp. This is sometimes called the silver skin because of its very flimsy and fibrous appearance when it is dissected from the grain. The thin pericarp layer is a very hard tissue that is highly impermeable to the movement of oxygen, carbon dioxide, and water vapour. When it is intact it provides very good protection against mould attack and oxidative and enzymatic deterioration of the underlying tissues. Beneath the pericarp is the tegmen, which is a layer several cells in thickness. These cells are also a part of the seedcoat but are less fibrous than the pericarp layer. They are rich in oil and protein but contain little starch. Beneath the tegmen is a layer of tissue several cells in thickness commonly known as the aleurone layer or bran. This layer of cells is very rich in protein, oil, and vitamins with a relatively small amount of starch. The shape of the cells is somewhat hexagonal to spherical. The innermost tissue of the caryopsis is the starchy endosperm, which contains only a very small percentage of protein. In the central core of the grain the starchy cells are somewhat hexagonal in shape, but between the centre and the outside they are elongated with the long walls radiating outwards from the centre. It is the radial walls of the starchy cells that form thousands of potential cleavage planes that may result in breakage of the grain as a result of mechanical impact or thermal or moisture stress during processing.

In cross section the total caryopsis has an undulating shape, the undulations corresponding with those of the husk. The undulating form is important in the whitening process because the bran layer can only be removed entirely when the undulations have been completely levelled.

Significance of Grain Anatomy in Processing and Handling

The paddy grain, which is very fibrous and covered with hard spines, is very abrasive and easily causes wear and tear in mild steel conveying ducts. For this reason, chain, flight, and belt conveyors are often used.

The distinct space between the husk and

the caryopsis in dried grain allows the grain to be dehusked without any or with very little abrasion to the pericarp. Provided the clearance between the shearing surfaces of the hulling machinery is very critically adjusted, the palea and the lemma can be separated from the caryopsis with only a minimal mechanical stress against the surface of the caryopsis. Dehusking between rubber rollers can be effective without scratching the pericarp. On the other hand, with the emery disc type of hulling, even if very well adjusted, it is difficult to avoid at least some abrasion of the pericarp. When such abrasion does occur, it usually results in damage to the oily layers beneath the pericarp that release lipase enzyme, which results in enzymatic hydrolysis of the oil to produce free fatty acids, that are commonly manifested as rancidity. If the grain is to be stored in the form of brown rice, it is extremely important that the pericarp of the caryopsis is not damaged during the dehusking process. There are a number of advantages to be gained from storing the grain as brown rice, principally the fact that brown rice occupies about half the volume of an equivalent quantity of paddy. It may also be useful to store the grain as brown rice in large milling centrals because they are equipped to dispose of the large quantities of husk created.

The radiating configuration of the outer starchy cells of the endosperm makes breakage very easy in the grain. The risk of such breakage is quite clearly much greater when impact is exerted along the side of the grain rather than at the end. It has been observed that breakage during the manual beating of grain, even at a moisture content of about 20%, is much greater than in certain types of mechanical threshing where the force is applied to the ends of the grain. The alignment of the longitudinal walls of the starch cells across the body of the grain makes it very friable during the drying process and when the temperature of the grain reaches 48 °C, thermal stress is likely to cause breakage. Further mechanical stress may be the cause of grain breakage during conveying and milling.

It is very important to avoid breakage of the rice because in the whitening stage of the milling process, the surface area of the grain exposed to abrasion is much greater, and much more than bran is lost. This results in a low total recovery and a low recovery of whole grain.

Some Staining Techniques that Reveal the Action of Milling Machinery

It has been mentioned that in rubber roll hulling the husk may be removed without damage to the pericarp layer of the caryopsis. This is particularly important in storage, because the pericarp layer is highly impervious to gaseous exchange, and protects the bran oil from oxidation and hydrolysis. On the other hand, it is difficult to avoid at least some abrasion of the pericarp during emery disc type hulling. This effect can be observed with the naked eye by staining the grain with a standard solution of iodine in alcohol and water. Where the pericarp is damaged the exposed starchy cells below take on an almost black colour, and the pericarp and bran cells are not affected.[1] With rubber roll hulling there may be no starchy endosperm exposed, but almost invariably emery disc hulling leaves the pericarp extensively pitted, resulting in the corresponding pattern of black stains with iodine. Such abrasion of the pericarp tissue may also be accompanied by grain breakage or cracking as a result of mechanical stress.

Iodine staining may also be used to determine at what point during the whitening cycle the bran is removed completely. During whitening the pericarp may be removed during the first 15 s, leaving the starchy endosperm virtually untouched and covered with most of the bran. At this point the fibrous tissue, which is usually regarded as objectionable from the eating point of view, is already removed completely. Most of the soft bran tissue is removed during the next 1.5–2 min, leaving only a small amount of bran with most of the starchy endosperm exposed. Continued whitening usually results in the removal of the ridges of the caryopsis only, still leaving the strips of bran in the depressions between the ridges. Com-

[1]Details of the chemical composition of the rice grain are found in "Biochemical Studies."

plete whitening, with removal of almost all the bran, may only be achieved by polishing, following 4–6 min of whitening.

The grain might be considered as quite palatable after only 1.5–2 min of whitening and if this were the ease, it would fortunately coincide with high recovery and high nutritional value because most of the protein and vitamins, in addition to oil, are in the bran layer.

The removal of the bran may also be demonstrated by staining the progressively whitened rice with a standard solution of Sudan 4 in alcohol and water. This stain causes a red coloration in oily tissue, and consequently the bran and the germ are very clearly stained. This staining produces a pattern, which is the reciprocal of the iodine staining.

The staining techniques described above cannot be universally standardized because they are useful only to describe what happens in a particular set of rice machinery. The removal of the bran, with the same rice variety, has a different rate in, for example, cone-type whitening, abrasive disc-type whitening, and horizontal steel cylinder whitening. — JOHN RAWNSLEY. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

Biochemical Studies

The rice grain consists of the edible portion, brown rice, enclosed by the hull or husk. Starch is the major constituent of rice and is present in the endosperm as compound granules 3–10 μm in size. Protein is the next major constituent and exists in the endosperm as bodies 1–4 μm in size. The concentration of nonstarch constituents is higher in the bran and germ fractions than in the endosperm. Starch and protein accumulation in the grain is essentially complete 3 weeks after flowering. Opaque portions in nonwaxy or nong[illegible]us grains contribute to high grain breakage during milling. Cooking time is affected directly by the gelatinization temperature of the starch and by the protein content. The amylose/amylopectin ratio is the major factor influencing water absorption and volume expansion during cooking, as well as the texture and gloss of boiled milled rice. However, varieties of similar amylose content are known to differ in eating quality due to differences in starch gel consistency and viscosity. Aging through storage results in higher total and head rice yields, greater water absorption and volume expansion during boiling, a more flaky boiled rice, and reduced solubility of starch and protein in water.

Gross Composition and Properties of Brown Rice

Proximate Analysis

The edible portion of rough rice, the brown rice, consists of about 8% protein, 75% carbohydrates, and small amounts of fat, fibre, and ash at 14% moisture (Table 1). Milled rice (endosperm) has 7% protein and 78% carbohydrates (mainly starch). These nutrients are unevenly distributed in the rice seed. The nonstarchy constituents, particularly fat, fibre, minerals (ash), and vitamins, are concentrated in the aleurone layers and germ; whereas, starch is found mainly in the endosperm. Protein distribution in the grain cross section becomes more even as protein content increases.

Properties of Starch and Protein

Starch and protein are the major constituents of milled rice. Starch is present in the form of compound granules 3–5 μm in size. These starch granules are polyhedral due to their close packing in the endosperm cells of the mature grain. The protein in the endosperm exists in the form of discrete particles (protein bodies) 1–4 μm in size.

TABLE 1. Caloric and nutrient contents of brown and milled rices and the losses during milling.

	Brown rice (Pinawa)	Milled rice (Bigas)	Loss during milling (%)[a]
Moisture	14.0	14.0	10
Food energy (Kcal/100 g)	352	354	10
Protein (g/ 100g)	8.3	7.1	23
Fat (g/100 g)	1.9	0.5	76
Total carbohydrate (g/100 g)	74.9	77.8	6
Fibre (g/100 g)	0.7	0.4	49
Ash (g/100 g)	1.1	0.6	51
Calcium (mg/100 g)	9	8	20
Phosphorus (mg/100 g)	183	104	49
Iron (mg/100 g)	1.6	1.2	32
Thiamine (mg/100 g)	0.29	0.10	69
Riboflavin (mg/100 g)	0.07	0.05	36
Niacin (mg/100 g)	3.9	2.3	47

[a]Based on 10% bran removal and on the total nutrient content of brown rice.

Starch molecules in the granule occur in an orderly arrangement giving crystallinity to the granule in both waxy and nonwaxy rices. One characteristic physical property of the starch is its gelatinization temperature, the temperature range in which the starch granules start to swell irreversibly in hot water with loss of crystallinity. The range of final gelatinization temperature of rice starch is 56–59 °C. Gelatinization temperature is measured by the extent of disintegration of milled rice in the alkali test.

Starch granules are fairly hygroscopic; therefore, the moisture content of the rice grain readily changes with a change in storage temperature or relative humidity. Its moisture content is about 14% at 75% relative humidity (27–32 °C).

Starch is made up of glucose units and occurs as two distinct fractions – a branched fraction amylopectin and a linear fraction amylose. Starch may be classified as waxy or glutinous (mainly amylopectin or less than 2% amylose), or nonwaxy or nonglutinous (containing more than 5% amylose). Waxy starch stains reddish brown with iodine; nonwaxy starch stains purple blue with iodine; and amylose stains blue with iodine. This amylose-iodine blue colour is the basis for the analysis of the amylose content of nonwaxy starch. Amylose content of nonwaxy milled rice ranges from 7 to 33%. This corresponds to 9–37% amylose in the starch and to 63–91% amylopectin in the starch. Amylose content is, therefore, an index of amylose/amylopectin ratio. Amylose/amylopectin ratio and gelatinization temperature are generally independent properties of rice starch.

Rice protein is mainly water-insoluble. It is usually determined from Kjeldahl nitrogen multiplied by 5.95, based on the mean nitrogen content of 16.8% of rice protein. Like starch granules, the protein bodies show in cross section an orderly arrangement of alternating electron-dense and electron-thin concentric rings.

Changes During Seed Development

Dry matter production is essentially complete 3 weeks after flowering at which time wet weight is maximum. Starch granules are first observed by 4 days after flowering and protein bodies by 7 days after flowering. In Los Baños, Philippines, maximum head rice yield is obtained between 4 and 6 weeks after flowering in the wet season (20–24% moisture) and between 4 and 5 weeks after flowering in the dry season (18–20% moisture). In a less humid climate, as in California, USA, optimum head rice yield is obtained at higher

moisture contents of 22–30% probably because of the greater stress on the grain during drying in the panicle.

Grain Dormancy

Most tropical rice varieties possess some degree of dormancy. The seeds will not germinate completely immediately after harvest and require an after-ripening period of 3–6 weeks at ambient temperature for complete germination. Dormancy in rice is not due to embryo dormancy since the excised embryo is capable of germination. The structures covering the embryo act as barriers to germination since dehulling partially breaks dormancy. Pricking the dehulled rice (brown rice) near the embryo (and not elsewhere) completely breaks dormancy. The covering structures probably reduce the diffusion of oxygen to the embryo in the dormant seeds, because dormancy may be broken by placing the grains in an oxygen atmosphere and dormant and nondormant grains have the same respiration rate during steeping in water. Hence, the causes of grain dormancy are probably biochemical.

When grains have to be planted after harvest, dormancy may be broken quickly by heat treatment up to 55 °C in open containers or by treatment with acid. The degree of dormancy is relatively less in the dry season than in the wet season due to the relatively higher temperature during the dry season.

Milling Quality

Opacity of waxy rice endosperm is due to the presence of micropores within the starch granules. Opacity of portions of nonwaxy rice grains, such as the white belly of IR8, is due to air spaces between the starch granules. Opaque portions in nonwaxy rice result in a softer grain that breaks more easily during milling than grains that are completely translucent. The endosperm of waxy rice, on the other hand, is just as hard as the endosperm of nonwaxy rice.

Studies on grain hardness are difficult to evaluate because head rice yield is affected by environmental conditions such as moisture content at harvest, conditioning and drying after harvest, and by aging during storage. In addition, coarse-grain varieties, which have more aleurone cell layers, usually require more pressure to mill to the same degree in a McGill mill than slender fine-grain varieties. Such differences in grain size and shape contribute to the difficulty in developing methods for estimating endosperm hardness.

Endosperm hardness may also be related to the packing density of the starch and grain, as reflected in the gelatinization temperature of the starch granules. Gelatinization temperature correlates with the resistance of the granule to corrosion by acid or starch hydrolyzing enzymes and to enzymic hydrolysis during early germination. However, most of the coarse grain *japonica* rices have a low gelatinization temperature, and most tropical rice varieties have an intermediate gelatinization temperature.

Cooking Quality

Rice is chiefly eaten as boiled milled rice. Cooking time is directly affected by the gelatinization temperature of the starch and by protein content. However, water absorption and volume expansion during cooking are directly affected by amylose content. Waxy or glutinous rice expands the least during cooking and its cooked grain has the heaviest bulk density.

Some rices, like Basmati D25-4 and certain Iranian varieties, show extreme elongation when presoaked grain is cooked. The nature of this property is not well understood. These samples tend to have a gelatinization temperature below 74 °C and an amylose content below 25%, but not all varieties with this combination of properties show extreme elongation.

Water soluble vitamins, such as thiamine, riboflavin and niacin, may be partially lost during washing of the milled rice before boiling and in the cooking process, particularly if the rice is cooked in excess water and the cooling gruel is discarded. Protein loss is minimal since it is essentially insoluble in water.

Eating Quality

Amylose/Amylopectin Ratio and Gel Consistency

The ratio of amylose to amylopectin in starch, as indexed by amylose content, is the chief influence on eating quality. It correlates negatively with taste panel scores for cohesiveness, tenderness, and gloss of the boiled rice. Cooked waxy rice is very sticky, tender, moist, and glossy. It retains these properties even after storage for a few hours up to a few days. It is the staple food in parts of Laos and northern Thailand. The texture of freshly boiled waxy rice is not affected by differences in gelatinization temperature; however, cooked samples with a high gelatinization temperature (74–78 °C) of the starch tend to harden faster on storage, due to the higher molecular weight of their amylopectin.

Most tropical nonwaxy varieties have amylose contents of 20% or higher, although a few, such as Khao Dawk Mali from Thailand, Chhuthana in Khmer, and IR24 in the Philippines, have lower amylose contents (14–18%). Most of these varieties have a gelatinization temperature between 70 and 74 °C. Amylose content may be classified as low (below 20%), intermediate (20–25%), and high (above 25%).

Low amylose rice is preferred in Japan and South Korea for its stickiness, tenderness, gloss, and taste (Table 2). It is more sensitive to overcooking than rices with over 20% amylose and its cooked grains disintegrate when soaked overnight. Most *japonica* varieties have a low gelatinization temperature.

Filipinos and Indonesians prefer intermediate amylose rice, because it remains soft even when stored overnight. This kind of rice has between 20 and 25% amylose.

High amylose rices differ widely in the rate of hardening of cooked rice. A gel consistency test, based on the tendency of cooled rice gel (100 mg flour in 2 ml 0.2 *N* KOH) to flow, readily classifies high amylose varieties into those with hard (26–35 mm), medium (36–50 mm), or soft (51–100 mm) gel consistency. In most of Asia, high amylose rice with

TABLE 2. Ranges of amylose content, gel consistency, and BEPT types of milled rices obtained from rice producing countries.

Country	Varieties	Amylose content range (% dry basis)	Gel consistency types[a]	BEPT types[b]
Bangladesh	20	15–26	S > MH	I > L
Burma	10	20–31	—	I
China	5	22–32	S > MH	LI
India (Hyderabad)	24	15–27	S > MH	LI
India (Maharashtra)	14	18–26	MH > S	LI
Indonesia	10	18–23	S > M	I > LH
Japan	12	12–17	S	L
Khmer Republic	6	13–26	S > H	I > L
Laos	8	waxy, 16–24	—	LI > H
Malaysia	19	10–28	SM > H	I > LH
Nepal	16	18–25	SH	L > I
Pakistan	7	21–29	HMS	LI
Philippines	18	22–30	S > MH	L > I
Sri Lanka	10	24–28	H > M	I
Taiwan	10	15–26	S > H	L > I
Thailand	12	waxy, 10–28	S > MH	L > I
South Korea	10	16–21	S	L
South Vietnam	10	18–29	S	I

[a]S = soft; M = medium; H = hard; > greater than.
[b]L = low; I = intermediate; H = high; > greater than.

a soft gel consistency is preferred over rice with a hard gel consistency. Cooked rice with a hard consistency hardens faster during cooling, shows a higher amylograph setback, a higher gel viscosity, and has a lower level of water-soluble amylose at 100 °C than rice with a soft consistency. Differences in the gel viscosity of starches of similar amylose content, including waxy starches, are due mainly to differences in the viscosity of the amylopectin fraction of starch. In Sri Lanka where most varieties have high amylose content, "samba" varieties (small- and short-grained) are preferred to bold, long-grained varieties because of their greater resistance to splitting during boiling.

Such high correlation ($r = 0.8$) between texture of cooked rice and amylose content limits the extent to which any one variety can universally meet the different eating quality preferences in various countries. Texture differences in boiled rice, rather than actual differences in flavour level, may contribute to the reported flat taste of IR8 (high amylose content) in Indonesia as compared to intermediate amylose rice like Bengawan. However, a high amylose rice with medium to soft gel consistency like IR20 and IR26 may find wider acceptability in tropical Asia than an intermediate type such as C4-63G or a high type with hard gel consistency such as IR8 and IR22. Varietal differences in eating quality within the same amylose class are common, because amylose accounts for at most 65% of the differences in eating quality.

Other Factors

Protein content is a secondary factor affecting texture. It is important in countries where the amylose range of the rice varieties is narrow. Protein is the major quality factor in Spain, although the preferred variety is higher in both protein and amylose levels than the other varieties. Differences of two percentage points in the protein content among samples of a variety have no significant effect on the colour score of cooked milled rice.

Aromatic varieties are preferred in many countries, but the preferred aroma may differ from region to region. The exact nature of the aroma has not been studied, but varieties differ in the character of the aroma. Climatic factors have a marked effect on the intensity of the aroma because it is volatile.

Aging

The rice grain changes in some properties during the first 4–6 months of storage, particularly above 15 °C, regardless of whether it is stored in rough, brown, or milled form. The brown rice becomes progressively more resistant to milling and total and head rice yields increase. Volume expansion and water absorption of milled rice during cooking increase. The starch and protein become less soluble in the cooking water. In addition, except for waxy rice, the cooked rice becomes more flaky. Aroma is lost and seed viability decreases progressively during storage. Aging probably starts in the grain in the field prior to harvest and is accelerated by heat treatment during drying. In fact aging may be accelerated by treatment of the grain with dry or wet heat.

Parboiling probably originated with aging as its primary purpose. It consists of steaming presoaked grains and slowly drying them. The changes are mainly physical and the process results in a harder and more translucent grain. Milled parboiled rice is reported to have a higher content of water-soluble vitamins than milled raw rice because, during steaming, these vitamins diffuse into the endosperm. A more likely explanation is that parboiled rice is undermilled compared to raw rice under the same milling conditions and contains more vitamin-rich bran polish.

High temperature drying of moist grain may result in parboiling of the grain, as in hot-sand drying or infrared heat drying of rough rice. The parboiling effect during drying is more evident in the wet-season crop than in the dry-season crop.

Processed Rice

Varieties in the same amylose class may differ in the quality of processed rice. In

processed rice, including parboiled rice, which is not consumed immediately after processing, factors other than the amylose/amylopectin ratio may provide information on factors that are also important in boiled rice quality. Most of these differences are related to differences in the gel consistency and viscosity of the starch.

Waxy rices are used mainly for sweets, pudding, desserts, cakes, and sauces. In Japan, waxy rices that differ in cake quality also differ in gelatinization temperature and molecular weight of amylopectin. Philippine waxy parboiled flaked rices also differ in tenderness on reconstitution with water, especially after storage. Generally, waxy rices with a high gelatinization temperature (74–78 °C) give cooked products that are less sticky and harden faster than rice with a low gelatinization temperature.

Low amylose rices are preferred for breakfast cereals and baby foods because, among the nonwaxy rices, their gel has the least tendency to harden during storage. Puffed rice and popped rice manufacturers prefer waxy and low amylose rices for their greater puffed volume, which probably results from their higher equilibrium water content during steeping in water prior to parboiling. The higher water content results in a greater degree of parboiling, which directly affects puffed volume.

Intermediate amylose rices are used in canned soups in the USA. In preparing Philippine fermented rice cakes, varieties of intermediate amylose content with soft gel consistency are used because of their soft texture and optimum volume expansion on steaming.

High amylose rices, particularly those of hard gel consistency, are ideal for rice noodle manufacture, because of their greater stability and resistance to disintegration on overcooking. — BIENVENIDO O. JULIANO. *Department of Agricultural Chemistry, International Rice Research Institute, Los Baños, Laguna, Philippines.*

STANDARDS

Seed Multiplication

The seed as a component of the production phase in the grain industry can be considered as a 'mini-industry' that requires integration of production, processing, storage, and marketing, in addition to that part involving milling. Although only a small part of the total system, the seed has a strong influence on the viability of the industry because, as the most basic input, the seed sets the upper limits of productivity, product quality, and consequently price. The linkage of seed in the grain industry is illustrated in Fig. 1. The seed program in the grain industry, therefore, deserves full recognition in systems planning and implementation.

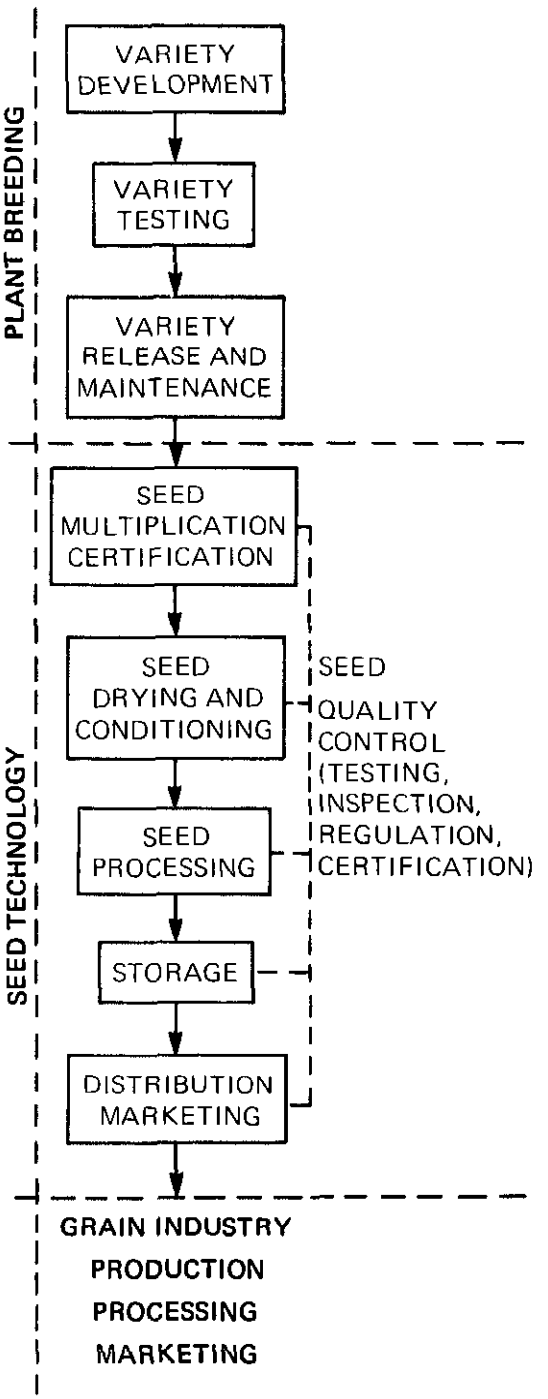

FIG. 1. Linkage of the seed in the grain industry (Gregg et al. 1970).

Systems of Seed Multiplication and Certification

In seed production, quality control has a central role. All phases from seed multiplication, processing, and storage to distribution and marketing should be subject to quality control either by seed testing, inspection, regulation, or certification. Therefore, the seed laboratory is essential to the quality control program (Fig. 2).

A system of seed production to provide the needed quantity of seeds with a given quality is illustrated in Fig. 3. In this system of seed production, there are two schemes for quality control, namely, the limited generation system of multiplication and seed certification.

In the limited generation scheme of seed multiplication, control of genetic or varietal purity is attained by limiting the number of generations that the seed may be increased from the original or breeder seed. In rice, under this system, the third generation is usu-

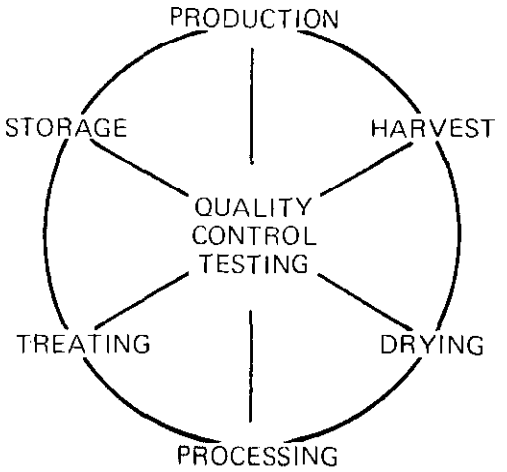

FIG. 2. The seed laboratory as the hub of seed quality control (Grabe 1968).

ally the seed intended for commercial crop production. Thus, this system recognizes the following classes of seed:

	No. of generations from breeder seed
Breeder	0
Foundation	1
Registered	2
Certified	3

The seed-class nomenclature may change from country to country, but what is essential is an understanding of the number of generations involved in seed multiplication. The concept is that the farther away the seed progeny is from the breeder seed, in terms of filial generation, the greater the chances of variation from the original purity.

In addition to quality control by means of the limited generation system of multiplication, seed certification is required in the production of the different classes of seed mentioned above to ensure that certain field and laboratory seed standards are satisfied. The process of certification consists of two successive phases: (1) field inspection; and (2) laboratory inspection or seed testing and analysis.

Certification presumes the existence of standards for inspecting seed fields and examining seed lots. In general, field standards provide for proper field isolation and tolerance for field mixtures; whereas, seedlot standards set tolerance limits for varietal and physical purity, percentage germination, and moisture content. Seed certification, therefore, focuses its evaluation on: (1) genetic or varietal purity; (2) physical purity; and (3) germination or planting value.

In field inspection, the main problem is sampling because it is impossible or impractical to examine every single plant in the seed field or every single portion of the field. In-field visits must be carefully planned for efficiency and reliability of inspection. Figures 4–7 are examples of field inspection route patterns for a rectangular field, showing the comparative efficiency and accuracy of each pattern.

Assuming that the field meets established standards of isolation and crop stand, the seed crop is gathered from the field. The field inspector draws a sample from the seed harvest and forwards it to the seed laboratory for the next phase in certification, which is seed examination. The seed sample is subjected to a series of tests and the results are matched with established seed quality standards to determine if the seed lot qualifies for the certification. If certified, a tag containing all the information on the seed lot pertinent to the quality factors

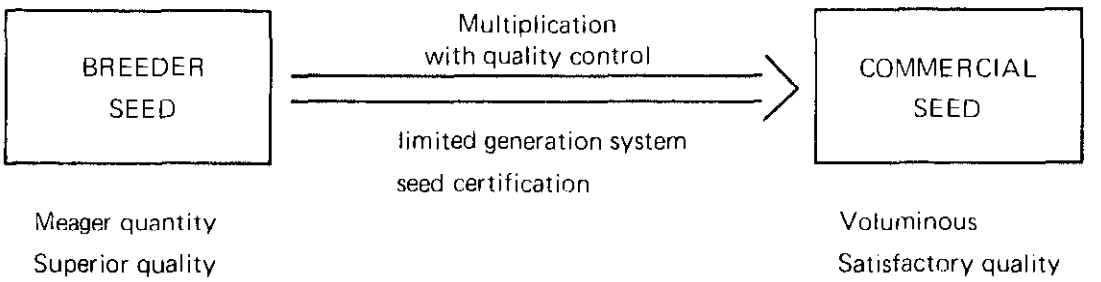

FIG. 3. Meeting seed quality and quantity needs by proper multiplication.

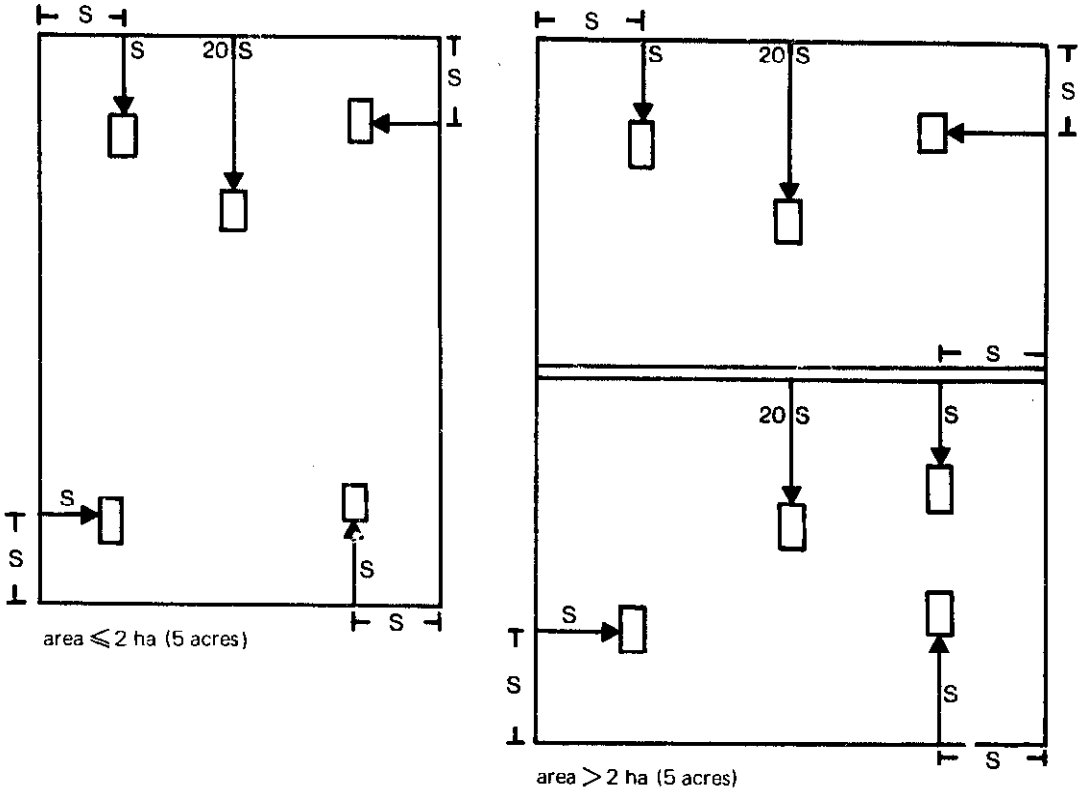

FIG. 4. Techniques of inspecting paddy fields (Seed Processing, Storage, and Distribution). Procedure: (1) inspector decides how many steps (s) he will take from corners and into the field before making count; (2) counts from centre of field at least 20 steps from edge.

is attached to each bag. Figure 8 shows the series of tests for ascertaining seed lot quality in rice.

The importance of proper sampling technique cannot be overemphasized because so much depends on the sample. However, as shown by field experience proper sampling is easier said than done. As a guiding principle, sampling should be done from as many positions within each seed bag and from as many bags as possible because the sources of sample differences are within-bag and between-bag variations.

Seed Processing Principles

In the broadest sense, seed processing encompasses all the steps involved in the preparation of harvested seed for marketing. These include handling, threshing, preconditioning, drying, cleaning, size-grading, upgrading, treating, and packaging. More commonly, however, seed processing refers only to preconditioning, cleaning, size-grading, and upgrading of seeds. The steps involved are similar to those in grain processing, except that the processed seed is intended for planting.

In seed processing a seed lot is conceived as a mixture of good seeds, undesirable seeds, and other types of materials. The removal of these undesirable materials from the good seeds (Fig. 9) converts a seed harvest into a marketable grade of seed. Obviously there are many steps involved (see Fig. 10).

The first step is receiving seeds at the processing plant in containers or in bulk. From the receiving station, seeds go into bulk storage for later processing, or to conditioning and precleaning, which includes removal of trash,

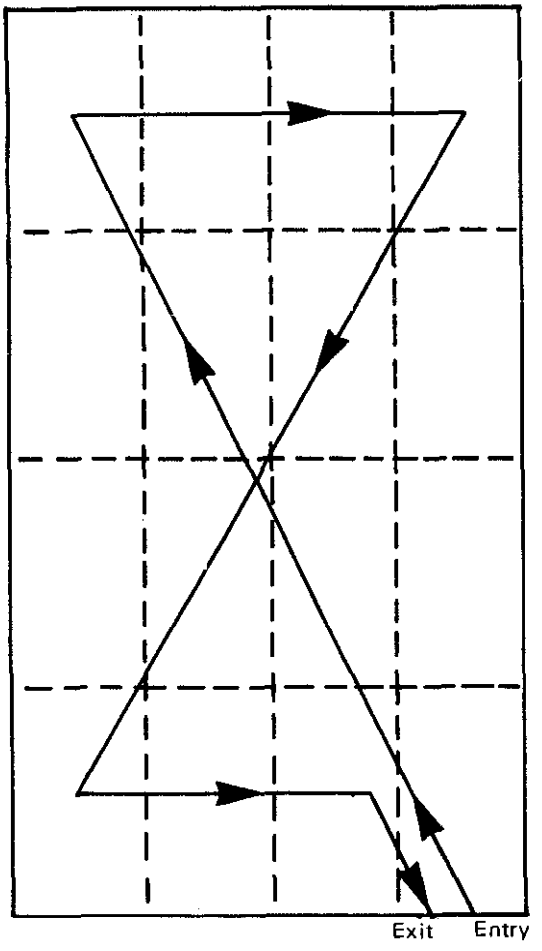

FIG. 5. Techniques for inspecting paddy fields (Revier and Young). Area 40 ha (100 acres), (805 × 503 m, 880 × 550 yards); travel 2605 m (2850 yards); coverage ¾ of field; centre covered twice; outer portion of mid-field not covered; remotest part from inspector 183 m (200 yards).

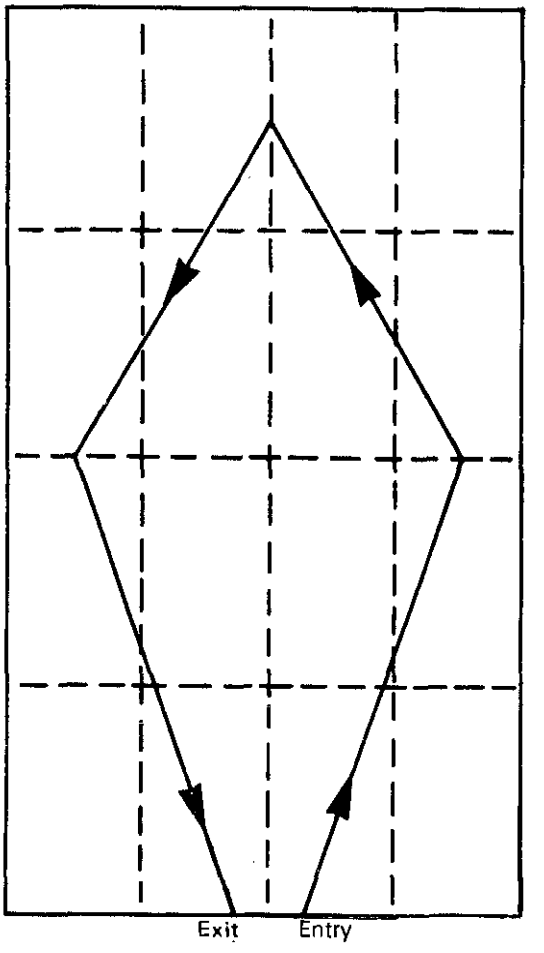

FIG. 6. Techniques for inspecting paddy fields (Revier and Young). Area 40 ha (100 acres), (805 × 503 m, 880 × 550 yards); travel 1737 m (1900 yards); coverage less than ½ of field; remotest part from inspector 365 m (400 yards).

debearding, etc. to make the next step, basic cleaning, more efficient. Basic cleaning is the first actual cleaning and/or upgrading step, and the air-screen cleaner is the most commonly used machine. If needed, the seed may go through more special separating or upgrading machines to remove specific mixtures. Then the seeds are ready for bagging, although chemical seed treatment against seed pests and disease organisms may be done before bagging. Finally, the seed is shipped or held in storage until needed.

Regardless of the type of machinery used for seed processing the basic interests of the processor are: (1) complete separation — removal of undesirable materials from the seed; (2) minimum seed loss — some good seeds are removed along with contaminants in almost every processing operation, but this loss must be kept at a minimum; (3) upgrading quality — improvement not only of purity, but also removal of rotten, cracked, broken, insect-damaged, injured, or low quality crop seed; (4) efficiency — the highest capacity

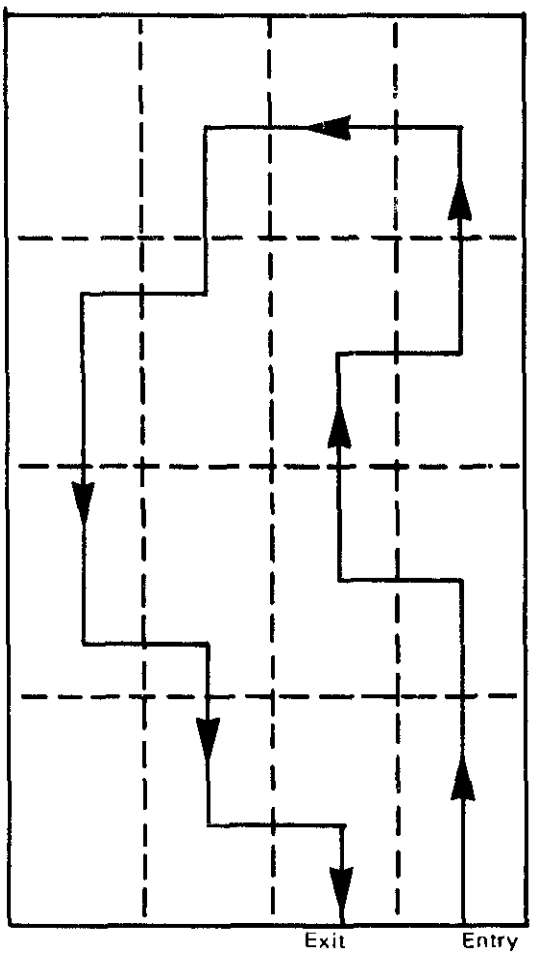

FIG. 7. Techniques for inspecting paddy fields (Revier and Young). Area 40 ha (100 acres), (805 × 503 m, 880 × 550 yards); travel 2432 m (2650 yards); coverage ⅞ of field; remotest part from inspector 91 m (100 yards).

consistent with effective separation; and (5) minimum labour — labour is a direct operating cost and cannot be recovered.

Seed processing equipment effects seed cleaning and separation on the basis of physical differences among seeds and between seeds and other materials in the seedlot. The principles of separation of some of the more common seed processing equipment are: (1) air-screen cleaner (Fig. 11 and 12) — makes separation based on seed size and weight differences; (2) gravity separator (Fig. 13 and 14) — based on seed weight, specific gravity, or relative density; (3) disc and cylinder separators (Fig. 15) — based on seed length difference; (4) graders, sizers (Fig. 16) — based on width and thickness; (5) incline draper (Fig. 17), spiral separator — based on shape of seed; (6) roll mill (Fig. 18), magnetic separator (Fig. 19), incline draper (Fig. 17), Buckhorn machine (Fig. 20) — based on differences in surface texture; and (7) electrostatic separator (Fig. 21 and 22), electric colour sorter — based on electrical property of the seed. — NOEL G. MAMICIPIC. *Department of Agronomy, University of the Philippines at Los Baños, College, Laguna, Philippines.*

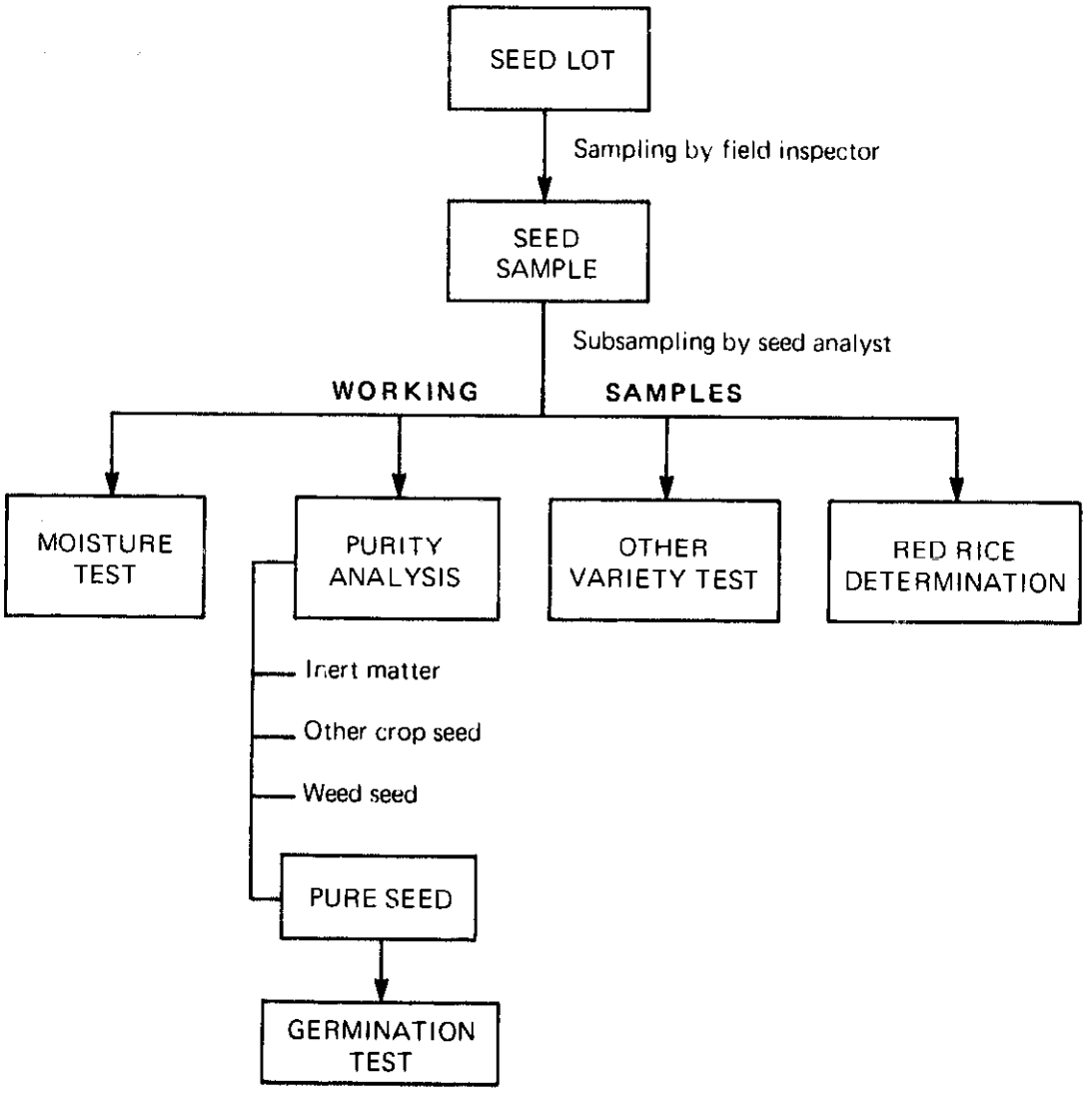

FIG. 8. Laboratory tests for rice seed certification.

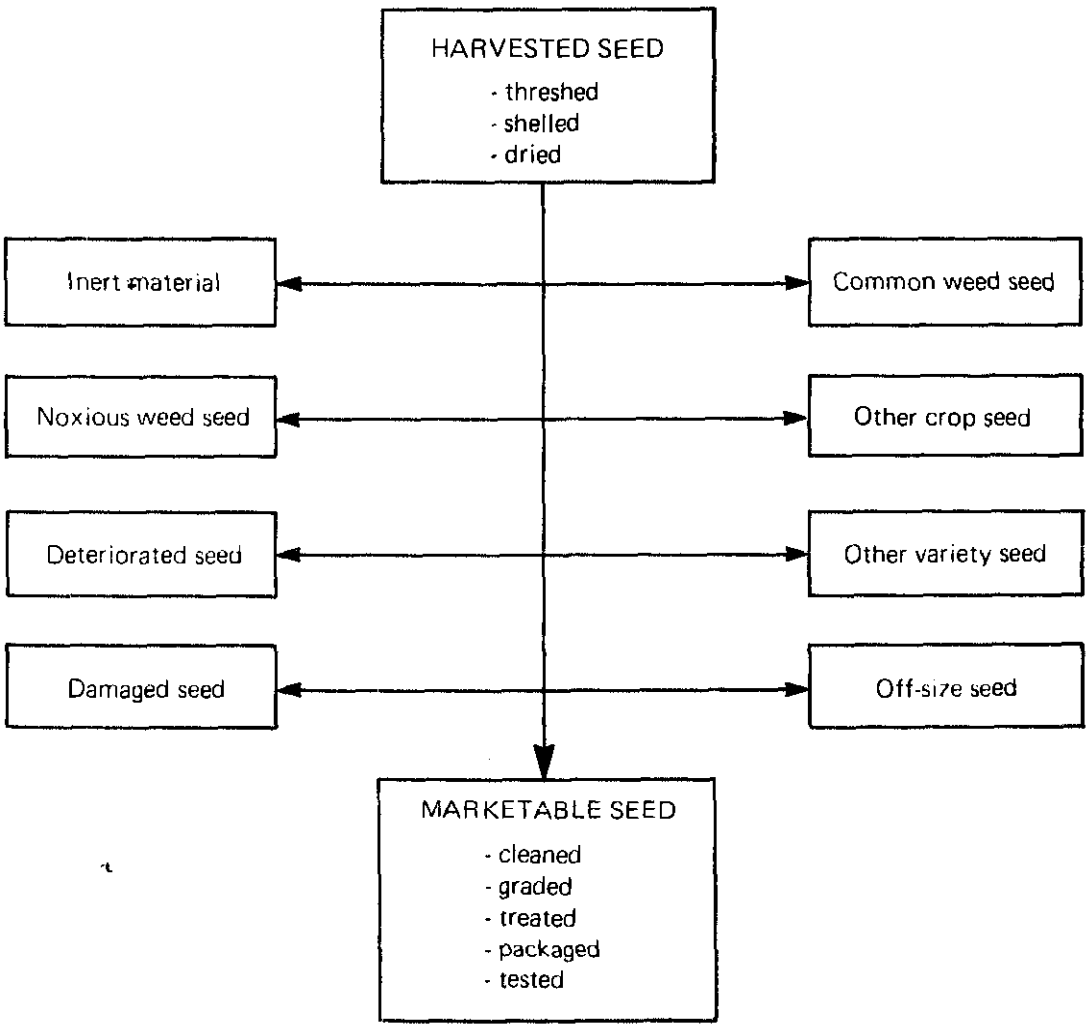

FIG. 9. Types of materials removed from seedlots during processing (Gregg et al. 1970).

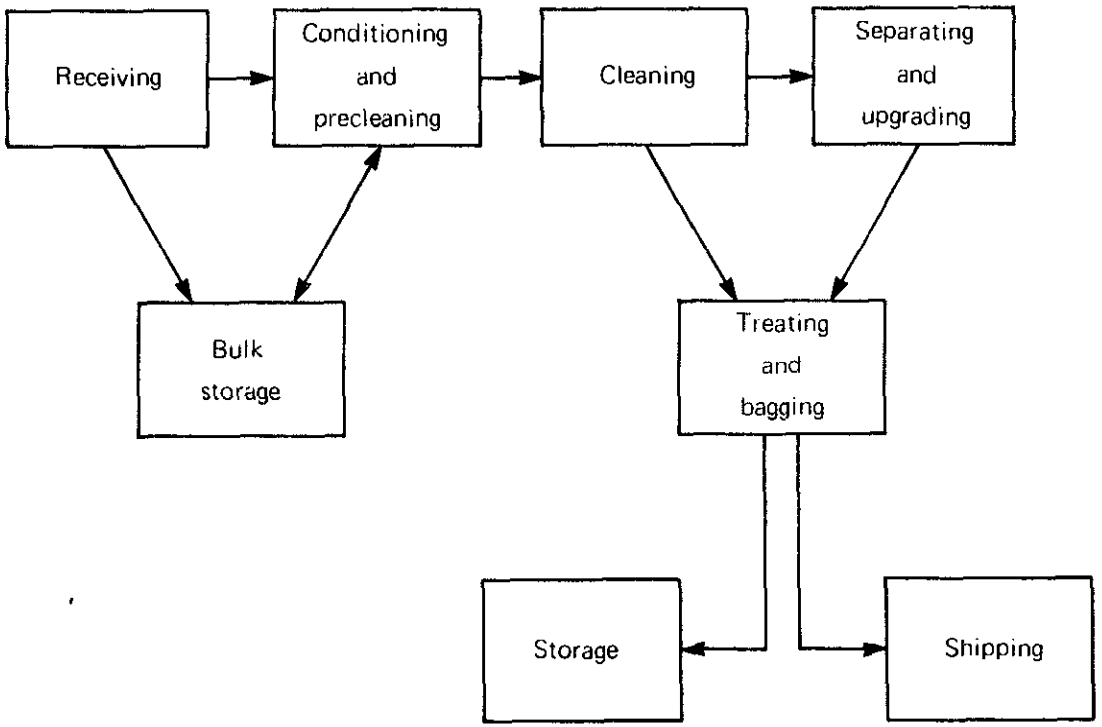

FIG. 10. Basic flow and essential steps in seed processing (Vaughan et al. 1968).

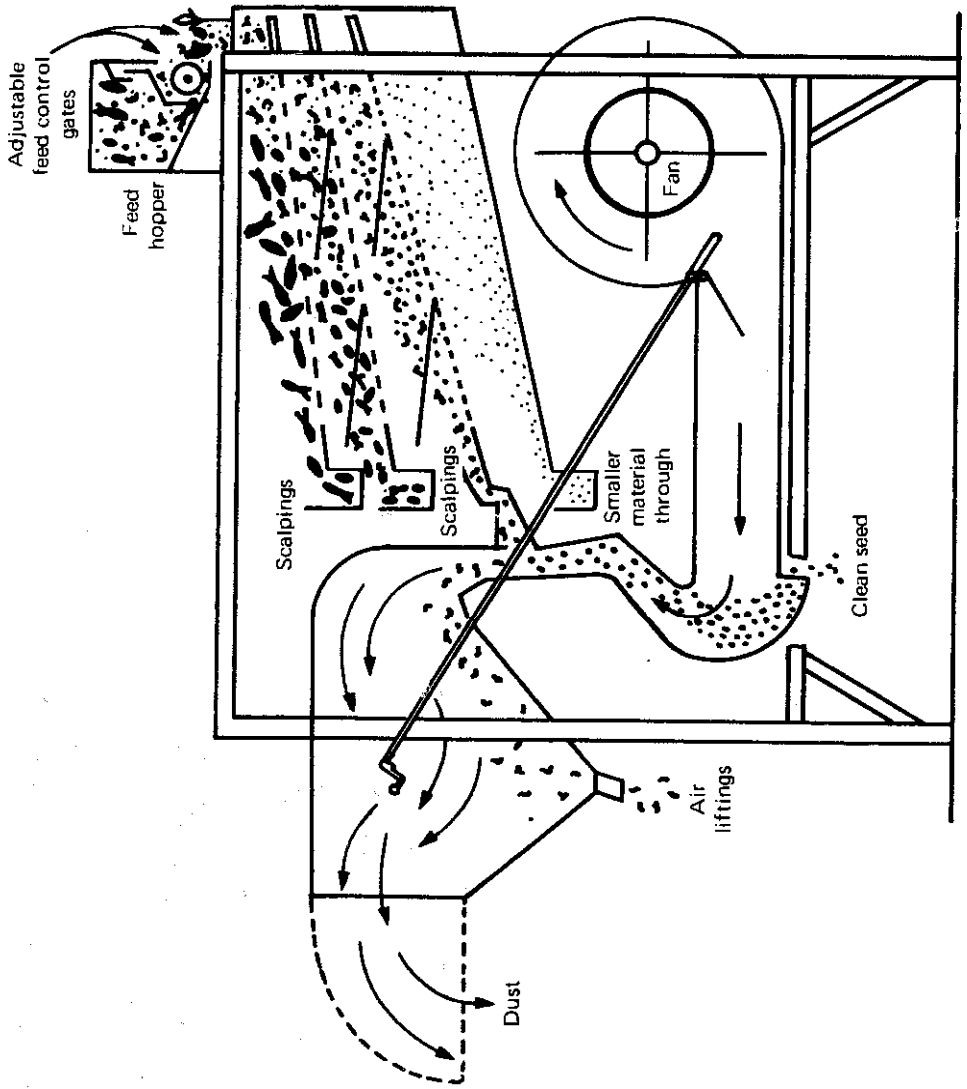

FIG. 11. Flow diagram of Crippen A-334 air-screen cleaner (Vaughan et al. 1968).

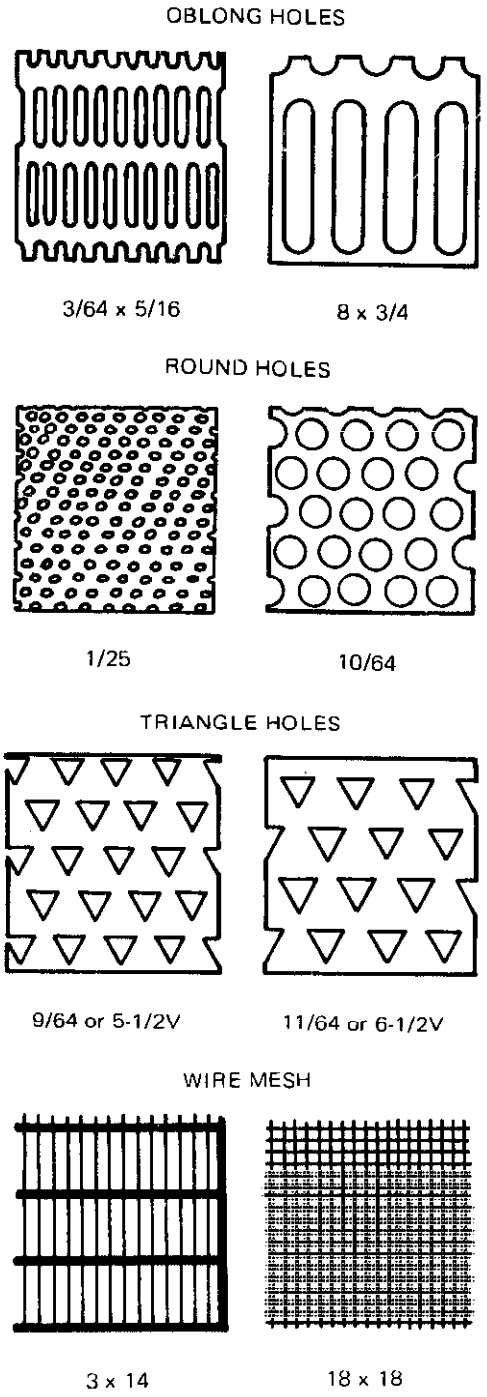

FIG. 12. Types of screens and perforations used in cleaning seeds (Vaughan et al. 1968).

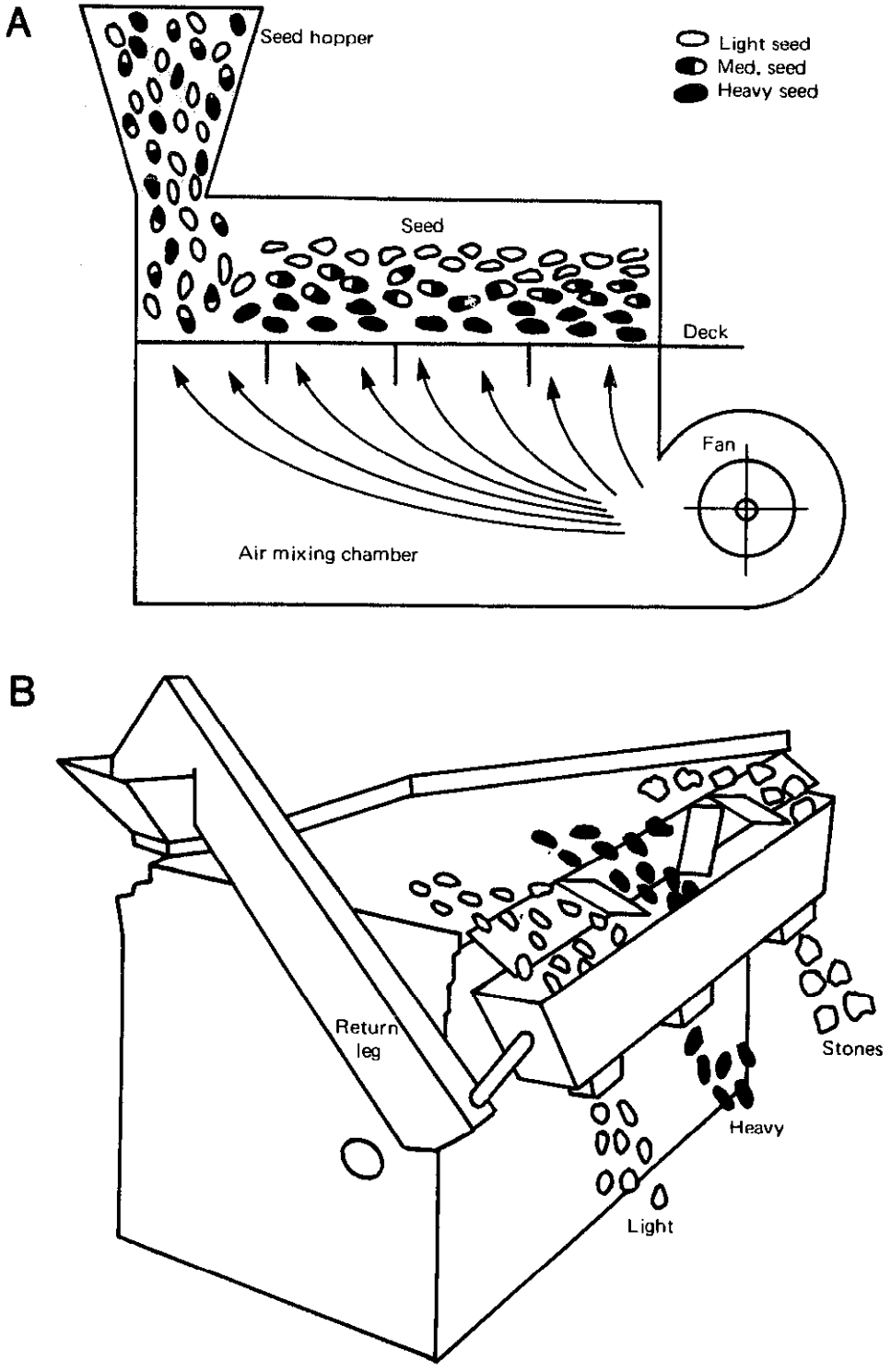

FIG. 13. (A) Diagram of the airflow through seeds on the deck of a specific gravity separator. Seeds are stratified into vertical zones by weight. (B) Diagram of gravity separator showing seed flow across the deck (Vaughan et al. 1968).

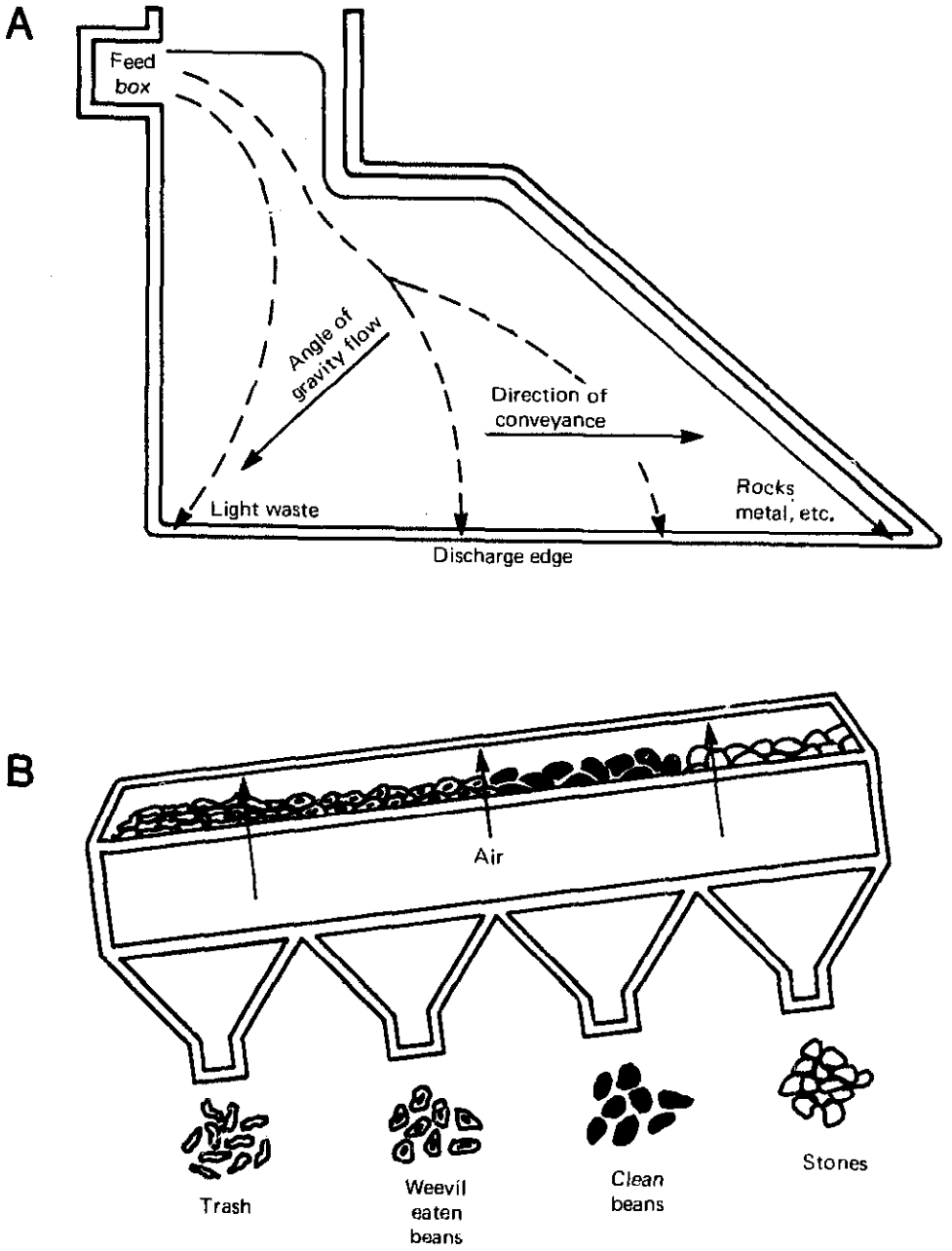

FIG. 14. (A) Flow pattern of seeds across deck of a gravity separator. (B) Discharge of separates along the edge of the gravity deck in a typical bean separation (Vaughan et al. 1968).

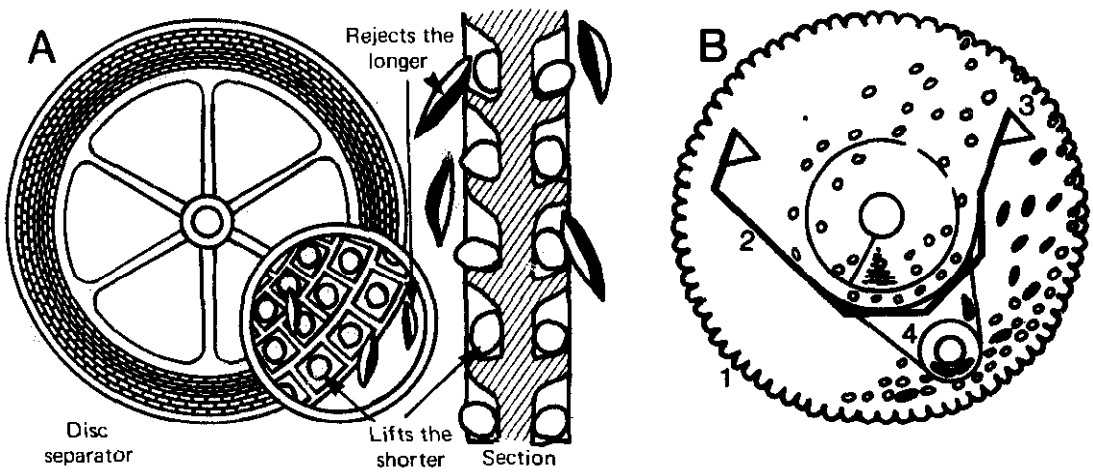

FIG. 15. (A) Face and cross section of a single disc. (B) Cross section of a cylinder length separator. (1) the cylinder wall with indents stamped on it; (2) the adjustable trough catching short lifted seed; (3) the separating edge of the adjustable trough; and (4) the auger conveyor at the bottom of the cylinder that conveys long rejected material out of the cylinder (Vaughan et al. 1968).

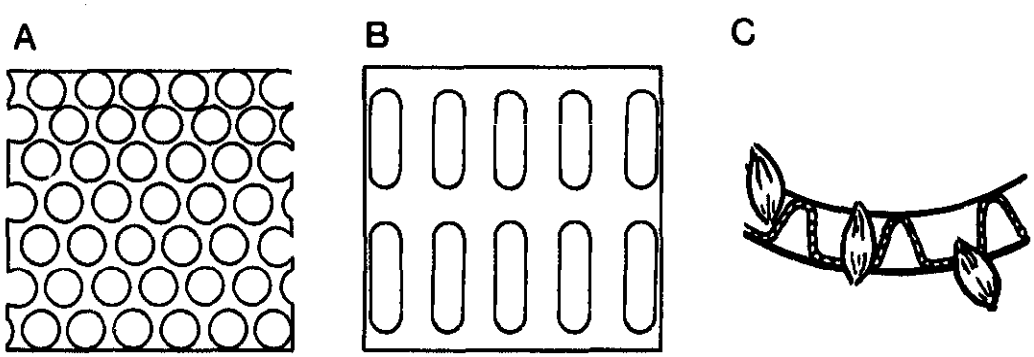

FIG. 16. (A), (B) Types of screens used in width and thickness sizing; round hole for width sizing and oblong opening for thickness sizing. (C) Sketch showing how separation is made (Vaughan et al. 1968).

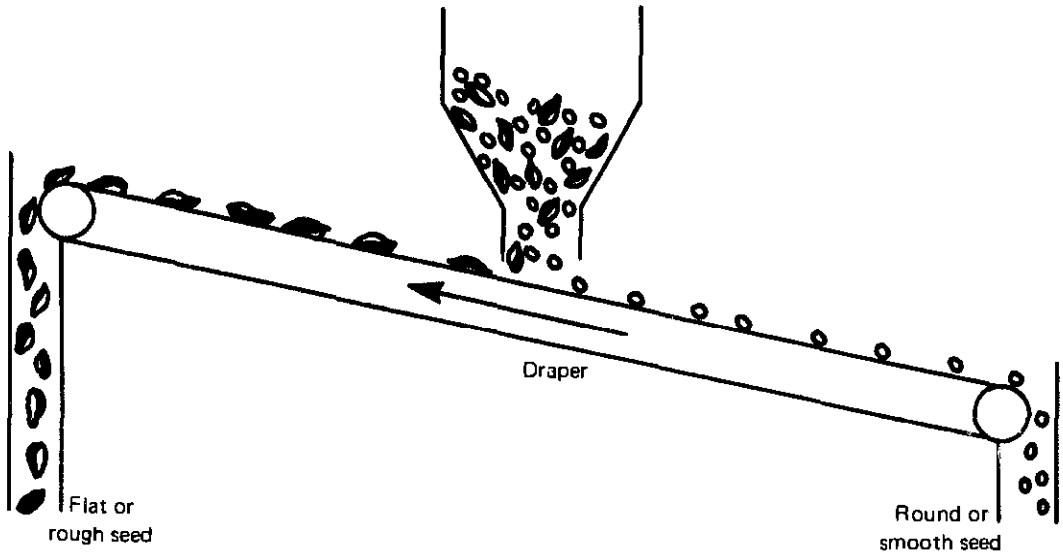

FIG. 17. Incline draper (Vaughan et al. 1968).

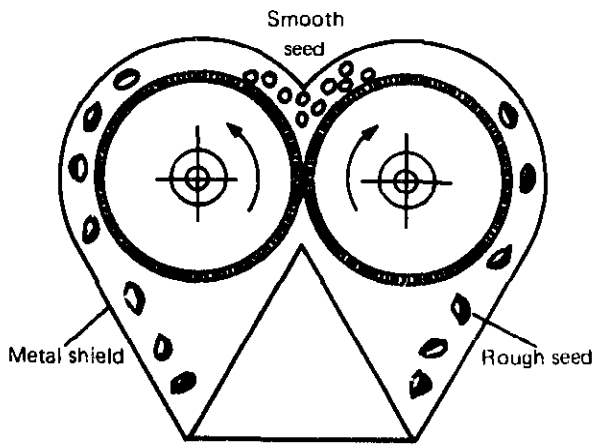

FIG. 18. Cross section of a pair of rollers illustrating movement of rough seed over rollers (Vaughan et al. 1968).

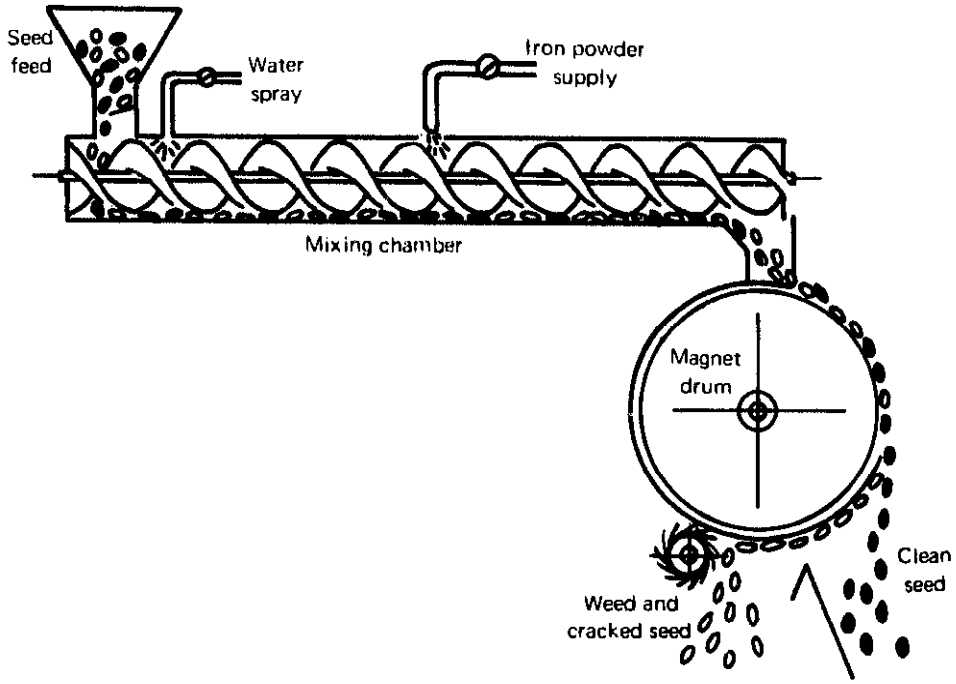

FIG. 19. Diagram of a drum-type magnetic seed separator (Vaughan et al. 1968).

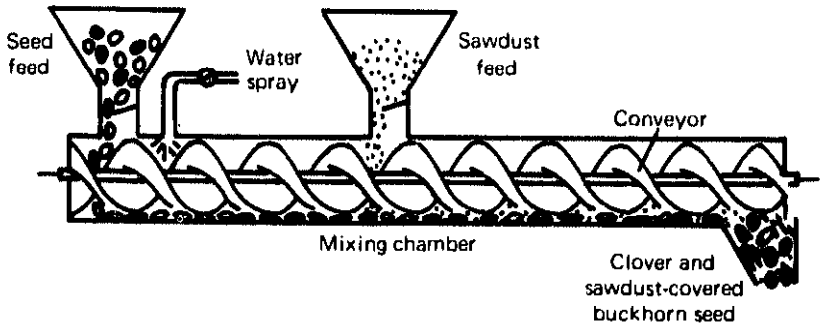

FIG. 20. Section view of buckhorn machine (Vaughan et al. 1968).

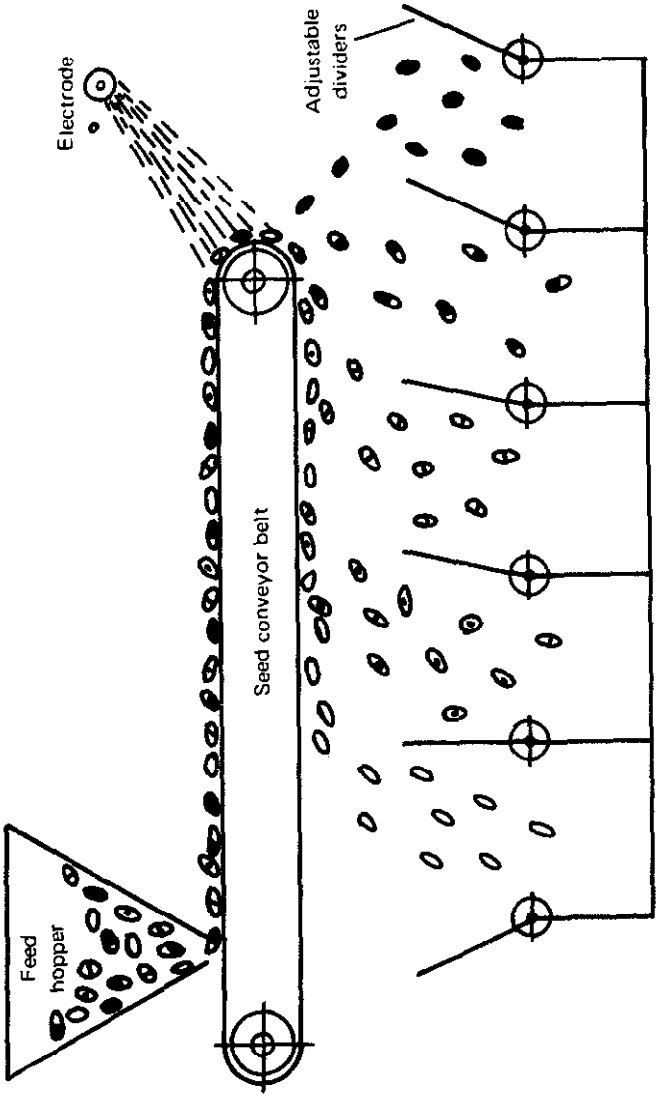

FIG. 21. Schematic drawing of a belt-type electrostatic seed separator (Vaughan et al. 1968).

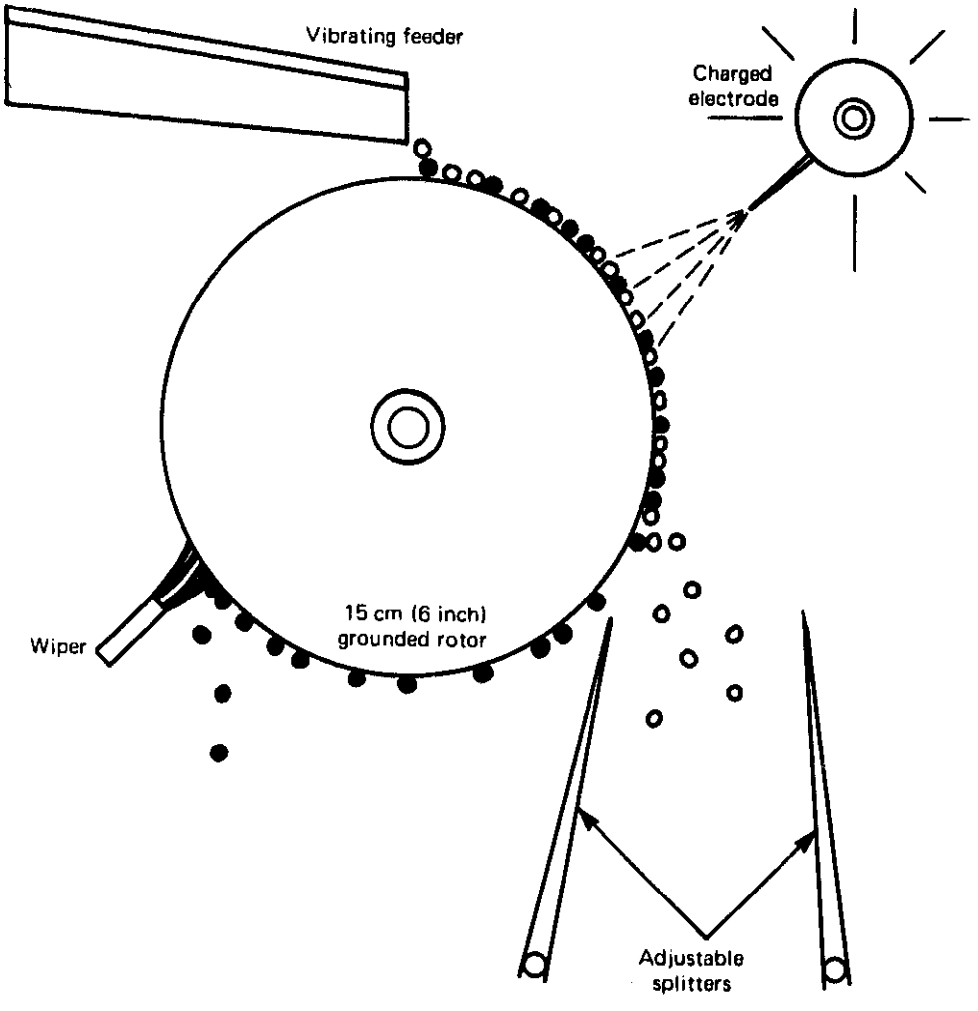

FIG. 22. Schematic diagram of an electrostatic separator set up to produce a discharging, high capacity field. Seeds that are poor conductors are pinned to the rotor; whereas, good conductors are pinned only momentarily, then continue to free fall (Vaughan et al. 1968).

Inspection

Grain grading has been neglected in agricultural teaching although it is necessary for assessment of the value of the grains. Too frequently, farmers market their grain without any idea of the grade of their grain. The producer or farmer should be vitally interested in getting the best grade and price for the quality of the product he offers.

The development of grain grading is essential for the establishment of standards so that the producer may be paid for the quality of the products that he produces. Even a small amount of knowledge and experience in grain grading helps the producer to secure proper payment for the grain he sells. Standardization mainly aids orderly marketing and efficient buying and selling.

Official standards are important in the marketing process because they furnish the means of describing variations in quantity and condition. They also provide a basis for merchandizing contracts, for quoting prices, for loans on products in storage, and for sorting or blending by producers to meet market requirements. They also offer an incentive to farmers to produce better crops because farmers have the assurance that their return is based on the quality of the grains produced.

Quality has become one of the dominant factors for consideration in the expansion of the rice milling industry. The first step towards achievement of quality rice is grading. Setting up modern processing units cannot solve the quality problem completely. Good milling results can only be obtained from graded paddy; therefore, as long as the producers do not differentiate between low and high quality paddy and are not paid for producing the best paddy, but are penalized for low quality, no substantial progress can be made in the production of quality rice. The only answer to the problem is the enforcement of standards and grades and the introduction of a grading system on an objective basis.

Representative Sample

The sample for examination or analysis should be representive of the lot from which the sample was taken. If the sample is not representative, no amount of care in making the determinations for the grading factors will assure proper grading of the rice. For quality inspection it is essential that the sample be: (1) large enough to permit the required tests to be performed; (2) properly identified, and (3) preserved in its original condition from the time it is taken until the grade or quality factors are determined.

Bulk Paddy in Trucks, Wagons, and Small Boats

The sample should be taken with a double-tube compartmented bulk grain probe. The grain should be probed in as many places as possible. Insert the probe or trier into the rice at an angle of about 10° from the vertical, with the slots closed. The slots should face up when the probe is opened. While the slots are open, give the probe two or more slight up-and-down motions so that all the openings are filled. Close the slots, withdraw the probe, and place the contents of the probe full length on a sampling cloth or tray.

Bulk Paddy in Flat-Storage and in Bin Silos

A long probe can be used to sample bulk paddy in flat-storage at a depth of 3–4.3 m (10–14 ft); however, extra hand pressure is required to probe deep into the stack. Sampling from bin silo storage is extremely difficult. Proper sampling can only be done when the grain is running into or out of the bin. Mechanical samplers can be installed to draw samples at regular and frequent intervals to obtain a representative sample.

Sacked Paddy and Rice

Samples from sacked paddy or rice can be taken with a sampling trier or a small probe of sufficient length to reach to the centre of the sack. The rice should be probed in as many places as possible to obtain representative samples. The usual commercial practice is to draw samples from 10% of the bags in a lot, provided that there is no significant variance in the grade or quantity. One hundred percent sampling is, however, necessary if the quality between sacks is not uniform.

The presence of live or dead insects, insect webbing, and odour would not be very noticeable from the sampled rice drawn with probes. In such cases, portions of the rice should be examined by opening the sacks.

If sacked rice is stacked so that not all the sacks are accessible for sampling, samples should be drawn from randomly selected sacks from the top, sides, and ends of the lot to enable the sampler to secure a representative sample from the accessible sacks. On the sample slip, the number of sacks in the stack and the number accessible for sampling should be noted.

Pooling the Sample

When all individual portions of a sample are found to be of one uniform quality, they should be pooled to form the sample of the lot. If any part of the lot is found to be of distinctly different quality than the balance of the lot, the samples from this part should be pooled separately.

Inspection and Grading

The important factors determining quality are: variety, moisture, dockage, milling yield, condition of grain, purity, and palatability.

Variety

Owing to the large number of rice varieties, grouping of varieties under slender and bold groups is made in certain countries; whereas, some countries have classified their varieties as fine, medium, and coarse for the purpose of grading. In the world market, much emphasis is placed on grain length as a criterion of quality. Although the combination of various shape factors such as length, width, and general contour of the grain has an important bearing on consumer preference, the palatability characteristics (appearance, cohesiveness, tenderness, and flavour) also constitute an important factor in quality grading.

The classification of paddy varieties should be made on the basis of kernel length and shape. Kernel length and breadth of both paddy and rice grains, are determined by measuring (in millimetres) whole grains selected at random and then calculating mean values. Uniformity in the size of the kernels is a good indication of varietal purity.

Moisture

High moisture directly reduces the grade of the rice; if the grain moulds or spoils, the grade is lowered even more. The moisture content has a bearing on: (1) keeping properties of grain during storage; (2) storage loss; (3) milling return; and (4) quality of milled rice. Moisture should be determined by the use of equipment and procedures prescribed by the government or its agency. The air-oven method is the basic method for determining the moisture content of paddy.

Accuracy with rapidity is an important point in determining moisture content. It is, therefore, necessary to use quick testing methods even if they are not 100% accurate, provided the error is constant. For calibration purposes, thermostatic ovens for the conventional determination of moisture content are essential to check the rapid-type moisture testers and work out correction factors.

Impurities and Foreign Matter

All material other than paddy or rice kernels is called foreign matter or impurities. This includes soil, stones, weed seeds, fragments of rice stalk, dust, husks, weevilled webs, and dead insects. The separation of impurities and foreign matter is made with the use of appropriate sieves and aspirator cleaning devices.

Hand sorting should be done wherever necessary.

Round perforations in a screen are measured by the diameter of the openings. Perforations of 6/64 inch and larger are measured in 64ths of an inch and are commonly stocked by manufacturers in sizes ranging to 80/64 inch. These screen sizes are commonly designated by using the numerator of the fraction, i.e. 6, 7, . . . , 64, 72, or 80. Round openings of 5.5/64 inch and smaller in diameter are measured in fractions of an inch and are so designated, i.e. 1/12, 1/13, 1/14, . . . , 1/25. Sizes ranging from 1/12th to 1/25th of an inch are readily available from most manufacturers.

Perforated metal screens with oblong or slotted openings are measured in two dimensions: the width and length of the opening. As was the case with round hole screens, openings of 6/64ths of an inch and larger in width are measured in 64ths of an inch; openings less than 6/64ths of an inch are expressed in fractions of an inch. Oblong openings are usually 1/4, 5/16, 1/2, or 3/4 inch in length. When designating these screens, it is common practice to give the width dimension first and the length dimension last, i.e. 5 1/2 × 3/4, 6 × 3/4, or 1/22 × 1/2, in cases where fractions of an inch denote the width.

Generally, the direction of the slot is the same as the direction of the flow of seeds on the screen. In large screen sizes, however, the slots can be across the direction of the flow of seed. These cross-slot screens are particularly useful for separating spilt seeds from varieties having a relatively thin shape. Also, among the small size slotted screens, there is a 1/22 × 1/2 diagonal screen that has its slots turned at a 45° angle from the usual direction of seed flow. This screen is useful for separating relatively short seeds from slightly longer seeds. Manufacturers commonly stock over 50 different oblong hole screens of assorted sizes, ranging from 1/24th × 1/2 to 32/64ths × 1 inch.

Test Weight per Bushel

The test weight is used as an indicator of good quality grain, and it is particularly useful when paddy is measured on a volume basis. In some countries the test weight is used for computing the quantity of paddy in the bins.

The determination of the test weight per bushel should be made on a 1.3–1.4 litre (1.1–1.3 quart) representative portion of the original sample. To determine the test weight per bushel of rough rice on the approved apparatus, the following procedure should be followed: (1) enough rough rice should be used to cause overflow on all sides of the kettle; (2) the filling and stroking of the kettle should be accomplished without jarring the apparatus; and (3) the stroking should be done cleanly with three full-length zigzag motions with the standard stroker held lightly on the kettle; the flat sides of the stroker should be in a vertical position. The accuracy of the kettle, the beam readings, and the sensitiveness of the beam should be tested periodically.

Milling Quality of Rice

After reexamining the foreign matter and ascertaining the moisture content and test weight per bushel, the potential milling properties are determined. Many factors influence the value of paddy and they require an expert for their identification, but even he is not infallible and his opinion cannot be precisely checked. Therefore, to avoid an empirical or biased verdict, a sample of the rice should be milled. The main objectives of sample milling are to ascertain: (1) the total milled yield, i.e. the total quantity of whole and broken grains recovered from the sample; (2) the head rice yield, which is the quantity of whole grains recovered from the sample; and (3) the quality of milled products.

The degree of hardness is strictly related to milling-breakage resistance. Chalky and defective kernels, being more brittle, reduce both total and head rice milling yield.

Assessing the milling quality calls for a testing device capable of simulating, in the smallest space and in the shortest time, the main processes that are carried out in a commercial mill. In all milling tests, it is extremely important that the degree of milling be constant.

Grading Factors

The following factors are used to grade paddy and rice.

Paddy: (1) moisture; (2) impurities and foreign matter; (3) seeds and foreign matter in test milled rice; (4) red grains and red streaks in test milled rice; (5) chalky and immature grains in test milled rice; (6) damaged grains in test milled rice; (7) foreign grains in test milled rice; (8) milling yield (total) in test milled rice; and (9) milling yield (head rice) in test milled rice.

Rice: (1) moisture; (2) head rice; (3) big brokens; (4) brokens; (5) chalky and immature grains; (6) damaged grains; (7) foreign grains; (8) red grains and thick red streaks; (9) paddy seeds; and (10) seeds and foreign matter.

Certification

As a practical example of the certification of rice, a sample certificate is reproduced below:

Paddy Inspection Certificate

This is to certify that the following described lot of paddy was inspected by the Institution. The inspection results are as stated below:

1. Date of inspection: *24/9/1969*
2. Sampled at: *Hock Chuan Aun*
   R. M. Butterworth
3. Sample code No.: *7-4-020*
4. Quantity: *2000 pikuls*
5. Variety/Class: *"Bahagia" long grain slender*
6. Grade: *Grade I*
7. Moisture (paddy): *12.3%*
8. Milling yield: *Total rice 68.7%*
   Head rice 91.7%
9. Impurities (paddy): *0.30%*
10. Red grains: —
11. Seeds/Foreign matter: —
12. Chalky/Immature grains: *0.60%*
13. Foreign grains: *0.05%*
14. Damaged grains: *0.07%*
15. Remarks: —

Dated *1/12/1969*

.....

Signature of Inspector

The grade of the paddy is designated on the basis of the results of analyses and observations, and on a comparison with the requirements of the standards.

The quality certificate is an important document particularly for commercial purposes. Rice inspection certificates are issued for: (1) lot inspection; (2) sample inspection; and (3) inspection of origin. A lot inspection certificate shows the results of the inspection of an identified lot. It cannot be issued as representing an identified lot unless the entire lot is accessible for examination and a representative sample is obtained. Sample inspection certificates are issued only for samples presented to the inspection agency and apply only to the sample described. In most cases, these samples are unofficial. Certificates of origin are generally issued for lot inspections. This certificate is issued primarily to certify that an identified lot of rice is the product of the soil and industry of a country (the name of the country to be given). — U THET ZIN. *Food and Agriculture Organization of the United Nations, Regional Office, Bangkok, Thailand.*

Grading

Normally paddy is not graded prior to milling, but under certain circumstances the grading of paddy is desirable or even necessary. Grading has several advantages: (1) immature grains are separated; (2) a more precise adjustment of the huller is possible, which minimizes breakages; and (3) independent milling of graded lots is possible.

In grading paddy, use is made of differences in the thickness or length of different varieties. Paddy grains having the same length but different thicknesses are graded by rotating graders; whereas, grains with the same thickness but different lengths, are separated by trieurs. If the mixture consists of grains having different thicknesses and lengths, separation is completed by both the rotating graders

and the trieurs. However, if the paddy consists of a mixture of varieties with about the same length and thickness, paddy grading is practically impossible.

Grading of milled rice refers to the separation of brokens from the head rice and the further classification of brokens into a prefixed selection of grades. In the Philippines, normally only the very small brokens and points are separated, leaving as the main product a mixture of small brokens, large brokens, and head rice. This mixture can be sold easily on the Philippine market because traditionally domestic production is not sufficient and rather high living costs dictate the purchase of this cheaper ungraded rice.

The introduction of the new high-yielding varieties (HYV's) and the fact that these HYV's, in general, are classified under "special varieties" provides bright prospects for export of this rice to quality conscious markets. This means the Philippines will have to export a product that meets the requirements of the customer. In the international trade of rice, in general, and of quality rice, in particular, the specification of these requirements always refers to the range and percentages of brokens that will be accepted. Consequently, the rice miller producing rice for export will have to grade his rice. The local demand for graded quality rice is also increasing; therefore, the grading of rice is becoming more and more important.

A milled rice grain is classified with respect to its length: 1/1 head rice; 7/8 head rice; 6/8 large broken; 5/8 large broken; 4/8 large broken; 3/8 small broken; 2/8 small broken; 1/8 small broken (points). When the specification of the rice to be produced requires: 70% head rice; 10% large brokens 6/8; 10% large brokens 5/8; 5% large brokens 4/8; and 5% small brokens 2/8–3/8, the rice miller will have to grade his rice first, then mix in accordance with the requirements. There is no other way to meet the customer's specification. When grading, use is made of differences in both the length and thickness of the particles (Fig. 23A,B).

In general the full range of rice grades can be produced by trieurs, which separate on the basis of differences in length. However, trieurs

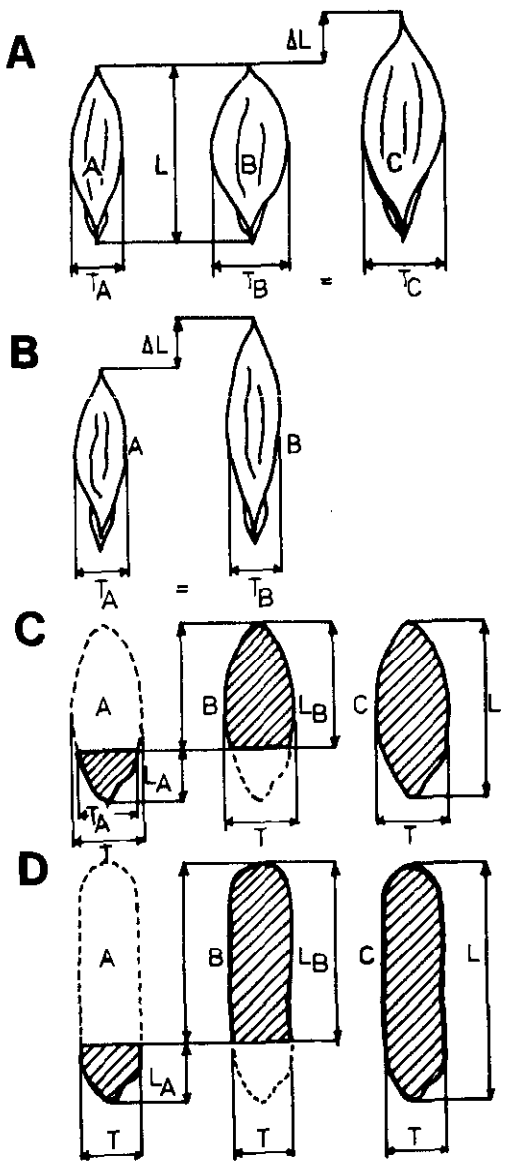

FIG. 23. Characteristics used for grading paddy and rice. (A) Grain A can be separated from B by thickness; A from C by thickness or length; B from C by length. (B) Grain A can be separated from B by length; (C) Grain A can be separated from either B or C by thickness or length; B from C by length. (D) Grain A can be separated from either B or C by length; B from C by length.

are more expensive than sieves and, where possible, sieves are used instead of trieurs.

Small brokens produced by a short medium but rounded variety of rice are thinner than the large brokens (Fig. 23C). Consequently, it is possible to separate these brokens by sieving. The large brokens, however, have the same thickness as the head rice so separation by sieves is impossible. A different situation exists with medium or long grain varieties that have long parallel sides (Fig. 23D). In this case the small brokens are the same width as the large brokens and head rice, and only grading, by length, in trieurs is possible. Points, however, can always be separated through sieves.

The machines involved in grading of paddy and rice are: (1) rotating graders (paddy); (2) trieurs (paddy and rice); (3) sieves (rice); and (4) volumetric mixers (rice).

Rotating Graders

These machines are also called "grading reels." Different designs have been made for thickness grading through these grading reels and basically three methods are used: (1) adjustable wire coil reels; (2) perforated sheets with slot perforations; and (3) wire screen reels.

Adjustable Wire Coil Reel (Fig. 24)

The operation of this rotating reel is based on the following principles. A coil spring always has a uniform clearance between the coils; however, when the spring is compressed, the uniform clearance between the coils is reduced (Fig. 24A,B). If a compressed spring contained a selection of steel balls of different sizes, only the small balls having a diameter equal to or smaller than the coil clearance would fall through. However, if the pressure on the spring was released, larger balls would fall through when the clearance was equal to the ball diameter.

The adjustable wire coil reel operates on this principle. One, two, or sometimes three adjustable wire coils are held by the rotating frame of the reel. The clearance of the first coil is made smaller than that of the second coil. A mixture of thin, normal, and thick paddy is fed into the machine and is slowly moved through the machine by a spiralled scoop. The thin paddy grains fall through the first wire coil, the normal sized paddy is discharged by the second coil, and the thick grains leave the reel as its overflow. When three coils are installed, the first coil normally separates the immature grains, the second coil separates the thin grains, the third coil grades the normal sized paddy, and the thick grains are discharged through the overflow (Fig. 24C,D).

The reels of this type of machine, as well as the other rotating graders, are continuously cleaned by a rotating brush (Fig. 24D, no. 1) installed on top of the reels and driven directly from the main shaft of the machine.

Grader With Perforated Sheets (Slots) (Fig. 25)

Instead of the adjustable wire coil reel, a fixed clearance can be used. In this case the lining of the rotating reel consists of perforated sheets with a slot-perforation of preselected mesh (Fig. 25A, no. 1). The length of these slots normally is about 20 mm, the width varies between 2 and 3.5 mm. The range of slot widths to be installed and kept in stock depends on the varieties of paddy grown in the country concerned. For instance, for IR20 a slot mesh of 2.2 mm will hold the paddy and a mesh of 2.4 mm will let the paddy through. Immature grains are then graded with a 2 or 2.1 mm slot mesh, the main product with a 2.4 mm slot mesh, and the thicker grains are discharged as the overflow of the machine. The machine operates the same way as the adjustable wire coil reel, the only difference being that when other slot meshes are required, the sheets must be changed (Fig. 25B).

Grader With Wire Screen Reels (Fig. 26)

Instead of perforated sheets a wire screen of preselected mesh can be used. These screens consist of steel wire welded at prefixed equal distances on a crossbar that is normally a steel wire too (Fig. 25A, no. 2). The distance be-

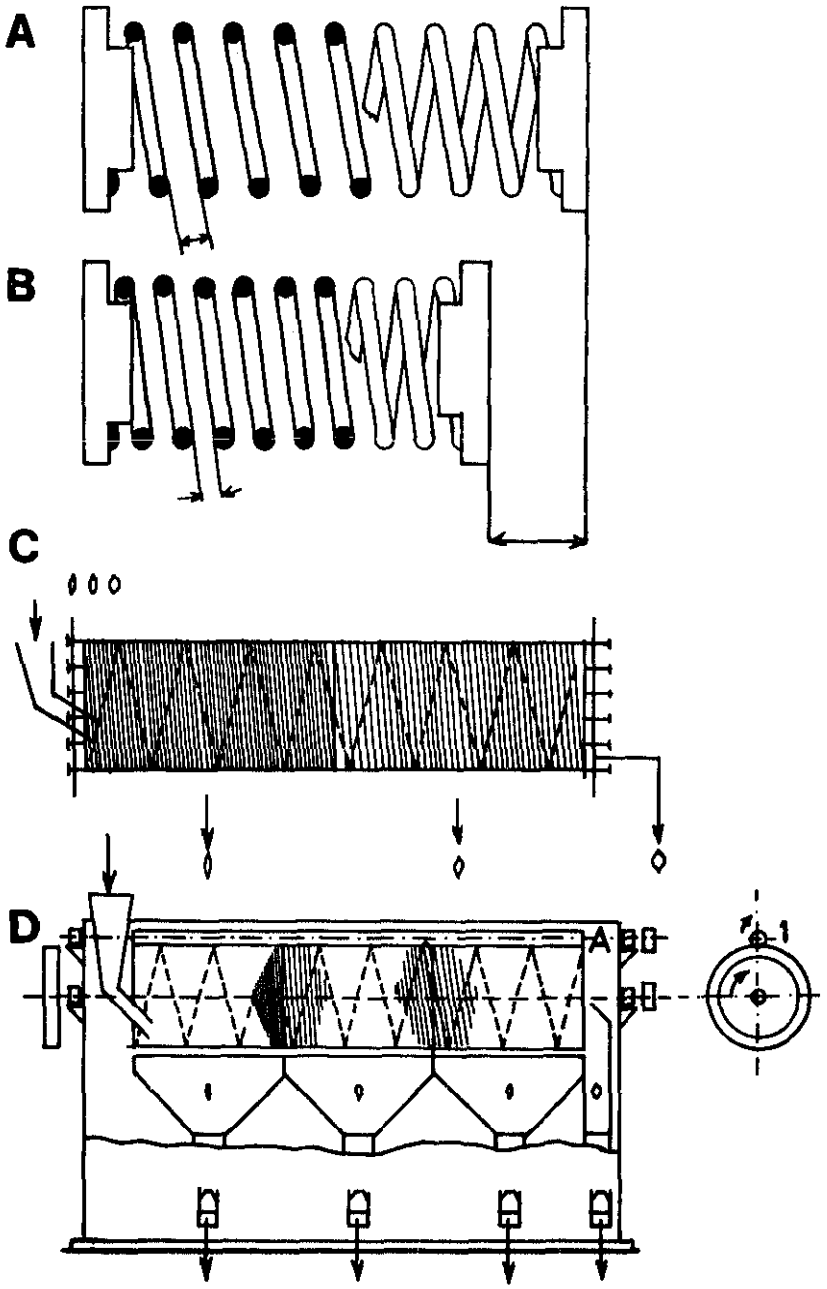

FIG. 24. Paddy grading with an adjustable wire coil reel. (A) The clearance between the coils of a spring is always equal. (B) When the spring is compressed the spacing between the coils is reduced equally. (C) A reel with two different sized adjustable coils separates thin paddy through the first coil, normal paddy through the second, and the overflow is thick paddy. (D) Using three coils the first separates immature paddy, the second thin paddy, the third normal paddy, and the overflow is thick paddy.

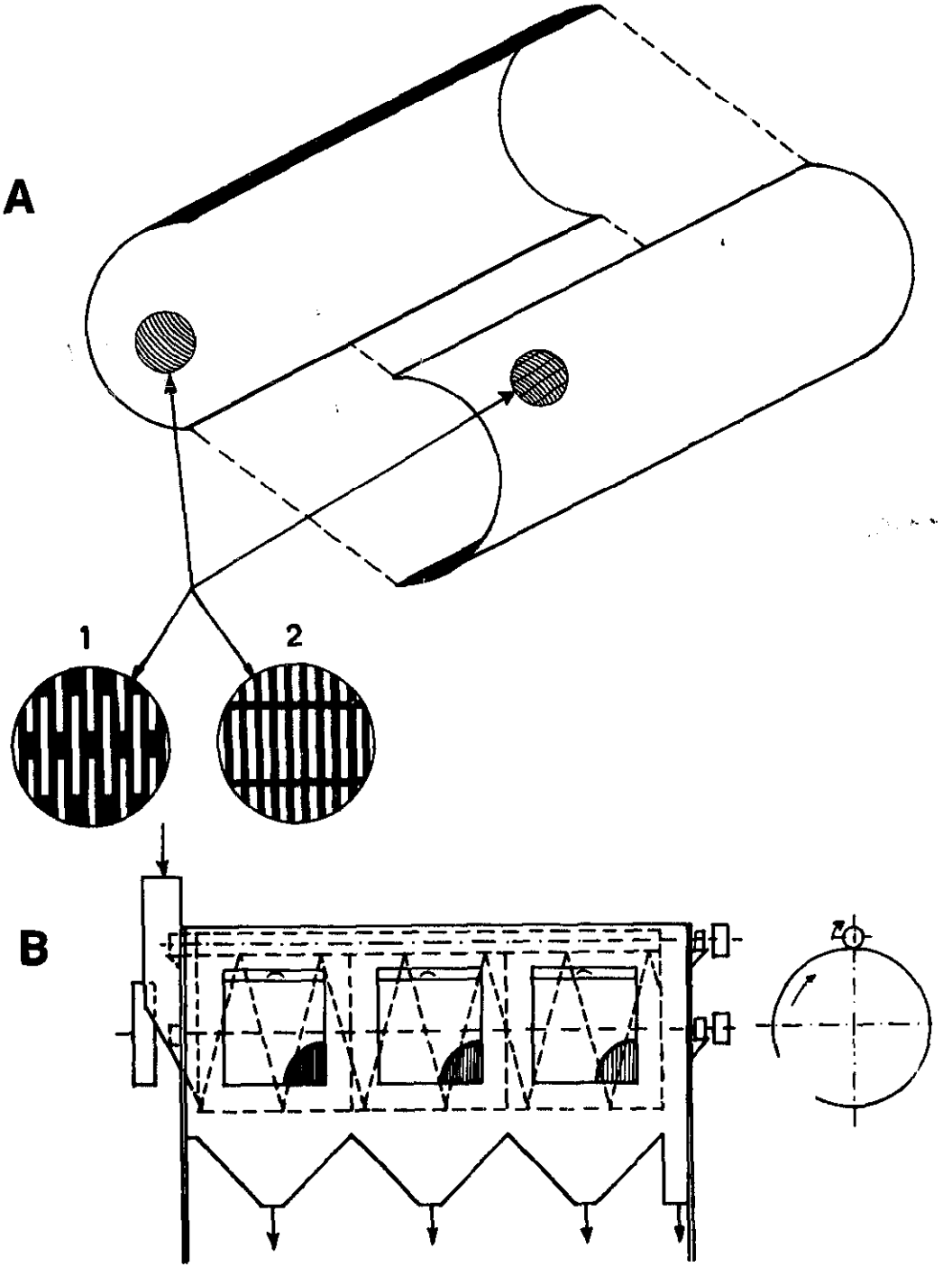

FIG. 25. Rotating grader. (A) The rotating cylinder can be a perforated sheet (1) or a wire screen (2). (B) The operation of this machine is the same as the wire coil reel except that when other slot-meshes are required the cylinders must be changed.

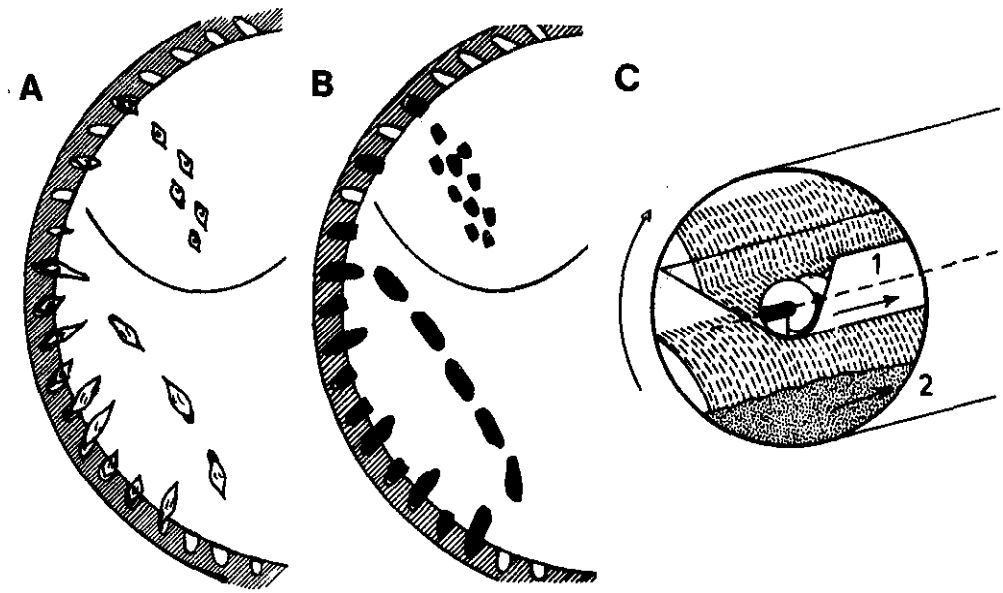

FIG. 26. Principle of grading using a trieur. (A) As the drum is rotated both long and short paddy grains are lifted in the indents; however, the short grains are held longer and fall into an adjustable collector plate. (B) Grading of white rice is identical except the size of the indents is different. (C) A screw conveyor (1) discharges the short grain at the centre of the lower end of the trieur, the overflow (2) is the long grain.

tween the wires represents the mesh of the screen and varies, for paddy separation, between 2 and 3.5 mm. A selection of screen meshes must also be available to meet variable requirements. The grading performance and operation of this machine are identical to the other two types of rotating graders.

The Trieur (Rotating Indented Steel Cylinder)

For both paddy and white rice grading, trieurs are used when grading by length is desired or is necessary. A trieur mainly consists of a slightly inclined rotating steel sheet cylinder that has thousands of pocket-like indents pressed in the steel at a slight angle. The diameter of these pockets varies from 2 to 8 mm. The size of the indents depends on the projected function of the trieur and the kind of product the trieur will have to process. For small brokens the indents are small, they become larger as the grade of the brokens increases, and are largest when large brokens must be separated. For paddy the size of the indent depends on the size (length) of the short grain that must be separated from the longer variety.

The mixed paddy, short and long, is unloaded into the trieur cylinder at the elevated end. The cylinder rotates slowly (about 50 rpm) and each pocket (indent) lifts either one long or one short paddy grain. At a certain point in their rotation the indents can no longer hold the long grains and they fall out of the indents. The short grains, however, are held in the pockets and fall out at a much higher point (Fig. 26A). The small paddy grains are caught by an adjustable collector-plate fixed inside the cylinder, and a screw conveyor discharges these grains at the centre of the lower end of the trieur (Fig. 26C, no. 1). The longer grains slowly move downwards over the lower part of the inclined cylinder, and are continuously lifted and released as explained above. The cylinder overflow represents the longer paddy variety (Fig. 26C, no.

2). When grading white rice the operation of the trieur is exactly the same; however, the size of the indents is different (Fig. 26B). In the case of white rice grading, the shorter rice particles are discharged at the centre and the longer particles (or the head rice) are discharged as the overflow of the trieur.

From this explanation it is clear that a trieur separates the short grains from the long grains and does *not* separate the long grains from the short ones, and that a trieur separates the small brokens from the large brokens and *not* the large brokens from the small ones. This aspect is very important since it concerns the capacity and performance of the machine.

Because a trieur is normally ordered for a given capacity and specified function, a sample of the product to be separated should be included with the order. If a trieur is ordered that has a throughput capacity of 1000 kg/h and can remove 15% large brokens (5/8–6/8) from the head rice it must not be overloaded. For example, if the rice to be graded contains 30% large brokens (5/8–6/8) the machine will not be able to remove them all and the overflow will be a mixture of head rice and large brokens. The same will happen if the rice holds 15% large brokens (5/8–6/8) and is fed at the rate of 1500 kg/h instead of 1000 kg/h. In the first case not all brokens can be removed because the number of indents is insufficient. In the second case not enough pockets are available to lift the brokens because too many of the pockets are filled with head rice grains, and consequently, not all the brokens can be separated.

Examples of Paddy Grading

With rotating reels and trieurs perfect paddy grading can be achieved. A large number of combinations are possible although sometimes one pass through a single machine will do. Since the grain flow through the grading equipment depends on the condition of the product to be graded, the grain flow should be made flexible and, consequently, it should be made possible to bypass certain machines.

(1) Using one trieur (Fig. 27A) the paddy can be graded into long grains (LG) and short grains (SG).

(2) Using one grading reel with two compartments the paddy can be graded into immature grains, thin grains, and thick grains.

(3) Using one single compartment grading reel and one trieur (Fig. 27B) the paddy can be graded into thin short grains (TS), thin long grains (TL), and thick grains.

(4) Using one single compartment grading reel and two trieurs in series (Fig. 27C) the paddy can be graded into thin short grains (TS), thin medium grains (TM), thin long grains (TL), and thick grains.

(5) Using one double compartment grading reel and two trieurs in series (Fig. 28) the paddy can be graded into immature (dead) grains, thin short grains (TS), thin medium grains (TM), thin long grains (TL), and thick grains.

(6) Using one triple compartment grading reel and two trieurs in parallel (Fig. 29) the paddy can be graded into immature (dead) grains, thin short grains (TS), thin long grains (TL), thick short grains (THS), thick long grains (THL), and round grains.

The Oscillating Grading Sieve

Oscillating grading sieves are commonly used in the Philippines as paddy precleaners for the processing of both huller and whitening-cone discharge. Only the latter process actually refers to a white rice grading function. An oscillating sieve is a slightly inclined sieve, supported by flexible wooden or steel bars, that is moved back and forth by a vertical eccentric drive from a transmission shaft. The frequency of the stroke varies between 200 and 400 cycles per minute.

The actual sieve is a perforated steel sheet with preselected round perforations or a wire screen with preselected mesh. For perfect performance the sieve should be self-cleaning; however, this is not normally the case in rice mills made locally in the Philippines. The oscillating sieves can be of the single or double layer type. In the Philippines the rice discharged from the whitening cone is passed through a double layer type sieve. The rice

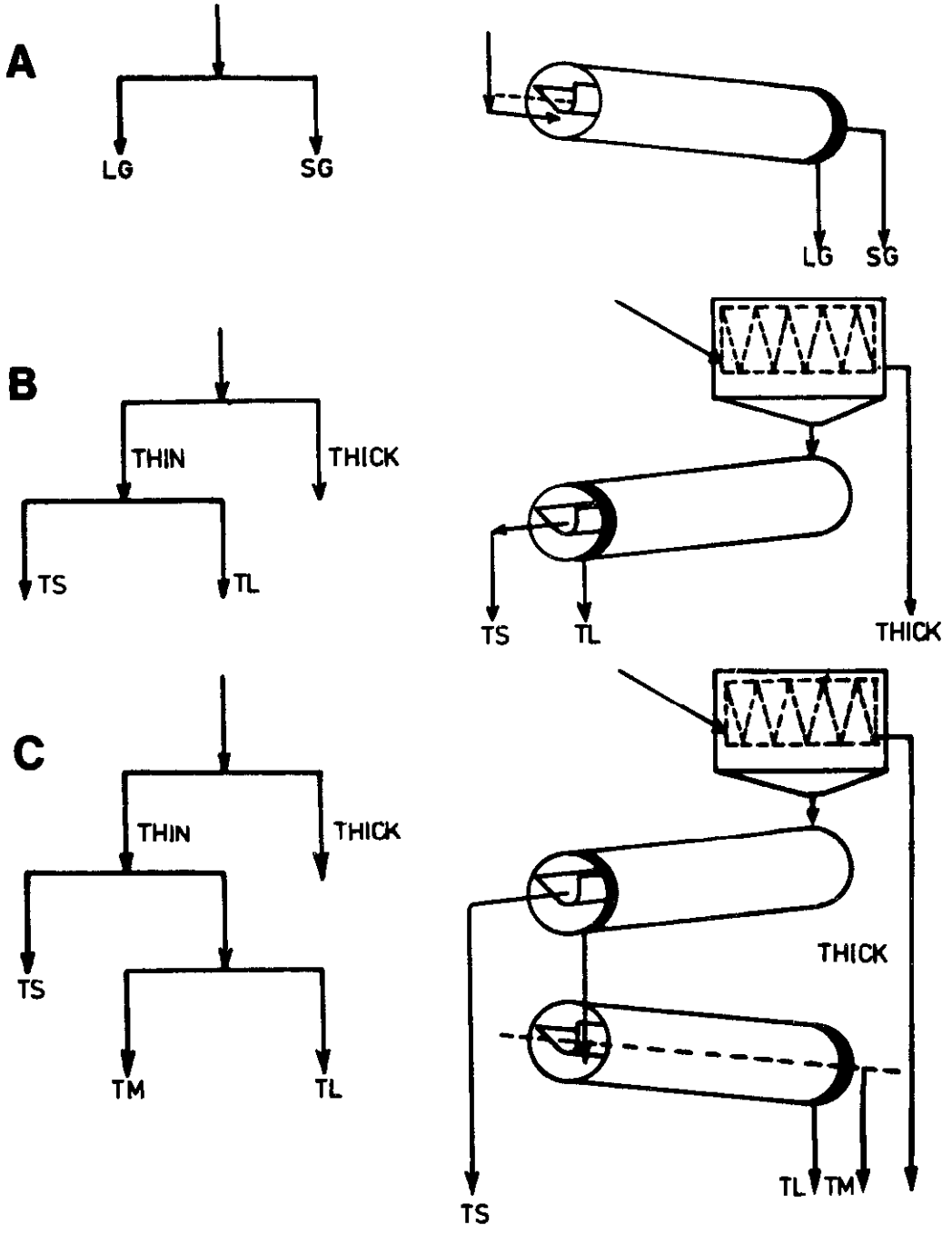

FIG. 27. Examples of paddy grading. (A) One trieur. (B) One grading reel with two compartments. (C) A single compartment grading reel and one trieur.

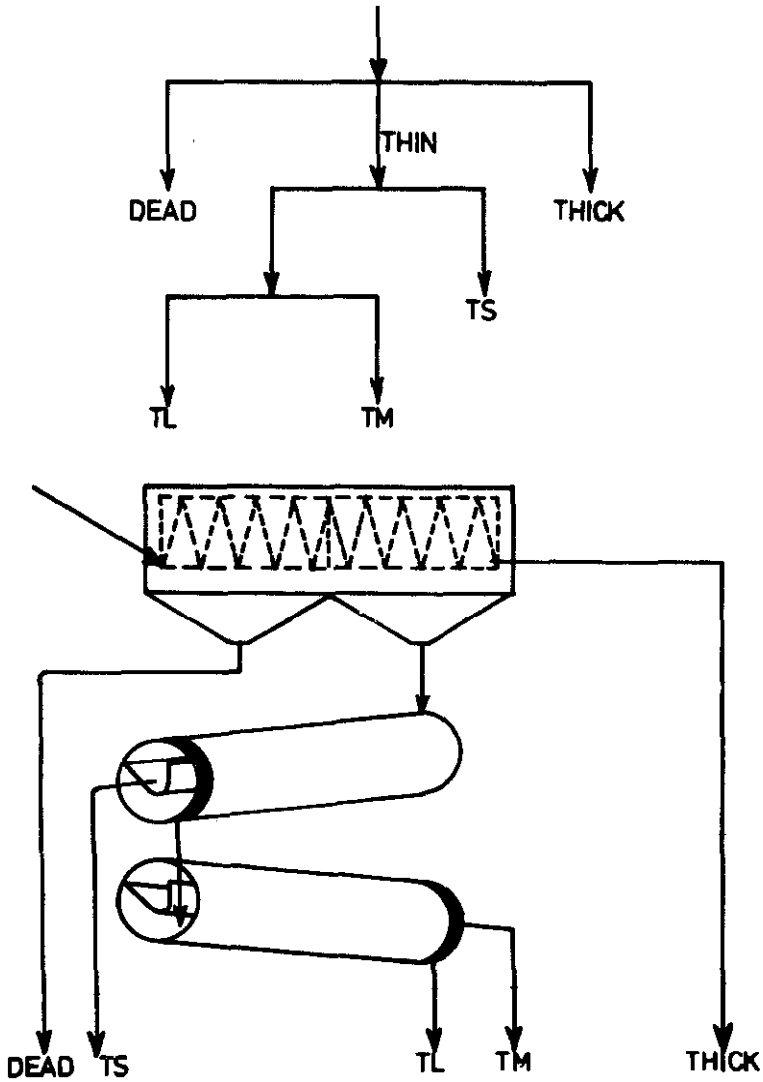

FIG. 28. Grading of paddy using one double compartment grading reel and two trieurs in series.

passes the first tray when unloaded by the first cone, and the second tray when discharged by the second cone. Actually this machine is a combination of two single tray sieves because the perforations in the sheets of both trays are the same. Their function is to remove the points, germs, and very small brokens from the rice, which is a grading function. However, single and double layer oscillating sieves can be exclusively used for the grading of fully whitened and polished rice.

If a single tray sieve is used (Fig. 30A) small brokens (1/8–2/8) (SB) can be separated from the large brokens (LB) and head rice (HR). A double tray sieve that has two different sizes of perforations can separate small brokens (1/8), small brokens (2/8), and large brokens and head rice (Fig. 30B). The same separation performance is obtained if two single tray sieves are used (Fig. 30C).

The grading capacity per square foot is rather low since, at the end of each stroke, the movement of the grain is brought to a full stop to change the direction of movement of the grain. The grains, therefore, are continuously accelerating and decelerating between

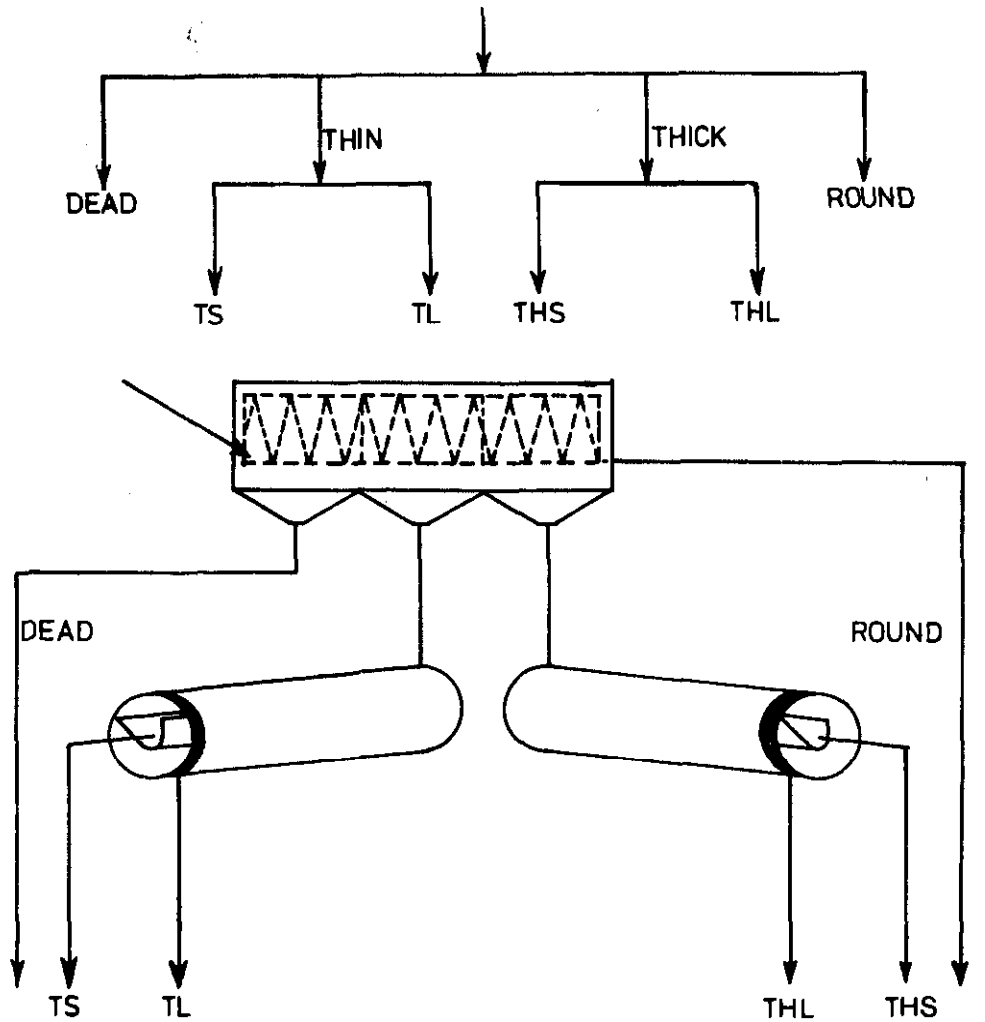

FIG. 29. Grading of paddy using one triple compartment grading reel and two trieurs in parallel.

the limits of zero and maximum. When there is practically no movement of the grain over the tray, the separation efficiency is very low. Since the grain movement over the trays is very variable, the separation of the small brokens will also be very irregular. This problem does not exist when the movement of the grains over the tray is constant. This is the case with so-called swing sieves or plansifters.

The Plansifter (Swing Sieve)

The plansifter, in general, is a single layer sieve hanging on four steel cables (Fig. 31A). The tray is directly or indirectly driven by a horizontal eccentric that makes the tray swing around in its hanging position, following the movement of an eccentric drive (Fig. 31B). The perforated sieve of the tray can be uniform in its perforations, in which case the plansifter is only separating one product, normally small brokens and points. However, the sieve can be divided into two sheets with different perforations, in which case two grades of brokens can be separated from the main product (Fig. 32A). This single layer plansifter can be driven by an electric motor through a V-belt transmission mounted on a drive assembly under the sieve (Fig. 31A), or by a flat-belt transmission that is normally mounted over the machine (Fig. 32A).

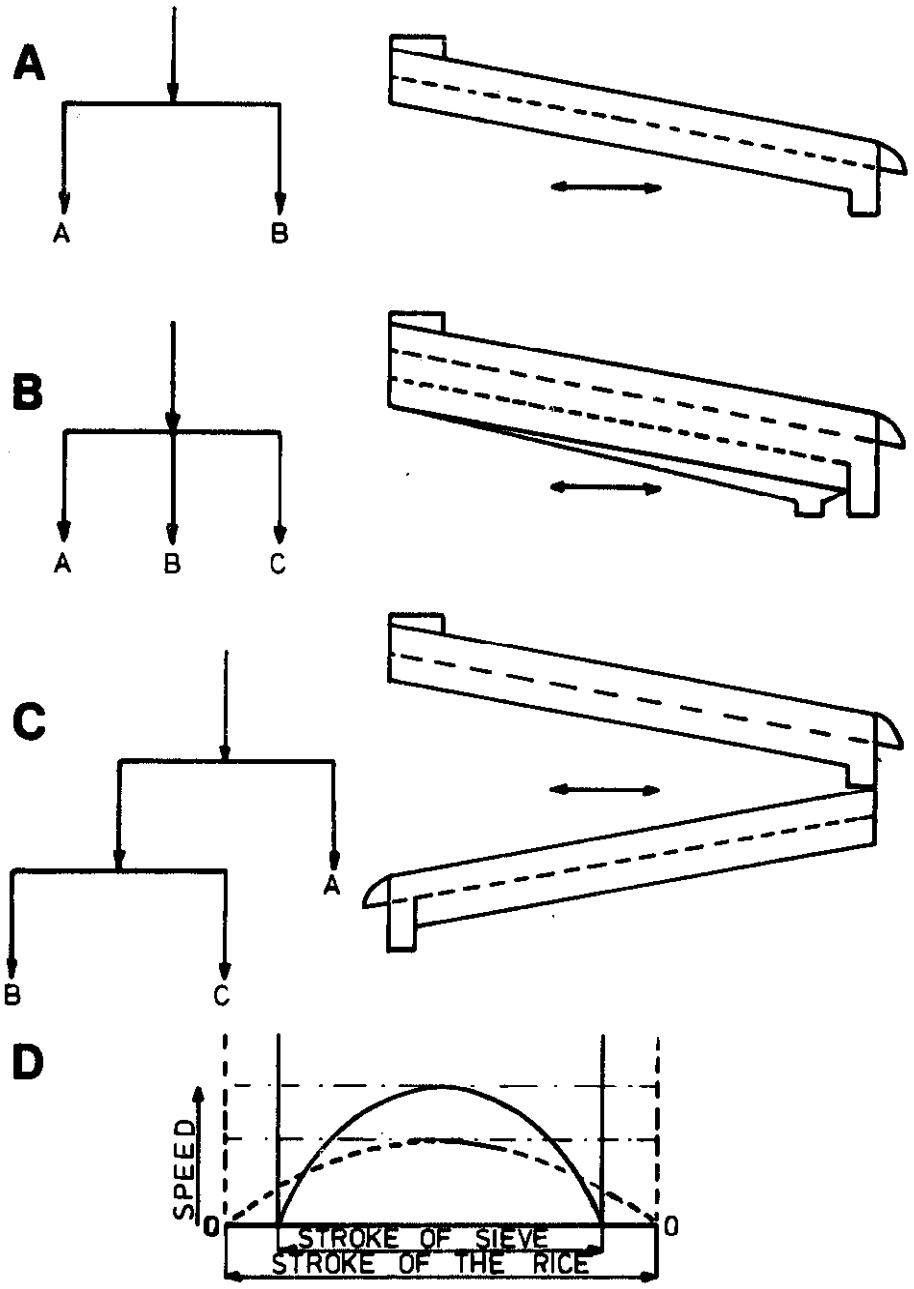

FIG. 30. Grading of white rice by oscillating grading sieves. (A) A single tray sieve. (B) A double tray sieve (C) Two single tray sieves used in series. (D) During the operation of the sieve the grains are continuously accelerated and decelerated and separation efficiency is reduced.

The movement of the grain over the swinging tray is nonstop, slowly downwards, and in a spiral-like direction over the perforated sheet. The movement is nonstop because the tray does not accelerate and decelerate in its movement (Fig. 31C) and is downwards because of the tray inclination. The movement is spiral-like and not fully circular because the grain direction is the result of the peripheral speed of the eccentric and the centri-

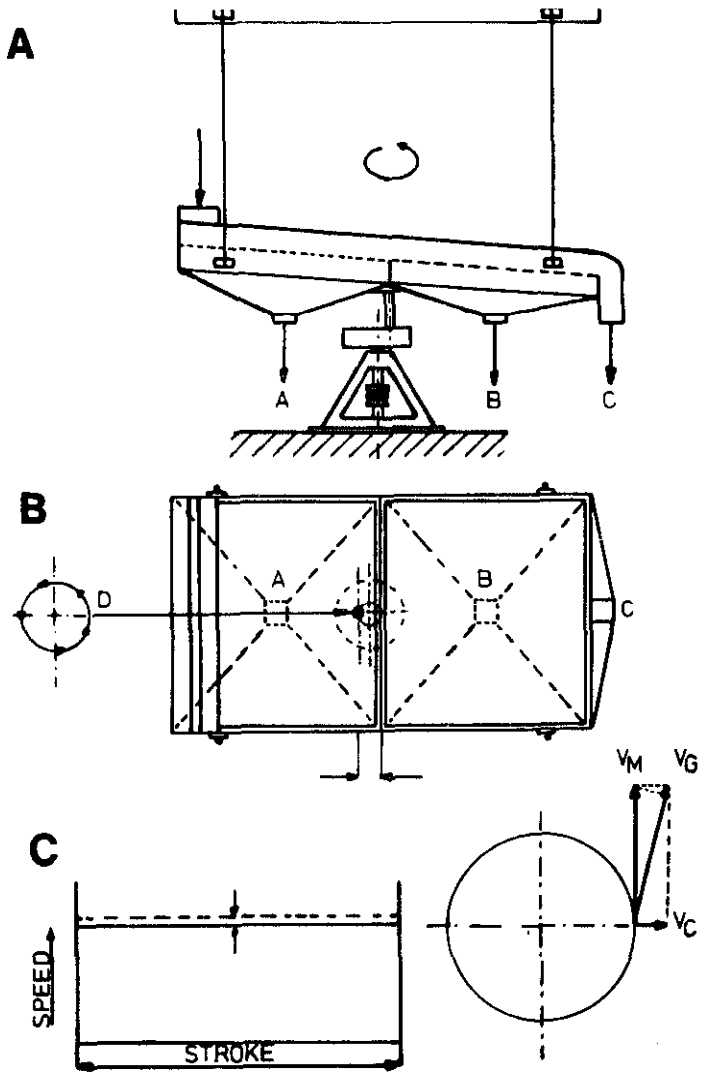

FIG. 31. The plansifter is a single layer sieve hanging on four cables. (A) The screen has uniform perforations for the separation of a single product. (B) The tray is driven by a horizontal eccentric that makes the tray swing around following the movement of the eccentric drive. (C) The movement of the grain over the tray is constant; therefore, the separation performance is more regular and efficient than the oscillating sieve.

fugal speed of the tray. Consequently, the grains always move slowly to the sides of the sieve trays.

Plansifters can also be made with two or more trays, each tray having a different perforation: the largest perforations for the top tray; the smallest perforations for the bottom tray. These plansifters are more compact and can be made as self-supported machines by hanging the plansifter in the steel frame that supports the electric motor drive and eccentric. One of these machines was constructed by a German manufacturer, it is totally enclosed and incorporates a bran aspiration system (Fig. 32B). This machine produces two grades of rice (2,3) with a mixture of brokens and head rice (4) as its overflow. Other combinations are always possible by changing the

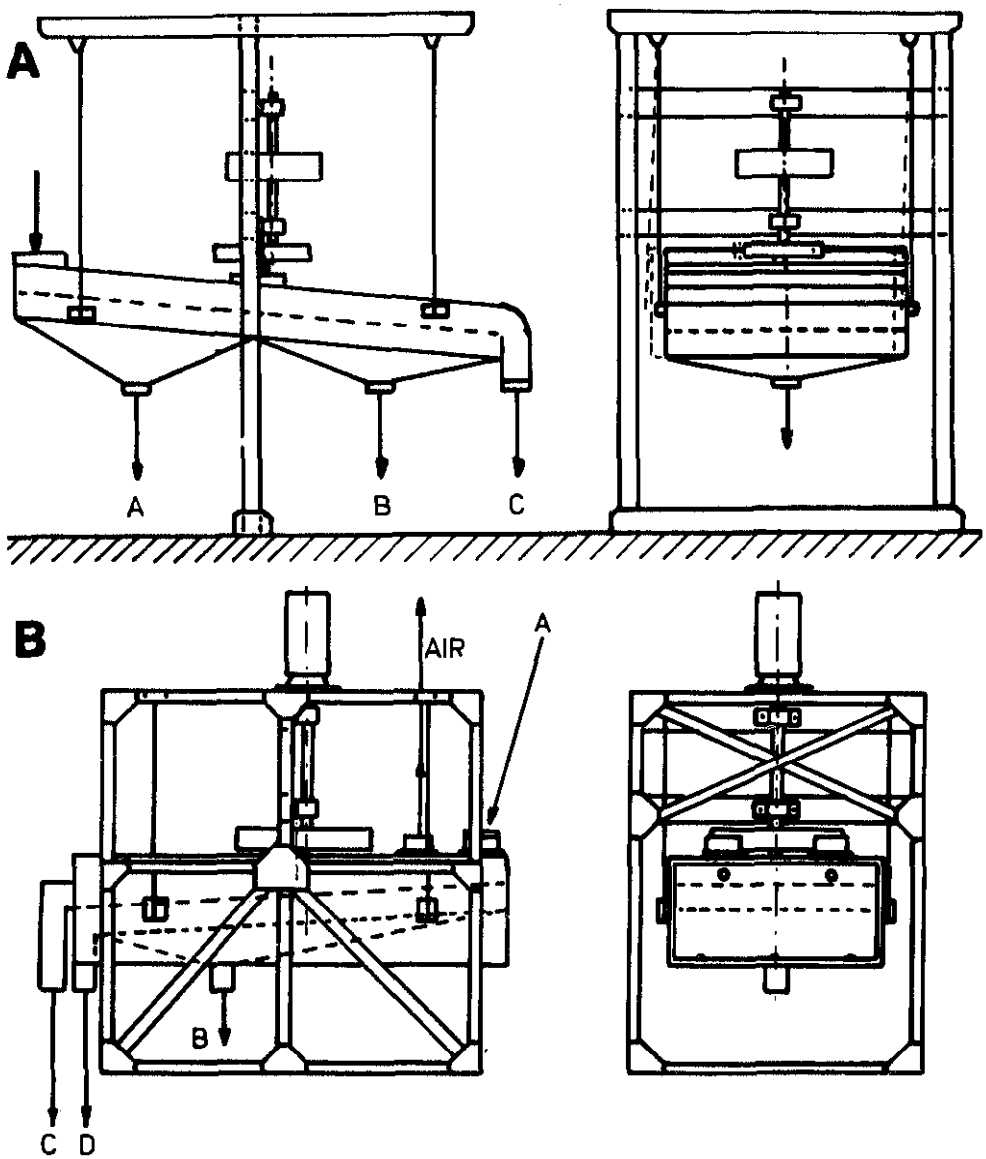

FIG. 32. Plansifters. (A) Sieve divided into two sheets with different sized perforations for the separation of two grades of brokens. (B) The "compact" Schule plansifter that incorporates a bran aspiration system.

mesh of the screens.

In large capacity rice mills so-called high capacity plansifters are used. These very compact machines consist of two, four, six, or eight rectangular steel boxes or sections that hold a large number of trays that have different mesh wire screen sieves (Fig. 33A). The trays are specially designed and follow a fixed pattern for grain overflow and screen discharge. The number of trays per section varies between eight and twelve depending on the capacity and product to be graded. Because of the multi-tray design and the repetition of grading functions, it is possible to separate as many as four grades in one pass. These machines are used in rice mills, corn mills, flour mills, and feed mills. The eccentric drive with counterweights is located in the

centre of the machine and always divides the number of sections into two equal parts (Fig. 33B).

The sections are framed together making one compact block. This swinging block of plansifter sections hangs on a large number of rattan bars that are solidly fixed in the top section of the supporting frame. Each section has five outlet spouts, four for the separated grades and one for the main overflow. Through a spout system these grades are fed into bins or to machines for further processing.

In some of the rice mills and corn mills in the Philippines these high capacity plansifters have already been installed. Their horsepower consumption is very low, their flexibility in grading performance is unlimited, and their worn screens can be replaced with practically no loss of time. Simply open a door, remove the damaged tray, replace it with a new one, close the door, and continue operations.

Rice grading plants can be very simple or they can be very complicated and offer a large program of alternative grain flows. Some examples of white rice grading units using plansifters (or oscillating sieves) and trieurs are given below.

(1) Using one single layer sifter and two trieurs in series (Fig. 34A) the paddy can be graded into points and very small brokens (P), small brokens (SB), large brokens (LB), and head rice (HR).

(2) Using one double layer sifter and two trieurs in parallel (Fig. 34B) the paddy can be graded into points (P), small brokens 1/8–2/8 (SB), large small brokens 3/8 (LSB), large brokens (LB), and head rice (HR).

(3) Using one double layer sifter and three trieurs in series (Fig. 34C) the paddy can be graded into points (P), small brokens 1/8–2/8 (SB), small large brokens 3/8–4/8 (SLB), large brokens 5/8–6/8 (LB), and head rice (HR).

(4) Using one double layer sifter, and five trieurs operating in parallel or in series, including change valves (Fig. 35), the grading results are flexible and the paddy can be graded into points (P), small brokens 2/8 (SB 2), small brokens 3/8 (SB 1), large brokens 4/8 (LB 2), large brokens 5/8 (LB 1), and head rice 6/8–7/8–1/1 (HR) or combinations of brokens and/or head rice.

Volumetric Mixers

Volumetric mixers are used in rice mills where export markets require the rice to be mixed in accordance with preset programs after it has been graded. There are volumetric mixers of different designs but basically they follow the same principle.

Grain is loaded into a rotating compartment drum (Fig. 36A, no. 1) and is unloaded through an opening in the drum housing (Fig. 36A, no. 2) that can be partly closed to set the volume of grain to be discharged (Fig. 36A, no. 3). This controls the discharge volume per rotation and because the shaft speed of the compartment drum is made variable, a wide range of capacities can be obtained. There are provisions for inspection of the operation (Fig. 36A, no. 4) and sampling of the discharged product (Fig. 36A, no. 5). At the same time it is possible to bypass the mixer for free discharge of the bin in question (Fig. 36A, no. 6). The setting of the sleeve, which partly closes the opening of the drum housing, can be adjusted manually by a handle (Fig. 36B, no. 1), which can easily be locked (Fig. 36B, no. 2). These volumetric mixers are mounted under the bins holding the graded rice.

A simple installation for the grading of milled rice (Fig. 37) into points, small brokens, large brokens, and head rice followed by mixing consists of: (1) a bin holding the ungraded rice; (2) a single layer plansifter for the separation of points; (3) an elevator to lift the rice; (4) a trieur for the separation of the small brokens; (5) a bin for small brokens; (6) a second trieur for the separation of the large brokens and head rice; (7) a bin for large brokens; (8) a bin for head rice; (9) volumetric mixers; (10) a belt conveyor; (11) an elevator; and (12) a bin for bagging.

These sample installations are made for rice mills with a capacity of 2000 or more kilograms of paddy intake per hour (525 cavens/12 h) and can already be made in the

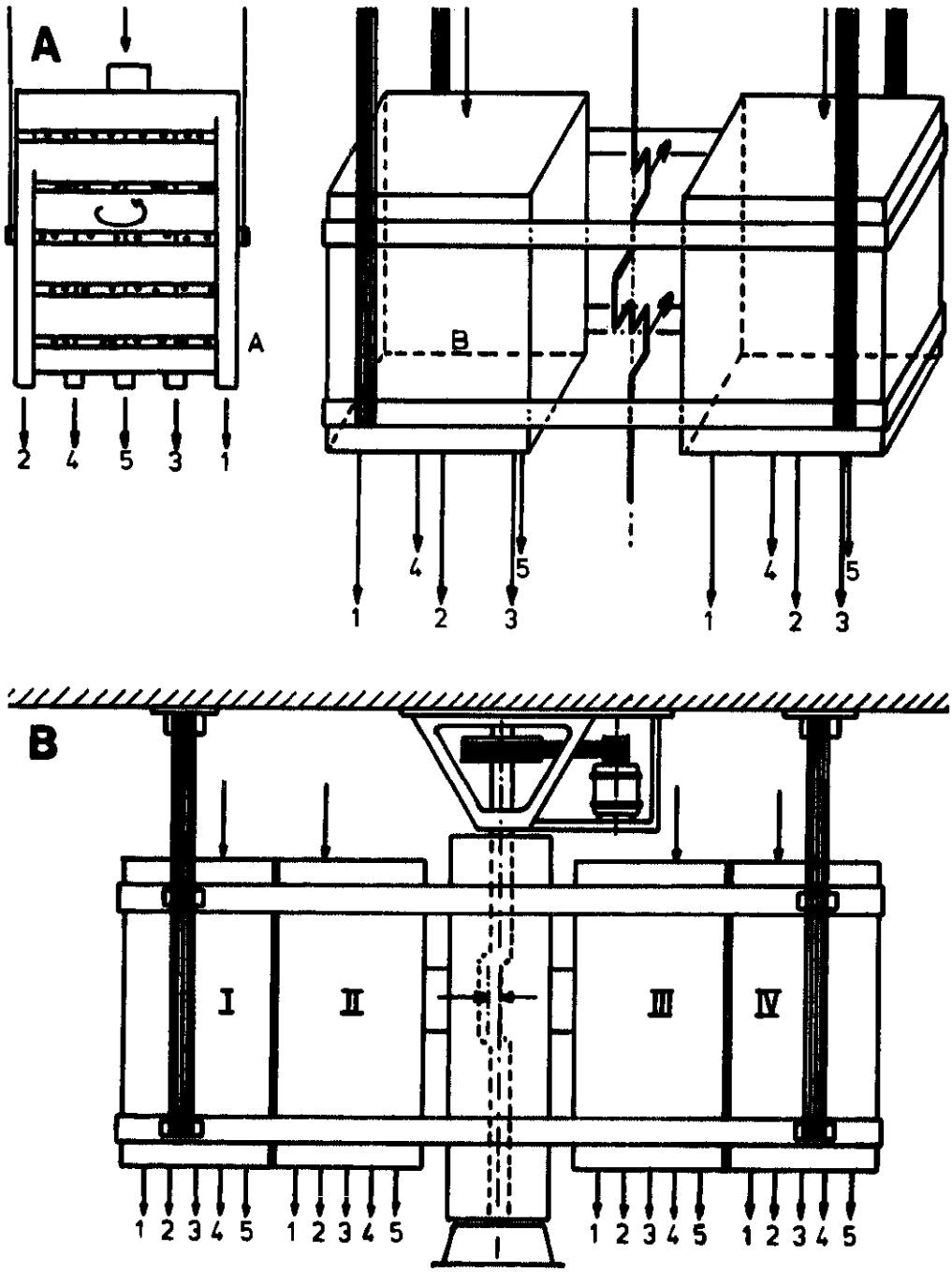

FIG. 33. (A) High capacity plansifters consist of rectangular steel boxes that hold a variety of sieves. (B) The eccentric drive divides the number of sections into equal parts. Each section has five outlet spouts, four for the separated grades and one for the main overflow.

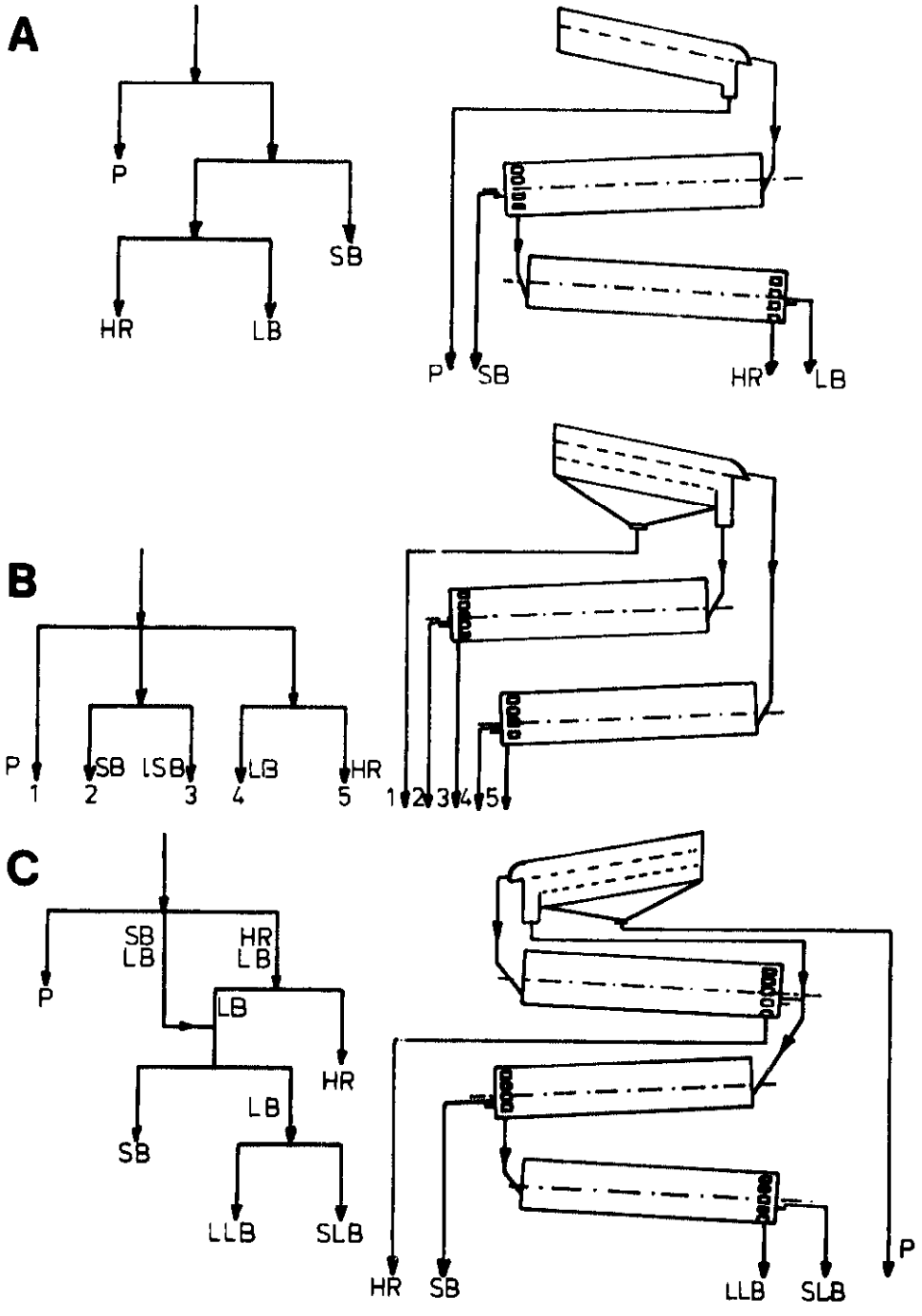

FIG. 34. Examples of white rice grading. (A) One single layer sifter and two trieurs in series. (B) One double layer sieve and two trieurs in parallel. (C) One double layer sifter and three trieurs in series.

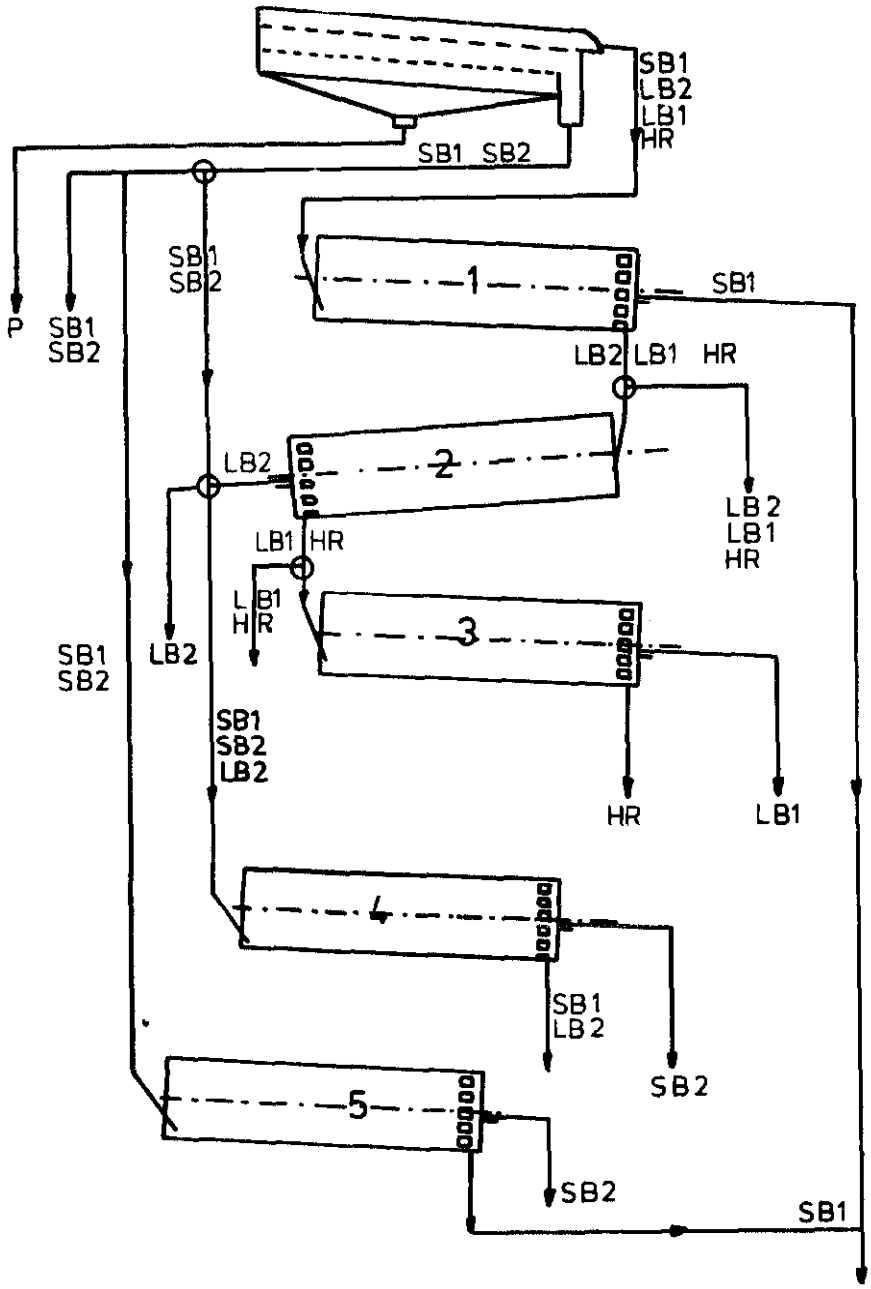

FIG. 35. Flexible grading of white rice is obtained by using one double layer sifter and five trieurs operating in parallel or in series.

Philippines. Their use, however, depends on the market situation and requires a study of their feasibility in relation to the market requirements. — HARRY VAN RUITEN. *Department of Agricultural Engineering, University of the Philippines at Los Baños, College, Laguna, Philippines.*

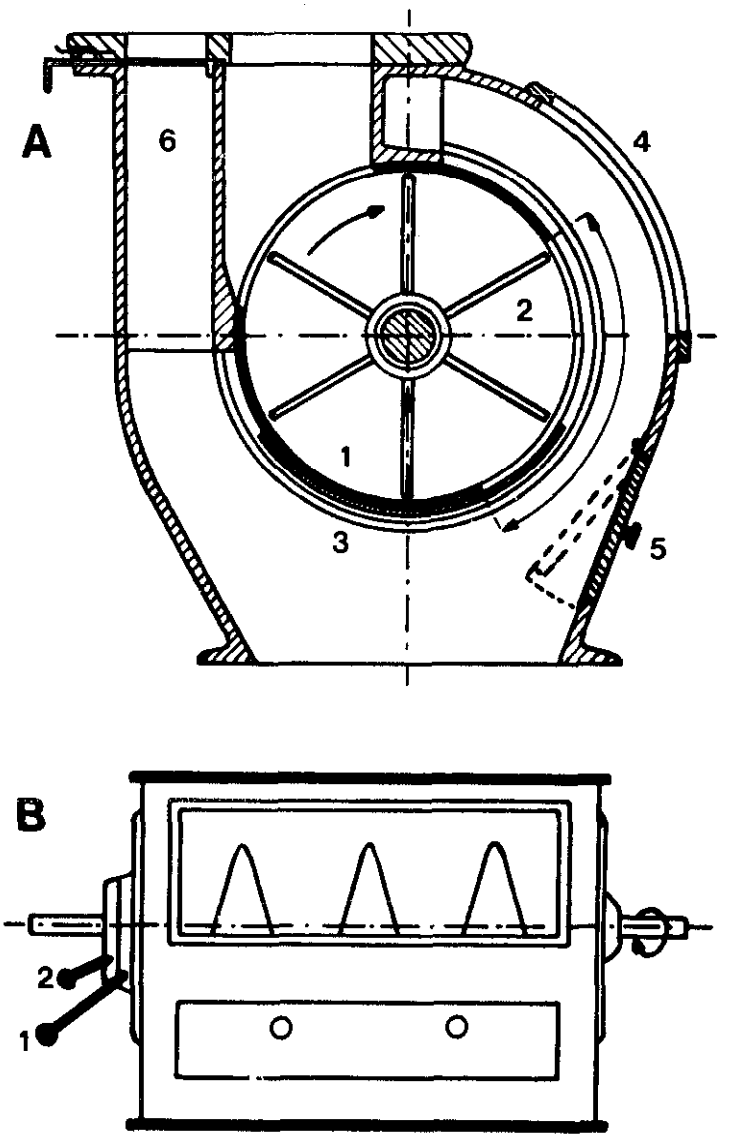

FIG. 36. Volumetric mixer. (A) The volume of grain released from the rotating compartment drum is controlled by a sleeve (2) that adjusts the amount of discharge per rotation. (B) The adjustment of this sleeve is controlled by an external handle (1) that can be locked in position (2).

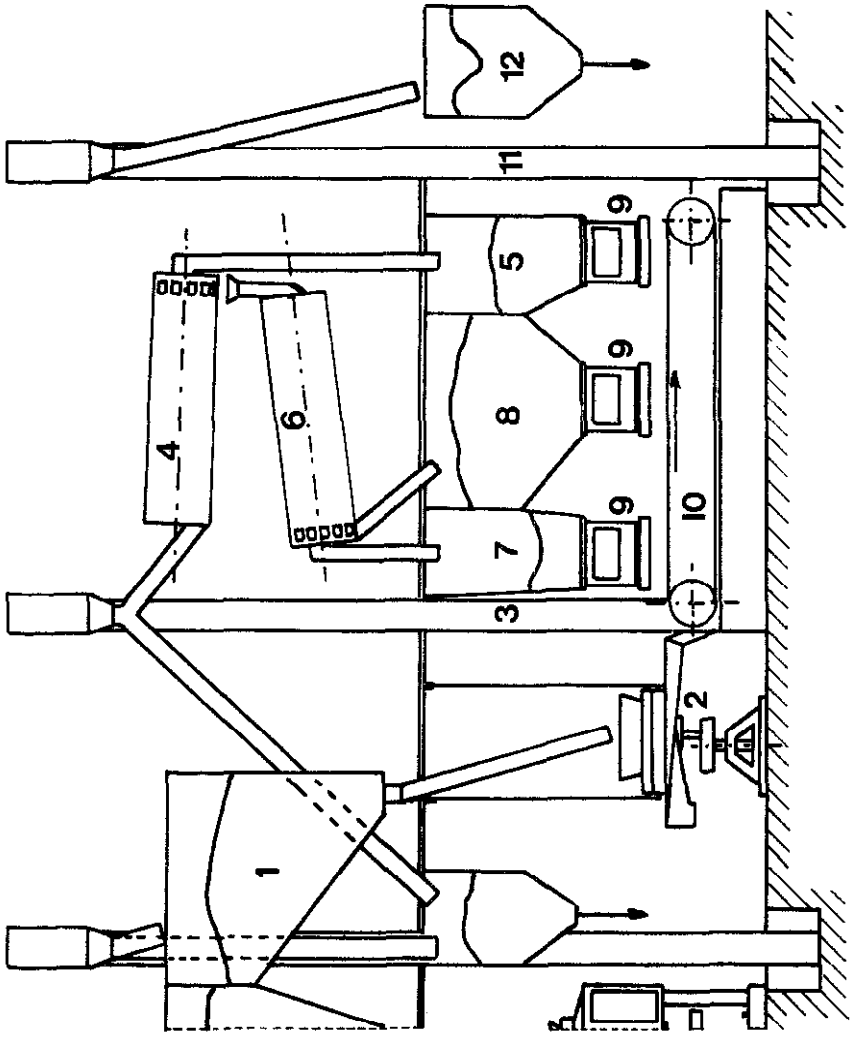

FIG. 37. Simple installation for the grading of milled rice into points, small brokens, large brokens, and head rice followed by mixing: (1) holding bin (ungraded rice); (2) single layer plansifter; (3) elevator; (4) trieur; (5) holding bin (small brokens); (6) trieur; (7) holding bin (large brokens); (8) holding bin (head rice); (9) volumetric mixers; (10) belt conveyor; (11) elevator; and (12) bin for bagging.

Experimental Design

Measurement

In statistics we recognize four levels of measurement: (1) nominal scale; (2) ordinal scale; (3) interval scale; and (4) ratio scale. The following illustration will clarify these various scales.

Three rice samples, denoted by the letters A, B, and C are to be examined according to the following objectives: (1) to identify the varieties by a symbol or number; (2) to rank the samples according to texture; (3) to determine the temperature setting in drying the sample to 14% MC in 5 h drying time; and (4) to determine the protein content. The results of the examination are given in Table 3.

Concept of Random Variables and Their Distributions

The observations that we make in our experiments may employ one or more of the four levels of measurement. The measurements that we observed are in general governed by the laws of chance, hence, they are generally called random variables. Each possible outcome in an experiment is also said to have its own probability of occurrence. The two examples given below illustrate these concepts.

Example 1

A 100-grain sample of milled rice is examined and each grain is classified as either "whole" or "not whole." The following measure is adopted: $x = 0$ if the grain is not whole and $x = 1$ if the grain is whole. The results are given in Table 4.

From these results we can say that a grain selected at random has a probability of 0.30 of being not whole or a probability of 0.70 of being whole. This is an example of a binomial random variable and binomial probability distribution.

The Bernoulli probability function is an example of a binomial population with probability function

$$f(x) = \theta^x(1 - \theta)^{1-x}, x = 0,1$$

where: $\theta = P_r$ (whole) and

$1 - \theta = P_r$ (not whole)

Example 2

The percentage protein content, x, of 100 samples of clean rice is determined. The summary of the data is shown in Table 5.

This experiment is a typical example wherein the random variable is in the ratio scale (continuous). The probabilities under this type of distribution are defined only between interval

TABLE 4. Results for grain classification.

Random variable (x)	Number corresponding to x ($N_{(x)}$)	Relative frequency of probability ($P_r(x) = N_{(x)}/N$)
0	$N_{(0)} = 30$	30/100 = 0.30
1	$N_{(1)} = 70$	70/100 = 0.70
Sum:	$N = 100$	1

TABLE 3. Results of the examination of three rice samples.

Purpose of measurement	Sample A	Sample B	Sample C	Level of measurement (scale)
(1) Identification	BPI-76	IR8	C4	Nominal
(2) Texture ranking	2	1	3	Ordinal
(3) Temperature setting (°F)	210	215	205	Interval
(4) Protein content (%)	10.1	12.1	9.8	Ratio

values. Thus from the table we have $P_r(11.75 \leq x \leq 17.94) = 0.25$ and $P_r(x > 12.34) = 0.05$.

The normal distribution is an example of a theoretical frequency function of a continuous random variable x. The function is:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-1/2[(x-\mu)^2/\sigma]}, \text{ for } -\infty < x < \infty$$

The graph of a normal curve is:

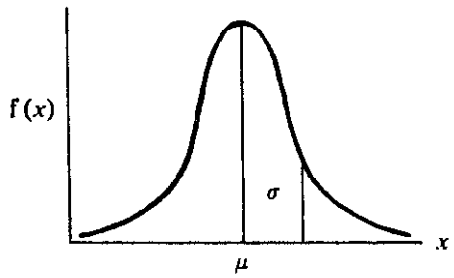

The curve is symmetric, bell-shaped, and asymptotic to the x-axis. The parameters of the distribution are μ, which is the mean (a measure of average) and σ, which is the standard deviation (a measure of spread or variability).

Sampling, Estimation, Testing Hypotheses, and Sample Size

The two main purposes of sampling are: (1) to estimate the population parameters such as μ and σ; and (2) to test hypotheses concerning population parameters. A random mechanism such as the use of a table of random numbers must be employed so that the tests of the hypotheses will be valid.

Table 6 shows a summary of the estimation and testing hypotheses procedures under the normal and binomial populations. Using σ levels of significance the critical values for the test statistics are:

$$\text{for } t_c\text{: } t_{tab} = t_{\alpha/2,n-1}$$

$$\text{for } \chi^2{}_c\text{: } \chi^2{}_{tab} = \chi^2{}_{\alpha/2,n-1} \text{ or } \chi^2{}_{(1-\alpha/2),n-1}$$

$$\text{for } Z_c\text{: } Z_{tab} = Z_{\alpha/2}$$

To determine the sample size needed to estimate the population mean, μ, with a given precision $d = x - \mu$ and a degree of confidence of $[100(1 - \alpha)]\%$ that the estimate will be within the desired precision, we use the equation

$$n = \frac{[(Z_{\alpha/2})\sigma]^2}{d^2}$$

To use this formula, we must have a good estimate of σ. For example, if we wish to estimate the mean percentage of protein content of IR8 within $\pm$ 0.05% with a degree of confidence of 95% and $\sigma = 0.3$ the sample size should be:

$$n = \frac{[Z_{0.025}(0.3)]^2}{(0.05)^2}$$

$$= \frac{[(1.96)(0.3)]^2}{0.0025}$$

$$= 138$$

TABLE 5. Percentage protein content of 100 samples.

Interval values of x	Midpoint values of x	Frequency (f)	Relative frequency (rf)
11.15–11.34	11.245	7	0.07
11.35–11.54	11.445	14	0.14
11.55–11.74	11.645	19	0.19
11.75–11.94	11.845	25	0.25
11.95–12.14	12.045	18	0.18
12.15–12.34	12.245	12	0.12
12.35–12.54	12.445	5	0.05
Sum	—	$N = 100$	1.00

Simple Statistical Designs and Analysis of Data

The three main principles of experimental design are: (1) replication; (2) randomization; and (3) local control. Replication provides for an estimate of the experimental error (variation due to experimental units treated alike). It also provides for the increase in the precision of the estimate of treatment effects. On the other hand, randomization ensures an unbiased estimate of experimental error and makes the test of significance valid. Proper choice of experimental design, proper choice of size and shape of experimental units, and full utilization of concomitant variables (covariance analysis) are ways to minimize the magnitude of the experimental error of the experiment.

TABLE 6. Summary of the estimation and testing hypotheses used for normal and binomial populations.

Population	Parameter	Sample estimate	Null hypothesis (H_0)	Test criterion
Normal	μ	$\bar{x} = \frac{\sum x_i}{n}$	$\mu = \mu_0$	$t_c = \frac{(\bar{x} - \mu_0)n}{s}$
	σ^2	$s^2 = \frac{\sum(x_i - \bar{x})^2}{n - 1}$	$\sigma^2 = \sigma_0^2$	$\chi_c^2 = \frac{(n - 1)s^2}{\sigma_0^2}$
Binomial	θ	$p = \frac{n_E}{n}$	$\theta = \theta_0$	$Z_c = \frac{(p - \theta_0)\sqrt{n}}{\sqrt{\theta_0(1 - \theta_0)}}$

TABLE 7. Data for completely randomized design (CRD).

Machine	Replications 1	2	3	4	5	Total (T)	Mean (x)
A	68.2	68.1	68.5	68.7	68.5	342.0	68.4
B	66.3	66.9	66.6	66.7	66.5	333.0	66.6
C	67.9	68.0	67.7	68.2	67.7	339.5	67.6
Grand total and mean:						1014.5	$\bar{\bar{x}} = 67.6$

The Completely Randomized Design (CRD)

The main objective in setting up an experiment in CRD is to compare the means of effects of two or more treatments. We shall let k = number of treatments. The use of this design assumes that the total number of experimental units, say n, are homogeneous or more or less homogeneous. The treatments then are assigned into the experimental units giving: n_1 replications to treatment 1; n_2 replications to treatment 2;. . .; and n_k replications to treatment k.

Example

Fifteen samples of rough rice are available to study the mean performance of three milling machines. The samples are assumed to be homogeneous. The layout and the data on the percentage of whole grains, x, are shown below:

1	4	7	10	13
A 68.2	C 67.9	A 68.1	B 66.3	B 66.9

2	5	8	11	14
B 66.6	C 68.0	B 66.7	A 68.5	A 68.7

3	6	9	12	15
C 67.7	C 68.2	A 68.5	B 66.5	C 67.7

The tabular format for these data is given in Table 7. We next compute the following quantities (sum of squares, SS) for the analysis of variance table (AOV).

$$\text{Correction factor (CF)} = \frac{(1014.5)^2}{15} = 68\,614.02$$

$$\text{Total SS} = (68.2)^2 + (66.3)^2 + \ldots + (67.7)^2 - \text{CF}$$

$$= 68\,623.27 - 68\,614.02$$

$$= 9.23$$

$$\text{Machine SS} = \frac{(342.0)^2}{5} + \frac{(333.0)^2}{5} + \frac{(339.5)^2}{5} - \text{CF}$$

$$= 68\,622.65 - \text{CF}$$
$$= 8.63$$

$$\text{Error SS} = \text{Total SS} - \text{Machine SS}$$
$$= 0.60$$

The AOV table is given in Table 8. Since $F_c = 86.3 > F_{0.01(2,12)} = 6.93$, we conclude that the means differ significantly at the 1% level.

Several methods are available for determining which pair of means differ significantly. One of the best of these methods is Scheffé's Test. The procedure is given below.

Let $L = \bar{x}_i - \bar{x}_j$, where $i \neq j$. We find the following quantities:

(1) $$\text{var}(L) = s_E^2\left(\frac{1}{n_i} + \frac{1}{n_j}\right)$$

(2) $$F_o^2 = (k-1)[F_{\alpha,(k-1,n-k)}]$$

The comparison L is significant at the α level if:

$$|L| \geq \sqrt{(F_o^2)\,\text{var}(L)}$$

The summary of the analysis usually includes the treatment means, the standard error of a treatment mean, $\text{SE}(\bar{x}_i) = \sqrt{s_E^2/n_i}$, the coefficient of variation, $\text{CV} = (\sqrt{s_E^2}/\bar{x})\,100$, and the comparison L.

Randomized Complete Block Design (RCB)

As in the CRD, the main objective in the use of this design is to compare the means of k treatments where $k \geq 2$. The n experimental units can no longer be assumed to be homogeneous and it is possible to subdivide them into r blocks. The experimental units within each block are then assumed to be more homogeneous compared to experimental units from block to block. The number of experimental units within each block is k. The k treatments are allocated at random within each block.

Example

The same machines, A, B, and C are to be tested using the same variety of rice but the tests are to be conducted at four different places. The rice samples now are assumed to be homogeneous only with respect to moisture content within places, but they may differ from place to place.

The layout and data are shown below (x = % whole grain).

Place 1	Place 2	Place 3	Place 4
A 68.2	C 66.0	A 68.4	A 68.5
C 67.8	B 67.5	B 66.3	C 67.8
B 66.1	A 68.0	C 67.9	B 66.6

The data format is shown in Table 9. The computation of SS and AOV is as follows:

$$\text{CF} = \frac{(809.1)^2}{12}$$
$$= 54\,553.57$$

$$\text{Total SS} = (68.2)^2 + (66.1)^2 + \ldots + (67.8)^2 - \text{CF}$$
$$= 54\,562.85 - \text{CF}$$
$$= 9.28$$

$$\text{Machine SS} = \frac{(273.1)^2 + \ldots + (269.5)^2}{4} - \text{CF}$$
$$= 54\,559.03 - \text{CF}$$
$$= 5.46$$

$$\text{Place SS} = \frac{(202.1)^2 + \ldots + (202.9)^2}{3} - \text{CF}$$
$$= 54\,553.94 - \text{CF}$$
$$= 0.37$$

$$\text{Error SS} = \text{Total SS} - \text{Machine SS} - \text{Place SS}$$
$$= 3.45$$

The analysis of variance is given in Table 10. Since $F_c = 4.75 \leq F_{0.05(2,6)} = 5.14$, the machine means are equal. No further test is necessary in this case.

For RCB, the summary of analysis includes: (1) the treatment means, $\bar{x}_i$; (2) $\text{SE}(\bar{x}_i) = \sqrt{s_E^2/r}$; (3) $\text{CV} = (\sqrt{s_E^2}/\bar{x})\,100$; and (4) the comparison L if the computed F value is significant.

Latin Square (LS)

Again the main objective in the use of this design is to compare the effects of k treatments. It is best for k between 5 and 8.

TABLE 8. Analysis of variance (AOV) table for completely randomized design (CRD).

Source of variation (SV)	Sum of squares (SS)	Degrees of freedom (DF)	Mean square (MS)	F value
Total	9.23	$n - 1 = 14$		
Machine	8.63	$k - 1 = 2$	$4.315 = s_M^2$	$s_M^2/s_E^2 = 86.3$
Error	0.60	$n - k = 12$	$0.05 = s_E^2$	

The features of this design are: (1) the total number of experimental units is $n = k^2$, i.e. a perfect square of k; (2) when used in field experiments, it is assumed that the experimental area (rectangular or square) varies in two directions, say, by row and column. It may also be used in experiments where the effects of two other factors (the row and column factors) are also to be investigated, but it is assumed that the effects of the factors are independent.

In LS, the randomization is restricted in two ways: (1) the treatments are allocated at random within each column and within each row; and (2) no two treatments must appear more than once within each row and within each column.

Example

Let A, B, and C be the machines, C_1, C_2, and C_3 be the moisture content, and V_1, V_2, and V_3 be the varieties. Measurement x = the percentage of whole grain in the sample. The layout for this 3 × 3 LD design is shown below.

	C_1	C_2	C_3
V_1	B 68.2	C 67.8	A 66.1
V_2	A 68.2	B 67.7	C 66.2
V_3	C 66.6	A 68.4	B 66.3

The tabular format for computation of the AOV is shown in Table 11.

Machine total: A = 202.7; B = 202.2; and C = 200.6

Machine mean: $\bar{x}_A = 67.6$; $\bar{x}_B = 67.4$; and $\bar{x}_C = 66.9$

Computation:

$$CF = (605.5)^2/9 = 40\,736.69$$

TABLE 9. Data format for randomized complete block (RCB) design.

Machine	Place 1	Place 2	Place 3	Place 4	Machine total	Machine mean
A	68.2	68.0	68.4	68.5	273.1	68.3
B	66.1	67.5	66.3	66.6	266.5	66.6
C	67.8	66.0	67.9	67.8	269.5	67.4
Total:	202.1	201.5	202.6	202.9	809.1	
Mean:	67.4	67.2	67.5	67.6		67.4

TABLE 10. *Analysis of variance (AOV) table for randomized complete block (RCB) design.*

Source of variance (SV)	Sum of squares (SS)	Degrees of freedom (DF)	Mean square (MS)	F value
Total	9.28	$kr - 1 = 11$	—	
Machine	5.46	$k - 1 = 2$	2.73	$s_M^2/s_E^2 = 4.75$
Place	0.37	$r - 1 = 3$	0.12	
Error	3.45	$(k - 1)(r - 1) = 6$	0.575	

$$\text{Total SS} = (68.2)^2 + \ldots + (66.3)^2 - \text{CF}$$
$$= 40\,744.07 - \text{CF}$$
$$= 7.38$$

Moisture content SS

$$= \frac{(203.0)^2 + \ldots + (198.6)^2}{3} - \text{CF}$$
$$= 40\,742.06 - \text{CF}$$
$$= 5.37$$

$$\text{Variety SS} = \frac{(202.1)^2 + \ldots + (201.3)^2}{3} - \text{CF}$$
$$= 40\,736.84 - \text{CF}$$
$$= 0.15$$

$$\text{Machine SS} = \frac{(202.7)^2 + \ldots + (200.6)^2}{3} - \text{CF}$$
$$= 40\,737.50 - \text{CF}$$
$$= 0.81$$

$$\text{Error SS} = \text{Total SS} - \text{Moisture content SS} - \text{Variety SS} - \text{Machine SS}$$
$$= 1.05$$

The AOV table is given in Table 12.

Factorial Designs

When the effects of two or more factors are being investigated in an experiment in which the factorial combination of the various levels of the factor is the total number of treatment, then the design is said to be factorial. For instance, if factor A has a levels, factor B has b levels, and the treatment combination AB has been used in any one of the basic designs, then the design is an $a \times b$ factorial in CRD, RCB, or LS. Factorial design measures the effect of the various main effects and interaction effects. — M. B. DE RAMOS. *College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

TABLE 11. Tabular format for computation of analysis of variance (AOV) for Latin square (LS) design.

Variety (row)	Moisture content (MC) (column)			Variety total	Variety mean
	C_1	C_2	C_3		
V_1	(B) 68.2	(C) 67.8	(A) 66.1	202.1	67.4
V_2	(A) 68.2	(B) 67.7	(C) 66.2	202.1	67.4
V_3	(C) 66.6	(A) 68.4	(B) 66.3	201.3	67.1
MC total	203.0	203.9	198.3	605.5	
MC mean	67.7	68.0	66.2		$67.3 = \bar{x}$
Machine total	A = 202.7	B = 202.2	C = 200.6		
Machine mean	$\bar{x}_A = 67.6$	$\bar{x}_B = 67.4$	$\bar{x}_C = 66.9$		

TABLE 12. Analysis of variance (AOV) table for Latin square (LS) design.

Source of variance (SV)	Sum of squares (SS)	Degrees of freedom (DF)	Mean square (MS)	F value
Total	7.38	$k^2 - 1 = 8$	—	
Moisture content	5.37	$k - 1 = 2$	2.685	5.11^{ns}
Variety	0.15	$k - 1 = 2$	0.675	1.29^{ns}
Machine	0.81	$k - 1 = 2$	0.405	1
Error	1.05	$(k - 1)(k - 2) = 2$	$0.925 = s_E^2$	

NOTE: ns = not significant; $F_{0.05(2,2)} = 19.00$.

Laboratory Tests

A laboratory analysis shows the value of the sample tested. To determine the quality of the whole bulk of rice, from which the sample has been taken, it is essential that the sample be truly representative; it should: (1) contain the same elements present in the whole; (2) contain these elements in the right proportion; and (3) maintain these elements in a stable condition. The first two points involve proper sampling techniques; the third is related to the preservation of the sample (dry airtight containers).

The representative sample collected from the bulk grain is in excess of the quantity required for laboratory tests and reference purposes. To ensure that the parts of the sample contain the same proportion of light and heavy grains, dust, and other impurities as the bulk, the sample must be properly mixed and divided.

A hand turned seed mixer (Fig. 38) is used to mix the sample. After a thorough mixing the sample is divided in a sample divider (Fig. 39). The grain from the hopper (1) flows through a throttle (2) over the surface of a cone where it is collected by pockets (3) and is channelled into two containers (4).

Rice samples can also be mixed and divided by hand if the sample is spread in a thin layer on a board and then divided and subdivided into even portions.

Laboratory Scales

All figures used for rice testing are expressed or referred to in weight. When paddy, according to local custom, is measured by volume, data obtained from laboratory tests must be converted.

In rice testing, accurate weighing is of paramount importance as any slight weighing error can greatly alter the results of the analysis.

Two types of scales are required for rice testing (Fig. 40): (1) A scale for weighing the paddy samples. It should have a capacity of 500–1000 g and be accurate to 0.1 g. The scale pan is removable and shaped to facilitate pouring the grain into the hoppers of the milling equipment; (2) A precision balance to weigh dust and other foreign matter that is generally present in very small quantities. It should have a 50 g capacity and be sensitive to 0.1 g.

The bulk density of a sample is determined by weighing a known volume of grain, which is obtained by pouring the grain into a container with a known capacity and levelling with a straight edge.

Cleaning (Dockage)

Three distinct operations are needed to clean rough paddy or milled rice: (1) separation of straw, dust, chaff, and other coarse materials from the grains; (2) removal of weed seeds; and (3) grading to separate immature, undersized, and broken kernels from whole grains. These operations are done with various screens and sieves and indented plate graders.

The difference between a sieve and a screen is not in the component's construction, but in the type of work performed. With a sieve the good grain falls through the openings (scalping); whereas, a screen allows the good

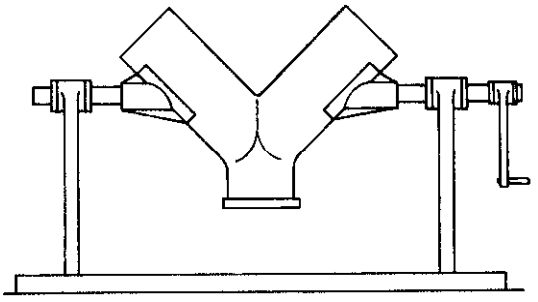

FIG. 38. Hand turned sample mixer.

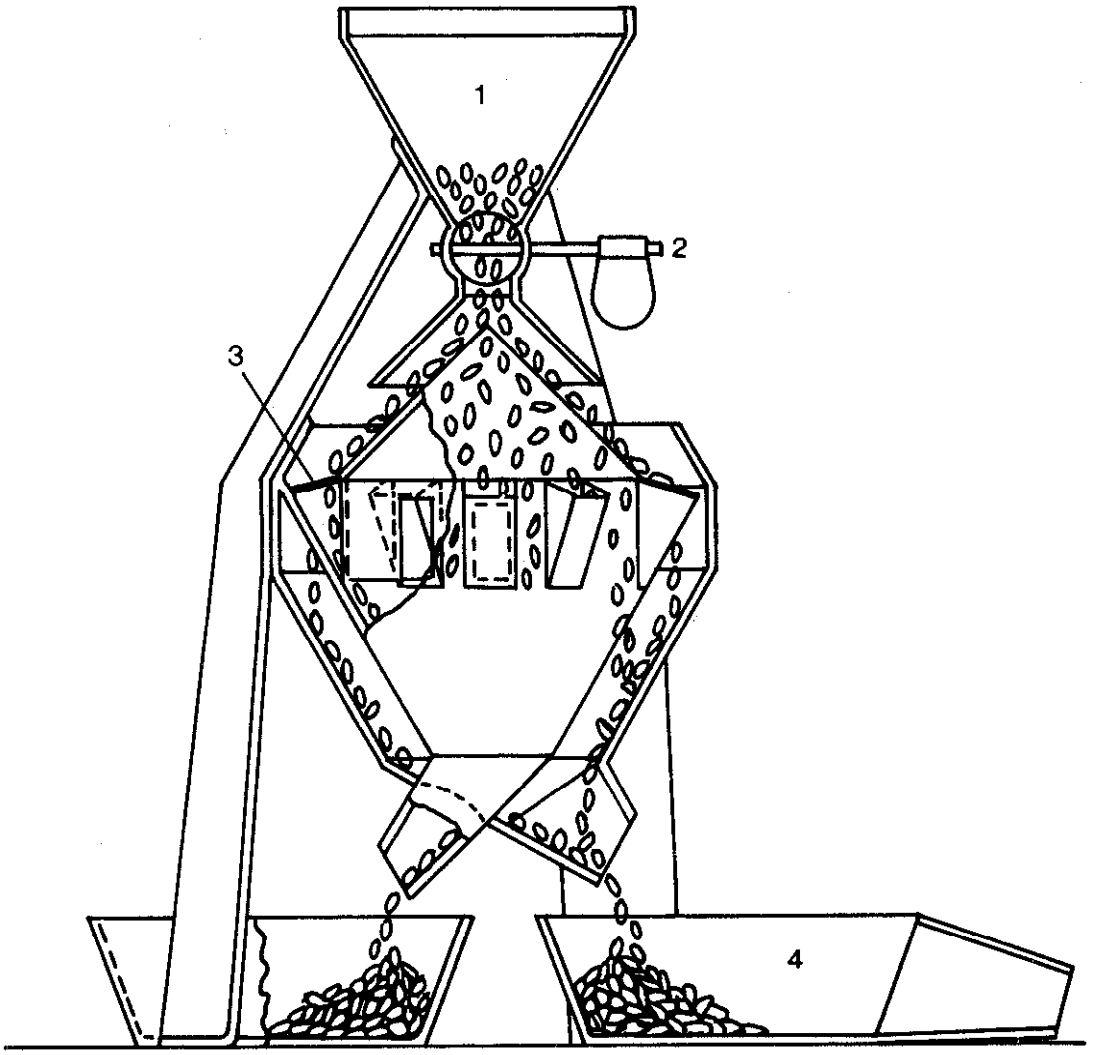

FIG. 39. Sample divider: (1) hopper; (2) throttle; (3) pockets; and (4) containers for divided samples.

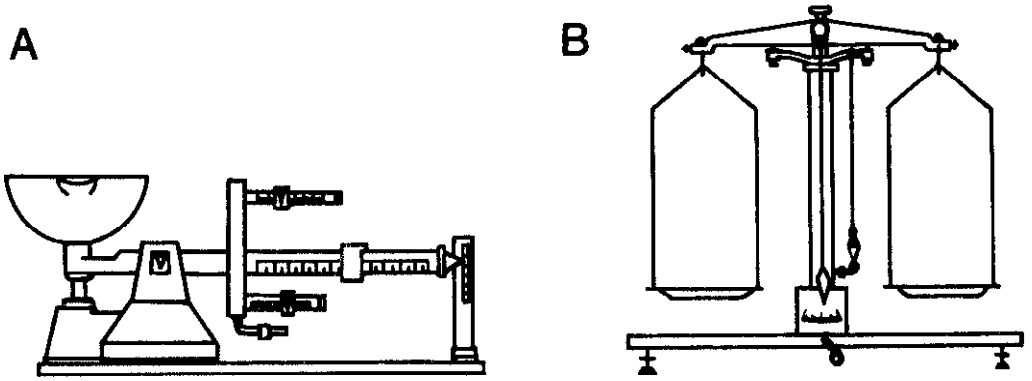

FIG. 40. A. Scale for grain sample. B. Analytical dial-reading balance.

grain to pass over the top while the weed seeds and small dockage fall through the sieve apertures (screening).

Wire-mesh, perforated plates, and indented plates for laboratory use can be made into pans for hand operation, or built into machines of the following main types: reciprocating sieve or vanner; plansifter; and rotating reel or trommel. Special machines using indented discs are also available. The plates and discs on laboratory machines should be interchangeable to suit the work to be done. There should be an ample range of sifting pans to deal with different rice varieties.

Foreign matter is separated in the laboratory with the same methods that are used in commercial milling, i.e. by taking advantage of the difference in size, shape, and weight of foreign matter as compared to the good grain.

Simple hand sieves and a special hand machine can be used to separate by thickness (Fig. 41). The hand machine consists of a helical wire cylinder (1), which is turned by hand. Rice is poured through the opening (2) and after screening, it is discharged at the other end of the cylinder; whereas, weed seeds and undersized materials passing through the screen are collected in a hopper (3). A comb (4) keeps the screen clean.

Figure 42 is a sectional drawing of a laboratory apparatus for removing light foreign matter by an air blast. The paddy is poured through the receiving hopper (1) and flows through the regulating valve (2) into the second hopper (3) where an induced blast of air removes light foreign material from the paddy and delivers it into the cylone (4). The blast of air can be adjusted by regulating the speed of the fan through control (5).

Figure 43 shows a laboratory fanning mill. From the hopper (1) the paddy falls on the reciprocating sieve through which the good grains pass to the screen underneath. Coarse foreign matter is collected in (2) while good seeds and dockage fall through the screen and are collected in (3). As the grain falls from the screen it passes through the air blast that blows dirt and chaff into a bag (4). Clean paddy is collected in (5). The strength of the blast has to be such that unwanted matter, but not the good grains, is blown out. Depending on the type of mill, the blast can be adjusted either by regulating the speed of the fan (6) or by altering the air spout in the fan housing.

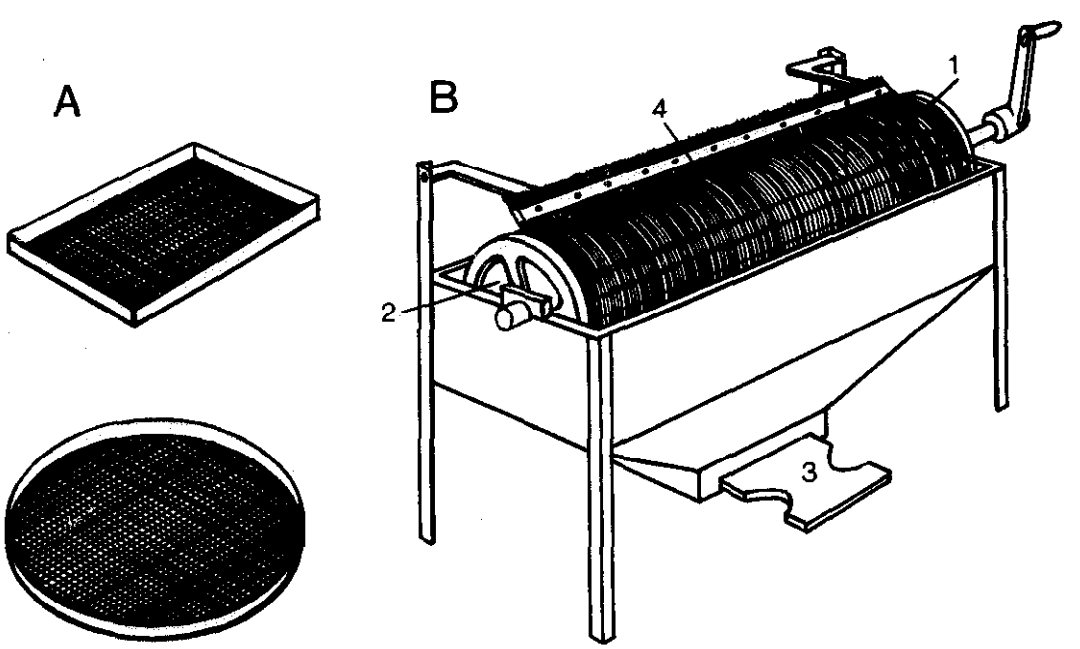

FIG. 41. A. Hand sieves. B. Hand operated rice grader with concave wire screen.

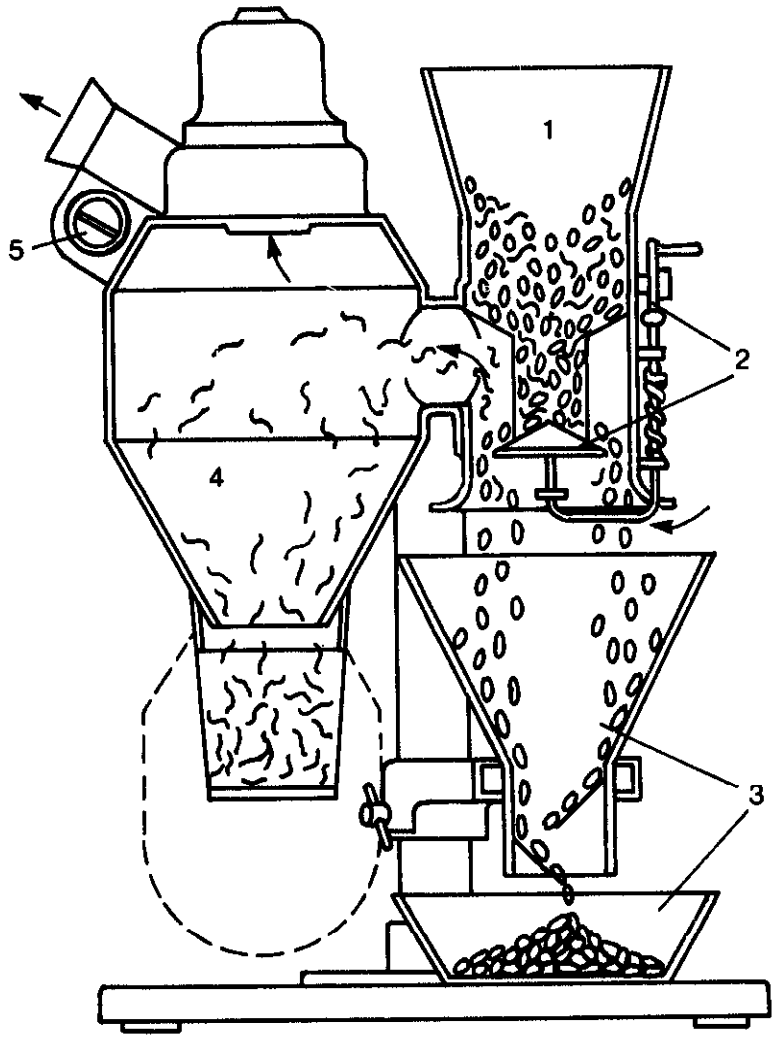

FIG. 42. Laboratory grain cleaning aspirator: (1) receiving hopper; (2) regulating valve; (3) second hopper; (4) cyclone; and (5) fan control.

Moisture Content

The moisture content of rice has a bearing on: (1) keeping quality; (2) loss of weight by evaporation during storage and processing; (3) milling output; and (4) cooking characteristics of milled rice.

It is, therefore, important to determine the moisture content of paddy during the following stages: (1) in the field to determine the proper time of harvesting; (2) on the farm or in the drying facility, to control the degree of drying; (3) during storage to obtain safe storage, and determine possible evaporation losses; and (4) during milling, to prevent excessive breakage.

Accuracy combined with rapidity are the most important points. Because accurate, direct, methods are time consuming, quick testing methods are used even if they are not 100% accurate, provided the error is small and constant.

Thermostatic ovens for the conventional determination of moisture content are essential in any laboratory to check rapid-type moisture testers, to ascertain their errors, and

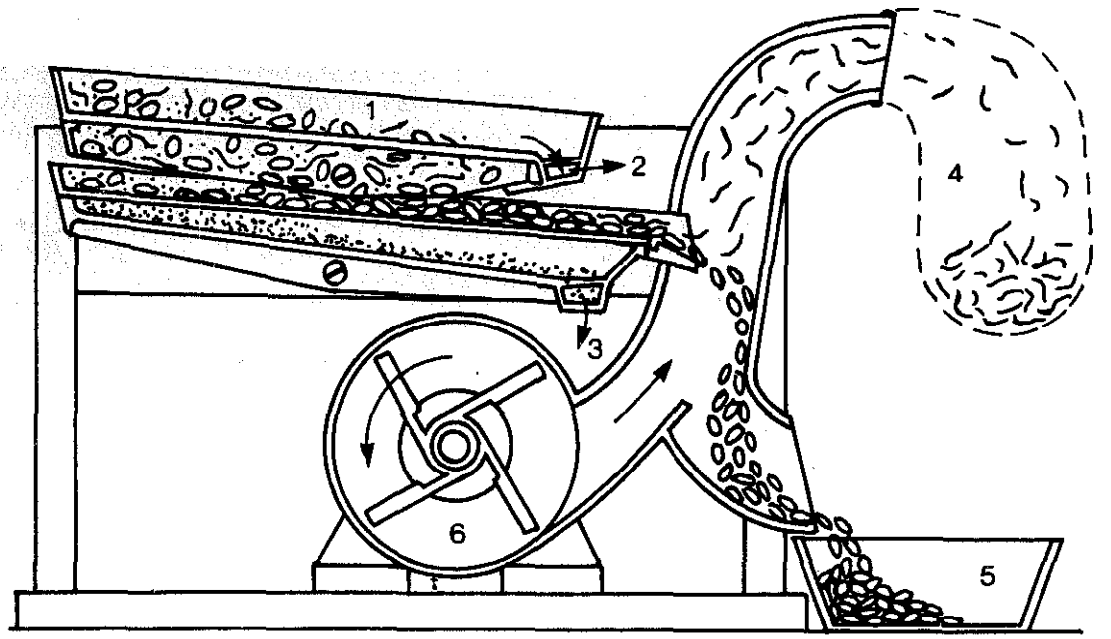

FIG. 43. Laboratory fanning mill: (1) hopper; (2) path for coarse foreign matter; (3) path for good seed and dockage; (4) bag for chaff and dirt; and (5) bin for clean paddy.

work out correction factors (calibration).

The methods used to determine moisture content can be divided into four groups, based on their principles of operation: (1) evaporation; (2) direct distillation; (3) alteration in some physical property; and (4) chemical reactions.

Testing methods based on water evaporation are the most popular and practical. Because of the biological aspect of the rice grain, errors between 0.5 and 1.0% are not uncommon. Too high a temperature may also gelatinize some of the external part of the kernel, which impedes water evaporation.

Moisture determinations based on direct distillation involve the use of hydrocarbons such as toluol and xylol that, after dilution with water, condense in separate layers in a graduated tube to allow quick determination of distilled water.

Chemical methods are based on a reaction between a given substance and the water contained in the grain. For example, the "Chopin" method is based on the measurement of the amount of acetylene gas generated by the reaction of calcium carbide with the water in the rice kernels.

Electric moisture testers base their measurements on changes in the electrical properties of the grain. For example, the higher the moisture content, the higher the conductivity, and the higher the flow of electric current through the metre.

Purity of Rice Variety

The degree of purity of rice varieties is related to: (1) varietal impurity; and (2) natural diversity.

Varietal impurities are caused by the presence of other varieties in the bulk. Natural diversity is malformation with respect to the morphological characteristics of the variety. Such malformations can be of heritable origin or may be caused by alterations that occur during the growing and ripening process.

Rice varieties can be grouped according to the shape of the kernel – long, medium, short, or round. As a consequence, when the mass includes varieties of different shapes, separation can be done with sieves and screens to grade the sample according to length and thickness. On the other hand, when different varieties of the same group are present (i.e.

having the same shape) grading can only be done by hand.

Grading for purity can be carried out on both paddy and milled rice.

Drying Paddy Samples

If the paddy sample to be tested is milled after threshing and before drying, the milling test will either give inaccurate results or not be possible at all. Damp paddy cannot be milled, and very dry paddy may produce a higher (or even lower) percentage of brokens than paddy dried to the correct degree of moisture for safe storage.

Laboratory paddy driers have been developed that enable testing of damp paddy samples taken after threshing. All laboratory samples obtained from the same lot should be dried in the same manner. In addition, the drying process should be as similar as possible to commercial drying, or should give the same results, or, at least, constantly proportional results.

Drying can be carried out in stages with resting periods to allow the moisture inside the kernel to become evenly distributed. Drying time, temperature, air pressure, velocity, and resting periods should be chosen in accordance with the moisture content of the grain and to attempt to reproduce as closely as possible commercial drying methods.

While drying, moisture losses are checked by weighing the sample, i.e. by determining reductions in weight due to water evaporation. Once the moisture contents before and after drying are known, the percentage reduction in weight of the sample that occurred during the drying process is found:

$$\% \text{ reduction in weight} = 100 \times \frac{\% \text{ MC before} - \% \text{ MC after}}{100 - \% \text{ MC after}}$$

For example: original MC = 17.5%; MC after drying = 12%

$$\% \text{ reduction in weight} = 100 \times \frac{17.5 - 12}{100 - 12} = 6.25\%$$

Milling Quality

After removing foreign matter, drying the sample, and ascertaining the moisture content, the potential milling properties are determined. Many factors have an influence on the value of paddy and they require an expert for their identification, but even he is not infallible and his opinion cannot be precisely checked. Therefore, to avoid an empirical or biased verdict, this operation should be done mechanically, by actually milling the rice.

The main objectives of sample milling are to ascertain: (1) the total milled yield, i.e. the total quantity of whole and broken grains recovered from the sample; and (2) the head rice yield, which is the quantity of whole grains recovered from the sample.

Assessing the milling quality calls for a testing device capable of simulating in the smallest space and in the shortest time the main processes that are carried out in a commercial mill. Moreover, the device must give results closely approximating those of the mills, so that its output can be compared with that from a commercial mill.

Several different types of testing devices are available. The performance of each is closely related to the principles of operation, accuracy of adjustment, and to the capability of the operator in interpreting the results. They can be classified according to steps followed, type of feeding, and the principle of operation.

(1) Steps followed while processing, i.e. (a) shelling and whitening followed in two different steps through two different machines; or (b) shelling and whitening in one run through a single machine.

(2) Whether or not feeding is continuous, i.e. (a) batch type, which is fed with a given quantity of grain; (b) a unit fed with a continuous flow of grain; or (c) a combination of the two, e.g. a continuous feed sheller and a separate batch fed whitening unit.

(3) The principle of operation, i.e. (a) following the European method, which includes the pearling cone; or (b) following the American method where whitening is done by the so-called huller.

The milling technique practiced in the country concerned will decide the type of

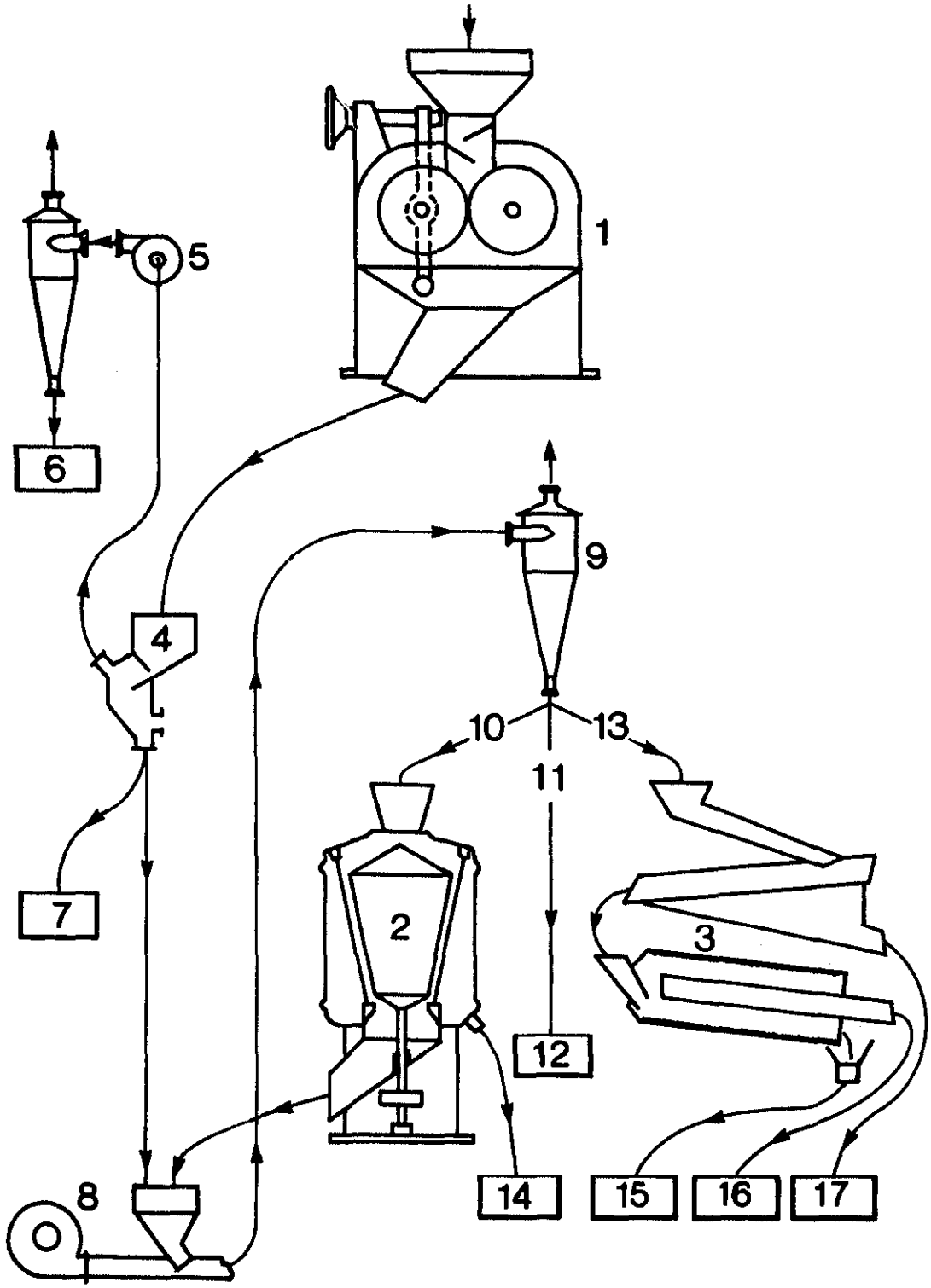

FIG. 44. Flowchart showing the complete operation of a rice testing mill: (1) sheller; (2) whitening machine; (3) grader; (4) separator; (5) aspirator; (6) bin for aspirated material; (7) bin for husked rice; (8) blower; (9) cyclone; (10) conduit to whitening machine; (11) conduit to bin for total yield; (12) bin for total yield determination; (13) conduit to grader; (14) bin for bran; (15) bin for head rice; (16) bin for big brokens; and (17) bin for small brokens.

laboratory mill to be used.

Figure 44 shows in principle the layout of a complete sampling unit, including sheller (1), whitening machine (2), grader (3), and mechanical handling devices. After the sheller the products pass into a separator (4) where the husks are removed by an aspirator (5) and collected in (6). The husked rice is delivered to (7), or it may continue through milling machines. In the latter case the grain is transported by blower (8) into cyclone (9), from where, through conduit (10) it is conducted into the whitening machine (2), which discharges the bran into (14) and the rice kernels back to (8) again to be elevated and recycled once more. By repeating the cycle several times the rice is progressively whitened until it reaches the desired milling condition.

The cyclone can now be placed at position (11) to deliver the product into (12) if the total milling yield must be determined. On the other hand, if separation of brokens from head rice is desired, by moving the cyclone to (13), the product can be discharged into the grader (3), which delivers head rice into (15), big brokens into (16), and small broken into (17). Such a testing unit will determine: the husked rice yield in (7); the total milling yield in (12); and the whole grain yield in (15). — *Extensive use was made of Gariboldi's 1973 paper "Rice testing methods and equipment" in the preparation of the text and adaptation of the illustrations for the foregoing section on Laboratory Tests.*

Model Grading System

The standardization of national rice grading systems as a means of facilitating international trade in rice has been one of the objectives pursued by the FAO Intergovernmental Group on Rice since its inception in the mid-1950's. The Group's earlier efforts materialized in 1958 in the approval of a Model System of Grading Rice in International Trade, including standard definitions of terms, which was recommended for adoption by governments.

A number of countries used the Model in revising their grading systems, but many new developments also occurred in methods of grading, in the varieties available for export, and in the milling practices. Taking stock of these developments over a 10-year period, the Group agreed at its thirteenth session in 1969 that the Model System needed reconsideration. It was felt that it should be made more broad-based by taking into account all the important characteristics of rice traded currently in the world market.

The task of revising the original Model System and the definitions of the terms used in rice trade has been accomplished by the Intergovernmental Group's subsidiary body — the Sub-Group on Rice Grading and Standardization — with the collaboration of national experts and government representatives from 41 countries during its two meetings in 1970 and 1972. The Recommended Model Grading System for Rice in International Trade and the definitions of terms, as revised by the Sub-Group, are presented here.

In considering the results of this work, the Intergovernmental Group on Rice agreed that the practical value of the Model System would be determined by the follow-up action taken by governments to ensure that national rice standards were generally compatible with the recommended principles, provisions, and terms. At its request, therefore, the Director-General of FAO transmitted the recommended Model Grading System for Rice in International Trade, together with the definitions, to all governments concerned with achieving consistency in national rice grading standards.

Recommended Model Grading System for Rice in International Trade

(As revised by the Seventh Session of the Sub-Group on Rice Grading and Standardization, May, 1972)

1. The description of rice entering international trade should cover three main headings:

A. Intrinsic character, i.e. the class, or variety of rice; B. Processing; C. Acquired characteristics, i.e. qualities not inherent in, but subsequently acquired by the same class of rice.

A. Intrinsic Character

2. The intrinsic character must be described through classing by external characteristics, with indication of size and/or shape. Additionally, the variety and weight may be specified, where required.

3. Four classes should be provided for describing rice by the external characteristic 'size':

Aa: *Extra-long:* Rice with 80 percent or more of whole milled kernels having a length of 7.0 mm and above.

Ab: *Long:* Rice with 80 percent or more of whole milled kernels having a length of 6.0 to 6.99 mm.

Ac: *Medium:* Rice with 80 percent or more of whole milled kernels having a length of 5.0 to 5.99 mm.

Ad: *Short:* Rice with 80 percent or more of whole milled kernels having a length of less than 5.0 mm.

4. Three classes should be provided for describing rice by the external characteristic 'shape':

Ae: *Slender:* Rice with whole milled kernels having length/breadth ratio over 3.0. Also known as '*Long grain rice.*'

Af: *Bold:* Rice with whole milled kernels having length/breadth ratio between 2.0 and 3.0. Also known as '*Medium grain rice.*'

Ag: *Round:* Rice with whole milled kernels having length/breadth ratio less than 2.0. Also known as '*Short grain rice.*'

5. Three classes for describing rice by the external characteristic 'weight' should be provided:

Ah: *Extra heavy:* Rice with whole milled 1000 kernels, with 14 percent moisture, weighing over 25 grams.

Ai: *Heavy:* Rice with whole milled 1000 kernels, with 14 percent moisture, weighing 20 to 25 grams.

Aj: *Moderately heavy:* Rice with whole milled 1000 kernels, with 14 percent moisture, weighing under 20 grams.

6. In the description of milled rice, the adjective 'glutinous' should be added, wherever applicable. All rice not bearing this adjective should be regarded as nonglutinous.

B. Processing

7. National standards should specify:

Ba: Parboiling[2] and any other processing prior to milling; and

Bb: The degree of milling; and

Bc: Any processing supplemcntary to ordinary milling.

8. In addition to the category of husked rice, four degrees of milling should be defined:

Bba: *Husked rice:* Paddy from which the husk only has been removed. Also known as 'brown rice,' 'cargo rice,' 'hulled rice,' 'loonzain rice,' and 'sbramato rice.'

Bbb: *Undermilled rice:* Paddy from which the husk, a part of the germ, and all or part of the outer bran layers, but not the inner bran layers, have been removed.

Bbc: *Reasonably well milled rice (Medium milled rice):* Paddy from which the husk, the germ (part of the germ in the case of round rice), the outer bran layers, and the greater part of the inner bran layers have been removed, but parts of the lengthwise streaks of the bran layers may still be present on not more than 30 percent of the kernels.

Bbd: *Well milled rice:* Paddy from which the husk, the germ (part of the germ in the case of round rice), the outer bran layers, and the greater part of the inner bran layers have been removed, but parts of the lengthwise streaks of the bran layers may still be present on not more than 10 percent of the kernels.

[2]Since parboiling is a process applied prior to milling, different degrees of milling (such as 'parboiled – well milled,' 'parboiled – extra-well milled' etc.) should be provided wherever applicable.

Bbe: *Extra well milled rice:* Paddy from which the husk, the germ (part of the germ in the case of round rice), and the bran layers have been completely removed.

9. Bc: When rice is subjected after milling to further processing either to improve its appearance and keeping quality, or to enhance its nutritive value, or to ameliorate its cooking characteristics, such processing supplementary to milling should be mentioned in the description to enable buyers of rice to examine it in relation to the existing regulations in their countries. The use of soap-stone containing magnesium silicate should be prohibited.

10. When milled rice is coated or treated to enhance its nutritive value, the term '*enriched*' should be added in the description of the rice.

C. Acquired Characteristics: Grades

11. When describing rice, a clear distinction should be made between intrinsic characteristics and acquired characteristics. Differences in acquired characteristics should be regarded as constituting the *quality* of rice, and should form the basis for distinction between grades.

12. The following *essential criteria* should be included in national grading standards:

Ca: Percentage of broken kernels;
Cb: Percentage of red and red-streaked kernels;
Cc: Percentage of damaged kernels;
Cd: Percentage of chalky kernels;
Ce: Percentage of foreign materials;
Cf: Percentage of paddy;
Cg: Percentage of contrasting classes of rice;
Ch: Percentage of moisture;
Ci: Percentage of yellow kernels;
Cj: Percentage of immature or green kernels;
Ck: Maximum limit of chemical residues;
Cl: Minimum limit of whole rice.

13. One or more of the following two *optional criteria* may be included in national grading standards where considered necessary:

Cm: Percentage of stained or spotted kernels.
Cn: Percentage of other discoloured kernels.

14. In the case of *parboiled rice*, the following two optional criteria may be included:

Co: Maximum limit of nongelatinized kernels;
Cp: Maximum limit of nonparboiled kernels.

15. The maximum or minimum limit for each of the above criteria should be on the basis of weight and not on the basis of volume.

16. When grading by the percentage of broken rice, there should be at least two categories of brokens:

Caa: *Big brokens:* Pieces of kernels smaller than three fourths but bigger than one half the average length of the unbroken kernel.
Cab: *Brokens other than big brokens:* Pieces of kernels equal to or smaller than one half the average length of the unbroken kernel.

Intergovernmental Group on Rice of the Committee on Commodity Problems, Food and Agriculture Organization of the United Nations, Rome, Italy.

Specifications[3]

Rough Rice

This standard specification for Philippine Palay or Rough Rice is hereby promulgated under a fixed designation PTS (Philippine Trade Standard) No. 042-01.02; 1968. This standard was formulated by the Philippine Standards Council, in order to fix a uniform basis for determining quality. The cooperation of the Rice and Corn Administration, Rice and Corn Board, U. P. College of Agriculture, Bureau of Plant Industry, International Rice

[3]Philippine Trade Standard Specifications for Palay (Rough Rice) PTS 042-01.02; 1968, and Milled Rice (Second Revision) PTS 042-02; 1973.

Research Institute, Rice and Corn Production Coordinating Council, Agricultural Productivity Commission, Araneta University Foundation, and Greater Manila Rice and Corn Association, were in a large measure responsible for the formulation of this standard.

Suggestions for revision should be addressed to the Bureau of Standards, P.O. Box 3719, Manila, Philippines.

1. Scope

1.1 This standard covers the system of classifying and grading palay of Philippine origin.

2. Definition of Terms

2.1 For the purpose of this specification, the following terms are hereby defined:

2.1.1 Rough rice — Those which contains 50% or more of unhulled kernels.

2.1.2 Foreign matters — These are impurities such as stones and sand but excluding weed seeds.

2.1.3 Immature kernels — Those which are mostly green and/or chalky.

2.1.4 Damaged kernels — Those which are distinctly discoloured or damaged by water, insects, heat, or any other means.

2.1.5 Other varieties — Those kernel which differ distinctly from the characteristics of the palay under consideration.

2.1.6 Fermented kernels — Those which are yellowish or otherwise discoloured.

2.1.7 Cracked kernels — Those which are either cracked or broken.

2.1.8 Red rice — Those palay, the kernels of which are red.

2.1.9 Weed seeds and other crop seeds — All seeds which are other than palay.

2.1.10 Moisture content — This is the water content of the grain computed on a wet basis, as received.

2.1.11 Percentages — These are quantities expressed in weight.

3. General Requirements

3.1 It shall be free from such foreign odors as mouldy ground, insect, rancid, sharp acrid and chemical, which are common to unsound rice.

3.2 It shall be free from live insect infestation.

3.3 The unit of trading shall be by weight expressed in kilograms or in metric tons.

4. Classification and Grading

4.1 Palay varieties shall be classified in accordance with the length of the kernel.

4.1.1 The types of palay based on the length of the brown kernel shall be the following:

Type I — Long grain — the length of the kernel is above 6.5 mm.

Type II — Medium grain — the length of the kernel ranges from 5.5 to 6.5 mm.

Type III — Short grain — the length of the kernel is below 5.5 mm.

4.2 Each type of palay shall be grouped as follows:

4.2.1 Fancy — the kernels have a flinty uniform appearance, and are shiny, translucent, or creamy white.

4.2.2 Special — the kernels exhibit a desirable uniform white, creamy white, or gray colour.

4.2.3 Ordinary — the kernels exhibit a white to dull white or light gray colour.

4.2.4 Inferior —

1. Milled rice with coloured pericarps regardless of cooking characteristics and translucency.
2. Milled rice which is discoloured due to handling and storage.

4.3 Each group of palay shall be graded according to the result of analysis as follows:

4.3.1 Grade I — Palay having at least 98% purity, foreign matter not more than 2%, weed seeds none, immature kernels none, damaged grains 2%, cracked kernels 3%, other varieties 3%, fermented kernels none, red rice trace, moisture content not exceeding 14%.

4.3.2 Grade 2 — Palay having at least 96% purity, foreign matter not more than 4%, weed seeds none, immature kernels 2%, damaged kernels 3%, other

TABLE 13. Standard grade requirements for rough rice.

Grade	Purity (max %)	Foreign matter (max %)	Weed and other crop seed (max %)	Cracked kernels (max %)	Immature kernels (max %)	Damaged kernels (max %)	Other varieties (max %)	Fermented kernels (max %)	Red rice (max %)	Moisture content (max %)
1	98	2	none	3	none	2	3	none	trace	14
2	96	4	none	4	2	3	5	0.5	1	14
3	94	6	trace	5	4	4	8	1	2	14
4	92	7.75	0.25	6	7	6	12	2	3	15
5	90	9.5	0.5	7	10	8	17	3	4	15

NOTE: Paddy + Foreign matter + Seeds = 100%.

TABLE 14. Variety—Classification of grain as to group and size.

Fancy	Special	Ordinary
Type I—Long size grain		
1. None	1. Tjeremas	1. Ramadia
	2. Intan	2. Peta
	3. Bengawan	
	4. AC 440 Dr. 260	
	5. Azucena	
	6. BPI-121	
	7. Raminad Str. 3	
Type II—Medium size grain		
1. Milfor	1. BE-3	1. Peta
	2. BPI-76	2. IR-8
	3. Macapagal	3. Macan
	4. Raminad	4. Kinandang Puti
	5. 12–36	5. Kinandang Pula
	6. Bencer	6. Ramai
	7. Sinampablo	7. Palawan
	8. Seraup Ketchil	
	9. Kinanda	
	10. Elon-Elon	
	11. C-18	
	12. Milbuen	
	13. Dinalaga	
Type III—Short size grain		
1. Milagrosa	1. Hinumay	1. Binato
2. Wagwag		2. Palagad Imus
3. Minantika		3. Ninoro
		4. Mangarez
		5. Macan—700

varieties 5%, cracked kernels 4%, fermented kernels 0.5%, red rice 1%, moisture content not exceeding 14%.

4.3.3 Grade 3 — Palay having at least 94% purity, foreign matter not more than 6%, weed seeds trace, immature kernels 4%, other varieties 8%, damaged kernels 4%, cracked kernels 5%, fermented kernels 1%, red rice 2%, moisture content not exceeding 14%.

4.3.4 Grade 4 — Palay having at least 92% purity, foreign matter not more than 7.75%, weed seeds 0.25%, immature kernels 7%, damaged kernels 6%, other varieties 12%, fermented kernels 2%, red rice 3%, cracked kernels 6%, moisture content not exceeding 15%.

4.3.5 Grade 5 — Palay having at least 90% purity, foreign matter not more than 9.5%, weed seeds 0.5%, immature kernels 10%, damaged kernels 8%, other varieties 17%, fermented kernels 3%, red rice 4%, cracked kernels 7%, moisture content not exceeding 15%.

4.3.6 Sub-standard grade — Palay that would not meet any of the above requirements but the moisture content shall not exceed 16%.

5. Packing and Marking

5.1 Packing

5.1.1. Palay shall be packed in jute gunny sacks or in similar protective containers, weighing 50 kilograms net on the basis of 14% moisture content.

5.2 Marking

5.2.1 Each bag shall be properly labelled in big letters with a suitable tag measuring approximately 18 × 12 cm, containing the following information:

5.2.1.1 Province where grown and crop year

5.2.1.2 Type, group, variety, and grade

5.2.1.3 Name and address of warehouse

5.2.1.4 Net weight in kilograms

6. Sampling

6.1 Samples are drawn from the lot with the use of sampling instruments like the Stick Trier or Sleeve-type Trier or Hobbe Trier. When there are 10 bags or less, each bag shall be sampled. If there are more than 10 bags but not exceeding 100 bags at least every tenth bag but not less than 10 bags shall be sampled. If a lot contains more than 100 bags, at least 10% of the number of bags shall be sampled at random.

6.2 When a lot is sampled, several individual samples are drawn from different places in the bulk. Each probe or each handful of sample is called the primary sample. All primary samples drawn are combined in a suitable container. This combined primary sample is called the composite sample. When the composite sample has been properly reduced, it is called the submitted sample. This sample is submitted to the laboratory for quality tests. The reduced sample, obtained from the submitted sample, is termed the working sample.

6.3 The sampling shall be done at random from the top, middle, and bottom of each container. The inspector shall be responsible for sampling the entire lot and the submitted samples should carry the following information:

6.3.1 Name and address of owner

6.3.2 Variety name

6.3.3 Lot number

6.3.4 Number of bags in the lot

6.3.5 Date harvested

6.3.6 Name of inspector

6.4 Preparation of the working sample — Samples received in the laboratory are reduced to a working sample. The sample submitted shall be repeatedly divided so that the working sample will be as representative as the original. An efficient divider must be used.

6.4.1 Use of Mechanical Divider — The equipment usually used is the Boerner Sample Divider. The sample is emptied into a hopper at the top of the divider and released by a hand lever to let it flow over an inverted cone. It passes through a series of slots around the circumference of the cone and falls into two chutes. At the mouth of each chute is a bucket into which half of the sample runs. The sample is divided into approximately

equal halves again and again until it is about 1 kilogram.

6.4.2 Halving Method — In the absence of a mechanical sample divider, the halving method will be used. The submitted sample is repeatedly divided until about 100 grams of the quantity remains.

7. Inspection

7.1 Destination Inspection — When the palay is passed through points other than destination, the contract may require that the palay be inspected at destination for quantity and quality.

7.2 At the time of loading palay for foreign trade, shipping weights shall be taken and certified before the inspectors of the Bureau of Standards or a government weigher in the locality.

8. Test Methods

8.1 Grading Test — Weigh about 100 grams of palay from the representative sample. The palay shall be separated from other extraneous matters and weighed to determine the percentages.

8.2 Moisture content determination — The moisture content of palay shall be determined by using a properly calibrated moisture tester.

8.2.1 Brown-Duvel Moisture Tester — Duplicate samples of 100 grams each are taken from a thoroughly mixed palay sample. Each weighed sample is transferred into the flask of the tester, which is then filled with 450 ml of the Brown-Duvel testing oil (Spica oil has similar properties). A thermometer is inserted through the stopper of this flask. Four-fifths of the mercury bulb of the thermometer should be submerged in the sample and the oil. After tightly fitting the stopper, the flask is connected to the condensing tube of the tester. Heat is applied until the cut-off temperature, or 210 °C, is reached. The moisture distilled off is collected in a clean, dry graduated cylinder. The amount of moisture collected will determine directly the percentage moisture content of the sample. It is read after the temperature has gone down to 160 °C (as prescribed in the direction for using the Brown-Duvel Moisture Tester).

8.2.2 Air-Oven Method — Two to five grams of the sample are ground and weighed in a weighing bottle with a constant weight. The powdered sample is placed in an electric oven for 5 hours at a temperature of 130 °C. Then it is allowed to cool inside a desiccator and weighed afterwards. The percentage moisture content is computed on the wet basis.

9. Effectivity

9.1 This Standards Administrative Order shall take effect upon its approval.

Milled Rice

This standard specification for Milled Rice is hereby promulgated under a fixed designation PTS (Philippine Trade Standard) No. 042-02; 1973.

This standard was revised due to the request of the National Grains Authority and upon the suggestion of the Technical Committee to update the standard specification and the definition of terms to suit the present trend in the rice industry. It also includes the weight per sack of rice to be 50 kilograms in accordance with NGA Act.

Suggestions for revision should be addressed to the Bureau of Standards, P.O. Box 3719, Manilla, Philippines.

1. Scope

1.1 This standard specification covers milled rice produced in the Philippines, both for foreign and domestic trade.

2. Definition of Terms

2.1 For the purpose of this standard, the following terms relating to milled rice are hereby defined as follows:

2.1.1 Milled rice — whole or broken kernels where the hulls and at least the outer bran layers and a part of the germ are removed.

2.1.2 Nonglutinous rice — generally translucent with greater amylose content than amylopectin and turns bluish when treated wih potassium iodide – iodine solution.

2.1.3 Glutinous rice — generally opaque, sticky when cooked, with higher amylopectin than amylose content and turns reddish-brown when treated with potassium iodide – iodine solution.

2.1.4 Brewer or binlid — portions of a kernel which will pass through a 4/64 sieve (1.587 mm).

2.1.5 Broken kernels — milled rice smaller than head rice but larger than brewer or binlid.

2.1.6 Chalky kernels — kernels with 50% or more white portion.

2.1.7 Flinty kernel — kernel with less than 50% white portion.

2.1.8 Foreign matter — impurities such as weed seeds, stones, sand, dirt, etc. foreign to milled rice.

2.1.9 Head rice — whole kernels and those not less than ¾ in size.

2.1.10 Kernel — edible portion of a paddy grain.

2.1.11 Milling degree — the extent or degree of polishing the rice kernel.

2.1.12 Other varieties — rice kernels of different variety/ies other than the variety under consideration.

2.1.13 Paddy or Palay — unhulled grain.

2.1.14 Red rice — rice with any degree of redness.

2.1.15 Yellow kernel — yellowish milled rice due to fermentation or heat.

2.1.16 Damaged kernel — kernels attacked by microorganisms, insects and/or other means.

3. Classification and Grading

3.1 Philippine milled rice shall be of the following type based on the length of the kernel.

3.1.1 Type I — Long grain — longer than 5.9 mm.

3.1.2 Type II — Medium grain — length ranges from 5.0 to 5.9 mm.

3.1.3 Type III — Short grain — shorter than 5.0 mm.

3.2 Each type shall be graded into subtypes according to the shape based on the length-width ratio.

3.2.1 Slender — Length-width ratio 3.0 or more.

3.2.2 Bold — Length-width ratio ranges from 2.0 to 2.9.

3.2.3 Round — Length-width ratio is less than 2.0.

3.3 The description of the milled rice according to types and sub-types shall be taken collectively under the term Grain type.

3.4 Rice shall be classified according to varietal names. See Table 16.

3.5 Each group of milled rice shall conform to any of the following classes according to the degree of milling.

3.5.1 First class — milled rice from which the husk, the germ, the outer and the inner bran layers have been removed.

TABLE 15. Standard grade requirements for Philippine milled rice.

	Premium grade	Grade I	Grade II	Grade III
1. Head rice (%)	95 min	85.0 min	75.0 min	65.0 min
2. Brokens (%)	4 max	12.0 max	20.0 max	28.0 max
3. Binlid (Passes through sieve 4/64) (%)	1	3.0 max	5.0 max	7.0 max
4. Yellow and damaged (%)	0.5	1.0 max	2.0 max	4.0 max
5. Chalky and immature kernels (%)	2.0	4.0 max	6.0 max	8.0 max
6. Paddy (No. /100 g)	none	1 max	2 max	3 max
7. Other varieties (%)	2	4 max	6 max	8.0 max
8. Red rice (%)	none	0.50 max	1.0 max	1.5 max
9. Foreign matter (%)	none	0.25 max	0.5 max	1.0 max

TABLE 16. Philippine rice varieties classified as to grain types and subtypes.

Variety	Length (mm)	Width (mm)	L/W ratio	Type	Subtype
1. Milagrosa	4.095	2.020	2.02	III	Bold
2. Milfor	5.468	2.041	2.67	II	Bold
3. Wagwag	5.314	2.246	2.36	II	Bold
4. C-4-63-G	6.877	2.097	3.27	I	Slender
5. C-4-137	7.000	2.163	3.23	I	Slender
6. C-18	6.751	2.096	3.22	I	Slender
7. C-12	6.028	2.156	2.79	I	Bold
8. Intan	6.795	2.041	3.32	I	Slender
9. BE-3	5.502	2.293	2.30	II	Bold
10. BPI-76	5.904	2.251	2.62	II	Bold
11. BPI-121	6.820	2.136	3.19	I	Slender
12. IR-22	6.199	1.952	3.17	I	Slender
13. IR-24	6.636	2.081	3.18	I	Slender
14. IR-661	6.460	2.187	2.93	I	Bold
15. IR-20	5.503	2.130	2.58	II	Bold
16. IR-12	5.876	2.261	2.59	II	Bold
17. IR-5	6.131	2.450	2.50	I	Bold
18. IR-8	6.440	2.387	2.69	I	Bold
19. Tjeremas	6.770	2.083	3.24	I	Slender
20. Seraup Ketchil	5.617	2.457	2.28	II	Bold
21. Peta	6.168	2.474	2.49	I	Bold
22. Pinili	5.774	2.233	2.58	II	Bold
23. Binato	4.971	2.500	1.98	III	Round
24. Ramadia	6.005	2.339	2.56	I	Bold

3.5.2 Second class — milled rice from which the husk, germ, the outer and the major part of the inner bran layers have been removed.

3.5.3 Third class — milled rice from which the husk, a part of the germ and outer bran layer but not the inner bran layer has been removed.

3.5.4 Pinawa (brown rice) — milled rice from which only the husk and part of the germ has been removed.

3.6 Each class of milled rice shall be graded according to the following description.

3.6.1 Premium grade — Head rice not less than 95%, not more than 5% of which are ¾ kernels, broken 4%, binlid 1%, yellow and damaged 0.5%, chalky and immature kernels 2%, paddy none, other varieties 2%, red rice none, and foreign matter none.

3.6.2 Grade I — Head rice not less than 85%, not more than 5% of which are ¾ kernels, broken 12%, binlid 3%, yellow and damaged 1%, chalky and immature kernels 4%, paddy 1 grain/100 grams, other varieties 4%, red rice 0.5%, and foreign matter 0.25%.

3.6.3 Grade II — Head rice not less than 75%, not more than 5% of which are ¾ kernels, broken 20%, binlid 5%, yellow and damaged 2%, chalky and immature 6%, paddy 2 grains/100 grams, other varieties 6%, red rice 1%, and foreign matter 0.5%.

3.6.4 Grade III — Head rice not less than 65%, not more than 5% of which are ¾ kernels, broken 28%, binlid 7%, yellow and damaged 4%, chalky and immature kernels 8%, paddy 3 grains/100 grams, other varieties 8%, red rice 1.5%, and foreign matter 1%.

4. General Requirements

4.1 Moisture content shall not exceed 14%.

4.2 It shall be free from unpleasant and/or repulsive odor.

4.3 It shall be free from insect infestation.

4.4 The unit of trading shall be by weight expressed in kilograms or metric tons.

5. Packing

5.1 Milled rice shall be packed in new or good used Hessian cloth bag, jute gunny, or plastic sacks without patches and weighing 50 kilograms net to afford maximum protection from normal hazards of transportation and handling. Smaller packages may be allowed provided the net weight shall be in full kilograms of 1, or multiple of 5 kilograms subject to buyer/seller agreement.

6. Marking

6.1 Each bag shall be properly labelled with the following information:

(a) Type and subtype, variety, class, and grade
(b) Name and address of miller
(c) Net weight in kilograms
(d) Crop year and date of milling

7. Sampling

7.1 Ten percent (10%) of the total number of bags should be sampled but in no case should the number of bags sampled be less than five (5) bags.

7.2 Each probe or handful of sample drawn is called the primary sample. The combined primary samples are called a composite sample. When a composite sample has been properly reduced, it is called the submitted sample. A sample obtained from the submitted sample is called a working sample.

7.3 The submitted sample should carry the following information:

7.3.1 Name and address of owner
7.3.2 Variety
7.3.3 Lot number
7.3.4 Number of bags in the lot
7.3.5 Crop year and date of milling
7.3.6 Date of sampling
7.3.7 Name of inspector

7.4 Preparation of the working sample — Samples received in the laboratory are reduced to a working sample. The sample submitted shall be repeatedly divided so that the working sample will be the representative of the original. An efficient divider must be used in the absence of a mechanical divider.

8. Test Method

8.1 Grading test — Weigh about 100 grams of milled rice from the representative sample. The head rice shall be separated from other extraneous matter and weighed to determine the percentage.

8.2 Moisture content determination — The moisture content of milled rice shall be determined by using a properly calibrated moisture tester or by oven drying. In the air-oven method the temperature should be maintained at 105 °C ± 0.1 C°.

8.3 Potassium iodide – iodine test — In case of doubt whether a variety is glutinous or not, a KI-I test shall be made on the kernels.

9. Effectivity

9.1 This Standards Administrative Order shall take effect 20 days after completion of its publication.

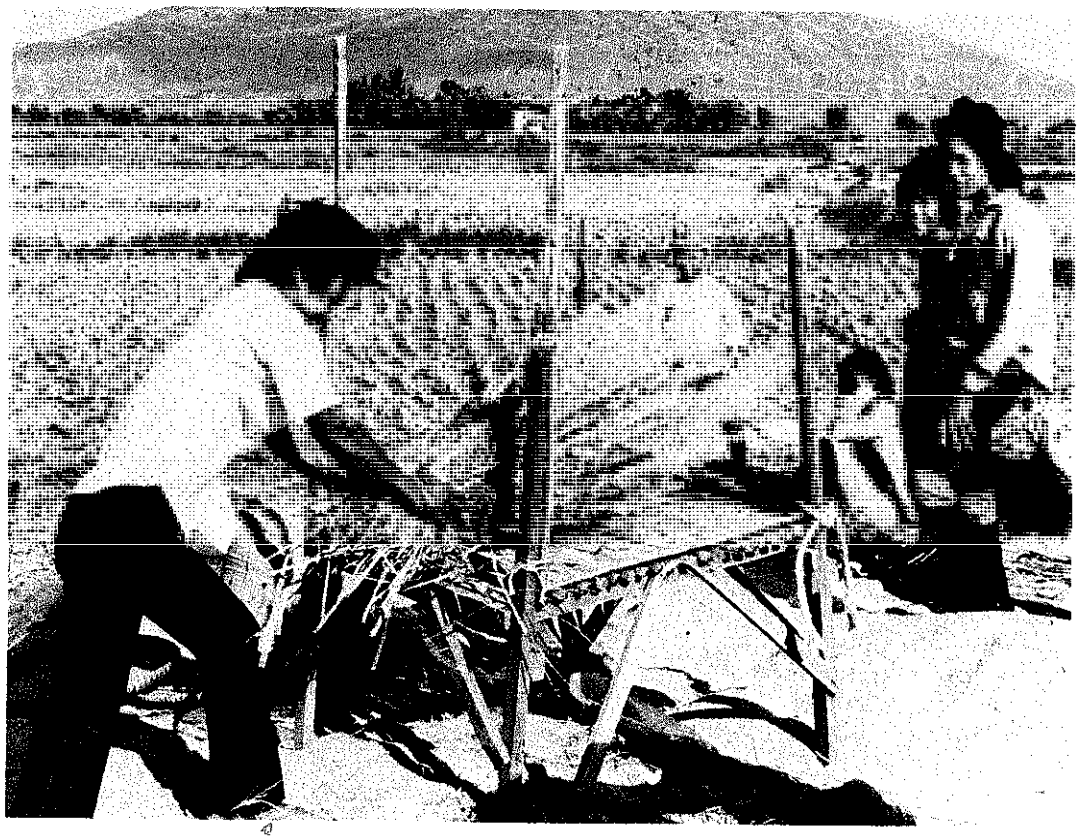

HARVESTING and THRESHING

Equipment and Operations

Improper harvesting and threshing usually result in losses of up to 5% of the crop; therefore, better production techniques alone are not sufficient to solve the food problem. Attention must also be paid to the correct methods for harvesting and threshing to minimize field losses. These two processes constitute about 30% of the total time spent in producing clean dry paddy that is ready for milling.

As harvesting approaches, the plants must be observed daily, and the panicles on the most mature tillers inspected. Water is drained from the field 1–1.5 weeks before harvesting. Harvesting should be carried out when the hulled grain on the upper portion of the panicles are clear and firm and most of the grain at the base of the panicle is in the hard dough stage. At this time at least 80% of the grains are straw-coloured.

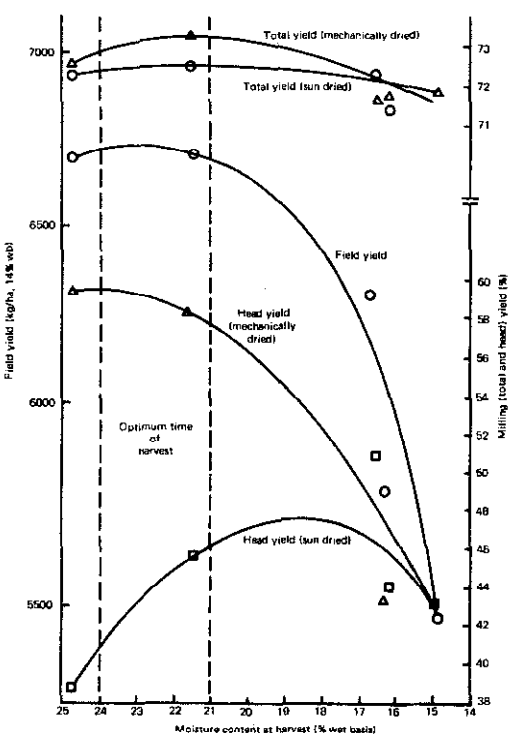

FIG. 45. Effect of moisture content at harvest on field yield and milling yield of IR8 (Bhole et al. 1970).

The moisture content of the paddy at harvest varies with location. In most areas of Asia the paddy is left standing in the field to sun dry, in some areas it is harvested at a moisture content of 20–25% and stacked until it is dry before it is threshed; whereas, in other areas, it is harvested and threshed at a relatively high moisture content. Figure 45 shows the effect of moisture content at harvest on the field and milling yields of IR8. It can be seen that the optimum moisture content for harvesting is 21–24%.

Ruiz (1965) concluded that the average grain losses at different harvesting times were: 1 week before maturity 0.77%; at maturity 3.35%; 1 week after maturity 5.63%; 2 weeks after maturity 8.64%; 3 weeks after maturity 40.70%; and 4 weeks after maturity 60.46%.

Therefore, timing of the harvest and the moisture content at harvest are very important for achieving maximum yield and quality of the rice.

With the introduction of new varieties of rice, fertilizers, and pesticides, the problems of harvesting and threshing have increased because of the greater amount of crop that has to be handled. In the double-cropping areas, the harvesting and threshing of the first crop and the land preparation for the second crop come so close together that it is often difficult to handle these operations with traditional methods. Johnson (1968) studied the labour requirements for rice production in the Philippines for both the single- and the double-cropped farms. The study indicated that while there was some surplus of labour during the slack period, a labour shortage occurred during the harvesting-threshing season.

The predominant methods used in the tropics consist of manually harvesting the paddy plants and then threshing either by manual, animal, or mechanical means. In the advanced countries, however, harvesting and threshing of rice has almost entirely changed to mechanical methods and this has resulted in tremendous labour savings. Stout (1966)

TABLE 17. Power requirements for rice harvesting in man-hours, animal-hours, and rated horsepower-hours per hectare (information collected from various publications in rice production, Johnson 1963).

	Man-h/ha			Animal-h/ha			Rated hp-h/ha		
	Min	Max	Average range	Min	Max	Average range	Min	Max	Average range
Hand harvest, individual panicles with small knife			240						
Hand harvest with sickle, transport, and stack			69*						
	72	370	80–160						
Tractor and binder (40 hp)									
1. Binding	4.0						80		
2. Shocking (stacking)	8.0						—		
3. Threshing	12	30					240		
4. Hauling	2						80		
Combine, 2-man crew (60–80 hp)									
1. In US	2.2	7.5	4.4						175
2. In tropics	3.2	21.5	6–12				100	600	180–360
Thresh									
1. Foot threshing by man	200								
	69*								
2. Flail threshing	16*	35*	20–30*						
3. Beating on bamboo frame, basket, etc.	16*								
4, Pedal thresher	8–10*	25*	100						
			20*						
5. Trample by ox or buffalo	60			150					
	89			178					
	6*			6*					
6. Powered Japanese thresher 0.5–3 hp	48	197	100				15	25	
	20*	25*					3*	5*	
7. Treading with standard tractor			80				55	150	80
8. Treading with 15-hp tractor and disc harrow							50*	80*	
9. Stationary large thresher	12	30	12				90	180	
10 NIAE thresher	52*	155*	80*				3.2*	9.7*	5*
Cleaning of grain									
1. Tossing in air	10*								
2. Field winnowing with hand fan			6.7*						
3. Fan mill, hand operated	1.5*	7*							
4. Chaff sieve	4.0*	8.0*							

NOTE: Figures marked with asterisk (*) are for number of hours per 1000 kg (or metric tonne).

estimates that countries of Southeast and Far East Asia expend 5–7 h of labour to produce 20.4 kg of rice while only 5–7 min are required to produce the same amount of rice by highly mechanized production methods. Johnson (1963) collected the power requirements for harvesting and threshing of paddy by different methods from various references (Table 17). With the exception of Japan, where rice is mechanically harvested and then dried on straw before threshing, the rest of the advanced countries have changed to direct combining of rice. Even in Japan, with the recent introduction of small head-threshing

type combines, a shift to direct combining of paddy is rapidly taking place.

In the tropics, interest in mechanizing the harvesting-threshing operation is high due to the increasing cost and seasonal shortage of labour and the timing problems involved in double cropping. The recently introduced dwarf paddy varieties are also better suited for mechanized harvesting and threshing. Furthermore, the increased income of the farmers from higher paddy yields has provided additional incentive for mechanization. There are, however, a number of constraints that have hindered the mechanization of harvesting-threshing operations.

Farmer Constraints

Low income, inability to raise capital, reluctance to change traditional methods, poor mechanical aptitude, and the desire to save straw for other uses.

Farm Constraints

Small farm holdings, very small plot size with high bunds, poor water control, inadequate ground support for harvesting equipment, and lack of access roads to the fields.

Crop Constraints

Excessive moisture content at harvest time, uneven ripening, severe lodging and entangling of paddy (especially the traditional varieties), varieties with high-shattering tendency, and low grain-straw ratio.

Equipment Constraints

Lack of functionally and economically suitable equipment for tropical conditions, and the high cost of imported equipment, which must compete with relatively low-cost labour.

In spite of some of these impediments, interest in mechanizing the harvesting-threshing operation is substantial in the tropical region. The introduction of new high-yielding varieties that are less susceptible to lodging and ripen more evenly has been the most encouraging development for the introduction of mechanized harvesting-threshing practices. The present combines have been developed to a stage where crop moisture is no longer a major problem. Some new combines can harvest paddy at moisture levels of 25–30%. The problems of inadequate ground support and machine mobility are being tackled by reducing machine weight and increasing ground contact area. Adequate water control in the farmers' fields is still a difficult problem and will have to be approached both from the machine design and the farm improvement level.

The various operational elements of paddy harvesting and threshing are cutting, binding, transporting, threshing from panicle, separating grain from straw, separating grain from chaff, separating grain from empty grains and finer impurities, and the delivery of grain for storage or drying. Various harvesting systems have evolved in different parts of the world and some do not necessarily follow the above sequence in total. In the most mechanized system of harvesting-threshing, all the operations are simultaneously done in the field with a combine that facilitates the operation and substantially reduces the labour requirements.

Harvesting of Plants

The operation of cutting a plant is achieved by four different actions: (1) slicing action with a sharp, smooth edge; (2) tearing action with a rough, serrated edge; (3) high-velocity, single-element impact with a sharp or dull edge; and (4) a two-element, scissors-type action.

Generally, manual harvesting involves slicing and tearing actions that result in plant structure failure due to compression, tension, or shear. The serrated sickle combines a slicing and a sawing action. The serrated edge used in cutting devices restricts the sliding action of the plant on the blade edge and helps to retain the plant on the blade for adequate cutting. It has also been reported that sickles with serrated edges do not require the repeated sharpening needed by smooth-edge sickles.

Single-element impact cutting is an economical method of cutting unrestrained vegetation and has been widely used in rotary

lawn mowers, forage choppers, and some tractor-mounted cutterbars. Generally, machines based on this principle are quite simple. Usually a single-element, sharp-edged blade requires a velocity of about 10 m/s (2000 fpm) for impact cutting. The sharpness of the cutting edge has a significant effect on the velocity necessary for effective cutting. A dull-edged, single-element blade requires a velocity of about 45 m/s (9000 fpm) for cutting. Most rotary cutters operate at blade velocities of 40–70 m/s (8000–14 000 fpm).

A tractor-mounted swath harvester cutterbar based on the single-element impact cutting principle is marketed by a European manufacturer. This machine has a series of small-hinged rotating blades mounted closely on a frame to harvest a wide swath. The machine is popular in Europe for upland crops and brush cutting operations. It is more rugged than the conventional reciprocating cutterbar, which is the most popular crop-harvesting mechanism. The single-element cutting approach has been used, in Japan, for some portable paddy harvesters and two makes of reapers. These machines are equipped with high-speed rotary saws for cutting plants.

The two-element scissors action is the most widely used for harvesting agricultural crops. The reciprocating cutterbars that are commonly used for harvesting paddy use this principle. Cutting is done by shearing rice stems between moving knife sections and ledger plates. The included angle between the cutting edges is about 38 degrees. Serrated blades permit a larger included angle because the plants cannot easily slip between the two cutting edges. Reel cutters also use the two-element scissors action but their use has been limited to lawn mowers and some forage choppers. Reciprocating cutterbars do an excellent job of harvesting but are characterized by high energy losses, short service life, dynamic imbalance, and restricted operating speeds. Improvements have been relatively limited by the high inertial and frictional forces involved in this type of mechanism. Many experimental attempts have been made to replace the reciprocating cutterbars; however, none of the experimental devices has been able to match their overall performance.

Manual Methods

The practice of harvesting paddy plants, drying in the field, and then threshing predominates in the major rice-growing areas of the tropics. A sickle is generally used for manual harvesting of paddy. There are many variations in sickle designs and both smooth and serrated blades are popularly used. Chancellor (1963) studied energy requirements for cutting rice stalks with smooth and serrated sickles and concluded that both are equally effective in cutting the plants. Paddy plants are harvested by holding the sickle in one hand and gathering the plants for cutting with the other hand. Plants are cut from 3 to 20 cm above the ground depending on the method of threshing to be used. The hand-holding of straw, while harvesting, reduces grain scatter losses as compared to harvesting with tractor mowers (Fig. 46). Ezaki (1963, 1969) reports that the harvesting output of a skilled man in nonlodged rice is about 0.01 ha/h and that of a woman is about 0.006 ha/h.

In some parts of Indonesia, Malaysia, and the Philippines, only the panicles are harvested. This is done by using a small knife or a special tool that has a small metal blade fitted in a short wooden block. This is a high labour-consuming practice that requires about

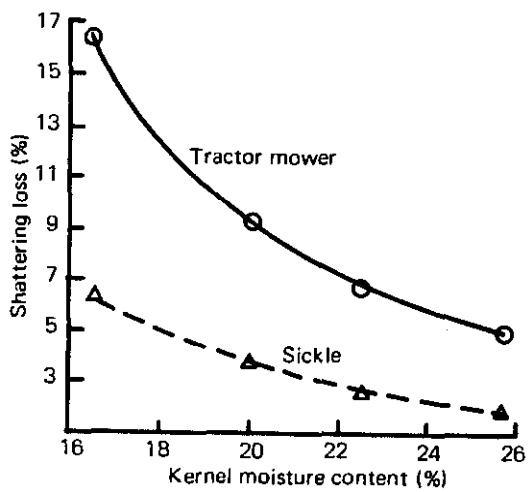

FIG. 46. Effect of two methods of harvesting on shattering losses at different kernel moisture levels. Paddy variety Dular (Gupta 1963).

175% more labour than sickle harvesting. Often religious or traditional reasons are given for this practice. In Java, custom allows a harvester to gather only one basket from each field for it is believed that taking more than a basket will displease the "godmother of good harvest." This practice, however, seems to have some practical reasons in areas where fields are inaccessible by roads and the harvested paddy has to be carried for miles along field levees. In such areas, fields are far away from the roads and no threshing equipment can be conveniently carried into the fields. Harvesting of paddy with long straw under such conditions would certainly create a serious transportation problem. The harvested panicles are tied in small bundles for sun drying. Usually a skilled person can harvest about 15 kg of paddy per hour.

In Japan, a manually operated, push-type harvester called a hand dropper was developed. It consisted of a pair of serrated blades mounted at a 30 degree angle to each other, a mechanism to retain the harvested plants, and a lever to drop the harvested plants. A harvesting rate of 0.02–0.025 ha/h has been reported by Ezaki (1963, 1969); however, Taneja (1963) reported that such a dropper was tried in India on rice, but it was not found satisfactory.

Animal-drawn reapers have been tried at the Central Rice Research Institute at Cuttack, India, for harvesting rice. Using a pair of bullocks, an average output of 0.2 ha/h (0.5 acre/h) has been reported. Compared to manual harvesting, working costs were less than one-third. However, these were old horse-drawn reapers from Western countries and many operational problems were encountered in harvesting rice; therefore, the units were not considered practical for harvesting paddy in India.

Power-Operated Harvesters

In the early stages, the mechanical harvesters developed in Japan were single or multirow side-delivery windrowers (Fig. 47), equipped with reciprocating cutterbars and some type of side-delivering mechanisms.

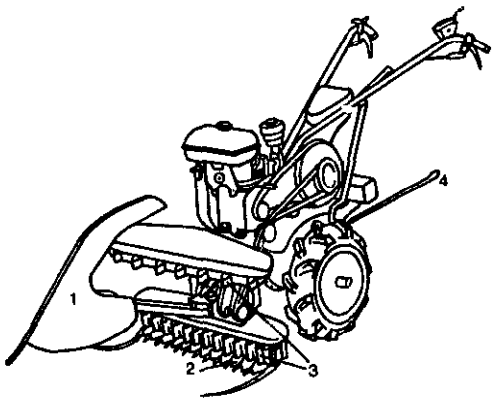

FIG. 47. Multi-row side-delivery windrower: (1) deflecting cover; (2) cutter bar; (3) feeding conveyor; and (4) manual header control.

Paddy plants were laid in a continuous swath. These harvesters were equipped with 60–70 cm cutterbars and were mostly offered as attachments to small walking tractors. Subsequently, some machines, called droppers, were developed that intermittently dropped untied bundles of paddy, making it easier to collect the harvested crop. In the last few years, portable power scythes have been marketed by Japanese manufacturers with rice harvesting attachments. Most of these harvesters have not been well accepted by the farmers. A slightly different Japanese reaper, which has been in production for some years, is equipped with a small rotary saw mounted on a planetary drive arrangement. A 1-m wide swath is harvested by the small saw and is collected inside a circular passage. The collected untied bundles of paddy are dropped to one side of the machine.

Ezaki (1963, 1969) reports that in 1950, work on developing a binder was started at the Institute of Agricultural Machinery at Omiya, Japan. Subsequently, many manufacturers developed binders that dropped tied bundles of paddy on one side of the machine. During the last few years, these new binders have received wide acceptance in Japan. Sales figures of 1000 units in 1966, 10 000 in 1967, 80 000 in 1968, and 150 000 in 1969 have been reported.

These binders are equipped with reciprocating cutterbars. Plants are cut with the cutterbar and are conveyed to the side for tying

in bundles. The bundles are ejected on the side and fall at right angles to the plant rows with the panicles away from the machine. These binders have moving nylon fingers for lifting lodged crops with a combing action. The binders can work successfully even when paddy is lodged at angles of 20–30 degrees. Generally the grain losses average about 2%.

The earlier binders were designed for one- or two-row operation; however, during the last few years, many manufacturers have introduced three- and four-row machines. The one- and two-row, side-delivery binders are equipped with offset-mounted cutterbars and this necessitates manual harvesting of one or two rows of paddy before harvesting with the machine. The larger three- and four-row machines have in-line cutterbars that do not require the initial manual harvesting. Another interesting low-cost, single-row binder recently introduced in Japan is designed to drop the paddy bundles along the travel path of the machine. The manufacturer claims that this feature facilitates the collection of bundles from the ground. The larger tractor-trailed or self-propelled harvester-binders from Western countries have not been successful for harvesting rice in the tropics.

Threshing

Threshing involves the detachment of paddy kernels from the panicle and can be achieved by three methods: (1) rubbing action; (2) impact; and (3) stripping. The rubbing action occurs when paddy is threshed by trampling by men, animals, or tractors. It is not an efficient method of threshing. The impact method is the most popular method of threshing paddy. Most mechanical threshers primarily utilize the impact principle for threshing, although some stripping action is also involved.

Paddy threshers can be classified by two methods of feeding: (1) hold-on; and (2) throw-in. In the hold-on method, paddy straw is held stationary while threshing is done by the impact on the panicle from cylinder bars, spikes, or wire loops. In the throw-in type of machines, whole paddy plants are fed into the machine and a major portion of the grain is threshed by the initial impact of the bars or spikes on the cylinder. The initial impact also accelerates the straw and further threshing is accomplished as the moving panicles hit the spikes or bars of the concave.

The third type, stripping, has also been used in paddy threshing. Some impulsive stripping occurs ordinarily with impact threshing in conventional threshing cylinders. Non-impulsive type of stripping has been experimentally tried in centrifugal threshers and strippers but no commercial machine has so far been successfully developed.

Cleaning of grain involves the separation of bulk straw, chaff, empty kernels, and very light and fine impurities from the grain. In the simplest form, straw and chaff is manually separated and the grain is dropped through a cross wind to remove the lighter impurities. Air can only remove impurities that have different aerodynamic properties from the grain. Many different grain cleaning systems are used in threshers, depending mostly on the type of feeding method and the threshing capacity. In the hold-on type of thresher, a major amount of the straw does not pass through the machine and only the removal of chaff and light impurities from the grain is necessary. This is achieved mostly by pneumatic means and in some cases by a combination of screens and air. In the throw-in type of thresher, a large amount of straw is handled through the machine. These machines use straw walkers to initially separate the loose grain from the large bulk of straw and chaff. A chaffer screen is used to separate chaff from the grain before the finer impurities are removed by an air blast.

Manual Threshing

The methods used for threshing rice manually are: treading by feet; flail-threshing; and beating on tubs, threshing boards, or racks. A man can thresh from 15 to 40 kg of brown rice per hour by these methods. The only mechanical equipment used for manual threshing is the pedal thresher that originated in Japan during the early stages of mechanization. This thresher is also popular in Taiwan where a threshing team of 5–7 men work with

each machine. The crew moves in a circle, while one or two men are threshing the others collect and bring new paddy bundles. The cylinder rotates at about 300 rpm and the inertia of the cylinder keeps the drum rotating as men take turns at pedalling the machine. There is no cleaner with this thresher. Tests at IRRI with this thresher indicate an output of about 30–70 kg of paddy per hour. Attempts have been made to introduce the pedal thresher in other Asian countries; however, it has not been well accepted. In Taiwan, 60–65 man-h/ha are required for threshing with a pedal thresher, which gives an approximate output of about 50–80 kg/h. The improved pedal thresher performance in Taiwan is perhaps due to better coordination and teamwork of the threshing crew.

Power Threshing

Treading under Tractor Tires

This method of threshing paddy has been used in some Asian countries. It is quite popular in Ceylon for custom threshing. The popularity of this method can be attributed only to a lack of suitable tractor PTO-driven threshers. A threshing capacity of 640 kg/h has been reported from Ceylon when two threshing floors are alternately worked with one tractor.

Threshing Cylinders

All power paddy threshers are equipped with one of the following types of cylinder and concave arrangement: (1) rasp bar with concave; (2) spike tooth with concave; (3) wire loop with concave; and (4) wire loop without concave. Tests at IRRI indicate that the spike tooth cylinder performs well both with the hold-on and the throw-in methods of feeding and its threshing quality is less affected by changes in cylinder speed. Figure 48 illustrates the cylinder test stands and Fig. 49 and 50 show their comparative performance with the two methods of feeding. The wire loop cylinder exhibited excellent performance with the hold-on method of feeding. The following optimum cylinder peripheral velocities, in feet per minute, were obtained for threshing paddy based on the performance limits of 2.0% minimum unthreshed paddy, 1.0% maximum milled paddy, and 85% minimum head grain yields:

	Hold-on method	Throw-in method
Wire loop without concave, overfed	2650	3650[4]
Wire loop with concave, underfed	2150	2900
Peg tooth	2150	2900
Rasp bar	2650	3650

Hold-On Thresher

Three types of hold-on threshers are popular for paddy.

(1) Engine-driven threshing drum. In Taiwan and some other countries, pedal threshers have been converted for power operation by using small air-cooled engines. These machines have no grain separators or winnowers. Cleaning is a time-consuming problem and the output is relatively low. These threshers are, however, simple and can be manufactured in most Asian countries. Attempts are being made in many Asian countries to incorporate simple separating and winnowing mechanisms in such threshers. A number of small manufacturers have recently introduced such threshers in the Philippines.

(2) Japanese power threshers. These machines are equipped with a wire loop threshing drum and regular cleaning and winnowing mechanisms. Due to the hold-on method of feeding, output is not too high, but the machine can do a good job of grain cleaning. Relatively high labour is required because the paddy bundles have to be held by the operator until threshed. Gupta (1963) reported the visible and invisible seed damage with this type of thresher in tests conducted in India on Aman paddy (Fig. 51).

Both single- and double-drum threshers are offered by Japanese manufacturers. These machines can be operated either as hold-on or

[4]Compromise cylinder peripheral velocity wherein: unthreshed paddy loss = 2.01%; milled paddy at threshing = 0.64%; and head grain yield = 78.9%.

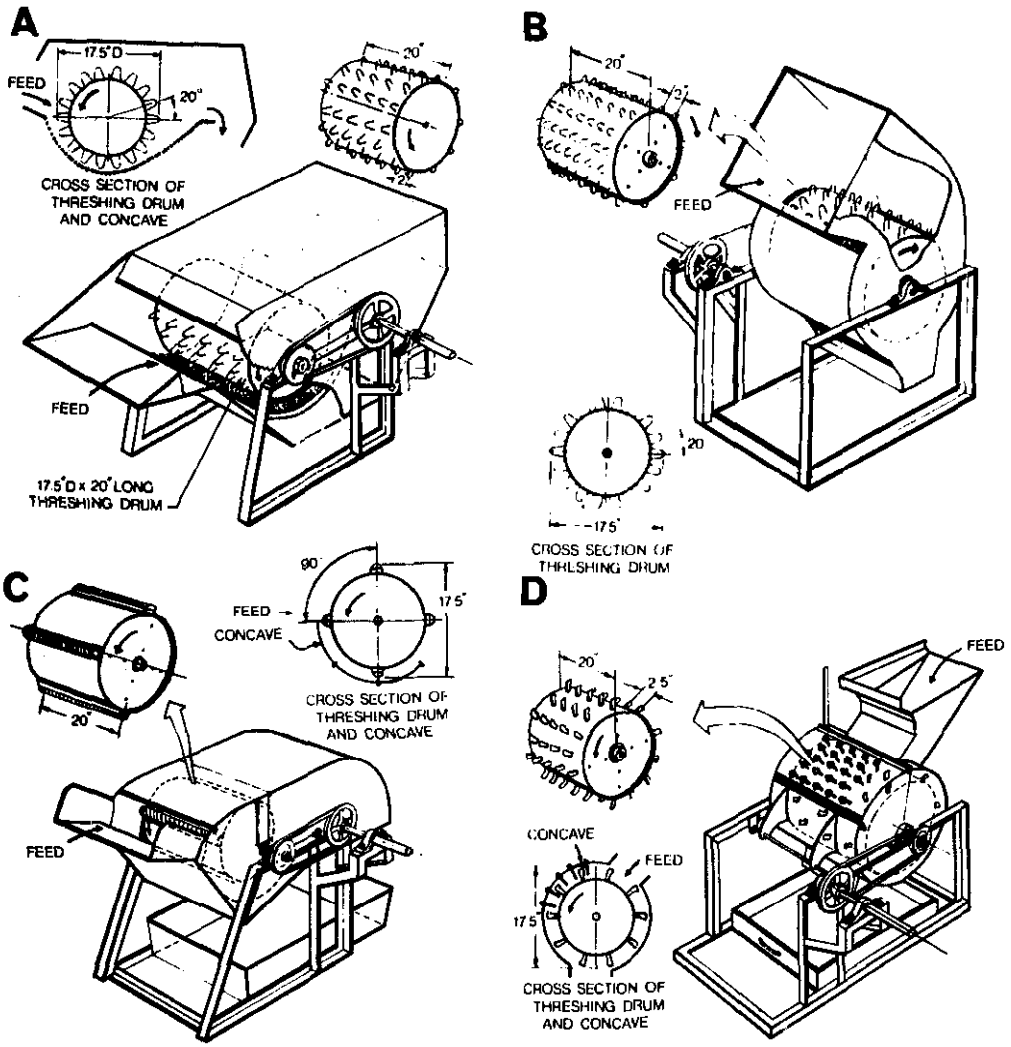

FIG. 48. Threshing cylinder test stand.

throw-in threshers. In the throw-in operation, threshed material is moved axially along the cylinder axis because of the helical arrangement of the wire loops and fins in the cylinder cover. Most of the threshing occurs at the first cylinder, which operates at a slower speed. The hard-to-thresh grain is threshed in the second cylinder, which rotates at a higher speed. The machine will perform well when the quantity of straw is not too excessive. Experience with the double-drum thresher in the Philippines indicates that it is quite well suited for threshing both wet and dry paddy and other agricultural crops such as wheat and sorghum.

(3) Self-feeding automatic threshers. These machines are similar to the nonautomatic thresher except that these machines are equipped with paddy gripping feed chains that automatically feed the paddy in a continuous layer. The threshing output is high and the machine requires less labour.

Tests conducted at IRRI on a Japanese automatic thresher equipped with a 3100 W (4.2 hp) engine indicated an output of about 200 kg/h with three operators. Comparative

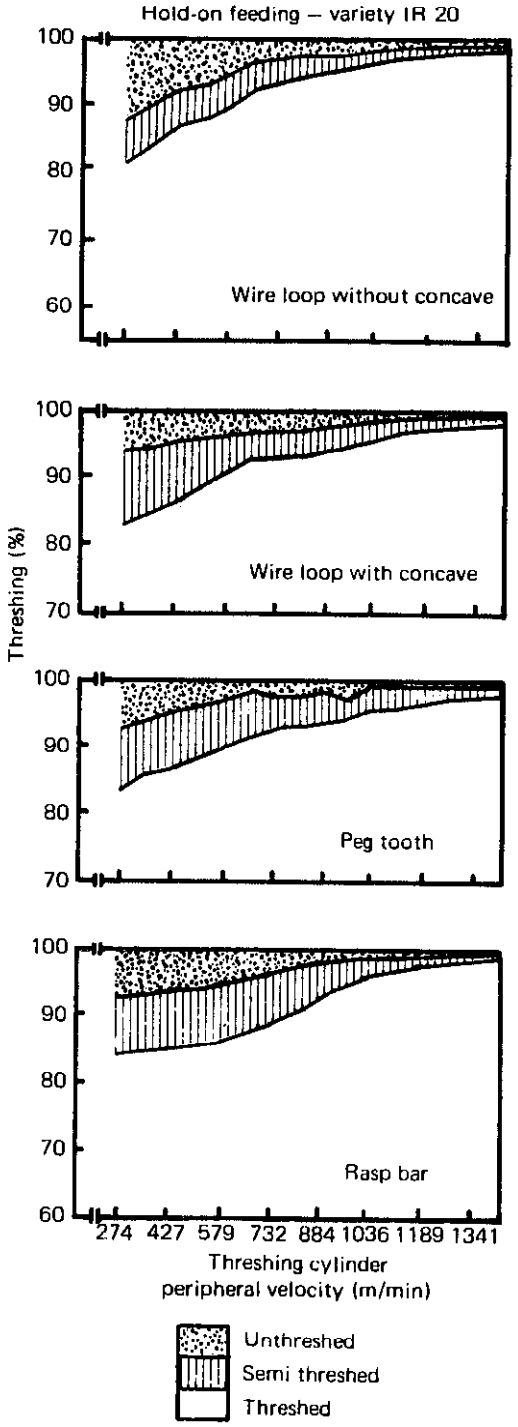

FIG. 49. Comparative threshing cylinder performance for hold-on feeding.

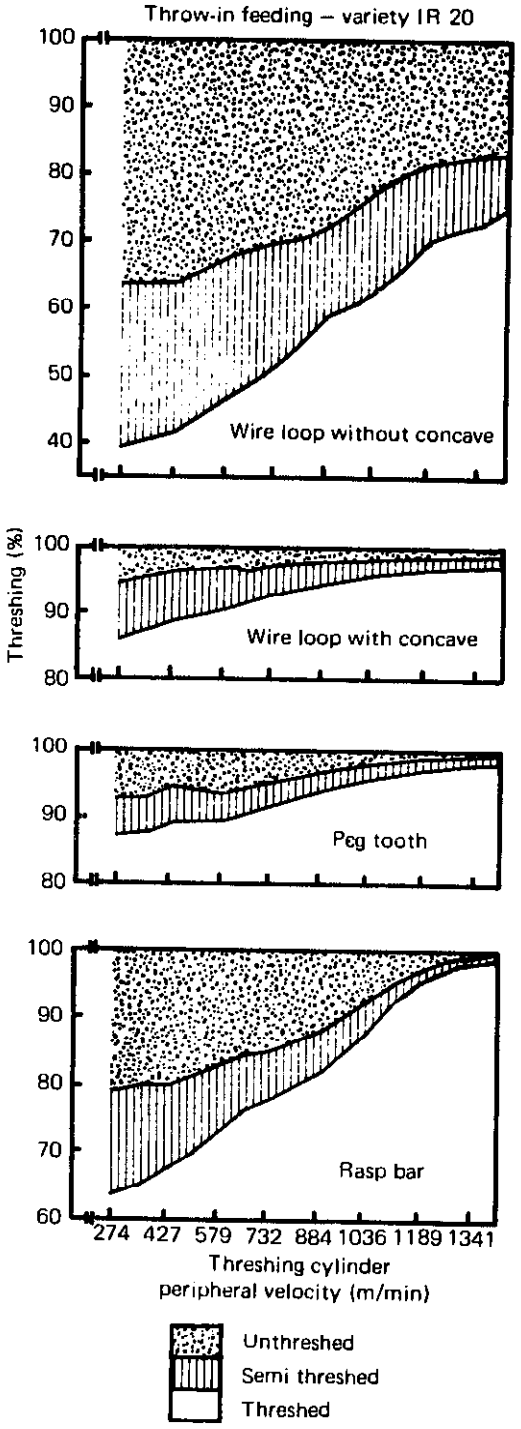

FIG. 50. Comparative threshing cylinder performance for throw-in feeding.

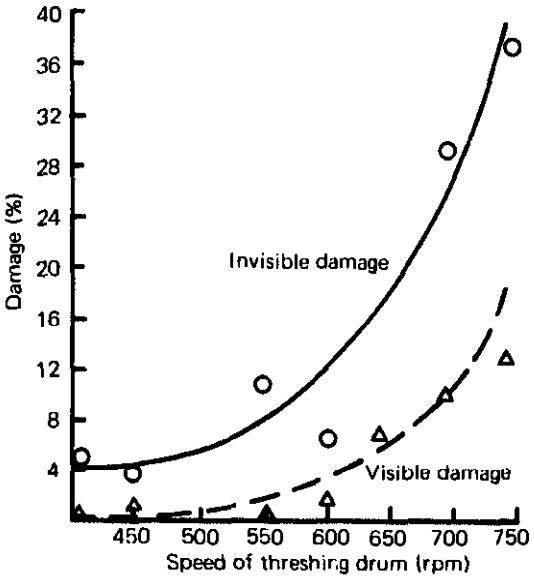

FIG. 51. Visible and invisible seed damage at different threshing drum speeds of a Japanese power thresher (Gupta 1963).

performance of nine paddy threshers tested at IRRI in 1968 is listed in Table 18. These tests include the performance results on the two IRRI threshers, the drum and the table threshers. The table thresher is of a nonconventional design with a flat, rotating threshing surface with a built-in radial fan on its underside. This machine can thresh high-moisture paddy without clogging.

Through-Flow Threshers

In this type of thresher, paddy plants are completely fed into the machine. These machines are equipped with a threshing cylinder and concave and have some separating and cleaning mechanisms. The rasp bar cylinder was previously considered suitable for rice; however, all of the new rice threshers and combines are equipped with spike tooth cylinders. The spike tooth cylinder can operate without clogging even with large amounts of straw at fairly high moisture levels, and the grain is subjected to lower intensity impact forces resulting in lower grain damage.

In the Philippines, large McCormick-type threshers are widely used for custom threshing. These threshers are exact copies of the old threshers that were developed 50–70 years ago in Europe and America. Many small machine shops fabricate this machine in the Philippines. A major portion of the paddy in the Central Luzon area of the Philippines is custom threshed with these threshers. These threshers are belt-driven from a 45 000 W (60 hp) tractor PTO pulley. Usually a crew of 8–12 men operates these machines, which thresh about 20–30 t of paddy per day. Because of the high threshing capacity, the machine is moved often, which results in substantial down time. This type of thresher is equipped with an elevator feeder mechanism, rasp bar cylinder, straw walker, chaffer, sieves, blower, and straw thrower. Since the introduction of combines in the developed countries, new threshers have not been developed. Consequently, the 50- to 70-year-old designs are still being fabricated in the Philippines. These threshers are sold in the Philippines for about US$5000. Studies at IRRI indicate a need for a lightweight, tractor PTO-driven, three-point-linkage mounted thresher with a capacity of approximately 12–15 t/day for custom threshing in many Asian countries.

Axial-Flow Thresher

The axial-flow thresher, which combines threshing with air and screen cleaning mechanisms, was developed by IRRI. It is lightweight and is mounted on wheels to provide good mobility in either wet or dry soil (Fig. 52). It can be pulled behind a small hand tractor, a jeep, or a truck.

The machine consists of a steel cylinder equipped with peg teeth (Fig. 53). The fins on the upper concave are positioned spirally to move the material axially to the discharge end. A blower is located under the concave, which winnows the chaff and empty grain that fall through the concave. An auger collects and conveys the winnowed grain to a rotary screen sieve. This sieve separates pieces of straw that pass through the perforated concave and that are not blown by the air from the full grain. The grain from the screen sieve drops to a trough and is then conveyed by elevator flaps to the bag.

The thresher is powered by a 5200 W (7

TABLE 18. Comparative performance of selected rice threshers (IRRI, Los Baños, Laguna, Philippines, 1968).

Thresher model	Threshing blade type	Machine performance		Power performance		Labour performance			Economic performance	
		kg/h	ha/h[a]	Engine hp	hp-h per 44 kg	No. of men[b]	man-h per ha[a]	Grain output per man-h (kg)	Machine cost	Threshing cost per 44 kg (pesos)
Pedal thresher	Wire loop	68.64	0.0156	—	—	2	128.20	34.32	NA	
Locally manufactured nonautomatic single drum	Wire loop	158.40	0.0360	4.0	1.333	3	83.33	52.80	2464	0.930
IRRI drum type	Wire loop	252.12	0.05373	4.2	0.695	5	87.26	50.42	3000	1.06
IRRI table type	Wire loop	228.80	0.0520	4.2	0.807	5	96.17	45.76	2500	0.912
Japanese automatic	Wire loop	195.36	0.0444	4.2	0.946	3	67.56	65.12	3500	0.765
Locally manufactured drum type	Spike tooth	117.04	0.0266	12.5	4.700	4	172.94	29.26	6750	1.512
Vogel nursery	Spike tooth	126.72	0.0288	10.0	3.473	4	138.81	31.68	NA	
Turner "Economy"	Rasp bar	170.72	0.0388	10.0	2.577	4	120.00	39.60	NA	
Garvie Type DA	Rasp bar	163.24	0.0371	17.5	4.717	4	107.85	40.79	NA	

[a]Based on 4400 kg/ha yield.
[b]Number of men includes one man who collects and sacks the grain.
SOURCE: Semi Annual Substantive Report No. 8 and No. 9, IRRI-AID Mechanization Research Contract, IRRI, Philippines.

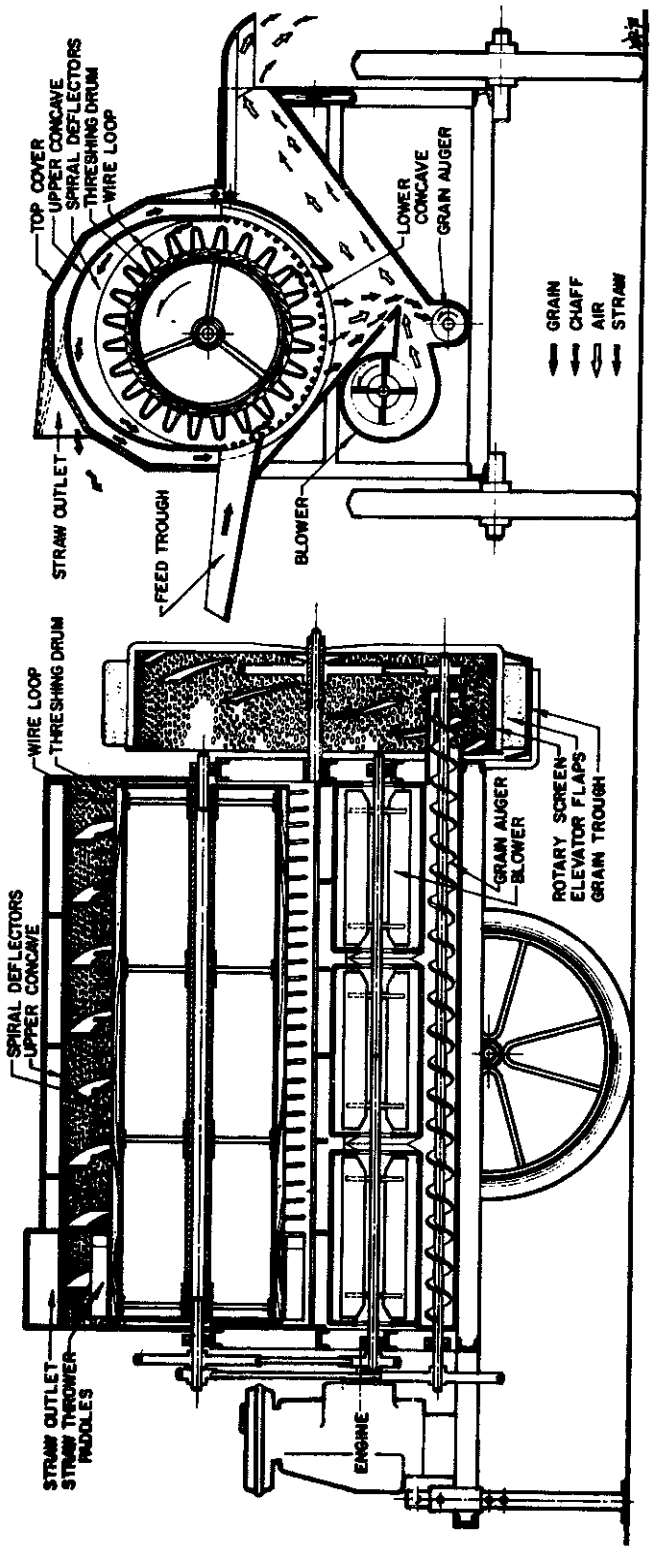

FIG. 52. Schematic drawing of IRRI axial-flow thresher.

FIG. 53. Threshing cylinder and upper concave exposed in IRRI axial-flow thresher (courtesy IRRI).

hp) air-cooled engine, and can handle freshly harvested paddy with good separation and cleaning performance. The operation requires three men to feed, thresh, and bag the paddy, and the output is 1 t/h. Because of the simplicity of the design there are few operation and maintenance problems.

Direct Field Harvesting-Threshing

Head-Threshing Combines (Japanese Style)

During the late fifties and sixties interest was generated in Western style combines in Japan. Between 1962 and 1968 about 400 such combines with 1.5- to 2.4-m (5- to 8-ft) headers were imported in Japan. A number of Japanese manufacturers also developed their own versions of small, through-flow type combines that were basically patterned after the Western style through-flow machines. These machines, however, were not well accepted as the grain loss and damage was generally higher than the Japanese farmers were willing to accept. These machines also consumed more power and required larger engines due to the energy lost in bruising the straw. The very small field size in Japan also created some operational problems.

Simultaneously, with the development of the small, Western style, through-flow combines in Japan, some manufacturers developed small head-threshing type combines. Basically, these combines consisted of a Japanese automatic thresher mounted on a self-propelled crawler platform and equipped with paddy lifting, cutting, elevating, and feeding mechanisms. Because the straw is not damaged in harvesting, Japanese farmers prefer these machines to the through-flow combines. The automatic threshers used in these combines were already popular in Japan for threshing dry paddy. The threshers used with the earlier combines did not perform well because of the high moisture levels encountered in direct combining. The major limitations of the Japanese automatic threshers are in the separating and cleaning mechanisms when working with high-moisture paddy. A number

of companies have now improved the cleaning capacity of the threshers by installing straw walkers and oscillating sieves; therefore, these machines can successfully harvest high-moisture paddy.

These improved head-threshing combines have 2–3% grain loss, and less than 1% grain damage. The machines are equipped with well-designed dividers and moving nylon pickup fingers that lift the lodged crop with a combing action. Two-row walking combines weigh approximately 600 kg and are equipped with crawler tracks that enable them to work in wet paddy fields. However, these machines still encounter problems of mobility in wet fields with a very high clay content or a very deep hardpan.

Although this type of thresher has gained acceptance in Japan, it has not been marketed successfully in other parts of Asia.

Through-Flow Combines (Western Style)

There are three types of through-flow combines: (1) tractor-trailed; (2) tractor-mounted; and (3) self-propelled. The trailed combines bave almost been replaced by the self-propelled machines because of improved mobility and performance. One European manufacturer has recently developed a tractor-mounted 1.8-m (6-ft) combine that is lower-priced than the self-propelled combine and offers somewhat similar field mobility. The manufacturer claims that it can work in rice; however, no test data or information is available on its performance with rice.

The earlier tractor-drawn combines had 1.8-m (6-ft) cutterbars and an output of 3.22 ha/10 h although these combines required about 50% more labour than the self-propelled machines. However, these machines required one-third as much labour as with the old binder method. A self-propelled 3.6-m (12-ft) combine can harvest about 5.9 ha/10-h working day and a 4.2-m (14-ft) combine can harvest about 6.88 ha/10-h day.

A standard self-propelled rice combine consists of components for cutting, feeding, threshing, separating grain from straw, cleaning, and temporary storage. Power is provided both to the wheels and the harvesting-threshing mechanism from an engine mounted on the combine. Rice combines differ from other grain combines because they have higher ground clearance, a higher header lift, crawler tracks instead of wheels for improved mobility in muddy fields, sealed bearings, adjustable pickup-type reel and lift guards for lodged crops, and oversize straw walkers. Almost all machines are equipped with spike tooth cylinders and the cylinders rotate at a slower speed for rice than for other grains.

Manufacturers claim that nearly 80–90% of the grain is separated from the straw at the concave, thus improving grain separation at the rack and reducing losses with straw. Generally, the popular header size is from 2.4 to 4.2 m (8 to 14 ft) although combines with up to 8.2-m (27-ft) headers are now being manufactured in the United States. The new combines are equipped with hydrostatic transmission drives and make extensive use of hydraulic motors for driving the harvesting and threshing components. The use of hydraulics has simplified the design of the combine and has resulted in easier operation.

Careful operation and adjustments are necessary to obtain satisfactory performance from the modern combine. A brief description of various losses and the precautions necessary to minimize such losses are given below.

Scatter Losses

These are due to natural causes, such as overripe paddy, wind, rain, and birds.

Cutting Table Losses

Pickup reels, rather than bat reels, are essential for rice harvesting as nearly all fields have some lodged or tangled plants. In standing rice, pickup reels are driven 50% faster than the forward speed of the combine. In lodged rice, reel speed should be about twice the forward speed. The pickup fingers should be adjusted about 2.5–5 cm above and 35–43 cm ahead of the tip of the knife section when the fingers are in their lowest position. When the crop is flat on the ground, harvesting must be done along the direction of lodging. Cutter-

bar losses may increase due to dull knives and ledger plates, improper register, or too fast a reel speed.

Cylinder Losses

Spike tooth cylinders are normally used. The cylinder peripheral velocity ranges from 20 to 25 m/s (4000 to 5000 ft/min). If the rice is dry (14–18%), or is harvested for seed, cylinder speed should be set at about 20 m/s (4000 ft/min). Cylinder and concave tooth overlap should be about one-half the tooth length. The cylinder has teeth over the whole surface; whereas, the concave usually only has two to four rows of teeth at the front of the concave. Losses depend on the cylinder speed, the clearance between cylinder and concave, the condition of cylinder and concave, the combine travel speed, the variety of rice, the stage of maturity, the moisture content, the weather conditions, and the straw-grain ratio. Early morning or late evening harvest increases cylinder loss. Minimizing cylinder loss (unthreshed grain) can sometimes result in increased field hulling and damage to the paddy.

Rack Loss

This is affected by varietal characteristics and the amount of straw passing through the racks. In down rice, plants are harvested very close to the ground and because more straw passes through the machine the rack losses are increased.

Shoe Loss

Air-blast control is most important to minimize losses. Air should be sufficient to lift and float the chaff and light material and prevent it from falling through the sieves. The air should blow evenly throughout the entire area of the sieves. The air setting must be based on the amount of grain loss rather than the cleanliness of the grain in the tank. Damp, green paddy requires more air than dry paddy.

Hulling and Breaking

In long grain varieties, paddy is more easily removed from the panicle than in medium and short grain varieties. Too dry a crop (below 16% moisture content) can result in more hulling.

Operator Losses

These are perhaps the most important. Cutting the rice too high with less straw results in increased cutterbar and cylinder losses. Many heads on shorter straw or lodged straw are lost in the field. When the straw is too short it cannot be held by the beater and the feed rolls while the cylinder impacts it; therefore, cylinder losses are higher. If cutting is too low, excessive straw can clog the cylinder. Operating the machine too fast overloads it and increases losses.

Lo. s in Down Rice

Combine loss in down rice is usually double the loss in standing rice. The proper speed of the pickup reels is essential. The pickup reel should not have a combing action in down rice or it will knock off some of the grain or panicles. To reduce losses, combining must be done in the direction of lodging. Combining in a cross-direction is not recommended. The least amount of straw is taken into the machine when the cutting is in the direction of lodging.

Some rice combines have been tried in Malaysia, Vietnam, and the Philippines, mostly in government farms or farmers with large holdings. During August 1970, a study was made on six Clayson 975 rice combines with 53 500 W (72 hp) diesel engines and 4-m (13-ft) cutterbars. These machines weighed nearly 7 t each and were equipped with crawler tracks. The average production was found to be 1.74 ha/10-h working day. An average of 2.77 machine-h/ha was considered realistic, which is much more than the 1.23 h/ha quoted in other reports on combine harvesting. Some of the major causes of high downtime were: (1) rainy weather; (2) mechanical breakdown, mostly of a minor nature; and (3) poor field organization in locating farmers' plots for harvesting.

This study showed an inverse relation between plot size and harvesting time per unit area. It indicated that beyond a 0.8-ha (2.0-

acre) plot area, the effect of plot area on combine productivity is not too significant. It also indicated poor combining output on plots of less than 0.4 ha (1 acre). The main problems were: (1) shortage of access road systems and strong bridges; (2) uneven ripening of crop within a farming locality; (3) too large initial investment for farmers; and (4) inability of the machine to work in areas where the soil has a very high clay content or a very deep hardpan.

The study indicated, however, that it would be potentially profitable to operate these combines in spite of the high initial costs. Problems of accessibility, soil conditions, and small size of plots limit the areas available for combine harvest in the Muda region. The selling price of some of the self-propelled through-flow combines ranges from US$20 000 to $25 000 in the Philippines and other Asian countries.

It is highly doubtful that even some of the larger farmers in the tropics could raise that much capital. Perhaps such machines could only be bought by governments. The experience in the Muda Irrigation Scheme of Malaysia, where these combines are now being used for harvesting crops on a custom basis, should be watched carefully. If it is successful it may have application elsewhere.

Lawrence (1970) reports a study in which he compared the economic aspects of seven levels of mechanization in Pakistan from the traditional animal-drawn implements to a completely mechanized system of farming. He concludes that in the cropping sequence considered in this study, the labour demand for field operations fell only slightly when tractors were introduced and lower levels of mechanization actually increased labour demand. Combining, on the other hand, did reduce the demand for field labour considerably. The employment effects of introducing large combines will clearly continue to be a matter of concern.

Recent Developments and Trends

The idea of directly stripping grain from standing plants in the field has been experimentally tried for some time. A small stripper-harvester has been developed for plot harvesting in Australia; however, when this machine was tried at IRRI on rice, loss of grain on the ground due to scatter was excessive. Strohman et al. (1965) reported the development of a stripper-harvester with a conical rotor. The machine performed well with very low grain losses in tests conducted on rice in Arkansas. The large diameter of the conical rotor, however, did not adapt well for multi-row harvester design. Experimental stripper-harvesters have also been built in Taiwan and Japan but none have reached a commercial stage.

The idea of stripping grain is of special interest for paddy harvesting because the elimination of handling straw through the machine can reduce substantially the machine weight and improve its mobility in soft paddy fields. Also, the cutting and elevating mechanisms can be dispensed with in a stripper. The IRRI Agricultural Engineering Department has been working on the development of a swath type stripper-harvester rather than a row machine. This concept differs primarily from all other experimental attempts in that initially, the plants are gently bent into the machine before a violent contact is made with the belt-type threshing mechanism. The deflection of plants is done to reduce grain scatter on the ground and to improve the collection of grain. The experimental machine (Fig. 54) is able to thresh all the grain on the plant panicles. However, grain loss is still above acceptable limits, and work is underway to minimize this loss.

Interest in stripper-harvesters is high and it is hoped that a successful machine can be developed, because it would certainly be better suited for harvesting rice in the tropics than the Japanese or the through-flow Western style combines. From the recent developments it seems probable that within a few years lightweight stripper-harvesters may be offered by manufacturers.

Recent developments in conventional through-flow rice combines are mostly directed toward increasing the machine capacity and size with increased width, wide flexible cutterbars, larger grain tanks, and bigger engines. Whereas these developments are well

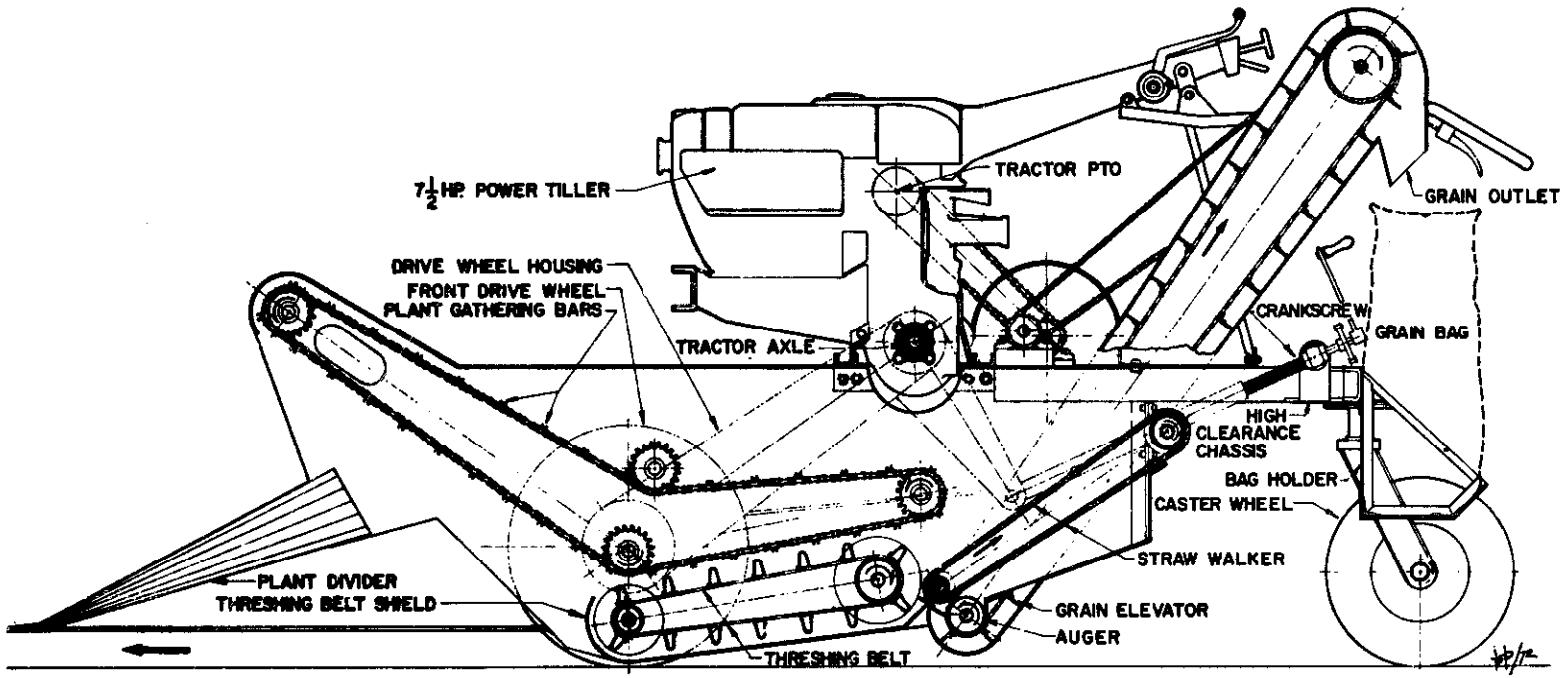

FIG. 54. Schematic drawing of IRRI field stripper-harvester.

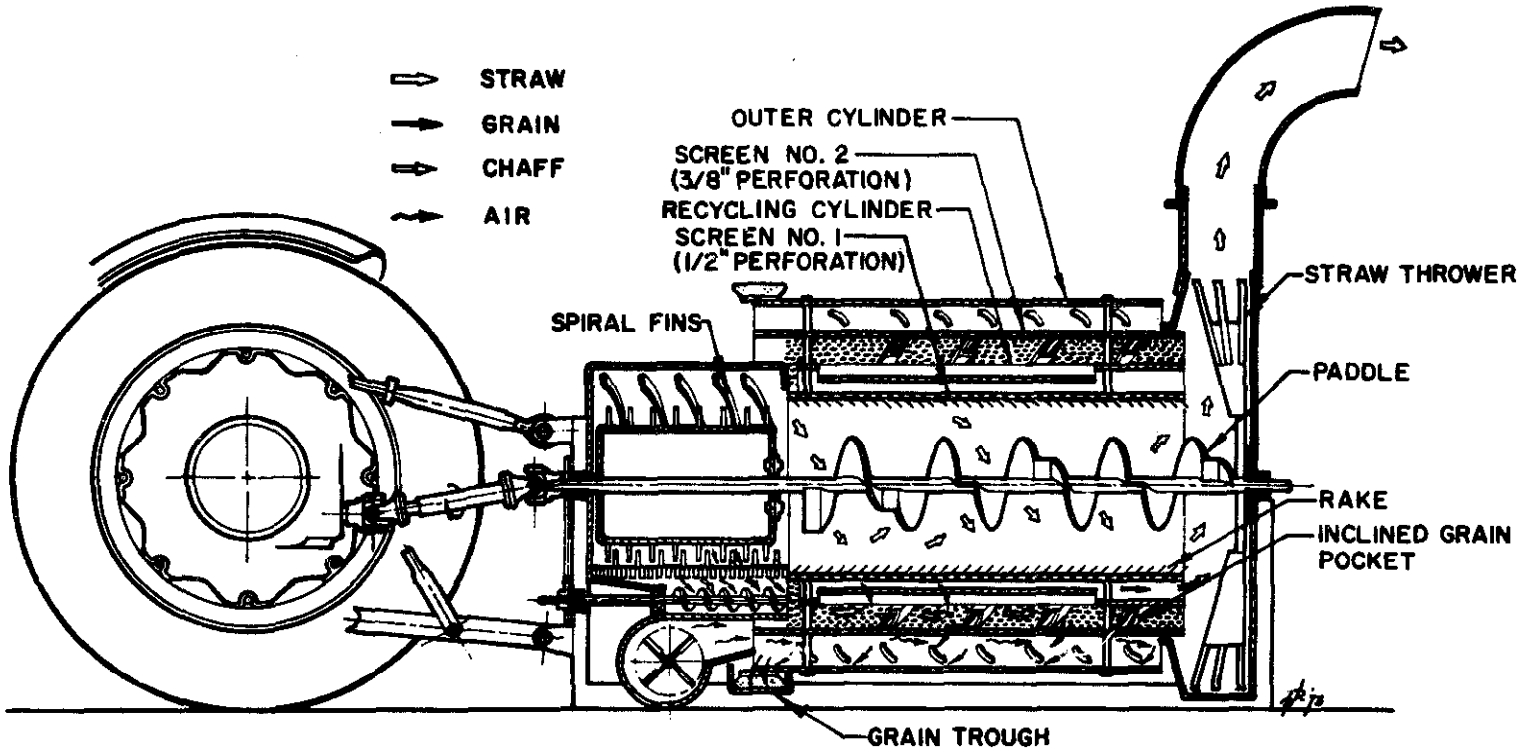

FIG. 55. Schematic drawing of the IRRI PTO-driven thresher.

suited for the advanced countries, this trend, unfortunately, is taking the newer combines farther away from the requirements of the developing countries. It is highly doubtful that such large machines could be widely accepted in the developing areas of the world.

For some years IRRI has been working on the development of a thresher using rotary threshing and separating components. A tractor-mounted, PTO-driven, through-flow thresher (Fig. 55) is currently under development at the Institute and so far the test results are very promising. The machine can thresh high-moisture paddy without clogging. It uses a spike tooth threshing cylinder and a multi-screen rotary cleaner that are mounted uni-axially. The threshed material continuously moves in a spiral path through the threshing cylinder and the rotary cleaner. Up to 92% grain-straw separation has been achieved at the cylinder concave. Work is on hand to optimize the recovery of the remaining grain in the rotary cleaner. The thresher concept is such that it can be easily adapted for a low-cost rice combine. Harrington (1970) also reports the development of a multicrop, tractor-mounted, PTO-driven thresher in India using a large-diameter beater-type threshing mechanism. The machine can thresh paddy, wheat, and many other crops.

Recent developments in Japan on harvesting and threshing machines indicate a rapid shift to combining. The basic Japanese automatic head-threshing machine has remained unchanged in design for a long time. During the last 2 years, some marginal improvements have been made in the cleaning mechanisms to improve performance with wet crops and increase capacity. These were necessitated because these threshers are used with combines that harvest high-moisture paddy. Combine size is gradually increasing from two rows to three and four rows. The Japanese combine can work well in the tropics for harvesting and threshing of paddy. Recent attempts to introduce this machine in Asia, however, indicate that it is not very economical. The Japanese combine is a complex piece of equipment, and from a design point of view, it is doubtful that the basic machine concept could be sufficiently simplified to substantially reduce the price. The home market in Japan is moving towards larger three- and four-row combines that are even higher-priced than the two-row machines.

Requests received at IRRI for information on threshers for tropical countries indicate an intense demand for machines, both for the individual farmers and for custom threshing operators. Attempts are being made in many developing countries to manufacture simple hold-on type drum threshers.

The Japanese automatic threshers are gradually being introduced in Asia but their high landed cost restricts their acceptance. The indigenous manufacture of small threshers is gradually developing in many tropical countries but is hampered by the lack of thresher designs that can be manufactured by simple production methods. Developments indicate considerable interest in large PTO-driven threshers and it is hoped that some successful design will appear in the near future. It seems doubtful that rice harvesting in Asia will go through the reaper-binder stage like in Japan and the United States.

There is little doubt that in the long run the harvesting and threshing of paddy in the tropics will have to be done directly in the field. The present combines, however, do not seem to meet the special requirements of tropical regions. Recent developments indicate an intense interest in developing simpler machines for paddy harvesting and threshing. Looking at some of the recent technical developments, it seems that a breakthrough can be made in the development of economical, small-sized machines for direct field-harvesting and threshing of paddy in the tropical regions of the world.

Comparing Machinery, and Capacity and Cost Data

Grain harvesting, threshing, and cleaning affect the final product. Therefore, there is a need to have a more critical look at the available processing methods for harvesting, threshing, and cleaning. We wish to be able to determine where and when losses in efficiency occur during the entire process of cutting the

standing crop, removing the grain from its parent attachment, and cleaning the grain prior to drying. To accomplish this, we must be able to evaluate the performance of existing machines or methods against a standard, which considers many variables. For example, it is not sufficient to associate milling damage only with the effects of threshing, whether it be the traditional method of beating or a more modern mechanical method, because there are many other constraints in the process. In time we must be able to identify these variables whether they are biological, time-space, or socioeconomic in nature.

It is important that the rated capacity of a machine be determined when evaluating its performance. However, this performance must be based on standardized variables; otherwise, comparisons between different machines are not possible.

One of the most important variables to consider when evaluating the performance of a machine is the moisture content of the grain. Because the same machine may have an entirely different capacity for wet and dry grain, the moisture content of the grain should always be recorded when evaluating the rated capacity. The capacity of the machine should be stated either for raw and wet paddy with a moisture content greater than 15%, or for precleaned and dried paddy with a moisture content equal to 15%.

The threshing efficiency of a hold-on thresher could reach 100% because the threshing time can be increased until all the grains are removed. However, for a throw-in type of thresher one of two indices can be used to determine threshing efficiency, depending on whether the rice is threshed raw and wet or clean and dry.

(1) Raw standard

$$\% \text{ raw threshing efficiency} = \frac{\text{unclean grain}}{\text{unclean grain} + \text{unthreshed grain}} \times 100$$

(2) Dry standard

$$\% \text{ effective threshing efficiency} = \frac{\text{clean grain}}{\text{clean grain} + \text{unthreshed grain}} \times 100$$

A machine is considered to have good threshing characteristics when the efficiency is equal to or greater than 97%.

The amount of mechanical damage caused by the machine must be minimal. Damage in excess of 1% of the rated capacity is considered to be high. In addition, the machines must not lower the germination percentage of the grain. The germination percentage is acceptable only when it is greater than 80%.

Other factors that should be considered when evaluating the performance of a machine are fuel consumption (1/kg), labour supply (man-h/kg), and investment cost (per kg). Although standards have not yet been established for these variables they should always be recorded.

By using standardized variables, accurate comparisons of the performance of different machines are possible. — AMIR U. KHAN. *Department of Agricultural Engineering, International Rice Research Institute, Los Baños, Laguna, Philippines.*

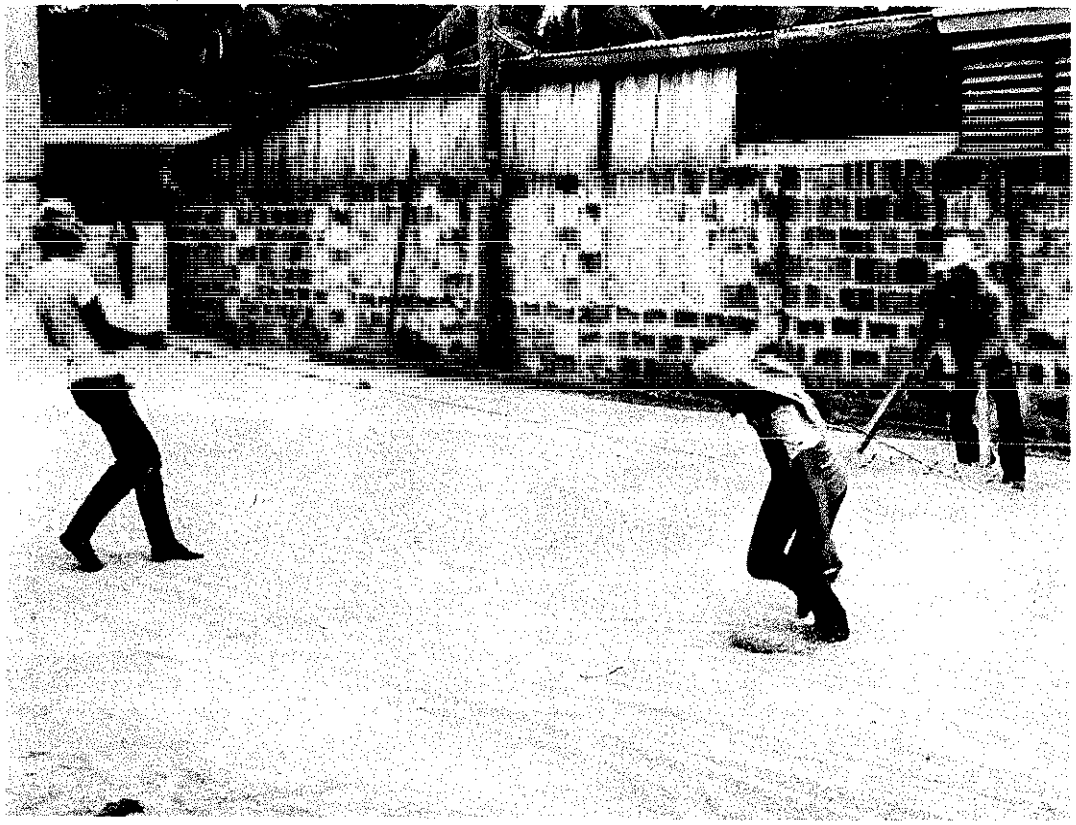

DRYING

Psychrometry

A knowledge of the terms used in psychrometry, which is the study of the properties of the air, and use of the psychrometric chart are essential for an understanding of the processes involved in grain drying and storage and for analyzing individual requirements for a particular climatic condition.

Psychrometric Chart

The psychrometric chart is a device that simplifies the measurement of air properties and eliminates many time-consuming and tedious calculations that would otherwise be necessary. Different air-conditioning manufacturers have slightly different forms of this chart, which may differ in the location of information. All, however, are basically the same in that any psychrometric chart is simply a graphic presentation of the conditions or properties of air, such as temperature, humidity, and dewpoint.

Psychrometric Terms

The essential terms that are most commonly thought of in connection with the psychrometric chart are dry-bulb temperature, wet-bulb temperature, relative humidity, dewpoint, and grains of moisture. *Dry-bulb temperature* is the temperature of the air as measured by an ordinary thermometer such as a household thermometer (Fig. 56). *Wet-bulb temperature* is the temperature of the air as measured by an ordinary thermometer whose glass bulb is covered by a wet cloth or gauze (Fig. 57). The temperature is recorded after the thermometer has been moved rapidly in the air. A wet-bulb thermometer is so-called because the bulb of the thermometer is wet when a temperature reading is taken. This is accomplished by slipping a cloth "sock" onto the bulb end of the thermometer and then dipping both into water. Except for the "sock," a wet-bulb thermometer is the same as a dry-bulb or ordinary thermometer. To measure wet- or dry-bulb temperature, a sling psychrometer is used. A sling psychrometer (Fig. 58) has two thermometers mounted on a base plate. The one with the "sock" is the wet-bulb thermometer; the other is the dry-bulb. The wet-bulb extends below the dry-bulb. This is done purposely so that the "sock" can be dipped in water without wetting the dry-bulb thermometer. If the "sock" is wetted as described, and the two thermometers are moved quickly through the air until the water evaporates from the "sock," the thermometer with the dry-bulb will register the dry-bulb or ordinary temperature, and the thermometer with the wet "sock" on the bulb will register a wet-bulb temperature. Although the air passing over the dry-bulb is the same temperature as the air passing over the wet-bulb, the temperature registered by the two thermometers is not the same. The dry-bulb always registers the actual air temperature; the wet-bulb registers a temperature that is lower than the dry-bulb reading. The key to the seemingly apparent

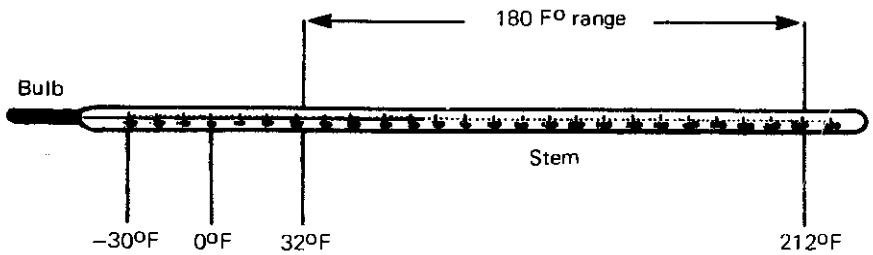

FIG. 56. Dry-bulb thermometer. The bulb is the sensitive portion of the instrument. As the temperature of the bulb increases, the liquid in the bulb expands and rises in the stem.

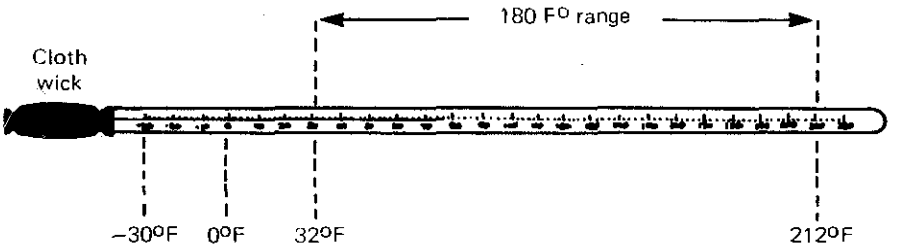

FIG. 57. Wet-bulb thermometer. The clean cotton wick absorbs water. Evaporation of this water reduces the temperature of the wick, and the resultant temperature is indicated by the mercury in the thermometer stem.

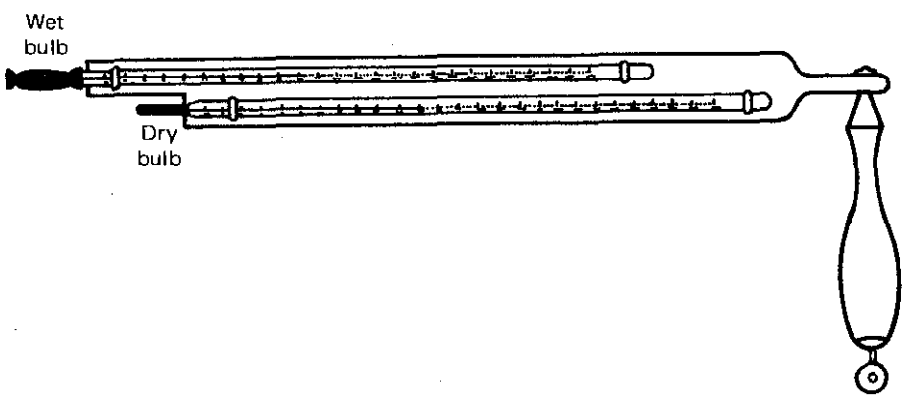

FIG. 58. Sling psychrometer. The two thermometers should be matched by the manufacturer; that is, the readings obtained when the wick is removed and both thermometers are exposed to dry-bulb conditions should be the same. The instrument is rotated about two to three times per second until readings attain constant values.

discrepancy in temperature readings is the word "evaporation." As moisture evaporates from a surface, it removes heat from the surface. In this instance, moisture evaporates from the wet "sock" on the wet-bulb thermometer and consequently cools the surface of the thermometer bulb. This is primarily the reason for a lower wet-bulb thermometer reading.

The temperature spread between the dry-bulb and wet-bulb readings depends upon the amount of moisture in the air. If moisture content is high, evaporation at the "sock" on the wet-bulb takes place at a slower rate. If the moisture content of the air is low, the air is dry and can readily absorb moisture. Therefore, evaporation at the "sock" takes place rapidly and heat is removed in larger quantities. This makes the surface of the wet-bulb cool rapidly. As a result, the reading on the wet-bulb thermometer is lower than for air that has a high moisture content. Dry air, or air that has a low moisture content, therefore, has a low wet-bulb temperature; humid air, or air that has a high moisture content, has a high wet-bulb temperature. In fact, when the moisture content reaches 100%, or 100% relative humidity, the wet-bulb temperature becomes the same as the dry-bulb temperature. This can readily be seen on the psychrometric chart. At this condition evaporation ceases because the air cannot absorb more moisture. Therefore, it is not possible to remove heat by evaporation from the "sock" on the wet-bulb, and the two thermometers register the same temperature.

Relative humidity is the ratio of the partial pressure of water vapour in the air to the pressure that saturated water vapour exerts at the temperature of the air. *Grains of mois-*

ture is the unit of measurement used to determine the amount of moisture in the air; 700 grains equal 1 lb (0.45 kg) of water. *Dewpoint temperature* is the temperature at which moisture condenses on a surface.

In relation to the psychrometric chart, these terms can quickly tell many things about the condition of the air: if the dry-bulb and wet-bulb temperatures are known, the relative humidity can be read from the chart; if the dry-bulb temperature and relative humidity are known, the wet-bulb temperature can be determined; if the wet-bulb temperature and relative humidity are known, the dry-bulb temperature can be found; if the wet-bulb and dry-bulb temperatures are known, the dewpoint can be read from the chart; and if the dry-bulb temperature and relative humidity are known, the dewpoint can be found.

The grains of moisture in the air can be determined from any of the following combinations: dry-bulb temperature and relative humidity (RH); dry-bulb temperature and dewpoint; wet-bulb temperature and relative humidity; wet-bulb temperature and dewpoint; dry-bulb and wet-bulb temperatures; or dewpoint alone.

Identification of Lines and Scales on the Chart

Picture the chart as a shoe or boot with the toe on the left and the heel on the right. Refer to the skeleton psychrometer charts, Fig. 59 (A–F), to clarify the following points. (1) The dry-bulb temperature scale extends along the sole from toe to heel. The dry-bulb lines extend straight up from the sole, one for each degree of temperature. (2) The wet-bulb scale extends along the instep from the toe to the top of the shoe. The wet-bulb lines extend diagonally downward to the sole and the back of the shoe, one for each degree of temperature. (3) The condensation or dewpoint is the same as the wet-bulb scale. However, the dewpoint lines extend horizontally to the back of the shoe, one for each dewpoint temperature. (4) The relative humidity lines are located along the side of the shoe and follow approximately the same curve as the instep. The instep line is actually the 100% relative humidity line. (5) The grains of moisture scale follows along the back of the shoe from the heel to the top. The lines are the same as the dewpoint lines. (6) All properties of air at any given condition can be represented on a psychrometric chart by plotting a single point.

Relationship of Terms

The following examples illustrate all of the foregoing relationships. Each example directly relates to the psychrometric chart; therefore, the chart should be used to clarify the solution to each example.

Example 1

To calculate from the dry-bulb and wet-bulb temperatures the relative humidity.

Given: Dry-bulb = 78 °F and wet-bulb = 65 °F

Find: Relative humidity

Solution: (Fig. 60, chart 1)

(1) Locate 78 °F on dry-bulb scale at bottom of chart; (2) draw a line straight up the 78 °F line to the curve line at the instep; (3) follow down the instep (wet-bulb scale) to 65 °F; (4) draw a line diagonally along the 65 °F wet-bulb line until it crosses the 78 °F dry-bulb line; and (5) read 50% relative humidity at the intersection of the dry-bulb and wet-bulb lines.

Example 2

To calculate from the dry-bulb and wet-bulb temperatures the dewpoint.

Given: Dry-bulb = 78 °F and wet-bulb = 65 °F

Find: Dewpoint

Solution: (Fig. 60, chart 2)

(1) Find the intersection of the 78 °F dry-bulb line and the 65 °F wet-bulb line; (2) proceed horizontally to the instep line; and (3) read 58 °F dewpoint temperature. At 78 °F dry-bulb and 65 °F wet-bulb, the dewpoint temperature is 58 °F.

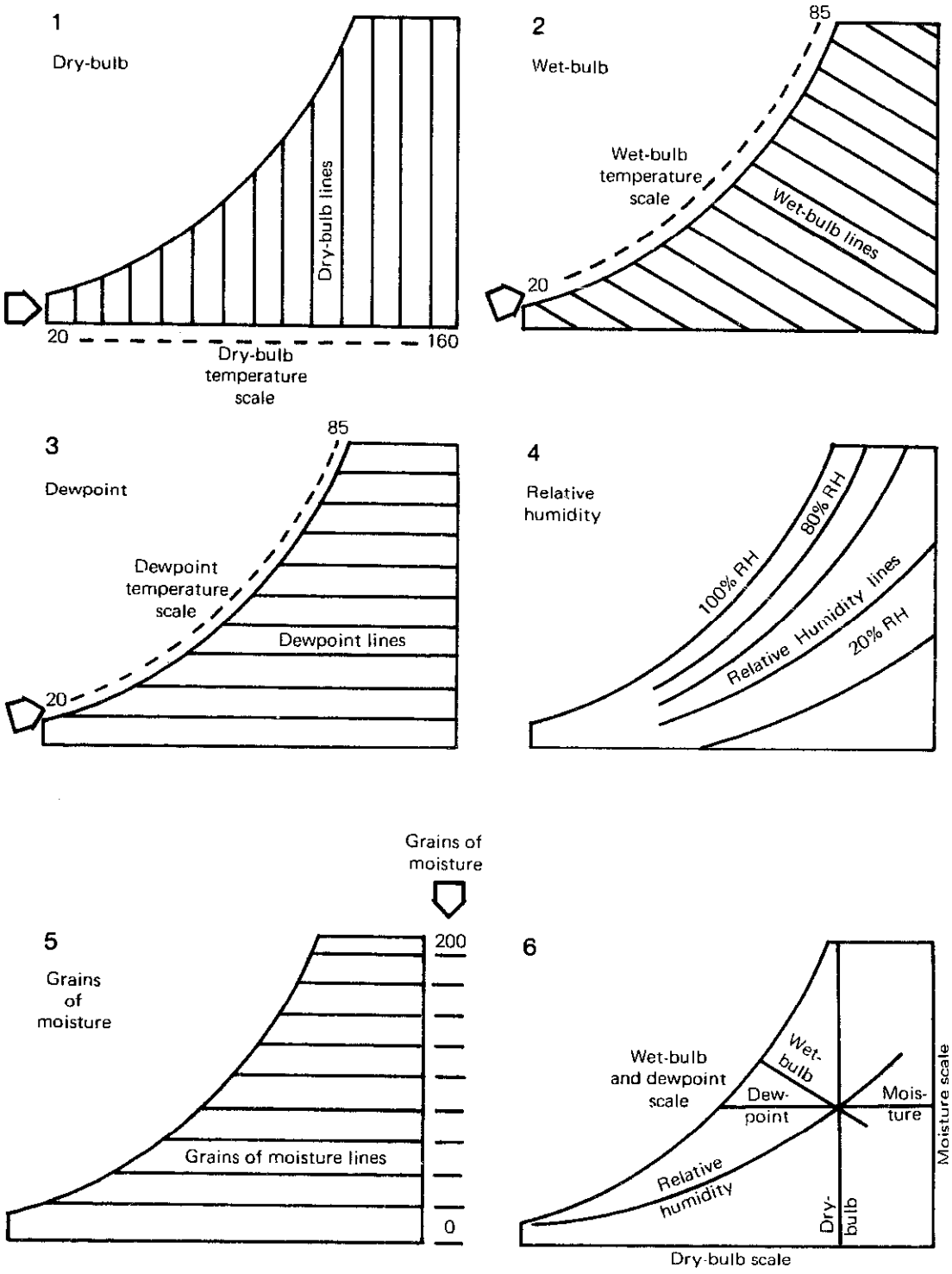

FIG. 59. Skeleton psychrometric charts identifying the lines and scales on the chart.

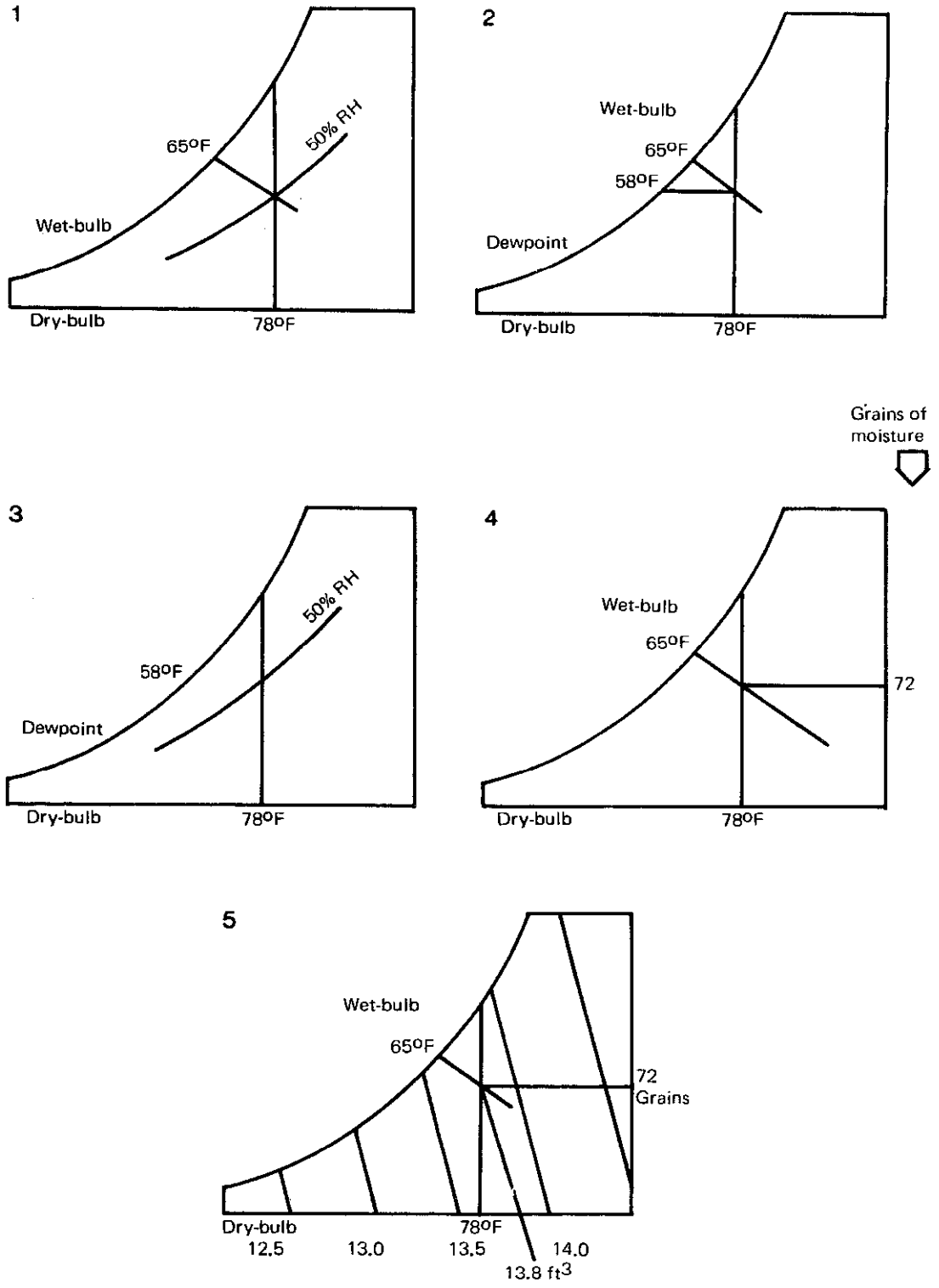

FIG. 60. Skeleton psychrometric charts demonstrating the relationships between the psychrometric terms.

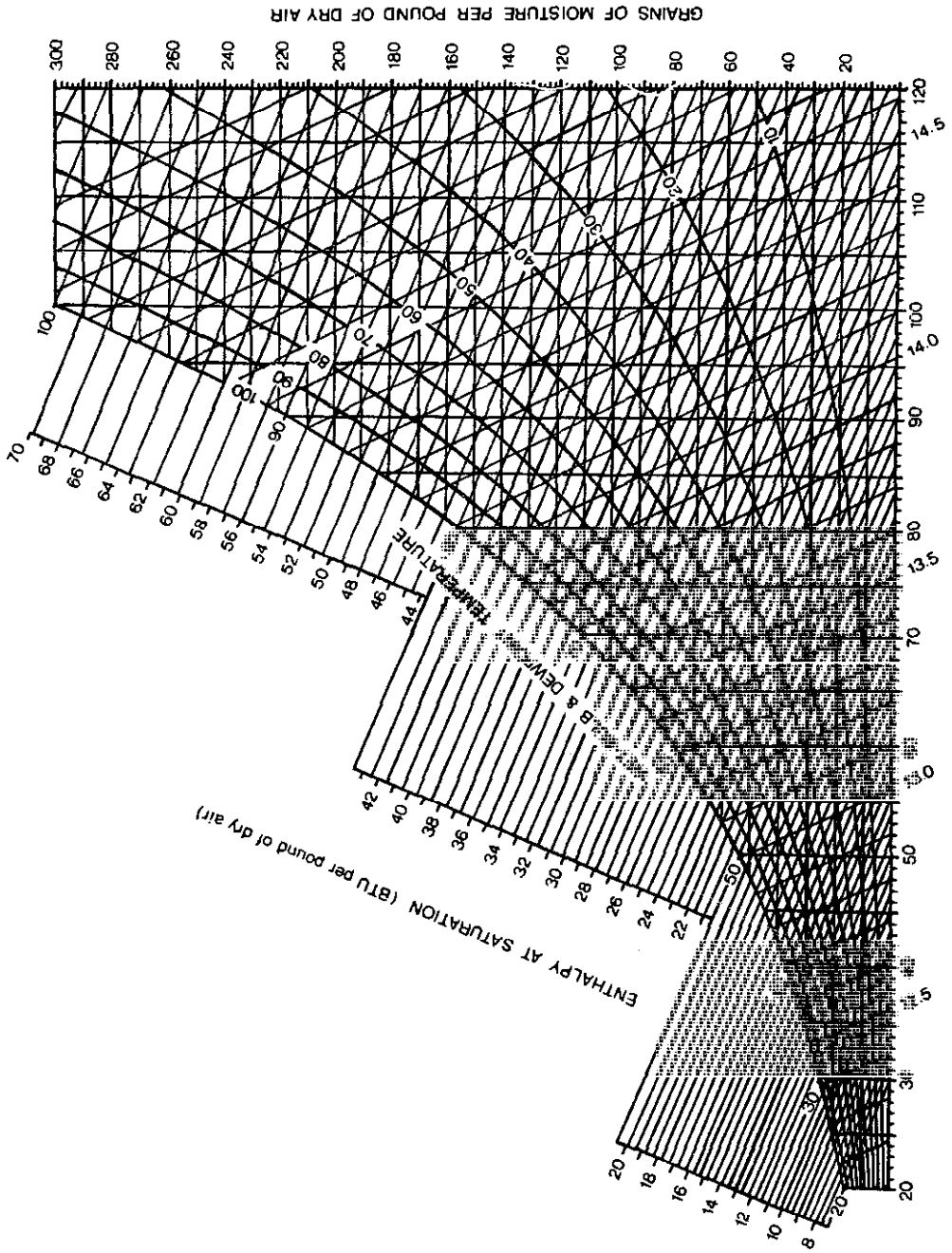

FIG. 61. A typical psychrometric chart (barometric pressure 14.696 lb/in.2).

Example 3

To calculate from the dry-bulb temperature and relative humidity the dewpoint.

Given: Dry-bulb = 78 °F and relative humidity = 50%

Find: Dewpoint

Solution: (Fig. 60, chart 3)

(1) Find the intersection of the 78 °F dry-bulb and 50% RH lines; (2) proceed horizontally to the instep line; and (3) read 58 °F dewpoint temperature. At 78 °F dry-bulb and 50% RH the dewpoint temperature is 58 °F.

Example 4

To calculate from the dry-bulb and wet-bulb temperatures the grains of moisture.

Given: Dry-bulb = 78 °F and wet-bulb = 65 °F

Find: Grains of moisture

Solution: (Fig. 60, chart 4)

(1) Find the intersection of the 78 °F dry-bulb and 65 °F wet-bulb lines; (2) proceed horizontally along the grains of moisture line, to the back of the shoe; and (3) stop at the first column of numbers. This column is the grains of moisture scale. Read 72 grains.

This example shows how to find grains of moisture by using dry-bulb and wet-bulb temperatures. Grains of moisture can also be found on the psychrometric chart by using other combinations of psychrometric properties. These combinations are listed below. Simply find the intersection of the lines listed here and then follow across the chart to the grains of moisture scale: dry-bulb temperature and relative humidity; dry-bulb temperature and dewpoint; wet-bulb temperature and relative humidity; or wet-bulb temperature and dewpoint.

Grains of Moisture Per Pound of Dry Air or Per Cubic Foot of Air

Notice (Fig. 61) the words "grains of moisture per pound of dry air." This means that at 78 °F dry-bulb and 65 °F wet-bulb temperature, the air holds 72 grains of moisture per pound. Moisture can be measured per pound of air or per cubic foot of air. To find the moisture in a cubic foot of air, using the same conditions (78 °F dry-bulb and 65 °F wet-bulb) proceed as follows (Fig. 60, chart 5): (1) find the intersection of the 78 °F dry-bulb and 65 °F wet-bulb temperature lines; (2) proceed horizontally along the grains of moisture line to the grains of moisture scale; (3) read 72 grains; (4) find the cubic foot scale along the sole of the shoe. The cubic foot lines extend diagonally from the sole of the shoe to the instep; (5) again locate the intersection of the 78 °F dry-bulb and 65 °F wet-bulb lines; (6) draw a line parallel to the cubic foot line, from the intersection located in Item 5, to the sole of the shoe. The line crosses the sole at a point that is over halfway between 13.5 and 14 on the cubic foot scale, say 13.8 ft^3; (7) divide 72 grains by 13.8 ft^3; and (8) moisture in air equals 72 ÷ 13.8 = 5 grains/ft^3, approximately. Therefore, at 78 °F dry-bulb and 65 °F wet-bulb temperature, the moisture in the air can be read as 72 grains/lb, or 5 grains/ft^3.

The psychrometric chart simplifies the measurement of air properties. If the value of any two of the psychrometric terms is known, the value of any other term can be found on the psychrometric chart; therefore, its use is very important for an understanding of the processes involved in grain drying and storage.

— JAMES M. BECK. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

Moisture

The moisture content of grain is one of the most important indices for determining whether the grain should be harvested, is dry enough for safe storage, or can be milled with maximum recovery. Therefore, it is essential to understand the common methods of representing moisture, and be able to determine moisture content accurately.

Moisture Content Representation

Wet Basis

The rice industry expresses moisture content (MC) as a percentage of the total weight. Algebraically it is expressed as:

$$\% \text{ MC}_{\text{wb}} = \frac{W_{\text{m}}}{W_{\text{t}}} \times 100$$

$$= \frac{W_{\text{m}}}{W_{\text{m}} - W_{\text{dm}}} \times 100$$

where: wb = wet basis; W_{m} = weight of moisture (H_2O) in the grain; W_{t} = total weight of the grain; and W_{dm} = weight of dry matter in the grain.

In the wet basis of expressing moisture content, it is incorrect to state that one has removed 7% of 100 kg or 7 kg of water from 100 kg of grain if the moisture content of 100 kg of grain is lowered from 20 to 13%. This is because the denominator of the equation changes in relation to the amount of moisture removed. For example, at 20% MC, 100 kg of wet grain contains 20 kg (0.20 × 100) of water and 80 kg of dry matter. If the same amount (100 kg of wet grain) is dried to 13% MC, the resulting weight of moisture is calculated using the following equation:

$$0.13 = \frac{W_{\text{m}}}{W_{\text{m}} + 80}$$

$$W_{\text{m}} = \frac{(0.13)(80)}{0.87}$$

$$= 11.96 \text{ kg}$$

Therefore, the amount of water removed from the 100 kg of wet grain when it is dried from 20 to 13% is 8.04 kg (20.00–11.96).

Because it is necessary to reduce the moisture content of the grain to 13% for safe storage, Table 19 has been prepared to facilitate the computation of moisture load. It gives the moisture load in pounds or kilograms of water per pound or kilogram of the wet grain at different moisture contents. For example, at an initial moisture content of 20%, the moisture load is 0.0804 kg/kg of grain. Therefore, drying 100 kg of wet grain to 13% moisture requires evaporation of 0.0804 × 100, or 8.04 kg of water.

Dry Basis

Representing moisture on a dry basis rather than on a wet basis is more convenient. In the dry basis method, the moisture is expressed as a percentage of the bone-dry weight of the grain. Algebraically this is expressed as:

$$\% \text{ MC}_{\text{db}} = \frac{W_{\text{m}}}{W_{\text{dm}}} \times 100$$

This method is usually used in expressing moisture of soils and other inert matter. The dry basis of representing moisture is sometimes encountered in literature on cereals, and one must be able to convert the dry basis values to a wet basis. For convenience in converting one value to another, Table 20 may be used.

The Importance of Moisture Content Determination

Experienced rice dealers can qualitatively determine whether paddy is wet or dry enough for milling by cracking the grain with their teeth. More accurate methods, however, must be used to determine moisture content for seed certification and safe storage. Accurate de-

TABLE 19. Moisture load in drying grain to 13% moisture content on a wet basis.

Initial moisture content (wet basis)	lb water/lb of wet grain (kg water/kg grain)
25	0.1380
24	0.1265
23	0.1150
22	0.1035
21	0.0920
20	0.0804
19	0.0690
18	0.0575
17	0.0460
16	0.0345
15	0.0230
14	0.0115
13	0.0000

TABLE 20. Table for conversion of percentage moisture on a wet basis to percentage moisture on a dry basis.

% moisture content (wet basis)	% moisture content (dry basis)
10	11.0
11	12.3
12	13.6
13	15.0
14	16.3
15	17.6
16	19.0
17	20.5
18	21.9
19	23.5
20	25.0
21	26.5
22	28.2
23	29.9
24	31.6
25	33.3
26	35.1
27	37.0
28	38.9
29	40.8
30	42.8

TABLE 21. Variation in the weight of a bag of paddy at different moisture contents.

Initial moisture content (% wet basis)	Wet weight of one cavan of paddy required to produce a 44-kg bag at 14% moisture
25	50.5
24	49.9
23	49.3
22	48.5
21	48.0
20	47.4
19	46.9
18	46.2
17	45.7
16	45.1
15	44.6
14	44.0
13	43.6
12	43.1
11	42.7
10	42.1

termination of moisture content is also absolutely necessary for individuals and corporations that purchase, store, or mill thousands of tonnes of paddy. There is about a 0.5 kg change in weight of a 44 kg bag of paddy for every 1% change in moisture content. For instance, if 1000 bags of paddy stored at 16% moisture dry to 15% moisture, there is a loss of 500 kg or 11 bags by weight. Table 21 dramatically shows the variations in the weight per bag of paddy at different moisture contents.

Methods of Determining Moisture Content

Numerous methods for the quantitative determination of moisture are available. The choice of the method to use for a specific product depends upon several factors: (1) the form in which water is present; (2) the nature of the product analyzed (whether easily oxidized or decomposed); (3) the relative amount of water present in the product; (4) the rapidity of the determination; (5) the accuracy desired; and (6) the cost of the equipment required.

Grain moisture can be determined either by primary (direct) or secondary (indirect) methods. The primary method is used by researchers to obtain highly accurate moisture measurements. The values obtained with this method are used to calibrate all the secondary type of moisture-measuring devices. The steps used in the primary method are too cumbersome and time consuming for use in the field or warehouse; therefore, secondary methods, which are much faster and usually depend on the electrical properties of the grain, are used in these cases.

The different forms of water (absorbed, colloidally bound, mechanically accluded, and water of crystallization) vary in the tenacity with which they are held in various products. For this reason, depending upon the forms of water present, the various moisture methods determine more or less the "moisture" in the product. This has necessitated the adoption of standard or official methods for most agricultural and biological products. Whenever possible, these standards should be used if accurate results are desired. If only compara-

tive results are needed, moisture methods other than the standard ones are satisfactory.

Moisture methods that involve oven drying require a sensitive analytical balance and a thermostatically controlled electrically heated vacuum or drying oven. Electrical methods involve more or less complicated and expensive electrical equipment. Distillation methods require the least expensive apparatus of all because only a balance of low sensitivity and a distillation setup are necessary. Methods based on an interaction of a chemical and water also require relatively inexpensive equipment.

Moisture determinations are empirical methods because the various moisture methods determine more or less the water present in the product. In other words, the conditions of the method govern to some extent the amount of moisture obtained. Thus it is necessary to specify the method used along with the moisture percentage, for example 13.5% moisture determined in a vacuum oven at 135 °C.

Primary or Direct Methods

Vacuum-Oven Method

A representative sample of the bulk (2–3 g) is ground and then dried in a vacuum oven (25 mm vacuum) for 72–96 h at 100 °C, and the drop in the weight of the grain is measured based on its initial weight.

Air-Oven Method

(1) One stage — This method is used for grain with a moisture content less than 13%. Grind duplicate 2- to 3-g samples and heat them at 130 °C for 1 h. Place the samples in a desiccator and then weigh. The samples should check to within 0.1% moisture. The American Official Association of Chemists requires drying at 135 °C for 2 h, giving slightly higher moisture content values.

(2) Two stage — This method is used for grain with a moisture content greater than 13%. Remove moisture from the grain sample (25–30 g) until the moisture drops to less than 13%. This usually takes 14–16 h of drying. Then continue as in the one stage method.

Water-Oven or Air-Oven Method

Place duplicate grain samples (25–30 g) in an oven heated to 100 °C. Dry for 72–96 h and then place in a desiccator and weigh. The samples should check to within 0.1% moisture.

Brown-Duvel Fractional Distillation Method

The results of the Brown-Duvel metre (Fig. 62) are considered official. The metre determines moisture by fractional distillation. The whole-grain sample (100 g) is heated to a temperature considerably above the boiling point of water in 150 ml of mineral oil. For unmilled rice the sample should be heated to 190 °C; for brown rice to 190 °C, with a 2-inch diameter by 0.25-inch thick glass-wool pad in the bottom of the flask; for milled rice (first and second head) to 200 °C using the glass-wool pad; and for rice screenings and brewers rice the sample should be heated in a special double-walled flask with 150 ml of oil between the walls of the flask and 150 ml inside the flask. The oil inside the flask should reach 200 °C in 26 min.

The vaporized moisture is condensed and measured in a graduate cylinder. The amount of moisture collected (in millilitres) is also

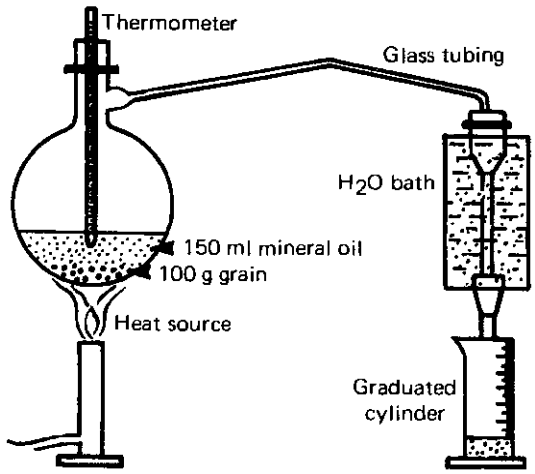

FIG. 62. Brown-Duvel fractional distillation method, used to directly determine the percentage moisture content of grain.

the percentage moisture content on a wet basis. The method takes about 30 min, and the results can be reproduced accurately when the time of heating is properly adjusted.

A comparison of the water-oven method with the Brown-Duvel method using 28 samples gave the following results: (1) Brown-Duvel 17.40%; (2) water-oven 17.26%; (3) a difference of 0.14%. This is valid for moisture levels between 11.54 and 27.05%. The lower reading obtained with the water-oven is expected because starchy grains dried in the oven give levels of free water slightly below the true value. Water-oven drying took 96–120 h (136 h for hard kernels). Using whole kernels the average moisture content in another Brown-Duvel test was 20.13%, using ground kernels it was 20.05%. This relationship between test results for whole and ground kernels is true for moisture contents from 12.71 to 36.68%. A variation of 1–1.5% for samples from the same bulk at the same time is expected because of nonuniformity of the kernels.

Secondary or Indirect Methods

Electrical Resistance Method

This method is based on the principle that the electrical resistance or conductivity of a material depends upon its moisture content. The Universal Moisture Meter, with a self-contained power supply, measures the elec-

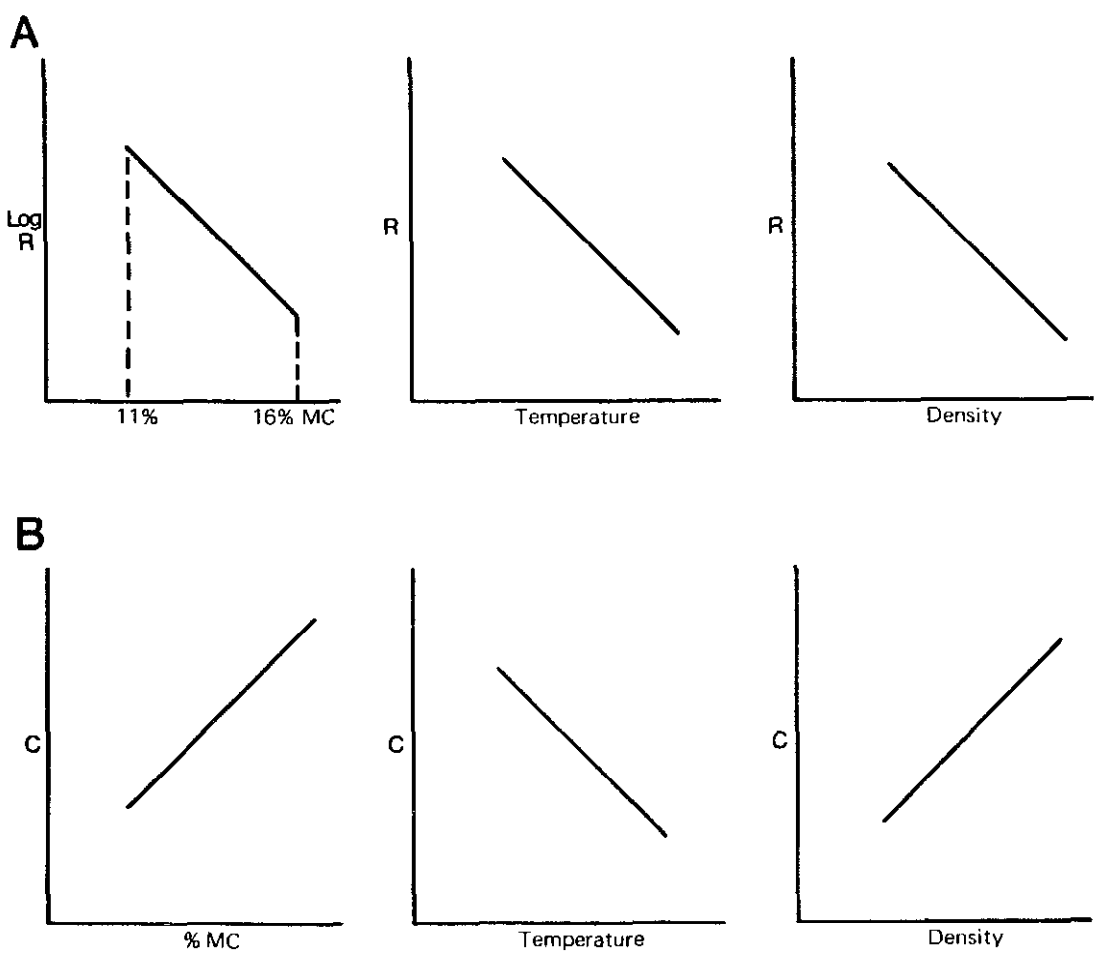

FIG. 63. Indirect methods of determining percentage moisture content by measuring changes in the electric properties of the grain: (A) resistance method; (B) dielectric method.

trical resistance of the grain at a given compaction, which varies with temperature, moisture, degree of compaction, and cleanliness of the grain (Fig. 63A). The readout device gives the moisture content on a wet basis.

Dielectric Method

The dielectric properties of grain are also dependent on moisture content. In the Steinlite Moisture Meter the grain is placed between two capacitor plates and the measured capacitance varies according to the amount of grain moisture, the degree of compaction, and the temperature (Fig. 63B).

The bridge or tuned circuits, which comprise the circuitry of these metres, can be serviced by competent electronic technicians. However, local dealers must carry an inventory of spare parts. It may be necessary to calibrate the electronic moisture metres for each type of rice grain or to each of the recommended varieties because the electrical properties of grain differ in different varieties.

Chemical Method

Water is removed from the sample by the addition of chemicals that either decompose or combine with the water. Calibration curves are established for the quantity of gas produced or the decrease in the weight of the sample due to the chemical reaction, and they are used to calculate the amount of water originally in the sample. The chemical reaction for one method is:

Calcium carbide + water →
Calcium hydroxide + acetylene

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$$

Hygrometric Method

The sample of the grain is placed in a sealed container and allowed to equilibrate with the air in the container, which has a known relative humidity and temperature. The relative humidity of the air when it is in equilibrium with the sample gives a measure of the initial moisture content of the sample. — D. B. DE PADUA. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

Principles and Systems

Threshed rice with hull (palea and lemma) is called palay, rough rice, or paddy. Rice grain dehulled by milling is termed milled rice. Paddy storage requires special precautions because it is not an inert product, but a living, respiring biological product. Unfortunately, this very important property of paddy is often unknowingly overlooked in the design and operation of grain drying and storage systems. The respiration process in the grain is externally manifested by decreases in dry weight, utilization of oxygen, evolution of carbon dioxide and moisture, and release of energy in the form of heat. The respiration rate is influenced by the degree of dehydration of the tissue (Fig. 64). Thus, one method of preserving or suppressing the biological deterioration of paddy is to reduce grain moisture by drying. At low moisture content (13–14%), the grain is relatively dormant and can be stored for long periods under proper conditions.

In traditional rice production, when yields averaged 30–40 cavans/ha, the old methods of harvesting, threshing, sun drying, and sack storage of grain were adequate for Philippine farmers. However, the picture changed with the introduction of the new high-yielding varieties and an aggressive irrigation program that led to extraordinary increases in yield. Today's farmers may have to use grain driers to enable them to dry their greater production.

Optimum Moisture Content for Storage and Milling

In the Philippines, the moisture content of newly harvested rice usually ranges from 20

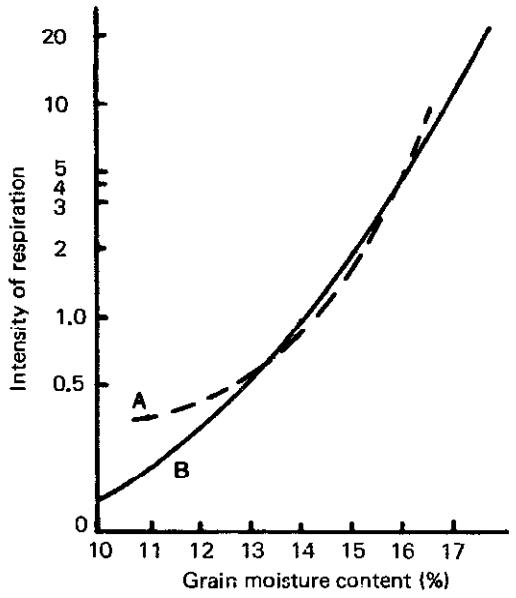

FIG. 64. Intensity of respiration of paddy grain in relation to its moisture content (at 37.8 °C). (A) C. H. Bailey and Cuyon; and (B) C. H. Bailey.

to 26%. These grains are too wet for milling and storage. The optimum content of 14% is considered the threshold value for safe storage. For prolonged storage of over 6 months grain moisture should be reduced to 13%.

Researchers estimate that about 10% of the crop is lost if the grains are left in the field to dry down to 14–16% before they are harvested. Thus, farmers may lose a considerable portion of their produce unless they use more efficient postharvest practices. Other advantages of the use of grain driers are: (1) the drying operation can be controlled more accurately, and thus, the moisture content of the grain can be reduced more closely to the levels necessary for milling with maximum head rice recovery and effective preservation of seed viability; (2) drying can be done in foul or fair weather; and (3) farmers can plan the harvest season for more efficient use of available labour.

The Hygroscopic Nature of Grain

Crop grains are hygroscopic in nature. This means that grains become wet or dry depending on the temperature and relative humidity of the surrounding air. If the vapour pressure of the moisture within the grain is higher than that of the moisture in the atmosphere, the grain will lose its moisture to the surrounding air. In effect, then, the grain undergoes a drying process. Conversely, if the grain is dry and the surrounding atmosphere is wet or humid, the reverse process will occur and the grain will gain or absorb moisture.

Relative Humidity and the Drying Process

The actual vapour pressure of the air relative to saturation is called relative humidity (RH). Relative humidity is expressed as a percentage. In the common convection process of drying, the air must have a relative humidity low enough to absorb moisture from the grain.

A simple method of lowering the relative humidity of the air is heating. Increasing the temperature of air by 11 C° will reduce the relative humidity to half its original value. For example, if air with a temperature of 29 °C and a relative humidity of 90% is heated to 41 °C, the relative humidity will drop to 45%. Air with 45% RH and 41 °C temperature stabilizes moisture content of paddy at about 8%. This means that when paddy with a moisture content higher than 8% comes in contact with air heated to 41 °C, the paddy will lose some of its moisture or will dry until its moisture content is 8%. When in contact with the wet grain, the heated air raises the temperature of the grain and increases the vapour pressure of the moisture within the grain. The heating hastens the transfer of moisture from the grain to the heated air.

The drying rate is, therefore, influenced by the following factors: (1) the temperature of the drying air; (2) the relative humidity of the drying air; (3) the availability of moisture at the surface of the grain where it can be evaporated; and (4) the velocity of the air moving through the grain mass.

A convection drying system is composed of: (1) a method of heating the drying air; (2) a blower to force the heated air through

the grain mass; (3) a device to hold the grain being dried; (4) a system for loading, moving, and unloading the grain on the holding device; (5) a central system for programming the drying process for the prevention of damage to the quality of the grain; and (6) a safety control network.

Heating the Drying Air

Theory of Combustion

The combustible matter in the various heating fuels is composed of carbon, hydrogen, and sulfur. Combustion is the chemical combinations of the fuel elements with oxygen. The equations for combustion are:

$$C + O_2 \rightarrow CO_2$$
$$2C + O_2 \rightarrow 2CO \text{ (partial combustion)}$$
$$2H_2 + O_2 \rightarrow 2H_2O$$
$$S + O_2 \rightarrow SO_2$$

The weight of oxygen required for complete combustion is:

$$W_o = 2.67\,C + 8\left(H - \frac{O}{8}\right) + S$$

where: W_o = weight of oxygen (lb/lb of fuel).

Values of C, O, H, and S are obtained directly from the ultimate analysis for solid and liquid fuels; however, for gaseous fuels a conversion from the volumetric analysis is required.

Because O_2 is rarely supplied in a pure state, but is generally supplied as a constituent of air, it is necessary to include the nitrogen weight to obtain the total products of combustion.

$$W_a = 11.5\,C + 34.5\left(H - \frac{O}{8}\right) + 4.32\,S$$

where: W_a = weight of air (lb/lb of fuel).

In actual practice, an excess amount of air greater than W_a is required.

$$\text{Excess air (percentage)} = \frac{(W_A - W_a)}{W_a} \times 100$$

where: W_A = actual amount of air supplied per pound of fuel.

The volume of air corresponding to W_A or W_a for any air temperature and pressure is found by the gas equation:

$$V = \frac{(W_A \text{ or } W_a)(53.3)(T_a - 460)}{144\,P_a}$$

where: V = air volume (ft³); T_a = temperature (°F); and P_a = air pressure (psi, absolute).

In the case of gaseous fuel, the weight or volume of air is expressed in terms of cubic feet rather than pounds. The previous equations have been developed on the basis of 1 lb of fuel (gas, liquid, or solid) for which the density of the fuel-gas mixture is needed. If not known, it can be obtained from the molar relations by:

$$D_m = \frac{MW}{359(14.7/P_m)(T_m + 460)/492}$$

where: D_m = density of fuel-gas mixture (lb/ft³); P_m = gas pressure (psi, absolute); T_m = gas temperature (°F); and MW = molecular weight of gas mixture.

The combustion process does not go to completion at high temperatures. Even while the combustion reactions are proceeding, the resultant products dissociate to a certain degree into other components. Thus, the equilibrium equation,

$$CO + \tfrac{1}{2}O_2 \rightleftharpoons CO_2$$

shows that the reaction may proceed in both directions at the same time. At a given condition of temperature and pressure, an equilibrium among the gases is reached so that the amounts of CO, O_2, and CO_2 present will remain constant. The extent of dissociation of the CO_2 will give an indication of the degree of completeness of the combustion. Just as heat is released in the exothermic process of forming the CO_2, much of the heat is absorbed when the CO_2 is broken down into CO and O_2. Thus the dissociation reactions of combustion products are endothermic, and the theoretical combustion temperature can never be attained if dissociation exists.

Heaters

Heaters are divided into two types based upon the method of heat transfer: (1) direct;

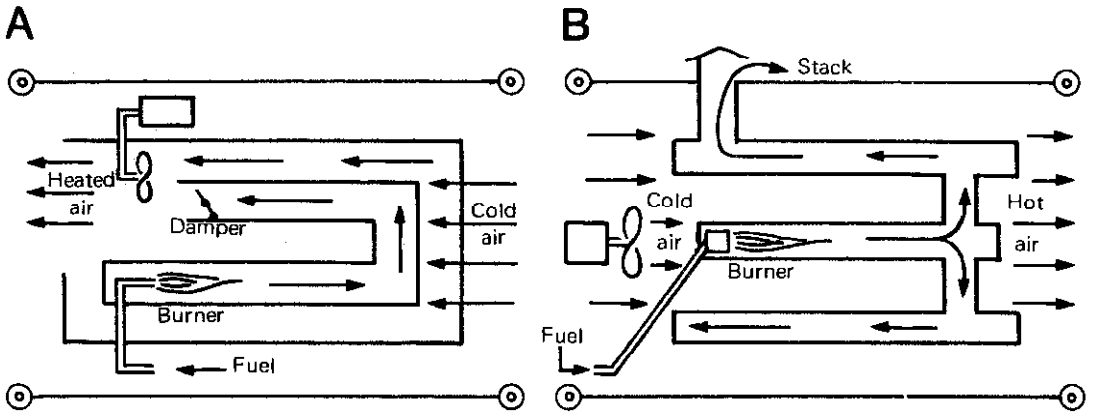

FIG. 65. A. Direct burner in which the products of combustion are mixed with the drying air. B. Indirect burner that uses a heat-exchanger surface to ensure that soot does not get into the drying air.

and (2) indirect. In a direct heater the products of combustion are forced through the product with the drying air (Fig. 65A). The direct heater is less expensive and makes more efficient use of the energy of the fuel; however, there is a greater possibility that the grain may be damaged by smoke. In the indirect heater a heat transfer surface is heated and the air that is used for drying is circulated around the outside of the heat transfer surface and then through the product (Fig. 65B). The products of combustion are removed and not permitted to mix with the drying air.

Types of Burners

There are three kinds of burners used in grain driers: (1) gas; (2) oil; and (3) solid fuel.

Gas Burner

Gas burners operate on the principle that a part or all of the air for combustion must mix with the gas before ignition. A burner is high pressure if the gas is at 350–2800 kg/m^2 (0.5–40 psi) pressure. Atmospheric burners that use gas at pressures of 5–30 cm (2–12 inches) of water are more popular because of their simplicity. The principle is the same as that of a Bunsen burner. Figure 66 shows a typical atmospheric burner. Gas is a very convenient fuel to use, complete combustion is easily attainable, and it does not emit objectionable odours. However, in general, gas burners are more expensive to operate.

Oil Burners

There are many types of oil burners that can be used to heat drying air. The burners for industrial oils No. 1 and 2 are provided with either a positive gear pump or a pressure tank containing the fuel. The tank is connected to an air compressor to force the fuel through an atomizing nozzle at pressures from 2800 to 7000 kg/m^2 (40 to 100 psi). The primary air for combustion is provided by the draft of the main blower or by a built-in auxiliary blower. For more complete combustion, some means of controlling the secondary air is sometimes provided. Gravity flow or vapourizing-pot type burners are suited for kerosene or any liquid fuel with an end point not over 316 °C (600 °F). This type of burner is used on many of the driers employed in the Philippines because it is simple and reasonably cheap (Fig. 67). The liquid is metered to the pot by an adjustable needle valve. As the fuel flows out over the bottom of the pot, it is evaporated by radiant energy received from the combustion chamber walls and the flame. The vapours rise in the pot and mix with primary air flowing through the holes in the bottom of the pot. When the burner is operating normally, the fuel-air mixture near the bottom of the pot is too rich to support combustion. The flame

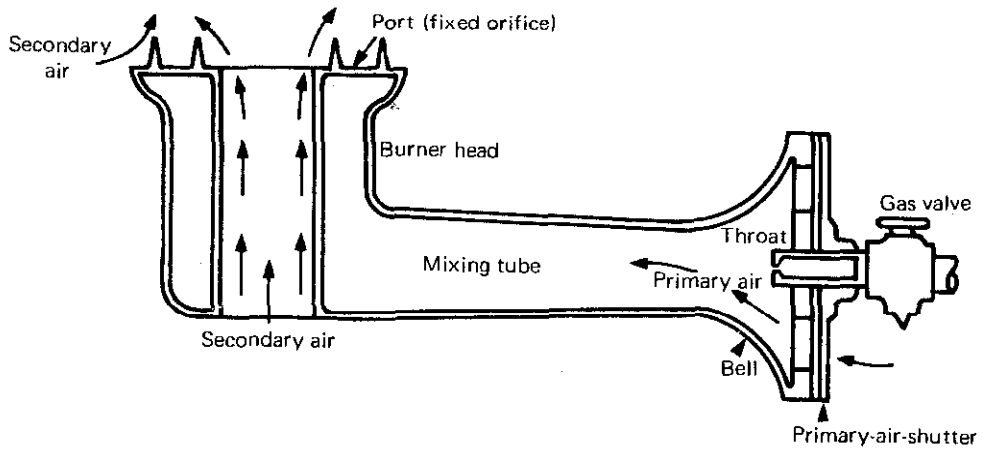

FIG. 66. A typical atmospheric gas burner showing the main parts.

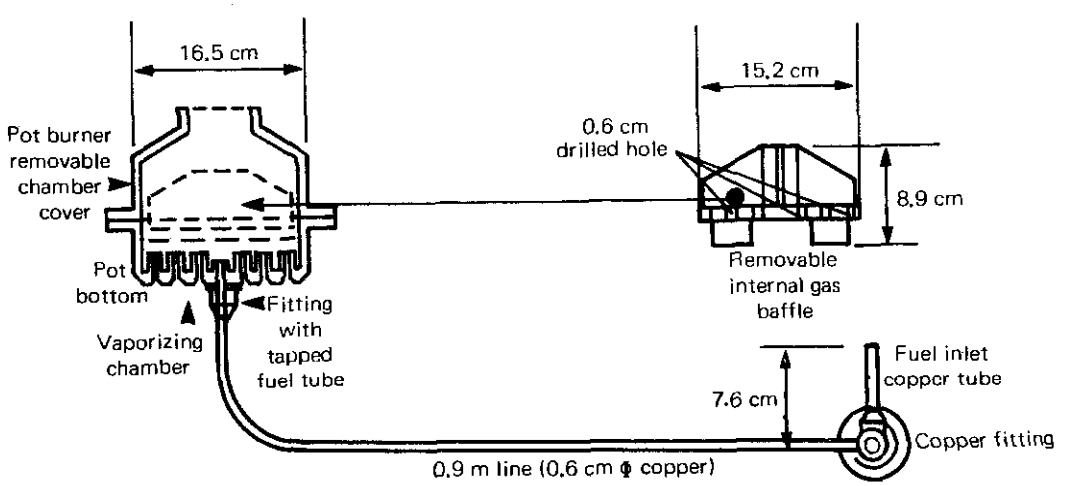

FIG. 67. Section details of kerosene pot burner showing fuel control.

rises to a position above the rim, and at this point enough air is mixed with the vapours to give a good burning mixture.

Burners for heavier oil must use a heat-exchanger surface because the oils produce a lot of soot. Roughly, the heat transfer efficiency is directly proportional to the size of the heat exchange surface. Because of limitations in physical size, heat exchangers sold on the market have a heat utilization efficiency of about 40%. This low efficiency reduces the advantage derived from the low cost of fuel oils.

Solid Fuel Burners

Burners have been designed to burn rice hull, which is a waste product from milling. Rice hull liberates about 3500 kg-cal/kg (6274 Btu/lb) when burned. About 20 kg of hulls would be enough to dry 1 t of paddy from 20 to 14% moisture content. About 100 kg of paddy would yield 20 kg of hulls. However, temperature control is critical in grain drying, and controlling temperatures in furnaces that use raw fuel is difficult without the use of steam boilers.

Other Possible Heat Sources

Other possibilities worthy of investigation are the harnessing of heat from hot springs and the utilization of engine heat, including

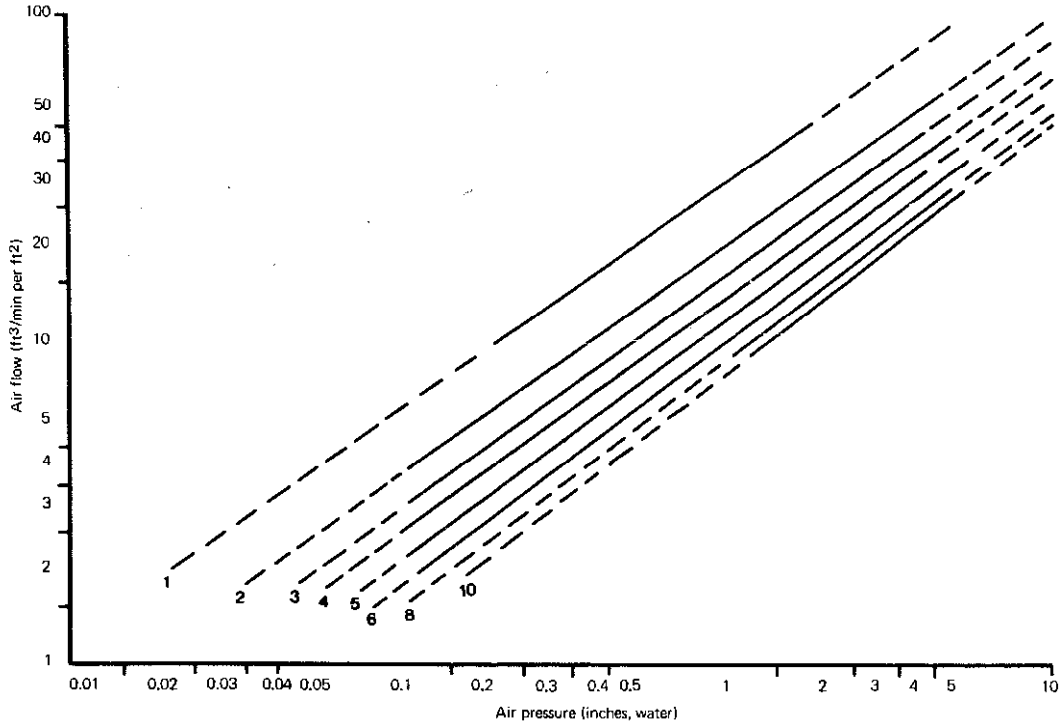

FIG. 68. Air pressure requirements to achieve a desired flow of air through different depths of clean rough rice. Note that broken lines are extrapolated beyond test data reported. Numbers on lines correspond to depth of rice in feet.

exhaust gases of gasoline and diesel engines. Where hot springs may be tapped, the design of the heat exchanger coils is straightforward and should not be a problem. Engine heat and heat from the exhaust gases may be utilized to drive the main blower. Calculations indicate that the energy available from engine heat and exhaust gases is not enough for multipass thin-layer drying; however, it can serve as supplemental heat to reduce the cost of drying. It takes about 8800 g-cal/min (35 Btu/min) to heat an airflow of 28 m^3/min (1000 ft^3/min) from 30 to 40 °C (85 to 105 °F) at 80% RH.

Blowing the Heated Air

In the drier, the grain pack is dense; therefore, pressure is required to force the drying air through the grain. Pressure requirements are proportional to the desired airflow rate and the thickness of the grain pack. The pressures in grain drying systems are relatively low and are measured as the number of centimetres or inches of a water column that the pressure can support. A grain bed 30 cm (1 ft) deep that needs an airflow rate of 6.5 m^3/min per square metre (20 ft^3/min per square foot) of bed requires a pressure of 1.3 cm (0.5 inches) of water (Fig. 68). In computing the total pressure requirement, the pressure losses in the manifolds in the entrance to the pressure chamber and in the blower itself must be taken into account. To make allowance for pressure losses, specifications for blower capacity should be increased by 100%. Ordinary room fans cannot be adopted for grain drying purposes because they are designed merely to move large volumes of air at zero static pressure; therefore, special fans must be used. Fans may be placed into one of two general classes: those that operate by centrifugal force, or radial flow, where the flow is perpendicular to the axis of rotation; and those that operate

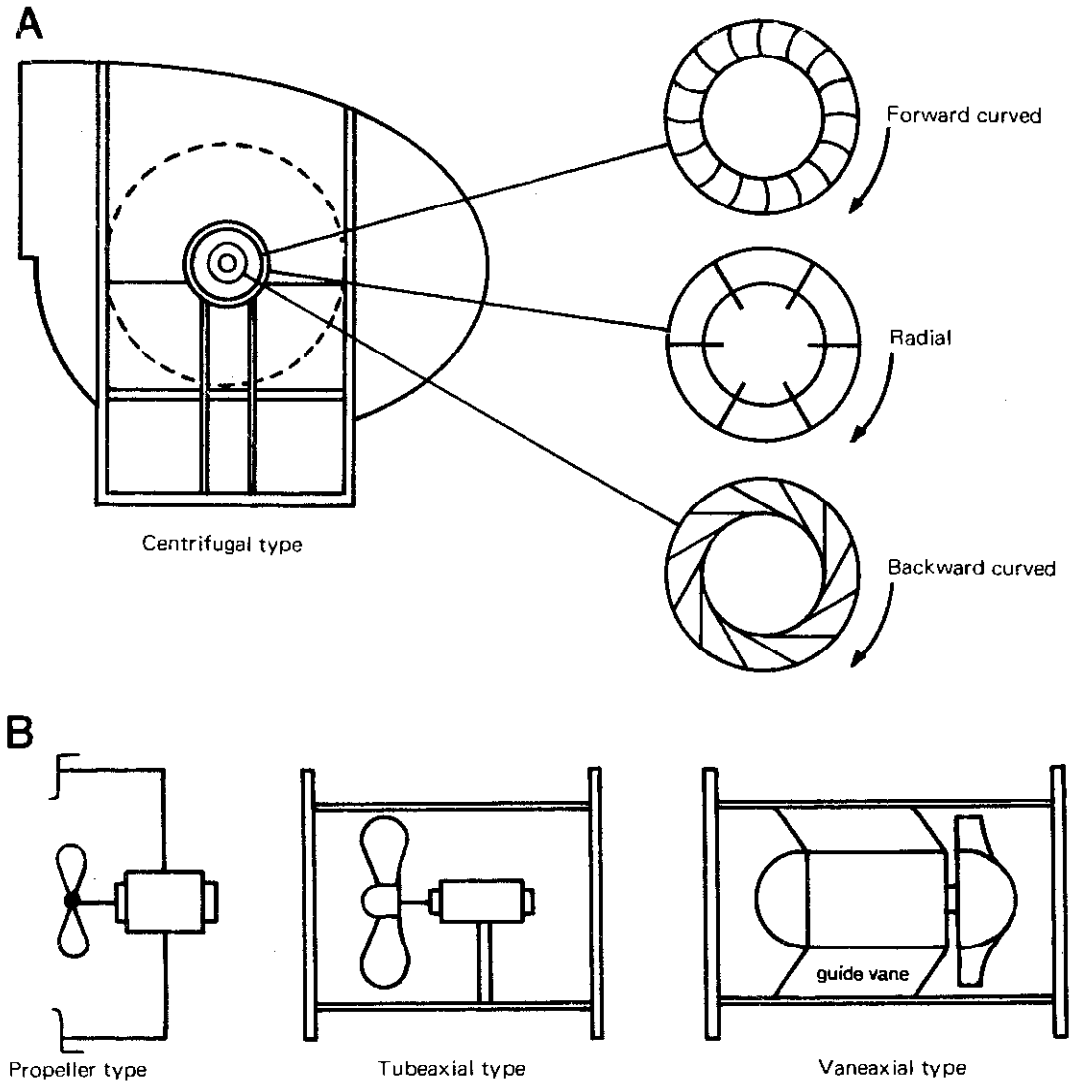

FIG. 69. Different types of fans. A. Centrifugal-type fans illustrating forward-curved, radial, and backward-curved designs. B. Axial-flow fans illustrating propeller type, tubeaxial type, and vaneaxial type.

by axial flow where the flow is parallel to the axis of rotation of the fan blade.

Centrifugal Fans

Centrifugal fans consist of a wheel that is rotated in a spiral housing (Fig. 69A). The three basic types are: (1) forward curved fans, which have 24–64 blades inclined in the direction of wheel rotation; (2) radial blade fans, which have 4–24 blades that are radial elements of the wheel; and (3) backward blade fans, which have 8–16 blades inclined away from the direction of rotation. These blowers are capable of developing the high pressures required to drive the drying air through the grain mass. The backward curve blowers are preferred because they have more stable operating characteristics, i.e. the power requirement does not tend to overload the drier should there be a change in the load or the bin is emptied. Forward curve blowers may burn out unprotected electric motors.

Axial Flow Fans

There are three distinct types of axial flow

fans (Fig. 69B): (1) propeller fans, which have two or more blades mounted on a hub and set at a pitch of about 15 degrees; (2) vaneaxial fans, which have large hubs and short blades, are mounted in a cylinder, and have stationary straight vanes to prevent rotation or swirling of the air; and (3) tubeaxial fans, which are similar to the vaneaxial fans except that they do not have guide vanes.

Propeller fans with multiple blades are used in driers operating at low pressures. Normally pressures of up to 1.9 cm (0.75 inches) of water can be developed with these fans and they are used in small portable drying systems.

Grain-Holding Bins

Grain-holding bins may be designed for either batch-type drying or continuous-flow drying.

Batch Type

Deep-Bed Drying

Deep-bed drying is usually employed in on-the-farm drying, in which case the bin doubles as a storage unit (Fig. 70). The air-distribution system is usually a false floor covered with a screen mesh. Airflow rates per cubic foot of grain are low and are based on the minimum values required to prevent spoilage of the grain in the grain holder. The airflow rates are based on minimum requirements because a large amount of power is required to develop the high pressures necessary to force a large volume of drying air through the grain.

The biggest difficulty in deep-bed drying is that the bottom layers may be over-dried. To minimize this difficulty, drying air with a low temperature must be used. The layer of grain, where the drying air enters, dries down approximately to the equilibrium moisture content corresponding to the temperature and relative humidity of the drying air. A drying front, which moves in the direction of the airflow, is thus established. It is desirable that the drying front moves quickly enough to reach the top layer before moulding occurs. The rate of movement of the drying front is controlled by the velocity of the drying air.

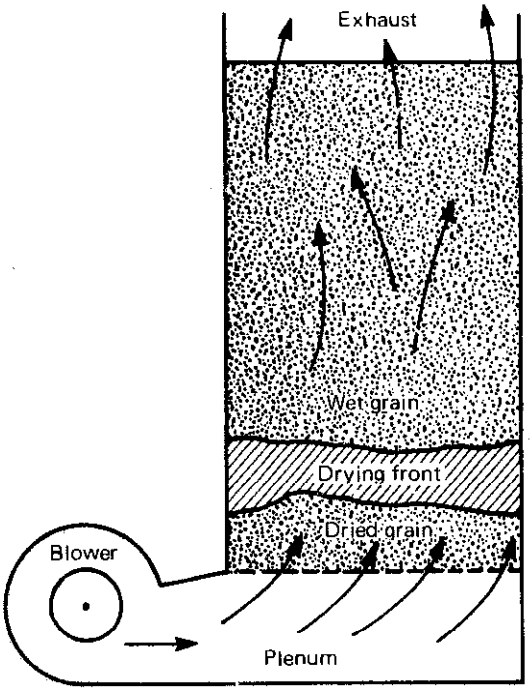

FIG. 70. Deep-bed drier.

Thin-Layer Drying

The thin-layer batch-type drier is similar to the deep-bed drier except that the surface area of the drier is increased and the depth of the drying layer of rice is decreased (Fig. 71). The main advantages of this drier are: (1) the whole batch is dried sooner so there is less chance of spoilage due to moulding; (2) there is less likelihood of over-drying of the grain; and (3) a lower air pressure is required to force the drying air through the rice.

Continuous-Flow Type

These driers are columnar in design. The rice flows by gravity from the top to the bottom of the drier, where it is discharged. The rate of discharge is controlled by metering rollers or oscillating rockers. If the rice flows in a straight path the drier is called a non-mixing type; if the path of the rice is diverted the drier is called a mixing type.

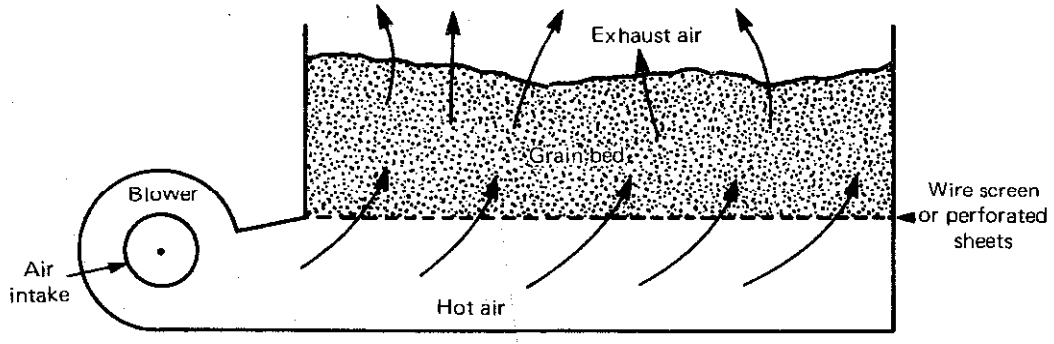

FIG. 71. Flat-bed drier.

Nonmixing Type

Two types of nonmixing driers are shown in Fig. 72 and 73. These driers are simple in design, and the drying takes place between two parallel screens that are usually 0.15–0.23 m apart. Since the grain cannot be blown out, comparatively high air velocities can be used. Because the grain flows straight down the column, the layer of rice closest to the input screen is dried by hotter and drier air than the layer of rice next to the exhaust screen. In this respect it is like thin-layer batch-type drying with the thickness of the layer equal to the separation between the screens. However, in this case mixing does occur when the rice is discharged and conveyed to the tempering and storage bins.

Mixing Type

Baffle Type. This drier is similar in design to the nonmixing-type columnar drier except that it is equipped with sheet metal baffles, which create turbulence and mixing (Fig. 74).

LSU Type. The Louisiana State University drier consists of a vertical compartment in which there are rows of air channels (Fig. 75). The air channels are shaped like an inverted "V." One end of each channel is open and the other end is closed. The rows alternate between hot air intakes and exhaust air outlets, and the alternate rows are staggered to provide mixing action.

In mixing-type driers, chaff and other light materials are blown out with the exhaust air, which improves the quality of the rice; however, if the air pressure becomes excessive whole kernels will also be removed. As the rice descends in the drier it is mixed so that individual grains are not exposed to only the hottest air, but rather a combination of both hotter and cooler air. Because of this, mixing-type driers generally use higher air tempera-

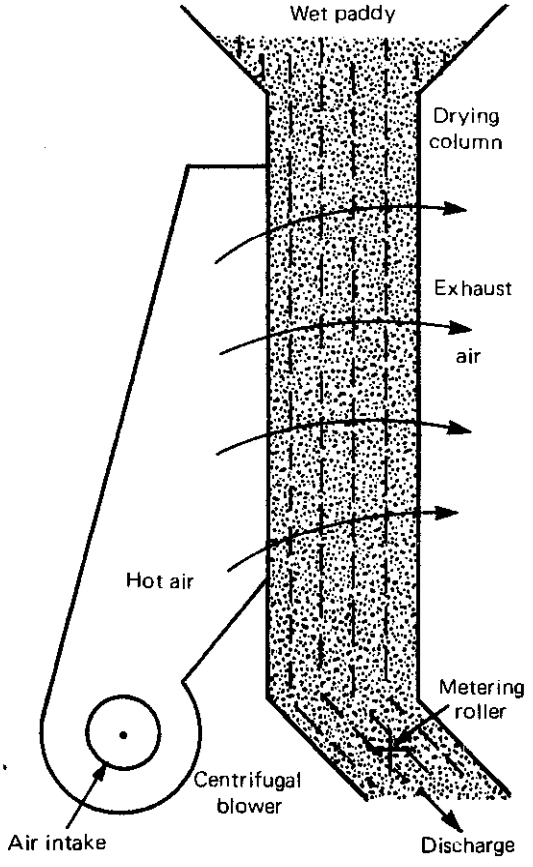

FIG. 72. Nonmixing-type columnar drier.

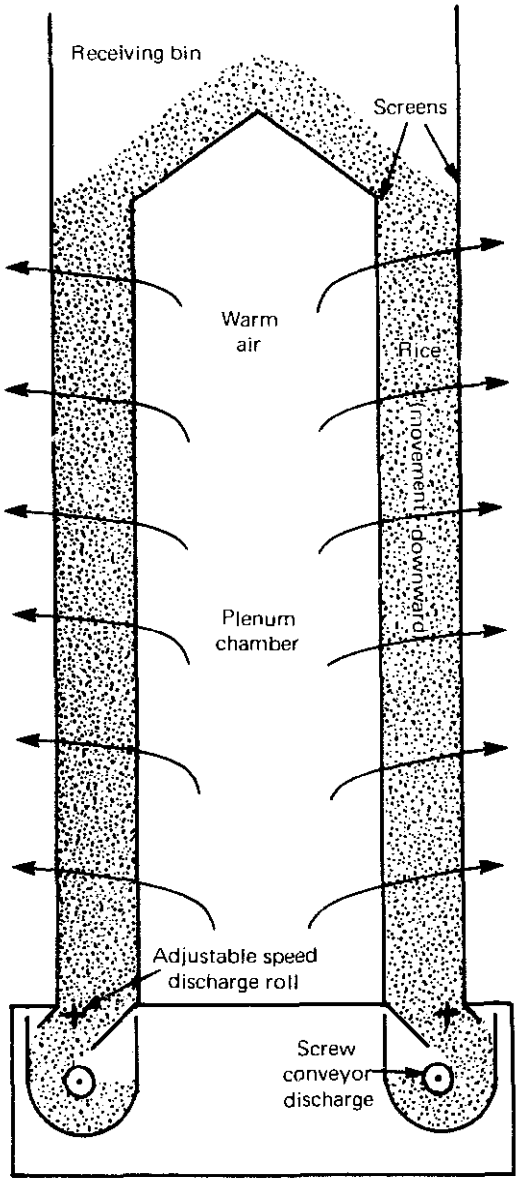

FIG. 73. Nonmixing-type columnar drier.

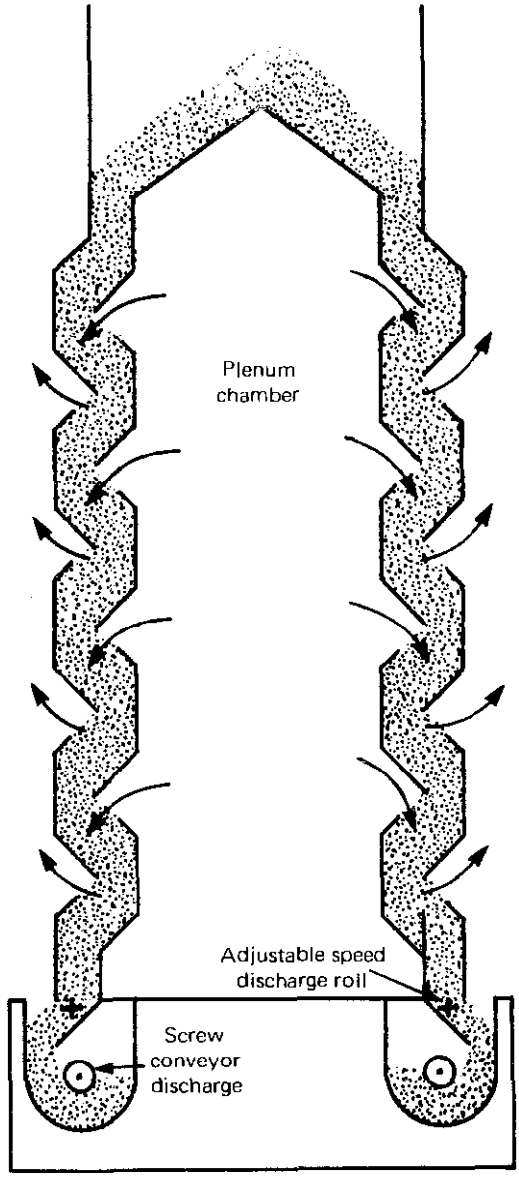

FIG. 74. Mixing-type columnar drier with baffles.

tures and lower air velocities than nonmixing driers.

Multipass Drying

In continuous-flow driers a multipass procedure is used to avoid excessive drying stress (Fig. 77). During each pass, the rice is exposed to the heated air for only a short time (15–30 min) and only about 2–3% of the moisture content on a dry weight basis is removed. Between drying passes the rice is moved from the drier to a tempering bin where the moisture content within the grain is equalized. The tempering period usually lasts from 4 to 24 h, and during this time the moisture in the grain slowly moves to the surface. The reduction in the moisture content of rice as a result of multipass drying is shown in Fig. 76. Notice that the moisture content

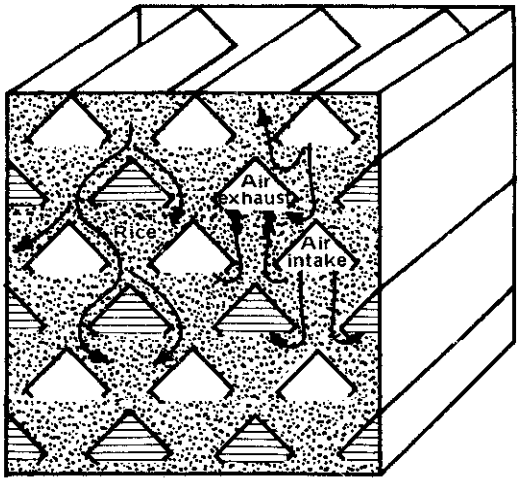

FIG. 75. Pattern of air and rice flow in LSU-type drier.

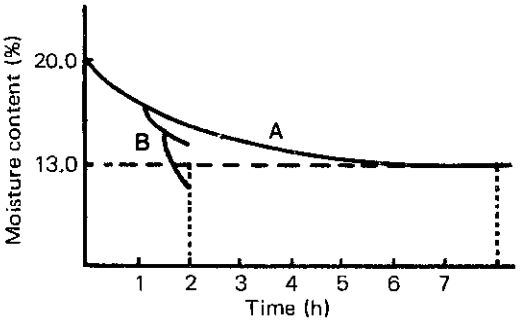

FIG. 76. Reduction in moisture content over time: (A) continuous drying; (B) multipass drying with three passes.

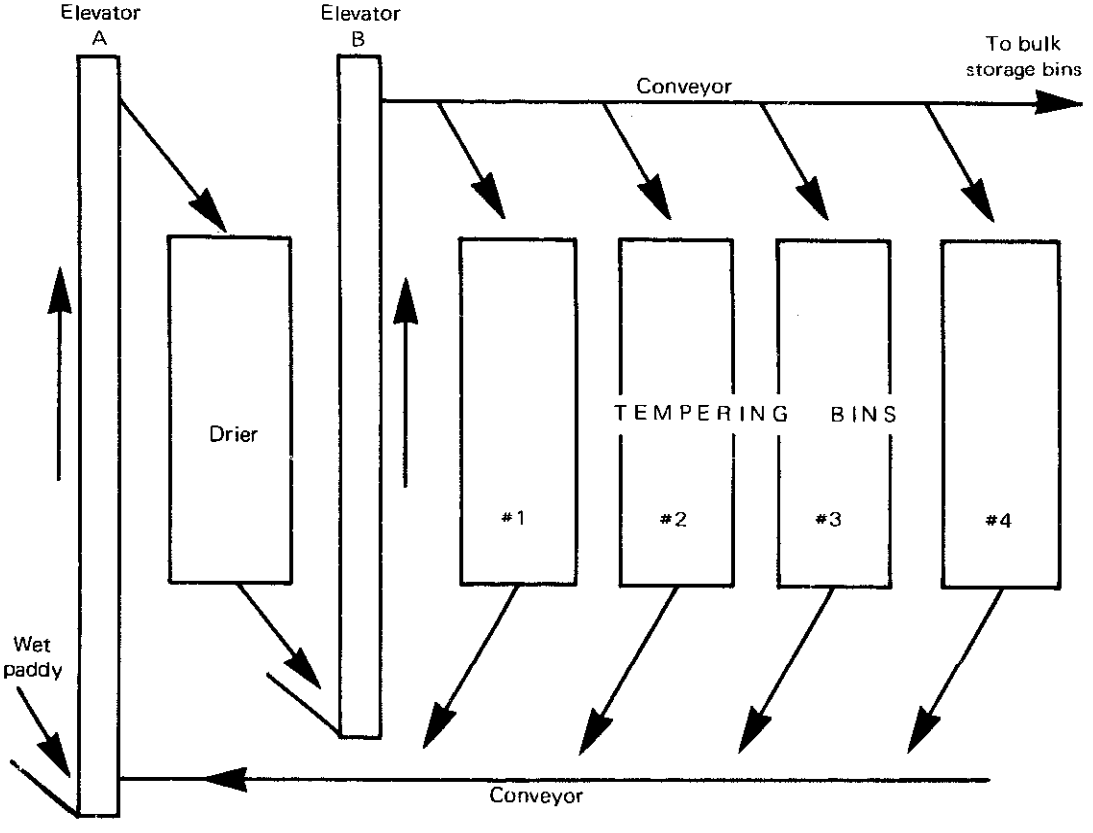

FIG. 77. Direction of flow and equipment required for multipass mechanical grain drying system.

is reduced to a lower level in a much shorter time. The multipass procedure is more efficient because the drier is used only when the kernel surfaces are relatively moist, as a result of tempering.

Figures 78 and 79 show the effects of drying temperature and the number of passes on head rice yield. Head rice yield increases with both an increase in the number of passes and a decrease in the temperature of the drying air. The best drying conditions, therefore, combine a relatively low drying temperature with a large number of drying passes.

Handling of Rice

Handling operations include weighing, sampling, dumping, and conveying. These operations are covered in other parts of this manual.

System of Programming

Proper management of the drying system requires: (1) drying in separate bins designed for drying with hot air; (2) preventing overdrying of part of the product, by using low drying temperatures and as thin layers as possible in a batch system or by regulating the rate of flow and number of passes in a continuous-flow system, to prevent cracking of the grain; (3) determining when the product is dry by using a moisture metre or measuring the time required to dry the grain; (4) cooling and tempering the grain after drying; (5) preventing condensation from accumulating on the top layer of grain by providing adequate aeration; and (6) preventing mechanical damage to the product.

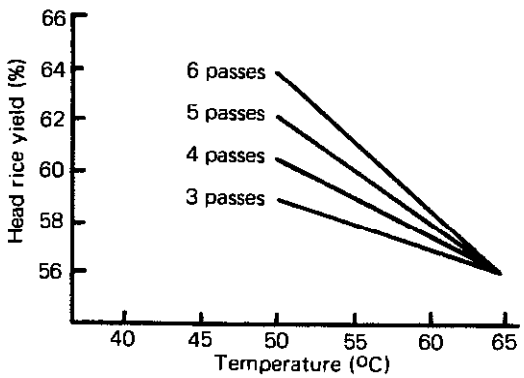

FIG. 78. Relationship between drying temperature and head rice yield.

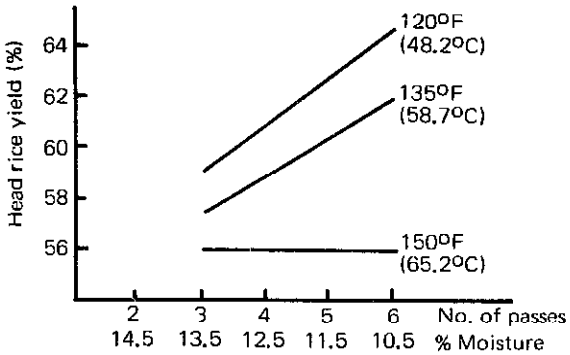

FIG. 79. Relationship between number of passes in drier and head rice yield.

Safety

Burner

Burners designed for safe operation should include: (1) a flame control to turn off the fuel supply in case of ignition failure; (2) a high temperature limit switch that will stop the burner but allow the fan to run; (3) a temperature control to prevent overheating the heater; and (4) proper electrical wiring connecting the fan and burner to the electrical circuit. All control systems should be designed to fail "safe."

Installation

A properly designed heater can be used in an unsafe fashion. Safety features of the installation should include: (1) locating the fuel tank and pipes a safe distance from the burner flame; (2) protecting the fuel line from mechanical damage; (3) locating fuel tanks at least 5 m from all buildings; (4) refueling only when the drying unit is not operating or refueling a safe distance away from the drier; (5) separating the drying and storage facilities; (6) keeping batch driers at least 5 m from all buildings; and (7) connecting the burner to the drier by a duct made of flameproofed canvas or other noncombustible material. — D. B. DE PADUA. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

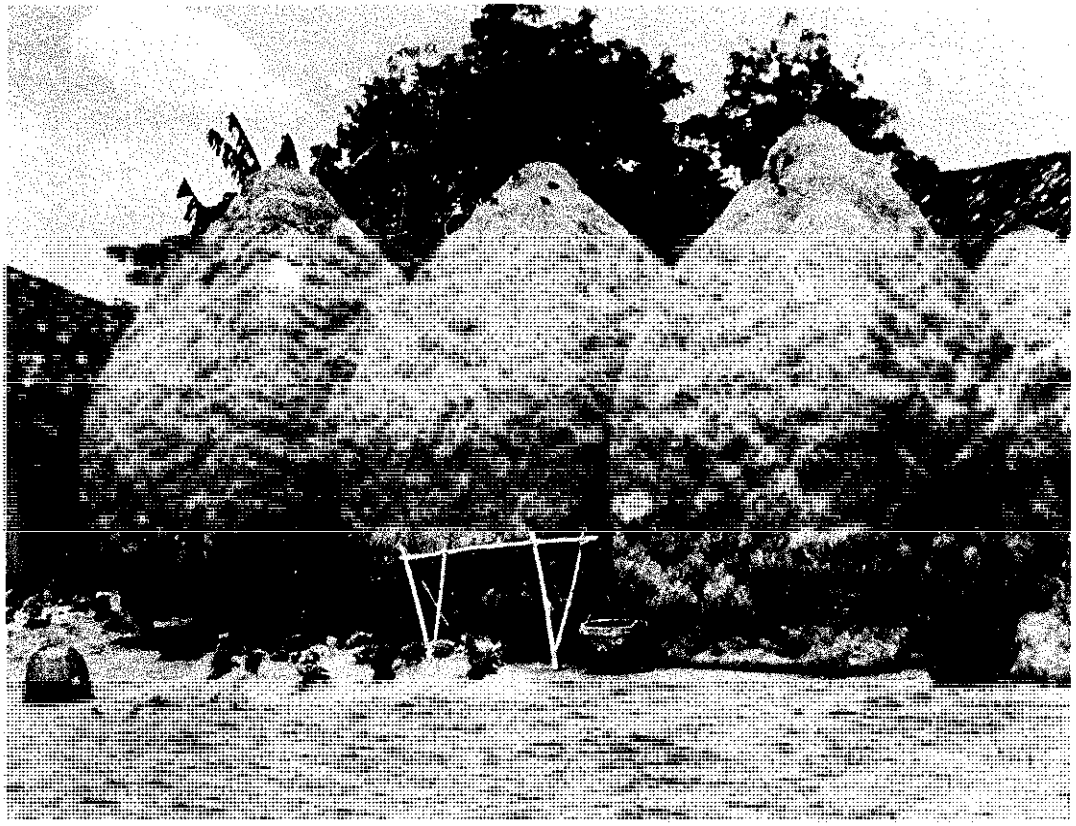

STORAGE

Constraints

Biological Considerations

Atmosphere and Water Relationships

The lower atmosphere of much of Southeast Asia is warm and moist with an average temperature of about 30 °C (85 °F) and an average relative humidity (RH) of 85%. This warm, moist atmosphere is of course subjected to intermittent solar radiation that alters its relative humidity. In certain areas, however, there is a distinct dry season with higher temperatures and lower average relative humidity.

The fundamental measure of air humidity is absolute moisture content, generally expressed as grams of water vapour per cubic metre of air. The water-holding capacity of air increases as the temperature increases. Figure 80 shows that at 10 °C (50 °F) air can accommodate about 10 g of water per cubic metre. If a saturated mass of air is heated from 10 to 38 °C (50 to 100 °F) it has a total moisture absorption capacity of 45 g/m³. In other words, the air contains 10/45 (22%) of the amount of water that it can hold at the saturation point, or its relative humidity is 22%.

In an atmosphere at 38 °C (100 °F) and 22% relative humidity, there is a strong tendency for the air to absorb water; this makes the moisture unavailable for absorption by anything else that is present in the atmosphere. If the same atmosphere (still with 10 g of water per cubic metre) is cooled to 32 °C (90 °F), its relative humidity is 10/30 or 33%. Its tendency to absorb water is reduced and, therefore, the availability of water to substances or organisms is increased.

Figure 81 indicates the decrease in relative humidity, in an atmosphere of unchanging absolute water content, when the temperature is raised. Any organism living in the atmosphere, as it is heated, will experience increasing difficulty in acquiring water because of the increased tendency of the atmosphere to absorb moisture.

The Moisture Requirements of Microbial Saprophytes

The fungi (moulds) and bacteria that cause the spoilage of food are very exacting in their

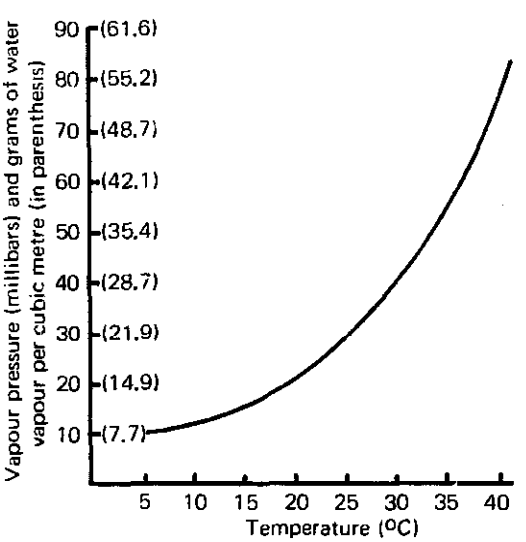

FIG. 80. Levels of saturation of the vapour pressure (water content) of air at different temperatures.

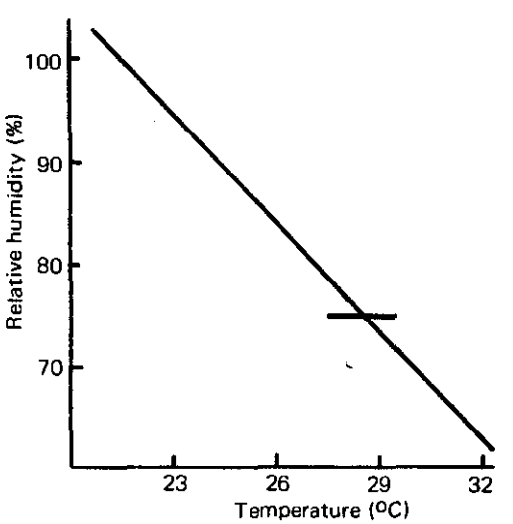

FIG. 81. The variation in relative humidity over a range of temperature in an atmosphere with a constant water content of 21.7 g/m³.

moisture requirements. The moulds, both Phycomycetes and Ascomycetes, generally have a lower limit of about 75% relative humidity for normal vegetative and sexual development. However, certain moulds, like the *Aspergillus* spp., may develop slowly at 10–75% relative humidity. The bacteria of food spoilage generally require a relative humidity of at least 90% for normal development.

Moulds and bacterial spores, where they occur, are resistant to much lower levels of relative humidity. In many moulds and certain bacteria, the vegetative bodies may also be resistant to desiccation. Therefore, if the atmospheric relative humidity is at a suitable level for mould development, it may be necessary not only to suppress moulds but to eliminate them. For instance, if a packed food containing resistant spores or mycelium is opened, but not entirely consumed, the remainder may quickly become contaminated.

The temperature requirements of microbial saprophytes may exceed the range of 10–38 °C (50–100 °F), but at no point in this range will they develop if the relative humidity is unsuitable. At the optimum temperature, which is about 27 °C (80 °F), development is most rapid if the relative humidity is suitable. In most of Southeast Asia it is necessary to contend with the fact that the normal temperature range includes the optimum for microbial saprophytes.

Relative Humidity and Moisture Content Equilibria in Foodstuffs

Most foodstuffs, and many other things such as salt solutions, characteristically lose or gain moisture passively until they are in equilibrium with the relative humidity of the surrounding air. At a particular level of humidity, different foodstuffs have different moisture content equilibria. Figure 82 shows the moisture content – relative humidity equilibria for milled rice, paddy, and some other products. The practical significance of these equilibria is that, because mould development commences at relative humidities above 70%, it is important to know the equilibrium moisture content at 70% relative humidity of any food that is to be preserved by drying.

Biology

It is generally true that insects assume the temperature of the atmosphere around them; the loss of heat from the body approximately balancing the heat generated by metabolic processes. It is also a general rule that the metabolism of warm-blooded animals decreases (within limits) when the temperature increases; whereas, the metabolism of cold-blooded animals increases.

In insects the extra energy derived from temperature increases is often expressed in adults by more rapid movement and in the developmental stages by more rapid development. Within certain limits, the influence of temperature on insect development follows a pattern similar to that in chemical reactions, i.e. the rate increases as the temperature increases. The main difference is the complete cessation of metabolism at low and high temperatures, which results in death. For each species of insect, somewhere between its low and high temperature limits, there is an optimum temperature for development. Various criteria have been presented to measure this optimum, including: number of eggs laid; percentage viability; preadult development; and adult life span. From the food scientist's point of view, perhaps the most satisfactory criterion is the rate of increase of the population in question. The rate of increase is most useful in anticipating damage that may be caused by an observed infestation, especially when the damage per individual is known (Fig. 83). *Tribolium casteneum*, *Sitophilus oryzae*, and *Lasioderma serricorne* are all serious pests of food in the Philippines.

The importance of relative humidity in insect development is equal to that of temperature; the two are closely related. The retention of water is a ubiquitous problem for small land animals. In insects the loss of water from the body is mostly by evaporation through the cuticle and from the tracheal system. It has been proposed that the evaporation of water from a surface is proportional to the saturation deficiency of the air. In its most simple form the law may be expressed as: evaporation rate = saturation vapour pressure × (100 – RH), at a particular temperature. However, some

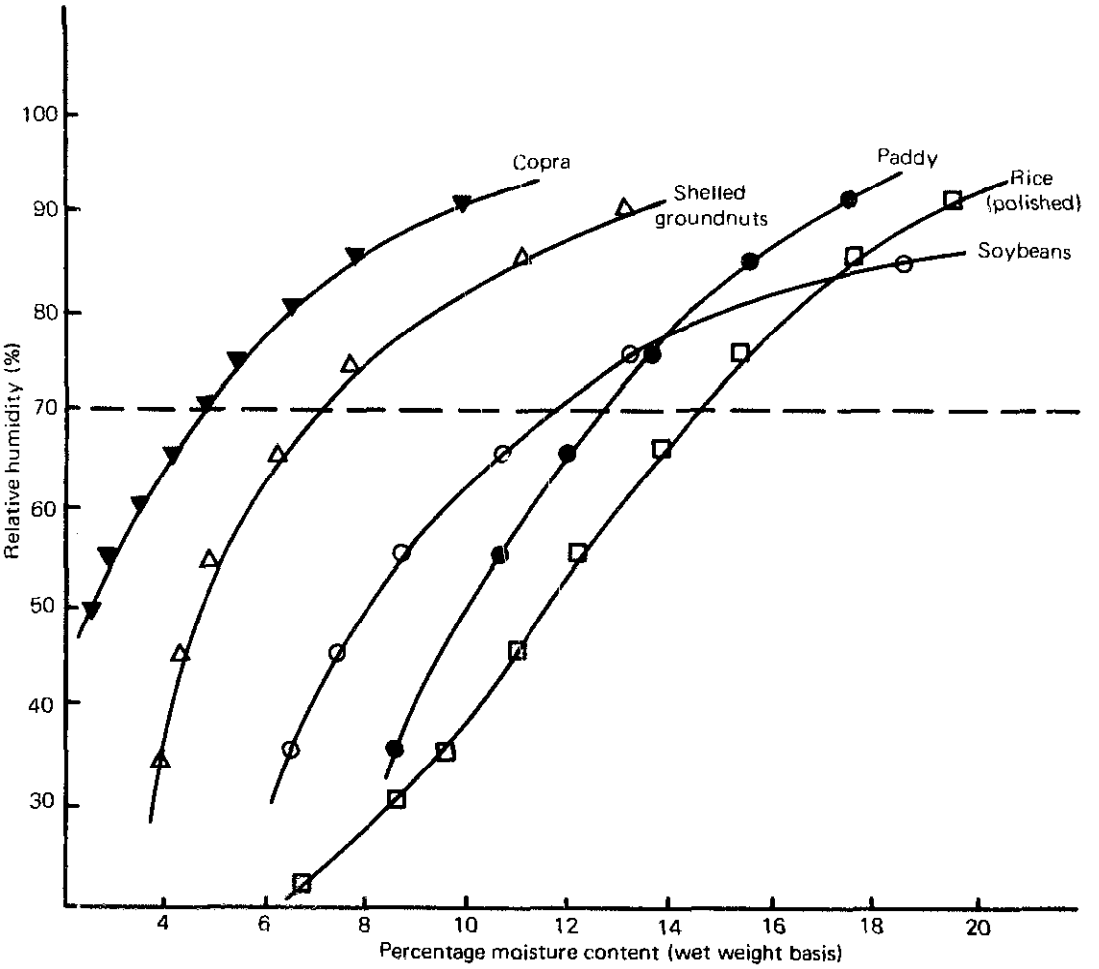

FIG. 82. Moisture content/relative humidity equilibration curves. Each curve has been compiled from results of several workers to present a guide to the moisture content/relative humidity equilibria values, which vary between varieties of the same species of food product. (By courtesy of Miss P. M. Davey, Tropical Stored Products Centre, England).

necessary deviations from this rule must result from: (1) the increase in permeability of insect cuticle with increased temperature; and (2) the increase in water diffusion with increased temperature when the saturation deficiency is the same. The shortening of the development period with increased humidity, at suitable temperatures, has been observed for many insect species.

Figure 84 illustrates the relationship between development period, temperature, and humidity. Saturation deficiency increases sharply with increased temperature, and insect development declines rapidly towards the thermal death point of a particular species. Therefore, in an atmosphere of constant moisture (relative humidity decreasing with temperature rise), the optimum temperature for development is about the point where the product of development time and saturation deficiency is the lowest (intersection of lines A and B, Fig. 84).

In most of Southeast Asia the optimum conditions for the development of moulds and certain insect pests of food fall within the normal ranges of atmospheric humidity and temperature. It may be deduced that moulds would normally be prolific throughout South-

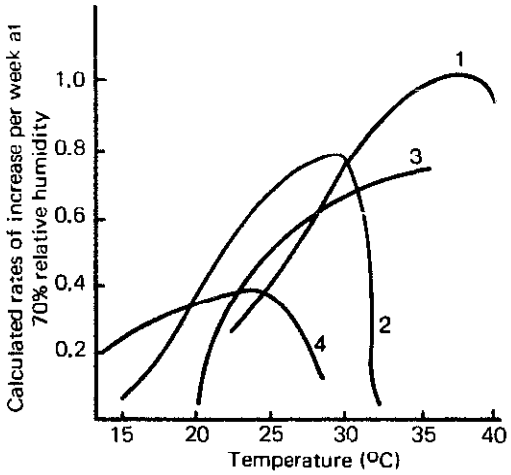

FIG. 83. The influence of temperature on the innate capacity for increase of insect pests of stored food: (1) *Tribolium castaneum*; (2) *Sitophilus oryzae*; (3) *Lasioderma serricorne*; and (4) *Ptinus tectus*.

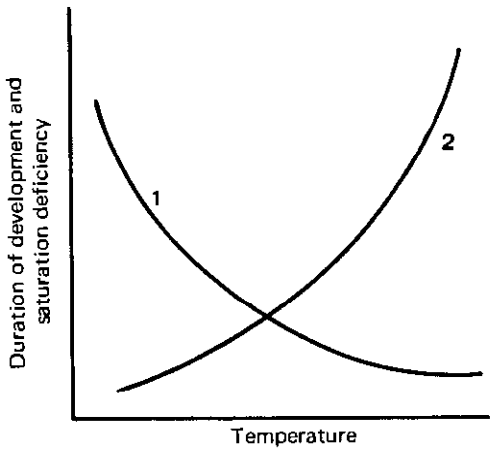

FIG. 84. Generalized chart to show the effect of temperature on: (1) duration of insect development; and (2) saturation deficiency of atmosphere.

east Asia except perhaps in the hot, dry seasons that occur in some countries and districts. Figure 83 indicates that the climatic data for Southeast Asia favour the development of *Tribolium*, *Lasioderma*, and *Sitophilus*; however, development of *Ptinus tectus* is verv much restricted because the temperature approaches the death point of this species.

As may be expected from the climatic data, the spoilage of foodstuffs by microscopic moulds such as *Mucor*, *Rhizopus*, *Penicillium*, and *Aspergillus* is very common. In certain cases the moulds produce toxic substances, e.g. the production of aflatoxin as a metabolite of *Aspergillus flavus*, and the damage caused to foodstuffs is much more serious than can be calculated from the actual amount of weight lost. Because of the proliferation of moulds, including those producing mycotoxins, it is important to dry and safely store grain very soon after maturation of the crop. This is one of the factors that will increase the demand for mechanical drying in areas where sun drying is not possible. Timely harvesting followed by drying is also very effective in reducing the populations of insect specics that attack grain in the field before and about the period of maturity, and that continue their life cycles over the storage period. This is particularly true of the grain weevil *Sitophilus oryzae*, which is tolerant of a very large range in moisture content (about 30% down to 9%). Also, the damage caused to mung beans by a number of bruchid weevils, such as *Callosobruchus chinensis*, can also be prevented to a large extent by timely harvesting and drying. This bruchid weevil also begins its attack in the field and continues during storage.

Principles Involved in the Application of Insecticides

It is a simple matter to kill insects in food, but without the proper precautions many undesirable side effects may result. Consideration of the principles involved in the control of insects with chemicals will automatically reduce risks and at the same time ensure the required control. Each practical problem will require individual consideration, and the following notes are simply offered as guidelines.

Residual Toxicity to Humans or Livestock

Many insecticides are toxic to humans as well as to insects. The comparative biochemical aspects of insecticidal action on mammals and insects will be discussed later. For the moment it may be stated that in some

cases there is a wide difference in toxicity; in other cases a dual toxicity but a different basis. For example, pyrethrins are highly toxic for most insects but weakly so to man; DDT is toxic to both. The toxicity is usually expressed as the lethal dose for 50% of the individuals being examined (LD_{50}). The limits of tolerance of insecticide residues in food are expressed as parts per million (ppm). Figures have been published from time to time by various authorities and, at the present time, the International Standards Organization is attempting to create a universal basis for tolerance limits. The first consideration in the use of an insecticide is to ensure that any residues are within the levels of tolerance.

Taint

Even in the absence of residual toxicity, there may in some cases be an off-flavour in the food caused by the insecticide. For example, benzene hexachloride (BHC) may cause a taint in the flesh and the eggs of poultry fed with treated corn, but the amount of BHC present may be less than the accepted tolerance limit.

Effect of Climate on the Insecticide

Many solid insecticides, such as BHC, melathion, and DDVP (2,2-dichlorovinyl dimethyl phosphate) are volatile and, especially at tropical temperatures, may quickly lose their activity. Others, especially pyrethrins, are easily broken down by strong light and by temperatures about 30 °C (86 °F). On the other hand, gases such as methyl bromide are much more effective at higher temperatures.

Differential Toxicity in Insect Life Stages

An insecticide may be highly effective against one life stage (i.e. egg, larva, pupa, or adult) but not against the others. Pyrethrins, 0.5% in oil fog, are highly effective against the adults of the moth *Cadra cautella*, but not against the larvae.

Formulation of the Insecticide

The base that acts as a conveyor for the active ingredient may play an important part in the toxic properties of the formulation. Malathion soon becomes inactive when applied as dust, but it is much more stable when treated with resin to inhibit volatilization. The carrier base itself, as well as restricting volatilization, may have a mechanical insecticidal effect. Light oil often used as a carrier for pyrethrins and other insecticides gives a 20% control of the grain weevil, *Sitophilus oryzae*, when used alone, and a 90% control with the addition of 1.0% pyrethrins. Possibly the female weevil is prevented from laying eggs on the grain surface because it is rendered slippery by a microscopic oil film.

Habits of a Pest in Re[illegible] Control

An insect in flight m[illegible]izing rapidly, may be more susceptible t[illegible] particular dose of insecticide than it would be when settled or walking. Being in flight may furthermore make it more accessible. The beetle, *Tribolium casteneum*, and the moth, *Cadra cautella*, are most vulnerable to spraying during their habitual dusk flights.

Parasitic Relationships

Whereas a particular chemical may be found in the laboratory to give a 90% control of a certain pest, it may in practice effect a 100% control on a parasite of the pest that was perhaps unobserved. The practical result might be an increase in the pest population. For example, the moth *Cadra cautella*, has a small hymenopterous parasite; *Bracon hebetor*, that attacks the moth larvae. Although a 0.5% oil solution of pyrethrins is very effective against the parasite, it has little control over the moth larvae. It was found that a spray application at 3-day intervals caused an increase of the pest because of the elimination of the parasite.

Effect of Insecticide on the Pest other than Direct Toxicity

The adult fertilized females of *Cadra cautella*, when knocked down and killed by any one of a large variety of insecticides, involuntarily discharge the eggs they contain. The

eggs are viable in the same proportion as those laid by normal females. Thus, an apparent kill of adults may not give complete control of the pest because the eggs may hatch and the population progress.

An insecticide used indiscriminately, for instance in too low a concentration, may result in the manifestation of a resistant strain of the pest by selection. A 10% initial survival of a pest may result in 100% resistance if the survival is due to an innate resistance of the pest. Several resistant strains of insect pests of stored products have already been found.

Seed Viability

Overdoses of fumigants may result in the loss of seed viability by actually killing the germ. This is most likely to happen in seeds with a high moisture content, because respiration is higher and chemical absorption is greater.

Interrelationship of Pest Species

Where two pests are present, control of one but not the other, if they were in competition, may only result in a dominance of the survivor. Laboratory tests have shown that the application of BHC to maize infested with *Sitophilus oryzae* and *Tribolium casteneum* causes a decrease of the former and an increase of the latter. There is also evidence that this has occurred in practice.

Some Comparisons in the Biochemistry of Insects and Mammals with Special Reference to Selectively Toxic Insecticides

Selective toxicity in medicine is already well known. Penicillin prevents the synthesis of the cell wall in bacteria by blocking the utilization of uridine nucleotide, a biosynthesis that does not occur in mammals. Sulfonamides block bacterial utilization of aminobenzoic acid, which is important to bacterial metabolism but not critical in mammalian metabolism.

In research on insecticides, consideration should be given to the possibility of selective toxicity, especially because there is now evidence of its existence. This is particularly important in countries where food losses are great and where the use of insecticides on foodstuffs appears to be inevitable. The subject is undoubtedly an extremely complicated one, and if it seems, from the extensive acceptance of insecticides, that man is less affected by them than are insects, it is mainly because he receives a smaller dose per unit body weight.

The study of selective toxicity can only proceed from an understanding of the differences and similarities in insect and mammalian metabolism.

Glycolysis

The respiratory quotients of mammals, and many insect species, indicate the use of carbohydrate and fat as primary and secondary fuels. The glycolytic breakdown of carbohydrate to pyruvate involves the formation of phosphorylated intermediates that have been found to have similar occurrence, for example, in the flight muscle of the housefly and in rat muscle:

	Fly	Rat
Adenosine triphosphate (ATP)	37.2	33.6
Adenosine diphosphate (ADP)	1.2	2.4
Phosphagen	10.9	33.7
Adenylic acid	6.9	3.2
Glucose-6-phosphate	7.8	5.2
Phosphoglycerate	20.8	2.9
Inorganic phosphate	15.2	15.3
Other compounds	0.0	3.7
Total:	100.0	100.0

The numbers represent the phosphorus in each compound expressed as the percentage of total acid soluble phosphorus.

Oxidative Metabolism

In mammalian tissue, pyruvate undergoes decarboxylation with the production of acetate that condenses with oxaloacetate and undergoes the Krebs cycle so that the initial carbohydrate is completely oxidized to carbon dioxide and water. The same metabolic pathways have been detected in the tissue of a

number of insect species, including houseflies, bees, and *Drosophila*. Furthermore, the physiological site of oxidative metabolism in mammals, the mitochondria, have their counterpart in the sarcosomes in insect flight muscle.

Amino Acid Metabolism

The amino acids essential to the growth of insects and mammals are similar. Aspartic acid, glutamic acid, alanine, and proline may be synthesized in insects by transamination reactions, and the intermediates of carbohydrate oxidation are the same as the glycogenic amino acids of mammals.

Although these and perhaps other remarkable similarities occur, there appear to be certain differences between the metabolisms of insects and of mammals that may be significant in selective toxicity.

Enzymes

The inhibition of acetylcholinesterases by organophosphorous compounds serves as an example. The enzymes of the housefly, honeybee, and mouse are all inhibited by parathion, but only the enzyme of the housefly is inhibited by the isopropyl analogue of parathion. This suggests that a specific molecular structure of the fly enzyme is different and allows access to the isopropyl analogue. Another enzymic difference is that the phosphagen of insect muscle is arginine phosphoric acid; in mammals it is creatine phosphoric acid. This suggests a different transphosphorylase that may be a point of selective toxicity. It is also conceivable that the enzymes associated with insect metamorphosis, being absent in mammals, may be a point of attack.

The insecticide malathion actually possesses a favourable insect to mammal toxicity ratio that has a biochemical basis. In living tissue malathion is converted to an anticholinesterase by enzymic oxidation. The pathway of P-labelled malathion injected into the hen, mouse, and cockroach clearly shows a selective toxicity. Detoxication and excretion of water-soluble metabolites of low anticholinesterase activity occurs in the vertebrates but not in the insect.

Other biochemical bases for selective toxicity probably exist although no relevant selectively toxic insecticide may yet have been discovered. For instance, insects require a dietary source of cholesteros for normal growth; whereas, in mammals it is synthesized from relatively simple metabolites. The blockage of cholesteros utilization by an antimetabolite in the insect diet is a possibility for selective toxicity.

Control of Insect Pests of Stored Food

Some similarities in the biochemistry of insects and of mammals have been discussed. These similarities should remind the food scientist to exercise caution in the use of insecticides. Also discussed were some possibilities and one known example of selective toxicity in insecticides, based on biochemical differences between insects and mammals.

There is clearly no long-term future for the use in stored food of insecticides that are also toxic to humans. The purpose of these notes is to discuss the types of chemicals and treatments that may be useful and relatively safe for the time being, and other possible methods of insect control that may provide a basis for development in this field.

Killing of Insects by their Ingestion of Poisonous Substances

About a century ago copper acetoarsenite (Paris green) was used as an insect stomach poison to control the Colorado potato beetle. Paris green and other arsenic compounds, fluorine compounds, and various organic compounds are used as insect stomach poisons in agriculture and against domestic insect pests. Although such poisons have been used in food stores, this practice is rapidly disappearing.

Insecticidal Action by Contact of Poisonous Substances with the Insect Integument

The insect cuticle is so permeable to a wide range of chemicals that when applied to the surface of the insect they produce their symptoms in almost the same degree as if they were injected. Insecticides applied to the insect sur-

face may enter the blood stream, nerve centres, or both. Contact insecticides are normally classified as: plant derivatives, e.g. pyrethrins, nicotine, and rotenone; or synthetic organic compounds, e.g. chlorinated hydrocarbons (DDT, BHC), organophosphorous compounds (malathion, DDVP), and carbamates (sevin, isolan).

These contact insecticides are at the present time used extensively in the food industry as: applications to the structures of food stores; space sprays in food stores; applications to packaging materials; and direct applications to foods such as cereal grains, legumes, fruits, root crops, and oil seeds. These insecticides are formulated as solutions, emulsions, dispersible powders, dusts, granules, and resins. They all possess some degree of toxicity to mammals, and quite clearly they cannot be used as direct applications to such finished foods as flour, cereal grains, and meals.

For direct application to unprocessed food, the most useful contact insecticides are those that possess the lowest mammalian toxicity, a secondary consideration being their stability in response to atmospheric moisture, heat, and light. An excessive stability, of course, increases the hazard of residual toxicity, which is probably less a problem in the tropics than in temperate climates. Probably the only contact insecticides that are surviving the competition for direct application to food are pyrethrins, malathion, DDVP, and lindane (pure benzene hexachloride gamma isomer). Carbaryl (sevin), the recently introduced carbamate, may possibly be useful.

Insecticidal Action by the Application of Poisonous Gases to Infested Food in Enclosed Spaces

For treatment of infested flour, grain meals, and other finished food, fumigation with gases such as methyl bromide and phosphine is extensively employed. In the treatment of grain and legumes, fumigation has the special advantage that the intragranular stages of the weevils are killed.

Although fumigated foods may be freed from the fumigant by ventilation, diffusion, or forced extraction, there remains the risk of residual toxicity because the fumigants are to some extent irremovably absorbed into the food. A hot climate provides the advantages of both the well-established increased effect of fumigants at higher temperature and the higher rate of gaseous diffusion.

New and Possible Developments in the Control of Insect Pests of Stored Food

It is excusable to use toxic substances provided: (1) full precautions and scientific applications are adopted; (2) there is economic necessity; and (3) the possibilities for the control of insects without the use of toxic substances have been considered.

Airtight Storage of Grain. In grain storage bins that are *completely* airtight, respiratory exchanges of both the grains and the insects result in a depletion of oxygen and a high concentration of carbon dioxide in the intergranular space. Such an atmosphere is toxic to insects (the lethal factor is depletion of oxygen) and, to a lesser extent, to the grain. If death of the grain is not important, then this method may be useful.

Cooling and Heating. Most insect pests of stored food have low and high thermal death points. When a limited maintenance of these temperatures does not adversely affect the food, a safe method of control presents itself. High temperature is more effective than low temperature. Insect development is generally limited below 10 °C (50 °F) and above 45 °C (113 °F). Heated-air drying of grain is a very effective initial control method against all insect pests of stored grain.

Moisture Relationship. Certain foods, particularly cereals, may be dried to a moisture content too low for the development of pests. A moisture content on a non-fat basis of 8%, corresponding to a relative humidity of about 40% at 25 °C (77 °F), generally excludes grain weevils from development; however, *Trogaderma granarium* may survive these conditions.

Irradiation. Ionizing radiations (alpha particles, beta particles, neutrons, and gamma rays) have all so far been used either experimentally or in practice in insect control. Beta radiation has been used to kill beetles in flour

and in wood and plant tissues on a limited scale. Gamma rays in dosages of about 65 000 R are required to kill storage insects, but they may be sterilized by dosages of about 16 000 R. This is at the present time receiving much international interest from two points of view: (1) the sterilization of entire populations; and (2) the sterilization and release of males of species in which the females mate only once.

Sex Attractants. Many insects have a keen olfactory sense that in many cases guides them to their food. It has also been observed that in some species the females emit "pheromones" that attract the males for the purpose of mating.

Male insects may be attracted by pheromones over distances of greater than a mile. The sex attractant of the silk worm moth has been synthesized recently and found to be biologically active. For example, an effective control of *Cadra cautella*, the tropical warehouse moth, may be conducted by releasing a fog of oil-based pyrethrins into grain stores during the dusk mating flight. The control could perhaps be more economic if a sex attractant could be released to first of all bring the males to a focal point.

Pests of Stored Food

Insects

Of the thirty or so orders of insects, the food scientist should be familiar with at least the Coleoptera (beetles) and the Lepidoptera (moths).

Whereas in temperate climates storage insect pests do not normally occur in the field, in the tropics it is normal for them to begin their attack there. These insect pests can be divided on the basis of whether their larva develop inside the seed or dried root or whether they are free-living within the food.

Larva develop inside the seed or dried root. The pupae occur in a distinct pupal cavity near the surface of the seed or root; the cavity opens to the outside by a distinct window after emergence of the adult. The adults are free-living and lay eggs in a characteristic manner on or just beneath the surface of the seed or root.

Larva free-living within the food. The pupae occur freely (beetles) or in cocoons (moths). The adults are free-living and lay eggs randomly on suitable food.

Some of the common Coleoptera and Lepidoptera are listed in Table 22 according to their mode of life, and some examples of the foods they attack are given.

Rats and Mice

Rats and mice are serious pests of stored grains. They are not only destructive because of the amount of grain they consume but also because they transmit disease. The main three species that cause problems are: (1) the Norway rat (*Rattus norvegicus*); (2) the roof rat (*Rattus rattus*); and (3) the house mouse (*Mus musculus*).

Sanitation. Good housekeeping is one of the most economical and effective ways to reduce rodent problems. Waste grain should be removed; lumber, old screens, and grain sacks should be stored about 50 cm from the floor; old trash and junk should be destroyed; and the grain should be protected with concrete, wire, or sheet metal. Weeds and carelessly strewn debris, which might provide harbourage for rodents, should be eliminated.

Chemical Control. The chemicals used to kill rats and mice are called rodenticides. Rodenticides are usually mixed with baits such as fresh meats, bacon, fresh or canned fish, rice, peanut butter, and melon. A binder of molasses, or vegetable, mineral, or fish oil is often used with dry baits to hold the poison and bait together. An emetic is usually added to the bait to protect other animals although the acceptability of the baits is then reduced. Rats are among the few animals that are unable to vomit. The bait must be mixed as directed because too little will not poison and may result in "bait shyness"; whereas, too much may give the bait a strong taste or odour and increases the danger to man and domestic animals. Extreme caution must always be exercised when handling poisons.

Traps. Two types of traps are commonly used: (1) snap traps; and (2) cage or box traps. In snap traps the bait must be securely fastened to the trigger. Placing cage or box

TABLE 22. Some examples of insect pests and the foods they attack.

Order	Family	Species	Food attack
Larva develop in seed or dried root			
Coleoptera (beetles)	Curculionidae	*Sitophilus oryzae* Linnaeus	Mainly cereal grains
	Bruchidae	*Callosobruchus maculatus*	Mainly beans
	Anthribidae	*Araecerus fasciculatus* Degeer	Mainly dried roots, also maize and dry cocoa
	Bostrychidae	*Rhizopertha dominica* Fabricius	Dried roots and grain
	Anobiidae	*Lasioderma serricorne* Fabricius	A wide range of dried seeds including beans, grain, and cocoa, root crops, and compact meals
Larva free-living within the food			
Coleoptera	Tenebrionidae	*Tribolium castaneum* Jacquelin du Val	Mainly ground grain and meals
		Gnathocerus maxillosus Fabricius	Weevil-damaged grain, legumes, dry cocoa, and oil seed cake
	Silvanidae	*Oryzaephilus mercator* Fauvel	Similar to *Tribolium*
		Cathartus quadricollis Guer	Maize, usually when the moisture content is above 14%
	Dermestidae	*Dermestes maculatus* Degeer	Dried fish, skins, bones, etc.
		Trogoderma granarium Everts	Dried animal products, grain, and oilseed products
	Nititulidae	*Carpophilus* spp.	Usually associated with mould on a wide range of foods
	Cuculidae	*Cryptolestes* spp.	Grain and grain products
	Ostomidae	*Tenebroides mauritanicus* Linnaeus	Similar to *Tribolium* but usually after heavy infestation by other insects
		Lophocateres pusillus Klug	Same as *Tenebroides*
Lepidoptera (moths)	Pyralidae	*Cadra cautella* Walker	Similar to *Tribolium*
	Tineidae	*Sitotroga cerealella* Olivier	Mainly grain and grain products

traps in dark places and covering them with material such as burlap bags will increase catches.

Burrow Gases. This is a supplementary measure for killing rodents and should not be attempted by untrained operators. Calcium cyanide is very effective but is highly toxic and quickly fatal; therefore, extreme care is necessary. Carbon monoxide from automobile exhausts can also be piped into a burrow system.

In tight clay soils, filling burrows with water from a garden hose may drive rodents out so they can be killed with clubs.

Rat Proofing. This consists of changing structural details to prevent the entry of rodents into buildings. The stoppage work, to be economical, should be confined to the most likely points of entry and not to every possible entrance.

Physical Considerations

The progressive approach to grain storage

in the Philippines is concerned with bulk handling and storage systems rather than sack storage. It may be expected that the tendency towards intensified production will be accompanied by: (1) the need to handle larger crops over a limited period of time; and (2) the centralization of storage. The bulk handling and storage of grain offers a number of economic advantages over sack storage: (1) savings in the cost of sacks; (2) reduction in labour costs; (3) better control of losses and quality; (4) reduction in land costs because a given volume can accommodate more grain in bulk than in sacks. The ratio is, for example, more than 10 to 1 when tall silos are used instead of sack storage in sheds; (5) facilitation of national grain policy operations; and (6) simplification of inventory.

Bulk handling and storage installations are not economically sound unless the storage capacity is about 1000 t or more. Capital is depreciated more rapidly with an increase in turnover frequency and this is a factor that contributes to the selection of a storage system. For example, a fully mechanized outdoor silo system may cost US$150/t of static storage capacity compared with US$50/t in a medium-size installation utilizing indoor rectangular or cylindrical bins. These two different systems may be designed in such a way that the technical advantages to be derived from bulk handling, and the overall function, are the same. For equal economic return, however, the frequency of turnover must be three times greater in the concrete silo system. It follows that such high-cost installations are usually regarded as economical only when they are associated with frequent or continuous stock turning operations such as those required for large capacity milling or port handling. However, a government may consider their use for subsidized grain marketing programs that are in themselves of economic and social importance.

Very careful logistic and marketing studies are necessary whatever type of handling and storage system is envisaged.

Before considering the relevant climatic factors, characteristics of structural materials, and the various systems available for handling and storage, it is useful to review briefly the characteristics of bulk grain because they refer to all of the other factors.

Characteristics of Bulk Grain

Certain physical and biological features of a mass of bulk grain are related to any bulk storage system whether it is refrigerated storage, airtight storage, or normal dry-grain storage.

Thermal Properties

Grain is a very poor conductor of heat, its conductivity being similar to first-class insulating materials. This means that any heat generated by the grain itself or absorbed by contact with storage structures (e.g. silo walls heated by the sun) remains localized, dispersing only very slowly from the source. The greatest significance of this is that the locally heated grain develops a high vapour pressure and gives off moisture vapour. This vapour may rise slowly through the bulk due to the convectional airflow created in the intergranular space, or it may maintain the same location, according to air density. In any case, the water vapour will probably condense to liquid water in another part of the silo where heating does not occur, or at the same place when the heat diminishes (e.g. sunset or overcast weather conditions following sunshine). The free liquid water is absorbed into the grain in another cooler part of the grain mass and a deterioration chain is triggered off.

The low capacity of grain for heat transfer can be used to advantage in the technique of chilled grain storage for seed. Once the grain is cooled to a safe level, it can remain cool for long periods provided the storage structures are correctly designed.

Moisture Relationships

Grain has the capacity to absorb or lose moisture according to the humidity of the surrounding atmosphere (intergranular space). One beneficial effect of this feature is the possibility of slow drying when a relatively dry mass of air is forced through a grain bulk.

This ability to give up moisture freely can also be used for evaporative cooling of the grain and is useful in conditioning bulk grain during storage. Conversely, caution is needed to ensure that the moisture in the intake air is not sufficiently high to cause wetting of the grain by absorption (see Table 23).

TABLE 23. The equilibrium moisture content of paddy over a range of relative humidity and temperature.

Temperature (°F)	Relative humidity 50	60	70	80	90
80	10	12	13	14.8	17
90	9.3	11	12.5	14.2	16.5
110	7	9.8	12	14	16.2

If dry paddy (say 13% moisture content) is subjected to in-storage aeration from an ambient atmosphere of 27 °C (80 °F) and 90% relative humidity, it will tend to absorb moisture up to the equilibrium level of 17%. At the same temperature a relative humidity of 70% or less is safe.

Biological Characteristics

A bulk of grain may be regarded as a mass of living organisms (the grain itself, moulds, and insects) that consumes oxygen and the reserve food material of the grain and produces carbon dioxide, water vapour, and heat in the same manner as the many other forms of life (Fig. 85).

In certain circumstances (airtight storage) the depletion of oxygen and the increase of carbon dioxide concentrations in the intergranular space can be used to advantage to produce an atmosphere that will retard or prevent the growth of insects and microorganisms. In ordinary bulk storage, however, the heat produced by grain respiration can become a problem if uncontrolled, especially if the grain moisture content is high: grain and mould respiration increases with an increase in moisture content and is very much restricted at low moisture content, e.g. 13% or less.

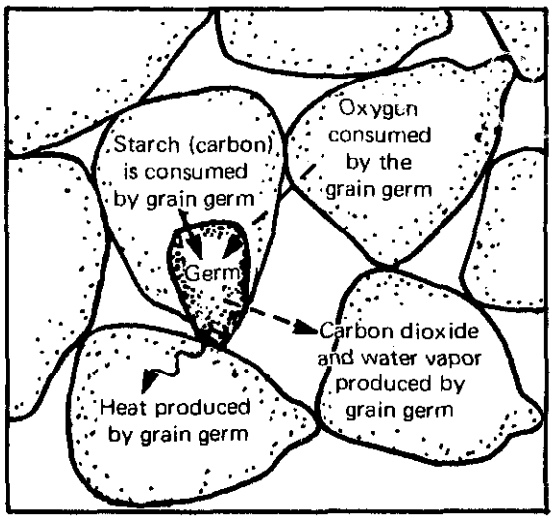

FIG. 85. The intergranular atmosphere, which is initially the same as ordinary air, is modified by the respiratory action of the grain germs, moulds, and insects: oxygen diminishes, water and carbon dioxide increase in concentration, and the temperatures of the intergranular space and the grain rise due to the heat evolved in respiration. The basic expression of this energy relationship is:

12 g carbon + 32 g oxygen = 44 g carbon dioxide + heat

Because respiration increases with increased moisture content, heat production increases and the temperature of the grain mass increases.

Resistance to Airflow

A bulk of grain exerts a resistance to airflow according to the dimensions of the bulk and to the shape and structure of the grain. Although the total intergranular space is fairly constant (30–40%) for all grain types, the configuration of the space is very different and determines the static pressure developed by different grain types for a given rate of airflow within a bulk of given dimensions. For example, shelled maize and soybeans, which have smooth surfaces, are spherical, and are relatively large, present low resistance to airflow. Paddy grain on the other hand, which has a rough surface and is slender and elliptical, exerts a high resistance — the grains being closely applied to each other to form a net-

work of small, predominantly horizontal spaces.

Because the power requirement for forcing a given volume of air through a grain bulk of given dimension is a function principally of air volume and static pressure, it follows that if the volume is the same, the power requirement will be greater for paddy than for maize. The power requirement to provide a bulk of paddy, and maize, of dimensions 10 ft × 10 ft × 10 ft with 2 ft^3 of air per minute per cubic foot of grain, through a flat-bottom aeration floor is:

	Air volume (cfm/ft^3 of grain)	Static pressure (inches of water)	HP required
Paddy	2	3.8	12
Maize	2	1.7	3

The airflow characteristics of sorghum are similar to those of paddy.

During the design and specification of aerated bulk storage, it is clearly necessary to consider the grain types to be handled.

Characteristics of Structural Materials

Since steel and concrete are the most likely materials to be used in the construction of new grain silos, it is necessary to consider their thermal properties.

Steel is a good conductor of heat; therefore, it readily transfers solar heat from the outside to the grain mass immediately inside the silo wall. (This fact should be considered together with the observations on the thermal properties of grain and its significance.) Conversely, steel cools readily at sunset, or in intermittent fair and overcast weather, and then acts as a condensation surface for water vapour produced from the heated grain.

Since steel is the most practical and economical material for silos designed for the ordinary systems of dry grain storage, consideration must be given to necessary factors that compensate for its undesirable thermal properties. These are grain moisture content and aeration. When the moisture content of grain stored in outdoor metal silos is 13% or less, the grain is not so susceptible to an elevation of vapour pressure and the consequent loss of water vapour. Forced ventilation in metal silos is essential to equalize the temperature of the grain mass with the ambient temperature, apart from the need to provide normal conditioning ventilation.

Refrigerated grain storage is not very practical in outdoor metal silos because of the continual heat gain from the exterior.

Concrete has a low thermal conductivity and presents a buffer against the amplitude and the intensity of variations in ambient temperature. Concrete silos are usually more expensive per tonne of storage capacity than steel silos, but their use may be justified in certain cases.

The heat reflectivity of all types of silo can be increased by painting them white.

Weather-proofing is of course essential in both steel and concrete silos. In steel silos this is accomplished by meticulous attention to the sealing and bolting of plates during construction and in concrete silos by the application and correct composition of water barriers.

It is to be noted that concrete is used for the base for steel silos and the same attention must be given to composition and damp-proofing to prevent capillary rise of groundwater.

Basic Requirements for Bulk Grain Storage

The basic requirements for ordinary bulk grain storage are: (1) the grain moisture content must be at the level at which grain respiration is limited; (2) the grain must be free of debris so as to facilitate forced ventilation; (3) a forced ventilation system must be included in the silo design; (4) ventilation must be programmed according to prevailing climatic conditions; (5) ventilation systems must be designed according to the types of grain to be stored; (6) silos must be weatherproof, constructed on firm, water-impermeable foundations, and oriented advantageously with respect to solar radiation; and (7) mechanical conveying systems must be provided.

Review of Storage Methods Available

Aerated Storage of Dry Grain for Long-Term Storage

Paddy, maize, and sorghum having a moisture content of 13–14% can be stored for

long periods in steel or concrete silos that are equipped with a suitable forced-air ventilation system. The functions of the ventilation system are: (1) to replace the intergranular atmosphere; and (2) to equalize the temperature of the grain bulk with the ambient temperature. Silo units (individual bins) of several hundreds to a few thousand metric tonnes are used for this purpose and total tonnages of 1000 and above are normally considered as economic capacity.

The airflow rate for any grain storage is about 0.10 ft^3/min per cubic foot of grain applied at daily intervals for a period of about 15 min during the period of minimum relative humidity.

Aerated Storage of Wet Grain

Grain with a moisture content above 14% can be maintained in good condition for periods of about 2 weeks to 2 months at 29 °C (85 °F) provided adequate ventilation is employed. Grain of 14–16% moisture content requires 1 ft^3 of air per minute per cubic foot of grain daily for a period of about 30 min during the period of minimum relative humidity. Under these conditions, 14–16% moisture content grain can be held safely for 2 months. At this airflow rate, the grain moisture content is reduced only negligibly, but evaporative cooling is adequate. However, if an airflow of about 5 ft^3/min per cubic foot of grain is applied to 16% moisture grain for several hours a day at 70% relative humidity or less, the grain moisture content will be reduced to 14% in several weeks. The grain can then be subjected to reduced aeration as indicated above.

It may be desirable to hold for short periods grain of 16% or more moisture content so as to provide a buffer in the delivery of wet grain into driers. This technique spreads the drying load, maximizes the utilization of drying capacity, and consequently abbreviates the period of capital amortization. Such wet-grain holding is normally carried out in bins of less than 100 t capacity using an airflow of at least 5 ft^3/min per cubic foot of grain for about 3 h per 12 h.

Refrigerated Storage
(Chilled Grain Storage)

The application of cooled air (e.g. 4 °C (40 °F)) to bulk grain either dry or semidry (14–16% moisture content) is effective in reducing grain respiration and deterioration to a negligible degree. The cooled air is applied with an ordinary aeration system equipped with a cooling plant.

Airtight Storage

If a filled silo is completely sealed, the grain respiration causes a drastic modification of the intergranular atmosphere — oxygen is depleted and carbon dioxide is increased. The result is that the grain is killed and respiration ceases. Insect and mould development is inhibited or excluded by the modified grain atmosphere but certain yeasts and bacteria may grow if the grain moisture is high (18% or more).

Since this method changes the flavour and milling quality of grain, it is not useful for application to human food grains. It cannot be used for seed grain because the grain is killed. It can be useful for storing animal feed grain for periods of several months, especially because it is not necessary to dry the grain, and the grain is usually required wet for feed blending.

Methods Applicable in the Philippines

Three types of conventional bulk storage with aeration systems would seem to be applicable to the Philippine grain production and marketing patterns, according to location and required capacity.

Bin Storage Systems

These are for installation within existing sack storage buildings or new buildings of a similar type. These indoor silos may be of the rectangular type with flat-floor aeration or of the cylindrical type with cross-flow aeration.

The rectangular bin system offers a number of operations derived from the same installation: (1) holding of wet grain prior to drying; (2) slow in-bin drying from about 18%

moisture content to 14% or less, as a supplement to heated-air drying in continuous flow or batch driers; (3) tempering between heated-air drier passes; and (4) grain unloading using the same aeration system used for in-bed drying and regular conditioning aeration.

The cylindrical system is comparable in its function with the rectangular system except that hoppering is needed for grain unloading and space is not used so efficiently.

These installations are generally suitable for provincial operation up to a capacity of 2000 t. The scale of economy begins at about 1000 t. Capital cost per tonne of static capacity, i.e. tonnes of throughput, is a vital economic factor, as in all storage systems.

Steel Cylindrical Outdoor Silos

The range of size is great and they can be installed economically over a static capacity range of about 1000–10 000 t or more. At 1000 t capacity, the capital cost per tonne for all operations is about US$100 and about US$50 at 10 000 tonnes capacity.

Silo systems of this type may have provincial or terminal application.

Concrete Silo Systems

This system is already used in the Philippines at flour and feed mills and at one rice mill. The economic scale starts at about 10 000 t static capacity with a capital cost per tonne of about US$150 at that level for all necessary operations. Concrete silo systems are generally employed as part of the handling system at high-capacity grain processing installations or port facilities where the turnover is frequent — usually at least four times per year and often as many as twenty. — JOHN RAWNSLEY. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

Microorganisms

One of the major problems that confronts the agricultural industry in the Philippines and other developing countries having tropical climates is the proper postharvest handling and safe storage of agricultural commodities such as cereal grains and oilseeds.

The main hazard caused by mishandling and poor storage of grains and other stored products is the loss in quality due to invasion by microorganisms and insects. In the Philippines, the predominant microorganisms usually associated with stored products are fungi or moulds, mainly *Aspergillus* and *Penicillium* types. These moulds occur throughout the world as common contaminants of food, but they are considered to be more serious in tropical areas like the Philippines where high temperature and moisture favour their rapid growth. Although these moulds do not attack actively growing plants, their minute spores may contaminate the outer layers of the seeds, especially at maturity or harvest time. If cereal grains, oilseeds, and other agricultural commodities are not properly dried after harvest they are subject to attack by moulds.

In the Philippines, where rice is harvested by hand, there is sometimes a delay between harvesting and threshing, and often the panicles are heaped in the rice field until they can be dealt with. Such temporary storage of grain with a high moisture content (usually as high as 30%) will lead to development of high temperatures, serious deterioration in the form of discoloration and off-odours, and ultimately, reduced milling yield due to the growth of moulds and other microorganisms. Similarly, if milled rice is stored under damp conditions mould growth will occur. The actual invasion occurs under storage conditions of high humidity (70–75%) and high temperature (25–30 °C). Under these conditions, the spores germinate and penetrate the seed. They attack with ease any section

of the moist seed, and result in mouldy grains. Storage fungi colonies also develop at the site of insect and mechanical damage to the seed.

In a recently concluded survey in the Philippines, samples of different grains, peanuts, soybeans, and copra that were not properly dried always yielded colonies of moulds, mainly *Aspergillus flavus* (Table 24).

Effects of Moulds on Stored Products

Mould growth produces a number of deteriorative effects on grain, grain products, and oilseeds: (1) discoloration and loss of luster; (2) bad odour and off-flavour that make the grain objectionable either as animal feed or food for human consumption; (3) reduced processing quality, for example, it is more difficult to separate starch from protein in wet milling of corn; (4) loss of viability, making the grain unsuitable for planting; (5) loss of competitive position in world markets due to poor quality; and (6) production of highly toxic substances called mycotoxins that poison and kill animals and livestock and possibly also cause health hazards to humans.

Mycotoxins

Mycotoxins are toxic substances produced by fungi, several of which are known to cause specific diseases of animals and man. The first recognized toxic fungi metabolite was the notorious ergot of rye and other cereal grains. Ergot contains a mixture of active substances (primarily ergotamine) that causes mental and physical suffering in man. Present scientific literature reports other mycotoxins that affect animals as well as man (Tables 25 and 26).

Of the many fungal toxins so far reported, few have stirred as much interest as the mould toxin known as "aflatoxin." In England in 1960–1961, 100 000 young turkeys mysteriously died. After an infectious disease was ruled out, it was discovered that what these turkeys had in common was their ration of mouldy peanut meal, which had been imported from Brazil. The meal contained a high population of the mould *Aspergillus flavus*. Studies revealed that this mould produces several related compounds known as aflatoxins B_1, B_2, G_1, and G_2. The most toxic is aflatoxin B_1 that has a lethal dose (LD_{50}) of 18 μg in ducklings. It has been definitely proven that aflatoxin can cause liver cancer in animals, and it is probably safe to assume that aflatoxin can also cause primary liver cancer in human beings through cumulative consumption of contaminated cereals and other food products, the main ingredients of which are either cereals and/or nuts. Table 27 shows the results of analyses of different foods and native delicacies for aflatoxin content conducted by the Food and Nutrition Research Council of the Philippines (FNRC).

Studies have been undertaken to find means of removing or destroying aflatoxin from foodstuffs. Procedures like autoclaving, use of chemicals, and irradiation have been tried, but these methods have either been unsuccessful or impractical. To date the best means of controlling mould infestation of agricultural commodities is by prevention. This means proper harvesting, drying, storing, and processing.

Some Broad Principles and Practices for Preventing Mould Growth

Environmental factors such as high moisture and temperature, which exist in tropical countries like the Philippines, are the conditions that lead to mouldiness of agricultural products. Consequently, commodities must be dried, without damage, to a safe moisture level soon after harvest and maintained at a low level of moisture and temperature during storage and handling.

Other storage practices are essential. (1) Always thoroughly clean storage premises before refilling. Leftovers may contain insects, moulds, and other microorganisms that will infect new materials. (2) Clean the grain of grain dust, foreign material, and broken kernels before it is stored. This makes the grain less attractive and less susceptible to insect and mould infestations. Do not mix new grain and other bulk agricultural commodities with old stock because organisms that cause quality

TABLE 24. Percentage of *Aspergillus flavus* and aflatoxin content in samples of crops collected in the Philippines, September 14 to October 2, 1970.

Code[a]	Sample description	No. of units cultured	Units yielding *A. flavus* (%)	Aflatoxin B_1 (ppb)
Corn				
B-1	Whole corn on cob, drying yard, rural areas	21	71	343
B-2	Whole corn, shelled, drying yard	20	55	107
C-1	Whole corn, shelled, used in milling procedure	21	14	343
C-2	Corn starch derived from C-1	—	—	14
C-3	Corn gluten meal derived from C-1	25	20	333
C-11	Whole corn on cob standing in fields, improved varieties, over mature, some ears on ground	21	70	929
C-12	Whole corn on cob, drying on cement, rural areas. Mixed varieties	20	70	1074
D-13	Whole corn on cob, wet, stored in sacks in barrio bodegas	20	35	948
GS-5	Corn oil filter from oil refining	—	—	600
Peanuts				
B-4	Peanuts in shell, dry from stored 1970 crop, variety CES-101	20	60	14
CMC-2	Small segregated peanuts sold on market for food use:			
	smooth	20	45	Composite
	wrinkled	20	75	29
CMC-3	Production line "pickouts" removed from stocks:			
	smooth	20	65	Composite
	wrinkled	20	95	986
IS-4	Farmer commercial peanut stock, in bulk storage, dry, 1970 crop, in shell	20	10	257
IS-5	"Pickout" from farmer stock (IS-4) sorted at shelter, shelled	20	0	477
Copra				
C-18	Filter residue from copra oil extraction process and oil clarification	—	—	357
D-10	Crude copra infested with fungi in pile	20	100	314
Sorghum				
B-6	Sorghum, mixed varieties in large moulding pile, very mouldy sample obtained	44	25	208
C-10	Sorghum dry in storage	30	0	0
Rice				
D-7	Mouldy unmilled rice from milling company bodegas	30	0	0
I-2	Rice, exposed in field experiment, improperly dried, variety IR-8-68	40	15	0
Soybeans				
B-3	Soybean, drying on mat	27	16	21

[a]Code letters refer to geographical area in which sample was collected; B—Bacolod; C—Cebu; D—Davao; GS—General Santos; I—Iloilo; IS—Isabela; and CMC—Manila market.

TABLE 25. A partial list of animal diseases attributed to fungi toxins.

Condition	Animals	Fungus source	Food material	Toxic agent
Slobbering	Guinea pigs	*Rhizoctonia legumi-nicola*	Legumes	Slaframine
Trembling and convulsion	Laboratory animals	*Aspergillus* sp. *Penicillium aplopium*	Various foods	Tremorgens (2 or more)
Liver necrosis, cancer, and body hemorrhage	Dogs, fowl, rats, and cattle	*Aspergillus flavus*	Corn, peanuts, sorghum and coconut	Aflatoxins (6 or more
Cerebral necrosis	Equine animals	*Fusarium moniliforme*	Corn	Unknown

TABLE 26. Diverse toxic conditions of man attributed to mycotoxins.

Condition	Fungus source	Food material	Toxic agent
Skin photosensitization	*Sclerotinia schlerotium*	Pink rotted celery	Psoralens
Polyuria	*Rhizopus nigricans*	Millet	Unknown
Bone marrow depression (ATA)	*Fusarium* sp.	Cereal	Not well determined
Hepatitis with hemorrhagic phenomena	*Stachybotrys atra*	Cereal grains	Not well described

TABLE 27. Summary of FNRC analyses for aflatoxin content of different foods (1970).

	No. of samples	Percentage of samples with concentrations greater than 30 ppb	Percentage of samples containing no aflatoxin	Range of concentration (ppb)	Mean concentration (ppb)
(1) Peanuts					
raw	7	0	42.86	0–103	9
boiled	7	14.28	0	trace–103	16
toasted	56	14.28	12.50	0–371	45
brittle					
whole	13	7.69	23.08	0–158	28
diced	6	33.33	16.67	0–74	32
ground	7	42.86	0	6–171	58
sugar coated	15	20.00	46.67	0–35	31
with chocolate	14	42.86	35.71	0–215	73
with tokwa	3	33.33	10	16–68	37
soy peanut	12	16.67	33.33	0–750	115
peanut butter	77	100	0	43–8600	287
(2) Corn					
dried	37	81.08	0	3–398	106
boiled	13	0	23.08	0–20	11
pop (with sugar)	17	0	52.94	0–24	14
pop (with salt)	12	8.33	33.33	0–660	20
canned sweet corn	6	0	33.33	0–9	6
bran	3	1100	0	197–265	242
Corn starch	3	0	66.67	0–trace	
Corn with coconut	17	17.65	17.65	0–143	37

(*continued*)

TABLE 27. (*continued*).

	No. of samples	Percentage of samples with concentrations greater than 30 ppb	Percentage of samples containing no aflatoxin	Range of concentration (ppb)	Mean concentration (ppb)
(3) Copra	143	18.88	21.68	0–458	42
copra meal and cake	27	7.40	62.96	0–36	20
coconut products	33	6.06	78.79	0–857	134
(4) Rice					
rice straw	14	0	78.52	0–trace	
rice and sugar	23	0	78.26	0–22	13
rice, sugar, and coconut milk	54	5.56	35.18	0–786	39
rice, sugar, and linga	4	0	75.00	0–trace	
pop rice	2	0	50.00	0–3	5
bran	3	33.33	0	28–31	29
pinipig	6	0	33.3	0–6	5
cereal preparation	5	0	0	trace–14	9
binlid	2	0	0	trace–11	11
(5) Tubers					
Camote					
raw	11	27.27	9.09	0–86	27
with sugar and coconut	2	0	100		negative
Cassava					
raw	7	14.28	0	4–35	12
with sugar and coconut	18	50.00	0	trace–1073	322
Ubi					
raw	6	0	50.00	0	7
with sugar and coconut	20	25	35.00	0–443	136
Gabi					
raw	8	0	62.5	0–3	3
Potato					
raw	3	0		0–28	25
Carrot	2	50	0	14–64	39
Radish	2	0	50	0–trace	
Singkamas	2	0	50	0–28	28
(6) Commercial feeds					
(unlabelled)	4	0	(2) 50	0–8	7
Laying mash	6	33.33	0	trace–133	39
Growing mash	13	38.46	0	10–151	47
Starter mash	9	44.44	0	8–129	43
Pigeon mash	5	40	0	11–47	29
Boiler mash	4	50	0	15–171	66
Hog mash	8	62.5	0	12–200	68
Trigo	2	0	0	14–23	19
(7) Mongo					
dried	12	8.33	0	trace–32	9
with coconut	8	37.50	12.50	0–857	332
sugar with flour	5	0	20	0–13	8
sugar sprout	2	0	50	0–trace	

(*continued*)

TABLE 27. (*concluded*).

	No. of samples	Percentage of samples with concentrations greater than 30 ppb	Percentage of samples containing no aflatoxin	Range of concentration (ppb)	Mean concentration (ppb)
(8) Beans (dried)					
string beans	3	33.33	0	trace–96	55
China	1	0	0	8	8
Kadyos	4	0	75	0–4	4
paayap	6	16.67	0	trace–86	15
patani	2	0	50	0–trace	
tapilan	2	0	0	trace–9	5
kidney	10	20	10	0–180	69
chickpea	3	0	0	trace–9	4
canned beans	11	0	0	trace–21	6
(9) Soybean products					
misu	4	0	0	trace–3	
taburi	4	0	0	trace–16	5
tausi	5	0	20	0–28	9
misi	3	0	0	trace–2	
tokwa	8	0	25	0–9	4
(10) Fish					
dried	19	0	0	trace–6	4
smoked	23	0	(10) 43.48	0–9	5
meal	1	0	0	5	5
bagoong	2	0	0	5–7	6
patis (sauce)	16	0	0	trace–7	5
(11) Other nuts					
pili nuts	1	0			
pili nuts with sugar	12	8.33	33.33	0–64	12
kasoy nuts	12	0	58.33	0–7	5
kasoy nuts with chocolate	1	0	0		6
(12) Miscellaneous					
coffee	11	0	100	0	
cocoa (processed)	10	0	60	0–28	12
cocoa raw	1	0	0	17	17

deterioration will most likely be introduced into the new crop. (3) Conduct periodical surveillance tests in bulk-stored agricultural commodities for mould growth and colour appearance. (4) Keep insects, mites, and rodents in check by fumigation or the application of protective sprays. — FLORENDO C. QUEBRAL. *Department of Plant Pathology, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

Control Systems

The general requirement for good seed storage is a dry and cool environment. Seed operations located in climatic areas with

high temperatures and relative humidities must have some system of controlling both the relative humidity and the temperature of the air inside seed storage rooms. Sealed storage (vapour-proof containers) has been used for many years in the vegetable seed industry; however, two factors have limited the use of this method for storage of field crop seeds: (1) the cost of vapour-proof containers; and (2) the moisture content of the seed, which must be 2–3% lower than that normally considered safe for seed packaged in non-moisture-proof containers.

Before considering several systems that can be installed to maintain low relative humidities and temperatures, let us consider the basic requirements: (1) a structure must be provided that will keep infiltration of moisture and heat to a minimum; (2) there must be some means of dehumidification (removing moisture from the air); and (3) there usually must be some provision made for lowering the temperature of the air.

Storage Room Construction

The question of how to build a good seed storage room becomes a question of what is the best way to construct a "large container" and make it as airtight as possible. This is necessary to keep the initial cost and the operating expense of the dehumidifying and cooling equipment at a minimum.

For low humidity conditions, it is essential that adequate vapour barriers be included in the construction and that they be installed with the greatest of care, making sure that all joints are properly sealed. Thermal insulation requirements will vary with geographic location. Obviously, the size of the storage area should not be larger than absolutely necessary. If seeds are to be stored in a large warehouse, it is more economical to condition only a small portion of the warehouse rather than to attempt to dehumidify and cool the entire structure.

Dehumidification

Generally speaking, there are two major categories of dehumidifiers: refrigeration-type, and chemical- or absorption-type.

Refrigeration-Type

The refrigeration-type dehumidifier operates by drawing warm moist air over a metal coil through which a refrigerant such as Freon is circulated. A part of the atmospheric moisture condenses on this cooling coil and is collected in a pan or bucket or is drained off. The cooled air coming from over the coil, which now has a low temperature and a high relative humidity, is reheated by the condenser coil of the refrigeration system; thus raising the temperature and lowering the relative humidity. The water removal capacity of this type of system is dependent on the difference in temperature between the entering air and the cooling coil. Although these units are quite effective at high temperatures they lose efficiency below 21 °C (70 °F) or 50% relative humidity. Heat from the electric motors that drive the compressor and fans add sensible heat to the atmosphere.

Absorption-Type

The absorption-type dehumidifier operates by drawing moist air over a solid drying agent (desiccant) that has the ability to extract and retain moisture on its surface by a phenomenon known as "absorption." The air is filtered and dried to a very low dewpoint in the process, and the desiccant is periodically regenerated by means of heated outside air that vaporizes the moisture and dispels it to the outside of the conditioned space. Continuous operation of these machines is achieved by either using two desiccant beds that switch back and forth automatically, or by using rotating beds of desiccant, a portion of which is always dehumidifying the air while the remainder is being regenerated.

Desiccant dehumidifiers provide maximum efficiency at low temperatures and are able to maintain constant relative humidities even below 10%. A factor that should not be overlooked is that heat is added to the controlled atmosphere although the unit is placed outside the storage room. The latent heat of vapori-

zation of the moisture that is removed is converted to sensible heat. There is also a certain amount of residual heat left in the desiccant after reactivation, which increases the air temperature.

Heat Removal

Because an excessive heat buildup will usually be experienced when either type of dehumidifier is used alone to reduce the relative humidity in a seed storage room, let us consider several means of removing this heat. The most common and familiar method is by using a refrigeration-type air conditioner, which can also be used to "dehumidify." It operates in a manner similar to the refrigerant dehumidifiers except that it has a larger cooling coil area and provides air or water cooling of the condenser coils.

Water after-coolers can be used with a desiccant-type dehumidifier if the sensible heat load of the storage room is not excessive and a supply of cool water is available. Pre-cooling and after-cooling coils that are cooled by a refrigeration system are a most efficient way of removing large amounts of moisture with a desiccant dehumidifier. At temperatures below 10 °C (50 °F), silica gel will remove nearly 90% of the moisture from the airstream; at 38 °C (100 °F) this removal ratio is only about 50%.

Depending upon the temperature, relative humidity requirement, moisture, and sensible heat load, one method or system is usually more efficient than another. Therefore, let us consider eight possible systems for maintaining the required temperature and relative humidity in a conditioned seed storage facility.

Dehumidification System — Type I

As shown in Fig. 86, a refrigeration-type dehumidifier is placed inside the conditioned space. This self-contained unit consists of the following components: refrigeration compressor; motor and fans; and evaporator and condenser coils. The air inside the room is recirculated through the unit until the set relative humidity is reached and a humidity control switch in the electrical circuit shuts the unit off. The humidistat will automatically turn the unit on again when the moisture content of the air begins to increase due to infiltration or movement of moisture from the storage product or from other moisture inside the room. This system can be used satisfactorily only in locations where temperature control is not necessary, that is, where the sensible heat increase does not raise the air temperature above safe limits.

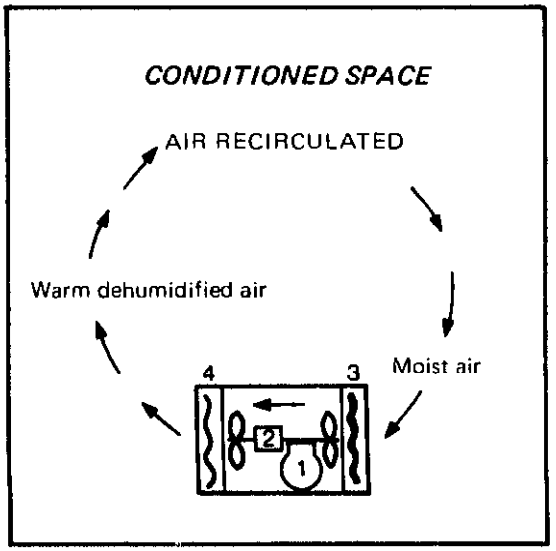

FIG. 86. Dehumidification system – type I: (1) compressor; (2) motor and fans; (3) evaporator coil; and (4) condenser coil.

Dehumidification System — Type II

Figure 87 shows a desiccant dehumidifier located outside the conditioned space. This self-contained desiccant unit has the following components: desiccant (usually silica gel); heater coils; conditioned air blower; and reactivation blower. The air in the conditioned space, through a closed system, is recirculated through the unit until the set relative humidity is reached. A humidistat, located inside the conditioned space, controls the running of the conditioned air blower. Most desiccant dehumidifiers are wired so that the reactivation cycle continues even though the conditioned air blower stops. This is desirable only when the unit must run most of the time to maintain the relative humidity in the conditioned space;

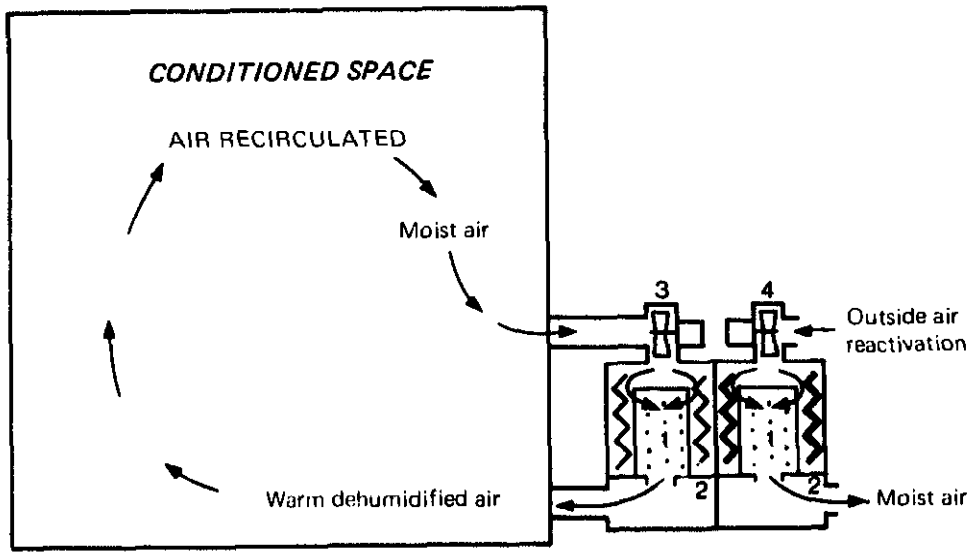

FIG. 87. Dehumidification system – type II: (1) desiccant; (2) heater coils; (3) blower; and (4) reactivation blower.

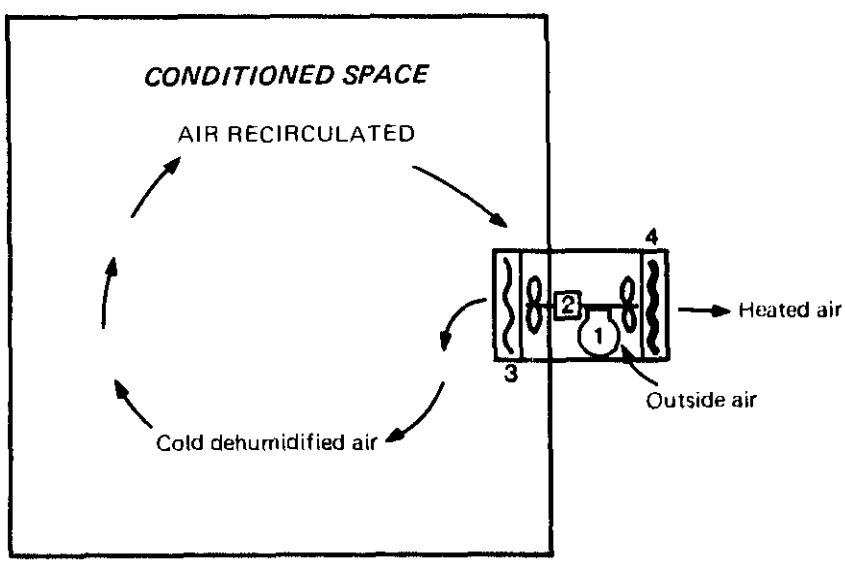

FIG. 88. Dehumidification and cooling system – type III: (1) compressor; (2) motor and fans; (3) evaporator coil; and (4) condenser coil.

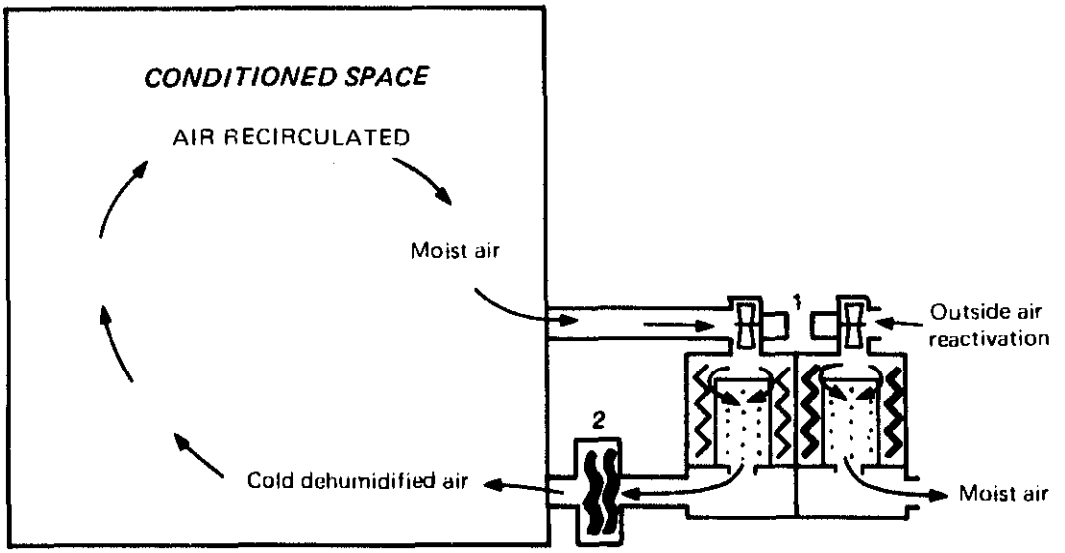

FIG. 89. Dehumidification and cooling system – type IV: (1) desiccant dehumidifier; and (2) water after-cooler.

otherwise, the result is excessive heat and expense. By having the reactivation heaters and fan wired to shut off when the conditioned air blower shuts off and by locating the machine outside the conditioned space, the heat build-up can be kept to a minimum.

Dehumidification and Cooling System — Type III

A conventional-type air conditioner can be used to maintain temperature and relative humidity when the reduction of temperature is necessary for control of the sensible heat load. As shown in Fig. 88, only the evaporator section of the refrigeration unit is placed inside the conditioned space. The air within the conditioned space is recirculated over the cold evaporator coil, where moisture is condensed out of the air. Outside air is drawn over the condenser coils releasing the transferred heat to the atmosphere. The unit is controlled by a thermostat that shuts the compressor off when the temperature of the inside air is reduced to the set level. Because moisture is removed only when the room temperature is too high, sizing of the air conditioner for the sensible heat load becomes critical. For dehumidification, the compressor must run to keep the evaporator coils cold To maintain a more constant relative humidity condition, electric heater strips are sometimes used to add heat to the air, which keeps the unit running longer. If these heater strips are connected through a humidistat, they can be turned on and off automatically as the humidity inside the conditioned space changes.

Dehumidification and Cooling System — Type IV

The system shown in Fig. 89 consists of a desiccant dehumidifier with a water after-cooler. The water cooler is used to reduce the air temperature as it leaves the desiccant dehumidifier. The size of the after-cooler coil and the quantity and temperature of the water that passes through the coil determine the amount of heat that can be removed. This system is very effective for maintaining low humidities, and temperatures in the range of 5–10 degrees above the water temperature. A magnetic valve can be used in the water supply system to automatically regulate the water flow, and thus keep the air temperature within the set limits.

Dehumidification and Cooling System — Type V

Figure 90 shows a high capacity moisture removal system that utilizes a refrigeration unit

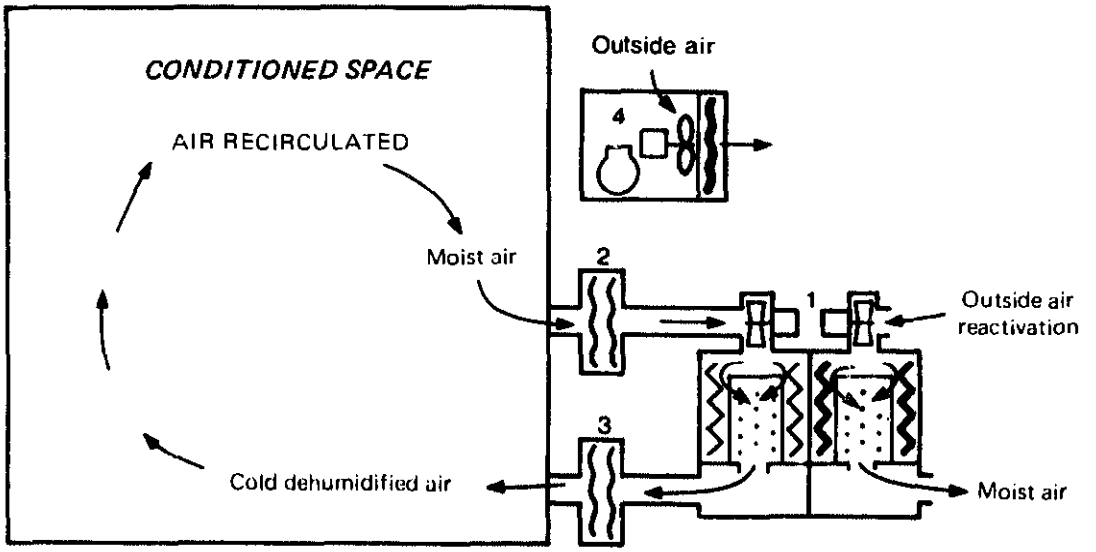

FIG. 90. Dehumidification and cooling system – type V: (1) desiccant dehumidifier; (2) pre-cooling coil; (3) after-cooling coil; and (4) refrigeration unit.

in conjunction with a desiccant dehumidifier. Cooling for the pre-cooling and after-cooling coils is provided by a refrigeration system. Because silica gel can remove nearly 90% of the moisture from air at a temperature below 10 °C (50 °F), the air in the conditioned space is cooled by the pre-cooling coil before it contacts the desiccant in the dehumidifier. In the process of absorption, latent heat of condensation is converted into sensible heat. Because this sensible heat increase may increase the air temperatures as much as 28 C° (50 F°), the after-cooling coil is necessary to reduce the temperature to safe limits. With automatic controls the temperature of both cooling coils can be regulated; thus it is possible to maintain, within close tolerances, low humidities and temperatures inside the conditioned space under a wide range of load conditions.

Dehumidification and Cooling System — Type VI

A simple system for controlling the temperature inside a conditioned space while removing large quantities of moisture at higher temperature is shown in Fig. 91. A self-contained refrigeration-type dehumidifier that is located inside the conditioned space removes the moisture from the air and is controlled by a humidistat. The sensible heat load is handled by a refrigeration unit that transfers the heat to the outside atmosphere. The air temperature inside the conditioned space is kept within set limits by a thermostat that turns the refrigeration compressor on and off. This type of system loses efficiency at temperatures below 21 °C (70 °F) and relative humidities below 50%.

Dehumidification and Cooling System — Type VII

A dual system, as shown in Fig. 92, can be designed to maintain low humidities and low temperatures in the conditioned space over a wide range of load conditions. The refrigeration system will dehumidify (within limits of design) as well as cool the air. It works independently from the desiccant unit; however, in normal operation the two systems complement each other. The desiccant dehumidifier has a much higher moisture removal capacity because cold moist air enters the machine. Under extreme load conditions, the temperature of the air leaving the unit can be high enough to pick up sufficient moisture before entering the evaporator so that a certain amount of water will condense onto the cold coils.

Because either part of the system can lower

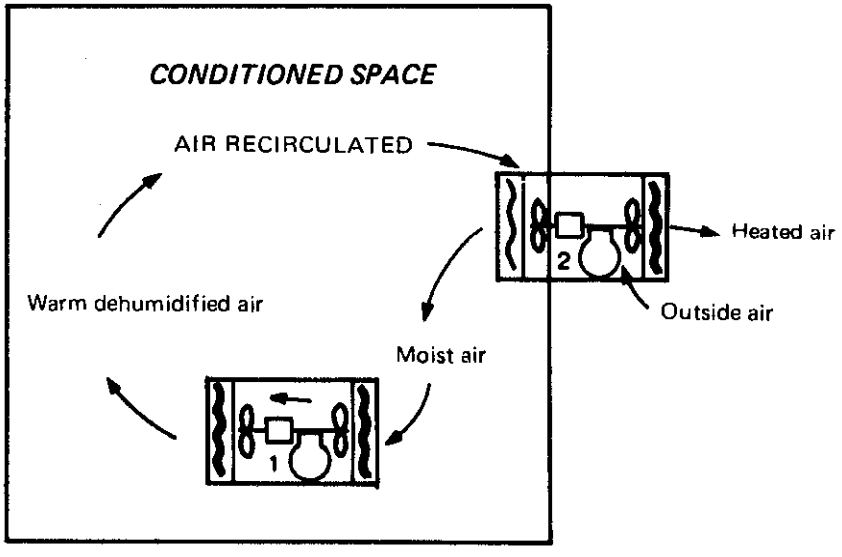

FIG. 91. Dehumidification and cooling system – type VI: (1) refrigeration-type dehumidifier; and (2) self-contained refrigeration unit.

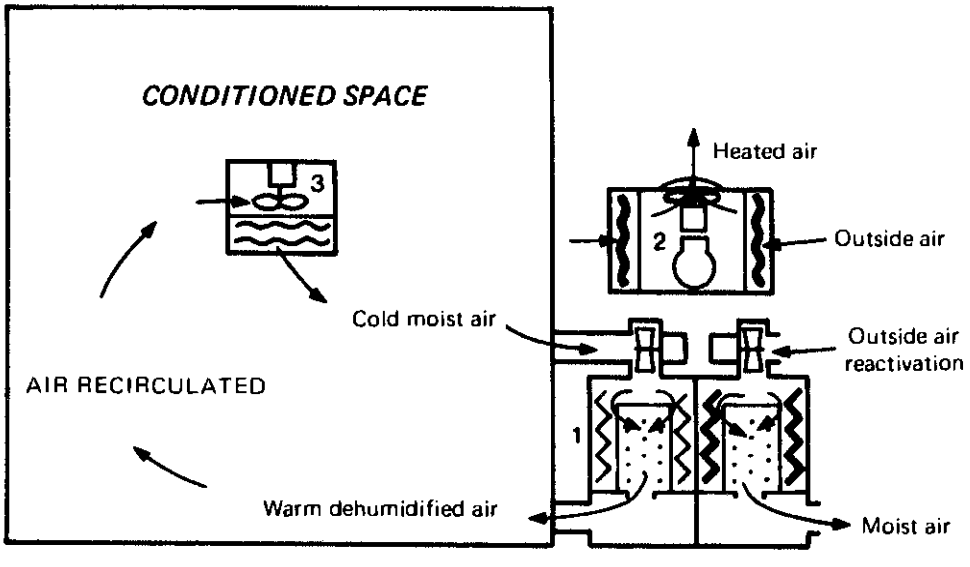

FIG. 92. Dehumidification and cooling system – type VII: (1) desiccant dehumidifier; (2) remote refrigeration unit; and (3) evaporator.

the humidity to a certain extent, this dual system offers a safety factor in case of mechanical failure.

Dehumidification and Cooling System — Type VIII

A mechanical refrigeration system, as shown in Fig. 93, can be designed to maintain low humidities as well as low temperatures inside a conditioned space. Because the evaporator coil temperature must be below the dewpoint of the conditioned air at low temperatures and relative humidities, the moisture that condenses out will freeze, forming ice on the coils. Some provision must be made to melt this ice and remove it as water from the conditioned space. In the illustration, a hot-gas defrost system is shown. Using a time

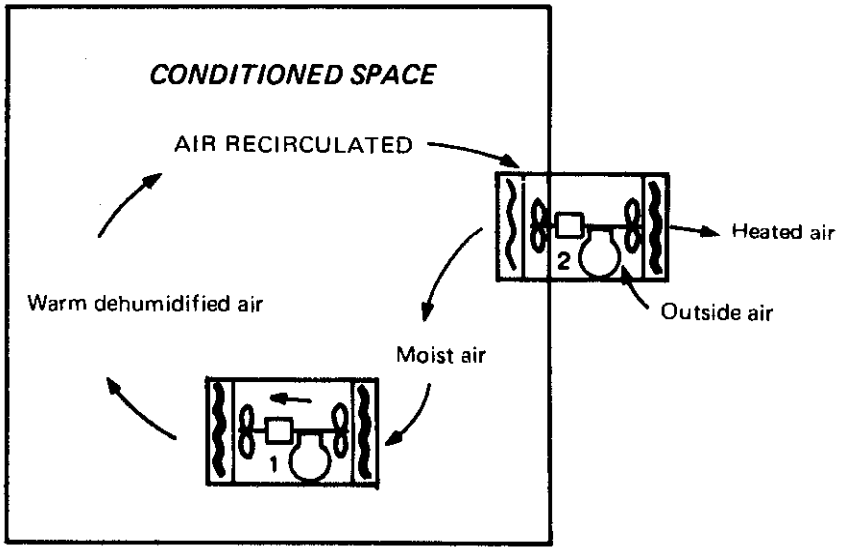

FIG. 91. Dehumidification and cooling system – type VI: (1) refrigeration-type dehumidifier; and (2) self-contained refrigeration unit.

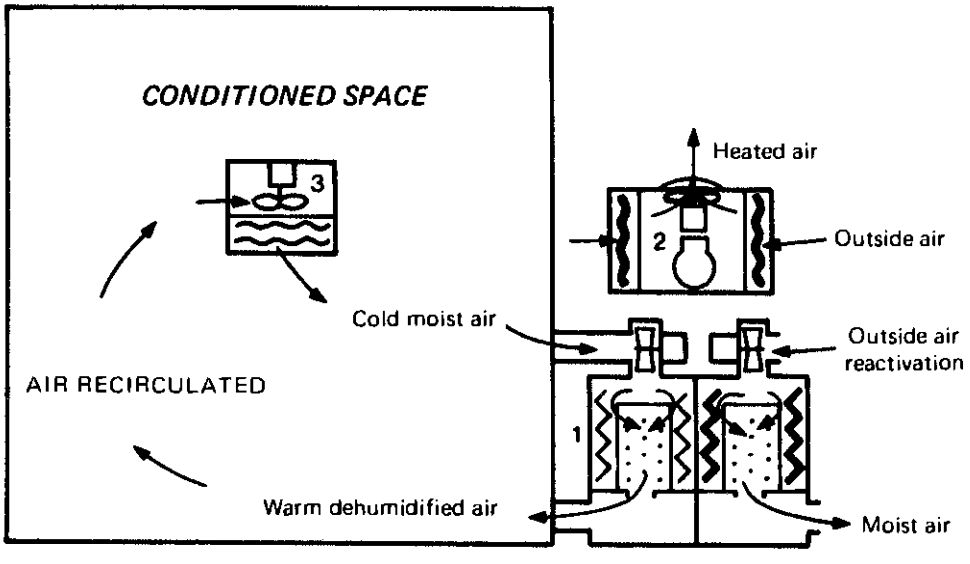

FIG. 92. Dehumidification and cooling system – type VII: (1) desiccant dehumidifier; (2) remote refrigeration unit; and (3) evaporator.

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Dehumidification and Cooling System — Type VIII

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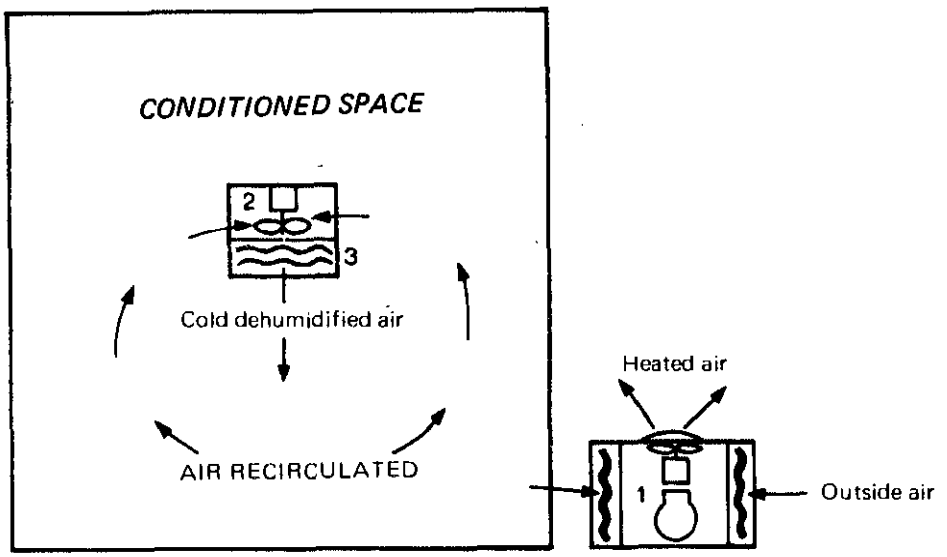

FIG. 93. Dehumidification and cooling system – type VIII: (1) remote refrigeration unit; (2) evaporator; and (3) hot-gas defrost system.

clock, hot discharge gas from the refrigeration compressor is directed through the evaporator coil at regular intervals.

It should be pointed out that a refrigeration system that will function well at temperatures below 21 °C (70 °F) and 50% relative humidity is not composed of standard "comfort" or "cold storage" refrigeration components. Humidity control must, therefore, be built into the coil design and other components of the system. — JAMES M. BECK. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

PARBOILING

Technology

Rice has been used as a staple food since ancient times, and today, more than half of the world's population eats rice as the main food in their diet. Rice is obtained from paddy by milling, which removes the hull and bran (a mixture of pericarp, seed coat, and some of the aleurone layer, Fig. 94). The objective of milling is to get whole grain rice and preserve most of the rice kernels in their approximate original shape. Some varieties of paddy do not yield much head rice (a rice kernel or a piece of kernel having length equal to or greater than 3/4 of the average length of the unbroken kernel) because of their inherent poor milling quality or due to the effects of bad weather or uneven processing conditions. Both preharvest and postharvest factors cause breakage of rice during milling. Preharvest factors include varietal characteristics, agronomical practices, and environmental conditions; whereas, postharvest factors include unevenness in processing conditions during mechanical handling, drying, or storage and the type of milling machinery used and its adjustment.

Even if the proper precautions are used in postharvest processing, some varieties of paddy produce a low head rice yield because of inherent poor milling quality. To counteract this, premilling treatments have been developed in certain parts of Asia, particularly in India, Bangladesh, Pakistan, Burma, Ceylon, Malaysia, and Thailand (Borasio and Gari-

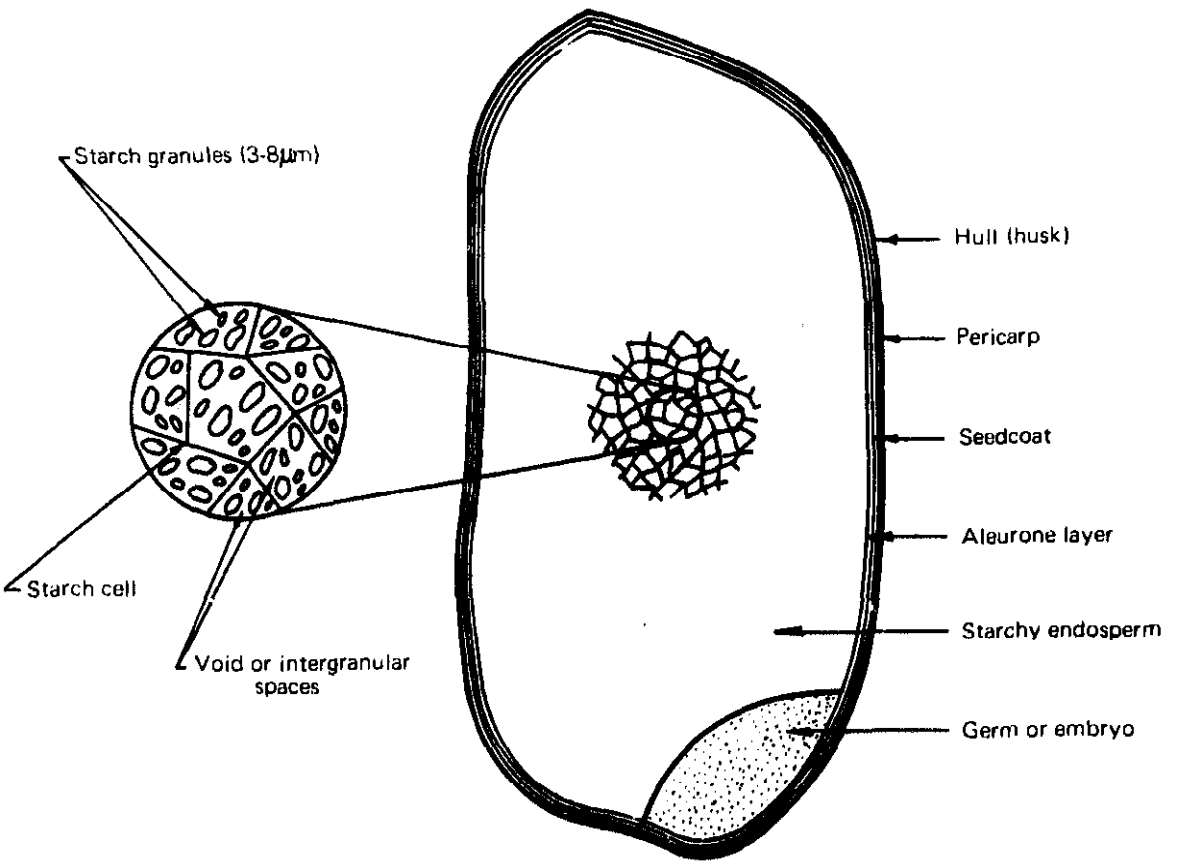

FIG. 94. Diagrammatic representation of the structure of a paddy grain in longitudinal section.

boldi 1965; Jones and Taylor 1933; Jones et al. 1946; Matz 1959; Mazumdar et al. 1960; Roberts et al. 1954; Shivanna 1971).

Premilling Treatments

Because the milling process has long been known to remove much of the vitamins and minerals from the grain, different types of premilling treatments of paddy have been devised to improve its milling, nutritional, cooking, and keeping qualities. The rice obtained from milling pretreated paddy is known as parboiled rice; whereas, the rice obtained from milling untreated paddy is known as raw rice or white rice. The different premilling treatments are described below.

Atapa

In the atapa treatment, which was originated in Bengal, India, paddy is soaked in water at room temperature for 24 h and then dried in the sun (hence the name atapa, or sun dried). The dried paddy is then milled by the traditional milling equipment, mortar and pestle, or in a husking mill (huller). During milling many of the grains are broken.

Balam

This treatment, which was also developed in Bengal, India, is slightly better than atapa because the paddy is sprinkled with hot water, which inflates the grain due to sudden thermal expansion. When the paddy is dried in the sun and milled, the hull is easier to remove.

Josh

During the josh (boiling) treatment, developed in Larkhana, Pakistan, the paddy is first sieved to remove the dirt. Large earthen pots filled with cleaned paddy and water are placed on a 15-cm layer of hull that is used as fuel. The pots are then heated, and remain on the fire all night. The next day the water is drained and the paddy is subjected to a second heating in shallow iron pans placed on the fire for 1 h. The paddy is then taken out of the pans and dried in the sun. Sometimes, soaking is done in iron tubes instead of in earthen pots. In this case, the water in the tubes is first heated to the boiling point and the fire is removed. The cleaned paddy is put in the tubes for 8 h. The water is then drained and the paddy is heated in shallow iron pans and dried as described earlier. Because the rice is semicooked, the hull easily separates in milling and there is no breakage of grains. In addition, it is claimed that such rice has better keeping quality.

Sela

In this treatment, which was originated in Saharanpur, India, paddy is soaked in water at room temperature for 24–48 h and then gently roasted in hot sand (80–90 °C). Experience is required for judging the correct temperature of the sand and the duration of roasting. The heat supplied should be just sufficient to evaporate the moisture from the wet paddy without causing parching of the rice. The roasted paddy is then further dried in the sun and milled.

Siddha

In the Siddha treatment, originated in Bengal, India, paddy is soaked in water at room temperature for 24 h, boiled for a few minutes, dried, and milled. In this method, rice from over-soaked paddy becomes dark-coloured; rice from over-boiled paddy becomes coarse in appearance; and rice from over-dried paddy shows poor milling quality.

Parboiling

Parboiling is one of the latest well-developed premilling treatments given to paddy to improve its quality. The different modifications parboiling made to the product were considered merely accidental; however, after the

introduction of mechanical milling, parboiling not only survived but even began to spread all over the world because of its economical and nutritional advantages (Gariboldi 1972; Kurien 1964).

Very little is known about its origin; however, since early times paddy has been treated with cold or hot water and dried before hand-pounding or milling. Parboiling may originally have been used merely for a hygienic treatment to clean the threshed grain, or because of its hardening effect and the consequent improvement in milling quality, or a combination of these (Kisan Krishi Yantra Udyog 1972; Kuppuswamy 1972). There is no record of who first discovered the process but there is no doubt that parboiling was being practiced in India long before it was known to other parts of the world (Ghose *et al.* 1960). Parboiling has been practiced in the United States, Italy, and British Guiana on a commercial scale since 1940 (Matz 1959).

Basic Concept of Parboiling

Before describing the various advantages, disadvantages, methods, equipment, and the quality of parboiled rice, let us first consider the structure of a paddy grain itself. Figure 95 shows cross sections of raw and parboiled rice (International Rice Research Institute 1969). The endosperm, which constitutes the major volume of the rice grain, is mainly composed of polygonal starch granules. The voids or intergranular spaces are filled with air and moisture. The presence of voids, fissures, and/or cracks, developed during maturity, causes breakage of rice during milling. This breakage may be eliminated by gelatinizing the starch, which fills the voids and cements the fissures and cracks.

Swelling of Starch

The starch granules may be swelled by soaking the paddy in water. During soaking, water penetrates into starch granules, forms hydrates by hydrogen bonding, and causes swelling. Starch granules exhibit only a limited capacity for absorbing water, and swelling in cold water is due to the presence of hydrogen bonds between the amylose and amylopectin fractions of the starch. During hot soaking, energy supplied in the form of heat weakens the granule structure by disrupting the hydrogen bonds; therefore, more surface area is available for water absorption by the starch granules. This permits further hydration and irreversible granule swelling caused hy the increase in the number of dissociated water molecules. This phenomenon is called gelatinization of starch. The temperature at which gelatinization takes place is known as the gelatinization temperature and is specific for each variety. At the end of the gelatinization process, the paddy has acquired a moisture content of about 45–50% and must be dried before further processing. (All moisture content valves quoted here are expressed on a dry basis.) The starch in the paddy grain may be gelatinized by either of two methods: (1) the paddy may be soaked in water at or above its gelatinization temperature for a time, which depends on the variety; or (2) the paddy may be soaked in water at or below its gelatinization temperature for some time to facilitate the uniform hydration of the rice kernel, and then heated to produce irreversible expansion and fusion of the starch granules. The heat should be moist, or the soaked paddy will start to dry. The best source of this heat is steam. This method is commonly used in practice.

Chemical Composition of Rice

Chemical analysis of rice shows that most of the nutrients, which are concentrated in the outer layers (bran and polish) of the rice kernel, are lost during milling (Houston and Kohler 1970). This loss of nutrients may be reduced to a certain extent either by consuming shelled or under-milled rice, or by making some of the nutrients present in the outer layers penetrate the kernel, so that they are not removed during milling. The former is not advisable because of consequent digestion trouble; however, if the paddy is soaked in water and subsequently steamed, the water soluble nutrients may be retained to some extent in the kernel.

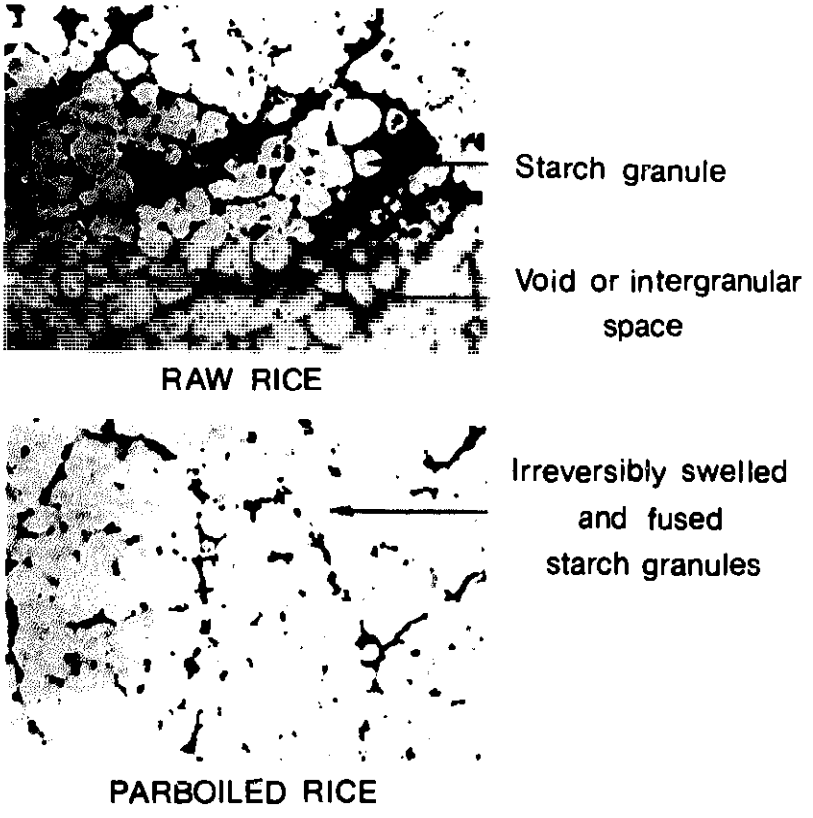

FIG. 95. Cross section of rice endosperm.

It may, therefore, be concluded that to minimize the breakage of rice and reduce the loss of nutrients during milling, the paddy should be soaked, steamed, and dried before milling. This premilling treatment of paddy is known as parboiling. The major objectives of parboiling are to: (1) increase the total and head rice yield of paddy; (2) prevent the loss of nutrients during milling; (3) salvage wet or damaged paddy; and (4) prepare the rice according to the requirements of consumers in certain parts of the world.

Advantages and Disadvantages of Parboiling

The parboiling process, developed by tradition in India and improved by various researchers, provides a unique tool for improving not only the milling quality but also other qualities of paddy. In general, the parboiling process has the following advantages: (1) shelling of parboiled paddy is easier because the husk is split during parboiling; (2) the extra strength acquired by the rice kernel during parboiling helps reduce the number of brokens; (3) parboiled rice retains more proteins, vitamins, and minerals than raw milled rice of the same variety; (4) parboiled rice, because it is harder, is more resistant to insect infestation during storage compared to raw rice; (5) the loss of solids into the gruel during cooking is less in parboiled rice compared to raw rice; (6) parboiled rice withstands overcooking without becoming pasty; and (7) the bran from parboiled rice contains about 25–30% oil; whereas, raw rice bran contains about 15–20% oil. The heat treatment of paddy during parboiling destroys, to a certain extent, the lipase enzyme that is responsible for the hydrolysis of oil (development of free fatty acids); therefore, the oil is of a superior quality because it has a lower concentration of free fatty acids (FFA).

Parboiling has the following disadvantages: (1) heat treatment during parboiling destroys some natural antioxidants; therefore, parboiled rice develops more rancidity than raw rice during storage; (2) parboiled rice takes more time to cook to the same degree of softness than raw rice, and may develop a taste, texture, and characteristic flavour and colour not liked by many raw rice eaters; (3) because the parboiled paddy has a high moisture content for a long time, mycotoxins that are hazardous to human health may develop; (4) parboiled paddy must be dried from 45–50% to 14–16% moisture for proper milling and storing, which adds an extra drying cost to the total processing cost; (5) shelled parboiled rice is more difficult to polish because it is harder, and consequently the mill throughput capacity is lowered and the milling power requirement is increased; (6) parboiled paddy may choke the polisher because of the higher oil content of the bran; and (7) the parboiling process needs an extra investment of capital.

In spite of these disadvantages, the higher outturn of total rice (about 1–2%) as well as head rice brings in additional profit to the miller and at the same time ensures a lower price to the consumer (Central Food Technological Research Institute 1969). The comparative production cost of parboiled rice using one of the modern methods (Kisan Krishi Yantra Udyog 1972) is presented in Table 28 to illustrate the economic benefits that can be obtained from parboiling. Table 28 shows that the cost of production of parboiled rice is less than that of raw rice. The difference is about 5 paise/kg of rice produced. Nearly 50% of the total paddy produced in India is parboiled; therefore, there is scope for saving approximately Rs. 1000 million annually.

Characteristics of the Paddy for Parboiling

The paddy varieties preferred for parboiling are those that are the most brittle because of the soft structure of their endosperm and those that give a low output after milling because of special conditions associated with cultivation, harvesting, and drying. Varieties

TABLE 28. Comparative production costs for 1 t of raw and parboiled rice (Kisan Krishi Yantra Udyog 1972).

	Cost of raw rice (Rs.)	Cost of parboiled rice (Rs.)
Cost of paddy	500.00	500.00
Incidentals, transport, handling, etc.	12.00	12.00
Depreciation in gunny bags (6 times reused)	6.00	6.00
Charges for drying	10.00	—
Charges for parboiling and drying	—	18.00
Milling charges	23.00	23.00
Total cost:	551.00	559.00
Less realization from by-products:		
Brokens in raw rice (60 kg, @ Rs. 600/t)	36.00	—
Raw rice bran (29 kg @ Rs. 350/t)	8.75	—
Parboiled rice bran (28 kg @ Rs. 450/t)	—	12.69
Net cost of rice realized	506.25	546.40
Cost per kg (raw rice 620 kg and 60 kg brokens; parboiled rice 710 kg)	0.82	0.77
Packaging charge	0.02	0.02
Total cost per kilogram:	0.84	0.79

NOTE: (1) there is a difference in cost of 5 paise/kg of rice produced; and (2) assuming that about 50% of India's rice is parboiled there is scope for saving at least Rs. $50 \times 20 \times 10^6$ = Rs. 1000 million/year.

that are long and slender are usually parboiled because they are fragile compared with short or medium length grains, which stand up better to the ordinary milling process (Gariboldi 1972). Scented and fine varieties, which have good milling quality, are generally not parboiled.

Some characteristics of the paddy affect the final product both quantitatively and qualitatively (Gariboldi 1972): (1) the presence of partially or fully shelled grains, which may be destroyed or misshapen by the process, cause the parboiling plant to function irregularly; (2) the awn and hairiness of the husk may make the soaking operation difficult because of the tendency of the grains to float on the surface of the water, which produces scum and other waste materials; (3) the pigmentation of the husk and pericarp may be dissolved during the soaking and steaming operations and deepen the colour of the endosperm; (4) bacterial infestation may cause a partial or total darkening of the endosperm; and (5) even minute injuries on the seed, caused either mechanically or by insects, may lead to partial discoloration of the parboiled rice.

Parboiling Process

Parboiling of paddy is a hydrothermal process that may be defined as the gelatinization of starch within the rice grain. During the process, an irreversible swelling and fusion of starch granules occurs that changes the starch from a crystalline form to an amorphous one. As a result of this transformation, the orderly polyhedral structure of the compound starch granules changes into a coherent mass (Raghavendra Rao and Juliano 1970).

Parboiling of paddy requires three steps: soaking, steaming, and drying (Fig. 96). In the soaking process the void spaces in the hull and rice kernel are filled with water, and the starch granules absorb water and swell, which causes an increase in the volume of the paddy (Ali and Pandya 1974). During steaming, soaked paddy is exposed to steam heat for a given duration and the starch present in the rice kernel is gelatinized. Subsequently, the paddy is dried to 16% moisture content, which imparts the hardness that the grains require for milling.

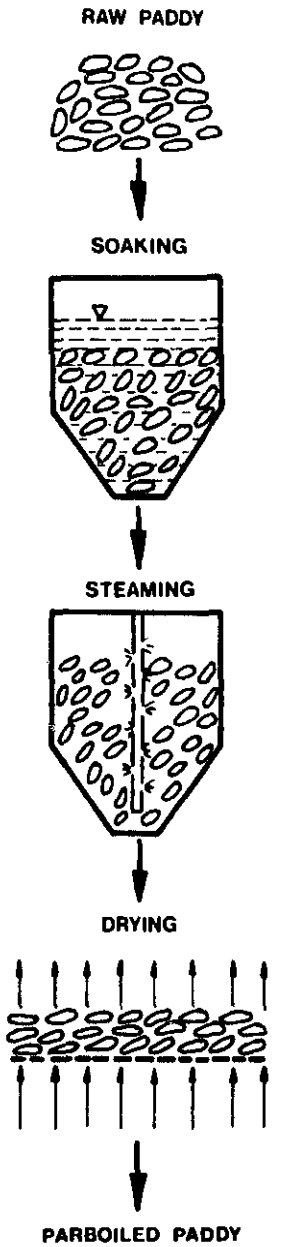

FIG. 96. The three steps required for parboiling.

Physicochemical Changes During Parboiling

The most notable change during parboiling is the gelatinization of starch and the disintegration of protein bodies in the endosperm

(Raghavendra Rao and Juliano 1970). As a result, the starch and protein expand and fill the internal air spaces. The starch granules are closely appressed, which creates strong cohesion between them. Both fissures and cracks present in the endosperm are s d, making the grain translucent and hard and tough enough to withstand milling stresses. This increases the total yield of edible rice and minimizes the number of broken grains.

The colour of the rice changes from white to a yellow or yellowish brown depending upon the different process variables, such as paddy variety, soaking temperature and time, steaming pressure and temperature, and other postharvest factors that will be discussed later. There is little colour difference between raw and parboiled rice after cooking; however, parboiled rice takes a little longer time to cook to the same degree of softness than raw rice of the same variety.

Less protein and starch are lost from parboiled rice into the cooking water (Raghavendra Rao and Juliano 1970). The diffusion and heat-sealing of B-vitamins and other water soluble nutrients into the endosperm during parboiling and the lesser removal of bran during polishing enhance the nutritive value of parboiled rice. The presence of vitamin E is particularly noted in parboiled rice (Borasio and Gariboldi 1965). Slight dextrinization of the starch and destruction of the lipase enzyme occurs during parboiling (Kisan Krishi Yantra Udyog 1972). The presence of dextrins aids in digestion of cooked parboiled rice and contributes to the agglutination and firmness of the cooked product. However, the heat treatment during parboiling causes destruction of some natural antioxidants, and may result in increased rancidity of parboiled rice during storage.

Principles of Parboiling

Theoretically, soaking of paddy can be done at, or below, its gelatinization temperature. The lower the temperature used, the slower is the process of soaking and vice versa (Ali and Pandya 1974; Bhattacharya and Subba Rao 1966*a*). However, the temperature should not be more than 75 °C, or the paddy will be cooked. Soaking time can be reduced by subjecting the paddy to vacuum for a few minutes before soaking and/or by soaking under pressure in hot water.

Heat for gelatinization of the starch is supplied by saturated steam. The higher the temperature of the steam and the longer the steaming time, the harder the rice and the darker its colour. Keeping steamed paddy in a heap is equivalent to prolonged steaming and induces the same effect.

Parboiled paddy may be dried in the shade, in the sun, or with hot air. Shade drying takes longer but gives an excellent milling quality. Rapid drying in the sun or with hot air causes higher breakage during milling. In continuous drying, breakage starts as the moisture content reaches about 18% and increases rapidly with further drying (Bhattacharya and Indudharaswamy 1967). Therefore, the most efficient practice would be to dry in two passes, with a tempering period, to a moisture content of about 20%.

Soaking of Paddy

Paddy, being a hygroscopic material, can absorb water both as a vapour and as a liquid, and thereby swells. The process of simultaneous water absorption and swelling is known as soaking, steeping, or imbibition. It is basically a diffusion process. The movement of water into the paddy will continue as long as the vapour pressure inside the grain is less than that of the soak water and will stop when equilibrium is reached.

Two conditions appear to be necessary for soaking: (1) a certain affinity must exist between absorbent and absorbate; and (2) a diffusion pressure gradient must exist between the water vapour of the absorbent and that of the material to be imbibed. The diffusion pressure of dry paddy is practically zero; therefore, when it is immersed in water, a steep diffusion pressure gradient is established and water moves rapidly into the grain.

Mechanism of Soaking

Soaking is the result of different phenomena, such as, molecular absorption, capillary absorption, and hydration (Ali and Ojha 1975*a*). During soaking of paddy, water molecules first adhere to the surface of the hull and then penetrate through the micropores of the hull into the rice kernel where they may be retained in voids or intergranular spaces due to capillary absorption. Some of the water molecules will be absorbed by starch granules; whereas, others will enter into the lattice of the starch molecule where they will be held as water of hydration. Experimentally, it is very difficult to determine precisely what percentage of the moisture content is held by each of the different phenomena (Mohsenin 1968).

Volume and Energy Changes

There is always a concomitant increase in the volume of paddy with soaking. However, the final volume of the soaked paddy is always less than the sum of the initial volume of paddy and the volume of the water absorbed (Ali and Ojha 1975; Mohsenin 1968). This is due to the fact that some of the absorbed water occupies the minutes spaces in the paddy grain and, therefore, produces no swelling. Moreover, the absorbed water molecules are held with a greater force on the absorbing surface and occupy less space than when in the free state.

The soaking process always results in the release of heat. When water molecules are absorbed a considerable amount of their kinetic energy is lost as heat. The maximum evolution of heat occurs during the initial stage of soaking because a large portion of the water absorbed in the beginning is more firmly absorbed than water absorbed later. However, the actual temperature increase during soaking of the paddy is very small and may be disregarded (Ali and Ojha 1975*a*).

Amount of Water Absorbed

When soaking paddy, it is generally desirable to know the amount of water that has been absorbed at a particular temperature over a given time. Soaking involves diffusion of water into a swelling medium accompanied by immobilization of diffusion substances. In some cases leaching is also involved.

The relationship between moisture content of the paddy at different soaking temperatures and time indicates a direct relationship between the temperature used and the rate of the process (Fig. 97). Initially, the rate of soaking is very high at all temperatures, but it gradually decreases with increased soaking and tends to zero at soaking temperatures of 30 and 60 °C as shown in Fig. 98 (Ali and Ojha 1975*a*). However, at temperatures equal to or greater than the gelatinization temperature, following gelatinization of the starch and bursting of the grain, the soaking rate again increases. After some time, the rate decreases and comes to zero when the starch reaches its equilibrium moisture content.

The rapid rate of water uptake at the beginning of soaking is due to three reasons: (1) the hull absorbs water very quickly and becomes saturated; (2) the space between the hull and the rice kernel becomes filled with water immediately after the commencement of soaking; and (3) the capillary action of the shallow pores in the pericarp causes rapid absorption. The slow increase in the moisture content of the paddy after the initial stage of soaking suggests that the absorption of water by the kernel itself proceeds more slowly.

The dependence of soaking rate on temperature may possibly be explained as follows: (1) Air in the pore spaces of the paddy grain, which resists water entry, expands and leaves the pore spaces with the rise in temperature; therefore, water can replace the air in the pore spaces; (2) Water is a dipole compound and is regarded as a polymer of hydrogen bonded water molecules. As the water becomes warmer, more and more of the hydrogen bonds are broken. Therefore, with a rise in soaking temperature, the hydrogen bonds in the water and the hydrogen bonds in the starch granules, which hold the micellar structural units together, tend to dissociate. The smaller dissociated water molecules at a high energy level are, therefore, able to permeate the weakened starch structure and gradually hydrate many of the hydroxyl groups of the

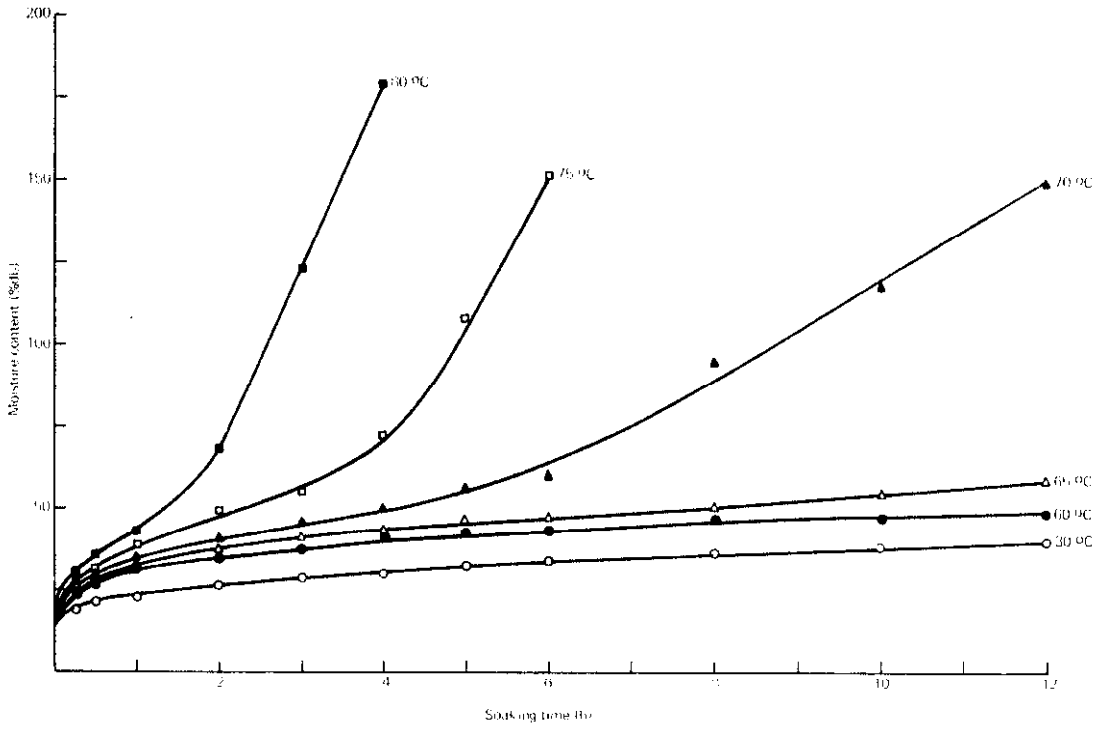

FIG. 97. Soaking curves for IR8 at different temperatures.

starch molecules; (3) Absorption of water by paddy is a diffusion process and depends on a diffusion coefficient that increases with the rise in temperature because of changes in some of the properties of water, such as, vapour pressure, viscosity, density, and surface tension. Therefore, soaking proceeds at a faster rate at higher temperatures and vice versa. Figure 99 shows that the absorption of water by paddy proceeds in two distinct phases. The first phase of soaking continues until the paddy gains 24–45% moisture, depending upon the soaking temperature. The second phase starts after this. Paddy absorbs water very slowly when soaked below the gelatinization temperature (30 and 60 °C) and reaches an equilibrium moisture content (Fig. 100), but at higher temperatures, when the paddy grains reach 40–45% moisture content, the grains start to burst and the rate of soaking becomes very fast. The moisture content of the paddy when the first phase of soaking ends and the second phase starts may be defined as the critical moisture content in soaking. Its value depends both on the soaking temperature and the variety of the paddy (Table 29).

TABLE 29. Average value of the critical moisture content (dry basis) of different varieties of paddy during soaking at various temperatures (Ali and Ojha 1975*a*).

Soaking temperature (°C)	IR8	Patnai-23	Sitasal
30	40	40	36
60	45	42	42
65	59	43	45
70	60	45	45
75	60	58	57
80	53	57	52

Varietal Differences in Soaking Characteristics

The soaking curves of different varieties of

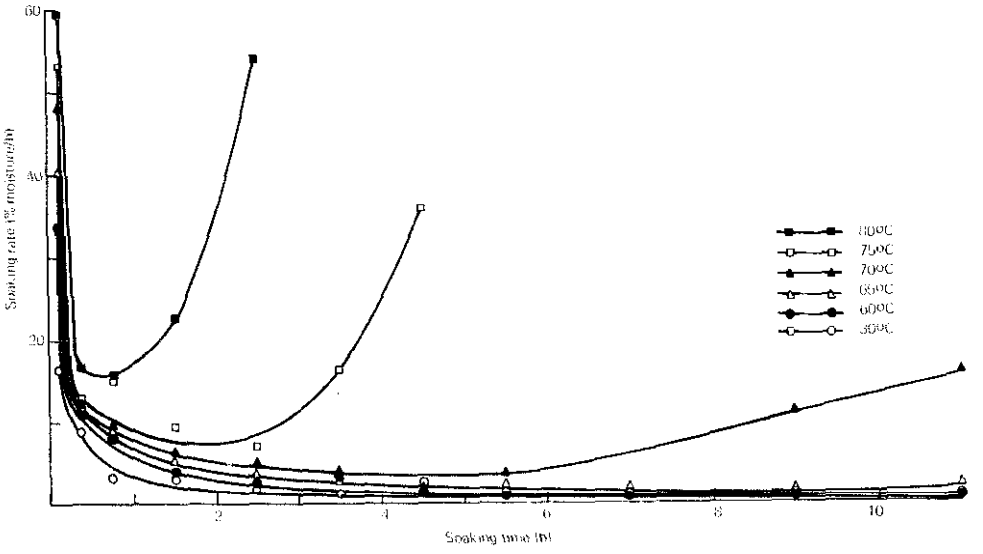

FIG. 98. Soaking rate versus time for IR8 at different temperatures.

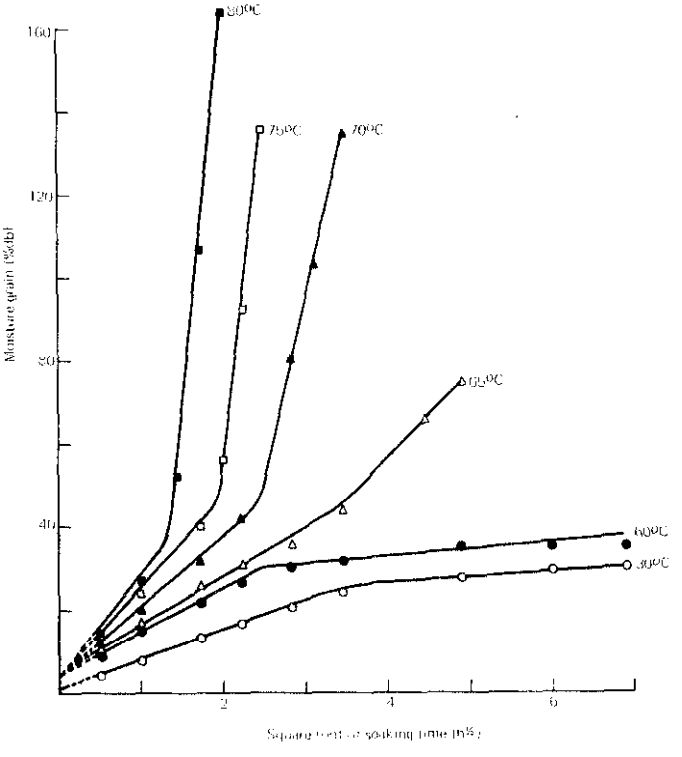

FIG. 99. Moisture gain of IR8 as a function of square root of soaking time at different temperatures.

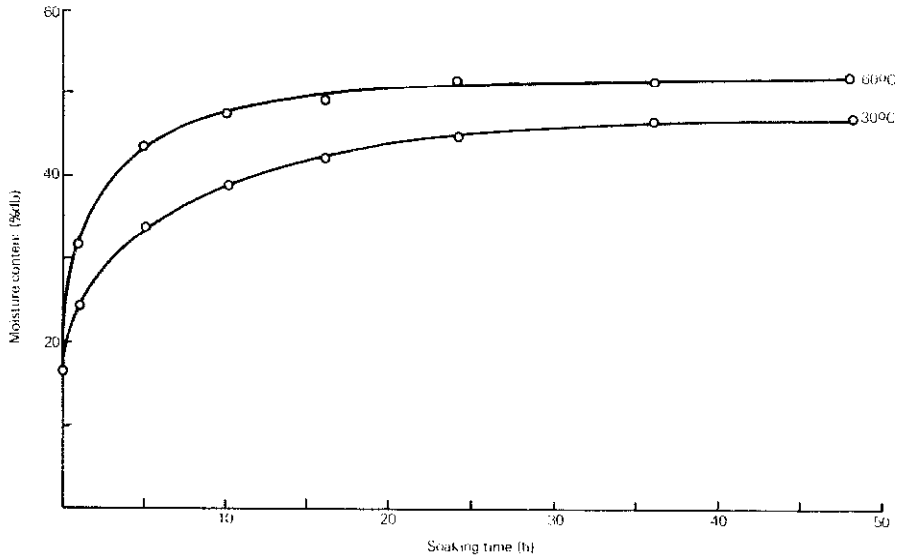

FIG. 100. Moisture content versus soaking time for IR8 at 30 and 60 °C.

paddy are similar to IR8. However, in a study of three varieties, the rate of soaking was IR8, Patnai–23, and Sitasal for all soaking temperatures (Ali and Ojha 1975*a*). This may be due to differences in the gelatinization temperatures and the physical characteristics of the grains. From the soaking curves it was inferred that the gelatinization temperature of IR8 was in the range of 65–70 °C; whereas, the gelatinization temperature of the other two grains was in the range of 70–75 °C. The soaking rate of paddy shows up varietal differences and indicates the importance of testing the soaking characteristics of each variety.

Initial Moisture Content Versus Water Absorption

Experimental results (Ali and Ojha 1975*a*) show that the initial moisture content of the paddy does not affect its soaking characteristics. Although differences may exist in the initial moisture content of the paddy, the differences decrease with soaking time. Therefore, after the paddy is soaked for 2.5, 4, and 24 h at temperatures of 80, 70, and 30 °C, respectively, the moisture content of the paddy is practically the same irrespective of the initial moisture content. This shows that a difference of 5–10% in the initial moisture content of the paddy may not make any difference to the optimum soaking time required during parboiling. Therefore, different lots of paddy with different initial moisture contents can be mixed safely for parboiling without any loss in quality or quantity.

Swelling of Paddy

Soaking of paddy is always associated with an increase in volume. The change in volume of paddy at different moisture contents was calculated by the method of Ali and Pandya (1974). The moisture content of the paddy was increased by soaking it in water at 70 °C, which is the most common temperature used for soaking in the modern methods of parboiling.

The swelling curve (Fig. 101, curve A) extrapolates to zero at zero moisture content and also indicates that the swelling increases at a relatively slow rate up to about 50% moisture content and then increases at a higher rate. The comparatively slow increase in the volume of paddy during the first phase of soaking may be due to two reasons: (1) part of the water absorbed may be utilized in wetting the hull and filling the space between the hull and the pericarp and in filling the pore spaces in the endosperm; therefore, the water pro-

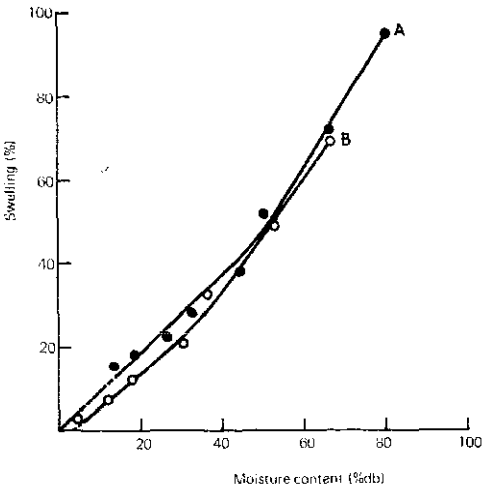

FIG. 101. Relationship between swelling and moisture content for IR8.

duces only a very small increase in the volume of paddy; and (2) a considerable amount of the water is held by molecular absorption and because of this, an absorption compression occurs that causes a decrease in the total volume of the paddy-water aggregate (Mohsenin 1968). The higher rate of swelling above 50% moisture may be due to the bursting of the grain, which exposes more of the kernel area to water and enables the paddy to absorb more moisture. At higher moisture levels, increases in the moisture content of the paddy result in approximately equivalent volume increases (Mohsenin 1968).

When percentage swelling is plotted as a function of moisture gain, by considering the initial moisture content of paddy to be zero moisture gain and by calculating the amount of swelling based on the volume at the initial moisture content, the curve does not extrapolate to zero at zero moisture gain (Fig. 101, curve B). This is contrary to curve A (Fig. 101). This can be explained by considering the paddy grain at zero moisture content to be in a shrunken state. As the moisture content of the paddy increases, the hull and pericarp expand until they reach more or less their normal size, which is their size when the moisture content is in equilibrium with the atmospheric conditions. This moisture content generally varies from 10 to 20%, depending upon the atmospheric temperature and relative humidity. At this stage, further increases of 4–5% in the moisture content may not produce any noticeable swelling because the paddy is at its normal size and resists any change in its dimensions. As the moisture level continues to rise, the paddy swells and increases in size until the hull splits to relieve the stresses caused by the increasing swelling force. After this, the swelling proceeds as explained earlier.

Steaming of the Soaked Paddy

The use of steam for gelatinizing the starch in the paddy grain is preferable to other methods of heating because it does not remove moisture from the soaked paddy, rather it adds moisture by condensation, which increases the total moisture content of the grain (Gariboldi 1972). The other advantages of steam are that its high heat content is applied at constant temperature, it is sterile, and it can be used to produce power before it heats the paddy. During steaming, the following points should be considered (Gariboldi 1972): (1) whether the steam is saturated or superheated; (2) the pressure of the steam, which determines the temperature at which heat is transmitted; and (3) the steaming time, which determines the total heat supplied to the paddy to cause the gelatinization of the starch.

The total amount of heat applied to the paddy is equal to the heat provided by the soaking and steeping water plus the heat derived from the condensation of steam during the steaming operation.

The temperature of the steam has a considerable effect on the colour of the rice although the causes are not yet fully understood. Apart from the spread of colouring pigments contained in the husk and bran, it seems that colouring of the endosperm is caused by absorption of reducing sugars that react with the amino acids, and by fusion of the aleurone layers of the endosperm with the starchy core (Gariboldi 1972). However, by steaming the paddy with nonpressurized steam (at 100 °C), as in the traditional oriental methods, only small variations are found in the colour and quantity of soluble starch and in the amount of swelling of the milled parboiled rice (Gariboldi 1972).

Generally, saturated steam at a pressure of 1–5 kg/cm^2 is used for steaming the soaked paddy in the different methods of parboiling (Bal et al. 1974). The duration of steaming is dependent upon the quantity of paddy to be steamed. For small batches steaming takes 2–3 min; whereas, larger batches of about 6–8 t take about 20–30 min (Bal et al. 1974). It has been reported that splitting of the husk can be taken as an indication of completion of the steaming process (Agrawala 1963; Central Food Technological Research Institute 1969; Ghose 1963; Jones and Taylor 1933; Jones et al. 1946; Mecham et al. 1961) although it is not a necessary condition and the paddy can be properly parboiled without any splitting of the husk (Bal et al. 1974).

The steam requirement per tonne of paddy parboiled in a modern parboiling plant using steam at a pressure of 4–5 kg/cm^2 is about 120 kg for soaking, 60 kg for steaming, and 20 kg in losses (Bal et al. 1974; Central Food Technological Research Institute 1969).

Drying Characteristics of Steam-Parboiled Paddy

Drying of steam-parboiled paddy is essential for proper milling and storing, but it is different from drying raw paddy because the steamed paddy has a high moisture content (45–50%) and is hot. The main aim of the drying process is to reduce the moisture content to 14–16% without causing cracks or stresses in the rice caryopsis, which may lead to breakage during milling.

The manner in which this excess moisture is removed is of considerable importance. If the moisture is removed at a very slow rate, microorganisms will grow and partially or fully spoil the parboiled paddy. On the other hand, if drying is done rapidly and continuously, cracks may develop and the rice will break during milling. However, if parboiled paddy is uniformly dried by any means (shade, sun, or hot air), practically no breakage will occur. Improper drying conditions may result in as high as 100% breakage; therefore, parboiled paddy should be dried with great care.

It has been reported (Bhattacharya and Indudharaswamy 1967; Central Food Technological Research Institute 1969) that drying of parboiled paddy in the shade will give less than 1% brokens; however, if the same paddy is dried rapidly in the sun or by hot air to the same moisture level, enormous breakage (20–100%) may occur. It is, therefore, the rate of drying that is the main factor that controls the breakage of rice.

When parboiled paddy is dried rapidly, a steep moisture gradient develops between the surface and the centre of the kernel. This sets up a stress, and at a certain stage the kernel relieves the stress by cracking. These cracks are irreversible and set up lines of weakness, along which fractures easily occur under the mechanical stresses of milling. This behaviour is also observed in the drying of raw paddy.

During drying, two points are of great importance. First, breakage does not occur throughout the drying process. It occurs only when the moisture content reaches and then crosses 18% (Bhattacharya and Indudharaswamy 1967), no matter how fast the drying (Fig. 102). After that, breakage increases sharply. Second, the cracks do not develop during drying, but over a period of 2 h after the drying has been terminated (Bhattacharya

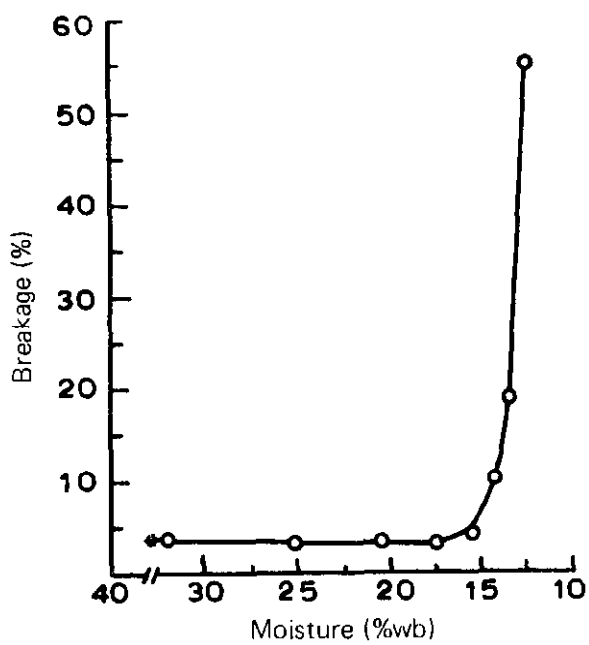

FIG. 102. Change in milling quality of parboiled paddy during continuous drying in an LSU drier.

and Indudharaswamy 1967). Drying of parboiled paddy should be done in two passes to avoid the breakage of rice during milling, although some successful experiments have been carried out in which the parboiled rice was dried until the moisture content was low enough for milling (Bhattacharya and Indudharaswamy 1967; Rama Rao and Bal 1973). In actual practice the two methods that are commonly used are sun drying and mechanical drying.

Sun Drying

Drying of parboiled paddy in a drying yard using the sun's energy is widely practiced by both conventional rice mills and small scale farmers. Through experience and practice over the decades, the process has been developed into a highly skilled and efficient method of large scale drying in spite of major drawbacks, such as, dependence on weather conditions and inherent losses during the drying operation (Bhattacharya and Ali 1970).

In India, as well as in most of the Asian countries, drying is carried out on large paved yards attached to the rice mills. A large number of workers constantly turn and mix the paddy with a number of indigenous wooden implements to achieve rapid and uniform drying.

The paddy is normally steamed in the evening and kept on the drying floor in equally spaced heaps of about 2 quintals (200 kg). Early the next morning, the paddy is spread to a thickness of 2–3 cm on the drying floor with a wide wooden board. After spreading, the paddy is continuously and systematically stirred and turned: (1) the spread paddy is raked into long ridges 20–30 cm high by the wooden spade to turn the paddy; (2) the paddy is thrown in either direction from the ridges to distribute the paddy uniformly over the drying area; (3) the paddy is spread by feet and then combed and stirred by a spiked plank that levels the paddy layer uniformly over the drying floor; and (4) the uniformly levelled paddy is turned by foot.

During these operations, the grain is continually mixed; therefore, each grain gets approximately equal exposure to the sun. These operations are repeated until the paddy is evenly dried to a moisture content of about 18–20%. Then the paddy is heaped and covered with mats or with thick caps made of straw and tempered for about 2–3 h. The tempered paddy is again spread and dried for about 1–2 h in the evening to complete the drying to 14–16% moisture content. The dried paddy is heaped on the drying floor, covered with straw caps or a tarpaulin, and left in the yard overnight. The next morning, the paddy is put into gunny bags and transported to the rice mill.

In hot and dry weather the paddy dries in a few hours, while in cold, cloudy, or humid weather it may take 2 days. During the night, or when rain comes, the paddy is heaped and covered. Depending on its size, a mill can handle 20–100 t of paddy this way every day (Bal et al. 1974).

Figures 103 and 104 show the general nature of moisture removal from the grain during sun drying. The total drying time is about 6–7 h during summer, and about 9–10 h during winter due to shorter day length and weaker radiation from the sun. The effect of tempering may be distinctly seen in Fig. 103. The grains are tempered for about 2–3 h after 5 h of drying in the sun. There is a steep increase in the moisture content of the grain after tempering because of migration of moisture from the inside to the surface of the grain.

Figure 104 shows the rate of moisture removal with respect to drying time. This curve is similar to the one obtained for hot air drying and shows two distinct zones of drying: (1) a zone of constant rate drying, which is limited to just 1 h of drying and a zone of first falling rate of drying (C–D); and (2) a zone of second falling rate of drying (D–E).

Grain temperature closely follows floor temperature (Fig. 105). The grain temperature was approximately 2 C° lower than the floor temperature, and the maximum grain temperature observed was 36.5 °C. High grain temperatures can cause cracks in the kernel; however, it appears that the parboiling process hardens the rice kernel so that the high grain temperature during the drying process does not produce cracks in the kernels.

The milling quality of parboiled paddy is not

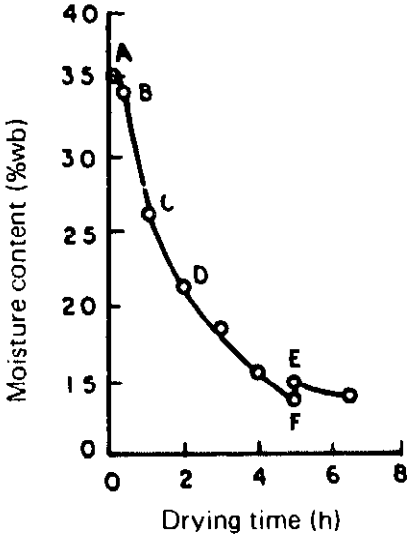

FIG. 103. Variation of moisture content of paddy with drying time (sun drying): AB = heating period; BC = constant rate period; CD = first falling rate period; DE = second falling rate period; and EF = tempering for 2.5 h.

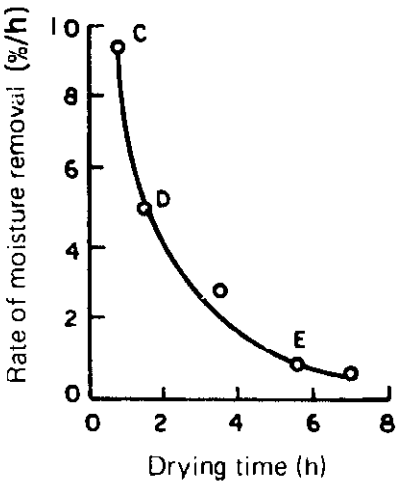

FIG. 104. Variation of drying rate with drying time (sun drying): CD = first falling rate period; and DE = second falling rate period.

affected by sun drying. A total yield of 72.5% and a head yield of 69% are the average figures for milling quality of parboiled paddy. Therefore, sun drying seems to be an effective means of drying parboiled paddy wherever facilities for the process are available. Further improvements in both techniques and facilities, which

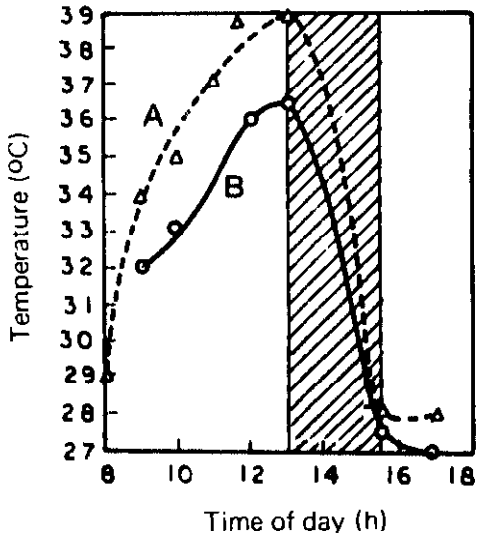

FIG. 105. Variation of grain temperature and floor temperature with time of day (sun drying): tempering from 13:00 to 15:30; A = drying floor temperature; and B = grain temperature

are based on scientific studies, are desirable to make this method more effective.

Case studies conducted by the Rice Process Engineering Centre at various commercial rice mills have shown that the total time required to dry parboiled paddy is 8–10 h in summer and 13–15 h in winter (Bal et al. 1974). They have also indicated that one female labourer can comfortably handle about 1 t of paddy during the drying operation. From these studies, the cost of drying was calculated to be about Rs. 9–10/t of dried paddy. They assumed that about 0.2% of the paddy was lost to birds, rodents, and insects and corrected for this loss in their estimate of the drying cost.

Mechanical Drying

Mechanical drying of parboiled paddy is of quite recent origin. Hot air is forced through the grain, which evaporates and carries away the moisture. Louisiana State University (LSU) continuous flow driers are usually used for drying parboiled paddy. The air is heated by an oil burning furnace or a steam heat exchanger. In India, most of the rice mills are now using the husk as fuel for generating the steam. The steam generated by burning the

husk obtained during milling is sufficient for the parboiling and drying operations (see "Estimate of Heat Required for Parboiling").

Very little research has been done on the drying of parboiled paddy; therefore, the present method of mechanical drying is based on the cumulative experience of the engineers and operators who operate the mechanical driers under different processing conditions. Presently, the drying of parboiled paddy is done in two passes that are separated by a tempering period. Each pass requires 0.5 h to load the drier, 2 h to recirculate the paddy while the hot air is blown through it, and 0.5 h to unload the drier. During the first stage of drying, the moisture content is reduced from about 50 to 25%. This is followed by 8–10 h of tempering to equalize the moisture within the kernels. The tempered paddy is then dried to 14–16% moisture during the second pass.

Most of the moisture in freshly parboiled paddy is surface moisture. The rate of removal of surface moisture from the grain is dependent upon the evaporating capacity of the drying air, which increases with temperature. However, after removal of the surface moisture, the rate of moisture removal is considerably reduced and depends upon the rate of moisture migration from the centre of the grain to its surface, which depends on the characteristics of the grain. Therefore, an increase in the temperature of drying air at this stage does not increase the drying rate. Unlike drying raw paddy, it is possible to use very high temperatures to dry parboiled paddy because of its increased hardness. To achieve faster moisture removal, drying air at a temperature as high as 120 °C is being used in commercial parboiling and drying plants (Bal et al. 1974). Due to the very high cost of the fuels (furnace oil) used for heating the air, astronomical figures for the cost of drying parboiled paddy (Rs. 50–120/t of paddy) have been reported (Bal et al. 1974). From the results of field experiments conducted by the Rice Process Engineering Centre, a combination of drying air temperatures has been determined to ensure optimum performance of the mechanical drier. To remove the bulk of the surface moisture during the first drying pass, the temperature of the drying air is kept at 95–100 °C. However, during the second drying pass, when moisture from the inner part of the grain is to be removed, the temperature of the drying air should be kept at 75 °C because a higher temperature will not increase the drying rate but will only result in an increased heat loss in the exhaust air.

Methods of Parboiling

The methods of parboiling may be classified into three groups (the name in parenthesis indicates where the method was developed or is being studied):

(1) Traditional methods
  (a) Single boiling
  (b) Double boiling
(2) Modern methods being used
  (a) CFTRI method (Indian)
  (b) Jadavpur University method (Indian)
  (c) Converted process (American)
  (d) Malek process (American)
  (e) Avorio process (Italian)
  (f) Cristallo process (Italian)
  (g) Fernandes process (Surinam)
(3) Modern methods under study
  (a) Brine solution method (Indian)
  (b) Kisan continuous method (Indian)
  (c) Pressure parboiling method (Indian)
  (d) RPEC method (Indian)
  (e) Sodium chromate method (Indian)

Traditional Methods

The traditional process consists of soaking in water at room temperature for 24–48 h or more, steaming in kettles, and drying in the sun. A flow diagram of a traditional parboiling plant is shown in Fig. 106.

Single Boiling Method

Paddy is soaked in ordinary water for 24–72 h and then transferred to cylindrical iron kettles for steaming in small batches under atmospheric pressure. The parboiled paddy is then dried in the sun before milling.

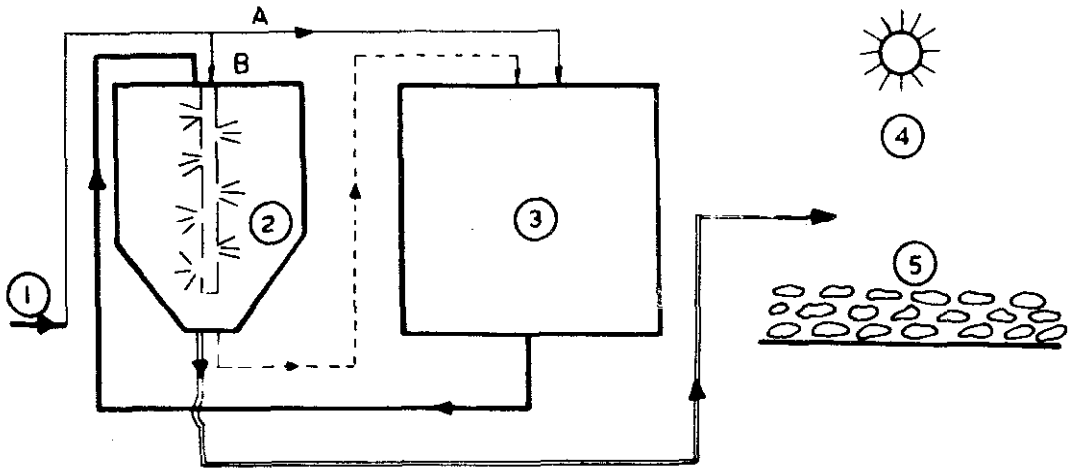

FIG. 106. Flow diagram of a traditional parboiling plant: (A) raw paddy goes to soaking tank directly (in single boiling method); (B) raw paddy goes to steaming kettle for first steaming and then to the soaking tank (in the double boiling method); (1) raw paddy; (2) steaming kettle; (3) masonry soaking tank; (4) sun; and (5) drying yard. Flow path of paddy: ——raw paddy; - - - first steamed or hot paddy; ▬▬ soaked paddy; and ═══ parboiled paddy. Note: handling of paddy is done by manual labour.

Double Boiling Method

In this method, steam is injected into the raw paddy in the steaming kettle before soaking. This hastens the soaking process. The hot paddy raises the temperature of the soak water to 45–50 °C, which reduces the soaking time to 24 h. Thereafter, soaked paddy is steamed as in the single boiling method. Sometimes, the soak water itself is heated to about 50 °C before the raw paddy is dumped into it. In this case, the first steaming of the raw paddy is not required.

The traditional method of parboiling has the following disadvantages: (1) during prolonged soaking, fermentation starts and the paddy acquires a smell; (2) it is conducive to the development of mycotoxins, such as alfatoxins, which are known to be quite harmful to humans; (3) in the process of drying, loss due to manual handling and consumption by birds, rodents, and insects occurs and may amount to about 1.5–2.0%; (4) sun drying is quite uncertain and is dependent on bright sunny weather; (5) sometimes an entire batch of parboiled paddy is spoiled because of delayed drying; (6) unhygienic conditions exist as a result of people treading on the paddy and contamination by dust and birds; (7) it requires a large area of land for drying; and (8) its labour requirement is high.

The main hazards that can be expected in traditional methods are the retention of a fermented smell in the parboiled rice after milling and the possible development of mycotoxins. However, parboiled rice is always good in other aspects. The modern methods being used in different countries have been very successful in overcoming the above limitations.

Modern Methods Being Used

CFTRI Method

This is one of the modern methods of parboiling paddy employed in India, Pakistan, and Ceylon. It was introduced by the Central Food Technology Research Institute (CFTRI), Mysore, India, in the mid-fifties. Large scale adoption of this method and production of parboiled paddy were started with the introduction of mechanical driers (LSU-type) in modern rice mills during the past few years. At present a few hundred thousand tonnes of paddy are parboiled in India by this method.

Parboiling tanks are filled with clean water that is heated to a temperature of about 85 °C by passing steam through the coils inside the

tank (Fig. 107). Sometimes, hot water is prepared in a separate hot water tank before it is pumped into the parboiling tanks. The second process saves time and increases the capacity. Paddy is dumped into the hot water as quickly as possible. In a fully automatic system the paddy is lifted by an elevator and dumped into the parboiling tanks for soaking. The resulting temperature of the paddy-water mixture in the tanks stays at about 70 °C. The soak water can be recirculated into the hot water tank to maintain a constant temperature of 70 °C. After letting the paddy soak for 3–3.5 h, the soak water is drained and the water discharge valve is left open to remove the water that condenses during steaming. Soaked paddy is exposed to steam heat by letting steam at a pressure of about 4 kg/cm^2 through the open steam coil. Splitting of the husks usually indicates completion of the parboiling process. After the steaming is complete, the paddy is removed for drying by opening the bottom door. If a mechanical drier is to be used, the parboiled paddy is conveyed to the drier by a conveyor and an elevator. If the parboiled paddy is to be sun dried, it is transported to the drying yard either in push carts or in baskets. Mechanical drying is preferable to sun drying because it saves space and minimizes the cost of production.

Before the paddy is fed into the parboiling unit, it is desirable to remove chaff, dirt, and other impurities by passing the paddy through a cleaner. Greater cleanliness can be achieved by washing the paddy in a separate tank before it is dumped into the parboiling tanks. In this operation, even light chaff and heavy stones can be separated from the paddy.

The CFTRI method of parboiling has the following advantages over the traditional method of parboiling (Central Food Technology Research Institute 1969): (1) there is a reduction in soaking time to 4 h, which considerably reduces the processing time and increases production; (2) the bad smell is entirely eliminated; (3) most of the microorganisms originally present will be destroyed because the paddy has been soaked in hot water and steamed; (4) the turnover of capital investment on the paddy is faster; (5) the rice can be prepared on short notice depending upon the market demands; (6) a yellow colour can be easily obtained in the rice to suit the needs of customers; (7) there is a reduction in labour charges; (8) the water requirement of this method is smaller than the cold soaking method because frequent changes of soak water are not necessary; (9) the yield of rice is reported to be slightly higher; (10) bran obtained from paddy parboiled by the CFTRI process is more stable than bran obtained from the traditional method; and (11) rice millers who have used this process claim that paddy parboiled by the CFTRI method is easier to shell and suffers less breakage during milling than paddy produced in the traditional method.

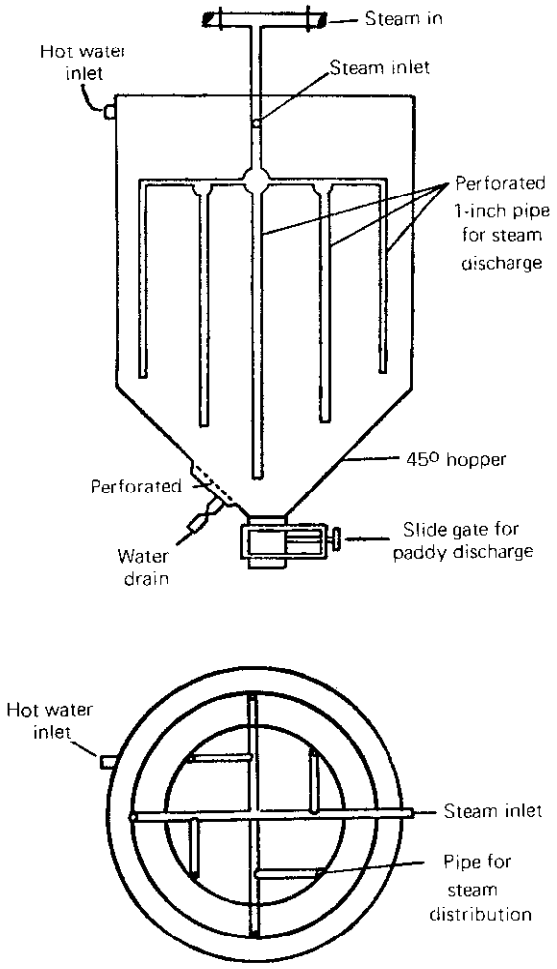

FIG. 107. Inside details of a parboiling tank (not to scale).

The size of the parboiling plant depends on the daily requirement for parboiled paddy by

the rice mill. For example a 2 t/h rice mill needs a parboiling plant with a capacity of 48 t/day and a 4 t/h rice mill requires a plant with a capacity of 96 t/day.

During parboiling, the water requirement is about 1.25 times the weight of paddy to be parboiled and the requirement for steam is about 200 kg/t of paddy (Central Food Technological Research Institute 1969).

Table 30 lists the main equipment required for parboiling plants with capacities of 12, 24, 48, 96, and 120 t/day capacity. The flow diagrams of these plants are shown in Figs. 108–111.

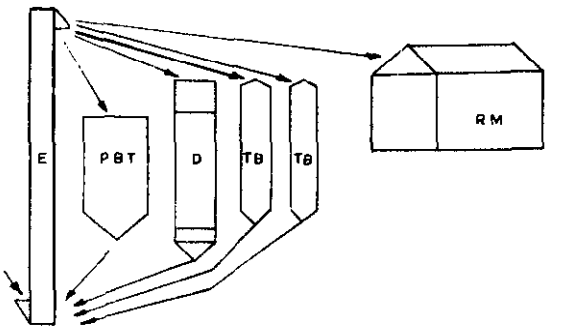

FIG. 108. Flow diagram of a 12 t/day parboiling plant: E = elevator; PBT = parboiling tank; D = drier; TB = tempering bin; and RM = rice mill building with receiving bin.

Jadavpur University Method

At Jadavpur University, India, studies were carried out to improve the method of parboiling by both batch and continuous techniques. The various operations of the integrated process include mechanical methods for soaking, steaming, cooling, and drying. These studies resulted in a reduction in the time required for soaking to 2.5–3 h depending upon the age and size of the paddy grains. The temperature of soaking varies from 65 to 70

TABLE 30. Equipment required for parboiling plants of different capacities (Radhey and Wimberly 1970).

	Capacity of the parboiling plant (t/day)				
	12	24	48	96	120
Receiving bin (t)					
Number	1	1	1	1	1
Capacity	12	24	48	96	120
Elevator (t/h)					
Number	1	1	2	2	2
Capacity	12	24	24	32	40
Holding bin (t)					
Number	—	—	1	1	1
Capacity	—	—	24	32	40
Parboiling tank (t)[a]					
Number	1	2	4	6	6
Capacity	7.5	7.5	7.5	6.7	8.3
Belt conveyor (t/h)					
Number	—	—	1	1	1
Capacity	—	—	24	32	40
Drier (holding capacity) (t)					
Number	1	1	1	1	1
Capacity	6	12	24	32	40
Tempering bin (t)					
Number	2	2	2	3	3
Capacity	6	12	24	32	40
Boiler capacity (kg/h)	300	600	1200	1600	2000

[a]Parboiling tanks are 25% larger than the tonnage capacity to allow for swelling during soaking.

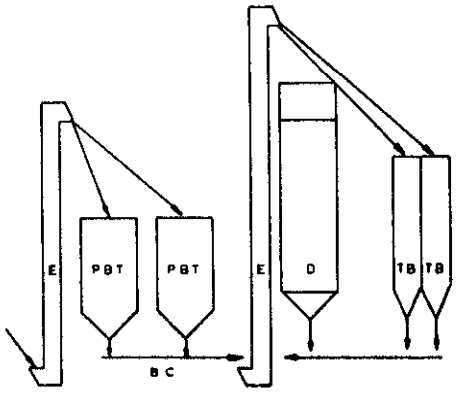

FIG. 109. Flow diagram of a 24 t/day parboiling plant: E = elevator; PBT = parboiling tank; BC = belt conveyor; D = drier; and TB = tempering bin.

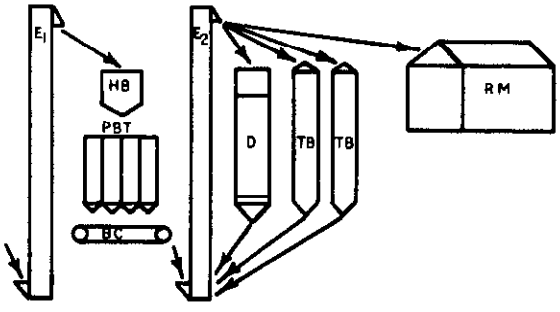

FIG. 110. Flow diagram of a 48 t/day parboiling plant: E = elevator; HB = holding bin; PBT = parboiling tank; BC = belt conveyor; D = drier; TB = tempering bin; and RM = rice mill.

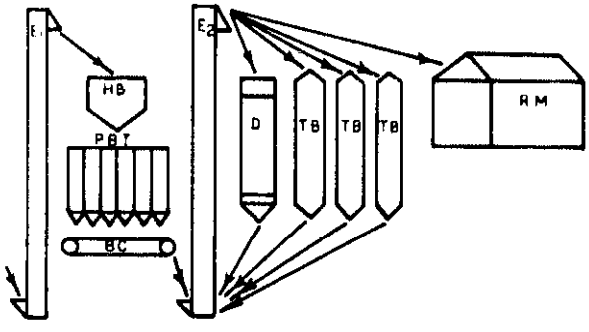

FIG. 111. Flow diagram of a 96 or 120 t/day parboiling plant: E = elevator; HB = holding bin; PBT = parboiling tank; BC = belt conveyor; D = drier; TB = tempering bin; and RM = rice mill.

°C according to the size of the grain. Moreover, the two steps of soaking and steaming are done in the same vessel. The steaming time is reduced to 3–5 min. The short time of soaking and the elevated temperature eliminate the possibility of fermentation during this operation and, therefore, reduce the chance of development of any off-flavour in the rice product. A flow diagram of the process is shown in Fig. 112.

In the batch process, the parboiling tank (soaker-steamer tank) is cylindrical, has a conical bottom, and is equipped to discharge the paddy after the soaking and steaming operations. The tank also has perforated steam pipes or coils for open steaming. In this process, the paddy is soaked at elevated temperature, gelatinized by exposure to open steam for 3–5 min, immediately cooled to room temperature by a continuous mechanical method, dried in a continuous rotary drier, and conditioned before it is milled (Ghose 1963).

The continuous soaker-steamer consists of a long semicircular jacket with suitable arrangements for paddy feeding and transportation and for the discharge of soaked and steamed paddy. The soaking and steaming operations are done in separate sections of the combined equipment. Heating is done either by condensing flowing steam in the jacket at low pressure or by passing hot water through the jacket. Provisions are also made for the continuous addition of soak water at elevated temperature.

The parboiled paddy is cooled by allowing it to fall through a cup and cone type vertical cooling tower, which has a counter current air draft. This operation appears to be essential to prevent browning of the rice during drying.

The rotary drier is composed of a long cylindrical rotating shell with a number of steam tubes and longitudinal lifter flights placed inside the shell. There is also an arrangement for blowing hot air through the unit; therefore, the parboiled moist paddy is simultaneously dried indirectly by steam in the tubes and directly by hot air.

The dried paddy discharged by the drier carries an appreciable amount of heat and care must be taken to allow the paddy to cool slowly. This is done by keeping the paddy in a

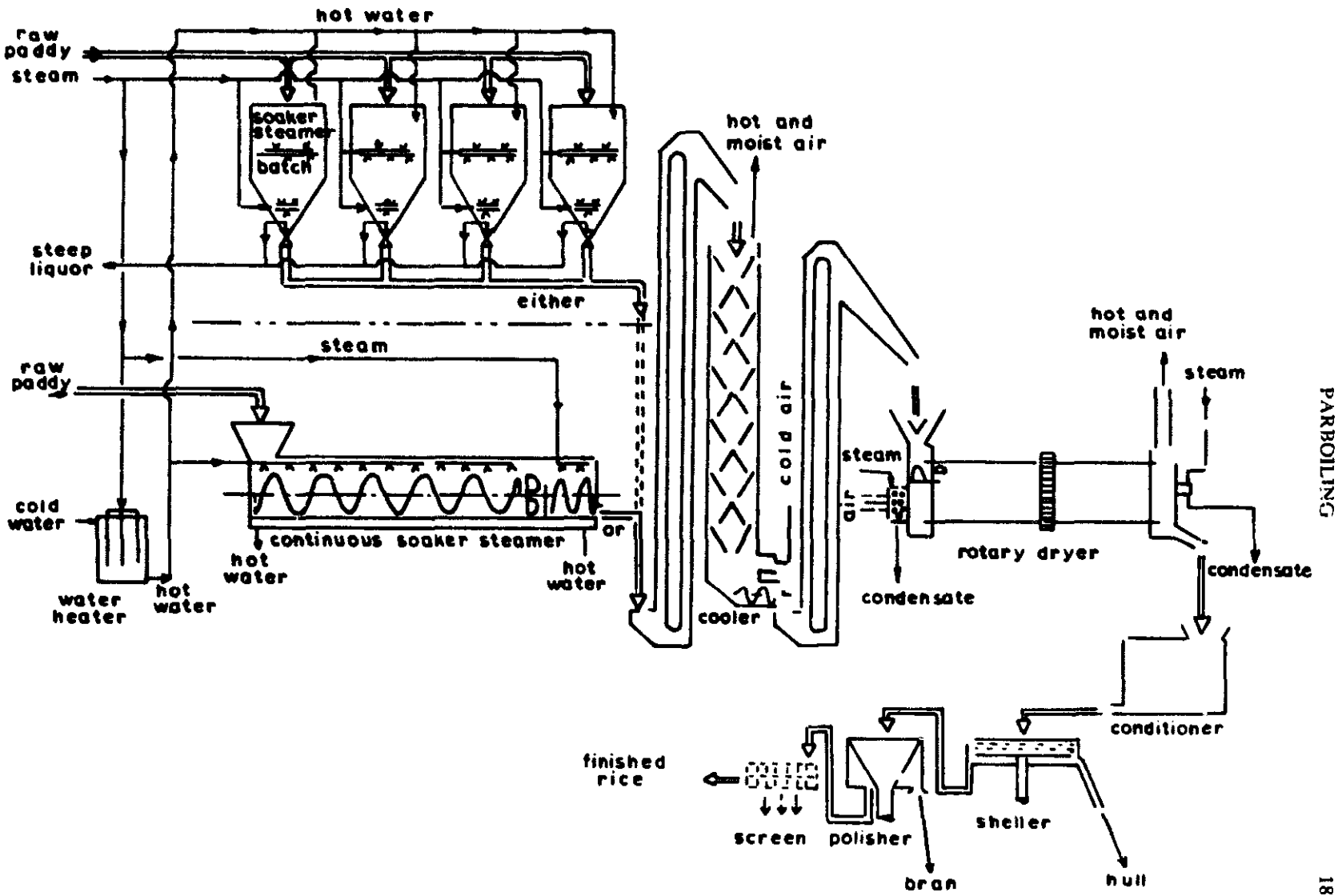

FIG. 112. Flow diagram of Jadavpur University method of parboiling paddy.

closed chamber so that the heat is distributed evenly and the moisture content becomes homogeneous throughout the kernel. This process is called aging or conditioning the dried grain.

This parboiling method has nearly the same advantages as the CFTRI method over the traditional method. In addition, the Jadavpur University method has two more advantages: (1) the process is continuous; and (2) the parboiled rice produced by the process is lighter in colour because the steamed paddy is cooled before drying.

Converted Process

This process, which was initiated in 1941–1942, was the first American parboiling process. The product is obtained by a complete gelatinization of the entire kernel. The parboiled product has an amber colour, is completely vitreous throughout. and has no white starchy centre.

Soaking in an autoclave begins with deaeration of the paddy by vacuum. This facilitates saturation and softening of the grain in water. A pressure treatment is applied to the soaking water in the autoclave that in combination with the vacuum reduces the soaking time to less than 3 h.

After soaking, the paddy is cooked in a rotary steam-jacketed autoclave. Applied vacuum then frees the grain of excessive water and the steam pressure is held at less than 1 kg/cm^2 for about 1 h. Final drying is carried out in the same autoclave by applying vacuum and heating with steam.

Malek Process

This method was perfected a little later than the converted process. The amber coloured parboiled paddy is prepared by successive unit operations that leave the grain remarkably hard. The paddy is steeped in tanks filled with hot water for 3–6 h. It is then cooked by the injection of steam into a vertical cylindrical autoclave that has a truncated cone bottom and is provided with charging and discharging ports or valves at the inlet and outlet, respectively. The paddy is moved in and out of the autoclave by gravity.

Drying is performed in two stages: (1) in a steam-heated rotary cylindrical drier; and (2) in a forced hot air columnar drier at low temperatures.

Avorio Process

This fully mechanized and automatic parboiling process was patented in Italy in 1936. The paddy is steeped in baskets that are mechanically submerged by an endless chain conveyor in a tank of continuously circulated and aerated hot water.

The duration of steeping is controlled by regulating the speed of the baskets in the tank and the total immersion time varies between 50 and 60 min depending upon the rice variety. After steeping, the paddy is cooked in pressure autoclaves containing rotating perforated cylinders that permit steam to be injected into the paddy, which reduces the cooking time to 15–20 min. The steam pressure depends upon the temperature and duration of the operation and varies from 0.5 to 1.0 kg/cm^2. Special valves or ports control loading and unloading of the autoclave.

Drying of the steamed paddy is preceded by a cold air cooling operation. The cooled paddy is then passed through a series of columnar hot-air driers using air at 45–50 °C.

This process, which is well controlled in all phases of the operation, produces a parboiled rice with a high head rice yield, excellent cooking characteristics, and an amber colour.

Cristallo Process

The paddy is first subjected to a special cleaning in water to eliminate the trash and imperfect grains. The cleaning takes place in an open tank in which hot water of controlled temperature is circulated.

Steaming and drying are performed in the same rotary auto-pressure autoclave with vacuum. The steam-jacketed autoclave is also equipped with a mechanism for uniform distribution of steam in the autoclave. The operation is well controlled and produces a range of products depending upon the varieties processed and the market demands.

Fernandes Process

This process was patented in 1952. The steeping, steaming, and drying operations take place in three similarly constructed cylinders. Each of the horizontal cylinders rotates and has an internal helical conveyor for movement of the paddy. At the centre of the rotary cylinders and extending along their length is a perforated tube. This tube carries hot water for steeping in the first cylinder, steam for cooking in the second, and hot air for drying in the third cylinder.

Modern Methods Under Study

Brine Solution Method

This is a modified CFTRI method (Shivanna 1971). The modification and other developments were done at the Research and Development Laboratory of the Modern Rice Mill at Tiruvarur, India, in the latter part of 1969. The main advantage of this method is a reduction in the drying time resulting from a reduction in the moisture content of the parboiled paddy.

In this method, a 15% brine solution (specific gravity about 1.10) is circulated for 10–20 min through hot paddy that has been soaked at 65 °C and has acquired a moisture content of nearly 45%. The paddy is then steamed at a pressure of 3–5 kg/cm^2 for 15–20 min. During steaming, paddy loses moisture and dries to a moisture level of about 30%. The parboiled paddy produced by this method requires only 2 h of mechanical drying (85–90 °C air temperature) to bring its moisture content to 14–16%.

It is claimed that the salt withdraws moisture by osmosis and does not enter the paddy. The percentage of salt reported on the rice is negligible (0.03–0.05%). The paddy does not open during the steaming operation and the brown rice remains free of dirt, dust, or other foreign matter. Opening of the husk along the beam is a unique feature of all methods of parboiling. Although nonopening of the paddy is a distinct disadvantage in this process, it may affect the efficiency of the sheller to a small extent.

Kisan Continuous Parboiling Method

Considering the need for modernizing the existing parboiling units and the scope for introducing more plants in India, a simple, cheap, and versatile unit has been designed to operate on a continuous basis (Kisan Krishi Yantra Udyog 1972; Kuppuswang 1972). A hexagonal tank with 12 compartments is filled with hot water into which paddy is discharged from an elevator head. These compartments are filled in a sequential order starting with No. 1, and leaving an interval of 15 min between successive compartment fillings. By the time the 12th compartment is filled, the first one is ready for steaming. By opening the discharge gate, water and paddy can be taken to the dump pit below the tank. This pit has a perforated floor plate that permits the drainage of water. From this pit a screw conveyor, with a capacity of 2 t/h, removes the soaked paddy for steaming. Because each compartment contains only 0.5 t, the pit is emptied in 15 min. However, at the end of the 15 min period, the paddy in the second compartment is emptied into the pit to continue the operation. Therefore, a series of batches emptied from the hexagonal tank continually feeds the parboiling unit. The size and ratings of the batches can be modified to suit individual requirements. The steaming cylinder is a simple device in which the paddy flows vertically down an annular chamber as a horizontal flow of steam radially heats and gelatinizes the grain. The size and speed of the paddy flow can be varied as desired.

This unit can be operated both as a continuous parboiler and as a batch system. The steaming unit can serve as a paddy drier if hot air is used instead of steam. Because it is possible to dry some other cereals in the drier during the off-season, it is a versatile piece of equipment that can be optimally utilized throughout the year.

The escaping steam from the parboiler is used to heat either the water tank or the paddy soaking tank. If a steam heat exchanger is employed to produce hot air in a mechanical drier, steam from the parboiler may be used in the heat exchanger.

Pressure Parboiling Method

This method was developed at Tiruvarur, India, in the latter half of 1969 (Shivanna 1971). The principle of the method is the penetration of moisture into the paddy in the form of water vapour under pressure, which causes gelatinization of the kernel. The paddy is soaked for nearly 40 min at a temperature of 85–90 °C and then steamed under pressure for 18 min. The air entrapped inside the rice kernel is driven out by the penetration of water vapour; therefore, the presence of white bellies in the resultant rice is avoided. It is claimed that the whole parboiling operation is completed in 1–1.5 h. The rice obtained by this method has a pleasing, slightly yellowish, uniform colour and is expected to have a great demand in many parts of India. The main advantages are a reduction in soaking time, an increase in shelling efficiency (nearly 80% of the paddy hull splits during steaming), and an increase in milling outturn because the grains are resistant to breakage. Increases in the fat content of the bran after milling and in the storage life of the grain have been observed. The process should be easy to convert to a continuous one, and has the potential to be introduced even in small size mills as a replacement for the traditional parboiling system.

RPEC Method

Parboiling of paddy is a process of gelatinization of rice starch in situ, which requires moisture and heat (Ali and Ojha 1975*b*; Ali and Pandya 1974). Moisture and heat can be supplied to the paddy by soaking it in water that is at or a little above the gelatinization temperature of the starch, instead of supplying moisture and heat in two different operations, namely soaking and steaming, as is presently done in conventional and modern methods of parboiling.

Therefore, to determine if parboiled paddy could be produced by supplying moisture and heat simultaneously, studies were carried out at the Rice Process Engineering Centre (RPEC), Indian Institute of Technology, during 1970–1973. The method consists of soaking the paddy in water, at or a little above the gelatinization temperature of the starch, for a suitable period, which depends upon the paddy variety. During soaking, the paddy absorbs moisture and heat and the parboiling process is completed.

The milling quality of the paddy produced by the RPEC method is similar to the quality of paddy parboiled by conventional methods, and after milling both rices look alike. The degree of gelatinization of the starch in hot-soaked parboiled rice was slightly less than in parboiled rice produced by conventional methods; however, this reduces the optimal cooking time. This is a great advantage because it reduces cooking costs and saves fuel for other purposes. Both of the parboiled rices, when optimally cooked, have nearly the same swelling indices.

The production of parboiled rice by hot soaking would be more economical than conventional and modern methods of parboiling because it eliminates the steaming operation; therefore, the boiler, which is one of the most costly items in a parboiling plant, can be eliminated. The water for soaking the paddy can be directly heated by a suitable husk or coal furnace.

Sodium Chromate Method

To try to control putrefactive changes and minimize the loss of dry matter during cold soaking, an extensive series of studies was carried out using a variety of additives in the soak water at the Paddy Processing Research Centre (Subrahmanyan 1972). It was observed that oxidizing agents were useful because they donated small doses of oxygen to the medium as they were required. Although more systematic work is needed to identify the mechanism of their action, the available evidence suggests that they react with the substances that are responsible for the foul odour, retard the action of putrefactive microorganisms and other organisms that lead to the loss of material from rice kernel, and do not affect the viability of paddy.

The process consists of soaking paddy in a 0.05% sodium chromate (Na_2CrO_4) solution for 40–48 h. This controls putrefactive

changes for 3 days. The other operations, i.e. steaming and drying, are done in the usual way and no extra costs are involved. There is absolutely no smell in the soaked paddy, resultant rice, or bran.

Using this method, it is claimed that a net saving of Rs. 6–8/t of paddy may be expected in the cost of operation. If this technique was combined with the brine solution method, an additional saving of Rs. 6/t of paddy would result.

Sequence of Operation for a Modern Parboiling Plant

To maximize the use of a processing plant and its machinery, a process analysis of all the unit operations is used to determine the sequence of the various operations and the utilization efficiency of the handling equipment (Bal et al. 1974). Preparation of the sequence diagram requires the application of various systems engineering principles. Table 31 gives the various unit operations of a parboiling process.

Using Table 31, a detailed flow process chart was prepared (Table 32). The flow process chart is the first step in preparing an optimum sequence diagram of a given system. This chart illustrates the interaction of one operation or event with the others, in a sequential manner, and describes the events and the individual time requirement of each event. This assures that the operations do not overlap, and helps to decide what equipment and machinery is required for the process.

A sequence diagram is a time schedule of product movement through the processing plant, with respect to the equipment and machines, that is expressed in the form of a histogram. This diagram is made with the help of the flow process chart (Table 32). Figure 113 shows a sequence diagram of a modern parboiling and drying plant. This sequence diagram is applicable to the equipment listed in Table 38 and represents the sequence presently followed in modern rice milling plants.

Effect of Parboiling on the Milling, Nutritional, and Cooking Qualities of Rice

During raw rice milling, several factors are generally recognized as probable causes of breakage of rice. Cracking or checking of the kernel is known to be one factor, because delayed harvesting, threshing, and too rapid

TABLE 31. Details of unit operations in parboiling and drying process.

Operation	Time required	Remarks
(1) Cleaning of raw paddy to remove dirt, dust, stones, chaff, and other impurities	—	Time of operation depends upon the amount of foreign material
(2) Soaking of clean paddy in hot water keeping the temperature of the paddy-water mixture constantly at 70 °C (recirculate water if required to maintain temperature)	3.5 h	
(3) Steaming the soaked paddy, after draining the steeping water, by injecting saturated steam at a pressure of 4 kg/cm^2	20–40 min	Time for steaming depends on quality of paddy to be steamed and capacity of the boiler
(4) First drying pass, paddy is recirculated in drier and 95 °C air is blown through the paddy	2 h	
(5) Tempering of paddy in tempering bin to equalize moisture	8 h	
(6) Second drying pass, paddy is recirculated in drier and 75 °C air is blown through the paddy	2 h	

TABLE 32. Flow process chart for 4 t/h paddy parboiling and drying system: V indicates vertical transportation distance; ○ operation; → transportation; □ inspection; D delay; and ▽ storage.

Process description of existing method	Chart symbols	Distance moved (m)	Unit time (h)					Man-h	Power (kWh)	Remarks
			Oper.	Insp.	Trans.	Delay	Storage			
Cleaning	○							1.00	5.00	
Inspection of foreign matter	□							0.02		Parboiling process starts
Loading parboiling tank	→	5 V			0.50			2.00	1.00	
Parboiling consisting of soaking paddy at 70 °C for 3.5 h and steaming for 0.5 h	○		4.00					4.00	6.00	
Delay in parboiling operation due to filling of soaking water and draining the water	D					1.00				
Inspection of parboiled paddy	□			0.02				0.02		
Unloading paddy from parboiling tank and loading it in the drier	→	10 V			0.50			0.50	1.00	
Delay in starting the burner and blower of the drier	D					0.08				
Drying pass I	○		2.00					2.00	10.00	
Unloading the drier and loading the tempering bin	→	5 V			0.50			0.50	1.00	
Tempering	▽						8.00			
Unloading the tempering bin and loading drier	→	10 V			0.50			0.50	1.00	
Drying pass II	○		2.00					2.00	10.00	
Unloading drier to the rice mill storage	→	10 (5 V)			0.50			2.00	1.00	Parboiling process ends
Temporary storage before milling	▽						Unspecified			

drying conditions that all favour cracking always increase the number of brokens. Immature and chalky kernels are considered to break relatively easily. Moisture content and infestation likewise appear to be contributing factors, as are the shape and hardness of the kernels. Rice varieties with short hard grains are usually considered to be the most resistant to breakage. The type and design of the milling machinery influences milling results (Bhattacharya 1969; Bhattacharya and Subba Rao 1966). Rice breakage is related to milling conditions, particularly the prevailing relative humidity and temperatures and the extent of milling (Bhattacharya 1969).

Progressive milling of raw and parboiled

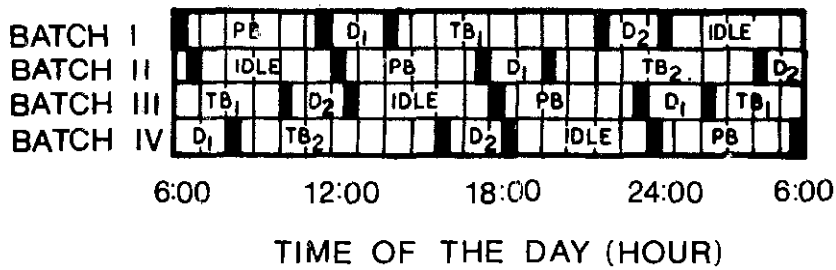

FIG. 113. Sequence diagram for a 4 t/h modern parboiling and drying plant: PB = parboiling; TB_1 = tempering bin 1; TB_2 = tempering bin 2; D_1 = drying pass 1; D_2 = drying pass 2; and ■ = loading and unloading.

rice shows that most of the breakage occurs during shelling (Desikachar et al. 1967; Raghavendra Rao et al. 1967). The grain that remains unbroken after shelling produces few brokens when separated and polished. Two facts indicate that breakage is mostly related to cracked and immature kernels: (1) brokens practically disappear after shelling; and (2) the total number of brokens in the sample is closely related to the total loss in head yield (Bhattacharya 1969).

The parboiling process is known to reduce rice breakage, and the improvement in milling quality is usually attributed to either greater hardness of the parboiled grain or to the healing of cracks. It has been established that cracks, incomplete grain filling, and chalkiness are completely healed during the parboiling process, apparently because of realignment and cementing of the grain constituents after starch gelatinization. Improvement in milling quality is evidently related to this phenomenon, and ideally, breakage should always be negligible after parboiling.

The most beneficial effect of parboiling is an increase in the head yield of paddy that has very poor milling quality either because of varietal characteristics or because of bad postharvest processing operations. There is a slight increase in the head yield of paddy that has good milling quality; however, in this case the net increase in the total yield of rice as a result of parboiling is fairly small.

During polishing, both the percentage of polish and breakage increase with time, but parboiled rice takes longer than raw rice to attain the same degree of polish (Fig. 114). Both raw and parboiled rice can be polished to 4–5% in a relatively short time; however, prolonged polishing is necessary to obtain higher levels of polish. This indicates that the outer bran layers are easier to abrade than the inner aleurone and endosperm layers (Raghavendra Rao et al. 1967). Breakage during polishing is lower in parboiled rice than in raw rice; however, parboiled rice requires three to four times as much abrasive load as raw rice to attain the same degree of polish (Raghavendra Rao et al. 1967). The effect of increasing the degree of polish on the breakage of raw and parboiled rice is shown in Fig. 115. Breakage during polishing increases steadily in the case of both raw and parboiled rice although the increment is more rapid in raw rice (Raghavendra Rao et al. 1967).

Removal of bran colour during polishing is faster in parboiled rice (especially red varieties) than in raw rice (Raghavendra Rao et al. 1969). The bran colour may be extracted from a 2-g sample of rice, polished to different degrees, by an alkaline methanol solvent (Raghavendra Rao et al. 1967). Loosely adhering bran is first removed by washing and decanting with 10 ml of water. The colour is then extracted by boiling the rice for 10 min in two successive 25-ml lots of 5% sodium carbonate solution. Twenty millilitres of methanol are added to the combined extract to prevent turbidity. The colour of the filtrate is measured in a photoelectric colourimetre at 420 mμ (No. 42 filter). The amount of bran colour extracted from shelled rice is taken as 100, and the amount of bran colour removed at any degree of polish is determined by measuring the residual colour in the rice. It has been noticed that parboiled rice needs to be slightly less polished

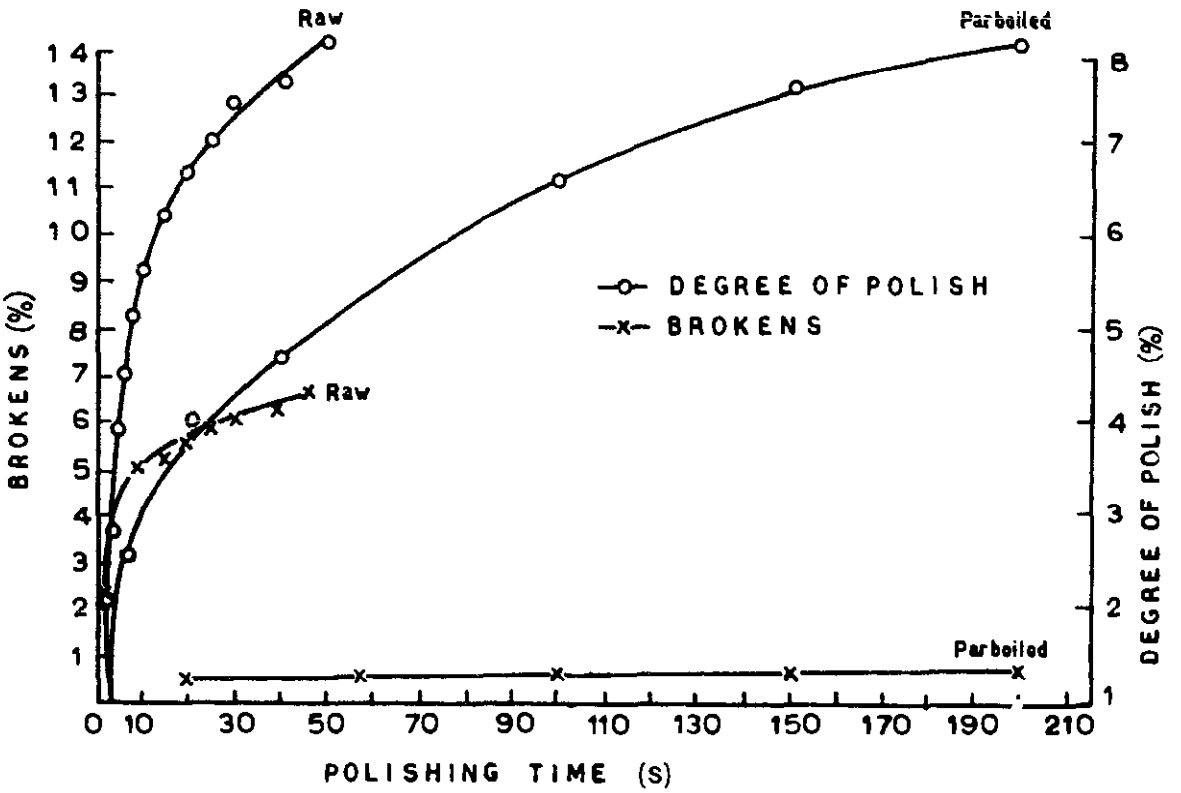

FIG. 114. Effect of length of time of milling on breakage and degree of polish of rice.

than raw rice to have the same minimum consumer acceptability. Figure 116 shows that to achieve an equal degree of surface bran removal, parboiled rice must be subjected to less polishing than raw rice (Raghavendra Rao et al. 1967). For instance, for 80% bran removal, the level of minimum consumer acceptability, parboiled rice must be polished to about 3%; whereas, raw rice must be polished to about 4%.

Bran from parboiled rice can be peeled off as flakes, and it contains less starch and more oil than raw rice bran. This shows that parboiling not only facilitates dehusking but also helps in the separation of surface bran without the loss of endosperm, although both a high abrasive pressure and a longer time may be required for polishing.

The amount of bran sticking to the rice is determined by the abrasive or scouring force used and the polishing time. The former controls the amount of bran scoured; whereas, the latter determines the amount of bran sieved through the perforations of the screen. The use of a high abrasion force with a short polishing time helps to remove more bran from the rice, but does not allow sufficient sieving time. If the polishing operation is prolonged after removal of the polishing load, the sticking bran gets brushed and sieved through the screen (Desikachar et al. 1967; Raghavendra Rao et al. 1967). In a commercial rice mill, the difficulty caused by sticking bran can be overcome by using a large number of polishing units so that sufficient brushing and sieving time is permitted. High moisture content enhances the tendency of the bran to stick to the rice; however, by running the machine longer with no extra load and increasing the sieving time, this difficulty can be eliminated.

It is pertinent to point out that the problem of bran stickiness is serious only in the milling of parboiled rice, and not in the milling of raw rice. Histological studies have shown the presence, in parboiled rice, of oil globules that are damaged and burst; in raw rice, the oil appears as roundish globules. Smearing of oil at a level of 0.5% on the surface of rice increases bran

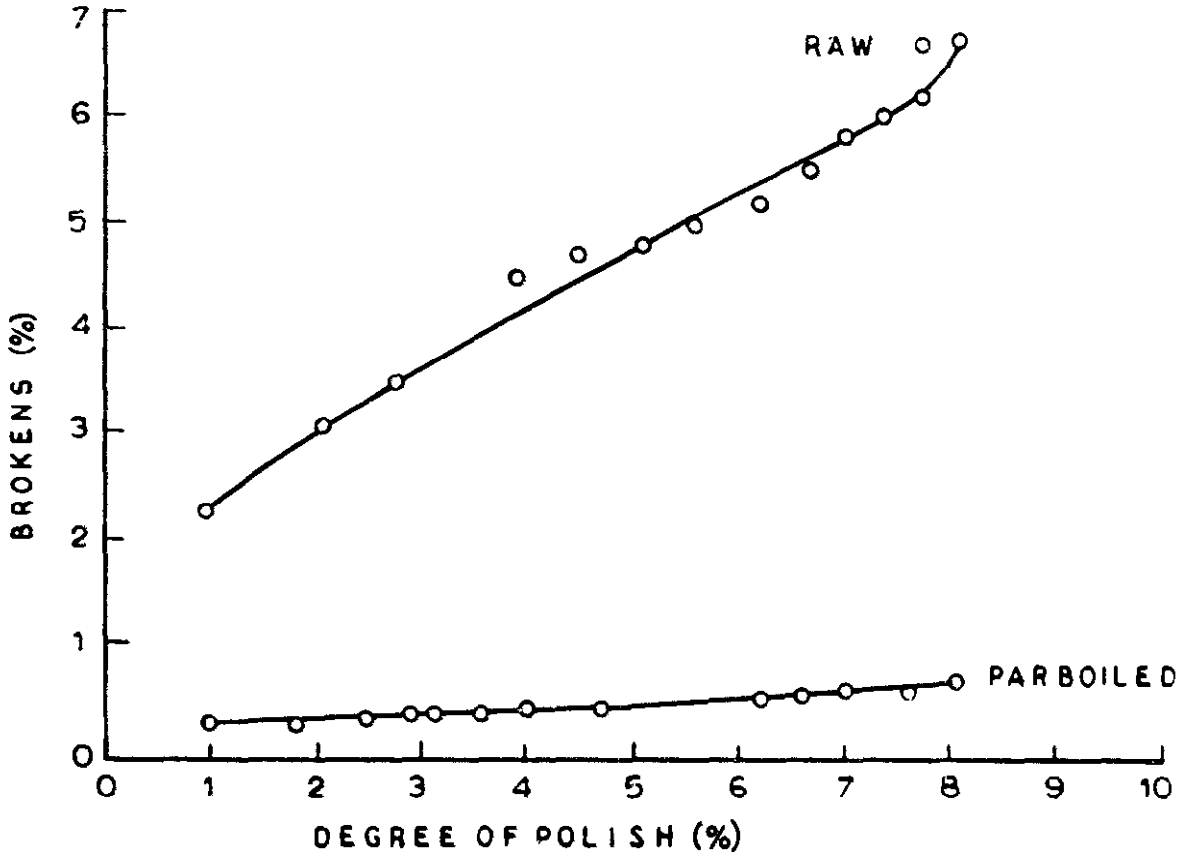

FIG. 115. Percentage of breakage at different degrees of polish of Ratnachudi rice.

stickiness in both raw and parboiled rice (Mahadevappa and Desikachar 1968*b*; Raghavendra Rao et al. 1967).

Parboiling restores the milling quality of both damaged raw and parboiled paddy. Parboiling is an excellent tool for salvaging the milling quality of paddy that has been inadvertently damaged by sun, rain, or faulty drying or paddy that contains a high proportion of immature kernels, which would otherwise be extremely fragile and would fragment during milled (Bhattacharya 1969; Battacharya and Subba Rao 1966*a*).

If the degree of polish is restricted to the level required for minimum consumer acceptability (80% of bran colour removed), parboiling increases the total yield by 1–1.5% and the yield of marketable rice by about 3.5%. Marketable rice is rice that does not contain brokens smaller than one quarter the size of the original. The profits obtained from the increased yield of rice by parboiling are almost neutralized by the increased processing costs. Therefore, parboiling will fetch profits only for those varieties that suffer high breakage in the raw state and cannot be milled economically.

Effect of Parboiling on the Nutritional Value of Rice

An average chemical composition of rice is shown in Table 33. It indicates that the concentration of nutrients in the bran is higher than in either raw or parboiled rice. Because bran is an admixture of the outer layers of the rice kernel, it appears that most of the nutrients are present in the outer layers of the shelled rice (Tables 34–36). Table 36 shows the approximate losses of important nutrients during milling (FAO 1954).

The loss of nutrients during milling is reduced to a certain extent by parboiling. It has been claimed that parboiled rice contains more

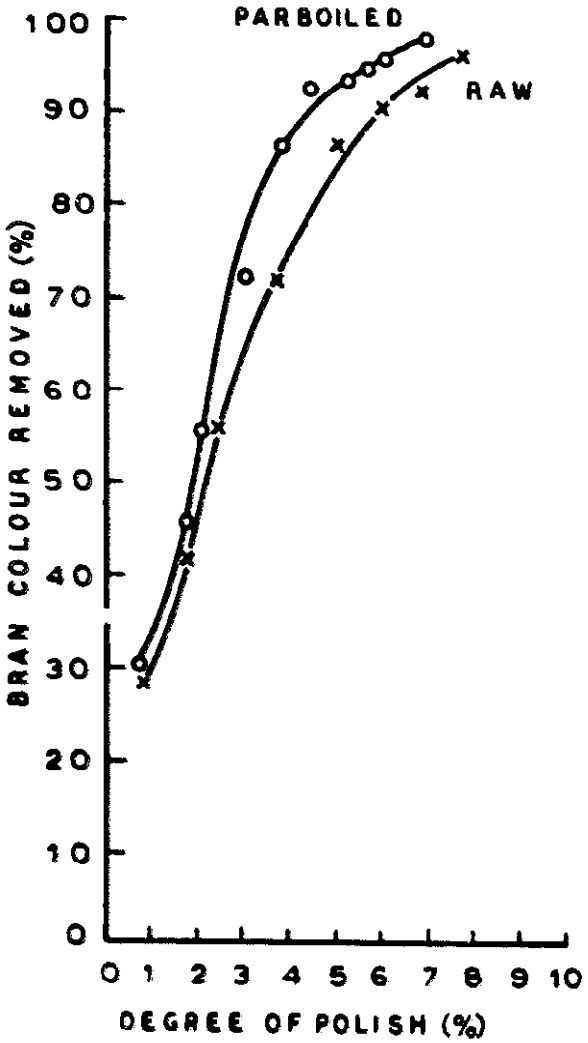

FIG. 116. Percentage of bran colour removed at different degrees of polish of red (kar) rice.

vitamins, proteins, and minerals and loses fewer nutrients during cooking than raw rice. The high nutritive value of parboiled rice may be due to: (1) the diffusion and heat sealing of vitamins and other nutrients into the endosperm; and (2) the low degree of polish required for consumer acceptability, which means that less bran and nutrients are removed.

Parboiled rice contains less oil or fat compared to raw rice because the soaking operation brings about certain enzymatic changes that release oil from the combined state in which it is present in the rice kernel; subsequent steaming causes the oil to move towards the periphery of the kernel, which is removed with the bran during milling.

Effect of Parboiling on Cooking Quality of Rice

The cooking quality of rice may be expressed with respect to: time of cooking; swelling capacity; expansion ratio; colour; solids in gruel; and pastiness.

Time of Cooking

Raw rice cooked in boiling water needs about 15–20 min to become fully cooked; whereas, parboiled rice requires 30–40 min to be cooked to a comparable degree of softness. Raw rice cooked beyond 20 min continues to absorb water, but the grains lose their shape, become almost flat, burst along the ventral line of fusion, and become pasty (Kurien et al. 1964; Mahadevappa and Desikachar 1968*a*).

Swelling Capacity

This is the ratio of the final to the initial volume or weight of the rice. The water absorption capacity, as reflected by the swelling ratio, is significantly lower for parboiled rice than for raw rice cooked for the same period. However, samples of raw rice and parboiled rice cooked to an equivalent degree of softness show that parboiled rice can absorb more water without losing its shape (Mahadevappa and Desikachar 1968*b*). Raw rice cooked for 15 or 20 min has a lower swelling ratio than parboiled rice cooked for 30 or 40 min, respectively. Semiparboiled rice has a swelling capacity between that of raw and parboiled rice.

Expansion Ratio

This is the ratio of the dimensions of the cooked and uncooked rice. The expansion ratios both along the length and breadth of parboiled rice are lower than the ratios for raw rice cooked for the same period (Mahadevappa and Desikachar 1968*b*). At an equivalent stage of softness, the parboiled

TABLE 33. Composition of rice and its milling products (Houston and Kohler 1970).

	Water (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate Total (%)	Carbohydrate Fibre (%)	Minerals and vitamins (mg/100 g) Calcium	Phosphorus	Iron	Sodium	Potassium	Thiamine	Riboflavin	Niacin
Brown	12.0	7.5	1.9	1.2	77.4	0.9	32	111	1.6	9	214	0.34	0.05	4.7
White fully milled (common)	12.0	6.7	0.4	0.5	80.4	0.3	24	94	0.8	5	92	0.07	0.03	1.6
White fully milled (waxy)	13.2	5.6	0.9	0.5	79.8	0.3	36	100	2.0	10	130	0.07	0.04	2.0
Enriched, all types	12.0	6.7	0.4	0.5	80.4	0.3	24	94	(2.9)	5	92	(0.44)	(—)	(3.5)
Long grain, parboiled	10.3	7.4	0.3	0.7	81.3	0.2	60	200	(2.9)	9	150	(0.44)	(—)	(3.5)
Long grain, precooked	9.6	7.5	0.2	0.2	82.5	0.4	5	65	(2.9)	1	—	(0.44)	(—)	(3.5)
Rice bran	9.7	13.3	15.8	10.4	50.8	11.5	76	1386	19.4	trace	1495	2.26	0.25	29.8
Rice polish	9.8	12.1	12.8	7.6	57.7	2.4	69	1106	16.1	trace	714	1.84	0.18	28.2

NOTE: Values in parentheses for iron, thiamine, and niacin are based on minimum level of enrichment specified in standards of identity. Those required for riboflavin are presently not in effect.

grain has expanded more along the breadth than raw rice. Differences in expansion along the breadth are significant; those along the length are not.

Colour

Parboiling changes the characteristics and appearance of the milled rice, but when cooked by boiling, the kernels are almost as white as raw rice.

TABLE 34. Comparative percentage distribution of thiamine and niacin in rice (Central Food Technological Research Institute 1969).

	Thiamine	Niacin
Pericarp, seed coat, and aleurone layer	34.50	85.50
Outer endosperm	4.30	7.80
Inner endosperm	3.70	4.50
Embryo	10.80	0.60
Scutellum	47.00	1.60

TABLE 35. Weight and protein content of successively removed fractions of shelled rice (Houston and Kohler 1970).

Kernel weight removed	Total cumulative weight removed	Protein in fraction	Amount of total protein in fraction	Total cumulative amount of protein removed
4.52	4.52	16.24	8.36	8.36
5.60	10.12	21.01	13.41	21.77
5.54	15.66	19.64	12.39	34.16
5.88	21.54	17.37	11.63	45.79
5.56	27.10	15.05	9.53	55.32
6.32	33.42	12.38	8.91	64.23
4.88	38.30	10.12	5.63	69.85
3.12	41.42	8.60	3.05	72.90

TABLE 36. Approximate percentage losses of important nutrients during milling (FAO 1954).

	Losses during milling (% of total)
Protein	15.0
Fat	85.0
Calcium	90.0
Thiamine	80.0
Riboflavin	70.0
Niacin	68.0
Pantothenic acid	62.0
Pyridoxine	56.0

Solids in Gruel

The loss of solids into the gruel is greater in raw rice than in parboiled rice because the starch is gelatinized in parboiled rice. Semi-parboiled rice has an intermediate amount of loss.

Pastiness

Parboiled rice cooks more flaky than raw rice because of gelatinization. Storage or ageing of the rice also improves this characteristic (Desikachar et al. 1969; Desikachar and Subrahmanyan 1959).

Parboiled rice grains, after cooking, appear larger than cooked raw rice grains of the same variety and give the impression that they are coarse, bold-grained strains (Mahadevappa and Desikachar 1968*a*). This could be due to differences in the time needed for cooking, the water absorption capacities, and/or changes in the dimensions of the grains as a result of parboiling. Because parboiling and the subsequent gelatinization harden the grain, it needs a longer time to cook to a soft consistency and swells more during this period without disintegration. The intrinsic water absorption rate of parboiled rice is low. Raw rice, on the other

hand, imbibes water more quickly and loses its physical structure, because of dispersal of the cell contents, when it is cooked beyond 20 min. The visual appearance of the grain depends on the ratio of its length to its breadth or thickness. The relatively greater expansion of parboiled rice along its breadth after cooking gives it a characteristic short and plump appearance (Mahadevappa and Desikachar 1968*b*).

Effect of Processing Conditions on the Quality of Parboiled Rice

The process of parboiling involves soaking and steaming, which cause swelling, and drying, which causes contraction. Incomplete shrinkage during drying may also cause an overall change in the dimensions of the grain. The average breadth of parboiled rice is greater than raw rice of the same variety. Microscopic examination shows rounding of the germ tip of the milled parboiled rice grain (Mahadevappa and Desikachar 1968*a*,*b*). This may account, in part, for a slight shortening in the length of the grain due to parboiling. The slightly lower degree of polish generally given to parboiled rice may be responsible for the slightly greater breadth of the parboiled rice grain.

The soaking of paddy in hot water at 60–65 °C significantly reduces the swelling capacity of the rice. The steaming operation that follows the soaking further reduces the swelling ratio; the longer the steaming period, the lower the swelling quality of the rice. The rate of decrease in the swelling quality, as a result of steaming, is observed to be greatest in a first 10–15 min of steaming. Although an increase in the period of steaming might harden the grain and result in a higher yield of head rice during milling, the swelling quality of the rice would be adversely affected.

The combined severity of the heat treatments during parboiling is clearly the main factor that determines the cooking quality and colour of parboiled rice. Soaking at a relatively low temperature (below 70 °C) for the minimum time required, using a minimum degree of steaming, and quickly cooling the steamed paddy are thus necessary if a parboiled rice with soft cooking quality and little colour is desired. Quick cooling after parboiling may be the most important factor in industrial scale operations. The reverse conditions are necessary to produce a hard rice with a lot of colour. However, there are some indications that steaming has relatively more effect on the cooking quality; whereas, soaking temperature has more effect on the colour (Bhattacharya and Subba Rao 1966*b*).

Discoloration during parboiling is chiefly due to nonenzymatic Maillard-type browning that can be inhibited by bisulfite; however, other factors also seem to be involved. The effect of soaking temperature and time, and steaming pressure and time on the whiteness of parboiled rice are shown in Fig. 117 (Jayanarayana 1965). A part of the bran is embedded in the endosperm during soaking and steaming. This bran layer will undoubtedly add to the colour of the rice, and the colour itself will be darkened by the Maillard reaction because the bran is rich in free sugars and amino acids. The husk pigment may also contribute colour by diffusion into the endosperm or by absorption into the grain if the grain splits during soaking. The husk pigment has been found in many grains during soaking. In many

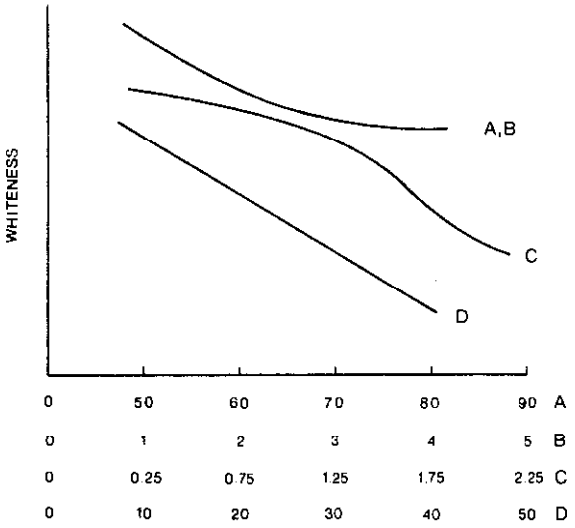

FIG. 117. Effect of processing variables on the colour of parboiled rice: A = soaking temperature (°C); B = soaking time (h); C = steaming pressure (kg/cm²); and D = steaming time (min).

varieties of paddy this pigment is appreciably soluble in hot water and is readily absorbed by milled raw rice if it is cooked in the husk extract. These two factors may partly explain the strong colour inducing effect of high temperature soaking.

The pH of the soaking medium also has an effect on the colour of parboiled rice. Discoloration increases on either side of pH 4.5 (Jayanarayana 1965).

Changes in Parboiled Rice During Storage

Parboiled rice may be stored in open or sealed containers. During storage, changes occur in moisture content, colour, composition, and oil fraction.

Moisture

The moisture content of rice stored in the open soon becomes equal to the moisture level of the surrounding air. The rice loses moisture faster and to a greater extent as the storage temperature is raised; therefore, the moisture content becomes different from samples of the same rice kept in closed storage.

Colour

Parboiled rice has a light to medium amber colour. The colour of dry whole-grain parboiled rice may be measured on the Hunter colour and colour-difference metre. Colour differences, *E*, are calculated from the measurements, using colour values of the original rice samples as standards (Houston et al. 1956).

Colour changes of parboiled rice are marked by a slight initial increase followed by little or no change over a period of about 1 year at room temperature (25 °C) in either open or sealed storage (Fig. 118). Rice exposed to light darkens slightly more than rice in the dark. At 38 °C colour differences again show an initial rise (Fig. 119). Little change takes place until about 4 months, and then progressive darkening begins and continues. During this phase rice in sealed storage becomes browner than rice in open storage. At 60 °C (Fig. 120) the

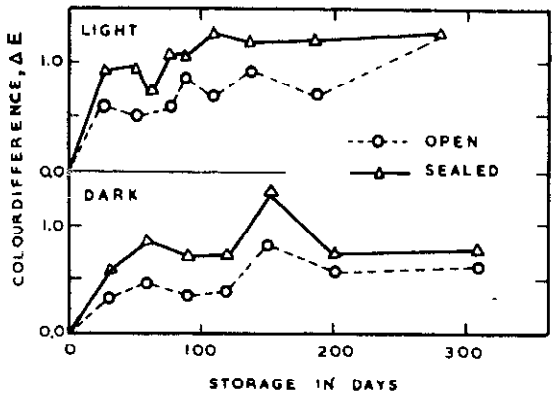

FIG. 118. Colour changes of parboiled rice at 25 °C.

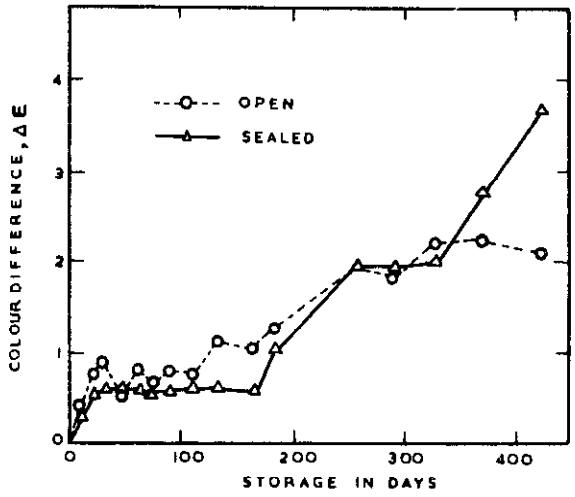

FIG. 119. Colour changes of parboiled rice at 38 °C in the dark.

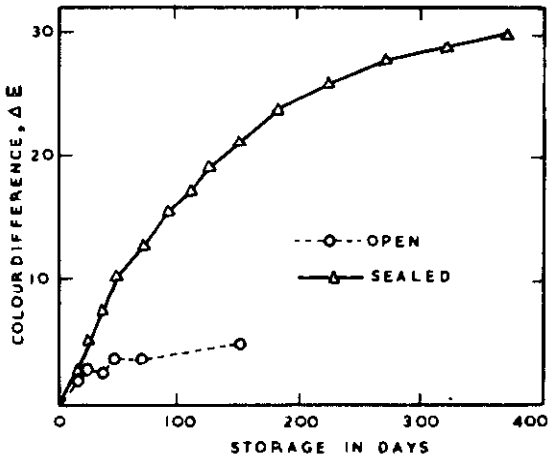

FIG. 120. Colour changes of parboiled rice at 60 °C in the dark.

distinction between open and sealed storage becomes significant. Open storage samples soon dry down to about 3% moisture content and show a moderate, gradually decreasing rate of browning. Sealed storage rice, with the original moisture content, continues to darken and finally becomes a deep mahogany brown.

Compositional Changes

Sulfur dioxide added during parboiling inhibits browning but does not delay rancidification and it gradually disappears during storage (Houston et al. 1956). Because the sulfur dioxide disappears more rapidly in sealed storage it does not evaporate. The losses of reducing sugars are about the same at 25 and 38 °C, but at 60 °C losses increase appreciably. These losses are also greater in closed storage, which is consistent with colour development. A reduction in the amount of available amino nitrogen also occurs.

Deteriorative Changes in Oil Fraction

Oil may be present as less than 1% of the grain, yet have marked effects on acceptability because of rancidity development. Both hydrolytic and oxidative rancidity may occur: hydrolytic action is favoured by high moisture content; oxidative action is favoured by low moisture (Houston et al. 1954).

Changes in the oil fraction of stored parboiled rice have been used as criteria for loss in quality. Rancidification and nonenzymatic changes in the oil of stored parboiled rice may be measured by peroxides, monocarbonyl compounds, and free acids.

Open Storage in Dark

In open storage, values for peroxides, monocarbonyls, and free acids remain low during an induction period, then rise markedly at or just before the time when a rancid odour is detected (Fig. 121–123). Peroxides and monocarbonyls then decrease to low residual values and rancidity disappears. Free acid values remain at the high level or continue to increase slowly. The monocarbonyl maxima occur at about 1 year at 25 °C, at about 1 month at 60 °C, and at about 1 week at 82 °C.

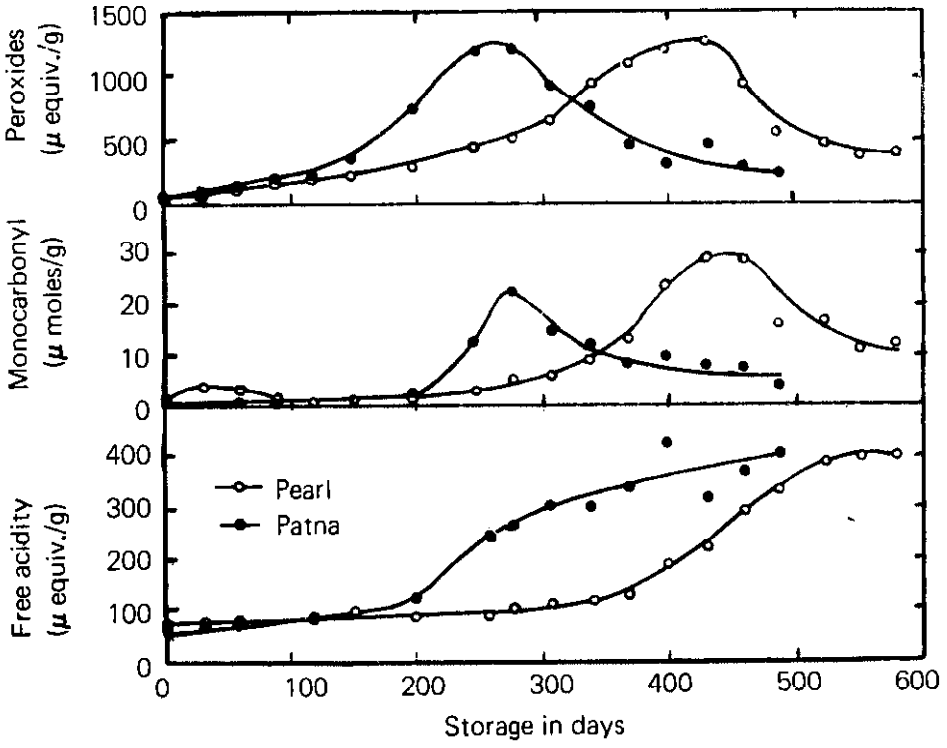

FIG. 121. Changes in the oil during open storage in the dark at 25 °C.

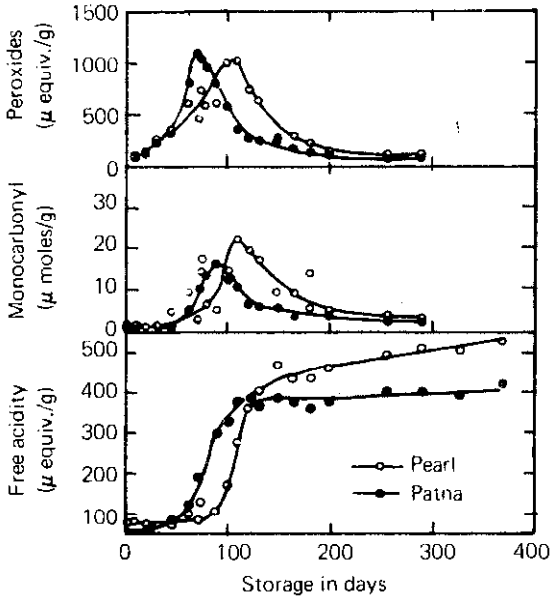

FIG. 122. Changes in the oil during open storage in the dark at 38 °C.

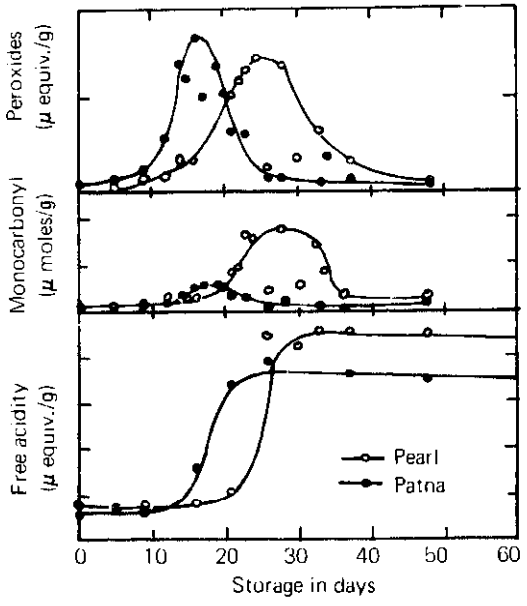

FIG. 123. Changes in the oil during open storage in the dark at 60 °C.

Sealed Storage in Dark

In closed storage at 25 and 38 °C peroxide and monocarbonyl changes are similar to those for open storage although the induction periods are longer. At 60 °C no rise is shown. Free acidity increases linearly for considerable periods at all three temperatures (Fig. 124–126).

Storage in Light

Light has a considerable effect in reducing the storage life of parboiled rice maintained at room temperature (25 °C). Rancidity starts during storage if the storage area is well lit (Houston et al. 1954, 1956). The differences between samples in open and in sealed storage are apparently less than the differences found between samples kept in dark storage conditions.

Studies have shown that the storage life of parboiled rice is dependent not on variety but on processing treatments. Therefore, it is possible to modify both the keeping quality and the appearance of the commercial product by varying the manufacturing process.

Estimate of Heat Required for Parboiling

To calculate the total heat required for parboiling a tonne of paddy, the following assumptions were made: (1) paddy moisture increases from 16 to 50%; (2) bulk density of paddy = 580 kg/m^3; (3) porosity of paddy = 50%; (4) temperature of water for soaking = 90 °C; (5) initial paddy temperature = 25 °C; (6) paddy-water mixture temperature = 70 °C; (7) paddy temperature just after soaking = 65 °C; (8) paddy temperature just after steaming = 100 °C; (9) heat lost while steaming = 20%; and (10) specific heat of dry paddy = 0.4 Kcal/kg-°C.

Soaking Operation

The total water required for the soaking operation is

$$W = Wd\,(m - m_0) + Wp$$

where: W = weight of water (kg); Wd = weight of paddy (kg); m = final moisture content (%); m_0 = initial moisture content (%); and Wp = weight of water required to fill the pore spaces (kg).

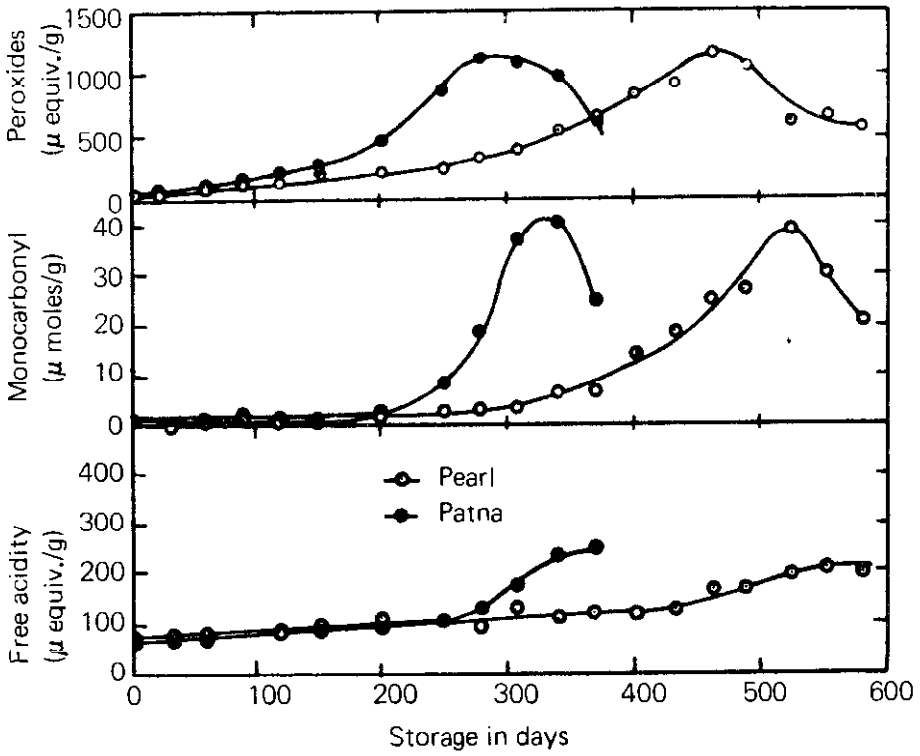

FIG. 124. Changes in the oil during sealed storage in the dark at 25 °C.

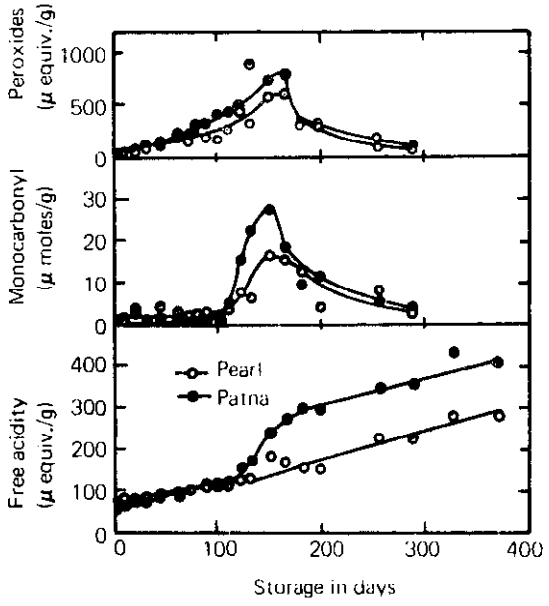

FIG. 125. Changes in the oil during sealed storage in the dark at 38 °C.

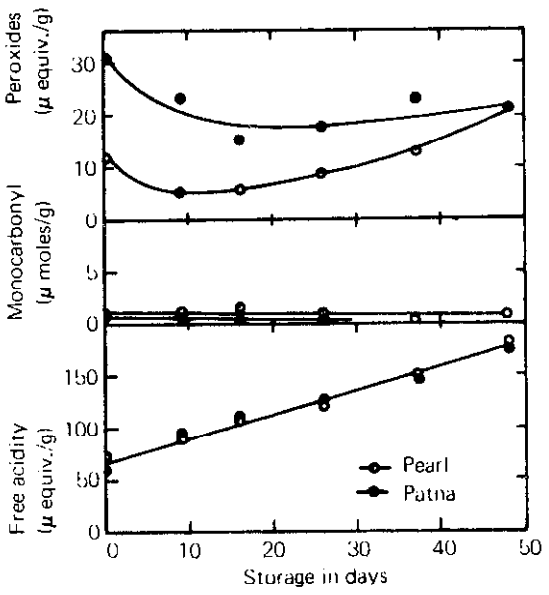

FIG. 126. Changes in the oil during sealed storage in the dark at 60 °C.

For one tonne of paddy,

$$W = 1000\,(50 - 16) + 0.5 \times \frac{1000}{580} \times 1000$$
$$= 340 + 862$$
$$= 1202 \text{ kg}$$

Adding 10% extra to account for losses during the operation, the total amount of water required = 1202 + 120
= 1322 kg.

The amount of heat (Kcal) required to raise the temperature of the water from 25 to 90 °C = 1322 × (90 − 25) = 85 930 ≃ 86 000 Kcal.

Steaming Operation

The heat gained by paddy during the steaming operation is

$$E = w_p \times C_p \times T + w_x \times C_w \times T$$

where: E = heat gained by paddy during steaming (Kcal); w_p = weight of dry paddy (kg); C_p = specific heat of dry paddy (Kcal/kg-°C); T = temperature difference between the steamed and soaked paddy (C°); w_x = weight of water in soaked paddy (kg); and C_w = specific heat of water (Kcal/kg-°C).

Therefore, E

$$= 667 \times 0.4 \times (100 - 65) + 333 \times 1 \times (100 - 65)$$
$$= 267 \times 35 + 333 \times 35$$
$$= 9345 + 11655$$
$$= 21\,000 \text{ Kcal}$$

Adding 20% extra for the heat losses during steaming, E = 21 000 + 4200 = 25 200 Kcal.

Drying Operation

Assumptions: (1) moisture to be removed = 50 to 16% (2) total drying time = 4 h; (3) holding capacity of the drier = 7 t; (4) airflow rate = 350 m³/min; (5) average atmospheric air temperature = 25 °C; and (6) drying air temperature = 80 °C.

Heat required to raise the air temperature from 25 to 80 °C is

$$Ed = A \times d \times C \times t$$

where: Ed = heat required to raise the air temperature (Kcal); A = airflow rate (m³/h); d = density of the air (0.865 kg/m³); C = specific heat of the air (0.24 Kcal/kg-°C); and t = temperature rise (C°).

Therefore,

$$Ed = 21\,000 \times 0.865 \times 0.24 \times (80 - 25)$$
$$= 21\,000 \times 11.42$$
$$= 239\,820$$
$$\simeq 240\,000 \text{ Kcal}$$

For 4 h of drying the total heat requirement = 240 000 × 4 = 960 000 Kcal. For drying 1 t of paddy the heat requirement (960 000/7) = 137 143 Kcal ≃ 137 200 Kcal. Therefore, the total heat requirement for parboiling 1 t of paddy equals the heat required for soaking, steaming, and drying = 86 000 + 25 200 + 137 200 = 248 400 Kcal ≃ 249 000 Kcal.

Fuel Value of the Paddy Husk

The average caloric value of the husk is 3000 Kcal/kg. On the average a paddy variety yields about 20% husk by weight. Therefore, the total husk obtained from 1 t of paddy will be 200 kg and the total heat content of this husk will be 600 000 Kcal. Assuming a 45% efficiency of the husk fired boiler, the heat available from the husk will be 270 000 Kcal. This shows that the total husk content of the paddy is sufficient to provide all the heat required for the parboiling operation. In India, there are some rice mills which are parboiling paddy using only the husk as fuel; however, they utilize the same boiler for generating the steam that is used for heating the drying air in the steam heat exchangers.

Cost Analysis (Bal et al. 1974)

Conventional Parboiling Plant (4 t/h)

The flow diagram of a parboiling plant is shown in Fig. 106. The following assumptions were made in the calculation of the parboiling cost (based on prices during the period 1972–1973):

(1) Cost of equipment and accessories (Table 37) = Rs. 210 000;

(2) Cost of land, buildings, and civil works (Table 37) = Rs. 400 000;

(3) Life of the equipment and accessories = 10 years;

(4) Life of the buildings etc. = 25 years;

(5) Number of working days per year = 250 days;

(6) Number of productive working hours per day = 20 h;

(7) Resale value = 10%;

(8) Interest on capital = 10%;

(9) Electricity = Rs. 0.70/t;

(10) Fuel = husk;

(11) Cost of fuel per tonne of paddy processed = nil.

(12) Staff: (a) one manager = Rs. 600.00; (b) one assistant manager = Rs. 400.00; (c) one cashier = Rs. 300.00; (d) three clerks = Rs. 750.00; (e) one chief mechanic = Rs. 400.00; (f) three watchmen = Rs. 450.00. Total cost per month = Rs. 2900.00.

The expenditure on staff is equally allocated to parboiling and milling units.

(13) Staff for parboiling and drying units only: (a) one boiler operator = Rs. 300.00; (b) three helpers = Rs. 600.00. Total cost per month = Rs. 900.00;

(14) Labour: (a) loading and soaking tanks = Rs. 0.06/bag; (b) sun drying labour = Rs. 2.00/t; (c) repair and maintenance = Rs. 0.90/t;

(15) Quantity of paddy processed per day (4 × 20) = 80 t/day;

(16) Quantity of paddy processed per year (80 × 250) = 20 000 t/year.

Calculation of Fixed Costs

(1) (a) Depreciation on plant and machinery

TABLE 37. Equipment and cost estimate for a conventional 4 t/h parboiling plant.

Item/equipment	Size	Quantity	Cost (Rs.)
Land	—	1.2 ha	60 000
Masonry soaking tanks (3 m × 5 m × 1.5 m)	160 t	4	40 000
Steaming kettles (1.5 m dia. × 3 m high)	1 t	8	25 000
Water pump	14 t	1	2 000
Drying yard @ Rs. 16/m²	75 000 m²	1	120 000
Godown @ Rs. 150/t, cost equally allocated to milling and parboiling unit	1600 t	1	120 000
Tube well	—	1	10 000
Boiler with accessories	1000 kg/h	1	150 000
Electrification	—	—	2 000
Platform scales	1-t capacity	1	2 000
Compound wall @ Rs. 30 per running metre equally allocated to milling and parboiling	600 m	—	9 000
Office @ Rs. 320/m² equally allocated to milling and parboiling	15 m × 5 m	1	12 000
Boiler house @ Rs. 200/m²	15 m × 8 m	1	24 000
Foundations, civil works, pipe fittings, etc.	—	—	10 000
Trollies with hopper bottom and pneumatic wheels for transporting paddy and paddy handling and stirring equipment, such as, baskets, spades, etc.	—	—	10 000
Miscellaneous	—	—	15 000
Total capital investment			611 000 (610 000)

= (210 000 − 0.1 × 210 000)/10
= Rs. 18 900/year

(b) Depreciation on land, building, and civil works
= (400 000 − 0.1 × 400 000)/25
= Rs. 14 400/year

Total depreciation on the plant
= Rs. 33 300/year

(2) Interest on capital invested
= 0.5 (610 000 + 0.1 × 610 000) (0.10)
= Rs. 67 100/year

(3) Annual maintenance
= Rs. 1500/year

Total fixed cost per year
= (1) + (2) + (3)
= Rs. 101 900/year

Calculation of Variable Costs

(1) Cost of electricity
= Rs. 0.70/t

(2) Cost of labour
(a) Loading and soaking tank
= Rs. 0.81/t
(b) Cost of labour for steaming
= Rs. 1.35/t
(c) Cost of labour for sun drying
= Rs. 2.00/t

Total cost of labour = (a) + (b) + (c)
= Rs. 4.16/t

(3) Cost of office and other staff
= Rs. 0.5 (600 + 400 + 300 + 750 + 400 + 450) + (300 + 600)
= Rs. 0.5 (2900) + (900)
= Rs. 1450 + 900
= Rs. 2350

Cost per tonne
= Rs. 2350/2400
(2400 t of paddy is processed per month)
= Rs. 0.98

(4) Cost of fuel
= nil

(5) Repair and maintenance
= Rs. 0.90/t

Total variable cost
= (1) + (2) + (3) + (4) + (5)
= 0.70 + 4.16 + 0.98 + 0 + 0.90
= Rs. 6.74/t

Therefore the total cost of parboiling and drying per tonne of paddy
= fixed costs + variable costs
= Rs. 101 900 × (1/20 000) + 6.74
= Rs. 5.10 + 6.74
= Rs 11.84

Modern Parboiling Plant (4 t/h)

The flow diagram for the parboiling and drying plant is shown in Fig. 110. The following assumptions were made in calculating the cost of parboiling.

(1) Cost of equipment and accessories (Table 38) = Rs. 550 000
(2) Cost of building and civil work (Table 38) = Rs. 190 000
(3) Life of equipment = 10 years
(4) Life of building = 25 years
(5) Number of working days per year = 250 days
(6) Resale value = 10%
(7) Interest on capital = 10%
(8) Electricity = Rs. 0.70/t
(9) Fuel = husk
(10) Cost of husk per tonne of paddy processed = nil
(11) Labour: (a) contract labour for loading tanks Rs. 0.04/bag of about 75 kg; and (b) five trained operators to operate parboiling plant and driers per shift Rs. 4.80 each.
(12) Staff: (a) one manager = Rs. 750; (b) one assistant manager = Rs. 500; (c) one head mechanic = 500; (d) four clerks = Rs.1000. Total = Rs. 2750/month. The permanent staff is equally allocated to the parboiling and drying plant and the rice mill.

Calculation of Fixed Costs

If the parboiling plant works 20 h/day then the total quantity of paddy processed per year
= 4 × 20 × 250
= 20 000 t/year

(1) Depreciation on plant and machinery
= (550 000 − 0.1 × 550 000)/10
= Rs. 49 500/year

Depreciation on building and civil works
= (190 000 − 0.05 × 190 000)/25
= Rs. 7220/year

TABLE 38. Equipment and cost estimate for a modern 4 t/h parboiling plant.

Item/equipment	Size	Quantity	Cost (Rs.)
Scalper precleaner	6 t/h	1	
Holding bin, hopper bottom	32 t	1	
Parboiling tanks (1.8 m dia. × 2.7 m high) with perforated steam pipes	6 t each	6	
Steam pipes			
Hot water tank	—	1	
Bucket elevator	32 t/h	1	
Belt conveyor	32 t/h	1	200 000
Hot water pump	28 l/s	1	
Foundation and civil works	—	—	
Pipe works for steam and water	—	—	
Electrical works	—	—	
Steel structure with platform and roof for the plant	—	—	
Mechanical driers	10 t each	2	
Bucket elevators for the driers	20 t/h	2	200 000
Tempering bins	20 t each	2	
Boiler (husk fired) with accessories	1000 kg steam/h	1	150 000
Godown @ Rs. 150/t, cost is equally allocated to milling and parboiling unit	1600 t		120 000
Tube well	—	1	10 000
Office @ Rs. 300/m², cost is equally allocated to milling and parboiling unit	12.5 m × 8 m	1	15 000
Boiler house @ Rs. 200/m²	15 m × 8 m	1	24 000
Miscellaneous			20 000
Total capital investment			739 000 (740 000)

Total depreciation on the plant
= Rs. 56 720/year

(2) Interest on capital invested
= 550 000 + 0.1 × 550 000 + 190 000 + 0.05 × 190 000) (0.10)
= Rs. 80 450/year

(3) Annual maintenance
= Rs. 2000 per year

Total fixed cost per year
= (1) + (2) + (3)
= Rs. 139 170/year

Cost per tonne
= Rs. 139 170/20 000
= Rs. 6.96/t

Calculation of Variable Costs

(1) Cost of electrical energy = Rs. 0.70/t

(2) Cost of labour for:

(a) loading parboiling tank = Rs. 0.54 t

(b) operating parboiling and drying plants
= (Rs. 4.80/operator) × (5 operator/shift) × (3 shifts/day) ÷ (30 t paddy/day)
= Rs. 0.90/t

Total labour cost
= Rs. 0.54 + 0.90
= Rs. 1.44/t

(3) Cost of permanent staff
= Rs. 2750/month

Cost per tonne
= Rs. 2750/month ÷ 2400 t/month
= 1.15/t

(4) Cost of fuel = nil

(5) Repair and maintenance = Rs. 1.50/t

Total operating cost
= (1) + (2) + (3) + (4) + (5)
= 0.70 + 1.44 + 1.15 + 0 + 1.50
= Rs. 4.79/t

Therefore, the total cost of parboiling and drying one tonne of paddy
= fixed cost + variable cost
= Rs. 6.96 + 4.79
= Rs. 11.75/t

These cost estimates and calculations are projected costs taking basic input data from the operation of paddy processing complexes. However, due to the very large quantity of paddy to be processed per day it is not possible to operate a conventional unit at the capacity of 80 t/day or 20 000 t/year. The cost estimates of two types of parboiled and drying systems have been made at the same capacity to compare the economics of the two systems.

The unit cost of parboiling and drying 1 t of paddy by the modern method is Rs. 11.75/t; whereas, the unit cost of parboiling and drying 1 t of paddy by the conventional method is Rs. 11.84/t.

An additional recovery of 1–2% of the rice has been reported by most of the rice millers using modern parboiling and drying methods. An increase of 1% in the rice outturn is nearly equivalent to a 1.5% increase in paddy. Assuming a paddy price of Rs. 700/t, the saving due to reduced losses by modern parboiling and drying system amounts to Rs. 10.50/t. Therefore, the net cost of parboiling and drying by a modern method is only Rs. 1.25/t (11.75 − 10.50). Therefore, although the modern parboiling and drying method may appear to be more expensive due to very high initial capital investments and higher operation cost, the extra rice outturn not only justifies the economics of the modern method but also provides 0.4–0.8 million tonnes of rice per year, based on a total production of 40 million tonnes per year. — NAWAB ALI AND T. P. OJHA. *Agricultural Engineering Department, Indian Institute of Technology, Kharagpur–721302 W.B., India.*

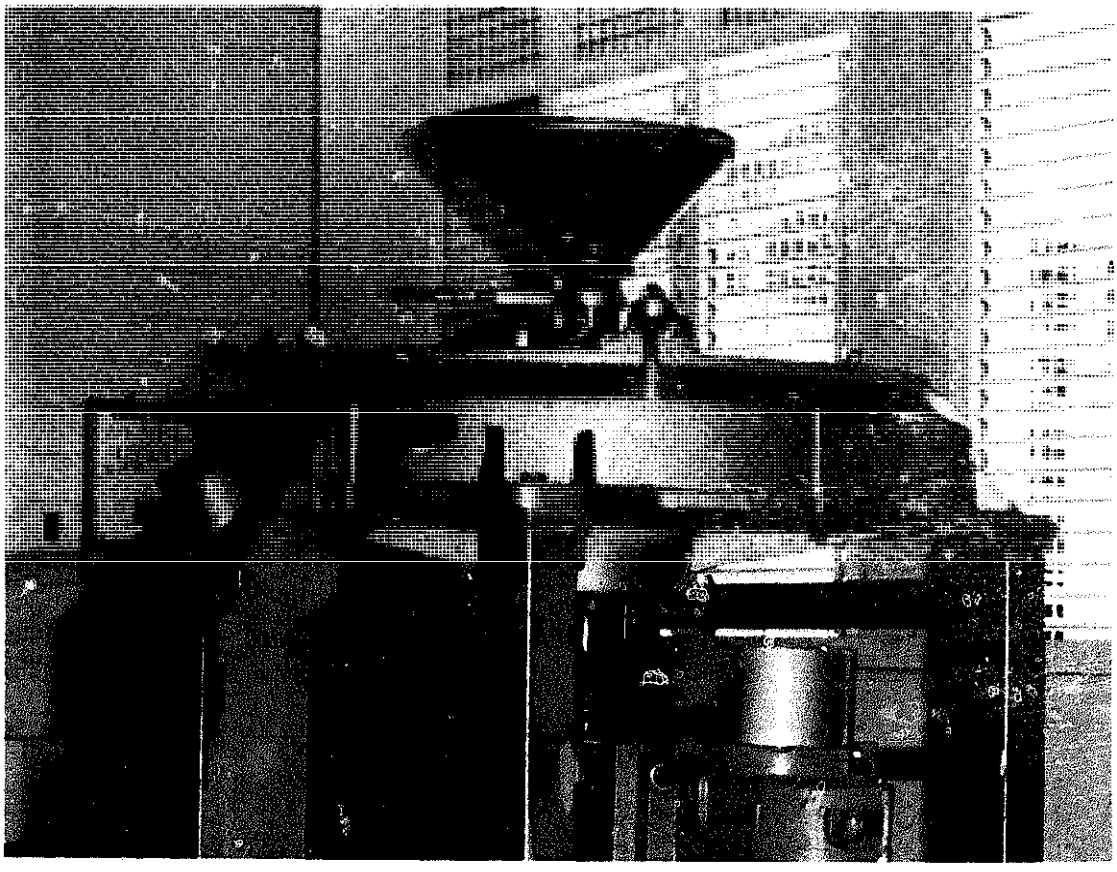

MILLING

Precleaning

Prior to the actual milling operation, the paddy received from the farmer is cleaned in precleaning machines. Foreign matter or impurities are removed to protect the processing equipment and improve the final product. The impurities can be divided into large impurities, small impurities, and impurities of about the same size as the paddy grain. Large impurities normally consist of rice straw, panicles, bag string, soil, stones, and sometimes iron parts. Small impurities consist of dust, sand, soil particles, weed seeds, insects, and small stones. Impurities of about the same size as the paddy grains can be empty grains, stones, and iron particles.

In the precleaning process use is made of differences in the size, weight, and sometimes length of the impurities compared to the paddy grain. Impurities lighter in weight than paddy can be removed by aspiration or by sieving. Large and small impurities heavier than paddy are removed by sieving; whereas, particles the same size but heavier can be removed by gravity separation. Foreign material about the same weight and size as the paddy grain is difficult to remove, and it is presumed to disintegrate during the actual milling process.

Weed seeds are generally small impurities normally separated through sieves. If they are not separated during the precleaning process, the seeds will not be processed during the milling operation and will finally be mixed with the end product, consequently downgrading the white rice. In those rice mills that produce mainly white rice for high-quality markets, trieurs (rotating grading cylinders) are used to remove the seeds based on differences in their length as compared to paddy grains.

Iron parts or particles are removed by sieving, by gravity separation, or by permanent or electro-magnets.

Open Double-Sieve Precleaner (Fig. 127)

In most of the rice mills in the Philippines, simple precleaning is performed through open double-layer oscillating sieves. The precleaners are driven directly by an eccentric drive from the main transmission shaft. The frequency of oscillation is equal to the speed of rotation of this transmission shaft and varies between 300 and 400 double strokes per minute.

The paddy is fed into the top of the machine (A), and passes to the first sieve (1) that has large perforations and retains only large impurities, which are conveyed to the overflow (B). The second sieve (2) with small perforations holds the paddy and allows small impurities to fall to the bottom pan where they are discharged (D). The precleaned paddy, held by the second sieve, is then removed (C).

This type of sieve has many disadvantages: (1) Since it is an open sieve, dust formation is considerable, and in fact this machine is mainly responsible for the very dusty appearance of the cone-type rice mills in the Philippines; (2) None of these precleaners has been equipped with self-cleaning sieves and consequently, most of the bottom sieves with small perforations are clogged, and separation efficiency is reduced considerably. Consequently, many weed seeds are not removed and white rice produced in the cone-type mills of the Philippines holds many weed seeds; (3) Impurities of about the same size as the paddy grains are not separated.

The precleaning efficiency of this type of machine, therefore, is insufficient.

Self-Cleaning Sieves (Fig. 128)

The introduction of self-cleaning sieves will improve the operation of the open double-sieve precleaner. Self-cleaning sieves are not only used in precleaning machines but also in other machines where sieves with round or slot perforations and wire screens are used in the rice milling process.

A self-cleaning sieve consists of a wooden frame dividing the sieve surface into square compartments of about 20 × 20 cm or larger. The top of this frame is covered with the

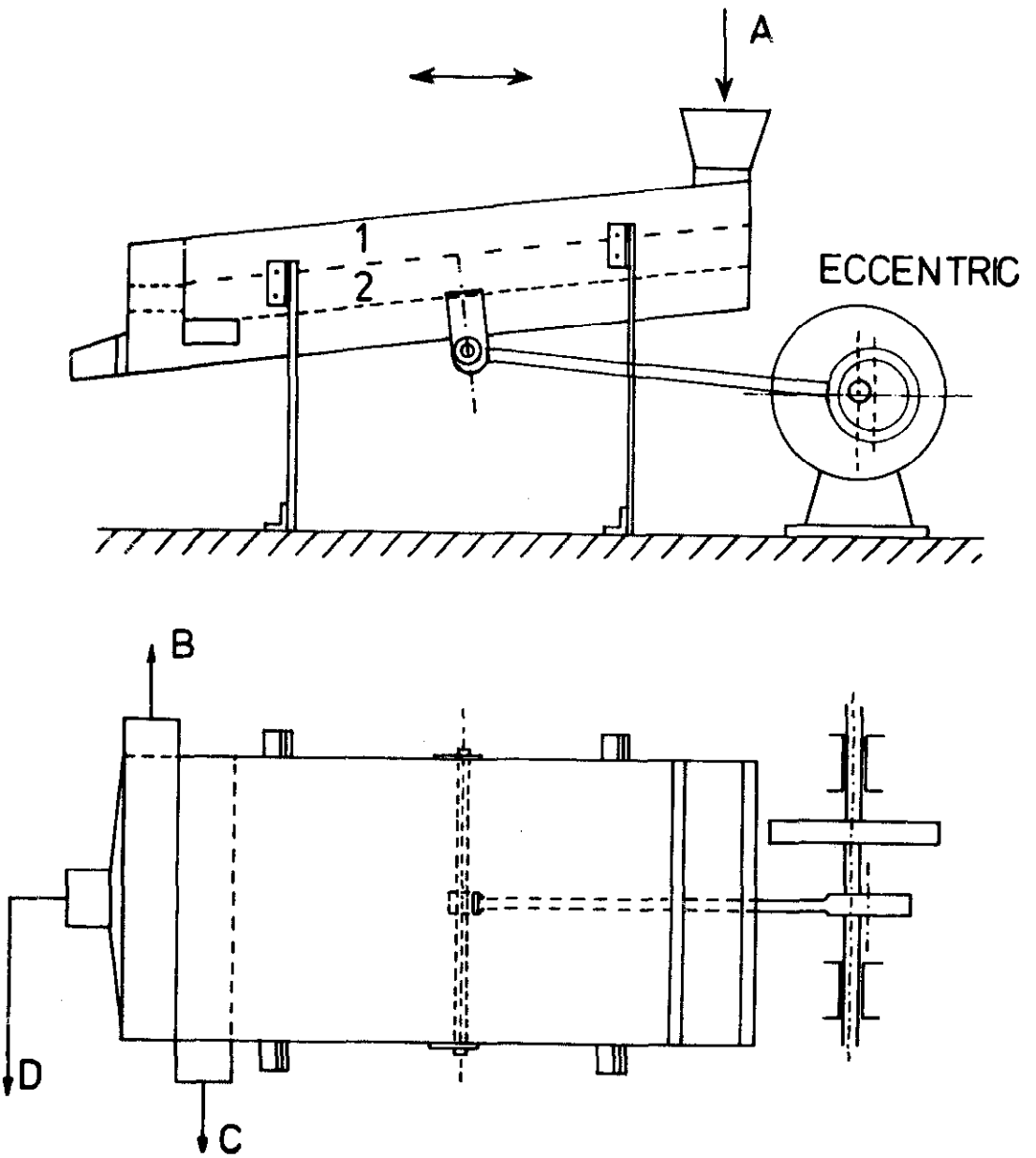

FIG. 127. Open double-sieve precleaner.

selected perforated sheet or wire screen, and the bottom is covered with a wire screen of large mesh for free discharge of the separated products (A). In the compartments are one or two rubber balls (B) varying between 1.9 and 3.2 cm (0.8 and 1.3 inches) in diameter depending on the size of the machine. During the operation of the machine these balls continuously hammer the top sieve and knock the particles, which normally clog the sieve, out of the perforations (C). Nevertheless, these self-cleaning sieves must be cleaned manually at least once a day.

Single-Action Aspirator-Precleaner (Fig. 129, 130, and 131)

To avoid the formation of dust by the pre-

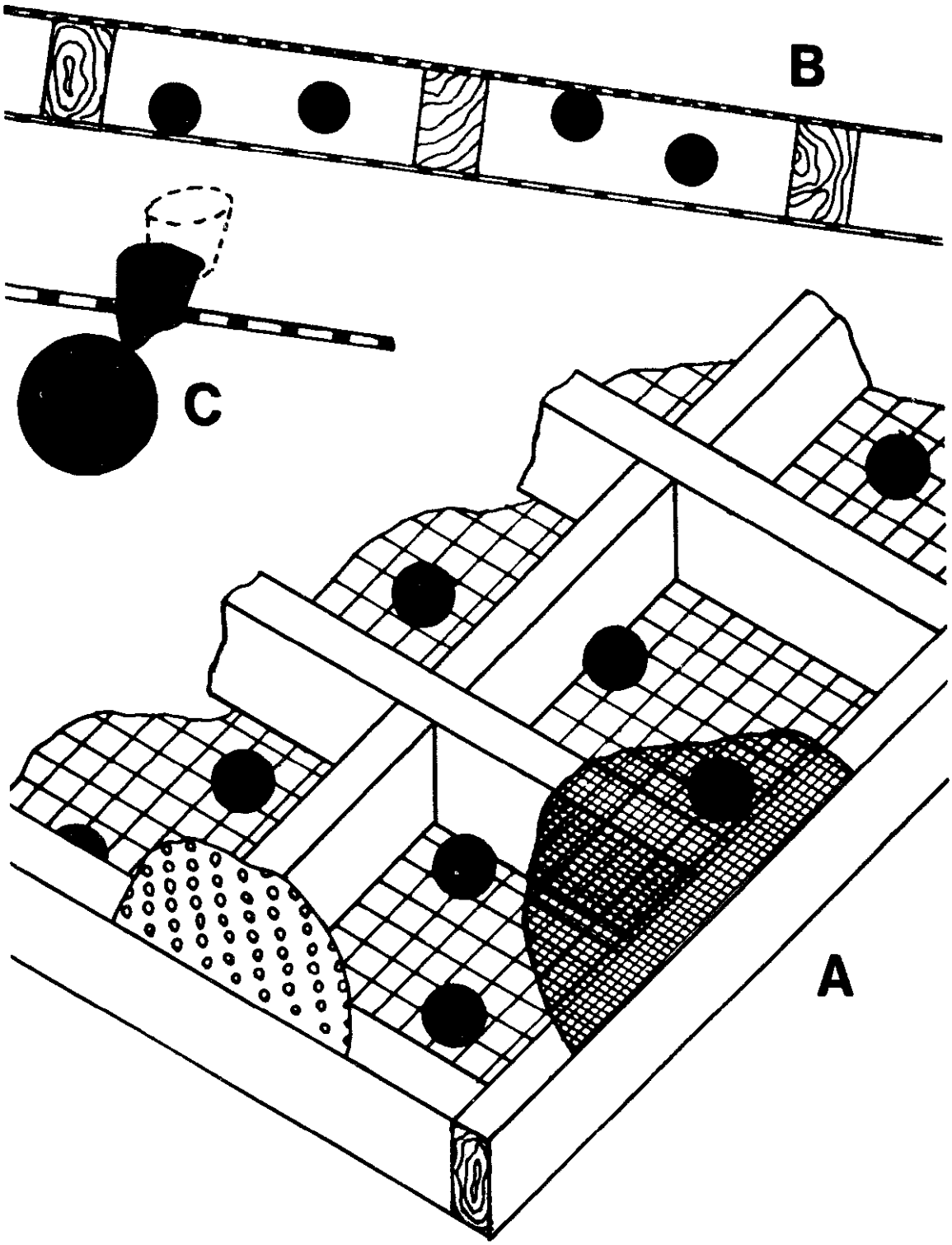

FIG. 128. Self-cleaning sieve. (A) Sieve frame showing square compartments and different mesh sizes. (B) One or two rubber balls are used in each compartment. (C) Balls strike particles in top mesh and knock them free.

cleaner, the machines can be combined with an aspirator (Fig. 129, I) and are known as closed-type aspirator-precleaners. These units consist of a stationary section and an oscillating section (Fig. 129, II). The stationary section is fixed in a wooden or iron frame and houses a suction fan. The oscillating section hangs in this frame and is driven by an eccentric from a transmission shaft (Fig. 130). The paddy is fed into this machine through an opening in the top (Fig. 129, A). The suction fan draws air through the film of grain and separates all dust and light impurities (Fig. 129, 1). The flow of the grain and the capacity of the suction air can be controlled (Fig. 129, 2).

The light impurities drop to the cone-shaped bottom of the aspiration housing for automatic discharge (Fig. 129, F) through double air valves (Fig. 131). The grain falls to a sieve with large perforations, for discharge of large heavy impurities (Fig. 129, B), and is unloaded on the long top sieve of the oscillating section, where more large impurities are removed (Fig. 129, C). (Quite often magnets are installed under the guide plate of the short top sieve (Fig. 129, 3).) The paddy and remaining impurities fall to the bottom sieve, which allows the small impurities to pass through (Fig. 129, D). The overflow of this sieve is the precleaned paddy (Fig. 129, E). The fan in the top section

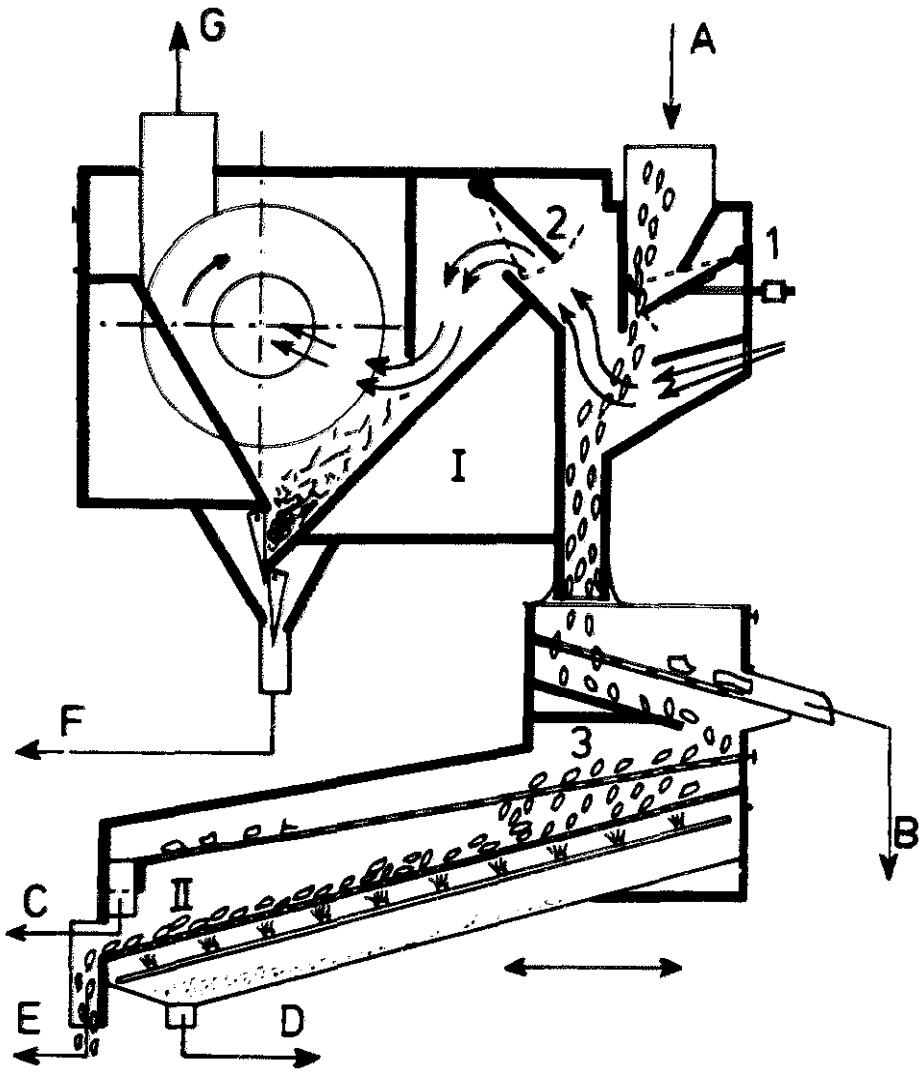

FIG. 129. Closed-type single-action aspirator-precleaner.

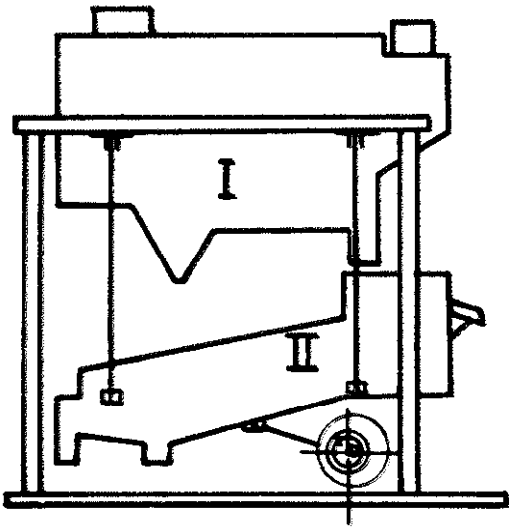

FIG. 130. Unmoving (I) and oscillating (II) section of aspirator-precleaner.

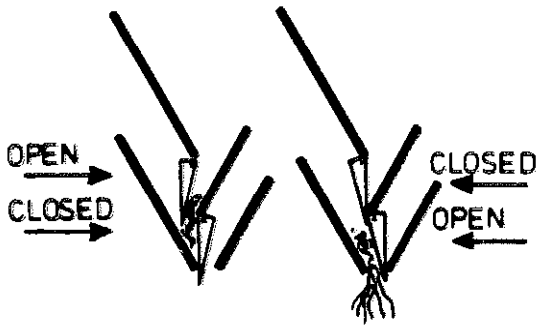

FIG. 131. Double air valves used for automatic discharge.

of this machine blows air and dust in a cyclone for dust separation, making the entire precleaning operation practically dust-free.

Double-Action Aspirator-Precleaner (Fig. 132)

This machine is basically the same as the single-action aspirator-precleaner. The only difference is that the precleaned paddy passes a second airstream for final removal of dust. The back part of the unmoving section of the machine (I), housing the suction fan, is equipped with an air compartment through which a controlled airstream is sucked by the blower (4). The air passes first through the precleaned paddy (E), absorbing all remaining light impurities, which will then drop into a cone-shaped section at the bottom of the aspirator housing for automatic discharge through double air valves. Being a double-action suction unit, the aspirator housing of this machine is equipped with two sets of double air valves for impurity discharge (F).

Double-Drum Type Precleaner (Fig. 133)

A number of drum-type paddy precleaners have been designed, one of which is a double-drum aspirator-precleaning unit, produced in West Germany. This machine basically consists of two horizontal perforated rotating cylinders and a suction fan.

The first cylinder has small perforations through which small heavy impurities are removed (B). At the same time an airstream is sucked through this cylinder, removing most of the light impurities. These impurities drop into the cone-shaped bottom of the fan-housing section for automatic discharge through a rotating air valve (F). The paddy and its large impurities then reach the second horizontal cylinder, this time equipped with a perforated sheeting of larger perforations for the separation of the large impurities (C). The precleaned paddy passes through this cylinder for direct discharge into the rice mill hulling section (E). The fan blows the air and dust into a cyclone for dust separation (D).

The flow of paddy into this machine (1) and the airstream can be controlled by adjustable valves (2, 3).

Single-Drum Precleaner (Fig. 134)

The Japanese have developed single-drum type precleaners, sometimes with gravity separation of stones. One of the single-drum type precleaners is made in combination with an oscillating sieve.

The horizontal rotating cylinder is covered with a wire screen of large mesh for the separation of the large impurities (B). Some of the large impurities, however, are separated by a vibrating inclined sieve prior to the drum cleaning process (1). The paddy and the smaller

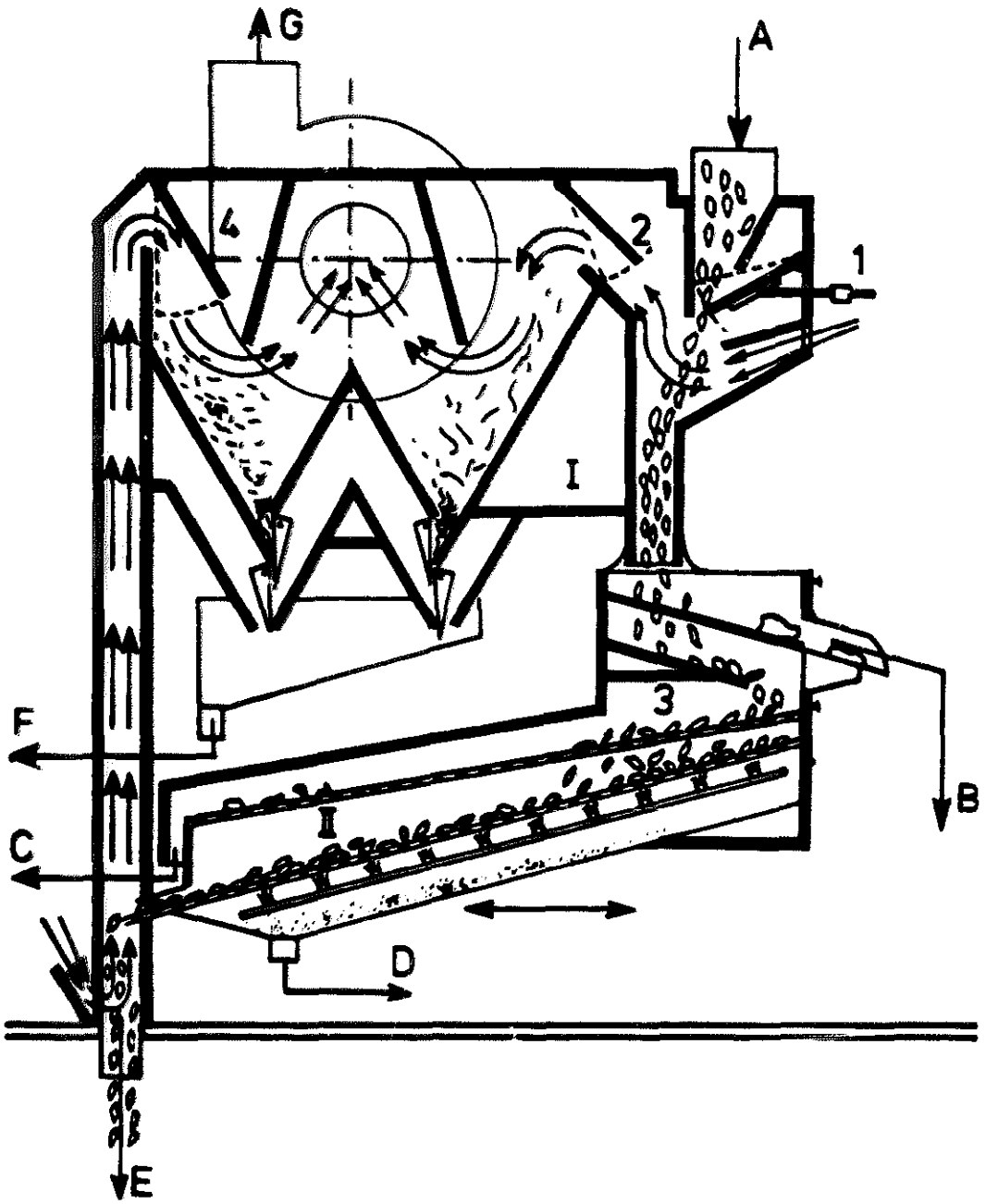

FIG. 132. Closed-type double-action aspirator-precleaner.

impurities drop through the wire screen of the drum and reach the oscillating sieve as a film of grain. On the way down, an airstream is sucked through the film of grain, removing light impurities and dust for discharge by the suction fan (C). This fan blows the air and dust into a cyclone for the separation of the impurities.

The oscillating sieve is a double-layer type. The top sieve has large perforations for the separation of the larger impurities (D) and the bottom sieve has small perforations for the removal of small impurities (E). The overflow of the bottom sieve represents the precleaned paddy (F).

Paddy input is controlled by an adjustable

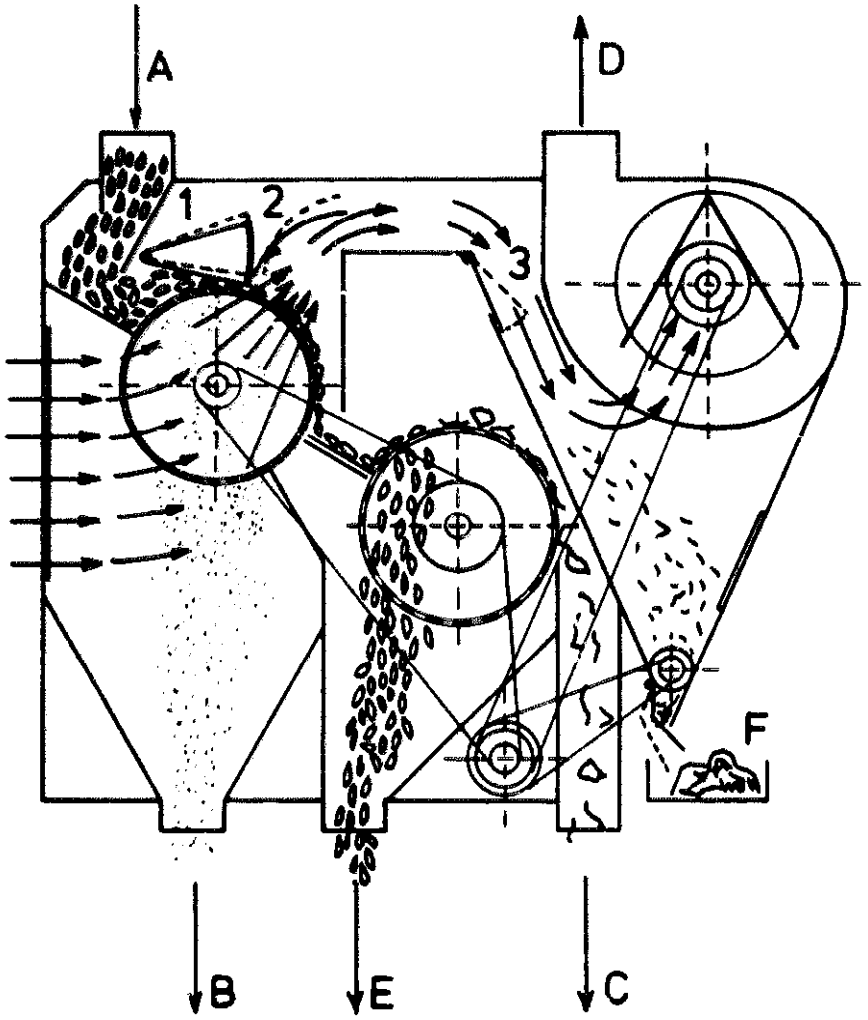

FIG. 133. Double-drum type of precleaner (West Germany).

valve (2), and equal distribution of the paddy over the full width of the vibrating top sieve and rotating cylinder is secured by a rotating paddle and adjustable flap (3, 4). The wide screen of the cylinder is continuously cleaned by a rotating drum cleaner (5) and a special scraping device on top of the oscillating sieve removes the separated impurities.

Stoner (Fig. 135 and 136)

Stones of about the same size as the paddy grains are separated by gravity separation methods. The basic principle is that the lighter paddy grains are carried away by the air-stream, leaving the stones behind. Different types of machines have been designed in Germany, the USA, and Japan.

One of the stoners now introduced in the Philippines is made in Japan. It consists of a perforated screen in an inclined position (Fig. 135). Through a parallel mechanism driven by an eccentric, this sieve makes an upward movement (Fig. 136).

A relatively large amount of air is blown from underneath through the sieve (Fig. 135, A), lifting the paddy grains from the sieve and slowly carrying them down to the discharge spout (Fig. 135, C). As a result of the upward movement of the sieve, little stones are transported to the top of the sieve. Any paddy grains transported upwards with the stones

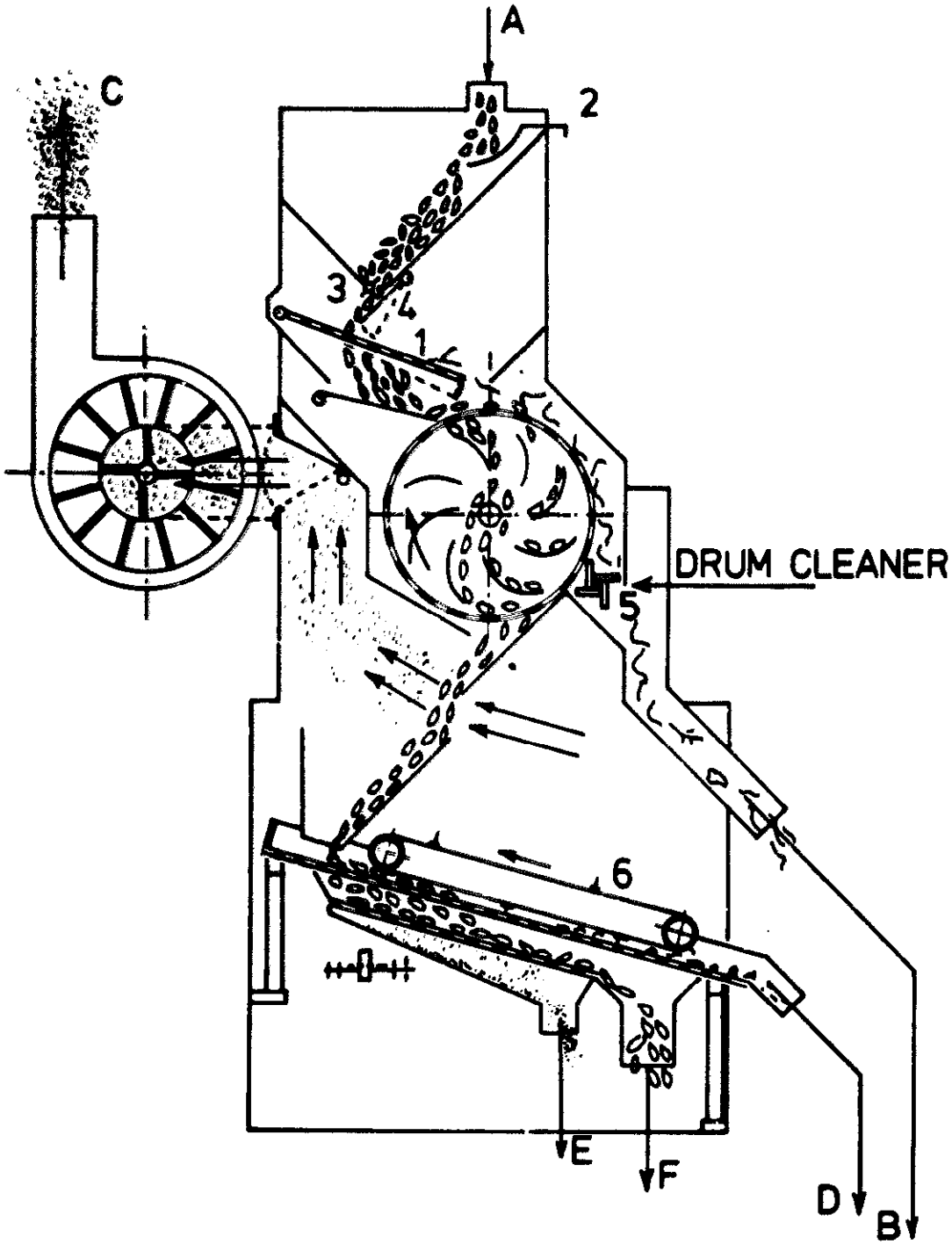

FIG. 134. Single-drum type of precleaner (Japan).

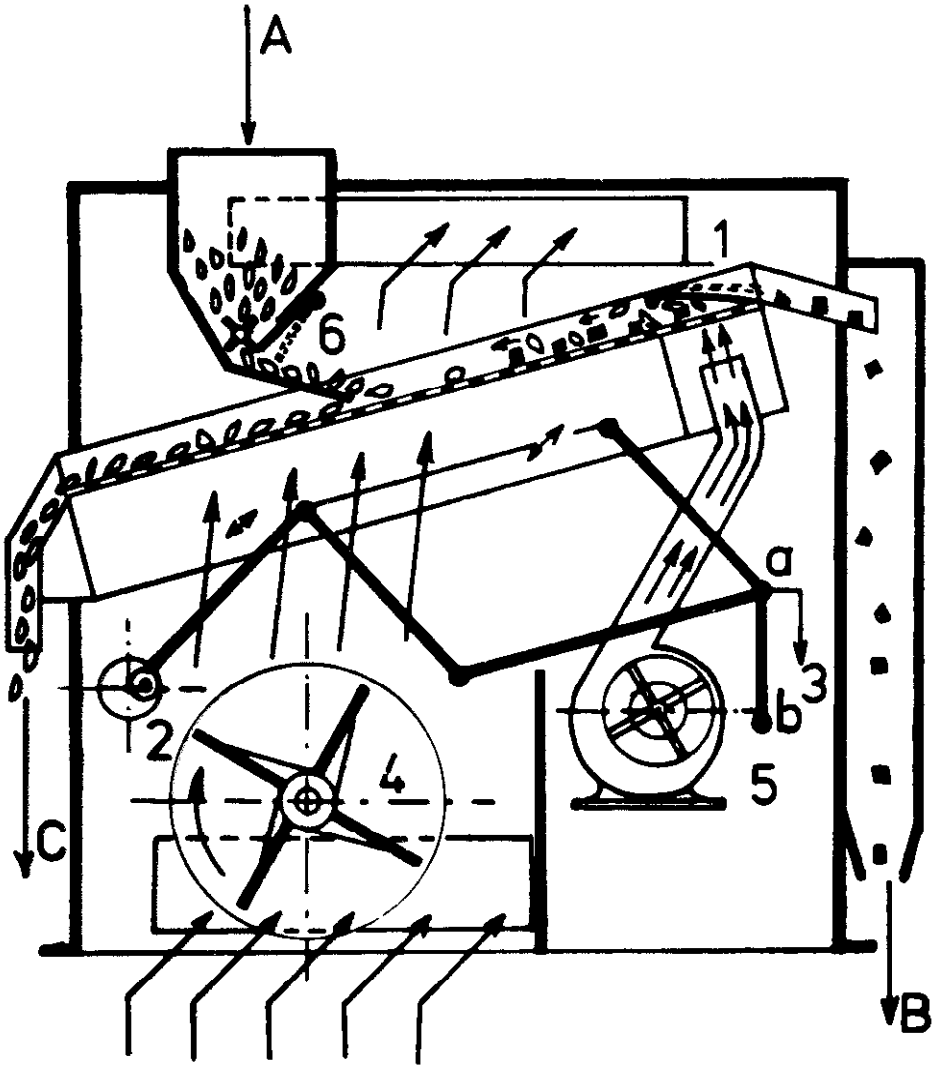

Fig. 135. Stoner (Japan).

are blown free by a smaller second blower mounted under the sieve (Fig. 135, 5). The stones are collected under a flap (Fig. 135, 1) and are unloaded into the discharge spout by manually lifting this flap (Fig. 135,B).

Because different varieties of paddy are to be processed, the inclination of the sieve has been made adjustable. This is done by manually changing the length of bar a–b, which changes the position of the parallel mechanism carrying the sieve, allowing the sieve inclination to be increased or decreased (Fig. 136).

The paddy is fed into the top of the machine and its flow and equal distribution are secured by a rotating paddle and adjustable valve (Fig. 135, A). Stoners are always used after the main precleaning process, so that only precleaned paddy is actually fed into these machines.

Magnetic Separator (Fig. 137)

The bulk of the iron particles mixed with the paddy is removed during the normal precleaning operation as large or small impurities. If no special stoner is installed, iron particles of about the same size as the grains can only be removed by magnetic separators. Nevertheless, we have to take into account that bolts

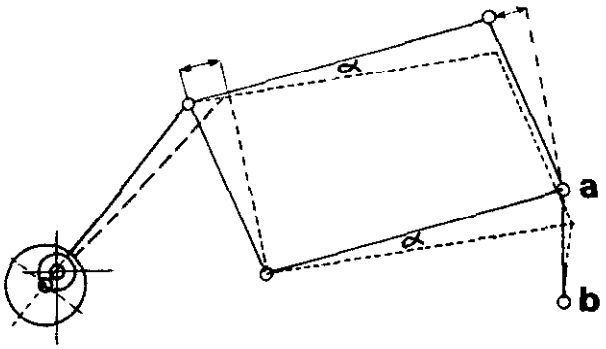

FIG. 136. Change in length of bar a–b changes inclination of sieve (α).

and nuts from the paddy processing machines may get loose any time and if not removed can seriously damage the processing equipment. Therefore, magnetic separators are installed not only in precleaning equipment but also in husk separators and the discharge spouts of elevators.

There are simple permanent magnets for machines and/or discharge spouts (Fig. 137A,B). Another type of permanent magnetic separator is a rotating brass cylinder passing over a half-round permanent magnet (Fig. 137C). The grain film is transported by the rotating cylinder that unloads the grain in the discharge spout (1), but holds the iron particles attracted on its surface because of the magnet. When the cylinder is not moving over the magnet, the iron is automatically released and is discharged separately (2). In some of the larger rice mills special high-capacity magnetic separators are installed for mechanical and continuous discharge of the iron. Most of the magnetic separators are of the permanent type; however, electromagnets may also be used. — HARRY VAN RUITEN. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

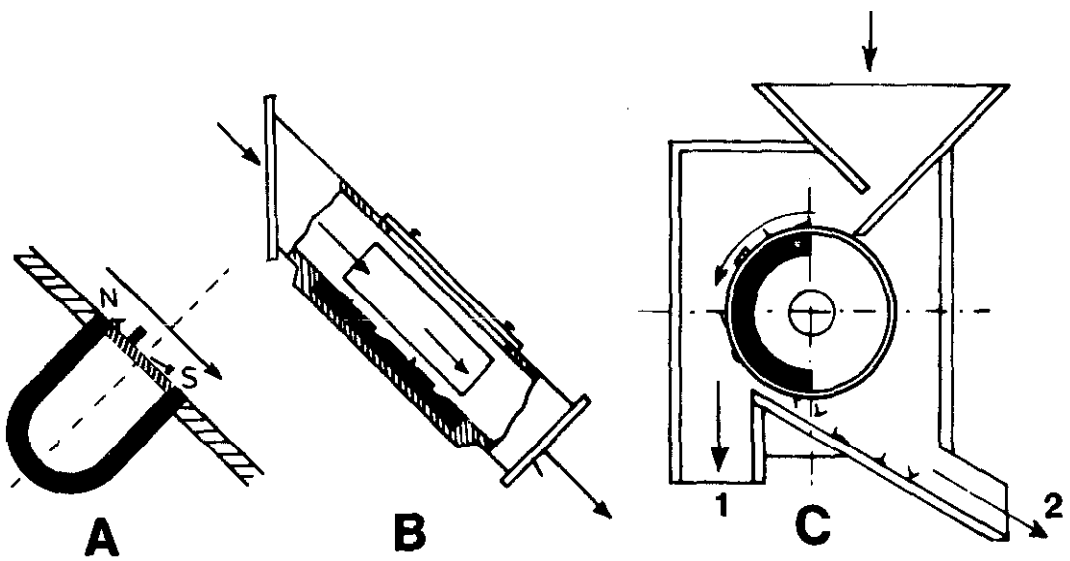

FIG. 137. Different types of magnetic separators: A, B simple permanent magnets; C rotating brass cylinder and permanent magnet.

Hulling

The objective of a hulling machine is to remove the husk from the paddy grain with a minimum of damage to the bran layer and, if possible, without breaking the brown rice grain.

Because the structure of the paddy grain makes it necessary to apply friction to the grain surface to remove the husk, a certain percentage of brokens cannot be avoided; however, much can be done to reduce this breakage. In this respect the construction of the machine, its precision, its maintenance, its adjustment, and the way it is operated can secure optimum performance in huller efficiency and head rice production. However, if the grain is damaged in the field as a result of moisture cracking (suncracking), breakage during the milling process cannot be avoided.

Because the adjustment of the huller depends on the variety of paddy to be processed, uniformity of the grain is essential for optimum performance. However, under most circumstances, pure varieties are not available and a mixture of varieties can be responsible for a less efficient hulling process. The negative effect on hulling of mixed varieties can be avoided by the grading of paddy prior to hulling or can be reduced by the rearrangement of the grain flow in a rice mill.

The most common machines used in hulling paddy are the under-runner disc huller, which is the most commonly used machine, and the rubber roll huller, which was introduced after World War II and is slowly gaining popularity. A rubber band huller developed in Europe in 1947–48 disappeared from the market shortly afterwards and the small centrifugal hullers are still in the experimental stage.

Hulling machines are known by different names, such as shellers, hullers, dehuskers, huskers, and hulling mills. Most commonly these machines are called "hullers." A huller has an efficiency that does not refer to its capacity but to its performance as a huller. The huller efficiency is the percentage of grain actually hulled with a minimum of breakage.

The Under-Runner Disc Huller, or Disc Huller (Fig. 138)

The under-runner disc huller consists mainly of two horizontal cast-iron discs, partly coated with an abrasive layer. The top disc is fixed in the frame housing; the bottom disc rotates. The rotating disc is vertically adjustable (2) so the clearance between the abrasive coating of the disc can be adjusted (3). This adjustment depends on the variety of paddy, the condition of the grain, and the wear of the coating.

The paddy is fed into the centre of the machine through a small hopper. A vertically adjustable cylindrical sleeve (1) regulates the capacity and equal distribution of the paddy over the entire surface of the rotating disc. By centrifugal force the paddy is forced between the two discs and under pressure and friction most of the grain is dehusked.

The adjustment of the clearance between the discs is rather critical and requires continuous rechecking to avoid excessive breakage or insufficient huller efficiency. Quite often, the effective width of the abrasive coating is made too large, causing unnecessary breakage of the grain. Empirically, it has been proven that this width should not be more than 1/6 to 1/7 of the stone diameter. The peripheral speed of the disc should be about 14 m/s, making the speed a function of the diameter of the stone. The larger the diameter, the lower the revolutions per minute of the shaft (Fig. 139).

Example

D = stone diameter = 700 mm (0.7 m); and V = peripheral speed = 14 m/s.

$$V = \frac{\pi \times D \times n}{60} \qquad \text{(m/s)}$$

$$n = \frac{60 \times V}{\pi \times D}$$

$$= \frac{60 \times 14}{3.14 \times 0.7}$$

$$= 380 \text{ rpm}$$

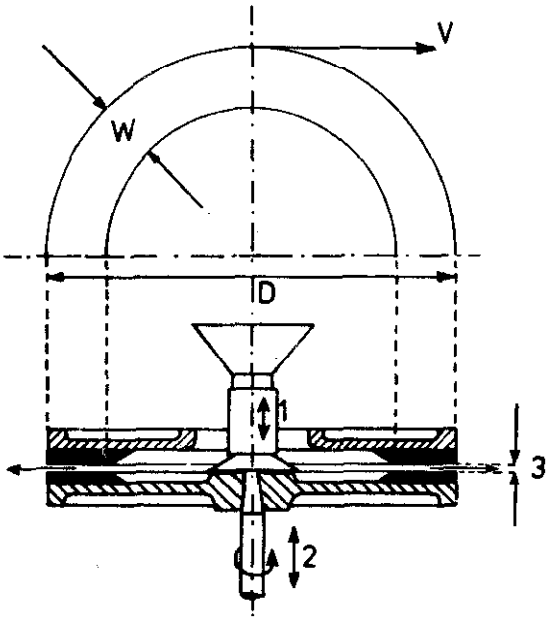

FIG. 138. Particulars of the under-runner disc huller: V = peripheral speed (recommended 14 m/s); W = width of coating; D = stone diameter; and $W/D = 1/6$ or $1/7$.

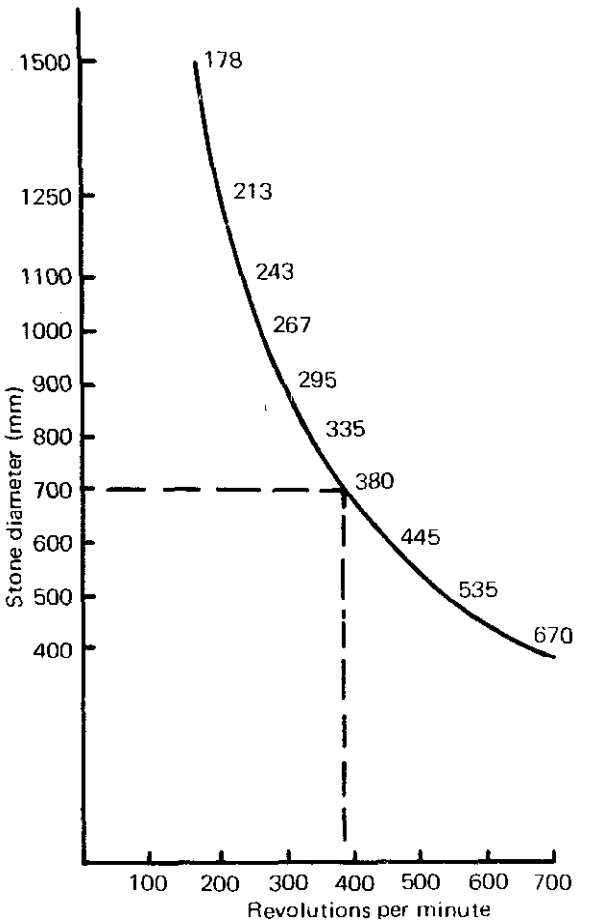

FIG. 139. Under-runner disc huller peripheral speed-curve for V = 14 m/s.

The wear of the abrasive coating of the disc is not equal over the full surface of the coating. Hulling is concentrated in the centre part of the coated surface and, consequently, wear in that section of the coating is greater than at the outer or inner rings. Slowly a small ridge is made at the outer ring of the coating (Fig. 140B), which is responsible for an excessive buildup of pressure on the grain between the stones. Consequently, the rice is broken not only because of this excessive pressure but also because of the presence of the ridge, which the hulled rice has to pass when leaving the machine. When these ridges are produced, the surface of the stones must be redressed (corrected), and the life of the coating is unnecessarily reduced (Fig. 140C). It is more effective with respect to the efficiency and the life of the coating to redress the stone surfaces more often so ridges will not be formed.

Vertical adjustment of the rotating disc is accomplished by moving the entire shaft-disc assembly. The housing of the shaft-end bearing is moved by a steel beam controlled by a handwheel adjustment (Fig. 141). The bar may be moved by two handwheels, or the supporting bar can be hinged on the base of the huller frame and controlled by a single wheel.

Vibration in the machine components is to be avoided because this breaks the rice. In this respect proper bearing of the shaft and maintenance of these bearings are very important. The shaft-end bearing absorbs radial and axial forces; therefore, a double bearing assembly is recommended. For this purpose a combination of a single or double ball bearing and a taper roller bearing can be used (Fig. 141). These bearings must be maintained and greased properly. If the roller bearing is not greased the ball grooves will be damaged, resulting in excessive tolerance and vibration, which can only be corrected by replacing the bearing. In a locally made huller (and also in a whitening cone), very often only a roller bear-

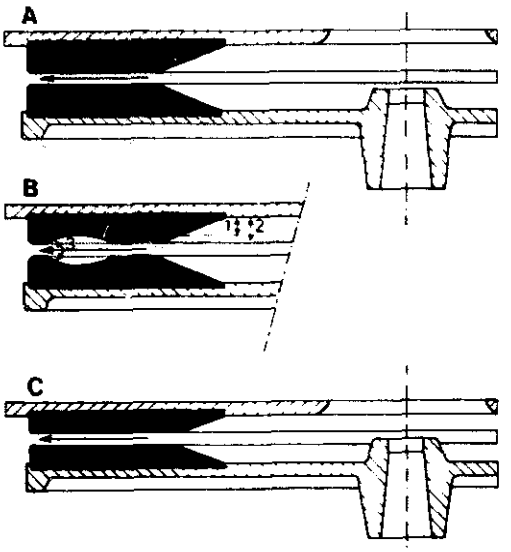

FIG. 140. Under-runner disc huller maintenance: (A) original condition of stone coating; (B) uneven wear developed at centre of coating; and (C) redressed surface of abrasive coating.

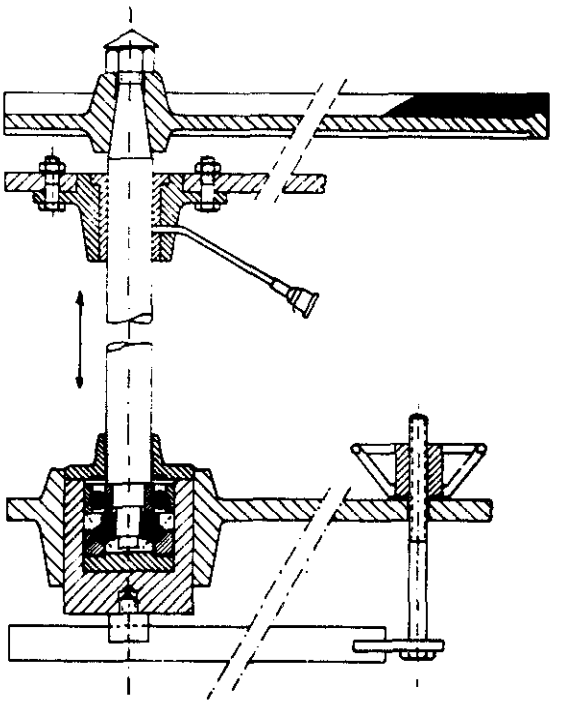

FIG. 141. Under-runner disc huller bearings and adjustment details.

ing is used for radial forces and a simple steel ball absorbs the axial forces (Fig. 142). In this case the end of the shaft is rounded. With this construction the actual contact area between shaft and ball is very small and, when not sufficiently greased, there is immediate damage to the shaft and the ball causing vibrations.

The upper part of the shaft is normally guided by a bronze bush bearing, lubricated by grease (Fig. 143). The grease is pressed between the bush and shaft; however, quite often only the lower portion of the bearing is lubricated. Friction between the upper portion of the bush bearing and the shaft then becomes excessive, causing heat and wear, and leads to vibrations in the upper portion of the shaft assembly (Fig. 143, wrong). This problem can be overcome by drilling an extra lubrication hole in the bronze bush bearing, allowing grease to be distributed over the full working surface of the bearing (Fig. 143, right). The housing for this bearing is normally bolted to the huller frame with bolts and nuts. When no spring washers are used the nuts may loosen and the upper part of the shaft will vibrate. Both surfaces of the discs should be fully level and remain level,

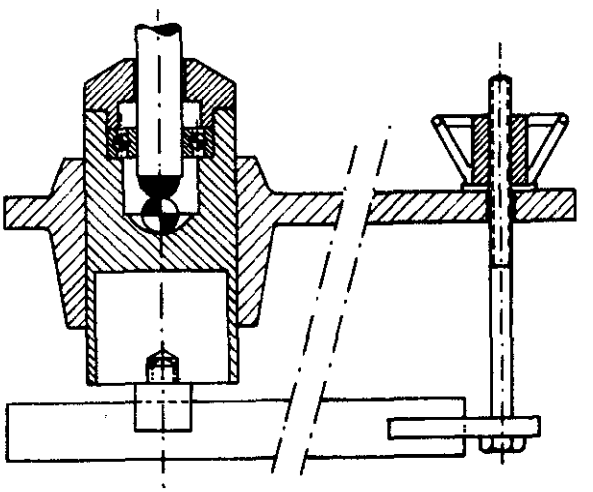

FIG. 142. An end-bearing assembly of the under-runner disc huller containing a roller bearing and steel ball (Philippines).

otherwise the huller will be transformed into a perfect rice breaker. Consequently, continuous maintenance remains essential.

The huller shaft is normally driven by a flat-belt or a V-belt transmission. When lifting the

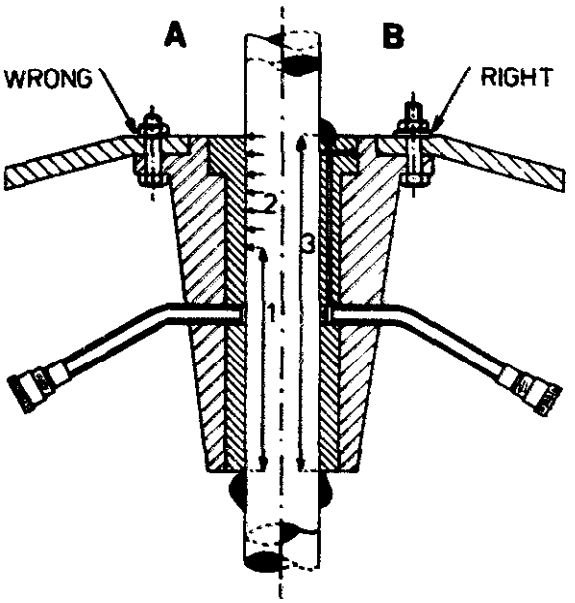

FIG. 143. Details of the bronze bush bearing used in under-runner disc huller: (A) poor lubrication; and (B) additional hole drilled providing proper lubrication.

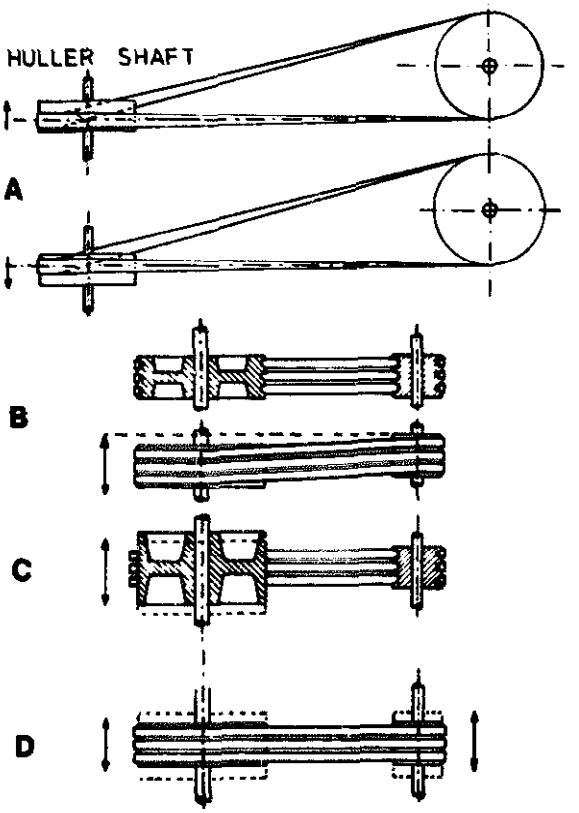

FIG. 144. Methods for transmission-drive: (A) flat belt pulley-drive; (B) full V-belt transmission; (C) V-belt on transmission shaft replaced by flat pulley, and (D) position of driving pulley changed.

shaft assembly for disc adjustment, the driven pulley on this shaft will also be lifted. For a flat-belt pulley-drive the transmission will remain unaffected by this adjustment since the extra width of the flat-belt pulley will allow free movement of the belt over the pulley (Fig. 144A). For a full V-belt transmission (two V-belt pulleys with V-belts), this belt correction is not possible and, consequently, the belt will be out of line when an adjustment is made (Fig. 144B). This causes extra friction on the belt, resulting in heat and excessive wear. Nevertheless, this method is used quite often in the Philippine-made rice mills. The problem can be overcome if the large V-belt on the huller shaft is replaced by a flat-belt pulley (Fig. 144C). However, this reduces the grip of the belts on the driven pulley and more belts are required.

The position of the driving pulley may be changed after adjustment of the huller shaft (Fig. 144D). This is done in electric motor-driven machines by lifting the entire motor support assembly.

A mistake often made, when driving a huller by flat-belt transmission, is not making the pulling part of the belt perpendicular to the main transmission shaft. This is essential for an optimum transmission of force from transmission shaft to machine (Fig. 145).

In many rice mills, the abrasive coating is applied to the stone in a rather primitive way making it practically impossible to secure a uniform, fully level, working surface. Fortunately, very simple and cheap tools can be made that provide a perfectly level surface of both the fixed and rotating discs, and any corrections on the surface of the abrasive coating can be done by simple redressing tools (Fig. 146).

The use of these tools is indispensable for smooth and efficient operation of the huller. In general, in the Philippines, a pure emery

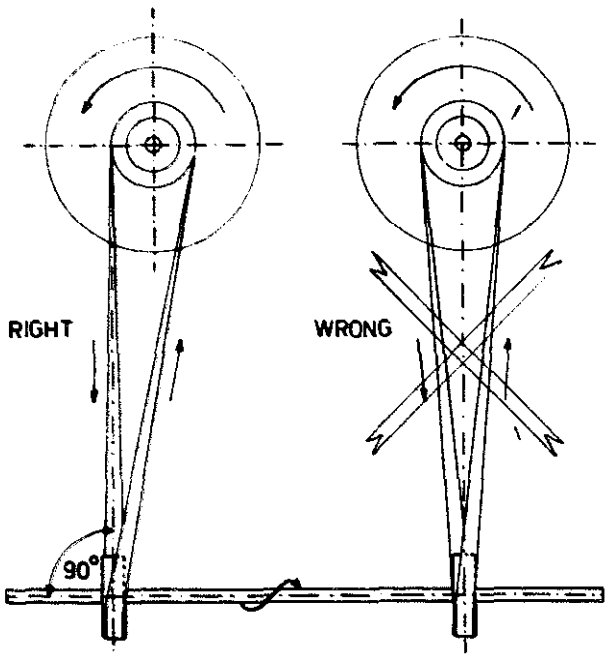

FIG. 145. Position of the drive-pulley in under-runner disc huller.

composition for the coating for the discs is used. Normally this composition consists of 100 weight units of emery grit 14, 20 weight units of magnesite, and magnesium chloride brine (30° Baumé). This composition became outdated many years ago and with the newly recommended composition much better huller capacity and huller efficiency, and longer life of the stone are obtained. The secret of the new composition is a new component silicium carbide (carborundum), whose hardness is about two and one-half times higher than that of emery. The recommended composition of the new coating is grit (50% by weight emery grit 14, 16⅔% by weight emery grit 16, and 33⅓% by weight silicium carbide grit 16), 20% by weight magnesite, and 20% by weight chloride brine (29° Baumé).

In the Philippines, the under-runner disc hullers are normally mounted on elevated concrete foundations so that the actual hulling section will be at working level on the first floor (Fig. 147A). The disc adjustment must be done on the ground floor level under less attractive working conditions. In some rice mills abroad, this adjustment is made from the working level on the first floor by simplification of the construction of the huller frame and by extension of the handwheel controlled adjustment device (Fig. 147B). In practically all horizontally projected rice mills in other countries, the huller is mounted on the ground floor level (Fig. 147C).

Because in the Philippines the paddy supplied to rice mills in general does not represent a pure variety and as paddy grading has not been implemented, quite often, because of the mixture of varieties, huller efficiency cannot be kept at a high level without breaking the brown rice. This is caused mainly by the varying thickness of the paddy grains. The mill operator wants to dehusk as many grains as possible and, therefore, reduces the clearance between the discs. By doing so he is actually cracking the thicker grains while dehusking the thinner ones. When he sees this, he readjusts the huller and consequently reduces the huller efficiency.

The paddy not hulled during the first pass through the huller is then separated by the paddy separator and, in most of the rice mills in the Philippines, returned to the paddy bin feeding the huller. However, when samples of the initial paddy and the paddy rejected by the paddy separator are analyzed carefully, it is seen that for the same volume, the weight of the initial paddy is more than 10% higher; whereas, the number of grains of the rejected paddy is about 10% higher. Consequently, the average size of the rejected paddy grain is smaller than the average size of the initial paddy grain. This was the main reason why these grains were not hulled and, therefore, it is not logical to return these grains to the same huller.

It is recommended that the rejected paddy be returned to a separate bin for independent hulling in a smaller huller that can be adjusted to the smaller size of the rejected paddy (Fig. 148). This allows the main huller to be adjusted to avoid excessive breakage of brown rice, and the total dehusking capacity of the huller section is increased by at least 20%.

The recommended rearrangement of the grain flow in the huller section is advantageous in rice mills with disc hullers as well as those with rubber roll hullers. However, urgent implementation is more important for disc hullers

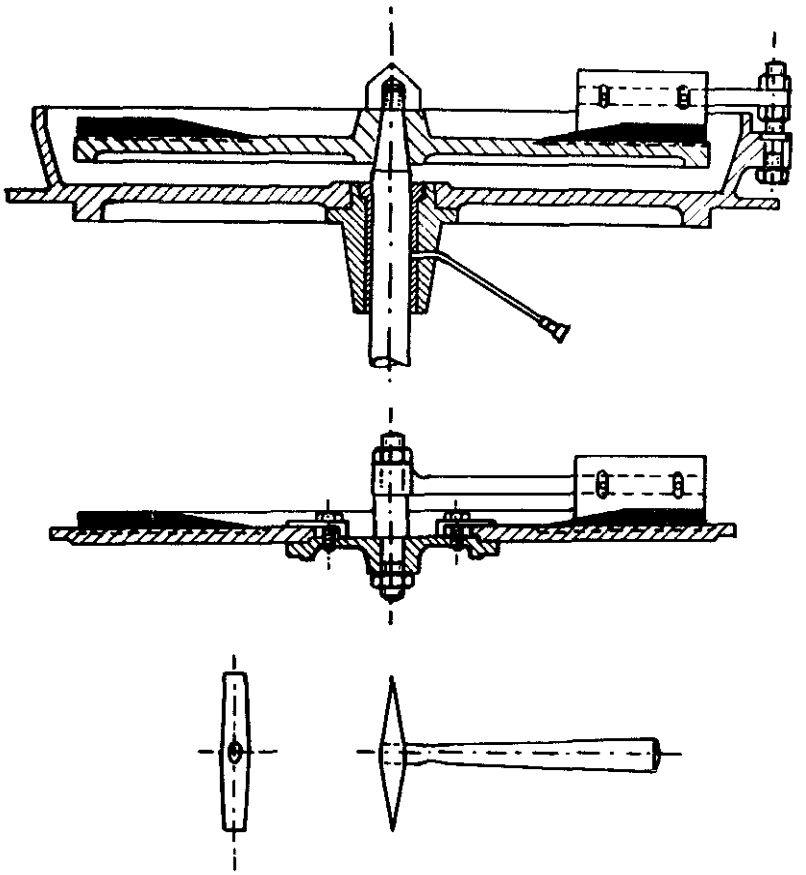

FIG. 146. Special tools used for resurfacing the abrasive surface.

than for rubber roll hullers because of the more flexible surface of the rubber rollers.

Rubber Roll Huller

In principle the rubber roll huller consists of two rubber rolls. One has a fixed position, the other is adjustable to obtain the desired clearance between the two rolls. The rolls are driven mechanically and rotate in opposite directions, the adjustable roll normally running about 25% slower than the fixed one. Both rolls have the same diameter, varying between 150 and 250 mm depending on the planned capacity, and the same width, about 60 to 250 mm..

When the rolls are new, their peripheral speed is about 14 m/s so that the smaller roll runs faster than the larger one (see table below).

Roll diam. (mm)	Roll diam. (inches)	Roll width (mm)	Roll width (inches)	High speed (rpm)	Low speed (rpm)
150	6	64	2.5	1320	900
220	8.5	76	3	1200	900
250	10	250	10	1000	740

The clearance between the two rolls is smaller than the thickness of the paddy grains, and because the rolls run at different speeds, their peripheral speeds differ. When the paddy is fed between the two rolls, the grains are caught under pressure by the rubber and, because of the difference in speed, the husk is stripped off (Fig. 149A). Wear on the rubber is considerable and, with reduction of the roll diameter, capacity is also reduced. The main reason for this capacity reduction is the decrease in the relative speed of the two rolls, and it is this relative speed that actually strips the husk from the paddy grain.

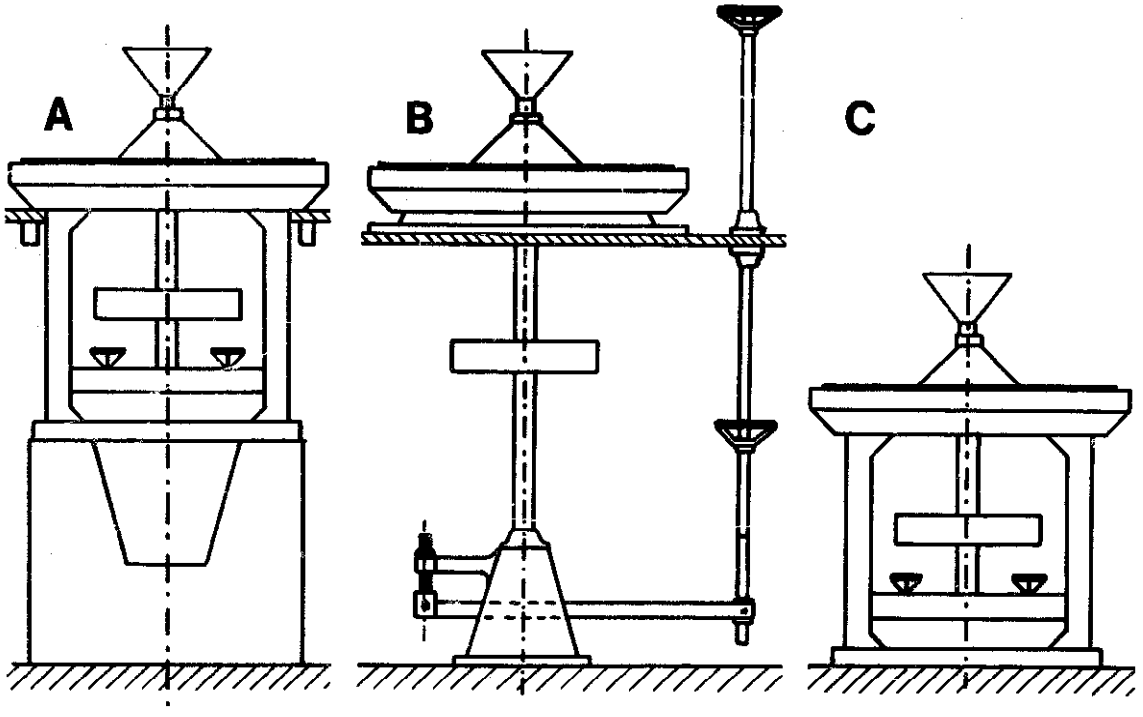

FIG. 147. Different setups for the under-runner disc huller: (A) mounted on elevated concrete foundation; (B) modified huller frame construction; and (C) mounted on ground floor.

Example (Fig. 150)

When the roll diameter is reduced from 254 to 216 mm (less 15%), the peripheral speed also drops by 15%. Because the speed of rotation of both rolls does not change, their relative speed, which is the difference in the peripheral speeds of both rolls, will also drop by 15%. At that point the hulling capacity of the machine has been reduced by about 15%.

In general the faster running unadjustable rubber roll wears out quicker than the adjustable roll. Because the rolls have been made interchangeable, it is recommended they be transferred from time to time to ensure even wear of the set of rolls. To obtain optimum hulling performance, the grain should be evenly distributed over the full width of the rolls. However, quite often the grain distribution device does not function correctly, and the roll surface wears out unevenly, which badly disturbs efficiency and capacity (Fig. 151). The roll surfaces are corrected by removing part of the rubber; therefore, the life of this set of expensive rolls is reduced considerably.

The efficiency of rubber rolls in tropical countries is still unfavourable and is slowing down their introduction. There are many reasons for this: higher temperature, higher humidity of the air, the structure of the husk, and especially the fact that in Japan short grain varieties are hulled; whereas, in tropical countries mainly long grain or medium grain varieties are hulled.

When hulling long grain varieties, the contact area of the grain with the rubber, the moment it is stripped off its husk, is much larger compared with short grain varieties. Consequently, the wear is higher and the life of the rubber is considerably shorter. Whereas 200 t of paddy can be hulled in Japan, the same quality of rubber will only hull about 100 t in tropical countries (Fig. 152). Better quality substitutes for the rubber exist; however, the increased durability in terms of tonnes of paddy hulled does not cover the much higher price of these substitutes.

The dehusking performance of this type of huller is superior to the conventional disc huller, because production of unbroken brown rice and huller efficiency are higher. However,

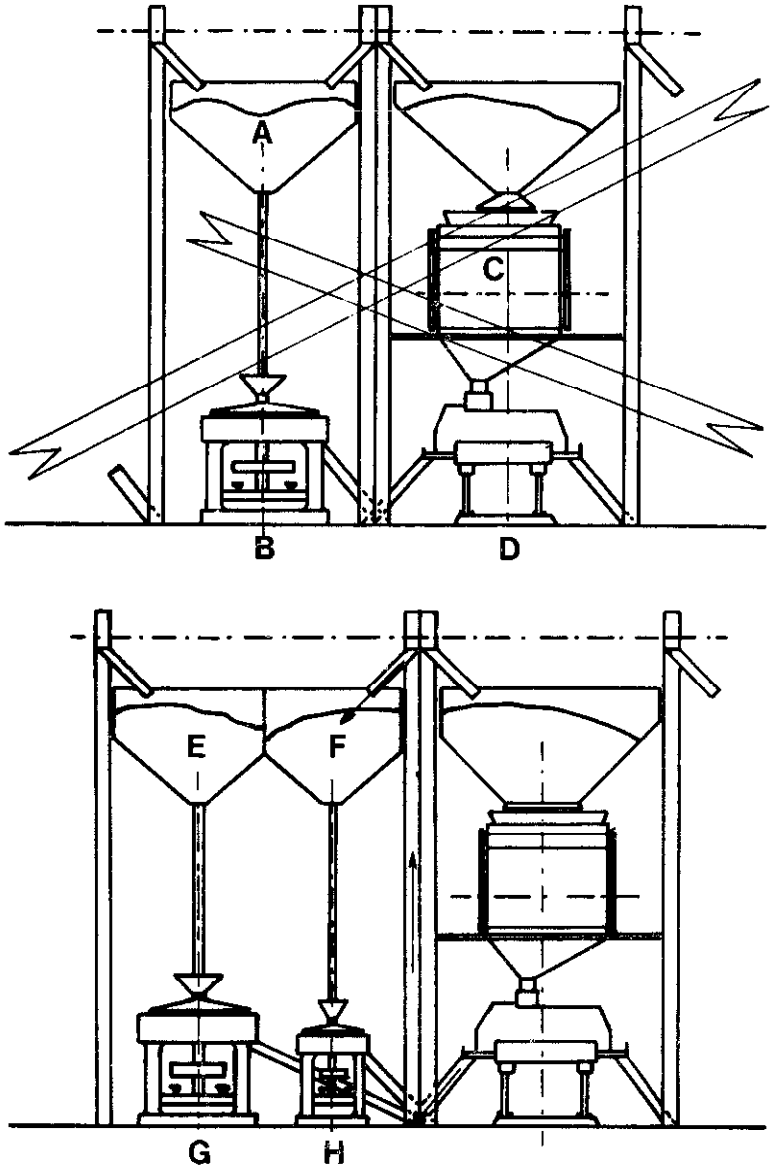

FIG. 148. Methods of return of rejected paddy:(top) grain flow without separate return hulling, not recommended; and (bottom) grain flow with separate return hulling, recommended. A = precleaned and returned paddy, B = huller, C = huskaspirator, D = separator, E = precleaned paddy, F = returned paddy, G = first huller, and H = return huller.

this does not mean the head rice yield of the mill is higher. Because the silver skin of the paddy is undamaged by the rubber roll huller, cracked grains appear as unbroken brown rice, but during the first pass of the whitening process these grains will break.

Rubber rolls can only be stored for a limited period because their durability slowly deteriorates (Fig. 153). Therefore, a continuous supply of rolls should be guaranteed in order to utilize them at optimum efficiency in the interest of total mill efficiency.

The fact that in a rubber roll huller one roll runs in a fixed position and the second roll is adjustable; that one roll runs clockwise while one roll runs counter-clockwise; and that both rolls are driven, requires special provisions in the drive mechanism. There are three

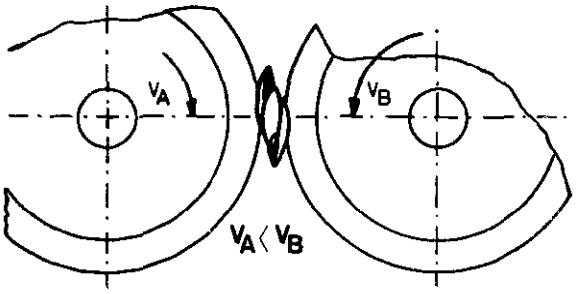

FIG. 149. Dehusking principle of rubber roll huller.

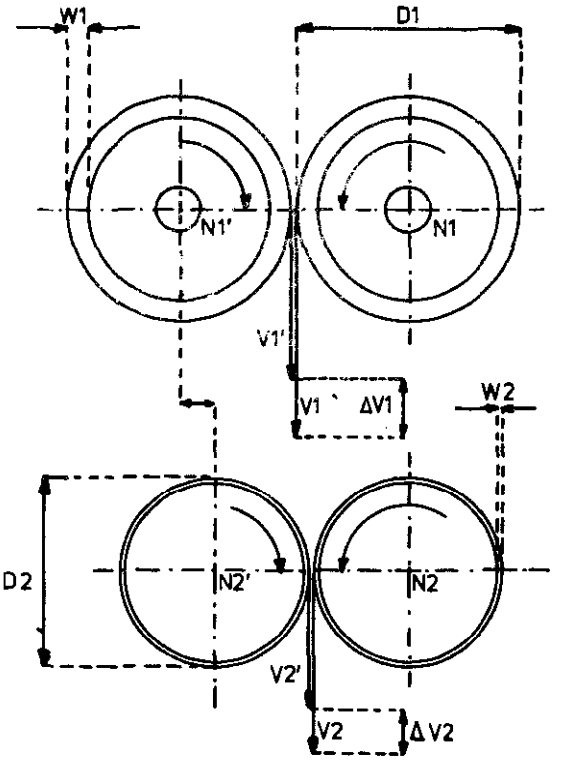

FIG. 150. Relation between diameter of rolls and capacity of huller: W1 − W2 = 19 mm; D1 = 254 mm; W1 = 25.4 mm; N1 = 1000 rpm; N1′ = 740 rpm; V1 = 13.30 m/s; V1 = 3.46 m/s; D2 = 216 mm; W2 = 6.4 mm; N2 − N1 = 1000 rpm; N2′ − N1′ = 740 rpm; V2 = 11.30 m/s; and V1 − V2 = 0.52 m/s = −15%.

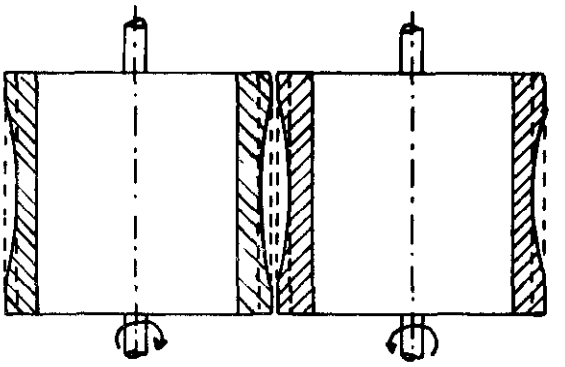

FIG. 151. Unevenly worn and damaged surface of rubber rolls as a result of unequal distribution of the paddy.

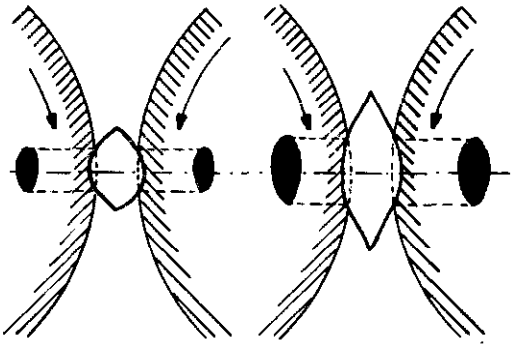

FIG. 152. The relation between paddy variety and hulling capacity.

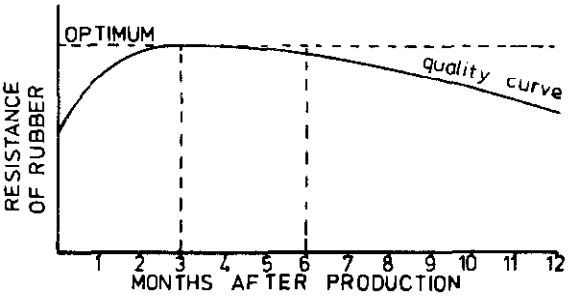

FIG. 153. Relation between durability of rubber rolls and age. The recommended period for utilization of rubber rolls for optimum efficiency is between 3 and 6 months after production.

kinds of drive transmission: (1) chain transmission; (2) V-belt transmission; and (3) gear-wheel transmission.

Chain Transmission

If both rolls always ran in a fixed position a simple endless chain over chain-wheels could drive the rolls. However, one roll must be

adjusted continually; therefore, chain tension must also be corrected immediately. A British-made design solved this problem by mounting the chain-wheel of the adjustable roll and two extra chain wheels for chain tensioning on one sturdy bevel plate that is tiltable over a fixed point (Fig. 154). To adjust the rubber roll clearance, the sturdy bevel plate is tilted by a handwheel adjustment, controlling both the rubber roll and the two extra chain wheels. The adjustment of these three gear wheels is not the same because their distance from the tilting point of the bevel plate differs.

The chain tension, however, is not fully corrected by this method and, therefore, one of the two extra gear wheels swings around the initial turning point of the gear wheel. This proved to be sufficient for continuous adjustment purposes. The advantage of this rather complicated system is the clearance of the rubber rolls can be adjusted when the machine is running even under full load. A simpler method for chain adjustment is a manually adjustable gear wheel for chain tensioning after adjustment of the roll clearance. However, in this case the roll clearance can only be adjusted when the huller is unloaded and not running, which is a great disadvantage.

V-Belt Transmission

This type of transmission is most commonly used for the rubber roll hullers. Figure 155 demonstrates the mechanical adjustment necessary to obtain the appropriate clearance between the rubber rolls. Assume the original positions of the linkages were A, B, C, and D for the V-belt pulleys driving the rubber rollers mounted at A and B. The belt tension is changed by moving the idler pulley at C, which is controlled by a screw adjustment. In this transmission system drive D is fixed, the rubber roller at A is fixed, and at B there is a spring loaded bearing mounted on a sliding plate, which allows the roller at B to move for appropriate clearance. For example, to reduce the clearance between the rollers, the handwheel screws out V-belt pulley C to position C′ and the corresponding position of B′ is obtained. Pulley C must be mounted like pulley B so that sliding is possible.

Gear Transmission

Figure 156 illustrates the third common method adopted for clearance adjustment of the rubber rollers. In this arrangement, assume A, B, C, and D are the positions of the gears prior to adjustment. A and C are fixed assuring the desired contact; whereas, B and D are adjustable. However, BD is rigid and maintains the required contact between gears B and D. By adjusting the position of gear B with the screw at the right, the clearance is determined, and the link BD starts to push D out of mesh with gear C; however, this is corrected by the spring loaded rigid bar shown below the adjustment lever. — HARRY VAN RUITEN. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

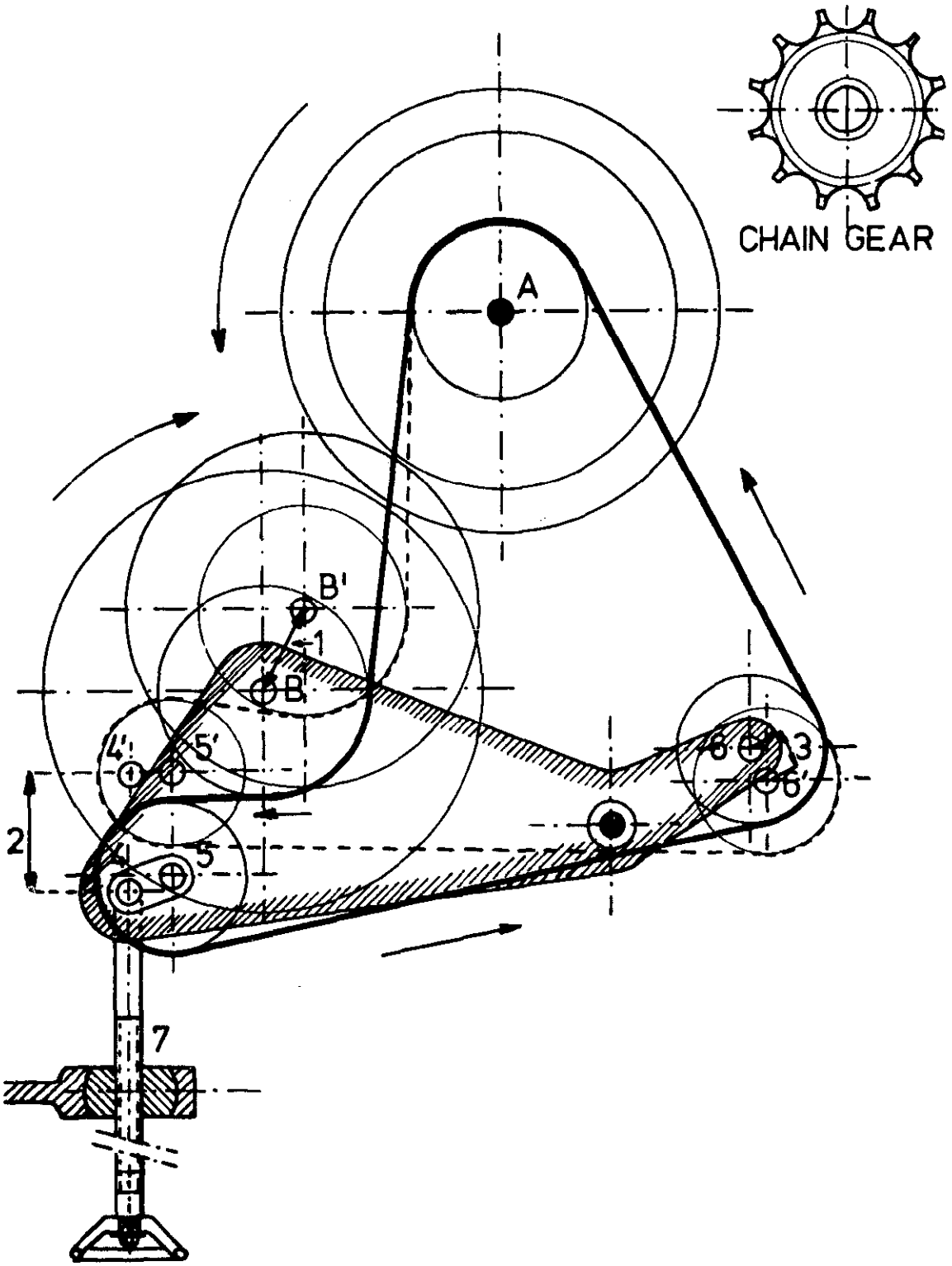

FIG. 154. Method of adjusting clearance of rubber rolls and tension of chain for a chain-drive transmission.

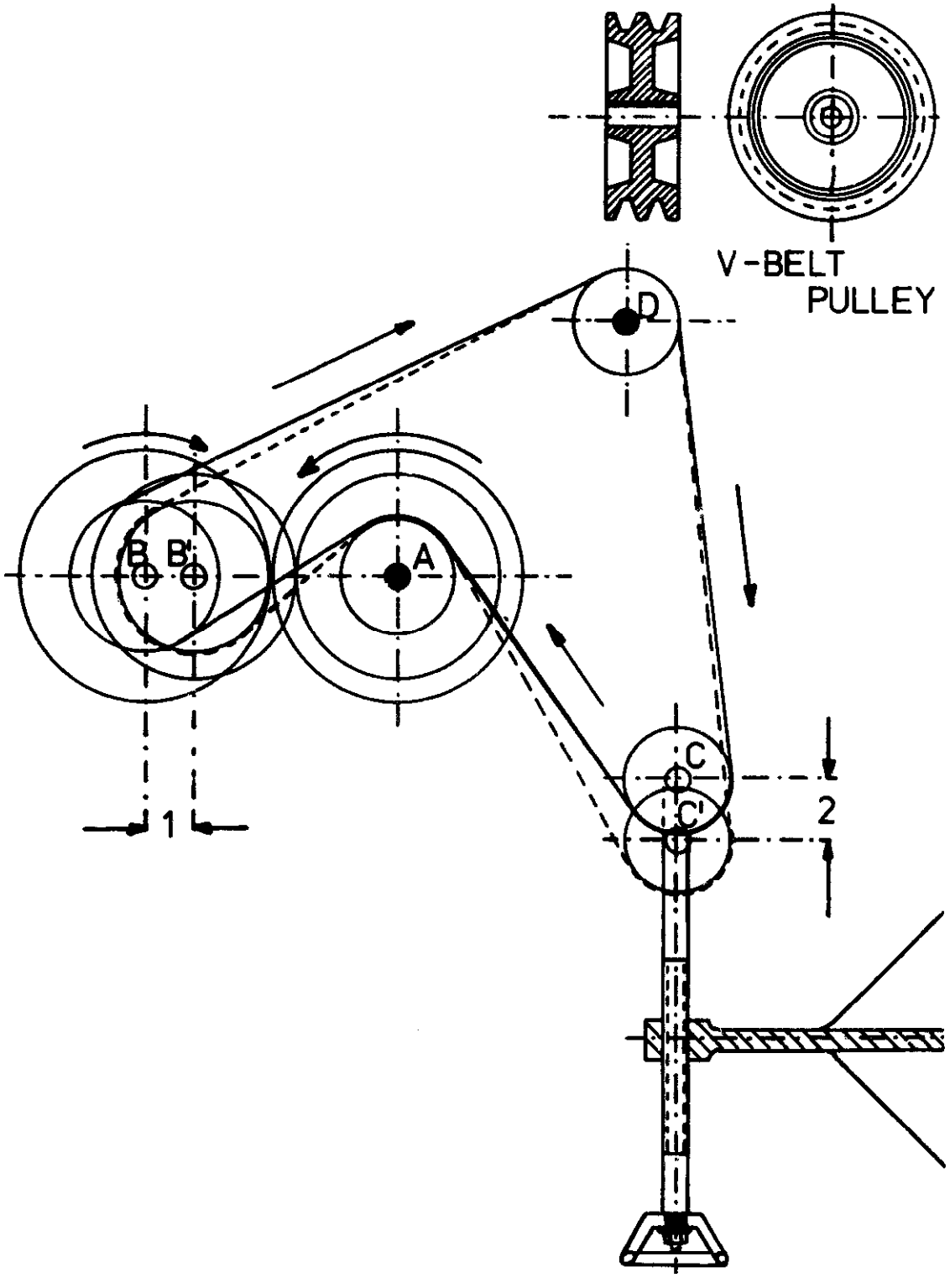

FIG. 155. V-belt transmission for the adjustment of the clearance between the rubber rolls.

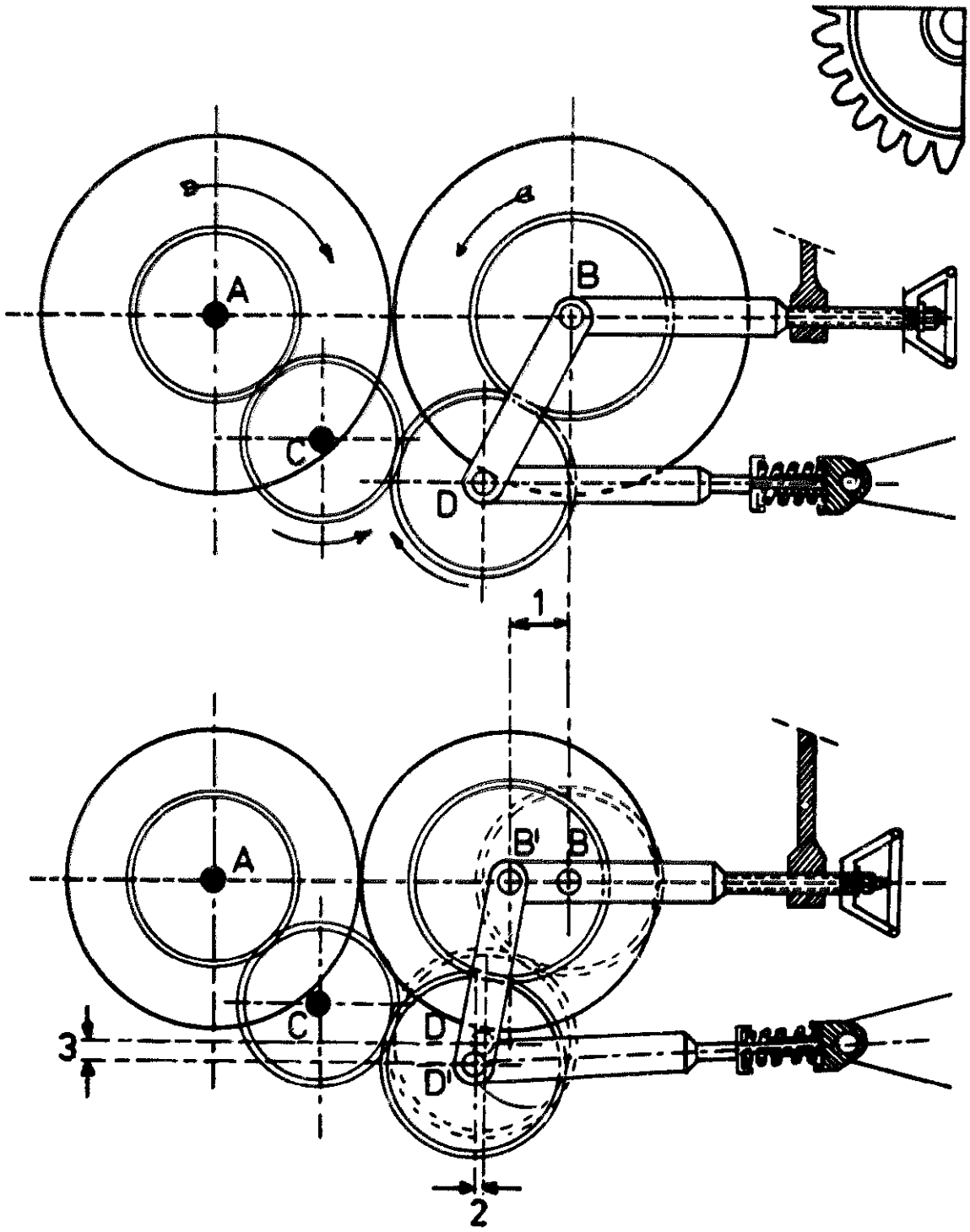

FIG. 156. Gear transmission for clearance adjustment of rubber roll huller.

Husk Separation

The discharge of a rice huller is a mixture of brown rice, paddy, husks, bran, dust, brokens, and immature paddy grains. The paddy separators normally only receive the brown rice, the paddy, and sometimes the immature paddy grains. Between these two rice mill machines the husks, bran, dust, brokens, and immature paddy grains must be removed.

Normally, the bran and dust are separated through an oscillating sieve with fine perforations and discharged as a waste product; however, they may be mixed with the bran and removed by the bran aspiration cyclone system. The separation of brokens and immature grain before husk aspiration is essential because both of these commercial by-products would be lost as waste through the husk aspiration system. Their recovery increases the efficiency of the mill in terms of production of commercial products and money. Losses of up to 2% of the paddy intake capacity of the rice mill have been recorded due to improper separation.

The brokens are normally separated through self-cleaning sieves and discharged directly to the whitening section. The separation of the immature grains is a more difficult problem and, when done prior to paddy separation, a system is normally incorporated into the actual husk aspirator. Quite often, however, the immature grains are separated from the brown rice after the paddy separator, and consequently, it is possible for the immature paddy grains to be blown out with the husks because this method only works on dehusked immature grains.

For these reasons, the husk separators are sometimes designed to separate more than just husks. A large number of machines have been developed for this purpose. However, no one machine combines all necessary functions, and quite often additional machines are necessary to achieve optimum performance. Because these extra investments are not made in most rice mills, a certain percentage of loss through husk separation cannot be avoided. However, much can be done to reduce this loss.

Out of the large range of husk separators the following are discussed in this paper: (1) husk aspirator with air traps and suction blowers, Philippines; (2) husk aspirator with suction blower, West Germany; (3) husk aspirator combined with plansifter, West Germany; (4) husk aspirator combined with a rubber roll huller, Japan; (5) closed circuit husk separator, West Germany; (6) double action husk aspirator, Philippines; and (7) high capacity husk aspirator, West Germany.

Husk Aspiration with Air Traps (Philippines)

In this system the husks are removed through air traps connected to suction blowers. Aspiration is introduced in two places between the huller and the paddy separator: (1) an air trap on top of the oscillating sieve that receives the discharge of the huller and removes through fine perforations the bran and dust (Fig. 157, no. 4); and (2) air traps between the holding bin for the huller discharge and the paddy separator (Fig. 157, no. 6).

For this double husk aspiration system two suction blowers (Fig. 157, no. 1 and 2) with a central pulley drive (Fig. 157, no. 3) are normally used. Usually there is one air trap on top of the oscillating sieve, and two to five traps between the holding bin and the paddy separator depending on the size of the separator. When more than three air traps are used between the bin and paddy separators, some of the air traps are connected with the suction blower, which is normally connected with the air trap on top of the sieve. When properly adjusted and controlled, this system gives efficient husk aspiration. However, many factors make control very difficult and in practice the mill operators do not know how to set a proper air and grain distribution.

What makes this setting so difficult? (1) Effi-

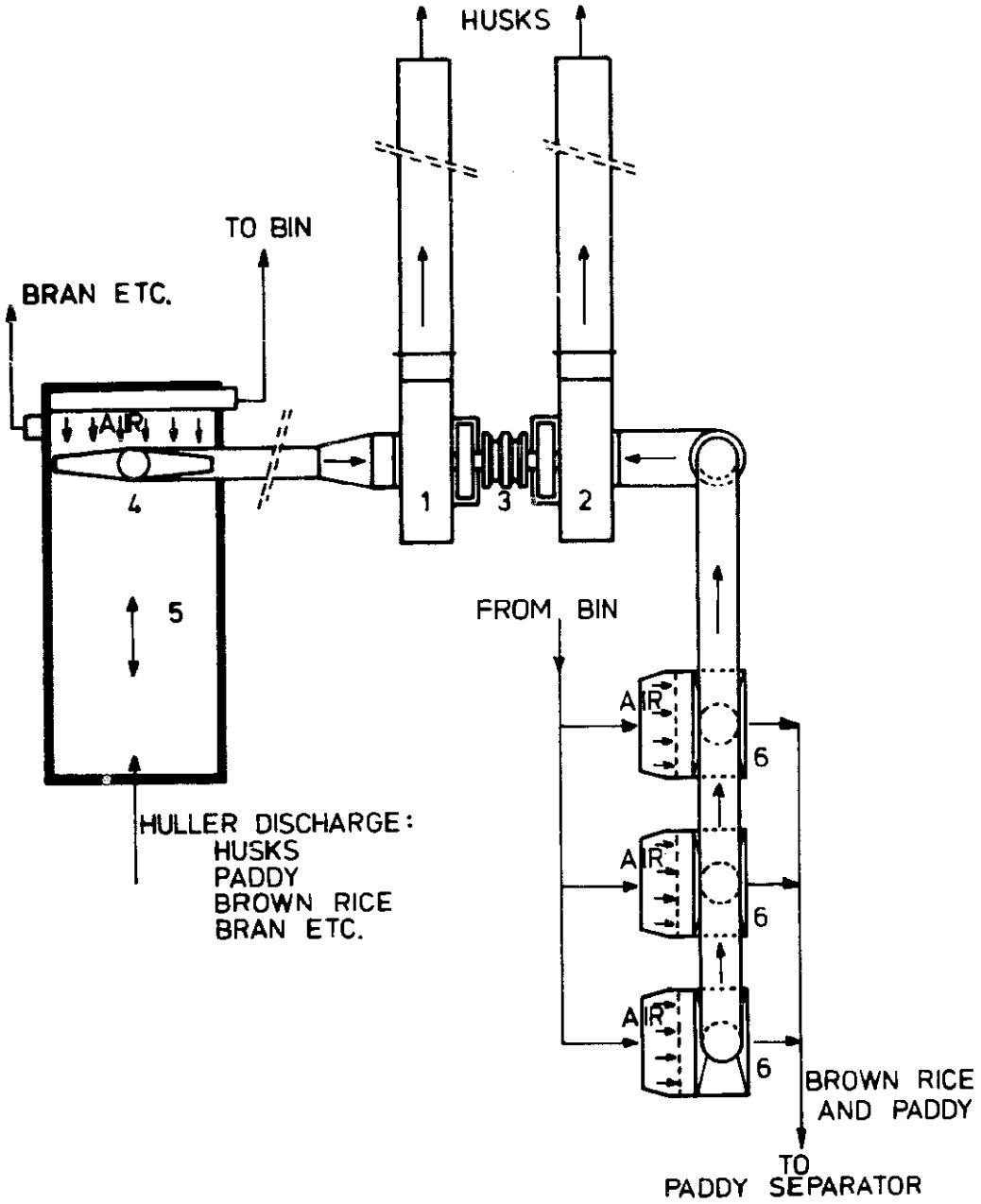

FIG. 157. Husk aspirator with air traps and suction blowers in cone-type rice mills (Philippines).

cient husk aspiration on top of the sieve can only be achieved when the huller discharge is equally distributed over the full width of the sieve. (2) The thickness of the grain-husk layer should be constant because this determines the clearance between the top of the grain layer and the bottom of the air trap. Through this clearance the air is sucked into the air trap, lifting the husks floating on top of the grain layer. (3) The airstream should be constant and not too strong; otherwise, grains will be lifted and discharged with the husks. (4) The distribution of the grain over the three, four, or five air traps on top of the separator should be equal. (6) The airstream in these air traps should not be too strong to prevent the loss of

grains with the husk discharge. (7) The efficiency of the air trap system strongly depends on the moisture content of the grain and the throughput capacity of the mill. The adjustment is different at low capacity than at full capacity.

The equal distribution of air and grain over the traps on top of the paddy separators seems to be especially difficult. The grain, feeding the traps, comes out of one holding bin (Fig. 158, A) and leaves the traps at the bottom (Fig. 158, B). The air is sucked through special openings in the air traps (Fig. 158, C), passes through the grain, and lifts the husks when entering the air tubes (Fig. 158, D). These separate air tubes with adjustable air sleeves are connected through a central air tube with the suction blower (Fig. 158, E). To obtain equal air distribution the air tubes must be separated from each other (Fig. 158). Although the principle of the system is sound, its implementation is responsible for considerable grain losses through husk discharge because the mill operators generally fail to adjust the air and grain flow properly.

Husk Aspiration with Suction Blower (West Germany)

These compact units are commonly used in German-made mills and are normally placed on a steel frame over the paddy separator. The machine has a double function because it removes the husks (Fig. 159, B) and separates the immature grains (Fig. 159, C). The grain (paddy, brown rice, and husks) is fed into the machine over its full width (Fig. 159, A). An adjustable sleeve and a belt-driven rotating paddle (Fig. 159, no. 4) release a thin film of grain. Air sucked through the grain lifts the husks that are discharged through the built-in suction blower. The airstream is strong enough to lift the immature grains as well. However, these grains drop into a V-shaped compartment for automatic discharge through double air valves (Fig. 159, no. 5 and 6).

The brown rice and the paddy leave the machine at the bottom for direct discharge into the paddy separator (Fig. 159, D). The airstream can be controlled by two adjustable air valves; one on top of the machine (Fig. 159, no. 2) controlling the husk aspiration efficiency; and the second valve inside the machine controlling the efficiency in the separation of the immature grains (Fig. 159, no. 1). A glass window allows visual inspection of the grain distribution inside the machine (Fig. 159, no. 7).

Quite often this machine is produced in combination with an oscillating self-cleaning sieve for the separation of the bran, dust, and brokens. The sieve is then fixed on top of the husk aspirator and they are sold as one compact unit.

Husk Aspirator Combined with Plansifter (West Germany)

In large rice mills the husk aspirator with suction blower is often combined with a plansifter, which is fixed in a solid steel frame above the husk aspirator (Fig. 160). The husk aspirator and the plansifter together are considered as one compact husk-aspirator unit. The plansifter is equipped with two self-cleaning sieves. The first sieve (Fig. 160, no. 1) has fine perforations for the separation of bran and dust, the second (Fig. 160, no. 2) has larger perforations for the discharge of brokens. Therefore, the sieve overflow is a mixture of husks, paddy, and brown rice.

Husk Aspirator Combined with Rubber Roll Huller (Japan)

The compact lightweight construction of the rubber roll huller makes it possible to combine the huller and the husk aspirator. Because the rubber roll huller does not damage the bran layer of the brown rice, the huller discharge does not contain any bran. Therefore, any dust produced by the huller can be discharged with the husks.

The operation of the machine is quite simple. The paddy fed into the huller is dehusked and fed immediately into the husk aspirator. The grain is distributed as a film over the full width of the aspirator, and an airstream is sucked through this film, carrying

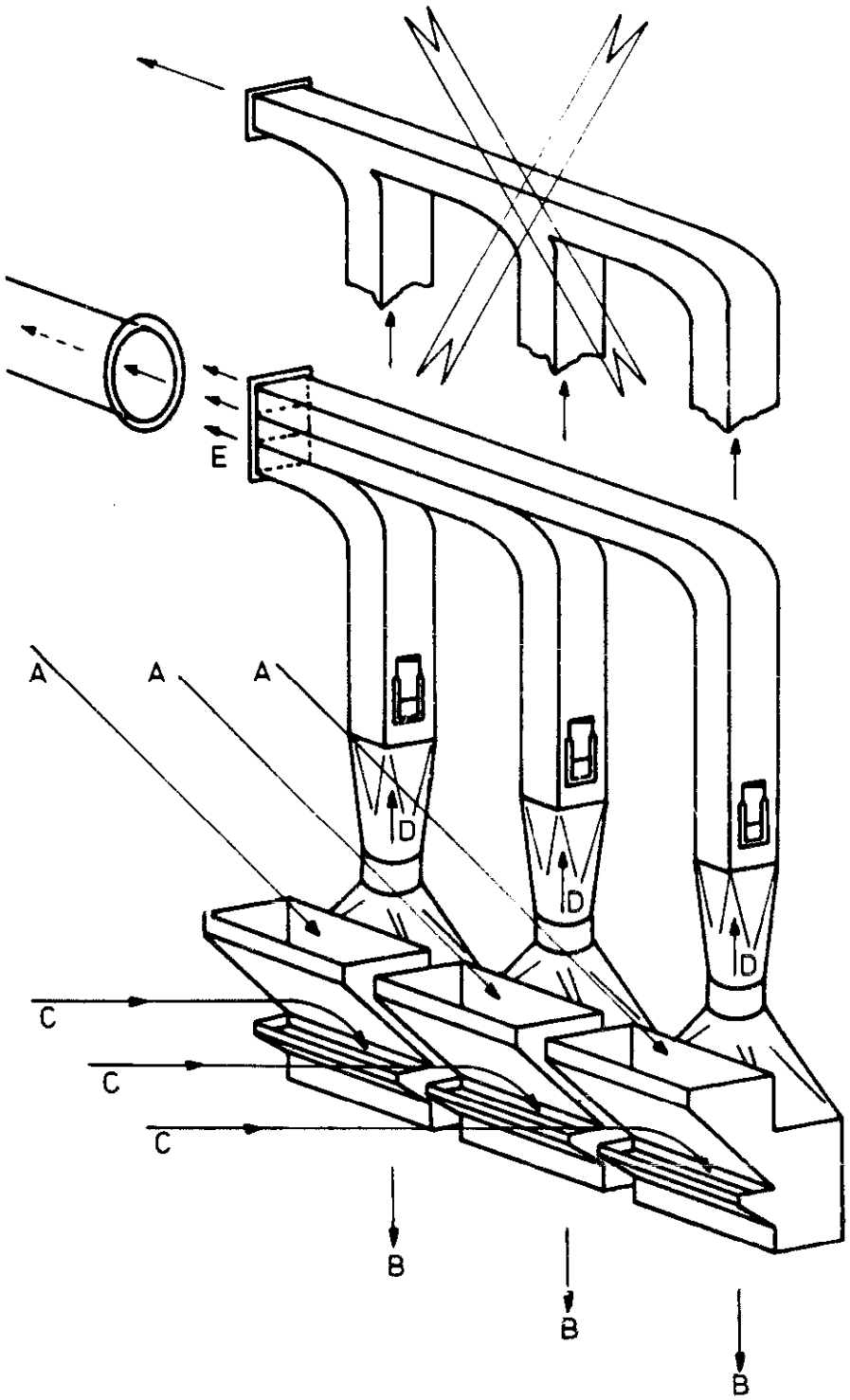

FIG. 158. System used to distribute air equally over the air traps for husk separation (Philippines).

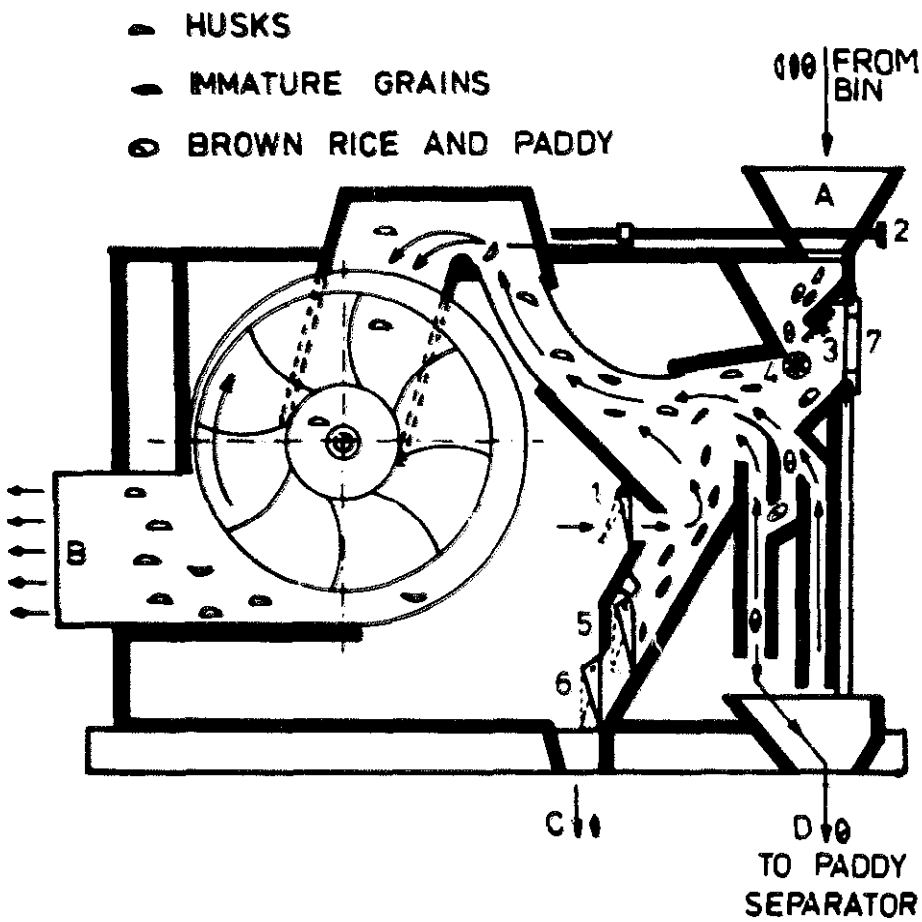

FIG. 159. Husk aspirator with suction blower (West Germany).

away the husks and lifting the immature grains. The immature grains drop into a separate hopper for discharge by a screw conveyor; the paddy and the brown rice leave the machine through a spout; and the husks are blown out by the strong suction blower.

A large air sleeve on top of the air duct controls the quantity of air drawn through the grain and the performance of the airstream with respect to the separation of the husks and immature grains is controlled by three valves (Fig. 161, no. 1, 2, 3). It requires experience to correctly adjust these valves. There are no provisions for the separation of small brokens. The separation of immature grains, in general, is not sufficient, and it is difficult to check whether or not immature grains and brokens are blown out with the husks. However, the husk aspiration efficiency is generally very high.

Closed Circuit Husk Separator (West Germany)

The closed circuit husk separator separates the husks and immature grains from the paddy and brown rice. The machine is called a "closed circuit" separator because it does not blow the husks out with the air; the air used for the separation of the husks is continuously recirculated (Fig. 162).

The mixture of paddy, brown rice, immature grains, and husks is loaded into a hopper on top of the machine. This mixture passes through inclined plates and falls as a grain film. A strong airstream built up by the pressure or discharge side of a built-in suction blower passes this film of grain and separates the husks from the mixture. Because of the special shape of the separator housing, the husks follow the housing pattern as in a

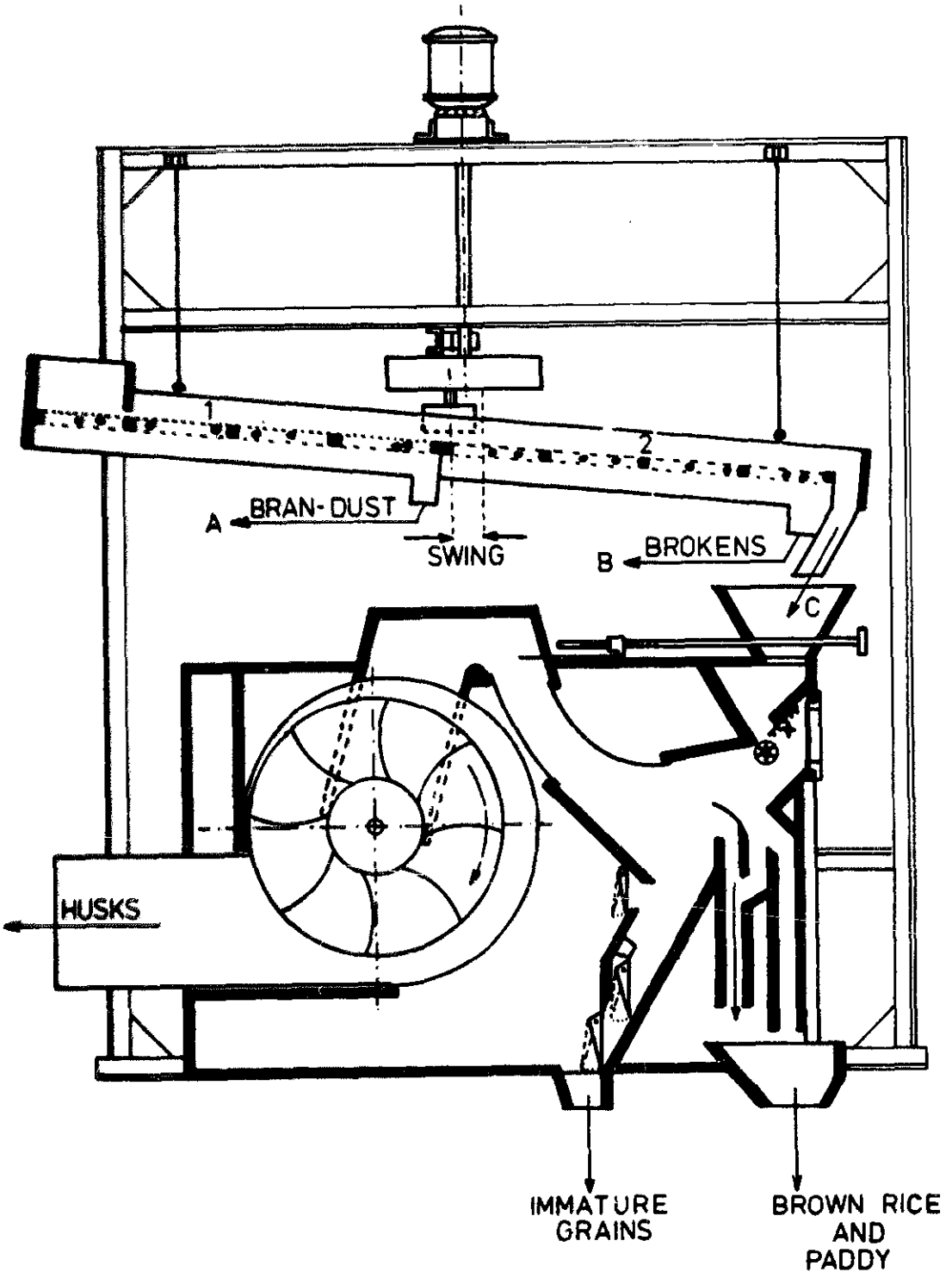

FIG. 160. Husk aspirator combined with plansifter (West Germany).

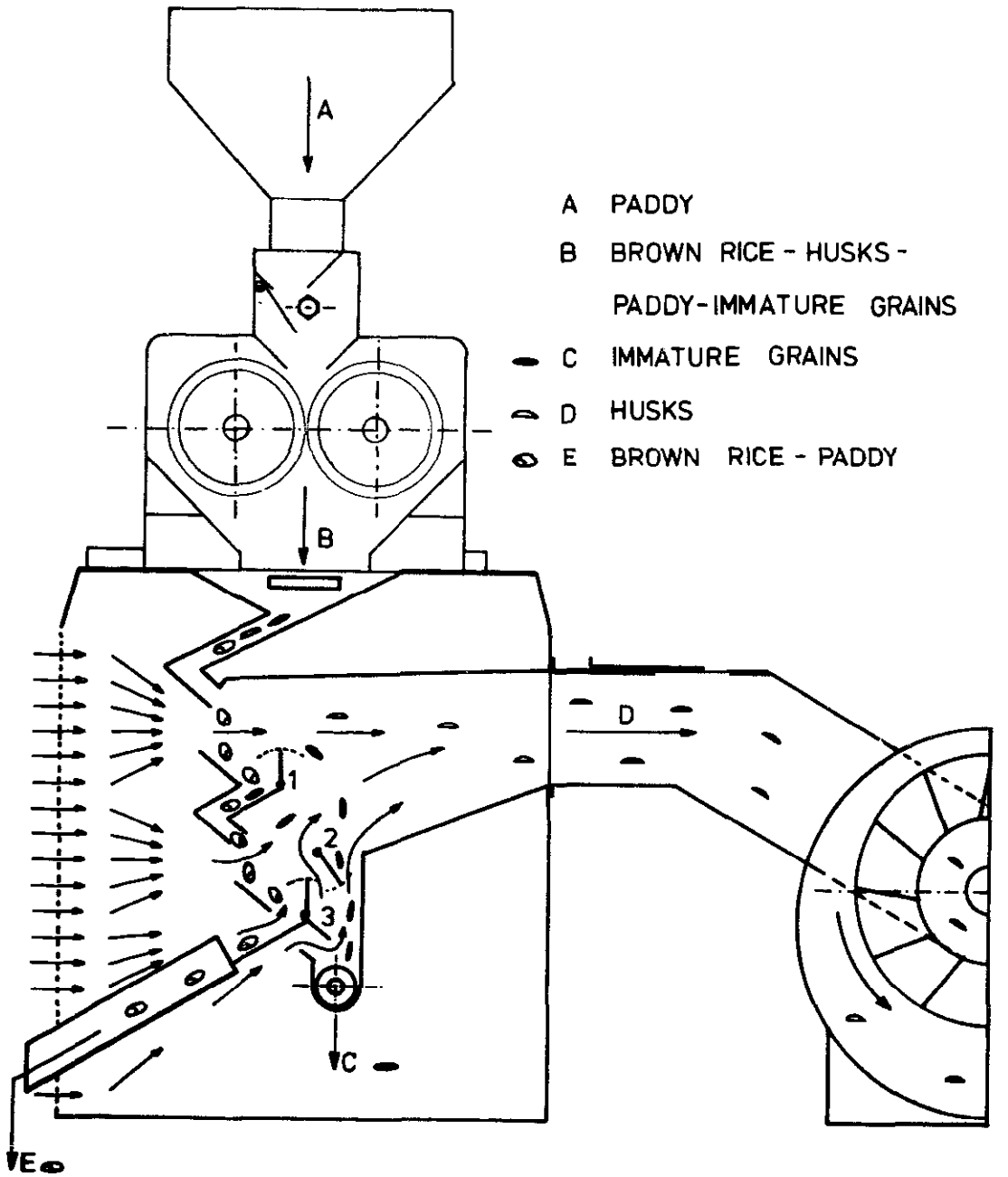

FIG. 161. Husk aspirator combined with rubber roll huller (Japan).

cyclone. As a result of the speed of the air and the impact of the separating centrifugal force, the husks are freed from the recirculating airstream and drop into the bottom of the V-shaped housing (Fig. 162, no. 1) for side discharge through a screw conveyor (Fig. 162, B).

The air, now free from husks, is recirculated by the blower and is used to lift the immature grains from the grain film. The immature grains and a mixture of brown rice and paddy fall into separate compartments and are discharged by screw conveyors (Fig. 162, no. 2, 3).

The quantity of air recirculated is controlled by a bypass valve (Fig. 162, no. 4) and the separation performance by an adjustable

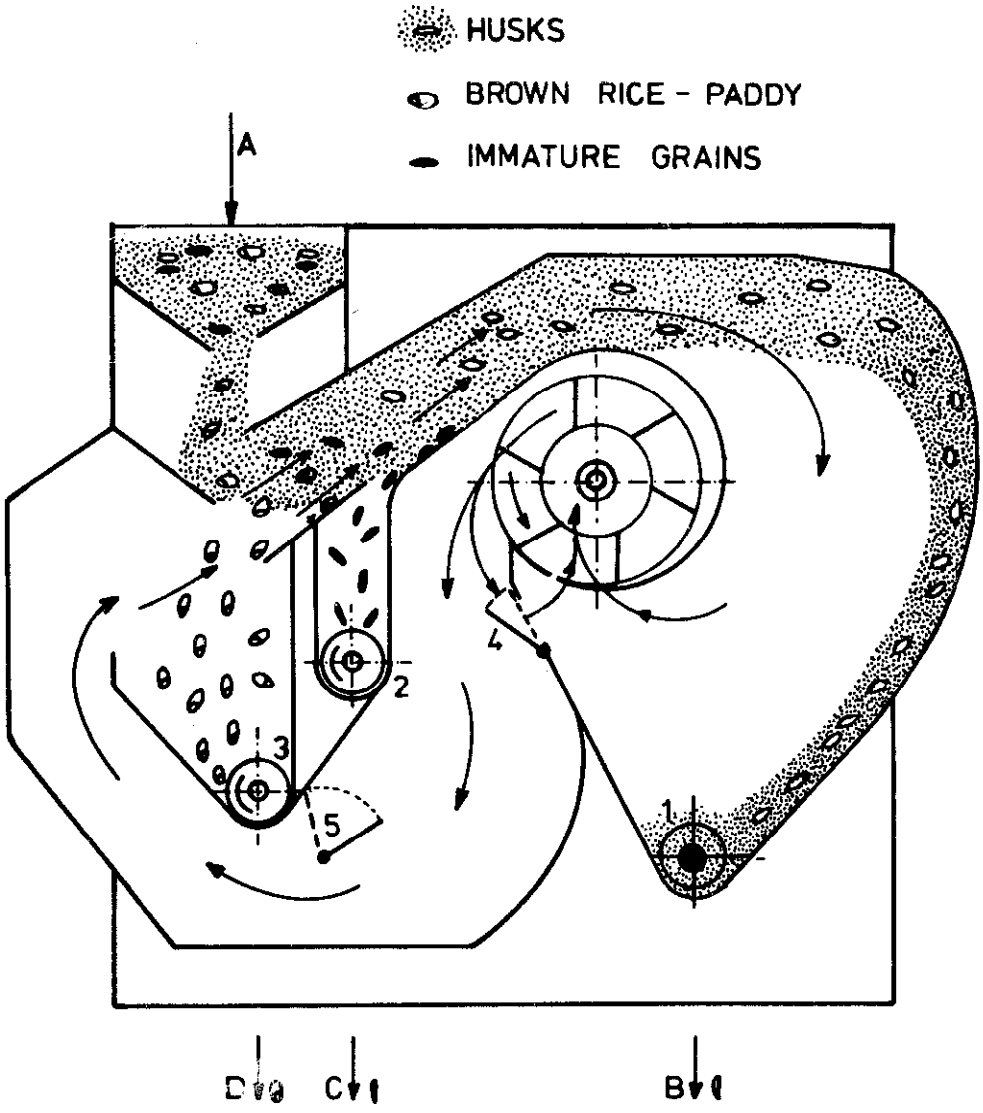

FIG. 162. Closed circuit husk separator (West Germany).

throttle valve (Fig. 162, no. 5). This machine does not separate bran, dust, and brokens from the huller discharge, so that prior to husk separation a plansifter or oscillating sieve must be installed.

Double Action Husk Aspirator (Philippines)

The double action husk aspirator as designed and made in the Philippines separates the husks from the brown rice and paddy and separates the brokens for later cleaning.

The mixture of husks, brown rice, paddy, brokens, bran, immature grains, and dust is discharged onto an oscillating sieve (Fig. 163, no. 1). Through the sieve perforations pass the bran, dust, and small brokens. The overflow, being a mixture of husks, paddy, and brown rice is unloaded into the actual husk aspirator and the grain falls as a film (Fig. 163, top). The airstream, caused by the built-in suction blower, is sucked through the front opening of the machine and separates the husks from the falling grains. These husks, carried away by the air, pass the suction blower and are discharged. The mixture of paddy

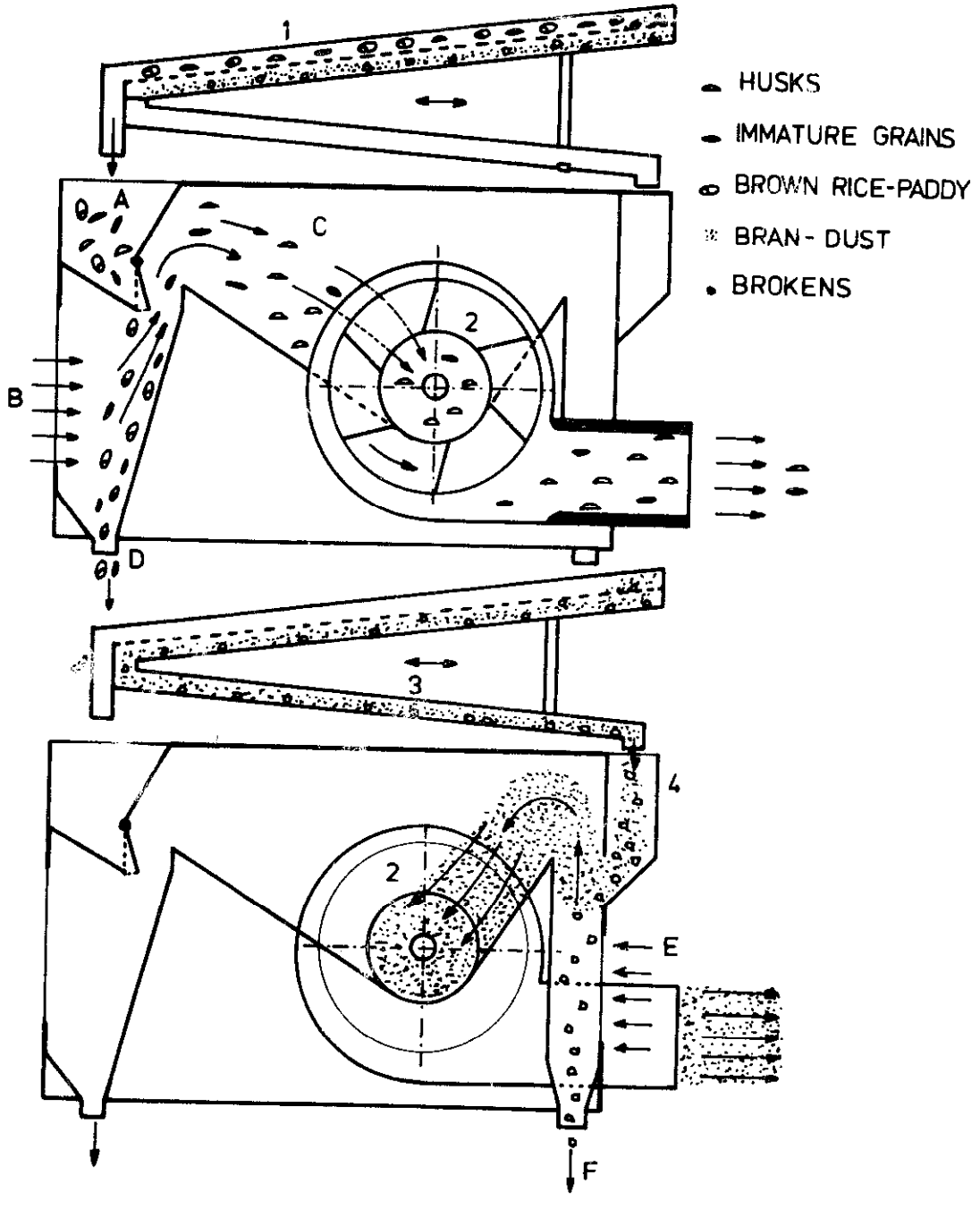

FIG. 163. Double action husk aspirator (Philippines).

and brown rice then leaves the machine through a bottom opening for direct discharge into the paddy separator. The bran, dust, and brokens, separated by the oscillating sieve, are discharged into two openings (left and right) at the back of the actual aspirator body (Fig. 163, bottom). An airstream passes through this falling product and separates the bran and dust from the brokens. These brokens are discharged through a bottom opening of the machine for further processing in the whitening section of the rice mill. If no separate fine-perforation sieve is installed between the huller and this husk aspirator, the bran will be lost because it will be blown out with the husks as mill waste.

No provisions for the separation of immature grains are included, and consequently some of these immature grains are separated with the husks, representing a loss. It should be possible to incorporate a recovery system for immature grains into this type of machine.

The sieve on top of the husk aspirator is never self-cleaning; therefore, brokens are not separated efficiently from the husks and are blown out of the machine. This loss could be avoided by using self-cleaning sieves. Wear of the husk discharge spout is enormous; however, this wear has been limited by coating the spout with the emery composition used for the under-runner disc huller.

High Capacity Husk Aspirator (West Germany)

In large, mainly vertical, rice mills, a strong central aspiration system with cyclones and filters is installed, which makes it possible to use aspiration air without installing separate suction blowers in the individual machines (Fig. 164). This makes the machines more compact and cheaper. In such installations, precleaners and husk aspirators with vertical aspiration are installed.

The mixture of paddy, brown rice, husks, brokens, bran, and dust is unloaded into the machine and spread over the full width of the self-cleaning sieve (B). This sieve is a high frequency vibrator driven by an electric motor through a V-belt transmission (S). The brokens, bran, and dust pass through the sieve perforations and are discharged through an outlet spout at the bottom of the machine (D). The bran and dust are removed from the brokens later in the process. The sieve overflow, consisting of husks, paddy, and broken rice, is discharged into the vertical aspiration tube through a specially shaped plate (F) that increases the spread of the grain to about two and one-half times that of the sieve. A strong airstream, moving upwards, enters the machine through a large opening in the front of the aspirator and through two side openings (G). On its way up the aspiration tubes (H), the air carries the husks and any paddy and brown rice grains that are in a horizontal position. However, as soon as the grain position is vertical, the grain falls and is discharged with the rest of the paddy and the brown rice through the main discharge spout (R), which often incorporates a permanent magnet. The quantity of air used for the vertical aspiration is controlled by an adjustable valve.

The operation of the machine, especially the effect of the airstream on those grains lifted by the air, can be observed through a transparent panel (L) which can be illuminated for more careful observation at night (N). This allows immediate adjustment of the aspirator in case grain is being discharged with the husks.

The transparent front of the machine shows the battery of vertical aspiration tubes that secures an optimum spread of the grains over the full width of the machine, a perfect distribution of the air, and, consequently, perfect husk aspiration performance. — HARRY VAN RUITEN. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

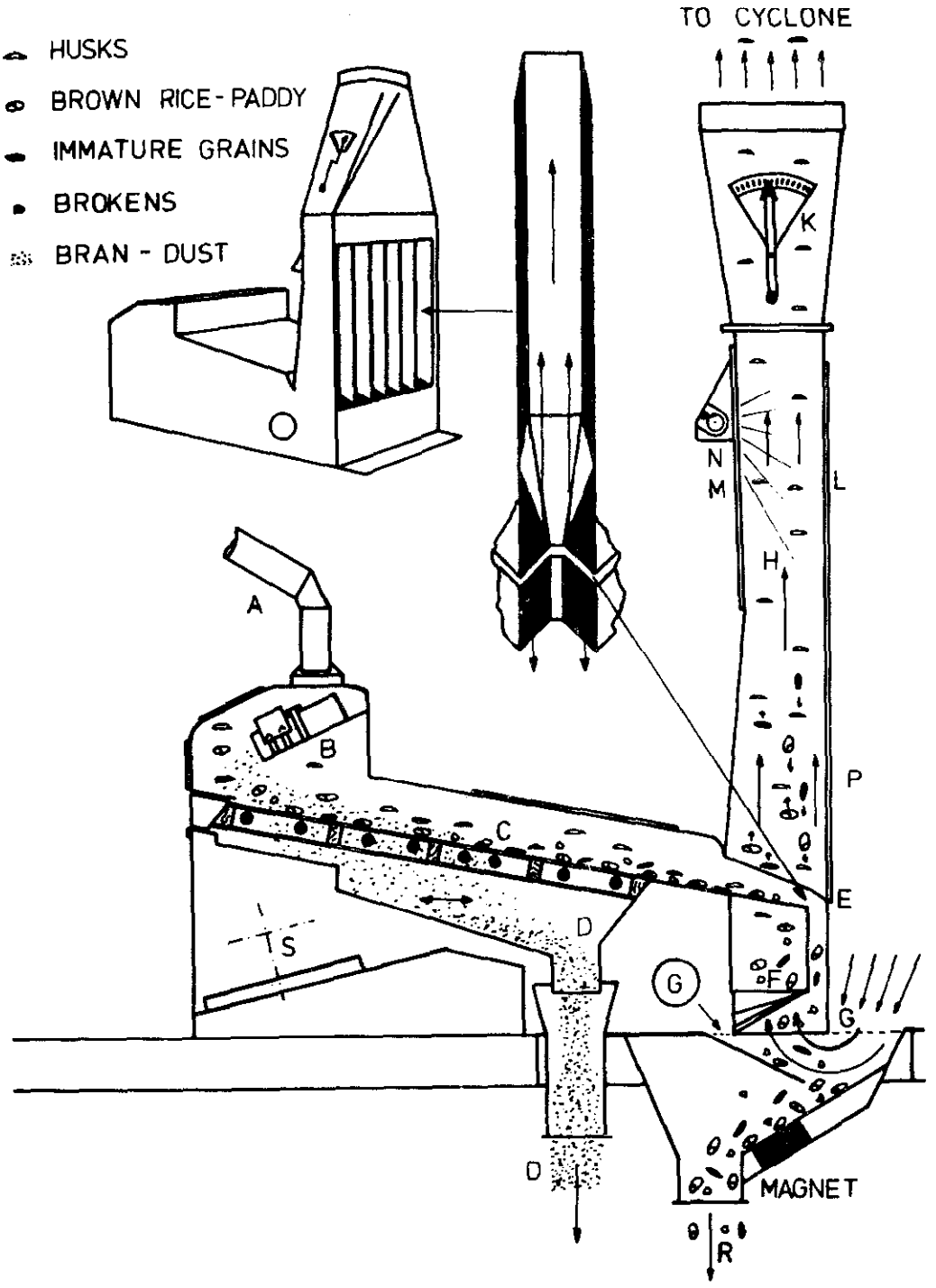

FIG. 164. High capacity husk aspirator (West Germany).

Paddy Separation

In the paddy hullers of a rice mill not all the paddy grains are hulled at once. The huller efficiency, namely the percentage of paddy actually hulled with a minimum of breakage, varies between 80 and 95% and depends on: (1) the uniformity of the paddy; (2) the variety of paddy hulled; (3) the condition of the paddy; (4) the type of huller; (5) the condition of the huller; and (6) the operator of the machine. The huller, therefore, produces a mixture of brown rice, husks, and paddy. After separation of the husks, dust, bran, and small brokens, a mixture of brown rice and paddy is obtained.

The amount of paddy that must be removed to produce brown rice free of paddy is indicated in the following example. If the huller efficiency is 80%, then 80% of the paddy will be hulled and 20% will be unaffected. The output will be 64% brown rice, 16% husks, and 20% paddy. The total of brown rice plus paddy is 84%; therefore, in this mixture there is 24% paddy ($20/84 \times 100$). When the huller efficiency is increased to 90% the output will be 72% brown rice, 18% husks, and 10% paddy. The total of brown rice plus paddy is 82%, meaning there is 12% paddy in this mixture. Therefore, when the huller efficiency is increased from 80 to 90% the amount of paddy is reduced from 24 to 12%. Consequently, a maximum of about 25% paddy must be removed from this mixture to produce a brown rice free of paddy.

This paddy is separated in a padd[illegible] rator. In the separation of paddy use is [illegible] of the different characteristics of paddy [illegible] brown rice. These differences are: (1) the average weight of paddy by constant volume is lighter than that of brown rice; this is sometimes expressed as "the specific gravity of paddy is lower than that of brown rice"; (2) the paddy grains are more buoyant than the brown rice kernels; (3) the paddy grains are longer than the brown rice; and (4) the paddy grains are wider and thicker than the brown rice kernels. Basically there are three types of paddy separators: the compartment-type, the tray-type, and the screen-type.

The compartment-type paddy separator uses differences in specific gravity and buoyancy of the paddy grain and brown rice; the tray-type separator uses differences in specific gravity and length; and the screen-type paddy separator uses differences in width and thickness. This last type of separator, however, is practically outdated and is very seldom used. Most of the paddy separators are compartment-type. It was only recently that the Japanese introduced the tray-type separators.

Compartment-Type Paddy Separators

The main part of this paddy separator is the oscillating compartment-assembly where the actual separation of paddy and brown rice takes place. This assembly is normally made of wood; however, full steel machines are also produced. The compartment-assembly consists of a number of compartments in one, two, three, or sometimes four decks. The number of compartments depends on the capacity of the rice mill, and varies from 5 to 80. For up to 10 compartments a simple deck will do; from 12 to 20 compartments two decks are normally used; up to 51 compartments, there are three decks; and up to 80 compartments, four decks are used.

For instance: 20 compartments, two decks each with 10 compartments; 48 compartments, three decks each with 16 compartments; and 80 compartments, four decks each with 20 compartments.

The capacity of a compartment is about 40 kg of brown rice per hour. This figure is normally used to determine the number of compartments required for a rice mill. Thus, a rice mill with a capacity of 2000 kg of paddy per hour (about 525 cavans per 12 h), and an efficiency of 80% would produce about 1600 kg of brown rice per hour. Therefore, the number of compartments required would be 1600/40

= 40. In this case a compartment separator of 48 compartments in three decks, each holding 16 compartments, would be sufficient.

It requires experience to balance the performance of the paddy separator at optimum capacity. A well-adjusted paddy separator discharges brown rice absolutely free of any paddy grains and paddy with no, or only a few, brown rice kernels. At the same time the machine must produce enough rice to meet the mill separation requirements. The capacity and feeding of the compartments are controlled by (Fig. 165): (1) a valve for the control of the main feeding; (2) an independent adjustment of the feeding of each compartment by an adjustable valve; and (3) a handwheel-controlled multisleeve valve controlling simultaneously the feeding of all compartments from zero to maximum. The separation performance is controlled by (Fig. 165): (4) the adjustable inclination of the separator assembly, also called separator table; (5) the adjustable overflow strips for paddy at each end of the compartments (paddy discharge side); and (6) the adjustable frequency of the oscillation.

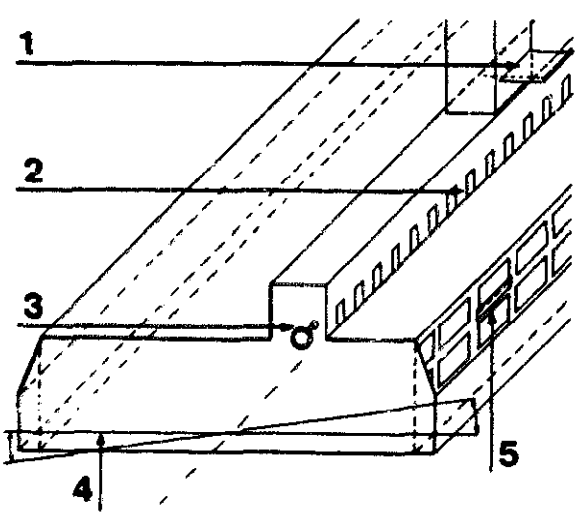

FIG. 165. Adjustability of paddy separators: (1) valve for control of feeding; (2) independent control of compartment feeding; (3) adjustable sleeve for all compartments; (4) adjustable inclination; and (5) adjustable paddy overflow strip. The frequency is also adjustable.

It is essential that a perfect distribution of the grain over the full length and width of the central feeding box on top of the separator is continuously maintained to feed all compartments. For this reason two grain-feeding spouts with control valves are sometimes installed. The feeding of each compartment can be adjusted from zero to maximum by a simple sleeve that can be lifted or lowered and whose position can be locked with a screw. This system makes it possible to reduce the number of operating compartments in case the actual feeding capacity is too small for the separator.

A multisleeve valve is not always installed in the conventional-type paddy separator; however, its presence is essential for a smooth and well-controlled equal distribution of the grain over the compartments. It mainly consists of a long steel strip with rectangular perforations overlapping the feeding box outlets to the compartments. By handwheel adjustment this strip can partly or even fully close simultaneously all outlets feeding the many compartments.

To obtain a perfect separation of paddy and brown rice the separator table should be slightly inclined, with the lifted position for that side of the table where the paddy will be discharged. This inclination depends on the percentage of paddy mixed with the brown rice, the variety of the paddy, the condition of the paddy, and the feeding capacity. Because all these factors are continuously changing, it is necessary to regularly check the performance of the separator and adjust the inclination when necessary. When the brown rice overflow contains paddy grains, the inclination must be reduced. This separation efficiency is not always adjustable through the table inclination and quite often the frequency of the oscillation must be increased or decreased as well. This is done by belt transmission adjustment when cone-shaped flat-belt pulleys are used, or by adjustment of a totally enclosed variable gear box transmission.

Each compartment has an adjustable strip fixed at the end of the compartment to control the overflow of paddy. This strip controls the presence of brown rice since the heavier brown rice kernels will remain in the compartment; whereas, the lighter paddy grain will float over

the brown rice and strip (about 5–8 mm) for immediate discharge.

Normally the stroke is not adjustable. However, a West German manufacturer patented a special design with adjustable stroke, which will be discussed later. The frequency of the separator table varies from 90 to 120 double strokes per minute. Generally this frequency is set between 95 and 105 per minute. When not adjustable, the length of the stroke normally is about 200 mm.

How to Operate the Paddy Separator

The bottom of the compartment is a highly polished steel sheet offering minimum resistance to the grains moving over its surface. The sides are Z-shaped steel flanks that have an impact angle of about 30° (Fig. 166). The grain, a mixture of paddy and brown rice, is fed into the centre of the compartment, which is slightly inclined, and moves over its width back and forth with a frequency between 95 and 105 movements per minute and a stroke of about 200 mm.

The impact of the Z-shaped flanks causes the paddy grains to slide upwards along the bottom of the compartment. The brown rice kernels, on the other hand, move downwards and leave at the lower end of the inclined compartment. When the inclination is too low, brown rice kernels move upwards with the paddy grains, and the paddy overflow becomes badly mixed with brown rice. This must be avoided because this brown rice will be returned to the huller, overloading the huller section and damaging the brown rice during its unwanted pass through the huller. When the inclination is too high, paddy grains move downwards with the brown rice kernels and are fed into the whitening section of the rice mill, which must be avoided. Consequently, the setting of the inclination should be controlled continuously.

When the paddy separator is built in two, three, or four decks, the lower decks are fed by small spouts. These spouts should pass through the idle triangles of the Z-shaped flanks and never through the working area of a compartment (Fig. 167). The triangles quite often become filled with grain and dust and

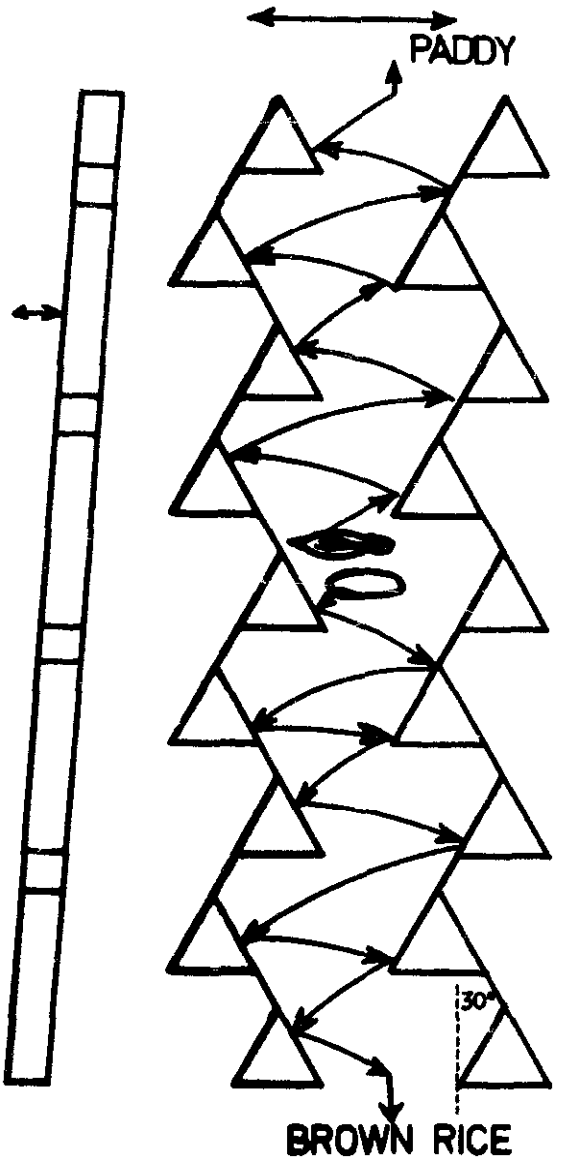

FIG. 166. Internal construction of one compartment of the paddy separator.

are a permanent source of insect infestation. Therefore, the triangles in the top deck of the separator should be sealed with a steel sheet cap or wooden plug.

Although the pattern of the Z-shaped flanks is basically the same, there are differences in the size and detail of the available designs. The German pattern is about the same as the one used in Italy, but the size of the Z-pattern of the German design is larger. The Indian pattern, also used in the Philippines, has rounded corners for a smoother flow of the

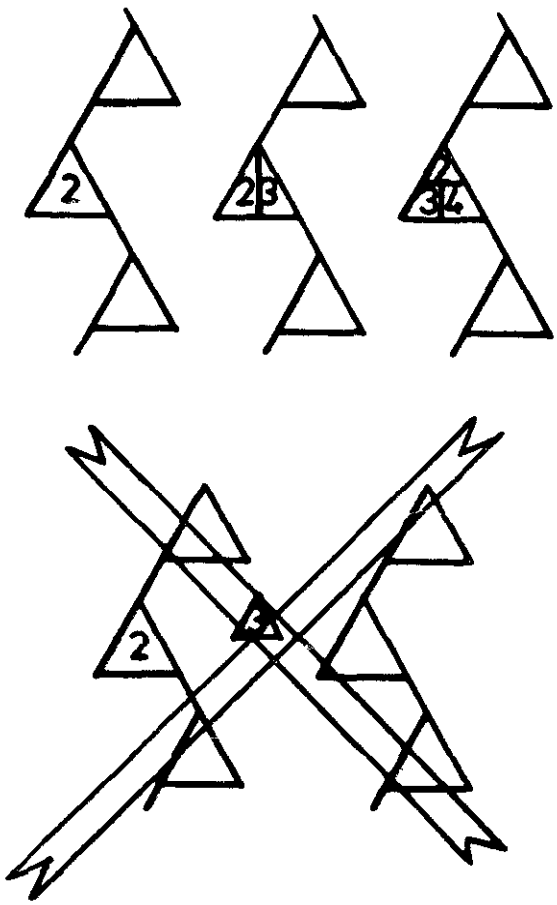

FIG. 167. Spouts to feed lower decks of separator pass through idle triangles of flanks not through the working area of the separator.

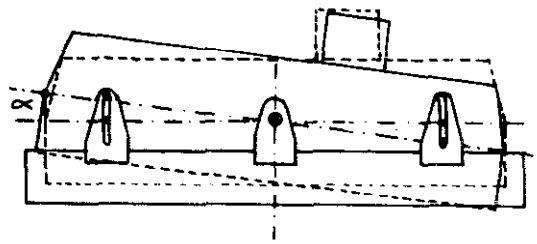

FIG. 168. Inclination of separator table is adjusted by turning a handwheel attached to a threaded shaft that moves the supporting swingable levers.

grain. For all patterns, however, an identical performance is recorded so no specific pattern can be recommended.

The inclination of the separator table can only be changed when the machine is stopped. It is adjusted by a handwheel fixed to a long threaded shaft under the table (Fig. 168). When this shaft is turned, two nuts supporting swingable levers are moved back and forth, lifting or lowering the separator table, which tilts on a central shaft. The inclined position of the table is locked by two handwheel screws (Fig. 169).

The separator table must move horizontally and remain perfectly aligned. The supports for this table, either four or six, are specially constructed to secure this pure horizontal movement and to make sure that this rather bulky machine will not move off its supporting frame. A British design (Fig. 170, A) uses swinging supports with teeth, rolling back and forth over a toothed steel bar bolted to the underframe. The pressure on the tooth transmission is reduced by a spring-loaded weight absorber. In German constructions (Fig. 170, B) the swinging supports have a side plate for guidance, and a smooth polished bottom surface that rolls back and forth over a smooth hard-steel bar. The position of the support is fixed by a spring-loaded assembly between the support and the underframe. In the Philippines, the supports are fixed on the underframe and roll- or ball-bearings are mounted on the top of the support (Fig. 170, C). The separator table moves over these bearings and its position is kept in line by steel guidebars mounted under the table. The movement is very smooth; however, the bearings are used under conditions violating all basic principles related to bearing techniques.

The separator table should always be horizontally levelled. However, since most of the paddy separators are made of wood and work under tropical conditions, they often bend, which badly disturbs separation performance. The bending of the table can be corrected if each side of the table is equipped with a straightening device (Fig. 171). This should be standard on all new machines; however, this device can still be installed on existing units.

The so-called "rocking" of a paddy separator happens very often and has a very disturbing effect on separation performance. The separator table should move horizontally and

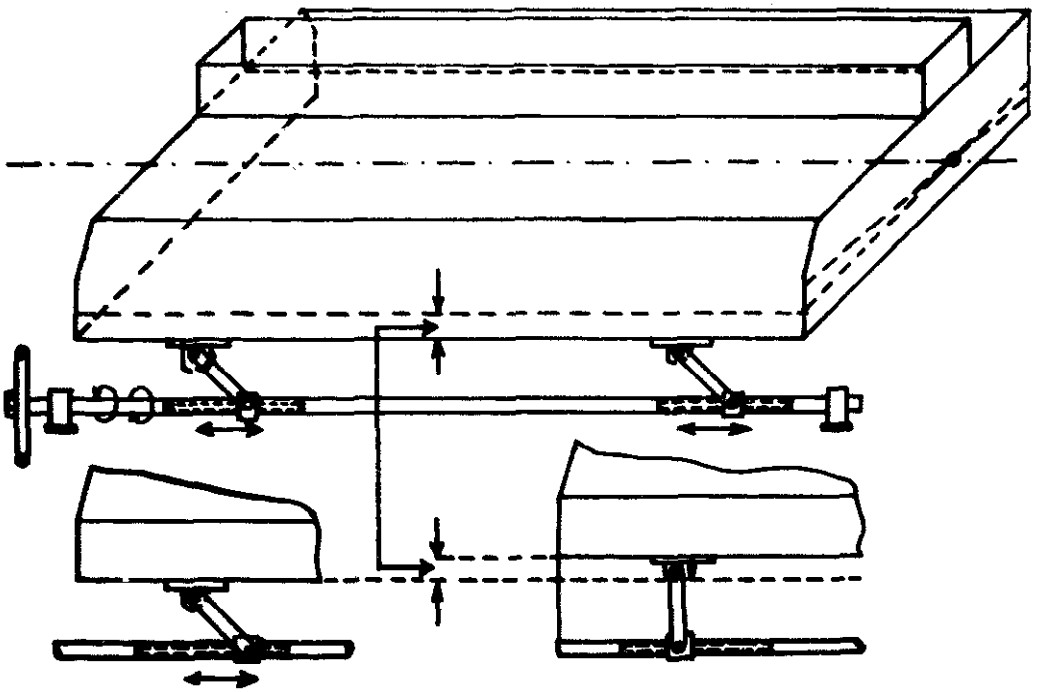

FIG. 169. The separator table tilts on a central shaft

in a straight line (Fig. 172, A). When the swinging supports have not been aligned correctly with respect to the separator table and the driving shaft, the table will not move in a straight line, but, when moving horizontally, will follow a curved line (Fig. 172, B). This results from movement in two directions. As a result the program of action of the grain, paddy as well as brown rice, in the compartments is disturbed and separation efficiency is reduced.

The separator is driven by a flat-belt transmission or by an electric motor through a variable speed gear and V-belt transmission. Conical pulleys are used to change the transmission ratio, which adjusts the frequency of the stroke between fixed limits (90–120 per minute). The conical pulleys are fixed on the main transmission shaft and an intermediate transmission shaft (Fig. 173, A), or can be mounted on an intermediate transmission shaft and the machine shaft driving the eccentric rod (Fig. 173, B). Very often a motor-driven variable gear box with V-belt drive over the flywheel of the separator is used to drive the paddy separator and to adjust, within specified limits, the frequency of the stroke (Fig. 173, C). Several methods are used to obtain this variable drive. One is a variable ratio setting controlled by an adjustable V-belt transmission with conical discs. This system may be used because the actual horsepower requirements are rather low for this bulky type of machine (about 0.6 hp for every 10 compartments). A heavy flywheel secures a smooth balanced operation of the machine.

The paddy separator may be placed in a variety of positions in the rice mill because, by design, the discharge spouts can be built in various positions (Fig. 174). The paddy discharge can be at the left or the right side, and even when two separators are used simultaneously, both separators can discharge the paddy at the right or left side. As an alternative, both separators can unload the paddy in the centre, or the brown rice in the centre. When two separators are installed in line, again the paddy can be discharged at the left or the right side. The separator compartments discharge the grain into a collector that can discharge in front of the machine, halfway to the separator table, or at the end of the machine. Therefore, when ordering a paddy separator both its position in the mill and the placement of the discharge spouts must be clearly stated.

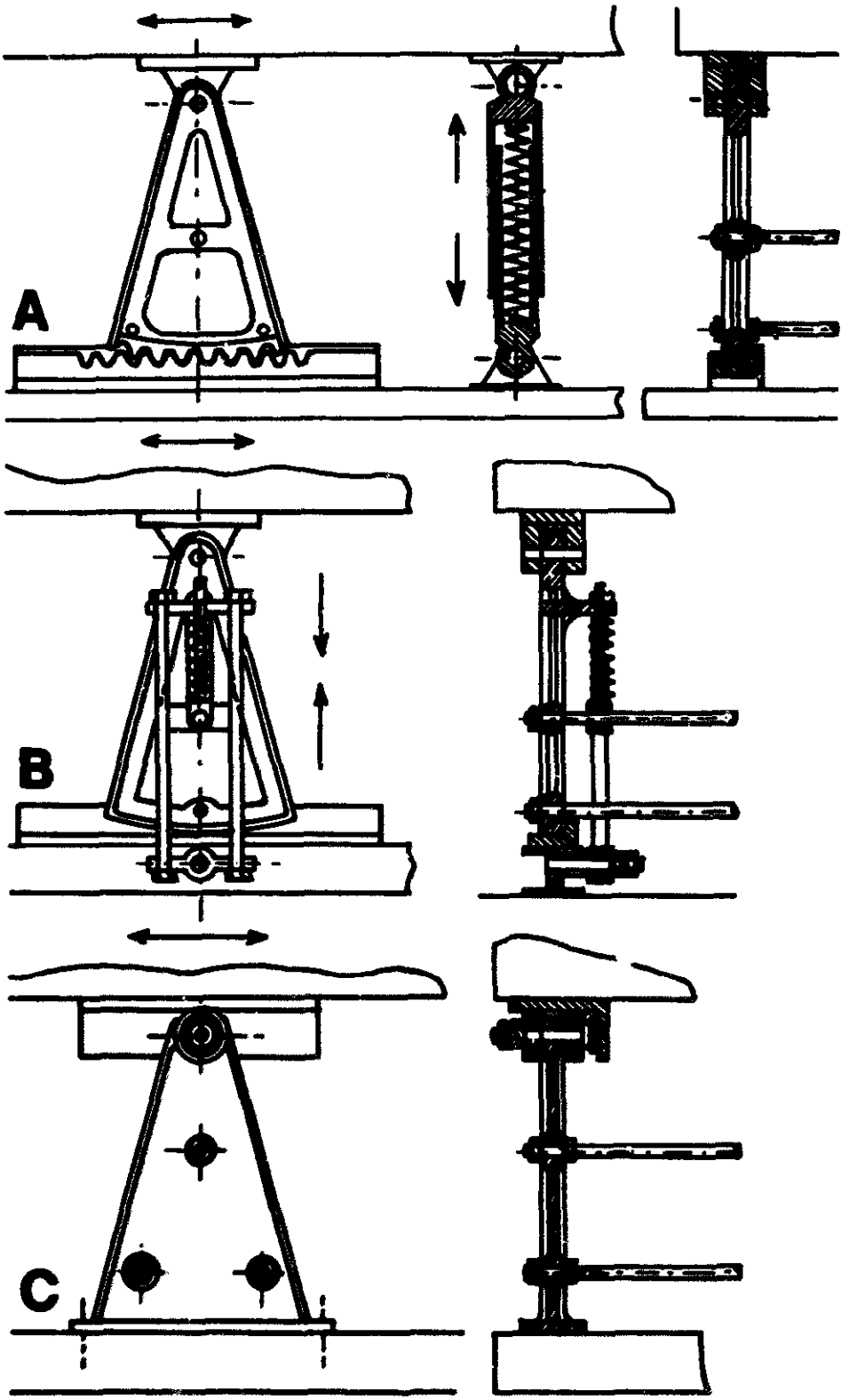

FIG. 170. Three different designs of supports for paddy separators: (A) British; (B) German; and (C) Philippine. See text for details.

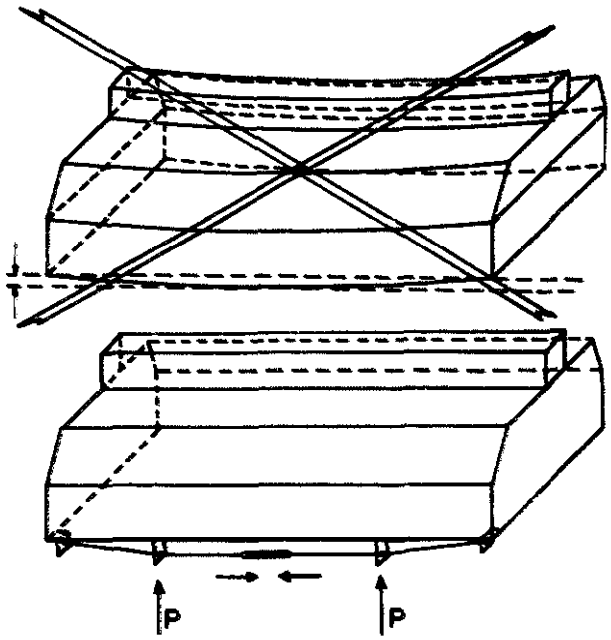

FIG. 171. Straightening device for paddy separators

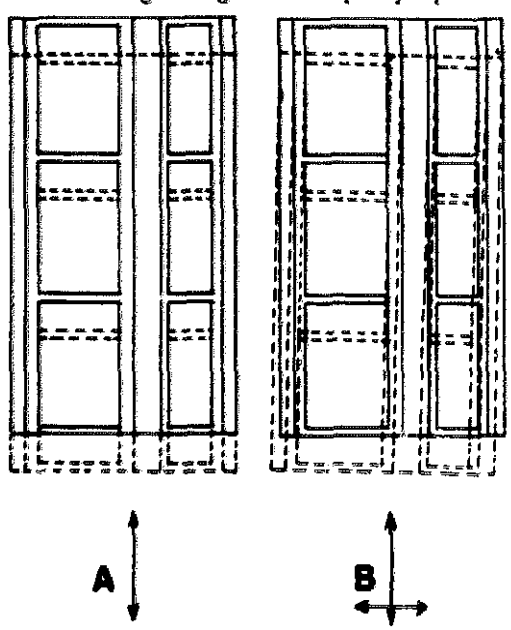

FIG. 172. Movement of the paddy separator. (A) normal straight-line movement. (B) rocking of separator caused by motion in two directions. Results in reduced separation efficiency.

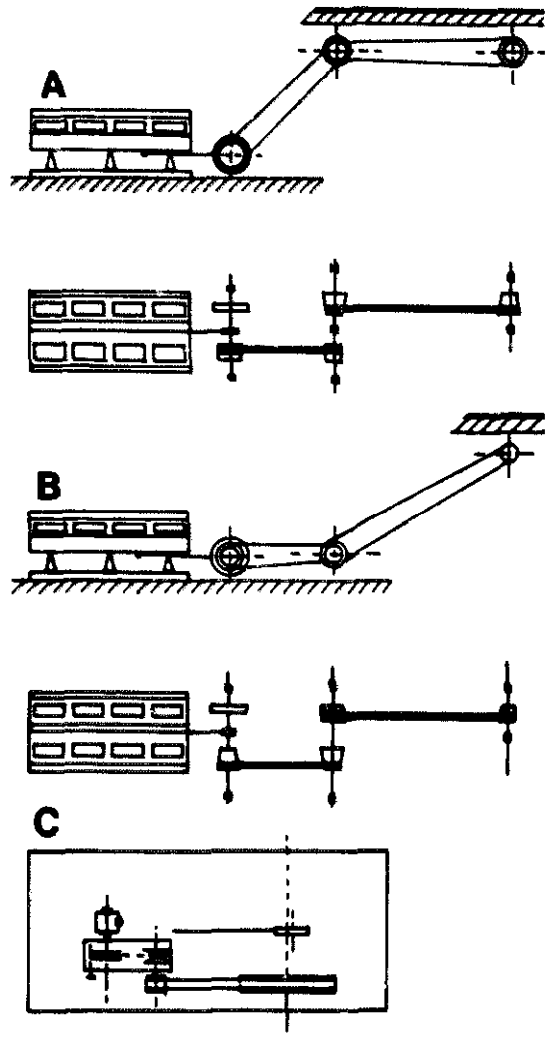

FIG. 173. Frequency adjustment of the paddy separator. (A) Conical pulley on main and intermediate transmission shafts. (B) Conical pulley on intermediate and machine shafts. (C and D) Motor driven variable gear box, with ratios controlled by adjustable V-belt transmission with conical discs (D).

Stroke Adjustment

Normally the stroke of a paddy separator cannot be adjusted; however, a German manufacturer has patented a system that allows stroke adjustment (Schule separator). This is a great advantage because the separation capacity of each compartment is increased by at least 50%. This allows smaller separators to be installed, meaning that if 60 compartments were required normally, now only 40 compartments are needed. The selection of capacities is very limited and only separators with 24, 35, or 45 compartments, all in three decks, can be supplied. Their capacities are about 1500, 2200, and 3000 kg of intake per hour, respectively. Because this type of machine has

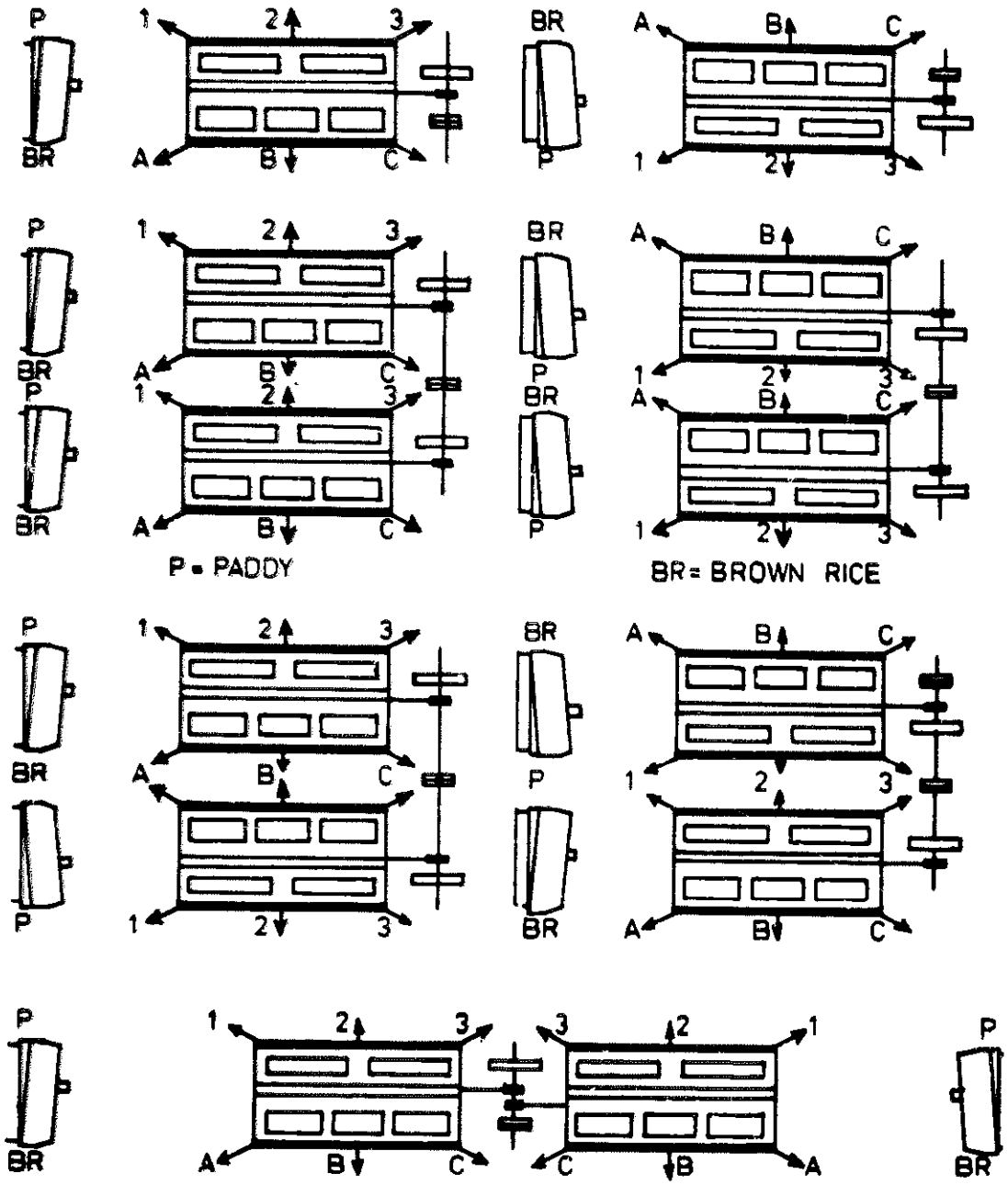

FIG. 174. Different positions the paddy separator can occupy in a rice mill because of its flexible design.

been introduced in the Philippines and already installed in two large rice mills, the principle of its operation will be explained. Our main concern is the way the length of the stroke can be adjusted.

Under normal circumstances the eccentricity is a fixed value (M-E)(Fig. 175, A), and consequently the stroke is fixed too namely, double the eccentricity (e.g. crankshaft and piston stroke) (Fig. 175, B). If, however, the eccentricity M-E is obtained by two rods M-S and S-E locked in a fixed position by a locking device at S, the stroke can be made adjustable by increasing or decreasing the angle between rods M-S and S-E (Fig. 176). When that angle is reduced to 0°, rods M-S and S-E are in one line, overlapping each other and the eccentricity M-E is at its minimum value (Fig. 177,

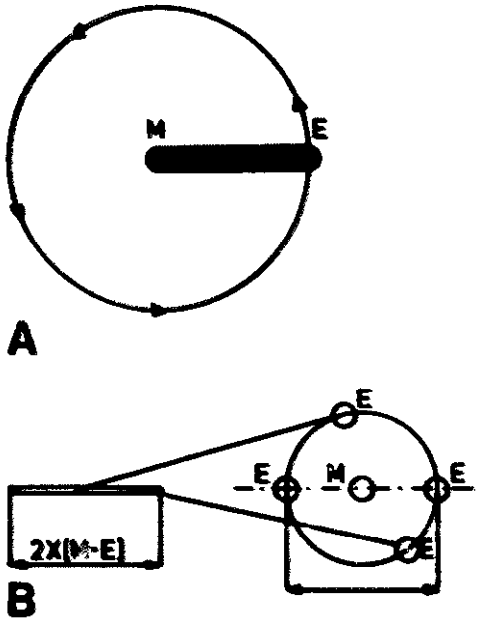

FIG. 175. Normal characteristics of separator movement: (A) stroke fixed at M-E; and (B eccentricity equal to 2 (M-E).

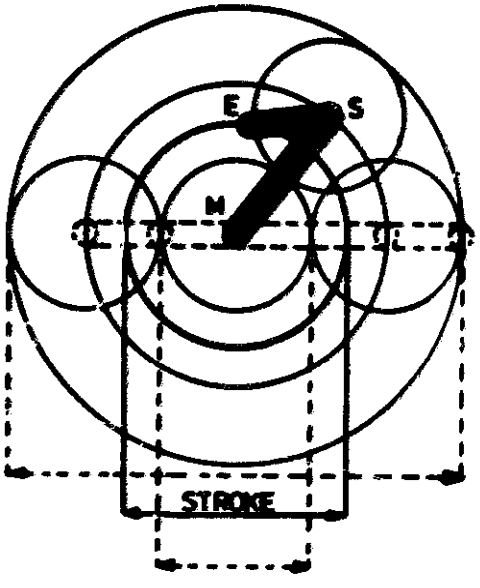

FIG. 176. Schule paddy separator with adjustable stroke obtained by changing angle between rods M-S and S-E.

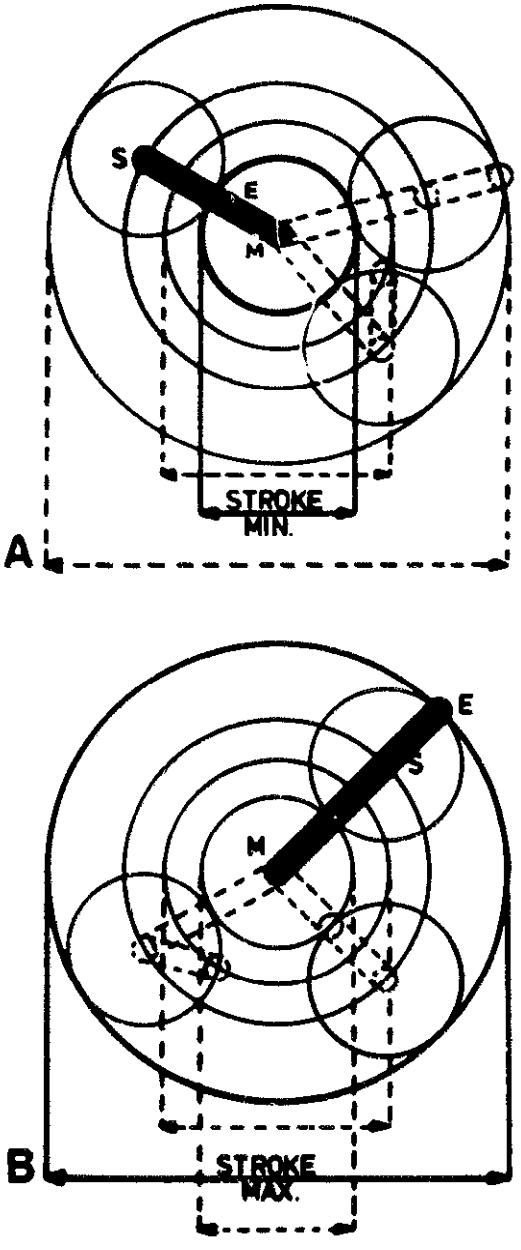

FIG. 177. (A) Angle between rods M-S and S-E is 0° and stroke is at minimum value. (B) Angle between the two rods is 180° and stroke is maximized.

A). Consequently, the stroke made by this eccentricity is of minimum length. However, when the angle is increased to 180°, rod M-S is in line with rod S-E, and both the eccentricity M-E and the stroke are at their maximum values (Fig. 177, B). Any angle of rods M-S and S-E between 0 and 180° will fix an eccentricity and stroke between the fixed minimum and maximum values.

This principle is implemented in the separator with adjustable stroke. Rod S-E is extended and equipped with a swing rod that

allows the whole device to be fixed with a screw into a circular groove on the horizontal flywheel. The centre of rotation of this flywheel is M and the pin causing the eccentricity is E. By moving the end of the V-shaped rod along this groove the length of the stroke is changed (Fig. 178). When the end of the rod is fixed in position 1 the angle between rods M-S and S-E is 0° and the stroke is minimized. At position 4 the angle is 180° and the stroke is maximized. Positions between locations 1 and 4 are selected to give any desired stroke length (e.g. position 3 in Fig. 178).

The flywheel is driven by an electric motor through a V-belt transmission. There are markings on the side of the flywheel that indicate the positions in the flywheel groove where the adjustment device should be locked for given stroke lengths (Fig. 179, A). The locking screw has a special safety design. The separator table is moved back and forth over the full length of the selected stroke because the eccentricity pin E moves between two guide plates of special design mounted under the separator table (Fig. 179, B). The entire mechanism of drive, flywheel, and stroke adjustment device is built under the separator table and is very compact (Fig. 179, C). The stroke, however, can only be adjusted when the machine is not operating. The table inclination is adjusted by a handwheel at the side of the machine that lifts or lowers the entire frame supporting the table (Fig. 180). The table rolls very smoothly over large wheels with rubber bands and is kept in line by guide-rolls. Heavy springs at both sides of the frame, supporting the table, partly neutralize the shock effect of the shaking table and reduce the wear on moving parts.

Although it is their main product, compartment separators are not exclusively designed for paddy. They are also used for separation of bird seeds, oats, peas, wheat, rye, barley, and millet.

Tray Separator

The tray separator was designed in Japan as a paddy separator and has now been intensively introduced in most of the Far East countries (Satake separator).

The machine is entirely made of steel and basically consists of from three to seven identical indented trays having a double inclined position. The trays are mounted one on top of the other with a spacing of about 5 cm (2 inches). The front inclination is fixed and very slight. The side inclination is adjustable (Fig. 181). The tray assembly as a whole moves up and forward, making a jumping, slightly bent

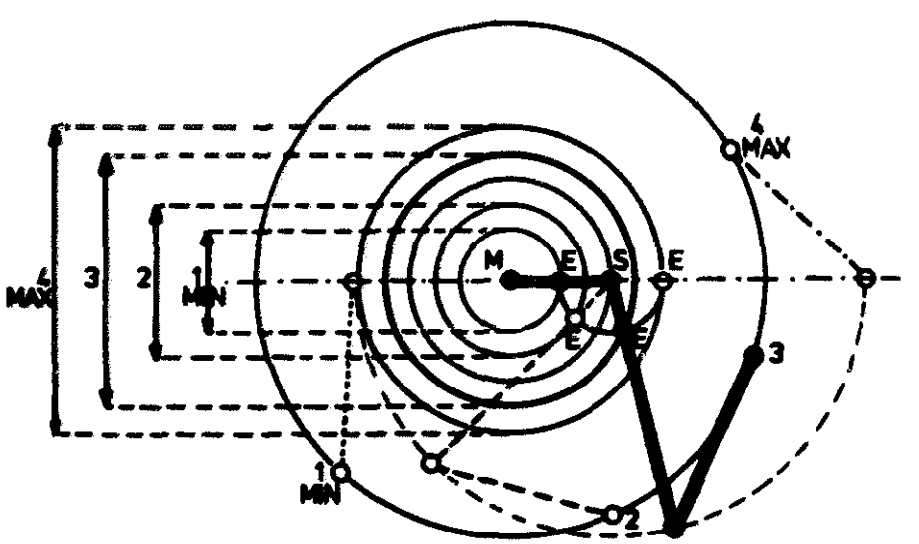

FIG. 178. V-shaped extension added to rod S-E is fixed in a circular groove on the flywheel. By sliding the rod along this groove the angle between rods M-S and S-E is changed and the length of the stroke is adjusted.

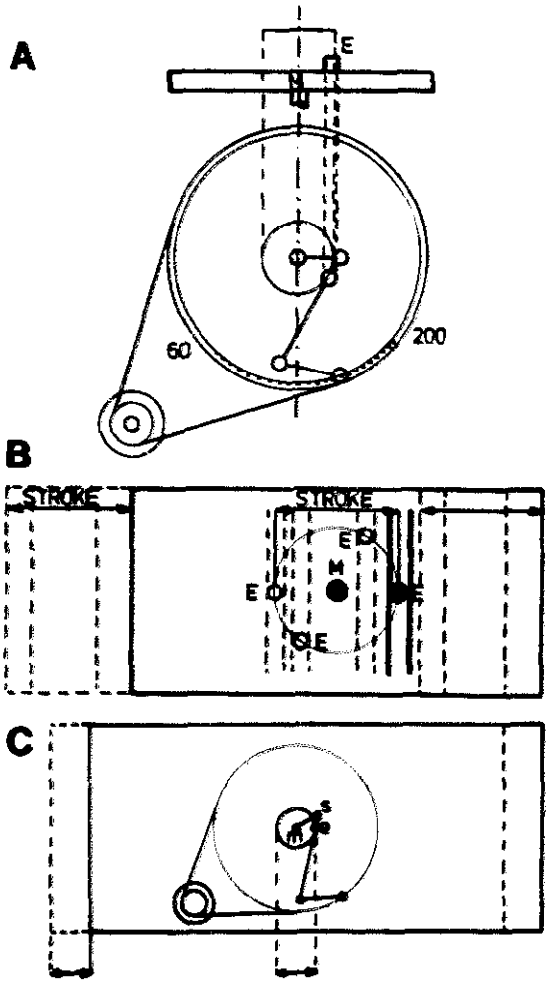

FIG. 179. Stroke adjustment of Schule separator. (A) Markings on flywheel indicate settings for specific stroke lengths. (B) The eccentricity pin, E, moves in special guide plates allowing separator table to move along full length of stroke. (C) The entire mechanism fits compactly under the separator table.

movement. The amount of grain fed into the left top side of the machine is adjustable, with each tray receiving an equal quantity of grain. Because of the double inclination and the jumping movement of the tray assembly, the paddy and brown rice slowly move to the right, separating brown rice on the top of the tray, paddy on the bottom of the tray, and leaving a mixture of paddy and brown rice in the centre part. The tray overflow, therefore, has three products (Fig. 181): (1) brown rice, fed to the whitening machine; (2) paddy, returned to the hullers; and (3) a mixture of paddy and brown rice recirculated immediately to the same separator. Consequently, the intake capacity of the tray is the sum of newly loaded grain plus the recirculated mixture.

In its separation process this type of machine makes use of differences in the specific gravity and length of the paddy grains and the brown rice kernels. Because of the upward jumping movement of the trays the grains will be lifted off the tray. The brown rice kernel jumps higher than the paddy (Fig. 182). Consequently, the brown rice kernel will reach the tray at a more remote point from its initial lifting point than the paddy grain. Its downward movement is partly neutralized by indents in the tray that are wide enough to have a grip on the brown rice kernels, but not to have a sufficient grip on the paddy (Fig. 182). The downward movement of the brown rice kernel over the tray, therefore, is less than the movement of the paddy. Slowly the brown rice creeps to the upper part of the tray and the paddy slowly moves down to the lower part of the tray. This separation is not completed when the grain reaches the overflow end of the tray, so three products are discharged: brown rice, paddy, and a mixture of brown rice and paddy.

The actual separation process starts the moment the paddy is loaded onto the tray. However, the production of pure paddy and brown rice can only be observed when the grain is about halfway down the tray. Different varieties of paddy produce different patterns of movement; therefore, it is necessary to adjust the inclination of the separator and the position of the flaps separating the three overflow chambers (Fig. 183).

The table inclination is adjusted by turning a handwheel that turns a shaft through a gear transmission. The principle of adjustment is the same as the compartment separator; however, with this machine the table inclination can be set when the machine is in full operation.

Difficulties with the performance of the machine are encountered when the shape of the indents do not correspond with the length characteristics of the paddy and brown rice or when wet or dirty grains are processed. In

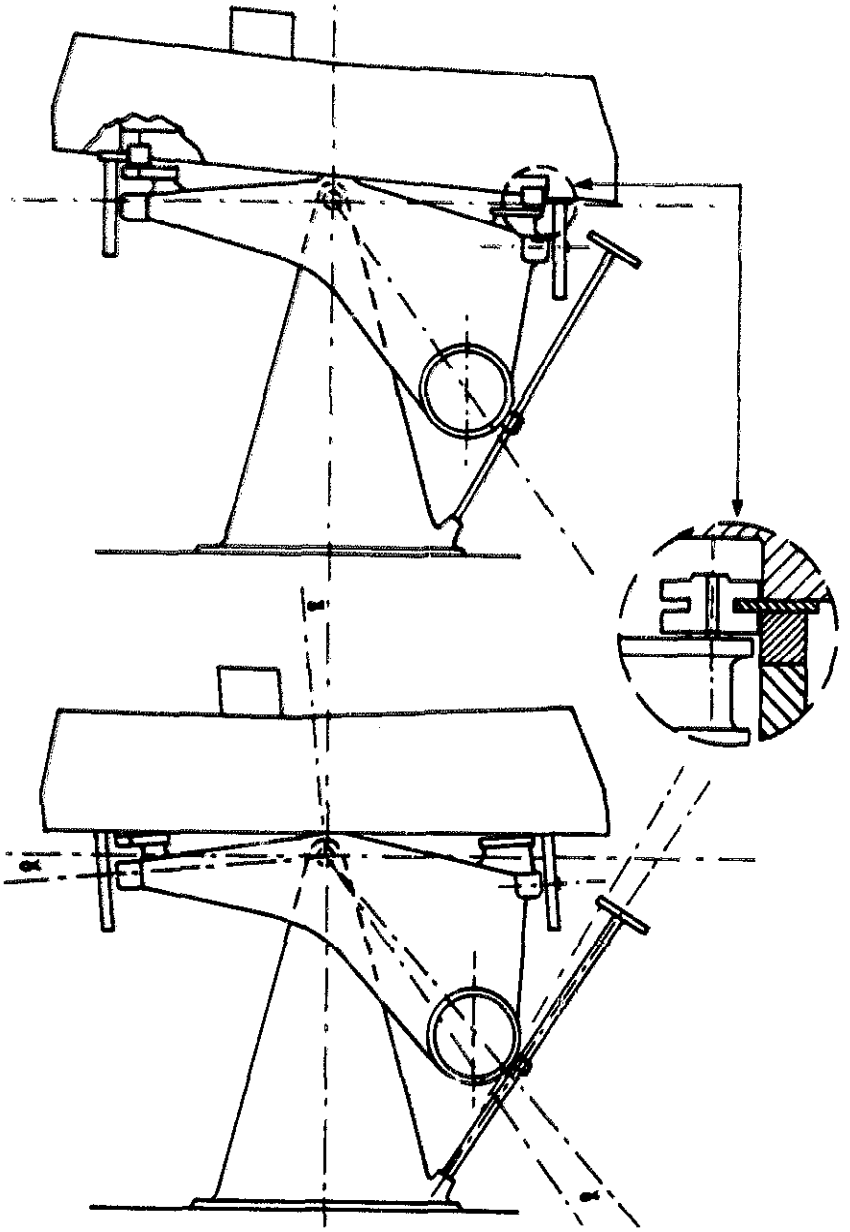

FIG. 180. Table inclination is adjusted by lifting or lowering the entire supporting frame. This adjustment is possible only when the machine is stopped.

the latter case the indents become filled with dirt making separation very inefficient.

Screen Separators

A screen-type paddy separator is very simply constructed. It is a multilayer oscillating sieve with from 6 to 15 screens. Each tray is covered with a wire screen that lets the brown rice pass through but not the paddy grains. Its operation, therefore, makes use of the differences in width and thickness of the paddy grain and brown rice kernel. The overflow of the trays is paddy, and the screen discharge is supposed to be the pure brown rice. Its separation efficiency, however, is insufficient and along with the brown rice many undersized paddy grains are discharged. Apart from its low efficiency, this type of separator has an additional disad-

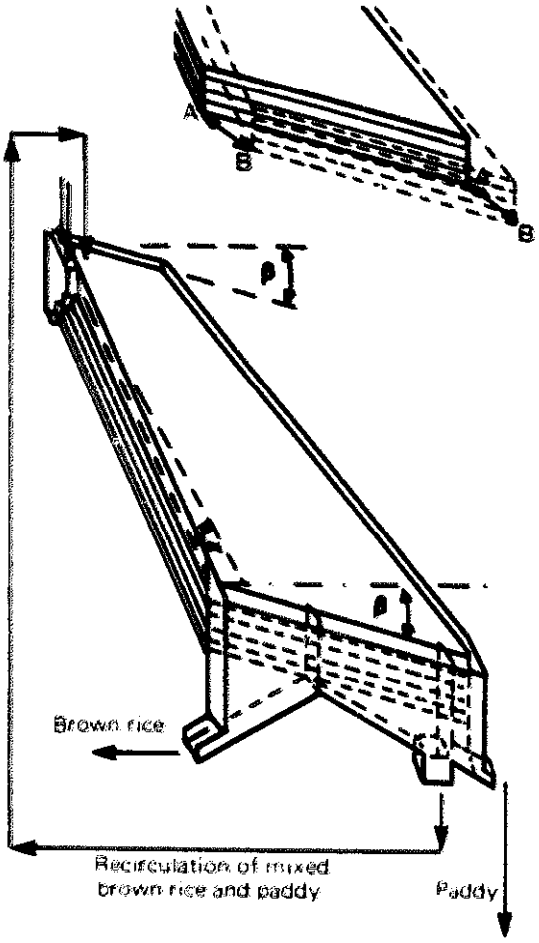

FIG. 181. Satake paddy separator. The separation products are: (1) brown rice; (2) paddy; and (3) a mixture of paddy and brown rice.

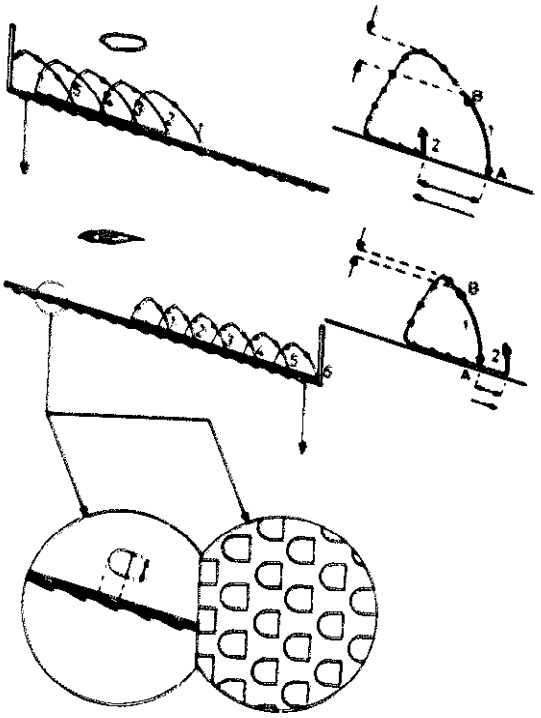

FIG. 182. Operation of Satake paddy separator. (A) Brown rice is lifted higher than the paddy and moves up the separator tray. (B) Indents in the tray grip the surface of the brown rice, but do not hold paddy very well and, therefore, the brown rice suffers less downward movement.

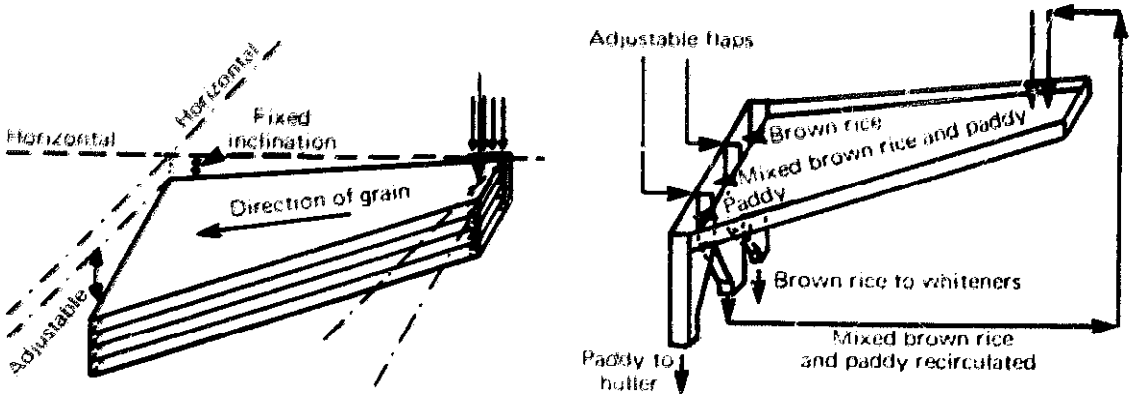

FIG. 183. The inclination of the separator and the flaps controlling the three overflow chambers are adjustable to accommodate the different patterns of movement of different paddy varieties.

vantage. For each different variety to be processed, a different screen mesh is required, making it necessary to change all the trays and to keep a selection of wire screens in stock.

In the rice mill industry this type of machine was abandoned many years ago. However, a Japanese manufacturer is still implementing this principle, and recently a small rice mill designed in the Philippines made use of the screen-type separator. — HARRY VAN RUITEN. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

Whitening and Polishing

In the process of whitening, the silver skin and the bran layer of the brown rice are removed. In the process of polishing the whitened rice, the bran particles still sticking to the surface of the rice are removed, and the surface of the rice is slightly polished to give it a shinier appearance. Polishing, therefore, always takes place after completion of the whitening process.

Some confusion exists about the words used for these processes. Whitening is sometimes called "polishing" or "milling." Polishing is sometimes called "refining" or "grinding."

Three kinds of whitening machines are widely used in the rice processing industry: (1) the vertical abrasive whitening cone; (2) the horizontal abrasive whitening machine; and (3) the horizontal jet pearler.

The vertical whitening machine in its present form is based on an initial European design. It is made by many manufacturers all over the world and is still widely used for the production of undermilled rice as well as for first-class rice milled for quality-oriented export markets.

The horizontal whitening machine developed in Japan after World War II is well suited to the short-grain Japanese varieties of rice; however, its introduction in other countries of the Far East and Asia has been delayed because sensitive adjustments are necessary to accommodate medium and long paddy varieties. When this machine is fully adjustable to all paddy lengths its introduction as a substitute for the vertical cone-type whitener will have bright prospects.

The horizontal jet pearler is basically a different design than the horizontal abrasive whitening machine. Actually the machine is partly a whitening machine and partly a polishing machine, with the whitening performance emphasized. It is called a jet pearler because it blows an airstream through the rice being processed in the machine. It was introduced about 10 years ago and is slowly gaining popularity.

Two types of polishing machines are used in the rice mill industry: (1) the vertical cone-type polisher; and (2) the horizontal polisher.

The vertical cone-type polisher looks similar to the vertical abrasive whitening cone; however, the abrasive coating is replaced by leather strips and no rubber brakes are installed.

The horizontal polisher, which is slowly gaining popularity, was developed in Japan about 10 years ago and is actually based on the same principle as the vertical cone-shaped machine.

The Vertical Whitening Cone

This machine basically consists of a cone-shaped cast iron cylinder with an abrasive coating. The cone is fixed on a vertical shaft that rotates either clockwise or counterclockwise. A wire screen that has a mesh size depending on the variety of paddy to be hulled is fixed around the entire cone. The average distance between the cone coating and the screen is about 10 mm. At regular intervals the wire screen is divided into segments by adjustable rubber brakes. These brakes are 30–50 mm wide depending on the size of the ma-

chine. The number of rubber brakes depends on the diameter of the cone and the preference of the manufacturer.

In Germany, the number of brakes is determined by the following formula: $n = (D/100) - 2$ where D = the cone diameter in millimetres. For example if $D = 800$ mm then $n = (800/100) - 2 = 6$. Therefore, the number of brakes is six. In Italy a different formula is used: $n = D/100$. For example if $D = 800$ mm the number of brakes is $800/100 = 8$.

The rotating whitening cone (Fig. 184) is vertically adjustable so the clearance between the abrasive coating of the cone and the wire screen can be adjusted. This adjustment depends on the variety of rice, the condition of the grain, the process method, and the wear of the coating. The rubber brakes (Fig. 184, no. 4) in the wire-screen frame are adjustable through a simple handwheel adjustment, and their clearance with the cone surface is only about 2–3 mm.

The brown rice is fed into the centre of the machine through a small hopper. A vertically adjustable cylindrical sleeve (Fig. 184, no. 1) regulates the capacity and equal distribution of the brown rice over the entire surface of the rotating cone. By centrifugal force the rice is fed between the cone and the wire screen. If no rubber brakes were installed, the rice would very quickly pass through the free space between the cone and wire screen and nothing would happen. However, the presence of the rubber brakes prevents the immediate discharge of the rice. The resistance built up by these brakes brings the grain under pressure and presses it against the abrasive coating of the cone and against the wire screen. This friction removes part of the bran layer. The bran passes through the wire screen and drops into the cone housing. The partly or fully whitened rice leaves the cone, falls into a self-unloading discharge spout (Fig. 184, no. 5), and is fed to a bin for further processing. The bran is scraped from the bottom of the cone housing by a rotating scraper (Fig. 184, no. 6) and is unloaded into a spout for bran discharge (Fig. 184, no. 7).

The rotating scraper is driven by a gear wheel (Fig. 184, no. 8) fixed on a vertical shaft that is driven by a flat-belt transmission from the vertical cone shaft (Fig. 184, no. 9). Air is sucked through this machine to cool the grain and at the same time to remove part of the bran (Fig. 184, no. 10). This makes it necessary to blow the air to a cyclone for bran separation.

Vertical adjustment of the rotating cone is done manually. The entire shaft-cone assembly is moved by moving the housing of the shaft end-bearing (Fig. 184, no. 11). A simple handwheel adjustment, which is mounted on the base of the cone frame, is used to lift or lower the steel bar that supports the bearing housing. The supporting bar is controlled by either one or two handwheels. If controlled by one, one end of the supporting bar is hinged to the base of the cone frame.

The peripheral speed of the cone should be about 13 m/s, making the speed of rotation of the shaft a function of the diameter of the cone. The larger the diameter of the cone, the lower the speed of the shaft (Fig. 185).

Example

If D = cone diameter = 700 mm (0.7 m), and V = peripheral speed = 13 m/s

$$V = \frac{\pi \times D \times n}{60} \quad \text{(m/s)}$$

$$n = \frac{60 \times V}{\pi \times D} = \frac{60 \times 13}{3.14 \times 0.7} = 355 \text{ rpm}$$

Quite often, whitening cones are not properly used. When the machine is only half-filled with rice, the rubber brake will not be able to build up a constant pressure and the rice will jump into the open space between the cone and the wire screen. This will unnecessarily break the rice, and the abrasive coating and rubber brakes will wear unevenly, making proper adjustment and performance of the machine practically impossible. Therefore, it is always necessary to run this type of machine with a fully loaded cone.

Because the whitening cone must run without any vibration, it is important to have this heavy part of the machine properly fixed to the top of the main shaft. To secure a perfect positioning of the cone on this shaft, the top end of the shaft is tapered (Fig. 186, A). How-

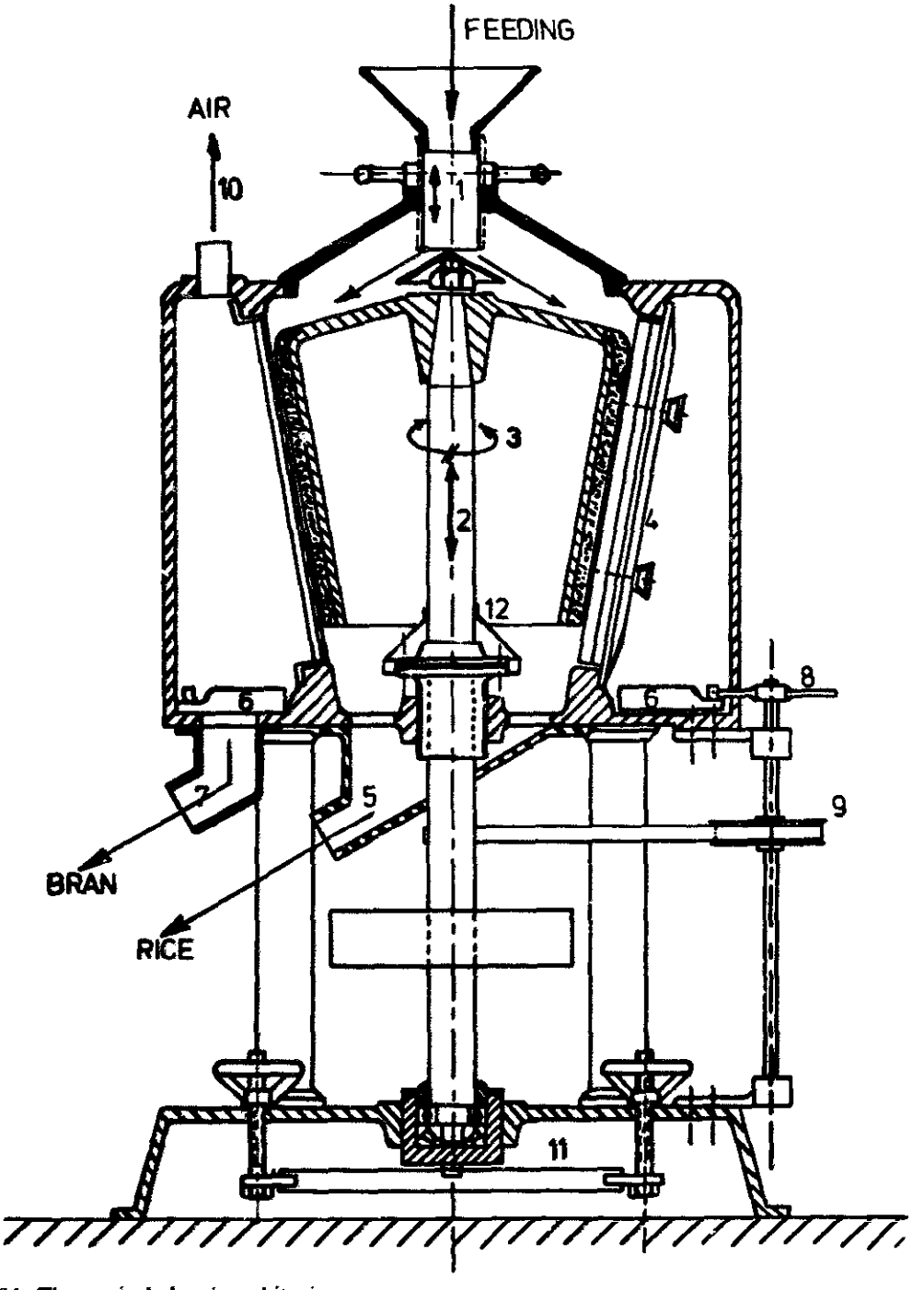

FIG. 184. The vertical abrasive whitening cone.

ever, a small impurity on this part of the shaft or the slightest damage to the tapered surface will make correct assembling impossible and vibration of the cone will result, causing excessive breakage of the rice. This risk is reduced when the taper of the shaft and cone is limited to two small areas, which still secure the same positioning of the cone on the shaft (Fig. 186, B). When the cone is lifted the clearance between the rubber brakes and the cone

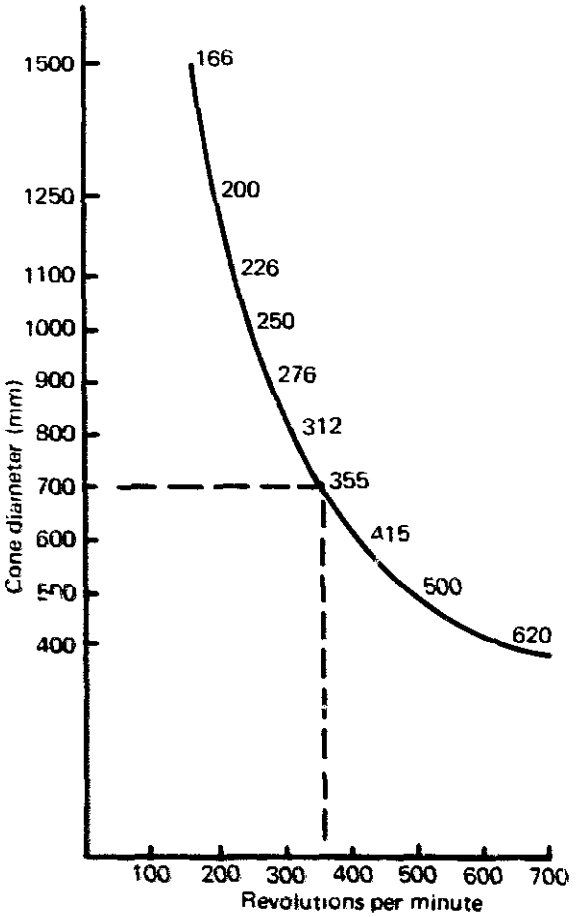

FIG. 185. Peripheral speed curve for whitening cone (V = 13 m/s).

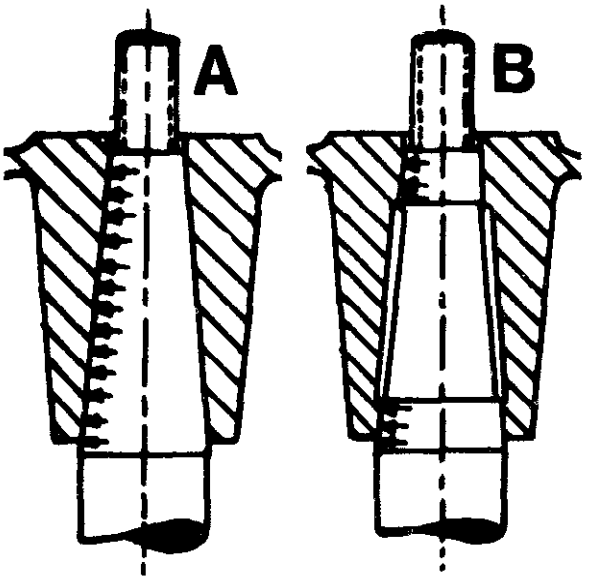

FIG. 186. Tapered end of shaft supporting whitening cone. (A) Complete taper. (B) Taper limited to two small areas to minimize the chance of a small impurity or damage to the tapered surface interfering with proper assembly.

is increased and must be readjusted. A similar adjustment is necessary if the rubber brakes wear. The rubber brake assembly, therefore, is made easily accessible. By opening the doors of the cone housing the required adjustment can be made by a simple handwheel (Fig. 187).

The replacement of worn brakes has also been made simple, although there are different methods of fixing the rubber on the clamps. The most commonly used system abroad is an external swallow-tail connection between the rubber and wood that secures a perfect clamping, leaves a maximum of solid rubber available for the operation, and makes it possible to use the wooden clamps continuously (Fig. 188, A). The internal swallow-tail connection is also used (Fig. 188, B); however, less solid rubber is made available here and quite often the swallow-tailed wooden clamp is damaged

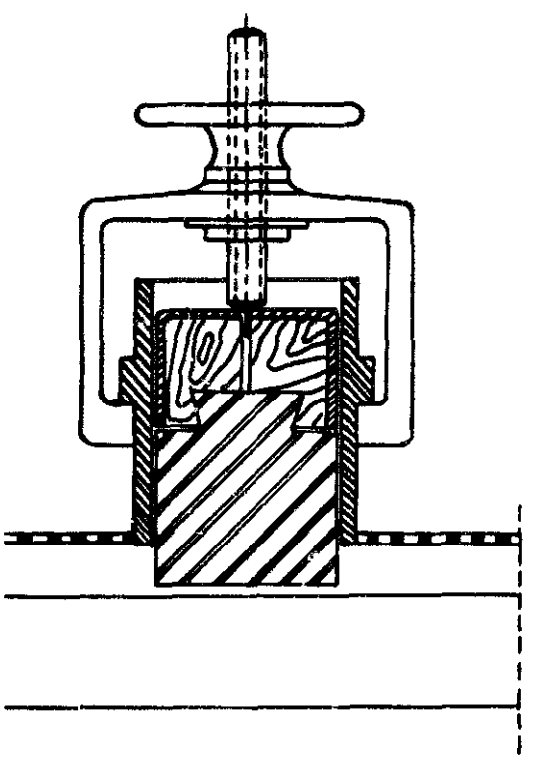

FIG. 187. Simple adjustment mechanism for rubber brake.

beyond repair. In the Philippines the rubber brake is normally glued onto the wood (Fig. 188, C). This system is not recommended.

New rubber brakes are straight square bars (Fig. 189, A). However, during the whitening process, because of the friction on the rubber when the rice passes between the brake and the cone, the brakes wear out and follow the pattern of the cone (Fig. 189, B). Eventually both the top and bottom parts of the brakes will have a so-called "nose" that disturbs the free flow of the rice and is responsible for unnecessary breakage (Fig. 189, B). These "noses" should be removed regularly.

The wire-screen casing, which follows the shape of the cone is built of three to eight segments, depending on the size of the cone and the preference of the manufacturer. Sometimes the brake assembly is part of the wire-screen segment and is fixed in the frame of these segments (Fig. 190, A). In another system the brake assembly is permanently fixed in the frame of the cone housing and the wire-screen segments fit between the assemblies (Fig. 190, B). The advantage of this system is that the screens can be replaced without disturbing the adjustment of the brakes.

Screen repair or replacement is often necessary. Because of the friction caused by the rice, the wire screen wears out and rice pours through the hole in the screen. This can be determined by checking the bran discharge regularly. When rice is mixed with the bran, it can be presumed that at least one screen segment needs repair or replacement. This replacement can only be done when the machine is empty and not running, so a quick replacement system is recommended.

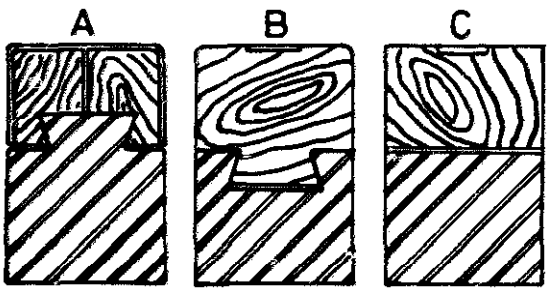

FIG. 188. Methods for attaching rubber to wooden clamps. (A) External swallow tail. (B) Internal swallow tail. (C) Glue.

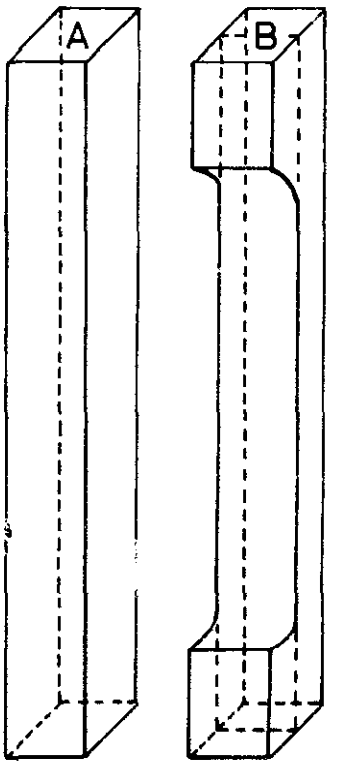

FIG. 189. (A) New rubber brakes are straight and square. (B) The brakes eventually develop "noses" that must be removed to avoid unnecessary rice breakage.

In this machine any vibration in the machine components must be avoided to prevent breakage of the rice. In this respect, proper bearing of the shaft and maintenance of these bearings is very important. What has been mentioned about shaft end-bearings of the underrunner disc huller with respect to construction and maintenance also applies to the whitening cones since the same designs are followed. The same applies to the bronze upper bearing, which mainly absorbs radial forces. For larger diameters of the cone this bronze upper bearing can be replaced by a self-centering ball-bearing assembly (Fig. 191). The entire assembly is clamped on the shaft and moves up and down with the shaft when the whitening cone is adjusted. For this reason the bearing assembly has a grooved guide block (Fig. 191, no. 1), that at the same time houses the self-

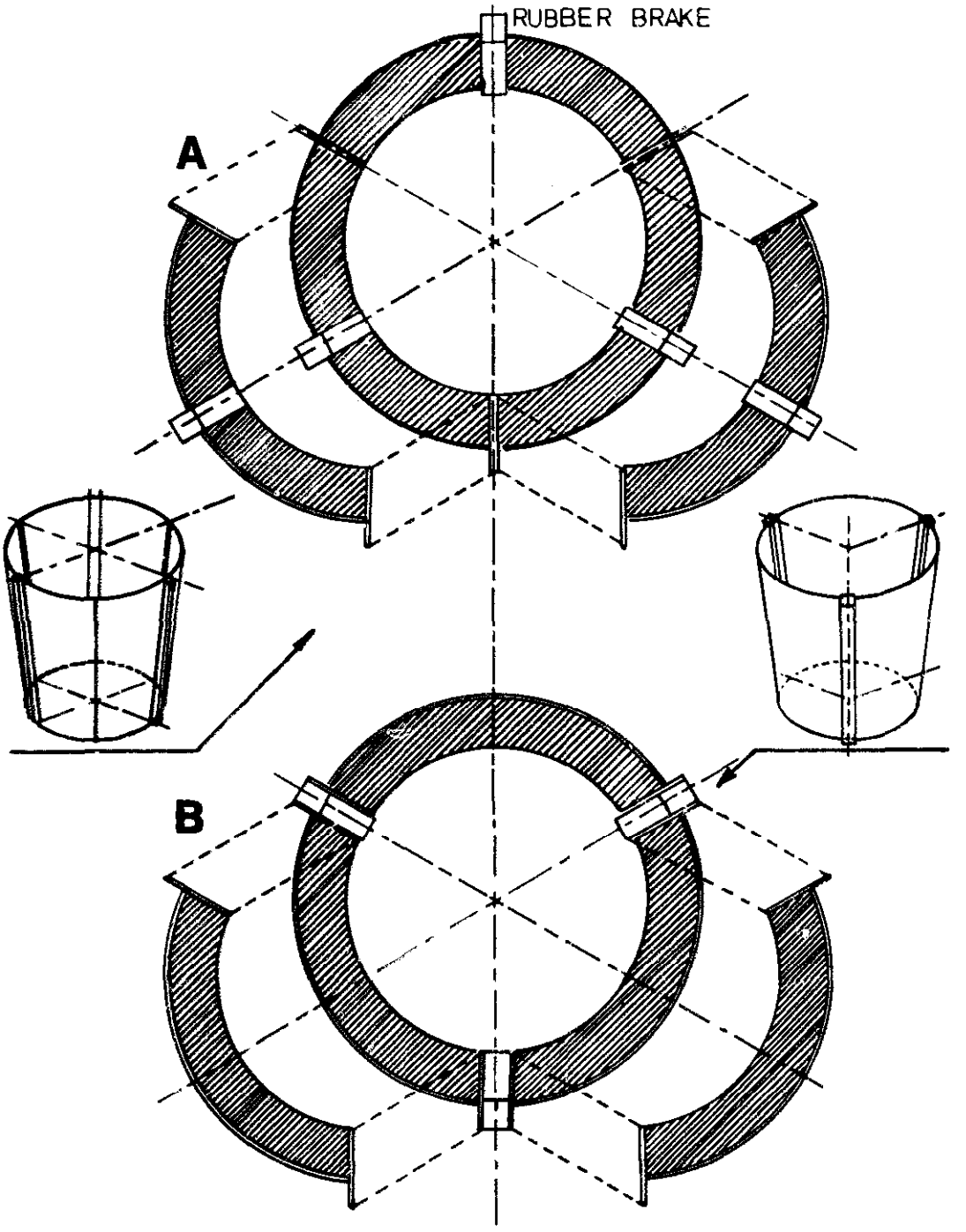

FIG. 190. (A) The brake assembly is part of the wire screen segment and is fixed in the frame of these segments. (B) The brake assembly is permanently fixed in the frame of the cone housing and the wire screen segments fit between the assemblies.

centering ball-bearing (Fig. 191, no. 2). This bearing is clamped on the shaft by a cone-shaped clamp bush (Fig. 191, no. 3). The entire bearing house (Fig. 191, no. 4) is filled with grease and sealed on the shaft by filterings. The bearing assembly is protected against direct infiltration of bran and rice particles by a steel cover, which is fixed on the shaft.

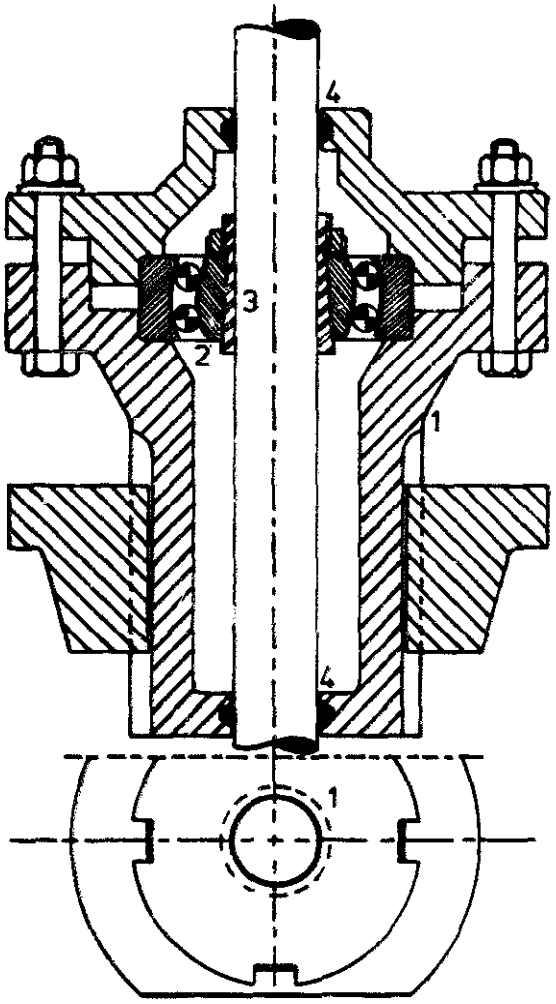

FIG. 191. Self-centering upper shaft ball-bearing assembly of the whitening cone.

The cone shaft is normally driven by either a flat-belt or a V-belt transmission, similar to those used for the under-runner disc huller. Therefore, what has been mentioned about flat-belt pulley drives, V-belt transmission drives, and belt adjustment problems of the under-runner disc hullers also applies to the whitening cones. However, because three or more whitening machines are usually installed in a mill, the direction of rotation of the machines sometimes requires special attention.

When mounted on independent foundations, the direction of rotation is of no importance and can be clockwise or counterclockwise for all machines. However, quite often the frame supporting the cone assembly is a part of the entire rice mill frame that supports practically all the rice-milling machines. A clockwise-rotating machine, in this case a whitening cone, causes a clockwise-directed tension in the frame of the mill. When multiplied by more machines, it may cause an unpleasant vibration of the entire mill frame. This effect can be neutralized by rotating the first machine clockwise, the second machine counterclockwise, and so on (Fig. 192).

In many rice mills the abrasive coating is applied to the cone in a rather primitive way so that it is practically impossible to secure a uniformly shaped working surface. However, very simple and cheap tools can be made that provide a perfectly shaped surface of the cone. In this respect two methods are used.

In the first method, with the cone turned upside down, the coating is applied manually and its uniform shape is formed by a rotating scraper (Fig. 193). The second method uses a

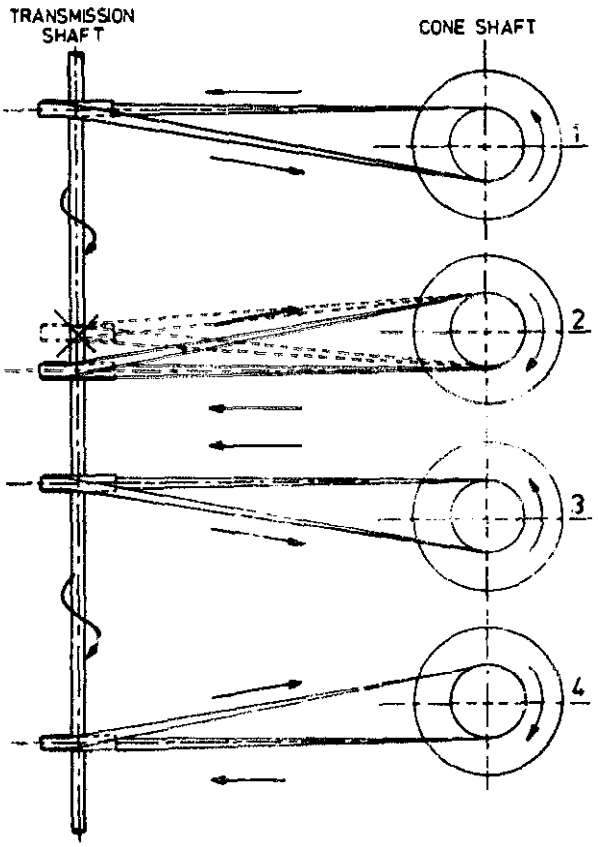

FIG. 192. Direction of rotation of the whitening cones should be alternately clockwise and counterclockwise for multipass whitening.

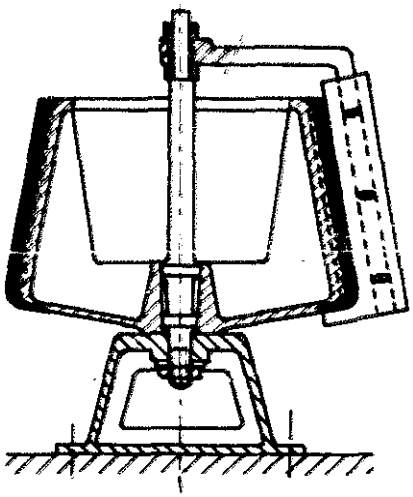

FIG. 193. Rotating scraper used to shape the whitening cone after it has been recoated.

special cone-shaped mould, following exactly the pattern of the cone (Fig. 194, no. 1). The coating is poured between the mould and the cone body, is rammed by a simple tool (Fig. 194, no. 2) to eliminate air bubbles, and is rounded by a hand scraper (Fig. 194, no. 3). Any correction to the surface of the abrasive coating is done by simple redressing tools, which can be fixed inside the cone housing (Fig. 194, no. 4). The use of these tools is indispensable for achieving smooth and efficient operation of the whitening cone.

In the Philippines a pure emery composition for the coating of the cones is generally used. Normally this composition consists of 100 weight units emery grit 16 (or sometimes 50 weight units of emery grit 16 plus 50 weight units of emery grit 18), 20 weight unit magnesite, and magnesium chloride brine (30° Baumé). This composition is not used abroad anymore and has been replaced by a new composition that has both better whitening capacity and efficiency and results in longer life of the coating. The recommended composition includes a new component, silicium carbide (carborundum), whose hardness is about two and one-half times higher than that of emery. The recommended composition for cones is: grit (25% emery grit 16, 50% silicium carbide grit 16, and 25% silicium carbide grit 18); 20% magnesite; and 20% magnesium chloride brine (30° Baumé). This composition is for the first and second whitening cones. For the third whitening cone the grit part of the composition can be 25% emery grit 18 plus 75% silicium carbide grit 18.

What applies to the positioning of the underrunner disc hullers in a rice mill also applies to the whitening cones; therefore, these machines can be installed on: (1) an elevated foundation (Fig. 195, A); (2) the ground floor level (Fig. 195, B); or (3) working floor level with frame support (Fig. 195, C).

A whitening machine removes the bran from the brown rice by friction, and the friction pro-

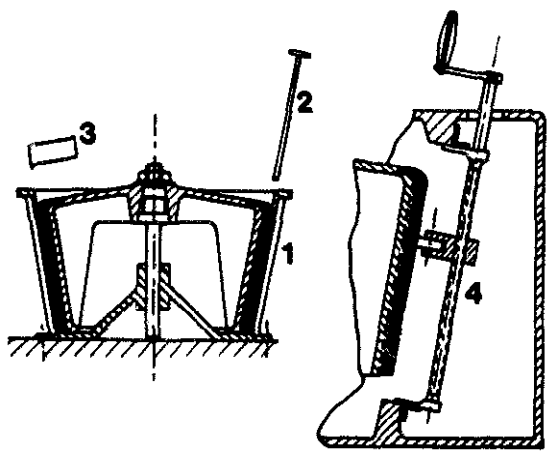

FIG. 194. Special tools for the recoating and redressing of the whitening cone: (1) cone-shaped mould; (2) simple ramming tool; (3) hand scraper; and (4) redressing tool.

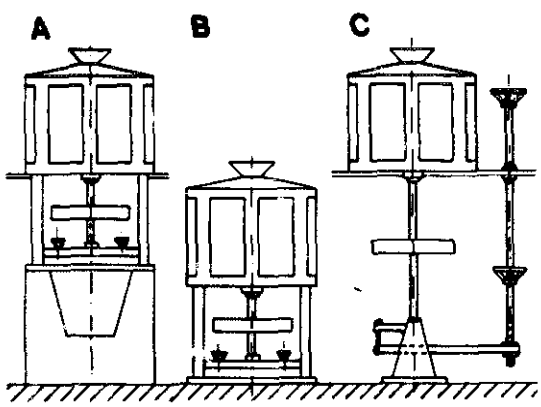

FIG. 195. Different positions for the whitening cone. (A) Elevated foundation. (B) Ground floor level. (C) Working floor level with supporting frame.

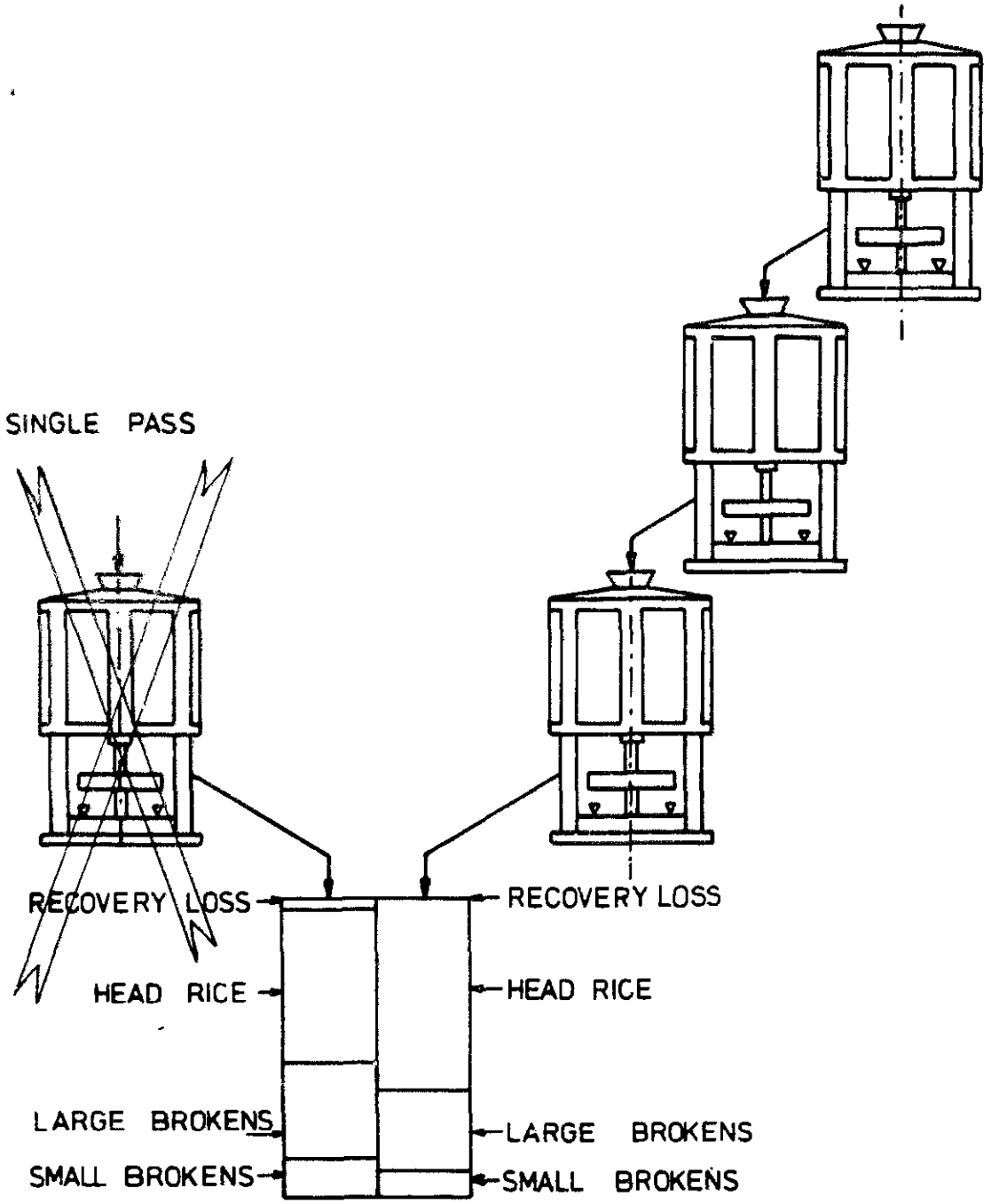

FIG. 196. Multipass whitening increases rice mill recovery by reducing the amount of rice breakage.

duces heat. When all the bran is removed in one simple whitening pass, the residence time of the grain is increased, and the clearance between cone and screen is reduced. Consequently, friction is applied to the grain, and the grain becomes hot. Since friction and heat are responsible for breakage of rice, and are to be avoided, it is recommended that the bran layer be removed in three or even more passes. This reduces the residence time of the rice in the machine and allows the clearance between the cone and screen to be increased. The amount of friction is thereby reduced and as a result the temperature of the rice is lowered. This process is called "multipass whitening" and is aimed at increasing rice mill recovery by reducing the amount of rice breakage (Fig. 196). Multipass whitening produces higher rice mill recovery because there is: (1) an increased head rice yield; (2) a reduced percentage of large brokens, and (3) a reduced percentage of small brokens.

Multipass whitening does not involve much more investment than single-pass or double-pass whitening. This is because the capacity of a cone for single-pass whitening is much lower than for multipass whitening because of differences in residence time and clearance adjustment. Thus, for a required capacity the size of the cone needed for single-pass whitening is much larger than the size of the whitening cones used for multipass whitening. For example, if a mill requires a capacity of 1200 kg of rice per hour this can be accomplished by: (1) single-pass whitening with one 1000-mm cone (Fig. 197, A); (2) double-pass whitening with two 800-mm cones (Fig. 197, B); or (3) multipass whitening with three 600-mm cones (Fig. 197, C). For cones 600 mm in diameter the capacities for the different whitening processes are: (1) single-pass whitening 700 kg/h; (2) double-pass whitening 1000 kg/h; and (3) multipass whitening (three cones) 1200 kg/h.

Compared to the sturdy, solidly constructed vertical whitening cone, the horizontal whitening machine developed by the Japanese is more compact in its construction details. Basically the machine consists of a cylindrical abrasive roll (Fig. 198, no. 2) clamped on a horizontal shaft (Fig. 198, no. 1) that runs at high speed

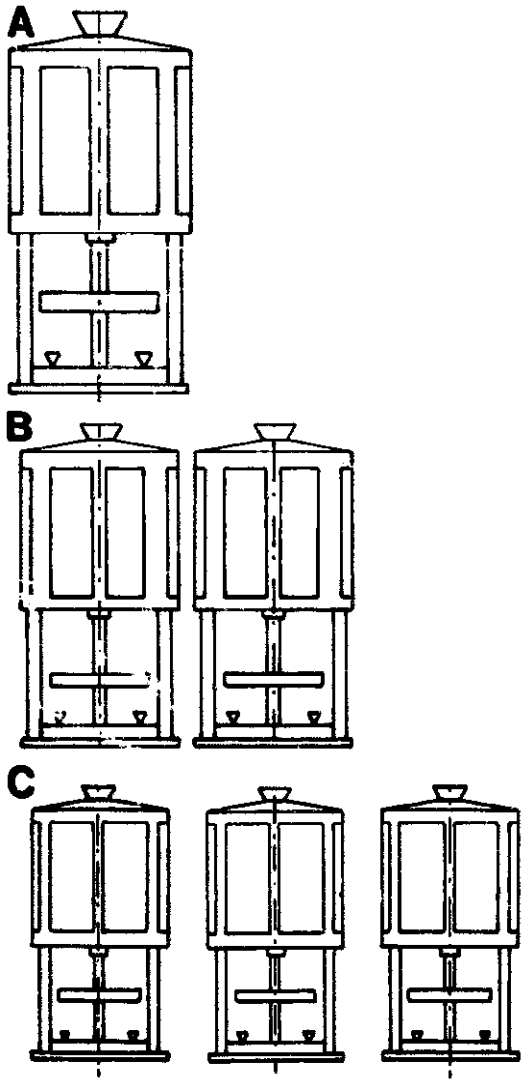

FIG. 197. Three ways of producing 1200 kg of rice per hour. (A) One 1000-mm cone. (B) Two 800-mm cones. (C) Three 600-mm cones.

(about 1000 rpm) in a cylindrical whitening chamber, which is covered with a slotted perforated sheet (Fig. 198, no. 6). A feeding screw (Fig. 198, no. 4), fixed on the horizontal shaft, feeds the rice into the free space between the abrasive roll and the slotted cylinder. A counter pressure is built up in this space by an adjustable valve (Fig. 198, no. 5) fitted in the rice outlet spout of the machine. The counter pressure of this valve, which is controlled by a weight balance, controls the pressure and

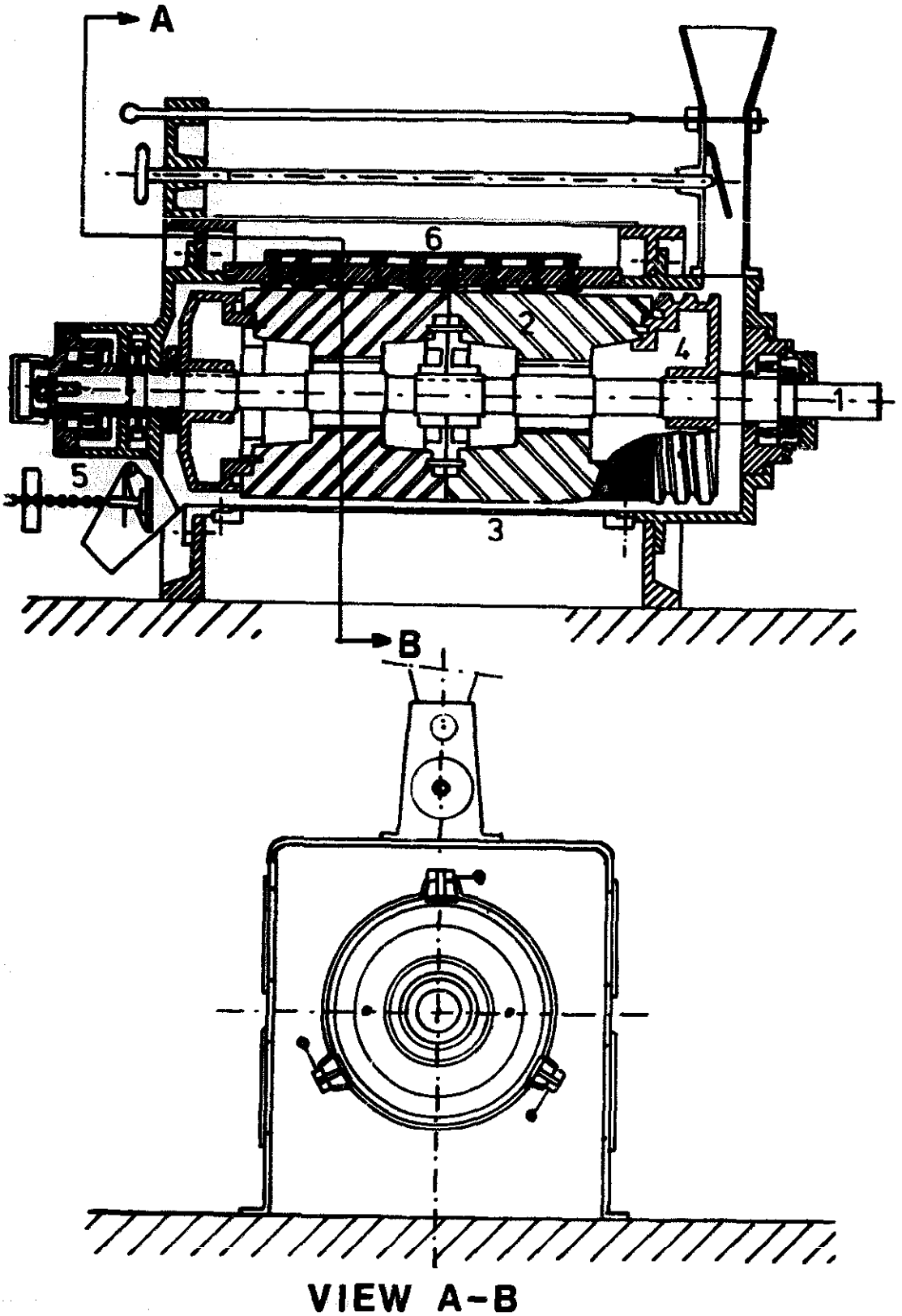

FIG. 198. Horizontal whitening machine (Satake).

friction applied to the rice inside the machine. Over the full length of the cylindrical housing three rows of adjustable steel brakes are installed that can be adjusted from 0° (axial) to 90° (radial) (Fig. 199, no. 1–3). These adjustable brakes direct the position of the rice grain inside the machine during the whitening process to obtain an optimum whitening efficiency.

For a long grain variety the position of the brakes is 0° (Fig. 200, A). The rice grains are lined up in an axial direction and roll under pressure through the whitening chamber. For short grain varieties the position of the brakes is 90° (Fig. 200, B). In this case the rice is lined up in a radial direction and tumbles through the pressure chamber of the machine. If long grain rice is processed in the machine at the 90° adjustment of the brakes the grain will be badly broken.

The brake adjustment has a range between 0 and 90° and the correct angle of adjustment depends on the variety of rice to be processed. This remains a very critical point in the operation of this machine and requires an experienced operator. A disadvantage of this machine is that the clearance cannot be adjusted. Once the diameter of the 250-mm roll is reduced by about 6 mm it must be replaced. The rolls, which are made of grit 32 silicium carbide, cannot be recoated and new supplies from the manufacturers have to be secured continuously.

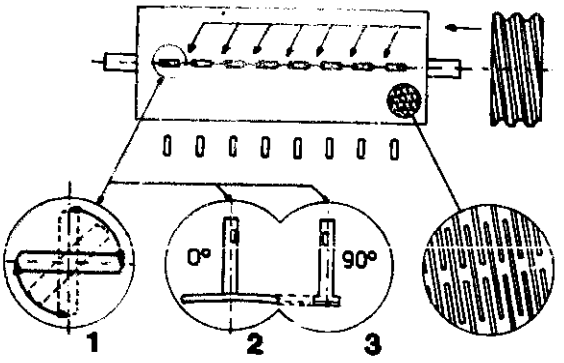

FIG. 199. Cylindrical abrasive roll of horizontal whitener showing the slots in the drum and the adjustable steel brakes.

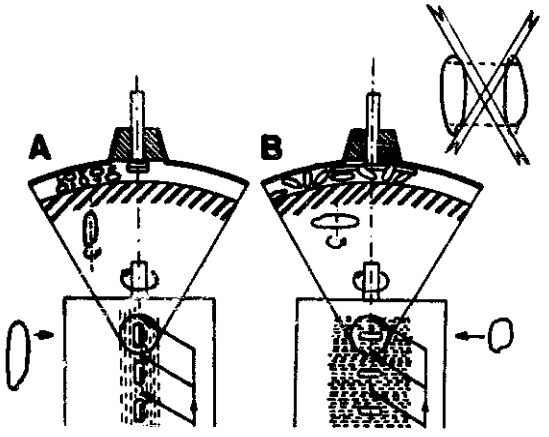

FIG. 200. (A) Brakes of the horizontal whitening machine are positioned at 0° for long grain varieties of rice. (B) The correct setting for short grain varieties is 90°.

The Jet Pearler

The jet pearler is a machine that, in a Japanese designed whitening process, is used for the last pass of the rice. Its objective is to remove the final part of the bran layer and simultaneously cool the grain through an airstream of ambient temperature.

It consists mainly of a horizontal, partly hollow, perforated shaft (Fig. 201, no. 1) on which a cast steel cylinder with friction ridges is clamped (Fig. 201, no. 2). Just behind the two ridges the cylinder has a long opening that allows the passage of air. This cylinder runs in a hexagonal chamber (Fig. 201, no. 5) consisting of two half-hexagonal perforated screens with slotted perforations (Fig. 202, A). A feeding screw (Fig. 201, no. 3), mounted on the solid part of the horizontal shaft feeds the rice into the press chamber of the machine. Here a counter pressure is built up by an adjustable valve fitted in the rice outlet spout of the pearler. A strong airstream is blown by a centrifugal blower (Fig. 201, no. 4) through the hollow shaft and the openings of the cast steel cylinder (Fig. 204, B). The air passes through the rice that is rolling under pressure in the chamber of the pearler and removes the freed bran as it leaves the machine through the slotted screens. The quantity of air blown through the machine can be adjusted by an air sleeve mounted at the air intake side of the blower (Fig. 201, no. 6).

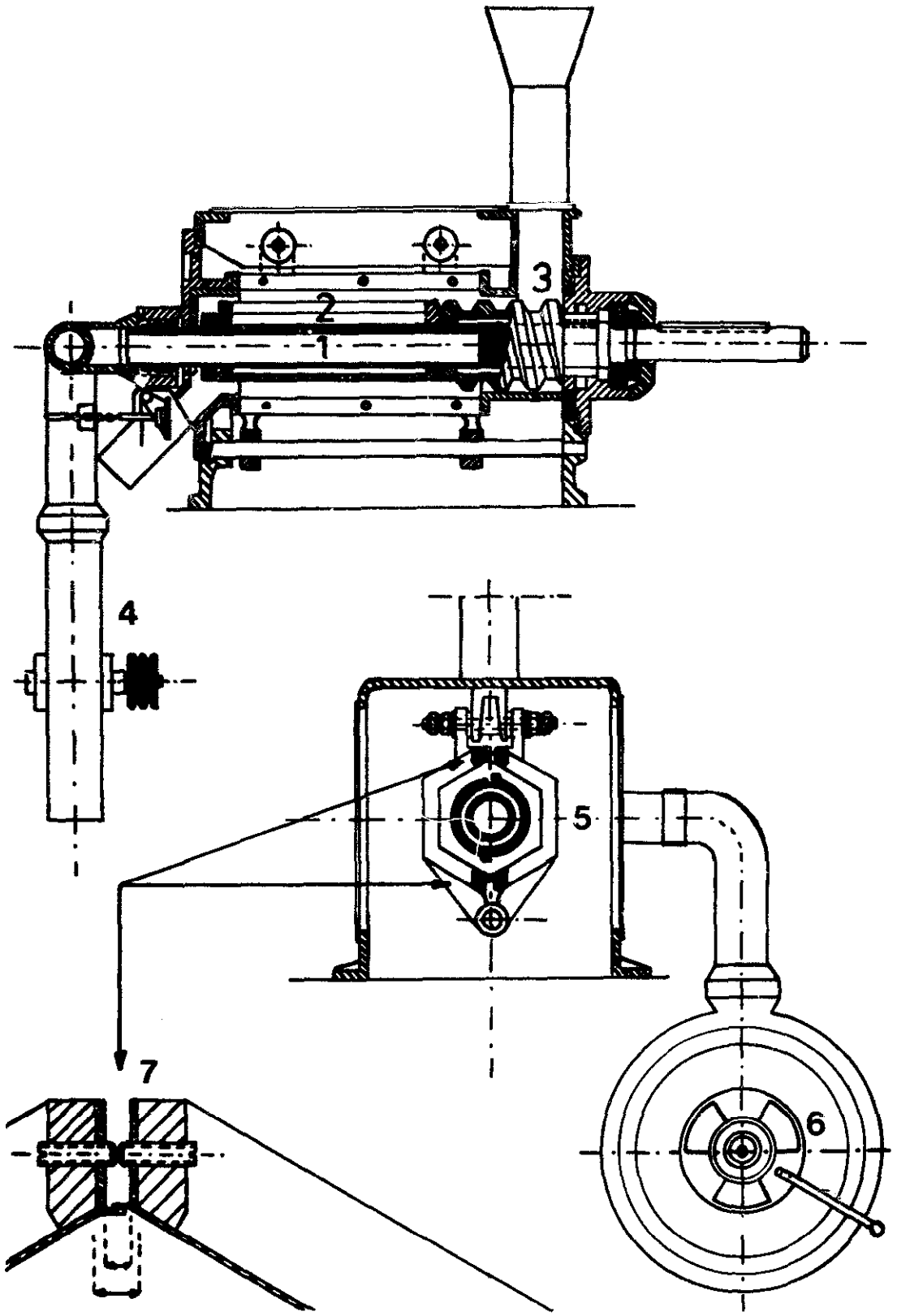

FIG. 201. Details of jet pearler (Satake).

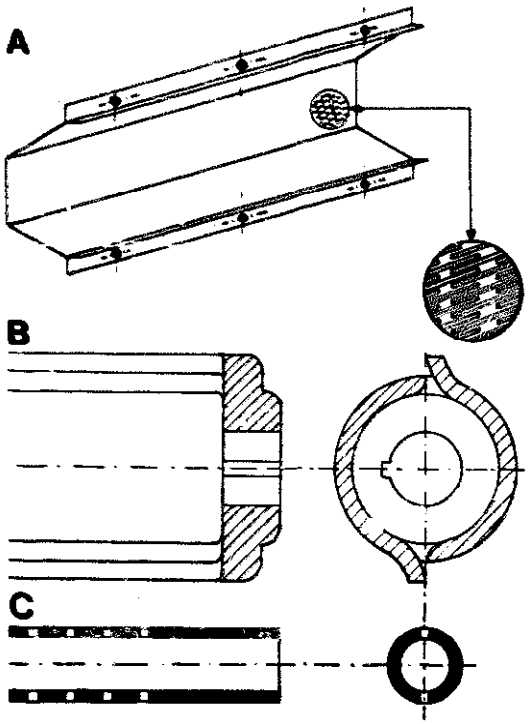

FIG. 202. (A) Hexagonal perforated screen used in jet pearler. (B) Friction ridges of the cast steel cylinder. (C) Hollow perforated shaft that the air stream is blown through.

The clearance between the hexagonal screen and the cast steel cylinder is adjustable by a screw controlling the distance between the two halves of the screen (Fig. 201, no. 7). Although the feeding pressure of the feeding screw is constant, the pressure inside the chamber is variable because the counter pressure caused by the valve in the outlet spout can be varied by adjustment of the counter weights (Fig. 204, A). The actual pressure on the grain is the total of the feeding pressure and the counter pressure.

The rice produced by this machine is free of bran, slightly polished, and cool. However, for medium- and long-grain varieties its performance is not as good as for short grain varieties and there is a considerable increase in the amount of brokens. In addition wear on the screen is considerable and replacement cylinders are quite expensive. Both of these parts are supplied by the manufacturer and a regular supply must be available.

The Vertical Polishing Cone

This machine looks similar to the vertical whitening cone (Fig. 203); however, there are basic differences: (1) the cone itself is made of a simplified steel construction and is covered with wood on which leather strips have been nailed (Fig. 206); (2) no rubber brakes are used; and (3) the speed of rotation of the cone is about 25% lower than the whitening cone.

The feeding of the rice into the machine is identical to the method used for the whitening cone. When the rice enters the space between the cone and the wire screen, it is gripped by the leather strips that roll the grains over each other and against the leather and the wire screen. Under slight pressure the remaining bran particles are removed and the rice becomes shinier or more transparent. This machine produces few brokens and its power consumption is slightly lower than a comparable-sized whitening cone.

The Horizontal Polisher (Refiner)

The horizontal polisher was designed in Japan and actually is based on the same

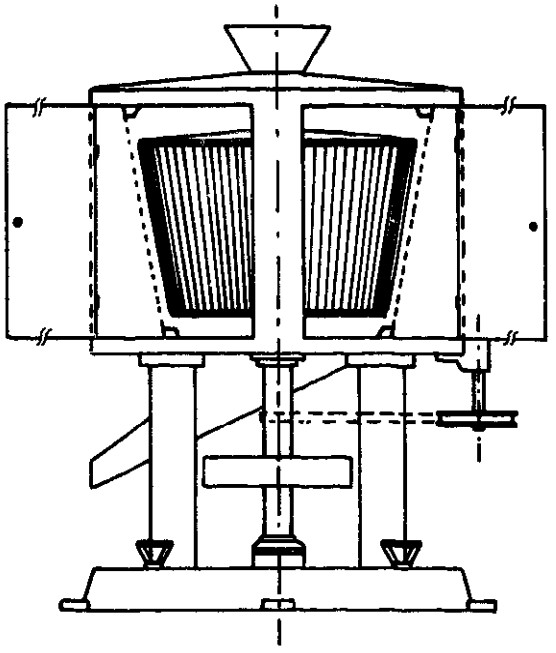

FIG. 203. Vertical polishing cor

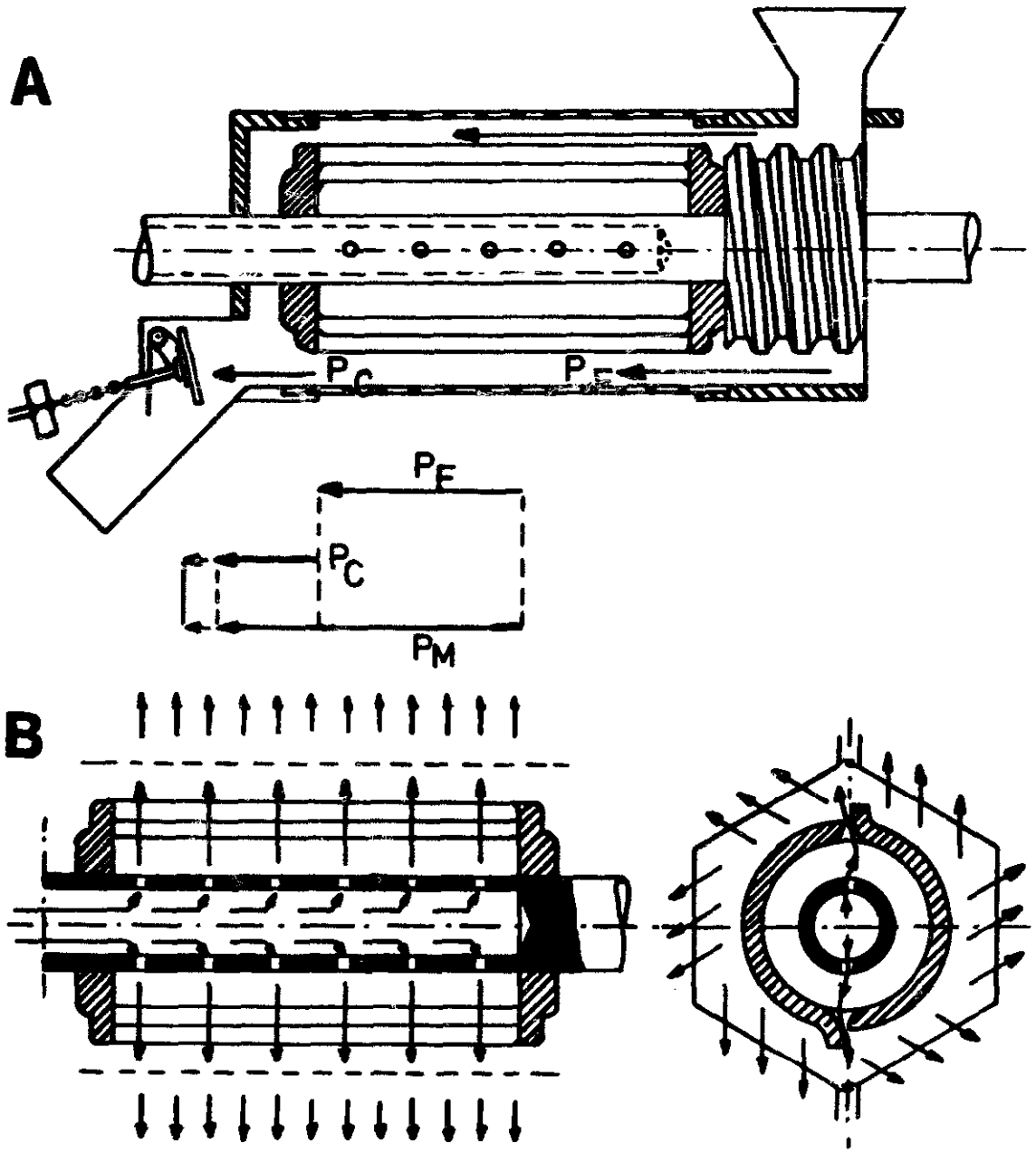

FIG. 204. (A) Counter pressure is regulated by a counter-weighted valve. Milling pressure is the sum of the feeding and counter pressures (P_F = feeding pressure = constant, P_C = counter pressure = variable, P_M = milling pressure = variable). (B) Air is forced through the hollow shaft and openings in the cylinder and removes the bran from the rice.

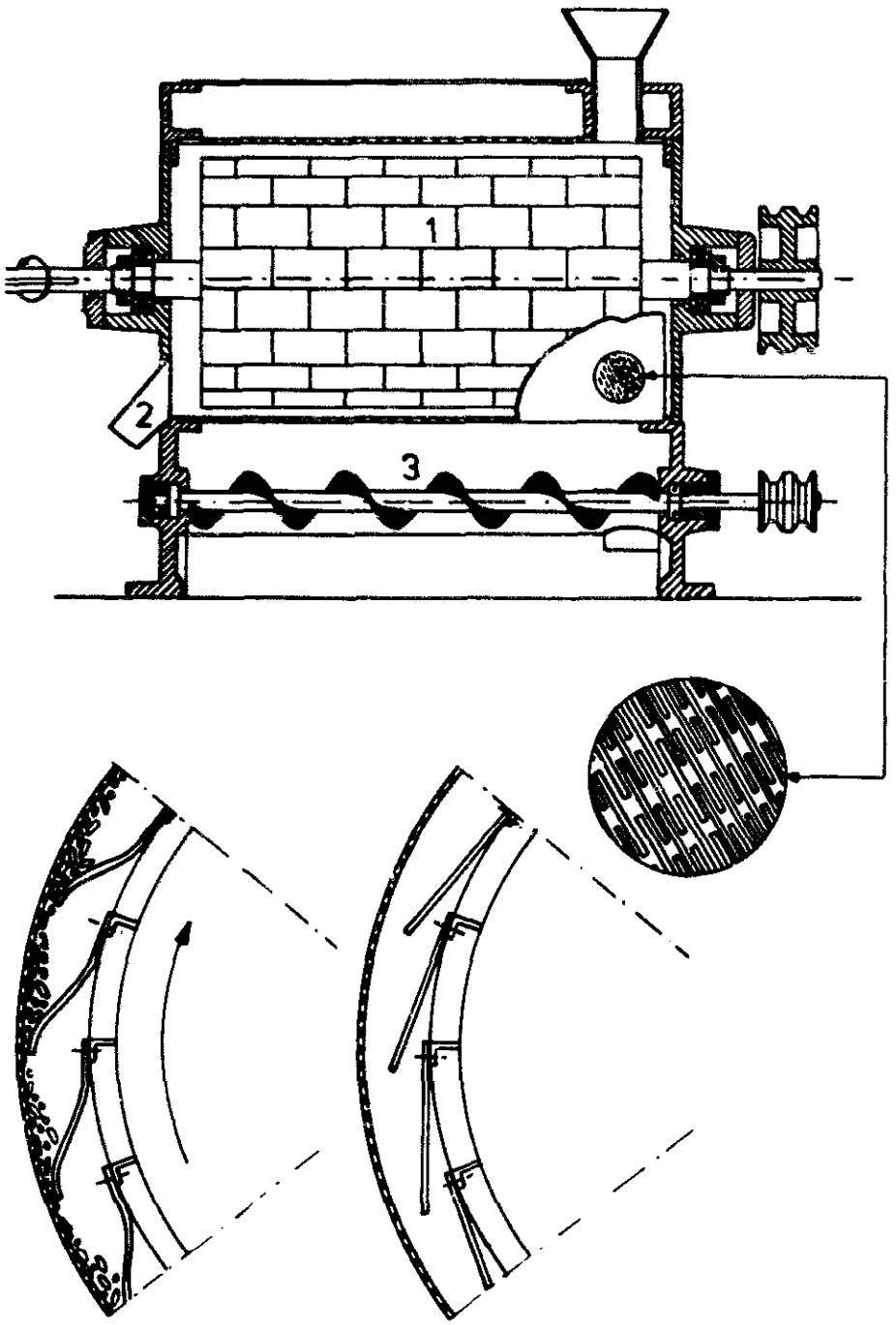

FIG. 205. Horizontal polishing machine (Satake refiner).

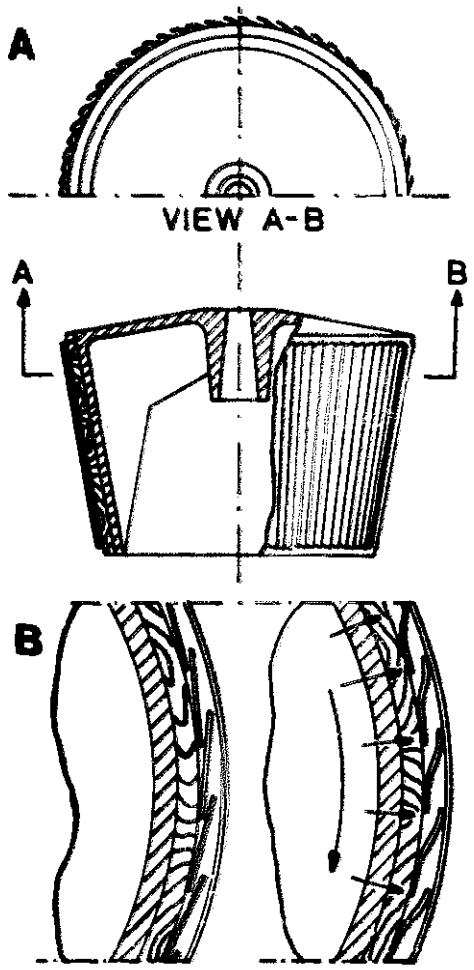

FIG. 206. (A) Cone of vertical polisher is covered with wood that has leather straps nailed to it. (B) Rice is gripped between the leather strips and the screen to remove the remaining bran and to polish the rice.

principles as the vertical polishing cone (Fig. 205).

It consists of a steel cylinder on which a large number of leather strips (8 × 17 cm) are screwed (Fig. 205, no. 1). This cylinder is mounted on a horizontal shaft that rotates inside a cylindrical chamber covered with slotted perforated screens. The polishing process is identical to that of the polishing cone. The rice leaves the machine through an outlet spout and the bran falls through the screens into a V-shaped collector for discharge by a conveyor.

The leather strips can easily be replaced and a local supply can be secured. The horsepower consumption of this machine is low compared with polishing cones of the same capacity, for example: a 2000 kg/h vertical polisher requires about 8 hp and a 2000 kg/h horizontal polisher about 5 hp. — HARRY VAN RUITEN. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

Glazing

In some countries there is a special demand for glazed rice. Glazed rice is rice that appears shinier and more transparent because the surface is coated with a thin layer of talc and glucose. The glazing process is more effective on rice that is already transparent by nature than on rice that is chalky or has a white belly. Normally only head rice is glazed; however, seldom is the full head rice production of a rice mill passed through the glazing plant. Therefore, glazing installations have a capacity that is normally much smaller than the head rice production of a rice mill.

Glazing equipment is not installed as a section of the rice mill but is installed as an independent unit in a separate building or location. The main machine in the glazing plant is a large, horizontal, rotating glazing drum.

Rice is normally glazed in batches. The glazing drum is partly loaded with rice and is slowly rotated. White shiny talc powder and

a glucose solution are then added to the rice. About 1–1.2% by weight of the dry talc powder is required (10–12 kg of talc for 1000 kg of the head rice). Glucose is added to the rice as a 1:1 solution with water that is thoroughly mixed and, if possible, slightly heated. The glucose solution is either added dropwise or by a spray mechanism. About a 10% glucose solution is required (100 kg solution for 1000 kg of rice). In the final step of the process the water is evaporated and the glucose and talc remain sticking to the surface of the rice grain. Consequently, from 1000 kg of milled rice, about 1060 kg of glazed rice are produced.

The Glazing Drum

Although many types of glazing drums have been designed they are all based on the same principle. Differences may exist in the diameter, length, shape, drive, or the unloading systems but all of the glazing drums are slowly rotating cylinders. The diameter of the drum varies between 600 and 2000 mm, and the length between 1500 and 5000 mm. The peripheral speed (V) of the drum should be about 1.3 m/s. To calculate the required speed of rotation of the drum in metres per second the relationship $V = (\pi \times D \times n) / 60$ is used. For a drum 1300 mm (1.3 m) in diameter the number of rotations per minute (n) is $(V \times 60) / (\pi \times D) = (1.3 \times 60) / (3.14 \times 1.3) = 19$ rpm.

Glazing drums are normally lined with wooden boards, and always rotate in a fully horizontal position on two or three sets of rolls (Fig. 207). The rollers on one side of the drum are fitted on a shaft that is driven by a flat-belt transmission, a V-belt transmission, or an electric motor – gear box transmission.

Rice, already mixed with the talc and the glucose solution, is fed into the centre of one end of the drum (Fig. 207, no. 1). A spiral-like scoop (Fig. 208, no. 1) supports the mixing performance of the rice and gives the rice the correct direction for unloading. After 1–2 h of continuous mixing, the grain is unloaded through endsleeves (Fig. 208, no. 2) and is discharged into an elevator spout or onto a belt conveyor (Fig. 208, no. 3).

Simple Glazing Plant (Batch Type)

A simple glazing plant (Fig. 209) consists of: (1) a bin holding the head rice; (2) a small container holding the dry talc; (3) a mixing conveyor in which the rice and talc are carefully mixed for immediate discharge into the glazing drum; (4) a container, which can be heated, that holds the glucose solution that is added to the rice on its way to the glazing drum; and (5) a horizontal rotating glazing drum.

For larger plants a fully automated glazing system can be installed. In this case, three functions of the batch-type glazing drum, mixing, drying, and cooling, are done by three dif-

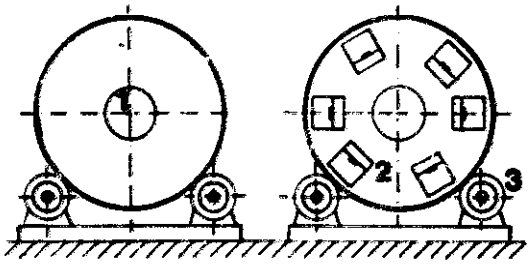

FIG. 207. End view of the glazing drum showing the input in the centre of the drum (1), the endsleeves for grain discharge (2), and the rollers that the drum turns on (3).

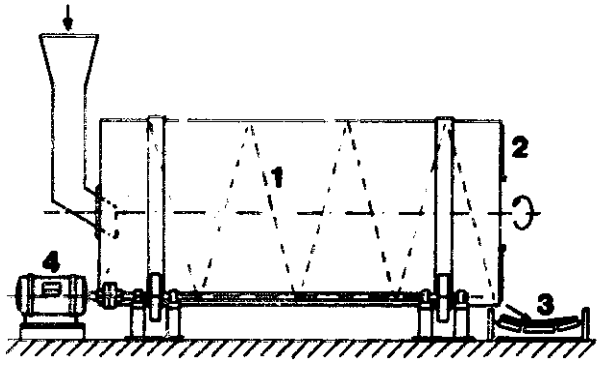

FIG. 208. Cross section of glazing drum showing the spiral-like scoop that aids mixing (1), the endsleeves (2), the belt conveyor for discharge (3), and the electric motor providing the power to turn the drum (4).

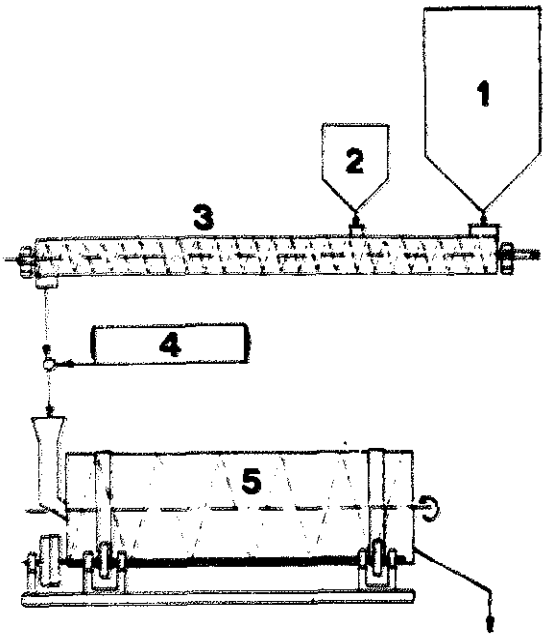

FIG. 209. Components of simple glazing plant (batch type): (1) bin holding head rice; (2) bin holding dry talc; (3) mixing conveyor; (4) container for glucose solution; and (5) glazing drum.

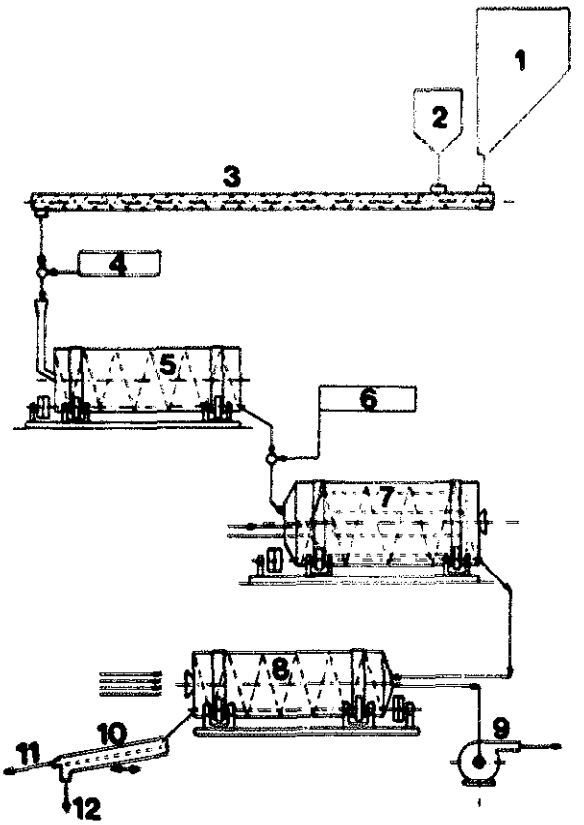

FIG. 210. Components of an automatic glazing plant: (1) bin for head rice; (2) bin for talc; (3) mixing conveyor; (4) container for glucose solution; (5) glazing drum; (6) rotating mixer; (7) heated paraffin container; (8) air-cooled mixing drum; (9) water-discharge fan; (10) oscillating sieve; (11) discharge for grains sticking together; and (12) discharge for loose glazed rice.

ferent machines. Sometimes melted paraffin is added to improve the glazing performance of the plant.

Fully Automatic Glazing Plant

Such a plant (Fig. 210) can consist of: (1) a bin holding the head rice; (2) a container holding the dry talc; (3) a talc-rice mixing conveyor; (4) a glucose-water solution container; and (5) a glazing drum that, in one slow pass, mixes the rice with the talc and the glucose solution. This drum continuously discharges the grain into a horizontal rotating mixer (6) that is indirectly heated by steam. On its way to this mixer, the rice is sprayed with heated paraffin stored in a heated container (7).

By heating the paraffin it remains in a liquid state and mixes well with the glucose. This ensures an equal distribution of this mixture over the surface of the grain and, at the same time, allows some water from the glucose solution to be evaporated and partly discharged. The heated mixer continuously discharges the grain into an air-cooled horizontal mixing drum (8), where the air, sucked through the mixer, cools the rice and discharges evaporated water at the same time (9). This air-cooled mixer continually discharges the grain onto an oscillating sieve (10) that removes head rice grains that, in spite of the intensive mixing performance, have stuck together as a result of the added glucose and paraffin. This sieve, which is normally covered with a perforated sheet with wide slots (3.5 mm), finally pro-

duces glazed head rice grains sticking together (to be reprocessed) (11) and glazed dry loose head rice grains (12) ready for bagging or packaging. — HARRY VAN RUITEN. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

Comparative Performance

The Government of India constituted a committee to study and evaluate the overall performance of seven modern rice mills set up in 1955–1966. The purpose of the committee was to compare the relative performance of these mills with the traditional sheller and huller mills based on yield and quality of rice in the various regions. Starting in 1966, the committee carried out a 2-year program of evaluation studies.

The committee was to determine the extent of the increase in the yield of total and head rice from modern mills as compared with the outturn from the existing-type sheller and huller mills in the respective region or area. The mills were to be used just as they were being operated, without any modification, improvement, or overhauling. Comparison of one modern mill with another was not included in this study.

Mill Equipment

The modern mill machinery, which was of four different makes, consisted of: a paddy precleaning system fitted with sieves, aspiration devices, and a magnetic separator; rubber roll shellers; improved husk and bran aspirators; efficient paddy separators; improved rice whiteners; bran sifters; graders; and auxiliary equipment such as elevators, conveyors, cyclones, and automatic paddy and rice weighing machines. The location of the mills, the capacity of the plants, and the type of equipment are given in Table 39. The mill complexes, in addition to the modern milling equipment, included other facilities for mechanical drying of field paddy, modern storage of paddy and rice, and improved parboiling of paddy followed by mechanical drying. Five of the seven integrated modern rice processing units also had silos of different designs and capacity with facilities for cleaning, drying, and mechanical conveying and handling of field paddy. The present discussion is, however, restricted to an evaluation of the mill machinery alone.

Selection of Mills

The general procedure adopted in each area was to select two or three rice mills operating in a particular region and to compare their working with that of the modern mill in that region. As far as possible, existing mills chosen for comparison had capacities similar to that of the modern mill, and representation was given to different types of existing mills such as the huller, sheller, sheller-huller, or sheller-cone-polisher type. The cooperation of the respective mill owners was a prerequisite to the selection of the mill.

Sampling of Paddy

The paddy used for each comparative trial in the different mills was obtained from a homogeneous lot varying from 20 to 50 t obtained by spreading and mixing a single commercial lot of paddy. After thorough mixing of the paddy, it was transferred to gunny bags and the bags were allotted by standard statistical techniques into experimental test lots for the various mills. Each lot represented a run of 1 or 2 h for the respective mills. Normally, there was a minimum of three replications in the earlier studies for each mill. This was increased to five in the studies carried out at Mandya and Raipur.

TABLE 39. Location of mills, capacity of plants, and types of equipment.

Location	Name and address of owner	Size and type of rice mill
Tiruvarur, Thanjavur District, Tamil Nadu	Tanjore District Cooperative Marketing Federation Ltd., Tiruvarur, Thanjavur District	4-t Schule mill from West Germany
Raipur, Madhya Pradesh	Raipur Vikas Khand Sahakari, Vipnan Sanstha Simit, Raipur	2-t Schule mill from West Germany
Tadepalligudem, West Godavari District, Andhra Pradesh	West Godavari District Cooperative Marketing Federation Ltd., Eluru, West Godavari District	4-t Satake mill from Japan
Memari, Burdwan District, West Bengal	West Bengal Apex Cooperative Agricultural Marketing Society, 3-Dalhousie Square, East Calcutta	2-t Satake mill from Japan
Mandya, Mysore State	The Ryots' Agricultural Produce Cooperative Marketing Society, Post Box No. 10, Mandya	1-t Satake mill from Japan
Bikramganj, Shahabad District, Bihar State	Government of Bihar, Patna	2-t Kyowa mill from Japan
Bargarh, Sambalpur, Orissa State	Regional Cooperative Marketing Society Ltd., Bargarh	1-t GDR mill from German Democratic Republic

Milling Procedure

Before each test run for a particular variety of paddy, there was a trial run carried out with the same lot of paddy that was to be put through the mill. This allowed setting of the units, filling of empty spaces of the conveying system, flushing of previous lots of rice, approximating the adjustment of the clearances of the sheller and polisher, and ascertaining that the mill was in a fit condition to undertake the tests. After this trial run, a weighed quantity of paddy from each test run was fed into the mill and records were kept of all the mill products and by-products including the impurities, rice brokens, and different types of bran. In the case of purely huller-type mills, bran could not be weighed separately because the bran and husk were mixed and it was not possible to separate one from the other.

The degree of polish given to rice from the same variety or lot of paddy was fixed at 4% since under the regulations in force, the degree of polish has to be maintained at this level. The Government of India has enforced this rule to increase the availability of rice. The degree of polish was adjusted by visual comparison to be very nearly the same as that of a standard, prepared for the purpose, using either a laboratory mill or in a few cases a modern mill. Differences often arose in adjusting the degree of polish due to personal variations in visual judgement. To obviate and correct such differences, the bran removed during milling was weighed, analyzed for its content of bran (after allowing for weight of brokens and husk), and suitable adjustments in weight made to ensure that samples so drawn had an equal degree of polish. This method suffered from certain limitations as bran could not be weighed in the case of huller mills. Moreover, some polishing occurs during shelling in disc sheller units and the sheller bran gets mixed with powdered husk, paddy dust, broken rice, and the awns of the paddy. It is, therefore, difficult to measure the sheller bran accurately. However, the amount of real bran in the sheller bran samples was roughly estimated

and necessary allowances were made, while making adjustments for equal degrees of polish.

Laboratory Analysis of Milled Rice

Representative samples of milled rice and milled brokens from each mill prepared by a Boerner sample divider were recombined in the proportion that the mill delivered to derive composite samples of the total mill outturn. These samples were subjected to quality analysis in the laboratory for impurities, bran, and brokens. Based on these data, calculations were made for clean edible rice free from impurities, and also for head and broken rice. Bran samples from the mill were also analyzed by a sieve-cum-aspiration procedure and necessary allowances were made for the amount of husk and brokens, while calculating the true bran weight.

A McGill sheller, a McGill polisher, and a sizing device were used for determining the amount of rice outturn recoverable in the laboratory. This amount was designated as the potential outturn of each representative lot of paddy. The percentage of rice outturn in the test mill was designated as mill efficiency. It was anticipated during the planning of these experiments that these mill efficiency values could also be utilized for the comparison of one modern mill with another. The large amount of data collected during the course of laboratory and mill analyses on various samples of paddy shows that variations do take place from run to run. Unless the laboratory determinations are replicated several times, and an efficient method of removal of unshelled paddy from unpolished rice during shelling is available, comparison of mills in terms of their mill efficiency ratios cannot be regarded as statistically accurate. Although the committee had all the data at its disposal, it was decided not to present the data on mill efficiency ratios for the various mills; therefore, data reported here pertain to direct comparisons between traditional and modern mills.

Calculations

Based on the mill and laboratory data, the percentage of total rice and the head rice outturn for each variety of paddy were calculated and all calculations were subjected to statistical analysis. Wherever large variations among replicate determinations were noticed, they were not included in the statistical analysis. Arithmetical average values were presented in such cases. The decision to exclude such mills from this analysis was made by the committee as it was thought that their inclusion would influence the results of statistical analysis of other mills experimented upon in the region.

Calculation of the outturn from huller mills presented certain difficulties because huller mills cannot deliver rice from paddy when the rice is milled to the standard degree of 4% polish used throughout the present experimental runs. The amount of paddy coming out with the rice at this level of polish varied from 5 to 10% in the case of raw paddy and 0.5 to 6.0% in the case of parboiled paddy. This proportion of paddy was subtracted from the rice output to arrive at the outturn; the percentage of paddy in the rice is indicated in parenthesis (Tables 40 and 41).

Economic Comparisons

An economic comparison has been made to determine the effect of differences in rice outturn on investment and operation costs (Table 42). This comparison is for the rice mill only. It does not reflect the cost of returns of mechanical drying, storage, or parboiling. Neither does it reflect the difference in quality of rice outturn, since the market value of the rice was a fixed price.

Summary of Results

Although the average milling outturn of total and head rice obtained for the different mills and the variation in yields are not given in this report, details may be obtained in a Government of India Report (Wimberly 1971).

The data have been statistically analyzed. Where individual variations among replicates were very large, only average results have been presented without testing for statistical sig-

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The data have been statistically analyzed. Where individual variations among replicates were very large, only average results have been presented without testing for statistical sig-

TABLE 40. The mean average percentage of additional outturn of total rice obtained in modern mills compared with traditional mills in each area.

Area and location of mill	Parboiled paddy[a]		Raw paddy[a]	
	Sheller	Huller	Sheller	Huller
Tamil Nadu (Tiruvarur)	—	—	4.2 (1.8)	5.3 (2.5)
Madhya Pradesh (Raipur)	0.9	2.5 (0.6)	2.7	12.5 (13.0)
Mysore (Mandya)	0.4	2.5 (0.9)	0.8	10.4 (9.8)
West Bengal (Memari)	—	0.3 (0.3)	2.8	6.8 (2.0)
Andhra Pradesh (Tadepalligudem)	0.8	—	2.9	—
Orissa (Bargarh)	1.3	1.5	1.8	1.8
Bihar (Bikramaganj)	—	1.4	—	2.6 (2.3)
Mean average percentage of additional outturn of rice of all areas	0.8	1.6 (0.6)	2.5	6.6 (6.8)

[a]Figures in parenthesis represent the percentage of paddy in the milled rice obtained in the huller mills; they have been subtracted from the milled rice output when calculating rice outturn.

NOTE: The mean average percentage of the additional outturn obtained in the modern mills has been worked out as the arithmetic average of the individual differences obtained from the different varieties of paddy and over different mills.

TABLE 41. The mean average of additional outturn of head rice obtained in modern mills compared with traditional mills in each area.

Area and location of mill	Parboiled paddy[a]		Raw paddy[a]	
	Sheller	Huller	Sheller	Huller
Tamil Nadu (Tiruvarur)	—	—	12.4 (1.8)	18.5 (2.5)
Madhya Pradesh (Raipur)	2.0	6.2 (0.6)	6.2	24.7 (13.0)
Mysore (Mandya)	0.8	8.5 (0.9)	3.1	20.1 (9.8)
West Bengal (Memari)	0.9	1.0 (0.3)	5.0	10.4 (2.0)
Andhra Pradesh (Tadepalligudem)	0.1	—	1.9	—
Orissa (Bargarh)	2.5	2.5	7.6	10.0
Bihar (Bikramganj)	—	2.5	—	6.9 (2.3)
Mean average percentage of additional outturn of head rice of all areas	1.3	4.1 (0.6)	6.11 (1.8)	15.1 (6.8)

[a]Figures in parenthesis represent the percentage of paddy in the milled rice obtained in the huller mills; they have been subtracted from the milled rice output when calculating rice outturn.

NOTE: The mean average percentage of the additional outturn obtained in the modern mills has been worked out as the arithmetic average of the individual differences obtained from different varieties of paddy and over different mills.

nificance. Studies with parboiling and sheller mills could not be included in every case as these facilities were not available at some locations at the time of evaluation. A summary of the average increase in milling outturn of total and head rice for each modern mill over sheller and huller mills for raw and parboiled paddy is given in Tables 40 and 41.

Conclusions

The modern mills have an overall increase in total rice outturn averaging 2.5% (0.8–4.2%) over sheller type units and 6.6% (1.8–12.5%) over huller units with respect to raw paddy. In the case of parboiled paddy, the corresponding increase in total rice yields from the modern mills averaged 0.8% (0.0–1.3%) over the sheller mills and 1.6% (0.3–2.5%) over the huller units.

The increase in head rice yield for raw paddy in the modern mills as compared with existing sheller mills averaged 6.1% (1.9–12.9%), as compared with huller mills, with a corresponding average increase of 15.1% (6.9–24.7%). For parboiled paddy, the correspond-

TABLE 42. Costs and returns in Indian rupees of different types of rice mills (each mill has 1 t/h capacity and mills 6000 t annually).

	Modern mill	Disk sheller	Huller
Investment cost[a]	90 000	65 000	22 500
Annual operation cost[b]	66 400	50 400	49 200
Paddy cost[c]	3 000 000	3 000 000	3 000 000
Total annual investment	3 066 400	3 050 000	3 049 200
Annual sales[d]	3 360 000	3 264 000	3 120 000
Annual returns	293 600	213 600	70 800

[a]Indian rupees: Rs. 7.5 = $1.00.
[b]Operation cost includes: power, labour, maintenance, depreciation, and interest. Huller rice mill, Rs. 8.20/t of paddy; disk sheller rice mill, Rs. 8.40/t of paddy; and the modern rice mill, Rs. 11.07/t of paddy (this includes Rs. 16 000/year for rubber rollers).
[c]Each rice mill mills 6000 t of paddy per year at Rs. 500/t.
[d]Rice sales at Rs. 800/t of rice. Total milling recovery of modern mill is 70%, of sheller mill 68%, and of huller mill 65%.

ing increase over sheller units averaged 1.3% (0.8–2.5%) and over huller mills 4.1% (1.0–8.5%).

Apart from giving significantly higher outturn of total edible rice and head rice, the modern mills yielded rice of superior quality with less brokens and a negligible incidence of foreign matter. — JAMES WIMBERLY, IRRI – *Ford Foundation Sri Lanka, Rice Processing Project, Colombo, Sri Lanka.*

HANDLING and CONVEYING

Methods and Systems

Harvested grain is transported, threshed, cleaned, and moved to a grading point, either manually in bundles or in sacks, or mechanically by combines that simultaneously accomplish the intermediate processes of threshing and cleaning while in transit. Tractor-drawn endless conveyors may also be used.

In tropical countries, simple grain cleaners are needed during threshing, before and after drying, and prior to milling and processing. Conventional winnowers popular in Asia clean grain by exposing it for a short duration to a high velocity airstream. These winnowers do not satisfactorily remove large straw, chaff, and unfilled grain from mature grain.

A popular winnower design in Asia consists of a paddle-type blower in a wooden housing, which directs the air against grain falling from a hopper. Baffles are used to separate the impurities from cleaned and semicleaned paddy. Semicleaned paddy is recycled through the winnower for further cleaning. The use of high air velocities to obtain a satisfactory degree of cleaning results in excessive loss of grain with the impurities.

Grain cleaners popular in the industrialized countries clean the grain in two stages: (1) the grain passes through a set of oscillating screens to remove the larger impurities; and (2) the grain falls through a high velocity air blast to remove the lighter impurities. Oscillating screens are often a source of mechanical problems and do not perform well when excessive amounts of straw and other large impurities are present in the grain. The short-duration exposure of the grain to the air blast does not satisfactorily remove all the unfilled, immature kernels.

Grain (especially seed grain) is moved in sacks as well as in bulk. The sack moving equipment establishes a connection between stories of the granaries and is used in part for sack loading of vehicles. Automatic loaders and lift trucks are used on the farms of large seed-producing firms and at railway goods stations, but the use of these machines is uneconomical within small agricultural enterprises (United Nations 1960).

The capacity of the vehicles serving the granary determines the maximum number of vehicles (30 an hour) that can be used, given proper organization. Immobilization due to waiting, turn-around, and movement of vehicles, together with stoppage, account for 30–40% of working time. The economic efficiency of vehicle operation is also influenced by the nature of the handling equipment in the granaries.

Large farms permit full use of vehicles and power loading devices. On small farms, physical labour is made easier by the use of a simple winch-operated mechanical shovel, which has a maximum capacity of 5–10 t/h for a motor rating of 4.5 kW.

However, in traditional rice countries of Asia, the following methods still prevail (FAO 1967–1968). Transportation of stack paddy is by shoulder poles for short distances. Over long distances the paddy is transported by means of boats, sledges, buffaloes, tractor-drawn carts, and in some cases by small hand-drawn carts mounted on bicycle wheels. Assuming an average production of 2.4 t of stack paddy per hectare, the transportation to remove the crop from 1 ha requires approximately 60 shoulder-pole loads; 30 sledge loads; 6 ox-cart loads; or 12 hand-operated cart loads.

When electrical energy is available many machines can be conveniently located on the farms. However, in developing countries rural electrification is limited and small gasoline engines are generally used. Small low-head hydraulic plants may become useful.

The handling of bulk grain in rice mills involves the movement of large quantities of material in both the horizontal and vertical directions. The rate at which grain is handled depends upon the capacity of the storage

facility and the type of operation being conducted. The conveying equipment must be selected and sized to meet the requirements of each particular operation.

A conveyor is a mechanism that moves material from one location to another in a continuous manner. Bulk grain handling systems utilize one or more of the following types of conveying equipment: (1) screw conveyor; (2) chain conveyor; (3) belt conveyor; (4) bucket elevator; (5) vibrating conveyor; (6) pneumatic conveyor; and (7) lift trucks.

Screw Conveyor

The screw conveyor is one of the oldest and simplest methods of moving bulk materials. It is a helix formed from a flat steel bar mounted on a pipe or shaft that is equipped with supporting brackets and bearings (Fig. 211). This screw operates in a U-shaped trough for horizontal conveying jobs, and in cylindrical tubes for vertical or inclined movement. The screw conveyor is simply constructed, inexpensive, and because it can be used in any position, it is easily adaptable to congested conditions.

Capacities of conveyors in cylindrical housings depend upon the auger diameter, operating speed, and angle of inclination (Fig. 212). Horsepower requirements are greatest with augers operating at angles of 30–60°.

Chain Conveyor

Chain conveyors are made in a variety of types for a variety of purposes. They are slow-moving and are often characterized by high power requirements. The drag or scraper conveyor is one of the common types. Depending upon the use to be made of the elevators, drags of varying shapes are mounted between two chains that are driven over end sprockets. The conveyor may operate horizontally or on a maximum inclined plane of about 45°. The capacity of such a conveyor should be increased by using larger flights rather than by increasing the speed.

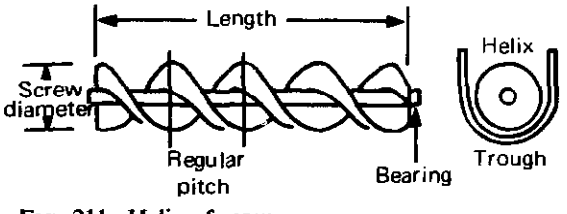

FIG. 211. Helix of screw conveyor

Belt Conveyor

A belt conveyor is an endless belt that operates between two pulleys and is carried by idlers that support the belt and its load. It is mechanically efficient, especially with anti-friction idlers. Its power requirement is low, it is dependable, and it will handle practically any type of material. If the belt is the proper size and has the correct idlers, ear corn, grain, and even bagged seed can all be handled on the same unit. The belt can be self-cleaning but usually is not in storage facilities. The initial cost of a heavy-duty, high-capacity installation is rather high; on the other hand, many small units employed in storage and milling facilities are relatively inexpensive.

The essential parts of a belt conveyor are the belt, the drive and the driven pulleys, the tension adjustment, the idlers, and the loading and discharging devices. The belt must be flexible enough to conform to the shape of the pulleys and idlers, strong enough to carry the load, and wide enough to deliver the capacity wanted. The drive should be at the discharge end of the belt and may be a conventional type of belt drive. The diameter of the drive pulley must be large enough to provide adequate contact with the belt. An idler can be used to provide more wrap contact with the drive pulley. The take-up or tension adjustment may be by manual or automatic screws on the foot pulley or on the idling pulley.

In simple installations, on short conveyors and with narrow belts, the load-carrying portion of the belt may be a smooth wood or steel surface; whereas, in installations involving heavy loads or long distances, anti-friction idlers support the belt. When the belt is "troughed" by conforming to the shape of the load-carrying idlers, the width and cross-sectional shape of the trough determine the

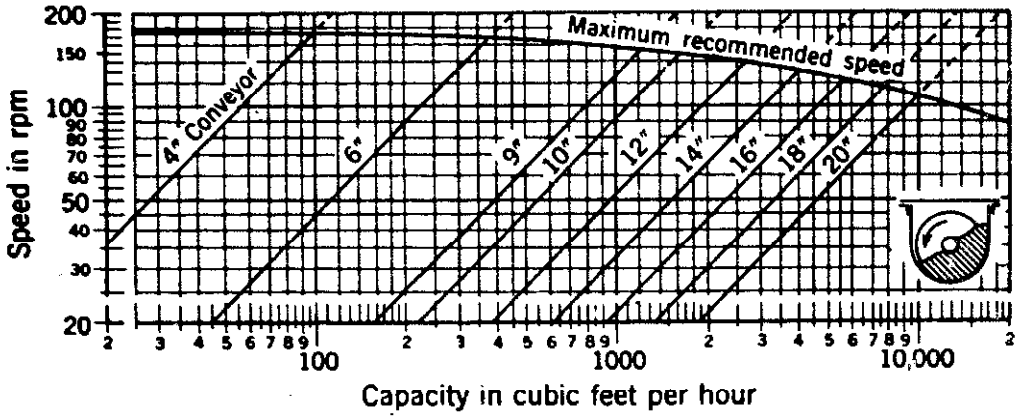

FIG. 212. Relationship between capacity and speed of a screw conveyor.

load that can be placed upon the belt (Fig. 213). Because of the cost of anti-friction idlers and the high per foot cost of wide belts, the majority of belt conveyors used in small facilities are supported by the floor of a flat-bottomed trough with vertical or angled sides that increase the capacity. Although the belt is self-cleaning, the trough often is not. Belt elevators may operate on an inclined plane of about 15°, but if the belt is equipped with flights the angle may be increased.

Material may be discharged over the end of the belt or along the sides by using diagonal scrapers or by tilting the belt. The most satisfactory way to empty a troughed belt is to use a tripping mechanism. Such a mechanism consists of two idler pulleys that cause the belt to take the shape of an S (Fig. 214). The material is discharged over the top pulley and to the side by a chute. Trippers are usually mounted on tracks so that they can be positioned any place along the length of the belt.

Tripslingers, with a high-speed reversing belt that gives left or right 90° discharge, are available to spread the grain over a wider area. Storage capacities can be substantially increased with this type of unit.

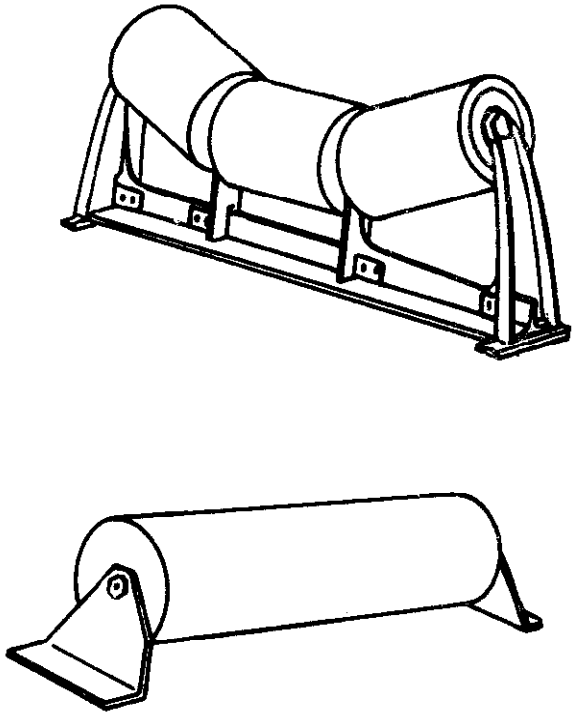

FIG. 213. Troughed and flat idler pulleys for belt conveyors. The straight pulley is used for the empty belt return and infrequently for carrying the load.

Bucket Elevator

If a belt or a chain conveyor was placed in a vertical position and buckets were attached to it at regular intervals, the result would be a bucket elevator (Fig. 215). A bucket elevator consists of: (1) a belt or chain(s) with buckets; (2) head and foot pulleys or sprockets; and (3) a method for feeding and discharging the load. The assembly is usually, but not always, enclosed by a steel or wood casing. The up- and down-legs may be enclosed in the same or separate casings. This kind of elevator is widely used in industry, in grain handling, and in seed processing. Belt-

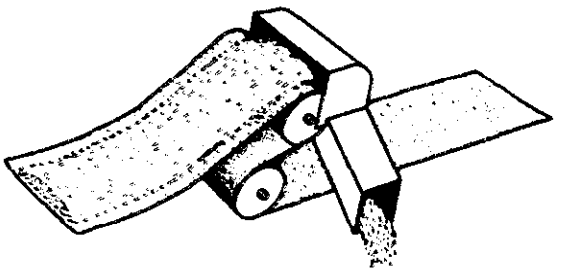

FIG. 214. Operational principle of the tripper.

type bucket elevators are quiet, efficient, and long-lasting. The chief disadvantages of some designs are: (1) the speed may damage the seed; and (2) enclosed units are difficult to clean. Feeding may be accomplished on the down- or up-leg in some types, on the up-leg only in other types. The belt can be tightened either by screw or by gravity on the foot or head pulley; however, for belts handling grain and seed the adjustment is usually on the foot pulley.

Based upon the method of discharge, bucket elevators may be classified into four types.

Centrifugal Discharge

This is the type most commonly used in the handling of free-flowing materials. Because discharge from the buckets is dependent upon both centrifugal force and gravity, the shape of the bucket, the speed and radius of the head pulley, and the position and angle of the chute must all be in the proper relationship for efficient operation. Elevators operated slower or faster than the speed for which they were designed cause back-legging, and excessive speed results in increased damage during pick-up and discharge.

If the foot pulley is smaller than the head pulley it is desirable to fill on the up-leg side of the elevator above the centreline of the foot pulley, because centrifugal force is zero on the portions of the belt not in contact with the pulley.

Bucket shapes vary with the manufacturer. They are ordinarily constructed of steel, less frequently of plastic or fibreglass. Centre spacing of the buckets depends upon their size, shape, belt speed, and the diameter of the head and foot pulleys.

Positive Discharge

The buckets on a positive or perfect discharge elevator are usually mounted on a pair of chains. They move slowly and are designed so that the material drops, without benefit (or interference) of centrifugal force, from each bucket to a chute positioned to accept the discharge. In some designs the material is scooped from the boot, whereas in others it is fed directly into the buckets. This elevator is often used on materials that are light, friable, easily damaged, or do not discharge readily from a centrifugal elevator.

Continuous Buckets

In this elevator the buckets are usually mounted as close together as possible on a chain(s). During discharge the material flows over the specially shaped bottom of the preceding bucket. This is a slow moving elevator that will handle a variety of materials, the most common being sand and gravel.

Internal Discharge

This is a continuous-type elevator in which loading and discharge take place from the inside of the bucket line rather than from the periphery. The buckets are so designed and positioned that they overlap during loading. Both loading and discharge may be accomplished from either side of the elevator. Some elevator designs use one foot and one head shaft, others are equipped with one foot and two head shafts, and still others have two foot and two head shafts. Some elevators are cased, some are not.

Vibrating Conveyor

Vibrating conveyors, also called oscillating or shaker conveyors, move materials uniformly in a continuous flow along a metal trough. The trough is mounted on rigid inclined toggles and is usually driven by a constant stroke eccentric drive. The horizontal motion resulting from the eccentric is transformed into an upward and forward pitching action by the

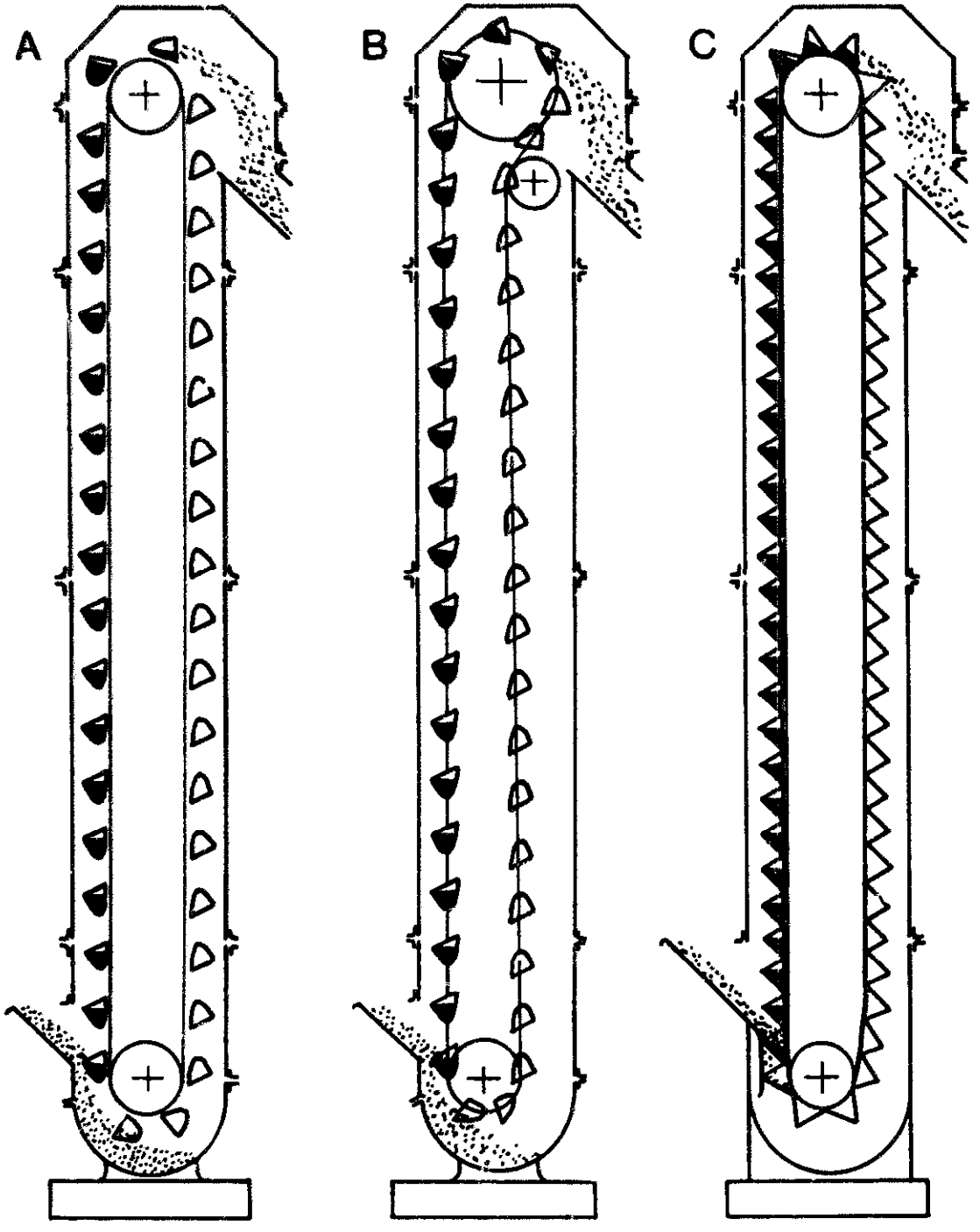

FIG. 215. Bucket elevators: (A) spaced-bucket centrifugal-discharge; (B) spaced-bucket positive-discharge; and (C) outside discharge, continuous.

inclination of the toggles. The material to be conveyed moves up and forward with each vibration while the trough returns backward and down. The result is a series of rapid pitching actions that produces a total net movement of the material toward the discharge end of the trough. Short feeding-type conveyors are sometimes powered by an electromagnet that can produce differing rates of vibration depending upon the rate of feed desired.

Pneumatic Conveyor

A pneumatic conveyor is a device that conveys materials as a result of a high velocity airstream. It has certain advantages that make it a suitable means for handling grain: (1) it is self-cleaning; (2) it has few moving parts; and (3) it may be installed around present equipment. This type of conveyor for grain, however, has two major disadvantages: (1) low mechanical efficiency; and (2) high probability of material damage.

The pneumatic conveyor is composed of: (1) conveying pipes and elbows; (2) equipment for entering grain into the systems; (3) some means for separating grain from the airstream; and (4) a fan or blower. These conveyors are classified with respect to the static pressure within the pipe, namely, negative or positive. The system is negative when the pressure in the conveying pipe is less than atmospheric pressure because the air-moving device is installed on the exhaust end of the system. The system is positive when the fan is installed upstream of the point where grain enters the pipe and the pressure is greater than atmospheric pressure.

Lift and Carrying Trucks

Lift trucks have several advantages that should be considered. With an adequate number of well-constructed and properly-sized boxes or trailers, they can double both as conveyors and as storage units. A lift truck is especially useful where a large number of lots are to be handled. Boxes or wagons equipped with perforated false floors provide excellent temporary storage bins prior to storage and processing. Lift boxes will substitute for a large number of permanent bins and will make it unnecessary to handle uncleaned grain in bags. By the use of pallets, the truck that carries the boxes can also transport and stack the bagged milled grain. — JAMES M. BECK. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

IMPLEMENTATION

Communication

The entire rice industry is made up of people. People produce the rice grain, process it, market it, and also eat it. Therefore, the technology of increasing rice productivity and minimizing postharvest losses in Asia must include the social technology of influencing human behaviour. In communication parlance, storage bins, columnar driers, and cono mills are the hardware of the rice processing technology. Equally important is the software, or the managament of human resources in the rice processing industry. These human resources are not only the people who will run the modern rice plants but also those who now operate existing processing facilities and even those who plant rice and eat rice. The art and science of getting all these people to understand, accept, adopt, and promote the improved rice processing technology come under the general heading of communication.

You may be saying to yourself, "But that's extension she's talking about." Yes, it is also extension I am talking about because extension is communication in the agricultural context. By communication, we mean that process by which individuals and social systems interact and affect or influence each other. Extension, therefore, is communication, but communication is not extension alone.

The kind of communication we are interested in aims at achieving certain objectives. Call it purposive or persuasive communication; call it development communication or agricultural extension, if your target is the rural family; call it advertising if you are wooing the consumer. In business circles it is called public relations or human management. The different names describe the same process: affecting or influencing people for some purpose of the communicator.

Using the communication approach, we can look at most situations as communication situations that can be analyzed into three basic parts: a source; a message; and a receiver. Linking these three horizontally, we already have a simple communication model. We can add another element to this model – the channel. The relationship between source, message, channel, and receiver can be verbalized in yet another way: "Who says what to whom through which channel." Implicit in this relationship is the communicator's purpose, which is to achieve some effect.

Our simple model can accommodate communication acts of different types. Communication can mean a face-to-face talk with a farmer, a whole extension service trying to promote better living for its clientele, or a national government preaching the gospel of development to all sectors of the citizenry. The communication process works essentially the same way for a barrio teacher teaching arithmetic to third graders or, at a higher level, for the educational hierarchy of a nation socializing its young population.

You can consider a training course as a communication situation where you are the receiver and the lecturers are the communication source. The message is the entire gamut of the rice processing technology that you are exposed to. When the training is over, you, in turn, become the source of the same message. Then you may ask yourself this question in preparation for the job you have to do: "To what groups of people; where; with what existing state of innovation awareness; what indigenous leadership/communication structures; what available material resources plus planned project inputs; and what existing socioeconomic practices; must the new ideas, attitudes, and specific techniques on rice processing be conveyed; when in relation to the project's target phrases; by whom and using what media?" (Childers and Vajrathon 1969).

This question breaks down into several steps: (1) identifying the groups of people that you must reach, including those who will adopt the rice processing technology as well as those who may influence, or provide the means that will make possible, the decision to adopt its various components; (2) assessing each group's state of knowledge and attitudes about rice processing; (3) assessing their habits and practices in relation to rice processing and allied

areas; (4) assessing their physical and economic resources; (5) identifying their leadership and communication patterns; (6) deciding what other material resources you must put in to augment existing ones; (7) designing the set of messages for each group that will help change its state of knowledge and attitudes, and/or teach it new skills about rice processing; (8) deciding the best combination of methods, strategies, and channels that will effectively transmit each set of messages; and (9) deciding the sequence of these activities and scheduling them in your project timetable.

Steps 1 to 5 have to do with your receiver or audience. As the terminal link in the communication chain and, therefore, the most crucial, the receiver of your message merits your most detailed study. A cardinal rule of communication is "know your audience." Only by knowing your audience can you devise suitable strategies that can affect or influence them.

It is often said that people are unpredictable creatures. This is true to a certain extent, but is sometimes said when what is meant is that people are not rational creatures. They are not always moved by reason or what to us seems reasonable; however, when we dig deeper, we find that people do have reasons for what, on the surface, seems unreasonable behaviour. It is by studying people as individuals and as members of groups that we can ferret out the reasons why they resist change.

When you offer people something new, when you introduce an innovation, more often than not you are asking them to exchange the familiar for the unfamiliar. If change does not go against practices backed by deep-seated attitudes and values, it will be relatively easy to communicate, but if it strikes at a practice or idea that is embedded in the way of life of a people, so that replacing it will wrench at the whole fabric of the social system, then it is natural that people will resist the change.

In Laguna, for example, rice stalks are harvested long because this is required for hand-threshing with the hampasan. On the other hand, many imported threshers are designed to process rice stalks cut short. The Laguna harvester has no reason to cut the stalks short since this would double his work. What is more, there would be no need to, unless the farm owner mechanizes his threshing, and he may not be prepared to do this for several reasons.

To harvest his crop, the farm owner contracts a group that also weeds the crop in the bargain. If he mechanizes his threshing, he loses his weeders. He also deprives his neighbours of their livelihood which, again, he may not be prepared to do because he has a social conscience or because he wants to keep his neighbours' goodwill. Besides, does he really need a thresher? He may feel that for his present volume of produce, a manual thresher does well enough.

A small Laguna farmer, therefore, under the present scheme of things, may not feel any need for a mechanical thresher. But a small, cheap drier may be something else. The small farmer who, season after harvest season, anxiously scans the skies for signs of impending rain that, in a matter of hours, can destroy the labour of months, does not need much convincing about the worth of a small drier. This small farmer may feel a distinct need for a small drier. He may feel little need as yet for a mechanical thresher. He must, therefore, be made to feel a need for a thresher, and this is where motivation comes in. What combination of incentives can make the small farmer feel that life would not be complete without a thresher? Motivational research is an indispensable element in most business circles. It is no less needed in the rice industry.

The technology of improved rice processing is a whole complex of recommended practices that can be broken down into several aspects: harvesting and threshing, drying, milling, and storage. Each aspect, by itself, requires a different set of knowledge and skills, not to mention attitudes. Each aspect has to contend with a different set of established practices brought about by the prevailing economic and social conditions. Adoption may, therefore, be slow and may need to wait until the economic environment becomes more favourable.

In view of the complexity of the rice processing technology, it probably should not be propagated all at once in its entirety, or in its chronological sequence, at the village level. We probably should identify the aspect that seems most needed in a village and start with

it. The other aspects can be emphasized as the village people begin to feel the need for them, they begin to be dissatisfied with the old methods, and the situational factors change.

Insofar as possible, the first of your series of innovations should be introduced with as little dislocation of community life as can be managed. A thresher that is less efficient than other types but complements present work patterns may not only be accepted faster but may be more economically feasible, given the nature of the local economy. The more sophisticated machines, although undeniably more efficient, may be more than the economic and social fabric of the community can bear. This may mean, when necesary, adapting and modifying the technology to suit actual village conditions. It will also mean formulating a different set of recommendations for large and small farmers.

In communicating the rice processing technology, a point to remember is that channels of communication can mean people no less than the so-called mass media. Indeed, for some audiences, personal channels may be more accessible or may be more familiar and, therefore, more credible. In most cases, village-based technicians, farmers' associations, and trained local leaders will constitute the main communication "media" through which the gospel of improved rice processing will be transmitted in the villages. The communication materials that need to be prepared are intended to reinforce and supplement their personal efforts.

It bears repeating that the technician's behaviour at all times can greatly influence the adoption of recommended practices. People may resist an innovation when it is actually the innovator that they are resisting. The technician's role should be to guide and advise. The people themselves must make the decision so that they will commit themselves to, and accept responsibility for, these decisions.

There are no pat recipes for the communication of the recommended rice processing technology; there never are when people are involved. But you cannot erase the people from the planning boards of the rice industry just because they cannot be categorized as exactly as grades of rice. For complex though they may be, people remain the real hope of the rice industry. — NORA C. QUEBRAL. *Department of Development Communications, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

Design Criteria

It is ironic that the new rice technology, while expanding total output significantly, may inadvertently lead to concomitant increases in the level of grain losses. Continued reliance on production, processing, and marketing systems employing traditional techniques may maintain the same percentage of output losses but at higher quantitative levels. Emerging problems of this type, which involve processing and marketing systems, are often labeled second generation problems because their emergence stems primarily from the increased output of the improved varieties (Falcon 1970).

This section addresses itself specifically to the problems of modernizing and upgrading the rice milling industry. More precisely, it is an attempt to critically assess the efficiency and economics of existing rice milling technologies. The objectives are to determine the potential for technical improvements in existing systems and, where feasible, the efficacy of initiating activities to design and develop new technologies that will increase efficiency and reduce losses. The analysis is confined principally to milling equipment and does not include an evaluation of issues related to storage or drying.

The first section contains a description of existing milling technologies now used in the Philippines; the second section examines some important structural characteristics of the rice processing industry in the Philippines; the third section is devoted to an economic evaluation of alternative milling systems; and the last section is an attempt to synthesize the results

into a series of recommendations relating to research on the design, development, and/or modification of milling equipment.

Rice Milling Technologies

Milling methods in the Philippines can be classified loosely under four broad headings: hand hulling; Engleberg mills; cono mills; and "modern" or rubber roller mills. The first category, because of its declining use in the Philippines, is not considered in this analysis. It should be recognized, however, that this technique is still widely used in other countries, most notably in Indonesia (Timmer 1972). For the remaining three categories, there exists a wide range of variation within mill types both in milling capacity and in the composition and configuration of individual milling systems.[5] Figure 216 illustrates some possible combinations.

Engleberg Huller (Kiskisan)

The Engleberg huller removes husk and bran in a single operation. Paddy is fed into one end of a hollow cylinder containing a rapidly rotating fluted roller. Axial movement of materials is accomplished by an integral, truncated screw conveyor located at the point where the paddy enters the mill. The lower half of the hollow cylinder is composed of slotted sheet metal. Husking is the result of the shearing action on the grain produced by the movement of the roller flutes past a stationary blade. The combination of rapid rotation, high pressure, and inter-grain contact results in removal of both hulls and bran as material moves axially through the machine. Hulls, bran, and broken rice pass through the perforated screen in the lower half of the cylinder while milled grain is discharged at the terminal end of the mill. Some control over the degree of milling may be achieved by adjustment of the distance between the static blade and the rotating fluted roller.

A variety of accessories may be added to the Engleberg mill. Two common attachments are a polisher composed of a rotating cylinder with leather strips attached to the periphery, which rotates in a perforated housing, and a simple husk aspirator.

If the area to be serviced is small and localized, if transportation facilities are poor and costly, and if quality standards are not critical, use of the Engleberg huller may represent a viable economic alternative. Use of this mill results in relatively low recovery rates, a high percentage of broken grains, mixing of bran and hulls, and a relatively high power requirement per unit of milling capacity. Total rice recovery from this method is generally less than 60% by weight, with head rice composing less than 50% of the total milled rice. The kiskisan does offer the advantages of simplicity in design, ease of maintenance, and local manufacture in the Philippines.

Cono

A second alternative, which processes the greatest share of rice entering the commercial market, is the cono system. It usually consists of one or more under-runner disc sheller units operated in conjunction with a number of vertical cone polishers. The hulling section of the cono mill consists of two cast iron discs that are coated with an abrasive composition material, usually emery stone. The upper disc remains stationary during operation while the lower disc rotates. Materials are fed into a central opening and centrifugal action causes radial movement of the paddy into the space between the discs. Contact of the grain with the two stones removes the husk from the grain. The machine has provisions for vertical adjustment of the clearance between the two discs, allowing a good level of precision in husk removal. Nonuniformity in grain size will result in some rough rice emerging from the machine. Unhulled paddy must be separated from the brown rice and recycled through the huller.

Bran is removed in a separate process in the cono system. The most commonly used ma-

[5]In analyzing processing technologies, the elements that make up a milling system should be evaluated independently to allow precise determination of areas where improvements will result in maximum benefits.

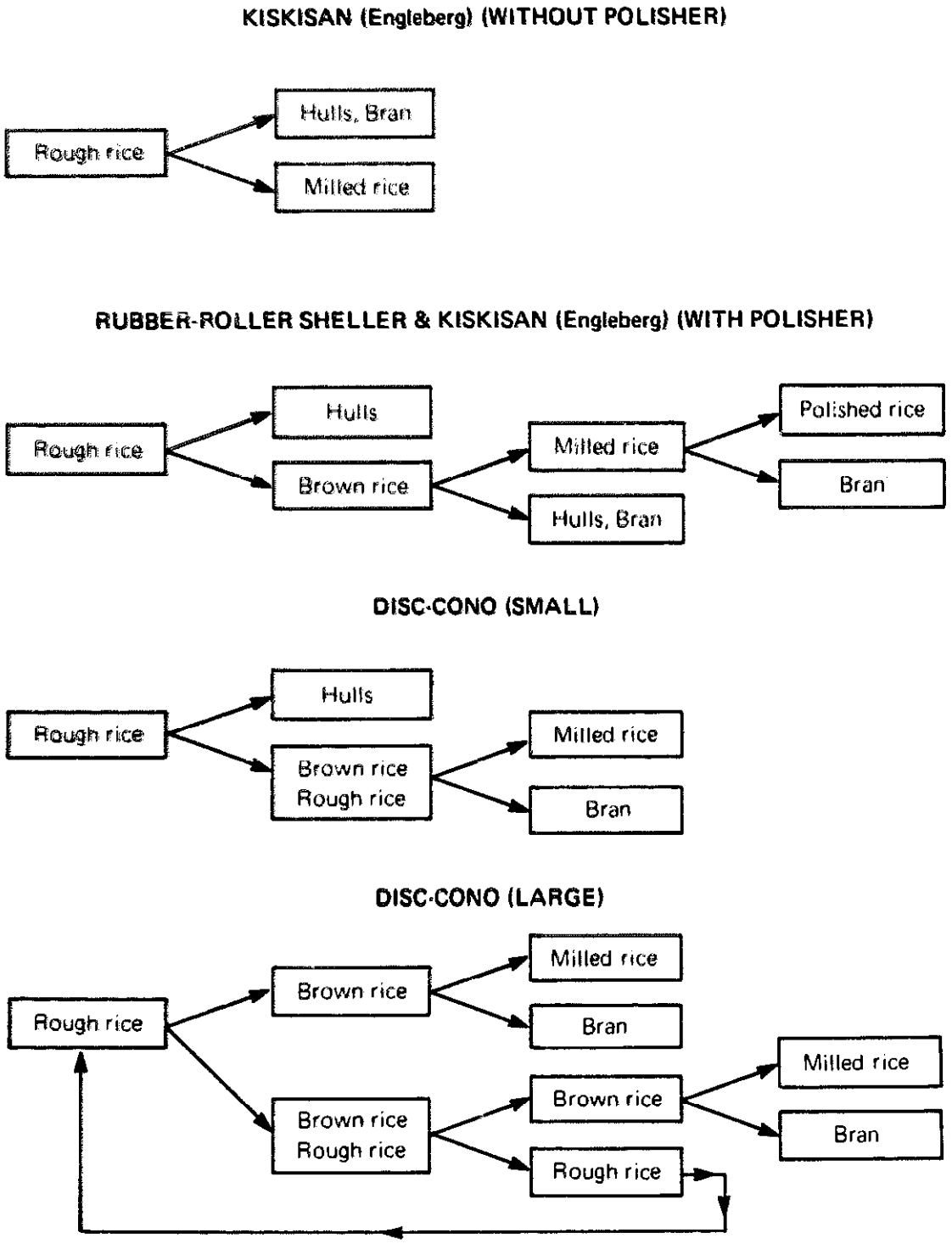

FIG. 216. Some alternative rice milling systems.

chine is the vertical cone pearler. Consisting of an emery-coated inverted cone that rotates in an enclosed perforated screen housing, the machine removes bran by a carefully controlled abrasive action on the brown rice, which occurs between the composition stone and perforated screen. Milled rice passes out the bottom of the machine.

Produced in the Philippines, the cono installation produces an appreciably higher recovery rate (up to 68% by weight) than the Engleberg huller. In addition, head rice recovery is also higher, bran and hulls are separated, and the degree of milling can be more closely controlled. The capacity of these installations ranges from less than 100 to 1000 cavans of paddy per 12-h day. Unlike the kiskisan, mills in this category are more fully attuned to commercial markets. A greater percentage of their business is derived from buying, processing, and selling milled rice as compared to the kiskisan, which is largely a custom milling operation.

Modern Systems

The third general category of milling equipment is the modern rubber roller technology developed in Japan. The most distinguishing element in this system is the sheller, which consists of two closely spaced rubber rollers rotating in opposite directions and at different speeds. A shearing action is created on the hull of the rough rice by contact with the rubber rollers. The actual removal is accomplished by a differential displacement action that removes the husk from the grain. As in the case of cono installations, variation in grain size will cause some unhusked paddy to pass through the machine. Operated in conjunction with an aspirator and paddy separator, it is possible to recycle unhulled paddy through the machine to achieve complete hulling.

When correctly adjusted, this method produces the highest total recovery and best head grain yields. Installations employing this technology are available in many sizes, ranging from below 100 to over 5000 cavans per 12 h of operation. In spite of its high technical efficiency, however, high initial investment costs combined with a lack of demand for high-quality rice have retarded diffusion of this technology in the Philippines.

Milling Efficiency

Figure 217 is an attempt to generalize the pattern of milling efficiency for the three milling systems described above. The numbers employed in this illustration should not be accepted uncritically as there exists considerable variability, both among milling technologies and between mills of the same type, in the rates of milled rice recovery and head rice yields. It is generally recognized, however, that the rubber roller sheller produces the highest recovery rates and the greatest proportion of head rice, the under-runner disc sheller (cono) is second, and the Engleberg (Kiskisan) huller gives the poorest results. Note also that the level of efficiency may be affected by the moisture content and variety of the grain, the method and speed of drying, the precision with which adjustments are carried out on the elements in the milling system, and the extent to which the practice of parboiling is utilized.

Equipment Investment Costs

Table 43 presents some typical machinery acquisition prices for a range of kiskisan and cono installation. These values do not include the cost of land, buildings, transportation equipment, and miscellaneous items that make up a complete processing system. Lack of widespread use of the rubber roller technology precludes its inclusion in the local cost data contained in Table 43.

The Engleberg huller ranks lowest in terms of total investment requirements and investment cost per unit of rated capacity. There is also a discernible downward trend in the cost per unit of capacity for both the cono and Engleberg machines as capacity increases. The same is also true to a lesser degree for the power requirement per cavan of capacity as size increases in both categories.

Structure of the Philippine Rice Processing Industry

Figure 218 depicts the distribution of milling capacity and mill numbers between the Engle-

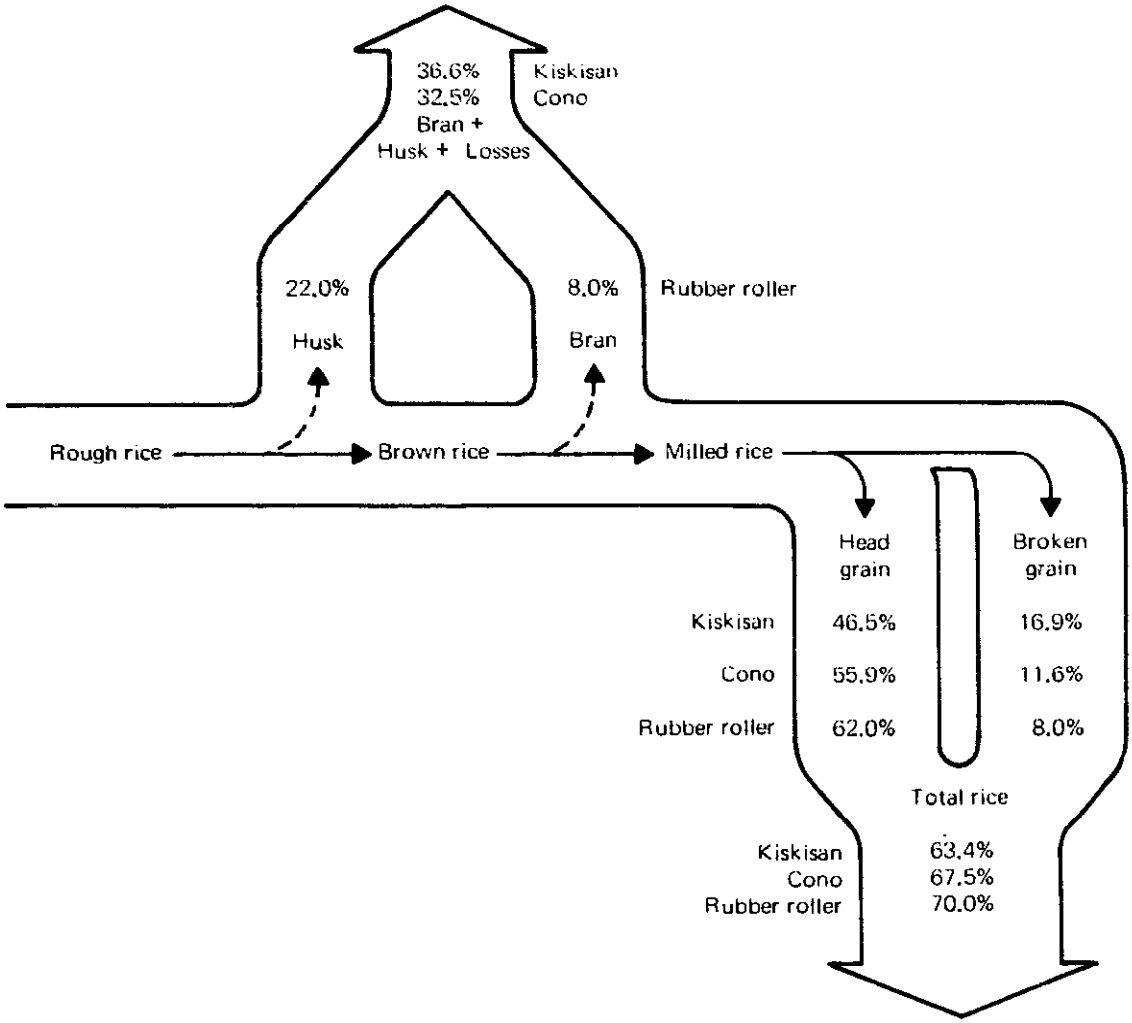

FIG. 217. Recovery efficiency for three rice milling systems.

berg and cono systems. Whereas the data supporting the absolute precision of the numbers shown are subject to question, the magnitude and pattern of the distribution between alternative milling types seem consistent with other independent estimates (Mears and Marquez 1972). The kiskisan represents 80% of the number of mills and 53% of industry rated capacity. The larger average size of the cono installations accounts for this seeming disparity.

From Table 44, it is possible to draw some conclusions regarding the concentration of both milling capacity and number of mills. Examination of the data for the cono installations indicates that both numbers and capacity are heavily concentrated in the Central Luzon and Southern Tagalog regions. This is in contrast to the kiskisan installations that are more evenly distributed throughout the country. As mentioned previously, the cono tends to be oriented towards milling activities involving the purchase of paddy and sale of milled rice to commercial centres; whereas, the kiskisan relies heavily upon small lot household milling for the bulk of its income. Consequently, when transportation facilities are lacking and markets are small and/or isolated, the kiskisan finds wide application. The growth of cono capacity and concentration seems to have exceeded paddy supplies in some areas. Barker's study on cono installations in Laguna Prov-

TABLE 43. Average investment costs for kiskisan and cono rice mills, by capacity.

Capacity (cavans/12 h)		Engine size (hp)	Average price[a] (pesos)	Power (hp/cavan of capacity)	Investment cost[b] (pesos/cavan of capacity)
Kiskisan[c]					
30–100	with	5–12	1789.00	0.167–0.12	113.19
120–180	polisher	16–20	2896.00	0.133–0.11	72.13
30–100	without	5–12	897.50	0.167–0.12	99.48
120–180	polisher	16–20	1545.00	0.133–0.13	67.63
30–100	with	5–12	1574.00	0.167–0.12	109.88
120–180	blower	16–20	2413.00	0.133–0.11	68.91
40–100	without	5–12	967.00	0.125–0.12	93.36
120–180	blower	16–20	1765.00	0.133–0.11	64.59
30–100	with	5–12	2246.00	0.167–0.12	120.22
120–180	polisher, sifter	16–20	3417.00	0.133–0.11	75.60
40–100	with	5–12	2011.00	0.125–0.12	108.28
120–180	blower, sifter	16–20	2971.00	0.133–0.11	72.63
Cono[d]					
50–100		15–24	16 799.00	0.300–0.24	376.37
150–250		25–30	36 417.00	0.167–0.12	286.08
250–350		32–45	47 481.00	0.128–0.13	260.65
350–450		45–55	56 936.00	0.128–0.12	219.13
450–700		60–80	83 601.00	0.133–0.11	193.14
700–1000		90–140	146 027.00	0.129–0.14	204.10

[a]Prime movers (diesel engines) are priced separately (pesos): 5–12 hp = 5568.50; 16–20 hp = 7923.00; 15–24 hp = 11 429.00; 25–30 hp = 20 800.00; 32–45 hp = 30 715.00; and 50–90 hp = 27 455.00.
[b]Taken at midpoint of capacity range and includes cost of prime movers.
[c]Source: A survey of six major equipment suppliers by the Agricultural Engineering Department, IRRI.
[d]Source: A survey of seven major equipment suppliers by the Agricultural Engineering Department, IRRI.

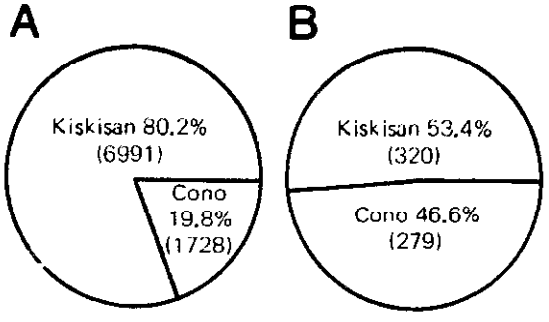

FIG. 218. Percentage distribution of rice mills by number and rated capacity, Philippines, 1968: (A) percentage distribution of number of rice mills; (B) percentage distribution of capacity of rice mills (thousands of cavans per day).

ince indicates that the concentration of mills has resulted in excess capacity in the province (Barker and Dozina 1970).

Rice Quality

In the Philippines, the two principal factors influencing consumer preferences for rice are variety and the visual appearance of the rice grain (International Rice Research Institute 1970). In 1968 the Philippines introduced a complete rice quality classification system that was largely patterned upon FAO standards. Quality determination of milled rice includes analysis of: (1) the variety; (2) the standard through classification; and (3) the moisture content.

The general criteria for grade classification (2 above) include: (1) intrinsic character; (2) degree of milling; and (3) Philippine Standard grades ranging from Grade 1 (the best grade) to Grade 5. The grades indicate percentage of head rice recovery, percentage brokens, a

TABLE 44. Rice milling capacity by mill type and region, Philippines, 1968.[a]

Region	Cono				Kiskisan				Cono + Kiskisan			
	Number	Percentage of total number of cono mills	Capacity (cavans/ 12 h)	Percentage of total capacity of cono mills	Number	Percentage of total number of kiskisan mills	Capacity (cavans/ 12 h)	Percentage of total capacity of kiskisan mills	Number	Percentage of total number of mills	Capacity (cavans/ 12 h)	Percentage of total capacity of mills
Ilocos	7	0.4	1 325	0.5	1186	16.9	39 377	12.3	1193	13.7	40 702	6.8
Cagayan Valley	63	3.6	11 685	4.2	526	7.5	25 975	8.1	589	6.8	37 660	6.3
Central Luzon	768	44.4	146 595	52.5	960	13.7	61 311	19.2	1728	19.8	207 896	34.7
Southern Tagalog	291	16.8	33 904	12.2	1222	17.5	55 382	17.3	1513	17.4	89 286	14.9
Bicol	116	6.7	17 974	6.4	658	9.4	33 474	10.5	774	8.9	51 448	8.6
Western Visayas	114	6.6	24 073	8.6	992	14.2	39 639	12.4	1106	12.7	63 712	10.6
Eastern Visayas	186	10.8	8 917	3.2	468	6.7	20 422	6.4	654	7.5	29 339	4.9
Southern and Western Mindanao	97	5.6	19 206	6.9	724	11.1	34 359	10.7	871	9.9	53 565	8.9
Northern and Eastern Mindanao	86	5.0	15 269	5.5	205	2.9	10 201	3.2	291	3.3	25 470	4.3
Total	1728		278 938		6991		320 140		8719		599 078	

[a]Source: Rice and Corn Administration, Quezon City, Philippines.

description of the kernels, and the presence of foreign matter.

Philippine Grade No. 1 milled rice is comparable to Thailand's rice grade of white-rice 5% (fifth from the top grade) and United States Grade No. 2 (second from the best grade). The maximum broken grain tolerance for Philippine Grade No. 1 is 10%; for Thailand Grade No. 5, 5–7%; and for U.S. Grade No. 2, 7%. The percentage of broken grains is an important factor affecting quality by international standards. Variety and grain appearance seem to be the most important quality factors by domestic standards (Barker and Dozina 1970).

Figure 219 illustrates that part of the Philippine quality classification system for grading rice based on the percentage of broken grains. This graph should be read in conjunction with Tables 45 and 46 to develop a full appreciation of the impact of local milling technologies on rice quality. The output of kiskisan mills rarely contains less than 50% broken grains, with many mills producing less than 40% head rice. Cono mills, when properly adjusted and maintained, can produce samples containing up to 90% head rice. The rubber roller technology has the potential of supplying output containing in excess of 90% head rice.

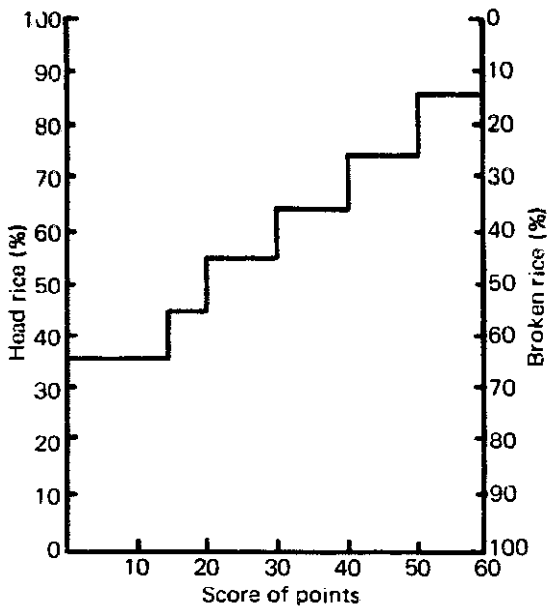

FIG. 219. Point allocation method for grading based on percentage of brokens under Philippine rice quality classification system.

Consumer demand obviously perpetuates the present system of archaic, inefficient mills producing a low-quality rice. An increase in quality consciousness would go far towards upgrading the quality of rice sold in the Philippines. It would also have the concomitant effect of increasing total rice recovery rates because of the more efficient technology necessary to produce a quality rice.

Economics of Milling

One of the most important decisions confronting a rice processor is the selection of a milling system that conforms with the technical, economic, and physical conditions of his market. Because of the magnitude of the financial and human resources that are dependent on this decision, care should be exercised to ensure that the final choice of plant equipment is optimal. In the preplanning stage, the investor should take cognizance of: (1) the volume of demand for milled rice; (2) the product characteristics that the market requires, i.e. quality, form, variety, location, and timing of product delivery; (3) the volume of paddy and site of the area from which supplies will be procured and the probability of an assured supply; (4) the transportation costs for shipping paddy and milled rice; and (5) the range of processing technologies available and their cost and performance characteristics.

Capacity

A major determinant of the economic viability for any rice mill is the degree of capacity utilization. When large-capacity mills are operated at output levels significantly below rated capacities, average total cost per unit of output is high. Similarly, when operations are maintained at levels in excess of design capacity, repair, maintenance, and administrative costs will increase, resulting in a decrease in plant efficiency and a rise in costs.

To illustrate the importance of size in the selection of processing installations, a series of budgets was prepared depicting a wide range of capacities within each equipment category

TABLE 45. Standard grade requirements for Philippine milled rice.[a]

Grade	Brokens (max) (%)	Binlid (max) (%)	Head rice (min) (%)	Yellow and damaged kernels (max) (%)	Chalky kernels (max) (%)	Paddy (max number/ 500 g)	Other varieties (max number/ 500 g)	Red rice (max) (%)	Foreign matter (max) (%)	Moisture content (max) (%)	Size of brokens
1	10	none	90	0.25	trace	none	2	none	none	14	Less than ¾ of a kernel
2	20	none	80	0.5	5	1	4	trace	0.5	14	Less than ¾ of a kernel
3	30	0.5	70	0.75	15	2	5	0.5	0.75	14	Less than ⅔ of a kernel
4	40	1.5	60	1.0	25	2	7	1.0	1.0	14	Less than ½ of a kernel
5	50	3.0	50	3.0	30	4	15	5	2.0	14	Less than ½ of a kernel

[a]General requirements: (1) no mixture of varieties; (2) free from unpleasant and/or repulsive odor; (3) free from insect infestation; and (4) the unit of trading shall be in kilograms or tonnes.

TABLE 46. Description of classification standards used for Philippine milled rice.[a]

	First class	Second class	Third class (brown rice)
Milling degree	Polished milled rice with shiny, smooth edge; no streaks or lines; foreign matter and bran from 0 to 0.5%	Polished milled rice with slightly smooth edge; with 2–3 streaks, brownish colour or spots, and rice bran sticking to the kernels	First stage in the milling where only the husk is removed, leaving a thin layer of the seed coat; very rough, brownish, and full of lines
	Type I	Type II	Type III
Type	Long grain, length shall be above 5.9 mm	Medium grain, length ranges from 5.0 to 5.9 mm	Short grain, length shall be below 5.0 mm

	Fancy	Special	Ordinary	Inferior
	The kernels have a flinty uniform appearance, glossy, shiny, translucent, or creamy white	The kernels exhibit desirable uniform white, creamy white, or light gray colour	The kernels exhibit a white to dull white or light gray colour	Milled rice with coloured pericarps (due to handling and storage)

[a]Source: U Thet Zin. Rice Inspection and Grading Covering the Sampling, Inspection, Grading and Certification. Paper prepared for the FAO International Food Technology Training Centre, Central Food Technological Research Institute, Mysore, India, March, 1971.

(Table 47). The results of this exercise are shown graphically in Fig. 216–220. Figure 220 illustrates the total costs of kiskisan installations over an annual output range of 0–12 000 cavans. Within this range, three discrete mill sizes were chosen for detailed analysis. The medium-sized mill, rated at 30 cavans/day, requires 7400 cavans/year, and the largest, rated at 50 cavans/day, must process 7700 cavans to cover all costs. Note that the milling fee charged (in the case shown, one peso per cavan of paddy milled) has an appreciable effect on the level at which these mills can be profitably operated. An increase in the milling fee, which reflects the average of income derived from both custom milling and sales of rice and binlids, has the effect of lowering the required level for profitable operation. Changes in any of the components which make up the total cost curve, such as the price of machinery, fuel, wages, and interest rates, will change the level and/or slope of the curves resulting in shifts in the break-even point.

Figure 221 illustrates a series of total cost and revenue curves for the cono type installation. In this case, the break-even levels for each mill size are considerably higher than for the kiskisan units. This is to be expected, given the higher fixed cost component for each of these installations. A similar trend is evident in Figure 222 depicting the modern milling system.

Figures 223 and 224 are average total cost curves for the operation of mills within the kiskisan and cono categories, respectively. Comparing these figures demonstrates that there are economies to be derived both from operating mills at or near rated capacity and from moving from mills with lower to those with higher annual capacity. There is also an indication that as one moves from the kiskisan to the cono technology, some economies of size are possible, particularly in the larger cono mill sizes. Note again that underutilization increases costs because the fixed cost (investment) component of average total cost remains high. It is only when installations approach design capacity that the operator is able to minimize this element of total cost. When cost minimization is the primary determinant of plant size, it may be more economic to invest in a smaller unit that will be operated at or near rated capacity than to install a unit that will be operated with excess reserve capacity.

The Composition of Costs and Flexibility in Plant Utilization

Figure 225 is an attempt to depict graphically the nature of the average total cost curves

TABLE 47. Estimated investment and operational costs for alternative rice milling technologies.

	Kiskisan			Cono			Modern (rubber roller)		
	Small (15 cavans/ day)	Medium (30 cavans/ day)	Large (50 cavans/ day)	Small (86 cavans/ day)	Medium (160 cavans/ day)	Large (240 cavans/ day)	Small (2 t/h)	Medium (5 t/h)	Large (10 t/h)
I. Investment cost[a]									
Buildings and machinery	8 516	15 677	23 818	30 494	51 104	52 320	120 800	302 000	604 000
Land	2 430	3 550	3 930	14 210	16 572	23 428	56 776	96 640	271 800
Transport equipment	570	1 140	1 900	3 500	6 550	9 800	17 640	31 752	47 628
Miscellaneous	45	90	150	300	580	880	1 760	3 344	5 016
Total investment costs	11 561	20 457	29 798	48 504	74 806	86 428	196 976	433 736	928 444
II. Operational costs[b]									
A. Fixed costs:									
Depreciation	711	1 135	1 667	4 574	7 666	9 848	18 120	45 300	90 600
Interest	511	941	1 429	1 830	3 066	3 139	7 248	18 120	36 240
Maintenance	360	480	600	650	1 000	1 500	1 950	4 875	9 750
Insurance	200	375	420	1 276	2 010	2 771	3 828	9 570	19 140
Taxes	163	266	304	1 331	1 746	2 358	5 856	9 952	18 392
Total fixed costs	1 945	3 197	4 420	9 661	15 488	19 616	37 002	87 817	174 122
B. Variable costs:									
Labour	2 160	2 400	2 880	8 340	16 140	21 120	29 820	37 920	46 020
Fuel and oil	756	1 510	2 057	3 560	5 022	6 570	14 170	28 340	56 678
Electricity	72	108	144	576	720	864	2 016	2 880	4 320
Total variable costs	2 988	4 018	5 081	12 476	21 882	28 554	46 006	69 140	107 018
Variable cost/cavan	0.83	0.56	0.42	0.60	0.57	0.50	0.35	0.21	0.16
Total operation costs	4 933	7 215	9 501	22 137	37 370	48 170	83 008	156 957	218 140
III. Annual capacity (cavans)[c]	3 600	7 200	12 000	20 640	38 400	57 600	130 752	326 400	653 760
Unit cost at capacity	1.37	1.00	0.79	1.07	0.97	0.83	0.63	0.48	0.33

[a]Investment costs: (1) buildings and machinery—based on price lists of 7 major rice mill manufacturers and dealers surveyed by Agricultural Engineering Department, IRRI, 1972 (see Table 43); (2) land—10 pesos/m² for kiskisan mills, 20 pesos/m² for cono and modern mills; (3) transport equipment—includes costs for trucks and jeeps that may be bought brand new or second hand; and (4) miscellaneous—office and plant supplies and fixtures.

[b]Operational costs: (1) Fixed costs: (a) depreciation—on buildings is calculated at 5% and on machinery at 10%. The life of the machine is quoted by manufacturers to be about 35 years; (b) taxes—include real estate tax, BIR taxes, and license. (2) Variable costs: (a) labour—wages paid for a mill operator and a labourer-helper at 240 and 180 pesos/month, respectively. Number of helpers varies with size of mill (cono and modern mills include in their staff an accountant, assistant manager, secretary, drivers, and security guards); (b) fuel and oil—based on diesel oil consumption at specified horsepower capacity (0.29 pesos/litre; (c) electricity—based on daily electricity consumption to light the rice-mill area (0.25 pesos/kWh).

[c]Annual capacity is the volume of paddy milled daily for 240 days in a year.

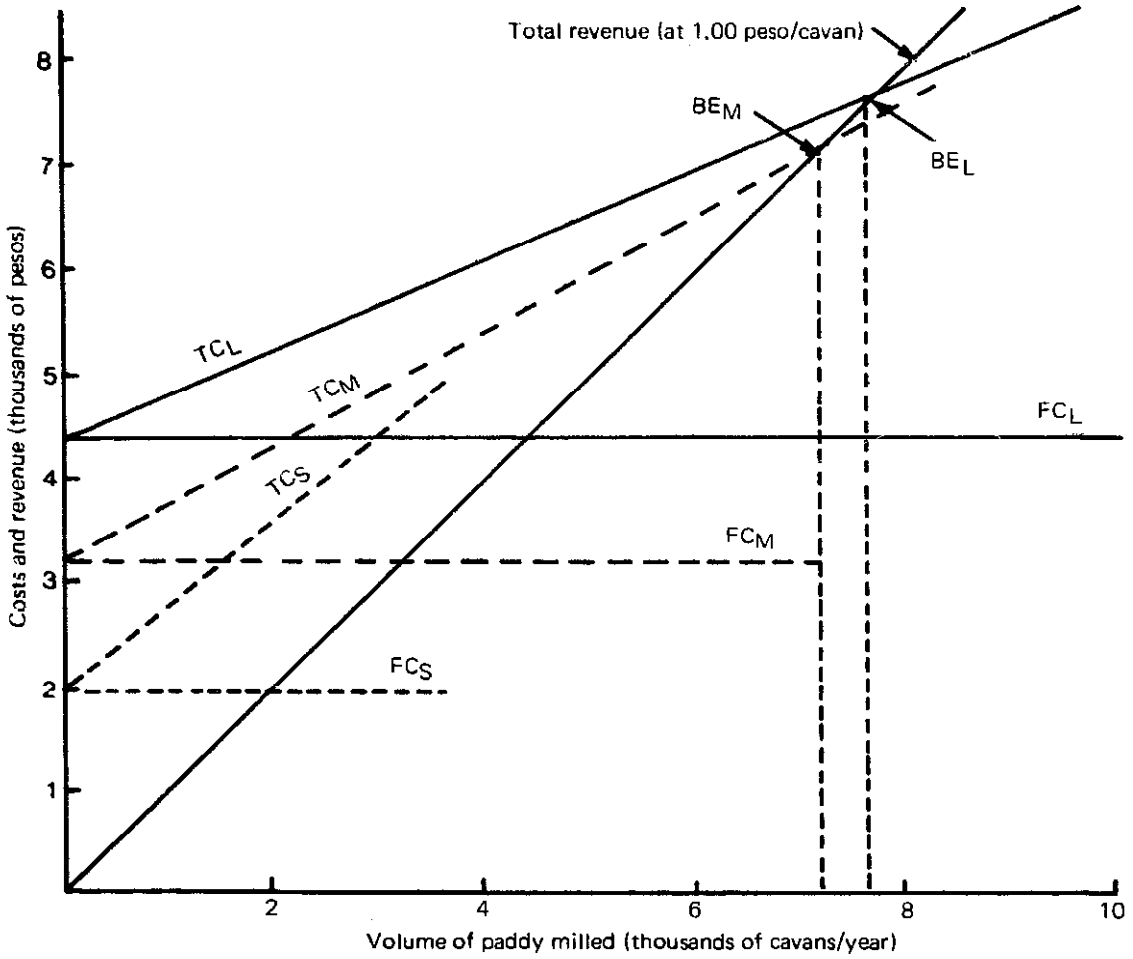

FIG. 220. Estimated total cost and revenue curves for three alternative sized kiskisan rice mills, Philippines, 1972: TC = total cost; FC = fixed cost; BE = break-even point; S = 15 cavans/day; M = 30 cavans/day; and L = 50 cavans/day.

for different sized milling units within two distinct milling technologies. Because the modern milling technology is relatively more capital-intensive, its fixed cost component is higher than the fixed cost for traditional technologies of comparable size. This causes a more rapid decline in the individual average cost curves for the new technology. For similar reasons and because there is relatively less flexibility to adjust variable costs in the new, as contrasted to the old, milling methods, a relatively steeper rise in the cost curve is observed when rated capacity is exceeded. The result is a narrowly defined range of output over which minimal costs may be achieved. The relatively gradual slope of the curves depicting the traditional technologies makes their average total cost less variable over a wider range of output conditions.[6]

Increasing Milled Rice Recovery

From the previous discussions related to levels of milling efficiency and relative rates of recovery, there appears to be considerable scope for increasing the output of milled rice by improving the recovery efficiency of tradi-

[6]A more complete conceptual framework needs to be developed to make comparative analysis between traditional and modern systems possible and eventually operational. Uma Lele's work on rice milling in India is an example (Lele 1970).

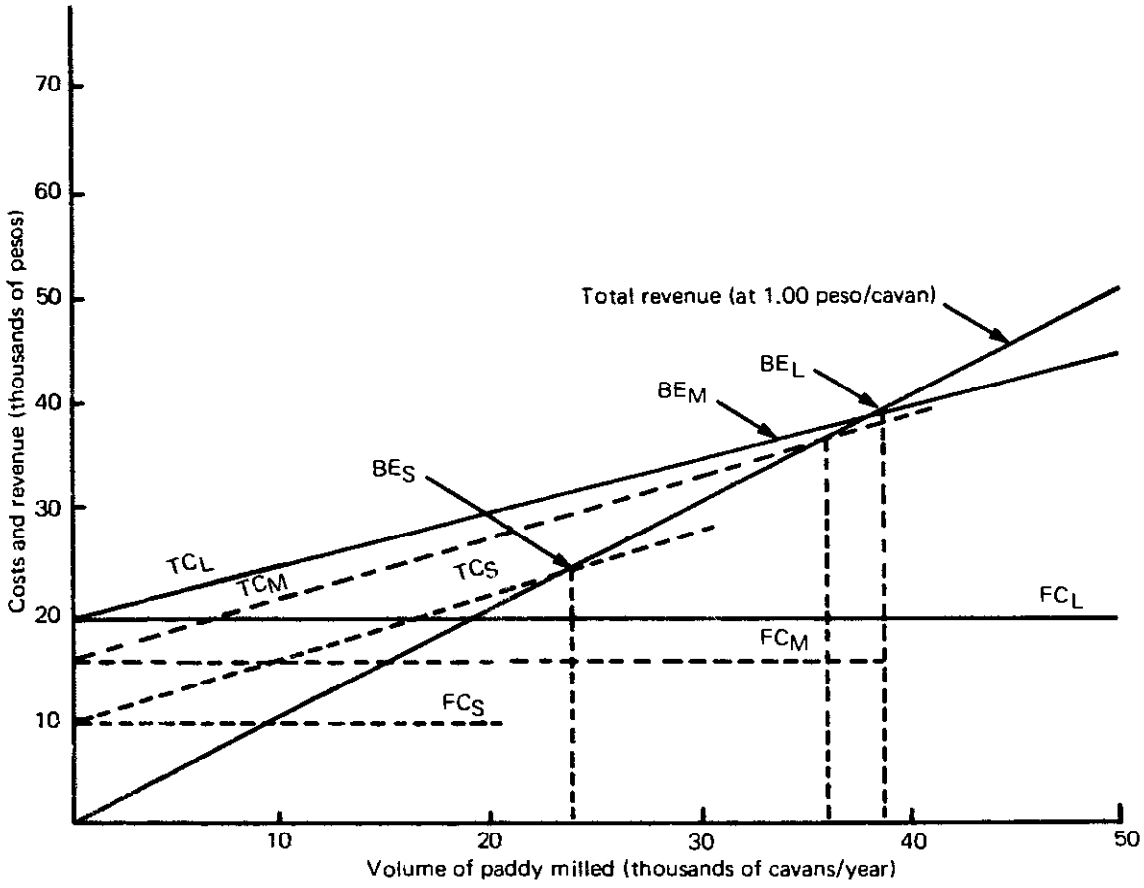

FIG. 221. Estimated total cost and revenue curves for three alternative sized cono mills, Philippines, 1972: TC = total cost; FC = fixed cost; BE = break-even point; S = 86 cavans/day; M = 160 cavans/day; and L = 240 cavans/day.

tional milling technologies. As an example of the potential for increasing recovery, consider the case of a kiskisan with a capacity of 12 000 cavans/year as compared to a cono mill with an annual capacity of 20 000 cavans. Suppose the kiskisan and cono had initial total milled rice recovery rates of 60 and 65% by weight, respectively. Further suppose that it is possible to increase recovery rates for both mills to 70%. Comparing the results in Figure 226, we find that the total increase in recovery is 1200 cavans for the kiskisan, as compared to 1000 cavans for the cono. The explanation for the higher increase achieved by the kiskisan lies in the greater range for increased efficiency embodied in the kiskisan technology. Figure 227 shows the increased income derivable from increases in milling recovery for the two mills.[7]

Net income increases from 29 200 to 116 200 pesos for the cono, and from 21 360 to 74 160 pesos for the kiskisan, as recovery rates rise from 50 to 70%. This represents an increase in net income of 298% for the cono and 247% for the kiskisan. To take a less extreme example, consider the effect on income of increasing milling recovery from 65 to 68%. In this case, net income increases from 95 200 and 60 920 pesos to 108 400 and 68 880 pesos for the cono and kiskisan, respectively. These are increases of 13.9% for cono and 13.1% for kiskisan. Even small changes in recovery efficiency have large effects on both output and income.

[7]The following prices and costs are assumed for these calculations: paddy 35 pesos/cavan; bran 35 pesos/kg; binlids 0.80 pesos/kg; milled rice 1.30 pesos/kg; milling cost for kiskisan 0.79 pesos/cavan; milling cost for cono 1.11 pesos/cavan.

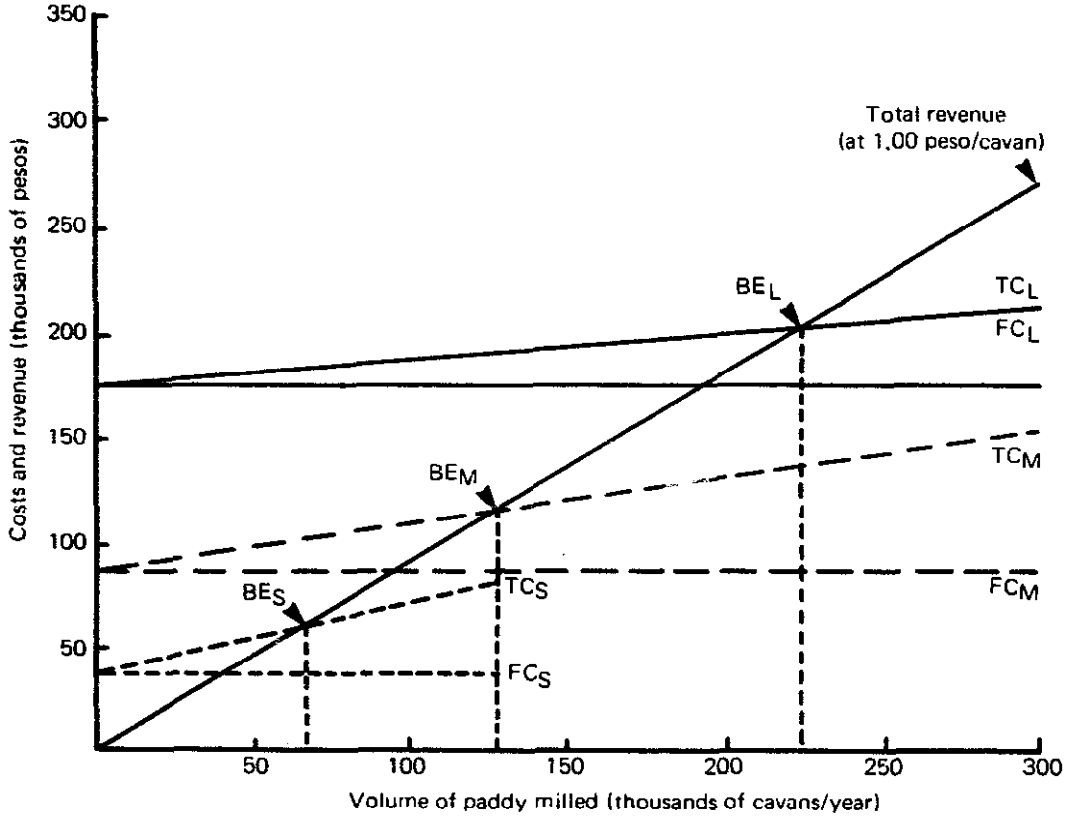

FIG. 222. Estimated total cost and revenue curves for three alternative sized modern rice mills, Philippines, 1972: TC = total cost; FC = fixed cost; BE = break-even point; S = 2 t/h; M = 5 t/h; and L = 10 t/h.

Design Parameters

Based on the evidence presented in the preceding sections, it is evident that there exists considerable scope for improving the performance of the rice processing industry in the Philippines. It is the purpose of this final section to synthesize some conclusions regarding the nature of innovations or improvements that might be made and the means of implementing these changes.

As they now exist, traditional milling technologies embody some potential for improvements without major investments in new capital equipment. Van Ruiten (1971) has demonstrated that improved maintenance and use of quality materials in the manufacture of milling equipment can have an appreciable effect on performance. In particular, utilization of improved composition stones, precleaning equipment, multipass whitening, and finer adjustments on the cono mill can result in increases in total rice recovery. Arboleda and de Padua (1965) have demonstrated that adjustments on the Engleberg huller also make possible increased recovery rates and higher head yields.

Regardless of the source of improved milling technology, whether from upgrading existing techniques through refinement and modification or the introduction of new designs, there must be a concomitant effort to upgrade the incentives for employing innovations that result in higher recovery and better quality rice. The common practice in the Philippines of using volumetric measures in merchandising milled rice tends to perpetuate a milling system that produces large percentages of broken grains. Because of the differences in the density of broken versus whole or head rice, the total weight of one ganta of brokens will be greater than a ganta of head rice. Many consumers

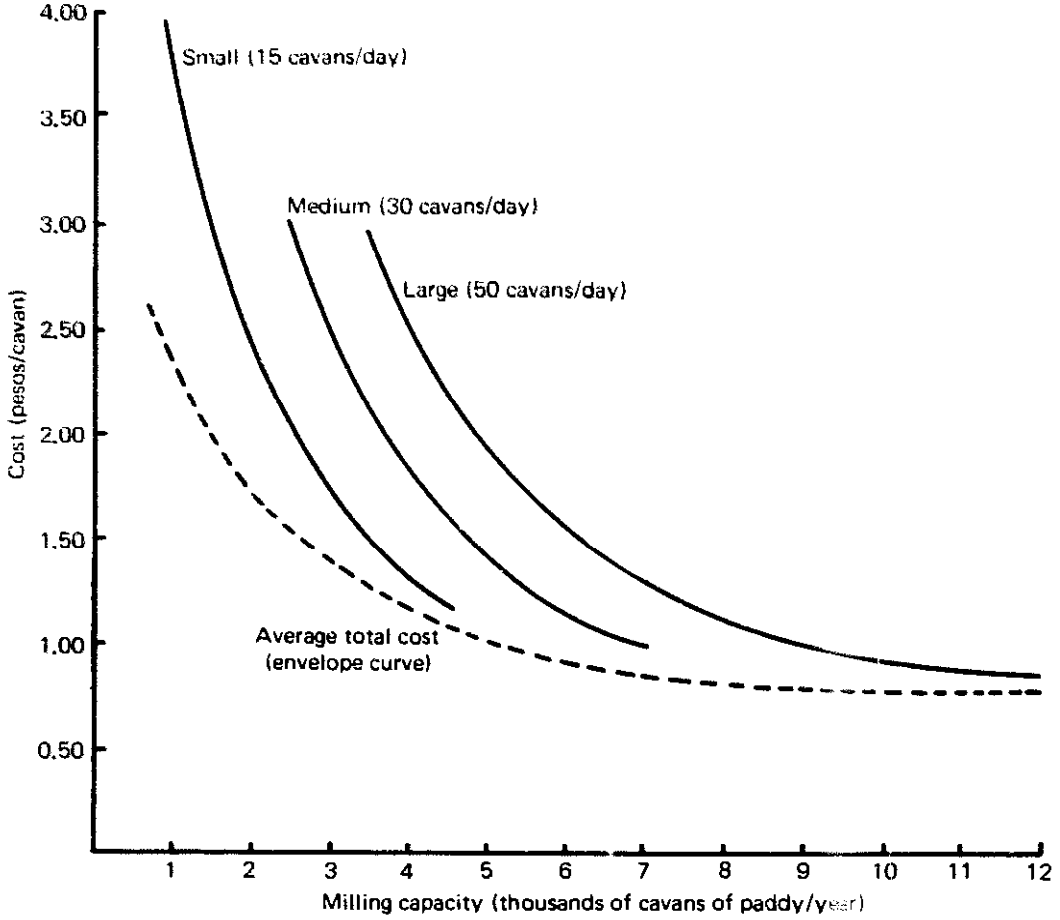

FIG. 223. Estimated total average cost curves for three alternative sized kiskisan rice mills, Philippines, 1972.

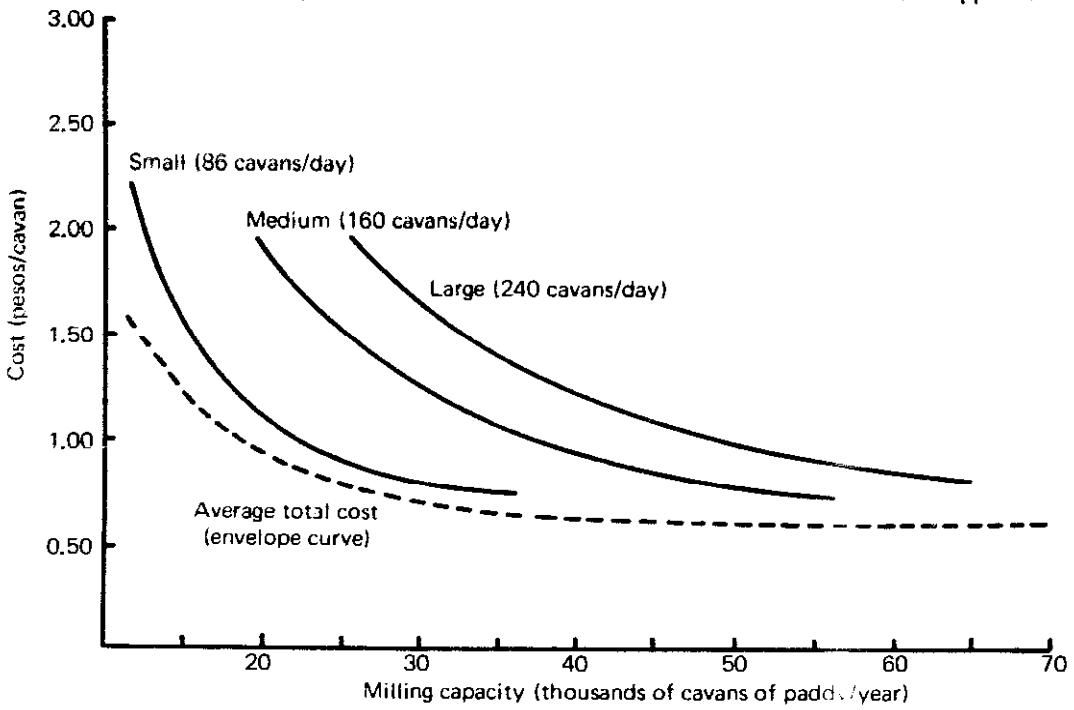

FIG. 224. Estimated total average cost curves for three alternative sized cono rice mills, Philippines, 1972.

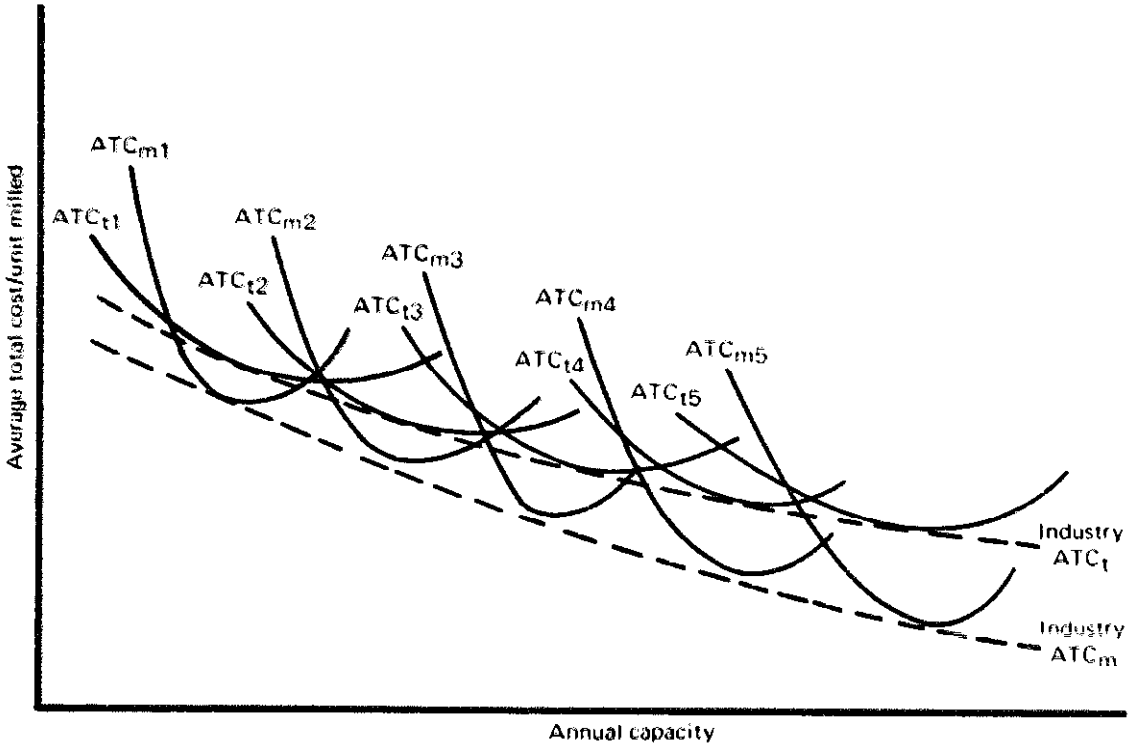

FIG. 225. Hypothetical average total cost curves for two alternative rice processing systems: ATC = average total cost; m = modern milling installations; and t = traditional milling installations.

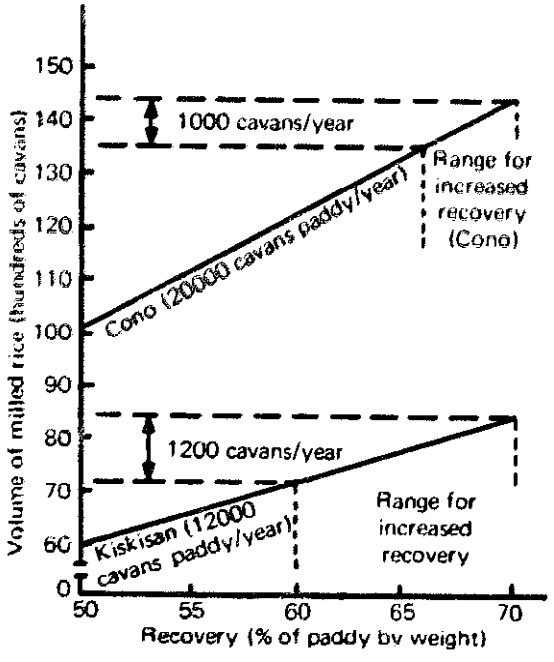

FIG. 226. Effect of increased milling efficiency on total rice recovery.

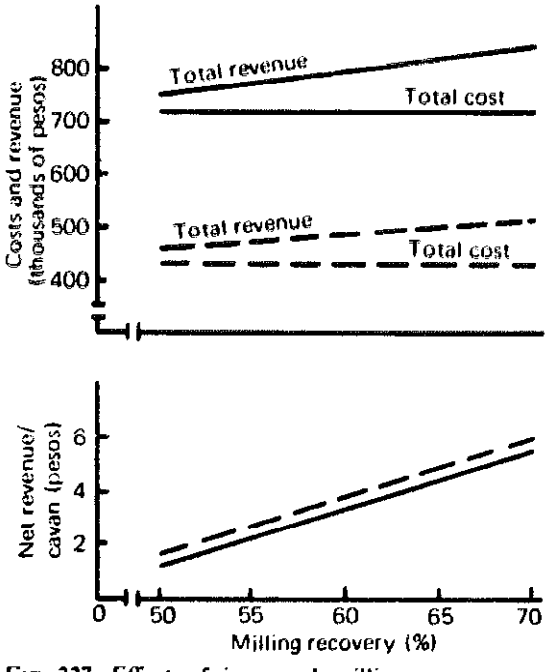

FIG. 227. Effect of increased milling recovery on total and net average revenue: —— cono (20 000 cavans/year); — — — kiskisan (12 000 cavans/year).

state a preference for broken rice for this reason. Another area requiring attention is the practice of paying for the milling service with the bran, binlids, and hulls. When the miller receives payment in bran and binlids, he has no incentive to decrease the number of broken grains because this practice results in a higher quality bran and more binlids from the milling process.

The present price of animal feed has risen to a point where most millers are receiving cash instead of bran and binlids in payment for milling services. The mixture of bran, binlids, and masticated rice hulls that emanates from the Engleberg huller is used as animal feed for both hogs and chickens. In the absence of an assured supply of cheap feed grains, the present practice of utilizing the high quality by-product mix from Engleberg mills will persist. These are policy related questions that deserve the attention of the industry and of the government.

To establish criteria for the design and development of new rice milling equipment, it is necessary to examine the concentration and distribution of rice milling capacity by mill size. Figure 228 contains cumulative frequency distributions showing total industry rated capacity and total industry utilized capacity. Superimposed on this chart are the ranges over which the kiskisan and cono type installations operate. Note that approximately 70% of the rated capacity falls within the size range of kiskisan installations; whereas, the cono installations cover approximately 50% of the range. The increasing segment of the frequency function from 40 to 110 cavans/day contains approximately 50% of the industry rated capacity. It is this range that appears to offer the greatest potential for design and development of new milling technologies. Note also that there appears to exist about 25% excess capacity in the milling industry, although it seems to be about evenly distributed over the entire range of mill size.

With increased commercialization, it appears appropriate to move towards the upper end of the range selected for improved equipment and concentrate development efforts there. This allows realization of some economies of size in milling operation, while at the same time keeping initial investment requirements at a level comparable with existing milling technologies. Employing the information contained in Tables 43 and 47 in conjunction with the above data, a suggested set of general design parameters are: (1) capacity 80–100 cavans/day; (2) power required 596–670 W (0.8–0.9 hp) per cavan of capacity; (3) total power 5960–7450 W (8–10 hp); (4) investment cost 60–80 pesos/cavan of capacity (including engine); (5) total investment 4800–8800 pesos; and (6) variable costs 0.35–0.40 pesos/cavan of output. Utilizing these general and very rough estimates, it remains an engineering problem to determine the feasibility of such a design.

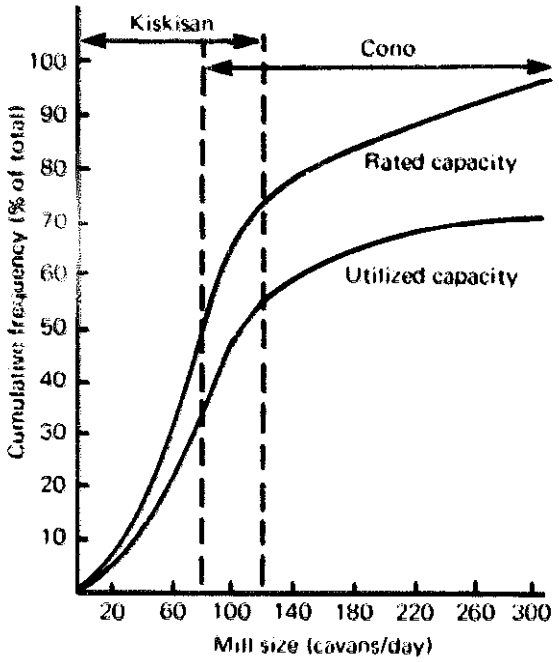

FIG. 228. Distribution of milling capacity by mill size, Philippines, 1970.

It is obvious that the above estimates are contingent upon the level of wages and prices now in effect. Changes in the economic environment or policies affecting the economic environment may change the level and/or composition of these estimates. — BART DUFF AND IDA ESTIOKO. *Department of Agricultural Engineering, International Rice Research Institute, Los Baños, Laguna, Philippines.*

Agribusiness Management

By definition, concepts are mental images abstracted from perceptions. As an analytical device, they are helpful in facilitating understanding and appreciation. They are a way of looking at things and, therefore, they can vary with different viewpoints.

In this section, some of the concepts of the structure and the linkages of the rice industry as well as the trends towards its integration are defined. The concepts are projected from a management standpoint and they regard the rice industry as a complex business that must be well understood to be managed. They are macro in dimension and it is hoped that although general in nature, they will offer a helpful frame of reference for the identification and solution of rice problems at the industry and firm levels.

Background

In the beginning, traditional agriculture was exemplified by a self-contained farmer who was both producer and market for his produce. He prepared and planted his land with his own seed, relied upon nature for the needed water, harvested, threshed, stored, and finally processed the harvest to meet his subsistence requirements. As with crops, the pattern was the same in the case of the animals he domesticated and raised.

With time, however, the technological revolution dispersed and distributed the functions of the farmer. His capacity to till the land increased, and so did his market, which expanded beyond himself and his family. These functions, providing the inputs on the farm, the farm operations, the assembly, transportation, storage, drying, processing, and selling of the produce, began to be performed by other firms that increasingly grew in size and number (Fig. 229).

The technological revolution was partly a product of population. The increasing numbers of people inevitably called for new ways of feeding them. At the same time, they constituted a widening market that encouraged the revolution of food production and distribution into complex agribusiness commodity industries.

In the agricultural economies of Asia, one can recognize commodity industries at various stages in the continuing movement that is changing the commodity industries. One such industry is the rice industry, which is supplying the staple food for hundreds of millions of people in this part of the world.

Structure and Character

The commercial rice industry may be generally viewed as vertical in structure with the following components: the input suppliers and distributors; farmers; processors; wholesalers; retailers; and consumers (Fig. 230). In each of these components, there are many firms operating, each one pursuing its activities with some degrees of independence, sometimes complementing each other, sometimes competing or contending with each other. They interact, and the events that occur in one component affect the events occurring in the others. Logically, the entire structure must be balanced and coordinated to be viable. Bottlenecks in one of the components retard industry growth. Balance and coordination enhance industry development.

In most countries in Asia, the millions of rice farmers generally own and operate 2 ha or less of land. This fact has certain implications. It complicates the coordination of the entire industry, suggesting that the grouping of rice farmers into cooperatives, associations, or other forms of business organization is imperative. The fragmentation of land ownership is a constraint on the distribution of inputs and the spread of technology, causing inconvenience, raising costs, and lengthening target time-periods. Also, assembly of the

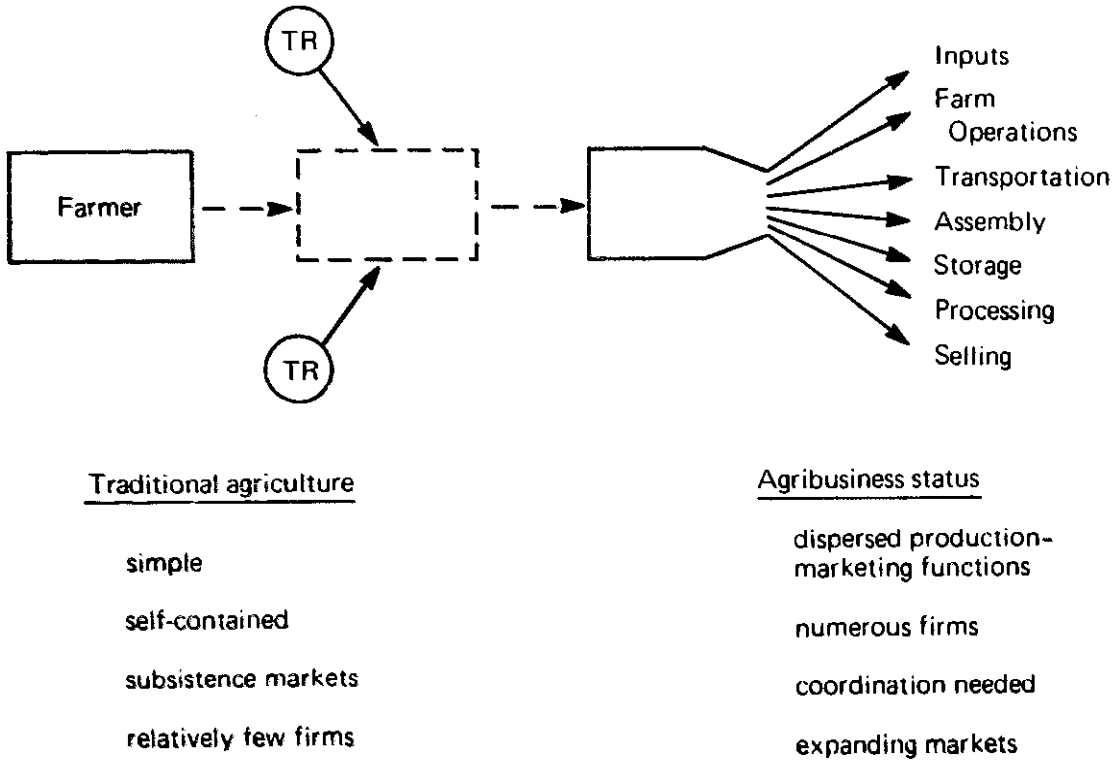

FIG. 229. The evolution of traditional agriculture to an agribusiness status (TR = technological revolution)

produce becomes a tremendous task. The small size of the farm units puts a big question mark on efforts to develop viable credit systems that will enable farmers to buy and use technology inputs, and limits each farmer's absorptive capacity for losses during the bad years.

In these regions, rice has traditionally been a seasonal crop, with the main harvest occurring during half of the year and secondary harvest during the rest of the year. This is partly due to the generally common monsoon climate and the natural difficulty of developing irrigation systems that will make adequate water available, particularly during the dry season. This coincidence of cropping seasons heightens the risk to Asian countries when adverse weather conditions prevail during the main cropping season. It is responsible for the marked difference in rice prices between the troughs during months of heavy supply and the peaks during the lean months. In deficit-producing countries, supply and price stabilization thus become quite a vexing problem.

The advent of the high-yielding varieties that are insensitive to photoperiod has made it possible to even the supply curve because they can be planted at any time, given the water requirements. But this is possible only to a certain extent because irrigated areas are relatively limited compared to the total hectarage devoted to rice, and the expansion of irrigatable areas is naturally a slow process.

The setting of the industry is a double-edged situation. The industry is located in the rural areas where the majority of the population is, and this gives it real importance in terms of the need to develop purchasing power in the countryside, which will expand the markets for the goods turned out by the industrial sector. But most governments are welfare-oriented as they run economics where poverty and low incomes are of major concern, and prices must, therefore, be kept low to be within the easy reach of the common man. Subsidies to please the producer or the consumer are not substantial enough and may not continue for long because they have to be financed by income transfers from the other sectors of the economy that, in most cases, are still unable to generate income for transfer on a continuing basis.

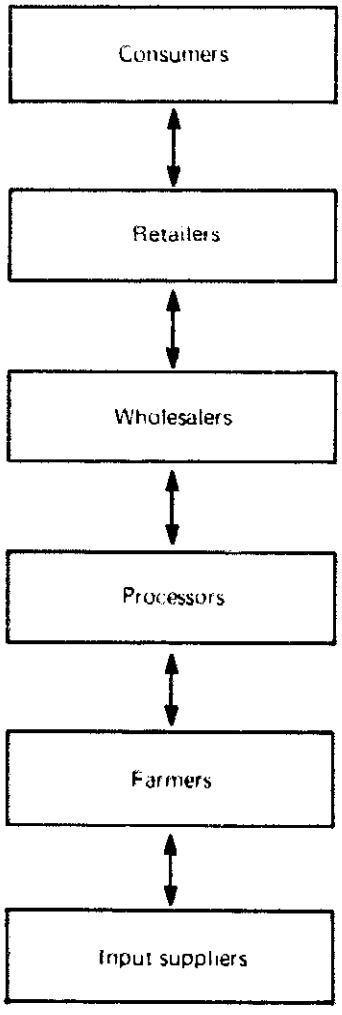

FIG. 230. Commercial rice industry structure.

Milled rice, the main product of the industry, reaches the market in different grades. The quality of the grain is related to varietal characteristics and milling efficiency. The more transparent the grain, the less chalky it is, the higher its milling degree, the more head rice it has, and the higher its price is in the world market. But in the rice-importing countries of Asia, indigenously grown rice is sold as turned out by the local mills, with hardly any distinguishing differences in head rice and broken rice ratios and relying more on distinction between varieties for price differentiation.

Technology

Rice production technology advanced tremendously in the 1960's, rapidly spreading the high-yielding varieties and the packages of practices they called for. The work to improve the technology in terms of better physical grain quality, higher protein content, wide spectrum resistance to disease, and adaptability to a wide range of conditions is bound to continue for many years.

But, already, there is widespread realization that advances in rice production technology have accentuated or created second generation problems with regard to harvesting, processing, and marketing. These problem areas are currently receiving more attention than ever before.

Post-production problems were noted as early as two decades ago. For instance, the existence of the inefficient kiskisan single-pass mills was regarded as one of the causes of perennial rice shortages in the Philippines. Because volume recoveries were as low as 45% and they processed a substantial portion of the national rice production, they were logically regarded as a deficit factor. Their recovery efficiency rate was about 10% below that of the more efficient cone-type mills used by commercial millers, and the annual shortages in rice rarely beyond 10% of the estimated annual production. In 1971, a survey conducted by the Asian Productivity Organization in 14 Asian countries disclosed that the working average physical losses in grain marketing was about 16.5% (Table 48).

The attention being focused on post-production rice problems is bound to improve the technology of processing and marketing. Improvement would result in diminished physical losses in rice handling or, in another sense, in increased supply of grain and more economic returns to the rice industry.

Linkages

The structure of the rice industry has many linkages. Besides its own components along the route of the industry's product flow, there are other organizations whose functions affect the industry in all its phases. These are organizations engaged in: research, training and extension; agricultural supply; credit; infrastructure

TABLE 48. Estimated grain losses in marketing (Stevenson 1970).

Process	Average percentage grain loss
Field transportation	2.0
Drying	2.0
Drying-to-storage transportation	1.5
Storage	4.0
Storage-to-processing transportation	1.0
Processing	5.0
Packaging for distribution	0.5
Transportation in distribution	0.5
Total	16.5

building; price stabilization; program coordination; and policy making (Fig. 231). Because of the multifarious relationships among these linkages, coordination problems push for integration at the industry and firm levels.

Integration

At the industry level, integration as a process takes the form of umbrella organizations attempting to simplify planning and implementation or of agencies pursuing development or stabilization programs.

In the Philippines, the National Food and Agriculture Council (NFAC) is an umbrella that covers agencies belonging to the Depart-

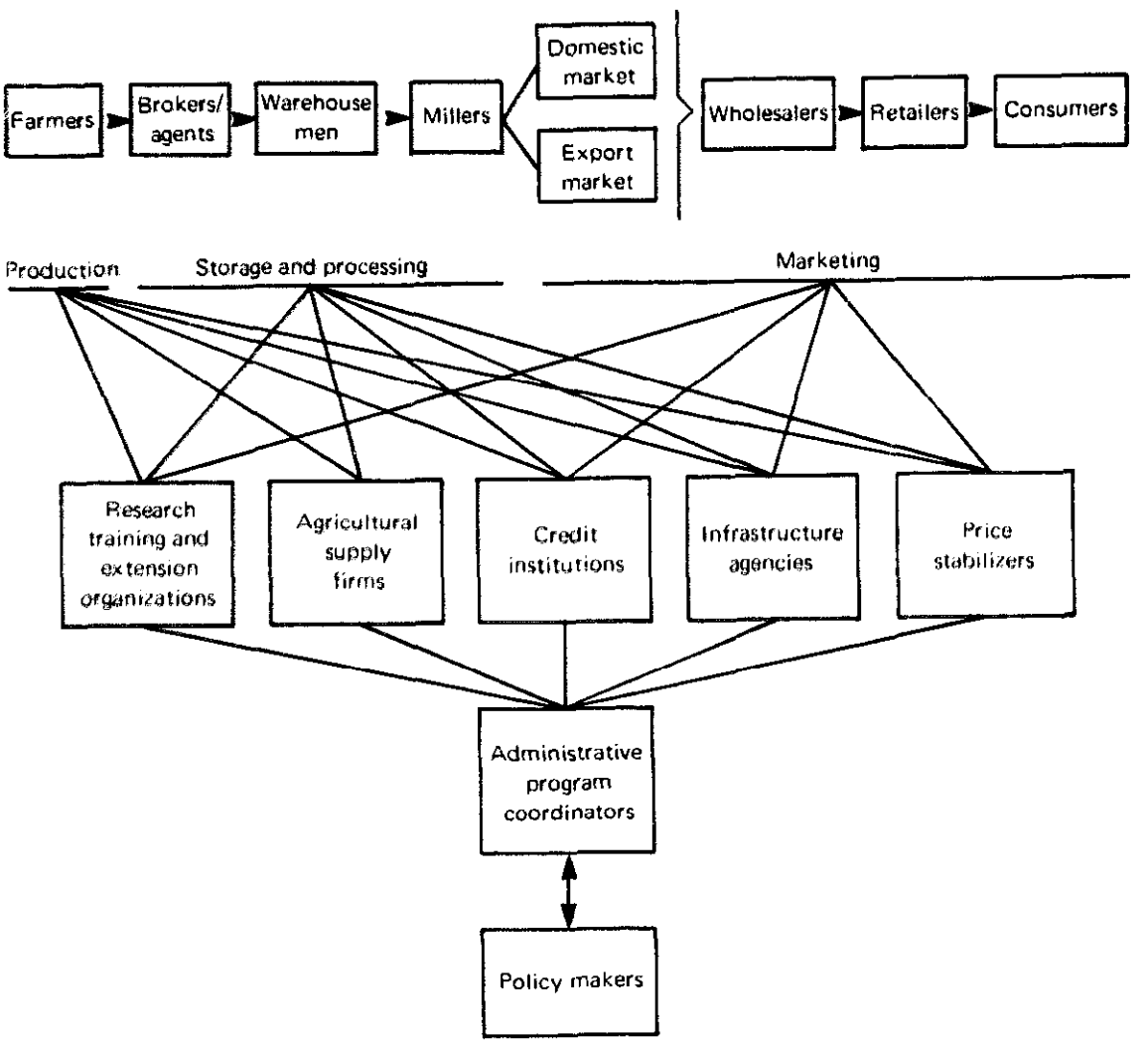

FIG. 231. Product flow and linkages in the rice industry.

ment of Agriculture and Natural Resources as well as other agencies whose responsibilities bear on the rice industry. These other agencies include the Rural Bank Department of the Central Bank, the Philippines National Bank, the Development Bank of the Philippines, the College of Agriculture of the University of the Philippines, the Food and Nutrition Research Council, the National Grains Authority, and government trading organizations. As a coordinating and integrating body, NFAC makes instant decision-making possible with respect to problems affecting rice production, processing, and marketing.

The National Grains Authority itself is an integrating body. In its function of stabilizing the prices of rice, it is charged with the maintenance of a floor or support price for paddy rice and a ceiling price for milled rice. In the performance of this responsibility, it should influence the behaviour of rice producers, processors, and merchants in a manner that will distribute equitably the margins associated with the growing and marketing of rice, and at the same time, ensure for the consumers, directly or indirectly, reasonably priced rice at any time of the year.

The Development Bank of the Philippines is administering a $14.3 million lending program for the modernization of rice processing facilities in the Philippines. The terms and conditions of the lending program and the campaign to promote the program are aimed at private processors for the improvement of their existing physical plant or the building of new ones in places where they are needed.

The cooperatives are integrative in nature. As an organizational scheme, they are expected to enhance the flow of technology, reduce the costs of inputs, prevent cut-throat competition, provide facilities that make for economies of scale, facilitate the acquisition and use of credit, and develop markets for the produce of its members.

At the firm level, integration is occurring in the rice industry in two ways: (1) in-plant vertical integration in which milling facilities increase their components from single-pass processing to multi-stage processing, in certain cases involving the use of driers, cleaners, in-bin ventilators, aspirators, separators, polishers, pearlers, graders, and packaging equipment (Fig. 232); and (2) production-marketing integration toward the development of rice districts in which the rice central is the main component, supported by satellite country elevators or stations (Fig. 233).

In-plant vertical integration is occurring in various degrees. In a number of countries in Asia, the single-pass mills are slowly being replaced by two-stage compact mills involving dehusking and polishing. The cone-type mills are being improved in certain components, particularly the cleaners, separators, polishers, and graders. A few installations have already been set up that include all the trappings of a modern mill plus auxiliary plants that use rice by-products such as an oil extractor, a bran pelletizer, and a power plant fueled by rice husks.

Production-marketing integration is seen in cooperatives or in confederations of cooperatives plus some processors corporate in form that are trying to encompass as many of the functions as possible that are involved in rice farming and marketing. Such integration is usually accompanied by in-plant integration. It is capital intensive and requires operation at relatively high volume.

Integration offers economies of scale and allows control of the operations at each stage. But it requires sophisticated management to successfully handle all stages of the operation so that a sufficient supply of the right quality is available to keep the processing plant at profitable capacity utilization rates and maintain the firm's foothold in a sensitive and dynamic market. The promised rewards are high, and so are the risks. — J. D. DRILON. *Southeast Asian Regional Centre for Graduate Study and Research in Agriculture, College, Laguna, Philippines.*

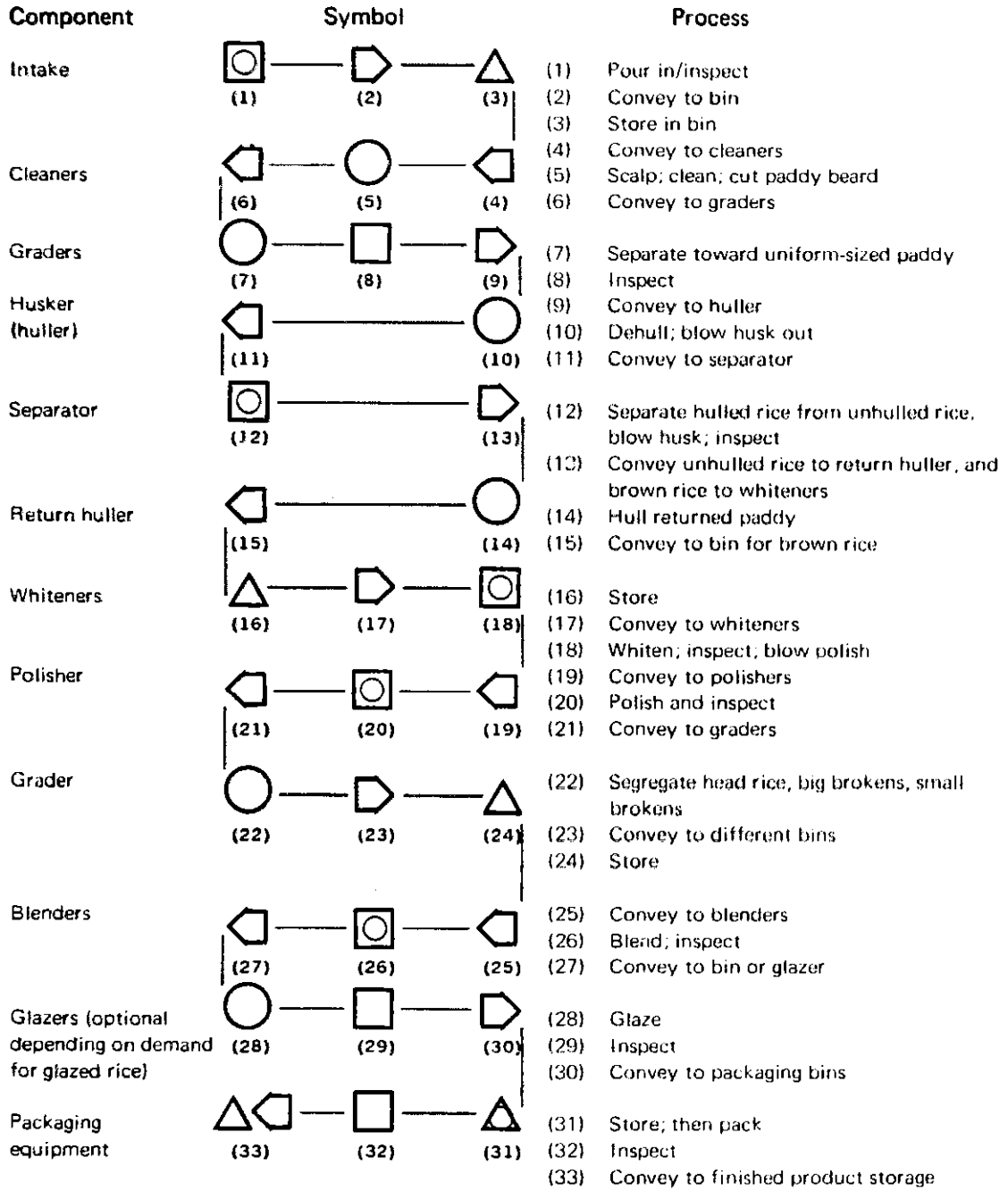

FIG. 232. Flowchart of a modern rice mill illustrating in-plant vertical integration: ○ operation; △ storage; □ occasional inspection; → transporting or conveying; and ⊡ combined operating/inspection.

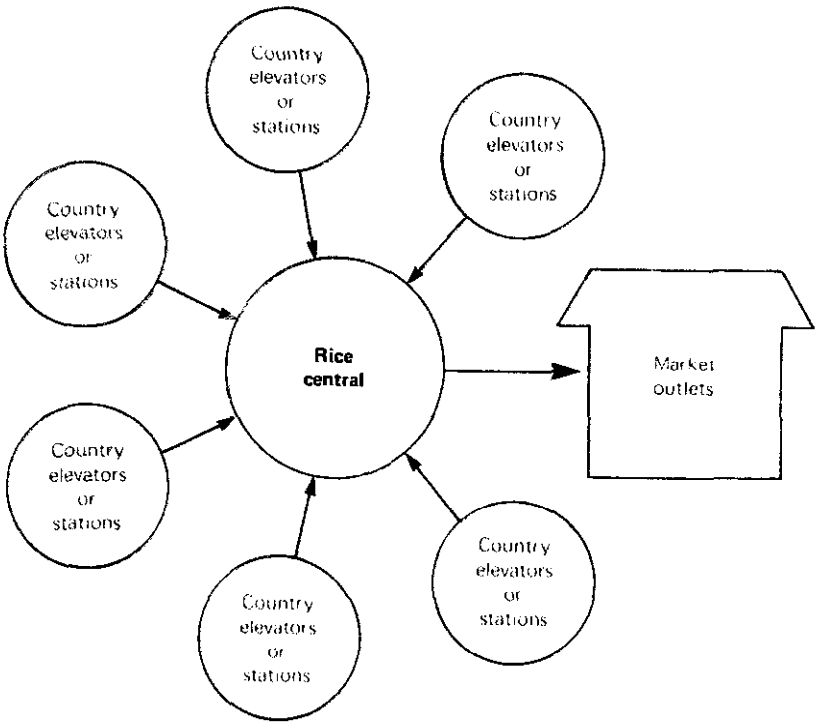

FIG. 233. Rice central concept, which results from production-marketing integration.

Cooperatives

The two main problems in the grain industry are low productivity and low farm income. These problems are due to the interaction of such factors as small farm size, lack of operating and working capital, inadequate credit institutions in the rural areas, inefficient postharvest practices including marketing, low levels of education, and a general lack of useful information, and negative attitudes and social values. To minimize, if not eliminate, such problems, the main aim of the Philippine government, as a matter of national policy, is to expand and accelerate agricultural and food production to meet the food requirements of its rapidly increasing population, to raise the traditional agricultural export production, to increase its foreign exchange earnings, and to increase the supply of raw materials for industrial processing.

The grain industry is the most important industry in the Philippines in terms of hectarage planted, number of people employed, and share of the gross national product. Advancement in the grain industry, therefore, spells agricultural progress and development. It is, therefore, essential that the grain industry have a lion's share of the resources available for economic and agricultural development. In the Philippines, rice and corn production is the first priority in food production programs. The in-industry is given massive financial support. For agricultural production loans alone, the total amount extended from 1966 to 1971 to paddy farmers was 2.4962 billion pesos; for paddy marketing, 482.8 million pesos; and for processing, 118.0 million pesos.[8] With the recent move of the Philippine National Bank to participate fully in the supervised credit

[8]Agricultural Credit Report. Prepared by ad hoc committee to study the agricultural credit system in the Philippines.

scheme for the production of rice, it is expected that there will be significant increases in the amount of credit for rice production and marketing. Together with credit extension, a number of programs have been instituted by the government to bring about desirable changes in agricultural production, the marketing system, and the standard of living of the rural population. One of the most significant programs is the development of agricultural cooperative institutions through which needed services are available to cooperative members.

Role of Cooperatives in Economic Development

Cooperatives as an instrument of economic development are in the forefront to promote not only economic prosperity but also social equity. In one historic meeting, the International Labour Organization in 1966 strongly recommended that the establishment and growth of cooperatives should be regarded as one of the instruments for economic, social, and cultural development as well as human advancement in development countries.[9] Cooperatives should be established and developed as a means of: (1) improving the economic, social, and cultural situation of persons of limited resources and opportunities; (2) increasing personal and national resources by encouragement of thrift and the sound use of credit; (3) increasing national income, export revenues, and employment by a fuller utilization of resources; (4) improving social conditions and supplementary social services; and (5) helping to raise the level of general and technical knowledge of their members.

His Excellency, President Ferdinand E. Marcos of the Republic of the Philippines, speaking before Asian cooperators, emphatically said: "Cooperatives are institutions of human beings with a firm and faithful commitment to the achievement of social justice and economic democracy on the strength of voluntary action to satisfy common economic and social needs of people. They are peculiarly suited to the economically weak and small for whom indeed they have been conceived. Propelled by the power of self-help and self-reliance, cooperatives can be effective means of rationalizing of credit both with respect to generation of funds and to their efficient management. As institutions of people they can replace or at least balance the institutions of private property that today constitute the citadels of the status quo. They can thus bring about the revolutional change that the temper of the times demands."[10] In view of this idea, President Marcos would like to solve socio-economic problems by convulsing the country with the cooperative approach.

Characteristics of Agricultural Cooperatives

Agricultural cooperatives, like the grain cooperatives, are democratic institutions whose control rests on the membership and whose main objective is to provide efficient services to members to effect savings and increase net income. The common purposes of organizing grain cooperatives in Asia are to increase farm productivity and income and, ultimately, to improve the quality of living in the rural areas. Under efficient management, cooperatives may help to safeguard the consumers' as well as the farmers' economic independence.

Through his cooperative, a farmer is linked with markets; he learns to adapt his production goals to market requirements and also learns new techniques that are important for undertaking new profitable enterprises. A multipurpose agricultural cooperative may also provide for a limited number of consumer goods and social services.

In general, the benefits of cooperation not only improve the economic situation of farmer-members, but they also tend to improve the market conditions for all farmers because, if the cooperatives are well organized and managed, private firms and merchants will

[9]Recommendation 27. International Labour Conference, 1966. Fiftieth Session (mimeographed).

[10]"A Cooperative Ideology for New Asia." Paper read by President F. E. Marcos, President of the Republic of the Philippines, at the opening ceremony of the First Asian Conference on Agricultural Credit and Cooperatives in Manila, December 1–10, 1970, Manila, Philippines, p. 22.

have to readjust their price policies if they do not want to lose all their customers to cooperatives. Thus, unreasonably high collection and distribution margins can be reduced by cooperative action. Cooperatives, therefore, may break monopolistic or oligopolistic situations. Primary cooperatives may organize secondary or tertiary federations that may enter new markets and processing and/or distribution activities. As a consequence, it is apparent that the agricultural cooperative movement may constitute a rationalizing and welfare instrument in a national economy. A system of agricultural cooperatives may even run its own marketing and price stabilization schemes.

Grain Cooperatives in the Agricultural Sector

Nowhere in the agricultural sector is the demand for development more urgent than in the grain industry. In the rural economy, there is the pressure of population growth, clear evidence of unemployment and underemployment, and serious limitations of employment opportunities. There is, however, an intense appreciation of the fact that the rural economy can improve only through increased grain production. The grain industry is important not only because the countries need to feed a vast and growing population but also because the grain industry depends on a large segment of the population for its livelihood. Since the grain industry is very important, it spells agricultural progress.

Grain cooperatives, as economic and social institutions, have vital roles to play in the drive for development and agrarian reform since it is the grain industry that is primarily covered by land reform in the Philippines. Cooperative organization appears to be the only feasible and worthwhile method of putting the small amortizing owner of very little or no means on his legs and assisting him. In cooperation with others he may become self-reliant, strong, and dignified. If the huge reservoir of potential entrepreneurs, leadership, and talent available among the mass of people in the rural areas is to be activated and utilized through democratic methods, cooperative efforts ought to be embraced by all peace-loving people.

In the Philippines, grain cooperatives (rice and corn) are the most numerous. As of June 30, 1969, out of 652 agricultural cooperatives with a total membership of 362 637 farmers, 376 were grain cooperatives with 252 139 members and a paid-up capital of 6.4 million pesos. Of the 376 grain cooperatives, 153 and 19 were active and semi-active, respectively.

The Role of Government in Cooperative Development

The problem of agricultural development is so obvious and so intensely demanding that governments cannot wait for cooperative institutions to develop by themselves on the basis of individual initiative and self-reliance. In fact, the member countries of the International Labour Organization have been encouraged to formulate and carry out a policy under which cooperatives receive aid and encouragement of an economic, financial, technical, or legislative nature, without adversely affecting their independence. One of the resolutions in the First Asian Conference in Agricultural Credit and Cooperatives was to strengthen the cooperative movement through administrative and financial assistance from the government.

Cooperatives in the more advanced countries, such as Denmark, have emerged and prospered with a minimum of government intervention and support. In this region, however, governments have to play a more aggressive role in providing a climate that is conducive to the healthy growth and development of cooperatives. It would not be sufficient for the government to help farmers organize and to provide financing and supervision to cooperatives. Initially, governments will have to carry the burden of providing opportunities for cooperative members' education and for management training. This can be done through the regular educational institutions, the agricultural extension services, and the state-financed training institutions. As cooperatives become stabilized and financially sound, then they can, and should, carry out their own educational and training programs through

their federations or national organizations.

A preferential government policy towards cooperatives will facilitate the full development of the movement. However, for the cooperatives to cover most farmers quickly, support through subsidy or through tax exemption privilege might be allowed during the initial stages of cooperative development. Care should, however, be taken that cooperatives are not used as agents of governments for assistance programs to agriculture that might run counter to the legitimate cooperative purpose and be implemented outside the cooperative framework. This may hasten the death of the cooperative movement. Undue reliance on government controls and subsidy programs creates an artificial atmosphere that may destroy instead of build up cooperatives once such programs are withdrawn.

Specific Functions of Grain Cooperatives

Grain cooperatives may contribute to the objectives of agricultural development and rural employment by serving as: (1) instruments for capital formation through which loans are issued to rice and corn farmers; (2) agents for procurement and distribution of quality farm supplies, at cost, to farmer members; (3) agents for the orderly and efficient marketing of farm products; and (4) instruments for the implementation of the government program for the development of the grain industry.

Saving and Lending in the Grain Cooperatives

The mobilization of available capital within the economy, including agriculture, requires an efficient network of credit institutions that will bring about the progressive shrinkage in size of nonmonetary areas. Authorities on farm credit agree that the credit institutions that are designed to serve the rural sectors, including rice and corn farmers, must be built on a solid foundation if they are to be of lasting benefit. For people to accept them, their operations should be suited to the traditions, habits, customs, and set ways of the rural people and must conform to the idiosyncrasies of rural living that have insured the growth and survival of indigenous leaders, such as the face-to-face relationships, the informal and simplified procedure, and the efficiency of loan releases. Not only must they be financially stable on rational commercial lines and operate in an atmosphere of growth, but they must also help, stimulate, and promote the initiative of rural people for greater savings and render to them technical guidance for more effective utilization of borrowed funds.

It is believed that cooperative credit institutions are the best possible form of credit institutions for rice farmers, more than 73% of whom cultivate not more than 3 ha. Cooperative management officials are usually more familiar with the local conditions, which is essential for a successful local lending institution. In general, rice cooperatives in the Philippines have failed in their lending operations because the local committees, which were supposed to be the extension arms of the cooperatives, did not perform their functions effectively.

Another basic reason for failure is the lack of understanding of the basic principles of cooperatives. To lift farmers from hardships, credit, together with other assistance, must be extended and should be tied to a planned program of increased agricultural production. This is necessary because, if the loans are linked with traditional agricultural practices, the credit will have no economic impact. In this connection, cooperative credit must be supervised to ensure that the loans are used wisely and effectively, and result in maximum benefits to the farmer-borrowers. Essential to the success of the supervised credit program of a cooperative are: trained farm management technicians who can assist farm borrowers in preparing farm and home plans; careful selection of borrowers; appropriate loan policies and procedures; continuous research and experimentation; and adequate financing.

Provisions of Agricultural Inputs

With the Green Revolution, "package technology," including technical inputs, has become a critical and a decisive factor. If charges

for fertilizers, insecticides, improved tools, and other agricultural inputs remain prohibitive, the full effects of other policies favourable to increasing farm production and rural progress cannot be achieved. For instance, the IRRI varieties will only yield the maximum quantity if correct dosage of fertilizer, chemical, and water has been applied to the rice fields.

Cooperatives in some countries have been able to overcome these pricing difficulties. Concentration of demand and supply is one inherent advantage of cooperatives over other forms of economic organization. By concentrating the requirements of the members for farm production, cooperatives can avoid some of the costs due to small and irregular purchases by individual farmers. In cooperatives, economy in operation is easily attainable. Furthermore, large discounts for these bulk purchases mean savings to members as a result of low prices. Cooperatives that are primarily interested in the welfare of the members are in a better position than any other organization to secure goods and services with the right quality, weight, and measurement.

In view of the monopolistic situation in many countries, more cooperatives should include in their operations the procurement and distribution of agricultural supplies to complement the credit provided to members. This will ensure the sound use of credit and at the same time secure quality inputs for farmers at the lowest possible costs.

Marketing of Farmer-Members' Products

Small rice farmers do not generally have good control over the marketing of their products. Middlemen have so entrenched themselves in the control of the marketing system that they can, and usually do, dictate their own price and manipulate the market. This control by the middlemen has meant that the farmers get relatively low prices for their produce and the consumers buy at relatively high prices.

Uniform standards of weights and measures for selling farm products are lacking, making it difficult to compare prices in the various markets and actually making the limited amount of available price information practically useless. Farmers usually sell their products individually and without regard to favourable market conditions as to when, where, and at what price they should sell.

As has happened in Japan, South Korea, and Taiwan, cooperatives may improve the discouraging marketing situation in the region by promoting orderly marketing and better merchandising of farm products. Cooperatives may make the supply of farm products for sale at the market equal to the demand of the buyers. When a rice farmer is acting for himself alone, he is often forced to sell most of his paddy at harvest time. This may be due to the perishability of his products, his need for cash, or his lack of storage facilities. Cooperative associations may avoid this problem if they can provide storage and credit facilities to their members.

In the Philippines, the government provided facility loans to paddy farmers' cooperative marketing associations to enable them to build their warehouses and operate their own rice mills. In 1967, of the 2712 warehouses in the country, 318 were owned by the rice farmers' cooperatives with a capacity of 7 290 800 cavans (Weitz Hettelsater Engineers 1968). This is approximately 18% of the total warehousing capacity in the Philippines. Many of these paddy farmer cooperative warehouses also operate rice mills.

Through large-scale procurement and distribution of paddy, marketing costs are reduced. Under a cooperative undertaking, distribution is done in large volumes and the cost of marketing is reduced. Cooperative marketing can also reduce, to one, the number of hands the farm products pass through; therefore, extra costs are eliminated.

In some countries, the pooling of farm products as a distinct cooperative practice is used by some cooperatives. Under the pooling system, the products are grouped into lots on the basis of grade, variety, or class and sold during a given period of time. The returns from the sale of the products are totaled and divided by the number of units sold to get the average sale price per unit. This is the price at which every unit of product in the pool is liquidated. Every farmer receives the same price for each unit of the product included in the pool.

Implementation of Government's Food Production Program

Cooperative associations could work with government agencies in the implementation of subsidy and price support programs to bring about the desired results. In Japan and Sri Lanka, cooperatives are the buying agents of the government in the purchase of rice or paddy. They are also used as the price stabilizing agency of the government. On a commission basis, some cooperatives provide to the government their warehouses, rice mills, and trucking facilities. In Taiwan, the farmers' associations are deputized by the government to collect fertilizer payment and land rent. They also undertake the warehousing and handling of paddy, and rationing of rice to the public, including the dependents of the Army.

Basic Requirements for a Cooperative to Succeed

Efficient Management

The failure of many cooperatives may be attributed to mismanagement. A newly organized cooperative very often cannot pay the salary of a qualified manager, but it is at this stage that the cooperative badly needs a competent manager; otherwise, it cannot expect to go far. Because of their inability to obtain the services of qualified management personnel, many cooperatives have died even before they could commence business operations. New and small cooperatives everywhere have particular difficulty in getting the services of capable managers. As beginning businesses, they cannot offer the salary, or the security, or sometimes even the potential of success that will attract the services of trained people. Salaries paid to managers tend to have a somewhat direct relationship to the size of the business. As it gets larger there are usually more employees to supervise and guide; there is an increase in capital; and there are more resources at stake. A mistake can be costly. As management decisions affect more people and capital, an increase in the compensation of the manager is justified.

Several measures have been used to solve the problem of inefficient management. One measure is to attract membership from the better educated and financially well-off members of the community so that they may lend not only their financial support but also their managerial abilities to the cooperative. But experience shows that combining the small and the large procedures in the same cooperative is not always possible. The government, therefore, more often than not, has to step in and provide opportunities for the training of managers and employees of cooperatives. The Agricultural Credit and Cooperatives Institute has been providing this function of training managers and employees of cooperatives for the last two years. National Cooperative Federations can eventually take over this training function and create a pool of trained managers who can be assigned to manage newly organized cooperatives or serve as trainers for newly recruited management personnel.

In the Philippines the new strategy for cooperative development includes the Management Training Program. This program will: (1) create a management training pool to be composed of top calibre cooperative managers who shall provide on-the-spot training to prospective cooperative managers; (2) develop suitable and practical management training materials and guides for the use of cooperative managers; (3) contract for and defray the cost of professional cooperative managers and/or firms that shall actually manage cooperatives as part of the training program. The Management Training Program shall be administered by an Advisory Board of five members that shall be appointed by the Secretary of the Department of Local Government and Community Development.

Another measure or method that provides a cooperative with the skills of management is a management service contract. Instead of the Board of Directors hiring a single general manager, as is usual, it contracts for the management function. This contract might be made with: (1) another cooperative; (2) a cooperative federation; or (3) a separate group of people who are organized specifically to provide the services of management to a cooperative or to a number of small cooperatives.

Adequate Volume of Business

A farmers' cooperative, like any other business enterprise, must be of a certain minimum size if the unit costs are to be reasonable.[11] In other words, a cooperative is a way of solving the very important problem of economies of scale for small farmers. In general, those cooperatives that are failing have a small volume of business. They do not have adequate income to finance the costs of a prospering agricultural business, and they are too small to hire competent managers and other staff, or to invest in warehouses, processing plants, and other facilities.

Satisfactory Membership Relations

A cooperative has to be operated or managed in the interest of, and in accordance with, the needs and wishes of the members. Unless this is the guiding principle in the operation of cooperatives, member participation, loyalty, and support cannot be sustained. The Board of Directors of a cooperative may serve as the connecting link between the association and the members. Being the policy-making body, the Board of Directors individually and collectively should constantly be in touch with the members to keep them informed of facts concerning their cooperatives as well as to hear their suggestions and complaints. Within the broad policies, the hired management should have wide latitude in planning and executing the day-to-day activities of the cooperative. In this way the policies and operations of the cooperative may continuously be geared to the members' requirements and desires. Prompt payment of dues, continuous patronage, good attendance at meetings, and efficient service to the cooperatives are all indicators of satisfactory membership relations.

Adequate Supervision and Guidance

Although the government regulatory authority may exercise guidance and restraints, it should not interfere with the freedom of the members, the board, or the manager to determine their own problems and work out their own solutions (Report of the Philippine Delegation 1968). The government may also provide an auditing service that will analyze cooperative operations and point out mistakes or weaknesses. Although some kind of direction and guidance by the government is necessary to ensure that cooperatives are properly run, there should be a planned withdrawal of government interference as cooperatives demonstrate their ability to run their affairs. The provision of management counseling is essential for the sound development of cooperatives. However, this can best be done by nongovernmental cooperative institutions as, for example, the Central Cooperative Union in Japan and the National Agricultural Cooperative Federation of Korea.

Adequate Capital Contribution from Members

The need for member equity capital in cooperatives cannot be overemphasized. Although governments in the region recognize the need for providing sources of liberal financing for cooperatives, there can be no substitute for the members' contributed capital. The best indication of a member's faith and interest in an association is his readiness to put capital into the association. Members' capital is also the cheapest capital that can be used by a cooperative. Members' participation, loyalty, and attachment to a cooperative may be heightened through a systematic plan of capital formation from members' contributions.

Whatever the capital structure of a cooperative may be, the capital burden should be apportioned among the members in some way proportionate to the use that each one makes of the cooperative. Those who derive more benefit from, and do more business with, the association should be required to carry a correspondingly larger share of the financial load than those who make less use of the association. One way of doing this is to assess each member for a capital subscription in relation to farm area cultivated or per unit of pro-

[11]Owens E. L. and Antholt. Coops Can Help – If Government Is Willing. Small Farmer Credit Analytical Paper. 5 p.

duce delivered regularly to the cooperative. Another way is deduction of a preagreed percentage of sales or proceeds of crops sold to or through the cooperative. In the new strategy for cooperative development in the Philippines, forced savings of 5% of production loans for the purchase of shares of stocks of rural banks and 1 cavan of paddy per hectare per harvest to be contributed to the Barrio Guaranty Fund are the methods being adopted.

Continuous Cooperative Education and Training

Management training and member education play a vital role in the overall growth of the cooperative movement. Underscoring the importance of cooperative education, a noted Swedish cooperator once said, "If we had occasion to start our movement afresh and if we were given the choice betwen two possibilities, that of starting without capital but with enlightened membership and staff or, on the contrary, that of starting with a large capital and ill-informed members, our experience would incline us to choose the first course" (Quintane 1969).

"The success or failure of a cooperative institution is greatly dependent upon the employment of highly capable management officers. Of equal importance is the need for providing proper education and training for the members of the board of directors as well as the general public. It is simply not enough for the members to know what they can do for the cooperative to insure its success. Education is the process of moving from a stage of cocksure ignorance to one of thoughtful uncertainty" says Mr. E. Patterson (1968), Assistant Director for Agricultural Development, USOM, Thailand.

In the Philippines, the training of management employees and the board of directors has been the main responsibility of the Agricultural Credit and Cooperative Institute. Religious organizations, private agencies, and cooperative federations have been providing limited training programs to management employees; however, they have more member education activities. There are about 30 such organizations doing membership education in varying degrees.

The national cooperative movements in advanced countries, such as Sweden, Denmark, Japan, Canada, and West Germany, have done a considerable amount of work in the field of member education that can provide us with experiences worth studying (Vir 1969).

In Sweden, the cooperative movement conducts large-scale education programs for its members mainly through study circles and correspondence courses. Member education classes are usually organized at the primary society level. Correspondence courses work very well in Sweden because of the high literacy among the rural people. Funding of the courses is the primary responsibility of the cooperative movement.

In Denmark, the high schools are the hub of general adult education activities including member education. As residential schools, they emphasize the importance of social attitudes and leadership qualities among the participants who learn and live together.

In Japan, cooperative member education is an important part of the extension classes organized by multi-purpose cooperatives for their members. The national organizations and the prefectural federations assist the primary societies in conducting member education programs. The government extension agencies assist Japanese farmers through their cooperative associations. Agricultural cooperatives, which are highly integrated and diversified, have been successful primarily because of the well-developed education programs prepared and implemented by voluntary as well as government sectors.

The Canadian experience in cooperative education through universities and colleges is relevant. Member education forms part of the adult education or extension programs conducted primarily for fishermen by Saint Francis Xavier University. This approach could be adopted in the Philippines if university and college authorities could be convinced to include member education in their general extension programs.

In India, a sophisticated program of cooperative member education is carried out through the National Cooperative Union, the

State Cooperative Unions, the District Cooperative Union, and ad hoc committees. The scheme, with about 750 cooperative education instructors, is primarily designed for agricultural cooperatives. These instructors are responsible for conducting training courses for secretaries, committee members, and ordinary members of cooperatives. The study circles are usually organized by the cooperative instructors. The member education scheme in Sri Lanka is substantially similar to that in India.

Conclusion

Never in the history of the region have cooperatives promised so much to promote social justice and economic independence among the impoverished masses of the people. However, the momentum of development varies in different countries. Some countries like Japan, South Korea, Taiwan, and Egypt have already succeeded in developing potent and viable cooperative organizations; some countries have just recently identified the ingredients of successful cooperative business enterprise; others have but feeble beginnings. But in all instances and in all countries in the region, there is definitely a recognition of the possibilities of cooperative strength, without which the countries will always remain backward and unable to enjoy their fair share of the dignified and decent life to which every human being aspires.

Cooperatives, if given favourable conditions for development, can truly be an effective instrument for economic and social development. They can alleviate the condition of the less fortunate segments of our society that are in need of social and economic amelioration, and should have the right to enjoy the privilege of self-development, social growth, and economic independence under a truly just and democratic society. — VICENTE U. QUINTANA. *Agricultural Credit and Cooperative Institute, University of the Philippines at Los Baños, College, Laguna, Philippines.*

India's Experience

This section discusses the developments in the rice processing industry in India during the past 9 years, and is restricted mainly to the technical aspects of harvesting, threshing, drying, storage, parboiling, and milling. It presents a picture of the traditional practices, the stages through which India moved to begin modernization programs, some of the things that were learned, the present situation, and the starting organizations.

Traditional Practices

Before discussing the modernization program in India, I will briefly discuss the traditional methods. This will give a clear indication of why we started modernization programs in India.

Harvesting and Threshing

Throughout India most paddy is harvested and threshed by hand. The paddy stalk is cut from the stubble and moved to the threshing floor. Paddy is then threshed by hand beating, trampling by bullocks, and some cases "trampling by tractor." In some areas different types of mechanical threshers have been used on a very limited scale. Needless to say these threshing practices incurred large losses in terms of field losses, handling losses, and threshing losses.

Drying

Until very recently most paddy harvested in India was sun dried. This was accomplished mainly by leaving the paddy standing in the field until it was dried to approximately 14%

moisture. In some cases this was not possible and the paddy was harvested earlier, at a higher moisture level, and spread on sun drying yards and roads to permit drying to a sufficient level. Paddy that was parboiled was also sun dried on drying floors after parboiling.

Storage

Many farmers retained a large portion of the harvested paddy, which was usually stored in mud constructions in the village. Paddy that moved to market was procured and stored in "godowns" or warehouses. These warehouses ranged in capacity from a very few tonnes to several thousand tonnes. Very limited attention had been given to storage facilities and storage practices, and because of this, large losses were incurred during storage mainly due to rodents, birds, insects, and fungus growth. Very few stores had wooden dunnage, hardly any stores had fumigating facilities, and most stores were open to rodents and birds.

Parboiling

Practically one-third of India's paddy is parboiled. In small local rice mills the paddy is soaked in concrete soaking tanks and then steamed for a short time in metal steaming kettles. In some cases both the soaking and the steaming operations were done in used oil barrels. Very little attention was given to the quality of the rice, the parboiling was not uniform, and there were a number of admixtures.

Milling

India was blessed with about 50 000 registered huller rice mills and some 2000 disk-sheller rice mills. Very few mills had paddy cleaners, and hardly any mills had rice graders. Mills varied in size from a few hundred kilograms per hour to several tonnes per hour. Until this time there had been no effort to look at or solve the problems related to this industry.

Pilot Project Development

Study and Recommendations

During 1963 a study team consisting of representatives of the Government of India assisted by Ford consultants conducted a comprehensive study of the milling industry in India. In September 1963 they submitted the findings of their study and their recommendations: (1) the paddy received from the farmers is low in milling quality, and improved production practices and varieties would provide better paddy for milling; (2) traditional storage in India does not provide adequate protection, and an estimated 5% of the paddy can be saved by improved storage techniques and facilities; (3) milling machinery manufactured in India was designed 30–50 years ago. Most of this machinery consists of hullers that give a rice outturn of 64%, the rest are sheller-type mills that give an outturn of 68%. Many improvements have been made throughout the world and modern milling machinery is expected to produce a rice outturn of 71–72%; (4) the design of, and suggestions for, modern storage and rice milling facilities for several installations in India were included; (5) for each of the modern storage and milling facilities, the expected increase in outturn of rice would save 1600 t of rice per year. This traditional outturn would have an estimated value of 1 100 000 rupees; (6) the proposed modern storage and rice milling facilities would operate at a lower cost than mills currently in use; (7) India needs 1000 modern rice mill installations, which could make a major contribution to food supply and reduce the cost of storage and milling; and (8) additional research and evaluation, and a training program for rice mill operators on improved storage and milling techniques were proposed.

Project Planning

Following the above report, the Ministry of Food and Agriculture made the decision to begin a pilot project in modern paddy storage and processing. Their plans called for establishing seven pilot plants. Each one was to include mechanical handling equipment, silos for storage, mechanical driers, modern parboiling equipment, and modern rice milling machinery. With the exception of the seven imported rice mills, all the equipment was to be manufactured in India, and all silos were to

be of reinforced concrete and constructed in India.

Project Implementation

Construction began at the sites in 1965 and companies began to manufacture equipment. This equipment had not been built in India previously. All the industries faced many new problems, simple and complex: How fast do you operate the belt conveyor? What are the design pressures? What air velocities and air temperature? It may be worthwhile pointing out that by early 1966 progress had slowed to a standstill, mainly due to insufficient plans, detail, and coordination and it was necessary to go "back to the drawing board." Detailed plans and equipment specifications for driers, cleaners, parboiling equipment, and conveying equipment were brought from abroad and given to the manufacturing firms. With replanning, project coordination, and a full-time consultant, the project began to move forward. By the latter part of 1966, some of the mills, driers, and parboiling plants were in operation. Still later the silos were commissioned and were ready for operation.

Since this was the first time for manufacturing firms to build driers and cleaners, much time was spent in the factories on designs and construction. As the modern facilities were completed, operational problems arose.

Commissioning and Tryouts

Mill, drier, parboiling, and storage operators had to be trained on the job. For example, manufacturing firms had built a drier, according to plans, but had no idea of how it was operated. Foreign rice mill suppliers sent their technicians to supervise installation of their machinery and conduct on-the-job training in its operation. During the tryout period many practical problems arose, for example the drier feed-rolls did not function properly. After rebuilding these on site, the driers were put into operation. Many similar small problems had to be worked out with the cleaning and conveying equipment. During 1966–1968 most of the problems related to the new industry were worked out, and the seven pilot plants were put into operation.

Supporting Industry

The success of the pilot project should be credited to many government and private industry personnel. Without their patience and initiative, the project may not have been completed. Consulting civil engineers assisted with the silo designs and the buildings and machinery foundations. The manufacturing industry did a magnificent job in turning out the new equipment. Contractors, working with all those concerned, coordinated the efforts and completed all construction without undue delays. As a result of this, India now has three major firms manufacturing modern rice mill machinery, in collaboration with foreign firms; several manufacturers with standard lines of mechanical driers, parboiling equipment, and conveying equipment; and a number of smaller manufacturing firms that offer various components for the rice processing industry, such as blowers, burners, gear drives, belting and even cleaners, rubber roller huskers, and paddy separators.

Some Things We Learned

Drying

Since the seven pilot projects were each considered a commercial rice mill (1, 2, and 4 t/h capacity) with supporting facilities, the LSU continuous flow drier was used in conjunction with tempering bins, storage bins, and the necessary conveying equipment.

The drier is much more efficient when paddy is precleaned. It averages 2% moisture reduction per 30-min pass (to dry paddy from 20 to 14%, three passes are required). Paddy is tempered between passes from 8 to sometimes 20 h. For drying field paddy, air temperatures ranging from 60 to 82 °C (140 to 180 °F) have been successfully used. Higher air temperatures dry paddy a little faster, but cause more paddy breakage during milling.

Parboiled paddy is recirculated in the drier, without tempering, at regular intervals. An air

temperature of 93 °C (200 °F) is used in the first part, and 82 °C (180 °F) for the remaining drying time. These higher air temperatures for parboiled paddy have not affected head yields. Furnace oil is being used, instead of kerosene, since it is cheaper. The drier is used as a direct fired unit, without heat exchangers. A steam heat exchanger has been used in a number of cases as the source of heat, and works most satisfactorily. Husk from the rice mill is burned in a husk-fired boiler, producing steam for the heat exchangers. This system has the lowest operating cost, even though its initial cost is higher.

Including depreciation, interest, maintenance, fuel, labour, and overhead cost, Mr. Bal from Kharagpur reports that the drying cost of parboiled paddy is 18.5 rupees/t of paddy, as compared to the sun drying cost of 12.5 rupees/t. It is assumed that if losses resulting from sun drying are considered, mechanical drying would be less expensive. Rao, from Kharagpur, reports that the drying cost of field paddy varies from 6 to 10.33 rupees/t.

Storage

The pilot project included reinforced concrete silos of different capacities, which had hopper bottoms for gravity flow unloading. Later a number of flat bottom silos were constructed, using labour and sweep augers for unloading. With the experience and particularly the economics of both types, it is recommended that large capacity silos for general storage, which are unloaded only a few times per year, be constructed as flat bottom silos. Silos used as receiving bins, working bins, or tempering bins should have a hopper bottom for easy unloading, with a minimum of conveying equipment and labour.

In several cases prefabricated metal silos were considered and even though their grain-keeping quality was good, they were more expensive than the reinforced concrete silos.

The first silo installations cost 380 rupees ($50.67) per tonne of storage capacity (260 rupees for civil works plus 120 rupees for the mechanical works). Today, new silo installations cost 210 rupees ($28) per tonne of capacity (150 rupees for civil works and 60 rupees for the mechanical works).

Godown construction costs vary considerably from one part of India to another. Costs range from 150 to 225 rupees ($20 to 30) per tonne of storage capacity. In most cases construction cost is generally higher in the case of godowns. This is mainly due to the cost of gunny bags and the labour required to move the gunnies (see Table 49).

TABLE 49. Costs for grain storage in India (in rupees).

	Silos	Godowns[a]
(1) Investment cost for 4000 t	880 000	680 000
(2) Operation costs		
(a) Staff salaries	7 200	7 200
(b) Labour costs	—	8 000
(c) Electricity	2 400	1 200
(d) Maintenance	8 800	13 600
(e) Depreciation	17 600	20 400
(f) Interest on investment	66 000	51 000
(g) Gunny bags	—	22 890
Total	102 000	124 290
(3) Storage cost/tonne/month	2.12 ($0.29	2.59 ($0.35)

[a]Note the high cost of maintenance and depreciation for locally built godowns.

Parboiling

The Central Food Technological Research Institute developed a parboiling process that has two simple steps: (1) soaking in hot water for 2–3 h; and (2) steaming for 15–30 min. A simple steel tank is constructed for soaking the paddy and hot water is recirculated during the soaking period.

Water temperature is kept at 60–70 °C. After soaking, the water is drained, and the paddy is steamed in the same tank. After steaming the paddy is unloaded, through the bottom of the tank, and moved on to either sun or mechanical drying. Husk-fired boilers supply the hot water and steam for the process, making the operation very economical. The size of the parboiling plants can vary, but they

usually are 24, 48, or 96 t/day to match the capacity of a 1, 2, or 4 t/h rice mill.

Milling

An analysis of milling studies is presented in "Comparative Performance" on pages 273–277.

Harvesting

Throughout India most of the paddy is harvested and threshed by hand. The paddy stalk is cut from the stubble and then moved to the threshing floor. The grain is then separated from the straw by hand beating or trampling by bullocks. Only in a few areas are simple mechanical threshers being used. Paddy moisture content at harvest varies with different practices. In most areas of India paddy is left standing in the field until it sun dries; in other areas, it is harvested at 20–25% moisture and stacked until dry before it is threshed; whereas, in other areas the paddy is harvested and threshed at a relatively high moisture content. Both the harvesting and threshing methods affect the quality and yield of paddy. Each variety of paddy has its individual properties known as "varietal characteristics," which means that varieties may differ from each other with respect to their requirements for harvesting, threshing, drying, and milling.

Several authors have reported results of harvesting and drying studies. The Rice Process Engineering Center at Kharagpur, India, reports that the optimum harvest moisture content of IR8 was found to be between 21 and 24%. The average field yield at this moisture level was 6740 kg/ha but it was reduced to 5550 kg/ha when the crop was harvested at 15% moisture level. During the sun drying process, the overmature paddy begins to shatter and fall and is lost in the muddy soil; some of the paddy is consumed by birds and rodents; and some is lost in cutting and transporting. These losses account for the 21.6% reduction in field yield during the field drying, harvesting, and threshing processes.

From this and other reports it may be summarized that paddy harvested at the optimum moisture level, following maturity, produces more yield per hectare than paddy allowed to remain in the field to sun dry. This provides a larger income to the paddy grower. Experience has also shown that paddy can be harvested and threshed by hand, at relatively high moisture levels, overcoming the traditional practices.

Expansion After the Pilot Project

Probably the most effective method of evaluating a pilot project is to observe the effects it has had on the industry. As the seven pilot rice mills went into production the industry immediately began to see the benefit of modern milling. Manufacturing firms then collaborated with foreign firms and began to manufacture modern rice milling machinery in India. From the seven pilot units, the first expansion was by the Food Corporation of India, which installed 24 modern rice mills. Today, approximately 4 years after the pilot plants were started, cooperative and private rice millers have built approximately 200 complete new modern rice mills and conducted several hundred modernization programs. A modernization program adds rubber roller shellers, paddy separators, and sometimes paddy cleaners and rice polishers to a miller's equipment. In many cases millers have also added modern parboiling tanks or mechanical driers.

Today there are also a number of smaller manufacturers that produce only rubber roll shellers, paddy cleaners, or other component machines for the industry.

Organization in India

A number of different organizations in India are supporting this modernization program in various ways. The Food Corporation of India has helped lead the way, both in milling and storage, and has also helped in quality control and in rice standards and grades. The Central Building Research Institute has studied problems of storage and designed a number of small, scientific, village storage facilities. They have also worked on the design and construction of larger silos, which has helped reduce

costs. FAO has a drying and storage project with the Storage Institute at Haipur. Here they are studying farm and village drying and storage problems. They also are assisting with extension education programs. The Ford Foundation has assisted the Government of India in establishing a Rice Process Engineering Center at Kharagpur. This is the first such institute in the world. Here they are engaged in research and development, teaching and training programs, and extension work in all aspects of paddy and rice storage and processing. The Central Food Technological Research Institute at Mysore has done work in parboiling, food technology, drying, and insect control.

These and other groups are assisting India in studying the problems, designing new equipment, implementing new programs, and generally expanding the concept of modern scientific storage and processing. — JAMES WIMBERLY. *IRRI – Ford Foundation Sri Lanka, Rice Processing Project, Colombo, Sri Lanka.*

Case Studies

Borromeo Integrated Rice Case

The following two presentations are case studies on a proposal by Mr. Carlos Borromeo to establish an integrated rice operation. Although these discussions are not illustrative of either correct or incorrect presentation of a case analysis, they provide an insight into the reasoning that should be used in an analysis and provide a basis for discussion.

Mr. Borromeo purchased a modern drying and storage central with a mill and proposed to undertake the drying and storage needs of the area. Because he did not own any rice paddies he based his supply upon purchasing paddy from local farmers. He wanted to purchase, dry, and store the paddy when it was at a low price and market a high quality rice at a premium price.

These case studies were able to forecast some of the troubles he would encounter.

Study 1

That the rice industry in the Philippines is extremely chaotic and in desperate need of rationalization is an observation that cannot be denied. The gross inefficiency of the whole system has adversely affected the well-being of both the producer and the consumer. Mr. Carlos Borromeo, a businessman, feels that this condition of the industry, coupled with dramatic technological breakthroughs, provides an excellent business opportunity. He envisions the development of an integrated rice operation that will overcome the credit, grading, storing, and retail problems of the rice industry.

Supply

Most of the rice produced in the country has substandard quality, and only a negligible portion would qualify for the world market. Because it is Mr. Borromeo's plan to deal with high quality rice, supply presents a formidable problem. It would be very difficult to get the farmers to produce quality rice even with the guaranteed price Mr. Borromeo is planning to offer. Besides planting, quality requires more fertilizer, knowledge of the modern methods of farming, better irrigation systems, and quality seeds, all of which result in higher expenses for the farmers. It would be difficult for the farmers to invest more, even with the prospects of increased earnings. To most of us the farmers' behaviour may be irrational, but for the farmers it is wise, and for some the only decision, because they have limited capital. Even if enough farmers agreed to produce quality rice, they might expect technological and financial assistance from Mr. Borromeo, which would increase the operating costs of the company.

Another problem would be the financial and personal commitments of the farmers. Many of them, because of hard-up conditions, borrow money from traders using their crops as

collateral; therefore, even before planting they have already sold their harvest. This relationship has existed for years, and is based not only on financial but on personal considerations. The traders are so entrenched in their position that it would be very difficult for Mr. Borromeo to dislodge them, especially if we consider that the projected requirement is 54 000 cavans of paddy. It is true that farmers can borrow from government institutions and rural banks, but experience has shown that it is much easier to borrow from traders.

Mr. Borromeo did not consider the risk from natural calamities. This is one reason why farmers would be reluctant to invest more. One strong typhoon and their investments would go down the drain, and Mr. Borromeo's supply would be gone. It would take time before a new crop was harvested, and meanwhile, his operating costs would be running continuously. It might be difficult for his company to look for quality rice in other areas, and transportation costs might be prohibitive. Furthermore, there is no assurance of the needed volume.

There are some factors in his favour, however. There are revolutionary developments in the rice industry that will result in higher and better production and credit is available from the Development Bank of the Philippines (DBP), Central Bank, rural banks, and other government institutions. Specifically, he may avail himself of the DBP's rice processing and storage program, the 100 000 peso CB–DBP Cereal Procurement Programme. It is doubtful, however, that these factors would be able to fully overcome the problems discussed. At best, he can meet his supply requirements after a few years, but not in his first year of operation.

Rice Processing

The government policy of encouraging the private sector in this area will help Mr. Borromeo; therefore, financing the equipment will not be much of a problem. We can assume that he will avail himself of modern facilities, e.g. warm air driers, bulk storage, and rubber roller mills; however, this area is not without problems. There is a scarcity of competent personnel who can run these facilities. Furthermore, only a few warehousemen invest in mechanical warm air driers because of their low returns. It does not necessarily mean that the company will have low returns on this, but this factor is worth considering. Problems in rice processing go hand in hand with supply. If there is insufficient supply, facilities will be underutilized, but the fixed costs will run at the normal level.

Finance

The financial projections of Mr. Borromeo are premised on highly questionable assumptions. (1) Adequate supply as early as the initial year of operations. As discussed earlier, this assumption is highly improbable. The breakeven point for the company is 40% assuming that his costs breakdown is correct. Mr. Borromeo should prepare to suffer initial losses, and his investment should give allowance for this. (2) All rice produced will be sold. Mr. Borromeo plans to sell quality rice in packages at a premium. Although this may sound like a novel approach to rice marketing, the probability of customers' rejection of the scheme is relatively high. Studies on consumer preference for packaged rice should have been conducted beforehand.

Furthermore, some costs were not considered. (1) Transportation expenses. Because he will sell his rice through retail outlets, Mr. Borromeo will have to deliver his rice to them. Transporting rice to retail outlets is expensive. It may even require acquisition of trucks. A modest provision for transportation expenses will raise his company's breakeven point to about 60–70% using 1825 t as the basis. (2) Working capital. Considering the volume of business, working capital is insufficient. For one thing, inventory alone requires a lot of money. To be able to supply on a continuous basis, Mr. Borromeo's company will have to store rice, particularly during the rainy season. He cannot expect the retailers to store rice for him. Considering that he is dealing with quality rice, the retail outlets he would be working with will be serving the middle and upper segments of society. These institutions normally expect some amount of credit to be

granted to them. Again accounts receivable would eat up a good portion of his working capital.

His financial projections undoubtedly have to be revised. Expenses are understated and sales projections are too optimistic. Furthermore, the income projections should be scaled to take into consideration the difficulties he will encounter in the initial years of operations.

Marketing

Mr Borromeo proposes to sell rice at 38.35 pesos a cavan[12] of rice to the retailers. Assuming a conservative retailer's margin of 10%, the cost to the consumer would be 42.20 pesos. The average retail value is approximately 30 pesos (figure used in the case); therefore, the premium is very high.

Mr. Borromeo's approach to marketing is novel. The rice would be packaged and sold through selected retail outlets although consumers are used to buying unpackaged rice. However, sugar packaged and sold at a premium gained acceptance. It may be argued that if it worked for sugar there is no reason why it will not work for rice. The difference lies in the amount of premium. In the case of sugar, the premium is very small, but from our computations, the premium for Mr. Borromeo's rice is very much higher. Besides, rice is our staple food; sugar is not. Even if it does gain acceptance, it may take some time. In revising the projections, this should be considered.

The government plays a very important role in the marketing of rice especially with its price control regulations. The price of rice is used conveniently by the people to gauge cost of living fluctuations. The government, knowing this, is doing its best to lower the price of rice as much as possible. If the government imposes a ceiling on the price of rice of all kinds, the profit picture of the company will be adversely affected. Mr. Borromeo can only hope that the government adopts the socialistic dual pricing system. It should be realized that the government does, and will always, meddle with the law of supply and demand as far as rice is concerned.

Recommendations

We do not know the primary motivation of Mr. Borromeo in pioneering a new approach to the rice industry. It is clear that the problems he is facing are far more complicated than he has imagined. His financial projections are oversimplified. The success of his approach depends so much upon factors beyond his control. It is doubtful whether he can really cash in on the technological breakthroughs in the industry. For instance, the buildup given to the miracle rice or the IR8 variety as the solution to the problems, not only of the Philippines but of the world, proved to be nothing short of dramatic nonsense.[13] Then there is the government. It is a plus factor as far as supply is concerned, but a negative factor in marketing. As a businessman whose primary purpose is to make money, he should abandon his project. This is not to say that his project is not viable per se. It may succeed in the future when some of the constraints discussed above are eliminated.

If, however, Mr. Borromeo's primary purpose is to have the self-actualizing act of pioneering a seemingly novel approach, then he should go on. I recommend the following changes in his strategy: (1) the capital should be at least doubled to prepare for probable initial losses and to provide more flexibility in the operations; (2) all possible government aid should be availed of particularly in the field of financing, to minimize his financial exposure in the company; and (3) integration should be done stage by stage. The marketing of packaged quality rice at a premium should be tried. If it gains consumer acceptance, then he can start his backward integration.

It should be emphasized that even with the above changes in strategy the risks are still

[12]Computed as follows: 1 400 000 pesos ÷ 1825 × 50 cavants/t = 38.35 pesos per cavan of rice.

[13]Credit should be given, of course, to the International Rice Research Institute for this significant contribution. The disappointments of many should be blamed on the media for their gross exaggerations.

high and returns uncertain. — MANUEL B. VILLAR, JR. *University of the Philippines at Los Baños, College, Laguna, Philippines.*

Study 2

Assuming that Mr. Borromeo can come up with a system for his processing operations that would be technologically feasible, it appears that the bottleneck or critical point in the system would be the inputs.

Borromeo, in this case, is assuming the role of a change agent/initiator in an environment traditionally oriented in values, thoughts, and means. He wants to trade an economic idea, with its corresponding financial commitments, which must be accepted by the farmer, for the inputs for his operation. This is precisely where his problems and difficulties lie, he must assemble adequate inputs for his project to be economically viable.

Attitude of the Farmers

Farmers do not readily adopt and accept modern farm technology and new improved rice varieties because they have not had previous experience with them and "fear the unknown." This is understandable because they would naturally not want to risk their borrowed financial investments on something that is not guaranteed or proven. So, to their mind, they may as well stick to age-old techniques and methods with traditional varieties that produce proven measurable outputs and consumer acceptability. Furthermore, from the point of view of money, these changes and shifts would mean additional financial outlays, which the farmers are relatively short of. Again, we cannot expect the farmers to venture into these prospects which require more out of pocket investments, without some proven results.

Granting, however, that a considerable number of farmers are eventually convinced to change and shift to new varieties of quality grains, the absence of developed quality standards, price premiums, and assurances would only lead to further chaos in the industry and disillusionment on the part of the farmers, even if they eventually turn out high quality grains, because there are no bench marks or measures as a basis for equitable guaranteed reward. I believe that if this setback occurred, it would be very difficult to rectify since anomalies and frauds would become entrenched and the rice farmers would become unresponsive and disillusioned.

Experience

Already the farmers have had sad experiences in the past with the FACOMA's. For one thing, because of mismanagement and corruption within these entities and other related agencies, many of the farmers were cheated or simply robbed of their produce. This has left deep scars and with time these sad experiences have generalized into contempt and lack of trust for any agency that assumes functions and services similar to those the FACOMA's offered before.

This feeling is also aggravated by the fact that the farmers do not fully understand the biological nature of their produce. As we experienced, they would have their paddy stored fresh after harvesting. Naturally, the paddy would still have a high moisture content. When they claimed their paddy, it would have had time to lose some of its moisture content and its weight would be less than when brought in, and they blamed the FACOMA for stealing their produce. Another thing the farmer cannot accept is the fact that when he brings his produce to institutional processing operations, the grains are inevitably mixed and the farmer loses all means of identifying his own particular produce. This apprehension stems from the belief that his own particular grains are always better than those of the other farmers. When the time comes to draw out his grains, he is wary about not getting grains of equivalent quality. These factors intermesh with the problem of setting up or developing quality standards for the grains.

Financial and Personal Commitments

This appears to be the most critical aspect because, through time, the business relation-

ship between the farmer and his creditor has developed into a friendly and well established personal bond. The Filipino "utang-na-loob" comes into consideration here because when Borromeo asks a farmer to bring his produce to him, the farmer will think: "It was Pare Andong who provided for me during the planting season. He took care of the needs of my family and even the hospitalization of the Boy. I owe it to him, my crop and my gratitude. So why should I sell to Borromeo? What has he done for me – I don't even know him."

If only 50% of the farmers targeted by Borromeo to supply his inputs think like the farmer cited, all of Borromeo's projections for economical utilization of his system would be thrown off and he would be left with a very big plant lying idle. Therefore, if Borromeo hopes to compete in this aspect of ensuring assembly of inputs for his operations, he must not only assume the role of creditor and middleman, but he must also develop ties and bonds with the people in the community. He must blend into the social structure or organization of the environment he has targeted to tap.

Trading Practices

The farmers who are inevitably caught in a financial stranglehold by their creditors have no recourse but to sell their crops upon harvest directly to their creditors or dealers, usually on terms dictated to them to pay off their debts and commitments.

The dealers in turn concentrate mainly on the trading aspect of the business and are very reluctant to invest and participate in bulk storage. This is due to the fact that the government is in the industry and is controlling prices. The dealers are afraid to get caught with big bulks of rice at a government price ceiling lower than their acquisition cost. Because trading in the industry is brisk, active and fast dealers find it easier to realize larger profits by concentrating only on the trading function rather than tying up capital in inventory and storage facilities and assuming more risks.

We have been traditionally a rice importing country. Our production has always been well below our consumption requirements. From the farmers, the assembly points, and the rice mill, therefore, the rice is directly marketed to the consumers to satisfy their immediate demand. Since theoretically there is no buildup of inventory or surpluses the need for facilities for long-term bulk storage has never been acutely felt. In fact, what we really often have are empty or under-utilized storage facilities.

Conclusion

I believe, that at this time, it was premature for Borromeo to set up his pilot project, which was beyond his capacity and capability.

With the monumental problems in the rice industry, which were recognized by Borromeo, it was foolhardy for him to have initiated the project without definite and adequate pledges from our decision makers and without having coordinating government agencies monitor his pilot project to give assistance and support and to institutionalize the project.

Recommendations

There are three oganizational levels working in the agribusiness system. In this context the following framework is recommended for formulating a working strategy and a method of implementation for Borromeo. It takes into account the involvement of both our decision-makers and government integrating and coordinating agencies.

Decision-Makers

(1) Determine and outline policy goals and objectives: (a) to provide government subsidy in the form of price assurances for grain crops, availability of cheap inputs like fertilizers, certified seeds, and insecticides; (b) to make available needed financing for production to farmers on low interest and easy payment terms; (c) to encourage formation of cooperatives to help farmers secure credit facilities, acquire equipment, and improve product marketing; (d) to implement infrastructure projects by the government, like irrigation systems and roads, to stimulate further growth in pro-

duction; and (e) to pursue the initial gains of increases in price production output brought about by land reform.

Integrators-Coordinators (DANR–NGA)

(1) Design a system for information gathering and feedback. (2) Allocate tasks to government implementing agencies for their respective participation: (a) NGA — determine pricing system to include assurances and support; promulgate policies on all activities related to processing, storage, transport, and marketing of grains; develop quality standards; determine priorities in setting up integrated facilities by physical location considering economical utilization of grain processing capacities and ensuring adequacy of supply at both ends of the system; encourage organized interrelationship among producers, warehouse millers, financiers, and farmer organizations; coordinate with other government agencies the program of extension service and infrastructural facilities; and encourage the adoption of proven systems in production processing and marketing phases to reduce costs and improve quality of grains; (b) Central Bank — formulate the credit policy and make available the needed financing for production, storage, processing, and marketing aspects; and (c) Bureau of Public Information — program public announcements to provide general information to the public at large about the rice industry; provide specific information about developments in the rice industry for people in the rice business; and educate the farmers and people concerned in the different functions of the industry. (3) Continually seek improvements and stimulate development of the rice industry.

Initiator

As the initiator in this case, Borromeo has the burden and responsibility of studying and analyzing the environmental factors that will affect the functional consideration of the integrated rice system he envisions.

From this system he should evolve his strategy that would be manifested in his ideas on how to compete, recognize opportunities, and allocate his resources. — JOSE C. LAPUS. *University of the Philippines at Los Baños, College, Laguna, Philippines.*

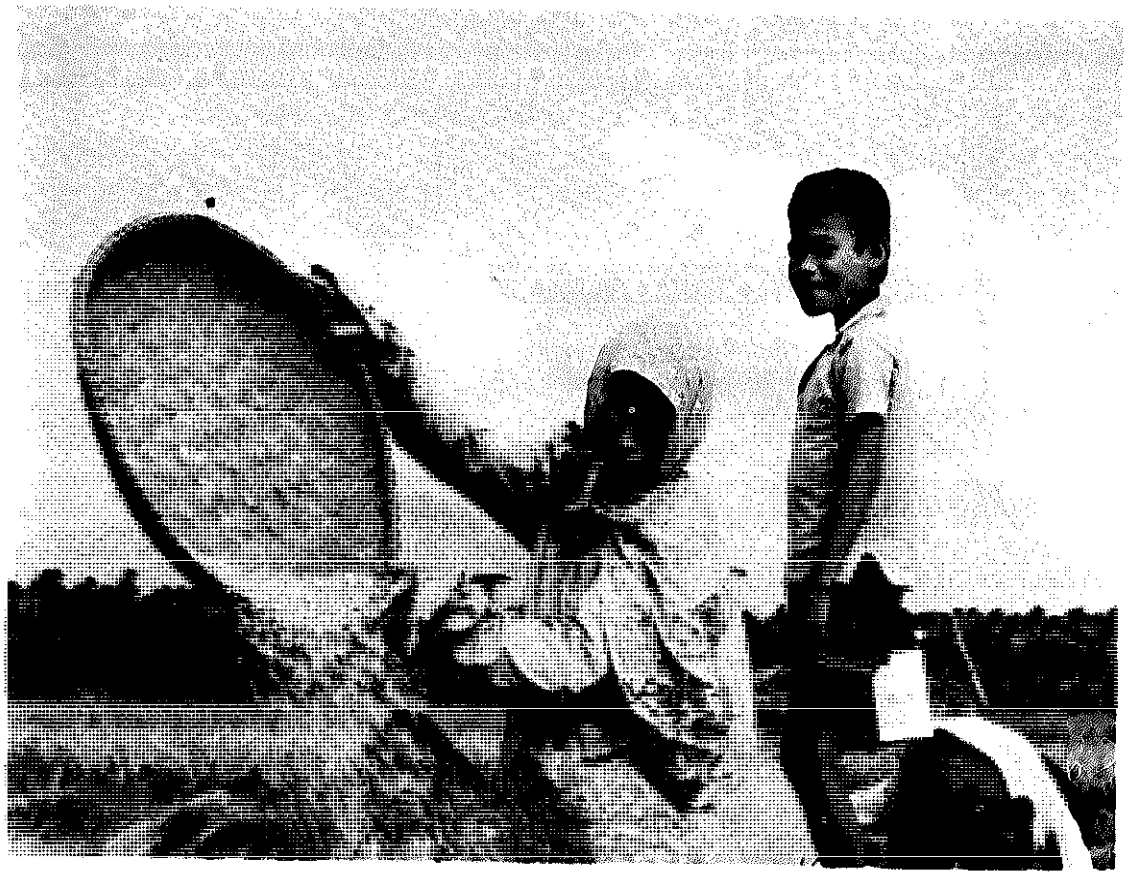

PROCESSING METHODS

India

India is one of the major rice growing areas in the world, and rice is consumed by more than half of its population. The increase in rough rice production in the last few years is due mainly to the Green Revolution, the introduction of high-yielding varieties, along with increased manuring, improved irrigation systems, pesticides, and the help of international organizations.

Although our country has many different languages and regions and the people have entirely different living systems and food practices, paddy is still cultivated, in all regions, as it was in the past. However, postharvest operations vary widely from region to region. The people initially obtained rice by hand pounding, which is very laborious, so they switched over to processing operations in Chakkies; however, when hullers were introduced, these two processing systems became totally outdated. There are indications, however, that in some of the hilly areas in India, these systems are still in practice, although the quantity processed is negligible when compared with the total production.

It is not known how and when parboiling started in India. Undoubtedly, the parboiling of paddy was found healthy, apart from economic advantages like higher yield from soft varieties. When there was an acute shortage of food grains in India during the sixties, a delegation from the Ford Foundation studied the problems in the country and indicated that if existing outdated processing units like hullers were replaced by suitable modern equipment, a few hundred thousand tonnes of extra rice could be obtained and fed to the hungry population. Hence, seven imported modern rice milling units were installed in different regions in the country.

Of the roughly 67 000 processing machines in India about 60 000 are hullers. However, it has been found that modern rice mills are capable of yielding more marketable rice than hullers and under-runner disc shellers. The extra yield obtained by processing raw paddy by modern mills instead of hullers and shellers is 6.6 and 2.5%, respectively. For parboiled paddy the increase over hullers is 1.6%; over shellers it is 0.8%.

Parboiling is a method of processing that combines soaking with heating by external sources. It helps to strengthen the kernel (gelatinization of starch) and enables even weak soft grains to withstand milling without breakage. In fact, sun-cracked grains bind themselves remarkably well and mill like hard whole grains after they are parboiled. Compared with raw rice, parboiled rice is richer in vitamin B and has much less cooking loss if the gruel is drained.

Cold Soaking Method

In this method, the paddy is allowed to steep in cold water for 2–3 days. At the end of this period, the soaked paddy is open steamed, dried, and milled. To reduce the length of the soaking time the raw paddy can be steamed prior to steeping in cold water. Both of these methods are now being adopted all over the country because of their obvious advantages of low cost and convenience in operation.

Hot Soaking Method

During the fifties, the Central Food Technological Research Institute (CFTRI) developed a method of hot soaking the paddy at 65–70 °C followed by open steaming. This method is, however, finding only limited application in the country partly because of the high cost of steam required for heating the water and, to a great extent, because of the difficulty of handling this paddy with the human labour that is used in most of the mills in the country.

Improved Method of Soaking Paddy

Recent studies conducted at the Paddy Processing Research Centre, Tiruvarur, have shown that during soaking, the paddy passes

from a resting to an active condition. It starts respiration, goes through changes that are preparatory to germination, and undergoes breakdown changes that result in part of the rice kernel passing into the surrounding aqueous medium. The soaking loss as a result of this averages 3.0% of the weight of the rice kernel, and increases with increased soaking time. It was observed that the unpleasant odour associated with parboiled paddy, which is caused by material passing from the kernel into the liquid medium, could be eliminated if an oxygen donating substance, for example a chromate, dichromate, permanganate, hypochlorite, ferric salt, or peroxide, was included in the medium. In the presence of such substances, there was also a 1.4–2.9% increase in the yield of brown rice (Table 50).

Parboiling in Modern Rice Mills

In the parboiling plants attached to modern mills, hot soaking is now being adopted to speed up the operations. But it has been reported that about 60% of the steam produced by the boilers is required to heat the water needed for parboiling. Removal of chaff and immature grains from hot soaked paddy is difficult; therefore, the resulting milled rice contains a high percentage of brown and dark residue from the immature grains, making it unattractive to consumers. The machinery that was installed for the production of parboiled paddy was not compatible with the capacity of the mills and the cost of operations were found to be high. The quality of the parboiled rice was also not up to the expectation of the consumer. The chief advantage of the modern rice mill is the high quality of its bran, but the return from it cannot adequately compensate for the extra cost involved. The major portion of this cost goes towards the drying of the parboiled paddy.

Rinsing of Soaked Paddy with Brine

The TCMF Laboratory, Tiruvarur, has developed a method of rinsing the soaked paddy with brine (specific gravity 1080–1100) that closes the paddy husk during parboiling and reduces the absorption of water during steaming, thereby saving on the cost of drying to the extent of Rs. 4–6/t of paddy. The mill machinery needs periodic protective coating against possible corrosion.

Continuous Steaming Method

The Paddy Processing Research Centre, Tiruvarur, in collaboration with the TCMF engineers, has developed a method of steaming in which the soaked paddy gets uniformly parboiled while it moves along a slow conveyor. The advantage of this method is that uniformity of parboiling is achieved, which

TABLE 50. Effect of treatment of steep water on the yield of parboiled rice from paddy.

Name of mill and location	Variety of paddy	Method of steeping and treatment of steep water[a]		Percentage increase in yield over control
		Experimental	Control (untreated)	
Veeyar Rice Mill, Kuttalam	CO-25	SS + C	DS	2.8
Veeyar Rice Mill, Kuttalam	Ponni	SS + C	DS	1.9
West Rice Mill, Kuttalam	Nellore, Samba	SS + C	DS	1.7
Appachi Gounder & Co., Somanur	ADT-27	SS + C	DS	2.2
Veeyar Rice Mill, Kuttalam	IR8	SS + C	DS	2.3
Veeyar Rice Mill, Kuttalam	IR5	SS + C	SS	2.9
Buddha Rice Mill, Sulur, Coimbatore	ADT-27	DS + C	DS	2.3

[a]SS = single steaming, i.e. cold soaking of raw paddy followed by steaming; DS = double steaming, i.e. soaking of steamed paddy followed by steaming; and C = addition of chromate at 0.05–0.1% to steep water.

results in a better appearance of the parboiled rice and an increase in the oil content of the bran.

Pressure Parboiling

The data collected show that pressure parboiling ensures more uniform parboiling than open steaming. If the paddy is merely wetted or steamed before pressure parboiling, loss of kernel material during parboiling can be eliminated. The oil content of the bran obtained from polishing the brown rice is about 30%.

Maximizing the Oil Content of Rice Bran

To increase the oil content of paddy, which is normally 1.2–2.0% by weight, a regular breeding program has been initiated. Some of the varieties of paddy were found to contain up to 4% the weight of rough rice in oil (Table 51).

Recent studies undertaken by the Paddy Processing Research Centre, Tiruvarur, have shown that the oil content of the rice bran can be increased up to 35% of its weight by manipulating the soaking and parboiling time. Prolonged soaking followed by steaming was found to increase the oil content to 25–30%; pressure parboiling increased the oil content of the bran to about 35%.

TABLE 51. Oil content of some varieties of paddy on a whole paddy basis (Paddy Processing Research Centre, M. R. Mills, Tiruvarur).

Variety	Oil content (%)
Cal rose/B_2b	1.15
B_2b Na HDA	1.41
B_2b HY 275/1	1.79
Black Pusher	1.8
AC-GGE	1.9
SLO-16	2.0
B_2b YPR-8	2.09
B_2b Assam-31	2.1
B_2b NORIN-1	2.22
B_2b NORIN-41	2.37
B_2b TKM 6	2.45
B_2b Assam-34A	2.55
IR20	2.6
Karuna	2.65
B_2b W 94	2.95
B_2b Dawn	3.02
ARC-5902	3.1
B_2b Hamsa	3.15
B_2b Agomimontakag	3.4
B_2b CH-45	4.1
YPR-6	4.45

Postharvest Care of Rice

Most of the rice-growing area is in the humid regions. In certain parts, there are incessant rains during the harvest stage. The respiratory and other attendant changes are accelerated if the paddy that is harvested during humid weather is not attended to immediately. The FCI, the major procuring and processing agency in this country, realizing the gravity of the problem, established a series of mechanical driers at strategic points. In practice, the drying cost is found to be high as a result of using oil-fired burners in these driers. The IIT, Kharagpur, and other institutions in India are working on the replacement of the oil-fired burners with husk-fired ones. The FCI has designed and developed a mobile husk-fired drier to meet the requirements of the villagers. This drier has proved to be suitable for the northern regions of India.

Preservation of Wet Paddy with Chemicals

The research studies undertaken at the Paddy Processing Research Centre, Tiruvarur, have shown the possibilities of arresting the germ activity and other attendant changes that lead to the loss of dry matter from the paddy due to increased respiratory activities. In addition, heating, discoloration, and damage to paddy are prevented. Of the various chemicals tried, common salt at a level of 5–6% of the weight of the paddy was found to confer the necessary protection. The germ activity was suppressed without affecting the viability. Dry matter loss, which was found to be up to 12% after 10 days of storage of untreated paddy at a moisture content of about 23%, was considerably reduced when the paddy was treated with salt at a 5% level and

stored after the water was drained. The salt withdraws the water from the paddy by exosmosis, without more than a trace of it entering the paddy. The rate of reduction of the moisture content is given in Table 52.

TABLE 52. Rate of reduction in the moisture content of the rice kernel as a result of dry salt treatment.

	Percentage moisture content of kernel	
Time (h)	ADT-27	IR8
0 (initial)	25.0	27.0
12	20.9	16.2
24	19.7	16.6
36	19.3	16.0
48	18.5	16.6
60	17.8	15.0
72	16.9	15.0
84	15.6	14.5
96	13.6	13.2

Increasing the Oil Content of Bran in Hullers

Generally the bran produced in the huller mills contains about 6% oil. Because of this low level, extraction of oil commercially is found to be unprofitable. To increase the oil-bearing material in the bran produced in hullers, work has been initiated at the Paddy Processing Research Centre, Tiruvarur, that has resulted in the production of bran containing about 15% oil by modifying the hulling and blowing operations. The paddy is first shelled using a wide blade clearance on the huller. The shelled mixture is passed into a winnower for separation of the husk and is then polished. The polished bran gives an oil content of 15% with a low ash content.

In modern milling, the brown rice is polished in two or three polishing cones. After the superficial bran layer is removed from the rice by the first polishing cone, the subaleourone layer can be removed separately. After extraction of the oil, the bran has a whiter colour and can be added to any suitable flour material.

By-Product Utilization

The germ is the most valuable component of the rice kernel that is removed during milling; however, it could be recovered in a clean condition if a completely shelled (brown rice free from grit and stones) and cleaned rice was used. This germ gives 35–36% oil and the extracted material gives 33% high quality protein. The germ produces a white flour with a flavour reminiscent of almond, and is a very good source of vitamin B1.

The extraction of silicate from partially charred husk is comparatively easy and deserves attention because of a growing demand for silicate in various industries. A completely ignited white product containing 95% silica could serve as a base for organic chemical industries.

Preharvest Spray of Brine to Hasten Ripening and Reduce the Moisture Content

Recent studies carried out at the Paddy Processing Research Centre have opened up a new line of approach hastening the ripening phase of the paddy crop. Spraying brine on matured paddy even if it is under water stagnation makes the grain uniformly ripe and reduces its moisture content. In one trial, applying brine (specific gravity 1100–1150) resulted in uniform yellowing of the paddy so that no green colour remained and the crop could be harvested in 2–3 days time; however, the untreated control took about 10 days to attain uniform yellowing. An appreciable drop in the moisture content was also noticed when the ears were sprayed with brine (Table 53).

Using two sprayers with double boom discharge mechanisms, it is estimated that about 4 ha (10 acres) of paddy crop can be sprayed by two workers in an 8 h day. The economic utilization of this new technique is shown in Table 54.

Conclusions

This is only a portion of the problems solved and the practices adopted in India. No doubt,

when compared with the old era of hand pounding, we have achieved much more than we imagined possible in a comparatively short period, but we still must solve the practical problems involved in the processing of rice in a large country like ours. — R. CHANDRASEKARAN AND P. PILLAIYAR. *Paddy Processing Research Centre, M. R. Mill, Tiruvarur, S. India.*

TABLE 53. Moisture drop after 4 days of salt spray treatment on standing matured paddy (variety CO-25).

Treatment	Paddy moisture (%)
Control	29.0
Salt solution (specific gravity 1.100)	14.5
Salt solution (specific gravity 1.200)	14.5

TABLE 54. Effect of preharvest spray of brine on paddy (variety IR20, Regional Research Station. Aduthurai)[a].

	Harvested Feb. 19, 1973		Harvested Feb. 24, 1973		Harvested March 9, 1973
	Control	Brine treatment Feb. 16, 1973	Control	Brine treatment Feb. 24, 1973	Control
Period from sowing (days)	140	140	145	145	158
Period from general flowering (days)	31	31	36	36	49
Yield on a wet basis (kg/acre)[b]	1704	1603	2004	2011	1743
Moisture content (%)	23.56	19.13	18.08	15.92	11.0
Yield on a dry basis (kg/acre)	1303	1280	1641	1692	1551

[a]Date of sowing October 2, 1972; date of planting November 16, 1972; and date of general flowering January 10, 1973.
[b]1 kg/acre = 2.47 kg/ha.

Indonesia

Indonesia, with 120 million people in 1972, is the fifth largest country in the world. The archipelago consists of over 3000 islands. The country is predominantly agricultural, with 85% of the total population living in rural areas.

Because rice is the staple food of the majority of the people, it is more generally preferred than any other crop. The soil and climate are suitable for the growth of rice and it is grown in all provinces of Indonesia. Rice is generally cultivated in "sawah" (irrigated land). Farmers also plant rice in the dry season if irrigation water is available.

Production

The country's average rice yield is about 11.4 million tonnes per year. While the consumption of rice increases rapidly as a consequence of the population growing at 23% per annum and the increase of per capita consumption, the production of rice is not keeping pace with the increasing consumption. To meet the local rice demand, the government, for the past several years, has resorted to importing rice, which has caused an annual drain on foreign exchange earnings of about 15%. In the last 13 years, Indonesia has been

importing rice amounting to over 10% of domestic production.

Starting in 1965, a promising program was initiated to induce rice farmers to increase their production at a profit both to themselves and the nation. This program is the so-called BIMAS (Mass Guidance).

The pattern of production is basically traditional, but it is in the process of changing. Many areas still use the traditional way of ploughing. Harvesting is done manually by hand with a sickle and "ani-ani." The moisture content of the paddy is 20–25%. The planting season in Indonesia varies from province to province, depending on the rainfall. The harvesting season also varies. One reason why harvesting and planting using machinery cannot be done is the small acreage owned by individual farmers. New varieties of paddy have been introduced, and they have to a certain extent given higher yields to the farmers. In fact, these varieties are considered to produce good rice and fetch a higher price.

Processing

At present, there are two types of rice processing facilities being used in Indonesia, namely, the traditional method (hand pounding) and the modern method (rice hullers and rice mills). More than 75% of rice processing is done by the traditional method. The whole paddy production of the country is milled and consumed locally.

A thresher is needed because a lot of the farmers store paddy on the stalk, which must be threshed before it can be processed. Some of the hullers are rubber-roller types and some are stone disc or steel types. Locally made hullers are usually stone or steel mills. Small rice mills and most imported rice mills are the rubber-roller type.

The distribution of hullers and small rice mills in the villages has resulted in about a 10% change in the method of processing rice for family consumption from hand pounding to milling. This is due to the increased recovery obtained from these machines (rice huller = 55% and rice mill = 65%). The huller owners do not purchase paddy because they do not have enough financing for purchasing paddy; they just process the rice. The big mills usually have complete facilities and services for their operation. The majority of them are owned by "BULOG/DOLOG" (National Logistic Authority). BULOG introduced the mechanical drier and the success of BULOG in using the mechanical drier has led to other commercial rice mills installing and using them.

Problems

The present rice industry in Indonesia is moving toward modernization; however, the actual capacity of the available processing facilities is lower by about 50% than the potential capacity. The rice hullers only operate about 175 days in a year, and the rice mills only operate about 123 days in a year because of the lack of raw material to be processed.

Indonesian rice farmers are at the subsistence and semisubsistence level. They sell a low percentage of their rice and the size of their rice fields is, on the average, 0.5 ha. Farmers still use the traditional methods of processing rice by hand pounding, and usually use family labour. — SJUHINAR BUSTAMI. *Rice Mill "Sinar Kongsi," 58 Diponegoro, Padang, W. Sumatra, Indonesia.*

Khmer Republic

Paddy is one of the main traditional crops in this agricultural country in which about 80% of the population is rural. Paddy has been grown for a long time, and growing methods vary with the soil type and the variety of the paddy. Upland rice is usually directly seeded in hills, grown without levees and inundation, and depends solely on natural rainfall. Lowland rice is grown in the whole

country on sandy, sandy-clay, or silty-clay soil. There are very early, mid-season, and late varieties. Floating rice is grown in the flooded zone of the Mekong, Tonle Sap, and Bassac Rivers and around the great lakes where the height of the water sometimes reaches 5 m when the flood is slow. Semi-floating rice has the same characteristics as floating rice except that it can only support a water level from 80 to 150 cm. Dry season rice is grown in the flooded zone after the water has receded.

In general, almost all the rice varieties grown in the Khmer Republic are photoperiodic. Wet season rice covers almost all the areas under rice cultivation. Varieties used are more or less late varieties (direct sowing: April, May, and June; harvest: December, January, and February of the following year). Rainfall is one of the main factors affecting paddy production.

Harvesting

Normally harvesting begins in December. Paddy is harvested when it reaches market maturity, i.e. when a third of the panicles are still green, because this produces a good quality paddy with a very low percentage of breakage. Physiological maturity is reserved for seed production, and in this case the percentage of breakage is high. Due to the lack of labour for harvesting, a lot of the paddy is harvested at physiological maturity, which is reached after the second half of January for late varieties.

Hand cutting, with a sickle, is generally practiced in the Khmer Republic. In some transplanting areas, farmers use a kind of sickle that has the handle curved in the opposite direction to the blade. This handle is used to gather the plants before cutting. In the direct sowing areas, especially in the province of Battambang, farmers use a curved sickle forming a semicircle with a short handle. The curved handle of the sickle gathers a number of plants in the left hand for cutting. The bunch of cut plants is then laid on higher ground to avoid wetting the panicles. When a certain amount of plants has been cut, they are tied together. In some cases the harvester only cuts the plants and another group ties the bundles, which are scattered in the fields. When the farmers finish a plot, they gather and stack the reaped paddy in one place. This method of putting the bundles in stacks is good for maintaining the quality of the paddy because it reduces the breakage percentage during milling. The bundles are carried by ox-cart to the threshing floor, which is prepared near the farmer's house or village.

The problem of harvesting paddy is becoming critical because labour force competition is reducing the amount of available labour. One can try to solve the labour problem by mechanization, but farm equipment is not manufactured in the country so spare parts are rare and difficult to find. In addition, fuel and lubricating oil are expensive. The following obstacles constitute the stumbling blocks to mechanization at present: (1) an inadequate system of irrigation and drainage; (2) local varieties lodge in the harvesting machines and cause high losses; and (3) selected varieties with short straw (IR8 for example) and a short cycle reach maturity in the rainy period; however, the sowing date cannot be delayed because the field would be flooded (rainy season) and would be impossible to sow.

Threshing

Hand threshing is done by one of two methods: (1) small bundles are beat by hand against an inclined wooden threshing table until all the grains fall, a team of four men can normally thresh about 200 kg of paddy in 1 h; or (2) five or six men trample a small stack; however, the yield obtained is very low.

Animal threshing consists of having from 4 to 8 oxen or buffalo trample the bundles on the threshing floor. The yield of the operation done by four oxen in a 3 h period is six sacks of paddy, or about 450 kg.

Mechanical threshing is done in the province of Battambang where there is partial mechanization. The sheaves are lined up on the threshing floor, and a tractor drives over them. When the tractor is stopped a few men shake the sheaves with long sticks. Driving is then resumed until most of the grains are separated

from the panicles. The tractor is stopped again; the straw is removed; and the operation is completed. Four to five operations can be done on the same threshing floor. After this operation the grains of paddy are winnowed.

Many foot-operated pedal threshers (Japanese type) have been introduced in certain rice areas, but it is difficult for the small-scale farmers to obtain many of them at once for the threshing operation. The capacity of the pedal thresher is low and the price is high.

Winnowing

Winnowing consists of separating the impurities from the grain. Farmers do it in three ways: (1) by the wind; (2) by a blower; and (3) by a hand-winnowing machine. For wind cleaning the grains are tossed into the air, and the chaff, straw, leaves, empty grains, and dust are carried away by the wind; whereas, the heavy grains fall onto the floor. Two or three operations of this kind are needed to obtain clean grain. For cleaning with a blower, the grains are dropped in front of a wind blower that blows away the dust and other impurities. In the hand-winnowing machine a draft is created by turning a handle that operates a fan. Paddy is fed into a hopper and falls through the draft, which removes the chaff. The clean grain is collected separately. One person manipulates the handle of the fan and adjusts the output of the grain from the hopper to synchronize it with the force of the wind. Two people feed the grain and another collects the clean grain and sacks it. The grain separated by the operation comes out through two channels; the grain from the second channel is considered uncleaned and must go through the operation one more time. The clean grain is dried and stored.

Drying

Drying is done immediately after winnowing. The grains are spread, under the sun, in a thin layer on the drying floor or on a mat. Normally drying takes 1 day. In certain areas the bundles are dried in the field, and in this case, after winnowing, the grain goes directly to the storehouse.

Storage

There are two ways of storing grains: (1) in bags; and (2) in bulk storage. Bag storage is the most widely used method even in rice mills with a high potential for transformation. The paddy is put in bags that are piled one on top of the other. This method facilitates handling, but the cost is high, it takes up a lot of space, and storage loss from rats can be high. Farmers use bulk storage of rice for family consumption. The storage room consists of an above-ground barn made of concrete, bamboo, or wood. This method reduces loss from rats.

Milling

Processing methods vary from simple hand pounding that uses a mortar and pestle to large scale processing in rice mill plants that use mechanized equipment and produce quality milled rice and by-products.

A mixture of varieties causes problems in milling because heterogeneous grain increases the percentage of breakage and reduces the amount of rice that is milled. Milling is done either by small scale dehuskers or, if the quantity is important, in large rice mill plants.

In rice plants, the paddy is stored first in a barn and then sent by elevator to a sieve that separates chaff and impurities from the grain. This cleaned paddy is transported to a hopper for discharge to a disc-huller that produces a mixture of husks, unhusked paddy, and brown rice. This mixture passes a fan that blows away the husks. The brown rice and unhusked paddy are separated on a table separator: the unhusked paddy returns to the huller, whereas the brown rice goes to the whitening cone.

In the first polishing cone some grains are broken, therefore, a mixture of white milled rice, large and small brokens, and rice polish is produced. The rice polish is removed by a fan and the unpolished grains go to a second cone. In this cone the rice is polished to the

desired norm and passes to a second separator that has three sieves. The first sieve retains head rice and first head, which are sent to a sieve that adjusts the percentage of head rice desired. The second sieve collects first head and the third collects second head. The processing of 2 piculs (120 kg) of paddy produces 100 kg of whole grain and heads, 12–13 kg of rice polish, and 6–7 kg of bran.

Marketing

Rice marketing can be done either by government agencies or by the private sector. Two government agencies are responsible for collecting and transforming paddy. Collecting paddy is under the control of the Ministry of Commerce and SATRAR; whereas, the service in charge of supply, transformation, and reconditioning is an autonomous enterprise of the OFFINACO, which is under the Ministry of Agriculture. The base price of paddy and the price of rice are fixed by the government. The private sector is made up of rice mill owners who perform the marketing operation. They buy paddy to run their mill and sell rice and by-products on the spot.

Special Problems and Actual Developments

To increase rice production, modern techniques are being disseminated by the agricultural service to the farmer. This is done by either extension work or demonstration plots. In addition, trials are being carried out by the agricultural service to find a formula for the combined use of fertilizers, high-yielding varieties, and crop protecting products.

Postharvest losses have not been solved because mechanization is not yet common. Losses can be reduced by harvesting at commercial maturity and stacking the bundles immediately afterwards; however, the loss problems can be solved only if harvesting is mechanized. There are cases where networks of irrigation and drainage are set up. A pioneer project is already being studied by the international agencies in three zones of the Khmer Republic to set up an irrigation system where the harvest would be done by complete mechanization and losses would be reduced. Apart from the Agricultural Service, other state institutions can help farmers to increase production: The National Office of Cooperation (OFFINACO) can supply fertilizers and insecticides; the Farmer Agricultural Banks (Banque agricole paysanne) can give loans to farmers to enable them to buy fertilizers and insecticides; and the Department of Community Development can act as an extension agent.

To increase rice production in the Khmer Republic, many technological inputs need to be organized. These include irrigation systems, mechanization, new cultivation techniques, high-yielding varieties of rice, fertilizers, rice processing methods, and pest controls. — KONG SAMOL AND CHHIEU NAM. *Agriculture Department, Phnom Pen, Khmer Republic.*

Laos

The economy of Laos is basically agricultural. Approximately 80% of the population lives in rural villages and is engaged in subsistence agriculture. The government of the Royal Kingdom of Laos (RLG) has undertaken an extensive program to accelerate agricultural development so that Laos can move towards economic self-sufficiency. To do this, the agricultural sector and rural development have been given top priority in the Laotian development program.

Since their settlement in the valley of the Mekong River, the Laotian people have been predominantly wet-rice farmers that live in small villages of anywhere from a few families to several hundred people. Each family farms an area just large enough to supply family needs. With the help of a buffalo, the farmer uses the few simple implements he has made for himself to plant, cultivate, and harvest his

crops by methods his ancestors followed centuries before.

The two major farming methods in Laos, which have remained relatively unchanged for centuries, relate to the cultivation of wet rice in irrigated fields and the cultivation of dry rice in forest clearings, which are called Rai in our native language.

The so-called wet rice is grown during the rainy season in paddy fields of two types: those utilizing irrigation canals and those where a system of dikes and terraces is designed to retain the rainwater. The regular paddy is planted in May or June and harvested in November or December. Not enough rice is grown locally to feed the urban population; therefore, some rice is imported into Laos, primarily from neighbouring Thailand.

The time of harvest depends on the type of rice, but the water in the paddy field has to be drained first. Harvesting involves the whole family and sometimes outside help as well. The rice plants are cut by sickle, tied together in small bunches, and then kept in the open air for a few weeks so that the grain moisture content is reduced.

Threshing is carried out by beating the plants either against boards or with sticks. No pedal or mechanical thresher is used at the present time.

In traditional rice milling, the rice is still milled in a wooden, foot-pedalled mortar and pestle device, but as a nation's agriculture develops, agriculture-related industries must also be developed. Though generally inadequate, the most important of these industries are the rice mills.

At this time, 407 rice mills of all sizes have been identified. The highest number of mills is found in Vientiane Province, which has 185 mills, the next highest number of mills is in Savannakhet Province, and the third highest in Borikane, which has 35. Of the 407 mills, only six have the capacity to produce an export-quality product. Most of the mills are rated 7.45 kW (10 hp) or less and are used primarily for custom milling of rice for local consumption. As the Agricultural Development Organization (ADO), created 8 years ago, became more involved in the marketing of rice, the need for greater milling capacity and higher quality milling grew.

Throughout the country there are small, sometimes portable, mills with a daily capacity of up to 1 t that husk and polish the subsistence rice needs of rural villages. However, most subsistence farmers, distant from urban centres, still mill their own rice by hand in the traditional fashion.

Rice millers usually operate their mills for 6–8 months of the year. This is the time span they consider necessary to earn a reasonable profit. The quantity of rice milled depends on the mill size and the milling time per day. As an average, a mill with a capacity of 25 t per 12-h day will require about 625 t of paddy per month or a yearly average of 3750–5000 t of paddy per year. However, generalization is dangerous as millings fluctuate markedly from year to year in response to unpredictable swings in supply and demand. Moreover, market information is unreliable and inadequate, therefore, profit margins tend to vary from one year to the next.

The natural barriers to trade in Laos are so immense that without massive investments in roads and other forms of transportation certain sections of the country will never be economically integrated with the rest of the country. Without adequate roads within homogeneous geographical areas, an efficient rice marketing system cannot be developed. Given the current security situation, the country can be readily divided into ten well-defined marketing zones or marketing areas. A certain amount of rice normally moves within each marketing zone. Generally this trading is confined to the exchange between farmers or exchange at the local market, which is the case for the other locally grown agricultural commodities. As individual farmers began to produce a greater quantity of rice, it became obvious that almost no formal rice marketing structure existed that was capable of absorbing excess rice from the market. This often left the ADO as the only marketing agency in the area.

Traditionally farmers have been conditioned to the lack of markets and have reacted in the expected way by not producing more than a subsistence requirement. The government found that a totally production-oriented agri-

cultural program was workable only as long as there was a marketing structure capable of absorbing the increased production. The entry of the ADO into the marketing of rice has provided farmers with an outlet for their surplus rice at prices quoted in advance. Compared to Thailand, the price of milled rice in Laos is generally higher, which reflects among other things the difficulty of marketing rice in Laos.

As far as rice storage is concerned, it is estimated that about 30% of the rice production is lost annually in Laos because of inadequate storage facilities and insect and rodent damage. It is expected that a great increase in rice production would worsen the storage problem. Consequently, losses may increase unless the producers and the ADO improve their warehousing facilities.

Several major problems encountered in the agricultural sector, especially the rice production sector, from 1969 to the present have particularly hindered development in Laos: (1) the security and refugee problem; (2) the floods in 1969 and 1971; (3) an inadequate and expensive transportation and marketing system (no price support and stabilization program); (4) high middlemen charges; (5) an inadequate banking system; and (6) a shortage of trained personnel.

The Royal Laos Government still maintains a liberal policy on agricultural products. The import restrictions for Thai rice entering Laos are very limited; therefore, no direct control is operated at the present time to cut down some of the competition from Thai rice in the local market.

The new government program orients farmers towards growing more rice by introducing new improved rice varieties and better cultural methods to meet the country's needs. To meet these needs, the ADO has the following goals: (1) distribute the improved seeds to farmers; (2) encourage farmers to grow quantities of rice in excess of their subsistence needs; (3) make available new capital inputs (such as fertilizer, insecticide, tools, and sprayers) to farmers at low prices; (4) help farmers to obtain agricultural credit; and (5) improve the rice marketing system. To prevent postharvest losses, the ADO is trying to improve storage facilities.

The government has taken some measures to increase rice production by increasing the irrigated area to 14 990 ha in 1970 and to 22 577 ha in 1973. This increase has made a second dry-season rice cropping possible. However, no attention has been given to the technical approach to be used for future development or the improvement of technology for postharvest operations in the grain industry. — THAO SOMMAI AND LUANG BACCAM. *Department of Agriculture, Vientiane Province, Laos.*

Malaysia

The economy of Malaysia is basically agricultural, and rice forms the staple diet of the people. The climate and soil are suitable for the growth of rice, which is grown in three main areas. The first is in the northwestern coast in the states of Perlis, Kedah, and part of Perak; the second is in the northeastern part of West Malaysia, in the states of Kelantan and Trengganu; and the third is in the south-central area, in the states of Selangor and Malacca.

The pattern of production is basically traditional, but it is now in the process of change. Many areas still use the traditional way of ploughing, and harvesting is done manually. For ploughing, however, the industry is changing towards mechanization at a very fast rate. In many areas, tractors and pedestrian power tiller are being used in the preparation of land.

At one time, Malaysia produced rice on a single-crop basis, but in view of the need for self-sufficiency, every encouragement has been given to double cropping.

Production Aspect

As a result of double cropping, Malaysia is expected to achieve 90% self-sufficiency by 1975. For the purpose of double cropping the Muda Agricultural Irrigation Scheme has pro-

duced about 105 000 ha of land. In addition to this, the Kemubu, Lemal, and Besut schemes in the northeastern coast have made about 40 000 ha available for double cropped. Other irrigation schemes are in operation in the Tanjong Karang – Sabak Bernam area, in the state of Selangor, and in the Krian district in the state of Perak. In addition to these big double-cropping areas there are other states with their own minor double-cropping schemes. The estimated acreage of paddy for main-season and off-season crops as of 1971 was:

	Main-season	Off-season
Johore	10 900	4 650
Kedah	292 370	145 160
Kelantan	169 560	17 750
Malacca	29 390	3 830
Negeri Sembilan	24 960	10 490
Pahang	45 730	5 060
P. Pinang/S. Prai	38 690	37 340
Perak	119 040	82 360
Perlis	65 630	27 500
Selangor	50 600	49 210
Irengganu	24 970	10 420
Total:	871 840	393 770

The main-season and off-season plantings vary from state to state. For the state of Kelantan the main-season crop is planted in December and January, whereas harvesting is done in March or April. Off-season crops are planted soon after the harvest of the first season, i.e. in April or May. In Kedah, the planting for the main-season crop is in October or December and the harvest of the main-season and planting of the off-season crop is in February and March. Harvesting is still done by traditional methods despite the fact that experiments have been made with machinery. Two reasons why harvesting by machinery cannot be done are the small fields owned by individual farmers and the soft soil conditions.

With the implementation of double cropping in the major rice producing areas, new varieties of paddy have been introduced. These varieties are mostly short-term varieties locally known as Mahsuri, Rai, and Bahgia. These varieties, to an extent, have given high yields to the farmers and because they produce a better quality rice they fetch a higher price. Despite the introduction of new varieties for short-term crops, many other local varieties, such as Taupek, are planted by the farmers. Although these varieties fetch a lower price, they should be planted when they are better suited to the land and soil conditions.

Milling Processes

The whole paddy production of the country is milled and consumed locally. Mills found in West Malaysia may be grouped into three main categories: small; medium; and large.

Small Mills

This sort of mill produces rice for home consumption and is found in most villages. It either belongs to an individual or to a small cooperative society in the village. The average milling capacity is about 3 piculs/h (180 kg/h). Some of the mills are licensed and others are not.

The small mills are the simplest and are usually powered by a diesel engine that is connected by belts to rotating shafts that move the major parts. The precleaner has a modern frame and uses a stone sheller.

Medium Mills

The medium-sized mills are those with a milling capacity between 1 and 2 t/h. They are usually located in the more urban areas and are owned by individuals or larger cooperative societies. The majority of the medium-sized mills provide rice for home consumption and for commercial sale. The medium-sized mills sell most of their rice to land schemes and low income groups; therefore, they try to achieve a 70% rice recovery. The quality of the rice produced by these mills is higher than that produced by the small mills because of commercial participation. Usually the medium-sized mills have ample facilities such as good weighing scales, drying yards, and transportation facilities.

The mode of operation of the medium-sized

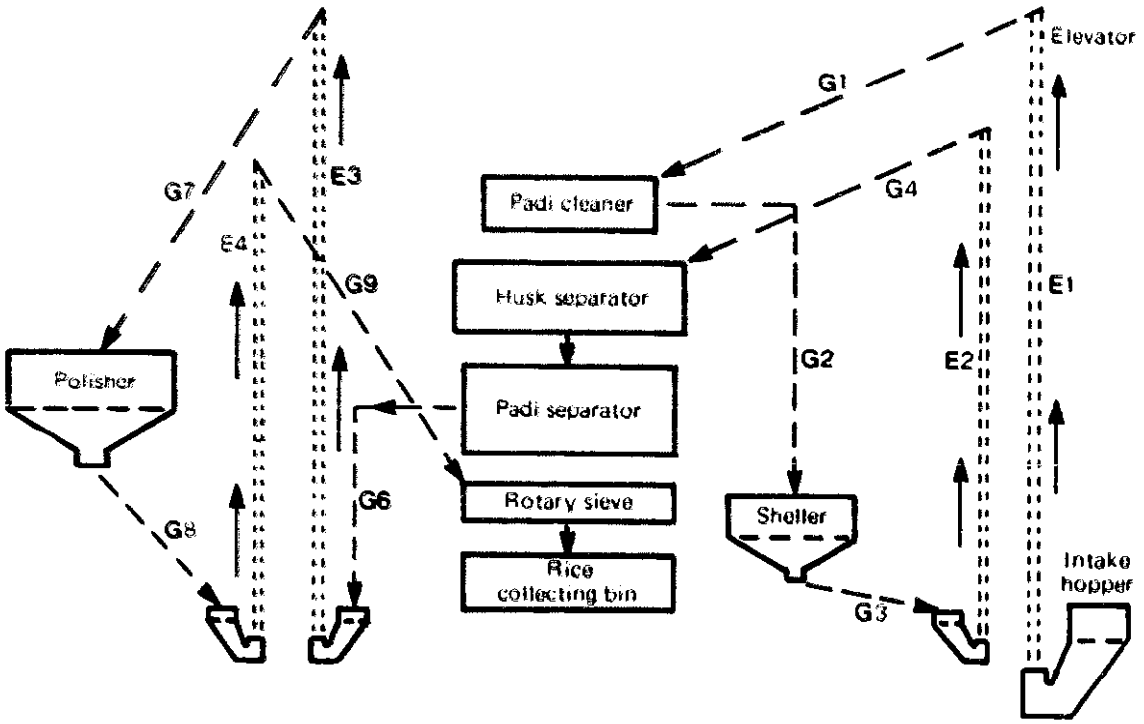

FIG. 234. Conventional small mill operated by diesel engine: E = elevator; and G = gravity flow.

mills, especially those made locally, is almost the same as that of the small mills (Fig. 234). The paddy is poured from the sacks into a hopper. From here it is transferred by an elevator to the paddy cleaner. The cleaned paddy goes to a sheller and then to a husk separator. In the paddy separator the paddy is extracted from the shelled rice, and is sent to the polisher. After polishing the rice passes to a rotary sieve, which usually has a number seven sieve for high rice recovery.

In small rice mills there is usually only one sheller/huller and one polishing cone; however, in medium-sized mills a large capacity polisher, which has a wider diameter and two or three polishing cones, may be used.

Large Mills

These mills have an average milling capacity of between 2.5 and 10 t/h, and are generally owned by companies or by the National Padi and Rice Authority (NAPRA). These mills usually have complete facilities and services for their operation. There are still many large mills that are using conventional machinery; however, the mills operated by NAPRA are mostly using up-to-date machinery. Despite the use of conventional machinery, a few of the large mills have been changing to improved parts, especially to the rubber-roll sheller from the old stone shellers.

Double-cropping means that the second crop must be harvested in the wet season. Therefore, the Padi and Rice Marketing Board (PRMB) under the FAMA[14] has introduced mechanical driers that have been so successful that other commercial mills are now using them. Aeroglide, Cimbria, and Satake driers are being used in different parts of the country.

[14]Before September 1971 all matters concerning paddy and its processing were under PRMB, a board formed under the Federal Agricultural Marketing Authority (FAMA). Later all PRMB assets were handed over to the National Padi and Rice Authority (NAPRA), which was formed to take over all the functions for paddy and rice. The NAPRA, which is a semi-governmental body, is the main force behind the modernization of the rice industry.

The Peringat Rice Mill

In 1971, a modern mill was built by improving the Sungai Besar mill built by the PRMB in Tanjong Karang. This integrated mill has a quoted capacity of 4.5 t paddy per hour (Fig. 235) and two mechanical driers with a combined capacity of 15 t of paddy per pass per hour. The mill is situated on the northeast coast of west Malaysia in the state of Kelantan, about 13 km (8 miles) south of Kota Bharu at a place named Peringat, and covers 6 ha (15 acres), of which about 1.2 ha (3 acres) are occupied by the mill buildings, godowns, and office.

The Mechanical Drier

The paddy is sent from the intake hopper to the precleaner by an elevator, which conveys three bags of paddy (4 piculs) per minute. Impurities, such as straw and immature grains, are removed in the precleaner and the paddy is sent at a continuous rate to the drying chamber of the Cimbria mechanical drier. During the 45 min pass through the drying chamber the moisture content of the paddy is reduced to 13–14%. The paddy is then transferred to tempering bins to be cooled. When the paddy is ready for milling, it is transferred to another storage bin in the mill. By having the storage bins attached to the mill a constant flow of paddy to the mill is assured.

Attaching a precleaner to the drier is helpful because it saves drying space since only paddy is dried, saves the trouble of frequent cleaning of the drying chamber, and reduces fire hazards in the chamber. If no precleaner, or an inefficient precleaner, is used, the flow of paddy in the drier may be slow. The precleaner should have a capacity that is larger than the intake capacity of the drier.

Rice Mill

The paddy, after being transferred from the drier into the rice mill bins, is passed on to the paddy cleaner where the dried clean paddy

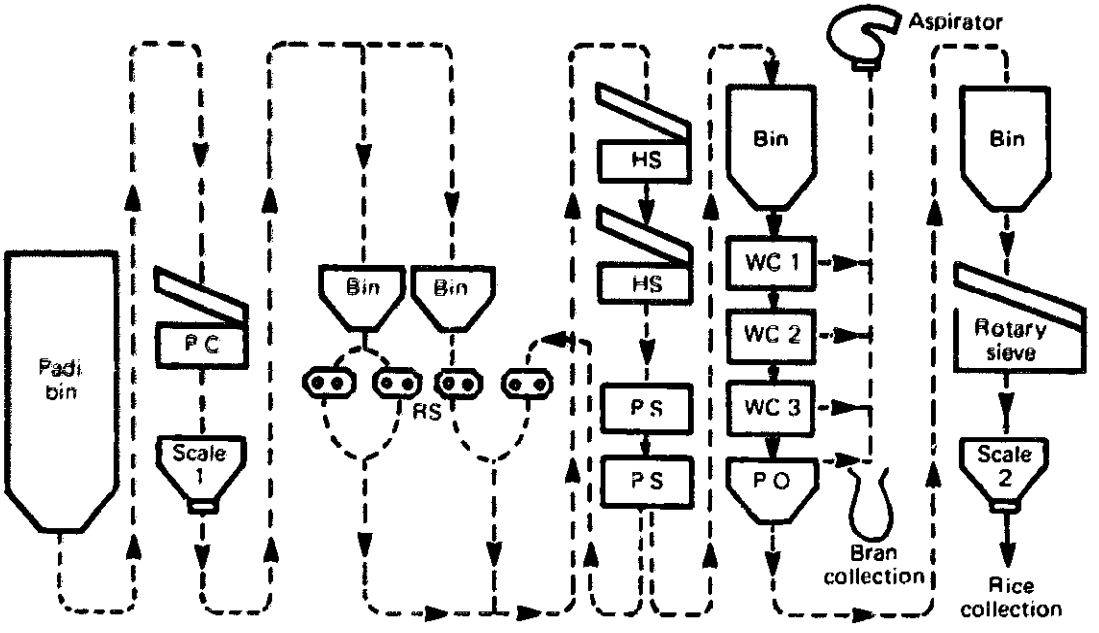

FIG. 235. Flowchart of NAPRA rice mill at Peringat, Kelantan, West Malaysia: (1) paddy bin used to give constant flow of paddy to the mill; (2) PC = paddy cleaner to remove impurities, stones, and metal (if it has a magnetic iron rod); (3) scale No. 1 to weigh net weight of dry paddy before going to the sheller, scale No. 2 to weigh rice output; (4) RS = rubber sheller (roller); (5) HS = husk separator; (6) PS = paddy separator; (7) WC = whitening cones 1, 2, and 3; (8) PO = leather polishing cone; and (9) S = rotary sieve.

is recleaned before being sent to the rubber roller. The cleaned paddy is weighed immediately after coming from the paddy cleaner, which gives the net weight of the dry clean paddy before milling. To ensure a constant supply of paddy to the rubber sheller, the paddy is first accumulated in a storage bin. The rubber roller lasts between 100–120 h before it has to be replaced.

One of the rubber shellers is reserved for paddy returned from the paddy separator. The shelled paddy is then passed to the husk separator, which leaves only the unshelled paddy and brown rice to be separated by the paddy separator. It was found that the husk separator performance was quite good in the sense that the grain is free from broken rice and splits.

The overall results obtained from the tests conducted on the rice mill machinery at Peringat showed that there was about 13% brokens. This brokens percentage is less than the 15% stated in the contract. The whole rice recovery is about 86% (grain above half-size is considered as whole grain). As mentioned earlier the quoted capacity of the mill is 4.5 t/h. From the test the rice produced per hour recorded at the automatic weighing scale is 3.8 t. Assuming a conversion rate of 65%, the quantity of paddy milled should be 5.8 t. However, as observed at the automatic weighing scale, the paddy weight was 5.7 t/h. Allowing for the fact that some of the paddy might have been stuck in the trunking of the scale, the quantity milled is estimated to be a little less than 5.7 t. Therefore, the actual capacity is more than the quoted capacity, probably because parts of the machinery installed at the mill had a larger than normal capacity. The total recovery of the mill was 77.7% (Table 55).

It should be noted that the mill and the drier form an integrated complex. Every part of the drier and the mill is run on the basis of one motor one machine. The mill and the drier are operated jointly by using a panel control in the control room. The panel, by means of electric eyes, can show the flow of paddy and rice at all points while the machine is in operation. It should be noted that this mill is comparatively quite free from dust.

TABLE 55. Mill returns for the Peringat Rice Mill.

	Net weight	Percentage
Dec. 31, 1972 – Jan. 31, 1973		
Paddy milled	27 745.20	
Rice produced	18 753.23	67.05
Brokens	478.74	1.72
Points	407.68	1.68
Bran No. I	1 270.20	4.93
Bran No. II	617.12	2.23
Total:		78.06
Paddy husks		21.94
Feb. 1, 1973 – Feb. 15, 1973		
Paddy milled	15 526.56	
Rice produced	10 603.12	68.29
Brokens	252.80	1.62
Points	186.44	1.02
Bran No. I	468.64	3.01
Bran No. II	528.96	3.04
Total:		77.52
Paddy husk		22.48
March 3, 1973 – March 7, 1973		
Paddy milled	4 551.12	
Rice produced	3 101.51	68.13
Brokens	60.04	1.31
Points	39.50	0.86
Bran No. I	237.84	5.22
Bran No. II	99.76	2.19
Total:		77.71
Paddy husks		22.29

Storage Capacity

The storage capacity of this mill is between 60 000 and 70 000 piculs of paddy. The storage availability, multiplied by the amount of paddy purchased every day, can just accommodate one season's operation at 22 h/day, leaving the other 2 h for service purposes. The godown is divided into these main sections; the large godown is for dry paddy, the godown adjacent to the drier accommodates wet paddy, and a rice godown was built adjacent to the mill.

Marketing System

A discussion of the processing industry would be incomplete without discussing mar-

keting. As the staple food for the people of Malaysia, rice is a controlled article. At one time a regulation was passed to control the purchase of paddy as well as rice; that regulation was under the food control ordinance. The urgency to coordinate production, processing, and marketing led to the formation of the National Padi and Rice Authority. This new organization has the powers to control everything that is concerned with paddy and rice.

NAPRA was formed to ensure fair prices of paddy to the farmers. The government has fixed a guaranteed minimum price of M$16.00/picul (100 katis) and NAPRA is to ensure the guaranteed price. To do this, NAPRA, with the aid of the government, has built many drying and milling complexes in major rice producing areas. So far considerable success has been achieved in this field.

Another function of the NAPRA is to ensure fair prices to the consumers. This has been done through licensing processes. The wholesalers and the retailers must apply for a license before they can sell any rice and there is a limit imposed on their storage capacity. Figure 236 shows the marketing channels for rice in Malaysia, and indicates that the paddy from the farmers is sold to licensed paddy dealers or purchasers who in turn sell it to commercial or NAPRA mills. The licensed paddy dealers are usually farmer organizations or private commercial mills. The rice is then sold and stockpiled or sold directly on the open market where it is bought by dealers and distributed to retailers.

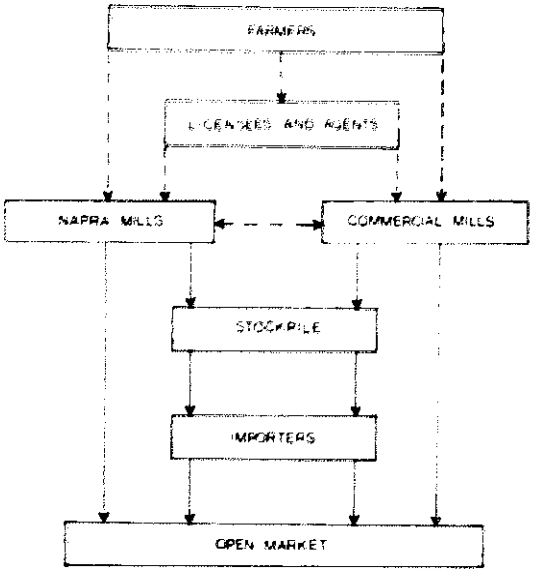

FIG. 236. Marketing channels for rice in Malaysia.

Conclusion

We can safely conclude that the rice processing industry in Malaysia is at the moment being influenced by the double-cropping process in the country. The new mills are mostly owned by NAPRA, and the private commercial mills are in the process of modernization and improvement. The rubber roller is increasing in use and has been replacing the stone husker. Some private mills have further improved their mills by using the rubber sheller for return paddy thus reducing the percentage of brokens. The mechanical drier has become a necessity and many private mills and all NAPRA mills have been installing this facility. Despite many improvements, however, very little has been done in the industry to solve the husk disposal problem. This factor has made the rice processing industry the centre of dust pollution.

Finally, we should caution ourselves that whatever improvement is made must reduce the production or processing cost in all fairness to the consumer. — AHMAD ANNUAR BIN MOHD. IBRAHIM, ABDUL RAHMAN BIN MOHD. DALIB, AND SALIM BIN ABDUL HAMID. *National Padi and Rice Board, Tingkat 20–21, Bangunan UMBC, 4 Jalan Sulaiman, Kuala Lumpur, Malaysia.*

Nepal

Rice is our staple food. Our economic build-up can primarily be spoken of as an economy of rice because 90% of the population is involved in agriculture. The production of rice,

followed by efficient processing, can create further potential for large export, which, in fact, is a beacon light for our national economy. Therefore, special attention must be paid to making our products attractive in the international market.

The annual production of paddy in Nepal totals 2 321 600 t (1.981 t/ha), of which 78% is produced in the plain of Terai. The estimated milling loss per year, from hullers that give about 55% recovery is 464 320 t. Our total export of milled and parboiled rice amounts to 100 000 t/year.

Harvesting and threshing practices are primitive, and have an important bearing on the amount of milling breakage. The paddy plant is cut manually by sickle and threshed either by hand beating, by bullocks moving around the stack, or by means of pedal-operated mechanical threshers. In the major rice producing areas, the paddy is first bundled in the field to facilitate transport and then brought to the threshing point, but this practice does not equilibrate the average moisture level in the bundle. The paddy is then threshed by means of bullocks moving around the paddy stack. The process of threshing is time-consuming and is at the mercy of the weather. In good weather, paddy containing fairly uniform moisture is obtained; however, in rainy weather, nothing can be predicted.

Rice milling is a major industry in our country. More than 700 small 6–9 kW (8–12 hp) huller-type mills are situated in the plain of Terai, which is the major rice producing area. Their milling yield, on the average, is hardly 55%, which is nearly 15–20% below the average obtained in most modern rice mills, and in addition, these hullers yield a high percentage of brokens. Therefore, there is a great need to improve the quality of the rice. Some improvement in rice processing can be achieved by the addition of precleaners and mechanical sieves at different stages in the milling process. Unfortunately, rice millers are not likely to undertake any improvement in processing as long as they are able to sell their rice, irrespective of quality, in the Indian market. His Majesty's Government of Nepal is trying to revolutionize the industry by replacing the old hullers with modern mills that can meet the requirements of the international market.

Both raw and parboiled paddy are processed in Nepal. Long, slender, and aromatic paddy varieties are milled as raw rice; whereas, inferior and mixed varieties are mostly parboiled. The parboiled rice is processed by cold soaking the paddy in cement tanks for 48–72 h, steaming, and sun drying. None of the millers use improved parboiling techniques, therefore, there is no control on steaming and drying. Because this process yields low quality products, quality control from harvesting to milling must be put into high gear.

More than 350 varieties of rice are planted and harvested year after year. One variety may have different names in different places, for instance, the variety called *kalonuniya* in Jhapa is known as *kalanamak* in Bhairawa. If a mixture of different paddy varieties is milled, the percentage of brokens is increased. The ability of grain to withstand the conditions of stress and the abrasive forces experienced during milling depends on the hardness of the grain; the harder the grain, the less the breakage. No milling equipment has been devised that can produce a high percentage of milled rice from a mixture of different varieties. Mixing leads to the undermilling of fine varieties and the overmilling of coarse varieties.

It is felt that a healthy foundation for the rice milling industry includes reducing the number of varieties of rice. The Agriculture Department is, therefore, launching extensive programs in paddy breeding and agricultural extension. Some of the high-yielding varieties that are recommended by the department for hilly areas are Chainan-2, Kausing-24, Taichung-176, Chainung-242, and Chainan-1, and for the Terai region IR8, BR-34, CH-45, and Taichung native-1.

There is no mechanization of storage in Nepal, and annual storage losses due to insects, rats, pests, moulds, and other factors is estimated to exceed 15% of the total paddy crop. Most of this loss is borne by the farmers at present.

The Agriculture Marketing Corporation is the semi-government organization dealing with rice trading in this country. This corporation is buying food grains to maintain proper buffer

stocks in areas where they are needed. These buffer stocks are maintained in different parts of the country to facilitate transportation to remote regions. The corporation is buying parboiled rice by employing two grades: Masino for fine and medium varieties, and Mota for coarse varieties. This grading is based entirely on an individual basis and no further specification has been laid down.

The millers in Nepal buy the paddy by employing their own grade, which is known as miller's grade. According to them, the paddy is classified into superfine, fine, medium, or coarse grade. Our test analysis indicates that this classification of paddy is based on: variety; shape; palatability; admixture of foreign grains; red grains; and translucence.

According to our study, the first consideration during the collection of paddy is the variety. Most of the fine quality varieties are very slender. The palatability characteristics (appearance, cohesiveness, tenderness, and aroma) have an important bearing on the existing quality grading, therefore, aromatic and slender varieties like Basmati and Kukurjali fetch a higher market price. Red and foreign grains are highly objectionable in the present grading system. Analysis shows that coarse varieties like Mansaro and Sathar may have up to 100% chalkiness.

All superfine and fine varieties of rice show a marked degree of translucency; therefore, it is an important factor in consumer preference. The yield of rice is higher for fine and superfine varieties; however, although the percentage of brokens produced from superfine grades is lower, the number of brokens produced by fine and medium grains is about the same. Our study indicates that the present grading system is based on: variety; general appearance; and grain size, colour, and brokens.

His Majesty's Government of Nepal has realized the problem, and the Department of Food and Agriculture Marketing Services is working on its effective solution. — T. B. KARKI. *Ministry of Food, Agriculture, and Irrigation, Department of Food, Agriculture, and Marketing Services, Shri Mahal, Kathmandu, Nepal.*

Philippines

Existing Postharvest Practices

Harvesting

Traditional manual harvesting of rice constitutes 22.1% of the total labour time. It is usually done by either of three popular instruments and methods: (1) a yatab that cuts the panicles without the leaves; (2) a lingkaw that is efficient for lodged varieties because it lifts and twists the stems together and makes them easier to cut; or (3) a sickle or scythe that cuts a number of stems at the same time. After the rice stalks are cut, they are bundled, piled, and left in the rice field for a few days before they are threshed.

Mechanical harvesters are hardly used in the Philippines because of the high cost of the machines, fragmentation of the farms, and the soil conditions.

Threshing

There are at least three methods widely used in this country, namely: the hampasan, trampling, and mechanical threshers. Of these the hampasan and trampling methods, either by man or animals, are more widely used although mechanical threshers are more popular in some areas. In the hampasan system the panicles are threshed by impact against a slotted board, pavement block, or piece of wood. The trampling method utilizes "rubbing action" for separating the grain from the panicle. The mechanical method of threshing utilizes impact and some stripping action to separate the grains from the panicle.

Cleaning

The prevalent grain cleaning method is winnowing. In this method, the removal of dockage such as straw, chaff, weed seeds, and other

foreign materials is accomplished by utilizing natural wind or manually operated blowers. In some instances, mechanical cleaning is integrated with threshing to fully utilize the power source, which is usually a 5–7 hp engine.

Mechanical cleaning is not very popular in the Philippines. Again, this is due to its high cost. A less expensive cleaner, which is locally manufactured, is the open double-layer oscillating sieve. It is directly driven through an eccentric drive from the main transmission shaft. The first sieve or perforated plate has large perforations. The overflow of this sieve is large impurities. The second sieve has small perforations, and its overflow is the precleaned paddy. The small impurities are discharged at the bottom. Other more expensive types of precleaners use an aspirator combined with the oscillating sieve or perforated rotating cylinders.

Drying

The most common grain drying method practiced in the Philippines is sun drying. Planting is usually timed so that the paddy will mature after the rainy season to permit sun drying.

Filipinos are accustomed to sun drying and possess ample skills in using it to the best advantage. Grains are spread on a flat dry surface, either on cement pavements or on bamboo mats, and occasionally stirred or raked so that the grain will dry uniformly. Some paddy is dried in shocks in the field.

There is, however, a great need for mechanical driers in the country today because of the introduction of new high-yielding, early maturing, and nonseasonal varieties. At present, there are no accurate figures on the number of driers and their capacity. The available statistics reveal that existing NGA driers and those leased to the private sector total only 66 units with a drying capacity of 526 t/day, which is very much below the required drying capacity.

Storing

The prevailing grain storage practice in the Philippines makes use of warehouses where the grain is stored in jute or plastic sacks. This method lends itself to segregation of different varieties but offers very little protection against storage pests. The sacks are susceptible to pest and rodent depredation and relatively fast container deterioration.

Two systems of piling stocks are utilized. One is the conventional stacking in which the bags are piled side by side and one on top of the other until the desired pile height is attained. In this system of piling there is no provision for ventilation space between bags. The other system, called the Japanese style, provides ventilation space between bags. This system of stacking the bags allows for the circulation of convective air currents that provide a medium for heat dissipation.

On a commercial scale, but to a lesser extent, bulk or open storage is practiced in the Philippines. In this storage practice, the grain is poured on the floor of the warehouse or into metal containers called silos. The former method of open storage is readily susceptible to attacks by storage pests and the latter storage structure cannot handle different varieties of grains.

Where the grain production and landholdings of the farmers are small, the method of storage uses bamboo mats. The bamboo mats are rolled into convenient sizes and are used as temporary or permanent storage receptacles. Other receptacles such as cans, barrels, boxes, woven bags, and earthenware are also used for temporary or permanent storage.

As a result of these antiquated and inadequate storage facilities in the country, we suffer from physical losses and deterioration of grain.

Milling

The rice milling equipment used in the Philippines can be classified loosely into: hand pounding equipment; Engleberg mills; cono mills; and rubber-roller mills. The first is still used in some parts of the Philippines. In this technique rough rice is dried and hand pounded in bundles (pongos) without passing through threshers.

A significant feature of the grain industry

in the Philippines is the use of a large number of Engleberg mills with capacities ranging from 15 to 50 cavans/day. The rice milling industry consists of far too many of these units, which are obsolete, poorly organized, and inefficient. It is estimated that the Engleberg mills process about 40% of the total annual paddy production. The majority of these Engleberg mills are widely distributed in rice producing and consuming areas, close to the source of raw materials and in close contact with the farmers. These mills are very wasteful. The milling recovery is very low (59% or less) and the value of the by-products is even lower. However, these mills require only a small capital outlay and are accessible in barrios, which justifies their popularity in the rural areas.

A more efficient under-runner disk huller rice mill coupled with whitening cones is popularly known in this country as a cono mill and is popular for commercial milling because of its capacity. Close to 3000 cono-type rice mills are in operation in the Philippines. Generally, most of these mills are produced locally. The capacity of these installations ranges from less than 100 to over 1000 cavans of rough rice per 12 h of operation. The distribution of these machines is still limited, but its performance is quite an improvement over the Engleberg type. Cono mills have a milling recovery of 65% or more by weight at second class milling degree.

The rubber-roller mill is already distributed in some parts of the country and has a milling recovery of over 69%. However, the problems with this type of mill are: (1) some units were installed in areas where the supply of paddy cannot meet the capacity; and (2) the cost of imported spare parts is high.

Marketing

Marketing of rice is open to any Filipino citizen who wishes to engage in the rice business. An individual may buy paddy, dry, mill, and sell the products at government regulated prices. The government establishes a floor price for paddy. If the price falls below the floor price the government, through the National Grains Authority, will procure paddy directly from the farmers to ensure a safe return of their investment. It is also a general rule that the NGA purchases 5–10% of the production to serve as a buffer stock for lean months. The ceiling price is designed to protect the consumers and at the same time give an incentive to the processors.

Price Stabilization Program

The NGA is geared to stabilize the price of grain both at the farmer's level and at the consumer's level. The government support price for paddy is 1.00 peso/kg, and the government ceiling price for milled rice is 1.90 peso/kg. The NGA has formulated a program of activities as follows: (1) massive procurement at the government support price; (2) distribution of buffer stocks at the regulated consumer's price; (3) utilization of the quedan system to facilitate the financing of more purchases and exchanges of grain inventories; and (4) establishment of a Grains Centre to serve both as a convenient clearing house for processing and distribution of grains and as a training centre.

Procurement Program

Every year there is a tremendous dollar drain out of the country for the procurement of foreign rice and corn to fill up production shortages and stabilize the consumer's price. It is for this reason that the government has set up a program to provide government funds for the massive procurement of paddy and corn at support prices to encourage farmers to produce more.

The procurement methods of the NGA are as follows: (1) direct procurement – NGA personnel will execute direct procurement operations; (2) procurement via Facomas and other Farmer Producers' Cooperatives — NGA will implement procurement operations by means of an agency tie-up with Facomas and other cooperatives, which can meet some qualifying requirements with respect to facilities, competence, and uprightness; (3) procurement through private warehousemen-millers — NGA will appoint private warehousemen-millers as agents to whom sufficient procure-

ment funds will be allocated without interest; and (4) procurement by means of quedans — establishment of a quedan system is among the main programs of the NGA.

Distribution Program

The distribution program requires careful planning because the Philippines is an archipelago of 7100 islands and there is a lack of transportation facilities. This is a major activity of the NGA that is vital in stabilizing the consumer's price for rice, especially during the lean months, July to September, when prices traditionally tend to increase beyond the reach of the great mass of the people. With these problems at hand, the NGA has set up a program of both short range and medium range activities.

Short Range

(1) Plan and implement the dispersal and distribution program prepared by the Directorate for Grains Economics.

(2) NGA shall move the stocks from unloading points to different warehouses in various provinces as soon as they are unloaded from vessels.

(3) Agency, branch, and regional offices shall conduct public biddings and/or scaled canvasses for the purpose of contracting integrated services.

(4) Screening committees shall be formed to carefully screen retailer-applicants and cooperatives wishing to retail NGA rice.

(5) Initiate supervision of the unloading and distribution of grains imported by the private sector.

Medium Range

(1) Study and promote a system of marketing utilizing the pattern of barrio councils (Samahang Nayon) and Area Marketing Cooperatives.

(2) Coordinate with the procurement division on the use of the quedan or warehouse receipt as a tool for grain distribution.

To ensure the success of the quedan program, the NGA has formulated new implementing policies: (1) to promote maximum participation and cooperation among all sectors involved in the grain industry, more specifically the financing; (2) to adopt rigid screening procedures in licensing bonded warehouses; and (3) to institute strict measures to control and supervise the system.

In addition to the above implementation policies the NGA has listed a program of activities: (1) to establish a rigid set of rules and regulations to govern the quedan system by April, 1973; (2) to prepare a uniform accounting system and record-keeping system in bonded warehouses, as prescribed by law, by March, 1973; (3) to furnish bonded warehouses with printed quedans in denominations prescribed by law, by July 1973; (4) to launch an information drive among all sectors involved in the grain industry stating the advantages and benefits of the quedan system starting April, 1973; and (5) to encourage the banking sector to engage in bonded warehousing.

Special Country Problems

The most important problems encountered by the Philippines in relation to rice production are related to infrastructure facilities required by the grain industry for self-sufficiency in food and feed grains.

Of utmost importance is the construction and maintenance of adequate irrigation facilities as a means of increasing the total effective area devoted to the production of lowland rice. Of the 3 200 000 ha cultivated in rice, only about 800 000 ha are irrigated during the rainy season and about 200 000 ha during the dry season. Considering that high production is possible only in irrigated areas, it is understandable that an increase in yield can only be attained where irrigation is sufficient. It can be assumed that all other modern inputs in production can be dispensed with and appreciable yields can still be obtained as long as there is irrigation. On the other hand, application of all other important inputs will be useless if there is insufficient irrigation.

The second problem is distribution of the produce from the rice field to the marketing centres. Out of 35 000 barrios in the Philip-

pines only 50% are accessible by feeder roads. This transportation problem results in a very low selling price in the production areas not easily accessible by land transportation. This acts as a disincentive to production in the rural areas.

What may be considered as a third major problem is lack of farm machinery suitable to the fragmented farms, a condition that prevents effective utilization of large and efficient farm machinery. Most of the small hand tractors marketed at present still require further improvements to be at par with the efficiency of dryland machinery.

The fourth problem is a lack of infrastructure facilities for drying and storage. Sun drying is still the most common method in practice, despite its unpredictability, because it is more economical. Mechanical driers are still too costly for the average Filipino farmer who has only 2.5–3 ha of riceland. This condition results in appreciable losses due to handling and storage and in low milling recovery and quality because of improper drying.

To rectify the adverse effects of these conditions, the Philippine government has embarked on a more aggressive program of infrastructure development. Irrigation systems, either by gravity or by pumps, are being built in cooperation with the private sector. Construction of new roads and improvement and repair of existing ones are pursued continuously. The manufacture of machinery suitable for small farms is being encouraged to improve grain facilities in strategic areas in the country. Continuous technical training to upgrade the quality of personnel involved in the grain industry has been included in the over-all program towards self-sufficiency in food and feed grains.

A National Grain Industries Development Authority has been created. This move is expected to promote efficiency in all sectors of the industry, which will lead towards self-sufficiency in food and feed grains and eventual participation in a grain export trade.

Current Developments

The creation of the National Grains Authority by virtue of Presidential Decree No. 4, which incorporated into one organization the functions of the defunct Rice and Corn Administration and the former Rice and Corn Board, is expected to strengthen and safeguard the stability of the grain industry in the Philippines.

Periodic evaluation of grain stocks is conducted to monitor and stabilize the relationship between supply and demand as a means of keeping grain prices above the cost of production but within reasonable reach of the ordinary consumers. Grain facilities are evaluated and monitored to promote better efficiency in grain handling and processing as a means of reducing losses in milled grain. Filipino inventions involving tractors and other farm implements, rice and corn mills, and driers and storage facilities adapted to unique Philippine conditions are being encouraged not only to improve both production and processing of grain products but also to generate more employment in manufacturing industries.

A study is underway to phase out the inefficient machines used for rice milling. This involves development, fabrication, evaluation, and production of more efficient types of rice mills for Philippine farms. A program for progressive conversion of conventional warehouses to bulk-storage facilities is contemplated, and feasibility studies are in preparation. A grain exchange scheme to prevent unnecessary movement of stocks as a means of ensuring sufficient supply in all areas during the lean months is being prepared to reduce losses resulting from transportation.

The present programs of the National Grains Authority for grain industry development are as follows: (1) construction of 45 provincial grain centres, nine regional centres, and one national centre that will have a complete line of postproduction machinery and facilities; (2) the construction of 10 conventional warehouses throughout the country; and (3) the rehabilitation, renovation, and/or transfer of the existing warehouses installed in different parts of the country. — ERNESTO TUBON AND JAVIER LOZADA, JR. *Technical Research and Services Division, National Grains Authority, Quezon Boulevard Extension, Quezon City, Philippines.*

Sri Lanka

According to the rainfall pattern of Sri Lanka, the cultivation year can be divided into two distinct seasons, namely, Maha and Yala. Cultivation during the Maha season takes place between October and March; whereas, the Yala cultivation is done between April and September. In Maha 460 000 ha are cultivated and in Yala 260 000 ha, therefore the yearly hectarage is 720 000. Harvesting of the Maha crop extends from January to April with a peak collection in March and April. Yala cultivation, which is done only with the help of supplementary irrigation, is harvested in July, August, and September. Although the bulk of the crop is harvested in August–September, there is no congestion in any place because the crop is not that large. But in the case of the Maha crop, a very large crop is obtained and to deal with the peak period of harvesting, a large storage space is required. Although the harvesting of paddy is concentrated in a very few months, the consumption of rice remains constant and, as a result, a large storage space is necessary to store the paddy until it is milled and marketed as rice.

The purchasing and milling of paddy in Sri Lanka is vested in a government organization known as the Paddy Marketing Board. The Paddy Marketing Board is the monopoly buyer of paddy as well as the sole authority in the milling and marketing of rice. There is a vast organization to execute the Board's functions, and in this the cooperative societies and private millers play a very important role. Paddy offered for sale is purchased by the various purchasing centres operated by the cooperative societies that act as agents of the Paddy Marketing Board. The stock of paddy thus purchased is kept in their godowns temporarily before it is delivered to the large stores owned by the Paddy Marketing Board. From these stores, quotas of paddy are issued to the Paddy Marketing Board mills and other private mills, which do the milling for the Board on a contract basis. From the private mills, rice is handed over to rice stores for storage prior to distribution to consumers.

There are about 4500 paddy purchasing centres scattered throughout the country, and these centres, which are managed by cooperative societies and a few cultivation committees, perform the important function of purchasing paddy from the farmers. The Government of Sri Lanka offers a guaranteed price for paddy, and this money is paid to the farmers at the time of acceptance of the paddy. For this purpose the Paddy Marketing Board has arranged the issue of loans to all authorized agents from a State Bank.

Certain conditions have been laid down by the Paddy Marketing Board for the procurement of paddy. All authorized agents who operate the paddy purchasing centres grade the paddy at the time it is purchased from the farmers. Dry paddy containing 1% or less extraneous matter is purchased according to the refraction. In areas where paddy is purchased by volume, a sliding scale of prices operates on the basis of percentage refraction such as 6, 7, 8, 9, 10, 11, and 12%. The highest price is payable to paddy having a refraction up to 6%. In areas where purchasing by weight is practiced, the paddy is divided into two groups according to refraction. Refraction of 1–6% receives the highest price, whereas the 7–12% refraction paddy receives a slightly lower price. Paddy is further graded according to the length and colour of the rice grain. "Madi" paddy includes paddy that gets damaged at harvesting as a result of heavy showers etc. Depending on the grading, varieties are further classified as unmixed and mixed. Pure or unmixed with a refraction of 6%, irrespective of the length of grain (whether long or short) and the colour of the rice grain (red or white), receives the highest price of 39 Sri Lanka cents per pound or US $134/t.

Paddy was purchased in all parts of Sri Lanka until 1971 by measuring with the bushel, which is approximately 20 kg of paddy. Purchasing by weight was introduced in eight districts in the latter part of 1972; in the remaining 14 districts purchasing by volume continues. The delay in the introduction of

the weight system is caused by the difficulty involved in supplying such a large consignment of weighing machines and the large expenditure that is involved.

Paddy produced in the country is stored in warehouses in gunny bags and, as a result, a large number of gunnies are required. The warehouses have not been constructed scientifically and as a result there is a wastage of grain. Grain is subject to damage by insects, rodents, and birds as well as to spoilage due to leaking roofs and seepage of water through the floor. Along with the establishment of the Paddy Marketing Board, due consideration has been given to this wastage and steps are being taken to correct the deficiencies. All this time, stacking has been done according to primitive practices, which do not provide adequate ventilation for the grain. Better methods of stacking are being introduced gradually so that the employees who are used to very old methods will not be confused as a result of the changes.

No dunnage has been provided to any of the stores, and this results in the spoilage of gunnies through the seepage of water from the floor. Storage of these bags for long periods results in the damage of grains as well. As the gunnies used for packing paddy are not produced locally, importation of gunnies is a drain on the country's foreign exchange. In this context, steps are being taken to provide wooden dunnage for the paddy stores to prevent this dual wastage. The high cost of supplying wooden dunnage has acted as an impediment to the provision of dunnage to the affected stores. Efforts are made to use local material such as cadjans, palmyrah leaves, and polyethylene sheets until wooden dunnage is provided.

The current storage capacity is around 16 million bushels, and as a result of the Green Revolution, the country faces an acute storage problem. As paddy offered for sale has to be stored somehow, the Paddy Marketing Board is using a system called "open storage" as a temporary measure during peak periods. This involves the storage of paddy in open air under polyethylene covers, which protect the grain from the weather. Under this system, the bags of paddy are subject to good ventilation when the polyethylene covers on the sides of the stacks are removed during favourable weather.

Although the purchasing of dry paddy at 14% moisture is anticipated, this would not happen at all times of the year. A crop of paddy that is to be harvested, if exposed to a series of showers, will not be at the ideal condition at the time of selling. Farmers do not have driers nor sufficient space to store the wet paddy and the moisture content will be very much more than 14% at the time of disposal. This happens very often in the case of the Yala crop as a result of late sowing of slow maturing paddy varieties. Even the Paddy Marketing Board store does not have any driers to dry paddy.

Milling of paddy is done by about 950 mills, most of which have a low capacity. The Paddy Marketing Board owns 19 large mills, which are larger than the other mills. The rest of the mills are privately owned but possess licenses issued by the Paddy Marketing Board. Some of the privately owned mills do milling exclusively for the Paddy Marketing Board. In such cases, paddy is issued to mills for milling on a hire basis. The transportation costs of paddy from the store to the mill and of rice from the mill to the rice store are borne by the Paddy Marketing Board.

The Paddy Marketing Board has fixed the quantity of rice required from the various grades of paddy. The highest outturn of 71% with 30% brokens and 3% bran removal is recovered from the grade one paddy that is issued for raw milling. The outturn fixed for grade two paddy is 70.5% for raw milling with the same degree of polish and brokens. In the case of parboiled rice a 71% outturn with 12% brokens and 4% bran removal is required for grade one paddy. For grade two paddy the outturn fixed by the Paddy Marketing Board is 70.5%.

The Paddy Marketing Board owns 19 rice mills: seven steel huller mills; four disc sheller mills, and eight rubber roll sheller mills. There are only three disc sheller mills owned by private millers. Mills that process parboiled rice possess steel hullers; whereas, mills that do raw milling usually possess rubber roll sheller mills. Milling of paddy in Sri Lanka is done in two ways. Paddy is either milled raw or

after parboiling. In the latter process paddy is soaked in water, steamed, and dried in the sun before milling. There is a consumer preference for raw milled rice in the southern part of the country, whereas the rest of the country prefers parboiled rice.

Parboiling is a cumbersome process but it has several advantages. Parboiling is done either by cold water soaking or hot water soaking. In the cold water soaking system, paddy is soaked in water for 3 days in large soaking tanks and subsequently steamed for about 30 min. The paddy is dried in the sun for a few days before it is milled. In the case of the hot water soaking system, the paddy is added to a tank of hot water having a temperature of about 70 °C, soaked for 2–3 h, and steamed for 20–30 min. The paddy is then dried in the sun for a few days, before milling. During cold water soaking, paddy tends to ferment and as a result a disagreeable odour is usually produced. Although this could be avoided by changing the water regularly, in areas where water is scarce the water is hardly changed, which increases bacterial fermentation. As a result of this, the processed parboiled rice often has a bad odour. However, the parboiling process has its use in salvaging much of the sun-cracked and Madi (or water-damaged) paddy that would otherwise produce a very high quantity of brokens.

The heat necessary for producing steam for the parboiling process is supplied by either burning firewood or husk. Most of the mills owned by the Paddy Marketing Board possess husk burners to produce the necessary heat for the parboiling process.

The current milling practice in Sri Lanka is largely centered around the Engleberg-type steel hullers. These work at a lower efficiency and require a large power input. A 0.75 t/h mill will need at least 33 kW (45 hp) to operate, while a modern mill of 2-t capacity would require only about 45 kW (60 hp). Most of the huller mills are locally manufactured and have a ravenous appetite for imported bearings. From these steel huller mills poor quality bran is obtained because of the mixing of husk and bran. Very often, the recovery of head rice is low as a result of the large number of brokens.

Although the country's paddy production has increased very rapidly in the past decade, no corresponding increase has been made in the storage and milling capacities. If the production of paddy is to reach 2 million tonnes in the future, rapid expansion of the storage and milling facilities is necessary. The milling capacity is just sufficient to meet the milling requirements during most parts of the year. During the peak period of March–April it is insufficient mainly due to poor distribution of the mills. A large number of the large privately owned mills are located in non-paddy-growing areas, which prevents the rapid milling of the existing stocks of paddy because of the need to transport the paddy from the producing area.

The Paddy Marketing Board is using bulk storage of paddy, and already the construction work for four storage-milling complexes has begun. Each complex will have a storage capacity of 9000 t, and to meet the future storage requirements more of these complexes may be erected. Bulk storage of paddy entails less operational cost, as compared to warehouse storage. The new mills that are to be installed in the complexes will be able to give a higher outturn of good quality rice. — B. D. E. M. Pereira and F. S. Y. Samuel. *Paddy Marketing Board, P.O. Box 205, Colombo 5, Sri Lanka.*

Thailand

Harvesting

Riceland in Thailand can be divided into four main parts: the Central Plain; the South; the North; and the Northeast. In the Central Plain, as well as in the North and the Northeast, farmers use similar harvesting techniques. They use a sickle to cut the rice stems, then tie the stems into bundles, which will yield about 10 kg of paddy grains each when promptly threshed. These bundles are normally lined up in the fields for a few days

before being moved to the threshing ground, so as to allow the moisture in the grains to evaporate a little before threshing.

The harvesting season in Thailand begins around late November or early December. When freshly harvested, paddy has a moisture content of approximately 20%. At threshing time it is preferable to have the moisture content at about 13–14%. In the Central area, the North, and the Northeast, threshing begins almost immediately after harvesting and before storing. However, farmers in the South employ a different technique. They cut the rice stem with a half-circle shaped knife that is locally called "kae." By using the knife instead of the sickle, farmers in the South have to cut the rice stems one by one. Obviously the sickle can do a much quicker job, but rice stems cut with "kae" are more even and are easier to store. Therefore, the Southern farmers tie the branched paddy into small bunches and store it unthreshed.

Threshing

In the North and South, a necessity in the threshing area is a huge, flat, round container made of bamboo sticks, which is widely known as "kra dong." In the North the paddy bundle to be threshed is placed securely between two pieces of wood that serve as a handle. The bundle is beaten against the "kra dong" so that the grains will come off the panicles. In the South, the branched paddy cut with a knife is too short to be threshed this way. Therefore, the Southern farmers place the bunches of paddy in the "kra dong" and thresh them with their feet. In the Central Plain and in the Northeast, farmers thresh their paddy on the ground. A dry, hard, and smooth area is chosen for the purpose. It is carefully cleared to get rid of every piece of sand, gravel, or stone. The farmers then coat the surface of the area with a mixture of buffalo dung and mud. This mixture cements the cracks in the ground and prevents the loss of paddy grains into these cracks. When the coated area is dry, the paddy bundles are beat against the ground. Some farmers let the buffaloes do the threshing by walking them over the paddy bundles. Small pickup trucks and tractors can also be used in a similar way. However, threshing with buffaloes, trucks, and tractors usually results in a greater loss of paddy grains because of grain cracking and dehusking. Therefore, threshing by human hands is still preferable to animal or mechanical threshing.

Cleaning

The most popular method is to put the paddy grains into a big deep container, toss the grains in the container up into the air, and let them fall on the prepared ground. The breeze will blow dirt and small foreign particles away from the rice grains. A big bamboo fan can be used to create air movement.

Another method widely used among farmers owning large quantities of paddy is cleaning with a locally made mechanical wind blower. The frame is made of teak wood, the blade is made of plywood, and the rotor as well as the other important parts are made of cast iron. An entire unit costs about US$30.

Drying

No special method has ever been used for drying paddy. Moist paddy is generally left to dry in the sun. In Thailand, where there is always strong sunshine during the postharvest season, farmers usually have no problem in getting the moisture of the paddy down to that of the air level. Unexpected rainfall during this season can be very dangerous. Paddy grains that are badly damaged by the rain are not stored but are sold to rice millers as quickly as possible because they have better equipment and facilities for drying paddy. Farmers, on the other hand, depend largely on the sun and the wind.

Storing

Most farmers sell their paddy before they have to store it. Usually in late September there is a great demand for new crops because

the crops of the previous year are running short. Middlemen travel with small trucks to the threshing grounds in different areas and buy paddy from the farmers right after threshing and cleaning. Of course there are some farmers who have a great deal of paddy and who are well-to-do enough to build good and safe storage facilities for their paddy. An average storage bin is made of wood, with a wooden floor raised a few feet from the ground and wooden walls, and has a galvanized iron roof. The storage capacity of each bin differs according to the economic status of the farmer and depending on the amount of paddy to be stored. An average bin can store approximately 7–10 kwiens (7–10 t).

Milling

In each village there usually is one small rice mill that mills only for local consumption. This kind of mill employs a very simple technique of dehusking and polishing using a very basic grinding stone without sifters or separators. Therefore, the milled rice is rough and broken, and a large number of husks are mixed with the bran. A medium sized mill employs a much better technique because the quality of the milled rice is emphasized, especially when the rice is sold to rice exporters. There are as many as twelve milling stones in this kind of mill for the purpose of dehusking and polishing alone. Big rice mills are also equipped with modern devices for sifting and separating. However, rice mills in Thailand still lack modern equipment and techniques. None of them is big or modern enough to accommodate a bran oil extractor. Bran released from all the mills is usually sold for animal feed or to oil extracting plants. According to a survey made by the Ministry of Industry, at the end of 1972 there were 38 494 rice mills in the kingdom. Only 125 mills have a daily milling capacity of 40 t or more; the rest are small and substandard.

Marketing

After milling, part of the rice is sold to wholesalers for distribution in the nearby markets and a small portion is sold directly to local consumers. A large portion of the rice is transported by barges and trucks to metropolitan areas.

Middlemen play a very important part in the rice market. There are hoarders who buy paddy from farmers in the early season and stock it until late in the season when rice supplies are decreasing and demands in foreign markets are increasing. Wholesalers buy rice from millers through the brokers. In the early season they buy a great amount and gradually distribute this to retailers as well as exporters. Retailers exist everywhere in the country. Small shops, big grocery stores, big cooperative stores, or even vendors of miscellaneous household goods and groceries can be rice retailers. Brokers also have an important part in rice marketing. They manage to quickly acquire the latest information on the current movements of price, both in the domestic markets and the world markets, and by advising millers, wholesalers, and exporters they have their own way of influencing, if not controlling, the price of the rice in the domestic market.

The amount of rice exported yearly from Thailand is about 1.2–1.6 million tonnes. Rice, therefore, has been and will remain the greatest source of income in Thailand.

Rice Breeding

The Thailand rice breeding program had its inception in 1950, under the late Dr H. H. Love. It primarily involved selection within indigenous varieties. In 1960, intensive work began on breeding for resistance to blast and in 1966 a formulation of breeding objectives and a vigorous hybridization program were begun. During the past 10 years, breeding for increased resistance to local diseases and insects has been emphasized. More recently, deep water rice, improved grain quality, and protein have been added to the breeding objectives.

The breeding program has resulted in the recent release of three dwarf, high-yielding varieties; a tall, stiff-strawed disease-resistant variety; and a semi-dwarf type capable of withstanding water depths of as much as 130 cm.

The breeding program has emphasized those objectives concerned with good grain quality, disease resistance, responsiveness to fertilizer, and wide adaption. This has been accelerated by the addition of grain quality laboratories for analysis of physical and chemical characteristics of the breeding lines and detailed cataloging of indigenous genetic stocks. Presently, 21 rice experiment stations participate in yield trials in addition to their own breeding work, which provides ample data for rapid evaluation of new breeding material.

The mutation work has shifted emphasis from treatment of tall, indigenous types that showed several defects to promising hybrid experimental lines that required improvement in only one or two major characteristics. Gamma rays, fast neurons, and chemical mutagens are being utilized to obtain the desired mutation.

Attacks by the tungro virus (known as yellow leaf in Thailand) from 1965 to 1966 and the concept of plant types fostered by the International Rice Research Institute caused a great change in the breeding program. New semi-dwarf types were used extensively in crosses with the tall, photoperiod sensitive, recommended Thai varieties in an effort to combine virus resistance and stiff straw with greater responsiveness to fertilizers.

Development of RD-1, RD-2, and RD-3

RD-1 and RD-3 were officially named and released in 1969. They were selected from the cross Leuang Tawng × IR8 by the pedigree method at Bangkhen Rice Experiment near Bangkok. Leuang Tawng, then the only nonphotoperiod sensitive variety recommended by the Rice Department, had hard, long, clear grains, but it was susceptible to lodging and diseases, such as blast and tungro virus. It was crossed with IR8 mainly to obtain lines similar to IR8 in plant type but with the long, slender, clear grain of Leuang Tawng. RD-1 and RD-3 are photoperiod insensitive, nonglutinous, resistant to tungro, have stiff straw, translucent grain, and mature in about 120–130 days. In yield trials conducted extensively throughout the country they consistently produced yields similar to those of IR8 at all levels of soil fertility.

RD-2 originated from a cross of Gam Pai-15 × Taichung Native-1 back-crossed to Gam Pai-15. Gam Pai-15 is a glutinous variety recommended for northeastern Thailand. The cross and initial selections were made at IRRI, but reselection within segregating F_4 and F_5 pedigree lines was made in Thailand and resulted in the identification of RD-2.

The performance of RD-1, RD-2, and RD-3 in yield trials under conditions of reasonably good soil fertility and water control suggests that, depending upon the cultural conditions, they can yield from 15 to 100% more than the conventional varieties.

Mechanization

Mechanized rice cultivation was initiated by the Engineering Division of the Rice Department 15 years ago. In 1957, the total tractor population for the cultivation of rice and other crops in Thailand was only 234, the majority being government owned. Since the Engineering Division implementation of the tractor contractor system in 1957 the purchase and use of tractors in Thailand has been increasing at a significant rate. From a total number of 234 tractors in 1957, there are now more than 80 000 units.

Development of the local farm equipment industry is also progressing at a significant rate. Besides imported agricultural machinery and implements, there are several types of farm machinery and implements that have been locally developed and produced for distribution by small workshops and large plants. This equipment is modified from imported materials and then redesigned for suitability to both the conditions and environment of each particular area in Thailand and the purchasing ability of the farmers with low financial standing.

Locally designed and manufactured farm machinery and implements are: (1) Different low-lift propeller pumps, driven by low horsepower engines and used for paddy field irrigation. The present annual production is 30 000 units. This type of pump was designed by the

Engineering Division 10 years ago; (2) Various sizes of puddling machines. These machines are of 7.5–11.2 kW (10–15 hp) and are used for soil preparation under wet field conditions. The present annual production is 2000 units; (3) Hand tractors (Iron Buffalo type) driven by 3.4–6.7 kW (4.5–9 hp) gasoline or diesel engines used for wet paddy soil preparation. Approximately 3000 units are manufactured annually; (4) A rice thresher designed by the Engineering Division as a mobile trailer unit, capable of threshing at a rate of 700 kg of cleaned paddy per hour; and (5) A centrifugal rice mill designed by the Engineering Division. Because the milling recovery is from 74 to 80%, pilot mills are being set up in farmers' cooperatives so that the farmers will receive higher returns of milled rice than what they now receive from local rice mills (45% recovery). Local manufacturers are now beginning to produce this new type of rice mill.

The current research and development activities in the Engineering Division are aimed at reducing the cost of rice to the minimum through complete use of machinery in all steps of rice production from irrigation, cultivation, harvesting, to milling.

Current Developments

Since the airplane has become an essential farm machine, it has made possible many of the cultural practices now used in the production of rice. The Engineering Division is now implementing a project by grouping together small farm holders into a single farm unit. For complete rice mechanization, heavy machinery, consisting of bulldozers, graders, and ditchers, has been bought and is now being used to implement the first stage of the project, land consolidation. For aerial seeding and fertilizing, airplanes from the Ministry of Agriculture are being used. The Government of New Zealand has given two Fletchers to this project. From Australia, a new type of airplane known as the Aritruck has been purchased, and is being used in this project for making artificial rain during the dry season.

This project is designed to assist the rice farmers in earning a higher annual income from rice as well as other crops. Therefore, this pilot project will be used for the various research programs designed to: (1) find the cost of remaking original farmers' land into productive irrigable land; (2) arrange crop diversification programs by the use of modern farm machinery and equipment, aerial seeding, fertilizing, and crop spraying to bring about the most efficient use of the land, resulting in the highest income for the farmers; (3) compare the cost of crop production and the income earned from such a project for the feasibility of expanding this program to other farming regions of Thailand; and (4) find out whether such a far-reaching project would be acceptable to the farmers as compared with their present method of farming.

This program is solely undertaken on the Ministry of Agriculture's own budget. The Engineering Division of the Rice Department is responsible for the implementation of this pilot project. Work is now being carried out following the various steps laid out and it is expected that this program will advance sufficiently so that enough facts and data will be available for the final evaluation. — CHAW SUVANSATIT AND PRAYOON SAWANGSAK. *516/19 Larnluang Road, Bangkok, Thailand, and College of Agriculture, Kasetsart University, Bangkok 9, Thailand, respectively.*

APPENDIX

Test Results

These results are from drying and milling tests conducted by the participants of a training course on postharvest technology. Because the conditions during the tests were not controlled or described, and the tests were not replicated and, therefore, give no measure of experimental error, the results must be used as presented and cannot be generalized. — D. B. DE PADUA. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

TABLE A1. Comparison of field losses (grains/m²) during combining and handcutting of paddy. The loss per square metre is the amount of grain collected from random metre-square areas of the rice field after harvesting (April 12, 1973, moisture content = 21%, yield = 6300 kg/ha).

	Harvest method	
	Handcutting	Combining
Group 1	157	1023
2	65	811
3	97	2192
4	78	679
5	82	1263
Mean	95.8	1194
Weight of 100 grains (g)	2.55	2.55
Loss per square metre (g)	2.45	30.50
Loss per hectare (kg)	24.5	305
Percentage loss	0.39	4.84

TABLE A2. Threshing evaluation using averages of the five class groups (April 11, 1973).

Type of threshing	Percentage of rice that is threshed	Head rice (%)	Large brokens (%)	Small brokens (%)	Moisture content (%)
Control	69.5	98.9	0.4	—	12.6
Hampasan[a]	67.1	97.9	1.7	0.3	12.3
Project thresher[b]	67.6	98.3	1.5	0.2	12.7
IRRI thresher[c]	69.3	97.7	1.5	0.2	12.8
Combine[d]	67.8	94.2	4.8	0.8	12.9

[a]The native hampasan, which is hand fed against the bamboo grid.
[b]The project thresher, which is a drum-type wire loop thresher.
[c]International Rice Research Institute table thresher.
[d]A Japanese manufactured harvesting and threshing combine.

TABLE A3. Evaluation of flat-bed grain drying by means of sample milling (April 12, 1973).

Sample type	Amount of paddy (g)	Amount of rice (g)	Head rice (%)	Large brokens (%)	Small brokens (%)	Average moisture content (%)	Average grain temperature during drying (°F)
Sun dried controls	1. 200	137.0	95.5	2.3	2.0		
	2. 200	139.7	96.5	3.5	—		
	3. 200	130.8	97.4	0.1	0.8	13.39	Room temperature
	4. 200	133.8	96.3	3.7	—		
	5. 200	130.2	97.0	2.7	0.2		
	Avg. 200	134.3	96.5	2.5	0.6		
Top of the grain layer	1. 200	135.1	96.8	1.5	1.7		
	2. 200	135.0	96.7	3.3	—		
	3. 200	135.2	96.6	2.8	—	14.86	91
	4. 200	132.7	97.4	2.6	—		
	5. 200	133.5	97.6	1.6	0.4		
	Avg. 200	134.3	97.2	2.8	0.4		
Centre of the grain layer	1. 200	139.0	96.3	0.9	2.2		
	2. 200	142.4	97.3	2.7	—		
	3. 200	133.8	97.2	2.5	—	12.32	99
	4. 200	135.3	97.5	2.0	0.5		
	5. 200	135.7	96.5	2.5	1.1		
	Avg. 200	137.2	96.6	2.1	0.7		
Bottom of the grain layer	1. 200	137.1	96.6	1.2	1.8		
	2. 200	140.4	97.1	2.9	—		
	3. 200	132.3	97.1	0.7	2.0	11.73	106
	4. 200	132.4	97.5	2.5	—		
	5. 200	139.1	96.6	2.3	1.0		
	Avg. 200	136.4	96.9	1.9	1.0		

TABLE A4. Drying gradient produced in a flat-bed drier for a 45.7-cm (18-inch) bed of grain dried at 43 °C (110 °F) for 2.5 h (April 11, 1973).

Group	Initial moisture content (%)	Moisture content after sun drying (%)	Moisture content after flat-bed drying (%)		
			Top	Centre	Bottom
1	16.73	13.56	15.38	12.54	12.00
2	16.97	13.08	14.76	12.00	11.46
3	15.96	12.75	14.91	12.00	11.46
4	16.48	14.18	14.44	12.83	12.29
5	16.78	13.37	14.81	12.21	11.46
Avg.	16.66	13.38	14.86	12.32	11.73

TABLE A5. The comparative test results of two commercial-scale milling operations.

	Locally made rice mill with one disc huller, and two whitening cones (very old)[a]	Satake rice mill with rubber roll huller, two abrasive and one friction type whitener (new)[b]
Weight of paddy (kg)	1000	1000
Weight of samples, etc. (kg)	6.36	16.59
Weight of paddy milled (kg)	993.64	983.41
Weight of milled rice (kg)	670.23	689.77
Weight of samples (kg)	10.63	14.44
Total weight of milled rice (kg)	680.86	704.21
Rice mill recovery (%)	68.52	71.6
Weight brewers' rice (kg), (% of paddy milled)	6.64, 0.67	6.41, 0.65
Weight coarse bran (kg), (% of paddy milled)	53.27, 5.36	20.5, 2.09
Weight fine bran (kg), (% of paddy milled)	40.09, 4.04	17.32, 1.76
Total weight bran (kg), (% of paddy milled)	93.36, 9.40	37.82, 3.85
Total milling time (min)	85	34
Capacity of rice mill (kg/h)	701	1735

[a]The rice mill was properly set for immediate production of semi-milled rice.
[b]The mill was not used for more than 1 year. It took about 20 min to adjust the mill, during which time a large quantity of under-milled rice was produced, which explains the too high recovery and too low bran production. The amount of paddy in the milled rice was too high.

Labour and Power

Labour and power requirements for rice harvesting and processing operations and the corresponding capital investment under Philippine conditions, 1975. Because the values are only approximations, the data must only be used for general comparisons. More detailed economic costing is required for specific case studies. — C. L. INTONG, JR. *Department of Agricultural Engineering, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines.*

Operation	Labour requirement or capacity[a]	Equipment rated-horsepower	Cost
I. Harvesting and Handling			
A. Manual			
1. Scythe reaping	34 man-h/ha		P3000–5000/1000 knives[b]
2. Cutting with sickle or knife	60–80 man-h/ha		
3. Ethiopian sickle	100–120 man-h/ha		
4. Hand harvesting with small knife	240 man-h/ha		
5. Cut, transport, and stack	80–160 man-h/ha		
6. Bundling	24 man-h/ha		
7. Handling	39 man-h/ha		
8. Carrying and stacking	25–45 man-h/ha		
9. Animal-drawn reaper	0.15–0.25 ha/h		
10. Reaper: 2-m cutter bar, 2 horses	0.6 ha/h		
B. Mechanical			
1. Windrower (cut and lay on ground)—1 man	5.4–10 man-h/ha	4–6 hp	
2. Tractor and binder		40–60 hp	P150 000
(a) Bind (2 men)	4 man-h/ha		
(b) Check (2 men)	8 man-h/ha		
(c) Haul (2 men)	2 man-h/ha		

(continued)

Labour and Power (*continued*)

Operation	Labour requirement or capacity[a]	Equipment rated-horsepower	Cost
3. Combine: Japanese, small			
(a) Single row—1.5-m wide cutter (1 man)	0.18 t/h		P5000–10 000
(b) Hand thresher (reaper) (2 men)	0.19 t/h		
(c) Regular type (miniaturized)	0.37 t/h		P10 000–20 000
4. Combine: USA and European	4–20 ha/h	50–200 hp	P150 000–400 000
(a) In the tropics (3–4 men)	3.2–21.5 man-h/ha		
(b) In the USA (2 men)	2.2–7.5 man-h/ha		
II. Threshing			
A. Manual			
1. Threshing flail	20–30 man-h/t		
2. Beating on bamboo frame	30–60 man-h/t		
3. Threshing with hand sticks	36 man-h/t		
4. Foot threshing by man	40 man-h/t		
5. Pedal thresher	80–100 man-h/t		
6. Trampling by ox	12–18 man-h/ha		
7. Treading by 2 bullocks	140 kg/h		
8. Treading: 3 animals and 3 men	490 kg/h		
B. Mechanical			
1. Treading with standard tractor	80 man-h/ha	40–80 hp	P40 000–100 000
(a) 2 threshing floors	620 kg/h		
(b) 3 threshing floors	960 kg/h		
(c) 4 threshing floors	1258 kg/h		
2. Japanese power thresher	48–197 kg/h	0.5–3 hp	P3000–10 000
3. National Institute of Agric. Eng. (England) thresher (5 men)	512 kg/h		
4. IRRI drum thresher	250 kg/h		
5. IRRI table thresher	350–400 kg/h		
6. IRRI axial flow thresher	1000 kg/h	7 hp	
7. IRRI PTO-thresher	2200 kg/h		
8. Large stationary thresher (McCormick type)	20–30 t/day		
III. Cleaning and Transporting			
A. Manual			
1. Winnowing basket	45 kg/h		P10 000–20 000 per 1000 baskets
2. Tossing in air	40 kg/h		
3. Chaff sieve	175–200 kg/h		
4. Winnowing sieve plus breeze	900 kg/h		
5. Hand fan in field	150 kg/h		
6. Hand-driven winnower	200–1700 kg/h		P500–1000
7. Carrying and stacking	25–45 man-h/ha		

(*continued*)

Labour and Power (*continued*)

Operation	Labour requirement or capacity[a]	Equipment rated-horsepower	Cost
8. Cut, transport, and stack	80–160 man-h/ha		
9. Loads on shoulders (40 kg)	120 loads/ha		
10. Loads on sledges (80 kg)	60 loads/ha		P100–200
11. Loads on ox carts (400 kg)	12 loads/ha		P300–500
12. Loads on hand-drawn carts —bicycle mounted (200 kg)	24 loads/ha		P200–300
B. Mechanical			
1. Cleaning fan mill	1.5–7 man-h/t		
2. Electric powered seed cleaner	600–700 kg/h	0.5–1 hp	P3000–5000
3. Electric powered precleaner	2–20 t/h	1–3 hp	P10 000–20 000
4. Electric powered aspirator	2–20 t/h	2–5 hp	P30 000–55 000
5. Electric powered belt conveyor (10 m)	2–20 t/h	1–5 hp	P5000–10 000
6. Electric powered bucket conveyor (10 m)	2–20 t/h	2–6 hp	P10 000–20 000
7. Electric powered screw conveyor (10 m)	2–20 t/h	3–9 hp	P15 000–30 000
8. Winch crane (1 man)	5–10 t capacity	2–5 hp	P3000–5000
9. Lift truck (1 man)	2–5 t capacity	30–60 hp	P30 000–60 000
10. Grain trucks (2 men)	5–10 t capacity	100–200 hp	P100 000–200 000
11. Tractor trailer (2 men)	3–7 t capacity	50–100 hp	P50 000–100 000
IV. Drying and Storage			
A. Manual (sun/sack)			
1. Sun drying on pavement	26.5 man-h/ha		
2. Sun drying on floor mats	35 man-h/ha		
3. Sack storage			
(a) Sacks (50 kg bag)	100 bags/ha		P2000–3000/1000 bags
(b) Building protection	1.5 m^3/t		P750–1000/ft^2 of building
B. Mechanical			
1. Manually loaded batch-type drier (2 t/8 h)	12–18 man-h/capacity	3–6 hp	P6000–10 000
2. Mechanically loaded batch-type drier (40 t/16 h)	6–9 man-h/capacity	10–25 hp	P200 000–750 000[c]
3. Columnar-type drier (2 t/h)	3–6 man-h/capacity	25–50 hp	P400 000–1 000 000[c]
4. Continuous flow drier (2 t/h)	3–6 man-h/capacity	30–75 hp	P500 000–1 500 000[c]
5. Bulk storage			
(a) Structure (silo and building)	500–3000 t/silo		Cost for 1300–6000 t silo P15 000–100 000
(b) Aeration equipment	1 or 2 men	10–30 hp	P30 000–150 000
(c) Fumigation requirement (usually part of aeration)	1 or 2 men	5–10 hp	
V. Milling and Storage			
A. Manual			
1. Asian treadle mortar	12–18 kg brown rice to 10–15 kg white rice/h		

(*concluded*)

Labour and Power (*concluded*).

Operation	Labour requirement or capacity[a]	Equipment rated-horsepower	Cost
2. African mortar and pestle	1 kg brown rice to 1 kg white rice in 4 h		
3. Sack storage			
(a) Sacks (50 kg)	67 sacks/ha		P2000–3000/1000 bags
(b) Building	1 m^3/t		P750–1000/ft^3 of building
B. Mechanical			
1. Kiskisan—complete mill	0.15–0.90 t/h	5–20 hp	P10 000–20 000
2. Cone-type mill—complete	0.25–1 t/h	15–140 hp	P40 000–250 000
3. Large cone-type mill—complete	2–10 t/h	150–1000 hp	P2 000 000–7 500 000
4. Rubber roll mill—complete	0.25–15 t/h	10–500 hp	P15 000
5. Bulk storage of brown rice			
(a) Structure	400–5000 t		
6. Parboiling			
(a) Conventional	4 t/h		Rs. 6.74/t (total cost of mill Rs. 610 000[d])
(b) Modern	4 t/h		Rs. 4.79/t (total cost of mill Rs. 740 000[d])

[a]1 ha = 1000 m^2 and yields approximately 5 t of paddy.
[b]7 pesos ≃ $1 (Canadian).
[c]Less conveyors and tempering bins.
[d]8 rupees ≃ $1 (Canadian).

Characteristics

Some Rice Varieties and Their Basic Characteristics

ADT-27. 1965. An *indica* × *japonica* hybrid of early maturity and height released by Madras State of India. Moderately responsive to nitrogen.

Apostol. A tall traditional variety of the Philippines that is sensitive to photoperiod.

Bahagia. 1968. A sister selection of IR5 released by West Malaysia. Intermediate in plant type and maturity.

BAM 3. A selection from a tall traditional variety. Released by the Orissa State of India.

Basmati 370. 1933. A selection from the Basmati variety of old India. Known for its aroma and kernel-elongation character. Late in maturity and low yielding. It commands a high market price in South Asia and East Africa.

Bengawan. 1941. Released by the Central Research Institute of Agriculture, Indonesia. It is a tall variety that is weakly sensitive to photoperiod and is noted for its good eating quality.

BPI-76. 1960. An intermediate variety developed by the Philippines Bureau of Plant Industry. It is strongly sensitive to photoperiod.

C4-137. 1969. An intermediately tall variety released by the University of the Philippines College of Agriculture. It is weakly sensitive to photoperiod.

C4-63. 1967. An intermediately tall variety developed by the University of the Philippines College of Agriculture. It is weakly sensitive to photoperiod and is noted for its good eating quality.

C4-63G. *ca.* 1968. A pure line selected from C4-63 having green basal leaf-sheath (green base).

C0-29. *ca.* 1960. A hybrid variety of Madras State (India) having early maturity and blast resistance. Moderately tall in stature.

C0-33. *ca.* 1970. A semidwarf variety of Madras State (India) originating from IR8 × ADT-27. Also known as Karuma. Early maturing and responsive to nitrogen.

Dara. 1960. A tall variety released by the Central Research Institute of Agriculture, Indonesia. It is relatively insensitive to photoperiod.

Dee-geo-woo-gen. A semidwarf variety of Taiwan. Insensitive to photoperiod. Taichung Native 1, IR8, and many semidwarf lines were derived from Dee-geo-woo-gen.

GEB-24. *ca.* 1930. A spontaneous mutant selected from a traditional variety of Madras State. It has good grain quality and became the parent of many Indian varieties. 150 day maturity.

Intan. 1940. A tall variety released by the Central Research Institute of Agriculture, Indonesia, but is also known in the Philippines. It is weakly sensitive to photoperiod.

IR8. 1966. A semidwarf variety. It is the first variety named by the International Rice Research Institute (IRRI). It is relatively insensitive to photoperiod; outstanding in nitrogen response. It has poor grain type.

IR5. 1967. Developed at IRRI. It is intermediate in height and weakly sensitive to photoperiod. It has poor grain type.

IR20. 1969. A semidwarf named by IRRI. It is weakly sensitive to photoperiod.

IR22. 1969. A semidwarf named by IRRI. It is weakly sensitive to photoperiod.

IR6. 1970. The name given to IR6-156-2 before it was named as Mehran 69 in Pakistan.

IR24. 1971. A semidwarf name by IRRI. It is relatively insensitive to photoperiod.

Jaya. 1968. A semidwarf variety released by the All-India Coordinated Rice Improvement Project. It is relatively insensitive to photoperiod. It has poor grain type.

Jhona 349. 1933. A selection from Jhona, a traditional variety of the Punjab area (India and Pakistan). It has a higher yielding ability than other local varieties but is poor in grain quality.

Karuma. see C0-33.

Kullakar. A 130 day traditional variety from which ADT-27 was isolated. Native to Madras State of India.

Malinja. 1964. A moderately tall and relatively early maturing (though sensitive to photoperiod) hybrid developed in Malaysia.

Mashuri. 1966. An intermediate variety released by the Rice Department of Malaysia. It is relatively insensitive to photoperiod and is prized for its fine grains.

Mayang Ebos. A tall and late traditional variety of Malaysia that has very strong grain dormancy. Sensitive to photoperiod.

Mehran 69. 1970. A semidwarf, long-grain selection from IR6-156-2 released in Pakistan.

Palman 246. 1939. A selection from Palman, a traditional variety of the Punjab area (India and Pakistan). It has good-looking grains but poor cooking quality.

PB5 (Peta Baru 5). Indonesian name for IR5.

PB8 (Peta Baru 8). Indonesian name for IR8.

Pebifun. A relatively early, moderately tall, *indica* variety of Taiwan. A major variety grown in the double-cropping area of West Malaysia during 1942–1964.

Pelita. 1971. Released by the Central Research Institute of Agriculture, Indonesia. It is weakly sensitive to photoperiod.

Peta. 1941. A tall variety released by the Central Research Institute of Agriculture, Indonesia, but is also grown in the Philippines. It is weakly sensitive to photoperiod.

Ratna. 1970. A semidwarf variety released by the Central Rice Research Institute, India. It is weakly sensitive to photoperiod and is noted for its high grain quality.

RD-1. 1969. A Thai semidwarf variety. It was the first hybrid variety named by the Rice Department (now Rice Division).

RD-3. 1969. A Thai semidwarf variety. Similar to RD-1, it is also nonglutinous.

RD-5. 1973. A moderately tall Thai hybrid variety having a plant type intermediate between the tall traditional type and the semidwarf. Weakly sensitive to photoperiod.

Ramadja. 1954. A tall variety released by the Central Research Institute of Agriculture, Indonesia. It is weakly sensitive to photoperiod.

Ria. 1966. IR8 under a Malaysian name.

Rojolele. A tall traditional variety of the bulu type: purified from a farmer's variety. It is relatively insensitive to photoperiod.

Siam 29. A tall traditional variety that is sensitive to photoperiod. Both Malaysian and Thai strains have the same name.

Sigadis. 1954. A tall variety developed by the Central Research Institute of Agriculture, Indonesia. It is relatively insensitive to photoperiod.

SLO-13. *ca.* 1950. An intermediately tall strain selected from a traditional variety. Developed in Andhra Pradesh, India.

Syntha. 1963. A tall variety developed by the Central Research Institute of Agriculture, Indonesia. It is weakly sensitive to photoperiod.

Taichung 65. 1927. A *ponlai* (*japonica*) variety of Taiwan that is well adapted to double cropping in the subtropics and tropics.

Taichung Native 1. 1960. The first semidwarf variety released by the Taiwan Provincial Department of Agriculture. It is relatively insensitive to photoperiod.

Tangkai Rota. A traditional variety of Malaysia having relatively erect leaves, intermediate height and maturity. A parent of IR5.

Tjeremas. *ca.* 1940. A tall variety developed in Indonesia that has the same parents as Peta. It is also grown in the Philippines. It is weakly sensitive to photoperiod.

TKM-6. *ca.* 1950. A relatively early and tall hybrid derived from GEB-24 × CO-18. It has slender grains and moderate resistance to stemborers. Developed in Madras State, India.

Characteristics of present Philippine Seedboard recommended lowland rice varieties

Characteristics	BPI-76(NS)	C4-63G	C4-137	IR8	IR5	IR20	FK-178A	IR22
Plant								
Maturity (days)	125–135	125–135	130–140	125–135	140–150	120–130	120–150	115–130
Photoperiod reaction	nonsensitive	nonsensitive	nonsensitive	nonsensitive	nonsensitive	weakly sensitive	sensitive	weakly sensitive
Height	medium	medium	medium	short	medium	short	tall	short
Lodging	moderately resistant	resistant	resistant	highly resistant	resistant	moderately resistant	moderately resistant	resistant
Tillering ability	medium high	medium high	medium high	high	high	high	medium low	high
Position of leaves at harvest	slightly drooping	semierect	semierect	erect	semierect	erect	drooping	erect
Blast disease	moderately resistant	moderately resistant	moderately resistant	resistant	intermediate	resistant	resistant	resistant
Bacterial leaf blight	intermediate	intermediate	moderately susceptible	intermediate	intermediate	intermediate	moderately resistant	moderately resistant
Tungro virus	intermediate	resistant	resistant	susceptible	intermediate	resistant	intermediate	susceptible
Grain								
Threshing characteristic	medium	easy	easy	easy	easy	medium	medium	medium
Head rice recovery	intermediate	high	high	high	low	high	high	high
Grain dormancy (weeks)	4	4	4	3	4	4	—	3
Grain type	medium, bold	long, slender	long, slender	long, bold	long, bold	medium, bold	long, bold	long, slender
Amylose content	intermediate	intermediate	high	high	high	high	—	high
Gelatinization temperature	intermediate	intermediate	intermediate	low	intermediate	intermediate	—	low
Eating quality	very good	excellent	very good	fair	good	good	very good	good

Characteristics	IR24	BPI 121-407	C12	BPI 3-2	PARC 2	C168	IR26	IR29
Plant								
Maturity (days)	125–130	125–130	125–135	125–129	123–128	126–131	116–125	115
Photoperiod reaction	nonsensitive	nonsensitive	nonsensitive	nonsensitive	nonsensitive	nonsensitive	nonsensitive	nonsensitive
Height	short	short	medium	medium	short	medium	short	short
Lodging	resistant	resistant	moderately resistant	resistant	resistant	resistant	resistant	moderately resistant
Tillering ability	high	high	medium high	medium high	medium high	medium high	medium high	high
Position of leaves at harvest	erect	erect	slightly drooping	drooping	erect	erect	erect	—
Blast disease	resistant	moderately resistant	moderately resistant	intermediate	intermediately resistant	intermediately resistant	—	resistant
Bacterial leaf blight	intermediate	moderately resistant	intermediate	intermediately resistant	intermediately susceptible	intermediately susceptible	intermediately susceptible	resistant
Tungro virus	intermediate	intermediate						resistant
Grain								
Threshing characteristic	medium	medium	medium	medium	—	medium	medium	—
Head rice recovery	high	high	high	high	intermediate	high	high	high
Grain dormancy (weeks)	4	4	4	4	—	4	4	4
Grain type	long, slender	long, slender	long, bold	medium, slender	—	long, slender	—	medium, slender
Amylose content	low	intermediate	intermediate	intermediate	intermediately high	intermediate	low	—
Gelatinization temperature	—	—	intermediate	—	—	—	—	low
Eating quality	very good	very good	very good	very good	—	very good	good	—

Equilibrium moisture content of rough rice

The hygroscopic equilibrium moisture content of rough rice at various temperatures and moisture contents. These values can be superimposed on a psychrometric chart to show the approximate variation of the equilibrium moisture content of the grain corresponding to the specific temperature and relative humidity of the atmosphere (from Huston 1972).[a]

% moisture (wb)	Equilibrium relative humidity (%) at the following temperatures, °F																							
	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
1	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.7	0.8	1.1	1.3	1.7	2.0	2.5	3.1	3.8	4.6	5.6	6.8	8.2	9.8	11.7	14.0
2	0.3	0.4	0.5	0.6	0.7	0.9	1.1	1.3	1.6	1.9	2.3	2.8	3.3	4.0	4.7	5.6	6.6	7.7	9.0	10.5	12.2	14.2	16.4	18.9
3	0.9	1.1	1.3	1.5	1.8	2.1	2.5	2.9	3.4	3.9	4.5	5.3	6.1	7.0	8.0	9.2	10.4	11.9	13.5	15.3	17.2	19.4	21.9	24.5
4	2.1	2.5	2.8	3.3	3.7	4.3	4.8	5.5	6.2	7.0	7.9	8.9	10.0	11.2	12.5	13.9	15.5	17.2	19.0	21.0	23.2	25.5	28.0	30.7
5	4.4	5.0	5.5	6.2	6.9	7.7	8.5	9.4	10.4	11.5	12.6	13.9	15.2	16.6	18.2	19.8	21.6	23.4	25.4	27.5	29.8	32.1	34.6	37.3
6	8.1	8.8	9.7	10.6	11.5	12.5	13.6	14.8	16.0	17.3	18.6	20.1	21.6	23.2	24.9	26.6	28.5	30.4	32.4	34.6	36.8	39.1	41.5	44.0
7	13.2	14.2	15.3	16.4	17.5	18.7	20.0	21.3	22.7	24.2	25.7	27.2	28.8	30.5	32.2	34.0	35.9	37.8	39.8	41.9	44.0	46.1	48.4	50.7
8	19.8	21.0	22.2	23.5	24.8	26.1	27.5	28.9	30.4	31.9	33.4	35.0	36.6	38.3	40.0	41.8	43.5	45.4	47.2	49.1	51.1	53.1	55.1	57.1
9	27.6	28.8	30.1	31.5	32.8	34.2	35.6	37.1	38.5	40.0	41.5	43.1	44.6	46.2	47.8	49.4	51.1	52.8	54.5	56.2	57.9	59.6	61.4	63.2
10	36.0	37.3	38.6	40.0	41.3	42.6	44.0	45.4	46.8	48.2	49.6	51.0	52.4	53.9	55.3	56.8	58.3	59.8	61.2	62.7	64.2	65.8	67.3	68.8
11	44.7	46.0	47.2	48.5	49.7	51.0	52.2	53.5	54.8	56.0	57.3	58.6	59.8	61.1	62.4	63.7	64.9	66.2	67.5	68.8	70.0	71.3	72.6	73.8
12	53.2	54.4	55.5	56.6	57.7	58.9	60.0	61.1	62.2	63.3	64.4	65.5	66.6	67.7	68.8	69.8	70.9	72.0	73.1	74.1	75.2	76.2	77.3	78.3
13	61.2	62.2	63.1	64.1	65.1	66.0	67.0	68.0	68.9	69.8	70.8	71.7	72.6	73.5	74.4	75.3	76.2	77.1	77.9	78.8	79.7	80.5	81.3	82.2
14	68.3	69.1	70.0	70.8	71.6	72.4	73.2	74.0	74.8	75.6	76.3	77.1	77.8	78.6	79.3	80.0	80.7	81.4	82.1	82.8	83.5	84.2	84.9	85.5
15	74.5	75.2	75.9	76.6	77.2	77.9	78.6	79.2	79.8	80.4	81.1	81.7	82.3	82.9	83.4	84.0	84.6	85.1	85.7	86.2	86.8	87.3	87.8	88.3
16	79.8	80.4	80.9	81.5	82.0	82.5	83.0	83.5	84.0	84.5	85.0	85.5	86.0	86.4	86.9	87.3	87.8	88.2	88.6	89.1	89.5	89.9	90.3	90.7
17	84.2	84.7	85.1	85.5	85.9	86.3	86.7	87.1	87.5	87.9	88.3	88.7	89.0	89.4	89.7	90.1	90.4	90.8	91.1	91.4	91.7	92.0	92.3	92.7
18	87.8	88.2	88.5	88.8	89.1	89.4	89.8	90.1	90.4	90.6	90.9	91.2	91.5	91.8	92.0	92.3	92.6	92.8	93.1	93.3	93.5	93.8	94.0	94.2
19	90.7	91.0	91.2	91.5	91.7	91.9	92.2	92.4	92.6	92.8	93.1	93.3	93.5	93.7	93.9	94.1	94.3	94.5	94.6	94.8	95.0	95.2	95.4	95.5
20	93.0	93.2	93.3	93.5	93.7	93.9	94.1	94.2	94.4	94.6	94.7	94.9	95.0	95.2	95.3	95.5	95.6	95.8	95.9	96.0	96.2	96.3	96.4	96.6
21	94.7	94.9	95.0	95.2	95.3	95.4	95.5	95.7	95.8	95.9	96.0	96.1	96.3	96.4	96.5	96.6	96.7	96.8	96.9	97.0	97.1	97.2	97.3	97.4
22	96.1	96.2	96.3	96.4	96.5	96.6	96.7	96.8	96.9	97.0	97.0	97.1	97.2	97.3	97.4	97.4	97.5	97.6	97.7	97.7	97.8	97.9	97.9	98.0
23	97.1	97.2	97.3	97.4	97.4	97.5	97.6	97.6	97.7	97.7	97.8	97.9	97.9	98.0	98.0	98.1	98.2	98.2	98.3	98.3	98.4	98.4	98.5	98.5
24	97.9	98.0	98.0	98.1	98.1	98.2	98.2	98.3	98.3	98.4	98.4	98.4	98.5	98.5	98.6	98.6	98.6	98.7	98.7	98.7	98.8	98.8	98.9	98.9
25	98.5	98.5	98.6	98.6	98.6	98.7	98.7	98.7	98.8	98.8	98.8	98.9	98.9	98.9	99.0	99.0	99.0	99.0	99.1	99.1	99.1	99.1	99.2	99.2

[a]Courtesy of Wratten and Kendrick (1970). Extrapolated data by Hogan and Karon (1955), and Karon and Adams (1949). Equation by Strohman and Yoeger (1967). Accuracy of extrapolated data beyond the range of 77 to 111 °F has not been verified experimentally.

Physical characteristics of the rice grain[a]

Bulk density	576 kg/m³ (36 lb/ft³)	Dielectric constant (frequency, 10–40 mc/s)	
Air velocity for conveying seed	15–25 m/s (3000–5000 fpm)[b]	10% moisture	3.8
		16% moisture	3.8
Voids, air space	48%	19% moisture	4.3
Kernel specific gravity	1.11	Specific heat	
Angle of repose	36 degrees	15% moisture	0.42 g-cal/g-deg C (0.42 BTU/lb-deg F)
Coefficient of friction			
Smooth steel	0.41	22% moisture	0.52 g-cal/g-deg C (0.52 BTU/lb-deg F)
Finished concrete	0.52		
Smooth wood	0.44		

[a]Taken in part from Hall 1957.
[b]Salisbury 1950.

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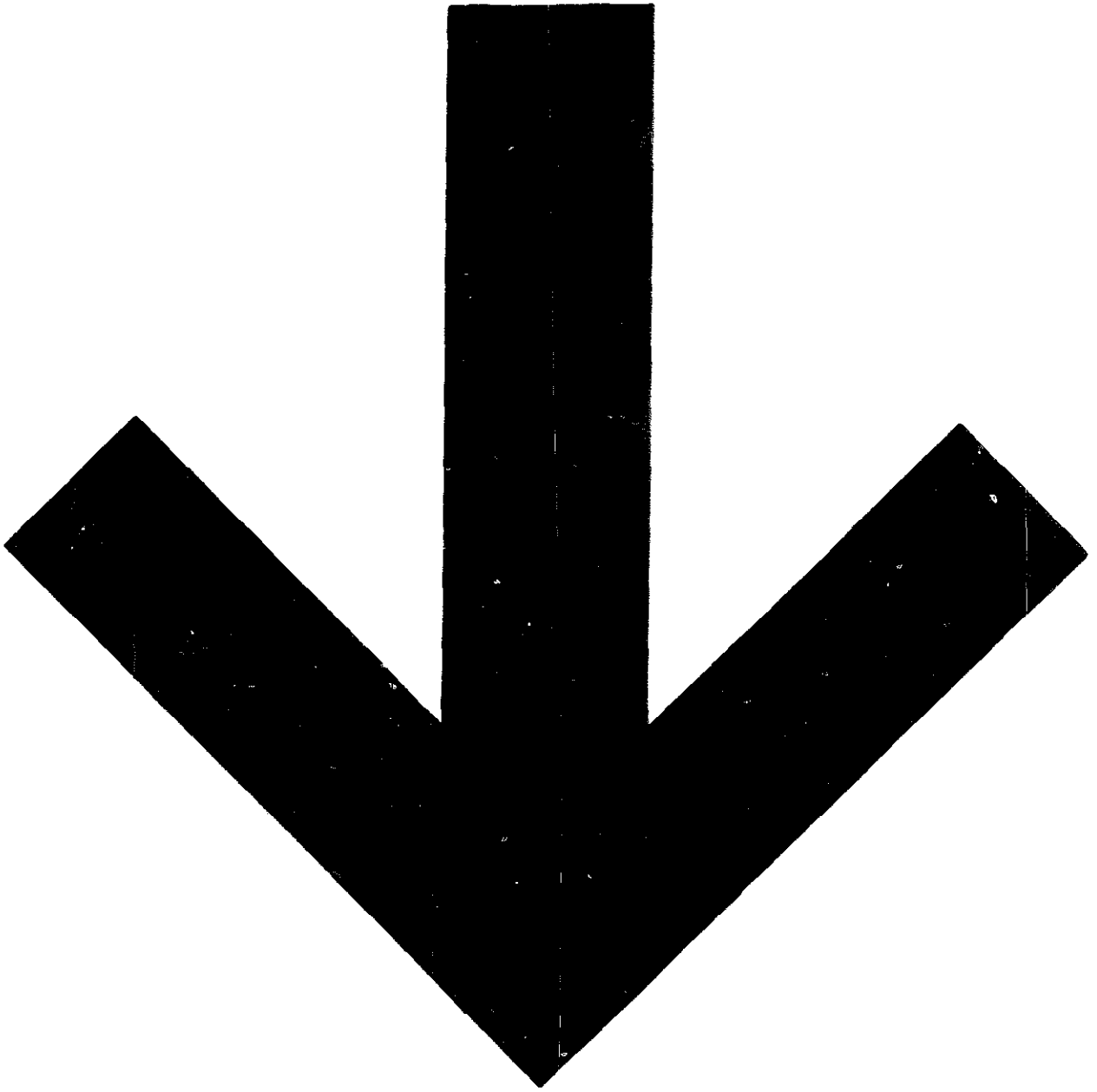

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Rice

From Wikipedia, the free encyclopedia

Rice is the seed of the grass species *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. It is the agricultural commodity with the third-highest worldwide production, after sugarcane and maize, according to 2012 FAOSTAT data.[1]

A mixture of brown, white, and red indica rice, also containing wild rice, *Zizania* species

Since a large portion of maize crops are grown for purposes other than human consumption, rice is the most important grain with regard to human nutrition and caloric intake, providing more than one-fifth of the calories consumed worldwide by humans.[2]

Wild rice, from which the crop was developed, may have its native range in Australia.[3] Chinese legends attribute the domestication of rice to Shennong, the legendary emperor of China and inventor of Chinese agriculture.[4] Genetic evidence has shown that rice originates from a single domestication 8,200–13,500 years ago[5] in the Pearl River valley region of Ancient China.[6] Previously, archaeological evidence had suggested that rice was domesticated in the Yangtze River valley region in China.[5]

From East Asia, rice was spread to Southeast and South Asia.[6] Rice was introduced to Europe through Western Asia, and to the Americas through European colonization.

Oryza sativa with small wind-pollinated flowers

There are many varieties of rice and culinary preferences tend to vary regionally. In some areas such as the Far East or Spain, there is a preference for softer and stickier varieties.

Rice, a monocot, is normally grown as an annual plant, although in tropical areas it can survive as a perennial and can produce a ratoon crop for up to 30 years.[7] The rice plant can grow to 1–1.8 m (3.3–5.9 ft) tall, occasionally more depending on the variety and soil fertility. It has long, slender leaves 50–100 cm (20–39 in) long and 2–2.5 cm (0.79–0.98 in) broad. The small wind-pollinated flowers are produced in a branched arching to pendulous inflorescence 30–50 cm (12–20 in) long. The edible seed is a grain (caryopsis) 5–12 mm (0.20–0.47 in) long and 2–3 mm (0.079–0.118 in) thick.

Rice cultivation is well-suited to countries and regions with low labor costs and high rainfall, as it is labor-intensive to cultivate and requires ample water. However, rice can be grown practically anywhere, even on a steep hill or mountain area with the use of water-controlling terrace systems. Although its parent species are native to Asia and certain parts of Africa, centuries of trade and exportation have made it commonplace in many cultures worldwide.

The traditional method for cultivating rice is flooding the fields while, or after, setting the young seedlings. This simple method requires sound planning and servicing of the water damming and channeling, but reduces the growth of less robust weed and pest plants that have no submerged growth state, and deters vermin. While flooding is not mandatory for the cultivation of rice, all other methods of irrigation require higher effort in weed and pest control during growth periods and a different approach for fertilizing the soil.

Cooked brown rice from Bhutan

The name wild rice is usually used for species of the genera *Zizania* and *Porteresia*, both wild and domesticated, although the term may also be used for primitive or uncultivated varieties of *Oryza*.

Rice can come in many shapes, colours and sizes. Photo by the IRRI.

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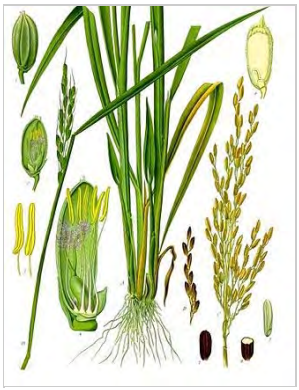

Oryza sativa, commonly known as Asian rice

Etymology

First used in English in the middle of the 13th century, the word "rice" derives from the Old French *ris*, which comes from Italian *riso*, in turn from the Latin *oriza*, which derives from the Greek ὄρυζα (*oruza*). The Greek word is the source of all European words (cf. Welsh *reis*, German *Reis*, Lithuanian *ryžiai*, Serbo-Croatian *riža*, Polish *ryż*, Dutch *rijst*, Hungarian *rizs*, Romanian *orez*, Portuguese *arroz*).[8][9][10]

The origin of the Greek word is unclear. It is sometimes held to be from the Tamil word அரிசி (*arisi*), or rather Old Tamil *arici*.[11][12] However, Krishnamurti[13] disagrees with the notion that Old Tamil *arici* is the source of the Greek term, and proposes that it was borrowed from descendants of Proto-Dravidian **wariñci* instead. Mayrhofer[14] suggests that the immediate source of the Greek word is to be sought in Old Iranian words of the types **vrīz-* or **vrinj-* (Source of the modern Persian word *Berenj*), but these are ultimately traced back to Indo-Aryan (as in Sanskrit *vrīhí-*) and subsequently to Dravidian by Witzel and others.

Cooking

The varieties of rice are typically classified as long-, medium-, and short-grained.[15] The grains of long-grain rice (high in amylose) tend to remain intact after cooking; medium-grain rice (high in amylopectin) becomes more sticky. Medium-grain rice is used for sweet dishes, for *risotto* in Italy, and many rice dishes, such as *arròs negre*, in Spain. Some varieties of long-grain rice that are high in amylopectin, known as Thai Sticky rice, are usually steamed.[16] A stickier medium-grain rice is used for *sushi*; the stickiness allows rice to hold its shape when molded. Short-grain rice is often used for rice pudding.

tteumul, water from the washing of rice

Instant rice differs from parboiled rice in that it is fully cooked and then dried, though there is a significant degradation in taste and texture. Rice flour and starch often are used in batters and breadings to increase crispiness.

Preparation

Rice is typically rinsed before cooking to remove excess starch. Rice produced in the US is usually fortified with vitamins and minerals, and rinsing will result in a loss of nutrients. Rice may be rinsed repeatedly until the rinse water is clear to improve the texture and taste.

Rice may be soaked to decrease cooking time, conserve fuel, minimize exposure to high temperature, and reduce stickiness. For some varieties, soaking improves the texture of the cooked rice by increasing expansion of the grains. Rice may be soaked for 30 minutes up to several hours.

Brown rice may be soaked in warm water for 20 hours to stimulate germination. This process, called germinated brown rice (GBR),[17] activates enzymes and enhances

amino acids including gamma-aminobutyric acid to improve the nutritional value of brown rice. This method is a result of research carried out for the United Nations International Year of Rice.

Processing

Rice is cooked by boiling or steaming, and absorbs water during cooking. With the absorption method, rice may be cooked in a volume of water similar to the volume of rice. With the rapid-boil method, rice may be cooked in a large quantity of water which is drained before serving. Rapid-boil preparation is not desirable with enriched rice, as much of the enrichment additives are lost when the water is discarded. Electric rice cookers, popular in Asia and Latin America, simplify the process of cooking rice. Rice (or any other grain) is sometimes quickly fried in oil or fat before boiling (for example saffron rice or risotto); this makes the cooked rice less sticky, and is a cooking style commonly called pilaf in Iran and Afghanistan or biryani (Dam-pukhtak) in India and Pakistan.

Dishes

In Arab cuisine, rice is an ingredient of many soups and dishes with fish, poultry, and other types of meat. It is also used to stuff vegetables or is wrapped in grape leaves (dolma). When combined with milk, sugar, and honey, it is used to make desserts. In some regions, such as Tabaristan, bread is made using rice flour. Medieval Islamic texts spoke of medical uses for the plant.[18] Rice may also be made into congee (also called rice porridge, fawrclaab, okayu, Xifan, jook, or rice gruel) by adding more water than usual, so that the cooked rice is saturated with water, usually to the point that it disintegrates. Rice porridge is commonly eaten as a breakfast food, and is also a traditional food for the sick.

Milled to unmilled rice, from left to right, white rice *(Japanese rice)*, rice with germ, brown rice

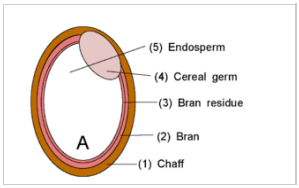

A: Rice with chaff
B: Brown rice
C: Rice with germ
D: White rice with bran residue
E: Musenmai (Japanese: 無洗米), "Polished and ready to boil rice", literally, non-wash rice
(1): Chaff
(2): Bran
(3): Bran residue
(4): Cereal germ
(5): Endosperm

Nutrition and health

Importance

Rice is the staple food of over half the world's population. It is the predominant dietary energy source for 17 countries in Asia and the Pacific, 9 countries in North and South America and 8 countries in Africa. Rice provides 20% of the world's dietary energy supply, while wheat supplies 19% and maize (corn) 5%.[19]

A detailed analysis of nutrient content of rice suggests that the nutrition value of rice varies based on a number of factors. It depends on the strain of rice, that is between white, brown, red, and black (or purple) varieties of rice – each prevalent in different parts of the world. It also depends on nutrient quality of the soil rice is grown in, whether and how the rice is polished or processed, the manner it is enriched, and how it is prepared before consumption.[20]

An illustrative comparison between white and brown rice of protein quality, mineral and vitamin quality, carbohydrate and fat quality suggests that neither is a complete nutrition source. Between the two, there is a significant difference in fiber content and minor differences in other nutrients.[21]

Comparison to other major staple foods

Rice, white, long-grain, regular, unenriched, cooked without salt

Nutritional value per 100 g (3.5 oz)

Energy	130 kcal (540 kJ)	
Carbohydrates	28.1 g	
Sugars	0.05 g	
Dietary fiber	0.4 g	
Fat	0.28 g	
Protein	2.69 g	
Vitamins		
Thiamine (B_1)	0.02 mg	(2%)
Riboflavin (B_2)	0.013 mg	(1%)
Niacin (B_3)	0.4 mg	(3%)
Pantothenic acid (B_5)	0 mg	(0%)
Vitamin B_6	0.093 mg	(7%)
Minerals		
Calcium	10 mg	(1%)
Iron	0.2 mg	(2%)
Magnesium	12 mg	(3%)
Manganese	0 mg	(0%)
Phosphorus	43 mg	(6%)
Potassium	35 mg	(1%)
Sodium	1 mg	(0%)
Zinc	0.049 mg	(1%)
Other constituents		
Water	68.44 g	

Link to USDA Database entry (https://ndb.nal.usda.gov/ndb/foods/show/6614)

Units
µg = micrograms • mg = milligrams
IU = International units

Percentages are roughly approximated using US recommendations for adults.

Source: USDA Nutrient Database (http://ndb.nal.usda.gov/ndb/search/list)

Rice, white, long-grain, raw

Nutritional value per 100 g (3.5 oz)

Energy	1,527 kJ (365 kcal)	
Carbohydrates	80 g	
Sugars	0.12 g	
Dietary fiber	1.3 g	
Fat	0.66 g	
Protein	7.13 g	
Vitamins		
Thiamine (B_1)	0.0701 mg	(6%)
Riboflavin (B_2)	0.0149 mg	(1%)
Niacin (B_3)	1.62 mg	(11%)
Pantothenic acid (B_5)	1.014 mg	(20%)
Vitamin B_6	0.164 mg	(13%)
Minerals		
Calcium	28 mg	(3%)
Iron	0.80 mg	(6%)
Magnesium	25 mg	(7%)
Manganese	1.088 mg	(52%)
Phosphorus	115 mg	(16%)
Potassium	115 mg	(2%)
Zinc	1.09 mg	(11%)
Other constituents		
Water	11.61 g	

Units
µg = micrograms • mg = milligrams
IU = International units

Percentages are roughly approximated using US recommendations for adults.

Source: USDA Nutrient Database (http://ndb.nal.usda.gov/ndb/search/list)

Nutrient contents in %DV of common foods (raw, uncooked) per 100 g

	Protein		Fiber	Vitamins													Minerals									
Food	**DV**	**Q**	**DV**	**A**	**B1**	**B2**	**B3**	**B5**	**B6**	**B9**	**B12**	**Ch.**	**C**	**D**	**E**	**K**	**Ca**	**Fe**	**Mg**	**P**	**K**	**Na**	**Zn**	**Cu**	**Mn**	**Se**
cooking Reduction %				**10**	**30**	**20**	**25**		**25**	**35**	**0**	**0**	**30**				**10**	**15**	**20**	**10**	**20**	**5**	**10**	**25**		
Corn	20	55	6	1	13	4	16	4	19	19	0	0	0	0	0	1	1	11	31	**34**	15	1	20	10	**42**	0
Rice	14	71	1.3	0	12	3	11	**20**	5	2	0	0	0	0	0	0	1	9	6	7	2	0	8	9	**49**	22
Wheat	27	51	40	0	28	7	**34**	**19**	**21**	11	0	0	0	0	0	0	3	20	36	**51**	12	0	28	28	**151**	**128**
Soybean	**73**	132	0	31	**58**	**51**	8	8	19	**94**	0	**24**	10	0	4	**59**	**28**	**87**	**70**	**70**	**51**	0	**33**	**83**	**126**	25
Pigeon pea	**43**	91	1	50	**43**	11	15	13	13	**114**	0	0	0	0	0	0	13	29	**46**	**37**	**40**	1	18	**53**	**90**	12
Potato	4	112	7.3	0	5	2	5	3	15	4	0	0	**33**	0	0	2	1	4	6	6	12	0	2	5	8	0
Sweet potato	3	82	10	**284**	5	4	3	8	10	3	0	0	4	0	1	2	3	3	6	5	10	2	2	8	13	1
Spinach	6	119	7.3	**188**	5	11	4	1	10	**49**	0	4.5	**47**	0	10	**604**	10	15	20	5	16	3	4	6	**45**	1

	Protein		Fiber	Vitamins													Minerals									
Food	**DV**	**Q**	**DV**	**A**	**B1**	**B2**	**B3**	**B5**	**B6**	**B9**	**B12**	**Ch.**	**C**	**D**	**E**	**K**	**Ca**	**Fe**	**Mg**	**P**	**K**	**Na**	**Zn**	**Cu**	**Mn**	**Se**
cooking Reduction %				**10**	**30**	**20**	**25**		**25**	**35**	**0**	**0**	**30**				**10**	**15**	**20**	**10**	**20**	**5**	**10**	**25**		
Dill	7	32	7	**154**	4	17	8	4	9	**38**	0	0	**142**	0	0	0	**21**	**37**	14	7	21	3	6	7	**63**	0
Carrots	2		9.3	**334**	4	3	5	3	7	5	0	0	10	0	3	16	3	2	3	4	9	3	2	2	7	0
Guava	5	24	18	12	4	2	5	5	6	12	0	0	**381**	0	4	3	2	1	5	4	12	0	2	11	8	1
Papaya	1	7	5.6	22	2	2	2	2	1	10	0	0	**103**	0	4	3	2	1	2	1	7	0	0	1	1	1
Pumpkin	2	56	1.6	**184**	3	6	3	3	3	4	0	0	15	0	5	1	2	4	3	4	10	0	2	6	6	0
Sunflower oil	0		0	0	0	0	0	0	0	0	0	0	0	0	**205**	7	0	0	0	0	0	0	0	0	0	0
Egg	25	136	0	10	5	28	0	**14**	7	12	**22**	**45**	0	9	5	0	5	10	3	19	4	6	7	5	2	**45**
Milk	6	138	0	2	3	11	1	4	2	1	7	2.6	0	0	0	0	11	0	2	9	4	2	3	1	0	5
Chicken Liver	**34**	149	0	**222**	20	**105**	**49**	**62**	**43**	**147**	**276**		**30**	0	4	0	1	**50**	5	**30**	7	3	18	25	13	**78**

Ch. = Choline; Ca = Calcium; Fe = Iron; Mg = Magnesium; P = Phosphorus; K = Potassium; Na = Sodium; Zn = Zinc; Cu = Copper; Mn = Manganese; Se = Selenium; %DV = % daily value i.e. % of DRI (Dietary Reference Intake) Note: All nutrient values including protein and fiber are in %DV per 100 grams of the food item. Significant values are highlighted in light Gray color and bold letters.[22][23] Cooking reduction = % Maximum typical reduction in nutrients due to boiling without draining for ovo-lacto-vegetables group[24][25] Q = Quality of Protein in terms of completeness without adjusting for digestability.[25]

The table below shows the nutrient content of major staple foods in a raw form. Raw grains, however, are not edible and can not be digested. These must be sprouted, or prepared and cooked for human consumption. In sprouted and cooked form, the relative nutritional and anti-nutritional contents of each of these grains is remarkably different from that of raw form of these grains reported in this table.

Nutrient content of major staple foods per 100g portion[26]

Nutrient component:	Maize / Corn[A]	Rice (white)[B]	Rice (brown)[I]	Wheat[C]	Potato[D]	Cassava[E]	Soybean (Green)[F]	Sweet potato[G]	Yam[Y]	Sorghum[H]	Plantain[Z]	RDA
Water (g)	10	12	10	13	**79**	60	68	77	70	9	65	3000
Energy (kJ)	1528	1528	**1549**	1369	322	670	615	360	494	1419	511	2000–2500
Protein (g)	9.4	7.1	7.9	12.6	2.0	1.4	**13.0**	1.6	1.5	11.3	1.3	50
Fat (g)	4.74	0.66	2.92	1.54	0.09	0.28	**6.8**	0.05	0.17	3.3	0.37	
Carbohydrates (g)	74	**80**	77	71	17	38	11	20	28	75	32	130
Fiber (g)	7.3	1.3	3.5	**12.2**	2.2	1.8	4.2	3	4.1	6.3	2.3	30
Sugar (g)	0.64	0.12	0.85	0.41	0.78	1.7	0	4.18	0.5	0	**15**	
Calcium (mg)	7	28	23	29	12	16	**197**	30	17	28	3	1000
Iron (mg)	2.71	0.8	1.47	3.19	0.78	0.27	3.55	0.61	0.54	**4.4**	0.6	8
Magnesium (mg)	127	25	**143**	126	23	21	65	25	21	0	37	400
Phosphorus (mg)	210	115	**333**	288	57	27	194	47	55	287	34	700
Potassium (mg)	287	115	223	363	421	271	620	337	**816**	350	499	4700
Sodium (mg)	35	5	7	2	6	14	15	**55**	9	6	4	1500
Zinc (mg)	2.21	1.09	2.02	**2.65**	0.29	0.34	0.99	0.3	0.24	0	0.14	11
Copper (mg)	0.31	0.22		**0.43**	0.11	0.10	0.13	0.15	0.18	-	0.08	0.9
Manganese (mg)	0.49	1.09	3.74	**3.99**	0.15	0.38	0.55	0.26	0.40	-	-	2.3
Selenium (µg)	15.5	15.1		**70.7**	0.3	0.7	1.5	0.6	0.7	0	1.5	55
Vitamin C (mg)	0	0	0	0	19.7	20.6	**29**	2.4	17.1	0	18.4	90
Thiamin (B1)(mg)	0.39	0.07	0.40	0.30	0.08	0.09	**0.44**	0.08	0.11	0.24	0.05	1.2
Riboflavin (B2)(mg)	**0.20**	0.05	0.09	0.12	0.03	0.05	0.18	0.06	0.03	0.14	0.05	1.3
Niacin (B3) (mg)	3.63	1.6	5.09	**5.46**	1.05	0.85	1.65	0.56	0.55	2.93	0.69	16
Pantothenic acid (B5) (mg)	0.42	1.01	**1.49**	0.95	0.30	0.11	0.15	0.80	0.31	-	0.26	5
Vitamin B6 (mg)	**0.62**	0.16	0.51	0.3	0.30	0.09	0.07	0.21	0.29	-	0.30	1.3
Folate Total (B9) (µg)	19	8	20	38	16	27	**165**	11	23	0	22	400
Vitamin A (IU)	214	0	0	9	2	13	180	**14187**	138	0	1127	5000
Vitamin E, alpha-tocopherol (mg)	0.49	0.11	0.59	**1.01**	0.01	0.19	0	0.26	0.39	0	0.14	15
Vitamin K1 (µg)	0.3	0.1	1.9	1.9	1.9	1.9	0	1.8	**2.6**	0	0.7	120
Beta-carotene (µg)	97	0		5	1	8	0	**8509**	83	0	457	10500
Lutein+zeaxanthin (µg)	**1355**	0		220	8	0	0	0	0	0	30	
Saturated fatty acids (g)	0.67	0.18	0.58	0.26	0.03	0.07	**0.79**	0.02	0.04	0.46	0.14	
Monounsaturated fatty acids (g)	1.25	0.21	1.05	0.2	0.00	0.08	**1.28**	0.00	0.01	0.99	0.03	
Polyunsaturated fatty acids (g)	2.16	0.18	1.04	0.63	0.04	0.05	**3.20**	0.01	0.08	1.37	0.07	

A yellow corn
B raw unenriched long-grain white rice
C hard red winter wheat
D raw potato with flesh and skin
E raw cassava
F raw green soybeans
G raw sweet potato
H raw sorghum
Y raw yam
Z raw plantains
I raw long-grain brown rice

Arsenic concerns

Rice and rice products contain arsenic, a known poison and Group 1 carcinogen.[27] There is no safe level of arsenic, but, as of 2012, a limit of 10 parts per billion has been established in the United States for drinking water, twice the level of 5 parts per billion originally proposed by the EPA. Consumption of one serving of some varieties of rice gives more exposure to arsenic than consumption of 1 liter of water that contains 5 parts per billion arsenic; however, the amount of arsenic in rice varies widely with the greatest concentration in brown rice and rice grown on land formerly used to grow cotton; in the United States, Arkansas, Louisiana, Missouri, and Texas.[28] The U.S. Food and Drug Administration (FDA) is studying this issue, but has not established a limit.[29] China has set a limit of 150 ppb for arsenic in rice.[30]

White rice grown in Arkansas, Louisiana, Missouri, and Texas, which account for 76 percent of American-produced rice had higher levels of arsenic than other regions

of the world studied, possibly because of past use of arsenic-based pesticides to control cotton weevils.[31] Jasmine rice from Thailand and Basmati rice from Pakistan and India contain the least arsenic among rice varieties in one study.[32]

Bacillus cereus

Cooked rice can contain *Bacillus cereus* spores, which produce an emetic toxin when left at 4–60 °C (39–140 °F). When storing cooked rice for use the next day, rapid cooling is advised to reduce the risk of toxin production.[33] One of the enterotoxins produced by *Bacillus cereus* is heat-resistant; reheating contaminated rice kills the bacteria, but does not destroy the toxin already present.

Rice-growing environments

Rice can be grown in different environments, depending upon water availability.[34] Generally, rice does not thrive in a waterlogged area, yet it can survive and grow herein[35] and it can also survive flooding.[36]

1. **Lowland, rainfed**, which is drought prone, favors medium depth; waterlogged, submergence, and flood prone
2. **Lowland, irrigated**, grown in both the wet season and the dry season
3. **Deep water** or floating rice
4. **Coastal wetland**
5. **Upland rice** is also known as **Ghaiya rice**, well known for its drought tolerance[37]

History of domestication and cultivation

Rice broker in 1820s Japan of the Edo period (*"36 Views of Mount Fuji"* Hokusai)

There have been plenty of debates on the origins of the domesticated rice. Genetic evidence published in the *Proceedings of the National Academy of Sciences of the United States of America* (PNAS) shows that all forms of Asian rice, both *indica* and *japonica*, spring from a single domestication that occurred 8,200–13,500 years ago in China of the wild rice *Oryza rufipogon*.[5] A 2012 study published in *Nature*, through a map of rice genome variation, indicated that the domestication of rice occurred in the Pearl River valley region of China based on the genetic evidence. From East Asia, rice was spread to South and Southeast Asia.[6] Before this research, the commonly accepted view, based on archaeological evidence, is that rice was first domesticated in the region of the Yangtze River valley in China.[38][39]

Morphological studies of rice phytoliths from the Diaotonghuan archaeological site clearly show the transition from the collection of wild rice to the cultivation of domesticated rice. The large number of wild rice phytoliths at the Diaotonghuan level dating from 12,000–11,000 BP indicates that wild rice collection was part of the local means of subsistence. Changes in the morphology of Diaotonghuan phytoliths dating from 10,000–8,000 BP show that rice had by this time been domesticated.[40] Soon afterwards the two major varieties of indica and japonica rice were being grown in Central China.[39] In the late 3rd millennium BC, there was a rapid expansion of rice cultivation into mainland Southeast Asia and westwards across India and Nepal.[39]

In 2003, Korean archaeologists claimed to have discovered the world's oldest domesticated rice.[41] Their 15,000-year-old age challenges the accepted view that rice cultivation originated in China about 12,000 years ago.[41] These findings were received by academia with strong skepticism,[42] and the results and their publicizing has been cited as being driven by a combination of nationalist and regional interests.[43] In 2011, a combined effort by the Stanford University, New York University, Washington University in St. Louis, and Purdue University has provided the strongest evidence yet that there is only one single origin of domesticated rice, in the Yangtze Valley of China.[44][45]

Rice spread to the Middle East where, according to Zohary and Hopf (2000, p. 91), *O. sativa* was recovered from a grave at Susa in Iran (dated to the 1st century AD).

Regional history

Africa

Rice crop in Madagascar

African rice has been cultivated for 3500 years. Between 1500 and 800 BC, *Oryza glaberrima* propagated from its original centre, the Niger River delta, and extended to Senegal. However, it never developed far from its original region. Its cultivation even declined in favour of the Asian species, which was introduced to East Africa early in the common era and spread westward.[46] African rice helped Africa conquer its famine of 1203.[47]

Asia

Today, the majority of all rice produced comes from China, India, Indonesia, Bangladesh, Vietnam, Thailand, Myanmar, Pakistan, Philippines, Korea and Japan. Asian farmers still account for 87% of the world's total rice production.

Nepal

Ricefields at Santa Maria, Bulacan, Philippines

Rice is the major food amongst all the ethnic groups in Nepal. Agriculture in Madesh mainly depends on the rice cultivation during rainy season in trai areas of Nepal. Rice production is acutely dependent on rainfall and farmers use irrigation channels throughout the cultivation seasons with to the support of the Government and NNF Nepal . The principal cultivation season, known as "Berna-Bue Charne", is from June to July and the subsidiary cultivation season, known as "Ropai, is from April to September. During Ropai period, there is usually enough water to sustain the cultivation of all rice fields, nevertheless in Berna-Bue Charne period, there is only enough water for cultivation of few of the land extent. The Agricultural Development Office of every district take care of crop in Nepal.

Philippines

The Banaue Rice Terraces (Filipino: *Hagdan-hagdang Palayan ng Banawe*) are 2,000-year-old terraces that were carved into the mountains of Ifugao in the Philippines by ancestors of the indigenous people. The Rice Terraces are commonly referred to as the "Eighth Wonder of the World".[48][49][50] It is commonly thought that the terraces were built with minimal equipment, largely by hand. The terraces are located approximately 1500 meters (5000 ft) above sea level. They are fed by an ancient irrigation system from the rainforests above the terraces. It is said that if the steps were put end to end, it would encircle half the globe.[51] The terraces are found in the province of Ifugao and the Ifugao people have been its caretakers. Ifugao culture revolves[52] around rice and the culture displays an elaborate array of celebrations linked with agricultural rites from rice cultivation to rice consumption. The harvest season generally calls for thanksgiving feasts, while the concluding harvest rites called *tango* or *tungul* (a day of rest) entails a strict taboo on any agricultural work. Partaking of the *bayah* (rice beer), rice cakes, and betel nut constitutes an indelible practise during the festivities.

Rice fields in Dili/East Timor

The Ifugao people practice traditional farming spending most of their labor at their terraces and forest lands while occasionally tending to root crop cultivation. The Ifugaos have also[53] been known to culture edible shells, fruit trees, and other vegetables which have been exhibited among Ifugaos for generations. The building of the rice terraces consists of blanketing walls with stones and earth which are designed to draw water from a main irrigation canal above the terrace clusters. Indigenous rice terracing technologies have been identified with the Ifugao's rice terraces such as their knowledge of water irrigation, stonework, earthwork and terrace maintenance. As their source of life and art, the rice terraces have sustained and shaped the lives of the community members.

Indian women separating rice from straw

Sri Lanka

Rice is the staple food amongst all the ethnic groups in Sri Lanka. Agriculture in Sri Lanka mainly depends on the rice cultivation. Rice production is acutely dependent on rainfall and government supply necessity of water through irrigation channels throughout the cultivation seasons. The principal cultivation season, known as "Maha", is from October to March and the subsidiary cultivation season, known as "Yala", is from April to September. During Maha season, there is usually enough water to sustain the cultivation of all rice fields, nevertheless in Yala season there is only enough water for cultivation of half of the land extent.

Cambodian women planting rice.

Traditional rice varieties are now making a comeback with the recent interest in green foods.

Thailand

Rice is the main export of Thailand, especially white jasmine rice 105 (Dok Mali 105).[54] Thailand has a large number of rice varieties, 3,500 kinds with different characters, and five kinds of wild rice cultivates.[55] In each region of the country there are different rice seed types. Their use depends on weather, atmosphere, and topography.[56]

The Banaue Rice Terraces in Ifugao, Philippines.

The northern region has both low lands and high lands. The farmers' usual crop is non-glutinous rice[56] such as Niew Sun Pah Tong rice. This rice is naturally protected from leaf disease, and its paddy (unmilled rice) (Thai: ข้าวเปลือก) has a brown color.[57] The northeastern region is a large area where farmers can cultivate about 36 million square meters of rice. Although most of it is plains and dry areas,[58] white jasmine rice 105—the most famous Thai rice—can be grown there. White jasmine rice was developed in Chonburi Province first and after that grown in many areas in the country, but the rice from this region has a high quality, because it's softer, whiter, and more fragrant.[59] This rice can resist drought, acidic soil, and alkaline soil.[60]

The central region is mostly composed of plains. Most farmers grow Jao rice.[58] For example, Pathum Thani 1 rice which has qualities similar to white jasmine 105 rice. Its paddy has the color of thatch and the cooked rice has fragrant grains also.[61]

In the southern region, most farmers transplant around boundaries to the flood plains or on the plains between mountains. Farming in the region is slower than other regions because the rainy season comes later.[62] The popular rice varieties in this area are the Leb Nok Pattani seeds, a type of Jao rice. Its paddy has the color of thatch and it can be processed to make noodles.[63]

Companion plant

One of the earliest known examples of companion planting is the growing of rice with Azolla, the mosquito fern, which covers the top of a fresh rice paddy's water, blocking out any competing plants, as well as fixing nitrogen from the atmosphere for the rice to use. The rice is planted when it is tall enough to poke out above the azolla. This method has been used for at least a thousand years.

Middle East

Rice was grown in some areas of Mesopotamia (southern Iraq). With the rise of Islam it moved north to Nisibin, the southern shores of the Caspian Sea (in Gilan and Mazanderan provinces of Iran)[64] and then beyond the Muslim world into the valley of the Volga. In Egypt, rice is mainly grown in the Nile Delta. In Palestine, rice came to be grown in the Jordan Valley. Rice is also grown in Saudi Arabia at Al-Hasa Oasis and in Yemen.[65]

Europe

Rice was known to the Classical world, being imported from Egypt, and perhaps west Asia. It was known to Greece (where it is still cultivated in Macedonia and Thrace) by returning soldiers from Alexander the Great's military expedition to Asia. Large deposits of rice from the first century AD have been found in Roman camps in Germany.[66]

The Moors brought Asiatic rice to the Iberian Peninsula in the 10th century. Records indicate it was grown in Valencia and Majorca. In Majorca, rice cultivation seems to have stopped after the Christian conquest, although historians are not certain.[65]

Muslims also brought rice to Sicily, where it was an important crop[65] long before it is noted in the plain of Pisa (1468) or in the Lombard plain (1475), where its

cultivation was promoted by Ludovico Sforza, Duke of Milan, and demonstrated in his model farms.[67]

After the 15th century, rice spread throughout Italy and then France, later propagating to all the continents during the age of European exploration.

In European Russia, a short-grain, starchy rice similar to the Italian varieties, has been grown in the Krasnodar Krai, and known in Russia as "Kuban Rice" or "Krasnodar Rice". In the Russian Far East several *japonica* cultivars are grown in Primorye around the Khanka lake. Increasing scale of rice production in the region has recently brought criticism towards growers' alleged bad practices in regards to the environment.

Caribbean and Latin America

Rice is not native to the Americas but was introduced to Latin America and the Caribbean by European colonizers at an early date. Spanish colonizers introduced Asian rice to Mexico in the 1520s at Veracruz; and the Portuguese and their African slaves introduced it at about the same time to colonial Brazil.[68] Recent scholarship suggests that enslaved Africans played an active role in the establishment of rice in the New World and that African rice was an important crop from an early period.[69] Varieties of rice and bean dishes that were a staple dish along the peoples of West Africa remained a staple among their descendants subjected to slavery in the Spanish New World colonies, Brazil and elsewhere in the Americas.[47]

United States

South Carolina rice plantation, showing a winnowing barn (Mansfield Plantation, Georgetown)

In 1694, rice arrived in South Carolina, probably originating from Madagascar.[68]

In the United States, colonial South Carolina and Georgia grew and amassed great wealth from the slave labor obtained from the Senegambia area of West Africa and from coastal Sierra Leone. At the port of Charleston, through which 40% of all American slave imports passed, slaves from this region of Africa brought the highest prices due to their prior knowledge of rice culture, which was put to use on the many rice plantations around Georgetown, Charleston, and Savannah.

From the enslaved Africans, plantation owners learned how to dyke the marshes and periodically flood the fields. At first the rice was laboriously milled by hand using large mortars and pestles made of wood, then winnowed in sweetgrass baskets (the making of which was another skill brought by slaves from Africa). The invention of the rice mill increased profitability of the crop, and the addition of water power for the mills in 1787 by millwright Jonathan Lucas was another step forward.

Rice culture in the southeastern U.S. became less profitable with the loss of slave labor after the American Civil War, and it finally died out just after the turn of the 20th century. Today, people can visit the only remaining rice plantation in South Carolina that still has the original winnowing barn and rice mill from the mid-19th century at the historic Mansfield Plantation in Georgetown, South Carolina. The predominant strain of rice in the Carolinas was from Africa and was known as 'Carolina Gold'. The cultivar has been preserved and there are current attempts to reintroduce it as a commercially grown crop.[70]

In the southern United States, rice has been grown in southern Arkansas, Louisiana, and east Texas since the mid-19th century. Many Cajun farmers grew rice in wet marshes and low-lying prairies where they could also farm crayfish when the fields were flooded.[71] In recent years rice production has risen in North America, especially in the Mississippi embayment in the states of Arkansas and Mississippi (see also Arkansas Delta and Mississippi Delta).

Rice cultivation began in California during the California Gold Rush, when an estimated 40,000 Chinese laborers immigrated to the state and grew small amounts of the grain for their own consumption. However, commercial production began only in 1912 in the town of Richvale in Butte County.[72] By 2006, California produced the second-largest rice crop in the United States,[73] after Arkansas, with production concentrated in six counties north of Sacramento.[74] Unlike the Arkansas–Mississippi Delta region, California's production is dominated by short- and medium-grain *japonica* varieties, including cultivars developed for the local climate such as Calrose, which makes up as much as 85% of the state's crop.[75]

Rice paddy fields just north of the city of Sacramento, California.

References to "wild rice" native to North America are to the unrelated *Zizania palustris*.[76]

More than 100 varieties of rice are commercially produced primarily in six states (Arkansas, Texas, Louisiana, Mississippi, Missouri, and California) in the U.S.[77] According to estimates for the 2006 crop year, rice production in the U.S. is valued at $1.88 billion, approximately half of which is expected to be exported. The U.S. provides about 12% of world rice trade.[77] The majority of domestic utilization of U.S. rice is direct food use (58%), while 16% is used in each of processed foods and beer. 10% is found in pet food.[77]

Australia

Rice was one of the earliest crops planted in Australia by British settlers, who had experience with rice plantations in the Americas and India.

Although attempts to grow rice in the well-watered north of Australia have been made for many years, they have consistently failed because of inherent iron and manganese toxicities in the soils and destruction by pests.

In the 1920s, it was seen as a possible irrigation crop on soils within the Murray-Darling Basin that were too heavy for the cultivation of fruit and too infertile for wheat.[78]

Because irrigation water, despite the extremely low runoff of temperate Australia,[79] was (and remains) very cheap, the growing of rice was taken up by agricultural groups over the following decades. Californian varieties of rice were found suitable for the climate in the Riverina,[78] and the first mill opened at Leeton in 1951.

Even before this Australia's rice production greatly exceeded local needs,[78] and rice exports to Japan have become a major source of foreign currency. Above-average rainfall from the 1950s to the middle 1990s[80] encouraged the expansion of the Riverina rice industry, but its prodigious water use in a practically waterless region began to attract the attention of environmental scientists. These became severely concerned with declining flow in the Snowy River and the lower Murray River.

Although rice growing in Australia is highly profitable due to the cheapness of land, several recent years of severe drought have led many to call for its elimination because of its effects on extremely fragile aquatic ecosystems. The Australian rice industry is somewhat opportunistic, with the area planted varying significantly from

season to season depending on water allocations in the Murray and Murrumbidgee irrigation regions.

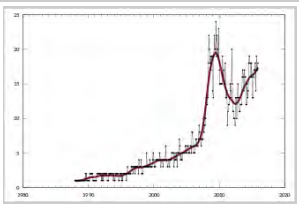

Monthly value (A$ millions) of rice imports to Australia since 1988

Production and commerce

Production

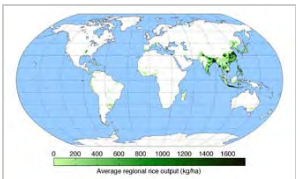

Worldwide rice production

The world dedicated 162.3 million hectares in 2012 for rice cultivation and the total production was about 738.1 million tonnes.[82] The average world farm yield for rice was 4.5 tonnes per hectare, in 2012.[82]

Rice farms in Egypt were the most productive in 2012, with a nationwide average of 9.5 tonnes per hectare.[83] Second place: Australia – 8.9 tonnes per hectare.[83] Third place: United States – 8.3 tonnes per hectare.[83]

Top 20 Rice Producers by Country—2012 (million metric ton)[81]	
China	204.3
India	152.6
Indonesia	69.0
Vietnam	43.7
Thailand	37.8
Bangladesh	33.9
Myanmar	33.0
Philippines	18.0
Brazil	11.5
Japan	10.7
Pakistan	9.4
Cambodia	9.3
United States	9.0
South Korea	6.4
Egypt	5.9
Nepal	5.1
Nigeria	4.8
Madagascar	4.0
Sri Lanka	3.8
Laos	3.5
Source: Food and Agriculture Organization	

Rice is a major food staple and a mainstay for the rural population and their food security. It is mainly cultivated by small farmers in holdings of less than 1 hectare. Rice is also a wage commodity for workers in the cash crop or non-agricultural sectors. Rice is vital for the nutrition of much of the population in Asia, as well as in Latin America and the Caribbean and in Africa; it is central to the food security of over half the world population. Developing countries account for 95% of the total production, with China and India alone responsible for nearly half of the world output.[84]

World production of rice has risen steadily from about 200 million tonnes of paddy rice in 1960 to over 678 million tonnes in 2009. The three largest producers of rice in 2009 were China (197 million tonnes), India (131 Mt), and Indonesia (64 Mt). Among the six largest rice producers, the most productive farms for rice, in 2009, were in China producing 6.59 tonnes per hectare.[85]

Many rice grain producing countries have significant losses post-harvest at the farm and because of poor roads, inadequate storage technologies, inefficient supply chains and farmer's inability to bring the produce into retail markets dominated by small shopkeepers. A World Bank – FAO study claims 8% to 26% of rice is lost in developing nations, on average, every year, because of post-harvest problems and poor infrastructure. Some sources claim the post-harvest losses to exceed 40%.[84][86] Not only do these losses reduce food security in the world, the study claims that farmers in developing countries such as China, India and others lose approximately US$89 billion of income in preventable post-harvest farm losses, poor transport, the lack of proper storage and retail. One study claims that if these post-harvest grain losses could be eliminated with better infrastructure and retail network, in India alone enough food would be saved every year to feed 70 to 100 million people over a year.[87] However, other writers have warned against dramatic assessments of post-harvest food losses, arguing that "worst-case scenarios" tend to be used rather than realistic averages and that in many cases the cost of avoiding losses exceeds the value of the food saved.[88]

Burning of rice residues after harvest, to quickly prepare the land for wheat planting, around Sangrur, Punjab, India.

The seeds of the rice plant are first milled using a rice huller to remove the chaff (the outer husks of the grain). At this point in the process, the product is called brown rice. The milling may be continued, removing the bran, *i.e.*, the rest of the husk and the germ, thereby creating white rice. White rice, which keeps longer, lacks some important nutrients; moreover, in a limited diet which does not supplement the rice, brown rice helps to prevent the disease beriberi.

Either by hand or in a rice polisher, white rice may be buffed with glucose or talc powder (often called polished rice, though this term may also refer to white rice in general), parboiled, or processed into flour. White rice may also be enriched by adding nutrients, especially those lost during the milling process. While the cheapest method of enriching involves adding a powdered blend of nutrients that will easily wash off (in the United States, rice which has been so treated requires a label warning against rinsing), more sophisticated methods apply nutrients directly to the grain, coating the grain with a water-insoluble substance which is resistant to washing.

In some countries, a popular form, parboiled rice (also known as **converted rice**) is subjected to a steaming or parboiling process while still a brown rice grain. The parboil process causes a gelatinisation of the starch in the grains. The grains become less brittle, and the color of the milled grain changes from white to yellow. The rice is then dried, and can then be milled as usual or used as brown rice. Milled parboiled rice is nutritionally superior to standard milled rice, because the process causes nutrients from the outer husk (especially thiamine) to move into the endosperm, so that less is subsequently lost when the husk is polished off during milling. Parboiled rice has an additional benefit in that it does not stick to the pan during cooking, as happens when cooking regular white rice. This type of rice is eaten in parts of India and countries of West Africa are also accustomed to consuming parboiled rice.

Despite the hypothetical health risks of talc (such as stomach cancer),[89][90] talc-coated rice remains the norm in some countries due to its attractive shiny appearance, but it has been banned in some, and is no longer widely used in others (such as the United States). Even where talc is not used, glucose, starch, or other coatings may be used to improve the appearance of the grains.

Rice bran, called *nuka* in Japan, is a valuable commodity in Asia and is used for many daily needs. It is a moist, oily inner layer which is heated to produce oil. It is also used as a pickling bed in making rice bran pickles and *takuan*.

Raw rice may be ground into flour for many uses, including making many kinds of beverages, such as *amazake*, *horchata*, rice milk, and rice wine. Rice does not contain gluten, so is suitable for people on a gluten-free diet.[91] Rice may also be made into various types of noodles. Raw, wild, or brown rice may also be consumed by raw-foodist or fruitarians if soaked and sprouted (usually a week to 30 days – gaba rice).

Processed rice seeds must be boiled or steamed before eating. Boiled rice may be further fried in cooking oil or butter (known as fried rice), or beaten in a tub to make *mochi*.

Rice is a good source of protein and a staple food in many parts of the world, but it is not a complete protein: it does not contain all of the essential amino acids in sufficient amounts for good health, and should be combined with other sources of protein, such as nuts, seeds, beans, fish, or meat.[92]

Rice, like other cereal grains, can be puffed (or popped). This process takes advantage of the grains' water content and typically involves heating grains in a special chamber. Further puffing is sometimes accomplished by processing puffed pellets in a low-pressure chamber. The ideal gas law means either lowering the local pressure or raising the water temperature results in an increase in volume prior to water evaporation, resulting in a puffy texture. Bulk raw rice density is about 0.9 g/cm³. It decreases to less than one-tenth that when puffed.

Harvesting, drying and milling

Unmilled rice, known as "paddy" (Indonesia and Malaysia: padi; Philippines, palay), is usually harvested when the grains have a moisture content of around 25%. In most Asian countries, where rice is almost entirely the product of smallholder agriculture, harvesting is carried out manually, although there is a growing interest in mechanical harvesting. Harvesting can be carried out by the farmers themselves, but is also frequently done by seasonal labor groups. Harvesting is followed by threshing, either immediately or within a day or two. Again, much threshing is still carried out by hand but there is an increasing use of mechanical threshers. Subsequently, paddy needs to be dried to bring down the moisture content to no more than 20% for milling.

Rice combine harvester Katori-city, Japan

A familiar sight in several Asian countries is paddy laid out to dry along roads. However, in most countries the bulk of drying of marketed paddy takes place in mills, with village-level drying being used for paddy to be consumed by farm families. Mills either sun dry or use mechanical driers or both. Drying has to be carried out quickly to avoid the formation of molds. Mills range from simple hullers, with a throughput of a couple of tonnes a day, that simply remove the outer husk, to enormous operations that can process 4,000 tonnes a day and produce highly polished rice. A good mill can achieve a paddy-to-rice conversion rate of up to 72% but smaller, inefficient mills often struggle to achieve 60%. These smaller mills often do not buy paddy and sell rice but only service farmers who want to mill their paddy for their own consumption.

After the harvest, rice straw is gathered in the traditional way from small paddy fields in Mae Wang District, Chiang Mai Province, Thailand

Distribution

Because of the importance of rice to human nutrition and food security in Asia, the domestic rice markets tend to be subject to considerable state involvement. While the private sector plays a leading role in most countries, agencies such as BULOG in Indonesia, the NFA in the Philippines, VINAFOOD in Vietnam and the Food Corporation of India are all heavily involved in purchasing of paddy from farmers or rice from mills and in distributing rice to poorer people. BULOG and NFA monopolise rice imports into their countries while VINAFOOD controls all exports from Vietnam.[93]

Trade

World trade figures are very different from those for production, as less than 8% of rice produced is traded internationally.[94] In economic terms, the global rice trade was a small fraction of 1% of world mercantile trade. Many countries consider rice as a strategic food staple, and various governments subject its trade to a wide range of controls and interventions.

Drying rice in Peravoor, India

Developing countries are the main players in the world rice trade, accounting for 83% of exports and 85% of imports. While there are numerous importers of rice, the exporters of rice are limited. Just five countries – Thailand, Vietnam, China, the United States and India – in decreasing order of exported quantities, accounted for about three-quarters of world rice exports in 2002.[84] However, this ranking has been rapidly changing in recent years. In 2010, the three largest exporters of rice, in decreasing order of quantity exported were Thailand, Vietnam and India. By 2012, India became the largest exporter of rice with a 100% increase in its exports on year-to-year basis, and Thailand slipped to third position.[95][96] Together, Thailand, Vietnam and India accounted for nearly 70% of the world rice exports.

The primary variety exported by Thailand and Vietnam were Jasmine rice, while exports from India included aromatic Basmati variety. China, an exporter of rice in early 2000s, was a net importer of rice in 2010 and will become the largest net importer, surpassing Nigeria, in 2013.[94][97] According to a USDA report, the world's largest exporters of rice in 2012 were India (9.75 million tonnes), Vietnam (7 million tonnes), Thailand (6.5 million tonnes), Pakistan (3.75 million tonnes) and the United States (3.5 million tonnes).[98]

Major importers usually include Nigeria, Indonesia, Bangladesh, Saudi Arabia, Iran, Iraq, Malaysia, the Philippines, Brazil and some African and Persian Gulf countries. In common with other West African countries, Nigeria is actively promoting domestic production. However, its very heavy import duties (110%) open it to smuggling from neighboring countries.[99] Parboiled rice is particularly popular in Nigeria. Although China and India are the two largest producers of rice in the world, both countries consume the majority of the rice produced domestically, leaving little to be traded internationally.

World's most productive rice farms and farmers

The average world yield for rice was 4.3 tonnes per hectare, in 2010.

Australian rice farms were the most productive in 2010, with a nationwide average of 10.8 tonnes per hectare.[100]

Yuan Longping of China National Hybrid Rice Research and Development Center, China, set a world record for rice yield in 2010 at 19 tonnes per hectare on a demonstration plot. In 2011, this record was surpassed by an Indian farmer, Sumant Kumar, with 22.4 tonnes per hectare in Bihar. Both these farmers claim to have employed newly developed rice breeds and System of Rice Intensification (SRI), a recent innovation in rice farming. SRI is claimed to have set new national records in rice yields, within the last 10 years, in many countries. The claimed Chinese and Indian yields have yet to be demonstrated on seven-hectare lots and to be reproducible over two consecutive years on the same farm.[101][102][103][104]

Price

In late 2007 to May 2008, the price of grains rose greatly due to droughts in major producing countries (particularly Australia), increased use of grains for animal feed and US subsidies for bio-fuel production. Although there was no shortage of rice on world markets this general upward trend in grain prices led to panic buying by consumers, government rice export bans (in particular, by Vietnam and India) and inflated import orders by the Philippines marketing board, the National Food Authority. This caused significant rises in rice prices. In late April 2008, prices hit 24 US cents a pound, twice the price of seven months earlier.[105] Over the period of 2007 to 2013, the Chinese government has substantially increased the price it pays domestic farmers for their rice, rising to US$500 per metric ton by 2013.[94] The 2013 price of rice originating from other southeast Asian countries was a comparably low US$350 per metric ton.[94]

On April 30, 2008, Thailand announced plans for the creation of the Organisation of Rice Exporting Countries (OREC) with the intention that this should develop into a price-fixing cartel for rice.[106][107] However, little progress had been made by mid-2011 to achieve this.

Worldwide consumption

As of 2009 world food consumption of rice was 531.6 million metric tons of paddy equivalent (354,603 of milled equivalent), while the far largest consumers were China consuming 156.3 million metric tons of paddy equivalent (29.4% of the world consumption) and India consuming 123.5 million metric tons of paddy equivalent (23.3% of the world consumption).[108] Between 1961 and 2002, per capita consumption of rice increased by 40%.

Food consumption of rice by country – 2009 (million metric ton of paddy equivalent)[108]	
World Total	531.6
China	156.3
India	123.5
Bangladesh	50.4
Indonesia	45.3
Vietnam	18.4
Philippines	17.0
Thailand	13.7
Japan	10.2
Burma	10.0
Brazil	10.0
South Korea	5.8
Nigeria	4.8
Egypt	4.6
Pakistan	4.3
USA	3.8
Nepal	3.5
Cambodia	3.4
Sri Lanka	3.2
Madagascar	3.2
Malaysia	3.1
North Korea	2.8

Rice is the most important crop in Asia. In Cambodia, for example, 90% of the total agricultural area is used for rice production.[109]

U.S. rice consumption has risen sharply over the past 25 years, fueled in part by commercial applications such as beer production.[110] Almost one in five adult Americans now report eating at least half a serving of white or brown rice per day.[111]

Environmental impacts

Rice cultivation on wetland rice fields is thought to be responsible for 11% of the anthropogenic methane emissions.[112] Rice requires slightly more water to produce than other grains.[113] Rice production uses almost a third of Earth's fresh water.[114]

Long-term flooding of rice fields cuts the soil off from atmospheric oxygen and causes anaerobic fermentation of organic matter in the soil.[115] Methane production from rice cultivation contributes ~1.5% of anthropogenic greenhouse gases.[116] Methane is twenty times more potent a greenhouse gas than carbon dioxide.[117]

A 2010 study found that, as a result of rising temperatures and decreasing solar radiation during the later years of the 20th century, the rice yield growth rate has decreased in many parts of Asia, compared to what would have been observed had the temperature and solar radiation trends not occurred.[118][119] The yield growth rate had fallen 10–20% at some locations. The study was based on records from 227 farms in Thailand, Vietnam, Nepal, India, China, Bangladesh, and Pakistan. The mechanism of this falling yield was not clear, but might involve increased respiration during warm nights, which expends energy without being able to photosynthesize.

Rainfall

Temperature

Rice requires high temperature above 20 °C (68 °F) but not more than 35 to 40 °C (95 to 104 °F). Optimum temperature is around 30 °C (T_{max}) and 20 °C (T_{min}).[120]

Work by the International Center for Tropical Agriculture to measure the greenhouse gas emissions of rice production.

Solar radiation

The amount of solar radiation received during the 45 days leading up to harvest determines final crop output.[120]

Atmospheric water vapor

High water vapor content (in humid tropics) subjects unusual stress which favors the spread of fungal and bacterial diseases.[120]

Wind

Light wind transports CO_2 to the leaf canopy but strong wind causes severe damage and may lead to sterility (due to pollen dehydration, spikelet sterility, and abortive endosperms).[120]

Pests and diseases

Rice pests are any organisms or microbes with the potential to reduce the yield or value of the rice crop (or of rice seeds).[121] Rice pests include weeds, pathogens, insects, nematode, rodents, and birds. A variety of factors can contribute to pest outbreaks, including climatic factors, improper irrigation, the overuse of insecticides and high rates of nitrogen fertilizer application.[122] Weather conditions also contribute to pest outbreaks. For example, rice gall midge and army worm outbreaks tend to follow periods of high rainfall early in the wet season, while thrips outbreaks are associated with drought.[123]

Insects

Major rice insect pests include: the brown planthopper (BPH),[124] several spp. of stemborers – including those in the genera *Scirpophaga* and *Chilo*,[125] the rice gall midge,[126] several spp. of rice bugs[127] – notably in the genus *Leptocorisa*,[128] the rice leafroller, rice weevils and the Chinese rice grasshopper.[129]

Chinese rice grasshopper (*Oxya chinensis*) Borneo, Malaysia

Diseases

Rice blast, caused by the fungus *Magnaporthe grisea*,[130] is the most significant disease affecting rice cultivation. Other major rice diseases include: sheath blight, rice ragged stunt (vector: BPH), and tungro (vector: *Nephotettix* spp).[131] There is also an ascomycete fungus, *Cochliobolus miyabeanus*, that causes brown spot disease in rice.[132][133]

Nematodes

Several nematode species infect rice crops, causing diseases such as Ufra (Ditylenchus dipsaci), White tip disease (Aphelenchoide bessei), and root knot disease (Meloidogyne graminicola). Some nematode species such as *Pratylenchus* spp. are most dangerous in upland rice of all parts of the world. Rice root nematode (*Hirschmanniella oryzae*) is a migratory endoparasite which on higher inoculum levels will lead to complete destruction of a rice crop. Beyond being obligate parasites, they also decrease the vigor of plants and increase the plants' susceptibility to other pests and diseases.

Other pests

These include the apple snail *Pomacea canaliculata*, panicle rice mite, rats,[134] and the weed *Echinochloa crusgali*.[135]

Integrated pest management

Crop protection scientists are trying to develop rice pest management techniques which are sustainable. In other words, to manage crop pests in such a manner that future crop production is not threatened.[136] Sustainable pest management is based on four principles: biodiversity, host plant resistance (HPR), landscape ecology, and hierarchies in a landscape – from biological to social.[137] At present, rice pest management includes cultural techniques, pest-resistant rice varieties, and pesticides (which include insecticide). Increasingly, there is evidence that farmers' pesticide applications are often unnecessary, and even facilitate pest outbreaks.[138][139][140][141] By reducing the populations of natural enemies of rice pests,[142] misuse of insecticides can actually lead to pest outbreaks.[143] The International Rice Research Institute (IRRI) demonstrated in 1993 that an 87.5% reduction in pesticide use can lead to an overall drop in pest numbers.[144] IRRI also conducted two campaigns in 1994 and 2003, respectively, which discouraged insecticide misuse and smarter pest management in Vietnam.[145][146]

Rice plants produce their own chemical defenses to protect themselves from pest attacks. Some synthetic chemicals, such as the herbicide 2,4-D, cause the plant to increase the production of certain defensive chemicals and thereby increase the plant's resistance to some types of pests.[147] Conversely, other chemicals, such as the insecticide imidacloprid, can induce changes in the gene expression of the rice that cause the plant to become more susceptible to attacks by certain types of pests.[148] 5-Alkylresorcinols are chemicals that can also be found in rice.[149]

Botanicals, so-called "natural pesticides", are used by some farmers in an attempt to control rice pests. Botanicals include extracts of leaves, or a mulch of the leaves themselves. Some upland rice farmers in Cambodia spread chopped leaves of the bitter bush (*Chromolaena odorata*) over the surface of fields after planting. This practice probably helps the soil retain moisture and thereby facilitates seed germination. Farmers also claim the leaves are a natural fertilizer and helps suppress weed and insect infestations.[150]

Among rice cultivars, there are differences in the responses to, and recovery from, pest damage.[127][151] Many rice varieties have been selected for resistance to insect pests.[152][153] Therefore, particular cultivars are recommended for areas prone to certain pest problems. The genetically based ability of a rice variety to withstand pest attacks is called resistance. Three main types of plant resistance to pests are recognized as nonpreference, antibiosis, and tolerance.[154] Nonpreference (or antixenosis) describes host plants which insects prefer to avoid; antibiosis is where insect survival is reduced after the ingestion of host tissue; and tolerance is the capacity of a plant to produce high yield or retain high quality despite insect infestation.[155]

Chloroxylon is used for Pest Management in Organic Rice Cultivation in Chhattisgarh, India

Over time, the use of pest-resistant rice varieties selects for pests that are able to overcome these mechanisms of resistance. When a rice variety is no longer able to resist pest infestations, resistance is said to have broken down. Rice varieties that can be widely grown for many years in the presence of pests and retain their ability to withstand the pests are said to have durable resistance. Mutants of popular rice varieties are regularly screened by plant breeders to discover new sources of durable resistance.[154][156]

Parasitic weeds

Rice is parasitized by the weed eudicot *Striga hermonthica*,[157] which is of local importance for this crop.

Ecotypes and cultivars

While most rice is bred for crop quality and productivity, there are varieties selected for characteristics such as texture, smell, and firmness. There are four major categories of rice worldwide: indica, japonica, aromatic and glutinous. The different varieties of rice are not considered interchangeable, either in food preparation or agriculture, so as a result, each major variety is a completely separate market from other varieties. It is common for one variety of rice to rise in price while another one drops in price.[158]

Rice cultivars also fall into groups according to environmental conditions, season of planting, and season of harvest, called ecotypes. Some major groups are the Japan-type (grown in Japan), "buly" and "tjereh" types (Indonesia); "aman" (main winter crop), "aus" ("aush", summer), and "boro" (spring) (Bengal and Assam).[159][160] Cultivars exist that are adapted to deep flooding, and these are generally called "floating rice".[161]

The largest collection of rice cultivars is at the International Rice Research Institute[162] in the Philippines, with over 100,000 rice accessions[163] held in the International Rice Genebank.[164] Rice cultivars are often classified by their grain shapes and texture. For example, Thai Jasmine rice is long-grain and relatively less sticky, as some long-grain rice contains less amylopectin than short-grain cultivars. Chinese restaurants often serve long-grain as plain unseasoned steamed rice though

short-grain rice is common as well. Japanese mochi rice and Chinese sticky rice are short-grain. Chinese people use sticky rice which is properly known as "glutinous rice" (note: glutinous refer to the glue-like characteristic of rice; does not refer to "gluten") to make zongzi. The Japanese table rice is a sticky, short-grain rice. Japanese sake rice is another kind as well.

Rice seed collection from IRRI

Indian rice cultivars include long-grained and aromatic Basmati (ਬਾਸਮਤੀ) (grown in the North), long and medium-grained Patna rice, and in South India (Andhra Pradesh and Karnataka) short-grained Sona Masuri (also called as Bangaru theegalu). In the state of Tamil Nadu, the most prized cultivar is *ponni* which is primarily grown in the delta regions of the Kaveri River. Kaveri is also referred to as ponni in the South and the name reflects the geographic region where it is grown. In the Western Indian state of Maharashtra, a short grain variety called Ambemohar is very popular. This rice has a characteristic fragrance of Mango blossom.

Aromatic rices have definite aromas and flavors; the most noted cultivars are Thai fragrant rice, Basmati, Patna rice, Vietnamese fragrant rice, and a hybrid cultivar from America, sold under the trade name Texmati. Both Basmati and Texmati have a mild popcorn-like aroma and flavor. In Indonesia, there are also *red* and *black* cultivars.

High-yield cultivars of rice suitable for cultivation in Africa and other dry ecosystems, called the new rice for Africa (NERICA) cultivars, have been developed. It is hoped that their cultivation will improve food security in West Africa.

Draft genomes for the two most common rice cultivars, *indica* and *japonica*, were published in April 2002. Rice was chosen as a model organism for the biology of grasses because of its relatively small genome (~430 megabase pairs). Rice was the first crop with a complete genome sequence.[165]

On December 16, 2002, the UN General Assembly declared the year 2004 the International Year of Rice. The declaration was sponsored by more than 40 countries.

Biotechnology

High-yielding varieties

The high-yielding varieties are a group of crops created intentionally during the Green Revolution to increase global food production. This project enabled labor markets in Asia to shift away from agriculture, and into industrial sectors. The first "Rice Car", IR8 was produced in 1966 at the International Rice Research Institute which is based in the Philippines at the University of the Philippines' Los Baños site. IR8 was created through a cross between an Indonesian variety named "Peta" and a Chinese variety named "Dee Geo Woo Gen."[166]

Scientists have identified and cloned many genes involved in the gibberellin signaling pathway, including GAI1 (Gibberellin Insensitive) and SLR1 (Slender Rice).[167] Disruption of gibberellin signaling can lead to significantly reduced stem growth leading to a dwarf phenotype. Photosynthetic investment in the stem is reduced dramatically as the shorter plants are inherently more stable mechanically. Assimilates become redirected to grain production, amplifying in particular the effect of chemical fertilizers on commercial yield. In the presence of nitrogen fertilizers, and intensive crop management, these varieties increase their yield two to three times.

Future potential

As the UN Millennium Development project seeks to spread global economic development to Africa, the "Green Revolution" is cited as the model for economic development. With the intent of replicating the successful Asian boom in agronomic productivity, groups like the Earth Institute are doing research on African agricultural systems, hoping to increase productivity. An important way this can happen is the production of "New Rices for Africa" (NERICA). These rices, selected to tolerate the low input and harsh growing conditions of African agriculture, are produced by the African Rice Center, and billed as technology "from Africa, for Africa". The NERICA have appeared in *The New York Times* (October 10, 2007) and *International Herald Tribune* (October 9, 2007), trumpeted as miracle crops that will dramatically increase rice yield in Africa and enable an economic resurgence. Ongoing research in China to develop perennial rice could result in enhanced sustainability and food security.

Golden rice

Rice kernels do not contain vitamin A, so people who obtain most of their calories from rice are at risk of vitamin A deficiency. German and Swiss researchers have genetically engineered rice to produce beta-carotene, the precursor to vitamin A, in the rice kernel. The beta-carotene turns the processed (white) rice a "gold" color, hence the name "golden rice." The beta-carotene is converted to vitamin A in humans who consume the rice.[168] Although some rice strains produce beta-carotene in the hull, no non-genetically engineered strains have been found that produce beta-carotene in the kernel, despite the testing of thousands of strains. Additional efforts are being made to improve the quantity and quality of other nutrients in golden rice.[169]

The International Rice Research Institute is currently further developing and evaluating Golden Rice as a potential new way to help address vitamin A deficiency.[170]

Expression of human proteins

Ventria Bioscience has genetically modified rice to express lactoferrin, lysozyme which are proteins usually found in breast milk, and human serum albumin, These proteins have antiviral, antibacterial, and antifungal effects.[171]

Rice containing these added proteins can be used as a component in oral rehydration solutions which are used to treat diarrheal diseases, thereby shortening their duration and reducing recurrence. Such supplements may also help reverse anemia.[172]

Flood-tolerant rice

Due to the varying levels that water can reach in regions of cultivation, flood tolerant varieties have long been developed and used. Flooding is an issue that many rice growers face, especially in South and South East Asia where flooding annually affects 20 million hectares.[173] Standard rice varieties cannot withstand stagnant flooding of more than about a week,[174] mainly as it disallows the plant access to necessary requirements such as sunlight and essential gas exchanges, inevitably leading to plants being unable to recover.[173] In the past, this has led to massive losses in yields, such as in the Philippines, where in 2006, rice crops worth $65 million were lost to flooding.[175] Recently developed cultivars seek to improve flood tolerance.

Drought-tolerant rice

Drought represents a significant environmental stress for rice production, with 19–23 million hectares of rainfed rice production in South and South East Asia often at risk.[176][177] Under drought conditions, without sufficient water to afford them the ability to obtain the required levels of nutrients from the soil, conventional commercial rice varieties can be severely affected – for example, yield losses as high as 40% have affected some parts of India, with resulting losses of around US$800 million annually.[178]

The International Rice Research Institute conducts research into developing drought-tolerant rice varieties, including the varieties 5411 and Sookha dhan, currently being employed by farmers in the Philippines and Nepal respectively.[177] In addition, in 2013 the Japanese National Institute for Agrobiological Sciences led a team which successfully inserted the DEEPER ROOTING 1 (DRO1) gene, from the Philippine upland rice variety Kinandang Patong, into the popular commercial rice variety IR64, giving rise to a far deeper root system in the resulting plants.[178] This facilitates an improved ability for the rice plant to derive its required nutrients in times of drought via accessing deeper layers of soil, a feature demonstrated by trials which saw the IR64 + DRO1 rice yields drop by 10% under moderate drought conditions, compared to 60% for the unmodified IR64 variety.[178][179]

Salt-tolerant rice

Soil salinity poses a major threat to rice crop productivity, particularly along low-lying coastal areas during the dry season.[176] For example, roughly 1 million hectares of the coastal areas of Bangladesh are affected by saline soils.[180] These high concentrations of salt can severely affect rice plants' normal physiology, especially during early stages of growth, and as such farmers are often forced to abandon these otherwise potentially usable areas.[181][182]

Progress has been made, however, in developing rice varieties capable of tolerating such conditions; the hybrid created from the cross between the commercial rice variety IR56 and the wild rice species *Oryza coarctata* is one example.[183] *O. coarctata* is capable of successful growth in soils with double the limit of salinity of normal varieties, but lacks the ability to produce edible rice.[183] Developed by the International Rice Research Institute, the hybrid variety can utilise specialised leaf glands that allow for the removal of salt into the atmosphere. It was initially produced from one successful embryo out of 34,000 crosses between the two species; this was then backcrossed to IR56 with the aim of preserving the genes responsible for salt tolerance that were inherited from *O. coarctata*.[181] Extensive trials are planned prior to the new variety being available to farmers by approximately 2017–18.[181]

Environment-friendly rice

Producing rice in paddies is harmful for the environment due to the release of methane by methanogenic bacteria. These bacteria live in the anaerobic waterlogged soil, and live off nutrients released by rice roots. Researchers have recently reported in *Nature* that putting the barley gene SUSIBA2 into rice creates a shift in biomass production from root to shoot (above ground tissue becomes larger, while below ground tissue is reduced), decreasing the methanogen population, and resulting in a reduction of methane emissions of up to 97%. Apart from this environmental benefit, the modification also increases the amount of rice grains by 43%, which makes it useful tool in feeding a growing world population.[184][185]

Meiosis and DNA repair

Rice is used as a model organism for investigating the molecular mechanisms of meiosis and DNA repair in higher plants. Meiosis is a key stage of the sexual cycle in which diploid cells in the ovule (female structure) and the anther (male structure) produce haploid cells that develop further into gametophytes and gametes. So far, 28 meiotic genes of rice have been characterized.[186] Studies of rice gene OsRAD51C showed that this gene is necessary for homologous recombinational repair of DNA, particularly the accurate repair of DNA double-strand breaks during meiosis.[187] Rice gene OsDMC1 was found to be essential for pairing of homologous chromosomes during meiosis,[188] and rice gene OsMRE11 was found to be required for both synapsis of homologous chromosomes and repair of double-strand breaks during meiosis.[189]

Cultural roles of rice

Rice plays an important role in certain religions and popular beliefs. In many cultures relatives will scatter rice during or towards the end of a wedding ceremony in front of the bride and groom.[190]

The pounded rice ritual is conducted during weddings in Nepal. The bride gives a leafplate full of pounded rice to the groom after he requests it politely from her.[191]

In the Philippines rice wine, popularly known as *tapuy*, is used for important occasions such as weddings, rice harvesting ceremonies and other celebrations.[192]

Dewi Sri is the traditional rice goddess of the Javanese, Sundanese, and Balinese people in Indonesia. Most rituals involving Dewi Sri are associated with the mythical origin attributed to the rice plant, the staple food of the region.[193][194] In Thailand a similar rice deity is known as *Phosop*; she is a deity more related to ancient local folklore than a goddess of a structured, mainstream religion.[195] The same female rice deity is known as *Po Ino Nogar* in Cambodia and as *Nang Khosop* in Laos. Ritual offerings are made during the different stages of rice production to propitiate the Rice Goddess in the corresponding cultures.

A 2014 study of Han Chinese communities found that a history of farming rice makes cultures more psychologically interdependent, whereas a history of farming wheat makes cultures more independent.[196]

Ancient statue of Dewi Sri from Java (c. 9th century)

See also

- Artificial rice
- Rice production
- Indonesian rice table
- List of dried foods
- List of rice dishes
- List of rice varieties
- Maratelli rice
- Post-harvest losses
- Protein per unit area
- Puffed rice
- Rice Belt
- Rice bran oil

- Rice bread
- Rice wine
- Risotto
- Straw
- System of Rice Intensification
- Wild rice
- Upland rice

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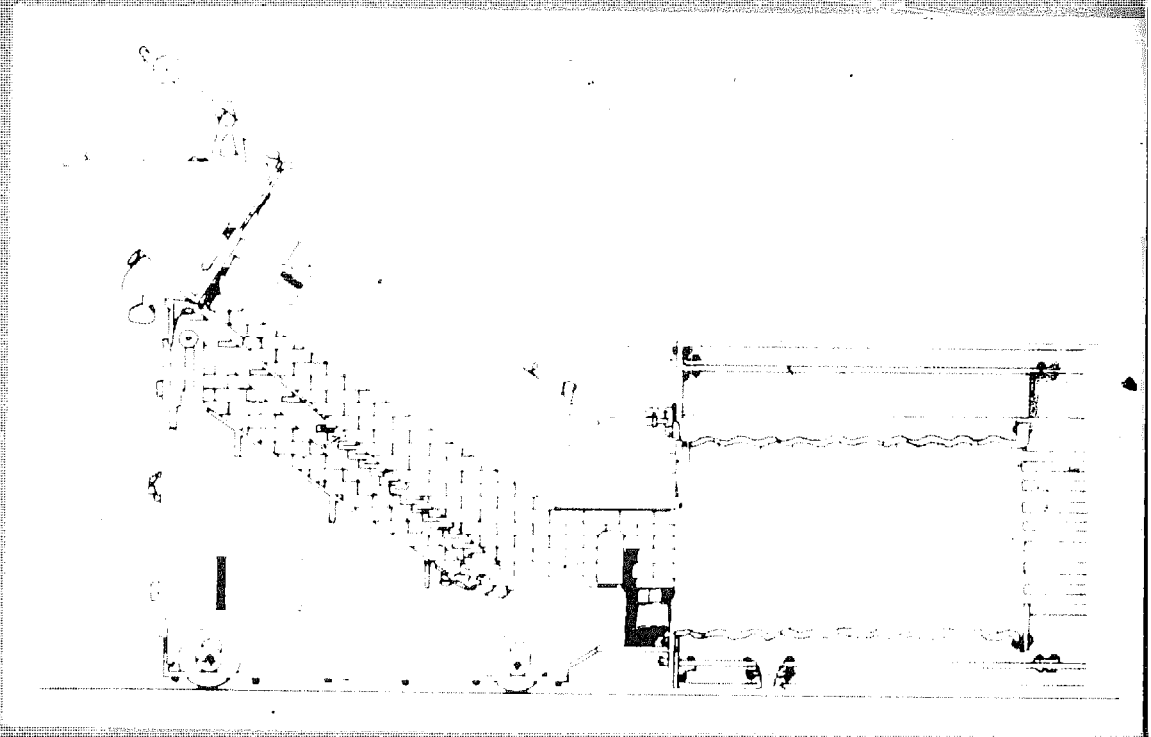

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS ROME

FAO AGRICULTURAL SERVICES BULLETIN 31

rice-husk
conversion to energy

by
e.c. beagle
fao consultant

food and agricultural industries service
agricultural services division

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 1978

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FOREWORD

The focal point of this study is the pressing need to utilize rice husk as an energy source, especially in the developing countries. It surveys the available processes and equipment for burning rice husk for energy production, mainly inside rice mills, combined with high grade ash production and potential utilization. After reporting on studies and interviews at the principal research institutions, machinery suppliers, and companies that make use of ash, it puts forward suggestions for further research and development activities, with special emphasis on the requirements of the developing countries.

The information contained in this paper includes the views of the author and knowledge obtained from organizations and individuals. Reference to a company and/or product name by the author does not imply approval or recommendation of the process or product to the exclusion of others which may also be applicable or suitable.

The author wishes to express his sincerest appreciation for the interest, data, advice and assistance he received from the many persons who contributed to the accomplishment of this study.

Comments and requests concerning this paper should be directed to the Chief, Food and Agricultural Industries Service, Agricultural Services Division, FAO of the United Nations, Viale delle Terme di Caracalla, 00100 Rome, Italy.

Chapter 1: INTRODUCTION - DISCUSSION

1.0 INTRODUCTION

In view of the crucial need to introduce modernized processes that will permit the utilization of rice husks as an energy source, especially in the developing countries, FAO commissioned Mr. Eldon Beagle to survey the available processes and equipment for burning rice husk to produce energy, mainly inside rice mills, leading to high-grade ash production as well as potentials for ash utilization.

This survey includes a desk study based upon Mr. Beagle's extensive experience with rice husks and their utilization as well as visits to major research institutions, machinery suppliers and companies concerned with the conversion to energy and the utilization of the residue.

The author visited some 30 countries and talked with millers, researchers, teachers, government officials, and industrial leaders. He also engaged in extensive correspondence with interested and knowledgeable persons in those world-wide areas he was unable to visit. The results of the survey are reported herein, along with suggestions for further research and development activities. Special emphasis is placed upon the requirements of the developing countries.

1.1 GENERAL DISCUSSION

1.1.1 BASIC CONSIDERATIONS

Husks are the largest milling by-products of rice, constituting one-fifth of the paddy by weight. With current annual world paddy rice production at 300 million tons, some 60 million tons of rice husks are produced each year. Proper utilization of this vast quantity, either through commercial application or other useful consumption, could have a major impact on the economies of both the rice milling industry and the country concerned.

1.1.2 RICE HUSK UTILIZATIONS

A broad variety of actual and potential industrial rice-husk utilizations exists, but the consensus has been that only a small percentage of the available husks are being utilized in any manner whatsoever. Traditionally, one of the major uses of rice husks was as fuel to provide energy for rice-mill operation, but the ever-increasing number of diesel and electrically-driven rice mills has largely eliminated such use except in certain areas. Consequently, it is believed that most rice husks remain as unused waste material and create a significant disposal problem. Common practice has been to dump the rice husks onto open fields or into nearby waterways. At times the husks are burned first and the residual ashes dumped. However, both char and ash can be utilized in a beneficial manner. Appendix A discusses some typical further utilizations of rice-husk chars and ash.

Recent field investigations, however, have provided increased data as well as accuracy and it was found that the utilization of rice husks is greater than has been originally estimated, particularly in the production of energy and its residual by-products. It now appears that about half of the available 60 million tons of rice husks are actually utilized in some manner. Since some of these usages are to expedite husk disposal, they may not represent the most beneficial utilization, and therefore in total offer the largest opportunity for improvement. Of the remaining half, it appears that some 30% do not currently and cannot in the foreseeable future lend itself to any economically feasible scheme, largely because the quantities available at any one site are inadequate. However, the last 20% offer full opportunity for beneficial development.

One of the best examples of beneficial use exists in India, where 40% of the rice husks available nationally are used as the energy source for parboiling 45 to 47% of the total rice crop. However, most of these steam-producing installations do not operate at high efficiency, so that in no known case does the available husk provide both motive power

and necessary process steam. In a very few cases a small amount of electricity is generated for ancillary purposes.

Considerable confusion arises from the fact that many discussions of husk utilization really involve huller bran and not husk. 30% of the husk in the world comes off as huller bran. This is not a problem of husk utilization but rather one of utilizing the usable rice by-products.

Huller bran is not husk and not a waste. The first operation is to separate the mixture--recover the husk, utilize the bran for feed and utilize the husk for energy. However, in some cases the huller bran could be used in total as an animal feed--in the manner of the use of rice-mill by-product.

The utilization of rice husks as a source of energy production very possibly represents an entirely new dimension in utilization thinking, offering the possibility that this disposal nuisance can now be thought of as a basic raw material, "a national treasure" as it is considered in Japan.

There is repeated emphasis in this report upon the local opportunity concept of feasible rice-husk utilization. It must be remembered that solutions satisfactory for any specific set of conditions are most likely to be completely unsatisfactory when applied to another set of conditions, because of such vital considerations as husk availability, technological capability, and actual market potential. Therefore, in every instance, particularly where energy is a prime consideration, both the entrepreneur and any interested government must fully evaluate all the pertinent factors before the validity of any utilization concept can be established.

1.1.3 WORLD-WIDE ENERGY CONSIDERATIONS

Although some countries are better endowed than others with the natural resources (viz., fossil fuels) commonly used to produce energy, there is a real and increasing world-wide concern about what was thought to be an almost limitless abundance rapidly being transformed into short supply, leading to upward spiralling costs, and non-recoverable depletion. There is widespread realization that no energy source can be wasted, either now or in the future.

As oil, coal, and natural gas availability decreases and prices increase, substitute means for maintaining existing levels of energy consumption must be developed and applied. The alternative is reduced consumption, which has broad negative implications, especially in the developing countries where the need for energy is on the increase.

While this situation will spur the development of hydro- and nuclear-produced electric power, the latter are certain to become more expensive and their use more discriminating. This means that a reappraisal of the most beneficial usages of all energy and resources is necessary. Additionally, the influence of cost factors must be reassessed and probably relegated to a less significant role. This has special significance for the developing countries, because it means that existing, proved technology should be applied to produce energy through the utilization of indigenous renewable fuels, freeing the more precious resources for applications where they can be most efficiently utilized domestically or exported in order to generate foreign exchange.

Need now exists for an alternative type of small prime mover which can be operated using such fuels as low-grade coal, lignite, wood, and agricultural and industrial wastes. The need for such a small engine is most acute in countries with few or no indigenous resources of liquid fuel and where mechanization of agriculture as well as village industries is one way of raising standards of living.

When a rice mill is operated from a power grid, it must be considered that either foreign exchange or a national resource is being utilized. In Indonesia, for example, it might be more advantageous to utilize indigenous fuel even at a higher energy economic cost and then sell the freed petroleum in foreign trade. Governments should loan, offer credits, or otherwise extend incentives to the individual miller to induce as well as enable him to build his own power plant using indigenous fuels and thus to reduce the load on the national or public generation facilities and the national or public distribution grids.

1.1.4 RICE HUSKS AS AN ENERGY SOURCE

Today, in considering any utilizations of rice husks, the significant changes in needs and economic conditions throughout the world exert an overriding influence upon the definitions and practicality of any plan for beneficial use. The rapid emergence of a universal need for energy resources has reshaped the feasibility potentials for by-products that can be utilized in the production of energy. This need also results in a broadening of perspectives regarding such usage: utilizations must now be viewed for their potential contribution to energy saving as a whole as well as in relation to specific local and national considerations.

The declining energy supplies, rapidly increasing consumption, and increasingly severe environmental constraints sharply focus attention on the need for additional amounts of clean energy sources. Conversion of the plentiful supply of organic solid wastes into clean energy forms provides an opportunity to expand the energy resource base while reducing the pollution now associated with waste disposal. Successful development of such conversion methods thus broadens the beneficial usage not only of rice husks, but also of other crops, some of which are grown specifically to provide additional energy from the sun because both sources consist essentially of cellulose. Possibly, this could be considered the first major practical application of solar energy to alleviate the energy shortage. The concept appears all the more attractive because the proposed energy resources are renewable, while the current utilization of fossil fuels is a non-recoverable depletion of energy resources.

Considerations of this nature prompted FAO to consider in early 1974 that the most practical use of rice husk in the foreseeable future was as fuel to provide energy, first of all for the rice processing industry, including parboiling, rice bran extraction and industries directly related to the rice industry.

Thus, rice husks now appear very attractive as a raw material, particularly in a "vertically integrated" energy system, wherein the raw material is used to produce energy while the resultant residue is marketable at higher prices than the raw material. This concept is especially applicable to rice husks because of the high residue levels obtainable. However, in order to receive full benefits it will be necessary to develop new methods of burning to produce higher grade and more uniform residues than are now obtainable with existing methods. Therefore, a basic need exists for developing more efficient methods to extract maximum heat from rice husks in a salable fashion consistent with feasible utilization of the residue.

There is a continuing challenge to develop heat-conversion processing units (furnaces, boilers and reactors) for the efficient conversion of rice husk into salable heat and residue. Most existing furnace designs convert about half of the available energy in the husk, which represents the volatizable level of the husk, the remaining heat potential existing in the fixed carbon portion. At least two methods have been developed for converting the fixed carbon heat potential; one uses high oxygen levels in the combustion cycle and the other features infra-red penetration in the transparent frequency range. Either method results in the release of all the heat potential and a carbon-free residue as well as a controlled carbon-silica product.

Also of considerable importance are other methods of conversion such as pyrolysis (for the production of char and oil) and gasification (for the production of producer gas). Several on-going research and development projects are concerned with the individual processes and equipment necessary. A detailed discussion of each possibility is presented in later sections of this paper.

Improved conversion methods should not only be geared toward obtaining maximum energy, but should be equally concerned with producing an improved, consistent grade of residue. Utilization of rice-husk derivatives has been limited because of the lack of uniformity. Higher quality derivatives are needed in a number of applications, including chemical usages, rubber reinforcement, and as a ceramic additive.

The urgency of carrying out heat-related research becomes obvious not only from current energy considerations but also from a consideration of the energy contained in a ton of husk. 6,000 BTU are available in a pound of husk, and a ton of husk replaces 84 gallons of heating oil of 140,000/BTU/gal at a price of 20¢/gal: the monetary equivalent is therefore US$16.80/ton of husk.

The beneficial use of rice husks as a fuel probably dates back well over a thousand years. For centuries, the Chinese burned a mixture of rice straw and husks in an open-top burner for cooking. The resultant black ash (char) was then used as an absorbent for human waste and this mixture spread on the fields as fertilizer. More recently, a furnace designed to utilize rice husks as fuel was developed in 1880 by C.R. Cowie of the English firm bearing his name (3)1/; in a few years every Burmese rice mill was powered with a husk-fired boiler. A portable husk furnace, along with supporting power plant equipment and even a suction gas producer, is illustrated in a 1910 publication which showed the advanced state of the market at that time.

In 1913, P. Poli (181A) suggested research on the utilization of rice husk as fuel. It has been reported that such utilization was practiced extensively in Brazil in 1915, and by 1925 most commercial rice mills in the world were operated by steam engines--generally of British, French or German manufacture, and usually of improved superheat design. Continuing development and use of steam equipment and processes appeared to lag shortly thereafter, primarily as a result of the advent of electrical power. New mills utilized this source of energy or diesel power and many of the existing mills were converted to electricity, which appeared to be inexhaustible, cheaper and a readily available source of power for milling purposes.

Casual interest in rice husks as a fuel began to reappear in the 1950s, but largely as a means to facilitate disposal of the nuisance waste. Some mills were using husks as fuel in their steam boiler furnaces to facilitate their disposal and in several countries many continue to use them. By 1970, the realization that the increasing consumption of energy derived from fossil fuels represented a serious energy problem became firmly established, and interest in renewable energy sources was rekindled. In the United States, there was talk of rejuvenating old technologies and turning to the beneficial use of non-fossil energy resources. In France, interest was aroused by publicity on a German-built automobile that had completed 15,000 miles of tests running on a fuel produced from straw.

It is obvious that the utilization of rice husks for energy purposes is not necessarily confined to rice mills. Husks should be considered as an available raw material in the same manner as any other raw fuel source. The practicality of its use is influenced by the following factors:

1/ Numbers in brackets refer to the Bibliography; numbers preceded by the letter W refer to the list of Workers, Suppliers and Institutions.

- quantity available in each location
- area available
- seasonal considerations
- transportation costs
- low density
- competitive fuels or power sources available.

According to one opinion, a change in point of view would accelerate acceptance of steam-raising equipment throughout the world. Such plants should be viewed first from the steam- and power-generating perspective and secondly as incinerators-furnaces. These plants should be operated only by the most efficient method which is, of course, the heat-coupled or back-pressure method of operation.

An Italian expert insists that any system which will assure full utilization of rice husks for energy purposes requires strict government regulation. Licensing and price control are essential elements, as is mill operation on a regular full-time basis throughout the year, with husk being pro-rated for the most efficient operations.

1.2 GENERAL PROBLEMS

1.2.1 LACK OF VALID DATA BASE

There is a classic approach to good planning. Simply stated, it is to identify the problem, examine the alternative solutions, select the most feasible approach, and implement it. When addressing the problem of rice-husk utilization, whether for energy or other purposes, the underlying problem which thwarts any valid application of the planning process is the almost universal lack of reliable data. Even within a single country, only broad generalizations are possible without adequate and accurate basic information. In most countries (Australia is a notable exception) no entity exists that can provide accurate and timely information regarding the national production and disposition of rice husks. There is usually no inventory of producers, nor, in most countries, of the rice mills themselves, let alone data on husk production, disposal, and utilization. Such utilization information as exists generally comes from individuals on a personal basis and results from limited personal observations. As a consequence, much of the information is incomplete or inaccurate. Usually, the situation in one mill or group of mills is generalized to include all of the mills in the observer's vicinity or experience. Actually, there can be a wide variance between two mills in the same town.

1.2.2 INEFFICIENT MILLS

The lack of data and formal planning, and outside-industry interference of the rice industry throughout large parts of the world, have resulted in many countries in a proliferation of inefficient mills. This inefficiency is a reflection of mill size in relationship to the paddy available as well as the potential utilization of the offal.

In many developing countries, there is a tendency to favour the low head-yield huller mill with its bran-husk mix, which creates a significant problem in most beneficial use, especially if parboiling is a consideration. Steam plants supplying the process steam are feasible only in larger mills.

Conversely, large, highly sophisticated rice mills have been built at great expense in situations that do not reflect the actual needs of the country. Consequently, when they do operate it is only for short periods or at reduced capacity, and they offer little or no overall potential for beneficial usage in energy conservation.

When considering the efficient utilization of rice husk for energy purposes, it should be remembered that this efficiency is a function of the actual amount and rate of paddy processed. In most existing systems for converting husk to steam in white rice milling, the milling units are too small to provide enough efficiency to warrant the capital outlay.

1.2.3 FINANCING

A financial capability is needed to plan, install, and operate viable sized rice mills that can efficiently process the paddy available within a reasonable area surrounding it and make most beneficial usage of the offal, particularly as regards husk utilization for fuel. This calls for new thinking and special consideration by the governments involved to provide the initial capital loans and other incentives to make such an approach feasible as well as attractive. While initial capital outlays are greater in this approach, the benefits to the country justify this higher investment over the long run.

Some countries (Indonesia and Italy for example) currently have a tax based on the basic energy unit. Any use of indigenous fuel under these circumstances will of necessity be taxed to produce the same income. This exerts a tremendous restraint on the utilization of indigenous energy sources--a sort of negative incentive. The government on the one hand is very desirous of encouraging the development of indigenous energy sources, but on the other hand is completely discouraging them. A ready solution to this complex problem is not easily formulated.

1.2.4 THE RICE HUSK ITSELF

There are four distinct problem areas associated with any consideration of rice husk utilization. Firstly, there is the husk itself, which must be disposed of in some manner. Secondly, the quantity of husks varies considerably from one place to another, and this significantly influences opportunities for utilization. Thirdly, there are large variations in local opportunities as well as marketing potentials for the utilization of rice husks and its residue. Finally, the physical and chemical properties of the rice husk themselves are of special significance because they affect handling, storage and utilization.

1.2.4.1 The existence of paddy husks: The morphological development of the rice plant has resulted in the evolution of a protective envelope which must be removed to gain access to the edible rice grain. This envelope is commonly known as the husk or the hull and constitutes about 14 to 26% of the harvested paddy weight. Common milling practice is to remove the husk at the correct time in the cycle to produce the best possible milling yield.

An understanding of what is obvious to all rice growers and rice millers is essential in any consideration of husk utilization. Rice husks are the inevitable by-product of rice milling, but rice is not milled to provide a supply of husks for any utilization scheme. Consequently, the first consideration for any husk utilization scheme is that it be compatible with local milling practices to assure a reasonably consistent source of supply. Next, such schemes must be measured against technical feasibility, the proposed beneficial use, and the realistic distribution potential. The latter aspect is of special significance because to manufacture a product that has no market within the possible distribution range merely replaces one disposal problem by another.

1.2.4.2 Production irregularity: The single most important factor in the so-called "rice-husk problem" is an obvious, albeit unappreciated, one. It is simply the amount of husk available for any projected utilization or to be disposed of. In each instance, significant variations stem from purely local considerations. Additionally, no apparent correlation has been found between the seriousness of the problem and the quantity of

rice grown, the rice milled, or the husks available for processing. Thus, the existence of twice as much husk does not double either the disposal problem or the utilization opportunity. Each situation remains unique.

This becomes most apparent by comparing the situations existing in the United States and Bangladesh. In the state of California, the annual rice crop is 2 million tons of rough rice, with a peak production of 1,900 tons of husks per day from the eight mills in the state. This maximum output continues on a seven-day-a-week basis for several months, after which the output is drastically curtailed over another indeterminable period. The peak production periods show no seasonal correlation or predictable occurrence. As a result, any planned utilization of rice husks calling for quantities exceeding the minimal amounts available necessitates that the cash return be sufficient to offset the cost of storing large quantities of husks. Bangladesh is at the opposite end of the production scale. It has an annual rice crop of approximately 19 million tons of rough rice, but 80% of this is milled in the villages by hand pounding, and the commercial portion of the operation is spread among a large number of small mills, the largest of which have production capacities of six tons of husks per day, while most mills produce only one or two tons of husks per day, and in many cases this is huller bran (about 29% of the paddy weight) as produced in huller mills. Thus, it becomes immediately evident that there is little in common between the California and Bangladesh utilization problems. Similarly, the circumstances affecting every other rice-producing area of the world are unique and the most feasible approach to overall utilization concepts is one based upon local opportunity, with all the local conditions becoming weighted factors.

As an obvious result of this situation, most proposals and discussions that appear reasonable to a miller in the United States, with a production capacity of 450 tons of husks per day, are almost unintelligible, if not outright ridiculous, to the Bengali miller whose production is limited to one or two tons per day. Also, the interests of the millers in the other rice producing regions of the world lie somewhere between those of the United States and Bangladesh. Therefore, it is impossible to attempt a single discourse on the problem of husk utilization that will satisfy the needs of the two widely divergent millers while addressing the broad spectrum of problems that lie between the two.

1.2.4.3 Variations in local opportunities and the marketing potential for products: Just as there are broad differences in the rates of rice husk production throughout the world, there are significant variations in the local opportunities for utilizing these rice husk residues. Some of these differences can be attributed to the geographical isolation of the miller from commercial markets and his lack of an aggressive sales orientation. In other instances, no understanding of the distribution potential, in actual distances, exists. Similarly, failure to grasp the concept of beneficial use acts as a deterrent to any improvements in residue utilization.

The desire to develop a technological capability for turning residues into salable commercial products must be tempered with a realistic consideration of the actual marketing potential for these products, including adequate evaluations of the economic feasibility of transportation and of the user market. Conversely, when local opportunity does exist, along with a valid marketing potential, there must be an active willingness on the part of the entrepreneur to project imagination and to participate in a feasible rice husk utilization scheme. In Pakistan, for example, the husks are used as the fuel in the rudimentary "chatti" process of parboiling, yielding a net economic benefit for the miller, who would otherwise have to invest in costly fuel and still dispose of the husks.

A more sophisticated and commercial utilization of rice husks is found in Europe, where Italian husks are sold to a converter, who turns them into ash which is then shipped to Germany and England for refractory use. All of this is possible because a technological market exists along with an adequate transportation system. Small amounts of ash also have been shipped from India to Europe, the miller obtaining a significant

economic benefit from the sale of his husks. Additionally, the activities of the converter contribute to the gross national product. However, in this case no utilization is currently made of the husks' heat value, which is all lost through open burning.

Very often, the entrepreneur does not pursue a utilization scheme because he is unaware of how to ascertain the validity of the concept. However, the approach to making such determinations is relatively straightforward; it can generally be considered to be made up of the following basic elements:

- complete familiarity with the properties of rice husks;
- an inventory of locally available sources of supply, skills and facilities;
- maximum utilization of existing literature to permit the valid selection of applicable technologies;
- evaluation of the available market potential in the context of actual market needs. Here, marketing horizons must be limited by practicality rather than provincialism;
- the need for overcoming traditional product use and regulatory barriers by educating potential customers;
- a continuing, aggressive sales campaign.

1.2.4.4 Physical and chemical peculiarities: Rice husks are difficult to handle because of their silica-cellulose structural arrangement, which imparts peculiarities different from those of any other plant offal. No other plant offal even approaches the amount of silica found in rice husks. The peculiar silica-cellulose "drinking-straw bundle" structural arrangement of the husks results in an object that does not burn or even liberate heat in a manner resembling that of any other organic substance. These minute silica-crested tubular structures offer an inherent resistance to burning. Often, they seal off and prevent the thorough, uniform burning essential to obtaining a desired end-product.

In its normally available shape, the protective envelope has an apparent density that is quite low, usually, 7 to 9 lb/ft^3 1/. After grinding, its concavo-convex form remains evident and the apparent density is in the range of 17 to 25 lb/ft^3, well below that normally expected, since rice husks have a true density of approximately 45 lb/ft^3. Some of the properties of rice husks and their derivatives are shown in Chapter 3.

The physical peculiarities of rice husks makes them difficult to store in outdoor piles. They are easily drifted by the wind, and when rainsoaked and decomposing, the piles can be set afire by spontaneous combustion. Dry storage in a warehouse is expensive because of the low density of the husks, and its cost is usually excessive when compared to the value to be derived from beneficial use. However, the size and shape of the husks also permit fluidity and ease of bulk handling using normal conveying equipment. At the same time, their lightness imposes problems in volume handling. For example, conveying equipment that can accommodate 50 tons of paddy can handle only ten tons of husks in the same time period. Additionally, husks have a low inertia and a high air resistance, so that any handling that involves throwing them through the air is rendered relatively difficult. They also cause excessive wear on handling machinery because of their high silica content. However, the adaptability of husk to pneumatic conveying is an important feature utilized in most husk handling systems.

1/ For conversion factors, see Appendix

Chapter 2: GENERAL ENERGY CONVERSION CONSIDERATIONS

2.0 INTRODUCTION

Rice husk can be converted to energy through the use of a number of different technologies. In many cases it cannot be said that a single technology is being used in a given process, a number of different situations being involved in the transition of the raw husk to an energy form and the resulting residue, because of overlapping reactions and split reactions. The difficulty is compounded by contradictions in definitions, since there seems to be no definition that is agreed upon by all workers in almost any phase of energy conversion. Appendix contains a list of definitions and terms as they are used in this report.

Processes and technologies exist today for extracting energy from rice husk at quite high efficiency levels. Methods have been developed for converting fired carbon heat potential; one features infra-red penetration in the transparent frequency range, which results in the release of all the heat potential and the production of a carbon-free residue. This process also offers the advantage of producing a product of any desired carbon/silica ratio, to enable further by-product utilization. (See also Section 5.3.1.4.)

Characteristics of rice husk combustion have been discussed for many years--formally since about 1880 (Cowie). One of the best and most descriptive was written by Burrows (109A):

> "Rice husks are flame retarding and, at ordinary temperatures, self-extinguishing. A lighted match, tossed onto a pile of rice husks will generally burn out without producing a self-sustaining flame in the husks. Heated in a crucible over an open bunsen flame, the husks produce a flammable gas and smoke, which ignites, leaving a black cinder of almost the same size as the original husk. Distillation of the husk decomposes the cellulose to carbon and steam, driving off volatile residues and tars with the steam. Neither ignition nor distillation removes the carbon residue from the cinder, nor does any silica, as such, become apparent in the cinder at this stage. Heated to a red heat, in a stream of air or oxygen, the carbon is partially or completely burned off as carbon dioxide, leaving residues of carbon-silica or silica.
> In attempting to maintain a red heat within a column of husk cinders, without external heating, for sufficient time to completely remove the carbon, one is faced with very delicate requirements of draft control, cinder size distribution, column wall insulation, oxygen level in draft air, etc. In preliminary experiments, we have produced a product, utilizing controlled forced draft, but no heat other than the heat of combustion of the cinder, and no supplemental oxygen in the draft air. With additional heating and an increase in the oxygen level, the carbon is completely burned off, the residue consists of microparticulate silica."

In the following sections, each of the various methods or technologies available to effect the conversion of rice husk to energy is discussed.

2.1 BURNING IN AN EXCESS OF AIR

Although the energy in the husk could be released directly by burning, there are several reasons why this is not always the answer. Raw husks cannot be easily stored and do not burn cleanly or easily. Energy recovery efficiency is low or non-existent.

In a simple form, the energy released cannot be stored, but must be used as it is produced. The combustion products may be corrosive or pollutants. Finally, the supply of husks may be irregular, seasonal, or otherwise erratic, out of tune with energy demand. Therefore, excess-air burning or use of a field-burning disposal system is possible only in special circumstances.

In situations where the amount of gas transferred is more than the amount of air necessary for efficient, clean combustion, an external combustion chamber may be called for. When combustion is completed in the separate combustion chamber at low excess-air rates, process efficiency (in terms of net heat production at minimum flue-gas volume) is maximized, and reduction in the size of the air pollution equipment required is obtained.

2.1.1 BURNING IN AN ATMOSPHERIC PILE

If the pile is very thin and there is some air blanket turbulence, as on an open field, true burning will occur. It will also occur in an air-suspended burner or furnace. However, as soon as the unburned mass is brought up to a temperature of about 350°C, decomposition sets in, and the volatile component of the husk distills off and will flare upon ignition if given the chance in the configuration of the action.

Except in a driven-wind situation, a thin outside pile without other fuel generally acts as if in a controlled atmosphere, which it is, because it does have a CO_2 blanket control system.

Very seldom will thermal convection be sufficient to create excess-air burning conditions unless there is sufficient externally induced turbulence.

2.1.2 BURNING IN A CLOSED AREA (INCINERATION)

Incineration is a combustion process designed to reduce the weight and volume of a waste on a controlled basis. The term is used only for burning materials for disposal, and in this respect differs specifically from the term "pyrolysis".

An incinerator for husk would be a closed area or vessel built specifically in which to burn husk for disposal. Some of the burning buildings in France could be called incinerators, and there are probably other areas in which a formal burning-disposal enclosure is used.

A properly designed incinerator with an adequate stack for draft and a simple step grate could automatically solve many of the problems of husk disposal in various parts of the world, Malaysia being one. The only requirement would be an ash removal system that operated simply and efficiently and was of adequate capacity.

2.1.3 BURNING IN A FURNACE

2.1.3.1 Traditional style: In furnace burning, the resultant product and type of burning depend on the grate system employed and the depth of material on the grate; also relevant are the radiation derived from the interior surfaces of the furnace, and the flow of air through the grate.

In general, the more benign the furnace, the greater the percentage of heat conversion, and the lower the carbon in the ash available. However, this is not compatible with high-ratio output, so most furnaces are somewhat of a compromise in design. In some boilers, design parameters allow husk burning in the tubes; in others, attempts are made to allow no unburned material or residue to enter the tubes. If this is the desire, the design of the furnace must be such as to ensure that the gas flow is settled out in the furnace section, so that the residue can be removed in the furnace section, with no

particulate matter entrained at the entrance to the boiler tube sections. If natural draft is employed with no scrubbing or filtration, the tubes must have an adequate section, so as not to create an excessive pressure differential. In this case, attention must be given to the furnace design to ensure that no particulate enters the tube section, as the velocity of gas in the tubes may not be sufficient to convey the particulate matter through. In some cases it is advisable to use a steam soot-cleaning system, which will also scour the husk residue that would otherwise insulate the tubes, lowering the operating efficiency of the boiler.

There is a great range of efficiencies in the various designs of grating systems, as in furnace design as a whole. No results are available to indicate the value of one system as compared with another. As a standing rule, it is felt, as was recommended by B.R. Wolf, that for natural draft systems or furnace discharge, induced-draft systems must not create over 1.0 m/sec air flow through the grate in order to ensure the retention on the grate of the particulate residue. Of course, this limit dictates the size of the grate, as the necessary combustion air for any given quantity of husk can be calculated.

A furnace carrying the residue through the tubes requires a velocity of not less than 3.5 m/sec. The furnace tubes should not be less than 70 mm (2.8 in) in internal diameter; too small a tube will aggravate the tendency for tubes in certain areas to plug. The head areas must be adequate in section so as not to create air-flow channels which will deprive certain tubes of equal pressure drop. Well designed and adequately sized fire-tube boilers conveying all of the husk residue through the tubes have operated for many years without any maintenance whatsoever other than the required annual cleaning and inspection. Following direct questioning and inspection, the author has never found a single case of wear of inlet radii and thinning of tubes.

2.1.3.2 Air-suspended: Air-suspended turbulent cyclonic furnaces can be described as

- direct fired
- tangentially fired
- top extraction
- bottom extraction

Several modern facilities using suspension-burning principles may be divided into two categories: those which suspend the burning fuel in the gas stream in the combustion enclosure, and those which suspend it both in the gas stream and in another medium: the fluidized bed. Although the principles are not new to the power or process industries, the application of suspension burning to husk-fueled power systems is innovative at this time. Advantages of flue-gas stream suspension burning include a more rapid response to automatic control, an initial cost saving due to the lack of grate surface and mechanical stoking devices, and the ability to achieve complete combustion with a much smaller percentage of excess air in the furnace (which represents a significant economy where the husk is a useful fuel and every BTU has a value).

A good example of the direct-fired type is the Gariboldi smoke-tube boiler system, in which a portion of the heat is released in the furnace, and burning continues while in the boiler tubes. A tangentially fired power system external furnace is typified by the Pitts combustion chamber.

2.1.3.3 Fluid-bed furnaces: Fluidized-bed suspension burning systems have all of the advantages of the flue-gas stream suspension, plus one which is important where a system must operate intermittently (e.g. one shift per day). Fluidized beds, usually sand, comprise a "thermal flywheel" of large capacity. When the operating temperature is reached, they retain heat over a long period, losing only about 110°C during an overnight shutdown. The savings on auxiliary fuel for preheat on the next start-up are appreciable and tend to offset fuel preparation costs.

A unique use of the fluid-bed furnace principle is typified by that described in UNIDO-ID/WG 89/20, Use of inert media (sand and paddy husk powder) in simultaneous parboiling and drying of paddy, by N.G.C. Iengar and R. Bhasker. However, no commercially installed fluid-bed furnace working on raw rice husk is known to the author, though the "Copeland" furnace has at various times been suggested for that use. One objection to fluid-bed furnaces is their high power requirement and capital outlay, and except in very special circumstances it may be difficult to justify their installation. (See also Section 6.3.2.5.)

2.1.3.4 Allowable heat release: It would, however, be interesting and educative to determine the allowable and possible heat release in an air-suspended combustion system using a cyclonic furnace, in practice similar either to the Pitt or Finch designs. The author has no knowledge of any proprietary investigation to determine its advantages or disadvantages.

2.1.3.5 Spot heating: In an air-suspended burning system, each particle of husk volatilizes and burns individually. Usually in this type of furnace the resultant char product is partly crystalline or has very low carbon content when the uncontrollable temperatures and varying air/fuel ratios create individual hot spots. This can be seen in practice: in general there is a black char residue, but upon examination small silver flecks or grey blacks seem to be visible. These are the grain or portions of the grain that either were exposed to a different temperature/air fuel ratio or differed in some way in residence time from other particles or pieces of particles.

In an air-suspended excess-air furnace, it would appear to be difficult to obtain a constant and homogeneous level of product.

2.1.4 FINE-PARTICLE FUELS

For many years, occasional interest has been expressed concerning the practicality, effects and efficiency of burning finely divided fuels. In the literature available, only one reference--Ramzin (182)--shows any effort to learn about the effects of use of rice husk as a fuel of fine granulation. It would appear that only under the most special conditions would the cost of grinding husk to a fine powder be justified. Rice husk is a very abrasive material and is possibly the most expensive agricultural by-product to reduce in size. It would appear, however, that transport considerations would make it feasible to crack (grind coarsely) the husk. A very low cost grind through 1/4" to 3/8" hammer-mill screens will raise the density from 8 to 17-18 lb/ft^3, making the transport or collection of the husk profitable.

2.2 BURNING IN A CONTROLLED ATMOSPHERE (BCA)

This situation is very close to all of the other methods of conversion, but in a simplistic view of things.

BCA is very close to distillation, gasification and pyrolysis, and assuredly some readers will differ with the following classification and definitions used.

In order of completeness of coverage, the list of means of heat conversion includes:

- burning in a controlled oxygen situation
- gasification
- distillation
- pyrolysis
- carbonization
- thermal decomposition

each lower classification being a little less comprehensive than the preceding one.

In this paper, "distillation" is used when discussing a process in which the gaseous portion is fractioned out to a range of products similar to those investigated comprehensively in the years before 1940; "gasification" normally refers to generation for gas use purposes, such as producer gas generators. "Pyrolysis" and "pyrolytic conversion" are generally used to express the current ideas of conversion to synthetic fuel oils, chars, gases, etc. For all these terms, the process is the same: heat decomposition under controlled-atmosphere conditions.

According to Lewis (120A), "A number of process variables determine the ultimate yield and final composition of the solid, liquid, and gaseous products from pyrolysis and gasification. For pyrolysis processes, the major variables are chemical composition of raw material, heating rate, and ultimate material temperature. One conclusion that may be drawn, based on several investigations of these and other process parameters, is that the complexity of these interactions makes it impossible to predict the final product characteristics."

2.2.1 Burning in an atmospheric pile: While it is normally thought that open pile or atmospheric burning is essentially an excess oxygen situation, in reality it is not, in ideal conditions. This is because the process is self-limiting by the CO_2 blanket and controls itself to regulate automatically the gas formation and generation-distillation by blanket control and oxygen access. Practically, however, this does not happen, as the air currents around such a pile disturb the blanket. By mass configuration there is some control on the resultant analysis and phase result. In other words, if a purely amorphous product is desired, the pile configuration must be such that internal temperatures do not rise above about 900°C, a temperature at which amorphous products crystallize. The radiation and convection from the mass must balance the rate of heat release from the decomposition to hold the temperature in balance. In the ideal pile, atmospheric process is closer to pyrolysis than to burning.

2.2.2 Burning in a closed area or volume: This is more fully covered in a later section on burning buildings (see Section 5.3.2.6.). In this type of burning it is usually possible to maintain control of the oxygen input and, the whole activity taking place within the walls, there is no disturbance of the inert blanket covering the pile. A natural thermal convection creates a slight draft through the pile, but the lower air control keeps the temperature at any desired level. One of the problems of burning raw husk in a building involves the gasification of the mass and subsequent flaring, which is less controllable than the carbon burning sequence. In a US patent, Hughes (169) considered that by first volatilizing in a distillation-type converter and then burning the char under controlled conditions in the enclosure, a marketable product might be produced. The problem here was to retain sufficient heat in the mass to ensure continuation of the conversion. Otherwise, when the proper amount of oxygen was introduced, the cooling effect would eliminate any possibility of further burning.

A similar problem has been considered by Burrows (109A): "It has been demonstrated that the charred hulls produced may be oxidized by air to a form in which silica is predominant, most of the carbon being burned off. This requires special equipment to confine the heat of combustion and to control the air feed rate. For some applications, it might be desirable to retain more of the carbon, utilizing the combination process to increase the silica-to-carbon ratio and achieving some activation by opening additional channels for absorption. This could be accomplished in the same equipment by simply increasing the air flow rate."

Brick firing (in "burnout brick") is another example of burning in a closed area. The energy contained in the husk mixed in the body of the brick is liberated when the brick is baked in the kiln, and the energy value of the entrapped husk is added to the value of fuel used in calculating the total energy supplied. The burning of the husk in the brick is under very controlled conditions, and gasification develops because of the porosity of the brick.

2.2.3 Infra-red burning: The controlled processing of rice husk using infra-red penetration has been developed in recent years. The infra-red radiation from the incandescent overbody heats the husk to burning temperature, while the counter-current air coming through the belt cools the belt and furnishes sufficient and controllable combustion air. No other type of burner can do this.

The total heat used for kindling and radiant energy in the second stage and the total heat release of the husk in the machine can be captured in the conversion sections of the system with ducting above the afterburner to boiler section. It is the only way a large-particle, low-density, amorphous ash can be produced commercially.

2.2.4 Enriched-air combustion: For some applications of microparticulate silica in industry, it is necessary to have a silica essentially free of coloured matter (predominantly black); for such applications, it is necessary to carry the combustion to completion, burning off all the carbon. This can be accomplished by adding just enough oxygen to the air stream to maintain the conditions of complete combustion. A very moderate increase in the oxygen level of air suffices.

However, one drawback to such a use is the fact that the carbon is not the only impurity present in the ash. There is also a residue of about 5% of other compounds and fluxing agents intimately mixed in the silica matrix, composition varying with both the variety and geographical planting location. The commercial practicality of rice husk as a silica source has never been demonstrated.

2.2.5 Other controlled burning: Several similar methods and apparatus developments are in existence though none have attained any commercial viability. Three of these are Kocee (170), Gravel (167) and Finch (168).

In 1970 Thomas (155) studied the physical makeup, ashing and decomposition of husk. The results of this work were widely reported and have proved most helpful to many workers.

2.3 DESTRUCTIVE (DRY) DISTILLATION

This is a process in which substances are heated (600-1000°C) in the absence of air or oxygen so that thermal decomposition occurs and gases and vapours of the decomposition products are passed to a collecting and condensing system. A solid non-volatile residue remains when the process comes to an end. The term carbonization is often used for such a process.

Bituminous coal is subjected to destructive distillation in large quantities to produce coke, coal tar, and coal gas.

Large quantities of wood were formerly subjected to destructive distillation to produce methanol, acetone and other chemicals. Such destructive distillation processes could not compete economically with synthetic methods, but charcoal is still produced by destructive distillation (W19).

The recovery of oils and chemicals from oil shale or tar sands requires that these be subjected to heating in the absence of air, and this process is therefore at least partially an example of destructive distillation.

The terms cracking, pyrolysis, and thermal decomposition have the same general meaning and are roughly synonymous with destructive distillation. The latter, however, is applied particularly to coal, while cracking refers most often to petroleum. Pyrolysis and thermal decomposition are used more generally.

Depending on operating conditions, husk will yield char, tar and pitch, light oil, organic acids and alcohols, ammonium sulfate, and gases. These products (Table 1) can be separated and sold or used as fuel.

TABLE 1

Products of destructive distillation of rice husk

(Source: 118)

Product	Percent by Weight	
	Min.	Max.
Liquor	40.90	43.20
Charcoal	37.10	39.80
Acetic acid	2.99	3.58
Methanol	1.30	2.07
Acetone	0.41	0.81
Loss (by diff.)	17.30	10.50

Most so-called distillation units are either controlled-burning or pyrolysis units. Distillation is used in this paper to describe a process in which the fractions are utilized in an identifiable production. It is usually used to describe older (1910-1950) work. Most recent work can more correctly be called pyrolysis.

When rice husk is heated in the absence of air to about 320°C, spontaneous decomposition takes place, with a generation of heat. The residue is charcoal and the vapours on condensation result in a gas of low calorific value and a water solution which, on distillation, can be separated into methanol, acetic acid and tar. The charcoal formed is finely divided and difficult to remove from the process. The methanol and acetone are commercially produced today in synthesis plants at a lower cost. This competition apparently renders the use of rice husk uneconomical.

There are a number of good background papers on rice husk distillation. Vigino Francesco (142A) obtained at 700°C from 100 kg of husk: gas 26 m^3; distillate 20 kg containing 4% acetic acid; tar 5 kg; and 40 kg of carbon containing 38% ash. Marcusson (125) at a lower temperature (200-300°C) obtained: gas 20 m^3 of about 2700 calories; distillate 33 kg; tar 6 kg; and carbon 41 kg.

According to data received from Iyengar (W129), further distillation of the tar portion produces a gas containing 21% CH_4, 18% H_2, 27% CO and 31% CO_2.

TABLE 2

Analysis of rice-husk distillate

(Source: 142A)

Acetic acid	7.32%
Acetone	.91%
Ketone	.05%
Methyl alcohol	trace
Alcohol	.01%
Tar distillate 100-125	2.80%
Tar distillate over 125	2.70%
Tar mineral	.04%

Possenti (129; 130) and Borasio (108) also did considerable analysis and presentation of distillation products. Fieger reviewed progress in his report (219) as did Tucker (229) in his thesis, on which Fieger's paper is based. A good overall study and presentation on a modern level was made by Staackman (228). The general feeling has been fairly negative, and this has been borne out by the lack of commercial use of this method.

The only commercial rice-husk distillation units known to the author to be operating are usually used only as char producers or disposal units, and the excess flue gas is flared off.

2.4 PYROLYSIS

Pyrolysis is the name given to the transformation of a compound into another substance or substances by heat alone. Although the term frequently carries the implication of decomposition into smaller fragments, there are many examples of pyrolytic change which involve either isomerization with no change in molecular weight, or building-up reactions (polymerization) giving rise to compounds of higher molecular weight. Hence, the term "pyrolysis" is broader in its scope than "thermal decomposition".

Like incineration, pyrolysis is a controlled-combustion process. Unlike incineration, however, pyrolysis does not imply that a waste is being burned; in fact, the pyrolysis process has been used for years by industry (e.g. production of charcoal and methanol from wood, and coal gasification). The process requires raising the fuel to a temperature at which the volatile matter will distill (boil off), leaving carbon and inert material behind. The carbon and volatiles do not burn in the process, owing to an intentional deficiency of air in the primary reactor. Volatile matter may be burned off as waste in a secondary chamber to which air is added, or may be cooled and condensed to selectively recover oils and tars. Alternatively, the gases may be cleaned and used as a gaseous fuel.

By contrast, however, solid residues from processes may be marketed as charcoal or as a filtre-absorbent for use in waste-water treatment. Since the process involves combustion in an air-deficient atmosphere, the volume of off-gas is lower than with incineration--a large benefit for air-pollution control. The combustible gas is seldom emitted, however, and is usually burned as a fuel or processed for recovery of hydrocarbons.

The potential of agricultural residue pyrolysis as an effective method of capturing renewable solar energy is well documented. Traditionally, agriculture has been considered a source of essential calorific energy to drive the biochemical engine of man. There is no reason to prevent the industry from providing calorific energy for other applications-heating, electric power generation, etc. Unfortunately, the latent heat energy of agricultural residues is not in a suitable form for utilization in these applications. However, pyrolysis represents an excellent method for converting this latent heat energy into a useful form of energy: high-temperature producer gases. The problem has been to find an efficient, low-cost pyrolyzer with large-scale throughput. Several such systems are described below.

As compared with hydrogenation and hydrogasification, pyrolysis has the advantage of operating at normal atmospheric pressures, reducing construction and operating costs.

The oxygen-free atmosphere is obtained by recycling a portion of the product gas. Heat requirements for the process are in the range of 500° to 900°C. The importance of this process lies in the fact that it yields multiple products, all of which are combustible without polluting the environment. Depending upon the feed, 90% or more of the energy in the feed can be recovered as low-sulphur fuels that can be burned by conventional methods. This results in the production of an easily convertible, transportable or storable high-grade fuel from low-grade fuel. The process of making

charcoal by pyrolysis dates back to 2000 B.C. Pyrolysis is used in the manufacture of coke, coal being heated in the absence of oxygen to drive off the major fraction of the volatile organics. The fuel gas produced by this process is known as coke-oven gas.

Pyrolysis reactor designs include the fluidized bed and vertical and rotary reactors. The main reactor criteria are the method of heating (indirect or direct), feed condition, temperature of reactions, and air pollution considerations.

An allied development which, although it has never directly used rice husk as the input, nevertheless shows promise of development along that line is the pyrolytic converter of the Georgia Institute of Technology (W178). The output is in the form of sterile char. No use is currently made of stack heat but any form of waste heat utilization would be possible.

The Wallace Atkins Oil Corp (W223) has offered, on a proprietary basis, a pyrolytic process for conversion of rice straw and husk to usable oil, gas and char. No definite information is available.

Garrett (W179) has operated for several years a federally funded research project designed to demonstrate the economic and technical effectiveness of the flash-pyrolysis process to convert agricultural wastes, including rice husk, activated carbon and heating oil being produced as by-products. A modified 4-ton/day pilot plant has been operated utilizing rice husks to provide process engineering data for the design of commercial-scale demonstration plants. Results on the laboratory pyrolysis reactor show a recovery of 40% synthetic oil; 33% char; and 8% gas.

Detailed descriptions of several similar processes are set out in other sections of this report (see Sections 5.3 and 6.5).

Pyrolytic processing of husk is involved in the production of silicon tetrachloride ($SiCl_4$) (233, 234), as the first step in the manufacture of $SiCl_4$ from rice hulls must be the pyrolysis of the hulls. In this step, drying occurs, followed by decomposition of cellulose and saccharides to carbon and water vapour, and cracking of other organic compounds to carbon and volatile substances. The pyrolysis gas thus contains a variety of organic compounds, some of which are condensable, but it is essentially free of inorganic particulates. Residual hydrogen content must be very low to prevent excessive consumption of chlorine, and residual water must be negligible to prevent hydrolysis.

A new system has also been developed for resource recovery from solid wastes by pyrolysis using high-power plasma arc torches. The commercial applications of this process applied to rice husk are not known.

The US Bureau of Mines has done considerable work on pyrolytic conversion of agricultural products, some of which is applicable to rice hulls. Crentz (174) produced a scrubbed pyrolysis gas with a 74% energy recovery. However, no direct rice-husk work appears to have been done by the Bureau of Mines.

2.5 GASIFICATION - PRODUCER GAS

When rice husk is burned in the presence of only a limited supply of air, it gives rise to a mixture of gases, known collectively as producer gas, consisting principally of carbon monoxide and hydrogen, which are inflammable, and the non-inflammable gases carbon dioxide and nitrogen. If water vapour is introduced into the generator the proportion of hydrogen in the mixture is increased.

The use of this gas mixture in internal-combustion engines has been practiced for many years, but has been confined chiefly to the stationary engine, in which the weight

and size of the necessary generator and cleaners are unimportant. Its successful utilization as a fuel for motor-powered vehicles presents difficulties, but from time to time efforts have been made to adapt it to them. During World War II, producer-gas-fueled vehicles were extensively used in many countries.

Countries most interested, for both economic and political reasons, in the utilization of producer gas as a source of power are those dependent on foreign supplies of oil.

Producer gas can be utilized for drying purposes, for steam generation, for partial substitution of SNG in internal-combustion engines, for the generation of electricity or for other commercial heating usage. It can also be used to replace or supplement liquid fuels if the burner or engine is equipped with the proper mixing and control mechanisms.

During World War II, rice-husk-derived producer gas was used to supplement the town gas system in Vercelli, Italy. The mixture used (59% fossil gas of 4350 cal and 40.5% rice-husk gas of 1500 cal) resulted in a net 3200 cal gas, yielding an overall saving of 23% of the coke requirements of the town's system.

Also, a few rice mills utilized rice-husk gas derived from fueled producer-gas units for fuel for paddy trucks, bottled at about 200 atm.

In Italy during and immediately after World War II there were 57 rice-husk-powered rice mills. Only one remained with the installation intact in 1975. It has recently been reported that a rice mill at Kouroma, Mali, is powered with a Chinese producer gas/ic engine system.

The principle involved in a gas producer is the combustion of carbon in the presence of some oxygen to produce, first, carbon dioxide and then, with further reduction, carbon monoxide. The burning conversion of one pound of carbon directly to carbon monoxide produces 4,451 BTU. If the carbon monoxide is caused to combine with fresh oxygen any time after it leaves the gas generator, this second combustion process produces 10,093 BTU. The producer-gas heat value per pound of carbon is then 14,544 BTU (123).

Producer gas can be used to operate internal-combustion engines, to fire boilers, as a fuel for gas dryers to dry any commodity-air (fluid or direct-contact), for kilns (either tunnel or rotary) or for heat-treatment furnaces.

From 100 kg of husk, Possenti (129) produced 100-130 m^3 gas, 2-4 kg tar, 20-25 kg carbon, 1.22-1.24 kg/m^3 density of gas with a heating value of 1300-1600 $kcal/m^3$.

TABLE 3

Producer-gas analyses under varying operation conditions (Balestra distillation unit)

Gas	Content
CO_2	4.2 - 7.7 %
O	2.4 - 2.8 %
H	4.8 - 7.8 %
CH_4	7.2 - 4.5 %
CO	25.0 -22.7 %
N	56.4 -54.5 %
Heat	1586 -1350 $kcal/m^3$

1 hp/hr requires 1.8-2.4 kg of husk, assuming 20-22% efficiency.

It is possible to produce a generator gas of 2500 kcal/m^3, as compared with the 8000 kcal/m^3 of natural gas.

In experimental work by Maheshwari et al. in 1974 (178; 179) a gas was produced with an approximate analysis of CO_2: 8% CO: 16% N_2 + other: 76% with a heat value of approximately 150 BTU/ft^3.

Another comparison of gas composition and comparative caloric values of wood blocks, sawdust and rice husks is shown in Table 4.

TABLE 4

Gas composition and caloric values of rice husk and other fuels

FUEL DATA	For Reference: Wood Blocks	For Reference: Sawdust	Rice Husk
Net. Cal. Value per lb (dry)	7,750 B.Th.U.	6,350 B.Th.U.	6,340 B.Th.U.
Fixed Carbon	18.7 %	20.67 %	17.4 %
Moisture	0.0	0.0	0.0
Volatiles	77.0	78.4	60.9
Ash	4.3	0.93	21.7
Lbs./B.H.P. (Dry)	1.75	2.2	2.2
Lbs./B.H.P. (29% Moisture)	2.2	2.8	2.8
CO_2	6.9 %	12.2 %	3.0 %
O_2	0.2	0.8	0.4
CO	28.1	18.2	32.2
H_2	13.9	10.2	6.4
CH_4	3.7	3.2	0.6
N_2	47.2	55.4	57.1
Cal. Value per cu. ft. gross at 60° and 30''	170 B.Th.U.	123 B.Th.U.	135 B.Th.U.
Cu. Ft./Lb. of Fuel (Dry)	32	33	30
Cu. Ft./Lb. of Fuel (20% Moisture)	25	26	24

excerpt courtesy Power Gas Corp.

The calorific value and the percentage of combustible gas varies according to furnace design as well as the presence of wet or dry gas. Table 5 shows the results obtained with different types of producers.

TABLE 5

Combustible gas produced under varying conditions

Type	Production of combustible gas
1. Up-draft dry-gas producer	37.5%
2. Up-draft wet-gas producer	44 %
3. Cross-draft dry-gas producer	37.5%
4. Cross-draft wet-gas producer	38.5%

The calorific value of the gases gives the advantage to No. 2 which is about 13% higher than the other types, owing to the presence of water gas. The development of wet-gas-type producers with the necessary filtres and scrubbing can increase the thermal energy of the gas by approximately 11%, with a 14% increase in combustible gas.

A primary advantage of gas-producer systems is that minimum attendance is required. The system is relatively simple in design and thus maintenance is nil. One of the most critical design requirements is the removal of ash from the producer. It is important to note that depending on the ultimate usage, the producer gas may or may not require a filtring and scrubbing system to remove entrained particulates.

In summary, rice husks can be economically gasified to produce a combustible gas with a calorific value of approximately 130 to 150 BTU/ft^3. This producer gas can be utilized to drive a gas engine or turbine-generator or to provide steam to drive a rice mill or electric generator in the range of 5 to 220 HP or even higher. Coupled with generating units, these gas engines would prove a valuable source of power for general industrial and lighting purposes, and particularly for developing the rice industry. They can provide an ample and cheap power supply for irrigation pumps, farming equipment, milling plants and by-products processing installations.

As a practical circumstance, the local- or farm-level unit must be able to use any indigenous fuel, not only rice husk.

Working on current projects involving the construction of experimental gas producer generators and test systems are Paras (W135) and Cruz (W136). Horsefield (W219) is currently involved in design and application work. There are undoubtedly many more workers in different institutions and laboratories all over the world studying, designing and constructing such equipment. It is difficult to identify them except by chance or when their results enter the publications and reference systems. Equipment for gas producer systems is discussed in Section 6.5.

2.6 OTHER CHEMICAL, THERMO-CHEMICAL AND BIOCHEMICAL PROCESSES

2.6.1 BIOCHEMICAL FUEL CELLS

Some popular interest was generated several years ago by a popular article by Halacy (177A), describing biochemical fuel cells, their development, history, and operation. The background information cites the various scientists and government and private agencies engaged in the development of such devices. In one type of biochemical fuel cells, rice husks (hulls) are employed as an activator or electrolyte "carrier".

"In a more specific sense, the properties which characterize biochemical fuel cells may be summarized as follows:

(i) Biochemical fuel cells require mild conditions of electrolyte concentration and temperature.
(ii) Unusual and complex reactants may be used such as natural products, vegetable or animal matter (either freshly produced or waste) and as oxidant oxygen, or air or oxygen containing anions which occur naturally and in sea water.
(iii) Catalyst regeneration may be continuous, therefore the cell has a very long life.
(iv) The operating power density is likely to be very low. Typical fuels can be prepared from carbohydrates, fats, or proteins. Examples of the carbohydrates are waste cellulose starch or sugar solutions. These are regarded as primary fuels which have to be degraded into simpler substances such as glucose before they can be thought of as electro fuels." (Hart)

2.6.2 COMPOSTING - MULCHING

Rice husk serves as a compost or mulching agent in several manners: as a moisture retention helper or as a weed growth inhibitor, the heating effect of the pile of husk while decomposing assisting in the sterilization of the soil. When rice husks are mixed with sewage sludge and allowed to heat properly, a sterilized, odourless mulch results. This process, "Tillo" (W207) utilizes the energy of decomposition only to cure its own matrix.

2.6.3 WASTE HEAT

The recovery or utilization of the waste or stack heat from any rice-husk conversion process represents a special form of conversion: that from an unusable reservoir of heat to a captive convertible source. Any process which generates heat can be utilized as the source of waste heat; only economic factors can determine its inclusion or rejection as part of the overall energy system.

2.6.4 FERMENTATION

"A process has been developed by the USDA-NRRL, using the organism clostridium acetobutylicum, for fermenting xylose or pentose sugars obtained from agricultural residues including rice husk to liquid fuels or solvents. H.M. Tsuchiya, J.M. Van Lanen, and A.F. Langlykke, U.S. Patent 2,481,263, September 6, 1949." Lathrop (223).

No other reference to a fermentation approach to rice-husk energy conversion has been found in the literature.

2.6.5 HYDROGENATION

Hydrogenation, also called deoxygenation, is a chemical reduction reaction in which oxygen is abstracted from cellulose by carbon monoxide and steam, under 100 to 250 atmospheres pressure, at temperatures between 240° and 380°C in the presence of as much as a 5% alkaline catalyst. Using appropriate combinations of these conditions, dependent upon the type of catalyst and reacting waste materials, 99% of the carbon in the waste material can be converted to oil. Quantitatively, this gives a product yield close to 2 barrels oil/ton dry husk, ash-free basis.

A release from India reports as follows: "Hydrogenation of Agricultural Waste: bench scale experiment on the conversion of paddy husk to fuel oil by reaction with CO and water gas in presence of catalyst and water has been carried out in 500 ml autoclave.

Under optimum conditions more than 99 percent of organic matter in the husk was converted into liquid and gaseous products. Out of this 40-50 percent is benzene, soluble liquid product and the rest is gaseous products." (Annual Report, 1973/74: CFRI Jealgora, Dist. Dhanbad, Bihan (W59)).

It has been indicated that the principal cost factors are the high capital investment for high-pressure equipment and the cost of the carbon monoxide. With the uncertainty of these costs and some unresolved technical problems, no one is willing or perhaps able to estimate the economic feasibility of a full-scale plant.

There appears to be no indication of commercial activity regarding the hydrogenation of rice husk.

2.6.6 ACID HYDROLYSIS

Acid hydrolysis converts cellulose waste into fermentable sugars (glucose) by heating the material with an acid at an elevated temperature. The sugars can then be fermented to produce ethyl alcohol, citric acid, animal fodder, and other useful substances.

Iyengar (W78) has mentioned acid-hydrolysis conversion of rice husk to sugar and to methane as a distinct and attractive possibility. Other than indirectly (furfural), no utilizable hydrolysis processes for energy conversion utilization are known.

2.6.7 SINGLE CELL PROTEIN (SCP)

Research efforts to produce SCP by direct fermentation are centred on two approaches --one by W193 and the other by W180. The processes are initially similar, but use different cultures and conditions. Interest concerning rice husk as a cellulosic source is, however, essentially academic.

2.6.8 ENZYMATIC HYDROLYSIS

Processes operating under mild chemical and physical conditions have been developed (U.S. Army NATICK Laboratories, Natick, MA, USA) utilizing a cellulase-producing microorganism to break down the cellulose, glucose being the final product. Yields of up to 80%, glucose basis, have been achieved. The glucose, in solid or syrup form, can be utilized either for nutrition or fuel. Current association with rice husk has been limited to composition references in published literature.

2.6.9 WET OXIDATION

Wet oxidation converts cellulose waste into carbon monoxide, carbon dioxide, a mixture of organic acids, and a solid fibrous sludge by heating the material under pressure with water and oxygen.

No references have been found to the use of this process in the conversion of rice husk to energy.

2.6.10 HYDROGASIFICATION AND HYDROCARBONIZATION

Another process (developed by the Bureau of Mines' Pittsburgh Energy Research Center) which converts waste to a usable fuel is hydrogasification. The process reacts any carbonaceous feed material with hydrogen at pressures around 1,000 psig, and temperatures near 650°C. In contrast to hydrogenation, hydrogasification yields a pipeline-quality gas as a product consisting primarily of methane and ethane.

There appears to have been no work of this type concerning rice husk.

2.6.11 CATALYTIC CONVERSION OF SYNTHESIS GAS

A little-considered substitute or auxiliary fuel is methanol. If small amounts of other alcohols, such as ethanol, propanol and isobutanol, are mixed with methanol, a new product with a higher energy value results: methyl fuel.

There are several processes available for producing methyl fuel, but only two of them are on a commercial scale. The developers and manufacturers of these processes are Imperial Chemical Industries (Davy-Powergas) (W157) and Vulcan-Cincinnati Inc. Both produce methyl fuel by a catalytic conversion of synthesis gas. Synthesis gas (carbon monoxide and hydrogen) has been in production for many years. Traditionally, it has been produced from methane or coal, but it can be produced by the partial oxidation of any carbonaceous fuel. Synthesis gas itself has been in use by Europeans without further conversion.

In addition to automobiles, methanol has been suggested for use in home heating and as fuel for burning at steam electric-generating stations and for fuel cells.

2.6.12 ANAEROBIC DIGESTION (BIOGAS PRODUCTION)

Anaerobic digestion employs anaerobic bacteria to convert cellulose waste, at high temperatures and in an oxygen-free atmosphere, into methane, carbon dioxide, hydrogen sulfide, and a solid residue.

No practical instance of either mesophilic or thermophilic digestion of rice husk is known to the author. Rice husk is not sufficiently biodegradable to be of significance for such production.

Chapter 3: PHYSICAL AND CHEMICAL CHARACTERISTICS OF RICE HUSK

3.1 PERCENTAGE OF HUSK

Percentages of husk in paddy vary widely, but 20% can be taken as a fair average. Some varieties in Italy show as low as 14%, while varieties in other countries reach as high as 26 and 27%. In Alor Setar, Malaysia, the analysis of two local paddy varieties showed 18.1 and 22.59% respectively, and these could be milled, in subsequent lots, in the same mill. Fraps (87) reported Japanese 17.9% husk, Honduras 20.98% husk, Blue Rose 17.9% husk. It is easier to visualize wide differences in widely separated countries with different varieties and climatology than to accept wide variations in adjacent fields.

In some countries, particularly those that harvest a form of stalk rice, the term "husk" is sometimes thought of to include all dockage that is brought to the mill from the paddy field. In this case there is a disproportionate amount of straw. To illustrate, an analysis in Sri Lanka showed 26% husk, which was really 22% husk, the balance being straw and other dockage. The accuracy of testing depends on techniques of collection, pre-cleaning and milling; the other variable is the consequence of local terminology.

Attempts are currently being made to increase the weight of paddy without increasing the weight of husk. Plant breeders expect that in the future husk proportions will be less than 15%.

3.2 ANALYSIS OF HUSK

Analyses of husks are variable by type and variety. There are many characteristics in which the paddy was shelled. Rubber-roll shellers yield about 1% more rice. The epidermis (silver skin), when shelled with a disc (stone), stays with the husk percentage; when shelled in a rubber roll, the analysis shows a higher rice outturn and thence a higher bran outturn. An analysis shows less silica and more cellulose for a disc-shelled sample, and more silica and less cellulose for a rubber-roll-shelled sample. Similarly, in disc shelling the rice germ is trapped inside the grain, and this affects fat and protein analyses, as well as fuel values.

In milling parboiled paddy, husk is obtained, free of broken grains and of germ. This is because of the better milling yields of parboiled paddy, the tougher grains. The germ is melted into the caryopsis. The epidermis is always included in the husk percentage, the water separating the bond holding it to the grain.

Table 6 shows a tabulation by Houston (8) of analyses of hull over a hundred-year period. A tabulation of husk analyses, partially overlapping Houston's but containing more easily comparable data, appears at Table 7.

Analyses of rice husk have also been made from the standpoint of its characteristics for use as fuel. A tabulation of these analyses appears in Table 8.

TABLE 6

Composition of rice hull (% by weight)
Source: 8

H_2O	Crude Protein	Crude Fat	Nitrogen-Free Extract	Crude Fiber	Ash	Pentosans	Cellulose	Other	Year
9.7	3.4	1.4	27.0	42.8	15.7	...	...		1871
8.27	2.87	0.85	34.99	38.15	13.85	...	...		1889
8.97	3.50	0.49	37.86	41.89	18.29	17.24	...		1904
10.0	3.7	1.4	32.3	...	...	...	38.1		1907
8.5	3.6	0.9	29.4	39.1	18.6	18.14	...		1916
6.62, 6.12	2.56, 2.69	0.50, 0.86	...	35.99, 36.08	18.70, 20.10	18.17, 18.14	...		1916
...	4.4	1.6	35.5	4.15	17.1	...	...		1919
11.04	1.7	0.4	28.95	...	...	...	43.12		1920
...	5.95	2.22	38.97	31.71	21.13	...	...	1.76 starch	1924
9.2	7.26	0.90	...	...	18.0	...	65.00[b]		1926
8.80	...	0.89	...	...	17.80	...	34.34	46.97 lignin	1926
9.3	3.3	1.1	34.0	35.4	16.9	...	...		1927
11.35	3.90	1.27	25.83	40.22	17.43	...	...		1928
9.8-11.00	2.94-3.62	0.8-1.20	24.70-27.90	...	15.68-18.24	...	41.10-42.90		1928
7.7, 6.8	1.8, 2.0	0.6, 0.6	32.7, 30.0	35.0, 38.9	22.3, 21.7	...	...		1933
9.03	1.79	0.44	25.79	40.67	22.29	...	...		1940
8.25	...	...	...	...	21.30	20.90	...		1943
3.74	6.06	1.33[a]	27.25	...	17.03	16.94	35.48		1943
8.1	3.0	0.9	...	...	18.5	18.1	39.1		1944
8.1	3.1	0.9	28.9	40.1	18.9	...	...		1946
...	...	...	...	...	13.6	...	43.7	39.2 lignin	1947
...	2.86	0.92	...	38.43	21.41	19.32	...		1949
8.49	3.56	0.93	29.36	...	18.59	...	...		
8.3	2.88	3.5[a]	...	...	22.6	26.0	42.2	19.2 lignin	1950
9.23	6.38	0.65	31.58	31.30	...	...	39.05		1952
0.0	...	...	...	...	19.03-29.04	...	...		1953
10.0	2.00	1.20[a]	...	...	17.60	21.95	41.22	32.88 lignin	1953
10.23	1.94	0.52	29.6	...	18.33	...	39.39		1954
8.0	3.0	0.8	28.4	40.7	...	...	...		1956
...	1.75	2.98	26.05	44.81	24.16	...	...		1962
8-11	2-3	0.5-1	25-30	36-45	22-24	...	...		1964
0.0	1.8-2.6	0.56, 0.81	29.9, 30.8	44.5, 46.3	21.2-24.0	...	...		1969
0.0	2.18-4.84	0.38-0.78	26.0-34.1	47.28-49.92	15.27-20.32	...	...		1970
2.4-11.35	1.7-7.26	0.38-2.98	24.7-38.79	31.71-49.92	13.16-29.04	16.94-21.95	34.34-43.8	21.4-46.97	Range

[a]Alcohol extract. [b]Cellulose plus pectin.

TABLE 7

Composition of rice husk
(% by weight)

Investi-gator	Description	year	Moisture	Ash	Protein	Fat	Fiber	N.F.E.	Insoluble
Auriol	50 S. variety Vietnam		10.23	18.32	1.94	0.52	39.39	29.60	17.64
Borasio	Neruvialong	1928	10.50	15.68	3.62	1.20	41.10	27.9	14.50
	Tolmino	1928	10.00	18.24	2.94	0.88	42.40	25.54	17.50
	Originario	1928	10.30	18.20	3.10	0.90	42.80	24.20	17.20
	Originario	1928	9.80	17.80	3.00	0.95	42.10	26.35	16.70
	Maratelli	1928	11.00	16.10	2.98	1.10	42.90	25.92	15.50
Browne	not known	1904	8.97	18.29	3.50	0.49	41.89	27.86	17.24
Fontillas	not known	1941		24.91	2.19	2.69	49.22	20.67	
Fraps	minimum	1916	6.11	14.83	1.78	0.54	31.43	24.56	13.69
	maximum	1916	10.95	22.00	5.00	1.98	46.37	36.83	20.84
	average	1916	8.49	18.59	3.56	0.93	39.05	29.38	17.52
Grist	not known	1959	9.02	17.14	3.27	1.18	35.68	33.71	
Joachim	Ceylon	1928	11.35	17.43	3.90	1.26	40.22	25.83	
Morrison	not known	1956		19.1	3.0	0.8	40.7	28.4	
Morse	California	1965	7.08	25.51	2.37	0.24	42.23		
Possenti	Italian	1941	10.3	18.2					
Reed	minimum	1917	5.00	16.4	1.75	0.51	36.57	15.27	
	maximum	1917	9.69	22.03	4.12	1.31	46.82	20.98	
	average	1917	7.91	19.54	2.66	0.80	41.29	18.58	
Ross	not known	1889	8.27	13.85	2.89	0.85	38.15	34.99	
Wise	Hondourus	1916	6.62	18.70	2.56	0.50	35.99		
	Japan	1916	6.12	20.10	2.69	0.86	36.08		

Fuel-related characteristics of rice husk

Invest-igator	basis	year	Heating Value		Ash	Mois-ture	Carbon	Silica	Hydro-gen	Nitrogen	Sulfur	Oxygen	Volatile Matter	Fixed Carbon
			K cal/Kg	Btu/lb										
Agnew #1	dry	1972		6958	18.1								65.0	16.9
Agnew #2	dry	1972		6530										
Beagle		1968		6389	1913	5.72	39.71		5.01	0.46	0.07	29.90		
Beagle	dry	1968		6777	20.29	0	42.12		5.31	0.49	0.07	31.72		
Fontillas					24.91									
Greaves Cotton		1975		6165										
Grist		1959		6000	17.14	9.02								
Maheshwari — IR8	dry	1974	3090		17.4	3.56	39.26		4.99	1.99	0.10		68.6	14.0
Patnai	dry	1974	3560		15.8	3.56	38.92		5.10	2.17	0.12		69.3	14.9
Paoman	dry	1974	3065		18.6	3.56	38.19		4.67	1.52	0.11		68.7	12.7
Dular	dry	1974	3560		16.5	3.56	38.51		4.88	1.82	0.10		67.6	15.9
Basmati	dry	1974	2980		16.5	3.56	38.68		5.08	2.09	0.10		66.6	16.9
Nelson		1950			22.6	8.3		95.8						
Possenti		1941	3300											
Power Gas		1950		6340	21.7								60.9	17.4
Ricegrow. — Char		1970				2.8	55.8	37.05						
Rodgers #1		1936		6074										
Rodgers #2		1936		6152										
Spilling		1970	2900	5500	23.0									
Thai A863		1922	3619		18.7	9.1	40.0		5.0	0.30			56.4	15.8
Thai A864		1922				1.1	2.2		0.2					
Tucker		1952		6274					5.0	0.32				
Tulio		1972		6708		9.8								

A tabulation by Houston (8) of analyses of rice-hull ash appears at Table 9, while Table 10 tabulates rice-husk ash analyses.

TABLE 9

Composition of rice-hull ash
(% d.b.)
(Source: 8)

SiO_2	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	Cl	Year
93.21	1.53	0.30	0.51	0.07	0.45	2.69	0.42	0.15	1870
89.71	1.60	1.58	1.01	1.96	0.54	1.86	0.92	...	1871
96.97	0.58	...	0.57	0.12	...	0.57	...	...	1916
...	...	1.75	...	...	...	...	...	...	1917
97.3	...	...	0.43	...	0.38[a]	1.44	...	...	1925
...	...	...	1.38	...	...	2.78	...	...	1928
94.50	1.10	0.78	0.25	0.23	tr	0.53	1.13	tr	1928
...	0.75	...	1.3	...	...	0.23	...	...	1929
95.4	...	...	...	...	...	...	...	...	1930
95.49	1.88[b]		0.86	0.28	0.94[a]	0.36	...	...	1933
...	1.8–2.5	...	1.0–1.5	...	...	0.5–2.0	...	...	1941
96.5	1.00	0.4	0.25	0.25	tr	0.3	1.00	tr	1952
96.62[c]	1.59	0.0	0.32	0.76	...[c]	...	0.40	0.42	1953
...	...	...	0.52	...	...	0.32	...	...	1962
96.20	0.79	...	0.24	0.24	...	0.46	...	...	1966
92.47–95.04	1.70	...	0.25	0.23	...	0.67	...	...	1966
92.6	...	...	0.2	...	...	0.2	...	...	1966
86.9–96.2	...	...	...	...	...	...	...	...	1966
93.96	...	...	0.88	0.76	...	2.85	...	...	1968
91.16	4.75[b]		0.65	0.99	0.21	...	0.10	...	1970
86.9–97.3	0.58–2.5	0.0–1.75	0.2–1.5	0.12–1.96	tr–0.54	0.2–2.85	0.10–1.13	tr–0.42	Range

[a]Total of iron plus aluminum as oxides.

[b]Total of potassium plus sodium as oxides.

[c]Trace elements present include aluminum, copper, iron, and manganese as well as detectable amounts of barium, boron, and zinc. Tin was not found.

TABLE 10

Composition of rice-husk ash

INVESTIGATOR		YEAR	C	S_1O_2	H_2O	CaO	MgO	Na_2O	K_2O	Fe_2O_3	P_2O_5	$Al2O_3$	MnO_2	SO_3	Cl
BEAGLE		1965		95.00		0.70	0.015			0.09		0.08	0.50		
BORASIO		1928		94.50		0.25	0.23	0.78	1.10	TR	0.53	TR	TR	1.13	TR
		1929		94.23		2.27	0.12	0.39	2.22	0.53	0.24	TR	TR		
		1930		93.95		2.28			3.15	1.01					
FRAPS		1916		96.97		0.57	0.12		0.58		0.57				
GARBARINO	IGN	1942	0	90.27	5.00	0.94	0.67	0.40	1.25	TR	0.51	TR	TR	0.33	TR
	CHAR	1942	25.50	65.00	6.50	0.65	0.49	0.34	0.95	TR	0.37	TR	TR	0.27	TR
JOACHIM		1928			11.35		0.27				0.50				
JONES		1954		96.50		0.25	0.25	0.40	1.00	TR	0.30		TR	1.00	TR
THAI-863	IGN	1922		95.7		2.70					0.30				TR

Chapter 4: USE OF RICE HUSK AS FUEL

4.1 GENERAL

The carbon in rice husk was fixed by solar conversion of carbon dioxide and water via photosynthesis. It is one of the most abundant renewable agriculture-based fuel materials in the world that can be feasibly collectible. The production of rice husk is today about 60 million tons per year, equivalent in energy to 130 million barrels of oil.

However, the husk supply must be realistically appraised as to its potential, not purely by multiplication. The widespread, very small, sources of husk production affect critically the potential for commercial or beneficial utilization.

Although rice husk has been utilized as a fuel, primarily in rice mills, for over a century, this utilization has never attained commercial status because of the bulk, erratic supply, transportation difficulties, lack of straightforward technological results and a paucity of coordinated efforts on the problem. The first recorded use of husk was in Burma in 1880 (Cowie 3); a furnace he designed and built was installed in a mill, and in less than five years almost every mill in Burma had a furnace of similar design. Apparently this was an external furnace utilizing a step grate of now-conventional design.

Some of the drawbacks to the use of husk as a fuel were its low density, its low calorific value and the amount of residue (as high as 50%) resulting from normal furnace burning.

In many countries, rice husk is used as a fuel for household use. Some use husk for fuel for operating rice mills, in brick kilns, in dryers. This is an easy and cheap source of energy, involves no foreign exchange cost and disposes of the husk. When fuels are used away from the mill, there is a small income to the miller; when the energy is used in the mill, there is a real cash saving.

Where there is a need for process steam, the utilization of husk for fuel is most advantageous, and most utilizations today stem around a process-steam or process-heat use. Only in large installations is husk used for independent power: two excellent power plants (one in the Philippines, one in Surinam), of 1200 kw and 1900 kw, utilize husk-produced steam for electrical generation without use of process steam. This point will be touched upon several times below.

The use for drying heat or kiln heat is of long standing; it is becoming more popular where conditions warrant such use.

Ramzin (182) was one of the first to investigate the combustion of fuels of fine granulation without pulverization. His work included rice husk. (See section 2.1.4.)

The calorific value of husk derived from a rubber-roll sheller is always less than that derived from a disc sheller.

Briquetting (compression, or extrusion of raw husk) has been advanced as a solution to the density and transportation cost problem. There have been efforts in several countries, Japan, India and Switzerland, to develop a machine capable of producing a marketable product. Rice husk briquetted on the Swiss machine operated by an Oregon concern (W162) shows the characteristics set out in Table 11.

TABLE 11

Rice-husk briquettes
Source: W162

Bulk wt. of loose material (10% H_2O	5.93	lb/ft^3
Bulk wt. of briquetted material	43.7	lb/ft^3
Specific wt. of briquette	81.15	lb/ft^3
Upper calorific value of briquette (0% H_2O)	6958	BTU/lb
Lower calorific value of briquette (0% H_2O)	6473	BTU/lb
Ash content at charring	18.1	%
Fixed carbon at charring	16.9	%
Volatiles at charring	65	%

Several incidences of briquetting the char from specific carbonization plants or furnace residue have been documented, some in conjunction with petroleum by-products and some straight char briquettes (Mifugi) from large-scale carbonization plants. Another approach is that of Park (48A), who mixes 5 to 9% carbonized rice husk with low-grade anthracite before briquetting, with good results. However, no lasting commercial utilization of such efforts is known, primarily because of the cost and maintenance of the equipment; in addition the burning of such compressed units made with rice husk creates certain problems.

Not everyone is enthusiastic about the utilization of husk for fuel: "We are convinced that it is irrational to use husk as fuel, and in our rice mills the furnaces for burning husk have been dismantled." (Pvt. communication, I. Leonov (USSR) to E. Beagle 1-3-74).

4.2 RICE HUSK AS A BOILER FUEL

Bhatia (214) gives a comparison of several fuels, as shown in Table 12.

TABLE 12

Economics of boilers
Source: 214

Fuel	Calorific Value	Cost of Fuel	Boiler Efficiency	Steam Output	Cost of Steam Production at 100 ps @ 30000 lb/hr
Coal	10,000	Rs 50/ton	50%	6 lb/lb of fuel	Rs. 256 ($35.84)
Oil	18,000	Rs. 1.75/gallon	75%	16 lb/lb of fuel	Rs. 356 ($49.84)
Husk	2,500	Rs 7/ton	40%	1.2 lb/lb of fuel	Rs. 235 ($32.90)

The comparative studies of boiler utilizing different fuels show that husk fired boilers are cheapest because of low cost of the raw-material

Utilizing Bhatia's parameters, the author arrived at a slightly different result, using 1 lb of steam = 1025 BTU as shown in Table 13.

TABLE 13

Economics of boilers
(Beagle)

Fuel	Cost of Fuel	Lb of steam per lb of fuel	Cost of Steam ¢ per lb	Cost of 30,000 lb per hour
Coal 10,000 BTU/lb 50% efficiency	Rs 50/ton $ 7.00/ton ¢ .318/lb	4.87	.0652	$19.56
Oil 18,000 BTU/lb 75% efficiency	Rs 1.75/gal $ .21875/gal ¢ 2.28/lb	13.17	.1725	$51.75
Husk 5,500 BTU/lb 40% efficiency	Rs 7.0/ton $ .98/ton ¢ .044/lb	2.14	.021	$ 6.33

A good utilization and analysis of husk for fuel has been done in India by Scopa Chemicals (W83). They provide the following costs and comments:

Coal $2.83 per 1000 lb of steam (approx) generated (at 100 psi)
Husk $0.91 per 1000 lb of steam (approx) generated (at 100 psi) incl. transport

"With alterations, and not very costly ones, we feel all the existing Small Scale Industries which require steam up to 1 ton per hour having conventional vertical cross tube or fire tube boilers and which use coal as a fuel could change over. Provided, of course, that they plan effectively. With the use of husk the steam generation capacities drop to about 60 percent as compared to coal. A judicious balance of husk and coal in existing industries and boilers of larger capacities for new ones would offset this.

"The use of husk in fire tube boilers requires cleaning of the fire tubes after every forty-eight hours. Therefore, the husk is not suited for continuous operation of plants. In water cross tube boilers this difficulty does not arise." (Note: This caution applies when using a grating system designed for coal.) (See section

4.3 RICE HUSK AS A DRYER FUEL (See Section 6.2)

"Experimental evidence shows that 20 kg of husk which can generate 220,000 to 264,000 BTU when burnt would be enough to dry a ton of paddy from 20 percent to 14 percent moistur content." (Pingale) (227).

The tabulated results of an excellent study (179) of drying needs and costs are presented in Table 14.

TABLE 14

Comparative costs of fuels for various operations
Source: 179

Fuel	Cost $/Kg	Mechanical drying of raw paddy			Mech. drying of parb. paddy			Parboiling of paddy	
		Fuel reqd per tonne of paddy, Kg	Cost of fuel, per tonne of paddy .$	Remark	Fuel reqd. per tonne of paddy Kg	Cost of fuel .$	Remark	Fuel reqd. per tonne of paddy Kg.	Cost of fuel .$
Diesel	.175 47¢/gal	5.16	.90	without heat exchanger	15.6	2.73	without heat exchanger	16.4	2.67
Kerosene	.17 46¢/gal	5.12	.86	-do-	15.5	2.60	-do-	16.3	2.74
Furnace oil	.07 19¢/gal	11.50	1.02	with heat exchanger	34.4	3.02	with heat exchanger	17.1	1.51
Coal	.02 20.00 /tonne	54.00	.51	-do-	163.0	2.74	-do-	45.5	0.77
Electricity	.022/Kwh	52.50 Kwh	.96	-	158.0 Kwh	3.18	-	147.0 Kwh	2.94
Rice husk	.0015 1.50 /tonne	50.00	.08	without heat exchanger	152.0	0.22	without heat exchanger	140.0	0.20

Adapted from chart by T.P. Ojha , R.C. Maheshwari and B.D. Shukla IIT, Kharagpur 1974.

Another comparison of fuel costs, this time for a commercial kiln dryer, shows the dramatic savings possible with husk as an opportunity fuel. (Table 15).

TABLE 15

Kiln fuel comparison (14-million BTU/hr kiln)

Natural gas 100,000 BTU/therm 14,000,000 BTU/hr divided by 100,000 = 140 therms/hr at .1125/therm		$15.75/hr
Propane 92,000 BTU/gallon 14,000,000 BTU/hr divided by 92,000 = 152.17 gal at .27 gal		$41.09/hr
Actual fuel mix Natural gas use 2/3 of year; propane use 1/3 of year		$24.20/hr
Rice husk 5,800 BTU/lb 14,000,000 BTU/hr divided by 5,800 = 2,414 lbs 2,414 @ 2.13/ton		$ 2.57/hr
Savings/year (24-hour day) 6336 x 24.20 propane/gas 6336 x 2.57 rice husk	$153,300 16,284	
Fuel savings/year with rice husk	$137,046	

4.4 HEAT COUPLING

The largest utilization of husk in the world today is for energy. This is usually developed in traditional-type boilers and is used for process steam or for powering a prime mover. These systems are generally of quite low efficiency. There are, however, several outstanding examples of highly sophisticated power generation systems using rice husk as a raw fuel. As highly efficient as these target systems are, they are not utilizing to the fullest degree the modern concept of "heat power coupling", which can bring a process/power system using steam to an overall efficiency of at least 62% using reasonably obtainable pressures and temperatures. Here the prime mover (engine, motor, turbine) can satisfy all demands, as it fulfils the role of the always uneconomical reducing valve which, however, supplies heating processes with steam of a fixed pressure and temperature. The reducing valve actually destroys the available steam pressure gradient without utilizing it.

This sort of system for process (parboiling, bran-oil extraction) steam and power generation for mill operation would revolutionize the external energy requirements of the rice mill. It is not necessarily limited to installation in large (6 TPH and over) mills but can be successfully designed and built for 1, 2 or 4 TPH mills.

The largest single opportunity for the use of rice husk is for increasing efficiency where process steam is used; for example, Wimberly (W142) said, "The goal of Asian parboiling (and of course all parboiling) is to generate heat for all needs (cleaning, heating, processing, drying, milling) from husk fuel." Here the efficiency obtained from a heat power coupling (back pressure or extraction) system would give the necessary power and also the necessary process steam. Efficiency in a combined system (steam side) reaches about 65%. However, the boiler efficiency must also be improved over the traditional systems, primarily by the use of sophisticated grating units.

From the practical point of view, the objective is to produce the required quantity and quality of steam as and when required at the lowest cost. In assessing this cost, all the contributory factors must be taken into account, including fuel, labour, water and water treatment, parts, maintenance, repairs and capital charges. Of these costs, that of fuel is almost invariably by far the most important. It generally exceeds 70%; neglecting capital charges, the cost of the fuel is generally over 80% of the total cost of producing steam.

It is important to recognize that in industry, the attainment of maximum thermal efficiency is not the only object in steam-raising, although increased efficiency is important in decreasing costs. Increases in efficiency and economy go together so long as the improved efficiency results from better methods of working. But when maximum efficiency is obtained with the existing plant, an increase can be obtained only by modifying the plant; in other words, by incurring greater capital charges. It then becomes a question of striking a balance to determine the point at which charges due to improvements in the plant will offset the value of the heat saved.

Even in the most efficient stations, however, no more than about 30% of the potential heat in the fuel is converted into electrical energy, although the efficiency of the boiler plant may approach 90%. The principal loss is due to the fact that the exhaust from the prime mover consists of steam and water, and in the condenser the latent heat of the steam is transferred to the circulating water as low-grade heat, which is useless.

A graphic and tabular representation of the losses and gains from a boiler-turbine system appears in Figure 1.

Figure 1

Power Plant - Graphic Balance

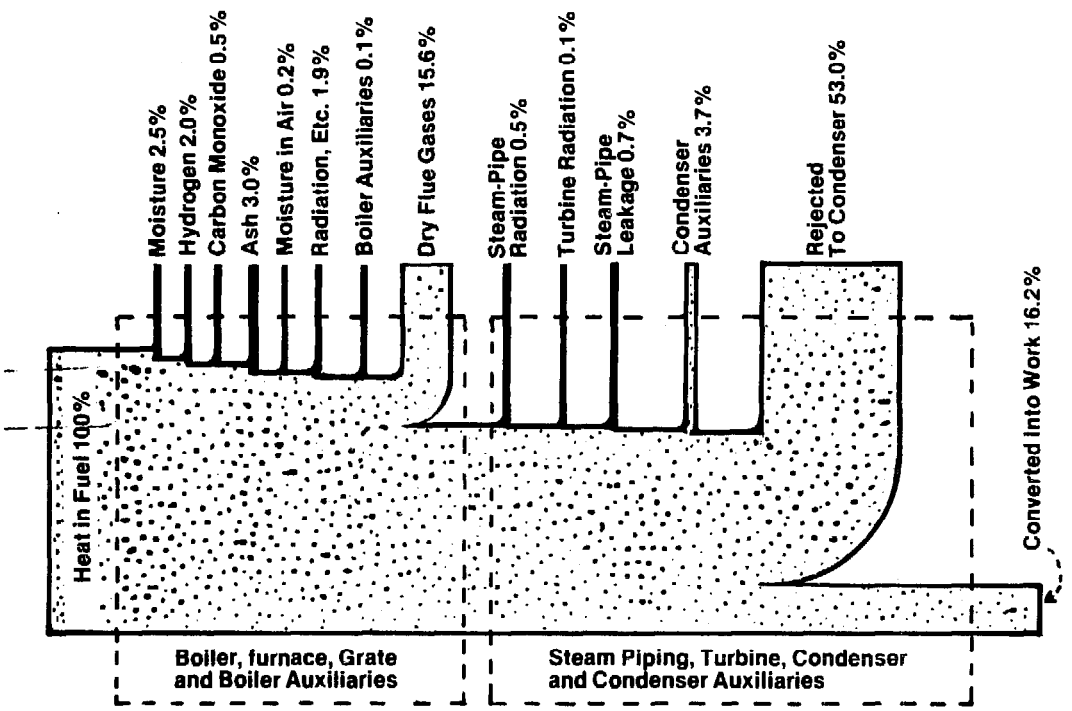

As we have seen, the production of power from steam is always inefficient, for it is never possible to employ usefully more than a fraction of the latent heat of condensation of the steam. Whatever the initial state of the steam supplied to a prime mover, the exhaust can never be water, but must always consist preponderantly of steam. Steam which is used for process work, on the other hand, can be used efficiently, since its function is to carry heat at a temperature which is sufficiently high to ensure a reasonable rate of transfer of heat to the material which is to be heated. If the temperature difference is sufficient, condensation is encouraged, since the coefficient of heat transfer is then higher than when condensation does not take place.

Usually, the steam is not employed expansively, but at constant pressure, and frequently under substantially isothermal conditions. There is no advantage to be gained from superheat, except to prevent condensation while the steam is in transit from the boiler to the mill. Superheated steam behaves as a permanent gas; the film resistance to transfer of heat is high, so that the quantity of heat that passes in a given time may be less if superheated steam is used than if saturated or wet steam at a lower temperature is employed. There is also a greater danger of overheating and possibly damaging the rice with superheated than with saturated steam, while if superheated steam is blown directly into a liquid there may be insufficient time of contact for de-superheating to take place, with the result that bubbles of superheated steam may be blown completely through the liquid and be wasted.

Steam should therefore be delivered at the mill without appreciable superheat at a temperature and pressure which will permit reasonable transfer of heat through the heating surfaces. Condensation is advantageous because the coefficient of film resistance is lowered, and transfer of heat for a given drop in temperature from the heating medium to the material being heated is facilitated. The steam may be taken direct from the boiler, which should be operated at the necessary pressure, or exhaust steam from engines may be used.

Considerable economy can often be realized where both power and process steam are required, by exhausting the steam from the prime movers at a pressure sufficiently high to allow the demands for process steam to be met from that source. The power is thus obtained as a by-production.

It has been felt that the use of steam engines is not possible where process steam is used for edible products, because of the small amount of oil that may leave the engine. However, the engine can be specified to operate with no cylinder lubrication (NCL) if such operation is needed. There would thus be no oil introduced, and the exhaust would be as clean as a turbine exhaust. The only requirement for NCL is that no superheat be used.

The use of low-efficiency systems designed only to provide process steam is an error. With a bit more sophistication and use of engine or turbine, the power can be had almost without cost, as shown by Figure 2.

It is instructive to observe the effect of varying the quantity of process steam withdrawn on: (i) the amount of power which could be generated; (ii) the overall efficiency of the plant; (iii) the pounds of husk required per hour; and (iv) the temperature of the feedwater. This has been done, and the results of the study are shown in Figure 2. It is found that, for every thousand pounds of process steam withdrawn, 51.4 kw less can be generated, 27 lb less husk will be required per hour, the efficiency rises by 2.62%, and the temperature of the feedwater to the boiler increases by 6.5°F. Even when the prime mover is employed primarily as a reducing valve and de-superheater, giving 18,620 lb process steam per hour at 50 lb/in^2, 800 kwh of electricity will also be produced. At the other extreme, when all the steam is being used to produce power, the output would be 1,758 kwh, but the efficiency would be only 19.4% compared with the 67.4% realized when the demand for process steam was 18,620 lb/hr.

Figure 2

Results of Heat Coupling

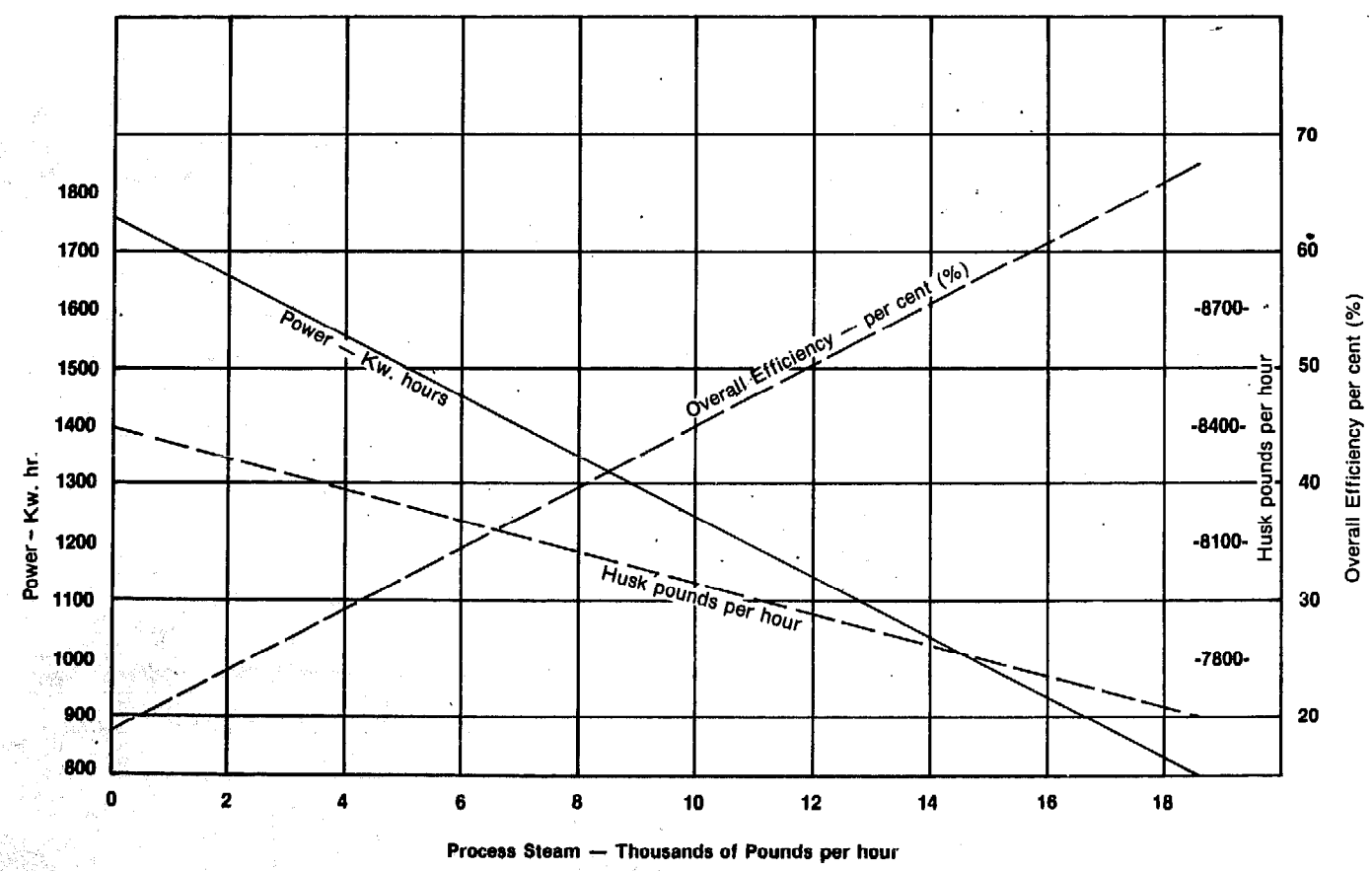

4.4.1 STEAM CONSUMPTION

Table 16 shows typical full-load steam consumption specifications, as compared with the observed performance of two representative engines (W154), operating with dry saturated steam at the engine stop valve.

TABLE 16

Steam Consumption

Inlet Pressure (psig)	Exhaust Pressure	Typical Specifications: Small (100 kw) Engines (lb/kwh)	(kg/kwh)	Large (500 kw) Engines (lb/kwh)	(kg/kwh)	Engine A 210kw-305 HP consumption: 10300 lb/hr (lb/kwh)	Engine B 350 kw-510 HP consumption: 17260 lb/hr (lb/kwh)
225	35 psig	47.2		44.9			
225	2.5 kg/cm^2		21.5		20.5		
225	40 psig	49.3		47.3			
225	3.0 kg/cm^2		23.2		22.1		
227	43 psig						49.3
225	45 psig	52.1		49.8			
235	45 psig					49.0	

4.4.2 MILL POWER REQUIREMENTS

4.4.2.1 Installed power: While the installed power of a rice mill can vary considerably according to the type of mill and many other factors, the general consensus is that 2.4 to 3.6 HP are needed per 100 kg/hr of paddy, the figure declining somewhat as mill size increases. Table 17 shows a good guide, subject to the complexity of the mill.

TABLE 17

Installed mill power requirements

Paddy Input (TPH)	Power Requirements (HP) min.	max.
.5	10	30
1.0	25	65
2.0	70	100
4.0	140	200
6.0	200	300
15.0	530	800
25.0	900	1200

In sophisticated mills (return shellers, multiple break systems, more elevators, grading equipment), the HP requirement can be twice as high as in simple mills of the same size; where ancillary operations (drying, storage, threshing stalk-rice situations in Indonesia) are carried out, the power requirement can be tripled.

The total power requirement of a machine is roughly the same whether a lineshaft or an individual drive is used, but with electric motors the connected load may be higher. The power loss due to transmission lines in a lineshaft drive reaches about 9%, and in individual drives, the V-belt loss is 1 to 1.5%, but individual motor efficiencies, oversizing and conservative installation can bring the total connected load to 30-40% above

the minimum requirement. Experience in specific cases shows an actual consumption of 62% of connected load. Lineshaft mills tend to minimize this problem, and the more sophisticated and modern a mill, the less is the tendency to oversize. However, every installation must have a reserve, the installed horsepower being about 20% greater than the actual load; for individual machines that can be adjusted and overloaded by the operators, the nominal load should be calculated at 40% over the actual load. Thus, if 11 HP are needed, or even 9 HP for a heavy-duty machine, a 15-HP drive will generally be used.

Table 18 shows the advertised horsepower requirements of specific mills. The variations among them are obvious, and the only possible conclusion that can be drawn is that each installation must be planned according to its own requirements.

TABLE 18

Advertised horsepower requirements

Paddy Input (TPH)	Manufacturer	Power Requirements (HP)
.25	Satake	10
.50	Satake	25
1.2	Satake	36
1.4	Schule	50
1.7	GDR	43
3 - 4.5	Satake	135
4	Satake	64.5
4	Satake	112
4	Dandekar	120
5	Schule	150

4.4.2.2. Hydraulic drives: Consideration should be given to the possibility of using hydraulic motors as individual drives. Powered either from a steam engine/turbine unit or from a producer-gas prime mover, they would offer advantages in simplicity, power balancing and safety.

4.4.2.3 Steam-powered mill requirements: One boiler HP is sufficient to supply 3 engine HP, while with poorer types of engines it will supply steam for about 1/2 engine HP. Compounding is advisable for large units with reasonably uniform loads; with fluctuating loads the simple engine governs better and is about as economical.

It is generally agreed that 1 kg of husk will produce 2.4-2.7 kg of steam, and that 1 HP will be produced by 7.5-11 kg of steam. B.R. Wolf engines ran 6.0 to 8.5 BHP/hr per kg steam maximum, with some degree of superheat. Wolf stated (Bianchi; private communication) that 300 kg/hr of husk would produce 38/44 HP plus about 260 kg of process steam. In this they calculated that about half of the available energy content of the husk would be liberated. This corresponds to other statements showing a 40% boiler efficiency on husk, as compared to 75-80% on gas or oil.

According to Schule, on the average about 15 kg of rice husk are required for generating necessary power for processing 100 kg of paddy into white rice, while about 20-24 kg of rice husk are produced in milling, leaving a substantial surplus. For driving rice mills, the multi-cylinder models of steam engines prevail. Steam consumption varies between 6.5 and 8.0 kg per BHP/hr, according to the number of cylinders per engine and the size and rating of the steam power plants.

The Philippine mill and power plant of Tulio consists of a 25 TPH mill and 1920 kw of engine-generator (Spilling) power generation using 5 TPH of husk, or about 400 kw/ton capacity. The Surinam power plant of SML, with a 15-TPH mill and 1200 kw turbine (Terry) generator, again shows a 400 kw/ton of capacity. It would appear that this is a conservative level of production when the power unit is over 1000 kw.

The older engine type (BR. Wolf) would produce 40 HP/300 kg husk, or 280 HP/ton or 210 kw/ton. The differences in efficiency are to be explained in two ways: the efficiency of size and the efficiency of the sophisticated grating systems on the modern furnace installations (Lambion). Using rice husk, these furnaces show efficiencies comparable with those of other fuels.

4.5 WASTE-HEAT RECOVERY

When recovered heat is put to some beneficial use, a corresponding quantity of fossil fuel is not burned, thus eliminating emissions from this source. The heat recovery thermal reduction method for solid-waste processing has been widely used in Western Europe for many years.

Heat recovery equipment can be incorporated into any incinerator system. Conventional systems may include this capability through a downstream waste-heat boiler associated with a refractory furnace, or by building the furnace with water-cooled walls as a boiler, which normally also includes a "convection section".

The two most common designs for waste-heat recovery installations involve steam generation by a boiler located immediately after a conventional refractory furnace, or by water-bearing pipes embedded in the furnace walls (water wall). The furnace/boiler combination is simpler and cheaper to construct, but requires 150-200% excess air to prevent refractory lining damage. The second design, with more efficient heat transfer, requires only 50-100% excess air and reduces the required air pollution control equipment. Both systems make unnecessary special cooling of effluent gases to protect this equipment. Heat recovery can offset a fraction of incineration costs, if the variable heat output can be matched to a customer's variable demand.

4.6 SMALL PRIME MOVER SYSTEMS

For mills that do not need process steam (white rice milling), the situation is totally different from that of a parboiling process mill. At the present time it is unrealistic to propose the use of steam-generating systems for motive power in this type of mill, particularly in mills of under 10 TPH paddy capacity. Since the number of larger mills (above 6 TPH) is insignificant in the world's total of rice mills, the development of some system other than the conventional steam process is indicated in order to bring the greatest benefit to the industry as a whole.

It appears that the best solution to the problem of the powering of small and medium mills* would be to use as a prime mover an engine fueled by a gas produced from the husk removed from the rice in the mill (gasogeno). This system of "producer gas" is of proven technology, having been in continuous use for over 75 years.

Advantages of a producer-gas unit prime mover over a furnace-type boiler unit prime mover include:

* In this study, "small" mills are taken as having a capacity under 3 TPH in Europe, Thailand and Japan, and under 1 TPH in India; "medium" mills as having a capacity of 3-5 TPH in Europe, Thailand and Japan, and 1-3 TPH in India; and "large mills" as having a capacity in excess of those figures.

- on 1 shift operation - easy to turn off and on
- less maintenance
- no water purification (unless water scrubber used)
- good efficiency on shift basis
- boiler needs inspections - pressure vessel; gasogeno needs none
- boiler needs cleaning; gasogeno needs none
- seasonal shutdowns if boilers create problems
- gasogeno creates no air pollution problems (smoke or particulate)
- gasogeno requires no attendant
- maintenance of gas producer unsophisticated
- gas producer can be installed in outside areas

There are therefore two possibilities:

- Where there is a use for the steam produced for process purposes, the producer-gas boiler heat-coupled unit would give excellent efficiency.

- Where there is no use for steam, then use should be made of a dual-fuel or direct-fueled internal combustion engine system, either with a direct drive or with a combination of these, the large power consumption machinery being driven directly, and the smaller, more isolated, units driven electrically, together with the lighting, pumping, air conditioning, etc. This then would prove to be a very practical system.

Most in-house gas generator systems seem particularly suited to the 25-250 HP range.

A small rice mill handling 2 TPH of paddy requires about 100 HP. The 100-HP engine would consume about 180 to 240 kg/hr of husk. The 2 tons of paddy would yield 400 kg of husk, which would result in a surplus of husk of about 160 to 220 kg/hr, so that actually a 150-160 HP engine could be used, driving a generator and using modern individual drive practice as to the milling machinery, plus the necessary ancillary electrical requirements. More detailed treatment of the gas producer and equipment will be found in Section

4.7 CENTRAL LOCATION GAS PRODUCER

Another way to use boiler fueling is to produce gas with a "Balestra" unit* and burn it in a package boiler. In this way the husk-derived gas can be used as supplemental gas or stored for non-concurrent use (108) (129).

In white-milling areas where there are a number of small mills within a reasonable distance, a "Balestra" unit could be installed at each mill and the gas piped to a central gas holder and power plant. In the power plant, a dual-fuel pilot-fuel engine can be used for generation, giving complete flexibility as to fuel supply, while taking full advantage of the indigenous fuel source. Otherwise, if process steam is needed at a local mill or food processing or other plant, a heat-coupled steam system would give otherwise unattainable efficiency.

Composite systems such as envisaged here can only be designed when the engineer is fully cognizant of all the opportunities of the various systems and of the complete appreciation of all variables.

* A "Balestra" unit is an updraft gasogeno of Italian design.

4.8 USE OF RICE HUSK IN MAKING PORTLAND CEMENT (See also Section A.3)

Portland cement is made by mixing and calcining calcareous and argillaceous materials in the proper ratios. The product consists primarily of lime, silica, alumina, and iron oxide, with gypsum added to regulate the setting time. Natural materials, such as limestone and shale, are combined in the basic process. Other materials (such as sand, sandstone, bauxite, and iron ore) are sometimes added to adjust the composition of the mix. The proportion of silica in various cements ranges from 18 to 20%. A Stanford Research Institute report (URS citings) indicates that the average new cement plant uses 0.9 to 1.0 million BTU per barrel (5.85 barrels = one metric ton).

Studies conducted by Staackman (228) suggest the economic feasibility of utilizing the energy generated from burning husks to ash, and of subsequently using the silica in the manufacture of Portland cement. Comparative cement plant operating costs are summarized in Table 19.

TABLE 19

Portland Cement Plant Operating Costs

	1970 Traditional Cement Plant	1976 Traditional Cement Plant	1976 Cement Plant Utilizing Rice Husk
Labour	$ 0.32	$ .32	$ 0.34
Fuel	0.50	1.50	0.44
Power	0.22	.22	0.23
Miscellaneous supplies	0.21	.21	0.21
Maintenance materials	0.12	.12	0.12
Supervision and overhead	0.12	.12	0.12
Depreciation	0.35	.35	0.36
Cost per barrel	$ 1.84	$ 2.84	$ 1.82
Cost per metric ton	$10.76	$16.61	$10.65

While there are variables in the amount of heat needed per ton of cement, the Staackman report puts forward a figure of 5.2 to 7.6 million BTU, while Pitman states that the requirement is between 300 and 700 lb of coal.

The general approximate feeling is that rice husk could furnish about one half of the energy needed for a traditional Portland cement producer. In 1970 Staackman suggested this as his first choice among husk utilization potentials. Since that time, the advantages of this use have increased sharply.

In Northern California, the cost of fuel in 1970-73 was $0.05 per therm ($10^5$ BTU), but during 1974 it had risen to $0.095, and by 1975 it reached over $0.15/therm. The economies delineated by Staackman now are much more considerable, so that when possible every cement plant should be using all available husk for fuel.

That this is happening and is practical is shown by the mid-1975 start-up of use, in a California cement plant (W176), of rice husk as a fuel and silica source, furnishing 1/2 of the energy and 15% of the silica needed to produce 35 TPH of cement. Considering that rice husk contains about 12 x 10^6 BTU/ton of energy and that cement manufacturing requires 6 x 10^6 BTU/ton, 10 tons of rice husk per hour can supply 57% of the energy requirement for 35 TPH. Again, considering that the silica content of rice husk ash is

17%, 10 tons of rice husk per hour can provide 18.6% of the silica needed for 35 TPH of production of a 26% silica cement.

At the current gas cost of $150 per 1000 therm, the rice-husk heat equivalent is 1200 therm per hour or a gas cost of $180. The laid-in cost of the husk is about $9 per ton, which allows $90/hr or $2,160/day for amortization of handling equipment and storage and the additional "confusion costs" of having to operate a dual-fuel operation. It appears that it would be very profitable to consider the use of husk on an "as provided" opportunity basis, particularly if the supplier would participate in the transportation costs. The only constraint would appear if the combustion conditions were such that a very poor heat release was obtained. Inspection of the husk residue particulate would indicate the combustion efficiency. An additional plus factor would be the ability of the plant to operate with allocation restrictions that otherwise would seriously hamper anything approaching a normal operation.

4.9 HUSK AS A "RAW" FUEL SOURCE

The thinking that husk energy must be used in the vicinity of the producing rice mill is misleading and erroneous.

A change in point of view would speed up acceptance of utilization techniques. These units should be seen as power plants first and disposal techniques second. Instead of rating plants according to the benefits derived for disposal purposes, they should be measured in terms of the power they could potentially generate. Indeed, the plants could be so efficient that it would be possible to include them among the national sources of energy.

Husk must be looked on as a raw-available fuel, in the same sense as any other raw fuel.

Considerations relevant to this view are the quantity available in each location; the area available; fluctuations in supply according to the season; transportation costs; the low density of husk; and the availability of competitive fuels (water power, gas, electricity, fuel oil).

In the light of these considerations, a study should be made of the amounts of energy needed, the market for husk energy, and the alternative disposal costs.

Capital considerations include the ease of capital acquisitions, interest costs, and labour cost and availability. After such a study it is possible to make an appropriate choice.

4.10 USES IN INDIVIDUAL COUNTRIES

In Argentina, Frugone & Preve (W1) operate seven rice mills, all having operation by steam engines and some being capable of alternative electrical operation. All were originally lineshaft-drive mills, but some have changed over to single-unit driven operation. The company can selectively use the cheapest method of operation. If the price of husk for commercial sale is such that it is better to operate on electricity and sell the husk, then this is done. If the price is low, so that it is cheaper to use the husk internally for fuel, then that is the mode used. At the time of writing, husk prices provide about a 30% benefit margin when the husk is sold and the mills that are capable of electrical operation are so run. However, the husk market has been dropping, so it could be that in the near future the mills will again be operating on steam. This arrangement has tremendous advantages. The mills operate on a purely economic basis, essentially

always returning the full market value of husk, and never less than the equivalent value of the electricity. The flexibility available to the operator is clearly evident.

Brazil - Husk is presently used for steam power for mills.

Burma - Steam-powered mills are said still to exist.

France - Husk is used as fuel in one precook-parboil mill at Gimeaux.

India - A portion of the husk from white-milling in the South is sold for a good price. Some is used for fuel in the manufacturing of building brick (kiln firing). In 1974, the price was 40 Ks/Rs or 3.00/ton, and there was a good demand at that price. About 95% of the parboiling mills (approximately 50% of production) use husk-fired boiler units for their process-steam requirements. There are many installations of direct-fired dryers and of steam-powered white-milling units.

Iran - Has steam-powered mills, said not to be running because of a lack of supplies of paddy.

Italy - Husk is used as fuel in several parboiling rice mills, and as fuel in one producer-gas unit for white-milling. It is also used as domestic fuel for home and water heating.

Japan - Husk is used as domestic fuel for home heating, and as fuel in drying furnaces. None is known to be used for power. Many carbonization units exist, but very few utilize the heat from stacks.

Korea - Husk is used as domestic fuel; char is used as an additive in fuel briquettes.

Malaysia - Some mills (white) are powered by steam; all new ones, however, are powered by electricity. Husk is used for fuel for process steam for parboiling.

Mexico - Husk is not used as fuel as far as is known.

Pakistan - Only one formal utilization is known: a direct-fired dryer near Lahore. There may well be other installations, both for process and for power. The traditional methods use husk almost exclusively.

Philippines - Husk is used for fuel for steam for electric generation (Mindanao). It is also used for power to drive rice mills, mostly older ones.

Portugal - Husk is still used for mill power.

Spain - Husk is not used as fuel, but it is used in several char manufacturing facilities which do not make use of heat.

Sri Lanka - Husk is used for fuel for process steam for parboiling in boilers, and in "Goya" units. No mills, but only process units, are currently steam powered.

Surinam - Husk is used for fuel for electrical generation (W144).

Thailand - Husk is used for fuel for both parboiling and white-milling power, and for parboil process steam and drying steam. The standard Thai mill is steam driven from husk. No direct-fired drying appears to exist.

U.S.A. - Husk is used as process-steam fuel, and as fuel in cement manufacturing.

Vietnam - There was considerable use of steam powered mills. The current situation is unknown.

Chapter 5. PROCESSES USING HUSK AS AN ENERGY SOURCE

5.0 INTRODUCTION

Current practice is almost always to consider the conversion of husk to energy in parallel with its use as a source of raw material. In no case does the original concept ignore the possibility of a residue utilization, but in some the selected utilization is of doubtful value.

Grouping of the various processes in any logical pattern is difficult because most embrace several areas of technology, so that unavoidable duplications occur in descriptions. This chapter is designed so as best to embrace all the material available.

5.1 WET HEAT SOURCE

5.1.1 BOILERS FOR STEAM RAISING

For almost a century, the use of husk as a fuel for the production of steam has been common throughout the world. The design of the boilers and combustion systems varies widely, as does the efficiency of the systems.

Individual type and design of boilers are covered in Section 6.1, and furnaces are discussed in Section 6.3.

A great deal of confusion surrounds the use of rice husk as a fuel in boilers. In most peoples' minds, the low efficiency of such an installation is due to its use of husk fuel and it is not recognized that the efficiency depends upon the sophistication and workmanship of the furnace and boiler combination. There has however been considerable improvement in the traditional styles of furnaces and gratings, both in static-bed units and in turbulent-air suspended furnaces, used either as external furnaces or in conjunction with a waste-heat boiler.

Few water-tube boilers use husk, for several reasons, the most important being that usually the installation is not large enough to warrant the cost of water-wall furnaces and water-tube units, and that usually the heat release is not high enough to justify a water-wall furnace construction.

However, several designs of turbulent-air suspended systems have used water-tube boilers in a waste-heat boiler configuration to give high steam factors at reasonable cost. One of the classic husk-fired installations using a water-tube boiler is the Babcock & Wilcox unit at the Frugone & Preve mill in Robbio, Italy, a 750 kw generating plant installed in 1927 and operating until 1975, when a fire (not originating in the power system) necessitated changes in the mill configuration. Both of the newest large generating plants (Mindanao (W134) and Surinam (W144)) utilize fire-tube boilers with Lambion furnaces. This use of fire-tube boilers at pressures formerly attained only by water-tube boilers illustrates the advances in metal and construction capabilities in the last 50 years.

Integrated parboiling/milling operations often use husk-fired boilers (VCT, traditional or locomotive), particularly in operations of long standing. More sophisticated operations use multi-pass tube-type horizontal boilers. In Thailand, traditional design boilers are being newly constructed for steam-engine prime mover operation. Most mills in Thailand are husk-fired and steam powered.

5.1.2 HOT WATER HEATERS

Any boiler installation can be considered to be only a high-pressure hot-water heater, so that comments on boilers also are relevant to hot-water heaters.

However, in some instances, specific use of rice husk to heat water on a commercial basis has been noted. Development units have been noted in both India (W66 and Japan (W105) and some units featuring dual fuel (husk/oil) capability are installed.

In Japan the utilization of husk to furnish hot water is on a commercial basis; the manufacture of water heaters utilizing husk as a fuel or as an alternate fuel has been noted.

In India husk is used in commercial water-heating in motels and restaurants. Usually these are rudimentary units, obtaining husk from the local rice mill specifically for heating water. To illustrate the value of husk as a source of energy for water heating, a cooperative (Ryots) in Mandya (northeast of Mysore), India, sells about half of the husk produced by their two mills to local hotels for hot-water heating, both for space heating and domestic use of hot water. The price received during the demand season reaches 2 Rs/40 Kilo or $7.00 M.T. f.o.b. the mill.

It is certain that in many other instances husk is used as a fuel to heat water for a variety of uses.

In Italy, husk is used to fuel hot-water generators for domestic hot water and for heating purposes. The units are sophisticated and operate completely automatically. A small mill in Monticello (W82) uses husk for direct firing of a small water heater for use in radiant-heat systems in the mill, owners' homes and adjacent buildings.

5.2 DRY HEAT SOURCE

It is conceivable that rice husk would make a satisfactory dry-heat source for many uses not presently known. The slow, even heat release, the contained control that is inherent in the silica shell structure of the husk should be able to be used with distinct advantage. Very few, if any, of the competitive fuels have the controlled release capability found in burning rice husk. In a rudimentary fashion this feature is utilized when husk is used as a domestic fuel, but nowhere does it appear to be used commercially.

5.2.1 DRYERS FOR PADDY OR PARBOILED RICE AND OTHER DRYING TASKS

Rice husk makes a very successful fuel for all drying purposes. However, any projected use must be approached with a full appraisal of the supply (location - seasonality) in relation to fuel requirements. Many projected uses of rice husk as a fuel initially do not allow for the variability of supply, problems of storage and transportation, the resulting residue or the peculiarities of rice-husk combustion. Therefore, what seems to be a potential use becomes at times impossible.

It would seem that in many drying situations the best use of husk would be in the role of a supplementary fuel, even if the supplementary fuel would comprise 80 or 90% of the fuel requirement. It is best to make as much use of the available husk supply as possible in order to derive the maximum economic benefit.

At today's fuel price levels, rice husk often becomes an important raw fuel for drying purposes, both from the cash standpoint and from the standpoint of the utilization of national indigenous fuel resources.

In drying uses there are several obvious categories and these will be discussed separately; see also Section 6.2, where the equipment is discussed in more detail.

5.2.1.1 Farm or field-type drying (See also Section 6.2.1)

Considerable work has been done in recent years by both IRRI (W130) and UOP (W135) on the further development of box-type dryers, fired both by kerosene and by rice husk. A discussion of the various manufacturers, etc, appears in Section 6.2.

This type of dryer was in a highly developed state as early as 1914, as is evidenced by publication of details and photos of a modern box dryer in the 15 October 1914 issue of Il Giornale di Risicoltura (W98). This type of dryer had obviously been in use for a number of years, because by the time of publication a quite sophisticated unit was being produced.

A diagramatic view of a modern rice-husk fired box-dryer is shown in Figure 3. This is an indirect-heat exchanger type dryer.

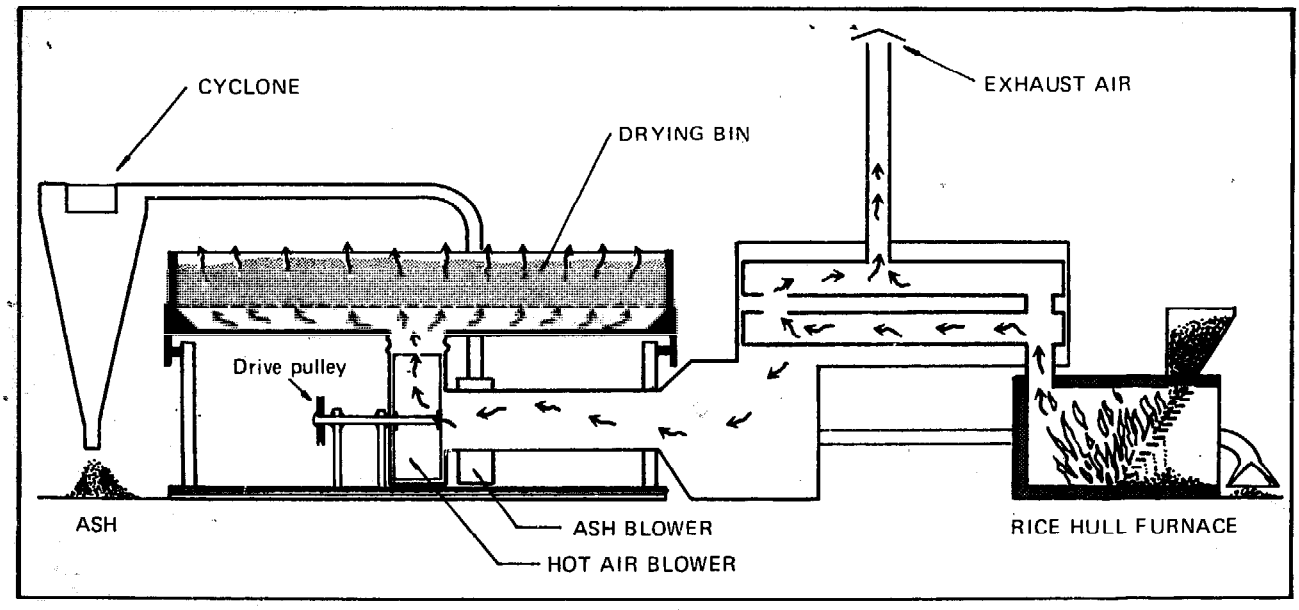

Figure 3 - Rice-husk fired box-dryer

A typical (W135) drying test of this type of unit showed that 1728 kg of paddy were reduced to 1603 kg of lower-moisture paddy in 4.5 hr, a 27.7 kg/hr moisture removal. The rice husk used totaled 55 kg, or 60,500 BTU/hr or 316,500 BTU total, indicating a burner efficiency of 33.5% and a heat utilization efficiency of 11.6%.

Losses can occur in heat transfer, stack losses, radiation, and the carbon remaining in ash/char residue.

The use of box-type dryers is limited to special situations where labour is available to fill and empty the drying chamber. In Italy box-type dryers have been developed with a continuous-flow system that charges and discharges mechanically.

Box-type dryers have the advantage of low initial cost. This feature was important in the adoption of this type of dryer for paddy-collection station use in Sri Lanka. The knockdown feature is also important, as it allows the dryer to be stored out of the way and out of the weather in the off season.

The economics of rice-husk fired vs. kerosene-fired box-dryers depends entirely on local usage, hours of use, and proximity of a source of rice husk to the dryer. In every case found, the cost of the rice-husk furnace was much higher than that of the kerosene burner. The higher cost can be amortized if the unit is used for extended periods of time. In many cases, raw-paddy rice drying is desired at a point considerably distant from the mill. In these situations it would be hard to justify the use of rice-husk fired box-dryers for field paddy-drying.

Each situation must be assessed according to local conditions. Any indigenous fuel furnace must be able to handle the complete range of locally-available agricultural and forest products. The typical furnace designed specifically for husk is usually not suitable for other material, particularly wood and wood trash. The furnace should be able to be constructed locally by farm labour from locally-available material, accept any fuel, and offer good efficiency.

5.2.1.2 Commercial or industrial - direct- and indirect-fired (See also Section 6.2.3.)

It can be expected that more use will be made of dryers in Asian countries, particularl because of the effect of higher labour costs in the economics of yard (sun) drying, primarily of the intermediate step in parboiling. As labour and yard drying become more costly, there is a trend to mechanical drying, and nothing is more obvious than the use of a direct husk-fired dryer. Parboiling is normally done at the point of husking, and in some concurrent fashion with the husking, so that sufficient husk is available without transportation costs. In many cases, the husk is [illegible] o fire the boiler for the parboiling process steam; either a stack heat-exchanger or [illegible] use of the stack gases could be used for the intermediate dryer. In most cases the efficiency of the system is such that steam heat-exchanger drying is feasible [illegible] parboil plant. This system is used in many parts of the world in existing parboil plants.

Considerable work has been done at IIT-Kharagpur (W63) concerning the cost of various fuels. Comparison of costs appears in Table 14. Their use of a step-grate rice-husk furnace has given them 72% recovery in the flue gas, and with a feed rate of 11 kg/hr they can maintain 1000 ft^3/min at 100°C out, with 30°C in. This is a direct-fired step grate with curtain wall and an ambient bleed to control dilution and drying air temperature This general system is followed in most direct-fired installations; excellent examples of this bleed system on a large dryer are near Amritsa (Punjab) and near Lahore (Pakistan), where this system has been in operation for over six years.

Some indirect-fired units have been in operation for 15 or 20 years; in Santo Domingo, Costa Rica, Madagascar, and Bangladesh, indirect-fired column-type dryers were installed many years ago. In Japan in the early 60s, some husk-fired dryers were installed, many of them in the Toyama prefecture, but it was felt that the labour cost of the husk-fired unit was too high, and they were converted to oil. One could wonder if today they might not be reconverted to husk-firing.

In India the government has encouraged considerable work on husk-fired dryers of new design (Kuppuswamy), a combustor using a plate igniter and an air-suspended system coupled with a shell and tube heat-exchanger. These units are undergoing production testing. This project favours the use of indirect (heat-exchanger) operation on parboiled paddy because of the following considerations:

- particulate matter is high in stack gas, and might reduce quality because of impact of particulate;
- discolouration of dried paddy;
- dust nuisance;
- husk in parboiled is split slightly; endosperm is then directly impinged.

In this combustor, 6:1 is given as the air/fuel ratio, and a 20:1 ratio of dryer to combustor air flow is specified. This ratio seems to correspond to most other bleed-air or exchanger-air systems. A 2'6" husk combustor will pass through the heat-exchanger about 6000 ft^3/min of dry hot air. The dryer necessary for a 2 TPH parboiling plant would require 15000/18000 ft^3/min, so that three small combustor units would be necessary.

One deterrent to the use of rice-husk fired dryer units is that because of the variability of supply of husk, a standby oil fuel system--tanks, pumps, burners-- is also needed. The question is whether the fuel saving is worth the additional cost of the furnace, the heat-exchangers, husk-feed and ash-removal systems. In a parboil dryer it appears that it is; in seasonally available raw-paddy drying the use of a husk-fired system is usually not viable. The payout for fuel savings on the parboiled unit would be about 5 times as fast as for a raw paddy unit.

There has been some interest and design work on systems utilizing husk firing with oil as a transfer medium--a thermal fluid system. This would remove many of the objections of fluid heat-exchanger maintenance and problems of steam-boiler maintenance. It would be particularly attractive in a white-milling plant where there was no need for process steam.

A new type of fluid-bed direct-fired dryer (see 6.2.2.1) has been developed in Madras (India). This unit is in current commercial production, but its use as a paddy dryer is limited by the supply of husk. As a parboiler and parboil dryer it is more valid, as it then becomes a piece of mill equipment and has a local husk source.

There has been comment that a classic step-grate system will never be able to give a constant air supply to a dryer. If air is desired for a dryer, it is necessary to have a reasonably constant air temperature into the dryer. The step grate is difficult to control as to the furnace temperature conditions; however, if the temperature control problem could be diminished, the advantages of the traditional furnace (possibility of local manufacture, low-cost material, simplicity in operation, low maintenance and long life) would offer an inducement to the designer to install this system.

One little-known feature of direct firing for drying is that it inhibits insects from the gas stream entering the dryer.

5.2.1.3 Steam heat-exchanger types The use of steam heat-exchanger dryers has been common for many years. Quite sophisticated systems are 35-40 years old and in continuing operation. In a parboil plant it makes good sense to use this type of dryer. The overall efficiency is good. The boilers can be large enough to obtain good efficiency, and the average maintenance cost is low. Further, in a parboil plant the continuous use assists in the amortization of the high initial cost.

5.2.1.4 Use in drying materials other than paddy: The use of husk-fired dryers for materials outside of the rice spectrum depends only on the correct combination, a need to dry, a source of husk and an assessment of the economics to provide a favourable balance. There are many cases where husk can be used as a supplemental fuel for drying, but because of the variability of its supply, which could be out of phase with the drying need, and difficulties in storage and handling, only in special circumstances are there positive factors concerning its use as a prime fuel. But as a supplementary fuel there are many more opportunities. Rice husk could become an important factor in the indigenous fuel supply picture in many countries.

In Japan a rice-husk fueled kiln unit is manufactured (see 6.2.2.2) which is designed to produce an internal temperature of 1000°C, to completely burn the husk with surplus heat for drying paddy or other grains, seaweed, vegetables, fruits, fish, etc.

5.2.1.5 Indirect methods of utilizing husk as a fuel: In Japan and neighbouring countries there has been activity regarding use of rice-husk char as a fuel for rice dryers. A prototype machine for making rice-husk charcoal has been constructed by Liang (267) and a dryer to utilize this has been constructed (private communication).

5.2.2 DOMESTIC STOVES (See also Section 6.7)

In many countries of the world, husk is used as a domestic fuel in one way or another and in varying degrees. This has been normal for thousands of years, and some very good designs have been developed; in the recent past newer types of units have come into use, and with the onset of higher fuel prices there has been renewed activity, both in use and in design, in areas that had drifted away from the traditional practices.

The information available on the amount of use in a given area is almost totally lacking--very little formal information on stove use is available. It is likely, however, that the amount of husk used in domestic areas is much greater, and that its use is much more widespread, than is generally supposed.

5.2.2.1 Types of stoves:

a. Modified step grate: The use of the traditional concept of a step grate enabling a controllable blanket of husk to be maintained and fired in a small furnace-like chamber would be perfectly practical. A design by Bergoni is shown in Figure 4.

b. Pot of burning husk: The most rudimentary form of stove is simply a pot containing the husk with a suitable air bleed for necessary combustion air. This type is seen almost everywhere and exists in a broad range of sophistication of feed control and heat use.

c. Centre burner: The Garbarino design shown in Figure 5 illustrates the simplicity of this design. It is a centre-tube burner type, and would gasify well.

d. Hopper-hearth type: In a design by Pizzi, the control is on the rate of feeding, as there would be an excess of air through the hearth. This was an excellent design, particularly as a space heater. This stove was manufactured in Turin, Italy, beginning in 1912.

e. Briquettes or logs of husk: Great interest has been shown recently in the use of conventional pressing or extrusion techniques to produce a high-density fuel. Two types are the Hullite (Japan-India) and Glomera (Swiss-US), but no commercial applications of either are known to use rice husk.

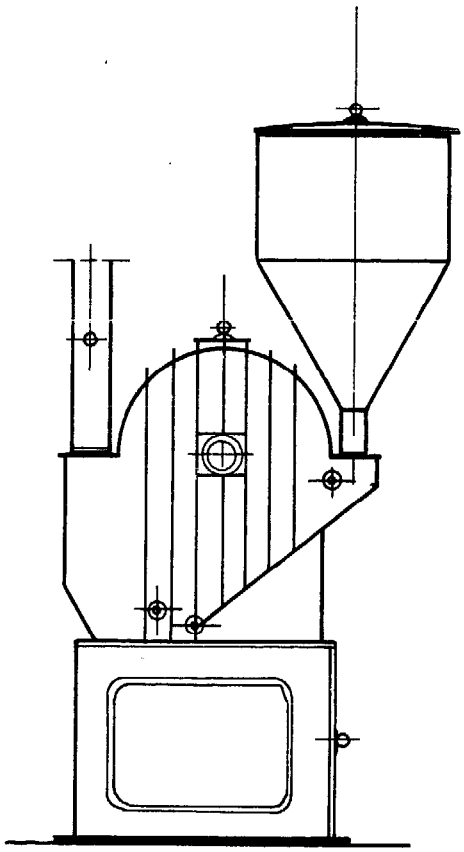

Figure 4 Modified step-grate stove (after Bergoni)

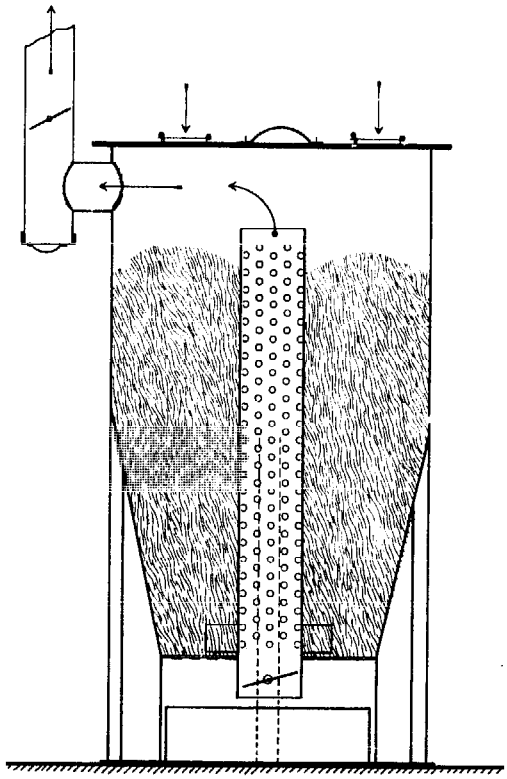

Figure 5 Centre-burner stove (after Garbarino)

f. Briquettes of char: Briquettes of char (both of husk char and mixtures of husk char and another (sometimes coal) fuel) have been used in several countries, both on a development and a commercial basis.

Many of the household stoves built use light and thin components, and with faulty operation the temperature reaches high enough values to melt or burn through the thin sections. Experimental stoves of type b above, are in use in India (W68), utilizing cast sections to minimize this possibility.

The problem of ash disposal has resulted in original systems for removal of the ash from the hearth section. Borasio (Italy) describes an automatic mechanism to effect ash disposal. As in the overall design, the range of complexity in the removal of ash varies widely.

5.2.2.2 The use of stoves in various countries:

China - It appears that for centuries husk has been used as fuel for the home. This gives each family one independent fuel supply. The traditional unit was built out of firebrick like a fireplace, and with a brick chimney. The resultant ash was utilized as a carrier in a mix for fertilizer use on the family's fields.

India - Husk has been used for centuries as a fuel in the household and small hotels, when other sources of fuel are lacking or economies are possible to counter-balance the negative features of husk use. Special stoves have been developed to utilize the husk

for fuel. At W68, experimental stoves built by Singh feature a metal stove using loose paddy husk. Two models have been built, and at least one is in operation.

In Kharagpur a stove is made of two concentric tubes - 12" and 3" approximate diameter. A mixture of 25% sawdust and 75% husk is packed and tamped tightly into the space between tubes: then the small tube is removed and the block is lit, burning under self control from the inside circumference, until all of the fuel is exhausted, in a manner somewhat like a solid-fuel rocket motor. This stove has sufficient capacity for cooking a meal, and is on sale at a local hardware store at a very low price.

Also at W68, development work is progressing on a system utilizing a "Hullite" (Japanese design) machine to extrude logs of husk, 10" long and 2 1/2" diameter, one of which, in a "chullah" open-type burner pot, would provide sufficient fuel for cooking two meals for five people. A "Hullite" unit has been installed at the FCI Thanjavur rice mill, but the high maintenance cost of the extruder has prevented the commercial exploitation of this system.

Japan - Domestic heating and cooking units utilizing rice husk as a fuel were popular in Japan during the fuel-short years of World War II. This use faded during the post-war years, until the "oil shock" revived interest in such units, whose sales have risen in rural areas.

An article from a current Japanese newspaper describes a stove used to burn husk. The retail price is the yen equivalent of $102. Farmers having 1.5 hectares of paddy can produce enough husk to cook for five persons for one year. The required husk is stored in a small storage unit requiring 3 m^2 of floor space. The manufacturer (Hitachi Koki Haramachi Factory in Fukushima Prefecture) planned to sell 50 units in 1975, but has already sold 250.

Korea - In a similar but different situation, a hollow-core unit, usually made of coal powder or a mixture of paddy-husk char and coal powder, is used extensively. One of these units, 12" long and 6" diameter approximately, is said to cover the heat requirements of a family for a day.

There has been considerable work by W115 on the addition of 5-10% of rice-husk char to a low-grade anthracite, to improve the intensity and duration of the resulting fire. Details on this work can be seen in a paper provided by Park (266) (in Korean).

Malaysia - No domestic use of husk has been noted, but an interesting project concerning husk utilization has been drawn up, although apparently never executed.

A combination carbonization-briquette plant was proposed and designed for installation in Malaysia, intended for production of fuel briquettes and paddy charcoal for export, apparently primarily for the Japanese market. The specifications of the plant indicated that 80% of the weight of the raw husk would be produced as finished briquettes. This indicates that a large amount, in fact, almost all of the volatiles would be left in the char, and there might be an odour problem from burning these briquettes. This plant was based on Japanese technology and construction practices.

This plant appears not to have been built. The advisability of husk for charcoal in Malaysia is very doubtful; it would seem that a better investment would contemplate using a different raw material that would produce a higher-quality charcoal. The local use of rice-husk char as a fuel is proper and wise, but for export conditions higher-grade (lower non-active components (ash)) products would be preferable and more capable of long-term production because they have a more competitive position.

Philippines - The use of husk-fueled stoves is commonplace. Many homes have storage bins in the house, filled by merchants who haul the husk from the mill and retail it to the domestic user.

The housewives use special, locally constructed stoves--usually block, masonry or mud. Many use the concentric-tube type stove. Normally the rice mills do not charge for the husk, and the retail costs cover distribution only. There is also similar use in restaurants and other public establishments. Information concerning new stove designs can be had from the Industrial Research Center of NIST, Manila. At IRRI (W130) interest in efficient design and development of stoves is shown by Kahn.

Vietnam - In Saigon there has always been an organized market for husk for home fuel use. 50 kg bags are commonplace, a price of 35,000 piastres (US$51) per MT is the normal retail level; the use of polypropylene bags accounts for part of the price.

5.2.3 AIR-SUSPENDED FURNACES

In air-suspended furnaces, the particles are burned while in an air suspension or turbulence, as opposed to grate burning where the air filtres through a bed of husk at a predetermined rate (according to B.R. Wolf less than 1.0 m/sec velocity).

Obviously the air-suspended furnace will have a much higher air/fuel ratio and excess-air ratio, with consequent dilution and lower exit temperatures. However, the heat release is much faster, so that within a given volume of furnace the capacity will be much greater than a grate type. Further, the particulate matter in the airstream is the total weight, because the furnace gas stream is also the conveying stream, and thus could create a particulate problem. However, the smallness of the furnace for a given heat release may offset the complexity of the particulate removal from the gas effluent.

References to these furnaces appear in Kocee (170) in 1959, Gravel (167) in 1964, Finch (168) in 1969 and Mehta-Pitt (72) in 1974. These all feature turbulent combustion, high excess-air ratio and various ideas for collection of the effluent and uses of the residue.

The two which are currently being developed are described below.

5.2.3.1 Mehta-Pitt: Rice husks as a fuel for producing energy. An efficient, low-cost, easily operated method for utilizing rice husks to produce energy has been developed as illustrated by the flow diagram. It was designed to operate in conjunction with a process for producing industrial materials from rice husks (171).

It consists essentially of a feeder, special furnace, heat-recovery boiler, ash collector and draft fan. A continuous flow of husks is delivered by a mechanical feeder from a surge bin to the furnace, where the husks ignite and burn without other fuel. Combustion air is supplied by an induced draft. The hot combustion gases and ash residue pass from the furnace through the heat-recovery boiler to a dust collector in which the ash is removed from the exhaust gases. A granular ash without clinkers is produced.

The furnace is a fabricated steel, refractory-lined vessel having neither grate nor other moving parts. The style of the boiler and dust collector can be varied to suit local conditions and environmental considerations. The entire system has essentially only two moving components: the husk feeder and the draft fan.

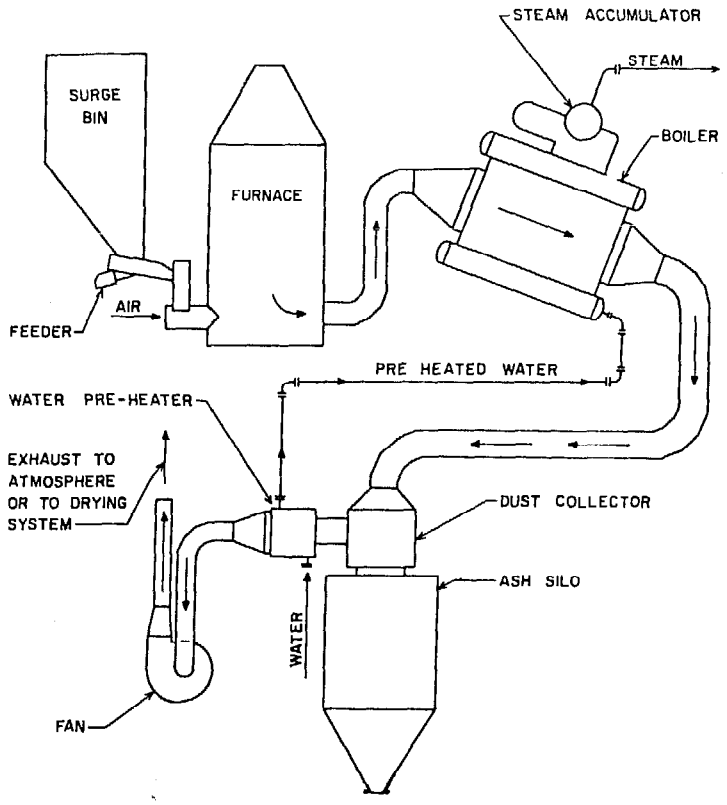

SCHEMATIC FLOW DIAGRAM OF PLANT FOR PRODUCING STEAM

Figure 6 Schematic flow diagram of plant for producing steam

When the system is operated to produce commercially useful materials as well as energy, approximately 7,000 lbs of steam, at pressures from 100 to 400 psi, can be produced per metric ton of husks processed. On the other hand, if operated for maximum boiler efficiency solely to produce energy, up to 10,000 lbs of steam can be produced per metric ton of husks.

A pilot plant, designed to produce industrial materials and using this energy-recovery system, has been in operation in Sacramento, California since 1971. It burns 800 lbs of husk/hour and produces approximately 2500 lbs of steam/hour. A large commercial plant with a capacity of 15,000 lbs of husks/hour to produce 48,000 lbs of 200 psi steam/hour, as well as industrial materials, has been completed in Stuttgart, Arkansas, USA and has operated on a test basis.

5.2.3.2 Finch-McIntyre Engineering: Method of making a carbonized product useful as a filtre medium from rice hull. The rice hulls are fed continuously to a combustion zone of hot swirling gases, where the hulls are partially burned and carbonized while dispersed, after which the carbonized particles are removed. The product has a skeletal silica in the form of a lattice structure with carbon dispersed therein (168).

5.2.4 REFRIGERATION FROM HUSK - ADSORPTION SYSTEMS

There appear to be no commercial or experimental systems today utilizing husk for refrigeration in any way; however, the concept is a practical one and in circumstances where the economics are favourable, it should be considered.

The development of a cold-storage system using husk-fired direct-flame type refrigeration units could provide a direct use of husk in an area deficient of fuel and needing cold storage. Ash residue could be used as an insulation filler material.

Considering that rice is normally cultivated in tropical or sub-tropical zones, where cold-storage capacity is needed, and that the milling season is usually in the hot dry months, the feasibility of such a system is shown.

The cold-storage use would offer a direct utilization of husk, eliminating losses due to the use of multiple systems (husk-boiler-electricity-compressor).

That this concept is not new is shown in a letter from B.R. Wolf to Enrico Bianchi of 16 October 1942. Wolf detailed the following: 100 kg/hr paddy husk = 33 kg coal in calorific value; 300 kg/hr - 38-44 HP at 350° - 12/15 ctm.

After producing 38-45 HP from the escaped steam, 300 kg/hr of steam gives 192,000 calories from which one can recover 172,500 calories, corresponding to 450 kg of ice.

This concept has not been neglected in modern-day thinking. In May 1975, Walter H. Higa published "Stirling Cycle Engine and Refrigeration Systems". The Stirling cycle is an external-combustion cycle which could utilize heat from rice-husk combustion to power a Stirling engine.

5.2.5 ALTERNATIVE COMBUSTION CYCLES

Alternative combustion cycles can be fueled by any outside fuel as an external-combustion system. Any heat source will suffice, so that conceivably rice husk could be used to provide energy for the operation of these prime movers.

5.2.5.1 Stirling Engine: It is conceivable and possibly practical to have a large Stirling engine utilizing an external rice-husk furnace as its heat source. There is considerable interest in the development of Stirling engines for developing countries to utilize indigenous fuels. The Ford Motor Company has done experimental and development work on Stirling engines. United Stirling (Malmo, Sweden) has considered a low-cost engine which would use solid fuel or a producer-gas fuel source. Existing Stirling engines are not suitable for low-technology areas, but it is felt by United that less sophisticated equipment could be built to utilize indigenous fuels.

5.2.5.2 Gas Turbine: It is entirely feasible to operate a gas turbine on the energy provided by a husk source. An extended development (W171) is currently under way using as a fuel the local municipal waste (400 tons/day produces 15,000 kw). The energy source could just as easily be an equivalent supply of husk.

There are several methods to convert the raw husk into the energy supply for a gas turbine. Their relationships are shown in Figure 7.

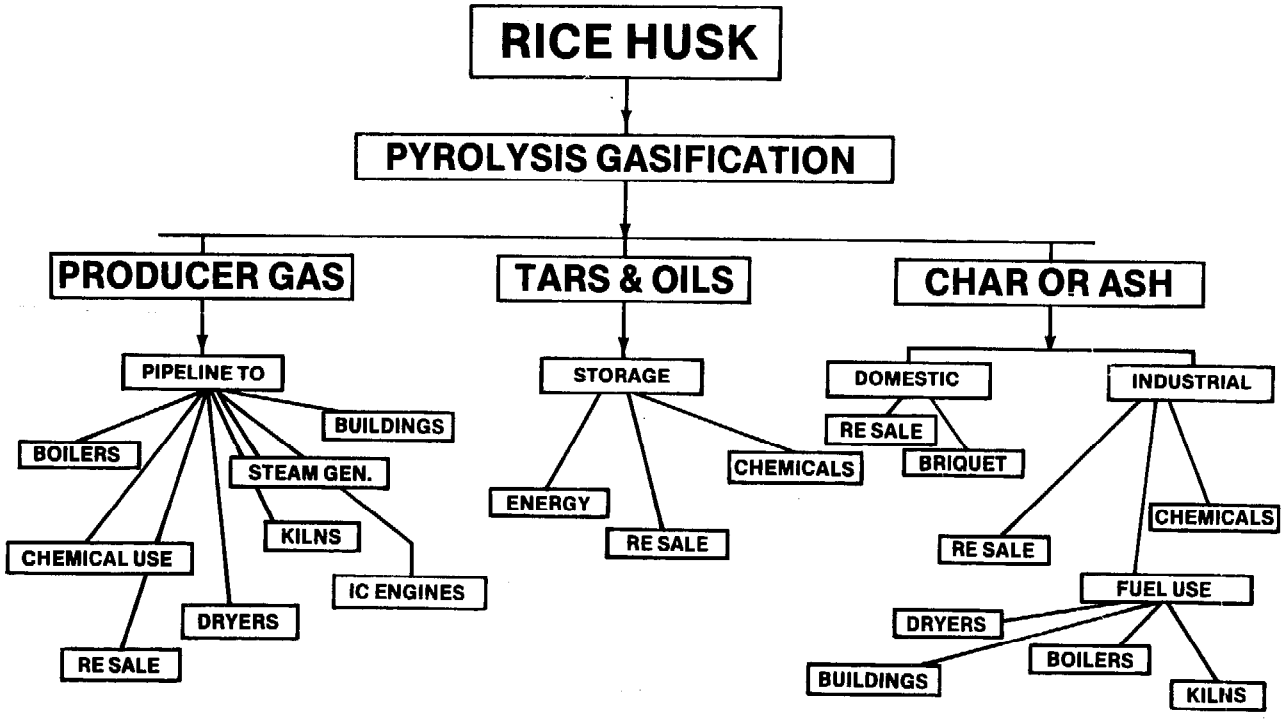

Figure 8 Pyrolysis

One of the economic attractions of flash pyrolysis is the high conversion to volatile products obtainable, as compared to longer residence-time processes. In all laboratory runs, the total volatile content of the products exceeded the volatile content of the feed. Furthermore, in many cases the weight loss from the feed (gas, water and oil yields) was greater than the volatile matter in the feed. This means that during flash pyrolysis there occurs not only devolatilization but also a substantial amount of gasification of the fixed carbon in the feed. This result, demonstrating the advantage of flash pyrolysis over long residence-time processing, is of great economic significance.

The synthetic fuel oil derived from rice hulls was supplied to an independent combustion-testing laboratory for firing in a test boiler. The results were as follows:

1. The pyrolytic oil gave satisfactory combustion in the tests. It is acidic, its properties are fairly easily changed by overheating, and it can form deposits on valves and heating surfaces if the combustion system is not properly designed. However, the system changes necessary to accomodate pyrolytic oils may not be more difficult than, say, the changes needed to accommodate No. 6 heating oil in a system designed for No. 2 oil. (See Section 6.3.2.8.)

2. The pyrolytic oil can be blended and co-fired with most residual fuel oils.

3. U.S. air pollution limitations on new units can apparently be met by using stage combustion.

4. Due to its low sulphur content, no problems due to sulphur oxide corrosion or emissions are anticipated from the pyrolytic oil.

5.3.1.2 Wallace-Atkins: The Wallace-Atkins Oil Corporation (W223) is offering, on a proprietary basis, a cracking destructive-distillation process for the conversion of rice straw and hulls to usable crude oil, "natural gas" and char. They claim theoretical yields of: weight straw and/or hulls: 2000 lbs; recovered crude oil: 1-2 barrels; gas: 16,000 ft^3; char: 750 lbs.

They state that the secret of the process is the use of a catalyst manufactured by them. No other information is available.

5.3.1.3 EES-Georgia Tech: Georgia Institute of Technology (W178) has designed and constructed a mobile pyrolytic converter intended to transform cellulosic wastes to a high-energy char-oil fuel. At the present time the units have not operated on rice husk, but rice husk could be used as an alternative input material.

Economics and commercial feasibility have yet to be proven on this system, particularly as regards rice husk.

5.3.1.4 Infra-red Pyrolysis: The equipment designed and built several years ago had as its prime objective the complete combustion of the organic compounds and the free carbon of the rice husk as a continuous process. The machine is a continuous processor, with raw husk as a feed material and a low-carbon or carbon-free residue that is unique in its physical and chemical properties. It is also capable of varying the degree of carbonization as desired. The ash residue is of low density; no breakage or pulverization of the husk form occurs during the pyrolysis. The generated heat can be utilized through any appropriate system for steam generation or for drying purposes. The machines are modular in concept and have low initial cost, maintenance and operation costs. Further details are available from the author.

5.3.1.5 Egyptian Refractories: The Egyptian Company for Refractories (W11) has developed and is using a pyrolytic-process system to produce a residue suitable for production of refractory brick. In their system, charred husk from the pyrolysis unit is processed in a kiln to produce the necessary white silica. Pyrolysis gas is used to provide energy for the processing, water heating for the hydrolyzers or fuel if desired; fractional distillation is also possible.

5.3.2 GASIFICATION

5.3.2.1 U.C.D. (W219): A current study and development programme (Wii5) is under way at the Davis campus of the University of California concerning gasification of crop residues. One of those being tested is rice husk. Operating producer-gas generators of the down-draft type have been designed and constructed to provide producer gas for the operation of a modified internal-combustion engine of the gasoline type. Development work is also progressing on the adaption and conversion of a used diesel engine to dual-fuel (P.G.Diesel) operation.

5.3.2.2 T.P.I. (W161): Gasification of cellulosic raw materials, one of which is rice husk, is the focus of current work at the Tropical Products Institute at Culham, U.K. A programme resulting in construction of a gas generator and associated prime mover equipment is under way. Use of dual-fuel engines and conversions of low-compression engines are being investigated, drawing on the experience and background of W160 in the design and construction of producer-gas generators.

5.3.2.3 Monticello (W92): Mention of the existing rice-husk producer-gas generator and gas engine prime mover in Monticello (Pavia), Italy, must be made here to describe what is, as far as is known, the only remaining installation of a Balestra gasogeno and complete system in operating condition. In the 1940s there were many of these units powering rice mills in this region of Italy. This is a traditional-style system, of about 60 HP, powering both the mill lineshaft and an electric generator. There appears to be no similar unit in any other country.

5.3.2.4 Thermex: An integrated unit which can use rice husks as a fuel for the production of producer gas has been developed by the Research Council of the Government of British Columbia (Canada), and an exclusive license has been granted to Alberta Industrial Developments, Ltd. for marketing the equipment under the name "Thermex Reactor". This system utilizes a fluidized bed to convert small particles of suitable raw material into a combustible gas with a thermal value about twice as high as that produced by a conventional gas-producer. It is also claimed that the design encompasses safety features not normally found in producer-gas generators. Charcoal and oil are the end products, their composition depending on the characteristics of the desired gas production.

5.3.2.5 Refratechnik Albert: W43 has developed a procedure and an installation for the production of low-carbon ash (<3%C), tar and furfural. This technology, named "Rice Husk Refinery", can decompose the rice husk in one process under production of ash for refractory building materials and heat insulating plates (calcium silicate), tar and furfural, under conditions inoffensive against environment, by integration of the installation into a rice mill. The latent heat capacity of the rice husks is being utilized so that the process passes off without additional energy. Refratechnik has an established know-how for the processing of the ash to refractory bricks and building materials.

Patent applications for the procedure and the installation have been filed.

Low-carbon, white rice-husk ash suitable for use in manufacturing refractories and building materials is prepared by first removing volatile constituents (furfural, vapour, gas) by heating the husks to a relatively low temperature, below their ignition point. Fixed carbon is then oxidized in the presence of a reagent by heating the husks to a second temperature above the separation temperature but below the crystallization temperature of the SiO_2 in the husks: a heat treatment at a third temperature, above the crystallization temperature of the SiO_2 follows, to produce a uniform SiO_2 crystal structure.

The first pilot equipment was built in 1974. It showed qualitative results for the production of low-carbon ash, vapour, gas, furfural and tar in the discontinuous process. Pilot equipment, with a production of 150 kg husks/hour, is currently being operated in a test regime. (See also Section 7.7.1.1.)

5.3.2.6 Building-burning:

Burning of husk in buildings or roofed walled areas has been done in a great number of countries. It is most frequent today in Japan, in a variety of types of buildings, one type which is shown in Figure 9 after a design by Ban (W103). Somewhat similar ideas, but on a much larger scale, have been used for many years in the United States. Most of the commercially-used ash in France is produced in similar buildings. In many countries, quite sophisticated structures are used in order to control the burning rate and subsequently the ash analysis; a typical building in the United States is 40 feet wide, 100 feet long, about 36 feet high, of steel-plate construction with asbestos roof-sheeting. It is loaded pneumatically to a depth of about 28 feet, and air-supply feeders in the floor are controlled to furnish the correct amount of combustion air for total combustion. The typical cycle, shown in Figure 10, requires 39 days. The building will hold about 200-250 tons of husk, which produces 40-50 tons of salable ash. Air-pollution control dictates the configuration and sophistication of the buildings.

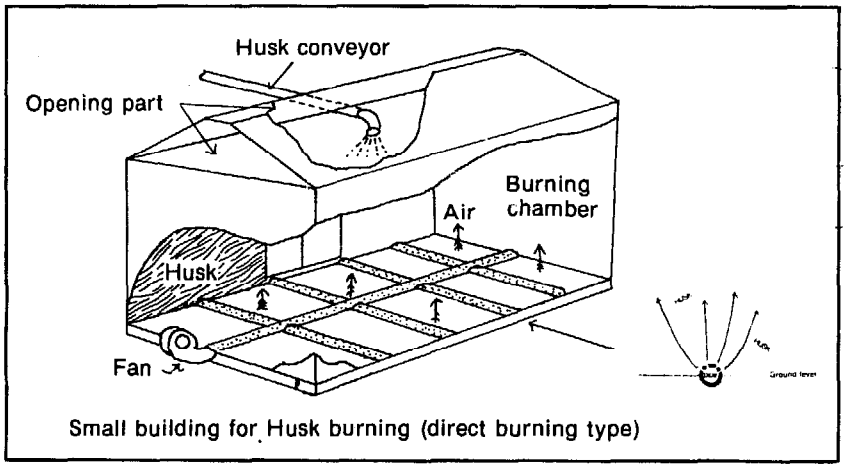

Figure 9 Building-burning of husk (after Ban)

Two new mills (Japanese-designed and built) are being installed in Sri Lanka (Uda-Walawe project). Both feature controlled husk-burning as an integrated feature.

The primary feature of the construction is that the burning rate of a mass of husk can be accelerated and a desired end-product can be produced consistently. In areas where rainfall is not a problem, no roof, but only walls and the air-feed system are needed.

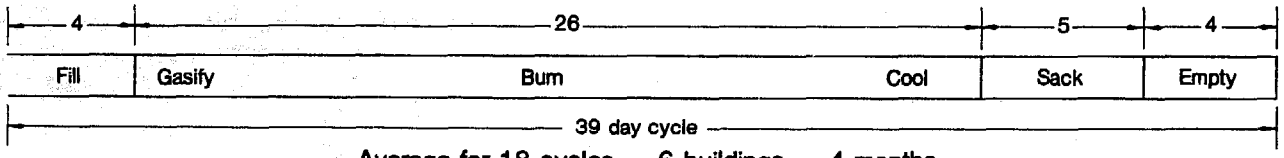

Average for 18 cycles — 6 buildings — 4 months
TOTAL PRODUCTION — 52,257 bags.

Figure 10. Building-burning husk - Time cycle

5.3.2.7 Lantz: A Lantz converter is a hybrid pyrolysis, gasification and carbonization unit (W187). The carbon or char recovery varies according to the gas characteristics desired.

A unit being fed 2 tons/hr of rice husk will produce about 16 million BTU/hr net output, using about 3 million BTU for internal operation of the unit. Operating temperatures normally run 600° to 800°C but can range from 120 to 980°C. Usually the Lantz Converter has been installed as a waste-disposal aid, the heat generated sometimes being used for steam or drying.

5.3.3 DISTILLATION

5.3.3.1 Japanese: Distillation is normally thought of to provide for the production of various fractions from the volatiles and of a char containing essentially the carbon portion of the residue along with the silica content. Carbonization as sometimes carried out in Japan is essentially distillation, but no use is made of the fractions. The whole process is designed for the production of char for domestical or industrial use. Some Japanese carbonizers are of the rotary kiln type, some of them the furnace type.

Work was done primarily by Jacobs (118) concerning distillation and distillation products. Marcusson (125) earlier was concerned with rice-husk distillation. Several times over the past years there have been projects to utilize distillation procedures, but no successful commercial exploitation of any aspect of distillation of rice husk appears to exist at the present time.

5.3.3.2 Resource Recovery Systems (W199): Work is in progress to recover fuel gas and chemicals from agricultural wastes, including rice husk. The chemicals include ammonia, light aromatics, alcohols and ketones. The residue is sterile, inert and odourless. Crane (110A) describes the current results using rice husk as an in-feed material, and states that the state of the art may be considered as ready to progress from a pilot-plant-sized installation to a full-sized resource-recovery operation. The furnace utilizes a molten-lead bath reaction zone, with the feed material falling onto the fast-moving stream of molten lead. The analysis of the husk in feed material was given as: 8.54% moisture, 59.9% volatile matter, 14.24% fixed carbon, and 17.63% ash. The fuel gas has 500 BTU/ft^3, with 21.13% H_2, 33.80% CO, 18.25% CH_4, and 19.30% CO_2.

5.4 INTEGRATED SYSTEMS

5.4.1 PARBOILING

5.4.1.1 Traditional Systems: Traditional parboiling techniques, which often utilize husk as the energy source, include the "chatty" system of Pakistan, which consists in filling small earthenware jars with paddy and water, and standing them on a bed of rice husks mixed with huller bran. The bed is then set alight by sprinkling it with hot ashes. Combustion is slow, and the water in the jars is gradually brought up to 50-60°C. The paddy remains from six to twelve hours in this hot water and absorbs enough to make it ready for the steaming stage. The water is then poured off, and the grain is put in large iron containers, wide and shallow in shape, which are placed over a furnace fired with rice husks. The damp rice is continually stirred, and small amounts of water are added from time to time to compensate for the evaporation. The heating operation may last from 30 to 60 minutes, after which the rice is spread out to dry in the sun on a hard earth or concrete floor.

A second-generation parboiling system of the type described as a "Goya plant", common in Sri Lanka, normally uses rice husk as its fuel, though some firewood is also used. The "Goya" system uses the husk furnace under the tank first to heat the water for soaking, and then for steaming. A small power-driven husk-blower is sometimes used to feed the husk to the furnace area, but in some cases manual flicking of the husk is the method used. Usually the wet paddy is spread on a drying floor to be sun-dried.

5.4.1.2 Modern Techniques: However, "the introduction of mechanized milling in the Far East and the consequent adoption of the boiler and steam-driven engine to produce energy for the processes have altered parboiling techniques by the use of pressurized steam" (Gariboldi). Obviously, the best way to produce this steam is with the husk produced in milling the parboiled paddy.

Later parboiling techniques utilize formal boilers, both horizontal and vertical. There are many variations of the conditions. An illustration of the pressure balances in a modern Italian unit is given in Figure 11.

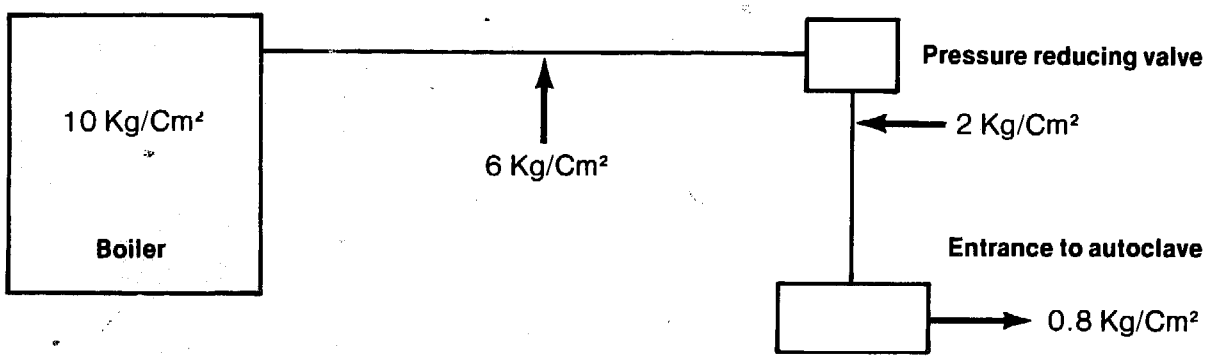

Figure 11 Pressure balances in a parboiling unit

The amounts of steam needed for parboiling also vary, of course, according to the efficiency and sophistication of the installation.

For example, an old report (W60) says that 600 kg/hr of steam is needed for drying, and 200 kg/hr for soaking/steaming, for a total consumption of 800 kg/hr. Processing 1 ton/hr would provide 200 kg/hr of husk and about (at a 3.0 ratio) 600 kg of steam, which would fall short of the calculated need of 800 kg. Another estimate gives 120 kg for soaking, 60 kg for steaming, 550 kg for drying, and 20 kg for loss, for a consumption of 750 kg/ton of paddy. These consumption requirements point up the necessity for an efficient steam-raising system first, and for attention to parboiling system losses and inefficiencies secondly, if full utilization of the husk fuel available is desired.

There is a great difference between Asian and Western parboiling in the consumer demand of quality of the milled parboiled rice. The Asian goal in energy-free parboiling is to provide steam and hot water for soaking and steam; drying; and power for mill operation, using the husk supply as the only raw fuel.

If this goal can be achieved, the Asian boiler can enjoy complete independence. But none appears able to do this, because the only feasible way would be to use a heat-coupling system; while there are many systems which could be set up this way, this has never been done, because of the lack of knowledge of how to do it and the ignorance of the advantages of such a system. There are obviously some situations (due to the method used for parboiling) where an "all three" system cannot be used. If the parboiling process requires much more steam than is available, then a dual use is impossible. However, in almost every case a practical and economic system can be installed that will enable the desired parboiling and drying to be accomplished and will produce adequate power for all milling and ancillary needs.

Most systems use steam heat-exchanger dryers for the intermediate step, although there have been instances of direct transfer designs. One by WIIO utilized furnaces for the dryers with a heat release of 1.5 x 10^6 kcal/hr, and a boiler for the steam supply with an evaporative capacity of 750 kg/hr. This was a 2 ton/hr plant on nominal capacity.

The amount of steam needed to heat one ton of paddy varies according to the degree to which the starch in the caryopsis must be gelatinized and also according to the methods of heating. In a modern plant it is considered that 80 kg of steam are required for heating one ton of paddy. If steaming is done in open containers by injection at ambient pressure, the quantity will, of course, be considerably greater. In a modern plant the quantity of steam needed to heat a ton of paddy is a mere fraction of that required for the whole process, because steam is also needed for heating the steeping water and the air in which the paddy is artificially dried. The steam required to produce parboiled rice in modern plants comes from high-pressure boilers and is piped out to the various points where it is needed at a lower pressure. Steam used for direct heating must be saturated when it comes into contact with the paddy, so that most of its heat is transmitted at the lowest temperature corresponding to its pressure.

In high-intake plants the steam can be produced at high pressure and used to power turbines or engines before it enters the heating system of the parboiling plant at low pressure. In this case, before it comes into contact with the paddy every trace of mineral oil coming from the lubricants used in the motor or steam turbine must be removed.

Modern plants use either a continuous or a batch-type cycle. In the former, the steam produced in the boiler is in constant demand, as the individual operations are continuous. In the latter, steam utilization has its peak and off-peak points according to the work to be done.

To avoid the need for large boilers which can produce enough steam to meet the peak demand levels with continuous adjustments to the fuel supply, an accumulator is sometimes placed between the boiler and the plant's piping system. This accumulator takes up the excess produced in the boiler, and supplies it as and when the plant requires it. The quantity of fuel consumed is to a great extent determined by the burner output, by heat insulation and by all the various economizers commonly used in modern steam-generating plants.

The husk obtained from shelling provides the cheapest form of fuel usually available at the mill. If properly utilized and if the plant is efficient, it is enough to supply all the heat needed for the whole parboiling process. One ton of paddy yields 180 to 200 kg of husk; i.e., about 3,000-3,500 kcal/kg, or 5,200-5,500 BTU/lb. The steam obtainable from burning this quantity of husk is 550-600 kg, a quantity sufficient for a rationally organized process.

When used to make steam, the husk is usually burnt in horizontal or vertical smoke-tube boilers. The cheaper vertical boiler has the disadvantage of providing a lower output of steam, as the water surface is much smaller than in the horizontal type of boiler. The latter is usually preferable if the capacity of the plant exceeds one ton/hr.

In India, a very large portion of the rice milled is parboiled, and almost all the parboiling systems, large or small, use the husk as their fuel. In Kollegal (Mysore), a small plant using a vertical cross tube (VCT) boiler (99 ft^2) of about 8 years of age had had no problems during this use. It uses chemically treated water and processes about 2000 kg of paddy per hour, using 10 to 12 25-kg bags of paddy husk to fire the boiler, with a traditional step-grate furnace.

A plant in Madras (W84) uses a new type of parboiling unit, which has 4 cylinders (fluid-bed screw conveyors), two on either side of the furnace, one over the other. The paddy is soaked in soaking tanks in ordinary cold water for about 24 hours. This paddy, with a moisture content of over 30% is fed through the hopper and passes through the cylinders one after the other in a continuous process. In the first two cylinders, the paddy is parboiled, in the third cylinder it is dried, and in the fourth, with the help of fresh cool air, it is cooled. The heat requirements of this parboiler are covered by a centrally located husk-fired furnace of an essentially traditional design.

In Alor Setar, Malaysia, a mill (Thean) used two husk-fired boilers to provide steam for mill motive power and for soaking and steaming. Drying is done on a sun-drying floor. Here two types of boilers are used: a classic locomotive type and a modified marine type. A vertical steam engine drives one mill and a horizontal engine the other. Both parboiled and raw milling is done.

In Thailand, most rice is not parboiled, but the portion parboiled uses husk-fired systems. The leading Thai rice mill (W146) uses a parboiling and drying system of their own design, utilizing husk from the rice mill. Their parboiling resembles semi-parboiling, a rice hardening which penetrates partially and increases the milling yield. This produces a light product with no appreciable change in flavour.

Table 20

Fuel balance for a parboiled-rice mill

Requirements per ton of paddy			Husk equivalent
Water -	2,200 litres		
Steam -	250 kg for steam uses		100 kg Husk
Fuel oil -	25 kg for drying		75 kg Husk
Electricity (parboiling)	20 kw	60/65 kw	
Electricity (milling)	40 kg		160 kg Husk
			335 kg Husk

Table 20 shows that with traditional methods it is not possible to operate a parboiling plant fully fueled by husk. However, if heat-coupling generation and steam heat-exchanger dryers were used, it would be possible to operate the complete plant on the husk removed.

Thus, parboiling and drying would use 750 kg steam/ton of paddy, which at the traditional ratio of 3:1 would require 250 kg of husk, which is impractical, while with a modern sophisticated system a ratio of 4:1 is feasible, and this would meet the requirement. (For example, the system at Gimeaux, France (W23), is operating at a 4:16 ratio. The Tulio power plant (W134) operates at a 4:1 ratio, and the Surinam plant (W144) at greater than 4:1.) By using a back-pressure (heat coupled) engine generator system the necessary electrical energy (60/65 kw) could reasonably be produced and the process requirement be supplied from the low-pressure side.

In many Asian countries only one function is performed at present by the use of husk-fired systems. Many low-technology operations use yard drying, and because of the low efficiency of their boiler-furnace system, all of their husk is consumed just to produce the steam necessary for the first steps. While achievement of the desire to perform all three functions is several years away, it is currently entirely possible to perform two. The most practical is to install heat-exchanger mechanical-drying units for the intermediate drying step.

Most boilers are relatively inefficient; many are old vertical cross tube, Lancashire, Cornish or locomotive types, with a makeshift or undersized furnace. Usually, no insulation is provided, the possibly favourable economics being hardly thought of. One outstanding parboiling design at Chavalakade, Sri Lanka, (British design) combines pressure parboiling with excellent steam heat-exchanger units. Husk-fired boilers backed up by oil-fired boilers originally provided steam for all purposes, including power generation for the milling process. Today there is no need for the oil-fired boilers, as the old steam engines were replaced several years ago by grid power, so that the husk-fired units provide the steam necessary.

In France, at Gimeaux (W23), a husk-fired boiler installation provides steam for parallel lines of parboiling and pre-cooking processing. This unit is a sophisticated pass-through type utilizing combustion-tube burning.

In Italy, Bariboldi builds for sale (W90), and uses (W94), efficient pass-through type boilers performing a degree of combustion-tube burning. These are modern, high-technology, sanitized installations that provide completely adequate steam for parboiling, drying and plant heating duties.

Husk-fired boiler units in parboiling mills have been traditionally installed in southern India. There are several experienced, capable manufacturers of husk-fired boilers for this purpose. Most use traditional step-grate systems. None uses air-suspended types which allow much greater heat-release values.

Subject to satisfactory performance of the new installation by Pitt at Stuttgart, Arkansas, U.S.A. the design of husk-fired steam-producing systems can be expected to advance.

5.4.2. MOTIVE POWER - PROCESS-RELATED

Husk can be utilized in the operation of rice mills in the following manner:

1) via boiler-generated steam,

   a) to operate steam engines or turbines and drive the rice milling machines, either

      i) directly by lineshaft or
      ii) indirectly by electricity

   b) to operate steam engines or turbines as in a) above and concurrently produce and utilize exhaust steam for heating purposes in processing (parboiling).

2) via producer gas (gasogeno),

   a) to fire a steam boiler, then as in 1) above

   b) to provide fuel for internal-combustion engines, either

      i) gas engines or
      ii) dual fuel engines (pilot fuel)

When considering rice husk as a fuel for an in-plant power system to compete with mains electricity there are several factors which must be considered before the decision to proceed is made on purely economic grounds.

First is the need to consider that the system selected will only attain a long life, with a continuation of the original output and efficiency, if the proper steps are taken for maintenance and upkeep. In the words of Hawkey (W159), "We find that normally they (the operators) do not clean or maintain the system (boilers, engines, condensers, heat-exchangers, etc.) and the system deteriorates due to a lack of upkeep. The system is dying from the moment of startup."

Unless the proper preventative maintenance is contemplated, it is irrational to install an expensive system that is supposed to pay its way from the savings generated. It is necessary to design the system properly for long life (water treatment being the prime consideration), and then to operate it in such a fashion that the long life is realized.

Secondly, it must always be remembered that there is no need to generate more power (electric or steam) than is required on a purely economic or national-interest basis; in other words, there is no need to have husk left over. One should not strive to install equipment to make a more efficient plant than is practical - there would be husk that would have to be disposed of, and there would be a greatly increased capital cost to reach the higher efficiencies. In areas where mains power is cheap (excess hydro-electric power, for instance) there is no need to install an expensive husk-fired generating system. It also must be remembered that a husk-fired boiler costs about twice as much as a gas- or oil-fired boiler of the same rated capacity, because of the exchange ratio of 15/18 kg of steam/m^2 of surface for the former and 40/42 kg of steam/m^2 for the latter. Also, there is the additional cost of the external furnace.

If, however, the desire is to furnish electricity for other than the rice mill alone and on a continuous basis, it would be best to consider the husk as a supplementary fuel, primarily because of its possibly discontinuous supply. This approach is valid only when the use of indigenous fuel is dictated by national or economic reasons: any use of husk for power alone, based on its fuel value, will result in too high a cost, both for capital outlay and operation, particularly in a smaller plant. Only in a very large plant would husk firing be practical and thus best as a supplemental fuel.

For example, in Germany (1974), a power plant for a 2 ton/hr rice mill was quoted at $106,700, and another 4 ton/hr mill at $432,000 (two different kinds of power plant).

Again, in Italy (1975) the electricity cost for a large rice mill was quoted as about $100,000 per year. They calculate that a husk-fired power plant would cost about $60,000 in labour alone, while interest is at a 15% prime rate. In this situation, there is no question but that a husk-fired power system is impractical.

In order to enable the reader to better understand the details of some factors of husk-powered units, some selected installations are discussed below.

(1) The steam power plant at the SML mill at Wageningin, Surinam (W144) was as originally installed: two Kusters-Aken boilers (1956) with a Mannesman-Meer vertical steam engine driving a 570 kw generator. Pressure was 16 atm, temperature 300°C, and consumption 5.5 tons of steam per hour. The steam plant, built in 1958 with no water treatment, had major problems in 1959/61; in 1963, two water softeners were installed and changes were made in boiler systems. The unit then ran with no appreciable problems until 1971, when cracking of the steel plates of the boilers was experienced. A survey was conducted and decision was made to dismantle the old system and install a new one.

The old steam generator was used in conjunction with several diesel-driven generators to provide an overall plant capability of 3200 kw. The peak requirement of the complex today is 1780 kw, of which the new husk-fired turbine unit furnishes 67%. The present standby diesels are 2-500 kw and 2-450 kw, which barely allow peaking capability on

diesels alone but can be used in combination. In the original plans there were two other diesels of 350 kw each, because the husk-fired unit had less than half of the new installation capacity.

The new one has two Lambion furnaces; two Sillers & Jarmat boilers, 27 atm, 450°C, 5.5 tons/hr each, with a 5-stage Terry turbine, 1200 kw AEG generator. The new plant uses 3 tons of husk per hour to produce 11 tons of steam which generates 1200 kw.

The old plant had a much higher maintenance cost because it was non-condensing and therefore needed total makeup water; without the boiler feedwater treatment system, the result was poor. Ash removal was labour-intensive with very difficult working conditions; the new plant has an ash channel for water removal of the ash, which is dumped wet.

(2) The power plant at Tacurong (W134) was part of an overall Buhler - MIAG installation (25 ton/hr mill). The Spilling-furnished power plant equipment has two Lambion dual-mode grates, two Sillers & Jarmat boilers of 20,000 lb/hr each, with three Spilling 640 kw, 4 cyl steam motor-generator sets. These furnaces have a movable two-section grate. Of the electricity generated, about 800 kw are used on plant for mill operation and other plant functions, about 1,000 kw are sold commercially to the local community and 120 kw are available for reserve.

In the design of the plant, three engines were chosen in preference to one large turbine to secure flexibility, and later this proved to have been a wise choice since so far the plant has often operated spasmodically (sometimes at only 20% capacity) owing to lack of paddy.

The furnace performance here is good: it delivers a 25% ash residue, a burning efficiency of 92-93% and a boiler efficiency of 78%. The fuel consumption rate is a maximum of 2500 kg/hr per furnace, the excess-air ratio 1.7:1. For the husk developed within the mill, the cost was .12 peso (Philippines) per kw; outside fuel brought in, where transportation costs are borne by the mill, cost .22 peso/kw.

In order for this plant to be self-sufficient in paddy requirements, a growing area of 20,000 ha is needed. At the present (1975) the mill has only 200 ha of its own and has a surrounding 2800 ha furnishing paddy. The development of the surrounding farming land did not match the requirements of the mill--the shortfall was about 80%. Therefore, the economies of the mill and power plant have not been optimized.

The installation of the three generator sets with two boilers gives however good flexibility to the plant. When paddy is short, the milling operation can be run easily with one boiler and one engine, and the husk stored to provide longer hours of commercial supply, albeit at a lower kw level. Thus the power plant becomes a profit centre that can produce two periods of income for each period of mill operation. The original design also provided for a rice-bran oil-extraction plant, which has not yet been added.

(3) A traditional system installed in Robbio, Italy run from 1917 to 1970 (when the mill destroyed by fire, the power plant not being harmed), used two Babcock & Wilcox water-tube boilers, 17 atm, and a 750 CV Rateau turbine driving a Brown-Boveri 625 KVA (550 kw) generator. During its operational life, this plant ran smoothly and well. It had available 2 tons/hr of husk to produce the 550 kw; however, not all of the husk supply was used as a fuel, or it was burned in excess as a disposal technique.

Borasio writes that it used 1200-1300 kg per hour, which would indicate an efficiency comparable to, or a little better than, current power plants.

(4) The traditional Lokomobile type engine-boiler was manufactured by B.R. Wolf and also by Esterer. A typical one, at Tiruvarur in India (W69), furnishes 1100 kg/hr of steam with a 140 HP engine using a nominal 400-500 kg of husk per hour; according to Pingale (227) the husk burned is one fourth of that produced, but according to Ramalingam (181B) the 400 figure is nominal. The engine (140 HP) uses about 980 kg/hr of steam; the boiler has an estimated area of 1,000 ft^2, and is superheated. This engine also powers a 30 kw generator in addition to powering the mill. These engines had a load capability ranging widely; a normal 230 HP-rated engine could run continuously at 270 HP and would easily pull 325 HP for extended periods if necessary. They ranged from 25 HP to 430 HP (normal ratings).

(5) Lokomobile units are found in almost every country in the world--some very old, but still performing. They were built from about 1900 until the 1960s, when B.R. Wolf discontinued their production. In Asia many of these engines still operate. In Italy only two are known: one at the Campiverdi mill near Bologna and one at S.A.P.R.I. near Pavia (W96). These units were often used in back-pressure operation.

Schule says that in their situation normal rice-milling requires about 65-75% of the husk available when used in a Lokomobile-type system, with a stepped grate furnace.

According to Borasio (108):

100 kg of rice-milling capacity requires 5-6 HP
1 kg husk = 2.5-3 kg steam
1 HP = 4.5-5.2 kg steam.

Schule says 1 HP = 8-6.5 kg steam.

According to Spilling a Lokomobile has an overall efficiency of 17%.

Normally, such units do not use much over 300 psi because of safety restrictions on fire/smoke tube boilers.

(6) A projected Malaysia installation could take the following form: a 6 ton/hr mill (current LPN installation); installed: 800 HP total; actual requirements at various seasons: peak for drying and handling and milling: 550 HP; half-load drying and milling: 400 HP; milling with some handling: 280 HP; plus 40 HP for lighting and accessory use.

A practical solution seems to call for three units: a steam unit of 350 kw; a diesel unit of 250 kw; and a diesel unit of 50 kw. This combination would provide the lowest overall cost compatible with the feasibility needed. Such a combination would be economically feasible if 1974 fuel costs rose by 50%. The system was said to cost about $675,000, plus about $120,000 for the civil works. (Malinowski, W119).

It must be remembered that such an installation could only be considered at a location where mains power is not available because there is no power grid in the area of construction, or the present mains system does not have the capacity to accept the additional load (in that case it would be best to eliminate the 50 kw generator and service the lighting and small accessories from the mains), or where the design utilizes indigenous fuels in the national interest.

(7) Mention should be made of the use of husk-fired power plants in Thailand and the use of Thai plants in other countries. Most (95%, it is said) of the Thai rice mills are husk-powered, usually with a traditional (Lancashire-Cornish) boiler design and an engine patterned after English (Marshall) or French horizontal engines of 1900/1910 design. These engines and boilers are constructed locally (24 manufacturers in Bangkok alone), usually as an element of the mill construction programme, in individual shops (factories)

specializing in complete rice mills. In some cases the boilers are constructed spearately. Usually these are riveted boilers, heads hand-formed, with hand riveting and hand peening. Several mills in Malaysia have been constructed by Thai firms. One at Butterworth, completely manufactured in Thailand, has a capacity of 6 tons/hr.

(8) General comments. a) Ramalingam (181B) has shown that the running cost of a steam engine and boiler (under 10 HP) will be comparable to that of a diesel engine if the cost of fuel is below $4.20/ton, the 1975/76 figure would be $7.00/$8.00. In a country such as India it would be well, because of national interest, to use an indigenous fuel, even at a higher cost. Moreover, the small steam unit is labour-intensive, a factor that must be considered when calculating costs.

(b) Interesting is the knowledge that a 300-kw generator set run by a waste-heat boiler will provide about 2 million kwh/year; at 1 cent per kw this is equivalent to about $20,000/year.

(c) At the Tacurong plant the power plant represented 32% of the total plant cost; however, it must be remembered that only 31% of the power plant's capacity is used for operating the mill, the balance being used either for running other equipment or for commercial sale.

(d) In India the purchase of a new engine/boiler unit is sometimes not feasible from an economic standpoint or not possible because of political considerations. However, in India there is a goodly supply of used units capable of powering a 2 ton/hr paddy mill. A used 50 HP engine and a matching boiler can be found on the market at the reasonable price of about $14,000.

(e) The efficiency of husk in firing boilers is 35 to 40% that of coal. It must be remembered, however, that husk is almost always used in coal boilers with an external furnace added. The external furnace is almost always a step grate furnace, and the air flow requirements are probably not always matched properly for maximum overall efficiency. These installations are operated in a mode that results in an excess of husk for the assigned task, so efficiency is not thought of as being paramount.

(f) Hawkey (W159) has stated that in 1973-75 15 husk-fired power units were installed in the following countries: Nigeria, Liberia, Sierra Leone, Pakistan, Indonesia, Sri Lanka, Bangladesh, Malaysia, Nepal, Philippines, South Korea, Taiwan. These were in 2 to 5 ton/hr rice mills, and over half were lineshaft mills. It was not clear whether all were new or whether some were reinstallations. Another projected husk-fired power plant is a 5,000-kw unit for a 34 ton/hr (2 unit) rice mill to be built near Palembang, Sumatra. Its present status is indeterminate.

(g) A comprehensive study of the relation of costs incurred in the use of steam and diesel engines has been carried out by El-Mawla (175). Studies such as this, showing comparative values, and in fact any cost relation determination, must always be accepted under current conditions of fuel, investment and operation costs, to be of value in planning.

It was brought out in this study that the factors of availability and cost of qualified operators and the necessary spare parts are important when considering the various options available.

5.4.3 BRAN STABILIZATION

Rice bran stabilization concerns itself with methods to obtain better keeping qualities of freshly milled rice bran. Our interest is in methods utilizing a heat source to inhibit the FFA rise so that the bran can be stabilized at the receiving level.

Some methods of stabilization utilize dry heat, others a transfer medium, but in any case rice husk could easily and logically be used as the raw fuel of opportunity.

In some cases, where moisture is added, a simple method is to use direct application of the steam and then transport in a heated air stream; of course, husk is always used as the raw fuel.

Stabilization using husk as fuel is suitable where 20-40 satellite rice mills furnish stabilized bran to a central oil-extraction plant. The fueling of the stabilization systems at each mill, utilizing their in-house supplies of husk for fuel, would be simple, but there appears to be no commercial bran stabilization plant of this type.

5.4.4. PROCESS STEAM - FURFURAL

In the processing of rice husk for the extraction of furfural, it is common practice to use the residue as fuel or as supplemental fuel for the boilers furnishing the process steam.

The raw husk is used as the raw material, and the reactor residual is then used as fuel. It is in a wet form, so it must be burned in a furnace equipped with a grating system that will allow the use of the wet fuel.

After removal from the furnace the char/ash final residue is sometimes utilized commercially.

There is no furfural plant operating on rice husk that uses the heat-coupling principle to generate electricity as well. In some cases, the rice husk is charged into the reactors along with another available raw material and the residue is therefore a mixture. The mixture of furfural residues has particular properties, and in some uses exhibits better characteristics than either of the residues alone.

There is no general agreement on the equipment to be used in a wet-residue furnace/boiler system. Each of the few operators (four are known) of this type of plant has his own views on the best way to burn the wet fuel.

5.5. OTHER RELEVANT FACTORS

There are several areas of concern that must be considered whenever husk is used as a fuel.

5.5.1. CORROSION (See also Section 6.1.6.4.)

In all heat systems, care must be taken to accommodate the occurrence of corrosive condensation if in the discharge of the heat source the temperature is allowed to fall below the dew-point of the gas. In the practical sense it should not fall below 200°C at the entrance to the stack; otherwise corrosion will be heavy, and replacement of affected parts or the use of corrosion-resistant materials in the original installation will be required.

The loss of efficiency by use of a high stack temperature must be balanced against the maintenance cost of corrosion-related elements. This is particularly true when considering direct-fired dryers. In the dryer, of course, the discharge temperature must, by dilution or in some other way, be brought down to a low enough temperature for

proper drying of the product. Obviously, if this is below the dew-point of any conveyed moistures it will then invite corrosive problems. Therefore, in a dryer designed for continued operation the use of corrosion-resistant materials must be considered.

The problem in a direct-fired dryer is not of the same severity as in the stack of a boiler, because in a dryer the dilution of a quantity of ambient air to get the proper paddy-drying temperature reduces concentration to an acceptable level.

5.5.2. FLAVOUR PROBLEMS

Concern has been expressed regarding the flavour change in the rice grain when subjected to husk-fired direct drying. There are widely divergent opinions as to whether there is any flavour change, and if there is, whether it is a problem.

Some feel that if combustion is not complete in the furnace section there will be unburned gases due to gasification, but that if combustion is properly regulated there is no flavour problem.

At IIT-Kharagpur, when direct-fired paddy drying has been studied (179), the workers feel that there are no bad effects on the paddy.

Pingale (W60) feels that on small moisture reduction passes (2% more or less) there would be no problem. Only if a large moisture reduction (6-8%) was attempted would there be an odour.

Bhattacharya (W50) feels that one should not use direct heat on the intermediate drying of parboiled paddy because in parboiling the husk is split slightly, and the endosperm is therefore directly impinged. It is not clear whether direct drying is a good idea, but it is felt that until testing is performed it would be better to use indirect drying in parboiling.

At IRRI-UOP (W130) the husk-fired dryers developed have been of both types, and as yet no results either way have been noted.

Manalo noted in his work on husk-fired dryers (105-106) that the presence of flue gas in the drying air did <u>not</u> lower the quality of the milled rice appreciably. It is unclear, however, whether the quality was considered to be milling yield, etc., or whether it also included a definitive appraisal of taste and odour ramifications.

In the thesis by Acasio (100) quality is mentioned as a function of the completeness of the burning of the husk. Again the meaning of the word "quality" is unclear.

5.5.3. EFFICIENCY CONSIDERATIONS

Usually the lack of definitive specifications on furnace design has been of no concern to the classic designer and builder of steam power units for the operation of rice mills. In fact, the realities of the situation encourage inefficiency. In most areas the resulting char from the boiler is easier to dispose of, and occasionally sell, than the raw husk, so the operator is only interested in an efficiency capable of producing enough steam to operate the mill. If he had a more efficient unit he would then have a husk disposal problem for the unused portion of his husk production. In the case of a parboiling operation, the classic situation is such that the miller has sufficient husk available to perform two of the three essential functions. Where yard (sun) drying is practical, there is only need for two functions; however, where multiple-cropping or

weather patterns require mechanical (artifical) drying for the wet parboiled rice, the normal practice is to use the steam produced for two of the functions, and outside energy for the third. In drying in a parboiling operation, it would be beneficial to use a highly efficient system and perform all three functions. The year-round use of the dryer makes the capital cost of the system more reasonable than when husk-produced energy for a raw rice dryer is only used during the harvest. However, in some cases it is necessary to dry the wet-season harvest artificially, so that the cost of a husk-energy related system may not be possible or practical.

5.5.4. DISCONTINUOUS OPERATION

It is a fact that small plants, particularly in the Far East and Africa, must operate discontinuously. The farmer or trader brings in paddy, and the miller operating receives toll in cash or kind. Therefore, the miller must be ready to start at any time. His operation is determined not only by the size of the mill but the method of milling operation. Many multi-stage mills operate on a discontinuous basis. Electric power involves only pressing a button. A steam- or gas-powered operation is of course awkward and inconvenient as compared to mains electric service. Always, when contemplating a husk-fueled installation, consideration must be given to the value of convenience and effortlessness on the part of the ultimate operator.

Chapter 6:

EQUIPMENT AND MACHINERY TO CONVERT RICE HUSK TO ENERGY AND FOR OTHER RELATED FUNCTIONS

6.0 INTRODUCTION

The equipment necessary for commercial installation for conversion of husk to energy is, in general terms, available to the purchaser-user. In some instances a specific item is difficult to find, or the choice is limited for several reasons; the difficulties created by language differences and the resultant lack of information transfer, and the lack of a coordinated comprehensive worldwide "buyers' service". There are a number of national or regional publications that do an admirable job, considering the enormity of the task, but it is often said that nowhere in the world is a certain machine being commercially produced, when in reality there may be many manufacturers of that particular machine in many countries. Admittedly, the choice in the marketplace is sometimes limited, but this is due usually to the fact that the suppliers are not aware of a need by users. Every supplier will build machinery, within his capabilities of manufacture, of whatever type his customers request.

Most of the equipment involving rice-husk utilization has been commercially produced earlier, and only went out of production owing to the advent of alternatives where were cheaper or more convenient in operation or acquisition, or when the consuming industry so changed its pattern of use that certain technologies were rendered obsolete.

It is interesting to observe the effect of changing economic levels of energy cost and availability on the manufacture of equipment. The 1880s saw the formal advent of rice-husk fired furnaces; a 1910 sales catalogue lists and pictures a complete line of boilers, steam engines, gas producers, and gas and oil engines, indicating that at the end of the 19th century development had been fast; steam-powered mills were dominant in South America by 1915, and apparently by 1925 the change to steam power for commercial mills was made complete by the introduction earlier of the Lokomobile-type unit and its relatively high efficiency. But the lower and lower costs of electricity, gas and oil, and the establishment of effective distribution grids dictated the changeover to individual unit drives and the configuration of the "modern" mill as it is known today. This change spelled the demise of the large-scale manufacture of steam and gas motive power equipment and the diminishing use of husk-fired steam systems for process steam.

The current trends in prices and availability of these alternative fuels have dictated a serious reassessment of the possibility of the manufacture, distribution and utilization of equipment using husk energy.

The following discussions of individual types of equipment and the reference list of manufacturers and interested workers should show widespread availability of equipment and give some idea of the types available. Obviously they do not include all usable equipment or all manufacturers. The inclusion or lack of inclusion does not in any way indicate anything more than information or lack of information, and does not constitute a recommendation or lack of recommendation for any manufacturer or type of processor equipment. Again, it is primarily a matter of communication.

6.1 STEAM RAISING

6.1.1. BOILER EFFICIENCY

$$\frac{\text{Heat in water (steam)} \times 100}{\text{Heat in fuel}} = \text{boiler efficiency (\%)}$$

The gases from fuel combustion cannot be cooled to air temperature in the boiler room, and therefore all the heat which is realized by the combustion of the fuel cannot be transferred to the water in the boiler. The efficiency of a boiler is therefore always less than 100%; in a super power station, efficiencies of over 90% have been recorded; 80% is not uncommon in well-operated plants; but in ordinary industrial practice, an average efficiency of 60% is probably not far from the mark, and many boiler plants must fall below even this low standard.

The chief loss is almost invariably the heat carried away in the waste gases. The efficiency of a boiler depends on: i) the design of the plant; ii) the conditions under which it operates (other things being equal, the more constant the load the higher the efficiency); iii) the correct selection of the fuel; and iv) the skill and care expended in maintaining and running the plant.

The conditions under which steam is raised vary greatly; the pressure may be from a few pounds above that of the atmosphere to the critical pressure (3,200 lb/in^2), while the output per hour from a single boiler may be from a few hundred to a million pounds or more. The load may be relatively constant, as in base-load stations for the generation of electricity, or it may vary rapidly over a wide range. In view of this diversity of conditions, the number of types of boiler is very great, but all embody a furnace and a vessel, the boiler proper, which contains the water; the heat of combustion of the fuel is transmitted through the heating surface which forms the partition separating the hot gases from the water. Whatever the pressure and output of steam and whatever the design of the plant, the fundamental principles of its efficient operation are the same.

Straight power generation brings overall efficiency down to about 20%. It can therefore be said that practically, steam should be made from husk only when process steam is required; it would be better to find other ways to utilize energy from husk if electrical or mechanical energy is needed and there is no utilization of the exhaust steam.

However, if process steam is used, the most efficient approach is a combination of power generation and subsequent process use. It should be borne in mind that a husk-fired boiler costs 2 or 2-1/2 times the comparable gas- or oil-fired boiler of equal capacity, for several reasons: the need for an external furnace of large size and considerable use of expensive refractory materials; the generally lower exchange ratio, leading to lower furnace temperatures and gas temperatures when using a passive husk firing system; and the system additions required for collecting the residue and removing particulate matter in the stack gas.

This is not necessarily true when using a turbulent-flow air-suspended furnace, in which a water-tube boiler or a waste-heat boiler design can be incorporated, as in the Pitt-designed (151A) Stuttgart plant.

Comparative figures (Gariboldi) show that a husk-fired boiler will produce 15-18 kg steam/m^2 of surface against 40-42 for an oil- or gas fired one. The ratios are about proportional to the comparative BTU values.

The requirement for an efficient boiler must be considered jointly with the need for husk disposal. For example, the ratio of steam output to husk raw fuel infeed for boilers of various efficiencies (see Table 21) is sometimes shown as calculated by engineers of Greaves Cotton (W77), differently from actual tests (see Section 6.1.3.1.).

Table 21

Steam/husk ratios as a function of boiler efficiency

Efficiency of Boiler/Furnace (%)	Steam/Husk Ratio
50	2.83
55	3.12
60	3.40
65	3.68
70	3.97
75	4.26
80	4.54
85	4.83

Where the maximum output of steam is needed, it is obvious that a most efficient boiler/furnace combination is capable of giving the desired results. Most of the installations using husk for fuel for steam generation are operating at less than the 50% level, either because of inefficient design and construction (Mandya, India) or because of the deterioration of the capability of a good design and well manufactured plant (Chavalakade, Sri Lanka).

6.1.2. TYPES OF BOILERS

Boilers may be conveniently divided into: i) internally-fired, in which the furnace is an integral part of the boiler itself, its dimensions being restricted by the fact that it must be accommodated within the structure of the boiler. These include small vertical, Lancashire, Cornish, locomotive, economic, Scotch marine, and combustion-type boilers; ii) externally-fired, in which the design of the furnace is more or less independent of the design of the boiler proper.

There is a great deal of confusion and overlapping of terms concerning some types of boilers and their firing system. Three basic types exist: smoke-tube, fire-tube, and combustion-tube. A smoke- or fire-tube boiler would be a combustion-tube type if the fuel entered the tube section in a partially or totally unburned condition.

In a smoke-tube boiler, all combustion is completed within the furnace or the under-tank area wherein a shell boiling design is used. The gas analysis should be stabilized before its entrance into the tubes. There is no ash beyond the furnace curtain wall except for entrained particulate.

In a fire-tube, some burning of gases occurs within the tube area, but all the fuel is converted to gas before entering the tube. This includes boilers of the external furnace type or the Lancashire type, but applies in particular to one with a more aggressive gas-flow pattern, as in the smoke-tube: no ash beyond the furnace.

Table 22

TYPES OF BOILERS — CHARACTERISTICS

	VERTICAL CROSS TUBE	CORNISH LANCASHIRE	SUPER LANCASHIRE LOCOMOTIVE SCOTCH MARINE	WATERTUBE
Working pressure	Up to about 120 lb. per sq. in.	Up to a maximum of about 200 lb. per sq. in. 120 to 160 lb. more usual.	Up to 250 lb. per sq. in. Super-Lancashire up to 300 lb. per sq. in.	Up to 1,100 per lb. sq. in.
Steaming capacity	Up to about 5,000 lb. per hour	A 9 ft. 3 in. Lancashire boiler will evaporate about 9,500 lb. per hour.	From 6,000 to 25,000 lb. per hour.	From as low as 400 to as high as 500,000 lb. per hour, or even more.
Setting	Self-contained; no brickwork setting required.	Brickwork setting necessary.	Self-contained; no brickwork setting is necessary.	Boiler suspended from steel girders, with brickwork built between them.
Furnace arrangements	Integral with the boiler	Dimensions rigidly controlled by the dimensions of the boiler shell, unless an external Dutch oven type of furnace is installed.	These boilers being internally fired are subject to the same limitations as Cornish and Lancashire boilers.	The furnace may be designed to suit the fuel; its dimensions are not controlled by the design of the heating surfaces.
Methods of firing	May be fired by hand or mechanically	Lends itself well to hand-firing.	May be fired by hand or mechanically.	Cannot be successfully fired by hand if steam output exceeds 14,000 lb. per hour. Mechanical firing is generally more efficient than hand-firing.
Rate of raising steam	Quicker than in Cornish and Lancashire boilers	On accounts of the great heat capacity of the setting and the large amount of water in the boiler, raising steam from cold is slow.	Quicker than in simple cylindrical boilers.	Since the water capacity is small and there is no heavy brick setting, rate of steam-raising is high.
Reserve of water in boiler		In Lancashire boilers, equal to about 5 hours' steaming.	Less than in Cornish and Lancashire boilers. Probably equal to 3 to 4 hours' steaming.	Equal to from 2 to 3 hours' steaming.
Superheat		Superheaters may be fitted to give 200°F. (or higher) superheat.	Super heaters may be fitted to give any required degree of superheat.	Superheaters may be fitted either in the radiant or the convection portions of the heating elements.
Economizer		Should always be fitted. Cast-iron economizers may be used up to 200 lb. per sq. in.	The extra heating surface provided by the tubular disposition of the heating surface may render the installation of an economizer unnecessary.	May or may not be fitted. In the larger sizes of boiler, economizers are usually integral with and superposed on the boiler.
Floor-space occupied	Relatively little	For a given output of steam a cylindrical boiler occupies more ground space than a water-tube-boiler and the discrepancy increases as the output (and therefore the number of cylindrical boilers) increases and is still greater if economizers are installed.	Less than for Lancashire of Cornish boiler of equal capacity.	Less than for equivalent cylindrical boiler, particularly in large plants and where economizers are installed.
Wear and tear, cost of maintenance		Relatively low. These boilers have been known to last 50 years; a life of 20 years is common.	Since the boiler is more complicated than the simple cylindrical boiler, unless skilled attention is provided, the cost of upkeep and liability to breakdown are higher.	Careful and skilled attention are necessary, otherwise the liability to breakdown will rise; maintenance costs may then become high.
Skilled attention	Always desirable, but its absence is of less moment in these, the simpler types of boiler plant.			
Feed-water purification		Although desirable, feed-water purification need not be carried as far as with tubular boilers. Moderate scale is less detrimental than in water-tube boilers.	Feed-water should always be treated; moderate scale has serious effects on the wear and tear of the boilers.	
Efficiency		Unless an economizer is installed, the efficiency is generally less than with tubular boilers.	Higher than with simple cylindrical boilers.	

Efficiency depends not only the design of the plant but also to a great extent on the care and attention it receives, the methods of control adopted, the quality of the feed water, and the variation in the demand for steam.

*Fire-tube boilers include also locomotive and Scotch marine boilers. Although the latter were at one time popular for steam-raising on land, they are now seldom installed.

In a combustion-tube boiler some or all of the vapourization and/or conversion occurs within the tube lengths. This is the type of boiler (see Figure) which has no or limited furnace volume or in which not all of the combustion occurs in the combustion chamber. There is an overlapping area of these types--the important aspects are the type of furnace, the ash-removal system, and their effect on the distribution of fuel and ash. The most efficient combination (both output and original cost) is always a matched furnace and boiler design, wherein the boiler tubes and gas flow are matched to the desired performance of the furnace. While it is true that almost any combination will produce some steam, it can be expected that improper matching will create problems in both operating and maintenance costs. By definition, this design would require char/ash collection after the boiler, either in the stack base or in a cyclonic-negative pressure system. Boilers of this type include those with pressure fuel injection into an air-free pre chamber or directly into the internal firing chamber.

The Lancashire boiler consists of a horizontal cylindrical shell with flat or dished ends provided with two internal furnace-flues. The boiler is installed in a brickwork setting arranged so that the hot gases on leaving the rear end of the furnace-flues pass to the front end of the boiler by way of the sole-flue, to the back of the boiler via the two side-flues and by way of the main-flue to the chimney. Cornish boilers are smaller and have a single furnace-flue.

Lancashire and Cornish boilers contain a large volume of water compared with their output of steam (5 1/2 to 6 hours' supply) and can therefore respond rapidly to sudden demands for steam; this is one of the reasons for their popularity in industry. They are simple in design and, within limits, will stand up to a good deal of ill-usage. The large water capacity carries with it the disadvantage that to bring the boiler on load from cold requires several hours.

In the Super-Lancashire Boiler and variations of fire-tube (smoke-tube) boilers, the heating surface is increased by introducing a number of longitudinal tubes through the water-space below the furnace-flues in the boiler. There is thus no sole-flue; the gases from the rear of the furnace pass to the front end of the boiler via tubes at high velocity, so that the rate of transfer of heat is increased. The side-flues are dispensed with and the waste gases travel back to the rear of the boiler through tubes around the outside of which the primary air for combustion is passed. In consequence of the increased heating surface, time is shorter for a given output of steam, and pressures up to 300 lb/in^2 may be carried. The Super-Lancashire Boiler is self-contained and requires no bulky brickwork setting, so that it occupies less space than a Lancashire boiler of equal evaporative capacity.

When the fire-tube (smoke-tube) boiler is equipped with an external furnace, this is usually a shell boiling type with the furnace heat just meeting the bottom shell of the tank and then passing through the tubes in one, two or three passes. The earliest designs were simple horizontal-return tubular boilers, with shell boiling and a single return pass through tubes. The Scotch-type boiler had an internally-fired large tube with small return tubes above. Later types were a combination, as in Figure 12, and then a modern multi-pass design as in Figure 13.

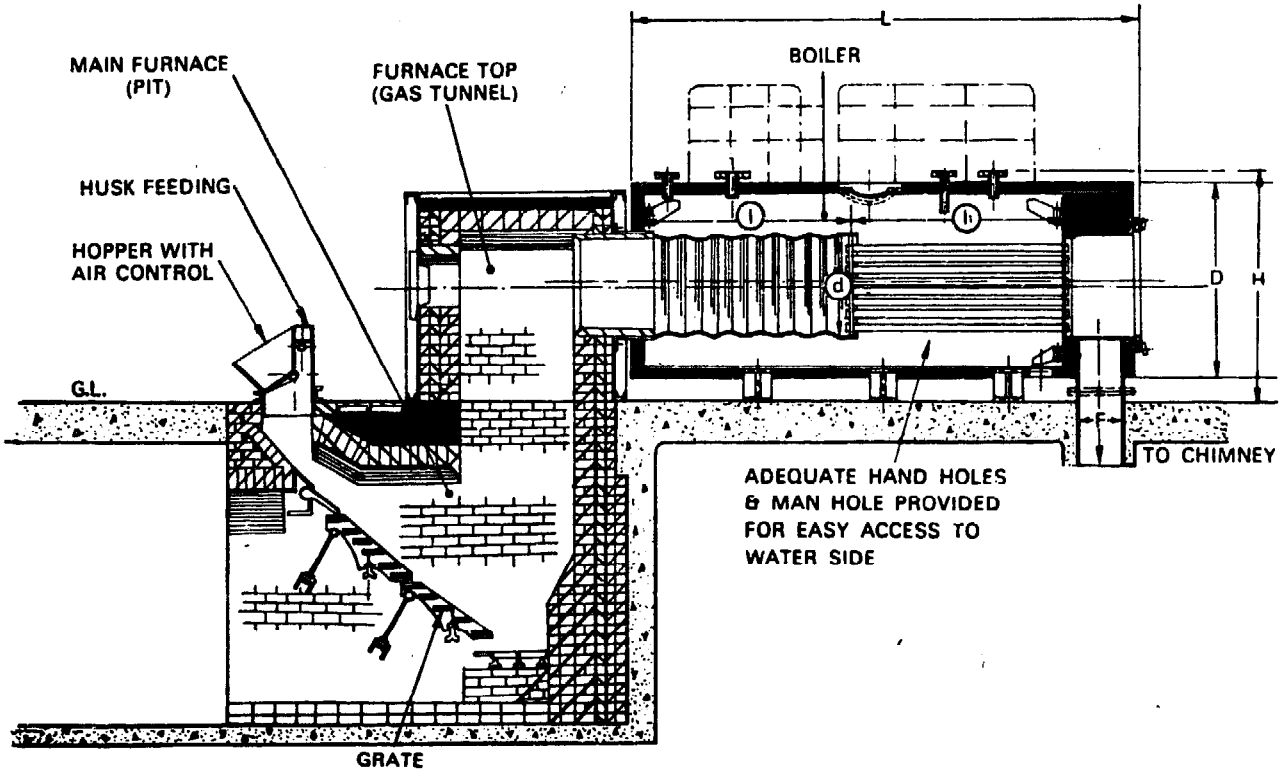

Figure 12
A currently-offered boiler design, patterned after a traditional "Locomobile" design (under- floor furnace installation)

Vertical boilers. For outputs of steam up to about 5,000 lb/hr and for pressures up to 120 lb/in^2, vertical boilers are frequently employed. They are completely self-contained and require very little preparation of the ground on which they are to stand, beyond levelling. Of the many types which are available, one only is illustrated: the Cochran fire-tube boiler (see Figure 13).

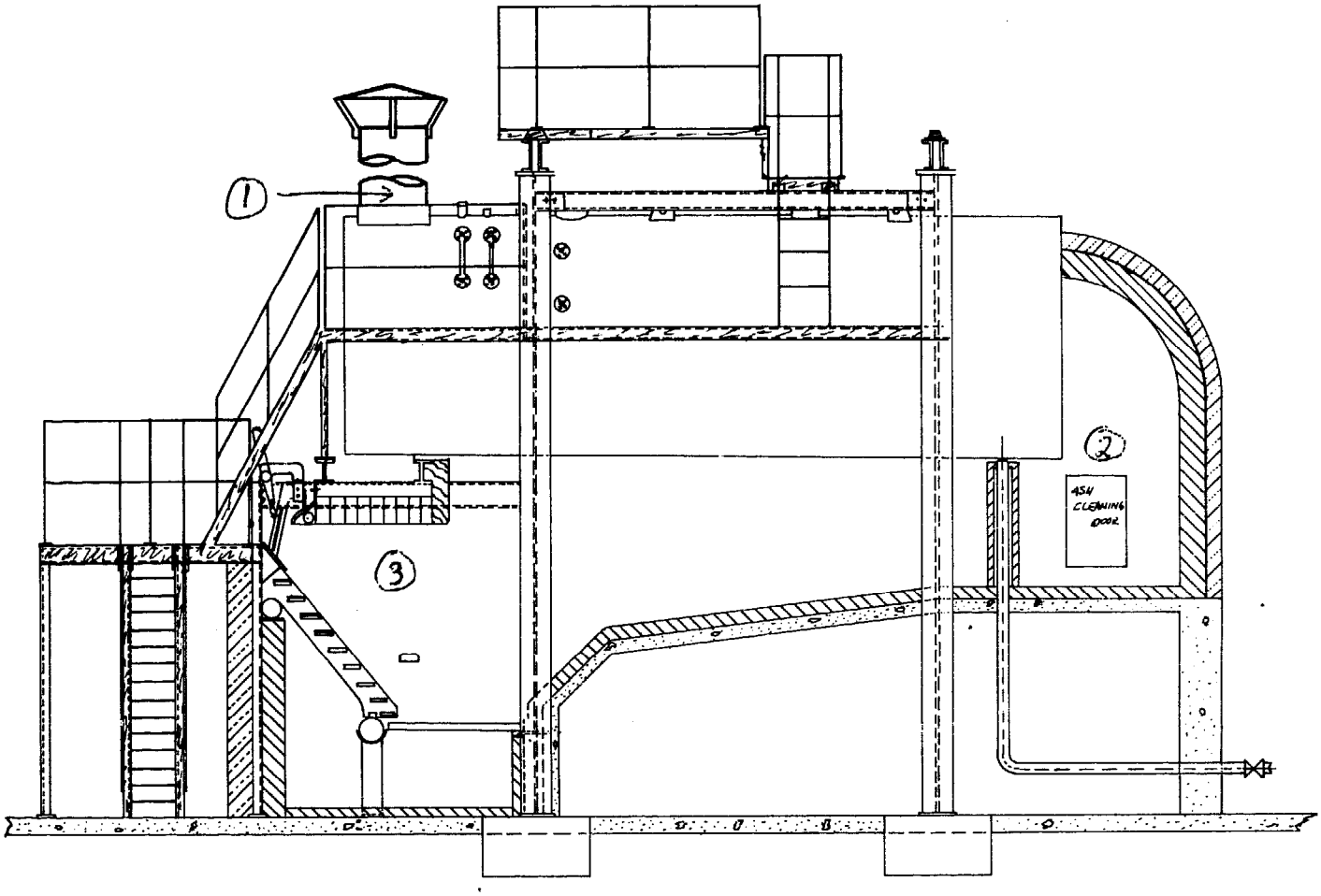

Figure 13
A shell boiling multi-pass design (Above-floor installation)

Water-tube boilers. While internally-fired boilers are available in capacities up to 25,000 lb steam/hr and for pressures up to 300 lb/in^2 according to the type of boiler and the quality of the workmanship, where larger outputs of steam are required from a single unit, or where higher pressures must be carried, water-tube boilers are universally employed. These boilers are fired externally; therefore, the shape and dimensions of the combustion chamber are practically independent of the steam-raising unit proper and great flexibility in design is possible.

Designs include four-drum, two-drum and single-drum, cross-drum, long-drum, integral furnace, Stirling open-pass and radiant. Because of erosion problems when using husk as fuel, it is best to use a single-pass two-drum boiler with low gas velocities.

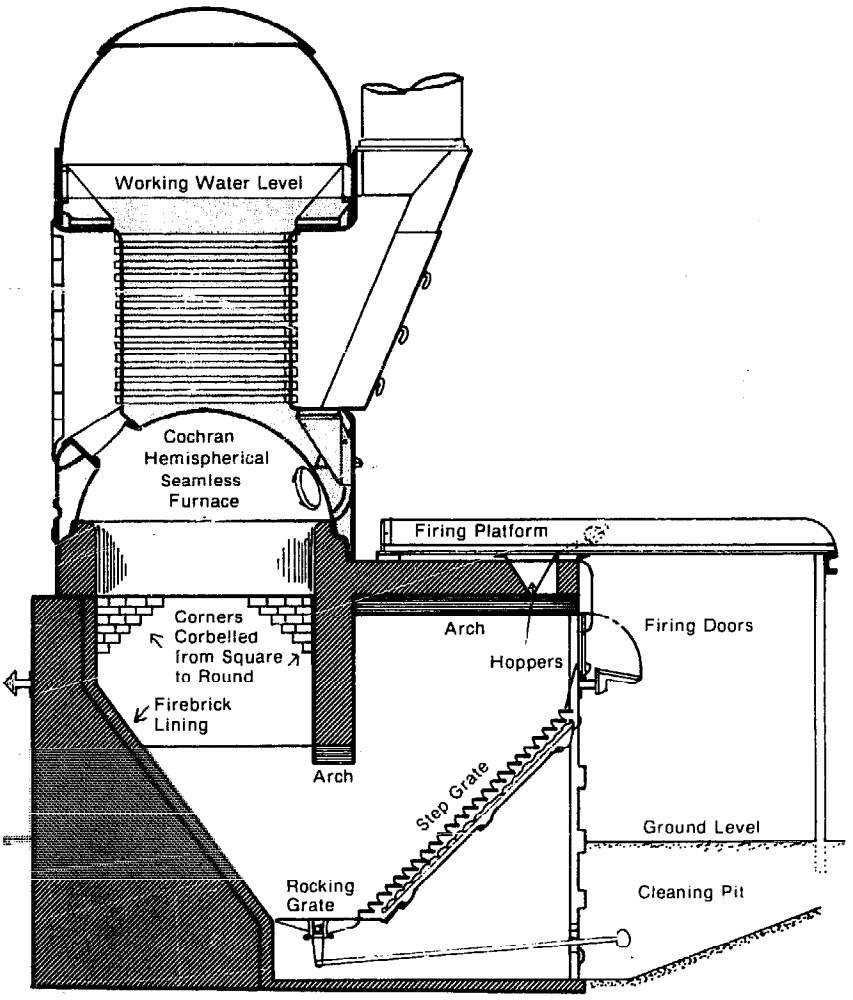

Figure 14
The Cochrane fire-tube boiler

Ample cavities must be provided in the unit for the placement of retractable soot blowers to keep the surfaces clean. Designs must be conservative to provide for this service.

The combustion-tube smoke-tube arrangement varies according to the manufacturer's preference. There seems to be no accepted "best" arrangement. In surveying a small percentage of all boiler manufacturers, no agreement or common arrangement of the components was found. Each manufacturer tries to make the best and most competitive product that he can, particularly in three-pass boilers. Every conceivable configuration exists. Water-tube boilers also vary. The only one of somewhat common construction is the vertical cross-tube.

A waste-heat boiler can be installed downstream of any external furnace, either a passive grate system or a turbulent air-suspended (cyclonic) furnace. Waste-heat boilers are in essence gas/water heat exchangers with provision made to extract the steam produced. Waste-heat boilers can be of both smoke-tube and water-tube types. There are no definite design configurations. They can be adapted to any set of circumstances.

Multi-fuel boilers. There are many possible configurations of a multi-fuel boiler. The one shown in Figure 15 can accommodate three forms of fuel: gas/oil with the furnace at the right end; wood, blocks, coal on the conventional internal grate on the left end; and pulverized fuel, such as husk, through the pneumatic injection system from the top. This is a three-pass unit, primarily for low-pressure operation, but the fuel feeding systems could be adapted easily to intermediate-pressure units.

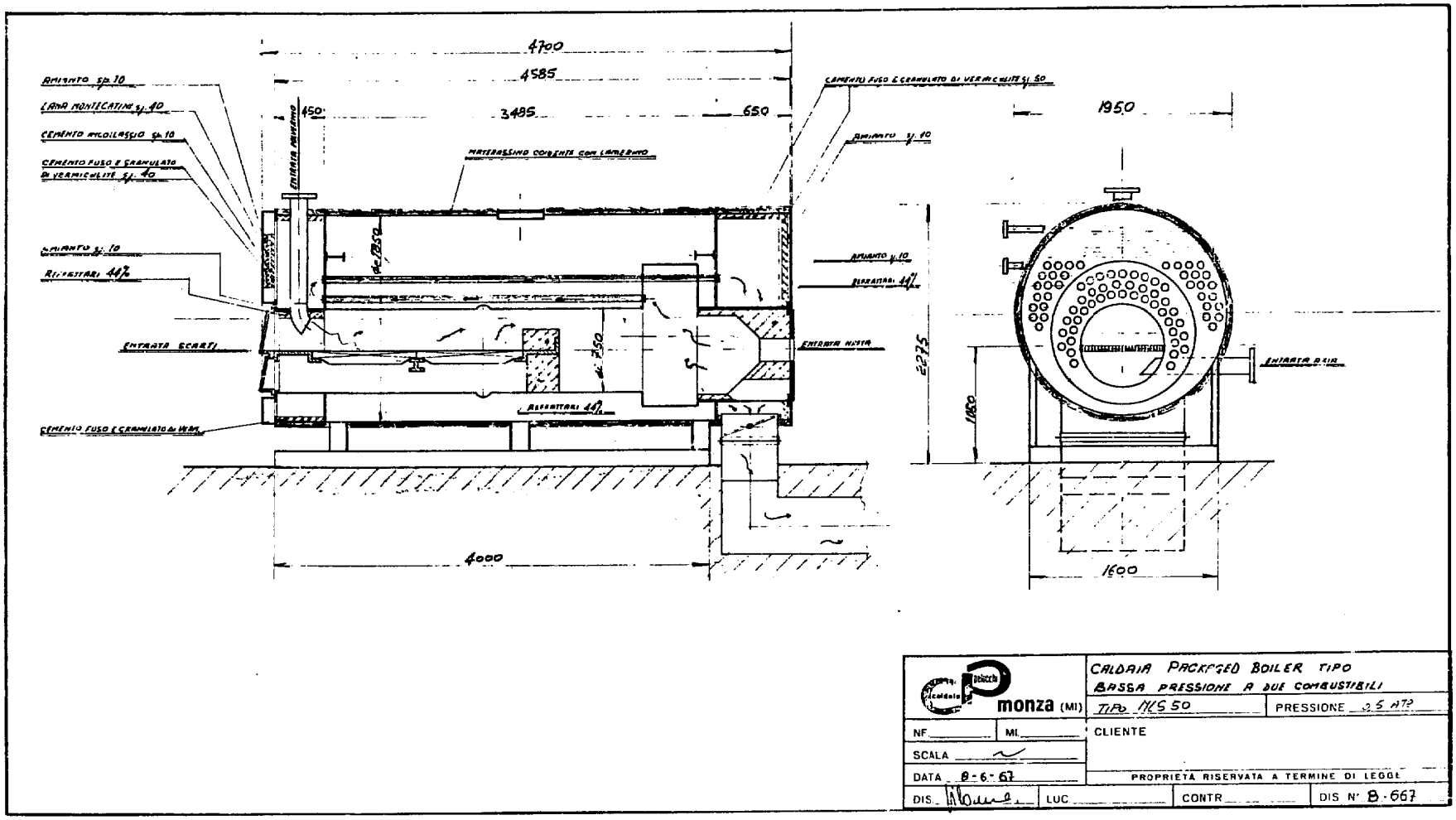

Figure 15
A multi-fuel boiler

6.1.3. DESIGN DETAIL

The U.K. Ministry of Fuel's Fuel Efficiency Bulletin No. 37 states that "the small vertical cross-tube boiler is probably the most inefficient steam raising unit employed today." This boiler is cheap and simple, but it has a low production of steam for a given size because of its low reaction-water surface.

Husk-fired units are generally more successful in boilers that have greater volumes of water, which help to take up the variation in fuel characteristics. This type of boiler can be used only below 30 atm (400 psi) working pressure; above that pressure it is advisable to use a water-tube unit.

Dry-back boiler. In the smaller multi-pass units it has been found that the greater accessibility for maintenance and cleaning in the dry back more than offsets the gains from having a wet back. Therefore, normally boilers up to and including 160 HP are constructed on the dry-back principle.

Wet-back boiler. Experience has shown that a point is reached where benefits can be obtained by changing from dry-back to wet-back construction, as refractory walls become more sensitive as they increase in size. Boilers above 160 HP are therefore normally made in wet-back construction.

Temperature considerations. Assuming 60-75% excess air, the following spot temperatures have been estimated, using rice husk as fuel, at the points shown in Figure 12:

Temperature point	Jaya	Greaves
(1)	650°F	300°C
(2)	1200°F	900°C
(3)		1150°C

6.1.3.1. Performance and characteristics of typical husk-fired units: Published performance figures of a vertical cross-tube boiler and of a multi-pass fire-tube boiler appear in Tables 23 and 24 respectively.

Table 23

Performance of a vertical cross-tube boiler

Evaporation capacity at 100°C (kg/hr)	Heating surface (m^2)	Grate area (m^2)	Husk consumption (kg/hr)	Empty boiler weight (tonnes)
282	9	0.71	150	6
470	15	1.04	230	7.5
785	23.5	1.50	380	9
1255	36	2.00	610	11
1725	50	2.54	850	12

Evaporation Capacity from at 100°C kg/hr	Heating Surface m^2	Grate Area m^2	Husk Consumption kg/hr	Empty Weights Boiler Tonnes	Empty Weights Furnace Grate Hoppers Tonnes
500	19	1	200	6	3
750	38	1.5	300	8	3
1000	55	2	400	10	3
1500	75	3	600	12	3.5
2000	100	4	800	14	3.5
2500	125	5	1000	16	4

Table 24

Performance of a multi-pass fire tube boiler

In an actual test of a modern multi-pass, mechanically drafted, combustion-tube boiler (1974), a nominal 1500 kg/hr steam rated boiler producing 1200 kg/hr had a fuel rate of 333 kg/hr of husk, a 75% efficiency at full output, with an effective husk/steam ratio of 3.66 kg steam/kg husk. The vacuum at the stack entrance was 70 mm water, and at the firing area 6 mm water. The stack temperature was 238°C. Steam produced at 6.6 kg/m^2 was at 167.5°C, and the actual evaporative capability was 15.7 kg steam/m^2 of surface.

A boiler properly installed can be operated at 200% of rated capacity for extended periods. However, the problem is not the boiler, but rather the furnace. To get the required heat release to produce the overload boiler transfer is another matter.

Passive grates will normally provide 8.5-10 boiler HP per square foot of grate area. It is very difficult to double this figure, particularly with a fuel such as rice husk, because of the physical limitations of the feed rate and the ash-handling system.

Usually the boiler manufacturer specifies the performance of the boiler at 100°C, but in most practical operations somewhat less than that is fed, often at an ambient level. Performances are reduced accordingly. Figure 16 shows dramatically the derating due to low feedwater temperatures.

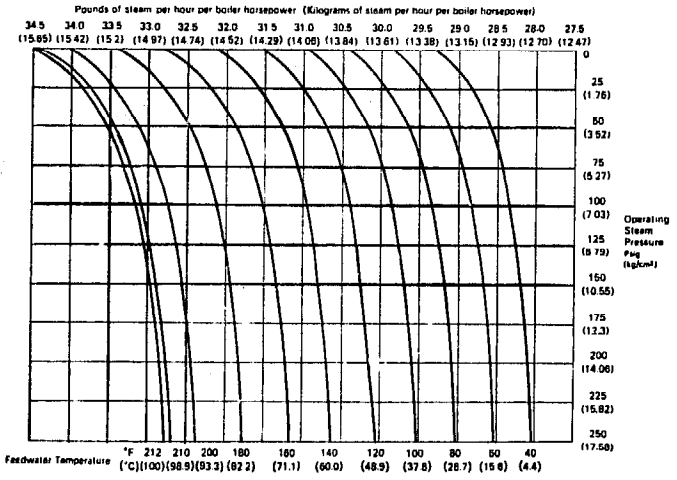

Figure 16

Steam output and pressure as functions of feedwater temperature

6.1.3.2. Efficiency requirement. Sophisticated installations will, of course, include an economizer and possibly an air heater, both of which increase the efficiency of the overall installation. In many husk-fired installations the efficiency of the system is of no great concern, because there is adequate husk to use as fuel to provide what steam is necessary for steeping and steaming for parboiling. Most rice-husk fired installations can be said to be low-technology units, and the losses are taken as a matter of course.

6.1.3.3. Water treatment. For good boiler performance and long life, with low maintenance, a sophisticated water-treatment plant is mandatory. Regenerative, cationic treatment systems are usually required. The necessary chemicals are not always available, and of course this requirement adds to the original cost and the operating costs. Where the steam is solely for process use, there is obviously no reuse of condensed makeup water, and a simple, easy to clean, cheap boiler is the most economic solution.

For power-generation units, pressures and temperatures are usually higher, and the use of non-condensing engines creates many problems. For example, the SML plant in Surinam operated seven years as a non-condensing plant with no feedwater treatment, and its performance record was poor. After the installation of a treatment plant, performance improved noticeably.

6.1.3.4. Automatic operation. In fully automatic boiler operation using husk as the primary fuel, it is necessary to use a small amount of oil/gas as pilot fuel, and to ensure constant capability the boiler should be equipped for full-capacity dual-fuel operation. With this equipment a number of combinations are possible:

Programme 1. Ignition flame oil with husk injection. With this fully automatic programme, the oilburner starts, and after a short interval the husk injection comes in. When the husk is ignited and a sufficient firing temperature is reached, the oil burner is shut off, and only the husk injection and possibly the oil burner ventilator remain on. Should the temperature in the combustion chamber fall below the safety ignition temperature, a thermostat shuts off the feeding system and injection blower.

Programme 2. Husk injection and oil burner. This fully automatic programme is used only for peak demand. Oil burner and husk injection are both running with permanent ignition.

Programme 3. Oil burner alone. This fully automatic programme is used when no husk is available. The oil burner has to supply the full load demand.

Programme 4. Husk injection alone. In this programme the boiler-room operator has to start the base fire before the husk injection can be started. The following sequence is much as in Programme 1. The combustion-chamber thermostat acts as an injection safety, and the grate fire is self-sustained for full boiler capacity.

6.1.3.5. Miscellaneous:

India - The Government of India has sponsored work to develop a 5 HP vertical boiler and a matching steam engine/water pump for farm pumping chores, utilizing as fuel indigenous production, either a residue product (such as husk) or a specifically grown wood or straw material. A cost of about 15,000 Rs ($2,100) is envisaged for the complete package. The development units have been built.

Ricardo - In the 1950s the Government of the United Kingdom (NRDC) sponsored work on a small boiler/engine designed by Ricardo (185). A number of units were built and tested under varying conditions and locations. The system did not attract further commercial interest at that time. It is possible that under today's economic conditions a reappraisal of this engine development should be undertaken.

Mini-boiler - Many manufacturers in India are manufacturing a low-cost, small, "mini-boiler", usually for parboiling or other operations requiring a small amount of steam. These boilers are under the legal size (5 gal holding capacity at 50 lb/in^2). They are especially popular in southern India for continuous parboiling operations.

A small water-tube boiler could be constructed locally in India - 26 atm at 450°C is practical. Its cost would be 2-3 times that of a fire-tube boiler, but the higher the temperature and the pressure, the higher the efficiency. On the other hand, it is not always necessary to be highly efficient, but only to do the job.

An Italian 2500 lb/hr steam boiler, complete with all accessories, was quoted in 1975 at about $86,000, including all brick, water treatment systems, feedwater systems, stack, char collection and handling machinery and bins. It was said that this cost could be amortized in about 1.5 years on fuel savings alone.

6.1.4. CONSTRUCTION AND MAINTENANCE DETAIL

One concern prevalent is the wear of the inner surface and entrance curve of the tubes of combustion-tube boilers. In this type of boiler all the fuel and all the residue pass through all the tubes. In inspecting a boiler of this type with 70 mm diameter tubes, 6 mm walls on 110 mm centre line, no wear was discernable. This installation was six years old and is inspected once a year; there never has been a noticeable wearing of the entrance curve of the tube. In this boiler all combustion occurs in the fire tubes. There is no effective furnace volume.

In the Buckau R. Wolf boilers the tube diameter was 120 mm, and the velocity was low enough so that no particulate matter was maintained in suspension. The step-grate furnace had a maximum air-flow velocity of 1 m/sec, and this did not entrain any appreciable material in the gas stream through the boiler. In the Gariboldi design there is a minimum of 3.5 m/sec, ensuring sufficient velocity to obviate any need for cleaning the tube sections.

Traditionally, F.H. Schule would never recommend a 3-pass boiler because of the many troubles with ash buildup in the fire tubes. Improved design eliminated this problem, and for the past 15 years Schule has recommended 3-pass boilers, either on a negative-pressure system or with blower-steam soot ejectors.

It has been said several times that one reason why western-designed boilers are not popular in South Asian installations is that welded-end boilers are difficult to clean and require sophisticated water-treatment practices. This is not necessarily true. It over-simplifies the comparative features and costs of two types of boilers.

Several boiler factories were visited in Bangkok. The Huay (W148) factory builds boilers to match the size of the engines acting as prime movers for Thai-built rice mills. They are Cornish type, requiring one month to complete. They are hand riveted and peened, the ends being forged by hand. All work is done by hand on the premises, the raw material being Japanese steel in sheets 16 x 1524 x 6096 mm. The 5' x 20' boiler costs about $9,000. In Thailand it is said that 95% of the rice mills are steam-powered, utilizing their husk as fuel. This practice has been of long standing in southeast Asia; many Lokomobile units were furnished to these countries, and in the late 1800s and early 1900s great utilization was made of husk-fired power units in the whole area. Even as late as 1940 it was common

practice for new Asian rice mills to be powered in this way, and until the advent of individ ually driven machinery there was hardly any question of the configuration of the mill.

In Milan, a parboiling mill, with steam produced by a husk-fired primary oil-fire supplemental boiler system, uses the steam for all process work and for heating all buildings in the area. Oil firing is utilized if the mill is not running and the husk supply is depleted, or if the raw husk has a greater value when sold commercially. This system utilizes a reduced-area grate with a capacity ensuring that sufficient combustion occurs before conveying begins, so that entrance temperatures are not raised too high. Continued burning takes place in the central (Lancashire type) tube and continued combustion in the second and third passes. All residues are collected in the cyclonic collector, and none go through the fan that provides both the combustion and conveying gas. Because of the necessity for additional protection against air pollution, a secondary collector or filter or scrubber is fitted to the fan discharge.

In India, Jaya (W78) and Westerworks (W87) have built many husk-fired boilers for use in India. These include packaged and bricked units with single and three-pass boilers, with a variety of furnace location options.

At Kollegal, India, a mill with a small (99 sq ft) vertical cross tube (VCT) boiler, furnishing steam for parboiling, was visited. This unit had been installed new, eight years before and had operated without problems. A 57 ft^2 boiler, (VCT), 3.5' diameter and 8.0' tall, used husk as a fuel to produce steam for a tyre recapper. The step grate was inclined at 45° with an arc of 2.5' x 5.8' or 14.5 ft^2.

At Coimbatore, India, a two-pass smoke-tube boiler was built for an FAO project in Sri Lanka. It was a 1000 kg/hr, 7 kg/m^2 (100 lb/in^2) natural-draft unit, with a 60' high stack, a surface area of 496 ft^2, and a husk consumption calculated at 350 kg/hr with an estimated 2200 Kcal/kg recovery from the husk.

At Gimeaux (W23), a parboil/precook process plant obtains steam from a Parent (W21) boiler of 2500 kg/hr, using 600 kg of husk as fuel, a 4.16 recovery ratio. This is an induced-draft unit, with all fuel and residue passing through the tubes and being collected in a primary filter; a bag-type secondary filtration takes place at 100°C. Cooling of the stack gas is accomplished by an automatic fresh-air bleed system. There is a formal furnace section with a controlled feed, using screw conveyors into the furnace volume.

At Mandya, India, the efficiency of a Texmaco (India) Cornish boiler, 6' x 20', with about 500 ft^2 of heating surface, was estimated at 45%, but information about the husk handling practices indicates the actual efficiency is less. The boiler furnishes steam for parboiling during part of the year.

The Srinivas Rice Mill, India, uses a Westerwork 750 kg/hr boiler. The actual fuel consumption for this unit during a test period was 154 kg husk/hr, which would indicate a conversion ratio of 4.9; this is probably an error, because the boiler is not delivering, and the parboil plant is not using, the rated 750 kg/hr. The quoted efficiency for this boiler/furnace unit is 50/60% and a reasonable calculation of the ratio is about 2.76, which is probably closer to actual performance. Husk-consumption figures must be relied on only when checked against actual feedwater consumption or steam-flow measurements.

Scopa Chemicals (W83) use rice husk as an alternative fuel in their VCT and fire-tube boilers. They find that with husk as a fuel the steam generation capacity of their boiler is about 60% of the output when coal is fired. They feel that a mixture of the two would be a very good system. The buildup of ash in the tubes of the fire-tube boilers was their only problem, frequent cleaning being required (48-hour intervals). If a grating system designed for husk is used, of course, this is no problem. The desirability of using husk arises from the cost of steam; Scopa's cost records show, for extended periods, a cost when using coal of $2.83 per 1000 lb of steam at 100 lb/in^2, against $0.91 when using rice husk. They believe that with alterations, and not very costly ones, all existing small-scale

industries which require steam up to 1 ton per hour and VCT or fire-tube boilers using coal as a fuel could convert.

6.1.5. ACCESSORIES

A simple boiler may consist of only a furnace/boiler container and a means of injecting feedwater. However, if there is a requirement for higher efficiency than can be obtained with a simple system, various additions to the system can be included.

6.1.5.1. Economizers. An economizer consists of a number of sets of cast-iron or steel tubes placed vertically, horizontally or inclined in the path of the waste gases; the feedwater passes through the tubes and the gases pass over the exterior of the tubes in a a direction substantially opposite to that of the water. Roughly, for every 11° or 12° increase in the temperature of the feedwater, resulting from the recovery of heat otherwise wasted, the saving in fuel is 1% (see Figure 16). Apart from the saving of heat, there are contingent advantages in feeding a boiler with hot water: the rate of steaming is increased, and thermal stresses set up when cold feedwater is used are eliminated. Since the draft available in the furnace is reduced when an economizer is installed unless mechanical draft is employed, maximum savings are not likely to be realized because the the economizer will generally be too small for the plant. Where there is mechanical draft, the economizer can be proportioned to give the maximum recovery of heat. It is important not to chill the gases below the dew-point, or serious corrosion of the tubes is almost certain to take place, as the liquid deposited consists of a weak (and therefore very corrosive) solution of acids. Moreover, when condensation occurs, adherent deposits of "fly" ash and particles of unburned carbon are likely to be formed on the tubes of the economizer, and these impede transfer of heat to the water.

6.1.5.2. Air heaters. Where the gases leaving the economizer are insufficiently cooled, further recovery of heat may be effected by installing extra heating surface for preheating the air required for combustion. The advantages of this are: (i) direct return to the furnace of heat otherwise wasted; (ii) more complete combustion with less excess air, since the temperature in the furnace is increased and the velocity of reaction augmented; (iii) higher rates of transmission of heat to the water in the boiler arising from the higher temperature of the furnace; and (iv) greater steaming capacity of the boiler--increases of up to 50% have been attained.

With pre-heated air, in addition to the increased load that can be carried by the boiler, the negative effects of high loads on efficiency are reduced.

Air heaters are of two types: recuperative and regenerative. In recuperative heaters transfer of heat from the gases to the air takes place in a normal heat exchanger. In regenerative heaters the transfer takes place through a transfer medium.

Air-cooled furnace walls or floors, sometimes used as sources of heat to improve combustion conditions, are not normally included in the term "air heater".

6.1.5.3. Superheaters. While a superheater affords extra heating surface (and therefore increases the ratio of heating surface to grate area) the object of superheating steam is not so much to increase the efficiency of the boiler plant as to enhance the value of the steam after it has left the boiler. The degree of superheat will depend on the use of the steam. Some superheat is always desirable for the following reasons: (i) dry steam is delivered to the plant in which it is to be used and the heavy loss of heat which results when condensation takes place in the steam-pipes is thereby avoided; (ii) higher velocities are admissible with superheated than with saturated steam, so that smaller pipes can be used; and (iii) there is less wear and tear on valves, and loss of steam by leaking joints in the mains.

As regards rice-husk fired boilers, the most notable use of superheaters occurred on the Buckau R. Wolf type of Lokomobile boiler/engine combination.

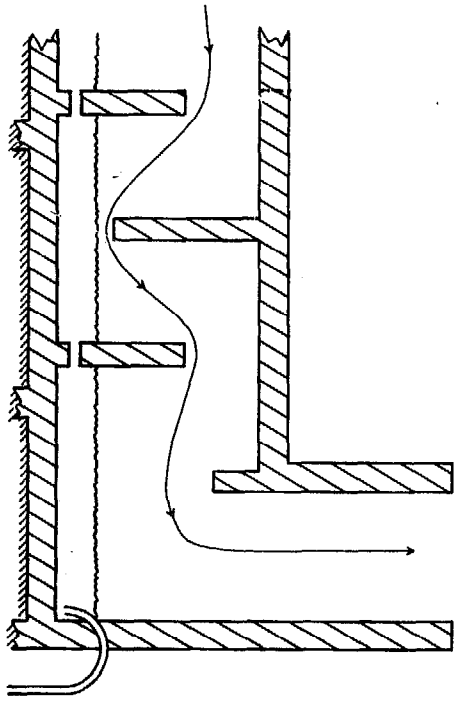

Figure 17. Simple water scrubber

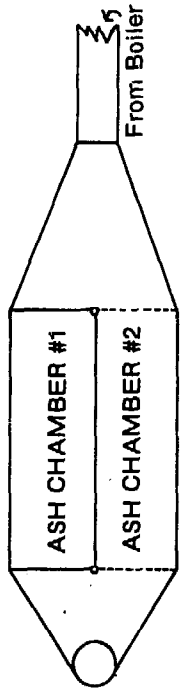

Figure 18. Ash chamber installation

6.1.5.4. Scrubbing. The particulate matter entrained in the gas flow through the boiler and out to the stack must, in some situations, be removed before effluent discharge. A simple two/three-pass water scrubber that can be constructed locally of diverse materials is shown in Figure 17. The water should be removed by the system as shown. Adequate access for cleanout must also be provided.

If water scrubbing is not necessary or desired on a natural draft unit, an ash chamber can be installed at the base of the stack. With proper sizing of the chamber one can expect 95% of the particulate matter to settle out. An alternate flow/cleanout is suggested in Figure 18.

6.1.6. CONSTRAINTS

Regulations and restrictions concerning boiler construction and operation vary considerably from country to country. The various types, sizes and construction features are in most cases in use because of local requirements. For example, some countries today are still governed by the English boiler law of 1922 which says that all boilers must be riveted. Therefore, the cost of a boiler, and of course the feasibility of a project, is in some ways wholly dependent upon the location or country and not necessarily on the quality of the husk as a fuel.

Operation of the boiler and the staffing of the plant depend to a great degree on the pressure developed by the boiler. In most cases a high-pressure boiler requires the constant attendance of a qualified operator, the cost of which will vary widely. However, for moderate-pressure boilers (for instance, in Italy, those with a working pressure below 12 kg/cm^2), no boiler man is needed if three independent, cascading safety devices are fitted and a licensed employee is in attendance in the plant.

In some cases the requirement is based on a combination of pressure and volume of water contained, so various methods have been devised to build legal units. Steam generators and the Indian mini-boiler are examples.

Because of legal restrictions there are instances of one-way traffic in boilers between countries. Thus, a Thai boiler may not be used in Malaysia or Singapore, but many used boilers are shipped to Thailand, which has no effective boiler code.

Of course all these considerations directly affect the cost of the boiler, and indirectly the decision whether husk-fired units would be practicable. For instance, Frugone & Preve's decision not to reactivate their long-used, very successful power plant in Robbio, Italy was almost entirely due to the labour/mains electricity cost ratio.

Any new plant in a country that has stringent regulations and high labour costs must be sophisticated enough to operate without attendants and to conform in safety features to the local regulations. To justify a boiler/straight power generation unit is difficult; only when there is a process steam requirement is it possible to consider a husk-fired boiler plant.

6.1.6.1. Losses. The operation of a boiler system for long life and high efficiency depends not only on the original design but on the continued proper operation and maintenance. If, as said by Hawkey (W159), "the system begins to die the day it is started up", excessive cost increases because of deterioration are not tolerable. For example,

dirty boilers can cause losses up to 25%,
leaky settings up to 15%, and
poor firing up to 40%.

These are all directly due to poor operation or maintenance, or to insufficient maintenance. As an example, one plant in India (Mandya) had a husk consumption nearly twice what was to be expected of an originally low-efficiency (Cornish) installation. At the opposite extreme, an Italian parboil plant (Garisi) improved its conversion ratio over the original installation through good maintenance and improving the system in the normal course of operation.

6.1.6.2. Stack losses in boiler operation. The chief loss of heat in steam-raising almost always derives from heat being carried away in the waste gases, and if the highest efficiency is to be attained, the stack loss must be kept down to the irreducible minimum; it can never be entirely eliminated, since it is not practicable to reject the gases at the temperature of the atmospheric air.

6.1.6.3. Effects of excess air in boiler operation. While a certain amount of excess air is necessary to ensure reasonably complete combustion, an undue excess is deleterious, quite apart from its direct effect in increasing chimney losses. The effect, moreover, depends on the point at which the air enters the system and is more serious when the leakage is at the furnace than at some later stage. Excessive introduction of air into the furnace may cause combustion to be less complete than it otherwise would be, by reason of the cooling of the gases below their ignition temperatures; transmission of heat is also impeded owing to the lowered temperature, and if chimney draft is employed, the chimney may be overloaded and the rate of combustion decreased.

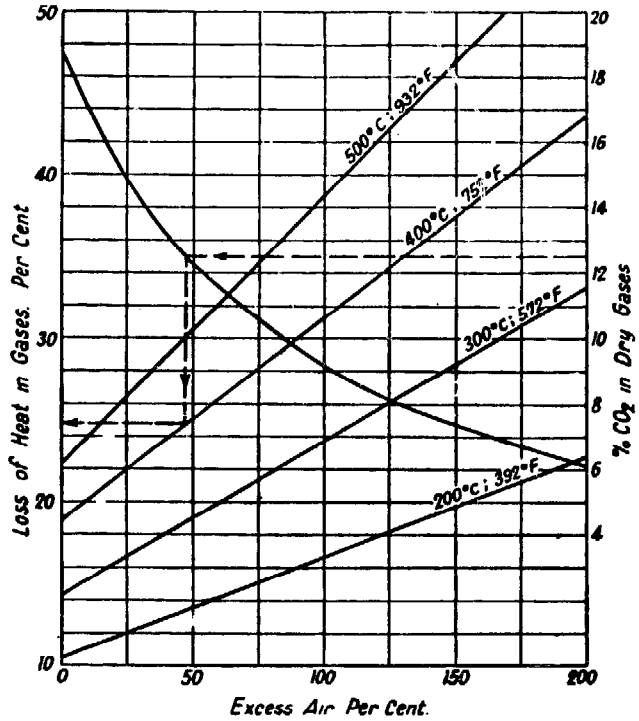

Figure 19 Effects of excess air in boiler operation

6.1.6.4. Corrosion (See also Section 5.5.1.) In designing the boiler system it is important to maintain the stack temperature above 200°C at the discharge end of the tubes, in order to control corrosion. If the temperature in the stack falls below the dew point the condensate causes excessive corrosion.

Since the efficiency of the boiler is directly affected by the stack temperature, the cost of efficiency must necessarily be balanced against corrosive effects, but some of these can be offset by a higher capital cost created by the use of corrosive-resistant materials.

6.1.6.5. Radiation losses. Another aspect of the installation is the cost of insulation of components to reduce the losses due to radiation from the furnace shell and boiler shell.

6.1.6.6. Conclusion. Almost all factors concerning the design and use of rice-husk fired boilers are in a balancing situation. The most important factors are the size of the unit, the duty for which it is intended and the country in which it is to be located. Relative economies depend wholly on the cost and availability of competitive fuels, the capital cost of the installation, the relative cost of operation (mainly labour), and the direct cost of alternative methods of husk disposal or utilization of the raw husk, char or ash.

6.2 DRYING (See also Section 4.3.5.)

Drying of paddy by use of husk-devised energy was discussed in Section 5.2.1. This section deals primarily with the equipment available for this purpose. Because of wide differences, it will be considered in two categories, 1) box-type or batch-type dryers; 2) continuous-flow dryers. Three methods of implementation will be envisaged: direct-fired, indirect (heat exchange) fired, and steam-heat exchanger types.

6.2.1. BOX-TYPE OR BATCH DRYERS

This type of dryer today is an Asian development, though in the early development stages of mechanical drying (around 1914), box-type dryers almost identical to today's design were produced in serial production in Italy. Most of the building of this type of dryer is now concentrated in the Philippines or Japan. Both direct and indirect units are manufactured in the Manila area (W129, W132, W133, W134), primarily as an outgrowth of development and popularization work by IRRI (W130) and the University of the Philippines (W156). A number of experimental variations of husk-fired furnaces for the box dryers have been developed: Manalo (105-6) established a usage of 1 kg husk/cavan (44 lbs) paddy to dry from 22.5% to 14% moisture. Batch time for 1144 kg was 4 hours.

The cost of the husk-fired box dryer complete, by Nation (W128) was 10,000 pesos in 1974, while a comparable kerosene-fired unit cost 6,000 pesos. Only under certain circumstances could the fuel saving justify the additional cost of a box dryer, because its utilization factor is low. Kamalig (W137), in their Philippine operation, uses about 150 box-type dryers, of which a portion are husk-fired, along with kerosene and multi-fueled (wood, straw, etc.). The earlier husk-fired units were not satisfactory, but the deficiencies have been corrected. The primary factor in the utilization of husk-fired units is that the dryer is to be operated in proximity to a source of husk. At one installation east of Los Baños (Philippines), a normal step-grate furnace furnishes heat for a UOP-designed box dryer. One advantage is that the dryer assembly itself can be knocked down for storage in the off season.

A great number of Japanese box dryers have been sold, but all appear to be kerosene- or oil-fired. The Japanese practice does not seem to be indicative of the effectiveness of husk-fired box dryers. Most of the stimulus for this development is generated by DePadua (W135) and Khan (W130). For all intended purposes the box dryer is satisfactory, and the only real development could come through improving its capability of using indigenous fuel. The control of the temperature is important; in practical situations, the husk-fired furnace must have an attendant to monitor the fuel firing to keep the temperature within limits, and to remove ash. An automatic husk feed-control system would be awkward and expensive, and no practical system has as yet been developed. (An oil-fired unit can be unattended and controlled automatically.) However, the husk-fired unit's main drawback is the fact that usually, where the dryer is used, there is no husk available, so practically the main problem is husk acquisition, although the higher initial cost of the unit is also a major obstacle.

6.2.1.1. Rotary husk-fired dryers. A novel type direct-fired dryer using a centrally located rice-husk furnace which furnishes hot gases to a fluid-bed progressive dryer has been tested and marketed for several years in India (W84). It has porous bottom-screw conveyors to move the drying paddy and maintains a temperature of 120°C with the use of 50 kg of paddy husk/hr. It has a capacity of 3 tons/hr of wet paddy when using 24% intake paddy with 16% discharge after 3 passes. This would indicate a use of 50 kg of husk for fuel for each ton of paddy ultimately dried. This usage corresponds to the usage of husk as fuel as reported by Manalo (105-6) using an IRRI-UOP type box dryer.

6.2.1.2. CeCoCo (Japan) (W101) offers a Japanese-type kiln furnace which will produce a 1000°C working medium; as an external-furnace assembly, the heat generated is used to dry grains, seaweed, vegetables, fruits, fish, etc. The firm also represents Kansai Sangro (W102), offering carbonizers and allied products. The stack discharge from these carbonizers makes an excellent source of heat for drying purposes.

6.2.1.3. Husk charcoal as a fuel. In Asia, there has been considerable interest in the use of husk charcoal as a fuel for drying. A dryer by Faith Eng. Co. Ltd. is specifically designed to utilize the husk charcoal fuel. Work has also been done on a concentrating machine (W9) to briquette or extrude the product for transport and handling advantages. (See section 6.7.3.)

6.2.2. CONTINUOUS-FLOW DRYING

Continuous-flow dryers range widely in size. A typical manufacturer (Schule) offers a range of dryers whose performance data appear in Table 25.

Table 25

Capacity of continuous-flow dryers
(kg paddy intake per hr)

Dryer	Type		2	3	4	5	6	8	10	15
1-pass	L		22[illegible]	3500	5100	6500	7900	10500	13200	18700
	R		17[illegible]	2800	4080	5200	6320	8400	10560	14960
2-pass	L		1100	1750	2550	3250	3950	5250	6600	9350
	R		880	1400	2040	2600	3160	4200	5280	7480
3-pass	L		733	1166	1700	2166	2633	3500	4400	6233
	R		586	933	1360	1733	2106	2800	3520	4988
4-pass	L		550	875	1275	1625	1975	2625	3300	4675
	R		440	700	1020	1300	1580	2100	2640	3740
Dry air m^3/h			7200	10800	14400	18000	21600	28800	36000	50000
Htg Cpy (kcal/hr)		max.	105000	155000	205000	255000	300000	410000	515000	710000
		min.	72000	107000	143000	179000	205000	280000	358000	495000
Husk Cons. kg/hr		max.	31.5	46.5	61.5	76.5	90.0	123.	154.5	213.
		min.	21.1	32.1	42.9	53.7	61.5	88.4	102.4	148.5
kw Cons			3	3.5	4	5	6	8	10	15

L = long grain R = round grain

Any heat source may be used, but while the husk consumption data are correct theoretically it would be prudent to increase the consumption by 10-15% to allow for furnace inefficiency not planned.

Large husk-fired dryers, both direct- and indirect-fired, have been and can be furnished by many firms. They are in use in Bangladesh, Pakistan, Dominican Republic and elsewhere.

In Japan there are many dryers (not only for paddy) using husk for fuel. One type of furnace (almost a gas producer design) is shown in Figure . It burns 340 kg of husk per hour, providing 745,000 Kcal/hr; the exchanger has an efficiency of 53.5%, transferring 399,000 Kcal/hr. The stack discharge represents 31.5% or 235,000 Kcal. The indirect-air product balances at a temperature of 230°C. Manufacturers (W107, W111, W112) are varied, usually in conjunction with a carbonization plant or equipment. Determining the extent of husk-fired drying use is difficult.

In Thailand the general practice is to use steam-exchanger dryers with coils from India (W146). One local manufacturer offers a complete line of heat-exchanger dryers. A 4 ton/hr 2-pass dryer providing 8% removal was under construction in Bangkok at Sathorn (W152). There appear to be no direct-fired dryers in Thailand.

In India again there are many steam-heat exchanger dryers, probably because there are always other uses for process steam in the parboiling plant. The heat-exchanger coils are usually manufactured in India under a Swedish license, but British-built heat exchangers are also in use.

At ITT-Kharagpur, Ojha-Maheshwari (W63) built and tested a direct-fired continuous dryer and showed that the gas/air mixture is nearly as good as heated ambient air. The step-grate/curtain-wall furnace used a feed rate of 11 kg/hr to supply 1000 ft^3/min of heated air-flue gas mixture maintained at 100°C. The furnace provides a combustion with no traces of smoke in the flue gas. This corresponds to Acasio's comment: "For ideal drying conditions, the exhaust gases must be completely burned before they can be used directly for drying grain crops." That their combustion was good is shown by Maheshwari's flue-gas analysis of 3% CO_2, 16% O_2, 0% CO, balance N_2.

The comparative cost chart in Table 14 developed from Ojha-Maheshwari work at IIT-Kharagpur covers fully the range of options of fuels and necessary processes concerned with the drying of paddy rice.

6.3. FURNACES

Any burning-type conversion of rice husk to energy must be done in a reactor of some sort; usually this is thought of as a furnace. The complexity and sophistication of such furnaces can vary widely, from the pile of husk under a dished pan in a "chatty" parboiling operation, through a pile of husk on a flat grate, to an inclined step-grate--a sophisticated pitch movable grate--to a fluid-bed furnace. All of these are furnaces whose only purpose is to combine fuel and air under the most efficient and controllable conditions to provide heat for some beneficial utilization of the raw husk.

There are several types of furnaces with fundamental differences. They include fixed-bed, flat-grate, inclined step-grate, movable inclined step-grate, fluid-bed, air-suspended, gas-combustor (Takano) and dual-fuel system furnaces.

Methods of stoking (feeding) the husk vary with each type of furnace. There are several commercial types of underfeed stokers, some designed for coal (W90, W44) and some designed for wood chips/sawdust (W10). The use of rice husk in an underfeed stoker is possible. The underfeed stoker of the Argusfyr type has an added advantage of needing no grate or underground fire box when used with a floor-mounted boiler. One boiler manufacturer (W33) states that the use of this type of underfeed stoker attained, in his tests, a 4.8% higher efficiency than a classic inclined-step grate. Possibly this was due to greater containment and therefore less radiation loss.

The husk can be fed into an internal furnace chamber of a boiler pneumatically, into a safety chamber, the combustion occurring in suspension and probably partially in the tube. Transport air will be in the range of 60 ft^3/lb of husk. About 95 ft^3/lb of husk are required for proper combustion. There are several methods of addition; the difference is determined primarily by whether the installation is on induced draft or natural draft.

The air speed behind the ejection nozzle should be more than 45 ft/sec in order to avoid back-firing. As additional protection, two safety ports are installed before the injection nozzle. These valves are opened by the flow of transport air and close automatically when the air speed is reduced.

The traditional method for burning husk and high-humidity materials has been by an indirect step-grate. A classic design (Kampnagel) of a fixed-angle step-grate furnace is shown in Figure 20. Feed to the top of the step grate can take place by gravity slide, rotary valve or vibrating feeder--any method of ensuring the necessary sealing of gas/air and desired metering of the husk feed material.

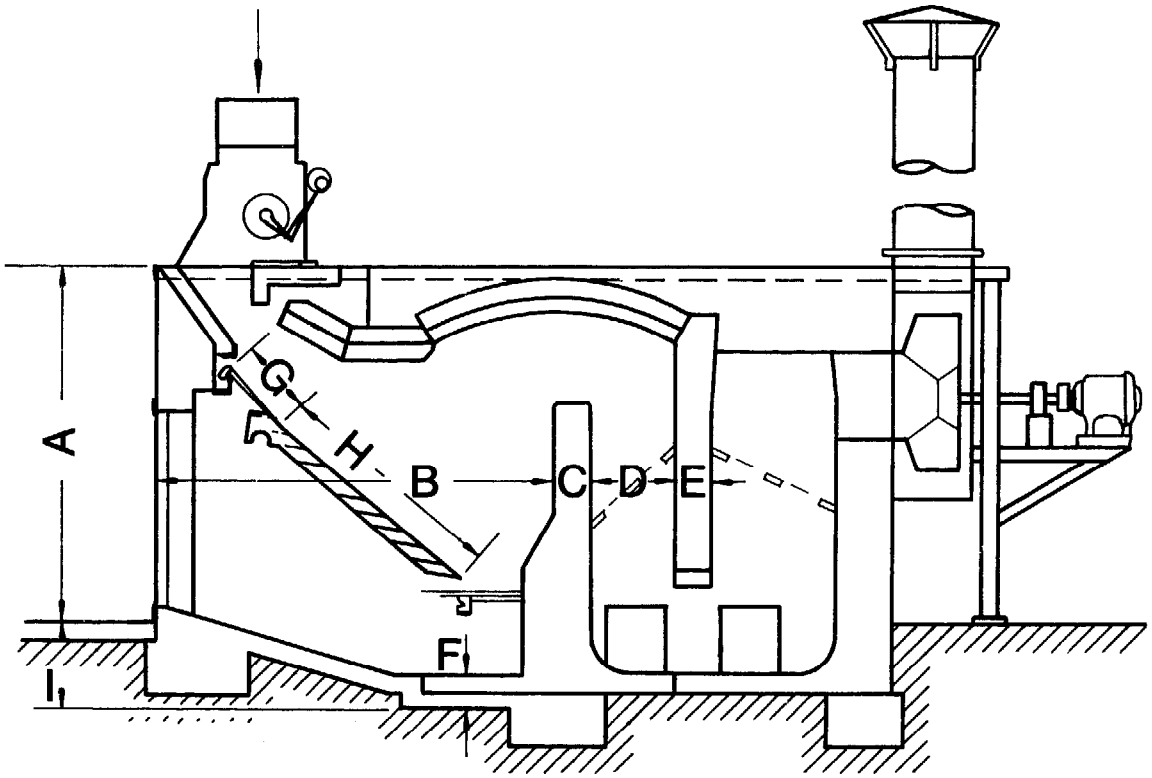

Fixed-angle step-grate furnace
(Kampnagel)

A movable step-grate is fed in the same way.

A fluid-bed furnace must have an in-line pressure feed.

An air-suspended cyclonic-type furnace injects the husk either with the full amount of air or with separate feeds, tangentially, for the air and the husk fuel.

In his 1952 paper Lathrop (223) described a furnace fed by a screw conveyer which dropp the husk into a jet stream of air directed at a small target. This is somewhat similar to the unit developed by Kuppuswamy (W66), in which the fuel is injected toward a small hot plate target which ensures ignition.

6.3.1. THERMAL ACCUMULATION OF HEAT IN A FURNACE

To have certain and steady combustion it is necessary to design the furnace so that when more output is required, calling for additional air and fuel, the drawdown of the heat-sink cannot reduce the temperature below that necessary to ensure good gasification and burning of husk. Several methods are possible. One is to preheat the air coming in, using air passing over the furnace so that the furnace radiation can be utilized. Also, if it is impractical to install an economizer, the feedwater inlet can be plumbed so as to use waste heat from the furnace area. For details on the importance of feedwater heating, see Figure 16.

6.3.2. TYPES OF FURNACE

6.3.2.1. Fixed-bed furnaces. The fixed-bed furnace has no grate. The husk burns in a pile on the floor, or ground, or any other surface. The ash is removed manually, although in some cases the work is moved instead.

6.3.2.2. Flat-grate. Normally, when a flat grate is used on a rice-husk fueled furnace, the husk is being used as an alternative fuel. The use of a flat grate with rice husk requires a special firing technique to be successful. Usually, the husk is added as a supplemental feed on top of a bed of wood or coal. A typical user of husk on a flat grate, Scopa describes their method of firing as follows:

"If the husk is allowed to burn completely, the fire bed either chokes or falls through the grates. First the boiler is fired with coal so that a base for husk is formed. The husk is then periodically spread over the fire bed and fed after every five minutes. The grate is also agitated so that partially burnt husk falls out. The burning bed forms a loose porous layer. If the husk burns completely the bed cannot be sustained. We later on made a hopper which had a sliding door. This door was adjusted and the husk was sucked in by the draft. The ash removal was accomplished by means of bent steel rod from below the grates."

Many attempts to utilize husk as a fuel on flat grates have failed, because a sustained fire bed could not be established.

6.3.2.3. Inclined-step grate. This is the traditional design which, since its introduction in Burma in 1880 (Cowie), has dominated installations for rice-husk burning.

There are three basic variations:

Under floor level Above floor level	These stationary furnaces are employed for all boilers that have no withdrawable tubular system.
Pull-away	Sometimes called Portable.

Under-floor: This is illustrated in Figure 12. In this case the boiler chasis is possible at floor level, but rice husk can create problems with ash removal.

Floor-level: As shown in the classic design in Figure 21, the floor-level grate also has a floor-level boiler. Only the ash removal system is sunken. This (Bergoni) design shows a small external volume for the furnace and a rather large combustion tube in the boiler, which apparently is a Cornish type that would allow this configuration. Figure 13 shows a more modern above-floor grate with a second-level boiler installation.

Pull-away: A traditional style of pull-away furnace feeding a locomotive-type fire-tube boiler is shown in Figure 22. The portable furnace is appropriate when the boiler has withdrawable tubes or the cleaning of the tubes cannot be effected otherwise.

There are also several variations in style with emphasis on the special form of the grate bars and the proper inclination of the step grate, an economical and sufficient combustion to depending a great extent on these features:

- Single-section grate
- Multi-section grate
- Multi-section, variable-pitch grate

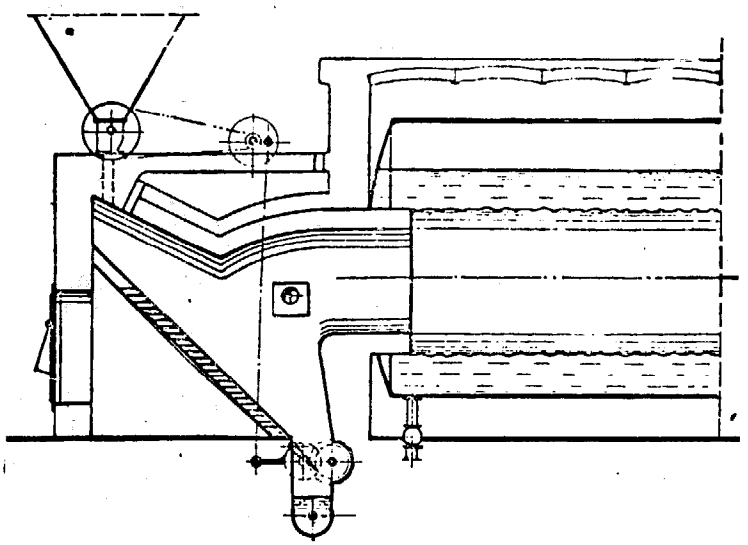

Figure 21 Floor-level inclined step-grate furnace (Bergoni)

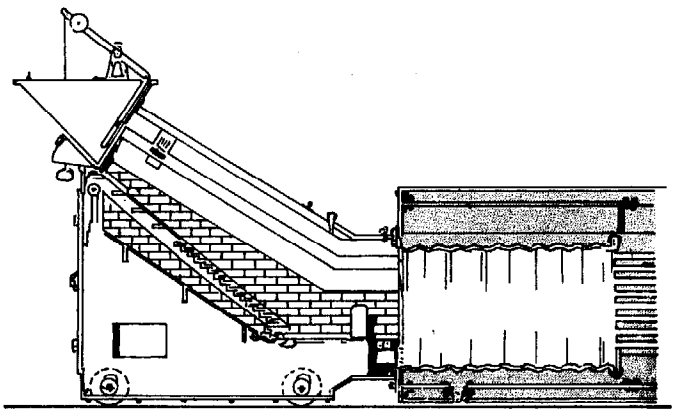

Figure 22 Pull-away furnace

The angle of repose of rice husk depends upon several factors: the variety of paddy, the moisture content, the type of sheller (disc, rubber, centrifugal) used, the amount of extraneous material (dockage), whether parboiled or raw rice milling, and within the furnace the amount and stage of gasification, which depends on the design and internal radiation of the furnace and the actual density of the husk furnished.

Very important is the necessity to have a uniform draught through the grate (B.R. Wolf says not over 1.0 m/sec) and therefore a uniform porosity of the layer of husk and derived products further down the grate. It can be necessarily different, and can change at any time when the characteristics of the in-feed of husk change. Therefore it is always necessary to consider a multi-section, variable-pitch grate that can be adjusted as desired to tailor the angle to the proper conditions. The slope can be changed to accommodate the installation in a variety of ways and with varying degrees of ease.

6.3.2.4. Movable inclined step-grate (Lambion W39). Experimental values show that satisfactory high-yield combustion is impossible by means of a fixed grate. For this reason, revisions have been made to the feed grate with special regard to the combustion of husk, as only this type of grate makes it possible to control the introduction zone, the combustion zone and the residue zone separately. A hydraulic drive for the motion of the different combustion zones ensures a maximum range of control. The grate covering is designed so as to meet all these demands in the best possible way, and it has proved to be very successful in many plants.

The combustion air is divided according to the different grate zones and can thus be supplied in concentrated form into the main burning zones. Furthermore, special attention is paid to correct planning for the combustion chamber in order to achieve maximum burnout and optimum ignition.

A section depicting this type of grate design is shown in Figure 23. Two highly efficient power plants (W126, W134) utilize this grate system to reach a quite high conversion ratio. Both are three-section units and consist of:

- a rigid grate part, the angle of inclination of which can be regulated; and
- a mechanically operated feed-grate, part which is longitudinally divided into two zones of motion.

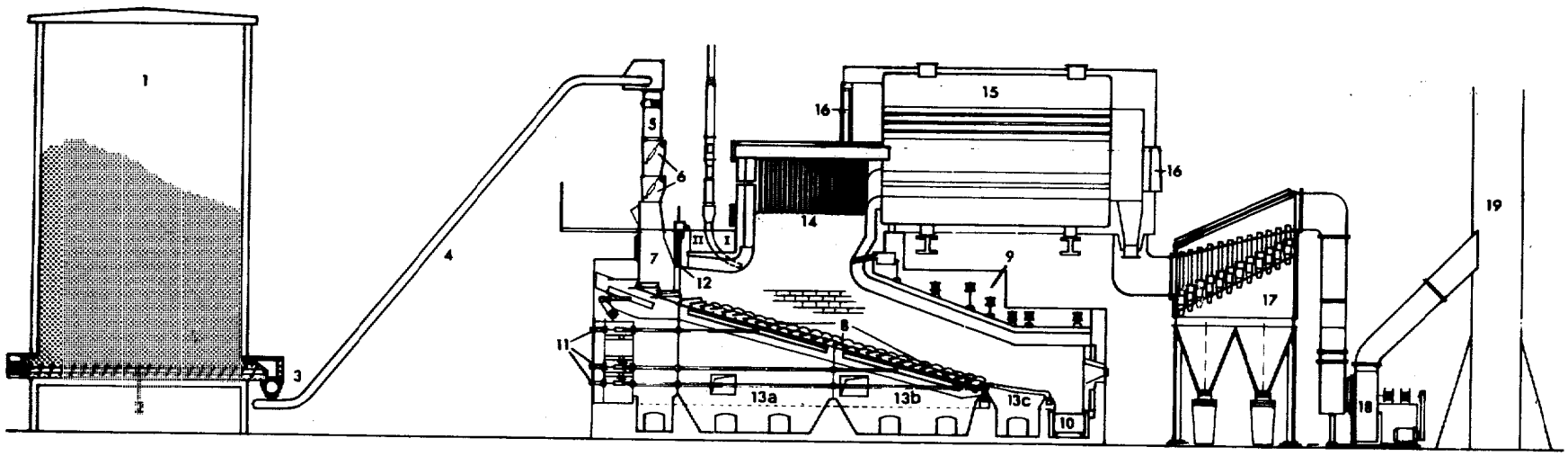

(1) bin
(2) travelling screw conveyor
(3) screw collector
(4) conveyor belt
(5) fuel distributing apparatus
(6) fuel feeding flaps-type apparatus
(7) feeding chute
(8) grate
(9) furnace bloc
(10) ash pit
(11) hydraulic cylinder and connecting rods
(12) fuel layer thickness regulator
(13) a,b,c, undergrate blast zones
(14) intermediate casing
(15) three pass boiler
(16) cleaning doors
(17) flue gas dust extraction plant
(18) induced draught fan
(19) chimney

Figure 23

Movable inclined step-grate furnace

Obviously the major disadvantage of this grating system is its cost. But when balanced against the increased efficiency it appears that in moderately sized units (10,000 lb of steam and larger) the cost is justified.

6.3.2.5. Fluid-bed. No large fluid-bed furnace installations operating on rice husk are known. A typical design of a 26'-diameter fluid-bed reactor operating at 1100°C would consume about 24,000 lb/hr of rice husk and develop 80,000 lb/hr of steam. The conversion ratio would be 3:33. Exhaust gas exits at 75°C. (See also Section 3.1.3.3.)

6.3.2.6. Air-suspended. Cyclonic turbulent flow furnaces can be either external (Pitt) (W185) or internal (Gariboldi) (W90). The external cyclonic furnace can be designed to produce either heat alone or a residue product alone or a combination of these. Designs of air-suspended furnaces are shown in Figures 14 and 15. It has been said that a husk-fueled furnace does not furnish a temperature high enough for efficient boiler operation at high steam pressures and temperatures. This is not true when a properly designed air-suspended furnace is used ahead of a suitable waste-heat boiler.

In a pneumatically fed internal combustion boiler, when husks are blown into the combustion chamber, no grate is necessary because combustion takes place completely in suspension. The fuel is blown through the injection nozzle into the fire tube in such a way that it moves in a spiral path through the combustion chamber, ensuring better burning and combustion. Here, however, the entire amount of the combustion air required must be blown in. Total air volume is made up of the transport air and secondary air supplied by a fan. In these furnaces it must be possible to operate with variable load. The secondary air fan is controlled as contingent upon the fuel volume. A high air volume must be used, since there is no grating, and the ash residue must be conveyed through the tube section. An induced-draught fan is helpful in maintaining proper control.

The furnace designed by Kuppuswamy (W66) utilizes air-suspended burning.

A new project at IIT-Kharagpur is concerned with an air-suspended furnace. It is a pressure-feed, tangential pre-combustion chamber with side extraction. Ash removal takes place through a bottom hopper with an interruptible discharge.

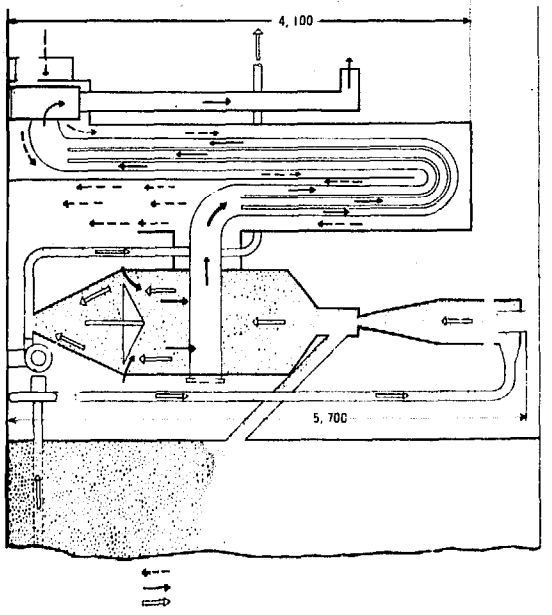

Figure 24

Gas-combustor furnace (Takano)

6.3.2.7. Gas-combustor. Figure 24 shows a typical Japanese furnace (Takano), which produces heat for use in drying or processing 340 kg/hr and generates 745,000 Kcals/hr; the residue produced is a char of approximately 50% carbon and 50% ash. The tested efficiency of the heat exchanger is 53.5%. This furnace is really a carbonizer utilizing gasification. The core section action is like that of a gas producer. It produces heat for various purposes as a by-product. Its main usage is as a carbonizer.

The suction-system rice-husk combustion furnace sold by Yamamoto (W112) is similar. Considerable development work on types of combustion equipment has been done by Shimizu (W104). Test data produced by the Institute of Agricultural Machinery, typical of their type of combustion furnace, are shown in Table 28.

6.3.2.8. Dual-fuel furnaces. In furnaces with pneumatic injection, by far the greater part of fuel burns in a state of suspension, while coarse particles fall partially burned onto the grate and complete their combustion there. An oil burner for No. 2 fuel or, at high operating pressure, for Nos. 5 or 6 fuel[1/] can be fitted to the end plate of the boiler fire-door. For automatic operation the oil burner is used to start the fire, since the husk cannot be lighted by an electric spark; it also supplements the fuel supply during the peak season or when not enough husk is available for the desired output.

In compact boilers and combustion-tube boilers, muffles are installed before the combustion chamber. The oil burner is mounted in front of the muffle, and the husk is blown into the muffle area around the path of the boiler flame, so that it passes the muffle area and combustion chamber in a spiral path. The oil burner functions as pilot burner and can provide additional fuel at peak loading.

6.3.3. DUST CONTROL

It can be said in general of furnaces that the amount of combustion air they require depends largely on the type of firing. In general, the air capacity should be great enough to ensure that only a very faint trace of exhaust gas can be seen rising from the chimney stack; there should never be black smoke.

To meet stricter pollution codes, the secondary air should be regulated. The area underneath the grate should be sealed air-tight and the air needed for combustion injected by an air blower, governed by an electronic-emission gas meter, located behind the furnace.

In very strict air-pollution control areas, the environmental contamination due to the dust contents of the flue gases is subject to legal regulations concerning the emission of solid matters.

The typical flue gas has a dust load of between 1 and 2 gr/ft^2 that cannot be extracte at the prevailing temperature of approximately 1000°C. It is necessary to cool the flue gases below 300°C before they penetrate the dust extractor. For this purpose, a three-pass somke-tube boiler is generally used.

In order to comply with emission regulations, various dust extraction systems of well-known manufacturers are used. Installations can be equipped with the following typica flue-gas dust-extraction plants:

1/ No. 2 fuel is distillate with maximum Saybolt Universal 100°F rating of 40. Nos. 5 and are residual-type oils with minimum Saybolt Universal 100°F ratings of 150.

- multiclone dust extractor (0,2 gr/ft^3 12% CO_2)
- three-phase dust extractor (0,1 gr/ft^3 12% CO_2)
- electro dust extractor (below 0,065 gr/ft^3 12% CO_2)

6.3.4. ASH REMOVAL

One of the most important factors in furnace selection is the manner in which the ash-char is removed. The under-floor systems usually depend on water removal methods, mechanical or manual lifting of ash to discharge height, or vacuum conveying methods. Several typical examples are shown in Figures 14, 21 and 23. It must be borne in mind that when rice husk is used as a fuel, ash-char production is greater than with any other type of fuel, and that when the ash-char comes out of the grate area it will most likely be at a high temperature unless provision is made to percolate a portion of combustion makeup air through it to cool it.

When a combustion-tube induced-draught boiler is used, in which all of the husk enters the combustion chamber and the ash continues through the tubes, the char-ash is collected by one- or two-stage cyclonic collectors before the discharge gases are passed up through the stack. If necessary, a scrubber or a bag filter can be used in the fan discharge dust.

6.3.5. MISCELLANEOUS

The Punjab Agricultural University (PAU) at Ludhiana (W68) is working on a developmental furnace and dryer combination. This project has been under way by FCI for some time, but no results have been released. PAU is surveying the practices of all regional mills and is trying to develop an improved standardized furnace design for rice mills.

In Thailand, Imasuri (W146) has installed a new furnace of proprietary design at his mill near Bangkok, to furnish heat to a parboiling process-steam boiler.

For details of a furnace suitable for drying or other heat uses, the paper by Ojha (179) contains a detail of construction and test that includes all necessary information.

6.4 STEAM PRIME MOVERS (ENGINES AND TURBINES)

The engine of the steam cycle may be of either of two general types: the reciprocating engine, commonly referred to as the steam engine; or the turbine engine, commonly referred to as the steam turbine. Given the same initial conditions of the steam and the same exhaust conditions, the ideal thermal efficiencies of the steam engine and the turbine are exactly the same. The use of one or the other for a specific purpose is determined by practical or economic considerations. The measures of efficiency and performance are applicable to both the steam engine and the steam turbine.

Steam prime movers are exceptionally well suited to operation in combination with paddy-rice parboiling processing, because line steam is used for steeping, soaking, steaming, drying and other activities.

Where relatively low powers are involved, the choice of the steam engine rather than the steam turbine (often produced by the same manufacturers) is due to the favourable steam consumption of an engine when working under the steam conditions required by the process. To obtain the required temperature in the process-steam supply, the prime mover should exhaust saturated steam at a pressure of 35-45 lb/in^2 (2.5-3.2 kg/cm^2).

Using the limited fuel availabe from rice husk, a steam engine will drive a mill satisfactorily, in addition to furnishing its full process-steam requirements, by operating

with dry saturated steam at a pressure of 225 lb/in^2 (16 kg/cm^2) at the inlet valve.

On the other hand, a single-stage turbine operating under the same steam conditions requires 33% more steam than the engine, and there could conceivably be insufficient husk available to perform the desired operations.

It is, of course, possible to reduce the turbine's steam consumption to an acceptable level by using higher-pressure superheated steam, but this can only be obtained at the cost of complications and is inadvisable in remote areas, where simplicity of the plant and maintenance procedures is a vital economic factor.

For example, the additional equipment required to reduce a turbine's steam consumption to that of a steam engine would include:

- more comprehensive water treatment and deaerator plant
- more expensive boilers
- superheaters
- desuperheater (with associated control equipment) for the exhaust steam when the turbine is running on a light load
- desuperheater (with associated control equipment) for the make-up steam that bypasses the turbine

Furthermore, these items require skilled operators or maintenance engineers, expensive and undoubtedly difficult to find and keep.

According to Spilling (W46) "The economic borderline in the range of applicability between a steam motor and a back-pressure turbine varies between 1000 HP and 2000 HP per engine unit. As changing steam throughputs and energy demands often require three sets or more, a comparative rentability calculation with plants of 1000 to 5000 kw has to decide whether a steam motor or a steam turbine is more adequate. The back-pressure turbine has a lower thermo-dynamic efficiency up to 1000 to 2000 HP, especially under partial loads, if compared to the steam motor. The same quantity of steam therefore allows a higher output with a steam motor than with a steam turbine."

These points support the view that while the initial cost of a steam engine is higher than that of a single-stage steam turbine, the overall cost of the complete boiler plant/power station installation is generally lower.

6.4.1. THE STEAM ENGINE

The two earliest "modern type" steam engine designs were the Willans (built 1884) which, before it was rendered obsolete by the steam turbine in 1904, had a formidable rival in the double-acting engine built by Belliss and Morcom (W154) (pattented 1890), which is still being built by the same company in Birmingham, England.

Other non-marine engines built today are few. The only modern type is the steam motor, a vertical unit by Spilling (W46). There is a Brazilian Lokomobile unit by Mernak, and there are a number of Thai engines built by individual shops in Bangkok. These are mainly compound engines based on a classic design (about 1900), probably by Marshall.

6.4.1.1. Steam engine types. A simple steam engine is one in which the expansion of steam is completed in one cylinder. A compound steam engine is one in which the steam progressively expands in two or more cylinders. The term compound, without qualification, refers to the two-cylinder arrangement. Triple expansion means that the expansion is completed in three stages or cylinders, and quadruple expansion that the expansion is completed in four stages or cylinders. Compound engines may have the cylinders arranged in various ways: tandem-compound (cylinders placed one behind the other in line), angle-compound, (cylinder

axes placed at right angles to one another), cross-compound (cylinders arranged side by side), and vertical triple-expansion (three cylinders placed with axes vertical).

Engines with expansion-valve gear with single, compound or duplex configurations were built up to almost 300 HP.

Engines with drop-valve gear were built as single cylinder, two-crank compound, tandem compound and triple expansion engines up to 3000 HP.

"Lokomobile"-type semi-portable engines were built as single cylinder and compound engines up to 800 HP.

Uni-flow engines with positive drop gear were built to supply up to 2000 HP.

6.4.1.2. Belliss & Morcom engines. The presently built series of engines has been continuously in production since 1890. These engines are two-cylinder vertical engines, in the 100 kw to 500 kw size range. If oil-free exhaust steam for process use is desired, engines can be operated as NCL (no cylinder lubrication) on dry saturated steam.

Typical steam consumption figures for these enginges in back-pressure operation were presented in Table 16.

6.4.1.3. Mernak. The only engine of the Lokomobile type built today is manufactured in Brazil by Mernak (W7). They offer two series of engines with the following specifications shown in Table 26.

Table 26

Specifications for Lokomobile-type engines (Mernak)

Nominal Rating	120/140 HP	170/190 HP
Stroke & bore	1600 x 350 mm	1800 x 350 mm
Speed	220 rpm	230 rpm
Pressure	12 atms	12 atms
Wt of unit	16500 kg	19800 kg

Not much is known about these engines outside of South America, although Balerdi (W1) is using them and is familiar with all their aspects. The design appears to follow closely the older Buckau R. Wolf engines, one of which Bianchi (24) had installed: a 195 HP, 12 atm, 340°C unit that used only half of the husk produced to drive the mill. He purchased a second Buckau R. Wolf engine in 1955: a 380 HP, 18 atm, 340°C unit which gave an excellent performance, pulling more than the 380 HP load using one ton of husk per hour. This compares closely with the performance of both the Tulio (W134) and the SML (W144) modern plants, with their conversion ratio of 400 HP ton of husk, or about 4 kg steam/1 kg husk, but it is a considerably higher figure than earlier reported consumptions of Buckau R. Wolf engines.

6.4.1.4. Spilling. The steam motor furnished to a great number of modern installations is built in Hamburg by Spilling (W46). These engines range from 1 to 10 cylinders, with 70-1700 lb/in^2 (5/114 atm) inlet pressures. The back pressure is one half of the inlet pressure or less. The bore of the engine is changed to match the desired power output to the available pressure differential. These engines can also be furnished NCL.

6.4.1.5. Thailand. In the workshops of Bangkok, a great number of steam engines can be seen under construction by the rice-mill manufacturers who furnish most of the equipment for the mills. As most Thai mills are still lineshaft driven with husk-fueled steam plants, and as there are no other engine manufacturers still operating (in these sizes) in the Western countries, the Thai shops have used a tried and proven (probably Marshal) design

and constructed a matched engine to accompany their rice mills. In some cases the boiler is also built by the same shop (W150), but elsewhere (W149) the boiler is built in another independent shop (W148) and is purchased by the contractor to go in with the new mill and engine. Imasuri (W146) states that there are at least 24 shops in Bangkok capable of supplying a complete rice mill. Two such shops build single and compound, single- and double-expansion engines with specifications shown in Table 27.

Table 27

Specifications for Thai-manufactured steam engines

	Lee (W150)	Kwang (W149)
Horsepower	75 (for 10" engines)	?
Bore-large	18" or 14"	15" - 10" (2 cyl.)
Bore-small	12" or 10"	10" - 6"
Stroke	24"	?
RPM	105	?
Inlet pressure	150 lb/in^2	?
Cost	$14,000 (280,000 baht)	?
Rice-mill paddy capacity	4 tons/hr	?

It is said to take two months to complete the steam engine and six months to build the complete rice mill. The crankshaft billets are forged in Singapore, but all other pieces are apparently made in Bangkok.

An adequate number of used engines are said to be available on the market.

Thai engines and rice mills are exported (newly installed Thai engines exist in Malaysia), but their boilers are not.

6.4.1.6. India. No engine manufacturer appears to exist in India, but a large number of used engines and generator sets, mostly from other industries than rice, are to be found on the market. Newspaper advertisements request engines and alternators; one calls for a 150/200 BHP, 140 lb/in^2 engine and another for a Belliss & Morcom, 250/350 kw generator set, 140 lb/in^2; this indicates that a viable market exists for this type of equipment, and that the market requirement can be expected to be filled.

6.4.2. STEAM TURBINES

The availability of turbines for husk-fueled applications is much greater than that of engines. In the traditional rice mill, most prime movers were engines and from a numerical point of view, engines still outnumber turbines in new installations today. However, in any planned, sophisticated installation, the engineering studies should include parameters reflecting all facets of the proposed installation. Only after a wide-ranging consideration of the mill requirement, the process requirement and cost balancing factors, should the selection of the components be made. While no such installation has ever been attempted, it would be interesting, since all individual-drive rice-milling machines are designed for electric motors, to consider an installation using small individual steam turbines.

6.4.2.1. Types of turbines. Figure 25 shows the principal types of turbines manufactured today for commercial applications. The turbine may have from one to many stages, according to the design requirements of the installation.

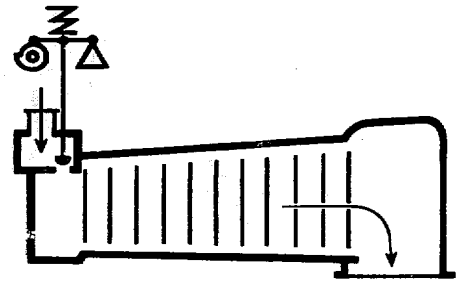

Non-condensing

A straight non-condensing turbine is the economic choice when all exhaust steam can be used for process or heating.

If high-pressure steam is available for the turbine and the lower pressure exhaust can be used to supply other prime movers or a process, a non-condensing turbine can be applied to increase power output for the same fuel consumption.

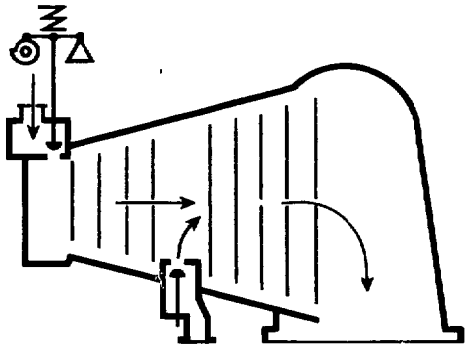

Condensing mixed-pressure

A condensing mixed-pressure turbine automatically uses as much low-pressure steam as available, supplementing it with as much high-pressure steam as required to carry the load. This type is used when more power must be generated than is possible with the available low-pressure steam.

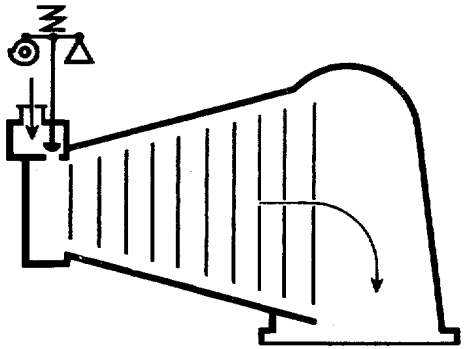

Condensing

A straight condensing turbine is used when electrical power generation is the only concern and it must be produced on a minimum amount of steam. To improve the plant's efficiency these units can be provided with multiple uncontrolled extraction openings for feedwater heating.

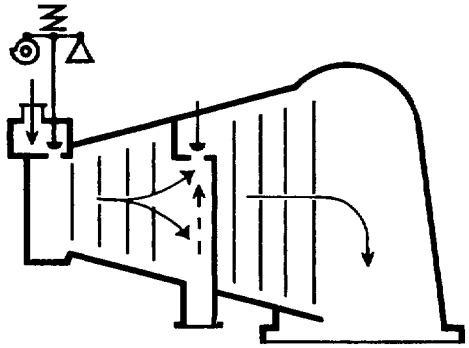

Mixed-pressure extraction

This unit operates either as a mixed-pressure or an extraction turbine, depending on steam balance. As the turbine generates power, it holds constant pressure on the low-pressure steam line, extracting or admitting steam as required.

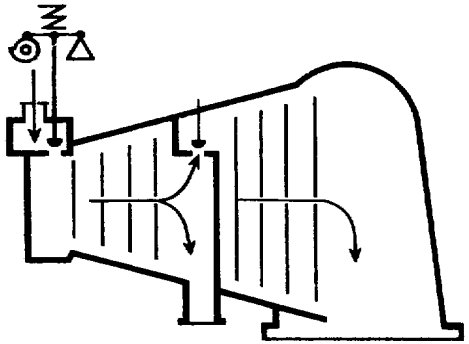

Condensing controlled extraction

A condensing controlled extraction turbine bleeds off part of the main steam flow at one (single extraction) or two (double extraction) points. It is applied where process steam is required at pressures below the inlet pressure.

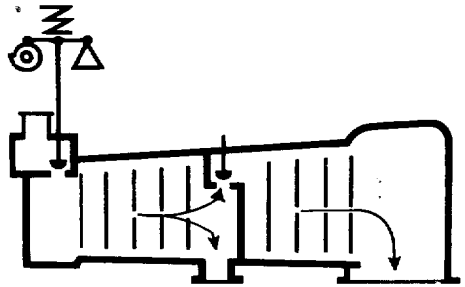

Non-condensing controlled extraction

A non-condensing controlled extraction turbine bleeds part of the main steam flow at one (single extraction) or two (double extraction) points. It is applied where process steam is required at several different pressures with variable or intermittent flows.

Figure 25

Principle types of turbines (after Worthington)

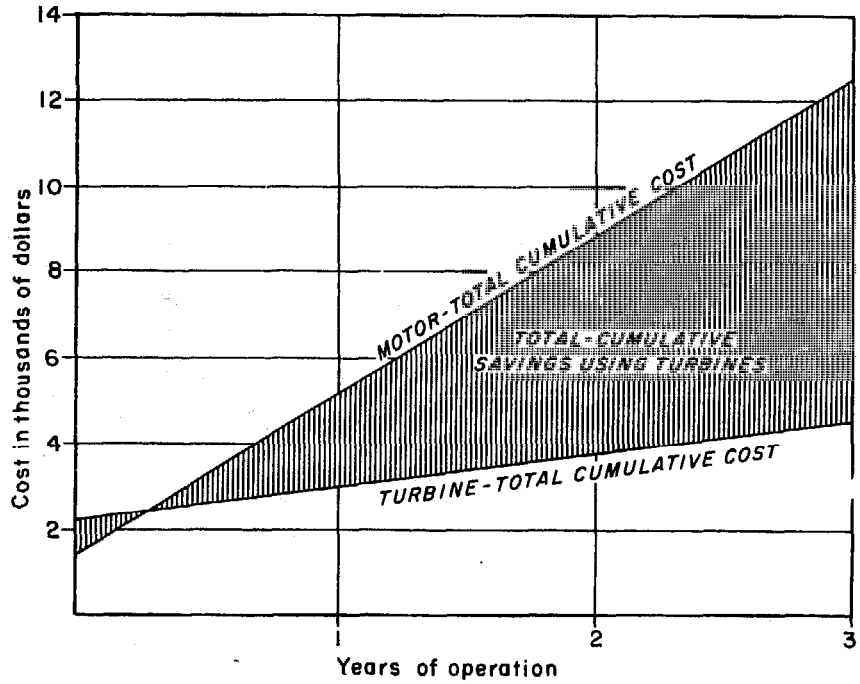

Figure 26

Cumulative costs: turbine vs. electric motor (400 HP)
(after Coppus)

6.4.2.2. Turbine applicability. The use of a steam turbine in preference to other prime power sources (such as electric motors) will not only help conserve a precious fuel supply but will effect significant reductions in initial capital investment and overall operating costs. For a cost comparison, see Figure 26.

Wherever high-pressure steam is available and there is a need for low-pressure (zero to 50 lb/in^2 gage) steam for heating or process work, a steam turbine can save a high percentage of the cost of energy required to operate other types of mechanical drives by developing practically "free" horsepower while acting as a pressure-reducing valve. Historically, the "free" horsepower has been evaluated in terms of financial savings, but with the present energy shortage, it is critical to evaluate steam turbine characteristics on the basis of fuel conservation.

Steam turbines are manufactured to specifications according to various parameters such as inlet steam pressure, comparative desired extraction points, exhaust or back pressure, brake horsepower output, speed, etc. Economic steam rates over a wide range of power requirements can be obtained. The various factors which affect steam rates are:

- speed - high turbine speeds afford improved steam rates;
- total temperature of steam - high total temperatures (degree of superheat) improve steam rates;
- inlet steam pressures - high inlet pressures improve steam rates;
- exhaust pressures - low exhaust pressures improve steam rates.

The use of the steam turbine as a motivating power for rice milling with required steam is highly advantageous in cost-saving and supplementation of critical energy. Various turbine manufacturers indicate that the present turbine design can be readily adapted to the use of steam from a rice-husk boiler. Boiler manufacturers can also modify their boilers to accept husk as fuel. In various countries, most of the steam generated by many small boilers in use is used to provide steam for parboiling, as these units are rudimentary and inefficient. Fire-tube boilers which produce steam pressure as high as 378 lb/in^2, which is suitable for turbine operation, are being used in Surinam.

6.4.2.3. Size and cost of turbines. Discussion is always possible concerning the practicality of a turbine as an engine and the availability of a full range of sizes for the different machines. Engines are available from small (50 HP) to moderately large (3000 HP) units. Turbines are available worldwide in a complete range: micro (less than 1 HP) to leviathan (500,000 HP). The range of sizes suitable for using rice husk as a fuel runs from 1-5 HP small, individual-drive machines to 300-500 HP prime movers, and on up to 5,000 kw power generators. The largest rice-husk fueled power-generation unit that has been proposed (Indonesia) is 5,000 kw. The largest husk-fired power plant that has been built (Philippines) is 1920 kw, and the largest turbine unit appears to be the 1200 kw Surinam unit.

Several years ago Schule (W44) studied in considerable depth the eternal question of engine or turbine. Their best judgement was that the crossover point was at about 500 HP, under this figure the engine being preferable, and above it the turbine.

Blohm & Voss, a reputable turbine manufacturer, feels that 500 HP is the minimum practical size.

However, Triveni (W85), Indian licensee of Peter Brotherhood, U.K., builds much smaller turbines, down to 200 HP, as do many other manufacturers. Terry-Kuhnert (W49) offers models down to 35 HP.

As for cost, a February 1975 Nadrowski (W41) tender quoted a 900 HP turbine generator set at $54,000.

6.5. GAS-PRODUCER SYSTEMS (See also Section 6.3)

Systems for the production of gas have been used since about 1900. Their designs and layout can be classified simply: classic (traditional) and modern. The flow pattern of both is similar, but some of the components have slightly different functions.

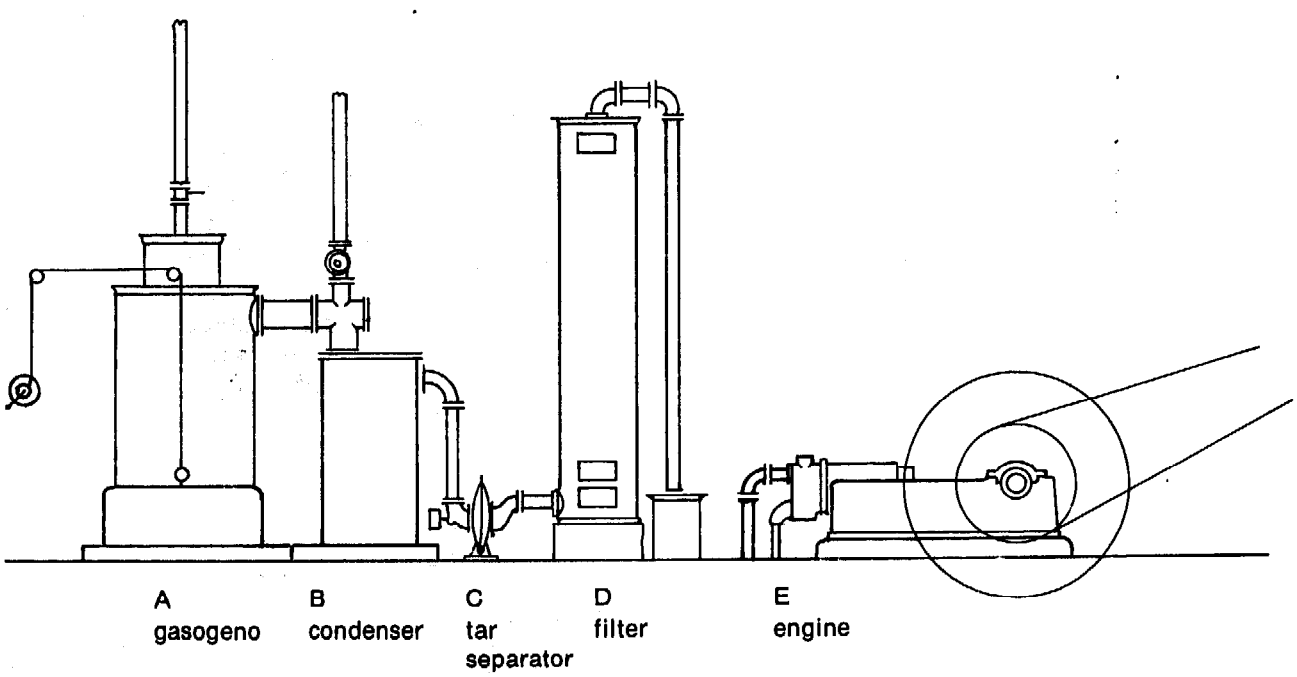

Figure 27

Classic gas-producer system (Monticello)

The classic layout shown in Figure 27 reflects almost exactly the existing unit at Monticello (W92). Balestra designed the gasogeno, which was constructed locally in 1940; it requires about 200 kg of husk per hour to provide 60 HP, adequate to drive the small rice mill. The engine is Italian built--Langen & Wolf--60 HP, 300 rpm.

6.5.1. MODERN SYSTEMS

The modern system can have the same flow pattern as the traditional, or it can include the features of a dual (pilot) fuel system. This concept was explored by the British (134, 135, 136) in the 1950s. The concept is commercial today using fuel other than rice husk, but there is no reason for not using rice husk if an adequate supply can be obtained. Many of the constraints of design and cost surrounding the traditional system are eliminated when dual (pilot) fuel operation is selected. Duvant (W20) has pioneered the installation of dual (pilot) fuel engines, normally of larger size than would be used in driving a small rice mill, but this only because commercial demand has been for units as generator sets in the 1000 kw range.

Italian gas generators have been built from 20/220 HP sizes. Some are provided with devices allowing fully automatic unattended operation. Once started up by a properly instructed operator, no further attention need be paid to the unit until shutdown. On a stationary unit, starting is no problem; if no other method is available, a hand-operated fan will initiate operation.

6.5.2. GASOGENO (PRODUCER-GAS GENERATOR)

A gas-producer consists of a vessel arranged to hold a fuel bed having gas-tight means of charging fuel and facilities for removing ash. The vessel must be capable of withstanding high temperatures and must incorporate features to admit air and steam or water for the process and to take off the gas which is produced.

Producer-gas is made by burning fuel to ash by means of a mixture of air and steam, the resulting gas being a mixture of burnt and combustible gases. The combustible portion of the fuel consists mainly of carbon. When air comes into contact with hot carbon, the latter is burned to a mixture of carbon monoxide (partly burnt carbon) and carbon dioxide (completely burnt carbon), together with nitrogen from the air. If air only is used, the producer becomes very hot and the ashes melt and form a fused ash.

Steam or water added to the air blast prevents the temperature in the oxidation zone from rising too high, thus reducing the tendency to fused ash formation. At the same time is itself preheated until it reaches a temperature sufficient for the steam to be decomposed to form a mixture of hydrogen, carbon monoxide and carbon dioxide. Thus the primary reduction zone is formed.

In producer plants delivering cold clean gas, the termal efficiency, usually expressed as the cold gas efficiency, is the ratio of potential heat in the gas produced to the heat available in a unit weight of fuel. The sensible heat in the gas leaving the producer should be used as effectively as possible for preheating the fuel, so that as much as possible of the original heat in the fuel appears as potential heat, and not sensible heat, in the gas.

A full range of cellulosic wastes, including rice husk, has been used as fuel for producer-gas generators. The first successful gas-producer is generally attributed to Bischof of Germany in 1839. An improved design was introduced into England in 1861. Table 3 shows constituents of producer gas manufactured from rice husk.

Rice-husk gas-producers were in use in the early 1900s; as the Schule 1910 catalogue was advertising for sale a suction gas-producer for engines with an output to 120 HP.

There was also use in Burma, but details are unavailable. The earliest details found in the literature are in the Italian (142A) and French (120) journals, which in the 1920s reflected considerable activity on gasogenos. It was not, however, until Balestra, in the 1930s, designed an improved gasogeno that the use of rice husk as a producer-gas fuel became a commercial reality. Producer-gas generators using rice husk as a fuel, the driving of rice mills with internal combustion engines using that gas, and the blending of rice-husk gas with other commercial gases, are purely an Italian accomplishment of the 1930s and 1940s. One unit at Monticello is representative of many of the units of that period.

6.5.2.1. Design of gasogenos. In order to realize the full potential of the use of rice husk as a gasogeno fuel, the gas-producer must be designed -

- to give a gas having the highest calorific value;
- to enable the use of a fuel carrying a maximum volatile content;
- to have a controlled gasification and fire zone, embodying a sufficiently high temperature, to convert the substances produced from the volatile matter in the fuel into fixed gases, so as to ensure that purification of the generator gases will occur satisfactorily;
- to give the foregoing results without complicated mechanisms calling for skilled operation and adjustment, and also without heavy refractory linings requiring frequent replacement in the fire zone.

Attention must be given to rendering the gasogeno regenerative by utilization of otherwise lost heat to raise the temperature of the feed water to steam or to the highest temperature possible. The use of a wet-gas producer, when combined with the necessary in-line filters and scrubbers, affords an 11% increase in the BTU value of the gas produced and a 14% increase in the percentage of combustible gas. Any stationary gasogeno can easily be arranged as a wet-gas producer with the necessary accessories.

In order to provide a cool, filtered gas product, it is best to use a two-stage cooler for the hot gas from the generator: first the feedwater steamer, and second the cooler/scrubber-washer.

The hydrogenation of the fuel while it is undergoing gasification gives rise to reactions that are of a very intricate nature due to the complex substances treated, and many of them are not fully understood. The aim of every designer of a gas-producer is to encourage and assist the chemical changes which result in the production of the combustible gases CO and H_2, at the same time keeping the non-combustible gases, CO_2 and N_2, in as small a volume as possible.

The classic arrangement and the one from which all subsequent variations have been forthcoming, together with the fundamental reactions, is shown in Figure 28.

6.5.2.2. Types of gas-producers. There are three fundamental types of gasogenos (see Figure 29):

a. updraught type
b. downdraught type
c. crossdraught type

Maheshwari (W63) describes these various producer-gas units as follows: "In updraught producers, the flow of air and gas is in an upward direction; it is in a downward direction and current-wise with the fuel flow in down draught producers. In cross-draught producers, the flow of air and gas is across the producer, though not necessarily in the same horizontal plane. The fuel flow is downward.

"The first gas-producers were very simple, consisting of vertically mounted cylindrical steel shells lined with fire bricks, an opening at the top for charging fuel, and an opening

at the bottom for cinder removal. A third opening at or near the top of the cylinder provided an outlet for the discharge of gas. Grates were installed inside the shell near the bottom to hold the ash bed and to secure an even distribution of air through the fuel. The air was admitted either by suction or forced draught. It was called a built-in producer with horizontal grate.

"The next development in producer construction was the semi-extended type, which partially projected from the main setting. It was more accessible and permitted easier charging and leveling of the fuel.

"The attached gas-producer further simplified its operation by eliminating the difficulties encountered with other types. The attached producer was equipped with water-cooled step-grates and curtain walls, and could be operated with either natural or forced draught."

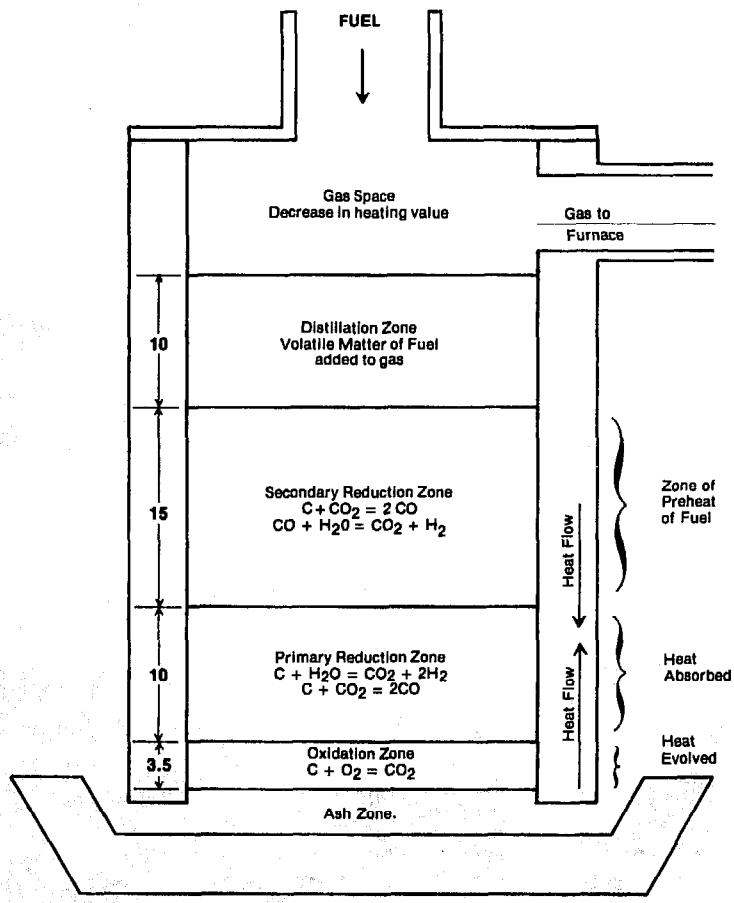

Figure 28 Gas-producer arrangement and reactions

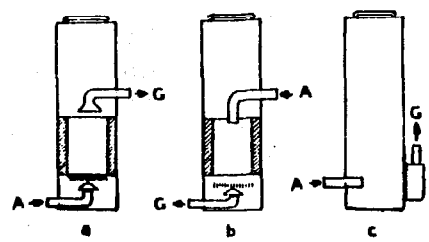

Figure 29 Types of gas-producers

6.5.2.3. Manufacture and design.

a. Deutz (116, 117). Pre-World War II activity involved the use of alternative fuels, and this resulted in the design and subsequent patenting of a rice-husk fueled gas-producer in Germany.

b. Romana (131). Developed a converter of rice husk to produce gas. The generator was equipped with a continuous-feed arrangement, a gas scrubber, a tar extractor and a gas-receiving tank. The gas generator consisted of a steel cylinder lined with fire bricks. The rice husks were charged from the top onto a grate at the bottom. The generated gas was

the product of incomplete combustion of rice husk in a deep bed of several feet. The gas produced was withdrawn at the top of the gas generator and passed through a wet scrubber for cleaning and cooling. From the top of the scrubber, the gas was sucked into a centrifugal tar extractor and then was collected in the gas-receiving tank. A 10 HP engine was run on the producer-gas supplied by the generator.

It is not known whether any further development or commercial use was made of the Romana effort.

c. Neil & Spencer (W160). During World War II, this company was a major manufacturer of automotive coal-fired gas-producer units. They have recently designed a modern unit for use on trucks or buses. Their expertise concerning gasogenos is available whenever a commercial response to gas power-generation from rice husk appears.

d. Powergas Ltd (W157). The pioneer company of producer-gas technology was formed in 1901 to exploit the patent of Dr. Ludwig Mond. After that date Powergas was the builder of a full range of producer-gas installations utilizing every conceivable fuel, including rice husk. Their standard units ranged from 50 to 1000 HP - 3800 to 7500 ft^3/hr. As the commercial demand for these units dwindled in the face of the availability of oil and natural gas, manufacture ceased. Today the expertise and capability of the company lie with their former engineers and designers, Brockwell and Milner (W156).

e. Wellman. Lustig (122) indicates that this company has manufactured gas-producers for many years. A typical Wellman gasogeno has a 72-inch inside diameter and a capacity of 51,600 ft^3/hr. This unit is a double fire-zone producer with internal gasification and cracking of tarry heavy hydrocarbons. Average BTU value for produced gas is 135 BTU/ft^3 or about 7,000,000 BTU/hr. Efficiency is 70 to 75%, and consumption of rice husk is about 1700 lb/hr.

A low-pressure gas engine consumes 10,000 BTU/HP/hr, while a dual-fuel engine on the diesel cycle requires only 8,000 BTU/HP/hr, 20% less than the gas engine. Of this, 80% can be considered as coming from the gas portion of the fuel, representing a power output of 1100 HP from the use of 1700 lb/hr of rice husk, or 1.5 lb/HP/hr.

f. Dual-zone producers. It is possible to take advantage of local use factors in dual-zone operation of a producer-gas unit, wherein the gas produced in the hot zone is used for internal-combustion engine purposes and the lower BTU gases are channeled to a furnace or drying system.

g. Lacotte (W19). Gas-producers utilizing the "système de Lacotte" have for many years been operating in France and other countries. This system has advantages both in efficiency and in maintenance costs, particularly when charcoal is desired as a by-product. The system utilizes a split gas-stream from an external combustion area that in cracking the tarry components delivers an essentially clean gas from the gasogeno. The high ash content and silica nature create some conditions in this gasogeno not previously encountered This system has thus far never utilized rice husk as a fuel, and possibly some design changes would have to be incorporated for this use. Testing of rice husk as a fuel has been arranged.

6.5.2.4. Constraints. One of the problems of gas-producer systems is the use of a water scrubber to clean the gas; the treatment or disposal of the effluent must be taken into consideration if a water scrubber is being contemplated. The earlier practice was to dump the water mixture, but that approach may no longer be possible.

On the other hand, in the scrubber hot water is produced which might be utilized for some benefit. The production of tar and tar oil is a factor if the system is large enough to make the commercial aspect of tar production a viable consideration.

In earlier times, problems of corrosion created design difficulties, but the proper selection of construction material easily solves them. Some 45-year-old operating gas-producers show no evidence of corrosive deterioration.

In some of the early gas-producers in which the engine was connected direct, when the engine was necessarily or accidentally shut down, this caused the gas to build up at the top of the gasogeno. Air coming in at the bottom, an explosive mixture resulted. Balestra designed a cheap workable design that solved this problem; therefore, this type of unit even today carries his name.

6.5.3. PRIME MOVERS FOR USE WITH PRODUCER-GAS SYSTEMS

The low-BTU gas generated by a gas-producer may be utilized in several ways: a) as a fuel for boilers, kilns, dryers or any other equipment in which the gas is burned in a suitable burner and the heat is directed to its end use; and b) as a fuel for a prime mover, an engine (internal or external combustion) or turbine that can provide either power for driving the rice mill, or for another use (electrical generation, etc.) outside of the milling operation.

6.5.3.1. Internal-combustion engine. Producer-gas has been used in conventional combustion engines at low efficiency. As for conventional fuels, air must be mixed with the producer-gas before it can be burned in a conventional 6.5:1 compression ratio) engine. The heating value of this mixture is approximately 68 BTU/ft^3, while petrol is rated at 94 BTU/ft^3. This means that an engine operating on producer-gas develops 30 to 40% less power than when operating on petrol (see Heywood (115)). To compensate for part of this power loss, the most common practice is to increase the compression ratio. By increasing the compression ratio from 6.5 to 8, about 70% as much power can be expected from producer-gas operations as from petrol. A higher ratio could be used, but this would introduce difficulties in petrol operation. The requirement of equivalent power gives an advantage to the consideration of burning producer-gas in a diesel engine.

It appears that a properly designed turbo-charged intercooled dual-fuel diesel would therefore be the most capable of dealing with the need of producer gas for higher compression ratios. However, when the efficiency of the systems can be lower (because of the high availability of fuel) the use of a derated low-compression spark-ignition engine, new or used, may be the best overall choice. The capital cost will obviously be much lower, and this alone may justify the use of such a system.

In deciding the gas feed for use in internal-combustion engines, the primary consideration is that the calorific value of the gas should be high; its composition matters comparatively little, and provided that the content of combustibles is high the saturation temperature of the blast is immaterial. Gas which is to be used in internal-combustion engines must be completely rid of tar and dust, and it should be cooled to atmospheric temperature before entering the engine.

6.5.3.2. Available engines. There are many manufacturers of small oil- or gas-engines which could be used as rice-husk fueled prime movers. The usual choice would be a traditional horizontal engine of the Ruston type, built in the first half of the century in almost every country. Today this type of engine is being built in India: Kirloskar (W80) and Greaves (W77) are among many others currently building it in series production. The use of modern higher-speed engines for use with low-BTU gaseous fuels is being further developed by Horsfield (W219) and by Paddon (W161). There are a number of manufacturers of diesel engines throughout the world whose engines would be suitable for conversion to dual-fuel operation utilizing producer-gas as a fuel. However, only one, Duvant (W20) is known to be currently offering engines and accessories "off the shelf" for producer-gas operation. As soon as there is a demonstratable commercial demand, the availability of the necessary engine types should be widespread.

6.5.3.3. Engine conversions. Some of the features of engine conversion and its problems are cited by Giffen (113) and the Ministry of Fuel (136). Conversion of any internal-combustion engine to producer-gas or dual-fuel operation is in fact possible.

One advantage of the development of techniques for engine conversion to producer-gas operation is to enable the utilization of used engines that are commercially available. In many countries, used diesel engines have been utilized to power rice mills for many years. These engines would be very easy to convert for dual- or pilot-fuel operation. To modify a petrol spark-ignition engine, new or used, is more difficult if a comparable power output is desired. Therefore, in any study of the use of gas-producer engines for prime movers, the existence of used or second-hand diesel engines should be a favourable factor.

To compensate partially for the reduced volumetric efficiency and lower calorific value of producer-gas, spark-ignition engine conversions should theoretically be accompanied by an adjustment to increase the compression ratio.

However, for practical reasons this compensation cannot be arranged because -

- it entails expensive major engine modifications unlikely to be practicable in an emergency;
- to create the initial draught through the fire bed of the gas-producer, the engine must be started up on petrol of a quality suitable to its compression ratio. If the compression ratio is increased beyond the detonation point of this petrol, serious damage to the engine may result.

In high-speed engines, the slower burning of producer-gas in the combustion chamber necessitates a greater advance in the ignition timing, although this is affected in some degree by the hydrogen content of the gas: the lower the hydrogen content, the greater the amount of advance tolerated by the engine. As a general rule, about ten degrees of ignition advance over the normal petrol setting should be made.

When converting a compression-ignition engine to producer-gas, ignition problems are simpler to handle, and to overcome the slower burning of the charge the injection timing of the fuel pump is advanced to approximately 32 degrees before top head centre. This may vary slightly with the type of engine being converted. But as the sole reason for these conversions is to compromise in the use of liquid fuels, modifications to the fuel pump itself are necessary.

6.5.3.4. Dual (pilot) fuel engines. Dual-fuel engine development by the British (136) in the 1950s has shown that commercial development of this system is possible on a large scale. In 1947 Lustig (122) described design and development work on dual-fuel engines and improved gas-producers by Wellman Engineering Company. The use of a Bruce MacBeth engine proved successful and provided on rice husk a fuel rate of about 1.7 lb BHP/hr. Current investigations by Paddon (W77) are further enhancing our knowledge and expertise on such engines. Commercial utilization in France, such as the engines built by Duvant (W20) show the economic possibility of use of producer gas derived from cellulosic fuels.

The dual-fuel system implies a true alternative fuel utilization, in which any amount or proportion of the available gas supply is intended to be used. Most installations within this concept comprise liquid fuel use at about the 20% level. To be preferred, however, is pilot-fuel operation, wherein the pilot fuel is used mainly to start the engine easily, and to be available in case of overload of the gas fuel availability, or of non-availability of the gas fuel. Thus, under normal conditions, the basic concept is to use the pilot fuel (usually diesel) for lubrication and cooling of the injection system at a 5 to 10% level of total fuel requirements.

Advantages of dual-fuel engine operation include:

- normal starting;
- total power available (instead of 60% on straight engines);
- lower engine cost (through the use of low conversion cost production diesel engines).
- wear and tear on engine much less (see Section 6.5.3.5.);
- ability to utilize high compression ratio and therefore high efficiency (tests[1] have shown that low BTU fuels work best at compression ratios of 14:1 or more)
- a marked decrease in fuel cost, as only about 10 to 20% of fuel needs to be purchased.
- complete engine/power system availability even if no indigenous fuel is available. This would be advantageous for operation as a power system; in case of need for continous operation, rice husk is an entirely adequate supplemental fuel.

6.5.3.5. Wear in producer-gas engines. It has been said that increased wear on the cylinders and bearings of the engine is inevitable, because of the abrasive dust carried over with the gas, and also because of the increased compression ratio. Such fears are not justified. Experience has proved that the wear and tear of engines run on producer-gas is less than that of petrol engines because:

- the heat of the explosion, or detonation, of gas is very much lower than that of petrol vapour.
- the detonation of gas is not of the same intense explosive character, but rather more of the nature of heat expansion;
- the gas being dry and relatively cold, dilution of lubricating oil does not take place as in petrol vapour which, if not properly vaporized, enters the cylinders as a liquid;
- no carbon deposit is occasioned by the burning of producer gas, and, consequently, decarbonization of cylinders and valve grinding is reduced to a minimum;
- the purification and filtering of the gas is, and can be, so effective that a gas more than 99.5% pure can be expected; with the use of correct filtering procedures, this ensures that no deleterious or corrosive gases are carried over with the combustible gas.

6.5.3.6. Starting of producer-gas fueled engines. The drive can be started in one of several ways:

- In dual-fuel/pilot-fuel diesel operation, the engine starts as a diesel and uses the producer-gas as supplemental fuel up to a point of 10% diesel, 90% producer-gas.
- Petrol engines with lower compressions start on petrol; after temperatures and gas production have leveled off, the petrol is shut off completely. This is necessary where the initial gas flow of the gasogeno is induced by the engine vacuum.
- Compressed-air starting and gas-flow induction is normally used only on larger engines. It requires a gas holder.
- Electrical starting motor systems are normally used only on smaller engines. It requires a gas holder and an adequate battery.

1/ S. Neyeloff and W.W. Gunkel, in a paper presented at the 1975 Agricultural Waste Management Conference at Cornell University.

6.5.4. GAS TURBINES

The success of gas turbine technology is a well-known fact. The more common image of a gas turbine is for propulsion, but there are numerous successful installations of gas turbine driven electric generators. There appear to be none, however, fueled by rice husk.

Investigations indicate that to obtain hot combustion gas produced by the burning of rice husk is highly feasible and practical. There exist at least four proved methods of burning husks to produce gas which reaches an adquate (930°C) temperature, the first three of which require excess air for combustion: 1) burning in conventional furnace; 2) burning in suspended air; 3) burning in fluidized bed (for simplicity, a fluidized bed may be classified as burning in suspended air); and 4) producer-gas generator. (See Figure 7.)

However, the practicability of a generation system such as 1, 2, or 3 above, using rice husk as a fuel, is doubtful. The low efficiency of the turbines and necessary use of a low-BTU gas, coupled with the filtering problems ahead of the turbine because of the detrimental effect of particulate matter on the turbine, are negative factors.

The big problem facing any nation contemplating such a utilization would be the choice between constructing large incinerators or relatively small packaged units to minimize transportation costs. Only in a very few isolated circumstances would it appear practical to use such an installation for rice-husk utilization.

The only known project that resembles a conceivable rice-husk fired gas-turbine power system is that of Combustion Power Co. Inc. (W171). Its federally assisted development project features a 15,000 kw gas turbine generator set. Hundreds of such units consume 400 tons per day of solid waste--the amount generated by 160,000 persons--to produce between 5 and 10% of the total power consumed by the same number of people.

No consideration has been given to the utilization of rice husk in this unit.

The advantages of utilizing rice husks to produce heated gas which in turn drives a turbine engine to produce electricity are obvious; however, gas produced by most incinerators contains abrasive particles and requires filtering before it can be introduced into the turbine. Removing particles from the gas stream at a temperature of approximately 930°C requires an expensive filtering system.

The producer-gas generator (system 4 above) could provide a simple soultion as a gas supplier to a combustion system incorporating a gas-turbine prime mover. The producer generators can be expected to provide efficiencies in the 70-75% range, and this would increase the feasibility of such a system.

6.6. CARBONIZERS

Carbonizers, as differentiated from gasifiers, normally include only the units having both the form and the purpose of the carbonization units currently being built and used in Japan, which are processing primarily for husk disposal the recovery of the char, or carbon, rather than for the gas produced or for a combination of these. In some cases the fuel gas derived from the unit is utilized as a drying fuel, but generally it is not. It can be expected that there will be a gradually increased utilization of the fuel gas and an incorporation of more efficient processes in the near future.

It is an error to consider the residue from these carbonization furnaces as a charcoal in the same sense as a wood charcoal. The rice-husk char contains a large percentage of ash, considering that the normal analysis of husk is 10% moisture, 20% ash, 50% volatiles, and 20% carbon. A carbonizer burning no fixed carbon would produce about 50% of ash. If 50% of the available carbon is burnt out, this would leave about 65% ash in the char.

However, the product produced today in Japan is marketable and serves its market well.

6.6.1. CHARRING

Usable char can be produced in either of two primary methods:

1. Burning or incineration - excess of air
   The husk can be ignited in a suitable burner-incinerator in which the heat of combustion is utilized to maintain ignition. In this event, volatiles and smoke would be emitted, and must therefore be trapped or entrained in suitable condensors and/or precipitators in order to avoid air pollution. The products of the incineration process are then -

   a) the charred husk, consisting primarily of silica and carbon;
   b) the solids and liquids separated from the exhaust;
   c) exhaust gas, principally carbon dioxide and water vapour.

2. Pyrolysis or distillation - controlled atmosphere
   Husk can be heated in an inert atmosphere to drive off all natural and pyrogenic volatiles. In this event, heat is required (e.g., by combustion of natural gas), and the volume of condensed products will be considerably increased since none would be burned off. The products of the destructive distillation are -

   a) the charred husk, essentially the same as above;
   b) the distillate, consisting of water, organic liquids and tars, together with some particulates;
   c) additional solids entrained in a downstream precipitator;
   d) exhaust gas, principally carbon monoxide and/or hydrocarbons, that can be cycled to the fuel gas.

Most furnaces can be used as char producers by allowing the combusting husk to cool before all of the carbon has been burned from the silica maze. However, there is a great difference in the char produced by the burning-type units as compared with the pyrolysis units: the homogeneity of the residue can vary widely in incinerators, whereas the controlled-atmosphere units enable much closer control.

Furnace burning units have been described in Section 5. The residue from any of these systems is or can be char.

6.6.2. DETAILS OF CARBONIZERS

6.6.2.1. Institute of Agricultural Machinery (IAM). Ban (W103) and Shimizu (W104) have developed and tested the IAM system combustion furnace.

The test data in Table 28 indicate results, with varying parameters, of this continuous, low-cost unit.

Table 28

IAM combustion furnace (test data)

Air feed rate	m^3/min	0.18	0.17	0.48
Feed rate	kg/hr	5.44	10.47	8.00
Residue outturn	kg/hr	1.24	2.41	3.42
Residue as % of input	%	22.8	23.0	42.8

Table 28 clearly shows the increase in yield of char upon the increase of feed air. This result is entirely in line with expectations.

6.6.2.2. Nichiyu-Koki. Equipment designed by this manufacturer (W107), described as "rice chaffs baking equipment" makes chaff charcoal by a forced reduction process while the husks move through a U-shaped gutter. Subsequent to the initial ignition by oil, the husks burn and carbonize themselves without auxiliary fuel.

6.6.2.3. Satake. Equipment for carbonization of husk is furnished by a subsidiary of Satake (W110) on the island of Hokkaido and by another subsidiary, Nihon-Kanetsu, in Tokyo. The unit at Shimodate City, manufactured by Nihon, is a rotary-kiln controlled-atmosphere distillation unit without waste heat utilization and with two stages of product cooling. This same system is used for making activated charcoal from coconut husk.

6.6.2.4. CeCoCo (W101). This company offers six sizes of carbonizers, from 75 kg/hr to 1125 kg/hr capacity, weighing 1200 to 51,000 kg. The four smaller units are designed for outdoor installation. These units are of adequate design and many have been installed.

6.6.2.5. Yamamoto (W112). This company offers equipment described as a "suction-system rice-husk combustion furnace" that produces char and also makes provision for utilizing the stack gas for heat, usually for drying or water heating.

6.6.2.6. Takano (W111) manufactures a suction-system furnace, similar to that in Section 6.6.2.5., with a design somewhat between a producer-gas generator and a controlled-atmosphere furnace. These units have heat exchangers for utilization of the stack heat. Details of heat data when operating at its design feed rate of 340 kg/hr will be found in Section 6.3.2.7. Char production is at 30% of feed rate.

6.6.2.7. Kojima. This system is produced by Kansai Sangro Co. Ltd. (W102) and is offered in a range of sizes. It has been built for the last ten years and to date over 120 units have been constructed, all for installation in Japan. This firm also builds units for CeCoCo (W101).

6.6.3. CONCLUSION

The use of carbonizers is involved in handling about 10% of the husk produced in Japan. There have been many designs of units and methods of processing, most of which show some heat exchanger methods to utilize the hot stack gases, but in actual installations, the exhaust gas is discharged to the atmosphere.

6.7 DOMESTIC STOVES (See also Section 5.2.2.)

There are several general classifications of husk-fired domestic stoves.

- use of raw husk, loose or compacted fill
- use of carbonized husk or husk charcoal
- briquetting

6.7.1. LOCALLY-PRODUCED UNITS

In many countries husk is used for domestic purposes. The stove is either made of local materials or a factory-made unit, but little is known of the latter, which are locally produced. Fabricated units exist both in Japan and India; the Japanese is a pot-fixed grate type, similar to a Hibachi, while the Indian construction is a canister with open centre tube. In Italy, about 50 years ago, there was considerable development of heating units, but those exist today only as drawings and descriptions.

Many countries have both cooking and heating units made from local materials, usually of brick construction with a metal grate and metal lid.

6.7.2. VARIATIONS

The use of carbonized material as charcoal is practical in some areas, sometimes as an additive (266) to other materials, to improve either their burning characteristics or their BTU factor.

6.7.3. BRIQUETTING

There have been several developments concerning briquetting. At least three briquettors have been used or tested in producing rice-husk logs:

- Hullite machine
  Japanese manufacture - this machine has been used to briquet husk; in India there has been a concerted effort to adapt the machine to local conditions, but as yet there has been no commercial application.

- CeCoCo machine (Miike) (W101)
  Japanese manufacture - this machine has been normally used to briquet charcoal.

- Fred Hausmann Briquettor (Glomera) (W162)
  Swiss manufacture - this machine, normally used on wood products, has been tested on rice husk, but no commercial rice-husk applications are known.

Two other machines are known to exist, but details on them are not available.

The use of briquettes or extruded fuel logs has long been common in the utilization of waste wood products. However, their application to rice husk is not without some problems, both in physical manufacture and also in burning. The primary reason for the operation is to provide a cleaner, more easily handled, denser fuel. However, the lack of a binding/bonding component (e.g. wood resin) in rice husk increases the cost of production; the abrasive nature of husk causes accelerated wear of the pressure and conveying sections of the machine. Satisfactory logs from a wood standard of homogeneity are hard to kindle, sustain combustion poorly, have a high (20%) ash content, and do not burn with a pleasant odour. They work better with a movable grate which scrubs the ash from the burning surface as it builds up, allowing a fresh surface to be offered to the combustion air. Some machines feature a product with a hollow core that promotes somewhat better combustion, but only scouring of the surface ash (either external or internal buildup) allows satisfactory use.

7 CONCLUSIONS

7.1 GENERAL

7.1.1. NEED FOR DATA COLLECTION

Data regarding the full cycle of rice production through to its final point of offal utilization are generally lacking or inadequate. No effective, centralized, or worldwide system for accumulating such information, especially that related to rice-husk utilization, exists. This situation also broadly prevails in most of the individual rice-producing countries of the world and is very detrimental to the thousands of persons now participating in projects related to husk-energy research and development or to residue utilization. The single most negative factor in the extension of the use of the energy from rice husk is the inability of interested processors or workers to obtain definitive and accurate information pertinent to their investigations.

Practices in one country do not become used or even known in neighboring countries. Further, in some cases a use known in many countries but the knowledge of its use is totally lacking. Thus, husk, char or ash is used in the steel industry in almost every part of the world, but in most countries the users believe that they are alone in using it. Sometimes it becomes a situation of "reinventing the wheel", wherein a sincere worker believes he has developed a totally new, very comprehensive technique, and will scarcely believe that in nearby countries the very same technique has been standard practice for decades.

7.1.2. UTILIZATION TRANSITIONS

There is greater utilization of rice husk throughout the world than has been generally estimated, but usage for enegery purposes over the past 50 years has fallen by some 80%. The availability of low-priced oil and gas after World War II caused the disappearance of the use of paddy husk as an energy source, as the result of economic pressures and considerations of convenience. During and before World War II there had been great utilization of all such cellulosic products because of shortages and blockades. Even where almost all of the rice husks are still used to produce energy for milling operations, as in Nepal and Thailand, there is less than full beneficial usage because there is no appreciable utilization of the residue.

In other countries, such as Japan, the reverse is true, in that almost none of the rice husk is utilized to produce energy, but is burned to produce char, much more of which than is generally known being channelled into beneficial use.

7.1.3. UTILIZATION OPPORTUNITIES

On the surface, in almost all countries, vital interest is expressed in seeking technologies and processes which would allow utilization of rice husks as a renewable energy resource. However, the introduction of new processes may prove to be very difficult in a number of areas because of traditional considerations. There is an inherent resistance to the adaptation of any new or revised concept that might conceivably damage the innovator. Everyone may agree that a new or reintroduced technique may produce spectacular advantages and results, but no one wants to be the innovator within his own field. The selling of the idea of the first conversion is the hardest task of all.

Actually, in many countries, political and social influences have exerted a negative effect upon rice milling, both from the aspects of yield and milling efficiency. This is especially true where fragmentation of the industry by the emergence of smaller growing and

milling units has resulted in reducing the number of medium or large commercial mills. The problems of utilization of husk from a small mill are far greater than in a larger unit, which has many options open to it for utilization both of the energy and of the residue. The small and very small mill has almost no option other than that of on-the-spot utilization, and usually this is not made because the amount of material involved is trifling.

7.1.4. LACK OF PADDY

There are a number of large, sophisticated milling complexes that are not operating for various reasons. One major reason appears to be that some large mills are not viable where they are located because of the inadequately uniform paddy availability for efficient operation. This is especially true where a large number of varieties are grown in the supply area and are such that co-mingling is not practicable.

7.1.5. PLANT UTILIZATION

Adequate technology appears to be available to provide reasonably full utilization of the rice husk produced in the world and of its derived residue providing some means can be found of acceptably levelling off the high rice-husk production variances which now exist. There has been considerable discussion of the physical characteristics of rice husk, of the variations in production schedules and in the size and concentration of processing mills. It must not be overlooked that most of these problems are overcome when the husk is used as a raw fuel material, generating power or heat to provide at the mill, and in sequence with the mill operation, a concurrent utilization system. If the residue is utilized, a closed-circuit situation exists, in which the husk is considered to be a raw material for a necessary milling function.

7.1.6. MANUFACTURING CAPABILITIES

Manufacturing capabilities for rice-husk energy related equipment are, on a general worldwide basis, greater than previously believed. Manufacture is however more or less concentrated in specific areas. Difficulty is experienced in an "off the shelf" capability of competitive equipment. Only in Thailand is there an integrated competitive supply capability, with 24 producers of heat-related equipment and/or complete rice mills. Five of these 24 are known to be capable of producing adequate, though traditional-type, mills and power plants. In no other country does there appear to be integrated manufacture of components, though several would contract on a turnkey basis. In Japan, furnace and carbonizing equipment is quite highly developed and competitive, though no general use is made of the heat liberated.

7.1.7. HEAT-COUPLING

Technology exists and expertise is available to transform every process-steam user into a highly efficient, completely integrated and self-sufficient supplier of all energy requirements of his milling and processing operations, fueled entirely by the husk available from his milling operations. The physical problems of handling, storing and processing the husk are minimized by this integrated approach. At the same time, a valuable salable residue is produced which when marketed properly can provide additional income, either for amortization of the process plant or for the operator's overall margins. In every rice-milling operation using process steam, the "heat-coupling" possibilities must be considered: this concept can give overall efficiencies of about 65%, whereas the maximum available from normal power generation is not over 22%. Therefore, the motive power used to drive the mill, etc., is obtained at almost a zero cost to the miller, who need cover only charges for amortization, interest and maintenance. Either a turbine or an engine will be equally efficient as the prime mover under equal conditions, but the cost

and practicability of the unit must be determined before a choice is made to fit any given set of conditions. In some cases the determining factors are water-treatment problems more than any other single factor. In the case of a condensing, closed system, however, water treatment is of minimal importance.

7.1.8. PRODUCER-GAS

Producer-gas generators of proven technology exist which utilize rice husks as a raw fuel. This gas can be used for a wide variety of industrial heating and process purposes. In particular, it can be used directly in internal combustion engines to generate electric power at a higher overall thermal efficiency, particularly on a smaller scale, than the most advanced steam turbine installation. In white-rice milling in small and medium rice mills where there is no requirement for steam, the use of producer-gas generators is the only feasible method of utilizing the heating potential of the derived husk. In a small mill with a producer-gas generator the motive power can be supplied in two ways: (1) directly from the prime mover, using a lineshaft mill drive; or (2) indirectly by generating electricity and using individual drives for the rice-milling equipment. The prime mover can be one of three types: (1) an ordinary petrol engine, slightly modified, which on producer-gas will produce about 50 to 60% of its rated power output on petrol; (2) a natural-gas engine of high compression ratio specifically designed for such installations, which will give 100% of its rated output; and (3) a dual-fuel (pilot-fuel) standard diesel engine with minor modifications, running on a fuel mix of 90% producer-gas and 10% diesel fuel, which will give 100% of its rated output. These producer-gas generators are simple. In-country fabrication would be possible, even in areas with the most rudimentary manufacturing capabilities.

Units of this type using rice husk as a raw fuel have been used in powering rice mills for at least 75 years. Admittedly, since 1945 the number of units has declined, in most cases because of the existence of convenient and low-cost electric power or the availability and low cost of diesel fuel. Pilot-fuel engine operations are not new. The first general use was during World War II, though designs and use date back to the early 1930s. Very little modification (only to the induction manifold and injection pump) is necessary to any new or used diesel engine of any size to adapt it to full-scale producer-gas operation. The residue from the producer-gas generator is usable as a char or ash in the same way as the residue from the steam-producer unit.

7.2 LONG-TERM ACTION FOR DEVELOPMENT

7.2.1. INFORMATION TRANSFER

This survey has provided an integrated view of the main problems which affect rice husk utilization and has identified some of the measures which are required to stimulate development. At the global level, a definite need exists to intensify the transfer of information and this, perhaps, could best be attained by a rice-industry data centre, an international clearing-house for all information related to the rice industry. Its publications should include technical bulletins and manuals tailored to fit the practical needs of small, medium and large operations in various parts of the world. Energy-related publications could be modeled after the fuel efficiency bulletins published by the British Ministry of Fuel and Power. Special, early emphasis should be placed upon research.

7.2.2. INITIAL AREAS OF RESEARCH

The following three energy-related areas of research offer the greatest potential for providing maximum benefits for the cost involved:

- Furance design and construction should be analyzed and tested to accumulate useful data that can be applied in selecting the highest-potential design for any specific application;

- Heat-coupled producer-gas generator process steam systems should be developed and installed to provide the necessary electrical or motive power while covering the process-steam requirement in small and medium parboiled-rice mills, both existing and newly designed;

- A new generation of producer-gas generators should be developed and built, utilizing modern materials and techniques as well as the excellent technology accumulated in this century. This development offers maximum potential for benefiting all types of rice mills, especially white milling, where process steam is not required. At the same time, there is need for appropriate commercial development of suitable engines or necessary modification of existing ones, including both petrol and dual-fueled (diesel/producer gas) engines using a pilot-fuel system. This recommendation is realistic, because the technology for producer-gas units, particularly those utilizing rice husks as the raw fuel, now exists. Similar considerations apply to the engine: one World War II-vintage producer-gas generator engine system continues to operate in Italy after some 35 years. This 60-horsepower system provides motive power for a two ton/hr rice mill and utilizes rice husks as the raw fuel source. There appears to be little danger of error in predicting that it can easily operate for another 35 years without serious problems.

7.2.3. IN-DEPTH COUNTRY STUDIES

While a host of recommendations could be made for individual countries from casual observation alone, few would be genuinely constructive or professional on such a basis. To properly develop activities, an in-depth study of the conditions in each country is essential. This involves full knowledge of the country's rice production, a complete inventory of its rice mills and their capabilities, the overall energy outlook, the economic situation, and a study of available markets, both domestic and foreign. Obviously, this can be accomplished only with the active cooperation of the appropriate government agencies, institutions and knowledgeable individuals within the country. If this is forthcoming, such a study is not difficult in itself. Its completeness would be limited only by time constraints and the actual availability of information.

Some countries are making maximum use of rice husk to produce energy. Thailand is one of the best examples. In almost every instance, rice husk is used to fuel the boiler which provides the motive power to operate the mill. Even in the small percentage of parboiling which takes place, husk-produced steam is used in the process. However, this utilization does not reflect maximum beneficial usage because there is almost no utilization of the residue. It is in this latter area that the greatest potential for improvement in Thailand lies.

Neighbouring Malaysia presents an interesting contrast, in that only a small percentage of the rice husks available are used for fuel, and this largely in the older mills only. The more modern Malaysian rice mills have no provision for husk utilization at all, and the quantities being produced are becoming a serious disposal nuisance. Malaysia could benefit from encouraging the design and construction of a furnace-type incinerator to produce char. While the production of power from rice husk does not appear to be feasible in Malaysia because of electricity availability from a public grid, and there is no need to raise steam since milling is white only, there is a long-standing utilization of char for agricultural purposes. The minimum amounts currently available from the older steam-powered rice mills are eagerly sought after.

In those countries where rice milling is a developing industry and parboiling is desired, serious consideration should be given to installing husk-fired power units and process-steam producers at the outset.

7.2.4. INCENTIVES

Since it is in the best long-range national interest of any country to utilize its indigenous energy sources, it would be beneficial for each country to establish financial agencies to make available long-term loans, credits, or incentives at reasonable interest rates to encourage the construction of power plants permitting the utilization of indigenous renewable natural resources. The initial effort should include investigation of the feasibility of using available husk as a supplemental fuel. This concept could make it worth while for a cooperative of rice millers to go into the power-generation business. Husk could be collected centrally from a number of mills. Husk should be cracked; this can be accomplished at a very low cost and makes transportation and collection feasible because the density is raised to some 17 lb/ft^3. The collected husk then could be utilized as an energy source to produce steam for immediate consumption or for electricity.

In cold-storage plants, such a utilization could efficiently provide power by using the husk as it becomes available or storing quantities for use as a supplement during high-demand periods or when the gas or oil supply is interrupted. Cost feasibility depends upon the availability and costs of electricity for power generation, as well as of natural gas, oil, or coal for steam generation. This general application also is possible using a producer-gas generator located at the individual mill and featuring a piped collection system for distribution or to blend with the primary fuel as a supplement. A likely area for this utilization would be in the Punjab area of India. Ideally, the system, if a steam-powered plant, could provide process steam to an adjacent industry such as an oil mill, dairy processing plant or similar process-steam user.

7.2.5. A WORD OF WARNING

No rice mill can be made more efficient than local circumstances warrant. Beneficial efficiency requires the maximum utilization of all available rice husks as a source of energy and their residues for other purposes. To provide a more sophisticated boiler and engine that accomplishes the mill operation using less than all the available husks only creates a disposal problem. Any extensions of capability must be suited to the realities of the local situation and be accomplished in a smooth, slow and rational manner.

7.3 SHORT-TERM ACTION FOR DEVELOPMENT

While there is scope for systematized, long-term development activities, two practically-oriented projects could lead to valuable results within a limited period. The objective here would be to utilize existing technology to build prototype power units respectively based on producer-gas generator and heat-power coupling, especially designed for smaller mills.

7.3.1. PRODUCER-GAS

At mills where paddy is milled raw, without parboiling, the basic problem is to obtain mechanical power at the lowest cost of conversion by means of simple equipment. To help solve this problem, a prototype power unit including producer-gas generator, internal-combustion engine and electric generator should be constructed; it should develop 100 kw to operate a two ton/hour mill. The producer-gas generator should be simple in design and suitable for local fabrication. The internal-combustion engine should be a currently produced model, with suitable adaptations to facilitate converting second-hand liquid-fuel

engines into dual-fuel engines. Such a project would imply the evaluation and selection of existing equipment, design and construction, testing the unit in a developing country and preparing a "do-it-yourself" manual. The goal here is to provide a means for developing construction and operation capability in areas completely devoid of infrastructure.

7.3.2. HEAT POWER COUPLING

The second project is conceived to assist small millers who parboil and mill paddy. Their problem is that of using husk efficiently enough to obtain heat for both operations: thus, a down-scaled heat power-coupling system should be designed and constructed, consisting of furnace, boiler, steam engine and electric generator capable of operating a two ton/hour mill. The prime mover should produce all the power required for milling and should discharge exhaust steam at suitable pressures and temperatures for the mill's parboiling and drying requirements. The project would imply designing the best possible combination of components to fit selected specific requirements. When one or two representative heat-coupling systems have been designed and constructed and are operating under proof conditions, a manual of theory, design and practice should be developed by personnel of the project for use to interest and instruct others who have similar requirements. The first one or two units would be well able to develop the parameters necessary for designing any applicable systems and to show the differences and/or advantages that may accrue from using rice husk as a raw fuel.

7.4 RESIDUE UTILIZATION

7.4.1. CURRENT STATUS

In every case of utilization of husk for energy, the residue remaining has a value if properly collected, processed and marketed. Presently, in many countries, good use is made of the residue, in some cases char and in others ash. The energy conversion process is the primary consideration and the form of the residue is secondary. Therefore, the utilization of the residue is usually a matter of opportunity. In such situations, marketing efforts are the prime consideration, with a determined, intelligent campaign to bring eventual success.

7.4.2. CURRENT OPPORTUNITIES

There are available today existing technology and markets to utilize all residue produced with only three limitations: 1) that the quantities produced be sufficient to match the requirement of the market available; 2) that transport to the market be available and economically feasible; 3) that long-term and sincere support be given the marketing effort and an intelligent and knowledgeable selection of the potential market areas be included.

APPENDIX A

OTHER UTILIZATIONS OF RICE-HUSK CHARS AND RESIDUES

A.0. INTRODUCTION

Whenever rice husks are converted to energy a residue remains. At the lowest level, this can be the percentage of ash in the variety being converted, usually 17 to 22% of the weight of the paddy husk. The upper limit of this residue is about 35% of the initial weight; it represents conversion only of the volatiles present in the raw husk and the retention of the full content of carbon.

The utilization of the char/ash residue has taken many varied paths. In each country that produces rice there is some utilization made of the residue; the degree of utilization varies from almost zero upwards. The value of the utilization is purely relative, depending entirely on the concept of beneficial utilization (137). Table 29 summarizes some technical commercial opportunities for rice-husk, ash and char utilization.

A.1. CHAR

Char is defined as the residue remaining from a burning or pyrolytic conversion of rice husk, with carbon content of over 1.5%. Its utilizations and their commercial feasibility are varied.

A.1.1. Organic uses. From a tonnage standpoint, the largest utilization of char practiced is as a nursery planting or potting component or for use in paddy seedling propagation. In Japan, where the mean cultivated rice-field area is about 1 hectare, approximately 10% of the country's 3.2 million tons of husk is produced in "rice centres" where there is sufficient husk available to establish a profitable conversion operation. Most of these centres produce annually from 200 to 600 tons of husk.

It is traditionally said that something yielded from the rice field should be brought back to the field. Chaff cinder is an inorganic material whose main ingredient is silicic acid. It has various characteristics that make it supperior to calcium silicate. At present, 15 micro-elements have been determined necessary for a rice field, and almost all these elements are contained in chaff cinder. It is highly recommended for raising soil/water temperature, watering and supplying air to roots of plants.

As in Japan, the Mekong riparian countries take advantage of chaff charcoal for planting paddy seedling and vegetable seedlings in truck gardening.

Chaff charcoal is advantageously used to improve the soil for planting seedlings, horticulture, pomiculture and truck gardening, as well as to mix in feedstuffs. Although it is not a fertilizer in nature, it helps stimulate speedy and vigorous growth. When it is properly adapted, it deoxidizes the ingredients of silicon for more tasty rice, and by helping to retain soil moisture it facilitates root division and active elongation for dense growth. Yield increases of over 20% have been obtained.

About 20 l/m^2 of chaff charcoal are scattered to cover the seed-rice planted. Seed-bed containing 20 to 30% chaff charcoal in bulk substantially increases the tensility of seedling cord in terms of mechanical transplanting of waterfield rice. It is also widely recommended that 10 to 20% chaff charcoal be added to the nursery soil for tobacco plantation.

In the Philippines the use of char from the Tacurong (W134) power plant was found by Golden (W182) to reduce drastically the amount of nursery seed necessary. It was found that normally several seeds were planted per hill, because the stalks were very thin and in pulling the seedlings had excessive breakage. Golden tripled the area of the nursery so that the seedlings could grow more vigorously, then added char to loosen the soil. Instead of 75 kg of seed per hectare, they can now plant 10 kg. Seed is very costly, and the new method produces as many and in some cases more plants than the old method, with 1/7th the seed.

Seed-beds using char are normally warmer than those not using it.

Table 29

Technical/commercial opportunities for rice-husk ash and char utilization

Category	Form	Technical Status: Proved	Technical Status: Possible	Technical Status: Conceptual	Commercial Status: Proved	Commercial Status: Possible
ABSORBENT						
Marine spills	LC			+		
Oil absorbent (Greasweep)	LC	+			xo	
Sweeping & floor cleaning (Greasweep)	LC					
BUILDING MATERIAL COMPONENT						
Calcium heterolsilicate brick (Silicior)	LC	+				o
Cement (impingement process)	LC		+			o
Concrete (acid-resistant)	HC		+			o
Concrete blocks	LC	+				o
Lightweight concrete	LC	+				o
CARBON SOURCE						
Fine filter media (water purification)	HC		+			o
Activated carbon	HC	+				o
Decolorizing charcoal	HC	+				o
Adsorption media (water purification)	HC		+			
Coagulant aid (water purification)	HC		+			
CARRIER						
Catalyst	LC		+			
FERTILIZER						
Anti-caking agent	LC	+			xo	
Coating for prills	LC		+			o
FILTER MEDIA						
Liquid, gas or oil	LC	+				o
Solids removal	LC	+				o
FILLER MATERIAL						
Rubber compounding (as carbon silica)	HC		+			x
Silica aerogel insecticides	LC			+		
Grit toothpaste	LC	+			o	
Rubber compounding (as silica)	LC		+			x
HYDROPONIC MEDIA						
Ash media	LC	+				o
INSULATION USES						
Hot tops (steel plant)	LC	+			o	
Bridge undercoat, steel beams, etc.	LC	+				o
Ingot insulation (steel plant)	HC	+			xo	

Category	Form	Technical Status: Proved	Technical Status: Possible	Technical Status: Conceptual	Commercial Status: Proved	Commercial Status: Possible
PIGMENT						
Varnish - shoe polish	HC			+		
Paint				+		
Porcelain enamel suspension agent	LC			+		
Carbon paper, ink extender	HC			+		
REFRACTORIES						
Heat-insulation brick from ash	LC	+			o	
Porous media (Ontario Research)	LC	+				o
Ceramics	LC	+			o	
Insulating brick (Medium Temperature)	LC	+			o	
SILICA SOURCE						
Silicon tetrachloride	LC		+			
Silicon carbide nitride	LC		+			
For production of sodium silicate	LC		+			o
Dehydrating agent	LC			+		
Thickening agent	LC			+		
Dessicant and deodorizer	LC			+		
Fumed silica				+		
Finely divided silica			+			o
Silica coating (welding electrode)	LC			+		
Silica rocks for landscaping effects	LC	+				o
Silica source for glass manufacture	LC		+			o
Sintered glass material				+		
SOAP MANUFACTURING						
Soap ingredient from ash	LC	+			o	
SOIL USE						
Silica regeneration in silica-deficient soils	LC		+			o
Mulch media for surface control	HC	+			xo	

LEGEND

FORM OF HUSK PRODUCT: LC = Low-Carbon Ash
HC = High-Carbon Ash

STATUS: + = Techincal feasibility
o = Commercial, small use
x = Commercial, extensive use

In southern India, it is common practice for the local farmers to buy 30-kg bags of char to use in their fields and nurseries. In the Birbhum district of West Bengal char has been used for many years in the soil of onion and potato fields.

In Italy, the brightest and most colourful flowers grown for sale throughout Europe, in the Genoa-San Remo areas, grow with char from the parboiling mills (with husk-fired boilers) in the Milan area.

Char is also most beneficial in the growing of young trees; it is an excellent substitute for sphagnum or peat moss.

A.1.2. Steel manufacturing. The utilization of pure husk, char or ash for insulation and anti-slagging in the iron and steel industry is much more widespread than has ever been realized. References and sightings have been made in countries all around the world: in the United States and Canada, the United Kingdom, the F.R.G., Spain, Romania, the U.S.S.R., India and Japan.

The superior heat-absorbing features and insulation characteristics of paddy-husk char promote its use as a solidifying material for steel ingots. The maintenance of uniformity of physical and chemical characteristics within molten steel during ingot molding is essential. Without effective preventive measures, carbon, silicon, manganese, phosphorus, sulphur, etc. tend to concentrate in the centre of the ingot because of the lower content of impurities during solidification, and produce air holes, deflection, cracking, etc. This tendency can be eliminated if gas production is prevented, either by adding a deoxidizer such as aluminium to the molten steel or making some arrangement to keep temperature uniform. This can be done effectively by covering the steel ingot with paddy-husk char. Lathrop (223) implies that as far back as 1944 this use was of long standing and of accepted practice.

Black char from Italy is also sold in France and the F.R.G. for ingot insulation.

In Valencia, Spain, char is produced on a specific basis (no use being made of the produced heat) by Bonora (W140) for shipment to the steel mills in Bilbao.

Thousands of tons are sold in Japan to steel mill users, including Yawata, Fuki, Nihon Koken and Kawasaki.

In general, the amounts are used in such small quantities, in relation to what is available, that not a great deal of development work has ever been done to extend the use of this material, and one large steel producer in Japan reports that they are looking for a replacement material because of the physical problems of acquisition and use of this char. A large user in England also reports problems in using ash. It would be desirable to carry out research in order to maintain this utilization at its current level, or even to expand it. Individual producers do not realize its importance, and it is not a large enough factor of these operations for them to be concerned. This is an industrial and worldwide problem.

There are several such uses, with a great world impact but a small individual one. This is a very difficult area of development, because the successes have to be looked at on an overall international basis.

A.1.3. Water purification. As far as is known, there is today no commercial use of rice-husk char for water purification purposes.

Staackman (228) claims that finely ground rice-hull char is comparable in performance to diatomaceous earth. This attributed largely to its "spiekular" particle configurationç i.e., the char particles are basket-like, and as a result, filter beds should be less likely to become clogged or block off the flow through one another. Finch (168) obtained a U.S. patent for making a carbonized product useful as a filter medium. The product had a skeletal silica with a lattice structure with carbon disposed therein. Rice-hull char, however, is not much in use for this purpose and faces competition with diatomaceous earth.

Rice-hull char could also be used as a coagulant aid in the treatment of contaminated fresh or waste water. Fly ash from coal-powered power plants currently enjoys widespread acceptance for this use in the United States. Rice-hull char can do the same job by acting as relatively large nucleation sites to which suspended colloidal impurities can become attached, being subsequently swept out of the suspension as the ash particles settle.

In the early 1970s considerable work was done in Thailand on the use of rice-husk char as a filter aid and filter medium. Kitsavadhi (269; 270; 271) found that a properly treated char (with the silica partly removed by a caustic-soda wash) could also be substituted for diatomite.

A.1.4. Concrete aggregate. The use of char as a concrete aggregate is distinct from the use of low-carbon ash as described in Section 7.3.1. The use of char is, as far as is known, exclusively involved in the work of Mehta (72) in developing acid-resistant concrete. Mehta states that the resistance to acid derives from the replacement of lime in the concrete, and not in the inclusion of char carbon as a cement.

The acid-resistant nature of concrete made from paddy-husk char with lime should be of great interest to the food-processing industries, in which an acidic condition exists in many products to be processed.

As a parallel utilization Mehta has suggested the use of char as a cement in architectural concrete because of its unique colouring capabilities. However, smear resistance in this type of product is low. It is very similar to Silicior (A.1.7) in its marking action.

A.1.5. Rubber reinforcement. An early reference to the use of rice husk in rubber compounding is found in Angladette (1). Later references include Bianchi (24), Rubber Age (26), Beagle (137).

The earliest commercial use known is that by Bianchi, starting in 1930. Pirelli used the product made by Bianchi to cover its carbon-black requirements during World War II, but returned to carbon black when it became available again, because of price differentials.

In 1968, renewed interest in this utilization was shown by Koppleman (43A), who contemplated producing a material that would be acceptable by the rubber compounders. However, the promotion was a failure.

Recently Pitt (151A) announced an extension of the Mehta (72) process to produce a satisfactory material.

As a filler for rubber compounding, experiments have shown that higher or equivalent mechanical properties of cured rubber were obtained from batches containing char in proportions as high as 60% by weight. Superior mechanical properties were claimed for natural rubber compounds loaded with rice-husk char.

At times of high carbon-black prices, a blend of carbon black and rice-husk char is feasible; cost factors can determine the use of mixtures.

By analysis, rice-hull char contains 90% amorphous silica and 10% carbon (Industrail Materials Company analysis 10 Jan. 1975). Their published nitrogen surface area of 30 to 60 m^2/gram is indicative of some porosity considering the 0.1 to 2.0 micrometre particle size. The relatively high pH of 10.4 is usually an aid to sulphur vulcanization with organic accelerators. Rubber properties seen in the literature do indicate rice hull char does impart "many of the properties and characteristics of medium thermal blacks".

A.1.6. Antiskid additives. The high silica content and abrasive character of the char indicate potential value as excellent antiskid abrasive in tyres and shoe soles.

Mountain-climbing boots, work boots, and other special footwear are sometimes provided with antiskid soles. In both the tyre and footwear applications, the abrasive material must be tough enough to stand a shearing action equal to or greater than presently used materials.

A.1.7. Silicior. A building material utilizing char as the raw material was patented by Abdellatif (10) and was developed to be adapted to the housing problems of the lesser developed rice producing countries. The product is a light-weight brick or can be also produced as a lightweight aggregate. The brick can be sawn, riveted or nailed in a conventional fashion. It has excellent resistance to heat and cold, easy to mortar, with a crushing strength of 120 kg/cm^2. Recently a renewal of efforts on behalf of the silicior concept was announced by a company in southern France. The validity of the concept is without question and would doubly contribute if in some way utilization of the latent heat of the husk was realized during the carbonization process. With the residue then being utilized as a raw material for lightweight aggregate or building bricks or blocks.

A.1.8. Marine spills. In 1971 Kojima (166) in Japan showed that the clearing of oil from the surface of a lake or bay was successful using a char product. The use of a char product for this purpose is unique; the clearing of the spills was accomplished in a short time and with minimum effort.

A.1.9. Snow removal. Char is used in Japan to sprinkle on snow. Its superior heat-absorbing capacity proves effective for snow removal.

A.1.10. Landfill. Usually the last technique, because of its low (or possibly negative) relative cash return to the miller, is landfill. In every area of the world where husk is or has been burned, large areas have been filled in with the boiler residues. In Bangkok, where 40 years ago the municipal power plant was, and almost every rice mill is, husk fired, greater quantities of char have been used for fill. Saigon, in the years of husk-fired mills, saw large filled areas. This is however more a disposal than a utilization method.

A.2. ACTIVATED CARBON

Activated carbon can be made from paddy husk by two methods, depending on the quality required and whether sodium silicate is required as a by-product for the soap industry. The chars obtained by a) incineration and b) destructive distillation should theoretically be essentially the same, i.e., carbon and silica in virtually the same ratios and physical state (although in practice differences occur). Hence, the term carbonization is used to refer to either process.

These chars can be rendered more useful by one or more of the procedures employed in the activation of carbon:

- Prior to carbonization, rice hulls are saturated with an aqueous solution of a suitable inorganic material (e.g., zinc chloride, potassium carbonate, potassium thiocyanate, etc.) and dried. After carbonization, the chars are washed to remove the chemicals, and then heated to activation temperature. A typical procedure is: 1) saturation with a 35% solution of potassium thiocyanate; 2) drying and heating to 300-350° C. It should be noted here that, to an unknown extent, the silica content of rice hulls appears to have an activating effect upon its char similar to that produced by added chemicals.
- Subsequent to carbonization, but without prior treatment, portions of the char are subjected to heat, with and without oxidizing gases (air, H_2O, CO_2, etc.). Typical procedures are roasting with steam at 750° C. or with carbon dioxide at 800-900°C.

If both sodium silicate and activated carbon are required, paddy-husk char from the rice mills can be used. The process involves removal of the silica with a sodium hydroxide solution, leaving activated carbon.

It appears that most processes for producing activated carbon from rice husk do not include a step for the sensible use of heat from the reaction.

Research in this field has been or is being carried out by W50 and W53. Two excellent literature reviews of activated carbon are Tucker (229) and Lathrop (223).

A.2.1. Use of furnace char. In the direct utilization of residue from a boiler or pyrolysis unit for the preparation of activated carbon, the ash level severely limits the char's usefulness as a raw material.

There is no agglomerating character inherent in the material, and the nitrogen surface area, 150 m^2/gm carbon, though low when taken on a per gram of carbon basis, is high for a raw char. If normalization is carried out, the rates for rice husk are significantly lower. The lower reactivity may be due not to a difference in the carbon substrate but rather to a blockage of the activating gas as a result of the high ash content.

Under microscopic study, rice-husk char is seen to contain three distinct fractions:

- semi-carbonized material consisting of large, flat thin particles;
- fully carbonized material, consisting of short fibres of intermediate particle size;
- very small carbonized particles of spherical shape, which are very friable.

The high surface area and suitable reactivity of carbon in raw rice-husk char indicate that it may be useful as a raw material for activated carbon if, by processing during or after char generation, the ash in the final product can be minimized or eliminated before activation.

A.2.2. RRL-Hyderabad. A recent announcement from this laboratory (W53) describes its process developed to produce a low-ash, high-adsorption activated carbon. The carbonized material is subjected to steam activation, then to treatment for silica removal by a caustic soda method. The sodium silicate can be marketed as well as the carbon.

A.2.3. Thailand. Research work by Kitsavadhi (42) showed the technical practicability of using a range of activating agents, but indicated that all the methods available are too expensive to produce a competitive product. There is therefore no commercial utilization of this concept in Thailand.

A:2.4. Anil Starch. The only known commercial producer of activated carbon from rice husk Anil Starch (W70), which produces commercial activated carbons, trademarked "Carbanil", in a range suitable for any refining or bleaching activity.

Their specification sheets show 2 to 5% ash content, with completely adequate characteristics as regards decolourization, colloidal separations, odour removal, etc. 2 tonnes per day of carbon are currently being produced from rice husk by their proprietary process, details of which are not available.

A statement by their management confirms that the market penetration capability of quality rice-husk carbon depends entirely on the acquisition cost of the raw husk. It is not clear whether any utilization is made of the silica removed.

A.3. CEMENT - CONCRETE (See also Section 4.6)

The use of low-carbon paddy-husk ash (as distinguished from char; see Section A.1.4.) as a cement or as a concrete aggregate has for many years been the subject of intense and widely ranging research and development. Early references are two German patents (67) of 1924. And yet today there appears to be no commercial utilization of rice-husk ash for cement or concrete purposes. Usually the products have higher insulating values than ordinary concrete but do not have adequate strength and stability. In order to obtain suitable strength the cement content must be so high that the product is not economical.

The report by Hough (11) covers very well the developments to date.

Mehta (private communication) reports that hydraulic cements with satisfactory properties can be made by intensive intergrinding of siliceous materials with 10 to 25% lime. The intensity of the mechanical activation treatment required for a particular siliceous material depends on the mineralogical character of the silica. Opaline materials do not require very intense mechanical action, so that by careful control of the calcination conditions, opaline silica should be formed from the rice-husk ash. In preliminary tests, the quality of cement made by mechanical interaction of a rice-hull ash lime mixture was excellent.

Yost (77) conducted research into the use of rice husk in cement. His definition of pozzolanic activity fills a sorely needed gap in the literature.

Staackman (228) discusses at length the utilization of rice husk in cement manufacture. His section on fuel utilization has today been proved quite valuable by the inception of a project at the Calaveras Cement Plant in Redding, California, U.S.A.

A.3.1. India. The Central Building Research Institute (W56) reports having studied the probable uses of rice husk and its ash as building materials. The pozzolanic properties of partially and fully decarbonized rice-husk ash were determined by lime-reactivity test. A high-quality pozzolanic material was obtained by burning a mixture of rice husk and clay with certain other admixtures. No additional fuel was required for firing, since the fuel value of rice husk itself was found to be sufficient. The product obtained was soft and easy to grind for use as a cementitious material or portland cement.

Lime produced by burning waste lime sludge with rice husk showed hydraulic properties and was used for soil stabilization. Maximum wet compressive strength up to 25 kg/cm^2 was obtained.

The Indian Institute of Technology (W62) reports that the rice-husk ash, when simply ground with hydrated lime, gives a cement-like material called ASHMOH. It was estimated that an ordinary steel 3 x 3 ft batch ball mill, with a 7.5 HP motor for the grinding operation, will convert a rice mill into a mini-cement plant as well, with an annual output of about 200 tons of cement.

ASHMOH cement has been tested on fairly extensive scale in the laboratory, but no large-scale construction has been carried out to date. Standard 1:3 sand mortar cubes made with ASHMOH attain compressive strengths of 100 to 150 kg/cm^2 in three days and 125 to 180 kg/cm^2 after 7 days. Compressive strength of 1:2:4 concrete blocks in 7 days has been as high as 180 kg/cm^2. The cement is very fine and plastic, like a clay ball, and it should have good waterproofing properties for plastering and lining of canals to prevent seepage.

Pingale (W60) reports a commercial operation in the Punjab utilizing rice-husk ash in a cement/lime combination.

IIT-Kharagpur (W63) is engaged in a project for manufacturing cement-mixed ingredients combined in an air-rice vertical kiln. Cement blocks using cement and husk ash in various ratios are being tested.

A.3.2. Other countries. Seng (W122) has shown considerable interest in the use of paddy-husk ash as a cement ingredient in concrete sections, both poured in place and precast. The NISIR laboratories have done considerable work on the burning of husk and the utilization of grey and white ash residues in concrete. Their results to date have had no commercial implications.

In Thailand, concrete blocks and concrete test specimens were produced around 1965 by the Department of Science. The experimental work was deemed to be of no value and was discontinued at that time.

A.4. CERAMICS - GLASS

There is very little information on this subject. The age and extent of the ceramic use of rice husk are not generally realized. The original glazing ash used on Celadon stoneware was derived from rice husks. The technique was brought from China to Thailand, but disappeared in the 14th century.

In Japan, husk is used to give a pinkish grey colour in firing earthenware crockery.

In the Philippines, OPIANA (79) wrote of glazing Philippine pottery ware.

Proctor (9) in 1882 wrote of the use of husk ash for polishing uses in the glass industry.

A.5. SILICA AND SILICATES

A.5.1. Sodium silicate. Sodium silicates have a great variety of uses in chemical and other industries. The principal applications are connected with their adhesive properties, their wetting powers, their usefulness as raw materials for a large number of industrial products and their binding and detergent properties. A new and very important use is as chief raw material for the production of colloidal silica, which is widely used in the petroleum industry. Finely divided silica is also much used in the refrigeration industry. Silicates in the form of water-glass find use as a mordant in the dyeing and printing industries. A major use of sodium silicate is as a bonding agent for raw rice husks as decorative architectural board.

Research conducted by the Paddy Processing Research Centre (245A) demonstrated that silica grey ash can be easily extracted from rice-husk with sodium hydroxide or sodium carbonate at relatively low temperatures to yield sodium silicate of high quality. Of the two extraction agents sodium carbonate is much cheaper and easier to handle.

In India, because of the large quantity of grey ash resulting from the burning of rice husks as fuel in small mills, it is felt that process development on pilot-plant and product scale is warranted. The high price of sodium silicate makes such development economically attractive. A pilot-stage processing plant exists at IIT-Kanpur (W62) in collaboration with the Food Corporation of India acting

as an agent of Ministry of Food.

However, some of these contemplated methods of producing sodium silicate require the use of caustic soda, which is in short supply in India, and is relatively expensive. This constraint may account for the minimal commercial production, the only apparent sodium silicate production being as a by-product of carbon production (A.2.4.).

Thailand, too, has investigated the use of rice husk as a raw material in the manufacture of sodium silicate as an end product in the production of activated carbon (A.2.2.). The literature lists prior work on such utilization (243 to 246). In a report by Suyasinto (246), the by-product from carbon separation was discussed for use in detergent manufacture.

In the U.S.A., Staackman (228) reported on possible alternative recovery processes and on the economic feasibility of silicate production under varying conditions. He advocated the use of the husk to provide part of the sensible heat input as well as silica. However, there is no such plant using rice husk and no thorough economic study is being undertaken toward this concept.

A report by El Bouseily (245) indicates Egyptian interest in sodium silicate production.

A question that always arises when discussing sodium silicate production regards the purity of the finished product. If the approximately 5% of outside compounds present in normal rice-husk ash are of no consequence, then production is feasible. However, if the desired use requires a pure silica rice husk cannot be used.

A.5.2. Silicon tetrachloride. P.K. Basu (233-234) developed a laboratory process for the manufacture of silicon tetrachloride (used in the manufacture of electronic grade silicon, colloidal silica and silicone polymers) from rice husk. The process is a combination of chlorination and pyrolysis of rice husk, leading to a very intimate mixture of the silica and the carbon formed by the carbonization of the cellulosic matter in the hulls. It is possible that a pre-carbonized char could be used as the initial raw material for a similar process, using the subsequent procedure of Basu. Laboratory experiments indicate that chlorination of rice husk requires a considerably lower temperature than the mixture of sand and coke. The new process is claimed to have an economic advantage over the manufacturing processes now being used.

A.6. BUILDING MATERIAL

Char is used in various parts of the world for building material applications, as loose fil', bonded, or compressed; it is in all applications a sterile, weed-free and insect-resistant material. In some of the products the high pH (11) creates a definite insect barrier.

Compared with raw rice husk as a building material, charred husk offers some saving in the cost of the cement binder.

The use of char as a radiation barrier was discussed by Hough (14), but no utilization seems to have been made of this interesting property.

At one time it was reported that a process similar to the French Silicior development was at a considerably advanced stage of development in Iran. In this process, by Chittenden (W161), white ash was used in facings of a compression-moulded concrete.

In Thailand, sand/lime/ash brick production is reported by Suyasinto (20). It was found that a 10% lime content was most favourable and that shrinkage was high and the strength correspondingly less with higher lime percentages.

The use of ash in an adobe brick was discussed by Hough (11), describing development work in 1953.

In India, Iyengar (W78) produced samples of paddy-husk ash bricks of proprietary manufacture. Also at RRL, Jorhat (W54), development work has progressed on building bricks.

In Egypt considerable work has been done on a 20% carbon brick. This was reported by Maksoud (16), who also (15) evaluated building bricks prepared by five different methods of formation of the bonding material.

A.6.1. ME-HA . The most extensive commercial use of charred paddy husk in the building material field appears to be the loose-fill applications in the F.R.G. by ME-HA (W40). Extensive use is made of charred husk to provide an excellent insulation material sold there under the trademark "MEHABIT".

A.7. REFRACTORY USE - HEAT INSULATION

The use of rice-husk residue as a refractory material is widespread; in some uses, in a strict sense it should be called a heat-insulating material, but all such uses are included here under one heading.

There are three principal areas of use: pressure-formed brick; air-dried heat-insulating coatings; and fired refractories or heat-insulating uses.

Manufacture is carried out in several countries, primarily Egypt, the F.R.G. and Japan, and the products are sold in many countries.

There has been a great amount of development work toward refractory use. Some processes have enjoyed success for a number of years, including those of Jones (196, 197, 198, 200, 201, 202, 203) and Rowland (263, 264). The patents of Jones are said to cover all uses of rice-husk ash in a fired condition and those of Rowland to cover the uses as castable and facing, air-dried. Both of these developments had a number of years of commercial success (202), but such activity appears to have ceased. The work of Abdellatif (10) which resulted in the Silicior (A.1.7.) concept is in the building material field rather than as a refractory; however, the patent does mention use as a refractory.

A.7.1. Orylex. The best commercial refractory from rice-husk residue today is produced by Refratechnik Albert GmbH, Gottingen, F.R.G., (W43) and their licensee, Asahi Glass Company, Tokyo, Japan (W100).

This product is a light-weight refractory brick for the preheating zones of rotary cement kilns. The patents were issued in 1963 (208) and 1965 (205), and the brick went into production shortly afterward. The use of 65% rice-husk ash is known. The properties of the brick, both in abrasive-wear characteristics and in crack-resistance, added to its exceptional insulation properties, make it a worldwide success.

Some of its advantages are:

- The low loss of heat by radiation makes the kiln more economical to run;
- low shell temperatures and low weight of the refractory lining preserve the kiln structure and increase its service life;
- because of the low specific heat, the kiln can be put quickly into operation making for flexible working;
- the product binds and holds the alkalies at its surface. This reaction layer protects the brick from alkali attack and reduces mechanical wear. A crust formed by dust is frequently observed to develop on this layer and enhance the surface protection;
- the brick is of crystalline composition and has excellent volume stability. No fatigue phenomena have been found to occur.

The ash for this production has been imported from Italy, Pakistan and India. (See also Section 5.3.2.5.).

A. 7.2. Intermat. This company, based in Trino (Italy), is a subsidiary of Refratechnik Albert GmbH. It processes ash for shipment not only to its parent company but to other industrial users in Austria, France, F.R.G. and the U.K. It burns husk for its own account and also purchases a finished ash product from Po Valley rice mills for processing, packaging and shipping. Ash is produced in a density range from 200 kg/m^3 for a normal product to 700 kg/m^3 for a milled product. A maximum moisture of 5% is allowed.

A.7.3. Super-insulators (1948) Silex. These thermal super-insulator bricks were described in a technical bulletin (207) It is not known whether they are being marketed currently. A similar brick was mentioned in a series of reports (211) about four years later. Its use was in kilns, and a 50% increase in production was claimed.

A.7.4. Jones-Mount Royal Rice Mills. During the 1950s a considerable amount of work was done by Jones (195, 196, 197, 198, 200) and others (201, 202, 203) on fired refractory products utilizing rice-husk ash as the principal ingredient. Commercial production of some of the items continued for several years. The difficulty of obtaining a satisfactory raw material (grey ash) at a reasonable cost contributed to the discontinuance of this utilization.

A.7.5. Rowland. In 1967 Rowland (263, 264) obtained patents covering the manufacture of refractory materials from rice-husk ash (5 parts by volume), aluminous cement (1 part by volume), a filler (broken refractory bricks or pearlite - 2 parts by volume), and iron oxide (3% by weight). Considerable use of Rowland's product was made in the steel mills in Canada, both in linings and in "hot tops". His castable refractories were of particular benefit. Difficulties in procuring the necessary quality of ash at a reasonable cost made it hard to be competitive.

A.7.6. The Egyptian Company for Refractories (WII) produces high-quality refractory bricks in Alexandria using local rice-husk ash. Densities range from 0.72 to 1.10 gr/cm^3. These bricks have attained a solid reputation in the local refractory market owing to their unique properties and good behaviour in different industrial furnaces. They permit high temperatures of use (over 1200°C.) and have low bulk density. They have good thermal shock properties: the silica is amorphous and crystallization is slow. Their white colour helps reflection of heat in linings. As a result of their low iron content, there is no problem of iron migration in electric furnaces. Their conductivity is adequate for industrial furnaces. Their volume stability is high, owing to the absence of a crystalline phase. Table 30 shows details of the properties of certain of the ECR refractory bricks.

Table 30

Properties of ECR refractory bricks

Chemical and Physical Properties	Kafif 72	Kafif 85	Kafif 110
A. Chemical Analysis			
SiO_2 %	93.2	90.15	90.7
Al_2O_3 %	Nominal	3.15	Nominal
Fe_2O_3 %	Nominal	0.40	Nominal
Cao %	3.0	2.8	5.6
Alkalies Na_2O, K_2O %	3.8	3.5	3.7
B. Physical Properties			
Apparent bulk density gm/cm^3	0.72	0.85	1.1
Water absorption %	94.5	73.5	48
Apparent porosity %	68.0	62.5	53
Cold crushing strength kg/cm^2	15	40	170
Thermal shock resistance (0-1200°C)	Excellent	Excellent	Very good
Working temperature max.	1200°C	1180°C	1200°C
Thermal conductivity Kcal/m/h/°C	0.207	0.250	0.280
Volume stability	Very good	Very good	Very good
Pyrometric cone equivalent °C	1485	1400	1430

A.8. OIL ABSORBENT

Continuous commercial use of rice-husk ash since 1936 in the oil-absorbent field has been primarily due to the developments of Beagle (213). This largest utilization of low-carbon ash known is carried on in California and in Mexico. Pile burning, building burning and experimental machine burning have provided a supply of "GREASWEEP" for various oil-absorbent needs for over 40 years. As an absorbent material (sweeping compound), ash is used primarily to clean up oil spills and stains, and as an antiskid medium for concrete or asphalt paving in automobile service stations and repair facilities. No other product performs the unique function of "GREASWEEP".

A.9. OTHER COMMERCIAL USES

The Italian supplies of ash are channeled to uses of "hot tops", ingot insulation and other steel-mill insulation duties, as well as for refractory use.

Some other ceramic uses employing small quantities of ash are known in France.

In India and Sri Lanka, white ash is commercially used for tooth powder (Lever Bros.-Lamken) and as cleansing powder (Vim). It is also used non-commercially by the local people for the same purposes.

Ash furnished in quantity by Beagle in the 1940s and 1950s has been used as the filler body in hand soaps in the United States but this use has diminished since 1965. Similar uses are reported in West Africa, and exist in India. The use was mentioned by Lathrop (223) in his 1952 report.

Ash has in the past been used at times to coat ammonium nitrate fertilizer pills to facilitate their handling. This is not being done at the present time, so far as is known.

Ash has been used by Vaughn in West Virginia, U.S.A., as a component of fireproof insulation coatings for buildings, bridges and tanks. Davis, in Missouri, U.S.A., used ash in a sprayed-on material for insulation and fireproofing of steel structures.

A.10. CONCEPTUAL OR DEVELOPMENTAL USES

It has been suggested in the U.S.A. (159, 160) in India (162) and in Japan (163) to utilize a rice-husk ash product as an insect prevention and control method. The mechanism of action is that the silica acts as an abrasive on the waxy coating of the thorax of the insect, thereby upsetting the normal metabolism, and the insect dies. As far as is known, this approach has had no further development.

Yost (77) has investigated the properties of rice-husk ash/lime/soil mixtures for the stabilization of soils for roadbeds. He concluded that for certain soils the use of rice-hull ash increases the compressive strength over "natural" strength and uses "5% lime" strength and that, if economically feasible, the product was suitable for commercial use as a soil stabilizer.

DEFINITIONS

Ash - The residue remaining from a burning or pyrolytic conversion of rice husk, having a carbon content of less than 1.5%.

Baked air chaffs - A Japanese name for char.

Bioconversion - A general term describing the conversion of one form of substance into another by animals, plants or micro-organisms, accompanied by the absorption or release of energy.

Biomass - Any biodegradable material produced from a living source.

British thermal unit (BTU) - (generally used in engineering work in the UK and the USA). 1/180 of the heat required to raise the temperature of 1 lb of water from 32° to 212°F. (Formerly defined as the quantity of heat required to raise 1 lb of water from 62° to 63°F).

Burn - To undergo rapid combustion or consume fuel in such a way as to give off heat, gases and, usually, light. To consume with fire, to reduce to ashes. A rapid, self-perpetuating form of oxidation.

By-Product - An unavoidable secondary or incidental product.

Carbonization - Pyrolysis. Not normally used when discussing any reforming or when the residuals are other than char and flue gas.

Chaff cinder - A Japanese name for char.

Char - The residue remaining from a burning or pyrolytic conversion of rice husk having a carbon content of over 1.5%.

Conversion - The chemical or biochemical transformation of a waste material into a useful product.

Destructive distillation - A process in which coal, wood or other cellulous compounds are heated in the absence of air or oxygen so that thermal decomposition occurs, gases and vapours of decomposition products being passed to a collating and condensing system, leaving a solid non-volatile residue; carbonization; pyrolysis.

Distillation - By evaporation and condensation. The driving off of gas or vapour from materials (e.g. by heat) and condensing some or all the products.

Dispersant - The utilization of rice husk, char or ash to disperse other materials with which they are mixed.

Dry distillation - The reduction of a material to its components by decomposition in a controlled atmosphere.

Drying efficiency - $\frac{\text{moisture to be evaporated}}{\text{heat input}} \times 100 = \text{percent}$

Dual fuel engine - An engine prime mover that can operate on two fuels, usually one liquid and one gaseous.

Efficiency - The attainable value of an energy converter based on the ratio of the useful energy delivered by the system to the energy supplied to it.

Energy - The capability of doing work. Forms of energy include kinetic, potential, thermal, nuclear, rotational and electromagnetic. One form of energy may be converted to another, as when rice husk is burnt to produce steam to drive a turbine which produces electricity.

The energy content of a system can be measured in many ways, e.g. by measuring the temperature increase produced in water, or by measuring the current, voltage, and period of flow of electricity.

Energy efficiency - The amount of useful work or product divided by the fuel or energy input (e.g., in the generation of electricity, the amount of electricity produced per unit of fuel consumed).

Energy resources - All materials potentially usable by man as an energy source. Includes estimates based on geological evidence for quantities still undiscovered or whose exploitation will require more favourable economic conditions or better technology than now exists.

Enthalpy - The heat content per unit mass, expressed in BTU/pound.

Fuel - A material that develops usable energy during oxidation, or during a nuclear chain reaction.

Fuel cell - A device for directly converting the energy released in a chemical reaction into electrical energy.

Fuel gas - Gas from the combustion of fuel, the heating value of which has been substantially spent and which is therefore released to the flue or stack.

Fluidized bed - The result of the flow of a fluid, usually a gas, upward through a bed of suitably sized solid particles at a velocity high enough to buoy the particles, to overcome the influence of gravity, and to impart to them an appearance of great turbulence. Used in the petroleum and food industries.

Fluidized bed boilers - A means of generating power by moving powdered fuel (coal), in a liquid-like stream by use of air or other gases, into a combustion chamber.

Fossil fuel - a naturally occurring organic fuel (e.g. coal, crude oil, natural gas).

Fractional distillation - A method of separating the constituants of a substance by distillation and collecting the distillate in several portions (fractions) as the temperature rises.

Furnace - That part of the boiler designed for burning the fuel.

Gasification - The conversion of a solid or liquid to a gas. In the thermal processing of rice husk, a fraction of the stoichiometric oxygen required by the rice husk is admitted directly into the fuel bed to liberate the heat required for endothermic gasification reactions. The volatile portion of rice husks are pyrolized by the heat of the fuel gases, and the outlet gas composition reflects both processes.

Gas producer - A furnace designed especially for the gasification process to make a combustible, gaseous fuel from a variety of carbonaceous materials, such as rice husks, coal, charcoal, and coke, by reaction with steam and steam/air mixtures.

Gross (heat) value - See High heat value.

High heat value (also called "gross value") - Term generally used in the United States for combustion calculations, in which it is assumed that all water vapour formed by the burning of the hydrogen constituent is condensed and cooled to the initial temperature in the calorimeter at the start of the test. The heat of vaporization is therefore present in the reported values.

Isomerism - A condition in which substances having the same chemical formula differ in certain physical characteristics.

Hydrocarbons - Gaseous, liquid or solid compounds containing only carbon and hydrogen. There are a very large number of these compounds, which form the basis of petroleum products.

Hydrogasification - The treatment of an organic material at high temperatures and pressures to produce methane.

Low heat value (also called "net value") - Term generally used in Europe for combustion calculations, in which it is assumed that none of the water vapour condenses and that all of the product of combustion remains in a gaseous state.

Net (heat) value - See Low heat value.

Particulate matter - Solid particles, such as ash, which are released from a combustion process in the exhaust gases.

Pollutant - Any contaminant whose presence in a substance (generally air or water) detracts from or interferes with the latter's desired usage.

Polymerization - A method of combining smaller molecules to make larger ones, developed during the late 1930s to utilize refinery gases which were often wasted or burned as fuel. The opposite of cracking.

Power - The rate at which energy is used or at which work is done.

Power gas (also called "producer gas") - A low-energy gaseous fuel, sometimes produced from coal or rice husk, whose principal combustible components (carbon monoxide and hydrogen) are greatly diluted by air. Because of its low energy content, power gas cannot be transported economically, and is generally burned at the production site.

Producer gas - See Power gas.

Pyrolysis - The transformation of a substance into another compound or compounds by the application of heat in the absence of oxygen. In the context of energy, pyrolysis is the heating of organic materials (e.g. coal, wood, petroleum, solid wastes and agricultural crop residues) in the absence of oxygen with provision for recovery of the desired combustible products. If heat is applied slowly, the initial products are water vapour and volatile organic compounds. Increased heat leads to recombination of the organic materials into complex hydrocarbons and water. The principal products of pyrolysis are gases, oils, and char. It is possible to produce great variations in the relative proportions of these products by varying the pyrolysis conditions.

Reforming - Recombination of pyrolysis products into complex hydrocarbons and water.

Thermal decomposition - An irreversible chemical change brought about by the action of heat in an atmosphere devoid of oxygen; pyrolysis.

Thermal efficiency - A ratio indicating the available heat input that is converted to useful purposes. It is applied, generally, to combustion equipment. $E = \frac{\text{heat output}}{\text{heat input}} \times 100$

Utilization - Turning to profitable account.

Waste heat - The heat released to the environment from a heat source.

Waste - Any material not being put to useful function. Usually used in the USA to describe urban refuse or municipal solid waste.

CONVERSION TABLE

One acre = 43,560 ft^2, 4046.86 m^2, 0.4047 ha	
One acre = 100 m^2, 1076.387 ft^2	
One hectare (ha) = 100 are, 2,47 acres	
One centalweight (cwt)	= 100 lbs
One pikul	= 133 1/3 lbs
One catty	= 1 1/3 lb
One cavan	= 44 lbs
One kilogram (kg)	= 2.2046 kbs
One quintal	= 100 kilograms - 220.45 lbs
One metric ton (MT)	= 1000 kilograms - 0.9842 long ton - 1.1023 short ton
One kg/ha	= 0.89 lb/acre
One lb/acre	= 1.121 kg/ha
One barrel (rice) U.S.A.	= 162 lb paddy
One bushel (U.S. or Imp.)	= 8 gal (U.S. or Imp.)
One ft^3	= 0.0283 m^3
One barrel (oil)	= 42 U.S. gal - 306 lbs
One U.S. gallon	= 3.785 litres
One atmosphere (atm)	= 14.7 lbs/in^2 (Eng)
One metric atmosphere	= 1 kg/cm^2
One kg/cm^2	= 14.2234 lb/in^2
One lb/in^2	= 0.0703= kg/cm^2
One BTU	= 0.252 Kcal
One Kcal	= 3.968 BTU

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LIST OF WORKERS, SUPPLIERS AND INSTITUTIONS

Number	Name/Address	Contact	Scope of Interest
		ARGENTINA	
W1	Frugone & Preve Lda. S.A. H. Yrigoyen 1628 BUENOS AIRES	Mr. Jorge A. Balerdi	Rice miller user of rice husk power plants steam for motive power to drive rice mill.
W2	Avda. Belgrano 355 BUENOS AIRES	Mr. J. Agrest	Combustion consultant.
		AUSTRALIA	
W3	Rice Growers Cooperative Mills Limited P.O. Box 406 GRIFFITH, N.S.W. 2680	Dr. R.P. Coulter Grp Mgr, By-Products	Rice milling, research & development on rice husk utilization.
W4	Applied Energy Pty, Ltd. 18/20 Clarice Road Box Hill South VICTORIA, 3128	Mr. Adolfo Cittadini Managing Director	Specialists in combustion applications.
W5	John W. Barret 85 Killeaton St. East ST. IVES, N.S.W. 2075		Consulting engineer.
		AUSTRIA	
W6	Light Industries Section UNIDO P.O. Box 707 VIENNA	Mr. Andras Miklovicz-Chf Mr. E.D. Manning Mr. Horst Koenig	UNIDO is concerned with the whole spectrum of rice husk utilization from the industrial point of view.
		BRAZIL	
W7	Mernak, S.A. Rua Otto Mernak 276-Caixa Postal 23 Cachoeira Do Sul RIO GRANDE DO SUL	Mr. Eloi	Builds two series of Lokomoveis (Lokomobile) similar to Buckau R. Wolf and Esterer engines.
		CANADA	
W8	Ontario Research Foundation SHERIDAN PARK, Ontario	Mr. James D. Jones Dir., Dept. of Proj. Devp.	Pioneer worker patent holder in the use of rice husk ash in refractories and ceramics.

		CHINA	
W9	Joint Commission on Rural Reconstruction, 37 Nan Hai Rd. TAIPEI 107	Mr. Tien-song Peng Farm Machinery Specialist Mr. Jun-liang Liang Taichung Dist.Ag.Imp.Sta.	Machine for making rice husk charcoal
		DENMARK	
W10	Argus Fyr A/S Femagervej 39 2650 HVIDOVRE	Mr. S.E. Perning	Manufacturer of power stokers for rice husk as a fuel.
		EGYPT	
W11	The Egyptian Co. for Refractories P.O. Box 1211 ALEXANDRIA	M. Shams El Din El Sioufi Chairman	Producer of refractories, white silica from rice husk.
W12	The Egyptian General Organization for Rice Mills 6 Falaky Square CAIRO	Mr. A. Ezzat Said,Dr.Gen. Mr. A. Talaat Aziz, Chm. Mr. G. Kerdany, Dir.Gen. Agr. Eng.	National organization
W13	Ein-Shams University EIN-SHAMS	Dr.Eng. Ahmed El-Said Gad El-Mawla Asst.Prof.of Heat Engines Faculty of Engineering	Study of various prime movers used in rice milling.
W14	National Research Council CAIRO	Mohammed A. Arafah, Res. Mr. Abdel Maksoud, Res. Mr. A.A. Khalil, Res.	Studies of building bricks using black ash and lime by steam curing and chemical bonds under normal conditions.
W15	Rashid Rice Milling Co. P.O. Box 854 ALEXANDRAI	Moh. Sherif El-Herrawi Chm., Board of Directors	Experienced in utilization of rice husk.
W16	University of Tanta TANTA	Dr. Tayseir El Shamy	Sodium silicate awareness.
W17	University of Alexandria ALEXANDRIA	Dr. Ahmed El Bouseily Dr. Mohamed Hussien Abdel-Megid, Chem. Eng. Dept.	Sodium silicate studies.
		FRANCE	
W18	Conservatoire National des Arts-et-Metiers 27 bis, Quai Anatole-France 75007 PARIS	Prof. Dr. J. Girerd	Research and development of rice-husk residue utilization.

W19	Distibois Rans, 39700 ORCHAMPS (Jura)	Mr. A. de Lacotte	Designs and builds gas producers. Operator of dual fuel (pilot fuel) engines from producer gas.
W20	Duvant Moteurs Diesel Boîte Postale 2 36 59308 VALENCIENNES	Dr. A. Dennetière Tech. Dir.	Manufacturer of dual fuel (pilot fuel) engines for producer-gas operation.
W21	Etablissements Parent NERAC (47)		Builder of rice-husk fired boiler at Gimeaux.
W22	Ferbeck et Vincent PARIS		Builder of rice-husk fired furnace at Gimeaux.
W23	Sica France Riz 13200 ARLES	Mr. J. Moureau	Rice processor husk-fired boiler for process steam.
W24	Société des Produits Chimiques Alumineux 13240 SEPTEMES-LES-VALLONS	Ing. Edgard Harari Dr. A. Abdellatif	Manufacture of bricks, blocks, slabs, "Silicior"
W25	SODETEG BP 15 92 PLESSIS ROBINSON	Prof. M. Girerd	Interested in rice husk utilization.
W26	Syndicat des Riziculteurs de France Rue Romain-Rolland 13200 ARLES	Mr. R. Metz, Dir.	Public organization. Interested in utilization of rice husk.
W27	SACM (Société Alsacienne de Constructions Mécaniques) 1 rue de la Fonderie 68054 MULHOUSE		
		GERMAN DEMOCRATE REPUBLIC	
W28	VEB Maschinen und Muhlenbau Wittenberg Betrieb des VEB Kombinat Fortschnitt 46 WITTENBERG, Lutherstadt	Mr. Hans Georg Kaiser	Rice milling machinery manufacturer.
		GERMANY, FEDERAL REPUBLIC OF	
W29	AEG-Kanis Turbinenfabrik GmbH 8500 NURNBERG 1 Frankenstrasse 70-80		Turbines of all types. 400 KW up - for all uses.
W30	Amandus Kahl Nachf. Hamburg Postfach 260343 Dieselstrasse 5-9 2057 Reinbek (HAMBURG)	Mr. Joachim Behrmann	Manufacturer of pelleting machinery.

W31	Buhler-MIAG GmbH D33 BRAUNSCHWEIG Postfach 3369	Mr. Karl-Heinz Kunde Mr. M. Wehmann	Rice milling machinery Constructor husk fired. Power plant builder.
W32	Cornelius Schmidt, Eisen und Stahlwerk Von Kettelenstrasse 1 509 LEVERKUSEN, Kuppersteg	Mr. Simon Mr. Paland	Manufacturer of rice husk burning furnaces and grates. Dedusting and scrubbing equipment.
W33	Eisenwerk Theodor Loos GmbH 8820 GUNZENHAUSEN Nurnbergerstrasse 71-75	Ing. H. Ernst	Boiler manufacturer.
W34	Gebrüder Wagner 7 STUTTGART-Bad Cannstatt Hofenerstrasse 118-126		Boiler manufacturer
W35	Gerbrüder Weiss KG 6343 FROHNHAUSEN (Dillkreis)		Specialize in boilers & combustion equipment for use on solid cellulosic fuels.
W36	Peter Hansen 2000 HAMBURG 60 Agnesstrasse 26	Peter Hansen, Director Mr. Wolfgang Schneede	Broker-rice husk and residues.
W37	Institut fur Landmaschinenforschung d. Forschungsanstalt für Landwirtschaft 3301 BRAUNSCHWEIG	Dr. W. Baader	Research on gas producers - equipment.
W38	Kuhnle, Koop & Kausch FRANKENTHAL (Pfalz)		Turbines
W39	A. Lambion Maschinenfabrik D3549 WETTERBURG (Waldeck)	Mr. Alfred Lambion	Furnaces, grates, boilers. Experience in furnaces for rice husk burning.
W40	ME HA Dammstoff-Fabrik GmbH D6707 SCHIFFERSTADT Postfach 102		User of rice husk char for insulation material "Mehabit"
W41	Turbinenfabrik J. Nadrowski GmbH 48 BIELEFELD Postfach 6104		Small and medium-sized turbines, direct and geared. 2 KW to 2,100 KW
W42	Naumann & Co. D2000 HAMBURG 74 Berzeliusstrasse 7-11		Hanseata rice mills and rice machinery. Husk fired dryers.
W43	Refratechnik Albert GmbH 34 GOTTINGEN Postfach 2	Dr. P. Bartha Dr. G. Hotz	Producer of refractories using rice-husk ash in manufacture. Research and development on rice husk and derivatives.

W44	F.H. Schule GmbH 2 HAMBURG 26 P.O. Box 260620	Mr. Hans G.W. Keesenberg Mr. H. Petersen Mr. R. Runte	Rice milling machinery complete rice mills, complexes, dryers, par-boiling plants, steam power plants
W45	Siller & Jamart KG 56 WUPPERTAL-Barmen Horather Str. 20-24		Husk-fired boilers.
W46	Spillingwerk HAMBURG GmbH 2000 HAMBURG 11 Postfach 11 05 29	Mr. H. Spilling	Steam motor manufacturers. Complete husk-fired power plants. Contractors.
W47	Standardkessel Duisburg 4100 DUISBURG Wilhelmschoehe 3		Prefabricated boilers and steam boilers.
W48	Streckel & Schrader K.G. 2 HAMBURG 70 Hinschenfelderstrasse 35	Dipl. Ing.Karl Streckel	Rice milling equipment manufacturers. Complete rice mills.
W49	Terry GmbH 42 OBERHAUSEN 1 Postfach 10 16 29	Mr. V.P. Leupolz	Terry and Kuhnert turbines and generator sets among a full line of turbines. Generator sets 300 to 750
		INDIA	
W50	Council of Scientific and Industrial Research Central Food Technological Research Institute Cheluvamba Mansion MYSORE-570013	Dr. B.L. Amla, Director Dr. H.S.R. Desikachar Mr. L.K. Lakshmin Narayana Mr. K.R. Bhattacharya	Research projects concerning rice husk.
W51	Council of Scientific and Industrial Research Rafi Marg NEW DELHI-110001	Mr. Baldev Singh, Chief Technology Utilization Mr. K. Rajagopal, Scientist	Interested in spectrum of waste utilization including rice husk
W52	Council of Scientific and Industrial Research Structural Engineering Research Centre Adyar, MADRAS-6000020	Prof. G.S. Ramaswamy, Director	Research on fly ash for structural use in buildings. Parallels for rice husk.
W53	Council of Scientific and Industrial Research Regional Research Laboratory HYDERABAD-500009	Mr. G.S. Sidhu, Director Mr. Bharat Bushan, Dep.Dr. Mr. E.R. Saxena, Scien. Mr. S. Rajender Rao, Scien. Mr. S. Raghavendar Rao, Lib.	Research and development of processes. Fuel-related, carbons, activated carbons.
W54	Council of Scientific and Industrial Research Regional Research Laboratory JORHAT (Assam)		Has conducted rice-husk research and development, both heat-related and other.

W55	Council of Scientific and Industrial Research Regional Research Laboratory JAMMU (Tawi)		Research and development on heat- and energy-related use of husk as well as other facets of husk utilization.
W56	Central Building Research Institute ROORKEE, (U.P.)	Mr. A.C. Banerjee, Scientist	Working on the utilization of husk in cementitious materials.
W57	Cement Research Institute of India M-10, South Extension (II), Ring Road NEW DELHI 110049	Director	Use of ash as cementitious material.
W58	Central Rice Research Institute CUTTACK	Dr. S.Y. Padmanabhan, Director	
W59	Central Fuel Research Institute JEOLGORA (Dhanbad) Bihar	Mr. M.G. Krishna, Dir. Prof. S.K. Dasgupta, Deputy Director	Research, development and testing of husk-fired equipment.
W60	The Food Corporation of India Bara Khambolane Connaught Place NEW DELHI-110011	Dr. S.V. Pingale Dr. S.N. Sharma	Research and development and publication of husk-related processes and utilization particularly in reference to sodium silicate production.
W61	Indian Agriculture Research Institute Hillside Road NEW DELHI-110012		
W62	Indian Institute of Technology Kanpur IIT Post Office KANPUR-16 U.P.	Mr. P.C. Kapur	Have developed a hydraulic-setting cement called "Ashmoh", made from rice-husk ash. Ongoing programmes concern high-temperature silica thermal insulation refractory-light-weight concrete blocks, fillers, additives.
W63	Indian Institute of Technology Rice Process Engineering Centre KHARAGPUR, West Bengal	Dr. T.P. Ojha Mr. R.C. Maheshwari Mr. B.D. Shukla	Research and development - construction of husk-fired furnace-dryer. Gas producer. Air-suspended husk furnace.
W64	Indian National Scientific Documentation Centre Hillside Road NEW DELHI-110012	Dr. S. Parthasarathy Scientist-in-Charge	National centre.

W65	Faculty of Engineering and Tech. Dept. of Food Technology & Bio-Chemical Engineering Jadavpur University CALCUTTA-700032	Mr. Sunit Mukherjee, Professor	Studying effects of heating under controlled conditions to produce white ash - modification of husk-fired furnace.
W66	Ministry of Food & Agriculture Krishi Bhavan NEW DELHI-110011	Mr. P.K. Kymal, Ex.Dir. Food & Nut. Bd Mr. M. Kuppuswamy, Chief Engineer Mr. N.S. Gangadharan, Engineer	Research and development of all rice-husk related processes and equipment, particularly husk-fired furnaces and dryers.
W67	National Committee on Science and Technology Dept. of Science & Technology Technology Bhavan NEW DELHI-110029	Mr. P.K. Bhatnagar Dr. J.K. Sridhar Rao Coordinator-Waste Util.	
W68	Punjab Agricultural University College of Agricultural Engineering LUDHIANA, Punjab	Dr. Pathak, Head Dept. of Ag. Engineering Mr. A.P. Bhatnagar, Head Dept.Process. & Structures	Development of dryers, furnaces and domestic stoves utilizing rice husk
W69	Thanjavur Cooperative Marketing Federation Paddy Processing Research Centre Lab Modern Rice Mill P.O. Vijayapuram TIRUVARUR 610 108 (TAMIL NADU)	Dr. V. Subrahmanyan, Pro. Head	Sodium silicate experience and data on the use of paddy husk as fuel for parboiling and drying.
W70	The Anil Starch Products Ltd. Regd. Office Anil Road, P.B. No. 1062 AHMEDABAD-380002	Mr. Shripal Chinubhai Sheth, Managing Director	Producers of specification grades of activated carbon made from rice husk.
W71	Binny Limited P.O. Box 111 Meenam Bakkam MADRAS 6 00 061	Mr. B.S. Dass Mr. G.V. Rao Mr. S. Balasubrahmanyam	Rice milling machinery.
W72	Chemech Engineers Private Ltd. 16/3, Sterling Road Nungambakkam MADRAS-600034		Dryers, parboiling, construction.
W73	Damodar Enterprises Ltd. 1-A, Vansittart Road CALCUTTA-1		Rice milling equipment manufacturer.
W74	G.G. Dandekar Mach. Works Ltd Dandekarwadi Bhiwandi, (Thana) MAHARASHTRA	Mr. A.K. Goil	Rice milling machinery. Interested in husk-fired dryers.

W75	East India Rice Mills Assn 7A, Elgin Road CALCUTTA-20	Mr. V.S. Aggarwal, President	Development of husk-related processes.
W76	Engineering Services Corp. No. 2, R.S.V. Naidu St. Kilpauk, MADRAS-10		Developing hot-air generator fired by husk. Rice milling and handling equipment constructor-designer.
W77	Greaves Cotton & Co. Ltd. 1 Dr. V.B. Gandhi Marg P-B No. 91 BOMBAY 400023	Mr. I.P. Gopal-Ram Mr. R.V. Natu Mr. I.K. Kumar	Westerworks boilers, gas engines.
W78	M.S. Iyengar & Associates (P) Limited D-II/4, NPL Quarters Dr. K.S. Krishnan Road NEW DELHI-110060	Dr. M.S. Iyengar Managing Director	Consultant: background of research in husk utilization.
W79	Jaya and Company Boiler Engineers Post Box No. 1347, Trichy Rd. COIMBATORE-641018	Mr. J.S. Kamath Partner	Husk-fired boilers.
W80	Kirloskar Oil Engines Ltd. Corporate Office 11, Koregaon Road POONA-411001	Mr. S.K. Joshi	Rice milling equipment (Schule, Dandekar) - gas, oil and diesel engines.
W81	Modern Machineries Corp. 5 Clive Row CALCUTTA-1	Mr. Shrish Aggarwal	Rice mills, rice milling machinery. Concessionaire Dandekar, parboiling plants.
W82	Sarda Rice & Oil Mills P.O. Ahmadpur (Birbhum) 731201 (WEST BENGAL)	Mr. P.S. Sarda, Pres. Bengal Rice Mills Assn.	Rice miller, oil miller
W83	Scopa Chemicals 15, Mahendra Nagar, Canal Rd. JAMMU (Tawi) 180001	Mr. Ashok Thussu	User of rice husk as a raw fuel in boilers.
W84	Shaw Wallace & Co., Ltd. 7, Linghi Chetty St.-P.B. 14 MADRAS-1	Mr. L.R. Sharma, Div. Mgr.	Manufacturer of husk-fired dryers and parboiling equipment.
W85	Triveni Engineering Works Ltd NSIC Building P.O. Udyog Nagar NAINI-Allahabad		Single- and multi-stage turbines manufactured in collaboration with Peter Brotherhood, U.K.
W86	Wanson, India (P), Ltd. Chinchawad - (POONA) 19		Supplier of boilers to Dandekar

W87	Westerwork Engineers PVT.Ltd. 5-D Vulean Insurance Bldg. Veer Nariman Rd., Churchgate BOMBAY 400020		Husk-fired boilers and furnaces.
		ITALY	
W88	Ente Nazionale Riso Centro Ricerca MORTARA	Dr. Baldi, Director Dr. Francesco Ranghino	Library; research on rice husk.
W89	Ente Nazionale Riso Piazza Pio XI, 1 MILANO	Mr. Tino Morbello	National Board - publishes "Il Riso"
W90	Gariboldi S.N.C. Via Bertarini 72 20061 CARUGATE (Milano)		Manufacture of husk-fired steam plants, parboiling plants, boilers, furnaces.
W91	Intermat S.a.S. Casella Postale 13 13039 TRINO	Mr. Danilo Bertolotti	Producers of rice-husk ash for refractory, steel industries.
W92	Riseria di Monticello MONTICELLO		Producer-gas power system.
W93	Politecnico Instituto di Chimica Industriale Via Boccaccio, 26 MILANO	Dott. Ing. Pino Cucchetti	Consulting capability some facets of rice-husk utilization, furfural and residue utilization.
W94	Riseria Gariboldi 20 Via Pienza 20142 MILANO	Mr. Franco Gariboldi	Rice milling, user of husk-fired process steam for parboiling.
W95	Riseria Rosasco Bianchi ROSASCO (Pavia)	Mr. Antonio Bianchi	Rice millers, experience in husk-fired steam power, gas producers, residue production.
W96	S.A.P.R.I. Via C. Campari 68 27100, PAVIA	Dr. Carlo Grugni	User of husk-fired process steam for parboiling.
W97	Societa Italiana Furfurolo S.p.A. Via Gen. Albricci 8 20122 MILANO	Dr. Guido, Director	Furfural production, residue utilization.
W98	Stazione Sperimentale di Risicoltura VERCELLI	Dr. Russo, Director	Research station, formerly active on rice-husk developments. Library.
W99	STICED Via XX Settembre, 27 20123 MILANO	Dr. Riccardo Cucchetti	Consulting capability - some facets of rice utilization, furfural and residue utilization.

JAPAN

W100	Asahi Glass Company, Ltd 1-2, Marunouchi 2-chome, Chiyoda-ku, TOKYO	Mr. K. Mushakoji, Dir. Int'l Division	Producers of refractories using rice-husk ash.
W101	Chuo Boeki Goshi Kaisha (Central Commercial Co.) Ibaraki P.O. Box 8 IBARAKI CITY	Mr. T. Kagawa, Pres.	Builders and sellers of carbonizers, husk-fired dryers, husk-fired furnace.
W102	Kansai Sangro Co., Ltd. 1666, Minami Kawase-cho HIKONE CITY, Shiga-522-2	Mr. Masahiro Kojima President	Builder of carbonization, incineration and gasification equipment
W103	Inst. of Agric. Machinery 1-chome, Nissin-cho, Omiya-shi SAITAMA-ken	Mr. Toshizo Ban, Chief Processing & Storage	Involved in rice-husk utilization.
W104	Iwate University 3 Ueda MORIOKA CITY, Iwate	Mr. Hiroshi Shimizu	Studies on combustion furnaces, furnaces for drying, hot-water heater, domestic use.
W105	Kishida Publications Shin-Norin Building 7, 2-chome, Kanda Nishikicho Chiyoda-ku TOKYO, 101	Mr. Yoshisuke Kishida Chief Editor	Farming- processing- and milling-oriented trade magazines, "Farming Mechanization", trade catalogue.
W106	New Food Processing Techniques Assn. Post No. 162-Room 1002 Ichigaya Heights 28-4 Honmuracho-Shinjuku-ku TOKYO-162	Prof. J. Sakurai, Dir.	Interested in all facets of rice-husk energy utilization and residue utilization.
W107	Nichiyu Koki Co., Ltd. No. 11-5, Hacchobori Chuo-ku, TOKYO	Mr. Sakai	Builders of carbonizing furnaces.
W108	Okura Trading Co., Ltd. 3-6, Ginza 2-chome Chuo-ku, TOKYO 104	Mr. Kozo Susuki	Sellers of dryers and machinery.
W109	Pacific Projects Ltd. Int. P.O. Box 5361 TOKYO 100-31	Mr. Frank L. Turner	Consultant, agricultural economics.
W110	Satake Engineering Co., Ltd. Ueno Hirokoji Bldg. Ueno 1-19-10, Taito-ku TOKYO	Mr. Yoshiharu Satake, Managing Director Mr. Hisashi Ishida, Manager Overseas	Builders of rice milling machinery, dryers, carbonizers, etc.
W111	Takano Seisakusho Co. 470 Kamikumano TOYAMA		Builder of carbonizing furnace for dryers, water heaters, etc.

W112	Yamamoto Mfg. Co., Ltd. 813-17, Tendo-ko, Tendo-shi YAMAGATA-ken 994		Builder of carbonizing furnaces and husk-fired dryers.
W113	Yanmar Diesel Engine Co. Ltd 1-11-1 Marunouchi, Chiyoda-ku TOKYO	Mr. Yasuo Watanabe Mr. Seisuke Sakemi	Builders of rice milling machinery (Kyowa).
W114	Kaneko Agricultural Machinery Co., Ltd. HANYU CITY Saitama Prefecture	Mr. Y. Saito	Builders of husk-fired dryers. Gasification, combustion, carbonization and heat supply equipment.
		KOREA	
W115	Chemical Engineering Development Laboratory Korea Institute of Science and Technology P.O. Box 131, Dong Dae Mun SEOUL	Dr. Won Hee Park, Chief Dr. C.K. Yun	Utilization of low-grade anthracite fuels by mining carbonized rice husk 5-9%.
W116	Department of Chemical Eng. Seoul National University P.O. Box 105 Cheong Ryang SEOUL	Professor Shik Namkoong	Research papers cover use of carbonized rice husk as filtering aid catalyst in waste water treatment.
		MALAYSIA	
W117	National Paddy & Rice Board UNBC Building KUALA LUMPUR	Mr. Ismail bin Shamsuddin	Public agency.
W118	Industrial Boilers & Allied Equipment SDN. BHD. Shah Alam Works Selangor, G.P.O. Box 635 KUALA LUMPUR		Husk-fired boilers.
W119	The East Asiatic Co., Ltd. Denmark House 84 Jalan Ampang KUALA LUMPUR-04-05	Mr. Hans Malinowski	Rice milling machinery; construction and design of milling and drying complexes.
W120	Folin & Brothers SDN. BHD. Lot 16 Jalan 223 PETALING JAYA, Selangor	Mr. Wong Foh Ling Mr. Wong Boon Sun Mr. Teoh Geok Leong	Husk-fired boilers and furnaces.
W121	Federal Industrial Development Authority (FIDA) P.O. Box 618 KUALA LUMPUR 23-03	Mr. Liew Tet Seng (for the director)	Interested in the commercial development of rice husk and derivatives.

W122	National Institute for Scientific Industrial Research (NISIR) Lot 10-20 Peringkat III & IV Kawasan M.I.E.L. SHAH ALAM, Batu Tiga, Kelang, Selangor	Dr. Ong Kong Seng	Research and development on rice husk. Particularly working on cement manufacture from rice-husk ash and the use of cementitious materials.
W123	Malaysian Agricultural Research & Development Institute (MARDI) P.O. Box 208, Sungai Besi SERDANG, Selangor	Dr. T.K. Van, Dep.Dir. Dr. C. Devendra, Head-Animal Science	Research and development of utilization of rice husk.
		NETHERLANDS	
W124	B.V. Interutil Kommiezenlaan 32, Post box 3029 SCHIEDAM	Ir. H.R. Karstel	International consultants for utilities. Designed new husk-fired power plant installed in Surinam.
W125	Lindeteves-Jacoberg Export bv (Ex R.S. Stokvis de Zonen N.V.) P.O. Box 5014 WEERDESTEIN 17	Mr. J.A. Jetten Mr. J.J. Koster	Suppliers of rice milling machinery.
W126	S.M.L. Stichting voor de Ontwikkeling van Machinale Landbouw in Surinam Koninginnegracht 66 THE HAGUE	Mr. Schram	Netherlands headquarters of project in Surinam which has new, highly sophisticated rice-husk burning power plant.
		PAKISTAN	
W127	Industrial Development Bank of Pakistan P.O. Box 5082 KARACHI-2	Mr. Nazir Uddin Mahmood Director Mr. Khalid M. Nagra, Chief Off-Eng. Dept. Mr. M.J. Rahman, Mgr.-Eng.	Interestedin all facets of rice husk utilization.
		PHILIPPINES	
W128	Agri-Products, A Division of Bendana, Brown, Pizarro & Associates, Inc. 123 Pioneer Street MANDALUYONG, Rizal		Manufacture of husk-fired dryer, "Nation Dryer".
W129	Corwen, Inc. 708 Aurora Blvd. QUEZON CITY D 502	Mr. Manfred B. Fischer	Experience in construction of husk-fired power plants. Builder of rice mills.

W130	The International Rice Research Institute P.O. Box 933 MANILA	Dr. Nyle C. Brady Dr. Amir U. Khan Dr. Randolph Barker Dr. F.B. Duff	International organizaation. Research and development of rice-husk related equipment, particularly dryers and stoves.
W131	Kalayaan Engineering Co. Inc. 4255 Emilia Street P.O. Box 665 Makati Comm.Ctr. MAKATI, Rizal	Mr. Rafael A. Lahoz, Jr. President	Manufacture of husk-fired dryer.
W132	Kaunlaran Industries, Inc. Kaunlaran Bldg., Calamba LAGUNA, 3717	Mr. Arsenio E. Dungo, President	Manufacture of husk-fired dryer.
W133	Marinas Machinery Mfg.Co.Inc. Rizal Street, Pila, LAGUNA	Mr. Ernesto M. Marinas, Pres.-Gen. Mgr.	Building rice-husk fired dryer. UOP-IRRI Box type.
W134	Mindanao Progress Corp. 447 Del Monte Avenue QUEZON CITY	Mr. Roberto A. Tulio	Operator of rice-husk fired steam-power plant for mill operation.
W135	University of the Philippines at Los Baños Department of Agricultural Engineering LAGUNA	Mr. Dante De Padua, Dir. Mr. Anacleto Paras, Jr., Eng. Mr. Silvestre C. Andales, Asst. Prof.	Research and development work on rice-husk fired furnaces, dryers and all other facets of rice husk utilization.
W136	University of the Philippines College of Engineering QUEZON CITY	Dr. Ibarra Cruz	Worked on gas producers using cellulosic indigenous fuels.
W137	Kamalig Philippines, Inc. D & E Building QUEZON CITY	Mr. Casimiro R. Nadala	Operators of box-type dryers.
		SINGAPORE	
W138	International Development Research Centre Regional Office-Asia 30 Orange Grove Road SINGAPORE-10	Miss E.V. Araullo	International organization. Interest in rice husk utilization.
		SPAIN	
W139	Instituto de Agroquimica y Tecnologia de Alimentos Jaime Roig 11 VALENCIA-10	Dr. S. Barber Dr. E. Tortosa	Research and development concerning all by-products of rice; international coordinator.
W140	Jose/Cardona/Bonora Division Azul, 24 Benetuser, VALENCIA		Producer of "Cenicar", a char used in building materials and the steel industry.

SRI LANKA

W142	The International Rice Research Institute P.O. Box 205 COLOMBO 5	Mr. James E. Wimberly Project Leader	User of husk-fired boilers to generate process steam for par-boiling.
W143	FAO Project SRL/71/531 964 Stage II, New Town ANURADHAPURA	Mr. J. Ramalingam Project Manager	User of husk-fired boilers to generate process steam for par-boiling.

SURINAM

W144	S. M. L. Stichting voor de Ontwikkeling van Machinale Landbouw in Surinam WAGENINGEN, Dist. Nickerie	Ir. R. Shankar	Operator of sophisticated rice-husk fired power plant 1200 kw

SWITZERLAND

W145	Spilling Consul. Ag. Sonnenweg 4 CH-5610 WOHLEN	Dipl. Heinz Spilling	Power plant and utility consultants; built sophisticated rice-husk burning power plant.

THAILAND

W146	Amorn Chai Co., Ltd. 295/26 Suriwong Road BANGKOK	Mr. Kamchai Iamsuri	Rice miller-designer, user of husk-fired boilers for motive power, process steam.
W147	Department of Science Ministry of Industry Rama VI Street, Payathai BANGKOK 3	Mr. Vichien Sakornmonkol M.S., Dir. Res. Div. Mr. Anuchit Kijswasdi Chief, Res. Div Mr. Anuchitta Gisswadhi Res. Div. Miss Tweelak Boonkong Librarian	Research and development on rice-husk cement sodium silicate, activated carbon; National Library.
W148	Huay Nam Boiler Factory 164 Ma Kua Lane, Wat Phya Krai Yannava District BANGKOK 12	Mr. Kitti Thiranonda	Husk-fired boiler manufacture (Cornish type).
W149	Kwang Thai Seng Factory 216 Talad Lwang Bang-rak BANGKOK	Ms. Khun Pornphun Viri Yayonthr	Builder of steam engines. Complete rice mills.
W150	Lee Yung Cheing Factory Opposite of Wat Pratum Talad Noi BANGKOK		Builder of steam engines and boilers. Complete rice mills.

W151	C.A.E. Nana & Son 3 Sukumvit Soi 13 BANGKOK 11	Mr. M.C. Nana Mr. E.C. Nana	Millers and developers. Interested in rice husk utilization
W152	Sathorn Works Co. Ltd. 124/10 Soi Rewadi Tiwanond Road NONDTHABURI	Mr. Bamrung Sathorn Managing Director	Steam-heat exchanger dryers, rice milling machinery, pellet mills.
W153	Technological Research Inst. Applied Scientific Research Corporation of Thailand 196 Phaholyothin Road BANGKOK	Dr. Kasem Balajiva Research Director	Research organization. Experience in energy-related utilization of rice husk and residues.
		UNITED KINGDOM	
W154	Belliss & Morcom Manufacturing Limited Icknield Square BIRMINGHAM B16 OOL	Mr. C.S. Shephard Engineering Dept.	Manufacturer of V-type compound steam engines. 130 HP (100 kw) to 670 HP (500 kw).
W155	The British Library Science Reference Library 25 Southampton Buildings Chancery Lane LONDON WC2A 1AW		National Reference Library.
W156	A.J. Brockwell & Partners 21 Thornbury Rise DARLINGTON, DL3 9NE	Mr. A.J. Brockwell	Consultants - Producer-gas generator, design and construction
W157	Davy Powergas Ltd. 8 Baker Street LONDON W1M 1DA	Mr. Ian Nichols	Interested in gas producers.
W158	Lewis C. Grant Ltd. East Quality Street Dysart, Kirkcaldy Fife KY1 2UA SCOTLAND	Mr. R.M. Storie	Manufacturers of rice milling machinery, grain dryers.
W159	Ron Hawkey Partners P.O. Box 429, HOVE Sussex BN3 4PY	Mr. Ron Hawkey	Consultant, rice milling and construction of rice mills. Experience in husk-fired steam operations.
W160	Neil & Spencer Limited Station Road LEATHERHEAD, Surrey	Mr. J.P. Spencer Mr. J.J. Boex	Builder of producer-gas generators.
W161	Tropical Products Institute CULHAM, Abingdon, Berkshire	Dr. A.E. Chittenden Mr. A.R. Paddon	Research and development on cellulosic materials - producer-gas generators, steam production, all facets of rice husk utilizatior

UNITED STATES OF AMERICA

W162	Agnew Environmental Products P.O. Box 1168 GRANTS PASS, OR. 97526	Mr. Larry Sullivan	Manufacture and sales - furnaces, briquetter.
W163	Aerojet Energy Conversion Company P.O. Box 13222 SACRAMENTO, CA. 95813	Mr. Eugene M. Vanderwall Mr. Roy E. Jones, Jr. Project Manager Waste Mgmt Systems	Fluid-bed liquid waste dryer, chemical equilibrium work, advanced heat exchangers.
W164	Aerojet Liquid Rocket Co. P.O. Box 13222 SACRAMENTO, CA. 95813	Mr. Rudi Beichel Senior Scientist	Interested in advanced combustion-fluid bed incinerators-husk utilization.
W165	Babcock & Wilcox Company Power Generation Group One California Street SAN FRANCISCO, CA. 94111	Mr. Dennis E. Gregor Industrial Boilers Sls. Mr. L.A. Vais, Manager Gen. & Mech.Const.Ser.	Boiler manufacturers, power plant builders.
W166	Barbour Stockwell Company 300 Third Street CAMBRIDGE, MASS. 02142	Mr. Winthrop B. Coffin Vice President	Turbines - 1 1/2" to 20" dia. to 150,000 RPM, 1/4 HP to 550 HP.
W167	Battelle Columbus Laboratories 505 King Avenue COLUMBUS, OH 43201	Mr. C.N. Ifeadi	Research concerning energy from residuals.
W168	Copeland Process Corp. Oak Brook Prof. Building 120 Oak Brook Mall OAK BROOK, ILL. 60521		Fluid-bed furnaces.
W169	Carling Turbine Blower Co. 8 Nebraska Street WORCESTER, MASS. 01604	Mr. A.R. Carlson President	Steam turbines.
W170	Center for Housing, Building and Planning United Nations GCPO Box 20 NEW YORK, N.Y. 10017	Mr. E. Paul Mwaluko, Director	Interested in rice-husk ash as a building material - process to produce it.
W171	Combustion Power Co. MENLO PARK, CA.	Mr. R. Chapman	Developmental work - gas turbine power plant.
W172	Coppus Engineering Corp. WORCHESTER, MASS. 01613		40 to 700 HP, single-stage horizontal and vertical turbines.
W173	Deltak Corporation 6950 Wayzata Blvd. MINEAPOLIS, MINN. 55426	Mr. Dennis L. Swanda Vice President	Waste heat boilers of all types.

W174	Dow Chemical U.S.A. 2800 Mitchell Drive WALNUT CREEK, CA. 94598	Mr. Barrie H. Bieler Scientist	Rice-husk related research.
W175	Elliott Company General Offices HEANNETTE, PA. 15644		Small,medium and large turbines and turbo-generator, 1 to 10,000 HP
W176	The Flintkote Company Calaveras Cement Div. 8750 Wonderland Road REDDING, CA. 96001	Mr. Bill Siemering	User of rice husk as an energy and silica source in the manufacture of Portland cement.
W177	FMC Corporation 1450 Coleman Street P.O. Box 1178 SAN JOSE, CA. 95108	Mr. Frank Hickey	Parboiling specialists.
W178	Engineering Experiment Sta. Georgia Institute of Tech. ATLANTA, GA. 30332	Prof. W.H. Burrows, Head, Special Projects Dr. John W. Tatom, Principal Engineer Dr. Howard G. Dean Jr.	Research and development on pyrolysis.
W179	Garrett Research and Development Company, Inc. 1855 Carrion Road LA VERNE, CA. 91750	Mr. George M. Mallan Dir., Resource & Recovery Programs	Operates pilot plant - developed process for pyrolytic production of char and oil.
W180	General Electric Company Power Generation Division 55 Hawthorne St. P.O. Box 3736 SAN FRANCISCO, CA. 94119	Mr. D.E. Cecich Sales Engineer	Turbine generation systems. Large and super large turbo generation systems to 1,500,000 kw.
W181	Mr. Ward N. Harris RFD #2, Box 205 STUTTGART, ARK. 72160		Consultant - rice husk.
W182	Hawaiian Agronomics P.O. Box 3470 HONOLULU, HI. 96801	Mr. Wm. G. Golden Mr. Rayburn E. Parker	
W183	David F. Houston 223 Behrens Street EL CERRITO, CAL. 94530		Retired Western Regional Research Laboratory worker, author of Rice Chemistry and Technology.
W184	J.B. Hunt Company P.O. Box 9 STUTTGART, ARK. 72160	Mr. John B. Hunt President	Supplier of rice husk for all types of users.
W185	Industrial Materials Co. 2921 Leonis Blvd. LOS ANGELES, CA. 90058	Mr. Norman Pitt, Pres. Mr. Webb L. Nimick, Gen. Mgr.	Producers of finely ground chars usable for acid-resistant concrete and rubber reinforcing.

W186	Kansas State University Dept. of Grain Science & Industry MANHATTAN, KS. 66506	Mr. Ulysses A. Acasio	Research and development of husk-fired dryers.
W187	E. Keller Company 238 West Street WILLIAMSPORT, PA. 17701	Mr. Robert E. Lantz	Boiler manufacture - water and smoke tube.
W188	Kewanee Boiler Corp. 101 Franklin Street KEWANEE, ILL. 61443	Mr. G.L. Kasparian	Design information; supplier of boilers and stokers.
W189	League for International Food Education 1155 - 16th St. N.W. WASHINGTON, D.C. 20036	Dr. J. Ritchie Cowan President	A consortium of eight technical societies formed to help solve the world food and nutrition problems through education.
W190	James Leffel & Co. SPRINGFIELD, OH. 45501		Scotch boilers - underfeed stokers.
W191	The Library of Congress Reference Department Science & Tech. Div. WASHINGTON, D.C. 20540		Research Library.
W192	Liquid Processing Systems, Inc. 640 -143rd Avenue SAN LEANDRO, CA. 94578	Mr. Harvey Finch	Patent holder on char product process - interested in heat recovery and utilization, especially for water purification.
W193	The Department of Chemistry Louisiana State University BATON ROUGE, LA. 70803	Prof. Harlon O. Traylor Mr. Reid M. Grigsby	
W194	McBurney Stoker & Equipment Co., Inc. P.O. Drawer 47848 ATLANTA, GA. 30340	Mr. W.B. McBurney	Stokers and husk-fired power plants.
W195	Michigan State University Agricultural Engineering Dept. EAST LANSING, MI. 48823	Dr. B.A. Stout, Chmn.	Interested in energy implications of rice husk.
W196	M&M World Marketing Inc. Hispania Towers 7330 Northwest 12th Street MIAMI, FLA. 33126	Mr. G.E. Mustelier, Jr.	Rice-husk power complexes.
W197	Nathan Manufacturing Div. Wegner Machinery Corp. 35-41 Eleventh Street LONG ISLAND CITY 6, N.Y.	Mr. Jack N. Swendsen Manager	Series of very small and small turbines.

W198	The Quaker Oats Company Merchandise Mart Plaza CHICAGO, ILL. 60654	Mr. Leonard Stieger V. Pres.-Chemicals	Furfural production from rice-husk residue and production of steam.
W199	Resource Recovery Systems Barber Colman Co. IRVINE, CA.	Mr. T.H. Crane Sr. Prog. Engineer	Pyrolysis development, chemical recovery.
W200	Rice Growers Assn. of Ca. P.O. Box 958 SACRAMENTO, CA. 95803	Mr. Robert R. Mickus Research Director	Rice hull producer - research and development.
W201	Rice Journal Enterprises P.O. Box 14260 WASHINGTON, D.C. 20004	Mr. Carlisle B. Morrison Editor Mr. Gordon S. Carlson, Pub.	The Rice Journal magazine
W202	The Rice Millers Assoc. 1048 Pennsylvania Building WASHINGTON, D.C. 20004	Mr. J. Stephen Gabbert Executive V. Pres.	United States Millers' organization.
W203	Riviana Foods, Inc. P.O. Box 2636 HOUSTON, TX. 77001	Dr. John W. Hunnell	Rice milling and processing - fundamental interest in rice husk utilization.
W204	Stanford Research Institute 333 Ravenswood Avenue MENLO PARK, CA. 94025	Mr. F. Michael Lewis Sr. Mech. Eng.	Research on pyrolysis and gasification. Development work on char for rubber compounding.
W205	Skinner Engine Company ERIE, PA. 16512	Mr. R. Dennis Whiting	Steam turbines.
W206	Terry Corporation P.O. Box 1200 HARTFORD, CONN. 06101	Mr. Peter R. James	A complete line of turbines.
W207	Tillo Products Co. P.O. Box 34165 SAN FRANCISCO, CA. 94134	Mr. D.G. Westerbeke	Commercial utilization of husk as sewage sludge dispersant.
W208	Turbodyne Corporation Steam Turbine Division WELLSVILLE, N.Y. 14895	Mr. Gordon M. Grantier	Worthington turbines. A full line of turbines.
W209	Uncle Ben's Foods P.O. Box 1752 HOUSTON, TX. 77001	Mr. K.K. Keneaster Dir. Tech. Services	Rice milling and processing firm. Interested in all facets of husk utilization.
W210	Southern Regional Research Laboratory Agricultural Research Ser. United States Dept. of Ag. 1100 Robert E. Lee Blvd. NEW ORLEANS, LA. 70124	Mr. James J. Spadaro	National laboratory - research and development work on rice husk.

W211	Western Regional Research Laboratory Agricultural Research Ser. United States Dept. of Ag. 800 Buchanan Street ALBANY, CA. 94710	Dr. Arthur I. Morgan Jr. Director Mr. R.M. Saunders, Proj. Leader Mr. Robert L. Roberts, Technologist	National laboratory - research and development work on rice husk.
W212	National Agricultural Library U.S. Dept. of Agriculture BELTSVILLE, MD. 20705		National library.
W213	U.S. Dept. of Commerce National Technical Info. Ser. SPRINGFIELD, VA. 22151		National information service.
W214	U.S. Energy Research & Development Administration 1016 16th Street, N.W. WASHINGTON, D.C. 20545	Mr. John Tosh	Energy implications of rice husk for energy programs.
W215	Pacific Northwest Environmental Research Lab. U.S. Environmental Pro. Agency CORVALLIS, OR. 97330	Dr. H. Kirk Willard	Garrett pyrolysis project.
W216	Solid & Hazardous Waste Research Laboratory U.S. National Environmental Research Center CINCINNATI, OH. 45268	Mr. Robert L. Stenburg, Director	EPA function concerning rice husk.
W217	Dept. of Chemical Engineering University of California BERKELEY, CA. 94720	Prof. Scott Lynn	Development of production of silicon tetrachloride from rice husk.
W218	Dept. of Civil Engineering University of California 537 Davis Hall BERKELEY, CA. 94720	Dr. P.K. Mehta Assoc. Prof. Eng. Sci.	Inventor of process to produce cement from rice-husk ash and char.
W219	Dept. of Agricultural Eng. University of California DAVIS, CA. 95616	Dr. Brian Horsfield Asst. Prof.	Gas producers - designed and built a test suction gas-producer for use on renewable agricultural fuels - producer design - gasification theory - economic factors.
W220	College of Engineering The University of Utah SALT LAKE CITY, UT. 84112	Dr. Ivan B. Cutler, Prof.	Inventor of process to produce silicon carbide and silicon nitride from rice husk. Consultant on production of silicon nitride from rice husk.

W221	The University of Toledo 2801 W. Bancroft Street TOLEDO, OH. 43606	Dr. Wilhelm Eitel	Basic silica research.
W222	URS Research Company 155 Bovet Road SAN MATEO, CA. 94402	Mr. Milton Staackman Sr. Chem. Engr. Mr. Thomas C. Goodale	Research company - did 1970 USDA report on rice husk utilization.
W223	Wallace-Atkins Oil Corp. 2001 Kirby Dr., Suite 906 HOUSTON, TX. 77019		A holder of process for production of char and oil from rice husk.
W224	Eldon C. Beagle P.O. Box 874 WEST SACRAMENTO, CA. 95691		Consultant, rice husk utilization.

THE FAO AGRICULTURAL SERVICES BULLETINS

1. Farm planning in the early stages of development, 1968 (E** F* S*)
2. Planning for action in agricultural development, 1969 (E* F* S*)
3. Karakul processing, 1969 (E*)
4. Bread from composite flour, 1970 (E*** F* S*)
5. Sun-drying of fruits and vegetables, 1970 (E* F* S*)
6. Cashew nut processing, 1970 (E* F*)
7. Technology for the production of protein food from cottonseed flour, 1971 (E* F* S*)
8. Cassava processing, new edition (1977) available (E, F, S) in the FAO Plant Production and Protection Series
9. World list of food technology institutions, 1971 (Tri***)
10. Technology for the production of protein foods from groundnut, 1971 (E* F* S*)
11. Technology for the production of protein foods from soybean, 1972 (E* F* S*)
12. Guide to instructors in organizing and coordinating agricultural engineering training courses, 1971 (E* F* S*)
    - Suppl. 1. Elements of agricultural machinery, Vol. 1, 1977 (E* S*)
    - Suppl. 2. Elements of agricultural machinery, Vol. 2, 1977 (E* S*)
13. Fruit juice processing, 1972 (E* F** S*)
14. Environmental aspects of natural resource management – agriculture and soils, 1972 (E* F* S*)
15. Sericulture manual: Vol. 1 – Mulberry cultivation, 1976 (E* F*)
    - Vol. 2 – Silkworm rearing, 1973 (E* F*)
    - Vol. 3 – Silk reeling, 1972 (E* F*)
16. Use of aircraft in agriculture, new edition (1974) available (E, F, S) in the FAO Agricultural Series
17. Airtight grain storage, 1973 (E* F* S*)
18. Rice testing – methods and equipment, 1973 (E*)
19. Cold storage – design and operation, 1973 (E* F* S*)
20. Processing of natural rubber, 1973 (E*)
21. Rev. 1 – Agricultural residues: world directory of institutions, 1978 (Tri*)
22. Rice milling equipment – operation and maintenance, 1974 (E*)
23. Rice drying (E***)
24. World list of textile research institutes, 1974 (Tri*)
25. Utilization of molasses, 1975 (E* F* S*)
26. Tea processing, 1974 (E*)
27. Some aspects of earth-moving machines as used in agriculture, 1975 (E*)
28. Mechanization of irrigated crop production, 1977 (E*)
29. Non-mulberry silks, 1977 (E*** F*** S***)
30. Machinery servicing organizations, 1977 (E*)
31. Rice-husk conversion to energy, 1978 (E* F*** S***)
32. Blood utilization (E*** F*** S***)
33. Agricultural residues: compendium of technologies, 1978 (Tri*)
34. Farm management data collection and analysis, 1977 (E* F*** S***)
35. Bibliography of agricultural residues, 1978 (Tri*)

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E – English	* Available
F – French	** Out of print
S – Spanish	*** In preparation
Tri – Trilingual	

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Manual of Information: RIFE Hydraulic Rams

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MANUAL OF INFORMATION

RIFE HYDRAULIC WATER RAMS

SINCE 1884

"WATER PUMPS WATER"

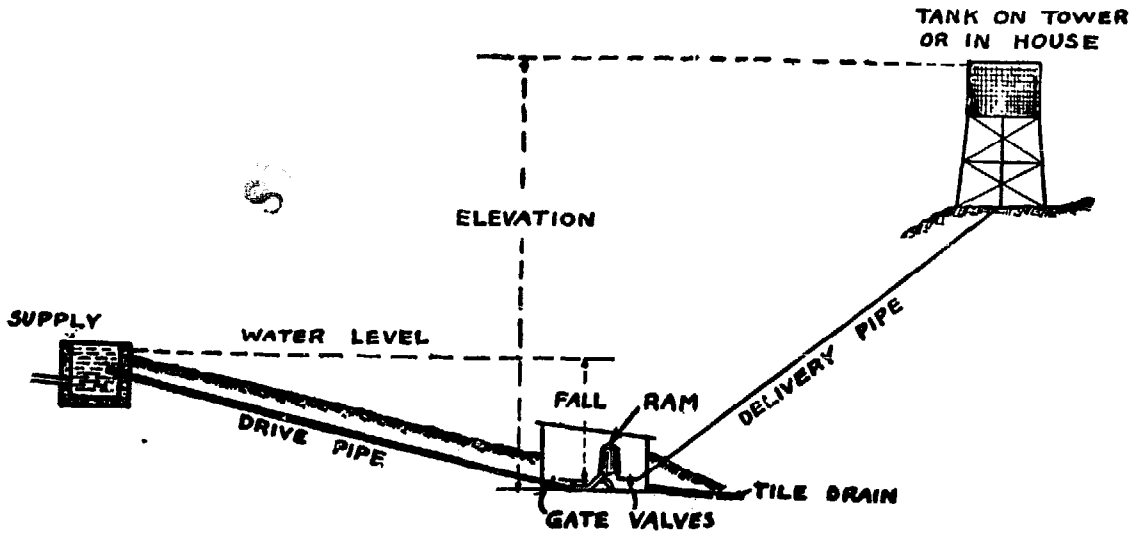

Manufactured By
Rife Hydraulic Engine Manufacturing Co.
Rife Ram and Pump Works
316 W. Poplar Street
Norristown, PA 19401
(215) 279-2997

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RIFE RAMS

What They Are and What They Will Do

A RIFE HYDRAULIC RAM is a device for pumping water by means of water-power, connected with a Spring, Creek, or Artesian Well, with a flow of 1½ gallons per minute or more. It is necessary to have a Fall or "Head" of 20 inches or more. When so located, it will automatically pump a good volume of the water to a height of 25 feet for each one-foot of Fall available. (For example, if there is a Fall of 3 feet, the Ram will pump a good volume of water 75 feet high.)

RIFE HYDRAULIC RAMS are built on the "HIGH BASE" principle, embracing a Positive and Automatic Air Feed which maintains indefinitely the all-important "Air Cushion" in the Air Chamber, preventing the Air Chamber filling up with water. They are the last word from the standpoint of efficiency and freedom from service interruptions. They use NO GASOLINE, NO ELECTRICITY, NO POWER BILL. *A RIFE RAM will pump a continuous flow of water day in and day out, year in and year out, without one cent operating cost.* THE FLOW AND FALL OF YOUR OWN WATER DOES THE PUMPING.

RIFE RAMS have been manufactured continuously since 1884 and since that time more than 50,000 have been sold in every State of the Union and in many foreign countries.

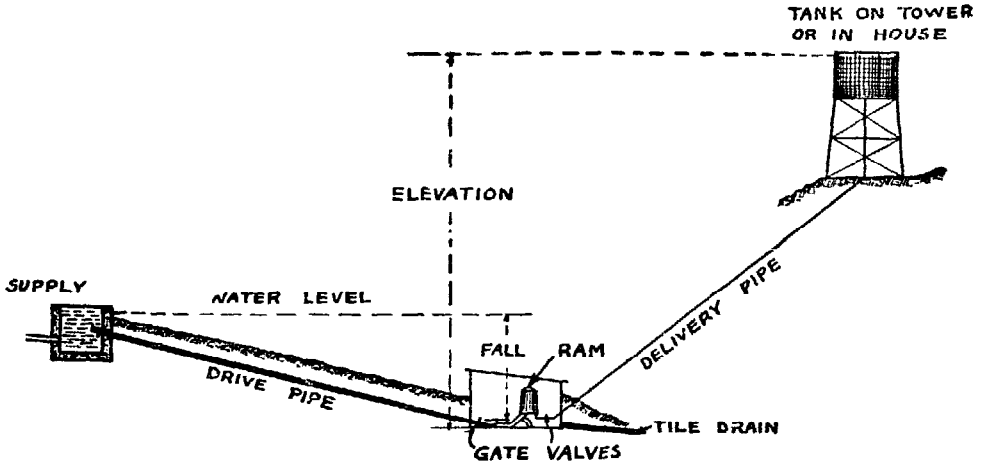

USUAL METHOD OF INSTALLING A RIFE HYDRAULIC RAM. THIS MAY BE VARIED, DEPENDING ON LOCAL CONDITIONS. SEE FOLLOWING PARAGRAPHS.

HOW A RIFE HYDRAULIC RAM WORKS

The operation of a Rife Hydraulic Ram may be briefly expressed as follows: Water flows down the Drive Pipe to the Ram and develops a certain power due to its weight and velocity. It flows through the Outside Valve until it reaches a certain velocity, then the Valve closes suddenly. The column of water continues on through the Inside Rubber Valve into the Air Chamber. When the pressure in the Air Chamber equalizes and overcomes the Drivng Force behind it, a rebound takes place. This operation is repeated from 25 to 100 times per minute working on a Hydraulic principle, building up pressure in the Air Chamber, which in turn forces water through the Delivery Pipe up to where it is desired.

With each stroke of the Ram the water in the Drive Pipe rebounds or backs up, which causes a partial vacuum under the Outside Valve, allowing it to drop away from its seat. Momentarily the water again begins to flow down the Drive Pipe and the action is repeated. When the rebound takes place a small amount of air is sucked through the Air Feed Valve and lodges in the upper portion of the Base and is forced into the Air Chamber when the next blow takes place; this prevents the Air Chamber from filling up with water.

INFORMATION REQUIRED

For each prospective installation it is necessary to have the following information—

1. Flow of Supply Water { Spring / Creek / Artesian Well } in Gallons per minute.
2. The Vertical Fall in feet from the Source of Supply to Location of Ram.
3. Distance between Point of Supply and where Ram is to be located.
4. Vertical Height above Ram the water is to be raised.
5. Pipe Line distance water is to be delivered.
6. Number of Gallons requried per day of 24 hours.

FLOW OF SUPPLY WATER AVAILABLE IN GALLONS PER MINUTE

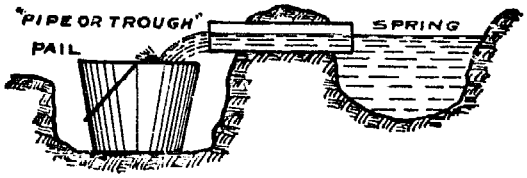

DETERMINE HOW MANY SECONDS ARE REQUIRED TO FILL A BUCKET OF KNOWN CAPACITY.

Do not guess at this: Be sure to measure it! If the supply is small, run the water into a bucket or tub of known capacity, using the second hand of a watch to figure how much supply water is available in gallons per minute. This should be figured on basis of flow at dryest season of the year.

MEASURING LARGE QUANTITIES OF WATER

Where the flow of water is large and therefore not practical for measuring by means of a bucket or tub, make use of a notch in a board, known as a "Weir."

Measure the width of the notch "W" and the height of the water in the notch "H". The height should be measured on a level 2 feet up from stream from the notch.

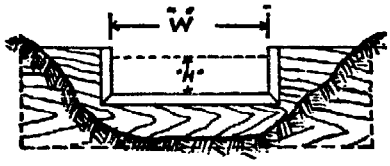

THE RATE OF FLOW CAN BE QUICKLY DETERMINED BY REFERRING TO THE "WEIR TABLE" BELOW.

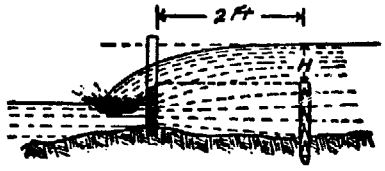

WEIR TABLE FOR DETERMINING THE FLOW OF STREAM

INCHES	0	⅛	¼	⅜	½	⅝	¾	⅞
0	0.00	0.01	0.05	0.09	0.14	0.19	0.26	0.32
1	0.40	0.47	0.55	0.64	0.73	0.82	0.92	1.02
2	1.13	1.23	1.35	1.46	1.58	1.70	1.82	1.95
3	2.07	2.21	2.34	2.48	2.61	2.76	2.90	3.05
4	3.20	3.35	3.50	3.66	3.81	3.97	4.14	4.30
5	4.47	4.64	4.81	4.98	5.15	5.33	5.51	5.69
6	5.87	6.06	6.25	6.44	6.62	6.82	7.01	7.21
7	7.40	7.60	7.80	8.01	8.21	8.42	8.63	8.83
8	9.05	9.26	9.47	9.69	9.91	10.13	10.35	10.57
9	10.80	11.03	11.25	11.48	11.71	11.94	12.17	12.41
10	12.64	12.88	13.12	13.36	13.60	13.85	14.09	14.34

This table gives the number of cubic feet of water that will pass over a weir 1 inch wide and from ⅛ to 10⅞ inches in depth. The figures in the first upright column represent whole inches and those in the top horizontal line represent fractional parts of an inch of depth over the weir. The figures in the second upright column indicate the number of cubic feet of water that will flow per minute over the weir for whole inches in depth, and in the succeeding columns, whole inches and the fractions under which they occur. Then the number of cubic feet thus found multiplied by the width of the weir in inches will give the capacity of a stream.

Example: To find the required number of cubic feet of water that will flow over a weir 4¼ inches in depth and 30 inches in width, follow down the left-hand column of figures in the table to 4, then across until directly under the ¼ in the top line, where will be found 4.14; this, multiplied by 30 (width of notch in weir) will give 124, the number of cubic feet of water that passes over the whole weir per minute. To reduce to gallons per minute multiply by 7½ which equals 930 gallons per minute.

DETERMINING THE VERTICAL FALL

The Fall or difference in the Vertical elevation between the level of the water at the source of supply and where the Ram will be located is known as the Fall. This can be easily and quickly measured by the use of an ordinary carpenter's level on a stick, starting at where the Ram will be located and going upwards, as shown in the following illustration.

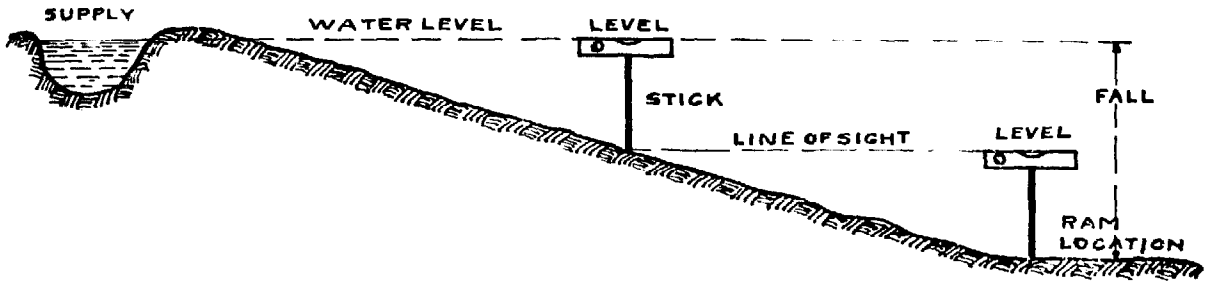

METHOD OF USING CARPENTER'S LEVEL TO DETERMINE THE FALL OR HEAD.

Bear in mind that the more Fall available, the more water the Ram will pump—all other conditions being the same. For example: With a Fall of 8 feet the Ram will pump exactly twice as much water as with a Fall of 4 feet. Therefore it is advisable to take advantage of all the Fall available. In most instances, to get more Fall, it is merely a matter of locating the Ram further downstream.

VERTICAL ELEVATION

The VERTICAL ELEVATION—that is the height which the water is to be pumped above the Ram location—can easily be determined by use of an ordinary carpenter's level on a stick as illustrated, see page 4, for determining the amount of Fall. Start measurements at Ram location and work upward to the highest point at which water is to be delivered.

DISTANCE WATER IS TO BE DELIVERED

This is the Pipe Line distance from the the Ram Location to the farthest point water is to be delivered.

RULE FOR CALCULATING THE NUMBER OF GALLONS OF WATER RIFE RAMS WILL PUMP

As soon as you have the "Information Required," as listed on page 3, you can easily figure the amount of water a Ram could deliver for you. Multiply the available flow in gallons per minute (V) by the vertical fall in feet (F), divide by the vertical elevation (E), and multiply the result by 6/10 (60%), the normal efficiency of a Ram installation:

$$V \times F/E \times 6/10 = D$$

This will give you the delivery (D) in gals. per min. using all the available water supply. To obtain gals. per hr., multiply this amount by 60 and to gals. per day, multiply by 1440.

CHOICE OF MODEL AND SIZE OF RAM

Consult the Specification Sheet. Select first the model designed to handle your vertical fall and lift; then, in that model, the smallest size which will handle the available flow of water in gals. per min. which you have. You can confirm your calculation from the chart on page 5, which gives the percentage of the water used (V) a RIFE Ram will deliver under various conditions of vertical fall and vertical lift.

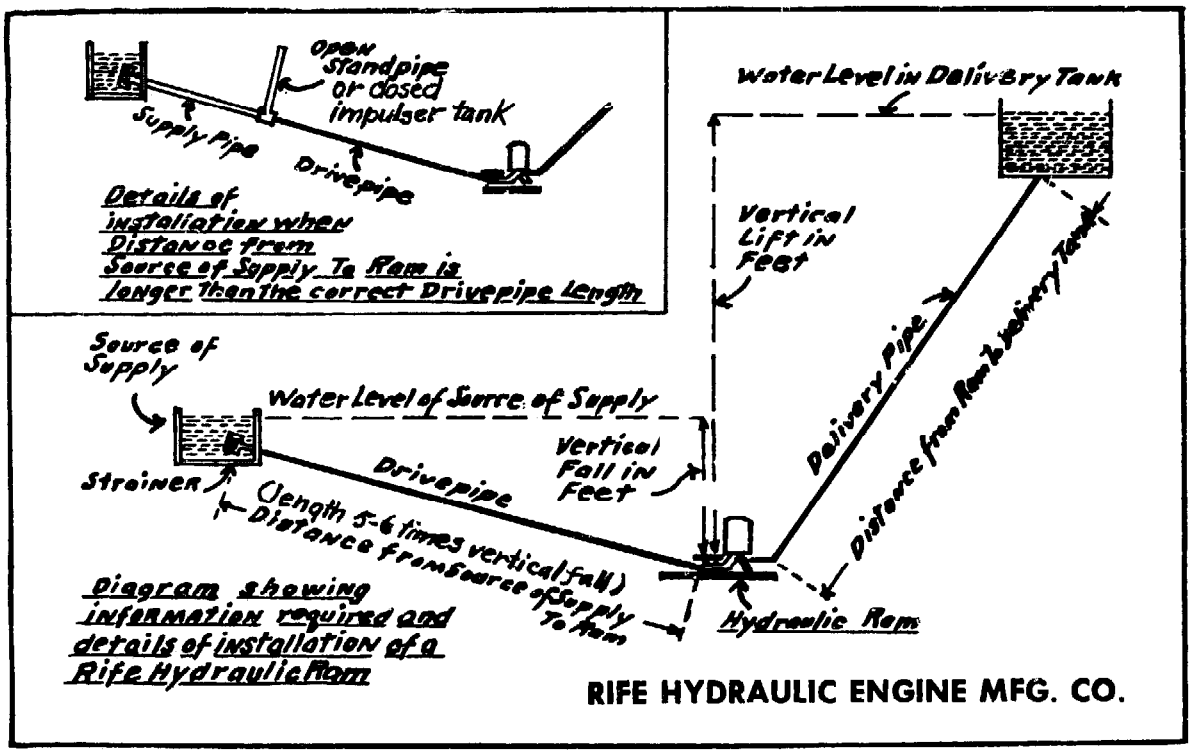

PERFORMANCE CHART FOR RIFE HYDRAULIC RAMS

SHOWING THE PERCENTAGE OF THE WATER USED WHICH THE RAM WILL DELIVER UNDER VARIOUS CONDITIONS OF VERTICAL FALL AND LIFT

Vertical Fall in Feet

	8	16	25	50	75	100	125	150	200	250	300	400	500	
4	22.5%	12.5%	8.0%	3.6%	1.6%									4
8		22.5%	16.0%	9.6%	6.4%	4.5%	3.5%	2.7%	2.0%					8
12			21.5%	13.2%	9.6%	7.2%	5.7%	4.8%	3.3%	2.4%	2.0%			12
16				16.0%	11.7%	9.6%	7.7%	6.4%	4.8%	3.5%	2.9%	2.0%		16
20				18.[illegible]%	14.7%	12.0%	9.6%	8.0%	6.0%	4.8%	4.0%	2.5%	2.0%	20
25				22.5%	16.7%	13.8%	12.0%	10.0%	7.5%	6.0%	5.0%	3.8%	2.5%	25
30					18.0%	15.0%	13.2%	12.0%	9.0%	7.2%	6.0%	4.5%	3.3%	30
35					21.0%	17.5%	15.2%	14.0%	10.5%	8.4%	7.0%	5.3%	4.2%	35
40						18.0%	16.0%	14.7%	12.0%	9.6%	8.0%	6.0%	4.8%	40
50						22.5%	18.0%	16.7%	13.8%	12.0%	10.0%	7.5%	6.0%	50
	8	16	25	50	75	100	125	150	200	250	300	400	500	

Vertical Fall in Feet

Vertical Lift in Feet Including Delivery Pipe Friction

NOTE: The amount of water used and pumped by RIFE Hydraulic Rams increases with increase in the vertical fall from the source of supply to the Ram, and with increased lift of the lever arm above the lever rest during the stroke. This lift determines the opening of the outside valve and is adjustable. The range of intake capacity of each model and size of the new RIFE High Capacity Models is listed on the sheet, "Specifications of RIFE Rams". The "Normal Intake Capacity" listed in gals. per min. corresponds to operation with vertical fall of half the maximum permissible for that model, and with half the possible lift of the lever.

EXAMPLE TAKEN FROM THE ABOVE CHART: A RIFE Ram, using vertical fall of 12 ft., will deliver to elevation of 125 ft. 5.7% of the water used. For a No. 30BU Ram using 40 gpm, this would be about 2¼ gpm. One gpm = 60 [illegible] per hr., or 1440 gals. per day.

RIFE HYDRAULIC ENGINE MFG. CO.

DRIVE PIPES

THE DRIVE PIPE SHOULD BE METAL, (usually galvanized steel), unless encased in concrete. It should be straight as possible without elbows, and normally the same pipe size as intake end of the Ram. It should be watertight and rigidly anchored, with strainer in source of supply to keep refuse out of Ram. THE DRIVE PIPE ITSELF MUST BE OF CORRECT LENGTH. For Rife rams with vertical fall of up to 15 ft. this length is about 6 times the vertical fall; for 25 ft. fall 4 times, and for 50 ft. 3 times. With special conditions ask us for correct length and diameter of drivepipe to assure maximum delivery.

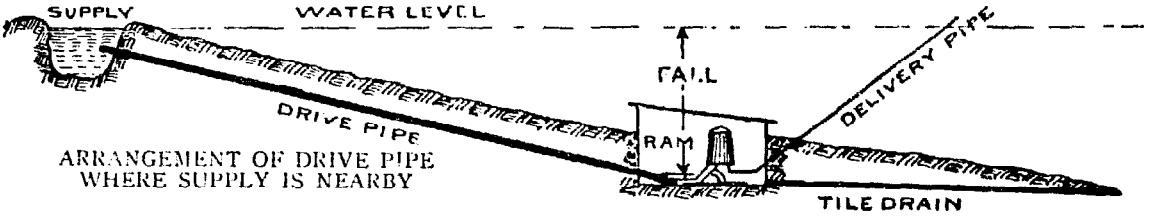

ARRANGEMENT OF DRIVE PIPE WHERE SUPPLY IS NEARBY

Where you have to go down-stream some distance to obtain MORE Fall, it is necessary to use a Standpipe and use a combination of Drive Pipe and Supply Pipe. When practical to run both Supply Pipe and Drive Pipe straight through from the source of supply to where the Ram is located on a straight incline, this can be done by the use of an open Steel Standpipe as illustrated below.

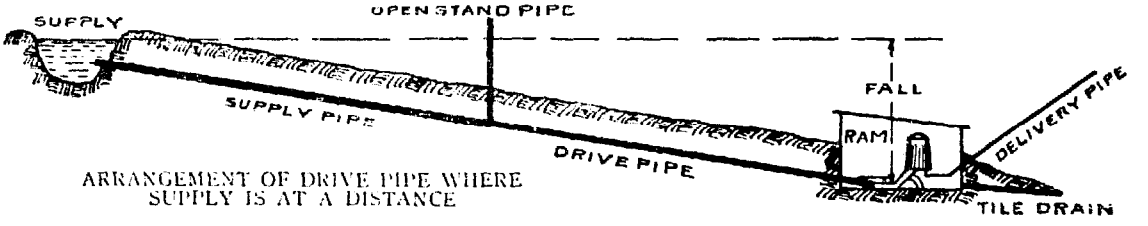

ARRANGEMENT OF DRIVE PIPE WHERE SUPPLY IS AT A DISTANCE

The Supply Pipe must be ONE SIZE LARGER THAN THE DRIVE PIPE. Where the two pipes come together, use a "T" pipe fitting into which is fitted the Open Steel Standpipe, which should be two sizes larger than the Supply Pipe. The top of the Standpipe should be a few inches ABOVE the level of the water at Source of Supply.

In cases where the Supply Pipe and Drive cannot be carried through on a straight incline, or where the Supply Pipe and Drive Pipes come together at different angles, it is necessary to install a Concrete Pit, the top of which should be several inches above the level of the water at the Source of Supply. Water can be conveyed as much as One Mile through a Supply Pipe when necessary, to get the Fall required to pump the amount of water needed.

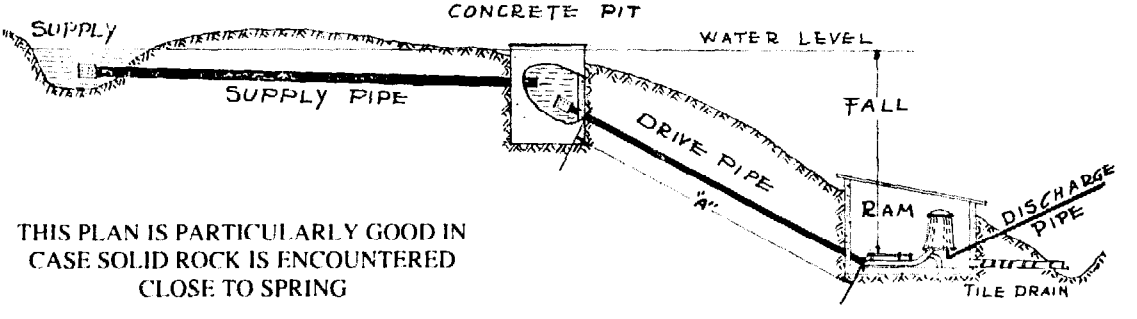

THIS PLAN IS PARTICULARLY GOOD IN CASE SOLID ROCK IS ENCOUNTERED CLOSE TO SPRING

The upper end of the Drive Pipe should be so installed so that it will be at least 1 foot under water at all times in order to avoid whirlpools forming and sucking air into the Drive Pipe.

Where economy is a matter of consideration or where it is impractical to use a Concrete Pit, a joint of large Terra Cotta Tile can be installed as a substitute.

GENERAL INSTRUCTIONS FOR INSTALLING RIFE RAMS

Rife Rams are easy to install when instructions are followed. There are many different ways Rams can be installed, depending mainly on lay and character of ground and other local conditions. If your conditions are different from those described elsewhere in this Manual, write us, giving full details and we will advise you explicitly regarding the proper method of installing the Ram.

THE BEST LOCATION FOR THE RAM

Always locate the Ram as near the source of supply and the delivery point as is possible while maintaining the lowest elevation. This will insure the minimum expense for pipe. Sinking a deeper ram pit and digging out for drive pipe and waste line might improve the installation at a saving.

FOUNDATION AND RAM PIT

A concrete slab or a large flat rock provides a good solid foundation on which to set the Ram. The best procedure is to put in a concrete slab as a foundation, slightly sloping towards the rear where the waste water will be carried off. After the Drive Pipe and Delivery Pipe are installed and the Ram is in operation, the Ram should be enclosed in a concrete pit. The Ram pit should be large enough to give a clearance of 18" from Ram on all sides in order to expedite removal of bolts should occasion necessitate. The pit should be high enough to prevent normal flood water getting in. Sloping shed roof of boards provides a good cover or protection. However, in colder climates it is well to cover with a concrete slab in order to prevent freezing.

A manhole or metal cistern cover can be used to provide an opening to get into the Ram pit. This metal manhole covering can be provided with a lock if desired.

DELIVERY PIPE

Correct size Delivery Pipe should be the dimensions given for each particular size Ram. Do not install Delivery Pipe smaller than that specified, because to do so increases the amount of friction loss and a consequent reduction in the amount of water delivered. Avoid right angle elbows wherever possible to reduce friction loss. Use a good grade of red or white lead on the joints and screw up good and tight. DO NOT FILL UP THE DITCH UNTIL THE RAM IS STARTED AND IN OPERATION SO THAT IN CASE LEAKS DEVELOP THEY CAN BE EASILY LOCATED AND STOPPED BEFORE COVERING THE DELIVERY PIPE.

The installation of a Gate Valve (D) in the Delivery Pipe at the Ram is a great convenience for cutting off water when it is necessary to adjust or repair Ram. The ditch for the Delivery Pipe should be sufficiently deep to be below the frost line.

In case Delivery Line goes over the top of a hill and down into a valley on its way from the Ram to the house, a small Air Release Valve or Pet Cock should be installed in the Delivery Pipe at the highest point to release accumulations of air from time to time. Otherwise air will collect in such volume it will retard the free flow of the water.

In connecting up to a reservoir, the Delivery Pipe should enter the *bottom* and when being laid "T" pipe fittings should be installed at convenient points to take off service connections wherever desired.

The overflow pipe should also enter the *bottom* of the reservoir and terminate with a sleeve joint connection. Into this sleeve joint is screwed a piece of pipe the length of which determines the height of the water in the reservoir. An emergency overflow should be provided in the side of the reservoir at the top a few inches above the level of the regular overflow.

DRAIN TILE

The Ram pit should be provided with drain tile to carry off the waste water. In many cases the total amount of Fall available can be materially increased by sinking the Ram pit deep into the ground and carrying off the waste water through a long line of drain tile on a Fall of 1½ to 2 inches per 100 feet and of sufficient length to bring it out at water level down stream. In many cases it is a choice between increasing the length of the Supply Pipe or running a line of drain tile. In most cases it is cheaper to use more tile and less length of steel Supply Pipe.

OPERATION

SECTION DRAWING OF
"NEW MODEL" SERIES BU RAM

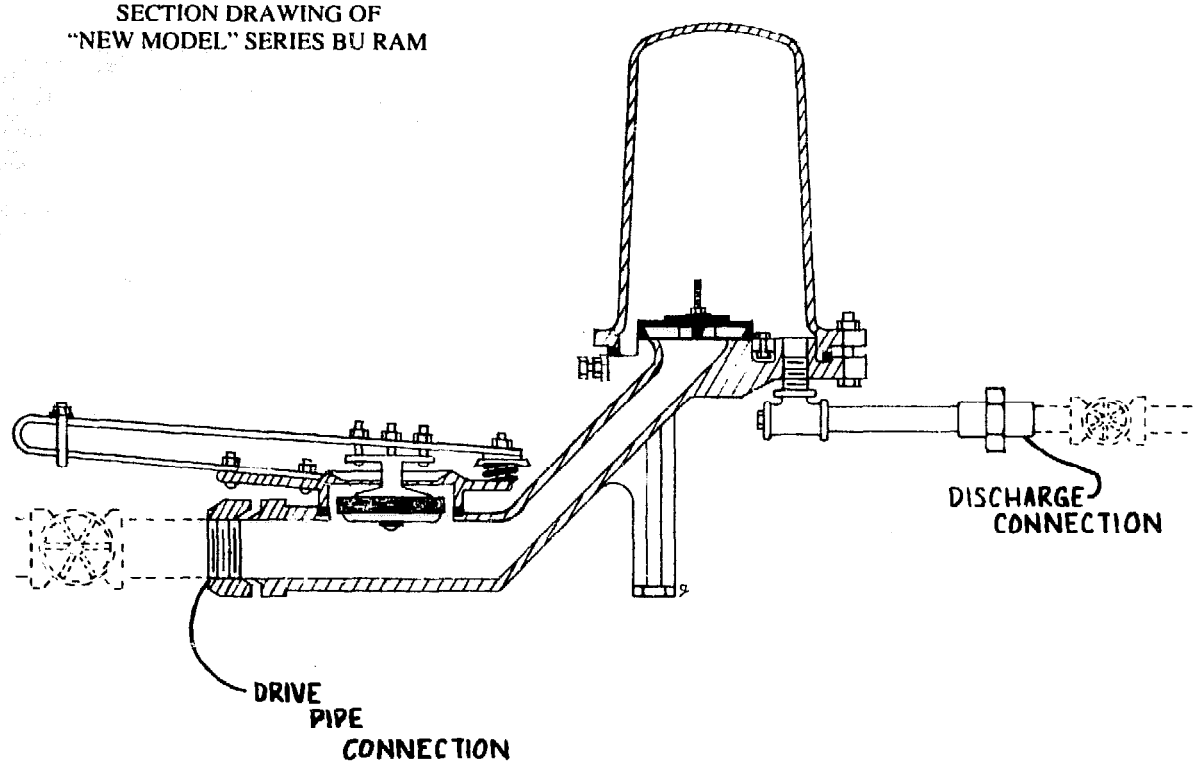

HOW TO START A RIFE HYDRAULIC RAM

The Drive Pipe must be full of water. If there is a valve between the RAM and the Drive Pipe, this must be open. If there is a valve between the RAM and the delivery pipe, this should be closed.

Then open the waste (outside) valve by pushing the valve down for about 2 seconds allowing the waste from the drive pipe to escape through the valve. Release the valve which will then close from the pressure of the water below. The water in motion will then drive forward entering the air chamber through the inside valve. The inside valve will close, the waste valve will re-open, and the RAM should begin to operate automatically forcing water continuously into the air chamber. If the RAM does not begin to work automatically at once, repeat the opening of the waste valve several times.

If there is a valve between the RAM and the delivery pipe this should be opened after the RAM has made 10 to 15 strokes.

As soon as the delivery pipe is full, water will begin to flow from its upper end.

If the pressure on the waste valve is too great to allow it to be opened (depressed) by hand the same result can be obtained by alternately opening and closing the valve between the drive pipe and the RAM.

The RAM is started by the same process and operates in the same manner whether or not there are valves at each or either end of the Ram.

The air feeder valve should be set so that it gives a small spurt of water with each stroke. If the valve is too far open, the air chamber will fill with air and the RAM, while continuing to operate, will pump only air. If valve is not sufficiently open, the water going through the RAM will absorb all the air in the air chamber and the RAM will begin to pound with a metallic sound at every stroke. This condition should be immediately corrected by increasing the opening of the air feeder valve as it might result in breakage of some part of the RAM.

ADJUSTMENT:

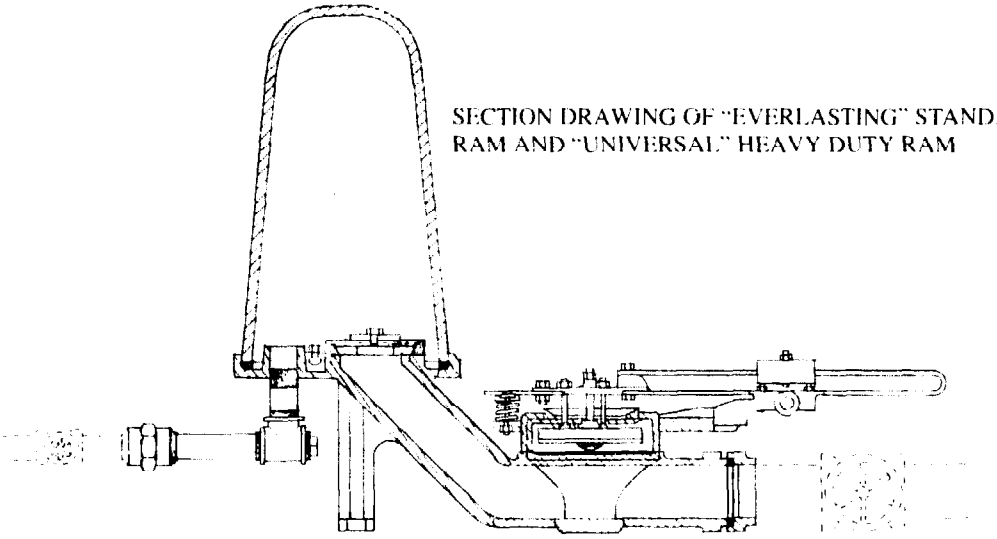

SECTION DRAWING OF "EVERLASTING" STANDARD RAM AND "UNIVERSAL" HEAVY DUTY RAM

REGULATING AIR SUPPLY

The air feeder valve should be set so that it gives a small spurt of water with each stroke. If the valve is too far open, the air chamber will fill with air and the RAM, while continuing to operate, will pump only air. If valve is not sufficiently open, the water going through the RAM will absorb all the air in the air chamber and the RAM will begin to pound with a metallic sound at every stroke. This condition should be immediately corrected by increasing the opening of the air feeder valve as it might result in breakage of some part of the RAM.

SETTING AT MAXIMUM CAPACITY

To regulate the Ram to operate at *maximum* capacity under average conditions, the Outside Valve should operate at 20 to 40 strokes per minute.

SETTING AT MINIMUM CAPACITY

To regulate the Ram to operate at *minimum* capacity under average conditions, the Outside Valve should operate at 60 to 100 strokes per minute.

Each larger size Ram has slower max. and min. strokes.

USING MORE OR LESS WATER

The *slower* the strokes per minute of the Outside Valve the more water the Ram uses and the more water it pumps. The *faster* the strokes per minute of the Outside Valve the less water the Ram uses and the less water it pumps.

To slow down the strokes per minute at which the Outside Valve operates, lower the Lever Rest by screwing down the nuts on bolts that hold it in place.

To increase the number of strokes per minute of the Outside Valve raise the Lever Rest by unscrewing the nuts on bolts that hold it in place.

Each Rifle Ram will regulate with a *minimum* and *maximum* amount of water, which provides for variation in flow of supply water during droughts and wet seasons. Regulation to vary the amount of water used by the Ram would, therefore, be accomplished by raising and lowering the Lever Rest.

A careful study and observance of the above instructions will soon enable any one to properly regulate the stroke of the Ram to any number per minute from full capacity down to a minimum supply of water in dry season.

Carefully check over Ram once a week for several months to make certain no bolts have worked loose.

MAINTENANCE and REPAIRS:

We endeavor to maintain at all times a complete supply of replacement parts for our RAMS in all sizes for immediate shipment. Parts list and assembly diagram will be mailed upon request.

In ordering parts please specify Model size and serial number of RAM.

DOUBLE ACTING RAM

RIFE'S DOUBLE ACTING RAM is used where there is not sufficient Pure Spring Water available to operate a Ram, but where there is a nearby creek with sufficient water and Fall to operate the Ram. In this instance the creek water is used to furnish the power to operate the Ram, and pump the Pure Spring Water. It is possible for a RIFE RAM to pump two-thirds of the Pure Uncontaminated Spring Water. The other one-third mixes with the creek water and is wasted through the Outside Valve.

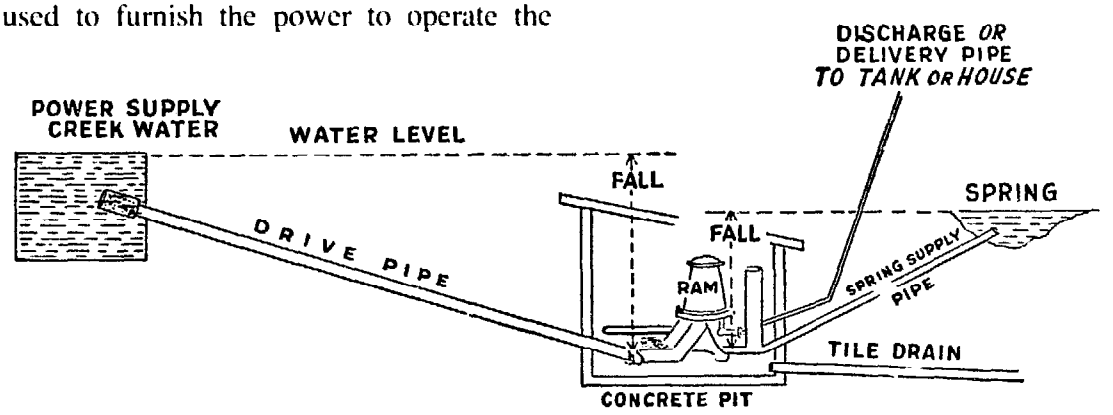

Layout of Double Acting Ram Installation. Spring Water connections can be brought into Ram from any direction. Delivery Pipe can likewise be led away from RAM at any desired angle. A minimum fall of 18 inches is required from Spring to Ram location. Take advantage of all Fall possible of Creek Water.

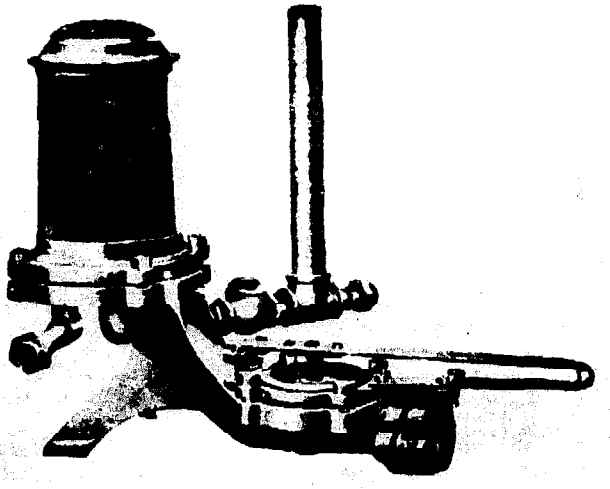

RIFE #20BU DOUBLE ACTING RAM

Showing impure water intake at right, pure water intake with check valve and open standpipe at upper centre, and pure water discharge at left.

SPRING SUPPLY PIPE

The size of the Spring Supply Pipe for each Double Acting Ram is the *same size* as its Delivery Pipe and therefore proper size Spring Supply Pipe for each size Ram.

It is necessary to install a Gate Valve (B) in the Spring Supply Pipe in order to regulate the flow of the Spring Water and to avoid overflowing the Steel Standpipe of the Double Acting Connection, in cases where the Fall from Spring to Ram exceeds 2 feet.

A minimum Fall of 18 inches is required from Spring to Ram Location.

HOW DOUBLE ACTING RAM WORKS

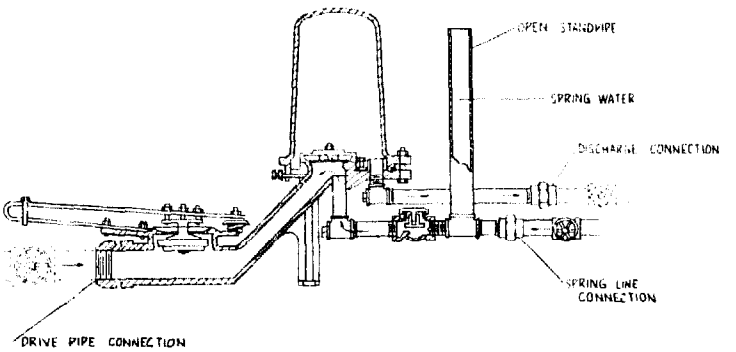

Creek Water provides the Source of Power through Drive Pipe and operates Ram.

At end of each stroke the rebound creates a vacuum beneath Inside Valve which draws pure spring water through Spring Supply Pipe and fills up the area in the base between the Outside Valve and Inside Valve. This action is assisted by reservoir of water in Open Standpipe. A small part of the spring water comes in contact with creek water and is wasted through Outside Valve. The remaining pure, clean uncontaminated spring water is rammed into the Air Chamber through Inside Rubber Valve and delivered through Discharge Pipe to where desired.

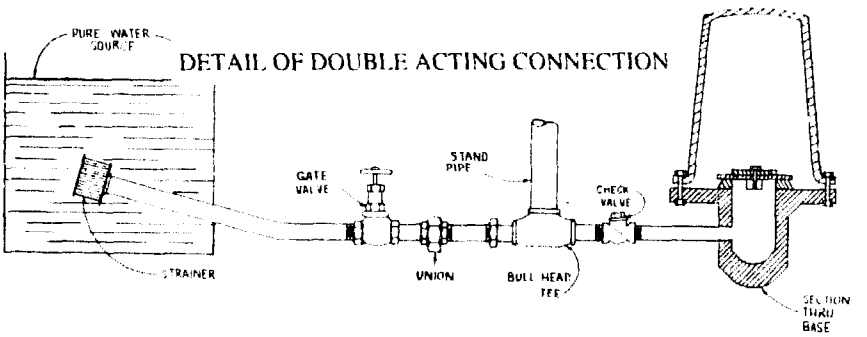

PNEUMATIC PRESSURE TANK WATER SYSTEM

A PNEUMATIC PRESSURE TANK WATER SYSTEM consists of an air-tight steel tank into which water is pumped by the Ram. This tank can be located in the cellar of the house, in the Ram Pit, or any other convenient place. Its location depends upon whether or not use of the waste water is desired. If the overflow or waste water is to be used in a Watering Trough, Dairy, Rock Garden, etc., the Pneumatic Pressure Tank should be installed in the basement or some other location near the house. If no use is to be made of the overflow or waste water, the Pneumatic Tank can be installed in Ram Pit.

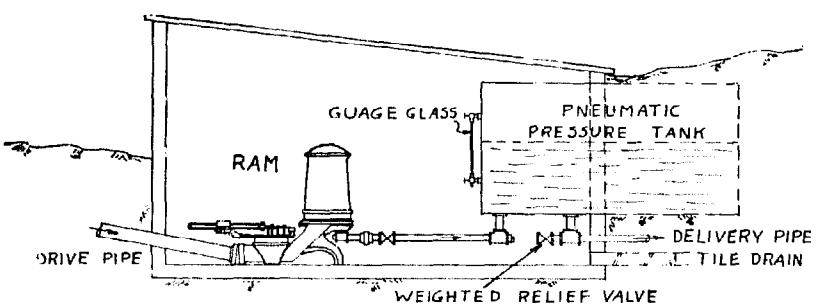

A Relief Valve is installed in the Delivery Pipe. When the pressure in the Tank, corresponding to the setting of the Relief Valve is reached, the water by-passes through the Relief Valve. The location of the Relief Valve should be such that this waste water flows in a downward direction from the Relief Valve to where it is desired. A setting of 20 lbs. on Relief Valve will force water approximately 45 feet above the Tank. A setting of 30 lbs. will force the water approximately 75 feet above the Tank. To *lower* or *raise* water level in pressure tank, feed *more* or *less* air through Air Feed Valve on Ram.

RIFE RAM—ARTESIAN WELL INSTALLATION

An Artesian (flowing) Well provides an ideal source of Supply Water for operating a Rife Ram. Because the constantly flowing sand in the water from Artesian Wells rapidly wears Bronze or other metal valves, Special Composition Rubber Valves are used in Rife Rams, thus eliminating damage from this source.

There are various methods of connecting a Ram to an Artesian Well, as illustrated.

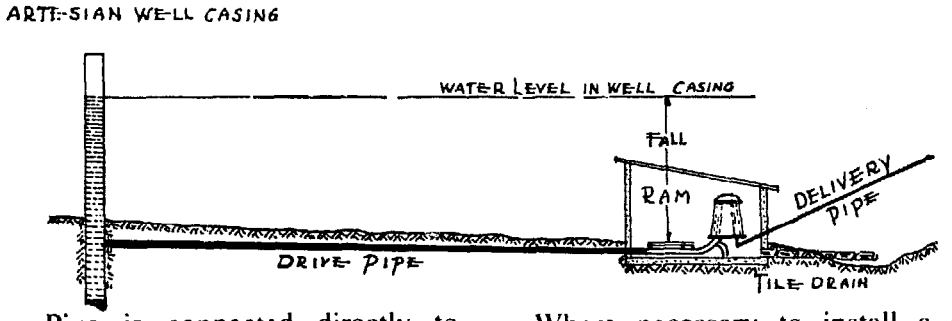

Drive Pipe is connected directly to Well-casing slightly below the level of the ground. Give Drive Pipe as much Slope or Fall to where it connects on to the Ram as the lay of the ground will permit. This method is ideal for small domestic installations.

Where necessary to install a smaller well-casing inside a larger one, and therefore impractical to connect the Drive Pipe directly to the Well-casing below the level of the ground, the installation illustrated below is ideal and inexpensive.

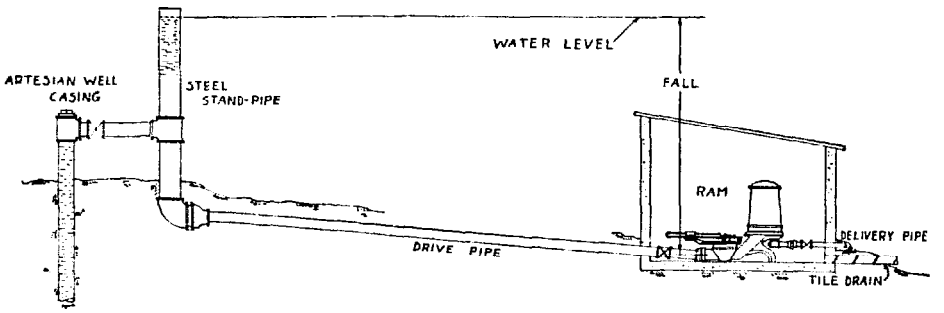

A "T" Pipe-fitting is installed on top of the casing with a Gate or Cut-off Valve controlling the flow of water into the Steel Standpipe, the latter being high enough to prevent overflowing. This type of installation is particularly well adapted to Medium-sized jobs.

LARGE ARTESIAN WELL—RAM INSTALLATION

For Irrigation, Municipal Water Supply and other large installations, this illustration shows a most effective manner of installing the Rife Ram to be operated from Artesian Well. It is particularly well adapted where Two or more Rams are installed in a battery. A Gate or Cut-off Valve controls the flow of water from the well-casing into the Concrete Pit—the Pit being high enough to prevent over-flowing. Note the Drain at the bottom of Concrete Pit for removal of sand accumulation.

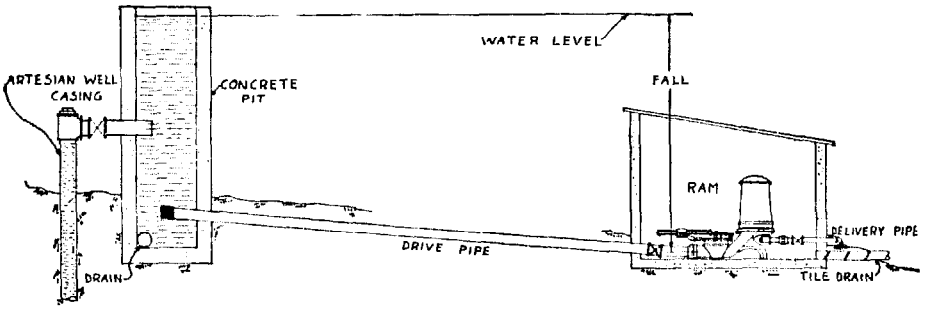

The Correct Length of Drive Pipe
for Artesian Well is determined in the same manner as for Spring or Creek.

INSTALLATION OF TWO OR MORE RAMS

In case two or more Rams are installed along side of each other, it is necessary for each Ram to have its own individual Drive Pipe, but both or all of them can pump into one common Delivery Pipe of sufficient size to carry the water pumped by the Rams.

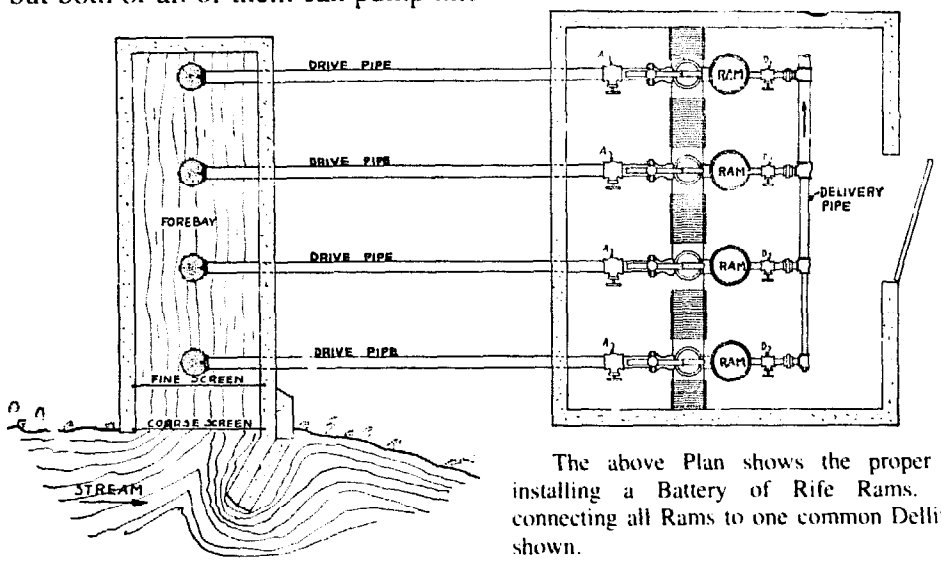

The above Plan shows the proper method of installing a Battery of Rife Rams. Method of connecting all Rams to one common Dellivery Pipe is shown.

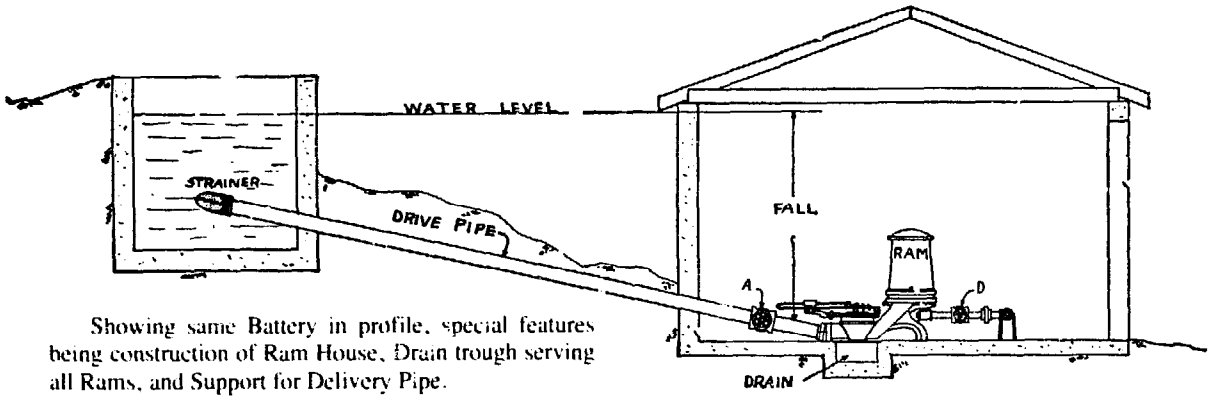

Showing same Battery in profile, special features being construction of Ram House, Drain trough serving all Rams, and Support for Delivery Pipe.

On Irrigation, Municipal Water Supply or other large projects a Battery of 2 or more Rife Rams offers unlimited possibilities for an efficient and economical water system. It is often desirable to install 2 medium sized Rams to pump the same amount of water that could be pumped by one larger sized Ram. For instance, a Golf Course requires much more water in Summer than in Winter. With a Battery Installation the number of Rams kept in operation can be governed by the amount of water required.

We have a number of installations in which a battery of up to six Rams are placed together drawing water from the same source through individual Drive Pipes but pumping through a common Delivery Pipe. This arrangement will deliver a correspondingly larger amount of water than could be obtained with a single Ram.

STORAGE OF WATER

It is often advisable to pump the water into a Storage Tank of some kind so as to have available at all times a large supply for ready use. The storage can either be an outside overhead tank, a concrete pit in the side of a hill, a steel or wooden tank in the attic or a Pneumatic Pressure Tank in the basement. In case the amount of water being pumped exceeds one gallon per minute, a Storage Tank, in most cases, is unnecessary, except for fire protection.

The flow of water from a Rife Ram is continuous 24 hours per day WITHOUT ATTENTION. The water that is not used at the house or the overflow water can be piped to any convenient place such as a Watering Trough, Spring House, Dairy, Pool. Rock Garden, etc.

THE NEW HIGH CAPACITY MODELS OF RIFE AND DAVEY HYDRAULIC RAM PUMPS

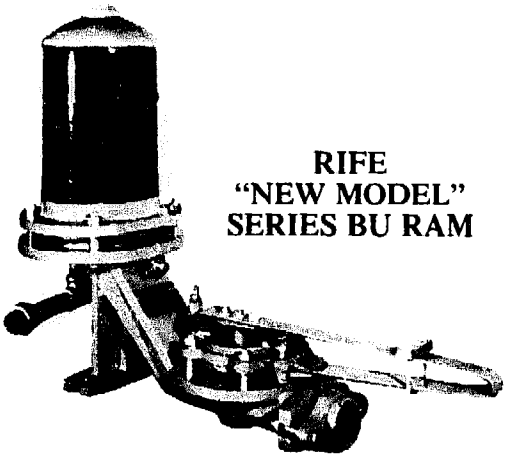

RIFE
"NEW MODEL"
SERIES BU RAM

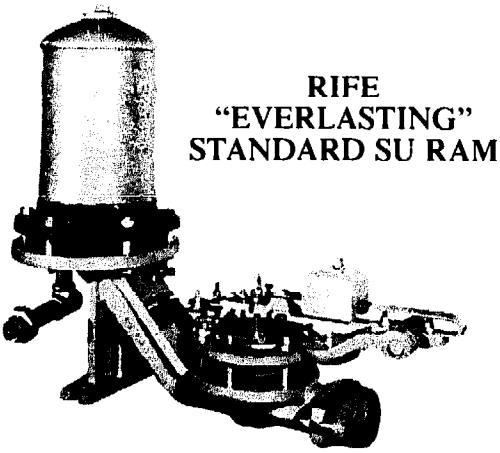

RIFE
"EVERLASTING"
STANDARD SU RAM

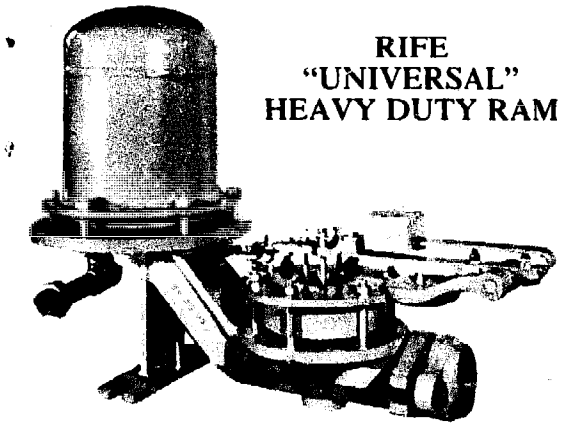

RIFE
"UNIVERSAL"
HEAVY DUTY RAM

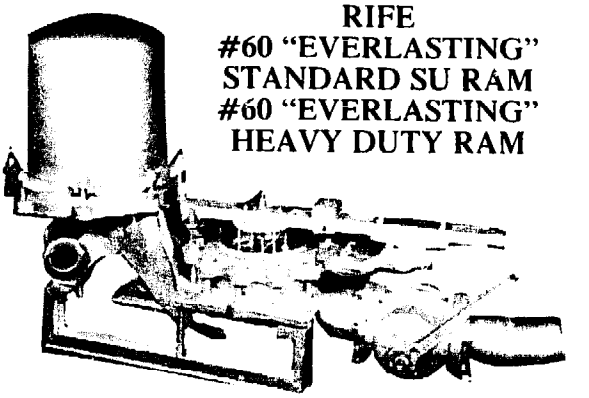

RIFE
#60 "EVERLASTING"
STANDARD SU RAM
#60 "EVERLASTING"
HEAVY DUTY RAM

DAVEY RAM

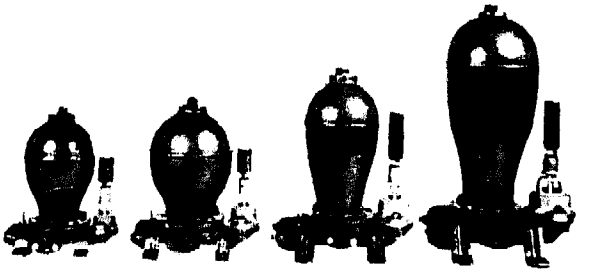

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Information Sheet

For

Proposed Rife Hydraulic Ram Installation

1. Available supply of water in gallons per minute _____

2. Vertical fall in feet _____
   (Measure the amount of vertical fall in feet from the water level of the source of supply down to the level of the foundation on which the Ram will rest.)

3. Distance from source of supply to Ram _____

4. Vertical lift in feet _____
   (Measure the vertical lift in feet from the level of the foundation on which the Ram will rest up to the elevation of the highest point to which the water is delivered.

5. Distance in feet from Ram to delivery tank. _____

6. Number of gallons required to be delivered per day. _____

NAME _____

ADDRESS _____

_____

PHONE _____

If you will fill out this sheet and send it to us, we will send you, without obligation, our recommendation of the size of RAM required and our estimate of the number of gallons per water which it will deliver per day. The diagram on the reverse side of this sheet illustrates a typical RAM installation.

NOTE — The usual hydraulic RAM installation consists of supply basin or reservoir, an inclined drive pipe leading down to the hydraulic RAM, which operates without power, and a delivery pipe and tank located at higher elevation than the supply basin. The amount of the vertical fall to the RAM can be between four and thirty feet and the amount of lift from the RAM to the delivery tank must be at least twice but not more than twenty times the amount of vertical fall.

RETURN TO

RIFE HYDRAULIC ENGINE MFG. CO.
316 W. Popular Street, P. O. Box 790
Norristown, Pennsylvania 19401
(215) 279-2997

RIFE HYDRAULIC ENGINE MANUFACTURING CO.
Rife Ram & Pump Works
P.O. Box 790
Norristown, PA 19404
U.S.A.

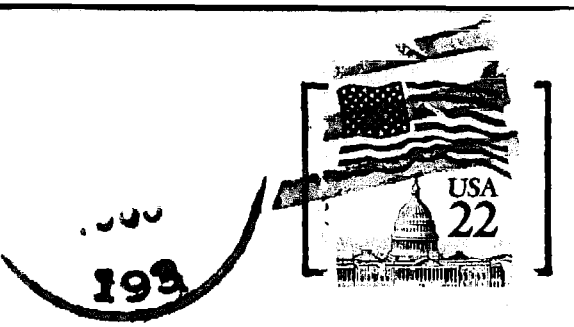

KEN DARROW
APPROPRIATE TECHNOLOGY PROJECT
P O BOX 4543
STANFORD CA 94305

RIFE
SINCE 1884

DAVEY FIGURE 84 HYDRAULIC RAM

RIFE
SINCE 1884

RIFE HYDRAULIC ENGINE MANUFACTURING CO.
Rife Ram & Pump Works
316 W. Poplar St./P.O. Box 790
Norristown, PA 19401
U.S.A.

(215) 279-2997

Nov. 1985

WATER PUMPING EQUIPMENT WORLDWIDE

CONDITIONS FOR A SATISFACTORY DAVEY HYDRAULIC RAM INSTALLATION

There must be three or more feet of fall from spring or pond to Ram. There must be some fall away from Ram so that water discharged from Impetus Valve can drain away from Ram.

The lenght of Intake or Drive Pipe should be no less than five times and no greater than ten times the height of fall.

Intake and discharge Pipe should be the same size their entire length as their respective tappings in Ram.

Gate Valves should be installed close to Inlet and Outlet of Ram so that by closing these Valves adjustment or servicing of Ram can be done without draining the water from supply or discharge Pipes.

Ram and Gate Valves should be installed in a frost proof pit and the supply and discharge Pipes buried below the frost line.

Air or snifter Valve must have cap removed when Ram is operating and must at no time be immersed in the waste water from Impetus Valve.

Entrance to intake or Drive Pipe in spring or pond must be fitted with a strainer to keep out sticks, etc.

The Davey Ram is designed to use a supply head of 3 - 20 ft. and deliver to elevation of 5 - 10 times the supply head, maximum 100 ft.

SIZE OF RAM No.	QUANITY OF WATER FURNISHED PER MIN. BY SPRING OR BROOK TO WHICH RAM IS ADAPTED	SIZE OF PIPE DRIVE	DISCHARGE	PRICE	VALVE KIT	WT
2	3 Quarts to 2 Gallons	3/4"	½"	$ 264.00	$ 34.00	16
3	1½" Gallons to 4 Gallons	1"	½"	$ 308.00	$ 37.00	25
4	3 Gallons to 7 Gallons	1¼"	3/4"	$ 358.00	$ 58.00	30
5	6 Gallons to 14 Gallons	2"	1"	$ 429.00	$ 77.00	51

**NOTE: We recommend that plug type Valves be installed at both ends of the Davey figure 84 Ram. We can ship the proper Valves with each Ram at the cost listed above.

*PRICES AND SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

SPECIFICATION AND PRICES OF RIFE HYDRAULIC RAMS
New High Capacity Models

RIFE
SINCE 1884

RIFE HYDRAULIC ENGINE MANUFACTURING CO.
Rife Ram & Pump Works
316 W. Poplar St./P.O. Box 790
Norristown, PA 19401
U.S.A.

(215) 279-2997

Nov.1985

WATER PUMPING EQUIPMENT WORLDWIDE

RAM MODEL #	INTAKE DRIVE PIPE	DISCHARGE DELIVERY PIPE SIZE	INTAKE CAP GPM USED MIN. MAX.	MIN,VERT FALL REQ (IN fett)	SHIP & WT IN Lb. APPROX.	PRICE SINGLE ACTING F.O.B.NORRISTOWN, PA	
RIFE "NEW MODEL" SERIES BU RAMS (4-BOLTS DESIGN) Maximum vertical fall 15 ft. Maximum vertical lift 150 ft.							
						RAM	VALVE KIT
10BU	1¼"	3/4"	2 - 7	3	120	$ 549.00	$ 51.00
15BU	1½"	3/4"	5 - 13	3	120	$ 561.00	$ 51.00
20BU	2"	1"	8 - 20	3	120	$ 633.00	$ 75.00
RIFE "EVERLASTING" STANDARD RAMS A more rugged development of the previous series "A" (6-Bolts Design) Maximum vertical fall 25 ft. Maximum vertical lift 250 ft.							
10SU	1¼"	3/4"	3 - 10	3	125	$ 706.00	$ 51.00
15SU	1½"	3/4"	5 - 14	3	125	$ 726.00	$ 51.00
20SU	2"	1"	10 - 22	4	125	$ 825.00	$ 75.00
20SUL	2"	1"	12 - 30	4	270	$1056.00	$ 75.00
25SU	2½"	1"	15 - 45	4	270	$1072.00	$174.00
30SU	3"	1¼"	20 - 70	4	270	$1210.00	$221.00
40SU	4"	2"	35 - 125	4	565	$2013.00	$319.00
60SU	6"	3"	75 - 350	4	1325	$4395.00	$495.00
RIFE "UNIVERSAL" HEAVY DUTY RAMS (6-BOLTS DESIGN) Maximum vertical fall 50 ft. Maximum vertical lift 500 ft.							
10HDU	1¼"	3/4"	3 - 10	3	170	$ 853.00	$ 51.00
15HDU	1½"	3/4"	5 - 15	3	170	$ 877.00	$ 51.00
20HDU	2"	1"	10 - 25	4	170	$ 963.00	$ 75.00
20HDUL	2"	1"	12 - 33	4	310	$1183.00	$ 75.00
25HDU	2½"	1"	15 - 45	4	310	$1265.00	$174.00
30HDU	3"	1¼"	25 - 75	4	310	$1375.00	$221.00
40HDU	4"	2"	35 - 150	5	565	$2475.00	$319.00
60HDU	6"	3"	75 - 400	5	1325	$5247.00	$495.00

Note: BU, SU, AND HDU shipped with strainer for intake end of drive pipe. We recommend taht valves be installed at both intake and discharge ends of Rife Hydraulic Rams. We can ship the proper valves with each Ram at th the cost listed above. We can also furnish Double Acting Attachments.
*PRICES AND SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

Rift Valley fever

From Wikipedia, the free encyclopedia

Rift Valley fever (RVF) is a viral disease that can cause mild to severe symptoms. The mild symptoms may include: fever, muscle pains, and headaches which often last for up to a week. The severe symptoms may include: loss of sight beginning three weeks after the infection, infections of the brain causing severe headaches and confusion, and bleeding together with liver problems which may occur within the first few days. Those who have bleeding have a chance of death as high as 50%.[1]

Rift Valley fever

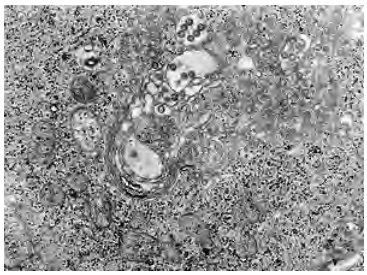

TEM micrograph of tissue infected with Rift Valley fever virus

Classification and external resources

Specialty	infectious disease
ICD-10	A92.4 (http://apps.who.int/classifications/icd10/browse/2016/en#/A92.4)
ICD-9-CM	066.3 (http://www.icd9data.com/getICD9Code.ashx?icd9=066.3)
DiseasesDB	31094 (http://www.diseasesdatabase.com/ddb31094.htm)
MeSH	D012295 (https://www.nlm.nih.gov/cgi/mesh/2017/MB_cgi?field=uid&term=D012295)

The disease is caused by the RVF virus, which is of the *Phlebovirus* type. It is spread by either touching infected animal blood, breathing in the air around an infected animal being butchered, drinking raw milk from an infected animal, or the bite of infected mosquitoes. Animals such as cows, sheep, goats, and camels may be affected. In these animals it is spread mostly by mosquitoes. It does not appear that one person can infect another person. The disease is diagnosed by finding antibodies against the virus or the virus itself in the blood.[1]

Prevention of the disease in humans is by vaccinating animals against the disease. This must be done before an outbreak occurs because if it is done during an outbreak it may worsen the situation. Stopping the movement of animals during an outbreak may also be useful, as may decreasing mosquito numbers and avoiding their bites. There is a human vaccine; however, as of 2010 it is not widely available. There is no specific treatment and medical efforts are supportive.[1]

Outbreaks of the disease have only occurred in Africa and Arabia. Outbreaks usually occur during periods of increased rain which increase the number of mosquitoes.[1] The disease was first reported among livestock in Rift Valley of Kenya in the early 1900s,[2] and the virus was first isolated in 1931.[1]

Contents

- 1 Signs and symptoms
- 2 Cause
  - 2.1 Virology
  - 2.2 Transmission
- 3 Pathogenesis
- 4 Diagnosis
- 5 Prevention
- 6 Epidemiology
  - 6.1 Outbreaks
  - 6.2 2006/07 outbreak in Kenya and Somalia
  - 6.3 2010 South Africa outbreak
- 7 Biological weapon
- 8 Research
- 9 References
- 10 External links

Signs and symptoms

In humans, the virus can cause several syndromes. Usually, sufferers have either no symptoms or only a mild illness with fever, headache, muscle pains, and liver abnormalities. In a small percentage of cases (< 2%), the illness can progress to hemorrhagic fever syndrome, meningoencephalitis (inflammation of the brain and tissues lining the brain), or affect the eye. Patients who become ill usually experience fever, generalised weakness, back pain, dizziness, and weight loss at the onset of the illness. Typically, people recover within two to seven days after onset.

About 1% of people with the disease die of it. In livestock, the fatality level is significantly higher. Pregnant livestock infected with RVF abort virtually 100% of foetuses. An epizootic (animal disease epidemic) of RVF is usually first indicated by a wave of unexplained abortions.

Other signs in livestock include vomiting and diarrhoea, respiratory disease, fever, lethargy, anorexia and sudden death in young animals.[3]

Cause

Virology

The virus belongs to the Bunyaviridae family. This is a family of enveloped negative single stranded RNA viruses. All Bunyaviruses have an outer lipid envelope with two glycoproteins—G(N) and G(C)—required for cell entry. They deliver their genome into the host-cell cytoplasm by fusing their envelope with an endosomal membrane.

Rift Valley fever virus	
Virus classification	
Group:	Group V ((-) ssRNA)
Order:	*Unassigned*
Family:	*Bunyaviridae*
Genus:	*Phlebovirus*
Species:	***Rift Valley fever virus***

The virus' G(C) protein has a class II membrane fusion protein architecture similar to that found in flaviviruses and alphaviruses.[4] This structural similarity suggests that there may be a common origin for these viral families.

The virus' 11.5 kb tripartite genome is composed of single-stranded RNA. As a *Phlebovirus,* it has an ambisense genome. Its L and M segments are negative-sense, but its S segment is ambisense.[5] These three genome segments code for six major proteins: L protein (viral polymerase), the two glycoproteins G(N) and G(C), the nucleocapsid N protein, and the nonstructural NSs and NSm proteins.

Transmission

The virus is transmitted through mosquito vectors, as well as through contact with the tissue of infected animals. Two species—*Culex tritaeniorhynchus* and *Aedes vexans*—are known to transmit the virus.[6] Other potential vectors include *Aedes caspius*, *Aedes mcintosh*, *Aedes ochraceus, Culex pipiens*, *Culex antennatus*, *Culex perexiguus*, *Culex zombaensis* and *Culex quinquefasciatus*.[7][8][9] Contact with infected tissue is considered to be the main source of human infections.[10] The virus has been isolated from two bat species: the Peter's epauletted fruit bat (*Micropteropus pusillus*) and the aba roundleaf bat (*Hipposideros abae*), which are believed to be reservoirs for the virus.[11]

Pathogenesis

Although many components of the RVFV's RNA play an important role in the virus' pathology, nonstructural protein: S segment (NSs) is the only component that has been found to directly affect the host. NSs is hostile and combative against the hosts interferon (IFNs) antiviral response.[12] IFNs are essential in order for the immune system to fight off viral infections in a host.[13] This inhibitory mechanism is believed to be due to a number of reasons, the first being, competitive inhibition of the formation of the transcription factor.[12] On this transcription factor, NSs interacts with and binds to a subunit that is needed for RNA polymerase I and II.[12][14] This interaction cause competitive inhibition with another transcription factor component and prevents the assembly process of the transcription factor complex, which results in the suppression of the host antiviral response.[12][14] Transcription suppression is believed to be another mechanism of this inhibitory process.[12] This occurs when an area of NSs interacts with and binds to the host's protein, SAP30 and forms a complex.[12][14] This complex causes histone acetylation to regress, which is needed for transcriptional activation of the IFN promoter.[14] This causes IFN expression to be obstructed. Lastly,

NSs has also been known to affect regular activity of double-stranded RNA-dependent protein kinase R.. This protein is involved in cellular antiviral responses in the host. When RVFV is able to enter the hosts DNA, NSs forms a filamentous structure in the nucleus. This allows the virus to interact with specific areas of the hosts DNA that relates to segregation defects and induction of chromosome continuity. This increases host infectivity and decreases the host's antiviral response.[12]

Diagnosis

Diagnosis relies on viral isolation from tissues, or serological testing with an ELISA.[3] Other methods of diagnosis include Nucleic Acid Testing (NAT), cell culture, and IgM antibody assays.[15] As of September 2016, the Kenya Medical Research Institute (KEMRI) has developed a product called Immunoline (http://www.nation.co.ke/news/Kemri-develops-kit-for-rapid-test-of-viral-disease/1056-3370550-12brmvu/), designed to diagnose the disease in humans much faster than in previous methods.[16]

Prevention

A vaccine has been conditionally approved for use in animals in the US.[17] It has been shown that knockout of the NSs and NSm nonstructural proteins of this virus produces an effective vaccine in sheep as well.[18]

Epidemiology

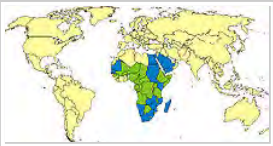

Distribution of Rift Valley fever in Africa: Blue, countries with endemic disease and substantial outbreaks of RVF; green, countries known to have some cases, periodic isolation of virus, or serologic evidence of RVF

RVF outbreaks occur across sub-Saharan Africa, with outbreaks occurring elsewhere infrequently. In Egypt in 1977–78, an estimated 200,000 people were infected and there were at least 594 deaths.[19] [20] In Kenya in 1998, the virus killed over 400 Kenyans. In September 2000, an outbreak was confirmed in Saudi Arabia and Yemen. On 19 October 2011, a case of Rift Valley fever contracted in Zimbabwe was reported in a Caucasian female traveler who returned to France after a 26-day stay in Marondera, Mashonaland East Province during July and August, 2011[21] but later classified as "not confirmed."[22]

Outbreaks

Outbreaks of this disease usually correspond with the warm phases of the El Niño/Southern Oscillation. During this time there is an increase in rainfall, flooding and greenness of vegetation index. This leads to an increase in mosquito vectors and is seen for a number of reasons.[23] RVFV can be transmitted vertically in mosquitos, meaning that the virus can be passed from the mother to her offspring. During dry conditions, the virus is able to remain viable for a number of years in the egg. Mosquitos lay their eggs in water, where they eventually hatch. Since water is essential for mosquito eggs to hatch, it can be understood why rainfall and flooding cause an increase in the mosquito population, and in turn, an increased potential for the virus.[24]

2006/07 outbreak in Kenya and Somalia

In November 2006, a Rift Valley fever outbreak occurred in Kenya. The victims are from the North Eastern Province and Coast Province of Kenya, which had received heavy rain in recent months, causing floods and creating breeding grounds for mosquitoes, which spread the virus of the fever from infected livestock to humans.

By 7 January 2007, about 75 people had died and another 183 were infected.[25] The outbreak forced the closure of livestock markets in the North Eastern Province, affecting the economy of the region.[26]

The outbreak was subsequently reported to have moved into Maragua and Kirinyaga districts of Central Province of Kenya.[27]

On 20 January 2007, the outbreak was reported to have crossed into Somalia from Kenya and killed 14 people in the Lower Jubba region.[28]

As of 23 January 2007, cases had started to crop up at the Kenyan capital, Nairobi. Businesses were suffering large losses, as customers were shunning the common meat joints for the popular *nyama choma* (roast meat), as it was believed to be spreading the fever.

In December 2006 and again in January 2007, Taiwan International Health Action (Taiwan IHA) began operating missions in Kenya [29] consisting of medical experts assisting in training laboratory and health facility personnel, and included donations of supplies, such as mosquito sprays. The United States Centers for Disease Control also set up an assistance mission and laboratory in Kenya.

By the end of January, 2007, some 148 people had died since the outbreak began in December.

As at 14 March 2007, the Kenyan government declared RVF as having diminished drastically after spending an estimated 2.5 million in vaccine and deployment costs. It also lifted the ban on cattle movement in the affected areas.

As of 2 November 2007, 125 cases, including 60 deaths, had been reported from more than 10 localities of White Nile, Sinnar, and Gezira states in Sudan. Young adult males are predominantly affected. More than 25 human samples have been found positive for RVF by PCR or ELISA.[30]

2010 South Africa outbreak

As of 8 April 2010, the Ministry of Health South Africa had reported 87 human cases infected with Rift Valley fever (RVF), including two deaths in Free State, Eastern Cape and Northern Cape provinces.[31] Most of these cases reported direct contact with RVFV-infected livestock and or were linked to farms with confirmed animal cases of RVF. The human cases are: farmers, veterinarians and farm workers. All cases were confirmed with RVF by test conducted at the National Institute of Communicable Diseases (NICD) in Johannesburg, South Africa.

An ongoing outbreak of Rift Valley fever virus (RVFV) infection is affecting sheep, goats, cattle and wildlife on farms within Free State, Eastern Cape, Northern Cape, Western Cape, Mpumalanga, North West, and Gauteng provinces. As of 29 March 2010, about 78 farms reported laboratory-confirmed animal cases, with extensive livestock deaths.

Outbreak investigations by the Department of Health and the Department of Agriculture, Forestry and Fisheries are ongoing, and are being supported by the South African Field Epidemiology and Training Programme and NICD. The Department of Health and the Department of Agriculture are taking measures to enhance disease surveillance among cattle and in managing the control of the disease outbreak.

Sporadic cases of RVFV infection in animals have been documented in South Africa in recent years. The last major outbreak of the disease in humans occurred between 1974 and 1976, where an estimated 10,000 to 20,000 cases were recorded.[32]

The disease claimed the life of Springbok rugby player Juan Smith's father Giel.[33]

Biological weapon

Rift Valley fever was one of more than a dozen agents that the United States researched as potential biological weapons before the nation suspended its biological weapons program in 1969 due to possible bomb threats that might cause a panic in the United States.[34][35]

Research

The disease is one of several identified by WHO as a likely cause of a future epidemic in a new plan developed after the Ebola epidemic for urgent research and development toward new diagnostic tests, vaccines and medicines.[36][37]

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External links

- CDC RVF Information Page (http://www.cdc.gov/ncidod/dvrd/spb/mnpages/dispages/rvf.htm)

- Rift Valley Fever disease card at OIE (http://www.oie.int/fileadmin/Home/eng/Animal_Health_in_the_World/docs/pdf/Disease_cards/RIFT_VALLEY_FEVER.pdf
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Categories: Arthropod-borne viral fevers and viral haemorrhagic fevers | Zoonoses | Insect-borne diseases | Sheep and goat diseases | Biological weapons | Virus-related cutaneous conditions

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Trajectory of the throwing knife and right distance to the target

In the beginning, you try to always make the same movements with your arm and body, with always the same force. Having mastered that constant movements for the throw, you can now find the distance from the target where the knives stick if you throw them with this movements.

In his flight towards the target, the knife will turn around his center of gravity, blade and handle will take turns pointing to the target. The throwing knife will rotate in a way that, if thrown from the handle, the blade will go **downwards** at first.
The first distance for a stick is about three meters from the target (Always measured from the tip of your rear foot!). Grip the knife at the handle, throw it, and after one full rotation it will stick. If it doesn't, move back or forward a little (see chapter on training).
The second distance is about one meter behind the first. Now you grip the knife at the blade (if possible), and after one and a half turn the knife will stick. It is important that you do not have to do anything to get this turns, they will just come. (In fact, later you will be trying to get less rotations to be in better control if you throw from further away.)
From the third distance, you once again use a handle grip, just now you get two full rotations of the knife till it sticks. Because you always throw with the same movements and force, the knife rotates in the same manner, and flies with the same speed every time. Therefore you can calculate or feel how much you have to go back so that the knife has completed another half turn. The pros with many years of experience can throw from distances where the knives make seven full rotations! Once you found your distance, you should measure it off and note it down. Note that the distance will slightly differ the next training day.
You might want to check out the turn-distance formula at StickingPoint.

(By changing your grip on the knife a little, you can stick it from distances between those of half turns. If you take more of the knife in your grip, it will spin slower, allowing you to move a little bit back from the target. Gripping it more towards the end will increase the spin.)

RINGBOLT HITCHING:

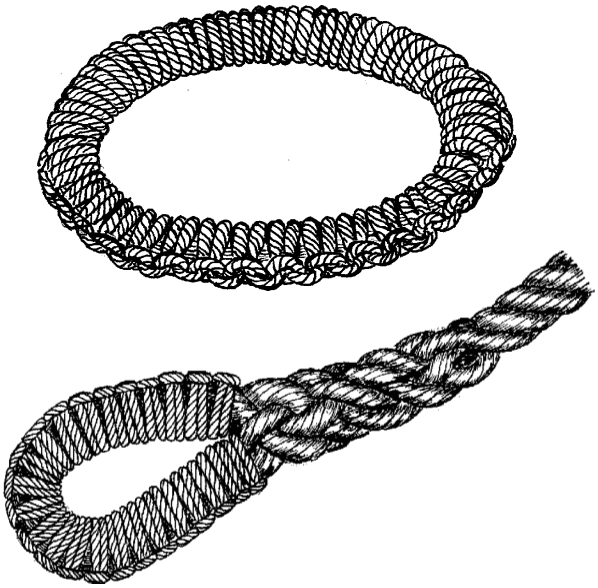

Description ---- A series interlocking lark's head knot that form a ridge around the outside of a ring or loop.

Use ---- To prevent chafing; as a decoration.

Comments ---- There are many forms of ringbolt hitching, the form shown here is one of the simplest and does not require the use of a needle as many other forms do. Ringbolt hitching was used to prevent chafing of ropes that were reeved through hand forged iron rings and to keep them from clanging against objects around them. In the present, ringbolt hitching can be used to protect synthetic ropes that are easily chafed by a applying a layer of material that is not easily chafed.

Other Names ---- Platted Ring; Hog Backing; Cockscombing.

Narration ----- (For **ringbolt hitching** knotboard.) **(1)** Start the ringbolt hitching by tying a half knot around the object. **(2)** Tie a half hitch around the object so that the standing end is trapped under the half hitch. **(3)** pull the half hitch tight. **(4)** Tie the next half hitch in the opposite direction around the object. **(5)** Pull the half hitch tight. **(6)** Tie another half hitch in the opposite direction around the object; the same direction as the first half hitch. **(7)** Pull

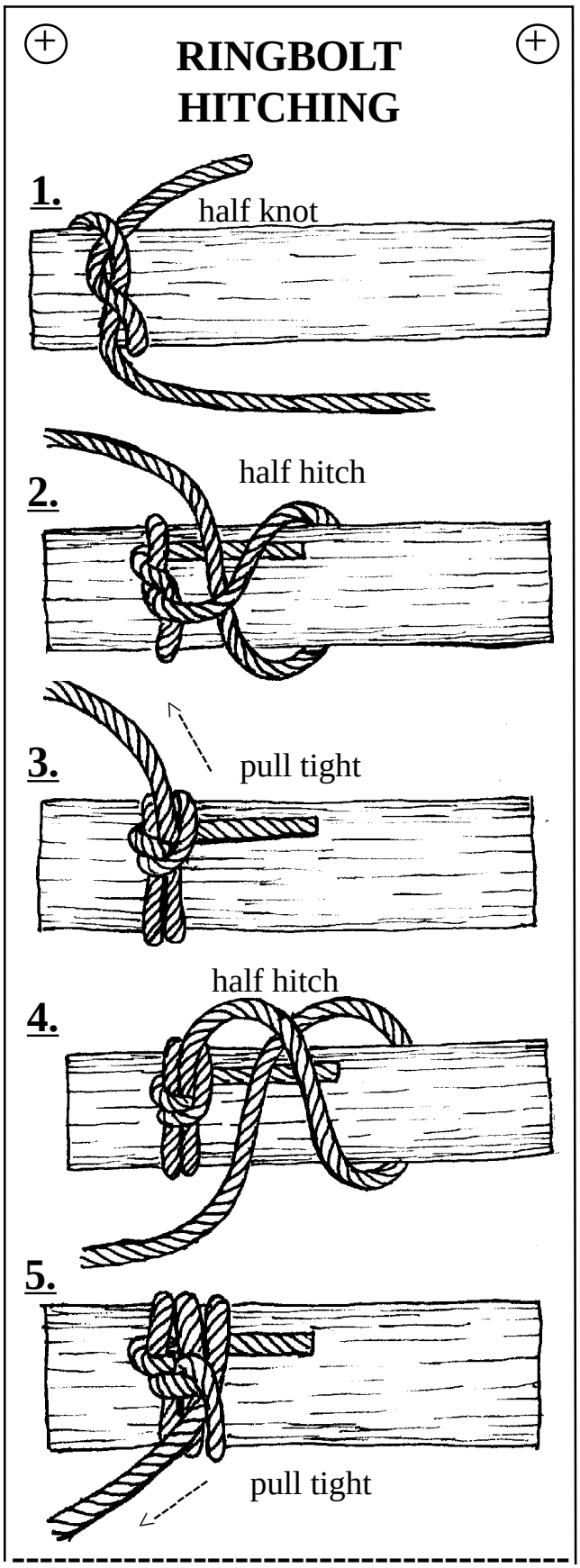

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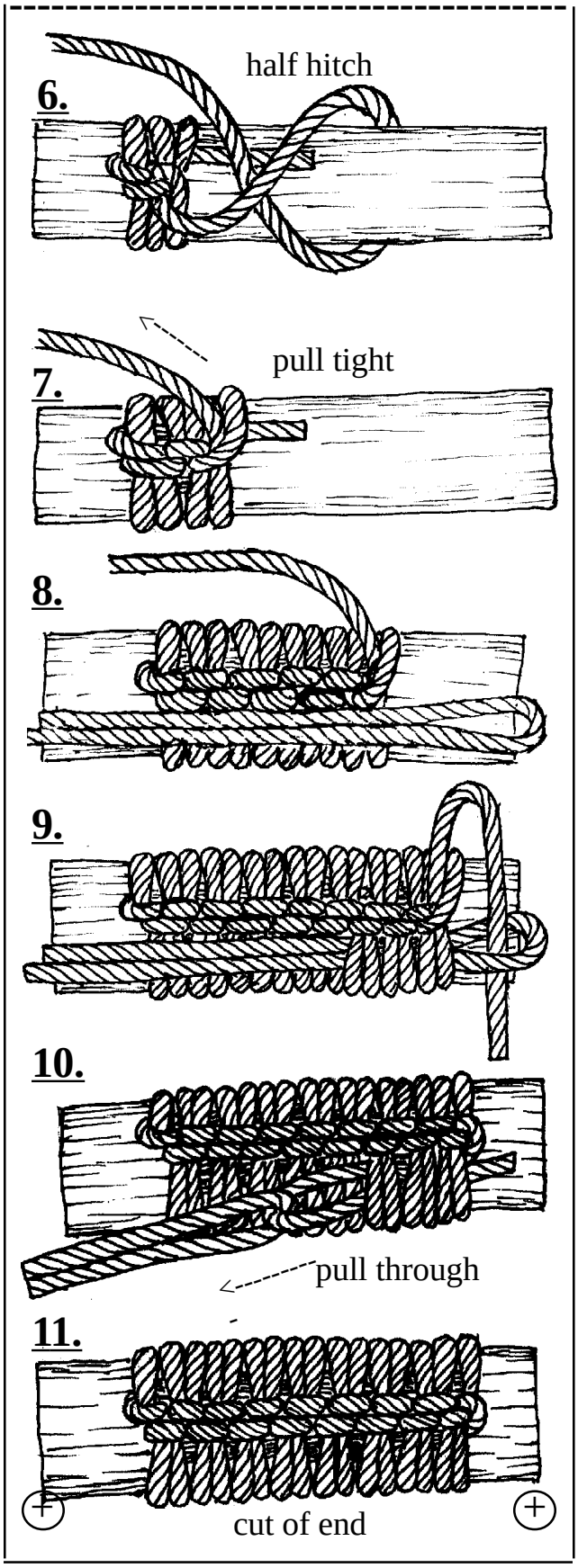

half hitch tight. **(8)** When the length of the ring-bolt hitching is within 5 or 6 half hitches of being long enough; form a bight in the a short piece of twine so that the eye of the bight is toward the end of the work. **(9)** Continue to add half hitches until the ringbolt hitching is completed; reeve the running end through the eye of the bight. **(10)** Use the short piece of twine to pull the running end under the half hitches. **(11)** Cut off the end of the twine.

[NOTES]

U.S. Naval Observatory Astronomical Applications Department

Rise, Set, and Twilight Definitions

(For specific rise, set, and twilight computations, see Complete Sun and Moon Data for One Day or One Year's table of Sunrise/Sunset, Moonrise/Moonset, or Twilight Times in **Data Services**.)

Horizon: Wherever one is located on or near the Earth's surface, the Earth is perceived as essentially flat and, therefore, as a plane. The sky resembles one-half of a sphere or dome centered at the observer. If there are no visual obstructions, the apparent intersection of the sky with the Earth's (plane) surface is the horizon, which appears as a circle centered at the observer. For rise/set computations, the observer's eye is considered to be on the surface of the Earth, so that the horizon is geometrically exactly 90 degrees from the local vertical direction.

Rise, Set: During the course of a day the Earth rotates once on its axis causing the phenomena of rising and setting. All celestial bodies, stars and planets included, seem to appear in the sky at the horizon to the East of any particular place, then to cross the sky and again disappear at the horizon to the West. The most noticeable of these events, and the most significant in regard to ordinary affairs, are the rising and setting of the Sun and Moon. Because the Sun and Moon appear as circular disks and not as points of light, a definition of rise or set must be very specific, for not all of either body is seen to rise or set at once.

> **Sunrise and sunset** conventionally refer to the times when the upper edge of the disk of the Sun is on the horizon, considered unobstructed relative to the location of interest. Atmospheric conditions are assumed to be average, and the location is in a level region on the Earth's surface.
>
> **Moonrise and moonset** times are computed for exactly the same circumstances as for sunrise and sunset. However, moonrise and moonset may occur at any time during a 24 hour period and, consequently, it is often possible for the Moon to be seen during daylight, and to have moonless nights. It is also possible that a moonrise or moonset does not occur relative to a specific place on a given date.

Transit: The transit time of a celestial body refers to the instant that its center crosses an imaginary line in the sky - the observer's meridian - running from north to south. For observers in low to middle latitudes, transit is *approximately* midway between rise and set, and represents the time at which the body is highest in the sky on any given day. At high latitudes, neither of these statements may be true - for example, there may be several transits between rise and set. The transit of the Sun is local solar (sundial) noon. The difference between the transit times of the Sun and Moon is closely related to the Moon's phase. The New Moon transits at about the same time as the Sun; the First Quarter Moon transits about 6 hours after the Sun; the Full Moon transits about 12 hours after/before the Sun; and the Last Quarter Moon transits about 6 hours before the Sun.

Twilight: Before sunrise and again after sunset there are intervals of time, twilight, during which there is natural light provided by the upper atmosphere, which does receive direct sunlight and reflects part of it toward the Earth's surface. Some outdoor activities may be conducted without artificial illumination during these intervals, and it is useful to have some means to set limits beyond which a certain activity should be assisted by artificial

lighting. The major determinants of the amount of natural light during twilight are the state of the atmosphere generally and local weather conditions in particular. Atmospheric conditions are best determined at the actual time and place of events. Nevertheless, it is possible to establish useful, though necessarily approximate, limits applicable to large classes of activities by considering only the position of the Sun below the local horizon. Reasonable and convenient definitions have evolved.

> **Civil twilight** is defined to begin in the morning, and to end in the evening when the center of the Sun is geometrically 6 degrees below the horizon. This is the limit at which twilight illumination is sufficient, under good weather conditions, for terrestrial objects to be clearly distinguished; at the beginning of morning civil twilight, or end of evening civil twilight, the horizon is clearly defined and the brightest stars are visible under good atmospheric conditions in the absence of moonlight or other illumination. In the morning before the beginning of civil twilight and in the evening after the end of civil twilight, artificial illumination is normally required to carry on ordinary outdoor activities. Complete darkness, however, ends sometime prior to the beginning of morning civil twilight and begins sometime after the end of evening civil twilight.
>
> **Nautical twilight** is defined to begin in the morning, and to end in the evening, when the center of the sun is geometrically 12 degrees below the horizon. At the beginning or end of nautical twilight, under good atmospheric conditions and in the absence of other illumination, general outlines of ground objects may be distinguishable, but detailed outdoor operations are not possible, and the horizon is indistinct.
>
> **Astronomical twilight** is defined to begin in the morning, and to end in the evening when the center of the Sun is geometrically 18 degrees below the horizon. Before the beginning of astronomical twilight in the morning and after the end of astronomical twilight in the evening the Sun does not contribute to sky illumination; for a considerable interval after the beginning of morning twilight and before the end of evening twilight, sky illumination is so faint that it is practically imperceptible.

Technical Definitions and Computational Details

Sunrise and sunset. For computational purposes, sunrise or sunset is defined to occur when the geometric zenith distance of center of the Sun is 90.8333 degrees. That is, the center of the Sun is geometrically 50 arcminutes below a horizontal plane. For an observer at sea level with a level, unobstructed horizon, under average atmospheric conditions, the upper limb of the Sun will then appear to be tangent to the horizon. The 50-arcminute geometric depression of the Sun's center used for the computations is obtained by adding the average apparent radius of the Sun (16 arcminutes) to the average amount of atmospheric refraction at the horizon (34 arcminutes).

Moonrise and moonset. Moonrise and moonset are defined similarly, but the situation is computationally more complex because of the nearness of the Moon and the eccentricity of its orbit. If the computations are carried out using coordinates of the Moon with respect to the Earth's center (the usual method), then moonrise or moonset is defined to occur when the geometric zenith distance of the center of the Moon is

> 90.5666 degrees + Moon's apparent angular radius - Moon's horizontal parallax

Under normal atmospheric conditions at sea level, the upper limb of the Moon will then appear to be tangent with a level, unobstructed horizon. No account is taken of the Moon's phase; that is, the Moon is always regarded as a disk in the sky and the upper limb might be dark. Here again, a constant of 34 arcminutes (0.5666 degree) is used to account for atmospheric refraction. The Moon's apparent radius varies from 15 to 17 arcminutes and its horizontal parallax varies from 54 to 61 arcminutes. Adding all the terms above together, the center of the Moon at rise or set is geometrically 5 to 10 arcminutes above the observer's "geocentric horizon" - the horizontal plane that passes through the Earth's center, orthogonal to the observer's local vertical.

Accuracy of rise/set computations. The times of rise and set phenomena cannot be precisely computed, because,

in practice, the actual times depend on unpredictable atmospheric conditions that affect the amount of refraction at the horizon. Thus, even under ideal conditions (e.g., a clear sky at sea) the times computed for rise or set may be in error by a minute or more. Local topography (e.g., mountains on the horizon) and the height of the observer can affect the times of rise or set even more. It is not practical to attempt to include such effects in routine rise/set computations.

The accuracy of rise and set computations decreases at high latitudes. There, small variations in atmospheric refraction can change the time of rise or set by many minutes, since the Sun and Moon intersect the horizon at a very shallow angle. For the same reason, at high latitudes, the effects of observer height and local topography are magnified and can substantially change the times of the phenomena actually observed, or even whether the phenomena are observed to occur at all.

Twilight. There are three kinds of twilight defined: civil twilight, nautical twilight, and astronomical twilight. For computational purposes, civil twilight begins before sunrise and ends after sunset when the geometric zenith distance of the center of the Sun is 96 degrees - 6 degrees below a horizontal plane. The corresponding solar zenith distances for nautical and astronomical twilight are 102 and 108 degrees, respectively. That is, at the dark limit of nautical twilight, the center of the Sun is geometrically 12 degrees below a horizontal plane; and at the dark limit of astronomical twilight, the center of the Sun is geometrically 18 degrees below a horizontal plane.

This information is derived from the Explanatory Supplement to the Astronomical Almanac, ed. P. K. Seidelmann (1992), pp 482ff.

Onchocerciasis

From Wikipedia, the free encyclopedia

Onchocerciasis, also known as **river blindness**, is a disease caused by infection with the parasitic worm *Onchocerca volvulus*.[1] Symptoms include severe itching, bumps under the skin, and blindness.[1] It is the second most common cause of blindness due to infection, after trachoma.[2]

The parasite worm is spread by the bites of a black fly of the *Simulium* type.[1] Usually, many bites are required before infection occurs.[3] These flies live near rivers, hence the name of the disease.[2] Once inside a person, the worms create larvae that make their way out to the skin.[1] Here, they can infect the next black fly that bites the person.[1] There are a number of ways to make the diagnosis including: placing a biopsy of the skin in normal saline and watching for the larva to come out, looking in the eye for larvae, and looking within the bumps under the skin for adult worms.[4]

A vaccine against the disease does not exist.[1] Prevention is by avoiding being bitten by flies.[5] This may include the use of insect repellent and proper clothing.[5] Other efforts include those to decrease the fly population by spraying insecticides.[1] Efforts to eradicate the disease by treating entire groups of people twice a year is ongoing in a number of areas of the world.[1] Treatment of those infected is with the medication ivermectin every six to twelve months.[1][6] This treatment kills the larva but not the adult worms.[7] The antibiotic doxycycline weakens the worms by killing an associated bacterium called *Wolbachia*, and is recommended by some as well.[7] The lumps under the skin may also be removed by surgery.[6]

About 17 to 25 million people are infected with river blindness, with approximately 0.8 million having some amount of loss of vision.[3][7] Most infections occur in sub-Saharan Africa, although cases have also been reported in Yemen and isolated areas of Central and South America.[1] In 1915, the physician Rodolfo Robles first linked the worm to eye disease.[8] It is listed by the World Health Organization as a neglected tropical disease.[9]

Onchocerciasis

Synonyms	river blindness, Robles disease

An adult black fly with the parasite *Onchocerca volvulus* coming out of the insect's antenna, magnified 100x

Pronunciation	/ˌɒŋkoʊsɜːrˈsaɪəsɪs, -ˈkaɪ-/

Classification and external resources

Specialty	infectious disease
ICD-10	B73 (http://apps.who.int/classifications/icd10/browse/2016/en#/B73)
ICD-9-CM	125.3 (http://www.icd9data.com/getICD9Code.ashx?icd9=125.3)
DiseasesDB	9218 (http://www.diseasesdatabase.com/ddb9218.htm)
eMedicine	med/1667 (http://www.emedicine.com/med/topic1667.htm) oph/709 (http://www.emedicine.com/oph/topic709.htm#)
MeSH	D009855 (https://www.nlm.nih.gov/cgi/mesh/2017/MB_cgi?field=uid&term=D009855)

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Signs and symptoms

Adult worms remain in subcutaneous nodules, limiting access to the host's immune system. Microfilariae, in contrast, are able to induce intense inflammatory responses, especially upon their death. *Wolbachia* species have been found to be endosymbionts of *O. volvulus* adults and microfilariae, and are thought to be the driving force behind most of *O. volvulus* morbidity. Dying microfilariae have been recently discovered to release *Wolbachia* surface protein that activates TLR2 and TLR4, triggering innate immune responses and producing the inflammation and its associated morbidity.[10] The severity of illness is directly proportional to the number of infected microfilariae and the power of the resultant inflammatory response.[11]

Skin involvement typically consists of intense itching, swelling, and inflammation.[12] A grading system has been developed to categorize the degree of skin involvement:[13][14]

- Acute papular onchodermatitis – scattered pruritic papules
- Chronic papular onchodermatitis – larger papules, resulting in hyperpigmentation
- Lichenified onchodermatitis – hyperpigmented papules and plaques, with edema, lymphadenopathy, pruritus and common secondary bacterial infections
- Skin atrophy – loss of elasticity, the skin resembles tissue paper, 'lizard skin' appearance
- Depigmentation – 'leopard skin' appearance, usually on anterior lower leg
- Glaucoma effect – eyes malfunction, begin to see shadows or nothing

Ocular involvement provides the common name associated with onchocerciasis, river blindness, and may involve any part of the eye from conjunctiva and cornea to uvea and posterior segment, including the retina and optic nerve.[12] The microfilariae migrate to the surface of the cornea. Punctate keratitis occurs in the infected area. This clears up as the inflammation subsides. However, if the infection is chronic, sclerosing keratitis can occur, making the affected area become opaque. Over time, the entire cornea may become opaque, thus leading

to blindness. Some evidence suggests the effect on the cornea is caused by an immune response to bacteria present in the worms.[11]

The skin is itchy, with severe rashes permanently damaging patches of skin.

Mazzotti reaction

The Mazzotti reaction, first described in 1948, is a symptom complex seen in patients after undergoing treatment of onchocerciasis with the medication diethylcarbamazine(DEC). Mazzotti reactions can be life-threatening, and are characterized by fever, urticaria, swollen and tender lymph nodes, tachycardia, hypotension, arthralgias, oedema, and abdominal pain that occur within seven days of treatment of microfilariasis.

The phenomenon is so common when DEC is used that this drug is the basis of a skin patch test used to confirm that diagnosis. The drug patch is placed on the skin, and if the patient is infected with *O. volvulus* microfilaria, localized pruritus and urticaria are seen at the application site.[15]

Patch test

Nodding disease

This is an unusual form of epidemic epilepsy associated with onchocerciasis.[16] This syndrome was first described in Tanzania by Louise Jilek-Aall, a Norwegian psychiatric doctor in Tanzanian practice, during the 1960s. It occurs most commonly in Uganda and South Sudan. It manifests itself in previously healthy 5–15-year-old children, is often triggered by eating or low temperatures and is accompanied by cognitive impairment. Seizures occur frequently and may be difficult to control. The electroencephalogram is abnormal but cerebrospinal fluid (CSF) and magnetic resonance imaging (MRI) are normal or show non-specific changes. If there are abnormalities on the MRI they are usually present in the hippocampus. Polymerase chain reaction testing of the CSF does not show the presence of the parasite.

Classification

Onchocerciasis causes different kinds of skin changes, which vary in different geographic regions; it may be divided into the following phases or types:[17]:440–441

Erisipela de la costa

An acute phase, it is characterized by swelling of the face, with erythema and itching.[17]:440 This skin change, *erisípela de la costa*, of acute onchocerciasis is most commonly seen among victims in Central and South America.[18]

Mal morando

This cutaneous condition is characterized by inflammation accompanied by hyperpigmentation.[17]:440

Sowda

A cutaneous condition, it is a localized type of onchocerciasis.[17]:440

Additionally, the various skin changes associated with onchocerciasis may be described as follows:[17]:440

Leopard skin
: The spotted depigmentation of the skin that may occur with onchocerciasis[17]:440

Elephant skin
: The thickening of human skin that may be associated with onchocerciasis[17]:440

Lizard skin
: The thickened, wrinkled skin changes that may result with onchocerciasis[17]:441

Cause

The cause is *Onchocerca volvulus*

Life cycle

The life of the parasite can be traced through the black fly and the human hosts in the following steps:

1. A *Simulium* female black fly takes a blood meal on an infected human host, and ingests microfilaria.
2. The microfilaria enter the gut and thoracic flight muscles of the black fly, progressing into the first larval stage (J1.).
3. The larvae mature into the second larval stage (J2.), and move to the proboscis and into the saliva in its third larval stage (J3.). Maturation takes about seven days.
4. The black fly takes another blood meal, passing the larvae into the next human host's blood.
5. The larvae migrate to the subcutaneous tissue and undergo two more molts. They form nodules as they mature into adult worms over six to 12 months.
6. After maturing, adult male worms mate with female worms in the subcutaneous tissue to produce between 700 and 1,500 microfilaria per day.
7. The microfilaria migrate to the skin during the day, and the black flies only feed in the day, so the parasite is in a prime position for the female fly to ingest it. Black flies take blood meals to ingest these microfilaria to restart the cycle.

Prevention

Various control programs aim to stop onchocerciasis from being a public health problem. The first was the Onchocerciasis Control Programme (OCP), which was launched in 1974, and at its peak, covered 30 million people in 11 countries. Through the use of larvicide spraying of fast-flowing rivers to control black fly populations, and from 1988 onwards, the use of ivermectin to treat infected people, the OCP eliminated onchocerciasis as a public health problem. The OCP, a joint effort of the World Health Organisation, the World Bank, the United Nations Development Programme, and the UN Food and Agriculture Organization, was considered to be a success, and came to an end in 2002. Continued monitoring ensures onchocerciasis cannot reinvade the area of the OCP.[19]

In 1995, the African Programme for Onchocerciasis Control began covering another 19 countries, mainly relying upon the use of ivermectin. Its goal is to set up a community-directed supply of ivermectin for those who are infected. In these ways, transmission has declined.[20] In 2015, WHO was facilitating launch of an elimination program in Yemen.

In 1992, the Onchocerciasis Elimination Programme for the Americas, which also relies on ivermectin, was launched.[21] On July 29, 2013, the Pan American Health Organization (PAHO) announced that after 16 years

of efforts, Colombia had become the first country in the world to eliminate the parasitic disease onchocerciasis.[22] In September 2015, the Onchocerciasis Elimination Program for the Americas announced that onchocerciasis only remained in a remote region on the border of Brazil and Venezuela.[23][24] The area is home to the Yanomami indigenous people. The first countries to receive verification of elimination were Colombia in 2013, Ecuador in 2014, and Mexico in 2015.[25] Guatemala has submitted a request for verification. The key factor in elimination is mass administration of the antiparasitic drug ivermectin. The initial projection was that the disease would be eliminated from remaining foci in the Americas by 2012.[26]

No vaccine to prevent onchocerciasis infection in humans is available. A vaccine to prevent onchocerciasis infection for cattle is in phase three trials. Cattle injected with a modified and weakened form of *O. ochengi* larvae have developed very high levels of protection against infection. The findings suggest that it could be possible to develop a vaccine that protects people against river blindness using a similar approach. Unfortunately, a vaccine to protect humans is still many years off.

Treatment

In mass drug administration (MDA) programmes, the treatment for onchocerciasis is ivermectin (trade name: Mectizan); infected people can be treated with two doses of ivermectin, six months apart, repeated every three years. The drug paralyses and kills the microfilariae causing fever, itching, and possibly oedema, arthritis and lymphadenopathy. Intense skin itching is eventually relieved, and the progression towards blindness is halted. In addition, while the drug does not kill the adult worms, it does prevent them for a limited time from producing additional offspring. The drug therefore prevents both morbidity and transmission for up to several months.

The burden of onchocerciasis: children leading blind adults in Africa

Ivermectin treatment is particularly effective because it only needs to be taken once or twice a year, needs no refrigeration, and has a wide margin of safety, with the result that it has been widely given by minimally trained community health workers.[27]

Antibiotics

For the treatment of individuals, doxycycline is used to kill the *Wolbachia* bacteria that live in adult worms. This adjunct therapy has been shown to significantly lower microfilarial loads in the host, and may have activity against the adult worms, due to the symbiotic relationship between *Wolbachia* and the worm.[28][29] In four separate trials over 10 years with various dosing regimens of doxycycline for individualized treatment, doxycycline was found to be effective in sterilizing the female worms and reducing their numbers over a period of four to six weeks. Research on other antibiotics, such as rifampicin, has shown it to be effective in animal models at reducing *Wolbachia* both as an alternative and as an adjunct to doxycycline.[30] However, doxycycline treatment requires daily dosing for at least four to six weeks, making it more difficult to administer in the affected areas.[27]

Ivermectin

Ivermectin kills the parasite by interfering with the nervous system and muscle function, in particular, by

enhancing inhibitory neurotransmission. The drug binds to and activates glutamate-gated chloride channels.[27] These channels, present in neurons and myocytes, are not invertebrate-specific, but are protected in vertebrates from the action of ivermectin by the blood–brain barrier.[27] Ivermectin is thought to irreversibly activate these channel receptors in the worm, eventually causing an inhibitory postsynaptic potential. The chance of a future action potential occurring in synapses between neurons decreases and the nematodes experience flaccid paralysis followed by death.[31][32][33]

Ivermectin is directly effective against the larval stage microfilariae of *O. volvulus*; they are paralyzed and can be killed by eosinophils and macrophages. It does not kill adult females (macrofilariae), but does cause them to cease releasing microfilariae, perhaps by paralyzing the reproductive tract.[27] Ivermectin is very effective in reducing microfilarial load and reducing number of punctate opacities in individuals with onchocerciasis.[34]

Epidemiology

Disability-adjusted life year for onchocerciasis per 100,000 inhabitants

no data	90–100
less than 10	100–150
10–50	150–200
50–60	200–300
60–70	300–400
70–80	more than 400
80–90	

About 37 million people are infected with this parasite;[35] about 300,000 of those had been permanently blinded.[36] As of 2008, about 99% of onchocerciasis cases occurred in Africa.[37] Onchocerciasis is currently endemic in 30 African countries, Yemen, and isolated regions of South America.[38] Over 85 million people live in endemic areas, and half of these reside in Nigeria. Another 120 million people are at risk for contracting the disease. Due to the vector's breeding habitat, the disease is more severe along the major rivers in the northern and central areas of the continent, and severity declines in villages farther from rivers. Onchocerciasis was eliminated in the northern focus in Chiapas, Mexico,[39] and the focus in Oaxaca, Mexico, where *Onchocerca volvulus* existed, was determined, after several years of treatment with ivermectin, as free of the transmission of the parasite.[40]

According to a 2002 WHO report, onchocerciasis has not caused a single death, but its global burden is 987,000 disability adjusted life years (DALYs). The severe pruritus alone accounts for 60% of the DALYs. Infection reduces the host's immunity and resistance to other diseases, which results in an estimated reduction in life expectancy of 13 years.[38]

History

Onchocerca originated in Africa and was probably exported to the Americas by the slave trade, as part of the Columbian exchange that introduced other old world diseases such as yellow fever into the New World. Findings of a phylogenetic study in the mid-90s are consistent with an introduction to the New World in this manner. DNA sequences of savannah and rainforest strains in Africa differ, while American strains are identical to savannah strains in western Africa.[41] The microfilarial parasite that causes the disease was first identified in 1874 by an Irish naval surgeon, John O'Neill, who was seeking to identify the cause of a common skin disease along the west coast of Africa, known as "craw-craw".[42] Rudolf Leuckart, a German zoologist, later examined specimens of the same filarial worm sent from Africa by a German missionary doctor in 1890 and named the organism *Filaria volvulus*.[43]

Rodolfo Robles and Rafael Pacheco in Guatemala first mentioned the ocular form of the disease in the Americas about 1915. They described a tropical worm infection with adult Onchocerca that included inflammation of the skin, especially the face ('erisipela de la costa'), and eyes.[44] The disease, commonly called the "filarial blinding disease", and later referred to as "Robles disease", was common among coffee plantation workers. Manifestations included subcutaneous nodules, anterior eye lesions, and dermatitis. Robles sent specimens to Émile Brumpt, a French parasitologist, who named it *O. caecutiens* in 1919, indicating the parasite caused blindness (Latin "caecus" meaning blind).[45] The disease was also reported as being common in Mexico.[46] By the early 1920s, it was generally agreed that the filaria in Africa and Central America were morphologically indistinguishable and the same as that described by O'Neill 50 years earlier.

Robles hypothesized that the vector of the disease was the day-biting black fly, *Simulium*. Scottish physician Donald Blacklock of the Liverpool School of Tropical Medicine confirmed this mode of transmission in studies in Sierra Leone. Blacklock's experiments included the re-infection of Simulium flies exposed to portions of the skin of infected subjects on which nodules were present, which led to elucidation of the life cycle of the Onchocerca parasite.[47] Blacklock and others could find no evidence of eye disease in Africa. Jean Hissette, a Belgian ophthalmologist, discovered in 1930 that the organism was the cause of a "river blindness" in the Belgian Congo.[48] Some of the patients reported seeing tangled threads or worms in their vision, which were microfilariae moving freely in the aqueous humor of the anterior chamber of the eye.[49] Blacklock and Strong had thought the African worm did not affect the eyes, but Hissette reported that 50% of patients with onchocerciasis near the Sankuru river in the Belgian Congo had eye disease and 20% were blind. Hisette Isolated the microfilariae from an enucleated eye and described the typical chorioretinal scarring, later called the "Hissette-Ridley fundus" after another ophthalmologist, Harold Ridley, who also made extensive observations on onchocerciasis patients in north west Ghana, publishing his findings in 1945.[50] Ridley first postulated that the disease was brought by the slave trade. The international scientific community was initially skeptical of Hisette's findings, but they were confirmed by the Harvard African Expedition of 1934, led by Richard P. Strong, an American physician of tropical medicine.[51]

Society and culture

Since 1988, ivermectin has been provided free of charge for use in humans by Merck through the Mectizan donation program (MDP). The MDP works together with ministries of health and nongovernmental development organisations, such as the World Health Organization, to provide free ivermectin to those who need it in endemic areas.[52]

In 2015 William C. Campbell and Satoshi Ōmura were co-awarded half of that year's Nobel prize in Physiology or Medicine for the discovery of the avermectin family of compounds, the forerunner of ivermectin. The latter has come to decrease the occurrence of lymphatic filariasis and onchoceriasis.[53]

Uganda's government, working with the Carter Center river blindness program since 1996, switched strategies for distribution of Mectizan. The male-dominated volunteer distribution system had "failed to take advantage of traditional kinship structures and roles." The program switched in 2014 from village health teams to community distributors, primarily selecting women with the goal of assuring that everyone in the circle of their family and friends received river blindness information and Mectizan.[54]

Research

Animal models for the disease are somewhat limited, as the parasite only lives in primates, but there are close

parallels. *Litomosoides sigmodontis* , which will naturally infect cotton rats, has been found to fully develop in BALB/c mice. *Onchocerca ochengi*, the closest relative of *O. volvulus*, lives in intradermal cavities in cattle, and is also spread by black flies. Both systems are useful, but not exact, animal models.[55]

A study of 2501 people in Ghana showed the prevalence rate doubled between 2000 and 2005 despite treatment, suggesting the parasite is developing resistance to the drug.[30][56][57] A clinical trial of another antiparasitic agent, moxidectin (manufactured by Wyeth), began on July 1, 2009 (NCT00790998 (http://clinicaltrials.gov/ct2/show/NCT00790998)).[58]

A Cochrane review compared outcomes of people treated with ivermectin alone versus doxycycline plus ivermectin. While there were no differences in most vision-related outcomes between the two treatments, there was low quality evidence suggesting treated with doxycycline plus ivermectine showed improvement in iridocyclitis and punctate keratitis, over those treated with ivermectine alone.[59]

See also

- Carter Center River Blindness Program
- List of parasites (human)
- Neglected tropical diseases
- Rodolfo Robles
- United Front Against Riverblindness
- Harold Ridley (ophthalmologist)

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- CDC Parasites of public health concern (http://www.dpd.cdc.gov/dpdx/HTML/Filariasis.htm)

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Parasitic infestations, stings, and bites of the skin

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RL circuit

From Wikipedia, the free encyclopedia

A **resistor–inductor circuit** (**RL circuit**), or **RL filter** or **RL network**, is an electric circuit composed of resistors and inductors driven by a voltage or current source. A first-order RL circuit is composed of one resistor and one inductor and is the simplest type of RL circuit.

A first order RL circuit is one of the simplest analogue infinite impulse response electronic filters. It consists of a resistor and an inductor, either in series driven by a voltage source or in parallel driven by a current source.

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Introduction

The fundamental passive linear circuit elements are the resistor (R), capacitor (C) and inductor (L). These circuit elements can be combined to form an electrical circuit in four distinct ways: the RC circuit, the RL circuit, the LC circuit and the RLC circuit with the abbreviations indicating which components are used. These circuits exhibit important types of behaviour that are fundamental to analogue electronics. In particular, they are able to act as passive filters. This article considers the RL circuit in both series and parallel as shown in the diagrams.

In practice, however, capacitors (and RC circuits) are usually preferred to inductors since they can be more easily manufactured and are generally physically smaller, particularly for higher values of components.

Both RC and RL circuits form a single-pole filter. Depending on whether the reactive element (C or L) is in series with the load, or parallel with the load will dictate whether the filter is low-pass or high-pass.

Frequently RL circuits are used for DC power supplies to RF amplifiers, where the inductor is used to pass DC bias current and block the RF getting back into the power supply.

This article relies on knowledge of the complex impedance representation of inductors and on knowledge of the frequency domain representation of signals.

Complex impedance

The complex impedance Z_L (in ohms) of an inductor with inductance L (in henrys) is

$$Z_L = Ls\,.$$

The complex frequency s is a complex number,

$$s = \sigma + j\omega\,,$$

where

- j represents the imaginary unit: $j^2 = -1$,
- σ is the exponential decay constant (in radians per second), and
- ω is the angular frequency (in radians per second).

Eigenfunctions

The complex-valued eigenfunctions of *any* linear time-invariant (LTI) system are of the following forms:

$$\begin{aligned} \mathbf{V}(t) &= \mathbf{A}e^{st} = \mathbf{A}e^{(\sigma+j\omega)t} \\ \mathbf{A} &= Ae^{j\phi} \\ \Rightarrow \mathbf{V}(t) &= Ae^{j\phi}e^{(\sigma+j\omega)t} \\ &= Ae^{\sigma t}e^{j(\omega t+\phi)}\,. \end{aligned}$$

From Euler's formula, the real-part of these eigenfunctions are exponentially-decaying sinusoids:

$$v(t) = \operatorname{Re} V(t) = Ae^{\sigma t}\cos(\omega t + \phi)\,.$$

Sinusoidal steady state

Sinusoidal steady state is a special case in which the input voltage consists of a pure sinusoid (with no exponential decay). As a result,

$$\sigma = 0$$

and the evaluation of s becomes

$$s = j\omega\,.$$

Series circuit

By viewing the circuit as a voltage divider, we see that the voltage across the inductor is:

$$V_L(s) = \frac{Ls}{R + Ls}V_{\text{in}}(s)\,,$$

and the voltage across the resistor is:

$$V_R(s) = \frac{R}{R+Ls} V_{\text{in}}(s)\,.$$

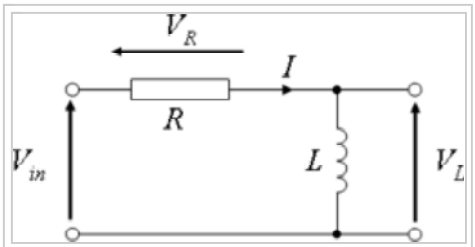

Series RL circuit

Current

The current in the circuit is the same everywhere since the circuit is in series:

$$I(s) = \frac{V_{\text{in}}(s)}{R+Ls}\,.$$

Transfer functions

The transfer function to the inductor voltage is

$$H_L(s) = \frac{V_L(s)}{V_{\text{in}}(s)} = \frac{Ls}{R+Ls} = G_L e^{j\phi_L}\,.$$

Similarly, the transfer function, to the resistor voltage is

$$H_R(s) = \frac{V_R(s)}{V_{\text{in}}(s)} = \frac{R}{R+Ls} = G_R e^{j\phi_R}\,.$$

The transfer function, to the current, is

$$H_I(s) = \frac{I(s)}{V_{\text{in}}(s)} = \frac{1}{R+Ls}\,.$$

Poles and zeros

The transfer functions have a single pole located at

$$s = -\frac{R}{L}\,.$$

In addition, the transfer function for the inductor has a zero located at the origin.

Gain and phase angle

The gains across the two components are found by taking the magnitudes of the above expressions:

$$G_L = |H_L(\omega)| = \left|\frac{V_L(\omega)}{V_{\text{in}}(\omega)}\right| = \frac{\omega L}{\sqrt{R^2 + (\omega L)^2}}$$

and

$$G_R = |H_R(\omega)| = \left|\frac{V_R(\omega)}{V_{\text{in}}(\omega)}\right| = \frac{R}{\sqrt{R^2 + (\omega L)^2}}\,,$$

and the phase angles are:

$$\phi_L = \angle H_L(s) = \tan^{-1}\left(\frac{R}{\omega L}\right)$$

and

$$\phi_R = \angle H_R(s) = \tan^{-1}\left(-\frac{\omega L}{R}\right).$$

Phasor notation

These expressions together may be substituted into the usual expression for the phasor representing the output:

$$V_L = G_L V_{\text{in}} e^{j\phi_L}$$
$$V_R = G_R V_{\text{in}} e^{j\phi_R}$$

Impulse response

The impulse response for each voltage is the inverse Laplace transform of the corresponding transfer function. It represents the response of the circuit to an input voltage consisting of an impulse or Dirac delta function.

The impulse response for the inductor voltage is

$$h_L(t) = \delta(t) - \frac{R}{L} e^{-t\frac{R}{L}} u(t) = \delta(t) - \frac{1}{\tau} e^{-\frac{t}{\tau}} u(t)\,,$$

where $u(t)$ is the Heaviside step function and $\tau = \frac{L}{R}$ is the time constant.

Similarly, the impulse response for the resistor voltage is

$$h_R(t) = \frac{R}{L} e^{-t\frac{R}{L}} u(t) = \frac{1}{\tau} e^{-\frac{t}{\tau}} u(t)\,.$$

Zero-input response

The **zero-input response** (ZIR), also called the **natural response**, of an RL circuit describes the behavior of the circuit after it has reached constant voltages and currents and is disconnected from any power source. It is called the zero-input response because it requires no input.

The ZIR of an RL circuit is:

$$I(t) = I(0) e^{-\frac{R}{L}t} = I(0) e^{-\frac{t}{\tau}}\,.$$

Frequency domain considerations

These are frequency domain expressions. Analysis of them will show which frequencies the circuits (or filters) pass and reject. This analysis rests on a consideration of what happens to these gains as the frequency becomes very large and very small.

As $\omega \to \infty$:

$$G_L \to 1 \quad \text{and} \quad G_R \to 0\,.$$

As $\omega \to 0$:

$$G_L \to 0 \quad \text{and} \quad G_R \to 1\,.$$

This shows that, if the output is taken across the inductor, high frequencies are passed and low frequencies are attenuated (rejected). Thus, the circuit behaves as a *high-pass filter*. If, though, the output is taken across the resistor, high frequencies are rejected and low frequencies are passed. In this configuration, the circuit behaves as a *low-pass filter*. Compare this with the behaviour of the resistor output in an RC circuit, where the reverse is the case.

The range of frequencies that the filter passes is called its bandwidth. The point at which the filter attenuates the signal to half its unfiltered power is termed its cutoff frequency. This requires that the gain of the circuit be reduced to

$$G_L = G_R = \frac{1}{\sqrt{2}}\,.$$

Solving the above equation yields

$$\omega_{\mathrm{c}} = \frac{R}{L}\ \mathrm{rad/s} \quad \text{or} \quad f_{\mathrm{c}} = \frac{R}{2\pi L}\ \mathrm{Hz}\,,$$

which is the frequency that the filter will attenuate to half its original power.

Clearly, the phases also depend on frequency, although this effect is less interesting generally than the gain variations.

As $\omega \to 0$:

$$\phi_L \to 90^\circ = \frac{\pi}{2}\ \text{radians} \quad \text{and} \quad \phi_R \to 0\,.$$

As $\omega \to \infty$:

$$\phi_L \to 0 \quad \text{and} \quad \phi_R \to -90^\circ = -\frac{\pi}{2}\ \text{radians}\,.$$

So at DC (0 Hz), the resistor voltage is in phase with the signal voltage while the inductor voltage leads it by 90°. As frequency increases, the resistor voltage comes to have a 90° lag relative to the signal and the inductor voltage comes to be in-phase with the signal.

Time domain considerations

This section relies on knowledge of e, the natural logarithmic constant.

The most straightforward way to derive the time domain behaviour is to use the Laplace transforms of the expressions for V_L and V_R given above. This effectively transforms $j\omega \to s$. Assuming a step input (i.e., $V_{\text{in}} = 0$ before $t = 0$ and then $V_{\text{in}} = V$ afterwards):

$$V_{\text{in}}(s) = V \cdot \frac{1}{s}$$
$$V_L(s) = V \cdot \frac{sL}{R+sL} \cdot \frac{1}{s}$$
$$V_R(s) = V \cdot \frac{R}{R+sL} \cdot \frac{1}{s}\,.$$

Partial fractions expansions and the inverse Laplace transform yield:

$$V_L(t) = Ve^{-t\frac{R}{L}}$$
$$V_R(t) = V\left(1 - e^{-t\frac{R}{L}}\right)\,.$$

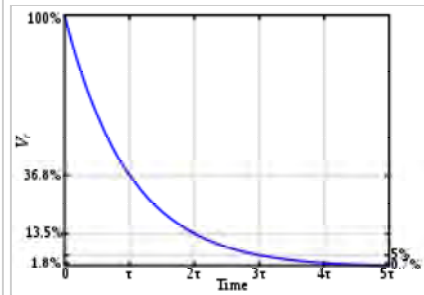

Inductor voltage step-response.

Thus, the voltage across the inductor tends towards 0 as time passes, while the voltage across the resistor tends towards V, as shown in the figures. This is in keeping with the intuitive point that the inductor will only have a voltage across as long as the current in the circuit is changing — as the circuit reaches its steady-state, there is no further current change and ultimately no inductor voltage.

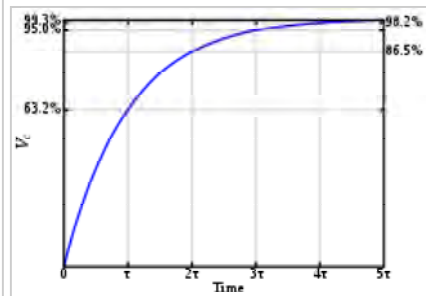

Resistor voltage step-response.

These equations show that a series RL circuit has a time constant, usually denoted $\tau = \frac{L}{R}$ being the time it takes the voltage across the component to either fall (across the inductor) or rise (across the resistor) to within $\frac{1}{e}$ of its final value. That is, τ is the time it takes V_L to reach $V(\frac{1}{e})$ and V_R to reach $V(1-\frac{1}{e})$.

The rate of change is a *fractional* $1-\frac{1}{e}$ per τ. Thus, in going from $t = N\tau$ to $t = (N+1)\tau$, the voltage will have moved about 63% of the way from its level at $t = N\tau$ toward its final value. So the voltage across the inductor will have dropped to about 37% after τ, and essentially to zero (0.7%) after about 5τ. Kirchhoff's voltage law implies that the voltage across the resistor will *rise* at the same rate. When the voltage source is then replaced with a short-circuit, the voltage across the resistor drops exponentially with t from V towards 0. The resistor will be discharged to about 37% after τ, and essentially fully discharged (0.7%) after about 5τ. Note that the current, I, in the circuit behaves as the voltage across the resistor does, via Ohm's Law.

The delay in the rise or fall time of the circuit is in this case caused by the back-EMF from the inductor which, as the current flowing through it tries to change, prevents the current (and hence the voltage across the resistor) from rising or falling much faster than the time-constant of the circuit. Since all wires have some self-inductance and resistance, all circuits have a time constant. As a result, when the power supply is switched on, the current does not instantaneously reach its steady-state value, $\frac{V}{R}$. The rise instead takes several time-constants to complete. If this were not the case, and the current were to reach steady-state immediately, extremely strong inductive electric fields would be generated by the sharp change in the magnetic field — this would lead to breakdown of the air in the circuit and electric arcing, probably damaging components (and users).

These results may also be derived by solving the differential equation describing the circuit:

$$V_{\text{in}} = IR + L\frac{dI}{dt}$$
$$V_R = V_{\text{in}} - V_L\,.$$

The first equation is solved by using an integrating factor and yields the current which must be differentiated to give V_L; the second equation is straightforward. The solutions are exactly the same as those obtained via Laplace transforms.

Short circuit equation

For short circuit evaluation, RL circuit is considered. The more general equation is:

$$v_{in}(t) = v_L(t) + v_R(t) = L\frac{di}{dt} + Ri$$

With initial condition:

$$i(0) = i_0$$

Which can be solved by Laplace transform:

$$V_{in}(s) = sLI - Li_0 + RI$$

Thus:

$$I(s) = \frac{Li_o + V_{in}}{sL + R}$$

Then antitrasform returns:

$$i(t) = i_0 e^{-\frac{R}{L}t} + \mathcal{L}^{-1}\left[\frac{V_{in}}{sL + R}\right]$$

In case the source voltage is a Heaviside step function (DC):

$$v_{in}(t) = Eu(t)$$

Returns:

$$i(t) = i_0 e^{-\frac{R}{L}t} + \mathcal{L}^{-1}\left[\frac{E}{s(sL + R)}\right] = i_0 e^{-\frac{R}{L}t} + \frac{E}{R}\left(1 - e^{-\frac{R}{L}t}\right)$$

In case the source voltage is a sinusoidal function (AC):

$$v_{in}(t) = E\sin(\omega t) \Rightarrow V_{in}(s) = \frac{E\omega}{s^2 + \omega^2}$$

Returns:

$$i(t) = i_0 e^{-\frac{R}{L}t} + \mathcal{L}^{-1}\left[\frac{E\omega}{(s^2 + \omega^2)(sL + R)}\right] = i_0 e^{-\frac{R}{L}t} + \mathcal{L}^{-1}\left[\frac{E\omega}{2j\omega}\left(\frac{1}{s - j\omega} - \frac{1}{s + j\omega}\right)\frac{1}{(sL + R)}\right]$$
$$= i_0 e^{-\frac{R}{L}t} + \frac{E}{2jL}\mathcal{L}^{-1}\left[\frac{1}{s + \frac{R}{L}}\left(\frac{1}{\frac{R}{L} - j\omega} - \frac{1}{\frac{R}{L} + j\omega}\right) + \frac{1}{s - j\omega}\frac{1}{\frac{R}{L} + j\omega} - \frac{1}{s + j\omega}\frac{1}{\frac{R}{L} - j\omega}\right]$$
$$= i_0 e^{-\frac{R}{L}t} + \frac{E}{2jL}e^{-\frac{R}{L}t}2j\mathrm{Im}\left[\frac{1}{\frac{R}{L} - j\omega}\right] + \frac{E}{2jL}2j\mathrm{Im}\left[e^{j\omega t}\frac{1}{\frac{R}{L} + j\omega}\right]$$

$$= i_0 e^{-\frac{R}{L}t} + \frac{E\omega}{L\left(\left(\frac{R}{L}\right)^2 + \omega^2\right)} e^{-\frac{R}{L}t} + \frac{E}{L\left(\left(\frac{R}{L}\right)^2 + \omega^2\right)} \left(\frac{R}{L}\sin(\omega t) - \omega\cos(\omega t)\right)$$

$$= i_0 e^{-\frac{R}{L}t} + \frac{E\omega}{L\left(\left(\frac{R}{L}\right)^2 + \omega^2\right)} e^{-\frac{R}{L}t} + \frac{E}{L\sqrt{\left(\frac{R}{L}\right)^2 + \omega^2}} \sin\left(\omega t - \tan^{-1}\left(\frac{\omega L}{R}\right)\right)$$

Parallel circuit

The parallel RL circuit is generally of less interest than the series circuit unless fed by a current source. This is largely because the output voltage V_{out} is equal to the input voltage V_{in} — as a result, this circuit does not act as a filter for a voltage input signal.

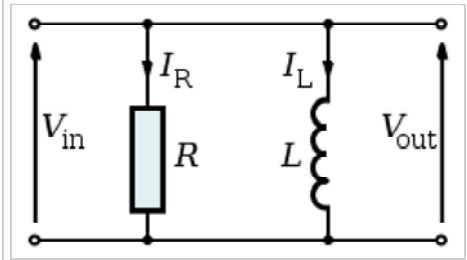

Parallel RL circuit

With complex impedances:

$$I_R = \frac{V_{\text{in}}}{R}$$
$$I_L = \frac{V_{\text{in}}}{j\omega L} = -\frac{jV_{\text{in}}}{\omega L}\,.$$

This shows that the inductor lags the resistor (and source) current by 90°.

The parallel circuit is seen on the output of many amplifier circuits, and is used to isolate the amplifier from capacitive loading effects at high frequencies. Because of the phase shift introduced by capacitance, some amplifiers become unstable at very high frequencies, and tend to oscillate. This affects sound quality and component life (especially the transistors), and is to be avoided.

See also

- LC circuit
- RC circuit
- RLC circuit
- Electrical network
- List of electronics topics

References

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RLC circuit

From Wikipedia, the free encyclopedia

An **RLC circuit** is an electrical circuit consisting of a resistor (R), an inductor (L), and a capacitor (C), connected in series or in parallel. The name of the circuit is derived from the letters that are used to denote the constituent components of this circuit, where the sequence of the components may vary from RLC.

A series RLC circuit: a resistor, inductor, and a capacitor

The circuit forms a harmonic oscillator for current, and resonates in a similar way as an LC circuit. Introducing the resistor increases the decay of these oscillations, which is also known as damping. The resistor also reduces the peak resonant frequency. Some resistance is unavoidable in real circuits even if a resistor is not specifically included as a component. An ideal, pure LC circuit exists only in the domain of superconductivity.

RLC circuits have many applications as oscillator circuits. Radio receivers and television sets use them for tuning to select a narrow frequency range from ambient radio waves. In this role the circuit is often referred to as a tuned circuit. An RLC circuit can be used as a band-pass filter, band-stop filter, low-pass filter or high-pass filter. The tuning application, for instance, is an example of band-pass filtering. The RLC filter is described as a *second-order* circuit, meaning that any voltage or current in the circuit can be described by a second-order differential equation in circuit analysis.

The three circuit elements, R, L and C, can be combined in a number of different topologies. All three elements in series or all three elements in parallel are the simplest in concept and the most straightforward to analyse. There are, however, other arrangements, some with practical importance in real circuits. One issue often encountered is the need to take into account inductor resistance. Inductors are typically constructed from coils of wire, the resistance of which is not usually desirable, but it often has a significant effect on the circuit.

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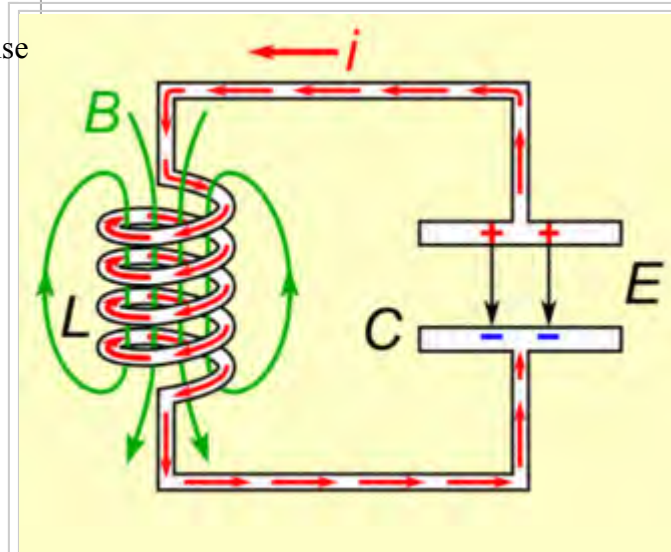

Animation illustrating the operation of an LC circuit, an RLC circuit with no resistance. Charge flows back and forth between the capacitor plates through the inductance. The energy oscillates back and forth between the capacitor's electric field (E) and the inductor's magnetic field (B). RLC circuits operate similarly, except that the oscillating currents decay with time to zero due to the resistance in the circuit.

Basic concepts

Resonance

An important property of this circuit is its ability to resonate at a specific frequency, the resonance frequency, f_0. Frequencies are measured in units of hertz. In this article, however, angular frequency, ω_0, is used which is more mathematically convenient. This is measured in radians per second. They are related to each other by a simple proportion,

$$\omega_0 = 2\pi f_0 \,.$$

Resonance occurs because energy is stored in two different ways: in an electric field as the capacitor is charged and in a magnetic field as current flows through the inductor. Energy can be transferred from one to the other within the circuit and this can be oscillatory. A mechanical analogy is a weight suspended on a spring which will oscillate up and down when released. This is no passing metaphor; a weight on a spring is described by exactly the same second order differential equation as an RLC circuit and for all the properties of the one system there will be found an analogous property of the other. The mechanical property answering to the resistor in the circuit is friction in the spring–weight system.

Friction will slowly bring any oscillation to a halt if there is no external force driving it. Likewise, the resistance in an RLC circuit will "damp" the oscillation, diminishing it with time if there is no driving AC power source in the circuit.

The resonance frequency is defined as the frequency at which the impedance of the circuit is at a minimum. Equivalently, it can be defined as the frequency at which the impedance is purely real (that is, purely resistive). This occurs because the impedances of the inductor and capacitor at resonance are equal but of opposite sign and cancel out. Circuits where L and C are in parallel rather than series actually have a maximum impedance rather than a minimum impedance. For this reason they are often described as antiresonators, it is still usual, however, to name the frequency at which this occurs as the resonance frequency.

Natural frequency

The resonance frequency is defined in terms of the impedance presented to a driving source. It is still possible for the circuit to carry on oscillating (for a time) after the driving source has been removed or it is subjected to a step in voltage (including a step down to zero). This is similar to the way that a tuning fork will carry on ringing after it has been struck, and the effect is often called ringing. This effect is the peak natural resonance frequency of the circuit and in general is not exactly the same as the driven resonance frequency, although the two will usually be quite close to each other. Various terms are used by different authors to distinguish the two, but resonance frequency unqualified usually means the driven resonance frequency. The driven frequency may be called the undamped resonance frequency or undamped natural frequency and the peak frequency may be called the damped resonance frequency or the damped natural frequency. The reason for this terminology is that the driven resonance frequency in a series or parallel resonant circuit has the value[1]

$$\omega_0 = \frac{1}{\sqrt{LC}}\,.$$

This is exactly the same as the resonance frequency of an LC circuit, that is, one with no resistor present. The resonant frequency for an RLC circuit is the same as a circuit in which there is no damping, hence undamped resonance frequency. The peak resonance frequency, on the other hand, depends on the value of the resistor and is described as the damped resonant frequency. A highly damped circuit will fail to resonate at all when not driven. A circuit with a value of resistor that causes it to be just on the edge of ringing is called critically damped. Either side of critically damped are described as underdamped (ringing happens) and overdamped (ringing is suppressed).

Circuits with topologies more complex than straightforward series or parallel (some examples described later in the article) have a driven resonance frequency that deviates from $\omega_0 = \frac{1}{\sqrt{LC}}$, and for those the undamped resonance frequency, damped resonance frequency and driven resonance frequency can all be different.

Damping

Damping is caused by the resistance in the circuit. It determines whether or not the circuit will resonate naturally (that is, without a driving source). Circuits which will resonate in this way are described as underdamped and those that will not are overdamped. Damping attenuation (symbol α) is measured in nepers per second. However, the unitless damping factor (symbol ζ, zeta) is often a more useful measure, which is related to α by

$$\zeta = \frac{\alpha}{\omega_0}\,.$$

The special case of $\zeta = 1$ is called critical damping and represents the case of a circuit that is just on the border of oscillation. It is the minimum damping that can be applied without causing oscillation.

Bandwidth

The resonance effect can be used for filtering, the rapid change in impedance near resonance can be used to pass or block signals close to the resonance frequency. Both band-pass and band-stop filters can be constructed and some filter circuits are shown later in the article. A key parameter in filter design is bandwidth. The bandwidth is measured between the 3 dB points, that is, the frequencies at which the power passed through the circuit has fallen to half the value passed at resonance. There are two of these half-power frequencies, one above, and one below the resonance frequency

$$\Delta\omega = \omega_2 - \omega_1\,,$$

where $\Delta\omega$ is the bandwidth, ω_1 is the lower half-power frequency and ω_2 is the upper half-power frequency. The bandwidth is related to attenuation by

$$\Delta\omega = 2\alpha\,,$$

where the units are radians per second and nepers per second respectively. Other units may require a conversion factor. A more general measure of bandwidth is the fractional bandwidth, which expresses the bandwidth as a fraction of the resonance frequency and is given by

$$F_\mathrm{b} = \frac{\Delta\omega}{\omega_0}\,.$$

The fractional bandwidth is also often stated as a percentage. The damping of filter circuits is adjusted to result in the required bandwidth. A narrow band filter, such as a notch filter, requires low damping. A wide band filter requires high damping.

Q factor

The Q factor is a widespread measure used to characterise resonators. It is defined as the peak energy stored in the circuit divided by the average energy dissipated in it per radian at resonance. Low-Q circuits are therefore damped and lossy and high-Q circuits are underdamped. Q is related to bandwidth; low-Q circuits are wide-band and high-Q circuits are narrow-band. In fact, it happens that Q is the inverse of fractional bandwidth

$$Q = \frac{1}{F_\mathrm{b}} = \frac{\omega_0}{\Delta\omega}\,.$$

Q factor is directly proportional to selectivity, as the Q factor depends inversely on bandwidth.

For a series resonant circuit, the Q factor can be calculated as follows:[2]

$$Q = \frac{1}{\omega_0 RC} = \frac{\omega_0 L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}\,.$$

Scaled parameters

The parameters ζ, F_b, and Q are all scaled to ω_0. This means that circuits which have similar parameters share similar characteristics regardless of whether or not they are operating in the same frequency band.

The article next gives the analysis for the series RLC circuit in detail. Other configurations are not described in such detail, but the key differences from the series case are given. The general form of the differential equations given in the series circuit section are applicable to all second order circuits and can be used to describe the voltage or current in any element of each circuit.

Series RLC circuit

In this circuit, the three components are all in series with the voltage source. The governing differential equation can be found by substituting into Kirchhoff's voltage law (KVL) the constitutive equation for each of the three elements. From the KVL,

$$V_R + V_L + V_C = V(t)\,,$$

where V_R, V_L and V_C are the voltages across R, L and C respectively and $V(t)$ is the time varying voltage from the source. Substituting in the constitutive equations,

$$RI(t) + L\frac{dI}{dt} + \frac{1}{C}\int_{-\infty}^{t} I(\tau)\,d\tau = V(t)\,.$$

For the case where the source is an unchanging voltage, differentiating and dividing by L leads to the second order differential equation:

$$\frac{d^2}{dt^2}I(t) + \frac{R}{L}\frac{d}{dt}I(t) + \frac{1}{LC}I(t) = 0\,.$$

This can usefully be expressed in a more generally applicable form:

$$\frac{d^2}{dt^2}I(t) + 2\alpha\frac{d}{dt}I(t) + \omega_0^2 I(t) = 0\,.$$

α and ω_0 are both in units of angular frequency. α is called the *neper frequency*, or *attenuation*, and is a measure of how fast the transient response of the circuit will die away after the stimulus has been removed. Neper occurs in the name because the units can also be considered to be nepers per second, neper being a unit of attenuation. ω_0 is the angular resonance frequency.[3]

For the case of the series RLC circuit these two parameters are given by:[4]

$$\alpha = \frac{R}{2L}$$
$$\omega_0 = \frac{1}{\sqrt{LC}}\,.$$

A useful parameter is the *damping factor*, ζ, which is defined as the ratio of these two; although, sometimes α is referred to as the damping factor and ζ is not used.[5]

$$\zeta = \frac{\alpha}{\omega_0}\,.$$

In the case of the series RLC circuit, the damping factor is given by

$$\zeta = \frac{R}{2}\sqrt{\frac{C}{L}}\,.$$

The value of the damping factor determines the type of transient that the circuit will exhibit.[6]

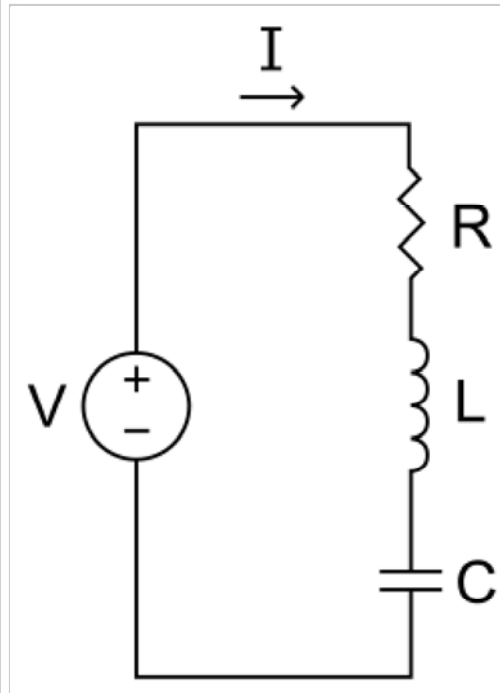

Figure 1: RLC series circuit
V, the voltage source powering the circuit
I, the current admitted through the circuit
R, the effective resistance of the combined load, source, and components
L, the inductance of the inductor component
C, the capacitance of the capacitor component

Transient response

The differential equation for the circuit solves in three different ways depending on the value of ζ. These are underdamped ($\zeta < 1$), overdamped ($\zeta > 1$) and critically damped ($\zeta = 1$). The differential equation has the characteristic equation,[7]

$$s^2 + 2\alpha s + \omega_0^2 = 0\,.$$

The roots of the equation in s are,[7]

$$s_1 = -\alpha + \sqrt{\alpha^2 - \omega_0^2}$$
$$s_2 = -\alpha - \sqrt{\alpha^2 - \omega_0^2}\,.$$

The general solution of the differential equation is an exponential in either root or a linear superposition of both,

$$I(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t}\,.$$

The coefficients A_1 and A_2 are determined by the boundary conditions of the specific problem being analysed. That is, they are set by the values of the currents and voltages in the circuit at the onset of the transient and the presumed value they will settle to after infinite time.[8]

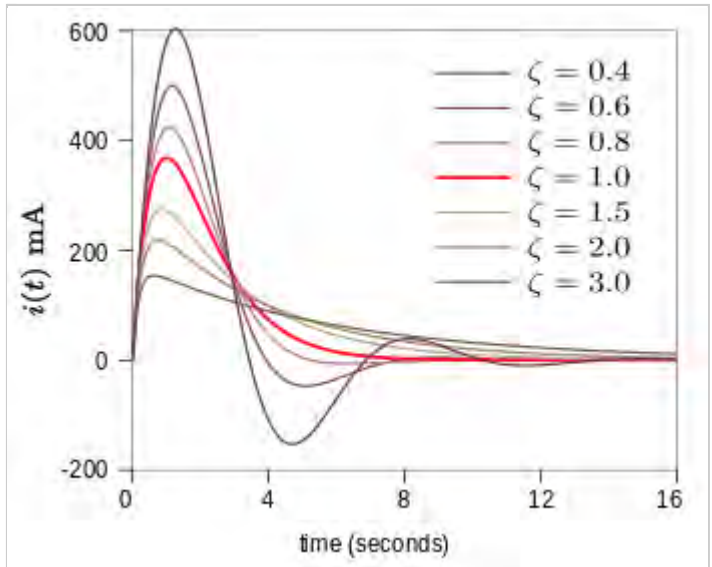

Plot showing underdamped and overdamped responses of a series RLC circuit. The critical damping plot is the bold red curve. The plots are normalised for $L = 1$, $C = 1$ and $\omega_0 = 1$.

Overdamped response

The overdamped response ($\zeta > 1$) is[9]

$$I(t) = A_1 e^{-\omega_0\left(\zeta+\sqrt{\zeta^2-1}\right)t} + A_2 e^{-\omega_0\left(\zeta-\sqrt{\zeta^2-1}\right)t}\,.$$

The overdamped response is a decay of the transient current without oscillation.[10]

Underdamped response

The underdamped response ($\zeta < 1$) is[11]

$$I(t) = B_1 e^{-\alpha t}\cos(\omega_\mathrm{d} t) + B_2 e^{-\alpha t}\sin(\omega_\mathrm{d} t)\,.$$

By applying standard trigonometric identities the two trigonometric functions may be expressed as a single sinusoid with phase shift,[12]

$$I(t) = B_3 e^{-\alpha t}\sin(\omega_\mathrm{d} t + \varphi)\,.$$

The underdamped response is a decaying oscillation at frequency ω_d. The oscillation decays at a rate determined by the attenuation α. The exponential in α describes the envelope of the oscillation. B_1 and B_2 (or B_3 and the phase shift φ in the second form) are arbitrary constants determined by boundary conditions. The frequency ω_d is given by[11]

$$\omega_\mathrm{d} = \sqrt{\omega_0^2 - \alpha^2} = \omega_0\sqrt{1-\zeta^2}\,.$$

This is called the damped resonance frequency or the damped natural frequency. It is the frequency the circuit will naturally oscillate at if not driven by an external source. The resonance frequency, ω_0, which is the frequency at which the circuit will resonate when driven by an external oscillation, may often be referred to as the undamped resonance frequency to distinguish it.[13]

Critically damped response

The critically damped response ($\zeta = 1$) is[14]

$$I(t) = D_1 t e^{-\alpha t} + D_2 e^{-\alpha t}\,.$$

The critically damped response represents the circuit response that decays in the fastest possible time without going into oscillation. This consideration is important in control systems where it is required to reach the desired state as quickly as possible without overshooting. D_1 and D_2 are arbitrary constants determined by boundary conditions.[15]

Laplace domain

The series RLC can be analyzed for both transient and steady AC state behavior using the Laplace transform.[16] If the voltage source above produces a waveform with Laplace-transformed $V(s)$ (where s is the complex frequency $s = \sigma + j\omega$), the KVL can be applied in the Laplace domain:

$$V(s) = I(s)\left(R + Ls + \frac{1}{Cs}\right)\,,$$

where $I(s)$ is the Laplace-transformed current through all components. Solving for $I(s)$:

$$I(s) = \frac{1}{R + Ls + \frac{1}{Cs}} V(s)\,.$$

And rearranging, we have

$$I(s) = \frac{s}{L\left(s^2 + \frac{R}{L}s + \frac{1}{LC}\right)} V(s)\,.$$

Laplace admittance

Solving for the Laplace admittance $Y(s)$:

$$Y(s) = \frac{I(s)}{V(s)} = \frac{s}{L\left(s^2 + \frac{R}{L}s + \frac{1}{LC}\right)}\,.$$

Simplifying using parameters α and ω_0 defined in the previous section, we have

$$Y(s) = \frac{I(s)}{V(s)} = \frac{s}{L\left(s^2 + 2\alpha s + \omega_0^2\right)}\,.$$

Poles and zeros

The zeros of $Y(s)$ are those values of s such that $Y(s) = 0$:

$$s = 0 \quad \text{and} \quad |s| \to \infty\,.$$

The poles of $Y(s)$ are those values of s such that $Y(s) \to \infty$. By the quadratic formula, we find

$$s = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}\,.$$

The poles of $Y(s)$ are identical to the roots s_1 and s_2 of the characteristic polynomial of the differential equation in the section above.

General solution

For an arbitrary $V(t)$, the solution obtained by inverse transform of $I(s)$ is:

- In the underdamped case, $\omega_0 > \alpha$:

$$I(t) = \frac{1}{L}\int_0^t V(t-\tau)e^{-\alpha\tau}\left(\cos\omega_\mathrm{d}\tau - \frac{\alpha}{\omega_\mathrm{d}}\sin\omega_\mathrm{d}\tau\right)d\tau\,,$$

- In the critically damped case, $\omega_0 = \alpha$:

$$I(t) = \frac{1}{L}\int_0^t V(t-\tau)e^{-\alpha\tau}(1-\alpha\tau)\,d\tau\,,$$

- In the overdamped case, $\omega_0 < \alpha$:

$$I(t) = \frac{1}{L}\int_0^t V(t-\tau)e^{-\alpha\tau}\left(\cosh\omega_\mathrm{r}\tau - \frac{\alpha}{\omega_\mathrm{r}}\sinh\omega_\mathrm{r}\tau\right)d\tau\,,$$

where $\omega_\mathrm{r} = \sqrt{\alpha^2 - {\omega_0}^2}$, and $\cosh$ and $\sinh$ are the usual hyperbolic functions.

Sinusoidal steady state

Sinusoidal steady state is represented by letting $s = j\omega$, where j is the imaginary unit. Taking the magnitude of the above equation with this substitution:

$$|Y(j\omega)| = \frac{1}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}\,.$$

and the current as a function of ω can be found from

$$|I(j\omega)| = |Y(j\omega)| \cdot |V(j\omega)|\,.$$

There is a peak value of $|I(j\omega)|$. The value of ω at this peak is, in this particular case, equal to the undamped natural resonance frequency:[17]

$$\omega_0 = \frac{1}{\sqrt{LC}}\,.$$

Parallel RLC circuit

The properties of the parallel RLC circuit can be obtained from the duality relationship of electrical circuits and considering that the parallel RLC is the dual impedance of a series RLC. Considering this, it becomes clear that the differential equations describing this circuit are identical to the general form of those describing a series RLC.

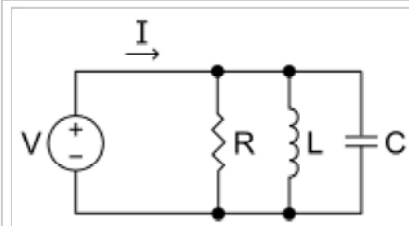

Figure 2. RLC parallel circuit
V – the voltage source powering the circuit
I – the current admitted through the circuit
R – the equivalent resistance of the combined source, load, and components
L – the inductance of the inductor component
C – the capacitance of the capacitor component

For the parallel circuit, the attenuation α is given by[18]

$$\alpha = \frac{1}{2RC}$$

and the damping factor is consequently

$$\zeta = \frac{1}{2R}\sqrt{\frac{L}{C}}\,.$$

Likewise, the other scaled parameters, fractional bandwidth and Q are also reciprocals of each other. This means that a wide-band, low-Q circuit in one topology will become a narrow-band, high-Q circuit in the other topology when constructed from components with identical values. The fractional bandwidth and Q of the parallel circuit are given by

$$F_\mathrm{b} = \frac{1}{R}\sqrt{\frac{L}{C}}$$
$$Q = R\sqrt{\frac{C}{L}}\,.$$

Notice that the formulas here are the reciprocals of the formulas for the series circuit, given above.

Frequency domain

The complex admittance of this circuit is given by adding up the admittances of the components:

$$\begin{aligned}\frac{1}{Z} &= \frac{1}{Z_L} + \frac{1}{Z_C} + \frac{1}{Z_R} \\ &= \frac{1}{j\omega L} + j\omega C + \frac{1}{R}\,.\end{aligned}$$

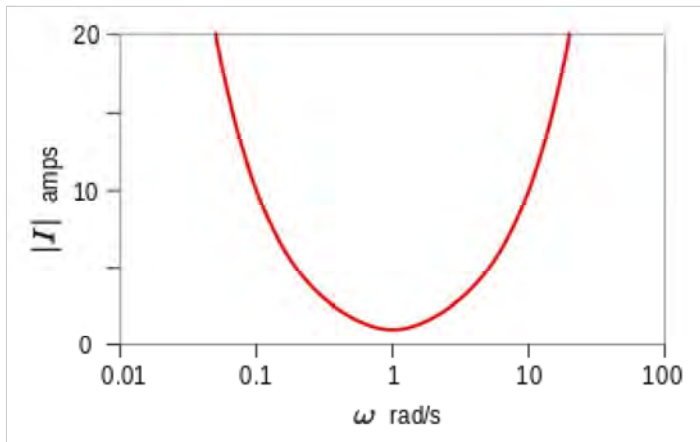

Figure 3. Sinusoidal steady-state analysis. Normalised to $R = 1\ \Omega$, $C = 1$ F, $L = 1$ H, and $V = 1$ V.

The change from a series arrangement to a parallel arrangement results in the circuit having a peak in impedance at resonance rather than a minimum, so the circuit is an antiresonator.

The graph opposite shows that there is a minimum in the frequency response of the current at the resonance frequency $\omega_0 = \frac{1}{\sqrt{LC}}$ when the circuit is driven by a constant voltage. On the other hand, if driven by a constant current, there would be a maximum in the voltage which would follow the same curve as the current in the series circuit.

Other configurations

A series resistor with the inductor in a parallel LC circuit as shown in Figure 4 is a topology commonly encountered where there is a need to take into account the resistance of the coil winding. Parallel LC circuits are frequently used for bandpass filtering and the Q is largely governed by this resistance. The resonant frequency of this circuit is[19]

$$\omega_0 = \sqrt{\frac{1}{LC} - \left(\frac{R}{L}\right)^2}\,.$$

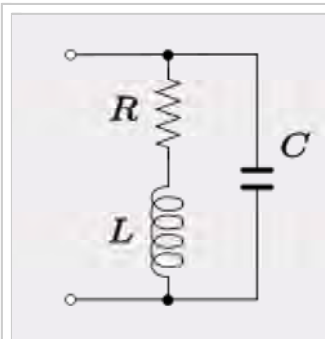

Figure 4. RLC parallel circuit with resistance in series with the inductor

This is the resonant frequency of the circuit defined as the frequency at which the admittance has zero imaginary part. The frequency that appears in the generalised form of the characteristic equation (which is the same for this circuit as previously)

$$s^2 + 2\alpha s + {\omega'_0}^2 = 0$$

is not the same frequency. In this case it is the natural undamped resonant frequency:[20]

$$\omega'_0 = \sqrt{\frac{1}{LC}}\,.$$

The frequency ω_{m} at which the impedance magnitude is maximum is given by[21]

$$\omega_{\mathrm{m}} = \omega'_0 \sqrt{-\frac{1}{Q_L^2} + \sqrt{1 + \frac{2}{Q_L^2}}}\,,$$

where $Q_L = \frac{\omega'_0 L}{R}$ is the quality factor of the coil. This can be well approximated by[21]

$$\omega_{\mathrm{m}} \approx \omega'_0 \sqrt{1 - \frac{1}{2Q_L^4}}\,.$$

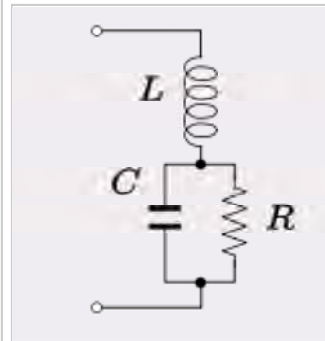

Figure 5. RLC series circuit with resistance in parallel with the capacitor

Furthermore, the exact maximum impedance magnitude is given by[21]

$$|Z|_{\max} = RQ_L^2 \sqrt{\frac{1}{2Q_L\sqrt{Q_L^2+2} - 2Q_L^2 - 1}}\,.$$

For values of Q_L greater than unity, this can be well approximated by[21]

$$|Z|_{\max} \approx RQ_L^2\,.$$

In the same vein, a resistor in parallel with the capacitor in a series LC circuit can be used to represent a capacitor with a lossy dielectric. This configuration is shown in Figure 5. The resonant frequency (frequency at which the impedance has zero imaginary part) in this case is given by[22]

$$\omega_0 = \sqrt{\frac{1}{LC} - \frac{1}{(RC)^2}}\,,$$

while the frequency ω_{m} at which the impedance magnitude is maximum is given by

$$\omega_{\mathrm{m}} = \omega'_0 \sqrt{-\frac{1}{Q_C^2} + \sqrt{1 + \frac{2}{Q_C^2}}}\,,$$

where $Q_C = \omega'_0 RC$.

History

The first evidence that a capacitor could produce electrical oscillations was discovered in 1826 by French scientist Felix Savary.[23][24] He found that when a Leyden jar was discharged through a wire wound around an iron needle, sometimes the needle was left magnetized in one direction and sometimes

in the opposite direction. He correctly deduced that this was caused by a damped oscillating discharge current in the wire, which reversed the magnetization of the needle back and forth until it was too small to have an effect, leaving the needle magnetized in a random direction.

American physicist Joseph Henry repeated Savary's experiment in 1842 and came to the same conclusion, apparently independently.[25][26] British scientist William Thomson (Lord Kelvin) in 1853 showed mathematically that the discharge of a Leyden jar through an inductance should be oscillatory, and derived its resonant frequency.[23][25][26]

British radio researcher Oliver Lodge, by discharging a large battery of Leyden jars through a long wire, created a tuned circuit with its resonant frequency in the audio range, which produced a musical tone from the spark when it was discharged.[25] In 1857 German physicist Berend Wilhelm Feddersen photographed the spark produced by a resonant Leyden jar circuit in a rotating mirror, providing visible evidence of the oscillations.[23][25][26] In 1868 Scottish physicist James Clerk Maxwell calculated the effect of applying an alternating current to a circuit with inductance and capacitance, showing that the response is maximum at the resonant frequency.[23]

The first example of an electrical resonance curve was published in 1887 by German physicist Heinrich Hertz in his pioneering paper on the discovery of radio waves, showing the length of spark obtainable from his spark-gap LC resonator detectors as a function of frequency.[23]

One of the first demonstrations of resonance between tuned circuits was Lodge's "syntonic jars" experiment around 1889[23][25] He placed two resonant circuits next to each other, each consisting of a Leyden jar connected to an adjustable one-turn coil with a spark gap. When a high voltage from an induction coil was applied to one tuned circuit, creating sparks and thus oscillating currents, sparks were excited in the other tuned circuit only when the inductors were adjusted to resonance. Lodge and some English scientists preferred the term "*syntony*" for this effect, but the term "*resonance*" eventually stuck.[23]

The first practical use for RLC circuits was in the 1890s in spark-gap radio transmitters to allow the receiver to be tuned to the transmitter. The first patent for a radio system that allowed tuning was filed by Lodge in 1897, although the first practical systems were invented in 1900 by Anglo Italian radio pioneer Guglielmo Marconi.[23]

Applications

Variable tuned circuits

A very frequent use of these circuits is in the tuning circuits of analogue radios. Adjustable tuning is commonly achieved with a parallel plate variable capacitor which allows the value of C to be changed and tune to stations on different frequencies. For the IF stage in the radio where the tuning is preset in the factory the more usual solution is an adjustable core in the inductor to adjust L. In this design the core (made of a high permeability material that has the effect of increasing inductance) is threaded so that it can be screwed further in, or screwed further out of the inductor winding as required.

Filters

In the filtering application, the resistor becomes the load that the filter is working into. The value of the damping factor is chosen based on the desired bandwidth of the filter. For a wider bandwidth, a larger value of the damping factor is required (and vice versa). The three components give the designer three degrees of freedom. Two of these are required to set the bandwidth and resonant frequency. The designer is still left with one which can be used to scale R, L and C to convenient practical values. Alternatively, R may be predetermined by the external circuitry which will use the last degree of freedom.

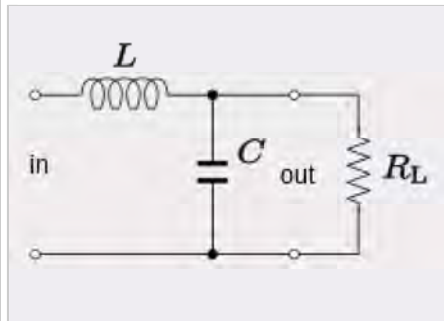

Figure 6. RLC circuit as a low-pass filter

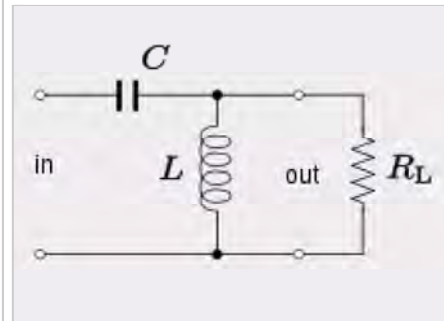

Figure 7. RLC circuit as a high-pass filter

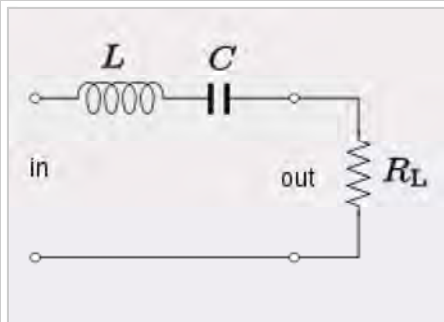

Figure 8. RLC circuit as a series band-pass filter in series with the line

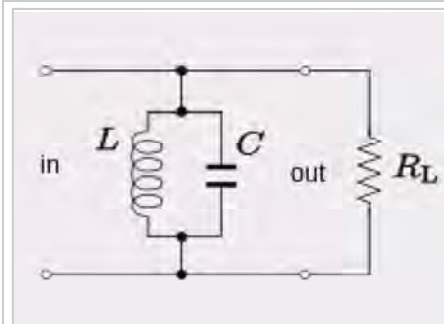

Figure 9. RLC circuit as a parallel band-pass filter in shunt across the line

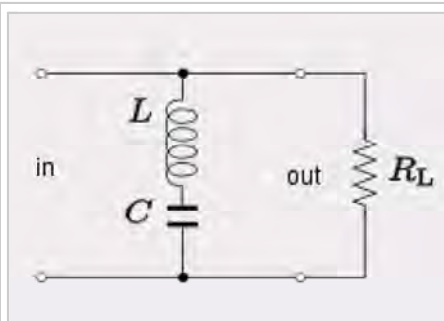

Figure 10. RLC circuit as a series band-stop filter in shunt across the line

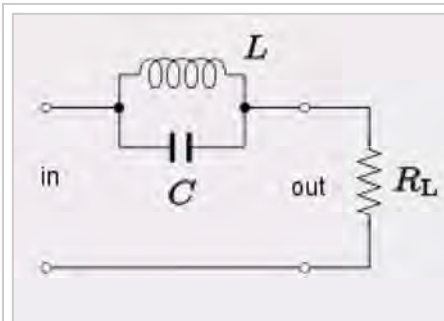

Figure 11. RLC circuit as a parallel band-stop filter in series with the line

Low-pass filter

An RLC circuit can be used as a low-pass filter. The circuit configuration is shown in Figure 6. The corner frequency, that is, the frequency of the 3 dB point, is given by

$$\omega_c = \frac{1}{\sqrt{LC}}\,.$$

This is also the bandwidth of the filter. The damping factor is given by[27]

$$\zeta = \frac{1}{2R_L}\sqrt{\frac{L}{C}}\,.$$

High-pass filter

A high-pass filter is shown in Figure 7. The corner frequency is the same as the low-pass filter:

$$\omega_{\mathrm{c}} = \frac{1}{\sqrt{LC}}\,.$$

The filter has a stop-band of this width.[28]

Band-pass filter

A band-pass filter can be formed with an RLC circuit by either placing a series LC circuit in series with the load resistor or else by placing a parallel LC circuit in parallel with the load resistor. These arrangements are shown in Figures 8 and 9 respectively. The centre frequency is given by

$$\omega_{\mathrm{c}} = \frac{1}{\sqrt{LC}}\,,$$

and the bandwidth for the series circuit is[29]

$$\Delta\omega = \frac{R_L}{L}\,.$$

The shunt version of the circuit is intended to be driven by a high impedance source, that is, a constant current source. Under those conditions the bandwidth is[29]

$$\Delta\omega = \frac{1}{CR_L}\,.$$

Band-stop filter

Figure 10 shows a band-stop filter formed by a series LC circuit in shunt across the load. Figure 11 is a band-stop filter formed by a parallel LC circuit in series with the load. The first case requires a high impedance source so that the current is diverted into the resonator when it becomes low impedance at resonance. The second case requires a low impedance source so that the voltage is dropped across the antiresonator when it becomes high impedance at resonance.[30]

Oscillators

For applications in oscillator circuits, it is generally desirable to make the attenuation (or equivalently, the damping factor) as small as possible. In practice, this objective requires making the circuit's resistance R as small as physically possible for a series circuit, or alternatively increasing R to as much as possible for a parallel circuit. In either case, the RLC circuit becomes a good approximation to an ideal LC circuit. However, for very low-attenuation circuits (high Q-factor), issues such as dielectric losses of coils and capacitors can become important.

In an oscillator circuit

$$\alpha \ll \omega_0 \,,$$

or equivalently

$$\zeta \ll 1 \,.$$

As a result,

$$\omega_{\mathrm{d}} \approx \omega_0 \,.$$

Voltage multiplier

In a series RLC circuit at resonance, the current is limited only by the resistance of the circuit

$$I = \frac{V}{R} \,.$$

If R is small, consisting only of the inductor winding resistance say, then this current will be large. It will drop a voltage across the inductor of

$$V_L = \frac{V}{R}\omega_0 L \,.$$

An equal magnitude voltage will also be seen across the capacitor but in antiphase to the inductor. If R can be made sufficiently small, these voltages can be several times the input voltage. The voltage ratio is, in fact, the Q of the circuit,

$$\frac{V_L}{V} = Q \,.$$

A similar effect is observed with currents in the parallel circuit. Even though the circuit appears as high impedance to the external source, there is a large current circulating in the internal loop of the parallel inductor and capacitor.

Pulse discharge circuit

An overdamped series RLC circuit can be used as a pulse discharge circuit. Often it is useful to know the values of components that could be used to produce a waveform this is described by the form

$$I(t) = I_0 \left(e^{-\alpha t} - e^{-\beta t}\right) \,.$$

Such a circuit could consist of an energy storage capacitor, a load in the form of a resistance, some circuit inductance and a switch – all in series. The initial conditions are that the capacitor is at voltage, V_0, and there is no current flowing in the inductor. If the inductance L is known, then the remaining parameters are given by the following – capacitance:

$$C = \frac{1}{L\alpha\beta}\,,$$

resistance (total of circuit and load):

$$R = L(\alpha + \beta)\,,$$

initial terminal voltage of capacitor:

$$V_0 = -I_0 L\alpha\beta\left(\frac{1}{\beta} - \frac{1}{\alpha}\right)\,.$$

Rearranging for the case where R is known – capacitance:

$$C = \frac{\alpha + \beta}{R\alpha\beta}\,,$$

inductance (total of circuit and load):

$$L = \frac{R}{\alpha + \beta}\,,$$

initial terminal voltage of capacitor:

$$V_0 = \frac{-I_0 R\alpha\beta}{\alpha + \beta}\left(\frac{1}{\beta} - \frac{1}{\alpha}\right)\,.$$

See also

- RC circuit
- LC circuit
- RL circuit
- Electronic oscillator
- Linear circuit

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5. Agarwal and Lang, p. 646.
6. Irwin, pp. 217–220.
7. Agarwal and Lang, p. 656.
8. Nilsson and Riedel, pp. 287–288.
9. Irwin, p. 532.
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11. Nilsson and Riedel, p. 295.

12. Humar, pp. 223–224.
13. Agarwal and Lang, p. 692.
14. Nilsson and Riedel, p. 303.
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16. This section is based on Example 4.2.13 from Debnath, Lokenath; Bhatta, Dambaru (2007). *Integral Transforms and Their Applications* (2nd ed.). Chapman & Hall/CRC. p. 198–202. ISBN 1-58488-575-0. (Some notations have been changed to fit the rest of this article.)
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29. Kaiser, pp. 7.21–7.27.
30. Kaiser, pp. 7.30–7.34.

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Categories: Analog circuits | Electronic filter topology

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RO membrane specifications "100 gpd" TFC

http://www.isopurewater.com/products/dow-filmtec-tw30-1812-series-replacement-reverse-osmosis-tfc-membrane.html

FILMTEC reverse osmosis membrane elements for home drinking water are the industry's most reliable. Advanced membrane technology and automated fabrication allow these elements to deliver consistent performance that equipment suppliers, water treatment dealers, and residential customers can rely on. FILMTEC elements are shipped dry for convenient handling and long shelf-life. These elements are NSF/ANSI Standard 58 listed.

FILMTEC home drinking water elements are rated at 50 psi and will purify about 20% more water than competitive elements rated at 60 psi.

Available Membranes:

- TW30-1812-24 -- 24 GPD @ 50 PSI
- TW30-1812-36 -- 36 GPD @ 50 PSI
- TW30-1812-50 -- 50 GPD @ 50 PSI
- TW30-1812-75 -- 75 GPD @ 50 PSI
- TW30-1812-100 -- 100 GPD @ 50 PSI

Specifications:

- Dimensions: 1.8" Diameter x 12" Length
- Weight: 15 oz
- Fits most conventional units
- Membrane Life: 2-5 years
- Operating Pressure: 40 psi to 145 psi
- Operating Temperature: 40-100 F

FILMTEC TFC membrane specifications "100 gpd" TFC

http://www.dow.com/liquidseps/prod/prd_film.htm

www.filmtec.com got the above

Summary:

I recommend using FILMTEC reverse osmosis membrane element TW30-1812-75 – rated at 75 GPD & 50 PSI (77 degree F). They make a 100 GPD but the salt rejection is only 90% where as the 75 GPD is 98%. The operating pressure range is 40 psi to 145 psi with a maximum of 300 psi. The operating temperate

is 40 to 100 degree F with a maximum of 113 degree F. Dimensions fit a standard home housing: 1.8” Diameter by 12” long. Weight 15 oz. Membrane life: 2-5 years. Will work up to 2000 ppm. A 10 degree temperature increase or decrease will increase or decrease the flow rate by 15 gpd. The flow rate of Individual elements may vary by as much as 20%. The flow rate at 60 psi is about 93 GPD, 70 psi – 110 GPD, 80 psi – 128 GPD, and 90 psi – 145 GPD.

http://www.dow.com/liquidseps/prod/prd_film.htm

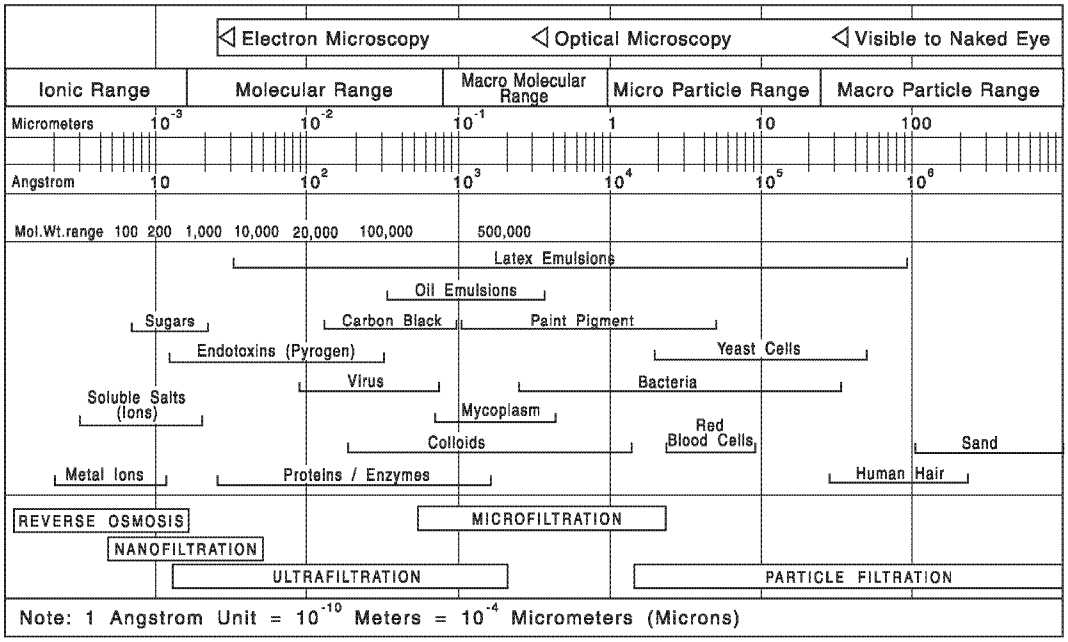

RESIDENTIAL R.O. INSTALLATION TIPS!

1) Always use extra length tubing to make your connections, you may want to move the unit to replace the filters in the future.

2) Read the push -in fitting material, make sure you push the tube completely in. Page 2

3) If a fitting is not push-in, then use moderate pressure to snug up the fittings. Modern fittings do not rely on brute strength. They rely on Teflon tape, o-rings or gaskets to make the seal (just snug the fitting to make it secure) Do not over tighten, plastic fittings that have been screwed on to tightly are subject to splitting. Stressed fittings may take days or even months to split and leak .

4) Please, Please, Please read the installation guide before installing the unit. This guide will answer a lot of your basic R.O. questions.

5) Ok ! You installed it without reading the guide. Please read the guide before calling or e-mailing us with any questions or problems.

6) Remember a 50GPD system makes a maximum 2 Gallons per hour, a slow trickle. Yes more water goes to drain than is made. All RO systems send water to drain while operating.

Thanks,

Walter The H2O Guru

Air, Water & Ice, Inc.

By the way this is the automatic shut off valve ASOV

How to Push in Fittings

Cut tube square

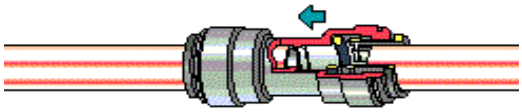

Cut the tube square. It is essential that the outside diameter be free of score marks and that burrs and sharp edges be removed before inserting into fitting.

Insert tube

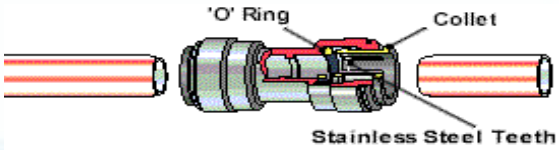

Fittings grips before it seals. Make sure tube is pushed in the tube stop

Push up to tube stop

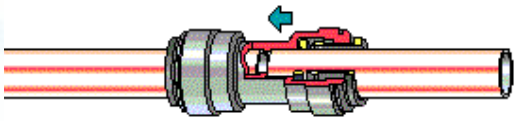

Push the tube into the fitting, to the tube stop. The collet (gripper) has stainless steel teeth which hold the tube firmly in position while the 'O' ring provides a permanent leak proof seal.

Pull to check secure

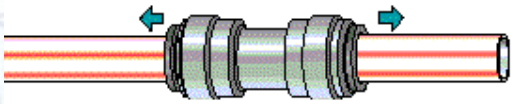

Pull on the tube to check it is secure. It is a good practice to test the system prior to considering your handy work is done. The system doesn't full pressurize until the tank is full.

Disconnecting

Push in Collet and remove tube

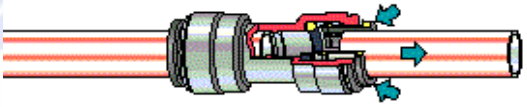

To disconnect, ensure the system is depressurized before removing fitting. Push in collet squarely against face of fitting. With the Collet held in this position, the tube can be removed. The fitting can then be re-used.

If you tube will not stay in check to see if you have removed the little white collet.

The fitting could have a blue tube in it which is a dust or dirt cap that needs to be removed. Before you can remove or insert a tube you will need to remove small blue retaining clip

INSTALLATION GUIDE FOR THE INSTALLATION OF RESIDENTIAL REVERSE OSMOSIS SYSTEMS

Please read this guide it is also a basic lesson in Reverse Osmosis systems

This is a generic guide. Our intent is to instruct you about the installation of the common components of these systems.

Prior to cutting the tubing to length, make sure it is long enough to allow you to move the unit for filter changing.

You need only simple tools and patience to complete a leak free reliable installation of your system.

Please exercise caution! You are in charge here.

1) Turn off electrical power near the work area. Check to make certain that you will not encounter any electrical wires or outlets. If you are unsure turn the power off to the work area.

2) Just look around before you drill a hole or pull on something. Will you have enough light to see what you are doing? Our equipment is marketed throughout the world, it may or may not meet local code requirements.

3) As is always the case, you should comply with local codes. Be prepared for spills with some rags and a small bucket. Turn off the water supply where you are working until you have finished the installation. Then turn it on slowly and leave it partially closed, until you verify that you have no leaks.

Air, Water & Ice, Inc.

I like to start the installation of a drinking water system with the Goose neck faucet.

4) The place to start is where the faucet will be. You need to consider looks, function, and space requirements. The area should be flat for at least an inch around the faucet. The location must allow for adequate space underneath the sink for the faucet as well as room for you to make and tighten the connection.

You will need to drill a hole in the sink.

5) I prefer to use a punch to make a dent for starting the drill.

5a) If you do not have a punch use a 1/8 to 1/4 inch drill bit and slowly with light to moderate pressure to start a small hole. Do not push too hard or the drill bit will skid and possibly scratch the sink.

6)The hole size varies with the style of a faucet (7/16 - 9/16) of an inch being the range. I like to use a battery powered drill, see #1. They are safer and they turn more slowly than power drills. (If you do use a power drill make sure it is properly grounded and in good condition.) Slow speed steady light pressure will give you the best results. (If you want to buy a great tool get a step bit). They drill various size holes with the same bit. Don't rush it or push too hard on the drill.

7) Now that you have drilled the hole mount the faucet.

8) Now attach enough tubing to the faucet bottom to reach the rest of the equipment. Cut the tube, leave enough for moving the system for filter changes.

9) The faucet will connect to the system at the final filter. That filter will have an arrow on it. 9a) That arrow will point to the connection for the faucet. The other side of the filter is connected to the tank pressure tank. I will cover that later, when we discuss the pressure tank.

10) Next I install the supply valve. ***(Please Note: The supply valve is not designed to work on braided hose.If you home has braided hose you will need an adaptor. This part is available from us or at your local hardware store.The adaptor is a watts brass fitting #BPAV-664)*** It has

a couple of parts the valve assembly which includes small rubber washer on the under side of the valve, a small aluminum block with two concave sides and a brass screw. (See photo left) The valve mounts on a cold water supply tube. (See photo right) **Never install this valve in front of the stop valve under your sink. This valve is to be installed on the supply tube between the stop valve and the sink faucet . The stop valve is the valve that allows you to turn off the water.**

If you are not sure which supply tube is cold, go up to the faucet and turn on the hot water for a couple of minutes, turn off the hot water, go back under the sink and feel the supply tubes. The hot water supply tube will be warmer than the cold

water supply tube. The cold water supply tube can be either 3/8 or ½ inch. If you are not sure about your pipe than just lay the aluminum piece next to the pipe and use the concave side that fits the profile best. Pick a spot on the supply tube that is a couple of inches away from any other valve and mount the valve. Be careful not to interfere with the travel of the spray wand hose, if your sink is equipped with one. Just mount the valve securely not too tight. You just snug up the brass screw against the aluminum block that is fitted against the tube. The valve should not wiggle or turn when properly secured. (very snug do not over tighten). We will return to this valve later.

11) The drain saddle. This drain water is the life blood of the system. If the system cannot drain correctly, it will not function for long. The system is self flushing and the drain should never be blocked or restricted. This is really simple. The drain saddle is two plastic parts that clamp over the waste water plumbing of your home. There is small rubber foam washer that needs to be attached to the inside of the connection on one piece of the drain saddle. Now clamp the drain saddle in place 3-5" above the top of the bend in the P Trap. (see photo left) Again, just snug the drain saddle in place. Do not over tighten. Now drill a 1/8 to 1/4 inch hole thru the fitting hole thru one side of the waste pipe. (see photo right) Do not drill into the back side of the waste pipe. Simple wasn't it? Connect enough tubing to the drain saddle to reach the unit 's drain connection.

Almost done! Really the hard part is over.

12) Mount the system to the cabinet with care. Do not drill or screw into something on the back side of the cabinet. Most cabinets today are made of particle board so do not hang the system. Just place it on the cabinet floor and secure it. Particle board is famous for coming apart and dropping the system.

13) Locate the pressure tank connection, the pressure tank and the tank ball valve. The tank has only one plumbing connection, it is a threaded fitting at the top or side of the tank.
That connection need's Teflon tape applied to the threads, prior to attaching the tank ball valve.
How can this tank work with only one connection for the inlet and the outlet? Think

about a balloon you blow it up and if you release it the air rushes back out the same opening.

14) Once you have mounted the tank ball valve, connect tubing to it and connect the other end to the open end of the final filter. This is the small filter laying down along side the membrane housing.
This is also the filter that is connected to the faucet. (see 9a)

15) Now locate the waste line of the R.O. unit. The waste line has a flow restriction device on it. The flow restriction device looks like this.

It also has an arrow on it. Please check that the arrow is pointing toward the drain saddle, water flowing to drain away from the machine. **Never impede, restrict or stop the waste water flow.** Your system automatically controls the waste water.

16) Now locate the supply connection. It is usually an elbow shaped fitting that is located on one end of the unit. It is screwed into the first vertical filter unit. The first filter is always the sediment filter. The water flows thru this filter first then on to the rest of the system. Got it? Good connect some tubing to this fitting then to the supply valve.

Now we need to return to the supply valve. (see # 10) It is a self piercing valve. It has a needle in it that will poke a hole in the supply tube. Screwing the valve tee handle to the right will drive the needle into the tube. Slow steady pressure will work better than rushing it. Do not force it. Once you have bottomed out the needle turning the tee handle to the left will start the flow of water. At first you want to open the valve just a little bit, and check for leaks. Ok let the water run for a few minutes and open the valve fully. (It will not fall out unless you really over do it and manage to unscrew the cap nut as well.)

Your installation is complete But you are not done yet!

17) You need to check on the system after about 4-5 minutes.

18) Check it agin in another fifteen minutes and again over the next couple of hours. Why the system is filling and it may take three to six hours fo the last part of the system to fill.

19) You will not be aware of any leak in that part of the system until it fills.

20) once the system has filled open the faucet and leave it open until the water slows to a trickle or small stream.

21) Now close the faucet and your system will be ready for use when it refills. Fill time is dependant on water pressure, temperature and membrane size.

It is your house. Use care and diligence in checking for leaks.

Remember to push the tubing completely into the fitting see push-in fittings page.

Your membranes output was determined using 77 degree water at 50 pounds of pressure per square inch. If you have 50 degree water you can expect 60% of the rating. If you water pressure is lower than 50psi your production will be lower.

Your system and it's care:
Once installed your system should not produce any vibration or noise. In some instances if you listen for it you may hear water running to drain. It also appears not to be making any water, water is running to drain but none is being made. This is normal the system needs to displace a lot of air and the membrane needs to be rinsed of the preservation chemical it was stored in. Please be patient. At least ten to twenty minutes before you will get some water at the R.O. faucet.
Remember to test or verify the operation of your unit. Also, empty the contents of the storage tank every couple of weeks. Just flip the faucet handle up or open it until the water becomes a small stream.

Remember the blue plastic dust caps are to be removed according to the instructions on the push in fitting page: " Push in Collet and remove tube"

Typical questions:

How do I know when to change the filters?
The sediment filter traps dirt and will become clogged. When it becomes clogged, the system production will slow down. This is how you determine when to change it. You may go all year.

The Carbon block filters have a very high capacity for chemical removal. The average family of four on average city water can go all year . Please change your filters at least annually. Failure to maintain the filters will result in poor quality water or in the failure of the membrane.

The Membranes typically provides (1-4) years of service. It is a thin film composite membrane and is not subject to bacterial attack. It can be damaged by exposure to chlorine. Once damaged it has to be replaced. Many water chemistry matters go into membrane life and we cannot predict how your membrane will preform or how long it will last.

The final filter sees extremely good quality water and lots of our customers go (2) years between changes. I prefer you change it annually.

The system will on occasion trap air in it when first installed. This trapped air will be absorbed by the water in a couple of days.

Sometimes trapped air prevents the automatic shut off valve from working correctly. This trapped air will cause water to go to drain nonstop. Do not worry it's not that much water and it will stop in either hours or at most three days.

System production may be slow during the first (96) hours. But by that time it should be as good as it will get. Please wait (96) hours prior to calling with production questions.

Your system may run water to drain for the first several hours after the unit is installed. Once you purge the system it will run agin for a long time. Once the system is full, the drain water will stop running. When you use water again, the drain water will run agin but only long enough to replenish the water used.

Thanks for reading our guide.

How to use Push In Fittings

Cut tube square

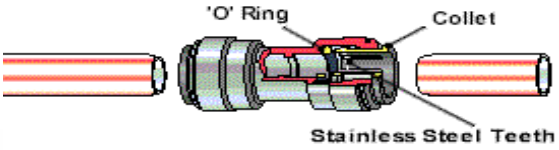

Cut the tube square. It is essential that the outside diameter be free of score marks and that burrs and sharp edges be removed before inserting into fitting.

Insert tube

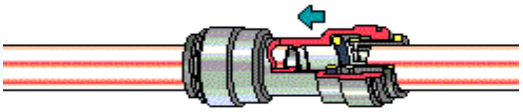

Fittings grips before it seals. Make sur tube is pushed in the tube stop

Push up to tube stop

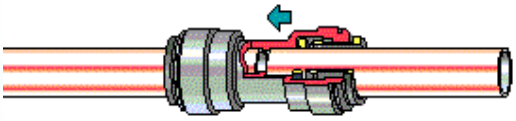

Push the tube into the fitting, to the tube stop. The collet (gripper) has stainless steel teeth which hold the tube firmly in position while the 'O' ring provides a permanent leak proof seal.

Pull to check secure

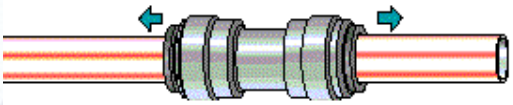

Pull on the tube to check it is secure. It is a good practice to test the system prior to considering your handy work is done. The system doesn't full pressurize until the tank is full.

Air, Water & Ice, Inc.

Disconnecting

Push in Collet and remove tube

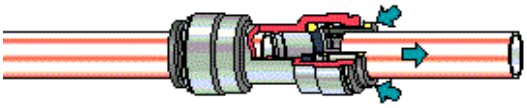

To disconnect, ensure the system is depressurized before removing fitting. Push in collet squarely against face of fitting. With the Collet held in this position, the tube can be removed. The fitting can then be re-used.

Road surface

From Wikipedia, the free encyclopedia

Road surface or **pavement** is the durable surface material laid down on an area intended to sustain vehicular or foot traffic, such as a road or walkway. In the past, gravel road surfaces, cobblestone and granite setts were extensively used, but these surfaces have mostly been replaced by asphalt or concrete laid on a compacted base course. Road surfaces are frequently marked to guide traffic. Today, permeable paving methods are beginning to be used for low-impact roadways and walkways.

A road being resurfaced

Contents

- 1 Asphalt
- 2 Concrete
- 3 Composite pavement
- 4 Recycling
  - 4.1 In-place recycling
- 5 Bituminous surface
  - 5.1 Thin membrane surface
  - 5.2 Otta seal
- 6 Gravel surface
- 7 Other surfaces
  - 7.1 Gallery
- 8 Acoustical implications
- 9 Surface deterioration
- 10 Markings
- 11 See also
- 12 Notes
- 13 External links

Asphalt

Asphalt (specifically, asphalt concrete), sometimes called flexible pavement due to the nature in which it distributes loads, has been widely used since the 1920s. The viscous nature of the bitumen binder allows asphalt concrete to sustain significant plastic deformation, although fatigue from repeated loading over time is the most common failure mechanism. Most asphalt surfaces are laid on a gravel base, which is generally at least as thick as the asphalt layer, although some 'full depth' asphalt surfaces are laid directly on the native subgrade. In areas with very soft or expansive subgrades such as clay or peat, thick gravel bases or stabilization of the subgrade with Portland cement or lime may be required. Polypropylene and polyester geosynthetics have

Closeup of asphalt on a driveway

also been used for this purpose[1] and in some northern countries, a layer of polystyrene boards have been used to delay and minimize frost penetration into the subgrade.[2]

Depending on the temperature at which it is applied, asphalt is categorized as hot mix, warm mix, or cold mix. Hot mix asphalt is applied at temperatures over 300 °F (150 °C) with a free floating screed. Warm mix asphalt is applied at temperatures of 200–250 °F (95–120 °C), resulting in reduced energy usage and emissions of volatile organic compounds.[3] Cold mix asphalt is often used on lower volume rural roads, where hot mix asphalt would cool too much on the long trip from the asphalt plant to the construction site.[4]

An asphalt concrete surface will generally be constructed for high-volume primary highways having an average annual daily traffic load greater than 1200 vehicles per day.[5] Advantages of asphalt roadways include relatively low noise, relatively low cost compared with other paving methods, and perceived ease of repair. Disadvantages include less durability than other paving methods, less tensile strength than concrete, the tendency to become slick and soft in hot weather and a certain amount of hydrocarbon pollution to soil and groundwater or waterways.

In the mid-1960s, rubberized asphalt was used for the first time, mixing crumb rubber from used tires with asphalt.[6] While a potential use for tires that would otherwise fill landfills and present a fire hazard, rubberized asphalt has shown greater incidence of wear in freeze-thaw cycles in temperate zones due to non-homogeneous expansion and contraction with non-rubber components. Also, application of rubberized asphalt is more temperature-sensitive, and in many locations can only be applied at certain times of the year.

Study results of the long-term acoustic benefits of rubberized asphalt are inconclusive. Initial application of rubberized asphalt may provide 3–5 decibels (dB) reduction in tire-pavement source noise emissions; however, this translates to only 1–3 decibels (dB) in total traffic noise level reduction (due to the other components of traffic noise). Compared to traditional passive attenuating measures (e.g., noise walls and earth berms), rubberized asphalt provides shorter-lasting and lesser acoustic benefits at typically much greater expense.

Concrete

Concrete surfaces (specifically, Portland cement concrete) are created using a concrete mix of Portland cement, coarse aggregate, sand and water. In virtually all modern mixes there will also be various admixtures added to increase workability, reduce the required amount of water, mitigate harmful chemical reactions and for other beneficial purposes. In many cases there will also be Portland cement substitutes added, such as fly ash. This can reduce the cost of the concrete and improve its physical properties. The material is applied in a freshly mixed slurry, and worked mechanically to compact the interior and force some of the cement slurry to the surface to produce a smoother, denser surface free from honeycombing. The water allows the mix to combine molecularly in a chemical reaction called hydration.

Concrete roadway in San Jose, California

Concrete surfaces have been refined into three common types: jointed plain (JPCP), jointed reinforced (JRCP) and continuously reinforced (CRCP). The one item that distinguishes each type is the jointing system used to control crack development.

- Jointed plain concrete pavements contain enough joints to control the location of all the expected shrinkage cracks. The concrete cracks at the joints and not elsewhere in the slabs. Jointed plain

pavements do not contain any steel reinforcement. However, there may be smooth steel bars at transverse joints and deformed steel bars at longitudinal joints. The spacing between transverse joints is typically about 15 feet (4.6 m) for slabs 7 to 12 inches (180 to 300 mm) thick. Today, a majority of US state agencies build jointed plain pavements.
- Jointed reinforced concrete pavements contain steel mesh reinforcement (sometimes called distributed steel). In jointed reinforced concrete pavements, designers increase the joint spacing purposely, and include reinforcing steel to hold together intermediate cracks in each slab. The spacing between transverse joints is typically 30 feet (9.1 m) or more. In the past, some agencies used a spacing as great as 100 feet (30 m). During construction of the interstate system, most agencies in the Eastern and Midwestern United States laid jointed-reinforced pavement. Today only a handful of agencies employ this design, and its use is generally not recommended as both of the other types offer better performance and are easier to repair.
- Continuously reinforced concrete pavements do not require any transverse contraction joints. Transverse cracks are expected in the slab, usually at intervals of 3 to 5 ft (0.91 to 1.52 m). These pavements are designed with enough steel, 0.6–0.7% by cross-sectional area, so that cracks are held together tightly. Determining an appropriate spacing between the cracks is part of the design process for this type of pavement.

A concrete road in Ewing, New Jersey. The original pavement was laid in the 1950s and has not been significantly altered since.

Continuously reinforced designs may cost slightly more than jointed reinforced or jointed plain designs due to increased quantities of steel. Often the cost of the steel is offset by the reduced cost of concrete because a continuously reinforced design is nearly always significantly thinner than a jointed design for the same traffic loads. Properly designed, the two methods should demonstrate similar long-term performance and cost-effectiveness. A number of agencies have made policy decisions to use continuously reinforced designs in their heavy urban traffic corridors.

One of the major advantages of concrete pavements is they are typically stronger and more durable than asphalt roadways. They also can be grooved to provide a durable skid-resistant surface. A notable disadvantage is that they typically can have a higher initial cost, and can be more time-consuming to construct. This cost can typically be offset through the long life cycle of the pavement. Concrete pavement can be maintained over time utilizing a series of methods known as concrete pavement restoration which include diamond grinding, dowel bar retrofits, joint and crack sealing, cross-stitching, etc. Diamond grinding is also useful in reducing noise and restoring skid resistance in older concrete pavement.[7][8]

The first street in the United States to be paved with concrete was Court Avenue in Bellefontaine, Ohio in 1893.[9][10] The first mile of concrete pavement in the United States was on Woodward Avenue in Detroit, Michigan in 1909.[11]

Composite pavement

Composite pavements combine a Portland cement concrete sublayer with an asphalt. They are usually used to rehabilitate existing roadways rather than in new construction.

Asphalt overlays are sometimes laid over distressed concrete to restore a smooth wearing surface.[12] A

disadvantage of this method is that movement in the joints between the underlying concrete slabs, whether from thermal expansion and contraction, or from deflection of the concrete slabs from truck axle loads, usually causes *reflective cracks* in the asphalt. To decrease reflective cracking, concrete pavement is broken apart through a *break and seat, crack and seat*, or *rubblization* process. Geosynthetics can be used for reflective crack control.[13] With break and seat and crack and seat processes, a heavy weight is dropped on the concrete to induce cracking, then a heavy roller is used to seat the resultant pieces into the subbase. The main difference between the two processes is the equipment used to break the concrete pavement and the size of the resulting pieces. The theory is frequent small cracks will spread thermal stress over a wider area than infrequent large joints, reducing the stress on the overlying asphalt pavement. Rubblization is a more complete fracturing of the old, worn-out concrete, effectively converting the old pavement into an aggregate base for a new asphalt road.[14]

An example of composite pavement: hot-mix asphalt overlaid onto Portland cement concrete pavement

Whitetopping uses Portland cement concrete to resurface a distressed asphalt road.

Recycling

Distressed road materials can be reused when rehabilitating a roadway. The existing pavement is ground or broken up into small pieces, through a process called milling. It can then be transported to an asphalt or concrete plant and incorporated into new pavement, or recycled in place to form the base or subbase for new pavement. Some methods used include:

An asphalt milling machine in Boise, Idaho.

In-place recycling

- Rubblizing of concrete pavement. Existing concrete pavement is broken into gravel-sized particles. Any steel reinforcing is removed, then the remaining gravel-sized particles are compacted and overlaid with asphalt pavement.[15]
- Cold in-place recycling. Bituminous pavement is ground or milled into small particles. The asphalt millings are blended with a small amount of asphalt emulsion or foamed bitumen, paved and compacted, allowed to cure for seven to ten days, then overlaid with asphalt.[16]
- Hot in-place recycling. Bituminous pavement is heated to 250 to 300 °F (120 to 150 °C), milled, combined with a rejuvenating agent or virgin asphalt binder, and compacted. It may then be overlaid with a new asphalt overlay. This process only recycles the top two inches (50 mm) or less, so it can be used to correct rutting, polishing or other surface defects. It is not a good procedure for roads with structural failures. It also generates high heat and vapor emissions, and may not be a good candidate for built-up areas.[16]
- Full depth reclamation is a process which pulverizes the full thickness of the asphalt pavement and some of the underlying material to provide a uniform blend of material. A binding agent may be mixed in to form a base course for the new pavement, or it may be left unbound to form a subbase course. Common binding agents include asphalt emulsion, fly ash, Portland cement or calcium chloride. It can also be mixed with aggregate, recycled asphalt millings, or crushed Portland cement to improve the gradation of the material, and can provide a design life cycle of 30 years with proper lab testing and field verification.

[16][17]

Bituminous surface

Bituminous surface treatment (BST) or **chipseal** is used mainly on low-traffic roads, but also as a sealing coat to rejuvenate an asphalt concrete pavement. It generally consists of aggregate spread over a sprayed-on asphalt emulsion or cut-back asphalt cement. The aggregate is then embedded into the asphalt by rolling it, typically with a rubber-tired roller. This type of surface is described by a wide variety of regional terms including "chip seal", "tar and chip", "oil and stone", "seal coat", "sprayed seal"[18] or "surface dressing"[19] or as simply "bitumin."

BST is used on hundreds of miles of the Alaska Highway and other similar roadways in Alaska, the Yukon Territory, and northern British Columbia. The ease of application of BST is one reason for its popularity, but another is its flexibility, which is important when roadways are laid down over unstable terrain that thaws and softens in the spring.

Other types of BSTs include micropaving, slurry seals and Novachip. These are laid down using specialized and proprietary equipment. They are most often used in urban areas where the roughness and loose stone associated with chip seals is considered undesirable.

Thin membrane surface

A thin membrane surface (TMS) is an oil treated aggregate which is laid down upon a gravel road bed producing a dust free road.[20] A TMS road reduces mud problems and provides stone free roads for local residents where loaded truck traffic is negligible. The TMS layer adds no significant structural strength, and so is used on secondary highways with low traffic volume and minimal weight loading. Construction involves minimal subgrade preparation, following by covering with a 50 to 100 millimetres (2.0–3.9 in) cold mix asphalt aggregate.[5] The Operation Division of the Ministry of Highways and Infrastructure in Saskatchewan has the responsibility of maintaining 6,102 kilometres (3,792 mi) of thin membrane surface (TMS) highways.[21]

Otta seal

Otta seal is a low-cost road surface using a 16–30-millimetre (0.63–1.18 in) thick mixture of bitumen and crushed rock.[22]

Gravel surface

Gravel is known to have been used extensively in the construction of roads by soldiers of the Roman Empire (see Roman road) but a limestone-surfaced road, thought to date back to the Bronze Age, has been found in Britain.[23] Applying gravel, or "**metalling**," has had two distinct usages in road surfacing. The term ***road metal*** refers to the broken stone or cinders used in the construction or repair of roads or railways,[24] and is derived from the Latin *metallum*, which means both "mine" and "quarry".[25] The term originally referred to the process of creating a gravel roadway. The route of the roadway would first be dug down several feet and, depending on local conditions, French drains may or may not have been added. Next, large stones were placed and compacted, followed by successive layers of smaller stones, until the road surface was composed of small stones compacted into a hard, durable surface. "Road metal" later became the name of stone chippings mixed

with tar to form the road surfacing material tarmac. A road of such material is called a "**metalled road**" in Britain, a "paved road" in Canada and the US, or a "sealed road" in parts of Canada, Australia and New Zealand.[26]

A granular surface can be used with a traffic volume where the annual average daily traffic is 1,200 vehicles per day or less. There is some structural strength as the road surface combines a sub base and base and is topped with a double graded seal aggregate with emulsion.[5][27] Besides the 4,929 kilometres (3,063 mi) of granular pavements maintained in Saskatchewan, around 40% of New Zealand roads are unbound granular pavement structures.[21][28]

The decision whether to pave a gravel road or not often hinges on traffic volume. It has been found that maintenance costs for gravel roads often exceed the maintenance costs for paved or surface treated roads when traffic volumes exceed 200 vehicles per day.[29]

Some communities are finding it makes sense to convert their low volume paved roads to aggregate surfaces.[30]

Other surfaces

Pavers (or **paviours**), generally in the form of pre-cast concrete blocks, are often used for aesthetic purposes, or sometimes at port facilities that see long-duration pavement loading. Pavers are rarely used in areas that see high-speed vehicle traffic.

Brick, cobblestone, sett, wood plank, and wood block pavements such as Nicolson pavement, were once common in urban areas throughout the world, but fell out of fashion in most countries, due to the high cost of labor required to lay and maintain them, and are typically only kept for historical or aesthetic reasons. In some countries, however, they are still common in local streets. In the Netherlands, brick paving has made somewhat of a comeback since the adoption of a major nationwide traffic safety program in 1997. From 1998 through 2007, more than 41,000 km of city streets were converted to local access roads with a speed limit of 30 km/h, for the purpose of traffic calming.[31] One popular measure is to use brick paving - the noise and vibration slows motorists down. At the same time, it is not uncommon for cycle paths alongside a road to have a smoother surface than the road itself.[32][33]

Likewise, macadam and tarmac pavements can still sometimes be found buried underneath asphalt concrete or Portland cement concrete pavements, but are rarely constructed today.

There are also other methods and materials to create pavements that have appearance of brick pavements. The first method to create brick texture is to heat an asphalt pavement and use metal wires to imprint a brick pattern using a compactor to create stamped asphalt. A similar method is to use rubber imprinting tools to press over a thin layer of cement to create decorative concrete. Another method is to use a brick pattern stencil and apply a surfacing material over the stencil. Materials that can be applied to give the color of the brick and skid resistance can be in many forms. An example is to use colored polymer-modified concrete slurry which can be applied by screeding or spraying.[34] Another material is aggregate-reinforced thermoplastic which can be heat applied to the top layer of the brick-pattern surface.[35] Other coating materials over stamped asphalt are paints and two-part epoxy coating.[36]

Gallery

Concrete pavers

Replacing the old road with concrete blocks in Bo'ao Road area, Haikou City, Hainan, China

Polymer cement overlaying to change asphalt pavement to brick texture and color to create decorative crosswalk

Acoustical implications

Roadway surfacing choices are known to affect the intensity and spectrum of sound emanating from the tire/surface interaction.[37] Initial applications of this knowledge occurred in the early 1970s. Roadway surface types contribute differential noise effects of up to four dB, with chip seal type and grooved roads being the loudest and concrete surfaces without spacers being the quietest. Asphaltic surfaces perform intermediately relative to concrete and chip seal. These phenomena are, of course, highly influenced by vehicle speed. Rubberized asphalt has been shown to give a marginal 3–5 dB reduction in tire-pavement noise emissions, and a marginally discernible 1–3 decibel reduction in total road noise emissions when compared to conventional asphalt applications.

Cobbles

Rectangles

Decorative wavy pattern on La Rambla.

Decorative mock-brick pattern.

More decorative brickwork patterns.

Surface deterioration

Deteriorating asphalt

As pavement systems primarily fail due to fatigue (in a manner similar to metals), the damage done to pavement increases with the fourth power of the axle load of the vehicles traveling on it. According to the AASHO Road Test, heavily loaded trucks can do more than 10,000 times the damage done by a normal passenger car. Tax rates for trucks are higher than those for cars in most countries for this reason, though they are not levied in proportion to the damage done.[38] Passenger cars are considered to have no practical effect on a pavement's service life, from a fatigue perspective.

Other failure modes include aging and surface abrasion. As years go by, the binder in a bituminous wearing course gets stiffer and less flexible. When it gets "old" enough, the surface will start losing aggregates, and macrotexture depth increases dramatically. If no maintenance action is done quickly on the wearing course, potholes will form. If the road is still structurally sound, a bituminous surface treatment, such as a chipseal or surface dressing can prolong the life of the road at low cost. In areas with cold climate, studded tires may be allowed on passenger cars. In Sweden and Finland, studded passenger car tires account for a very large share of pavement rutting.

Several design methods have been developed to determine the thickness and composition of road surfaces required to carry predicted traffic loads for a given period of time. Pavement design methods are continuously

evolving. Among these are the Shell Pavement design method, and the American Association of State Highway and Transportation Officials (AASHTO) 1993 "Guide for Design of Pavement Structures". A new mechanistic-empirical design guide has been under development by NCHRP (Called Superpave Technology) since 1998. A new design guide called Mechanistic Empirical Pavement Design Guide (MEPDG) was developed and is about to be adopted by AASHTO.

The physical properties of a stretch of pavement can be tested using a falling weight deflectometer.

Further research by University College London into pavements has led to the development of an indoor, 80-sq-metre artificial pavement at a research centre called Pedestrian Accessibility and Movement Environment Laboratory (PAMELA). It is used to simulate everyday scenarios, from different pavement users to varying pavement conditions.[39] There also exists a research facility near Auburn University, the NCAT Pavement Test Track, that is used to test experimental asphalt pavements for durability.

In addition to repair costs, the condition of a road surface has economic effects for road users. Rolling resistance increases on rough pavement, as does wear and tear of vehicle components. It has been estimated that poor road surfaces cost the average US driver $324 per year in vehicle repairs, or a total of $67 billion. Also, it has been estimated that small improvements in road surface conditions can decrease fuel consumption between 1.8 and 4.7%.[40]

Markings

Road surface markings are used on paved roadways to provide guidance and information to drivers and pedestrians. It can be in the form of mechanical markers such as cat's eyes, botts' dots and rumble strips, or non-mechanical markers such as paints, thermoplastic, plastic and epoxy.

See also

- Asphalt
- Bleeding (roads)
- Diamond grinding of pavement
- Ecogrid
- Good Roads Movement
- List of road types by features
- Pavement management
- Plastic armour
- Road construction
- Road slipperiness
- Sealcoat

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External links

- PaveShare - Concrete Paver Education (http://www.paveshare.org)
- "Pavements" website of the US Department of Transportation's Federal Highway Administration (http://www.fhwa.dot.gov/pavement/index.cfm)

Wikimedia Commons has media related to ***Pavements***.

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Categories: Pavements | Road infrastructure | Road hazards

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Road

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A **road** is a thoroughfare, route, or way on land between two places that has been paved or otherwise improved to allow travel by foot or some form of conveyance, including a motor vehicle, cart, bicycle, or horse.

Roads consist of one or two roadways (British English: carriageways), each with one or more lanes and any associated sidewalks (British English: pavement) and road verges.

Roads that are available for use by the public may be referred to as parkways, avenues, freeways, interstates, highways, or primary, secondary, and tertiary local roads.

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Definitions

The Organisation for Economic Co-operation and Development (OECD) defines a road as "a line of communication (travelled way) using a stabilized base other than rails or air strips open to public traffic, primarily for the use of road motor vehicles running on their own wheels, "which includes" bridges, tunnels, supporting structures, junctions, crossings, interchanges, and toll roads, but not cycle paths."[1]

In urban areas roads may diverge through a city or village and be named as streets, serving a dual function as

urban space easement and route.[2] Modern roads are normally smoothed, paved, or otherwise prepared to allow easy travel.[3] Historically many roads were simply recognizable routes without any formal construction or maintenance.[4]

United Kingdom

In the United Kingdom there is some ambiguity between the terms highway and road. The Highway code details rules for "road users".[5] For the purposes of the English law, Highways Act 1980, which covers England and Wales but not Scotland or Northern Ireland, the term *road* is defined to be "any length of highway or of any other road to which the public has access, and includes bridges over which a road passes."[6] This includes footpaths, bridleways and cycle tracks, and also road and driveways on private land and many car parks.[7] Vehicle Excise Duty, a road use tax, is payable on some vehicles used on the public road.[7]

The definition of a road depends on the definition of a highway; there is no formal definition for a highway in the relevant Act. A 1984 ruling said "the land over which a public right of way exists is known as a highway; and although most highways have been made up into roads, and most easements of way exist over footpaths, the presence or absence of a made road has nothing to do with the distinction.[8][9] Another legal view is that while a highway historically included footpaths, bridleways, driftways, etc., it can now be used to mean those ways that allow the movement of motor-vehicles, and the term *rights of way* can be used to cover the wider usage.[10]

United States

In the United States, laws distinguish between *public roads*, which are open to public use, and *private roads*, which are privately controlled.[11]

History

The assertion that the first pathways were the trails made by animals has not been universally accepted; in many cases animals do not follow constant paths.[4] Others believe that some roads originated from following animal trails.[13][14] The Icknield Way is given as an example of this type of road origination, where man and animal both selected the same natural line.[15] By about 10,000 BC, rough roads/pathways were used by human travelers.[4]

Transfăgărășan, named "the best road in the world"[12]

- The world's oldest known paved road was constructed in Egypt some time between 2600 and 2200 BC.[16]
- Stone-paved streets are found in the city of Ur in the Middle East dating back to 4000 BC.[4]
- Corduroy roads (log roads) are found dating to 4000 BC in Glastonbury, England.[4]
- The Sweet Track, a timber track causeway in England, is one of the oldest engineered roads discovered and the oldest timber trackway discovered in Northern Europe. Built in winter 3807 BC or spring 3806 BC, tree-ring dating (Dendrochronology) enabled very precise dating. It was claimed to be the oldest road in the world[17][18] until the 2009 discovery of a 6,000-year-old trackway in Plumstead, London.[19][20]

- Brick-paved streets were used in India as early as 3000 BC .[4]
- In 500 BC, Darius I the Great started an extensive road system for Persia (Iran), including the Royal Road, which was one of the finest highways of its time.[21] The road remained in use after Roman times.
- In ancient times, transport by river was far easier and faster than transport by road,[18] especially considering the cost of road construction and the difference in carrying capacity between carts and river barges. A hybrid of road transport and ship transport beginning in about 1740 is the horse-drawn boat in which the horse follows a cleared path along the river bank.[22][23]
- From about 312 BC, the Roman Empire built straight[24] strong stone Roman roads throughout Europe and North Africa, in support of its military campaigns. At its peak the Roman Empire was connected by 29 major roads moving out from Rome and covering 78,000 kilometers or 52,964 Roman miles of paved roads.[18]
- In the 8th century AD, many roads were built throughout the Arab Empire. The most sophisticated roads were those in Baghdad, which were paved with tar. Tar was derived from petroleum, accessed from oil fields in the region, through the chemical process of destructive distillation.[25]
- The Highways Act 1555 in Britain transferred responsibility for maintaining roads from government to local parishes.[18] This resulted in a poor and variable state of roads. To remedy this, the first of the "Turnpike trusts" was established around 1706, to build good roads and collect tolls from passing vehicles. Eventually there were approximately 1,100 trusts in Britain and some 36,800 km (22,870 miles) of engineered roads.[18] The Rebecca Riots in Carmarthenshire and Rhayader from 1839 to 1844 contributed to a Royal Commission that led to the demise of the system in 1844,[26] which coincided with the development of the UK railway system.

The Porta Rosa, a Greek street dating from the 3rd to 4th century BC in Velia, with a paved surface and gutters

A paved Roman road in Pompeii

Old tractor road over farmland, Ystad, Sweden

Design

The subject of road design is considered part of highway engineering. Structural road design is the science of designing a road for its environment in order to extend its longevity and reduce maintenance. The Shell pavement design method is used in many countries for the design of new asphalt roadsides.

Road terminology

Alignment

the route of the road, defined as a series of horizontal tangents and curves.

Adverse camber

where a road slopes towards the outside of a bend, increasing the likelihood that vehicles travelling at

speed will skid or topple. Usually only a temporary situation during road maintenance.

All-weather road

Unpaved road that is constructed of a material that does not create mud during rainfall.

Banked turn

Bicycle boulevard

A motorway open to all traffic but optimized for cycling

Cycling infrastructure

cycling-friendly infrastructure integrated into the roadway or in its own right of way

Camber (or crown)

the slope of the road surface downwards away from the centre of the road, so that surface water can flow freely to the edge of the carriageway, or on bends angling of the surface to lean traffic 'into the bend' reducing the chance of a skid.

Cant

superelevation

Cross slope

The slope of the pavement, expressed as units of rise per unit of run, or as a percentage.

Grade

longitudinal slope

Belisha Beacon

an orange globe, lit at night, used to highlight a pedestrian crossing.

Bollard

Rigid posts that can be arranged in a line to close a road or path to vehicles above a certain width

Byway

Highway over which the public have a right to travel for vehicular and other kinds of traffic, but is used mainly as a footpath or bridleway

Bypass

Road that avoids or "bypasses" a built-up area, town, or village

Bottleneck

Section of a road with a carrying capacity substantially below that of other sections of the same road

Botts' dots

Non-reflective raised pavement marker used on roads

Cat's eye

reflective raised pavement marker used on roads

A beach road (Newcastle NSW Australia)

Chicane

Sequence of tight serpentine curves (usually an S-shape curve or a bus stop)

Chipseal

Road surface composed of a thin layer of crushed stone 'chips' and asphalt emulsion. It seals the surface and protects it from weather, but provides no structural strength. It is cheaper than asphalt concrete or concrete. In the United States it is usually only used on low volume rural roads

Corniche

Road on the side of a cliff or mountain, with the ground rising on one side and falling away on the other

Curb (kerb)

A raised edge at the side of the roadway.

Curb extension

(also kerb extension, bulb-out, nib, elephant ear, curb bulge and blister) Traffic calming measure,

intended to slow the speed of traffic and increase driver awareness, particularly in built-up and residential neighborhoods.

Drainage gradient

Farm-to-market road

a state road or county road that connects rural or agricultural areas to market towns.

Fork

(literally "fork in the road") Type of intersection where a road splits

Green lane

(UK) Unsurfaced road, may be so infrequently used that vegetation colonises freely, hence 'green'. Many green lanes are ancient routes that have existed for millennia.

Guide rail

Prevents vehicles from veering off the road into oncoming traffic, crashing against solid objects or falling from a road. Also called a guard rail or traffic barrier.

Gutter

a drainage channel usually at the edge of the road or along a median.

Interstate Highway System (United States)

System of Interstate and Defense Highways

Layby (Pullout, pull-off)

A paved area beside a main road where cars can stop temporarily to let another car pass.

Loose chippings

the hazard of stone chippings that have come loose

Median

On dual carriageway roads, including controlled-access highways, divided highways and many limited-access roads, the central reservation (British English), median (North American English), median strip (North American English and Australian English), neutral ground [Louisiana English] or central nature strip (Australian English): Area that separates opposing lanes of traffic

Mountain pass

A relatively low level route through a range of mountains

Milestone

One of a series of numbered markers placed along a road, often at regular intervals, showing the distance to destinations.

National Highway

Road built and maintained by a national authority.

Pavement

The road regarded as a geoconstruction. In the UK the term is road surface and the pavement is a pedestrian walkway alongside the road.

Pedestrian crossing

Designated point on a road where road marking or other means helps pedestrians cross safely

Pelican crossing

(officially *Pelicon crossing*) (UK) a PEdestrian LIght CONtrolled crossing.

Private highway

Highway owned and operated for profit by private industry

Private road

Road owned and maintained by a private individual, organization, or company rather than by a government

Profile

the vertical alignment of a road, expressed as a series of grades, connected by parabolic curves.

Public space
Place where anyone has a right to come without being excluded because of economic or social conditions

Ranch road
U.S. road that connects rural and agricultural areas to market towns

Road number
Often assigned to identify a stretch of public roads— often dependent on the type of road, with numbers differentiating between interstates, motorways, arterial thoroughfares, etc.

Road-traffic safety
Process to reduce the harm (deaths, injuries, and property damage) that result from vehicle crashes on public roads

Roadworks
Part or all of the road is occupied for work or maintenance

Roughness
Deviations from a true planar pavement surface, which affects vehicle suspension deflection, dynamic loading, ride quality, surface drainage and winter operations. Roughness have wavelengths ranging from 500 mm up to some 40 m. The upper limit may be as high as 350 m when considering motion sickness aspects; motion sickness is generated by motion with down to 0.1 Hz frequency; in an ambulance car driving 35 m/s (126 km/h), waves with up to 350 m will excite motion sickness.

Roundabout
a road junction where typically three or more roads are joined by a circular section of road. Traffic 'on the roundabout' has priority over traffic on approach roads, unless indicated otherwise. In countries where traffic drives on the left the roundabout is travelled in a clockwise direction. Also known as an *island* in parts of the UK.

Shoulder (also hard shoulder)
A clear, level area to the side of the roadway available for stopping if needed.

State highway
Road numbered by the state, falling below numbered national highways (like U.S. Routes) in the hierarchy *or* a road maintained by the state, including nationally-numbered highways

Traffic
Pedestrians, ridden or herded animals, vehicles, bicycles, and other conveyances using any road for purposes of travel.[27]

Texture (roads)
Deviations from a true planar pavement surface, which affects the interaction between road and tire. Microtexture have wavelengths below 0.5 mm, Macrotexture below 50 mm and Megatexture below 500 mm.

Traffic calming
Set of strategies used by urban planners and traffic engineers to slow down or reduce motor vehicle traffic, thereby improving safety for pedestrians and bicyclists and improving the environment for residents

Traffic island
(UK) a small raised area used to help define the traffic flow, which may also act as a refuge for pedestrians crossing the carriageway or a location for signs, barriers or lights—a synonym for roundabout in some parts of the UK

Traffic light
Also known as a traffic signal, stop light, stop-and-go lights—a signaling device at a road intersection, pedestrian crossing, or other location that assigns right of way to different approaches to an intersection

Zebra crossing (UK)
a pedestrian crossing marked by black and white stripes on the carriageway

Construction

"roadbed" (from the 'related terms' Bed (geology) & streambed), as well as the term "Road building" redirects here.

Surveyor at work with a leveling instrument

Road construction requires the creation of an engineered continuous right-of-way or **roadbed**, overcoming geographic obstacles and having grades low enough to permit vehicle or foot travel.[28] (pg15) and may be required to meet standards set by law[29] or official guidelines.[30] The process is often begun with the removal of earth and rock by digging or blasting, construction of embankments, bridges and tunnels, and removal of vegetation (this may involve deforestation) and followed by the laying of pavement material. A variety of road building equipment is employed in road building.[31][32]

Asphalt layer and Hamm road roller

After design, approval, planning, legal and environmental considerations have been addressed alignment of the road is set out by a surveyor.[24] The radii and gradient are designed and staked out to best suit the natural ground levels and minimize the amount of cut and fill.[30] (page34) Great care is taken to preserve reference Benchmarks [30] (page59)

Roads are designed and built for primary use by vehicular and pedestrian traffic. Storm drainage and environmental considerations are a major concern. Erosion and sediment controls are constructed to prevent detrimental effects. Drainage lines are laid with sealed joints in the road easement with runoff coefficients and characteristics adequate for the land zoning and storm water system. Drainage systems must be capable of carrying the ultimate design flow from the upstream catchment with approval for the outfall from the appropriate authority to a watercourse, creek, river or the sea for drainage discharge.[30] (page38 to 40)

Sub-base layer composed of cement-based material being applied during construction of the M8 motorway in Ireland

A borrow pit (source for obtaining fill, gravel, and rock) and a water source should be located near or in reasonable distance to the road construction site. Approval from local authorities may be required to draw water or for working (crushing and screening) of materials for construction needs. The top soil and vegetation is removed from the borrow pit and stockpiled for subsequent rehabilitation of the extraction area. Side slopes in the excavation area not steeper than one vertical to two horizontal for safety reasons.[30] (page 53 to 56)

Old road surfaces, fences, and buildings may need to be removed before construction can begin. Trees in the road construction area may be marked for retention. These protected trees should not have the topsoil within the area of the tree's drip line removed and the area should be kept clear of construction material and

equipment. Compensation or replacement may be required if a protected tree is damaged. Much of the vegetation may be mulched and put aside for use during reinstatement. The topsoil is usually stripped and stockpiled nearby for rehabilitation of newly constructed embankments along the road. Stumps and roots are removed and holes filled as required before the earthwork begins. Final rehabilitation after road construction is completed will include seeding, planting, watering and other activities to reinstate the area to be consistent with the untouched surrounding areas.[30] (page 66 to 67)

Processes during earthwork include excavation, removal of material to spoil, filling, compacting, construction and trimming. If rock or other unsuitable material is discovered it is removed, moisture content is managed and replaced with standard fill compacted to meet the design requirements (generally 90-95% relative compaction). Blasting is not frequently used to excavate the road bed as the intact rock structure forms an ideal road base. When a depression must be filled to come up to the road grade the native bed is compacted after the topsoil has been removed. The fill is made by the "compacted layer method" where a layer of fill is spread then compacted to specifications, under saturated conditions. The process is repeated until the desired grade is reached.[30] (page 68 to 69).

General fill material should be free of organics, meet minimum California bearing ratio (CBR) results and have a low plasticity index. The lower fill generally comprises sand or a sand-rich mixture with fine gravel, which acts as an inhibitor to the growth of plants or other vegetable matter. The compacted fill also serves as lower-stratum drainage. Select second fill (sieved) should be composed of gravel, decomposed rock or broken rock below a specified particle size and be free of large lumps of clay. Sand clay fill may also be used. The road bed must be "proof rolled" after each layer of fill is compacted. If a roller passes over an area without creating visible deformation or spring the section is deemed to comply.[30] (page 70 to 72)

Typical pavement strata for a heavily traveled road

Geosynthetics such as geotextiles, geogrids and geocells are frequently used in the various pavement layers to improve road quality. These materials and methods are used in low-traffic private roadways as well as public roads and highways.[33] Geosynthetics perform four main functions in roads: separation, reinforcement, filtration and drainage; which increase the pavement performance, reduce construction costs and decrease maintenance.[34]

The completed road way is finished by paving or left with a gravel or other natural surface. The type of road surface is dependent on economic factors and expected usage. Safety improvements such as traffic signs, crash barriers, raised pavement markers and other forms of road surface marking are installed.

According to a May 2009 report by the American Association of State Highway and Transportation Officials (AASHTO) and TRIP—a national transportation research organization—driving on rough roads costs the average American motorist approximately $400 a year in extra vehicle operating costs. Drivers living in urban areas with populations more than 250,000 are paying upwards of $750 more annually because of accelerated vehicle deterioration, increased maintenance, additional fuel consumption, and tire wear caused by poor road conditions.

When a single carriageway road is converted into dual carriageway by building a second separate carriageway alongside the first, it is usually referred to as *duplication*,[35] *twinning* or *doubling*. The original carriageway is changed from two-way to become one-way, while the new carriageway is one-way in the opposite direction. In the same way as converting railway lines from single track to double track, the new carriageway is not always

constructed directly alongside the existing carriageway.

Maintenance

Like all structures, roads deteriorate over time. Deterioration is primarily due to accumulated damage from vehicles, however environmental effects such as frost heaves, thermal cracking and oxidation often contribute.[36] According to a series of experiments carried out in the late 1950s, called the AASHO Road Test, it was empirically determined that the effective damage done to the road is roughly proportional to the Fourth power of axle weight.[37] A typical tractor-trailer weighing 80,000 pounds (36.287 t) with 8,000 pounds (3.629 t) on the steer axle and 36,000 pounds (16.329 t) on both of the tandem axle groups is expected to do 7,800 times more damage than a passenger vehicle with 2,000 pounds (0.907 t) on each axle. Potholes on roads are caused by rain damage and vehicle braking or related construction works.

"Road works ahead" sign, typically used in Europe

Pavements are designed for an expected service life or design life. In some parts of the United Kingdom the standard design life is 40 years for new bitumen and concrete pavement. Maintenance is considered in the whole life cost of the road with service at 10, 20 and 30 year milestones.[38] Roads can be and are designed for a variety of lives (8-, 15-, 30-, and 60-year designs). When pavement lasts longer than its intended life, it may have been overbuilt, and the original costs may have been too high. When a pavement fails before its intended design life, the owner may have excessive repair and rehabilitation costs. Some asphalt pavements are designed as *perpetual pavements* with an expected structural life in excess of 50 years.[39]

Manual road repair taking place in Howrah, India

Many asphalt pavements built over 35 years ago, despite not being specifically designed as a perpetual pavement, have remained in good condition long past their design life.[40] Many concrete pavements built since the 1950s have significantly outlived their intended design lives.[41] Some roads like Chicago, Illinois's "Wacker Drive", a major two-level viaduct in the downtown area, are being rebuilt with a designed service life of 100 years.[42]

Virtually all roads require some form of maintenance before they come to the end of their service life. Pro-active agencies use pavement management techniques to continually monitor road conditions and schedule preventive maintenance treatments as needed to prolong the lifespan of their roads. Technically advanced agencies monitor the road network surface condition with sophisticated equipment such as laser/inertial Profilometers. These measurements include road curvature, cross slope, asperity, roughness, rutting and texture. This data is fed into a pavement management system, which recommends the best maintenance or construction treatment to correct the damage that has occurred.

Line marking in rural India

Maintenance treatments for asphalt concrete generally include thin asphalt overlays, crack sealing, surface rejuvenating, fog sealing, micro milling or diamond grinding and surface treatments. Thin surfacing preserves, protects and improves the functional condition of the road while reducing the need for routing maintenance, leading to extended service life without increasing structural capacity.[43]

Maintenance for the older concrete pavements that develop faults includes the technique called dowel bar retrofit. This involves cutting slots in the pavement at each joint, placing dowel bars in the slots, then filling them with concrete patching material. This method can extend the life of the concrete pavement for another 15 years.[44]

Failure to maintain roads properly can create significant costs to society, in a 2009 report released by the American Association of State Highway and Transportation Officials (USA) about 50% of the roads in the USA are in bad condition with urban areas worse. The report estimates that urban drivers pay an average of $746/year on vehicle repairs while the average US motorist pays about $335/year. In contrast, the average motorist pays about $171/year in road maintenance taxes (based on 600 gallons/year and $0.285/gallon tax).

Slab stabilization

Distress and serviceability loss on concrete roads can be caused by loss of support due to voids beneath the concrete pavement slabs. The voids usually occur near cracks or joints due to surface water infiltration. The most common causes of voids are pumping, consolidation, subgrade failure and bridge approach failure. Slab stabilization is a non-destructive method of solving this problem and is usually employed with other Concrete Pavement Restoration (CPR) methods including patching and diamond grinding. The technique restores support to concrete slabs by filing small voids that develop underneath the concrete slab at joints, cracks or the pavement edge.

The process consists of pumping a cementitous grout or polyurethane mixture through holes drilled through the slab. The grout can fill small voids beneath the slab and/or sub-base. The grout also displaces free water and helps keep water from saturating and weakening support under the joints and slab edge after stabilization is complete. The three steps for this method after finding the voids are locating and drilling holes, grout injection and post-testing the stabilized slabs.

Slab stabilization does not correct depressions, increase the design structural capacity, stop erosion or eliminate faulting. It does, however, restore the slab support, therefore, decreasing deflections under the load. Stabilization should only be performed at joints and cracks where loss of support exists. Visual inspection is the simplest manner to find voids. Signs that repair is needed are transverse joint faulting, corner breaks and shoulder drop off and lines at or near joints and cracks. Deflection testing is another common procedure utilized to locate voids. It is recommended to do this testing at night as during cooler temperatures, joints open, aggregate interlock diminishes and load deflections are at their highest.

Testing

Ground penetrating radar pulses electromagnetic waves into the pavement and measures and graphically displays the reflected signal. This can reveal voids and other defects.

The epoxy/core test, detects voids by visual and mechanical methods. It consists of drilling a 25 to 50 millimeter hole through the pavement into the sub-base with a dry-bit roto-hammer. Next, a two-part epoxy is poured into the hole—dyed for visual clarity. Once the epoxy hardens, technicians drill through the hole. If a void is present, the epoxy will stick to the core and provide physical evidence.

Common stabilization materials include pozzolan-cement grout and polyurethane. The requirements for slab stabilization are strength and the ability to flow into or expand to fill small voids. Colloidal mixing equipment is necessary to use the pozzolan-cement grouts. The contractor must place the grout using a positive-displacement injection pump or a non-pulsing progressive cavity pump. A drill is also necessary but it must produce a clean hole with no surface spalling or breakouts. The injection devices must include a grout packer capable of sealing the hole. The injection device must also have a return hose or a fast-control reverse switch, in case workers detect slab movement on the uplift gauge. The uplift beam helps to monitor the slab deflection and has to have sensitive dial gauges.[45][46]

Joint sealing

Also called joint and crack repair, this method's purpose is to minimize infiltration of surface water and incompressible material into the joint system. Joint sealants are also used to reduce dowel bar corrosion in Concrete Pavement Restoration (CPR) techniques. Successful resealing consists of old sealant removal, shaping and cleaning the reservoir, installing the backer rod and installing the sealant. Sawing, manual removal, plowing and cutting are methods used to remove the old sealant. Saws are used to shape the reservoir. When cleaning the reservoir, no dust, dirt or traces of old sealant should remain. Thus, it is recommended to water wash, sand-blast and then air blow to remove any sand, dirt or dust. The backer rod installation requires a double-wheeled, steel roller to insert the rod to the desired depth. After inserting the backer rod, the sealant is placed into the joint. There are various materials to choose for this method including hot pour bituminous liquid, silicone and preformed compression seals.[45][47][48][49]

Safety considerations

Careful design and construction of roads can increase road traffic safety and reduce the harm (deaths, injuries, and property damage) on the highway system from traffic collisions.

Pedestrian crossing, line markings and street furniture.

On neighborhood roads traffic calming, safety barriers, pedestrian crossings and cycle lanes can all protect pedestrians and cyclists.

Lane markers in some countries and states are marked with Cat's eyes or Botts dots, bright reflectors that do not fade like paint. Botts dots are not used where it is icy in the winter, because frost and snowplows can break the glue that holds them to the road, although they can be embedded in short, shallow trenches carved in the roadway, as is done in the mountainous regions of California.

For major roads risk can be reduced by providing limited access from properties and local roads, grade separated junctions and median dividers between opposite-direction traffic to reduce likelihood of head-on collisions.

The placement of energy attenuation devices (e.g. guardrails, wide grassy areas, sand barrels) is also common. Some road fixtures such as road signs and fire hydrants are designed to collapse on impact. Light poles are designed to break at the base rather than violently stop a car that hits them. Highway authorities may also remove larger trees from the immediate vicinity of the road. During heavy rains, if the elevation of the road surface isn't higher than the surrounding landscape, it may result in flooding.[50]

Environmental performance

Careful design and construction of a road can reduce any negative environmental impacts.

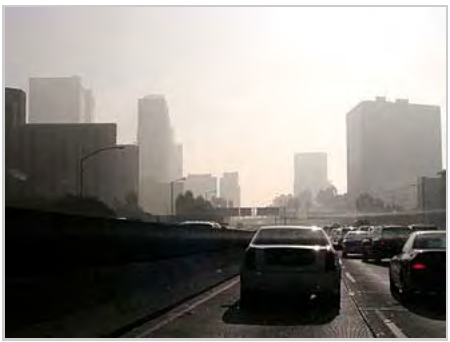

Air pollution along Pasadena Highway in Los Angeles, California

Water management systems can be used to reduce the effect of pollutants from roads. Rainwater and snowmelt running off of roads tends to pick up gasoline, motor oil, heavy metals, trash and other pollutants and result in Water pollution. Road runoff is a major source of nickel, copper, zinc, cadmium, lead and polycyclic aromatic hydrocarbons (PAHs), which are created as combustion byproducts of gasoline and other fossil fuels.[51]

De-icing chemicals and sand can run off into roadsides, contaminate groundwater and pollute surface waters;[52] and road salts can be toxic to sensitive plants and animals.[53] Sand applied to icy roads can be ground up by traffic into fine particulates and contribute to air pollution. Sand can alter stream bed environments, causing stress for the plants and animals that live there.

A dual carriageway section of National Highway 8 connecting Delhi to Gurgaon

Roads are a chief source of environmental noise generation. In the early 1970s it was recognized that design of roads can be conducted to influence and minimize noise generation.[54] Noise barriers are used to reduce noise pollution, in particular where roads are located close to built-up areas. Regulations can restrict the use of engine braking.

Motor vehicle emissions contribute air pollution. Concentrations of air pollutants and adverse respiratory health effects are greater near the road than at some distance away from the road.[55] Road dust kicked up by vehicles may trigger allergic reactions.[56] In addition, on-road transportation greenhouse gas emissions are the largest single cause of climate change, scientists say.[57]

Road after rain

Regulation

Right- and left-hand traffic

Traffic flows on the right or on the left side of the road depending on the country.[58] In countries where traffic flows on the right, traffic signs are mostly on the right side of the road, roundabouts and traffic circles go counter-clockwise/anti-clockwise, and pedestrians crossing a two-way road should watch out for traffic from the left first.[59] In countries where traffic flows on the left, the reverse is true.

About 33% of the world by population drive on the left, and 67% keep right. By road distances, about 28% drive on the left, and 72% on the right,[60] even though originally most traffic drove on the left worldwide.[61]

Economics

Transport economics is used to understand both the relationship between the transport system and the wider economy and the complex network effects when there are multiple paths and competing modes for both personal and freight (road/rail/air/ferry) and where Induced demand can result in increased on decreased transport levels when road provision is increased by building new roads or decreased (for example California State Route 480). Roads are generally built and maintained by the public sector using taxation although implementation may be through private contractors).[62][63] or occasionally using road tolls.[64]

The A22(T) with line markings near Summer Hill, East Sussex, England

Public-private partnerships are a way for communities to address the rising cost by injecting private funds into the infrastructure. There are four main ones:[65]

- design/build
- design/build/operate/maintain
- design/build/finance/operate
- build/own/operate

Road with guard rails in Kaluga Oblast, Russia

Economics and society depend heavily on efficient roads. In the European Union (EU) 44% of all goods are moved by trucks over roads and 85% of all people are transported by cars, buses or coaches on roads.[66] The term was also commonly used to refer to roadsteads, waterways that lent themselves to use by shipping.

Construction costs

According to the New York State Thruway Authority,[67] some sample per-mile costs to construct multi-lane roads in several US northeastern states were:

- Connecticut Turnpike — $3,449,000 per mile
- New Jersey Turnpike — $2,200,000 per mile
- Pennsylvania Turnpike (Delaware Extension) — $1,970,000 per mile
- Northern Indiana Toll Road — $1,790,000 per mile
- Garden State Parkway — $1,720,000 per mile
- Massachusetts Turnpike — $1,600,000 per mile
- Thruway, New York to Pennsylvania Line — $1,547,000 per mile
- Ohio Turnpike — $1,352,000 per mile
- Pennsylvania Turnpike (early construction) — $736,000 per mile

Road with traffic signs in the outskirts of Bern, Switzerland

Statistics

The United States has the largest network of roads of any country with 4,050,717 miles (6,518,997 km) as of 2009.[68] The Republic of India has the second largest road system in the world with 4,689,842

NH 73 going Bangalore

kilometres (2,914,133 mi) of road (2013).[69] The People's Republic of China is third with 3,583,715 kilometres (2,226,817 mi) of road (2007). The Federative Republic of Brazil has the fourth largest road system in the world with 1,751,868 kilometres (1,088,560 mi) (2002). See List of countries by road network size. When looking only at expressways the National Trunk Highway System (NTHS) in China has a total length of 45,000 kilometres (28,000 mi) at the end of 2006, and 60,300 km at the end of 2008, second only to the United States with 90,000 kilometres (56,000 mi) in 2005.[70][71]

Highway 401, a route with a collector / express setup

Global connectivity

Eurasia, Africa, North America, South America, and Australia each have an extensive road network that connects most cities. The North and South American road networks are separated by the Darién Gap, the only interruption in the Pan-American Highway. Eurasia and Africa are connected by roads on the Sinai Peninsula. The European Peninsula is connected to the Scandinavian Peninsula by the Øresund Bridge, and both have many connections to the mainland of Eurasia, including the bridges over the Bosphorus. Antarctica has very few roads and no continent-bridging network, though there are a few ice roads between bases, such as the South Pole Traverse. Bahrain is the only island country to be connected to a continental network by road (the King Fahd Causeway to Saudi Arabia). Even well-connected road networks are controlled by many different legal jurisdictions, and laws such as which side of the road to drive on vary accordingly.

The wide Coastal Road in the Philippines now called the Manila-Cavite Expressway

Many populated domestic islands are connected to the mainland by bridges. A very long example is the 113-mile (181.9 km) Overseas Highway connecting many of the Florida Keys with the continental United States.

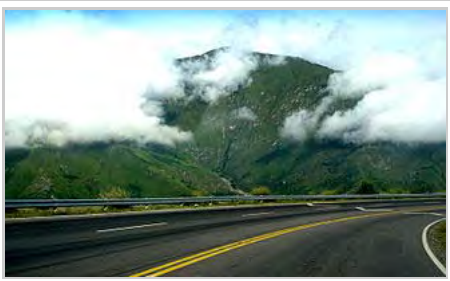

Road in Jujuy Province, Argentina

Even on mainlands, some settlements have no roads connecting with the primary continental network, due to natural obstacles like mountains or wetlands, remoteness, or general expense. Unpaved roads or lack of roads are more common in developing countries, and these can become impassible in wet conditions. As of 2014, only 43% of rural Africans have access to an all-season road.[72] Due to steepness, mud, snow, or fords, roads can sometimes be passable only to four-wheel drive vehicles, those with snow chains or snow tires, or those capable of deep wading or amphibious operation.

Cities on the mainland of continents which do not have road access include:

- Iquitos, Peru, population 437,376 (2015) in the Amazon rainforest
- Juneau, Alaska, population 32,406 (2014)
- Nome, Alaska, population 3,788 (2014)
- Rankin Inlet, Nunavut, population 2,577 (2011)
- Supai, Arizona, population 208 (2010) in the Grand Canyon

Most disconnected settlements have local road networks connecting ports, buildings, and other points of

interest.

Where demand for travel by road vehicle to a disconnected island or mainland settlement is high, roll-on/roll-off ferries are commonly available if the journey is relatively short. For long-distance trips, passengers usually travel by air and rent a car upon arrival. If facilities are available, vehicles and cargo can also be shipped to many disconnected settlements by boat, or air transport at much greater expense.. The island of Great Britain is connected to the European road network by Eurotunnel Shuttle - an example of a car shuttle train which is a service used in other parts of Europe to travel under mountains and over wetlands.

In polar areas, disconnected settlements are often more easily reached by snowmobile or dogsled in cold weather, which can produce sea ice that blocks ports, and bad weather that prevents flying. For example, resupply aircraft are only flown to Amundsen–Scott South Pole Station October to February, and many residents of coastal Alaska have bulk cargo shipped in only during the warmer months. Permanent darkness during the winter can also make long-distance travel more dangerous in polar areas. Continental road networks do reach into these areas, such as the Dalton Highway to the North Slope of Alaska, the R21 highway to Murmansk in Russia, and many roads in Scandinavia (though due to fjords water transport is sometimes faster). Large areas of Alaska, Canada, Greenland, and Siberia are sparsely connected. For example, all 25 communities of Nunavut are disconnected from each other and the main North American road network.[73]

A city street in Mumbai, India with left-hand traffic

Road transport of people and cargo by may also be obstructed by border controls and travel restrictions. For example, travel from other parts of Asia to South Korea would require passage through the hostile country of North Korea. Moving between most countries in Africa and Eurasia would require passing through Egypt and Israel, which is a politically sensitive area.

Some places are intentionally car-free, and roads (if present) might be used by bicycles or pedestrians.

Roads are under construction to many remote places, such as the villages of the Annapurna Circuit, and a road was completed in 2013 to Mêdog County. Additional intercontinental and transoceanic fixed links have been proposed, including a Bering Strait crossing that would connect Eurasia-Africa and North America, a Malacca Strait Bridge to the largest island of Indonesia from Asia, and a Strait of Gibraltar crossing to connect Europe and Africa directly.

See also

- AASHO Road Test
- Byway (road)
- Dirt road
- Drainage gradient
- Gravel road
- Lane
- List of roads and highways

- Pedestrian zone
- Pavement management system
- Road slipperiness
- Road transport
- Shoulder (road)
- Structural road design
- Trade route

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ROADS AND RESOURCES

APPROPRIATE TECHNOLOGY IN ROAD CONSTRUCTION IN DEVELOPING COUNTRIES

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The World Employment Programme (WEP) was launched by the International Labour Organisation in 1969, as the ILO's main contribution to the International Development Strategy for the Second United Nations Development Decade.

The means of action adopted by the WEP have included the following:
- short-term high-level advisory missions;
- longer-term national or regional employment teams; and
- a wide-ranging research programme.

Through these activities the ILO has been able to help national decision-makers to reshape their policies and plans with the aim of eradicating mass poverty and unemployment.

A landmark in the development of the WEP was the World Employment Conference of 1976, which proclaimed inter alia that "strategies and national development plans should include as a priority objective the promotion of employment and the satisfaction of the basic needs of each country's population". The Declaration of Principles and Programme of Action adopted by the Conference have become the cornerstone of WEP technical assistance and research activities during the closing years of the Second Development Decade.

This publication is the outcome of a WEP project.

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Roads and Resources

Appropriate technology in road construction in developing countries

Edited by G.A. Edmonds and J.D.G.F. Howe

A study prepared for the International Labour Office within the framework of the World Employment Programme

An Intermediate Technology Publication

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FOREWORD

In recent years, developing countries have been increasingly preoccupied with the need to create additional employment as a means of alleviating poverty. Attention has been paid to the feasibility of reducing unnecessary use of equipment in civil construction works with a view to making more effective use of labour. Although for many years civil construction works have been recognised as a means of employment generation, the notion that these works could be executed through the use of efficient labour-intensive methods is of a recent origin.

In this book, prepared within the framework of the ILO World Employment Programme (WEP), the editors, Drs. Edmonds and Howe, have selected a sample of operational programmes using labour-based methods (in India, Afghanistan, Iran, Mexico and Kenya) to throw light on the planning, management and administrative aspects of their widespread application.

Early WEP studies on road construction technology like the ones in Iran, Thailand and the Philippines were concerned mainly with question of the technical and economic feasibility of alternative techniques. Although some of these studies, in particular the one on Iran, did discuss the ways in which private contractors could be encouraged to use socially optimal methods through fiscal incentives and other governmental regulations, they were less preoccupied with the broader questions of organisation, management and large-scale implementation of labour-intensive techniques. It was first considered essential to overcome well-established prejudices on the parts of engineers and economists alike, against these techniques, by presenting hard facts based on field experiments. The case studies, especially the one in the Philippines, clearly demonstrated that the labour-intensive techniques need not be inferior, that certain construction

tasks are economically viable whether one uses market or social price tags on physical quantities, that it is possible to devise technically efficient labour-intensive techniques.

The next objective of the technology research programme in this sector was to examine the constraints and opportunities in implementing these alternative techniques on a large-scale to alleviate the unemployment problem of the Third World. The papers and case studies in this book are in the series of these institutional investigations.

Conventional thinkers have criticised the use of labour-intensive techniques in construction on the grounds of their low productivity and slowness. For example, it has been argued that very low labour productivity makes these techniques inefficient. It is further maintained that labour-intensive methods tend to delay the completion of construction activities. Chief engineers who have fixed budgets and target dates for task completion are tempted to bring in bulldozers to do the job in time rather than having to rely on large number of labourers. It is generally forgotten that construction delays often occur not so much due to low labour productivity as to lack of adequate project planning, insufficient control over project schedules and poor designing. In principle, a given construction output can be produced by labour-intensive techniques with the same gestation lag provided the much larger work-force required is available or can be easily mobilised. Thus, given technical choice, length of construction may be considered a planning variable which can be manipulated by changing the degree of labour concentration. This indeed has been vindicated by the experience of the Government of Kenya with its Rural Access Roads Programme on which Chapter 3 of this book by Bertil Nilsson is largely based. Labour-based methods used under this programme did not necessarily lead to an increase in costs or duration of the projects largely because a special effort was made to reappraise and adapt conventional equipment-oriented systems and procedures (relating to bidding, procurement, training and administration) to the requirements of the labour-based programme.

Within the framework of WEP research on construction technology institutional studies are examining more and more the extent to which labour productivity could be raised

through proper planning, better organisation and site management, improved tools and equipment and by incentive schemes including local participation of potential beneficiaries in road construction activities. Some of these issues are also discussed in various chapters of this book.

It is encouraging to note that despire the early prejudices of engineers and policy makers, accumulated knowledge of the viability of labour-based methods has led several developing countries, notably Kenya, Botswana and Ethiopia, to launch operational programmes experimenting in these methods with ILO assistance.

The WEP activities on civil construction technology are now being developed in a broader context of rural development. The types of roads to be built and the techniques to be used in building them cannot be divorced either from transport planning and infrastructure or from the choice of the type of vehicles to be used. Experience gained in road construction is also being applied to explore alternative techniques in small and large-scale irrigation works that can make significant contribution to the growth of agricultural output and employment.

Some of the chapters of this book were originally presented as papers at a Seminar on the Application of Appropriate Technology in Road Construction and Maintenance held in Manila in May 1977. This Seminar was organised by the ILO and financed jointly by the Swedish International Development Authority (SIDA) and the Asian Development Bank (ADB).

A.S. Bhalla,
Chief,
Technology and Employment
Branch,
International Labour Office.

INTRODUCTION

This book is concerned with appropriate construction technology in the building and maintenance of roads. It is one of a series resulting from the World Employment Programme of the ILO.

Traditionally, labour-based[1] methods have been viewed as a way of providing employment and/or income on a large scale; or as a means of mitigating the effects of disasters such as droughts, famine, earthquakes, etc. Their use has generally been conceived, planned and administered by, on the one hand, government planners and, on the other, relief organisations. Rarely has their use been initiated by those responsible for the execution of civil construction (i.e. engineers).

By drawing upon the detailed studies that have been carried out by the ILO and experience from recently executed labour-based programmes, the book shows that the use of more labour-intensive techniques can be technically and economically efficient. It also shows that the level of planning and organisation required for efficient labour-based programmes is no less demanding than that for equipment-based programmes. Moreover, as the existing systems in the construction sector of many developing countries are oriented towards the use of equipment, it often is necessary to pay careful attention to the detailed modification of these procedures so that labour-based techniques can achieve their full potential.

The book is in two parts. The first deals with the institutional framework within which the application of appropriate technology is proposed and with the various aspects of the implementation of appropriate technology. Having discussed the institutional framework it continues with a discussion of the major aspects of labour-based road construction, using as a basis the various ILO studies and programmes in Iran, Thailand, Nepal, the Philippines, India and Kenya. The following chapter, the author of which has been closely involved in

the work of both the World Bank and the ILO, shows how the detailed planning and administration of a labour-intensive programme requires a different, though no less demanding, approach than an equipment-orientated programme. In particular, it indicates that the use of more labour-intensive methods has to be integrated into the procedures and systems of public works departments. This often requires that existing systems be modified as they are usually biased towards the use of equipment. The fourth chapter in this part discusses the potential for improving and adapting simple equipment to meet the needs of labour-based methods. If labour-based methods are to be adopted on a large scale, then the private sector will inevitably be involved. The final chapter in Part I describes the constraints on the growth of the domestic construction sector in Asia and shows how the application of appropriate technology could provide the means for the more rapid development of the sector.

Part II comprises four chapters describing on-going or recently completed labour-based programmes. However, because of the diverse conditions under which they have been formulated, there is a consequent variation in emphasis from one programme to the next. Thus, the Border Roads Organisation, India, was set up along military lines in a country which has traditionally used labour-based methods. The project in Iran, on the other hand, was much less ambitious and in a country with which one would not usually associate the use of labour-based methods. The Mexican programme is probably the largest of its kind and was initiated with little or no external assistance. The programme in Afghanistan is the odd one out in that it has been set up as a self-help programme and is more in line with the traditional use of labour-based methods as discussed above.

Finally, in the summary, the editors draw together the main aspects that arise from the preceding chapters and discuss the implications of the use of a more appropriate technology in road construction in developing countries.

Notes and references

[1] Because of the inefficiency of traditional methods used by labour, the term labour-intensive can no longer be considered adequate.

Whilst it was originally used to describe those techniques in which labour was used intensively, i.e. efficiently and effectively, there has been a tendency to apply the term to those techniques that are "labour-extensive", that is, where labour is used on a large scale but inefficiently for employment generation or other reasons, little attention being paid to improving productivity. To avoid confusion, the general term "labour-based" has been adopted. The terms "labour-intensive" and "labour-extensive" could then be used to differentiate between schemes which are concerned with the efficient use of labour and those in which employment creation or other societal objectives are paramount, respectively.

PART 1 INSTITUTIONS AND ISSUES OF IMPLEMENTATION

CHAPTER 1. APPROPRIATE ROAD CONSTRUCTION TECHNOLOGY AND THE INSTITUTIONAL FRAMEWORK

by G.A. Edmonds and J.D.G.F. Howe

The suggestion that the technology used in developing countries should be appropriate to the physical and financial resources seems at first sight so much of a truism that it hardly requires further investigation. Unfortunately, however, simple concepts often have very complex implications. In its most elementary form the suggestion is that in labour-surplus economies more labour-intensive methods would appear to be appropriate. However this elementary statement conceals a much deeper aspect of the concept of appropriate technology. Put bluntly, in accepting an economic policy based on technology which is appropriate to the available resources one is adopting a pattern of social and economic development.

In an age when social development has lagged behind the development of technology it is, perhaps, not surprising that the concept of appropriate technology has been seen as an alternative path by which developing countries can attain economic independence and stability. It is certainly true that the development strategies of the 1950s and 1960s which emphasised the rapid growth of GNP did very little to improve the living standards of the mass of the population. The expected "trickle-down" effect just did not materialise. In fact the real income of the rural population of many developing countries remained static or decreased[1]. According to the ILO the number of persons designated as seriously poor and destitute increased by 10 per cent or 120 million people between 1963 and 1972[2]. Of those considered seriously poor nearly 80 per cent live in the rural areas[3]. The near static condition of the income of the mass of the population of developing countries during the last 10-15 years is in sharp contrast to the

rapid growth rate both in apparent per capita income and agricultural production. The indiscriminate use of modern industrial technology has been seen as one of the causes of the lack of distribution of the benefits of high growth rates[4]. Nevertheless it would be quite wrong to assume that by providing an alternative technological package one is dealing with the causes of poverty and unemployment. One must be absolutely clear that the concept of appropriate technology will have little effect if it is presented and implemented as a neutral package which will help to restore the balance of inequality within a given framework. Technology is not neutral nor is the choice of technology made in an economic or political framework which allows an equitable assessment of the available resources. The suggestion that "to intermediate levels of development there must correspond intermediate levels of technology"[5] assumes that the development process is neutral, free of political and social considerations.

There is little doubt that much of the technology being used in many developing countries is inappropriate in that it ignores the economic facts of life: that there is a shortage of capital and a surplus of available manpower. It is simple to show that if one applies the same level of investment per head that applies in the capital-intensive societies of the developed world to the developing countries, the level of employment created would be extremely small. (4.4 per cent in India, 5.1 per cent in Nigeria). But the acceptance of the concept of appropriate technology should also imply a political commitment to a strategy of development geared to the benefit of the mass of the population. If this commitment is not there then appropriate technology will be merely a useful gimmick for the traditional sectors of the economy. It will be viewed as a second-best alternative foisted on developing countries by well-meaning liberals from the developed world.

This book is about road construction. The preceding discussion may therefore seem a little out of place to engineers and planners concerned with achieving output targets within limited budgets. However the implementation of appropriate construction technology is not merely concerned with improving the productivity and efficiency of labour. It is also concerned with the institutional barriers to the application of a more appropriate technology. Whether these be due to education,

to administrative standards and procedures set up in the past or to inappropriate design standards, they can be considered as part of the political structure in the broadest sense.

For example, if we look at the road network and administration of many developing countries we can see that they were a natural development when set in the historical context of the colonial period and the need to provide ready access for the export of the basic raw materials required by the industrialised countries. The focus of the transportation network was to the outside world; to ensure that exportable products were transported as quickly and efficiently as possible out of the country. The economies of many developing countries depended on the foreign exchange earned by the export of cash crops[6]. The need therefore was perceived as being for railways or high standard paved roads from the interior to the ports. The administration of road construction was generally centralised in the capital and either because of colonial tradition or because of the need to build up the primary network as fast as possible, the procedures adopted tended to be similar if not carbon copies of those used in the industrialised countries. Thus, the development of the road network was automatically locked into a developed country framework with the additional factor that it was geared to exportation rather than internal development. Little attention was given to the development of a transportation network which served the mass of the population who lived in the rural areas.

As far as technology was concerned, the techniques used were those that appeared to be most productive. The initiators of road construction programmes were often from the already industrialised countries. These countries had already passed from the use of labour-intensive methods to reliance on equipment for a variety of socio-economic reasons and they viewed the former as an inefficient means of production. However, in the industrialised countries, the historical development of construction technology reflects the resources of the economy at the time they were developed. That is, labour-intensive techniques were used when the availablility of investible funds was low in relation to labour supply whilst equipment-intensive techniques developed later when a greater level of investment was available in relation to labour supply. The memory of labour-intensive techniques is one of lower productivity. This,

however, is principally related to the limited technical knowledge available at the time of the use of these techniques[7].

Thus, equipment-intensive techniques in the developing countries were introduced because in the industrialised country environment they were no longer viable. Little consideration was given to the fact that the economic conditions of most developing countries closely matched those of the industrialised countries at the time when labour-intensive techniques were considered appropriate.

Recently there has been a growing recognition that the potential for balanced growth in developing countries lies less in technological and economic dependence on the industrialised countries and more in providing stimulation for the development of the rural areas. This concentration on internal development has important implications since it implies a redistribution of the benefits of growth to the mass of the population. As far as road transportation is concerned this means an increasing emphasis on the rural road network. This will ensure not only that access is provided for social services, but that the potential for agricultural development and rural industrialisation can be achieved. It also implies a popular participation in decision-making and development. The emphasis should be on providing inputs into the rural areas which will stimulate growth rather than access to ensure the maximum level of exportation. If this type of development strategy, which emphasises the development of indigenous capacity and self-reliance, is pursued then appropriate technology can play a major role. The use of methods which rely on the efficient and productive use of labour can then be viewed in their true perspective as the most effective use of a country's natural resources.

The systems and procedures developed for road construction were, as we have seen, directly related to policies of export maximisation and rapid, centralised industrialisation. A change to a more balanced strategy of development which is also concerned with socio-economic factors will require that these institutional factors are reconsidered. Thus, the application of a more appropriate technology in road construction will require that the whole system of road planning, design, management and construction is reappraised.

Road construction consumes a large proportion of government investment[8]. If it were possible therefore to make the techniques used in road construction more labour-intensive, whilst being still efficient, then this large government expenditure could be used to promote employment and reduce the level of dependence on foreign imports and technology.

Apart from the obvious benefits, there are however other good reasons to consider road construction. There is, after all, a historical precedent for the use of labour-intensive methods. In 19th century Europe and America, before the advent of the internal combustion engine, roads were built by men using simple hand tools and animal-drawn equipment. Furthermore, in countries like India, roads built using large equipment are the exception rather than the rule. Then, again, the tasks involved in road construction are relatively simple and can be carried out by relatively unskilled labour who require little training. Much of the labour to be used will be from the rural areas and the tasks, tools and techniques utilised in the major activities such as earthworks are not dissimilar from those used in agricultural activities. In addition, the possible pay-off appears high. The amount of employment created per unit of investment is potentially large.

In most developing countries there is migration on a large scale from the rural to urban areas. Thus, whereas the average population growth rate is of the order of 2.5 per cent, in the cities it ranges from 7 to 10 per cent. Employment-creating activities which take place in the rural areas, as much of the road construction programmes do, could help to limit this migration.

Construction equipment is a major import in many developing countries. Furthermore, import of such equipment implies the future importation of spare parts. On the other hand, the cost of using the equipment is extremely high, requires skilled personnel and relies on fuel which is permanently subject to international economic factors. Any reduction in the level of equipment imports would reduce the pressure on limited foreign exchange resources.

In most developing countries the construction industry is dominated by large expatriate-owned companies. These companies, whilst fulfilling a vital role, tend to use the equipment-intensive methods and practices they are most familiar with.

The development of the local construction sector tends to be orientated towards the use of equipment-intensive methods. An acceptance of the viability of labour-based methods could allow local contractors to develop using indigenous methods and materials with which they are familiar.

The underlying rationale for the evaluation of labour-based techniques is that of the most efficient use of the available resources. Hand in hand with this evaluation would go an assessment of the most appropriate materials to be used.

There is also scope for the increased use of labour-based methods in the extremely important activities of road maintenance, particularly for routine activities such as ditch clearance, culvert maintenance and minor road surface repairs.

Finally, as we shall see later, there is a good reason to believe that the economic criteria generally used in project selection are biased against the use of labour-based methods.

The case for an evaluation, at least, of the feasibility using more labour-intensive methods is therefore very strong. It would be wrong, however, to assume that there are no objections to their use. Indeed some of the arguments against their use are quite potent and it is useful at this stage to present them.

First, and perhaps most important from the technical, economic and psychological standpoints, is the feeling that the use of labour-based methods will automatically produce a reduction in standards of construction. There is certainly some justification for this objection, particularly in relation to the compaction of earthworks and the final surfacing where it is true that it is extremely difficult to provide the same standard using labour-based methods. It would be wrong to suggest that these methods should be used when they produce inferior quality. Indeed, the approach should be that the methods used should be the most appropriate. If this means that equipment must be used, then that should be the solution. There is, however, another aspect to this issue. The standard of construction is specified by the design. Often the design is orientated towards the use of equipment and it is therefore not surprising that labour-based methods cannot meet the requirements. In addition, it can be argued, as we do later in this chapter, that the standards of construction may be artificially high and there exists an economic trade-off between

construction standards and future maintenance costs.

Second, it is suggested that the productivity of labour-based methods is low. This naturally has repercussions in terms of the duration of projects. It is pointed out that low productivity either means an extension of the project time or that the number of labourers on the site has to be very high causing managerial and logistic problems. Unimproved, traditional labour-intensive methods do have a very low level of productivity. On the other hand, there is a large variation in the productivity of manual methods. In the activity of excavation for instance, the World Bank[9] noted a six-fold difference in productivities for different parts of the world. Clearly there is a potential for improvement of productivity given the right environment. There is therefore some validity in this criticism and consequently the improvement of productivity is a major factor in the development of viable labour-based methods. In one respect, however, low productivity may not be detrimental. There are certain construction activities which are non-critical, that is, the extension of their duration will not adversely affect the over-all construction time. On these activities it could be feasible to use labour-based methods even if they are not as productive as equipment.

Third, it is generally assumed that, partly because of low productivity and partly due to other factors, the cost of using these methods is prohibitive. There is, as we discuss later, an automatic bias in most project appraisal criteria against labour-based methods. Nevertheless some studies that have been done to try and make comparisons of labour- and equipment-intensive methods give credence to the idea. It is worth noting, however, that in general these studies attempted to evaluate what could happen if labour-based methods had been used on an actual project which had used equipment. The comparison is therefore carried out in a framework orientated towards the use of equipment. To equitably assess the most appropriate methods the whole construction process must be "opened up" to allow the consideration of alternatives. In the section on design in Chapter 2, for instance, we show that it is the total cost of construction that must be considered and that the design must be orientated towards the most appropriate techniques. In the final analysis, however, it is cost that is supremely important. The public works ministry

or highways department has a limited budget for which it is accountable. It has to be sure that the best use is being made of that money. The use of labour-based methods must be shown to be not only socially but also economically appropriate.

Fourth, there is a strong feeling that the use of labour-based methods requires a high level of supervision which gives rise to high overhead costs not only on site but also in terms of additional training programmes. It is certainly true that these methods require a different kind of supervision. After all, one is considering the management of large bodies of men, not fleets of equipment. Whether the supervision is more costly is open to question, certainly experience so far does not substantiate this claim.

Finally, there are institutional forces within the construction industry which militate against the use of labour-based methods. The design methods, specifications, conditions of contract and methods of tendering all tend to reflect the dominating influence of expatriate consultants and contractors and their equipment-oriented framework. Even the methods of selecting contractors are often based on the amount of equipment they have and not on any ability to manage men. There is a natural inertia or resistance to change within the industry which could make the introduction of labour-intensive methods difficult.

In summary, there seem to be two categories of problem. First, the purely technical problems of low productivity, limitations of quality and high cost. There are then other problems which seem to have more to do with existing systems in the construction industry. These systems seem to be ill-suited to the introduction of labour-based methods. In the following chapters we look more closely into these aspects.

Notes and references

[1] ILO, *Poverty and Landlessness in Rural Asia*, Geneva, 1977.

[2] ILO, *Employment Growth and Basic Needs* Tripartite World Conference on Employment, Income Distribution and Social Progress and the International Division of Labour, Geneva, June 1976. Report of the Director-General and Declaration of Principles and

Programme of Action adopted by the Conference. Second edition, Geneva 1978.

[3] I. Ahmed, *Technological Change in Agriculture and Employment in Developing Countries*. Vol. 2. International Population Conference, Mexico, 1977, published by the International Union for the Scientific Study of Population.

[4] See for example F. Stewart, *Technology and Underdevelopment*, Macmillan, London, 1977.

[5] Intermediate Technology Development Group, information leaflet.

[6] This has even led to the substitution of cash for subsistence crops, to the extent that some developing countries are now net importers of subsistence crops in which they were previously self-sufficient.

[7] For a comprehensive coverage of historical/economic development of technology see F. Stewart, *Technology and Underdevelopment*, Macmillan, London, 1977.

[8] On average 60 per cent of total public investment in developing countries goes into construction and between 40 and 60 per cent of this construction investment is in road construction.

[9] *Study of the Substitution of Labour and Equipment in Civil Construction*. Phase I. International Bank for Reconstruction and Development, 1972.

CHAPTER 2. ROAD CONSTRUCTION AND RESOURCE USE

by G.A. Edmonds[1]

1. Introduction

Since the early 1970s the ILO has conducted a series of studies and programmes which have analysed and evaluated the feasibility of using methods of road construction which rely heavily on the use of labour[1].

In this chapter the main conclusions of this work are presented and examined in the light of the experience of the ILO and also of other agencies and institutions, such as the World Bank, who have been concerned with this subject. The final section discusses the policy measures that could be adopted to assist in the implementation of appropriate technology in road construction.

2. Planning and administration

2.1 *Choice of technology at the planning stage*

The use of appropriate technological construction methods requires that the whole construction process needs to be reassessed to ensure that at no stage is the choice of technology prejudged. Naturally, the further back one goes in the process, the less risk there is. Nevertheless, even at the overall planning stage there is some risk that, by default, the technology to be used is assumed. At this level, the consideration of alternative techniques would concentrate on such broad considerations as (i) what is the resource availability? (ii) are alternative techniques going to increase costs and/or duration? (iii) is it possible to integrate projects using labour-based and equipment-intensive methods?

In relation to the resources available, the supply of labour ready and willing to work would of course be of overriding

importance in the consideration of using labour-based methods. The availability of labour, in sufficient numbers, is a prerequisite for any labour-based construction programme. Data must be collected, therefore, regarding this availability. The assumption that in labour surplus economies it is sufficient to establish the demand and there will be no difficulty as regards the availability of labour is not necessarily true. In this connection, it is also worth mentioning that the attitudes of the available labour towards work is an important factor which needs consideration. Earthwork is a predominant activity in most construction works. In certain countries earthwork activities rank below agricultural work in the hierarchy of employment. Therefore, it is necessary to ascertain the willingness of the available labour to accept employment on construction work.

The seasonal fluctuations in the demand for labour in agricultural activities are another aspect of labour supply and demand which have a significant effect on the progress of construction projects. It is of little value beginning a project using manual methods only to find an inadequate number of site workers during the harvesting season.

In making the assessment of labour that will be available for the construction projects, labour requirements for projects in various sectors running concurrently and also those required for the maintenance of existing infrastructure should be assessed carefully. It may be that, even if technically feasible, the labour supply situation precludes any chance of using labour-based methods. The ILO study in Pakistan was particularly concerned with this issue[2].

The integration of labour-intensive and capital-intensive methods is possible at the project level. It is of course also possible at the programme level. Let us assume that whilst it is as inexpensive to build a particular group of secondary roads labour-intensively it does, in fact, take longer. However, the secondary roads are of little value unless the main arterial to which they connect is constructed. There could be a case therefore for using the labour-based methods for the distributors and this could be recognised at the over-all planning stage. (In this simple example it is assumed that no other benefits are lost by extending the completion of the distributor roads.)

The choice of technology, therefore, can be assessed within a framework of an over-all planning time schedule. A careful analysis of this time schedule may preclude the use of a technology for reasons of delays in completion. On the other hand it might provide the opportunity for using alternative technologies because of the interdependency of one project on another.

2.2 *Centralised and decentralised systems*

The detailed planning of projects which depend to a great extent on the use of local resources is difficult to accomplish from a central administrative organisation. Nevertheless, it is also necessary for the planning and programming of projects to fit into the over-all framework of a national development plan. This can only be achieved effectively by a central organisation. In the case of centralised planning, although the central organisation may have control over the project proposal it is possible that it does not cater sufficiently for local needs. In the case of a decentralised system it is likely that the local needs will be identified; however, it may be difficult to integrate these proposals into a national plan. From the point of view of the most appropriate allocation of resources it is extremely important that, whether the emphasis is on centralised or decentralised planning, the final national road network plan is integrated and coherent. This will require that at this stage the over-all evaluation is made of the economic costs and benefits of making the maximum use of the resources available.

2.3 *Programme planning*

The use of labour-based methods may necessitate a large number of smaller projects or that large projects need to be divided into small units for efficient execution. This is true whether the work is to be undertaken by direct labour or by local contractors. Often the local contractors in developing countries are geared towards the use of indigenous resources and therefore tend to be more labour-intensive. The local contractors' resources are usually restricted and as a result where the projects are not divided into small works it becomes impossible for them even to qualify for bidding. In the use of

direct labour on the other hand, various factors such as recruitment of labour, disbursement of wages, and procurement of material limit the size of projects that can be executed effectively.

2.4 *Programme administration*

The programme in Kenya,[3] in particular, has shown the importance of having effective administrative procedures for the implementation of programmes relying on the use of large labour forces. Often existing administrative procedures are orientated towards the use of equipment. In a labour-orientated programme it is vital that the procedures for pay, procurement of supplies, recruitment and reporting should encourage the smooth flow of operations.

Regular payment of workers is vital in achieving a high level of morale. Labour-based projects are often dispersed and require well-structured but decentralised systems of payment. In addition, although it is clear that piece-rate systems greatly improve productivity, many administrative procedures do not permit the use of any other than a daily-paid system of payment for direct labour.

The procurement of tools and equipment is of major importance in a labour-orientated programme. The administrative arrangements must provide for the even flow of these supplies to the project sites.

The evidence so far available suggests that it would be wrong to attempt to provide wholly new procedures of administration. What is required is the adaptation of the existing procedures to ensure that labour-based programmes are not put at a disadvantage.

3. **Project appraisal**

At some stage in choosing the most appropriate technology for a road construction project, it is necessary to make a cost comparison, for in the final analysis it is on the basis of cost, in its broadest sense, that decisions will be taken. It is extremely important therefore that the cost estimates accurately reflect the use of resources.

Of the data required for a reasonable evaluation, two problems are of particular importance in developing countries:

(i) unreliable statistical data, and (ii) use of inappropriate costing formulae, especially when hourly equipment costs are being estimated.

The first factor is fairly common and the obvious remedial measure is the development of a reliable data base. In the case of construction costs, reliable data are needed particularly for the estimation of hourly costs for various types of equipment. The project evaluator should beware of using the manufacturer's suggested unit costs, since conditions under which equipment is operated in developing countries are very much different from those in industrialised countries. The manufacturer's suggested unit costs tend, in general, to be lower than those prevalent in most developing countries. The main reason for this is that equipment yearly utilisation rates are usually much higher in industrialised countries than in developing countries. Methodologies for data collection have been described in an ILO manual[4].

The use of inappropriate formulae also seriously affects the reliability of estimated costs. In particular, many contractors and public works departments make use of inadequate formulae for the estimation of equipment depreciation costs. Often, these formulae tend to underestimate these costs, and therefore favour the adoption of capital-intensive technologies[5].

3.1 *The use of shadow pricing*

The evaluation of projects at market prices in developing countries often does not reflect the actual cost to society of utilising the resources available.

Road costs and benefits are usually estimated at "market" prices and/or institutional prices (i.e. prices fixed by government decree such as minimum wages, fuel prices, etc.). Furthermore, whenever costs and benefits are discounted to the present, an institutional interest rate is generally used for this purpose. Finally, whenever equipment and materials are imported, the local cost of these items is usually estimated on the basis of the official foreign exchange rate.

Evaluation of alternative technologies at market or institutional prices fails to allocate material resources in a way which maximises social welfare. In particular, the use of these criteria in the evaluation of alternative technologies in developing

countries may lead to the unwarranted adoption of capital-intensive technologies, the wastage of scarce foreign exchange, and the increase of unemployment levels. There may therefore be a need to use adjusted market prices, often referred to as "shadow" or "accounting" prices, in order to offset the distortions inherent in market and institutional prices[6].

Shadow prices are a reflection of the opportunity foregone of using the resources in question for other purposes.

It should be stressed that the use of shadow prices in project evaluation is not just an economist's trick used to make labour-based technologies more attractive. The use of shadow prices does have a real and positive impact on the use of national resources. Nevertheless, the decision to adopt shadow prices rather than market prices in project evaluation is one to be taken by the highest authorities in the country, inasmuch as it is partly a political decision. The consequence of such a decision is that all public investment projects are evaluated on the basis of shadow prices.

The use of shadow prices in project evaluation is fairly straightforward once the adjustment coefficients are known. First, projects are evaluated on the basis of market prices, yielding estimates for various project inputs (e.g. skilled labour, unskilled labour, equipment depreciation costs, equipment operation costs, materials). Next, total costs should be disaggregated into skilled labour costs, unskilled labour costs, foreign exchange costs, local materials costs, etc. Finally, each of the above cost items should be multiplied by the appropriate adjustment coefficients provided by the planning, or other, government agency. The result is that all market costs will be translated into shadow costs. If an analysis based on shadow prices was applied to all proposed road projects, it is likely that a different hierarchy of priorities would emerge than if it had been done at market prices. Nevertheless, the total budget restrictions would be the same in either case. Shadow prices are therefore being used as a tool to distribute more equitably the funds available in relation to the relative scarcity of the resources.

ILO studies in Iran[7], Thailand[8] and the Philippines[9] clearly show that the use of shadow pricing eliminates the inbuilt bias in market analysis towards the use of capital-intensive methods.

4. **Design**

It is often said that labour-based methods are incapable of complying with accepted standards of design, the general implication being that these methods are therefore inferior. The standard of design referred to, however, is one that is appropriate in developed countries. It would be better if one questioned the appropriateness of using these design standards in a developing country.

4.1 *The choice of design*

One can approach the question of design and the choice of construction techniques in two distinct ways.

First, and most commonly, it can be assumed that the design is fixed and it is merely necessary to choose the most effective construction methods.

Second, the design, either in terms of the pavement or the geometric alignment, is variable to allow the consideration of alternative construction methods. This may or may not also imply that the maintenance and operating costs are fixed.

Let us consider the first case. The road is designed on the basis of certain economic and engineering criteria. In the simplest terms it goes from A to B and the route it takes will generally be governed by the economic objectives it hopes to achieve. The actual engineering standards of design will govern the type of pavement, the vertical and horizontal alignment and the structures required to carry the predicted traffic load. Let us look a little more closely at what this means in terms of the choice of technique. We will leave aside the question of the reliability or validity of traffic projections in developing countries, for this is a major issue in itself. The pavement design will generally be based on practice originating in the developed countries. There will almost inevitably be a bias towards equipment-intensive methods. This can happen in one of two ways. First, it is, of course, possible to produce the required strength and durability by using different materials. The laying of certain materials however does not lend itself to the use of labour-based methods. It is, for instance, difficult to lay bitumous material this way; however, an effective alternative such as, for example, stabilised soil can be laid effectively using labour. The first point therefore is that care must be taken not to specify materials which limit the scope of labour-based

methods unless there is no alternative. Secondly, there is a natural tendency, reinforced by developed country practice, for the pavement thickness to be as small as possible. Put another way, the compaction of the sub-grade should be as high as possible. Whilst compaction achieves a variety of objectives, it is possible to consider that there is some sort of trade-off between sub-grade improvement and pavement thickness. Effective compaction being one of the operations that is difficult to execute using manual methods, a reduction in compaction (i.e. equipment) cost may be justified if it is not more than offset by the increased material cost of extra pavement thickness. In the recent ILO Manual,[10] an attempt has been made to quantify this trade-off. It should be recognised that in the case of a fixed design, there is no question of affecting the recurring maintenance and operating costs. The suggestion is merely that the design, being fixed in relation to certain standards, should allow the use of materials which may be more suited to the use of labour-based methods.

The question of the level of design standards leads us directly to the second case when the design is considered as variable depending upon the techniques involved. What we are really suggesting here is that instead of considering the construction costs only, we should evaluate the alternatives in terms of total costs. That is, we may be prepared to accept a lowering of design standards, reflected in a reduction in construction costs, if the increased cost of recurrent maintenance and vehicle operation did not exceed this reduction. Naturally one is thinking of modifying the design standards so as to make labour-based methods more attractive. For instance, it is often suggested that gradients should not exceed a certain value, say 6 per cent. This may require heavy earthworks when traversing hilly terrain. A relaxation of the gradient limitation may allow the road to take a more direct route, reducing the earthworks which will reduce costs and allow labour-based techniques to be considered. Naturally it would be necessary to assess whether the attendant increase in operating costs offsets the reduction in construction costs. Taking another example, the standards for minimum horizontal curvature are dictated by the design speed. A reduction in design speed would allow the road alignment to more easily follow the terrain contours, again reducing the level of earthworks and

not only reducing cost but also favouring the consideration of labour-based techniques. In regard to design speed, it is in fact possible to quantify the relationship between design speed and construction costs for various types of terrain. Taken to its logical conclusion, the argument for choosing designs which minimise the total cost of construction, maintenance and operating costs could mean the actual change of route. If the direct route necessitated heavy earthworks, large structures and major rock excavation, it could be possible to use an alternative, more circuitous route, which minimises earthworks and structures, favouring the use of labour-based construction methods. This could of course produce a change in economic benefits which would have to be considered in the analysis.

The evaluation of total costs would compare the present value of the maintenance and operating costs over the life of the road with the construction costs for each design alternative. The evaluation should also consider the question of whether the maintenance methods to be employed will be capital-intensive or labour-intensive as there would clearly be additional secondary benefits with the use of the latter.

In a limited way an ILO study in Kenya[11] attempted this sort of analysis by assessing whether the total cost of providing a gravel road in the initial stage was less than that of providing an earth road with guaranteed periodic maintenance.

The detailed assessment of the total cost of design alternatives requires that much more attention is paid to maintenance activities. It is of little value justifying a particular design on the basis of a certain level of maintenance unless it is actually provided. Maintenance activities need to be financed, organised and implemented. The consideration of a certain level of maintenance in the economic evaluation is not a guarantee that this level will be achieved. Impassable or badly maintained roads throughout the world testify to the low priority that they are given.

4.2 *Structures*

The design of drainage structures, retaining walls and bridges is an integral part of the design of a road. In their design it is equally important to consider the most appropriate use of the resources available. It has been argued elsewhere[12]

that for simple earth and gravel roads drainage is as important, if not more so, than the actual configuration of the road. A relaxation of gradient standards, for instance, may be possible if there is ample provision for the water to get away in the form of scour checks, drainage ditches and run-outs. Furthermore the provision of the right kind of drainage structures can prolong the life of the road whilst making use of indigenous materials.

Retaining walls are often constructed in concrete and as cement is generally an expensive import item, it is preferable to limit their size. If possible, one can eliminate them by the use of such alternatives as dry rubble walling. For revetments and abutments, the use of masonry is often a useful substitute for concrete.

A discussion of alternative bridge designs could be the subject of a separate paper. The main points to note here are that (i) the maximum use should be made of local materials; (ii) prefabrication is generally not an economic proposition; and (iii) there are often indigenous craftsmen skilled in building masonry or timber bridges of sufficient durability and strength. The first question to ask, however, with regard to bridge structures, is whether a structure is really necessary. For example, in many developing countries, a river that a bridge crosses is dry for 10 or even 11 months of the year. The economic consequences of closing the road for 4 to 6 weeks may not justify the expenditure on such a major structure. Another alternative is to consider the use of causeways.

4.3 *Appropriate education*

The whole question of design and the choice of the most appropriate construction methods is complicated by an education system in both developed and developing countries which tends to be orientated towards a type of construction industry that does not exist in the developing countries.

It is of course necessary to have a grasp of sophisticated, analytical techniques. They must be used, however, for designing roads which are suited to their environment. Designs which consistently require that a large proportion of the total construction cost goes in foreign exchange[13] when there are viable alternative techniques using local resources must be considered to be fundamentally inappropriate.

5. **Road maintenance**

In the section on design we stressed the importance of road maintenance. If it is carried out effectively it may be possible to limit the construction cost. If done badly it may mean that the estimated life of the road is drastically reduced.

It is, perhaps, because the cost of maintenance is a relatively small part of the total cost of road construction that little attention is paid to it. Indeed, it is often the case that in times of economic depression, road maintenance programmes are the first part of public works expenditure to be cut. However, this lack of emphasis is misguided and shortsighted. A well organised and well administered maintenance programme can defer the cost of major reconstruction thus releasing funds for other projects. Furthermore, whilst the foreign exchange costs of major reconstruction are considerable, of the order of 30 per cent, that of maintenance is generally less than 10 per cent. It is not therefore merely a question of deferment of costs but that the expenditure is channelled into local resources.

Maintenance comprises two elements. Routine maintenance, which is virtually independent of the amount of traffic. This involves clearing vegetation and keeping the drainage system clear. There is also the maintenance work that is dependent upon the traffic flow and is concerned with repairing damage caused by vehicles. Routine maintenance is relatively constant for all types of road varying only with the road width and the scope of the drainage system. Reparation maintenance is dependent upon the level of traffic and would increase with the increase of traffic. To provide an adequate level of maintenance, therefore, a basic minimum should be specified for feeder roads with little traffic and the level of maintenance should then be designated for each road in relation to its traffic volume. Unfortunately this rarely happens. Too often the maintenance budget is limited and only the major roads receive any maintenance at all.

It was suggested above that a greater investment in maintenance would have major benefits not only in deferring the reconstruction of the roads but also by conserving foreign exchange. Even in the developed countries, maintenance is a relatively labour-intensive operation. The operations are simple and can be efficiently carried out by manual methods.

Even regrading can be done by animal-drawn scrapers or graders. Unfortunately, many rural roads are built to a width greater than justified by the projected traffic flow to allow a mechanical grader to maintain them. This ignores the fact that there are labour-intensive methods available and also assumes that there will be a mechanical grader available to maintain the road.

For simple routine maintenance the scheme of having a "maintenance man" or group responsible for a section of road has been used in many parts of the world. Supervised effectively, and provided the worker (or group) is given the right incentives, this can be very effective. It has the advantage that the responsibility for maintenance is easily defined. This means not only that there can be effective supervision, but that the local people also know who is to blame if the road is improperly maintained. Often the worker or group can be given a certain minimum kit of tools (wheelbarrow, pick and shovel) to execute the work. Whilst there is an intuitive feeling that labour-based methods could and should be used in maintenance operations, it is clear that a more rational data base is required, so that the options can be quantified.

6. **Project management**

It is only in recent years that management principles have been actively applied in the construction industries of the developed countries. Apart from the social and public responsibility that a manager carries, it has become clear that the use of scientific management principles is vital for the effective implementation of projects. In principle the process of management consists of seven recognised processes which can be grouped under two main headings: planning and executive functions. In very broad terms the planning functions (forecasting, planning and organising), deal with material things whilst the executive functions (motivation, controlling and co-ordinating) deal with the human aspects of operations. The seventh process, communication, ties all the other functions together.

This introduction, whilst being commonplace to many, provides a useful basis for discussing the management appropriate to projects which employ methods which are orientated towards labour. One of the principal functions of management

is to motivate the members of the organisation. in the industrialised countries this generally refers to projects utilising large fleets of equipment. If one replaces the major pieces of equipment by large bodies of men then it is clear that a certain amount of rethinking has to take place in relation to the various management functions defined above. In the following section we will look at what reorientation may be necessary in the light of the seven basic management functions.

6.1 *Forecasting*

By clearly defining the objectives of the project in terms of progress, duration and quality it is possible to specify in some detail the level of resources required at any particular time or location. This, of course, is a routine activity on any project. However, on a project involving the use of labour-based methods the forecasting function is given an additional role to play. It is first necessary to predict what will be the demand for labour. As in the demand for equipment, this will be based on the level of productivity expected. In recent years a sufficiently sound body of knowledge has been developed for estimates to be made for most labour-based construction activities. There are, in addition, various methods of making an assessment of productivity rates[14]. Apart from the reliability of data, the problems of forecasting labour demand are not severe. Labour supply is more complex. We have touched upon this problem in relation to programme planning. At the project level, however, it is necessary to assess the availability of labour for each activity in relation to the seasonal fluctuations of labour supply and the demand of other projects in the area. The project manager must have a clear idea of the relative levels of labour supply and demand so that the detailed plans can allow for any shortfall in supply and either defer activities until there is sufficient labour or use equipment for these activities. In its broader sense forecasting in the case of labour-based construction also means an assessment of the needs of the large labour force. The recreational, social, health and welfare facilities that must be provided need to be assessed at the initial planning stage. The number of supervisory personnel required will have repercussions in relation to any existing training programmes.

6.2 *Planning*

One of the major problems of using labour-based methods in road construction is that the flow of work has to be relatively even and not subject to large or frequent changes. A relatively stable labour force is more effective because morale is not reduced by constant hiring and firing and because management problems are reduced. Further, delays in projects that are equipment-intensive can often be easily dealt with by bringing extra machines on to the site. This is, often, simply not possible with labour-based methods owing to the number of workers that are required to do the same work as a machine. It is imperative therefore that (i) the project is planned in such a way that the labour demand does not vary enormously and (ii) that there is an even flow of resources to the project. As far as an even level of output is concerned, there are of course various techniques such as critical path network, PERT, bar or Gantt charts or the more recent Time and Location Chart, which can be used to arrange the activities in the optimum way. Once the basic requirement of a relatively steady labour demand is specified, these techniques are then used in the normal way. (Naturally allowances would have to be made for agricultural peak seasons.) These techniques can also be used to ensure the effective integration of labour-intensive and equipment-intensive techniques. For instance, it is often possible that those activities which are non-critical can be executed labour intensively and the planning techniques would indicate how this was possible.

The even flow of resources to a project is perhaps more difficult to achieve because the project manager is dependent upon external factors. Nevertheless, it will be possible to assess what resources are required at any time during the duration of the project. Of specific importance is the supply of hand tools, and any planning process should provide some indication, based on the life of each type of tool, of when deliveries will be required.

A planning system relies for its effectiveness on the reliability of the data used and the efficiency of the reporting systems which allow the system to be updated. A good planning system can provide the basis for effective control of the project. In the case of labour-based projects, which are particularly dependent upon an even flow of output, a system which will ensure a steady flow of resources is vital.

6.3 *Organisation*

Having predicted the requirements and planned their use the next step, prior to implementation, is to provide an organisation structure capable of executing the project. It can be argued that if labour-based methods are to be used the whole organisation structure used for equipment-intensive projects must be changed. Whilst there is some evidence from China that this can work, it is certainly not yet proven in general. Experience from the ILO studies has been that what is required is an adjustment of the structure to take account of the fact that the main resource being employed is labour not equipment. This means that gang size and distribution becomes extremely important. So also is the question of whether the gangs are arranged along functional lines or whether each gang or group of gangs is given a certain section of the road to deal with. Equally as important as the balance and distribution of gangs however is the type and level of supervision. How many workers can one gang leader effectively control? How many gang leaders can one foreman direct? Furthermore, there is the problem of ensuring good communication both down from the project manager and back up from the foreman and supervisors. The organisation structure can be extremely important when motivation and co-ordination is considered. In the former case the workers must feel that they are in touch with the project management and the objectives of the project. In the latter case good co-ordination is a function of communication which, in turn, is dependent upon an effective organisation.

6.4 *Motivation*

If a large labour force is to be used it is of paramount importance that they are motivated to achieve their potential in terms of output. It is fair to say that in most countries financial reward is the main motivation for good performance. The ILO studies have clearly indicated that workers paid on a piece-rate system produce much higher output than under a daily-paid system[15,16,17]. The system of pay, however, if it is to be a good motivator must not only be fair but must be seen to be fair. In the case of task or piece rates the targets set must be scrupulously defined to ensure that there is no exploitation of the worker.

Money however is not the only motivator. A sense of belonging, good relations with fellow workers and adequate social and welfare facilities are others. A good project manager will ensure that all these aspects are well taken care of.

6.5 *Controlling*

In the discussion on planning we noted that a good system will ease the problems of control. The physical and financial control of projects can be relatively simple as long as the original plan is constantly updated by means of data derived through an effective communication system. The supervisory staff must therefore be trained to provide clear and concise information regarding attendance, output and future requirements. An effective communication system must exist which allows this information to be channelled to the project management for evaluation, decision and action. Not only will this ensure that the project is provided with the resources required at the right time but also it will pinpoint inefficient working or work that is behind schedule. This can be immediately investigated. In this way a good control system can instil in the workers a feeling of participation.

6.6 *Co-ordination*

If labour-based methods are to be used it is likely that the number of supervisory staff will increase. The methods may also be integrated with the use of equipment. To ensure that integration is possible and that the large labour force is working as a coherent mass, not as a set of independent units, it will be necessary to bring the supervisory staff together at regular intervals to discuss the work programme. This would also be the time when labour relations problems could be discussed.

Finally, we can provide no better summary of the problems involved than the words of a famous writer on construction management[18]. "Not only is it necessary for a manager to be able to organise technologies but he must also be capable of organising individuals. He must be able to view the management activity as a whole and not from the bias of his own particular education and training. In the organisation of human beings it is necessary for the manager to realise that improvements in the workers' physical and social conditions

together with the sharing of a sense of participation in the enterprise are the two effective prime movers of effective performance."

7. **Tools, equipment and techniques**

Most textbooks on construction management will almost certainly have a section on the choice and utilisation of construction equipment. A typical phrase from a well-known book[19] reads "correctly chosen and well operated plant will enable a construction project to be completed quickly and economically". Given that on a road construction project in the developed countries, equipment may account for upwards of 50 per cent of the total cost, it is not surprising that so much attention is paid to this item. If the resource utilisation is changed, however, and it is labour which is the predominant cost item then it is clear that much more attention has to be paid to their organisation and level of productivity. The labourer does not, however, work with his bare hands, he uses tools and simple equipment. In projects which are labour-intensive, therefore, the choice of the right sort of tool is as important as the choice of the right type of machinery in a capital-intensive project[20]. The cost of tools is not normally a major item even on labour-based projects, being generally of the order of 5-10 per cent of the total. It is their effect on the productivity of labour, however, which is of particular importance. Few detailed studies have yet been done on the difference in productivity for workers with "good" and "bad" tools[21]. Nevertheless all the experience reinforces the intuitive feeling that a well-designed, well-manfactured tool that is appropriate for the task increases the level of productivity.

7.1 *Appropriate tools*

If we are to invest money in the use of labour-based methods it will be necessary to spend much more time in considering the most appropriate tools for the particular job in hand[22]. A labourer is perfectly well aware of the most effective method of using traditional tools; what is needed is the most effective shape or type of blade so that, in the case of a hoe, for instance, it cuts each particular type of soil in the most effective manner.

In the consideration of appropriate tools, the first lesson to learn is that we must beware of imposing preconceived notions of what is the best tool for a particular job. Many of the basic activities of road construction and maintenance, such as excavation, loading and spreading, have counterparts in agricultural work. The labourers employed for road construction will generally be quite familiar with the most appropriate tools. Simple expedients such as reinforcing the blade of the tool at critical points to make it more durable for heavy excavation work seem to be the type of improvement that can be made. On the other hand, construction activities are much more demanding than agricultural ones and the tools used may have to be correspondingly more robust.

It is when the activities of workers become interdependent, such as in excavating and loading, or where the operations are markedly different from agricultural activities such as compaction, bitumen spreading or hauling with light equipment, that there is scope for the implanting of new techniques or the modification of existing ones. Consider for instance the question of haulage vehicles. Such methods as wheelbarrows, small trucks on rails, headbaskets, and animal-drawn carts are all generally in use in agricultural work. However, workers are used to using them individually and their design can often be improved in relation to the haulage of soil or aggregates. The wheelbarrow, for example, apart from being generally poorly manufactured is often also badly designed. The weight distribution is wrong, the size and type of wheel is ill-suited to construction sites. Furthermore the efficient use of wheelbarrows often requires a careful consideration of the balance between the loaders and the haulers.

Animal-drawn carts are often used in rural areas for the transportation of produce. The unloading is carried out by hand so as not to spoil the saleable goods. As far as the movement of soil in construction works is concerned, one of the main objectives is to unload the cart as fast as possible. Some system of tipping or bottom discharging would therefore have obvious benefits.

For long-haul distances it may be appropriate to use trucks or tractors and trailers. The important point to mention here is that the integration of labour-intensive and equipment-intensive

methods requires special care. It is of little value asking labourers to excavate and load in a similar fashion to machines. If they are asked to load into trucks or trailers the height of loading must be appropriate and furthermore the size of the truck must not be so big that it requires such a large number of workers to load it that they are in each other's way.

The work carried out so far indicates that even for those road construction and maintenance operations which are not directly comparable to agricultural activities it is possible to adapt and modify agricultural equipment to do these operations effectively.

7.2 *The scope for intermediate technologies*

In recent years a great deal of attention has been given to the idea of developing so-called "intermediate" techniques. These would be oriented towards the use of labour whilst reducing the level of physical work by the use of small-scale mechanical devices. The idea that these intermediate techniques provide a missing link between labour-intensive and capital-intensive technology has gained some credence. In the studies on road construction, at least, this idea has not been well substantiated in practice[23]. The evidence suggests that there is scope for major increases in productivity by the selection of appropriate tools and the modification and adaptation of traditional techniques. It has not been shown that it is possible to implant alternative technologies to any noticeable degree. This, of course, may purely reflect the fact that for most construction and maintenance activities there are obvious traditional alternatives which can be made effective.

7.3 *Techniques and work balance*

The specific problems of site organisation and planning have been discussed in section 5. It is worth mentioning here, however, that the productivity of particular tools and equipment often depends on the organisation of work. The disposition of labourers excavating, loading and hauling can make an enormous difference in the over-all output. Two simple examples will illustrate the point. In the operation of excavating, loading and hauling material using labourers and tractors and trailers, the most expensive element is the tractor. It must therefore be working full time for over-all economic efficiency.

This can only be done if there is the correct balance between the number of labourers, trailers and tractors.

In the operation of surfacing using tar spray and chippings, it is imperative that the rate of spreading of chippings is synchronised with the rate of tar spraying. Further, the roller that is used must also have an output that is in keeping with the rate of surface production. If labour-based methods are used for spreading and spraying the gang balance must be correct for output to be matched.

7.4 *Procurement systems*

The provision of hand tools and light equipment for a project using equipment is of relatively minor importance. In a labour-based programme it is absolutely vital that the requisite number of small tools are provided in the right place at the right time, otherwise the work will stop. It will often be necessary to develop special procurement systems for labour-based programmes and to provide detailed specifications to manufacturers. Certainly the system of least cost tendency without specifications should be avoided. Furthermore, the increased attention that has to be paid to well designed and well maintained tools will place a much greater emphasis on having well qualified personnel to direct the provision and procurement of tools.

7.5 *Small-scale industry development*

This aspect is far too broad a topic to deal with comprehensively here. Nevertheless the implementation of large-scale labour-based construction programmes could have important repercussions on the development of small-scale industry. Certainly if there were a capability in the rural areas to manufacture the tools and light equipment required this could be a major area for effective development investment. There are of course many problems such as quality control, transportation costs, co-ordination, centralised tendering systems, etc. Nevertheless, small-scale industry development is one of the potential secondary benefits of labour-based construction programmes.

In Kenya, the World Bank has already carried out work to assess the scope for the local manufacture of the tools and equipment required for the Rural Access Roads Programme.

The initial findings of this study suggest that the problems are more to do with the basic inflexibility of administrative systems rather than any inherent lack of capacity in the manufacturing sector.

8. Policies for larger-scale implementation

In the previous pages the detailed problems of using more labour-based methods in road construction have been discussed. In the long term the concern is with the most appropriate use of resources in the construction of roads in the developing countries. The use of appropriate technology is not an emergency measure to counteract unemployment. It will do this but it is much more basic than that. The use of the most appropriate technological methods will automatically reduce unemployment because it will be using the available resources, including labour, in the most appropriate manner. It is, therefore, not merely a question of providing a proper framework of design, planning and management. The long-term, large-scale implementation of more appropriate technological methods in road construction, as in other sectors, will require that various policy measures are adopted in keeping with the shift away from the technologies which are patently inappropriate but for various reasons are presently preferred. In this section an attempt is made to present various measures that could be adopted. Where possible, examples are given of attempts that have been made to implement these measures.

8.1 *Fiscal policies*

In section 3 the use of social cost benefit analysis was discussed. This is a tool which can be used to take account of the distortion of market prices in developing countries. We saw that this distortion tends to favour capital-intensive methods. The use of accounting or shadow prices does not make any change to the actual prices, it merely takes account of the distortion to give a more rational allocation of resources. In the public sector the assessment of the most socially profitable techniques can be made on the basis of the shadow price coefficients provided by a central planning agency. The manager in the public sector then executes projects up to the maximum number his market budget will allow based on the

accounting prices. In the private sector, however, the use of social accounting would be extremely difficult to implement. It would definitely require some form of government intervention to ensure that the contractor perceives that there is no loss in profit if he uses the alternative technologies. In the long term, however, the use of these technologies should prove to be profitable and a great deal depends upon educating the private sector in the use of labour-based methods. The government can, however, take various financial and fiscal measures which would assist in the acceptance and implementation of appropriate technology in road construction. These range from the very simple to the very complex. They are discussed below.

(a) *Surcharge* — one very simple method for allowing for the distortion of prices is to accept that it exists, to recognise that it favours equipment-intensive methods and to take the labour-based alternative where it is technically competitive as long as the market price is not more than a certain percentage more expensive than the capital-intensive methods. In the Philippines this has been done and labour-based methods are accepted if the increase in cost is not more than 10 per cent. In a way, this is an implicit social accounting procedure as it implies that the distortion in market prices is of the order of 10 per cent. This may seem crude and would, of course, require substantiation. However, given the complexity of the calculations to provide social prices it may be the most acceptable.

(b) *Tariffs on imported equipment* — in an effort to promote import substitution and to protect domestic consumer goods industries, many developing countries have adopted systems which provide high tariffs for consumer goods and low tariff rates for capital goods and raw materials. As far as road construction and maintenance is concerned this has the effect of allowing the importation of construction equipment at low tariff rates and thus effectively distorting the real cost to the economy of using the equipment. There are various ways in which this problem can be solved. One is to provide discriminatory tariffs on equipment which would be used on activities that can be carried out labour-intensively. This may, of course, be extremely difficult to implement in practice as a machine may carry out various functions some of which could not be done labour-intensively. An alternative is to make the

importation of equipment dependent upon the provision of a licence which would be provided by the government only after it was convinced that the equipment was needed.

(c) *Adjustment of the market rate of interest* — many governments impose low ceilings on interest rates in order to prevent private banks from exploiting their monopoly power. However, if the capital market does not function properly low ceilings may have negative effects. Small investors in the unorganised sector are often unable to borrow money since the banking institution prefers to deal with the modern organised sector, where risks of default seem to be lower. Under these conditions, large contractors can easily borrow money to import construction equipment, and find it profitable to do so since the low ceilings on interest rates result in a decrease in the equipment rental rate. In some cases, moreover, given high inflation rates, low ceilings on interest rates imply a negative real interest rate on loans, and imports of equipment and the adoption of capital-intensive technologies becomes even more attractive. The proper government policy if there are low ceilings on interest rates is to remove the ceilings completely or to set them at much higher levels. High ceilings on interest rates will lead contractors to think twice before asking for loans in order to import construction equipment, and may thus induce them to reconsider their position with respect to efficient labour-based technologies[24].

(d) *Taxation of owned capital equipment* — a number of factors including low ceilings on interest rates, difficulty of importing spare parts for construction equipment, lack of proper equipment for repair and maintenance facilities — tend to make contractors import more pieces of equipment than may be strictly necessary in order to be sure that construction work will not be slowed as a result of lack of equipment. The government may put an end to this situation by imposing a tax on owned capital equipment. The cost of keeping construction equipment idle will therefore increase, and contractors will refrain from importing more equipment than is really needed. Furthermore, the imposition of such a tax will increase equipment rental rates. A tax on capital equipment is, however, difficult to administer. The government must annually assess the value of pieces of equipment at various

degrees of depreciation. Needless to say, such an assessment is difficult to make and may lead to a large amount of litigation between contractors and the government. This type of government intervention is therefore not very practical and should not be attempted unless other types of action are not politically or economically feasible.

(e) *Wage policies* — the question of the most appropriate measures in relation to wages is perhaps the most difficult of all. This is partly because the difference between the market and shadow wage is often so marked. Other issues such as minimum wage legislation and trade union activity also have an effect.

Action in relation to wages is often seen as an effective way of favouring labour-based methods. All too often, however, the action is counter-productive because it directly interferes with market supply and demand. For example, the use of wage subsidies has been advocated. In its simplest terms this is the payment, by the government, to the contractor of a subsidy for each man-day of unskilled labour used on a project. Unfortunately, the result of this is that the contractor can continue to use capital-intensive methods, the increased labour force stands and watches[25] and the contractor pockets the subsidy. It is not sufficient to make it financially feasible for contractors to use methods which require more labour. They must also be convinced of the technical and managerial efficiency of these methods.

Finally, in regard to fiscal policies a comment from the Iran study[26] is particularly apt. "The argument concerning the relative merits of specific tariffs, quantity restrictions and wage subsidies does not turn on any simple notion of economies in government finance. The issue is basically one of ease of administration and relative efficiency of the set of measures adopted. Tariffs or quantity restrictions would appear to have a certain appeal as they are more easily administered than a direct wage subsidy. By themselves, however, they will not guarantee the adoption of appropriate technology. In the final analysis it will be the practitioners who choose the technology and any fiscal measures must go hand in hand with the appreciation of the technical feasibility of using appropriate technological methods."

8.2 *Policies on standards and specifications*

The ILO's employment strategy mission to Sri Lanka noted that "the problems in the construction industry were aggravated by the stolid enforcement of regulations, professional codes of practice or contractual procedures, the inadequacies of which have long been recognised in the very industrialised countries from which they were copied; copied moreover in the face of unquestionable evidence of their ineffectiveness in local conditions."[27] The situation in Sri Lanka is probably no different from that in many other developing countries. The unsuitability of European standards and specifications is most blatantly illustrated by such examples as the application of snow-loading criteria for roof construction in tropical Africa. Less obvious, but more common, however, is the specification of materials, methods of working and testing procedures which would be perfectly appropriate in Europe and North America but not in the developing countries.

There is no suggestion here that the systems and procedures used in the construction industries of developed countries are inefficient. Within their own environment they are generally effective. To expect them to work as efficiently in an environment where the basic economic situation is totally different, where the administrative systems are limited and where the information flow to the local construction sector is poor is somewhat optimistic. The basic dichotomy in construction caused by the division of responsibilities for design and construction becomes an even greater problem in countries where contractors are struggling with the basic problems of lack of financial and managerial expertise.

In regard to specifications and codes of practice therefore, governments need do no more than make an investigation of whether they are orientated towards the environment in which they are supposed to operate.

As regards methods of tendering it is clear that certain aspects of the normal tendering procedures are biased towards the use of equipment. One can think of the selected tender where only those with, among other things, a minimum plant holding will be eligible to tender. As far as government is concerned what is recommended is a more flexible approach to tendering procedures. These procedures were developed in the industrialised countries where there is an inherent tradition

of contract responsibility and where the design, construction methods and procurement of materials are already institutionalised. They may apply also to vast development projects: however it would be surprising if they are wholly appropriate to construction industries whose members have relatively limited financial and managerial resources.

8.3 *The influence of foreign consultants and contractors*

If one accepts that infrastructure development is vital to economic development, it almost goes without saying that this implies some form of foreign involvement in the construction industry. This may merely be in the form of feasibility studies or managerial assistance. More commonly it will involve the use of foreign consultants and contractors. Properly arranged, their involvement can be mutually profitable. Unfortunately certain conflicts often present themselves. It has already been noted that procedures and systems with which large foreign firms are familiar may not be appropriate. Of more direct importance is the fact that, as the ILO's study in Iran showed[28], foreign firms will draw their technology from an international market in which innovation has consistently moved in the direction of equipment-intensive methods. As the consulting engineer is often involved at the feasibility, design and supervision stages, the technology used is dictated by his expertise and background and only too rarely by a detailed consideration of the most appropriate resource allocation. In addition one has a contractual system based on the industrial country practice, and a contractor who, if not foreign or foreign-owned will have been schooled in the efficient use of equipment; it is not surprising therefore that the technology chosen is extremely capital intensive.

The use of foreign expertise in the development of a country's infrastructure is a fact of life and has many beneficial effects. Properly handled, foreign firms can be a great asset in assisting in the growth of the local construction sector. It would be wrong however to view the activities of foreign firms in any philosophical way. Principally, their object is to make a profit. Whilst governments should support this objective it should also ensure that profit is generated in a beneficial way for the country. This means that when the government, as a client, hires a consultant to carry out a feasibility study for a

road project, it makes it quite clear that the study should assess the construction technology to be used. It means that in its dealing with foreign contractors it should insist that labour is used to the fullest extent compatible with technical and economic efficiency whilst the importation of equipment is kept to a minimum. Governments can also take measures to support the growth of local contractors. This can be done not only by preferred treatment but also by putting money into training courses on financial management, administration and the most appropriate construction techniques. In the long term each developed country must have a viable domestic construction industry, whether public or private, for its own economic stability.

9. Summary

At the end of a fairly detailed coverage of the problems of the most appropriate technologies in road construction the overall problem of what are the required policy measures for large-scale implementation appears particularly broad. In general, however, what is required is a flexibility of approach, firm direction and support from the highest level and motivation for all concerned in the road construction process so that the most appropriate methods in terms of resource allocation are also the most efficient in the execution of projects.

Notes and references

[1] The author wishes to thank Dr. M. Allal and Mr. M.I. Hussain for their valuable comments during the preparation of this chapter. Dr. Allal's contributions on the economic aspects are gratefully acknowledged.

[2] *Study on the use of labour-intensive methods for the Indus SuperHighway*, ILO Report to the Government of Pakistan, Chapter 6.

[3] ILO, "Implementation of appropriate road construction technology in Kenya", report of the joint Ministry of Works/ILO /NORAD project (mimeo.), Geneva, Nov. 1976.

[4] M. Allal and G.A. Edmonds, *Manual on the Planning of Labour-intensive Road Construction*, ILO, Geneva, 1977, Chapter 5.

[5] See W. McCleary et al, *Equipment versus employment: A social cost benefit analysis of alternative techniques of feeder road construction in Thailand*. ILO, Geneva, 1976, Appendix 2.

[6] For a detailed discussion of this issue see M. Allal and G.A. Edmonds, op. cit., Chapter 8.

[7] G.W. Irwin, et al. *Roads and Redistribution — Social Costs and Benefits of Labour-intensive Road Construction in Iran*. ILO, Geneva, 1975.

[8] W.A. McCleary, et al. *Equipment versus Employment, op. cit.*

[9] Deepak Lal, et al. *Men or Machines: A Philippines case study of labour-capital substitution in road construction*, ILO, Geneva, 1978.

[10] *Manual on the Planning of Labour Intensive Road Construction, op. cit.*

[11] Report of the ILO/MOW/NORAD study, op. cit.

[12] Report of the ILO/MOW/NORAD study, op. cit.

[13] An average figure would be of the order of 30 per cent.

[14] See Manual, op. cit., Chapter 3.

[15] Deepak Lal, et. al., op. cit.

[16] Report of ILO/MOW/NORAD study, op. cit.

[17] The example of the effective piece-rate system devised by the Chinese in Nepal is particularly relevant here. This is quoted in H. Rieger and B. Bhadra, "A comparative evaluation of road construction techniques in Nepal", Centre for Economic Development and Administration, Tribhuvhan University, Kathmandu, Aug. 1978.

[18] R. Pilcher, *Principles of construction management*, McGraw-Hill, London, 1966.

[19] R. Pilcher, *op. cit.*

[20] *Manual on the Planning of Labour-Intensive Construction, op. cit., Chapter 3.*

[21] A recent study on appropriate technology in forestry operations in the Philippines was particularly successful in showing that efficient hand tools could considerably increase labour productivity. (See ILO, "Appropriate Technology in Philippine Forestry" (mimeo), ILO, October 1977).

[22] The ILO is at present preparing a *Guide to Tools and Equipment for Labour-Based Road Construction*.

[23] Some reasons for this are presented in Chapter 4, which also suggests that the scope is considerably broader than thought at present.

[24] The ILO's Employment Mission to the Philippines in 1973 recommended that interest rates on lending should be increased to 17-18 per cent. This has since been done.

[25] This effect of wage subsidy payments was observed in Kenya during the ILO Employment Mission in 1972.

[26] *Roads and Redistribution, op. cit.*

[27] *Matching Employment Opportunities and Expectations: A Programme of Action for Ceylon.* Report and Technical Papers, ILO, Geneva, 1971.

[28] *Roads and Redistribution, op. cit.*

CHAPTER 3. PLANNING AND ADMINISTRATION OF LABOUR-BASED ROAD CONSTRUCTION PROGRAMMES

by B.E. Nilsson

1. Introduction

The author has worked for several years with two of the projects that have contributed to this new way of looking at the matter, namely the Capas — Botolan project in the Philippines[1], and the Rural Access Roads Programme in Kenya[2]. While these two projects are good examples of the viability of labour-based methods they have also shown that it requires careful planning and foresight to make such projects successful. One must not be deceived into believing that the need for planning of labour-based work is less than that for equipment-based work. However, it is not always fully appreciated that the planning and administration of a labour-based project need to be approached in a somewhat different way than for an equipment-based project. Furthermore as there are yet very few engineers and managers with any substantial experience of labour-based methods in many countries it can be argued that a greater and more conscious effort has to be made when planning labour-based work.

In this chapter some of the most important aspects of the planning and administration[3] of labour-based work will be discussed. Much of the discussion is based on observations and lessons learned from the Kenya Rural Access Roads Programme. It is hoped that this programme will be a model for implementation elsewhere.

2. Programme planning

Let us assume that the public works department (PWD) of a certain country has taken the decision to execute a road construction programme using a technology appropriate to the

country's labour-abundant economy. This does not mean that labour-based methods will be used indiscriminately but that serious and unbiased consideration should be given to how to carry out the various road construction activities so that the programme is compatible with the conditions and economy of that particular country. It also means that already at the design stage due consideration should be given to such aspects as standards, size of projects and construction time in order to avoid conditioning the choice of technology. However, as mentioned in the introduction, design will not be covered in this chapter and the discussions here thus assume that questions about standards and quality have been analysed without bias towards any particular technology.

2.1 *Labour availability and costs*

This has been discussed in detail in Chapter 2. Suffice it to say in addition that the cost of labour normally has an overriding influence on whether labour-based methods are economically justifiable or not. It is however not possible to give an exact "break-even" figure above which labour-based methods would be uneconomical because labour and machine productivity differ so much from country to country. Moreover, factors such as the type of project, its location, the availability of staff and (machine) service facilities play an important role. The question of whether to use market or "shadow" prices should also be noted. Market prices are easier to establish but it is generally accepted that shadow prices better reflect the "real" effect of using different technologies on a (developing) country's economy because market prices are often distorted in one way or another.

2.2 *Selection of methods*

If the conditions are generally favourable for labour-based methods one should examine to what degree it is feasible to use them. For a low-standard feeder road with small requirements on compaction and smoothness of the riding surface and not involving long-haul distances, all or nearly all activities can be done by labour. For a main road with high requirements on compaction and riding surface it would be difficult to achieve the required standards without using some kind of mechanical equipment. Nevertheless, clearing, earthworks

and structures (which typically account for considerably more than half of the cost of a road project) can be done satisfactorily by labour. Thus, even on a main road it is feasible to use labour-based methods to a great extent if the economic conditions are favourable.

When deciding upon the optimum mix of labour and machines the planning engineer will have to go through the main activities and calculate the cost of each activity using either market prices or shadow prices. Obviously interdependent activities have to be regarded together to avoid mismatching and suboptimisation. Consider for example an excavation to fill operation where compaction by a mechanical roller is required to fulfil set standards. The excavating, loading, hauling, unloading and spreading activities may be most economically done by manual labour. Compaction however has to be done by a roller. Looking at the compaction activity alone it is likely that one would conclude that a large roller would give a lower cost per unit of output than a small roller. But the capacity of a large roller is so much greater than that of an ordinary earthwork gang that the roller would be idle most of the time thus greatly increasing compaction costs. A small roller could do the job equally well if the thickness of the layers was reduced and/or the number of passes was increased. Another advantage with the small roller would be that it could be moved more easily and thus be used at two or more adjacent fills. Another example is hauling over long distances. The hauling work may be least expensively done by large trucks. If, however, it is economical to do the loading by labour the long idle time of the truck during loading might make the use of trucks uneconomical. In such a case and over medium- to long-haul distances one tractor and two or more trailers might be economical as only the cheap component, the trailer, would be idle during loading. In countries where work animals are common these could also be extremely useful for short- to medium-haul distances.

The productivity and cost of resources need to be known when comparing different methods. A great deal of data is available on equipment-intensive techniques while comparatively little exists on labour-based techniques. A word of warning is however necessary regarding the use of cost and productivity data on machines. It is the experience of the

author that when calculating hourly costs of machines, little consideration is given to low utilisation and idle time caused by less than ideal work planning and breakdowns.

At the same time productivity figures may be taken from manufacturers' handbooks which tend to be optimistic in general and reflect conditions in the land of manufacture, often an industrialised country. Taken together this can contribute to considerable underestimation of unit costs.

Labour productivity data may not be available to planning engineers in many PWDs. It is always advisable to use local data but if no systematically organised labour-based work of any scale has been done recently in the country, international sources can be used. The World Bank and the International Labour Organisation, among others, now have data from several parts of the world. Such data should however be used only for tentative planning and it should be the aim to establish local data as soon as possible[4].

2.3 *Time schedule*

Having made the choice of methods, a tentative time schedule should be drawn up. In the case of a large road project a bill of quantities will have been prepared. In the case of a feeder road programme only the approximate length of roads to be constructed may be known. In such a case an estimate of the quantities involved must be made. This can be done by classifying the different types of terrain encountered and estimating quantities per kilometer for each type of terrain. Knowing (or estimating) the number of kilometers in each type of terrain a tentative bill of quantities for the entire programme can be calculated.

When making the time schedule it must be borne in mind that the work may have to stop, or at least be reduced, during certain periods due to non-availability of labour or to unsuitable weather. However labour-intensive methods are less sensitive to rain than machine methods. If the rain periods are not too intensive in a particular region, labour-intensive work may be carried on with minimal interruption.

2.4 *Organisation and staff*

The time schedule should show the resources that would be needed at any given time. It must be checked carefully to

ensure that it is possible to obtain the resources needed. Moreover, the level of resources required must be suitable from the technical point of view. For example, if too many labourers are crowded into one section of the road, productivity and economy will suffer. If the site is likely to become overcrowded the possibility of working simultaneously on more sites should be investigated. Where it is not possible to obtain the necessary resources, especially if there are shortages of supervisory staff, the time horizon of the programme would need to be lengthened.

If the road(s) to be built go through populated areas it is normally advantageous to employ labour who arrange their own transport to and from work. This is usually on foot and restricts the area from which labour can be drawn to 5-10 kms from the site. As the construction work progresses the distance to walk will be too great for the workers and new ones will have to be employed. The disadvantage with this system is that it takes a little time for the labourers to reach their full productivity. Thus, if the average length of employment is short, over-all productivity will suffer. The alternatives are to provide transport to the workers or to arrange labour camps. Both alternatives are costly and bring with them administrative and social problems. Therefore, if the turnover of labour can be kept to three to six months the slight loss in productivity incurred by employing new labour is generally preferable to the provision of transport or camps.

Naturally the organisation will depend on the size of the project and the type of the road(s). One proven organisation structure is to have one gang leader for every 20-25 workers and one foreman in charge of 3-4 gangs. The gang leader should be a worker who has the confidence of his fellows. He would leave the project when his gang terminates its employment, although the best gang leaders could be kept for training to become foremen. The foremen should be permanent or semi-permanent employees and kept throughout the project. Their technical skill need not be particularly high. In general, more consideration should be given to their ability to organise and motivate labourers. It is possible to train gangleaders with the right personal qualities to become foremen through comparatively short training courses. This is important because on large labour-intensive projects a great number of foremen are

needed. Their performance is crucial to labour productivity and thereby also to the economy of the project.

For every two to four foremen (200-400 workers) a supervisor with good experience and knowledge of road construction would be needed. A technician with engineering training would be suitable for this post. He would be the man to solve most of the technical problems on projects consisting of many small and scattered sites.

Finally, there should be a roads engineer who could supervise two to three technicians and be assisted by supporting staff for surveying, accounting, supply and stores, work studies and other administrative matters.

The following number of supervisory staff would then be needed for a project employing about 1,000 workers:

1	Engineer
3	Technicians
10-12	Foremen
40-50	Gang leaders (casual employees)

It is emphasised that this is an example and that each project merits its own analysis of the need for staff. A project with many small sites will need more supervisory staff than a project with 1,000 workers at one site.

The demand for supporting staff is a function of the type of road and the size of sites. A high-standard main road will need a number of surveyors while a low-standard feeder road project might not need any surveyors at all. The supply function for a small site project will be more complicated than for a big site project. Each small site must have its own small store and a storeman (possibly a casual employee) which may serve only 100 workers, while the store at a big site might serve a much larger number of workers.

2.5 *Training*

Unless labour-based projects of some scale have been executed before in a country it is likely that the number of staff needed is not readily available. In that case training programmes must be set up before the start of the programme. If a big programme is envisaged the most suitable formula would be to start on a comparatively small scale (pilot project) for one or two years and during that time gain experience of the type of training that is needed and the most appropriate way to

carry it out. If the programme will ultimately employ a very large labour-force, say in the order of tens of thousands, a build-up over several years will be required and training will be continuous.

It is likely that the training need is most crucial at the level of site foremen. It is extremely important that they be fully competent in the work methods to be used, as they will give the daily instructions on site and train the gang leaders and the workers. They can be recruited from the level of gang leaders provided they have a sound knowledge of basic arithmetic and an understanding of simple planning and reporting. Above all, they must have an aptitude for man management.

Training courses might also be needed for the technicians and engineers and possibly also for drivers, operators and mechanics if some equipment is to be used.

The emphasis of the training should be on field work. In many PWDs there are staff training departments where a special branch could be created to carry out the necessary training for labour-based projects. The management of a project should be ultimately responsible for the training but not for the day-to-day running of it. It is recommended that the training branch be given a special field unit where they can plan the construction work according to the training needs.

Ideally, instruction and training manuals should be written for the programme. Existing handbooks can be useful but do not reduce the need for manuals specific to the programme. These should deal with administrative routines, work methods and organisation, planning and reporting procedures as well as productivity, cost and production targets and resource allocation. The best way of using existing "universal" manuals is to extract and amend certain sections of them to suit specific country and programme conditions.

Feedback from field units to the training branch is very important. Some form of periodic review of the training course should be carried out between all the involved parties, i.e. the programme headquarters, the field personnel and the training branch. At these reviews certain questions should be examined. These would include the effectiveness of the training (whether the trainees know and can apply what they have been taught), the relevance of the syllabuses to the field

requirements and whether the methods taught correspond to actual, practical field procedures.

Gang leaders and workers and also some of the administrative staff would not be subject to any formalised training. In their case on-the-job training will be of great importance. It is absolutely essential that all levels of supervisors are made aware of this. This sort of informal training is done in the course of their daily duties and should take the form of both instructions and practical demonstrations. It should be followed up by control and repetitions if necessary.

Labour-based work carries relatively little "status" and it is therefore particularly important to promote interest in training and in the daily work by offering promotion possibilities. In a new and growing programme there is fortunately a good chance for this. However, promotion should be given on merit and not based only on years of service. Persons participating in courses should know that if they have performed well they will stand a good chance of being promoted. Care must therefore be exercised when selecting people for courses. The potential trainee's performance in his present job is of course important. Even more essential however is the assessment of how he would perform in his next job which might require different personal qualities.

2.6 *Tools and equipment*

The general aspects of tools and equipment have been discussed in Chapter 2. However, as far as specific programmes are concerned planners should investigate the whole range of questions related to tools at least one year before the intended start of a programme. The first important issue is to decide broadly which work methods are going to be used. Knowing that and the parameters such as soil types, it is then possible to decide the types of tool to be used and to make a rough estimate of the numbers needed. The number needed of each type of tool is dependent on the quantity of each activity, the number of workers and the parameters and the quality of the tools. Spare tools and handles must also be provided for.

When types, specifications and numbers of tools have been decided a survey of the local market has to be carried out. If the desired tools are available on the local market, laboratory

tests and also, if possible, field tests, should be carried out. If the tools are not available or if they fail the tests it might be possible to get local factories to take up new products and/or to improve the quality of their existing range of products. If this is not possible preparations for importation of tools have to be made.

It is usually economic to repair or recycle tools, for example, to weld a new blade to a hoe, a new prong to a fork or reforging a pickaxe. For this, a small workshop equipped with an electric arc-welding machine, a grinding machine, a forge and a couple of anvils and vices, etc., is needed.

As stated above, the selection of work methods governs the requirement for tools and equipment. If for example work animals are going to be used there will probably be a need for rippers, scrapers and various types of cart. Again agricultural-type implements may not be suitable and efforts may be needed to develop and manufacture better ones. A lot of development work has however been done by various organisations in several countries and by consulting them development work will not have to start from scratch.

2.7 *Budget*

At this stage a tentative budget can be made. The assessment of costs of resources in terms of labour, staff, material, tools and equipment, including running costs, camps, offices and related overheads is comparatively straightforward once input/output relationships are established and methods chosen. The cost of training facilities, management and planning staff at headquarters and method study personnel is more difficult to estimate but should not be forgotten. To a large extent the cost of these items depends on whether existing facilities and procedures are suitable for a labour-based programme or not. It is extremely important to examine this aspect in detail before the start of a programme. A thorough analysis should be done of how existing routines need to be modified by someone familiar with labour-based work. This must commence well in advance, at least a half to one year before the intended start of a programme. The time and money spent on this will certainly pay off in terms of reduced disruptions and delays. Nevertheless, if labour-based work on a big scale is completely new to a PWD, adjustments of

administrative routines and the organisational structure may have to be done after the start of a project even though considerable time has been spent on this in advance. The productivity of labour and estimates of quantities and material will also be subject to correction when experience has been gained. It is therefore natural that, unless the PWD has recent extensive experience of labour-based programmes, the tentative budget may be a best estimate only.

The tentative budget is of course of utmost importance for the financial negotiations for the project. It seems that both bilateral and multilateral development agencies look favourably upon labour-based projects. A sound budget for a well-planned programme is a valuable asset in such negotiations.

3. **Administration — policy and procedures**

If a PWD has not earlier employed large numbers of casual labour there would be a need to establish a labour and staff policy for the project. The changes or amendments to administrative procedures may also be so far-reaching that it is worth setting up new administrative policies.

3.1 *Labour policy*

Most PWDs, being part of a country's civil service. employ their labour, including unskilled labour, on a permanent or semi-permanent basis. Consequently existing codes and regulations do not fit a situation where casual labour is employed on a large scale. A new set of regulations may have to be created. As far as possible this should be done before the start of a project and in consultation with the Ministry of Labour to avoid disputes regarding the terms of employment.

a) *Wages*[5] — If there is a legal minimum wage this will often be the actual wage paid to the workers. An exception might have to be made if the wage for casual labour in, for example agriculture, is higher than the minimum wage. In a country with large unemployment this would probably only happen in certain regions or seasons unless the minimum wage regulations are very old. If wages lower than the minimum wage are common for casual agricultural work the minimum wage has to be used for budgeting purposes whilst a shadow wage could be used when choosing technology. Care must be taken that road construction does not disrupt agricultural production in an area.

This could happen if the wages paid to road workers were higher than agricultural wages and the labour supply insufficient for both activities during peak agricultural seasons.

Payment in kind, i.e. when a certain portion of the wages is paid not in cash but, for example, as foodstuff, has been tried from time to time. If a large portion of the wage is paid in kind it seems that the workers look upon their job as a kind of welfare programme and motivation is often lacking. Payment in kind is also administratively burdensome and the author's opinion is that it should be avoided[6].

The pay period should if possible be one month. Shorter pay periods require more administrative work and greater loss of working time. Local practice may however require shorter pay periods. Daily payment is unsuitable for large-scale projects.

b) *Working time*[7] – Manual road construction work is arduous and in a hot climate it is not possible to keep a high output over eight hours. To avoid the worst heat, work should preferably start early in the morning, break for several hours around noon and continue in mid-afternoon. This is not always easy to arrange but should be aimed at where feasible. If work animals are used they often set their own pace which man has to follow whether he likes it or not.

Rules about remuneration when work cannot be carried out, for example, due to inclement weather, should be included in the terms of employment.

c) *Social benefits and security*[8] – The nature of casual employment implies that the workers will have to be dismissed after the completion of a project, subproject or a certain stretch of road. This procedure, however, must be compatible with the labour legislation in the country. Some countries have labour laws which automatically make employment permanent after a certain period of time. However desirable from the social point of view, it may in some circumstances completely defeat the idea of labour-based work which in many cases is tied to the concept of temporary employment.

Other questions on social security concern sickness and accidents. If the labourers are to be paid for days when they are sick what kind of control should be implemented? Will the PWD be responsible for accident during work and if so to what extent? Should social security charges (if applicable) be deducted from the wages or covered by the PWD?

d) *Incentives* — If labour-based work is to be economically viable it is fundamental to keep a high labour productivity. To achieve this it is important that the workers feel that their job is meaningful. If they live near the road to be constructed they normally feel well motivated as the road will serve them when completed. The workers should also feel that they are not unfairly treated and that their terms of employment and working conditions are reasonable.

Some form of incentive payment scheme can raise productivity considerably. The obvious method is piecework, i.e. the worker is paid for each unit of output. The harder he works, the more money he gets. Another method is taskwork. Taskwork means that a worker, or more often a gang of workers, gets a task to finish in a certain period of time (often one day but it can be longer). When the gang has completed the task satisfactorily the labourers are free to go home still earning a full day's pay. The incentive is not that they can earn more money, as in piecework, but they can get more spare time to use as they please, e.g. for work on their farms. Piecework and taskwork can increase productivity by 50 per cent or more compared with non-incentive timework (i.e. daily paid without any set task).

Piecework usually yields somewhat higher productivity than taskwork but is not always more economical because it is more burdensome and costly to administer. For small sites where no bill of quantities is made and little or no surveyor assistance is available taskwork is recommended. For large roads these facilities are usually provided and piecework can be introduced for many of the main activities. Before either is introduced a good knowledge of labour productivity must be obtained through work studies to prevent large changes in the set rates. A policy should also be established on action to be taken if the workers fail to finish a task during normal working hours and whether workers on piecework should be allowed to work longer days in order to earn more.

e) *Tools, equipment, work animals* — In this regard responsibility of the employer and the employees should be laid down. Tools and equipment are preferably provided by the employer and the worker's responsibility in case of loss should be agreed upon. Work animals on the other hand need care and food even after working hours and would be a burden for

the site management to own or keep. It is therefore preferable to hire work animals with a driver. In the agreement the responsibility of both the owner/driver and the employer (particularly in case of illness, accidents or death) should be spelt out.

3.2 *Staff policy*

The staff requirements for labour-based work are different from those of capital-intensive work. The latter requires fewer supervisors and most of them need a good technical education. The execution of labour-based work requires more supervisory staff but many of them need comparatively little technical education. As capital-intensive methods in many countries are the prevalent way of constructing roads, staff regulations are naturally geared towards their use with emphasis on academic qualifications. For labour-based work, supervisors need to have man-management and organisational abilities rather than sophisticated technical training. This does not mean that their work carries little responsibility. On the contrary they often have to work quite independently at a fairly low level in the hierarchy. A foreman at a small site project is commonly alone on an isolated site and has to do the daily planning, reporting, instruction and supervision by himself. The problem is that government regulations often do not recognise that persons with little formal education can take on this kind of responsibility and therefore their employment and promotion will be difficult to accomplish. If a government wants to carry out labour-based work it must accept the different requirements and make it possible to employ and keep the type of personnel needed.

In this context it can also be pointed out that existing rules for housing and field allowances and overtime should be examined to see if they are applicable and relevant to a situation which may not have been foreseen.

3.3 *Distribution*

The distribution of supplies of tools should not be a problem if the project consists of only a few large sites. Each site would then have its own store facilities and possibly also the authorisation to buy small quantities of tools directly. With

many small sites it is quite a different matter. It would be uneconomical to store large quantities of every item which may be needed at each site. The only solution seems to be very careful planning and the establishment of depots in various parts of the country, each of them serving a number of sites. The importance of a good distribution system is frequently overlooked although the lack of tools, spares or material is a major bottleneck on many construction sites whether they are capital intensive or use labour-based methods.

3.4 *Payment of wages*

It is extremely important that the workers get paid on time. Hardly anything lowers the morale of the labour force as much as delayed pay. Most PWDs have no experience of paying very large numbers of workers in the field and scattered all over the country. This must therefore be given careful consideration and, if necessary, new routines created. To ensure punctuality the system should be decentralised as far as the calculation of wages and payment is concerned. Necessary checks and auditing would of course be done afterwards at headquarters.

A system along the following lines would have a good chance of functioning properly. The engineer requests well in advance of pay day that the approximate amount of money needed (not to be underestimated) be paid to a local bank from headquarters. The men who keep the muster rolls, normally the foremen, send them to the engineer one week before pay day covering the period from one week before last pay day to one week before this pay day. The individual wages are then calculated at the engineer's office. The engineer should personally make the payment on at least one site per month (not known which in advance) as a precaution against fraud. Another check that should be done at irregular intervals during the month is tnat the number of workers present at the site corresponds with the number on the muster roll that particular day.

The above system requires that the engineer is given authority which he may not enjoy according to existing regulations. It is however difficult to run a programme of widely spread small sites without giving a large amount of authority to field officers.

4. **Site management**

4.1 *Organising the work*

Before any large number of workers is employed offices, store and tools should be furnished. The alignment also needs to be established for the first part of the road. On a high-standard road this would be done by a surveyor in the conventional way according to drawings provided. On a low-standard road the alignment might be decided on the spot. The technician (referred to in the organisation previously outlined) should be able to do that assisted by the foreman but might, in complicated cases, take advice from the engineer. When the centre line is set out the foreman can set out road width, ditches and cut levels together with his gang leaders.

The recruitment of labour can be done in various ways. The easiest way is to ask a local chief, community leader or barrio captain to organise it. Another method is to let it be known that labour will be employed on a certain day and if the number arriving is greater than needed, make the selection by drawing of lots. The latter method eliminates, or at least reduces, the possibility that somebody draws unfair advantages from the recruitment situation.

As both labourers and gang leaders are casual employees they will know little about the work to begin with. It will be up to the foreman to instruct them, a task which initially will take much of his time. It is therefore desirable to have a staggered start to the work. Each foreman should engage a new gang with at least two or three days interval. This also contributes to good work sequencing. The first gang would do bush clearing, the second gang removal of topsoil, the third gang excavation, etc. Depending on quantities involved two or three gangs would be needed for one task and maybe only half a gang for another. The aim is to get an even progress of the work so that each task is sufficiently well ahead of the following task without getting so far in advance that supervision becomes difficult. The above applies also to large sites with the exception that each foreman would specialise in one task and all his gangs would do the same task. At the gang level a specialisation is desirable, regardless of size of site, to improve productivity.

It is important, but often neglected, to teach the labourers

efficient work methods. Take, as an example, the excavation of soil from one side of the road to be used as fill on the other side. Often workers move the soil three or four times, about one meter at a time, instead of throwing it across the road in one throw. For a given amount of soil the latter method is quicker and less fatiguing. Other examples are to place a wheelbarrow in the right place and position to ease loading, to see that the runway for a wheelbarrow is smooth and hard, to circulate activities within a gang in order to distribute the most strenuous work. These are all small details but taken together they will have a major impact on productivity and considerably facilitate the work for the labourers.

The importance of incentive systems has been stressed earlier. It is obvious that a decrease in the pay per unit of output (for piecework) or an increase in the daily task (for task-work) will not be popular among the workers. This implies that the pay per unit should be kept on the low side and the daily task on the high side to start with if there is uncertainty about what rates to set. The idea being that any change would be favourable to the workers and therefore not meet with resistance. But if the pay appears too low or the task too big the workers would not feel motivated and the experiment be useless. This is a delicate situation and the best thing to do when uncertain is to work on a timework basis for some time while studying productivity. This should preferably be done in a way that enables measurement of work periods and rest periods to assess whether the pace of work is reasonable or not.

4.2 *Planning*

When planning construction work it must be remembered that the hourly or daily productivity is not the same as long-term productivity. The former is what can be achieved when work progresses more or less uninterrupted while the latter indicates what can be expected over longer periods — a month or a season. Over such periods disturbances are bound to occur and cause idle time whether the work is executed by labour or machines. One purpose of planning is to minimise idle time.

A frequent reason for delays is inclement weather. However, this follows a yearly pattern and consideration of this must be taken in the plans. Breakdowns are another common

reason for work stoppages on equipment-intensive work. The equivalent of this in labour-based works would be labour absenteeism or shortages. Labour supply estimates, particularly in respect of differences between agricultural off seasons and peak seasons, can however minimise problems of this nature.

The relationship between long-term productivity and daily productivity thus depends on factors such as the quality of planning, the weather and "breakdowns" taken in a wide sense to include such things as labour shortages. Daily productivity can be assessed relatively quickly through work studies. Only experience over a long time, however, can give the frequency of work disruptions and hence the long-term productivity. Good planning, including consideration of the weather and the study of the labour supply, can however bring the two concepts close to each other in value.

The planning techniques which can be used differ depending on the type and size of road. For a big main road project the same well-known techniques as for capital-intensive jobs can be used, for example, bar chart, time and location chart or the critical path method. More detailed planning will however be necessary, as the standard unit of input, a gang of labour, has an output which is only a fraction of that of a big machine. It is desirable to have at least two levels of plan. There should be at one level an over-all plan stating in general terms the expected progress and needed resources over the life of the project. The other plan, drawn up fortnightly or monthly, would detail where and in what numbers each resource (labour, equipment, material) would be needed and the expected output.

At a small site the planning has to be simplified. Often there is a lack of most or all of the needed facilities such as drawings, bills of quantities, surveyors and most of all a person familiar with sophisticated planning techniques. The foreman would normally do the short-term planning which probably would extend over a few days or possibly up to one week. A simple form listing the common activities with the number of workers and the chainage for the actual activities would be an adequate format for this planning. Volumes of excavation in bulk could be estimated by the "slotting techniques". This means that a vertical slot, perpendicular to the direction of the road should be excavated to the intended level of cut. The slot would be as

wide as is convenient to excavate and extend to the intended backslope of the road. The height and width of the cut can then be measured without using any instrument and the volume calculated by the foremen in order to set appropriate tasks. This method is well suited only for sidecuts and not for "full" cuts but these are unusual on low-standard roads.

Small sites may not need a comprehensive bill of quantities. However, an estimate of the quantities of the major activities is desirable in order to make a rough plan for the whole road and to have something with which to compare input of resources. A technician trained and experienced in estimating quantities could do this work. He would walk along the road and estimate the density of bush, the approximate height of cuts and relevant parameters such as soil class, location of culverts and bridges, etc. If the same person made the estimate on all roads it would be sufficiently reliable for simple planning and control of efficiency.

The yearly construction programme for simple rural roads has to be based more upon judgement of the terrain types than upon actual estimates.

4.3 *Reporting and control*

Planning is aimed at getting the right resource in the right numbers at the right place at the right time. To be useful the planning has to be updated regularly in relation to the present situation and recent experience. Therefore the progress and the use of resources must be controlled. The control process will take place at all levels of the organisation hierarchy and, to enable this, a flow of reports must be established. A good reporting system is particularly essential in a programme with many small sites as the project management cannot visit each site often. As one moves up the hierarchy of reports, they must be more and more condensed. The project manager would obviously not have time to go through detailed reports from a large number of sites but must have them in a form which quickly tells him the status of the programme.

The reporting starts from the foreman level with a daily report of input in terms of labour, equipment and material. This is fairly simple and should be standardised. The reporting of output is more complicated and the format may vary depending on conditions. If there is a reliable bill of quantities,

reporting of chainage or station number is meaningful as it can be translated into quantities. If there is no bill of quantities less direct methods of measurement have to be employed. If task work or piecework has been used quantities for at least the major activities must have been estimated and should be reported. Where no exact and comprehensive measurement of quantities has been done the roads should be grouped into classes related to their degree of difficulty of construction. This could be based on the rough estimate done by the engineer's assistant mentioned earlier. A division into four or five classes would be sufficient to help judge whether the number of man-days used and the incurred costs are reasonable or not for the actual road. Due consideration must of course be given to large structures or other non-typical items.

The foreman should summarise his daily reports into a monthly report. This should go to the next level in the hierarchy which earlier has been called the technician. After having checked his foreman's reports they would be summarised and the technician's own costs added. These would consist of his own staff costs and overheads and transportation and various items which the foreman cannot easily price, for example, material or the use of equipment. Depending on conditions such as the availability of clerical staff the calculation of costs and summary of reports could alternatively be done at the engineer's office where of course his overheads should also be added.

The engineer should submit monthly reports to the project manager (headquarters). As a minimum these should contain:

- projects started, on-going and finished;
- progress in kilometers for different classes of roads;
- average costs and input of man-days per kilometer for different classes of roads;
- average costs and inputs of man-days per unit of output for different activities (where quantities are measured);
- breakdown of expenditure into labour wages, staff wages, equipment costs, tools, materials and camp and office costs;
- costs, type and sizes of structures;
- staff situation;
- total number of casual employees and worked man-days;

– utilisation of vehicles and equipment.

The control and reporting system should serve as an indication to supervisors at all levels whether his unit is functioning well or not. It can also be used as a feed-back system to continuously obtain more reliable data for planning at all levels and to improve fair piecework and taskwork rates.

5. Conclusions

It is not possible to simplify the planning and administration process by saying that there is one solution for capital-intensive work and another for labour-based work. Procedures and regulations are not the same in all countries and this has to be respected. Moreover, it is not possible or desirable to completely change the pattern of work within a PWD when introducing labour-based methods. Nevertheless, modifications and adjustments will be needed. For a programme to have any chance of success will depend on the possibility of making these changes or, in other words, the seriousness of the government's commitment.

The type and the size of the project is of great importance for planning and administration. A low-standard road project often consists of many small sites where each site, of necessity, will have limited staff and facilities. This obviously calls for other procedures than for the construction of main roads because there the technical requirements are higher, the sites are normally bigger and more labour and staff are involved at each site.

If the PWD has little or no previous experience of labour-based work the planning process must start well in advance of the construction of roads. The supply of labour must be analysed, particularly in respect of seasonal and regional variations. The role of the middle-management staff is crucial and some form of training will be necessary. It has to be recognised however that formal education is less important than man-management ability for most of the supervisory staff. Both staff policy and labour policy must be open to reconsideration. Because so many people are involved, standardised and formalised routines are indispensable.

The problems have to be identified and solved in each individual case and country. Engineers and administrators

must take the decisions and responsibilities. Nevertheless, persons with experience of similar types of projects from other countries can be of help in identifying problem areas before the problems arise and indicate solutions which have been effective elsewhere.

Notes and references

[1] Capas — Botolan is a main highway project about 100 kms north of Manila. A 6 km section of it was built as a pilot project using labour-based methods in 1974. It employed some 800 labourers and a large number of work animals. This is described in Deepak Lal, *Men or Machines: A study of labour-capital substitution in road construction in the Philippines*. ILO, Geneva, 1978.

[2] The Rural Access Roads Programme involves the construction of some 14,000 kms of minor roads in rural areas all over Kenya using labour-based methods. It started in 1974 and by the end of 1977 about 2,000 casual workers were employed. It is finally expected to employ about 20,000 workers and be completed by 1983. (See MOW/ILO/NORAD report, op. cit., and ILO, *The Rural Access Roads Programme, Kenya*, forthcoming publication.)

[3] The concept of planning and administration is here used in a rather wide sense although some facets of it, notably technical design, are excluded.

[4] See World Bank/ILO. *Programme Planning and Management Handbook*. Forthcoming publication.

[5] Various aspects of the payment of wages are covered under the Protection of Wages Convention, 1949, adopted by the International Labour Conference.

[6] Payment in kind is dealt with under the Protection of Wages Convention, 1949, adopted by the International Labour Conference. Inter alia, this restricts payment in kind to not more than 50 per cent of the total wage. This applies only to those people to whom wages are paid or payable.

[7] The recommended working week is 40 hours as laid down in the Reduction of Hours of Work (Public Works) Convention, 1936, adopted by the International Labour Conference.

[8] Questions related to the safety and health of workers have been dealt with in the ILO "Code of practice on safety and health in building and civil engineering work", ILO, Geneva, 1972. Questions related to accommodation and welfare facilities for workers have been dealt with in the Welfare Facilities Recommendation, 1956, and in the Workers' Housing Recommendation adopted by the International Labour Conference.

CHAPTER 4. EQUIPMENT FOR LABOUR-BASED ROAD CONSTRUCTION

by J.D.G.F. Howe and I. Barwell

1. Introduction

The efficiency of mechanised road construction methods has improved continuously because the manufacturers of plant and equipment, the main elements of production, have developed new and better machines which reduce construction costs and raise productivity. The main elements of production in labour-based road construction are the hand tools and simple items of equipment used. Yet, in those countries where labour-based methods are used there has been little effort made to improve the design of existing implements or to introduce new, simple techniques. This contrast was highlighted by ESCAP[1] 20 years ago when they described earthwork by manual labour as an ancient art in which there had been little or no progress in the techniques used. On the other hand they noted that mechanised earthwork, which is of comparatively recent origin, had made rapid strides because plant and equipment had been and are constantly being improved.

The scant attention paid to the implements used in labour-based road construction is difficult to explain fully, but two possible factors are worth highlighting:

i) while the implements are the *main* elements of production they are a very *minor* element of the construction *budget* and therefore their significance tends to be overlooked;

ii) the implements used are generally the traditional tools of the society undertaking the work and their familiarity means that the possibility of change or improvement is not considered.

The paucity of effort expended on developing appropriate

equipment for labour-based road construction is in itself a compelling reason for believing the potential for improvement to be virtually untapped. This contention is supported by the recent studies of the ILO and the IBRD to establish the limit to which labour can be substituted for equipment in road construction. Amongst the significant conclusions to emerge from these studies are:

i) that traditional labour-intensive civil works are inefficient and economically inferior to capital-intensive works, except at extremely low wage levels;
ii) that a major cause of the inefficiency of traditional labour-based methods is simply that the tools, equipment, techniques and organisation are invariably primitive; and
iii) that there exists a *range* of technically and economically feasible methods – varying from the most labour-intensive through *intermediate* techniques to the most equipment-intensive – depending upon the circumstances of the site and the application of superior tools, high incentives and good management.

The fact that the primitive nature of the technology has a limiting effect on efficiency is crucial because arguably it is the starting point in a series of events that at present condemn traditional labour-based methods.

Austen[2] speaks of:

> The vicious circle of primitive technology leading to low productivity leading to low wages leading back to primitive technology because we cannot afford to pay higher wages.

Two other elements could be introduced into the circle. Low wages leading to *"poor motivation"* – which accentuates the low productivity due to the primitive technology – and low productivity leading to *"the economic uncompetitiveness of labour with capital equipment"*. The wider use of more appropriate construction technologies that utilise wherever possible the labour resources most developing countries possess in abundance will clearly depend upon this circle being broken in as many places as possible. Improvements to tools and equipment is certainly a sensible starting point.

There are, however, formidable obstacles to be overcome. It is sobering to note that while gains in productivity from improved tools and equipment have been demonstrated

experimentally, there is little evidence that such improvements are being widely applied in practice. There are a number of reasons for this:

i) there is, unfortunately, no professional prestige in organising unemployed manpower: the glamour lies in the employment of sophisticated equipment. That this sentiment is widespread is undeniable, but why and what to do about it? Clearly there are many psychological reasons connected with the status and image of the engineer in the eyes of society at large and of his professional colleagues. If that is the case, there is reason for optimism in the changing attitudes towards more appropriate technologies that can be discerned world-wide;

ii) more specifically, present indifference by the engineer towards labour-based methods is perhaps because the *need for good quality, well-designed tools and equipment*, the *scope for using intermediate technologies* and the *inherent technical challenges* are not appreciated;

iii) there is no commercial pressure group to stimulate the development and use of new and better simple implements, in contrast to the situation that exists in the case of large, mechanised road construction equipment;

iv) in many developing countries the capability of local manufacturers to produce good quality, efficient implements is limited;

v) even where the capability exists, local manufacturers may be unwilling to take the financial risks involved in producing new or improved implements because there is a lack of proof of demand.

Attention to the design of existing tools is only one part of the problem of improving the technology of labour-based road construction. In most developing countries road construction practice remains highly labour intensive or highly capital intensive. Little use is made of intermediate techniques which are designed to be labour intensive, but incorporate some capital outlay on light equipment so as to improve technical or economic efficiency. The most promising future for labour-based road construction may well lie in the widespread adoption of these intermediate technologies.

Table 1: Available construction methods

Loading, Hauling and Unloading	Labour-Intensive Methods			Intermediate Methods		Equipment-Intensive Methods	
0-50 m	Hoe[1] into headbasket					Dozer	Wheeled loader alone
50-100 m		Hoe, wheel-barrow	Hoe, animals[2], panniers	Power winch wheelbarrow or rail wagon up slope of bank	Manually operated rail system		
100-200 m							
200-500 m		Hoe, animals[3], carts				Scraper with or without pusher	
500-1000 m			Hoe & head-basket or shovel into tractor/ trailer, unload by tipping or hoe or shovel	Hoe & head basket or shovel into flatbed truck, unload by hoe or shovel			Wheeled loader or tracked excavator into dump truck
1000-2000 m							
2000-5000 m							
over 5000 m							

Notes:
[1]The word 'hoe' is used in the study to describe the back-acting tool used for digging in soft soil and for loading, variously named 'powrah', 'mamti', etc.
[2]i.e. mule, donkey or camel.
[3]i.e. mule, camel or bullock.

The purpose of this chapter is to demonstrate the potential for intermediate techniques in labour-based road construction by focusing on earthwork operations and discussing the possibilities for developing some of the simple equipment currently used and for introducing new types of equipment. While the chapter is specifically concerned with earthworks this aspect of road building has been chosen simply as a means of illustrating the wider potential for intermediate techniques and the conclusions drawn can be applied equally to other road construction operations.

2. **Equipment and earthmoving**

The technical and economic feasibility of a range of technologies for construction is particularly well illustrated by the loading, hauling and unloading cycle for earthworks. Table 1 gives a summary of the results from recent World Bank studies in India and Indonesia[3]. For the purposes of this discussion there are two noteworthy aspects. First, the list of methods experimented with is not exhaustive and there are notable omissions. Second, there is a close correlation between the preferred construction method and the length of haul. From these observations and a detailed study of the experimental work on equipment it is possible to put forward two propositions that will form the basis of subsequent discussions.

First, that there remains considerable scope for improving existing methods and further gains in productivity and/or the haul range over which they are technically and economically feasible could be realised.

Second, that there already exist — generally outside the labour-abundant countries, either as working units in non-construction activities or as prototypes — a number of *other* possible innovative means for moving earth that could probably extend still further the choice for the engineer of technically and economically feasible construction methods.

In civil construction the current choice of earthmoving modes is much more limited than the diverse range of devices available for the transport of general goods. This observation is important since in civil construction hauling is fundamentally a transport operation, though it has certain specific characteristics:

i) the equipment is used very intensively in arduous conditions, and therefore needs to be ruggedly constructed if it is to be reliable and have a long life;
ii) the loading and unloading elements of the earthmoving cycle are critical in terms of maximising productivity and equipment utilisation.

Thus, while the principles of many of the devices currently used for goods transport can *potentially* be applied to haulage in civil construction, they will need to be adapted to the specific characteristics of this activity, if they are to be used with success. Discussion will be limited to methods which in table 1 are broadly classified as either labour-intensive or intermediate, lying between the headbasket and the flat-bed truck.

The headbasket is probably the supreme example of appropriate technology in road construction. It is simple, can be very cheap if made from local materials, and for certain tasks is as near optimum as any other method, e.g. very short hauls of 30 m or less, particularly on difficult terrain, and for the excavation and spoilage of material from deep culvert trenches. It offers little scope for improvement other than to find ways of introducing it to the many areas where it is not at present used. Two problems have to be combatted. First, lack of knowledge about the techniques and materials for making baskets, and the organisation and execution of work when they are used. Second, prejudice about the carrying of loads on the head, which is the case in parts of Africa, the Caribbean and Central South America. There are several sources of information about the first of these problems[4,5], whilst the second might best be overcome by a combination of education, demonstration and incentives.

Although table 1 classifies flat-bed trucks as an intermediate method of haulage this must surely be in an opportunistic sense only. If the facility is not being employed for the transport of conventional goods then it might be worthwhile to use it for relatively long-distance haulage. However, it can rarely be the optimum technological choice since as an expensive capital asset it cannot be economic to have it idle whilst it is being loaded and unloaded. The latter operation, particularly, is inherently slow. There seems to be little justification for trying to improve flat-bed trucks for earth haulage: better to develop more appropriate alternatives.

The technical options which follow are considered in order of their increasing power output: human, animal and engine.

3. **Human**

All labour-based methods of moving material require a somewhat different approach to the design of roads from that usual when equipment-intensive means are used. *This point cannot be over-emphasised as it is one of the most common misunderstandings.* Fundamentally labour-based methods require that haul distances be minimised wherever possible. Fortunately in most developing countries the borrowing and tipping of soil adjacent to the road is the normal practice rather than the balancing of cuts and fills along the length of the road which is usual with capital-intensive construction. The minimisation of haul distances is of course especially important for all human powered methods of haulage.

Wheelbarrows. Potentially the wheelbarrow is probably the single most useful item of equipment for labour-based road construction. For haul lengths of greater than about 20 m-30 m the use of wheelbarrows or handcarts increases the productivity of labour in earthmoving tasks compared with head, back or shoulder loading since the energy of labour is used much more efficiently.

A conventional wheelbarrow has a single wheel of fairly small diameter (up to 400 mm) positioned in front of the load pan. The single-wheeled barrow is superior to a two-wheeled handcart, primarily because, on the rough ground which prevails on construction sites, a cart is likely to be diverted from its direction of travel every time one wheel hits a bump, pothole or rock. However, many of the wheelbarrows commonly in use are of an extremely inefficient design and are poorly manufactured.

Perhaps the oldest of modern attempts at improved wheelbarrow design is to be found in the ILO Study, *Men who Move Mountains*[6]. It is surprising that the excellent work in this study has found little appreciation even among subsequent experimental investigators, much less so in practice. More recently the World Bank has initiated detailed investigative work on the use of wheelbarrows for haulage[7,8,9]. From these and other studies general design principles have been evolved.

For optimum performance of the wheelbarrow, resistance

to motion must be minimised, and this implies efficient bearings, maintenance of the haul route in good condition, and the use of a wheel with low-rolling resistance. (In this context a pneumatic tyre is beneficial and performance is improved by using a large diameter wheel.) Wheelbarrows must be very sturdily constructed to have a useful working life in the arduous conditions of a construction site.

Because of its low power-to-weight ratio, a loaded wheelbarrow pushed by a single person cannot normally operate on uphill gradients greater than about 6 per cent (World Bank) though short, steeper slopes can be negotiated by taking a run and using the momentum of the wheel to ascend the incline. For longer, steep slopes, assisted haulage can be used either by multi-person operation on the gradient, or by employing a winch. The latter practice was commonplace in the construction of railways and canals in Europe in the last century, although as then executed, using horse-powered winches, it was considered to be dangerous[10].

The Chinese Wheelbarrow. The wheelbarrow used in China has developed quite independently and differs from the conventional configuration in three fundamental ways[11,12]:

i) it uses a large diameter wheel and consequently has a very low rolling resistance. Traditional Chinese wheelbarrows had solid or spoked wooden wheels approximately 1 m in diameter[13]; Contemporary versions use a pneumatically tyred, tension-spoked steel wheel of about 700 mm diameter[14];

ii) the load is positioned so that its weight acts just behind the line of the wheel axle. This minimises the portion of the load which must be supported by the operator, though he has to apply some upward force at the handles. This upward force facilitates control of the barrow when turning or traversing bumpy ground. The load is carried above or on either side of the wheel, often retained in light woven wicker baskets;

iii) the operator uses a strap which passes across his shoulders and is attached to the handles of the barrow. This overcomes the tendency of the barrow to tip sideways due to the placement of the load. To avoid possible discomfort the operator may wear a broad leather collar on which the strap rests.

Because of the location of the load and the low rolling resistance of the large wheel a greater weight can be carried on the Chinese wheelbarrow than is possible on the conventional type. These barrows are extensively used in China for earth-moving work on construction sites, frequently operating in large fleets with additional labour to provide assisted haulage on gradients. The evidence of Chinese literature is that the operation of these fleets is not haphazard but is carefully planned and organised[15].

Experience of the device outside China is still very limited. The World Bank have carried out tests on conventional and Chinese wheelbarrows. The large diameter (626 mm) of the motor-cycle wheel used on the Chinese wheelbarrow significantly reduced rolling resistance and increased operator comfort by eliminating jolting. Greater loads of up to 180 kg could be carried at speeds comparable with other barrows, but the use of the shoulder strap was essential. The hill-climbing ability of the Chinese wheelbarrow was good at shallow gradients, where the effect of the low rolling resistance was probably significant, but on steeper slopes it was worse than other configurations because of the greater load. Assisted hauling was tried as was winching, but it proved difficult to balance the barrow on very steep grades. The general conclusion of this initial study was that the advantages of the Chinese wheelbarrows became more apparent on the longer, flatter haulage runs in excess of about 50 m.

The available evidence strongly suggests that there is an important role for the Chinese wheelbarrow in labour-based civil construction. It is worthwhile to examine the technical effort still required to optimise its use.

Further study is needed in the following areas:

i) determination of optimum wheel size, tyre width and tyre type, to minimise rolling resistance on the terrain found on construction sites;

ii) development of designs for strong, light, large diameter wheels that can be manufactured in developing countries, using local resources where at all possible. Suitable wheels are not readily available in many places, and while those from motor cycles can be used they are expensive and not necessarily the optimum size;

iii) optimisation of the design of shoulder straps. For construction work it may be that the best solution is a harness worn by the operator, into which the barrow handles fit;

iv) investigation of the effect of the position of the load on the barrow, including its placement above the wheel, on either side of it, or some combination of the two, so as to determine the optimum weight distribution;

v) detailed examination of the techniques used in China; of particular interest would be the programming of labour for hauling, loading and assisting on steep slopes;

vi) extensive testing in different countries to gain field experience.

Rail systems. Rail systems — manually, animal or machine powered — have always been of considerable importance in mining and tunnelling. The ILO's pioneering study, *Men who move mountains*[16], was probably the first of recent attempts at evaluating the general usefulness of manually operated rail systems in civil construction. More recently still the IBRD have conducted some studies, also in India[17]. The IBRD found that the ease and frequency of track laying were crucial factors affecting the viability of a rail system. Thus, unless they can be made light and easily portable, manual rail systems are likely to be most viable when large quantities of material have to be moved over a fixed route. This is not often the case with road works unless the terrain is severe or centralised borrow-pits and quarries have to be exploited. Clearly their use is also very sensitive to the ruling gradients of the site. The ILO found that the maximum slope that could be managed comfortably by a team of 4 pushers was 1 in 40 (2.5 per cent) with a payload of 1,250 kg.

Both studies concluded that under the right conditions manually operated rail systems were capable of giving worker outputs at least 3 times as great as those using traditional methods. Notwithstanding this encouraging result, it has to be pointed out that in neither case could the quality of the experimental work be considered high. The equipment tested was largely "as found" with only minor development modifications. (The photographic evidence suggests that the trucks were designed for locomotive rather than manual haulage and thus were probably unnecessarily heavy.)

Clearly there is considerable scope for further development work on the vehicles and track which the ILO study both acknowledged and provided constructive suggestions for. These included[18]:

- determining the optimum capacity of the trucks;
- lowering the loading edge;
- improved shape to assist unloading;
- reduced weight;
- improved tipping geometry;
- provision of pushing bars; and
- improved winching arrangements where necessary.

It is worth nothing that manually powered rail systems are used in East Africa for harvesting sisal. The plantations are usually large and presumably the method is viable only because both the track and vehicles are light and have been designed for maximum portability.

Pedal power. The bicycle is ubiquitous throughout the developing world and in several countries — predominantly Asian — the pedal powered system of propulsion has been applied to goods carrying tricycles and, to a more limited extent, to stationary applications such as water pumping and crop processing. Although the principle of generating human power by applying the legs to rotating cranks is a highly effective and well-proven method[19], it does not seem to have been employed in civil construction[20].

Wilson[21] has pointed out that in terms of ergonomic efficiency (energy consumption per unit weight per unit distance) transport by cycle is supreme among moving creatures and machines. However, the cycles that have been developed for goods transport are invariably economically inefficient. Any form of gearing is rare so that acceleration from rest when loaded or ascending even modest gradients is very strenuous. Few have an efficient brake system and most are unnecessarily heavy, but these difficulties are relatively easy to overcome as Wilson[22] has shown. A recent study in Bangladesh emphasised the problems of the conversion of urban cycle rickshaws for use in the rural areas[23].

However, it is likely that the greatest potential for increasing the efficiency of human labour in civil construction by the use of pedal power lies in devices rather different from those employed in road transport. Such devices would be designed

to meet the particular operational requirements of earthmoving activities. For example, a pedal-driven vehicle specifically designed for earthmoving might well be operated by more than one person, as in the radical concept proposed by Wilson[24]. Termed the "pedal rover" it is a four-wheel-drive vehicle having four large wheels, 1 or 1.1 m in diameter, each directly pedalled by one man sitting astride as on the early "penny-farthing" bicycles. The front and rear halves of the vehicle are hinged together at the centre in such a way as to provide steering (by means of cables) and also to allow relative twisting of the two halves to accommodate uneven ground without strain on the chassis. Since the weight of each rider is directly above each wheel and the load compartment is in line with the axles the bending load on the structure is minimised so a usefully large load, e.g. 400 kg should be possible with a modest vehicle weight.

Another possible application of pedal power to wheeled haulage is in the propulsion of rail carts, an innovation that could well enhance the productivity of these systems.

Finally, the available evidence[25] suggests that the useful power output of winches would be at least doubled by using a pedal drive system in place of hand-cranking. These could be applied to various aspects of construction such as hauling wheelbarrows up inclines.

4. **Animal**

The experimental work of ILO and IBRD shows that, under the right circumstances, animals can be a most appropriate source of power for haulage in civil construction. Yet, except in a few areas, they are rarely used for this work. In such continents as Africa, where the domestication of animals for work purposes is still uncommon this is understandable. However, the repudiation of animal-based agriculture as a backward step in the "modernisation" of African farming is becoming less common and the majority of countries are actively promoting its use. Thus, conditions are becoming more favourable for the use of animals in construction. In Asia, where animals are used extensively as a source of power, both in agriculture and in transport, their limited use in civil construction appears to result largely from the unsuitability of the indigenous technology, i.e. poor pannier and cart design.

Animal panniers. The use of animals equipped with panniers for hauling road construction materials is a very specialised technology that appears to be uncommon outside of certain parts of the Indian subcontinent. It is, however, a form of haulage that has peculiar advantages wherever the terrain results in uneven or steeply sloped working conditions and wheeled transport becomes inoperable. In these circumstances the famous surefootedness of the donkey and mule, in particular, come into their own. Experience in India[26] suggests that donkeys are capable of carrying 100-200 kg of earth (for haul lengths which typically are between 75 and 200 metres) in woven-rope panniers, but whether this is the maximum payload or optimum carrying device is uncertain[27]. In other countries horses and camels are used as pack animals, but little information is available on typical loads or the optimum design of panniers for the carriage of soil. Indeed a recent IBRD literature survey[28] found very little information which was directly relevant to the use of animals in civil construction and nothing to suggest that any substantial research had been done in this field.

Clearly there is considerable scope for improving our understanding of the use of pack animals in construction activities. The major area for improvement is pannier design which is likely to affect not only the maximum load that can be carried but perhaps more important, the speed with which it can be loaded and unloaded.

Animal carts. In the countries where animal carts are common there is a growing appreciation that the scope for improving their general design is considerable. India, perhaps the home of the bullock cart, is actively trying to overcome the defects of designs that have hardly changed since the Mohanjadaro civilisation (3000—2000 BC). Pioneering work in identifying these defects has been done by Mr. N.S. Ramaswamy, Director of the Indian Institute of Management (IIM), Bangalore[29]. The major drawbacks of the traditional vehicles are poor axle bearings, wobbling wheels, excessive tare weight, the absence of a braking device, excessive friction between the road and the wheel, and poor weight distribution over the cart length. But the worst part of the design is the damage and cruelty caused to the animals. A crude harnessing device, a wooden bar, rests on the animal's neck in front of the

hump, making the skin calloused and very often cancerous. Moreover, in the traditional design, the animal's neck forms one of the resting points of the payload. Almost invariably these factors are wasteful of pulling power since they conspire to exert a throttling force on the animal in proportion to the effort it attempts to exert: it is hardly surprising that the animals appear unwilling to work!

In conditions encountered on construction sites, a pneumatic tyred wheel running on ball bearings is likely to be more appropriate than traditional wooden designs, and the intensive use of the carts should justify the higher cost involved. Pneumatic tyres specifically intended for animal cart use are manufactured commercially in India under the name ADV (Animal Drawn Vehicle). A simple way of constructing a cart with this type of wheel is to use an old truck axle complete with hub mountings. However, this is likely to be excessively heavy, and a better approach is to develop a fabricated axle. In a joint project, the IIM and College of Engineering, Coimbator have designed a new cart for rural use which has a lightweight integrated chassis and draw-bar fixed on a fabricated axle. This is said to cost little more than the traditional design.

The problems of traditional yoke harnesses can probably best be overcome by the use of the three-pad collar harness developed in Germany some 40 years ago, and now used universally on European bullock carts[30]. This harness rests on pads on the neck and shoulders while leaving the front of the neck unrestricted so that the animal can breathe freely. In addition to eliminating the discomfort of the animal the harness transmits its power, which is generated largely by the strong shoulder muscles, more effectively. It has been estimated that this harness can double the useful output of the animal[31].

It is necessary to recognise that materials haulage for civil construction poses its own peculiar requirements for cart design: low loading height and ease of unloading. Neither problem has received much attention, but there are signs that this is changing. In the Philippines the ILO[32] modified the traditional animal-drawn cart by substituting a removable bamboo mat for the fixed floor, thus enabling a crude form of "bottom discharge" to be effected.

There have also been various attempts to produce a cart

whose body can be tipped without unyoking the animals for the unloading operation, notably at the Agricultural Farm, Nagpur, in India[33] and at Ahmadu Bello University in Nigeria[34].

All single-axle carts must invariably cause much stress to the animals, with consequent loss of pulling power, under the rough surface conditions typical of construction sites. Therefore, a more beneficial line of development might be with two-axled carts. These were the dominant means of haulage during the great era of European railway and canal construction. In many cases a light rail track was laid and the cart equipped with flanged railway-type wheels. This is arguably a *forgotten* rather than an *inferior* technology since the labour productivities were typically six times as great as those currently achieved in labour-based earthwork operations in developing countries. Since the latter are already competitive with equipment-based methods in some circumstances, the potential benefits of raising labour productivities towards the levels achieved in the past are considerable. The available evidence suggests that the operation of animal-drawn carts on light construction rails is a technology that is worthy of re-examination.

Animal-drawn scrapers. The main application of these devices is for the movement over short distances of previously loosened earth.

Although this is not included in the list of methods given in table 1, they have been used in the past, particularly for the levelling of land for agricultural purposes. More recently the ILO has demonstrated their suitability for road construction during studies in the Philippines[35]. The report on these studies makes clear that there is scope for improving the design and manufacture of the scrapers which were developed from the traditional bamboo (originally Chinese) scraper used in agriculture. Furthermore it seems likely from the photographic evidence of the experiments that the harnessing arrangements could also be improved in the same way as for bullock carts. The range of soils for which scrapers can be used will be proportional to the tractive effort the animal(s) can provide and this is very sensitive to the harnessing system.

5. **Engines**

There exists at present a huge gulf in terms of power output

between animal-drawn earthmoving devices and conventional capital plant such as scrapers, dozers and dump trucks. It is therefore, worthwhile to consider the potential, in earthmoving for using devices powered by small, low-output engines. In general, diesel engines are likely to be more suitable for construction work than petrol engines for reasons of reliability, longevity, maintenance and running costs.

Single-axle tractor. The two-wheeled, or as it is more commonly known, single-axle tractor, powered by a single cyclinder 7.5-9 kw (10-12 hp) diesel engine has played a vital role in the mechanisation of Chinese agriculture and is also a major element of the rural transport system when hitched to a trailer[36]. In this mode it provides transport from the commune to the town and back again, with a payload of 1,000 kg and a maximum speed of 15 km/hr. It would appear from the evidence that single-axle tractors are also used for some construction activities in China, but the extent of this practice is not known.

Single-axle tractors are now beginning to find a place in India, and in the Philippines where some 7,000 machines are produced each year to a design developed at the International Rice Research Institute (IRRI)[37]. The IRRI design, which sells for about half the price of comparable imports, is illustrative of how such a device can be produced economically by small industries in developing countries. IRRI have achieved this by developing a design which makes extensive use of readily available components such as motor-cycle and automotive parts, and limits production operations to fabrication and simple machining. Single-axle tractors are also used on a wide scale in agriculture in Switzerland, Germany and Austria.

Single-axle tractors could be used in civil construction for hauling and for other operations (e.g. ploughing, ripping, grubbing, rotavating, etc.) since they have much of the flexibility associated with conventional, but very much more expensive, agricultural tractors. Their principal advantages would appear to be low-cost and robust simplicity, but whether these qualities are cost effective when employed as an aid to labour on civil construction remains unproven.

Small cargo carriers. A wide range of three-wheeled, motorcycle based vehicles are used in cities in Asia, Southern Europe and Central America for goods and passenger transport. In

certain places the operation of these vehicles has begun to extend from urban to rural areas. Partly as a result of this, and also because of the influence of single-axle tractors, a new breed of three-wheelers is emerging specifically designed to meet the more arduous conditions and somewhat different requirements of rural transport. Perhaps the most notable are a number of cargo carriers now being manufactured on the island of Crete[38]. These differ in details of design, but typically use a single-cylinder diesel engine of 6-9 kw (8-12 hp), have a payload of about 1,000 kg and maximum speed of 40-45 km/hr. These vehicles are robust, easy to maintain, and can be produced economically by small-scale enterprises. In the Philippines the IRRI has developed a motorised cart consisting of a single motorised and steered wheel hitched to the front of a two-wheeled trailer. This was originally designed as a means of transporting a portable rice thresher from place to place, but is now in great demand as a general-purpose goods carrier[39].

With the exception of a water bowser similar vehicles for civil construction have not been evolved, yet there would seem to be considerable potential for their use. Light, fast and maneouvrable yet robust vehicles based on a well-established technology should logically be intermediate in application between the simplicity of animal power on the one hand and the complexity and *expense* of conventional tractors or capital earthmoving plant on the other. There is some evidence that this is being recognised. They are especially favoured by municipal maintenance organisations whose activities typically involve restricted loads and journey lengths for which their use is economic. Serious attempts to extend the use of such vehicles to civil construction and to determine what potential, if any, they possess, have yet to be undertaken.

Tractor-trailers. Theoretically the tractor-trailer combination appears very attractive for labour-based construction. It is usually presumed that in agricultural communities tractors should be available for at least part of the year. However, the main justification for considering them as complementary to labour-based construction is that one tractor can be used with several trailers for transporting spoil of fill material. Thus, instead of a whole dump-truck unit standing idle whilst it is being hand loaded, only the trailer is stationary: the tractor,

which is the expensive component of the combination, is fully occupied in shuttling trailers back and forth. It also has several other useful capabilities such as ground preparation by ploughing and ripping; grubbing; rotavating for mix-in-place lime, cement or bitumen stabilisation; compaction with towed rollers; and general haulage of water, cement, culverts, labour etc. The IBRD has published comprehensive advice on the use of tractor-trailer combinations in civil construction together with analytical methods for assessing their viability in relation to conventional trucks[40]. However, practical experience of their use is very limited. The most ambitious attempt to use them in road construction has been in the Kenya Rural Access Roads Programme[41]. This has given valuable experience on the most appropriate forms of tractor-trailer combination. It has also shown that trailers, in particular, need to be very carefully constructed if they are to withstand the rigours of a construction site and special designs have had to be produced[42].

A further lesson from the Kenya experience relates to tractor size. Initially, 75 hp tractors were specified, but smaller, 45 hp machines have now been substituted. These smaller tractors are considerably cheaper, are quite satisfactory for the work involved and, since they haul smaller trailers with reduced sill height, loading by shovel is easier[43].

6. **Discussion**

We have sought to demonstrate that there is considerable scope both to *improve*, and to introduce *innovations* into the range of equipment currently used for labour-based road construction. We have done so by considering only the "earth-moving" phase, but the arguments and conclusions could be applied equally to the other phases of civil construction. The purpose of either improvements or innovations would be to increase the competitiveness of labour with machinery and thereby its employment prospects. However, it would be mistaken to think that the technical problems are so simple that they can be solved with little effort or skill. Experience has shown that it often requires the very best technological skills to solve, what look to the untrained eye, to be simple problems. The humble wheelbarrow has been used in civil construction for well over 100 years yet the great majority continue to be badly engineered and, in a scientific sense, to

contain fundamental deficiencies in design. Neither of these problems will be overcome without the best technological skills.

To suggest that an alternative technological choice exists or that traditional techniques can be upgraded is, of course, merely the first step. There are considerable obstacles both to their development and application.

The manufacturers of capital equipment are very organised nationally and internationally, and well able to promote their products among government agencies and to supply adequate maintenance and spare parts facilities. There are no comparable pressure groups of manufacturers for equipment suitable for labour-based construction and because there are few present demands, maintenance and spares are poor or non-existent. Indeed, for most of the equipment described in this chapter there is rarely any indication of whether local manufacturers would be capable of meeting demands if they existed. Conversely without such a demand an entrepreneur is unlikely to invest in producing, say, an improved animal-drawn scraper unless he is reasonably sure that sales will at least cover costs. Under these circumstances credit to finance such an investment is also equally doubtful. To overcome these obstacles will require an initial financial commitment by government to develop and test the type of equipment described. If this is successful then the equipment could be used on various pilot projects to establish its long-term efficiency.

It is important that the development engineers should work in co-operation with potential local manufacturers preferably in the small-scale sector to ensure that the equipment is sutiable for indigenous production. At the production stage it may well be necessary to assist local manufacturers with finance, with technical advice and with support in such matters as ensuring the supply of specified materials in the small quantities which are all their limited capital resources will permit. However, perhaps the most important form of assistance, if small industries are to accept the risk involved in embarking on a new manufacturing venture, is to ensure that they have a secure market for their products.

Certain of the technologies which are described in this chapter already exist in some countries but have not been

applied in others, or have not been used in labour-based road construction. If the maximum benefit is to be realised from these, and from hardware development programmes in different parts of the world, then there is a need to make detailed information on new or improved implements widely available.

As has been shown, the potential for improving the technology of labour-based road construction is virtually untapped, and there is no shortage of soundly based ideas to be developed and tested. What is needed now is the will and commitment to do so.

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CHAPTER 5. THE PRIVATE CONSTRUCTION SECTOR AND APPROPRIATE TECHNOLOGY

by A.D. Austen

1. Introduction

The three previous chapters have been concerned with problems of implementation. By and large they have viewed the issue from the standpoint of the government. In this chapter we look at the private sector and the implications for it in the use of appropriate technology. For most developing countries, the provision of roads, houses, irrigation, water supply and sanitation accounts for a major portion of annual capital expenditure. Furthermore, industrial development, too, has a large construction element. Thus, whatever the political, social or economic theories may be which determine the allocation of national resources, the translation of development plans into reality relies heavily on the construction sector. It is also true to say that, without exception, the implementation of government programmes of infrastructure development is in the hands of government ministries, departments or state enterprises. Inevitably, such programmes involve an ever-increasing expenditure on the maintenance of the works which they produce.

Despite the fact that the money for infrastructure development, and indeed for a great deal of industrial development, comes from government and that government agencies are almost exclusively responsible for implementation, the private construction sector plays a major part in the execution of these programmes in most of the countries of Asia and the Pacific. It is therefore not sufficient to consider the problems and implications of appropriate technology as they affect government agencies only, we must also take into account the instrument by which those agencies execute many of their schemes — in other words, the private construction sector.

In order to do this, it is necessary to examine the nature of the industry which has unique characteristics. Many millions of words have been written on this subject, so in this paper attention is concentrated on those factors which influence the neglect, adoption or rejection of appropriate technology in the private sector. This is done by first of all discussing the environment within which the industry operates, and then considering the latter's internal structure. Finally, some suggestions are made as to how some of the factors which inhibit the application of appropriate technology may be removed.

It is of course realised that in a regional context both the analysis of problems and suggestions for their solution is necessarily generalised, since conditions vary from country to country. Nevertheless, there is likely to be sufficient similarity in the nature of the problems encountered to engender a meaningful discussion, although ultimately each country must evolve its own national solutions for its national problems.

2. The operating environment of the construction industry

The market for the products of the industry is dominated by the government. This is probably a universal fact, but because of the greater need for infrastructure development in developing countries, the dominance amounts to a near monopoly. Therefore, government policies, legislation, regulations and the attitudes of its civil servants are largely responsible for moulding the industry into its present form. This does not imply inevitability, exclude the possibility of change, or remove all responsibility from the shoulders of the private sector but, as in nature, the contractor must adapt to his environment or perish.

Another important factor is the existence in many countries of a large pool of unemployed and underemployed workers who can be hired and fired on a casual basis. Indeed, it has been stated[1] that, in India at least, this is the major reason for the lack of innovation within the industry.

This operating environment is now discussed under the following headings:

- government policies;
- conditions of contract;

- attitudes;
- functional divisions;
- employment.

2.1 *Government policies*

The construction sector is used by many countries, both industrialised and developing, as a crude but effective economic regulator. When the chill winds of recession blow it is a relatively simple matter to slow down or stop the construction of motorways, power stations, water supplies, houses, etc., since all of these depend on government financing. That many thousands are thereby thrown out of work is unfortunate, but politically is not too disastrous since the construction industry even in a highly industrialised country relies heavily on casual labour. Such labour is accustomed to cyclical swings, and also tends to be less organised than labour in other industries. Furthermore, the impact on the ultimate consumer is not immediate, since most construction projects are relatively long term, so that by the time the effect of the non-provision of a motorway or the reduction in maintenance is felt by the general public the economy may again be on the upswing, in which case public protest will be muted. A current example of the converse situation is to be seen in Japan where, in order to stimulate domestic demand, the Government has embarked on an ambitious public works programme.

Thus, whether used as a brake or an accelerator, construction offers a simple and politically safe way of controlling the economy, and its appeal is therefore irresistible, although there are many cogent agruments why such a policy is a short-sighted one.

It is not only at the macro level that government policies affect the industry, but also at the micro level. In most Asian countries, construction budgets are allocated annually by the treasury or budget bureau. This means that even projects which have started may find themselves without funds when the annual budget is allocated, since short-term financial considerations rather than longer-term economic objectives or engineering logic reign supreme.

In many countries, construction is not recognised as an industry in the same way as are manufacturing or processing

or steel making or mining, etc. This means there is no legislation framed specifically for construction. However, it does have to operate within, for example, a factories act. This can produce some very strange results: if the factory act requires that the air in the factory be kept free of dust, and a worksite is a factory within the meaning of the act, then a 10, 50 or 100-mile road construction project is a site, and how do you keep *that* free of dust? In practical terms, of course, everybody realises that in these circumstances the law is just not applicable, but this means that the law falls into disrepute, and then such important matters as the safety, health and welfare of workers in the industry are not adequately provided for.

For the private contractor, this lack of recognition means that not only does he lack the status of other industrialists but that he probably has problems in raising capital from lending institutions. These problems are particularly acute for the smaller contractor and are intensified if he is using a labour-based technology, since this means that his fixed assets of equipment and plant are lower in relation to his working capital than in a machine-based technology. Even if lending institution can be persuaded to lend money to this category of contractor, it will only be against the security of his fixed assets and not to meet his weekly or monthly wage bill, so that the larger the latter is relative to the former the more difficulties he faces, particularly as contract payments will usually be at least one month behind work completion.

2.2 *Conditions of contract and government regulations*

It is the usual practice that contractors working for the government are classified according to its own assessment of their capacity to carry out projects up to certain maximum values. The criteria used for the assessment will include such factors as financial standing, technical staff, experience, and available plant. The greater the value of the contracts to be undertaken, the more need there is assumed to be for larger items of mechanical equipment. This could mean that the small contractor proposing to use bullock-drawn carts and scrapers would not get on the register of approved contractors because, for example, there was a requirement that he own at least two tipper lorries and a grader, whilst a larger contractor prepared to mobilise a large labour force using appropriate

technology equipment would also not qualify as a major contractor because he was required to own heavy earthmoving equipment.

In addition to regulations governing the contractor in his tendering for government contracts, the conditions of contract and specification themselves often militate against the use of appropriate technology. These are in general based on western practices and may therefore specify the use of plant when there may be alternative methods of achieving the same result. Performance specifications are still relatively rare — that is to say, a specification stating what the performance of the finished product should be without stating how that performance should be achieved. Thus, a base course might be required to have a dry density of 100 per cent, without going on to say that it will be given a minimum number of passes of a 12-ton roller. Of course, the use of this type of specification implies technical competence on the part of the contractor, and particularly in the case of small contractors this is frequently lacking. Nevertheless, the specifications presently in use do inhibit the use of any new or different technology.

2.3 *Attitudes*

As soon as one begins to discuss attitudes, one is moving into a somewhat subjective and sensitive area. Nevertheless, since attitudes do have an important bearing on the subject of application of appropriate technology, they should be discussed openly and frankly.

The attitude of the professional engineer to the private contractor will naturally vary from person to person and will be coloured by all sorts of complex relationships, but certain behavioural patterns can be detected. Among these is a feeling of superiority arising from superior technical knowledge, superior education, and something of a master-servant relationship. Do not think that this is unique to the Asian scene — even today in industrialised countries the term "contractor" often has a denigratory connotation, but this is far less the case than it used to be.

Coupled with this feeling of superiority is a tinge of envy, since the contractor may be making a great deal more money than the professional engineer, many of whom are relatively poorly paid. Thus, the large Mercedes, the unlimited expense

account, the modern house are conspicuous marks of success to which the engineer cannot attain.

Finally, there may be a feeling of guilt and dependence if the engineer is engaged in corrupt practices. This is naturally a very sensitive area, but it is no use pretending that these things do not occur, and none of our societies, whether of the East or West, is free of such practices, which have a marked effect on the relationships between engineers and contractors.

Now an industrial psychologist could undoubtedly explain these relationships in technical terms and the above may appear rather simplistic; what matters, however, is the effect on the application of appropriate technology. The principal effect is that because contracting is regarded as somewhat inferior to engineering, there is reluctance on the part of qualified engineers to move over into the private sector. This is much more marked in the case of the small contractor, since the large contractor can offer status and compensatory awards for the engineer who moves over. The net result is that the small private contractors are starved of the talent which could introduce new ideas and improved technologies. It may be argued that there is no reason why the engineer should not be able to infuse these ideas into the private sector from his existing position, but he is not motivated to do so. The engineer accepts no responsibility for the actual execution of the work and would regard any effort on his part to introduce new ideas as merely contributing to increased profits on the part of the contractor without any benefit to himself.

These attitudes, then, mean that the private contractor is nearly always regarded as innately inferior in status to the engineer, and this is self-perpetuating since it starves him of the managerial and technical expertise which he needs to improve his status. It is this talent which could make him more innovative and thus more likely to adopt appropriate technologies.

2.4 *Functional divisions*

Much has been written about the inefficiencies arising from a system whereby the responsibilities for design and for construction are usually separate and distinct, so it is not intended to rehearse the arguments. What this does mean is that there is no incentive whatsoever for the contractor to innovate. He is

given a design, he is expected to stick strictly to that design and, incidentally, he is still held to be responsible if the structure falls down. Furthermore, the contractor is in business, naturally enough, to make a profit, and the only way he can be sure of doing this is by working within the system and relying on conventional methods. His instinctive reaction to the suggestion that he try something different will be: "Show me it working successfully and profitably somewhere else, then I might consider it".

Not only does the construction system militate against innovation, but it also offers no real incentive for efficiency, and this is especially true as regards small contractors. On the face of it, a system whereby every project is open to competitive bidding, and where the lowest tender must be accepted, should result in a high level of efficiency, but in practice this is not so, for the following reasons:

a) The contractor has no control over the design and specification of the product he manufactures. In this respect he differs radically from the man who manufactures teapots, for example. If the latter can improve his design and the efficiency of his manufacture he can presumably sell more teapots at a higher profit. The incentive therefore exists for him to do some market research to find out what his customers want, then to design a teapot which will not only satisfy market needs but which will be economic to produce. The system prevents anything similar happening in the construction sector, since the contractor can influence neither the design nor the market for his product. (Like all analogies this one must not be pushed too far, but it serves to illustrate the point.)

b) The competitive tendering system merely establishes a market price, it does not contribute one iota to efficiency. A contractor can still make an adequate profit even though he is operating inefficiently, provided that he is operating at about the same level as other contractors. For any given project, the material content is fixed so that the size of the contractor's margin depends on only two factors: (1) his overhead costs, and (2) his labour productivity. Now the overhead costs of the small contractor in particular are likely to be very low – he

probably works from an office in his house and has a staff of a foreman and a clerk-cum-storekeeper. There is therefore little or no scope for any reduction. This leaves labour productivity. All the small contractors working in a particular area will be drawing on the same pool of labour, and that labour will employ the traditional tools and methods, so that productivity will not vary greatly whether the labour works for contractor A, B or C. Furthermore, the contractor's profit margin will not be affected because all the contractors are adding a percentage to what might be called the lowest common denominator of labour output.

c) Finally, the engineer's estimate of the final product, be it a road or an irrigation system or a building, is almost always known before tenders are invited. This estimate is necessary for budgeting purposes, and most engineers tend to be conservative when preparing it since over-expenditure on a project will involve them in interminable arguments with their financial controllers. It therefore establishes a maximum figure beyond which any bid is almost certain to be rejected. On the other hand, it certainly does not necessarily represent an estimate of a reasonable price, assuming efficient operation on the part of the contractor. Experience soon teaches a contractor what percentage below this figure he must bid at to have a reasonable chance of winning.

Thus, the way in which the total cnstruction system is organised, and about which the contractor can do nothing, is inefficient, and the spur of real competition is lacking. Safe and traditional methods of working are therefore preferred and the adoption of appropriate technology is inhibited.

2.5 *Employment*

One of the unique characteristics of construction which has an important bearing on the industry's attitude towards innovation is the structure of the labour force. Not only is the proportion of unskilled labour very high, but this labour is employed on a casual basis. Most of the reasons for this are well known:

- lack of continuity in work supply to the contractor;
- the "one-off" nature of the projects;

- climatic conditions;
- the wish on the part of employers to avoid social welfare obligations.

The most important reason, however, is the existence in most if not all of the countries in Asia of a large pool of labour which is willing, nay anxious, to work on this basis.

Thus, the employer, whether government or private, can easily match his fluctuating workload with a fluctuating workforce. Add to this that the workforce is unorganised, illiterate and poor, that the contractor can still make a reasonable profit margin despite the low productivity of his workers, and one sees why the industry has no incentive to change. As Johri and Pandey[2] say, "...the industry is capable of quantitative expansion but not of qualitative change". This is especially true of the small contractor who often works with a technology which has not changed for centuries.

Given then that the industry has no incentive to adopt an improved technology largely because of the existence of a large pool of unskilled labour, the dilemma that must be faced is: if by some means it *were* persuaded to adopt an appropriate technology, would not the improvement in productivity result in the employment of *fewer* workers?

Let us look at this a little more closely.

It is of course true that if productivity can be increased, then for a given total output the labour input will decrease. If these inputs and outputs are expressed in money terms, this means that the difference between the two will also increase.

There are then three ways in which this differential can be used:

a) improved wages for the workers;
b) higher profits for the contractor;
c) lower total cost for the client (usually the government).

The first of these is obviously of benefit to the worker and achieves one of the objectives of the ILO's World Employment Programme — that is better income distribution — whilst the third benefits the community as a whole. It has already been pointed out that the contractor can make a reasonable profit margin despite low productivity, and this is an argument for not giving him higher profits; on the other hand, since we want to encourage him to increase productivity, some incentive is probably necessary. The way in which the benefits arising

from improved productivity are distributed is an example of a situation where one cannot pontificate on a regional basis; each country must decide for itself in the light of its national circumstances. What is generally certain is that if the application of appropriate technology results in increased productivity the industry has the opportunity to break out of the vicious circle of primitive technology leading to low productivity leading to low wages leading back to primitive technology because we cannot afford to pay higher wages.

This still leaves unsolved, however, the problem of increasing the total amount of employment available, even though the wages and conditions of those who *are* employed can be improved. The clue here lies in the use of word "substitution". Thus the World Bank calls its study "the substitution of labour (sic) and equipment in civil construction"[3]. The implication is clear, namely that work which would otherwise be done by machine can become available for labour, subject of course to the various constraints that have been discussed. Thus the reduction in total employment arising from increased productivity can be more than compensated for by increasing the market share of labour-intensive projects. Indeed, it is a prerequisite of increasing the share of the market that productivity be increased so as to compete with capital-intensive technologies. Furthermore, a private sector equipped with appropriate tools and techniques will possess the enterprise to seize the opportunities thus presented.

In summary, the existence of a large pool of unskilled labour enables the private contractor, especially the small one, to expand and contract to suit the market without any need for internal change. His margins are unaffected by low productivity, there is little genuine competition, so the impetus for innovation is negligible. If, however, the right environment and motivation can be found for the application of appropriate technology, productivity will increase, wages and conditions of workers will improve and the greater share of the market now available will result in employment creation.

3. **Structure of the private construction sector**

This is characterised by two extremes: the large contractor, indistinguishable in most respects from his counterpart in the industrialised world, and the very small local contractor short

of capital, equipment and know-how. This represents an important difference from the situation in the industrialised countries where, in addition to these extremes, there is a middle section comprising medium-scale contractors, many of whom are old established and competent within the limitations of their capacity. The existence of a more or less complete spectrum means that movement across it is a possibility for those that wish to make it, whereas, in Asia, to cross the gap would require a leap beyond the capability of most. Thus the small contractor remains trapped in a situation from which he cannot escape by his own efforts.

Let us examine a little more closely these two extremes; firstly, the large contractor.

3.1 *The large contractor*

In this category are included state-owned corporations, such as the National Engineering Corporation of Nepal, or the National Buildings Construction Corporation of India, since, although these are government owned, they are intended to operate in the same way as a private contractor, and they are generally similarly structured. Large can only be defined quantitatively in the context of each individual country, since what is large in Afghanistan with a population of 19.5 million[4] may be small in Indonesia with a population of 134.7 million, but in the sense of this paper a large contractor is one capable of undertaking major construction projects such as highways, major irrigation schemes, housing developments, hotel developments, etc., whilst a small contractor is one capable only of building rural roads, minor irrigation schemes, small housing projects, etc.

In the early stages of development of most countries in the Asian region, there was no local contracting industry capable of carrying out major works, many of which depended also on large amounts of foreign capital, so it was perhaps inevitable that foreign contractors should be brought in. In course of time, local businessmen seized the opportunities afforded by an expanding construction sector and set up as contractors, modelling themselves, naturally enough, on the examples before them and frequently starting as subcontractors. The more successful of these entered into joint ventures with the foreign companies, and in many cases ultimately took over all

the business, although sometimes retaining a name linking them with the parent company. Examples of these are Ital-Thai in Thailand, and McDonald Layton Costain of Pakistan.

At this end of the spectrum, therefore, we have large contractors of three types:

a) international contractors, usually working on large projects financed by IBRD or ADB;
b) joint venture contractors working on similar projects, but some of which may be locally financed;
c) local contractors (including state corporations) working on large national government and private contracts.

All three categories will, however, have similar financial and organisational structures, which is hardly surprising since, as indicated above, they are all descended from the same stock and they are all working within the same kind of contractual framework.

An important feature of the operation of the large local contractor is the extent to which the work is executed through subcontractors, and this has widespread implications, which will be examined later. These subcontractors are essentially suppliers of skilled labour only, and generally do not supply materials or equipment which remain the responsibility of the main contractor. This is not to imply that they are only agents for the supply of labour — they are more than that, since they undertake to carry out certain sections of the work for a fixed price or at an agreed rate. Thus the carpentry subcontractor will agree to fix the centring for a bridge span at a certain price, with the main contractor supplying the necessary timber, scaffolding, etc., but with the subcontractor supplying and paying all the labour, for which the main contractor accepts no responsibility. An important consequence of this is that this labour does not appear on the payroll of the main contractor. This constitutes an important difference between large national contractors in Asia and those in Europe since, although the latter frequently use subcontractors, the use of labour-only subcontractors is generally illegal.

This type of subcontractor constitutes an informal group within the formal organisation of the main contractor and will be bound together by traditional ties of craftsmanship, tribe, caste, religion, and so on. Operating as it does in a competitive market, and often with a high demand for its skills, this group,

which resembles in some ways the old guilds of Europe, has a vested interest in restricting membership and is thus not very susceptible to change.

The implication of the foregoing as far as appropriate technology is concerned is that the large contractor is unlikely to be very interested. He operates in the tradition of his counterpart in the industrialised world, where the emphasis is on labour saving; the system of labour-only subcontracting removes from him most of the problems associated with the management of men rather than machines; the subcontractors themselves have a vested interest in maintaining their exclusiveness. In addition to the consequent reluctance on the part of the large contractor to adopt appropriate technology, the project design and specification requirements may provide a genuine reason why he cannot.

3.2 *The small contractor*

In the almost complete absence of statistics, and having regard to the great diversity of countries in the region, it is impossible to define quantitatively what is meant by a small contractor. It is, however, generally understood to mean one who is capable of small-scale works only, such as rural road construction and improvement, small-span bridges, culverts, and so forth. He may be a carpenter or mason possessed of the initiative to set up business on his own, although this is more likely to be the case in building than in road construction. Alternatively he may be an entrepreneur to whom contracting is merely one outlet for the capacity for seizing opportunities, taking risks, adapting and working hard, which characterise his kind. Whether he be one or the other, entry into or exit from the industry is remarkably easy. As the ILO study of labour-based road construction in Iran[5] says, " ... it is possible to build a road with no more than a telephone, so to speak, while holding one or more other jobs as well ... ". This type of contractor has no real commitment to the industry, and is not therefore particularly interested in the investment in human resources which is necessary if long-term improvements are to be achieved.

Not only this, but with limited capital resources it is easier to get credit for the hire of machines than for the payment of wages, added to which there is the problem of managing

people, which is also more difficult than managing machines.

The situation described above relates specifically to Iran. In many countries in Asia there is no equipment-rental market, so that the question of the small contractor hiring machines does not arise. Unfortunately, he knows of no alternatives: either he uses primitive and unproductive methods or he needs sophisticated machines. This is precisely where appropriate technology fits into the picture by providing the appropriate mix of labour and machines to bridge the gap.

The constraints which trap the small contractor are:

- lack of capital and the difficulty of obtaining credit for payment of wages;
- lack of managerial know-how;
- lack of technical expertise;
- too great a gap between the large western-style contractor and himself.

Above all, as discussed under the heading "Employment", there is the lack of any real impetus for innovation because of the existence of a large pool of labour. In short, as with the large contractor, but for somewhat different reasons, there are major obstacles to the adoption of appropriate technology by the small contractor.

4. Rationale for appropriate technology in the private sector

In section 2 of this chapter there was an examination of the environment within which the private sector operates, and the general conclusion reached was that government policies, contractual conditions, the attitudes of engineers and the functional divisions of the industry are not conducive to the application of appropriate technology. Similiarly, the section 3 analysis of the structure of the industry concluded that the existence of virtually only two categories of contractor, namely "large" and "small", was an inhibitng factor, and that, for different reasons, neither has any particular interest in appropriate technology.

Given these circumstances, two questions must be asked, or perhaps more strictly a main and a subsidiary question. The main question is this:

"*Should* appropriate technology be applied in the private sector?"

and the subsidiary question is

"*Can* appropriate technology be applied in the private sector?"

The answer to the first question must be a resounding yes, for the following reasons.

Whilst the capital for infrastructure development comes almost entirely from government sources and the management of projects rests largely with government departments, the actual execution of works is often in the hands of the private sector. There is a school of thought which maintains that the private contractor is a source of inefficiency, is guilty of exploiting labour and of making large profits, and that particularly on small-scale rural projects he should be eliminated. Without entering into the social/political controversies of which this is a reflection, it must be noted that in those cases where this has been done there is no evidence of improvement in either over-all efficiency or the lot of the workers. More compellingly, the fact remains that to attempt a wholesale change of the existing system as a necessary prelude to the introduction of appropriate technology would almost certainly end in failure. What the proponents of appropriate technology are saying is that its application offers the opportunity for the better use of human resources, and what we maintain is that this should be done within the system of project execution which is most commonly used throughout the region. Hence the positive answer to the first question.

As to the question of whether appropriate technology *can* be applied in the private sector, the answer here is yes — but .... In other words, a positive response, but a qualified one. Politics has been described, somewhat cynically, as the art of the possible; perhaps engineering should be described (but of course not cynically) as the science of the possible, since engineers are both realistic and practical. Therefore, practicability must be a paramount consideration in discussing the steps necessary to introduce appropriate technology into the private sector. This leads to the conclusion that attention should be concentrated on the small contractor. The large contractor is, in general, much more capable of taking care of himself than the small one, and in any event there are likely to be more serious technical problems in applying appropriate technology to large-scale than to small-scale works. Furthermore, development needs a healthy construction industry with a complete range of technical capacity. Appropriate

technology provides a means of bridging the gap between the two extremes which presently characterises the private sector.

5. Action necessary to introduce appropriate technology in the private sector

There is scope for national action in the following fields, not only to remove constraints but to positively encourage the application of appropriate technology in the private sector.

5.1 *Legislation, regulations and conditions of contract*

Government recognition of the construction industry as such would enable the framing of laws and regulations appropriate to the industry. It would, so to speak, give it respectability and thus improve the status of private contractors, especially the small ones. Legislation and regulations could be framed which would make the contractor credit-worthy and thus able to use the tools and equipment of appropriate technology. The regulations which govern the registration of contractors could be amended so as to avoid a bias against labour-intensive methods.

Contractual conditions and specifications should be drawn up so as to allow the maximum possible choice of methodology. This is not a plea for the lowering of standards, but there are often alternative ways of producing the same end result, and specifications should not be so rigid as to permit of only one method.

The possibility should be investigated of writing conditions of contract which would offer the contractor an incentive for using labour-intensive methods, whilst at the same time maintaining productivity[6].

These matters would probably need to be dealt with nationally by some sort of committee or commission comprising professional engineers, lawyers, government officials, employers' and employees' associations.

5.2 *Research*

This is an important field in which, although a certain amount has been accomplished, a great deal more needs to be done. Both the ILO and the World Bank have been prominent in this field.

Most of the work to date has concentrated on demonstrating that, by using appropriate technology, the substitution of labour for capital is feasible, but there has been practically no investigation of the implications for the private sector. This work is now being extended by the ILO and the World Bank to cover the structure and organisation of the construction industry.

a) *The structure and organisation of the private sector* — At national levels there is an urgent need to determine what proportion of construction output is carried out by small contractors, how many of these there are, how many people they employ, how they operate, how permanent they are, what expertise they possess, and so forth. This kind of work can usually be undertaken by national bodies such as universities, technical institutes or business colleges.

One point that needs stressing is that research in this field should not be purely academic, but should be aimed at producing practical improvement. Thus analysis should only be regarded as a first step towards a programme of action.

b) *The use of physical resources by the private sector* This area can be further subdivided into:

i) methodologies and techniques;
ii) use of indigenous materials;
iii) development of tools and equipment.

i) *Methodologies and techniques*: As stressed in the previous section, research should be directed towards improvement in the methods currently used. Most small contractors operate in ways which have been traditional for many years. Simple changes in organisation and methods can often increase productivity. Why does this not happen, and what can be done about it?

ii) *Use of indigenous materials*: A great deal of research has gone on, and is still going on, into the use of the local building materials, yet these materials are still not in general use. For such materials to be more widely adopted, a number of things must happen:

- the properties of the materials must be known and manufacturing standards must be drawn up;
- architects and engineers must specify their use;
- adequate and economically priced supplies must be available;

– contractors must know how to use the materials.

Responsibility for the first two rests largely with the government sector and is therefore outside the scope of this paper. The last two are within the private sector, however, and merit research into such matters as:

- the availability of raw materials;
- the economics of manufacture, including pricing structures, import substitution, etc.;
- the scale of manufacture;
- application techniques;
- construction costs.

The foregoing refer to the use of materials in permanent structures, but there is another research area which has been almost completely neglected, and that is the use of local materials for temporary structures. In practice, very little tubular steel scaffolding is used in Asia, most of it being bamboo or timber. Steel scaffolding, being a manufactured product, possesses predictable properties, yet there have recently been some spectacular failures, which would indicate that we know less about its behaviour than we thought[7]. How much smaller is our knowledge of the behaviour of bamboo or timber scaffolding? Not only is this important from the aspect of the safety of the structure and the workers thereon, but because the contractor must usually allow for the cost of these temporary strcutures in his price for the permanent structure. Similar research is needed into the use of local timber for the shoring of trench sides. This again is an item the cost of which is deemed to be included in the excavation price. Unfortunately, whereas a bridge or high building cannot be constructed without scaffolding, trenches can be dug without shoring, often with fatal results for the diggers.

iii) *Development of tools and equipment*: The ILO has started to compile a *Guide to Tools and Equipment for Labour-Based Road Construction*, and this is a useful first step, but the same entrepreneurial drive that has produced intermediate forms of transport needs to be harnessed at national level in the interest of construction equipment. This will require activity similar to that undertaken by the International Rice Research Institute in developing appropriate agricultural machinery, coupled with

the creation of a market for the products by the encouragement of appropriate construction technology.

c) *The use of human and animal resources* — Reference has already been made to the studies carried out in this area by the World Bank and the ILO, and a particularly valuable output is the joint standard methodology for the measurement of productivity[8]. However, as these studies make clear, the variables affecting the output of men or animals are much more numerous than those affecting machines. It is therefore necessary that there should be continuing national research into productivity and the factors which affect it.

One of the vital factors is that of motivation and incentive, and here the research field is virtually untouched. Since this paper is concerned with the private sector, the assumption is that the motivation of the contractor is a desire to make a profit. This is perfectly legitimate, but the reason for advocating the application of appropriate technology is *not* primarily to allow him to make a large profit! It is to create employment, generate income and improve productivity, thereby benefiting all three parties, namely the government, the worker and the employer.

There have been many examples of the development of tools for increasing productivity which have never found acceptance. Why is this? The reasons are twofold:

i) as has already been pointed out, in an environment where productivity is generally low, the contractors can still make an adequate profit without bothering to improve productivity.

ii) the worker is naturally unwilling to increase his output if this is merely going to mean increased profits for his employer.

Socio-economic research is therefore needed to identify the factors governing the introduction of new tools and techniques into a contracting company, and to devise means of sharing the benefits in such a way as to encourage their adoption.

5.3 *Information*

The modern world devotes a great deal of effort and resources to the provision of more information, further information and more accurate information. In some cases, as

for instance airline booking systems, this has resulted in noticeable improvements. On the other hand, the speed of delivery of letters often seems to be completely unaffected by technological advances. In general terms, however, our ability to process data into information more readily than our predecessors at least gives us the opportunity to manage our resources better. Whether or not we grasp that opportunity is another matter. Consideration of the techniques to be used for the supply of information is beyond the scope of this paper, but here is a situation where the appropriate technology may well be the most advanced technology available. If, for example, the logistics of supplying scattered rural works projects are helped by the provision of radio communication, this is a more appropriate technology than that of a runner with a cleft stick, even though the projects themselves may use very little equipment.

As far as the private sector is concerned, there are two categories of information required, namely external and internal. By the former is meant information which relates to the political, social and economic environment within which the contractor operates. It is this kind of information which creates an awareness of the availability of alternative technologies, of the social responsibilities of management, and so on. Arising from this awareness there should spring the need for the second category of information, which is that relating to the internal operation of the contractor's business. This will include cost and productivity analyses, progress reports, and so forth. The contractor who is not generally aware of what is going on around him is unlikely to have a highly developed internal information system.

The large contractor, because of the size of projects he is undertaking and his technical contacts, has access to a great deal of information. Of course, much of this will be biased towards capital-intensive technologies because of the magazines and brochures produced by equipment manufactures, but he is at least attuned to the concept of receiving new ideas, so that literature relating to appropriate technology would at least receive some attention. Furthermore, many large contractors are organised into federations or associations which allow the interchange of ideas both nationally and internationally. Therefore, information relating to appropriate

technology can be disseminated through existing channels.

The case of the small contractor is, however, completely different. As far as external information is concerned, there are a number of serious problems:

a) that of language. Whereas the large contractor will be able to read literature in at least one of the world's major languages, the small contractor may not be able to do so;
b) availability of suitable information. A great deal needs to be done in the structure of the private sector, the systems whereby it operates, and so on. Our lack of factual knowledge regarding small contractors is abysmal. Until this situation is corrected, it is difficult to know what external information the small contractor needs;
c) lack of managerial and technical know-how. Even if suitable external information in his own language were made available to the small contractor, he would probably not be able to formulate his needs for internal information due to these limitations;
d) cost of information. Small contractors simply cannot afford publications printed at high cost in the western world.

What can be done to solve these problems? An obvious first step is the identification of the information needs of the small contractor, followed by consideration of the best means of fulfilling those needs. It would appear that the research needed for this first step could provide an opportunity for regional or at least subregional co-operation, since there are many similarities between the way small contractors operate in say the subcontinent of India or in the ASEAN countries. The carrying out of some such research programme would not, however, solve the problem of making the information available to the contractor in his own language and at a reasonable cost. Patently the necessary steps for this to happen would have to be taken at country level and should preferably involve a national institution: it might be a national productivity centre, or a rural development academy, or an engineering faculty of a university.

What the foregoing amounts to is that if appropriate technology is to be adopted by small contractors they must have

ways of knowing about it. Since information channels for this purpose are restricted or non-existent, positive steps are needed to remedy this. The kind of information needed can probably be established on a regional or subregional basis, but the channels of communication will need to be set up at the country level.

5.4 *Training*

As has already been seen, there are many external factors which require influencing if appropriate technology is to be successfully introduced into the private sector of construction. Changes are also necessary within the industry itself in the form of better information and control systems, improved managerial and supervisory capability, greater technical know-how. Some of these improvements can be wrought by the provision of suitable training, but whilst there are few, if any, contractors whose performance is not susceptible to improvement through training, the need is greatest amongst the small contractors. Additionally, it is in this category that the greatest potential exists for the productive use of appropriate technology. For these reasons, the discussion that follows concentrates on training for small contractors, whose general needs fall into the three categories:

a) management and organisation;
b) finance;
c) technical.

For a contractor employed on small-scale works, his training needs in the fields of estimating, costing, financial control and the running of a small business generally are independent of the construction technology employed. However, the application of appropriate technology does involve some special management issues such as:

- methods of payment, especially where work animals are used;
- incentive schemes;
- measurement and control of productivity;
- training of workers in the use of tools and equipment.

As regards the need for technical training, it is self-evident that the introduction of a technology different from that currently used by the contractor involves teaching him how to manage it, and his labour how to handle the equipment.

When it comes to the mechanisms whereby training is to be imparted to the small contractor, it is the author's view that the training needs which arise directly from the application of appropriate technology cannot be separated from those arising from any other reason. The small contractor needs training which will raise his general standard of competence. For him, *appropriate* training will include not only appropriate technology but general business management, simple accounting, planning, and so forth. There are a number of special problems to be overcome if this training is to be effective.

In the first place, there is very little training in construction management available in Asia for small contractors such as there is for the large contractor. A start has been made in Malaysia, with technical assistance from the ILO, to develop within an existing institution, a training programme specifically for small-scale contractors, but this is thought to be the first attempt in the whole region. Programmes will therefore need to be developed from scratch with no past experience for guidance.

Secondly, only a few studies have been carried out on the characteristics of these small-scale contractors[9]: what education and technical training have they had? What do they know of business management? What permanent staff do they employ? How do they pay their casual labourers? And so on. Until there is more information, it is difficult to design a suitable training programme.

Thirdly, there is often little permanence amongst these contractors. Reference has already been made to the use by governments of the construction industry as an economic regulator, so that when the supply of projects is cut off, many contractors go out of business, and conversely new ones may emerge when there is economic growth. Additionally, whilst a large contractor will not find it difficult to release a member of his staff for training, the small contractor may be an owner/manager, engineer, storekeeper all rolled into one, and therefore cannot afford to neglect his business whilst he receives training. A related problem is largely psychological: the type of contractor under discussion is obviously an entrepreneur and may be suspicious of formal training, especially if it is not immediately obvious how he is to benefit financially.

Finally, any training programme for this target group must be in the local language, and since the literature even for "standard" subjects such as accounting is unlikely to exist in that language, the translation problems are formidable.

In the context of this chapter it is not possible to do more than sketch some possible solutions, but a long and difficult path must be trodden before success is achieved. It is of prime importance to know and understand the target group for training, and this can only be achieved through national studies. As part of its research under the World Employment Programme the ILO has initiated a study in the Philippines and will be carrying out similar studies in various other Asian countries. These efforts are very useful in providing models for future work, but conditions vary so widely from country to country and even within countries that specific country studies will be needed throughout the region.

The almost total lack of existing training is a strong argument for using existing technical institutions which already possess training competence, since this is a necessary foundation on which to build. Such institutions should have an engineering and practical orientation, otherwise they will possess little credibility with their trainees. Another argument for using local institutions is that they will understand local conditions and needs, and will also conduct their training in the local language.

Now, although every country will ultimately have to develop its own programmes, for it to do so in isolation without drawing on expertise and experience from elsewhere will be too long and wasteful a process in the light of its pressing development needs. One way of solving this problem would be for international assistance to be given to groups of institutions in the preparation of training packets and the training of instructors. This could be done by bringing together instructors from a number of institutions within a large country (such as India), or from a group of smaller countries (such as the ASEAN) and helping them to develop a generalised training packet which they would subsequently adapt to local requirements. The ILO has made a start in Africa by running a six-week regional training course to teach management trainers from 18 countries how to deliver a basic repertoire of courses to small-scale building and construction contractors. The author has

proposed something on similar lines for Asia, but with continuing help to the national institutions on a longer-term basis, and with provision for interchange of know-how and experience between institutions themselves.

These ideas are by no means exhaustive and there may well be other and perhaps better ways of tackling the training problems, but the subject is one worthy of an exploration in depth which cannot be attempted here.

6. Summary and conclusions

The role of the private construction industry in the development of the countries of Asia and the Pacific is a vital one, since it is the means by which most governments execute their projects. A healthy and efficient industry is therefore in the interests of both governments and contractors. It is, however, also in the interest of construction workers for whom there can be greater employment prospects and improved earnings.

The private sector is presently characterised by an imbalance between the relatively small number of large contractors, modelled on their counterparts in industrialised countries, and the many thousands of small contractors trapped in a sequence of primitive technology, low productivity, hence low wages leading back full circle to primitive technology. It is necessary to break this circle and encourage the creation of a middle category of contractor which will bridge the gap between large and small. This will enable the more enterprising amongst the small contractors to move upwards. Appropriate technology affords one means whereby this natural growth can be achieved. It follows that efforts in the field of appropriate technology should concentrate on improving the performance of the small contractor.

In order to do this, it is necessary to consider the environment within which the industry operates, as well as the structure of the industry itself. Since government has a monopoly of the market for the small contractor, it is government policies which control the operating environment. The legislation, regulations and conditions of contract which relate to the construction industry must therefore be examined and amended as necessary in order to encourage the upgrading of the small contractor. There is also a need to reduce the intellectual and technical gap between government engineers and contractors, so

that there is greater understanding of each other's problems.

As regards the industry itself, there is a dearth of statistical data, and research is needed to provide a realistic foundation on which to build a sound structure. If he is to apply new ideas and technologies, the contractor must have access to information. This must be simple, available cheaply and in his own language. Finally, the small contractor needs training if his standards are to be raised. Since these are generally low, the training should not concentrate on appropriate technology alone, but should include it in a general syllabus. The more aware the contractor becomes of relevant management and technical techniques the more likely he is to innovate. International assistance should be given to suitable national institutions to enable them to introduce training for small contractors.

This paper has spelled out in some detail the formidable, but none the less surmountable, obstacles which impede the adoption of appropriate technology in the private sector. What it is hoped has emerged is that obstacles are an impediment not only to the adoption of appropriate technology but to the progress which the construction industry must achieve if it is to meet the challenge of development. There must therefore be a concerted effort on the part of all concerned, whether in the public or private sectors, to tackle the problems.

Notes and references

[1] *Employment relationship in the building industry* by C.K. Johri and S.M. Pandey. Published by Shri Ram Centre for Industrial Relations and Human Resources, New Delhi.

[2] op. cit.

[3] IBRD, *Study of the Substitution of Labour and Equipment in Civil Construction*. Transportation Department, World Bank, Phase I, 1971.

[4] *1976 World Population Data*, Population Reference Bureau, Washington DC.

[5] G.W. Irvin, *Roads and redistribution - social costs and benefits of labour-intensive road construction in Iran*, ILO, Geneva, 1975.

[6] This has been attempted in the Philippines. See D. Lal, *Men or machines*, op. cit.

[7] 1976 saw the failure of temporary bridge structures in Germany

and Britain, and a failure during construction at the Montreal Olympic Stadium.

[8] IBRD/ILO, Technical Memorandum No. 8, *A Field Manual for the Collection of Productivity Data from Civil Construction Projects*.

[9] See, for instance, J. Capt and G.A. Edmonds, "Small contractors in Kenya", WEP Technology and Employment Working Paper No. 33 (mimeo.), Jan. 1978.

PART II CASE STUDIES

CHAPTER 6. THE "ROADS AND LABOUR" PROGRAMME, MEXICO[1]

by G.A. Edmonds

In 1971 the Mexican Government launched an extremely ambitious programme of rural road construction. The primary objective of this programme was to provide communication to the mass of the rural population where presently none existed[1].

At the time of the inception of the programme it was estimated that as many as 12 million people (60 per cent of the rural population) living in a total of 16,000 villages had no proper transport access[2]. Whilst the major transportation links had been constructed there had been little attention paid to providing the necessary minor roads without which the rural areas were incapable of developing effectively. It was the intention therefore to reverse the ratio of the kilometrage of major to minor roads during the period of the programme. Thus in 1971 80 per cent of the roads already constructed were major trunk roads. By a massive programme of labour-based road construction it was hoped to reduce this value to 20 per cent. This implied the construction of some 150,000 kms of minor roads.

The major objective of the programme therefore was to provide communication to the mass of the population. However, it was decided that a policy of labour-based construction would be adopted not only to provide employment and income but also because this policy was geared to popular and grass-roots participation in the construction process. The programme was not conceived therefore as a public works scheme to generate employment but as an effective means of providing access to markets and amenities to a large proportion of the rural population. As with the Ministry of Works in Kenya, the Secretaría de Obras Públicas, who are responsible

for the programme, wished to use labour-based methods to the extent that they were commensurate with technical and economic efficiency.

1. Programme organisation and administration

In the capital town of every state in Mexico there is a centre of the Secretaría de Obras Públicas (Secretary of Public Works). Its director is responsible for all public works carried out by the federal government in that state. In each centre there is a senior resident engineer who is in charge of the construction of rural roads[3]. Working for him is a team of resident engineers each located in a different region of the state. Each resident engineer has a team of engineers, surveyors, administrative personnel and supervisory staff. The exact number of his staff depends upon the number of roads being planned or constructed. The supervisory staff consists of supervisors and foremen. Supervisors are in charge of 3 to 5 foremen, whilst each foreman is in charge of 30 to 60 men.

The central headquarters of the programme is located in Mexico City in the Secretaría de Obras Públicas (SOP). A special unit has been set up to supervise the programme (Dirección General de Caminos Rurales). This unit consists of four main departments. These are:

Department of Works — responsible for monitoring the progress and cost of the programme and advising when action is necessary.

Department of Programming — responsible for preparing the budget and allocating funds to the SOP centres in the various states.

Technical Department — responsible for supervision of the technical aspects of the programme. This includes drawing up guidelines on technical specifications, cost estimates for labour, materials, equipment, etc. and productivity standards. It also collects data from the field in order to update these guidelines.

Department of Research and Special Studies — responsible for carrying out special studies on technical and economic aspects of the programme. In addition there is what is termed a promotion branch which is responsible for giving advice and assistance to the resident engineers in the field as regards the promotion within local communities of road-building activities.

This is necessary because the programme is dependent upon, and derives from, the willingness of local communities to become involved in road construction.

In the first instance a community will request that a road be built or upgraded. One of the resident engineer's staff then visits the community, assesses the situation and collects data pertaining to the number of households, agricultural production, social services, etc. If a decision is then taken to meet the community's request the official returns and explains that it is their responsibility to build and maintain the road. To this end a committee is elected which represents the community in its dealings with the resident engineer's office. A memorandum of understanding is drawn up in which the obligations of the two parties are clearly spelled out. Thus the committee undertakes to provide the necessary manpower; the free use of borrow pits and the right of way for the road. The DGCR undertakes to provide technical assistance, payment for the labourers, construction materials, hand tools, equipment and transport.

Two points are worth mentioning here. First, the system is designed to ensure the involvement of the community in the construction of the road, which it is hoped will guarantee its maintenance. Second, the DGCR has no official relations with the labourers except in terms of supervising the construction operations. The workers are paid by the committee and all labour relations are dealt with by them. The labourers therefore are not in any way employees of the Government. In a programme as large as this one decentralisation of administrative responsibility presents major problems of accounting and planning. To help to cope with these problems each SOP centre has a computer which is used to plan and control the financial disbursements of the programme. In turn the information from all the SOP centres is fed to the main computing centre at SOP headquarters which allows the Department of Works and Department of Programming to monitor and allocate the financial resources.

2. **Technical aspects**

2.1 *Design*

It was assumed that the traffic volume on the roads to be

constructed would be less than 50 vehicles/day. The roads were therefore designed to a design speed of only 20 – 30 kms per hour. This permits the use of radius of curvature as little as 15 – 20 m and maximum over-all gradient of 12 per cent.

The roads are designed for one-way traffic flow. The total formation width is 4.6 m with a 4.0 m wide, 15 cms deep gravel pavement. Every 500 m a 10 m stretch is widened to 6.0 m to allow vehicles to pass.

On simple rural roads, drainage is particularly important. This has been appreciated in the programme and special attention is given to it. The formation is crowned with a cross-fall of 4 per cent. Side drains of 1 m width and 1:3 side slopes are constructed. These have a minimum gradient of 0.5 per cent and where the gradient exceeds 6 per cent they are protected with a layer of hard pitched stone. On sloping ground catch drains are placed on the high side of the road to discharge run-off water before it reaches the road. Various culvert designs have been introduced but the most effective has proved to be corruged steel pipe.

To the extent possible, rivers and streams have been traversed by means of masonry fords. Where bridges have been necessary they were initially constructed as masonry arches. Recently however masonry pillars and reinforced concrete superstructure have been introduced. One interesting aspect has been the use of cobblestone roads where the gradient was unavoidably greater than 12 per cent.

2.2 *Construction*

Prior to construction work commencing the resident engineer and his staff prepare a simple bill of quantities which specifies the amount of work to be carried out in each of the major activities. This is then used to plan the work in terms of duration and resource requirements. This is possible because the reporting system incorporated into the programme provides detailed information on labour and equipment productivity under various climatic, topographical and soil conditions.

The resident engineer's team then sets out the centre line of the road. Tasks for each of the major activities are then fixed. These tasks generally cover a 3 to 4-day period. Each foreman,

who is in charge of 30 to 40 labourers, is briefed regarding the task levels set and any particular points that need attention. In turn he assigns his labourers to the various tasks.

Site clearance and top soil removal is almost always carried out by manual methods except (in the case of site clearance) when the vegetation is extremely dense.

The roads are designed and aligned to minimise cut and fill operations and to ensure that, in general, the excavated material for side drains and culverts can be used directly to form the basic road formation. Thus the material from ditching and sloping is used for spreading on the formation. This means that these operations can be carried out effectively by labour-intensive methods.

Where bulk excavation is unavoidable it has been found that labour-intensive methods are effective as long as the total volume does not exceed 2,500 m^3 per kilometre[4]. Where this figure is exceeded equipment is used. This is often operated by small contractors who are paid a fixed sum related to the type of soil being excavated.

Gravel for the pavement is obtained from borrow pits. Excavation and loading of the gravel is carried out either by labour or equipment depending on location, material and loading conditions. Dump trucks are used for hauling the material. Spreading and laying is carried out entirely by hand.

2.3 *Tools*

Each labourer is provided with a shovel and a pick-axe. Other hand tools such as crowbars, axes, hammers, etc. are distributed according to the type of activities being executed. The tools are produced in Mexico and their quality is very reasonable. For haul distances of up to 100 m wheelbarrows are used. The wheelbarrows used have a capacity of 0.07 to 0.09 m^3 and have massive rubber tyres.

2.4 *Recruitment and remuneration*

The community itself recruits the labour to work on the roads. Each labourer is guaranteed a minimum of two week's work. (In fact during the period 1971-75 53 per cent of the workers were employed for less than one month, 21 per cent for one to three months and 26 per cent for more than three

months.) In general the community committee attempts to ensure that all those who wish to work are given some employment.

Payment is usually at the level of the minimum rural wage, with one paid rest day per week. During the period 1972-75 the minimum rural wage rose from 25.38 pesos ($2) in 1972 to 40.89 pesos ($3.27) in 1975. The present rate of remuneration is approximately 70 pesos per day ($3.1). The actual direct cost of labour is a factor of 1.167 greater per day owing to payment for one rest day per week.

2.5 *General*

Some general indications can be given of the 64,000 kms of road already constructed under the programme. Only 14 per cent of the roads are in fact new roads, the great majority being improvements to the alignment, width, drainage and surfacing of existing tracks. The average length of the roads constructed is 10 kms and average construction period 9½ months.

The topography in which the roads have been constructed was classified in three categories, i.e. plain, hilly and mountainous[5]. Only 7.5 per cent of the roads were constructed in mountainous terrain, the rest being equally distributed between plain and hilly terrain.

The type of soil was classified into three types: soft, firm and hard. Nearly 60 per cent of the soils encountered were firm, 35 per cent soft and the remainder were hard. The vegetation through which the roads were constructed was generally (50 per cent) medium in density, a further 40 per cent was very light, whilst 10 per cent of the roads were constructed through jungle or forest.

2.6 *Selection of roads*

With such a large programme of road construction it was necessary to develop certain criteria of selection.

It was decided to concentrate road-building efforts on those communities of 500 – 2,500 population of which 65 per cent had no means of communication. This would provide access to the major part of 12 million people mentioned previously.

An initial, broad, identification was made to decide which

states in the country should be given priority. The criteria used for this broad selection were:

a) level of rural income;
b) number of localities between 300 and 800 inhabitants;
c) metres of constructed road per square kilometre of land surface;
d) metres of constructed road per 1,000 inhabitants;
e) number of vehicles per 1,000 inhabitants.

Actual project selection within each state was carried out based on certain specific criteria which related to maximising the "combined utility of the road". This was measured in terms of:

a) number of localities served by the road;
b) potential agricultural development;
c) permanent employment generated by construction of the road;
d) general socio-economic level;
e) zone of influence of the road.

The selection was qualified by such factors as budget restrictions, availability of labour, duration of construction and the technical difficulty of construction.

3. **Achievements**

3.1 *General*

During the five-year period 1971 – 75, 64,000 kms of road have been built at a total cost of 4,596 million pesos ($368 million). That is an average cost of $5,750 per kilometre. The total length of roads built under the programme amounts to 35 per cent of the length of the current road network in Mexico. In all, 6,174 communities with a total population of some 6 million have been provided with access. At its peak in 1973 the programme was providing temporary employment of 105,000 jobs per month. A rough calculation based on the time (relatively short) that workers spent on road construction suggests that over 1.5 million people were provided with temporary employment during the five-year period up to 1975.

3.2 *Output*

The actual construction output has varied considerably over

the five years 1971 – 75 as shown below:

Year	Output (kms)
1971	3 500
1972	11 000
1973	28 500
1974	10 500
1975	10 500
Total	64 000

A weighted average of the programmes indicates that 1,700 man-days per kilometre were used.

Detailed figures of labour productivity for various activities are shown in table 1 and a breakdown of the average quantity of work per kilometre is given in table 2.

Table 1. Labour productivity

Operation	Soil type	Output (m^3/man-day)
Cut to fill	Soft	4.5
	Firm	3.0
	Hard	1.2
Simple excavations	Soft	5.0
	Firm	3.0
	Hard	1.2
Spreading	All	15.0

Table 2. Average quantity of material per kilometre constructed

Operation	Average quantity per kilometre	
	Improved track	New road
Clearing	0.3 hectares	1 hectare
Excavation	1 670 m^3	2 800 m^3
Fill	1 313 m^3	1 415 m^3
Gravel	710 m^3	815 m^3

3.3 *Costs*

During the period 1972 – 74, for which a detailed analysis

has been carried out, the average direct costs for improvement of an existing track was 65,600 pesos per kilometre ($5,250) and for a new road 106,885 pesos per kilometre ($8,550).

For the bulk of the roads, which were improved tracks, the breakdown of costs was as follows:

Wages	60%
Materials	12%
Tools	4.5%
Services[6]	20%
Site supervision	3.5%

The cost and breakdown does not include the cost of central administration and headquarters which, in the case of the Mexican programme, is likely to have been quite considerable.

During this period (1972–74) the average minimum daily wage was 41 pesos. An analysis of the costs in 1975 shows[7] that the direct costs per kilometre for an improved track had risen to 93,500 pesos ($7,500).

Over-all it is estimated that of the direct cost 50 per cent is spent on earthworks, 3 per cent on drainage and 3 per cent on the gravelling operation.

A comparison was made of the costs of constructing an improved track by equipment-intensive methods under prevailing Mexican conditions[8]. This suggested that, even at market prices, there was little difference between labour and equipment even though the duration of construction for the equipment-intensive techniques was considerably less. It is worth noting that the on-site overheads for the equipment-intensive method (a total of 23.5 per cent of the total direct cost in the case of labour-based methods) was 33 per cent of the total direct cost.

3.4 *Employment*

The actual level of direct employment created is difficult to quantify as at least half of the workers were employed for less than a month. From the available figures[9] it is possible to suggest (i) that over 1.5 million people were provided with employment as a direct result of the road construction programme; (ii) during the period 1972–74 over 4 million man-months of employment were created.

Employment created using labour-based methods was five times that which could have been expected using equipment

and, as we have seen above, for the same investment cost.

Van Ginneken[10] has estimated that of the 5 million paid economically active persons in agriculture as many as 4 million are employed for less than 150 days a year. This should be seen in relation to the structure of agricultural employment which is basically of four types. The day-labourer having little or no land who hires himself out for work through the year; the co-operative farmer whose demand for employment depends upon the distribution of crop land; the small farmer (having less than five hectares) whose subsistence farming is often augmented by working as a day-labourer; large farmers. Employment in the programme was drawn from the first three. We can see therefore that even if a labourer works for only one month on the road he is, at the most conservative estimate, increasing his annual employment by 20 per cent, and consequently his earnings.

A sample survey which formed part of the work of the DGCR showed that three-quarters of the labourers working on the road had access to land; however, the average size of plot was only 2.9 hectares. This is extremely small when it is appreciated that the average family size was 6.3 and of the total family, an average of 3.6 were available for work. In over 90 per cent of the families all or part of the family labour force was available for work (i.e. unemployed or underemployed).

The average annual income of the families studied was approximately 7,000 pesos[11] which amounts to an annual income per economically active person of 2,000 pesos. One month's employment on the programme therefore amounted to an increase of 50 per cent in individual income or 15 per cent of family income.

A micro survey carried out by DGCR suggested that it was the day-labourers who benefited most from the programme whilst those who had land (not surprisingly) and the totally unemployed (surprisingly) benefited much less.

4. **Socio-economic impact**

Up to 1975 the programme had provided access to over 6,000 communities. A sample survey of these communities showed that:

a) for 70 per cent of them the only previous means of communication was on foot or by horse;

b) for the great majority the time taken to reach the nearest town was at least one hour and generally more than three hours;

c) 37 per cent lacked all types of services, 70 per cent had no potable water, 60 per cent no electricity, 60 per cent no school of any description, 90 per cent no medical service.

The survey also showed that over 90 per cent of the wages earned by workers on the programme was spent on consumption items.

The direct socio-economic impact of the construction of the roads was therefore an increase, in most cases a substantial increase, in family income. Unfortunately, because of the existing lack of facilities and the economic system this income was generally not spent in the communities but in towns to the merchants who supply basic commodities. The addition of funds to the community did not produce an increase in the local production of consumer goods. It is fair to add that this would only come about if complementary rural development activities took place at the same time as the road construction. Furthermore, the DGCR found that the improved communication provided by the roads tended to reinforce the existing economic structure. The richer members of the communities took advantage of the access provided whilst the poorer members, because of their lack of income, derived very little benefit from the access. Thus a richer family would now have access to fertiliser which they could afford and thus increase the quality and quantity of crops produced. The income derived by the poorest, though relatively substantial, was only used to increase consumption, partially because the previous consumption was so low and partly because of the class structure which did not allow them to break out of their subsistence economy. Thus the additional income provided the means whereby the basic needs of clothing, food and shelter could be obtained but were not sufficient to provide a basis for a continuing improvement in the people's economic condition. In this regard the survey found that the least impact occurred when the class structure was particularly rigid and land ownership vested in the hands of a few.

5. **Summary**

The programme is probably the largest of its kind presently in

operation. It has indicated clearly that even in economies where the agricultural wage rate is as high as $2.5, labour-based methods can be effective. However, it also shows that these methods require very detailed planning, organisation and management.

The detailed studies carried out by the DGCR have also shown that for a programme of rural road construction to be truly effective in the long term it must be accompanied by complementary rural development activities. If not then improvements to the standard of living of the mass of the population are unlikely to be achieved.

Notes and references

[1] This chapter is based on the various publications of the Secretaría de Obras Públicas, Mexico, related to this programme, in particular Secretaría de Obras Públicas, *Caminos y de Mano de Obra*, Mexico 1977.

[2] Defined as having no year-round access to a truckable road.

[3] It is interesting to compare this system with the RARP in Kenya where the RAR engineers are not part of the Provincial Engineers Organisation but report directly to the Central Headquarters.

[4] A similar conclusion has been reached from the Kenyan RARP.

[5] The classification was designated if more than 60 per cent of the road was in one type of terrain.

[6] This is principally transportation costs.

[7] SOP, *op. cit.*

[8] ibid.

[9] SOP, op. cit.

[10] W. Van Ginneken, *Socio-economic groups in Mexico: a study of income distribution and employment, forthcoming ILO publication*.

[11] This implies a per capita income of 1,100 pesos which should be compared with the *national* per capita income at the time of the survey of 11,000 pesos.

CHAPTER 7. THE SELF-HELP APPROACH: AFGHANISTAN

by G. Glaister

1. Introduction

This chapter describes a major programme of labour-based construction in Afghanistan. Unlike the programmes in Kenya, Philippines, India and Mexico referred to elsewhere, this programme is based on the principle of self-help, that is, the workers donate their services free or for the provision of food. Nevertheless the objective is not primarily the generation of employment but the development of rural infrastructure.

In Afghanistan there are two major agencies engaged in the construction and maintenance of roads. These are:

a) the Ministry of Public Works;

b) the Rural Development Department.

The former is responsible for primary and secondary roads and the latter for tertiary roads. In this context primary roads are defined as those connecting the provincial capitals with the centre (Kabul) and with the major international border crossing points and points of entry. Secondary roads are defined as those connecting the district capitals with the provincial capitals either directly or via the primary road system. Tertiary roads are defined as those connecting villages and other centres of production or marketing with the primary and secondary road systems.

The construction of the primary road system is well advanced and of the 27 provincial capitals, 17 are served by asphalt or concrete, two-lane, all-weather roads, 4 are served by good quality all-weather gravel roads and the other 6 by lower-grade earth or gravel roads which may be impassable in the wet season because of high water levels.

The secondary road system is much less developed and all-weather secondary roads are the exception. The bulk of them are low-grade earth tracks with few bridges or other drainage structures. A number of district capitals are not connected by road.

The tertiary road system consists in the main of earth tracks which are frequently impassable during the wet season.

The Ministry of Public Works is concentrating on completing the primary road system and the more important secondary roads. It uses relatively equipment-intensive methods with the bulk of the labour being provided by the "Labour Corps", a unit of the Afghan army.

The Rural Development Department (RDD) uses entirely labour-based methods. The policy of the department obliges it to use voluntary unskilled labour sometimes supported by food assistance from the World Food Programme (WFP).

2. The Rural Development Department (RDD)

More than 85 per cent of the population of Afghanistan lives in the rural areas and the basic economy of the country depends on their productivity.

The Rural Development Department provides direct assistance to village people to carry out schemes for which they themselves felt the need and to which they were prepared to give their labour and other resources. The basic policy of the RDD is therefore to help villagers to help themselves. This does not mean that it adopts a passive role. On the contrary, it adopts an active leadership role in stimulating ideas in the villages, discussing and identifying their needs and helping them to plan for themselves. The planning process, socio-economic survey and technical survey is carried out in close consultation with the villagers themselves. For example, the location of a road or the siting of a bridge is discussed with the village and if there are technical reasons for a particular location these technical reasons are explained to the villagers and their general agreement is obtained. No decision is imposed on a village and if agreement cannot be reached the project is not usually undertaken. The RDD provides assistance to a village on the understanding that the village itself will contribute its own resources to the project in terms of voluntary labour, local materials and sometimes a cash contribution. In this way the

execution of the project is very much a joint effort and when it is completed the villagers consider it as their project.

2.1 *Organisation structure*

The RDD is headed by a President with two Vice-Presidents, one in charge of the technical side of the department and the other in charge of administration. Under the technical Vice-President are four general directorates. These are:

a) Director-General, Planning and Programming: in charge of over-all planning, programming, budgeting and monitoring of all departmental activities both technical and non-technical.
b) Director-General, Technical Planning: in charge of all technical planning from the project initiation stage to the production of final drawings and estimates.
c) Director-General, Social Services and Agriculture: in charge of non-engineering programmes in agriculture, non-formal education, health, co-operatives, rural industries, etc.
d) Director-General, Construction: in charge of construction of roads, buildings, irrigation structures and canals, domestic water supplies, individual bridges, foot bridges, culverts, etc.

The RDD headquarters sends teams into the field to carry out socio-economic surveys, technical surveys and construction.

The initiation of projects takes the form of a request from the village to the provincial office of the RDD. The procedure is as follows:

a) a request is made from the village to the RDD provincial office;
b) the village is visited by a technician from the RDD provincial office who identifies the necessary local contribution of labour and materials;
c) the request is forwarded to RDD headquarters by the RDD provincial office with the information gathered in (b) and the recommendations of the RDD provincial Director and the Governor;
d) a socio-economic survey team from RDD headquarters visits the village and appraises the project;

e) if the project is considered viable a technical survey team from RDD headquarters surveys the site;
f) the project is designed in RDD headquarters and, subject to final technical and financial appraisal, is approved;
g) a mobile construction team from RDD headquarters is assigned to provide construction supervision and management, transport, eqipment, non-local materials and certain categories of skilled labour not available locally.

The construction team would be supplemented by voluntary unskilled labour provided by the village or villages and paid skilled labour either from the village or the nearby locality. The construction team lives on the site either in accommodation provided by the village or in tents. The construction team has administrative support from, and is supplied through, the provincial RDD office which is also responsible for seeing that the construction team gets the labour which has been promised by the village. If necessary the RDD Provincial Director will call on the assistance of the Provincial Governor to ensure this.

The construction equipment and transport available to these teams is extremely limited. This equipment is maintained by a small central workshop in Kabul which has inadequate resources to provide any field services except to nearby provinces. The RDD is procuring a considerable quantity of basic construction equipment. This is being financed from both Afghan, bilateral and multilateral sources, the total expected to be procured in the next two or three years amounting to about $3 million. This equipment is of two basic types:

a) To equip road and irrigation construction teams to enable better quality to be achieved and more economic design criteria adopted. These teams will operate on a labour-based basis, equipment and transport being provided only for those operations which are difficult or impossible by hand methods, e.g. rock drills, dump trucks, concrete vibrators and mixers, pumps, back hoes for deep excavation, etc.

   Three road teams and two irrigation teams are planned to operate in the more backward and thinly populated

provinces whose development requires particular attention.

b) Basic equipment for general use throughout the 27 provinces of Afghanistan. This equipment consists in the main of concrete mixers and vibrators and pumps.

A central workshop and mobile field teams are being set up to service this equipment.

The RDD has 27 field offices at provincial level. These offices provide liaison services between the provincial government, the villages and RDD headquarters. They generate new projects and are in constant direct touch with the villagers analysing their needs and suggesting solutions to their problems. These provincial offices also organise all local resource inputs to construction programmes and other RDD activities. They are responsible for the administrative and supply back-up to the construction teams.

In the longer term it is intended to decentralise the technical operation of the department to the provincial offices. At the present time however there is insufficient technical staff to be able to do this, the department having only 34 engineers to cover administration, management and technical functions.

Construction supervisors are recruited to RDD as 12th grade school leavers. They undergo a four months' course in construction methods at the RDD training institute at Gulzar near Kabul. This course is very basic and practical in nature. A construction handbook in Farsi has been prepared and forms the basis of the course. The course includes instruction on reading simple drawings, setting out, simple measurements of areas and volumes, the techniques of mixing and placing concrete, building in random rubble masonry and brickwork, the construction of simple formwork and falsework, etc. It also includes basic instruction in keeping simple site records and organising labour. On completion of their course they are assigned to a construction team to gain practical field experience. Refresher courses are held from time to time.

3. Construction resources

In any labour-based programme the major resource utilised is labour and, when voluntary or semi-voluntary labour is used, the well spring of this resource is motivation. The identification of this motivation and the means of sustaining it therefore

becomes a major consideration in the planning process. Three types of unskilled labour, entirely confined to males, are in regular employment on RDD schemes:

a) voluntary labour;
b) voluntary labour supplemented by food rations;
c) labour supplemented by food rations plus a small cash payment. (The value of the food ration plus the cash is always less than the ruling rate for paid labour.)

The motivation of the purely voluntary labour is the desire for access to the national transport system. The villagers of Afghanistan are acutely aware of the economic benefits arising from cheaper transport. In most cases the farmers are owner occupiers who have a farm surplus to export from their area. They are fully aware of the price differentials between the farm gate, the district market, the provincial market and the national market and the effect of transport costs and middlemen's margins on these price differentials. The motivation is therefore mainly economic although there is a growing awareness of the social benefits which can accrue. For example it is most difficult for a village to attract and keep a good school teacher if it is not connected by a road.

In the case of roads which serve a number of villages the incentive to provide purely voluntary labour varies with the location of the actual worksite relative to the location of the village. For example, in the case of a bridge those villagers living on the near side of the river have little or no incentive to construct the bridge as the benefits will go to villages located on the far side of the river. Where a village is located close to and on the near side of the bridge the villagers are a very convenient potential source of labour; however, if no benefits accrue to them they will not provide voluntary labour. The villagers living on the far side of the river who stand to benefit from the bridge may live a considerable distance away and it may not be feasible for them to travel to the worksite each day. In such cases it has been found necessary to provide an additional incentive to the villagers on the near side of the river to provide labour for the construction. This incentive usually takes the form of food rations provided by WFP. In some cases, where this incentive does not produce the necessary labour, a cash incentive is paid in addition to the food. This

cash incentive usually amounts to 20 per cent of the going wage rate.

Similar considerations apply to the construction of individual lengths of road which form parts of a complete road. Thus, on a particular length, all three types of labour, voluntary, WFP supported and WFP plus cash supported, may be working in the same gang at the same time; the proportion of each type depending on the benefits which that particular length of road will provide to each individual group.

Indigenous materials such as random rubble masonry, stone, gravel and sand aggregates for concrete, timber poles for concrete falsework are normally provided by the villagers themselves either in the form of voluntary labour for winning stone and aggregates or as a contribution from the village of a portion of their timber resources. As in the case of the voluntary labour similar incentive considerations apply.

Imported materials such as reinforcing steel and nationally indigenous materials such as cement and sawn timber are provided by the RDD. When planning the road the designs adopted deliberately minimise the requirement for materials which are not available locally. Thus for retaining walls dry random rubble would be used in preference to random rubble in cement mortar even when the value of the labour and materials in the former would exceed the latter. The greater the proportion of the resource inputs provided by the village itself the greater the sense that the road is *their* road.

The construction methods are entirely labour based. The only equipment which might be provided consists of:

a) pumps for dewatering structural foundations;
b) dump trucks where materials have to be moved beyond the range of hand carry or donkey transport;
c) concrete mixers — only in the case of large reinforced concrete structures (only two mixers are available for more than 90 projects):
d) concrete poker-type vibrators (the RDD's total holding is 3 units).

It might be considered that the use of voluntary labour as a construction resource would divert labour from agricultural production activities. In fact there is a considerable reservoir of unemployed and underemployed labour available in the villages on a seasonal basis.

4. **Design criteria**

The design criteria must always be considered as being flexible. They must also be compatible with the resources available and the construction techniques to be used. The design criteria discussed below are orientated to a situation of voluntary or semi-voluntary labour-based construction using the minimum of manufactured materials.

The use of unskilled village labour which works only on one project does not allow the building up of elementary construction skills in the labour force. The construction techniques involved must therefore be confined to very basic unskilled operations plus the use of any indigenous skill available in the local environment such as dry-stone masonry, construction of earth and stone coffer dams, etc. Designs have been deliberately developed which can tolerate such limitations in the resources available. This has led to the extensive use of random rubble masonry (both dry and in cement mortar), crib construction and gabion construction.

There is a further constraint to be considered when designing roads which are constructed by voluntary labour. The villagers will only do such work as they consider necessary to achieve the objective, i.e. a means of access to their village. Thus, if they consider that a 3.5 m or 4 m wide formation width is adequate it is most difficult to get them to construct the 6 m wide formation which might be dictated by considerations of traffic use and safety. Similarly if they do not consider a culvert to be necessary they will not construct it. In this type of work therefore design criteria must always be considered as guideline targets rather than an immutable minimum.

The design criteria adopted for tertiary roads in Afghanistan are based on the following assumptions:

a) that the Average Daily Traffic (ADT) does not exceed 100 vehicles per day (vpd);
b) that the traffic mix will be in the proportions of 17 per cent cars and jeeps, 33 per cent light trucks and buses (1½ tonne payload or 20 seats) and 50 per cent medium trucks and buses (6 tonne payload or 40 seats);
c) that traffic delays up to 24 hours are acceptable.

The rural tertiary road design standards in use are given in Annex 1 at the end of this chapter.

Various types of structure are now in use. Most of these

make maximum use of local materials. In the case of bridges, for instance, timber trusses up to 30 metre spans have been designed. In the case of culverts, the usual type used up to the present time has random rubble masonry walls with reinforced concrete slab decks. Pipe culverts are seldom used because of the constraints of casting the pipes on the sites with the lack of control over concrete quality. Transport problems preclude the use of pipes manufactured at central locations.

Retaining walls and bank protection are generally of random rubble dry-stone masonry. The village people have developed skills in its use as it is used for boundary walling, housing and land terrace wallings. Such walling is often "stitched" with brushwood or timber poles.

Caseways or "saddle" bridges have often been adopted because in Afghanistan's semi-arid climate there are a large number of stream and river crossings which are dry (or have very small flows) for the greater part of the year. Such drainage channels are called washes. At certain times, often for very short periods, such washes run with considerable flows. They are often very wide (up to 1 km) and to bridge them with a dry crossing for tertiary road traffic volumes would be uneconomic. In some cases the flow pattern is such that for nine months of the year the flow will be nil or minimal followed by three months of significant flow interspersed with periods of high flow of very short duration. The solution adopted for this situation is to construct a causeway which has a cross section designed to discharge the three months significant flow at a fordable depth (usually taken as 35 cms) allowing the road to be interrupted during the short periods of high flow. Such causeways may be of unvented masonry or pervious gabion construction. In cases where there is a significant dry-weather flow, slab culvert vents are provided.

The roads constructed by RDD are not normally paved, consisting of earth or improved earth surfaces. In the rare cases where gravel surfacing is provided it is usually spread in a number of thin layers, each layer being compacted by traffic. No compaction equipment is owned or used by RDD. Compaction of embankments and behind abutments of bridges and culverts is achieved by the use of wooden-pole rammers. Action is being taken to acquire a limited number of vibrating rollers and impact rammers to improve compaction in such cases.

5. **Stage design for roads**

The concept of stage construction of roads is well-known. It consists of the construction of the various elements of a road, earthwork, sub-base, base and surfacing in stages. Each stage is constructed at the point in time when traffic volumes dictate that particular stage. Thus, in the first instance, when low-traffic volumes are forecast, the road is constructed with narrower formation widths and lower pavement strengths than are predicted for the final stage.

In such cases it has usually been assumed that the road must be constructed on the same horizontal alignment in the first stage as will be required in the final stage. The vertical centre line may be adjusted in stages to accommodate the progressively higher sight distance standards demanded by increasing traffic volume. The same may apply to the widening of cuts or removal of obstacles to increase horizontal sight distances. The horizontal alignment of the centre line, apart from minor adjustments such as the insertion of transition curves and adjustments to curve radii within the earthwork width, is however usually fixed by considerations of the final traffic volume to be accommodated.

This general method of stage construction is a valid and economic concept in flat or rolling country as the effect of higher horizontal alignment standards involves a comparatively small increment in earthwork costs. For example, the cost differential of joining tangents by large radius curves instead of small radius curves is usually a small percentage of the total earthwork cost. In mountainous country however, where a road is running up a steep-sided valley (a very prevalent case) the cost differentials may be very high. If a large number of small radius curves are acceptable the road centre line can follow the contour with a minimum of earthwork. A higher standard of curvature and sight distance will involve cutting through spurs and filling through re-entrants. This not only involves higher volumes of earthwork but also the longitudinal movement of earth from cut to fill as opposed to the lower, standard case of lateral movement of earth short distances from cut to downhill waste. In addition, the filling of re-entrants on steep-side slopes often means considerable expenditure on retaining walls and pre-fill benching.

In such cases the principle of stage design can often achieve significant savings on initial construction costs. There is no doubt that such an approach will result in a higher total construction investment by the time the final stage is reached. However, if the traffic growth rate is expected to be small and the initial traffic volume is low (less than 50 vpd) the effect of postponing the capital expenditure required by the later stages can, by the effect of discounting the costs, result in lower net present costs. This effect, in cases where benefits are low, can have a decisive effect on the economic equation and convert a non-viable to a viable investment.

The question of ruling and maximum gradients, which are often critical design parameters in mountainous regions, requires special attention if stage design is to be adopted. The gradient criteria should be applied to the *final improved alignment* and the profile of the initial alignment adjusted to control points where the initial alignment crosses the final alignment. Thus the distance along the centre lines between two coincidental points on the two alignments might be 1,000 metres on the initial alignment and 500 metres on the final alignment. If the final design grade were to be 5 per cent, i.e. a rise of 25 metres over the 500 metres section then the gradient on the initial design section would have to be restricted to 2.5 per cent so that when the final design is achieved the final design gradient criteria can be met.

A second point requiring careful planning is the question of culverts and drainage structures. In the initial stage permanent culverts should only be located in positions where the initial and final alignments coincide or nearly coincide. In other cases either road dips (pitched to prevent erosion) can be provided, or dry-stone random rubble abutment walls supporting precast concrete slabs should be used. At the final stage these can be transferred to the final location culverts.

Bridges should be considered as control or obligatory points and constructed on the final alignment. In cases where this proves very difficult to achieve, prefabricated bridges such as Bailey can be used. Alternatively where traffic growth indicates that the final alignment will not be required within the life span of a temporary bridge (say 15-20 years) then a timber structure can be provided. In cases where initial traffic

volumes are low (say less than 25 vpd) interruption of traffic for limited periods (say 24-48 hours) can usually be accepted and pitched fords can be constructed on the initial alignment.

The decision to adopt stage design must be preceded by a carefully considered judgement of the traffic growth pattern (an analysis based on statistical method is seldom possible). An element of risk is of course always involved but the possible savings offered by the method are such that they allow much needed access to be provided to villages and small towns which would otherwise remain in isolation with all that involves in terms of the lack of economic and social development.

This approach can also offer a solution to the dilemma of being unable to construct a road to the final alignment requirements because its construction would require mechanical equipment (heavy rock cuts, etc.) which is not available in the country. The stage design approach enables a road to be built, as the side hill cut operation can always be achieved by hand labour using handtools. Thus, road access can be provided in many cases where the conventional design approach would involve costs which rule out viability. In such cases the villages and towns involved are condemned to indefinite stagnation in an isolated environment.

6. Organisation and management of labour

There are four distinct elements in the process of converting human physical energy into infrastructure. These are:

a) the generation and maintenance of the energy output itself;
b) the acquisition and application of skill;
c) the identification and provision of optimum tools and equipment to provide the means of converting the energy and the skill into physical infrastructure;
d) the organisation and methods used in the construction process to co-ordinate the three elements (a), (b) and (c).

In the normal case the maintenance of output is a function of incentives. The incentive may be financial reward or it may be by the negative incentive of a closely supervised environment which insists on a certain minimum output as a requirement of employment. Financial incentives may be on an

individual or on a group/gang basis. Such incentives include piecework where payment is in direct proportion to production and task plus bonus systems where a minimum task is linked to a day's work and additional payment is made for each unit of production achieved in addition to the minimum task. In some cases a mixture of the financial incentive and supervision incentive systems operates when labour contractors are employed[1], the contractor being paid on a production basis and his labour being paid on a supervised fixed-wage basis. But such systems are not considered desirable as they lead to the exploitation of labour by labour contractors.

In the case of purely voluntary labour the incentive, while it has an individual element, is essentially a group incentive and not directly linked to financial reward. As the labour is voluntary the relationship between the supervisor and the labour is quite different than that between a normal employer and employee. In the case of voluntary labour it is absolutely essential that the supervisory personnel adopt an attitude of offering their services to the village to assist them in achieving their objective. In the case of structures the fact that RDD provides cement and reinforcement provides some hold over the village but in the case of roads the provision of such materials is often minimal and control over the construction must be achieved by the co-operative attitude and leadership qualities of the RDD personnel.

The case where voluntary labour is supported by WFP aid lies between the purely voluntary case and the normal case. However the Afghan farmer is a fiercely independent individualist and the methods of man management adopted must tend towards the voluntary-labour case rather than the employed-labour case.

There are certain construction or quasi-construction skills which are inherent in Afghan village life. These vary somewhat in differing areas of the country in sympathy with the locally available construction materials. One skill which is very widespread is the management of flowing water. Irrigation is the life-blood of the Afghan farmer and he is highly skilled in drainage works, the construction of coffer and diversion dams. In areas where stone is available, masonry skills both in dry-stone walling and mud-mortar walling are indigenous. Labour which works on construction projects on a continuous

basis although nominally unskilled, has in fact significant skills both in excavation work and in support of skilled artisans. Such labour also has an awareness of the construction site environment with its attendant hazards. The acquisition of these skills is usually by a process of absorption through working with experienced construction labour. In the case of construction labour which is voluntarily supplied by a village for an isolated project the construction operation is a new experience and there is no core of experienced labour to emulate. This labour has to be trained in organisation methods and safety precautions completely from scratch by the RDD supervisory personnel. This process has to be repeated for every job because in every new project the labour, being indigenous to the village concerned, starts with no construction experience.

Before the construction team arrives on the site a construction plan has been prepared at RDD headquarters which shows in bar-chart form the starting date and time programmed for each operation and also the resource inputs required. Earthwork on roads is often carried on at several locations at the same time. These locations are selected on the basis of convenient distances from individual villages. Having identified the sections of road and the quantity of labour to be provided by the village or villages assigned to that section, the technician meets the Malik (headman) of the village and discusses the construction of the section in detail. The work is set out and the shape of the excavation is shown to the villagers. Work then proceeds supervised by the construction supervisors who indicate lines and levels and advise on management at the site to achieve the optimum productivity. This advice covers such points as the best division of labour between excavators, carriers, placers in fill or throwers to spoil. As has been stated previously the productivity of purely voluntary labour is a direct function of their own motivation and site management is largely confined to showing the labour how they can achieve greater productivity with the same effort.

In the case of labour supported by WFP food rations, reward (in terms of food rations) can be correlated with productivity. Production norms have been established for excavation tasks. These norms have been based on six soil categories linked to the process of excavation (table 1).

Table 1: Man-hours of labour-required per cubic metre

	Soil type[1]					
	1	2	3	4	5	6
Excavate into barrows or baskets	1.0	1.6	2.0	3.0	6.0	10.0
Excavate into trucks	1.6	2.2	2.8	3.6	6.6	10.8
Trench excavation 1.5 metres	2.0	3.6	4.0	5.0	10.0	14.0
Hauling in barrows over 20 metres	1.0	1.1	1.2	1.3	1.4	1.4
Hauling by baskets over 20 metres	1.8	1.9	1.9	2.1	2.5	2.5
Spreading and compacting in 15-cm layers	1.0	1.0	n.a.	1.0	n.a.	n.a.

[1] Soil type
1 – Loose sand or soil
2 – firm sand or soil
3 – clay or heavy adhesive soil
4 – compact soil or gravel
5 – soft rock
6 – hard rock

These norms are translated into metre-runs of completed road for the various configurations in the section being constructed. These configurations normally fall into four general categories:

A. Flat ground, no embankments. Side drains excavated and filled to centre to form camber. 5.50 m wide between drains.
B. Embankment 1 m high, 6 m wide.
C. Side hill cut on side slopes up to 30°.
D. Side hill cut on side slopes over 30°.

The quantity of excavation, carry, and filling in each metre-run is calculated for the average section and the number of man-hours work involved. This is translated into rations of food on the basis of eight hours work. The number of rations allowed per metre-run for each length of each configuration in

the section is then agreed with the labour force. The section is then divided into "lengths" with an approximately equal number of rations payable for each length. Each length is marked and allocated to a group of labour (a gang). Payment of rations is made on production achieved. In cases where the food ration is supplemented by a cash payment the cash payment is made on an individual man-day basis rather than on a productivity basis. This is done to comply with government accounting regulations.

Skilled labour employed on the construction of bridges, culverts, retaining walls and drainage outfalls is paid on a man-day basis. WFP-supported unskilled labour is paid food rations at the rate of one ration per man-day worked.

7. **Methods, tools and equipment**

The greatest bulk of the work performed is in excavation which is carried out entirely by hand (including rock drilling). The tools used are:

a) long-handled, round-mouthed shovels;
b) picks with sharp and chisel points;
c) crowbars with moil points for soft rock and boulder excavation and with chisel points for rock drilling;
d) two-man carrying litters.

These tools are the traditional tools of the farming community of Afghanistan.

The bulk of excavation in road works is in side hill cut or in the excavation of parallel drains on level ground using the material excavated from the drains to form a central camber. Movement of material from the excavation to spoil rarely exceeds 10 m and is usually of the order of 5 to 6 m. In the case of side hill cut excavated material is moved laterally to waste down the hillside. This is achieved by double handling the material, the excavator throwing to the excavated bench and a second man throwing it to waste by shovel. The number of excavators served by one double handler depends on the soil category involved and the length of throw. In the case of soil category 4 (see section 6, seventh paragraph) which forms a large proportion of the excavated material, one double handler can serve two or three excavators. If the distance to be moved is more than 6 m (two throws, triple handled) carrying litters may be employed. Attempts have been made to introduce

wheelbarrows as these have about half the labour input of a two-man litter. These efforts have had mixed success but where sufficient barrows can be obtained of suitable quality the indications are that they will be accepted in most cases. The use of baskets, headpans, etc., is not accepted by the Afghan farmer who is not accustomed to carrying any load on the head. Where carries exceed about 30 m, donkeys with twin panniers are used if they are available and can be spared from other transport demands. In cases where there are other competitive transport demands at the time of construction (e.g. taking the surplus crops to the bazaar), donkey transport has to be hired, at other times it is provided free by the village. In cases where long carries (in excess of 1 km) are involved the RDD provides dump trucks. These cases are usually confined to hauling construction materials such as masonry stone and concrete aggregates rather than excavated material to fill or spoil.

Rock drilling is done with crowbars which are "jumped" in the hole (not driven by hammer). A group of three men are usually employed. Two men "jump" the bar and the third washes and clears drillings from the hole, a length of hooked wire being used for this purpose. The bars are usually 1½ m long and 40-50 mm in diameter. Productivity achieved depends on the rock type but rarely exceeds 1 m per shift. It is therefore a slow and laborious process which often holds up other work. The RDD is procuring self-contained mechanical drills to speed up the process. Due to access difficulties the use of air-compressors and jack-hammers will be confined to sites where truck access is possible.

The greatest problems are encountered when excavating in pits or trenches for foundations, particularly to bridge piers and abutments where dewatering is necessary. The normal method is to construct a coffer dam or diversion dam of mud and stones reinforced with brushwood. The excavation is carried out in open pits without timbering which means that, allowing for tolerable side slopes, the area of the excavation is large. In gravel and boulder beds where percolation rates are high the volume of water entering the excavation is very high and when heads of more than about 2 m are involvd the inflow becomes unmanageable. 10 cm and 15 cm suction centrifugal pumps are used but in practice it has been found that foundation

depths beyond about 2 m are extremely difficult to achieve in the dry. This is being tackled in a number of ways:

a) by modifying designs by adopting shallow self-scour protecting structures (gabion and cribs);
b) by modifying designs by adopting open caissons to reduce foundation areas and reduce inflows;
c) to acquire excavation equipment (back hoes);
d to introduce timbering techniques.

It is difficult to introduce new tools and techniques to the extremely conservative Afghan farmer. This is particularly the case where voluntary labour is involved. The farmer will do it his way or not at all. It requires great persistence and the clear demonstration that a method is easier if there is to be any chance of getting it adopted. Construction supervisors and field engineers and technicians continuously try to improve techniques but the process is slow. A second problem when the labour force continuously changes from village to village is that by the time one village is convinced that a new technique is worth while a new batch of villagers from another village takes over the construction process.

8. Special considerations involved in the use of voluntary village labour

The primary objective of the Rural Development Department is to raise the standard of living of the rural people of Afghanistan by providing such supplementary inputs to the efforts of the people themselves as will help them to greater efficiency, productivity and social well-being. In the context of road building, it is not RDD's primary objective to construct the roads themselves but to use the road-building process as a vehicle for enhancing the self-reliance of the villages concerned and to increase their capacity to manage their own resources for the benefit of the community.

This policy of giving primary importance to voluntary village participation poses a number of problems which are not generally encountered when planning comes from the top downwards and construction is by paid labour.

The tertiary road construction programme emerges from the aggregation of village requests to construct roads and their agreement to provide the labour to do so. The shape of the programme and the relative economic priorities of the projects

comprising the programme are not therefore based on rational over-all regional requirements. When the RDD receives a request from a village to build a road a socio-economic survey is carried out which examines the transport need and makes a rough comparison between benefits (both quantifiable and non-quantifiable) and costs. The voluntary labour and local materials contribution is not counted in these costs as they are not transferable to other alternative projects. If this survey demonstrates viability the project is normally approved. When considering viability in this context the position of the road vis-a-vis the rest of the road system of the region is considered and a project would be approved provided it contributed to the totality of the transport system. However it might not, as an individual road, make a higher contribution than any other alternative. In this sense therefore it would offend against the principles of rational planning that investments should be progressively made in those projects giving the highest return. The attitude adopted by the RDD is therefore dictated by their basic policy of bottom-up initiative and not by the strict rationale of economic planning criteria.

Typical costs of tertiary roads in Afghanistan range from $1,500 per km for roads with few structures and no major bridges, to $12,000 per km for roads in isolated mountainous areas involving paid labour and considerable structural work in retaining walls, culverts and bridges. These costs demonstrate the simple design criteria adopted.

Design criteria which are based on good technical practice and considerations of functional efficiency and safety are not always self-evident requirements to a village which is required to make major contributions to a scheme. For example, a road is now under construction to link the Parsa valley to the main road in the province of Parwan bordering Central Afghanistan. This road is entirely in side hill cut through difficult boulder-strewn soil, rock talus slopes and, in some lengths, solid rock. Excavation conditions are difficult and laborious. The design criteria call for a cut bench width of 6 m, 5.50 m for the formation and 0.50 m for the hillside drain. The villagers have excavated a bench 3.5-4.0 m in width and light buses are negotiating the road and providing a transport service. The villagers are most reluctant to provide any further labour to widen this bench to the design width and it may prove impossible to

achieve the design criteria. The village has achieved its objective, a transport connection which is operating. As far as they are concerned this is enough. On this same road there is a difficult climbing section involving a double hair-pin bend. Drystone walling has been built to provide the bare minimum geometry which will enable a light truck to negotiate the bend by reversing on the hair-pin bends. This is a dangerous procedure and from a highway engineering point of view the design is unacceptable. A new design has been prepared which will require new retaining walls to be constructed. The first reactions of the villagers to providing labour to construct these walls was unfavourable but it is hoped that they will be persuaded to construct the new design before a major accident occurs.

Labour management has to be based on persuasion and mutual respect between the RDD team and the village. It cannot be based on the usual criteria of labour discipline and financial incentive. The incentives and motivation behind the village's voluntary contribution are discussed in section 3 (paragraphs 1-4). This requires an entirely different style of management based on leadership and sympathy rather than "commercial" methods. Arising from this is the fact that the construction processes involved have to be discussed in much greater detail to convince the villagers that the method advocated is to their advantage.

The present policy of initiation, planning and execution of tertiary road projects from the bottom up and with the close involvement of the village at all stages will be continued. As virtually the whole of village contributions consist of unskilled labour the use of this resource is obligatory which in turn means that labour-based methods must continue to be used. This policy is not confined to road construction but extends to all infrastructure works carried out by the Rural Development Department.

Notes and references

[1] Editor's note: the use of labour contractors is not encouraged by the ILO as it often leads to abuse. Their use is covered by the Convention concerning the protection of wages, Convention No. 95, adopted by the International Labour Conference in September 1952.

Annex I — Tertiary road design standards

a) formation width:
   i) in cut 5.50 m excluding drains;
   ii) in fill 6.00 m;
   iii) in rock 3.50 m excluding drains;

b) carriageway width 3.50 m;

c) passing places:
   i) generally 6.50 m wide, 35 m long at intervals of 500 m or the sight distance whichever is the less;
   ii) in rock cuts 5.50 m wide 25 m long at intervals of 150 m;

d) gradients:
   i) over-all gradients: earth surfaced 3 per cent, gravel surfaced 4 per cent;
   ii) maximum gradients: earth surfaced 10 per cent, gravel surfaced 12 per cent.

   Gradients through sharp bends, particularly hairpin bends, should not exceed 5 per cent between the tangent points of the bend plus 15 m at each end;

e) curvature: the maximum radii compatible with the terrain should be adopted with the following minima:
   i) minimum inside radius of carriageway — 9 m;
   ii) minimum outside radius of carriageway — 13.5 m;

f) surfacing:
   i) generally gravel surfacing will only be provided when traffic exceeds 100 pcu per day (cars 1 pcu, light trucks 1 1/2 pcu, medium trucks 3 pcu);
   ii) gravel surfacing will also be provided in particular cases where soil moisture or drainage conditions make it necessary;
   iii) in cases where the natural earth is of a plastic nature, cohesionless material such as sand or fine gravel is mixed with the top of the formation to stabilise the surface;
   iv) in other cases the natural formation will be used.

CHAPTER 8. THE BORDER ROADS ORGANISATION IN INDIA: LABOUR-INTENSIVE CONSTRUCTION ON A LARGE SCALE

by Major General J. S. Soin
Director, Border Roads Organisation

1. Introduction

The Border Roads Organisation (BRO) was created in 1960 to undertake road construction programmes in North and North-East India in areas where little or no road existed. The urgency for socio-economic development of these backward areas and the impediments to achieving this owing to the lack of road communications resulted in a crash programme of priority roads being roughly assesed in 1960 and efforts made to mobilise resources. The programme of road construction envisaged in the formative stages of the organisation was the completion of about 3,000 kms of roads (new construction and improvement) over a three-year period.

It was expected that when the objectives of the crash programme were realised, it would be possible for other development agencies to carry out maintenance and improvements and to expand the road communication complexes with many more arterial routes and feeder roads in the years ahead. However, the need for faster and dependable road communications systems increased and the BRO was entrusted with the construction of more roads on the basis of their performance and expertise.

2. Terrain and climate — effect on technology, design and specification

The BRO had to undertake work in areas of difficult terrain and extreme climatic conditions. The terrain is mostly mountainous, with many escarpments where the strata is geologically

very young, and unstable. The roads have been constructed from the foothills going up to 5,000 metres altitude.

There are regions which are generally arid and experience heavy snowfalls during winter months, and where very low temperatures obtain, in certain places as low as -40°C with high velocity winds as well. In other regions, forest growth is dense and rainfall is as high as 500 cms per year with frequent high-intensity rainfall during short periods, often associated with cloudbursts. Severe weather conditions pertain for almost five to six months of the year.

These climatic conditions obviously have an adverse effect on the efficiency of workmen and on the performance of machines and materials. Terrain and climatic conditions have, therefore, a special significance and have long-term effects on the organisational set-up, the design and specifications for the roads, the type of technology and the mode of working.

Initially, the bad terrain and extreme climatic conditions were governing factors in the adoption of machine-intensive work on roads. Availability of labour was also found to be poor as the working conditions were not conducive to attract people to venture into such areas. However, with the opening up of the areas and development taking place these areas became more habitable and working conditions improved so that it was possible to make a beneficial transition towards more labour-intensive methods.

3. **Design standards**

The width of roads constructed was that considered adequate to allow free one-way traffic or restricted two-way traffic. While adopting these specifications, it has also been kept in view that it will be possible to upgrade the roads if such a necessity arises due to traffic growth. A ruling gradient of 1 in 20 for hill roads was fixed keeping in view the effect of altitude and snowfall on vehicles.

To make the best use of local materials and those produced during the course of earthwork such as trees, stones and so on, it was decided at the start to provide temporary log culverts, retaining and drainage structures with stone masonry (wherever possible with dry stone), to use stone as soling to form the sub-base of the pavements, to limit paved roads to 3.75 metres and adopt a simple type of wearing

course, like surface dressing, for the pavement. Even in the construction of bridges for spanning small streams and major rivers, prefabricated equipment components were accepted, to be replaced with permanent bridges later on.

4. Selection of technology

The road construction programmes entrusted to the BRO were very large and were required in a relatively short period.

It became clear that the appropriate technology for road construction would be a combination of equipment-intensive and labour-based methods. This principle has been quite successfully adopted by the BRO not only in respect of road construction but for maintenance as well.

4.1 *Balancing of machines and labour: new construction*

For reasons outlined previously, it was initially planned to make the BRO basically machine based. However there was a considerable gap between the availability and requirements of machines necessary to realise the stated targets. In order to make up these shortfalls by manual efforts, it was necessary to evaluated the relative effects of using manpower as against machines and to examine the extent to which the labour-based methods could be used in realising the targets without in any way increasing the fixed and predetermined overhead costs. Accordingly, the BRO carried out a study of the labour required to replace machines for the major items of works in road building, namely earthwork in road formation, protective works and pavement construction. The results of the study are summarised below:

a) *Number of men required to replace equipment*
   - i) Crawler tractor (150-180 hp) : 200 men
   - ii) Compressor : 170 men
   - iii) Stone crusher (5-6 tons/hour) : 100 men

b) *The number of men required for 100 kms of road length per year even if earthwork and surfacing is done by equipment*
   - i) Earthwork : 3,000 men per day (jungle clearance, dressing of hill slopes, assisting machines, levelling road formation and so on)

ii) Protective and drainage works : 1,300 men (all works) per day

iii) Pavement : 1,900 men (stone collection, feeding of crushers, spreading of various courses, watering, assisting road rollers, berm dressing and so on)

Total : 6,200 men per day

c) The required labour force to execute 100 kms of road construction by various percentages of machines and labour (assuming that protective works have to be done only by labour) is depicted in Figure 1 overleaf.

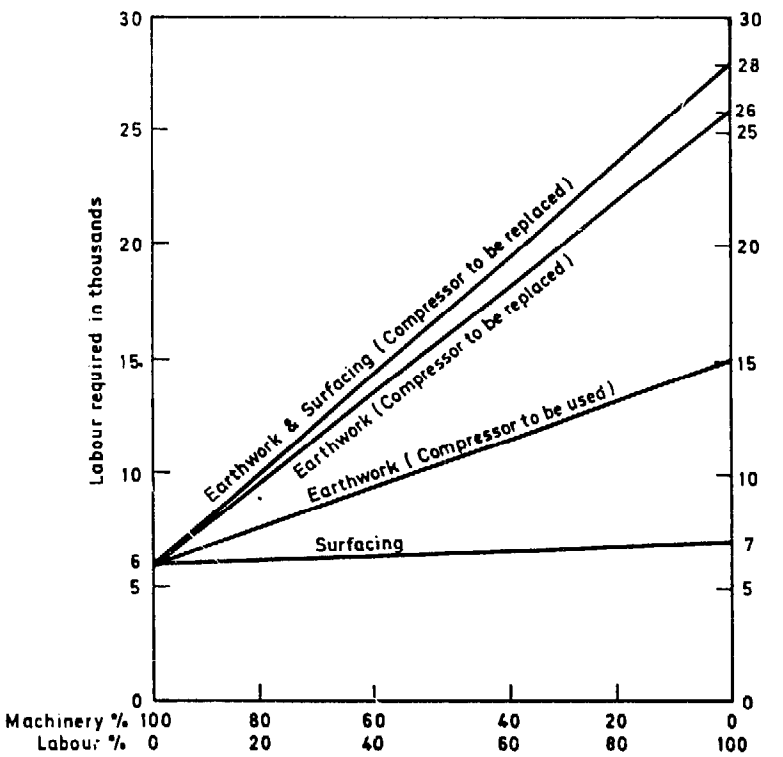

FIG. 1 MACHINERY AGAINST LABOUR

d) It will be seen from Figure 1 that the labour requirement steadily increases with the reduction in the proportion of machines. According to the graph the annual requirement of labour for executing 400 kms of road works per year is of the order of 25,000 men if equipment-intensive methods are used.

The use of a large labour force for road works poses recruitment problems which imply increases in the number of supervisory and administrative staff. Resorting to man-intensive earthwork has its own drawbacks and the deployment of men over virgin stretches of land becomes difficult. Further, wide variations in the requirements for labour will create problems at both the recruitment and discharge stages. The most important factor that has a bearing on costs is the requirement to accelerate road formation works. If this is not done the provision of the surfacing and protective works is delayed and causes an escalation of direct and indirect costs.

Nevertheless the move to a more labour-based method of working was such that during the peak years of work, i.e. 1965-68, around 25,000 regular departmental labour supplemented by about 65,000 casual labour were employed.

5. **Organisation**

The work of the BRO was a pioneering effort to open up inaccessible areas. To manage the technical and administrative problems that are encountered while working in difficult terrain and climatic conditions, a self-contained organisation was considered essential. This would have its own complement of men, machinery and stores, and with the capability of carrying out planning execution, management and inspection.

It was decided therefore that the organisation should be set up on a "task force" pattern charged with the specific responsibility of road development. The organisation devised for the task force was such that it was capable of tackling all the jobs that arise during the course of construction as well as carrying out the administrative and logistics functions. The evolution of the organisation from 1960 and the modifications carried out over the years as the result of experience are described below.

The task force, headed by a superintending engineer, was charged with the responsibility of technical and financial control over the constructional activities. The task force was given three types of *unit* to enable it to discharge its functions:

a) construction units;
b) logistic units;
c) administrative units.

Construction units are allotted to task forces for the following purposes:

a) construction company in charge of a sector of road;
b) earth-moving plant company holding a complement of tractors for earthwork. This provides the plant needs of the construction company;
c) construction equipment company for holding equipment like compressors, rock drills, stone crushers, concrete mixers, and so on, to be used by the construction company;
d) pioneer company to provide department (regular) labour force.

To assist the construction companies in their tasks, the following supporting units were provided:

a) field workshop to provide repair and maintenance facilities for vehicles, plant and equipment;
b) transport company/transport platoons to supply vehicles for construction and administrative purposes.

To provide administrative services, the following units were constituted:

a) supply platoons to provide rations and primary and secondary oils;
b) workshop and park company to hold and supply stores;
c) medical units;
d) postal sections.

All the units indicated above were placed under the task force which controlled the ground organisation and whose functions were technical, financial and administrative. The task force normally had two or three construction companies and one each of the supporting and administrative units and two pioneer companies. Each of the task forces were capable of being employed at any time on about 100 kms of new roads in different stages of development.

A task force with the organisational structure described was found to be effective in the formative stages. However, in due course of time, with the progressive improvement of communications and the necessity to adopt superior specifications including provision of large-scale protective work and all-weather pavement, it was found necessary to reorganise some of the units on a functional basis.

Therefore, a review of the functioning of the units of the BRO was carried out.

The review resulted in the following types of unit under the task force:

a) road construction company;
b) road maintenance platoon;
c) surfacing platoon;
d) permanent works platoon;
e) formation cutting platoon;
f) transport platoon.

The expected output of the functional platoons is as follows:

a) formation cutting platoon: 20 kms of road per year;
b) permanent works platoon: 300,000 dollars per year;
c) surfacing platoon: 20 kms of pavement per year;
d) road maintenance platoon: 100 kms road maintenance; 25 kms of renewal of wearing course and 80,000 dollars of protective works.

Each task force may have two to four road construction companies. Each road construction company may have either two formation cutting platoons or three surfacing/permanent works platoons or five road maintenance platoons with a budget of 1 million dollars per year. As such, a task force has the potential to undertake works worth 3 million dollars per year.

Such an organisation has been found to function effectively. The controlling headquarters for this organisation is that of the chief engineers of projects who each have two to four task forces under them. The project chief engineer has over-all responsibility for the task forces under him and his jurisdiction is defined from work and geographical considerations. The chief engineer is responsible to ensure the arrangement of all resources as well as their management and personnel administration.

The projects come under the over-all control of the Director-General, Border Roads who is responsible for co-ordinating the functions of the organisation, laying down technical standards, procurement of vehicles, plant and equipment as well as the allocation of resources and funds to projects.

For the construction of 100 kms of new road in one year the rough requirement for the major categories of personnel and machinery is tabulated below:

	Category	Requirement
	Manpower	
1	Officers (engineers)	100
2	Supervisors	
	(a) senior	200
	(b) junior	250
3	Tradesmen: (masons, concretors and so on)	750
4	Operators and mechanics	1 000
5	Regular labour	3 000
6	Casual labour (skilled and unskilled)	9 000
	Machinery	
1	Light vehicles	100
2	Load carriers (3 to 7 tons)	350
3	Crawler tractors (150-180 hp)	45
4	Compressors (2 drills)	45
5	Road rollers	25
6	Stone crushers up to 10 t/hour	20
7	Bitumen heaters	15
8	Hot-mix plant (20-30 t/hour)	3
9	Concrete mixers (up to $0.3m^3$)	6

6. **Employment of labour**

6.1 *Departmental (regular) labour*

Both skilled and unskilled labour is employed on road works.

The BRO has a certain complement of these in its own establishment who are regular government employees paid according to fixed scales of pay. Certain special concessions like rations, clothing and so on are also provided. There are some 3,000 skilled and 20,000 unskilled workers in this category. They are moved from place to place as necessary. Their cost to the BRO is about twice that of casual labour.

6.2 *Casual labour*

In many instances the BRO has supplemented departmental (regular) labour with a large complement of civil labour recruited locally or from outside and introduced into the area. Civil labour is employed on monthly rates of pay but they are not regular government employees and do not have any permanent hold on their job. Their services are liable for termination at any time and are governed by normal labour laws.

Imported labour is recruited from outside the immediate project area when there is scarcity of local labour. They are

recruited for a minimum period of six months and are paid train/bus fares to the project site from the place of recruitment and some pocket expenses. The facilities provided to the casual labour both local and imported are as follow:

a) issue of ration on payment;
b) limited medical services;
c) weekly paid holidays;
d) improvised living accommodation;
e) death/injury compensation.

The wages fixed for civil labour are not less than those for similar categories employed in other government agencies in the area, and also take into account the difficult working conditions where they are deployed. The range of rates prevalent are:

a) unskilled: 20-25 dollars per month;
b) skilled: 25-30 dollars per month.

The availability of labour is seasonal as labour is mainly drawn from rural areas and they go in search of employment during the non-agriculture season. By and large, the BRO has been able to get an assured supply of labour because gangs or groups of labour have been working for years with particular units. Thus, they have moved with the units wherever new works are taken up: moreover labour has taken up permanent residence in many of the areas where road communications have been developed and are employed as maintenance gangs.

The average strength of skilled and unskilled casual labour employed by the BRO over the last few years is 3,000 skilled and 60,000 unskilled.

7. **Contracts**

The bulk of the work of the BRO is done departmentally. However, with the opening up of the areas, the availability of construction contractors, as well as contractors for transport, has increased considerably. In view of this, it was considered desirable to entrust some works on contract, at least in the areas where development has taken place. Accordingly, certain works like supply and transportation of stone, aggregates, sand and so on, and to a limited extent construction of small items of work like culverts and retaining walls, are being awarded to contractors to augment departmental resources

especially vehicles. In addition, the construction of major bridges is being entrusted to specialist firms.

8. **Logistics**

One of the major problems of the BRO when operating in remote and difficult areas is logistics. It involves not only procurement and provisioning of an assortment of vehicles, plant and equipment and other stores but also transportation to work sites situated as much as 500-600 kms away from rail-heads.

Enormous efforts are required to position all types of stores and vehicles, plant and equipment at work sites at proper times and in predetermined quantities. These should be available in a state of fitness for utilisation. Unless the logistics problems are tackled, the constrcution work will not proceed as programmed.

One of the responsibilities of the Director-General, Border Roads and Project Chief Engineer is to look into the aspects of logistics and inventory management. Base workshops cater for repairs of vehicles, plant and equipment and provide a spares back-up. Stock and inventory control functions for constructional stores are attended to by stores depots under the project chief engineers.

9. **Conclusions**

Developing countries embarking on road construction programmes have to choose between labour-based and capital-intensive methods keeping in view the problems obtaining in their countries. It is possible to undertake large-scale construction programmes by organising the construction force modelled on the lines of the BRO.

The BRO has moved steadily over the years from a reliance on equipment-intensive methods to the use of effective labour-based methods.

It should be borne in mind however that the BRO is run along military lines. Whilst this produces relative efficiency it is not necessarily representative of labour-based work throughout India. It does indicate however that even when large numbers of unskilled labour are employed it is possible to organise and manage labour-based methods effectively.

CHAPTER 9. SOCIAL AND ENVIRONMENTAL FACTORS: LESSONS FROM IRAN

by R.S. McCutcheon

1. Introduction[1]

Several innovatory rural development programmes have recently been initiated in Iran. One of these — the Selseleh Integrated Development Project (SIDP)[2] is based in the Alashtar Valley of the Lorestan Province, about 450 kms south of Tehran. The town of Alashtar has a population of 6,000 inhabitants and is the commercial and administrative centre of a fertile and well-watered plain, which has over 200 villages whose total population is about 40,000. The people of the plain are members of the Lur Tribe, partly settled and partly nomadic. The income of the region derives almost entirely from nomadic pastoralism and agriculture, the main cash crops being wheat, soy beans and sugarbeet.

The SIDP was based upon notions of self-reliance and participation. Particular stress was laid upon the need for both collective and individual development to be endogenous (i.e. to grow from within the local society itself) and not be based upon alien models. Trainees were to be selected from among the local population. At the end of their training programme it was intended that they should return to their villages and act as "agents of change". The trainees would help the people decide upon their own developmental priorities. Concurrent with the training programmes it was intended that the project should initiate the provision of a developmental infrastructure (public baths, schools, roads, etc.) in accordance with the principles of endogenous development.

The headquarters of the project is in Teheran which is mainly responsible for budgetary matters and liaison with other ministries. The total budget for March 1975 to March

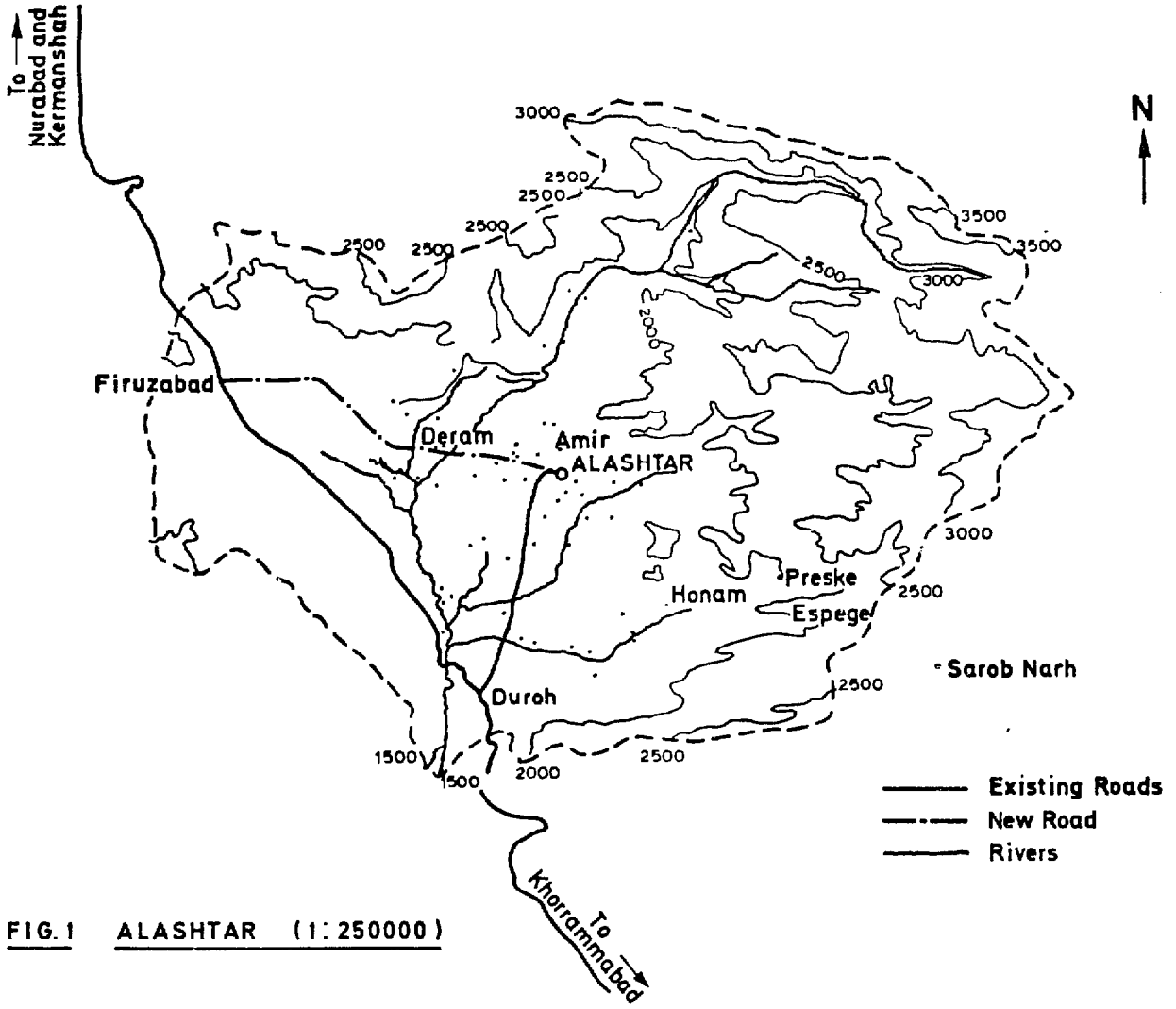

FIG. 1 ALASHTAR (1: 250000)

1976 was of the order of 10 million tomans ($1.4 million)[3]. Field programmes were devised and administered in Alashtar itself.

The large budget of the project allowed the purchase of significant amounts of equipment. Before the start of the project the town of Alashtar boasted perhaps four jeeps and three trucks. After one year the project had imported a garage of over 20 landrovers, jeeps and vans, as well as four 13-ton trucks, ten tractors and trailers and various equipment, and the staff attendant to the equipment.

2. **Road construction and the SIDP**

Road-building was also carried out under the auspices of the project. At the time of the author's arrival the road-building work showed the results of the theoretical framework of the project combined with the loose decision-making process and ample funds. Firstly, it was claimed that, in accordance with the theory of endogenous development, low-cost minor roads should be built by voluntary labour and that experience in Alashtar proved that they could be built by these means. Secondly, it was claimed that voluntary labour could also form the basis for constructing an all-weather road across the mountain between Espege and Sarob Narh (see figure 1), thus forming a major route between Alashtar and the City of Borujerd. Thirdly, work had actually started upon this route across the mountain but in contrast to the theory construction was neither based on voluntary labour nor was it low cost. A bulldozer had been hired and was working under the guidance of one of the professional staff, an agricultural engineer. About 21 km of track had been created. In one valley three routes had been carved out of the wheatfields: two had quickly become waterlogged, a third at the side of the valley was just passable. Higher up the pass one stretch of 3 km had an average gradient of 16 per cent (1:6.2), but in some places gradients were 30 per cent (1:3.3). There was much discussion amongst colleagues responsible for various other project programmes as to where the bulldozer should be working. The author recommended to the Field Director that the bulldozer should be immediately sent off site until a coherent programme be developed. This was for the following reasons :

a) the visible product of the bulldozer's activity was neither low cost nor usable;

b) there was no plan of operation nor was equipment available to carry out the necessary back-up operations, particularly drainage and surfacing; equally, delays were anticipated in equipment supply and difficulties with regard to maintenance;
c) there was no map of the mountain route nor had any reconnaissance survey been carried out to establish preliminary routes or levels;
d) the spring rains were torrential; and the terrain soft sandstone: besides being idle during the rain, any work carried out by the bulldozer resulted, with each storm, in a morass. The work being carried out would have to be redone in the dry season. At the same time the higher reaches of track had become extremely dangerous to traverse;
e) as all the work being done by the D6 could be carried out manually, the money being spent on it could be used for hiring labour.

There were other reasons for a postponement of the road-building programme. While endogenous self-help is a noble idea and a case may be made for certain types of road building based on these principles, there were apparent constraints to the immediate implementation of such a programme. Firstly, in the face of visible evidence of the amount of money at the project's disposal (both in relation to the size of the staff and the vehicles imported), the local people were somewhat bemused at the need for ongoing voluntary labour on their part. Secondly, this attitude was exacerbated by evidence of the ready availability of equipment for construction. Equally, throughout the region it was frequently voiced that nowadays roads were built using machines (in particular bulldozers) and not men. Thirdly, neither the people nor project colleagues were unanimous as to the routes and types of road required. In sum, insufficient time and energy had been devoted to the careful pre-planning necessary to ensure the success of a self-help road-building project. However, there were two reasons why the bulldozer could not be returned. Firstly, a deposit of 50,000 tomans ($7,150) had been made for the D6. So far the bulldozer had not carried out 50,000 tomans of work. It was feared that should the bulldozer be returned the project would not be able to claim the balance from the equipment contractor.

Secondly, the bulldozer provided visible evidence that the project was active.

This, then, was the background to the initiation and implementation of labour-based road-building programme.

3. Social, environmental and technical factors

We now turn to a consideration of the various ways in which the standard of the road required by the project, a social decision, was affected by technical considerations and the environmental conditions of Alashtar. The method by which the road was to be built, voluntary participation, was affected firstly by the nature of the product required to fulfil the expected standard, and secondly by cultural factors. We will also show how interpretations of the theory of endogenous development made by professional colleagues and a certain bias in favour of machines militated against the adoption of a paid labour-based programme. At the same time the existing state of data on the relative merits of labour-and capital-intensive construction did not provide incontrovertible evidence of the technical efficiency of labour. Thus, in the face of opposition to any form of work using paid labour, it was not possible to present a clear-cut case for the adoption of a paid labour-based programme founded on its technical efficiency. Finally, we suggest the social factors which led to the eventual adoption of a paid labour-based programme.

3.1 *The standard of the road*

It has been mentioned above that the project was intent upon building low-cost minor roads.

Several environmental and technical factors suggested that the standard of road required for all-weather traffic was somewhat higher than that so far achieved through voluntary participation or the use of the D6. These factors included the following: the severe climatic conditions; the susceptibility of the terrain to these climatic conditions; the frequency of the cross-drainage necessitated by the existing irrigation system; the volume of tractor traffic and the destructive effect of tractors upon the existing tracks; the results of the traffic survey which showed that the new road would carry over 100 vehicles per day.

After consideration of the standard required — an all-

weather road — it was concluded that the road should be built as close to secondary standards as the lack of planing allowed. On the basis of this assessment and the poor quality of the work that had been carried out previously, it was contended that just running a bulldozer through would neither provide an all-weather route for commercial traffic nor, in the long run, would it be low cost[4].

3.2 *The method of construction*

a) *Voluntary participation* — We have seen above that one of the major objectives of the project was to foster self-reliance through the means of voluntary participation. It was therefore expected that low-cost roads should also be built using voluntary participation. It was agreed that improved maintenance would result: villagers would be acquainted with the techniques of construction and proud of their work, therefore they would be able and willing to perform maintenance operations.

It became clear that the theory conflicted with reality. Firstly, whatever the level of socio-economic conditions prevailing in the region, the scale of voluntary participation expected of the people seemed to be high. Initially it had appeared reasonable that one might expect sporadic co-operation from the villagers in relation to certain village or personal amenities. But from the outset it seemed unreasonable to expect anything to be built by voluntary labour that was either time-consuming or that did not directly affect a particular village.

Secondly, the lack of response by the people to the calls for voluntary participation was not aided by the lack of enthusiasm amongst many of the project trainees themselves. This was in part the result of the fact that two of the three trainee groups were derived essentially from the better-educated and wealthy in the Alashtar region. Anthropological work[5] has shown that, amongst the better-educated and wealthy of Alashtar, manual labour is considered to be undignified: the project trainees were averse to implementing that part of the theory which emphasised the role of manual labour.

Further, remarks of the people concerning the project indicated that at a very basic level a lack of appreciation existed amongst them as to its purpose. The activities of the professional staff were interpreted as "All those engineers just eat

and sleep and drive up and down in landrovers". And in relation to moral exhortations to participate voluntarily: "Those engineers get paid for not doing any work so why should I work and not get paid?" or "The project is part of the Government and the Government has lots of money so why should I work for nothing?". In addition, the project's concentration upon the need for voluntary work was interpreted as an attempt by the Government to foist third-class goods upon an unsuspecting public.

More fundamentally, the lack of voluntary participation reflected socio-economic characteristics. The low level of rural income in Lorestan is partly the result of seasonal unemployment. The climate of North and South-Western Iran (including Lorestan) is such that there is a slack period of six months in agriculture and at least four months in construction. The active periods for two of the major sources for earning income overlap. In Alashtar the intensive cycle of wheat, beans and sugarbeet means that during the best building weather agricultural activity is in progress. During the good weather, if other work is not available locally, those not employed in agriculture go to the cities, mostly to Teheran construction sites. However, the building season in Teheran is similar to that the Lorestan. During the long off-season unless workers migrate south there is very little work available and thus seasonal unemployment is high. While it is not possible to find data for Lorestan which clearly support such a commonly expressed criterion of visible underemployment/seasonal unemployment, a recent report concluded that, out of the 3.8 million agricultural workers in Iran, about 1 million "may thus be potentially unemployed, while those reported as seasonally unemployed are mainly landless labourers probably working much less than 100 days a year"[6].

Further to the short span of time available to accrue income, anthropological work in Lorestan[7], supported by other work in Iran[8], suggested that the vast majority of peasants were in debt to village headmen, local princes (Khans), or usurers. Thus, within the constraints of a low average income, the short span of time available for productive work, debt and social mores, there was little room for altruism during the best building weather.

There were therefore various socio-economic constraints upon the acceptance of the need for voluntary participation.

The theory of low-cost construction based upon voluntary participation conflicted with reality in the actual mode of operation. This was because expensive machinery had been hired without any coherent programme of operation. It was also proposed that further equipment be either bought or hired (graders, bulldozers, rollers, trucks). Voluntary labour was to complement equipment. However, the existing mode of operation and the equipment contemplated suggested that either construction would prove expensive or it would require inordinate amounts of voluntary labour.

The prevailing socio-economic conditions and the apparent need for employment creation were such that it was necessary to question whether most of the budget should be spent on buying or hiring of equipment or whether the funds might form the basis for an employment-creation programme. The title of the project suggested that it should include employment creation.

Socio-economic conditions indicated not only that extensive voluntary participation would not be possible but that there was a need for additional sources of income-generating employment in the region. The scale of funds at the project's disposal indicated that it possessed the resources to fulfil such a need. Consideration was therefore given to the role that might be played by a road-building programme based on paid labour.

b) *Technical efficiency of labour* — A feasibility study using the available literature was carried out. The results are summarised in tables 1-4. They show that for bulk excavation by labour, estimates vary from 0.12 m^3/hr to 2.28 m^3/hr (1,900 per cent variation) and for a D7 bulldozer from 64 m^3/hr to 410 m^3/hr (640 per cent variation).

Several utilisation rates were considered in calculating the cost of substitution of labour for equipment. For a utilisation rate of 2,500 hours per year, at a bulldozer cost of 32,600t/month ($4,650), the possible spectrum for substitution varies from 29.1 men costing 14,500t/month ($2,080) to 7,120 men costing 3,560,000t/month ($509,000).

Taking the figures at face value it was not possible to reach

any conclusion in favour of labour at market prices. Equally, whereas the literature produced by the ILO is cautiously optimistic about the technical efficiency of labour substitution[9], the IBRD consider that modifications have to be made to existing techniques in order to make the substitution of labour for machines competitive[10]. However, certain factors suggested that the higher ranges of equipment productivity and utilisation rates would not apply in Alashtar. The project lacked maintenance facilities capable of ensuring high utilisation of equipment. Further, without continual supervision it was not possible to authenticate the amount of work carried out by the bulldozer. Moreover, in a situation where optimum planning did not prevail, it would be impossible to keep the dozer continually active. However, in the case of a hired machine such inactivity would have to be paid for by the project. Thus for various reasons it was considered that the utilisation rates would be lower than optimum.

Such reasoning led to the following interpretation of the data: for a utilisation rate of 1,500 hrs/yr, at a low- to middle-range labour productivity of 0.82 m^3/hr, and the lower order of bulldozer productivities, the following might apply: 48.8 men costing 24,400t/month ($3,490), 91.5 men at 45,700t/month ($6,530) or 109.5 men at 54,700t/month ($7,815) would be equivalent to a D7 bulldozer costing between 30,000 and 33,000t/month ($4,280 to $4,720).

The proposal that an experimental paid labour-based programme should be initiated was based upon the following factors:

i) the role which could be played by a paid labour-based programme in regional employment creation;
ii) the flexibility of labour as opposed to machinery in particular the bulldozer;
iii) the heavy capital costs of equipment and the equally heavy, though somewhat milder, costs of maintenance;
iv) Muller's contention that the use of labour-based methods had also resulted in improved maintenance because of a greater feeling of involvement[11];
v) a case could be made for the technical efficiency of labour when compared with capital-intensive work.

c) *Voluntary labour v. paid labour v. equipment* — The proposal met with severe opposition. Firstly, it was widely held

that the payment of labour conflicted with the basic premises of the project. Secondly, it was held that the productivity of men could not possibly compete with that of machines ... in particular the bulldozer[12]. The caveats presented as to long-term maintenance costs of equipment and average efficiency were received sceptically.

Repeated experiences in connection with the bulldozer led to the conclusion that both local people and the project staff were almost in awe of the machine. Time and time again the villagers approached the project for the use of the bulldozer for activities which were totally beyond its ability. It appeared that one reason for the mainfest belief in the all-powerfulness of the bulldozer lay in its representation of modernity. To have work done by a bulldozer was the modern way of doing things.

Secondly, whereas the virtues of voluntary labour were declaimed, it was equally maintained that labour could not possibly compete with machines in respect of productivity. Paid labour was not only in contradiction to theory but more expensive and retrogressive as well. Voluntary labour in the context of a large equipment component was not.

The proposal that a labour-based programme be undertaken was therefore rejected out of hand on two basic grounds: paid labour was not in accordance with the theory of endogenous development and men could not compete with machines.

d) *Voluntary v. paid labour* — The project pressed ahead with road building by voluntary participation. Two factors resulted in the eventual adoption of an experimental programme using paid labour. The most important being the fact that, despite repeated attempts to recruit volunteers, no volunteers presented themselves. In addition, the employment that could be created for the money involved was pointed out, viz:

i) A full programme of capital-intensive work would utilise about 11,000t/day ($1,575). Implementing a programme where only 56 per cent of the cost was spent on labour would release 6,160t/day ($832) for their employment. At the current rate of 20t/day ($2.86) this would be sufficient to hire 308 people;

ii) the money presently spent upon the bulldozer alone could provide employment for 1,920/20 = 91 men per day.

The authorities were impressed by the sheer numbers of people who could be employed for the same amount of money as that being expended for the hiring of equipment. In the face of the continued lack of volunteers and the real need for visible product, they were sympathetic to the other arguments which had been put forward to support the initiation of an experimental programme of paid labour-based road construction. The combination of these factors caused the authorities to advocate the initiation of such a programme.

4. Summary of work programme and comment

4.1 *The work programme*

The programme consisted of the use of a combination of labour-based and equipment-intensive methods in the construction of some 15 kms of road over a 9-month period.

Detailed evaluations were made of the work completed (see table 5), the equipment and labour employed, the total costs and the various productivities for the following activities: embankment, gravelling, bridges and irrigation canal crossings. It must be pointed out that the size of staff did not permit accurate observation of quantities. The calculations were based on the daily reports compiled by the timekeeper and the head foreman, modified by observations made by the author.

4.2 *Comment on work completed*

First we will deal with aspects of the work which are to some extent quantifiable.

a) It was calculated that the productivity of labour for work which was considered in the feasibility study to be "excavate and load", varied from 3.44 to 3.8 m^3/man-day. The work was carried out under task work conditions which amounted to a working day of six hours. This is in the low range of labour productivities as derived from various sources and presented in table 4 (at this end of this chapter)[13].

b) The productivity of the D155A-1 (320 hp) bulldozer was found to vary as follows:
bulk excavation: (haul $<$ 20 m) : 105 m^3/hr; (average haul 50 m) : 42 m^3/hr;
excavate and shape embankment: (haul $<$ 20 m) : 41.7-67 m^3/hr.

These results vary from *3.6* to *9.1* per cent of the maximum manufacturer's productivities quoted in IBRD Technical Memorandum No. 7[14]. The productivity of the D6 (140 hp) for excavating and shaping the embankment (haul $<$ 20 m) was 27.5 m^3/hr or *5.5* per cent of the maximum quoted in Technical Memorandum No. 7[15]. Two points may be ventured in respect of the extremely low productivities obtained by the bulldozers. Firstly, the area adjacent to the route which was encroached upon during construction was five to ten times greater in the case of the bulldozer than in the case of labour. Secondly, the system of work employed by the dozer in making the embankment entailed a greater bulk movement of earth than that used by labour-based methods. The road was created by a series of movements entailing first the dumping of earth in large mounds followed by the shaping of these mounds into place.

c) It was possible to compare unit costs of labour and bulldozer for embankment construction. For labour this varied from 7 to 7.35t/m^3 (1 to 1.05\$$m^3$), whilst that for the bulldozer amounted to 3.83t/m[16]. At the rates charged for the bulldozer it can be seen that the labour-based work was distinctly inefficient: 83 to 92 per cent more expensive[17].

It must be stressed that the rate charged through the Governor General's office for a 320 HP bulldozer (D155A-1) was 140t/hr (\$20). The author has not been able to ascertain the market price of the same piece of equipment but the following comparisons may be made: from a rental contractor a "special price for the project" of a 270 hp (D8) had been 192t/hr (\$27.5/hr), the normal rate from the same contractor being 220t/hr (\$31.5/hr). By comparison with this rate it may be seen that the rate through the Governor General's office was generous, to say the least.

On the basis of rental contractors' rates for a D7 and a D8, the rate for a D155A-1 (320 hp) would be of the order of 265t/hr (37.90/hr). Using such a rate we find that the cost productivity of the bulldozer amounts to 6.83t/m^3 (\$0.98/m^3), i.e. *2.5* to *7.5* per cent cheaper than labour. Excluding the roller common to both we find the cost

productivity of the bulldozer amounts to 6.34t/m³, i.e. equipment becomes 3.1 to 3.6 per cent more expensive than labour. These estimates do not include transport costs (equivalent to two days' work). Thus, at prevailing market prices for the same piece of equipment, labour-intensive work becomes far more competitive than at the rates through the Governor General's office.

d) In the spreading operation, productivity amounted to 2.95 m³/man-day. However, it is felt that this productivity was severely inhibited by the frequent passage of trucks which disrupted the work.

e) The costs of gravel haulage amounted to 23 per cent of the cost (excluding river re-route and bridges).
Due to the loaders being supplied as part of the package from the Governor General's office, it was not possible to substitute labour for the loading process. Loading and haulage amounted to 28.4 per cent of the cost: at market prices this would amount to 32.5 per cent.

f) The method of constructing irrigation canal crossings based upon second-hand barrels was found to be satisfactory. The cost of one of these amounted to $147 as opposed to $345 using 45 cm diameter reinforced concrete pipes.

g) Self-driven vibrating rollers were bought in place of the tractor-drawn rollers specified. Not only were these vibrating rollers extremely sensitive — the smaller one was almost permanently out of action — but they could only travel on a level roadway which considerably restricted manoeuvreability.

h) Excluding the cost of re-routing the river and building the bridges, but including an estimate for completion of gravelling, the over-all cost per kilometre amounted to 105,500 tomans ($15,000). Using market rates for the hire of the bulldozer, trucks and loaders, the over-all cost per kilometre would have been 122,750 tomans ($17,525). These figures are well below contractors' estimates for similar standard roads in neighbouring areas, these being of the order of 200,000 to 230,000 tomans per kilometre ($28,600 to $32,800).

i) Tables 6 and 7 summarise the employment creation in man-days per kilometre for the different tasks and for

different combinations of the tasks. For the section of the road in which the embankment, spreading and water crossings were constructed by essentially labour-based means, the employment creation amounted to approximately 2,800 man-days per kilometre. For the section in which only spreading and water crossings were carried out by labour-based methods and the rest constructed by capital-intensive methods, the employment creation amounted to approximately 840 man-days per kilometre. It was possible to compare the costs per kilometre of construction of the whole road by the different methods, and the relative proportions of labour and equipment. Excluding overhead costs (salaried officials) a breakdown is given in table 5 and the results are summarised in table 8. The actual cost of the section in which embankment construction, water crossings and spreading were carried out by essentially labour-based means was 101,880 tomans per kilometre ($14,550). The actual cost of the section in which only spreading and water crossings were carried out by labour-based means and the rest was constructed by capital-intensive methods was 81,930 tomans per kilometre ($11,700).

We see that the actual cost of construction using a higher proportion of capital to labour was 19.5 per cent cheaper than that using nearly equal proportions of labour and capital. However, at market rates for equipment we find that the cost of the section which was constructed using a higher ratio of labour to capital would have amounted to 112,575 tomans per kilometre ($16,090), while the section constructed with a higher proportion of capital would have cost 113,175 tomans ($16,170). In this case, the section completed using a higher proportion of labour would have been 0.5 per cent cheaper.

Experience in the Alashtar programme also contributes to the less quantifiable aspects of the on-going debate as to the relative merits and demerits of labour-based and capital-intensive methods.

a) During the height of the agricultural season there was no difficulty in recruiting 100 men for the small labour-intensive programme. Later, when the workforce was

expanded, agricultural activity was still in progress. No difficulty was experienced in hiring 288 men.

By contrast, during the best building weather, there were often delays in the delivery of machinery. Therefore, in Alashtar, greater difficulty was experienced in locating machinery than men.

b) Some idea of the utilisation rates of equipment and the maintenance required has been given above. Mention should also be made of the repercussive effect that breakdowns had upon the work.

c) In Alashtar, when the programme or the weather changed, men could be laid off and recruited when necessary. By comparison, if one wished to lay off equipment for a short period, then one had to pay for the period laid off. If one wished to lay off equipment for a long period, then one could not be sure of being able to obtain it again on demand.

d) It has been suggested[18] that the ease of labour mobilisation and the lower overheads might be offset by the costs and organisational problems of running a large labour camp. In Alashtar this was not the case as the men were recruited from villages alongside the route. By contrast, it was found necessary to run a small road camp for the equipment operators and many difficulties were experienced in keeping them satisfied with the standard of food and accommodation.

It would seem therefore that for a small isolated programme without a rigorous work schedule (and limited workshop facilities), the hiring of machines is potentially more expensive than the hiring of men.

4.3 *Labour organisation*

The substitution of men for machines in Alashtar was facilitated by the fact that until abour 12 years ago, roads in Lorestan were built using labour as a major component. Many of the men were therefore familiar with the work.

Perhaps more important is that, in Alashtar, one of the forms of labour organisation is based upon gangleaders. Gangleaders find the work, supply the labour, and themselves supervise the working of the gang. As such, the reintroduction of labour-based work is not dependent upon extensive training

in labour organisation or the chance discovery of experienced foremen.

With a small staff it was necessary to promote workers who were willing and capable. It was found that unless care was taken to ensure that the delegation of authority was understood by all concerned (over 300 people), those to whom authority was delegated were unable to act. Conversely, once authority had been acknowledged, many of the new men were able to function very well.

Finally, while costs of labour mobilisation and overheads were very low, recruiting labour from villages along the route did result in a certain amount of friction as to who was entitled to work on a particular stretch of road.

5. **Conclusions**

5.1 *Conclusions related to technical aspects*

a) At the hiring rates available through the Governor General's office (almost half the market price), it was not possibie to achieve a technically efficient substitution of manual labour for machines. At market prices, however, estimates showed equipment-intensive methods to vary between 3.6 per cent more expensive and 7.5 per cent cheaper than labour-based methods.

b) Productivities for earthmoving equipment were found to be as low as 5 to 10 per cent of that of the maximum manufacturer's data quoted in the World Bank Technical Memoranda No. 7[19].

c) The variety of labour productivities presented in the literature was so varied that probably a month of work on site is necessary before an adequate estimate may be obtained for planning purposes.

d) In a small isolated community development project machine-intensive work is potentially more expensive than labour.

5.2 *Conclusions related to social aspects of the work*

a) Under the particular conditions obtaining in Alashtar, it was found difficult to introduce labour-based methods for the following reasons:

i) the professional staff were committed to the concept of voluntary work;
ii) the professional staff found it extremely difficult to accept that labour could be as technically efficient as machines;
iii) foremen tended to view labour-based work as giving them less status than equipment-intensive work;
iv) villagers and townspeople echoed professional staff opinion as to the manifold advantages of the bulldozer over labour. The villagers could see that the project had financial resources for equipment and consequently saw no necessity for *voluntary* labour-based methods of construction. The bias was removed once labour changed from voluntary to paid.

Under these conditions, it is considered that it is no more difficult to organise a labour-based work programme than any other civil engineering programme. If anything, the equipment side of the project provided more problems for the engineer.

b) Labour-based construction has often been seen to be particularly relevant to capital-scarce and labour-abundant economies. It might be argued that the material context of a capital-rich and rapidly modernising economy like Iran obviates the need for labour-based work. However, in Alashtar, the response to labour recruitment was such as to indicate that at the regional level an abundance of labour still exists. Within such a context the expansion of labour-based construction would be valid.

c) Seasonal variation of labour has often been seen as a restriction upon labour-based construction. Experience in Alashtar suggests that a quite substantial body of men could be hired for the whole building season. They could be employed in smaller teams to carry out particular parts of work scattered along the route — such as bridge construction, irrigation canal crossings and the more complicated pieces of embankment work.

d) Experience in Alashtar certainly substantiates the statements in the IBRD Phase I report that labour-based work should be "socially acceptable to the people of the country"[20].

Equally, that for labour-based work to be successful it should be "actively supported ... at the highest possible level"[21].

Notes and references

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[2] For an overview of SIDP the reader is referred to M.T. Farvar and C. Razawi-Farvar, "The lessons of Lorestan, achievements and shortcomings of a project in endogenous development" *CERES* 9 (2), March-April 1976, pp. 44-47. In the present introduction the author has presented only the barest outline of the SIDP concentrating upon aspects pertinent to the road-building programme.

[3] The rial is the unit of currency in Iran. In 1977, 70 rials = $1. Colloquially the toman is used; 1 toman = 10 rials. The author has referred to tomans throughout the paper; 7 tomans = $1.

[4] The first 9 km of track originally created by the D6 had to be graded or dozed four times in as many months.

[5] Jacob Black, "Tyranny as a strategy for survival in an 'egalitarian' society: Luri facts versus an anthropological mystique", *MAN*, 7 (4), Dec. 1972, 614-634. Jacob Black-Michaud, "An ethnographic and ecological survey of Luristan, Western Persia: modernisation in a nomadic pastoral society", *Middle Eastern Studies*, 10 (2), May 1974, 210-228.

[6] Employment and Incomes Policies for Iran, Geneva, ILO, 1973, p. 27.

[7] Jacob Black, op. cit.

[8] N.R. Keddie, "The Iranian village before and after land reform", in Henry Berstein: *Underdevelopment and Development, The Third World Today, Selected Reading* (Harmondsworth, Penguin, 1973), pp. 152-174.

[9] Deepak Lal, *Men or Machines* (Geneva, ILO, 1978).

[10] *Study of the Substitution of Labour for Equipment in Civil Construction, Phase II — Final Report* (IBRD, Staff Working Paper No. 172, Jan. 1974).

[11] Muller, "Labour-intensive methods in low-cost road construc-

tion: a case study", *International Labour Review*, 101, Apr. 1970, pp. 359-375.

[12] It was also held that it must be easier to organise a small team of equipment operators than a large labour force, which indicated the scale of voluntary activity anticipated and therefore the equipment-intensive nature of the programme envisaged.

[13] See also "Report of first road demonstration project", Technical Memorandum No. 9 (IBRD, Aug. 1975), p. 19.

[14] "Productivity rates of earthmoving machines", Technical Memorandum No. 7 (IBRD, May 1975), p. 43.

[15] ibid., p. 42.

[16] Excluding the roller common to both methods, we find that labour varies from 6.12 to 6.15t/m^3 (0.875 to 0.878\$/m^3), while the bulldozer productivity amounts to 3.35t/m^3, i.e. 83 to 83.4 per cent more expensive. It is perhaps worth noting the obvious that the percentage of equipment cost increased with the decrease in the number of people employed to the detriment of labour cost productivities: for 120 men equipment was only 25.9 per cent of total costs, for 70 men it rose to 35.5 per cent.

[17] Irvin, op. cit., p. 34. Here 67.5 rials = \$1, i.e. 6.75t = \$1.

[18] IBRD (1971), op. cit., p. 91.

[19] IBRD (May 1975), op. cit.

[20] IBRD (Oct. 1971), op. cit.

[21] IBRD. ibid.

Table 1: Productivity estimates from various sources for a 180 HP bulldozer

Source	m^3/hr. for haul up to 20 m
Muller (70)[1]	27.5
Lal (74)[2]	64.0
Lal (74)[3]	91.0
Geddes (67)[4]	95.0
Lal (74)[5]	120.0
35% manufacturer's maximum for D7[6]	143.5
45% manufacturer's maximum for D7[7]	184.0
Lal (74)[8]	190.0
Peurifoy (70)[9]	225.0
Manufacturer's maxima as quoted by Lal (74)[10]	
Komatsu D80A-12	235.0
Caterpillar D7	410.0
25% manufacturer's maximum for D7[11]	205.0
Manufacturer's maxima as quoted by IBRD Tech. Memo No. 7[12]	
Komatsu D804.12	603.0
Caterpillar	820.0

[1] Muller (1970), productivity derived from data on p. 236; unfortunately Muller does not clarify whether he used a D4 or a D7.

[2] Lal (1974), lower range estimate for D7 on p. 57.

[3] Lal (1974), average estimate for D7 on p. 57.

[4] Geddes (1967), productivities given on p. 161 for a 35 hp D4, a 55 hp D6, an 80 hp D7, and a 113 hp D8; productivity in table derived by extrapolation to 180 hp.

[5] Lal (1974), upper range estimate for D7 on p. 57. Irvin (75), p. 141, gives an estimate for a D8 which adjusted using Lal's graph on p. 57 gives the same productivities.

[6] Lal (1974), pp. 153 and 155, Lal recommends that productivities are of the order of 35 per cent of Caterpillar maxima.

[7] Lal (1974), p. 22, "a figure of 40-50 per cent of the published productivity rates would provide a realistic degradation factor for operating equipment in a less developed country". The IBRD report only refers to Caterpillar equipment bulldozers. The productivity given is derived from 45 per cent of the data in Lal (74), p. 155.

[8] Lal (1974), p. 41, gives "ex ante estimate" for D7 and 100 m haul; above figures derived by adjusting the 20 m using Lal (74), p. 57.

[9] Peurifoy (1970), p. 164. The data in Peurifoy are for tracked bulldozers varying from 32 hp to 132 hp; productivity in table derived by extrapolation to 180 hp.

[10] Lal (1974), p. 155.

[11] IBRD (1975), Tech. Memo No. 7, p. 21. IBRD recommend that outputs are 25 per cent of Caterpillar maxima. It should be noted that the maximum in TM No. 7 are double those quoted by Lal (74), p. 155.

[12] ibid., pp. 42 and 43.

Table 2: Estimates of monthly productivities for various utilisation rates

	Hrs./yr.	1 000[13]	1 500[14]	2 000[15]	2 500
	Hrs./mth.	83.4	125	166.5	208
Source	m^3/hr.				
Muller[1]	27.5	2 270	3 430	4 580	5 720
Lal (74)[2]	64.0	5 340	8 000	10 670	13 350
Lal (74)[3]	91.0				
Geddes (67)[4]	95.0	7 940	11 900	15 850	19 750
Lal (74)[5]	120.0	10 000	15 000	20 000	25 000
35% (Lal)[6]	143.5	11 950	17 950	23 900	29 800
45% (Lal)[7]	184.0	15 300	22 900	30 600	38 200
Lal (74)[8]	190.0				
Peurifoy[9]	225.0	18 750	28 100	37 500	46 800
Manuf. ex Lal[10]					
Komatsu	235.0	19 600	29 300	39 100	48 800
D7	410.0	34 200	51 200	68 300	85 200
25% manuf.[11] (IBRD)	205.0	17 100	25 600	34 100	42 700
Komatsu (IBRD)[12]	603.0	50 400	75 500	100 500	125 800
D7 (IBRD)	820.0	68 300	102 500	136 500	171 000
Rates t/hr. (Irvin)		340	240	190.5	160.6

[1 – 12] As for table 1.
[13] Lower range utilisation reported by IBRD (74).
[14] Border roads IBRD (75).
[15] Upper range also IBRD (75), also Peurifoy (70).
[16] Irvin (75).

Table 3: Bulk excavation

Sources	m^3/hr.	m^3/day	m^3/mth.	Soil type	Method of payment
IBRD (74)[1]	0.12	0.96	24	Ord.	
Lal (73)[2]	0.216	1.73	43.2		
Muller (70)[3]	0.337	2.7	67.5		
Lal (74)[4]	0.443			6	Daily
Lal (74)	0.535			5	Daily
Muller (70)[5]	0.55	4.4	110		
Lal (74)[4]	0.785			6	Task
Lal (74)	0.82			(4 (6	Daily, piece
Lal (74)	0.945			5	Task
Lal (74)	0.99			5	Piece
Lal (74)	1.235			3	Daily
Lal (74)	1.44	11.5	228	4	Task
Lal (74)	1.51			4	Piece
IBRD (74)[6]	1.66	13.25	331.5	Ord.	
Lal (74)[4]	2.2			3	Task
Lal (74)	2.28	18.25	455	3	Piece
Allal and Edmonds[7]	1.25 0.57		118	2	Daily

[1] IBRD (74), p. 22, lower range.
[2] Lal (73), provisional draft of *Men or machines*, p. 44, estimate for excavation of structure.
[3] Muller (70), p. 366.
[4] Lal (74), pp. 138 and 139.
[5] Muller (70), p. 366, derived from data on p. 366.
[6] IBRD (74), p. 22, upper range.
[7] Allal and Edmonds (75), p. 123, table 5.2, European Standard.

Table 4: Labour productivity estimates from various sources

2. Excavate and load

	m^3/hr.	m^3/day	m^3/mth.	Soil type	Method
Lal (74)[1]	.3			5	Daily
Lal (73)[2]	.375	3.0			
Lal (74)[1]	.39			4	Daily
Geddes (67)[3]	.42	3.36	84	Gravel and compact soil	
Lal (74)[1]	.433			3	Daily
Lal (74)	.475			5	Task
Geddes (67)[4]	.477	3.81	95	Gravel and compact soil	
Lal (74)[1]	.55			5	Piece
Lal (74)	.57			4	Task
Lal (74)[5]	.625	5.0	125		
Geddes (67)[6]	.63	5.04	126	Sandy clay	
Lal (74)[1]	.664			3	Task
(74)	.68			4	Piece
Geddes (67)[7]	.764	6.11	153		
Lal (74)[1]	.8			3	Piece
Lal (73)[8]	.85	6.8		Common soil	
Lal (73)[8]	1.0	8.0		soft sort	
Allal and Edmonds[9]	1.1			3	Piece

[1] Lal (74), derived from data on pp. 138 – 141. Productivity ratios for excavation piece : task : daily : : 1.85 : 1.77 : 1.00. Productivity ratios for loading to 1 m piece : task : daily : : 1.85 : 1.42 : 1.00.
[2] Lal (73), provisional draft of Lal (74), p. 60.
[3] Geddes (67), p. 148 to vehicles.,
[4] ibid. to barrows.
[5] Lal (74), p. 41 ex ante estimate.
[6] Geddes (67), p. 148 to vehicles.
[7] ibid to barrows.
[8] Lal (73), p. 60.
[9] Allal and Edmonds (75), table 5.4, p. 124.

Table 5: Costs per kilometre of various methods of construction

1. *Labour-intensive embankment and spreading, and capital-intensive excavation, load and haul*
   Actual costs per km

	Labour	Equipment	Materials	Total
Embankment	34 200	11 850		
Excavation		2 680		
Load and haul		29 400		
Spreading	10 160	1 130		
Canal crossings	3 580	3 760	5 120	
Totals	47 940	48 820	5 120	101 880
%	47.0	48.0	5.0	100

2. *Capital-intensive embankment, excavation, load and haul, and labour-intensive spreading*
   Actual costs per km

Embankment		26 100		
Excavation		2 680		
Load and haul		29 400		
Spreading	10 160	1 130		
Canal crossings	3 580	3 760	5 120	
Totals	13 740	63 070	5 120	81 930
%	16.8	77.0	6.2	100

3. *Labour-intensive embankment and spreading, and capital-intensive excavation, load and haul*
   Costs per km *at market rates*

Embankment	34 200	11 850		
Excavation		5 075		
Load and haul		37 700		
Spreading	10 160	1 130		
Canal crossings	3 580	3 760	5 120	
Totals	47 940	59 515	5 120	112 575
%	42.5	52.9	4.6	100

4. *Capital-intensive embankment, excavation, load and haul, and labour-intensive spreading*
   Costs per km *at market rates*

	Labour	Equipment	Materials	Total
Embankment		46 650		
Excavation		5 075		
Load and haul		37 700		
Spreading	10 160	1 130		
Canal crossings	3 580	3 760	5 120	
Totals	13 740	94 315	5 120	113 175
%	12.1	83.4	4.5	100

Table 6: Employment creation per task

Task	Length m	Vol m3	Labour: Skilled No	Skilled Mandays	Skilled Cost	Unskilled No	Unskilled Mandays	Unskilled Cost
Embankment								
1. Total	3500	2300	1	60	2100	112	6700	117500
Labour	(2620)	(17450)	(1)	(60)	(2310)	(70.5)	(4640)	(81200)
Intensive	6120	40650		120			11340	
2. Total	1520	4070						
Capital	1200	.11350						
Intensive	2720	15420						
3. Mixed	3240	21200	1	27	945	136.5	3680	64300
Gravelling								
1. Excavation		18240						
2. Haulage								
(a) (i) Base	5500 a) 12.5	13500						
	4000 a) 25							
(ii) Fill		2240						
(b) Base	1250 a) 25	2500						
Spreading								
(i)	5500m a) 12.5	16000	1	60	2100	89	5347	94500
(ii)	5250m a) 25							
Water Crossings	No	Length						
1. Canal Crossings	78	10.5 m	1	156	5450	9	1404	25350
2. Canal Crossings	8	9	1	16	560	9	144	2600
3. Bridges (a)	1	13	1	60	2100		484	8467
(b)	1	11.5	1	59	2065		468	8186

*including gift to diver

Equipment: Type	No	Skilled Mandays	Cost	Materials (Cost at Approx. Market Rates)	Employment Creation (Skilled and Unskilled): Total Mandays	Mandays Per KM	Mandays Per M3
Tractors	4	240	41450		7000	2000	0.279
Rollers	(4)	(264)	(45960)		(4970)	(1898)	(0.283)
D6	1	15	28800	(18000)	11970	1955	0.294
D155A-1	2	34	39756*	(72000)			
R90	1	17	5440		51	42.5	
D155A-1	2	31	27160*	(49300)			0.0045
R90	1	27	8640*				
Tractors	3	81	9990		3846	1190	0.1815
D155A-1	2	29	25444*	(46110)	29	3.05	
Trucks	5	275	176000				
Loaders	2	110	41250		385	40.5	0.0245
				(358050)			
Trucks	2	42	42000				
Loaders	1	21	10500				
Gift			10000				

	Equipment			Materials		Employment Creation (Skilled and Unskilled)		
Type	No	Skilled Mandays	Cost	(Cost at Approx. Market Rates)		Total Mandays	Mandays Per KM	Mandays Per M3
Bowsers	1	19	3040					
R90	1	24	7680			5450	573	0.341
			24960		24725	1720	181	
			10815		23920			
			11550		46502			
			10360		38645			

Table 7: Comparison of employment creation per kilometre

1. *Labour-intensive embankment and spreading and capital-intensive excavation, load and haul*

	Mandays per km
Embankment	2 000
Excavation	3.1
Load and haul	40.5
Spreading	573
Canal crossings	181
	2 797.6

2. *Capital-intensive embankment, excavation, load and haul, and labour-intensive spreading*

	Mandays per km
Embankment	42.5
Excavation	3.1
Load and haul	40.5
Spreading	573
Canal crossings	181
	840.1

Table 8: Comparison of various methods of construction costs and proportion per km

1. *Labour-intensive embankment and spreading, and capital-intensive excavation, load and haul*
   Actual costs per km

	Labour	Equipment	Materials	Total
Cost	47 940	48 820	5 120	101 880
%	47.0	48.0	5.0	100

2. Capital-intensive embankment, excavation, load and haul, and labour-intensive spreading
Actual costs per km

	Labour	Equipment	Materials	Total
Cost	13 740	63 070	5 120	81 930
%	16.8	77.0	6.2	100

3. *Labour-intensive embankment and spreading, and capital-intensive excavation load and haul*
Cost per km at market rates

	Labour	Equipment	Materials	Total
Cost	47 940	59 515	5 120	112 575
%	42.5	52.9	4.6	100

4. *Capital-intensive embankment, excavation, load and haul, and labour-intensive spreading*

	Labour	Equipment	Materials	Total
Cost	13 740	94 315	5 120	113 175
%	12.1	83.4	4.5	100

EDITORS' SUMMARY

Whilst the studies and programmes executed, by the ILO and the World Bank in particular, have shown that labour-based methods are technically and economically viable, there is a natural reluctance, particularly on the part of engineers, to adopt their use. Robert McCutcheon's description of the project in Iran illustrates this point very well. The project staff clearly felt that labour-intensive methods were useful for self-help programmes which would encourage popular participation but not as effective alternatives to equipment. It is also fair to point out, in mitigation of this attitude, that previous experience with the use of labour-intensive methods particularly on major relief programmes, tended to support their basic assumption that these methods were neither technically nor economically effective. Whilst programmes such as that described by Glaister in Afghanistan are extremely useful in mobilising human resources and endeavour in the rural areas, their very nature is such that they are unlikely to be economically justifiable.

The reluctance of engineers to accept that labour-based methods are a viable technological alternative is most effectively overcome by demonstration. Recent work on appropriate construction technology has had many aspects, however, perhaps the most important single element has been the physical proof that labour-based methods can be used for a wide range of construction activities without any reduction in standard or increase in cost (whether measured in economic or financial terms). Furthermore, this conclusion has been reached not only from studies carried out in experimental conditions but also in fully operational construction projects. Nevertheless, the suggestion that we should think of these methods as feasible alternatives to the use of equipment rather than useful methods of providing employment and income does present other major problems. In the first place, it means

that their application has to be integrated into the institutional framework of the construction sector. It requires that the procedures and systems, developed principally for the use of equipment-intensive methods, have to be modified to incorporate the use of labour-based methods. This is well illustrated in Bertil Nilsson's paper, in particular in relation to training, procurement and administration.

Above all what emerges, in particular from the descriptions of the operational labour-based programmes, is *the need for commitment*. This is true whatever level is concerned. It is particularly vital that the government should be seen to be supporting the implementation of labour-based programmes: this not only confers respectability but should ensure that problems which will inevitably arise in their implementation receive sympathetic consideration. This could be reflected in the acceptance of tendering by specifications for hand tools, as in Kenya, or more broadly, in the endorsement of a programme by a senior politician, as in Iran.

At the other end of the scale there needs to be commitment at the grass-roots level. Unless the people themselves are convinced that the benefits of road construction will come to them, there is little likelihood of them being motivated to work effectively. The level of this popular participation can, of course, vary and leads logically to a socio-political discussion which is outside the scope of this book. However, there are clearly advantages and disadvantages whatever level is chosen. In Afghanistan, George Glaister found that where resources are extremely scarce there is great advantage in mobilising those of the rural population by giving them the responsibility for the selection and planning of work. However, there are serious disadvantages too, in that the people will only construct that which they feel is necessary and not that which might be necessary for safety and the type of traffic. In Mexico, on the other hand, whilst the people proposed and selected the roads, a contract was then made between the local community and the Direccion General de Caminos Rurales (DGCR) which ensured that the requisite number of labourers was available to construct a road whose standards were laid down by the DGCR. The basic difference, of course, between the Mexican and Afghanistan programmes is that in the former the labourers are paid whilst in

the latter they are not. This point is strongly made by McCutcheon. When the programme was based on self-help the villagers were unwilling to work for they could see that money was available to pay for machinery. When this money was utilised to pay labourers there was no difficulty in obtaining an adequate work force.

The move from equipment-intensive to labour-based methods therefore has ramifications outside the merely technical. Popular participation and commitment become important even in the decision-making process.

In his discussion of the private sector, Angus Austen also raises the question of commitment. If there is a real desire on the part of the government to develop the domestic construction sector then this implies a recognition of the biases in the procedures and systems against such development. He suggests that appropriate construction technology would be one means of allowing the small contractor to grow. The World Bank have also suggested that for certain countries to eliminate bias against the use of labour-based methods a "neutralisation" procedure could be adopted in the contractual process. This, of course, is a useful starting point but if labour-based methods are to achieve their full potential then the procedures and systems will have to be modified throughout so that a rational choice can be made by all involved in the construction process.

Even if the commitment exists, there still remains the detailed problems of modifying or reassessing all aspects of the construction process in relation to the application of labour-based methods. The main aspects of this are covered in Chapter 2. Nevertheless, they are reinforced by the evidence from the various programmes described. In relation to planning and administration it is interesting to compare the programmes in India, Kenya, Afghanistan and Mexico. The Border Roads Organisation is run on military lines and as such the hierarchy of responsibility is very clearly defined. It is also heavily centralised as the level of supervisory and administrative personnel indicates. At the other extreme, in the Afghanistan programme, the responsibility is devolved to the workers and the Rural Development Department officials act only as advisers not supervisors. The question of how far responsibility should be devolved depends on many factors

not least the nature of the programme. The Kenya Rural Access Roads Programme (RARP) covers the whole country and with such a dispersal of sites it is natural that the engineers in the field should have a large measure of responsibility. The same applies to the Mexican programme, however there is one basic difference. The RARP field structure is totally separated from that of the provincial engineer, who is the regional representative and executing agency of the Ministry of Works. Conversely, the Mexican programme is run through the field offices of the DGCR. The reasons for setting up specialised field units for the RARP are mainly to do with the shortage of qualified staff in the Ministry of Works provincial engineers offices and, perhaps more significantly, the fact that the RARP is, in large part, financed by external funds. The Mexican programme on the other hand is almost entirely financed by government funds. Whilst the Kenya RARP is proving to be a model for application elsewhere it would be more appropriate if such programmes were implemented within the structure of the public works ministry to ensure the involvement of its personnel. This would also be in line with the general philosophy that the use of labour-based methods should not be separated into a distinct programme, as if it were something of an oddity, but integrated into the framework of the operational ministries. This comes over clearly in Nilsson's paper. He strongly recommends that one should not set up separate systems of training, management administration and procurement for labour-based programmes, but modify and adapt the existing systems to allow their effective use. Glaister points out the Rural Development Department constructs tertiary roads on a self-help basis using labour-based methods whilst the Ministry of Public Works constructs primary and secondary roads using equipment. This division is not conducive to an acceptance within the Ministry of the use of labour-based methods. In fact it tends to reinforce the natural bias against their use on any projects except those constructed under relief programmes.

In the planning of a labour-based programe one of the major problems is in assessing the level of productivity that can be achieved. McCutcheon notes how difficult this was, not only because of lack of data, but because of the wide variations in that which does exist. What is clear is that the productivity

achieved on *traditional* labour-based schemes is grossly inferior to that on a well-organised, well-planned labour-based programme. Furthermore, motivation has a great deal to do with the level of productivity achieved. If the workers feel that the road they are constructing will be of direct benefit to them they are likely to achieve a reasonable level of productivity. This was clearly recognised in the Mexican programme. Moreover, whilst financial incentives do increase productivity this has to be viewed in relation to the present income and level of employment of the workers. In India and Kenya where the level of underemployment is high, the introduction of task rate working was sufficient to increase productivity. It is interesting to note that even in the self-help project on Afghanistan task work was introduced to increase productivity. .

Incentives and community spirit can increase productivity. However, innovations also have a role to play. Whilst the World Bank's view[1] is that the prospects of using "intermediate technologies" to improve productivity has been much overrated it is fair to point out that this conclusion is based on limited experience. Certainly the type of innovations made in the Philippines[2] can greatly increase the competitiveness of labour-based methods. Howe and Barwell's paper shows that there is a wide range of light equipment which could be developed effectively and that, to date, the amount of effort directed towards this aspect has been minimal when compared with the resources poured into the development of heavy construction equipment.

Little work has so far been done on the measurement of benefits that accrue through the use of labour-based methods in road construction. In general the benefits are assumed: increased employment, increased rural income, development of small-scale manufacturers, better access to markets and social services. Whilst this could be the subject of a book in itself, certain aspects are worth examining here.

Employment is the most obvious, direct benefit. The great majority of the workers hired on the various programmes discussed were hired on a casual basis. This was for various reasons: ease of administration, seasonal fluctuation of supply, the dispersed nature and limited length of the projects. "Casual" has, however, various interpretations. In the Border Roads Organisation the "casual labour" may have worked

with the BRO for years. In the Mexican Programme the average duration of employment was less than a month, whilst in Kenya 4-6 months is about average. Naturally, the shorter the duration the less is the benefit not only as regards income but also in terms of skill acquisition and physiological changes.

Even limited employment has substantial impact. The average increase of family income for workers on the Mexican programme was 15 per cent. Nevertheless, the ultimate object in the application of appropriate construction technology is a general increase in productive employment. It is perhaps a little unfair to criticise the programmes so far initiated for not providing more stable employment. They are isolated programmes, as yet, hopefully paving the way for a more general application. The criticism becomes somewhat cyclical. Appropriate construction technology must be adopted on a large scale in order to have an impact on employment. For this to happen demonstration projects must be set up which, by themselves, have little impact on employment.

The question of skill acquisition is perhaps more pertinent. In the long term, is one looking for underemployed workers to provide the basis of the workforce, or is one looking for the development of a construction labour force? Presumably the latter. However, this will take more time, even assuming that labour-based methods are implemented on a large scale both in the public and private sectors. What can be done now however is to ensure that there is a basis for the development of this labour force. This can be assisted by selecting from within the labour force those with management potential, for supervisor jobs. If appropriate construction technology achieves growing acceptance there will then be at least a cadre of people capable of implementing the work on the site. That some of those trained may choose to set up in business as private contractors should be viewed as a benefit not a loss. Angus Austen has shown that these people would have the means by which they could break out of the series of constraints that limit the development of the domestic construction sector.

The increase in income, particularly in the rural areas, should mean that more money is available for investment with a likely increase in agricultural production and rural industrial activities. However, there are constraints here. First the construction

of the rural road will not produce development, only the means by which it can take place. The complementary activities of extension services, social and welfare facilities must also take place. In this regard the construction of rural roads must be integrated into an over-all rural development framework for the expected benefits to take place. Second, as the Mexican programme has shown, the workers are generally the poorest of the population. The increase in income therefore allows them to rise up to or above the subsistence level, but not to the state where they can accumulate savings or use the money for increasing their agricultural yield. The people who benefited most from the Mexican programme were the rural elite, a minority no doubt, who could use the extra income for purchasing more land, better fertilisers or for planting a second crop. Nevertheless, the fact that 70 per cent of the investment in the Rural Access Roads Programme remains in the rural areas does indicate that this type of programme provides an effective means for initiating rural development.

One natural by-product of the use of labour-based methods is the need for a large number of good quality hand tools and light equipment. This presents an opportunity for the small-scale manufacturer to meet this demand and develop his business.

The essays in this book indicate the depth of knowledge already accumulated on the use of labour-based methods. They also show what still needs to be done.

Angus Austen's critical analysis of the problems facing the construction industry of developing countries shows clearly that we know very little about the sector of the economy within which one is proposing a modification of resource use. As he points out, in many countries the sector is not even recognised as a separate entity. Much more work needs to be done in defining the needs and basic statistics of the industry, so that effective programmes can be initiated for its development[3].

At the other end of the scale, it is clear that the work on tools and equipment has merely scratched the surface. Not only must the existing knowledge be catalogued (as in the forthcoming ILO *Guide to Tools and Equipment for Labour-Based Road Construction*) but also money must be invested in the development of tools and equipment.

We have talked a great deal about the need for commitment; however we have also recognised that "to see is to believe". Programmes like the Kenyan RARP provide a live demonstration of the viability of labour-based techniques. It will however be necessary to initiate more of these demonstration projects if engineers and policy makers are to be convinced.

Often information on new ideas tends to circulate among those who are already convinced of their rationality. The dissemination of information on the new ideas should really have two levels. First, what might be called propaganda material to policy makers to make them aware of the basic arguments. Second, detailed information to those who wish to attempt to implement the idea. McCutcheon makes a plea for a more concerted effort to provide specific information in a form which is immediately usable.

There has been recently a recognition of the need for construction management training. As Austen points out, however, it is vital that this type of training includes in it the presentation of the wide range of technologies available and the problems associated with the implementation of labour-based as well as equipment-based technologies.

Finally, transportation is a system of road and vehicle. To date the work on appropriate technology has concentrated on the road and its construction assuming that the vehicles that travel on them are the most appropriate. There is certainly a strong case to be made for the use of simpler vehicles, particularly in the rural areas, which are more in keeping with the needs and resources of the rural population[4].

There is now sufficient evidence both in the form of data and live projects, to show that labour-based methods are technically and economically viable. Many engineers are now taking the matter seriously. There are in-built prejudices which it will take time to change. However, the facts are there for those who care to see them. For policy makers and politicians the decision is less of a technical nature than one based upon broad socio-economic considerations. The use of labour-based methods would seem, however, to meet all the criteria upon which development planning is based. They serve the mass of the population, their implementation can involve popular participation in the decision-making process, they are

an instrument of self-reliance, they can enhance the potential for rural development and they can, by providing income, serve to improve the standard of living of the mass of the population. Why, one might ask, is their use not being implemented on a larger scale? The answer to that question is perhaps more political than rational. The means are available, what is now required is the will to use them.

Notes and references

[1] IBRD, *Substitution of Labour and Equipment in Civil Construction Phase II Report*, Washington, 1974.

[2] D. Lal, Men or Machines, ILO, Geneva, 1978.

[3] The ILO and the World Bank have recently initiated a series of studies on the construction industry in developing countries.

[4] I. Barwell and J.D.G.F. Howe, "Appropriate transport facilities for the rural sector in developing countries", ILO background paper prepared for the UNIDO World Forum on Appropriate Industrial Technology, Delhi, Nov. 1978.

Climbing Time

by Gary P. Joyce

I*f you think for a minute that one column can teach you to climb, you're out of your mind.* Get some lessons from a professional. Call the American Mountain Guide Association (303/271-0984) for a listing of guides in your area. Failing that, go to your local shop and ask for a referral. Don't figure you can do this by yourself unless you've got a death wish. That said, here's what you can expect if you decide to get involved in climbing. . .

Equipment

Start up costs aren't terrible; it's more a choice of what you want versus what you need. Essentials are: shoes, harness, locking carabiner, figure eight, belay device and chalk bag. This is assuming you'll find a partner (and finding a partner is one of the most difficult aspects of climbing) who has more cash than you and has already sprung for the rest of the gear.

If you've got a buddy who is also starting out, duplicate the above and add a rope, hardware, slings and more. Rock shoes have a sticky but smooth sole and rand and cost in the $100-$150 range; a harness should go about $40-$50; a locking biner about $10-$15, ditto with the figure eight, belay device and chalk bag (this holds gymnastic chalk).

The rope you use is specifically made for climbing- it has stretch in it, so when you fall (and you will fall) it'll give some. This type of rope is called a kernmantle rope; it has a braided outer sheath to protect the inner workings from abuse. Take care of your rope; don't step on it, don't tie the dog up with it, don't pull your car with it. Keep it out of the sun, don't store it in your trunk. Figure about $150 for a 50-meter dry (treated with water repellent) line.

Hardware is way too involved to go into here, but will cost you the biggest portion of cash. There're carabiners, camming devices, rocks, hexes and a zillion other combos. Budget about $500 for this for starters and figure on spending more as fast as you get better.

Ice gear is another story money-wise. If you purchased a fairly adjustable harness, you'll be able to use tha. Your rope will be fine, and so will your biners, belay devices and figure eight. Then tack on: two ice axes $350; plastic double boots $200-$400; crampons $150; helmet $50; hardware (ice screws, deadmen, etc.) $250; clothing $500 -$1200 depending on what you buy. (I swear by Gore-Tex and that ain't cheap. Don't forget, it's gonna be cold- and it can be wet.)

I have purchased climbing gear off the Internet at a substantial savings. I wouldn't buy a used rope or

carabiners, but just about anything else is a safe bet.

Terminology

Here are some words that'll make you sound like you know what you're talking about. . .

Free climbing - climbing with hands and feet; the rope is used only to hold a fall.
Solo climbing - climbing without a rope.
Bouldering - climbing, well, boulders. Usually unroped.
YDS - the Yosemite Decimal System. A rating system for climbs. It starts at 5.0 and goes to 5.14d. The letters come into play above 5.10. Climbing starts to get reeeeal hard above 5.9.
Lead climber - the climber going first.
Belay or belayer - The person holding the other end of the rope for the lead.
Second - the belayer and/or second climber up a route.
Top roping - how you'll learn to climb. The rope goes from a belayer on the ground up to an anchor and down to the climber. Routes are usually no more than 70 feet high.
Anchor - a fixed point above the climber the rope will run to and through.
Placement - where/how your hardware or protection (pro) is put into the rock on a free climb (non-top rope).
Rappelling - sliding down the ropes to return to where you started. More people get hurt doing this than in climbing. Pay mucho attention.
Pitch - the distance between belay points on any given climb. Limited to the length of your rope.
Carabiner or biner (beaner) -a oval or D-shaped piece of metal with a gate.

Getting Ready

At the lower levels of the rating system, and in your beginning days as a climber, you'll be able to overcome most difficulties with arm strength. This is a game in which legs are every bit as important as arms, though it will help if you have really strong forearms and fingers. I have one of those spring grips hanging from my rearview mirror and work out in sets of 50; I average about 200 per hand per day when I'm driving around.

Calf muscles are also important: do a lot of toe raises. Stand up on your toes and lower. No bouncing. To make it harder, do it on a raised platform so your heels can drop lower than your toes.

Eventually just about every other muscle in your body will come into play. You won't see any muscle-bound rock jocks, but you won't see any flab on any of them either. They're all cord, sinew and zero body fat. (I'm old, got a belly, shut up. I still climb.)
If you're hands aren't rough, they'll rip, and even rough hands tear on granite. They'll get used to it.

Moving

There are methods and means of foot and hand placement that vary according to medium (ice or rock) and what the rock (or ice) will give you. These are the things you'll learn from an instructor, so I won't go into it here. Here are some things to think about, however.

There's no room for ego when learning. Listen, do what you're told, ask questions, but keep your opinions to yourself; you're there to learn, and this is a serious game.
This is a thinking sport as well as a physical one. Use your mind when confronted with the "impossible."

Trust your foot gear. Rock shoes will stick if you use them right, as will crampons. Believe in your shoes.

Remember to make a concentrated effort to use your legs. You'll be surprised at what they'll do if you focus your power there.

When you "come off" (fall), try to come off in a controlled manner. You'll usually know it's going to happen and have time to say (yell?) to the belayer "falling" (honest). When you do come off, don't figure there's nothing else to do. You'll be going back into the face pretty much right away and you should be ready to absorb it. Slamming into things ain't fun.

Don't be afraid to improvise. When I was learning, I sort of shot it all about midway up the third pitch of a climb. There was a huge crack about shoulder level, so I jammed my arm in there elbow first and found I could rest almost all my weight on that arm. My instructor allowed how she'd never seen that maneuver before. It may not have been great form, but it worked.

Pro placement is a learned skill achieved by watching those more experienced than you, knowing the rock and knowing the limits of your hardware. Remember, if your placement fails you're now skydiving without a chute.

A word on helmets. When you're taking lessons, you'll have to wear one. Generally speaking, I rarely wear one when I climb rock (especially if I "know" the area). I always wear one on the ice, however. That said, a little piece of rock can attain a speed of 40-50 mph in about two seconds-think about getting conked with it.
Where To Go

Fortunately the Northeast is blessed with some great climbing areas. In New York you've got the famed Shawangunk Mountains (The Gunks) with zillions of routes, the Adirondacks for real wilderness/expedition-feeling climbing [article on the Gunks and the Dacks], the Delaware Water Gap area and more. Connecticut has the Traprock area, New Hampshire the White Mountains and Maine has Acadia National Park.

Then there are the climbing gyms which are springing up everywhere. These are great places to learn, work out and perfect technique, aren't weather dependent and provide a reasonable facsimile of real rock. There is a difference, however. You can perfect technique in a gym, but applying it to real-world rock starts another learning curve. The chances of getting hurt or killed in a gym are minimal to zero. The chances of getting hurt or killed on the rock aren't. They are two different mediums-as different as rock and ice. Don't think expertise in one, means expertise on the other.
Yes, it takes some work and takes some learning... but nothing beats sitting at the top of climb and looking down to the tops of trees as hawks and airplanes fly below you.

And to think, you got there all by yourself.

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Rock climbing

From Wikipedia, the free encyclopedia

Rock climbing is an activity in which participants climb up, down or across natural rock formations or artificial rock walls. The goal is to reach the summit of a formation or the endpoint of a usually pre-defined route without falling. Due to the length and extended endurance required and because accidents are more likely to happen on descent than ascent, Rock Climbers do not usually climb back down the route. It is very rare for a climber to downclimb, especially on the larger multiple pitches (class III- IV and /or multi-day grades IV-VI climbs). Professional Rock climbing competitions have the objectives of either completing the route in the quickest possible time or attaining the farthest point on an increasingly difficult route. Scrambling, another activity involving the scaling of hills and similar formations, is similar to rock climbing. However, rock climbing is generally differentiated by its sustained use of hands to support the climber's weight as well as to provide balance.

A rock climber

Rock climbing is a physically and mentally demanding sport, one that often tests a climber's strength, endurance, agility and balance along with mental control. It can be a dangerous activity and knowledge of proper climbing techniques and usage of specialised climbing equipment is crucial for the safe completion of routes. Because of the wide range and variety of rock formations around the world, rock climbing has been separated into several different styles and sub-disciplines.[1]

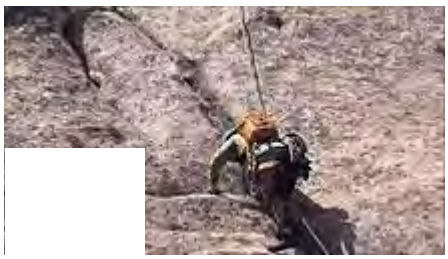

Rock Climbing

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History

Paintings dating from 200 BC show Chinese men rock climbing. In early America, the cliff-dwelling Anasazi in the 12th century were thought to be excellent climbers. Early European climbers used rock climbing techniques as a skill required to reach the summit in their mountaineering exploits. In the 1880s, European rock climbing become an independent pursuit outside of mountain climbing.[2]

Although rock climbing was an important component of Victorian mountaineering in the Alps, it is generally thought that the sport of rock climbing began in the last quarter of the nineteenth century in various parts of Europe. Rock climbing evolved gradually from an alpine necessity to a distinct athletic activity.

Aid climbing, climbing using equipment that acts as artificial handhold or footholds, became popular during the period 1920-1960, leading to ascents in the Alps and in Yosemite Valley that were considered impossible without such means. However, climbing techniques, equipment and ethical considerations have evolved steadily. Today, free climbing, climbing using holds made entirely of natural rock while using gear solely for protection and not for upward movement, is the most popular form of the sport. Free climbing has since been divided into several sub-styles of climbing dependent on belay configuration.

Over time, grading systems have also been created in order to compare more accurately the relative difficulties of the rock climbs.

Style

In *How to Rock Climb*, John Long notes that for moderately skilled climbers simply getting to the top of a route is not enough; how one gets to the top matters.[3] In rock climbing, style refers to the method of ascending the cliff. There are three main styles of climbing: on-sight, flash, and redpoint. To on-sight a route is to ascend the wall without aid or any foreknowledge. It is considered the way to climb with the most style. Flashing is similar to on-sighting, except that the climber has previous information about the route including talking about the beta with other climbers. Redpointing means to make a free ascent of the route after having first tried it.[4][5][6]

Climbing in Germany, circa 1965. Note the lack of intermediate protection points and the potentially unsafe tie-in method, which demonstrate the maxim of the day: "The leader must not fall."

Types of climbing

Most of the climbing done in modern times is considered free climbing—climbing using one's own physical strength, with equipment used solely as protection and not as support—as opposed to aid climbing, the gear-dependent form of climbing that was dominant in the sport's earlier days. Free climbing is typically divided into several styles that differ from one another depending on the choice of equipment used and the configurations of their belay, rope and anchor systems.

As routes get higher off the ground, the increased risk of life-threatening injuries necessitates additional safety measures. A variety of specialized climbing techniques and climbing equipment exists to provide that safety. Climbers will usually work in pairs and utilize a system of ropes and anchors designed to catch falls. Ropes and anchors can be configured in different ways to suit many styles of climbing, and roped climbing is thus divided into further sub-types that vary based on how their belay systems are set up. Generally speaking, beginners will start with top roping and/or easy bouldering and work their way up to lead climbing and beyond.

Aid climbing

Still the most popular method of climbing big walls, aid climbers make progress up a wall by repeatedly placing and weighting gear that is used directly to aid ascent and enhance safety.

Free climbing

The most commonly used method to ascend climbs refers to climbs where the climber's own physical strength and skill are relied on to accomplish the climb. Free climbing may rely on top rope belay systems, or on lead climbing to establish protection and the belay stations. Anchors, ropes and protection are used to back up the climber and are passive as opposed to active ascending aids. Subtypes of free climbing are trad climbing and sport climbing. Free climbing is generally done as "clean lead" meaning no pitons or pins are used as protection.[7]

Bouldering

Climbing on short, low routes without the use of the safety rope that is typical of most other styles. Protection, if used at all, typically consists of a cushioned bouldering pad below the route and a spotter, a person who watches from below and directs the fall of the climber away from hazardous areas. Bouldering may be an arena for intense and relatively safe competition, resulting in exceptionally high difficulty standards.

Bouldering in Joshua Tree National Park, United States.

Solo climbing

Deep-water soloing (DWS)

Deep-water soloing (or psicobloc) is similar to free soloing in that the climber is unprotected and without a rope, but should the climber fall, it is into deep water instead of onto the ground.

Free soloing

Free soloing, referred to as "soloing" in the UK, is single-person climbing without the use of any rope or protection system whatsoever. If a fall occurs and the climber is not over water (as in the case of deep water soloing), the climber is likely to be killed or seriously injured. Though technically similar to bouldering, free solo climbing typically refers to routes that are far taller and/or far more lethal than bouldering. The term "highball" is used to refer to climbing on the boundary between free soloing and bouldering, where what is usually climbed as a boulder problem may be high enough for a fall to cause serious injury (20 ft. and higher) and hence could also be considered to be a free solo.

Roped solo climbing

Solo climbing with a rope secured at the beginning of the climb allowing a climber to self-belay as they advance. Once the pitch is completed the soloist must descend the rope to retrieve their gear, and then reclimb the pitch. This form of climbing can be conducted free or as a form of aid climbing.

Lead climbing

Lead climbing is a climbing technique. The lead climber ascends with the rope passing through intermittent anchors that are below them, rather than through a top anchor, as in a top-roped climb. A partner belays from below the lead climber, by feeding out enough rope to allow upward progression without undue slack. As the leader progresses he or she clips the rope into, using a runner and carabiners, intermediate points of protection such as active cams, or passive protection such as nuts; this limits the length of a potential fall. The leader also may clip into pre-placed bolts. Indoor gyms might have short runners pre-attached to fixed anchor points in the wall.

Unlike top-rope climbing where the climber is always supported by an anchor located above the climber, lead climbing often has scenarios where the climber will be attached to a point under him or her. In these cases, if the climber were to fall, the distance fallen would be much greater than that of top-rope and this is one of the main reasons lead climbing can be dangerous. The fall factor is the ratio of the height a climbers falls and the length of rope available to absorb the fall. The higher the fall factor, the more force placed on the climber as the ropes decelerates them. The maximum fall factor is 2. It is often advised that climbers who are interested in lead climbing should learn from experienced climbers and participate in training sessions before actually lead climbing on their own.

Multi-pitch climbing

The climbing rope is of a fixed length; the climber can only climb the length of the rope. Routes longer than the rope length are broken up into several segments called pitches; this is known as multi-pitch climbing. At the top of a pitch, the leader, the first climber to ascend, sets up an anchor and then belays the second climber up to the anchor; as the second climber follows the route taken by the leader, the second climber removes (cleans) the carabiners and anchors placed along the way in order to use them again on the next pitch. Once both climbers are at the top anchor, the leader begins climbing the next pitch and so on until the top of the route is reached.

Leader belays the second on *Illusion Dweller* in Joshua Tree National Park, United States.

In either case, upon completion of a route, climbers can walk back down if an alternate descent path exists, or rappel (abseil) down with the rope.

Sport climbing

Unlike traditional rock climbing, sport climbing involves the use of protection (bolts) placed with power drills or on rappel or permanent anchors which are attached to the rock walls. This is separate from bolted trad face climbing.

Traditional climbing

Traditional or *trad* climbing involves rock climbing routes in which protection against falls is placed by the climber while ascending, or bolts placed on lead. Gear is used to protect against falls but not to aid the ascent directly. Traditional bolted face climbs are different than sport climbs. Trad bolted climbs use either a hand drill and or are bolted on lead. This means there are far fewer bolts and they are spaced out farther than sport climbs.

Bottom rope climbing and top rope climbing

Bottom rope climbing

Commonly known as "Top Roping": belaying a climber from the ground or the base of the route. A belay system resembling a pulley in which an anchor has been created at the top of a climb, through which the rope runs through from the belayer on the ground, to the climber on the ground *(position before starting the climb)*. The rope is "taken-in", to clear up the slack as the climber moves upwards, so in the event of a fall the climber falls the shortest distance possible. The length of a fall is normally no more than a meter, but can vary depending on the length of the route *(*the longer the rope, the more stretch the rope will undergo when weighted*)* and the weight of the climber compared to that of the belayer, among other things.

Top rope climbing

Also known as "seconding," or belaying a climber from the top of a route, bringing them up to walk off or continue on to next pitch. A similarly safe system of climbing a route, except the belayer has set the anchors at the top of the climb (normally after leading a route) to belay the climber either indirectly (belayer is part of the

system and can be vunlnerable when exposed to unexpected directions of pull and loading of the rope) or directly (belayer is not part of the system and belaying is done direct from the anchors using either an Italian / Munter Hitch or adapted use of a belay device), up the route from the top. If bolts have been clipped or traditional gear placements have been made, it is the job of the climber to collect and clean the route.

Top roping *Balthazar* (12), in the Morialta Conservation Park near Adelaide, South Australia. Top roping is the most accessible style of climbing for beginners.

Via ferrata

A method of fairly easily ascending a route, heavily dependent on permanent protection rather than using natural rock features to proceed.

Climbing techniques

Different types of rock require different techniques to successfully climb.

Crack climbing

Crack climbing is a type of rock climbing that ascends cracks and uses specialized climbing techniques. Cracks used in climbing vary in size from the width of a finger to those that fit an entire body. Climbers use techniques such as jamming, laybacking, and stemming. Some climbers use gloves made out of athletic tape to protect their hands.

climber with climbing aids attached at his waist

Face climbing

Face climbing is a type of climbing where climbers use features and irregularities in the rock such as finger pockets and edges to ascend a vertical rock face.

Slab climbing

Slab climbing is a type of rock climbing where the rock face is at an angle of less steep than vertical. It is characterized by balance- and friction-dependent moves on very small holds.

Simul climbing

When two climbers move at the same time. The pseudo-lead climber places gear that the pseudo-follower collects. When the leader runs low on gear they construct a belay station where the follower can join them to exchange gear. The stronger climber is often the pseudo-follower since a fall by the follower would pull the leader from below towards the last piece of gear—a potential devastating fall for the leader. In contrast, a fall from the leader would pull the follower from above, resulting in a less serious fall. Most speed ascents involve some form of simul climbing but may also include sections of standard free climbing and the use of placed gear for advancement (i.e. partial aid or pulling on gear).

Via ferrata

A method of fairly easily ascending a route, heavily dependent on permanent protection rather than using natural rock features to proceed.

Grading systems

Climbing communities in many countries and regions have developed their own rating systems for routes. Ratings, or grades, record and communicate consensus appraisals of difficulty. Systems of ratings are inherently subjective in nature, and variation of difficulty can be seen between two climbs of the same grade. Hence, there may be occasional disagreements arising from physiological or stylistic differences among climbers. The practice of rating a climb below its actual difficulty is known as sandbagging.

The most commonly used rating systems in the United States are the Yosemite Decimal System and the Hueco V-scale bouldering grade. The current ranges for climbing routes are 5.0 for easy beginner routes to 5.15 being world class and V0 - V16, respectively. As the limit of human climbing ability has not yet been reached, neither grading system has a definite endpoint and is thus subject to revision.[8]

The ratings take into account multiple factors affecting a route, such as the slope of the ascent, the quantity and quality of available handholds, the distance between holds, ease of placing protection and whether advanced technical maneuvers are required. Typically the rating for the hardest move on the wall will be the rating for the whole climb. While height of a route is generally not considered a factor, a long series of sustained hard moves will often merit a higher grade than a single move of the same technical difficulty. For example, a climb with multiple 5.11 moves with no rests may thus be rated a 5.12.

ROCK CLIMBING RATING SYSTEMS

	Sierra (USA)	British (UK)		French	UIAA (Central Europe)	Austr-alian	GDR (Eastern Europe)
Easy	5.4						
	5.5	4a	vs				
	5.6	4b					
	5.7	4c		5a	5+	15	VIIa
	5.8		hvs	5b	6-	16	VIIb
	5.9	5a		5c	6	17	
Moderate	5.10a		E1	6a	6+	18	VIIc
	5.10b	5b			7-	19	VIIIa
	5.10c		E2	6b	7	20	VIIIb
	5.10d	5c			7+	21	VIIIc
Difficult	5.11a		E3	6c		22	IXa
	5.11b				8-	23	IXb
	5.11c	6a	E4	7a	8	24	IXc
	5.11d				8+	25	
Advanced	5.12a		E5	7b		26	Xa
	5.12b	6b			9-		Xb
	5.12c		E6	7c	9	27	
	5.12d	6c			9+	28	Xc
	5.13a		E7	8a		29	
	5.13b				10-		
	5.13c	7a		8b	10	30	
	5.13d		E8		10+	31	
	5.14a			8c		32	
	5.14b	7b			11-		
	5.14c		E9		11	33	
Extreme	5.14d	7c		9a	11+		

Climbing grades simplified. There are many other grades but these are the most used.

Terminology

As climbing routes or problems increase in difficulty, climbers learn to develop skills that help them complete the climbs clean. There are several techniques for hands and feet as well as terms for motions that combine the two. For indoor gyms, route setters visualize and create routes for climbers, placing different kinds of holds in specific parts of the wall at particular angles because they intend climbers to use certain techniques.

Environments

Indoor climbing

Indoor climbing occurs in buildings on artificial rock structures. This permits for climbing in all types of weather and at all times of day. Climbers climb indoors to improve their skills and techniques, as well as for general exercise or fun. Indoor climbing gyms typically provide rope setups and ensure that new climbers know safe techniques.

Outdoor climbing

Outdoors, climbs usually take place on sunny days when the holds are dry and provide the best grip, but climbers can also attempt to climb at night or in adverse weather conditions if they have the proper training and equipment. However, night climbing or climbing in adverse weather conditions will increase the difficulty and danger on any climbing route.

An indoor climbing wall.

Equipment

Most climbers choose to wear specialized rubber climbing shoes which are often of a smaller size than their normal street shoes in order to improve sensitivity towards foot placements and use the tightness to their advantage. Climbing chalk ($MgCO_3$) is commonly used as a drying agent to minimize sweating of the hands. Most other equipment is of a protective nature. Rock climbing is inherently dangerous, so to minimize the potential consequences resulting from a fall, climbers use protection. The most basic protective equipment is a climbing rope. Climbing pioneers would attach the rope to themselves; in the event of a fall, the rope would usually cause injury to the climber in the hope that it prevented death. With advances in technology came the development of specialized harnesses, carabiners which are used for clipping into belay and rappel anchors and connecting gear, and belay devices which are used to catch a falling climber, hold or lower a climber and for rappelling. Eventually, the placement of bolts with the use of quickdraws led to the rise of sport climbing. Traditional climbers developed the spring-loaded camming device, which increased safety over chocks, hexes, and pitons. Some climbers choose to wear a specialized climbing helmet to protect them from falling rocks or equipment or head injuries from crashing into rocks.[9]

Injuries

Injuries in rock climbing are mainly sports injuries that occur due to falls or overuse. Injuries due to falls are relatively uncommon; the vast majority of injuries result from overuse, most often occurring in the fingers, elbows, and shoulders.[10] Such injuries are often no worse than torn calluses, cuts, burns and bruises. There are a number of skincare products specifically for climbers available in the market. However, overuse symptoms, if ignored, may lead to permanent damage especially to tendons, tendon sheaths, ligaments, and capsules. Injuries from lead climbing are common.

Planning your climb, knowing your partner, talking about your climb, checking your equipment and the conditions of the rocks, checking the weather, using good judgement and always paying attention minimize the risk of injury.[11]

Access to climbing areas

Indigenous culture considerations

Some areas that are popular for climbing, for example in the United States and Australia, are also sacred places for indigenous peoples. Many such indigenous people would prefer that climbers not climb these sacred places and have made this information well known to climbers. A well-known example is the rock formation that Americans have named Devils Tower National Monument.[12] Native American cultural concerns also led to

complete climbing closures at Cave Rock at Lake Tahoe,[13] Monument Valley, Shiprock and Canyon de Chelly.[14]

Climbing activities can sometimes encroach on rock art sites created by various Native American cultures and early European explorers and settlers. The potential threat to these resources has led to climbing restrictions and closures in places like Hueco Tanks, Texas,[15] and portions of City of Rocks National Reserve, Idaho.

In Australia, the monolith Uluru (Ayers Rock) is sacred to local indigenous communities and climbing is banned on anything but the established ascent route (and even then climbing is discouraged).

Indigenous peoples are not the only cultures that object to climbing on certain rock formations. Professional climber Dean Potter kicked off a major controversy when he ignored long-accepted convention to scale Delicate Arch in 2006, resulting in strict new climbing regulation in Arches National Park.[16]

Climbing on private property

Many significant rock outcrops exist on private land. Some people within the rock climbing community have been guilty of trespassing in many cases, often after land ownership transfers and previous access permission is withdrawn. In the U.S. the climbing community responded to access closures by forming the Access Fund. This is an "advocacy organization that keeps U.S. climbing areas open and conserves the climbing environment. Five core programs support the mission on national and local levels: public policy, stewardship and conservation (including grants), grassroots activism, climber education and land acquisition."[17] In the U.K. the British Mountaineering Council represents climbers and their interest of public access to crags, cliffs and boulders.

Environmental impact

Although many climbers adhere to "minimal impact" and "leave no trace" practices, rock climbing is sometimes damaging to the environment. Common environmental damages include: soil erosion, breaking rock features, chalk accumulation, litter, abandoned bolts and ropes, human excrement, introduction of foreign plants through seeds on shoes and clothing, as well as damage to native plant species (especially those growing in cracks and on ledges as these are often intentionally removed during new route development through a process commonly referred to as *cleaning)*.

Clean climbing is a style of rock climbing which seeks to minimize some of the aesthetically damaging side effects of some techniques used in trad climbing and more often, aid climbing by avoiding using equipment such as pitons, which damage rock.

Climbing can also interfere with raptor nesting, since the two activities often take place on the same precipitous cliffs. Many climbing area land managers institute nesting season closures of cliffs known to be used by protected birds of prey like eagles, falcons and osprey.[18]

Many non-climbers also object to the appearance of climbing chalk marks, anchors, bolts and slings on visible cliffs. Since these features are small, visual impacts can be mitigated through the selection of neutral, rock-matching colors for bolt hangers, webbing and chalk. The use of certain types of climbing gear is banned altogether at some crags due to the risk of damage to the rock face. In such cases, climbers use knotted slings and ropes for climbing protection.

Blowtorching is another climbing induced impact that effects the rocks themselves. Blowtorching is when a

climber uses a blowtorch to dry holds on a wet route. This mainly happens in areas that tend to have wet climbing conditions. Blowtorching is not only detrimental to the rock itself and can have permanent damage but it also leaves a very large burn mark that most non-climbers would object to the appearance of.

Vandalism

The most significant form of vandalism directly attributable to rock climbers is alteration of the climbing surface to render it more climber-friendly.

With the advent of hard, bolted sport climbing in the 1980s, many routes were "chipped" and "glued" to provide additional features, allowing them to be climbed at the standard of the day. This attitude quickly changed as the safer sport climbing technique allowed climbers to push hard without much risk, causing the formerly more-or-less fixed grades to steadily rise. Altering routes began to be seen as limiting and pointless.

Unlike traditional climbing which generally uses protection only as a backup in case of falls, some forms of climbing—like sport climbing, canyoneering or, especially, aid climbing—rely heavily on artificial protection to advance, either by frequent falls or by directly pulling on the gear. Often these types of climbing involve multiple drilled holes in which to place temporary bolts and rivets, but in recent years an emphasis on clean techniques has grown.

Today, the charge of vandalism in climbing is more often a disagreement about the appropriateness of drilling and placing permanent bolts and other anchors. Although new fixed anchors are rarely placed by climbers, their dependency on the existing fixed anchors results in the difference between life and death. But the existing anchors remain on the climbing structure for long periods of time, changing the dynamic of the structure itself. Due to the permanent impact of the fixed anchors in wilderness areas, it was prohibited by the Wilderness Act. However, in 1990, there was a movement by the Forest Service and the Task Group to change the regulations to where fixed anchors would be allowed but still regulated in wilderness areas. These improvements lead to protection for both the climbers and the Wilderness Act.[19] Typically in the USA, the first ascensionists decide where to place protection on a new route and later climbers are supposed to live with these choices. This can cause friction and retro-bolting when the route is perceived to be dangerous to climbers who actually lead at the grade of the climb, since the first ascensionists often lead at a higher grade and therefore don't require as much protection. Failing to properly design a new route at its grade is considered arrogant and very poor form. Even in strongholds of rock-climbing tradition like Yosemite National Park, many routes are being gradually upgraded to safer standards of protection.

See also

- Lists and glossaries
  - List of climbers
  - List of climbing topics
  - Deaf climbers
  - Climbing organisations
  - Glossary of knots common in climbing
- Related activities
  - Outdoor education
  - Salto del pastor (aboriginal rock gymnastic sport of Canary Islands)
  - International Federation of Sport Climbing

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Categories: Climbing | Rock climbing

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Rock-climbing equipment

From Wikipedia, the free encyclopedia

A wide range of equipment is used during rock or any other type of climbing. The most popular types of climbing equipment are briefly described in this article. The article on protecting a climb describes equipment commonly used to protect a climber against the consequences of a fall.[1]

See also the Glossary of climbing terms for more equipment descriptions.

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Rope, cord and webbing

Rope and climber's shoes

Climbing ropes are typically of kernmantle construction, consisting of a core (kern) of long twisted fibres and an outer sheath (mantle) of woven coloured fibres. The core provides about 80% of the tensile strength, while the sheath is a durable layer that protects the core and gives the rope desirable handling characteristics.

Ropes used for climbing can be divided into two classes: dynamic ropes and low elongation ropes (sometimes called "static" ropes). Dynamic ropes are designed to absorb the energy of a falling climber, and are usually used as Belaying ropes. When a climber falls, the rope stretches, reducing the maximum force experienced by the climber, their belayer, and equipment. Low elongation ropes stretch much less, and are usually used in anchoring systems. They are also used for abseiling (rappelling) and as fixed ropes climbed with ascenders.

Modern webbing or "tape" is made of nylon or Spectra/Dyneema, or a combination of the two. Climbing-specific nylon webbing is generally tubular webbing, that is, it is a tube of nylon pressed flat. It is very strong, generally rated in excess of 9 kN, or about 2,020 pounds of force. Dyneema is even stronger, often rated above 20 kN (about 4,500 lbf or 2000 kg) and as high as 27 kN (about 6,070 lbf or 2700 kg). In 2010, UK-based DMM performed fall factor 1 and 2 tests on various Dyneema and Nylon webbings, showing Dyneema slings can fail even under 60 cm falls. Tying knots in Dyneema webbing was proven to have reduced the total amount of supported force by as much as half.[2]

When webbing is sewn or tied together at the ends, it becomes a sling or runner, and if you clip a carabiner to each end of the sling, you have a quickdraw. These loops are made one of two ways—sewn (using reinforced stitching) or tied. Both ways of forming runners have advantages and drawbacks, and it is for the individual climber to choose which to use. Generally speaking, most climbers carry a few of both types. It is also important to note that only nylon can be safely knotted into a runner (usually using a water knot or beer knot), Dyneema is always sewn because the fibers are too slippery to hold a knot under weight.

Webbing has many uses such as:

- Extending the distance between protection and a tie-in point.
- An anchor around a tree or rock.
- An anchor extension or equalization.
- Makeshift harnesses.
- Carrying equipment (clipped to a sling worn over the shoulder).
- Protecting a rope that hangs over a sharp edge (tubular webbing).

Carabiners

Carabiners are metal loops with spring-loaded gates (openings), used as connectors. Once made primarily from steel, almost all carabiners for recreational climbing are now made from a light weight aluminum alloy. Steel carabiners are much heavier, but harder wearing, and therefore are often used by instructors when working with groups.

Carabiners exist in various forms; the shape of the carabiner and the type of gate varies according to the use for

which it is intended. There are two major varieties: locking and non-locking carabiners. Locking carabiners offer a method of preventing the gate from opening when in use. Locking carabiners are used for important connections, such as at the anchor point or a belay device. There are several different types of locking carabiners, including a twist-lock and a thread-lock. Twist-lock carabiners are commonly referred to as "auto-locking carabiners" due to their spring-loaded locking mechanism. Non-locking carabiners are commonly found as a component of quickdraws.

Carabiners are made with many different types of gates including wire-gate, bent-gate, and straight-gate. The different gates have different strengths and uses. Most locking carabiners utilize a straight-gate. Bent-gate and wire-gate carabiners are usually found on the rope-end of quickdraws, as they facilitate easier rope clipping than straight-gate carabiners.

Carabiners are also known by many slang names including *biner* (pronounced beaner) or *Krab*.

The first climber who used a carabiner for climbing was German climber Otto Herzog.[3]

The Maillon (or Maillon Rapide) performs a similar function to a carabiner but instead of a hinge has an internally threaded sleeve engaging with threads on each end of the link, and is available in various shapes and sizes. They are very strong but more difficult to open, either deliberately or accidentally, so are used for links which do not need to be released during normal use, such as the center of a harness.

Quickdraws

Quickdraws (often referred to as "draws") are used by climbers to connect ropes to bolt anchors, or to other traditional protection, allowing the rope to move through the anchoring system with minimal friction. A quickdraw consists of two non-locking carabiners connected together by a short, pre-sewn loop of webbing. Alternatively, and quite regularly, the pre-sewn webbing is replaced by a sling of the above-mentioned dyneema/nylon webbing. This is usually of a 60 cm loop and can be tripled over between the carabiners to form a 20 cm loop. Then when more length is needed the sling can be turned back into a 60 cm loop offering more versatility than a pre-sewn loop. Carabiners used for clipping into the protection generally have a straight gate, decreasing the possibility of the carabiner accidentally unclipping from the protection. The carabiner into which the rope is clipped often has a bent gate, so that clipping the rope into this carabiner can be done quickly and easily. Quickdraws are also frequently used in indoor lead climbing. The quickdraw may be pre-attached to the wall. When a climber ascends the wall, (s)he must clip the rope through the quickdraw in order to maintain safety. The safest, easiest and most effective place to clip into a quickdraw is when it is at waist height.

Harnesses

A harness is a system used for connecting the rope to the climber. There are two loops at the front of the harness where the climber ties into the rope at the working end using a figure-eight knot. Most harnesses used in climbing are preconstructed and are worn around the pelvis and hips, although other types are used occasionally. Usually young children use a full body harness because it gives more support for the body.

Different types of climbing warrant particular features for harnesses. Sport climbers typically use minimalistic harnesses, some with sewn-on gear loops. Alpine climbers often choose lightweight harnesses, perhaps with

detachable leg loops. Big Wall climbers generally prefer padded waist belts and leg loops. There are also full body harnesses for children, whose pelvises may be too narrow to support a standard harness safely. These harnesses prevent children from falling even when inverted, and are either manufactured for children or constructed out of webbing. Some climbers use full body harnesses when there is a chance of inverting, or when carrying a heavy bag. There are also chest harnesses, which are used only in combination with a sit harness; this combination provides the same advantages as a full body harness. However, test results from UIAA show that chest harnesses can put more impact on the neck than sit harnesses, making them slightly more dangerous to use.

Apart from these harnesses, there are also caving and canyoning harnesses, which all serve different purposes. For example, a caving harness is made of tough waterproof and unpadded material, with dual attachment points. Releasing the maillon from these attachment points loosens the harness quickly.

Canyoning harnesses are somewhat like climbing harnesses, often without the padding, but with a seat protector, making it more comfortable to rappel. These usually have a single attachment point of Dyneema.

Belay devices

Belay devices are mechanical friction brake devices used to control a rope when belaying. Their main purpose is to allow the rope to be locked off with minimal effort to arrest a climber's fall. Multiple kinds of belay devices exist, some of which may additionally be used as descenders for controlled descent on a rope, as in abseiling or rappelling.

ATC-XP on locking carabiner

Belay devices are available in both passive and active designs:

Passive belay devices rely on the belayer's brake hand and a carabiner to lock off the rope. Sticht plates and the Air Traffic Controller (ATC) line of belay devices by Black Diamond Equipment are examples of passive belay devices. If a belay device is lost or damaged, a Munter hitch on a carabiner can be used as an improvised passive belay device.

Active belay devices have a built-in mechanism that locks off the rope without the help of any other pieces of equipment. The GriGri by Petzl is an example of an active belay device. The offset cam in the GriGri locks off the rope automatically to catch a falling climber, much like a seat belt in a car locks off to hold a passenger securely.

However, the GriGri's automatic action can lead to less alert belayers. The GriGri is not a hands-free belay device and constant vigilance is required by the belayer no matter what kind of device is used. One common mistake with the GriGri is reverse threading it, rendering the camming action useless.[4] Though, in a fall with a reverse threaded GriGri, bending the rope sharply under the GriGri provides more than enough friction to hold a falling climber as long as the belayer locks off the rope as they would with a tube style (passive) device.

It's important to note that in the event of a fall, automatic belay devices place more force on the anchors so are better suited for sports/indoor climbing. Most only work with thick single ropes, and they are not as versatile as other devices.[5]

An example of traditional belay is the Body Belay or the Hip Belay, where the rope is wrapped around the body to provide enough friction to catch a climber. This is often used in Alpine climbing where efficiency is important.

Rappel devices (descenders)

These devices are friction brakes which are designed for descending ropes. Many belay devices can be used as descenders, but there are descenders that are not practical for belaying, since it is too difficult to feed rope through them, or because they do not provide sufficient friction to hold a hard fall.

Figure eight

Sometimes called "figure of eight" or just "eight", this device is most commonly used as a descender, but may also be used as a belay device in the absence of more appropriate equipment.

It is an aluminum or steel "8" shaped device, but comes in several varieties. Its main advantage is efficient heat dissipation. A square eight, used in rescue applications, is better for rappelling than the traditional 8.

Figure eights allow fast but controlled descent on a rope. They are easy to set up and are effective in dissipating the heat caused by friction but can have a tendency to cause a rope to twist. Holding the brake hand off to the side twists the rope, whereas holding the brake hand straight down, parallel to the body, allows a controlled descent without twisting the rope. An 8 descender can wear a rope more quickly than a tube style belay/rappel device because of the many bends it puts into the rope. Many sport climbers also avoid them because of the extra bulk a Figure 8 puts on the climbing rack. However, many ice climbers prefer to use the 8, because it is much easier to thread with stiff or frozen rope.

A figure eight descender

Rescue eight

A rescue eight is a variation of a figure eight, with "ears" or "wings" which prevent the rope from "locking up" or creating a larks head or girth hitch, thus stranding the rappeller on the rope. Rescue eights are frequently made of steel, rather than aluminum.

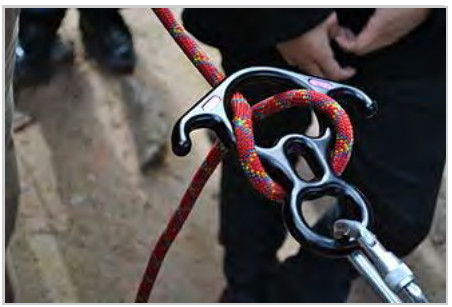

Rescue eight

Petzl Pirana

The Petzl Pirana is a slight variation to the traditional Figure 8 rappel device. The Pirana consists of a single loop of metal with double prongs jutting out of the bottom. Designed primarily for canyoneering, the Pirana allows for a variety of friction modes and, therefore, lowering speeds.[6] The Pirana supports three different braking positions, each supplying a different amount of friction, thereby changing the lowering speed. In contrast to the Figure 8, the Pirana can be loaded or disconnected from the rope without having to be removed from the carabiner.

For comfort, the Pirana can be extended away from the climber with nylon webbing or with a number of locking carabiners.[7]

Rappel Rack

This consists of a 'U' shaped frame, attached to the rappeller's harness, into which snap multiple bars that pivot

from the other side of the frame. The rope is woven through as many of the bars as are required to provide sufficient friction. This arrangement allows for variations in rope diameter and condition, as well as controlled rate of descent. Racks are seldom used in sport climbing. Cavers often use racks on long rappels because friction can be adjusted by adding or removing bars.

Ascenders

Ascenders are mechanical devices for ascending on a rope. They are also called Jumars, after a popular brand.

Jumars perform the same functionality as friction knots but less effort is needed to use them. A Jumar employs a cam which allows the device to slide freely in one direction but tightly grip the rope when pulled on in the opposite direction. To prevent a jumar from accidentally coming off the rope, a locking carabiner is used. The Jumar is first attached to the climber's harness by a piece of webbing or sling, and then the Jumar is clipped onto the rope and locked. Two ascenders are normally used to climb a fixed rope. For climbing a fixed rope attached to snow anchors on a steep slope, only one Jumar is used as the other hand is used for holding the ice axe.

Another type of ascender allows rope to feed in either direction, slowly, but locks up when pulled quickly. Such self-locking devices allow people to protect solo climbs because the amount of rope is automatically adjusted.

Sling

A **sling** or **runner** is an item of climbing equipment consisting of a tied or sewn loop of webbing that can be wrapped around sections of rock, hitched (tied) to other pieces of equipment or even tied directly to a tensioned line using a prusik knot, for anchor extension (to reduce rope drag and for other purposes), equalisation, or climbing the rope.

Daisy chain

A daisy chain is a strap, several feet long and typically constructed from one-inch tubular nylon webbing of the same type used in lengthening straps between anchor-points and the main rope. The webbing is bar tacked at roughly two-inch intervals (or, in the past, tied) to create a length of small loops for attachment. Unlike the use of similar devices in backpacking, daisy chains in technical rock climbing are expected to be of sufficient strength to be "load bearing,". Daisy chain pockets however are not rated to full strength, and can only take static loads.

A daisy chain

When clipped in, daisy chains should not be shortened by clipping in another pocket to the same carabiner. Failure of the pocket stitching results in the daisy chain disconnecting from the anchor, with potentially fatal consequences. If shortening the daisy chain when clipped in, in order to eliminate dangerous slack, a second carabiner should be used to connect to the anchor.[8]

Though daisy chains are sometimes used by free climbers as a type of sling (a quick attachment used from harness directly to a belay anchor), and for ad hoc purposes similar to those of the backpacker, the canonical use for a daisy chain is in aid climbing, wherein the leader will typically attach one end to the harness, and the

other to the top-most anchor placement (by carabiner or fifi hook), particularly after having ascended in étriers as high as possible. This allows the leader to hang from the daisy chain while preparing the next anchor placement. The closely spaced loops allow fine-tuning the length from harness to anchor, thereby allowing the best possible reach for the next placement.

Daisy chains should not be confused with étriers, also known as *aiders*, which are short ladders made in the same way, but with larger loops, also used in aid climbing, nor with load-limiting devices often known as screamers (from their first trade name) designed to simulate a dynamic belay.

Protection devices

Protection devices, collectively known as *rock protection* or *pro*, provide the means to place temporary anchor points on the rock. These devices may be categorized as *passive* (e.g., nuts) or *active* (e.g., SLCDs). Passive protection acts "merely" as a choke when pulled on, and constrictions in the rock prevent it from pulling out. Active protection transforms a pull on the device into an outward pressure on the rock that helps the device set more firmly. The type of protection that is most appropriate varies depending on the nature of the rock.

Nuts

Typical nuts and a nut tool

Nuts are manufactured in many different varieties. In their simplest form, they are just a small block of metal attached to a loop of cord or wire. They are used by simply wedging them into narrowing cracks in the rock, then giving them a tug to set them. Nuts are sometimes referred to by the slang term, *wires*.

Black Diamond Hexcentrics

Hexes

Hexes are the oldest form of active protection. They consist of a hollow eccentric hexagonal prism with tapered ends, usually threaded with cord or webbing. They are frequently placed as a passive chock, but are more commonly placed in active camming positions. In the standard active placement, a fall causes the hex to twist in its placement exerting sideways force on the rock in which it is placed. They are manufactured by several firms, with a range of sizes varying from about 10mm thick to 100mm wide. Sides may be straight or curved.

Spring-loaded camming devices

These consist of three or four cams mounted on a common axle or two adjacent axles, in such a way that pulling on the shaft connected to the axle forces the cams to spread further apart. The SLCD is used like a syringe, by pulling the cams via a "trigger" (a small handle) which forces them closer, inserting it into a crack or pocket in the rock, and then releasing the trigger. The springs make the cams expand and grip the rock face securely. A climbing rope may then be attached to the end of the stem via a sling and carabiner. SLCDs are typically designed to maintain a constant camming angle with the rock to ensure that the normal force provided by the cam lobes against the rock face will supply enough friction to hold a cam in equilibrium with the

rock.[9]

An SLCD placed in a crack.

Tricams

A *Tricam* is a device that can be used as either active or passive protection. It consists of a shaped aluminium block attached to a length of tape (webbing). The block is shaped so that pulling on the tape makes it cam against the crack, gripping the rock tighter. Careful placement is necessary so that the "cam" does not loosen when not loaded. It is generally not as easy to place or remove as a SLCD but is much cheaper and lighter, and often is the only thing that will work in situations like quarry drill-holes and limestone pockets. The smaller sizes can work well in old piton scars, and can also be used passively as nuts.

Training equipment

Various items of equipment are employed during climbing-specific training.

Hangboards

A wooden or resin board used for improving contact strength for climbers. It develops the forearm muscles along with the tendons and pulleys of the fingers.

A wooden hangboard designed for increasing contact strength in rock climbers by Concept Climbing

They consist of a variety of different-sized pockets and edges that are designed to be hung from with various training protocols. These pockets and edges can range from large jug holds to micro crimp edges. When used effectively they can facilitate huge gains in forearm strength and lock off strength, mostly in the flexor digitorum profundus and flexor digitorum superficialis muscles of the fore arms. They are also an apparatus with the capability to injure the user, usually in the A1-4 pulleys or along sections of flexor carpi sheath linking the different FDS or FDP sections in the forearm.

Hangboards are the best way to increase contact strength for rock climbers, and when following a well established training protocol such as Eva Lopez's max weight min edge program, tremendous gains in strength can be made over the long term. Training is usually done in cycles.

Hangboards are usually mounted above a doorway, or anywhere that allows the user's body to hang freely, one of the best available attachment areas is to roof beams. They are also called fingerboards.

Grip savers

A small device that can help in developing the antagonist muscles to those used while gripping with the hand. Use of such a device can prevent the ligament injuries that are frequently experienced by climbers.

Campus boards

A series of horizontal rungs attached to an overhanging surface that may be climbed up and down without the

aid of the feet. When used properly, campus boards can improve finger strength and so-called "contact strength".

Bachar ladder

A bachar ladder is made by stringing large diameter PVC piping on webbing and is climbed without using the feet. It can help improve overall upper body strength as well as core strength.

Specialized clothing

In the early days of climbing, many would have considered specialised clothing to be cheating. In fact, the first climbers considered an untucked shirt or unbuttoned sport jacket a sign of weakness. Several climbers even chose to climb barefoot, an act that modern climbers would find amazing. In the 1980s and early 1990s, the trend was to wear tight, brightly coloured clothes often made from Spandex. The trend, now, is to wear looser-fitting clothing. Trousers can be tailored to prevent them from restricting movement by adding features such as articulated knee joints and diamond crotch.

Helmet

Black Diamond Equipment Half Dome climbing helmet

The climbing helmet is a piece of safety equipment that primarily protects the skull against falling debris (such as rocks or dropped pieces of protection) and impact forces during a fall. For example, if a lead climber allows the rope to wrap behind an ankle, a fall can flip the climber over and consequently impact the back of the head. Furthermore, any effects of pendulum from a fall that have not been compensated for by the belayer may also result in head injury to the climber. The risk of head injury to a falling climber can be further significantly mitigated by falling correctly.

A Petzl Elios climbing helmet designed for caving and mountaineering

Climbers may decide whether to wear a helmet based on a number of factors such as the type of climb being attempted, concerns about weight, reductions in agility, added encumbrances, or simple vanity. Additionally, there is less incentive to wear a helmet in artificial climbing environments like indoor climbing walls (where routes and holds are regularly maintained) than on natural multi-pitch routes or ice climbing routes (where falling rocks and/or ice are likely).

Climbing shoes

Specifically designed foot wear is usually worn for climbing. To increase the grip of the foot on a climbing wall or rock face due to friction, the shoe is soled with a vulcanized rubber layer. Usually, shoes are only a few millimetres thick and fit very snugly around the foot. Stiffer shoes are used for "edging", more compliant ones for "smearing". Some have foam padding on the heel to make descents and rappels more comfortable.

Climbing shoes can be re-soled which decreases the frequency that shoes need to be replaced.

Belay gloves

A belay glove is a glove constructed from either leather or a synthetic substitute, is used to protect the hands when belaying, and is especially useful if using a classic or body belay. They are also very useful for controlling the belay with single, lead ropes that are 9.5 mm or smaller.[10] Ultimately, belay gloves can lessen the possibility of rope burn and the subsequent involuntary release of the rope.

A Belay glove

Miscellaneous equipment

Tape

Medical tape is useful to both prevent and repair minor injuries. For example, tape is often used to fix flappers. Many climbers use tape to bind fingers or wrists to prevent recurring tendon problems. Tape is also highly desirable for protecting hands on climbing routes that consist mostly of repeated hand jamming.

"Tape" can also refer to nylon webbing.

Haul bag

A haul bag refers to a large, tough, and often unwieldy bag into which supplies and climbing equipment can be thrown. A rucksack or day pack often has a webbing, haul loop on the top edge.

Haul bags are often affectionately known as "pigs" due to their unwieldy nature.

Gear sling

A gear sling is usually used by trad (traditional), or big wall climbers when they have too much gear to fit onto the gear loops of their harnesses. The simplest forms are homemade slings of webbing; more elaborate forms are padded.

Chalk

Chalk is used by nearly all climbers to absorb problematic moisture, often sweat, on the hands. Typically, chalk is stored as a loose powder in a special chalk bag designed to prevent spillage, most often closed with a drawstring. This chalk bag is then hung by a carabiner from the climbing harness or from a simple belt worn around the climber's waist . This allows the climber to re-chalk during the climb with minimal interruption or effort. To prevent excess chalking (which can actually *decrease* friction), some climbers will store their chalk in a chalk ball, which is then kept in the chalk bag. A chalk ball is a very fine, mesh sack that allows chalk release with minimum leakage when squeezed so that the climber can control the amount of chalk on the hands.

Chalk is most frequently white, and the repeated use of holds by freshly-chalked hands leads to chalky build-up. While this isn't a concern in an indoor gym setting, white chalk build-up on the natural rock of

outdoor climbs is considered to be an eyesore at best, and many consider it a legitimate environmental/conservation concern. In the United States, the Bureau of Land Management advocates the use of chalk that matches the color of the native rock.[11] Several popular climbing areas, like Arches National Park have banned white chalk, instead allowing the use of rock-colored chalk. Garden of the Gods has gone further, banning the use of calcium carbonate (the most common chalk) outright, requiring the use of a rock-colored substitute. A handful of companies make colored chalk or a chalk substitute designed to comply with these environmental conservation measures.

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Rocket

From Wikipedia, the free encyclopedia

A Soyuz-U, at Baikonur cosmodrome's Site 1/5 in Kazakhstan

A **rocket** (from Italian *rocchetto* "bobbin")[nb 1][1] is a missile, spacecraft, aircraft or other vehicle that obtains thrust from a rocket engine. Rocket engine exhaust is formed entirely from propellant carried within the rocket before use.[2] Rocket engines work by action and reaction and push rockets forward simply by expelling their exhaust in the opposite direction at high speed, and can therefore work in the vacuum of space.

In fact, rockets work more efficiently in space than in an atmosphere. Multi-stage rockets are capable of attaining escape velocity from Earth and therefore can achieve unlimited maximum altitude. Compared with airbreathing engines, rockets are lightweight and powerful and capable of generating large accelerations. To control their flight, rockets rely on momentum, airfoils, auxiliary reaction engines, gimballed thrust, momentum wheels, deflection of the exhaust stream, propellant flow, spin, and/or gravity.

Rockets for military and recreational uses date back to at least 13th century China.[3] Significant scientific, interplanetary and industrial use did not occur until the 20th century, when rocketry was the enabling technology for the Space Age, including setting foot on the moon. Rockets are now used for fireworks, weaponry, ejection seats, launch vehicles for artificial satellites, human spaceflight, and space exploration.

Chemical rockets are the most common type of high power rocket, typically creating a high speed exhaust by the combustion of fuel with an oxidizer. The stored propellant can be a simple pressurized gas or a single liquid fuel that disassociates in the presence of a catalyst (monopropellants), two liquids that spontaneously react on contact (hypergolic propellants), two liquids that must be ignited to react, a solid combination of fuel with oxidizer (solid fuel), or solid fuel with liquid oxidizer (hybrid propellant system). Chemical rockets store a large amount of energy in an easily released form, and can be very dangerous. However, careful design, testing, construction and use minimizes risks.

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History

The first gunpowder-powered rockets were developed in Song China, by the 13th century. The Chinese rocket technology was adopted by the Mongols and the invention was spread via the Mongol invasions to the Near East and Europe in the mid 13th century.[4] Medieval and early modern rockets were used militarily as incendiary weapons in sieges.

An early Chinese text to mention the use of rockets was the *Huolongjing*, written by the Chinese artillery officer Jiao Yu in the mid-14th century. Between 1270 and 1280, Hasan al-Rammah wrote *al-furusiyyah wa al-manasib al-harbiyya* (*The Book of Military Horsemanship and Ingenious War Devices*), which included 107 gunpowder recipes, 22 of which are for rockets.[5][6] In Europe, Konrad Kyeser described rockets in his military treatise *Bellifortis* around 1405.[7]

Drawing of a Chinese soldier lighting a rocket's fuse (1890)

Depiction of a rocket (1405)

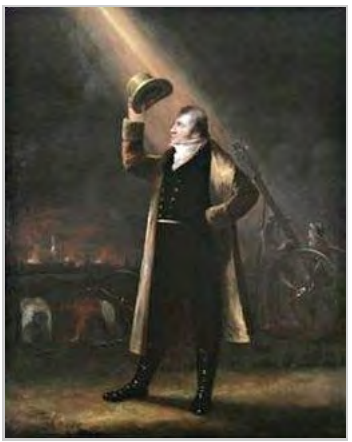

William Congreve at the bombardment of Copenhagen (1807)

The name *Rocket* comes from the Italian *rocchetta*, meaning "bobbin" or "little spindle", given due to the similarity in shape to the bobbin or spool used to hold the thread to be fed to a spinning wheel. The Italian term was adopted into German in the mid 16th century by Leonhard Fronsperger and Conrad Haas, and by the early 17th century into English.[1] *Artis Magnae Artilleriae pars prima*, an important early modern work on rocket artillery, by Kazimierz Siemienowicz, was first printed in Amsterdam in 1650.

The first iron-cased rockets were developed in the late 18th century in the Kingdom of Mysore, adopted and improved as the Congreve rocket and used in the Napoleonic Wars. The first mathematical treatment of the dynamics of rocket propulsion is due to William Moore (1813). In 1815, Alexander Dmitrievich Zasyadko constructed rocket-launching platforms, which allowed rockets to be fired in salvos (6 rockets at a time), and gun-laying devices. William Hale in 1844 greatly increased the accuracy of rocket artillery. The Congreve rocket was further improved by Edward Mounier Boxer in 1865.

Konstantin Tsiolkovsky (1903) first speculated on the possibility of manned spaceflight with rocket technology. Robert Goddard in 1920 published proposed improvements to rocket technology in *A Method of Reaching Extreme Altitudes*. In 1923, Hermann Oberth (1894–1989) published *Die Rakete zu den Planetenräumen* ("The Rocket into Planetary Space")

Modern rockets originated when Goddard attached a supersonic (de Laval) nozzle to the combustion chamber of a liquid-fueled rocket engine. These nozzles turn the hot gas from the combustion chamber into a cooler, hypersonic, highly directed jet of gas, more than doubling the thrust and raising the engine efficiency from 2% to 64%. Use of liquid propellants instead of gunpowder greatly improved the effectiveness of rocket artillery in World War II, and opened up the possibility of manned spaceflight after 1945.

In 1943, production of the V-2 rocket began in Germany. In parallel with the guided missile programme, rockets were also used on aircraft, either for assisting horizontal take-off (RATO), vertical take-off (Bachem Ba 349 "Natter") or for powering them (Me 163, see list of World War II guided missiles of Germany). The Allies' rocket programs were less sophisticated, relying mostly on unguided missiles like the Soviet Katyusha rocket. The Americans captured a large number of German rocket scientists, including Wernher von Braun, and brought them to the United States as part of Operation Paperclip. After the war, rockets were used to study high-altitude conditions, by radio telemetry of temperature and pressure of the atmosphere, detection of cosmic rays, and further research; notably the Bell X-1, the first manned vehicle to break the sound barrier. Independently, in the Soviet Union's space program research continued under the leadership of the chief

Goddard with a liquid oxygen-gasoline rocket (1926)

designer Sergei Korolev.

During the Cold War, rockets became extremely important militarily as modern intercontinental ballistic missiles (ICBMs). The 1960s became the decade of rapid development of rocket technology particularly in the Soviet Union (Vostok, Soyuz, Proton) and in the United States (e.g. the X-15). Rockets were now used for space exploration, with the American manned programs Project Mercury, Project Gemini and later the Apollo programme culminated in 1969 with the first manned landing on the moon via the Saturn V.

Types

Vehicle configurations

Rocket vehicles are often constructed in the archetypal tall thin "rocket" shape that takes off vertically, but there are actually many different types of rockets including:[8][9]

Saturn V is the biggest rocket to have successfully flown.

- tiny models such as balloon rockets, water rockets, skyrockets or small solid rockets that can be purchased at a hobby store
- missiles
- space rockets such as the enormous Saturn V used for the Apollo program
- rocket cars
- rocket bike[10]
- rocket-powered aircraft (including rocket assisted takeoff of conventional aircraft- RATO)
- rocket sleds
- rocket trains
- rocket torpedoes[11][12]
- rocket-powered jet packs[13]
- rapid escape systems such as ejection seats and launch escape systems
- space probes

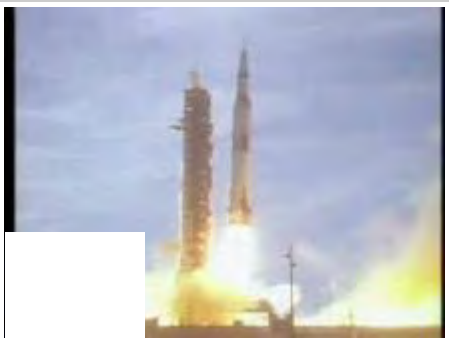

Launch of *Apollo 15* Saturn V rocket: $T - 30$ s through $T + 40$ s

Design

A rocket design can be as simple as a cardboard tube filled with black powder, but to make an efficient, accurate rocket or missile involves overcoming a number of difficult problems. The main difficulties include cooling the combustion chamber, pumping the fuel (in the case of a liquid fuel), and controlling and correcting the direction of motion.[14]

Components

Rockets consist of a propellant, a place to put propellant (such as a propellant tank), and a nozzle. They may also have one or more rocket engines, directional stabilization device(s) (such as fins, vernier engines or engine gimbals for thrust vectoring, gyroscopes) and a structure (typically monocoque) to hold these components together. Rockets intended for high speed atmospheric use also have an aerodynamic fairing such as a nose cone, which usually holds the payload.[15]

As well as these components, rockets can have any number of other components, such as wings (rocketplanes), parachutes, wheels (rocket cars), even, in a sense, a person (rocket belt). Vehicles frequently possess navigation systems and guidance systems that typically use satellite navigation and inertial navigation systems.

Engines

Viking 5C rocket engine

Rocket engines employ the principle of jet propulsion.[2] The rocket engines powering rockets come in a great variety of different types; a comprehensive list can be found in rocket engine. Most current rockets are chemically powered rockets (usually internal combustion engines,[16] but some employ a decomposing monopropellant) that emit a hot exhaust gas. A rocket engine can use gas propellants, solid propellant, liquid propellant, or a hybrid mixture of both solid and liquid. Some rockets use heat or pressure that is supplied from a source other than the chemical reaction of propellant(s), such as steam rockets, solar thermal rockets, nuclear thermal rocket engines or simple pressurized rockets such as water rocket or cold gas thrusters. With combustive propellants a chemical reaction is initiated between the fuel and the oxidizer in the combustion chamber, and the resultant hot gases accelerate out of a rocket engine nozzle (or nozzles) at the rearward-facing end of the rocket. The acceleration of these gases through the engine exerts force ("thrust") on the combustion chamber and nozzle, propelling the vehicle (according to Newton's Third Law). This actually happens because the force (pressure times area) on the combustion chamber wall is unbalanced by the nozzle opening; this is not the case in any other direction. The shape of the nozzle also generates force by directing the exhaust gas along the axis of the rocket.[2]

Propellant

Rocket propellant is mass that is stored, usually in some form of propellant tank or casing, prior to being used as the propulsive mass that is ejected from a rocket engine in the form of a fluid jet to produce thrust.[2] For chemical rockets often the propellants are a fuel such as liquid hydrogen or kerosene burned with an oxidizer such as liquid oxygen or nitric acid to produce large volumes of very hot gas. The oxidiser is either kept separate and mixed in the combustion chamber, or comes premixed, as with solid rockets.

Sometimes the propellant is not burned but still undergoes a chemical reaction, and can be a 'monopropellant' such as hydrazine, nitrous oxide or hydrogen peroxide that can be catalytically decomposed to hot gas.

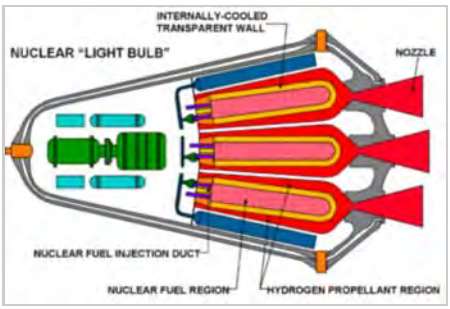

Gas Core light bulb

Alternatively, an inert propellant can be used that can be externally heated, such as in steam rocket, solar thermal rocket or nuclear thermal rockets.[2]

For smaller, low performance rockets such as attitude control thrusters where high performance is less necessary, a pressurised fluid is used as propellant that simply escapes the spacecraft through a propelling nozzle.[2]

Uses

Rockets or other similar reaction devices carrying their own propellant must be used when there is no other substance (land, water, or air) or force (gravity, magnetism, light) that a vehicle may usefully employ for propulsion, such as in space. In these circumstances, it is necessary to carry all the propellant to be used.

However, they are also useful in other situations:

Military

Some military weapons use rockets to propel warheads to their targets. A rocket and its payload together are generally referred to as a *missile* when the weapon has a guidance system (not all missiles use rocket engines, some use other engines such as jets) or as a *rocket* if it is unguided. Anti-tank and anti-aircraft missiles use rocket engines to engage targets at high speed at a range of several miles, while intercontinental ballistic missiles can be used to deliver multiple nuclear warheads from thousands of miles, and anti-ballistic missiles try to stop them. Rockets have also been tested for reconnaissance, such as the Ping-Pong rocket, which was launched to surveil enemy targets, however, recon rockets have never come into wide use in the military.

A Trident II missile launched from sea.

Science and research

Sounding rockets are commonly used to carry instruments that take readings from 50 kilometers (31 mi) to 1,500 kilometers (930 mi) above the surface of the Earth.[17]

Rocket engines are also used to propel rocket sleds along a rail at extremely high speed. The world record for this is Mach 8.5.[18]

Spaceflight

Larger rockets are normally launched from a launch pad that provides stable support until a few seconds after ignition. Due to their high exhaust velocity—2,500 to 4,500 m/s (9,000 to 16,200 km/h; 5,600 to 10,100 mph)—rockets are particularly useful when very high speeds are required, such as orbital speed at

approximately 7,800 m/s (28,000 km/h; 17,000 mph). Spacecraft delivered into orbital trajectories become artificial satellites, which are used for many commercial purposes. Indeed, rockets remain the only way to launch spacecraft into orbit and beyond.[19] They are also used to rapidly accelerate spacecraft when they change orbits or de-orbit for landing. Also, a rocket may be used to soften a hard parachute landing immediately before touchdown (see retrorocket).

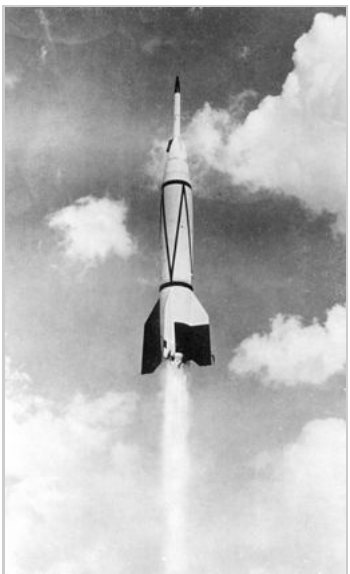

A Bumper sounding rocket

Rescue

Apollo LES pad abort test with boilerplate crew module.

Rockets were used to propel a line to a stricken ship so that a Breeches buoy can be used to rescue those on board. Rockets are also used to launch emergency flares.

Some crewed rockets, notably the Saturn V[20] and Soyuz[21] have launch escape systems. This is a small, usually solid rocket that is capable of pulling the crewed capsule away from the main vehicle towards safety at a moments notice. These types of systems have been operated several times, both in testing and in flight, and operated correctly each time.

This was the case when the Safety Assurance System (Soviet nomenclature) successfully pulled away the L3 capsule during three of the four failed launches of the Soviet moon rocket, N1 vehicles 3L, 5L and 7L. In all three cases the capsule, albeit unmanned, was saved from destruction. It should be noted that only the three aforementioned N1 rockets had functional Safety Assurance Systems. The outstanding vehicle, 6L, had dummy upper stages and therefore no escape system giving the N1 booster a 100% success rate for egress from a failed launch.[22][23][24][25]

A successful escape of a manned capsule occurred when Soyuz T-10, on a mission to the Salyut 7 space station, exploded on the pad.[26]

Solid rocket propelled ejection seats are used in many military aircraft to propel crew away to safety from a vehicle when flight control is lost.[27]

Hobby, sport, and entertainment

Hobbyists build and fly a wide variety of model rockets. Many companies produce model rocket kits and parts but due to their inherent simplicity some hobbyists have been known to make rockets out of almost anything. Rockets are also used in some types of consumer and professional fireworks. A Water Powered Rocket is a type of model rocket using water as its reaction mass. The pressure vessel (the engine of the rocket) is usually a used plastic soft drink bottle. The water is forced out by a pressurized gas, typically compressed air. It is an example of Newton's third law of motion.

The scale of amateur rocketry can range from a small rocket launched in your own backyard to a rocket that reached space.[28] Amateur rocketry is split into three categories: low power, mid power, and high power.

Australia, Austria, Canada, Germany, New Zealand, Switzerland, the United Kingdom, and the United States

have high power rocket associations which provide certifications to its members to fly different rocket motor sizes. While joining these organizations is not a requirement, they often provide insurance and flight waivers for their members.

Hydrogen peroxide rockets are used to power jet packs,[29] and have been used to power cars and a rocket car holds the all time (albeit unofficial) drag racing record.[30]

Corpulent Stump is the most powerful non commercial rocket ever launched on an Aerotech engine in the United Kingdom.

Noise

Rocket exhaust generates a significant amount of acoustic energy. As the supersonic exhaust collides with the ambient air, shock waves are formed. The sound intensity from these shock waves depends on the size of the rocket as well as the exhaust velocity. The sound intensity of large, high performance rockets could potentially kill at close range.[31]

Workers and media witness the Water Sound Suppression System test at Launch Pad 39A.

The Space Shuttle generates 180 dB of noise around its base.[32] To combat this, NASA developed a sound suppression system which can flow water at rates up to 900,000 gallons per minute (57 m^3/s) onto the launch pad. The water reduces the noise level from 180 dB down to 142 dB (the design requirement is 145 dB).[33] Without the sound suppression system, acoustic waves reflect off of the launch pad towards the rocket, vibrating the sensitive payload and crew. These acoustic waves can be so severe that they can destroy the rocket.

A Saturn V launch was detectable on seismometers a considerable distance from the launch site.

Noise is generally most intense when a rocket is close to the ground, since the noise from the engines radiates up away from the jet, as well as reflecting off the ground. This noise can be reduced somewhat by flame trenches with roofs, by water injection around the jet and by deflecting the jet at an angle.[31]

For crewed rockets various methods are used to reduce the sound intensity for the passengers, and typically the placement of the astronauts far away from the rocket engines helps significantly. For the passengers and crew, when a vehicle goes supersonic the sound cuts off as the sound waves are no longer able to keep up with the vehicle.[31]

Physics

Operation

The effect of the combustion of propellant in the rocket engine is to increase the velocity of the resulting gases to very high speeds, hence producing a thrust. Initially, the gases of combustion are sent in every direction, but only those that produce a net thrust have any effect. The ideal direction of motion of the exhaust is in the direction so as to cause thrust. At the top end of the combustion chamber the hot, energetic gas fluid cannot move forward, and so, it pushes upward against the top of the rocket engine's combustion chamber. As the combustion gases approach the exit of the combustion chamber, they increase in speed. The effect of the convergent part of the rocket engine nozzle on the high pressure fluid of combustion gases, is to cause the gases to accelerate to high speed. The higher the speed of the gases, the lower the pressure of the gas (Bernoulli's principle or conservation of energy) acting on that part of the combustion chamber. In a properly designed engine, the flow will reach Mach 1 at the throat of the nozzle. At which point the speed of the flow increases. Beyond the throat of the nozzle, a bell shaped expansion part of the engine allows the gases that are expanding to push against that part of the rocket engine. Thus, the bell part of the nozzle gives additional thrust. Simply expressed, for every action there is an equal and opposite reaction, according to Newton's third law with the result that the exiting gases produce the reaction of a force on the rocket causing it to accelerate the rocket.[34][nb 2]

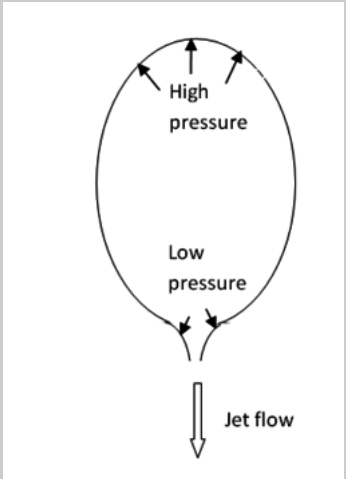

A balloon with a tapering nozzle. In this case, the nozzle itself does not push the balloon but is pulled by it. A convergent/divergent nozzle would be better.

In a closed chamber, the pressures are equal in each direction and no acceleration occurs. If an opening is provided in the bottom of the chamber then the pressure is no longer acting on the missing section. This opening permits the exhaust to escape. The remaining pressures give a resultant thrust on the side opposite the opening, and these pressures are what push the rocket along.

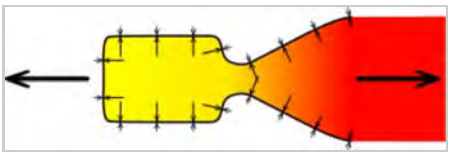
Rocket thrust is caused by pressures acting on both the combustion chamber and nozzle

The shape of the nozzle is important. Consider a balloon propelled by air coming out of a tapering nozzle. In such a case the combination of air pressure and viscous friction is such that the nozzle does not push the balloon but is *pulled* by it.[35] Using a convergent/divergent nozzle gives more force since the exhaust also presses on it as it expands outwards, roughly doubling the total force. If propellant gas is continuously added to the chamber then these pressures can be maintained for as long as propellant remains. Note that in the case of liquid propellant engines, the pumps moving the propellant into the combustion chamber must maintain a pressure larger than the combustion chamber -typically on the order of 100 atmospheres.[2]

As a side effect, these pressures on the rocket also act on the exhaust in the opposite direction and accelerate this exhaust to very high speeds (according to Newton's Third Law).[2] From the principle of conservation of momentum the speed of the exhaust of a rocket determines how much momentum increase is created for a given amount of propellant. This is called the rocket's *specific impulse*.[2] Because a rocket, propellant and exhaust in flight, without any external perturbations, may be considered as a closed system, the total momentum is always constant. Therefore, the faster the net speed of the exhaust in one direction, the greater the speed of the rocket can achieve in the opposite direction. This is especially true since the rocket body's mass is typically far lower than the final total exhaust mass.

Forces on a rocket in flight

The general study of the forces on a rocket is part of the field of ballistics. Spacecraft are further studied in the subfield of astrodynamics.

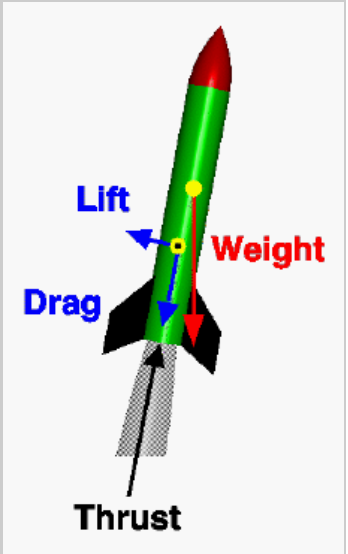

Forces on a rocket in flight

Flying rockets are primarily affected by the following:[36]

- Thrust from the engine(s)
- Gravity from celestial bodies
- Drag if moving in atmosphere
- Lift; usually relatively small effect except for rocket-powered aircraft

Rockets that must travel through the air are usually tall and thin as this shape gives a high ballistic coefficient and minimizes drag losses.

In addition, the inertia and centrifugal pseudo-force can be significant due to the path of the rocket around the center of a celestial body; when high enough speeds in the right direction and altitude are achieved a stable orbit or escape velocity is obtained.

These forces, with a stabilizing tail (the *empennage*) present will, unless deliberate control efforts are made, naturally cause the vehicle to follow a roughly parabolic trajectory termed a gravity turn, and this trajectory is often used at least during the initial part of a launch. (This is true even if the rocket engine is mounted at the nose.) Vehicles can thus maintain low or even zero angle of attack, which minimizes transverse stress on the launch vehicle, permitting a weaker, and hence lighter, launch vehicle.[37][38]

Drag

Drag is a force opposite to the direction of the rocket's motion. This decreases acceleration of the vehicle and produces structural loads. Deceleration force for fast-moving rockets are calculated using the drag equation.

Drag can be minimised by an aerodynamic nose cone and by using a shape with a high ballistic coefficient (the "classic" rocket shape—long and thin), and by keeping the rocket's angle of attack as low as possible.

During a rocket launch, as the vehicle speed increases, and the atmosphere thins, there is a point of maximum aerodynamic drag called Max Q. This determines the minimum aerodynamic strength of the vehicle, as the rocket must avoid buckling under these forces.[39]

Net thrust

A typical rocket engine can handle a significant fraction of its own mass in propellant each second, with the propellant leaving the nozzle at several kilometres per second. This means that the thrust-to-weight ratio of a rocket engine, and often the entire vehicle can be very high, in extreme cases over 100. This compares with other jet propulsion engines that can exceed 5 for some of the better[40] engines.[41]

It can be shown that the net thrust of a rocket is:

$$F_n = \dot{m}\, v_e$$ [2]:2–14

where:

$\dot{m} =$ propellant flow (kg/s or lb/s)

$v_e =$ the effective exhaust velocity (m/s or ft/s)

The effective exhaust velocity v_e is more or less the speed the exhaust leaves the vehicle, and in the vacuum of space, the effective exhaust velocity is often equal to the actual average exhaust speed along the thrust axis. However, the effective exhaust velocity allows for various losses, and notably, is reduced when operated within an atmosphere.

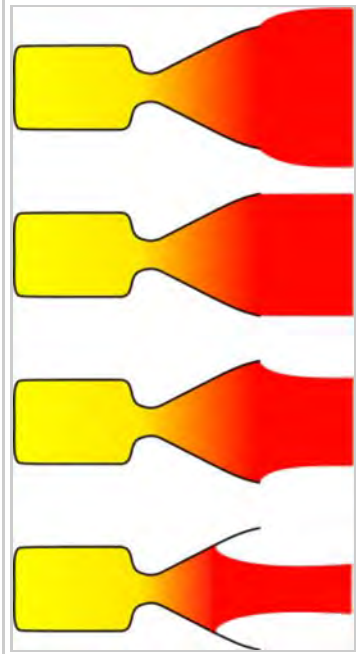

A rocket jet shape varies based on external air pressure. From top to bottom: Underexpanded Ideally Expanded Overexpanded Grossly overexpanded

The rate of propellant flow through a rocket engine is often deliberately varied over a flight, to provide a way to control the thrust and thus the airspeed of the vehicle. This, for example, allows minimization of aerodynamic losses[39] and can limit the increase of *g*-forces due to the reduction in propellant load.

Total impulse

Impulse is defined as a force acting on an object over time, which in the absence of opposing forces (gravity and aerodynamic drag), changes the momentum (integral of mass and velocity) of the object. As such, it is the best performance class (payload mass and terminal velocity capability) indicator of a rocket, rather than takeoff thrust, mass, or "power". The total impulse of a rocket (stage) burning its propellant is:[2]:27

$$I = \int F dt$$

When there is fixed thrust, this is simply:

$$I = Ft$$

The total impulse of a multi-stage rocket is the sum of the impulses of the individual stages.

Specific impulse

As can be seen from the thrust equation, the effective speed of the exhaust controls the amount of thrust produced from a particular quantity of fuel burnt per second.

An equivalent measure, the net impulse per weight unit of propellant expelled, is called specific Impulse, I_{sp}, and this is one of the most important figures that describes a rocket's performance. It is defined such that it is related to the effective exhaust velocity by:

$$v_e = I_{sp} \cdot g_0$$ [2]:29

where:

I_{sp} has units of seconds
g_0 is the acceleration at the surface of the Earth

I_{sp} in vacuum of various rockets

Rocket	Propellants	I_{sp}, vacuum (s)
Space shuttle liquid engines	LOX/LH_2	453[42]
Space shuttle solid motors	APCP	268[42]
Space shuttle OMS	NTO/MMH	313[42]
Saturn V stage 1	LOX/RP-1	304[42]

Thus, the greater the specific impulse, the greater the net thrust and performance of the engine. I_{sp} is determined by measurement while testing the engine. In practice the effective exhaust velocities of rockets varies but can be extremely high, ~4500 m/s, about 15 times the sea level speed of sound in air.

Delta-v (rocket equation)

The delta-v capacity of a rocket is the theoretical total change in velocity that a rocket can achieve without any external interference (without air drag or gravity or other forces).

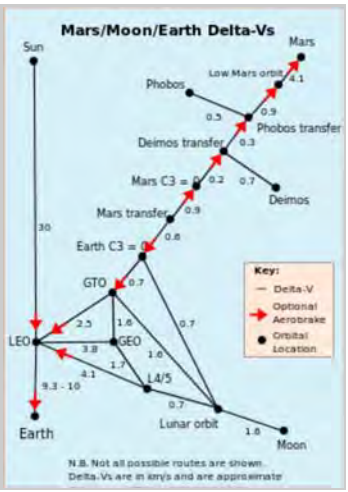

A map of approximate Delta-v's around the solar system between Earth and Mars[43][44]

When v_e is constant, the delta-v that a rocket vehicle can provide can be calculated from the Tsiolkovsky rocket equation:[45]

$$\Delta v = v_e \ln \frac{m_0}{m_1}$$

where:

- m_0 is the initial total mass, including propellant, in kg (or lb)
- m_1 is the final total mass in kg (or lb)
- v_e is the effective exhaust velocity in m/s (or ft/s)
- Δv is the delta-v in m/s (or ft/s)

When launched from the Earth practical delta-v's for a single rockets carrying payloads can be a few km/s. Some theoretical designs have rockets with delta-v's over 9 km/s.

The required delta-v can also be calculated for a particular manoeuvre; for example the delta-v to launch from the surface of the Earth to Low earth orbit is about 9.7 km/s, which leaves the vehicle with a sideways speed of about 7.8 km/s at an altitude of around 200 km. In this manoeuvre about 1.9 km/s is lost in air drag, gravity drag and gaining altitude.

The ratio $\frac{m_0}{m_1}$ is sometimes called the *mass ratio*.

Mass ratios

Almost all of a launch vehicle's mass consists of propellant.[46] Mass ratio is, for any 'burn', the ratio between the rocket's initial mass and its final mass.[47] Everything else being equal, a high mass ratio is desirable for good performance, since it indicates that the rocket is lightweight and hence performs better, for essentially the same reasons that low weight is desirable in sports cars.

Rockets as a group have the highest thrust-to-weight ratio of any type of engine; and this helps vehicles achieve high mass ratios, which improves the performance of flights. The higher the ratio, the less engine mass is needed to be carried. This permits the carrying of even more propellant, enormously improving the delta-v. Alternatively, some rockets such as for rescue scenarios or racing carry relatively little propellant and payload and thus need only a lightweight structure and instead achieve high accelerations. For example, the Soyuz escape system can produce 20g.[21]

Achievable mass ratios are highly dependent on many factors such as propellant type, the design of engine the

vehicle uses, structural safety margins and construction techniques.

The highest mass ratios are generally achieved with liquid rockets, and these types are usually used for orbital launch vehicles, a situation which calls for a high delta-v. Liquid propellants generally have densities similar to water (with the notable exceptions of liquid hydrogen and liquid methane), and these types are able to use lightweight, low pressure tanks and typically run high-performance turbopumps to force the propellant into the combustion chamber.

Some notable mass fractions are found in the following table (some aircraft are included for comparison purposes):

Vehicle	Takeoff Mass	Final Mass	Mass ratio	Mass fraction
Ariane 5 (vehicle + payload)	746,000 kg [48] (~1,645,000 lb)	2,700 kg + 16,000 kg[48] (~6,000 lb + ~35,300 lb)	39.9	0.975
Titan 23G first stage	117,020 kg (258,000 lb)	4,760 kg (10,500 lb)	24.6	0.959
Saturn V	3,038,500 kg[49] (~6,700,000 lb)	13,300 kg + 118,000 kg[49] (~29,320 lb + ~260,150 lb)	23.1	0.957
Space Shuttle (vehicle + payload)	2,040,000 kg (~4,500,000 lb)	104,000 kg + 28,800 kg (~230,000 lb + ~63,500 lb)	15.4	0.935
Saturn 1B (stage only)	448,648 kg[50] (989,100 lb)	41,594 kg[50] (91,700 lb)	10.7	0.907
Virgin Atlantic GlobalFlyer	10,024.39 kg (22,100 lb)	1,678.3 kg (3,700 lb)	6.0	0.83
V-2	13,000 kg (~28,660 lb) (12.8 ton)		3.85	0.74 [51]
X-15	15,420 kg (34,000 lb)	6,620 kg (14,600 lb)	2.3	0.57[52]
Concorde	~181,000 kg (400,000 lb [52])		2	0.5[52]
Boeing 747	~363,000 kg (800,000 lb[52])		2	0.5[52]

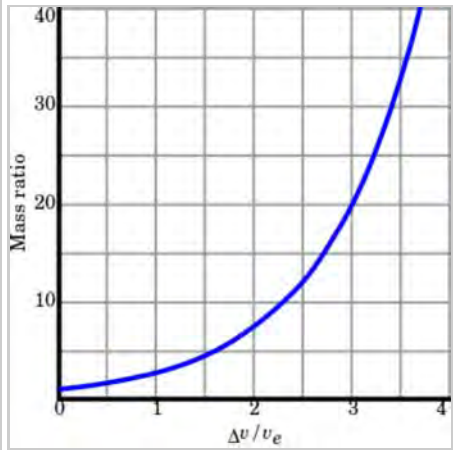

The Tsiolkovsky rocket equation gives a relationship between the mass ratio and the final velocity in multiples of the exhaust speed

Staging

Thus far, the required velocity (delta-v) to achieve orbit has been unattainable by any single rocket because the propellant, tankage, structure, guidance, valves and engines and so on, take a particular minimum percentage of take-off mass that is too great for the propellant it carries to achieve that delta-v. Since Single-stage-to-orbit has so far not been achievable, orbital rockets always have more than one stage.

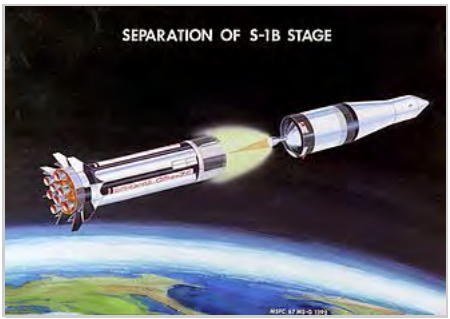

Spacecraft staging involves dropping off unnecessary parts of the rocket to reduce mass.

For example, the first stage of the Saturn V, carrying the weight of the upper stages, was able to achieve a mass ratio of about 10, and achieved a specific impulse of 263 seconds. This gives a delta-v of around 5.9 km/s whereas around 9.4 km/s delta-v is needed to achieve orbit with all losses allowed for.

This problem is frequently solved by staging — the rocket sheds excess weight (usually empty tankage and associated engines) during launch. Staging is either *serial* where the rockets light after the previous stage has fallen away, or *parallel*, where rockets are burning together and then detach when they burn out.[53]

Apollo 6 while dropping the interstage ring

The maximum speeds that can be achieved with staging is theoretically limited only by the speed of light. However the payload that can be carried goes down geometrically with each extra stage needed, while the additional delta-v for each stage is simply additive.

Acceleration and thrust-to-weight ratio

From Newton's second law, the acceleration, a, of a vehicle is simply:

$$a = \frac{F_n}{m}$$

Where m is the instantaneous mass of the vehicle and F_n is the net force acting on the rocket (mostly thrust but air drag and other forces can play a part.)

As the remaining propellant decreases, rocket vehicles become lighter and their acceleration tends to increase until the propellant is exhausted. This means that much of the speed change occurs towards the end of the burn when the vehicle is much lighter.[2] However, the thrust can be throttled to offset or vary this if needed. Discontinuities in acceleration also occur when stages burn out, often starting at a lower acceleration with each new stage firing.

Peak accelerations can be increased by designing the vehicle with a reduced mass, usually achieved by a reduction in the fuel load and tankage and associated structures, but obviously this reduces range, delta-v and burn time. Still, for some applications that rockets are used for, a high peak acceleration applied for just a short time is highly desirable.

The minimal mass of vehicle consists of a rocket engine with minimal fuel and structure to carry it. In that case the thrust-to-weight ratio[nb 3] of the rocket engine limits the maximum acceleration that can be designed. It turns out that rocket engines generally have truly excellent thrust to weight ratios (137 for the NK-33

engine,[54] some solid rockets are over 1000[2]:442), and nearly all really high-g vehicles employ or have employed rockets.

The high accelerations that rockets naturally possess means that rocket vehicles are often capable of vertical takeoff, and in some cases, with suitable guidance and control of the engines, also vertical landing. For these operations to be done it is necessary for a vehicle's engines to provide more than the local gravitational acceleration.

Energy

Energy efficiency

Rocket launch vehicles take-off with a great deal of flames, noise and drama, and it might seem obvious that they are grievously inefficient. However, while they are far from perfect, their energy efficiency is not as bad as might be supposed.

Space Shuttle *Atlantis* during launch phase

The energy density of a typical rocket propellant is often around one-third that of conventional hydrocarbon fuels; the bulk of the mass is (often relatively inexpensive) oxidizer. Nevertheless, at take-off the rocket has a great deal of energy in the fuel and oxidizer stored within the vehicle. It is of course desirable that as much of the energy of the propellant end up as kinetic or potential energy of the body of the rocket as possible.

Energy from the fuel is lost in air drag and gravity drag and is used for the rocket to gain altitude and speed. However, much of the lost energy ends up in the exhaust.[2]:37–38

In a chemical propulsion device, the engine efficiency is simply the ratio of the kinetic power of the exhaust gases and the power available from the chemical reaction:[2]:37–38

$$\eta_c = \frac{\frac{1}{2}\dot{m}v_e^2}{\eta_{combustion} P_{chem}}$$

100% efficiency within the engine (engine efficiency $\eta_c = 100\%$) would mean that all the heat energy of the combustion products is converted into kinetic energy of the jet. This is not possible, but the near-adiabatic high expansion ratio nozzles that can be used with rockets come surprisingly close: when the nozzle expands the gas, the gas is cooled and accelerated, and an energy efficiency of up to 70% can be achieved. Most of the rest is heat energy in the exhaust that is not recovered.[2]:37–38 The high efficiency is a consequence of the fact that rocket combustion can be performed at very high temperatures and the gas is finally released at much lower temperatures, and so giving good Carnot efficiency.

However, engine efficiency is not the whole story. In common with the other jet-based engines, but particularly in rockets due to their high and typically fixed exhaust speeds, rocket vehicles are extremely inefficient at low speeds irrespective of the engine efficiency. The problem is that at low speeds, the exhaust carries away a huge amount of kinetic energy rearward. This phenomenon is termed propulsive efficiency (η_p).[2]:37–38

However, as speeds rise, the resultant exhaust speed goes down, and the overall vehicle energetic efficiency rises, reaching a peak of around 100% of the engine efficiency when the vehicle is travelling exactly at the

same speed that the exhaust is emitted. In this case the exhaust would ideally stop dead in space behind the moving vehicle, taking away zero energy, and from conservation of energy, all the energy would end up in the vehicle. The efficiency then drops off again at even higher speeds as the exhaust ends up travelling forwards-trailing behind the vehicle.

From these principles it can be shown that the propulsive efficiency η_p for a rocket moving at speed u with an exhaust velocity c is:

$$\eta_p = \frac{2\frac{u}{c}}{1+(\frac{u}{c})^2}$$ [2]:37–38

And the overall (instantaneous) energy efficiency η is:

$$\eta = \eta_p \eta_c$$

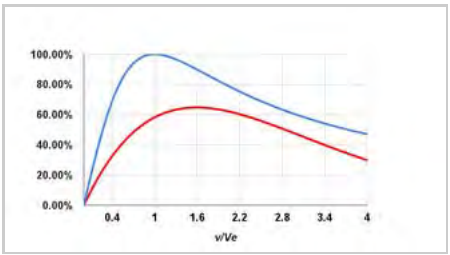

Plot of instantaneous propulsive efficiency (blue) and overall efficiency for a rocket accelerating from rest (red) as percentages of the engine efficiency

For example, from the equation, with an η_c of 0.7, a rocket flying at Mach 0.85 (which most aircraft cruise at) with an exhaust velocity of Mach 10, would have a predicted overall energy efficiency of 5.9%, whereas a conventional, modern, air-breathing jet engine achieves closer to 35% efficiency. Thus a rocket would need about 6x more energy; and allowing for the specific energy of rocket propellant being around one third that of conventional air fuel, roughly 18x more mass of propellant would need to be carried for the same journey. This is why rockets are rarely if ever used for general aviation.

Since the energy ultimately comes from fuel, these considerations mean that rockets are mainly useful when a very high speed is required, such as ICBMs or orbital launch. For example, NASA's space shuttle fires its engines for around 8.5 minutes, consuming 1,000 tonnes of solid propellant (containing 16% aluminium) and an additional 2,000,000 litres of liquid propellant (106,261 kg of liquid hydrogen fuel) to lift the 100,000 kg vehicle (including the 25,000 kg payload) to an altitude of 111 km and an orbital velocity of 30,000 km/h. At this altitude and velocity, the vehicle has a kinetic energy of about 3 TJ and a potential energy of roughly 200 GJ. Given the initial energy of 20 TJ,[nb 4] the Space Shuttle is about 16% energy efficient at launching the orbiter.

Thus jet engines, with a better match between speed and jet exhaust speed (such as turbofans—in spite of their worse η_c)—dominate for subsonic and supersonic atmospheric use, while rockets work best at hypersonic speeds. On the other hand, rockets serve in many short-range *relatively* low speed military applications where their low-speed inefficiency is outweighed by their extremely high thrust and hence high accelerations.

Oberth effect

One subtle feature of rockets relates to energy. A rocket stage, while carrying a given load, is capable of giving a particular delta-v. This delta-v means that the speed increases (or decreases) by a particular amount, independent of the initial speed. However, because kinetic energy is a square law on speed, this means that the faster the rocket is travelling before the burn the more orbital energy it gains or loses.

This fact is used in interplanetary travel. It means that the amount of delta-v to reach other planets, over and above that to reach escape velocity can be much less if the delta-v is applied when the rocket is travelling at high speeds, close to the Earth or other planetary surface; whereas waiting until the rocket has slowed at altitude multiplies up the effort required to achieve the desired trajectory.

Safety, reliability and accidents

The reliability of rockets, as for all physical systems, is dependent on the quality of engineering design and construction.

Space Shuttle Challenger was torn apart T+73 seconds after hot gases escaped the SRBs, causing the breakup of the Shuttle stack

Because of the enormous chemical energy in rocket propellants (greater energy by weight than explosives, but lower than gasoline), consequences of accidents can be severe. Most space missions have some problems.[55] In 1986, following the Space Shuttle Challenger disaster, American physicist Richard Feynman, having served on the Rogers Commission estimated that the chance of an unsafe condition for a launch of the Shuttle was very roughly 1%;[56] more recently the historical per person-flight risk in orbital spaceflight has been calculated to be around 2%[57] or 4%.[58]

Costs and economics

The costs of rockets can be roughly divided into propellant costs, the costs of obtaining and/or producing the 'dry mass' of the rocket, and the costs of any required support equipment and facilities.[59]

Most of the takeoff mass of a rocket is normally propellant. However propellant is seldom more than a few times more expensive than gasoline per kilogram (as of 2009 gasoline was about $1/kg [$0.45/lb] or less), and although substantial amounts are needed, for all but the very cheapest rockets, it turns out that the propellant costs are usually comparatively small, although not completely negligible.[59] With liquid oxygen costing $0.15 per kilogram ($0.068/lb) and liquid hydrogen $2.20/kg ($1.00/lb), the Space Shuttle in 2009 had a liquid propellant expense of approximately $1.4 million for each launch that cost $450 million from other expenses (with 40% of the mass of propellants used by it being liquids in the external fuel tank, 60% solids in the SRBs).[60][61][62]

Even though a rocket's non-propellant, dry mass is often only between 5-20% of total mass,[63] nevertheless this cost dominates. For hardware with the performance used in orbital launch vehicles, expenses of $2000–$10,000+ per kilogram of dry weight are common, primarily from engineering, fabrication, and testing; raw materials amount to typically around 2% of total expense.[64][65] For most rockets except reusable ones (shuttle engines) the engines need not function more than a few minutes, which simplifies design.

Extreme performance requirements for rockets reaching orbit correlate with high cost, including intensive quality control to ensure reliability despite the limited safety factors allowable for weight reasons.[65] Components produced in small numbers if not individually machined can prevent amortization of R&D and facility costs over mass production to the degree seen in more pedestrian manufacturing.[65] Amongst liquid-fueled rockets, complexity can be influenced by how much hardware must be lightweight, like pressure-fed engines can have two orders of magnitude lesser part count than pump-fed engines but lead to more weight by needing greater tank pressure, most often used in just small maneuvering thrusters as a consequence.[65]

To change the preceding factors for orbital launch vehicles, proposed methods have included mass-producing simple rockets in large quantities or on large scale,[59] or developing reusable rockets meant to fly very frequently to amortize their up-front expense over many payloads, or reducing rocket performance requirements by constructing a hypothetical non-rocket spacelaunch system for part of the velocity to orbit (or

all of it but with most methods involving some rocket use).

The costs of support equipment, range costs and launch pads generally scale up with the size of the rocket, but vary less with launch rate, and so may be considered to be approximately a fixed cost.[59]

Rockets in applications other than launch to orbit (such as military rockets and rocket-assisted take off), commonly not needing comparable performance and sometimes mass-produced, are often relatively inexpensive.

See also

Lists

- Chronology of Pakistan's rocket tests
- List of rockets
- Timeline of rocket and missile technology
- Timeline of spaceflight

General Rocketry

- Astrodynamics—the study of spaceflight trajectories
- Gantry
- Pendulum rocket fallacy—an instability of rockets
- Rocket garden—a place for viewing unlaunched rockets
- Rocket launch
- Rocket launch site
- Variable-mass system—the form of Newton's second law used for describing rocket motion

Propulsion and Propellant

- Ammonium Perchlorate Composite Propellant—Most common solid rocket propellant
- Bipropellant rocket—two-part liquid or gaseous fuelled rocket
- Hot Water rocket—powered by boiling water
- Pulsed Rocket Motors—solid rocket that burns in segments
- Spacecraft propulsion—describes many different propulsion systems for spacecraft
- Tripropellant rocket—variable propellant mixes can improve performance

Recreational Rockets

- High-powered rocket
- National Association of Rocketry
- Tripoli Rocketry Association

Recreational Pyrotechnic Rocketry

- Bottle rocket—small firework type rocket often launched from bottles
- Skyrocket—fireworks that typically explode at apogee

Weaponry

- Air-to-ground rockets
- Fire Arrow—one of the earliest types of rocket
- Katyusha rocket launcher—rack mounted rocket
- Rocket-propelled grenade—military use of rockets
- Shin Ki Chon—Korean variation of the Chinese fire arrow
- VA-111 Shkval—Russian rocket-propelled supercavitation torpedo

Rockets for Research

- Rocket plane—winged aircraft powered by rockets
- Rocket sled—used for high speeds along ground
- Sounding rocket—suborbital rocket used for atmospheric and other research

Misc

- Aircraft

- Equivalence principle—Einstein was able to show that the effects of gravity were completely equivalent to a rocket's acceleration in any small region of space
- Rocket Festival—Tradition bamboo rockets of Laos and Northeastern Thailand
- Rocket mail—the delivery of mail by rocket or missile.

Notes

1. English *rocket*, first attested in 1566 (OED), adopted from the Italian term, given due to the similarity in shape to the bobbin or spool used to hold the thread to be fed to a spinning wheel. The modern Italian term is *razzo*.
2. The confusion is illustrated in http://science.howstuffworks.com/rocket.htm; “If you have ever seen a big fire hose spraying water, you may have noticed that it takes a lot of strength to hold the hose (sometimes you will see two or three firefighters holding the hose). The hose is acting like a rocket engine. The hose is throwing water in one direction, and the firefighters are using their strength and weight to counteract the reaction. If they were to let go of the hose, it would thrash around with tremendous force. If the firefighters were all standing on skateboards, the hose would propel them backward at great speed!”
3. “thrust-to-weight ratio F/W_g is a dimensionless parameter that is identical to the acceleration of the rocket propulsion system (expressed in multiples of g_0) ... in a gravity-free vacuum”[2]:442
4. The energy density is 31MJ per kg for aluminum and 143 MJ/kg for liquid hydrogen, this means that the vehicle consumes around 5 TJ of solid propellant and 15 TJ of hydrogen fuel.

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External links

Wikimedia Commons has media related to ***Rockets***.

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Governing agencies

- FAA Office of Commercial Space Transportation (http://ast.faa.gov/)
- National Aeronautics and Space Administration (NASA) (http://www.nasa.gov/)
- National Association of Rocketry (USA) (http://www.nar.org/)
- Tripoli Rocketry Association (http://www.tripoli.org/)
- Asoc. Coheteria Experimental y Modelista de Argentina (http://www.acema.com.ar/)
- United Kingdom Rocketry Association (http://www.ukra.org.uk/)
- IMR - German/Austrian/Swiss Rocketry Association (http://www.modellraketen.org/)
- Canadian Association of Rocketry (http://www.canadianrocketry.org/)
- Indian Space Research Organisation (http://www.isro.gov.in/)

Information sites

- Encyclopedia Astronautica - Rocket and Missile Alphabetical Index (http://www.astronautix.com/lvs/)
- Rocket and Space Technology (http://www.braeunig.us/space/index.htm)
- Gunter's Space Page - Complete Rocket and Missile Lists (http://space.skyrocket.de/)
- Rocketdyne Technical Articles (https://web.archive.org/web/20070521025308/http://www.pwrengineering.com/data.htm)
- Relativity Calculator - Learn Tsiolkovsky's rocket equations (https://web.archive.org/web/20080820201246/http://www.relativitycalculator.com/rocket_equations.shtml)
- Robert Goddard--America's Space Pioneer (http://sites.google.com/site/rgoddardsite)

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Rodale Press's Research and Development folks have devised a homestead-scale thresher, which has been used at the New Organic Gardening Experimental Farm to thresh crops ranging from

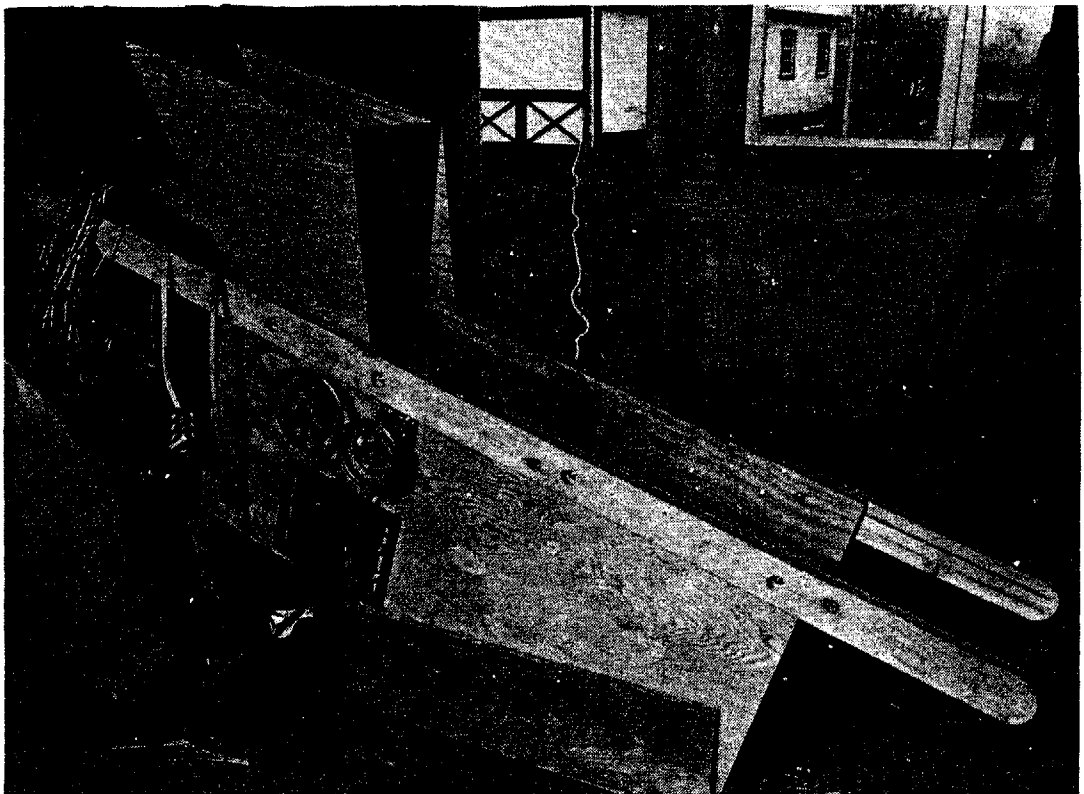

Rodale Thresher

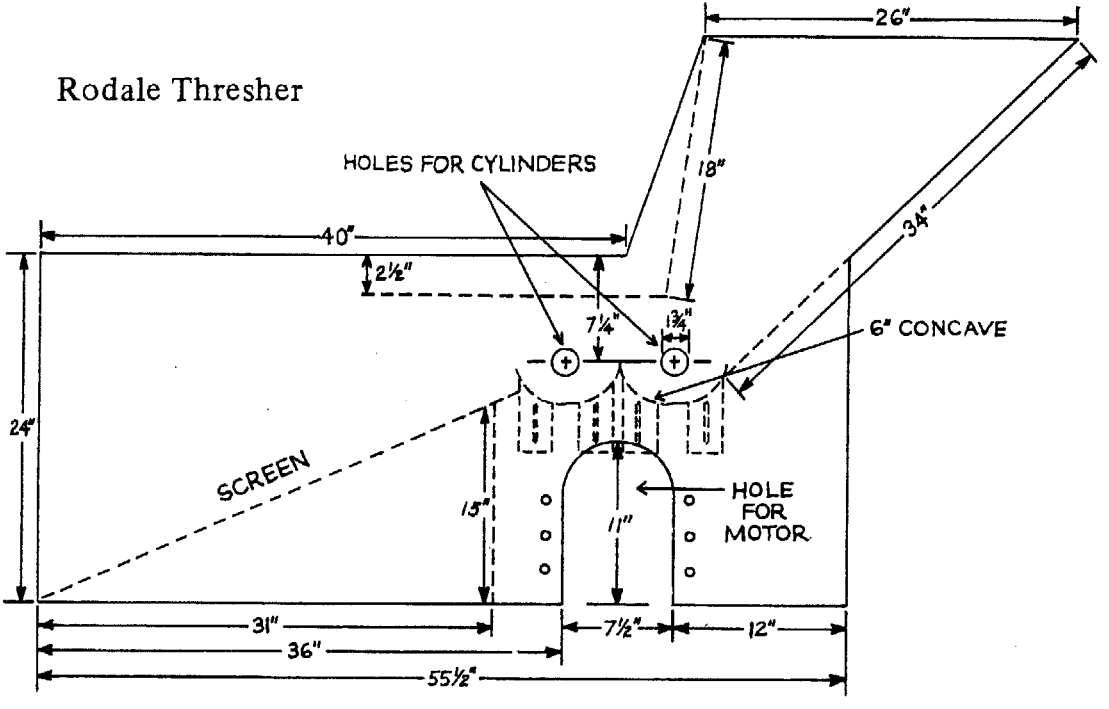

soybeans to amaranth. The machine is not fully refined, so a certain amount of hand-winnowing may be necessary. But it is an inexpensive alternative to the sophisticated and expensive seed threshers and cleaners on the market. It will separate most any cereal crop into seed and straw and can be operated by only one or two people. Different pulley sizes let you alter the threshing speed as best suits each crop.

Materials:

2–4′ × 8′ sheets of ¾″ exterior plywood	or	2 sides (see diagram) 1 pc. 12″ × 18″ 1 pc. 12″ × 34″ 1 pc. 12″ × 21″ 1 pc. 11¾″ × 5″
1′ length of 6″ steel pipe		
3/16″ steel plates		2 pc. 5 × 2½″ 1 pc. 10″ × 13″
4 pillar blocks for ¾″ shaft		
14½′ length of #130 5/16″ steel coil chain		26 sets, 3 links each, 6½″ long
2–1½′ steel shafts		
misc. #10 wood screws		
5/16″ or ⅜″ hex bolts and nuts		
1½ horsepower motor with step sheaves		

2–4″ pulleys
1–6″ pulley
1–8″ pulley

Construction: Cut all the plywood parts for the thresher body as indicated on the materials list. The sides are formed as shown, and each must have a 7½-inch-wide cutout for the motor and two 1¾-inch holes for the flail shafts. Fasten the parts together with 2-inch #10 screws.

To make the flail shafts, cut the 14½ feet of chain into 26 three-link sets. Weld the cuts shut and mount the middle chain link on the steel bars. Arrange the three-link sets so they fit snugly together at 90° angles to the link next to them. Now weld them to the shaft. Once 13 links have been fixed to each steel shaft, then secure the shafts in place with pillar blocks, bolting them to the side of the thresher.

The next job can be done with a hacksaw but if you have access to an oxyacetylene torch, use it. Divide the 1-foot-long

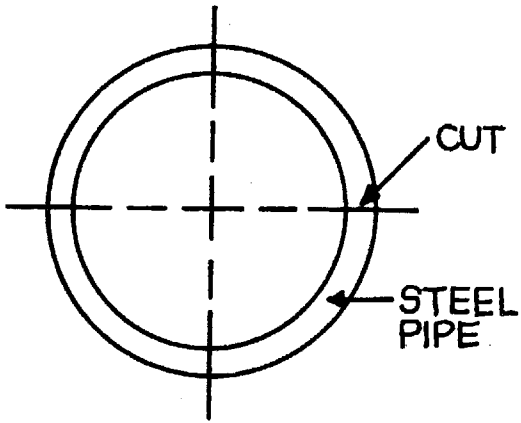
CUT
STEEL PIPE

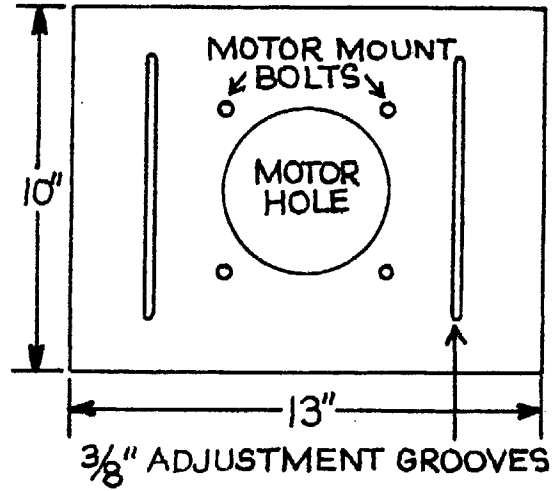
MOTOR MOUNT BOLTS
MOTOR HOLE
10"
13"
3/8" ADJUSTMENT GROOVES

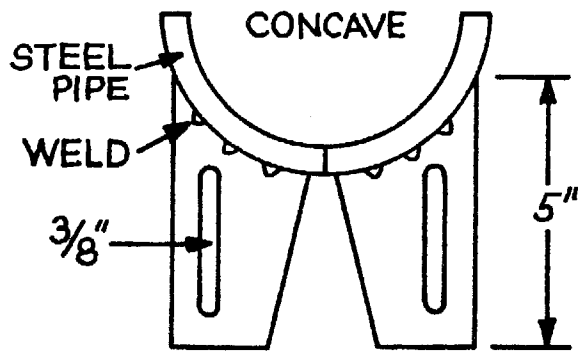
CONCAVE
STEEL PIPE
WELD
3/8"
5"

6-inch steel pipe into quarters lengthwise. Then cut supporting plates from scrap steel with grooves for a sliding adjustment, as shown. Weld the steel supports to each pipe section and mount them below the cylinders so that the spinning chain links just miss the pipe basin.

The motor mounting plate will have to be adapted to your particular motor but you can use this illustration as a guide.

You may select pulley (sheave) sizes to fit your purpose. To make ours adaptable, we used a four-inch step sheave on the motor, a six-inch step sheave on one cylinder end and an eight-inch sheave on the other cylinder end. On the side opposite the motor, install two identical pulleys of any size; we used four-inch ones. Run a V-belt around them so that the shafts turn in unison.

Attach the motor to the mounting plate with four bolts. Hoist the motor into a good central position so that any change you may want to make is only a vertical one. Now bolt the mounting plate to the side of the thresher and adjust the height according to the V-belt fitting.

Operation: You'll need a screen of appropriate size for each different grain you want to thresh. Make a frame one foot wide and anywhere from three feet to five feet long to fit in right below the second concave. Beaten grain and straw will fly from the cylinders onto the screen. The smaller, heavier grain will fall, while the straw is blown on through. You may find it a help to brush the straw against the screen to help separate the seed. Two people are better than one for this job.

We found that the thresher worked better at a slow speed for larger items, like soybeans, and at fast speeds for the small items. You can be your own judge here.

Caution! Be sure to keep your hands away from the grinding chamber. If you are allergic to dust, you may want to enclose the threshing chamber better.

Rohn Emergency Scale

From Wikipedia, the free encyclopedia

The **Rohn Emergency Scale**[1] is a scale on which the magnitude (intensity)[2] of an emergency is measured. It was first proposed in 2006, and explained in more detail in a peer-reviewed paper presented at a 2007 system sciences conference.[3] The idea was further refined later that year.[4] The need for such a scale was ratified in two later independent publications.[5][6] It is the first scale that quantifies any emergency based on a mathematical model. The scale can be tailored for use at any geographic level – city, county, state or continent. It can be used to monitor the development of an ongoing emergency event, as well as forecast the probability and nature of a potential developing emergency and in the planning and execution of a National Response Plan.

Contents

- 1 Existing emergency-related scales
- 2 Variables common to all emergencies
  - 2.1 Scope
  - 2.2 Topography
  - 2.3 Speed of change
- 3 Emergency scale mathematical model
  - 3.1 Scope
  - 3.2 Topographical change
  - 3.3 Rate of change
- 4 Simplified scale for public communications
- 5 References
- 6 External links

Existing emergency-related scales

Scales relating to natural phenomena that may result in an emergency are numerous. This section provides a review of several notable emergency related scales. They concentrate mainly on weather and environmental scales that provide a common understanding and lexicon with which to understand the level of intensity and impact of a crisis. Some scales are used before and/or during a crisis to predict the potential intensity and impact of an event and provide an understanding that is useful for preventative and recovery measures. Other scales are used for post-event classification. Most of these scales are descriptive rather than quantitative, which makes them subjective and ambiguous.

1805 Beaufort scale[7]
1931 Modified Mercalli intensity scale[8]
1935 Richter magnitude scale[9] (superseded by the Moment magnitude scale)
1969 Saffir–Simpson hurricane wind scale[10]
1971 Fujita scale[11] (superseded by Enhanced Fujita scale in 2007[12])
1982 Volcanic explosivity index
1990 International Nuclear Event Scale[13]
1999 Air quality index[14]

Variables common to all emergencies

According to the Rohn Emergency Scale, all emergencies can be described by three independent dimensions: (a) scope; (b) topographical change (or lack thereof); and (c) speed of change. The intersection of the three dimensions provides a detailed scale for defining any emergency,[1] as depicted on the Emergency Scale Website.[15]

Scope

The scope of an emergency in the Rohn scale is represented as a continuous variable with a lower limit of zero and a theoretical calculable upper limit. The Rohn Emergency Scale use two parameters that form the scope: percent of affected humans out of the entire population, and damages, or loss, as a percentile of a given Gross National Product (GNP). Where applied to a specific locality, this parameter may be represented by a Gross State Product, Gross Regional Product, or any similar measure of economic activity appropriate to the entity under emergency.

Topography

A topographical change means a measurable and noticeable change in land characteristics, in terms of elevation, slope, orientation, and land coverage. These could be either natural (e.g., trees) or artificial (e.g., houses). Non-topographical emergencies are situations where the emergency is non-physical in nature. The collapse of the New York stock market in 1929 is such an example, and the global liquidity crisis of August 2007[16] is another example. The model treats topographical change as a continuum ranging between 0 and 1 that gives the estimated visual fractional change in the environment.

Speed of change

An emergency is typified by a departure from normal state of affairs. The scale uses the change of the number of victims over time and economical losses over time to calculate a rate of change that is of utmost importance to society (e.g., life and a proxy for quality of life).

Emergency scale mathematical model

The scale is a normalized function whose variables are scope (*S*), topography (*T*), and rate of change (*D*), expressed as

$$E = Emergency = f(S, T, D).$$

These parameters are defined as follows:

Scope

$$\text{Scope} = \frac{\text{RawScope}}{\text{MaxScope}}$$

where

$$\text{RawScope} = \left(\frac{\text{Victims}}{\text{Population}} + \frac{\text{Monetary Losses}}{\text{GNP}}\right)^{W}$$

where

$$W = \left(\frac{\ln(\text{Victims})}{\ln(\text{Monetary Losses})}\right)^{\beta}$$

β is a coefficient which the model creator calculated to be 1.26 ± 0.03,
and

$$\text{MaxScope} = \left(\frac{0.7*\text{Population}}{\text{Population}} + \frac{0.5*\text{GNP}}{\text{GNP}}\right)^V,$$

where

$$V = \frac{\ln(\text{Victims})}{\ln(\text{Monetary Losses})}$$

The model loosely assumes that a society whose majority of the population (70% in this model) is affected and half of its GNP is drained as a result of a calamity reaches a breaking point of disintegration. Sociologists and economists may come up with a better estimate.

Topographical change

$$\frac{\text{Volume before the event}}{\text{Volume after the event}}$$ or zero for non-topographical events.

Rate of change

$$\frac{d(\text{Victims})}{d(\text{Time})} \text{ and } \frac{d(\text{Losses})}{d(\text{Time})}$$

comprise the rate of change that is of utmost importance to society and therefore incorporated in the model.

Simplified scale for public communications

In some instances, it may be preferable to have an integral scale to more simply and dramatically convey the extent of an emergency, with a range, say, from 1 to 10, and 10 representing the direst emergency. This can be obtained from the function above in any number of ways. One of them is the ceiling function. Another one is a single number representing the volume under the 3D emergency scale.

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External links

- "Large-Scale Disasters as Dynamical Systems". ASME. (provides an alternative measure of general disaster scaling)

Look up ***disaster*** in Wiktionary, the free dictionary.

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Roller-compacted concrete

From Wikipedia, the free encyclopedia

Roller-compacted concrete (**RCC**) or **rolled concrete** is a special blend of concrete that has essentially the same ingredients as conventional concrete but in different ratios, and increasingly with partial substitution of fly ash for Portland cement.[2] RCC is a mix of cement/fly ash, water, sand, aggregate and common additives, but contains much less water. The produced mix is drier and essentially has no slump. RCC is placed in a manner similar to paving; the material is delivered by dump trucks or conveyors, spread by small bulldozers or specially modified asphalt pavers, and then compacted by vibratory rollers.

The rebuilt upper reservoir of the Taum Sauk plant, nearing completion in this photo, is the largest RCC dam in North America.[1]

In dam construction, roller-compacted concrete began its initial development with the construction of the Alpe Gera Dam near Sondrio in North Italy between 1961 and 1964. Concrete was laid in a similar form and method but not rolled.[3][4][5] RCC had been touted in engineering journals during the 1970s as a revolutionary material suitable for, among other things, dam construction.[6] Initially and generally, RCC was used for backfill, sub-base and concrete pavement construction, but increasingly it has been used to build concrete gravity dams because the low cement content and use of fly ash cause less heat to be generated while curing than do conventional mass concrete placements. Roller-compacted concrete has many time and cost benefits over conventional mass concrete dams; these include higher rates of concrete placement, lower material costs and lower costs associated with post-cooling and formwork.

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Dam applications

For dam applications, RCC sections are built lift-by-lift in successive horizontal layers resulting in a downstream slope that resembles a concrete staircase. Once a layer is placed, it can immediately support the earth-moving equipment to place the next layer. After RCC is deposited on the lift surface, small dozers typically spread it in one-foot-thick (300mm) layers.[7]

Willow Creek Dam, RCC gravity dam, Oregon, USA

The first RCC dam built in the USA was the Willow Creek Dam on Willow Creek, a tributary in Oregon of the Columbia River. It was constructed by the Army Corps of Engineers between November 1981[8] and February 1983.[6] Construction proceeded well, within a fast schedule and under budget (estimated $50 million, actual $35 million). On initial filling though, it was found that the leakage between the compacted layers within the dam body was unusually high. This condition was treated by traditional remedial grouting at a further cost of $2 million, which initially reduced the leakage by nearly 75%; over the years, seepage has since decreased to less than 10% of its initial flow. Concern over the dam's long-term safety has continued however, although only indirectly related to its RCC construction. Within a few years of construction, problems were noted with stratification of the reservoir water, caused by upstream pollution and anoxic decomposition, which produced hydrogen sulfide gas. Concerns were expressed that this could in turn give rise to sulfuric acid, and thus accelerate damage to the concrete. The controversy itself, as well as its handling, continued for some years. In 2004 an aeration plant was installed to address the root cause in the reservoir, as had been suggested 18 years earlier.[6]

In the quarter century since Willow Creek, considerable research and experimentation have yielded innumerable improvements in concrete mix designs, dam designs and construction methods for roller-compacted concrete dams; by 2008, about 350 RCC dams existed world-wide.[9] Currently the highest dam of this type is the Chinese Longtan Dam, at 216 m, with the Pakistani Diamer-Bhasha Dam under construction at 272 m.

See also

- A list of roller-compacted concrete dams
- Asphalt concrete

Further reading

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External links

- History of Concrete (http://inventors.about.com/library/inventors/blconcrete.htm)
- Database of Worldwide Roller Compacted Concrete Dams (http://rccdams.co.uk/database_search.php)

Wikimedia Commons has media related to ***Concrete***.

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Rolling hitch

From Wikipedia, the free encyclopedia

The **rolling hitch** is a knot (see also Magnus hitch) used to attach a rope to a rod, pole, or another rope. A simple friction hitch, it is used for lengthwise pull along an object rather than at right angles. The rolling hitch is designed to resist lengthwise movement for only a single direction of pull.[1]

A common usage while sailing is for rigging a stopper to relax the tension on a sheet so that a jammed winch or block can be cleared.

Rolling hitch

Names	Rolling hitch, Magnus hitch
Category	Hitch
Related	Taut-line hitch, Icicle hitch, Jamming knot
Typical use	Sailing
ABoK	#503, #1190, #1465, **#1681**, **#1734**, **#1735**, **#1736**, #1791, #2555

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- 2 Tying
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  - 2.2 Rolling Hitch(2) #1735
  - 2.3 Magnus Hitch #1736
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Naming

At the turn of the 19th century the knot now known as the "rolling hitch" was called the "Magnus hitch" or "Magner's hitch", and the name "rolling hitch" referred to two round turns and two half-hitches.[2] In 1841 Richard Henry Dana, Jr. used the present-day names in his work *The Seaman's Friend*, and subsequent authors have continued to use this terminology.[1][3]

Names and reference numbers from ABOK, left to right: "Rolling Hitch (1)" (#1734), "Rolling Hitch (2)" (#1735), "Magnus Hitch" (#1736)

There are two slightly different hitches commonly known by the name of "rolling hitch". *The Ashley Book of Knots* identifies these two variations as "Rolling Hitch(1)" and "Rolling Hitch(2)" and numbers them #1734 and #1735 respectively. Despite the potential for confusion with the older usage, Ashley chose the name "Magnus Hitch" to refer to knot #1736, which is simply #1734 tied with the final hitch made in the opposite direction.[4] Since two distinct variations of the rolling hitch are widely referred to by the same name, and Magnus hitch now may refer to a different knot than it used to, the use of Ashley reference numbers for these related hitches can eliminate ambiguity when required. These hitches are pictured at the right.

When a rolling hitch or Magnus hitch is tied around the standing part of the rope to form an adjustable loop, it is often referred to as a taut-line hitch or one of several other names, although some sources fail to differentiate by using a separate name.

Tying

Rolling Hitch(1) #1734

This version is preferred when **attaching a rope to pole or rod.**[4][5] It is effectively a clove hitch with an extra initial turn.

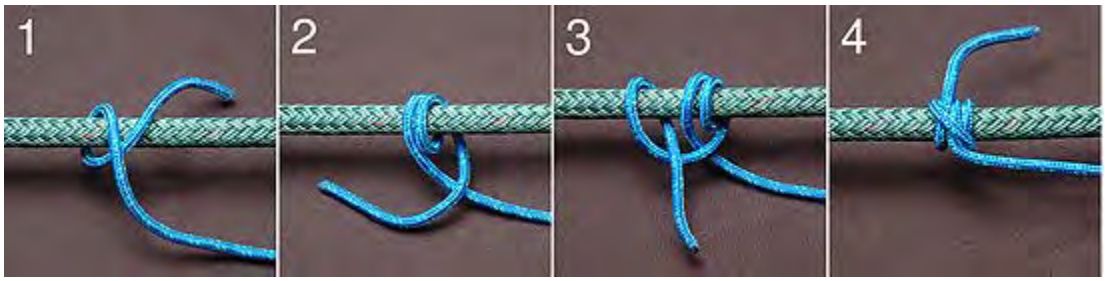

1. Start with a turn around the object. Bring the working end towards the direction of pull and between the standing part and the object.
2. Make another wrap around the object, completing a round turn. The wraps of the round turn should progress towards the desired direction of pull. Bring the working end out over the standing part away from the direction of pull.
3. Complete with a half hitch, moving around the object in the same direction as the first turns, as for a clove hitch.
4. Dress by snugging the hitch around the object before applying load.

Rolling Hitch(2) #1735

This version is preferred when **attaching rope to another rope.**[4][5] The first two turns create an **awning hitch** − a temporary hitch used by riggers when adjusting tent lines.[6] These first two turns are merely a subtle rearrangement in the position of the turns of #1734.

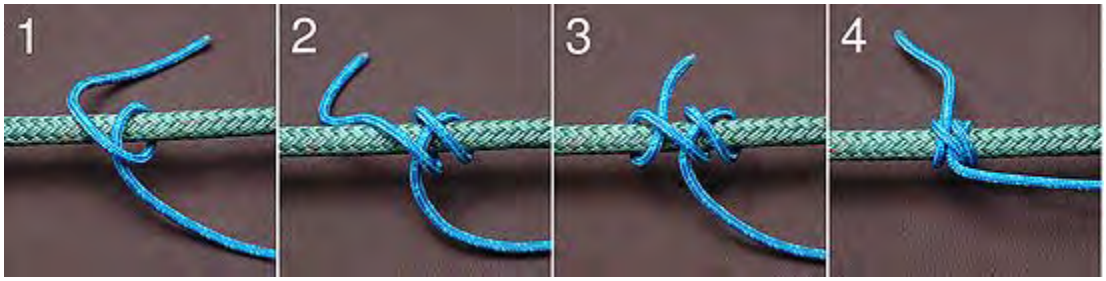

1. Begin by making a turn around the object, bringing the working end back between the object and the standing part. Cross over the standing part away from the desired direction of pull.
2. Make a second turn that exactly follows the first, and hence also passes between the object and standing part and then crosses over the standing part, away from the direction of pull. *Make sure the second turn "tucks" between the first turn and the standing part; that is what gives this version extra grip when made around another rope.*[7]
3. Finish with a half hitch, moving around the object in the same direction as the first turns, as for a clove hitch.
4. Dress by snugging the hitch around the object before applying load.

Magnus Hitch #1736

This is tied exactly as #1734, but with the final hitch in the opposite direction. It can be more tricky to snug-up, since both lines emerge from the same side of the hitch, but it has less tendency to twist under load.

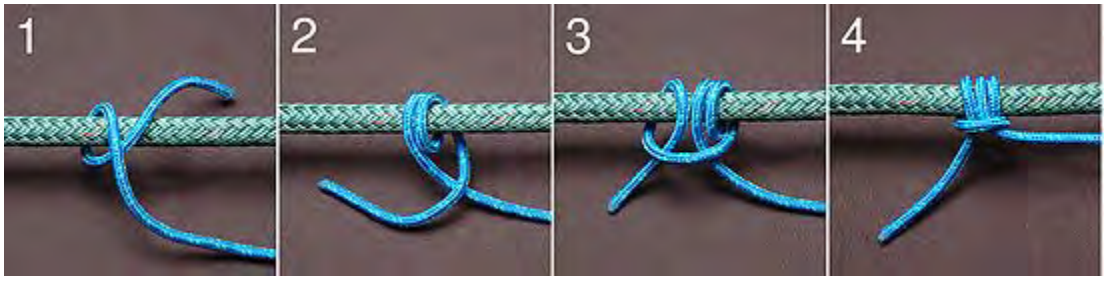

1. Start with a turn around the object. Bring the working end towards the direction of pull and between the standing part and the object.
2. Make another wrap around the object, completing a round turn. The wraps of the round turn should progress towards the desired direction of

pull. Bring the working end out over the standing part away from the direction of pull.
3. Complete with a half hitch, moving around the object in the *opposite* direction as the first turns, as for a cow hitch.
4. Dress by snugging the hitch around the object before applying load.

Security

If the hitch is not made very snug before applying any strain, it will not tighten further under load. When hitching to another rope, Ashley[4] and other sources[7][8] suggest #1735 is more secure. Ashley also states that #1736 has less tendency to twist.[6]

Though effective for moderate loads, the rolling hitch cannot be depended on to hold fast under all conditions. Using stiff and slippery modern fiber ropes, the rolling hitch may be difficult to make hold at all. Friction hitches with additional wraps and more complex structure may provide more security.

The August 2009 edition of *Practical Sailor* magazine tested various knots used for lengthwise tension applications, and came to the conclusion that when using modern synthetic rope the rolling hitch could not be regarded as secure. They recommended the Icicle hitch as a replacement.[9]

See also

- Taut-line hitch: Closely related adjustable hitch
- Adjustable grip hitch: Another related hitch
- Midshipman's hitch: Secure taut-line hitch
- Icicle hitch: More complex and effective friction hitch
- *The Ashley Book of Knots*: Knot reference work
- List of friction hitch knots

References

1. Clifford W. Ashley, *The Ashley Book of Knots* (New York: Doubleday, 1944), 292.
2. Lever, Darcy (1998) [1819], *The Young Sea Officer's Sheet Anchor* (2nd ed.), Mineola, NY: Dover Publications, p. 8, ISBN 978-0-486-40220-8
3. Richard Henry Dana, Jr., *The Seaman's Friend: A Treatise on Practical Seamanship, 14th Edition* (Boston: Thomas Groom & Co., 1879; Dover Republication 1997), 49.
4. Ashley, 298.
5. Nola Trower, *Helmsman Guides: Knots and Ropework* (Wiltshire: Helmsman Books, 1995), 31-32.
6. Ashley, 304.
7. Grog. "Rolling Hitch". *Animated Knots*. Retrieved May 5, 2013.
8. Brion Toss, *Chapman's Nautical Guides: Knots* (New York: Hearst Marine Books, 1990), 30-32.
9. "Practical Sailor Aug 2009 (subscription required)". *www.practicalsailor.com*.

External links

- Grog. "Rolling Hitch". *Animated Knots*. Retrieved April 2013. Check date values in: `|access-date=` (help)

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Categories: Hitch knots

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Life as an Apprentice in a Suction-Gas Fuelled Power House, at Roma (Queensland, Australia) c. 1950.

J.W. Watson

1. The Vision

Looking back more than half a century, I can see the skinny 13 year old boy who was myself, stopping as usual on his way home from school He is standing astride his Malvern Star bicycle gazing through the big open green doors of the old Roma Power House in Mayne Street, Roma.

He is enthralled as always by the sight of the steadily spinning shiny flywheels taller then himself, he mentally notes which engines are running, watches the open commutators occasionally softly sparking under their rows and columns of carbon brushes, sees the salient pole alternators with their smooth slip-rings. He sees the brass and nickel and glass and shiny black zelamite of the exposed switchboards with their overhead copper bus-bars softly gleaming through the light misty haze. He hears and feels the rhythmic throbbing of the engines and the occasional discordant CLANG as someone inside drops something or steps on an ill-fitting steel chequer plate covering a floor duct. A magical place! He will work there one day!

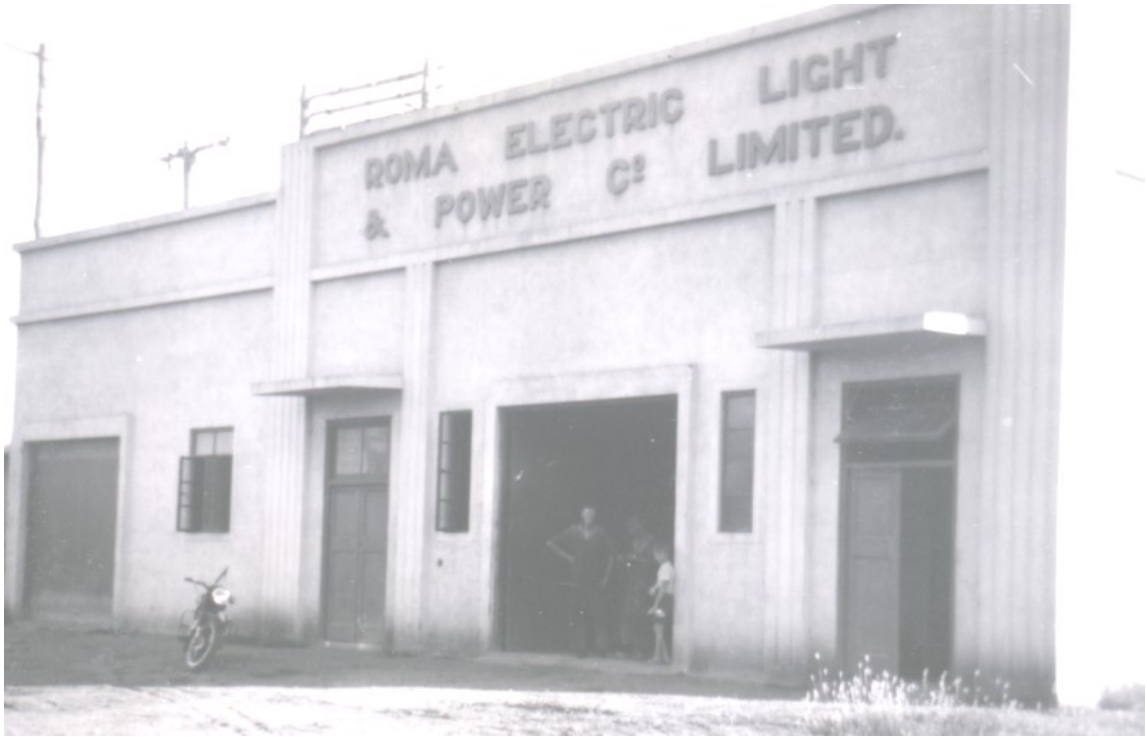

Photo 1. Roma Power House
(Author's new 1949 Velocette Motorcycle visible)

5. The Machines

In the 1950's, the plant at the Roma Power House (since demolished) at Mayne Street consisted of four suction-gas engines of some 150 to 200 HP each, and three Commonwealth 200 HP wood-burning down-draught suction-gas producer sets, about which there will be more later. I regret now that I have no record of the model or serial numbers of all of the engines, although I do have some crumpled Kodak 6/20 Box Brownie photographs.

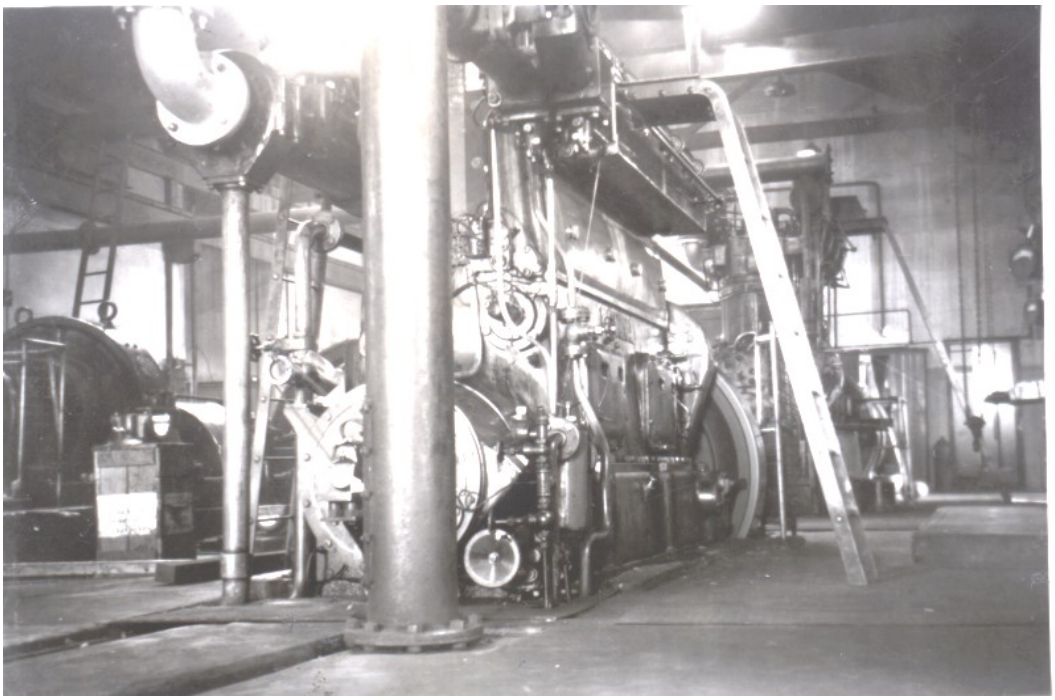

Photo 6. No.1 National Engine
The large vertical pipe in the foreground is the gas inlet

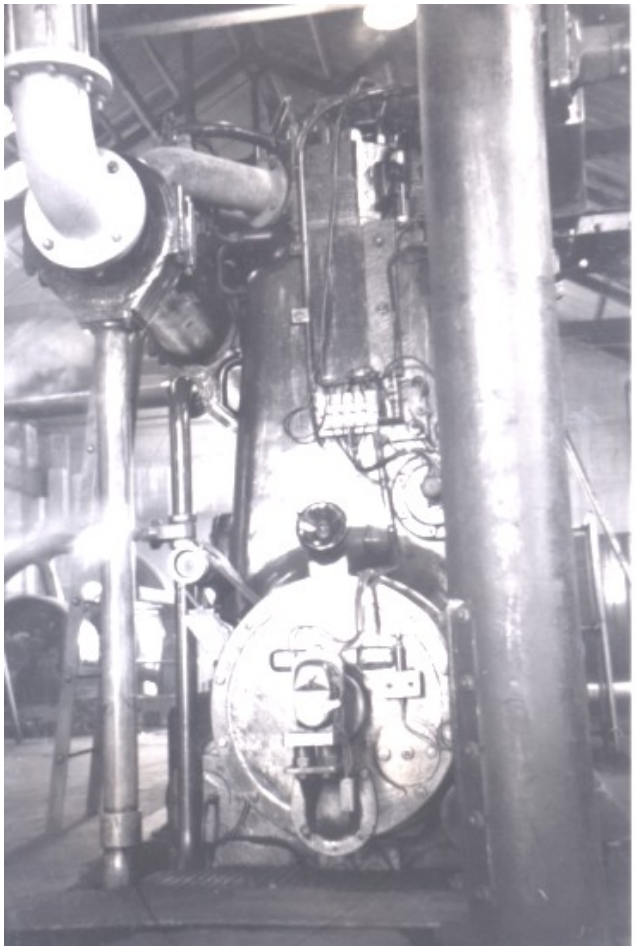

Photo 7. No.1 National Engine
Dual ignition system visible
Note a vague picture of Crossley No. 3 rear left

No.1 engine was a vertical four-cylinder National Gas engine Model FA2 (The "2" meaning two valves per cylinder) driving a "Lancashire" 240 volt DC generator at 428 rpm. She had a steel ladder on each side to gain access to the upper level. A quiet, clean and reliable engine, she was subject to violent pre-ignition when she didn't like the quality of the gas she was fed. She had dual ignition; a small open 4-bladed knife switch could select either the Scintilla magneto or the car-type battery/coil ignition system. The drivers somehow learnt that she liked to have the knife switch blades slightly open; the resulting 1/8" gap seemed to intensify the spark at the plugs. She had an external "Streamline" oil filter. Her exhaust note had a distinctive "ringing" tone, especially after her valves were freshly ground. After the town was fully converted to AC, she was re-equipped with an alternator and her speed re-adjusted to 375 rpm, (50 Hertz) but she was never the engine she had been at her design speed of 428.

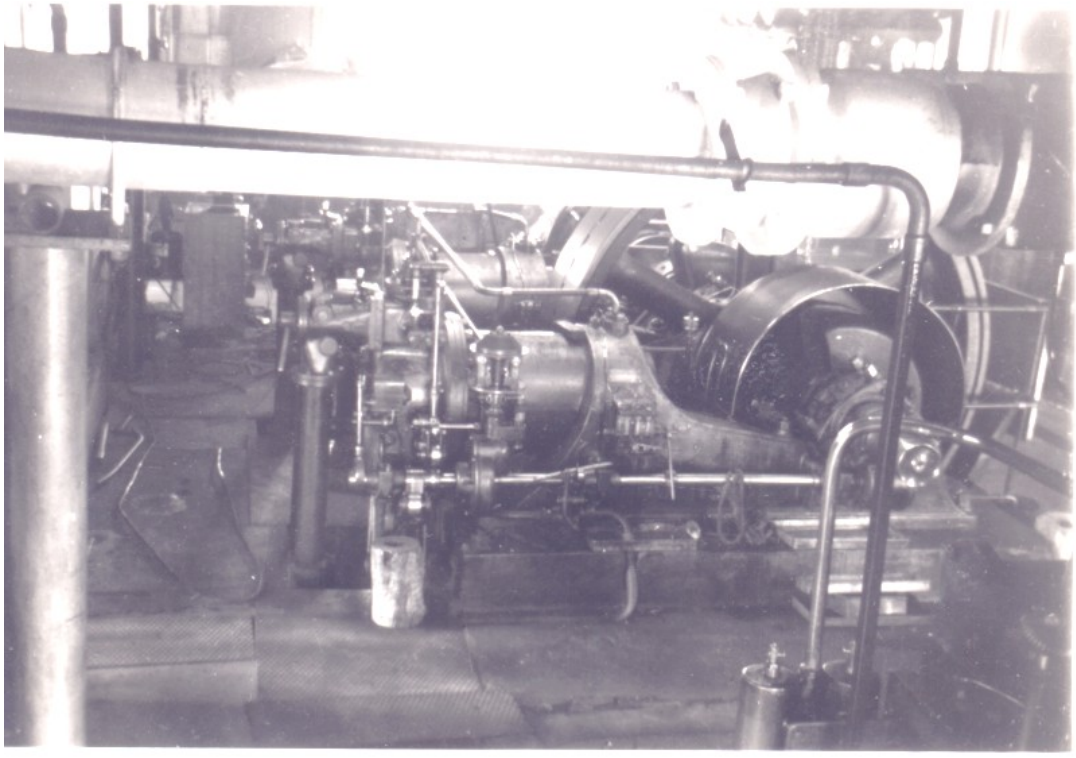

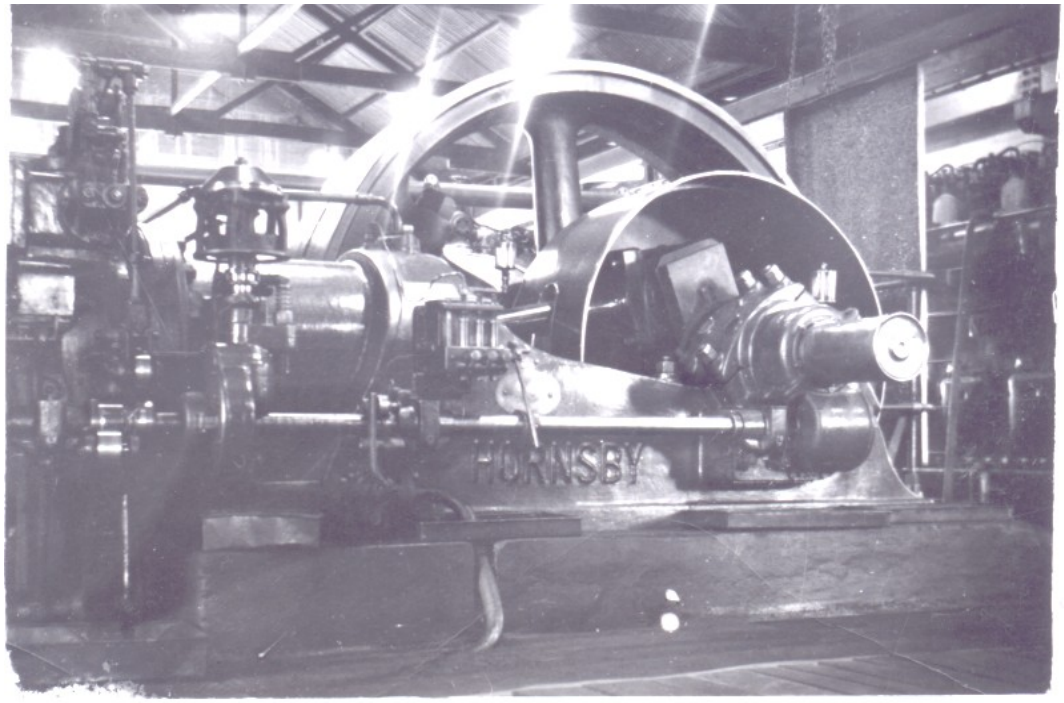

Photo 8. Two Views of No. 2 Hornsby Engine

No.2 engine was a majestic twin cylinder horizontal open-crank side-shaft Hornsby driving a handsome open 240 volt DC generator at 220 rpm, and was notable for an enormous flywheel between the cylinders. Each cylinder was in fact, practically a separate engine in its own right, sharing only the governor and the mechanical lubricator, thus being called a “Coupled Engine”.

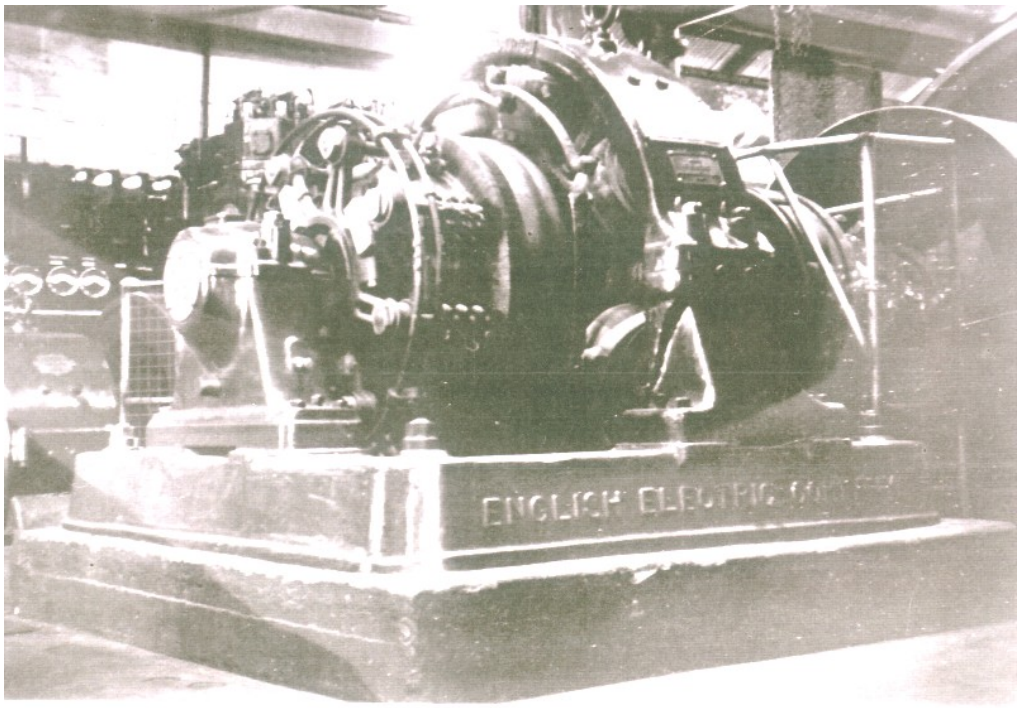

Photo 9. No.2 Engine's DC Generator

She and her "English Electric Dynamo" were beautifully painted dark green with rich gold transfers and ornate lining. She had low-tension trip-magnetos with a moving electrode on the ignitors.

I remember her as a reliable and favourite engine which once ran for 10 months continuously during a period of difficulty with other plant, No.2 was particularly prone to "reversing" if she lost power, more about which will be mentioned later. Her powerful steady "chuff chuff" exhaust note could be heard over a wide area, and those standing nearby could feel the concussion in their chest cavities. Loved by some of us, feared by others, but respected by all. Sadly, she was later to be blown up with dynamite and sold for scrap.

No. 3 engine (of which I have no clear picture) was a Crossley twin cylinder open crank engine driving a 240 volt DC generator, generally similar to No. 2, but on a smaller scale. Considered by the drivers to be a bit of a prima donna, pretty in appearance but with a nervous disposition and demanding attention to get the best out of her. She broke a crankshaft, perhaps due to a generator "reversal", and was out of commission for a long time. She was eventually repaired, but was too small to be of much use. Her DC generator was later removed and mounted alongside the No.5 engine, belt-driven from it in addition to its own shaft-coupled AC alternator. No. 3 was later demolished to make way for a larger engine.

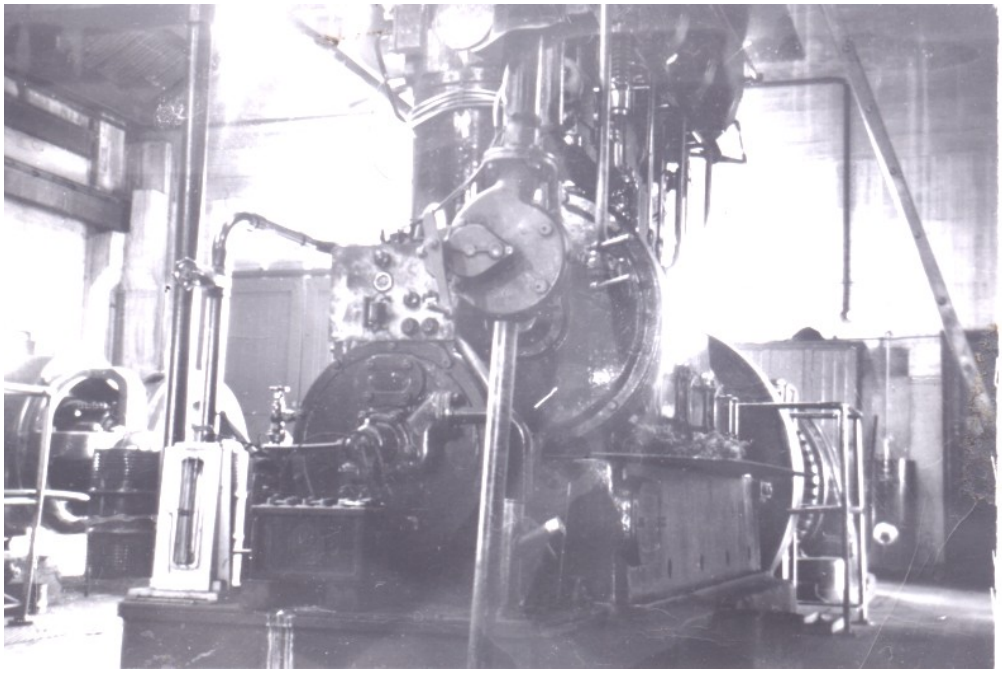

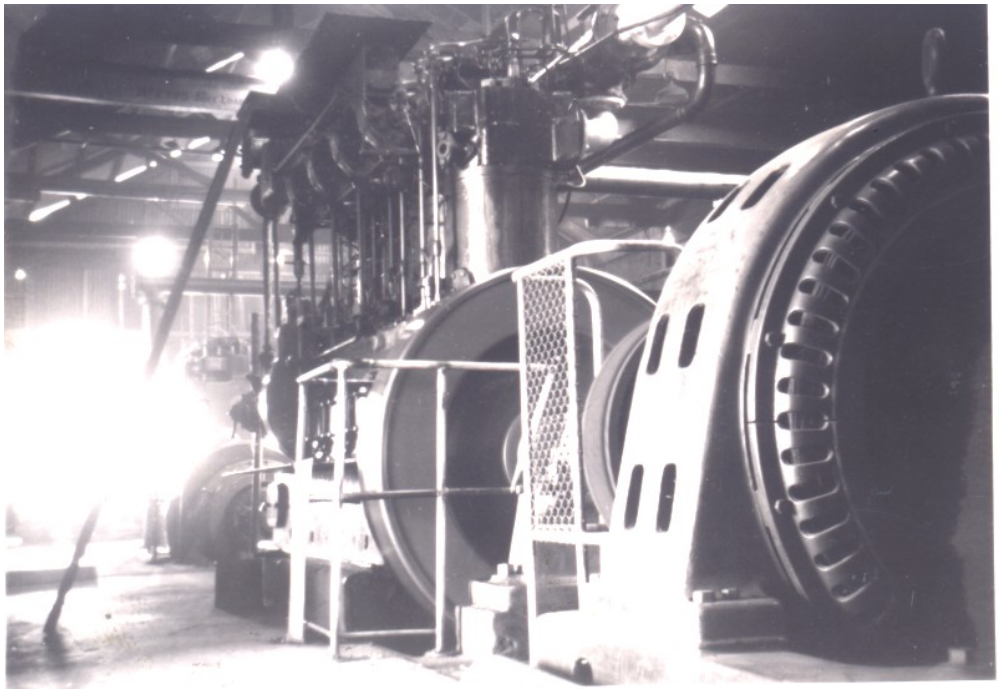

Photo 10. Two Views of No. 4 National Engine

No. 4 engine was a large four cylinder vertical National engine Model 13 x 14, (denoting bore x stroke), driving a 3-phase 240/415 volt AC alternator at 375 rpm. I understood that it was purchased second-hand from a butter factory in Armadale (NSW).

It was a temperamental engine unpopular with the drivers. He (never “she” for some reason) had twin high-tension BTH magnetos and two spark plugs the size of beer bottles per cylinder. A steel ladder gave access to two chequer-plate decks mid-way and at the top of the engine. None shed any tears when he was eventually demolished.

There was some suggestion later that the intake manifold had been incorrectly assembled upside-down when the engine was installed at Roma, resulting in a larger passage for the gas than for the air, but I cannot vouch for this.

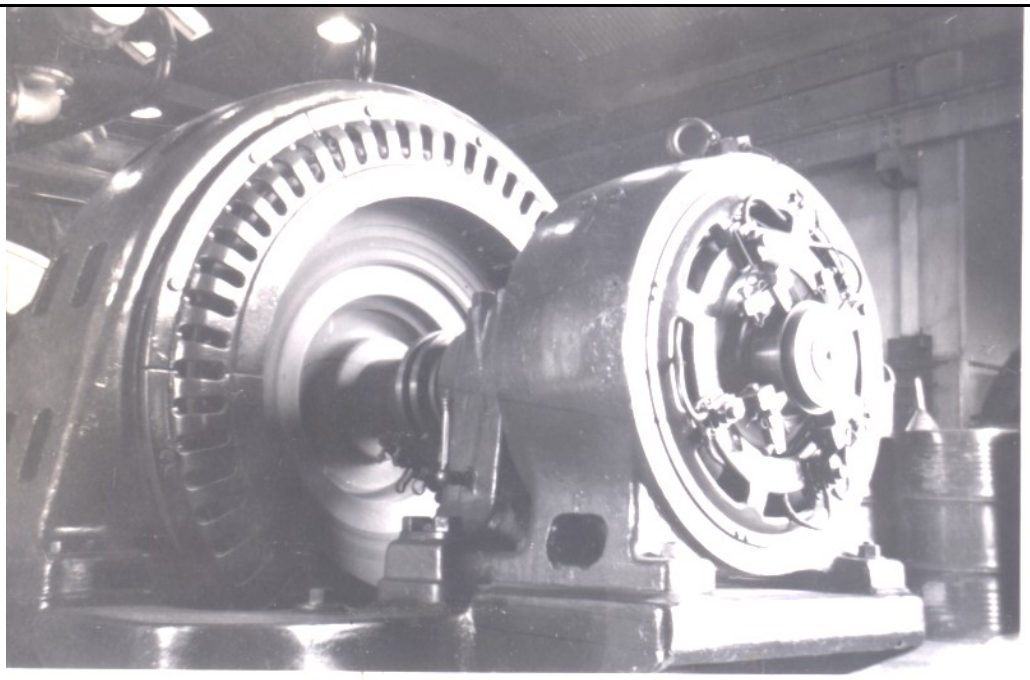

Photo 11. No. 4's Alternator

Then there was the "M.A." (motor/alternator), a 240 volt DC motor/generator set of about 100 HP, driving a similarly sized 3-phase 240/415 volt "Weymouth" AC alternator/synchronous motor via a set of ten "A" code vee-belts. The MA set was installed originally to provide the first AC supply in Roma, for the new hospital when it was built in about 1946. With the steady growth of the AC load, the next engine (No. 4) was later installed. The MA could provide either AC or CD as required from the alternate supply, whichever side had spare capacity at the time.

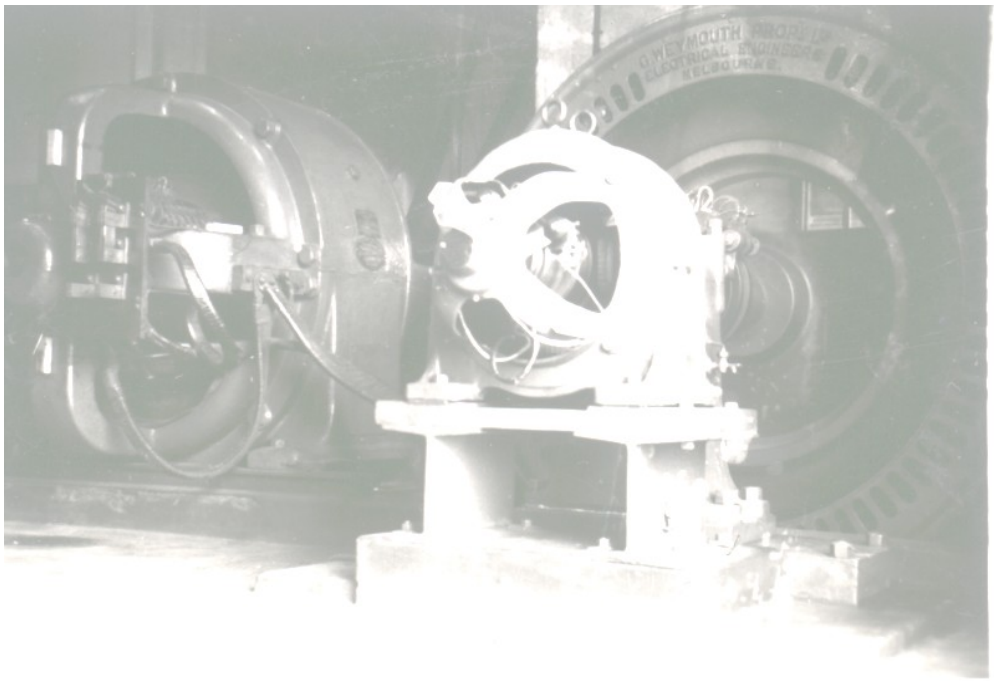

Photo 12. Motor Alternator ("MA") Set

6. Ancillary Plant

There was quite a lot of ancillary plant for the engine cooling systems and producer scrubber water circulation, fuel supply, lubrication oil reclamation, compressed air starting systems and so on. We had our own sub-artesian water bore pumped up by compressed air.

7. The Gas Producers

Three down-draught suction-gas producers, or gas generators, fed the four engines through a common header pipe. Fuel for the producers was sawn "Ironbark" hardwood (*Eucalyptus paniculata drepanphylla)* blocks. To supply the wood fuel, a small sawmill was operated on-site by contractors. The sawn blocks were loaded onto steel skips (wagons) running on 24 inch gauge rail tracks. Each skip was loaded to 15cwt. (3/4 ton or 1,680 lbs.) Each block would have been about 18 inches in diameter and 18 inches long, and each weighed some 80 lb. when dry. There would have been on average about 20 blocks per skip.

The skips were hand pushed to the back of the powerhouse (over a weighbridge) by contractors each weekday and left adjacent to the turntable for the use of the night shift engine drivers. Firing was done by the power house labourer during the day shifts on weekdays, and by the engine driver and/or an apprentice on night shifts and weekends. Apprentices worked with the drivers on day and afternoon shifts six days per week.

8. Producer Gas

In small generating stations where the capital cost of steam turbines is prohibitive, diesel generators are now generally used. Because power houses for small towns are, at the best, marginally profitable, the capital cost and the cost of fuel must be kept low. In those days, much of the transporting of diesel fuel was by means of 44 gallon drums, which added to the handling cost. One solution widely used in Australia in the early to mid twentieth century to avoid the cost of diesel fuel was to install gas-fuelled internal combustion engine generators.

Note: The use of the term "gas" in this article refers to Producer Gas, not to gasoline.

Suitable gases include natural gas or the manufactured gases – these could include town gas (obtained by heating coke), gas produced as a by-product of blast furnaces, water-gas (or blue gas) obtained from the action of steam on hot coke, coal gasification from the action of air and steam on pulverized coal and carburetted gas obtained from cracking or enriching oils.

Another alternative is gas generated by various types of simple gas producer adjacent to the engine. Some of these burnt coal, charcoal, wood or even combustible waste such as sawdust, wood-chips or "begasse", the waste fibre from sugar mills. Hardwood was preferable to the softer pines or fibrous material which burnt too quickly. These gas plants are similar in principle and action to the charcoal burning producers widely fitted to motor cars, trucks and tractors during WW2 in Australia and Europe.

When firewood was readily available in the district, many power houses installed wood-burning suction-gas producers. In later years when the supply of suitable wood diminished or its use became a concern, these plants fell into disuse and were replaced by diesel generators, and more recently by gas turbines fuelled by diesel or natural gas, when this became widely available.

In the Roma power house, wood-fired suction-gas producers were used from its inception in 1916 until the 1960's.

9. Constituents of Producer Gas

Wood fired producer gas typically consists of:

Combustible gas:

CO (Carbon Monoxide)	22.0%
CH_4 (Methane)	2.4%
H_2 (Hydrogen)	8.0%

Inert gas:

CO_2 (Carbon Dioxide)	6.6%
N_2 (Nitrogen)	61%

Plus small amounts of impurities - sulphur, ash, moisture, etc.

(Ref. "Standard Handbook for Mechanical Engineers" Baumeister & Marks 1967)

Photo 13. Gas Producer Shed at Roma

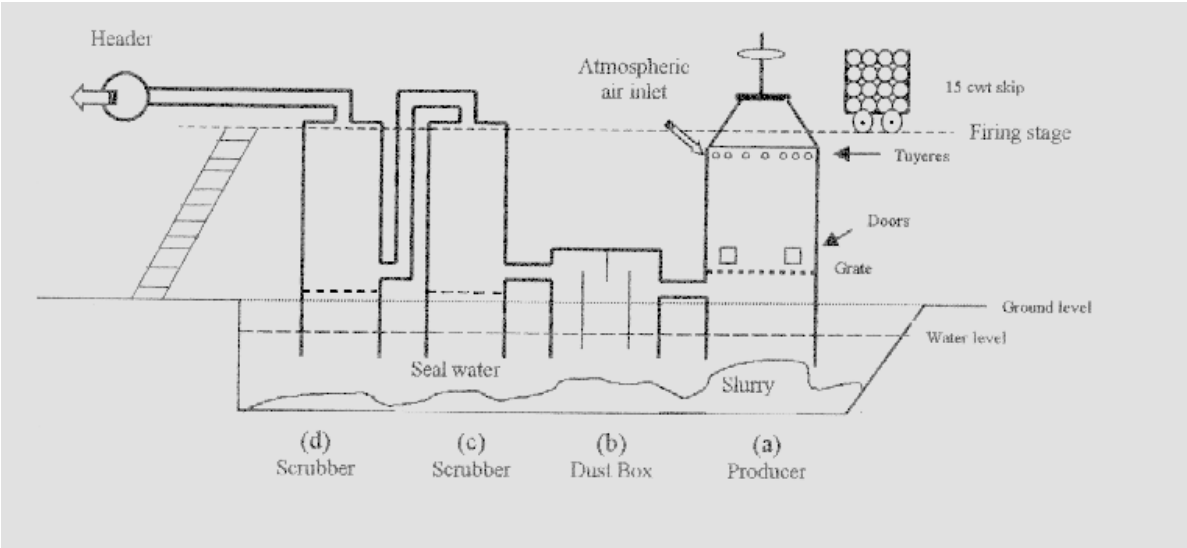

Drawing 10.1 Gas Producer

10. Gas Producer Construction

Referring to Drawing 10.1, each gas producer set consisted of (a) the producer, (b) the dust box and (c) and (d), the scrubbers, all mounted above (straddling) a water "seal" pit. A firing stage was constructed above, where a set of 24 inch gauge tracks ran along the line of producers. A typical producer was a vertical steel cylinder lined with firebrick, about 6 feet in diameter and 15 feet high with a conical top of a further 3 feet high tapering in to an opening of some 30 inches in diameter.

A cast iron cover sat on top fitted with a handwheel and a swivelling bracket allowing the lid to be raised a little and swung aside for charging with firewood. The producer had a grate about 3 feet above ground level.

Just above the grate were four steel doors arranged 90° around the circumference, to allow periodic raking of the grate to clear the ash and clinker, if any. Fine ash normally fell through the grate into the seal pit, but quite a lot hung up on the grate, especially if any clinker were present.

The bottoms of the producer below the grate, the dust-box and the scrubbers, consisted of open skirts projecting down below the water level of the "seal". The seal provided a safety valve in case of a "blow", or internal explosion. Ash fell through the grate into the seal and formed a slurry which had to be shovelled out regularly. This was a daily duty of the power house labourer. When the engines were working hard, the seal water would sometimes rock rhythmically due to the suction pulsations.

11. Producer Operation

Again referring to the Drawing 10.1, atmospheric air entered the producer through a series of radial holes of some 1.5 inches in diameter about half way up, usually fitted with venturi-like “tuyere” tubes or nozzles (pronounced “tweeair”).

The producer was started by lighting it from kindling on the grate and progressively adding larger pieces through the top until filled. The lids and doors were left open until the fire burnt well, often overnight. During this period dense clouds of smoke were produced, to the justifiable annoyance of neighbours downwind, as the power house was in a residential area. Once the doors were closed and the producer on line, there was no smoke or fumes emitted except when being fired (recharged with wood fuel) every two hours or so, as the interior of the producer operated slightly below atmospheric pressure, hence the name “suction gas”.

Simply stated, the contents of an operating producer is in the form of a bed of incandescent burning material sitting on the grate and extending perhaps half way up the producer, and above this right to the top lay the progressively less consumed fuel zones where physical and chemical changes occur, up to fresh wood at the top.

In operation, the engines drew atmospheric air in through the tuyeres. This then passed down through the zones to the firebed where the available oxygen was consumed, leaving “producer gas”, produced by the heat of the partially consumed fuel. There being insufficient atmospheric air (i.e., oxygen) for the complete burning of the fuel, the oxygen-starved environment resulted in unconsumed gas, (mixture of combustible and inert) which passed down through the grate.

The very hot gas then exited the producer horizontally between the grate and the water seal via an open bottomed steel dust-box, which contained baffles. The gas then passed upward through the two scrubbers in turn. These consisted of steel cylinders some 5 feet in diameter and 15 feet high, containing a variety of filtering material, typically blocks of firewood, coke or even rocks and perhaps wood-wool at the tops. Water was sprayed down through the scrubbers to cool and wash the gas. This water then drained into the seals which constantly overflowed to an underground tank from where recirculating pumps returned it to the scrubbers through cooling towers. The “clean” and cool gas now passed to the header pipe, running horizontally the length of the powerhouse, to which each engine has its gas intake pipe fitted. Annually the scrubbers were opened up and the filter material cleaned or renewed. This was a dirty and unpopular job.

There was no provision for the storage of gas – the rate of gas generation was determined by the demand of the engines at the time and it was consumed almost immediately.

12. Firing up

Every two hours, the producers had to be fired up. This operation consisted of the operator pushing by hand a full 15 cwt. loaded skip across the turn-table to the hoist platform at ground level. He then climbed the steep wooden stairs to the firing stage, started (with the face-plate starter) the 5 HP DC electric motor, winched up the skip, pulled it off the hoist onto the top turntable, and pushed the skip along the tracks running along the line of producers. The operator then opened the top of each producer in turn via a rather hot hand-wheel and swung the pivoted heavy cast-iron lid clear of the opening which was not much larger than the diameter of the larger blocks. He soon learnt to stand back and wait a few seconds for the *whoosh* while a mini fireball erupted as a gulp of atmospheric oxygen was sucked into the inferno to combine with some gas and momentarily ignite. He would then throw in half a dozen or so blocks. Heavy work for an apprentice, especially when alone! I don't know why, but we never thought of wearing gloves! (Gloves were rarely worn by manual workers in Australia, even to this day).

He would be careful not to leave the top open for more than a few minutes or the engines would begin to pre-ignite due to the rich gas resulting from an excess of air being drawn through the producer. This usually happened when blocks got stuck, and he was unable to close the lid within a few minutes. Sometimes logs hung up within the producer, and had to be released with a long steel bar. The load would drop with a *whoomp* and a shower of sparks, causing the fire to collapse and resulting in all the engines beginning to pre-ignite and backfire due to a surge of rich gas. He would have to slam the top shut if possible, (it was frequently obstructed by a block of wood which failed to drop cleanly), run down to the engine room and adjust the gas and air levers on each engine, then when they had settled down, back to finish the firing.

Engine drivers tended to be lean and agile with callused hands and permanently singed hair and whiskers!

13. Driving The Engines

The Roma plant at this time consisted of one Hornsby and one Crossley twin cylinder horizontal engine and two National vertical four cylinder engines as described.

The intake manifolds of each engine were divided internally into two sections – air and gas, each controlled by its own master control lever. Governing was attended to by control levers and rod-coupled butterfly or flap valves within each cylinder intake port. The air section of the manifold was larger than the gas section, and each section had its own interconnected but individually adjustable butterfly. Air and gas did not finally mix until they were within the combustion chamber. The intake valves had double seats.

Each engine had its individual peculiarity and its own best setting of the master air and gas control valves, and this had to be learnt by the new drivers mainly by experience. It is difficult to teach this technique - learning this magic mixture setting is the black art of producer-gas engine driving. It differs for each engine, for starting and running, even for fine or rainy days. It differs with differences in ambient temperature and humidity, the weather, the moisture content of the wood, and even, we said, with phases of the moon or the engine's mood!

Pre-ignition was common, usually due to a rich gulp of gas when firing-up or from overload. In those days (the 1950's) most power-houses were grossly overloaded from the post-war growth of housing and industry and the difficulty and delay in obtaining new plant.

Pre-ignition could manifest itself from anything from a dull bumping sound to a series of frightening explosions, and when it could not be cured by judicious adjustment of the master levers, the cause was usually incandescent carbon within the cylinder or valve cage. It is the nature of a suction gas plant that the scrubbers fail to remove a lot of the tar-like material from the gas which caries over into the manifolds, valves and cylinders, leading to deposits of soft carbon.

The remedy – first decide which cylinder was the culprit, then run for your tea-mug, fill it with water, scramble up the engine ladder, disconnect the gas butterfly by removing its clevis-pin then close it, unscrew the brass plug in the air manifold and pour in some water. Usually this quenched the glowing carbon, or perhaps the cooling effect broke it away.

It added much to the drama of the moment and to the amusement of the proceedings (from the spectator's point of view) if you managed to drop the brass plug or the clevis pin, either or both of which loved to fall onto the chequer-plate with an alarming *CLANG* to further disturb your quivering nerves, and to roll away out of sight as you were sprayed with sooty water being spat back at you. The engine of course would drop some of its load onto the others, adding to the excitement.

The fun of driving gas-producer powerhouses lay in the total inter-dependence of all of the engines. When one engine became upset by rich or lean gas, they all joined in the game one after the other or all together, since they all sucked on the same gas header. After a period of steady running the state of brightness of the fires and thus the quantity and quality of gas produced would eventually settle down to satisfy the demand.

Merely starting or stopping an engine had to be planned like a battle. Starting an engine meant a preparation period beforehand of raking the fires to dislodge any compacted ash or clinker from the grates and pricking the numerous tuyeres (inserting a long steel rod and wriggling it energetically to ensure the incoming air had a fair passage) in an effort to brighten up the fires and enrich the gas. Later we installed a fan to help brighten the fires to induce a supply of richer gas before starting a new engine and we fitted a test jet cock which we could light and so judge from its colour the richness of the gas.

When the next engine was started, you could expect a period of lean gas until the status quo was re-established. The amount of gas generated was to a large extent automatically controlled by the demand of the engines, and this took some time to equalize. The same enriching procedure was necessary before the peak load time was expected.

Conversely, when an engine was stopped a period of rich gas could be expected for a while. The problem usually was compounded when a sudden unplanned stoppage occurred, or if a load breaker tripped due to a line fault or during electrical storms, upsetting the steady-state conditions.

In rainy weather, when the wood was wet, the engines seemed to run better. This was certainly more fact than just imagination. As well as the oft discussed benefit claimed to be gained by adding a small quantity of water to the intake air, it is a fact that water or steam injected into the producer itself is an essential part of the design of other types of plant, e.g. the “water-gas” referred to in many texts. However, this was not installed in the producers in Roma, where it was generally the opinion that the wood already contained moisture which would not be present in, say, coal or charcoal, and (rightly or wrongly) that in our case this would give short time calorific advantages against long term corrosion and rust problems in all parts of the system including the engine.

19. Historical Footnote

On October 16th 1900, natural gas was discovered in Roma during the sinking of a water bore (well) on Hospital Hill. After six years of debate and bitter argument, the town was reticulated for gas, but this was abandoned when the gas pressure mysteriously fell fourteen days later. In 1908, a disastrous fire occurred at a nearby bore and burnt for three months before being extinguished.

Although there were many later sporadic natural gas and light oil discoveries in the district, the extent of the gas field was not realised or exploited until 1969 when a 300 mile long pipe line was built to supply Brisbane with Roma gas. At one stage, at least one engine at Roma was fuelled by the light crude oil direct, untreated, from a local well. Additional "gas-cum-oil" engines from the closed Dalby power house were installed in Roma, operating from Roma gas. Gas-cum-oil engines start and run on diesel and can be adjusted to run on up to 90% natural gas. They use at least 10% diesel at all times.

The original power house in Mayne Street became known as the OPH (Old Power House). This was demolished and eventually the site was levelled after the NPH (New Power House) was established on the eastern outskirts of Roma, adjacent to the site of the old original aerodrome. Here new engines and later, a 2.5 MW gas turbine were installed, operating from local natural gas. The NPH which eventually had a capacity of nearly 18 MW operated successfully for many years until it too was demolished some time after it closed at 1.15 am on 8th May, 1986, much to the disquiet of the locals. Roma then obtained its electricity supply from the huge Tarong steam power house which supplied a State grid.

Ironically, to complete the circle, a large gas-turbine stand-by power station was recently built on the now vacant Roma NPH site, fuelled by Roma Natural Gas!

Photo 19. Author with Ford Freighter Line Truck c.1951

Roman cement

From Wikipedia, the free encyclopedia

Roman cement is a substance developed by James Parker in the 1780s, being patented in 1796.[1][2]

The name is misleading as it is nothing like any material used by the Romans, but was a "natural cement" made by burning septaria – nodules that are found in certain clay deposits, and that contain both clay minerals and calcium carbonate. The burnt nodules were ground to a fine powder. This product, made into a mortar with sand, set in 5–15 minutes.[1][2][3] The success of Roman cement led other manufacturers to develop rival products by burning artificial mixtures of clay and chalk.[1][4][5]

Above the ornate south doorway of Lichfield Cathedral stand seven figures carved in Roman cement.

History

There has been recent resurgence of interest in Natural cements and Roman cements due mainly to the need for repair of façades done in this material in the 19th century. The major confusion involved for many people in this subject is the terminology used. Roman cement was originally the name given, by Parker, to the cement he patented which is a Natural cement (i.e. it is a marl (or limestone containing integral clay) dug out of the ground, burnt and ground to a fine powder).[2][5]

In 1791, Parker was granted a patent "Method of Burning bricks, Tiles, Chalk". His second patent in 1796 "A certain Cement or Terras to be used in Aquatic and other Buildings and Stucco Work",[1] covers Roman cement, the term he used in a 1798 pamphlet advertising his cement. He set up his manufacturing plant on Northfleetcreek, Kent.[2] It was notably patented late on but James Parker is still the subject of all the credit.

Later, in the 1800s various sources of the correct type of marl, known also as Cement Stone, were discovered across Europe and so there were a range of natural cements (with varying properties) in use across Europe.[2][5]

An Austrian standard from 1880, providing a contemporary definition of Roman cements, reads: "Roman cements are products obtained from argillaceous marlstones by burning below the sintering temperature. They do not slake in contact with water and must therefore be ground to a floury fineness."[footnote 1][3]

From around 1807 a number of people looked to make artificial versions of this cement (or more strictly hydraulic lime as it was not burnt at fusion temperatures). Amongst these were James Frost who had about twenty patents from 1811 to 1822 including one for "British Cement" and in 1824 Joseph Aspdin, a British bricklayer from Leeds, with his now famous patent for a method of making a cement he called

"Portland cement".[6] This was done by adding various materials together to make an artificial version of natural cement. The name "Portland cement" is also recorded in a directory published in 1823 being associated with William Lockwood, Dave Stewart, and possibly others.[2][5][7]

There then followed a number of independently discovered or copied versions of this "Portland cement" (also referred to as Proto Portland cement). Proto Portland cement had a different chemical makeup from other natural cements being produced at the same time: It was burnt at a higher temperature than other Natural cements and thus crosses the barrier between traditional Vertical Kiln fired Natural cement and the later Horizontal Kiln fired Artificial cements. This cement is not, however, the same as the modern ordinary Portland cement, which can be defined as artificial cement.[5]

The Alamo Portland and Roman Cement Works, in Brackenridge Park, San Antonio, Texas, United States

James Frost is reported to have erected a manufactory for making of an artificial cement in 1826.[8] In 1843, Aspdin's son William improved their cement, which was initially called "Patent Portland cement," although he had no patent. In 1848, William Aspdin further improved his cement and in 1853, he moved to Germany where he was involved in cement making.[7] William Aspdin made what could be called meso-Portland cement (a mix of Portland cement and hydraulic lime).[5][9]

Artificial cement: Development in the 1860s of rotating horizontal kiln technology brought dramatic changes in properties, arguably resulting in modern cement.[5] Certainly it is difficult to define whether an old render was a natural cement (single source marl) or an artificial one, but there is no doubt as whether the cement was fired in a vertical or horizontal kiln. The names Natural cement or Roman cement then defines a cement coming from a single source rock. Early or Proto Portland cement could be used for early cement that comes from a number of sourced and mixed materials.[5] There is no widely used terminology for these 19th-century cements. There had been, in order to rediscover this technology, two projects carried out by the European Union ROCEM and subsequently ROCARE[10] (an ongoing project). Both these only deal with Natural cement - referred to as Roman cement without reference to the early artificial cements.

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Notes

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Footnotes

1. modified in 1890: "Roman cements are products obtained from argillaceous marlstones by burning below the sintering temperature. They do not slake in contact with water and must therefore be ground to a floury fineness." It specifies the range of setting times which facilitated the choice of a suitable material for a given decorative task: "Roman cements bind fast, medium and slow. By fast binding cements one should understand those which with no addition of sand start to harden within 7 minutes from the moment water is added. Roman cement is considered a slow binding variety if hardening starts later than after 15 minutes."

External links

- Parker's Roman Cement 1796 (http://romanportland.net/files/doc/seminar2008/simon_swann_seminar2008s.pdf)

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Categories: Building materials | Cement

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Romance (love)

From Wikipedia, the free encyclopedia

Romance is the expressive and pleasurable feeling from an emotional attraction towards another person often associated with sexual attraction. It is eros rather than agape, philia, or storge.

In the context of romantic love relationships, romance usually implies an expression of one's strong romantic love, or one's deep and strong emotional desires to connect with another person intimately or romantically. Historically, the term *"romance"* originates with the medieval ideal of chivalry as set out in its *chivalric romance* literature.

Humans have a natural inclination to form bonds with one another through social interactions, be it through verbal communication or nonverbal gestures.

The Stolen Kiss by Jean-Honoré Fragonard (1786)

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General definitions

The debate over an exact definition of romantic love may be found in literature as well as in the works of psychologists, philosophers, biochemists and other professionals and specialists. Romantic love is a relative term, but generally accepted as a definition that distinguishes moments and situations within intimate relationships to an individual as contributing to a significant relationship connection.

1. The addition of drama to relationships of close, deep and strong love.
2. Psychologist Charles Lindholm defined love to be "...an intense attraction that involves the idealization of the other, within an erotic context, with expectation of enduring sometime into the future."[1]

Historical definition

Historians believe that the actual English word "romance" developed from a vernacular dialect within the French language meaning "verse narrative"—referring to the style of speech, writing, and artistic talents within elite classes. The word was originally an adverb of the Latin origin "Romanicus," meaning "of the Roman style." The connecting notion is that European medieval vernacular tales were usually about chivalric adventure, not combining the idea of love until late into the seventeenth century.

The word *romance* has also developed with other meanings in other languages such as the early nineteenth century Spanish and Italian definitions of "adventurous" and "passionate", sometimes combining the idea of "love affair" or "idealistic quality."

In primitive societies, tension existed between marriage and the erotic, but this was mostly expressed in taboo regarding the menstrual cycle and birth.[2]

Anthropologists such as Claude Lévi-Strauss show that there were complex forms of courtship in ancient as well as contemporary primitive societies. There may not be evidence, however, that members of such societies formed loving relationships distinct from their established customs in a way that would parallel modern romance.[3]

Bernger von Horheim in the *Codex Manesse* (early 14th century)

Before the 18th century, many marriages were not arranged, but rather developed out of more or less spontaneous relationships. After the 18th century, illicit relationships took on a more independent role. In bourgeois marriage, illicitness may have become more formidable and likely to cause tension. In *Ladies of the Leisure Class*, Rutgers University professor Bonnie G. Smith depicts courtship and marriage rituals that may be viewed as oppressive to modern people. She writes "When the young women of the Nord married, they did so without illusions of love and romance. They acted within a framework of concern for the reproduction of bloodlines according to financial, professional, and sometimes political interests." Subsequent sexual revolution has lessened the conflicts arising out of liberalism, but not eliminated them.

Anthony Giddens, in his book *The Transformation of Intimacy: Sexuality, Love and Eroticism in Modern Society*, states that romantic love introduced the idea of a narrative into an individual's life. He adds that telling a story was one of the meanings of romance. According to Giddens, the rise of romantic love more or less coincided with the emergence of the novel. It was then that romantic love, associated with freedom and therefore the ideals of romantic love, created the ties between freedom and self-realization.

David R. Shumway, in his book *Romance, Intimacy, and The Marriage Crisis*, states that the discourse of intimacy emerged in the last third of the 20th century and that this discourse claimed to be able to explain how marriage and other relationships worked. For the discourse of intimacy emotional closeness was much more important than passion. This does not mean by any means that intimacy is to replace romance. On the contrary, intimacy and romance coexist.[4]

The 21st century has seen the growth of globalization and people now live in a world of transformations that affect almost every aspect of our lives, and love has not been the exception. One example of the changes experienced in relationships was explored by Giddens regarding homosexual relationships. According to Giddens since homosexuals were not able to marry they were forced to pioneer more open and negotiated relationships. This kind of relationships then permeated the heterosexual population.

Shumway also states that together with the growth of capitalism the older social relations dissolved, including marriage. Marriage meaning for women changed as they had more socially acceptable alternatives and were less willing to accept unhappy relations and, therefore, divorce rates substantially increased.

The discourse of romance continues to exist today together with intimacy. Shumway states that on the one hand, romance is the part that offers adventure and intense emotions while offering the possibility to find the perfect mate. On the other hand, intimacy offers deep communication, friendship, and long lasting sharing.

Popularization of love

"La Belle Dame sans Merci" 1893, by John William Waterhouse (1849-1917)

The conception of romantic love was popularized in Western culture by the concept of courtly love. Chevaliers, or knights in the Middle Ages, engaged in what were usually non-physical and non-marital relationships with women of nobility of whom they served. These relations were highly elaborate and ritualized in a complexity that was steeped in a framework of tradition, which stemmed from theories of etiquette derived out of chivalry as a moral code of conduct.

Courtly love and the notion of domnei were often the subjects of troubadours, and could be typically found in artistic endeavors such as lyrical narratives and poetic prose of the time. Since marriage was commonly nothing more than a formal arrangement,[5] courtly love sometimes permitted expressions of emotional closeness that may have been lacking from the union between husband and wife.[6] In terms of courtly love, "lovers" did not necessarily refer to those engaging in sexual acts, but rather, to the act of caring and to emotional intimacy.

The bond between a knight and his Lady, or the woman of typically high stature of whom he served, may have escalated psychologically but seldom ever physically.[7] For knighthood during the Middle Ages, the intrinsic importance of a code of conduct was in large part as a value system of rules codified as a guide to aid a knight in his capacity as champion of the downtrodden, but especially in his service to the Lord.

In the context of dutiful service to a woman of high social standing, ethics designated as a code were effectively established as an institution to provide a firm moral foundation by which to combat the idea that unfit attentions and affections were to ever be tolerated as "a secret game of trysts" behind closed doors. Therefore, a knight trained in the substance of "chivalry" was instructed, with especial emphasis, to serve a lady most honorably, with purity of heart and mind. To that end, he committed himself to the welfare of both Lord and Lady with unwavering discipline and devotion, while at the same time, presuming to uphold core principles set forth in the code by the religion by which he followed.[7]

Religious meditations upon the Virgin Mary were partially responsible for the development of chivalry as an ethic and lifestyle: the concept of the honor of a lady and knightly devotion to her, coupled with an obligatory respect for all women, factored prominently as central to the very identity of medieval knighthood. As knights were increasingly emulated, eventual changes were reflected in the inner-workings of feudal society. Members of the aristocracy were schooled in the principles of chivalry, which facilitated important changes in attitudes regarding the value of women.[8]

Behaviorally, a knight was to regard himself towards a lady with a transcendence of premeditated thought—his virtue ingrained within his character. A chevalier was to conduct himself always graciously, bestowing upon her the utmost courtesy and attentiveness. He was to echo shades of this to all women, regardless of class, age, or status.[9] Over time, the concept of chivalry and the notion of the courtly gentleman became synonymous with the ideal of how love and romance should exist between the sexes. Through the timeless popularization in art and literature of tales of knights and princesses, kings and queens, a formative and long standing (sub) consciousness helped to shape relationships between men and women.

De amore or *The Art of Courtly Love*, as it is known in English, was written in the 12th century. The text is widely misread as permissive of extramarital affairs. However, it is useful to differentiate the physical from without: romantic love as separate and apart from courtly love when interpreting such topics as: "Marriage is no real excuse for not loving", "He who is not jealous cannot love", "No one can be bound by a double love", and "When made public love rarely endures".[10]

Some believe that romantic love evolved independently in multiple cultures. For example, in an article presented by Henry Grunebaum, he argues "therapists mistakenly believe that romantic love is a phenomenon unique to Western cultures and first expressed by the troubadours of the Middle Ages."[11]

The more current and Western traditional terminology meaning "court as lover" or the general idea of "romantic love" is believed to have originated in the late nineteenth and early twentieth centuries, primarily from that of the French culture. This idea is what has spurred the connection between the words "romantic" and "lover," thus coining English phrases for romantic love such as "loving like the Romans do." The precise origins of such a connection are unknown, however. Although the word "romance" or the equivalents thereof may not have the same connotation in other cultures, the general idea of "romantic love" appears to have crossed cultures and been accepted as a concept at one point in time or another.

Types

Romantic love is contrasted with platonic love, which in all usages, precludes sexual relations, yet only in the modern usage does it take on a fully asexual sense, rather than the classical sense, in which sexual drives are sublimated. Sublimation tends to be forgotten in casual thought about love aside from its emergence in psychoanalysis and Nietzsche.

Unrequited love can be romantic in different ways: comic, tragic, or in the sense that sublimation itself is comparable to romance, where the spirituality of both art and egalitarian ideals is combined with strong character and emotions. Unrequited love is typical of the period of romanticism, but the term is distinct from any romance that might arise within it.[12]

Romantic love may also be classified according to two categories, "popular romance" and "divine or spiritual" romance:

Popular romance
: may include but is not limited to the following types: idealistic, normal intense (such as the emotional aspect of "falling in love"), predictable as well as unpredictable, consuming (meaning consuming of time, energy and emotional withdrawals and bids), intense but out of control (such as the aspect of "falling out of love") material and commercial (such as societal gain mentioned in a later section of this article), physical and sexual, and finally grand and demonstrative.

Divine (or spiritual) romance
: may include, but is not limited to these following types: realistic, as well as plausible unrealistic, optimistic as well as pessimistic (depending upon the particular beliefs held by each person within the relationship.), abiding (e.g. the theory that each person had a predetermined stance as an agent of choice; such as "choosing a husband" or "choosing a soul mate."), non-abiding (e.g. the theory that we do not choose our actions, and therefore our romantic love involvement has been drawn from sources outside of ourselves), predictable as well as unpredictable, self-control (such as obedience and sacrifice within the context of the relationship) or lack thereof (such as disobedience within the context of the relationship), emotional and personal, soulful (in the theory that the mind, soul, and body, are one connected entity), intimate, and infinite (such as the idea that love itself or the love of a god or God's "unconditional" love is or could be everlasting)[13]

In philosophy

Greek philosophers and authors have had many theories of love.

Plato

Some of these theories are presented in Plato's *Symposium*. Six Athenian friends, including Socrates, drink wine and each give a speech praising the deity Eros. When his turn comes, Aristophanes says in his mythical speech that sexual partners seek each other because they are descended from beings with spherical torsos, two sets of human limbs, genitalia on each side, and two faces back to back. Their three forms included the three permutations of pairs of gender (i.e. one masculine and masculine, another feminine and feminine, and the third masculine and feminine) and they were split by the gods to thwart the creatures' assault on heaven, recapitulated, according to the comic playwright, in other myths such as the Aloadae.[14]

This story is relevant to modern romance partly because of the image of reciprocity it shows between the sexes. In the final speech before Alcibiades arrives, Socrates gives his encomium of love and desire as a lack of being, namely, the being or form of beauty.

French philosopher Gilles Deleuze linked this idea of love as a lack mainly to Sigmund Freud, and Deleuze often criticized it.

In *How to Make Good Decisions and Be Right All the Time*, British writer Iain King tried to establish rules for romance applicable across most cultures. He concluded on six rules, including:

1. Do not flirt with someone unless you might mean it.
2. Do not pursue people who you are not interested in, or who are not interested in you.
3. In general, express your affection or uncertainty clearly, unless there is a special reason not to.[15]

René Girard

Though there are many theories of romantic love—such as that of Robert Sternberg, in which it is merely a mean combining liking and sexual desire—the major theories involve far more insight. For most of the 20th century, Freud's theory of the family drama dominated theories of romance and sexual relationships. This gave rise to a few counter-theories. Theorists like Deleuze counter Freud and Jacques Lacan by attempting to return to a more naturalistic philosophy:

René Girard argues that romantic attraction is a product of jealousy and rivalry—particularly in a triangular form.

Girard, in any case, downplays romance's individuality in favor of jealousy and the love triangle, arguing that romantic attraction arises primarily in the observed attraction between two others. A natural objection is that this is circular reasoning, but Girard means that a small measure of attraction reaches a critical point insofar as it is caught up in mimesis. Shakespeare's *A Midsummer Night's Dream*, *As You Like It*, and *The Winter's Tale* are the best known examples of competitive-induced romance.[16]

Girard's theory of mimetic desire is controversial because of its alleged sexism. This view has to some extent supplanted its predecessor, Freudian Oedipal theory. It may find some spurious support in the supposed attraction of women to aggressive men. As a technique of attraction, often combined with irony, it is sometimes advised that one feign toughness and disinterest, but it can be a trivial or crude idea to promulgate to men, and it is not given with much understanding of mimetic desire in mind. Instead, cultivating a spirit of self-sacrifice, coupled with an attitude of appreciation or contemplation, directed towards the other of one's attractions, constitutes the ideals of what we consider to be true romantic love. Mimesis is always the desire to possess, in renouncing it we offer ourselves as a sacrificial gift to the other.[17]

Mimetic desire is often challenged by feminists, such as Toril Moi,[18] who argue that it does not account for the woman as inherently desired.

Though the centrality of rivalry is not itself a cynical view, it does emphasize the mechanical in love relations. In that sense, it does resonate with capitalism and cynicism native to post-modernity. Romance in this context leans more on fashion and irony, though these were important for it in less emancipated times. Sexual revolutions have brought change to these areas. Wit or irony therefore encompass an instability of romance that is not entirely new but has a more central social role, fine-tuned to certain modern peculiarities and subversion originating in various social revolutions, culminating mostly in the 1960s.[19]

Arthur Schopenhauer

The process of courtship also contributed to Arthur Schopenhauer's pessimism, despite his own romantic success,[20] and he argued that to be rid of the challenge of courtship would drive people to suicide with boredom. Schopenhauer theorized that individuals seek partners who share certain interests and tastes, while at the same time looking for a "complement" or completing of themselves in a partner, as in the cliché that "opposites attract", but with the added consideration that both partners manifest this attraction for the sake of the species:

> "But what ultimately draws two individuals of different sex exclusively to each other with such power is the will-to-live which manifests itself in the whole species, and here anticipates, in the individual that these two can produce, an objectification of its true nature corresponding to its aims." --World as Will and Representation, Volume 2, Chapter XLIV

Other philosophers

Later modern philosophers such as La Rochefoucauld, David Hume and Jean-Jacques Rousseau also focused on morality, but desire was central to French thought and Hume himself tended to adopt a French worldview and temperament. Desire in this milieu meant a very general idea termed "the passions," and this general interest was distinct from the contemporary idea of "passionate" now equated with "romantic." Love was a central topic again in the subsequent movement of Romanticism, which focused on such things as absorption in nature and the absolute, as well as platonic and unrequited love in German philosophy and literature.

Philosophers and authors interested in the nature of love, which may not have been mentioned in this article are Jane Austen, Stendhal, George Meredith, Marcel Proust, D. H. Lawrence, Sigmund Freud, Jean-Paul Sartre, Simone de Beauvoir, Ernest Hemingway, Henry Miller, Gilles Deleuze, and Alan Soble.

In literature

In the following excerpt, from William Shakespeare's *Romeo and Juliet*, Romeo, in saying "all combined, save what thou must combine By holy marriage" implies that it is not marriage with Juliet that he seeks but simply to be joined with her romantically. "I pray That thou consent to marry us" implies that the marriage means the removal of the social obstacle between the two opposing families, not that marriage is sought by Romeo with Juliet for any other particular reason, as adding to their love or giving it any more meaning.

> "Then plainly know my heart's dear love is set On the fair daughter of rich Capulet: As mine on hers, so hers is set on mine; And all combined, save what thou must combine By holy marriage: when and where and how We met, we woo'd and made exchange of vow, I'll tell thee as we pass; but this I pray, That thou consent to marry us to-day."
>
> --Romeo and Juliet, Act II, Scene III

Romeo and Juliet parting on the balcony in Act III.

Shakespeare and Søren Kierkegaard share a similar viewpoint that marriage and romance are not harmoniously *in tune* with each other. In Shakespeare's *Measure for Measure*, for example, "...there has not been, nor is there at this point, any display of affection between Isabella and the Duke, if by affection we mean something concerned with sexual attraction. The two at the end of the play love each other as they love virtue."[21] Isabella needs love, and she may reject marriage with the Duke because he seeks to beget an heir with her for her virtues, and she is not happy with the limited kind of love that implies.

Shakespeare argues that marriage, because of its purity, simply cannot incorporate romance. The extramarital nature of romance is also clarified by John Updike in his novel *Gertrude and Claudius*, as well as by *Hamlet*. This same supposition of romance is also found in the film *Braveheart* or rather apparent in the example of Isabella of France's life.

Romance raises questions of emotivism (or in a more pejorative sense, nihilism) such as whether spiritual attraction, of the world, might not actually rise above or distinguish itself from that of the body or aesthetic sensibility.

While Buddha taught a philosophy of compassion and love, still in his philosophy of anatman or non-self spiritual appearances are of a piece with the world and essentially empty. The contradiction between compassion and anatman seems to be a part of Buddhism. In that case a seemingly negative insight can result in very different overall views, for example if one compares Buddha and Shakespeare with Friedrich Nietzsche.

Kierkegaard also addressed these ideas in works such as *Either/Or* and *Stages on Life's Way*.[22]

Tragedy and other social issues

The "tragic" contradiction between romance and society is most forcibly portrayed in literature, in Tolstoy's *Anna Karenina*, in Flaubert's *Madame Bovary*, and William Shakespeare's *Romeo and Juliet*. The female protagonists in such stories are driven to suicide as if dying for a cause of freedom from various oppressions of marriage.

Even after sexual revolutions, on the other hand, to the extent that it does not lead to procreation (or child-rearing, as it also might exist in same-sex marriage), romance remains peripheral though it may have virtues in the relief of stress, as a source of inspiration or adventure, or in development and the strengthening of certain social relations. It is difficult to imagine the tragic heroines, however, as having such practical considerations in mind.

Romance can also be tragic in its conflict with society. The Tolstoy family focuses on the romantic limitations of marriage, and Anna Karenina prefers death to being married to her fiancé, however this is because she is tired of waiting and being hidden away from public, when her fiance makes failed attempts to get his mother's approval of the marriage. Even being aristocrats did not make them both free, as the society was nevertheless equally binding for all. Furthermore, in the speech about marriage that is given in Kierkegaard's *Either/Or*, Kierkegaard attempts to show that it is because marriage is lacking in passion fundamentally, that the nature of marriage, unlike romance, is explainable by a man who has experience of neither marriage nor love.

Reciprocity of the sexes appears in the ancient world primarily in myth where it is in fact often the subject of tragedy, for example in the myths of Theseus and Atalanta. Noteworthy female freedom or power was an exception rather than the rule, though this is a matter of speculation and debate.[23]

Psychology

Many theorists attempt to analyze the process of romantic love.

Helen Fisher

Anthropologist Helen Fisher, in her book *Why We Love*,[24] uses brain scans to show that love is the product of a chemical reaction in the brain. Norepinephrine and dopamine, among other brain chemicals, are responsible for excitement and bliss in humans as well as non-human animals. She is famous for the use of MRI to study the brain activity of a person "in love", discovering the importance of the ventral tegmental area and the caudate nucleus in this biological drive.

Fisher concludes that these reactions have a genetic basis, and therefore love is a natural drive as powerful as hunger.

John Townsend

In his book *What Women Want, What Men Want*,[25] anthropologist John Townsend takes the genetic basis of love one step further by identifying how the sexes are different in their predispositions.

Townsend's compilation of various research projects concludes that men are susceptible to youth and beauty, whereas women are susceptible to status and security. These differences are part of a natural selection process where males seek many healthy women of childbearing age to mother offspring, and women seek men who are willing and able to take care of them and their children.

Karen Horney

Psychologist Karen Horney in her article "*The Problem of the Monogamous Ideal*",[26] indicates that the overestimation of love leads to disillusionment; the desire to possess the partner results in the partner wanting to escape; and the taboos against sex result in non-fulfillment. Disillusionment plus the desire to escape plus non-fulfillment result in a secret hostility, which causes the other partner to feel alienated. Secret hostility in one and secret alienation in the other cause the partners to secretly hate each other. This secret hate often leads one or the other or both to seek love objects outside the marriage or relationship.

Harold Bessell

Psychologist Harold Bessell in his book *The Love Test*,[27] reconciles the opposing forces noted by the above researchers and shows that there are two factors that determine the quality of a relationship.

Bessell proposes that people are drawn together by a force he calls "romantic attraction," which is a combination of genetic and cultural factors. This force may be weak or strong and may be felt to different degrees by each of the two love partners. The other factor is "emotional maturity," which is the degree to which a person is capable of providing good treatment in a love relationship. It can thus be said that an immature person is more likely to overestimate love, become disillusioned, and have an affair whereas a mature person is more likely to see the relationship in realistic terms and act constructively to work out problems.

Lisa M. Diamond

Romantic love, in the abstract sense of the term, is traditionally considered to involve a mix of emotional and sexual desire for another as a person. However, Lisa M. Diamond, a University of Utah psychology professor, proposes that sexual desire and romantic love are functionally independent[28] and that romantic love is not intrinsically oriented to same-gender or other-gender partners. She also proposes that the links between love and desire are bidirectional as opposed to unilateral. Furthermore, Diamond does not state that one's sex has priority over another sex (a male or female) in romantic love because her theory suggests it is as possible for someone who is homosexual to fall in love with someone of the other gender as for someone who is heterosexual to fall in love with someone of the same gender.[29] In her 2012 review of this topic, Diamond emphasized that what is true for men may not be true for women. According to Diamond, in most men sexual orientation is fixed and most likely innate, but in many women sexual orientation may vary from 0 to 6 on the Kinsey scale and back again.[30]

Martie Haselton

Martie Haselton, a psychologist at UCLA, considers romantic love a "commitment device", or mechanism that encourages two humans to form a lasting bond. She has explored the evolutionary rationale that has shaped modern romantic love and has concluded that long-lasting relationships are helpful to ensure that children reach reproductive age and are fed and cared for by two parents. Haselton and her colleagues have found evidence in their experiments that suggest love's adaptation. The first part of the experiments consists of having people think about how much they love someone and then suppress thoughts of other attractive people. In the second part of the experiment the same people are asked to think about how much they sexually desire those same partners and then try to suppress thoughts about others. The results showed that love is more efficient in pushing out those rivals than sex.[31]

University research

Research by the University of Pavia suggests that romantic love lasts for about a year, before being replaced by a more stable form of love called companionate love.[32] In companionate love, changes occur from the early stage of love to when the relationship becomes more established and romantic feelings seem to end. However, research from Stony Brook University in New York suggests that some couples keep romantic feelings alive for much longer.[33]

Major theories

These are the major theories associated with current research on romantic relationships, especially in the context of positive psychology.

Attachment patterns

As mentioned in the introduction, attachment styles that people develop as children can influence the way that they interact with partners in adult relationships, with secure attachment styles being associated with healthier and more trusting relationships than avoidant or anxious attachment styles.[34][35] Hazen and Shaver found that adult romantic attachment styles were similar to the categories of secure, avoidant, and anxious that had previously been studied in children's attachments to their caregivers, demonstrating that attachment styles are stable across the lifespan.[36] Later on, researchers distinguished between dismissive avoidant attachment and fearful avoidant attachment.[37] Others have found that secure adult attachment, leading to the ability for intimacy and confidence in relationship stability, is characterized by low attachment-related anxiety and avoidance, while the fearful style is high on both dimensions, the dismissing style is low on anxiety and high on avoidance, and the preoccupied style is high on anxiety and low on avoidance.[38]

Romantic love definition/operationalization

Singer (1984a,[39] 1984b,[40] 1987[41]) first defined love based on four Greek terms: *eros*, meaning the search for beauty; *philia*, the feelings of affection in close friendships, *nomos*, the submission of and obedience to higher or divine powers, and *agape*, the bestowal of love and affection for the divine powers. While Singer did believe that love was important to world culture, he did not believe that romantic love played a major role (Singer, 1987[41]). However, Susan Hendrick and Clyde Hendrick at Texas Tech University (1992,[42] 2009[43]) have theorized that romantic love will play an increasingly important cultural role in the future, as it is considered an important part of living a fulfilling life. They also theorized that love in long-term romantic relationships has only been the product of cultural forces that came to fruition within the past 300 years. By cultural forces, they mean the increasing prevalence of individualistic ideologies, which are the result of an inward shift of many cultural worldviews.

Passionate and companionate love

Researchers have determined that romantic love is a complex emotion that can be divided into either passionate or companionate forms.[44] Berscheid and Walster (1978[45]) and Hatfield (1988[46]) found that these two forms can co-exist, either simultaneously or intermittently. Passionate love is an arousal-driven emotion that often gives people extreme feelings of happiness, and can also give people feelings of anguish. Companionate love is a form that creates a steadfast bond between two people, and gives people feelings of peace. Scientists have described the stage of passionate love as "being on cocaine," since during that stage the brain releases the same neurotransmitter, dopamine, as when cocaine is being used. [47] It is also estimated that passionate love lasts for about twelve to eighteen months. [48] Psychologist, Robert Firestone, has a theory of the fantasy bond, which is what is mostly created after the passionate love has faded. A couple may start to feel really comfortable with each other to the point that they see each other as simply companions or protectors, but yet think that they are still in love with each other. [49] The results to the fantasy bond is the leading to companionate love. Hendrick and Hendrick (1995[50]) studied college students who were in the early stages of a relationship and found that almost half reported that their significant other was their closest friend, providing evidence that both passionate and companionate love exist in new relationships. Conversely, in a study of long-term marriages, researchers (Contreras, Hendrick, and Hendrick, 1996[51]) found that couples endorsed measures of both companionate love and passionate love and that passionate love was the strongest predictor of marital satisfaction, showing that both types of love can endure throughout the years.

The triangular theory of love

Psychologist Robert Sternberg (1986[52]) developed the triangular theory of love. He theorized that love is a combination of three main components: passion (physical arousal); intimacy (psychological feelings of closeness); and commitment (the sustaining of a relationship). He also theorized that the different combinations of these three components could yield up to seven different forms of love. These include popularized forms such as romantic love (intimacy and passion) and consummate love (passion, intimacy, and commitment). The other forms are liking (intimacy), companionate love (intimacy and commitment), empty love (commitment), fatuous love (passion and commitment), and infatuation (passion). Studies on Sternberg's theory love found that intimacy most strongly predicted marital satisfaction in married couples, with passion also being an important predictor (Silberman, 1995[53]). On the other hand, Acker and Davis (1992[54]) found that commitment was the strongest predictor of relationship satisfaction, especially for long-term relationships.

The self-expansion theory of romantic love

Researchers Arthur and Elaine Aron (1986[55]) theorized that humans have a basic drive to expand their self-concepts. Further, their experience with Eastern concepts of love caused them to believe that positive emotions, cognitions, and relationships in romantic behaviors all drive the expansion of a person's self-concept. A study following college students for 10 weeks showed that those students who fell in love over the course of the investigation reported higher feelings of self-esteem and self efficacy than those who did not (Aron, Paris, and Aron, 1995[56]).

Mindful relationships

Harvey and Ormarzu (1997[57]) developed a model of minding relationships with five key components: seeking to know and be known by the other; using knowledge learned in a relationship to enhance the relationship; accepting the other person; being motivated to continue this process of learning, enhancing, and accepting; and developing a sense of appreciation in the relationship. Each of these components is considered adaptive, however, nonadaptive steps to minding a relationship were also theorized by the research team. The five nonadaptive components include: one or both partners out of step in seeking to know and be known by the other; not using the knowledge learned in a relationship to enhance the relationship (or using that knowledge to hurt the other); low acceptance and respect for the other person; not being motivated to continue the process of learning, enhancing, and accepting; and failing to develop a sense of appreciation in a relationship. Gottman studies the components of a flourishing romantic relationship have been studied in the lab (1994;[58] Gottman & Silver, 1999[59]). He used physiological and behavioral measures during couples' interactions to predict relationship success and found that five positive interactions to one negative interaction are needed to maintain a healthy relationship. He established a therapy intervention for couples that focused on civil forms of disapproval, a culture of appreciation, acceptance of responsibility for problems, and self-soothing (Gottman, Driver, & Tabares, 2002[60]).

Relationship behaviors

The most recent research on romantic love and relationships focuses on behaviors that either sustain a relationship or aid in its dissolution. These behaviors can be considered either appetitive or aversive. Appetitive relationship processes are considered the promotion of positive relationship behaviors, as determined by psychologists Gable and Reis (2001,[61] 2003[62]). Aversive relationship processes are described as eliminating behaviors that have a negative effect on relationships (Gable and Reis 2001,[61] 2003[62]). This new research has also allowed relationship success to be predicted as a function of these appetitive and aversive processes. This is all related to research that shows that sharing positive life events with one's partner is related to greater relationship satisfaction and intimacy (Gable et al., 2004[63]). In research by Gable et al. (2003) appetitive (promotion of positive relationship behaviors) and aversive (elimination of negative relationship behaviors) processes are independent constructs. A specific type of appetitive processing, capitalization, leads to increased relationship satisfaction and intimacy when one member of the relationship tells the other about positive life events and receive quality reactions and feedback from the partner (Gable, Reis, Impett, & Asher, 2004[63]).

Applications

Awareness of major theories on positive romantic relationships and knowledge of proven findings that support them gives couples the tools to strengthen their relationships and allows single individuals to have the resources to build a flourishing relationship in the future. Access to information like this could contribute to the reduction of divorce rates, as well as producing happier and healthier home lives for many families. For example, though there appears to be a correlation between an increased divorce rate and premarital cohabitation, living with a person of romantic interest before marriage still appears to be a common and growing trend.[64] Knowledge of this is one way positive psych could help aid flourishing relationships.

In addition to the aforementioned factors, awareness would also provide the opportunity for people to better understand or empathize with those who may not illustrate the level of positivity found in these major theories. Knowing this information can help with coming to terms with someone that is particularly difficult in a given romantic relationship, and could help one aid them to a better outlook through this gain of knowledge. The attachment style of individuals has a strong influence on the way future relationships are created and harnessed. While those with a secure attachment style fare better, one may be prone to more bumps in the road if having a disorganized style of attachment.

With a heightened awareness comes an upward spiral of positive relationships in general. Having younger individuals modeled by positive interactions would, in turn, greatly influence the probability of these individuals implementing such behaviors in their own social relationships.

It can be said that romantic love creates pair bonding between two individuals. It also increases the amount of available resources by combining those of two separate individuals thus leading to an increase in the reproductive fitness of potential offspring. This can be seen in the animal kingdom as well. For example, researchers observed the survival rate of mice offspring in father present and father absent environments and discovered that while both groups had approximately the same birth rate, with the father absent group even being a little bit higher, ultimately only 26% of the offspring in father absent group survived to emergence as opposed to the 81% of offspring that survived in the father present group.[65]

Controversies

Researchers such as Feeney and Noller question the stability of attachment style across the life span since studies that measured attachment styles at time points ranging from 2 weeks to 8 months found that 1 out of 4 adults' attachment style changed.[66] Furthermore, a study by Lopez and Gormley found that attachment styles could change during the first year of college and that changes to more secure attachment styles were associated with adjustments in self-confidence ratings and coping styles.[67] On the other hand, attachment styles in childhood mirror the ones found in adult romantic relationships.[68] In addition, research has shown that building interpersonal connections strengthens neural regulatory systems that are involved in emotions of empathy, enjoyment of positive social events, and stress management,[69][70] providing evidence that early social interactions affect adult relationships.

Another topic of controversy in the field of romantic relationships is that of domestic abuse. Following the theory that romantic love evolved as a byproduct of survival, it can be said that in some instances, it has turned into a maladaptation. Oxytocin is a neurophysical hormone produced in the brain. It is known to cause a decrease in stress response. It also can cause an increase in feelings of attachment. In the beginning stages of a romantic relationship, OT levels surge and then remain relatively stable over the duration of the relationship. The higher the surge of OT, the greater the likelihood is of partners staying together.[71] It plays an important role in increasing positive interpersonal behaviors such as trust, altruism, empathy, etc.[72] This response is not universal and can in fact, cause the opposite to occur depending on environment and individual. Individuals ranked high in rejection sensitivity exhibited aggressive tendencies and decreased willingness for cooperation, indicating a link between oxytocin and relationship maintenance.[73]

The feelings associated with romantic love function to ensure the greater reproductive fitness of individuals. The obligations of individuals in romantic relationships to preserve these bonds are based in kin selection theory, where by exhibiting aggressive behavior, a mate can use intimidation and dominance to ward off other potential predators, thus protecting the pair bond and their actual or potential offspring. This has however evolved to the point where it has become detrimental to the fitness of individuals; what is causing attachment to occur in a relationship, is now causing one partner to harm the other.

In the search for the root of intimate partner violence, intranasal oxytocin was administered to a control group and a group of participants with aggressive tendencies. Participants were then surveyed on how willing they were to engage in 5 behaviors towards their romantic partner. What they found was that oxytocin increased IPV inclinations only among the participants with a predisposition towards aggressive tendencies.[74] Oxytocin decreases trust and prosocial behavior in individuals with interpersonal difficulties. This, coupled with its role in relationship maintenance, illustrates that oxytocin serves to instill a sense of territoriality and protectiveness towards a mate.

See also

- Platonic love
- Chivalric romance
- Romantic orientation
- Interpersonal attraction

Romantic practices

- Romantic attraction
- Flirting

- Romanticism
  - Poetry
  - Drawing
  - Painting

- Courtly love
- Erotomania
- Erotophobia
- Infatuation
- Intimate relationship
- Love
- Marriage
- Love sickness
- Physical intimacy
- Romanticism
- Romantic friendship
- Romance novel
- Sexual relationship
- Valentine's Day
- *The Four Loves*
- *True Romance*
- Fraternizing
- Courtship
- Pet names
- Intimacy
  - Eye contact
  - Hugging
  - Holding hands
  - Kissing
- Interpersonal communication
  - Face-to-face
  - Love letter
  - Telephone
  - Internet romance
- Dating
  - Cooking
  - Couple dancing
  - Movies
  - Stargazing
  - Serenade

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14. *Symposium 189d ff.*
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A project of Volunteers in Asia

Roof Constructions for Housing in Developing Countries

By: Kiran Mukerji, Justin H. Whipple,
and Rodolfo Castillo Escobar

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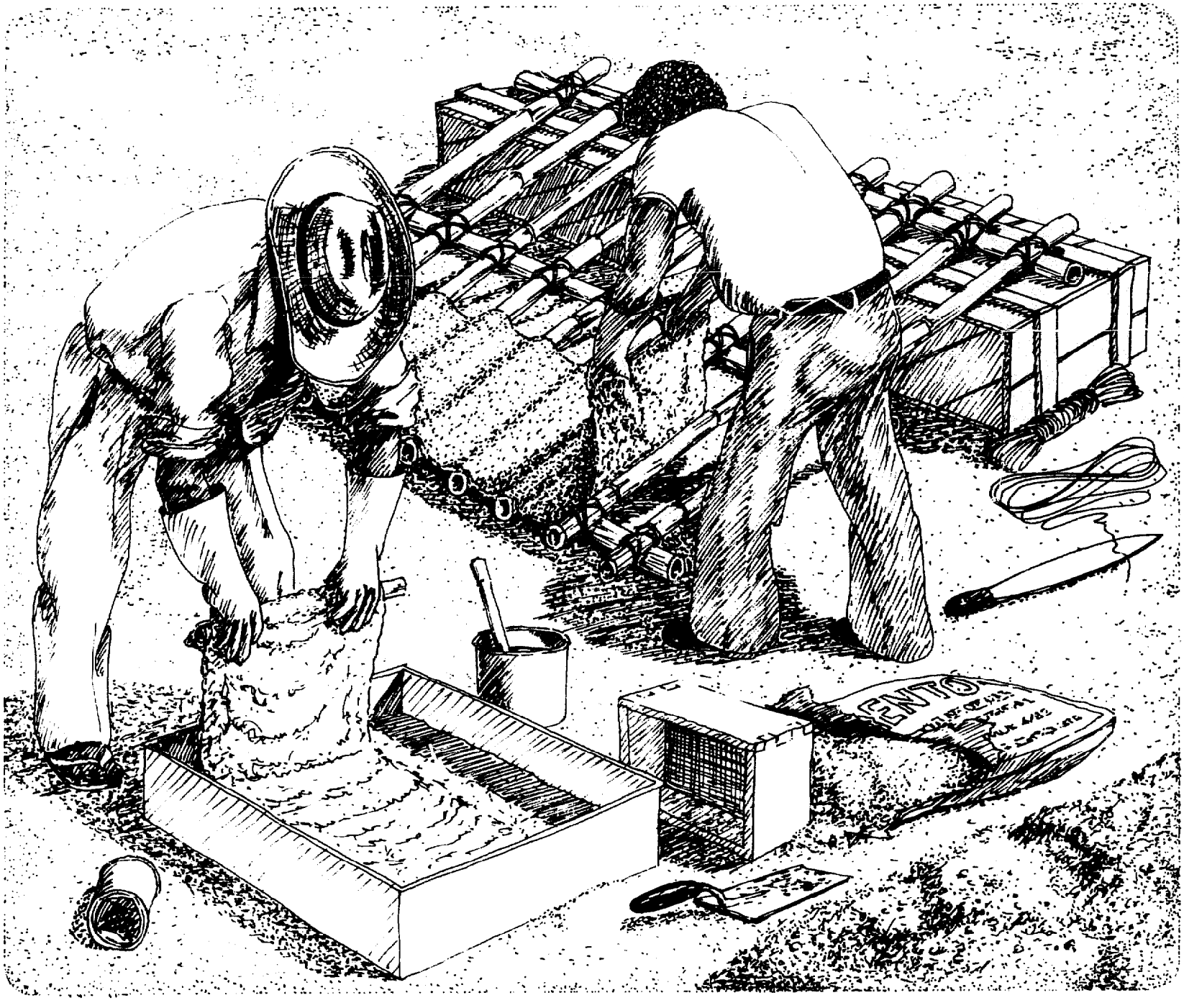

DACHKONSTRUKTIONEN FÜR DEN WOHNUNGSBAU IN ENTWICKLUNGS-LÄNDERN

ROOF CONSTRUCTIONS FOR HOUSING IN DEVELOPING COUNTRIES

DACHKONSTRUKTIONEN FÜR DEN WOHNUNGSBAU IN ENTWICKLUNGSLÄNDERN

Bericht über eine Forschungsstudie in Zentralamerika (1979)
im Auftrag von

gate

German Appropriate Technology Exchange
Dag-Hammarskjöld-Weg 1, 6236 Eschborn 1
(Projektnummer 77.2518.7)

Durchführung
Institut für Tropenbau, Dr.-Ing. Georg Lippsmeier (I.F.T.)
Waldschmidtstraße 6 a, 8130 Starnberg, Bundesrepublik Deutschland

in Zusammenarbeit mit
Instituto Centroamericano de Investigación y Tecnologia Industrial (ICAITI)
Avenida la Reforma 4 - 47, Zona 10, Guatemala City, Guatemala

Bearbeiter

Dipl.Ing. Kiran Mukerji (I.F.T.)

Ing. Justin H. Whipple
Sub-Chief, Industrial Services Division (ICAITI)

Ing. Rodolfo Castillo Escobar
Banco Nacional de la Vivienda (BANVI/ICAITI)

Eschborn, Juli 1982

ROOF CONSTRUCTIONS FOR HOUSING IN DEVELOPING COUNTRIES

Report on a Research Study in Central America (1979)
on behalf of

gate

German Appropriate Technology Exchange
Dag-Hammarskjöld-Weg 1, 6236 Eschborn 1
(Project Number 77.2518.7)

Carried out by
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in cooperation with
Instituto Centroamericano de Investigación y Tecnologia Industrial (ICAITI)
Avenida la Reforma 4 - 47, Zona 10, Guatemala City, Guatemala

Authors

Dipl.Ing. Kiran Mukerji (I.F.T.)

Ing. Justin H. Whipple
Sub-Chief, Industrial Services Division (ICAITI)

Ing. Rodolfo Castillo Escobar
Banco Nacional de la Vivienda (BANVI/ICAITI)

Eschborn, July 1982

Umschlagbild :

Experimentelles Niedrigkosten-Bedachungselement : auf einer Bambus-Unterkonstruktion wird Jute-Sackmaterial verlegt, unmittelbar nachdem es in einer dickflüssigen Mischung aus Bimssand, Zement und Wasser (bzw. Erde, Kalk und Wasser) getaucht wurde. Nach Glättung der Oberfläche entsteht der Eindruck einer Wellblech- oder Asbestzement-Deckung. (Siehe Abschnitt 6.2.2)

Cover illustration :

Experimental low cost roofing element : on a bamboo framework, jute sacking material is laid immediately after dipping it in a thick mixture of pumice-sand, cement and water (or soil, lime and water). After smoothening the surface, the roof resembles corrugated steel or asbestos cement sheeting. (See section 6.2.2)

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1. EINLEITUNG

1.1 Zielsetzung

Der gebräuchliche Spruch, "ein Dach über dem Kopf haben", vermittelt ein Gefühl der Sicherheit und Behaglichkeit. Viele Wohnungsbaugesellschaften und Bausparkassen verwenden das Dach als Symbol, wobei "Dach" und "Wohnstätte" als Synonyme verstanden werden. Aber auch technisch ist das Dach der wichtigste Teil des Hauses: es kostet am meisten; gerechnet nach Fläche und Orientierung ist es der Teil, der den Elementen am meisten ausgesetzt ist, und es ist der Teil, der hauptsächlich für den Komfort im Haus und für Schäden durch Erdbeben und Wirbelstürme verantwortlich ist.

Jedoch trotz dieser Bedeutung des Daches ist es wahrscheinlich der meist vernachlässigte Teil in bezug auf Forschung und Entwicklung. So werden in Entwicklungsländern, abgesehen von herkömmlichen Bauwerken, immer mehr verzinktes Wellblech und, in geringerem Maße, Asbestzement verwendet, obwohl diese eine Anzahl von schwerwiegenden Nachteilen mit sich bringen.

Diese Überlegungen und die Tatsache, daß mangelhafte Bedachung in katastrophengefährdeten Regionen, wie Zentral-Amerika, Tausende von Leben gekostet hat, waren die Motivierung für diese Forschungsarbeit. Initiiert und finanziert wurde sie von der Deutschen Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH im Rahmen der deutschen technischen Hilfe.

Zweck dieses neunmonatigen Forschungsprojektes war, alle verfügbaren Materialien über kostengünstige Bedachungen sowohl global als auch die Situation in Zentral-Amerika im Detail zu untersuchen, und auch Materialien, Bausysteme und Herstellungsmethoden zu identifizieren, die

- erdbeben- und hurrikanbeständig sind,
- für die gegebenen klimatischen Bedingungen geeignet sind,
- Kosten für Einfachwohnbau reduzieren helfen,
- für Selbsthilfe und genossenschaftliche Wohnbauprojekte angewandt werden können,
- maximalen Einsatz von lokalen Ressourcen ermöglichen,
- ausreichend dauerhaft sind und niedrige Instandhaltungskosten verursachen,
- örtlich hergestellt werden können, auch in kleinem Umfang.

Es muß betont werden, daß ein Forschungsbericht über Bedachungssysteme nie komplett sein kann. Die Vielfalt von Formen, Bauarten und Materialien, die verwendet werden, ist unbegrenzt. Das Ziel war jedoch, grundlegende Daten über die wichtigsten Aspekte von Bedachungsmaterialien und -konstruktionen in Entwicklungsländern vorzustellen und den Weg für weitere Forschung zu bahnen.

1. INTRODUCTION

1.1 Aim

The common phrase "to have a roof over one's head" communicates a sense of security and comfort. Many housing housing organizations and housing banks use the roof as a symbol, suggesting a synonymy of "roof" and "shelter". But even technically the roof is the most significant part of a house: it costs the most, by area and orientation it is the part most exposed to the elements, and it is the part primarily responsible both for indoor comfort and for damage suffered during earthquakes and hurricanes.

Yet despite the importance of the roof, it is probably the most neglected part in terms of research and development. Thus in developing countries, apart from traditional structures, corrugated galvanized iron and, to a lesser extent, asbestos cement are increasingly being used, even though they have a number of serious disadvantages.

These considerations, and the fact that deficient roofing in disaster prone regions, such as Central America, has cost thousands of lives, were the motivations behind this research study. It was initiated and financed by the German Agency for Technical Cooperation, Ltd. (GTZ) within the scope of German technical aid.

The object of the nine-month research project was to study all available material on low-cost roofing, both on a global scale as well as in detail on the situation in Central America, and to identify materials, construction systems and production processes that:

- are earthquake and hurricane resistant,
- are appropriate for the given climatic conditions,
- help to reduce costs for low-cost housing,
- can be implemented in self-help and cooperative housing schemes,
- make maximum use of local resources,
- have sufficient durability and low maintenance costs,
- can be produced locally even on a small scale.

It must be stressed that a research report on roofing systems can never be complete. The diversity of shapes, constructions and materials used is unlimited. However, the object was to present basic data on the most important aspects of low-cost roofing in developing countries and to prepare the way for deeper research.

1.2 Verfahrensweise

Während dieses Forschungsprojektes war das Sammeln von Daten die Hauptaufgabe. Dies geschah hauptsächlich durch

- bibliographische Ermittlungen
- Schriftverkehr mit verschiedenen Instituten und Sachverständigen in einer Anzahl verschiedener Länder
- Besuche von interessanten Baustellen und Produktionseinheiten für Baumaterialien, persönliche Kontakte mit Experten sowohl in Entwicklungsländern als auch in Industrieländern.

Zwischen Juni und Oktober 1979 wurden im Hauptsitz von ICAITI in Guatemala kleinere Versuche unternommen, um die Durchführbarkeit von Ideen für neue Entwicklungen, die sich aus der Datensammlung und -evaluierung ergaben, zu testen. Notwendigerweise konnte dies nur sporadisch sein, und das alleinige Ziel war, so viele verschiedene Materialien und Systeme auszuprobieren, wie es die Zeit erlaubte. Dies zeigte sich als eine wertvolle Methode, eine große Auswahl von Problemen und Möglichkeiten neuer Lösungen zu studieren, um die Ergebnisse und Empfehlungen zu qualifizieren.

Die Arbeit an diesem Projekt wurde zwischen den beiden Instituten geteilt, so daß ICAITI alle Daten über Zentral-Amerika sammelte und auswertete und die Einrichtungen sowie die Dokumentation der experimentalen Arbeit zur Verfügung stellte, während sich I.F.T. mit den übrigen Abschnitten, die grundsätzliche und detaillierte Informationen über Bedachungen in den Entwicklungsländern im allgemeinen behandeln, befaßte. Der größte Teil der experimentalen Arbeit, so wie die Formulierung der Schlußfolgerungen und Empfehlungen erfolgte gemeinsam. Das abschließende Arbeitsdokument wurde in Englisch geschrieben und danach von ICAITI in Spanisch und vom I.F.T. in Deutsch übersetzt. Die spanische Fassung wurde zur Verbreitung in Lateinamerika von ICAITI veröffentlicht.

1.2 Methodology

Throughout the research project, the collection of data was the major task. The means employed were primarily:

- bibliographic investigations,
- correspondence with various institutes and experts in a number of countries,
- visits to interesting project sites and production units for building materials, personal contacts with experts both in developing and industrialized countries.

Minor experimental work was undertaken between June and October 1979 at the headquarters of ICAITI in Guatemala, to test the feasibility of ideas for new developments arising from the data collection and evaluation. Of necessity this could only be sporadic and the sole aim was to try out as many different materials and systems as the time permitted. This proved to be an invaluable means of studying a wide range of problems and possibilities of new solutions, to qualify the conclusions and recommendations made.

The work on the project was divided between the two institutes, such that ICAITI collected and evaluated all data on Central America and provided the facilities and documentation of experimental work, while I.F.T. was concerned with the other sections, which involved basic and detailed data on roofing with respect to developing countries in general. Most of the experimental work as well as the formulation of conclusions and recommendations were carried out jointly. The final working document was written in English and subsequently translated into Spanish and German by ICAITI and I.F.T. respectively. The Spanish version was published by ICAITI for dissemination in Latin America.

2. DÄCHER FÜR DEN WOHNUNGSBAU

2.1 Herkömmliche Dachtypen

Die Hauptfunktion des Daches ist, Wohn- und Arbeitsraum zu überdecken und somit Schutz vor den Elementen zu geben. Dies kann durch unbegrenzte Varianten und Formen, Konstruktionssysteme und Materialien erreicht werden. Stark vereinfacht zeigt die folgende Zusammenfassung die grundlegenden Unterschiede, wobei ihre funktionalen Aspekte und geeigneten Verwendungszwecke, besonders im Zusammenhang mit dem sozialen Wohnungsbau, erläutert werden.

2.1.1 Flache Dächer

Bausysteme: Balken, massive Platten, leichte Platten

Abb. 2.1

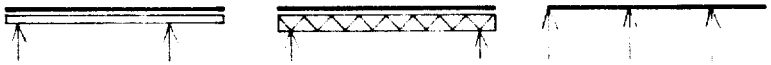

Typische Materialien:

(a. Tragkonstruktionen, b. Dachdeckung, c. Feuchtigkeitsisolierung)

- Holz (a, b)
- Stahlbeton (a, b)
- Stahl (a)
- Profilmetallplatten (a, b, c)
- Profilasbestzementplatten (a, b, c)
- Erde, auch grastragender Humus (b)
- Verschiedene Spanplatten/Verbundplatten (b)
- Dachpappe (c)
- Bitumen (c)
- Anstriche (c)

Bemerkungen:

- Nach Definition sind flache Dächer weniger als 10° zur Horizontalen geneigt. Für den Abfluß von Regenwasser ist eine Neigung von mindestens 2° nötig.
- Häufig vorkommender Dachtyp in überwiegend trocken-heißen Zonen, mit unbedeutenden Niederschlägen.
- Nicht geeignet für Hurrikanzonen, da die Sogwirkung von Windkräften Dächer abreißen kann.
- Zusätzlicher Lebensraum auf dem Dach (Haushaltaktivitäten, Schlafen bei Nacht).
- Leichte vertikale Erweiterung des Gebäudes.
- Dachplatten mit Gefälle und großen Überlappungen zu verlegen.

2. ROOFS FOR HOUSING

2.1 Common Roof Types

The prime function of the roof is to cover dwelling and working space and thus provide shelter from the elements. This is achieved by an unlimited variety of shapes, construction systems and materials. Generalizing to a large extent, the following summary of roof types shows their basic differences, discussing briefly their functional aspects and appropriate uses, especially in the context of low-cost housing.

2.1.1 Flat Roofs

Structural system: beams, girders, slabs, sheets

Fig. 2.1

Typical Materials:

(a. Supporting structure, b. Roof decking, c. Waterproofing)

- Timber (a, b)
- Reinforced concrete (a, b)
- Steel (a)
- Profiled metal sheets (a, b, c)
- Profiled asbestos cement sheets (a, b, c)
- Soil — also grass-bearing humus (b)
- Diverse composite building boards (b)
- Roofing felt (c)
- Bitumen (c)
- Liquid finishes (c)

Comments:

- By definition, flat roofs have inclinations of less than 10° to the horizontal. For rainwater run-off at least 2° slope necessary.
- Common roof type in predominantly hot dry areas, with inconsiderable precipitation.
- Not appropriate for hurricane prone areas, as wind forces tend to pull off roof by suction.
- Additional living space on roof (household activities, sleeping at night).
- Easy vertical extensions of building.
- Sheet decking must be laid in falls with large overlaps.

2.1.2 Pultdach, Satteldach und Walmdach

Bausysteme: Sparren, Pfetten, Binder, leichte Platten, massive Platten.

Abb. 2.2

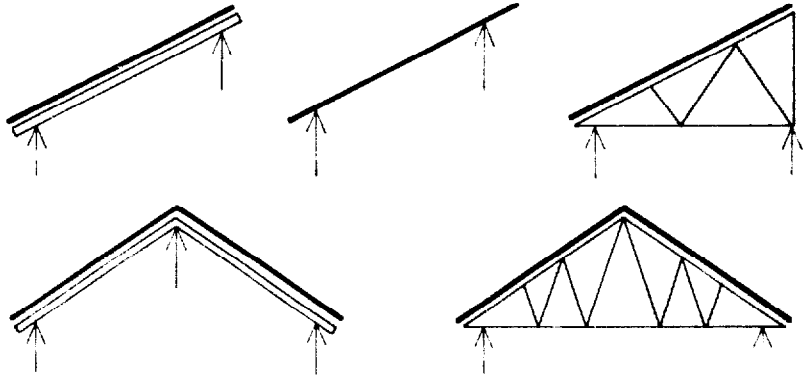

Typische Materialien:

(a. Tragkonstruktion, b. Dachdeckung, c. Feuchtigkeitsisolierung)

- Holz (a, b)
- Bambus (a, b)
- Stahlbeton (a, b)
- Stahl (a)
- Profilmetallplatten (a, b, c)
- Profilasbestzementplatten (a, b, c)
- Ziegel (b, c)
- Verschiedene pflanzliche Baustoffe, wie Stroh oder Matten (b)
- Verschiedene Spanplatten/Verbundplatten (b)
- Dachpappe (c)
- Bitumen (c)
- Anstriche (c)

Bemerkungen:

- Hauptsächlich in feuchtwarmen Zonen mit bedeutenden Niederschlägen.
- Geeignet für Hurrikanzonen, wenn Dachneigungen über 30° (ungefähr 1 : 1.7 oder 58%); flachere Dächer verursachen Sogkräfte, welche bei 10° am stärksten sind.
- Große Dachüberstände sind in Hurrikanzonen nicht geeignet, jedoch von Vorteil, um Wände und Öffnungen zu beschatten und um Abfluß von Regenwasser vom Gebäude fernzuhalten.
- Geringe Neigungen sind üblich, weil sie wirtschaftlich sind: weniger Baumaterial, weniger Dachfläche (demnach weniger Dachmaterial), Erweiterung in Gefälle-

2.1.2 Single Pitched, Gabled and Hipped Roofs

Structural system: rafters, purlins, trusses, sheets, slabs

Fig. 2.2

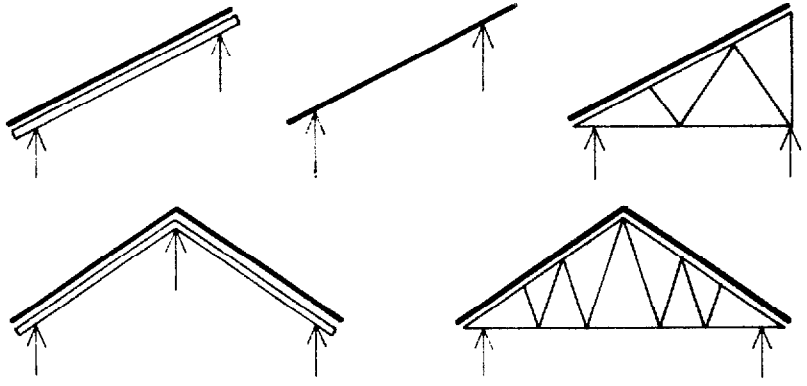

Typical Materials:

(a. Supporting structure, b. Roof decking, c. Waterproofing)

- Timber (a, b)
- Bamboo (a, b)
- Reinforced concrete (a, b)
- Steel (a)
- Profiled metal sheets (a, b, c)
- Profiled asbestos cement sheets (a, b, c)
- Burnt clay tiles (b, c)
- Diverse plant materials as thatch or matting (b)
- Diverse composite building boards (b)
- Roofing felt (c)
- Bitumen (c)
- Liquid finishes (c)

Comments:

- Used predominantly in warm humid regions with significant precipitation.
- Appropriate for hurricane prone areas, if roof slopes exceed 30° (about 1 : 1.7 or 58%); flatter roofs create suction forces which are strongest at 10° pitch.
- Wide overhangs disadvantageous in hurricane areas, but advantageous for shading of walls and openings and for discharging rainwater run-off clear of building.
- Low pitches are common, because they are economical: less wall construction material, less roof surface (consequently less roofing materials), extensions in direction of fall (e.g. verandahs) possible with sufficient head height.
- Each decking has its own appropriate slope (see Section 3.5).

richtung (z.B. Veranden) mit genügend Kopfhöhe möglich.
- Jede Deckungsart hat ihre erforderliche Mindestneigung (siehe Teil 3.5).
- Gefahr von Wasserdurchdringung, wenn die Neigung im Verhältnis zur Überlappung nicht ausreichend ist.
- Walmdächer schützen alle Wände (während Satteldächer die Stirnwände ungeschützt lassen), sind sparsam an Wandfläche und Kosten, leisten weniger Widerstand gegen Wind, sind aber schwieriger zu konstruieren.
- Angrenzende Satteldächer mit internen horizontalen Dachrinnen sind problematisch, selbst mit leichter Neigung: Ansammlung von Schmutz verhindert den Wasserabfluß, bringt schnellen Verfall des Dachmaterials.

2.1.3 Gekrümmte Dächer

Bausysteme: Gewölbe, Kuppeln, Zugbandbögen oder Schalenkonstruktionen.

Abb. 2.3

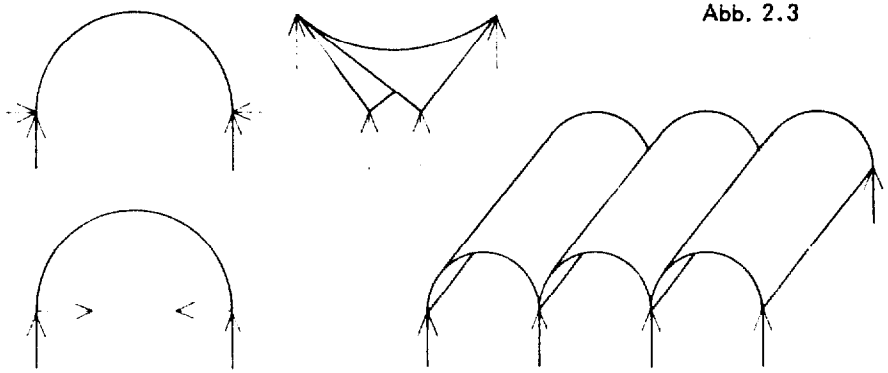

Typische Materialien:

(a. Tragkonstruktionen, b. Dachdeckung, c. Feuchtigkeitsisolierung)

- Stabilisierte Erdblöcke (a, b)
- Ziegel (a, b)
- Stahlbeton/Ferrozement (a, b)
- Holz (a, b)
- Bambus (a)
- Stahl (a)
- Profilmetallplatten (a, b, c)
- Profilasbestzementplatten (a, b, c)
- Faserverstärkte Kunststoffe (a, b, c)
- Verschiedene pflanzliche Baustoffe wie Stroh oder Matten (b)
- Verschiedene Spanplatten/Verbundplatten (b)
- Dachpappe (c)
- Bitumen (c)
- Anstriche (c)

- Water penetration occurs when slope in relation to overlap of decking elements is insufficient.
- Hipped roofs protect all walls (while gabled roofs leave end walls exposed), economize on wall area and cost, provide less obstruction to strong winds, but are more difficult to construct.
- Adjoining gabled roofs with internal horizontal gutters are problematic even with slight inclination: accumulation of dirt preventing passage of water, rapid deterioration of roofing fabric.

2.1.3 Curved Roofs

Structural System: true arches, domes, bow-string or shell structures.

Fig. 2.3

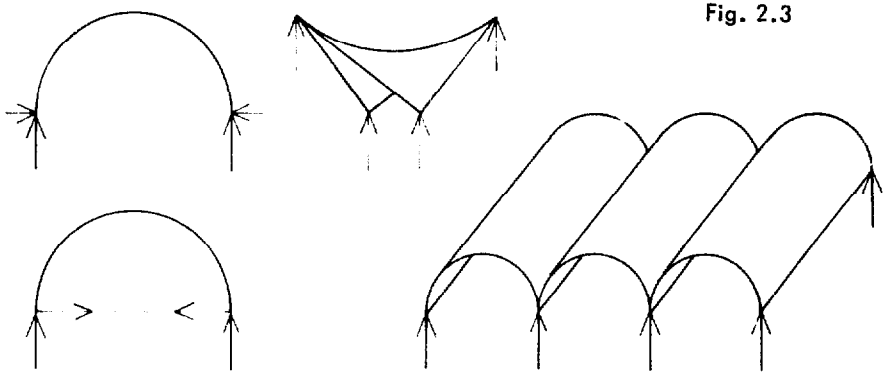

Typical Materials:

(a. Supporting structure, b. Roof decking, c. Waterproofing)

- Stabilized soil blocks (a, b)
- Burnt clay bricks (a, b)
- Reinforced concrete/Ferrocement (a, b)
- Timber (a, b)
- Bamboo (a)
- Steel (a)
- Profiled metal sheets (a, b, c)
- Profiled asbestos cement sheets (a, b, c)
- Fibre reinforced synthetic materials (a, b, c)
- Diverse plant material as thatch or matting (b)
- Diverse composite building boards (b)
- Roofing felt (c)
- Bitumen (c)
- Liquid finishes (c)

Bemerkungen:

- Gemauerte Bögen und Kuppeln sind für Erdbebenzonen höchst ungeeignet, während Zugband-Bögen und Schalenkonstruktionen ideal sein können.
- Schalenkonstruktionen sind normalerweise teuer, da sie meistens fortgeschrittene Technologie und Materialien von hoher Qualität (z.B. Spannbeton) erfordern. Einige Schalenkonstruktionen (z.B. Hartmoltopren-"Iglus" für Notwohnungen) sind schnell aufgebaut und verhältnismäßig billig, aber völlig ungeeignet für Behausungen.

2.1.4 Andere Dacharten

Die drei oben besprochenen prinzipiellen Dacharten umfassen alle gängigen Dacharten des Niedrigkosten-Wohnungsbaus in der Dritten Welt. Es gibt jedoch eine große Anzahl anderer Dachsysteme, welche für Kurzzeit- und Permanentbehausung angewandt werden, welche jedoch zu selten vorkommen, um deren detaillierte Beschreibung zu rechtfertigen.

Beispiele sind:

- Zugkonstruktionen
  die aus einem System von starken Membranen über Kabeln oder Seilen bestehen; große Spannweiten; verhältnismäßig wirtschaftlich, aber aerodynamisch unstabil mit leichter Decke; hauptsächlich für temporäre Bauten angewandt.
- Raumfachwerk-Dächer
  bestehend aus dreidimensionalen, dreieckigen Tragelementen; große horizontale Stabilität; leichte Dachdeckung; komplizierte, teure Bauweise; nur für sehr große Spannweiten geeignet.
- Faltplattendächer
  welche aus einer Serie von gleichen Platten mit geraden, steifen Verbindungen bestehen, deren Stärke in den aussteifenden Falzen, Gegenfalzen und stützenden Querscheiben liegt; geeignet für Vorfertigung; verhältnismäßig neues Bausystem mit unkonventionellen Formen, die eine verbreitete Anwendung bei Wohnungsbauprojekten verhindern.
- Luftgetragene Dächer
  meist kugel-, halbkugel- oder zylinderförmig, die grundlegend aus zwei Typen bestehen: der eine mit höherem internem Luftdruck als der der umgebenden Atmosphäre, und der andere aus aufgeblasenen Rohrelementen, bei dem das Innere nicht unter Druck steht; nur von Interesse für provisorische Unterkünfte oder bei großen Spannweiten; bedarf hochentwickelter Geräte und Technologie; sehr anfällig für Schäden.

Die Liste kann mit unbegrenzten freien Formen und Kombinationen der beschriebenen Dachtypen erweitert werden. Sogenannte "Anti-Dächer", wie z.B. Laubbäume (die im Sommer durch ihre Blätter Schatten spenden und die Sonne im Winter hindurchlassen) sind nur für Außenflächen von Interesse und haben keine Bedeutung für den Niedrigkosten-Wohnungsbau.

Comments:

- Masonry arches and domes are highly inappropriate for earthquake prone regions, while bow-string and shell structures can be ideal.
- Shell structures are usually expensive, since they often involve advanced technology and high quality materials (e.g. prestressed concrete). Some shells (e.g. polyurethane "igloos" for emergency housing) are quickly erected and relatively cheap, but totally unsuited as dwellings.

2.1.4 Other Roof Types

The three basic roof types dealt with above include all common roofs found in third world low-cost housing schemes. There are, however, a great number of other roofing systems, which may have applications in temporary or permanent housing, but are too rare to justify detailed descriptions.

Examples are:

- Tensile roofs
  using a system of tough membranes on cables or ropes; wide spans; relatively economical but aerodynamically unstable with light deck; generally used for temporary structures.
- Space frame roofs
  consisting of three-dimensionally triangulated supporting members; great lateral rigidity; light roof decking; complicated, expensive structure; appropriate only for extremely large spans.
- Folded plate roofs
  which consist of series of equal plates with straight, rigid junctions, deriving their strength from stiffening folds, counterfolds and supporting diaphragms; suitable for prefabrication; relatively new structural system with unconventional forms hindering wider use in housing schemes.
- Air-supported roofs
  usually of spherical, semispherical or cylindrical shapes, comprising basically two types: one having an internal air pressure greater than the ambient atmospheric pressure and one having inflated tubular members and unpressurized interior; only of interest as temporary dwellings or for large spans; requires sophisticated equipment and technology; highly susceptible to damage.

The list can be augmented by unlimited free forms and combinations of the described roof types. So-called "anti-roofs", such as deciduous plants (providing shade by their leaf cover in summer and allowing the sun in during winter) are of interest only for outdoor spaces and have no significant applications in low-cost housing design.

2.2 Gestaltungskriterien des Daches

Es wird generell angenommen, daß der Entwurf von Dächern in einer betreffenden Zone allein durch klimatische Anforderungen bestimmt wird und daß die vorhandenen Materialien die geeignetste Anwendung erfahren. Dies trifft zweifellos zu bei den meisten herkömmlichen Dachtypen, aber, wie Amos Rapoport in seinem Buch "House Form and Culture" darauf hinweist, können ähnliche klimatische Bedingungen und Materialien in verschiedenen geographischen und kulturellen Umgebungen völlig verschiedene Entwurfslösungen hervorbringen, welche gleichermaßen funktional sind. Seine Erklärung: "Die Unterschiede verschiedener Gebäudetypen in verschiedenen Regionen zeugen von Unterschieden in bezug auf vorhandene Kulturen, Rituale, Lebensweisen, Gesellschaftsstrukturen, Klimabedingungen und Landschaften, sowie Materialien und Technologie, während Ähnlichkeiten Bereiche aufzeigen, in denen nicht nur all diese Faktoren zufällig übereinstimmen, sondern auch einige grundlegende Übereinstimmungen in den Bedürfnissen und Wünschen des Menschen."

Demnach ist es klar, daß die Hausform — und somit auch Dachgestaltung — aus höchst komplizierten Entwurfskriterien resultiert, wobei, wie Rapoport meint, soziokulturelle Einflüsse vor den physikalischen Bestimmungsfaktoren rangieren.

Beispiele von sozio-kulturellen Entwurfskriterien sind:
- Religion
- Familien- und Sippenstruktur
- Lebensrhythmus
- Verteidigung
- Bautraditionen
- Zeitdimensionen
- Vermischung von Kulturen
- Einstellung gegenüber der Umwelt
- Mobilität

Diese Kriterien werden zum Teil in Abschnitt 3.1.1 „Örtliche Traditionen", besprochen.

Die Tatsache, daß Mobilität, als eines der wichtigen Entwurfskriterien, weit auseinandergehende Formen hervorgerufen hat (z.B. arabische Zelte, mongolische Yurts, indianische Tipis), zeigt, daß der Dachentwurf nicht einer einzigen Ursache zugeschrieben werden kann.

Die besondere Bedeutung von sozio-kulturellen Faktoren beim Dachentwurf führt oft zu physikalisch unzureichenden Lösungen. Zum Beispiel leben viele Stämme in der Amazonen-Region in großen Gemeinschaftshäusern ("malocas"), welche außerordentlich groß sind und dickwandige Bauweise für Stabilität und Dauerhaftigkeit erfordern, aber als Folge daraus so viel Wärme aufnehmen, so daß sie im Sommer nicht bewohnbar sind. Die wirtschaftlichen Aktivitäten der Hidatsa aus dem Missouri Valley, die im Sommer Bauern und im Winter Büffeljäger waren, lebten während des Sommers in massiven, wärmespeichernden Behausungen und in transportablen Zelten im Winter, obwohl klimatisch das Gegenteil geeigneter wäre.

2.2 Factors Influencing Roof Design

It is generally believed that the design of roofs in a certain region is governed solely by the climatic requirements and makes the most appropriate use of available materials. This is undoubtedly true for most traditional roof designs, but as Amos Rapoport in his book "House Form and Culture" points out, similar climatic conditions and materials in different geographical and cultural settings can generate completely dissimilar design solutions, which are equally functional. His explanation: "The differences between the types of buildings in different areas are evidence of differences in culture, rituals, ways of life, and social organization, climates and landscapes, and materials and technology available, while the similarities are evidence not only of areas where some or all of these factors have coincided, but also of some basic consistancies in man's needs and desires".

Thus it is clear that house form — and consequently roof design — results from a highly complex set of design criteria, whereby, as Rapoport maintains, socio-cultural forces outweigh physical determinants.

Examples of socio-cultural design criteria are:
- religion
- family and clan structure
- occupancy patterns
- defense
- building traditions
- time dimensions
- mixture of cultures
- attitude towards the environment
- mobility

These criteria are discussed to some extent in section 3.1.1 Local Traditions.

The fact that mobility, as one important design criterion, has induced greatly differing forms (e.g. Arab tents, Mongol yurts, Indian tepees) shows that roof design cannot be attributed to a single cause.

The predominance of socio-cultural factors in roof design occasionally lead to physically inadequate solutions. For example, many tribes in the Amazon area live in large communal houses ("malocas"), which are extremely large, requiring massive constructions for stability and durability, but as a result absorb so much heat that they have to be abandoned during the summer. The economic activity of the Hidatsa of the Missouri Valley, who were agriculturalists in summer and buffalo hunters in winter, causes them to live in heavy, heat absorbing dwellings in the hot months and light, transportable tents during the cold season, although climatically the reverse would be appropriate.

The principal physical determinants and requirements are:

- climate
  (exclusion of rain, wind and solar radiation, prevention of excessive heat penetration or entry of cold air, provision of shade for exterior walls and openings),

a. Behausungen aus einem Material (Schilf). Links: Uru-Haus, Titicaca-See, Peru. Rechts: Sumpf-Araber-Haus, Irak-Iran Grenzland.

a. Dwellings made of one material (reeds). Left: Uru dwelling, Lake Titicaca, Peru. Right: Marsh Arab dwelling, Iraq-Iran border.

b. Behausungen aus einem Material (Lehm). Links: Iran. Rechts: Pueblos, Südwest-USA.

b. Dwellings made of one material (mud). Left: Iran. Right: Pueblos, southwestern United States.

c. Transportable Zelte aus Stäben und Filz. Links: Arabisches Zelt. Rechts: Mongolischer Yurt.

c. Portable tents of sticks and felt. Left: Arab tent. Right: Mongol Yurt.

d. Zwei Beispiele aus der breiten Palette traditioneller Hausformen aus Holz mit Strohbedachung. Links: Masai Hütte (Afrika). Rechts: Yagua Haus (Amazonas).

d. Two examples from the great range of house forms using thatch and wood as materials. Left: Masai dwelling (Africa). Right: Yagua dwelling (Amazon).

Abb. 2.4 Vergleich zwischen verschiedenen Hausformen, bei Verwendung gleicher Materialien (aus: Amos Rapoport "House Form and Culture")

Fig. 2.4 Comparison of house forms, using the same materials (taken from: Amos Rapoport "House Form and Culture")

Abb. 2.5 Niedrigkosten-Wohnungsbau in Kolumbien
Fig. 2.5 Low-cost housing in Columbia

Abb. 2.6 Niedrigkosten-Wohnungsbau in Malawi
Fig. 2.6 Low-cost housing in Malawi

Abb. 2.7 Niedrigkosten-Wohnungsbau auf den Philippinen
Fig. 2.7 Low-cost housing in the Philippines

Abb. 2.5 bis 2.7 zeigen jeweils die gleiche Dachform und -konstruktion, trotz der grundsätzlichen sozio-kulturellen Unterschiede zwischen Lateinamerika, Afrika und Ozeanien.

Fig. 2.5 to 2.7 each show the same roof form and construction, despite the basic socio-cultural differences between Latin America, Africa and Oceania.

2.5

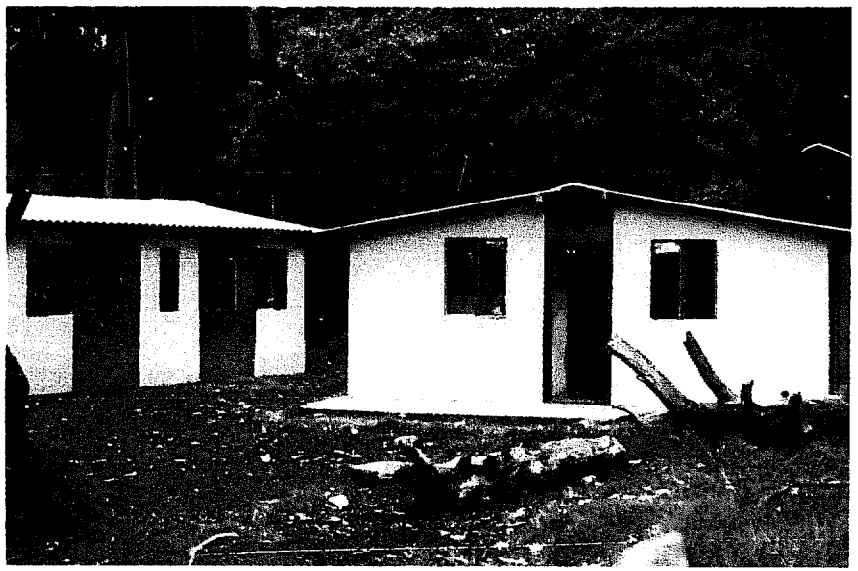

Die wichtigsten physikalischen Bedingungen und Erfordernisse sind:

- Klima
  (Ausschließung von Regen, Wind und Sonne, Verhinderung übermäßiger Wärmeeinwirkung bzw. Eindringen von kalter Luft, Beschattung der äußeren Wände und Öffnungen),
- Umwelt
  (Lärmschutzmaßnahmen, Ausschließung von Schmutz, Staub und fallenden Gegenständen, Schutz vor Einbrechern, Einfügung in die Landschaft),
- natürliche Risiken
  (Fähigkeit, Erdbeben und Wirbelstürmen zu widerstehen, Widerstand gegen und Verhinderung von schneller Feuerausbreitung),
- Materialien
  (Wirtschaftlichkeit, leichtes Handhaben, Errichtung und Instandhaltung, Dauerhaftigkeit, günstige ästhetische Erscheinung),
- Gesundheitsaspekte
  (Verhinderung von feuchten, zugigen und toxischen Bedingungen, Verhinderung von Ungezieferbrutstätten).

Die Bestimmungsfaktoren von Dachentwürfen sind vielfältig, was aber nicht heißt, daß alle relevanten Kriterien für jeden Dachtyp berücksichtigt worden sind, selbst wenn traditionelle Bauweisen über Jahrzehnte hin entwickelt und verfeinert wurden.

2.6

- environment
  (provision of sound insulation, exclusion of dirt, dust and falling objects, provision of no means for intruders to break into building, harmonization with landscape),
- natural hazards
  (capability of withstanding earthquakes and hurricanes, resistance to and prevention of rapid spread of fire),
- materials
  (economy, ease of handling, installation and maintenance, durability, aesthetical acceptability),
- health aspects
  (avoidance of moist, draughty or toxic conditions, no provision of nesting places for vermin).

The determinants of roof design are manyfold, but this does not imply that all relevant factors have been considered in each roof type, even if traditional structures have been developed and refined over centuries. Health aspects generally receive the least attention, as for instance, in New Guinea dirt dropping from thatched roofs cause chronic allergic lung diseases, or in Venezuela primitive house constructions harbour insects carrying "chagos".

It is also important to note, that change of materials does not necessarily alter form.

2.7

3. ENTWURFSÜBERLEGUNGEN

3.1 Örtliche Traditionen und Bauvorschriften

Wie im vorherigen Abschnitt verdeutlicht wurde, müssen technische oder klimatologische Überlegungen für den Entwurf von Dächern in der Wertigkeit hinter denen der örtlichen sozialen und gesellschaftlichen Anforderungen rangieren. Diese Aspekte sind jedoch zu komplex, um sie mit ausreichender Gründlichkeit auf globaler Ebene zu behandeln. Um den Umfang und die Art der Fragen, die daraus hervorgehen, zu zeigen, werden einige der wichtigsten nachfolgend besprochen.

3.1.1 Örtliche Traditionen

In den meisten Fällen werden die Entwurfskriterien für Dachkonstruktionen als selbstverständlich erachtet. Die meisten traditionsorientierten Gesellschaften widersetzen sich jedweder Änderung, und ihr Ziel ist es, nur den Standard der gut gebauten Häuser ihrer Umgebung zu erreichen. Jedoch, da Traditionen ihre Kontinuität verloren haben (durch Mischen von Kulturen, Änderungen in der ökonomischen Struktur, politische Einflüsse und dergleichen), ist die Funktion der Dächer und die Art, in der sie gebaut werden können, so vielfältig, daß nur eine gründliche Überlegung und exakte Definierung der verschiedenen Erfordernisse einen zufriedenstellenden Dachentwurf garantieren.

Funktionen des Daches

a. Soll das Dach, teilweise oder ganz, ein temporäres oder dauerhaftes Bauwerk sein?
Temporäre Dächer können im Falle von Beschattungselementen, Öffnungen (als Eingang oder Rauchabzug oder für Luft und Licht) und transportablen Gebäuden nötig sein.

b. Was soll das Dach schützen: Menschen, Tiere oder Güter?
Welche Aktivitäten sollen unter dem Dach stattfinden?

Beispiele von Aktivitäten, die die Dachkonstruktion beeinflussen können, sind:

- Lebensweisen im Zusammenhang mit, zum Beispiel, Schlafen, Lesen, Unterhalten, Spielen, Musikhören, Gäste empfangen, Kranke betreuen, Beten, welches Aktivitäten sind, die thermalen Komfort sowie optische und akustische Intimität verlangen;
- Arbeit, wie Handwerk, Kleinindustrie, d.h. sowohl manuelle wie auch nichtmanuelle Tätigkeiten, die alle genügend Licht und thermalen Komfort benötigen;
- Kochen, mit oder ohne offenem Feuer, bedarf guter Ventilation und Öffnungen im Dach oder Schornstein;
- Baden, Waschen, Gartenbau oder andere Tätigkeiten, die Feuchtigkeit erzeugen, der aber durch wirkungsvollen Gebäude- und Dachentwurf entgegengewirkt werden muß;

3. DESIGN CONSIDERATIONS

3.1 Local Traditions and Codes

As is evident from the previous section, technical or climatological considerations in designing roofs must give precedence to those of local social and communal requirements. These aspects are, however, too complex to deal with in sufficient depth on a global scale. But in order to show the extent and nature of the questions that arise, some of the important ones are discussed below.

3.1.1 Local Traditions

Much of the information required for the roof design is taken for granted. Most tradition oriented societies strongly resist change and their aim is merely to achieve the standards of the well built houses of the area. However, since traditions have lost their continuity (on account of mixture of cultures, changed economic structures, political influences and the like), the functions of roofs and the ways they can be built are so numerous, that only a thorough consideration and exact definition of the various requirements can guarantee a satisfactory roof design.

Functions of the Roof

a. Is the roof, partly or as a whole, meant to be a temporary or permanent structure?

Temporary roof structures could be necessary in the case of sun shades, openings (for access, light, air or release of smoke) and temporary or portable buildings.

b. What is the roof intended to provide shelter for: people, livestock or goods?
What activities are expected to take place under the roof?

Examples of activities that may be influenced by the roof construction are:

- living patterns involving, for instance, sleeping, reading, talking, playing, listening to music, receiving guests, nursing the sick, praying, which are activities requiring thermal comfort as well as optical and acoustic privacy;
- work, such as handicrafts, small-scale industry, i.e. manual as well as nonmanual labour, all of which require sufficient light and thermal comfort;
- cooking, with or without open fires, calling for good ventilation and openings in the roof or chimney;
- bathing, washing, horticulture or other activities creating moist conditions, which must be remedied by efficient building and roof design;
- storage of goods, whether edible or not, normally requiring cool, dark and dry conditions;

- Lagern von Gütern, ob eßbar oder nicht, erfordert normalerweise kühle, dunkle und trockene Bedingungen;
- Tierhaltung, wofür Luft und Licht besonders wichtig sind.

Nichtbeachtung einer dieser Aktivitäten mit der Begründung, daß sie verboten sei, oder weil die Menschen zur Änderung ihrer Gewohnheiten angehalten werden sollen, würde wahrscheinlich negative Konsequenzen haben, wenn zum Beispiel Aktivitäten unter dem Dach wegen übermäßiger Aufheizung unmöglich werden, offene Feuer unter brennbaren Dächern angezündet werden oder gelagerte Nahrung durch tropfendes Kondenswasser verdorben wird.

c. Für welche Zwecke — außer der Schutzfunktion — wird das Dach sonst noch genutzt?

Beispiele für mögliche Nutzung sind:

- Zugang zum Haus (wie in den pueblos von Neu-Mexiko),
- Schlafen bei Nacht (wie in den meisten trocken-heißen Zonen),
- Umleitung von Wind für Ventilation (wie in vielen Ländern des Mittleren Ostens),
- Einsammeln von Regenwasser,
- Speicherung von Wasser, Nahrung und anderen Dingen,
- Trocknen von Nahrungsmitteln,
- Getreideworfeln,
- Gartenarbeit,
- Installation von Solardestilliergeräten oder Solarwarmwasserbereitern,
- oder einfach Repräsentation (je nach Hierarchischem Status des Bewohners).

d. Für welche Lebensspanne sollte ein Dach entworfen werden?

Dies hängt im allgemeinen von der Lebenserwartung des restlichen Gebäudes und der Einstellung des Bewohners zu Instandhaltung und Reparaturen ab, sowie von seiner Geschicklichkeit. Sehr oft hängt es auch vom Alter des Bewohners ab, besonders dort, wo es Brauch ist, das Haus nach seinem Tod abzureißen.

e. Welche religiösen und sozialen Aspekte beeinflussen Dachentwürfe?

Kosmische Orientierung kann mancherorts eine der baulichen Voraussetzungen sein (ein rundes Haus kann nicht orientiert werden), während anderswo dimensionale Erfordernisse berücksichtigt werden müssen (z.B. große Familien oder selbst ganze Dorfgemeinden — wie in Ozeanien — leben unter einem Dach) ebenso wie Einstellungen zu Formen, Materialien und Farben (z.B. ist der Kreis die perfekte Form für die Hottentotten, in Zentralamerika werden Asbestzementdächer rot gestrichen, um die herkömmlichen roten Ziegel nachzuahmen). In gewissen Kulturen stehen die Größen der Dachbalken und des Daches im entsprechenden Verhältnis zu ihrer Funktion als Statussymbol, während in anderen der Dekoration der Wände und Eingangstüren größere Bedeutung beigemessen wird.

- livestock keeping, for which air and light are especially important.

Disregard of any of these activities on the grounds that it is prohibited or that the people should alter their habits, would most likely have negative consequences, when, for example, activities under the roof become impossible due to overheating, open fires are lit under inflammable roofs or stored food is ruined by dripping water due to condensation.

c. Besides providing shelter, to what uses will the roof itself be put?

Examples of possible uses are:

- access to the house (as in pueblos of New Mexico),
- sleeping at nights (as in most hot arid regions),
- catching wind for ventilation (as in many countries of the Middle East),
- collection of rainwater,
- storage of water, food or other items,
- drying food,
- winnowing grain,
- gardening,
- installation of solar stills or solar water heaters,
- or just representation (in accordance with the heirachial status of the dweller).

d. For what life expectancy should the roof be designed?

This normally depends on the life expectancy of the rest of the building and the attitude of the dwellers towards maintenance and repair, as well as their skills. Quite often it also depends on the age of the dweller, especially in places where it is customary to demolish the house after his or her death.

e. What religious or social aspects are associated with local roof designs?

There may be a necessity for cosmic orientation (a round house cannot be oriented), while consideration must be given to dimensional requirements (e.g. large families or even entire village communities — as in Oceania — live under one roof) and to attitudes towards shapes, materials and colours (e.g. for the Hottentots the circle is the perfect form, in Central America asbestos cement roofs are coloured red to copy the traditional clay tiles). In certain cultures the sizes of roof beams and roofs are related to their function as a status symbol, while in others more importance is given to the decoration of walls and entrance doors.

3.1.2 Bauvorschriften

In allen älteren Kulturen war Tradition der hauptsächliche Regulator für Entwurf und Konstruktion von Häusern. Das Errichten von Gebäuden verlangte wenig Fachkenntnisse, konnte schnell erlernt und von den Bewohnern selbst ausgeführt werden. Heute jedoch ist die Tradition als Regulator in den wenigsten Gesellschaften noch vorhanden. Amos Rapoport gibt hierfür drei Gründe:

- die steigende Anzahl von Bautypen, wovon viele zu kompliziert sind, um sie in traditioneller Weise zu bauen,
- Verlust gemeinsamer Werte und Weltanschauungen,
- und die Tatsache, daß diese Gesellschaften Originalität belohnen.

Der resultierende Mangel an Kopperation erfordert die Einführung von Gesetzen, Regeln und ähnlichen Einschränkungen, die in Art und Umfang von Ort zu Ort verschieden sind, ebenso wie die Durchsetzung dieser Maßnahmen.

Entwurfskriterien für Dächer, wie sie von örtlichen Behörden vorgeschrieben werden, beziehen sich beispielsweise auf:

- Form, Neigung und Dimensionen, welche mit der Umgebung harmonieren müssen,
- Dachrinnen, die verboten sind, um das Ansammeln von Schmutz und stehendem Wasser zu verhindern,
- Gebrauch von brennbaren Materialien und Abstände von Gebäuden, um die Feuergefahr auf einem Minimum zu halten.

3.2 Klimatische Anforderungen

Die Tropen, welche als die Zone zwischen den 20° Isothermen definiert sind, bestehen aus einer Anzahl von Klimata, je nach Lage (Entfernung von großen Wassermassen, Entfernung vom Äquator, Höhenlage), Topographie, Geologie, Vegetation und ähnlichen Faktoren. Die Kompliziertheit der klimatischen Einflüsse auf Bauwerke erlaubt keine detaillierte Diskussion in diesem Zusammenhang, zumal dieses Thema in anderen Publikationen ausreichend behandelt wurde. Da Klimata in den Tropen in zwei Hauptgruppen geteilt werden können, nämlich solche, die überwiegend feucht und solche, die überwiegend trocken sind, wird es ferner ausreichen, die Entwurfserfordernisse dieser beiden Gruppen zusammenzufassen, ohne dabei zu vergessen, daß dies nur allgemeine Richtlinien sein können. Modifikationen der genannten Entwurfsprinzipien werden für die meisten Situationen nötig sein, da Mischklimata eher die Regel sind.

3.2.1 Dächer für feuchtwarmes Klima

Klimamerkmale

Temperatur : Durchschnittliches Maximum um 27° bis 32°C, durchschnittliches Minimum um 20° bis 27°C. Geringe tägliche und jährliche Temperaturvariationen in konstant feuchtwarmen Zonen, bei ausgeprägten jahreszeitlichen Unterschieden, jedoch zunehmend.

3.1.2 Building Codes

In all older cultures tradition was the major regulator in the design and construction of houses. The erection of buildings required few skills, were easy to grasp and could be carried out by the dwellers themselves. Today, however, tradition as a regulator has disappeared in most societies. Amos Rapoport gives three reasons for this:

- the increasing number of building types, many of which are too complex to build in traditional fashion,
- loss of common shared values and images of the world,
- and the fact that these societies put a premium on originality.

The resulting lack of cooperation necessitates the introduction of codes, regulations and similar restrictions, the nature and extent of which vary from place to place, just as much as their enforcement policies do.

Examples of criteria for roof designs as prescribed by the local authorities, may refer to:

- shape, slope and dimensions, which must harmonize with the surroundings,
- gutters, which are prohibited to prevent accumulation of dirt and standing water,
- use of inflammable materials and spacing of structures, with a view to minimizing fire risks.

3.2 Climatic Requirements

The tropics, which are defined as the area between the 20° isotherms, comprise a variety of climates, depending on location (distance from large water masses, distance from Equator, altitude), topography, geology, vegetation and similar factors. The complexity of climatological influences on building constructions forbid a detailed discussion in this context, as the subject has been amply dealt with elsewhere. Furthermore, since climates in the tropics can be divided into two major groups, namely those that are predominantly humid and those predominantly dry, it will suffice to summarize the design requirements of these two groups, keeping in mind that these can only be basic guidelines. Modifications of the given design principles will be necessary for most situations, since composite climates are more common.

3.2.1 Roofs for Warm Humid Climates

Characteristics of Climate

Temperature : Mean maximum about 27° to 32°C, mean minimum about 20° to 27°C. Little diurnal and annual temperature variations in consistently warm humid regions, increasing as seasonal changes become more distinct.

Feuchtigkeit : Relative Feuchtigkeit zwischen 55 und 100%, aber meistens über 75%, Dampfdruck liegt zwischen 2000 und 3000 N/m^2. Schwere Wolkendecke und Feuchtigkeitsgehalt der Atmosphäre dienen als Filter für direkte Sonneneinstrahlung.

Niederschlag : Kann zu jeder Zeit vorkommen oder jahreszeitlich im Mischklima. Jährliche Regenmenge 2000 bis 5000 mm, aber weniger als 2000 mm in Mischklimata.

Wind : Hauptsächlich niedrige Geschwindigkeiten, nur eine oder zwei Hauptrichtungen, häufig windstille Perioden. Monsunwinde meistens stark und beständig.

Vegetation : Reichlich, schnellwachsend durch häufigen Regenfall, hohen Grundwasserspiegel und warme Bedingungen. In gemischtem Klima viel weniger Vegetation, mit schnellem Wachstum nur während der Regenzeit.

Besonderheiten : Ständige Gefahr von Schimmel- und Algenwuchs, Rost und Fäule. Große Insektenplage und entsprechende Gefahr für organische Baumaterialien. Dichte Wolkendecke und Luftfeuchtigkeit verursachen schmerzhafte Blendung. In gemischtem Klima verursachen jahreszeitliche Veränderungen der relativen Feuchtigkeit Schwächung von Baumaterial, Kondensationsprobleme, Gefahr von Bodenerosion während des Monsuns, Staub- und Sandstürme während der Trockenzeit.

Allgemeine Entwurfsprinzipien

Orientierung : Bestimmt durch zwei primäre Anforderungen:
1) Einfangen von maximaler Luftbewegung
2) Minimale Sonneneinstrahlung auf Wände (erreicht durch Ausrichtung der Gebäudelängsachse in Ost-West-Richtung). Orientierung für Luftbewegung sollte Vorrang haben, da Sonnenstrahlen leicht durch Beschattungsvorrichtungen abgehalten werden können.

Abstände : Weite Abstände für maximale Luftzirkulation.

Grundriß : Gebäude in Windrichtung ein Raum tief für maximale Querlüftung. Häuser mit Innenhof für gemischtes Klima geeignet.

Öffnungen : Groß, 40 - 80% der Wandoberfläche, geschützt vor Sonne und Regen. Kleinere Öffnungen in gemischtem Klima.

Wände : Leicht, mit geringer Wärmekapazität, geschützt vor Sonne und Regen. In gemischtem Klima problematisch, wo kältere Jahreszeiten höhere Wärmekapazitäten erfordern.

Oberflächen : Maximale Reflexion.

Humidity : Relative humidity between 55 and 100%, but generally above 75%. Vapour pressures lie in the region of 2000 - 3000 N/m^2. Heavy cloud cover and vapour content of the atmosphere act as filter to direct solar radiation.

Precipitation : May occur any time of the year or seasonally in composite climates. Annual rainfall 2000 to 5000 mm, but less than 2000 mm in composite climates.

Wind : Generally low velocities, only one or two dominant directions, frequent calm periods. Monsoon winds usually strong and steady.

Vegetation : Abundant, growing quickly due to frequent rains, high subsoil water tables and warm conditions. In composite climates far less vegetation, with rapid growth only during rainy seasons.

Special Features : Constant risk of mould and algal growth, rusting and rotting. Insects constitute large nuisance factor and hazard to organic building materials. Dense clouds and atmospheric vapour cause painful sky glare. In composite climates, seasonal changes in relative humidity cause weakening of building materials, condensation problems occur, risk of soil erosion during monsoons, dust and sand storms in dry seasons.

General Design Principles

Orientation : Determined by two prime requirements:
1) to catch maximum air movement,
2) to minimise exposure of walls to solar radiation (achieved by placing building lengthwise in east-west direction). Orientation for air movement should have priority, since solar radiation is easily eliminated by shading devices.

Spacing : Wide for maximum unobstructed air circulation.

Plan : Rooms single banked in the direction of prevailing wind for maximum cross-ventilation. Courtyard buildings suitable for composite climates.

Openings : Large, 40 - 80% of wall surface, protected against sun and rain. Smaller openings in composite climates.

Walls : Light with low heat capacity, protected from sun and rain. Problems in composite climates, where colder seasons call for high heat capacity.

Surfaces : Maximum reflectivity.

Dachentwurf

Gestalt : - Geneigt für schnellen Wasserablauf, Neigungswinkel mit der Wasserdurchlässigkeit der Dachhaut zunehmend.

- Traufe weit überhängend, um Regenwasserabfluß in ausreichender Entfernung auch vom unteren Wandbereich zu gewährleisten und um Wände und Öffnungen zu beschatten.
- Vermeidung von waagerechten Dachkehlen und internen Dachrinnen, in denen sich Schmutz und Wasser ansammeln können.
- In Misch- und Hochlandklimata mit warmen, trockenen Jahreszeiten gut entwässerte flache Dächer zum Schlafen unter freiem Himmel und für andere Aktivitäten eventuell erwünscht.

Konstruktion : - Leicht, mit niedriger Wärmekapazität (sowohl tragende Teile als auch Dachhaut), um Wärmeentwicklung zu verhindern, welche nicht über Nacht abgegeben werden kann, da kein Temperaturrückgang.

- Luftraum zwischen Dachschichten zur Verminderung von Wärmeübertragung ins Innere, könnte aber Kondensationsprobleme hervorrufen, wenn die unteren Schichten undurchlässig sind und der Luftraum erheblich unter die Innentemperatur sinkt.
- Öffnungen unterhalb des Daches oder abgehängter Decken notwendig, um angestaute Wärme abzuführen.
- Ventilationsöffnungen und Dachhohlräume gegen Eindringen von Vögeln, Nagetieren und größeren Insekten abgesichert (z.B. durch Maschendraht), jedoch Vorsicht geboten, um Luftdurchzug nicht zu beeinträchtigen.
- Sorgfältige Wasserabdichtung aller Dachanschlüsse sowie Maßnahmen für Schallabsorption, um Lecken und unerträgliche Geräusche während tropischer Regenfälle zu verhindern.
- Bewegungsfugen an Bauwerken mit mehr als 25 m Länge, um Wärme-, Feuchtigkeits- und Setzungsbewegungen zu erlauben.
- Reflektierende Oberflächen reduzieren Wärmelast und Wärmebewegungen.
- Im Misch- und Hochlandklima schattenspendende Teile von Dächern abnehmbar, um die Sonne während der kalten Jahreszeit durchzulassen.
- Ausreichende Festigkeit, um das Gewicht der Bewohner, die auf dem Dach schlafen, zu tragen.

Materialien : - Keine idealen Materialien, da Anforderungen zu vielfältig, um von einem einzigen Material erfüllt zu werden, daher Kompromisse erforderlich.

Roof Design

Form : - Sloped for rapid run-off of rainwater, angle of slope increasing with permeability of roofing material.

- Wide overhanging eaves to throw rainwater well away from base of walls and provide shading of walls and openings.
- Avoidance of horizontal valleys and internal gutters, in which dirt and water can accumulate.
- In composite or upland climates with warm dry seasons, flat roofs with good drainage possibly desirable for outdoor sleeping and other activities.

Construction : - Lightweight, low thermal capacity structures (both supporting structures and covering) to avoid heat build up which cannot be dissipated at night, since there is no temperature drop.

- Provision of air space between roof layers can minimize heat transmission to interior considerably, but may create condensation problems, if lower layer is impermeable and air space cools well below temperature of interior.
- Openings below roof or suspended ceiling necessary to discharge accumulated heat.
- Ventilation openings and roof cavities protected against birds, rodents and large insects by means of screens (e.g. wire mesh), taking care not to hamper air flow substantially.
- Careful waterproofing of all roof junctions as well as measures for sound absorption to avoid leakage and unbearable noise during tropical downpours.
- Movement joints on buildings exceeding 25 m length to permit thermal, moisture and deflection movements.
- Reflective surfaces to reduce heat load and thermal movements.
- In composite and upland climates, parts of roofs functioning as sun shades made removable to facilitate exposure to sun during cold seasons.
- Sufficient strength to support weight of occupants using roof for sleeping.

Materials : - No ideal material exists, since requirements are too diverse to be fulfilled by a single material, hence compromises are necessary.

- Primary requirements for roofing materials: low thermal capacity; resistance to rain penetration, yet permeable enough to absorb moisture (e.g. water vapour, condensation) and release it when air is drier; resistance to fungus, insects, rodents and ultraviolet

- Hauptsächliche Erfordernisse für Dachmaterialien: niedrige Wärmekapazität, jedoch durchlässig genug, um Feuchtigkeit aufzunehmen (z.B. Wasserdampf, Kondensation) und sie wieder freizugeben, wenn die Luft trockener ist; Resistenz gegen Pilzbefall, Insekten, Nagetiere und ultraviolette Strahlen; reflektierend; widerstandsfähig gegen Einschlag (Hagel, fallende Kokosnüsse und Steine, usw.); unempfindlich gegen Temperatur- und Feuchtigkeitsschwankungen; frei von Gerüchen und Dämpfen.
- Gebrauch von Dämmstoffen, um Sonnenwärmedurchgang abzuhalten, immer noch fraglich. Hauptargument dagegen: Beeinträchtigung der Wärmeabgabe des Daches während der Nacht, dadurch Unbehaglichkeit der Bewohner und Bildung von Kondenswasser an der Unterseite der Isolierung durch Temperaturunterschiede auf beiden Seiten.
- Wirksamer Wärmeschutz durch Beschattung und richtige Anwendung von reflektierenden Materialien (z.B. Aluminiumfolie auf der Oberseite von abgehängten Decken).
- Feuchtigkeitssperren nicht geeignet, da Wasserdampf nicht entweichen kann und Kondensation verursacht.

3.2.2 Dächer für trockenheißes Klima

Klimamerkmale

Temperatur : Durchschnittliches Maximum 43° bis 49°C während warmer Jahreszeit, 27° bis 32°C während kalter Jahreszeit, und entsprechendes durchschnittliches Minimum von 24° bis 30° und 10° bis 18°C. Große tägliche und jährliche Temperaturschwankungen, aber tiefere Temperaturen und geringere Schwankung in Küstengebieten.

Feuchtigkeit : Sehr niedrige relative Feuchtigkeit, von 10 bis 55% schwankend und bis 90% in Küstennähe steigend; entsprechender Dampfdruck zwischen 500 und 2000 N/m^2.

Niederschlag : Jahresmenge niedrig, meistens weniger als 250 mm, mit unregelmäßigen Schauern über das ganze Jahr. In manchen Gebieten mehrere Jahre kein Regen.

Wind : Heiße Winde, die Sand und Staub tragen, örtlich auftretend, oft als Wirbelwinde. Richtung der Küstenwinde: Meer zu Land während des Tages, Land zu Meer während der Nacht.

Vegetation : Spärlich, trotz fruchtbaren Bodens, durch Regenmangel und niedrigen Grundwasserspiegel.

Besonderheiten : Fehlen von Wolken erlaubt intensive direkte Sonneneinstrahlung während des Tages und schnelle Wärmeabgabe nach Sonnenuntergang. Intensive Blendung und Hitze, hervorgerufen durch Sonnen-

radiation; reflectivity; resistance to impact (hail, dropping coconuts, falling stones, etc.); resistance to temperature and moisture fluctuations; freedom from odours and fumes.

- Use of insulating materials to intercept solar heat penetration still disputable. Main argument against them: interference of cooling action of roof during nights, causing discomfort for occupants and inducing condensation on underside of insulation, due to temperature difference on either side.
- Elimination of heat more effective by shading and proper use of reflective materials (e.g. aluminium foil on upper surface of suspended ceiling).
- Waterproofing membranes unsuitable, since water vapour cannot escape and causes condensation.

3.2.2 Roofs for Hot Dry Climates

Characteristics of Climate

Temperature : Mean maximum in hot season 43° to 49°C, in cold season 27° to 32°C, and corresponding mean minimum 24° to 30° C and 10° to 18° C. Large diurnal and annual temperature variations, but lower temperatures and less variations in coastal regions.

Humidity : Very low relative humidity varying from 10 to 55% increasing to 90% near the coast, corresponding vapour pressure ranging between 500 and 2000 N/m^2.

Precipitation : Low annual total, usually less than 250 mm, with irregular showers throughout the year. No rain in some region for several years.

Wind : Hot winds, carrying sand and dust, occurring locally, often as whirlwinds. Direction of coastal winds: sea to land during the day, land to sea during the night.

Vegetation : Sparse, in spite of fertile soil, due to lack of rain and low subsoil water table.

Special Features : Absence of clouds permits intense, direct solar radiation during the day and rapid dissipation of accumulated heat after sunset. Intense glare and heat caused by reflection of sunlight on light coloured, dry ground. Additional structural loads and abrasion of materials

Abb. 3.1
Traditionelle Bauweise für feucht-warmes Klima (Philippinen)

Fig. 3.1
Traditional design for warm-humid climate (Philippines)

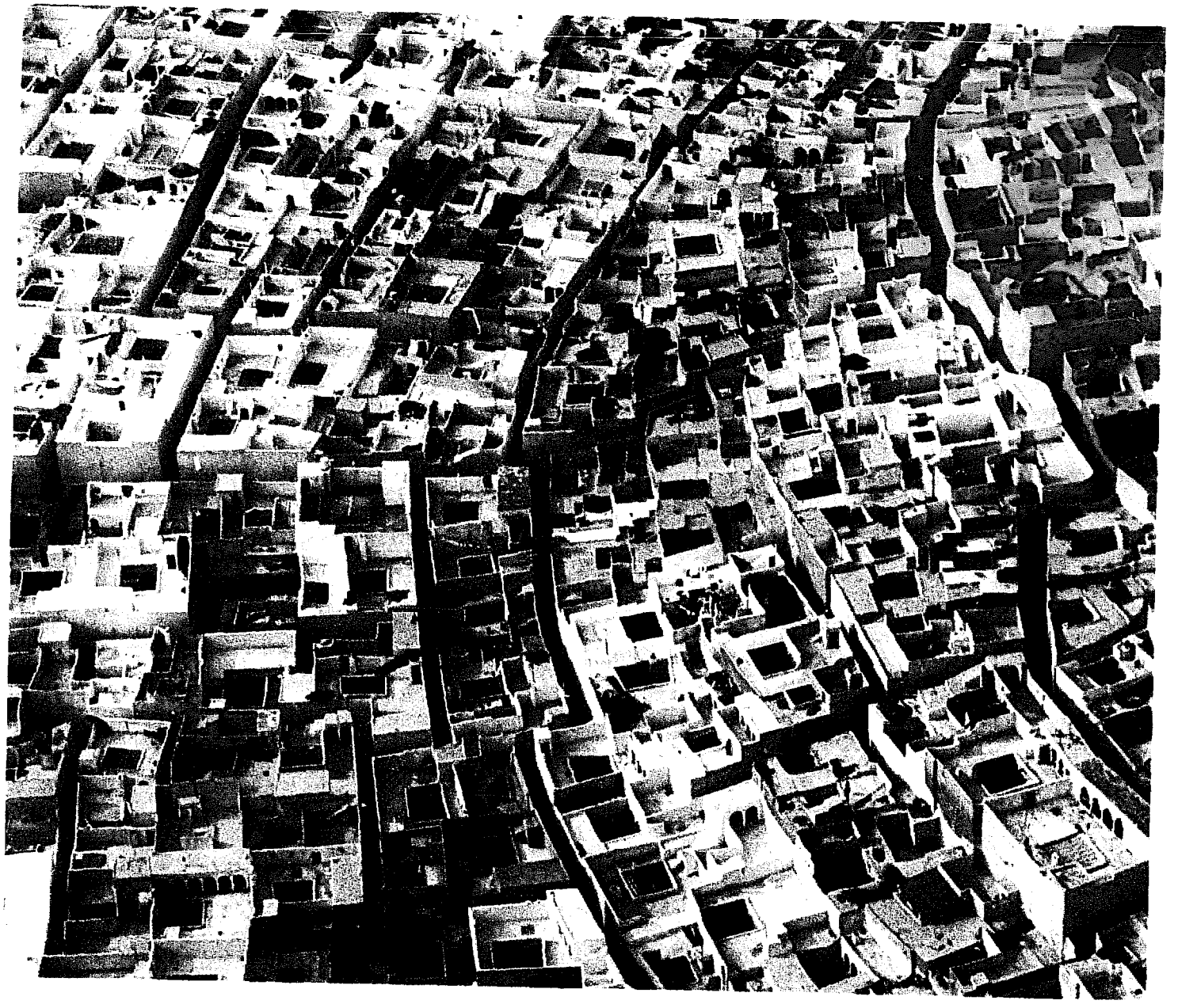

Abb. 3.2
Traditionelle Bauweise für trockenheißes Klima (Algerien).

Fig. 3.2
Traditional design for hot-dry climate (Algeria).

QUELLE/SOURCE:
Bauwelt 23/1976
"Wüstenstadt im M'Zab"

Luft, die damit in Kontakt kommt, abkühlt und zum Innenhof hin fällt, somit Kühlung angrenzender Räume;
2) Leichtes Einsammeln von Regenwasser, auch Verbesserung des Innenraumklimas.

- Windschaufeln, Türme mit Öffnungen zur Hauptrichtung des Windes zur Ableitung höher vorkommender Brisen in das Gebäude.

Konstruktion : - Vorwiegend schwere Konstruktionen mit hoher Wärmekapazität (wie für Wände), aber nicht für Erdbebenzonen geeignet.

- Zweischalige, leichte Dächer mit ausreichendem Hohlraum, um heiße Luft entweichen zu lassen.

- Äußere Schicht des Doppeldaches vorzugsweise mit Wärme-Isolierung, obere Flächen beider Schichten reflektierend.

- Für äußere Bereiche luftdurchlässige Dächer mit niedriger Wärmekapazität für Beschattung, jedoch ohne heiße aufsteigende Luft zurückzuhalten.

- In wasserreichen Gebieten Nutzung von Verdunstungskühlung durch Wasserflächen oder Sprühanlage auf dem Dach. Nachteile: Entstehung von Moskitobrutplätzen im Wasser, hohe Kosten für Sprühvorrichtungen.

- Geringe Gefahr von Schwitzwasserbildung, keine Dampfsperren nötig.

- Konstruktion ausreichend stark, um Gewicht der Bewohner auf dem Dach zu tragen.

- In Zonen mit extremen Temperaturschwankungen Bewegungsfugen alle 25 m erforderlich, die vorzugsweise ganze Teile des Gebäudes voneinander trennen. Reduzierte Wärmebewegungen durch Reflexion der Sonnenstrahlung und Beschattung.

Materialien : - Entweder Materialien mit hoher Wärmekapazität sowie äußere Isolierungsschicht, um die Wärmelast auf einem Minimum zu halten,

- oder zwei durch Luft getrennte Schichten niedriger Wärmekapazität, wobei die äußere oder beide aus Wärme-Isolierung bestehen.

- Wegen intensiver Sonneneinstrahlung höchstmögliche Reflexion der äußeren Oberflächen aller Schichten.

- Mit Rücksicht auf Dauerhaftigkeit sollte bedacht werden:
1) intensive Sonnenbestrahlung, gefolgt von schneller Abkühlung, macht Materialien spröde;
2) fliegender Sand und Staub verursacht Abrieb und Trübung der reflektierenden Oberflächen.

2) rainwater can be collected more easily, also improving indoor climate.

- Wind catchers, towers with openings facing main direction of wind, to redirect higher level breezes into building.

Construction : - Generally heavy, high thermal capacity structures (as for walls), but unsafe in earthquake zones.

- Double layered lightweight roofs with sufficient air space to dissipate hot air.

- Outer layer of double roof preferably with insulating material, upper surfaces of both layers reflective.

- For outdoor areas, permeable screen covers of low thermal capacity to give shade but allow rising hot air to escape.

- Where water is plentiful, pools of water or roof sprays provide cooling by evaporation. Disadvantage: risk of mosquito breeding in pools, high cost for spraying devices.

- Little risk of condensation, no vapour barriers required.

- Sufficient strength of structure to support weight of occupants frequenting roof.

- In regions with extreme temperature fluctuations, movement joints required every 25 m, preferably separating complete sections of buildings. Reduction of thermal movement by reflection of radiation and shading.

Materials : - Either high thermal capacity materials with external layer of insulation to minimize heat load,

- or two layers with low thermal capacity, and outer or both layers of heat resisting materials.

- Because of intense solar radiation, maximum possible reflectivity of outer surfaces of all layers.

- Considerations of durability should take into account:
1) intense solar radiation followed by rapid cooling, causing embrittlement of materials,
2) windblown sand and dust causing abrasion and dulling of reflective surfaces.

reflexion auf hellem, trockenem Boden. Zusätzliche Traglast und Abrieb von Materialien durch Staub und Sand. Schnelle Temperaturwechsel verursachen Schwächung und Zerfall von Materialien. Salzhaltige Luft beschleunigt Korrosion in Küstengebieten.

Allgemeine Entwurfsprinzipien

Orientierung : Bestimmt durch zwei primäre Anforderungen:
1) Ausschließen von heißer Luft, Sand und Staub
2) Reduzierung der Sonneneinstrahlung auf Außenflächen (erreicht durch Ausrichtung der größten Gebäudeflächen nach Norden oder Süden).

Abstände : Kompakte Anordnung der Gebäude, vorzugsweise mit Ost- und West-Wänden nahe beieinander, zur gegenseitigen Beschattung. Vermeidung von langen, geraden Straßen, um Durchzug von heißen Sandstürmen zu verhindern.

Grundriß : Nach innen gerichtet, mit der kleinstmöglichen Sonnenaussetzung. Kleine Innenhöfe (Breite weniger als Höhe) mit Wasser und Pflanzen zur Kühlung des Innenbereichs.

Öffnungen : Klein, 20 - 40% der Wandflächen, dicht unterhalb der Decke, gut beschattet. Idealerweise während des Tages geschlossen und während der Nacht geöffnet, obwohl aus Gründen der Intimität und Sicherheit schwierig durchzuführen.

Wände : Schwer, mit hoher Wärmekapazität und Phasenverschiebung von 9 - 12 Stunden, um Wärmedurchgang ins Innere bis zu den kühlen Stunden vor der Dämmerung zu verzögern und zur Erhaltung kühler Bedingungen im Inneren während Sonnenscheinperioden.

Oberflächen : Maximal reflektierend; glatte Oberflächen, um Ansammeln von Sand und Staub zu verhindern.

Dachentwurf

Gestalt : - Meistens flach, da Regenentwässerung kein Haupterfordernis ist, auch um Schlafen und andere Aktivitäten auf dem Dach zu ermöglichen.

- Gewölbe- und kuppelförmige Dächer sind auch häufig in heißen trockenen Klimata: gerundete Oberflächen verteilen Einstrahlung der hochstehenden Sonne, da Dachfläche größer als die Grundfläche, dadurch Reduzierung der Oberflächentemperaturen und Erleichterung der nächtlichen Rückstrahlung der Wärme.

- Dächer von Innenhofhäusern nach innen geneigt:
1) bei gut entworfenen und erhaltenen Dächern (gute Reflexion) nächtliche Abkühlung unter die umgebende Temperatur, so daß

due to dust and sand. Rapid temperature changes cause weakening and failure of building materials. Salt laden air in coastal areas accelerates corrosion.

General Design Principles

Orientation : Determined by two prime requirements:
1) to exclude hot air, sand and dust
2) to minimise exposure to solar radiation (achieved by facing larger dimensions of building towards north or south).

Spacing : Compact alignment of buildings, preferably placing east and west walls close together for mutual shading. Avoidance of long straight roads to check passage of hot sand storms.

Plan : Introverted, with smallest possible exposure to sun. Provision of small courtyards (width less than height) with water and plants for cool interiors.

Openings : Small, 20 - 40% of wall surface, placed close to ceiling, well shaded. Ideally, closed during day and opened at night, though difficult to implement for reasons of privacy and security.

Walls : Heavy, with high thermal capacity, and time-lag of 9 to 12 hours, to delay emission of heat to interior until cold pre dawn hours, and to retain cool conditions within during period of sunshine.

Surfaces : Maximum reflectivity, smooth surfaces to prevent collection of sand and dust.

Roof Design

Form : - Usually flat, since rainwater run-off is no major requirement, also to facilitate sleeping and other activities on roof.

- Vault and dome shaped roofs also common in hot dry climates: curved surface area, being considerably larger than base, distributes radiation of high sun, thus lowering surface temperatures and facilitating nocturnal reradiation.

- Roofs of courtyard houses sloping inwards:
1) well designed and maintained roofs (good reflection) cool below ambient temperature at night, so that air in contact with it cools and drops towards courtyard, cooling adjoining rooms;

Abb. 3.3
Traditionelle Bauweise für Hochlandklima (Guatemala).

Fig. 3.3
Traditional design for highland climate (Guatemala).

3.3 Schutz gegen Gefahren

Die Gefahren und deren jeweilige Schutzmaßnahmen in diesem Teil sind nur solche, die in Verbindung mit Dachkonstruktionen stehen. Es muß betont werden, daß sie generell im Zusammenhang mit der Konstruktion des übrigen Gebäudes gesehen werden müssen, wie stellenweise, wo erforderlich, darauf hingewiesen wird. Da sich die nachfolgend besprochenen Gefahren nicht auf bestimmte Klimazonen beziehen, werden diese nicht ausdrücklich erwähnt.

3.3.1 Biologische Schädlinge

Diese sind Insekten (Termiten, Bohrkäfer, Fliegen, Moskitos, usw.), Tiere (Ratten, Fledermäuse, Vögel, Schlangen, usw.) und Pilze.

Probleme

Auf Dächern nistende oder brütende Insekten können Gesundheitsrisiken (krankheittragende Moskitos und Fliegen) oder einfach eine Belästigung für die Bewohner des Gebäudes bedeuten. Gewisse Insekten (Termiten, Bohrkäfer) können organische Baumaterialien schwächen oder zerstören.

Ähnlich könnten Tiere, die sich in Hohlräumen verstecken, Gesundheitsprobleme oder Störung der Bewohner verursachen.

Durch Feuchtigkeit entstehende Pilze bilden unansehnliche Flecken auf fertigen Oberflächen, zerstören jedoch selten die Baustoffe selbst. Sie sind ein Zeichen von übermäßiger Feuchtigkeit, was unhygienische Bedingungen, schnellen Zerfall von organischen Baumaterialien und Korrosion von Metallen hervorruft.

3.3 Protection against Hazards

The hazards and the respective protective measures referred to in this section are only those associated with roof constructions. It must be stressed that they generally have to be dealt with in conjunction with the rest of the building construction, as is mentioned wherever necessary.
Since the hazards discussed below are not limited to any particular climatic regions, they are not specifically mentioned in the following.

3.3.1 Biological Agents

These include insects (termites, borer beetles, flies, mosquitos, etc.), animals (rats, bats, birds, snakes, etc.) and fungi.

Problems

Insects nesting or breeding on roofs can be a health hazard (disease carrying mosquitos and flies) or simply a nuisance to the occupants of the building. Certain insects (termites, borer beetles) can weaken or destroy organic building materials.

Similarly, animals lurking in roof cavities may create health problems or disturbances to occupants.

Fungi developing in moist conditions form unsightly patches on finished surfaces, but are seldom destructive to building materials. They are a sign of excess moisture, which can cause unsanitary conditions, rapid decay of organic building elements and corrosion of metals.

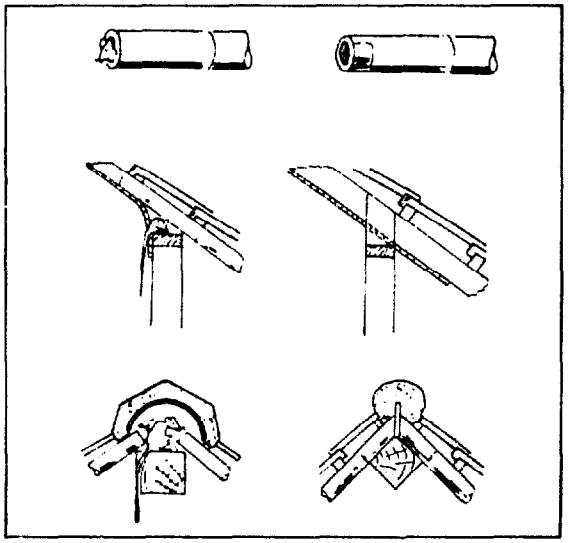

Abb. 3.4 Schädlingssichere Bambuskonstruktion (links: falsche, rechts richtige Methode)

Fig. 3.4 Vermin-proof bamboo construction (left: wrong, right: correst method)

QUELLE/SOURCE: United Nations "The Use of Bamboo and Reeds in Building Construction" (1972)

Schutzmaßnahmen

In bezug auf Insekten und Tiere:

- Vermeidung von Materialien, die Schädlinge anziehen, und von unkontrollierbaren Hohlräumen, in denen sie nisten können;
- Vermeidung von Löchern oder Vertiefungen, in welchen sich Wasser und Schmutz ansammeln können, worin Moskitos, Fliegen, Küchenschaben und ähnliches brüten können;
- Anbringung von Termitenblechen am Fundament des Gebäudes und Vergiftung der Erde, um unterirdischen Termiten den Zugang zum Dach zu verwehren;
- Behandlung von organischen Materialien mit Insektiziden, wenn natürlich widerstandsfähiges Material nicht verfügbar;
  (Bemerkung: Obwohl allgemein üblich, besteht hier die Gefahr, daß das Insektizid von Regen oder Kondenswasser weggespült wird, dadurch Herabsetzung der Termitenresistenz und Entstehung einer Gesundheitsgefährdung).
- Anbringung von Maschendraht, um Ungeziefer fernzuhalten;
- Gebrauch von Materialien, die innerhalb des Daches Temperaturen entstehen lassen, die zu hoch sind, um Ungeziefer bestehen zu lassen;
  (Bemerkung: Unerwünschte Hitze könnte dadurch im Gebäudeinneren entstehen);
- Vermeidung von dichter Vegetation in der Nähe des Gebäudes, um Schädlingen keinen leichten Zugang zu ermöglichen.

Protective Measures

With respect to insects and animals:

- avoidance of materials that attract pests and have uncontrollable cavities for them to nest in;
- avoidance of pockets or depressions in which water and dirt can accumulate providing breeding places for mosquitos, flies, cockroaches, etc.;
- provision of termite shields at base of building and poisoning of soil to prevent subterranean termites from gaining access to roof;
- poisoning of organic materials for termite resistance, if naturally resistant material is not available;
  (Note: though this is a common practise, there is a risk of insecticide being washed out by rain or condensation, thus reducing the termite resistance and constituting a health hazard)
- provision of wire mesh at openings, to keep out pests;
- use of materials creating temperatures within roof, too high for pests to exist;
  (Note: the consequence could be undesirable heating of building interior)
- avoidance of dense vegetation close to building to reduce access links for pests.

Abb. 3.5 (a, b) Methoden zur Behandlung von frischem Bambus mit chemischen Lösungen

a. Boucherie-Verfahren, wobei Bambussaft durch Schutzlösung ersetzt wird. Dauer: 5 Tage, aber mit Druckbehandlung nur wenige Stunden.

b. Tauchmethode, wobei chemische Lösung vom Stamm aufgesaugt wird aufgrund der Feuchtigkeitsabgabe von den Blättern.

Es kann eine große Anzahl anderer Schutzbehandlungen angewendet werden, wovon eine einfache, wirksame Methode darin besteht, die geschnittenen Rohre zur Beseitigung der Feuchtigkeit zu räuchern.

Fig. 3.5 (a, b) Methods of treating fresh bamboo with preservative solutions

a. Boucherie process, by which the sap of the bamboo is substituted by the preservative. Duration: 5 days, but with pressure treatment only few hours.

b. Dipping method, by which chemicals are drawn up the stem due to transpiration of moisture from leaves. Duration: 1 to 2 weeks.

A great number of other protective treatments may be employed, a simple and effective method being smoking of cut culms to remove all moisture.

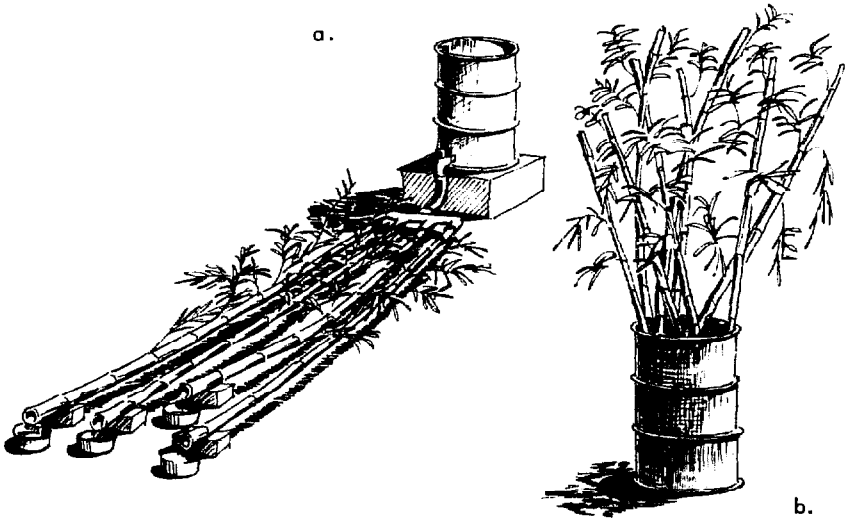

In bezug auf Pilzbildung:

- Verhinderung von Feuchtigkeitsansammlungen durch Ventilation und Entwässerung;
- Gebrauch von natürlich widerstandsfähigen Materialien (z.B. gut abgelagerte Hölzer, Zementfarbe, Kalkanstrich, nicht ölgebundene Leimfarbe), Fungiziden; geringe Verwendung von organischen Materialien.

Im allgemeinen:

- Aufrechterhaltung sauberer Bedingungen, um keine Nährböden für Ungeziefer und Pilze entstehen zu lassen;
- Ermöglichung von Zugang zu allen Teilen des Daches für regelmäßige Inspektionen.

3.3.2 Wind und Regen

Die Faktoren, die eine Gefahr für Gesundheit oder Leben der Bewohner darstellen und die für die Gebäudekonstruktionen schädlich sein können, sind örtliche Gewitterstürme, Sandstürme, Tornados, tropische Wirbelstürme, Wolkenbrüche und Hagel.

Probleme

Starke Winde (Tornados, tropische Wirbelstürme) verursachen, je nach Dachneigung, Überhang und Durchlässigkeit, positiven oder negativen Luftdruck (Sog) auf verschiedene Teile des Daches, wodurch Bruchschäden entstehen oder Dachelemente vollkommen abgerissen werden. Umherfliegende Gegenstände können Gebäude schädigen und Leben gefährden.

Fliegender Sand, der sich auf Dächern ansammelt, vergrößert die Traglast und gefährdet schwache Bauwerke. Er verursacht auch den Abrieb von Materialien, Trübung von Oberflächen und großes Unbehagen für die Bewohner.

Schwere Regen in den Tropen können
- Dachelemente lockern und loslösen,
- Bruchschäden und das Durchdringen von Wasser verursachen,
- Oberflächenanstriche, Insektizide und Fungizide fortspülen,
- auf nicht schallabsorbierenden Dächern erhebliche Geräuschbelästigung verursachen,
- Überschwemmungen von Gebäuden verursachen, wobei mit steigendem Wasser Luft unter dem Dach eingeschlossen wird und dadurch einen starken Auftrieb gegen das Dach und seine Befestigungen an den Wänden zur Folge hat. Zusätzlich entstehen hohe Verkehrslasten auf dem Dach durch Menschen, die Zuflucht vor der Überschwemmung suchen.

Abb. 3.6 (a, b) Wirkung der Dachneigung bei Winddruck: maximaler Sog bei etwa 10° Neigung

Fig. 3.6 (a, b) Effect of roof slopes on wind pressure: maximum suction at about 10° pitch

With respect to fungi:

- avoidance of moisture concentrations by means of ventilation and drainage;
- use of naturally resistant materials (e.g. well-seasoned timbers, cement paint, lime wash, non-oil-bound distempers) and fungicides, minimum use of organic materials.

In general:

- maintenance of clean conditions to provide no feeding grounds for pests and fungi;
- provision of access to all parts of roof for periodic inspection.

3.3.2 Wind and Rain

The factors constituting a hazard to the health or life of the occupants and which may be detrimental to building construction are local thunderstorms, sand storms, tornadoes, tropical cyclones, torrential downpours and hail.

Problems

Strong winds (tornadoes, tropical cyclones) exert positive and negative pressures (suction) on different parts of roofs, depending on their slopes, overhangs and permeability, causing partial breakage or complete displacement of elements. Flying objects can then damage other buildings and endanger lives.

Wind blown sand accumulates on flat roofs increasing loads and endangering weak structures. They also cause abrasion of materials, dulling of surfaces and great discomfort to dwellers.

Heavy rains in the tropics can
- loosen and dislocate roof elements,
- cause breakage and penetration of water,
- wash off surface coatings, insecticides and fungicides,
- create extreme noise disturbance on roofs which do not absorb sound,
- cause inundation of buildings, trapping air below the roof as water rises, thus imposing strong upthrust on the roof and its fastenings to walls. In addition high live loads are imposed on the roof by people seeking refuge from the floods.

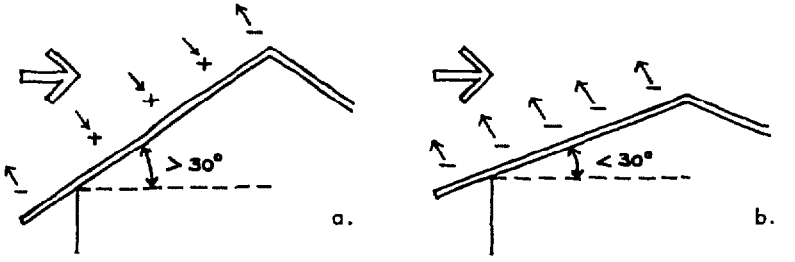

Hagelstürme mit großen Hagelsteinen können Dachelemente und andere Gebäudeteile beschädigen oder zerbrechen.

Gewitterstürme sind oft von gewaltigen Blitzeinschlägen begleitet, welche hochliegende Teile, die Metall oder Feuchtigkeit enthalten, treffen, und Verwüstung verursachen.

Schutzmaßnahmen

In bezug auf starke Winde:

- Vermeidung von flachen oder flach geneigten Dächern mit weniger als 20° (etwa 1 : 3),
- Vermeidung von leichten Dächern und breiten Überhängen,
- Gebrauch von dauerhaften Materialien (fähig, fliegenden Gegenständen Widerstand zu leisten), am Unterbau stark befestigt,
- unnachgiebige und starke Verankerung zum tragenden Bauwerk,
- Querverstrebungen, um Verwindungen und Bruchschäden der Dachelemente auf ein Minimum zu halten,

abgesehen von einer Anzahl anderer Schutzmaßnahmen für den Rest des Gebäudes.

In bezug auf vom Wind getragenen Sand:

- Vermeidung von Taschen und Oberflächen, in welchen sich Sand und Staub ansammeln können,
- Gebrauch von abriebfesten Materialien.

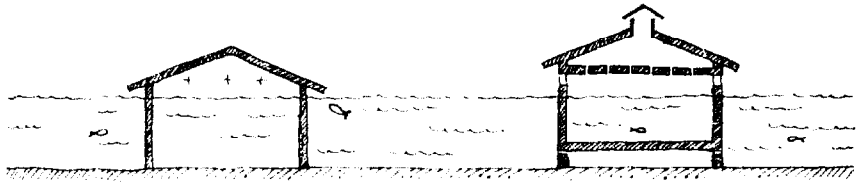

a. b.

Abb. 3.7 (a, b)

a. Druckverhältnis bei Überflutung des Gebäudes: starker Auftrieb gegen das Dach, verursacht durch Lufteinschluß zwischen Wasser und Dach.

b. Einplanung von Lüftungsöffnungen so hoch wie möglich, um Luft entweichen zu lassen.

Fig. 3.7 (a, b)

a. Effect of inundation of building: strong upthrust on roof due to air trapped between water and roof.

b. Provision of ventilation openings as high as possible to allow air to escape.

Hail storms with large hailstones can seriously damage or break roofing elements and other building parts.

Thunderstorms are often accompanied by violent air to ground lightening, which strikes high lying elements containing metals or moisture, causing devastation.

Protective Measures

With respect to strong winds:

- avoidance of flat or low pitched roofs with slopes less than 20° (about 1 : 3);
- avoidance of light roofs and wide overhangs;
- use of durable materials (capable of withstanding impacts of flying objects) firmly attached to substructure;
- rigid and strong anchorage of roof to supporting structure;
- cross-bracing to minimize distortion and breakage of roof members;

apart from a number of other protective measures involving the rest of the building.

With respect to wind blown sand:
- avoidance of pockets and surfaces on which sand and dust may accumulate;
- use of abrasion resistant materials.

Abb. 3.8

Erdbebenwiderstand mittels Stahlbetonringbalken, der mit dem Fundament Stahlbeton-Verbindung hat.

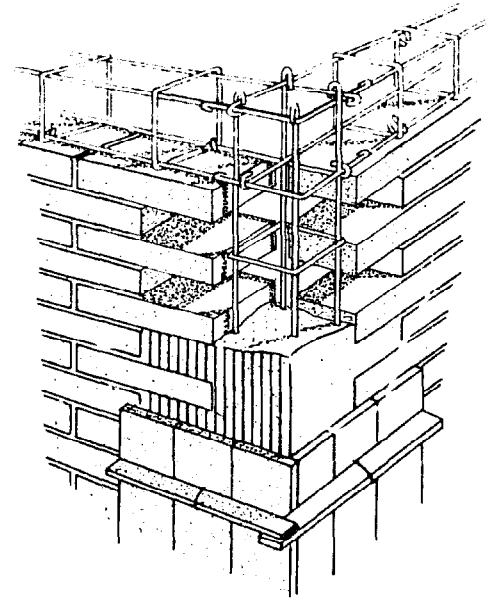

Fig. 3.8

Earthquake resistance by means of reinforced concrete ring beam which has strong reinforced connections to the foundations.

In bezug auf schwere Regenfälle (zusätzlich zu den Erfordernissen für Windwiderstand):

- hoch widerstandsfähige Wasserabdichtung (von Verbindungsstellen) und Oberflächenanstrich,
- minimaler Gebrauch von Insektiziden und Fungiziden,
- Verwendung von schalldämpfenden, wasserabweisenden Materialien,
- Öffnungen an den oberen Enden des Daches, um eingeschlossene Luft während Überschwemmungen freizulassen,
- starke Dachkonstruktionen, ausreichend, um Lasten heraufsteigender Flüchtlinge während Überschwemmungen tragen zu können,
- Aufbewahrung von empfindlichen Materialien im Dachboden (z.B. Beladen der Untergurte der Dachbinder), um sie vor Wasserschäden zu schützen und den aufwärts wirkenden Kräften entgegenzuwirken.

In bezug auf Hagelstürme:

- Gebrauch von Materialien, die Hagelsteineinschlägen widerstehen,
- ausreichende Dachüberstände, um Fenster zu schützen.

In bezug auf Blitzeinschlag beziehen sich Schutzmaßnahmen hauptsächlich auf Standortwahl (keine hohe Lage relativ zur Umgebung), Aufstellen von teuren Blitzableitern und Feuerschutz. Metall und feuchtigkeitaufnehmende Dächer in blitzgefährdeten Zonen erfordern daher fachmännische Beratung über Aufstellen von Ableitungsmasten und Erdung.

Im allgemeinen müssen alle Schutzmaßnahmen zur Verhinderung nachteiliger Folgen von Wirbelstürmen und Regen Möglichkeiten für Inspektion und Instandhaltung des Bauwerkes und der Befestigungspunkte einbeziehen. Fachgerechte Ausführung ist jedoch die wichtigste Schutzmaßnahme.

3.3.3 Erdbeben und Feuer

Diese beiden Gefahren können zusammen behandelt werden, da nach schweren Erdbeben in den meisten Fällen Feuer ausbricht.

Probleme

Schwere Dächer oder lose Teile, auch verschiedene Aufbauten wie Wasserbehälter, Schornsteine und Brüstungen, können abgeschüttelt werden oder zusammenbrechen und damit Unfälle herbeiführen.

Zusammenfallende Wände ziehen daraufliegende Dächer mit sich.

Schäden an Schornsteinen und Versorgungsleitungen verursachen generell das Ausbrechen von Feuer.

Schutzmaßnahmen

Widerstand gegen Zusammenbruch erfordert:

- entweder monolithische Dächer oder solche aus starken, flexiblen Elementen, die

With respect to heavy rains (in addition to the requirements for wind resistance):

- highly resistant waterproofing (of joints) and surface coating;
- minimum use of insecticides and fungicides;
- use of sound absorbing, water repellant materials;
- openings in top ends of roofs to allow trapped air to escape during floods,
- strong roof constructions, sufficient to carry live loads of refugees during floods,
- storage of vulnarable material in roof space (e.g. by loading bottom chords of roof trusses), thus protecting them from water damage and helping to counter-act upward loads.

With respect to hail storms:

- use of materials resistant to impact of falling hailstones;
- sufficient overhangs to protect windows below.

With respect to lightning, protective measures mainly involve siting (no high situation relative to surroundings), installation of expensive lightning conducting systems and fire protection. Metal or moisture absorbing roofs in lightning prone situations, therefore, require expert advice on erection of conductor masts and earthing.

In general, all protective measures to counteract adverse effects of wind storms and rain must incarporate means for inspection and maintenance of structure and joints. However, the prime protective measure is good workmanship.

3.3.3 Earthquakes and Fire

These two hazards can be seen together as fires nearly always occur after severe earthquakes.

Problems

Heavy roofs or loose elements, also various appendages, like water tanks, chimneys and parapets, are likely to be shaken off or collapse, causing casualties.

Wall failures cause roofs, resting on them, to fall down.

Breakage of chimneys and mains supply lines generally causes outbreak of fire.

Protective Measures

Resistance to collapse calls for:

- either monolithic roofs or ones comprising strong, flexible members, firmly tied

fest an das tragende Bauwerk gebunden sind,

- Dächer, die sicher an einem durchgehenden Ringanker befestigt sind, welcher wiederum durch Stahlbetonrahmen zusammengehalten wird,
- oder, alternativ, Dächer auf freistehenden Stützen, von den Wänden statisch getrennt, so daß im Falle des Versagens der Wände das Dach nicht einstürzen würde,
- kompakte symmetrische Formen in Grundriß und Aufriß, um eine möglichst gleichmäßige Lastverteilung zu erreichen,
- statische Trennung von Dachteilen, um bei unsymmetrischen Gebäuden unabhängige, kompakte Formen zu bilden,
  (Bemerkung: diese Trennung muß bis zum Fundament heruntergeführt werden, um wirksam zu sein),
- Vermeidung von großen Spannweiten,
- Vermeidung von überstehenden Teilen wie Brüstungen, Wasserbehälter, nicht-monolithische Schornsteine, sowie von losen Abdeckungen, die leicht herabfallen können,
- Vermeidung schwerer Materialien auf schwachen Stützen,
- Vermeidung von spröden Materialien oder von solchen, die nur oberflächlich verbunden sind, z.B. gemauerte Kuppeln oder Gewölbe,
- Schutzmaßnahmen, die das Schwächen von Dachelementen durch biologische Schädlinge verhindern.

Verhinderung von Feuer verlangt:

- Vermeidung von leicht entzündbaren Materialien in der Nähe von Schornsteinen und Strom- sowie Gasleitungen,
- nicht-brennbare Dachdeckung (z.B. Asbestzement) über Materialien, die weniger feuerbeständig sind,
- ausreichende Abstände zu Nachbardächern in der Hauptwindrichtung,
- Vermeidung von Hohlräumen in Dächern, die, als Rauchzug wirkend, das Feuer schnell verbreiten lassen,
  (Bemerkung: dies erfordert Kompromisse, wenn belüftete Dachhohlräume zur Verbesserung des Innenraumklimas erforderlich sind),
- chemische Behandlung von Materialien, wobei Imprägnierung besser ist als Oberflächenbehandlung, aber Dächer, die dem Regen ausgesetzt sind, erfordern regelmäßige Wiederholung dieser Behandlung,
- Vermeidung von leicht entzündbaren Materialien in der Nähe von potentiellen Feuerquellen.

Wie schon vorher erwähnt, können alle Schutzmaßnahmen für Dächer nur dann wirksam sein, wenn auch für den übrigen Teil des Gebäudes die entsprechenden Entwurfsmaßnahmen getroffen werden.

down to supporting structure,

- roofs securely fixed to a continuously reinforced ring beam on top of walls, which itself is held together by a reinforced framework,
- or alternatively, roofs fixed to independent supports, structurally separated from walls, which, in the event of failure, would not cause the roof also to collapse,
- compact, symmetrical shapes, in plan and elevation, to obtain as uniform a stress distribution as possible,
- structural separation of roof sections, to form independent compact shapes on unsymmetrical buildings,
  (Note: this separation must be carried through down to the foundations to be effective)
- avoidance of large spans,
- avoidance of projecting elements, such as parapets, water tanks, non-monolithic chimneys, and loose roof coverings that tend to fall down,
- avoidance of heavy material on weak supports,
- avoidance of brittle materials, or ones that only have surface bonding, e.g. masonry domes or vaults,
- protective measures that resist weakening of roof members by biological agents.

Resistance to fire calls for:

- avoidance of combustible materials near chimneys and power and gas lines,
- non-combustible cladding (e.g. asbestos cement) on materials less resistant to fire,
- sufficient separation of neighbouring roofs in direction of prevailing winds,
- avoidance of cavities or air spaces in roofs, which can act as flues spreading fire rapidly,
  (Note: this necessitates a compromise if ventilated roof space is required to improve indoor climate),
- chemical treatment of materials, impregnation being better than brush treatment, but roofs exposed to rain require regular renewal of treatment,
- avoidance of storage of combustible materials close to potential sources of fire.

As mentioned before, all protective measures for roofs can only be effective if corresponding steps are taken in designing the rest of the building.

3.4 Materialwahl

Es gibt kein universales Rezept für Bedachungsmaterialien; jedes hat seine Vor- und Nachteile, je nach Anwendungsmethode, Klima- und Umwelteinflüssen, Verfügbarkeit und ähnlichen Faktoren. Die Materialwahl für Bedachungen ist gewöhnlich ein Kompromiß, da die Anforderungen an eine ideale Dachkonstruktion sehr vielfältig sind, können sie selten von einem einzigen oder einer Kombination von Materialien erfüllt werden.

Der Zweck dieses Abschnittes ist es deshalb, allgemeine und spezifische Information über herkömmliche billige Bedachungsmaterialien zu geben, Information, die nötig ist, um deren geeignete Verwendung für eine gegebene Situation zu beurteilen.

3.4.1 Anorganische Materialien

Stein

Anwendung :
- Steinmetzgewölbe und Kuppeln
- Plattenbelag für Flachdächer
- Kiesbelag (z.B. weiße Steinsplitter als Sonnenschutz für Asphaltdächer)
- Zuschlagstoff für Betondächer

Vorteile :
- in den meisten Zonen ausreichend vorhanden
- gute Wärmeeigenschaften in trockenheißen Zonen
- keine Feuchtigkeitsbewegung, nur sehr gering bei Kalk- und Sandstein
- keine biologischen Risiken, wenn Oberflächen sauber sind

Nachteile :
- Wärmebewegungen können Risse verursachen
- CO_2 in Regenwasser greift Kalkstein und kalkhaltigen Sandstein an
- in Regenwasser gelöster Schwefel bildet wasserlösliches Sulfat in Verbindung mit Kalkstein — Hautbildungen und Erosion sind mögliche Folgen
- Angriffe von bestimmten Salzen und salzhaltiger Luft führt zur Ausblühung und zu Oberflächen-Ausbrüchen
- schwer, gefährlich (besonders während Erdbeben), wenn nicht gut gebaut

3.4 Choice of Materials

There are no universal recipes for roofing materials; each one has its advantages and disadvantages, depending on the method of application, climatic and environmental influences, availability and other similar factors. The choice of the roofing fabric is usually a compromise, since an ideal roof construction must fulfil a wide range of requirements, which rarely are satisfied by a single one or even combination of materials.

The purpose of this section is, therefore, to give general and specific information on common low-cost roofing materials, information that is required to be able to judge their oppropriateness for a given situation.

3.4.1 Inorganic Materials

Stone

Applications:
- Stone masonry vaults and domes
- Slabs as surface finish for flat roofs
- Gravel convering (eg. white stone chips as solar protection of bitumen roofing)
- Aggregate in concrete roofs

Advantages:
- In most regions sufficient supplies
- Good thermal performance in hot-dry areas
- No moisture movement, only very minor for limestone and sandstone
- No biological risks, if surfaces are clean

Disadvantages:
- Thermal movement can cause cracking
- CO_2 in rainwater attacks limestones and calcerous sandstones
- Sulphur dissolved in rainwater forms water-soluble sulphates with limestones — skin formation and erosion can occur
- Attack by certain salts and sea spray leads to efflorescence and spalling
- Heavy, dangerous (especially during earthquakes) if not well constructed.

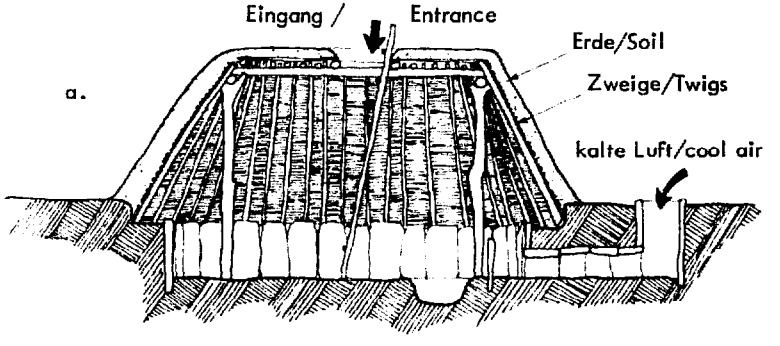

Abb. 3.9 (a, b, c) Traditionelle Erddachkonstruktionen
Fig. 3.9 (a, b, c) Traditional soil roof constructions

QUELLE/SOURCE: P. Bardou, V. Arzoumanian, "archi de terre" (1978)

Abhilfe : - Erhaltung sauberer Oberflächen; Regenwäsche reduziert Hautbildung durch Entfernung von löslichen Sulfaten

Erde

Anwendung : - Lehmziegel oder stabilisierte Erdblöcke für Kuppeln oder Gewölbekonstruktionen. Herkömmliche Stabilisierungsmittel:
a. Bewehrung — organische oder Mineralfaser
b. Bindemittel — Zement, Kalk (meistens billiger, ausreichende Stärke)
- Erdschicht über Holz, Bambus, Schilfunterbau
- gebrannte Tonziegel und Platten als Dachdeckung

Vorteile : - hohe Wärmespeicherungskapazität, gut für trocken-heiße Klimazonen
- fast keine Kosten, kein Transport
- keine biologischen Risiken, wenn Erde frei von organischen Substanzen ist

Nachteile : - obwohl reichlich vorhanden, Erden örtlich nicht immer geeignet, da Erdzusammensetzungen und -qualitäten sehr verschieden sind
- gebrannte Tonziegel nicht immer einheitlich, wenn örtlich hergestellt. Verschiebungen während Erdbeben, starke Schäden durch herabfallende Ziegel
- schwere Erddächer nicht für erdbebengefährdete Zonen geeignet
- schwache Erdmischungen können durch Wärme und Feuchtigkeitsbewegungen Risse hervorrufen und sich im Regen auflösen

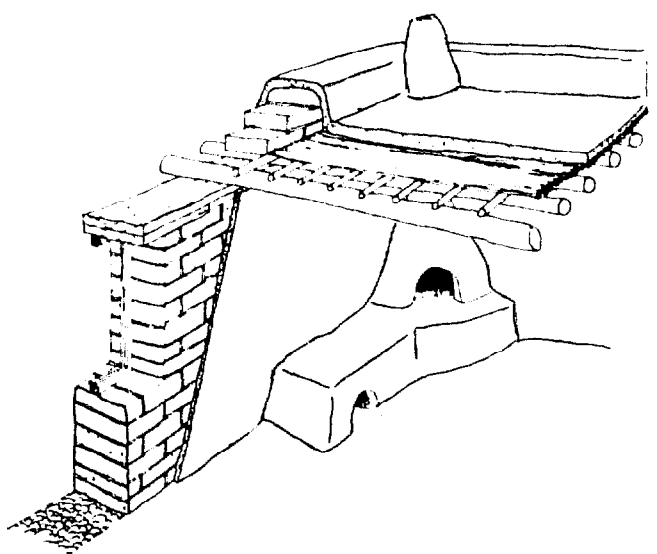

Remedies: - Maintenance of clean surfaces; rain washing reduces skin formation by the removal of soluble sulphates.

Soil

Applications: - Adobe or stabilized soil blocks as domes or vault structures. Common stabilizers:
a. reinforcement — organic or mineral fibres
b. binders — cement, lime (usually cheaper, sufficient strength)
- Soil layer over timber, bamboo, reed substructures
- Burnt clay bricks and tiles for roofing

Advantages: - High heat storage capacity, good for hot-dry climates
- Almost no cost, no transport
- No biological hazards, if soil is free from organic matter

Disadvantages: - Though abundantly available, local soils may not always be appropriate, since soil compositions and qualitities differ greatly.
- Burnt clay tiles not always uniform if locally made. Displacement during earthquakes, causing severe damage
- Heavy soil roofs unsuitable for earthquake areas
- Weak soil mixes quickly develop cracks with thermal and moisture movement, and disintegrate in heavy rains.

c.

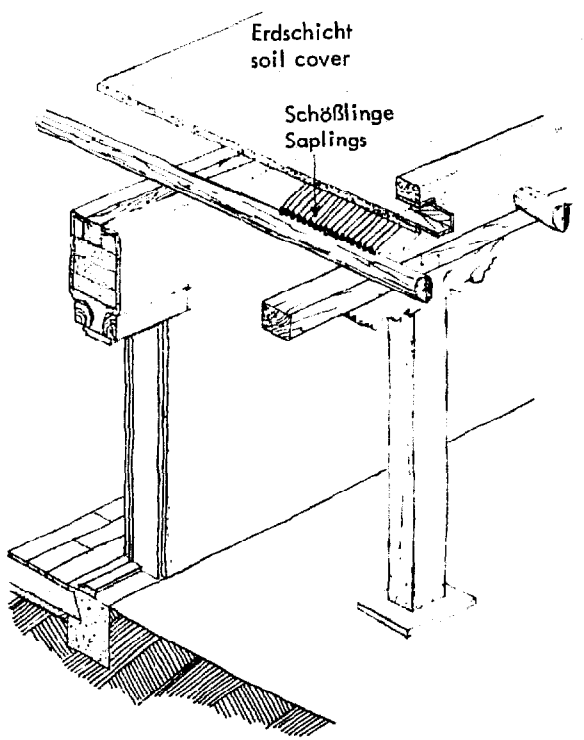

Abhilfe : - einfache Untersuchungsmethoden für die verschiedenen Erdetypen erforderlich
- Erdmischung so trocken wie die Verarbeitung zuläßt
- schützende Anstriche in regelmäßigen Abständen auftragen, um Erosion zu verhindern
- Zusatz von Mitteln zur Erhöhung der Wasserresistenz (z.B. Asphalt, Bitumen, Bitumenemulsion, Zement, und andere natürliche oder industriell hergestellte Produkte).

Remedies: - Simple tests for various soil types required
- Soil mixtures as dry as practical
- Protective coatings applied at regular time intervals to prevent erosion
- Addition of waterproofing agents (eg. asphalt, bitumen, cutback, cement and other natural or industrially produced materials).

Abb. 3.10 Tonziegeldach in China (ähnlich wie Mönch- und Nonnen-Deckung)
Fig. 3.10 Clay tile roof in China (similar to Spanish type)

Abb. 3.11 Tonziegeldach in Brasilien
Fig. 3.11 Clay tile roof in Brazil

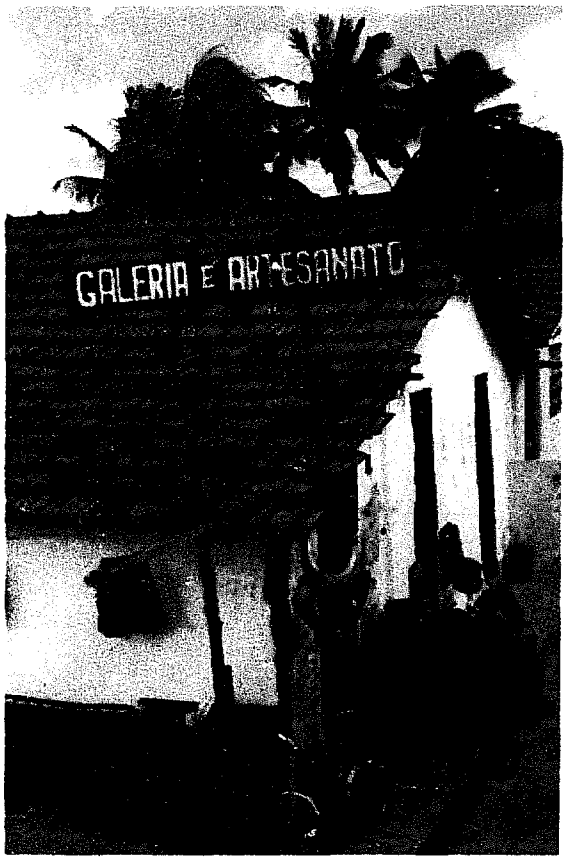

Metalle

Anwendung : - am häufigsten verzinktes Wellblech, weniger häufig Aluminiumblech. Beide Typen haben normalerweise größeres Ansehen als andere Materialien (andere Metalle und Legierungen sind zu teuer und nicht ausreichend vorhanden)
- Anschlußblech und Befestigungsmaterialien (z.B. Nägel)
- Bewehrungseisen für Stahlbetondächer
- Stahl und Aluminiumrahmen
- Netze zum Schutz von Öffnungen
- Dachrinnen

Metals

Applications: - Most common are corrugated galvanized iron sheets, less common aluminium sheets. Both types normally have greater prestige value than other materials. (Other metals and alloys too expensive and not sufficiently available)
- Flashings and fastening materials (eg. nails)
- Reinforcement in concrete roofs
- Steel or aluminium frames
- Netting for protection of openings
- Gutters

Abb. 3.12 Verzinkte Wellblechdächer in Somalia — am wenigsten geeigneter Dachtyp für die Region

Fig. 3.12 Corrugated galvanized iron roofs in Somalia — most inappropriate roof type for the region

Vorteile : - leichter Transport (niedriges Gewicht, keine Bruchschäden)
- große Spannweiten möglich, einfache Stützkonstruktion
- große Stärke und Flexibilität (gutes Erdbebenverhalten)
- hoher Widerstand gegen Aufschläge
- Widerstand gegen alle biologischen Schädlinge
- Wasserundurchlässigkeit
- einfache und schnelle Installation
- generell keine Ablehnung durch Bevölkerung

Nachteile : - wegen Mangel an Wärme-Isolierung übermäßig hohe Innentemperaturen während des Tages, sehr tiefe Temperaturen während der Nacht
- nächtliche Abkühlung verursacht Kondensation auf der Unterseite des Daches, dadurch Beeinträchtigung des Wohnkomforts
- Lärmbelästigung bei schweren Regenfällen
- Korrosion von Platten und Bewehrung bei Feuchtigkeit (in feuchtwarmen und Küstengebieten, bei Kondensation, usw.)
- Korrosion durch Elektrolyse, bei Kontakt zwischen verschiedenartigen Metallen
- Neigung der dünnen Bleche, an genagelten oder geschraubten Stellen unter starkem negativem Druck abzureißen (besonders wenn nur kleine oder keine Unterlegscheiben benutzt werden)
- in tropischen Wirbelstürmen: Zerstörungen durch umherfliegende Blech die abgerissen wurden
- Abrieb durch windgeblasenen Sand
- schlechtes Feuerverhalten
- teurer Transport durch zentralisierte Produktion, oft hoher Devisenanteil

Abhilfe : - Hitze und Kondensation: Vermeidung von Blechdächern in Gebieten mit intensiver Sonnenstrahlung und schnellen Temperaturänderungen. Zweischalige Dächer mit belüftetem Zwischenraum (untere Schicht wasserabsorbierend). Reflektierende Außenfläche.
- Korrosion: keine Verwendung unter feuchten Bedingungen. Geeignete Schutzanstriche periodisch erneuern. Regenwasser kann durch Herauswaschen schädlicher Salze Korrosion hemmen. Im Falle ungleicher Metalle Verwendung von nichtmetallischen Unterlegscheiben. Keine Kontakte zwischen Aluminium und Beton oder Mörtel (alkalische Korrosionsgefahr)
- Geräusch: kürzere Spannweiten und Bitumenanstrich auf der Unterseite. Außerdem sorgfältige Detaillierung der Befestigungspunkte und Anbringung von Dämmschichten oder abgehängten Decken
- Auftrieb: stärkere Bleche, bessere Verbindungen

Abb. 3.13 Demonstrationsbau in Togo: Abgehängte Bambusdecke unter dem Wellblechdach, mit belüftetem Dachzwischenraum

Advantages: - Easy transports (low weight, no breakage)
- Wide spans possible, simple supporting structure
- High strength and flexibility (good earthquake performance)
- High resistance to impact
- Resistance to all biological hazards
- Impermeable to water
- Easy and rapid installation
- Generally high acceptability

Disadvantages: - Due to lack of thermal insulation, intolerably high indoor temperatures during daytime, very low temperatures at night
- Nocturnal cooling causes condensation on underside of roofs, affecting indoor comfort
- Problem of noise generated by heavy rains
- Corrosion of sheets and reinforcement in moist (hot humid and coastal areas, condensation, etc.) conditions
- Corrosion by electrolytic action due to contact of dissimilar metals
- Tendency of thin sheets to tear off at nailed or bolted points (particularly with small or no washers) under strong negative pressure
- In tropical windstorms: havoc caused by whirling sheets that have been ripped off
- Abrasion caused by wind blown sand
- Poor fire resistance
- Expensive transports due to centralized production, often high foreign currency component

Remedies: - Heat and condensation: Avoidance of sheet metal roofs in areas of intense solar radiation and rapid temperature changes. Double layer roofs with ventilated air space (absorptive lower layer). Reflective outer surface
- Corrosion: Avoidance of use in moist conditions. Suitable protective coatings periodically renewed. Rainwashing can retard corrosion by removing contaminating salts. In case of dissimilar metals, non-metallic washers. No contacts of aluminium with concrete or mortar (risk of alkaline corrosion)
- Noise: Shorter spans and coating of bitumen on underside. Also careful detailing of suspension points and application of insulating layers or suspended ceiling
- Uplift: Thicker gauged sheets, better connections.

Fig. 3.13 Demonstration structure in Togo: suspended bamboo ceiling under corrugated iron roof, creating ventilated roof space.

Zement-Produkte

Anwendung :
- Bindemittel für verschiedene organische und nicht-organische Materialien, z.B. Erdzement, Bimsbeton, Asbestzement (siehe nächsten Baustoff), Bauplatten aus zementgebundenen Naturfasern
- Beton, Stahlbeton, Leichtbeton für Dachplatten, Balken, Schalen, usw.
- Ferrozement (im wesentlichen dünne Betonschichten mit Bewehrung aus Hühnerdraht) für Schalenkonstruktionen in beliebigen Formen
- Isolier- oder Gefälleestrich

Vorteile :
- extrem hohe Festigkeit
- gutes Erdbeben- und Wirbelsturmverhalten bei Stahlbeton
- wasserdicht, bei guter Verarbeitung
- feuerhemmend
- widerstandsfähig gegen biologische Einwirkung, wenn sauber gehalten
- Materialien von höherem Ansehen

Nachteile :
- in den meisten Ländern zu teuer und Zementversorgung weit unter dem Bedarf. In einigen Ländern nur eine Zementfabrik, dadurch hohe Transportkosten
- unter feuchten Bedingungen Gefahr des zu frühen Abbindens von gelagertem Zement
- in trockenheißen Gebieten Gefahr der Rissebildung durch zu schnelle Austrocknung von frischem Beton
- Schrumpfungsrisse durch Temperaturschwankungen
- Betonschwächung durch salzhaltige Aggregate oder Wasser
- Rosten von nicht ausreichend bedecktem Bewehrungsstahl führt zu Dehnungsrissen
- zur Erlangung der Festigkeiten von teurem stahlbewehrtem Beton sind erforderliche Betonquerschnitte mit billigerer Bambusbewehrung zu groß
- im allgemeinen schwere Konstruktionen und gefährlich bei Erdbeben, wenn nicht richtig geplant und ausgeführt

Abhilfe :
- Vermeidung von zu schnellem Abbinden durch Befeuchtung des Betons während der Aushärtung
- Prüfung von Betonproben zur Qualitätskontrolle
- gute Kornverteilung der Aggregate, um übermäßige Schrumpfung zu vermeiden und größere Stärke zu geben
- Einplanung von Dehnfugen, wo erhebliche Wärmebewegungen zu erwarten sind
- sorgfältige Zementlagerung (vor Feuchtigkeit schützen)

Cement Products

Applications:
- Binder for several inorganic and organic materials, eg. soil-cement, pumice cement, asbestos-cement (see next material), cement bound vegetable fibre boards.
- Concrete, reinforced concrete, light-weight concrete for roof slabs, beams, shells, etc.
- Ferrocement (basically thin layered reinforced concrete with chicken wire mesh) for free form shell structures
- Insulating roof screeds

Advantages:
- Extremely high strengths
- Good earthquake and hurricane performance of reinforced concrete
- Waterproof, if well done
- Fire resistant
- Resistant to biological hazards, if kept clean
- Materials of higher prestige value

Disadvantages:
- In most countries expensive and insufficient supplies of cement. In some countries only one manufacturing plant, therefore high transport costs.
- In presence of moisture, risk of premature setting of cement.
- In hot dry conditions, risk of cracks due to rapid setting.
- Shrinkage cracking due to temperature fluctuations
- Weakening of concrete due to aggregates or water containing salts
- Rusting of steel reinforcement, not sufficiently covered, leading to expansion cracks
- To achieve similar strengths as expensive steel reinforcements, necessary cross-sections for cheaper bamboo reinforcements are too large
- Generally heavy constructions and dangerous in earthquakes, if not properly designed and executed

Remedies:
- Avoidance of rapid setting by moistening of concrete during curing
- Sample testing of concrete for quality control
- Good grading of aggregates to avoid excessive shrinkage and to give greater strength
- Design of expansion joints, where substantial thermal movement is expected
- Careful storage of cement (protection from moisture).

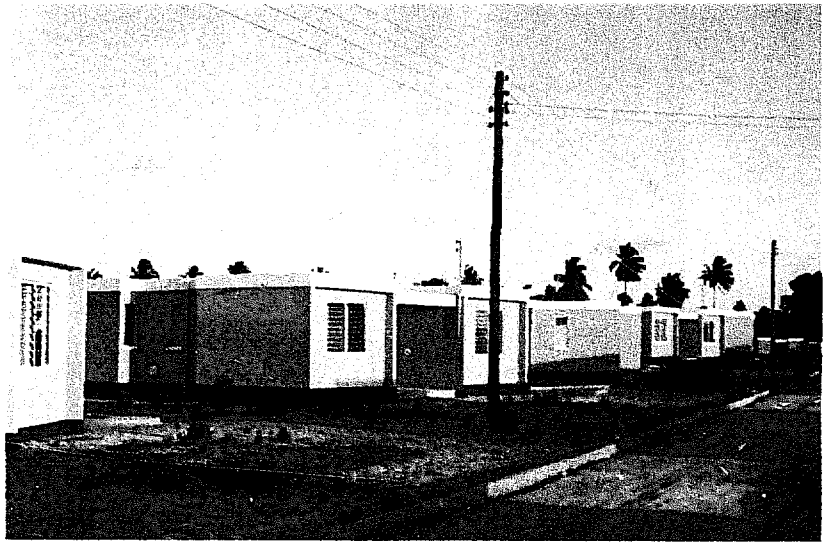

Abb. 3.14 Standard-Betondach in Tansania
Fig. 3.14 Standard concrete roofing in Tanzania

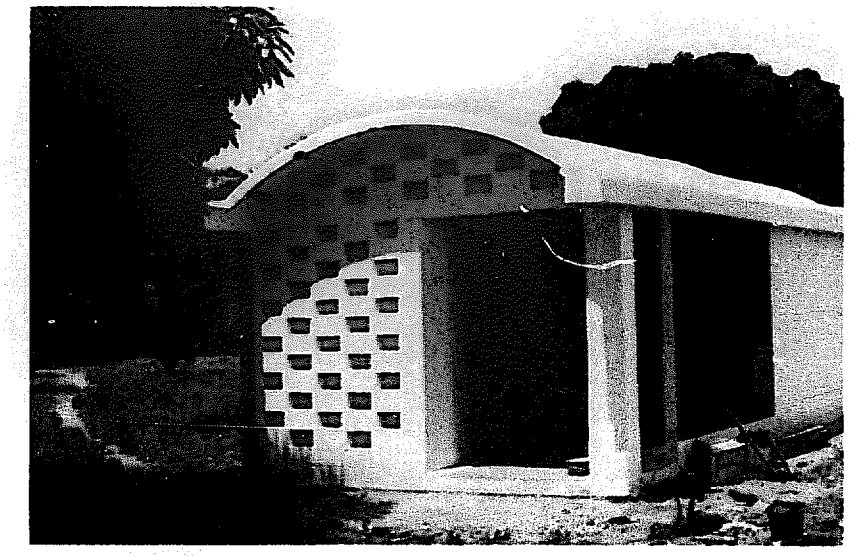

Abb. 3.15 Betonschalendach in Togo
Fig. 3.15 Concrete shell roof in Togo

Asbestzement

Anwendung :
- flache Platten, Schindeln
- Wellplatten
- trogförmige Elemente (z.B. Canaletas)
- Sonnenschutzvorrichtungen

Vorteile :
- leicht zu handhaben, geeignet für Selbsthilfe-Bauweisen
- feuerbeständig, wasserdicht
- Well- und Trogplatten: selbsttragend über große Spannweiten (kein Unterbau nötig)
- geringe Wärmebewegung
- bessere Wärme-Isolierung und weniger Geräusch bei Regen als mit Metallplatten

Nachteile :
- kontinuierliche Hydratation des Zements führt zu Längenzunahme
- unzureichender Widerstand gegen Einschlag (z.B. Schäden durch Hagelsteine)
- Schimmelbildung durch Ansammlung von Schmutz an den Fasern verursacht Erweichen und Verdunkeln der Oberfläche

Asbestos Cement

Applications:
- Flat sheets, shingles
- Corrugated sheets
- Trough shaped elements (eg. Canaletas)
- Sun screening

Advantages:
- Easy to handle, suitable for self-help construction
- Fire resistant, waterproof
- Corrugated and trough shapes: self-supporting over large spans (no substructure necessary)
- Low thermal movement
- Better heat insulating capacity and less noisy in heavy rain than metal sheets

Disadvantages:
- Continued hydration of cement causing length increase
- Insufficient resistance to impact (eg. damage by hailsones)
- Mould growth on fibre-held dirt, causing surface softening and darkening
- Warping and cracking promoted by combined carbonation and

- Verbiegen und Platzen, gefördert durch kombinierte Karbonation und Austrocknen
- Verringerung der Schlagbiegefestigkeit durch CO_2 in Gegenwart von kleinen Mengen H_2O
- Entfernen von Oberflächenschichten des hydratisierten Zements durch CO_2 oder durch die im Regenwasser aufgelösten Schwefelgase
- hohe Bruchverluste während des Transports

Abhilfe : - schützende Anstriche gegen Schimmelbildung
- Erhaltung von sauberen Oberflächen

hydration
- Decrease of impact strength by CO_2 in presence of small amounts of H_2O
- Removal of surface layers of hydrated cement by CO_2 or sulphur gases dissolved in rainwater
- High degree of breakage during transports

Remedies:
- Protective coating against mould growth
- Maintenance of clean surfaces

Abb. 3.16 Asbestzement-Trogplattendächer (canaletas) in El Salvador
Fig. 3.16 Asbestos cement channel roofing (canaletas) in El Salvador

3.4.2 Organische Materialien

Gräser, Palmen, pflanzliche Fasern

Anwendung : - Gräser:

a. herkömmliche Stroh- und Mattendächer
b. Strohbewehrung in Spanplatten, Erdzementmischungen, usw.
c. Strohpreßplatten (z.B. Stramit), industriell hergestellt mittels Hitze und Druck, ohne Bindemittel, aber mit Papier auf beiden Seiten
d. Schilf, gebündelt oder zu Platten zusammengebunden, oder gespalten und als Matten gewebt, für unterschiedliche Verwendung als Dachelemente
e. ganze Bambushalme für Tragkonstruktion, oder als Platten zusammengebunden
f. halbierter Bambus als Dachziegel und -rinnen
g. gespaltener Bambus als gewebte Platten oder Bewehrung für diverse Bauplatten.

- Palmen:

h. Blätter, unverarbeitet oder als Matten, für Dachdeckung
i. Stämme für tragende Bauteile

- Pflanzliche Fasern:

j. Seile
k. Faserplatten
l. Bewehrung für diverse Bauplatten

Vorteile : - meistens reichlich am Ort vorhanden, billig (oder kostenlos), schnell zu erneuernde Materialien. Können im Hinterhof angebaut werden.
- Traditionelle Verarbeitungstechniken (in den meisten Fällen), leicht verständlich und ausgeführt von Ortsansässigen
- Strohdächer, korrekt angewandt: gute Wärme- und akustische Eigenschaften und wasserdicht
- Schilf und Bambus: hohe Zugfestigkeit, gutes Gewicht/Festigkeit-Verhältnis, deshalb normalerweise gutes Verhalten bei Erdbeben und Wirbelsturm
- Strohpreßplatten: hohe dimensionale Stabilität, widerstandsfähig gegen Einschlag und Spaltung, nicht leicht entzündbar, (wenn trocken gehalten) widerstandsfähig gegen biologische Schädlinge, Verarbeitung wie Holzplatten
- generell gutes Erdbebenverhalten, aber gegen Wirbelstürme nur dann widerstandsfähig, wenn gut geplant und ausgeführt

Nachteile : - in den meisten Fällen niedrige Lebenserwartung, ungefähr 2 - 5 Jahre, doch durch gute Konstruktion und Instandhaltung kann längere Haltbarkeit erreicht werden
- biologische Risiken (Anziehung und Nisten von Insekten, Nage-

3.4.2 Organic Materials

Grasses, Palms, Fibrous Plants

Applications: - Grasses:

a. Traditional straw thatch and matting
b. Straw reinforcements in particle boards, soil cement mixes, etc.
c. Compressed straw slab (eg. Stramit), industrially produced by heat and pressure, without any binders, but paper on both sides
d. Reeds, bundled or tied together as boards or split and woven as mats, for various uses as roofing elements
e. Full bamboo culms as supporting structure, or tied together as boards.
f. Halved bamboo as roof tiles and gutters
g. Split bamboo as woven panels or reinforcement in composite roofing elements

- Palms:

h. Leaves as thatch or matting
i. Stems as structural members

- Fibrous Plants:

j. Ropes
k. Fibreboards
l. Reinforcement in composite roofing elements

Advantages: - Usually locally available abundant, cheap (or even no-cost), quickly renewable materials. Can be grown in backyard
- Traditional techniques (in most cases), easily comprehended and implemented by local people
- Straw thatch, properly applied: good thermal and acoustical properties and waterproofing
- Reeds and bamboo: high tensile strengths, good weight-strength ratio, hence usually good earthquake and hurricane performance
- Compressed straw slabs: high dimensional stability, resistance to impact and splitting, not easily ignitable, (if kept dry) resistance to biological hazards, handled like timber boards
- Generally good earthquake performance, but hurricane resistance only if well designed and constructed

Disadvantages: - In most cases low life expectancy, about 2 to 5 years, though with good constructions and maintenance greater durability achievable.
- Biological risks (attraction and nesting of insects, rodents, etc. and development of fungi and rot)
- Risk of fire, either originating underneath or spread through flaming or glowing fragments carried by wind

tieren, usw. und die Entwicklung von Pilzen und Fäulnis)
- Feuergefahr, entweder durch darunter entstehende Feuerquellen oder durch vom Wind getragene Flammen oder glühende Fragmente
- Tendenz, Feuchtigkeit aufzusaugen, infolgedessen Gewichtszunahme, beschleunigter Verfall und Entstehung unhygienischer Bedingungen
- Verformung und allmähliche Zerstörung durch ständig wechselnde Temperaturen und Feuchtigkeit
- nicht sehr beliebt aufgrund allgemeiner Ansicht, daß diese Materialien minderwertig sind und nur bei "Häusern armer Leute" gebraucht werden

Abhilfe :
- Imprägnierung der Materialien gegen biologische Schädlinge und Feuer, entweder durch Vorbehandlung oder durch Oberflächenauftragung (Vorsicht: diese sind teuer und werden leicht durch Regen fortgewaschen, wodurch die Umgebung und das von den Dächern gesammelte Trinkwasser verseucht werden. Ferner fördern Feuerschutzbehandlungen Schimmelbildung und somit schnellen Verfall)
- Reduzierung der Feuergefahr bei Strohdächern durch Auftragen einer Schicht stabilisierten Tons auf die Außenseite, um Entzünden durch fliegende, glühende Fragmente zu verhindern. Regel-

- Tendency to absorb moisture thus becoming heavy, accelerating deterioration and creating unsanitary conditions
- Deformation and gradual destruction due to constant fluctuations in temperature and humidity
- Low acceptance due to general view that these materials are inferior, used only for "poor peoples' houses"

Remedies:
- Impregnation of materials against biological hazards and fire, either by pretreatment or surface application. (Caution: These are costly, and easily washed out by rain, contaminating surroundings and drinking water collected from roof. Moreover fire resistant treatments may promote mould growth, leading to rapid decay).
- Reduction of fire risk on thatch roofs by application of thin coat of stabilized clay on exterior to prevent ignition by windborne fragments. Periodic renewal necessary.
- Reduction of rate of burning by restriction of air flow through thatch in event of fire, eg. by means of non-combustible material (asbestos cement sheets) attached to underside of roof.
- Maintenance of dry conditions within dwelling advantageous; development of smoke in interior said to prevent rot and nesting of insects.

3.17

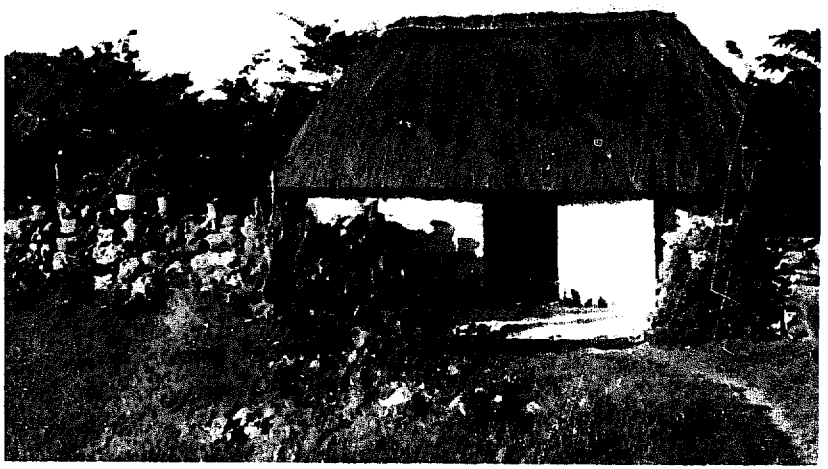

3.18

mäßige Erneuerung nötig.

- Reduzierung der Flammenverbreitung, indem der Luftzug durch das Stroh verringert wird, z.B. durch Befestigung von nicht brennbaren Materialien (Asbestzementplatten) unterhalb des Daches.
- Aufrechterhaltung trockener Bedingungen innerhalb der Behausung von Vorteil; interne Rauchentwicklung verhindert Fäulnis und Insektennisten.

Abb. 3.17 Strohdach in Mexiko
Fig. 3.17 Thatch roof in Mexico

Abb. 3.18 Palmblätterdeckung in El Salvador
Fig. 3.18 Palm leaf thatch in El Salvador

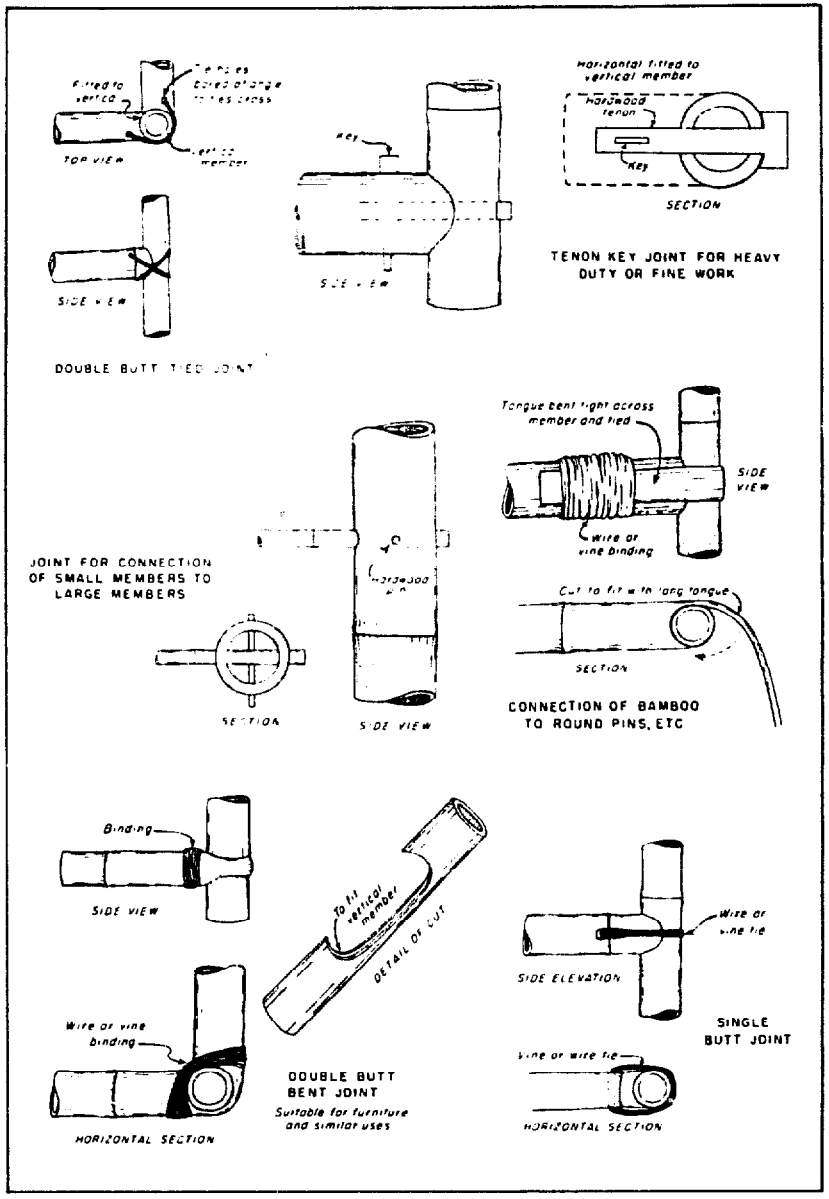

Abb. 3.19 Einige Bambusverbindungen
Fig. 3.19 Some bamboo joints

QUELLE/SOURCE: F.A. McClure: "Bamboo as a Building Material", US Department of Agriculture, Foreign Agricultural Service, Washington, D.C., 1953

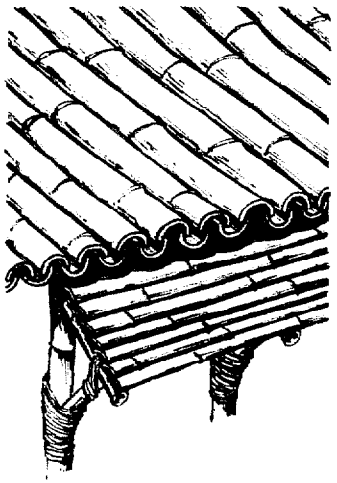

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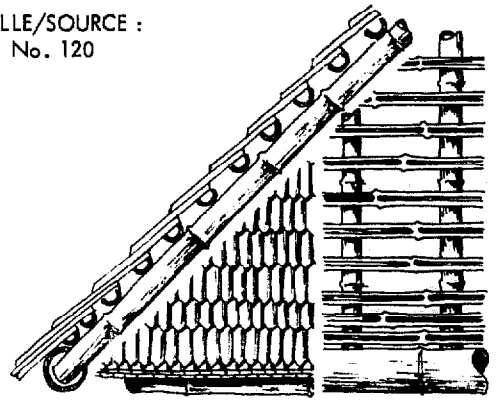

Abb. 3.21 Bambus-Schindeldach
Fig. 3.21 Bamboo shingle roof

Abb. 3.20 Bambus-Ziegeldach: halbierte Stämme als Mönch- und Nonnen-Deckung
Fig. 3.20 Bamboo tile roof: half culms laid like Spanish tiles.

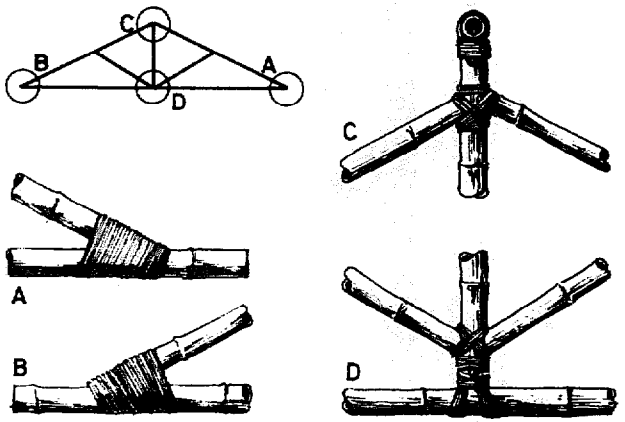

Abb. 3.22 Bambusbinder mit Verbindungsdetails.
Fig. 3.22 Bamboo roof truss with details of joints.

Holz

Anwendung : - alle Teile des tragenden Bauwerks, wie Ringbalken, Sparren, Pfetten, Binder, Streben, First
- Dachverkleidungen, wie Sperrholz, Tischlerplatten, Spanplatten oder Schindeln

Vorteile : - hohe Zugfestigkeit und gutes Gewicht/Festigkeit-Verhältnis, dadurch gute Erdbeben- und Wirbelsturmbeständigkeit
- traditionelle Materialien, die traditionelle Techniken erfordern
- gute Feuerbeständigkeit der dickeren Bauelemente: äußere Schichten entwickeln verkohlte Schutzschicht
- gute Wärme-Isolierung, auch schallschluckend

Nachteile : - schwindende Reserven durch Raubbau und Export, dadurch hohe Kosten
- Mangel an langsam wachsenden Hölzern (härter, stärker und widerstandsfähiger gegen Termitenbefall)
- Wärme- und Feuchtigkeitsbewegungen: Schrumpfung (aber nur in der Breite), Verzerrung, Spaltung
- anfällig gegen biologische Schädlinge
- Feuergefahr für kleinere Holzbauteile
- Korrosion der Metallverbindungen oder Schrumpfung an Anschlußpunkten, was zum Versagen der Verbindungen führt

Timber

Applications: - All parts of supporting structure, such as ring beam, rafters, purlins, trusses, struts, ridge
- Roof finishes, such as plywood, coreboard, chipboard or shingles.

Advantages: - High tensile strengths and good weight-strength ration, hence also good earthquake and hurricane resistance.
- Traditional material involving traditional skills.
- Good fire resistance of thicker timber members: outer layer develop protective charred surface.
- Good thermal insulation, also sound absorption.

Disadvantages: - Diminishing supplies due to uncontrolled cutting and exports, hence high costs
- Shortage of slow grown timber (harder, stronger and more resistant to termite attack)
- Thermal and moisture movement: shrinkage (but only in width), twisting, splitting
- Susceptible to biological hazards
- Fire risk of timber members with smaller dimensions
- Corrosion of metal connectors, or shrinkage at points of connection leading to failure of joints

Abhilfe : - Anstreichen oder Behandeln mit verschiedenen Holzschutzölen (feuchtigkeitsgefährdete Holzteile: Behandlung der später nicht zu erreichenden Teile vor dem Zusammenbau)
- Holzteile, die nicht dem Regen ausgesetzt sind: in Salzwasser (Meerwasser) vorbehandeln, um Pilzbefall zu vermeiden und weniger Verzerrungen durch den hohen Feuchtigkeitsgehalt
- Verhinderung von Pilzbefall bei gut abgelagerten Hölzern mit Feuchtegehalt von weniger als 20 Gewichtsprozent
- Schützen von Dachanschlüssen, in die Wasser eindringen kann, mittels Metall- oder Plastikabdeckprofilen, aber keine luftdichte Befestigung
- Verbindungen, die Bewegungen aufnehmen können

Remedies: - Painting or treatment with various wood-preserving oils. (Timber likely to become damp: primed in future inaccessible parts before assembly)
- Timber parts not exposed to rain-washing: soaked in salt water (sea water) for prevention of fungal attack and less warping, due to higher moisture content.
- Prevention of fungal attack with well seasoned wood containing less than 20% by weight
- Protection of joints liable to trap moisture by means of metal or plastic flashing, but no air-tight fastening
- Joints designed to accomodate movement.

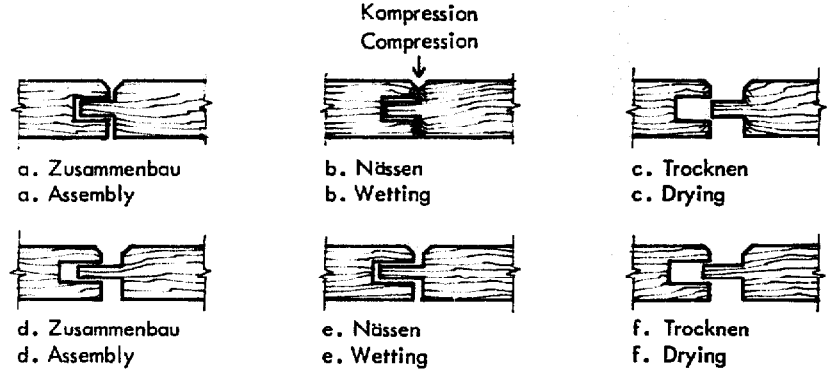

QUELLE/SOURCE : Bibl. No. 14

Abb. 3.23 (a, b, c) Schlechte Spundverbindung beim Nässen und Trocknen
(d, e, f) Verbesserte Verbindung

Fig. 3.23 (a, b, c) Tongue and groove timber connection showing bad performance during wetting and drying
(d, e, f) Improved connection

Bituminöse Produkte

Anwendung : - Dachpappe auf Holz- oder Betondächern
- Splittasphalt, geeignet für Dächer, die dem Fußverkehr ausgesetzt sind
- kalt aufgetragener Asphalt, meist emulsionbasiert, da gelöster Asphalt teuer und feuergefährlich ist
- Wellpappe, aus Abfallmaterialien hergestellt (weich zermahlen, imprägniert mit normalem Straßenasphalt, geschützt durch Mineralgranulat oder Farbe)

Bituminous Products

Applications: - Roofing felts laid on wood or concrete roofs
- Mastic asphalt, suitable for roofs subjected to foot traffic
- Cold applied bitumen, usually emulsion based, since solvent based bitumens are costly and constitute fire risk
- Corrugated roofing sheets made from waste materials (reduced to pulp, impregnated with common paving asphalt, protected with mineral granule or paint)

Vorteile : - Wellplatten: leicht, erfordern leichte Unterkonstruktion, nicht spröde, dadurch keine Transportschäden; keine Fachkräfte oder spezielle Werkzeuge erforderlich; kann direkt auf den Unterbau genagelt werden; wasserdicht; nicht wärmeleitend (Isolierungswert entspricht ungefähr einer 6 cm dicken Betonplatte)
- kalt aufgetragenes Bitumen: keine Fachkräfte nötig
- biologische Schädigung nicht sehr wahrscheinlich

Nachteile : - ultraviolette Strahlen verursachen Versprödeln, Rissebildung und das Entstehen wasserlöslicher Verbindungen
- Ausdehnung von eingeschlossener Luft oder Wasser führt zu Blasenbildung
- Hitze verursacht Erweichen und Fließen
- durch stehendes Wasser Entstehung von Haarrissen, Filzfasern können verrotten, Oberflächenschutzgranulat kann so vom Regen fortgewaschen werden
- Wasserlachen verursachen unterschiedliche Spannungen durch Verdampfungskühlung
- wiederholtes Nässen und Trocknen beeinflussen die visco-elastischen Eigenschaften
- starke Winde können Versprödung und Abreißen verursachen, Schutzgranulat wird fortgeblasen
- ungeeignet für Temperaturen über 44°C
- kaltes Bitumen begrenzt lagerfähig (schnell zu verbrauchen, innerhalb von drei Monaten; Verschiffungsprobleme)

Abhilfe : - ausreichender Schutz gegen Sonnenstrahlung durch reflektive Behandlung (z.B. Kalkanstrich, Aluminiumfarbe, hellfarbige Aggregatsplitter), eventuell auch Dachbeschattung
- ausreichende Dachneigung (mindestens 3%) und Entwässerung, um Wasserlachen zu verhindern
- Bewegungsfugen, die gegensätzliche Bewegungen zwischen Membrane und Unterkonstruktion ermöglichen
- Ankleben in Abständen, um Wasserdampfblasen zu vermeiden, aber bessere Aufklebung dort, wo Wirbelstürme vorkommen, die die Dachpappe lossaugen könnten
- Bewehrung der Dachpappe, vorzugsweise nicht organisch (z.B. Asbest oder Glasfaser); andere, wie Stoffilz, sind anfällig für biologische Schädigung
- Zusatz von Konservierungsmitteln, um Zerfall zu verhindern
- Kaltbitumen: gründliches Mischen vor Gebrauch, in dünnen Schichten auftragen (wenn kein Regen und nicht zu heiß)
- gute Facharbeit und regelmäßige Instandhaltung, d.h. Inspektion und regelmäßig alle paar Jahre neuer Bitumenanstrich

Advantages: - Corrugated sheets: light, requiring light substructure; not brittle, hence no transport breakage; no skilled labour or special fixing equipment; can be nailed to substructure directly; waterproof; non-conducting (insulation value corresponding to about 6 cm concrete slab)
- Cold applied bitumen: no skill required
- Attack by biological agents not very likely

Disadvantages: - Ultra-violet radiation causes embrittelement, cracking and formation of water soluble compounds
- Expansion of entrapped air or water gives blistering
- Heat couses softening and flow
- Standing water causes crazing, felt fibres may rot. Surface protective granules can thus be washed off by rain
- Standing puddles cause differential stresses due to evaporation cooling
- Repeated wetting and drying affects visco-elastic properties
- High winds can cause cracking and tearing, blowing off protective granules
- Unsuitable for temperatures exceeding 44°C
- Cold bitumen has limited storage life (quick use, within three months; shipment problems)

Remedies: - Adequate protection against solar radiation by reflective treatment (eg lime wash, aluminium paint, light-coloured aggregate chippings) possibly also roof-screening
- Sufficient roof inclination (minimum 3%) and drainage to avoid standing puddles
- Movement joints, allowing differential movements between membrane and substructure
- Adhesion at intervals to prevent blistering due to water vapour, but better adhesion where wind storms occur, which may suck off felt
- Reinforcements of roofing felts preferably inorganic (eg. asbestos or glass fibre). Others, like rag felt, are susceptible to attack by biological agents
- Addition of preservatives to prevent decay
- Cold bitumen: thorough mix before use, applied (when no rain and not too hot) in thin layers
- Good workmanship and regular maintenance, i.e. inspection and periodic coating of bitumen every few years.

Anstriche

Anwendung

- auf verzinktem Blech: Vorbehandlung — entfetten, "weißen Rost" entfernen, aufrauhen, korrosionsbeständiger Grundanstrich (z.B. zwei Anstriche mit Epoxidasphalt); Fertigfläche — ein oder zwei Anstriche mit Außenfarbe (z.B.Acrylharzemulsionsfarbe)
- auf Asbestzement, Beton, Mauerwerk: Vorbehandlung — Staub, Algen usw. abbürsten, Schutzschicht aus 1% Kupfer-Sulphat-Lösung gegen Algen; Grundierung — alkalibeständiger Anstrich; Fertigfläche — zwei Anstriche (z.B. Chlorkautschukfarbe, Kunststoffemulsionsfarbe, Zement- oder Kalkfarbe)
- auf Holz: Vorbehandlung — ablagern, abschmirgeln und säubern, Grundanstrich; Fertigfläche — Farben, die nicht die Poren schließen (Firnissen für Außenflächen nicht ratsam), Oberanstriche können Fungizide enthalten
- auf Bitumen: keine Vorbehandlung; Oberanstrich — Aluminiumpigment- oder bituminöse Aluminiumfarbe; Kalkanstrich auch möglich, aber weniger haltbar

Vorteile

- Schutz gegen Sonnenbestrahlung durch Reflexion
- Schutz gegen Wind und Regen durch Zusammenhalten loser Teilchen, Verschließen durchlässiger Materialien, korrosionsbeständig
- Schutz gegen biologische Schädigung durch den Gebrauch von Fungiziden und Insektiziden
- Verbesserung der äußeren Erscheinung und der hygienischen Bedingungen
- Verbesserung der Haltbarkeit

Nachteile

- plastikbasierte Farben müssen hauptsächlich von Industrieländern importiert werden (aber örtliche Herstellung nimmt zu)
- Farben werden durch Sonnenbestrahlung, Feuchtigkeit, windgetragenen Sand, atmosphärische Verunreinigungen, Schimmelbildung und Termitenbefall zerstört
- falsch aufgetragene Anstriche können zu beschleunigter Zerstörung der Substrate führen
- Kalkanstriche erfordern Erneuerung nach jeder Regenzeit

Abhilfe

- größte Wichtigkeit ist die Vorbereitung des Substrats, um maximale Haftfestigkeit des Oberanstrichs zu sichern
- Erhaltung von sauberen Oberflächen und periodische Erneuerung der Anstriche
- auf Substraten, die dazu neigen, Feuchtigkeit aufzusaugen, möglichst keine Verwendung undurchlässiger Farben; statt dessen Farben, die "atmen", z.B. Emulsions-, Kalk- oder Zementfarben

Paints

Applications:

- On galvanized iron: Treatment — degreasing and removal of "white rust", roughening, corrosion resistant primer (eg. two coats epoxy tar). Finish — one or two coats of exterior paint (eg. acrylic emulsion paint)
- On asbestos cement, concrete and masonry: Treatment — dust, algae, etc. brushed off, protective coating of 1% copper sulphate solution against algal growth. Primer — alkali resistant primer. Finish — two coats (eg. chlorinated rubber paint, plastic emulsion paint, cement paint or limewash).
- On timber: Treatment — seasoning, sand-papering and cleaning, primer. Finish — paints that do not seal pores (varnishing not advisable for exterior), finishes may incorporate fungicidal ingredients.
- On bitumen: No prior treatment. Finish — aluminium pigmented or bituminous aluminium paint. Also limewash possible, but less durable.

Advantages:

- Protection against solar radiation by reflection
- Protection against wind and rain by bonding loose particles, sealing permeable material, corrosion resistance
- Protection against biological hazards by use of fungicides and insecticides
- Improvement of appearance and sanitary conditions
- Improvement of durability

Disadvantages:

- Plastic based paints mainly imported from industrialized countries (but local production increasing)
- Deterioration of paints by solar radiation, moisture, wind-blown sand, atmospheric pollution, mould growth and even termite attack
- Wrongly applied paints may lead to quicker deterioration of substrates
- Limewash requires renewal after each rainy season

Remedies:

- Greatest importance given to preparatory treatment of substrate to ensure maximum adherence of finish
- Maintenance of clean surfaces and periodic renewal of coatings
- On substrates that tend to absorb moisture, avoidance of impervious coatings; instead paints that "breathe", eg. emulsion paints, lime or cement wash.

Kunststoffe

Anwendung :
- Feuchtigkeitsisolierung und Dampfsperren, z.B. Polyäthylen, Polyvinylchlorid (PVC), Butylkautschuk, Polyisobutylen
- Wärmedämmung durch Schaumstoffe (z.B. Polyurethan-Schaumplatten) und Verbundplatten
- begrenzter Gebrauch von Wellplatten, z.B. PVC und glasfaserverstärktes Polyester, wegen Verwitterungsproblemen
- monolithische Dächer, meist Doppelwölbungen oder Faltplattenanordnungen zur Aussteifung (z.B. glasfaserverstärktes Polyester)

Vorteile :
- große Auswahl an Formen, Farben und anderen physikalischen Eigenschaften; Nachahmung von traditionellen Produkten, um hiermit Verbraucherwiderstand gegen Unbekanntes zu überwinden
- leichtgewichtig, was Handhabung und Transport verbilligt und erleichtert; zusätzlicher Vorteil durch geringen Aufwand für Tragkonstruktion
- keine Korrosion, leicht sauberzuhalten
- keine Feuchtigkeitsbewegungen

Nachteile :
- Plastik verbreitet Flammen, entwickelt schädliche Dämpfe und dichten Rauch
- Mangel an Festigkeit, Tendenz sich allmählich zu verformen, selbst bei normalen Temperaturen, und schneller Verfall der mechanischen Eigenschaften bei höheren Temperaturen
- Verfall durch Ultraviolettstrahlung (immer noch unausreichende Information vorhanden über Kunststoffanwendung unter tropischen Bedingungen)
- große Wärmebewegungen im Gegensatz zu traditionellen Materialien
- hauptsächlich aus Industrieländern importiert, verhältnismäßig teuer
- die meisten Plastikarten, außer den harten Varianten, anfällig für Termitenbefall und Abrieb durch windgetragenen Sand

Abhilfe :
- möglichst keine Anwendung, wo Feuer entstehen kann
- Schutz gegen Hitzequellen
- Vermeidung von lang anhaltender mechanischer Belastung, welche zu Bruchschäden führen könnte
- weitgehende Abschirmung gegen Sonnenbestrahlung, falls kein hoch-widerstandsfähiges Material verwendbar
- Schutzmaßnahmen gegen Termiten und windgetragenen Sand

Plastics

Applications:
- Water proofing membranes and vapour barriers, eg. polyethylene, polyvinyl chloride (PVC), butyl rubber, polyisobutylene
- Thermal insulation with cellular plastics, eg. polyurethane foam slabs and sandwich panels
- Limited use of corrugated roofing sheets, eg. PVC and glass reinforced polyester, due to problems with weathering behaviour
- Monolithic roofs, usually employing double curvature or folded-plate arrangements for rigidity, eg. glass-fibre reinforced polyester.

Advantages:
- Capability to take on a wide variety of forms, colours and other physical properties. Imitation of traditional products, as a means of overcoming consumer resistance due to unfamiliarity
- Lightness in weight, making handling and transportation easier and cheaper. Additional advantage in reduction of supporting structure
- No corrosion, easily kept clean
- Not subject to moisture movements

Disadvantages:
- Ability of plastics to spread flame, develop noxious fumes and dense smoke
- Lack of rigidity, tendency to "creep", even at ambient temperatures, and rapid decline in mechanical properties at elevated temperatures
- Deterioration due to ultra-violet radiation (still insufficient data available on use of plastics in tropical conditions)
- Large thermal movement relative to most traditional materials
- Mainly imported from industrilaized countries, relatively high costs
- Most plastics, except hard varieties, susceptible to termite attack and abrasion by wind-borne sand.

Remedies:
- Avoidance of use, where fires are likely to occur
- Protection from heat sources
- Avoidance of prolonged mechanical stress, which could lead to breakage
- Minimum exposure to solar radiation, unless highly resistant materials are used
- Protective measures against termites and wind-borne sand.

3.4.3 Abfallmaterialien

Landwirtschaftliche Abfälle

Anwendung :
- Bewehrungsfasern für verschiedene Anwendungen (z.B. stabilisierte Erde und Beton) aus Bagasse, Kokosnußschalen, Bananenstengeln
- Füllstoffe für Spanplatten, Faserstoffplatten, usw. von Reisschalen, Kokosnußschalen, Holzrückständen
- leichtgewichtige Füllstoffe für Beton aus getrockneten Reisschalen, karbonisierten nicht-eßbaren Körnern
- pozzulanische Materialien aus Reisschalenasche
- wasserfeste Beschichtungen aus Bananenstengel (in ein wenig Wasser gekocht), flüssiges Harz aus Kaschunußschalen

Vorteile :
- extrem billige Rohstoffe
- Reduzierung der durch Anhäufung von Abfall geschaffenen Umweltprobleme

Nachteile :
- oft nicht ausreichend vorhanden, da viele Abfälle als billiges Heizmaterial benutzt werden, obwohl die Vorteile, sie in billiges Baumaterial umzuwandeln, viel größer sein könnten

Abhilfe :
- intensivere Forschung der technologischen Aspekte sowie Kosten/Nutzen-Analyse
- gesetzliche Maßnahmen für die Organisation der Abfallwiederverwertung

Industrieabfälle

Anwendung :
- Zuschlagstoffe für Beton aus Flugasche (befeuchtet, zu Kügelchen geformt und gesintert), Schaumhochofenschlacke (durch Zugabe von etwas Wasser zur schmelzflüssigen Schlacke)
- hydraulische Bindemittel aus Flugasche und "Surkhi" (pulverisierter Mauer- und Dachziegelausschuß, hauptsächlich in Indien verwendet)
- Mineralwolle (als Füllstoff für Bitumenpappe) aus Flugasche
- feuchtigkeitsisolierende Anstriche aus Schwefel

Vorteile :
- die gleichen wie für landwirtschaftliche Abfälle
- gut etablierte Technologien in vielen Ländern

Nachteile :
- nur bei Verwendung von Schwefel: Entwicklung von Giftstoffen und Gerüchen bei hoher Temperatur (50°C), Sprödigkeit und Schrumpfung während des Erhärtens, muß in flüssigem Zustand aufgetragen werden (Probleme des verfrühten Erhärtens), erfordert spezielle Werkzeuge
- verfrühtes Erhärten von Flugasche unter feuchten Bedingungen

Abhilfe :
- Erforschung neuer Techniken zur kostengünstigen Anwendung von Schwefel
- Lagerung von Flugasche mit der gleichen Sorgfalt wie von Zement.

3.4.3 Waste Materials

Agricultural Waste

Applications:
- Reinforcement fibres for various uses (eg. stabilized soil and concrete) from bagasse, coconut husks, banana stalks
- Fillers for particle board, fibreboard, etc. from rice hulls, coconut husks, wood residues
- Lightweight aggregates for concrete from dried rice hulls, carbonated non-edible grains
- Pozzolanic materials from rice hull ash
- Waterproof coatings from banana stalks (boiled in little water), cashew nutshell liquid resin.

Advantages:
- Extremely cheap raw materials
- Reduction of environmental problems caused by accumulation of waste

Disadvantages:
- Often insufficient availability, since much waste is being used as cheap fuel, even though the benefits of conversion into cheap building materials could be greater.

Remedies:
- Deeper research on technological aspects and cost/benefit analysis
- Legislative means in organizing waste reuse.

Industrial Waste

Applications:
- Aggregates for concrete from fly ash (moistened, nodulized and sintered), foamed blast furnace slag (by adding little water to molten slag)
- Hydraulic setting binders from fly ash and "surkhi" (pulverized brick and tile rejects, mainly used in India)
- Mineral wool (as filler for bitumen felt) from fly ash
- Waterproofing coats using sulphur.

Advantages:
- Same as for agricultural waste
- Well established technologies in many countries.

Disadvantages:
- Only in use of sulphur: high level of toxicity and odour at high temperature (50°C), brittleness, contraction during hardening. Necessity of application in molten state (problem of premature hardening) requiring special equipment
- Premature setting of fly ash in moist conditions.

Remedies:
- Research into low-cost sulphur-coating techniques
- Storage of fly-ash with same care as cement.

3.5 Verschiedene Gesichtspunkte

3.5.1 Dimensionen

Bei einfachen Dachkonstruktionen für den Wohnungsbau garantiert die traditionelle Bemessung und Montage der Bauelemente normalerweise eine adäquate und stabile Konstruktion. Jedoch, mit zunehmenden Spannweiten über das Optimum der jeweiligen Materialien hinaus, bewirken zunehmende Materialstärken (der statischen Bauteile und Dacheindeckung), Eigengewicht und Materialmengen, eine Verminderung der Wirtschaftlichkeit und limitieren die sinnvolle Ausnutzung der Materialeigenschaften. Eine Erhöhung der statischen Tiefe der Elementkrümmung, -faltung oder -wellung ist dann nötig, um einen Balkeneffekt zu erzeugen. Hierdurch kann ein verhältnismäßig dünnes Material benutzt werden für Spannweiten, die im Verhältnis zur Dicke der statischen Hülle sehr groß sind.

In bezug auf Höhen von abgehängten Decken oder flachen Dächern zeigten experimentelle Studien in Indien, daß die Erhöhung der Decken auf mehr als 2,70 m keine nennenswerten Temperaturvorteile zeigten, unabhängig von Ventilationsbedingungen und jahreszeitlichen Veränderungen.

Die Verwendung von Modulmaßen bei der Planung von Dächern ist noch nicht ausreichend verbreitet, doch besteht in den meisten Ländern eine Neigung, den Dezimeter als Grundmodul zu benutzen. Das Rastermaß muß ein Vielfaches des Grundmoduls sein (3, 6, 9, usw. sind übliche Multipeln), wobei es den Raum zwischen angrenzenden Komponenten mit einschließt, so daß die Komponentengröße kleiner ist als das Rastermaß. Die Modulmaßordnung kann auf diese Weise für Materialgrößen und Elementabstände, parallel zum Ortgang und zum First gemessen, angewandt werden. Die Hauptvorteile von Modulmaßen sind leichtere Montage, Austausch von Elementen durch andere Materialien, sowie Reduzierung der Materialverschwendung durch Verschnitt.

3.5 Miscellaneous Aspects

3.5.1 Dimensions

In simple domestic roof constructions, a tradition of member-sizing and assembly normally ensures an adequate and stable structure. However, as spans increase above the optimum for each material, increased thicknesses (of structural members and roof cover), dead weight and material usage make them inefficient and limit their capability. An increase of structural depth of the whole unit of curvature, folding or corrugation is then necessary in order to create a beam effect and by this means a basically thin material may be used over spans which are large in relation to the thickness of the structural surface.

As regards the heights of suspended ceilings or flat roofs, experimental studies undertaken in India have shown that raising the ceiling height above 2.70 m had no significant thermal advantage, irrespective of ventilation conditions and seasonal variations.

The use of modular coordination in roof design is still not sufficiently widespread, though there are tendencies in most countries to use the decimetre as the basic module. The modular dimension must be a multiple of the basic module (3, 6, 9, etc. are common multiples), and includes the space needed for joining the components, so that the component size is less than the modular dimension. Modular coordination can thus be applied to material sizes and spacing of members measured parallel to eaves and ridge. The main advantage of modular coordination is to facilitate assembly and even substitution of different materials and to reduce wastage due to cutting of excess material.

3.5.2 Dachneigungen

Dachneigungen werden oft in Grad angegeben (z.B. 15°, 20°, 22,5°), wahrscheinlich weil dieses leichter vor Augen zu führen ist. In der Praxis ist es jedoch sehr schwierig oder unmöglich für die Arbeiter auf der Baustelle oder in der Werkstatt, diese Winkel auszumessen. Deshalb werden Dachneigungen besser in dem einfachen Verhältnis zwischen Höhe und Spannweite angegeben (z.B. 1 : 1; 1 : 1,5; 1 : 2; 1 : 20), soweit möglich, unter Anwendung runder Zahlen.

Die Hauptfunktion der Dachneigung ist, Regenwasser ablaufen zu lassen, ehe es in das Dachmaterial eindringen kann. Je niedriger die Durchlässigkeit, desto weniger Dachneigung ist erforderlich. Jedes Dachdeckenmaterial hat demnach seinen eigenen optimalen Neigungswinkel. Einige der empfohlenen Mindestneigungen sind:

3.5.2 Roof Slopes

Inclinations of roofs are often given in degrees (eg. 15°, 20°, 22.5°), probably because these are easier to visualize. In practice, however, it is extremely difficult or impossible for workers on the site or in the workshop to measure out these angles. Therefore roof slopes are best expressed in simple relations between height and span (eg. 1 : 1, 1 : 1.5, 1 : 2, 1 : 20), preferably using round numbers.

The main function of roof slopes is to allow rainwater to run off before it is able to penetrate the roofing fabric. The lower the permeability, the less slope is required. Each roofing material therefore has its own appropriate pitch. Some recommended minimum slopes are:

Dachdeckenmaterial	erforderliche Mindestneigungen	
	Verhältnis	Winkel
Grasdeckung	1 : 1	45°
Holzschindeln:		
- unbehandeltes Holz	1 : 1	45°
- druckbehandeltes Holz	1 : 1,5	33°40′
Gebrannte Dachziegel:		
- Biberschwanz- und Mönch- und Nonnendeckung	1 : 1,5	33°40′
- Flachdachpfannendeckung (ohne wasserdichte Folie)	1 : 2	26°40′
- Flachdachpfannendeckung (mit wasserdichter Folie)	1 : 3	18°30′
Verzinktes Wellblech:		
- mit Überlappungen (d.h. mehr als eine Platte in Fallrichtung)	1 : 3	18°30′
- ohne Überlappung (d.h. eine Platte zwischen First und Traufe)	1 : 5	11°20′
Asbestzementplatten:		
- gewellt (mit Überlappungen)	1 : 3	18°30′
- gewellt (ohne Überlappung)	1 : 5	11°20′
- trogförmig (ohne Überlappung)	1 : 10	5°40′

3.5.3 Statisches Verhalten

Für die statische Festigkeit und Stabilität eines Daches muß sowohl das Eigengewicht als auch die Verkehrslasten berücksichtigt werden. Ersteres besteht aus dem Eigengewicht der Dachkonstruktion und der Dachhaut sowie aus den statischen Lasten von Geräten und Anlagen, die auf oder unter dem Dach befestigt sind. Haupterfordernis ist es, ein geringeres Eigengewicht pro Flächeneinheit zu erreichen, je länger die Spannweite ist (siehe 3.5.1 Dimensionen). Dies steht jedoch im Gegensatz zur Notwendigkeit dickwandiger Konstruktionen, um die Schallübertragung zu reduzieren, besonders der der Aufprallgeräusche von Regen und Hagel. Verkehrslasten sind jene, die durch Winddruck und Begehung des Daches hervorgerufen werden. In einigen Wüstengebieten muß mit Sandablagerungen gerechnet werden. Wo Erdbeben und Wirbelstürme erwartet werden, müssen besondere Entwurfsprinzipien beachtet werden, um ernste Schäden zu vermeiden.

Es muß jedoch betont werden, daß die statische Zulänglichkeit eines Daches zum größten Teil vom übrigen Gebäude abhängt, z.B. bei Häusern (mit unzureichendem

Roof covering material	Minimum slope required	
	Ratio	Angle
Grass thatching	1 : 1	45°
Timber shingles:		
- untreated timber	1 : 1	45°
- pressure impregnated timber	1 : 1.5	33°40′
Burnt clay roof tiles:		
- plain tiles and Spanish type	1 : 1.5	33°40′
- Roman type (without waterproofing membrane)	1 : 2	26°40′
- Roman type (with waterproofing membrane)	1 : 3	18°30′
Corrugated galvanized iron sheets:		
- with end laps (ie more than one sheet in direction of fall)	1 : 3	18°30′
- with no end laps (ie one sheet between ridge and eaves)	1 : 5	11°20′
Asbestos cement sheets:		
- corrugated (with end laps)	1 : 3	18°30′
- corrugated (with no end laps)	1 : 5	11°20′
- troughed (with no end laps)	1 : 10	5°40′

3.5.3 Structural Performance

For the structural strength and stability of a roof, attention must be given both to its dead load and imposed loads. The former consists of the self-weight of the roof structure and its claddings and any other static loads from equipment carried on or suspended from the roof. The principal requirement is to achieve lower dead weight per unit area, the longer the span is (see 3.5.1 Dimensions). This, however, is in conflict with the need for heavy mass for reduction of sound transmission, especially of impact noise from the drumming of rain and hail. Imposed loads comprise those due to wind forces and moving traffic. In some desert regions sand deposition in sandstorms may have to be taken into account. Where earthquakes or hurricanes are to be expected, special design principles must be observed to avoid serious damage.

It must, however, be stressed that the structural performance of a roof largely depends on the rest of the building, eg. with houses (having poor or no foundations) built on expansive soils, swelling and contracting of the ground can cause serious failures of building elements and their joints. Similarly, failure of walls under seis-

oder keinem Fundament), die auf dehnbarem Boden gebaut wurden, kann Schwellen und Zusammenziehen des Bodens zu folgenschwerem Versagen der Bauelemente und deren Verbindungen führen. Ähnlich kann das Versagen von Wänden unter seismischen Kräften den Zusammenbruch des Daches verursachen. Daher ist die Anbringung eines durchgehenden Ringbalkens entlang der Oberkante der Wände, die das Dach tragen, oft eine der wichtigsten Anforderungen. Alternativ dazu sichert eine völlige statische Trennung der Dachkonstruktion von den Wänden, indem also die Last über unabhängige Stützen direkt zum Fundament geführt wird, Stabilität, selbst wenn die Wände zusammenbrechen.

3.5.4 Wärme- und Feuchtigkeitsbewegungen

Die Aufnahme von Sonnenenergie während des Tages und der Abfluß von langwelliger Rückstrahlung während der Nacht bedeutet, daß Dächer in den Tropen relativ großen Temperaturschwankungen ausgesetzt sind, wobei die größten Temperaturspannen in den trockenen Tropen auftreten. Die resultierenden Wärmeausdehnungen und Schrumpfungen können zu ernsten Schäden der Dachelemente führen.

Je nach Art der Materialien, die dafür verwendet werden, kann die Dachkonstruktion Feuchtigkeitsbewegungen ausgesetzt sein, hervorgerufen durch das anhaltende Schrumpfen von Materialien, wie zum Beispiel austrocknendem Zement, und durch periodische Veränderungen der relativen Feuchtigkeit. In geringem Maße sind Verbiegungen und Verdrehungen statisch nicht immer schädigend, könnten aber bei Naturkatastrophen, wie Erdbeben und Wirbelstürmen, ein Risiko darstellen.

Um Wärme- und Feuchtigkeitsbewegungen entgegenzuwirken oder die Schäden auf einem Minimum zu halten, wären die folgenden Punkte von Interesse:

a. Ziegel-, Schindel- oder Wellplattendächer nehmen Wärmebewegungen durch verschiebbare Überlappung und flexible Materialien auf. Gefaltete oder gerundete Oberflächen nehmen die Bewegung durch Erhöhung und Vertiefung der Krümmungsprofile auf.

b. Starre Betonplatten und dünnwandige Dächer sollten oberhalb der Platte ausreichend isoliert sein, und die äußere Oberfläche sollte durch reflektierende Anstriche oder Beschattungsvorrichtungen geschützt sein.

c. Bewegungsfugen sollten bei Dächern vorgesehen werden, um relative Bewegungen zuzulassen, ohne die Dachkonstruktion zu schädigen oder zu schwächen. Ungeschützte Bewegungsfugen müssen völlig wasserdicht sein.

mic forces can cause roofs to collapse. Therefore the provision of a continuous ring beam along the top edge of the walls supporting the roof is often a prime necessity. Alternatively, a complete structural separation of the roof construction from the walls, transmitting loads via independent columns directly to the foundations, ensures stability even if the walls fail.

3.5.4 Thermal and Moisture Movement

The absorption of solar energy during the day and emission of long-wave radiation at night can mean that roofs in tropical areas can be subjected to fairly large ranges of temperature, the larger temperature ranges occuring in the dry tropics. The resulting thermal expansion and contraction can cause serious damage to roof components.

Depending on the materials used in its construction, the roof can also be affected by moisture movement, caused by permanent shrinkage of materials, such as concrete drying out, and by periodic changes in relative humidity. Within limits, deflection and distortion is not always structurally damaging, but could be a hazard in natural disasters, such as earthquakes and hurricanes.

To counteract thermal and moisture movement or minimize damage caused by it, the following points are of interest:

a. Tiled, shingled or corrugated-sheet roofs take up thermal movement by sliding overlaps and flexibility of materials. Folded or curved surfaces take the movement by a rise and fall of the curved profiles.

b. Rigid concrete slab and membrane roofs should be efficiently insulated above the slab and the outer surface should be protected by application of reflective coating or shading devices.

c. Movement joints should be provided in roofs to permit the relative movements to take place without damaging or weakening the roof structure. Exposed movement joints must be completely waterproof.

3.5.5 Wirtschaftliche Überlegungen

Selbst wenn zuverlässige Kostenvergleiche über Dachkonstruktionen vorhanden wären, hätten diese wenig praktischen Wert, da Dachentwürfe, Konstruktionsmethoden, Arbeits- und Materialkosten von Gebiet zu Gebiet sehr verschieden sind. Einige kostenbeeinflussende Prinzipien bestehen jedoch und sollten bei der Planung und Ausführung von Dächern berücksichtigt werden.

Die Anwendung eines Systems nahe an seinen größtmöglichen Spannweiten resultiert normalerweise in hohen Fertigungs-, Transport- und Montagekosten. Dies erfordert kleine Raumdimensionen, aber aus verschiedenen anderen Gründen ist dies bereits eines der Hauptmerkmale der Niedrigkosten-Bauweise.

Die anfänglichen Kosten auf einem Minimum zu halten, kann hohe Ausgaben für Instandhaltung und Reparaturen bedeuten. Schlecht entworfene Dächer können zu verminderter Leistungsfähigkeit und schlechtem Gesundheitszustand der Bewohner führen, welche ebenso wichtige Kostenfaktoren sind. Erhebliche Kenntnisse über örtliche Materialien, Preise und Facharbeit sowie über die Bedingungen, denen das Dach ausgesetzt ist, sind daher erforderlich, um einen wirtschaftlich geeigneten Dachentwurf zu finden.

Vorfertigung als ein kostenreduzierender Faktor hat begrenzte Anwendung für den Niedrigkosten-Wohnungsbau, außer für die Herstellung von Wellblech oder verstärkte Leichtbauplatten. Fertigbaukonstruktion, wie sie normalerweise verstanden wird, heißt Vorfertigung von großen Platten oder ganzen Dächern, was spezialisierte und teure Montagewerkzeuge erfordert. Leichte Handhabung und Baumethoden sind deshalb wichtiger als Vorfertigung.

Je einfacher der Entwurf und Bauablauf, desto besser und billiger wird im allgemeinen das System sein. Es sollte eine für Arbeiter einfach erlernbare Konstruktionsmethode vorsehen, den Einsatz von manueller Arbeit anstatt von teurem, kompliziertem Arbeitsgerät erfordern, nur örtlich vorhandenes, nicht-importiertes Material verwenden und Ungenauigkeiten tolerieren. Das ist in den Entwicklungsländern, wo Fachkräfte und kompetentes Aufsichtspersonal nicht ausreichend verfügbar sind, von besonderer Wichtigkeit.

3.5.5 Economic Considerations

Even if reliable cost comparisons of roof constructions were available, they would be of little practical value, as roof designs, construction methods, labour and material costs differ so greatly from region to region. A few principles governing cost do however exist and should be considered in roof design and construction.

The use of a system at the upper limits of its span capability normally results in higher costs of fabrication, transportation and assembly. This calls for small room dimensions, but, for a number of other reasons, this already is a common feature of low-cost housing design.

Keeping initial costs at a minimum may mean high expenses for maintenance and repair over long periods. Poorly designed roofs can result in reduced efficiency and bad health of the occupants, which are equally important cost factors. It therefore requires considerable knowledge of local materials, prices and workmanship, as well as the conditions to which the roofs are subjected, to find the economically most appropriate roof design.

Prefabrication as a factor of cost reduction has limited application in low-cost housing, except for the manufacture of corrugated or strengthened lightweight sheeting. Prefabricated construction, as it is normally understood, means prefabrication of large panels or whole roofs, which need specialized and expensive installing equipment. Ease of handling and erection therefore are of more importance than prefabrication.

In general the simpler the design and procedure, the better and cheaper the system will be. It should be easy for workers to learn construction methods, make use of manual labour rather than expensive, complicated equipment, use only locally available, non-imported material and tolerate inaccuracies. This is especially important in developing countries where skilled labour and competent supervisory staff can be in short supply.

4. ALLGEMEINE ÜBERSICHT ÜBER NIEDRIGKOSTEN-DACHSYSTEME

4.1 Herkömmliche Systeme

4.1.1 Traditionelle Dächer

Einheimische Häuser, in allen Teilen der Welt, haben zunehmend das Interesse von Architekten und Ingenieuren geweckt, nicht nur weil jedes traditionelle Bauwerk ein Stück Kunst ist, das oft handwerkliche Geschicklichkeit vorführt, die beim "modernen Mann" längst ausgestorben ist, sondern hauptsächlich, weil (mit ein paar Ausnahmen)viel über Gebäude-Klimatologie, Materialverwendung, Gefühl für Proportionen und den menschlichen Maßstab, Wirtschaftlichkeit bei Konstruktion und Instandhaltung sowie Interpretation von örtlichen Kulturen und menschlichen Bedürfnissen zu lernen ist. Die folgende Tabelle (welche aus naheliegenden Gründen nur eine sehr kleine Auswahl von mehreren tausend möglichen Beispielen ist) gibt eine allgemeine Vorstellung über die Vielfalt der Formen und Konstruktionen, wovon einige durch Zeichnungen detaillierter erläutert werden.

4. GLOBAL REVIEW OF LOW-COST ROOFING SYSTEMS

4.1 Systems in Common Usage

4.1.1 Traditional Roofs

Indigenous houses in all parts of the world have increasingly captured the interest of architects and engineers, not only because each traditional structure is a work of art, often displaying skills long extinct in "modern" man, but mainly because (apart from a few exceptions) much can be learnt from them with respect to building climatology, use of materials, sense of proportions and human scale, economy of construction and maintenance, and translation of local cultures and human needs.
The chart below (which for obvious reasons is only a minute selection from several thousand possible examples) gives a general idea of the diversity of forms and constructions, some of which are described by means of diagrams in more detail.

Abb. 4.1 Masai-Häuser (Kenia, Tansania)
Fig. 4.1 Masai dwellings (Kenya, Tanzania)

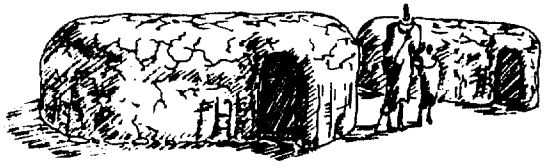

Abb. 4.3 Hausa Compound (Nord-Nigeria)
Fig. 4.3 Hausa compound (Northern Nigeria)

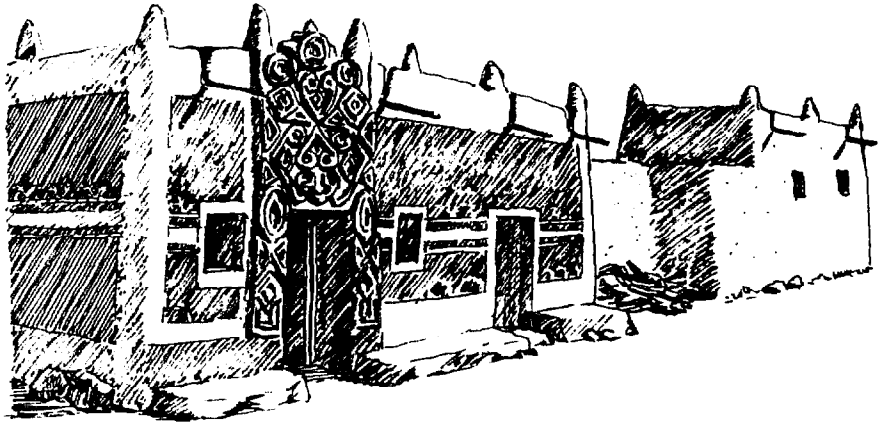

Abb. 4.2 Pueblo-Häuser (Südwest-USA)
Fig. 4.2 Pueblo houses (Southwestern United States)

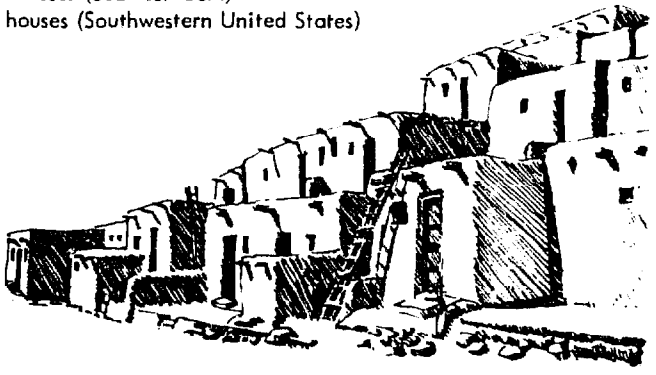

Haustyp Volksstamm/Kultur Land/Region	Materialien und Konstruktionen	Bemerkungen
FLACHE DÄCHER		
Dachgrundriß: oval oder rechteckig		
Boma der Masai, Kenia, Tansania	Fachwerk aus Ästen, mit Gras und Zweigen zusammengeflochten. Glatte Oberflächenbehandlung mit frischem Kuhdung. Zusätzliche Wasserfestigkeit mit Häuten. Schmale Tür als einzige Öffnung.	Frauen sind für Bauarbeiten verantwortlich. Sparsam mit Materialien und Aufwand, daher Höhe des Daches zu niedrig, um aufrecht zu stehen. Kleine Feuer brennen dauernd, füllen Raum mit Rauch. Stromlinienform (gerundete Ecken) und -oberflächenbearbeitung von Vorteil in windigen Gegenden.
Dachgrundriß: quadratisch oder rechteckig		
Pueblo-Behausungen z.B. der Hopi und Zuni, Südwest Vereinigte Staaten	Drei- bis fünfgeschossige Terrassenbebauung aus Lehmziegeln oder Steinen, mit Lehm verputzt. Dach bestehend aus geschälten Zederbalken, überdeckt mit kleinen Rundhölzern, Zederrinde und Gras, welches eine 10 cm dicke Lehmschicht trägt. Nur ein paar kleine Öffnungen in den äußeren Wänden.	Eingänge der Pueblos:hauptsächlich mittels Leitern erreichbare Öffnungen im Dach. Benutzung der Dächer zum Sitzen, Schlafen und Arbeiten. Da dicke Zederbalken in trockenen Zonen rar sind, werden sie nicht auf die erforderliche Länge geschnitten, sondern durchdringen die Außenwand und kragen beliebig weit aus. Diese Balken werden über Jahrhunderte immer wieder verwendet.
Compounds Hausa, Nord-Nigeria	Wände aus birnenförmigen Lehmziegeln und verputzt, Lehmdächer verstärkt durch Holz und Palmenzweige.	Alternativ gewölbte Dächer. Symbolische Dekorationen am Dachrand entlang und an den Wänden sehr charakteristisch.

House Type, Tribe/Culture Country/Region	Materials and Constructions	Comments
FLAT ROOFS		
Roof Base: oval or rectangular		
Bama of the Masai, Kenya, Tanzania	Framework of branches, interwoven with grass and twigs. Smooth surface finish with fresh cow dung. Additional water-proofing with layer of hides. Narrow door is the only opening.	Women responsible for building. Economy of materials and effort hence height of roof too low to stand upright. Small fires constantly burning in hut, fill rooms with smoke. Streamlined shape (corners rounded) and finish are advantageous in windy environment.
Roof Base: square or rectangular		
Pueblo dwellings eg. of Hopi and Zuni, Southwestern United States	Three to five storeyed, terraced houses of adobe brick or stone in adobe mortar, plastered with clay mud. Roofs consist of peeled cedar beams covered with small poles, cedar bark and grass, which support 10 cm coat of adobe. Only few small openings on exterior walls.	Access to pueblos generally through openings in roof, using ladders. Roofs used for sitting, sleeping, working. Since the thick cedar beams are rare in arid regions, they are not cut to required lengths, but allowed to project through face of exterior walls. These beams are used over again for hundreds of years.
Compounds Hausa, Northern Nigeria	Walls made of pear-shaped mud-bricks and plastered over. Mud roofs reinforced with wood or palm fronds.	Alternatively roofs are vaulted. Symbolic decorations along roof edges and walls are very characteristic.

Haustyp Volksstamm/Kultur Land/Region	Materialien und Konstruktionen	Bemerkungen
Innenhofhäuser, Dogon, Mali	Gruppenbehausungen mit lehmverputzten Lehmziegelwänden. Lehmverputzte Dächer ruhen auf Holzsparren, -balken und -stützen, wo erforderlich. Vorgefertigte konische Strohdächer bedecken zusätzlich flache Dächer von Getreidespeichern.	Häuseranordnung nach kosmologischem Schema, Mindestdimensionen, zweistöckig. Balken und Sparren, die aus den Außenwänden auskragen, werden als Gerüst für Konstruktion und Reparaturen am Haus benutzt. Konische Strohdächer auf viereckiger Grundfläche ergeben wellige Trauflinie.
Untergrundhäuser, z.B. Matmata, Sahara und Honnan, China	Behausungen aus weicher, poröser Erde geschnitten. Erdoberfläche selbst bildet das Dach.	Nutzung der unerschöpflichen Wärmekapazität der Erde: warm im Winter, kühl im Sommer.
Mehrgeschossige Häuser, Nordafrika und Mittlerer Osten	Hauptmaterial Lehm mit pflanzlicher Bewehrung, manchmal gebackene Lehmziegel. Dächer meistens aus Holz und Lehm.	Dächer häufig zum Schlafen benutzt. Konstruktion für überwiegend trockene Zonen geeignet. Oft Windtürme auf den Dächern, um Brisen ins Innere zu lenken.
PULTDÄCHER		
Windbrecher bei nomadischen Stämmen in vielen Ländern, z.B. Nordafrika, Türkei, Malaysia, Australien	Ganzes Bauwerk bestehend aus dem Dach und den tragenden Elementen (keine Wände), meistens an drei Seiten offen. Pflanzenmaterialien, die örtlich gefunden werden, leichte Matten oder Textilien.	Einzige Funktion: Schattenspenden und Schutz vor dem vorherrschenden Wind. Überraschend oft anzutreffen in Gebieten mit rauhem Klima, was dicht umschlossene Lebensräume aus isolierenden Materialien erfordert.

House Type, Tribe/Culture Country/Region	Materials and Constructions	Comments
Courtyard houses, Dogon, Mali	Cluster dwellings with mud plastered adobe walls. Mud plastered roofs rest on wooden rafters, beams and columns where necessary. Prefabricated conical straw roofs additionally cover flat roofs of graneries.	Layout of houses according to cosmological scheme, minimum dimensions, two storeys high. Beams and rafters penetrating exterior walls used as scaffoldings in construction and repair of houses. Conical straw roofs on square base make eaves always uneven.
Underground houses eg Matmata, Sahara and Honnan, China	Dwellings cut out of soft porous soil. Ground surface constitutes the roof.	Use is made of infinite heat capacity of earth: warm in winter, cool in summer.
Multistoreyed houses, North Africa and Middle East	Primary material mud with plant reinforcements, sometimes burnt clay bricks. Roofs usually of timber and mud.	Roofs frequently used for sleeping. Construction appropriate for predominantly hot dry regions. Often wind towers on roofs to divert breeze to interior.
SINGLE PITCHED ROOFS		
Windbreaks used by nomadic tribes in many countries, eg North Africa, Turkey, Malaysia, Australia	Entire structure consisting of roof and supporting members (no walls), usually open on three sides. Plant materials found locally or light matting or textiles brought by dwellers.	Only function is to give shade and protection from prevailing winds. Surprisingly often used in regions with harsh climates, requiring well enclosed spaces with insulating materials.

Abb. 4.4 Dogon-Siedlung (Mali)
Fig. 4.4 Dogon settlement (Mali)

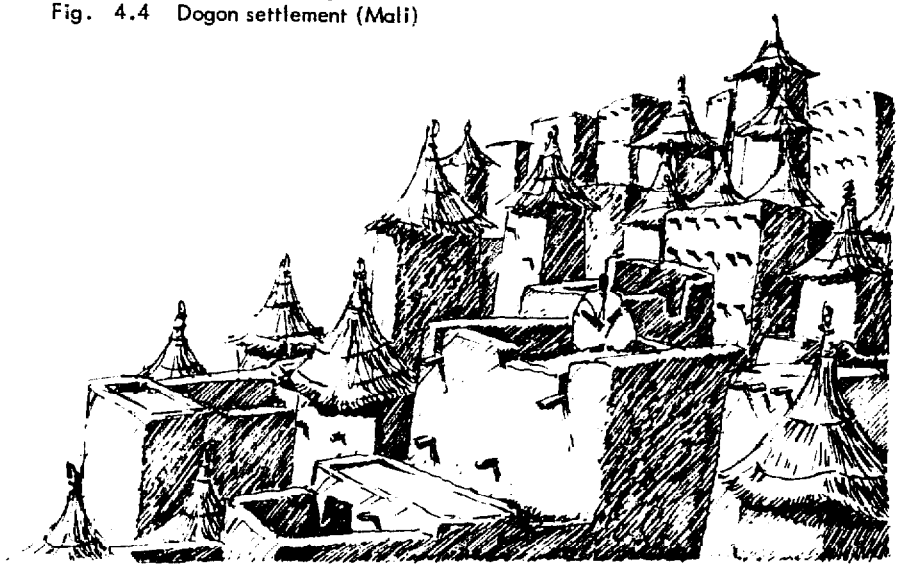

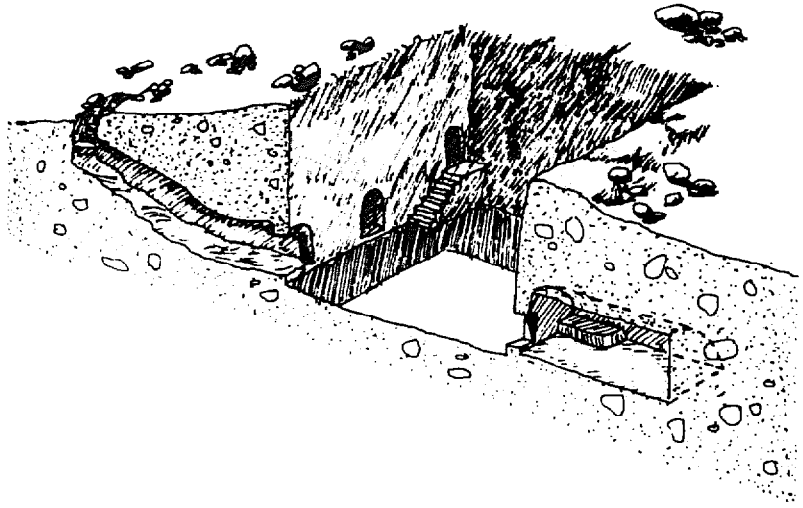

Abb. 4.5 Unterirdisches Haus (Matmata, Sahara)
Fig. 4.5 Underground dwelling (Matmata, Sahara)

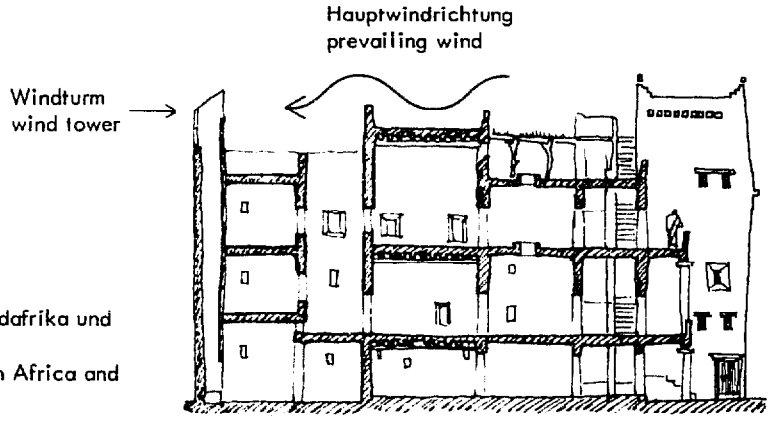

Abb. 4.6 Traditioneller Lehmbau (Nordafrika und Mittlerer Osten)
Fig. 4.6 Traditional mud house (North Africa and Middle East)

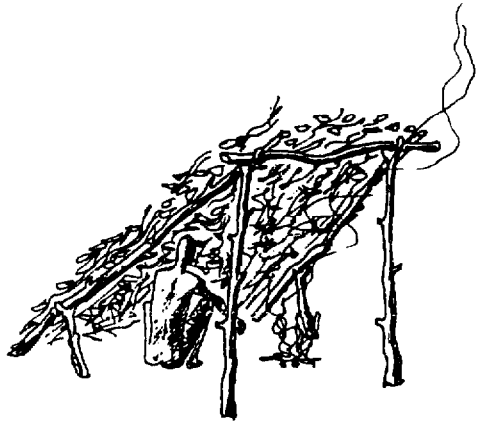

Abb. 4.7 Windbrecher
Fig. 4.7 Windbreak

Haustyp Volksstamm/Kultur Land/Region	Materialien und Konstruktionen	Bemerkungen
SATTEL- UND WALMDÄCHER		
Dachgrundriß: oval oder rechteckig		
Behausung der Maya, Yucatan-Halbinsel (Mexiko, Guatemala), sehr den Häusern auf den Fidschi-Inseln ähnlich	Einfache 1-Zimmer-Häuser mit ovalem Grundriß und Walmdächern. Leichte Wände aus Maisstengeln, gewebtem gespaltenem Bambus oder Flechtwerk mit Lehm (Bajareque). Bei fidschianischen Dächern Firstpfetten auf beiden Seiten auskragend.	Symmetrischer Entwurf mit Tür in der Mitte einer Breitseite. Gefahr des Niederbrennens des Hauses durch Kochen im Hausinneren mit offenen Feuern, aber Rauchentwicklung hilft Insekten und Tiere fernzuhalten.
Malocas der Indianer-Stämme im Amazonas-Becken	Große Gemeinschaftshäuser aus örtlichem Holz, Bambus, Gräsern und Blättern, um eine dicke Gebäudehülle zu schaffen. Ziemlich steile Dächer, die meistens am Boden beginnen. Keine Öffnungen, außer kleinem Eingang.	Wegen fehlender Ventilation und großer Wärmespeicherkapazität des dicken Daches müssen die Häuser in heißen Sommermonaten verlassen werden.
Dachgrundriß: rechteckig		
Totora-Häuser, Uru-Indianer, Titicacasee, Peru	Gebäude nur aus einem Material hergestellt — Totora — ein Schilf, das im See wächst. Wände aus Schilfbündeln, Dächer aus Schilfmatten.	Häuser gebaut auf künstlichen Schilf-Inseln, die auf dem See wie ein Floß schwimmen. Da die Inseln allmählich sinken, dauernde Erneuerung des Schilfs nötig.
Gemeinschaftshäuser, Yagua-Indianer, Peruanischer Amazonas	Wandlose Häuser mit Walm- oder Satteldächern. Holzrahmenkonstruktion mit Grasdach. Erhöhte Plattform aus gespaltenem Bambus.	Bestgeeignete Konstruktion für feuchttropisches Klima. Obwohl völlig offenes Gebäude, Privatsphäre erreicht durch Abwenden vom Zentrum des Hauses (kulturelle Konvention).

House Type, Tribe/Culture Country/Region	Materials and Constructions	Comments
DOUBLE PITCHED AND HIP ROOFS		
Roof Base: oval or rectangular		
Dwellings of Maya, Yucatan Peninsula (Mexico, Guatemala), very similar to houses on Fiji Islands	Simple one-room homes with oval plan and hip roofs. Light walls of corn stalks, woven split bamboo or wattle and daub (bajareque). Steep thatched roof. Fijian roofs have ridge poles protruding from each end.	Symmetrical design with door in centre of one broad side. Cooking with open fires in interior constitute risk of house burning down, but smoke helps to eliminate insects and pests.
Malocas of Indian tribes in the Amazon Basin	Large communal houses made of local timber bamboo, gresses and leaves to form thick building envelope. Fairly steep roofs, usually beginning at ground level, and no openings besides small entrance.	Due to lack of ventilation and large heat retaining capacity of thick roof, houses must be abandoned during hot summer months.
Roof Base: rectangular		
Totora houses, Uru Indians, Lake Titicaca, Peru	Buildings made only from one material — totora — a reed growing in the lake. Walls of reed bundles, roofs of reed mats.	Houses are built on artificial islands also made of reeds floating on the lake. Since islands gradually sink, constant renewal of reeds is necessary.
Communal houses, Yagua Indians, Peruvian Amazon	Open-walled hipped or gable roofed houses on piles. Timber frame structure with thatch roofs. Raised platform of split bamboo.	Most appropriate construction for the damp tropical climate. Though completely open building, privacy is obtained simply by turning away from centre of house (cultural convention).

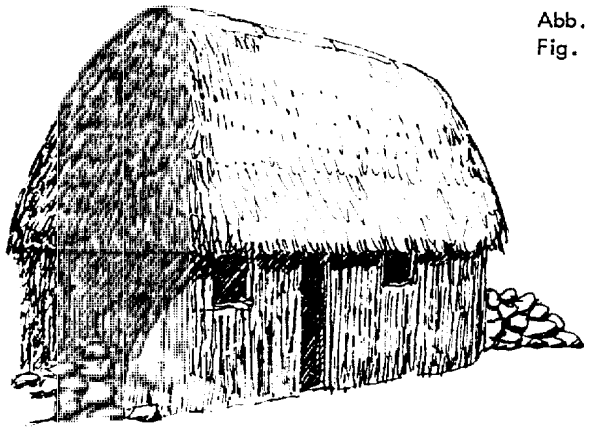

Abb. 4.8 Maya-Haus (Yucatan-Halbinsel)
Fig. 4.8 Maya house (Yucatan Peninsula)

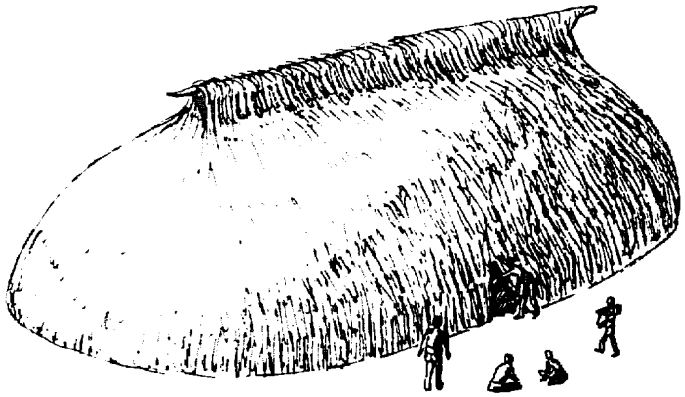

Abb. 4.9 Maloca (Amazonas)
Fig. 4.9 Maloca (Amazon)

Abb. 4.10 Schilfhäuser der Uru-Indios (Titicacasee, Peru)
Fig. 4.10 Reed houses of the Uru Indians (Titicaca, Peru)

Abb. 4.11 Gemeinschaftshaus der Yagua-Indios (peruanischer Amazonas)
Fig. 4.11 Communal house of Yagua Indians (Peruvian Amazon)

Haustyp Volksstamm/Kultur Land/Region	Materialien und Konstruktionen	Bemerkungen
Innenhofhäuser Asante Ghana	Rechtwinklige Häuser. Wände aus dickflüssigem Lehm mit Bewehrung aus Rohr, steiles Satteldach aus Gras.	Normalerweise vier separate Gebäude, im rechten Winkel um den Innenhof herum angeordnet; einige der zum Innenhof gerichteten Seiten sind offen oder haben Stützen (Palmzweige, bedeckt mit Lehm).
Stelzenhäuser Kokwê-See, Benin	Tragkonstruktion aus Holz (Mangrove), Wandausfachungen aus Palmen oder gespaltenem Bambus hergestellt, Dachstuhl aus Palmzweigen mit Grasdeckung.	Keine absolute Übereinstimmung bei Wahl der Dachform. Möglichkeit der individuellen Gestaltung. Bei manchen Walmdächern elegant geschwungene Linie bis zum First.
KONISCHE UND BIENENKORBFÖRMIGE DÄCHER		
Dachgrundriß: rund		
Tepee, Wigwam Flachland-Indianer, Nordamerika	Kiefernpfähle, kreisförmig in die Erde gesteckt und am oberen Ende zusammengebunden, um eine konische Form zu bilden. Äußere Eindeckung aus Büffelhaut, mit einem Loch am oberen Ende als Rauchabzug.	Anstatt der Häute wird auch Birkenrinde benutzt. Durch lange Stöcke betätigte Klappen an der Zeltspitze, um Rauch abzuführen, ohne Zugluft hereinzulassen. Einfacher Aufbau, Abbau und Transport der Zelte.
Rundhäuser z.B. Lasso in Togo und Hutu in Ruanda	Kreisförmige Wände aus gestampftem Lehm mit konischen Strohdächern.	Häufigster Dachtyp in Afrika. Steile Neigungswinkel, um Regenwasser schnell ablaufen zu lassen. Erneuerung nur jedes zweite Jahr erforderlich.
Behausungen der Mousgoum, Nord-Kamerun	Häuser ausschließlich aus Lehm, ohne Schalung gebaut (echte Kuppelbauweise), charakteristisches Reliefmuster der Außenflächen.	Bedeutung der äußeren Muster nicht bekannt, aber sie ermöglichen der Aufstieg zur Spitze, verleihen dem Bauwerk zusätzliche Festigkeit und verhindern Entstehung von Erosionsrinnen durch Regenwasser.

House Type, Tribe/Culture Country/Region	Materials and Constructions	Comments
Courtyard houses Asante, Ghana	Rectangular houses, walls made of pudded mud reinforced with cane, steep thatched saddle back roof.	Usually four separate buildings arranged at right angles around courtyard; some of the sides facing court are open or pillared (palm frond covered with mud).
Pile dwellings Lake Nokwê, Benin	Basic structure of timber (mangrove), walls of infill panels of palm or split bamboo. Roof made of palm frond structural framework with thick grass thatch.	No absolute consistency in roof design. Some hipped roofs have elegant curves to the ridge.
CONICAL AND BEEHIVE SHAPED ROOFS		
Roof Base: circular		
Tepee, Wigwam Plains Indians, North America	Poles of pine stuck in the ground in a circle and tied together at upper end to form conical shape. Outer skin of buffalo hide, leaving hole at the top for smoke to escape.	Instead of hides, also birch bark cover in common use. Two flaps at top end, adjusted by longer poles control ventilation, letting smoke escape without draughts entering. Easy erection, dismantling and transportation of tent.
Round houses e.g. Lasso of Togo and Hutu of Rwanda	Circular walls of compacted mud with conical thatch roof.	Most common roof type in Africa. Steep pitches allow rapid run-off of rainwater. Renewal required only every second year.
Dwellings of the Mousgoum, Northern Cameroon	Houses built entirely of mud with no formers (true dome construction). Significant relief pattern on outer surface.	Meaning of exterior patterns not known, but facilitates climbing to top, adds strength to structure and prevents erosion channels by rainwater.

Abb. 4.12 Asante-Hofhaus (Ghana)
Fig. 4.12 Asante courtyard house (Ghana)

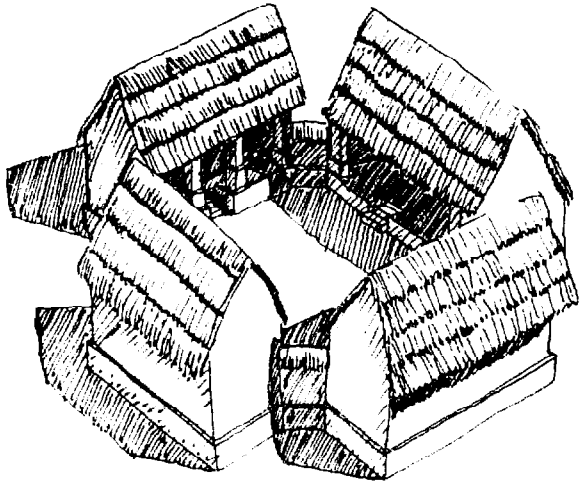

Abb. 4.13 Pfahlhäuser (Benin)
Fig. 4.13 Pile dwellings (Benin)

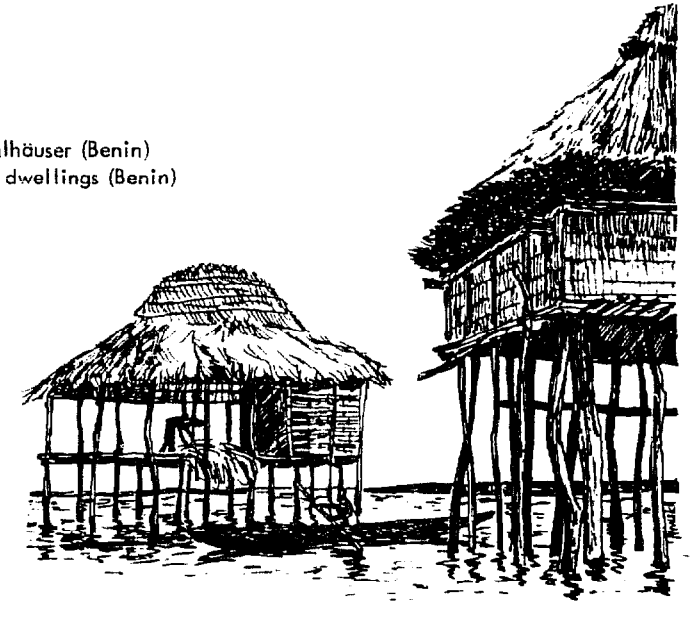

Abb. 4.14 Indianerzelt (Nordamerika)
Fig. 4.14 Tepee (North America)

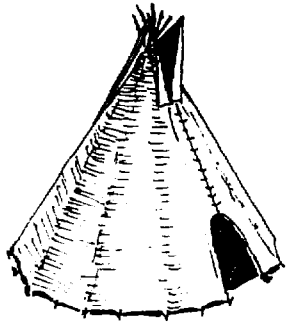

Abb. 4.15 Rundhäuser (Afrika)
Fig. 4.15 Round houses (Africa)

Abb. 4.16 Mousgoum-Häuser (Nord-Kamerun)

Fig. 4.16 Mousgoum dwelling (Northern Cameroon)

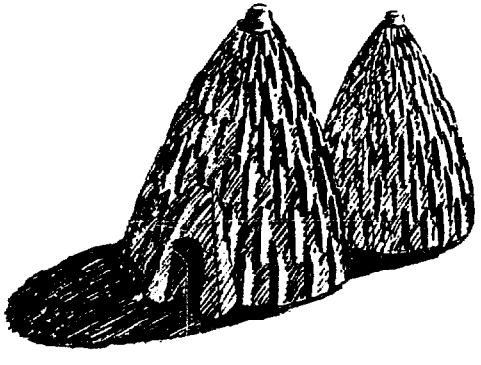

Haustyp Volksstamm/Kultur Land/Region	Materialien und Konstruktionen	Bemerkungen
Behausungen der Sidamo, Äthiopien	Gerüst aus flexiblen Stangen, in die Erde gebettet und oben unter Spannung zusammengebunden. Äußere Bedeckung aus gespaltenem Bambus, korbartig geflochten.	Extrem standfeste Konstruktion, keine Absackung durch das Gewicht mehrerer Männer auf dem Dach.
Dachgrundriß: quadratisch		
Behausungen der Bamileke, Kamerun	Wände, quadratisch angeordnet, aus Palmzweigen oder Bambus mit Lehmausfachung. Plattform als Dachbasis auf dem Boden vorgefertigt. Konisches Raumfachwerk als Dachstuhl; Strohdeckung.	Ungewöhnliche Hausform. Wichtige Häuser zusätzlich entlang der Dachkante mit Stützen umringt, um Veranda zu bilden.
Trulli, Murgia, Italien	Rechteckige Häuser mit quadratischen Zimmern, jedes mit einem konischen Dach. Gesamte Konstruktion (Wände u. Dach) aus flachen Steinen ohne Mörtel verlegt. Abschlußstein an der Dachspitze mit Kalkschlämme bestrichen, sonst keine Außenbeschichtung.	Trulli im Sommer angenehm kühl, im Winter kalt und feucht. Regenwassersammlung vom Dach.
Dachgrundriß: freie Form		
Felsenbehausungen, Göremetal in Anatolien, Türkei	Durch Wind- und Wassererosion natürlich geformte konische Felsen. Behausungen aus weichem Stein herausgeschnitten, d.h. Konstruktion "durch Subtraktion".	Göreme-Kegel meist mehrgeschossig, bis zu 16 Geschossen. Zugang oft nur mittels Strickleiter.

House Type, Tribe/Culture Country/Region	Materials and Constructions	Comments
Dwellings of the Sidamo, Ethiopia	Framework of flexible poles embedded in ground and tied at top under tension. Outer cover of split bamboo woven like basket.	Extremely stable construction, no sagging under weight of several men standing on roof.
Roof Base: square		
Dwellings of the Bamileke, Cameroon	Walls, square in plan, built of palm fronds or bamboo infilled with mud. Platform of roof prefabricated on ground. Conical thatched roof supported by spaceframe.	Unusual house form. Important houses are ringed by pillars below roof edge to form a verandah.
Trulli, Murgia, Italy	Rectangular houses with square rooms, each capped by conical roof. Entire construction (walls and roof) made of flat stones laid without mortar. Cap stone of roof lime plastered, otherwise no outer coating.	In summer trulli are comfortably cool, in winter cold and damp. Rainwater is collected from roofs.
Roof Base: free form		
Rock dwellings, Anatolian valley of Göreme, Turkey	Naturally formed conical rocks, eroded by wind and water. Dwellings were cut out of soft stone, i.e. construction "by subtraction".	Göreme cones mostly multistoreyed, up to 16 floors. Access is often by rope ladder.

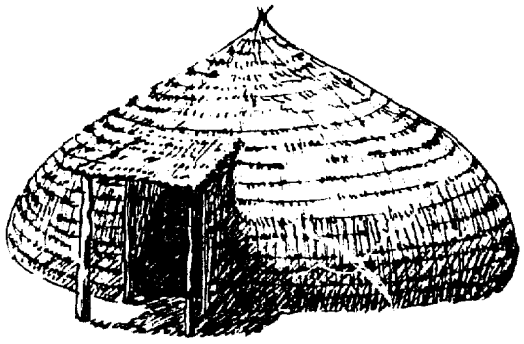

Abb. 4.17 Sidamo-Haus (Äthiopien)
Fig. 4.17 Sidamo dwelling (Ethiopia)

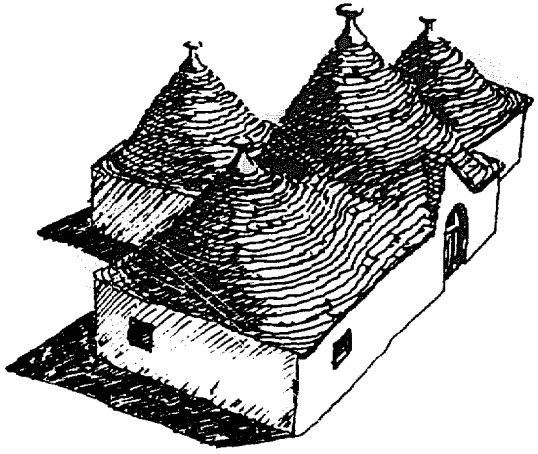

Abb. 4.19 Trulli (Italien)
Fig. 4.19 Trulli (Italy)

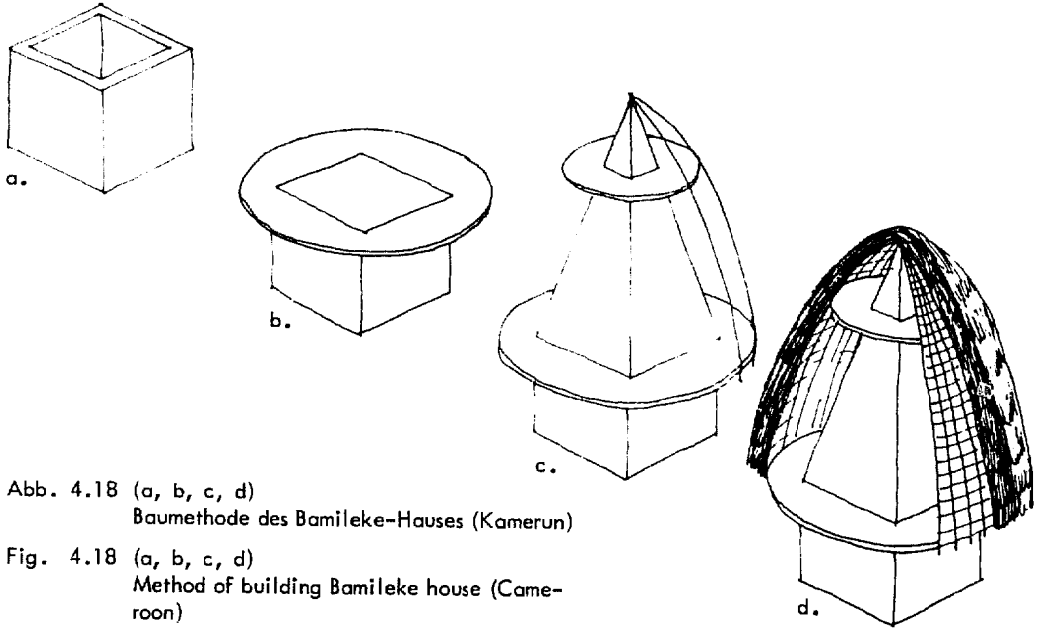

Abb. 4.18 (a, b, c, d)
Baumethode des Bamileke-Hauses (Kamerun)

Fig. 4.18 (a, b, c, d)
Method of building Bamileke house (Cameroon)

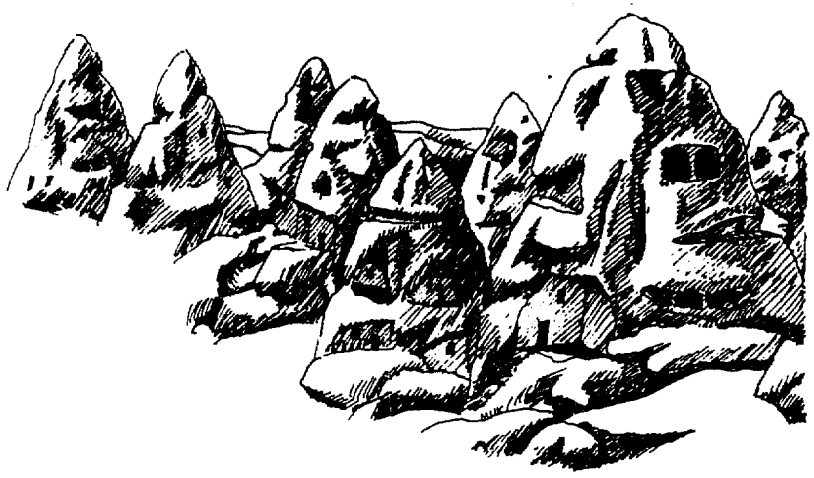

Abb. 4.20 Felsenbehausung (Göreme, Türkei)
Fig. 4.20 Rock dwellings (Göreme, Turkey)

Haustyp Volksstamm/Kultur Land/Region	Materialien und Konstruktionen	Bemerkungen
HALBKUGELFÖRMIGE DÄCHER		
Dachgrundriß: rund		
Yurt (Ger) Nomadische Stämme in Zentralasien (von der Türkei bis zur Mongolei)	Transportable Häuser mit Wänden aus faltbarem, leichtem Weidenholzgitterwerk, befestigt an Pfosten, die fest im Boden stehen. Dachrahmen aus Radialstäben mit hölzernem Druckring, der als Rauchzug fungiert. Außenhülle aus mehrlagigen Tierfellen, durch Seile befestigt.	Yurtform kann von Stamm zu Stamm variieren. Bietet sehr guten Schutz gegen rauhes Klima, besonders gegen starke Winde, aufgrund der Windschlüpfrigkeit. Rauchzug kann mit Fellstück durch Ziehen eines Stricks geschlossen werden.
Hogan Navajo-Indianer Südwest-Vereinigte Staaten	Einfamilienbehausung, in flachen Gruben gebaut, mit gabelförmigen Pfosten (meistens krumme), die Balken- und Lattenkonstruktion tragen. Kugelförmige Außenverkleidung durch Astgeflecht und dicken Lehmauftrag.	Innenraumklima ausgesprochen gut aufgrund hoher Wärmekapazität der Gebäudehülle. Keine Fenster vorhanden, lediglich Rauchzug im Dach und Tür in Ostrichtung.
Behausungen der Zulu, Swazi, Bantu Südafrika	Perfekte halbkugelförmige Bauwerke mit Grundgerüst aus gebogenen Schößlingen, mit Matten und Gras bedeckt und über gesamte Außenfläche netzartig mit Seilen zusammengebunden.	Hervorragende Wärmeisolierungseigenschaften der Konstruktion für Temperaturschwankungen zwischen 35°C und -4°C.

House Type, Tribe/Culture Country/Region	Materials and Constructions	Comments
HEMISPHERICAL ROOFS		
Roof Base: circular		
Yurt (Ger) Nomadic tribes in Central Asia (from Turkey to Mongolia)	Portable dwellings with walls of foldable lightweight willow latticework, lashed to poles firmly fixed in ground. Roof frame formed by radial poles fitted into wooden compression ring, which also serves as smoke hole. Outer cover made of several layers of felt held by ropes.	Design of yurt may vary from tribe to tribe. Displays high degree of protection against inclemency of weather, particularly strong winds, due to streamlined shape. Smoke hole may be closed by piece of felt drawn across by string.
Hogan Navajo Indians, Southwest United States	Single family dwellings, erected in shallow pit with forked posts (usually crooked) supporting beam and pole structure, covered by branches and thick soil layer, forming dome shape.	Indoor climate extremely good due to high heat capacity of building fabric. No windows are provided, only smoke hole in the roof and door facing the east.
Dwellings of the Zulu, Swazi, Bantu, South Africa	Perfect dome shaped structures made by basic framework of hoops, covered with mats, grass thatch and bound by network of rope.	Construction provides excellent insulation against temperature variations between 35°C and -4°C.

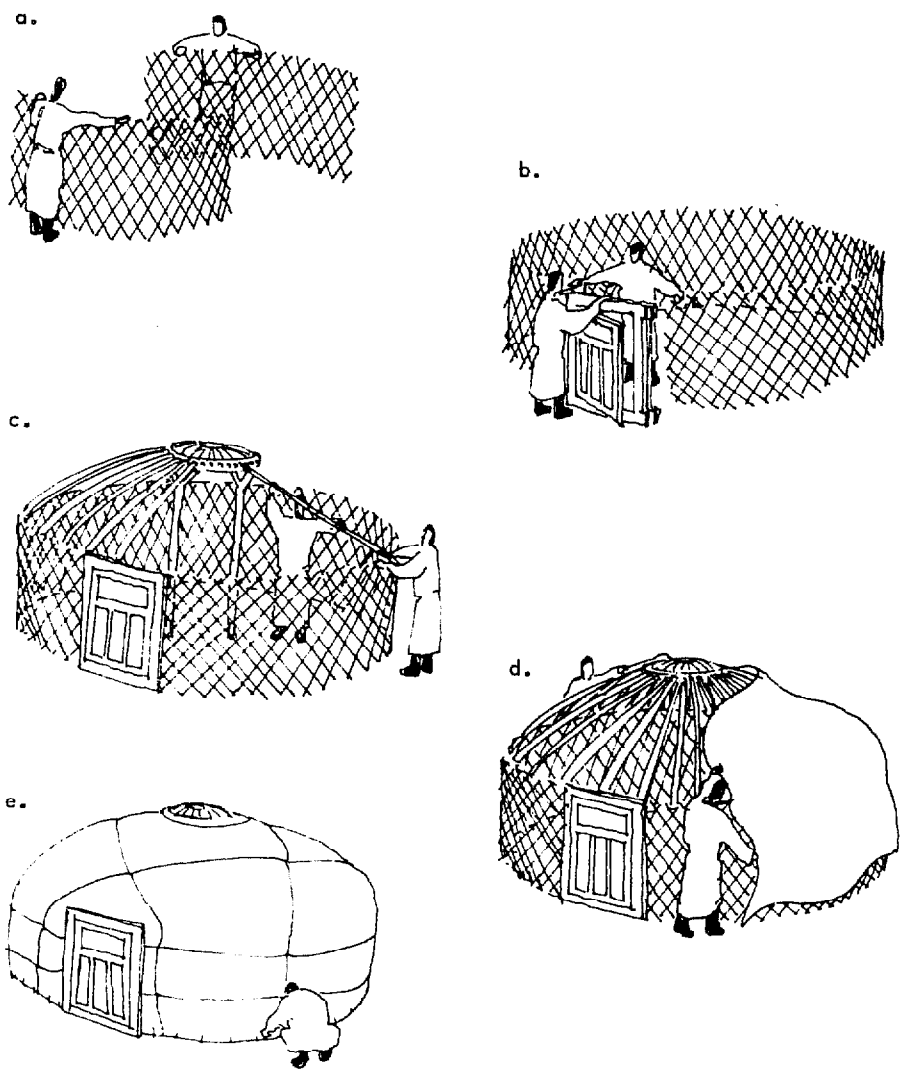

Abb. 4.21 (a, b, c, d, e)
Aufstellungsmethode eines mongolischen Yurts

Fig. 4.21 (a, b, c, d, e)
Method of erecting Mongolian yurt

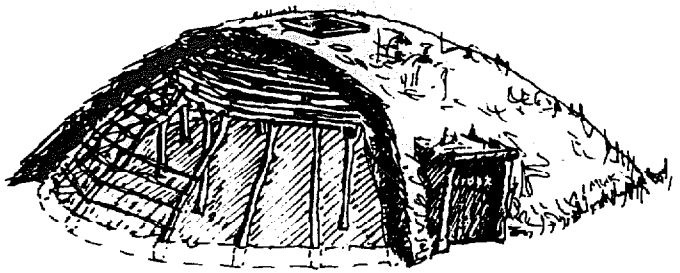

Abb. 4.22 Schnittbild eines Navaho hogan (Südwest-USA)

Fig. 4.22 Cutaway diagram of Navaho hogan (Southwest United States)

Abb. 4.23 Zulu-Behausung
Fig. 4.23 Zulu dwelling

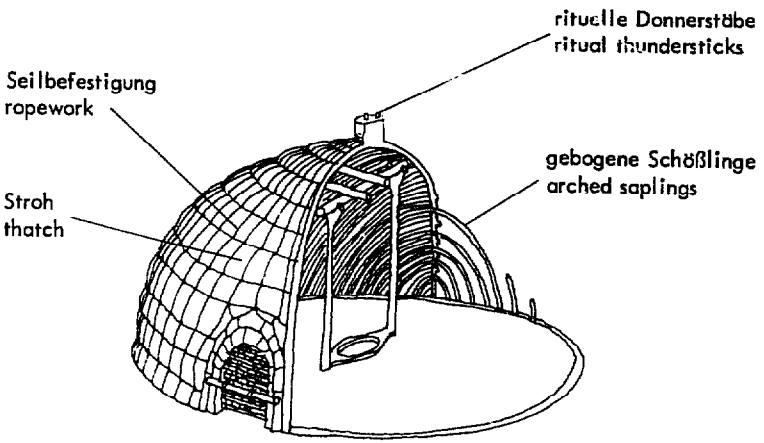

Haustyp Volksstamm/Kultur Land/Region	Materialien und Konstruktionen	Bemerkungen
Gemeinschaftshäuser, West-Samoa	Gebäude hauptsächlich bestehend aus kreisförmig angeordneten Holzstützen, die Dach aus geflochtenem Bambus mit Palm- oder Grasdeckung tragen.	Klimatisch geeignete Bauweise, jedoch nur zum Schlafen und Lagern verwendet. Gerollte Matten können entlang des Dachrandes heruntergelassen werden: zur Beschattung, ohne Beeinträchtigung der Querlüftung.
Dachgrundriß: quadratisch oder rechteckig		
Zelt, Tuareg, Sahara-Wüste	Transportable Behausungen aus mehreren schmalen Akazienstangen und -latten (oder Palmenästen) zu kuppelförmiger Rahmenkonstruktion zusammengebunden. Außenhülle aus fest angebundenen Grasmatten oder Häuten.	Mögliche Regenwasserdurchdringung der Matten; undurchlässige Hautverkleidungen im Sommer höchst unangenehm. Wegen starker Abkühlung während der Nacht Öffnung nach Osten gerichtet, um wärmende Sonnenstrahlen morgens einzufangen.
Kuppelbauten des Mittleren Ostens	Wände aus Bruchstein; Gewölbe und Bögen aus Lehmziegeln; glatte Oberfläche aus Lehmputz.	Hohe Festigkeit durch Doppelkrümmung, aber echte Kuppeln haben ungenügende Resistenz bei schweren Erdbeben.
TONNENFÖRMIGE DÄCHER		
Dachgrundriß: quadratisch oder rechteckig		
Ghorfas und andere traditionelle Häuser in Nordafrika	Bauten aus einem oder mehreren Geschossen gewölbter Zellen, gebaut aus Stein oder Lehmziegeln ohne Schalung.	Geniale Methode der Verlegung dreidimensionaler Ziegelschichten, so daß jeder Ziegel von den darunterliegenden getragen wird. Stabile, klimatisch angepaßte Bauweise, jedoch nicht erdbebenresistent.

House Type, Tribe/Culture Country/Region	Materials and Constructions	Comments
Communal dwelling Western Samoa	House basically consists of circle of timber columns supporting roof framework of woven bamboo and palm or grass thatch.	Climatically appropriate design, but merely used for sleeping and storage. Rolled up mats may be unfurled from roofs to provide shade and utilize breezes.
Roof Base: square or rectangular		
Tent, Tuareg, Sahara Desert	Portable dwelling consisting of several slim poles and laths from acacia or palm fronds laced to form dome shaped framework. Grass mats or skin tied down firmly, form the outer cover.	During rains mat covers tend to leak, in hot season impermeable skin covers are most unpleasant. Since temperatures drop sharply at night, open fronts face the east to catch warming rays of morning sun.
Domed houses of the Middle East	Walls made of stone rubble; vaults and arches of mud brick; smooth surface of mud plaster.	Good strength due to double curvature, but true domes have insufficient resistance in heavy earthquakes.
BARREL VAULTS		
Roof Base: square or rectangular		
Ghorfas and other traditional houses in North Africa	Structures consisting of one or several storeys of vaulted cells, built of stone or mud brick without shuttering.	Ingenious method of laying three-dimensional courses, such that each brick rests on the ones below. Stable and climatically appropriate structure, but not earthquake resistant.

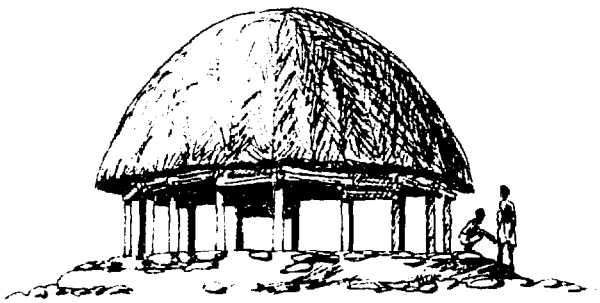

Abb. 4.24 Samoa-Haus
Fig. 4.24 Samoan dwelling

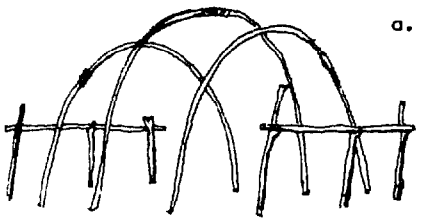

a.

Abb. 4.25 (a, b, c)
Aufstellung eines Tuareg-Zelts (Sahara)

Fig. 4.25 (a, b, c)
Erection of Tuareg tent (Sahara)

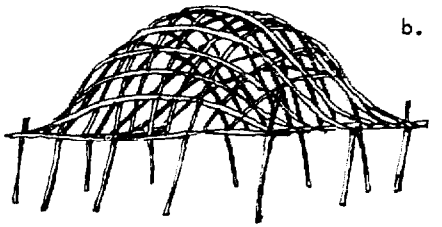

b.

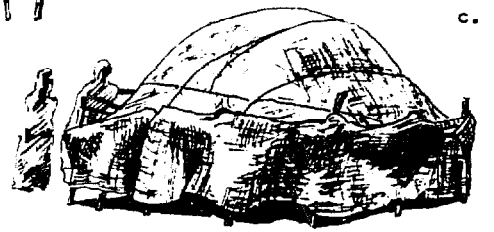

c.

Abb. 4.26 Kuppel-Haus (Mittlerer Osten)
Fig. 4.26 Domed house (Middle East)

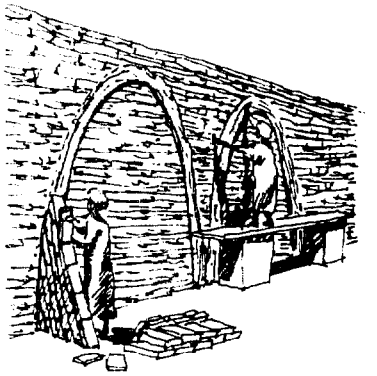

b. Traditionelle Gewölbebaumethode (Ägypten). Der Bogen wird mit Mörtel markiert; .....

b. Traditional vault construction method (Egypt). The arch is marked with mortar; .....

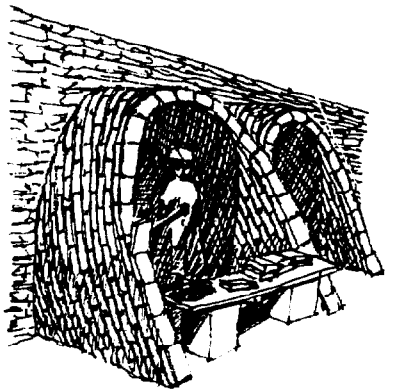

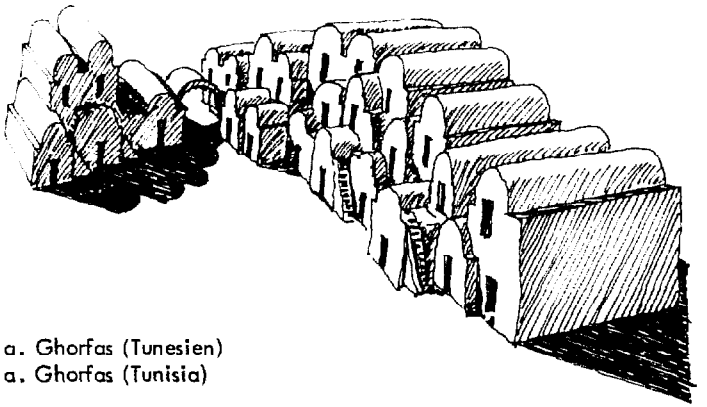

a. Ghorfas (Tunesien)
a. Ghorfas (Tunisia)

Abb. 4.27 (a, b, c) Gewölbebauten (Nordafrika)

Fig. 4.27 (a, b, c) Vaulted structures (North Africa)

c. ..... jeder Ziegel ruht auf den darunterliegenden, keine provisorische Abstützung nötig.

c. ..... each brick rests on the course below, no temporary supports required.

Haustyp Volksstamm/Kultur Land/Region	Materialien und Konstruktionen	Bemerkungen
Mudhifs der Madan (Sumpf-Araber), Süd-Irak	Gebündeltes Riesenschilf, in den Boden gesteckt und zu Bögen zusammengebunden; Außenverkleidung mit Matten aus gespaltenem Schilf.	6000 Jahre alte Bautechnik mit nur einem einzigen Material. Länge (etwa 6 m) und Flexibilität sind wichtigste Eigenschaften des Materials.
FREIE DACHFORMEN		
Dachgrundriß: rechteckig		
Araber-Zelte, Beduinen, Berber, Tekna in der Arabischen Wüste und West-Sahara	Transportable Einfamilien-Unterkünfte mit Tragkonstruktion aus Vertikalstäben, manchmal gabelförmig, mit Firstpfetten oder geschnitzten Firststücken (gerundete Kappen als Stützabschluß). Darüber Dachhaut aus gewebtem Kamel- oder Ziegenhaar, mittels Seilen gespannt und im Boden durch Pflöcke oder Steine verankert.	Zeltgrößen je nach Tragkapazität des Familienkamels. Innere Vorhänge zur Aufteilung verschiedener Wohnbereiche, äußere Vorhänge verschiebbar, um Brisen einzufangen oder als Schutz vor Sandstürmen. Vollständige Schließung des Zelts möglich.

House Type, Tribe/Culture Country/Region	Materials and Constructions	Comments
Mudhifs of the Madan (Marsh Arabs) Southern Iraq	Bundled giant reeds, stuck in the ground and bent to form arches; roof covering of split reed mats.	6000 year old building technique, involving a single material. The length (about 6 meters) and flexibility are the main advantages of the material.
FREE FORMS		
Roof Base: rectangular		
Arab tents, Bedouin, Berber Tekna of the Arabian and Western Sahara deserts	Portable single family dwellings with supporting structure of vertical poles, sometimes forked, and ridgepoles or carved ridge pieces. The cover, woven from camel or goats' hair, is stretched over and held by long ropes, anchored with pegs or rocks.	Tent sizes are limited to the carrying capacity of the family camel. Interior curtains divide living spaces, exterior curtains may be moved from one side to the other for breeze or protection from sand storms. Complete closure of tent is also possible.

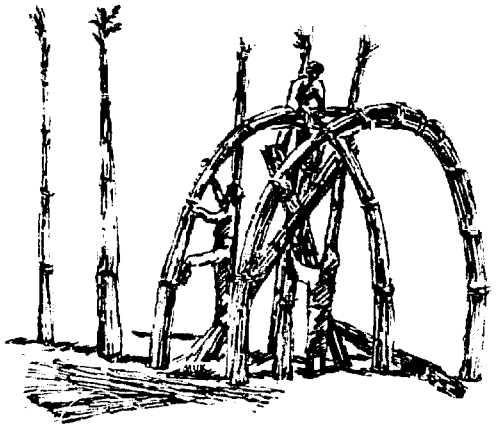

a.

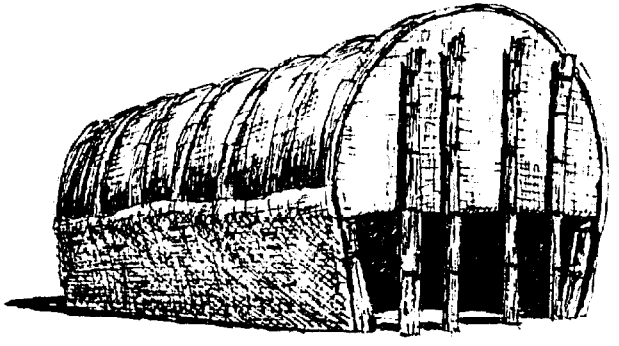

b.

Abb. 4.28 (a, b) Schilfbauweise (Süd-Irak). Schilfstativ wird bei der Verbindung von Schilfbündeln als Gerüst benützt.

Fig. 4.28 (a, b) Building of reed structure (Southern Iraq). A reed tripod serves as scaffolding for binding reed bundles together.

a. Tekna-Zelt (Marokko)
a. Tekna tent (Morocco)

b. Beduinen-Zelt (Arabische Wüste)
b. Beduin tent (Arabian desert)

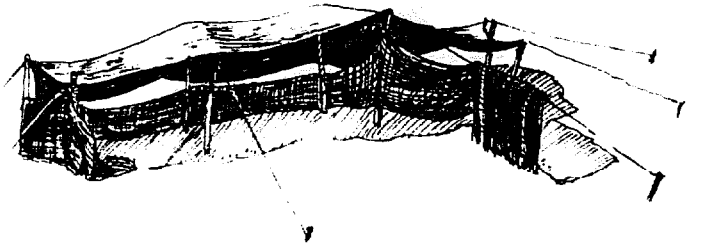

Abb. 4.29 (a, b) Arabische Zelte (Sahara und Arabische Wüste)

Fig. 4.29 (a, b) Arab tents (Sahara and Arabian deserts)

4.1.2 Gegenwärtige Standarddächer

Es gibt genügend Literatur über Methoden und Details für Dachkonstruktionen. Dieser Abschnitt soll keine Wiederholung solcher Publikationen sein, sondern zeigt einige Standardkonstruktionen aus dem heutigen Wohnungsbau.

4.1.2 Contemporary Standard Roofs

There are ample construction manuals showing design details of roofs. This section is not meant to be a repetition of such publications, but shows a few standard constructions found in present day housing schemes.

Holzkonstruktionen/Timber Constructions

Abb. 4.30 Typische Konstruktion für Flachdächer
Fig. 4.30 Typical framework for flat roofs

QUELLE/SOURCE : Bibl. No. 129

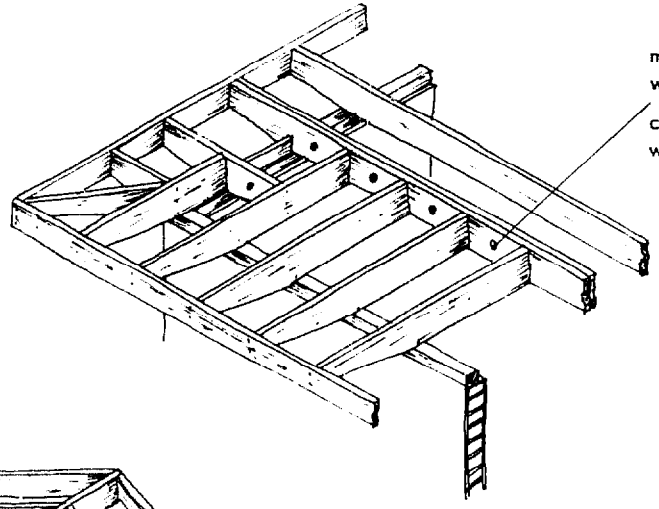

Abb. 4.31 (a, b) Typischer Dachstuhl für Giebeldach
Fig. 4.31 (a, b) Typical framework for gabled roof

QUELLE/SOURCE : Bibl. No. 107

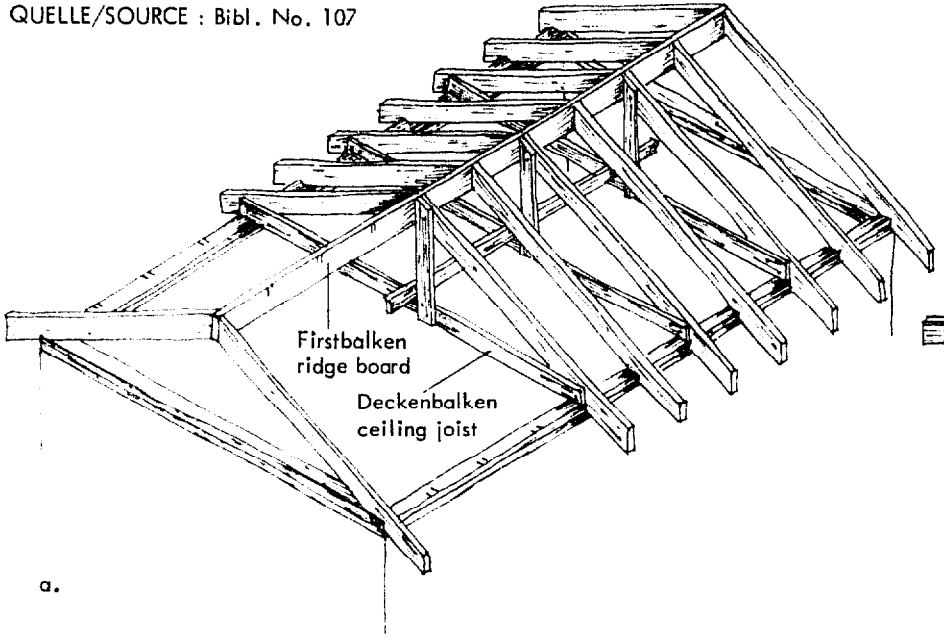

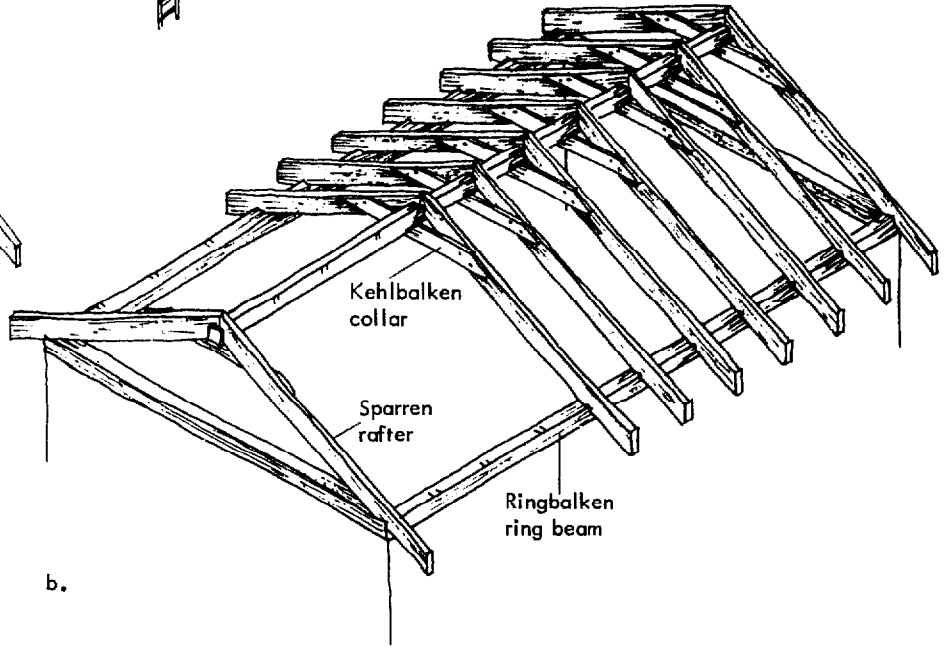

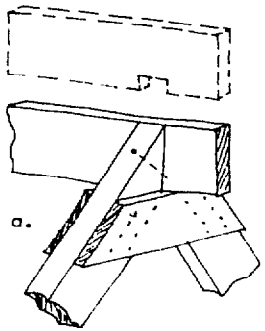

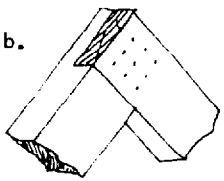

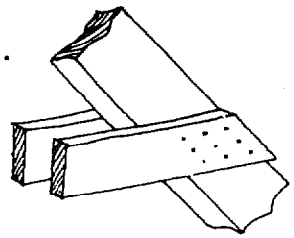

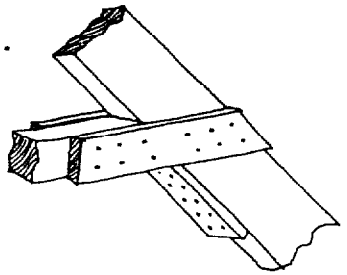

Abb. 4.32 (a, b, c, d) Holzdachverbindungen
Fig. 4.32 (a, b, c, d) Connections of timber roof members

QUELLE/SOURCE : Bibl. No. 11

Abb. 4.33 (a, b) Einfache Dachbinder

Fig. 4.33 (a, b) Simple roof trusses

QUELLE/SOURCE : Bibl. No. 107

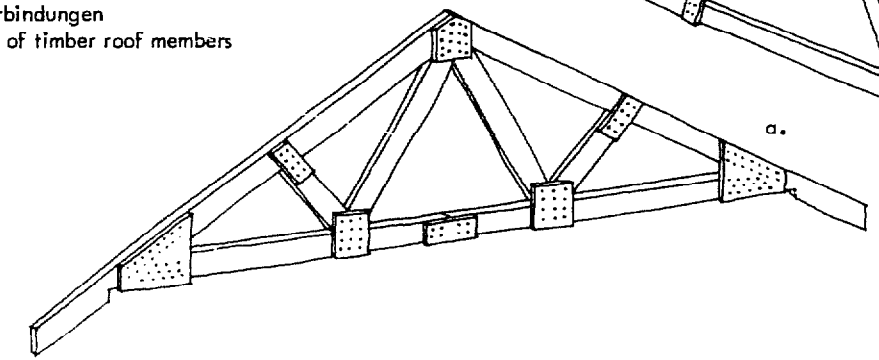

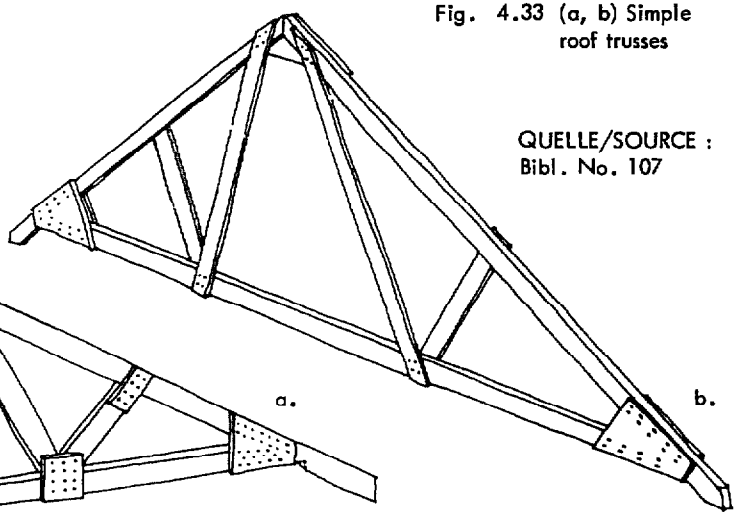

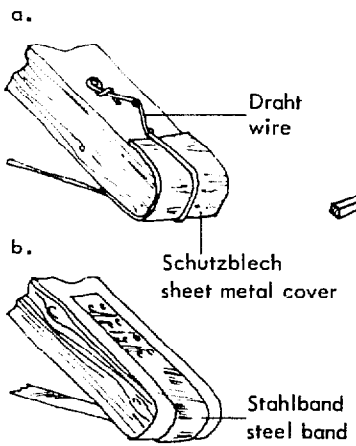

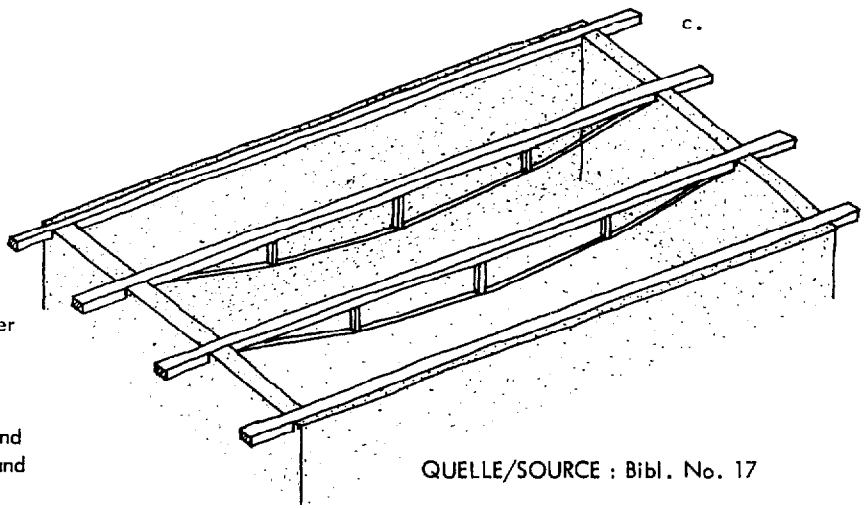

QUELLE/SOURCE : Bibl. No. 17

Abb. 4.34 (a, b, c, d) Ausgesteifte Dachelemente

Fig. 4.34 (a, b, c, d) Stiffened roof members

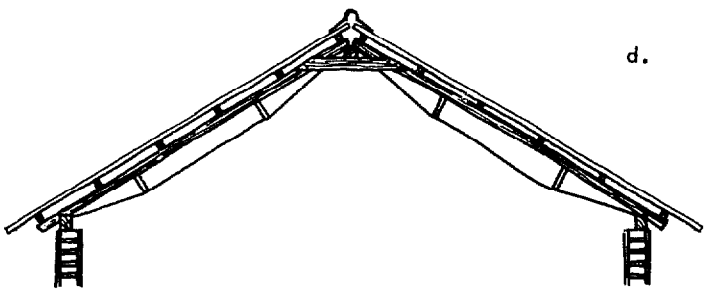

Abb. 4.35 (a, b, c, d, e)
Befestigung von Pfetten

Fig. 4.35 (a, b, c, d, e)
Fastening of purlins

QUELLE/SOURCE : Bibl. No. 14

a. Übliches Detail, aber nicht geeignet:
Der Sparren zieht sich in der Breite zusammen, aber der Hafter schrumpft nicht in der Länge; deshalb hängt letztlich die Pfette am Hafter, welcher durch die Bewegungen seiner eigenen Befestigungen spalten kann.

b.-e. sind bessere Befestigungen

a. Common detail, but inappropriate:
rafter shrinks in width but cleat does not shrink in length, therefore purlin ultimately hangs on cleat, which may split with fastenings moving together as rafter shrinks.

b.-e. are better fastenings

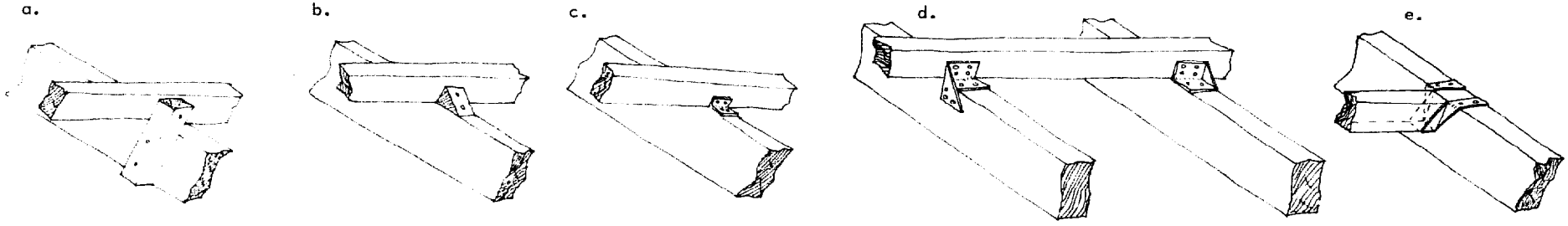

Dachziegel/Roof tiles

Abb. 4.36 Biberschwanzdeckung
Fig. 4.36 Flat tiles

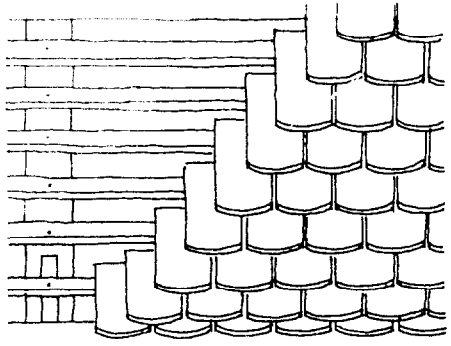

Abb. 4.37 Mönch- und Nonnen-Deckung
Fig. 4.37 Spanish tiles

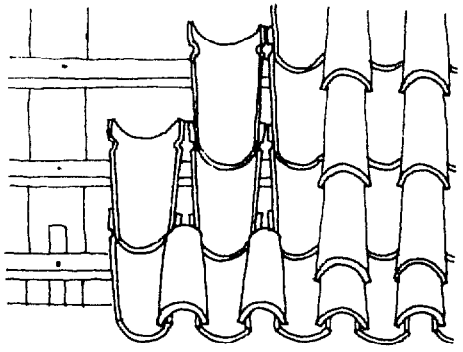

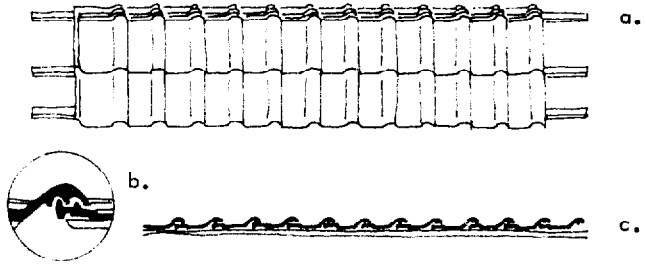

Abb. 4.38 (a, b, c, d)
Flachdachpfannendeckung

Fig. 4.38 (a, b, c, d)
Roman tiles

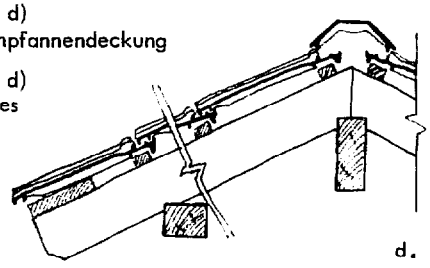

QUELLE/SOURCE :
Bibl. No. 11

Schindeldeckung/Shingle Decking

Abb. 4.39 (a, b) Holzschindel-Details
Fig. 4.39 (a, b) wood shingle details

QUELLE/SOURCE : Bibl. No. 129

a. Filzlagen zwischen Schindeln, um sie "atmen" zu lassen. Anordnung der Schindeln in Abständen von mindestens 5 mm, um Ausdehnung zu ermöglichen.

a. Felt liners installed between courses to let them "breathe". Gaps of at least 5 mm are required between shingles to facilitate expansion.

b. Firstabschluß — Wechselüberdeckung
b. Finishing ridge — note alternate overlaps

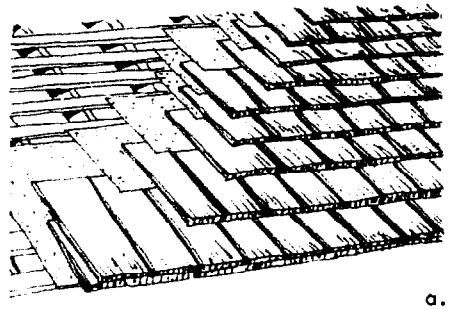

a.

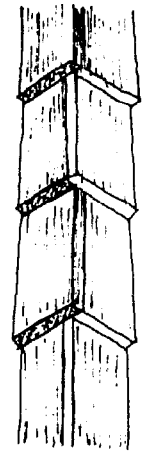

b.

Abb. 4.40 (a, b) Asbestzementschindeln
Fig. 4.40 (a, b) Asbestos cement shingles

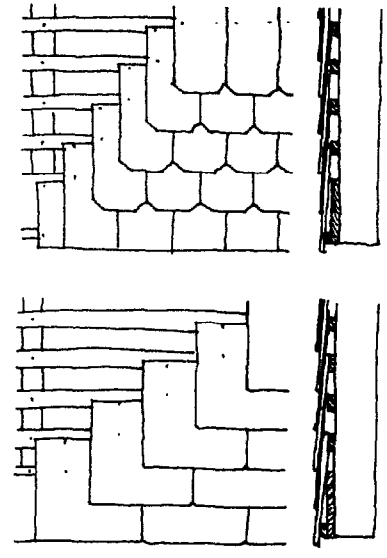

a.

b.

Metalldachdeckung/Sheet Metal Roofing

Abb. 4.41 (a, b, c, d, e) Anschlußdetails für Falzdeckung
Fig. 4.41 (a, b, c, d, e) Details of sheet metal connections and seams

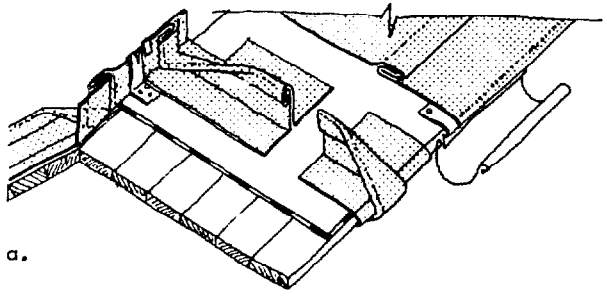

a.

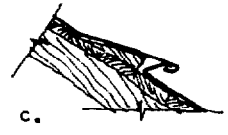

c.

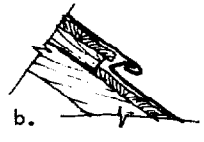

b.

QUELLE/SOURCE : Bibl. No. 72

Windrichtung
direction of wind

d.

Arbeitsgänge
Folding sequences

e.

Eine Bedachungsart, die in Entwicklungsländern seltener angewendet wird, da sie teurer ist als die meisten anderen Dachdeckungen und zur Befestigung besondere Fachkenntnisse erfordert. Vorteilhaft bei ungewöhnlichen Dachformen (die jedoch beim Niedrigkosten-Wohnungsbau selten sind).

A type of roofing less frequently used in developing countries, as they are more expensive than most roof constructions, and require skilled labour for installation. Advantageous for unusual roof shapes (which, however, are less common in low-cost housing).

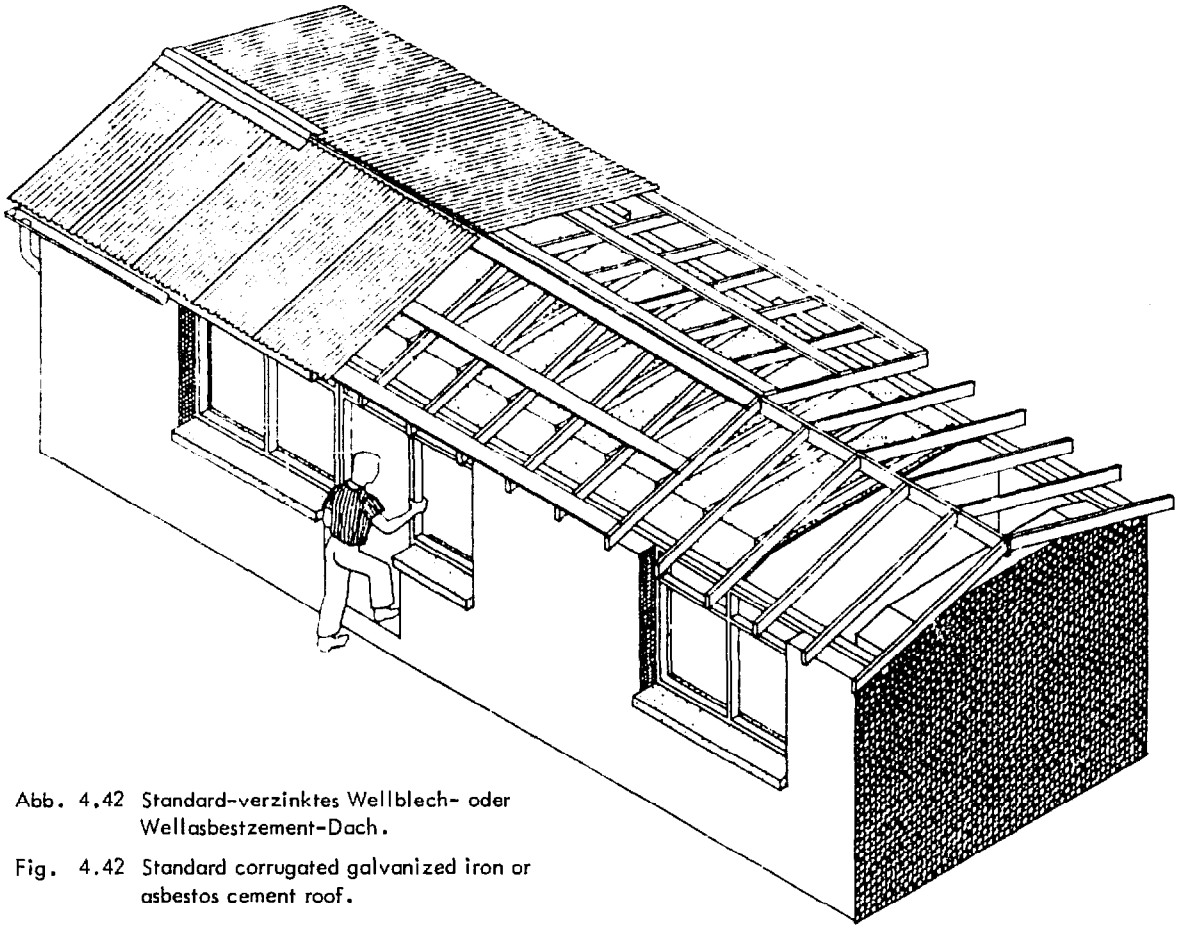

Abb. 4.42 Standard-verzinktes Wellblech- oder Wellasbestzement-Dach.

Fig. 4.42 Standard corrugated galvanized iron or asbestos cement roof.

QUELLE/SOURCE : Bibl. No. 118

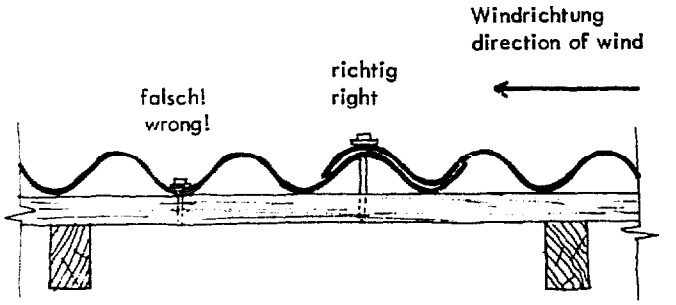

Abb. 4.43 Befestigung der Wellplatten an der Unterkonstruktion
Fig. 4.43 Fixing corrugated sheets to substructure

Abb. 4.44 Typischer Dachquerschnitt
Fig. 4.44 Typical roof section

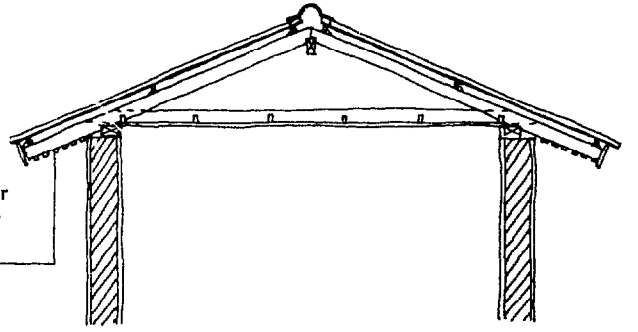

Schutz gegen tierische Schädlinge unter Beibehaltung der Belüftungsmöglichkeit für den Dachraum.

Protection against pests, but allowing ventilation of roof space.

Abb. 4.45 (a, b, c) Typische Betondachdetails
Fig. 4.45 (a, b, c) Typical concrete roof details

QUELLE/SOURCE : Bibl. No. 57 + 109

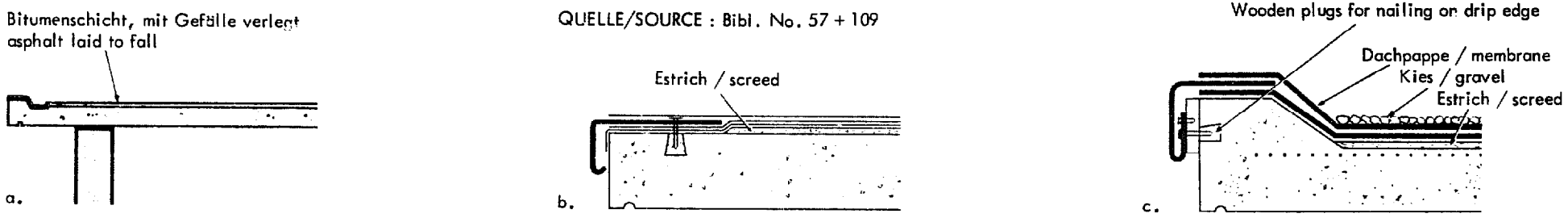

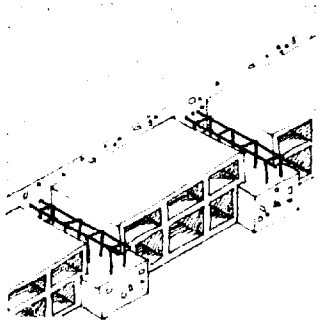

Abb. 4.46 Stahlbetonbalken mit Füllkörpern aus Leichtbeton oder gebranntem Ton.

Fig. 4.46 Slab and beam construction using hollow concrete or burnt clay blocks.

Abb. 4.48 Geneigtes Dach mit vorgefertigten Stahlbeton-T-Trägern.

Fig. 4.48 Sloping roof with precast reinforced concrete T-joists.

QUELLE/SOURCE : Bibl. No. 15

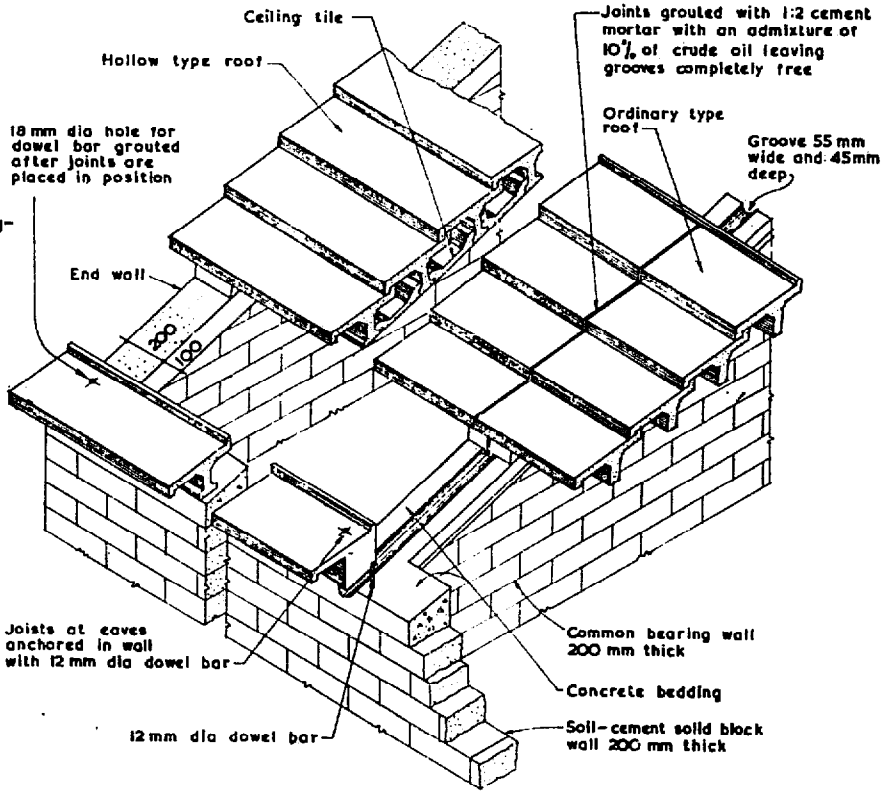

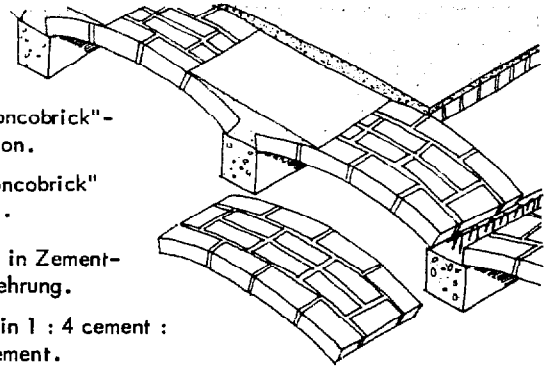

QUELLE/SOURCE :
Bibl. No. 71

Abb. 4.47 Vorgefertigte "Concobrick"-Schalenkonstruktion.

Fig. 4.47 Prefabricated "concobrick" shell construction.

Gewölbte Platten aus Ziegeln in Zement-Sand-Mörtel (1 : 4) ohne Bewehrung.

Arched panels made of bricks in 1 : 4 cement : sand mortar, without reinforcement.

Dachabdichtung auf Bretterschalung/Waterproofing on Timber Boarding

Abb. 4.49 Befestigungsdetails der Dichtungsbahnen.
Fig. 4.49 Details of fixing roofing felt.

QUELLE/SOURCE : Bibl. No. 109

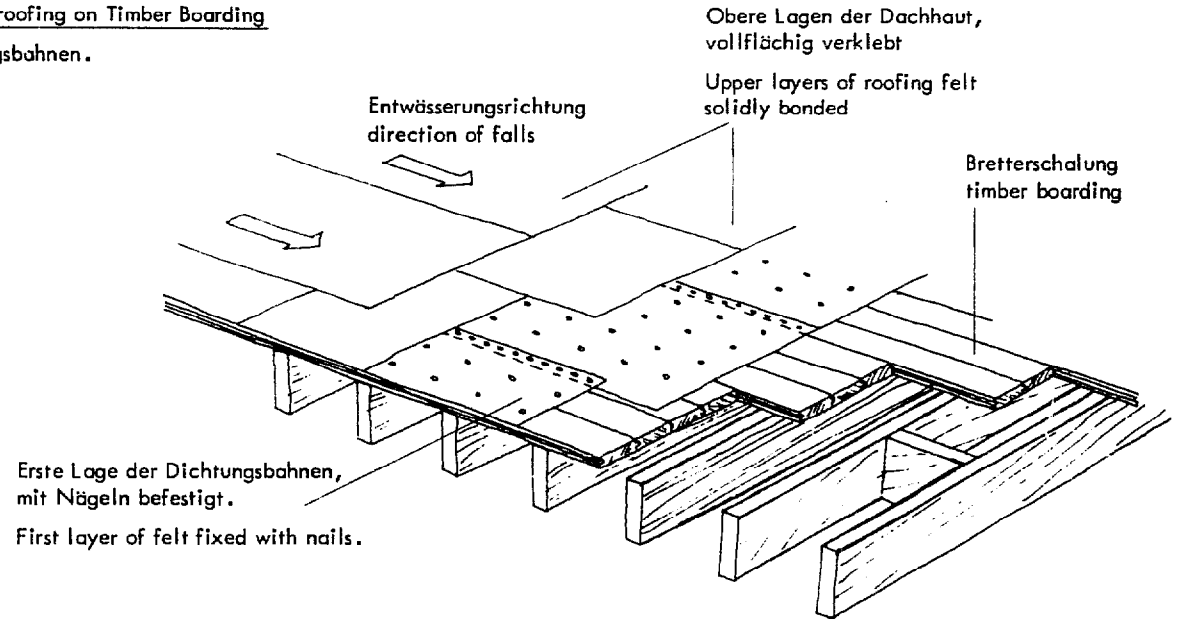

Leichtbauplatten/Lightweight Building Boards

Abb. 4.50 (a, b) Methoden der Plattenbefestigung
Fig. 4.50 (a, b) Methods of fixing panels

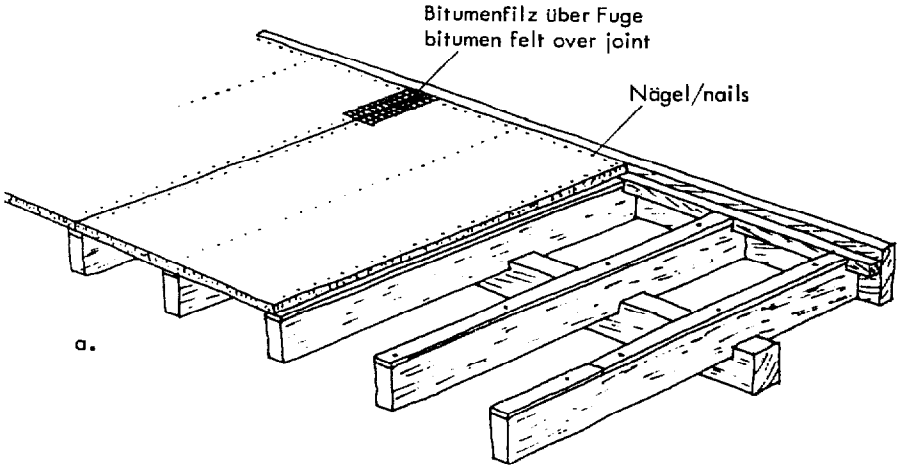

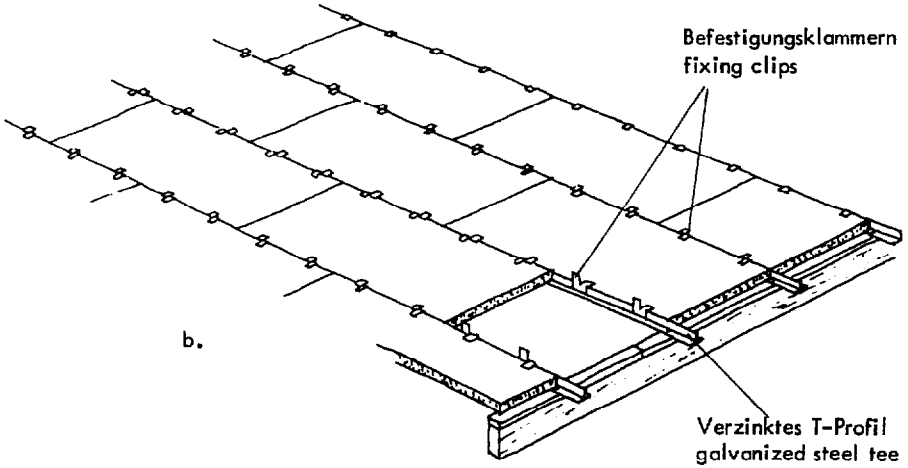

Dachbeschattung/Roof Shading

Abb. 4.51 (a, b, c, d)

a, b. Beschattung des Betondaches mittels gebogener Wellplatte (Schnitt und Seitenansicht)

c. Sonnenschutz mit Beton-Schattenfliesen

d. Sonnenschutz mit Beton-Schattenplatten

Fig. 4.51 (a, b, c, d)

a, b. Shading of concrete roof by means of curved corrugated sheets (section and side view)

c. Shading with concrete solar tiles

d. shading with concrete solar slabs

a.

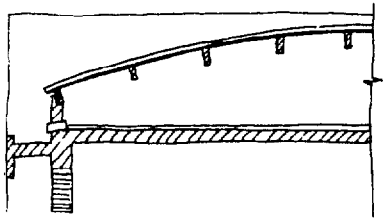

b.

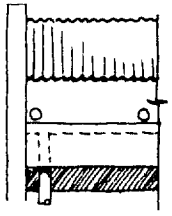

c.

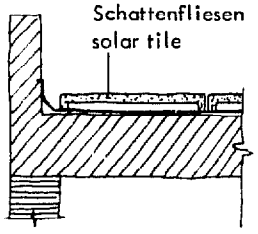

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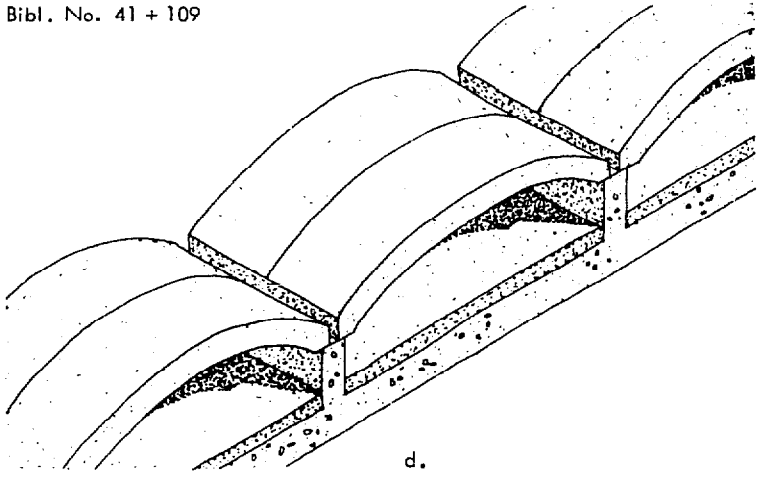

d.

Abgehängte Decken/Suspended Ceilings

Abb. 4.52 Deckenplatten, auf Holzlatten genagelt.

Fig. 4.52 Ceiling boards nailed onto timber lathing.

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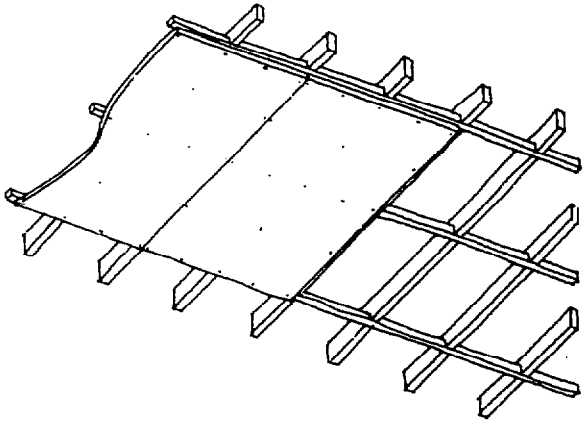

Abb. 4.53 Abgehängte Wellblechdecke
Fig. 4.53 Corrugated iron ceiling

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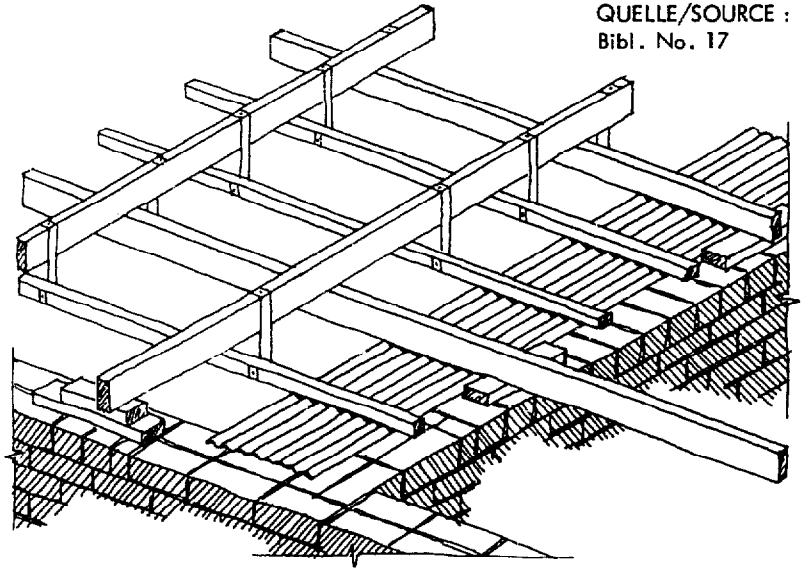

4.2 Neuentwicklungen

4.2.1 A.I.D.-Monsanto Forschungsprojekt für Low-Cost-Dächer

Das von der United States Agency for International Development, Washington D.C., unterstützte Forschungsprojekt wurde von der Monsanto Research Corporation, Dayton/Ohio, University of Washington, Seattle/Washington und Washington University, St. Louis/Missouri, von Mai 1973 bis Dezember 1977 durchgeführt.

Das Ziel war, Low-Cost Dachdeckungsmöglichkeiten aus einheimischen Materialien in drei Entwicklungsländern (Philippinen, Ghana und Jamaica) zu entwickeln, Dachprototypen (vier in jedem Land) zu montieren und zu testen und örtliche Fachleute und Firmen in die Forschungsarbeit einzubeziehen. Das Ziel, nur einheimische Materialien zu verwenden und den Devisenanteil zu vermindern, wurde später als weniger wichtig erachtet, als niedrigste Gesamtkosten für Bedachung zu erreichen.

Von etwa 50 erprobten Füllmaterialien wurde Bagasse (Zuckerrohrabfall) im Hinblick auf Produkteigenschaften, Kosten und Verfügbarkeit als das beste befunden. Als Bindemittel wurde aushärtendes Phenol-Formaldehydharz gewählt; gute Alternativen sind Naturkautschuk und ABS-Kunstharz. Vier Verbundplatten-Bedachungssysteme wurden entwickelt unter Verwendung hoher Prozentanteile von Bagasse und 5 bis 30% Bindemittel; die Kosten belaufen sich auf 0,7 bis 1,50 U.S.$/m^2. Es wurden wirtschaftliche Verfahren mit örtlich verfügbarem Gerät und Einrichtungen entwikkelt. Die Probeplatten waren entweder flach oder gewellt, aber bei den Musterdächern wurden hauptsächlich flache Schindeln verwendet.

Die Gesamtleistung der Mustereinheiten war gut, wenn man von kleineren Unzulänglichkeiten, wie Verwerfung der Schindeln, absieht. Aber alle Testdächer werden noch beobachtet, auch noch Beendigung des Projekts, um Daten über Langzeitverhalten zu erhalten. Weitere Entwicklungsarbeit wurde in den teilnehmenden Ländern empfohlen im Hinblick auf die Durchführung einer Massenfabrikation von äußerst stabilen, preiswerten, dauerhaften Dachplatten.

Quelle: "Development of low-cost roofing from indigenous materials in developing countries" (Contract No. AID/CM-ta-C-73-12)
Final Report, 20 February 1978
Monsanto Research Corporation, Dayton Laboratory, Dayton, Ohio 45407

4.2.2 Faserverstärkte Dachplatten

Zur leichten und schnellen Dachdeckung ist das beste Material große, dünne Platten, die eine größtmögliche Fläche bedecken bei kleinstmöglichem Volumen (daher leichter Transport). Weitverbreitete Dachplatten wie verzinktes Wellblech und Asbestzement sind für die meisten Eigenheimbauer in Entwicklungsländern zu teuer. Deshalb werden Versuche durchgeführt, Niedrigkosten-Dachplatten zu entwickeln, wo die Kostenverminderung entweder aus billigerem Material oder aus einfacher Herstellungsmethode (für Selbsthilfe geeignet) resultiert.

4.2 New Developments

4.2.1 A.I.D.-Monsanto Low-Cost Roof Research Project

The research project, sponsored by the United States Agency for International Development, Washington, D.C., was carried out by Monsanto Research Corporation, Dayton/Ohio, University of Washington, Seattle/Washington und Washington University, St. Louis/Missouri, between May 1973 and December 1977.

The aim was to develop low-cost roofing from indigenous materials in three developing nations (Philippines, Ghana and Jamaica), install and test prototype roofs (four in each country) and involve local experts and firms in the experimental work. The object of using only indigenous materials and minimizing the foreign exchange requirement was later regarded as being less important than achieving lowest total cost in roofing.

Of about 50 potential fillers tested, bagasse (sugar cane residue) was found to be best in terms of product properties, cost and availability. Phenol formaldehyde thermosetting resin was the selected binder, good alternatives being natural rubber and ABS thermoplastic resin. Four composite panel roofing material systems were developed which utilize major percentages of bagasse and 5 to 30% of binder, costing between 0.7 and 1.50 $ (U.S.)/m^2. Economical processes, using locally available equipment and facilities were developed. The test panels were either flat ar corrugated, but the demonstration roofs used mainly flat shingles.

The overall performance of the demonstration units was good, except for minor deficiencies, such as warping. But all test roofs are still being observed, even after termination of the project, in order to obtain long-term performance data. Further developmental work in the participating countries has been recommended, with a view to implementing large scale production of high-strength, low-cost, durable roofing panels.

Source: "Development of low-cost roofing from indigenous materials in developing countries" (Contract No. AID/CM-ta-C-73-12)
Final Report, 20 February 1978
Monsanto Research Corporation, Dayton Laboratory, Dayton, Ohio 45407

4.2.2 Fibre Reinforced Roof Sheets

For easy and rapid installation of roofs, the most appropriate materials are large, thin sheets, which cover maximum area with minimum volume (hence ease of transport). Widely used sheets, such as corrugated galvanized iron and asbestos cement, are too expensive for most home builders in developing countries. Therefore attempts are being made to develop low-cost roof sheets, by which the cost reduction results either from the use of cheaper materials or from the simplicity of production (suitable for self-help).

Abb. 4.54 - 4.57 A.I.D.-Monsanto-Projekt
Fig. 4.54 - 4.57 A.I.D.-Monsanto Project

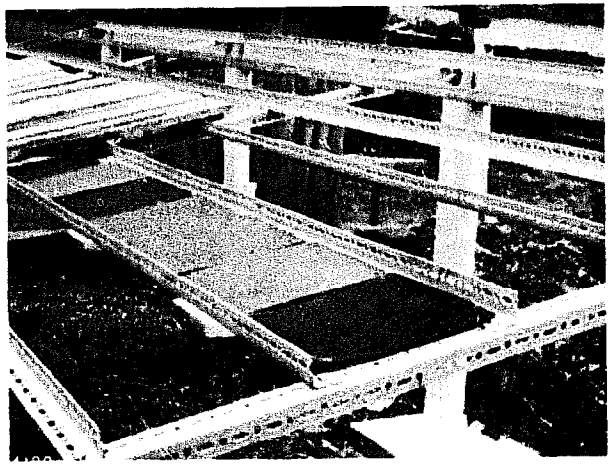

Abb. 4.54 Versuchsplatten in Ghana
Fig. 4.54 Test panels in Ghana

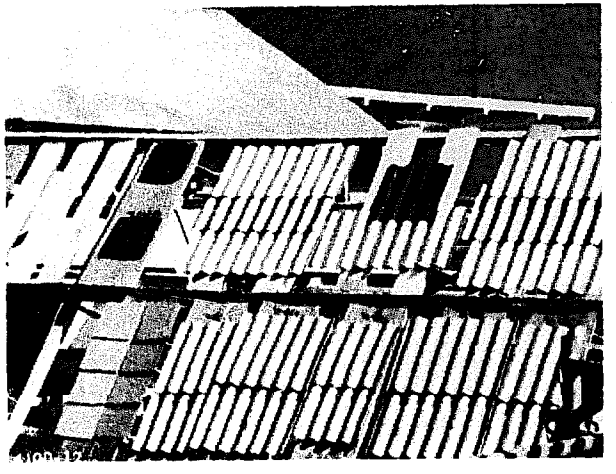

Abb. 4.55 Versuchsplatten auf Jamaica
Fig. 4.55 Test panels in Jamaica

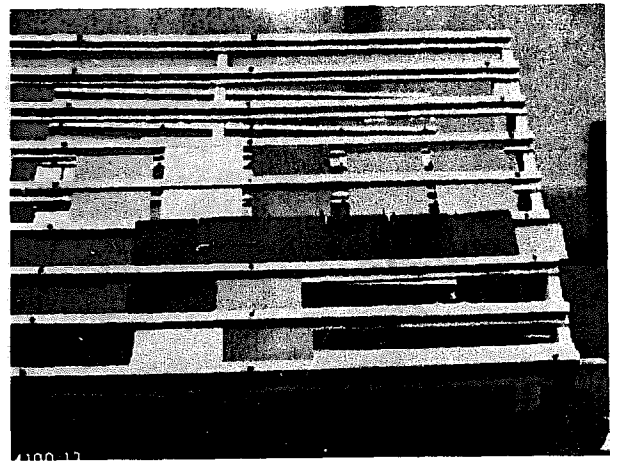

Abb. 4.56 Versuchsplatten auf den Philippinen
Fig. 4.56 Test panels in the Philippines

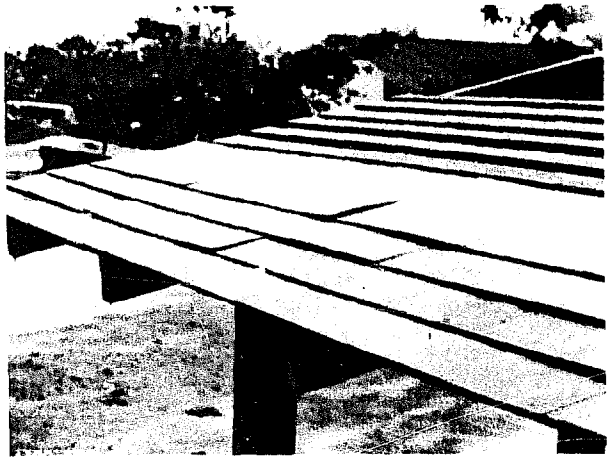

Abb. 4.57 Teilweise montiertes Versuchsdach in Ghana
Fig. 4.57 Partially installed test roof in Ghana

Abb. 4.58 Herstellungsmethode von Welldachplatten aus faserverstärktem Zement (Intermediate Technology Building Materials/Parry and Ass. Ltd.)

Fig. 4.58 Method of making corrugated roof sheets of fibre reinforced cement (Intermediate Technology Building Materials/Parry and Ass. Ltd.)

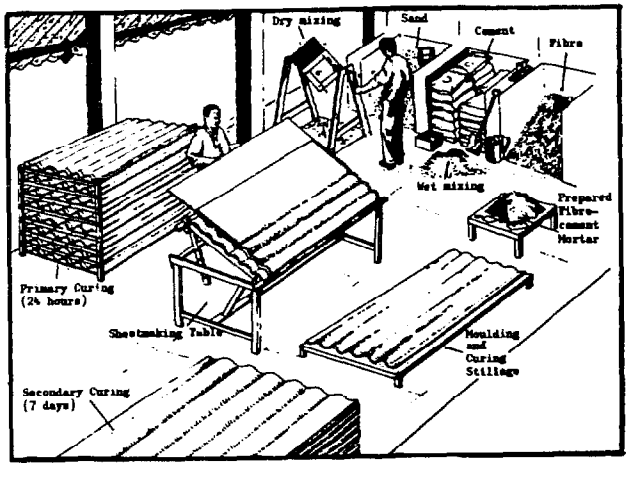

Hier werden zwei Entwicklungen beschrieben: eine beruht auf dem Material-Aspekt, die andere auf der Methode. Beides sind Dachplatten aus Fasermaterial mit Zement als Bindemittel.

a. Elefantengrasfasern als Bewehrung in Dachplatten (untersucht von Professor T.S.R. Ayyar und P.K. Mirihagalla, School of Engineering, University of Zambia, Lusaka).

Elefantengras ist eine große, aufrechte, stämmige Pflanze, ähnlich wie Bambus, ca. 20 mm dick und über 2 m hoch. Die Fasern werden mittels einer Walzenquetsche gewonnen. Sie dienen als vollwertiger Ersatz für Asbest bei flachen Faserzementplatten oder als teilweiser Ersatz für Asbest bei Wellplatten. Elefantengrasfaser kostet ungefähr nur 20% der Kosten für Asbestfaser, aber bei der ersteren sind die Platten brüchiger und geringfügig weniger stabil. Es wird angenommen, daß Verbesserungen bei der Produktion möglich sind, aber die Erreichung von Asbestzement-Qualität scheint beim Niedrigkostenbau nicht erforderlich zu sein.
Verfahrensweise: Zement-Wasser-Verhältnis war 1 : 0,45. Die Streichmasse aus Zement und Fasern wurde in eine Standard-Gußform gegeben und mit einem Gewicht von 400 N mittels eines flachen Brettes zwei Stunden lang gepreßt; danach konnte sie sieben Tage lang aushärten. Sowohl flache als auch gewellte Platten wurden vorbereitet und getestet.

b. Handgefertigte Welldachplatten (entwickelt vom Intermediate Technology Building Materials Workshop, J.P.M. Parry and Associates Ltd., U.K.)

Die Platten können aus jeder geeigneten natürlichen oder synthetischen Faser hergestellt werden, mit Sand und gewöhnlichem Portland-Zement (1 Sack für 2,5 Platten von 2,5 m Länge). Die Preise für fabrikmäßig hergestellte Dachplatten sollen viel höher sein als die entsprechende Menge Zement, und zusätzliche Kostenminderung wird durch Selbsthilfe-Bauweise erreicht.
Verfahrensweise: Die Fasern müssen im allgemeinen auf die erforderlichen Längen beschnitten und die Knoten entfernt werden. Die Mischung aus Fasern und nassem Sand-Zementmörtel wird in einem einfachen Rahmen auf einer glatten geschmierten Platte ausgebreitet. Nach Glättung des Mörtels mit einer Kelle wird der Rahmen entfernt. Der Tisch wird danach gekippt und das flache Formbrett langsam herausgezogen, wobei der Mörtel die Form der darunterliegenden gewellten Unterlage annimmt. Die frisch geformte nasse Platte kann zwei Tage lang tracknen. Vor der Befestigung auf dem Dach ist eine weitere Aushärtung von einer Woche erforderlich.

Quellen: Appropriate Technology (erscheint vierteljährlich):
a. Vol. 6 Na. 1 (Mai 1979) - Elephant grass fibres
b. Vol. 5 No. 4 (Februar 1979) - Handmade roof sheets

Two developments are described here, one based on the material aspect and the other on the method. Both are roof sheets made of fibrous material, using cement as binder.

a. Elephant grass fibres as reinforcement in roof sheets (investigated by Professor T.S.R. Ayyar and P.K. Mirihagalla, School of Engineering, University of Zambia, Lusaka).

Elephant grass is a tall, erect, stout plant, similar to bamboo, about 20mm thick and more than 2 m high. The fibres have to be extracted in a roller crusher. They are used to completely substitute asbestos in flat fibre-cement sheets, or partially replace asbestos in corrugated sheets. Elephant grass fibre is estimated to cost only 20% of the cost of asbestos fibre, but the former produces sheets that are more brittle and have slightly lower strengths. It is assumed that improvements in production are possible, but the attainment of asbestos cement qualities does not seem necessary in low-cost constructions.

Process: Water-cement ration was 0.45. The slurry of cement and fibre was placed in a standard mould and compressed by a weight of 400 N applied through a flat slab for two hours, after which it was allowed to cure for seven days. Both flat and corrugated sheets were prepared and tested.

b. Handmade corrugated roof sheets (developed by Intermediate Technology Building Materials Workshop, J.P.M. Parry and Associates Ltd., U.K.)

The sheets can be made of any appropriate natural or synthetic fibres, with sand and ordinary Portland cement (one bag is needed for 2.5 sheets of 2.5 meters length). It is claimed that the prices of factory produced roof sheets are far higher than the equivalent amount of cement and additional cost reduction is achieved by self-help production.

Process: The fibres generally require trimming to appropriate lengths and removing of knots. The mixture of fibres and wet sand cement mortar is spread into a simple frame on a smooth lubricated sheet. After trowelling the mortar flat, the frame is removed. The table is then tilted and the flat bed slowly drawn out, allowing the mortar to take the shape of the corrugated former underneath. The wet sheet is allowed to cure on the former for two days. A further week's curing is necessary before installation on the roof.

Sources: Appropriate Technology (published quarterly):
a. Vol. 6 No. 1 (May 1979) - Elephant grass fibres
b. Vol. 5 No. 4 (February 1979) - Handmade roof sheets

4.2.3 Woudenberg Jute-Plastik, Bangladesh

Die Erfordernisse für ein neues Dachsystem in Bangladesh waren:

- Wirbelsturmresistenz und klimatisch angepaßte Bauweise,
- Verwendung von Jutefasern (wichtigstes Produkt des Landes),
- Einfachheit der Herstellung und Montage mit örtlich ausgebildeten Fachleuten,
- Niedrige Kosten und annehmbar für örtliche Bevölkerung.

Forschung und Produktion wurden in Bangladesh seit 1971 von William F. Woudenberg unter der Gönnerschaft und mit Unterstützung einer großen Anzahl von örtlichen und internationalen Organisationen einschließlich UNESCO, Weltbank und CARE, durchgeführt. Das Material, das sich als am geeignetsten herausstellte, war mit Jutefaser verstärktes Polyester, das beliebig geformt werden kann. So konnten große, leichtgewichtige, selbsttragende Dachelemente in einer örtlichen Werkstatt hergestellt und von zwei Männern leicht gehandhabt werden. Da sie auf jedem herkömmlichen Unterbau befestigt werden können, z.B. traditionelle Ziegelstein-Häuser, wurden die Elemente häufig benützt, um Gebäude zu decken, deren Dächer von Wirbelstürmen abgerissen wurden.

Diese Dächer wurden in erster Linie für Schulen und Kliniken entworfen, eignen sich jedoch ebenfalls für den Hausbau. Die Abbildungen zeigen nur einen Dachtyp aus einer großen Vielfalt von Entwurfsvarianten, von welchen einige ganze Häuser umfassen.

Der größte Nachteil des Materials ist, daß das Polyesterharz in Bangladesh nicht

Abb. 4.59 Fig. 4.59

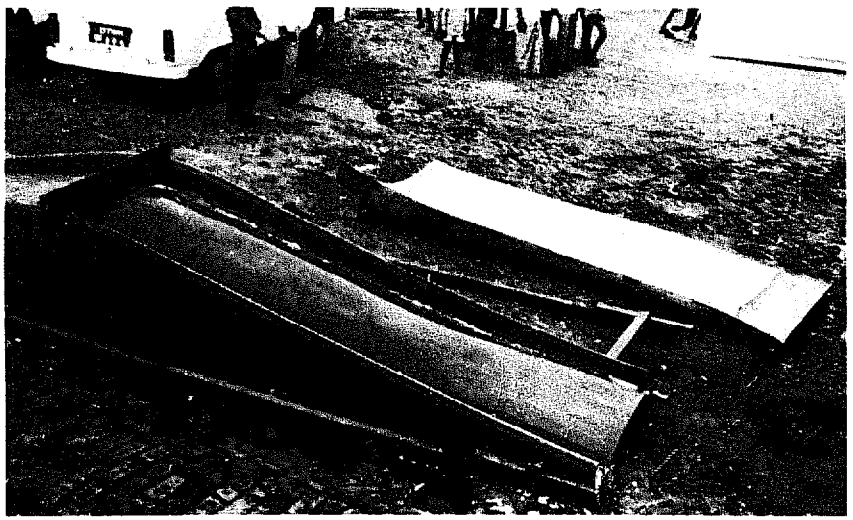

4.2.3 Woudenberg Jute-Plastic, Bangladesh

The requirements for a new roofing system in Bangladesh were:

- cyclone resistance and climatic appropriateness,
- utilization of jute fibres (principal product of the country),
- simplicity of manufacture and assembly with locally-trained technicians,
- low-cost and good local acceptance.

Research and production was carried out in Bangladesh since 1971 by William F. Woudenberg, under the auspices and with the support of a wide range of local and international agencies including UNESCO, World Bank and CARE. The material that proved most suitable was jute-fibre-reinforced polyester, which could be moulded to any shape. Thus large lightweight, self-supporting roofing elements could be manufactured in a local workshop and easily handled by two men. Since they can be fixed on any traditional structure, eg. common brick-walled houses, the elements were widely used to cover buildings whose roofs were ripped off during cyclones.

These roofs were primarily designed for schools and clinics, but are equally suitable for housing. The illustrations show only one roof type out of a large variety of design solutions, some of which incorporating entire houses.

The major disadvantage of the material is that the polyester resin is not available in Bangladesh. It is, however, claimed that the resin can be imported cheaply from various countries with petro chemical industries.

Abb. 4.60 Fig. 4.60

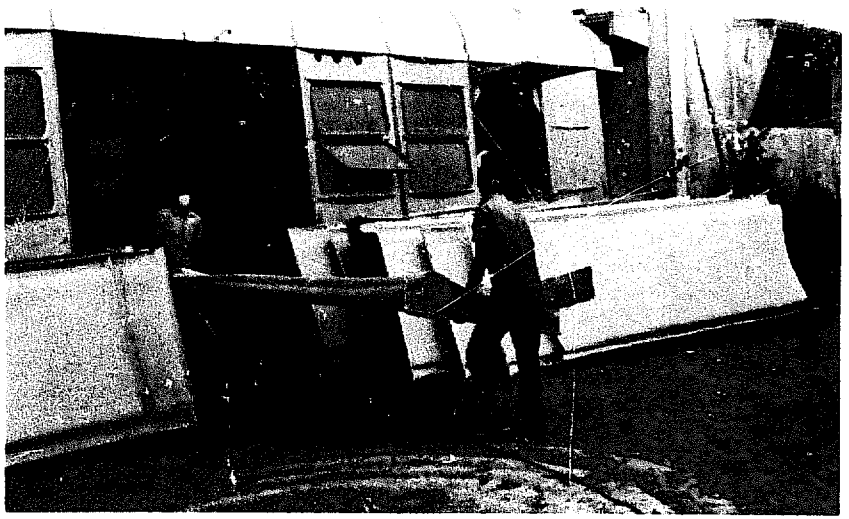

verfügbar ist. Es wird jedoch behauptet, daß das Harz aus Ländern mit Petrochemie-Industrie billig importiert werden kann.

Quelle: "Woudenberg Jute-Plastic: A New Concept in Low-Cost Construction". Broschüre, veröffentlicht von W.F. Woudenberg, G.P.O. Box 311, Ramna, Dacca 5, Bangladesh.
"Assembly Manual for Cyclone Resistant Roof for Primary Schools made from Jute Reinforced Polyester Resin", veröffentlicht von CARE in Bangladesh und UNESCO Regional Office for Education in Asia, Bangkok (Juli 1976).

Source: "Woudenberg Jute-Plastic: A New Concept in Low-Cost Construction". Broshure published by W.F. Woudenberg, G.P.O. Box 311, Ramna, Dacca 5, Bangladesh.
"Assembly Manual for Cyclone Resistant Roof for Primary Schools made from Jute Reinforced Polyester Resin", published by CARE in Bangladesh and UNESCO Regional Office for Education in Asia, Bangkok (July 1976).

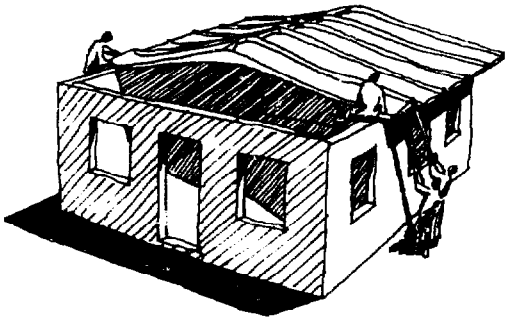

Abb. 4.61 Zusammenbau von Woudenberg Jute-Plastik-Dachelementen auf traditionellem Mauerwerkshaus (Bangladesh)

Fig. 4.61 Assembly of Woudenberg Jute-Plastic roof elements on standard brick-walled house (Bangladesh)

4.2.4 Ultra Low-Cost Housing für Bangladesh

Ein anderer Lösungsansatz für das Wohnungsproblem in Bangladesh wurde im Jahre 1974 - 75 durch die Carnegie Mellon University / INTERTECT Refugee Housing Team (Pittsburgh/Dallas) in einem Forschungsprojekt demonstriert, welches von der United States Agency for International Development finanziert wurde.

Die Flüchtlingsunterkunft, die für bessere Windbeständigkeit stromlinienförmig konzipiert ist, kann komplett aus lokalen Materialien mit traditionellen Bautechniken gebaut werden. Die tragenden Bauteile der A-Rahmen können aus Holz oder Bambus sein. Die vertikalen und horizontalen Abmessungen können variiert werden, ebenso wie die Dachdeckungsmaterialien (Strohschindeln, Matten, geflochtener Bambus), die durch andere geeignete Materialien ohne wesentliche Entwurfsabänderungen ersetzt werden können. Eine Lüftungsmöglichkeit ist in der Firstlinie vorgesehen, und Fenster können beliebig angeordnet werden.

Der größte Nachteil der A-Rahmen ist die an den Seiten verlorengehende Nutzfläche, was bei kleinen Gebäuden wesentlich ist. Aber abgesehen davon wurden die Bauten von der örtlichen Bevölkerung gut aufgenommen.

Quellen: "Feasibility Test of an Approach and Prototype for Ultra Low Cost Housing" Schlußbericht (1975) und Evaluierungsbericht (1977) von C.G. Goodspeed, V.H. Hartkopf, F.C. Cuny, V.P. Singh von der Interdisciplinary Working Party, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213.

4.2.4 Ultra Low-Cost Housing for Bangladesh

Another approach to the housing problem in Bangladesh was demonstrated in 1974 - 75 by the Carnegie Mellon University/INTERTECT Refugee Housing Team (Pittsburgh/Dallas) in a research project, funded by the United States Agency for International Development.

The refugee shelter, which is streamlined for better wind performance, can be built entirely of local materials, employing traditional building techniques. The structural members of the A-frames can be timber or bamboo. Vertical and horizontal dimensions are variable, just as the roofing materials (thatch shingles, mats, woven bamboo), which can be replaced by other appropriate materials without major design modifications. A means of venting is devised at the vertex and windows can be provided where needed.

The major disadvantage of the A-frames is the floor space lost at the sides, which is significant in small buildings. But apart from this, the structures found good acceptance by the local people.

Sources: "Feasibility Test of an Approach and Prototype for Ultra Low Cost Housing" Final Report (1975) and Evaluation Report (1977) both by C.H. Goodspeed, V.H. Hartkopf, F.C. Cuny, V.P. Singh of Interdisciplinary Working Party, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213.

Abb. 4.62 "Ultra-Low-Cost"-Haus für Bangladesh
Fig. 4.62 "Ultra low-cost" house for Bangladesh

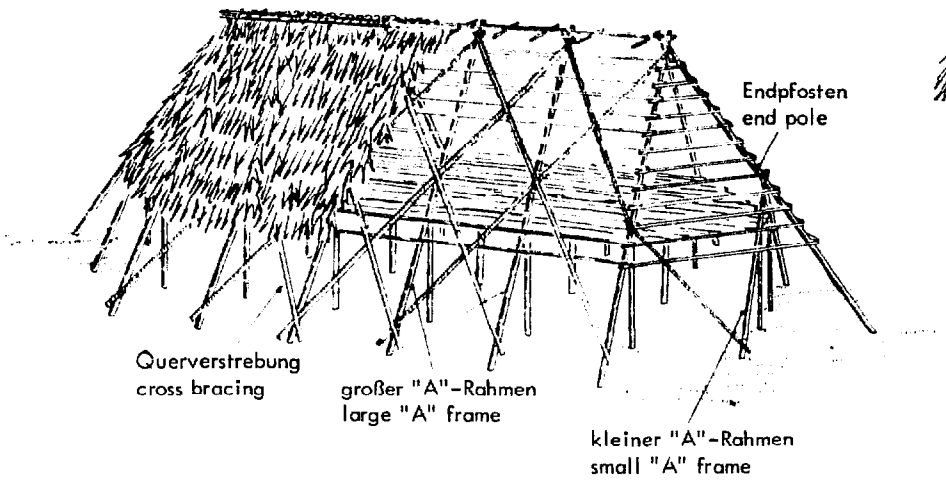

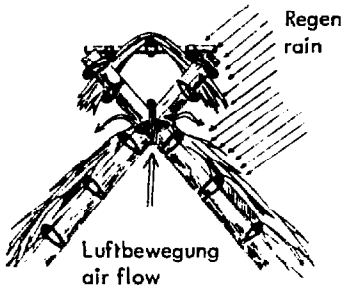

Abb. 4.63
Fig. 4.63

Abb. 4.64
Fig. 4.64

Druckausgleich durch Grasdach
Pressure equalization through thatch

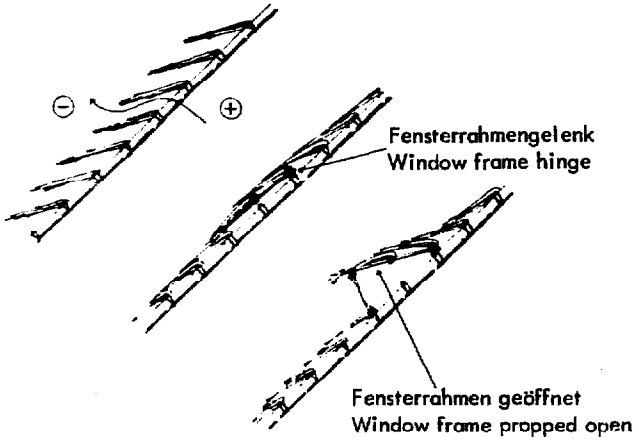

4.2.5 In Indien entwickelte Dachelemente

Von der großen Anzahl der am Central Building Research Institute, Roorkee, entwickelten Dachelemente werden hier drei Typen beschrieben.

a. Doppelt gekrümmte Dachplatten.
Die Plattenherstellung erfolgt in einfachen Holzrahmen, 70 x 70 cm, die mit Sackmaterial bespannt sind und mittels Nägeln straff gehalten werden. Der Rahmen liegt auf einem flachen Untergrund und wird 2 cm hoch mit Beton gefüllt, dann hochgehoben, so daß das Tuch unter dem Gewicht des Betons absackt und so die doppelt gekrümmte Dachplatte bildet. 8 bis 10 Dachplatten, die 24 Stunden lang getrocknet werden, dienen als Grundformen zur Herstellung weiterer Dachplatten. Plastikplanen oder Ölpapier, das man darauflegt, ergibt eine glatte Oberfläche und verhindert, daß die frischen Ziegel an den Formen ankleben. Die fertigen Dachplatten werden 24 Stunden getrocknet, 7 Tage lang in Wasser ausgehärtet und zur vollstän-

4.2.5 Roofing Elements Developed in India

Of a large number of concrete roof elements developed at the Central Building Research Institute, Roorkee, three types are described here.

a. Doubly curved tile roof.
The tiles are made in simple wooden frames, 70 x 70 cm, mounted with hessian cloth, held taut by nails. The frame lying on a flat surface is filled with concrete 2 cm thick and then lifted, so that the cloth sags under the weight of the concrete, forming the doubly curved tile. 8 to 10 tiles, dried for 24 hours, serve as base moulds for casting more tiles. Polythene sheets or oiled paper laid on top provide a smooth surface to prevent fresh tiles from sticking to the moulds. The finished tiles are dried for 24 hours, cured in water for 7 days and stored for 15 days to allow completion of drying shrinkage. Simple prefabricated beams are also made and installed at 76 cm distances to support the tiles. The gaps are filled with cement concrete,

digen Trockenschrumpfung 15 Tage lang gelagert. Einfache Balken werden auch vorgefertigt und in 76 cm-Abständen montiert, um die Dachplatten zu tragen. Die Lücken werden mit Zementbeton gefüllt, während die Wasserfestigkeit und der Oberflächenabschluß mittels Kalkbeton, der mit Tonfliesen bedeckt ist, erreicht wird.

b. Trogelemente.
Die Form für diese selbsttragenden Elemente ist nicht so einfach wie die vorhergehende, aber die Installierung auf der Baustelle ist leicht. Sie sind im Querschnitt trogförmig, die Seiten gewellt und an den Enden gerillt, um so die Lasten seitlich zu übertragen. Die Nennweiten sind 300 oder 600 mm, Tiefe 130 mm, während die Längen zwischen 2,5 und 4,2 m variieren können. Sie brauchen während der Bauzeit keine temporäre Unterstützung und benötigen keine Betonüberdeckung.

c. L-Pan-Dachdeckung.
Die Paneele werden auf der Baustelle in einfachen Formen gegossen, das Zusammenfügen des Daches ist ebenso einfach (Ortbeton wird nur bei Verbindungsfugen benötigt). Diese vorgefertigten Paneele mit L-förmigem Querschnitt werden für geneigte Dächer verwendet. Sie werden an parallelen Giebelwänden oder Bindern aufgesetzt und überlappen die angrenzenden darunterliegenden Paneele. Eine angemessene Paneelgröße könnte 300 x 48 x 12 cm sein, 4 cm dick, obwohl die Abmessungen verschiedenen Gebäudegrößen angepaßt werden können.

Quellen: Building Digest 43 (1966): Doubly curved tile roof
Data Sheet — Building Technical Series 5 (1977): Channel Units
Data Sheet — Building Technical Series 10 (1978): L-Pan roofing
sämtlich vom Central Building Research Institute, Roorkee, Indien.

while waterproofing and surface finish is provided by lime concrete covered with clay tiles.

b. Channel units.
The mould for these self-supporting units is not as simple as the previous one, but installation on the building is easy. They are trough-shaped in section, the sides are corrugated and grooved at the ends, to help transferring the loads transversely. Nominal widths are 300 or 600 mm and depths 130 mm, while lengths can vary between 2.5 and 4.2 m. They do not require any type of temporary support during construction and need no deck concrete.

c. L-Pan roofing.
Casting of panels is done on the site in simple moulds, assembly of the roof is equally easy (insitu concrete is only needed at junctions). These precast panels with L-shaped sections are used for sloping roofs. They are supported on parallel gable walls or trusses and overlap the adjacent lower panels. A suitable panel size could be 300 x 48 x 12 cm, 4 cm thick, though dimensions are adaptable to various building sizes.

Sources: Building Digest 43 (1966): Doubly curved tile roof
Data Sheet — Building Technical Series 5 (1977): Channel units
Data Sheet — Building Technical Series 10 (1978): L-Pan roofing
all from Central Building Research Institute, Roorkee, India.

In Indien entwickelte Dachelemente
Roofing elements developed in India

Abb. 4.65 (a, b) Doppelt gewölbte Dachplatte
Fig. 4.65 (a, b) Doubly curved roof tile

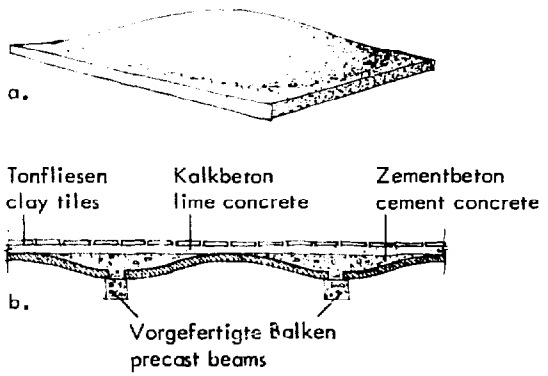

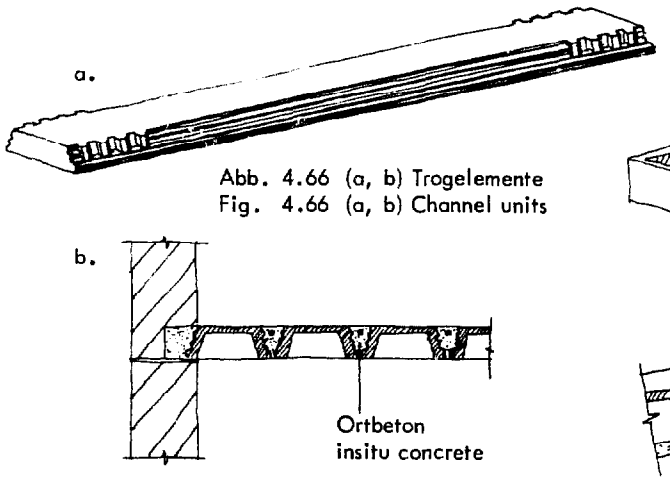

Abb. 4.66 (a, b) Trogelemente
Fig. 4.66 (a, b) Channel units

Abb. 4.67 (a, b) L-Pan-Dach
Fig. 4.67 (a, b) L-pan roofing

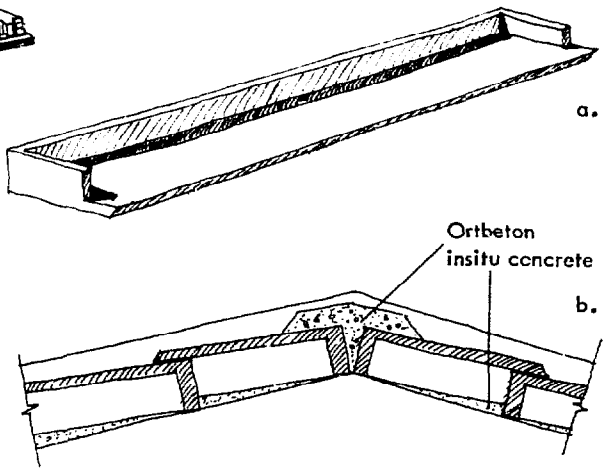

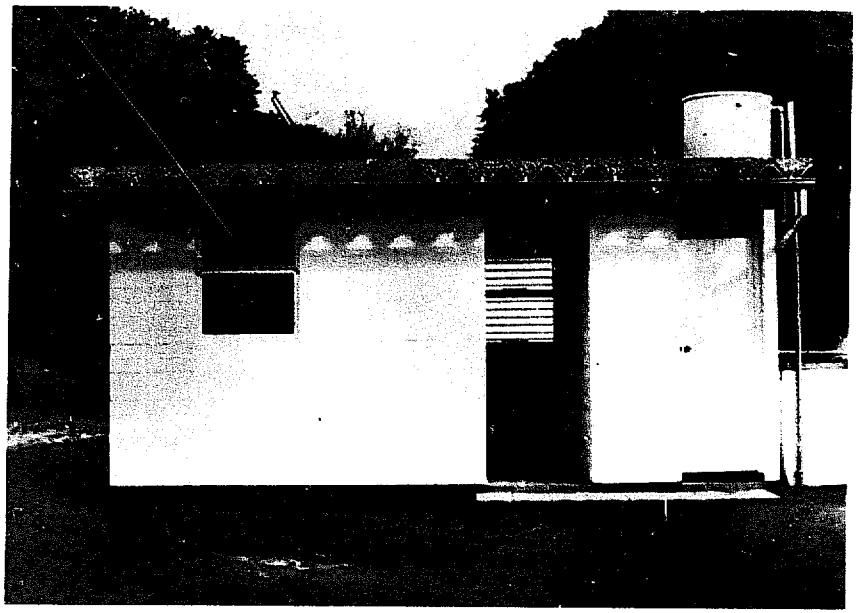

Abb. 4.68 In Südafrika entwickeltes Dachsystem
Fig. 4.68 Roofing system developed in South Africa

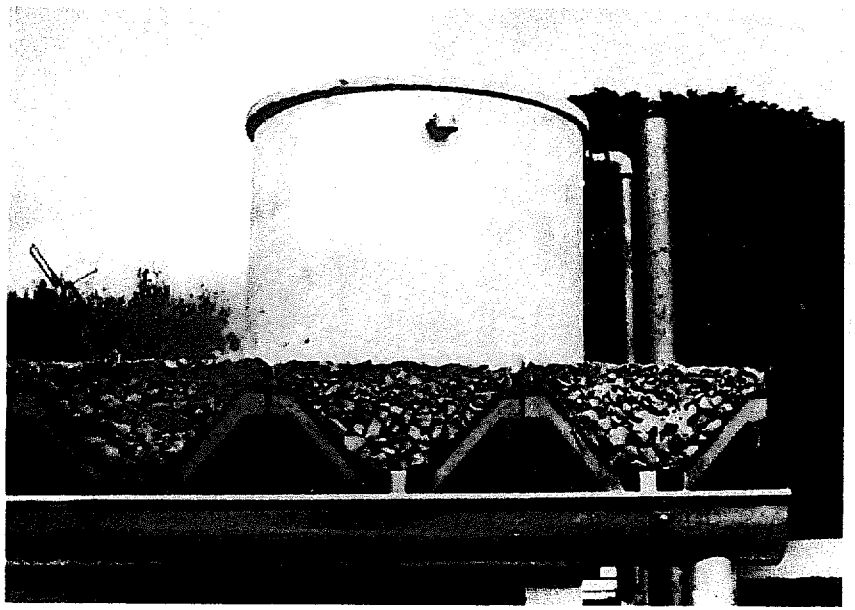

Abb. 4.69 Detail der vorfabrizierten trogförmigen Betonelemente mit Einkornbeton-Randabschlußblöcken

Fig. 4.69 Detail showing trough shaped prefabricated concrete elements, with no-fines concrete end-pieces

4.2.6 In Südafrika entwickeltes Dachdeckungselement

Ein trogförmiges vorgefertigtes Betondachelement wurde am National Building Research Institute, Pretoria, für ein Prototyp-Haus entwickelt. Das trogförmige Profil ermöglicht das Stapeln während der Herstellung. Das Dach wurde mit Plastikfolie auf den Betonelementen wasserdicht gemacht. Diese wurde mit einer lockeren Kiesschicht bedeckt, die die thermischen Eigenschaften des Daches beträchtlich verbessert. Der Kies wird von geformten, vorgefertigten Einkornbetonblöcken, die in den Trögen als Randabschluß liegen, festgehalten. Das Regenwasser sickert durch den Einkornbeton zur Dachrinne.

Quelle: "Research at Local Level: Description of NBRI Experimental Project", von J.L. Arrigone (Paper 24, Nov. 1978).
National Building Research Institute, Pretoria, Südafrika.

4.2.6 Roofing Element Developed in South Africa

A trough shaped prefabricated concrete roof element was developed at the National Building Research Institute, Pretoria for a prototype house. The trough-shaped profile allows for stacking during the casting operation. The roof was waterproofed with plastic sheeting placed on top of the concrete elements. This was covered with a layer of loose gravel that greatly improves the thermal performance of the roof. The loose gravel is kept in place by shaped, precast, no-fines concrete blocks placed in the roof troughs at the verges. The rainwater percolates through the no-fines concrete to the gutter.

Source: "Research at Local Level: Description of NBRI Experimental Project", by J.L. Arrigone (Paper 24, Nov. 1978)
National Building Research Institute, Pretoria, South Africa.

4.2.7 Ecol House, Canada.

Das "Ecol Operation" genannte Projekt, 1972 von der Minimum Cost Housing Group, Mc Gill University, Montreal, unternommen, umfaßte eine Anzahl von Bauneuerungen zum Zwecke der Kostenreduzierung und zur Vereinfachung von Baumethoden. Eine Erfordernis war es, ein einfaches, selbsttragendes Dach mit einer Spannweite von 3,60 m zu errichten. Eine Lösung, ähnlich der Asbestzement-Trogplattendächer (canaletas), die in lateinamerikanischen Ländern gebräuchlich sind, wurde gesucht, und eine billige Alternative wurde gefunden, indem man Asbestzemententwässerungsrohre der Länge nach in vier Teile schnitt und sie wie herkömmliche Mönch- und Nonnen-Ziegel verlegte. Pro Schnitt wurden für 25 mm dicke Rohre drei Stunden gerechnet, aber der Vorgang wurde dadurch vereinfacht und beschleunigt, daß man nur 6 mm tief schnitt, so daß das Rohr bei geringem Anheben und Fallenlassen entlang der Schnittliene brach. Ergebnis: vier Schnitte in der Stunde.

Quelle: "The Ecol Operation" von der Minimum Cost Housing Group, Mc Gill University, Montreal, Canada, 1972

4.2.7 Ecol House, Canada

The project, called the Ecol Operation, undertaken in 1972 by the Minimum Cost Housing Group, McGill University, Montreal, incorporated a number of building innovations, designed to reduce costs and simplify construction methods. One requirement was to erect a simple, self-supporting roof to span 3.60 m. A solution, corresponding to asbestos cement channel roofs (canaletas) common in Latin American countries, was sought and an appropriate, cheap alternative was found by cutting asbestos cement sewer pipes lengthwise in four parts and assembling them like traditional Spanish roof tiles. Cutting the 25 mm thick pipes was found to take three hours per cut, but the process was simplified and accelerated by cutting only 6 mm deep, so that when slightly raised and dropped, the pipe split along the score-line. Result: four cuts per hour.

Source: "The Ecol Operation" by Minimum Cost Housing Group, McGill University, Montreal, Canada, 1972

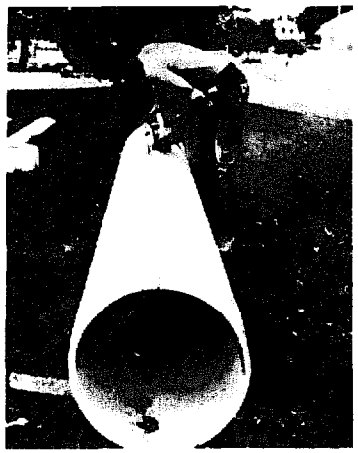

Abb. 4.70
Fig. 4.70

"The Ecol Operation" in Kanada
"The Ecol Operation" in Canada

Schneiden der Dachplatten .....
Cutting the roof tiles .....

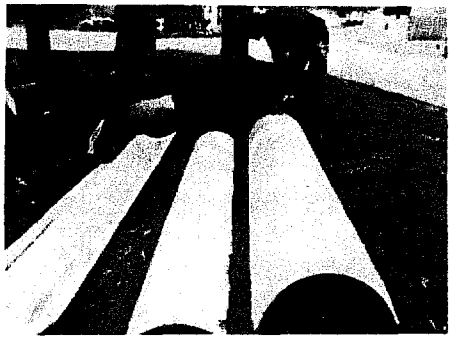

Abb. 4.71
Fig. 4.71

Abb. 4.72
Fig. 4.72

..... und Zusammenbau
..... and assembling them

Abb. 4.73
Fig. 4.73

4.2.8 Bambus-Polyurethan-Dachkonstruktion, Peru

Diese Dachlösung wurde von Christopher Alexander für eine low-cost-housing-Siedlung entworfen (Proyecto Experimental de Vivienda, internationaler Wettbewerb, ausgeschrieben von den Vereinten Nationen, der peruanischen Regierung und der Housing Bank, 1969). Es umfaßt ein System von Balken und Bohlen, die aus einem Polyurethan-Schaumstoffkern mit darumgebundenen Bambusrohren bestehen. Zur Verbindung, und um eine wasserdichte Begehungsfläche zu erhalten, erhalten die Planken eine Deckschicht aus einer flüssigen Schwefel-Sand-Mischung. Dies wurde in den Vereinigten Staaten umfassend getestet. Die Elemente sind leichtgewichtig, leicht zu handhaben und zu montieren, der Schaumstoffkern verleiht ausgezeichnete klimatische und akustische Bedingungen.

Quelle: "Houses Generated by Patterns" by C. Alexander, et al.
Center for Environmental Structure, Berkeley, California, 1969

4.2.9 Kokospalmdächer, Philippinen

Die Dachkonstruktion, die von Ian Athfield, Neuseeland (in seinem 1. Preis-Entwurf für den internationalen Wettbewerb für einen Stadtteil von Manila, 1975) vorgeschlagen wurde, basiert auf der Kokospalme und deren Nebenprodukten. Das Holz kann in seinem natürlichen Zustand verwendet werden, wenn es getrocknet und konserviert wird. Ganze, halbe oder geschnittene Kokosstämme wurden für den Dachrahmen vorgeschlagen. Die Dachdeckung bestand aus Kokospreßspanplatte an der Unterseite, einer Isolierschicht aus Kokos-Faser-Zement und einem mit Maschendraht bewehrten Außenputz aus Kokossägemehl, Sand und Zement.

Quelle: Architectural Record (Mai 1976), eine McGraw-Hill Veröffentlichung, New York.

4.2.8 Bamboo-Polyurethane Roof Structure, Peru

This is a roofing solution designed by Christopher Alexander for a low-cost housing scheme in Peru (Proyecto Experimental de Vivienda, international competition sponsored by the United Nations, Peruvian Government and Housing Bank, 1969). It comprises a system of beams and planks, all made of whole bamboo culms bound together around a polyurethane foam core. For jointing and to provide a waterproof walking surface, the planks receive a topping of molten sulphur mixed with sand. These have been widely built and tested in the United States. The elements are light, easy to handle and install, the urethane core giving excellent thermal and acoustical performance.

Source: "Houses Generated by Patterns" by C. Alexander, et al.
Center for Environmental Structure, Berkeley, California, 1969

4.2.9 Coconut Palm Roofs, Philippines

The roof construction, suggested by Ian Athfield, New Zealand (in his first-prize-winning design for the international competition for an urban environment in Manila, 1975), is based on the coconut palm and its by-products. The timber can be used in its natural state if dried and preserved. Whole, half or cut coconut logs were proposed for the roof frame. The roof cover consisted of coconut particle board on the underside, an insulation layer of coconut-fibre-cement and an exterior plaster with coconut sawdust, sand and cement over expanded wire mesh.

Source: Architectural Record (May 1976), A McGraw-Hill Publication, New York.

Abb. 4.74 (a, b, c) Bambus-Polyurethan-Dachkonstruktion (Peru)

Fig. 4.74 (a, b, c) Bamboo-polyurethane roof structure (Peru)

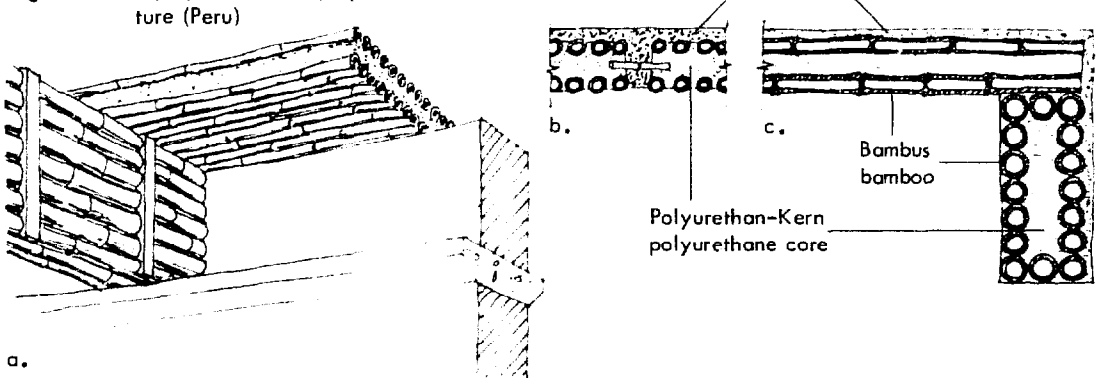

Abb. 4.75 Kokospalmendach (Philippinen)

Fig. 4.75 Coconut palm roof (Philippines)

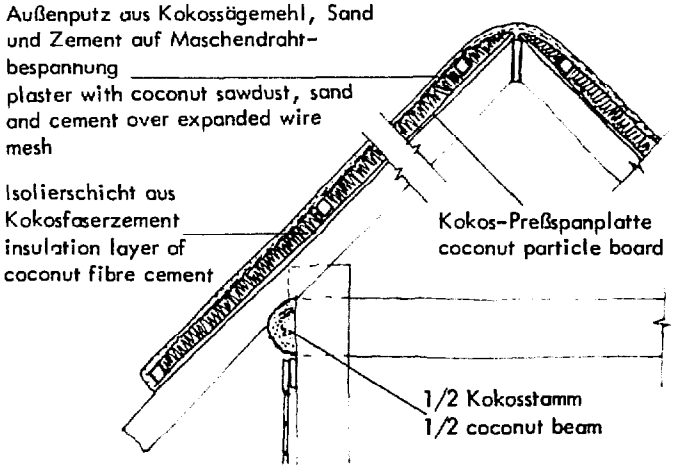

4.2.10 Hängedachsystem, Korea

Als Teil eines Forschungsprojektes, das an der Yeungnam Universität, Taegu, Korea, 1973 unternommen wurde, wurde dieser Dachtyp in erster Linie für Bauern- und Fischerdörfer entwickelt. Das System umfaßt Holzteile für First, Traufe und Zugbalken, während die Dachsparren von Stahlseilen, die in 1 m Abständen verlaufen, ersetzt werden. Eine Sperrholzdecke wird mittels Drahtseilen abgehängt. Holzpfetten werden durch Maschendraht ersetzt, der das Dach aus wasserdichten Polyäthylen-Folien, Strohmatten, Erde und Dachziegeln trägt. Die Hauptvorteile dieses Systems sind einfache Konstruktion und eine Kostenverringerung von ca. 35% im Vergleich zu herkömmlichen Systemen.

Quelle: "Low-Cost Housing for Agro-Fishery Villages in Korea" von Sun-Ho Choi, veröffentlicht in Proceedings of Adaptive Technology Workshop II, 1973, East-West Center, Honolulu, Hawaii.

4.2.10 Suspension Type Roof System, Korea

As part of a research project, undertaken at Yeungnam University, Taegu, Korea, in 1973, this roof type was developed primarily for agro-fishery villages. The system comprises timber members for ridge, eaves and tie beams, while the rafters are substituted by wire ropes spaced 1 m apart. A plywood ceiling is suspended from the wire ropes. Timber purlins are substituted with wire mesh, which is overlaid by waterproofing polyethylene sheets, straw matting, seating soil and roof tiles. The main advantages of this system are simple construction and cost reduction of about 35% as compared to conventional systems.

Source: "Low-Cost Housing for Agro-Fishery Villages in Korea" by Sun-Ho Choi, published in Proceedings of Adaptive Technology Workshop II, 1973, East-West Center, Honolulu, Hawaii.

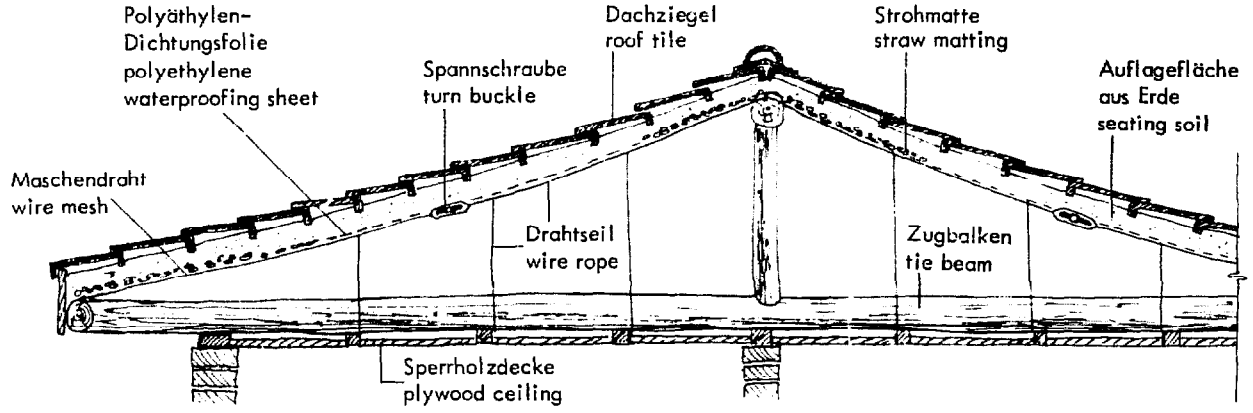

Abb. 4.76 Hängedachsystem (Korea)
Fig. 4.76 Suspension type roof system (Korea)

4.2.11 Versuchsbauten der Gesamthochschule Kassel, Bundesrepublik Deutschland

Die nachstehend beschriebenen Bauten wurden am Forschungslabor für Experimentelles Bauen, Gesamthochschule Kassel, unter der Leitung von Gernot Minke, entwickelt. Die Hauptziele der Forschungsarbeit, die 1974 begann, waren, neue Materialien und Methoden zur Low-Cost-Bauweise zu entwickeln bzw. bestehende Technologien zu verbessern. Das Resultat waren eine Anzahl interessanter Lösungen.

4.2.11 Experimental Structures of University Kassel, Germany

The structures described below were developed at the Laboratory for Experimental Construction, Kassel University, under the guidance of Gernot Minke. The prime objectives of the research work, which began in 1974, was to develop new materials and methods for low-cost construction or improve on existing technologies. This resulted in a number of interesting solutions.

a. Schwefel-Beton-Haus.
Das Rotationsparaboloid wurde aus einer Mischung von geschmolzenem Schwefel, Kies und Sägemehl hergestellt. Der Testkörper wurde mit Hilfe einer besonderen, eigens dazu entwickelten Rotationsgleitschalung gegossen. Diese Form, welche Genauigkeit garantierte und die Arbeit auf drei Personen reduzierte, wurde wegen der raschen Härtung des heißen Schwefels klein gehalten (20 x 40 cm). Das Hauptproblem ist die Entwicklung einer einfachen Vorrichtung, um den Schwefel in flüssigem Zustand zu halten. Drei Maschinen wurden entwickelt und getestet. Ein Vorteil des Materials ist, daß es abgebrochen und in der gleichen Weise wie vorher ohne Masseverluste wiederverwendet werden kann. Außerdem sind die benützten Materialien im allgemeinen billiges Abfallmaterial.

b. Vorgefertigtes Paneelhaus.
Die Wände und das Dach des abgestumpften Hexaoktaeders bestanden aus 13 quadratischen und 4 dreieckigen Paneelen, und zwar Holzrahmen mit verschiedenen Ausfachungen: mit Schwefel- oder Polyesterharz getränkten Glasfiber- oder Jutefaser (Abfall!)-Bespannungen, die mit Ausnahme der Dreiecks-(Licht)elemente mit einer schwefelgebundenen Blähtonschicht versehen wurden. Das Ziel war, diese Materialien in verschiedenen Zusammenstellungen zu testen.

c. "Bio-Bau".
Das Testgebäude mit parabelförmigem Querschnitt und drei halben Rotationsparaboloiden bestand aus Holzrippen- und -gitterschalen, die mit aluminiumverstärkten Polyäthylen-Folien (Abfall aus der chemischen Industrie) bedeckt waren, auf welchen erdgefüllte Säcke mit Pflanzen schuppenartig be-

a. Sulphur-concrete house.
The rotational paraboloid structure was made of a mixture of molten sulphur, gravel and sawdust, poured in a special rotating-sliding formwork. This formwork, which ensured accuracy and reduced labour to three persons, was kept small (20 x 40 cm) because of the rapid hardening of hot sulphur. The major problem is the development of a simple device for keeping the sulphur in the molten state for pouring. Three machines were developed and tested. An advantage of the material is that it can be demolished and reused in the same way as before, without volumetric loss. Besides, the materials used are generally cheap waste materials.

b. Prefabricated panel house.
On an octahedronal plan, the walls and roof were made of 13 square and 4 triangular panels, which were timber frames with varying infills: fibreglass or jute fibre (waste!) reinforcements with sulphur or polyester resin covered with sulphur-bonded expanded clay. The object was to test these materials in different combinations.

c. "Bio-building".
The test structure, with parabolic cross-section and three half rotational paraboloids, consisted of a wooden framework covered with aluminium reinforced polyethylene sheets (waste from chemical industry), on which soil filled sacks carrying plants were placed like shingles. Three types of soil and 17 different plant groups were tested. The aim of the project was to test simple, low-cost prefabrication and construction methods, using environmentally and structurally appropriate materials. New plant systems will be tried out from time to time.

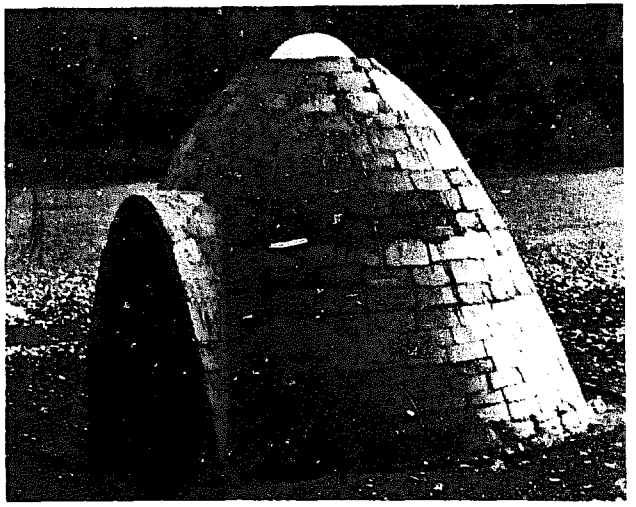

Abb. 4.77 Schwefel-Beton-Haus
Fig. 4.77 Sulphur-concrete house

Versuchsbauten der Gesamthochschule Kassel, Bundesrepublik Deutschland

Experimental structures at Kassel University, Germany

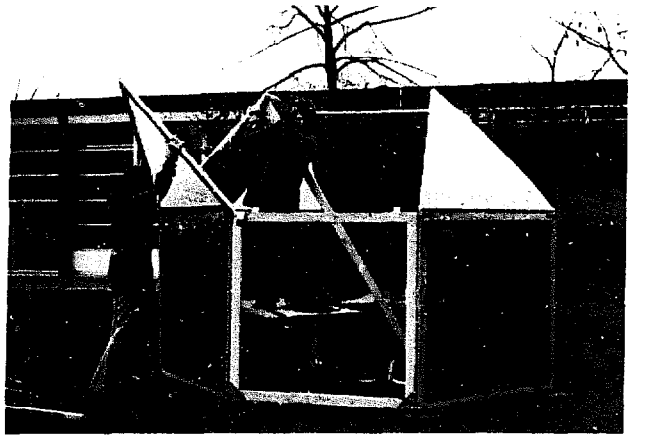

Abb. 4.78 Vorgefertigtes Paneelhaus
Fig. 4.78 Prefabricated panel house

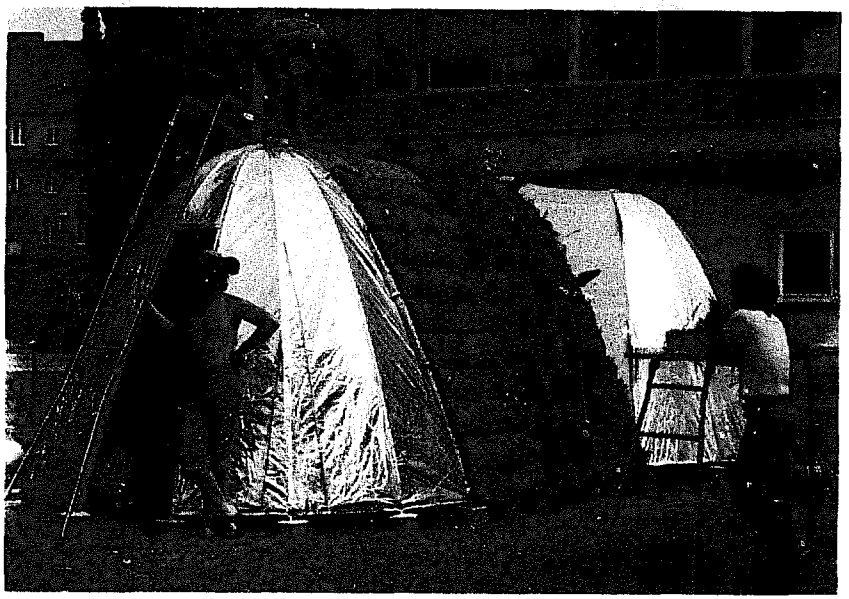

Abb. 4.79 "Bio-Bau"
Fig. 4.79 "Bio-building"

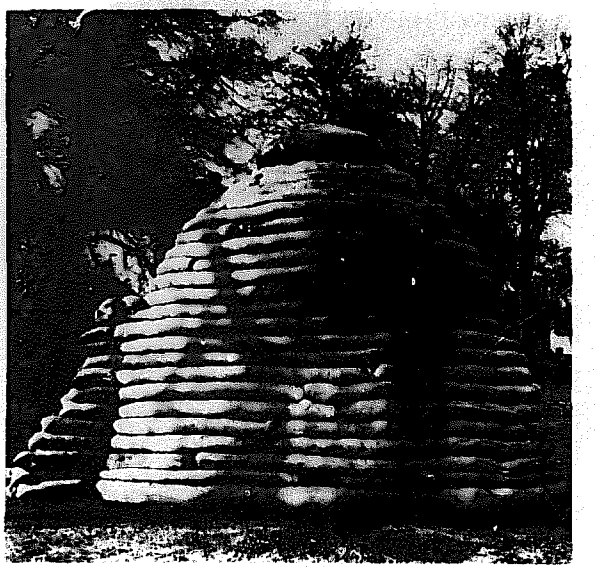

Abb. 4.80 Sandsack-Haus
Fig. 4.80 Sand-sack house

festigt wurden. Drei verschiedene Grundsubstrate und 17 verschiedene Pflanzengesellschaften wurden getestet. Das Ziel des Projekts war, einfache vorgefertigte Billigbauweisen unter Verwendung umwelt- und konstruktionsgerechter Materialien zu testen. Neue Pflanzsysteme werden von Zeit zu Zeit ausprobiert.

d. Sandsack-Haus.
Schlauchförmige Säcke, insgesamt 220 m lang, gefüllt mit Sand (für den unteren Teil des Gebäudes) und Blähton (für den oberen Teil) waren die hauptsächlich angewandten Materialien. Die Schläuche wurden ringförmig aufeinandergelegt, so daß der Querschnitt des Baukörpers der Form einer umgekehrten Kettenlinie entsprach, um Zugkräfte innerhalb des Wandquerschnitts auszuschalten. So wirkte jede Lage als Druckring.

e. Pappkarton-Haus.
Auf einer Unterkonstruktion aus halbkreisförmigen Holzbindern und Pfetten wurden wetterfeste Papptafeln befestigt. Die 8 mm dicke Pappe, die mit dem Secor-Verfahren im Vakuum imprägniert wurde, bestand aus zweilagiger Wellpappe mit drei Lagen 400 g-Karton. Bei der Befestigung auf der Unterkonstruktion wurden die einzelnen Pappen durch eine spezielle Falztechnik so miteinander verbunden, daß keine Abdichtungsmaßnahmen erforderlich waren und keine offenen Schnittkanten auftraten. Regen und Schnee weichten das Pappmaterial etwas auf und ließen es nur geringfügig auf-

d. Sand-sack house.
Tubular sacks, totalling 220 m, filled with sand (for lower part of building) and expanded clay (for upper portion) were the principal materials used. These were laid in circles on top of each other, forming a round building with an inverted chain-line (catinery) cross-section, to eliminate tensile forces. Thus each layer acted as a compression ring.

e. Paperboard house.
On a wooden vault-shaped framework impregnated corrugated paperboards were fixed. The 8 mm thick boards, vacuum impregnated by the Secor process, had two corrugations and three layers of 400 g carton. The attachment to the substructure incorporated special folding techniques to avoid open cut edges. Rain and snow caused only slight softening and swelling of covering material, but returned to normal after drying. Bitumen felts would have been more resistant but also more expensive. The paperboard house has a life-span of 3 to 5 years, depending on the climatic conditions to which it is exposed.

f. House from waste consumer packaging.
The walls and roof of the 19 m^2 house were made of sandwich elements, i.e. discarded cans or bottles, stuck together with bitumen, with corrugated paperboard (as used in previous structure) on either side. This system, which is only relevant for countries producing this kind of waste in abund-

quellen, es erhielt jedoch nach dem Trocknen wieder seinen Normalzustand. Bitumenpappe wäre widerstandsfähiger, aber auch viel teurer gewesen. Das Pappkarton-Haus hat eine Lebensdauer von 3 bis 5 Jahren, je nach den klimatischen Gegebenheiten.

f. Haus aus Abfall-Verpackungsmaterial.
Die Wände und das Dach des 19 m^2 großen Versuchsbaus bestanden aus Sandwich-Elementen, d.h. Einwegdosen und -flaschen, die mit Bitumen verklebt und beidseitig mit wetterfester Wellpappe (wie bei der vorhergehenden Konstruktion) versehen wurden. Dieses System, welches nur in denjenigen Ländern sinnvoll ist, die derartige Abfallprodukte in Mengen zur Verfügung haben, kann so extrem billige, ziemlich dauerhafte Konstruktionen ermöglichen und gleichzeitig zur Lösung eines gravierenden Abfallproblems beitragen.

g. Grasdach.
Ein Dachtyp, der traditionell sowohl in heißen als auch in kalten Regionen verwendet wird, wurde ebenfalls getestet. Das Dach besteht aus einer herkömmlichen Rundholzunterkonstruktion und wasserdichtem, PVC-beschichtetem Polyestergewebe, auf welches 8 - 10 cm dicke Grassoden gelegt wurden. Das Dach wurde so belassen, daß sich natürlicher Pflanzenwuchs entsprechend seinem eigenen ökologischen System entwickeln kann. Die Vorteile

Abb. 4.81 Pappkarton-Haus
Fig. 4.81 Paperboard house

ance, can thus provide extremely cheap, reasonably durable constructions and also help to solve a major disposal problem.

g. Grass roof.
A roof type traditionally used in both hot and cold regions was also tested. The roof substructure consists of a conventional roundwood framework and impermeable PVC-coated fabric, on which 8 - 10 cm thick sod pieces were laid. The roof was left to develop plant cultures naturally, according to its own ecological system. The advantages of grass roofs are:
- regulating effect on temperature fluctuations; temperatures of corrugated iron roofs can range periodically about 100°C, while grass roofs rarely exceed 30°C; during daytime cooling effect due to evaporation and consumption of heat by photosynthesis and warming effect by respiration process;
- heat retaining capacities of soil and water content, as well as heat insulation through air spaces in soil and between grass blades, thus suitable for almost any climate;
- no special maintenance.

Source: EX-BAU INFOS (Nos. 1 - 11) (1975 - 79) published by Forschungslabor für Experimentelles Bauen, Gesamthochschule Kassel, Federal Republic of Germany

Abb. 4.82 Haus aus Abfall-Verpackungsmaterial
Fig. 4.82 House from waste consumer packaging

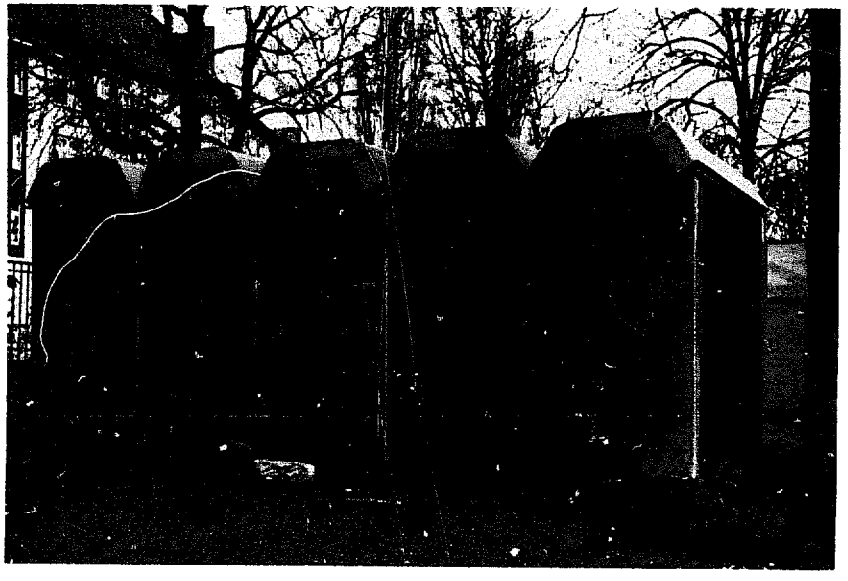

der Grasdächer sind:
- Ausgleichende Wirkung bei Temperaturschwankungen; die Temperaturen von Wellblechdächern können zeitweise ca. 100°C betragen, während Grasdächer sich kaum über 30°C erwärmen; während der Tageszeit Kühlungseffekt aufgrund von Verdunstung und Wärmeverbrauch durch Photosynthese, und während der Nacht Wärmeeffekt durch den Atmungsprozeß.
- Wärmespeicherfähigkeit der Erde und des darin enthaltenen Wassers sowie Wärmeisolierung durch Lufträume in der Erde und zwischen Grashalmen, und somit für fast jedes Klima geeignet.
- Keine besondere Wartung.

Quelle: EX-BAU INFOS (Nr. 1 - 11) (1975 - 79), herausgegeben vom Forschungslabor für Experimentelles Bauen, Gesamthochschule Kassel, Bundesrepublik Deutschland.

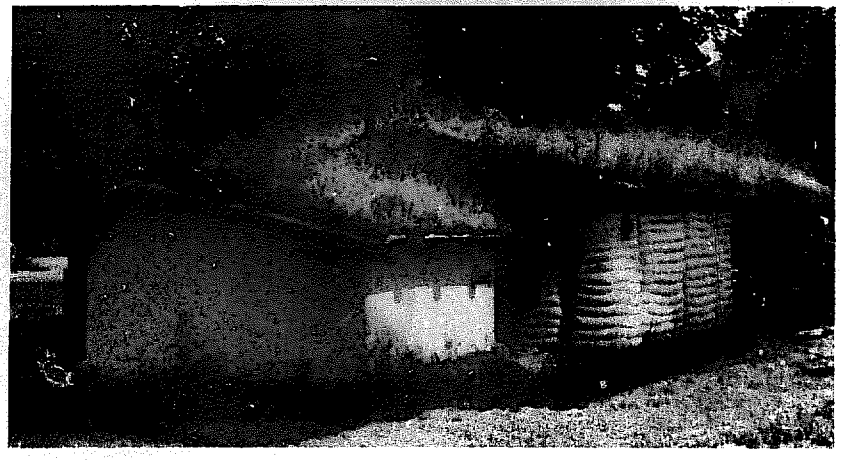

Abb. 4.83 Grasdach
Fig. 4.83 Grass roof

4.2.12 Schaumstoff-Iglus

Das System, welches vom deutschen Chemiewerk Bayer Leverkusen entwickelt wurde, bestand im Prinzip aus dem Aufblasen einer Ballonschalung, auf welche fester Moltoprenschaum aufgespritzt wurde, der 30 Minuten härtete; danach wurde der Ballon abgeblasen. Türen und Fenster konnten mit einer Säge leicht ausgeschnitten werden. Die ganze Behausung konnte von 10 - 15 Männern getragen werden.

Diese schnell-errichteten Billigbauten waren erdbebensicher und daher in erster Linie als Notbehausungen nach Erdbeben in der Türkei, in Peru und Nicaragua in den frühen 70er Jahren verwendet. Sie werden jedoch aus folgenden Gründen nicht mehr gebaut:

- Lüftung war schlecht, die Kuppeln waren im Sommer unerträglich heiß;
- der halbkugelförmige Baukörper verursachte Möblierungsprobleme und die Akustik war äußerst nachteilig;
- beschädigter Schaumstoff konnte nicht repariert werden, zerbrochene Stücke konnte man nicht wiederverwenden; im Sommer verursachte er üble Gerüche, und wenn die Schutzschicht abgewaschen war, nisteten Insekten darin.

Quellen: Informationsblatt von Bayer Leverkusen, 1971
Shelter II, Shelter Publications, Bolinas, California 1978

4.2.12 Foam Igloos

The system developed by the German chemical firm Bayer Leverkusen, basically consisted of blowing up a balloon-mould onto which rigid moltoprene foam was sprayed, allowing it to harden for 30 minutes, after which the balloon was deflated. Doors and windows were easily cut out by means of a saw. The whole dwelling could be carried by 10 - 15 men.

These quickly erected low-cost structures were earthquake resistant and hence used primarily as emergency housing units after earthquakes in Turkey, Peru and Nicaragua in the early 1970s. However, they are not being built any more for the following reasons:

- ventilation was poor, the domes were insufferably hot in summer;
- the hemispherical shape created difficulties in furnishing, and interior acoustics proved extremely disadvantageous;
- damaged foam could not be repaired, broken pieces were not reusable; in summer it exuded bad smells and, when the protective coat was washed off, harboured insects.

Sources: Information pamphlet of Bayer Leverkusen, 1971
Shelter II, Shelter Publications, Bolinas, California 1978

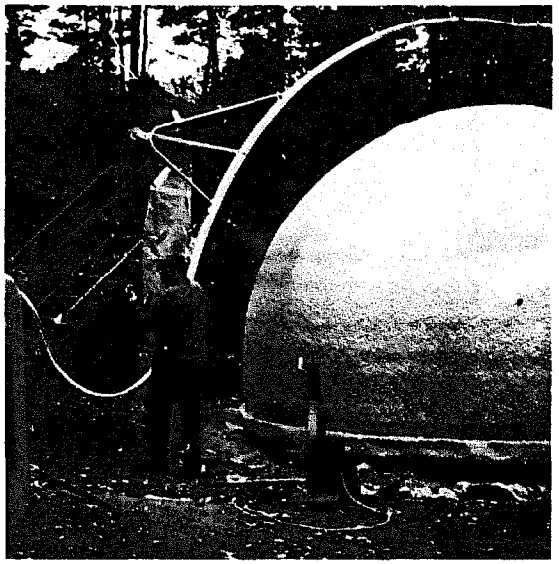

Abb. 4.84 a Spritzvorgang
Fig. 4.84 a Spraying of foam igloos

Schaumstoff-Iglus, Bundesrepublik Deutschland
Foam Igloos, Germany

Abb. 4.84 b Iglu-Siedlung für Erdbebenflüchtlinge in Peru
Fig. 4.84 b Igloo settlement for earthquake refugees in Peru

4.2.13 Membran-Konstruktionen, Bundesrepublik Deutschland

In einer Studie über Dachdeckungssysteme dürfen Membran-Konstruktionen nicht fehlen. Es sind leichtgewichtige Zelt- oder pneumatische Konstruktionen, die für Räume von fast unbegrenzten Formen und Größen geeignet sind. Sie basieren auf den Zugbeanspruchungs-Eigenschaften der verwendeten Membranen, Kabel und Netze. Konstruktionen dieser Art werden primär mit dem Namen Frei Otto in Verbindung gebracht, der das Institut für leichte Flächentragwerke an der Technischen Universität Stuttgart gründete, und der seit 1955 mit Forschungs- und Entwicklungsarbeiten Pionierleistungen vollbrachte. Die meisten seiner Entwicklungen sind Großprojekte; bis jetzt wurden sie im Niedrigkosten-Wohnungsbau nicht angewendet.
Sein früherer Mitarbeiter, Gernot Minke, hat jedoch Forschungsarbeiten über aufblasbare Konstruktionen durchgeführt und ihre Verwendbarkeit im Billigbau studiert, kam jedoch zu dem Schluß, daß deren Anwendung im Wohnungsbau sehr begrenzt ist. Da dies ein relativ neues Gebiet ist, ist es trotzdem wahrscheinlich, daß Lösungen für den Billigwohnungsbau — sogar für Entwicklungsländer in tropischen Gebieten — zu einem späteren Zeitpunkt aus der weiteren Forschung über leichte Flächentragwerke resultieren können.

Quelle: "The Work of Frei Otto and his Teams 1955 - 1976" IL 17
Institut für leichte Flächentragwerke, Universität Stuttgart.
"Light-Weight Structures for Self-Help, Low-Cost Housing Systems"
von Gernot Minke. Vortrag beim 3. Internationalen Symposium über Low-Cost Housing-Probleme 1974 in Montreal, Canada.

4.2.13 Membrane Structures, Germany

In a study on roofing systems, membrane structures cannot be omitted. These are lightweight tent or pneumatic structures, suitable for enclosing spaces of almost unlimited shapes and sizes. They are based on the tensile properties of the membranes, cables and nets used. Structures of this nature are primarily associated with the name of Frei Otto, who founded the Institute for Lightweight Structures at the Technical University Stuttgart, and who has been involved in pioneering research and development since 1955. Most of his developments are large-scale projects, there have been no applications in low-cost housing schemes so far.

His former colleague, Gernot Minke, has however, carried out experimental work on pneumatic structures and studied their appropriateness for low-cost housing, but came to the conclusion that they have very limited application for housing. Nevertheless, since this is a relatively new field, it is likely that solutions for low-cost housing — even for developing countries in tropical areas — may at a later date be derived from further research on tensile structures.

Source: "The Work of Frei Otto and his Teams 1955 - 1976" IL 17
Institut für leichte Flächentragwerke, Universität Stuttgart.
"Light-weight Structures for Self-Help, Low-Cost Housing Systems"
by Gernot Minke. Paper delivered at the 3rd International Symposium on Lower-Cost Housing Problems, 1974 in Montreal, Canada.

Membran-Konstruktionen, Bundesrepublik Deutschland
Membrane Structures, Germany

Abb. 4.85 (a, b, c, d) Einige zugbeanspruchte Dachformen

Fig. 4.85 (a, b, c, d) Some tensile roof forms

a.

b.

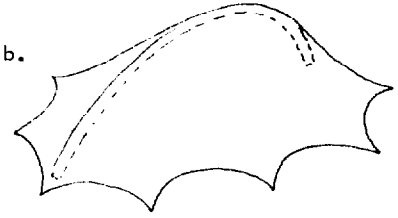

c.

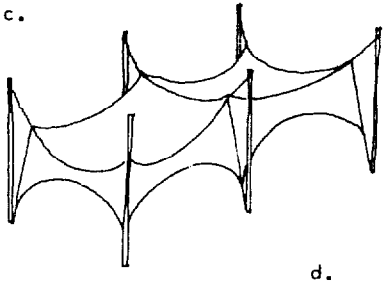

d.

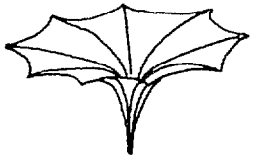

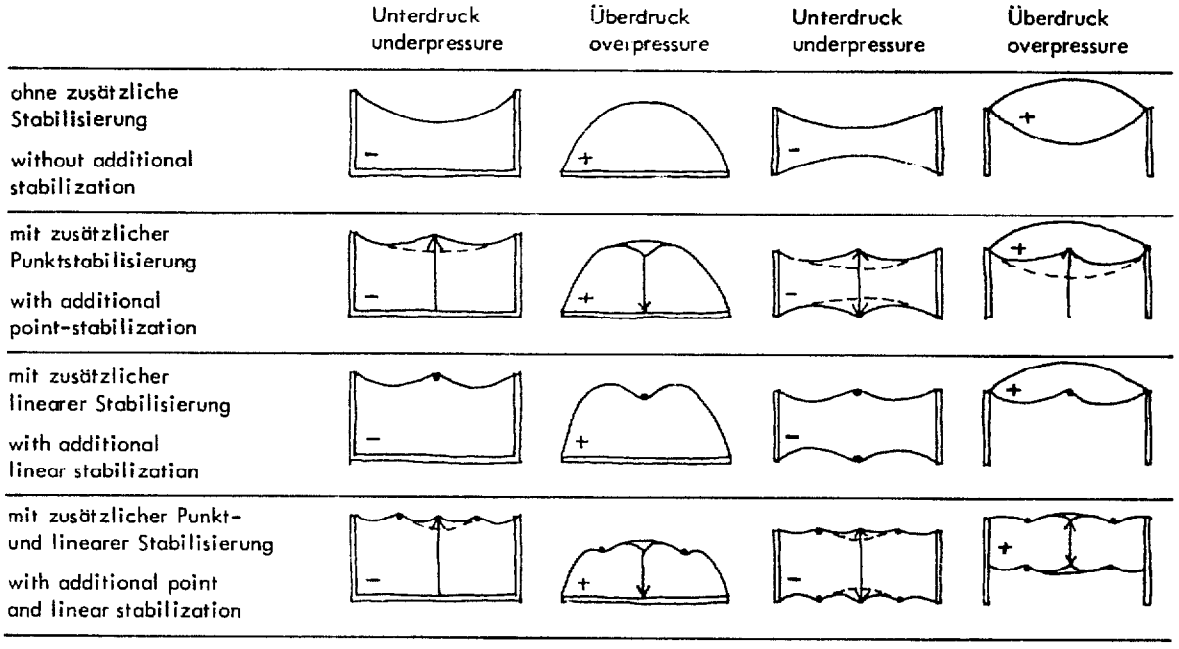

Abb. 4.86 Pneumatische Systeme mit Niederdruck (aus dem Vortrag von G. Minke beim "Low-Cost Housing"-Symposium in Montreal 1974)

Fig. 4.86 Low pressure pneumatic systems (taken from paper delivered by G. Minke at the low-cost housing symposium in Montreal 1974)

Faltwerk-Bauten, Großbritannien
Folded surface structure, United Kingdom

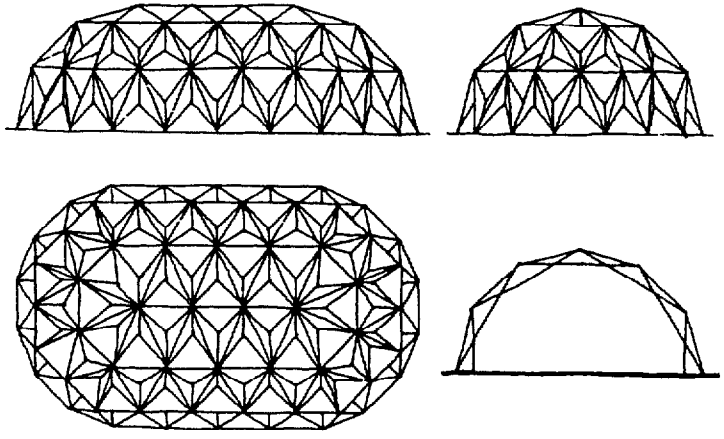

Abb. 4.87 Gewölbe mit zwei Halbkuppeln (V. Sedlak)

Fig. 4.87 Vault closed with two semi-domes (V. Sedlak)

4.2.14 Faltwerk-Bauten, Großbritannien

Forschung und Entwicklung dieser kostengünstigen Gebäudehüllen wurde von Vinzenz Sedlak an der Universität Surrey, Guildford, durchgeführt. Faltsysteme können eine große Vielfalt von komplexen selbsttragenden, lastentragenden Konstruktionen erzeugen, nur durch Zusammensetzung einer kleinen Anzahl von verschiedenen flachen, dreieckigen Elementen mit geringem Elastizitätsmodul. Sie sind für die Vorfertigung bestens geeignet und können extrem biegungs- und torsionssteif sein, weshalb sie erdbebensicher sind (Notbehausungen!). Ihr Verhalten bei Stürmen ist nicht bekannt. Sie können äußerst leichtgewichtig sein, zusammenfaltbar zur leichten Handhabung bei Transport und Aufbau, und sind zum "do-it-yourself"-Bau durch ungelernte Benutzer geeignet.

Quellen: "Paper Shelters", Artikel in Architectural Design (Dez. 1973);
"Folded Structural Forms — Their Geometry and Architectural Applications", Vortrag beim 3. Internationalen Symposium über Lower Cost Housing Problems 1974 in Montreal, Canada, beide von Vinzenz Sedlak.

4.2.14 Folded Surface Structures, United Kingdom

Research and development of these lower cost building enclosures was conducted by Vinzenz Sedlak at the University of Surrey, Guildford. Folded systems can create a large variety of complex self-supporting, load-bearing structures, only by assembling a small number of different plane triangular surface elements having low modulus of elasticity. They are ideally suited for prefabrication and can possess considerable stiffness and torsion resistance, making them safe in earthquakes (emergency housing!). Their performance in strong winds is not known. They can be extremely lightweight, collapsible for easy handling during transport and erection, allowing "do-it-yourself" construction by unskilled users.

Sources: "Paper Shelters", article in Architectural Design (December 1973);
"Folded Structural Forms — Their Geometry and Architectural Applications", paper delivered at the 3rd International Symposium on Lower Cost Housing Problems, 1974 in Montreal, Canada, both by Vinzenz Sedlak.

4.2.15 Abfalldächer, USA

Auf der Suche nach alternativen Lebensformen als Antwort auf die gegenwärtige Konsumgesellschaft haben Gruppen junger Leute in den letzten Jahren verschiedene Typen von "do-it-yourself"-Behausungen entwickelt, wovon viele von Abfallmaterialien Gebrauch machten. Drei Beispiele hierfür sind:

Drop City
Bei diesen Kuppelkonstruktionen, in willkürlicher Anordnung — wie Tropfen (Drops) — auf einer Ziegenweide in Süd-Colorado aufgebaut, wurden Abfallmaterialien von den verlassenen Häusern in der Umgebung benützt. Die Außenhaut der abgebildeten Kuppeln besteht aus Autodächern, die mit Äxten auf die benötigten Formen und Größen zugeschnitten wurden. Die Bleche, die billig und stark sind und ausgezeichneten Oberflächenschutz bieten, wurden mit Nägeln, Schrauben oder durch Zusammenschweißen einzelner Stücke an den Holzrahmen befestigt.

4.2.15 Garbage Roofing, U.S.A.

Groups of young people in search of alternative life-styles as an answer to present day consumer societies, have in recent years developed various types of "do-it-yourself" dwellings, many of which make use of waste materials. Three examples are:

Abfalldächer, USA
Garbage Roofing, USA
Abb. / Fig. 4.88 — 4.90
aus / from : Wolfgang M. Ebert, "Home Sweet Dome" (1978)

Abb. 4.88 Drop City
Fig. 4.88 Drop City

Einwegdosen-Haus

Aus der Tatsache heraus, daß die Menge von weggeworfenen Büchsen und Flaschen die Produktion von Ziegel- und Betonmaterialien um das Sechsfache übersteigt, werden Versuche unternommen, sie zum Bauen zu verwenden. Das abgebildete runde Haus ist ein Beispiel, das aus ungefähr 75.000 Einwegdosen hergestellt wurde. Andere benützen leere Flaschen, die auch zum Teil die Fenster ersetzen. In einigen Fällen werden die Büchsen mit Wasser gefüllt, so daß sie während des Tages Sonnenwärme speichern und diese Wärme bei Nacht abgeben.

Freie Form

Auf einem unfruchtbaren Stück Land in Neu-Mexiko errichtet, wurde diese zeltartige Konstruktion aus Bauschutt einer nahegelegenen Geisterstadt gebaut. Vorher wurden keine Pläne gemacht, die Form entwickelte sich aus den verwendeten Materialien. Aber ironischerweise wurde das Haus verlassen, nachdem es fertiggestellt war, und ist nun ein Abfallhaufen in der Wüste.

Quellen: "Home Sweet Dome" von Wolfgang Ebert, Verlag Dieter Fricke GmbH., Frankfurt/Main (1978)
"Shelter and Society", herausgegeben von Paul Oliver, Barrie + Rockliff: The Cresset Press, London (1969)
"Shelter", Shelter Publications, Bolinas, California (1973)

Drop City

These dome-structures, built at random — like drops — on a goat pasture in southern Colorado, made use of waste materials from abandoned buildings in the area. The domes illustrated were covered with car tops, cut to required shapes and sizes with axes. The sheets, which are cheap, strong and have excellent surface protection, were attached to the wooden frame by nails, screws or even by welding pieces together.

Tin Can House

Arising from the fact that the volume of discarded cans and bottles exceeds the production of brick and concrete materials by six times, attempts are made to use them for building. The illustrated round house is an example made of about 75.000 cans. Others use empty bottles, which also partially substitute windows. In some cases, cans are filled with water, so that they accumulate heat by solar radiation during the day and thus provide heating during the night.

Free Form

Erected on a barren piece of land in New Mexico, this tent-like structure was built of waste building materials from a nearby ghost-town. No plans were made beforehand, the form developed out of the materials used. But ironically, this building itself was abandoned after it was finished and is now a heap of waste in the desert.

Sources: "Home Sweet Dome" by Wolfgang Ebert, Verlag Dieter Fricke GmbH, Frankfurt/Main (1978)
"Shelter and Society" edited by Paul Oliver, Barrie + Rockliff: The Cresset Press, London (1969)
"Shelter", Shelter Publications, Bolinas, California (1973)

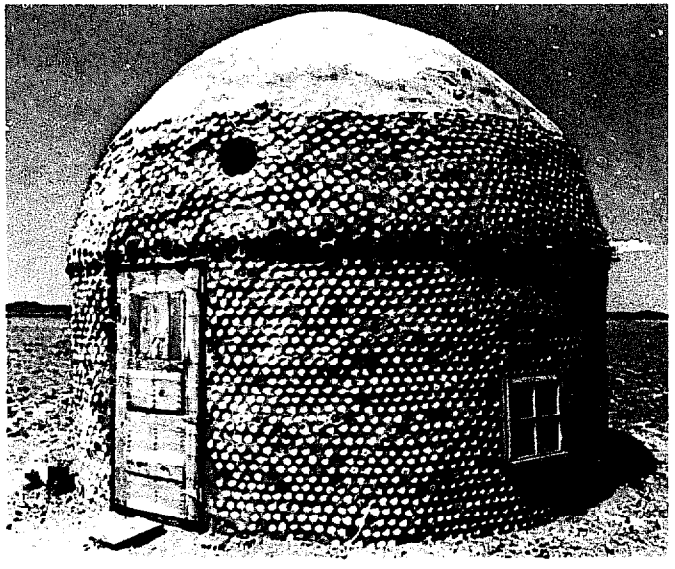

Abb. 4.89 Einwegdosen-Haus
Fig. 4.89 Tin-can house

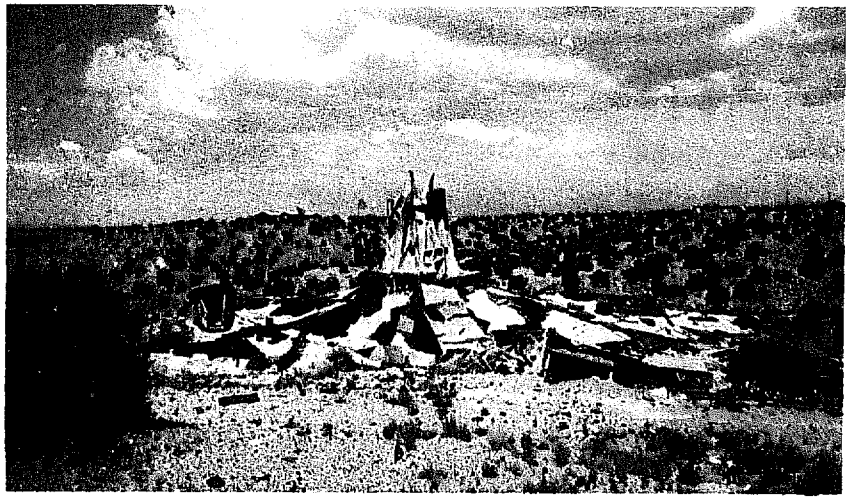

Abb. 4.90 Freie Form
Fig. 4.90 Free form

5. DÄCHER IN ZENTRALAMERIKA +

5.1 Allgemeines

5.1.1 Topographie, Klima und Naturereignisse

Geographisch erstreckt sich der zentralamerikanische Isthmus vom Tehuantepec Isthmus in Mexiko bis zum Atrato-Tiefland in Kolumbien; für die vorliegende Studie wurden jedoch nur die fünf Länder in Betracht gezogen, welche die Zentralamerikanische Wirtschaftsgemeinschaft bilden, nämlich — von Norden nach Süden — Guatemala, El Salvador, Honduras, Nicaragua und Costa Rica. Diese Länder umfassen ein Gebiet von 440 718 km^2. Nachstehend die Größen der einzelnen Länder:

	Gebiet (km^2)
Guatemala	108 889
El Salvador	21 041
Honduras	112 088
Nicaragua	148 000
Costa Rica	50 700

Topographie

Die Topographie der zentralamerikanischen Region ist sehr unterschiedlich; man kann sie jedoch in zwei Haupt-Topographiegebiete unterteilen:

1. Das zentrale Hochland einschließlich nördliche und südliche Gebirgsregionen, die Vulkankette am Pazifik und die damit verbundenen vulkanischen Hügel und Hochebenen, und
2. das Tiefland mit dem Petén-Gebiet von Nord-Guatemala und die pazifischen und karibischen Küstenebenen.

- Hochland.
  Ein beachtlicher Teil von Guatemala, Honduras und Nordwest-Nicaragua wird von der nördlichen zentralamerikanischen Gebirgskette mit Erhebungen über 1000 - 4000 m über NN bedeckt. Die südliche Gebirgskette von Zentral-Costa Rica durchzieht dieses Land von Norden nach Süden und reicht bis in den westlichen Teil Panamas.
  Die Vulkankette verläuft entlang einer geologischen Verwerfung, die sich fast parallel zur Pazifikküste erstreckt. Diese Kette entsteht an der Grenze zwischen Mexiko und Guatemala (Tacana Vulkan) und erstreckt sich in südöstlicher Richtung durch Guatemala bis zum Chingo-Vulkan an der Grenze zu El Salvador. Sie durchzieht El Salvador in ost-westlicher Richtung und verläuft dann südöstlich nach Nicaragua bis in den Norden von Costa Rica.

+ Die Bevölkerungszahlen, Kosten und anderen sich zeitlich ändernden Daten in diesem Kapitel, sowie die Ausdrücke "gegenwärtig" oder "in diesem Jahr" beziehen sich auf das Jahr 1979.

5. ROOFING IN CENTRAL AMERICA +

5.1 General Considerations

5.1.1 Topography, Climate and Natural Hazards

Geographically, the Central American Isthmus extends from the Tehuantepec Isthmus in Mexico to the Atrato lowlands in Columbia; however, for the purposes of the present study, only the five nations which make up the Central American Common Market have been considered. These include, from north to south, Guatemala, El Salvador, Honduras, Nicaragua and Costa Rica. These countries represent a total land area of 440 718 square kilometers and the relative size of each is as follows:

	Area (km^2)
Guatemala	108 889
El Salvador	21 041
Honduras	112 088
Nicaragua	148 000
Costa Rica	50 700

Topography

The topography of the Central American region is quite variable, but can be considered to consist of two principal topographical divisions:

1. the Central highlands including the northern and southern mountain ranges, the Pacific chain of volcanoes and the volcanic hills and plateaus associated with the chain; and
2. the lowlands which include the Petén area of Northern Guatemala and the Pacific and Caribbean coastal plains.

- Highlands.
  A considerable portion of Guatemala, Honduras and northwest Nicaragua is covered by the northern Central American mountain range with elevations above sea level of 1000 to 4000 meters. A secondary range of lesser elevations extends from this system into El Salvador. The southern mountain range located in Central Costa Rica crosses this country from north to south and extends into the western portion of Panama.
  The chain of volcanoes follows a geological fault which runs approximately parallel to the Pacific coast. This chain originates on the border between Mexico and Guatemala (Tacana Volcano) and extends in a southeast direction through Guatemala to the Chingo Volcano located on the border with El Salvador. It crosses El Salvador in an east-west direction and then turns southeast in Nicaragua extending into northern Costa Rica.

+ The population figures, prices and other data given in this section which change with time, as well as the terms "present" or "in this year" refer to the year 1979.

Die früheren Vulkantätigkeiten in dieser Region bildeten viele vulkanische Hügel und Hochebenen sowie weite Täler mit vulkanischem Gestein. Einige wichtigere Bevölkerungszentren liegen in diesen Tälern, z.B. Quetzaltenango, Guatemala; Santa Ana, El Salvador und San José, Costa Rica.

- Tiefland.
  Tiefebenen erstrecken sich entlang der gesamten pazifischen und karibischen Küste von Zentralamerika und sind im allgemeinen nicht höher als 200 m mit entweder flacher oder leicht ansteigender Topographie. Diese Tiefebenen entstanden in einigen Gebieten durch angeschwemmte Ablagen und in anderen Gebieten durch Erosion älterer Felsbildungen.
  Das nördliche Petén-Gebiet von Guatemala ist ein weites, flaches, stark bewaldetes Tiefland, welches fast 50% des gesamten Landes ausmacht, mit jedoch nur einem Prozent seiner Einwohner. Die niedrige Bevölkerungszahl liegt zum großen Teil an dem landwirtschaftlich wenig ertragreichen Gebiet mit einer dünnen Schicht Mutterboden auf porösem Kalkuntergrund.

Vegetation

- Karibische Küstenebene.
  Die dünn besiedelte karibische Küstenebene ist das Gebiet, welches gegenwärtig die weitest ausgedehnten Wälder von Zentralamerika hat, besonders entlang der Küste von Nicaragua und im Petén-Gebiet von Guatemala, wo man die Vegetation im allgemeinen als tropischen Regenwald einordnen kann. Diese Wälder bestehen aus großen, breitblättrigen Laubbäumen mit kleineren Bäumen, Büschen und Schattengewächsen als Unterholz.
  Entlang der Karibikküste besteht die landwirtschaftliche Aktivität hauptsächlich im Anbau von Bananen in Costa Rica, Honduras und, in geringerem Umfang, in Guatemala. In Honduras findet man auch Plantagen mit afrikanischen Palmen, die zur Speiseölgewinnung kultiviert werden. Kokosnußpalmen wachsen überall in diesem Gebiet, werden jedoch kaum zu kommerziellen Zwecken kultiviert.

- Zentrales Hochland.
  Pinien, Zypressen und verschiedene Arten von Laubbäumen bilden die natürlichen Wälder des zentralamerikanischen Hochlands. Die größten Pinienwälder befinden sich zur Zeit in Honduras, wo Pinienholz ein wichtiger Exportartikel ist. Ausnahmen gibt es in kleinen Gebieten von Nicaragua und Honduras und in einem Gebiet von etwa 300 km^2 in Zentral-Guatemala, wo wegen der geringen Niederschläge eine wüstenähnliche Vegetation von Zwergbäumen, Kakteen und anderen Dürre-unempfindlichen Pflanzen entstanden ist.
  Es ist der großen Bevölkerungsdichte in den Hochland-Gebieten zuzuschreiben, daß ein großer Teil des natürlichen Waldes vernichtet und das Land für landwirtschaftliche Zwecke genutzt wurde. Es ist dasjenige Gebiet, wo man die meisten Kleinfarmen (milpas) findet, welche Korn, Bohnen und Gemüse pflanzen, was oft nur als Existenzminimum reicht.
  Kaffeeplantagen bilden den Hauptanteil der landwirtschaftlichen Produktion in den Hochlandgebieten. Diese Plantagen haben waldähnlichen Charakter, da Kaffee gewöhnlich im Schatten von Laubbäumen wächst. Andere für den Verkauf be-

The past volcanic activity in this region has resulted in the formation of many volcanic hills and plateaus as well as wide valleys filled with volcanic materials. Some of the more important population centers are located in these valleys, for example: Quetzaltenango, Guatemala; Santa Ana, El Salvador and San José, Costa Rica.

- Lowlands.
  Lowland plains extend along the entire Pacific and Caribbean coastlines of Central America and are generally of elevations less than 200 m with either flat or gently sloping topography. These lowlands were formed in some areas by alluvial deposits, and in others, by erosion of the older rock formations.
  The northern Petén area of Guatemala is an extensive flat heavily forested lowland region which accounts for almost 50 per cent of the nation's land area, but only one per cent of its inhabitants. The low population figure is due in great part to the poor agricultural potential of this area, which possesses a very thin layer of topsoil covering a porous limestone base.

Vegetation

- Caribbean coastal plain.
  The sparcely populated coastal plain is the region which presently contains the largest forest extensions in Central America, particularly along the Nicaraguan coast and in the Petén area of Guatemala where the vegetation can be generally classified as a tropical rain forest. These forests consist of tall broad-leafed deciduous trees with an undergrowth of smaller trees, bushes and shade-growing plants.
  The major agricultural activity along the Caribbean coast is the cultivation of bananas in Costa Rica, Honduras and, to a lesser extent, Guatemala. Plantations of African palm trees grown as a source of edible oil, also are found in Honduras. Coconut palms grow throughout the region, but rarely are cultivated for commercial purposes.

- Central highlands.
  Pine, cypress and various species of deciduous trees make up the natural forests of the Central American highlands. The largest pine forests today are located in Honduras, where pine lumber is an important export product. Exceptions are formed in small areas in Nicaragua and Honduras and in an area of about 300 square kilometers in Central Guatemala, where conditions of low rainfall have resulted in a desertlike vegetation of dwarf trees, cactus and other drought-resistant plants.
  Due to the high population density of the highland regions, much of the natural forest has disappeared and the land converted to agricultural use. This is the region where most mini-farms (milpas) are found, producing corn, beans and vegetables, often at a subsistence level.
  Coffee plantations represent the most important large scale agricultural activity in the highlands. These plantations exhibit some forestlike characteristics since coffee is grown in shade usually provided by deciduous trees. Other commercial highland crops include wheat, sorghum, peanuts, highland rice and a great va-

stimmte Hochland-Produkte sind Weizen, Sorghum, Erdnüsse, Hochland-Reis und eine Vielfalt von Früchten und Gemüse.

- Pazifische Küstenebene.
  Obwohl das Klima der pazifischen Küstenebene demjenigen der karibischen Küste ähnelt, hat diese Region eine viel größere Bevölkerungsdichte und Vielfalt, was die landwirtschaftlichen Möglichkeiten betrifft, aufgrund ihres fruchtbaren Bodens und der kürzeren Entfernung zu den wichtigsten Bevölkerungszentren des Hochlands. In diesem Gebiet gibt es noch einige Wälder, aber man kann sagen, daß es praktisch fast ausschließlich aus Ackerland besteht.
  Hauptsächlich wird das Land für Viehzucht und die Herstellung von Baumwolle, Zuckerrohr und Tiefland-Kaffee genützt. Die afrikanische Palme wird in großem Ausmaß an der Pazifikküste von Costa Rica gepflanzt; Gummiplantagen gibt es in Guatemala. Reis, Getreide, Früchte und Gemüse werden ebenfalls in der Küstenebene erzeugt.

riety of fruits and vegetables.

- Pacific coastal plain.
  Although the climate of the Pacific coastal plain is similar to that of the Caribbean coast, this region has a much greater population and variety of agricultural activities due to its more fertile soil and greater proximity to the major highland population centres. Few forests still exist in the region, and for practical purposes it can be considered to consist almost exclusively of farmland. The major land use is for cattle raising and the production of cotton, sugar cane and lowland coffee. The African palm is cultivated extensively on the Pacific coast of Costa Rica, and rubber plantations exist in Guatemala. Rice, grains, fruits and vegetables also are produced on the coastal plain.

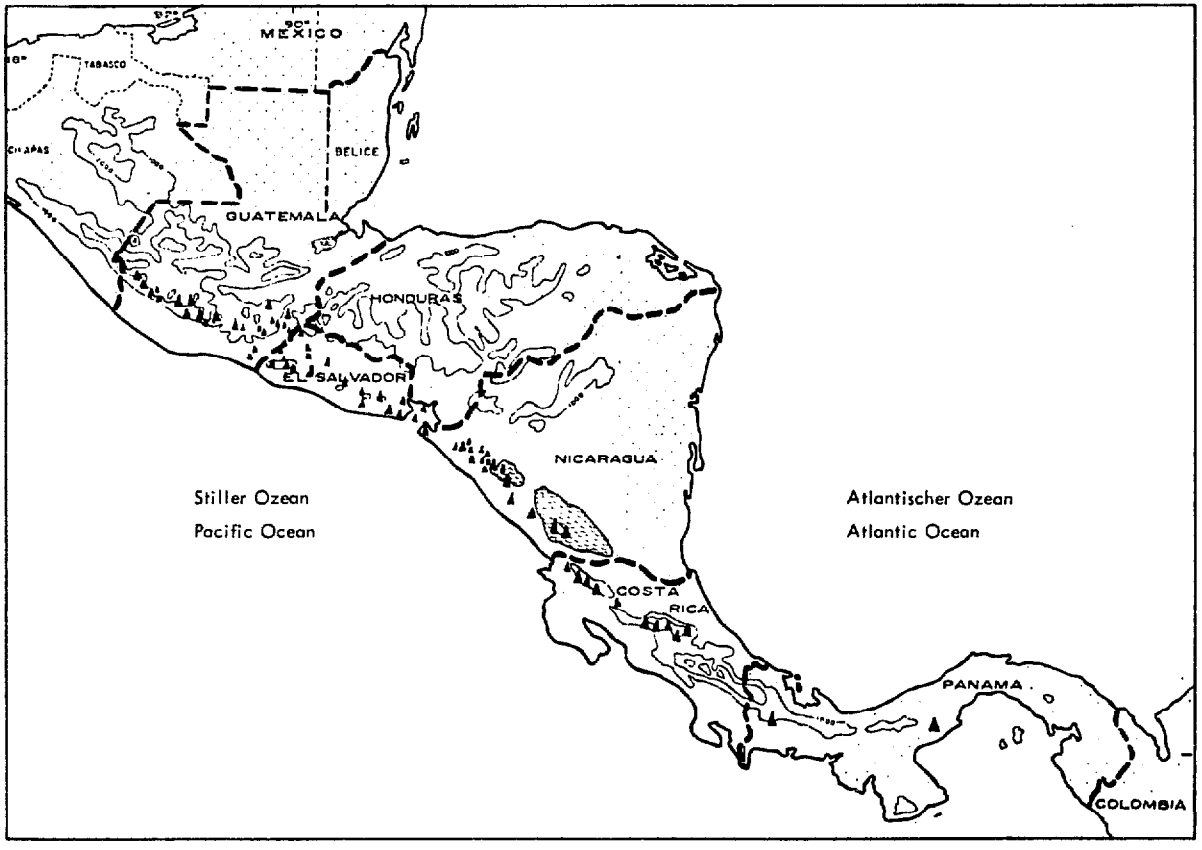

Abb. 5.1 ZENTRALAMERIKA : Topographische Karte mit pazifischer Vulkankette

Fig. 5.1 CENTRAL AMERICA : Topographical map showing Pacific chain of volcanoes

Klima

Das Klima der gesamten zentralamerikanischen Region kann im allgemeinen als tropisch bezeichnet werden, mit ziemlich exakt zu bestimmenden Regen- und Trockenzeiten.

Örtlich wird das Klima in drei Kategorien aufgeteilt: heiß, gemäßigt oder kalt, hauptsächlich je nach Höhenlage. Das "heiße" Klima mit Durchschnittstemperaturen zwischen 23 und 32°C herrscht im Tiefland vor bis zu einer Höhe von ca. 800 - 900 m, es umfaßt beide Küstenebenen, Süd-Mittel-Nicaragua und das Petén-Gebiet von Guatemala. Das gemäßigte Klima (Durchschnittstemperatur 17 - 23°C) findet man gewöhnlich bei 900 - 1900 m Höhe, während das "kalte" Klima mit Temperaturen unter 17°C in darüberliegenden Höhenlagen anzutreffen ist. Die niedrigste Temperatur in Zentralamerika (5°C) wurde am Gipfel des Tajumulco-Vulkans in Guatemala gemessen.

Climate

The climate of the entire Central American region generally can be considered as tropical, with fairly clearly defined rainy and dry seasons.

Locally, climate is classified in three categories: hot, temperate or cold, depending principally upon land elevation. The "hot" climate with average temperatures between 23 and 32°C prevails in the lowlands up to elevations of about 800 - 900 m, including both coastal plains, south-central Nicaragua and the Petén area of Guatemala. The temperate climate (average temperature of 17 to 23°C) is usually found at elevations of 900 to 1900 m; while "cold" climates with temperatures below 17°C occur at still higher elevations. The lowest temperature in Central America (5°C) was measured at the summit of the Tajumulco Volcano in Guatemala.

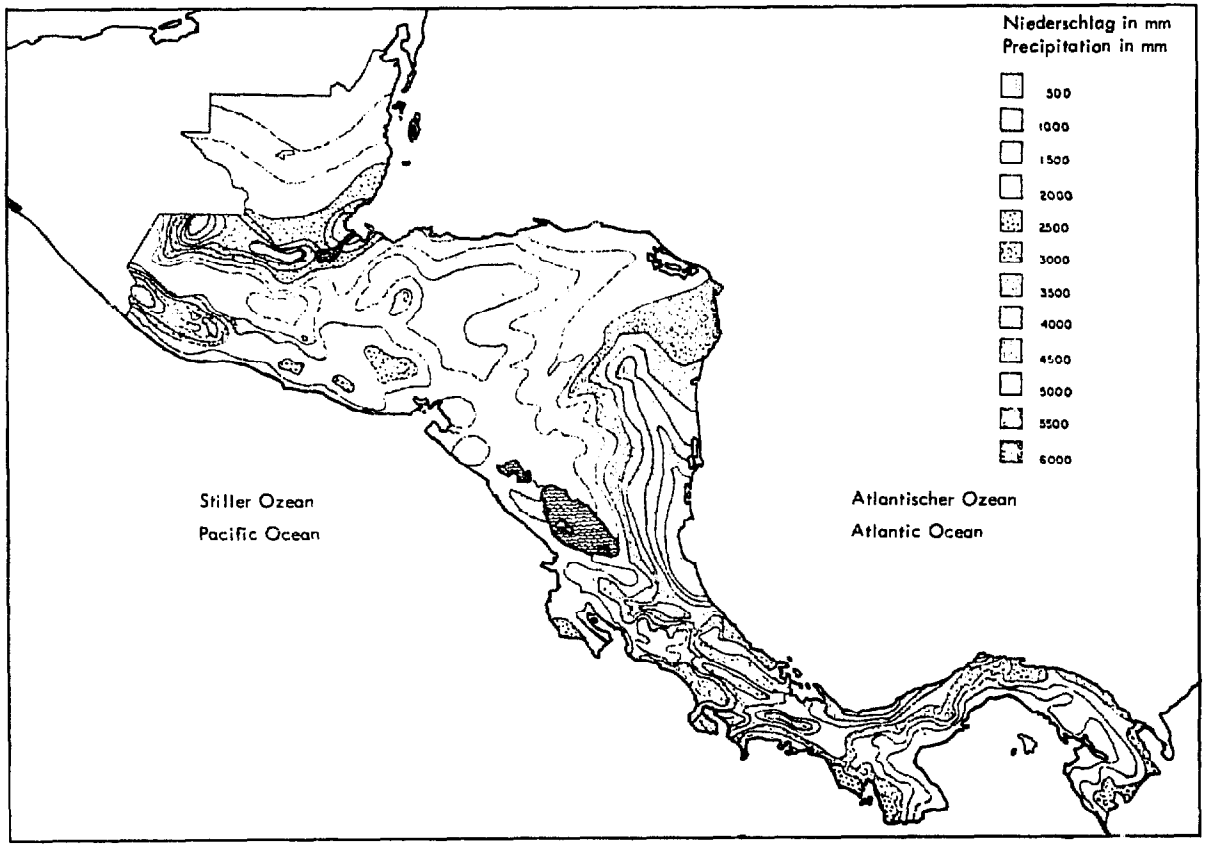

Abb. 5.2 ZENTRALAMERIKA : Jahresniederschlagsmenge

Fig. 5.2 CENTRAL AMERICA : Annual precipitation

Ziemlich strenge Nordwinde sind in den Hochlandregionen von Guatemala, Honduras und Nord-Nicaragua normal aufgrund des Durchzugs polarer Luftmassen durch Nordamerika während der Wintermonate. Weil Mittelamerika auch eine schmale und sehr gebirgige Landenge ist, findet man in den Küstengebieten viele verschiedene Windbedingungen sowohl im Seebereich wie auf dem Land.

Obwohl es örtliche Unterschiede gibt, ist die Regenzeit für alle zentralamerikanischen Länder ziemlich die gleiche; sie beginnt im Mai und erstreckt sich bis in den Oktober. Regen fällt normalerweise als tropische Wolkenbrüche, die sehr oft von Gewittern begleitet sind. Hagelstürme ereignen sich in Hochlandgebieten, und Wirbelstürme streifen gelegentlich die nördliche karibische Küste in den Monaten September und Oktober.

Die jährliche Regenmenge ist in der Region sehr unterschiedlich. Die Gebiete mit der niedrigsten Regenmenge (weniger als 1000 mm) liegen in den Hochländern von Guatemala und Honduras. Der meiste Regen fällt an der Karibikküste von Nicaragua mit einer jährlichen Niederschlagsmenge von bis zu 6.000 mm.

Naturereignisse

Die in Zentralamerika vorherrschenden Naturereignisse umfassen Erdbeben und Vulkanausbrüche sowie Wirbelstürme, Hagelstürme und Überschwemmungen während der Regenzeit.

- Erdbeben.
  Erdbeben stellen die größte Gefahr für Leben und Besitz dar. In diesem Jahrzehnt erlebte Zentralamerika die folgenden beiden Katastrophen:

  1. Am 23. Dezember 1972 wurden 60% der Stadt Managua, Nicaragua, durch ein heftiges Erdbeben zerstört; es gab über 14.000 Tote und nahezu 200.000 Obdachlose.
  2. Am 4. Februar 1976 verwüstete eine Serie von Beben in Guatemala, mit einer Stärke von 7.6 auf der Richterskala, weite Gebiete der Republik und berührte 20 der 22 Departments. Mehr als 24.000 Menschen verloren ihr Leben, und über 1.200.000 wurden obdachlos.

Auf den Seiten 98 und 99 :

(beide Fotos aus El Progreso / Guatemala)

Abb. 5.3 Typischer Erdbebenschaden mit sichtbarem Ringbalken, der den Einsturz des Hauses verhinderte: Adobe-Mauerwerk, Holzringbalken, verzinktes Wellblechdach.

Abb. 5.4 Notbehausungen nach dem Erdbeben (vom Roten Kreuz bereitgestellt): Holzrahmen und -wandkonstruktion, verzinktes Wellblechdach.

Fairly strong northerly winds are common in the highland regions of Guatemala, Honduras and northern Nicaragua, as a result of the effect of the movement of polar air masses across North America during the winter months. Also, since Central America is a narrow and very mountainous isthmus, many variable sea and land breeze conditions are found in coastal areas.

Although local variations exist, the rainy season for all of the Central American nations is roughly the same, starting in May and extending through October. Rainfall usually is in the form of tropical cloudbursts often accompanied by thunder and lightning. Hailstorms occur in highland areas, and hurricanes occasionally strike the northern Caribbean coast in the months of September and October.

The amount of annual precipitation varies widely throughout the region. The areas of lowest rainfall (less than 1000 mm) are found in the Guatemalan and Honduran highlands. Heaviest rainfall occurs on the Caribbean coast of Nicaragua where the annual precipitation reaches a maximum of 6000 mm.

Natural hazards

The climatic and seismic hazards prevalent in Central America include earthquakes and volcanic eruptions as well as hurricanes, hailstorms and floods during the rainy season.

- Earthquakes.
  Earthquakes represent the greatest hazard to life and property. During the present decade, Central America has experienced the following two catastrophes:

  1. On December 23, 1972, 60% of the city of Managua, Nicaragua, were destroyed by a violent earthquake which resulted in over 14 000 deaths, and approximately 200 000 persons homeless.
  2. On February 4, 1976, a series of tremors in Guatemala, starting with one of Richter 7.6, devastated large areas of the Republic, affecting 20 of the 22 Departments. Over 24 000 persons were killed, and more than 1 200 000 left without homes.

On pages 98 and 99 :

(both photos from El Progreso / Guatemala)

Fig. 5.3 Typical earthquake damage, showing the ring beam which prevented collapse of the building: adobe walls, timber ring beam, corrugated galvanized iron roof.

Fig. 5.4 Post-earthquake emergency dwellings (supplied by the Red Cross): timber framework and walls, corrugated galvanized iron roof.

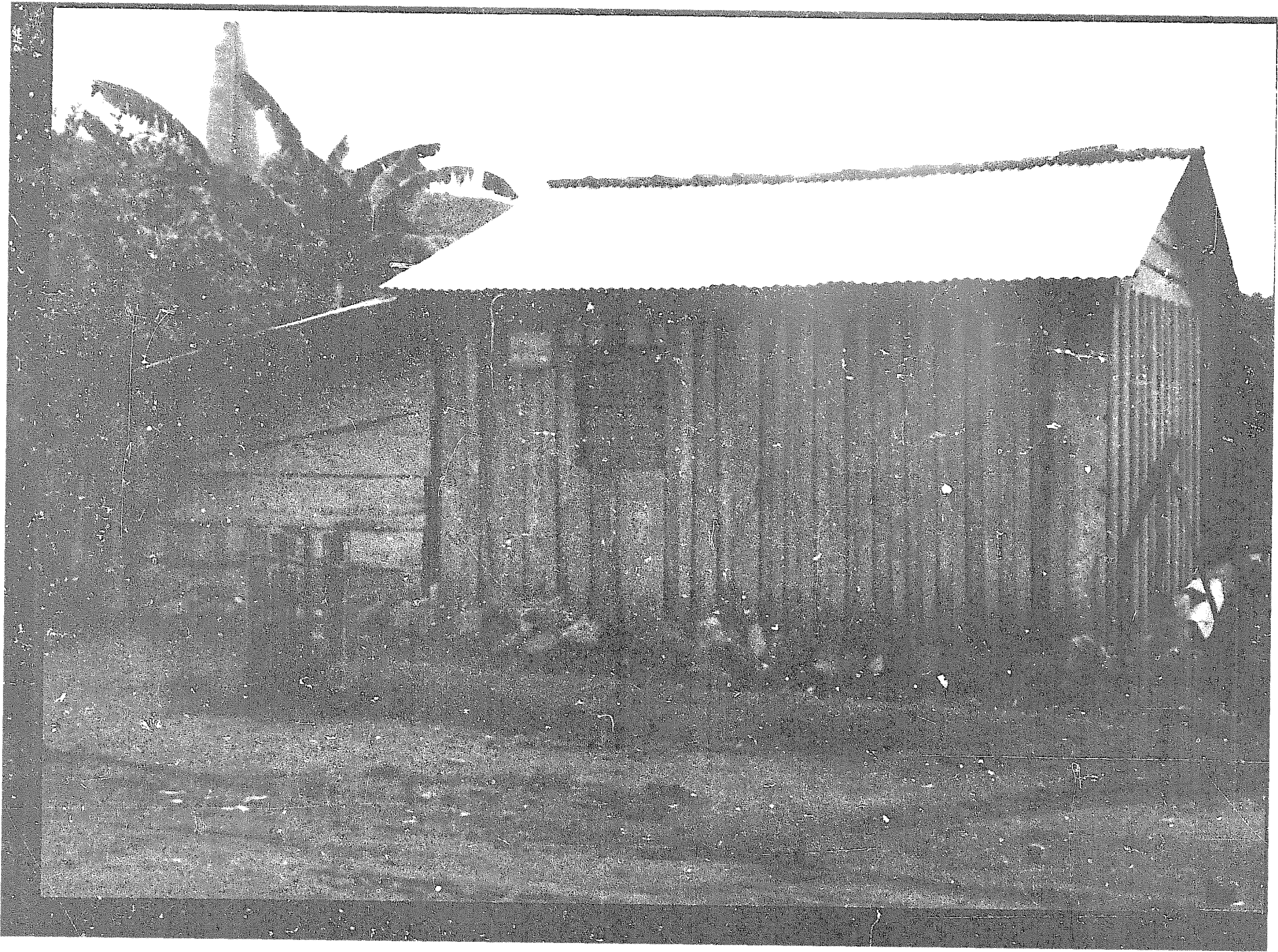

Zusätzlich zu den unheilvollen Erdbeben wird das Gebiet fast ständig von weniger starken Beben erschüttert. Guatemala berichtet über jährlich ca. 300 Beben, wovon ca. 1% gefährlich sein kann. Am 9. Oktober 1979 herrschte im Department of Santa Rosa ein Beben (Richter 5.8), welches über 200 Häuser zerstörte. Alle hatten Adobe- oder Bajareque-Wände, 75% Ziegeldächer und 25% Zinkblechdächer.
Seit dem letzten Erdbeben haben viele zentralamerikanische Regierungen die örtlichen Bauvorschriften verschärft, indem sie viele Anforderungen aus den strengen Bauvorschriften des Staates Californien, USA, übernahmen. Dies betrifft jedoch hauptsächlich den Bau von öffentlichen und kommerziellen Gebäuden in den größeren Städten. In den ländlichen Gebieten von Guatemala, wo es keine Bauvorschriften gibt, haben verschiedene Organisationen die örtliche Bevölkerung über sichere Bautechniken für Häuser mit Adobewänden unterrichtet, indem sie empfahlen, Zinkblechdächer oder Asbestzementdächer statt der gefährlicheren Ziegeldächer anzuwenden.

- Vulkanausbrüche.
  Außer in Honduras ereignen sich Vulkanausbrüche in allen zentralamerikanischen Ländern. Obwohl der unmittelbare Schaden nur ein kleines Gebiet betrifft, können Sand und Asche des Ausbruchs beträchtliche Flächen bedecken und somit die Ernte vernichten und aufgrund der Ablagerungen auf den Dächern Häuser beschädigen. In nur wenigen Fällen brach Feuer aus durch die heiße Vulkanasche, die auf Strohdächer fiel.

- Wirbelstürme.
  Tropische Stürme mit 35 - 65 Knoten Geschwindigkeit und Wirbelstürme (Windgeschwindigkeit über 65 Knoten) treffen gelegentlich die nördliche karibische Küstenlinie und in der Hauptsache die Küsten von Honduras. Der letzte Wirbelsturm war Fifi (14. September 1974), der etwa 5.000 Menschenleben kostete und 100.000 Personen obdachlos machte.

- Hagelstürme.
  Hagelstürme ereignen sich in ganz Zentralamerika, meistens zwischen Mitte April und Mitte Juni. Obwohl sie in erster Linie der Ernte schaden, können sie auch Dachziegel beschädigen. Strohdächer werden davon nicht betroffen.

- Überschwemmungen.
  Überschwemmungen während der Regenzeit ereignen sich meist in der pazifischen Küstenebene, es gibt aber auch Überflutungen in Hochlandgebieten durch übertretende Flüsse. Überschwemmungen stellen eine gewisse Gefahr für Häuser dar, jedoch nicht direkt für die Dächer.

In addition to the disastrous earthquakes, the region is almost constantly subjected to tremors of lesser magnitude. Guatemala annually reports about 300 tremors, about 1% of which can be hazardous. On October 9 of this year, a tremor (Richter 5.8) occurred in the Department of Santa Rosa, resulting in the destruction of over 200 homes. All had adobe or bajareque walls, 75% with clay tile roofs and 25% with galvanized steel.
Since the recent earthquakes, many Central American Governments have tightened local building codes, adopting many of the requirements stipulated in the stringent building code of the State of California, U.S. This, however, affects principally the construction of public and commercial buildings in the larger cities. In the rural areas of Guatemala, where building codes do not exist, various organizations have been instructing the local population in safer construction techniques for adobe-walled houses and recommending the use of galvanized steel or asbestos-cement roofing instead of the more dangerous clay tile.

- Volcanic eruptions.
  Volcanic eruptions occur in all of the Central American nations, except Honduras. Although the direct hazard only involves a very small area, sand and ash from the eruption can cover considerable extensions, causing damage to crops and occasionally representing a hazard to housing due to the accumulation of debris on the roof. Few cases are known of fires caused by hot volcanic ash falling on thatch roofs.

- Hurricanes.
  Tropical storms with winds of 35 to 65 knots and hurricanes (windspeed over 65 knots) occasionally strike the northern Caribbean coastline, principally affecting the coast of Honduras. The last hurricane to strike this region was Hurricane Fifi (September 14, 1974) which caused about 5000 deaths and left 100 000 persons homeless.

- Hailstorms.
  Hailstorms occur throughout Central America, usually between mid-April and mid-June. Although primarily a hazard to crops, hailstones can damage clay roof tiles. Thatch roofs are not affected.

- Floods.
  Flooding during the rainy season occurs most frequently on the Pacific coastal plain, but there also is some localized flooding in highland areas caused by swollen rivers. Floods obviously represent some hazard to housing, but do not directly affect roofs.

5.1.2 Bevölkerung, Kultur und Traditionen

Die Gesamtbevölkerung der fünf zentralamerikanischen Länder beträgt zur Zeit etwa 20 Millionen und wird im Jahre 2000 voraussichtlich 35 Millionen betragen. Die für 1980 geschätzte Bevölkerungszahl teilt sich auf die verschiedenen Länder wie folgt auf:

Land	Personen in Tausend	Prozent
Costa Rica	2.286	11,26
El Salvador	4.813	23,71
Guatemala	6.940	34,18
Honduras	3.595	17,71
Nicaragua	2.669	13,14
Insgesamt	20.303	100,00

5.1.2 Population, Culture and Traditions

The total population of the five Central American countries presently is about 20 million, and is expecred to reach 35 million inhabitants in the year 2000. The population per country estimated for 1980 is as follows:

Country	Thousands of Persons	Percent
Costa Rica	2 286	11.26
El Salvador	4 813	23.71
Guatemala	6 940	34.18
Honduras	3 595	17.71
Nicaragua	2 669	13.14
Total	20 303	100.00

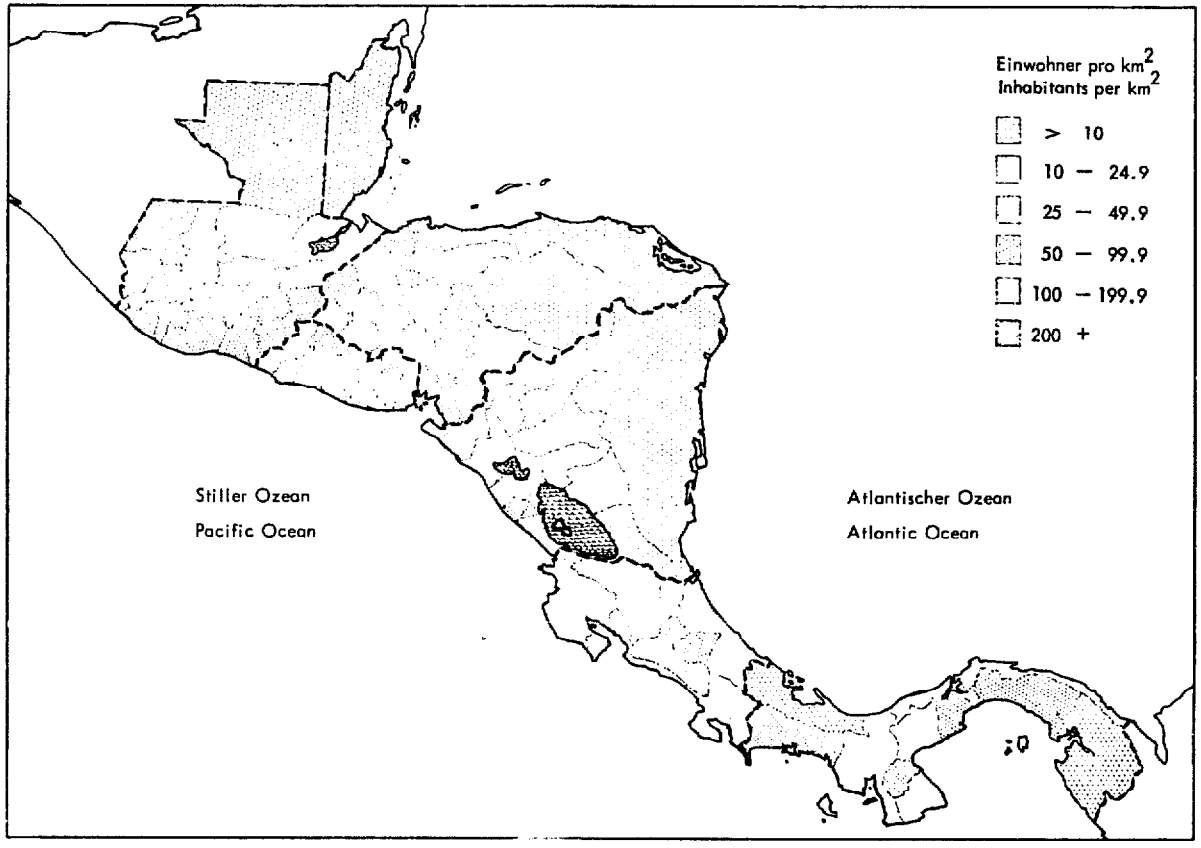

Abb. 5.5 ZENTRALAMERIKA : Bevölkerungsdichte

Fig. 5.5 CENTRAL AMERICA : Population density

Da die gesamte Fläche dieser Region etwa 440.000 km^2 umfaßt, stellen die oben genannten Zahlen eine durchschnittliche Bevölkerungsdichte von 46 Bewohnern/km^2 dar. Die Bevölkerung ist jedoch nicht gleichmäßig über das Land verteilt, sondern hauptsächlich auf das zentrale Hochland und die Pazifikküste konzentriert. Weite Gebiete entlang der Atlantikküste und im nördlichsten Department von Guatemala (El Petén) sind sehr dünn besiedelt.

Ackerbau ist die wirtschaftliche Hauptaktivität in allen fünf zentralamerikanischen Ländern. Nur ca. 30% der regionalen Bewohner werden der städtischen Bevölkerung zugerechnet (1); die restlichen 70% leben in ländlichen Gebieten, die meisten davon sind hauptsächlich im Ackerbau beschäftigt. Dies sind Kleinbauern, die vorwiegend Getreide und Bohnen erzeugen, wandernde Landarbeiter, die zur Erntezeit auf großen Plantagen angestellt werden (Kaffee, Zuckerrohr, Baumwolle, Bananen), und ständige Angestellte der großen Plantagen. Der letzteren Gruppe wird vom Plantagenbesitzer die Wohnung gestellt, die aus leicht zu installierenden vorgefertigten Materialien für die Dachdeckung (Zinkblech oder Asbestzement) bestehen. Die Mehrzahl der übrigen ländlichen Bevölkerung baut ihre Häuser mit traditionellen Materialien.

Die ethnische Aufteilung der Bevölkerung ist in El Salvador, Honduras und Nicaragua ähnlich, mit "ladinos" (indianisch-europäische Mischung), die ungefähr 85% der zusammengesetzten Bevölkerung dieser drei Länder ausmachen. Die übrige Bevölkerung umfaßt Personen europäischen Ursprungs, Indianer, und einen kleinen Prozentsatz farbiger Einwanderer von den karibischen Inseln.

Guatemala unterscheidet sich von den anderen Ländern etwas dadurch, daß mehr als 50% der Bevölkerung sich aus Indianern mit Maya-Quiché-Ursprung zusammensetzen, die immer noch ihre eigenen Bräuche und ihre Sprache aufrechterhalten. Auf der anderen Seite hat Costa Rica einen unbedeutenden Anteil an indianischer Bevölkerung, und die große Mehrheit seiner Bewohner ist europäischen Ursprungs.

Die Verschmelzung indianischer und europäischer (spanischer) Kulturen brachte zwei Typen traditioneller Dachdeckung hervor, die heute in ländlichen Gebieten Zentralamerikas, außer Costa Rica, vorherrschen. Dieses sind Stroh- oder Palmblatt-Dächer auf Pfosten- oder Bambus-Unterbau, die man vor allem in indianischen Dörfern sieht, und das rote Tonziegeldach, das von spanischen Siedlern eingeführt wurde.

Von den beiden oben genannten Systemen wird das Tonziegeldach sozial höher eingestuft, obwohl herunterfallende Ziegel während des Erdbebens in Guatemala im Jahre 1976 viele Menschen töteten. Dieser Dach-Typ ist optisch attraktiv und relativ frei von Insekten, was bei Strohdächern problematisch ist. Seine relativ hohen Kosten halten jedoch viele ländliche und städtische Bewohner von seinem Gebrauch ab.

In Costa Rica, dem Land mit dem höchsten Pro-Kopf-Einkommen in Zentralamerika, haben vorgefertigte Dachdeckungsmaterialien die traditionellen Systeme weitgehend verdrängt. Man findet jedoch immer noch einige Ziegel- und Strohdächer in diesem Land.

(1) Bewohner von Städten mit 10.000 oder mehr Einwohnern

Since the total land area of this region is approximately 440 000 square kilometers, the above figure represents an average population density of 46 inhabitants/square kilometer. However, in fact the population is not distributed evenly throughout the region, but is concentrated principally in the Central highlands and on the Pacific coast. Large areas along the Atlantic coast and in the northernmost department of Guatemala (El Petén) are very sparsely populated.

Agriculture is the primary economic activity in all five of the Central American nations. Only about 30 percent of the regional inhabitants are classified as urban dwellers (1); the remaining 70% live in rural zones with the vast majority engaged in agricultural activities. These include permanent small farmers producing principally corn and beans, itinerant farm workers who are employed by large plantations at harvest time (coffee, sugar cane, cotton, bananas), and the permanent employees of the large plantations. This latter group frequently is provided with housing by the plantation owner, usually using easily installed manufactured materials for roofing (galvanized steel or asbestos cement). The majority of the rest of the rural population build their own homes using traditional materials.

The ethnic distribution of the population is similar in El Salvador, Honduras and Nicaragua, with "ladinos" (mixture of Indian and European) representing about 85% of the combined population of the three countries. The remainder includes persons of European extraction, Indians and a small percentage of black immigrants from the Caribbean Islands.

Guatemala differs from the other countries in that slightly more than 50% of the population is made up of Indians of Maya-Quiché descent who still maintain their own customs and language. Costa Rica, on the other hand, has an insignificant Indian population, and the great majority of its inhabitants are of European extraction.

The merging of the Indian and European (Spanish) cultures has resulted in two types of traditional roofing systems which today predominate in rural Central America, except for Costa Rica. These include the straw or palm leaf thatch roof, supported by a pole or bamboo substructure, which is very common in Indian villages, and the red clay tile roof which was introduced by the Spanish settlers.

Of the above two traditional systems, the clay tile roof has the higher degree of social acceptability, despite the fact that falling tiles were considered to be responsible for some deaths during Guatemala's 1976 earthquake. This type of roof is visually attractive and relatively free of the insect problem associated with thatched roofs. Its higher relative cost, however, prevents its use by many of the rural and urban poor.

In Costa Rica, the Central American nation with the highest per capita income, manufactured roofing materials have largely substituted the traditional systems. However, some clay tile and thatched roofs are still found in this country.

(1) Residents of cities with population of 10 000 or more.

5.1.3 Baumaterialien

Die in Zentralamerika verfügbaren Materialien, die gegenwärtig zum Hausbau verwendet werden, umfassen natürliche Materialien wie Ton, Stroh und Bambus, die von den Armen auf Feldern gesammelt werden; Tondachziegel und gebrannter Kalk, der von einfacher ländlicher Industrie hergestellt wird, Sägewerk-Holz und eine Anzahl moderner Baumaterialien, die von größeren Betrieben hergestellt werden, welche normalerweise in den größeren Städten angesiedelt sind.

Natürliche Materialien

Obwohl sie augenblicklich nicht direkt als Dachdeckungsmaterial verwendet wird, ist Erde wahrscheinlich das wichtigste natürliche Material aufgrund seiner Bedeutung für die Herstellung von Adobeblöcken, einem der wichtigsten in Zentralamerika angewandten Wandkonstruktionsmaterialien. Erde wird auch in Verbindung mit Holzpfählen, Rohr oder Bambus zur typischen "bajareque"-Wandkonstruktion verwendet, die man vor allem in indianischen Dörfern vorfindet.

Die natürlichen Materialien, welche für Strohdächer verwendet werden, sind verschieden, je nach Vorkommen natürlicher Vegetation in verschiedenen geographischen Zonen. Palmblätter werden meist sowohl in atlantischen als auch in pazifischen Küstenregionen verwendet. Im zentralen Hochland ist Stroh von verschiedenen grasähnlichen Pflanzen (1), die in diesen Gebieten reichlich vorhanden sind, das wichtigste Material. Bambus oder Pfähle aus Ästen oder kleinen Bäumen dienen als Unterkonstruktion für die Strohdächer.

Dächer dieses Typs werden hauptsächlich gebaut von Landbewohnern, die aus wirtschaftlichen Gründen keine vorgefertigten Materialien kaufen können, und machen einen bedeutenden Prozentsatz der gesamten Dachkonstruktionen in Zentralamerika aus, ausgenommen Costa Rica. Das Strohdach hat den Vorteil der niedrigen Kosten aufgrund der Verwendung von örtlichen Materialien, es hält das Hausinnere kühl und hält dem Aufprall von harten Gegenständen stand.
Seine Hauptnachteile liegen darin, daß sich Insekten oder Nagetiere einnisten, der Unterhaltungsaufwand groß und das Material nicht feuerbeständig ist.

Von kleinen ländlichen Betrieben hergestellte Materialien

Rote Tondachziegel werden in kleinen primitiven Brennöfen überall in Zentralamerika hergestellt. Nach einer kürzlichen ICAITI-Untersuchung arbeiten im Augenblick über 3.800 dieser Unternehmen in dem Gebiet. Kalk wird auch in ähnlichen ländlichen Einrichtungen hergestellt und hauptsächlich als Kalk-Sand-Mörtel für den Innenputz verwendet.

Die Tonziegel sind, wie vorher erwähnt, das beliebteste Dachdeckungsmaterial in vier der fünf zentralamerikanischen Länder, besonders im zentralen Hochland. Wegen der starken Vermehrung der kleinen Fabrikationsbetriebe und des fast vollständigen Fehlens von Produktionskontrollen, können Qualität und Abmessungen der ört-

(1) z.B. pajón (Epicampes macroura)

5.1.3 Building Materials

The materials available in Central America, which are currently used for housing construction, include natural materials such as clay, straw and bamboo which are gathered by the rural poor in the field, clay roof tiles and quicklime produced by primitive rural industries, sawmill lumber and a number of modern construction materials manufactured by larger industries usually located in the principal cities.

Natural materials

Although not presently used directly for roofing applications, earth or clay probably is the most important natural material because of its role in the fabrication of adobe blocks, one of the principal wall construction materials in use in Central America. Earth also is used in conjunction with wooden poles, canes or bamboo in the typical "bajareque" wall construction usually found in Indian villages.

The natural materials used for thatched roofs vary depending upon the type of vegetation available in different geographical zones. Palm leaves are used most frequently in both Atlantic and Pacific coastal regions. In the central highlands, straw obtained from various grasslike plants (1) which abound in these regions is the principal material. Bamboo or poles cut from branches or small trees serve as support members for the thatched roof.

Roofs of this type are constructed principally by rural inhabitants unable for economic reasons to purchase manufactured materials, and represent a significant percentage of total roof construction throughout Central America, except Costa Rica. The thatch roof has the advantage of low cost through the use of locally available materials, tends to maintain the house interior cool and resists the impact of solid objects. Its chief disadvantages lie in its tendency to become infested with insects or rodents, its relatively high maintenance requirements and lack of fire resistance.

Materials Produced by Small Rural Industries

Red clay roofing tiles are produced in small primitive kilns throughout Central America. According to a recent ICAITI survey, over 3 800 of these enterprises currently operate in the region. Lime also is produced in similar types of rural installations and is used primarily in lime-sand mortar for interior finishing.

The clay tiles, as mentioned previously, represent the most popular roofing material in four of the five Central American countries, especially in the central highlands. Due to the wide proliferation of the small manufacturing enterprises and the almost complete lack of production controls, the quality and dimensions of local roof tiles can vary considerably. The most common tile is the curved variety known locally as

(1) i.e. pajón (Epicampes macroura)

lichen Dachziegel beträchtlich variieren. Der gebräuchlichste Dachziegel ist die gebogene Ausführung, örtlich als spanischer oder arabischer Ziegel bekannt (Mönch- und Nonnen-Ziegel), der 40 cm lang, an einem Ende 18 cm und am anderen 14 cm breit ist und durchschnittlich 2,07 kg wiegt. Da man etwa 30 Ziegel benötigt, um 1 m^2 Dachfläche zu bedecken, beträgt alleine das Materialgewicht für diesen Dach-Typ ca. 62,05 kg/m^2.

Gegenwärtig werden diese Dachziegel für $ 0.15 verkauft. Der qm-Preis für die Dachdeckung beläuft sich somit auf ca. $ 4.50.

Das Ziegeldach ist leicht anzubringen und zu reparieren, hat eine relativ lange Lebensdauer und sorgt für eine gleichmäßigere Innentemperatur des Hauses. Es ist optisch attraktiv und erfreut sich bei den Bewohnern großer Beliebtheit.

Die Nachteile dieses Dachtyps liegen in seinem übermäßigen Gewicht, das eine schwerere Unterkonstruktion erfordert, und in der Tendenz, aufgrund von Verschiebungen einzelner Ziegel Lecks zu bilden. Auch sind die Ziegel leicht zerbrechlich, und bei Erdbeben können herunterfallende Ziegel den Bewohnern gefährlich werden.

Industriell gefertigte Materialien

Die wichtigeren Materialien, die in Zentralamerika industriell hergestellt werden, sind Portland-Zement, Löschkalk, Zementblöcke, gebrannte Tonziegel, Holz (Pinien und Harthölzer), verzinkte Stahl- und Asbestzementplatten.

Sperrholz und Preßspanplatten werden in dieser Region ebenfalls hergestellt, werden in der Bauindustrie jedoch hauptsächlich für leichte Trennwände und abgehängte Decken verwendet. Wellplatten aus fiberglasverstärktem Plastik sind ebenfalls verfügbar, aber wegen ihrer relativ hohen Kosten und kurzen Lebensdauer in erster Linie aufgrund ihrer Lichtdurchlässigkeit zur Überdeckung von Patios verwendet, wo Zierpflanzen gezogen werden.

- Portland-Zement.
  Portland-Zement für Beton wird in allen zentralamerikanischen Ländern hergestellt. Moderne Betonherstellung ist in dem Gebiet wohlbekannt. Sand und Kies sind reichlich verfügbar, und jedes Land hat wenigstens ein Walzwerk zur Herstellung von Bewehrungseisen. Gegossene Betondächer werden für die meisten öffentlichen und Verwaltungsbauten verwendet, ebenso für höher standardisierte private Wohnhäuser.
  Der gegenwärtige offizielle Preis (ab Werk) pro Zementsack (42,5 kg) liegt zwischen $ 2.10 und $ 2.29 überall in Zentralamerika. Eine kürzliche Knappheit in Guatemala hat jedoch die Preise auf durchschnittlich ca. $ 4.00 hochgetrieben. Zusätzliche Transportkosten können in ländlichen Gebieten einen Preis von mehr als $ 5.00 pro Sack Zement zur Folge haben.
  Das gegossene Betondach ist das teuerste in Zentralamerika angewendete Dachdeckungssystem. Die geschätzten Kosten pro m^2 betragen zur Zeit $ 27.00. Darüber hinaus tragen die erforderlichen Stützpfeiler dazu bei, daß die Gesamtbaukosten steigen. Die Vorteile dieser Dachdeckungsart sind deren extrem lange Lebensdauer, ihre Resistenz gegen Beschädigung durch harte Gegenstände, Wasserundurchlässigkeit, Feuerfestigkeit und gute Wärmeisolierung.
  Viele der örtlichen Zementfabriken stellen auch Löschkalk her für Wandputz.

Spanish or Arabian tile, which has a length of 40 cm, maximum and minimum widths, respectively, of 18 and 14 cm, and an average weight of 2.07 kg. Since about 30 tiles are required to cover one square meter of roof surface, the material weight alone for this type of roof is about 62.05 kg per square meter.

Presently these tiles are sold at a price of $ 0.15 per unit. The material cost for one square meter of roofing, therefore would be about $ 4.50.

The tile roof can be easily installed and repaired, has a relatively long life and maintains a more constant interior temperature in the home. It is visually attractive and enjoys a high level of popularity among the regional inhabitants.

The disadvantages of this type of roof system are its excessive weight which requires a heavier support structure and its tendency to develop leaks due to shifting of individual tiles. Also, the tiles can be easily broken and, during earthquakes, falling tiles can represent a hazard to the residents.

Manufactured Materials

The construction materials of more importance which are industrially manufactured in Central America include portland cement, hydrated lime, cement blocks, clay bricks, lumber (pine and hardwoods), galvanized steel and asbestos-cement sheets.

Plywood and composition board also are produced in the region, but in the construction industry are used principally for interior partitions and false ceilings. Corrugated roofing panels made of fiberglass reinforced plastic also are available, but due to their relatively high cost and short life, are used primarily to take advantage of their translucent properties in special applications, such as the covering of patios where ornamental plants are grown.

- Portland Cement.
  Portland cement for concrete is produced in all of the Central American countries. Modern concrete technology is well understood in the region; sand and gravel are readily available, and each country has at least one rolling mill for the manufacture of steel reinforcing rod. Poured concrete roofs are used for most public and commercial buildings, as well as for higher cost private residences.
  The present official price (fob factory), per bag of cement (42.5 kg), varies from $ 2.10 to $ 2.29 throughout the Central American region; however, a recent shortage in Guatemala has driven prices up to an average of about $ 4.00. Additional transportation costs can result in prices in rural zones in excess of $ 5.00 per bag of cement.
  The poured concrete roof is the most expensive roofing system in common usage in Central America. The cost per square meter currently is estimated to be $ 27.00. In addition, the need for support columns tends to raise overall building construction costs. The advantages of this type of roof are its extremely long life, resistance to the impact of solid objects, impermeability, fire resistance and good thermal insulation properties.
  Many of the local cement plants also produce hydrated lime for use in mortar for wall finishing.

- Zementblöcke und Tonziegel.
  In jedem Land gibt es einige Fabriken für die Herstellung von Zementblöcken und Tonziegeln, die Hauptmaterialien für Wandkonstruktionen bei höher standardisierten Gebäuden und bei öffentlichen Low-Cost-Housing-Projekten. Für private Unterkünfte in ländlichen Gebieten ist Adobe oder Bajareque immer noch das wichtigste Wandbaumaterial, mit Ausnahme von Costa Rica, wo Holzhäuser vorherrschen.

- Holz.
  Jedes Land hat eine Anzahl von Sägewerken zur Herstellung von Brettern und den geläufigeren Holzbauteilen. Pinienholz ist das gebräuchlichste Holz, aber andere Arten werden ebenfalls, hauptsächlich für dekorative Zwecke, verwendet. In Costa Rica ist Pinienholz das am häufigsten vorkommende Hausbaumaterial; in den anderen Ländern wird es für Dachtragkonstruktionen zusammen mit Tonziegeln, verzinktem Stahl oder Asbestzement-Dachdeckung, in höher standardisierten Gebäuden zum Innenausbau, und als Betonschalung verwendet. Die Anwendung von Holzschindeln zur Dachdeckung ist unbedeutend.
  Obwohl Rodungsprobleme Regierungsbeschlüsse zur Einschränkung von Holzverwendung in Zentralamerika zur Folge hatten, erscheint der gegenwärtige Vorrat von Pinienholz für die Erfordernisse der örtlichen Bauindustrie ausreichend zu sein. Der Preis ist jedoch relativ hoch mit durchschnittlich ca. $ 0.25 pro Brett-Fuß (ab Sägewerk).

- Verzinktes Stahlblech.
  Glattes und gewelltes verzinktes Stahlblech wird in mindestens einer Fabrik in jedem Land hergestellt. Da Zentralamerika keine Zinkvorkommen und keine Walzwerke zur Herstellung von Flachstahl hat, werden beide Hauptrohmaterialien (kaltgewalztes Stahlblech und Zinkbarren) importiert.
  Das fertige Produkt wird dem Verbraucher als Blech mit einer Größe von mindestens 6'(1,83 m) bis maximal 14'(4,27 m) angeboten. Die gebräuchlichste Breite ist ca. 30" (76 cm). Eine Stärke von 2,6 mm wird meist zur Dachdeckung verwendet, es gibt jedoch auch 2,8 und 3,0 mm-Bleche (1).
  Das durchschnittliche Gewicht des 2,6 mm-Materials beträgt ca. 4,1 kg/m^2. Der gegenwärtige Verkaufspreis ist $ 0.60 pro lfd Fuß (30" Breite), was einen qm-Preis von ca. $ 2.58 ausmacht. Es ist das preiswerteste Dachdeckungsmaterial, das in Zentralamerika verwendet wird.
  Die Vorteile des verzinkten Stahlblechs bei der Dachdeckung sind folgende:
  - geringes Gewicht, welches geringere Dimensionierung der Holztragkonstruktion zuläßt
  - relativ geringe Kosten
  - einfache Anbringung
  - Bleche können leicht entfernt und ersetzt werden
  - unempfindlich gegen Beschädigung mit harten Gegenständen
  - kann gestrichen werden, um die Optik und Korrosionsresistenz zu verbessern

(1) Obwohl das metrische System in allen zentralamerikanischen Ländern offiziell gilt, werden englische Einheiten im Geschäftsleben angewandt. In diesem Bericht werden die in Zentralamerika gebräuchlichen Maße angegeben und, wo erforderlich, die metrische Umrechnung in Klammern gesetzt.

- Cement Blocks and Clay Bricks.
  Various factories exist in each country for the manufacture of cement blocks and clay bricks which are the principal materials used for wall construction in higher cost buildings and in public low cost housing projects. For private dwellings in rural zones, adobe or bajareque still is the major wall construction material, except for Costa Rica where wooden homes are more common.

- Lumber.
  Each country has a number of sawmills which produce boards and the more common wooden structural members. Pine is the most common wood variety, but other species also are processed, principally for decorative uses. In Costa Rica, pine lumber is the major housing construction material; in the other countries it is used for roof support systems in conjunction with clay tile, galvanized steel or asbestos-cement roofing, interior applications in higher cost buildings and for forms for poured concrete. The use of wooden shingles for roofing is insignificant.
  Although deforestation problems have resulted in Government regulations to restrict timber operations in Central America, the present supply of pine lumber appears to be adequate for the needs of the local construction industry. The price, however, is relatively high, averaging about $ 0.25 per board foot (fob sawmill).

- Galvanized Steel Sheets.
  Smooth and corrugated galvanized steel sheets are produced in at least one factory in each country. Since Central America does not produce zinc and has no rolling mills suitable for flat steel, both of the principal raw materials (cold-rolled steel sheet and zinc ingots) are imported.
  The finished product is offered to the consumer in sheets with lengths varying from a minimum of 6' (1.83 m) to a maximum of 14' (4.27 m). The most common width is about 30" (76 cm). 26 gauge thickness is used most frequently for roofing applications, but 28 and 30 gauge sheets are also available (1).
  The average weight of the 26 gauge material is about 4.1 kg/square meter. The present retail price is $ 0.60 per linear foot (30" width), which represents a cost per square meter of approximately $ 2.58. This is the least expensive of the manufactured roofing materials in common usage in Central America.

  The advantages of galvanized steel for roofing applications are the following:
  - light weight which permits a reduction in size of the wooden support members
  - relatively low cost
  - simple installation
  - sheets can be easily removed and replaced
  - resists the impact of solid objects
  - can be painted to improve appearance and resistance to oxidation (red is the preferred color to simulate the appearance of the traditional red clay tile roof).

  The disadvantages are:
  - fairly rapid deterioration due to oxidation, especially in coastal areas

(1) Although the metric system is official in all of the Central American countries, English units are often used commercially. In this report, the dimensions commonly used in Central America are shown, with the metric equivalent, where required, in parantheses.

(Rot ist die bevorzugte Farbe, um die Erscheinung des traditionellen roten Tonziegeldaches zu imitieren).

Die Nachteile sind:
- ziemlich schnelle Verwitterung aufgrund von Oxydation, besonders in Küstengebieten
- Kondenswasserbildung im Inneren der Häuser, wenn nicht eine abgehängte Decke eingezogen wird (1)
- übermäßige Lärmbelästigung während Regenstürmen
- übermäßige Temperaturschwankungen im Inneren des Hauses

- Asbestzement.
Asbestzementplatten werden in Zentralamerika mittels örtlichem Portlandzement und importierter Asbestfaser hergestellt. Es werden vielerlei Formen hergestellt, einschließlich einfacher Wellplatten und trogförmiger Elemente mit besonders großen hochgezogenen Kanten (canaleta) bis zu einer Länge von 7 m.
Die einfache Wellplatte wird vom "do-it-yourself"-Bauherm bevorzugt. Dieses Material wird in 5 mm Stärke mit einem Gewicht von 10,5 kg/m^2 und in 6 mm Stärke mit einem Gewicht von 12,2 kg/m^2 hergestellt. Die Platten sind 1 m breit und sind zwischen 6'(1,83 m) und 10'(3,05 m) lang. Der Verkaufspreis für das natürliche graue Material (6 mm) liegt bei ungefähr ₡ 4.60/m^2. Rot-pigmentierte Platten (zur Imitation der roten Tonziegel) gibt es mit Aufpreis (₡ 5.27/m^2).
Die "canaleta", die mehr für öffentliche Billigwohnbauten verwendet wird, hat ein durchschnittliches Gewicht von 18,65 kg/m^2 und kostet durchschnittlich ₡ 6.46/m^2.
Asbestzement wird, hauptsächlich wegen seiner höheren Kosten und seines größeren Gewichts, weniger oft gebraucht als Zinkblech. Er ist jedoch das bevorzugte Dachdeckungsmaterial zum Bau von öffentlichen Billigwohnbauten durch staatliche Institutionen, und seine Verwendung auf diesem Gebiet gewinnt immer mehr an Bedeutung.
Die Hauptvorteile des Asbestzementdaches sind folgende:
- wasserdicht, feuerfest, rostbeständig
- ausreichende Steifigkeit, um auf Zwischenstützen verzichten zu können
- insektenresistent
- lange Lebensdauer

Die Nachteile sind:
- höherer Preis und größeres Gewicht als Zinkblech
- relativ zerbrechlich, z.B. beim Transport und beim Einbau, nicht unempfindlich gegen Beschädigung mit harten Gegenständen
- Anbringung komplizierter als bei Zinkblech
- Kondenswasserbildung im Inneren, falls nicht eine abgehängte Decke eingezogen wird
- Übermäßige Temperaturschwankungen im Inneren des Hauses

(1) Dies kann in ländlichen Gebieten zu einem ernsten Problem werden, wo der Hausbesitzer oft Getreide im Haus lagert.

- interior condensation problems unless a false ceiling is installed (1)
- excessive noise during rain storms
- excessive temperature changes inside of the home

- Asbestos-cement.
Asbestos-cement sheets are produced in Central America using locally manufactured Portland cement and imported asbestos fibre. Various section configurations are manufactured, including simple corrugated sheets and trough-shaped elements with special tall upturned ends (canaleta) up to 7 m long.
The simple corrugated sheet is preferred by the "do-it-yourself" builder. This material is offered in 5 mm thickness with a weight of 10.5 kg/m^2 and in 6 mm, with a weight of 12.2 kg/m^2. The sheets are 1 m wide with lengths varying from 6' (1.83 m) to 10' (3.05 m). The retail price for the natural gray-colored material (6 mm) averages about ₡ 4.60/m^2. A red pigmented sheet (to simulate clay tile appearance) also is available at a premium price (₡ 5.27/m^2).
The canaleta, used more frequently for public low cost housing, has an average weight of 18.65 kg/m^2 and an average cost of ₡ 6.46/m^2.
Asbestos-cement is used much less frequently than galvanized steel due principally to its higher cost and greater weight. However, it is the preferred roofing material for the construction of public low cost housing by institutions, and its use in this field is of increasing importance.

The main advantages of the asbestos-cement roof are as follows:
- waterproof, fireproof and rustproof
- sufficient rigidity to eliminate the need for intermediate supports
- resistant to attacks by insects
- long life

The disadvantages are:
- higher price and greater weight than galvanized steel
- relatively fragile, can be broken during handling and installation, lacks resistance to the impact of solid objects
- installation more complicated than galvanized steel
- interior condensation problems unless a false ceiling is installed
- excessive temperature changes in the home

(1) This can be a serious problem in rural zones where the home owner often stores grain inside of the house.

5.2 Gebräuchliche Bedachungssysteme

5.2.1 Quantitativer Vergleich bestehender Bedachungssysteme

Die auf den folgenden Seiten in Tabellen dargestellten Zahlen beziehen sich auf die wichtigsten Materialien, die für die Konstruktion von Wänden und Dächern in Zentralamerika verwendet werden. Für jedes der fünf Länder wird gemäß der letztgültigen Bestandsaufnahme aufgezeigt, wieviele Häuser jeweils aus den verschiedenen Materialien bestehen (1). Obwohl diese Daten 5 - 8 Jahre alt sind, sind sie ziemlich repräsentativ für die gegenwärtige Situation in allen Ländern, mit Ausnahme vielleicht von Guatemala, wo einige der Tondachziegel während des Erdbebens 1976 zerstört und durch Zinkblech ersetzt wurden.

Die relative (prozentuale) Häufigkeit jedes einzelnen Konstruktionssystems wird in den Diagrammen nach den Tabellen gezeigt. Für Zentralamerika insgesamt zeigt die vorliegende Information, daß Tonziegel, Stroh und Zinkblech bei 92% der Häuser verwendet werden, die restlichen 8% bestehen aus Asbestzement, Beton und anderen Materialien.

Strohdächer sind in Guatemala am stärksten vertreten (ca. 30%); sie sind von einiger Bedeutung in El Salvador, Honduras und Nicaragua, man findet sie jedoch nur selten in Costa Rica.

Die Tonziegel-Dachdeckung ist in allen Ländern sehr beliebt, mit Ausnahme von Costa Rica, wo sie nur bei weniger als 6% aller Häuser angewandt wird. Den höchsten Prozentsatz (68,59%) findet man in El Salvador.

Zinkblech ist am beliebtesten in Costa Rica, wo es bei 88% aller Wohnhausdächer verwendet wird. Die geringste Bedeutung hat es in El Salvador mit 7,42%.

Was Wandkonstruktionen betrifft, so sind in El Salvador, Guatemala und Honduras die traditionellen Adobe- und Bajareque-Systeme vorherrschend, während Holzkonstruktionen von größerer Bedeutung sind in Costa Rica (77,53%) und Nicaragua (45,65%).

(1) Jahr der nationalen Bestandsaufnahme

Costa Rica:	1973
El Salvador:	1971
Guatemala:	1973
Honduras:	1974
Nicaragua:	1971

5.2 Roofing Systems in Common Usage

5.2.1 Relative Importance of Existing Roofing Systems

The figures shown in the tables presented in the following pages refer to the principal materials used in the construction of roofs and walls for housing in Central America. The number of homes using each type of material, according to the latest census data available, is shown for each of the five countries (1). Although these data are five to eight years old, they are probably fairly representative of the present situation in all of the countries, except possibly Guatemala, where some of the clay tile roofs destroyed in the 1976 earthquake were replaced with galvanized steel.

The relative percentage importance of each construction system is shown in the diagrams following the tables. For Central America as a whole, the information presented shows that clay tile, thatch and galvanized steel are used on 92 percent of the homes, with asbestos-cement, concrete and other materials accounting for the remaining 8%.

Thatched roofs are most common in Guatemala (about 30% of the total), are of some importance in El Salvador, Honduras and Nicaragua, but are rarely found in Costa Rica.

The clay tile roofing system shows considerable popularity in all countries, except Costa Rica where it is used on less than 6 percent of total homes. The highest percentage (68.59%) occurs in El Salvador.

Galvanized steel is most popular in Costa Rica where it is used on 88% of all home roofs. It is of least importance in El Salvador (7.42%).

As far as wall construction is concerned, the traditional adobe and bajareque systems predominate in El Salvador, Guatemala and Honduras, while wooden construction is of greater importance in Costa Rica (77.53%) and Nicaragua (45.65%).

(1) Year of National Census

Costa Rica:	1973
El Salvador:	1971
Guatemala:	1973
Honduras:	1974
Nicaragua:	1971

In Zentralamerika für den Hausbau vorwiegend benutzte Wandkonstruktionen
Principal Material Used for Walls in Central American Housing Construction

- Anzahl der Häuser -
- Number of Homes -

Wandbaumaterial/Wall material	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Insgesamt/Total
Rohr, Pfähle mit oder ohne Erdfüllung (1) Canes, poles with or without earth fill (1)	338.463	294.564	240.370	73.225	7.709 (2)	954.331
Holz/wood	174.219	62.764	139.180	138.115	256.517	770.795
Adobe	396.670	169.919	85.196	19.924	-	671.709
Ziegel, Zementblöcke oder Steine Brick, cement block or stone	87.375	90.662	61.820	65.909	55.745	361.511
Andere/others	16.090	36.630	-	5.371	10.886	68.977
Insgesamt/Total	1.012.817	654.539	526.566	302.544	330.857	2.827.323

(1) Bajareque
(2) einschl. Adobe/includes adobe

In Zentralamerika für den Hausbau vorwiegend benutzte Bedachungsmaterialien
Principal Material Used for Roofs in Central American Housing Construction

- Anzahl der Häuser -
- Number of Homes -

Bedachungsmaterial/Roof material	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Insgesamt/Total
Tonziegel/clay tile	282.332	448.936	262.928	156.831	17.377	1.168.404
verzinktes Blech/galvanized steel	343.401	48.553	117.952	76.097	290.096	876.099
Stroh/thatch	299.393	118.867	101.404	57.205	-	576.869
Asbestzement/asbestos cement	16.264	22.587	30.708	3.372	9.858	82.789
Beton/concrete	34.158	9.406	2.340	854	-	46.758
Andere/others	37.269	6.190	11.234	8.185	13.526 (1)	76.404
Insgesamt/Total	1.012.817	654.539	526.566	302.544	330.857	2.827.323

(1) einschließlich Stroh und Beton
(1) includes thatch and concrete

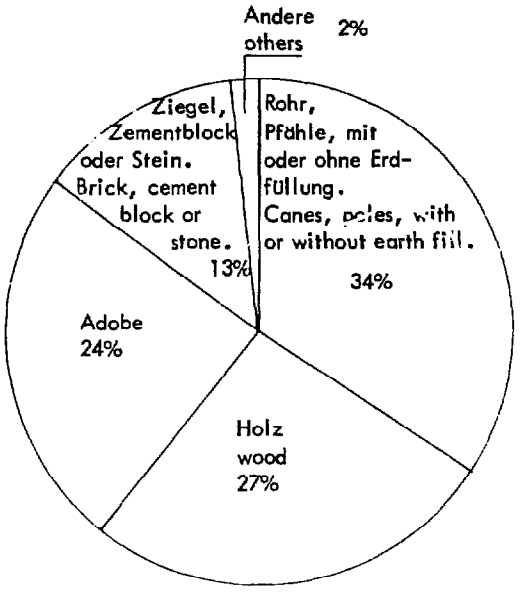

a. Hauptmaterial für Wandkonstruktionen (%)
a. Principal material in wall construction (%)

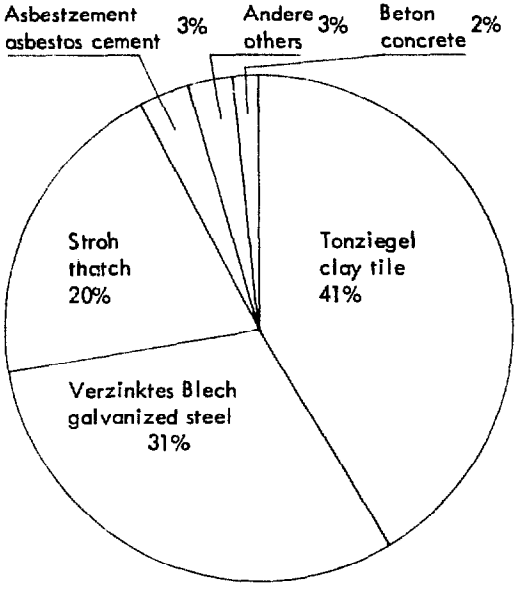

b. Hauptmaterial für Dachkonstruktionen (%)
b. Principal material in roof construction (%)

Abb. 5.6 (a, b) ZENTRALAMERIKA. Konstruktionsarten im Wohnungsbau.
Fig. 5.6 (a, b) CENTRAL AMERICA. Types of Housing Construction.

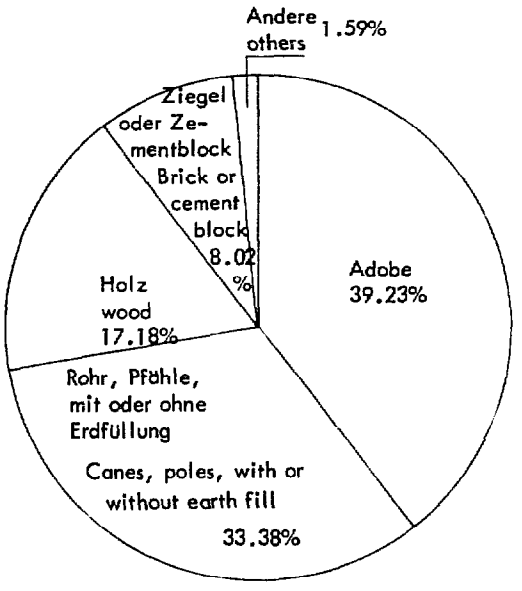

a. Hauptmaterial für Wandkonstruktionen (%)
a. Principal material in wall construction (%)

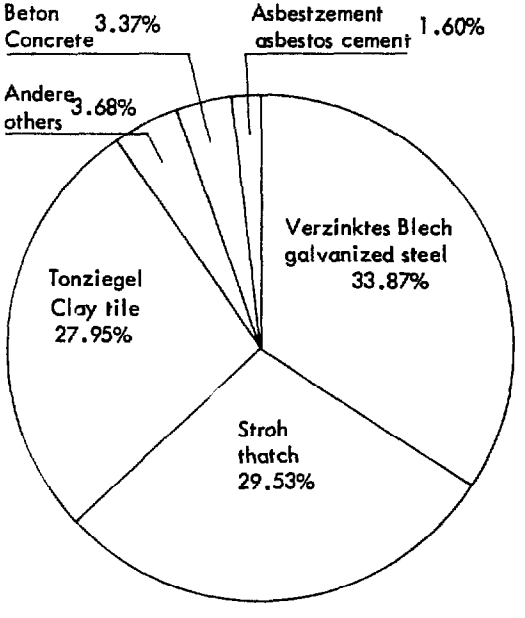

b. Hauptmaterial für Dachkonstruktionen (%)
b. Principal material in roof construction (%)

Abb. 5.7 (a, b) GUATEMALA. Konstruktionsarten im Wohnungsbau.
Fig. 5.7 (a, b) GUATEMALA. Types of Housing Construction.

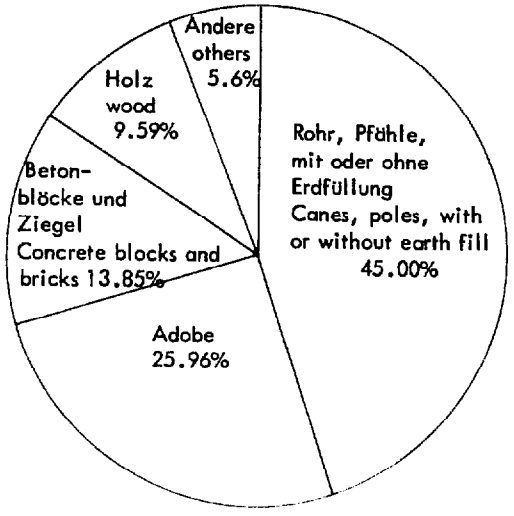

a. Hauptmaterial für Wandkonstruktionen (%)
a. Principal material in wall construction (%)

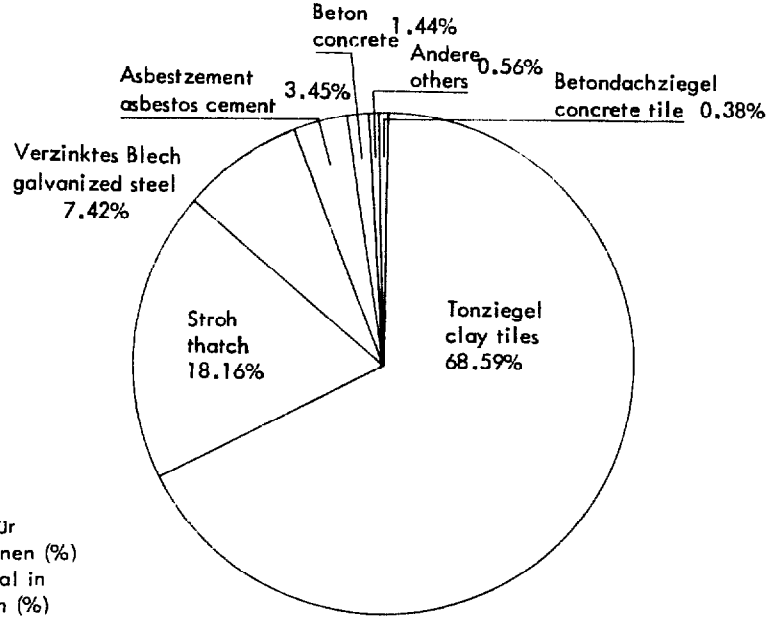

b. Hauptmaterial für Dachkonstruktionen (%)
b. Principal material in roof construction (%)

Abb. 5.8 (a, b) EL SALVADOR. Konstruktionsarten im Wohnungsbau.
Fig. 5.8 (a, b) EL SALVADOR. Types of Housing Construction.

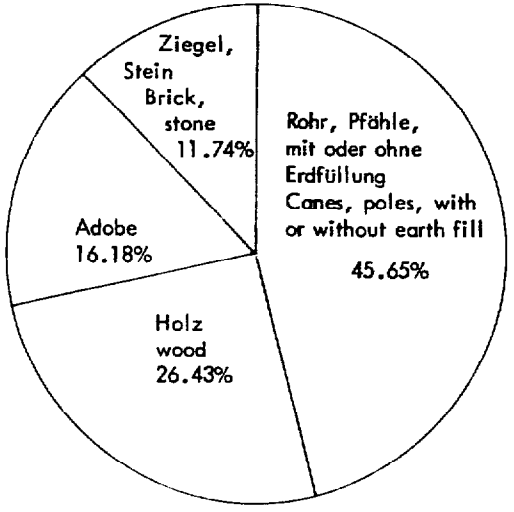

a. Hauptmaterial für Wandkonstruktionen (%)
a. Principal material in wall construction (%)

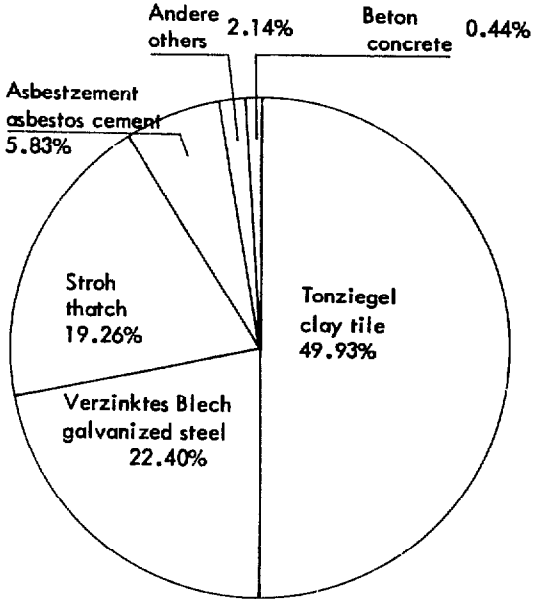

b. Hauptmaterial für Dachkonstruktionen (%)
b. Principal material in roof construction (%)

Abb. 5.9 (a, b) HONDURAS. Konstruktionsarten im Wohnungsbau.
Fig. 5.9 (a, b) HONDURAS. Types of Housing Construction.

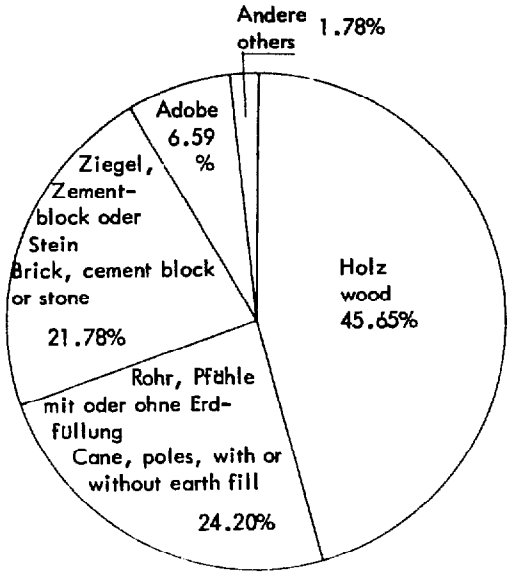

a. Hauptmaterial für Wandkonstruktionen (%)
a. Principal material in wall construktion (%)

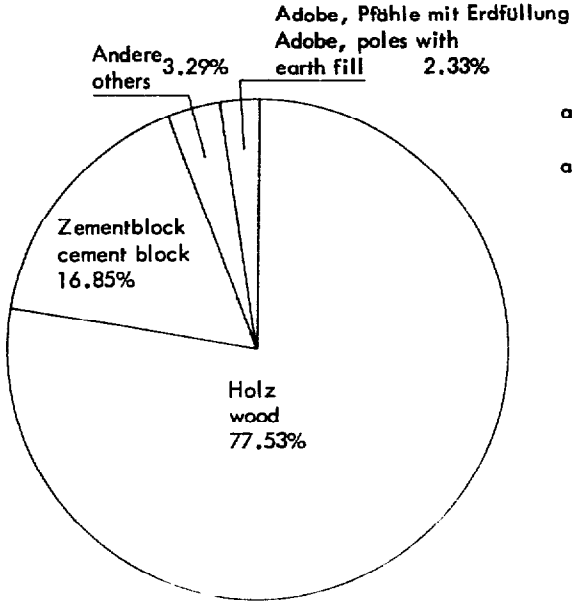

a. Hauptmaterial für Wandkonstruktionen (%)
a. Principal material in wall construction (%)

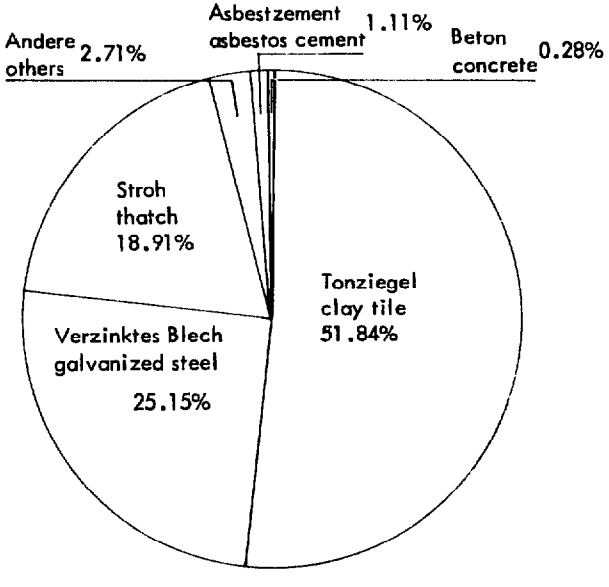

b. Hauptmaterial für Dachkonstruktionen (%)
b. Principal material in roof construction (%)

Abb. 5.10 (a, b) NICARAGUA. Konstruktionsarten im Wohnungsbau.
Fig. 5.10 (a, b) NICARAGUA. Types of Housing Construction.

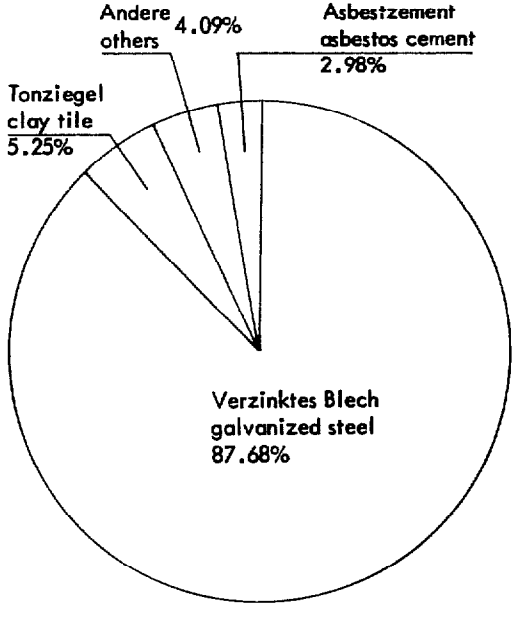

b. Hauptmaterial für Dachkonstruktionen (%)
b. Principal material in roof construction (%)

Abb. 5.11 (a, b) COSTA RICA. Konstruktionsarten im Wohnungsbau.
Fig. 5.11 (a, b) COSTA RICA. Types of Housing Construction.

5.2.2 Typische Beispiele für bestehende traditionelle und handelsübliche Dächer

Baumethoden

- Strohdächer.
  Obwohl einige Strohdächer auf Adobe-, Stein- oder Ziegelhäusern anzutreffen sind, wird die Mehrzahl in Verbindung mit dem "bajareque"-Wandbausystem angewandt, eine Bauweise, die bis in die Maya-Kulturen zurückreicht, welche in Zentralamerika lange vor der Ankunft der spanischen Konquistadoren ihre Blütezeit hatte. Bei dieser Bauweise werden Baumgabeln oder Äste als Dachstützen verwendet, mit einer Fachwerkkonstruktion aus zusammengebundenen Pfählen oder Rohr, die zwischen den Stützen befestigt ist. Diese Rahmenkonstruktion wird allgemein mit kompaktierter Erde ausgefacht und manchmal mit Kalkschlämme bestrichen.
  Stroh wird für Dachdeckung in Hochlandgebieten, und Palmblätter in den Küstenebenen verwendet. Das Stroh wird in ca. 20 cm dicke Bündel gebunden und über einem 60° geneigten Rundholzrahmen befestigt. Die Befestigung sowohl der Rundhölzer als auch der Strohbündel erfolgt mittels einer natürlichen Weinrebe (mecate), die zuvor in Wasser eingeweicht wird, um durch die Schrumpfung beim Trocknen ein Festziehen der Knoten zu erreichen.
  Die 60° Dachneigung bildet einen großen Freiraum unter dem Dach innerhalb des Hauses, was zur Kühlung der Raumtemperatur beiträgt. Durch die starke Neigung kann Wasser schneller abfließen; dadurch wird die Möglichkeit der Leckbildung vermindert.
  Häuser dieses Typs werden sehr oft in Dörfern gebaut, und zwar vom Hausbesitzer selbst, was oft mit Hilfe von Freunden und Nachbarn geschieht. Das Binden des Strohs erfordert einiges handwerkliches Geschick, und nicht alle Dorfbewohner sind in der Lage, diese Arbeit auszuführen. Deshalb muß wenigstens eine Person mit dieser Fähigkeit im Bau-Team integriert sein.

- Tonziegel.
  Tonziegeldächer werden sehr häufig bei Häusern aus Adobe-Blöcken verwendet, in geringerem Ausmaß bei Zementblock-, Ziegel-, Holz- oder "bajareque"-Häusern. Häuser dieses Typs findet man vorwiegend in den meisten kleinen Städten in zentralamerikanischen Hochlandebenen (ausgenommen Costa Rica) und bei größeren Farmen. Sie können vom Hausbesitzer selbst oder auch von einem Bauunternehmer gebaut werden.
  Der Tonziegel wird normalerweise über einer Rahmenstützkonstruktion angebracht, obwohl gelegentlich eine flache Holzschalung aus 1" Pinienbrettern als Unterlage für die Ziegel verwendet wird.
  Bei der typischeren Dachkonstruktionsmethode dient ein Pinienholzrahmen aus 3" x 4"-Trauf- und Firstbalken und 2" x 3" (5,08 x 7,62 cm)-Sparren als Unterbau für die Ziegel. Der Freiraum zwischen den Sparren ist ebenso groß wie das schmalere Ende des Tonziegels.
  Der Rahmen wird zuerst mit einer Lage Ziegel mit nach oben gerichteten Seitenaufkantungen gedeckt; danach wird eine zweite Lage andersherum aufgelegt, wobei die Fugen der ersten Lage überdeckt und die unteren Ziegel mindestens

5.2.2 Typical Examples of Existing Traditional and Proprietary Roofs

Construction Methods

- Thatched Roofs.
  Although some thatched roofs are found on homes constructed with adobe, stone or brick walls, the majority are used in conjunction with the "bajareque" system of wall construction, a method dating back to the Mayan civilization which flourished in Central America long before the arrival of the Spanish "conquistadores". In this type of construction forked tree trunks or branches are used as roof support columns, with a wall framework formed of poles or canes tied together and installed in the spaces between columns. This framework is usually filled with compacted earth and is sometimes painted with a lime slurry.
  Straw is used for thatching in highland regions, and palm leaves on the coastal plains. The thatch is formed into bundles about 20 cm wide, and is tied in place over a pole framework installed with a pitch of 60°. Tying of both the pole frame members and the thatch bundles is accomplished using a natural vine (mecate) which is soaked in water beforehand to permit shrinkage to tighten the knots.
  The 60° pitch results in a large open space under the roof in the interior of the house which aids in maintaining a cooler inside temperature. The extreme slope also sheds water more rapidly minimizing the possibility of leaks.
  Homes of this type are constructed most frequently in rural villages and usually are built by the homeowner himself, often with the aid of friends and neighbors. The tying of the thatch requires some specialized manual skill, and not all village inhabitants are capable of performing this task; therefore, at least one person skilled in this art must be included in the construction team.

- Clay Tile.
  Clay tile roofs are used most frequently on homes with an adobe block wall construction, and to a much lesser extent with cement block, brick, wood or "bajareque". Homes of this type predominate in most small towns in the Central American highlands (except Costa Rica) and on the larger farms. They may be built by the homeowner or by a professional building contractor.
  The clay tile usually is installed over a frame support structure, although occasionally a flat wooden surface of 1" pine planks is used as a base for the tile.
  In the more typical roof construction method, a pine lumber frame is built consisting of 3" by 4" beams which form the edges and ridge, and 2" x 3" (5.08 x 7.62 cm) members running from the ridge to the lower edge of the roof, which support the tile. The free space between these supports is equal to the minor width of the truncated clay tile.
  The frame is first covered with a layer of tiles with curved ends up; a second layer is then set in place with curved ends down, covering the joints of the first layer and overlapping the bottom tiles by at least 7.5 cm. Only the first course

Abb. 5.12 Typisches traditionelles Strohdach aus Palmenblättern.
Fig. 5.12 Typical traditional thatched roof of palm leaves.

7,5 cm überlappt werden. Nur die erste Ziegelreihe am unteren Ende des Daches wird mit Kalkmörtel befestigt, um ein Herabgleiten zu verhindern; alle anderen Ziegel werden ohne Mörtel verlegt.
Durch diese Art der Dacheindeckung entstehen Zwischenräume zwischen den Ziegeln; dadurch wird genügend Luftzirkulation ermöglicht, um Kondenswasserprobleme zu vermindern und ein kühleres Innenraumklima zu schaffen.

- Verzinkter Stahl.
  Wie im vorhergehenden Abschnitt erwähnt, ist verzinkter Stahl gegenwärtig das wichtigste Dachdeckungsmaterial in Costa Rica, und es scheint auch in anderen zentralamerikanischen Ländern an Beliebtheit zu gewinnen. In diesen letzteren Ländern wurde es lange Zeit für Dächer auf temporären oder ständigen Hütten in

of tiles at the lower edge of the roof is fixed in place with lime mortar to prevent slippage; all other tiles are laid without mortar.
This type of installation leaves open spaces between the tiles which allow the circulation of air, producing enough ventilation to minimize condensation problems and to maintain a cooler interior temperature in the home.

- Galvanized Steel.
  As indicated in the previous section, galvanized steel currently is the principal roofing material used in Costa Rica, and appears to be gaining popularity in the other Central American nations. In these latter countries, it has long been used for roofs on temporary or permanent shacks built in urban slums and squatter settlements, but now is found also in rural areas where it is starting to substitute the

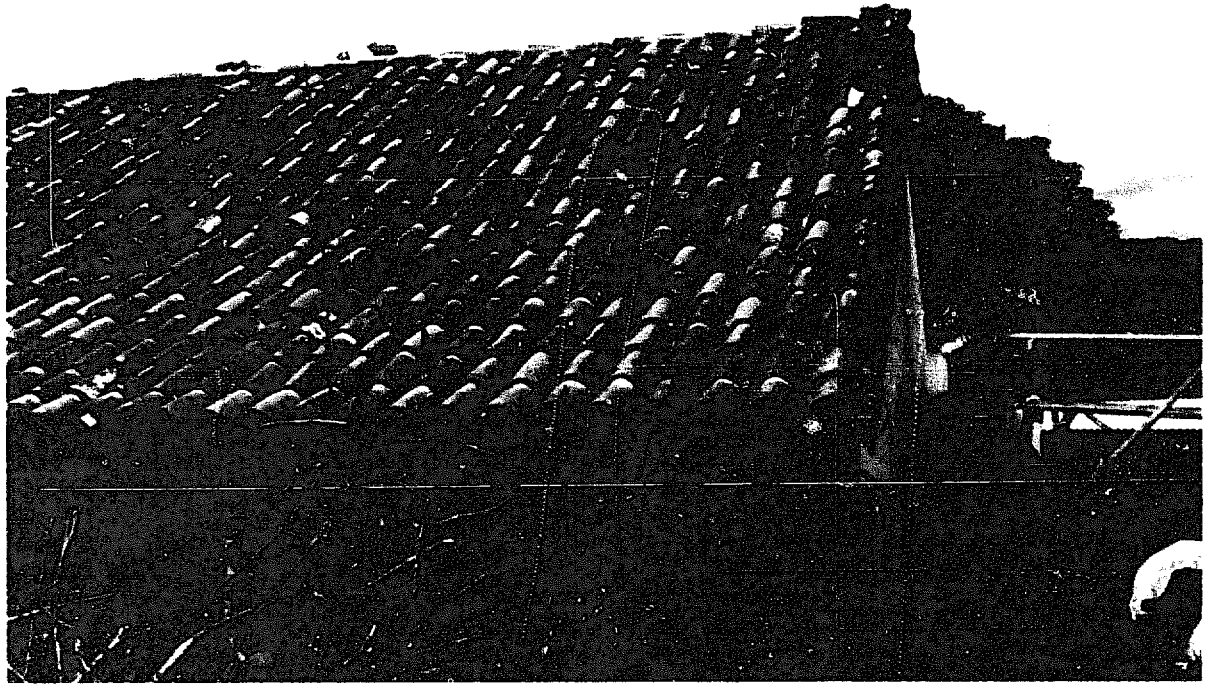

Abb. 5.13 Traditionelles Tonziegeldach (Mönch- und Nonnendeckung).
Fig. 5.13 Traditional clay tile roofing (Spanish type).

städtischen Slums und Squattersiedlungen verwendet, aber nun findet man es auch in ländlichen Gegenden wo es beginnt, die traditionellen Tonziegel- und Strohdächer zu verdrängen. Diese Tendenz ist am offensichtlichsten in Guatemala, wo die Angst vor Erdbeben die Beliebtheit des Tonziegeldaches zu dämpfen scheint. Verzinkte Stahlplatten sind leicht zu montieren und werden meist von "do-it-yourself"-Hausbauern verwendet. Dieses Material wird normalerweise über einem 2" x 4" (5,08 x 10,16 cm) Pinienholzrahmen mit einer Neigung von 20 - 25% befestigt.
Die verzinkten Wellblechplatten werden mit einer Längsüberlappung von 20 cm und einer seitlichen Überlappung entsprechend 1 1/2 Wellungen verlegt. Sie werden an den Ecken auf die Unterbauten genagelt und bei jeder dritten Welle in 30 cm Längsabständen mit großköpfigen verzinkten Nägeln.

traditional clay tile and thatch roofs. This tendency is most evident in Guatemala where fear of earthquakes may be dimming the popularity of the clay tile roof. Galvanized steel sheets are easily installed and are used most frequently by the "do-it-yourself" home builder. This material is normally installed over a 2" x 4" (5.08 x 10.16 cm) pine lumber frame with a pitch of 20 to 25%.
The corrugated galvanized sheets are laid with a longitudinal overlap of 20 cm and a lateral overlap equivalent to 1 1/2 corrugations. They are nailed to the supports at the edges and every third corrugation at 30 cm langitudinal intervals, using galvanized nails with large heads.

Abb. 5.14 Verzinktes Wellblechdach.
Fig. 5.14 Corrugated galvanized iron roof.

- Asbestzement.
  Wie bereits in vorangegangenen Abschnitten dieses Berichtes erwähnt, bieten die Asbestzementhersteller sowohl einfaches Wellasbest als auch Trogplattendeckung (canaleta) an, welche eine kompliziertere Profilierung hat. Die Wellplatten werden vom privaten Hausbauer bevorzugt, während die Trogplattendeckung, die weniger Holzstützen erfordert, das Hauptmaterial für Low-Cost-Housing-Projekte ist, die von öffentlichen Trägern durchgeführt werden.
  Die Wellasbestplatten werden über einem 2" x 4" (5,08 x 10,16 cm) Holzrahmen befestigt, der dem für die Dachdeckung mit verzinktem Blech ähnelt. Die seitliche Überlappung der Platten sollte ca. 1 Welle betragen, und die Längsüberlappung 15 cm. Der größte Abstand zwischen den Holzlatten ist 1,10 m für 5 mm dicke Asbestzementplatten, und 1,47 m für 6 mm dicke. Die Platten werden mit Nägeln oder Schrauben an den Latten befestigt, die Nagellöcher müssen vorher sorgfältig vorgebohrt werden.
  Die Trogplattendeckung kann Weiten bis zu 7 m ohne Zwischenauflager überspannen. Sie wird mit Nägeln oder Schrauben an den Mauerabschlußbalken befestigt; das Zusammenfügen der Platten erfolgt mittels Bolzen, Schraubenmuttern und Blei-, Zink- oder Asphalt-Unterlegscheiben.

- Stahlbeton.
  Stahlbetondächer werden bei höher standardisierten Privathäusern in ganz Zentralamerika angewendet, ebenso bei öffentlichen und Verwaltungsgebäuden. Dieser

Abb. 5.15 Asbestzement-Dach.
Fig. 5.15 Asbestos cement roof.

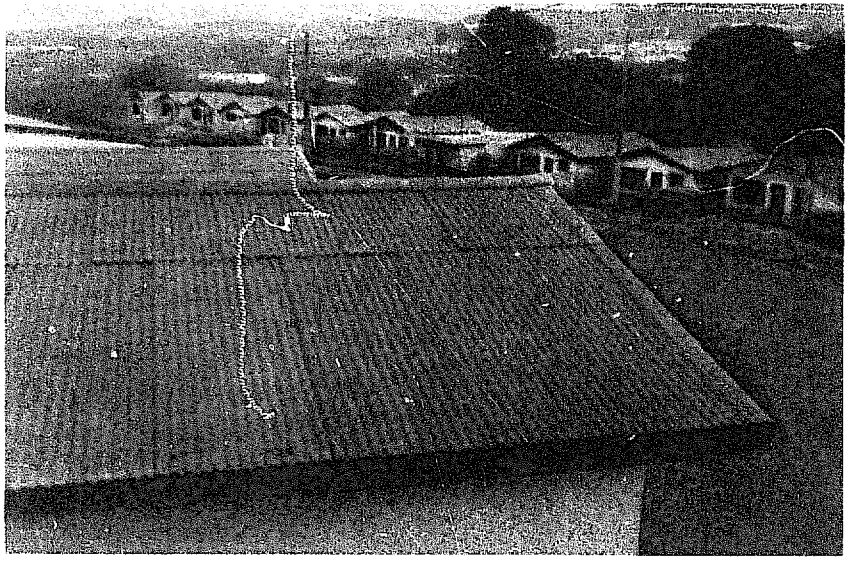

- Asbestos-cement.
  As mentioned in previous sections of this report, the asbestos-cement manufacturers offer both simple corrugated sheets and channel roofing (canaleta) which has a more complex section configuration. The corrugated sheets are preferred by the private home builder, while the channel roofing, which requires fewer wooden supports, is the principal material used by public institutions active in the low cost housing field.
  The corrugated asbestos-cement sheets are installed over a 2" x 4" (5.08 x 10.16 cm) wooden frame, similar to that used for galvanized steel. The lateral overlap between sheets should be about 1 corrugation, and the longitudinal overlap, 15cm. The maximum spacing between the wooden supports is 1.10 m for the 5 mm thick asbestos-cement sheets, and 1.47 for the 6 mm. The sheets are fastened to the supports with nails or screws, with all nailholes carefully perforated beforehand. The channel roofing can span distances up to 7 m without intermediate supports. It is fastened to the wall frame beams with nails or screws; the joining of sheets is accomplished with special bolts, nuts and lead, zinc or asphalt washers.

- Reinforced Concrete.
  Reinforced concrete roofs are used on higher priced private homes throughout Central America, as well as on public and commercial buildings. A professional building contractor usually constructs this type of roof.
  The construction procedure starts with the preparation of a pine lumber platform

Abb. 5.16 Stahlbeton-Dach.
Fig. 5.16 Reinforced concrete roof.

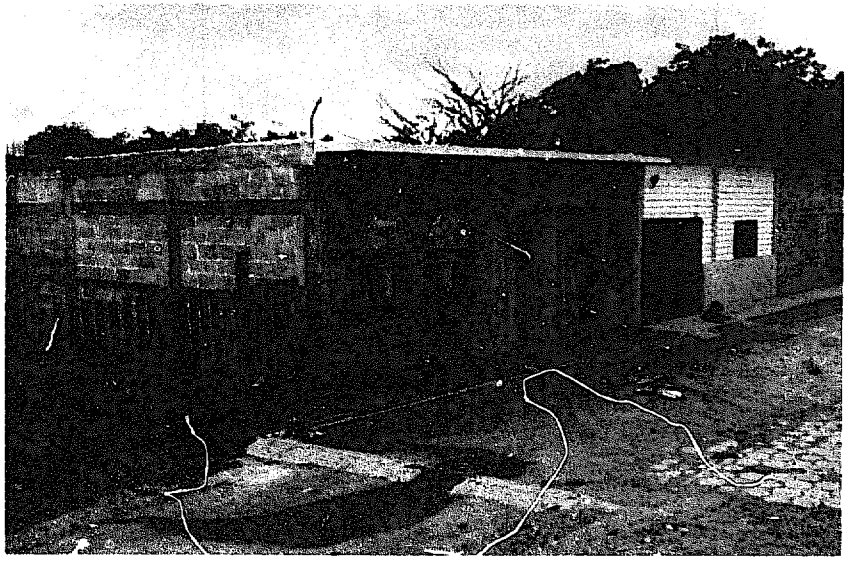

Dachtyp wird normalerweise von professionellen Bauunternehmern gebaut.
Die Gußform für das Betondach besteht aus einer Pinienholzschalung auf senkrechten Stützen. Ein Gitter aus Bewehrungsstahl, dessen Verbindungen mit Draht zusammengebunden werden, wird vorbereitet und in die Schalung gelegt. Das Gitter wird mit kleinen Steinen unterlegt, um einen Abstand von einigen Zentimetern zwischen dem Stahl und der Schalung zu erhalten.
Obwohl vorgemischter Beton in einigen der größeren Städte erhältlich ist, wird Beton normalerweise von Hand hergestellt (1 Teil Zement, 2 Teile Sand und 4 Teile Kies) und von Hand mit Eimern in die Form gegossen. Es stehen genügend Arbeitskräfte zur Verfügung, um das Dach in einem Tag fertigzustellen.
Das gegossene Betondach wird eine Woche lang täglich befeuchtet, und die Form wird normalerweise nach 15 Tagen entfernt. Zu diesem Zeitpunkt werden temporäre senkrechte Stützen angebracht und später, nach 28 Tage langer Erhärtung des Betons, wieder entfernt.

Kostenvergleiche

In der nachstehenden Tabelle werden vergleichbare Kosten für verzinkten Stahl, Asbestzement, Tonziegel- und Stahlbetondächer sowie Gesamtbaukosten unter Berücksichtigung verschiedener Wandbaumaterialien gezeigt. Diese Zahlen beinhalten Material und Lohn und wurden von öffentlichen Institutionen aufgestellt, die sich mit dem öffentlichen Wohnungsbau in Guatemala befassen (1).
Es existieren keine Kostenangaben über Strohdächer auf Bajareque-Wandkonstruktionen, da diese je nach Bauweise des Selbstbauers sehr unterschiedlich sind. Jedoch zeigen einige Kostenschätzungen, die auf diesem Gebiet in Guatemala durchgeführt wurden, daß die durchschnittlichen Gesamtbaukosten etwa $ 4,00/m² betragen können, wobei der Anteil für das Dach 50% ist.

Wohnungsbaukosten in Guatemala

Dachtyp	Wandkonstruktion	Gesamtbaukosten $/m²	Gesamtkosten Dach $/m²	% der Gesamtkosten
verzinktes Stahlblech	Zementblock	50.00	14.00	28
	Ziegel	70.00	14.00	20
	Adobe	40.00	14.00	35
Asbestzement	Zementblock	60.00	16.00	26
	Ziegel	90.00	16.00	18
	Adobe	45.00	16.00	36
Tonziegel	Zementblock	90.00	22.00	24
	Adobe	60.00	22.00	37
Stahlbeton	Zementblock	120.00	27.00	23
	Ziegel	160.00	27.00	17

(1) Banco Nacional de la Vivienda (BANVI). Banco Nacional de Desarrollo Agrícola (BANDESA).

with vertical supports which serves as the form for pouring the concrete roof. A grid of reinforcing rod with joints tied by wire is then prepared and placed over the platform. The grid is supported by small stones in order to leave a gap of several centimeters between the reinforcement and the platform surface.
Although pre-mixed concrete is available in some of the larger cities, concrete usually is mixed by hand (1 part cement, 2 parts sand and 4 of gravel) and manually poured into the form with buckets. Sufficient labor is provided to complete The poured concrete roof is moistened daily for one week, and the form is usually removed after 15 days. Temporary vertical supports are installed at this time and later removed after the concrete has been cured for 28 days.

Comparative Costs

In the following table, comparative costs are shown for galvanized steel, asbestos-cement, clay tile and reinforced concrete roofs, as well as total housing construction costs considering different wall materials. These figures include both material and labor costs, and were compiled by national institutions active in the public housing field in Guatemala (1).
Costs are not given for the thatched roof-bajareque wall construction, since these are extremely variable depending upon the procedures followed by the owner in the construction of his home. However, some estimates made in the field in Guatemala indicate that the average total construction cost may be about $ 4.00 /m² with the roof accounting for 50% of the total.

Housing Construction Costs in Guatemala

Roof Type	Wall Construction	Total Construction Cost $/m²	Total Cost Roof $/m²	% of Total Cost
Galvanized steel	Cement block	50.00	14.00	28
	Brick	70.00	14.00	20
	Adobe	40.00	14.00	35
Asbestos-cement	Cement block	60.00	16.00	26
	Brick	90.00	16.00	18
	Adobe	45.00	16.00	36
Clay tiles	Cement block	90.00	22.00	24
	Adobe	60.00	22.00	37
Reinforced concrete	Cement block	120.00	27.00	23
	Brick	160.00	27.00	17

(1) Banco Nacional de la Vivienda (BANVI). Banco Nacional de Desarrollo Agrícola (BANDESA).

5.2.3 Neue Entwicklungen

Die nachstehenden neuen Entwicklungen auf dem Gebiet der Dachkonstruktion in Zentralamerika wurden während örtlicher Untersuchungen durch ICAITI-Personal festgestellt.

- In Costa Rica wurde kürzlich ein neues industriell gefertigtes Dachdeckungsmaterial, bestehend aus asphalt-imprägniertem Karton in Form von Wellplatten, auf den örtlichen Markt gebracht.
- Ebenfalls in Costa Rica betreibt eine andere private Firma die Herstellung von Welldachplatten aus einer Mischung von Zement und gemahlenem Stein.
- In Guatemala macht das Engineering Department der National University Experimente mit Ferrozement-Dachelementen.
- Ebenfalls in Guatemala hat der dort ansässige Asbestzement-Hersteller ein neues Asbestzement-Dachpaneel entwickelt, das das Aussehen des Tondachziegels imitieren soll.
- In Honduras wurden Feldexperimente durchgeführt, um die ländliche Produktion von Zement-Faser-Wellplatten auszuwerten.

Asphalt-Karton-Paneele

Dieses in Costa Rica hergestellte Produkt wird örtlich unter dem Namen SUPERFLEX hergestellt. Es besteht offensichtlich aus Pappkarton oder ähnlichem mit Asphalt im-

5.2.3 New Developments

The following new developments in roofing in Central America were observed during the regional investigation by ICAITI personnel.

- In Costa Rica, a new manufactured roofing material, consisting of asphalt-impregnated cardboard formed into corrugated panels, has been recently introduced in the local market.
- Also in Costa Rica, another private industry is initiating the manufacture of corrugated roofing panels using a mixture of cement and crushed stone.
- In Guatemala, the Engineering Department of the National University is experimenting with ferrocement roofing elements.
- Also in Guatemala, the local asbestos-cement manufacturer has developed a new asbestos-cement roofing panel designed to simulate the appearance of clay tile.
- In Honduras, field experiments have been initiated to evaluate rural production of cement-fibre corrugated panels.

Asphalt-cardboard Panels

This product manufactured in Costa Rica is being sold locally under the brand name SUPERFLEX. It apparently consists of cardboard or similar material impregnated with

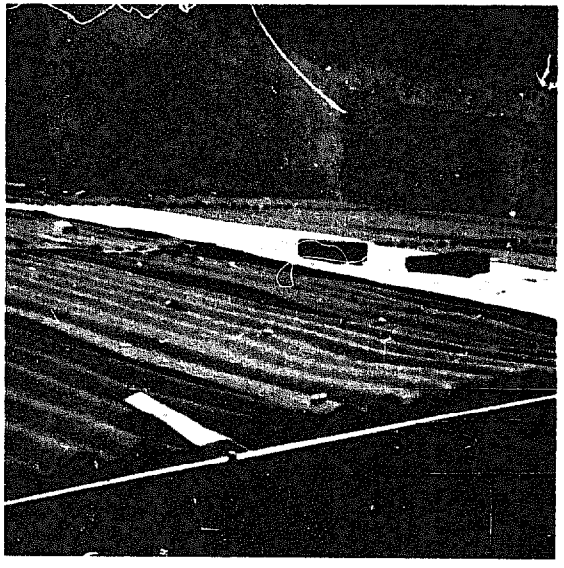

Abb. 5.17 Bitumen-Wellplatten mit schlechten Eigenschaften aufgrund von Materialschwäche (Costa Rica).

Fig. 5.17 Corrugated asphalt-based sheets, showing poor performance due to weak material (Costa Rica).

Abb. 5.18 Asbestzementplatten als Imitation von traditionellen Tonziegeln (Guatemala).

Fig. 5.18 Asbestos cement sheets simulating traditional clay tiles (Guatemala).

Abb. 5.19 Unkonventionelle Verwendung von Asbestzement-Trogplatten (canaletas), (Guatemala).

Fig. 5.19 Unconventional use of asbestos cement troughed sheets (canaletas), (Guatemala).

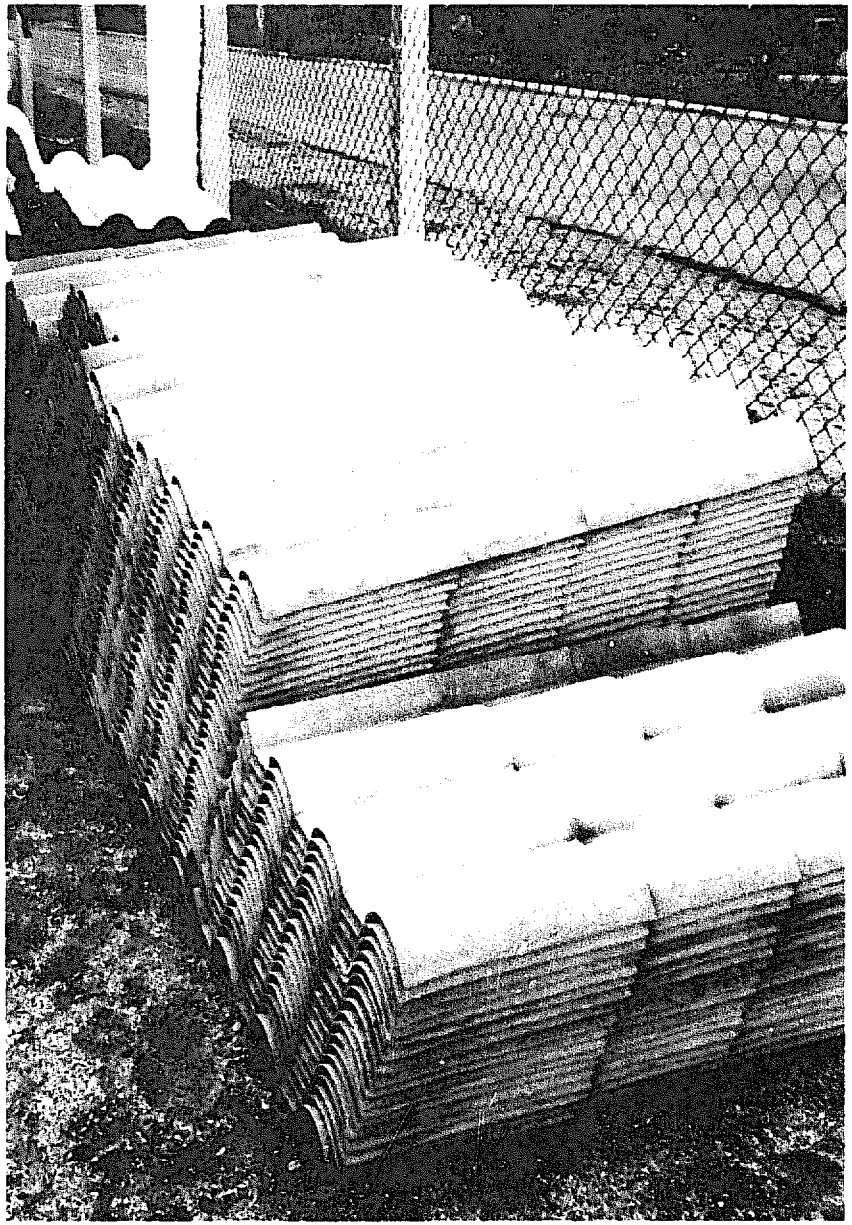

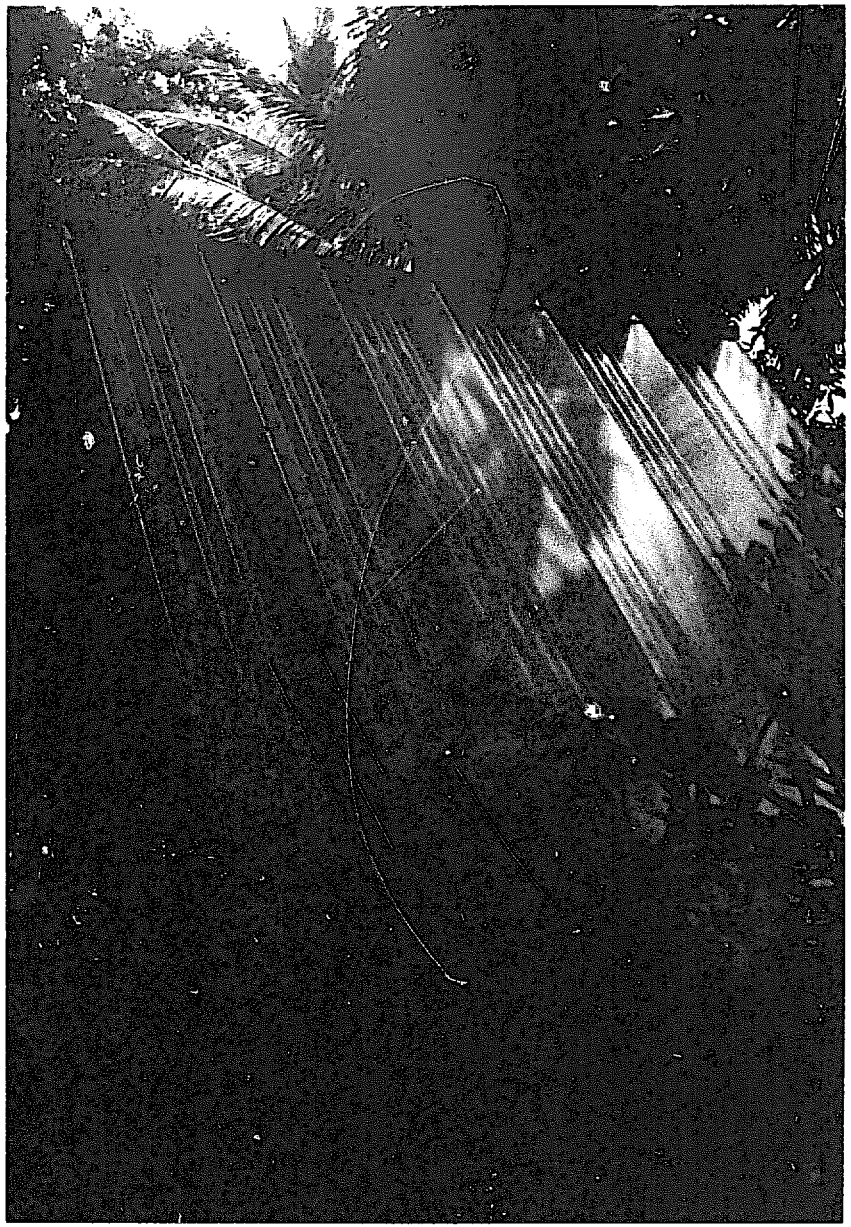

prägniertem Material und wird in drei Farben angeboten: Schwarz, Rot und Silber. Die Paneele sind gewellt und haben ähnliche Abmessungen wie die verzinkten Stahlbleche. Das Gewicht ist ungefähr 4 kg/m^2, und das Material kann genauso wie verzinkter Stahl installiert werden.
Der Preis ist niedriger als der des Konkurrenzproduktes (₡ 1,50/m^2), und das neue Material hat einige Beliebtheit gewonnen, besonders in Küstenregionen, wo das Rosten der verzinkten Stahldächer ein Problem ist. Da es jedoch Sonne und Regen ausgesetzt ist, weicht das Material auf, so daß die Wellen sich verflachen und verwinden. Außerdem ist das Material nicht feuerfest. Aufgrund dieser Nachteile wurde der Gebrauch des neuen Materials vom National Housing Institute eingestellt.

Zement-Stein-Dachdeckung

Eine weitere private Firma in Costa Rica entwickelt eine Wellplattendeckung, TECON, welche angeblich aus Zement und pulverisierten Steinen hergestellt ist, ohne irgendein weiteres Verstärkungsmaterial. Einige Vortests dieses Produkts durch das Material Laboratory des Costa Rica Housing Institute haben vielversprechende Ergebnisse gezeigt. Jedoch glauben Fachleute, daß das überhohe Materialgewicht, das 37 kg/m^2 betragen kann, dessen Anwendungsgebiet sehr begrenzen wird.

Ferrozement

Das Engineering Department der University of San Carlos in Guatemala hat in verschiedenen Anwendungsbereichen von Ferrozement Untersuchungen angestellt. Eine davon ist ein gebogenes Dachelement, ca. 2 m breit, mit einer Spannweite von über 3 m ohne Zwischenstützen, hauptsächlich für low-cost-Häuser mit Zementblock-Wänden. Das Material besteht aus 1 Teil Zement und 2 Teilen zermahlenem Bimsstein, mit zwei Lagen 22er Maschendraht verstärkt. Die Stärke ist ca. 2,5 cm.

Neues Asbestzement-Produkt

Vom guatemaltekischen Asbestzement-Hersteller wurde ein neues Produkt auf dem örtlichen Markt eingeführt. Es ist ein Dachdeckungspaneel (0,745 x 1,18 m) mit abwechselnd flacher und konvex geformter Oberfläche, entsprechend den Abmessungen der Tonziegeldeckung. Das Gewicht ist ca. 12,5 kg/m^2, und die Paneele werden auf einer Holzunterkonstruktion genau wie die herkömmlichen Asbestzement-Platten angebracht.
Der augenblickliche Preis beträgt 8.19 ₡/m^2. Der Hersteller bietet ebenfalls rote Farbe zu einem Preis von 9.80 ₡/Gallone (ca. 3,8 dm^3) an, so daß der Hausbesitzer damit ein Dach erhält, das dem Lehmziegeldach sehr ähnlich sieht. Unter Berücksichtigung von zwei Schichten Farbe entstehen Materialkosten von 8.97 ₡/m^2.

Zement-Faser-Wellplatten

In Honduras werden von A.I.D. unterstützte Feldversuche durchgeführt mit Zement-Faser-Wellplatten, welche mit einfacher Ausrüstung in den Dörfern hergestellt werden. Die Technologie ist ähnlich derjenigen, die vom Intermediate Technology Materials Workshop of the J.P.M. Penny & Associates Ltd. in England entwickelt wurde (s.4.2.2).

asphalt, and is offered in three colors: black, red and silver. The panels are corrugated and have overall dimensions similar to those of galvanized steel sheets. The weight is approximately 4 kg/m^2, and the material can be installed in the same manner as galvanized steel.
The price is lower than the competitive product (₡ 1.50/m^2), and the new material has gained some public acceptance, especially in coastal areas where rusting of the galvanized steel roofs is a problem. The effect of exposure to sun and rain, however, tends to cause flattening and distortion of the corrugations. Also, the material lacks fire resistance. Due to these deficiencies, use of the new material by the National Housing Institute has been discontinued.

Cement-stone Roofing

Another private industry in Costa Rica is developing a corrugated roofing panel, TECON, which reportedly is made of cement and pulverized stone without any other type of reinforcement. Some preliminary testing of this product conducted by the Materials Laboratory of Costa Rica's Housing Institute has shown some promising results; however, Institute personnel feel that the material's excessive weight, which may be as high as 37 kg/m^2, will greatly limit its field of application.

Ferrocement

The Engineering Department of the University of San Carlos in Guatemala has been conducting experiments on various ferrocement applications. One of these is a curved roofing element, about 2 m wide, designed to cover a 3 m span without intermediate supports, principally for low cost home with cement block wall construction. The material consists of 1 part cement to 2 parts crushed pumice reinforced with 2 layers of 22 gauge wire mesh. The thickness is approximately 2.5 cm.

New Asbestos-cement Product

A new product has been introduced in the lokal market by the Guatemalan asbestos-cement manufacturer. This is a roofing panel (0.745 x 1.18 m) especially formed with convex curved surface undulations which duplicate the dimensions of clay tile. The weight is about 12.5 kg/m^2, and the product is installed over a wooden frame in the same manner as conventional asbestos-cement sheets.
The current price is ₡ 8.19/m^2. The manufacturer also offers red paint at a price of ₡ 9.80/gallon so the homeowner can obtain a roof which more closely resembles clay tile. Considering the use of two coats of paint, this would increase the total material cost per square meter to ₡ 8.97.

Cement-fibre

In Honduras, field testing sponsored by AID has been initiated with cement-fibre corrugated roofing panels which are fabricated with simple equipment in rural villages. The technology used is similar to that developed by the Intermediate Technology Materials Workshop of the J.P.M. Parry & Associates Ltd., in England (see 4.2.2).

6. MÖGLICHE NEUENTWICKLUNGEN FÜR ZENTRALAMERIKA

6.1 Auswahl von Materialien für Vortests

Wie in vorhergehenden Abschnitten dieses Reports erwähnt, machen drei Typen von Dachdeckungssystemen über 90% aller Hausdächer in Zentralamerika aus. Diese schließen traditionelle Materialien (Tondachziegel und Stroh) und industriell hergestelltes verzinktes Stahlblech ein. Die Beliebtheit der traditionellen Dachdeckungssysteme scheint jedoch abzunehmen, möglicherweise aus folgenden Gründen:

- Das Strohdach, das hauptsächlich wegen seiner niedrigen Kosten Verwendung findet, wird von den örtlichen Einwohnern als weniger wünschenswert angesehen als andere Alternativen, was hauptsächlich seiner Neigung zur Insekten- und Ungeziefer-Einnistung zuzuschreiben ist. Auch erfordert seine Anbringung einiges handwerkliches Geschick, und es scheint, als ob in jeder folgenden Generation immer weniger Leute in der Loge seien, diese Arbeit auszuführen.
- Obwohl die Erscheinungsform des Tonziegeldoches von der örtlichen Bevölkerung geschätzt wird, ist dieses System wegen der kürzlichen Kostenerhöhung für Tonziegel für viele der Armen auf dem Lande viel zu teuer. Außerdem hat sich dieses Material bei Erdbeben als gefährlich erwiesen.

Das Dach aus verzinktem Stahl, das immer mehr die traditionellen Systeme ersetzt, ist die billigste zur Verfügung stehende Alternative, obwohl sogar dieser Preis für einige Landbewohner zu hoch ist, die weiterhin die Strohdachdeckung ausführen. Diese Dachdeckungsart ist aufgrund ihrer bereits in diesem Report erwähnten Unzulänglichkeiten weit davon entfernt, optimal zu sein, und ihr hoher Anwendungsfaktor zeigt nur, daß es keine andere gleichwertige Alternative gibt.

Aufgrund der oben beschriebenen Situation wurde beschlossen, eine Reihe von Voruntersuchungen durchzuführen, um die Möglichkeiten zur Entwicklung alternativer Dachdeckungssysteme auszuwerten, welche vom "do-it-yourself"-Bauherrn mit niedrigem Einkommen angewandt werden könnten, der gegenwärtig entweder verzinkten Stahl oder herkömmliche Dachdeckungsmaterialien verwendet. Um erfolgreich zu sein, sollte ein neues Dachdeckungssystem dieser Art einfacher anzubringen sein als Stroh, billiger als verzinkter Stahl, frei von Insekten- oder Ungezieferbefall, bedeutend geringeres Gewicht haben als Tondachziegel und bei Erdbeben keine Gefahrenquelle bieten.

Auch muß das Dachdeckungssystem angemessene Stabilität und Lebensdauer besitzen und sollte so weit wie möglich mit den Eigenschaften eines idealen Daches übereinstimmen, die in Abschnitt 7.2 dieses Reports angeführt sind. Um von der Bevölkerung besser akzeptiert zu werden, sollte es wie ein Wellblech- oder Tonziegeldach aussehen und, da dieses Projekt hauptsächlich auf die arme Landbevölkerung abgestimmt ist, sollten Materialien verwendet werden, die entweder auf dem Feld aufgesammelt oder einfach auf den örtlichen Märkten gekauft werden können.

In Anbetracht der oben genannten Kriterien wurde beschlossen, mit den folgenden Materialien zu experimentieren:

6. POSSIBLE NEW APPLICATIONS FOR CENTRAL AMERICA

6.1 Selection of Materials for Preliminary Testing

As indicated in previous sections of this report, three types of roofing systems account for over 90% of all house roofs in Central America. These include the traditional materials (clay tile and thatch) and industrially manufactured galvanized steel sheets. The popularity of the traditional roofing systems, however, appears to be diminishing, possibly due to the following reasons:

- The thatched roof, used principally because of its low cost, is considered less desirable than other alternatives by local inhabitants, due mainly to its tendency to become infested with insects and rodents. Also, its installation requires some manual skill, and it appears that fewer people in each succeeding generation are capable of performing this task.
- Although the appearance of the clay tile roof is esteemed by the local population, recent clay tile cost increases have resulted in this system being far too expensive for many of the rural poor. In addition, this material has been proven hazardous during earthquakes.

The galvanized steel roof which is tending to substitute the traditional systems is the lowest cost available alternative, although even this cost is too high for some rural inhabitants who continue to use thatch. This type of roofing system, due to the deficiencies discussed previously in this report, is far from optimum, and its high usage in Central America may simply reflect the lack of any other alternative.

In view of the above, it was decided to conduct a series of preliminary tests designed to evaluate the possibilities for developing alternative roofing systems which could be used by the low income "do-it-yourself" home builder, who currently uses either galvanized steel or traditional roofing materials. To be successful, a new roofing system of this type should be simpler to install than thatch, lower cost than galvanized steel, free from insect or rodent infestation, significantly lighter weight than clay tile and should present no earthquake hazard.

Also, the roofing system must have adequate strength and life, and should conform as much as possible with the characteristics of an ideal roof, which are listed in Section 7.2 of this report. Its appearance should tend to simulate the clay tile roof for better acceptability by the local population and, since this project is oriented principally towards the rural poor, materials should be used which can either be gathered in the field or easily purchased in local markets.

Taking the above criteria into consideration, it was decided to experiment with the following materials:

A. Hauptmaterial.
Mit Kalk stabilisierte Erde und mit Bims oder Sand vermischter Zement wurden als hauptsächlichste Dachdeckungsmaterialien ausgewählt, da sie in ganz Zentralamerika ohne weiteres verfügbar sind und bereits in der Bauindustrie Verwendung finden. Von den beiden Alternativen wäre stabilisierte Erde aus Kostengründen vorzuziehen, aber dieses Material ist bisher ausschließlich in Blöcken zum Bau von Wänden verwendet und noch nicht für die Anwendung als Dachdeckung ausgewertet worden. Zementmischungen könnten deshalb erforderlich werden, falls angemessene Festigkeiten mit stabilisierten Erden nicht erreicht werden können.

B. Bewehrungsmittel.
Die folgenden drei Materialarten wurden zur Verstärkung des Dachdeckungsmaterials in Betracht gezogen:

1. Natürliche Fasermaterialien, wie sie in vielen Gegenden Zentralamerikas vorzufinden sind, einschließlich Sisalfasern (die gegenwärtig zur örtlichen Herstellung von Säcken verwendet werden), Piniennadeln, Stroh und Kokosnußfasern.

2. Örtlich hergestellte Gewebe.
Jute- und Sisalsäcke, die in Zentralamerika hauptsächlich für Kaffeebohnen-Verpackung verwendet werden, und preiswerter Baumwollstoff, der in Guatemala hergestellt wird, wurden als Verstärkungsmaterialien ausgewertet.

A. Principal Material.
Lime-stabilized soil and cement mixed with pumice or sand were selected as the principal roof covering materials; since they are readily available throughout Central America and already are used in the construction industry. Of the two alternatives, stabilized soil would be preferable for cost reasons, but this material so far has been used exclusively in blocks for wall construction and has not been evaluated for roofing applications. Cement mixes, therefore, might be required in case adequate physical strength cannot be obtained with stabilized soil systems.

B. Reinforcement.
The following three types of materials were considered for reinforcement of the principal roof covering material:

1. Natural fibrous materials available in many areas in Central America, including sisal fibres currently used for the local manufacture of sacks, pine needles, straw and coconut fibres.

2. Locally produced fabrics.
Jute and sisal sacks used principally in Central America for coffee beans, and inexpensive cotton cloth produced in Guatemala were evaluated as reinforcing materials.

6.1

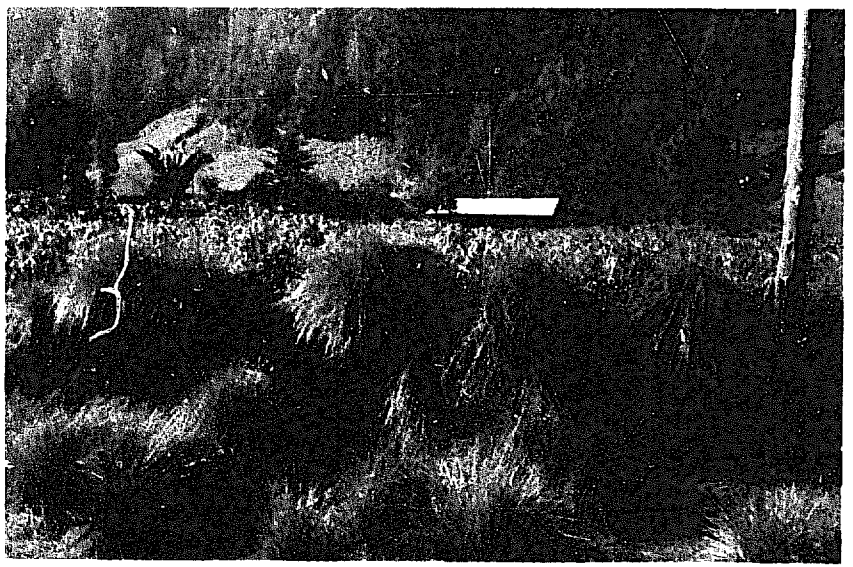

6.2

3. Maschendraht.
Draht wird in allen zentralamerikanischen Ländern produziert, und die gebräuchlichsten Drahterzeugnisse werden örtlich hergestellt. Hühnermaschendraht wurde als mögliches Verstärkungsmaterial in Betracht gezogen, jedoch als Alternative geringerer Priorität wegen seiner verhältnismäßig hohen Kosten.

C. Oberflächenschutz.
Als Oberflächenschutz für stabilisierte Erd-Dachdeckungen wurde sowohl Kalkanstrich als auch Bitumen in Erwägung gezogen. Da Kalk in den ländlichen Gebieten ganz Zentralamerikas hergestellt wird, sollte dieser Alternative, wenn sie erfolgreich ist, der Vorzug gegeben werden vor importierten Bitumenprodukten.

D. Unterkonstruktion.
Bei den Vorversuchen sollte der Gebrauch von teuren Pinienholz-Tragsystemen vermieden und die Möglichkeiten der Verwendung von Bambus oder bambusähnlichem Rohr, kombiniert mit örtlich hergestelltem Seil oder Schnur, untersucht werden. Zusätzlich zu dem Kostenvorteil für den Selbsthilfe-Hausbauer wurde angestrebt, die Unterkonstruktion so zu gestalten, daß die Dachdeckung eine Wellenform erhält und somit das Aussehen eines Wellplatten- oder Tonziegeldaches simuliert.

Die in diesen Experimenten ausgewerteten Materialien, die auf dem Feld (Hochland von Guatemala) kostenlos zur Verfügung standen, waren folgende:

Abb. 6.1 Caña de castilla, ein reichlich vorhandenes und leicht ersetzbares (schnell wachsendes) Rohmaterial.

Fig. 6.1 Caña de castilla, an abundant and easily renewable raw material.

Abb. 6.2 Pajón (Epicampes macroura).
Fig. 6.2 Pajón (Epicampes macroura).

Abb. 6.3 Erdprobe für Laborversuche, entnommen 50 cm unterhalb der Oberfläche, um Humus und organische Stoffe zu eliminieren.

Fig. 6.3 Soil samples for testing, taken from 50 cm below ground surface to eliminate humus and organic matter.

3. Wire mesh
Wire is drawn in all of the Central American countries, and most common wire products are produced locally. Chicken wire was considered as a possible reinforcing material, but as a low priority alternative due to its relatively high cost.

C. Surface Protection.
For surface protection of stabilized soil roof coverings, both lime slurry and bitumen were considered. Since lime is produced in rural areas throughout Central America, this alternative, if successful, would be preferable to the use of imported bituminous products.

D. Support System.
For the preliminary experiments, it was decided to avoid the use of high cost pine lumber support systems, and to concentrate efforts on the use of bamboo or bamboo-like canes combined with locally produced rope or twine. In addition to the cost advantage to the self-help home builder, it was felt that this type of support system could be designed in such a way as to give a corrugated effect of the roof covering, thereby tending to simulate the appearance of clay tile.

The materials evaluated in these experiments, which were obtained in the field (Guatemala highlands) without cost, were the following:

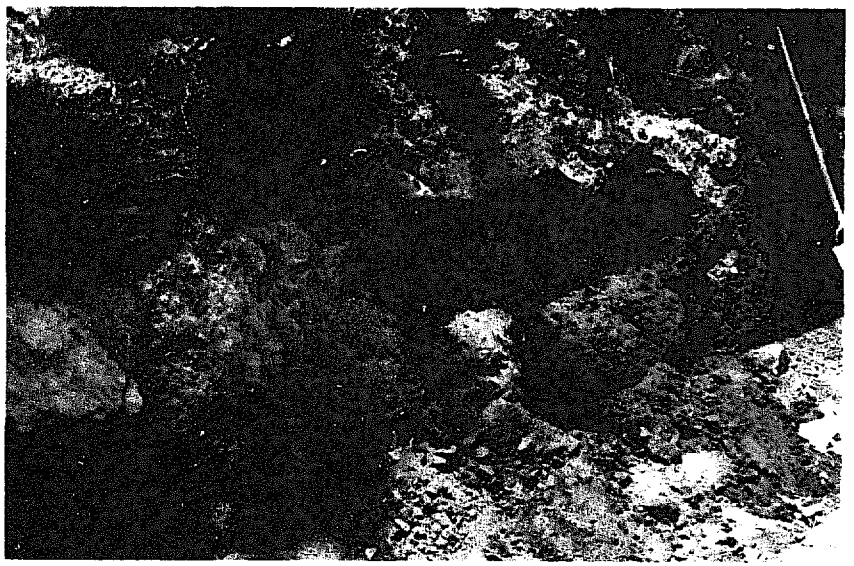

- Erde (verschiedene Proben aus verschiedenen Gegenden)
- Sand und gemahlener Bims
- Kokosnußfasern (von Schalen)
- Stroh (pajón)
- Piniennadein
- Bambus
- Caña de Castilla (bambusähnliches Rohr)

Nachstehend die gekauften Materialien und ihre Einheitspreise:

Material	Einheit	Einheitspreis
Portlandzement	kg	$ 0.08
Löschkalk	kg	$ 0.07
ungelöschter Kalk	kg	$ 0.05
Sisal- und Jute-Sackmaterial	m^2	$ 1.09
Baumwolltuch	m^2	$ 0.61
Hühnermaschendraht	m^2	$ 1.37
Seil	lfdm	$ 0.08
Bindfaden	lfdm	$ 0.01
Asphalt	Liter	$ 1.62
Verdünnungsmittel	Liter	$ 0.20

Es sollte erwähnt werden, daß zusätzlich zu den Experimenten mit den oben genannten Materialien, die im nächsten Abschnitt 6.2 erläutert werden, zu Beginn drei andere Versuche initiiert, später jedoch außer Erwägung gelassen wurden. Es folgt eine kurze Beschreibung:

1. Grasdach. (Siehe Abb. 6.14, Seite 134)
   Aus Bambusstützen, die mit Bindfaden zusammengebunden und mit Plastikfolie bedeckt waren, wurde ein kleines Prototyp-Dach gebaut. Eine Dachdeckung aus Baumwollsäcken, die mit Erde und Grassamen gefüllt waren, wurde dann über die Plastikfolie gelegt und am Stützrahmen festgebunden. Man hoffte, daß das Gras durch das Baumwollmaterial wachsen und schließlich eine homogene Masse bilden würde, die von dem Wurzelsystem der Gräser zusammengehalten wird. In der Praxis stellte sich heraus, daß, obwohl der Grassamen aufging und an einigen Stellen durch die Baumwollsäcke wuchs, weiteres Wachstum stagnierte und nicht ausreichte, den Rest des Daches zu bedecken. Auch erschien das Gewicht pro Flächeneinheit für dieses System extrem hoch. Der Versuch wurde als Mißerfolg angesehen, und weitere Arbeit auf diesem Gebiet wird nicht empfohlen.

2. Asphaltbestrichenes Stroh. (Siehe Abb. 6.10/6.11, Seite 133)
   Es wurde ein Prototyp-Dachsystem vorbereitet, das aus Stroh (pajón) bestand und auf welches Asphaltemulsion aufgebürstet wurde, und welches an eine Holz- und Hühnerdraht-Unterkonstruktion angebunden wurde. Dieses Experiment wurde durchgeführt, um die Möglichkeit der Verbesserung von bestehenden traditionellen Strohdächern zu untersuchen. Es stellte sich jedoch heraus, daß der für eine angemessene Oberflächenabdeckung benötigte Asphalt (ca. 1 Gallone/m^2) Materialkosten

- Soil (various samples from different areas)
- Sand and crushed pumice
- Coconut fibres (from husks)
- Straw (pajón)
- Pine needles
- Bamboo
- Caña de Castilla (bamboo-like cane)

The purchased materials and their unit costs were as follows:

Material	Unit	Cost/Unit
Portland cement	kg	$ 0.08
Hydrated lime	kg	$ 0.07
Quicklime	kg	$ 0.05
Sisal and jute sacking	m^2	$ 1.09
Cotton cloth	m^2	$ 0.61
Chicken wire	m^2	$ 1.37
Rope	lin.m	$ 0.08
Twine	lin.m	$ 0.01
Asphalt	liter	$ 1.62
Solvent	liter	$ 0.20

It should be mentioned that, in addition to the experiments with the above materials which are discussed in the next sub-section 6.2, three other trials were initiated early in the testing program, but were later dropped from consideration. A brief description of each follows:

1. Grass Roof. (See Fig. 6.14, page 134)
   A small prototype roof support system was constructed using bambao support members tied together with twine and covered with a polyethylene sheet. A roof covering consisting of cotton bags containing earth and grass seed was then placed over the plastic sheet and tied to the support frame. It was hoped that the grass would grow through the cotton fabric and eventually form a continuous mass held together by the grass root system. In practice, it was found that although the grass seed did germinate and grow through the cotton bags in some areas, later growth was stunted and did not propogate sufficiently to cover the rest of the roof. Also, the weight per unit area appeared excessive for this system.
   This trial was considered a failure and no further work in this area is recommended.

2. Asphalt-coated Thatch. (See Fig. 6.10/6.11, page 133)
   A prototype roof system was prepared consisting of thatch (pajón straw) brush-coated with asphalt emulsion, and tied to a wood and chicken wire support system. This experiment was conducted with a view towards evaluating the possibility of improving present traditional thatched roofs. However, it was found that the amount of asphalt required to obtain a reasonable surface covering (about 1 gallon/m^2) represented a material cost considerably greater than that required for a galvanized steel roof. This idea, therefore, was dropped for economic reasons.

verursachte, die beträchtlich über denjenigen für ein Dach aus verzinktem Stahl lagen. Diese Idee wurde deshalb aus wirtschaftlichen Gründen aufgegeben.

3. Chemische Imprägnierungszusätze. (Siehe Abb. 6.12/6.13, Seite 134)
Chemische Materialien (CONSERVEX und CONSOLID 444), die speziell für die Erdverfestigung von der Consolid AG, CH-9435 Heerbrugg S 6, Aechelistraße 18, Schweiz, hergestellt wurden, wurden zu Beginn des Programms als Zusätze für Dachdeckung aus stabilisierter Erde getestet. Zusatzmittelbeimengungen von einem Volumenteil CONSERVEX zu hundert und einem Volumenteil CONSOLID 444 zu tausend Volumenteilen Erd-Kalkmischung wurden gegen eine unbehandelte Erd-Kalkmischung getestet. Vom technischen Standpunkt waren die Ergebnisse recht vielversprechend, da die behandelte Probe gegenüber der unbehandelten bei den Laboruntersuchungen über Wasseraufnahme-Eigenschaften (35 ml/cm^2 gegen 45 für die Kontrolle) und ebenfalls, als es der Witterung ausgesetzt wurde, viel größere Widerstandsfähigkeit gegen Erosion aufwies.
Diese Chemikalien sind jedoch importierte Erzeugnisse und verhältnismäßig teuer (ca. 1.00 $/Liter CONSERVEX und 4.00 $/Liter CONSOLID 444). Sie werden wahrscheinlich hauptsächlich an öffentliche Bauträger und an private Baufirmen verkauft werden; ihre leichte Verfügbarkeit für den Landbewohner, der auf dem örtlichen Markt einkauft, ist zu bezweifeln. Deshalb wurde trotz der Vorteile der Chemikalien beschlossen, keine weiteren Experimente mit diesen Materialien durchzuführen, es sei denn, daß spätere Tests zeigen, daß ihre Anwendung von Bedeutung ist.

6.2 Vorbereitung und Erprobung von Prototyp - Bedachungssystemen

Wegen knapper Zeit und Ressourcen des vorliegenden Projektes konnten nur sehr unverbindliche Experimente durchgeführt werden. Das Ziel war, so viele Ideen und verschiedene Materialien wie möglich auszuprobieren, um diejenigen herauszukristallisieren, die zukünftige weitergehende Experimente rechtfertigen. Sowohl Testtafeln als auch komplexe Prototyp-Dachdeckungssysteme wurden von Hand gefertigt, unter Zuhilfenahme von nur wenigen einfachen Werkzeugen und Einrichtungen, um mehr mit den Methoden übereinzustimmen, die wahrscheinlich von einem Hausbauer mit niedrigem Einkommen in Zentralamerika angewendet werden.

6.2.1 Testtafeln

Für die erste Testserie wurden einfache Testtafeln angefertigt, um eine Auswertung der relativen Stärke von Kalk-stabilisierter Erde und Zement-Bims oder Zement-Sand-Mischungen zu ermöglichen und um eine Vor-Auswahl aus einer Anzahl möglicher Bewehrungsmaterialien zu treffen.

Die Tafeln (10 x 10 x 1,2 cm) wurden handgefertigt, indem mit einer Kelle die Mischung in eine Holzform gegeben und kompaktiert wurde. Erde, Sand und Bims wurden gesiebt, um Fremdmaterial zu entfernen; die trockenen Mischungszutaten wurden

3. Chemical Waterproofing Additives. (See Fig. 6.12/6.13, page 134)
Chemical materials (CONSERVEX and CONSOLID 444) manufactured especially for soil consolidation by Consolid AG, CH-9435 Heerbrugg S6, Aechelistraße 18, Switzerland, were tested early in the program as additives for stabilized soil roof coverings. One part per hundred by volume of CONSERVEX and one part per thousand of CONSOLID 444 were incorporated into a lime-stabilized soil sample and tested against an untreated control. From a technical standpoint results were quite promising, since the treated sample was superior to the control in laboratory water absorption tests (35 ml/cm^2 vs 45 for the control) and when exposed to the elements showed very significantly greater resistance to erosion.
These chemicals, however, are imported products and relatively high priced (approximately $ 1.00 per liter for CONSERVEX and $ 4.00/liter for CONSOLID 444). They will probably be sold principally to national institutions active in construction, and to private construction firms; their ready availability to the rural inhabitant who shops in local markets is doubtful. Therefore, despite the beneficial effect of the chemicals, it was decided not to conduct further experiments with these materials unless future testing shows their use to be essential.

6.2 Preparation and Testing of Prototype Samples

Due to time and resource limitations of the present project, only experiments of a very preliminary nature could be effected. The purpose of these was to screen as many ideas and material variations as possible in order to identify those which merit more detailed experimentation in the future. Both test plaques and more complex prototype roofing systems were prepared by hand, using only a few simple tools and fixtures in order to conform more closely with the methods that probably would be used by a low-income home builder in Central America.

6.2.1 Test Plaques

For the first series of tests, simple test plaques were prepared to permit an evaluation of the relative strength of lime stabilized soil and cement-pumice or sand mixtures, and to effect a preliminary screening of a number of possible reinforcing materials.

The plaques were hand made, trowelling the mixture into a wooden form designed for a plaque size of 10 x 10 x 1.2 cm. The soil, sand and pumice were screened to eliminate extraneous material; the dry mix ingredients were measured by volume and

nach Volumen bemessen und handgemischt. Es wurde nur so viel Wasser hinzugefügt, wie es die leichte Handhabung mit der Kelle erforderte. Die Stroh- und Piniennadel-Bewehrungen wurden auf ungefähr 3 cm Länge geschnitten und der nassen Mischung beigegeben. Gewebe- und Maschendraht-Verstärkungen wurden mit Scheren auf die erforderliche Größe zugeschnitten und über die erste Schicht der Mischung in der Holzform gelegt.

Diese erste Testreihe wurde durchgeführt, um eine grobe Auswertung der folgenden Variablen zu ermöglichen:

- Erden.
  Es lagen drei Bodenproben von verschiedenen Gegenden aus dem Hochland von Guatemala vor (Antigua, San Lucas und El Tejar). Es wurden alleine durch visuelle Prüfung diejenigen Erden ausgewählt, die den Anschein für die richtige Zusammensetzung zum Formen hatten.
- Kalk.
  Sowohl Löschkolk, der in Guatemala industriell angefertigt wird, als auch ungelöschter Kalk, der in kleinen ländlichen Kalkbrennereien hergestellt wird, wurde in 5 und 10%igen Beimengungen mit den Bodenproben trocken vermischt.
- Zementmischungen.
  Für Prüfzwecke wurden drei Zementmischungen verwendet: Zement-Bims (1 : 1), Zement-Bims (1 : 4) und Zement-Sand (1 : 4).
- Bewehrungsmaterialien.
  Als Bewehrungen wurden Baumwollgewebe, Jute- und Sisalsäcke, Maschendraht, Sisalfaser, Piniennadeln und Stroh ausgewertet.

Wie aus den nachfolgenden Tabellen ersichtlich, wurden 36 Tafeln mit stabilisierten Erdproben und 15 mit Zementmischungen hergestellt.

hand mixed. Only enough water to permit easy trowelling was added. The straw and pine needle reinforcing materials were cut to approximately 3 cm lengths and incorporated into the wet mix. Fabric and wire mesh reinforcements were precut to size with scissors, and were placed over the first layer of mixture trowelled into the wooden form.

This initial test series was designed to permit a preliminary evaluation of the following variables:

- Soils.
  Three soil samples were obtained from different locations in the Guatemala highlands (Antigua, San Lucas and El Tejar). Soils were selected which appeared, through visual inspection only, to have an adequate consistency for molding.
- Lime Stabilizer.
  Both hydrated lime industrially manufactured in Guatemala, and quicklime produced in small rural kilns were dry blended with the soil samples in 5 to 10 % concentrations.
- Cement Mixes.
  For control purposes, three cement mixes were prepared: cement pumice (1 : 1 ratio), cement-pumice (1 : 4) and cement-sand (1 : 4).
- Reinforcement.
  The reinforcing materials evaluated included cotton fabric, jute and sisal sacks, wire mesh, sisal fibre, pine needles and straw.

As shown in the following table, 36 plaques were prepared with stabilized soil samples, and 15 with cement mixes.

ERSTE SERIE TEST-TAFELN, HERGESTELLT 18. - 20. JUNI 1979

A. Stabilisierte Erden

Tafel Nr.	Erdprobe aus	Bindemittel	Bewehrung
1	Antigua	5% Löschkalk	Keine
2	Antigua	5% Löschkalk	Baumwollgewebe (1 Lage)
3	Antigua	5% Löschkalk	Baumwollgewebe (2 Lagen)
4	Antigua	5% Löschkalk	Jute-Sackmaterial (1 Lage)
5	Antigua	5% Löschkalk	Sisal-Sackmaterial (1 Lage)
6	Antigua	5% Löschkalk	Piniennadeln
7	Antigua	5% Löschkalk	Stroh
8	El Tejar	5% Löschkalk	Keine
9	El Tejar	5% Löschkalk	Baumwollgewebe (1 Lage)
10	El Tejar	5% Löschkalk	Piniennadeln
11	El Tejar	5% Löschkalk	Sisalfaser
12	El Tejar	5% Löschkalk	Hühnerdraht (1 Lage)
13	San Lucas	5% Löschkalk	Keine
14	San Lucas	5% Löschkalk	Baumwollgewebe (1 Lage)
15	San Lucas	5% Löschkalk	Hühnerdraht (1 Lage)
16	San Lucas	5% Löschkalk	Sisalfaser
17	San Lucas	5% Löschkalk	Piniennadeln
18	Antigua	10% Löschkalk	Keine
19	Antigua	10% Löschkalk	Baumwollgewebe (1 Lage)
20	Antigua	10% Löschkalk	Baumwollgewebe (2 Lagen)
21	Antigua	10% Löschkalk	Hühnerdraht (1 Lage)
22	Antigua	10% Löschkalk	Sisalfaser
23	Antigua	10% Löschkalk	Piniennadeln
24	Antigua	10% Löschkalk	Hühnerdraht (2 Lagen)
25	El Tejar	10% Löschkalk	Keine
26	El Tejar	10% Löschkalk	Baumwollgewebe (1 Lage)
27	El Tejar	10% Löschkalk	Baumwollgewebe (2 Lagen)
28	El Tejar	10% Löschkalk	Piniennadeln
29	El Tejar	10% Löschkalk	Sisalfaser
30	El Tejar	10% Löschkalk	Hühnerdraht (1 Lage)
31	El Tejar	10% Löschkalk	Hühnerdraht (2 Lagen)
32	San Lucas	5% gelöschter Kalk	Keine
33	San Lucas	5% gelöschter Kalk	Baumwollfaser (1 Lage)
34	San Lucas	5% gelöschter Kalk	Hühnerdraht (1 Lage)
35	San Lucas	5% gelöschter Kalk	Sisalfaser
36	San Lucas	5% gelöschter Kalk	Piniennadeln

FIRST SERIES OF TEST PLAQUES PREPARED JUNE 18 - 20, 1979

A. Stabilized Soil

Sample No.	Soil (Source)	Stabilizer	Reinforcement
1	Antigua	5% hydrated lime	None
2	Antigua	5% hydrated lime	Cotton fabric (1 layer)
3	Antigua	5% hydrated lime	Cotton fabric (2 layers)
4	Antigua	5% hydrated lime	Jute sacking (1 layer)
5	Antigua	5% hydrated lime	Sisal sacking (1 layer)
6	Antigua	5% hydrated lime	Pine needles
7	Antigua	5% hydrated lime	Straw
8	El Tejar	5% hydrated lime	None
9	El Tejar	5% hydrated lime	Cotton fabric (1 layer)
10	El Tejar	5% hydrated lime	Pine needles
11	El Tejar	5% hydrated lime	Sisal fibre
12	El Tejar	5% hydrated lime	Chicken wire (1 layer)
13	San Lucas	5% hydrated lime	None
14	San Lucas	5% hydrated lime	Cotton fabric (1 layer)
15	San Lucas	5% hydrated lime	Chicken wire (1 layer)
16	San Lucas	5% hydrated lime	Sisal fibre
17	San Lucas	5% hydrated lime	Pine needles
18	Antigua	10% hydrated lime	None
19	Antigua	10% hydrated lime	Cotton fabric (1 layer)
20	Antigua	10% hydrated lime	Cotton fabric (2 layers)
21	Antigua	10% hydrated lime	Chicken wire (1 layer)
22	Antigua	10% hydrated lime	Sisal fibre
23	Antigua	10% hydrated lime	Pine needles
24	Antigua	10% hydrated lime	Chicken wire (2 layers)
25	El Tejar	10% hydrated lime	None
26	El Tejar	10% hydrated lime	Cotton fabric (1 layer)
27	El Tejar	10% hydrated lime	Cotton fabric (2 layers)
28	El Tejar	10% hydrated lime	Pine needles
29	El Tejar	10% hydrated lime	Sisal fibre
30	El Tejar	10% hydrated lime	Chicken wire (1 layer)
31	El Tejar	10% hydrated lime	Chicken wire (2 layers)
32	San Lucas	5% quicklime	None
33	San Lucas	5% quicklime	Cotton fabric (1 layer)
34	San Lucas	5% quicklime	Chicken wire (1 layer)
35	San Lucas	5% quicklime	Sisal fibre
36	San Lucas	5% quicklime	Pine needles

B. Zementmischungen

Tafel Nr.	Mischungsverhältnis		Bewehrung
1	Zement - Bims	1 : 1	Keine
2	Zement - Bims	1 : 1	Sisalfaser
3	Zement - Bims	1 : 1	Baumwollgewebe (1 Lage)
4	Zement - Bims	1 : 1	Hühnerdraht (1 Lage)
5	Zement - Bims	1 : 1	Piniennadeln
6	Zement - Bims	1 : 4	Keine
7	Zement - Bims	1 : 4	Sisalfaser
8	Zement - Bims	1 : 4	Piniennadeln
9	Zement - Bims	1 : 4	Baumwollgewebe (1 Lage)
10	Zement - Bims	1 : 4	Hühnerdraht (1 Lage)
11	Zement - Sand	1 : 4	Keine
12	Zement - Sand	1 : 4	Sisalfaser
13	Zement - Sand	1 : 4	Baumwollgewebe (1 Lage)
14	Zement - Sand	1 : 4	Hühnerdraht (1 Lage)
15	Zement - Sand	1 : 4	Piniennadeln

Alle Tafeln konnten im Freien, geschützt vor Witterungseinflüssen, unter einer durchsichtigen Kunststoffolie zwei Wochen lang austrocknen, wonach die Tafeln durch leichtes Klopfen per Hand auf einer harten Fläche auf ihre Festigkeiten in Relation zu den verschiedenen Materialzusammensetzungen hin getestet wurden. Die Ergebnisse dieses einfachen Testvorgangs zeigten, daß die Stärke der Zementmischungen klar überlegen war; sie überstanden den Test ohne Probleme. Alle Tafeln aus stabilisierter Erde brachen leicht auseinander, und es konnte kein wesentlicher Unterschied zwischen Erdsorten, Kalk-Konzentrationen oder der Art des verwendeten Kalks festgestellt werden.

Was die Bewehrungen betraf, wurde folgendes beobachtet:

- Obwohl Stroh und Piniennadeln als Verstärkung für stabilisierte Erdblöcke benützt worden sind, erscheinen diese Materialien viel zu grob für die dünnen Materialquerschnitte bei der Dachdeckung, und sie neigen dazu, die Stabilität insgesamt zu beeinträchtigen. Weitere Experimente mit diesen Materialien werden nicht empfohlen.
- Sisalfaser, die viel feiner ist als die oben genannten Materialien, scheinen für diese Anwendung geeignet zu sein.
- Mit den Jute- und Sisalsäcken entstanden Probleme beim Zuschneiden auf Tafelgröße wegen des Ausfransens der zugeschnittenen Teile und auch beim Verdichten wegen der fehlenden Adhäsion zwischen Gewebe und Mischung. Deshalb wurden mit diesen Verstärkungsmaterialien nur zwei Tafeln angefertigt. Ihre Eignung als Bewehrungen wird jedoch bei großflächigen Versuchsplatten weiterhin untersucht werden.

B. Cement Mixes

Sample No.	Proportion of Mix		Reinforcement
1	Cement - pumice	1 : 1	None
2	Cement - pumice	1 : 1	Sisal fibre
3	Cement - pumice	1 : 1	Cotton fabric (1 layer)
4	Cement - pumice	1 : 1	Chicken wire (1 layer)
5	Cement - pumice	1 : 1	Pine needles
6	Cement - pumice	1 : 4	None
7	Cement - pumice	1 : 4	Sisal fibre
8	Cement - pumice	1 : 4	Pine needles
9	Cement - pumice	1 : 4	Cotton fabric (1 layer)
10	Cement - pumice	1 : 4	Chicken wire (1 layer)
11	Cement - sand	1 : 4	None
12	Cement - sand	1 : 4	Sisal fibre
13	Cement - sand	1 : 4	Cotton fabric (1 layer)
14	Cement - sand	1 : 4	Chicken wire (1 layer)
15	Cement - sand	1 : 4	Pine needles

All plaques, protected from the elements by a polyethylene cover, were allowed to cure for a period of two weeks, at which time each plaque was hand tapped against a hard surface in an attempt to establish relative strengths of the different variable combinations. The results of this simple testing procedure showed a clear superiority strengthwise for the cement-mixes which stood up to testing without failure. All of the stabilized soil plaques broke apart quite easily, and no significant differences could be detected between soils, lime concentrations or the type of lime used.

As far as the reinforcing materials were concerned, the following observations were made:

- Although straw and pine needles have been used as reinforcement for stabilized soil building blocks, these materials appear far too coarse for the thin sections involved in roofing applications, and tend to weaken overall structural strength. Further experimentation with these materials will not be recommended.
- Sisal fibre, much finer than the above materials, appears suitable for this application.
- Problems were encountered with jute and sisal sacking materials when cut to plaque size, due to unravelling and packing of the cut sections. For this reason, only two plaques were prepared with these reinforcing materials. However, their use will be further evaluated in larger size prototype samples.

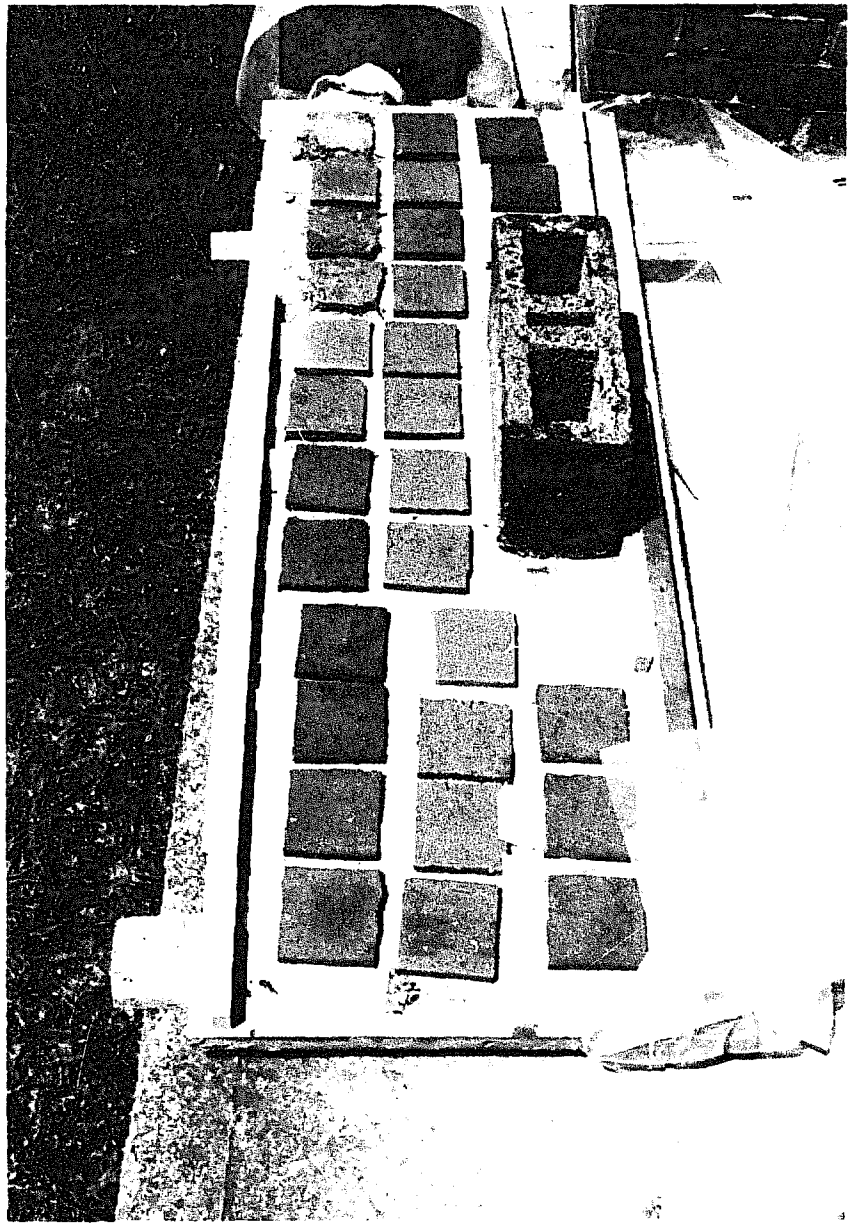

Abb. 6.4 Erd-Kalk-Probetafeln (10 x 10 cm), jede mit unterschiedlichem Kalkanteil und verschiedener Bewehrung, zur Aushärtung in der Sonne aufgestellt, unter einer durchsichtigen Kunststoffolienabdeckung.

Fig. 6.4 Soil-lime samples, 10 cm square, each having different percentages of lime and varying reinforcements, placed in the sun for curing under a transparent polythene sheet.

Abb. 6.5 Einige willkürlich zusammengestellte Erd-Kalk-Probetafeln, offen im Freien aufgestellt, nach dreimonatiger Aushärtung unter Folienabdeckung oder im Innenraum. (Anmerkung: Obwohl die Schlagfestigkeit nach zwei Wochen Aushärtung bei allen Proben gleich schlecht war, zeigte die Außenerprobung große Unterschiede im Witterungsverhalten, was offensichtlich auf den unterschiedlichen Tongehalt der Erdproben zurückzuführen ist).

Fig. 6.5 Some of the soil-lime samples, chosen at random, exposure tested after three months of hardening under cover or indoors. (Note: although impact resistance after two weeks curing was equally poor on all samples, the exposure test showed greatly differing material qualities on account of varying clay contents of the soil samples.

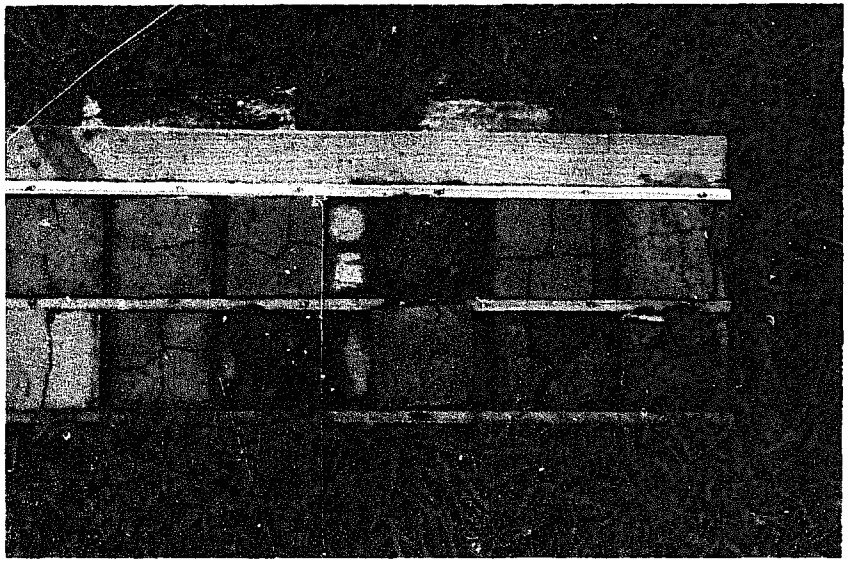

- Obwohl Baumwolltuch ein gutes Verstärkungsmaterial zu sein scheint, wurde es als schwierig empfunden, gute Haftung zwischen dem Gewebe und der stabilisierten Erde zu erreichen. Dies kann auf die verhältnismäßig trockene Mischung, die verwendet wurde, zurückzuführen sein, und es sollten weitere Erprobungen dieses Materials mit feuchteren Mischungen durchgeführt werden.
- Hühnerdraht ist ein gutes Verstärkungsmaterial, er wird jedoch, wie bereits in vorhergehenden Abschnitten erwähnt, wegen seiner höheren Kosten als Alternative mit geringerer Priorität betrachtet.

Da bei visueller Überprüfung der zerbrochenen stabilisierten Erdtafeln sich einige Absonderungen zeigten, wurde eine zweite Serie von 7 Tafeln angefertigt in der gleichen Art wie die vorhergehenden, außer daß das Handmischen der trockenen Zutaten sorgfältiger durchgeführt wurde. Es wurde eine neue Bodenprobe aus San Augustin, Guatemala, verwendet mit Kokosnußfaser als Verstärkung zusätzlich zu den Materialien, die in der ersten Testreihe vielversprechend zu sein schienen. Sämtliche Proben enthielten 10% Löschkalk als Stabilisierung; die Verstärkungsmaterialien waren folgende:

Probe	Verstärkung
1	keine
2	keine
3	Sisalfaser
4	Hühnerdraht (1 Schicht)
5	Baumwollgewebe (2 Schichten)
6	Kokosnußfaser (trocken)
7	Kokosnußfaser (vorgeweicht)

Nach der zweiwöchigen Austrocknungsperiode wurden die Tafeln mit der gleichen Methode, wie sie für die frühere Testreihe angewandt wurde, auf ihre Stärke hin geprüft. Die Ergebnisse waren identisch, da jede Tafel leicht gebrochen werden konnte, wenn sie gegen eine harte Unterlage gestoßen wurde. Die Kokosnußfaser schien als Verstärkungsmaterial der Sisalfaser ähnlich zu sein.

In Anbetracht der klaren Überlegenheit bei den Tafel-Tests der Zement-Sand- oder Bims-Mischungen im Vergleich mit stabilisierter Erde wurde beschlossen, die Bemühungen auf dieses Material zu konzentrieren bei der Herstellung von Prototyp-Dachdeckungssystemen. Weitere Versuche mit stabilisierter Erde werden jedoch wegen des offensichtlichen wirtschaftlichen Vorteils für den Verbraucher fortgesetzt werden, wenn es gelingt, die physikalischen Merkmale dieses Materials genügend zu verbessern, um eine angemessene Festigkeit für die Anwendung als Dachdeckung zu erreichen.

In der letzten Phase des Projekts, nach Beendigung der Prototyp-Dachdeckungs-Versuche, wurden einige der zerbrochenen stabilisierten Erd-Tafeln, die willkürlich ausgewählt wurden, während starker Regenzeit der Witterung ausgesetzt. Dieser Test zeigte, daß nach 2 1/2 Monaten Aushärtung (nach den Klopftests) Unterschiede in

- Although cotton fabric appears to be a good reinforcing material, it was found to be difficult to obtain good adhesion between the cloth and the stabilized soil. This may have been due to the relatively dry mixture being used, and future evaluation of this material with wetter mixes should be made.
- Chicken wire is a good reinforcing material, but, as mentioned in previous sections, is considered a low priority alternative due to its higher cost.

Since visual inspection of the broken stabilized soil plaques showed some evidence of lime segregation, a second series of 7 plaques was prepared in the same manner as the previous samples, except that more time and greater care was taken in hand mixing the dry ingredients. A new soil sample obtained in San Augustin, Guatemala, was used, and coconut fibres were evaluated as reinforcement in addition to the materials which appeared promising in the first series of tests. All samples contained 10% hydrated lime as the stabilizer; the reinforcing materials were as follows:

Sample	Reinforcement
1	None
2	None
3	Sisal fibre
4	Chicken wire (1 layer)
5	Cotton fabric (2 layers)
6	Coconut fibre (dry)
7	Coconut fibre (presoaked)

After the standard two week cure period, the plaques were tested for strength using the same procedure previously described for the first series of tests. Results were identical as each plaque could be easily broken when tapped against a hard surface. The coconut fibre appeared to be similar to sisal as a reinforcing material.

In view of the clear superiority shown in the plaque tests of the cement-sand or pumice mixes in comparison with stabilized soil, it was decided to concentrate efforts on this material in the preparation of prototype roofing systems. However, further experimentation with stabilized soil will be continued due to the obvious economic advantage to the consumer if the physical characteristics of this material can be improved sufficiently to reach acceptable strength levels for roofing applications.

After completion of the prototype roofing system experiments at the end of the present project, some of the broken stabilized soil plaques, selected at random, were exposed to the elements during a period of heavy rainfall. This exposure test showed differences between soil samples, after a 2 1/2 months cure period, which may be

den Proben festzustellen waren, was von großer Bedeutung sein kann. Die Tafeln aus El Tejar-Erde zeigten nach 24 Stunden schwere Auswaschungserscheinungen; etwas weniger Auswaschung wurde bei den Erdproben aus San Lucas bemerkt, und fast keine Auswaschungen gab es nach 1-monatiger Aussetzung bei den Proben aus Antigua-Erde. Dieses abschließende Experiment zeigt, daß sorgfältige Auswahl der Erde der wichtigste Faktor sein kann, um angemessene physikalische Stärke für stabilisierte Erd-Dachdeckungssysteme zu erhalten. Für weitere Programme wird deshalb empfohlen, eine Anzahl von Bodenproben auszuwählen, physikalischer und chemischer Analyse zu unterziehen und zu testen, welche Eigenschaften wesentlich sind. Diese Charakteristika sollten mit einfachen visuellen oder manuellen Tests feststellbar und in der Praxis von jedem einzelnen Hausbauer in Zentralamerika nachvollziehbar sein.

6.2.2 Prototyp-Bedachungssysteme

6.2.2.1 Verfahrensweise und Versuchsergebnisse

Erste Versuchsreihe

Für die erste Versuchsreihe für Dachdeckungssysteme wurde ein Befestigungsrahmen (45°-Neigung) aus Pinienholz hergestellt mit vier 1 m^2 großen offenen Flächen zum Bau von Prototyp-Dächern. Die erste dieser Flächen wurde für den Versuch mit asphalt-bestrichenem Stroh benützt, wie vorher in Absatz 6.1. beschrieben. Die anderen Experimente waren:

1-1 Mit Zement-Sand getränkte Säcke

Im zweiten Rahmenabschnitt wurde eine Tragkonstruktion aus drei in Fallrichtung verlaufenden Bambuspfählen, die in gleichem Abstand zueinander angeordnet waren, hergestellt. Statt Pfetten wurden horizontal verlaufende, um jeden Bambuspfahl gewickelte Seile befestigt. Der Abstand zwischen den Seilpfetten betrug im Durchschnitt 13 cm.
Gekaufte Sisalsäcke wurden in 30 x 50 cm große rechteckige Teile geschnitten und die Schnittkanten mit der Hand umgenäht, um ein Ausfransen zu vermeiden. Eine nasse Mischung aus einem Teil Zement und zwei Teilen Sand wurde hergestellt, und jeder Sack wurde in diese Mischung getaucht. Die imprägnierten Säcke wurden, noch naß und biegsam, sofort über die Stützenkonstruktion gelegt mit vertikalen und horizontalen Überlappungen von ca. 8 bis 10 cm.
Da die imprägnierten Säcke über die vertikalen Bambuspfähle gelegt wurden und mit den horizontalen Seilpfetten zurücksackten, wurde eine wellenförmige Wirkung erzielt, die einem Tonziegeldach etwas ähnlich sah. Die Säcke wurden von Hand an die Seilträger gebunden und ein Endanstrich aus nasser Zement-Sand-Mischung mit einer Bürste über die ganze Fläche aufgetragen. Nach einer einwöchigen Aushärtungszeit unter Dach wurde der Prototyp den Witterungseinflüssen ausgesetzt und erzielte ganz zufriedenstellende Ergebnisse. Aus dem Experiment gingen die folgenden Beobachtungen über diesen Dachdeckungstyp hervor:

very significant. Samples prepared with El Tejar soil showed very severe erosion after 24 hours exposure; somewhat less erosion was noted with the San Lucas soil samples, and almost no erosion occurred after one month exposure with the samples produced from Antigua soil. This final experiment indicates that proper soil selection may be the most important factor in obtaining adequate physical strength for stabilized-soil roofing systems. In future programs, therefore, it is recommended that a number of soil samples be selected, subjected to physical and chemical analyses, and tested to determine which characteristics are essential. These characteristics when determined should be correlated with simple visual or manual tests that could be carried out in the field by individual low-income home builders in Central America.

6.2.2 Prototype Roofing Systems

6.2.2.1 Preparation and Experimental Results

First Series

For the first series of roofing system experiments, an exposure deck (45° angle) was fabricated from pine lumber, with four one square meter open spaces available for the construction of prototype roofs. The first of these spaces was used for the asphalt-coated straw experiment discussed previously in Section 6.1. The other experiments were as follows:

1-1 Cement-sand Impregnated Sacks

A support structure was prepared with three equidistant vertical bamboo poles spanning the one meter space. Ropes looped around the bamboo poles and tied to the exposure deck frame were used as the horizontal support members. The spacing between the rope supports averaged about 13 cm.
Purchased sisal sacking was cut into 30 x 50 cm rectangular sections and the cut edges were hand sewn to prevent unravelling. A wet mixture of one part cement to two parts sand was prepared, and each sack was immersed in the mix. The impregnated sacks, still wet and flexible, were placed immediately over the support structure with vertical and horizontal overlaps of about 8 to 10 cm.
Since the impregnated sacks were laid over the vertical bamboo poles and allowed to sag against the horizontal rope supports, a corrugated effect was created somewhat similar to the appearance of a clay tile roof. The sacks were hand tied to the rope supports, and a final coat of wet cement-sand mixture was brushed over the entire prototype with a broom.
After a one week curing period under cover, the sample was exposed to the elements, with quite satisfactory results. The following observations concerning this type of roofing system resulted from the experiment:

Äußeres Erscheinungsbild

Obwohl die Oberfläche des imprägnierten Zementsacks ziemlich rauh war und viel mehr Arbeit darauf verwendet werden muß, um die Herstellungstechniken zu verbessern, war die Gesamterscheinung des Daches recht annehmbar. Seine Ähnlichkeit mit einem Tonziegeldach könnte die Chancen, von der Bevölkerung akzeptiert zu werden, erhöhen, besonders wenn der Mischung ein Pigment beigegeben werden könnte, um die rotbraune Farbe zu erzielen.

Aufbau

Probleme entstehen durch das übermäßige Absacken der Säcke zwischen den Seilträgern, und es scheint, als ob eine andere Art Unterkonstruktion entwikkelt werden sollte. Auch war es mühsam und zeitraubend, die Schnittränder der Säcke umzunähen und die Säcke an die Seile zu binden. Es werden einfachere Anbringungstechniken benötigt.

Witterungsbeständigkeit

Die Aufstellung des Prototyps im Freien hat gutes Witterungsverhalten gezeigt, sogar während einer starken Regenzeit. Nach drei Monaten ist die Oberfläche noch in zufriedenstellendem Zustand; es ging nur etwas leicht-gebundener Sand verloren, aber Lecks entwickelten sich nicht.

Appearance

Although the cement impregnated sack finish was quite rough, and much more work is needed to improve fabrication techniques, the overall appearance of the roof was fairly pleasing. Its similarity to the appearance of clay tile could improve its chances of acceptance, especially if a pigment could be incorporated into the mix to provide reddish-brown color.

Installation

Considerable difficulty was encountered due to excessive sagging of the sacks between the rope supports, and it appears that some other support system should be developed. Also, sewing the cut edges of the sacks and tying them to the ropes was a laborious and time-consuming procedure. Simpler installation techniques are needed.

Resistance to Exposure

The prototype stood up well in exposure tests even during a period of very heavy rainfall. After three months, the sample is still in satisfactory condition; only some lightly-bonded superficial sand was lost, and leaks did not develop.

Rahmen für die Erprobung verschiedener Unterkonstruktionen und Bedachungsmaterialien

Framework for testing different substructures and roofing materials

Abb. 6.6 Unterkonstruktion: Hühnermaschendraht
Fig. 6.6 Substructure: chicken-wire mesh

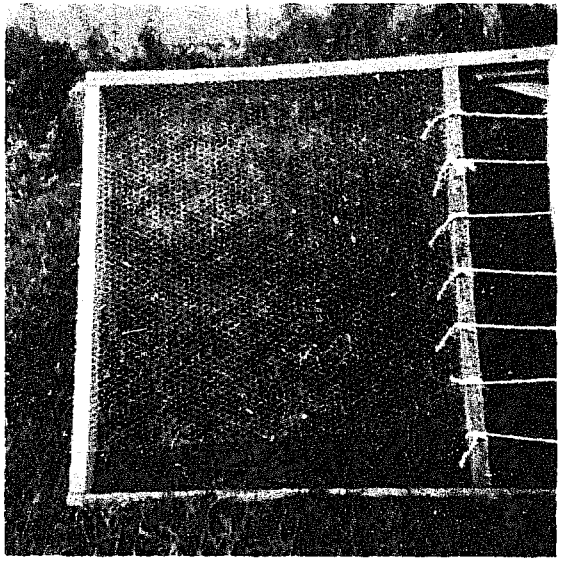

Abb. 6.7 Unterkonstruktion: Bambus und Seil
Fig. 6.7 Substructure: bamboo and rope

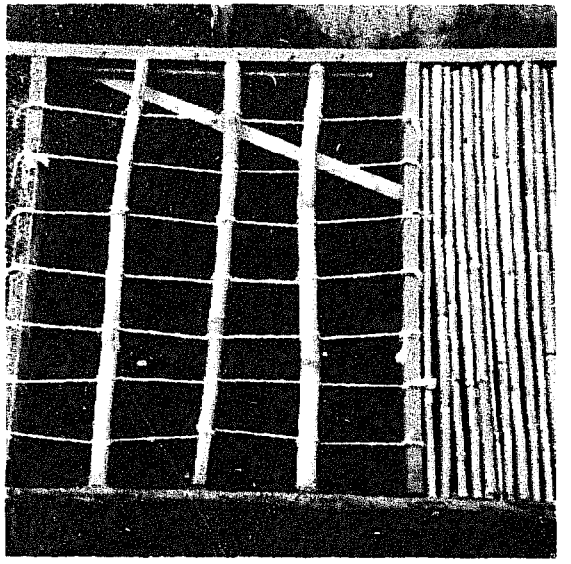

Abb. 6.8 Unterkonstruktion: caña de castilla
Fig. 6.8 Substructure: caña de castilla

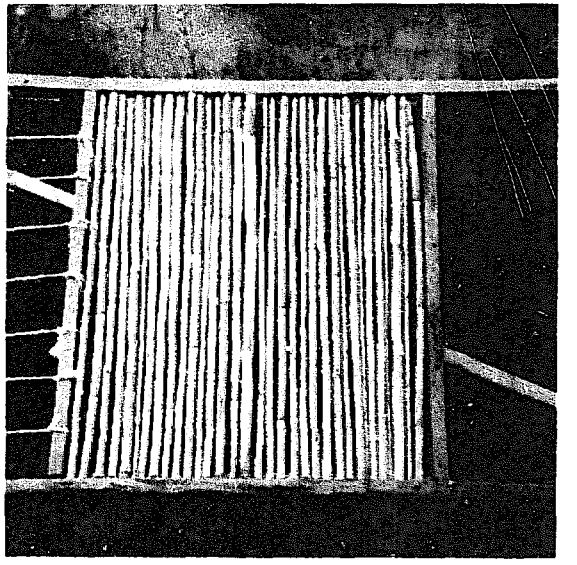

Gewicht

Das Gewicht der Dachdeckung betrug durchschnittlich ca. 14,3 kg/m^2, was, wenn auch schwerer als verzinkter Stahl, viel geringer ist als das Gewicht eines Tonziegeldaches (62 kg/m^2).

Schlußfolgerungen

Das Konzept, zementimprägnierte Säcke als Dachdeckung zu verwenden, indem sie über ein Tragsystem gelegt werden, das einen Welleffekt wie bei Tondachziegeln erzeugt, sollte unbedingt weiterverfolgt werden. Es muß jedoch viel Arbeit erbracht werden, um bessere Herstellungstechniken und Tragsysteme zu entwickeln, ehe dieses Dachdeckungssystem als zufriedenstellend angesehen werden kann.

Weight

The weight of the roof covering averaged about 14.3 kg/m^2, which, although heavier than galvanized steel, is far less than the weight of a clay tile roof (62 kg/m^2).

Conclusions

The concept of using cement impregnated sacks as a roof covering laid over a support system designed to provide an overall corrugated effect similar to the appearance of clay tile, definitely should be pursued further. However, much work is needed in developing better fabrication techniques and in support system design before this roofing system can be considered satisfactory.

Abb. 6.9 Auf der Bambus-Seil-Unterkonstruktion: Streifen von Sisalsackmaterial, in Bims-Zement-Mischung getaucht und in nassem Zustand verlegt.

Fig. 6.9 On bamboo-rope substructure, strips of sisal sacking material dipped in cement-pumice mix and placed in wet state.

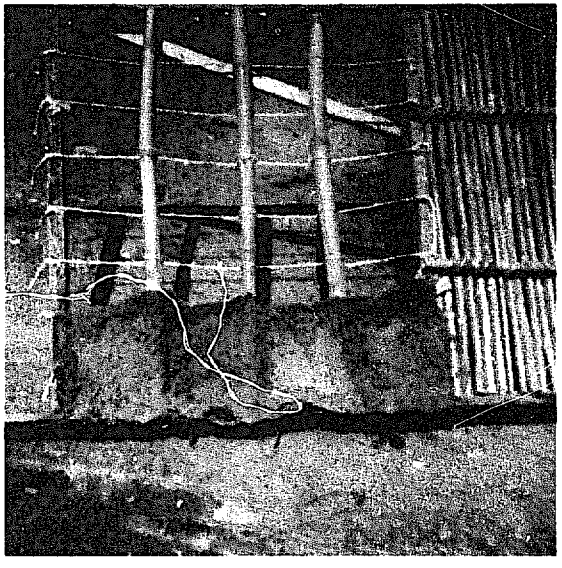

Abb. 6.10 Auf der Unterkonstruktion aus Hühnermaschendraht: erste Schicht aus Pajónbündeln. Jede Schicht erhielt einen Bitumenemulsionsanstrich zur Wasserabdichtung, ehe die neue Schicht daraufgelegt wurde.

Fig. 6.10 On chicken-wire substructure, first layer of pajón bundles, each layer receiving a coat of bitumen emulsion waterproofing before attachment of next layer.

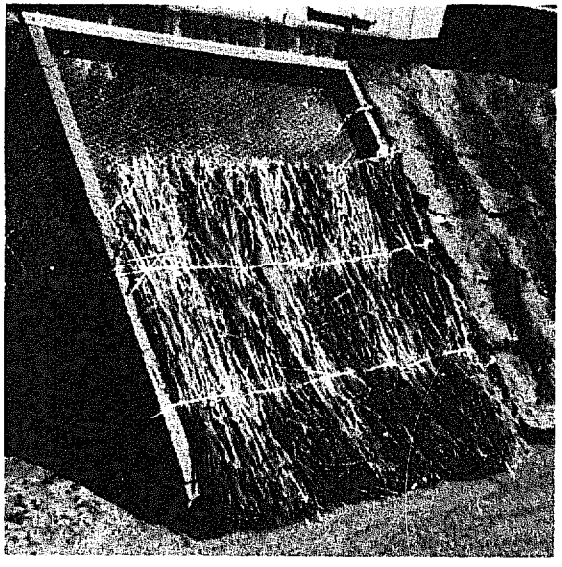

Abb. 6.11 Fertige Dachprobe mit Wasserdichtungsanstrich.

Fig. 6.11 Completed roofing sample with waterproof coating.

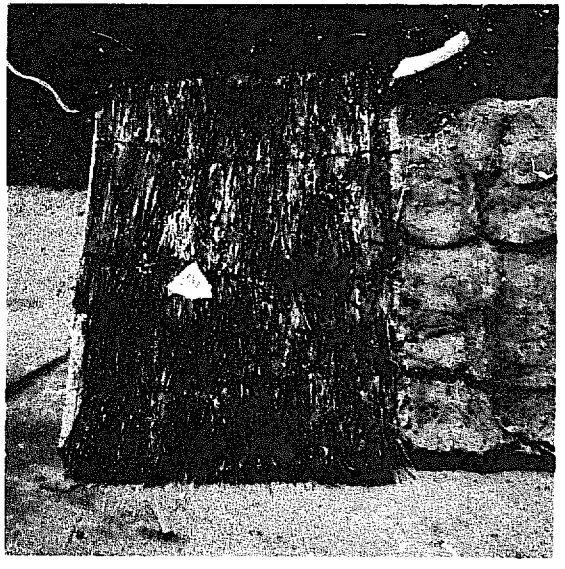

Abb. 6.12 Auf der Caña-Unterkonstruktion: drei verschiedene Mischungen (v.links nach rechts):
1. Bimssand und Zement
2. Erde und Kalk, ohne wasserabweisendes Zusatzmittel
3. Erde und Kalk, mit Consolid 444 und Conservex

Fig. 6.12 On caña substructure, three different mixes (from left to right):
1. Cement-pumice
2. Soil-lime, without water-resisting additives
3. Soil-lime, with Consolid 444 and Conservex

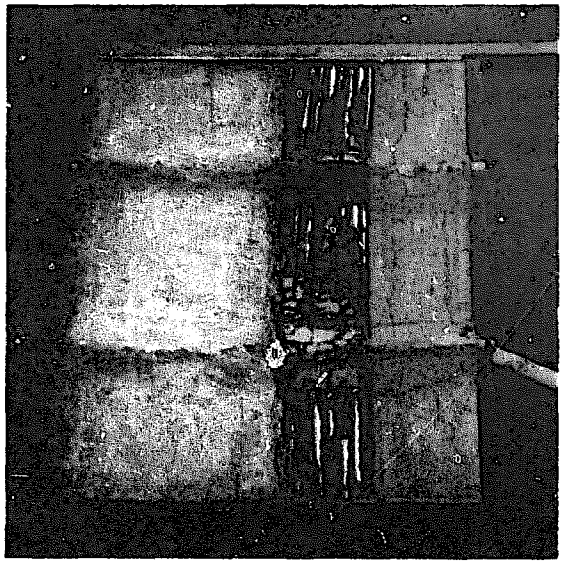

Abb. 6.13 Nach vier Wochen im Freien: etwa 50% der Erd-Kalkmischung ohne wasserabweisendes Zusatzmittel, vom Regen abgewaschen, wogegen die anderen zwei Proben intakt sind.

Fig. 6.13 After four weeks of exposure: about 50% of soil-lime without waterproofing washed out by rain, while the other two samples are intact.

Abb. 6.14 Probedach aus Baumwollsäcken, gefüllt mit Bimssand, Humus und Grassamen, wie Schindeln verlegt und zusammengenäht, auf einer Unterkonstruktion aus Bambus, Seil und Kunststoffolie.

Fig. 6.14 Roof specimen made of cotton cloth bags, filled with pumice, humus and grass seeds, laid and sewn together like shingles, on substructure of bamboo, rope and polythene sheeting.

1-2 Zement-Sand oder stabilisierte Erde auf Rohrunterkonstruktion

Die nächste Quadratmeter-Fläche wurde mit Rohrstangen (caña de Castilla) ausgelegt, die geschnitten und in vertikaler Richtung nebeneinandergelegt wurden. Diese wurden an drei in gleichen Abständen horizontal verlaufenden Rohren angebunden, die selbst am äußeren Rahmen befestigt wurden. Von links

1-2 Cement-sand or Stabilized Soil Applied Over Cane Support

The next square meter space was filled with canes (caña de Castilla) cut to length and laid one next to the other in a vertical direction. These were tied in place to three equidistant canes running in a horizontal direction and attached to the exposure deck frame. One vertical half of the area was covered

beginnend, wurde die halbe Fläche mit einer Mischung aus einem Teil Zement und zwei Teilen Bims bedeckt, und die andere Hälfte mit stabilisierter Erde (10% Löschkalk).
Auf dem Teil mit stabilisierter Erde wurde die Hälfte mit Erde unter Hinzufügung von imprägnierenden Zusätzen (siehe Abschnitt 6.1) bedeckt, die andere Hälfte mit unbehandelter Erde. Die Ergebnisse waren wie folgt:

Äußeres Erscheinungsbild
Die Dachdeckung, entweder aus Zement oder Erde, sieht nicht wie Tonziegeldachdeckung aus und ist nicht besonders attraktiv. Die drei Rohrverbindungselemente wurden in horizontaler Richtung angebracht, um ein Abgleiten der Mischung beim Auftragen zu verhindern; in der Praxis wurde dies jedoch für unnötig befunden. Offensichtlich sollten diese Stützen vertikal verlaufen, um eine attraktivere Wellwirkung zu erzielen.

Aufbau
Die für dieses Experiment benützten Rohre sind nicht so gerade wie Bambus, so daß die Verlegung der krummen Stäbe und deren Anbindung an die horizontalen Teile problematisch war. Es wurde ein 2-Mann-Team zum Aufbau benötigt. Das Auftragen der Mischung über die Rohre war keine schwierige Angelegenheit.

Witterungsbeständigkeit
Die Zement-Bims-Mischung zeigte gute Widerstandsfähigkeit gegen Wettereinflüsse. Die Probe aus stabilisierter Erde ohne wasserdichtende Zusätze zeigte fast unmittelbar nach dem Regen schwere Auswaschungen. Die wasserdichte Erdschicht war dem unbehandelten Muster weit überlegen, zeigte jedoch auch noch einen Grad von Erosion, der nicht akzeptiert werden konnte.

Gewicht
Das geschätzte Gewicht von 20,1 kg/m^2 für Zement-Bims und 22,7 kg/m^2 für stabilisierte Erde ist schwerer als dasjenige der zement-imprägnierten Säcke aus dem vorhergehenden Experiment. Diese Gewichtszahlen betragen jedoch nur ein Drittel des Gewichtes von Tondachziegeln.

Schlußfolgerungen

a) Eine Zement-Bims-Mischung, auf einer Rohrkonstruktion aufgetragen, scheint weitere Experimente zu rechtfertigen, besonders wenn man in Betracht zieht, daß dieses Material durch die Anwendung von Fasermaterialien noch verstärkt werden kann.

b) Stabilisierte Erde kann offensichtlich für diese Art der Anwendung nicht in Betracht gezogen werden, wenn kein Oberflächenschutz gegen Erosion vorgesehen wird.

c) Die bei diesem Experiment verwendete Unterkonstruktion sollte vollkommen neu gestaltet werden, um ein attraktiveres Erscheinungsbild des Daches zu erreichen.

with a mixture of one part cement to two parts pumice, and the other half with stabilized soil (10% hydrated lime).
In the stabilized soil section, half of the area was covered with soil containing waterproofing additives (see Section 6.1), and the other half with untreated soil. The results of this experiment were as follows:

Appearance
The roof covering, using either cement or soil, does not simulate the appearance of clay tile, and is not particularly attractive. The three cane support members were installed in a horizontal direction to prevent slippage of the mixture when trowelling, however, in practice this was found to be unnecessary. Obviously, these supports should run vertically in order to provide a more attractive corrugated effect.

Installation
The canes used for this experiment are not as straight as bamboo, and cane curvature was a problem in laying the supports and tying them to the horizontal members. A two-man installation team was required. Trowelling the mixture over the canes was not a difficult operation.

Resistance to Exposure
The cement-pumice mixture showed good resistance to exposure. The stabilized soil sample without waterproofing additives showed almost immediate severe erosion when exposed to rainfall. The waterproofed soil was far superior to the untreated sample, but still exhibited an unacceptable degree of erosion.

Weight
The estimated weight of 20.1 kg/m^2 for cement-pumice, and 22.7 kg/m^2 for the stabilized soil is heavier than that of the cement-impregnated sacks described in the previous experiment. These weights, however, are only about a third of the weight of clay tile.

Conclusions

a) A cement-pumice mixture applied over a cane support appears to merit further experimentation, especially when considering that this material can be further strengthened through the use of fibrous reinforcing materials.

b) Stabilized soil apparently cannot be considered for this type of application unless surface protection against erosion is provided.

c) The support system used in this experiment should be completely redesigned to provide a more attractive roof appearance.

1-3 Stabilisierte Erde mit Oberflächenbehandlung über Rohrunterkonstruktion

Der letzte Freiraum des Befestigungsrahmens wurde ähnlich wie bei dem vorhergehenden mit Rohr gefüllt, jedoch mit dem Unterschied, daß die Rohrstäbe in horizontaler Richtung übereinandergelegt und an drei vertikalen, in gleichem Abstand befestigten Stützelementen angebunden wurden. Das Rohrtragesystem wurde mit 10% kalkstabilisierter Erde bedeckt und in drei vertikale Abschnitte eingeteilt, wobei jeder eine andere Oberflächenbehandlung erhielt. Auf den ersten Abschnitt wurde Kalkschlämme aufgestrichen, nachdem die Erde einige Tage lang trocknen konnte. Beim zweiten Abschnitt wurde Baumwollgewebe zugeschnitten, in Kalkschlämme getaucht und auf die vorg .richene Fläche gelegt. Das imprägnierte Baumwollgewebe erhielt einen zusätzlichen Kalkanstrich, um den Stoff zu glätten.

Auf die Hälfte der restlichen Fläche wurde Stroh (pajón) in die nasse stabilisierte Erde gedrückt, um seine Wirksamkeit als Oberflächenschutz zu erproben. Ein Teil des Strohs wurde zum zusätzlichen Schutz mit Bitumen überstrichen; der Rest blieb unbehandelt. Die andere Hälfte dieser Fläche wurde mit zugeschnittenen Sackstreifen, die mit stabilisierter Erde imprägniert waren, bedeckt, die ihrerseits mit Stroh bedeckt wurden, während sie noch naß waren. Die Sackstreifen überlappten jeweils die darunterliegenden Strohschichten, um sie vor allem nach der Trocknung festzuhalten.

Die folgenden Ergebnisse wurden erzielt:

Äußeres Erscheinungsbild

Die Gesamterscheinung dieses Dachdeckungssystems wurde gegenüber dem vorangegangenen Experiment verbessert, ähnelt jedoch noch nicht ganz dem Tonziegeldach. Der Abstand zwischen den drei vertikalen Stäben war zu groß und die Stäbe selbst hatten zu geringen Durchmesser, um die gewünschte Kontur zu erreichen. Dieses Problem müßte jedoch durch die Neugestaltung der Unterkonstruktion korrigiert werden können.
Der zum Oberflächenschutz benützten Kalkschlämme sollten Pigmente beigegeben werden, um eine Tondachziegel-ähnliche Farbe zu erhalten.
Die Erscheinung der strohdegeckten stabilisierten Erde ist schlecht. Es war schwer, eine gute Haftung des Strohs mit der Erde zu erreichen, und die Abdeckung war nicht gleichmäßig.

Aufbau

Hier treffen dieselben Bemerkungen zu wie beim vorhergehenden Experiment.

Witterungsbeständigkeit

Obwohl fast sofort zahlreiche feine Risse in der Kalkoberflächenschicht entstanden, haben diese sich nicht weiter ausgebreitet, und die Probe blieb intakt, ohne nach zweimonatiger Wettereinwirkung Anzeichen von Erosion zu zeigen. Die Rissebildung war höchstwahrscheinlich auf eine zu dicke Kalkschlämme zurückzuführen.
Zwischen dem Oberflächenschutz mit Baumwollgewebe und -bewehrung und

1-3 Stabilized Soil With Surface Protection Over Cane Support

The last exposure deck section was filled with canes in a similar manner to the last experiment, except that the canes were laid one next to the other in a horizontal direction and tied to three equidistant vertical support members. The cane support system was covered with 10 percent lime-stabilized soil, and was divided into three vertical sections, each with a different type of surface protection.
The first section was brush-coated with a heavy lime slurry, after the soil had dried for several days. In the second area, cotton fabric was cut to size, immersed in a lime slurry, and placed directly over the stabilized soil. A second coat of lime was brushed over the impregnated cotton fabric.

On half of the remaining area, straw (pajón) was pressed into the wet stabilized soil to evaluate its effectiveness as surface protection. Part of the straw was coated with bitumen for added protection; the rest was untrected. The other half of this area was covered with stabilized soil impregnated sacks which, in turn, were covered with straw while still wet.

The following results were obtained:

Appearance

The overall appearance of this roofing system was improved over the last experiment, but still does not closely resemble the appearance of clay tile. The spacing between the three vertical supports was too great, and the supports themselves of too small a diameter to provide the desired contour. This problem, however, should be correctable through redesign of the support system.
The lime slurry used for surface protection probably should be pigmented to provide a clay tile-like coloring.
The appearance of the straw-covered stabilized soil is poor. Difficulty was encountered in obtaining good adhesion of the straw to the soil, and covering was not uniform.

Installation

Same comments as the last experiment.

Resistance to Exposure

Although numerous fine cracks (crazing) appeared almost immediately in the lime surface coating, these have not propagated further, and the specimen remains intact without signs of erosion after two months exposure. The crazing was most likely due to the use of too heavy a lime slurry concentration.
No significant difference was noted between the cotton fabric reinforced surface protection and the area with lime slurry alone.

der Fläche nur mit Kalk konnte kein nennenswerter Unterschied festgestellt werden.
Die strohbedeckte Probe war besser als man erwartet hatte, aber die durch Strohausfall freigelegten Erd-Kalk-Flächen beginnen nach zwei Monaten zu zerfallen.

Gewicht
Das geschätzte Gewicht der Dachdeckung ist dasselbe wie beim letzten Experiment, ca. 23 kg/m^2.

Schlußfolgerungen

a) Es wird als der Mühe wert angesehen, weitere Experimente mit stabilisierter Erde, mit Kalkanstrich geschützt (mit oder ohne Baumwollgewebe-Verstärkung), durchzuführen als möglicher preisgünstiger Ersatz für das Zement-Bims-Dach. Es sind jedoch viel mehr grundlegende Untersuchungen in bezug auf Erdauswahl, Optimierung der Kalkkonzentrationen und der Unterkonstruktions-Gestaltung, erforderlich.

b) Für die Anwendung von Stroh als Oberflächenschutz für stabilisierte Erde werden weitere Arbeiten nicht empfohlen.

The straw-covered sample stood up better than expected, but areas with exposed soil are beginning to deteriorate after two months exposure.

Weight
The estimated roof covering weight is the same as the last experiment, about 23 kg/m^2.

Conclusions

a) Further experimentation with stabilized soil protected with lime slurry (with or without cotton fabric reinforcement) is considered worthwhile as a possible lower cost substitute to the cement-pumice roof. Much more basic testing is necessary, however, relative to soil selection, optimization of lime slurry concentrations and support system design.

b) No further work is recommended with the use of straw as a surface protection for stabilized soil.

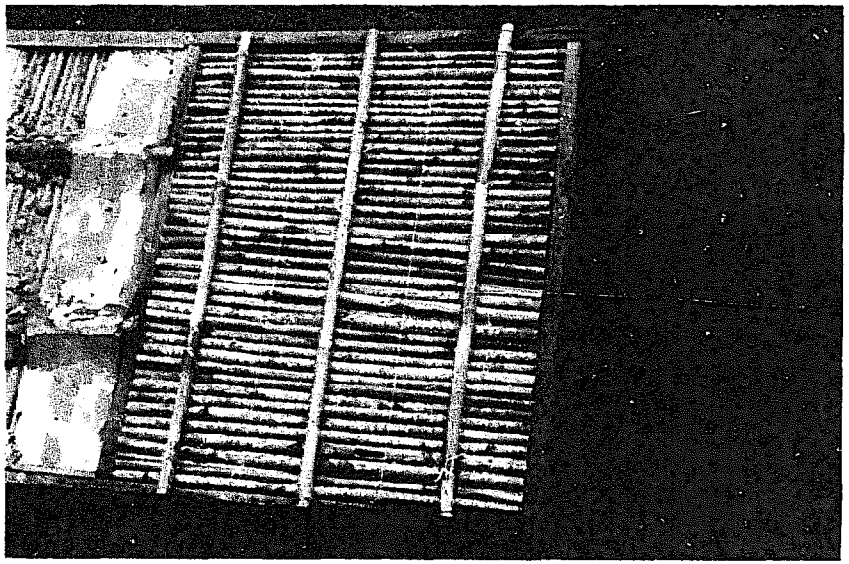

Abb. 6.15 Unterkonstruktion aus caña de castilla mit Unterteilung für drei verschiedene Oberflächenbehandlungen auf Erd-Kalk-Basis. Für bessere Haftung wurden die glatten Oberflächen der caña-Unterkonstruktion mit einer Machete aufgerauht.

Fig. 6.15 Caña de castilla substructure with subdivisions for three different types of covering based on soil-lime. For better bonding, the smooth surfaces of the caña were roughed by means of a machete.

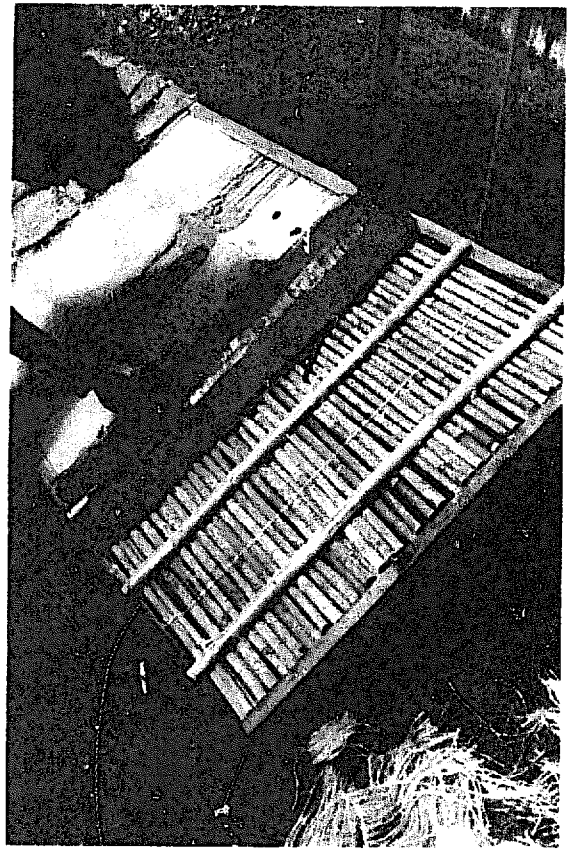

Abb. 6.16 Auftragung der Erd-Kalk-Mischung. Die Oberfläche wurde mit der Kelle glattgestrichen, dann mit der Bürste leicht aufgerauht zur besseren Haftung des Kalk-Schutzanstrichs.

Fig. 6.16 Application of soil-lime mix. The surface was evened out with a trowel and then slightly roughened with a brush as preparation for protective coating with limewash.

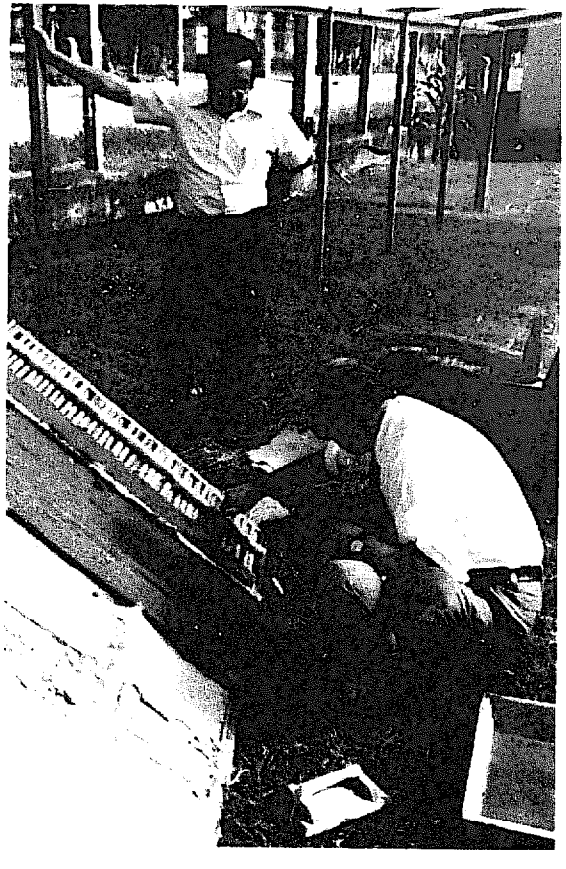

Abb. 6.17 Auftragung derselben Erd-Kalk-Mischung wie Abb. 6.16 für die Pajón-Oberfläche.

Fig. 6.17 Application of same soil-lime mix as in Fig. 6.16, as preparation for pajón finish.

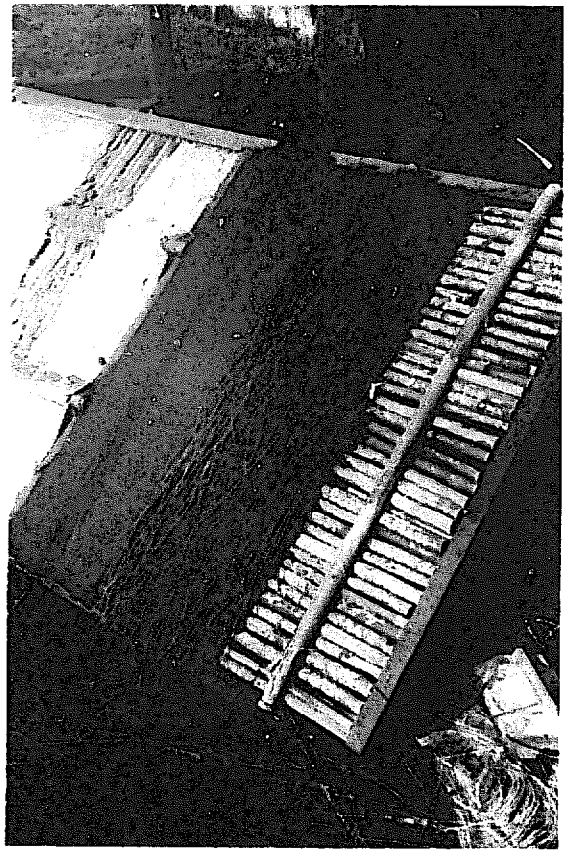

Abb. 6.18 Pajón, auf der Oberfläche dünn ausgebreitet und in die weiche Erd-Kalk-Mischung gedrückt.

Fig. 6.18 Pajón spread on surface in thin layer and pressed evenly into soft soil-lime mix.

Abb. 6.19 Erste Pajón-Schicht, auf die Erd-Kalk-Fläche gepreßt, wie unter Abb. 6.18.

Fig. 6.19 First layer of pajón pressed onto soil-lime base, as in Fig. 6.18.

Abb. 6.20 Mit dicker Erd-Kalk-Mischung getränktes Sisalsack-Material, die letzte Pajón-Lage überdeckend aufgeklebt, um dadurch den Pajón festzuhalten und nach dem Trocknen Verschiebungen zu verhindern.

Fig. 6.20 Sisal sack material, thickly impregnated with soil-lime mix, laid overlapping the previous pajón layer to hold it down and prevent displacement after drying.

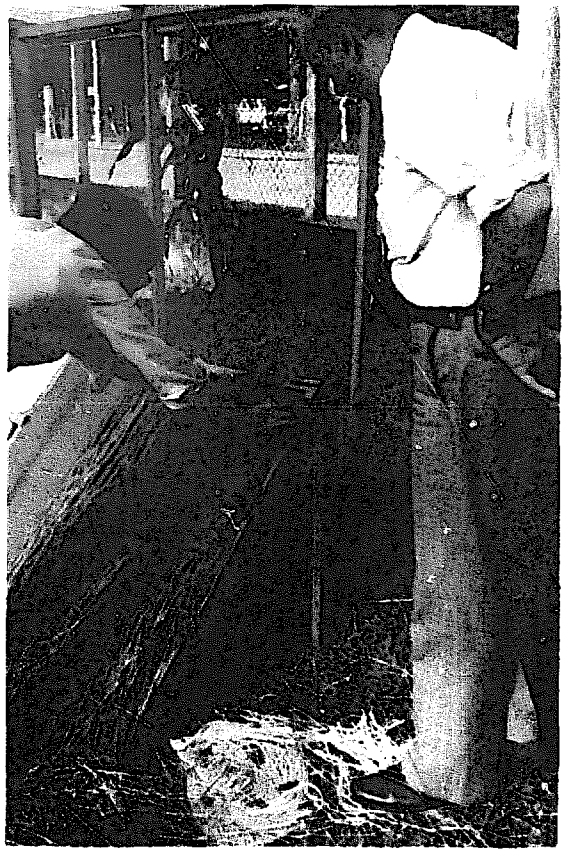

Abb. 6.21 Wiederholung des Vorgangs bis oben hin. Bei Bedeckung ganzer Dächer wären die getränkten Sackstreifen 30 bis 50 cm breit, mit horizontalen Längen entsprechend der leichtesten Handhabung.

Fig. 6.21 Repetition of procedure all the way to the top. When covering entire roofs, the impregnated sack material would be strips of 30 to 50 cm width and any practical horizontal length.

Abb. 6.22 Kalkanstrich auf der Erd-Kalk-Oberfläche.

Fig. 6.22 Application of limewash on soil-lime surface.

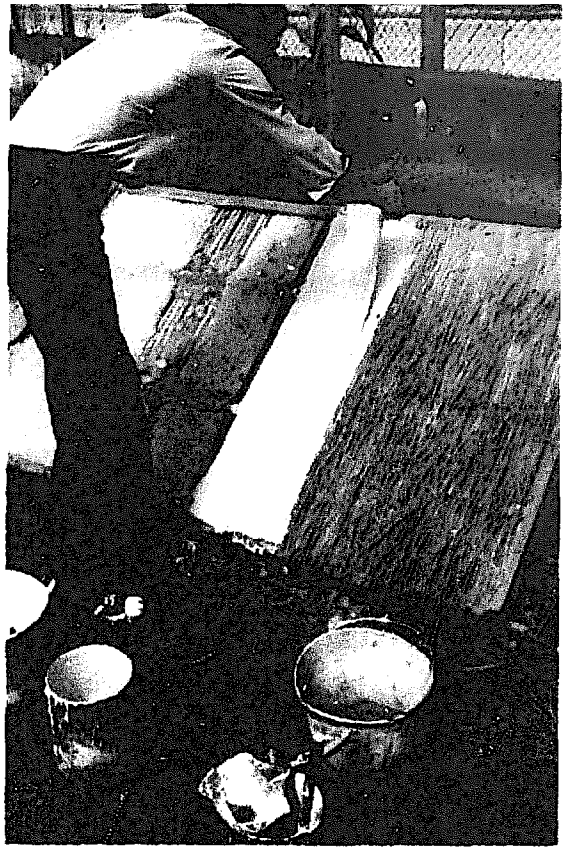

Abb. 6.23 Teilweise Verstärkung der Kalkschicht mit Baumwollstoff.

Fig. 6.23 Part of the limewash coating was reinforced with strips of cotton textile.

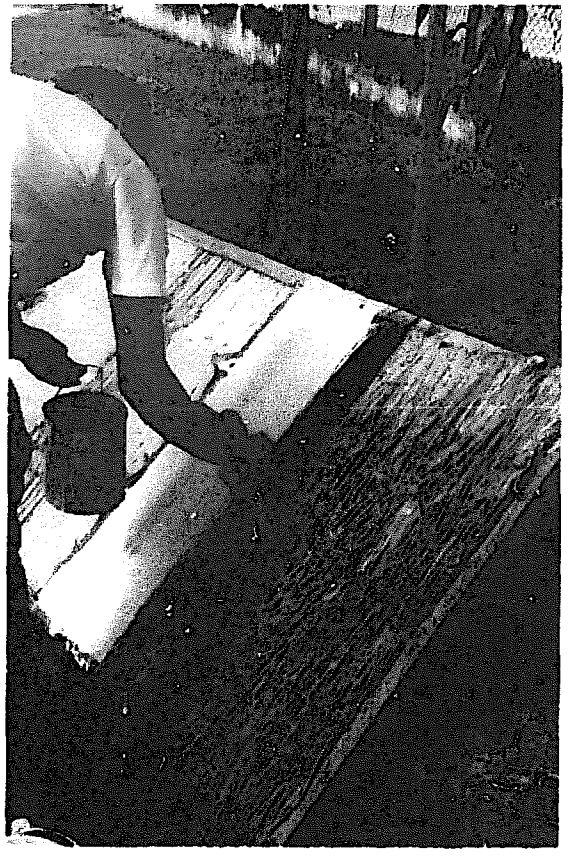

Abb. 6.24 Teile der Pajón-Deckung, mit einem wasserabweisenden Conservex-Anstrich versehen.

Fig. 6.24 Sections of the pajón covering received a coat of Conservex for waterproofing.

Zweite Versuchsreihe

Für die zweite Versuchsreihe über Dachdeckungssysteme wurden 50 x 50 cm große Probeplatten, bestehend aus einem Rohrgerüstbau und Dachdeckung, hergestellt und später, auf einem weiteren geneigten Rahmen befestigt, im Freien aufgestellt. Es wurden insgesamt sieben Muster angefertigt, einschließlich einem mit Unterkonstruktion aus gespaltenem und flachgedrücktem Rohr, das mit einer Schnur zusammengebunden und mit stabilisierter Erde bedeckt wurde. In der Praxis stellte sich heraus, daß es zu schwierig war, das zerdrückte Rohr zu verarbeiten und handhaben, deshalb wurde diese Idee aufgegeben.

Die anderen sechs Muster werden nachstehend beschrieben:

2-1 Zement-imprägnierte Säcke

Es wurden drei Muster hergestellt mit einem Rohrgerüst, bestehend aus Stäben, die in gleichen Abständen in Fallrichtung verliefen und mit Schnur an zwei darunterliegenden horizontal verlaufenden, vorgekerbten Stäben angebunden waren. Der Abstand zwischen den vertikalen Rohren wurde von Muster zu Muster verändert (5; 7,5 und 10 cm), um die Wirkung auf das Erscheinungsbild des Daches zu erproben und um Unterschiede in Einheitsgewicht und Festigkeiten festzustellen.

Sisal- und Jutesäcke wurden in 35 x 65 cm große rechteckige Teile geschnitten und in eine nasse Mischung aus einem Teil Zement und zwei Teilen Bims getaucht. Über jedes Rohrgerüst wurden zwei Säcke gelegt, die sich um etwa 20 cm überlappten und zwischen den vertikalen Stäben einsinken konnten, was dem Dach ein wellenförmiges Aussehen verlieh. Mit einer Bürste wurde ein Endanstrich aus Zement-Bims auf jedes Muster aufgetragen.
Die Ergebnisse waren folgende:

Abb. 6.25 Vorbereitung einer Unterkonstruktion aus caña de castilla: Kerben werden in gleichen Abständen geschnitzt, in denen Querstäbe einrasten.

Fig. 6.25 Preparation of sample substructure using caña de castilla: notches are cut at equal intervals to keep cross members in place.

Second Series

For the second series of roofing system experiments, 50 x 50 cm prototypes, including cane support system and roof covering, were fabricated and later attached to another exposure deck. A total of seven specimens were prepared, including one with a support system consisting of split and crushed cane tied together with twine, and covered with stabilized soil. In practice, the crushed cane was found too difficult to process and handle, and this idea was discarded.

The other six specimens are described below:

2-1 Cement-impregnated Sacks

Three specimens were prepared with support structures consisting of canes laid parallel in a vertical direction and tied with twine to two horizontal canes running underneath the vertical members. The spacing between the vertical canes was varied from sample to sample to evaluate the effect upon the roof appearance (5, 7.5 and 10 cm).

Sisal and jute sacks were cut into 35 x 65 cm rectangular sections and were immersed in a wet mixture of one part cement to two parts pumice. Two sacks were placed over each prototype support system, with an overlap of about 20 cm, and were allowed to sag between the parallel vertical supports, thereby providing a corrugated appearance to the roof. A final cement-pumice coating was brushed onto each specimen with a brush.
Results were as follows:

Äußeres Erscheinungsbild

Der Welleneffekt war, obwohl etwas unregelmäßig, bei allen Mustern recht gefällig. In bezug auf Wellenfrequenz waren alle Elemente akzeptabel, wobei die 7,5 cm-Abstände das gängige Wellblechmaß ist. Die äußere Erscheinung entsprach insgesamt den Asbestzement- und Zinkblech-Wellplatten, nicht so sehr den Tondachziegeln, aber die Anwendung dieser Methode bei großflächigeren Konstruktionen mit schwererem Bambus- oder Rohrgerüst könnte ein besseres Aussehen der Dachfläche bewirken.

Aufbau

Der Aufbau dieses Systems war beträchtlich einfacher als derjenigen der ersten Probeserien. Die meisten Schwierigkeiten lagen darin, ein einheitliches Einsinken der imprägnierten Säcke zwischen den vertikalen Stützenelementen zu erreichen. Um diesen Vorgang zu erleichtern, sollte in Zukunft eine Art Schablone vorgesehen werden.

Appearance

The corrugated effect, although lacking uniformity, was fairly pleasing on all samples, with little difference noted between the support spacing variations. On these samples, the effect more closely approximates the appearance of asbestos-cement or galvanized steel than clay tile, however, the application of this concept to larger scale constructions, with heavier bamboo or cane supports, could result in a better contoured roof surface.

Installation

The construction of this system was considerably simpler than those used in the first series of experiments. Most difficulty was encountered in attempting to obtain uniform sagging of the impregnated sacks between the vertical support members; a fixture should be designed in the future to facilitate this operation.

Abb. 6.26 Caña-Rahmen, fertig für den Überzug: Sisalsack wird in Bims-Zement-Mischung getaucht.

Fig. 6.26 Caña framework ready to receive covering: sisal sack dipped in cement-pumice mix.

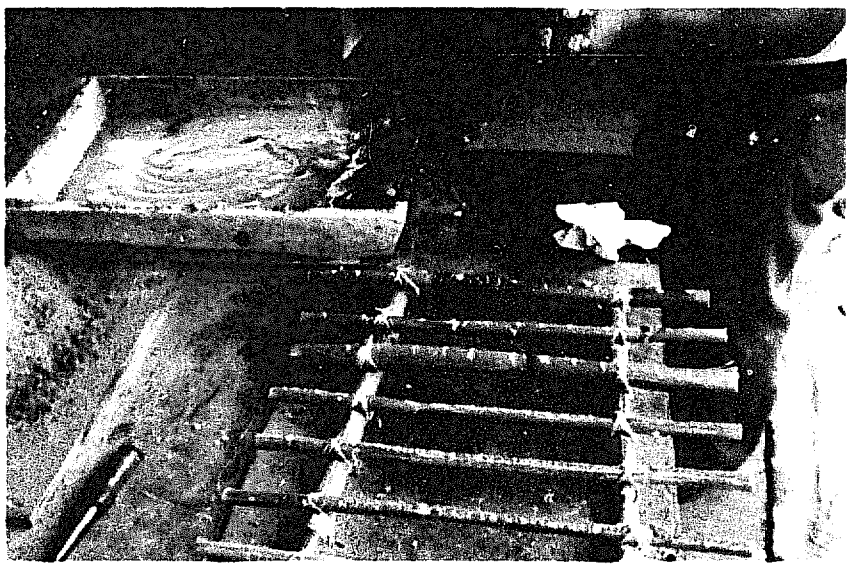

Abb. 6.27 Erste Schicht der Dachdeckung wird auf die Rahmenkonstruktion gelegt und sanft in die Zwischenräume gedrückt, um Wellen zu bilden und besseren Halt zu gewährleisten.

Fig. 6.27 First layer of roof covering laid on framework and gently pressed into gaps to simulate corrugation and give better hold on substructure.

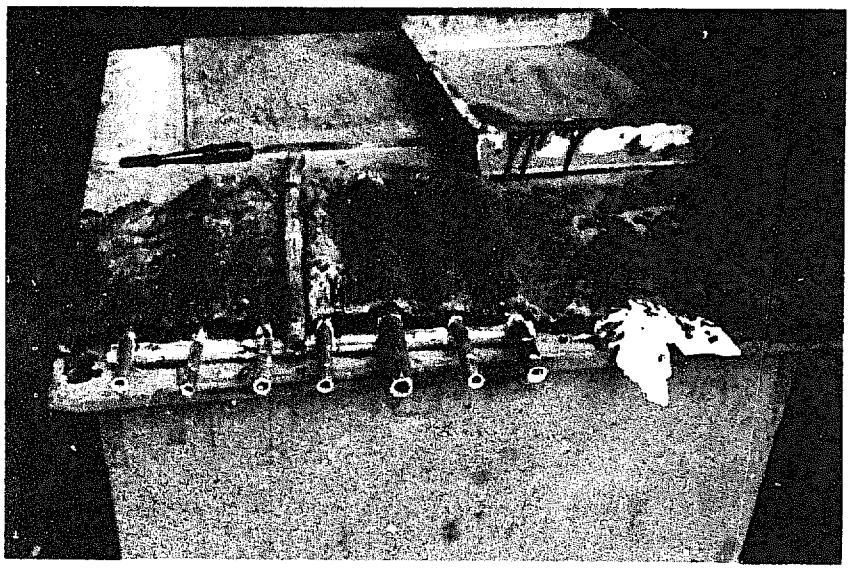

Witterungsbeständigkeit
Die mit Zement-Bims imprägnierten Säcke wurden zwei Monate lang der Witterung ausgesetzt; die Witterungsbeständigkeit war zufriedenstellend.

Gewicht
Das Durchschnittsgewicht der imprägnierten Sack-Dachdeckung war ungefähr 20 kg/m^2.

Schlußfolgerungen
Die Dachdeckung mit Zement-Bims-imprägnierten Säcken erscheint weiterhin vielversprechend, obwohl noch mehr unternommen werden sollte, um die Herstellungstechniken zu verbessern. Außerdem sind weitere Tests erforderlich, um die Haltbarkeit über längere Zeiträume festzustellen.
Die Unterkonstruktion, die aus parallelen vertikalen Rohrstäben oder Bambuspfosten besteht, die an die darunter verlaufenden horizontalen Elemente gebunden werden, ist eine Verbesserung gegenüber den Systemen aus der ersten Experimentenreihe. Die Optimierung dieses Systems sollte eines der primären Ziele jeglichen zukünftigen Experimentierprogramms sein.

Resistance to Exposure
Resistance of the cement-pumice impregnated sacks to the elements has been satisfactory over a two months exposure period.

Weight
The average weight of the impregnated sack roof covering was approximately 20 kg/m^2.

Conclusions
The cement-pumice impregnated sack roof covering continues to appear promising although more effort is needed to improve fabrication techniques, and more testing is required to prove resistance over longer periods of time.
The support system consisting of parallel vertical canes or bamboo poles tied to horizontal members running underneath, is an improvement over the systems evaluated in the first series of experiments. Optimization of the design of this system should be one of the prime goals of any future experimental program.

Abb. 6.28 Glättung der Oberfläche mit einer Bürste.

Fig. 6.28 Smoothening of surface with a brush.

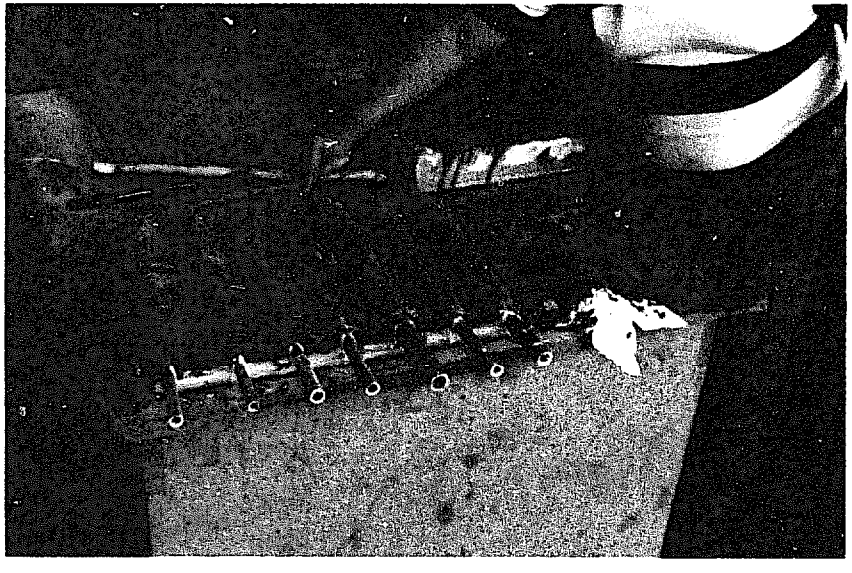

Abb. 6.29 Befestigung des Sackmaterials an der Unterkonstruktion mit einer Schnur.

Fig. 6.29 Tying the sacking material to the framework.

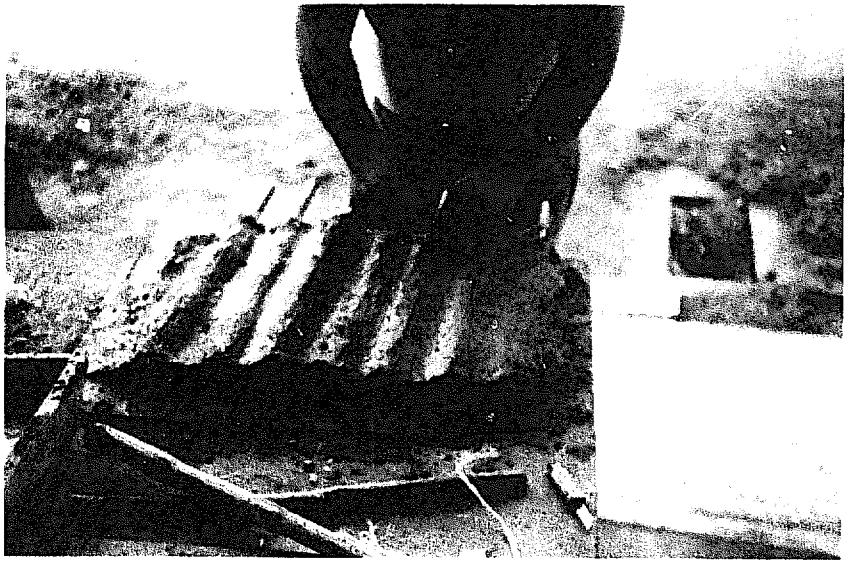

2-2 Mit stabilisierter Erde imprägnierte Säcke

Es wurde ein Muster ähnlich denjenigen in Experiment 2-1 hergestellt (7,5 cm Abstand zwischen vertikalen Stäben), außer daß die Säcke mit einer Erd-Kalk-Mischung (10% Löschkalk) imprägniert wurden, statt mit einer Zement-Bims-Mischung. Nach der Trocknung wurde eine Hälfte der Probe mit Kalkschlämme bestrichen, die andere Hälfte blieb unbehandelt.

Es wurden folgende Ergebnisse erzielt:

Äußeres Erscheinungsbild
Abgesehen vom Farbunterschied war die Gesamterscheinung des Musters ähnlich wie Experiment 2-1.

Aufbau
Siehe Bemerkungen bei 2-1.

Witterungsbeständigkeit
Sowohl die ungeschützte Fläche als auch die mit Kalkschlämme behandelte zeigte eine Anzahl von Rissen zu Beginn des Tests. Später wurde auf der unge-

2-2 Stabilized Soil Impregnated Sacks

A sample was prepared in an identical manner as those described in experiment 2-1 (7.5 cm spacing between vertical supports), except that the sacks were impregnated with soil stabilized with 10 percent hydrated lime, instead of cement-pumice. After drying, one half of the specimen was covered with lime slurry; the other half was left unprotected.

The following results were obtained:

Appearance
Except for the color difference, the overall appearance of the specimen was similar to experiment 2-1.

Installation
Same comments as 2-1.

Resistance to Exposure
Both the unprotected area and the section coated with lime slurry showed a number of cracks early in the exposure test, and flaking and erosion was ob-

Abb. 6.30 Ähnliches Dachelement mit Erd-Kalk-Mischung statt Bims-Zement-Mischung.

Fig. 6.30 Similar roofing element using soil-lime mix, instead of cement-pumice.

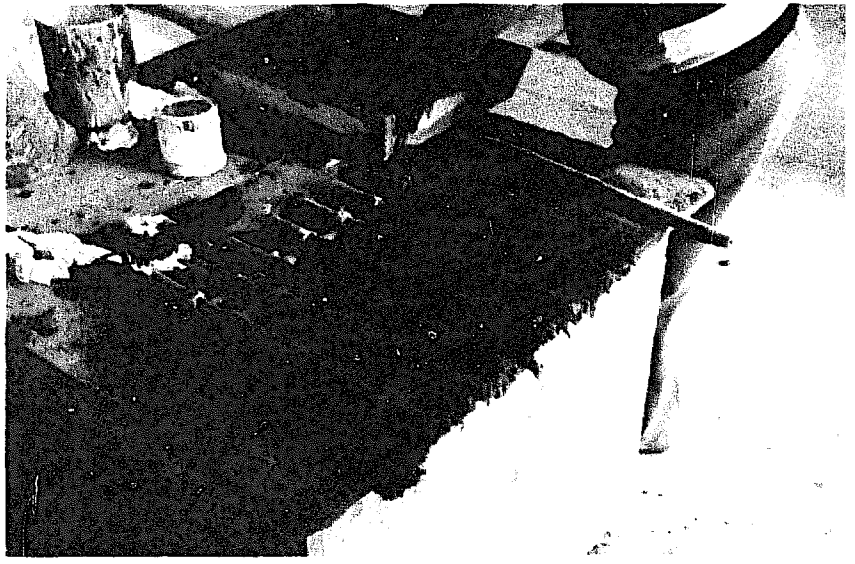

Abb. 6.31 Ähnliches Dachelement wie Abb. 6.26, aber Überbrückung der Lücke mit Pajón, um zu verhindern, daß die Bims-Zement-Mischung hindurchfällt.

Fig. 6.31 Similar roofing element as in Fig. 6.26, but gaps filled with pajón to prevent cement-pumice covering from falling through.

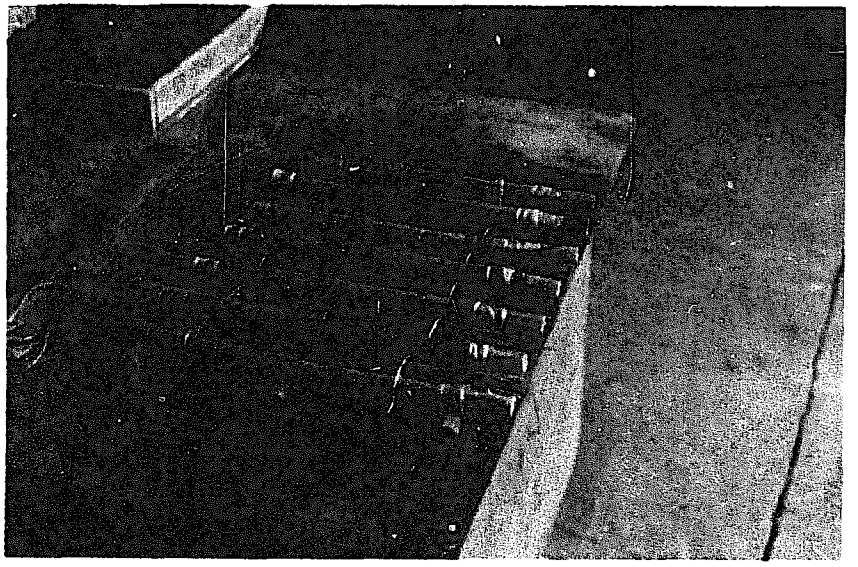

schützten Fläche Abblättern und Erosion festgestellt. Im allgemeinen kann die Witterungsbeständigkeit als nicht zufriedenstellend angesehen werden.

Gewicht
Das Durchschnittsgewicht der Dachdeckung wurde auf 15 kg/m^2 geschätzt.

Schlußfolgerungen
Wie bei den Witterungstests gezeigt, unterliegen die mit Erde imprägnierten Säcke physikalisch denjenigen mit Zement-Bims, und weitere Arbeit an diesem Dachdeckungssystem sollte als nicht vorrangig angesehen werden.

2-3 Unbewehrter Zement-Bims über Rohrgerüst

Es wurde ein Muster hergestellt mit einem Rohrgerüst wie bei den letzten Experimenten beschrieben, und mit einer Mischung aus einem Teil Zement und zwei Teilen Bims bedeckt. Eine dünne Lage Stroh diente als Füllmaterial zwischen den vertikalen Stäben, um die Zementschicht bis zur Trocknung abzustützen.

Aus diesem Experiment liegen folgende Ergebnisse vor:

served in the unprotected section. In general, resistance to exposure can be considered unsatisfactory.

Weight
The average weight of the roof covering was estimated at 15 kg/m^2.

Conclusions
As shown by the exposure tests, the soil impregnated sacks are physically inferior to those with cement-pumice, and any further work done with this type of roof covering system should be considered of low priority.

2-3 Cement-pumice Over Cane Support

A specimen was prepared with a cane support system identical to those described in the last experiments, and was then covered with a mixture of one part cement to two parts pumice. A thin layer of straw was used as a filler between the vertical supports to prevent spillage of the cement mixture.

Results of this experiment were as follows:

Abb. 6.32 Bims-Zement-Mischung ohne Sackmaterialverstärkung.

Fig. 6.32 Cement-pumice covering without sacking material reinforcement.

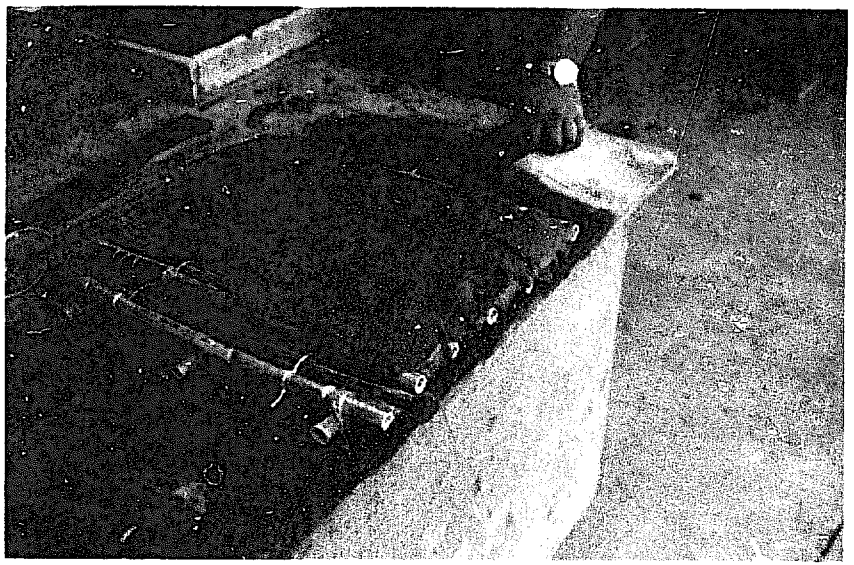

Abb. 6.33 Fertiges Dachelement mit glatter Oberfläche und Wellplattenform.

Fig. 6.33 Finished roofing element with smoothened surface and corrugated appearance.

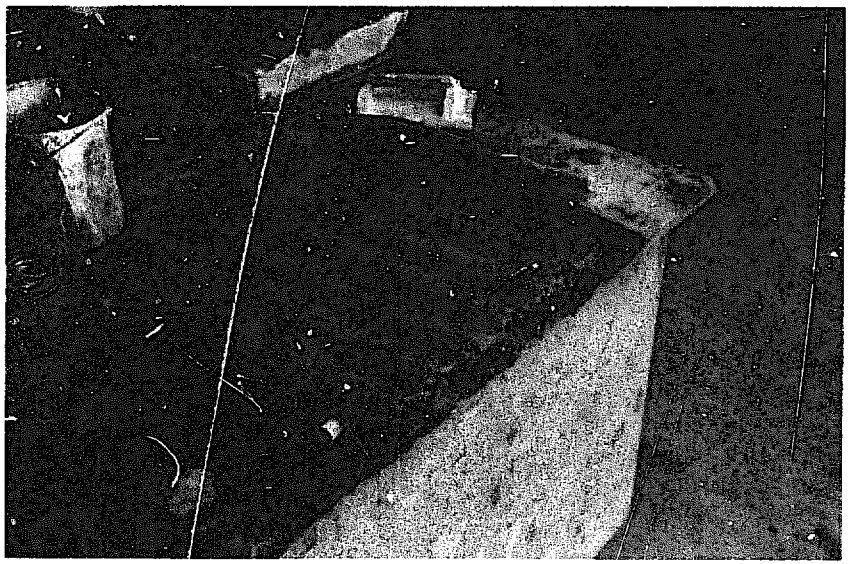

Äußeres Erscheinungsbild
Die Gesamterscheinung dieses Musters war nicht so gut wie das vorhergehende mit den imprägnierten Säcken, da der Welleneffekt viel weniger deutlich wurde. Der Grund dafür waren die Schwierigkeiten beim Auftragen der Mischung über dem Rohrgerüst mit einer Kelle; um diesen Vorgang besser kontrollieren zu können, wird eine Form benötigt.

Aufbau
Die Herstellung dieser Art von Dachdeckung ist nicht besonders schwierig. Es ist jedoch, wie bereits oben erwähnt, erforderlich, einige Werkzeuge und Formen zu entwickeln, um die Fertigungstechnik zu verbessern und einheitliche, klar erkennbare Wellenformen anzubringen.

Witterungsbeständigkeit
Kurz nach Herstellung der Probe zeigte sich ein vertikaler Riß parallel zu einer der Wellen. Dies kann zum Teil auf Schrumpfung zurückzuführen sein, die Hauptursache war jedoch die fehlende gleichmäßige Dicke des Materials aufgrund schlechter Auftragtechnik. Nach zwei Monaten im Freien wurden keine weiteren Auswirkungen beobachtet.

Gewicht
Das Durchschnittsgewicht der Zement-Bims-Abdeckung war ca. 20 kg/m^2.

Schlußfolgerungen
Da diese Methode eine Kostenreduzierung durch das Weglassen von gekauften Säcken bewirken kann, sollten weitere Experimente durchgeführt werden. Die Entwicklung von einfachen Geräten zur Verbesserung der Herstellungstechniken, Evaluierung der Anwendung von Naturfasern als Verstärkung und Optimierung der Unterkonstruktion sollten die wichtigsten Aufgaben sein, die bei einem weiteren Experimentierprogramm durchgeführt werden sollten.

2-4 Unbewehrte stabilisierte Erde auf Rohrgerüst

Dieses Probestück wurde in gleicher Weise wie im Experiment 2-3 hergestellt, außer daß 10% kalkstabilisierte Erde statt der Zement-Bims-Mischung als Dachdeckung verwendet wurde. Nach der Trocknung wurde die Hälfte der Fläche nur mit Kalkschlämme bestrichen; die andere Hälfte wurde zusätzlich mit kalkimprägniertem Baumwollmaterial bedeckt und nochmals mit Kalkanstrich versehen.

Es wurden folgende Ergebnisse erzielt:

Äußeres Erscheinungsbild
Es entstanden dieselben Schwierigkeiten mit schlecht ausgebildeten Wellen wie bei Experiment 2-3.

Aufbau
Siehe 2-3.

Appearance
The overall appearance of this sample was not as good as the previous impregnated sack experiment, since the corrugated effect was far less pronounced. This was due to difficulties encountered in contouring the mixture over the supports with a trowel, and a form is needed to permit better control over this operation.

Installation
The fabrication of this type of roofing system is not a particularly difficult operation. However, as mentioned above, some equipment development work is needed to improve trowelling technique and provide uniform well-defined corrugations.

Resistance to Exposure
Shortly after preparation of the sample, a vertical crack appeared running parallel to one of the corrugations. This may have been partially due to shrinkage but the primary cause was lack of material thickness uniformity due to poor trowelling technique. After two months exposure, no other defects have been observed.

Weight
The average weight of the cement-pumice covering was about 20 kg/m^2.

Conclusions
Since this method can result in cost reduction through the elimination of the purchased sacks, more experimentation should be carried out. Development of simple equipment to facilitate fabrication, evaluation of the use of natural fibres as reinforcement and optimization of the support system design should be the principal tasks included in any new experimental program.

2-4 Stabilized Soil Over Cane Support

This sample was prepared in an identical manner to experiment 2-3, except that 10% lime-stabilized soil was used as the covering instead of the cement-pumice mixture. After drying, half of the specimen was coated with a lime slurry; the other half was covered with lime impregnated cotton fabric and given a final brushed-on coating of lime slurry.

The following results were obtained:

Appearance
The same difficulties with poorly defined corrugations were encountered as with experiment 2-3.

Installation
Same comments as 2-3.

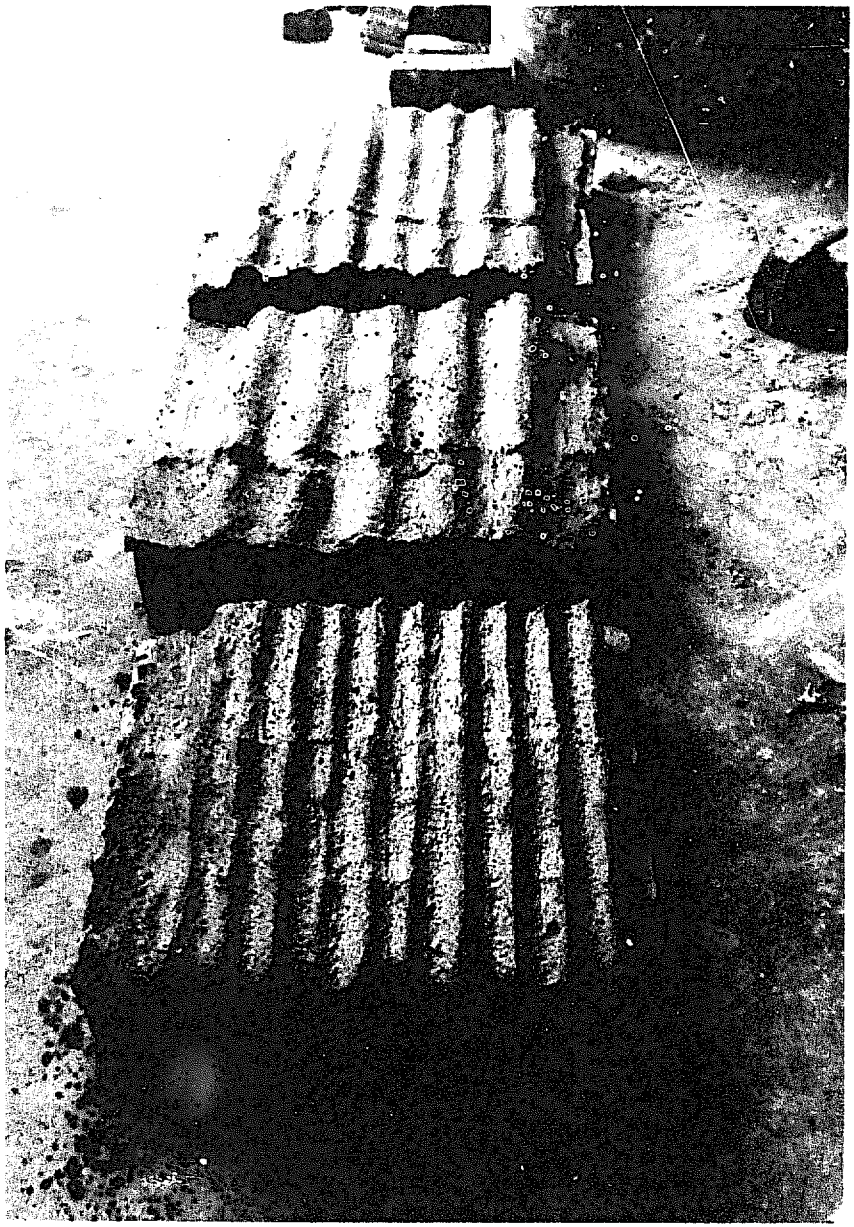

Abb. 6.34 Dachelemente mit Unterkonstruktion aus caña und mit Bims-Zement-Mischung getränkter Sackmaterialdeckung. Einzige Unterschiede liegen im Abstand der cañas: 5 cm, 7,5 cm, und 10 cm.

Fig. 6.34 Roofing elements with caña substructure and cement-pumice impregnated covering, only differing in caña spacing: 5 cm, 7,5 cm and 10 cm.

Auf den Seiten 148 und 149 : / On pages 148 and 149 :

Abb. 6.35 Dachelemente zur Erprobung im Freien, auf geneigtem Rahmen befestigt. Die Bims-Zementtafeln erhielten keine Oberflächenbehandlung, aber die Erd-Kalkproben wurden mit unterschiedlichen Schutzschichten versehen: Kalkanstrich mit oder ohne Stoffverstärkung und Conservex. Zum Vergleich wurde ein Teil der Oberfläche nicht behandelt.

Fig. 6.35 Roofing elements placed on framework for exposure testing. The cement-pumice samples received no surface treatment, but the soil-lime specimens received different protective coatings: limewash, with and without cloth reinforcement and Conservex. For comparison a section was left unprotected.

Abb. 6.36 Aufstellung aller Bedachungselemente im Freien, um die Auswirkungen von Sonnenstrahlung, Wind, Regen, Temperatur- und Feuchtigkeitsschwankungen sowie möglicherweise von Erdstößen zu untersuchen.

Fig. 6.36 Exposure of all roofing specimens, to test the effects of solar radiation, wind, rain, fluctuations in temperature and humidity and possibly earth tremors.

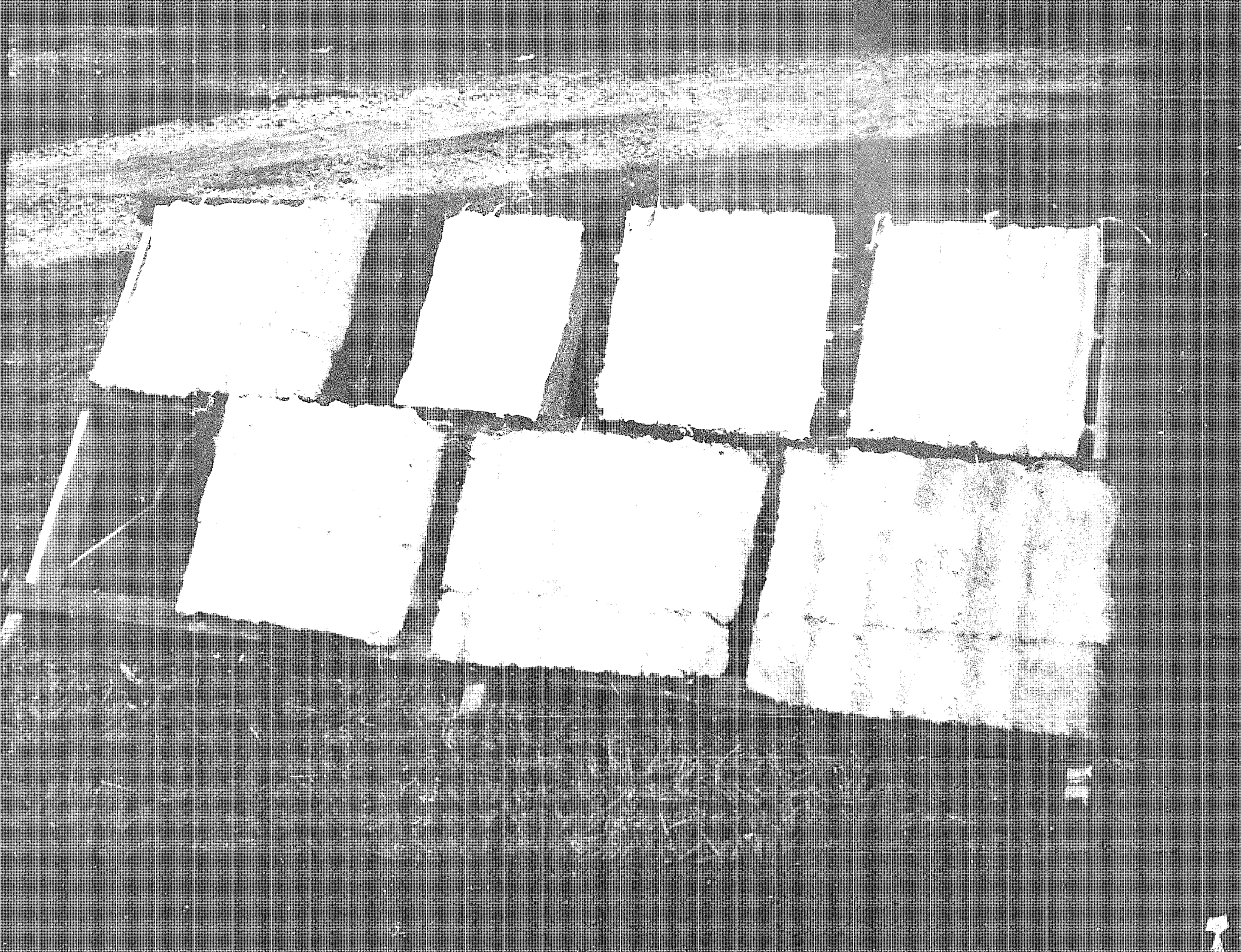

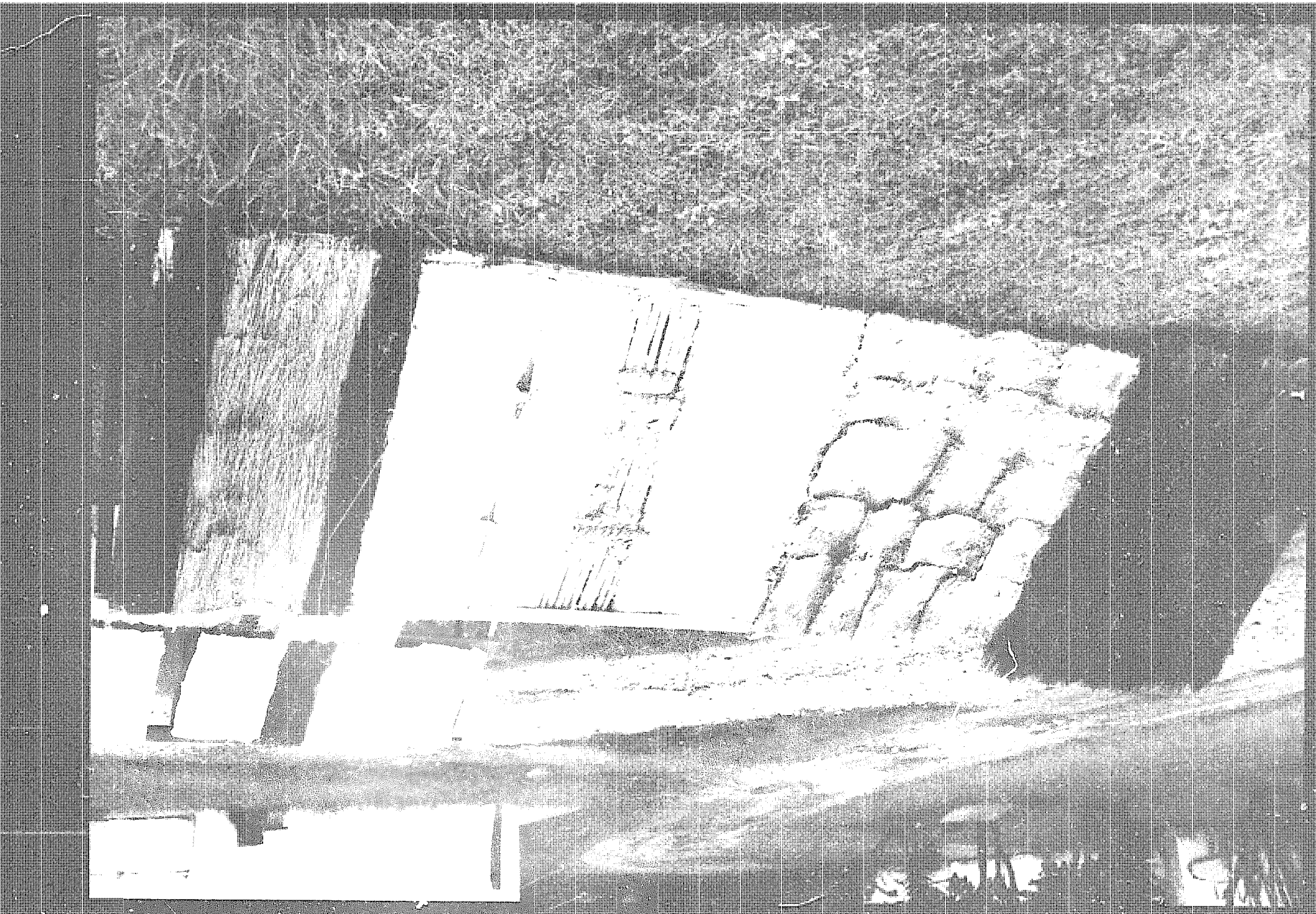

Witterungsbeständigkeit

Außer der oberflächlichen Rissebildung der Kalkschicht überstand die mit Baumwollmaterial geschützte Fläche die zweimonatige Probezeit gut. Die nur mit Kalk geschützte Fläche war sehr aufgerissen, zum Teil aufgrund von Beschädigungen bei der Handhabung, als das Probestück auf dem geneigten Rahmen befestigt wurde.

Gewicht

Das Durchschnittsgewicht für die Dachdeckung aus stabilisierter Erde mit Kalkanstrich wird auf ca. 26 kg/m^2 geschätzt.

Schlußfolgerungen

Wie bei den Schlußbemerkungen des Experiments 1-3, ist noch viel Basisforschung bei der Evaluierung der Erdauswahlmethoden sowie bei den Stabilisierungs- und Kalkanstrich-Techniken erforderlich, ehe entschieden werden kann, ob dieses Material in weiteren Prototyp-Experimenten getestet werden sollte oder nicht.

Resistance to Exposure

Except for superficial glazing of the lime coating, the area protected by cotton fabric stood up well to two months of exposure. The area protected with lime alone was badly cracked, partially due to damage during handling when attaching the specimen to the exposure deck.

Weight

Average weight for the stabilized soil covering with a lime coating is estimated to be about 26 kg/m^2.

Conclusions

As mentioned in the comments covering experiment 1-3, much more basic experimentation is necessary to evaluate soil selection methods, stabilization and lime coating techniques before a decision can be made as to whether this material should be tested further in prototype experiments or not.

6.2.2.2 Vorläufige Kostenschätzungen

Wie bereits früher in diesem Bericht erwähnt, ist das Dachdeckungssystem aus verzinktem Stahlblech die preiswerteste Alternative zum traditionellen Strohdach, die dem Hausbesitzer mit niedrigem Einkommen in Zentralamerika zugänglich ist. Die durchschnittlichen Gesamtbaukosten für dieses System sind, nach Schätzungen örtlicher Institutionen, 14 $/m^2, und werden folgendermaßen aufgeschlüsselt:

Position	Kosten/m^2
Galvanisierter Stahl (1)	4,75
Holz für Unterkonstruktion	1,90
Lohn	2,85
Abgehängte Decke (Holzplanken)	4,50
Insgesamt	14,00

Wird die abgehängte Decke weggelassen, so verringern sich die Gesamtkosten auf 9,50$/m^2.

Da angenommen werden kann, daß der Lohn für einen Hausbesitzer auf dem Lande, der sein eigenes Dach baut, kein wichtiger Faktor ist, dürften sein Hauptproblem, vom wirtschaftlichen Standpunkt aus betrachtet, wahrscheinlich die direkten Materialkosten für die Dachdeckung und Unterkonstruktion sein, welche in diesem Fall 6,65 $/m^2 betragen.

(1) einschl. Überlappung, Verschnitt, Nägel und Zusatzmaterial für die Firstabdeckung

6.2.2.2 Preliminary Cost Considerations

As mentioned previously in this report, the lowest cost alternative to the traditional thatched roof, available to the low-income home owner in Central America, is the galvanized steel roofing system. The average total construction cost for this system, as estimated by local institutions, is $ 14/m^2, and includes the following items:

Item	Cost/m^2
Galvanized steel (1)	4.75
Lumber for support system	1.90
Labour	2.85
False ceiling (wooden planks)	4.50
Total	14.00

If the false ceiling is eliminated, the total cost drops to $ 9.50/m^2.

Since labor may not be an important factor for the rural home owner who builds his own roof, his major concern from an economic standpoint probably would be the direct material cost for the roof covering and supports which, in this case, amounts to $ 6.65/m^2.

(1) Includes overlap, scrap, nails and the extra material required to cover the ridge.

Um dem Verbraucher einen wirtschaftlichen Vorteil zu bieten, sollte daher jedes neu einzuführende Dachdeckungssystem (Abdeckung und Unterkonstruktion) einen Materialkaufpreis haben, der bedeutend unter den oben erwähnten entsprechenden Kosten für das Dach aus verzinktem Stahlblech liegt.

In den nachstehenden Tabellen werden Schätzpreise der Materialkosten pro m^2 aufgeführt für jedes der im letzten Abschnitt beschriebenen Prototyp-Experimente, unter der Voraussetzung, daß Materialien wie Bambus, Rohr, Erde, Sand und Bims kostenlos im Felde gesammelt werden können. Wie man sehen kann, variieren die Kosten von mindestens 0,23 $/$m^2$ bis zu maximal 3,58 $/$m^2$, alle beträchtlich niedriger als die Kosten für galvanisiertes Stahlblech.

In order to represent an economic advantage to the consumer, therefore, any new roofing system to be introduced (covering and support) should represent a purchased material cost significantly less than the equivalent cost shown above for the galvanized steel roof.

In the following tables, estimates have been prepared of the material cost per square meter for each of the prototype experiments discussed in the last section, assuming that materials such as bamboo, cane, soil, sand and pumice can be gathered in the field without cost. As can be seen, costs vary from a minimum of $ 0.23/m^2 to a maximum of $ 3.58/m^2, all considerably lower than galvanized steel costs.

Geschätzte Materialkosten

Experiment 1-1

Dachdeckung: Sisalsäcke mit Zement-Sand-Mischung imprägniert.
Unterkonstruktion: Bambus und Seil.

Material	Einheit	Menge pro m^2	Einheitspreis ($)	Preis pro m^2 ($)
Bambus	m	3,20	-	-
Seil	m	10,80	0,08	0,86
Sisal-Säcke	m^2	1,90	1,09	2,07
Bindfaden	m	10,00	0,01	0,10
Zement	kg	6,90	0,08	0,55
Sand	kg	13,50	-	-
Gesamtkosten/m^2				3,58

Experiment 1-2 (a)

Dachdeckung: Zement-Bims-Mischung.
Unterkonstruktion: an Horizontalstäbe mit Bindfaden gebundene, dicht angeordnete Rohrstruktur.

Material	Einheit	Menge pro m^2	Einheitspreis ($)	Preis pro m^2 ($)
Rohr	m	42,00	-	-
Bindfaden	m	10,00	0,01	0,10
Zement	kg	10,70	0,08	0,86
Bimssand	kg	9,40	-	-
Gesamtkosten/m^2				0,96

Material Cost Estimate

Experiment 1-1

Covering: Sisal sacks impregnated with cement-sand mixture.
Support: Bamboo and rope.

Material	Unit	Quantity per m^2	Unit cost ($)	Cost per m^2 ($)
Bamboo	m	3.20	-	-
Rope	m	10.80	0.08	0.86
Sisal sacks	m^2	1.90	1.09	2.07
Twine for tying sacks	m	10.00	0.01	0.10
Cement	kg	6.90	0.08	0.55
Sand	kg	13.50	-	-
Total cost/m^2				3.58

Experiment 1-2 (a)

Covering: Cement-pumice mixture.
Support: Solid cane structure tied with twine to horizontal cane supports.

Material	Unit	Quantity per m^2	Unit cost ($)	Cost per m^2 ($)
Canes for support	m	42.00	-	-
Twine	m	10.00	0.01	0.10
Cement	kg	10.70	0.08	0.86
Pumice	kg	9.40	-	-
Total cost/m^2				0.96

Experiment 1-2 (b)

Dachdeckung: 10% Kalk-stabilisierte Erde ohne Oberflächenschutz.
Unterkonstruktion: an Horizontalstäbe mit Bindfaden gebundene, dicht angeordnete Rohrstruktur.

Material	Einheit	Menge pro m^2	Einheits-preis (Sh)	Preis pro m^2 (Sh)
Rohr	m	42,00	-	-
Bindfaden	m	10,00	0,01	0,10
Erde	kg	21,70	-	-
Löschkalk	kg	1,80	0,07	0,13
Gesamtkosten/m^2				0,23

Experiment 1-3

Dachdeckung: 10% Kalk-stabilisierte Erde mit Kalkanstrich.
Unterkonstruktion: an Vertikalstäbe mit Bindfaden gebundene, dicht angeordnete Rohrstruktur.

Material	Einheit	Menge pro m^2	Einheits-preis (Sh)	Preis pro m^2 (Sh)
Rohr	m	42,00	-	-
Bindfaden	m	10,00	0,01	0,10
Erde	kg	20,50	-	-
Löschkalk				
- als Bindemittel	kg	1,80	0,07	0,13
- als Anstrich	kg	1,90	0,07	0,13
Gesamtkosten/m^2				0,36

Experiment 2-1

Dachdeckung: Zement-Bims-imprägnierte Säcke.
Unterkonstruktion: mit Bindfaden gebundenes Rohrgerüst.

Material	Einheit	Menge pro m^2	Einheits-preis (Sh)	Preis pro m^2 (Sh)
Rohr	m	15,00	-	-
Bindfaden	m	10,00	0,01	0,10
Sisal-Säcke	m^2	1,40	1,09	1,53
Zement	kg	9,05	0,08	0,72
Bims	kg	9,05	-	-
Gesamtpreis/m^2				2,35

Experiment 1-2 (b)

Covering: 10% lime stabilized soil without surface protection.
Support: Solid cane structure tied with twine to horizontal cane supports.

Material	Unit	Quantity per m^2	Unit cost (Sh)	Cost per m^2 (Sh)
Canes for support	m	42.00	-	-
Twine	m	10.00	0.01	0.10
Soil	kg	21.70	-	-
Lime stabilizer	kg	1.80	0.07	0.13
Total cost/m^2				0.23

Experiment 1-3

Covering: 10% lime stabilized soil with lime surface coating.
Support: Solid cane structure tied with twine to vertical cane supports.

Material	Unit	Quantity per m^2	Unit cost (Sh)	Cost per m^2 (Sh)
Canes for support	m	42.00	-	-
Twine	m	10.00	0.01	0.10
Soil	kg	20.50	-	-
Lime stabilizer	kg	1.80	0.07	0.13
Lime coating	kg	1.90	0.07	0.13
Total cost/m^2				0.36

Experiment 2-1

Covering: Cement-pumice impregnated sacks.
Support: Cane grid tied with twine.

Material	Unit	Quantity per m^2	Unit cost (Sh)	Cost per m^2 (Sh)
Canes for support	m	15.00	-	-
Twine	m	10.00	0.01	0.10
Sisal sacks	m^2	1.40	1.09	1.53
Cement	kg	9.05	0.08	0.72
Pumice	kg	9.05	-	-
Total cost/m^2				2.35

Experiment 2-2

Dachdeckung: Erd-Kalk-imprägnierte Säcke mit Kalkanstrich.
Unterkonstruktion: mit Bindfaden gebundenes Rohrgerüst.

Material	Einheit	Menge pro m^2	Einheits-preis (S)	Preis pro m^2 (S)
Rohr	m	18,00	-	-
Bindfaden	m	6,00	0,01	0,06
Sisal-Säcke	m^2	1,48	1,09	1,61
Erde	kg	9,80	-	-
Löschkalk				
- als Bindemittel	kg	1,90	0,07	0,13
- als Anstrich	kg	1,80	0,07	0,13
Gesamtkosten/m^2				1,93

Experiment 2-3

Dachdeckung: Zement-Bims-Mischung.
Unterkonstruktion: Rohrgerüst mit Stroh als Zwischenraumfüllung.

Material	Einheit	Menge pro m^2	Einheits-preis (S)	Preis pro m^2 (S)
Rohr	m	16,00	-	-
Bindfaden	m	10,00	0,01	0,10
Zement	kg	11,00	0,08	0,88
Bims	kg	10,50	-	-
Gesamtpreis/m^2				0,98

Experiment 2-4

Dachdeckung: 10% Erd-Kalk-Schicht mit Baumwollgewebe-bewehrtem Kalkanstrich.
Unterkonstruktion: Rohrgerüst mit Stroh als Zwischenraumfüllung.

Material	Einheit	Menge pro m^2	Einheits-preis (S)	Preis pro m^2 (S)
Rohr	m	16,00	-	-
Bindfaden	m	10,00	0,01	0,10
Erde	kg	20,00	-	-
Löschkalk				
- als Bindemittel	kg	1,80	0,07	0,13
- als Anstrich	kg	2,50	0,07	0,18
Baumwollgewebe	m^2	1,10	0,61	0,67
Gesamtpreis/m^2				1,08

Experiment 2-2

Covering: Soil impregnated sacks with protective lime coating.
Support: Cane grid tied with twine.

Material	Unit	Quantity per m^2	Unit cost (S)	Cost per m^2 (S)
Canes for support	m	18.00	-	-
Twine	m	6.00	0.01	0.06
Sisal sacks	m^2	1.48	1.09	1.61
Soil	kg	9.80	-	-
Lime stabilizer	kg	1.90	0.07	0.13
Lime coating	kg	1.80	0.07	0.13
Total cost/m^2				1.93

Experiment 2-3

Covering: Cement-pumice.
Support: Cane grid tied with twine-straw filler between vertical supports.

Material	Unit	Quantity per m^2	Unit cost (S)	Cost per m^2 (S)
Canes for support	m	16.00	-	-
Twine	m	10.00	0.01	0.10
Cement	kg	11.00	0.08	0.88
Pumice	kg	10.50	-	-
Total cost/m^2				0.98

Experiment 2-4

Covering: 10% lime stabilized soil protected with lime impregnated cotton fabric.
Support: Cane grid tied with twine-straw filler between vertical supports.

Material	Unit	Quantity per m^2	Unit cost (S)	Cost per m^2 (S)
Canes for support	m	16.00	-	-
Twine	m	10.00	0.01	0.10
Soil	kg	20.00	-	-
Lime stabilizer	kg	1.80	0.07	0.13
Cotton fabric	m^2	1.10	0.61	0.67
Lime coating	kg	2.50	0.07	0.18
Total cost/m^2				1.08

7. ZUSAMMENFASSUNG UND SCHLUSSFOLGERUNG

7.1 Mögliche Lösungen

Das Dach, eine scheinbar einfache, individuelle Baueinheit, wird zu einem sehr komplexen Element, wenn man bedenkt, auf wieviele Arten es studiert und verbessert werden kann. Die Art und Vielfalt von Lösungen für das Dachproblem kann so fast unendlich variieren, wie die folgenden Überlegungen zeigen:

- Mögliche Lösungen können entweder Verbesserungen bestehender Systeme, vollkommen neue Entwicklungen oder eine Kombination von beidem sein.
- Sie können Teile des Daches betreffen (Unterbau, Abdeckung), das ganze Dach oder gewisse physikalische Eigenschaften (z.B. thermische und akustische Eigenschaften, Stärke, Lebenserwartung).
- Verbesserungen und Neuerungen sind möglich bei Materialien, Entwurf und Baumethoden.
- Aspekte der verbesserten Materialien können jegliche Bearbeitungsphase (von der Beschaffung von Rohmaterialien über Vorbehandlungen bis zum endgültigen Aufbau auf der Baustelle), Elementgröße, Form und Oberflächenbehandlung, umfassen.
- Entwurfsaspekte können sein: Kostenreduzierung, Verbesserung der Erdbeben- und Wirbelsturmsicherheit sowie Innenraumklima und Aussehen.
- Verbesserte Konstruktionsmethoden können vereinfachte und beschleunigte Verfahrensweisen, Tolerierung von Ungenauigkeiten und ungelernten Arbeitskräften, und doch insgesamt eine umfassende Verbesserung der wesentlichen Eigenschaften der Dachkonstruktion sein.

In Anbetracht der Situation in Zentralamerika hat die Untersuchung vier Typen von Dachdeckungssystemen für Billigwohnungsbau gezeigt, die gegenwärtig in dieser Gegend allgemein gebräuchlich sind. Sie umfassen Strohdächer, mit Rundholz- oder Bambusträgern und Tondachziegeln, verzinkte Stahlbleche oder Asbestzementplatten mit Holzunterkonstruktion.

Wenn man die in diesem Bericht aufgezeigten Daten zusammenfaßt, ergeben sich folgende Mängel an den bestehenden Systemen:

- Stroh:
  Hauptsächlich verwendet wegen seiner niedrigen Kosten; es benötigt jedoch zur Fertigung großen Zeitaufwand und einiges handwerkliches Geschick. Es neigt dazu, Insekten und Ungeziefer anzuziehen, und ist nicht feuersicher.
- Tondachziegel:
  Werden von den örtlichen Bewohnern als das attraktivste Dachdeckungsmaterial angesehen, aber ihre verhältnismäßig hohen Kosten machen deren Anwendung für einen großen Teil der Bevölkerung unmöglich. Das sehr hohe Gewicht erfordert ein schweres Stützsystem, und die Ziegel bilden eine Gefahr bei Erdbeben.

7. SUMMARY AND CONCLUSION

7.1 Possible Solutions

The roof, a seemingly simple, individual unit of construction, becomes a highly complex element when considering in how many ways it can be studied and improved. The type and magnitude of solutions to the roofing problem can thus vary almost indefinitely, as the following possibilities show:

- Feasible solutions can either be improvements of existing systems, completely new developments, or combinations of both.
- They can deal with parts of the roof (substructure, roof cover), the whole roof or certain physical characteristics (eg. thermal and acoustical properties, strength, life expectancy).
- Improvements and innovations are possible for materials, design and construction methods.
- Aspects of improved materials may involve any stage of handling (from obtaining raw materials, via pretreatments to final installation at building site), size of elements, shape and surface finish.
- Design aspects could be reduction of cost, improvement of earthquake and hurricane resistance, as well as indoor climate and appearance.
- Improved construction methods can mean simplified and accelerated operations, tolerance of inaccuracies and non-skilled labour, and yet basically an overall improvement in performance of the roof structure.

Considering the situation in Central America , the investigation has shown four types of roofing systems for low-cost housing to be in common usage in the region at the present time. These include thatched roofs with pole or bamboo supports, and clay tile, galvanized steel or asbestos-cement sheets supported by wooden frames.

Summarizing the data presented in the report, the principal deficiencies of the existing systems are the following:

- Thatch:
  Used principally because of its low cost, but requires considerable time and some manual skills for its installation. Tends to attract insects and rodents and lacks fire resistance.
- Clay tile:
  Considered the most visually attractive roofing system by local inhabitants, but its relatively high cost prevents its use by a large segment of the population. Excessive weight requires a heavy support system, and the tiles represent a hazard during earthquakes.

- Verzinktes Stahlblech:
  Wird wegen seiner einfachen Anbringung, seiner relativ niedrigen Kosten und des leichten Gewichts gebraucht. Hauptprobleme sind die kurze Lebensdauer aufgrund von Oxydation, wenn es nicht durch Farbanstrich geschützt ist (übersteigt die Mittel vieler armer Land- und Stadtbewohner), keine Wärmeisolierung (Hitzeabstrahlung nach innen), sehr hohe Geräuschbelästigung bei starkem Regen, Kondenswasserbildung im Innenraum.

- Asbestzement:
  Wird mehr bei öffentlichen Wohnbauprojekten benützt. Verhältnismäßig schwer, hohe Kosten. Schwieriger zu handhaben und zu installieren, leicht zerbrechlich. Dieselben Kondenswasserbildungsprobleme wie bei verzinktem Stahlblech.

In Anbetracht der oben erwähnten Beobachtungen sollte ein verbessertes Dachdeckungssystem für Zentralamerika folgenden Kriterien entsprechen:

- Weniger Zeit und handwerkliche Geschicklichkeit als für den Bau von Strohdächern benötigen. Umkompliziertere Aufbaumethode als bei Asbestzementdächern.
- Feuerbeständiger sein als Strohdächer.
- Die Eigenschaft, Insekten oder Ungeziefer anzuziehen, vermindern oder ausschließen.
- Bedeutend billiger sein als Tonziegel- oder Asbestzement-Dächer.
- Leichteres Gewicht als Tonziegeldächer haben.
- Die Gefahr von herabfallenden Dachelementen bei Erdbeben vermindern oder ausschalten.
- Weitgehend wie Tondachziegel aussehen, da diese von der örtlichen Bevölkerung bevorzugt werden.
- Frei sein von Korrosionsproblemen wie bei verzinktem Stahl.
- Übermäßige Geräuschbelästigung bei starken Regenfällen mindern oder ausschalten.
- Relativ leicht sein, ohne Bruchgefahr zu handhaben und zu verarbeiten.
- Kondenswasserbildung im Inneren mindern oder ausschalten.

- Galvanized steel:
  Used because of its simple installation, relatively low cost and light weight. Principal problems are its short life due to oxidation unless protected by paint (beyond the means of many of the rural and urban poor), lack of thermal resistance (radiation of heat to interior), excessive noise during rainstorms, and interior condensation.

- Asbestos-cement:
  Used more in public housing projects. Relatively heavy and high cost. More difficult to manipulate and install, can be easily broken. Same interior condensation problems as with galvanized steel.

Taking the above observations into consideration, an improved roofing system for Central America should respond to the following:

- Require less time and manual dexterity for its installation than for thatch roofs. Less complicated installation method than that used for asbestos-cement.
- Better fire resistance than thatch roofs.
- Reduce or eliminate the tendency to attract insects or rodents.
- Significantly less costly than clay tile or asbestos-cement roofs.
- Lighter weight than clay tile roofs.
- Reduce or eliminate danger from falling roof elements during earthquakes.
- Simulate the appearance of clay tile roofing systems, since this is preferred by the local population.
- Free of the rust problems associated with galvanized steel.
- Reduce or eliminate excessive noise during rainstorms.
- Relatively easy to handle and manipulate without breakage.
- Reduce or eliminate interior condensation problems.

7.2 Das ideale Dach

Die Analyse von Dachdeckungssystemen in verschiedenen Regionen, die in den vorhergehenden Abschnitten dieses Berichts erläutert wurden, ermöglicht eine Auflistung der wünschenswerten Eigenschaften eines idealen Daches.

Die Erfüllung aller aufgeführten Kriterien mögen in der Praxis undurchführbar sein, aber je mehr die Eigenschaften neuer Dachdeckungs-Lösungen mit den aufgelisteten übereinstimmen, desto größer sind die Chancen, daß sie größere Aufnahmebereitschaft und Anwendung finden und folglich dazu beitragen, ein wichtiges technologisches Problem beim Hausbau in Entwicklungsländern zu lösen.

Kriterien für Entwurf und Ausführung von Dächern in Zentralamerika
(zutreffend für fast alle Regionen der Dritten Welt)

Entwurf:

- dem Klima und der Umgebung angepaßt
  (in feuchten Gebieten Ausschließen von Wärme durch Materialien mit geringer Wärmespeicherkapazität und durch belüfteten Dachraum, dagegen in trockenen und Hochlandzonen Materialien mit Wärmespeicherkapazität; nicht gänzlich wasserundurchlässig, jedoch in der Lage, Regenwasser schnell abzuführen; helle äußere Oberfläche zur Reflexion der Sonnenstrahlung; Schallisolierung, besonders für starke Regenfälle)
- erdbebensicher
  (entweder monolithisch mit hoher Druckfestigkeit oder flexibel mit hoher Zugfestigkeit und festen Verbindungen; statische Trennung der Dachtragkonstruktion von den Wänden)
- wirbelsturmsicher, besonders in Küstengebieten
  (keine Flachdächer; stabile feste Verbindungen zum übrigen Gebäude; kein loses Material, das schwer oder scharfkantig ist)
- optisch annehmbar
  (keine radikal neuen Formen und Materialien, vorzugsweise Fortführung herkömmlicher Formen mit bedeutenden Verbesserungen bezüglich Konstruktion und Kosten)
- ausreichend dauerhaft
  (mindestens 5 Jahre ohne Wartung, vorzugsweise 20 Jahre mit geringer Wartung)

Ausführung:

- von ungelernten Arbeitern und Selbsthilfe-Bauherren leicht erlernbar und beareifbar
- ohne Bedarf an importiertem, kompliziertem Gerät, das nicht gewartet werden kann (das gebräuchlichste örtliche Werkzeug ist die "machete", ein Messer mit einer 30 - 50 cm langen und 5 - 7 cm breiten Klinge)

7.2 The Ideal Roof

The analysis of worldwide roofing systems discussed in the previous sections of this report permits a listing of the desirable characteristics of an ideal roof.

The fulfillment of all the given criteria may in practice be unachievable, but the more the characteristics of new roofing solutions coincide with those listed, the greater are the chances that they find wider acceptance and application, and consequently help to solve a major technological problem of housing in developing countries.

Criteria for Design and Construction of Roofs in Central America
(applicable for practically all Third World regions)

Design:

- Climatologically and environmentally appropriate
  (in humid areas, exclusion of heat by low thermal capacity materials and ventilated roof space, whereas in arid zones and highlands constructions with heat retaining capacity; not totally impermeable, but capable of shedding rainwater rapidly; light outer surface to reflect solar radiation; sound insulation, especially in heavy rains).
- Earthquake resistant
  (either monolithic with high compressive strengths or flexible with high tensile strengths and rigid bonds; structural separation of roof supports from walls).
- Hurricane resistant, particularly in coastal areas
  (no flat roofs; rigid, strong connections to rest of building; no loose material, which is heavy or sharp cornered).
- Aesthetically acceptable
  (no radically new shapes and materials, preferably continuation of conventional forms with significant improvements in construction and costs).
- Adequate life
  (at least 5 years without maintenance, preferably 20 years with minimum maintenance).

Construction:

- Easily learnt and understood by unskilled workers and self-help builders.
- No necessity of imported, complicated equipment which cannot be maintained (Most common local tool is the "machete", a knife with a 30 to 50 cm blade length and 5 to 7 cm width).

- in der Lage, Ungenauigkeiten zu tolerieren und keine komplizierten Qualitätstests zu erfordern
- schnell realisierbar mit minimaler Menschenkraft (z.B. zwei oder drei Personen, die etwa vier oder fünf Tage arbeiten)
- zu beliebiger Jahreszeit durchführbar

Materialien:

- örtlich verfügbar, ohne lange Transportwege, in gesunder Relation zu den finanziellen und technischen Mitteln der Bevölkerung (z.B. ohne Pkw-Transport, Entfernung nur so groß, daß das Material von einem Mann getragen werden kann)
- mit möglichst geringem oder vorzugsweise ohne Gebrauch von importierten Bestandteilen, oder solchem Material, das beispielsweise auf Rohöl basiert (mit steigenden Preisen und abnehmenden Vorräten)
- erneuerbar oder in unbegrenzter Menge verfügbar
- billig oder kostenlos (d.h. ohne weiteres für Bewohner erschwinglich)
- mit vorhandenem einfachem Werkzeug leicht bearbeitbar
- nicht zu schwer, so daß zwei oder drei Männer ein Dach bauen können
- frei von giftigem Material, dos vom Regen abgewaschen werden und die Umgebung verseuchen könnte
- unanfällig für Insekten, Vögel oder Ungeziefer sowie für Pilze
- feuerbeständig oder zumindest feuerhemmend
- für die klimatischen und Umweltbedingungen gut geeignet
- resistent gegen übermäßige Regenwasseraufnahme, jedoch nicht vollkommen wasserundurchlässig (besonders Dachunterseite), um Kondenswasserbildung zu verhindern
- geräuscharm bei schweren Regenfällen
- stoßunempfindlich (z.B. Hagelkörner) und fähig, das Gewicht einer auf dem Dach arbeitenden Person zu tragen
- ganz oder teilweise aus Abfallmaterialien, aber nicht denjenigen, die anderweitig verwendet werden können (z.B. Bagasse, Reis- oder Kokosnußschalen, die als Brennmaterial benützt werden)

- Should tolerate inaccuracies and not require sophisticated quality tests.
- Should be quickly erected with minimum manpower (eg two or three people working about four or five days).
- Should be possible to build any time of the year.

Materials:

- Locally available, no long transport distances, in accordance with the financial and technical means of the people (eg without motorized transport, maximum practical carrying distance for a man).
- Minimum use of, or preferably no imported material, or such based on fossil oils (with rising prices and diminishing supplies).
- Renewable or available in unlimited supply.
- Cheap or no cost (ie well within the means of the occupants).
- Easily handled with available, low technology equipment.
- Not too heavy, so two or three men can build the roof.
- No poisonous material, that can be washed off by rain and contaminate the surroundings.
- Materials that do not encourage nesting of insects, birds or rodents, or promote fungal growth.
- Fire resistant or at least fire retarding.
- Good thermal performance, with respect to the given climate and environment.
- Resistant to excessive rainwater absorption, but not completely impermeable (especially on the underside of roof) to avoid development of condensation.
- Not noisy during heavy rains.
- Resistant to impact (eg from hailstones) and capable of supporting weight of a person working on the roof.
- Possible use of waste materials, but not such that already have other uses (eg bagasse, rice and coconut husks used as fuel).

7.3 Schlußfolgerung

Das vorliegende Forschungsprojekt wurde initiiert, um die Probleme und Möglichkeiten von billigen Bedachungssystemen zu erfassen und grundlegende Informationen über Bedachungssysteme in verschiedenen Teilen der Welt sowie gezielte Daten über die Situation in Zentralamerika zu sammeln. Dies muß als wichtiges Einführungsstadium angesehen werden, von dem Impulse und Ideen abgeleitet werden können bei der Suche nach neuen geeigneten Bedachungsmöglichkeiten in Zentralamerika.

Die Experimentierphase des Projektes war vor allem einleitender Art. Sie wurde durchgeführt, um besonders solche örtlich verfügbaren Materialien, die gegenwärtig nicht für Dachkonstruktionen verwendet werden, zu testen und ihre Anwendungsmöglichkeiten für billige Bedachungssysteme auszuwerten. Da die Entwicklung, Verbesserung und Implementierung neuer Dachdeckungssysteme ein schwieriger und langer Prozeß ist, zeitigten diese anfänglichen Experimente kein unmittelbar annehmbares neues Dachkonzept. Die bis jetzt erreichten Ergebnisse der Tests mit Zement-Bims und Kalk-stabilisierten Erd-Mischungen, kombiniert mit verschiedenen Verstärkungsmaterialien und einfachen Bambus- oder Rohrkonstruktionen, erscheinen jedoch vielversprechend genug, um weitere Forschung auf diesem Gebiet zu rechtfertigen.

7.3 Conclusion

The present research project was conceived to obtain an understanding of the problems and possibilities of low-cost roofing and to collect basic data on roofing systems in the world in general, as well as specific information on the situation in Central America. This must be seen as an important introductory stage, from which impulses and ideas may be derived in the search for new appropriate roofing in Central America.

The experimental phase of the project was of a preliminary nature conducted primarily to screen locally available materials not currently used for roof construction to evaluate their potential as elements for low cost roofs. Since the development, improvement and implementation of new roofing systems is a difficult and long process, these initial experiments, as expected, did not result in an immediately acceptable new roofing concept. However, the results to date of the tests performed on cement-pumice and lime stabilized soil mixtures combined with diverse reinforcing materials and simple bamboo or cane support structures, appear sufficiently promising to warrant further research in this field.

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Roof tent

From Wikipedia, the free encyclopedia

A **roof tent** is an accessory which may be fitted to the roof of a motor vehicle which allows the users to sleep in relative safety and comfort above the vehicle, and leaves the internal load-space free. The first example of roof-tents appeared in Western Europe in the 1930s.[1]

ARB Simpson II roof top tent on a Nissan Patrol.

Roof tents are particularly seen on expedition-prepared four wheel drive vehicles such as Land Rovers, but can be fitted to almost any vehicle. Generally they will mount to a vehicles roof rack or aftermarket roof bars. They are particularly popular in Italy and one manufacturer advertises them using photographs of their devices fitted to cars as small as the Fiat Panda.

Designs and styles

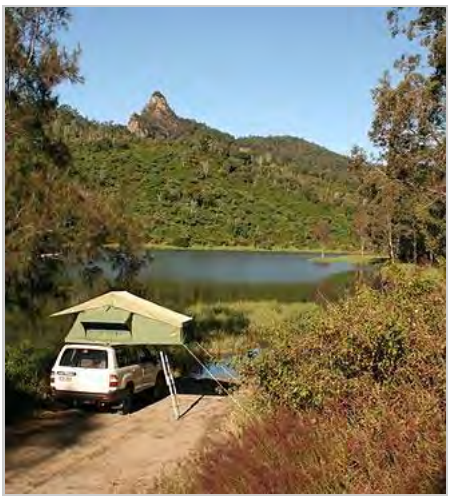

Gordigear roof tent on a Toyota Land Cruiser.

Roof tents have traditionally taken the form of a conventional ridge-pole tent which can be folded into a compact package, resting on marine plywood, and mounted on a roof rack. Beginning in 1958, more modern tent designs appeared - housed in a waterproof, moulded fiberglass or carbon fibre box, and are erected and taken down more quickly using a simple crank-operated cantilever arrangement or gas rams that automatically erect the tent when the latches are released. In 2003 a French manufacturer introduced another design of simple and lightweight tents, resembling modern sprung-pole types of ground tent.

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Categories: Tents | Automotive accessories | Camping stubs | Automotive part stubs

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Domestic Roofwater Harvesting
Research Programme

NEW TECHNOLOGY FOR VERY-LOW-COST DOMESTIC ROOFWATER HARVESTING

DFID KaR Contract R7833

April 2002

Development Technology Unit
School of Engineering, University of Warwick

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1 INTRODUCTION

This report is an output from a 27 month research contract (R7833) for the UK Department for International Development and describes work done during the 4 month prototyping phase of that project. The prototyping phase has developed out of the practice descried in the report to the DFID "R1, Very-Low-Cost Domestic Roofwater Harvesting in the Humid Tropics: Existing Practice" and the constraints identified in "R2, Very-Low-Cost Domestic Roofwater Harvesting in the Humid Tropics: Constraints and Problems". The work itself was carried out by the DTU along with members of the Lanka Rainwater Harvesting Forum in Sri Lanka, Water Action in Ethiopia and ACORD in Uganda.

The Sri Lankan portion of this work would not have been possible without the facilities and kind assistance of the Nation Builders Association. In particular we would like to thank Mr Adikarum, Mr Amarasinge, Mr Widasecara and Mr Siripala for their help, insight and patience during our time there.

1.1 The need

Surveys carried out in the initial phase of the project have pointed to cost as the number one constraint facing users adopting roofwater harvesting so if it is to become an affordable option for poor people in developing countries, the cost of systems must be reduced.

In R2 a methodology for cost reduction of roofwater harvesting systems was discussed. The method revolved around the building of a rainwater harvesting service framework as shown in Figure 1.1 focusing on the quality of structure as well as the quantity of water delivered. By reducing the structural quality to a level closer to the quality of housing found in poor areas, large savings can result.

Figure 1.1: Service framework for rainwater harvesting systems

a. Framework

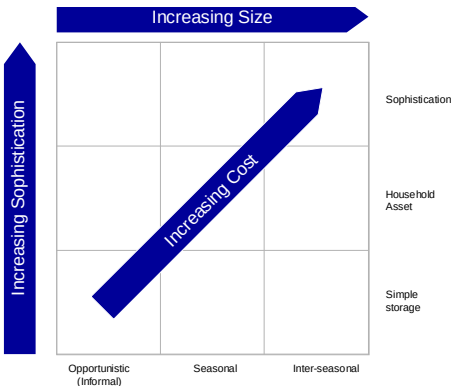

b. How current systems map onto the framework

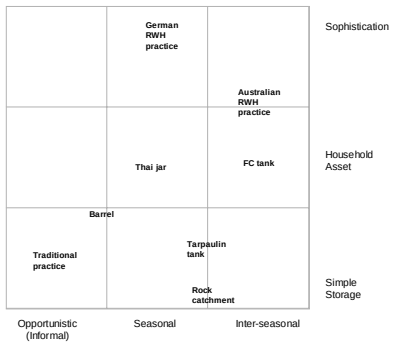

In reducing the quality, however, there are a number of critical functional constraints that should be regarded as a minimum specification:

- Gutters should deliver a good fraction of the water falling on the roof – dependent on the local rainfall, roof size storage size and demand pattern
- The tank should not have excessive loss through seepage or evaporation – <5% of the water drawn from it

- The tank should not present an excessive danger to its users, either by their falling in or by the tank failing violently
- The water must be of a quality consummate with its intended use – water that is used for drinking requires a certain care in transport and storage:
  - The catchment area should be smooth and free from accumulated debris
  - The water should be filtered to remove gross impurities or the first flush removed
  - The tank should be covered to prevent entry of light, and sealed against intrusion by vermin
  - The tank should be ventilated to prevent anaerobic decomposition of any washed-in matter

1.2 Methods of cost reduction

The methods used to reduce the cost of rainwater harvesting systems are covered in report R2, the methods described are:

- Material reduction (Improved formwork, Shape optimisation, Function separation)
- Material substitution (Using cheaper materials, use of "free" materials)
- Mass production
- Use of existing containers

1.3 Basis for cost comparison

Costing "rainwater harvesting systems for the poor" is more complex than simply adding up component costs on a bill of materials. Some materials are only available at a cost through purchasing channels, while others are available at no cost if one is willing to gather them. This report will group materials and labour into the following categories:

a. *Economic materials*; materials relying on industrial processes – in their purchase cash will be removed from the area

b. *Local economic materials*; materials which must be bought but where production is from local sources – the cash will remain in the community

c. *Skilled labour*; labour that must be paid for

d. *Local materials*; materials that can be gathered from the land – they may or may not have an economic value but tend to be freely available

e. *Householder labour*; labour that can be provided by the household – it may be skilled, but in locally used techniques (such as wattle and daub construction).

For the poor the latter two costs may be heavily discounted when compared to any cash outgoings, and consequently they will be are separated from the first three 3 in costings presented in this report.

Household labour is often ignored in costing programmes aimed at the poor, however this may become unrealistic if the household labour contribution becomes burdensome. Another approach is to allocate an opportunity cost of 50% of the unskilled labour rate to such a contribution to reflect the loss of time to the household. The real value of their time to a householder should lie between these two figures, so both will be quoted in this report They are referred to as "HH labour discounted" cost and "HH labour ignored" cost. A total cost with no discounting is also included for reference.

2 TANKS

2.1 Current state-of-the-art

Current practice is comprehensively described in report R1 so only a brief summary of current best practice will be given here as a baseline from which to judge new developments. Water storage forms the largest single cost component of a RWH system and so is the most likely candidate for cost reduction. Current state-of-the-art for storage tanks in developing countries is ferrocement construction, either based on a fixed solid mould or on an open framework. Generally, a solid mould results in a cheaper tank, as the wall thickness of the tank can be more tightly controlled and work is done against an inflexible surface. Open frameworks have the advantage of allowing greater flexibility in tank size but at the cost of plastering work taking place against an elastic backing which lets some mortar through resulting in greater and more variable wall thickness and a higher cost per tank. Tanks are also made from bricks which can reduce costs by material substitution but the savings are often not great although more of the money remains in the community. A graph of current costs of various techniques in the three study countries is given in Figure 2.1.

Figure 2.1: Tank costs

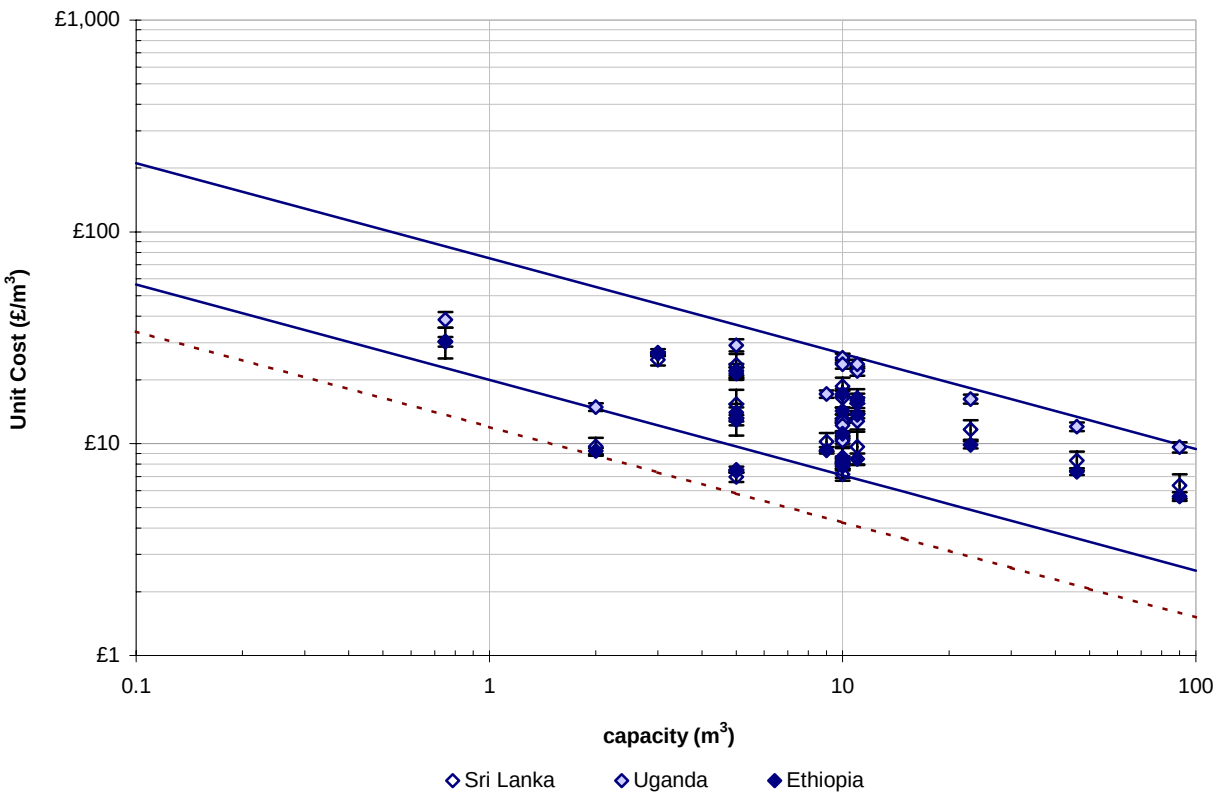

Notes: Points represent costs with household labour discounted, error bars represent the extremities when household labour is included in full or ignored altogether

Lines slopes correspond to a cost:capacity sensitivity of 0.6

A cost sensitivity to volume of 0.6 – 0.7 is the norm, so designs can be usefully compared over a wide range of capacities. The Solid blue lines represent the bounds of normal state-of-the-art. the dotted red line represents the lower limit of a region populated by “exceptional” designs such as the Thai jar and the Ugandan tarpaulin tank. It is this region that forms the target cost range. Tanks developed during the prototyping phase of the programme fall mainly into the benchmark range as shown in Figure 2.2.

Most of the designs also have a greater reliance on household labour and local materials so compulsory cash costs are kept lower still (as indicated by the bottom extent of the error bars).

Figure 2.2: cost comparison of tanks developed during the prototyping phase

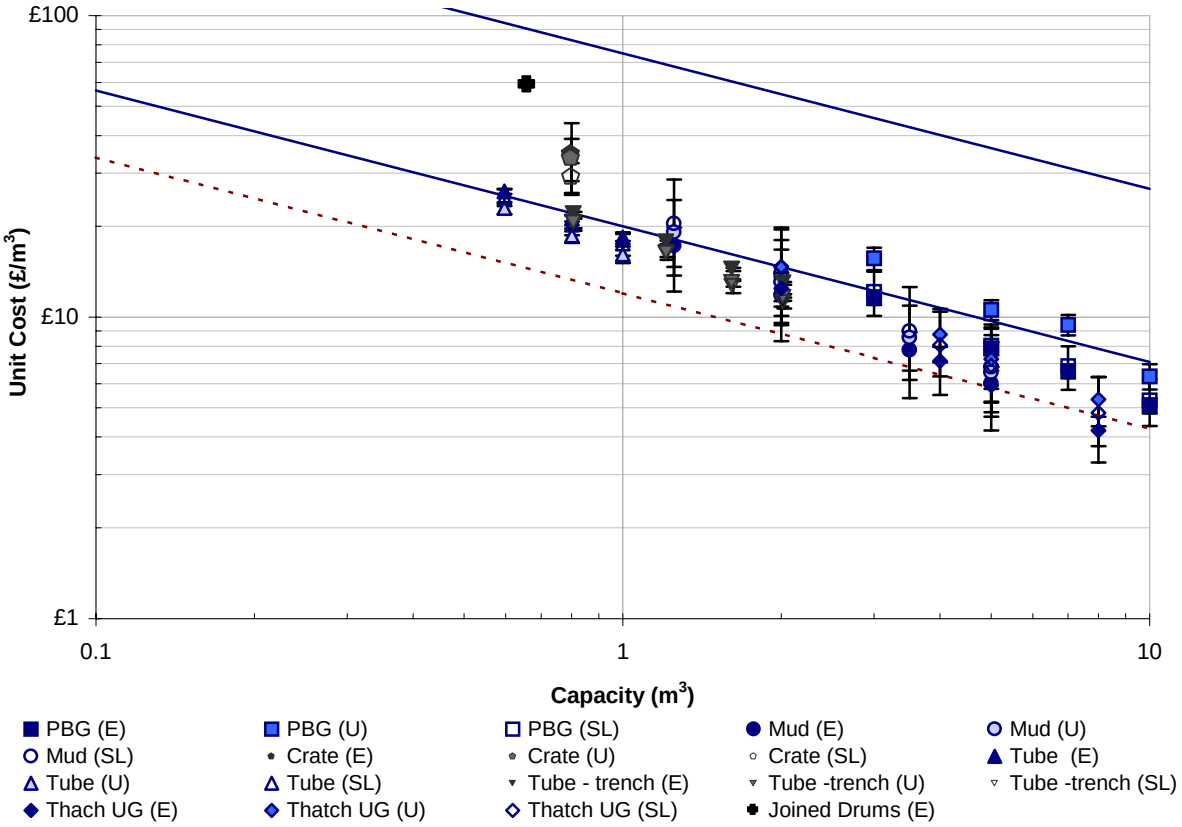

2.2 Below-ground designs

Below ground designs are the mainstay of low cost tank design. If built in stable soil, the ground itself will act as a stiff spring taking much of the load, reducing the role of the lining material to waterproofing. In these circumstances, tank wall thicknesses can be very small and materials that have good waterproofing properties but suffer from a low structural strength (such as polyethylene sheet) can be used.

Tube tank

The tube tank was originally developed by the DTU in July 2000 (Rees & Whitehead, 2000), as part of a technology development project funded in part by the Morris Laing Foundation. The design was based around a widely available plastic tube of about 500 microns thickness sold by the metre on a roll of 3ft width. The cost of this tube is £0.38 in Sri Lanka, £0.54 in Ethiopia and £0.40 in Uganda. When opened, the tube forms a cylinder of Ø54cm resulting in a volume of 0.23m^3 per metre length. The cost of storage, is therefore only £1.66, £2.33, £1.75 (SL, Et, Ug) per m^3 of storage for the tube itself. The original design (see Figure 2.3) was based on the partially below ground principle where most of the tank was below ground, but about 1m protruded as a brick parapet, avoiding stormwater ingress

and providing a visual presence for the tank. A hole was dug to accommodate the tube and a bag was formed by folding and tying off the end. The bag itself was fixed between two courses of bricks and an overflow pipe was fitted in a hole in the bag and sealed with a small amount of cement.

Figure 2.3: Original tube tank design. (all pictures from (Rees & Whitehead, 2000))

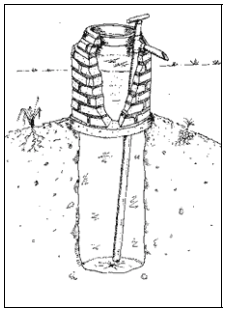

General arrangement of tube tank Mk 1

Digging the hole

Bag tying

Overflow arrangement and fixing of the bag between brick courses

The design was fairly successful and several of the tanks are in service however it has some problems, most which have become apparent after a year of use:

- The cost of the parapet wall dominates the overall tank cost and forces the design to compete directly with more robust and desirable designs such as the ferrocement jar
- The hole is difficult to dig
- The tied joint at the bottom can leak
- The liner is extremely difficult to remove if it is punctured – those that do leak have not been repaired
- The overflow can leak resulting in accumulation of water between the bag and the excavation walls

The new design (see Figure 2.4)addresses these problems by including the following changes:

- A more classic underground design using a precast concrete cover reduces the cost. The cover itself is similar to the arrangements found on some handpumps and so should be familiar to use. It is made using similar casting techniques to pit latrine covers (sanplats).
- The tube has been folded in two, eliminating the tied joint, making the hole 40% larger and consequently, easier to dig
- The tube itself is easily replaceable by using a retaining ring and binding wire to hold the tube in place.
- A variant folds the tank into a “L” shape reducing the depth of the excavation and replacing the vertical hole with a trench

Figure 2.4: Modified tube tank design.

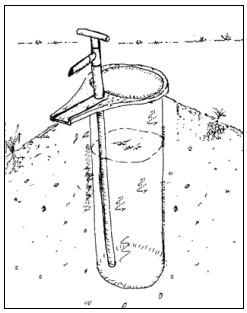

General arrangement of tube tank Mk 2

Retaining ring

Overflow

Horizontal folded tube tank being filled

With these modifications, the design is extremely inexpensive at less than £18 for a 700l tank and £26 for a 2m^3 folded tank. Although the prototypes were made using in-situ casting in the ground, the slab has designed with pre-casting in mind and so is well suited to factory production where savings of up to 50% can be made by drastically reducing labour content.

The tank design is also ideally suited to rapid implementation projects such as refugee camps; if the excavation is done by the householders, an agency can simply transport a number of prefabricated parts and each tank can be assembled within an hour.

Tank size is determined by hole depth so the deeper a household digs, the larger the store, extra storage is relatively cheap as the cost of the tank is dominated by the concrete slab. The alternative horizontal folded design is more suited to less stable soils as the excavation itself is about 60cm deep and can be tapered if necessary, however the cost is higher due to the need to cover the trench over. Costs of several capacities of each type of tube tank are shown against benchmarks in Table 2.1.

Table 2.1: costs of tube tanks

a. vertical

Capacity (m^3)	0.6	0.8	1.0
Total	£16 – 17	£16 – 17	£17 – 19
Total (HH labour discounted)	£14 – 16	£15 – 17	£16 – 18
Total (HH labour ignored)	£13 – 15	£14 – 17	£16 – 18
Target range	£9 –15	£11 –18	£12 –20

b. horizontal

Capacity (m^3)	0.8	1.2	1.6	2.0
Total	£17 – 18	£20 – 22	£21 – 24	£23 – 26
Total (HH labour discounted)	£17 – 18	£20 – 21	£20 – 23	£23 – 26
Total (HH labour ignored)	£16 – 17	£19 – 21	£19 – 23	£22 – 26
Target range	£11 –18	£13 – 22	£16 – 26	£18 – 29

Thin shell cement slurry lining

Neat cement is about 40% stronger and twice as flexible as mortar. It is also almost completely impermeable, making the material ideal for the construction of very thin shells to line pits. Initial experiments on a 1m depth pit of Ø1.5m revealed leakage of less than 10 litres/day and the surface showed no cracks. A larger pit of 3m depth was also tried, however the cement was applied without

due care and cracks developed. The leakage from this pit is 80 litres/day, however no additional cracking has been observed as a result of the significant head of water acting on the shell.

The thin shell cement lining technique can result in material economies of up to 50% when compared to conventional mortaring, however the care with which it must be applied to the soil may make it unsuitable to unsupervised (free market) construction at a local level.

Direct application of mortar

It is common practice to put mesh in an underground tank when lining with mortar. Typically this takes the form of a layer or two of chicken wire. The given reasons are that it:

- adds strength
- provides a surface upon which to plaster (lath)
- Reduces cracking

Looking at the first of these reasons, a single layer of chicken mesh will have an in-line volume fraction less than 0.2% when compared to the mortar (assuming a 1cm mortar layer), so its contribution to the strength of the composite is fairly minimal (about 20% using the law of mixtures). Of course, the strength of an underground tank is mostly from the reaction of the soil itself.

The second may be true, but the initial layer of mortar is usually applied to the hole *adding* the mesh (indeed placing mesh directly on the soil is risky as it will certainly corrode from contact with moist soil). Further layers can be built up by scoring the original thus providing keys in the mortar itself. Such scoring is also simple to add to a hard soil and should provide a good keying for mortaring.

Crack reduction can be a useful property, particularly in tanks with large surface areas, however in smaller, domestic tanks cracking is not big problem as witness the popularity of mortar tanks in Thailand.

Thus the supposed advantages of using mesh may be insubstantial in this application and are certainly small compared to the advantages of using the strength of the soil wall.

Conversely, the mesh itself will cause problems when added to a concave surface such as the inside of a hole. The problem is basically one of overconstraint. If one considers, for the sake of argument a flexible sheet placed inside a cylinder. It can be either just the right size, too small or too big. If it is too big, the loose mesh forms bubbles, losing the benefit of the earth wall's support, if it is too tight it will stretch tight across the wall rather than following the curve, resulting in voids. Adding fixing points is the usual solution to these difficulties but this often simply turns one large problem into several small ones. The more fixings, the better the fit but also the greater likelihood of human error – the result can even be areas of too tight mesh next to bubbles of too loose mesh.

Directly applying mortar to the walls has proven to be a simple technique to apply in the field. A thin layer of 1cm can be applied with ease and with good quality control. The mortar itself has no need for high strength so can be as lean as 1:8 (cement:sand) in a good soil. Waterproofing is provided by a thin cement slurry applied while the mortar is wet. Several tanks have been built using this method to depths of up to 2.5 meters with no visible cracking and lower leakage than evaporation. The direct application of lean mortar with a slurry coat is the basis for two interrelated designs of tank, the below-ground cement tank with a cheap roof based on organic material and the partially below ground tank with a ferrocement dome.

Below-ground cement tank with organic roof

Ring beam with trench

Shuttering for pump and overflow mounting

low-cost tank cover under construction

Finished tank with cover in place

As the cost of the below-ground waterproof tank is reduced, the cover of the tank becomes the dominant cost. Organic roofs are used on many buildings in poor households and so the skills to build them are common. The materials themselves also tend to fall into the "gatherable" class. To put an organic roof onto a water tank, however, a number of precautions must be taken.

- The organic material must not fall into the tank and contaminate the water
- Runoff from the organic roof will be of low quality and so must not be allowed to enter the tank
- The roof must provide a good barrier to vermin entry, especially as some creatures make their homes in thatch.
- The wooden supports must not be exposed to the humid atmosphere inside the tank which will make them liable to rot
- To aid bacteriological die off, the roof must provide a good barrier against sunlight entering the tank

A polyethylene barrier fulfils the need to protect the organic matter from moisture and also to protect the water from falling debris. If the joining is handled well, it can also act as an excellent seal – completed by the use of inner tubes around the rim. Prevention of water entry can be afforded by the use of a sloped ring beam which will divert the water away from the tank and into a drainage channel.

Below-ground tanks also need care with avoiding floodwater ingress and also with overflow arrangements. The new design uses a syphonic overflow by employing an upwardly facing elbow connected to an outflow pipe which leads either to a nearby slope or to an infiltration pit. Stormwater ingress is handled by digging a channel around the ring beam to a width and depth determined from the runoff.

The overall combination of direct mortar application and low cost roof yields a tank that uses very little material but is quite householder labour intensive. The costs for the tank are shown in Table 2.2.

Table 2.2: Cost of underground mortar tank with organic roof

Capacity (m^3)	2	4	5	8
Total	£28 – 40	£32 – 43	£33 – 46	£37 – 51
Total (HH labour discounted)	£25 – 29	£29 – 35	£30 – 36	£34 – 43
Total (HH labour ignored)	£19 – 23	£22 – 29	£23 – 29	£26 – 3`5
Target range	£18 – 29	£26 – 43	£26 – 48	£38 – 63

Partially below-ground tank with ferrocement dome

Lining the pit

Fixing the frame for the dome

first layer of mortar for the dome

Finished tank

A solution to the overflow and floodwater problems of an underground tank is a partially below ground design where most of the tank is underground takes advantage of the economies to be found from soil support but with some of the tank protruding. Partially below-ground tanks form a bridge between underground tanks and above-ground tanks. They are somewhat more expensive than purely underground tanks, as the above-ground section can cost 3-4 time more per unit volume than the underground section. The Below-ground cement tank can be upgraded to form partially below-ground tank by simply adding a ferrocement domed cover. The dome uses a removable frame that leaves behind only wire mesh as reinforcement. The mortar can either be applied without any other formwork by using one person outside to apply the mortar and one person inside to provide a backing (the addition of a small amount of sacking fibres to the mortar was found to help this process) or by making a temporary formwork from cardboard. The dome can be built when the tank is first commissioned or added later when more funds are available. The finished tank is slightly more expensive per litre than the organically roofed over tank but will require less maintenance. Costs for the tank are shown in Table 2.3.

Table 2.3: Cost of partially below-ground tank

Capacity (m^3)	3	5	7	10
Total	£37 – 43	£41 – 51	£49 – 62	£54 – 71
Total (HH labour discounted)	£35 – 39	£39 – 47	£46 – 57	£51 – 65
Total (HH labour ignored)	£30 – 35	£34 – 43	£40 – 52	£43 – 59
Target range	£22 – 37	£29 – 48	£35 – 58	£43 – 71

2.3 Above-ground designs

Above ground designs are generally more popular than below ground solutions, however the cost is often also higher as the tank must now cope with the full force of the water pressure acting on it. The principle of functional separation allows some scope for cost reduction. Waterproofing can be done by either mortar or a liner.

Fabric tank

end of fabric tank with bracket

top sheet showing rubber seal

completed fabric tank

An above-ground tank is almost essential in poor crowded urban areas as the ground can be very contaminated. Ideally, a tank should also be fairly portable as tenure in such communities can often be insecure and many squatter communities live under constant threat of being moved on. The fabric tank goes some way to fulfilling these needs by providing a tank with a small footprint, protruding only 45cm from the dwelling. The tank can also be collapsed down into a long, thin package for transport. A polyethylene tube is placed within a fabric sleeve which is hung on a framework. The fabric takes the pressure load while the polyethylene provides waterproofing.

Unfortunately, the tank has proved problematic as the fabric itself stretches and puts high loads on its fixings which then fail. The fixings could be made stronger and more expensive fabrics should stretch less, however they will make the tank unaffordable.

Crate tank

lid with hole for inlet

delivering the crate to the household

Internal configuration

Finished tank in use

A similar design to the fabric tank has a wooden crate forming the load-bearing structure. The design has the same small footprint as the fabric tank but is not as portable as it can only easily be knocked down into its component walls. It is, however, much better protected from accidental damage than the fabric tank. The design is similar in concept to the tube tank with a retaining ring holding the top of the tube to the top of the tank providing an inlet. The tube than folds around and the other end is attached to the overflow. A tap is attached at the bottom of the “U” and sealed with bitumen. The outlet and overflow can be on any of three sides of the tank to help it fit in with its location. The total cost of the tank is slightly higher than the target range, however the need for a slender profile and portability may make the tank usable in areas where cheaper alternatives will be inappropriate. The manufacture of the tank employs only skilled labour but is very portable (deliverable) so it lends itself to mass production at a central location which could reduce the cost.

Table 2.4: Cost of crate tank

Capacity (m^3)	0.8
Total	£23 – 28
Target range	£11 – 18

Wattle and daub tank

Bamboo frame

Detail of manhole

Mud blocks used for testing

Finished tank

A simple way of producing an above-ground tank with the economy of a below ground tank is to bring the ground up. Several earth technologies have been used in building for millennia and such techniques are often the mainstay of housing for the poor. Wattle and daub is a widespread practice for building from earth, particularly when householders their own homes. The technique uses unmodified mud to fill a frame structure made from roundwood. The materials necessary for this type of constructions are all in the "gatherable" class so cash costs are extremely low, being limited to the liner and plumbing.

A small sample of mud blocks from different sources were tested for tensile strength and it was found that they lay in the fairly narrow range of 730kPa to 900kPa with ant-hill mud generally at the higher end. This compares poorly with 2 – 5MPa for Portland cement mortar so walls have to me made quite thick – typically 15 to 20cm. Initial tests used cement as a liner, however the mud structure expands slightly under load and the lining cracked resulting in leakage and damage to the mud walls. The use of a plastic liner has proved much more satisfactory.

Table 2.5: Cost of wattle and daub tank

Capacity (m^3)	1.25	2	3.5	5
Total	£25 – 37	£27 – 40	£31 – 45	£34 – 48
Total (HH labour discounted)	£22 – 26	£24 – 29	£27 – 32	£30 – 35
Total (HH labour ignored)	£16 – 18	£17 – 20	£20 – 23	£22 – 26
Target range	£14 – 23	£18 – 29	£24 – 40	£29 – 48

Rammed earth

The use of rammed earth provides a stiffer structure than wattle and daub and can be rendered internally with mortar. The earth can also be stabilised with Portland cement to provide a better wet strength than with mud construction. The DTU has done some previous work with this technique to build cylindrical tanks (Rees, 2000) however they proved difficult to construct due to movement of the round mould during manufacture. To combat this, trials have taken place to develop a rectangular tank using traditional corner jointing methods and reinforcing. The trials are thus far incomplete but show some promise for a controllable product that can be used in sandier soils where mud construction is impossible.

Connected drums

Drums form an easily accessible form of storage and many households already have at least one drum performing various duties, among them water storage and even opportunistic rainwater collection. Very few households employ more than one such drum however despite the extra water this could provide. Drums also have a small footprint and are light enough to be portable. They do suffer from problems such as the possibility of residual toxicity and solar heating of the water through the metal.

Several configurations of 2 or 3 drums have been tried, including two forms of vertical connection and one horizontal one. The pros and cons of these are detailed in Table 2.6. Initial Cleaning of the drums is usually done by using a locally produced caustic soda, however there is still some uncertainty about its effectiveness.

Table 2.6: pros and cons of different drum configurations

Type	Pros	Cons
1. Vertically stacked drums connected by means of pipefitting.	• Doesn't require welding or electricity. • The piped outlet allows incorporation of a slow-sand filter • Small footprint	• There is some leakage in the lower drum between the lid and circular clamp.
2. Vertically stacked drums connected by means of welding.	• The number of fittings is reduced • There is no leakage in the system • Small footprint	• Depends on the availability of a welder.
3. Horizontally placed drums connected by means of pipefitting	• An unlimited number of drums can be connected without leakage from the top • Repeated filtering provides different grades of water. • Doesn't require welding or electricity	• The required space is relatively higher compared to others and thus the material for the plinth is greater

The final design uses two vertically stacked drums with welded seams to prevent leakage and an internal slow sand filter. As the slow flow through the filter could reduce the storage, particularly in heavy storms, an optional separate tank has been added to catch this overflow. The overall cost is quite high by very-low-cost standards but still within state-of-the-art boundaries especially considering the design incorporates quite sophisticated filtering.

Table 2.7: Cost of drum configurations[1]

Type	1	2	3	final
Number of drums	2	2	3	3
Capacity (litres)	340	420	620	540
Total	£30	£31	£36	£38
Target range	£7 – 11	£7 – 12	£9 – 15	£9 – 14
Upper limit of state-of-the-art	£41	$47	£58	£53

Note: Costs are based on Ethiopian experience

Several connected jerry cans

Many households already have a fair storage in the form of several jerrycans. The cans themselves are inherently portable and can be distributed throughout the dwelling to save space and so are a good solution for crowded urban areas. The requirement is for a system of plumbing to connect these cans together to form a continuous storage. The cans then fill up in turn with the water quality improving in

each successive can. A system of siphons empty the plumbing into the last can or to an overflow so there will be no leakage when a can is removed for use, however the problem of accidentally leaving a can out of the chain (with disastrous consequences when it rains) is still unsolved. The cost of the cans themselves is also a problem and could make the system uneconomic unless the household already has a reasonable number available.

Cascade of water jars

Many households use water jars for water collection. These jars are well suited to stacking in an array. The water runs down the outsides of one jar into the mouth of another with quality improving as it moves down the cascade. The rounded jars do allow the water to progress unhindered to the next, however the overall storage is quite low at 75 litres. The framework necessary is also quite expensive and puts the entire array into the higher end of the state of the art at about £16. the jars themselves are fairly low in price, however and so a cheaper frame (e.g. a suspended chain) could make the system more economic but it will never be a very-low-cost option.

3 ROOFS

Another difficulty with roofwater harvesting is its reliance on an impermeable roof. Penetration of corrugated iron sheet roofs is growing rapidly and the costs are becoming competitive with professionally thatched roofs, however many poor houses in developing countries still have organic roofs. The reasons for this include cost, particularly where the roof is made by the householder, insulation and ventilation of the smoke from cooking fires.

There are five strategies for utilising organic roofs for rainwater harvesting;

1. Use the water for secondary processes
2. Treat the water
3. Cover the roof with an impermeable cover
4. Build a separate roof structure in the household compound
5. Use a nearby public building

Covering the roof and roof structures are the most obvious technical solutions, however, it was found that covering an organic roof with an impermeable barrier can cause problems to the roof itself, as water cannot evaporate presenting ideal conditions for mould growth, and the ultimate rotting of the structure. The runoff water quality from a number of materials for that might be employed to either to cover a roof or on a separate structure was measured. The materials tried were corrugated iron sheet, corrugated asbestos sheet, polypropylene sacking, tar sheet and palm-leaf organic roofing (*cadjan*).. A typical set of runoff quality results is shown in Figure 3.1. The characteristic runoff quality follows a

power law decay with different materials having different starting points. Organic roofs predictably having the worst water quality while tar sheet, which is readily available and inexpensive has a good runoff characteristic, in line with asbestos but the water does contain petro-chemicals whose levels and rate of decay has not yet been quantified. Turbidity for the GI sheet is below the minimum level that can be discerned with the Del Agua turbidity meter used for this measurement and is therefore below the 5NTU level for turbidity set by the WHO (WHO, 1997)

Figure 3.1: Runoff quality of different roof types

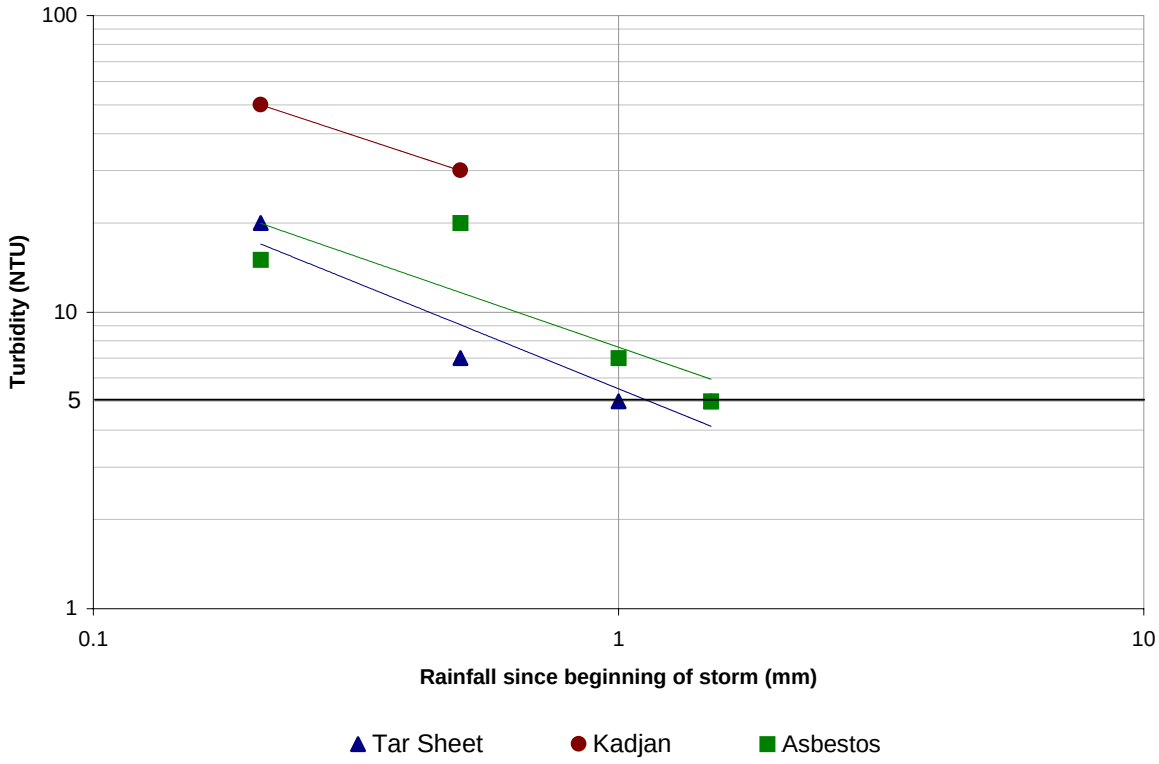

4 GUTTERS

Guttering on a very-low-cost roofwater harvesting system can take up a substantial amount of the cost so its optimisation is important here. Typical state-of-the-art gutters in developing countries tend to be quite expensive with a typical 10m length costing from £10 to £25. Some work has been done in East Africa with vee shaped gutters which have a typical cost of £8 for a similar length. Research at Warwick on optimising gutter size based on carrying capacity suggests that a vee shaped gutter of only 7.5 cm width is sufficient to carry water from all but the most severe downpours and will deliver more than 90% of the water it catches. Such a small gutter should cost less than £3 for a 10m run.

Water interception is a slightly more difficult issue. Water often has to fall some distance from the roof to the gutter and is thrown from the roof different distances depending on the intensity of the downpour. It can also be blown by wind in unexpected directions. Two solutions for this have been tried.

Figure 4.1: Gutters configurations

a. G-shaped gutter

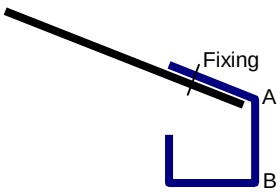

b. extended vee

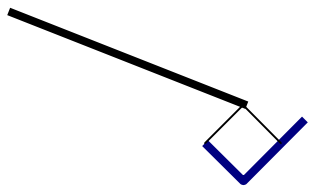

The first (Figure 4.1a) is a complete solution that captures the water at the end of the roof and directs it into the gutter below. The gutters are also very quick to install as the slope is determined by a variable manufactured length of vertical support (between A and B) so no adjustment is necessary. Cleaning is also simple as the inside edge is open for a brush all the way along its length. Problems with the gutter appear when the length to be guttered is longer than 5m or when thick roofs need to be accommodated. Under these circumstances the vertical support becomes very long and can flex causing the gutter to spill. This can be alleviated by using support wires with the loss of some ease of cleaning, however as the vertical support can use a substantial amount of material, the gutter starts to become expensive at over £9 for 10m.

The second uses the concept of a “upstand”, where one side of the gutter stands proud of the other, effectively raising the catchment height of the gutter. In the design the usual square gutter has been simplified to a vee and the upstand is merely an extension of one arm of the vee. This extends the catchment of the gutter upwards and moves the centre of the catchment out from the roof edge better matching the profile of water flowing from a roof. The gutter is extremely cheap (less than £3.50 for a 10m run) and can be applied to any sized roof without the need for a facia board. Like all suspended gutters, the design does need adjustment to maintain the slope and the suffers from guy wires obstructing cleaning.

5 CONCLUSION

The cost of rainwater harvesting systems can be reduced by a number of methods several of which have been presented here. The most promising are:

- The use of thin shell cement lining as found in the underground cement tank with an organic roof and the partially below-ground tank with a ferrocement dome
- The use of free materials and local techniques such as wattle and daub construction and organic roofs
- Earth technologies such as wattle and daub and rammed earth
- Mass production methods and the use of plastic linings as used in the tube tank and crate tank
- Incorporation of existing structures such as drums
- Smaller profile, sheet-metal gutters which can incorporate features such as water guides or extended catchment surfaces

Less successful were such techniques as:

- Distributed storage in jerrycans and multiple pots
- Very portable, yet fragile tanks such as the fabric tank

- Over-thin plastering techniques that rely on excessive quality control such as Thin shell cement slurry lining

Special circumstances can also be incorporated at little cost

- Tall thin structures such as the crate tank and vertically stacked drums can be built for crowded urban areas
- Auxiliary roofs can be constructed at little cost as an alternative to poor quality organic roof catchments

But

- Very portable, yet fragile tanks such as the fabric tank
- Roof covering treatments that are built onto an existing roof

Are problematic and cannot be recommended.

6 BIBLIOGRAPHY

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APPENDIX

Bills of materials and costings

Tube tank

Material	Unit Quantity	unit costs			Quantity Used			Ethiopia			Uganda			Sri lanka		
		Ethiopia	Uganda	Sri Lanka	0.6m3	0.8m3	1.0m3	0.6m3	0.8m3	1.0m3	0.6m3	0.8m3	1.0m3	0.6m3	0.8m3	1.0m3
Tank																
cement	bag	£2.67	£6.10	£2.69	0.4	0.4	0.4	£1.03	£1.03	£1.03	£2.36	£2.36	£2.36	£1.04	£1.04	£1.04
sand	m3	£3.57	£3.05	£3.32	0.037	0.037	0.037	£0.13	£0.13	£0.13	£0.11	£0.11	£0.11	£0.12	£0.12	£0.12
aggregate	m3	£15.25	£2.98	£11.07	0.061	0.061	0.061	£0.94	£0.94	£0.94	£0.18	£0.18	£0.18	£0.68	£0.68	£0.68
Plastic tube	m	£0.58	£0.41	£0.37	3.6	4.66	5.7	£2.10	£2.72	£3.33	£1.46	£1.89	£2.32	£1.35	£1.74	£2.13
Bracket	each	£0.70	£0.70	£1.39	1	1	1	£0.70	£0.70	£0.70	£0.70	£0.70	£0.70	£1.39	£1.39	£1.39
Basin 20"	each	£1.33	£0.41	£0.52	1	1	1	£1.33	£1.33	£1.33	£0.41	£0.41	£0.41	£0.52	£0.52	£0.52
Inner Tube 20"	each	£1.08	£1.08	£0.93	1	1	1	£1.08	£1.08	£1.08	£1.08	£1.08	£1.08	£0.93	£0.93	£0.93
Labour (skilled)	day	£2.50	£2.03	£2.80	1	1	1	£2.50	£2.50	£2.50	£2.03	£2.03	£2.03	£2.80	£2.80	£2.80
Labour (unskilled)	day	£0.58	£1.22	£1.87	1	1	1	£0.58	£0.58	£0.58	£1.22	£1.22	£1.22	£1.87	£1.87	£1.87
Sub																
Pump																
1 1/2" pipe	m	£0.70	£0.83	£0.17	1.9	2.4	2.9	£1.32	£1.67	£2.02	£1.58	£2.00	£2.42	£0.32	£0.41	£0.49
1 1/4" pipe	m	£0.88	£0.73	£1.74	1.575	2.075	2.575	£1.39	£1.83	£2.28	£1.16	£1.52	£1.89	£2.75	£3.62	£4.49
1 1/2" tee	each	£1.50	£1.02	£0.50	1	1	1	£1.50	£1.50	£1.50	£1.02	£1.02	£1.02	£0.50	£0.50	£0.50
1/2"pipe	m	£0.00	£0.00	£0.47	0.2	0.2	0.2	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.09	£0.09	£0.09
wood (2X2)	m	£0.00	£0.00	£0.00	0.1	0.1	0.1	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
wood screw	each	£0.00	£0.00	£0.01	2	2	2	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.01	£0.01	£0.01
Labour (skilled)	day	£2.50	£2.03	£2.80	0.5	0.5	0.5	£1.25	£1.25	£1.25	£1.02	£1.02	£1.02	£1.40	£1.40	£1.40
sub								£5.47	£6.26	£7.05	£4.77	£5.56	£6.34	£5.08	£6.04	£7.00
Total								£5.47	£6.26	£7.05	£4.77	£5.56	£6.34	£5.08	£6.04	£7.00
Total (discounted)								£5.47	£6.26	£7.05	£4.77	£5.56	£6.34	£5.08	£6.04	£7.00
Total (ignored)								£5.47	£6.26	£7.05	£4.77	£5.56	£6.34	£5.08	£6.04	£7.00

Underground tank with organic roof

Material	Unit Quantity	unit costs			Quantity Used				Ethiopiu				Uganda				Sri lanka			
		Ethiopia	Uganda	Sri Lanka	2m3	4m3	5m3	8m3	2m3	4m3	5m3	8m3	2m3	4m3	5m3	8m3	2m3	4m3	5m3	8m3
Tank																				
cement	bag	£2.67	£6.10	£2.69	0.9	1.5	1.6	2.2	£2.53	£4.10	£4.14	£5.90	£5.77	£9.38	£9.47	£13.47	£2.55	£4.14	£4.18	£5.94
sand	m3	£3.57	£3.05	£3.32	0.12	0.19	0.19	0.27	£0.43	£0.68	£0.70	£0.98	£0.36	£0.58	£0.59	£0.84	£0.40	£0.63	£0.65	£0.91
aggregate	m3	£15.25	£2.98	£11.07	0.06	0.06	0.07	0.07	£0.84	£0.84	£1.11	£1.11	£0.16	£0.16	£0.22	£0.22	£0.61	£0.61	£0.80	£0.80
6mm re-bar	m	£0.08	£0.16	£0.07	5	5	5	5	£0.39	£0.39	£0.39	£0.39	£0.78	£0.78	£0.78	£0.78	£0.33	£0.33	£0.33	£0.33
Binding wire	kg	£0.67	£0.81	£0.34	2	2	2	2	£1.33	£1.33	£1.33	£1.33	£1.63	£1.63	£1.63	£1.63	£0.67	£0.67	£0.67	£0.67
Bamboo	m																			
Thatch																				
Motorcycle tubes	each	£0.00	£0.00	£0.00	7	7	10	10	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Polythene	m2	£0.08	£0.14	£0.07	6	6	10	10	£0.50	£0.50	£0.83	£0.83	£0.81	£0.81	£1.36	£1.36	£0.45	£0.45	£0.75	£0.75
Basin	each	£1.50	£1.08	£1.08	1	1	1	1	£1.50	£1.50	£1.50	£1.50	£1.08	£1.08	£1.08	£1.08	£1.08	£1.08	£1.08	£1.08
24" Inner tube	each	£1.00	£0.93	£0.93	1	1	1	1	£1.00	£1.00	£1.00	£1.00	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93
Labour (skilled)	day	£2.50	£2.03	£2.80	3	3	3.5	3.5	£7.51	£7.51	£8.76	£8.76	£6.10	£6.10	£7.12	£7.12	£8.41	£8.41	£9.81	£9.81
Labour (unskilled)	day	£0.58	£1.22	£1.87	11	11	12	13	£6.42	£6.42	£7.01	£7.59	£13.42	£13.42	£14.64	£15.86	£20.55	£20.55	£22.42	£24.29
Sub									£22.46	£24.29	£26.78	£29.40	£31.06	£34.88	£37.81	£43.28	£35.98	£37.81	£41.62	£45.52
Pump																				
1 1/2" pipe	m	£0.70	£0.83	£0.50	2	3.2	2.5	3.5	£1.39	£2.22	£1.74	£2.43	£1.67	£2.67	£2.08	£2.92	£1.01	£1.61	£1.26	£1.77
1 1/4" pipe	m	£0.88	£0.73	£0.43	1.675	2.875	2.175	3.175	£1.48	£2.54	£1.92	£2.81	£1.23	£2.11	£1.60	£2.33	£0.72	£1.24	£0.93	£1.36
1 1/2" tee	each	£1.50	£1.02	£0.45	1	1	1	1	£1.50	£1.50	£1.50	£1.50	£1.02	£1.02	£1.02	£1.02	£0.45	£0.45	£0.45	£0.45
1/2"pipe	m	£0.00	£0.00	£0.17	0.2	0.2	0.2	0.2	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.03	£0.03	£0.03	£0.03
wood (2X2)	m	£0.00	£0.00	£0.45	0.1	0.1	0.1	0.1	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.04	£0.04	£0.04	£0.04
wood screw	each	£0.00	£0.00	£0.01	2	2	2	2	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.01	£0.01	£0.01	£0.01
Labour (skilled)		£2.50	£2.03	£2.80	0.5	0.5	0.5	0.5	£1.25	£1.25	£1.25	£1.25	£1.02	£1.02	£1.02	£1.02	£1.40	£1.40	£1.40	£1.40
sub									£5.62	£7.52	£6.41	£7.99	£4.93	£6.81	£5.71	£7.28	£3.67	£4.79	£4.14	£5.07
Total									£28.08	£31.81	£33.19	£37.39	£35.99	£41.69	£43.53	£50.56	£39.66	£42.61	£45.76	£50.60
Total (discounted)									£24.87	£28.60	£29.69	£33.59	£29.28	£34.98	£36.21	£42.63	£29.38	£32.33	£34.55	£38.45
Total (ignored)									£21.66	£25.39	£26.18	£29.80	£22.57	£28.27	£28.89	£34.70	£19.10	£22.05	£23.34	£26.31

Partially below ground tank

Material	Unit Quantity	Unit costs			Quantity Used				Ethiopia				Uganda				Sri lanka			
		Ethiopia	Uganda	Sri Lanka	3m3	5m3	7m3	10m3	3m3	5m3	7m3	10m3	3m3	5m3	7m3	10m3	3m3	5m3	7m3	10m3
Tank																				
cement	bag	£2.67	£6.10	£2.69	1.9	2.8	3.5	4.3	£4.99	£7.39	£9.31	£11.48	£11.40	£16.89	£21.28	£26.24	£5.03	£7.45	£9.39	£11.57
sand	m3	£3.57	£3.05	£3.32	0.2	0.3	0.4	0.5	£0.79	£1.06	£1.34	£1.63	£0.67	£0.90	£1.14	£1.39	£0.73	£0.98	£1.24	£1.52
aggregate	m3	£15.25	£2.98	£11.07	0.1	0.1	0.1	0.1	£0.84	£0.84	£1.11	£1.11	£0.16	£0.16	£0.22	£0.22	£0.61	£0.61	£0.80	£0.80
mesh	m3	£0.56	£0.75	£0.42	5.8	5.8	10.4	10.4	£3.24	£3.24	£5.77	£5.77	£4.39	£4.39	£7.81	£7.81	£2.42	£2.42	£4.30	£4.30
bolts	each	£0.07	£0.03	£0.03	10	10	16	16	£0.70	£0.70	£1.12	£1.12	£0.35	£0.35	£0.56	£0.56	£0.35	£0.35	£0.56	£0.56
Basin	each	£1.50	£0.41	£1.08	1	1	1	1	£1.50	£1.50	£1.50	£1.50	£0.41	£0.41	£0.41	£0.41	£1.08	£1.08	£1.08	£1.08
24" Inner tube	each	£1.00	£0.61	£0.93	1	1	1	1	£1.00	£1.00	£1.00	£1.00	£0.61	£0.61	£0.61	£0.61	£0.93	£0.93	£0.93	£0.93
Labour (skilled)	day	£2.50	£2.03	£2.80	5	5	5.5	5.5	£12.51	£12.51	£13.76	£13.76	£10.17	£10.17	£11.18	£11.18	£14.01	£14.01	£15.42	£15.42
Labour (unskilled)	day	£0.58	£1.22	£1.87	6.5	6.5	8.5	10	£3.80	£3.80	£4.96	£5.84	£7.93	£7.93	£10.37	£12.20	£12.15	£12.15	£15.88	£18.69
sub									£29.37	£32.04	£39.87	£43.21	£36.09	£41.81	£53.58	£60.62	£37.31	£39.98	£49.60	£54.87
Tooling																				
Frame		£0.56	£0.56	£0.56	10	10	16	16	£5.63	£5.63	£9.01	£9.01	£5.63	£5.63	£9.01	£9.01	£5.63	£5.63	£9.01	£9.01
6mm bar		£0.08	£0.16	£0.16	20	20	37	37	£1.57	£1.57	£2.91	£2.91	£3.13	£3.13	£5.79	£5.79	£3.13	£3.13	£5.79	£5.79
sub									£7.21	£7.21	£11.92	£11.92	£8.76	£8.76	£14.80	£14.80	£8.76	£8.76	£14.80	£14.80
sub/10									£0.72	£0.72	£1.19	£1.19	£0.88	£0.88	£1.48	£1.48	£0.88	£0.88	£1.48	£1.48
Pump																				
1 1/2" pipe	m	£0.70	£0.83	£0.50	2.2	3.4	2.9	3.9	£1.81	£2.64	£2.29	£2.99	£2.17	£3.17	£2.75	£3.59	£1.31	£1.92	£1.66	£2.17
1 1/4" pipe	m	£0.88	£0.73	£0.43	2.6	3.8	3.3	4.3	£2.01	£3.07	£2.63	£3.51	£1.67	£2.55	£2.18	£2.92	£0.98	£1.49	£1.28	£1.71
1 1/2" tee	each	£1.50	£1.02	£0.45	2.275	3.475	2.975	3.975	£1.50	£1.50	£1.50	£1.50	£1.02	£1.02	£1.02	£1.02	£0.45	£0.45	£0.45	£0.45
1/2"pipe	m	£0.00	£0.50	£0.17	1	1	1	1	£0.00	£0.00	£0.00	£0.00	£0.10	£0.10	£0.10	£0.10	£0.03	£0.03	£0.03	£0.03
wood (2X2)	m	£0.00	£0.00	£0.45	0.2	0.2	0.2	0.2	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.04	£0.04	£0.04	£0.04
wood screw	each	£0.00	£0.00	£0.01	0.1	0.1	0.1	0.1	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.01	£0.01	£0.01	£0.01
Labour (skilled)		£2.50	£2.03	£2.80	0.5	0.5	0.5	0.5	£1.25	£1.25	£1.25	£1.25	£1.02	£1.02	£1.02	£1.02	£1.40	£1.40	£1.40	£1.40
sub									£6.57	£8.47	£7.68	£9.26	£5.97	£7.85	£7.07	£8.63	£4.23	£5.35	£4.89	£5.82
Total									£7.29	£9.19	£8.87	£10.45	£6.85	£8.73	£8.55	£10.11	£5.11	£6.23	£6.37	£7.30
Total (discounted)									£7.29	£9.19	£8.87	£10.45	£6.85	£8.73	£8.55	£10.11	£5.11	£6.23	£6.37	£7.30
Total (ignored)									£7.29	£9.19	£8.87	£10.45	£6.85	£8.73	£8.55	£10.11	£5.11	£6.23	£6.37	£7.30

Crate tank

Material	Unit Quantity	unit costs			Quantity Used	Cost		
		Ethiopia	Uganda	Sri Lanka		Ethiopia	Uganda	Sri lanka
8 x 1 planks	m	£0.46	£0.45	£0.37	32.5	£15.06	£14.54	£12.15
tap	each	£0.92	£2.03	£0.70	1.00	£0.92	£2.03	£0.70
1/2" pipe	m	£0.25	£1.71	£0.17	0.20	£0.05	£0.34	£0.03
tap socket	m3	£0.21	£0.61	£0.21	2.0	£0.42	£1.22	£0.42
tap plug (?)	each	£0.21	£0.61	£0.21	1	£0.21	£0.61	£0.21
1" GI pipe	m	£0.25	£1.71	£0.70	0.2	£0.05	£0.34	£0.14
plastic tube	m	£0.58	£0.41	£0.37	5	£2.92	£2.03	£1.87
20" Basin	each	£1.33	£0.41	£0.52	1	£1.33	£0.41	£0.52
20" Inner tube	each	£1.08	£0.61	£0.93	1	£1.08	£0.61	£0.93
bracket	each	£0.70	£0.70	£0.70	1	£0.70	£0.70	£0.70
Labour (skilled)	day	£2.50	£2.03	£2.80	2	£5.00	£4.07	£5.61
Labour (unskilled)	day	£0.58	£1.22	£1.87	0	£0.00	£0.00	£0.00
Sub						$27.75	$26.90	$23.27
Sub (discounted)						$27.75	$26.90	$23.27
Sum (ignored)						$27.75	$26.90	$23.27

Wattle and daub tank

Material	Unit Quantity				Quantity Used				Ethiopia				Uganda				Sri Lanka			
		Ethiopia	Uganda	Sri Lanka	1.25m	2m	3.5m	5m	1.25m	2m	3.5m	5m	1.25m	2m	3.5m	5m	1.25m	2m	3.5m	5m
cement	bag	£2.67	£6.10	£2.69	0.4	0.5	0.6	0.8	£1.10	£1.36	£1.63	£2.07	£2.51	£3.12	£3.72	£4.73	£1.11	£1.38	£1.64	£2.09
sand	m3	£3.57	£3.05	£3.32	0.06	0.07	0.09	0.11	£0.21	£0.26	£0.31	£0.40	£0.18	£0.22	£0.27	£0.34	£0.20	£0.24	£0.29	£0.37
aggregate	m3	£15.25	£2.98	£11.07	0.10	0.12	0.15	0.18	£1.50	£1.86	£2.22	£2.82	£0.29	£0.36	£0.43	£0.55	£1.09	£1.35	£1.61	£2.04
Barbed wire	m	£0.03	£0.03	£0.03	31	41	50	66	£0.88	£1.14	£1.40	£1.84	£0.96	£1.25	£1.53	£2.01	£0.98	£1.27	£1.57	£2.05
Binding wire	kg	£0.67	£0.81	£0.34	2	2	3	3	£1.33	£1.33	£2.00	£2.00	£1.63	£1.63	£2.44	£2.44	£0.67	£0.67	£1.01	£1.01
Plastic	m2	£0.39	£0.27	£0.25	7	10	13	17	£2.83	£3.73	£5.22	£6.42	£1.97	£2.59	£3.64	£4.47	£1.81	£2.38	£3.34	£4.11
String	m	£0.00	£0.02	£0.01	0	0	0	0	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Mud	m3																			
Bamboo	m																			
Thatch																				
Basin	each	£1.50	£0.41	£1.08	1	1	1	1	£1.50	£1.50	£1.50	£1.50	£0.41	£0.41	£0.41	£0.41	£1.08	£1.08	£1.08	£1.08
24" Inner tube	each	£1.00	£0.93	£0.93	1	1	1	1	£1.00	£1.00	£1.00	£1.00	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93	£0.93
1 1/4" pipe	m	£0.88	£0.73	£0.43	1	1	1	1	£0.88	£0.88	£0.88	£0.88	£0.73	£0.73	£0.73	£0.73	£0.43	£0.43	£0.43	£0.43
1 1/4" elbow	each	£0.21	£0.21	£0.21	1	1	1	1	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21
1/2"pipe	m	£0.25	£0.83	£0.50	0.5	0.5	0.5	0.5	£0.13	£0.13	£0.13	£0.13	£0.42	£0.42	£0.42	£0.42	£0.25	£0.25	£0.25	£0.25
1/2" elbow	each	£0.21	£0.21	£0.21	1	1	1	1	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21	£0.21
1/2" socket	each	£0.21	£0.21	£0.21	3	3	3	3	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63	£0.63
Tap	each	£0.92	£2.03	£0.82	1	1	1	1	£0.92	£0.92	£0.92	£0.92	£2.03	£2.03	£2.03	£2.03	£0.82	£0.82	£0.82	£0.82
Labour (skilled)	day	£2.50	£2.03	£2.80	2	2	2	2	£5.00	£5.00	£5.00	£5.00	£4.07	£4.07	£4.07	£4.07	£5.61	£5.61	£5.61	£5.61
Labour (unskilled)	day	£0.58	£1.22	£1.87	11	12	13.5	14	£6.42	£7.01	£7.88	£8.17	£13.42	£14.64	£16.47	£17.08	£20.55	£22.42	£25.23	£26.16
Sub									£24.75	£27.17	£31.14	£34.20	£30.59	£33.44	£38.13	£41.25	£36.58	£39.89	£44.85	£48.00
Sub (discounted)									£21.53	£23.66	£27.20	£30.11	£23.88	£26.12	£29.90	£32.71	£26.30	£28.68	£32.24	£34.92
Sum (ignored)									£18.32	£20.16	£23.26	£26.02	£17.17	£18.80	£21.67	£24.17	£16.02	£17.47	£19.63	£21.84

A collaboration between the DTU and Lanka Rainwater Harvesting Forum, ACORD Uganda and Water Action Ethiopia.

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Roofing in Developing Countries

Research for New Technologies

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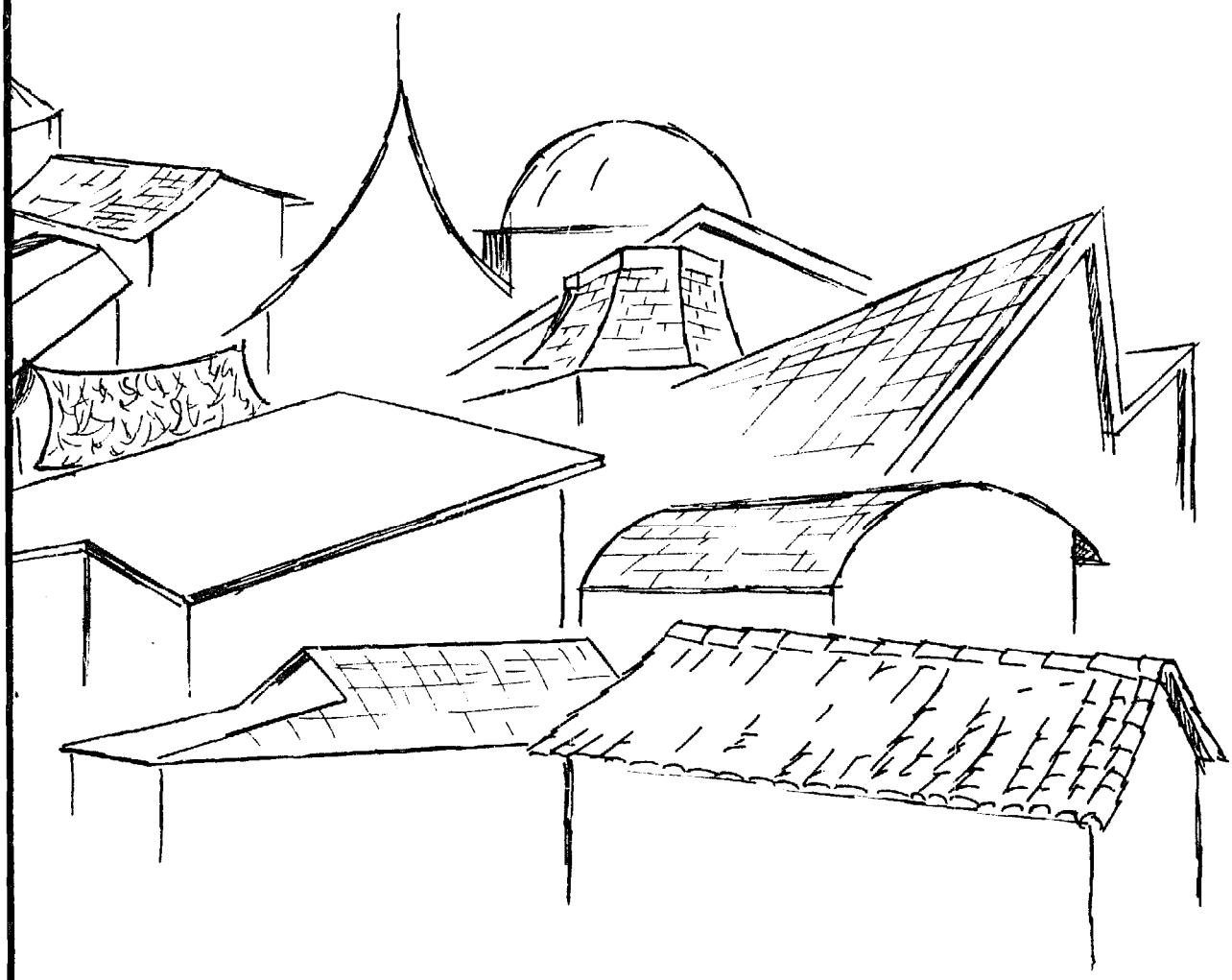

Roofing in Developing Countries

Research for New Technologies

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Commission on International Relations

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MATT M. JETTON, President, Sunstate Builders, Inc., Tampa, Florida

RUDARD A. JONES, AIA, Director and Research Professor of Architecture, Small Homes Council–Building Research Council, University of Illinois at Urbana, Champaign, Illinois

W. E. KEMP, Director, Technical Planning, Development Department, Koppers Company, Inc., Pittsburgh, Pennsylvania

WILLIAM G. KIRKLAND, Vice President, American Iron and Steel Institute, Washington, D.C.

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Foreword

Shelter, a basic human need, is chronically and critically in short supply in many developing areas of the world. Of all the elements of shelter, the roof is perhaps the most important in providing protection from harsh environmental conditions, and it often meets cultural needs as well. Emphasis on roofing needs, and thus research on improved roofing technology, is fully justified at this time and, indeed, an essential first step in improving housing technology.

Historically, people solved their shelter problems by using native materials. They considered traditional roofs of local materials adequate until they came in contact with distant places and learned of different techniques and materials. In efforts to improve roofing, they imported new materials and new technology, sometimes combining the imports with local or readily available substances. When imports required a departure from tradition, many communities rejected innovations because of the accompanying changes in art forms, lifestyles, and technology. In other instances, where new materials and technology have been accepted, they have proved too costly to meet the demand, or they have increased hazard to life and health, even though they represent an improvement in the provision of shelter per se. In many developing areas, climatic conditions alone decrease the durability of even the best roofing materials used in more industrialized, temperate-zone countries. The task of achieving substantive improvements in roofing is formidable.

This report represents the voluntary efforts of an Advisory Committee of the Building Research Advisory Board appointed especially to consider feasible and practical new-technology solutions to roofing problems in developing

countries. The committee included highly qualified individuals who, at the request of the National Academy of Sciences-National Research Council, gave freely of their time and expertise in behalf of advancing building technology in developing countries.

The Building Research Advisory Board appreciates the contributions committee members have made and takes this opportunity to acknowledge their effort. In addition, the board extends its appreciation to all others who assisted the committee, particularly William Reps, National Bureau of Standards; Frederick Krimgold, Doctoral Candidate, Stockholm, Sweden; Henry Sjaardama, CARE, Inc.; Robert J. Cowan, CARE, Inc.; W. Ludwig Ingram, Central American Research Institute for Industry (ICAITI), Guatemala; David DeSelm, U.S. Department of Housing and Urban Development; and Mario A. Piche Alfaro, U.N. Centre for Housing, Building and Planning.

Joseph H. Newman, *Chairman*
Building Research Advisory Board

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I. Introduction

THE ROOFING PROBLEM

The full impact and implication of the roofing problem currently experienced by developing countries cannot be realized without some familiarity with the overall housing problem. More than 80 developing countries suffer from an acute housing shortage, principally because of the ever-increasing need for new housing created by expanding populations and the periodic large-scale loss of housing from natural disasters. Each country must overcome serious social, economic, and technical obstacles if the most basic needs and demands for shelter are to be satisfied. For most developing countries, the housing deficit is the most complex problem and one that will become more serious as population growth continues.

The housing deficit is further compounded by the fact that population growth, and the demand for new and improved housing, is greatest in areas where social and technological impediments are the most difficult to address and personal income is lowest. Already enormous financial needs are continually aggravated by extremely limited purchasing power and the absence of a credit system. Much of the population has an income so low that it cannot afford even the most modest housing.

Needs, and thus the basic factors in reaching any solution to the overall housing problem, vary considerably according to location. Designs for new housing in urban areas should take into account the increased hazards to life and health created by population density; yet, doing so will increase costs.

At present the formation of new households and the migration of rural households, or heads of households, to places of employment frequently lead to uncontrolled new, and often population-dense construction surrounding major cities (e.g., Calcutta, Rio de Janeiro, Ibadan). Most such urban housing—and often rural housing as well—is uncontrolled, poorly constructed of scavenged materials, unsanitary, unsafe, and short-lived. Disaster-prone areas need housing that is both safe and capable of rapid and high-volume production. In planning housing for developing countries in tropical and subtropical regions, continuous attention must be given to the ever-present problems of the environment's deteriorating effects on materials.

The most serious obstacle to low-cost housing in the developing countires, regardless of setting or sophistication, is the lack of a low-cost roofing material that will provide satisfactory performance for a reasonable time under many adverse conditions. An essential component of a dwelling, the roof is critical to shelter, thermal comfort, privacy, and, in some localities, the satisfaction of other needs—for a status symbol, a refuge from floodwaters, a sleeping area, a water-collection system, a storage area, a food- and clothes-drying area.[1,2] In many developing countries roofing alone represents more than 50 percent of the total construction cost of a low-cost house.

Usually, roofing for low-cost housing in developing countries is not the product of any organized building industry or process. Instead, it is constructed with local self-help labor using rudimentary processes and materials. Most roofs made of low-cost, indigenous materials such as thatch or unfired clay lack durability and can be hazardous to health and safety. The materials often are subject to moisture-induced decay; they harbor vermin and insects and are particularly dangerous during fires, windstorms, earthquakes, and other disasters. To provide more permanent roof coverings, many developing countries expend scarce foreign exchange to import corrugated galvanized iron (CGI) and other metal roof-covering materials from industrialized countries in the temperate zone. These materials are often too costly for much of the population and, where they are used, do not solve the roofing problem. Metal products do offer the advantages of being relatively long lasting, salvageable after a disaster, self-supporting over short spans, easily maintainable, and simple to install. In hot climates, however, the heat absorbed by metal roofs converts homes into ovens. Where exposed to saltwater spray, ferrous metals corrode quickly.

OBJECTIVES OF THIS REPORT

In view of the magnitude and complexity of the roofing problem in developing countries, the Agency for International Development (AID) requested

the Board on Science and Technology for International Development (BOSTID) of the National Academy of Sciences to review the practicality of a major research effort to develop new solutions to roofing problems in developing countries.

BOSTID invited the Academy's Building Research Advisory Board (BRAB) to conduct the review. In turn, BRAB appointed a special advisory committee of individuals with special knowledge of the technical, social, economic, and manufacturing aspects of roofing in developing countries. Two members of the committee were from developing countries; each directs his nation's housing research efforts.

The committee reviewed past and current research and development (R & D) activities directed at solving particular roofing problems of developing countries, as well as more general roofing R & D in other countries throughout the world. The committee found that most such R & D deals with the problems associated with roofing materials now in common use, or aims at improving a specific material or product, or seeks better uses of materials or products already available but used for purposes other than roofing. The committee further determined that although none of the current R & D activities reviewed demonstrates immediate solutions to the roofing problem, limited work is being, and has been, conducted on materials currently used for roofing (such as thatch, CGI, aluminum, and clay) and an extensive literature exists.[1] The committee decided, therefore, to explore the feasibility of developing new low-cost products and processes with potential for providing roofing materials that offer better performance than those most commonly used today.

This report presents the committee's conclusions and recommendations concerning areas of research and kinds of materials indicating significant potential for the development of new roofing technologies that could provide early solution to the particular problems of developing countries. Ten appendices address various technical aspects of potential new roofing technologies.

CHAPTER I REFERENCES

1. For example, see Koenigsberger, Otto. 1965. *Roofs in the Warm Humid Tropics.* Architectural Association Paper Number 1. London: Architectural Association.
2. For further information, see

Dietz, A. G. H.; Koth, M. N.; Silva, J. A. 1968. *Housing in Latin America.* Cambridge, Massachusetts: MIT Press. p. 197.

Abrams, Charles. 1964. *Man's Struggle for Shelter in an Urbanizing World.* Cambridge, Massachusetts: MIT Press. p. 182.

II. Conclusions

Conditions in the developing world vary greatly among countries, and even within countries, making it virtually impossible for the committee to address all problems associated with specific locations. During the conduct of its study, however, the committee did consider such regional conditions as the economic, social, and political acceptability of various materials, the availability (or lack) of credit facilities, climate, biological agents, and transportation problems.

On the basis of its study and its own knowledge, the committee arrived at the following conclusions:

1. The introduction of high-performance roofing systems that are low in cost and capable of adaptation to satisfy local social-acceptance requirements, could, of itself, significantly accelerate production of more and better housing. Furthermore, research directed toward development of fresh approaches to roofing problems in developing countries is likely to be productive at this time; in polymer science, in innovative applications of cement and asphalt, and in the improved use of indigenous vegetable, animal, and mineral products, the committee members found sufficient unrealized potential to convince them that, given adequate research funding, new solutions can be found.

2. The roofing problems of developing countries are such that proposed solutions must be conceived, analyzed, and evaluated in terms of a system comprised of the following three principal elements, singly or in combination:

- the supporting structure (e.g., trusses, beams);
- the roofing substrate (e.g., concrete slabs, wood boarding); and
- the roof covering (e.g., tiles, built-up roofing materials, waterproof coatings).

3. For each of these three elements, consideration must be given to

- Availability of materials in or close to the locale in which they are proposed for use. Proposed roofing systems should maximize the use of materials either obtainable from, or manufactured in, the country for which the systems are intended. Wherever possible, the systems should make use of materials that can be obtained from, or produced near, the point of use, to decrease dependance on local transportation systems. Furthermore, materials requiring local material resources should be selected only after investigation determines that those resources are available. (For example, high-quality concrete requires a supply of clean, fresh water, which may not be available.)
- Availability of labor required for production, transportation, and erection or construction. Domestic production would generate employment and stimulate the growth of supporting industries and services, as well as provide opportunity for improving worker skills.
- Skills and skill levels required for production, transportation, and erection or construction. Most developing countries have an abundant supply of unskilled labor, especially in urban areas. Insofar as possible, roof systems should be of simple design and easy to install, to provide employment and skill-training opportunities for local labor.
- Potential hazards to the health and safety of housing occupants and the community. Health and safety are, of course, of paramount importance. If synthetic materials, particularly plastics, are to be utilized, the flammability, smoke generation, and toxic characteristics should be given special attention. For locations known to be subject to earthquakes, floods, and high winds, the roofing system should be designed and constructed both to provide occupant protection against such hazards and to ensure that even if structural failure occurs, the threat to the community from falling or flying debris will be minimized.
- First cost, durability, maintenance costs, and the effect of each on the total roofing system. A durable but inexpensive roof covering that requires a costly or complex structure for support can lead to a total roofing system that is so uneconomical that it is completely unacceptable. The durability of the structural support and the roof substrate material should be considered, as well as that of the roof covering. Each should employ materials that can be maintained easily by the occupants or by local labor.
- Environmental conditions of the locale in which the material is proposed for use, particularly if it will be subjected to tropical and subtropical

climates. Special attention should be given to the possibility of degradation by ultraviolet light, moisture, biological agents, and damage by rain, wind, and earth movement. The roof covering or substrate should have a thermal insulating value sufficient to protect the interior from the heat of the sun during the day and, if enclosed or enclosable, to preserve interior-produced heat during the night. In hot climates, the roofing system should be designed and oriented to reduce the effect of the sun's heat and to take maximum advantage of prevailing breezes.

4. Searches for low-cost materials or systems embodying the above-mentioned characteristics should include composites containing a reinforcement, a filler, and a coating, all of which are held together by a "binder."* Research into composite materials could lead to the development of roofing materials capable of utilizing a vast array of indigenous products. (For a discussion of some composites and related ingredients, see the appendices.)

5. Insofar as possible, local products should be utilized for each component of a composite. For example, vegetable fibers, rock wool, glass fiber, and wire mesh ought to be considered for reinforcement; soil, waste glass, rock, and sawdust ought to be considered for fillers; and paint, whitewash, and sand sprinklings ought to be considered for coatings. (See appendix J for a more extensive list of possible component materials.)

6. Although potential reinforcement, filler, and coating materials are available in each of the developing countries, suitable binders to hold them together generally are not. If suitable binders can be developed and simple, low-cost methods can be devised to use them in the manufacture of composites, such composites might well provide the versatility required to meet local needs in widely differing developing regions.

7. To the fullest extent possible, R & D in roofing technology ought to be conducted within the developing countries, even if the cooperation of public, private, or academic institutions of more developed countries must be sought. Research and design specialists living in developing countries will be more cognizant of available resources and the design requirements peculiar to their specific localities. Furthermore, new roofing technologies generated by a developing country will probably be more easily diffused among, and accepted by, the local population.

*In some composite materials one component may serve more than one function; in others, one function may be unnecessary. For example, a separate coating to protect the surface or a filler to give bulk and weight may not be required.

III. Recommendations

During its investigation, the committee identified a wide variety of materials that researchers could consider in a search for new roofing systems for developing countries (see appendix J). Since developing countries differ so widely in their needs, climates, and available materials and resources, each must determine independently which avenues of research are most promising. The committee believes, however, that an organized, systematic approach to the establishment and direction of R & D programs within the developing countries could lead to early results of immediate use for most, if not all, countries. Thus, the committee offers the following recommendations:*

1. AN INTERNATIONAL ADVISORY COMMITTEE

A standing advisory committee should be established under appropriate international auspices. Its efforts should be directed specifically to accelerate, enlarge, and consolidate the dispersed low-cost roofing research programs for developing countries that now exist. The committee should give emphasis to regional rather than global approaches.

*This report was completed before the recent rise in crude oil prices. Substantially increased costs of petroleum derivatives will adversely affect the competitiveness of polymeric binders and foamed plastics (recommendations 2 and 3) and will increase the attractiveness of the nonpetroleum-based technologies discussed in recommendations 4–10.

Typical of the needs such a committee could address is a systematic inventory of roofing materials and the design and construction practices currently utilized in developing countries, as well as roofing problems now being studied by those countries and other research organizations. Such an inventory would make possible the identification of research gaps and areas calling for more attention.

Most committee members should be housing experts from developing regions; others should be drawn from the most appropriate research and academic facilities worldwide and from technical assistance organizations that have substantial interest in, and considerable resources committed to, housing in developing countries (such as AID; World Bank; United Nations Development Programme; United Nations Centre for Housing, Building and Planning; Inter-American Development Bank; Organization of American States; CARE).

2. POLYMERIC BINDERS

Roof-covering research, development, and demonstration programs should be directed toward the use of existing, commercially available unsaturated polyester and related polymers for binding combinations of indigenous materials (such as vegetable fibers, earths, and fabrics) of selected developing countries.

Such effort could be productive now because the technology of fabricating building products using thermosetting (e.g., unsaturated polyesters) and thermoplastic resins and related polymers in combination with other materials is highly developed and well documented (see appendix A). If such products are compatible and blend with locally available raw materials, they could be made in almost limitless shapes and sizes to meet designs required by a variety of customs and traditions. The committee believes that a concerted program of pilot-level development and testing could produce composite materials suitable for low-cost roofing systems in most developing countries.

The major challenge will be to develop inexpensive composites that will resist deleterious elements such as moisture, ultraviolet light, insects, and fungi. Special emphasis should be placed on identifying potential hazards associated with products utilizing plastic materials. For example, if open-fire cooking is done indoors, certain plastic roofing elements may ignite and produce injurious smoke or toxic gases. Polymers can be treated by fairly simple techniques to perform well when directly exposed to fire. But, to date, applications of such treated polymers have been relatively expensive.

If materials that perform adequately can be developed at reasonable cost, the manufacturing technology and application probably could be transferred

throughout developing countries with little difficulty; the simplicity of producing synthetic-resin roofing materials would permit easy diffusion of the technology and ready commercialization by small-scale entrepreneurs. The finished building products are likely to be economically competitive with, or have a price advantage over, CGI. The materials also may be used for applications other than roofing.

The costs of manufacturing the roofing composite could be very small. The system would be versatile and lend itself to labor-intensive production.

In their raw state, basic resins and polymers are stable and can be stored for some time, but, to maintain their specified characteristics, they must be kept in a cool, shaded location. Since they are concentrated, they require little shipping and storage space and have little intrinsic value until processed into a building material. If the basic resins and polymers are not available in developing countries, they would have to be imported but would probably represent only a minor portion of the cost of the finished roof. No significant logistical problems need to be overcome in importing bulk resins and polymers—abundant supplies and numerous manufacturers exist, and end-point handling, storage, and transportation are not difficult.

Field-research efforts on this type of application should include a cost-benefit analysis of imported resins as opposed to alternatives such as imported CGI.

3. FOAMED-PLASTICS PROCESSING

A pilot project should be undertaken to process foamed plastics suitable for roof-covering materials and to develop a mobile, small-scale, foaming-equipment system that developing countries could produce economically.

Foamed plastics—lightweight cellular substances produced by introducing gas bubbles into plastic compounds during manufacture—offer significant potential as versatile, lightweight roofing materials with high insulating values that could be produced on site in a variety of shapes and sizes (see appendix B). To date, the use of foamed plastics has been severely limited by the lack of simple, low-cost, reliable foaming equipment capable of producing a high-quality, uniform product.

The customary foamed-plastic processing equipment generates the foam chemically and then sprays the stabilized, frothy mass of fine bubbles into the desired position. In the past, the processing equipment used in field demonstration projects in developing countries was quite complex and sensitive and required costly maintenance; recent advances in equipment design, however, have eliminated many of the problems experienced earlier. Therefore, it would seem most appropriate and timely to incorporate these advances

in the development of a mobile, small-scale foaming system that could be mass-produced by the developing countries. Such a system, coupled with a demonstration that foamed plastics can be used in conjunction with indigenous reinforcing fillers and coatings as roof-covering and substrate materials, could lead to the formation of profitable local business enterprises that would produce both the equipment and a variety of foamed-plastic products.

The recommended pilot project should be organized clearly as an experiment to assess and document the performance of the equipment, as well as the economics, consumer acceptance, use, longevity, and durability of the prototype roofs produced. The project might well be conducted as a cooperative effort between U.S. and developing-country enterprises, with participation of academic institutions, building-oriented professional and trade organizations, and technical assistance agencies in the housing field.

It should be noted that recently the U.S. Federal Trade Commission charged that polyurethane and polystyrene foams subjected to fire can be hazardous to life and health in certain housing applications. This fact is well known by building technologists; however, foams with reported low flame-spread and smoke development are available today and its is likely that further improvements will appear in the near future. Nonetheless, those researchers developing foamed plastics for roofing materials in developing countries should be cognizant of the potential fire-related hazards and keep abreast of technical developments in this area.

4. SULFUR

Sulfur should be given serious consideration as a material for binding mixtures of other indigenous materials, as a valuable coating and joint-grouting material, and as a material from which small-size roofing products, such as tiles, can be made.

Although sulfur has not been widely used as a building material, its full potential as a binder for use in low-cost roofing for developing countries (see appendix C) should be explored. Only in the last decade has the use of this material for construction purposes been subjected to comprehensive scientific investigation. Its use in developing countries is particularly worth consideration because many have abundant supplies of sulfur as a result of volcanic activity and as a by-product of oil refining. Sulfur also could prove to be an inexpensive import item for countries lacking an indigenous supply.

Previous research and testing have been directed primarily toward the use of sulfur in sulfur-concrete and as a surface bonding agent. Elemental sulfur is a bonding agent with unique properties: It becomes molten at 240 °F, only slightly higher than the boiling point of water; it is insoluble in water and

demonstrates qualities of water impermeability; it is odorless, nontoxic in normal use, and a poor conductor of heat; it has an indefinite storage life; and it can be reprocessed. All these features indicate excellent potential for use in developing countries as a roofing material.

Elemental sulfur is particularly suitable for labor-intensive construction methods, but does have certain limitations: It is highly flammable, and it must be converted to a liquid state before aggregates or fillers can be added. Product developers and users must also be aware of the possible release of sulfuric acid in the presence of moisture and the potentially harmful effects of ingestion. Advantages seem to outweigh the disadvantages, however, and a concerted R & D effort is warranted at this time.

5. CARBONIZED PLANT MATERIALS

A laboratory-research and field-demonstration program should be conducted on the transformation into low-cost, lightweight roofing sheets of carbonized and expanded, nonfood, high-starch plant products that have been combined with unsaturated polyester resins and related polymers (see appendix G). Research should include local field surveys to identify types, quantities, and availability within the developing countries of plant products suitable for this purpose.

6. AGRICULTURAL AND WOOD WASTES

An intensive program should be initiated to develop economical processes for manufacturing resins from native agricultural products (e.g., natural vegetation, bagasse) for use primarily as binders.

As noted in appendix G,[1] the lignin and furfural in vegetation can be used as *in situ* binders if heat and pressure are applied. This technology is well known in industrialized nations; it is probable that simplified processing methods would permit developing countries to produce an abundant supply of satisfactory building panels.

7. WASTES FROM PRIMARY INDUSTRIES

Wastes such as fly ash and blast-furnace slag from the steel industry have properties that make them suitable as cementitious binders (see appendix E) and should be investigated. These wastes could prove of particular value in countries lacking adequate limestone and portland cement resources.

Red mud, a copious by-product from bauxite refining that gluts many developing countries, also merits serious consideration, as do metallic wastes from the production of iron and steel. Disposal of these and similar waste products is an ever-increasing worldwide burden to heavy industry; their conversion to useful products would serve a two-fold purpose. Research in such alternative uses may be so attractive to the affected industries that they might be induced to contribute funds or materials.

8. CONCRETE

An analytical and laboratory testing program should be undertaken to develop more appropriate and economical reinforced concrete products. (See appendix H on ferrocement.) The research effort should focus on the use of reinforcing materials such as wire mesh, locally available chopped wire, glass fibers, rock wool, and various vegetable products such as bamboo,[2] bark, and wood fiber (wood-fiber concrete is known as "wood wool" in some parts of the world[3]). Consideration also should be given to substitutes for portland cement, some of which are suggested in appendix E.

9. CLAY-BASED MATERIALS

A research program should be undertaken to develop methods for improving the general performance and range of applications of clay-based roofing materials. (See appendix I.)

10. FIBER PRODUCTS

The suitability and effectiveness of waste raw materials from textile and other fiber industries (based on such fibers as jute, sisal, hemp, kenaf, and cotton) common in developing countries as a blend in a composite material for roofing components should be explored.

In summary, there are numerous promising avenues of exploration, and it is the opinion of the advisory committee that full advantage should be taken of them at this time.

CHAPTER III REFERENCES

1. See also *Production of Panels from Agricultural Residues.* December 1970. Report No. ID/79 (WG.83/15/Rev. 1). Geneva: United Nations Industrial Development Organization.
2. For further information, see F. B. Cox and H. G. Geymayer. 1969. *Expedient Reinforcement for Concrete for Use in Southeast Asia.* Technical Report C-69-3. Vicksburg, Mississippi: U.S. Corps of Engineers.
3. For further information, contact Dr. J. W. S. De Graft-Johnson, Director, Building and Road Research Insitute, CSIR, Kumasi, Ghana.

Appendix A. Plastics

By chemical definiton, plastics (also known as polymers) are synthetic, chainlike molecules of high molecular weight that are the end result of the chemical binding of large numbers of smaller molecules known as monomers. Today there are approximately 40 families of plastics.

Each plastic has a well-defined combination of properties, processing requirements, and economics that make it uniquely applicable in certain situations and unusable in others.

In developing countries, plastic resins containing monomers could, in principle, be combined with locally available reinforcement and fillers by local labor using low-cost equipment to form roofing sheets that could substitute for currently used corrugated metal sheets. The widespread availability of the chemicals, the relative ease of training local labor to make such roofing, and the low cost of equipment all strongly suggest that a project should be initiated to develop such roofing.

A development program for using plastic resins in this manner would have these advantages:

- A local industry might result, to manufacture roofing materials.
- The use of indigenous materials and local labor would contribute to the economic growth of less developed nations.

Contributed by Trayon Onett, Marketing Manager, Research Department, Koppers Company, Inc., Monroeville, Pennsylvania.

- The reinforced plastic sheets would be lightweight, weather resistant, translucent, verminproof, corrosion resistant, and potentially low cost.
- The use of this type of material would relate roofing solutions to the general housing problems of developing countries.
- The use of indigenous materials would help overcome the problem of local acceptance of shapes, styles, and aesthetics usually associated with the introduction of new materials. Though a new material is used, the house could be constructed in a traditional architectural form.
- The development program would establish the extent of training necessary to use existing talent and skills.
- Walls and floors could later be made from different proportions of the same ingredients.

To utilize these advantages and implement such a development program, it is recommended that

1. A complete program for evaluating indigenous reinforcing, fillers, various resins, additives, and stabilizers be initiated. The results of this program could be incorporated into pilot development plans for larger-scale construction, testing, and field evaluation.
2. As the physical testing and evaluation program are initiated, a market acceptance and economic feasibility program be started in a developing country.

SELECTION OF A PLASTIC

With over 40 families of plastics available and hundreds of variables possible within each, determining the balance of properties required in the end use becomes most important. Today, polymers can be tailored to produce bulk fiber, foam, film, coating, and adhesive plastics that may be hard or soft, rigid or flexible, rubbery or leathery, and porous or nonporous.

Some of the physical considerations that must be considered are the end-product requirements for the following characteristics:

Stiffness or flexibility
Temperature range
Tensile, flexural, and impact strengths
Intensity, frequency, and duration of loads
Color retention under environmental conditions
Electrical properties
Moisture resistance
Chemical resistances

Weather and sunlight resistance
Odor and taste
Production requirements (quantity and speed)
Material costs

The ratings of physical requirements will be assigned ranges (e.g., tensile strength: 4,218,600 kg/m^2 or 6,000 psi, essential; above 5,624,800 kg/m^2 or 8,000 psi, desirable; above 8,437,200 kg/m^2 or 12,000 psi, unimportant). Choosing the best plastic for a specific job then becomes a matter of finding the one material that best combines the necessary and desirable properties per unit cost.

Plastics are differentiated as either thermoplastic or thermosetting. Thermoplastic resins require heat to form plastics, and the final plastic can be remolded a number of times without loss of properties simply by applying more heat. Thermoplastic scrap can be reclaimed and reprocessed without difficulty. Chemically, the plastics they produce are linear molecular chains that fuse and solidify without serious chain breakage and without much cross-linking. Polyethylene, polystyrene, polyvinyl chloride, cellulosics, and nylon are examples of thermoplastic resins.

A thermosetting resin forms a plastic with a permanent shape that cannot be altered reversibly when heated. The final plastic after setting is a cross-linked, intractable, nonflowing material. Applying additional or higher heat only destroys it. Thermoset scrap cannot be reprocessed and can only be reused as filler material. Typical plastics in this family are polyesters, phenolics, and ureas.

Certain thermosetting resins require no heat and little or no pressure to form their final shape. They achieve cure by reacting with other chemicals at room temperature to create their tightly cross-linked chain structures. These reactions occur in relatively short times, and the final cure and set are permanent. Among these are some specific polyesters, epoxies, silicones, and polyurethanes.

THERMOPLASTIC RESINS

The descriptions of thermoplastics presented below will serve as a quick introduction to this branch of the plastics industry.

ACRYLONITRILE-BUTADIENE-SYTRENE (ABS)

Very tough; has an unusual combination of a high rigidity and impact strength; readily accepts decorating or plating; possesses excellent embossing properties; has fair chemical resistance, very low water absorption, good di-

mensional stability, and high abrasion resistance; formulation can be varied to obtain different combinations of flexibility, heat resistance, and toughness.

ACETAL

An engineering plastic with very high tensile strength, stiffness, and exceptional dimensional stability; has high chemical resistance, high abrasion resistance, low moisture absorption, excellent resistance to creep under load, and low tendency to stress cracking; is nontracking electrically; has low coefficient of friction and superior retention of physical properties if immersed in hot water. Two types are available—homopolymeric acetals that have higher strengths, and copolymeric ones that are easier to process.

ACRYLICS

Widely used for their high optical clarity and brilliant transparent colors; best of the transparent plastics in resistance to outdoor weathering; excellent electrical strengths; hard, glossy surface; fair chemical resistance. Available for fabrication as acrylic sheets or standard and high-impact molding powders.

CELLULOSICS

Among the toughest of plastics; five basic cellulose families—nitrate, acetate, propionate, butyrate, and ethyl celluloses. Nitrate, the toughest, is highly inflammable and explosive and embrittles with age. Acetate is easier to process and not explosive but has poor solvent resistance and embrittles with age. Propionate and butyrate are chemical and weather resistant.

FLUOROPLASTICS

Four general types—polytetrafluoroethylene (TFE), chlorotrifluoroethylene (CTFE), fluorinated ethylene (FEP), and polyvinylidene fluoride (PVF_2). TFE is nonburning and has very high heat and chemical resistance (up to 550 °F), excellent resistance to heat aging, the lowest coefficient of riction of any plastic, very high dimensional stability, and zero moisture absorption, but is very difficult to process. CTFE has most of the outstanding properties of TFE but is somewhat easier to mold. FEP is very easy to mold but is the most expensive of the fluoroplastics. PVF_2 has heat resistance to 300 °F, is the easiest to mold, and has higher tensile strength* and lower cold flow† than the other fluoroplastics.

**Tensile strength*: the pulling stress in pounds per square inch required to break a given specimen.

†*Cold flow*: the tendency to change dimensionally with time under load (e.g., creep at room temperature.

IONOMER

A generic name for polymers in which ionized carboxyl groups create ionic cross-links in the intermolecular structure. They offer excellent toughness and high optical clarity, superior resistance to oils, greases, and solvents, and high abrasion resistance. Their high melt strength permits very deep draws in thermoforming, and they are very resistant to stress cracking. Films have outstanding flexibility and are hard to tear but have easy tear propagation.

METHYL PENTENES

Offer excellent transparency; short heat resistance to 430 °F, good chemical resistance, and low water absorption. Have the lowest specific gravity (0.083) of any commercial plastic, superior electrical strengths at high temperatures, sharp melting point at 464 °F, and poor resistance to outdoor weathering. Are easier to process than most high-heat plastics.

NYLONS (POLYAMIDES)

Are self-extinguishing if ignited and offer outstanding toughness and wear resistance, a very low coefficient of friction, excellent chemical resistance, high electrical strengths, poor dimensional stability due to hygroscopy* and cold flow.

PHENOXIES

Offer outstanding chemical resistance except for organic solvents; are tough, hard, and ductile; show low shrinkage during molding. Compared to other thermoplastics, they have the lowest creep resistance, permeability to gases, and coefficient of thermal expansion.

POLYALLOMERS

Similar to polyethylene and polypropylene, but with high abrasion resistance, broader processing conditions, and better stress/crack resistance. Offer excellent embossing properties, low specific gravity, and short molding cycles.

POLYCARBONATES

Rigid, transparent, tough engineering thermoplastics offering excellent outdoor dimensional stability, very low creep under load, fair chemical resistance,

**Hygroscopy*: the tendency to absorb moisture.

and excellent impact resistance. Are self-extinguishing if ignited, physiologically inert, and ductile enough to yield rather than shatter under load.

POLYETHYLENE

An excellent combination of electrical and physical strength; lightweight, easy to process, and low cost; offers good toughness, flexibility, and chemical resistance; easily heat sealed, but heat resistance limited to 180 °F; has poor stress/crack resistance and is difficult to hold to tolerances in molding. Available as low-, medium-, and high-density polyethylene. The stiffness and physical strengths increase toward the higher density.

POLYAMIDES

Maintain heat resistance to 500 °F continuously and up to 900 °F for short periods; offer very low coefficient of expansion, outstanding resistance to heat aging, high impact strengths, and excellent wear resistance; are the most difficult to process so they must be sintered or solution coated; are very expensive.

PHENYLENE OXIDE

Engineering plastic, very tough over a temperature range of 275 °F to 375 °F; offers superior dimensional stability, low moisture absorption; highest resistance to creep under load, and excellent chemical resistance. Modifications available at lower cost but with lower heat resistance.

POLYPROPYLENE

Offers excellent resistance to stress or flex cracking, very low specific gravity, excellent impact strength, good chemical resistance; floats on water; forms films and fibers having superior strength, optical qualities, grease resistance, and moisture-barrier properties.

POLYSTYRENE

General-purpose grade very rigid; shows low moisture absorption, low shrinkage during molding, high optical clarity, and poor outdoor stability; many solvents attack polystyrene; easy to process. Many modifications of polystyrene are possible (e.g., adding butadiene for impact resistance, making copolymers of styrene-acrylonitrile for high strengths, or adding blowing agents for foamed parts).

POLYSULFONE

An engineering plastic showing good transparency, high mechanical strengths, high heat resistance, superior electrical strengths at high temperatures, unusual resistance to strong mineral acids and alkalis, and superior retention of properties on heat aging.

POLYVINYL CHLORIDES (PVC)

Of two basic types—rigid and flexible; tough, hard, and difficult to process; offer good outdoor stability, superior electrical properties, excellent resistance to moisture and chemicals; are self-extinguishing if ignited. Many copolymers and formulae variations are available for special applications.

THERMOSETTING RESINS

ALKYDS

Offer excellent dimensional stability, arc resistance, and high heat resistance; cure without creating volatile by-products; have very fast, low-pressure molding cycles making them easier to mold than most thermosetting resins; surfaces are hard, stiff, and tough. Various fillers and reinforcing fibers may be added to the resin to produce a wide variety of compounds, each offering a different combination of properties.

AMINOS (UREA AND MELAMINES)

Hard, rigid, and abrasion resistant; have excellent dimensional stability under load, good solvent resistance and chip resistance, and are self-extinguishing if ignited. Urea molds faster and costs less; melamine has higher surface hardness and heat resistance. Both are static-free and have excellent electrical properties. Fillers and reinforcing fibers are added for economy, better dimensional stability, and higher strengths.

DIALLYL PHTHALLATE (DAP)

Offers most exceptional dimensional stability of all the plastics as well as superior electrical properties and excellent heat and chemical resistance; surfaces are hard, tough, and have very low moisture absorption; is easy to mold at low pressures without forming volatile by-products; offers low postmolding shrinkage when glass-filled.

EPOXIES

Has outstanding physical and electrical properties and excellent adhesive properties; offers unusually low shrinkage during molding and superior dimensional stability under a wide variety of adverse environments; resins are normally liquids even without solvents or dilutants; some formulations can be cured without heat or pressure; many formulae variations.

PHENOLIC

Low-cost molding material with excellent combination of high physical strengths, high temperature resistance, good dimensional stability, and superior electrical properties; color limitation of black or brown; mineral, glass, and cotton flock materials commonly used as fillers.

POLYESTERS

Two types–saturated or unsaturated. Films and fibers are formed from the saturated polyesters; the unsaturated polyester resins, when reinforced, give products with excellent resistance to high temperatures and chemicals. Superior electrical properties and one of the most economic of all resin systems. Reinforced parts have high physical strengths and can be molded with little or no heat and pressure. Finished parts can be cast, molded, pultruded–or the opposite–laminated, foamed, or sprayed.

POLYURETHANE

Available as film, as well as rigid or flexible foam. Thermosetting types can be flexible and rigid, depending upon formulation. Good abrasion and wear resistance, superior impact resistance, and good electrical properties and chemical resistance. Thermoplastic forms are also available and are used to produce tough films and wear-resistant parts.

SILICONE

Offers excellent property retentions over wide temperature range, -100 to 500 °F; nonstick surface. Can be cured without heat or pressure; molding compounds can be rigid or flexible, depending on the type of silicone. Reinforcement with fillers yields extra strength. Silicone fluids are used to make mold releases, antifoaming agents, and water-repellent coatings. Physiologically inert.

REINFORCEMENT MATERIALS FOR PLASTICS

The addition of reinforcing materials to these families of resins can dramatically improve the strength, toughness, dimensional stability, and properties of electrical, thermal, and chemical resistance of the plastic formed from them. An initial screening of a resin and reinforcement system must include measurements of tensile strength, flexural modulus, impact resistance, heat deflection temperatures, flame retardance, and volumetric materials costs. The reinforcing material in greatest use in the United States is fiberglass, supplied as mat, cloth, roving (twisted strands of fiberglass), or continuous glass filaments. In addition, inert fillers of minerals, clays, and silicas are used to impart weather resistance and flame or chemical retardance. Final fabrication is accomplished by the addition of a catalyst for casting or ambient-temperature curing. If high production is required, the finished parts are usually pultruded, compression-die molded, bag molded, or vacuum formed. The addition of initiators, catalysts, fillers, and additives enables the processor to tailor a chemical system to the availability of materials, and the volumetric material costs.

Among the indigenous materials that can be used in reinforced manufacturing are asbestos fibers, fly ash, hemp, coconut fibers, jute, and groundnut shells (see also appendix J).

Appendix B. Foam Composites

The thermal characteristics and light weight of foamed materials suggest their potential for use in roofing if combined with reinforcement for increased structural strength.[1]

A major advantage of reinforced-foam roofs is that they incorporate in one unit the roof surface, insulation, supporting structure, and ceiling. The separate substructure and ceiling that must be used with other types of roofing materials is eliminated. As a result of the savings gained by eliminating the substructure, the cost of a bamboo-reinforced polyurethane composite roofing material, for example, is approximately one-third to one-half that of conventional materials. At present polyurethane is the most available of the matrix materials. Poor physical properties, high cost, or processing problems eliminate many other foams from further consideration for this application at this time.

Work on several different urethane foam formulations[2,3] indicates that rats, mice, and termites will not attack it. Rodents will chew and claw through only if it is placed between them and their regular food source. Work by Wessel[4] indicates that the urethanes have (on a scale of good, moderate, and poor) good resistance to attack by fungi and bacteria.

For use in residential structures, roofs must not pose a potential fire

Contributed by J. P. R. Falconer; adapted from a paper by D. J. Stubblefield, Falconer, and T. B. Moore, presented at the Third International Cellular Plastics Conference, Montreal, Canada, September 1972.

hazard to the occupants. This is a particularly important consideration when a foamed roof is used on a low-cost dwelling in a developing country since with no ceiling the foam is exposed to the interior where oil lamps, cooking fires, etc., could ignite it. Foams with low flame-spread and smoke-development ratings are available, and certain foams are nonburning. However, polyurethane and polystyrene formulations have recently come under question by the U.S. Federal Trade Commission as possibly representing a serious fire hazard. Furthermore, during combustion and even before ignition, some foamed materials have been shown to give off toxic fumes.

Aromatic polyurethanes and some other plastics undergo degradation when exposed to sunlight. This is particularly troublesome in tropical countries. Ultraviolet rays in sunlight produce free radicals that react with oxygen to produce a discolored, highly cross-linked, friable surface, which is sloughed off. This may be prevented by coating the foam with an elastomeric weather barrier.[5,6]

The long-term stability of a foam matrix in a hot, humid environment depends strongly on the molecular structure of the polymer. Work by Frisch et al.[7] indicates that polyurethane foam stability under hot, humid conditions is inversely related to the cross-link density. That is, foams with the lowest molecular weight between cross-links were the most stable. An extensive dis-

TABLE B-1. Cost of 500-sq ft Sprayed Bamboo/Foam Roof

Item	Cost (U.S.$)
Polyurethane foam	110
Bamboo	
700 culms @ 5¢	35
Mold cost	
200 2 × 10 ft panels/mold @ $40/mold	0
Release agent	0
Weather barrier @ 20¢/sq ft	100
Labor (fabrication and erection or spraying)	
125 hrs. @ 60¢/hr	75
Equipment*	+6
	326
30% overhead and miscellaneous	98
	424
Total cost, $/sq ft	$ 0.85

*500 houses per year for 5 years, $15,000 for spray. A foam cost of $0.50/lb and a labor rate of $0.60/hr are assumed.

cussion of the effects of a foam's chemical structure on thermal degradation is presented by Tilley et al.[8]

The theory of fiber-reinforced foam composites is covered in a recent paper by Rinde.[9] This paper also discusses the preparation and testing of several different types of foam/fiber composites. Since the mode of failure usually associated with roofing materials is excessive deflection rather than fracture, the major mechanical property of interest in evaluating potential materials is the modulus of elasticity. Once the modulus is known, the roof thickness may be adjusted to limit the maximum midspan deflection under a given loading condition, and roof costs can be determined.

For developing countries, vegetable fibers are attractive to consider as potential reinforcement for foams. These fibers typically have a modulus of elasticity of 1×10^6 to 4×10^6 psi, and tensile strengths of 1×10^5 to 2×10^5 psi. As reinforcing they have the distinct advantage of being relatively inexpensive (compared with typical fiber reinforcements such as steel or fiberglass) and are available where the roof will be produced and used. Bamboo is a particularly attractive reinforcement, and an extensive program of research into bamboo-reinforced polyurethane foam sheets for developing-country roofing is now under way at Washington University.* Table B-1 lists a typical cost breakdown for such roofing.

MAKING THE FOAM

Since a multicomponent chemical system must be blended in accurate proportions in foam making, the equipment is complex, specialized, and expensive.

The development of foam-processing machinery has accelerated rapidly during the past 10 years and should continue as applications of foams increase. Recent developments, centered around the use of positive-displacement piston pumps vs. rotary-gear pumps, will reduce the requirement for temperature-conditioning equipment and the physical size of the machinery. Current work indicates that this will also simplify operational procedures considerably and give a higher degree of portability for on-site work.

Today, equipment manufacturers must also constantly upgrade, redesign, and innovate to keep pace with the improving urethane chemical systems. We can look forward to improved machinery performance with fewer maintenance problems, and perhaps most importantly, simpler operating pro-

*For further information, contact J. P. R. Falconer, Center for Development Technology, Washington University, St. Louis, Missouri, U.S.A.

cedures. All these factors will contribute to increased acceptance of roofing made of urethane foam systems.

Because of the complexity of the equipment, it is mandatory that operators be given intensive training. Those who are eventually assigned the responsibility of operating the equipment should possess a relatively high mechanical aptitude, and have previous experience in mechanical-equipment repair or operation. Some basic training to familiarize personnel with the chemical system may be desirable but from a functional standpoint is not required. Particular emphasis should be placed on developing troubleshooting ability and proper machine-maintenance procedures. A thorough study of the machinery manufacturer's manual should be required.

The foam can be made rapidly. For example, a 3-in. thick, 10-ft long, 10-in. wide roofing element may be foam filled in 20 seconds with a machine having a throughput rating of 30 lb/min. (This includes the time needed to assemble reinforcing in the molds.) It is feasible to produce one such roofing element per minute with equipment of this size.

SPRAY-IN-PLACE BAMBOO/FOAM COMPOSITES

Through the centuries, techniques have been developed for working with bamboo. Various types of woven mats, and poles wired together, are used for many purposes. In developing countries bamboo mats are often used as structural wall elements and as the base for roofing such as thatch.

Foam can be sprayed on both sides of a bamboo mat to provide thermal insulation and to give a unitized, sealed roof. The underside becomes the ceiling. After the exterior side is coated with a weather coating, it becomes durable and weather resistant.

This type of roof construction is ideally suited to self-help housing, since the homeowner can contribute a large part of the work. Also, with the spray-in-place technique, the builder has a great deal of architectural latitude in the final roof design, because almost any configuration can be set up before it is sprayed. This helps to eliminate a sometimes undesirable situation in which each house looks just like its neighbors.

Urethane spray machinery must, of course, be highly portable. Good design dictates a lightweight spray gun equipped with a suitable method for purging mixed material if an internal mixing chamber is used. The entire system is designed into an equipment package as small and lightweight as practical. The proportioning pumps should be adaptable to a variety of material volume ratios. Suitable provision for temperature control should be incorporated throughout the pumping system and through the flexible hose as-

semblies to the gun. Power, if electricity is unavailable in the field, may be provided by a gasoline- or diesel-powered generator.

Using a system commercially available in the United States, a two-man crew can spray from 7000 to 9000 sq ft per 8-hour day, including adequate time for start-up and shutdown procedures. Complex structures or forms and the need to use ascending-descending ladders, platforms, and scaffolds reduce this.

For large projects truck-mounted bulk tanks are desirable. Properly designed and built, mobile foam-spray units are efficient and economical.

To use the foam-spray approach, considerable training of spray personnel is required. Training programs have to develop a thorough understanding of all component parts of the spray-foam machine. This extends to a complete discussion of each component part, its purpose, and the possible causes for its failure. The trainee must be capable of disassembling and rebuilding the machinery, and he should be placed in situations in which he must diagnose a failure or improper function of the machine. His ability to recognize the problem, select the proper solution, and then carry out the repair properly is invaluable in the field.

Considerable attention must also be given to proper spray technique. To develop a smooth arm motion requires muscular coordination and extensive practice. In spraying a roof, arm motion must take place while the worker moves, particularly when he walks backward. Personnel experienced in using paint spray guns will find the arm motion quite similar. However, coupling this arm movement with walking backward on a roof deck usually must be thoroughly practiced before an acceptable finished surface can be consistently applied.

A complete spray-foam-operator training program, including printed manuals and visual aid training films, is now being developed in the United States.

APPENDIX B REFERENCES

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Appendix C. Sulfur

Investigations of the past 10 years show that sulfur with plasticizers, aggregates, and fibers can be used in low-cost construction instead of, or in addition to, traditional materials.

Simple techniques and primitive equipment can be employed for melting and applying sulfur in small quantities (e.g., when it is used as a binder to cover joints in blocks, bricks, and slabs). However, to use large amounts of sulfur or for continuous production, practical techniques have yet to be developed.

Continued research is warranted and is justified by the following considerations:

- Sulfur is abundant in many parts of the developing world, particularly in volcanic regions. Oil refineries also produce sulfur in large quantities as a by-product.
- Sulfur can be used as a building material in low-cost construction, and its application requires relatively simple handicraft techniques.
- Sulfur is waterproof, adheres strongly to a wide range of materials, has no taste or smell, does not act on the skin, and is a poor heat and electricity conductor.
- Sulfur, when mixed with fibers, gains in tensile and flexural strength;

Contributed by A. Gonzalez-Gandolfi, Chief, Building Section, Centre for Housing, Building and Planning, United Nations, New York.

when mixed with natural and artificial aggregates, it produces a concrete of a quality acceptable for low-cost construction.

- Sulfur cures in minutes and can be cast in, and removed from, molds in a fraction of the time required for portland-cement concrete.
- Sulfur has high resistance to salt and acid solutions, and can be stored indefinitely.
- Sulfur can be reused.

However, sulfur has some drawbacks. One disadvantage—flammability—has prevented, until recently, its use as a building material. Today, a number of low-cost additives have been developed that reduce fire danger to levels meeting American Society for Testing and Materials (ASTM) performance requirements.[1] However, systems incorporating these have not yet been used widely enough to determine their cost-effectiveness.

Sulfur has been used in a minor way in housing for many years, for example, as grouting to fasten metal railings to masonry. Since about 1960, a systematic and wider investigation of this material has been undertaken. The Department of Chemistry and Chemical Engineering of the Southwest Research Institute, San Antonio, Texas, has built experimental buildings using sulfur and has investigated ways to spray sulfur and to make it more plastic and less flammable. The Texas institute has also developed methods to apply sulfur and to reinforce it with synthetic fibers.[1,2]

Further studies and experiments have been conducted in Guatemala,[3] Iraq, the United States (Columbia University),[4] Togo (sponsored by the United Nations), and Canada, by McGill University.[5]

SULFUR AS A COATING

If inexpensive sulfur spraying equipment can be developed, many building materials traditionally used for roofing (as well as some new ones) could be coated with sulfur to give increased strength and waterproofing. For example, even thatch roofs might be made more durable and waterproof.

A report of an exploratory study made by Columbia University under U.N. auspices states:

> A panel of reeds, a woven mat and a coarse cloth stretched on a wooden frame were impregnated and painted with sulfur. The resulting panels are quite stiff and completely waterproof even after cracks are induced by flexing the panels. Because of the low viscosity of the sulfur, the procedure is simplest with relatively dense fiber panels and tightly woven fabrics.
>
> Paper panels: the use of paper panels for low-cost, lightweight construction offering flexibility of form was considered in another project. The problem of waterproofing such panels can be solved with the use of sulfur coatings which adhered very well to

sample panels tested during the present study and also added to their strength in flexure.[4]

Some demonstrations in Guatemala proved that sulfur-sand and sulfur-pumice mixtures can be troweled onto wood-wool panels (wood fibers set in concrete). Further investigations have been recommended on roofing made of wood-wool panels with a waterproof coating of sulfur.[3] For coatings and some other uses, the brittleness of sulfur is a drawback but there are indications that this can be overcome.

Dr. B. R. Currell, Department of Chemistry, North London Polytechnic, reported in August 1971, that he had developed methods for plasticizing sulfur by adding unsaturated hydrocarbons to make it flexible.

SULFUR AS A BINDER

Sulfur-containing composite materials could provide strong, waterproof roofing membranes and high performance supporting structures. Experiments in the United States[1,2,4] and Guatemala[3] indicate the possibility of using sulfur as a binder with other materials, such as cement blocks and bricks, to make beams and slabs spanning 1.8288–2.4304 m (6–8 ft). Asbestos-cement is increased greatly in strength when impregnated with sulfur, and larger spans than those used in current asbestos-cement roofing practice might be possible.[5]

McGill University has produced very thin cast tiles. If they are cast in glass molds, a smooth 15 cm X 30 cm X 6 cm (6 X 12 X ¼ in.) rectangular roofing tiles are obtained. These could be used instead of clay or asbestos-cement tiles.

Slabs and tiles of different sizes, sulfur mixes, and finishes have also been made. A mix of sulfur, sand, and basalt aggregates, for example, was cast in a 60 cm^2 mold, 2 cm deep (24 X 24 X ¾ in.). The resulting slab can be used for flooring or roofing. Another demonstration was made using 50 percent of a local sulfur concentrate and 50 percent of pumice with which slabs 5 cm X 7 cm X 1 m (2 X 28 X 40 in.) were cast. Since the slabs are waterproof, they can be used as a roof plane without a roof cover on top, except for the joints. Techniques for grouting the joints should be investigated.[3]

Using sulfur in sulfur-concrete shells has been limited so far by difficulties in melting and pouring large quantities of sulfur. Sulfur-concrete composed of 70 percent sulfur, 25 percent sand, and 5 percent carbon black is reported to reach a tensile strength 47 kg/cm^2 (670 psi).[5] Demonstrations in Guatemala were successful with the following mix: 38.5 percent sulfur, 38.5 percent quartzite sand, and 23 percent pumice. Its compressive strength was 245 kg/cm^2 (3,500 psi).[3]

In 1969 a promising demonstration of sulfur's properties was made:

mineral resources indicates that future building material should, if possible, be produced from renewable resources such as vegetation. For example, in Europe mineral aggregates have become so scarce that roads now must be designed to eliminate the deep layers of gravel traditionally used as roadbeds.

To carbonize plant materials, kernels of common cereal grains—wheat, rice, corn—are expanded by applying heat and pressure, and the expanded kernels are converted to carbon by slow burning. The resulting product has a fine cellular structure containing entrapped air, which makes it an excellent lightweight insulator. The carbonization process renders the materials biologically inert, fire resistant (stable up to about 2000 °C or 3632 °F), and highly resistant to water and chemicals. Further development of this process will undoubtedly affect both the agricultural and construction industries.

To date, work in North America has centered on the use of edible cereal grains to produce the carbonized product; however, this can hardly be recommended for countries where food shortages exist. For these areas, research should focus initially on identifying locally available, nonedible grains or plant materials other than grains suitable for expansion and carbonization. Although it is likely that such indigenous materials exist or that exotic species of plants could be introduced and cultivated specifically for the purpose, there has been little reason to initiate such studies to date.

To develop roofing will require investigating suitable cements and binding agents for the carbonized particles. Some work has been done, again at Toronto, in binding the particles with low-penetration asphalt to produce a roofing board; asphalt, however, is a problem material in the tropics. Portland cement is an obvious alternative, which could produce lightweight insulating concrete for roof decks or precast roof slabs. But portland cement must sometimes be imported and, in such cases, raises the construction costs. Synthetic-resin binders may be viable in some areas, but might require pretreatment of the carbon particles.

The many variables and unknowns at this point of development suggest that the best approach is a comprehensive study in one or more tropical developing countries of the availability of suitable plant materials and an investigation of compatible binding agents to be developed specifically for use with those carbonized products that appear to hold the most potential for roofing in tropical environments.

The use of insulating building materials derived from plant products is an important concept for developing countries. They could be produced locally without draining foreign exchange reserve and could reduce the energy requirements for heating and cooling the buildings produced.

Appendix E. Hydraulic-Setting Cement Binders

This discussion deals with hydraulic-setting materials other than portland cement, which is well documented especially by the Portland Cement Association in the United States and similar organizations in other countries. The purpose here is to describe some other materials with hydraulic-setting properties that may be used as binders for roofing materials or, in some cases, as partial substitutes for portland cement.

Most materials described below offer binding properties deficient in some respects to those of portland cement. Accordingly, their usefulness as binders for roofing materials needs to be researched in terms of particular materials, applications, and locations.

It is hoped that some of these materials will offer a choice for developing a hydraulic-setting binder in areas where portland cement is available in limited quantities or not at all.

BACKGROUND AND POTENTIAL

The following six materials are starting sources for developing hydraulic-setting properties: (a) blast furnace slag, (b) fly ash, (c) limestone, (d) bauxite, (e) pozzolans, and (f) magnesia.[1]

Contributed by C. E. Bushnell, Manager, Building Products Research Unit, Armstrong Cork Company, Research and Development Center, Lancaster, Pennsylvania.

BLAST-FURNACE SLAG

Blast-furnace slag is formed in the process of iron manufacture from a combination of residues from the ore after separation of the iron, and from the limestone and ash from the coke used in the furnace. The slag rises to the surface and is removed from time to time. For use as a hydraulic-setting material, the slag is reduced in size by various means.

Finely ground blast-furnace slag alone does not produce a hydraulic set with water. Various materials must be added to "activate" the hydraulic-setting characteristic. Materials such as lime, portland cement, sodium and potassium hydroxides, and mixtures of salts giving high pH in solution are used.

Slag-based hydraulic-setting binders will probably offer lower strength than straight portland cement but otherwise should provide reasonable performance.

FLY ASH

Fly ash is a by-product of coal-burning power-generating plants. Created in abundance where such facilities operate, it is probably in oversupply since no single major use has been found for it. Probably not useful by itself as a hydraulic-setting binder material, fly ash does exhibit pozzolanic activity and is a practical extender for portland cement.

Certain fly-ash-containing concretes have demonstrated improved strength properties.

LIMESTONE

The greatest use of limestone is for portland cement manufacture; it is blended with other materials to provide hydraulic-setting properties. However, some impure limestone, usually argillaceous, possesses hydraulic-setting properties because its chemical composition is similar to that of portland cement. Lime calcined from limestone has been known to have binding properties for centuries. Hydraulic lime prepared by calcining impure carbonate materials, again argillaceous, also offers potential. Used for centuries in various regions, including South America and Asia, it has been replaced recently by portland cement and other newer materials.

With the exception of portland cement, materials derived from limestone would have less strength as binders and be somewhat water sensitive.

BAUXITE

Bauxite offers a starting point for developing aluminous cements, but it generally needs a source of limestone as well. To make hydraulic-setting materials, bauxite and limestone are fused at high temperatures and then the size of the resulting clinker is reduced. Various combinations of bauxite and calcium-producing materials can be used, and several heating methods are possible.

Aluminous cements are characteristically slow setting but are generally considered to provide high-strength material.

POZZOLANS

Pozzolans do not necessarily hydraulic set themselves, but they provide hydraulic-setting properties when combined with lime or portland cement. Natural pozzolans include certain volcanic glasses, pumices, tuffs, and high-silica-content materials such as diatomite. Some manufactured products, such as fly ash, are also considered pozzolans.

These materials may be used as extenders or with other hydraulic-setting materials. Lime alone has been used for centuries with various naturally occurring pozzolans. Properties developed will depend on the combination and amounts of pozzolans and lime or portland cement used.

MAGNESIA

Magnesia forms the basis for the so-called Sorel cements formed from a combination of magnesium oxide and a solution of magnesium sulfate. These materials, mixed together to form a binder slurry, react through a crystallization process. Magnesia can be replaced to some extent by calcined dolomite to provide wide latitude in raw material source.

These cements offer suitable strength as binders for roofing materials; magnesium oxychloride, particularly, is used to bind wood fiber into a board. However, the water sensitivity of these cements must be considered in any roofing application.

RECOMMENDATIONS FOR USE

Hydraulic-setting binders combined with various fibers and fillers should find application in preparing various types of roofing material—planks, boards, blocks, shingles, etc. Because of the nature of the setting mechanisms,

hydration and crystallization, hydraulic-setting binders must form a substantial portion of the composition. In addition, the density of the composition is usually high, otherwise strength will suffer.

Hydraulic-setting binders, except in the very densest uses or where slopes are such that drainage is rapid, do not waterproof, and some may deteriorate, usually by losing strength, when wet. Thus, this class of binder generally must be used with additional waterproofing, made extremely dense, or installed on slopes steep enough to allow quick drainage.

Hydraulic-setting binders are slurried with water and mixed with fiber, filler, etc., and the resulting mix is formed in a mold or press. Just enough water to slurry and mix should be used, since excess water adversely affects strength. The formed roofing material must be cured, for several days or weeks, to develop optimum strength. Either damp curing at ambient temperatures or various elevated-temperature processes may be used to speed the cure. After cure, the finished product is dried.

APPENDIX E REFERENCES

For more detail, see

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Appendix F. Asphalt Binders

ASPHALT

Asphalts and asphaltic substances have been used by man since the dawn of recorded history. They offer excellent binding qualities along with good weathering and waterproofing properties. Asphalt is derived from many sources including the distillation of petroleum, naturally occurring deposits (e.g., Trinidad Lake), and deposits of harder materials such as gilsonite found in seams and mined out of the ground. Asphalt is available with a wide range of properties from soft and sticky to hard and brittle and is made workable by heat, solution, or emulsification. Useful binders for roofing materials can be made by all three methods.

Asphalt or asphaltic substances can be mixed with a wide variety of materials to provide waterproofing coatings or mastics, or to function as binders for fibrous sheets or boards.

TARS AND PITCHES

Tars are the volatile oily decomposition products from heat processing of bituminous and other organic substances. Pitches are the residues resulting

Contributed by C. E. Bushnell, Manager, Building Products Research Unit, Armstrong Cork Company, Research and Development Center, Lancaster, Pennsylvania.

from the distillation of tars. Some materials useful as binders for roofing materials are tars and pitches from petroleum, coal, wood, rosin, peat and lignite, shale, fatty acids, bone, and other similar materials.

All these materials have characteristic properties and will vary in such things as waterproofness and weatherproofness, softness, brittleness, etc. Most are thermoplastic, but some have thermosetting or drying qualities that further enhance their usefulness. However, none would be considered highly developed in these respects. Any source of tar or pitch could usefully be explored as a basis for a roofing-material binder.

Appendix G. Agricultural and Wood Wastes

Solutions to the roofing problem in the developing world are needed urgently. Therefore a logical start for R&D is in areas that maximize the use of materials that are already available (and cheap) in developing countries, such as agricultural and wood wastes.

For example, locally available wood-wastes and agricultural wastes could be used to manufacture particle-board type roofing panels.[1] Research to develop roofing materials for low-cost dwellings might very well concentrate on one or more of the chemicals, present in wood and agricultural wastes, that could serve as binders.

Prime candidates are lignin and furfural. Lignin is a major ingredient in higher plants, where it binds together cellulose fibers to form the rigid woody structure. The lignin content of some plant materials that are widely available in most countries is shown in Table G-1. Furfural, too, is widely available from most agricultural wastes, which are used even in industrialized countries for the production of commercial furfural. Table G-2 shows the furfural content of some representative vegetable materials.

Considerable data are available on the use of lignin as a binder in plastics and laminated boards,[2] as well as for its use with phenolic resins, a combination which is claimed to be suitable as a wood particle-board binder. (See references at end of appendix.) Furfural also is used as an ingredient in in-

Contributed by W. Ludwig Ingram, Jr., Head, Industrial Services Division, Central American Research Institute for Industry (ICAITI), Guatemala City, Guatemala.

TABLE G-1. Lignin Content of Some Plant Materials

Plant Material	% Lignin Content
Wood	24 to 28
Bamboo	29 to 35
Rice hulls	40.0
Peanut shells	28.0
Bagasse	20.3
Coconut shells	31.9
Corncobs	30.4

Source: Based on data from *Encyclopedia of Chemical Technology*, 2nd ed. Vol. 12. 1967. Raymond E. Kirk and D. F. Othmer, eds. New York: John Wiley and Sons.

dustrial resin, especially the phenol-aldehyde type. Furthermore, it itself reacts readily with lignin, and, in the USSR, a lignin-furfural resin has been developed and used as a binder for molded wood products with encouraging results.[3]

Research aimed at developing cheap roofing suitable for developing countries might take advantage of the lignin binders already present in agricultural wastes. Research to explore using lignins alone or combined with furfural as binding agents in a particle-board type of roofing panel could be productive at this time. Of course, the furfural could also be obtained from agricultural wastes; thus, both binders could be produced from inexpensive waste materials already available locally in developing countries.

Building panels have been manufactured from agricultural and wood wastes for a number of years, and the following three general types are commercially available: hardboard, insulation board, and particle board (chipboard).

Hardboard panels, such as Masonite, have excellent physical properties and

TABLE G-2. Furfural Content of Miscellaneous Agricultural Wastes

Waste Material	% Furfural Content
Corncobs	22.0
Cottonseed hull brand	20.0
Cornstalks	16.5
Bagasse	17.0
Rice hulls	12.0
Peanut hulls	12.0

Source: Based on data from *Encyclopedia of Chemical Technology*. Ibid. Vol. 10. 1966.

have been used in some instances for the exteriors of housing in developed countries. Their ingredients can be cheaper than those of particle board, since a synthetic resin binder is not required. Hardboard, however, is usually pressed from wood fibers prepared by either the Masonite or Asplund processes, both of which require wood chipping, softening, defibrillating, and wet-sheet forming operations prior to panel pressing. Together these make a complex and costly process requiring, for developing countries, a high investment in equipment and plants. As a result, hardboard is not now manufactured in most developing countries and is an imported item even though suitable ingredients may be available locally. If lower cost processing can be achieved this might be changed.

The other two products, insulation boards and particle boards, have good physical characteristics and, with chemical additives, can be made resistant to fungus and insects. Particle boards have been made successfully from a variety of agricultural wastes as well as, more conventionally, from wood chips. The process is relatively simple, and particle board is now manufactured in some developing areas (e.g., Central America). The cost of these locally produced panels, however, is too high for it to be an ideal construction material for low-cost housing in developing areas. A major contributor to this cost is the synthetic-resin binder of petrochemical origin, which in many areas must be imported or produced locally from imported raw materials and which is required by current processing techniques.

Data published by the Food and Agriculture Organization (FAO) in 1957[4] on the production costs of three types of European-manufactured particle board indicate that raw material costs (wood scraps and resin) represent from 52 to 63 percent of the total manufacturing cost of the product. In Central America a particle-board panel made from wood chips and measuring 4 ft wide by 8 ft long and 1½ in. thick sells for $0.35 per square foot, and it is estimated that the resin binder represents over 50 percent of the total material cost in the manufacture of the particle board.

These costs suggest strongly that a low-cost building panel suitable for developing countries could be developed if processing costs could be reduced. This could be accomplished if the need for an imported synthetic resin binder could be eliminated from the particle-board manufacturing process.

Ideally presses of the type already developed for particle-board manufacture could be used. Because of the special requirements of most tropical countries, additives to enhance the insect and fungus resistance of, and to waterproof, the finished product will be necessary, but conventional chemical products currently used for these purposes may prove adequate. This approach is versatile and, in concept, could produce panels for roofing and for the exterior and interior walls of low-cost housing in both rural and urban areas. For the different uses, however, different densities may be re-

quired. For example, for roofing a low-density panel might be needed so that it could be saturated with a waterproofer such as asphalt.

Research directed toward this end might investigate new cheap, mechanical and chemical, methods for releasing lignin from woody materials. Lignin alone or in combination with furfural would have to be submitted to the usual tests of production pressure, temperature, and time and their relation to product quality.

Most developing countries lack research facilities and experienced personnel, especially in the specific case of lignin research. Although lignin has been extensively studied in industrialized countries, research for low-cost roofing materials might best be conducted in the more developed countries. However, the raw materials and the demographic, climatic, and other conditions are different in developing countries. It seems more reasonable to conduct new process development work in developing-country facilities and to appoint a principal investigator who has previously worked with lignin and is familiar with the manufacturing process of hardboard and particle board. Developing-country investigators could participate and not only learn and develop processes but also contribute significantly by supplying local statistics and such information as the availability and accessibility of suitable raw materials. In addition to laboratory equipment, a pilot-plant installation for particle-board manufacture would be desirable.

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4. FAO. 1959. *Tableros de Fibra y Tableros de Fibra Aglomerada.* Ch. V. p. 87.

Appendix H. Ferrocement

Ferrocement was not discussed by the committee because BOSTID had under way an in-depth review of ferrocement's potential for developing countries, which included its use for roofing. Since the committee's meeting, the ferrocement panel has published a report. Their evaluation of ferrocement is quoted here.

Ferrocement is a highly versatile form of reinforced concrete made of wire mesh, sand, water, and cement, which possesses unique qualities of strength and serviceability. It can be constructed with a minimum of skilled labor and utilizes readily available materials. Proven suitable for boatbuilding, it has many other tested or potential applications in agriculture, industry, and housing.

Ferrocement is particularly suited to developing countries for the following reasons:

- Its basic raw materials are available in most countries.
- It can be fabricated into almost any shape to meet the needs of the user; traditional designs can be reproduced and often improved. Properly fabricated, it is more durable than most woods and much cheaper than imported steel, and it can be used as a substitute for these materials in many applications.
- The skills for ferrocement construction are quickly acquired, and include many skills traditional in developing countries. Ferrocement construction does not need heavy plant or machinery; it is labor-intensive. Except for sophisticated and highly stressed designs, as those for deep-water vessels, a trained supervisor can achieve the requisite amount of quality control using fairly unskilled labor for the fabrication.[1]

The panel believes that ferrocement may prove a suitable material for low-cost roofing in developing countries. Applied-science laboratories in developing countries and technical assistance agencies should seriously consider this area for field trials and techno-economic studies. . . .

Ferrocement represents a potential solution to roofing problems because of its relatively low cost, durability, weather-resistance, and particularly its versatility. Unlike most conventional materials, ferrocement can be easily shaped into domes, vaults, extruded type shapes, flat surfaces, or free-form areas. Because ferrocement is easily fabricated, even in rural areas, by supervised local labor using mainly indigenous materials, it seems an excellent medium for on-the-site manufacture of small or large tiles (shingles) or other roofing elements. Where wooden timbers are very expensive, ferrocement beams might be made on site to replace wooden structures used to support indigenous roof coverings. Its most economical use, however, appears to be for fairly large-span roofs.

Ferrocement is not commonly used for roofing because its promise has not generally been recognized. Its use, particularly in developing countries, must be preceded by more research and experimentation in design and production techniques suited to construction by unskilled labor.[2]

Ferrocement roofing materials can be factory mass-produced in prefabricated form, a process best suited to the concentrated demand of urban areas. Though it might be more economical to mass-produce roofing in an urban factory and truck it to a rural area (should trucking be possible), ferrocement is also easily fabricated on site in rural areas, using local labor and materials.

Freer in concept and makeup than most conventional roofing, ferrocement can be shaped into domes, vaults, extruded shapes, flat surfaces, or free-form areas.

Before ferrocement can be used widely for roofing, research and experiments will be required to determine the shapes and types of roofing members to be manufactured, and to explore designs and methods for anchoring and bolting these various shapes to supporting walls.

After this research and experimentation is completed, on-the-job training centers may be required to introduce the new material and its new building techniques. Preferably, these centers should also offer programs dealing with other ferrocement applications.

Research efforts to find ferrocement modifications that prove less expensive or easier to manufacture are highly recommended. Possibly, for example, ferrocement can be sandwiched on two sides of a core of foam concrete or other lightweight material to make a less expensive and lightweight, yet still structurally strong, material.[3]

APPENDIX H REFERENCES

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2. Ibid. pp. 8, 9.
3. Ibid. pp. 35, 36.

Appendix I. Low-Cost Roofing Research in India

Over the years, roofing problems have been studied in depth at the Central Building Research Institute of India (CBRI) and are briefly described in the appendix.

CLAY

Clay roofs are common in developing countries because of the availability of clay and the low construction costs. In India, these include flat mud roofs, country-tiled roofs, and Mongalore-pattern clay tile roofs.

Research and development activities at CBRI have added several new techniques: (1) precast *Guna* clay tile units, (2) corrugated-clay roofing sheets, (3) structural-clay flooring/roofing units, (4) reinforced brick, and (5) reinforced-brick concrete. The salient features of these techniques are described below.

PRE-CAST GUNA CLAY TILE UNITS

Guna tile is a hollow, conical clay tile. A unit of the roofing system is about 110 cm long, 25 cm wide, and 12 mm deep (43.31 X 9.84 X 0.47 in.) and

Contributed by Professor Dinesh Mohan, Director, Central Building Research Institute, Roorkee, Uttar Pradesh, India.

weighs nearly 41 kg (90.40 lb). Compared with a conventional 10-cm (3.94-in.) reinforced concrete (RCC) slab, the saving in use of cement is 28 percent and of steel, 55 percent.

CORRUGATED-CLAY ROOFING SHEETS

A process has been developed for producing corrugated-clay roofing sheets (105 cm × 60 cm × 10 mm or 41.34 × 23.6 × 0.39 in.) from specially processed clay mix. These sheets do not warp or crack during drying and firing, and the process is simple enough to be implemented with hand labor in villages. The tensile strength of these sheets lies in the range 100–105 kg/cm^2 (1422–1493 psi), and water absorption is below 2 percent. Each sheet weighs about 15 kg (33.07 lb).

STRUCTURAL-CLAY FLOORING/ROOFING UNITS

In several developing countries, mechanized brick production is increasing. Taking advantage of this situation, CBRI has developed two types of structural flooring/roofing units. Plastic alluvial clays (kaolinite-illite mixtures) with a fairly wide range of workability are suitable for extruding these tiles. Tiles are pre-assembled on the floor: the units are placed end to end up to the required length, a 6-mm (0.24-in.) mortar joint being provided between the tiles. A triangular cage of mild steel bars is placed within the hollow space provided in the tile for the purpose, and it is then concreted. After concreting is done, two beams are placed on bearing walls at 45-cm (17.72-in.) centers and the intervening space filled up by placing ceramic blocks of the same design in an inverted position. A deck concrete is laid on to a thickness of 3 cm (1.18 in.). Compared with a conventional 10-cm (3.9-in.) RCC slab, the system is estimated to save 40 percent in cement consumption and 30 percent in steel. Deck concrete can be eliminated by slight modification of the design, thereby effecting further economy in cement consumption.

Tiles of another design have been developed for vertical construction of floor sections in the manner of a masonry wall. After the wall panels have acquired adequate strength, they are tilted to a horizontal position to form a flooring unit and placed on the bearing walls. This type of clay tile is likely to result in an economy of 60 percent in cement and 30 percent in steel, compared with a conventional RCC slab.

REINFORCED BRICK (RB)

Reinforced brick has essentially the same features as reinforced concrete, except that brickwork in cement mortar is substituted for cement-concrete.

Reinforcement is placed in the mortar joints, which are generally 2.5 to 3 cm (0.98-1.18 in.) wide. All other joints with no reinforcement are generally 1 to 1.2 cm (0.39-0.47 in.) wide. Good-quality bricks with a minimum strength of 70 kg/cm^2 (995.4 psi) should, however, be used. These bricks are of medium absorption (8-15 percent) and free from any trace of smooth glaze on the surface. The mortar used is 1:3 (cement:sand).

RB slabs may be designed for both one-way or two-way spanning. The design principles are the same as those for reinforced concrete, except that the permissible stresses and other design factors are different. For normal residential buildings, this type of slab has yielded a saving of about 10 percent compared with an RCC slab.

REINFORCED BRICK CONCRETE (RBC)

In this type, cement-concrete is used in conjunction with the bricks as a deck over the top surface of the bricks, as well as for filling the joints. The thickness of deck concrete generally varies from 4 to 6 cm (1.57-2.36 in.) and the joint thickness from 4 to 5 cm (1.57-1.97 in.). In general, the deck concrete at the top forms the compression zone, whereas the participation of brick in resisting compression is either nil or very limited. RBC slabs are also designed like RCC slabs and are used quite extensively in India as an alternative to RCC slabs for floors and roofs of residential buildings.

ORGANIC MATERIALS

Organic materials such as wood, thatch, and leaves are very commonly used for roofing purposes in developing countries. In India, thatched roofs are built of locally available grass or palm leaves. The roof is supported on wooden posts and rafters and is tied to suitably spaced bamboo battens. The incline of the roof depends on the intensity of rainfall and is usually 30-45°. This type of roofing is most popular in villages because of its cheapness and the ease and rapidity of its construction. In the tropics, however, thatch deteriorates rapidly and harbors insects. It also presents a serious fire hazard. Chemicals are available to improve the durability of thatch and render it fireproof, but they leach away during rains and need reapplication. CBRI has developed a stabilized mud plaster, which is applied on the lower surface of a thatch roof to reduce its rate of burning. The risk of fire spreading from one roof to the next is reduced by the application of a thin wash of stabilized mud on top of the roof. This mud wash, however, needs renewal after each monsoon, especially on palm-leaf roofs.

CBRI investigations have confirmed the possibilities of preparing a roof-

ing board based on particle boards prepared from the husks of mature coconuts. A board of density (753 kg/m^3 or 47.1 lb/ft^3), prepared with 0.5 percent P.F. resin adhesive, possesses modulus of rupture, in bending, of 232 kg/cm^2 (3299 psi). These boards can be rendered waterproof with cashew-nut-shell liquid. Tests have shown that they are self-extinguishing and need no fire-retardant treatments. CBRI has also developed a chipping machine, specially adapted for chipping the husks of mature coconuts. Because of the widespread availability of coconut husks in most developing countries, it could become a profitable source of roofing material and other products.

Corrugated-asphalt roofing sheets have recently been introduced in India. They tend to delaminate at the edges, and their dark color absorbs solar radiation and renders the internal environment uncomfortable. White-washing roofs helps to reflect the solar radiation and cools the ceiling by 2 to 3 °C.

CONCRETE

In building a strong base for industrialization, several developing countries are experiencing rapid urbanization of the countryside. In such a situation, judicious use of cement and steel can help to provide economic alternatives for the conventional in situ RCC slab. If the new techniques lend themselves to simple prefabrication, they could also help in mass housing programs. In CBRI several roofing units have been developed that economize in the consumption of cement and steel and can easily be precast at a factory or at the construction site. Some of these units are described below.

PRECAST DOUBLY CURVED TILE UNITS

The concrete tile unit is square–68.6 cm X 68.6 cm X 19 mm (2.25 ft X 2.25 ft X 0.75 in.). Its surface is curved in both directions, which enhances its resistance to both sustained and impact loads. It weighs only 27.2 kg (59.98 lb), and no reinforcement is needed in the edge beams. The casting process is very simple: To construct the roof, precast RCC beams are laid at 76.2-cm (30-in.) centers and provided with two temporary wooden props at middle-third points along the length. The tiles are laid on a bed of mortar put on the beam edges and carefully positioned. The haunches are next filled up with the cement concrete, leaving only a small ridge uncovered. The waterproofing-cum-insulating treatment is then provided over the roof in the con-

ventional manner. The roof is suitable for single-story schools, offices, and residential buildings where it is not likely to be subjected to a concentrated or heavy load and the spans do not exceed 4.25 m (13.94 ft). It results in substantial savings in cost, as well as in the consumption of cement and steel. For example, at a site in Delhi, the saving in the consumption of cement was 25 percent and of steel, 25 percent, compared with the conventional RCC slab.

PRECAST CELLULAR UNITS

These rectangular, concrete units could be used for roofs and floors. The unit size is 1 m X 0.5 m X 100 mm (3.28 X 1.64 X 0.33 ft), and it weighs nearly 55 kg (121 lb). It is provided with three to four hollow, hexagonal cells, running through its entire length. The unit is cast with the help of single timber formwork and provided with hexagonal slots at the two ends through which timber forms for creating the hollow cells are inserted.

For casting the roof, the units are placed on either rectangular beams or composite T-beams. Most beams are precast T-beams; temporary propping is needed. With rectangular beams, however, construction is relatively simple, and no supports are necessary during the construction, nor is reinforcement needed in the top concrete. With either type of beam, it is necessary to lay a minimum of 35 mm of lean concrete on top of the units to enhance their resistance to impact loading. The complete roof assembly has been tested and found suitable for a load of 0.19 kg/cm^2 (400 lb/ft^2). Compared with conventional RCC slabs, the percentage savings in the consumption of cement are about 30 percent and of steel, 70 percent, when rectangular beams are used to support the units. With T-beams, the corresponding savings are 20 and 50 percent.

CORED UNITS FOR ROOFING

CBRI has also developed prefabricated-concrete, doubled-cored units that provide a flush ceiling. They need no temporary propping. The units weigh about 136 kg (299.88 lb), and their dimensions are 30 cm X 12.7 cm X 3.7 mm (11.81 X 4.99 X 0.15 in.). Recently, a prototype of a machine using a pressure-cum-vibration technique has been developed at CBRI for casting concrete-cored units up to 61 cm (2.5 ft) in width and of various shapes and sizes.

The use of these units could effect savings of 15 percent in cement and 10 percent in steel, compared with the conventional 10-cm (3.94-in.) RCC slab (3.7-m or 12.14-ft span).

PRECAST-CHANNEL UNIT FLOORING/ROOFING SYSTEM

A precast RCC element, trough-shaped in section, the unit is structurally complete in itself and does not need propping during construction. It is generally 300 mm (11.91 in.) wide, 125 mm (4.92 in.) deep (the depth may vary depending upon the span and loading), and is 2.4 to 4.2 m (7.87–13.78 ft) long. The length can also be adjusted to suit the span. The shape of the unit allows for space between adjacent units for negative reinforcement over supports and laying of concrete in situ, which develops a monolithic structure and permits flexibility in designing the floor/roof as a continuous one-way slab. The wooden molds for the units are made of an outer rectangular frame and a trough-shaped inner frame. The units are precast with the flange on the underside and the ribs on the upperside and in the usual manner of casting concrete members. A unit 300 mm × 125 mm and 3.6 m long (11.81 × 4.92 × 141.73 in.) weighs about 122 kg (268.91 lb). A comparative-cost study of a continuous (3 bays of 3.5 m, or 11.48 ft, each) conventional RCC roof slab and a channel-unit roof of the same dimensions revealed almost no saving in steel, but saving in cement is about 40 percent.

PRECAST-CONCRETE WAFFLE UNITS

Recently, a scheme for precast-concrete grid floors and roofs for longer spans was developed at CBRI. It consists of waffle units 0.6 m^2 (6.46 ft^2) laid in a grid pattern. The reinforcements are laid in the gaps between the units, and concrete is placed to act as grid beams in two mutually perpendicular directions. The shape of the units was worked out to ensure load transfer from one unit to the adjacent one through the in situ concrete between them. Elimination of in situ deck concrete above the units is a distinct feature of the system. This system results in a saving of about 8 percent in steel and 30 percent in concrete, compared with the conventional 10-cm (3.94-in.) RCC slab of equal span.

MISCELLANEOUS MATERIALS

Metals, such as galvanized iron and aluminum, and minerals, such as natural stone, asbestos, etc., are also used for roofing in the developing countries. The use of corrugated aluminum sheets is gaining ground in Africa, the southeast Asian region, and Argentina. They improve physical comfort to some extent because of their high heat-reflecting factor in the initial stages. Roof framing is of the rafter and purlin type.

Slate roofs are generally adopted in hilly areas of India. They are laid over wooden trusses and purlins. The slates are normally 61 cm X 91.4 cm X 215 cm (2 ft X 3 ft X 1 in.) in size. Asbestos-cement corrugated sheets are also very commonly used for roofing in India. For this purpose, the chrysotile variety of asbestos is imported each year at a cost of Rs. 100 millions (U.S. $14 million). To conserve foreign exchange, the CBRI has developed a process for full or partial replacement of imported chrysotile with indigenous amphibole asbestos.

Appendix J. Potential Roofing Materials and Composites

During the committee's deliberations many materials were identified that might be considered when planning a research program to solve developing country roofing problems. The following list was developed by the panel early in their meeting. Because of time limitations no consideration was taken of the practicality of any of the materials (e.g., durability, pest resistance, strength). This list is included here only to convey a sense of the range of materials locally available in the developing world whose properties may make them worth considering for use in low-cost roofing research projects. For completeness, some materials already in standard use are included.

The list is divided into the following categories.

1. General roofing materials
2. Potential components of composite roofing materials
   binders
   reinforcement
   fillers/aggregates
   coatings

1 GENERAL MATERIALS THAT MIGHT BE USED FOR LOW-COST ROOFING IN DEVELOPING COUNTRIES

Plastic (as sheet, perhaps as a fiber in an "artificial thatch," or foamed or formed)

Bituminous products (either formed, built-up or as shingles)
Concrete (e.g., reinforced, ferrocement, foamed concrete, lightweight aggregate concrete)
Minerals (e.g., slate, stone, gypsum)
Formed clay products (e.g., as tiles or sheets)
Other materials from soil (perhaps stabilized or foamed)
Wood products [e.g., shingles/tiles, plywood, particle board, wood wool (wood fibers in concrete) or formed paper]
Vegetable products (as thatch or woven mats, e.g., grass and reeds, canes, bamboo)
Fabrics (e.g., canvas)
Animal products (e.g., leather, hides)

2 POTENTIAL COMPONENTS OF COMPOSITE MATERIALS

BINDERS

Portland cement
Other hydraulic-setting cements (e.g., products from blast furnace slag, fly ash)
Clay, calcinated clay, earth, etc.
Limestone, lime or gypsum
Magnesium oxychloride sulfate
Glass
Sulfur
Asphalt, coal tar derivatives, and petroleum derivatives
Pitches, rosins and gums (e.g., tall oil pitch, cottonseed pitch, soya bean oil residue)
Lignins, furfural
Starches (e.g., from grains or root crops)
Oils (e.g., drying oils such as linseed or cashew-nut-shell liquid, with or without catalyst)
Rubber and natural latex
Adhesive proteins [e.g., casein, animal and fish blood, legume protein, bone/hoof glue (animal glue and tannery waste)]
Animal grease
Silicates [e.g., sodium silicate (water glass)]
Plastic resins
- Unsaturated polyesters, polyolefins, etc.
- Urethanes
- Urea-formaldehyde

Other thermoplastics
Shellac

REINFORCEMENT

Metal (rod, fiber, wire mesh, "expanded" metal)
Mineral fibers (asbestos; wallostonite; amphibole; long fiber chrysotile; rock wool from blast furnace slag; glass fibers)
Vegetable waste (e.g., rice hulls; bagasse; cottonseed; peanut hulls and other seed hulls; cotton, jute, sisal and other textile-fiber wastes; coconut husks; straw)

COATINGS

Sulfur
Polymers/paints
Metal coatings (e.g., galvanized or metal foil)
Silicones
Cashew-nut-shell liquid
Bituminous products
Mineral particulates
Whitewash
Sand

FILLERS/AGGREGATES

Sand, soil, rock and clay
Expanded (bloated) clays, expanded shale, expanded perlite, expanded slag and glass
Sintered fly ash
Shells
Pozzolans
Diatomaceous earth
Waste glass
Air (as in foams)
Organic materials [e.g., bark; wood (sawdust, chips); cork and pitch, paper, coconut shell]
Carbonized plant products (charcoal expanded husks, cereal grains, seed hulls, etc.)

ESPAÑOL

Recomendaciones

El propósito de este informe es identificar una amplia variedad de materiales que los investigadores científicos pueden considerar en su selección para un nuevo sistema de techos en los países en desarrollo. Como las particularidades, necesidades, clima y disponibilidad de materiales y recursos de los países en desarrollo difieren extensamente, cada uno de ellos debe determinar independientemente cuáles de los cursos de investigación son los más promisores. Sin embargo, el comité cree que un plan organizado y sistemático en el establecimiento y finalidades de los programas de investigación e implementación dentro de los países en desarrollo puede conducir a prontos resultados para su utilización inmediata, en todos los países o al menos en la mayoría.*

1. COMITÉ ASESOR INTERNACIONAL

Debería establecerse un comité asesor permanente bajo el auspicio internacional apropiado. Sus esfuerzos deberían encauzarse específicamente a acelerar, expandir y consolidar los bien dispersos programas existentes de

*Este informe fue terminado antes del reciente aumento en los precios del petróleo crudo. Substancialmente el aumento de costos de los derivados del petróleo les afectará adversamente su posición competitiva con los adhesivos poliméricos y plásticos porosos (recomendaciones 2 y 3) aumentando la preferencia por las tecnologías que no hacen uso de subproductos del petróleo, discutidas en las recomendaciones 4 y 10.

investigación para techos de bajo costo en los países en desarrollo. El comité debería concentrarse en enfocar el problema desde el punto de vista global y no simplemente regional.

Típicamente el comité debería encausar la necesidad de efectuar un inventario de los materiales para techo y de las prácticas de diseño y construcción actualmente utilizados en los países en desarrollo, como también de los problemas que en la actualidad están siendo estudiados por esos países y otras organizaciones investigativas. Este inventario deberá facilitar la identificación de áreas aun no cubiertas en la investigación y de aquellas que requieren mayor atención.

La mayoría de los miembros del comité deberían ser expertos en vivienda para las regiones en desarrollo y otros deberían proceder de las más apropiadas organizaciones mundiales académicas e investigativas y de organizaciones de ayuda técnica que tengan un interés substancial y recursos considerables dedicados al aspecto de la vivienda en los países en desarrollo (tales como AID, Banco Mundial, Programa de Desarrollo de las Naciones Unidas, Centro de Planificación, Construcción y Vivienda de las Naciones Unidas, Banco Interamericano de Desarrollo, Organización de Estados Americanos y CARE.

2. CONGLOMERANTES POLIMÉRICOS

Los programas de investigación, demostración y desarrollo para cubierta de techos deberán encauzarse al uso de poliésteres no saturados y polímeros apropiados, existentes comercialmente, para producir combinaciones aglutinantes con materias primas (v.g. fibras vegetales, entelados y tierras) de los países en desarrollo seleccionados.

Estos esfuerzos pueden ser productivos porque actualmente la tecnología para productos empleados en la fabricación de edificios, usando fraguación térmica (v.g. poliésteres no saturados), resinas termoplásticas y polímeros correspondientes en combinación con otros materiales, está altamente desarrollada y bien documentada (véase apéndice A). Si estos productos son compatibles y pueden mezclarse con las materias primas disponibles localmente, será posible fabricar piezas de formas y dimensiones ilimitadas para satisfacer los diseños requeridos por las diferentes tradiciones y costumbres. El comité piensa que mediante un programa concertado de desarrollo y prueba, a nivel piloto se podrían producir materiales compuestos apropiados para sistemas de techo a bajo costo en la mayoría de los países en desarrollo.

La tarea mayor en desarrollar compuestos de bajo costo que puedan resistir elementos destructivos tales como humedad, rayos ultravioleta, fungus e insectos. Deberá darse especial énfasis a la identificación de los peligros potenciales asociados con el uso de productos de materiales plásticos. Por ejemplo, si se cocina con llama abierta en el interior de la vivienda, ciertos elementos plásticos del techo pueden inflamarse y producir humos dañinos o gases tóxicos. Los polímeros pueden ser tratados mediante técnicas relativamente

simples para soportar la exposición directa al fuego, pero hasta ahora la aplicación de estos polímeros tratados ha sido relativamente costosa.

Si se pueden elaborar materiales a un costo razonable y de alta confiabilidad, la tecnología de su fabricación probablemente podría ser transferida con poca dificultad a los países en desarrollo; la simplicidad en producir materiales de resina sintética para techos permitiría una fácil difusión de la tecnología y su pronta comercialización por empresas pequeñas. Los productos para terminación de edificios prometen competir económicamente con el hierro corrugado, inclusive ofrecen un precio más conveniente.

Los costos de fabricación de los compuestos para techos pueden ser muy bajos. El sistema sería versátil y se prestaría a una intensiva producción manual.

En su estado crudo, las resinas y polímeros básicos son estables pudiendo ser almacenados por cierto tiempo, pero para mantener sus características específicas deben mantenerse en un sitio frío y a la sombra. Como estos están concentrados, sólo requieren un espacio limitado para su transporte y almacenamiento y su valor intrínseco es muy pequeño hasta ser convertido en material de construcción. Si dentro de los países en desarrollo no se dispone de polímeros y resinas básicas, estos tendrían que ser importados pero probablemente sólo representarían una porción inferior a la del costo del techo terminado. No existen problemas de logística de importancia en la importación de resinas y polímeros a granel—existen numerosos fabricantes y abundante aprovisionamiento—ni tampoco es dificultuoso manejarlo, almacenarlo o transportarlo a su sitio de uso final.

Los estudios investigativos concernientes a este tipo de aplicación deberán incluir un análisis de costos-beneficios entre las resinas importadas y las alternativas opuestas, tales como el hierro corrugado importado.

3. PROCESAMIENTO DE PLÁSTICOS POROSOS

Deberá iniciarse un proyecto piloto para el procesamiento de materiales a base de plástico poroso apropiado para cubrir techos y para la fabricación de un equipo móvil a pequeña escala y cuya producción pueda resultar económico en los países en desarrollo.

Los plásticos porosos de baja densidad son substancias celulares producidas por la inyección de burbujas de gas durante la fabricación de compuestos plásticos—que representan un significativo potencial como material versátil, de peso liviano y alto aislamiento para techos y que puede ser producido en el sitio de la obra en una variedad de formas y dimensiones (véase apéndice B). Hasta la fecha el uso de plástico poroso ha sido limitado severamente por falta de un equipo mezclador sencillo, confiable y de bajo costo, capaz de elaborar un producto uniforme de alta calidad.

El equipo usual para procesar plástico poroso genera químicamente la espuma y luego distribuye, por pulverización, la masa congelante de finas

burbujas en la posición deseada. En el pasado el equipo de procesamiento usado para este tipo de demostraciones en los países en desarrollo, era bastante complicado y sensitivo, y requería un mantenimiento costoso. Sin embargo, los últimos adelantos en el diseño de equipos ha eliminado muchos de los problemas experimentados anteriormente. En consecuencia parece ser que esta es la oportunidad más apropiada para incorporar tales avances en el desarrollo de un sistema mezclador móvil y de pequeña escala que pueda ser producido en masa por los países en desarrollo. Este sistema en combinación con una demostración que pruebe que los plásticos porosos pueden ser utilizados para agregar rellenos y capas de refuerzos como material para capas inferiores y de cubierta para techos, puede dar lugar a la formación de empresas lucrativas locales que podrían producir el equipo y diversos productos de plástico poroso.

El proyecto piloto recomendado deberá ser organizado claramente como un experimento para evaluar y documentar el rendimiento del equipo, así como su economía, aceptación por el consumidor, uso, longevidad y durabilidad de los techos prototipos producidos. El proyecto puede ser perfectamente conducido como un esfuerzo cooperativo entre empresas de los EE.UU. y de los países en desarrollo, con participación de instituciones académicas, organizaciones comerciales y profesionales de la industria constructura, más la asistencia técnica de organismos especializados en vivienda.

Debe hacerse notar que recientemente "the U.S. Federal Trade Commission" estableció que ciertos productos plásticos de poliuretano y poliestereno usados en construcción de viviendas pueden ser peligrosos para la salud y la vida cuando se exponen al fuego. Este hecho es bien conocido por los técnicos en vivienda. Sin embargo ahora existen ciertos plásticos con baja producción de humo y propagación de llama, y se esperan mayores progresos en el futuro. A pesar de ello, los investigadores dedicados al desarrollo de materiales plásticos para techos en los países en desarrollo deberán estar advertidos de los peligros potenciales relacionados con el fuego y deberán mantenerse informados de los adelantos técnicos en esta materia.

4. AZUFRE

Debe prestarse seria consideración al empleo del azufre como material aglutinante para otros materiales nativos, como capa de revestimiento, como material para relleno de junturas y para la fabricación de productos pequeños para techos, por ejemplo, tejas.

A pesar que el azufre no ha sido usado extensivamente como material para construcciones, su empleo tiene muchas aplicaciones para techos a bajo costo en los paises en desarrollo, que deben ser exploradas (véase apéndice C). El uso de este material para fines de construcción en los países en desarrollo ha estado sujeto a una comprensiva investigación científica, en la última década. Su uso en tales países es particularmente digno de consideración en vista de

la abundante existencia de azufre debido a las actividades volcánicas y a ser un subproducto del petróleo. El azufre puede constituir un artículo de importación a bajo costo para aquellos países que carecen de azufre en estado natural.

Las pruebas e investigaciones previas han sido dirigidas principalmente a su empleo como agente adhesivo de superficie en el concreto sulfurado. El azufre elemental es un agente aglutinante con propiedades únicas: Su punto de fusión es 240°F, ligeramente superior al del agua; es insoluble en agua, teniendo propiedades de impermeabilización; es inodoro; no produce efectos tóxicos en su uso normal; es un mal deficiente conductor del calor; su vida de almacenamiento es ilimitada y puede ser procesada nuevamente. Todas estas características indican un excelente potencial para su uso como material para techos en los países en desarrollo.

El azufre elemental es particularmente apropiado para métodos de construcción de trabajo pesado teniendo ciertas limitaciones: es altamente inflamable y debe ser convertido a estado líquido antes de añadir agregados o rellenadores. Los fabricantes y aquellos que lo usan deben estar prevenidos del posible desprendimiento de acido sulfúrico en presencia de las humedad, así como de sus efectos perniciosos si llega a ser ingerido. Sin embargo, sus ventajas sobrepasan las desventajas, justificando todo esfuerzo de desarrollo e investigación en la actualidad.

5. MATERIALES DE PLANTAS CARBONIZADAS

Se deberán efectuar estudios investigativos de laboratorio y demostraciones concernientes a la transformación de resinas poliésteres no saturadas y polímeros relativos combinados con productos de plantas ricas en almidón, no comestibles carbonizadas y expandidas (véase el apéndice G) en planchas para techos de peso liviano y de bajo costo. La investigación deberá incluir la identificación de tipos y cantidades de los productos de plantas apropiadas para este propósito, así como su disponibilidad en los países en desarrollo.

6. RESIDUOS AGRÍCOLAS Y DE MADERA

Se deberá iniciar un programa extenso tendiente a desarrollar procesos económicos para la fabricación de resinas provenientes de productos agrícolas nativos (v.g. vegetación natural, residuos de caña) para ser utilizados principalmente como aglutinantes o adhesivos.

Como puede notarse en el apéndice G (Ref. 1) la lignina y furfural en vegetación pueden ser usados como adhesivos *in situ* si se les aplica presión y calor. Esta tecnología es bien conocida en los países industrializados y es probable que métodos de procesamiento simplificados puedan permitir a los países en desarrollo, producir una abundante cantidad de paneles apropiados para construcciones.

7. RESIDUOS DE INDUSTRIAS PRIMARIAS

Las cenizas y escoria del coque de los altos hornos empleados en la industria del acero tienen características que las hacen apropiadas para ser usadas como cementadores aglutinantes y deberán ser investigadas (véase el apéndice E). Estos residuos pueden ser de particular valor en aquellos países que carecen de piedras calizas y de recursos de cemento portland.

El "barro rojizo" que es un copioso subproducto de la refinación de la bauxita, abundante en muchos países en desarrollo, también merece seria consideración así como los residuos metálicos de la producción de hierro y acero. La eliminación de estos residuos y de otros productos similares constituye una carga constante para la industria pesada en todo el mundo; su conversión a productos útiles serviría un propósito doble. Las investigaciones para tales alternativas pueden atraer a las industrias afectadas hasta el punto de inducirlas a contribuir con fondos o materiales.

8. CONCRETO

Deberá efectuarse un programa analítico y de pruebas de laboratorio encaminado a desarrollar productos de concreto reforzado más económicos y apropiados (véase el apéndice H, hierro-cemento). Las investigaciones deberán concentrarse en el uso de materiales para refuerzos tales como malla de alambre, fibras de vidrio y lana pétrea disponibles localmente así como diferentes productos vegetales tales como bambú (Ref. 2), cortezas y fibras de madera (las fibras de madera se conocen en ciertas partes del mundo como "lana de madera" o "virutas de madera" (Ref. 3). También deberá prestarse consideración a los substitutos para cemento portland, algunos de los cuales se sugieren en el apéndice E.

9. MATERIALES A BASE DE ARCILLA

Se deberá conducir un programa de investigación para desarrollar métodos tendientes a mejorar el desempeño general y la amplitud de aplicaciones de los materiales a base de arcilla, greda o barro para techos (véase el apéndice I).

10. PRODUCTOS DE FIBRA

Deberá explorarse la conveniencia y efectividad del uso de residuos de las materias primas empleadas en la industria textil y otras industrias de fibras [basadas en fibras de yute, henequen (sisal), cáñamo, kenaf y algodón] que son comunes en los países en desarrollo, para aprovecharlos como mezcladores en un material compuesto para piezas de techos.

En resumen, existen numerosos medios promisorios de exploración y el comité asesor opina que es el momento de aprovechar al máximo estas ventajas.

CAPÍTULO III–REFERENCIAS

1. Véase también *Producción de paneles utilizando residuos agrícolas*, diciembre 1970. Informe No. 1D/79 (WG 83/15/Rev. 1) Ginebra: Organización de Desarrollo Industrial de las Naciones Unidas.
2. Par informaciones, véase *Refuerzo expedito para concreto usado en Asia Sud Oriental.* por F.B. Cox y H.G. Geymayer, Informe técnico C-69-3, Vicksburg, Mississippi: U.S. Corps of Engineers.
3. Para mayores informes, comuníquese con el Dr. J.W.S. De Graft-Johnson, Director, "Building and Road Research Institute," CSIR, Kumasi, Ghana.

FRANÇAIS

Recommandations

Ce rapport énumère une grande variété de matériaux qui pourraient intéresser des chercheurs pour la mise au point de nouveaux systèmes de couverture des toits dans les pays en voie de développement. Ces derniers ont des besoins, des climats, des matériaux et des ressources si différents qu'ils doivent déterminer individuellement les domaines dans lesquels la recherche apportera les meilleurs résultats. Cependant, le comité est d'avis que l'établissement et la direction de ces programmes de recherche et de développement devraient procéder d'une démarche systématique et organisée. Les pays en voie de développement obtiendraient ainsi des résultats immédiats qui pourraient être utilisés par la plupart d'entre eux, sinon par tous. Le comité propose donc les recommandations suivantes*:

1. UN COMITÉ CONSULTATIF INTERNATIONAL

Un comité consultatif permanent devrait être créé sous les auspices d'organisations internationales compétentes. Ses efforts devraient être particulièrement dirigés vers l'accélération, l'élargissement et la consolidation de programmes dispersés de recherche sur les toitures à bon marché qui existent

*Ce rapport a été terminé avant la recente augmentation des prix du pétrole brut. L'augmentation importante des prix des dérivés du pétrole se répercutera sur la concurrence des liants polymères et des mousses plastiques (recommandations 2 et 3) et augmentera l'attrait des techniques basées sur les produits qui no sont pas tirés du pétrole. Ces techniques sont examinées dans les recommandations 4 à 10.

déjà pour les pays en voie de développement. Le comité devrait mettre l'accent sur l'aspect régional plutôt que sur l'aspect mondial.

Représentatifs des besoins qu'un tel comité pourrait aborder seraient non seulement l'inventaire des matériaux de couverture, la conception et les pratiques de construction qui sont en usage dans les pays en voie de développement, mais aussi les problèmes de couverture des toits actuellement à l'étude dans ces pays et dans d'autres organismes de recherche. Un tel inventaire permettrait d'identifier tant les lacunes qui existent dans la recherche que les domaines qui réclament plus d'attention.

Le comité devrait être composé en majorité d'experts du logement venant des régions en voie de développement. Les autres membres devraient provenir d'organismes de recherche et d'établissements universitaires du monde entier et aussi d'organismes d'assistance technique dont l'intérêt majeur et les ressources considérables sont dirigés vers le logement dans les pays en voie de développement: l'AID; la Banque mondiale; le Programme des Nations Unies pour le développement; le Centre des Nations Unies pour le logement, la construction et la planification; la Banque interaméricaine de développement; l'Organisation des États américains; CARE, etc. . .

2. LIANTS POLYMÈRES

Les programmes de recherche, de mise au point et d'essais pratiques des couvertures et toitures, devraient être axés sur l'emploi des polyesters non-saturés et des polymères connexes existant sur le marché, comme liants dans les mélanges de matériaux produits localement, tels que les fibres végétales, des terres et des tissus en provenance de pays en voie de développement déterminés.

Un tel effort pourrait être productif actuellement puisque les techniques qui utilisent les résines thermoplastiques et thermodurcissables, les polyesters, par exemple, ainsi que les polymères connexes en combinaison avec d'autres substances pour la fabrication de matériaux de construction, sont parfaitement au point et tout à fait documentées (voir annexe A). Si de tels produits se mélangent bien avec elles, ils pourraient etre fabriqués dans une variété de formes et de tailles dont le nombre est pratiquement illimité et se plier ainsi aux différentes coutumes et traditions. Le comité est d'avis qu'un programme-pilote concerté de recherche et de développement pourrait engendrer dans la majorité des pays en voie de développement la production de matériaux mixtes convenant à des systèmes de couverture bon marché.

La plus grande difficulté à surmonter sera la mise au point de matériaux mixtes peu onéreux et qui résistent à l'action destructrice de l'humidité, des rayons ultraviolets, des insectes et des moisissures. Il faudra mettre particulièrement l'accent sur l'identification des dangers qui sont inhérents à l'emploi de produits contenant des matières plastiques. Par exemple, si la cuisine est faite sur des foyers à flamme nue, certains éléments de couverture pourraient se trouver enflammés par des étincelles et produire ainsi des fumées délétères

ou des gaz toxiques. A l'aide de techniques simples on peut traiter les polymères pour qu'ils aient une bonne tenue au feu. Mais, jusqu'à présent les applications de ces polymères traités ont été plutôt onéreuses.

Si des substances d'une bonne tenue peuvent être mises au point à un prix raisonnable, on pourra probablement transmettre sans difficulté leurs procédés de fabrication et leurs applications à tous les pays en voie de développement. La simplicité de la fabrication de matériaux de couverture à base de résines synthétiques permettrait une diffusion rapide des techniques et une commercialisation facile par les petites entreprises. Les produits finis de construction pourraient faire face à la concurrence de la tôle ondulée ou être d'un prix plus avantageux. Ces matériaux pourraient etre utilisés également dans d'autres domaines que la couverture des toits.

Le prix de revient de matériaux mixtes pour toitures pourrait être très bas. Le système serait très souple et pourrait s'adapter à une production utilisant une main-d'oeuvre importante.

Les résines et les polymères sont stables à l'état brut et peuvent ainsi être stockés pendant un certain temps, mais, pour garder leurs propriétés, ils doivent etre entreposés dans un endroit frais et à l'abri de la lumière. Du fait qu'ils se présentent à l'état concentré ils sont peu encombrants pour l'expédition et l'emmagasinage. Leur valeur intrinsèque est relativement faible tant qu'ils ne sont pas transformés en matériaux de construction. Si on ne trouve pas ces résines et ces polymères dans les pays en voie de développement, ils devront être importés. Même dans ce cas ils ne représenteront qu'une faible partie du coût total de la toiture. Pour l'importation en gros de ces résines et polymères, il n'y a pas de problème particulier de distribution—les stocks sont importants et il existe un grand nombre de fabricants. La manutention, l'emmagasinage et le transport à l'arrivée ne présentent pas de difficulté.

Les efforts de recherche sur place de ce type d'application doit comprendre une analyse couts-bénéfices des résines importées par rapport à un produit de remplacement importé tel que la tôle ondulée.

3. FAÇONNAGE DES MOUSSES DE PLASTIQUE

On devrait mettre en place un projet-pilote pour le façonnage de mousses plastiques qui puissent servir de matériaux de couverture et à cet effet mettre au point des appareils mobiles relativement petits que les pays en voie de développement soient à même de produire économiquement.

Les mousses plastiques—substances cellulaires légères produites par l'introduction de bulles de gaz dans les composants plastiques au cours de la fabrication—offrent un potentiel important en tant que matériaux souples et légers de toitures, tout en possédant une haute valeur isolante. Ces matériaux peuvent être fabriqués sur place dans une grande variété de formes et de tailles (voir annexe B). A ce jour, l'emploi des mousses plastiques a été sérieusement limité parce qu'il n'existait pas d'équipement de fabrication des mousses, simple, fiable et peu onéreux, qui soit capable de donner un produit uniforme de haute qualité.

L'équipement habituel de façonnage des mousses plastiques produit la mousse chimiquement et ensuite projette la masse écumeuse de fines bulles à l'endroit voulu. Autrefois, l'équipement de démonstration qui était utilisé sur place dans les pays en voie de développement, était complexe et fragile et exigeait un coûteux entretien. Néanmoins, les progrès récents apportés à la conception de l'équipement ont permis d'éliminer la plupart des problèmes auxquels on se heurtait auparavant. Il semblerait donc que le moment est venu de mettre à profit ces améliorations pour créer de petits appareils de façonnage de la mousse qui pourraient être fabriqués en série par les pays en voie de développement. De tels appareils, associés à une démonstration prouvant que les mousses plastiques peuvent être utilisées en combinaison avec des substances de renforcement et des enduits d'origine locale comme matériaux de couverture et de support, pourraient conduire à l'établissement profitable d'entreprises locales qui fabriqueraient non seulement l'équipement mais aussi divers produits en mousse de plastique.

Le projet-pilote recommandé devrait être organisé seulement à titre d'expérience pour permettre d'évaluer et de documenter le rendement de l'équipement, aussi bien que l'aspect économique, l'acceptation par les consommateurs, l'emploi et la durée des toitures prototypes ainsi réalisées. Le projet pourrait bien être conduit en coopération par entreprises américaines et celles des pays en voie de développement, et aussi avec la participation de centres de recherche, d'organismes professionnels orientés vers les matériaux de construction, d'organisations commerciales et avec le concours technique d'organismes s'occupant du logement.

Il est à noter que la U.S. Federal Trade Commission á récemment mis en garde les consommateurs sur le fait que les mousses de polyuréthane et de polystyrène, quand elles sont exposées au feu, peuvent offrir des risques pour leur vie ou leur santé dans certaines de leurs applications pour le logement. Ce fait est parfaitement connu des technocrates du bâtiment. Cependant, on dispose maintenant de mousses à faible production de fumée et ne permettant pas la propagation des flammes. Il est vraisemblable que de nouveaux progrès seront encore faits dans un proche avenir. Toutefois, les chercheurs qui mettent au point des plastiques moulés pour les éléments de toiture dans les pays en voie de développement, devraient être informés des dangers possibles d'incendie et tenus au courant des progrès techniques réalisés dans ce domaine.

4. SOUFRE

On devrait porter une attention particulière aux possibilités offertes par le soufre en tant qu'élément entrant dans la composition des liants pour d'autres matériaux d'origine locale, en tant qu'enduit et substance d'injection des joints et en tant que matériau à partir duquel on peut fabriquer des éléments de toiture de petite taille : les tuiles, par exemple.

Bien qu'on n'ait pas beaucoup utilisé le soufre comme matériau de construction, on devrait étudier l'étendue de ses possibilités comme liant dans les couvertures à bon marché dans les pays en voie de développement

(voir annexe C). C'est seulement au cours de la dernière décennie que l'emploi de ce matériau dans la construction a fait l'objet de recherches scientifiques approfondies. Son utilisation dans les pays en voie de développement devrait être particulièrement étudiée du fait que beaucoup de ces pays disposent de soufre en quantités importantes, soit qu'il provienne d'une activité volcanique ou du raffinage du pétrole. Le soufre peut également représenter un article d'importation peu onéreux pour les pays dont il n'est pas une ressource nationale.

Les recherches et les essais déjà faits dans ce domaine étaient principalement dirigés vers l'utilisation du soufre dans le béton—béton au soufre—et comme liant superficiel. Le soufre élément est un liant aux propriétés exceptionnelles. Il fond à 115 °C, quelques degrés à peine au dessus du point d'ébulition de l'eau. Etant insoluble à l'eau, il est ainsi imperméable à ce liquide. En emploi courant il n'a pas d'odeur et n'est pas toxique. Il est mauvais conducteur de la chaleur. Enfin, il peut être conservé indéfiniment et peut être recyclé. Toutes ces qualités en font une matière première de choix pour la couverture des toits dans les pays en voie de développement. Le soufre élément se prête particulièrement bien aux méthodes de construction utilisant une importante main-d'oeuvre. Toutefois il a certains inconvénients. Il est hautement inflammable et doit être liquéfié avant qu'on puisse y ajouter les agrégats ou la masse de remplissage. Les producteurs et les consommateurs du produit doivent être mis en garde contre les émanations possibles d'acide sulfurique en présence d'humidité et sur les conséquences dangereuses que pourait entraîner son ingestion. Les avantages semblent contrebalancer les inconvénients, cependant il est indispensable actuellement qu'un effort soit fait dans la recherche et le développement.

5. MATÉRIAUX VÉGÉTAUX CARBONISÉS

Il faudrait mettre sur pied un programme de recherche en laboratoire et d'essais pratiques sur la possibilité de transformer en plaques légères et bon marché des produits végétaux non-alimentaires et à haute teneur en amidon, carbonisés et expansés, qui ont été combinés avec des résines polyester non-saturées et les polymères connexes et qui pourraient servir pour les toitures (voir annexe G). La recherche devrait inclure des études sur place qui permettraient d'identifier le type, la quantité et l'existence dans les pays en voie de développement de produits végétaux qui pourraient servir à cet effet.

6. DÉCHETS AGRICOLES ET FORRESTIERS

On devrait établir un programme de recherche intensive sur les procédés de frabrication des résines destinées à être employées principalement comme liants à partir de produits agricoles locaux (végétaux, bagasse).

Comme on l'a noté dans l'annexe G[1], la lignine et le furfural des végétaux peuvent être utilisés sur place comme liants avec application de chaleur et en exerçant une certaine pression. Cette technique est bien connue des nations industrialisées. Il est probable que des méthodes simplifiées de fabrication permettraient aux pays en voie de développement de produire en grande quantité des panneaux de construction donnant toute satisfaction.

7. DÉCHETS DES INDUSTRIES DE BASE

Les déchets, tels que les escarbilles et le laitier de hauts-fourneaux provenant des aciéries, ont des propriétés qui leur donnent la possibilité d'être utilisés comme liants (voir annexe E). Ces déchets devraient être étudiés et ils pourraient présenter un intérêt particulier dans les pays qui ne disposent pas de ressources en calcaire et en ciment portland. Un sous-produit du raffinage de la bauxite, la boue rouge, qui est surabondante dans de nombreux pays en voie de développement, mérite également une sérieuse attention, au même titre que les déchets métalliques venant de la fabrication du fer et de l'acier. La disposition de ces déchets et d'autres résidus similaires pose un problème toujours grandissant pour l'industrie lourde du monde entier. Un double but serait atteint si on pouvait les transformer en produits utilisables. En fait, leur utilisation possible pourrait présenter un tel avantage pour les industries concernées qu'elles seraient incitées à fournir des fonds ou des matériaux pour la recherche dans ce domaine.

8. BÉTON

Un programme d'essais analytiques et en laboratoire devrait être mis sur pied pour la mise au point de produits en béton armé plus appropriés et plus économiques (voir annexe H sur le ciment armé). L'effort de recherche devrait être axé sur l'emploi de matériaux d'armature tels que le treillis métallique, la fibre de verre, la laine minérale et divers produits végétaux comme le bambou[2], l'écorce et la fibre de bois—le béton à la fibre de bois est connu sous le nom de "laine de bois" dans certaines parties du monde.[3] Une attention particulière doit aussi être apportée aux substituts du ciment portland dont certains sont énumérés à l'annexe E.

9. MATÉRIAUX À BASE D'ARGILE

On devrait établir un programme de recherche sur les méthodes destinées à améliorer le rendement et le champ d'application des matériaux pour toitures à base d'argile. (Voir annexe I.)

10. FIBRES

L'industrie textile et les autres industries apparentées utilisent des matières premières telles que le jute, le sisal, le chanvre et le coton qu'on trouve communément dans les pays en voie de développement. Il serait donc intéressant de rechercher si les déchets provenant de ces industries peuvent être utilisés en mélange dans un matériau mixte pour des éléments de toiture et quelle en serait l'efficacité.

En conclusion, le comité consultatif est d'avis qu'il existe de nombreuses voies à explorer et qu'il faudrait les mettre à profit dans les circonstances présentes.

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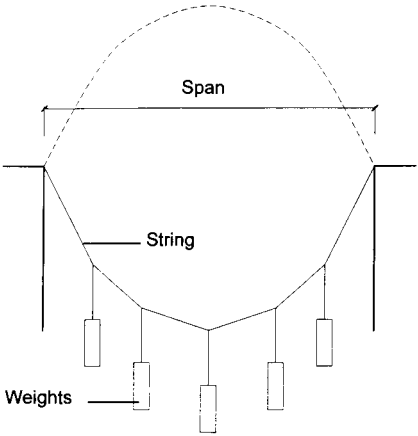

Fig. 1.60 Diagram showing a weighted string describing a catenary curve which, if rotated through 180 degrees, is an appropriate form for a vault of the same span and weight.

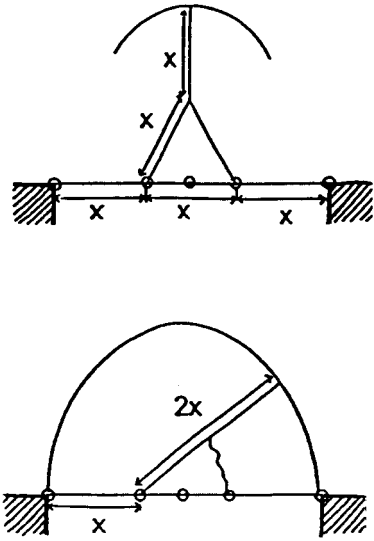

Fig. 1.62 Diagram showing the use of a Y-shaped string to mark out a catenary curve.

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Domestic Roofwater Harvesting
Research Programme

RECOMMENDATIONS FOR DESIGNING RAINWATER HARVESTING SYSTEM TANKS

O-DEV Contract No. ERB IC18 CT98 027
Milestone A6: Report A4

January 2001

Development Technology Unit
School of Engineering, University of Warwick

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1. INTRODUCTION

The water store (the 'tank') accounts for a large fraction of the cost of any roofwater harvesting system. Most poor households cannot afford to buy as large a tank as their roof catchment area might justify. There is therefore a strong incentive to seek cheaper yet adequate forms of tank.

The cost of a tank depends upon its size, the type and quantity of materials used in its construction, the labour needed to build it and in some areas the 'hire' of special equipment. The tank itself might be regarded as having two main parts; a water store and a set of ancillaries to lead water into and out of it (taps, an overflow, a filter, a level indicator etc.). In this paper, we restrict ourselves to considering just the water store.

Rainwater collection is in no way a new technology and is described in many publications (Gould & Nissen-Petersen, 1999; Lee & Visscher, 1992; Pacey & Cullis, 1996)In the last decade, there have been many attempts to identify better tank designs. Therefore this report starts with an analysis of needs and constraints and follows with an analysis of good existing designs. Lastly comes a description of our own work towards making tanks cheaper.

2 TANK REQUIREMENTS & CONSTRAINTS

2.1 Needs and specification

Tanks need to be watertight although some leakage (such as <5% of daily abstraction) might be tolerable if it does not weaken the structure or cause puddles. They also need to hold the required volume and to be adequately durable (say 25 years before they become unserviceable). Beyond these basic requirements we can list many further specific requirements. Tanks should:

- have a means of being charged with water without unduly disturbing tank-bottom sediments and if possible maintaining stratified flow (the bacterial quality of outlet water is maximised if the flow through the tank resembles 'pipe flow', namely 'last in is last out'
- be able to handle excess input by overflowing in a convenient and safe manner - preferably without leading water unnecessarily via the tank (such water may drop unwanted sediment in the tank)
- have a means by which the water can be extracted which is convenient for the user and which does not pollute the water left behind (as dipped buckets may)
- exclude vermin and as far as possible mosquitoes
- exclude light (so that algae do not grow and larval growth is inhibited)
- have some form of ventilation, especially if there is not an efficient filter to prevent organic material from entering the tank and decaying there
- be easy to access for cleaning (where cleaning is needed) and be unlikely to be damaged during cleaning
- have a sufficient structural safety factor to withstand wear and tear, some impacts and occasional large natural forces caused by winds and (in places) earthquakes

- not present hazards to passers-by or small children and (in some societies) offer some protection against deliberate poisoning
- not give the water a bad taste

2.2 Local constraints

There are often also local constraints upon the construction process, such as:

- absence or excessive expense of particular materials (e.g. cement, sharp clean sand)
- constraints upon the plan-area space, height or depth of a tank
- tank location; some designs are easier to locate than others

3 ROUTES TO CHEAPER TANKS

3.1 Changing To cheaper materials

Surface tanks for roofwater storage are commonly made of brick, ferrocement, concrete blocks, plastics and galvanised iron. Some of these materials are themselves variable in make-up (the cement or steel fraction within ferrocement can be varied) and all can be varied in thickness, as is discussed in the next section. Requiring a material to be both strong and waterproof considerably constrains its choice, Once however one accepts that waterproofing and structural strength can be separated and accommodated by different materials – a number of new materials options appear.

Bricks

Burned bricks are often made locally and are available much more cheaply than materials which have to be imported into an area such as plastics or cement. Tanks made from bricks can therefore be cheaper than those of "imported" materials and will also keep more of the money spent on the tank within the community. The challenge when building such tanks is to absorb the tensile stresses typical of water tank with a structure best suited to compressive forces. The Rainwater Harvesting Research Group has experimented with a number of alternatives such as external reinforcing and shaped bricks. This work is detailed in Section 7.

Stabilised soil

Another "earth technology" is to use a small amount of cement to hold together (stabilise) an otherwise soil based block. This technique can dramatically reduce the quantity of cement needed to make a tank of equivalent strength. The wet strength of stabilised soil is considerably lower than cement so the designer must either balance the cement content to ensure the wet strength is sufficient or employ some waterproof barrier to prevent water soaking into the blocks.

Rammed earth

Ramming earth between to walls ("shutters") compacting it, gives the wall a stiffness that simple soil building does not have. The technique uses only local materials and can be achieved without particularly specialised labour, it does however require some specialised tooling such as the shutters and a tamper to ram the earth into place but these can be made locally and used to make several tanks

spreading their cost. The tank wall, however, is not waterproof with this technique so a means of waterproofing the inside surface must be employed.

Wattle and daub

A traditional technique for house building in many marts of the world, wattle and daub used mud to fill in a structure made from collected roundwood. The technique is well known and practised at a village level and requires no specialised tooling or knowledge to implement. All materials are available locally and usually need only be collected, thus the only capital requirement is labour making it extremely suitable for “self help” projects.

Like all “raw” earth technologies, the technique, results in a structure that is not waterproof and so a method of holding the water must be employed. One excellent example of this is the Rwandan “tarpaulin tank” which utilises an UNHCR tarpaulin in an excavation to hold the water with a wattle and daub enclosure. This tank is further described in Section 6.

Plastics sheeting

Plastic sheeting is becoming available in many parts of the world and can be used for lining otherwise permeable tanks to render them waterproof. At a basic level this could be simple polythene sheet but this tends to have a short lifespan. There are also several fibre reinforced plastic sheets such as those used for tarpaulins becoming available in centres and also in areas of specialised demand. At present it is unlikely that these materials will shortly become widely available due to a lack of demand but appropriate promotion/dissemination could change this situation.

Waterproof coatings

Waterproof paints are quite common in the developed world where they are used to seal ponds, swimming pools etc. these paints are available in some LDC centres and local variants may be developed. Quality control will become a major issue for these to be used as any uncoated sections could result in dangerous catastrophic failure of the tank.

3.2 Minimising the volume of materials used

A second method of cost reduction is by reducing material quantities. In general we can save materials by four approaches, namely:

- removing material where it is not needed
- reducing overall material use by reducing safety factors if they are unnecessarily high
- making use of some existing structure (e.g. the wall of a house or the ground itself)
- adopting a more efficient shape whereby overall tank wall thickness can be reduced

Removing material

The first of these approaches is sometimes prevented by practicalities. Wall thickness is often dictated not by strength but by buildability. For example the upper part of the walls of a cylindrical tank are subject to lower pressure than the bottom and so theoretically could be thinner. Unfortunately it is impractical to taper bricks or even ferrocement as one builds up the wall. the. It is, however possible to go some way toward this ideal.

- If coiled wire reinforcing is used, the spacing can be varied from close-spaced at the bottom of a wall to wide-spaced near the top.
- Materials can be concentrated so that extra strength is provided only where actually needed; for example cement content of ferrocement or stabilised soil blocks can be varied with height above the base (using least at the top).
- Material thickness can sometimes be reduced step-wise by, for example using a double run of bricks at the bottom and reducing to a single run further up the tank.

Material savings should be balanced against the extra complexity of manufacture. All of these techniques have quality control implications and should be used only when workers are familiar with the techniques or are well supervised.

Reducing safety factors

The stresses in water tanks can be calculated and then the expected stress compared to measurable properties such as maximum tensile strength, compressive strength, change of shape under load, etc. So long as the expected stress is lower than the chosen maximum material stress (usually the tensile yield stress in the case of tanks), then the structure will not fail. In practical problems, the expected stress is multiplied by a safety factor (F_S) for a number of reasons.

- The local load may be larger than we realised (indeed our method of calculation may itself contain serious inaccuracies)
- The material may be weaker than it should have been or some of the original strength may have been lost through wear and tear
- The material will almost certainly not be homogeneous, that is it will be stronger in some places than others (this is especially true of building materials)

A safety factor of 5 is typical for a water tank made of building materials. If the safety factor is very large (say $F_S = 15$) then material is being wasted and savings can be made.

Few practitioners of DRWH in developing countries include a well-considered safety factor in tank design calculations. The safety factor is usually applied to tanks in one of two ways:

- by arbitrary application during design, usually leading to excessive wall thickness as the engineer errs on the side of caution
- by trial and error leading to many trials and many errors

Arbitrary application can be expensive in terms of materials, while trial and error is expensive in terms of broken tanks (and even downright dangerous if field trials use consumer tanks).

Defining a sensible safety factor can be difficult given the extreme variations in quality of materials and workmanship in developing countries. The normal engineering approach to safety factor application is to use standard engineering materials (of more or less known strength) and to look up the appropriate safety factor in an engineering data book or approved ‘code of practice’. The nature of tank construction in LDC’s is however such that ‘standard’ (well-quantified) civil engineering materials are rarely available. Sand and aggregates as found in the local village and cement itself is often of dubious quality. Reinforcement may be of poor quality and the strength of bricks fired in a clamp kiln will vary from one to another. Safety factors will therefore vary depending on the type and variability of the material used and the level of skill available to build the tank.. Some suggested Factors of Safety are in Table 1

Table 1: Factors of Safety

Material	Skill level	Factor of safety
Ferrocement	High	2-3
	Medium	4-5
	Low	7-8
Burned Brick	High	3-5
	Medium	6-8
	Low	9-12
Galvanised Iron	High	1.2-1.4
	Medium	1.5-1.8
	Low	1.9-2.3

Architectural integration

The third approach, of saving costs by integrating a rainwater tank with a house structure, has been discussed from time to time but rarely found to yield decisive economies. For space or aesthetic reasons, tanks have often been located within a house's structure (especially where the house is multi-storey) but it is hard to show that any significant material saving has been so obtained. A shallow tank with a large area may substitute for part of a roof, however the requirement that the tank's top be *lower* than the bulk of the roof from which it is supplied restricts this substitution to say veranda roofing or between stories of a multi-story dwelling. The volume of the tank is also limited by the structural integrity of the roof supports as $1m^2$ of water weighs in at one tonne!

Conversely a very tall tank might substitute for walling. This has been proposed by ??? for Australian houses (ref?) but the architectural detail of moving from normal to tank walling and back again is complex and the long, flat wall will be subject to large bending stresses. Moreover a deep, thin tank has a poor ratio of volume to wall area and may also be difficult to clean. A tank could be made as a core round which a house could be built, in the same way as some traditional village houses in India were built around grain stores. All in-house tanks, however have the problem of ensuring that tank overflow will never inundate the house – as often happens with roofs having 'internal' gullies. Any leakage from these tanks will also enter the house.

Finally tanks can be built into the basements of houses saving space and integrating the tank and house foundations. Laurie Baker has used this technique extensively in his design of The Centre for Development Studies in Karalla India albeit for non-drinking water purposes. If this strategy is to be used, account must be taken of the fact that even ground floor floors will have to be suspended and water will need to be pumped from the storage.

Optimal tank shape

Since the shape of a tank affects both the volume-to-surface ratio and the distribution of forces, it is worth examining the effect of tank shape upon material requirement. As always these material savings must be balanced against the additional complexity in manufacture, straight sides are much easier to form than curves and can be produced with a larger selection of materials. Table 2 shows a summary of tank shape from the viewpoint of induced stress, material use and construction. Three common tank shapes are considered: the cuboid, the cylinder and the doubly curved 'Thai' water jar shape.

Table 2: Relative merits of some common tank shapes

Tank shape or type		Stresses	Material usage	Construction
Cuboid	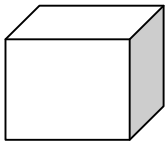	Stresses are unevenly distributed around the structure. Bending stresses are especially high near the edges.	The ratio between material usage and storage capacity is higher than for a cylindrical or doubly curved tank.	Construction is quite simple using most materials
Cylindrical	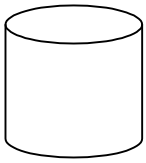	Stresses are more evenly distributed with bending stresses only near the bottom	There is an improvement in the material use to storage capacity ratio (a saving of 7.5% over a similarly proportioned cuboid)	Construction becomes more difficult with some materials e.g. bricks, but the shape is well suited to construction with materials that can be bent e.g. ferrocement and GI sheeting or built in sections
Doubly curved tanks (e.g. Thai Jar)	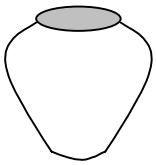	Stresses are well distributed. The base of the tank is of smaller diameter, reducing both hoop stresses and bending stresses there.	Material usage to capacity ratio is very good (savings of up to 20% over a cuboid)	Construction can be difficult, often relying on specialised moulds. Materials must be pliable and able to curve in two directions e.g. ferrocement and clay

The table shows that the cuboid shape fares relatively badly in terms of material use versus storage capacity and it is also associated with high peak stresses. The cylindrical shape deals quite well with stresses in comparison, and it has a lower (better) ratio of walling material to storage volume. It is still easy to manufacture, a technique well suited to circular or irregular forms. The 'Thai' style tank has the ideal shape to cope with the main induced stresses but requires greater skill and tooling to make.

Underground tanks

Significant material savings can be made if the tank is built underground. If the soil is suitable it can take the weight of the water and the walls can be made considerably thinner as they will simply be used as a waterproof layer stopping the water seeping into the soil. The geometry can also be very efficient (hemispherical) as the ground will act as a former for construction and the tank needn't stand up on its base like an above ground tank. This material advantage should be balanced against the additional cost of digging a hole (which can be significant if the ground is particularly hard) and the possibility of the tank becoming contaminated by leaks or a rising water table floating the tank out of the ground.

3.3 Minimising labour and equipment costs

Generally labour costs rise as equipment costs are reduced and *vice versa*, so one should seek to get the best balance. What that balance is clearly depends upon location. In rural Africa digging deep pits by hand is cheapest, in urban Asia it would often be possible and cheaper to hire a back-hoe for the

job. Similarly the transport of 'centrally' produced tanks or jars by motor vehicle might incur only modest costs in an urban area but quite excessive ones in a hilly rural area with few roads.

Employing moulds to build tanks improves their accuracy (and thereby may save materials) and also saves labour by reducing 'setting out' times. Moulds themselves become cheaper (per tank) if they are durable and can be used many times. Recycling moulds however requires suitable organisation – such as their attachment to a multi-system programme or availability for hire – and easy transportability.

In many cases, organisations assisting the construction of RWH systems have as their major objective the creation of income-earning opportunities in a specific locality. In consequence they seek to minimise the capital requirement associated with use of complex or motorised equipment, and to maximise the labour fraction of total costs. This approach may or may not minimise overall RWH tank costs.

3.4 Appropriate sizing

One of the simplest ways to make a tank cheaper is simply to make it smaller. Figure 1 shows the water demand satisfied by a tank compared to its size. As can be seen economics of tanks are such that the benefit of a tank is not strictly proportional to its size. The reason for this is that a smaller tank will be filled and emptied (cycled) often whereas a larger tank will only be cycled rarely. A fuller discussion of this is found in section 5

Figure 1: Benefits of tank sizing

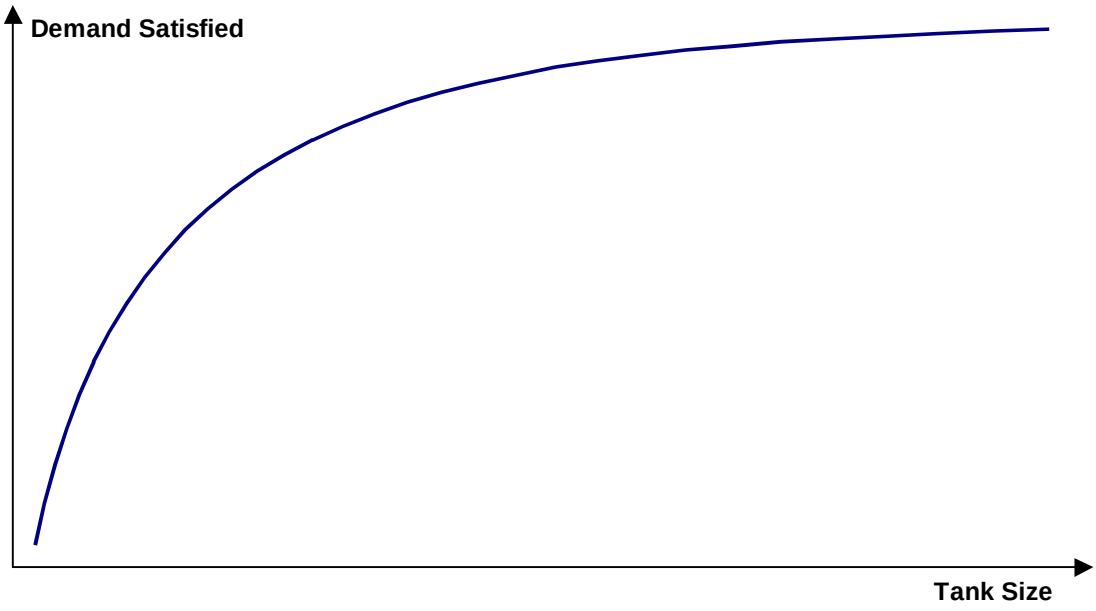

Thus, while a large tank may be beyond the affordability of a household, a smaller tank will usually provide significant time-savings, particularly during the rainy season when footing can be wet and slippery. Another tank may also be added later and the total system capacity grown this way. This modular approach has can be seen in many parts of Southeast Asia.

3.5 Mass production

Tanks (particularly smaller tanks) benefit from the economies of scale that come with mass-production. In Thailand, a country that has undergone a massive rainwater harvesting promotion

programme, 400 litre jars are produced for less than $US5. Another possibility is the mass production of some parts portion of a tank such a the lining and this way reducing the overall complexity of tank construction and allowing local materials and skills to fill in the balance.

4 STRUCTURAL STRENGTH & STRUCTURAL FAILURE OF TANKS

In a famous case over 150 years ago, the engineer Stephenson (who had no means of analysing structures) designed an early railway bridge by a careful series of experiments on a scale model. He built the model rather weak then loaded it until it collapsed. He then strengthened the part that broke first and repeated the procedure several times. By the end of the process the bridge had increased in weight by 50% but was 6 times stronger. We might use this technique to develop more materials-efficient tanks. Unfortunately the process would be long, expensive and perhaps unreliable (since testing long-term durability is harder for tanks than for steel bridges). Moreover today we have a much better (although incomplete) understanding of theory behind the structure of a tank.

4.1 Failure modes

There are number of possible modes of structural failure for a water jar or cistern, of which the most common are:

- Cracking and leaking (which may be temporarily repairable but often later progresses to failure)
- Leaning over, due to inadequate foundations
- Bursting (which can be dangerous, with fragments flying some distance)

It is a normal pattern that when a product like a RWH tank is first introduced to a new location a very ‘conservative’ design is used. It is in consequence expensive and may need subsidy. It should be the aim of any such programme to use the period of subsidy to simplify or cheapen the product by some degree of trial and error. Unfortunately failures resulting from a practical search for the design limits are embarrassing and can lead to mistrust of the product. For this reason it is prudent to perform such experiments in private (‘behind a hedge’) at least until the probability of failure appears low. Moreover the design should be chosen to exhibit functional failure such as leaking before any dangerous failure such as bursting.

4.2 Stresses due to the stored water

Pressure forces

Water exerts a pressure proportional to its depth equivalent to 10 kPa. Per meter. The pressure always applies a force perpendicular to the inside surface of the tank, so at the bottom it acts downwards, over most of the walls it acts outwards and near the top of a doubly curved tank it can even act upwards (see Figure 2)

Figure 2: Action of pressure in a water tank

a. Straight sided

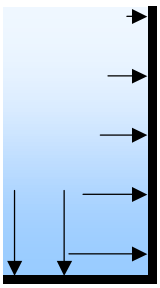

b. Doubly curved

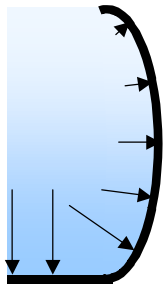

Generally this pressure puts the tank walls into tension (stretch). This is unfortunate because many materials traditionally used for building and transferred to tank construction are only 10% or 20% as strong in tension as they are in compression.

Stresses in cylindrical tanks

In the case of a simple cylinder, the tensile stress acts around the cylinder and is called “hoop stress”. This stress can be found using the equation:

$$\sigma_h = \frac{p\,r}{t} \tag{1}$$

Where:

σ_h is the hoop stress

p is the water pressure

r is the tank radius

t is the wall thickness

This simple result however is only true when the walls of the tank are free to move as shown in Figure 3a. The movement is only very small and can be achieved by using a flexible material between floor and wall such as bitumen or by allowing the wall to slide along the floor. Where the walls are fixed, such as at the base of a tank, they will tend to bow out as shown in Figure 3b

Figure 3: Movement of tank walls due to pressure

a. Unconstrained

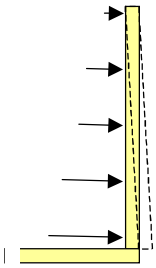

a. Constrained

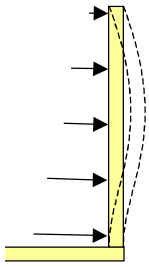

This will change the hoop stress and also cause two other stresses acting in different directions as are shown in Figure 4.

Figure 4: Stresses caused by constrained walls

a. Shear Stress

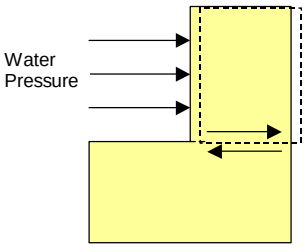

b. Bending stress

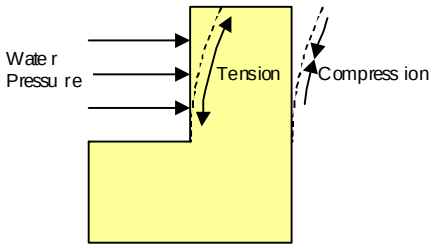

The wall will be stressed in shear at its edge where the water pressure forces it outwards but the base opposes this: the shear stress acts through the wall in a horizontal plane (Figure 4a). Another stress is due to bending of the tank walls as they bow outwards. This is especially high near the joint and will cause vertical compression of its outside face and tension on the inside face of a tank (Figure 4b) both acting vertically up the wall which can cause cracking of the inside face leading to failure.

Quantifying this situation is rather more complex and uses the technique of shell theory where the tank walls are idealised as being very thin (like egg shells). The theory also breaks the problem down into two parts. The first part considers the wall to be very flexible and therefore incapable of being stressed in bending or shear. The second part looks at the bending only and is confined to the boundaries between the wall and the floor where these forces are most prevalent. Furthermore the tank is considered to be made of a material whose properties are constant throughout and which will deform in direct proportion to the forces acting on it (Hooke's law). The relevant equations (Flugge, 1967) are:

$$N_\theta = \gamma r\left(h - x - he^{\frac{-\lambda x}{r}}\cos\frac{\lambda x}{r} + \left(\frac{r}{\lambda} - h\right)e^{\frac{-\lambda x}{r}}\sin\frac{\lambda x}{r}\right) \tag{2}$$

$$M_x = -\frac{\gamma r t}{\sqrt{12\left(1-v^2\right)}}\left(\left(\frac{r}{\lambda} - h\right)e^{\frac{-\lambda x}{r}}\cos\frac{\lambda x}{r} + he^{\frac{-\lambda x}{r}}\sin\frac{\lambda x}{r}\right) \tag{3}$$

$$Q_x = \frac{\gamma t \lambda}{\sqrt{12\left(1-v^2\right)}}\left(\left(\frac{r}{\lambda} - 2h\right)e^{\frac{-\lambda x}{r}}\cos\frac{\lambda x}{r} + \frac{r}{\lambda}e^{\frac{-\lambda x}{r}}\sin\frac{\lambda x}{r}\right) \tag{4}$$

where:

N_θ is the radial hoop force

M_x is the bending moment

Q_x is the shear force

γ is the specific weight of water (density times gravity)

r is the radius

h is the height water height

x is the height of the stress to be calculated

v is poisons ratio (the ratio of a materials change in shape in the direction of a stress to the change in shape perpendicular to the stress – as a rubber band is stretched it gets thinner)

λ is given by

$$\sqrt[4]{3\left(1-v^2\right)\left(\frac{r}{t}\right)^2} \qquad (5)$$

These fairly daunting equations can be easily coded into a spreadsheet and used to provide useful curves for designing tanks. Typical output is shown in Figure 5

Figure 5: Stress curves for cylindrical tank with fixed base

a. Hoop stress b. Bending stress c. Shear stress

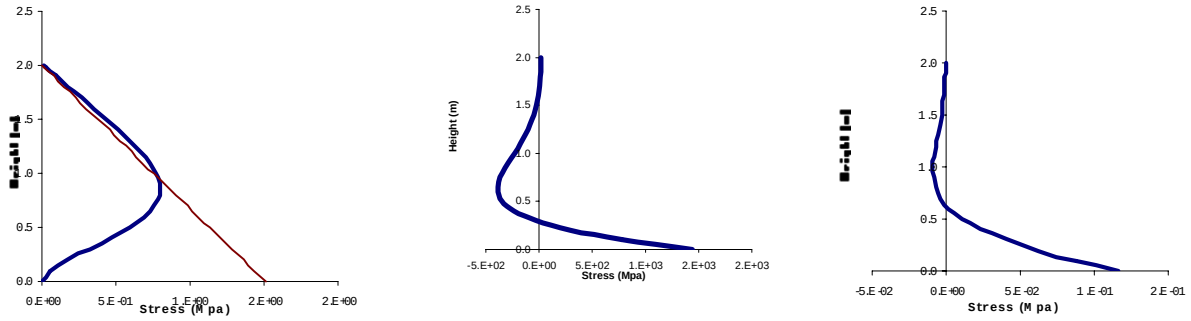

Design considerations

Design to resist tensile stresses, whether vertical due to bending, radial hoop stresses and shear stresses acting through the wall, obviously includes the use of adequate wall thickness and adequate material tensile strength. It is sometimes assumed that brick and concrete cannot carry *any* tensile stresses without failing, but this is not so. Although it may be prudent to include steel reinforcing in a tank wall to prevent dangerous bursting, it is uneconomic to include so much that the mortar or brick carries negligible tension. If one relied solely on the stiffness of the reinforcing, its movement under water-pressure would almost certainly result in cracking of the mortar or brick matrix, causing perhaps leakage and almost certainly rusting of the reinforcing. Reinforcement that passes from a base into the bottom of a tank's walls will help resist both shear and bending stresses. Extra wall thickness, or filleting at the joint between wall and base is also a useful strategy.

4.3 Stresses due to materials shrinkage

As well as the cyclic stresses due to the water rising and falling inside the tank, there are other stresses due to the material *shrinking* during construction. Cement mortar, concrete and stabilised soil all shrink slightly (about 1 part in 1000) as they cure or dry out. If mortar or other such material is restrained during curing - for example by a metal mould or by attachment to a base - there will be a struggle between the mortar trying to shrink and the constraint trying to stop it. In consequence large stresses can develop in the mortar causing it to crack. To reduce such shrinkage cracking, we could:

- Remove stiff constraints (e.g. putting lime mortar or a rubber strip between the wall bottom and the base plate or using flexible moulds);
- Reduce mortar shrinkage by using a very dry mortar mix or a low cement content: unfortunately the former makes the mix difficult to work and the latter reduces strength;
- In the case of soil, use a low clay content;
- Spread such cracks that form (so that there are many tiny cracks rather than one big one) by putting a metal or fibre mesh inside the mortar: this is particularly helpful in controlling leakage since splitting one wide crack into two narrow ones will reduce leakage flow about 4-fold;

- Choose a shape (e.g. a sphere) where there are no hard attachment constraints;
- Modify the material by the addition of a slightly expansive component that counteracts the normal shrinkage;
- In the case of a render applied only to achieve water-tightness, it is often possible to apply it in two layers and place a sealant such as cement-plus-water between the layers.

5 ECONOMICS OF TANK SIZING

5.1 Economic overview

All households already have some access to water from point sources. For some days per year, many also employ 'informal' rainwater harvesting, placing bowls and jugs under eaves or even trees during rainfall.

The introduction of more formal (and productive) RWH will normally be accompanied by three benefits. The most obvious is a reduction in the time spent carrying water from point sources – a reduction more or less proportional to the volume of water no longer carried. The second is an increase in household water consumption wherever it was previously constrained by the effort of collection. The third is a common, although not invariable, increase in water quality. All these benefits rise with DRWH storage capacity, albeit in a way showing diminishing returns.

The increase in water consumption with RWH has not been widely measured. Generally any increase is restricted to the wet seasons. DRWH is not generally capable in the dry seasons of supplying quantities larger than already obtained from point sources: this means that it will be used to supplement, but not to substitute point-source water.

The costs of DRWH are overwhelmingly capital costs, as neither operation nor maintenance usually involves significant expenditure. These capital costs are subject to economies of scale. The sensitivity (elasticity) of tank cost to storage capacity is about 0.6

5.2 Value of water

As with many other goods, water has a declining value with quantity. The first litre per day is worth more than the tenth. By examining the limited data available that relates household consumption per day to the effective unit cost of water (i.e. cost per litre), we might construct a curve such as shown in Figure 6. Each socio-economic group would have its own curve.

The cost line on 6 is horizontal, which reasonably represents the situation where water is fetched, each successive litre requiring the same input of labour. Such a line does not fairly represent harvested roofwater, where the effective cost general rises with daily consumption despite the economies of scale in tank construction. A typical cost v volume characteristic for RWH supply is shown in Figure 7.

Figure 6: value vs. quantity

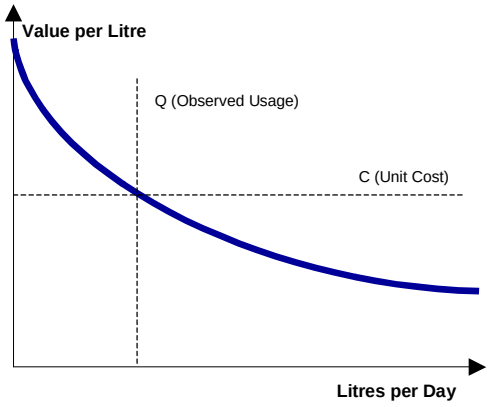

Figure 7: cost vs. volume

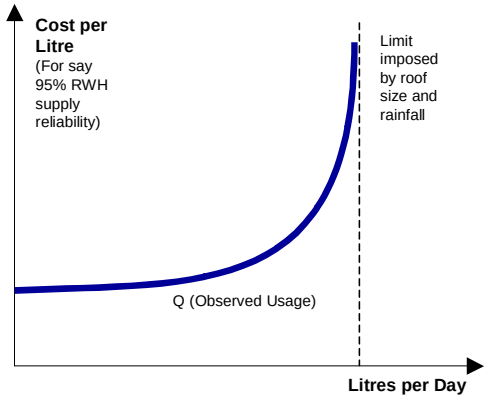

Sometimes we can find examples of water purchase and use them to infer the value of water. Richer households, or those experiencing illness, may pay for water to be brought to the house. More usually we have to infer costs indirectly through conversion of fetching distance/height into time and then time into money. Such costs, like the value of water discussed above, will be lower for poorer households than for richer ones.

5.3 Combining RWH with other water sources

For a given size and location of RWH system and for a given operating strategy, there will be a limit on the water it can supply per day, per week or per year. The maximum per year, corresponding to zero tank overflow, in litres will be the product of roof area (m^2), the annual rainfall (mm) and a run-off / capture factor (typically 0.85).

Consider first the situation where we can disregard seasonal factors, and assume that before RWH arrived, daily consumption from a point source was Q_P (litres/day). Q_P is determined by the interaction of the user's demand (cost v volume) curve and the unit cost C_P of supply from the point source. The daily cost to the user was therefore Q_P x C_P.

Figure 8: Value of rainwater

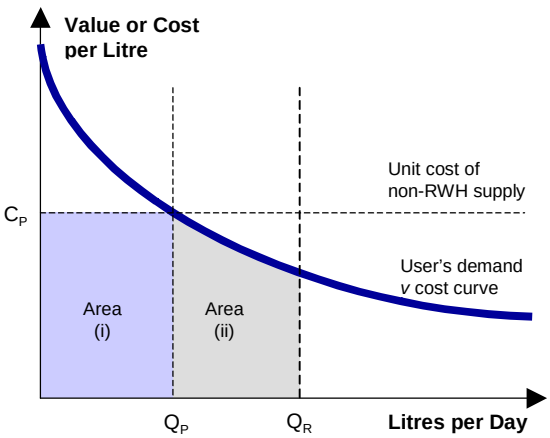

If the water Q_R available per day from RWH is *less* than Q_P, then the users will draw Q_R from the RW system and the remainder Q_P-Q_R from the point source. The total consumption will not increase and the effective value of the harvested rainwater will be the saving Q_R x C_P .

If the water Q_R available per day from RWH is *more* than Q_P, then the users will increase their consumption from Q_P to Q_R and the rainwater will be worth more than the former total cost Q_P x C_P. Exactly how much more will depend on the user's demand curve. The situation is represented in the diagram below, where Area (i) is the saving (Q_P x C_P) while Area (ii) is the value of the extra water.

Note that Q_R is the daily amount *available* from RWH, whereas Q_P is determined by the price of supply (from non-RWH sources). The total value Area(i) + Area(ii)) is less than (Q_R x C_P) because the extra water is per litre less valuable to the user than the water 'replaced'.

5.4 Seasonal effects and water management strategies

In the last section we ignored seasonal effects, although one can identify the condition $Q_R<Q_P$ as representing a dry season and $Q_R>Q_P$ as representing a wet one. However seasonality is central to the operation and performance of a RWH system. A user can choose to emphasise dry season security or alternatively to emphasise roofwater capture. To some extent the dry and wet season water needs are in competition with each other. Consider the following four water management strategies for an already built RWH system.

To make the strategies easier to visualise, assume a scenario typical of a homestead in the Great Lakes region where mean daily roofwater runoff is R = 100 litres). Assume that 'dry' weeks (runoff less than 350 litres per week) comprise 1/3 of each year and that the RW storage capacity is 700 litres (7 x R or '1 week'). This storage is only modest, but corresponds to perhaps 50 days drinking water or 14 days total water under very careful management.

Strategy 1 – *High Water Capture* – Water is withdrawn at a high rate, Q = 1.5 R, (e.g. 150 litres/day under our scenario) whenever it is available. This will result in fairly low occurrence of tank overflow, but leave little reserve for dry weeks.

Strategy 2 – *High Security* – Water is withdrawn at a low rate, Q = 0.5 R, (e.g. 50 litre/day) whenever it is available. Much water will overflow the tank, so annual capture will be low.

Strategy 3 – *Adaptive* – Water is withdrawn at a rate Q determined by how much is in the tank, thus:

Q = 1.5 R (e.g. at 150 lpd) if tank > 2/3 full;

Q = R if tank < 2/3 but >1/3 full;

Q = 0.5 R, if tank < 1/3 full.

Strategy 4 – *Maximum Security* – Water is saved for the dry seasons and drawn frugally (e.g. 50 litres/day) *only* after nearby point sources have run dry or after 2 weeks without rain.

The trade-offs involved between these alternatives are summarised in the following table, in which the word 'security' is taken to mean the fraction of days the demand is met by RW (the tank does not run dry). The factor K is the dry-season value of water (valued at its cost from the nearest point source) divided by its wet season value. Thus K=1 represents places where point-source water is unvarying through the year, whereas the extreme value K=10 represents places where in the dry months all local sources dry up, so water must be queued for, then carried from, very far away. A typical value of K in the humid tropics might be 2.

Table 3 suggests how we might account for seasonal differences in our economic evaluation, namely by assigning different wet and dry season values for water and operating the system to maximise their sum.

Table 3:System Performance under Different Operating Strategies

Strategy No	Annual consumption	Relative value of annual water harvested		Wet season security	Dry season security
		if K=1	if K=10		
1	high	high	med	high	v. low
2	low	med	med	high	low
3	medium	low	v. low	high	low
4	very low	med	med	nil	med

Table 4 represent the simulation of the four strategies applied to respectively a small DRWH system (storage volume V = 7 x mean daily run-off, R), a medium size system (V/R = 21) and a large system (V/R = 63). Daily rainfall data for 10 years has been used and a roof area of 45 m^2 has been selected to give the assumed mean run-off R = 100 litres/day. For Mbarara, the town used, the dry season (defined by rain in the last fortnight being under 50% of mean fortnightly rainfall) is 36% of the year.

Table 4: Relating RWH system performance to operating strategy and storage volume

Strategy number / type	V/R	Capture Efficiency	Tank Utilisation	Mean daily consumption Q in litres		'Security' (*S*) = fraction of days demand is satisfied by roofwater		
	tank size days	*E*	*U*	Q_1 *K*=1	Q_5 *K*=5	S_w Wet	S_d Dry	All year
Small tank,								
1 High demand High capture	7	**0.70**[1]	36.5	70	**95**	0.75	**0.22**	0.56
2 Low demand High security	7	**0.41**[3]	21.4	41	**80**	na	**na**	na
3 Adaptive	7	**0.66**[2]	34.4	66	**93**	0.94	**0.38**	0.74
4 Max security in dry seas	7	**0.17**[4]	8.9	17	**84**	na	**0.52**	na
Medium size tank								
1	21	**0.91**	15.8	91	**125**	0.90	**0.25**	0.67
2	21	**0.47**	8.2	47	**107**	na	**na**	na
3	21	**0.86**	14.9	86	**138**	1.00	**0.66**	0.88
4	21	**0.26**	4.5	26	**128**	na	**0.73**	na
Large tank								
1	63	**1.00**[1=]	5.8	100	**165**	0.92	**0.38**	0.72
2	63	**0.51**[3]	3.0	51	**123**	na	**na**	na
3	63	**0.99**[1=]	5.7	99	**203**	1.00	**0.98**	0.99
4	63	**0.37**[4]	2.1	37	**182**	na	**1.00**	na

Notes:
1. Data is for Mbarara, Uganda
2. Annual run-off = annual demand
3. na indicates strategy does not allow demand to be met.
4. Highlighted cells indicate best strategy or within 3% of best
5. Strategy 1 gives best $\mathbf{Q_1}$ (highest water capture)
6. Strategy 3 gives best $\mathbf{Q_5}$ (highest benefit if K = 5)
7. Strategy 4 gives best $\mathbf{S_d}$ (highest dry season security)
8. Strategy 3 is always best or second best by all measures.

‘Value’ is calculated assuming first litre per day is worth 1.5 falling via 0.5 at the 100th litre to zero at the 150th litre

Strategy 1 is to withdraw 1.5 times base demand when available (and otherwise what is available)

Strategy 2 is to withdraw 0.5 times base demand when available (and otherwise what is available)

Strategy 3 is to withdraw 1.5, 1 or 0.5 times base demand, according to amount in tank

Strategy 4 is to withdraw nothing in wet season and in dry season base demand when available (and otherwise what is available).As well as water supplied (column 5), a ‘weighted’ water supplied column is shown alongside in which effectively K = 5. This yields the weighting (a ‘wet season litre’ is a cost-equivalent volume): 1.0 dry season litre is deemed to be worth 5.0 ‘wet season litres’

The **bold** columns in the table contain the performance measures of most interest.

Column 3 shows ‘Capture efficiency’, (*E*) – a high value indicates that most of the roof run-off is being consumed.

Column 8 shows ‘Dry season water security’, (S_d) – the fraction of dry season that tank does not run dry and so demand has been satisfied; note however that under Strategy 1 the dry season demand is maintained very high at 1.5 *R*, whereas the other strategies are using demand of only 0.5 *R* for the dry season.

Column 6 shows weighted annual water consumption, Q_5, which is a measure that attempts to combine quantity, and security measures, by valuing wet season water much more highly than dry season water.

Examination of the top part of the table – which is for a small system with V/R only equal to 7 days – indicates that Strategy 1 (in which water is drawn generously whenever available) gives the highest annual water yield E, the lowest level of dry season security S_d, yet a high value for the seasonally-weighted yield W_e .

By contrast Strategy 4 (water is drawn sparingly and only in the dry season) gives the highest dry season security at the cost of the lowest annual yield. The seasonally-weighted yield is however also low. In fact we can dismiss Strategy 4 because even here, where per litre we have valued dry season water at *five times* wet season water, it still gives the lowest output valuation.

Strategies 2 and 3 are intermediate in performance, with Strategy 3 (adaptable) generally outperforming Strategy 2 (fixed low-demand).

From this table we can conclude that unless dry season water has exceptional value – e.g. it is per litre worth more than the 5 times wet season water assumed in the table – Strategies 1 (high usage) and 3 (adaptive) are superior to the other strategies.

The bottom band of the table is for a much more expensive system with 9 times larger storage. With such a large tank, the relative superiority of Strategy 3 is increased. We also see the benefit of the larger store. Comparing say Strategy 3 for the very large tank with that for the small one, we find a 50% increase in water harvested (E), a nearly 4-fold increase in dry season security (S_d) and under the assumed value ratio (K=5) a 120% increase in water value. Table 5 shows the variation in value of water harvested for varying values of K and for various sizes of tank. It confirms that small systems (V/R < 10 days) give a generally acceptable performance unless dry season water is deemed very much more valuable (e.g. K=5) than dry season water. Note the clear ‘diminishing returns’ with

increase in tank size. If water value had been plotted against tank *cost* rather than tank *size*, the same pattern of diminishing returns would appear but with a slightly reduced strength.

A small system in the humid tropics, attached to a 50m^2 roof, might be expected to harvest around 25,000 litres of water per year (say 75% of run-off), averaging about 90 litres per day in the wettest 8 months and 30 litres per day in the driest 4 months.

Table 5: Performance under Strategy 3 – Table showing variation of value ratio, capture efficiency and security with tank size

	dry:wet value per litre	Normalised tank size – V/R in days								
		1	3	5	7	14	21	30	60	90
Benefit ratio = value of water harvested ÷ value water demanded	if K=1	0.29	0.49	0.60	**0.66**	0.79	0.86	0.91	0.98	1.00
	if K=2	0.24	0.40	0.49	**0.53**	0.65	0.72	0.79	0.90	0.94
	if K=5	0.18	0.30	0.35	**0.38**	0.48	0.56	0.65	0.82	0.88
Capture efficiency		0.39	0.66	0.76	**0.82**	0.90	0.93	0.95	0.99	1.00
Security		0.15	0.41	0.57	**0.67**	0.81	0.86	0.90	0.98	1.00

Notes:
1. Under this strategy the demand is varied from 0.5 to 1.5 times the mean daily runoff according to how much water remains in the tank
2. V/R is tank size (normalised to mean daily run-off); K is dry-to-wet season water value ratio; the bold column shows the performance of a typical very-low-cost RWH system

6 ANALYSIS OF EXISTING TANK DESIGNS

In the course of the project a number of tank designs have been investigated by the RHRG. These have been written up as "case studies" and are available on the project web site at:

www.eng.warwick.ac.uk/dtu/rainwaterharvesting/casestudies.htm.

A summary of these designs is set out below

6.1 The Pumpkin Tank, Sri Lanka

The Sri Lankan Pumpkin Tank, and the associated construction technique, was developed as part of a World Bank sponsored Water and Sanitation Programme that was implemented in the country

between 1995 and 1998. The Community Water Supply and Sanitation Programme (CWSSP) covered 3 districts within the country – Badulla, Ratnapura and Matara Districts. Hundreds of these tanks have been built in areas where conventional supply schemes, such as piped supplies or groundwater supplies, were difficult to provide.

Catchment (typical) – 32m^2

Storage – 5 – 7 m^3

Storage cost - £112 (skilled labour - £19, Unskilled, £21 unskilled)

Material - ferrocement

Lessons

- Doubly curved structures
  - Material economies
  - Specialised techniques needed
  - Ferrocement construction
  - Use of mould for many tanks

6.2 Underground brick dome tank, Sri Lanka

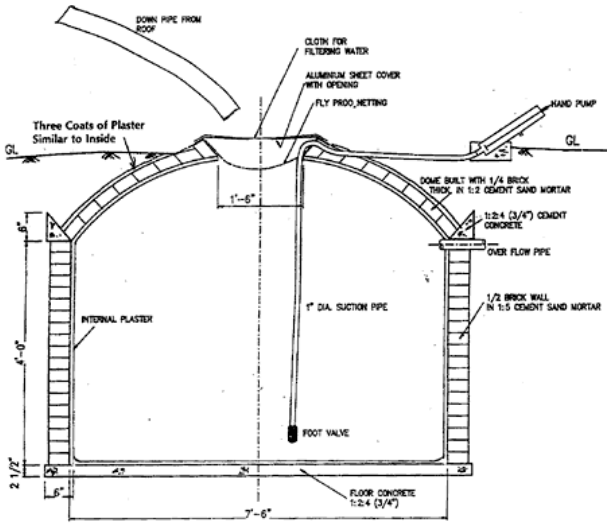

This is another RWH system which was developed by the CWSSP programme in Sri Lanka. The tank, a 5m^3 underground brick built tank.

Catchment – 28m^2

Storage – 5m^3

Storage cost - £125 (skilled labour - £15, Unskilled, £28 unskilled)

Material - Brick

Lessons

- Brick tank construction
  - Less skilled
  - *but* used as much cement as pumpkin tank

- Brick dome roof
- Low cost pumps for water extraction

6.3 Brick built storage tank, Sri Lanka

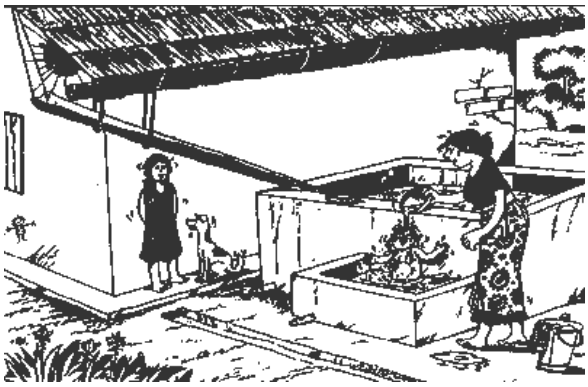

This is an example of local initiative in design and manufacture in DRWH. The tank in question was constructed in the village of Ahaspokuna, near Kandy, in the highlands area of Sri Lanka. The tank was built 10 years ago by a local mason for the Rajasomasari family and has since been copied so that there are now several of these tanks in the area.

Catchment – 90m^2

Storage – 3m^3

Storage cost - £80 (est.)

Material – Brick with cement render

Lessons

- Square construction
  - Good for bricks
  - Simple for local labour

6.4 Partially below ground brick built tank, Sri Lanka

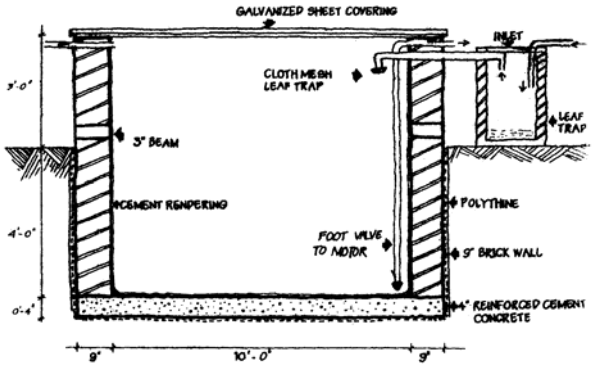

This tank was built by Mr G. Victor A. Goonetilleke in the hill town of Kandy,. Mr Goonetilleke decided to build his RWH tank after experiencing difficulty in sinking a well to sufficient depth to have a reliable perennial source of groundwater at the site of his newly built home.

Storage – 10m^3

Storage cost - £550

Material – Brick with cement render

Lessons

3 Partially below ground construction – many of the advantages of below ground construction but with several of the advantages of above ground construction

6.5 Underground storage cistern – 4 to 10 cubic metres, Uganda

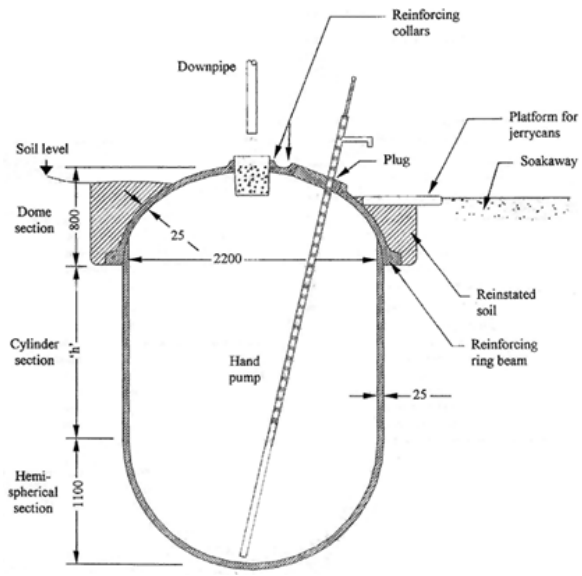

This tank (or cistern) was developed in Uganda by members of the Development Technology Unit, Warwick University and members of the Uganda Rural Development and Training Programme (URDT), between 1995 and 1997. Work is still continuing on the refinement of the tank. URDT is a service NGO located at Kagadi in Mid-Western Uganda. Several of these cisterns were built and tested with the aim of developing a low cost (under US$150), alley, domestic, water storage technology for the surrounding region.

Catchment – Varying

Storage – 4-10m^3

Storage cost – £90 (8m^3)

Material – Cement Mortar

Lessons

- Underground tanks – very thin walls are possible in appropriate soil
- Unreinforced mortar dome roof – lower cost due to no steel
- Ground as formwork – reduced cost amortisation of formwork

6.6 Ferrocement water tank using former

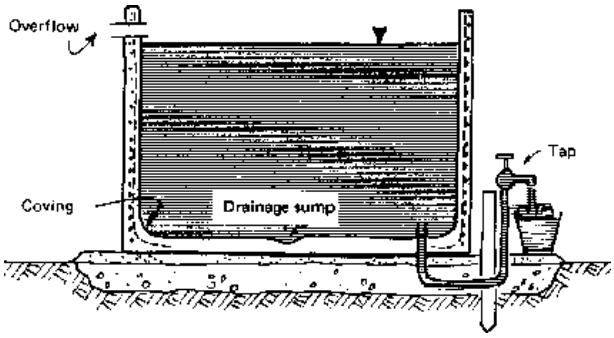

Used for many years in parts of Africa these tanks have been designed to be as simple as possible to build in self-help programmes. The users, who are at first unskilled in this sort of construction, can contribute their time and efforts in collecting sand and water, digging the foundations and preparing the mortar under the general guidance of a trained builder. With experience they quickly learn how to make the tanks without further guidance. A trained builder with 5 helpers takes approximately 3 days to complete the tank. The users often contribute some money towards the cost of the tank, which helps to cover the builders' wages, the cement, reinforcement and the hire of the corrugated iron formwork

Catchment – Varying

Storage – 10m^3

Storage cost – £90 (8m^3)

Material – Ferrocement

Lessons

- Reusable formwork with built-in depth gauge (corrugations)
- Adapted from successful commercial design from New Zealand
- Wire reinforcement graded through structure (more on bottom)
- Reinforcing from base to walls and filleted base join to avoid cracking at base

6.7 RWH in the barrios of Tegucigalpa, Honduras

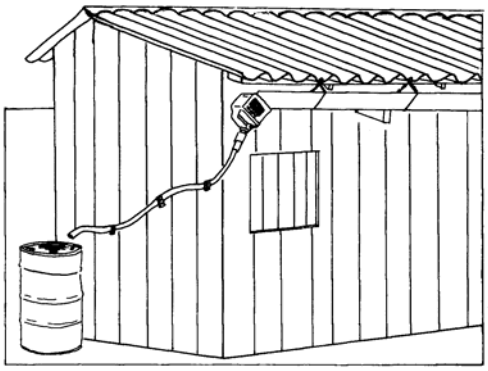

Health statistics show that the residents of the barrios are suffering from a number of water related diseases that could easily be avoided with provision of a reliable, clean water supply. Unfortunately, more than 150,000 residents have to find their own water. Although technically unsophisticated and

lacking some good health practice, the systems show what urban settlement have done to improve their own lot. Many of the systems make use of recycled or scavenged materials and some examples show high levels of initiative.

Storage – 0.2m^3 used barrels (up to 3) or 1-2m^3 open concrete tanks

Storage cost – £10 (drum) - £18 “small tank

Material – Steel drum or plastered bricks

Lessons

- Impact of very small storage
- Use of available containers

6.8 Tai Jar

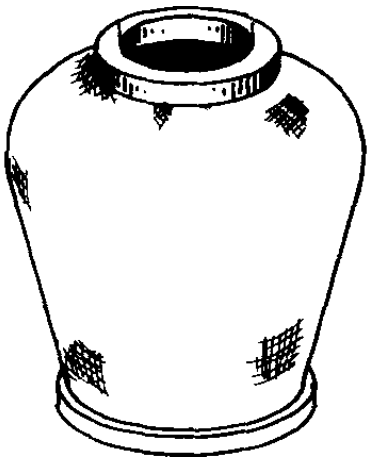

This type of water vessel was originally developed for a large country wide programme in Thailand that has installed over 10 million jars. Small jar making became a successful business with many companies producing up to 30 jars a day. The design has also been adopted in East Africa and South Asia

Storage – 0.5-2m^3

Storage cost – £ 30 for a 2m^3 jar

Material – Pottery or cement

Lessons

- Small tanks used modularly – several houses have more than one and up to 10 are used commercially
- Mass production – lead to much cheaper tanks
- Critical mass – the programme grew exponentially and became self sustaining within a few years

6.9 Plastic Lined tanks

Several experiments have been done using plastic sheets as a waterproof membrane in an otherwise wholly traditional structure. The bamboo tank developed by ARTI in Pune India uses a polythene sheet in a basket structure that is traditionally used for grain storage. In East Africa Rwandan refugees have used a tarpaulin distributed by UNHCR as a liner for an underground tank over which a wattle and daub enclosure is built to protect the water.

Lessons

- Small, portable imported input bolstering principally local technique – greatly reduced cost
- Some questions of durability

6.10 Summary

Table 6: Summary analysis of case study material

	Material costs	Percent Labour costs	Unit costs (per m^3)	Skills required	Equipment/ tools required	Space requirement	Suitability for incremental adoption	Reliability	Water quality, safety and health	Impact on insect breeding	Stage of maturity or experience
Pumpkin Tank	✓	✓	✓	✗	✗	O	✗	✓	✓	✓	✓
Underground brick dome tank	✓	✓	✓	O	✗	✓	✗	✓	✓	✓	✓
Brick built storage tank	O	O	O	✓	✓	O	O	✓	✗	✗	✓
Partially below ground brick built tank	✗	✗	✗	✓	✓	O	✗	✓	✓	O	O
Underground storage cistern	✓	✓	✓	✗	✓	✓	O	✓	✓	✓	O
Ferrocement water tank using former	✓	✓	✓	✓	✗	O	O	✓	O	O	✓
RWH in the barrios of Tegucigalpa	O	O	O	✓	✓	O	✓	O	✗	✗	O
Tai Jar	✓	✓	✓	O	✗	O	✓+	✓	✓	O	✓
Plastic Lined tanks	✓+	✓+	✓+	✓+	✓	O	✗	?	O	O	✗

Key ✓ Good O Medium ✗ Bad

7 RHRG RESEARCH INTO MEANS OF REDUCING TANK COSTS

7.1 Research strategy

Having collected information on existing rainwater systems and identified probable areas for design improvement, the RHRG has developed several cheaper tanks, concentrating on materials substitution and material reduction while working mainly with smaller tanks suitable for incremental adoption. The main materials investigated have been:

- Rammed Earth
- Stabilised soil blocks
- Bricks
- Plastic linings

Various underground tanks have also been developed mainly on the partly below ground model. A lift-on tank cover has also been developed to remove the need for formwork from the cover making process.

7.2 Use of externally reinforced bricks

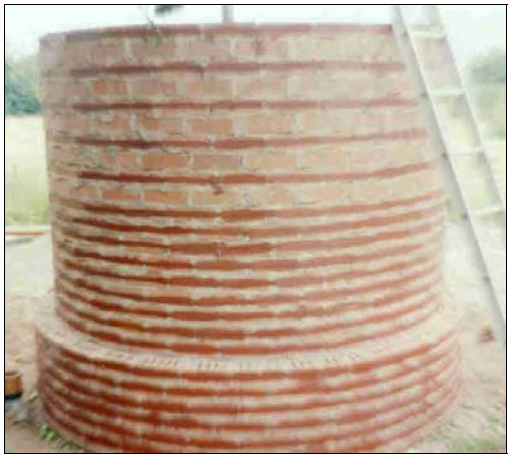

Brick is a material that is used widely in developing countries and is thus readily available. It is ideally suited to wall construction, but not quite so well suited to conventional larger volume tank construction. As it;

- has a poor strength in tension
- has a poor adhesion one brick to another through the mortar and so tensile forces must be spread through the brick runs which will be in sheer with one another
- can need more cement than an equivalent Ferrocement tank due to poorly fitting bricks

One way of improving the suitability of brick to low cost tank manufacture is by using external steel reinforcing to give additional hoop strength to cylindrical brick tanks. If an empty circular tank is wound with steel reinforcing wire on the outside, and the wire is then tightened, we will achieve 'post tensioning' whereby the masonry (brick/concrete) is initially in compression and the steel in tension. Putting the steel on the outside not only facilitates the post-tensioning but also makes it easier to protect the steel from being rusted by seepage from inside the tank. Filling the tank with water will

result in a lowering of the compressive stress and strain in the mortar and an increase in the tensile stress and strain in the steel. One such tank has been built and was detailed in Milestone Report A2

The technique holds some promise as it is easy to implement, however there is some doubt over the availability of tensioning tape as described in the report. It should, however be possible to use galvanised wire for this purpose although more will be necessary due to its lower tensile strength.

Table 7: Pros and cons of brick tanks

Pros	Cons
• low material cost • suitable material readily accessible locally in many parts of the world • a well-known and widely-used technology in many parts of the world • a simple technology that is easily taught to semi-skilled people	• not ideal for round tanks as extra mortar or special angled bricks are needed • Poor in tension – Needs reinforcing or very thick walls

7.3 Use of rammed earth

The use of rammed earth has been the subject of a previous report to the EU (Milestone A5: *Stabilised Soil Tanks for Rainwater Storage*, submitted September 2000) so only a brief summary will be presented here.

Rammed earth is a technique which is experiencing a resurgence of interest, particularly in developing countries where cement is expensive and in “green” architecture where its low energy use and excellent thermal properties are particularly appreciated. The technique has been used for centuries for the construction of houses many of which are still standing, attesting to its stability and longevity.

Just as it’s name suggests this technique involves earth being rammed between two shutters, using a rammer or tamp. The shuttering is removed to reveal the wall. Walls are usually constructed in sections of a few feet long by a foot or two deep with shuttering moved along to form a continuous wall. The shuttering is then raised and placed on top of the first ‘lift’ to construct the subsequent ‘lifts’.

Several experiments with rammed Earth have been undertaken by the RHRG both in the lab and in the field. The material has proved capable of withstanding the forces typical of a tank however there are some practical problems. The pros and cons of Rammed earth tank construction are listed in table

Table 8: Pros and cons of rammed earth tanks

Pros	Cons
• very low material cost • suitable material readily accessible locally in many parts of the world • a well-known and widely-used technology in many parts of the world • a simple technology that is easily taught to semi-skilled people	• not suitable for below-ground tanks or cisterns • in the case of leaks serious problems can develop, especially if unstabilised earth is used • high labour input

The main problem with rammed earth is its wet strength. The tank must be fitted with a waterproof lining to hold the water. If this liner becomes damaged and *any* water leaks, then the tank will almost certainly fail as any water ingress will ultimately seep out along with some soil, this process is continued until a hole forms ultimately growing large enough to destroy the tank's structural integrity.

7.4 Use of stabilised-soil

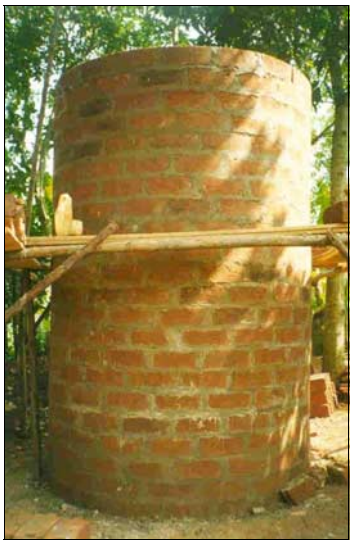

Stabilised soil has also been covered in a previous report (Milestone A5: *Stabilised Soil Tanks for Rainwater Storage*, submitted September 2000)

Stabilised, compacted, soil block technology involves compacting a suitable soil, which is often mixed with a small percentage (typically 5 – 10%) of cement, using a manual or hydraulically assisted ram or press. This compaction reduces the voids in the material and hence it susceptibility to attack from water. Special moulds can be manufactured to produce blocks of different shapes for special purposes.

Work has been carried out on stabilised soil blocks for tank construction in two locations (Uganda and Sri Lanka) In the case of the cylindrical tanks manufactured in Uganda, curved blocks were produced. For a cylindrical above-ground tank. In Sri Lanka a square underground tank was produced.

The Uganda work involved the building of two experimental cylindrical water tanks in collaboration with Dr Moses Musaazi, a lecturer at Makerere University. Both were built above ground of curved stabilised-soil blocks with end interlocking, 280mm x 140mm x 110mm high, made with an Approtec

(Kenyan) manual block press. The soil used was a red somewhat pozzolanic local soil previously known to make strong blocks. The tanks were built on concrete plinths, lined with 'waterproofed' mortar (3 parts sand, 1 part cement and .02 parts 'Leak Seal' waterproofing compound). There was no metal reinforcing.

Tank 1 was 2m high, with an internal diameter 1.3m, wall thickness 140mm (+ 15mm render) and used blocks incorporating 6% cement. It has been filled with water and briefly withstood a maximum head of 2.m at the wall bottom before failing catastrophically (and spectacularly). 2, for test purposes, has been built to 5m high, has internal diameter 1.0m and the same wall thickness, but with only 3% cement. It has been filled with water and therefore withstood a head of 5.0m at the wall bottom. The inconsistency of the result could be attributed to an undersupply of cement to the blocks which made up tank one resulting in a low wet strength, coupled with a cracking of the mortar used to line the tank.

The pros and cons of stabilised soil construction tank construction are listed in table 7

Table 9: Pros and cons of rammed earth tanks

Pros	Cons
• Reduced cement content resulting in inexpensive blocks •	• Low wet strength • Reduced cement content must be balanced against lower strength requiring thicker walls • Needs specialised tooling for compacted blocks • Low tensile strength of block joints

7.5 Lining tanks with plastic bags

Plastic linings can considerably reduce the cost of the tank by removing the need for any building work to be watertight. Indeed they can be simply placed in a hole to form a very cheap and portable tank (although a cover should be constructed). Plastic liners also allow removal for inspection, cleaning, maintenance and occasional repair.

Work on plastic linings by the RHRG includes the development of a technique for welding 250 micron construction or damp proof membrane (DPM) plastic sheet to make 'bags' (similar to large bin liners) that fit inside the tank structure to form a waterproof lining. The welds themselves have proved successful with the weld both watertight and stronger than the plastic itself. The technique uses simple tools and can be taught in a couple of hours to a reasonably skilled craftsperson. One skilled person should be able to make a bag in a single day and productivity can be greatly enhanced by batch production. However, while the welding technique has been successfully developed, there are still problems to be overcome in relation to the quality of 'off-the-shelf' plastic sheet and failure of the lining due to abrasion. Observations in the field suggest that plastics with a woven structure may be more resilient, however these will not weld with the technique developed at Warwick.

The availability of plastic tubes from local markets is quite wide spread and a 600litre "plastic tube tank" was also developed in the course of the project. Details of this tank can be found in DTU Technical Release *TR-RWH08 Plastic Tube Tank (600 litres) – Instructions for manufacture*. (Rees & Whitehead, 2000b)The 87cms diameter tube is the largest that was found at the time but the design could be easily modified for different sizes of tube. The tank is based on the partly below ground concept and consists of a brick parapet wall, which incorporates the inlet basin and handpump and the lower section ground excavation, lined with two plastic liners one inside the other. The tanks have developed slow leaks reducing their effectiveness but are still holding water and making a significant contribution to household water where they have been installed.

Table 10: Pros and cons of plastic linings

Pros	Cons
• Greatly reduced cost • Portable • No clambering on or in the tank is required during construction. • No curing time is required. • Can be removed for cleaning./inspection • Can be batch produced	• Fragile – likely to tear, subject to pin holes • UV degradation • Joining requires specialised techniques

7.6 Simple underground tanks in stable ground

The RHRG has also experimented with creating underground tanks using stabilised soil with bamboo reinforcing and a plastic liner for waterproofing. The work (undertaken by the Open University in Sri Lanka) .The tank was designed to contain 3600 litres of water. It is trapezoidal with 100cm x 100cm square cross-section at the top and 80cm x 80cm square cross-section at the bottom of the tank. Strips of bamboo are used both as a support to the tank walls and to protect the lining material, which is 500 gauge polythene sheet. During the development soil samples were tested for strength and durability and a 1:12 cement:soil ratio was found to be optimum with the local soil. This will, however differ with location.

The problems of covering such pits can still cause cost problems absorbing more than 2/3 of the cost of such a tank. Tanks have also been broken due to raising water table, punctured by tree roots and are vulnerable to infiltration by runoff.

Table 11: Pros and cons of simple underground structures

Pros	Cons
• Greatly reduced cost as surrounding ground gives support allowing lower wall thickness. • More difficult to empty by leaving tap on • Can be made unobtrusive	• Water extraction is more problematic – often requiring a pump • Leaks or failures are more difficult to detect • Contamination of the tank from groundwater and surface runoff • Tree roots can damage the structure • There is danger to children and small animals if tank cover is left off • Flotation or breaking of the cistern can occur if groundwater level rises

7.7 Partly-below-ground tanks

Several of the problems of underground tanks can be overcome by siting the tank partly above ground and partly below ground. These tanks have been described in Milestone Report A3. Details can also be found in the DTU Technical release *TR-RWH 01 Partially Below Ground (PBG) Tank for Rainwater Storage – Instructions for Manufacture*, (Rees, 2000b) available at: the DTU website. Over 20 of these tanks have been built in East Africa and feedback suggests that the tanks are easy to construct by masons with some training, at a reasonable cost.

Table 12: Pros and cons of Partially below-ground tanks

Pros	Cons
• Lower material requirements • Difficult to empty by leaving tap on • Reasonably unobtrusive • Surrounding ground gives support allowing thinner walls and thus reduce costs	• Requires a pump • Leaks or failures are difficult to detect • Contamination of the tank from is possible • Tree roots can damage the structure • Flotation of the cistern may occur

7.8 Lift-on tank covers

The lift on tank cover developed by the RHRG has been detailed in Milestone Report A2 and in DTU Technical Release *TR-RWH 04 – Low-cost, thin-shell, 2m diameter ferrocement tank cover - Instructions for manufacture (Rees, 2000a).* The thin-shell ferrocement tank cover is designed in such a way that it can be manufactured without the use of a mould or shuttering. It can also be manufactured remote from the tank to which it is to be fitted and moved into place once complete. The aim is to reduce the cost of the tank (cover) by eliminating costly shuttering or moulds and by reducing the quantity of material used to manufacture the cover. It also means that the cover can be removed at a later date for maintenance, refurbishment or cleaning. The cover can be manufactured by two persons (one skilled and one unskilled) in a single day (with some time required after that for curing) using tools required for the construction of a simple cylindrical ferrocement tank.

The design is based on a frame known as a reciprocal frame, that has spokes that, when loaded, put little radial loading onto the structure on which it sits. The frame is covered with a wire mesh that is then rendered with a sand cement mix.

Table 13: Pros and cons of lift on lank covers tanks

Pros	Cons
• low cost – reduced use of materials • no shuttering or mould required • strong and lightweight – the tank cover is designed to be strong (through good quality control) and light at the same time • good quality control can be achieved through easy working environment • can be manufactured by two people in a single day (one skilled and one unskilled) • no clambering on top of tanks required during construction • can be cured easily – in the shade and at ground level • can be batch produced at one site	• Needs skilled craftspeople • Needs good quality control to be effective • Available in one-size-only as frame angles must be recalculated for other sizes

8 COSTS ANALYSIS OF RWH TANKS

The aim of this exercise is to compare tanks from different parts of the world and to carry out a costing exercise so as to assist those considering DRWH to make an informed choice. Such choices are usually complicated by the fact that material costs, labour costs, per capita income, currencies and exchange rates all vary from one country to another. Cost of storage per litre also varies as tank size increases. To take into account this variability an effort has been made to normalise some of the figures.

- 8 tanks have been costed for each of three countries i.e. Uganda, Sri Lanka and Brazil using bills of materials from the designs and material cost information obtained from each of the countries in 2000/2001.
- All tank costs have been converted to $5m^3$ equivalent using sensitivity to size of 0.6.

The tanks under consideration are taken from 4 countries in 3 continents. The countries are Kenya, Uganda (Africa), Sri Lanka (Asia) and Brazil (South America). The tanks are listed in Table 14 and the final costings are in Figure 9

Table 14: Tanks used for costing exercise

	Tank name	Tank size(s)	Source of information
1	PBG Tank	10,800 litres (size can be varied)	DTU Technical Release 01
2	Ferrocement tank	3,000 and 11,000 litres	Eric Nissen-Peterson, ASAL, Kenya (Nissen-Petersen & Lee, 1990)
3	Small brick jar	750 litres	DTU Technical Release 07 (Rees & Whitehead, 2000a)
4	Tarpaulin tank	4,000 – 5,000 litres	ACORD, Uganda and DTU Web Page
5	Ferrocement Pumpkin Tank	5,000 litres	Lanka RWH Forum and CWSSP Reports, Sri Lanka (Hapugoda, 1995)
6	Below ground brick tank	5,000 litres	Lanka RWH Forum and CWSSP Reports, Sri Lanka (Hapugoda, 1995)
7	Cement Plate Cistern	10,000 and 20,000 litres	Johann Gnadlinger, IRCSA. Data from Juazeiro, Bahia State, 1998 (Gnadlinger, 1999)
8	Brick lime cistern	10,000 and 20,000 litres	Johann Gnadlinger, IRCSA. Data from Juazeiro, Bahia State, 1998 (Gnadlinger, 1999)

Figure 9: tank costs in three countries

a Brazil

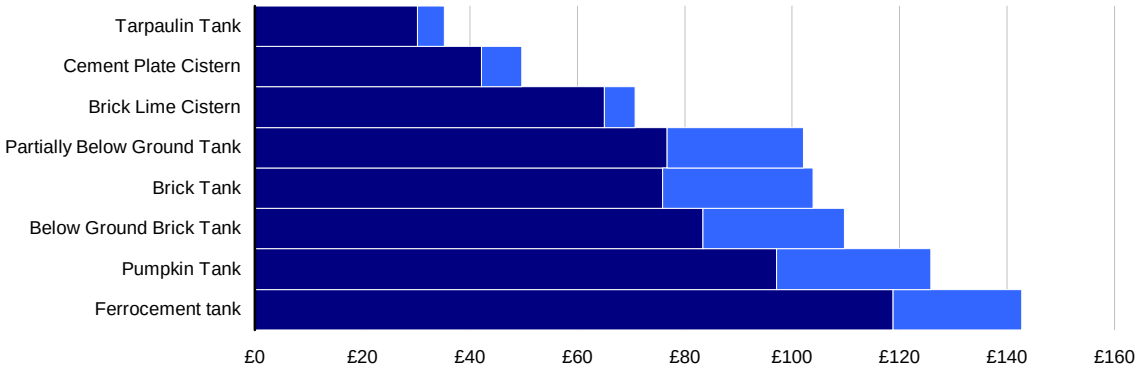

b Sri Lanka

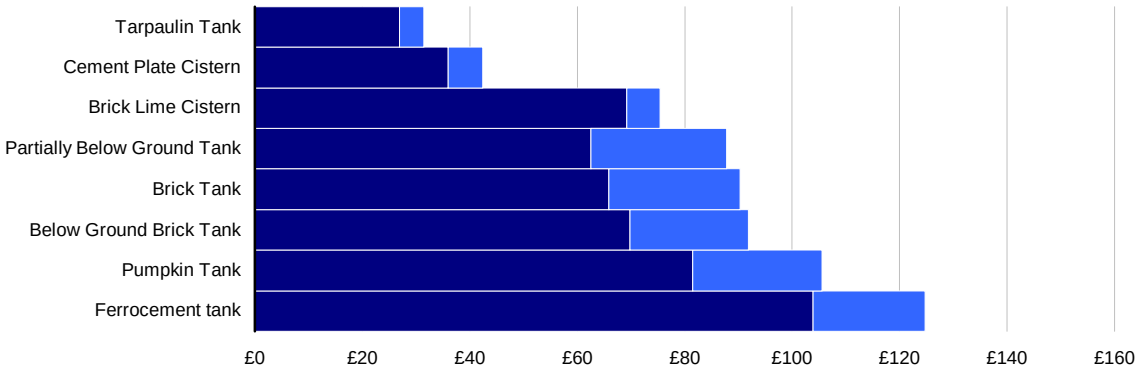

c Uganda

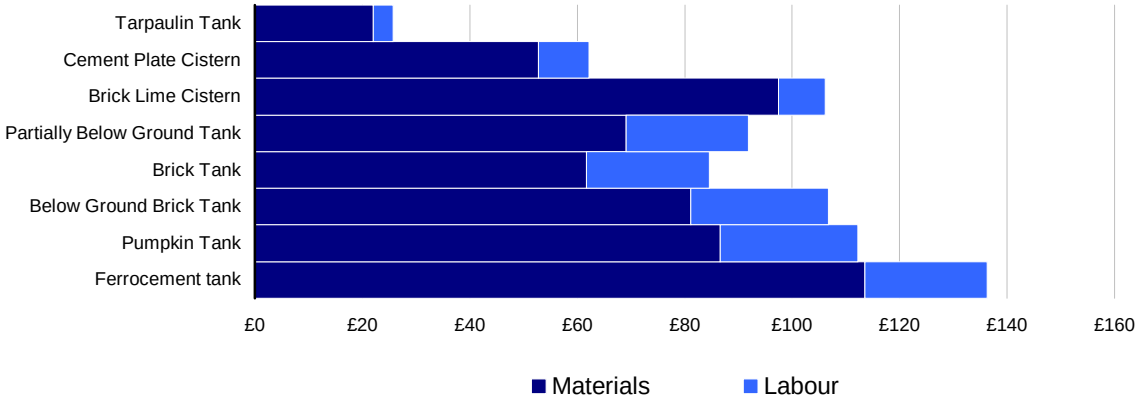

As can be seen the cost of building the tanks differs by quite some margin:

- The traditional ferrocement tank fares most badly, this is probably due to the design being quite old and suffering many years of "improvements" at various hands
- The Pumpkin tank would appear to provide some savings mainly through its more optimised shape and also due to the youth of the design
- The partially below ground tank also provides good economies with reduced material usage and similar labour costs to other cement tanks
- The brick tanks show some materials savings but a slightly higher labour content tends to favour countries where labour is cheap and materials expensive such as Uganda
- By far the cheapest tank is the tarpaulin tank, due in part to its extensive use of "free" local materials and also because of its quick construction
- The cement plate cistern is also an inexpensive option particularly in countries with cheap cement such as Brazil and Sri Lanka. Its unique construction using closely controlled sections of concrete assembled together on site results in substantial savings in material thickness. In more developed countries, this would be an excellent option as it is both durable and desirable as a household asset

Further insight is gained by discounting the labour content of the tanks as the community itself can often provide this. The Brick lime cistern is a case in point here. In Sri Lanka it is a fairly inexpensive option, however its low labour content means that for a self-help project it is less attractive (in Uganda it is the second most expensive in terms of material use!).

9 CONCLUSIONS

Rainwater harvesting tanks represent a mature technology. Their use goes back many centuries and development has been going on throughout history. This does not mean, however, that there is no room for improvement of the technology. Modern techniques and materials have great potential for the manufacture of rainwater tanks. Some of the most promising areas for cost reduction are:

- Plastic bag tanks such as the tarpaulin tank and the DTU tube tank
- Mass produced parts such as the cement plate cistern and lift on covers

- Partially below ground structures to combine the economies of below ground tanks with the safety and desirability of above ground tanks
- Considering the diseconomies of scale inherent in large tanks and using smaller tanks to provide partial supply or seasonal supply.

In considering cost reduction local conditions play a large part.

- Labour and material costs vary widely throughout both the developing and developed world resulting in different designs becoming cheaper
- Conditions may favour one design over another e.g underground tanks are only suitable for areas with stable soils and low water tables, plastic bag tanks are only suitable where insects are not a problem

These caveats notwithstanding the designs tried within the EU programme and many encountered in the field have demonstrated the cost of tanks can be significantly lowered. Domestic rainwater harvesting remains almost unique in that it allows householders to provide their own water supply without the need to wait for outside intervention and the challenge is to produce a system within the means of every household. With appropriate dissemination, the designs presented in this paper should go some way toward this.

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Milestone A3

‘Completion of one externally reinforced brick tank, two brick test cylinders, one partially below ground tanks and five thin-shell ferrocement tank covers’.

(Originally titled ‘Completion of 6 underground tanks with instrumentation’)*

University of Warwick

September 1999

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2. Partially below ground tanks 5
3. Thin-shell ferrocement tank covers 9
4. Appendices.....11

*Early in the programme, after the initial desk study had identified the areas where further research is required, it was decided to broaden the original scope of the water storage (technology) component of the programme to include above ground, free-standing water storage tanks as well as underground tanks. The focus of this work, as reported in Milestone A2, has been primarily the research into externally reinforced, single-skin brick tanks. It was also decided that we would put some resources into developing a simple, cheap, lightweight, tank cover, as this was seen as an area where little work has been done and where there was much scope for improvement for relatively little input. The title of this Milestone has therefore been altered to reflect the practical research work that has actually been carried out under the programme.

1. Externally reinforced brick tanks

The early work on this topic was reported in Milestone A2 and covered the early tests that were carried out on brick cylinder specimens that were constructed at the University's civil engineering laboratory.

The aim of the tests were to determine the suitability of single-skin, burnt-brick, externally-reinforced (with packaging strap in this case) cylindrical tanks for water storage. The specimens were subjected to pressure forces in order to determine the hoop stresses induced in the strapping and the behaviour of the brick-strapping combination under load and at failure. The test results were then compared with a spreadsheet model that had been generated earlier.

The early results proved promising but were inconclusive due to some uncertainties in the experimental procedure. Further tests are currently underway at the University to more fully model the behaviour of the tank under load.

Figure 1 below shows one of the specimens under test, showing the internal expansion ring used to apply pressure. Figure 2 shows the steel strapping with a strain gauge that was used to measure the hoop stress generated. For fuller details of the tests, please refer to the Milestone A2 report.

Further work has since been carried out on the construction of a full-sized tank for rainwater storage at a field site in Herefordshire. The tank has a capacity of approximately six cubic metres, with a diameter of 2m and a height of 2m. The tank is at present complete, but without instrumentation as yet. The aim of the experimental tank (shown under construction in Figure 3 below), is to further investigate the behaviour of the tank with particular regard to induced stresses under real conditions and also to investigate the feasibility of a number of peripherals designs.

The tank has been built at the site of a Herefordshire based educational charity who run regular residential courses. The tank will store water captured from the roof of a large shower and toilet complex and the water is then pumped to a header tank from where it is piped to the toilets for flushing. The tank will experience regular cycling (emptying and filling) and hence will allow regular analysis of the stresses and achieve a simulation of accelerated ageing. The cost of the system was shared between the University of Warwick and the charity. The schematic diagrams for the system are shown in appendix 1.

The site will also give us a valuable UK based field testing station at which we can pre-test any idea or component before passing them on to partners or field contractors for further testing and development. The site has already been used to test plastic tank liners which are being developed at the University, as well as being fitted with a novel overflow/ washout system. The system is fitted with WISY filters, which will be tested for efficiency at a later stage.

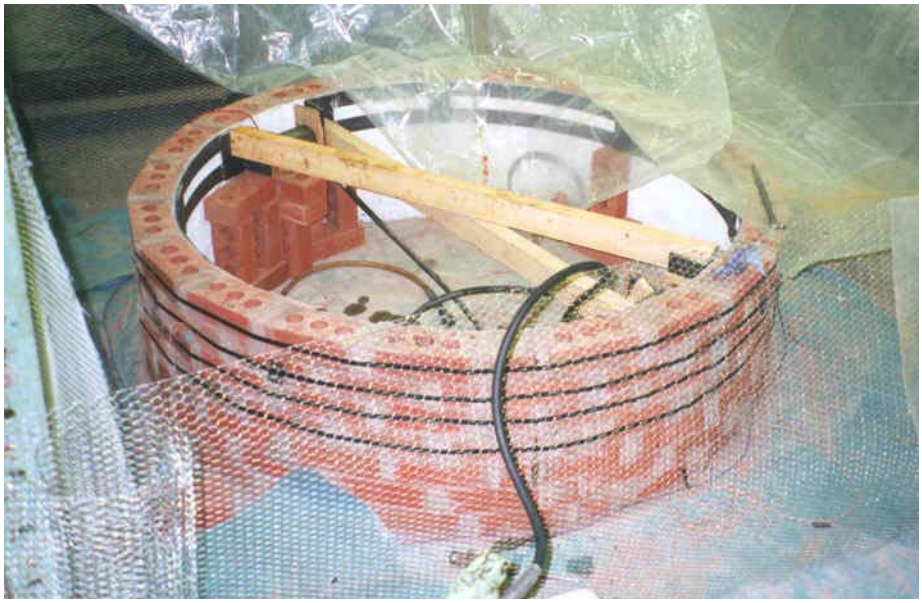

Figure 1 – Tests arrangement for externally reinforced brick cylinders

Figure 2 – Strain gauge used to measure hoop stress generated in steel strap during testing.

Future work in this area will include research into the use of cement stabilised soil blocks in place of brick, used in conjunction with a plastic tank liner, with the aim of reducing costs further.

Figure 3 – Full-size experimental tank under construction at field site.

Figure 4 – Strapping applied to experimental tank.

Results of the tests carried out at the University and at the field site will be reported in Milestone A5.

2. Partially below ground tanks

The work on partially below ground tanks is still in the very early stages and, to date, has been primarily field based. The work builds on previous DTU work in Uganda with fully below-ground tanks. Modifications were made to the original (fully below-ground) design to eliminate some of the problems commonly encountered with this type of tank, while still taking advantage of the beneficial aspects. These problems are:

- ingress of water from above ground causing contamination
- danger to children (and adults) if cover is left off the tank
- danger of collapse if driven over with a vehicle
- difficulties in excavation due to the construction process (see DTU Working Paper number 'Underground Storage of Rainwater for Domestic Use' at http://www.eng.warwick.ac.uk/DTU/workingpapers/wp49/index.html)
- no suitable overflow when tank overfills

The previous tank design is shown below in Figure 5. Approximately 15 of these tanks, which range from 8 to 10 cubic metres, have been built in western Uganda over the past 3 years with good results.

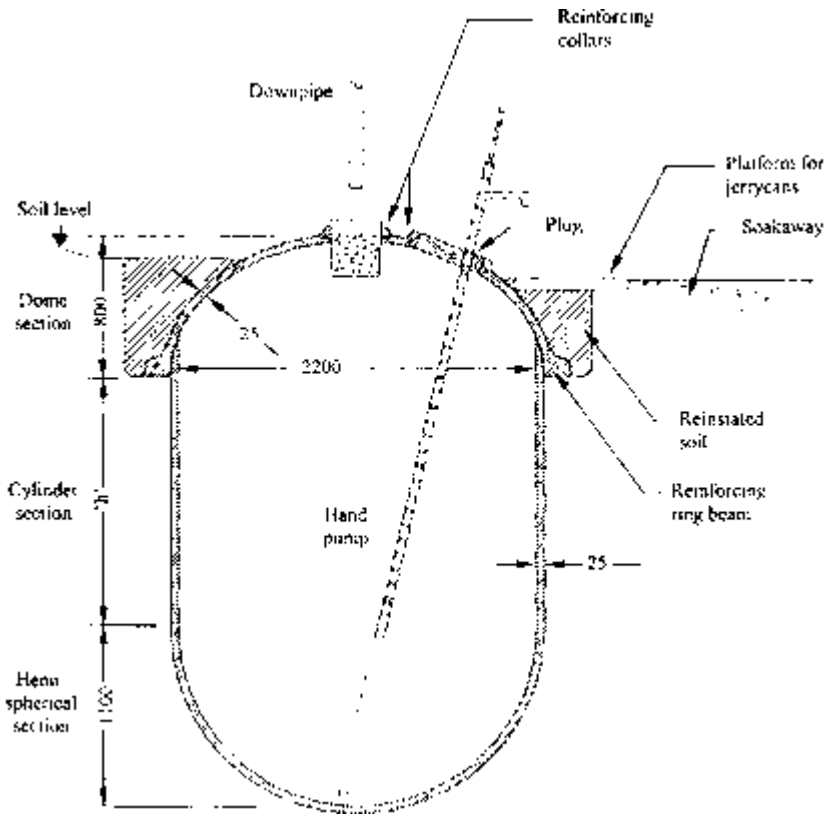

Figure 5 – DTU fully below-ground tank design

The tank is suitable only under certain soil conditions, namely where the soil is sufficiently stable to not cause any concern regarding subsidence. This is the case in many parts of Eastern Africa where the soil is lateritic.

The partially below ground tank (see Figure 6) is raised slightly above ground level in order to eliminate the problems listed above. The parapet wall sits atop a concrete ring beam through which the tank is excavated. The tank is lined with cement render and will, when the technology is sufficiently developed, be fitted with a continuous plastic lining. Water enters the tank through a pipe which directs it to the base of the tank which promotes rapid settling of sediment. The tank is fitted with an improved handpump and floating off-take. The floating off-take takes water always from slightly below the surface level of the water. These two innovations help maximise residence time in the tank, allowing full sedimentation to take place even when water is drawn off as fresh water is entering (except under conditions where the tank is almost empty).

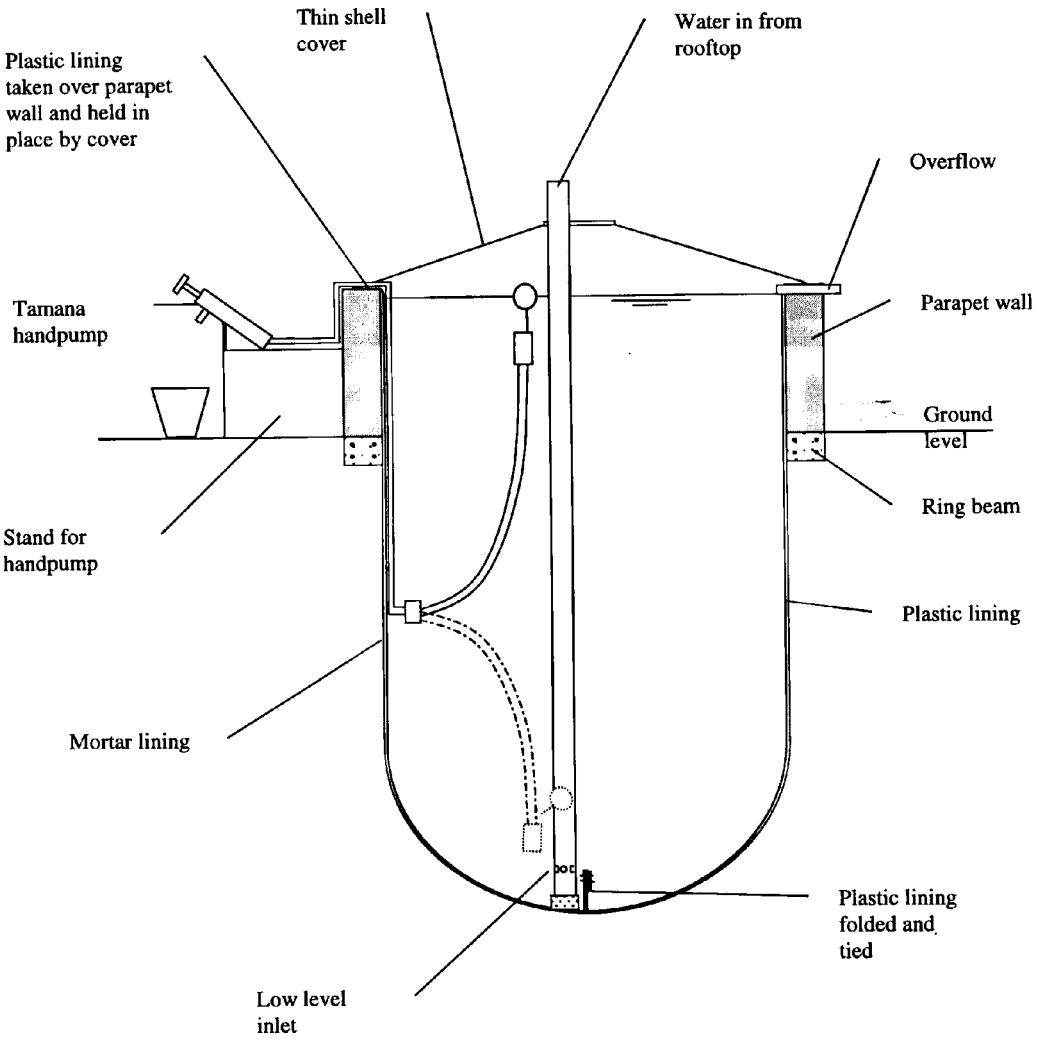

Figure 6 – Schematic representation of the cylindrical, partially below-ground tank

One partially below ground tank has been built in western Uganda. It was hoped that a number of tests would have been carried out by the time of writing this report, but due

to logistical problems (funds transfer to Uganda which took 3 months), the tank has not yet been tested.

Figures 7, and 8 below, show the partially below ground tank under construction, while Figure 9 shows the thin shell ferrocement cover being manufactured.

Figure 7 – Bird's eye view of the partially below-ground tank under construction.

Figure 8 – Partially below ground tank under construction in western Uganda, showing parapet wall.

Figure 9 – Thin-shell ferrocement cover being manufacture for partially below-ground tank in western Uganda

Further information and test results form this work will be included in Milestone A5 report.

3. Thin-shell ferrocement tank covers

Milestone A2 report included documentation regarding the instructions for manufacturing a thin-shell ferrocement cover (TSF cover).

The thin-shell ferrocement tank cover is designed in such a way that it can be manufactured without the use of a mould or shuttering. It can also be manufactured remote from the tank to which it is to be fitted and moved into place once complete. The aim is to reduce the cost of the tank (cover) by eliminating costly shuttering or moulds and by reducing the quantity of material used to manufacture the cover. It also means that the cover can be removed at a later date for maintenance, refurbishment or cleaning. The cover can be manufactured by two persons (one skilled and one unskilled) in a single day (with some time required after that for curing) using tools required for the construction of a simple cylindrical ferrocement tank.

The design is based on a frame known as a reciprocal frame, that has spokes that, when loaded, put little radial loading onto the structure on which it sits. The frame is covered with a wire mesh that is then rendered with a sand cement mix.

Details of the construction process are given in Milestone A2 for a 2.0m diameter cover that has an inspection chamber opening of 0.5m.

Benefits of the thin-shell ferrocement tank

- low cost – reduced use of materials
- no shuttering or mould required
- strong and lightweight – the tank cover is designed to be strong (through good quality control) and light at the same time
- good quality control can be achieved through easy working environment
- can be manufactured by two people in a single day (one skilled and one unskilled)
- no clambering on top of tanks required during construction
- can be cured easily – in the shade and at ground level
- can be batch produced at one site

Five of these covers have been produced to date, 3 for testing purposes and two that have been fitted to tanks. One has been made in Uganda by local masons (see Figure 9 above and Figures 10 and 11 below) with no complications.

Figure 10 – 6mm steel framework being formed by local masons in western Uganda for the TSF tank cover.

Figure 11 – TSF cover being completed by local mason in western Uganda. This cover was fitted to a partially below-ground tank.

Tests have been carried out on the cover to determine its strength and the results are shown in appendix 2.

4. Appendices

Appendix 1 – Schematic representations of RWH system at field station in Herefordshire. (2 pages)

Appendix 2 – Test results for Thin-shell ferrocement tank cover. (2 pages)

Research into single skin, externally reinforced, brick tanks

Interim Report
April 1999
Mr. D. G. Rees
DTU, University of Warwick

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1. Introduction

1.1 Project background

This work is being carried out as part of a programme titled 'Domestic Roofwater Harvesting in the Humid Tropics', which is an international 3 year, four partner, European Union funded, programme which started in August 1998.

Warwick is leading the sub-programme titled 'Low cost storage', the aim of which is to develop a number of techniques for construction of low cost water storage tanks or cisterns. As part of the programme we will look at several techniques for reducing costs, improving quality and improving health through good design and construction practice.

One such possible low cost design that will be investigated in detail is the externally reinforced, single skin brick tank. This Interim Report discusses the early research work that has been carried out on this design idea with the aim of clarifying the

findings of this work and the further work that is required to provide enough useful detail to confidently promote such a technology.

1.2 Brick tanks – design philosophy for Developing Countries

The design philosophy adopted for water storage tank design is one of local manufacture using materials that are available with relative ease in the locality. Cost control is of major concern in order that the technology becomes more accessible to the poor of developing countries.

Brick is one such locally manufactured, widely used, readily available material which is ideally suited to wall construction, but not quite so well suited to conventional larger volume tank construction. In this report we look at methods of improving the suitability of brick to low cost tank manufacture by using external steel reinforcing to give additional hoop strength to cylindrical brick tanks. We also look at methods of lining such tanks for water tightness – at this stage limited mainly to internal cement render. Plastic lining of tanks will be discussed in a later report.

2. The theory of stresses in cylindrical tanks

Cylindrical tank walls experience a 'hoop stress' which is proportional to the diameter, D, of the tank, the pressure, p, on the walls of the tank and the thickness of the tank wall, t (Equation 1). The stress on a cylindrical tank wall is also affected by

$$\sigma_t = \frac{pD}{2t} \qquad \textit{Equation_1 – Hoop Stress}$$

the type of joint between the tank base and tank wall. There are two obvious cases to consider as illustrated in Figure 1 below. Taking Case 1, if the tank wall is free to move at its base and still maintain a watertight seal, then the strain induced in the wall will cause the diameter of the tank to increase until the hoop stress is taken up by reinforcing in the wall (obviously the increase in diameter is exaggerated here for effect). In this case the force exerted by the water pressure on the tank walls will be taken up solely by the hoop tension in the walls. The maximum hoop stress will be experienced at the base of the wall and will decrease proportionally (linearly) according to Equation 1.

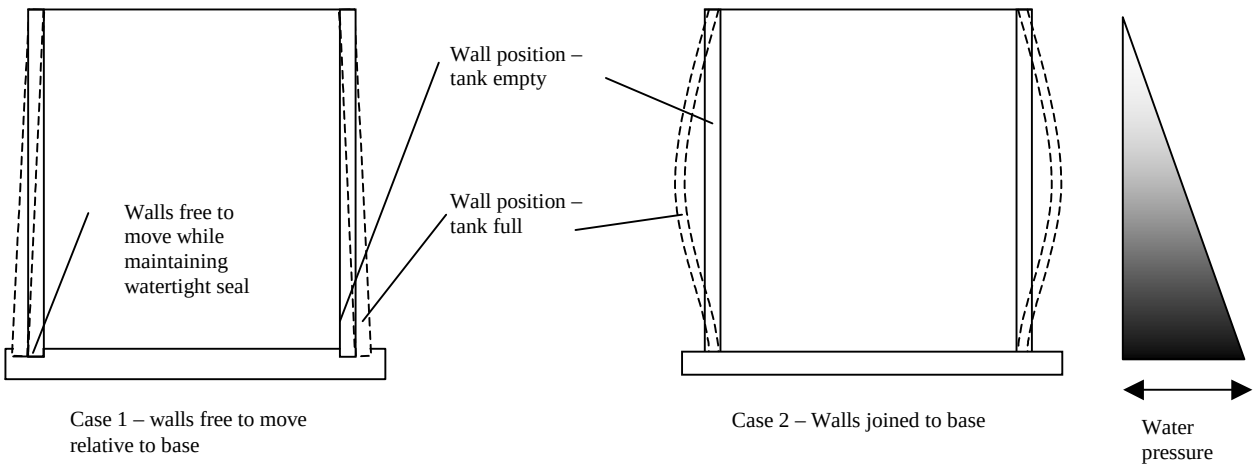

Figure 1 – The two cases for wall and base union in cylindrical tanks

Taking Case 2, if the wall and base are monolithic i.e. the wall and base are continuous, the situation becomes more complex as bending stresses are set up in the wall as a result of the restraining effect of the base slab. There now exists a complex combination of bending, shear and hoop stresses. Gray and Manning[4] suggest that if the wall is not free to move at its base, then the loading caused by the outward pressure is counteracted by a combination of hoop resistance and cantilever resistance. This is illustrated in Figure 2 which shows the load distribution diagram suggested by Gray and Manning. As the base of the wall is now restrained there is no freedom for the wall to move and take up the hoop stress and so the hoop stress there is reduced to zero. Maximum hoop stress is now experienced higher up the wall of the tank. All the restraining forces acting at the base are due to the cantilever.

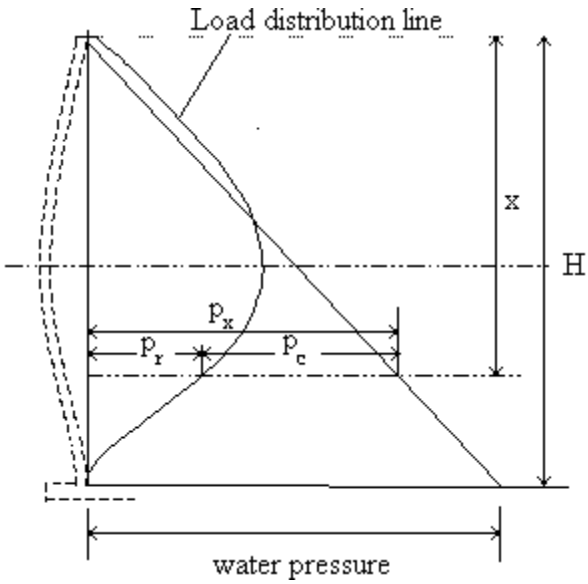

Figure 2 – Typical Load distribution diagram for a tank wall which is monolithic with base (modified slightly from Gray and Manning[4].

p_x – Total outward pressure load to be restrained
p_r – Portion of the load restrained by hoop stresses or radial constraints
p_c –Portion of the load restrained by cantilever
x – distance from top of tank
H – total depth of tank

As illustrated in Figure 2, the total pressure p_x at any depth of wall is composed of p_r (the portion of the load carried by the hoop restraints) and p_c (the portion of the load carried by the cantilever), such that,

$$p_x = p_r + p_c$$

The profile of the 'load distribution curve' is governed by the profile of the tank. Gray and Manning give a number of load distribution curves for a variety of tank profiles (see Figure 3). The tank profile is related to the distribution curve by Equation 2, all tanks with equivalent values of K having similar load distribution curves.

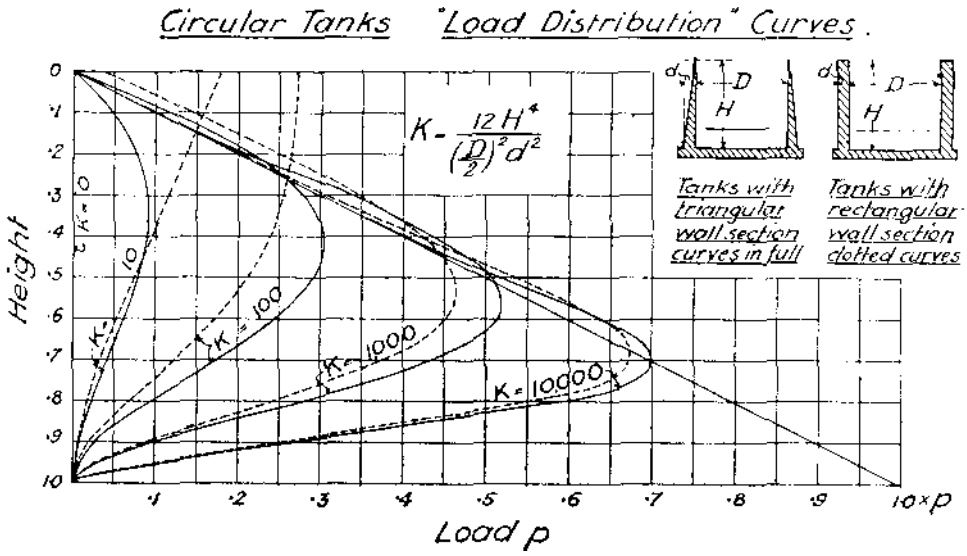

Figure 3 – Load distribution curves for a variety of K values (Gray and Manning[4])

$$K = \frac{12H^4}{\left(\frac{D}{2}\right)^2 d^2} \text{.....} Equation_2$$

where,
H = height of tank
D = diameter of tank
d = thickness of wall at foot

It is noted that cantilever load increases for diminishing values of K. K is tightly controlled by the value of H such that K increases to the fourth power of H. We also see that K falls as tank radius and wall thickness increase.

If we consider a typical cylindrical single skin, brick tank with homogenous wall and base of diameter 2m, height 2m and wall thickness of 0.1m, then we obtain a value of K equal to 19,200. This is beyond the value shown in Figure 3 and suggests a regime where p_r dominates i.e. the outward pressure load is resisted predominantly by hoop stresses. Cantilever forces act only at the extreme base of the tank wall (within the bottom 20%). The tank can therefore be dealt with as if the hoop stresses induced are similar to those of a tank with a free base joint. This still leaves the high bending and shear stresses in the base of the wall to be evaluated. Watt[2] suggests that the maximum bending stress on the inside face of the tank wall will be almost double the induced hoop stress for a similar tank profile. This can easily be compensated by increasing wall thickness at the base of the tank. As demonstrated by Equations 3 doubling the wall thickness, d, effectively decreases the bending stress in the wall by a factor of four.

Bending stress, $$\sigma_b = \frac{M\left(\frac{d}{2}\right)}{\left(\frac{bd^3}{12}\right)} = \frac{6M}{b}\left(\frac{1}{d^2}\right) \text{.....} Equation\ 3$$

where, $\frac{bd^3}{12}$ is the Second Moment of area

and b is the width of a strip of wall carrying local bending moment, M

Shear stress is very small compared with the bending and hoop stresses (Watt) and can therefore be neglected for the sake of this analysis.

Work is currently being carried out to develop a computer software programme for a fuller analysis of stresses set up in a variety of tank shapes and sizes.

2.1 Calculating hoop stresses in reinforced brick tanks

The task of calculating hoop stresses in the tank under consideration now becomes a simple task. We treat the tank as if its walls were unconstrained at the base and can thus use Equation 1. We will then deal with bending stresses separately by increasing wall thickness locally at the base as required.

For a tank with a brick wall and external steel reinforcing we need to understand what stresses are induced in each material and what function each material is performing. Table 1 shows a hoop stress analysis for the two materials that have been used during tests at the University. These materials are high tensile steel packaging straps (of 13mm width x 0.5mm thickness), and brick masonry (in this case with cement mortar). If we analyse the two materials separately we can see from Table 1 that the ability of the brick masonry to withstand the imposed hoop stress is unpredictable due to the unpredictable nature of the quality of the material. High tensile steel, on the other hand, has reliable and predictable strength and will afford almost four times the required hoop strength. The steel, then, provides the tensile strength required to prevent failure due to excessive hoop stress.

The brick masonry, on the other hand, provides the stiffness required to prevent failure due to bending stresses. For the example shown below the stiffness of the brick is many orders of magnitude greater that the 'virtual' steel wall stiffness (virtual wall thickness is the thickness that would exist if the straps formed a continuous steel shell - the straps themselves actually provide no vertical stiffness).

We therefore see that one material compliments the other. The steel provides a hoop strength up to eight times that of the brick masonry whilst the brick masonry provides the stiffness that could only be achieved in a steel tank with hundreds of times the quantity of steel used in the example given.

Properties	**High tensile steel strap (13mm x 0.5mm) – two straps per course of bricks**	**Brick masonry**	**Units**
UTS (Mpa)	833	0.1 – 1.0	Mpa
Yield strength	450		Mpa
Youngs modulus	210	25 - 100	Gpa
Wall thickness (equivilant)	173×10^{-6}	0.1	m
Tank diameter	2	2	m
Water depth	2	2	m
Hoop stress exerted by water force	113.19	0.196	MPa
Safety factor	3.98	0.51 – 5.10	

Table 1 – Hoop stress analysis for steel and brick masonry in cylindrical tank of 2m diameter and 2m height

2.2 Construction and application regimes to ensure strength

Some thought has to be given to the interaction between the brick masonry and the steel strap. The two materials must interact in such a way as to enhance the properties of the other as explained in the previous section. This can only be achieved when the construction of the walls and application of the steel strapping is performed in a certain way. The steel is applied externally to the brick wall, using a tool specially designed for applying this kind of strap. The strap should be applied with sufficient pre-tension to be able to counteract the normal water force that will be exerted upon the wall upon filling the tank. In consequence, the masonry is initially put into compression and remains in compression as the tank is filled. This will protect the brick masonry against failure (cracking) should the hoop strength of the masonry be unable to accept the load (due to inferior workmanship or poor material quality). Referring to Table 1, the hoop stress exerted by the water force is 113.19 MPa (say 114 MPa). Experiments were carried out at the University to confirm that such a pre-tension can be applied to the tank and the description and results of these experiments are shown in a subsequent chapter.

2.3 Stresses in tank foundations and base

Little work has yet been done to calculate stresses in the tank base. This will be included in the next report.

2.4 Stresses due to other factors

Stresses due to other factors such as wind forces, cyclic loading and seismic activity have not been considered in this analysis.

3. The theory of cracking in cement render

(This section is the work of Dr. T. H. Thomas from a paper titled 'The Causes and Prevention of Leakage through Cementitious Renders in Water Tanks')

3.1 Cementitious renders

Renders of cement or lime mortar are commonly used in water tanks when the tank itself is constructed of rather permeable materials such as brick, stabilised soil or even (in the case of underground tanks) of unstabilised soil. The render's primary purpose is water-proofing, for which it should have a sufficiently low permeability to protect the main tank material and to reduce water loss through walls to a tolerable level. Thus we might demand that the render keep wall leakage in a 10 m^3 tank to under 1 litre per day. The render may have secondary functions such as reducing the roughness of a masonry surface so that it can be easily cleaned down, or even of providing a little stability to the wall behind it.

Cementitious renders are usually sufficiently impermeable in themselves, but are so brittle and so intolerant of *tensile* strains that they commonly crack. It is the cracks that leak and preventing cracks should be a focus of research effort.

3.2 Sharing out any shrinkage between 'many' cracks

Shrinkage of a render constrained by underlying masonry is the main mechanism for producing cracks. Tensile stresses in the render are relieved by cracking. Tensile

strains are replaced by a combination of strain-free mortar interspaced by cracks carrying no tension forces. For a given shrinkage and a given material, the total volume or total width of cracks may be more or less fixed. However that total may be variously distributed between few or many distinct cracks. Consider for example the inside of a masonry tank of diameter 2 m where a render incapable of supporting any tensile strain has contracted by 1000 microstrain (0.1%) relative to the masonry. Around a circumference we might expect a total crack width of about 6 mm divided between say *n* individual cracks. We would certainly expect the leakage through an individual crack to be a rising function of its individual width. We might expect the total leakage to fall with rise in *n* - e.g. for two 1 mm cracks to leak less than one 2 mm crack.

Consider an individual crack of length L and width W penetrating a render of thickness T across which there is a pressure drop, from liquid to liquid, of p. The leakage velocities are very low and the key dimension (W) is small, so the Reynolds Number will certainly indicate laminar flow. As water behaves as a fairly Newtonian fluid, we can assume a viscous shear stress in the fluid proportional to the transverse velocity gradient in that fluid. Provided velocities are small compared with that corresponding to conversion of pressure head into velocity head, (i.e. $v^2 << 2p/\rho$) this gives a velocity profile of :

$v = \frac{p}{2T\mu}\left(Wy - y^2\right)$ where v is water velocity in the layer distance y from the side of the crack.

The consequent flowrate through the whole (assumed rectangular) crack is:

$Q = L\int_0^W v dy = \frac{pL}{12T\mu}W^3$ which is proportional to W^3, hence Q/W is proportional to W^2.

This suggests that replacing one large crack by two smaller (half-width) cracks will usefully reduce leakage by a factor of 4.

Inserting numbers: a 100 mm long crack of width 0.1 mm in a render 10 mm thick and subject to a water pressure of 10 kPa (1 m head) will leak 20°C water (μ = 1 mPa s) at nearly 750 litres per day. Replacing this crack by ten 0.01 mm cracks will reduce leakage to 7.5 litres per day. Even this is usually unacceptable, so we are looking to get crack widths below 10 μm. However at these capillary sizes, surface tension effects become dominant.

Surface tension is likely to prevent *any* flow through a plane crack whose thickness W is less than $2\gamma/p$ where γ is the surface tension of water (in Nm^{-1}). Thus for water at 20°C for which γ = 72.5 mN/m, a head of 1 m will not cause leakage through a gap smaller than 14.5 μm.

3.3 Prevention of cracking or of leakage through cracks.

Render cracks may form during ‘manufacture’ of a tank or when water pressure is first applied after manufacture or during moisture cycling through the life of a tank. We are studying the various shrinkage and crack-formation mechanisms associated

with cementitious materials. Generally such materials experience shrinkage of up to 2000 μstrain.

Strategies to prevent or reduce leakage through cracks include:

	Approach	Technique
a	Use non-shrinking render	1. Use mortar with very low water content 2. Pre-shrink the render 3. Cure under water
b	Remove the constraint provided by underlying masonry/reinforcement	1. Add reinforcement after curing 2. Use flexible mortar to lay bricks/blocks 3. Use very-slow setting mortar to lay them 4. Masonry same as render
c	Reduce constraint of base plate	1. Flexible or sliding wall-base joint 2. Thicken wall to reduce bending stresses
d	Distribute cracks (convert into more but smaller cracks)	1. Reinforce with mesh 2. Reinforce with fibre 3. Manipulate bond with masonry
e	Stagger cracks in multi-layer render	1. Plaster, cure, replaster 2. Plaster, cure, groove, fill
f	Use a flexible render	1. More (hydraulic) lime in mix 2. Add polymers like latex to mix
g	Prevent cracks opening under stress (strain induced by water pressure)	1. Hoop tension the reinforcement after curing the render 2. Do so before curing the render. 3. Thicken the masonry to reduce changes in strain when under load.

Table 2 – strategies for preventing cracking in cementitious renders

4. Building materials

One of the aims of this research is to investigate the behaviour and suitability of the materials listed in this chapter for use in construction of a water storage tank and to make recommendations for tank construction techniques using these materials. Tests and test results are shown later in this document. Now we will discuss the general nature of the materials and the general theory postulated for design.

Fired clay brick is a rigid, brittle building material. It is usually used in conjunction with a cementitious binder (such as cement or lime mortar) to form a wall which is strong in compression but weak in tension. There are a number of techniques used to give extra strength where required: this usually takes the form of laying the bricks in a

regular pattern to form an interlocking matrix of brick and mortar. Ties, buttresses, and other building aids and techniques give extra, localised strength where required. It is difficult to improve the tensile strength of brick masonry without creating a composite material by adding steel or timber.

The predominant stresses that will be set up in a tank wall are tensile stresses. As explained in an earlier section, these stresses are due to the water in the tank exerting hoop stresses and bending stresses in the structure. The brick and mortar construction alone cannot be expected to withstand these stresses and it is for this reason that steel strapping is used to take up the predominant tensile stresses. The brick gives rigidity (i.e. stiffness) and mass to the structure while the steel, with it's high tensile strength, performs the task of providing hoop strength. Together, using the cylindrical wall structure, they combine properties to provide a rigid structure with sufficiently high tensile strength.

A further requirement of the tank wall material is that it be watertight, and that it remain watertight for the lifetime of the tank. Brick masonry rarely achieves this requirement and so we will also look at methods of providing a waterproof membrane or lining within the tank. Therefore, we also look at cementitious renders which are applied to the inner surface of the tank wall to provide a continuous waterproof membrane. Later (in a later report) we look at low-cost plastic liners for water tanks.

We investigate the properties of these materials used together (brick masonry – steel – mortar render) to determine the optimum design specification that will give adequate strength, rigidity and watertightness, while minimising the quantity of material used (with the aim of keeping costs to a minimum). Each of the individual materials mentioned above has it's own unique behaviour and the biggest challenge comes in trying to match these materials in such a way that they act in synergistic fashion to provide a composite that gives the required properties.

Much thought has been given to the process required to achieve this synergy. A number of mortar and render types have been investigated and the methods of application and construction regimes have been considered carefully. In this report we will look in some detail at the following aspects of tank design and construction:

- behaviour of lime and cement mortars
- application of steel strapping to cylindrical steel tanks
- stresses in steel strapping in cylindrical brick tanks during application and under load conditions
- initial investigations into shrinkage and cracking in thin renders

4.1 Tank construction materials

Fired clay brick.

Low quality fired clay brick is a building material which is commonly found in many, many countries throughout the world. Brick masonry is a building technique that has existed for more than 4000 years. A variety of soils are available for the process of brick making and the process itself varies in complexity from small field based batch kilns capable of producing a few thousand bricks to large scale continuous mechanised technology capable of producing hundreds of thousands of bricks per day.

Cement mortar.
Nowadays, the most common methods of bonding fired clay bricks is with cement mortar. Cement mortar is a hydraulic binder made from a controlled mixture of sand and Ordinary Portland Cement (OPC), with or without a variety of admixtures that improve the properties of the mortar. Plasticisers are used to reduce the water requirement of mortar and hence improve strength, or to improve the workability for a given water content. Bagged lime is sometimes added to improve workability. A typical mortar would be made up of 1 part OPC to 4 parts clean, well-graded sand, although the quantity can vary enormously depending on strength requirements.

Lime mortar.
Lime has been used as a building material for over 2000 years. To make a lime binder or mortar, calcium carbonate (limestone) is burnt at a temperature of about 900°C to drive off the carbon dioxide and produce calcium oxide (quicklime). The quicklime is then 'slaked' (water is added) to produce hydrated lime powder. If further water is added a lime milk is formed and this is allowed to settle and mature for some time (months) in a pit to form a lime putty. This can then be used for a variety of applications including mixing with sand to form a lime mortar.

Lime mortars have certain benefits over cement mortars. The lime mortar slowly absorbs carbon dioxide from the atmosphere and this causes the mortar to harden as it returns to it's initial state as limestone. This process can take many years and in the meantime the mortar remains plastic. This can be beneficial where flexibility is required or where other less flexible materials are used in close proximity.

5. Reinforcing materials

5.1 Choice of reinforcing material

A number of materials were considered for use as external reinforcing for the tank. There are examples of similar designs from Thailand of brick masonry and steel wire tanks (Vadhanavikkit[6]), and from Uganda of stabilised soil cement blocks with barbed wire reinforcing (personal correspondence with Mr. Kimanzi Gilbert of the Uganda Rainwater Association) and other examples of brick and barbed wire tanks from Botswana.

As mentioned in the introductory chapter it is important that the materials used for the tank construction be available widely in the areas where they will be built (less developed tropical regions) and that the materials be of low cost. Those materials mentioned above i.e. steel wire and barbed wire, as well a number of other similar materials are readily found for other construction and agricultural applications.

In the cases mentioned above there is some concern (on our part) as to the control of the application of the reinforcing material and the amount of tension that can be achieved and maintained. Tying knots in wire, and maintaining tension at the same time, is a difficult business, especially when the wire needs to be tight against the

surface of a wall. We are therefore considering packaging strap as an alternative for the following reasons:

- it is widely available in any country where there is a reasonable manufacturing base;
- the strap is ideally suited to this application with a high tensile strength and flat surface that lays flat against the brick face;
- it is cheap once the tools have been purchased (even the tools themselves are not prohibitively expensive for a mason of reasonable standing). More research is currently underway into prices of strap and tools in developing countries;
- application is easy with the dispenser, tensioning and crimping tool
- a high pre-tension can be easily applied to the strap applying compression forces to the masonry.

Depending on feedback from a number of countries (Sri Lanka, Uganda, India, Kenya in particular), we will later reassess the suitability of this material and possibly look at alternatives.

5.2 Spacing of steel straps

Following on from Chapter 2.1 we are now able to calculate the spacing for the steel strapping, assuming pure hoop stresses are induced by the outward water pressure.

Virtual wall thickness, $t = \frac{w \times t_s}{s}$ ..... *Equation 5*

where, w = strap width
t_s = strap thickness
s = maximum strap spacing

Maximum strap spacing, $s = \frac{2\sigma_{ma} w t_s}{\rho g H d}$ ..... *Equation 6*

For the tank considered in Table 1, we can rearrange Equations 1 and 5 to give Equation 6. If we specify a value for maximum acceptable hoop stress in the strap, $\sigma_{ma,}$ of say 150 Mpa (one third of the yield strength of the steel), we can easily calculate the strap spacing using a simple spreadsheet calculation. Table 3 below is the data output from such a spreadsheet calculation for a small variety of tanks of a similar size and profile to that being considered.

	Distance from top water level						
Tank diameter (m)	<0.5m	0.5m - 0.75m	0.75m - 1.0m	1.0m - 1.25m	1.25m - 1.5m	1.5m - 1.75m	1.75m - 2.0m
1.00	398	265	199	159			
1.25	318	212	159	127			
1.50	265	177	133	106	88		
1.75	227	151	114	91	76	65	
2.00	**199**	**133**	**99**	**80**	**66**	**57**	**50**
2.25			88	71	59	50	44
2.50				64	53	45	40

Table 3 – Maximum strap spacing for a variety of tank diameters and depths

It can be seen that the minimum strap spacing (at the base of the wall) is less than the thickness of one course of bricks (80mm) and so two straps will be used on each course of bricks, giving a spacing of approximately 40mm.

6. Laboratory experiments

6.1 Introduction

The experiments described in this chapter were carried out at the University of Warwick between January and April 1999. Forming the basis for the tests were a number of brick masonry cylinder specimens built on a civil engineering 'strong floor'. Such a specimen is shown in Figure 4 below. The specimens were of internal diameter 1.5m and varying height. These specimens allowed experimentation and observation of mortar behaviour, cracking of renders with a number of different additives, application and loading of steel packaging strap, as well as providing through practice an insight into the merits of the construction technique.

Figure 4 – Brick masonry cylinder specimen

6.2 Mortar observation – lime and cement mortars

Two types of mortar were used for constructing the cement mortar specimens; cement mortar and lime mortar. The main purpose of this test was to observe the following:

- the plasticity of the mortar and the associated ability of the brick masonry to 'move' in compression;
- the behaviour of the brick masonry under load – particularly the load transfer characteristics of the masonry;
- render behaviour (particularly cracking) when applied to each type of brick masonry.

The cement mortar is composed of the following:

Sand cement ratio	5:1
Water cement ratio	0.5 (i.e. water content 50% by weight of cement)
Mortar plasticiser	10% of water content

The lime mortar is made up of 3 parts well-graded sand to one part lime putty. No water is required.

The first part of the experiment consisted of simply observing the brick masonry when applying the steel strap for signs of movement and, secondly, observing the tension in the strap to determine the ability of the masonry to go into compression without distortion (i.e. that the masonry is sufficiently rigid). Early in the experiment it was decided that the lime masonry was insufficiently rigid in the early days after construction and that, without further investigation of its properties it would be unwise to use this material for this application. Although the characteristic property of lime mortar to remain plastic can, in some cases, be a positive advantage (we subsequently see that render cracking is greatly reduced - almost eliminated even - when using lime mortar), it does mean that a wall built using lime mortar will be far less rigid than its cement mortar equivalent.

Cement mortar gives a strong, rigid wall with no sign of movement during application of the strapping. The load that can be applied to a cement mortar, brick masonry tank is outlined in Graphs 1 and 2. The figures shown in this graph demonstrate the rigidity of the material at characteristic loads (and beyond). Detailed tests of this nature have not been carried out to date on the lime mortar specimen, but visually the wall of the lime mortar specimen can be seen to move when strapping is applied.

The behaviour of renders on each of the specimens is detailed in the following chapter.

6.3 Render – shrinkage and cracking

A number of tests were carried out to observe cracking of renders of different types on specimens constructed with two different mortar types (cement and lime mortar). The base render was made up of 4 parts sand to one part OPC and a water content of 0.4 (this was slightly exceeded in most cases to provide a workable render) Mortar plasticiser was added in all cases at 10% of water content. The render thickness varied due to the uneven surface onto which it was being applied, but in general the thickness remained within 5 – 15mm. After a day the wall was painted with a thin white paint to help with the location of cracks (see Figure 5 below). Any visible crack was measured using a hand held x20 microscope. Shrinkage was measured by observing the separation of the render from the wall at the top of the specimen. In

Table 5, separation is indicated as a percentage of the visible joint line over which separation occurred and the minimum and maximum value of separation width (in mm).

Figure 5 – Cracks in renders

The additives used during the tests are shown below:

- **Mortar plasticiser** – a proprietary plasticiser used for mortars and renders in the building industry.
- **Re-in fibre** – a polypropylene fibre of 50 micron square cross-section and 6mm in length. This is a UK construction industry building material used for preventing cracking in thin renders and screeds.
- **Febond SBR** – a proprietary waterproofing solution for use in renders and for other application. It is a styrene-butadiene co-polymer latex specifically designed to improve water resistance and durability.

Five render types were tested. All were cement based renders. These are listed below in Table 4.

Render type number	Sand : cement ratio (by weight)	Water cement ratio (by weight)	Mortar plasticiser content (as %age of water)	Other additive	Curing regime
01	4:1	0.4 – 0.5	10%	none	basic*
02	4:1	0.4 – 0.5	10%	none	7 days**
03	4:1	0.4 – 0.5	10%	re-in fibre	basic*
04	4:1	0.4 – 0.5	10%	re-in fibre	7 days**
05	4:1	0.4 – 0.5	10%	sbr	7 days**

Table 4 – composition of renders used for cracking and shrinkage tests
*** basic infers no special curing regime employed – render left to cure in open air**
**** 7 days curing under soaked Hessian cloth**

Cement mortar used to lay bricks					
Render type (see Table XX)	Ave. crack length (mm)	Crack length per (mm /m^2)	Ave. crack width (mm)	Maximum crack width (mm)	Separation *
01	70.37	1135	0.13	0.35	90% 0.05 – 0.75mm
02	54.5	2546	0.29	0.55	10% 0.1 – 0.75mm
03	31.0	53	0.1	0.1	90% 0.05 – 1.5mm
04	No test				
05**	No test				
Lime mortar used to lay bricks					
Render type (see Table XX)	Ave. crack length (mm)	Crack length per (mm /m^2)	Ave. crack width (mm)	Maximum crack width (mm)	Separation *
01	No test				
02	0	0	0	0	no separation
03	No test				
04	0	0	0	0	no separation
05**	69.33	2207	0.32	1.3	no separation

Table 5 – Cracking in cement renders – values for a number of test results after 7 days
*** Separation given as a percentage of separation at the visible joint around the perimeter at the top of the specimen wall. Variation in crack width also given.**
**** although manufacturers instructions were followed carefully there is some concern about the validity of these results – possibly an incorrect quantity of SBR was added to the render.**

The results given in Table 5 lead us to a number of tentative conclusions:

- the re-in fibre (renders 03 and 04) significantly reduces cracking in renders;
- improved curing of renders on cement mortar wall (renders 02, 04 and 05) helps prevent separation at the cost of increasing cracking i.e. adhesion to the wall improves causing greater cracking – this is advantageous if we then seal the cracks with a nil coat (cement slurry) or other proprietary sealant ;
- separation of render is much greater on cement mortar walls due to the rigidity of the wall. In the case of lime mortar, the wall moves as the render shrinks, preventing cracking – as mentioned in an earlier chapter this is very beneficial for achieving crack-free renders but not so beneficial in terms of loss of rigidity.
- no conclusions are made about the characteristics of SBR render due to uncertain results

Further work is required to gain a better understanding of renders and their behaviour on internal tank walls. This work is outlined in the final chapter of this report.

6.4 Reinforcing straps – initial tensile strength tests

Initial tensile strength tests were carried out on a number of packaging straps to determine the strength of each (manufacturers specification was not available for all). The aim of the tests were to investigate the strength of woven polypropylene strap and the effect of crimping steel straps. The tests were carried out at the Universities civil engineering laboratory using the tensometer machine (see Figure 6).

Without going into detail here it can be stated that the *polypropylene* strap was insufficiently strong for the application under consideration with an Ultimate Tensile Strength half that of steel with ten times the strain.

In all cases the singly crimped steel band broke at the crimp at well below maximum UTS. During practical tests on the brick specimens, in which the strap had been fitted with two crimps, the strap broke remote from the crimp at a value close to UTS.

6.5 Reinforcing straps – applying the strap

This experiment aimed to investigate:

a) the pre-tension set up in the reinforcing straps during application with the tensioning tool - as mentioned in chapter 2 it is necessary that sufficient pre-tension exists in the strap after application to support the masonry in compression and prevent cracking when the tank is initially (and subsequently) loaded.
b) the distribution of the tension in the strap upon application – this experiment was to test the assumption that circumferential tension in the strap would vary due to the friction between the wall and the strap, from a maximum near the tensioner, to a minimum on the opposite side of the tank.

The experiment involved measurement of the strain in the reinforcing strap using strain gauges. The strain gauges had been calibrated beforehand (see Figure 6 below) so that the load in the strap could be derived directly and accurately from the strain values. Three strain gauges were placed on a single strap, at 0, 90 and 180 degrees around the specimen circumference, and readings taken as the strap was applied (see Figure 7).

Figure 6 – Calibration of strain gauges using tensometer

Figure 7 – Showing strain gauge fitted to the steel strap

Box 1

Applying the steel strap
The strap is applied to the brick masonry specimen using a manually operated tensioning tool. Once fully tensioned the strap is crimped (see Figure 9 below) using specially designed crimps and crimping tool and then the tensioning tool is removed. It can be seen from Figure 8 below that the tensioning tool holds the strap away from the wall in order to allow access for the jaws of the crimping tool. After initial experiments there was some concern about the loss of tension when the tool is removed.

Graph 1 shows the steps taken during the experiment and the load registered by the strain gauges. The term 'redis' in the graph means redistribution of the load. This was achieved by using a screwdriver to prise the strap away from the masonry slightly (moving around one brick at a time) to allow the tension in the strap to be redistributed.

Box 2

Strap pretension required to balance water pressure forces and prevent tensile stress being set up in masonry
- From Table 1, maximum hoop stress in steel due to water pressure is 114 Mpa
- Area of cross section of steel strap = 6.5mm^2
- Tension required in strap = 6.5 x 114 = 741 N

An analysis of the graph clearly shows the increase of tension in the strap as the strap is tightened and also shows that a certain amount of redistribution of that load takes place during the 'redis' phase. The drop off in tension during removal of the tool without packing (as illustrated in Figure 8) is completely unacceptable with the final tension being a small fraction of the tension created by the tool and insufficient to put the masonry into compression (see Box2). We see, however, that the tool is capable of tensioning the strap sufficiently – values of almost 2000 N being achieved during the tensioning phase.

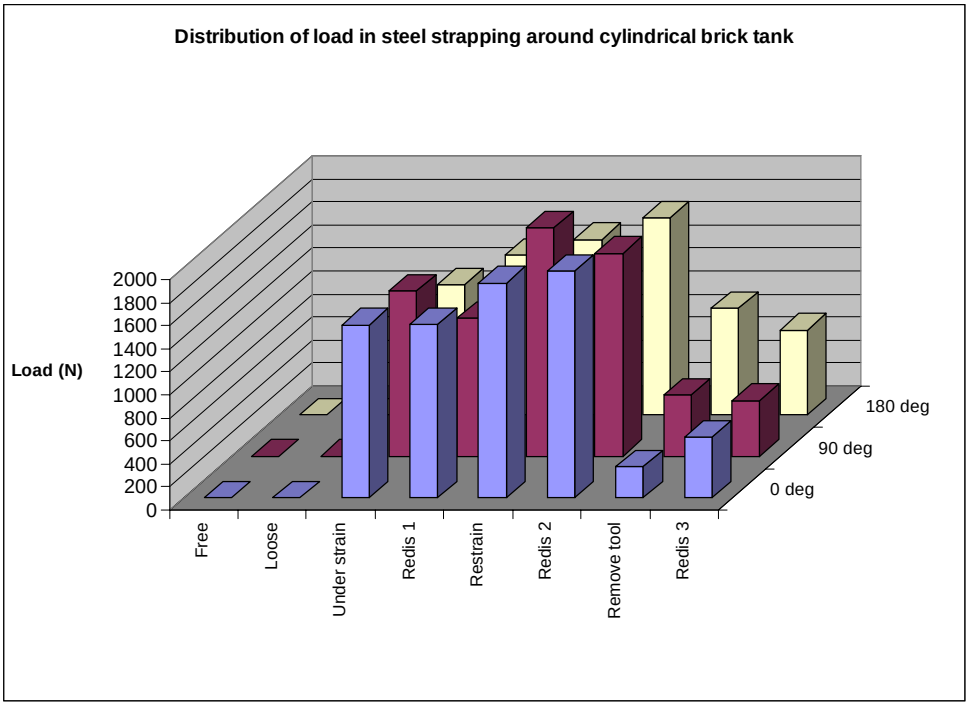

Graph 1 – Distribution of load in steel strap around cylindrical brick tank during application

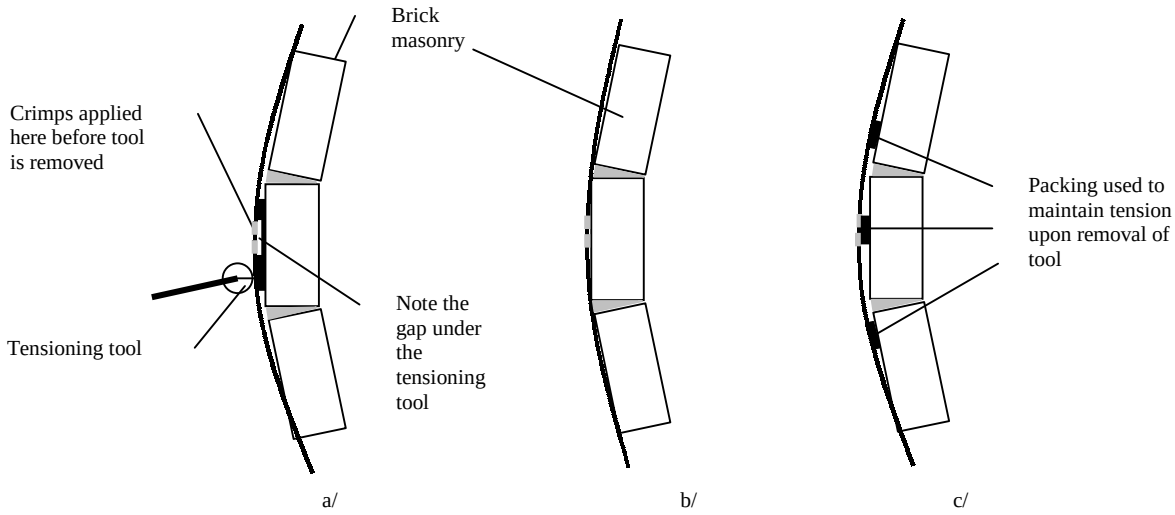

Figure 8 – showing tensioning and crimping arrangement for steel strapping a/ during the tensioning and crimping process b/ when crimping is complete and the tensioning tool has been removed and tension reduced c/ maintaining tension by using packing

Figure 9 – photograph of straps showing crimps

Figure 8 shows the method used to pack the strap to prevent loss of tension upon removing the tensioning tool. If this process is carried out the tension can be maintained as shown in Graph 2. In this case the tension, at 1777 Newtons, is more than double that required to prevent the masonry going into tension upon pressure loading. Practically, this involves placing some packing material behind each strap as it is applied. Further work is needed to define a practical method and a suitable material for this purpose.

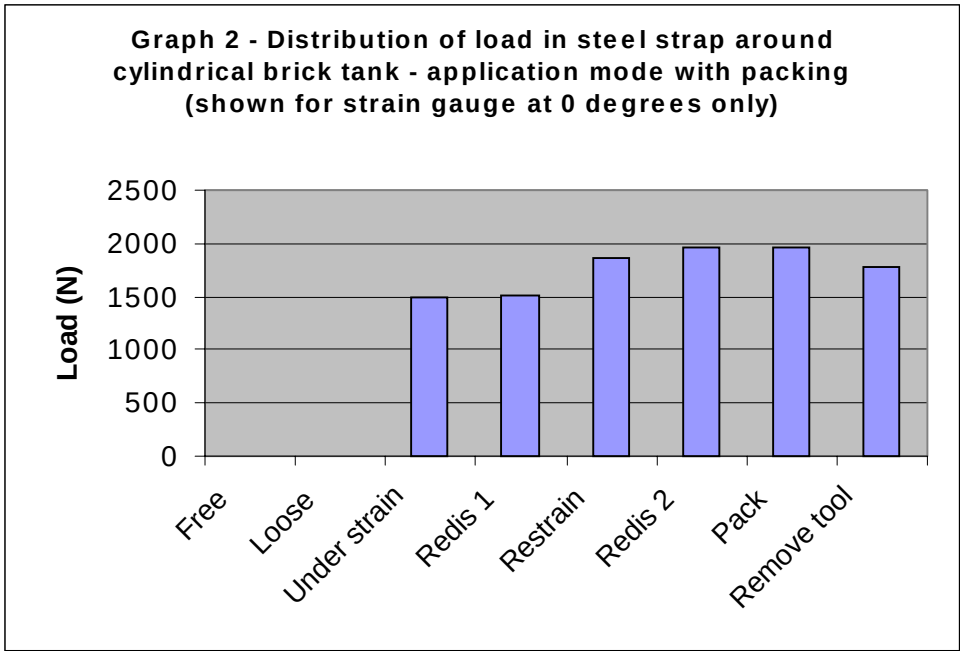

Graph 2 - Distribution of load in steel strap around cylindrical brick tank - application mode with packing (shown for strain gauge at 0 degrees only)

6.6 Reinforcing straps – loading and ultimate tensile strength

A test was carried out to determine the maximum load that can be applied to an externally reinforced brick tank. The aim of the test was to simulate water pressure acting on the wall of the tank and to observe the behaviour and failure mode of the tank as pressure was increased. Ideally the test would have been carried out using a sealed tank that could be pressurised to the point of failure but this was not practical at the University, especially indoors on the civil engineering strong floor. To simulate water pressure a steel expansion ring was manufactured as shown in Figure 10 below. The ring was made from 3mm mild steel to provide enough rigidity to prevent buckling but enough flexibility to take up the shape of the interior surface with which it came into contact. The ring was expanded using two 1 tonne hydraulic jacks, as shown in Figure 11. A load cell was placed in series with the jack to measure the applied load and is also shown in Figure 11 (this had been calibrated earlier). The ring spanned 2 courses of bricks that with hindsight, should have been free floating, but were not. The straps on the specimen were fitted with strain gauges at 0°, 90°, and 180° to measure the stress induced in the strap. Thus we could monitor the increase in load in the strap due to increased (simulated) water pressure.

Figure 10 – Specimen under test, showing expansion ring

As the hydraulic jacks were extended the ring slowly expanded putting the strap into tension. The jacks continued to be extended until the straps failed and the masonry broke. During this time observations were made of the following:

- the applied load
- the cracking of the render
- the cracking of the masonry
- the strain (and hence load) in the strap

Graph 3 (histogram) shows the general trend of increased load in the straps as the expansion ring is opened. Noting the horizontal axis of the histogram we see that jack pressure in the expansion ring is not rising continuously. Graph 4 shows a clearer representation of what is happening in one of the straps – namely the strap at 90°. There are some interesting phenomenon to observe:

1. Firstly, the force in the expansion ring is much greater that the force in the strap. There are a number of possible explanations for this:
    - the two courses of brick under test are not free-floating and so some energy is being required to stress the lower courses of bricks
    - in the early stages of the test, until the masonry fails, some of the load is taken by the masonry itself
    - there are four straps fitted on the specimen, all of which are accepting some of the load – two strap are directly under load

2. We see two distinct regions (see Graph 4 below), one where the pressure in the ring rises linearly with the load in the strap (region 1) and then a region where the pressure in the ring rises little, and indeed starts to fall, as the load in the strap increase and the ring continues to expand (region 2). This can be explained as follows (either or both of the following acting at any time):
    - as the cracking in the specimen worsens, the energy that was taken up 'bending' the lower part of the wall is now redistributed in the upper part of the wall (the test area) as the joint between the two fails.
    - the masonry breaks locally, and there is a significant repositioning of the brick (local to the ring) within the masonry as the ring expands further.

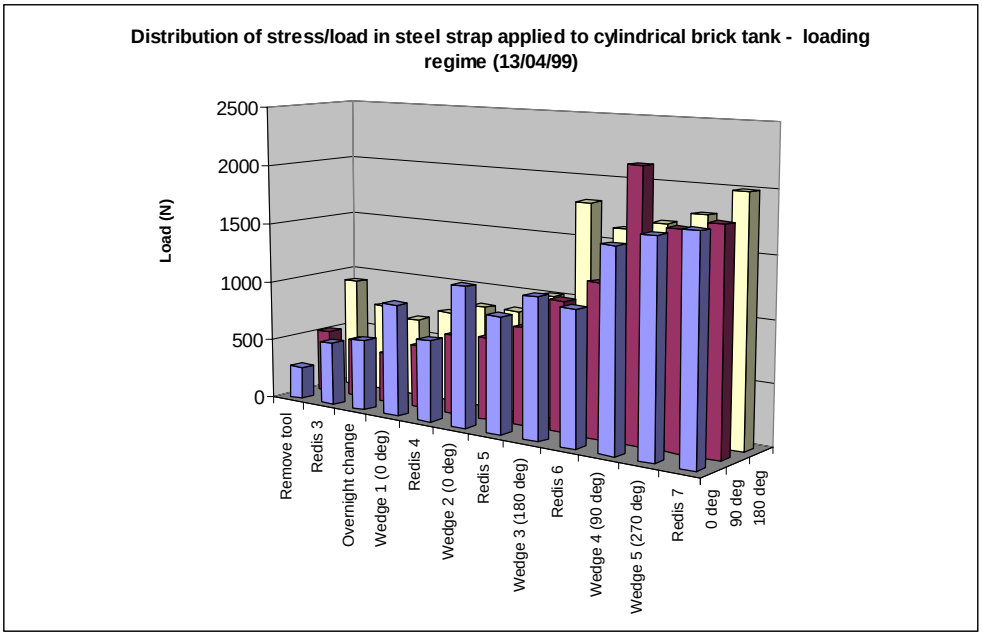

Graph 3 – Loading cylindrical tank using expansion ring

3. Large vertical and horizontal cracks appear (see Figure 12):
    - the horizontal cracks are due to shear as the upper section of the specimen wall shears away from the lower section
    - the vertical cracks are obviously the result of tension as the pressure is applied to the ring

Figure 11 – Specimen under test, showing close up of hydraulic jack and load cell

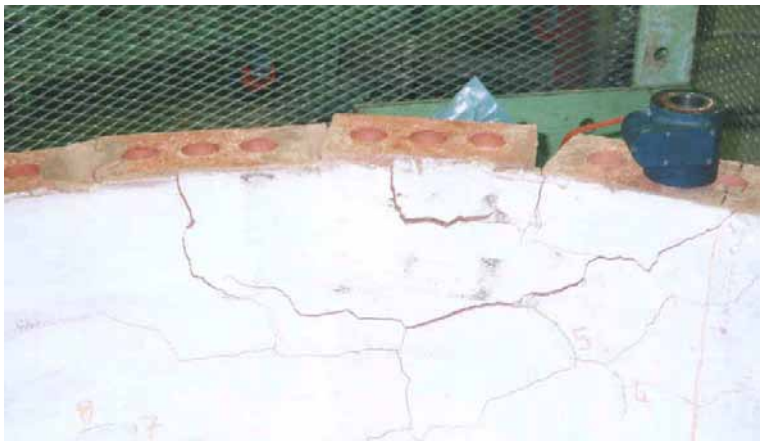

Figure 12 – Cracking in specimen after pressure test

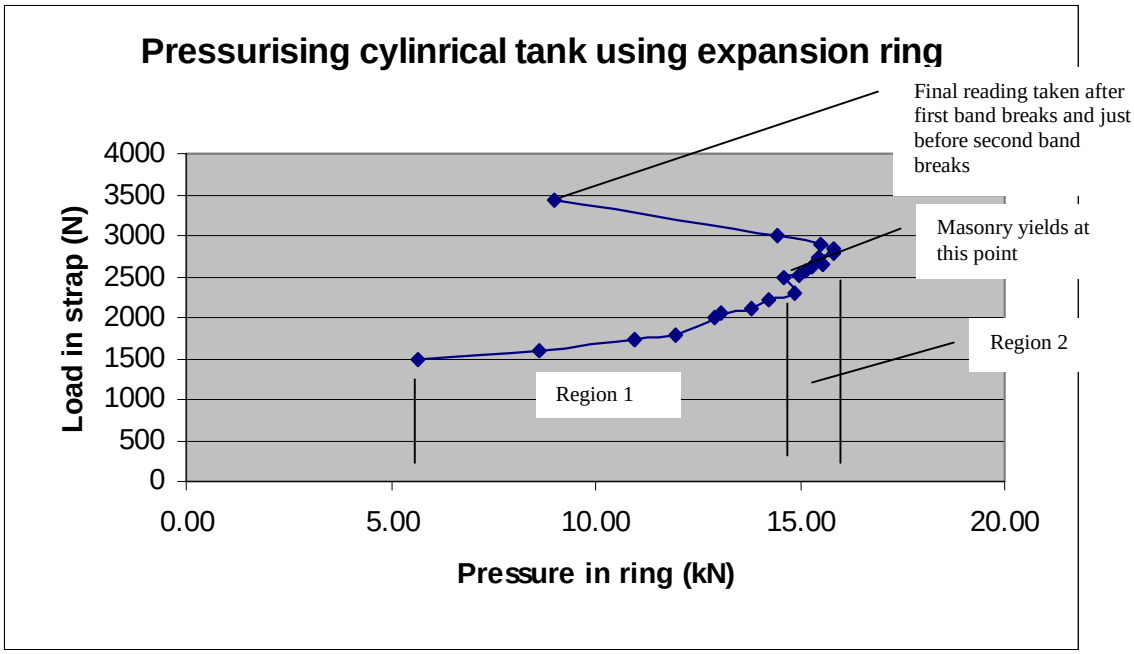

Graph 4 – Pressurising cylindrical tank using expansion ring – strain gauge readings at 90 degrees

In conclusion it should be strongly noted that although what we see is a realistic representation of what was going on in the test specimen during the test, and is of some value to us in understanding the behaviour of cylindrical tanks, it is not what we were looking for! This was due to improper experimental design. A further test will be carried out on a free-floating specimen i.e. a specimen set on a sliding ring to simulate an elemental horizontal slice of tank. This will hopefully yield results that will be of more interest to us.

7. Conclusions

The general conclusion is that the single skin, externally reinforced, brick tank is a viable alternative to more costly tank types available at present. The experiments carried out so far have shown that the construction technique adopted is sound, but further work is still required to achieve a full analysis of the ideas under discussion which will lead to a final design and set of construction guidelines for this type of tank. The work that still needs to be carried out is outlined in the following Chapter

8. Further work to be undertaken

The following have been identifies as areas needing further work:

From section number:	Description of work
1.2	Research into plastic linings for tanks
2.1	Carry out full computer analysis of stresses in cylindrical tanks
2.3	Analysis of stresses in foundations of tanks Foundation design
2.4	Analysis of stresses due to other forces (e.g. wind, earthquakes)
5.1	Research the alternatives to steel strap e.g. methods of adequately tensioning steel or barbed wire
6.2	Further tests on lime mortar specimens - strap application and loading tests
6.3	Further tests to characterise the behaviour of renders – cracking, shrinkage and adhesion with a variety of admixtures and curing regimes
6.6	Tests of free-floating brick cylinder specimens using both cement and lime mortars
Other	Preparation of design and construction guidelines for this style of tank. Construction of full size tank to look at the following: ▪ tank construction techniques ▪ stress analysis in full size tank – including cyclic loading and temperature effects ▪ shrinkage and cracking due to water pressure loading ▪ leakage

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Low-cost, thin-shell, ferrocement tank cover

Instructions for manufacture

Development Technology Unit
School of Engineering
University of Warwick
Coventry CV4 7AL
Tel: +44 (0)1203 522339
Fax: +44 (0)1203 418922
dgr@eng.warwick.ac.uk
http://www.eng.warwick.ac.uk/DTU/

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Introduction
The thin-shell ferrocement tank cover is designed in such a way that it can be manufactured without the use of a mould or shuttering. It can also be manufactured remote from the tank to which it is to be fitted and moved into place once complete. The aim is to reduce the cost of the tank (cover) by eliminating costly shuttering or moulds and by reducing the quantity of material used to manufacture the cover. It also means that the cover can be removed at a later date for maintenance, refurbishment or cleaning. The cover can be manufactured by two persons (one skilled and one unskilled) in a single day (with some time required after that for curing) using tools required for the construction of a simple cylindrical ferrocement tank.

The design is based on a frame known as a reciprocal frame, that has spokes that, when loaded, put little radial loading onto the structure on which it sits. The frame is covered with a wire mesh that is then rendered with a sand cement mix.

Details of the construction process are given here for a 2.0m diameter cover that has an inspection chamber opening of 0.5m. The cover pitch is 25°. Strength tests have proved acceptable up to this diameter. No guarantee is given for greater diameters. The spoke angles have to be recalculated for different diameters – this is one disadvantage of the cover design.

Benefits of the thin-shell ferrocement tank
- low cost – reduced use of materials
- no shuttering or mould required
- strong and lightweight – the tank cover is designed to be strong (through good quality control) and light at the same time
- good quality control can be achieved through easy working environment
- can be manufactured by two people in a single day (one skilled and one unskilled)
- no clambering on top of tanks required during construction
- can be cured easily – in the shade and at ground level
- can be batch produced at one site

Reciprocal frame construction guidelines – for 2m diameter cover

Materials and tools

Materials	Tools
♦ 8mm reinforcing bar – 40m ♦ tie wire – 0.5kg ♦ chicken mesh (0.9m wide; 10m long; ½" mesh) ♦ sand ♦ cement ♦ mortar plasticiser ♦ water ♦ plastic sheeting (reusable)	♦ hacksaw ♦ pliers ♦ tin snips ♦ vice (handy if available) ♦ masons trowel (small) ♦ masons trowel (large) ♦ plasterers float ♦ shovel ♦ buckets (2) ♦ wheel barrow (optional)

Stage 1 – making the frame

- Choose a location with plenty of space to work. The procedure requires bending long lengths of reinforcing steel and so a clear working area is essential. Also a ground space of 2m diameter will be needed where no other activity will be carried out for a week (while the cover is cured).
- The first step is to set up a jig for bending the reinforcing bar. The jig is made up of two pegs 5cms long, set about 5cm apart. The steel is placed in the jig and bent as shown in Figure 1. The jig needs to be fixed so that it cannot move when the steel is bent. A workbench is ideal where the pegs can be put into the vice. Alternatively the pegs can be driven into a heavy piece of timber and this arrangement can be used effectively. Steel re-bar (8mm) can be used to form the pegs, but slightly heavier steel is better.

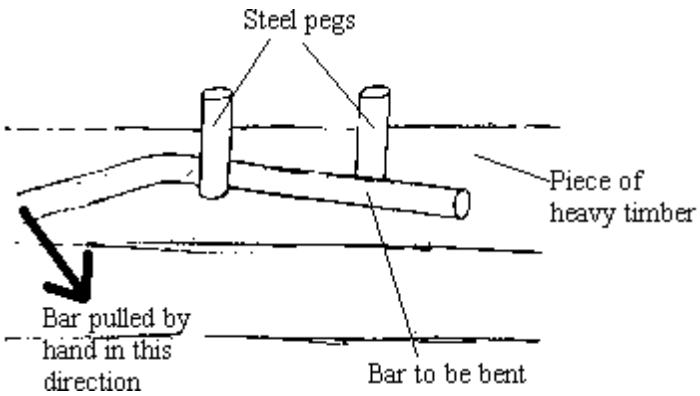

Figure 1 – Jig for bending steel reinforcing bar

Tip:
When bending the re-bar it does not bend exactly where it makes contact with the jig peg. The bending takes place a cm or two on the pulling side. This has to be allowed for when bending. The bending radius can be quite large because of the thickness of the steel. This doesn't present any real problems here.

- The next step is to bend the 8mm reinforcing steel into hoops. Four hoops, diameter 0.55m, 1.0m, 1.5m and 2.0m are required. To make the procedure easy, a peg can be knocked into the ground and used as a centre around which the four circles can be drawn using string and a marker (also mark the positions of the 8 spokes at 45° intervals for later use). The steel can then be bent gently in the jig to match the circles. The hoops ends are tied with two or three pieces of tie wire. For this the steel is cut slightly oversize to allow for tying. The cutting lengths are given in Table 1. Where the cover is to be fitted to an existing tank the outer hoop should be bent to fit the mean radius of the top of the tank wall and any irregularities in the shape should be taken into consideration.

Diameter	Steel cutting length (add 0.2m for overlap for tying in all cases)
0.55m	1.72m (1.92m)
1.0m	3.14m (3.34m)

1.5m	4.71m (4.91m)
2.0m	6.28m (2.48m)

- At this point all but the outer (largest) hoop can be put aside until later.
- The next step is to bend the spokes. There are eight in number and are bent in the jig to the dimensions shown in Figure 2. The cutting length is 1.33m. To aid the bending, the angles can be marked out on the ground (or on a bench) beforehand and then the bent steel can be matched against this. The angles to mark are:

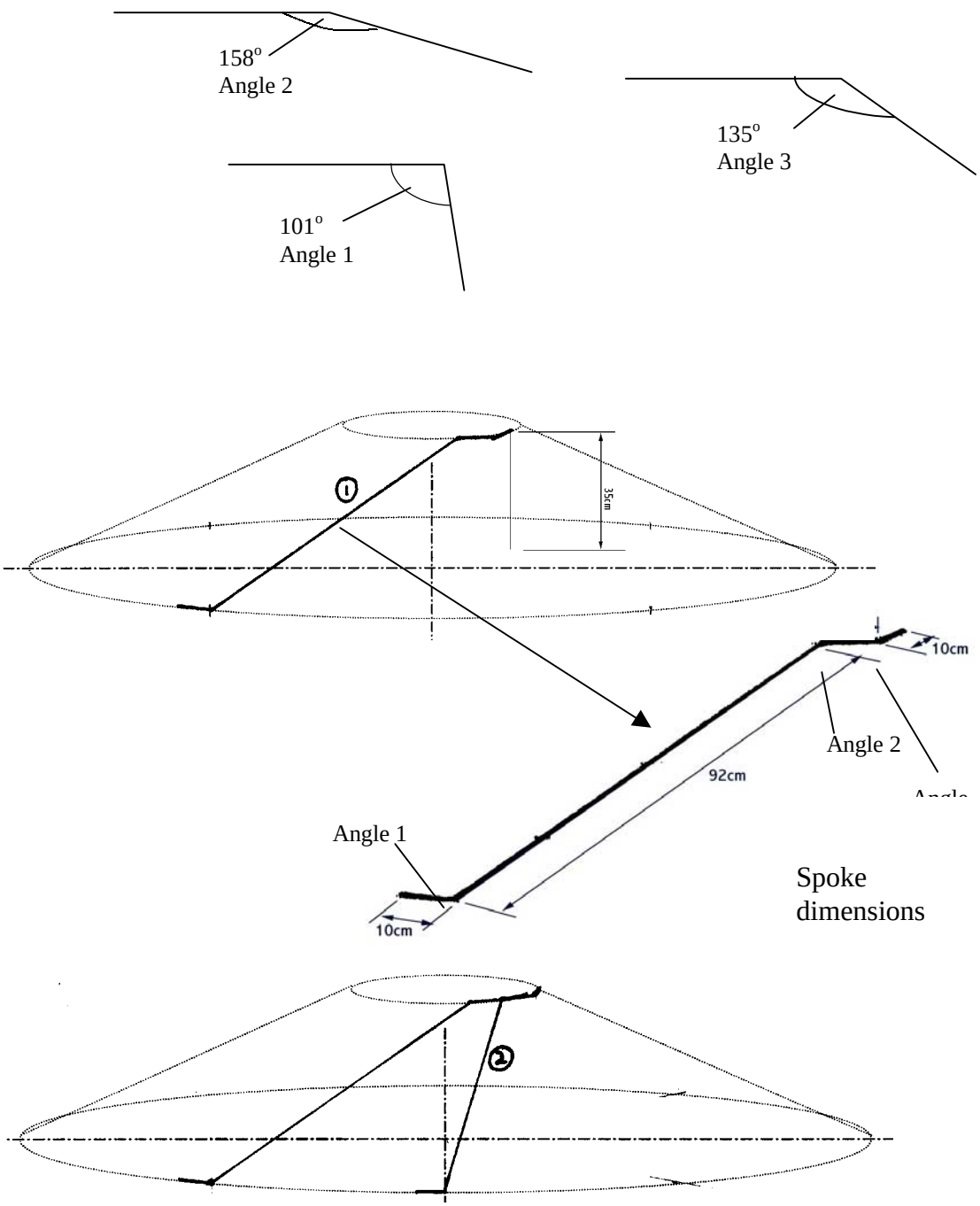

Figure 2. Dimensions and locations of frame spokes

- It is recommended that Angles 1 and 3 are bent first. These are bent in the same plane. The spoke is then turned through 90° and Angle 2 is bent.
- Eight secondary spokes are also cut to a length of 75cm. These are wired to the frame as shown in Figure 3 and support the mesh to reduce the 'panel' size.

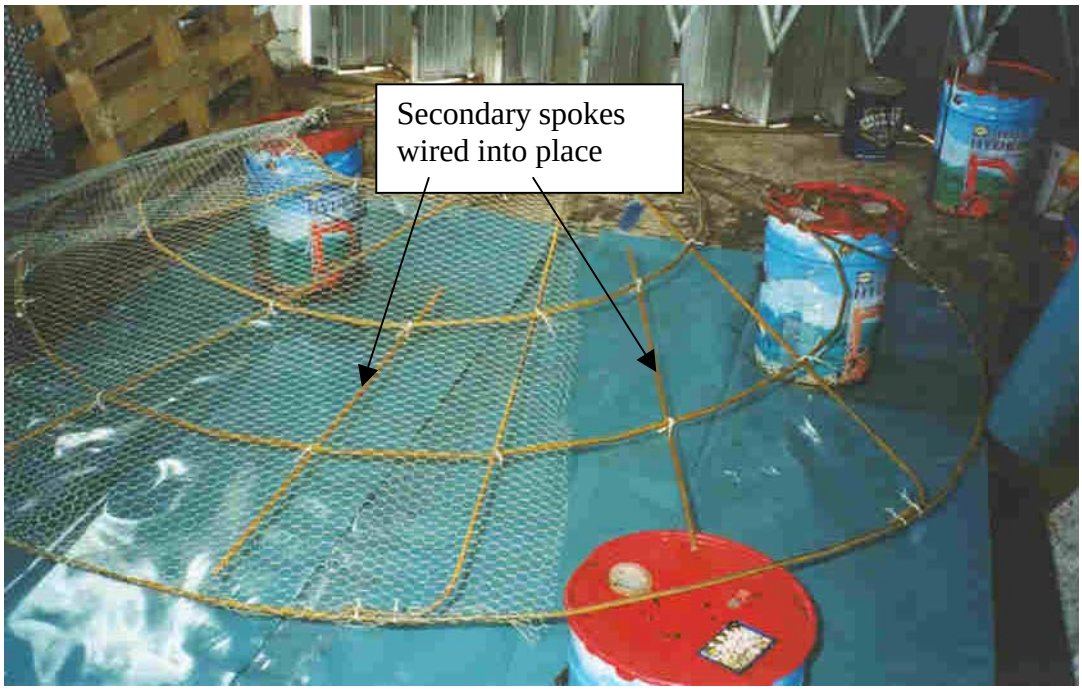

Figure 3. Secondary spokes in place

- Now the spokes are placed one by one inside the outer hoop (as shown in fig 2.) to slowly form the cover frame. It is convenient to have the outer hoop sitting on the ring marked out earlier with the position for the 8 spokes marked also. THERE IS NO INNER RING. This is made up as the separate spokes are joined together. (See Figure 4). Spoke one is placed on a support (a box or piece of wood) which is 35cm high. This is the height of the frame from the ground to the plane of the circular cover opening.

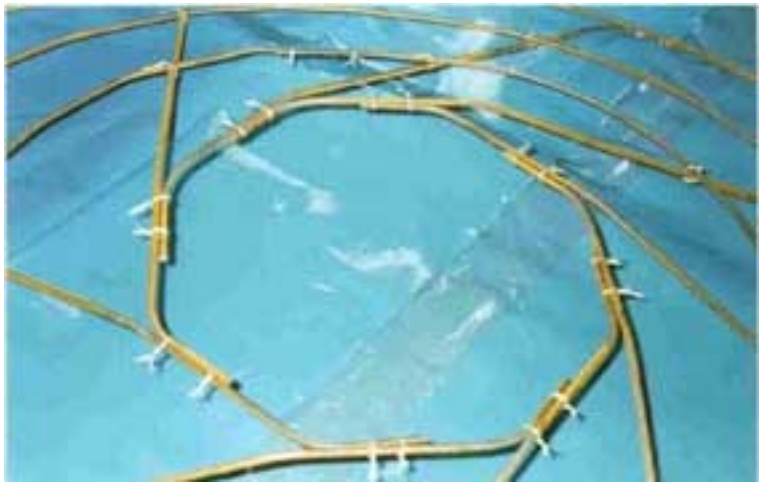

Figure 4. Showing the formation of the inner ring from individual spokes

- Tie the first spoke to the inner side of the outer hoop as shown in Figure 5.**(no 11).**

Figure 5. Showing arrangement for tying spoke to outer hoop.

- Place the next spoke 45° around the perimeter hoop (these spacings were marked earlier) and tie it to the first spoke as shown in Figure 6. Continue in this way until the final spoke is tied to the first spoke and all eight spokes are in place.

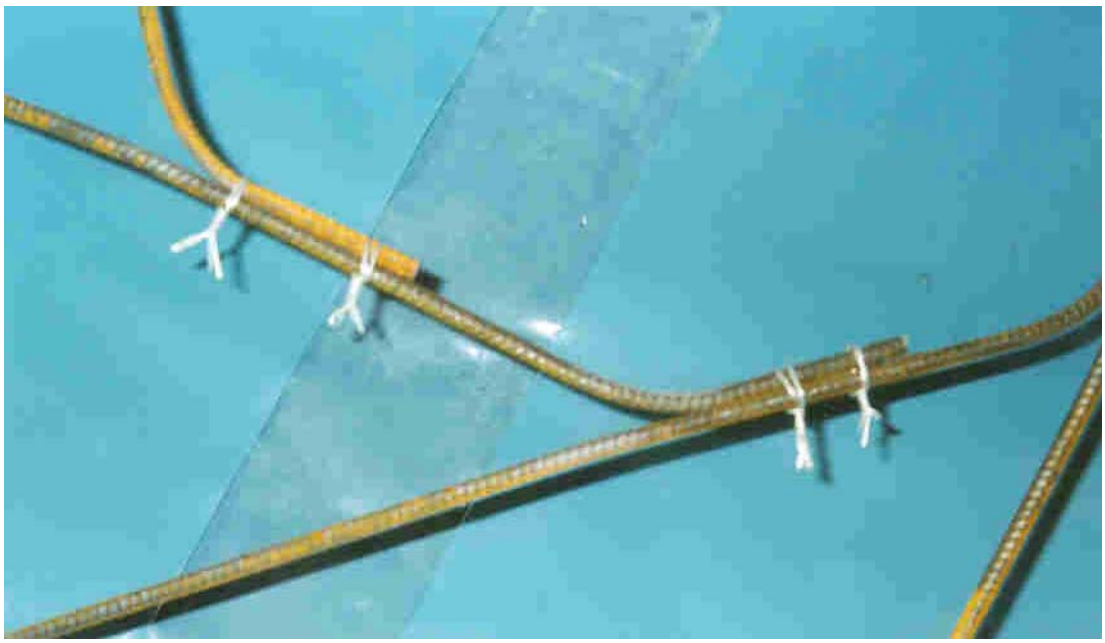

Figure 6. Arrangment for tying spokes to each other.

- Put the two inner hoops in position and tie them in place (Figure 7). The small inner hoop that was formed earlier will be used when the access hatch lip is made later.
- The frame in now ready to have the chicken mesh attached.

Figure 7. The frame with hoops in place.

- Use chicken wire of 0.9m roll width with a mesh size of ½ inch. Ten metres length is required. Two layers of chicken netting are applied.
- Eight pieces of chicken wire are cut to the dimensions shown in Figure 8. Two pieces can be cut from a 2.4m length of netting if cut as shown. A template can be drawn on the ground to aid cutting.

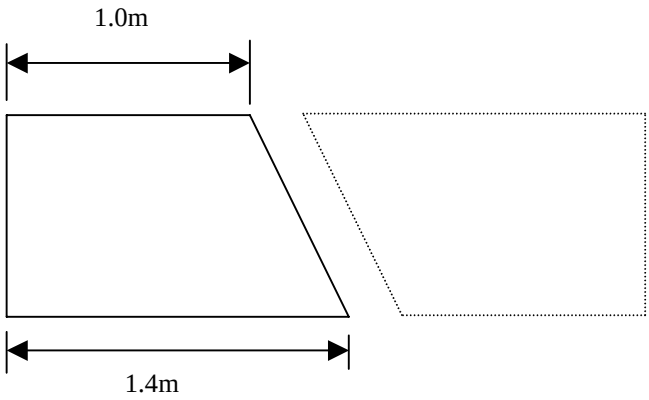

Figure 8. Cutting size for chicken mesh

- The pieces of netting are placed on the frame as shown in Figure 9 and Figure 10 and the overlapping edges are folded over and tied in place, pulling the wire as tight as is possible without distorting the mesh. Use the rough edges of the netting to tie the folded edges into place. Use as little tie wire as possible at this point, as the netting will tied securely when the second layer is in place.

Tip: a screwdriver can be used to pull the loose wires or end loops through holes in the mesh to tie the mesh in place.

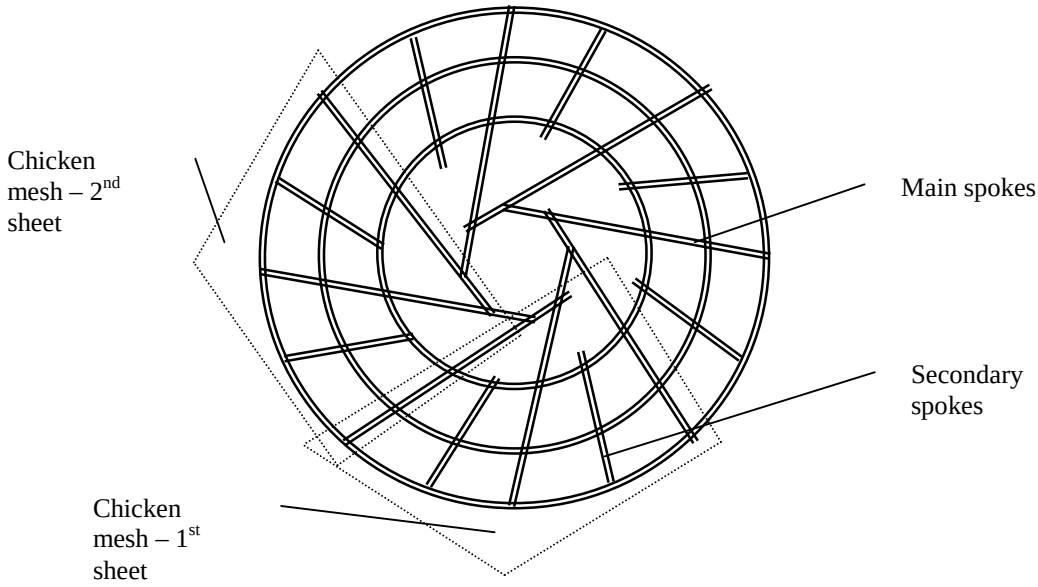

Figure 9. Pattern for application of chicken mesh

Figure 10. Applying the chicken mesh.

- When the first layer is complete start the second layer one spoke out of phase with the first and complete in the same manner.
- Carefully check that the mesh is folded as flat as possible and that both layers are close together. Tie the netting at regular intervals using the tie wire so that the netting is close to the rebar. Bend all tie wires into the plane of the cover. Remember that we are trying to keep the cover as thin as possible.
- The cover is now ready for the rendering (Figure 11).

Figure 11. Cover ready for rendering

Stage 2 - Rendering the cover

Materials

Sharp sand – 150kg
OPC – 30kg
Mortar plasticiser – 0.5 litres (soap powder can be used as a substitute)
Water - 20 litres (approximately)

Procedure

- It is important to use good quality materials and to maintain good standards of workmanship throughout the rendering process. The aim is to apply a layer of mortar to the chicken mesh that is as thin as possible. This, in practice, will vary between about 15mm and 25mm with an average thickness of about 20mm. The first coat is applied from the top and second coat applied from below.
- Put a plastic sheet on the ground so that render mix which falls through during rendering can be reused.
- Elevate the frame so that work can be carried out from above or below. Waist height is most suitable. The frame should be raised on 4 posts or boxes so that it is stable and can withstand the forces applied during rendering. A support should also be placed in the centre to prevent the centre sagging under the weight of the render (see figure 11 above).
- Render preparation: a mix of 3:1 (sand:cement by *volume*) is used. A sharp sand should be used i.e. not a fine sand but sand with a moderately large grain size. There should be no silt or other contaminant in the sand. (**See guidelines for checking sand quality)**. Ordinary Portland Cement (OPC) is used. The quantities should be carefully measured using a container – a bucket for example (do not measure using a shovel as this can be very inaccurate).
- The consistency of the render is very important. It should be dry enough not to fall through the netting while being plastic enough to be workable with a trowel. A mortar plasticiser is required to improve the workability of the render. This means that the water:cement ratio can be kept low while still keeping the render plastic. This ratio should be kept to approximately 0.4 by weight (i.e. 10 parts cement to 4 parts water by *weight*). Low water content not only gives a render which is easily applied to the mesh, but also gives improvements in strength and permeability of

the cured render. In practice it is difficult to control the water:cement ratio because there is usually an unknown quantity of water in damp sand and plasticity is often achieved before the minimum measured ratio is met. The practical method involves experimentation to achieve the desired plasticity with minimum water content. The plasticiser should be used according to the manufacturers instructions.

Tip: use soap powder instead of mortar plasticiser. Experiment to find a suitable quantity.

- Keep mixes small because the render 'goes off' quickly. It may be wise to mix enough render for the whole job and then add water to small amounts as required.
- Applying the render: this is fairly simple to do. Use a plasterers float and a small trowel. Put the float behind the mesh and work the mortar through the mesh onto the float as shown in Figure 12. Wipe the float away so that the mortar is slightly smoothed on the underside. Work small areas – take one 'panel' at a time and complete it. Some of the mortar will fall through onto the plastic sheet – this can be picked up immediately for reuse. Remember that the aim is to apply a very thin layer of mortar. The technique can be easily learned with a little practice.

Figure 12. Applying render to the chicken mesh.

- Where the cover stands on the supports, leave a small section of the outer hoop un-rendered. Wires can be threaded through these gaps later for lifting the cover into place and any securing to the tank body can be done here.
- The outer edge of the tank should be rendered roughly as this will blended into the tank wall when it is put into place.
- Once the first layer of mortar has been applied the cover should be left for a day to allow the render to gain strength.
- The area within 10cms of the inspection opening should be roughened for keying in the lip. A strip 20cms wide from the outer edge to the inner edge should also be roughened to take the access strip (see Figure 13). Tie wires should also be poked through from the underside to tie the access strip reinforcing in place when the render has gained strength.

Figure 13. Showing finished access strip and old tyre used as former for access hatch lip.

When the rendered cover has been sitting for one day the following work can be done:

- Three lengths of steel should be cut and placed radially where the access strip is to be located. They are tied in place. The access strip is then laid using 3:1 mix render to a depth of 2cms. This is then scored to give grip when climbing to the access hatch.
- The lip of the inspection chamber is built up with mortar to a total thickness of 4cms. The 0.55m steel hoop of is placed on top of the existing render and the lip built up to the desired shape. A former can be manufactured to aid in this process or an old car tyre can be cut to give the correct diameter and supported in place (see figure 133 above). A greater lip thickness gives a greater feeling of security to people working on or in the tank.
- The cover is then cured for 7 days. The tank should be wetted twice daily and covered with plastic sheeting to prevent evaporation of the curing water. It is essential that curing is carried out properly.
- A coat of ‘nil’ (pure cement water slurry) is applied to top and bottom after two days of curing.

Putting the cover in place on the tank

- When the cylindrical tank body is being constructed some thought should be given to the method of fixing the cover to the tank. If the cover is to be fitted to a thin walled ferrocement tank four (or more) tie wires should be left protruding from the tank wall and these are tied to the cover when it is in place. For brick, block or masonry walls, the cover can be laid on a bed of stiff mortar and then blended with the tank as shown in Figure 14 below.
- The cover can be lifted into place by four strong people. Strong wire can be placed around the outer hoop where the cover was left un-rendered. Two strong timber poles can be placed through these wires. These poles are then lifted by four (or eight) people Alternatively two poles can be placed under the rim of the cover, but this makes it more difficult to set the cover down.
- Special care should be taken not twist the cover or put any undue stress on it as this could cause it to crack.
- If the tank wall is quite high then a raised platform should be constructed (from earth or timber) to stand on.

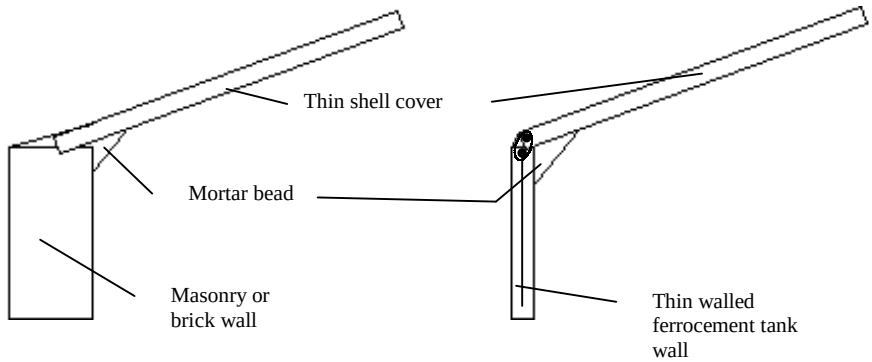

Figure 14. Blending the cover with the tank wall.

- A suitably sized ferrocement disc can be cast as the access hatch cover or another option used if so desired. This should be well fitting to prevent insects and contaminants entering the tank.

Tests for thin-shell, ferrocement tank cover

1. Point loading

The following load was applied with no adverse effect to the cover:

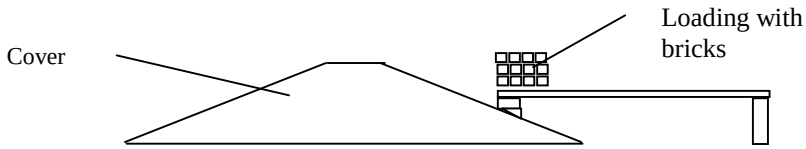

Figure 1 – Loading for point load test

Area of point load = 200 x 100mm = 20,000mm^2

Load applied 160 kg

i.e. 8kg / mm^2

2. Uniform loading

The cover was tested in two modes: constrained at the periphery to prevent slipping and unconstrained. In both cases the cover was loaded to approximately one thousand kg using house bricks (see Figure 4 below) and the deflection at the centre was less than 2mm in both cases, measured with a dial micrometer (Figure 3).

Figure 2 below shows the deflection against load for the constrained and unconstrained uniform loading.

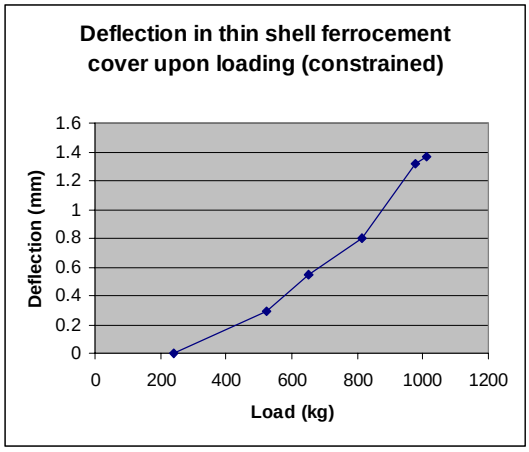

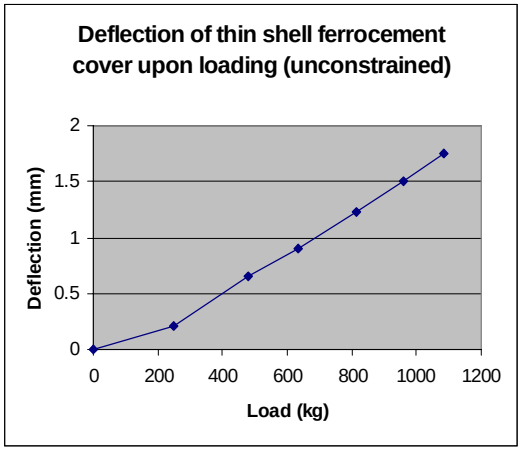

Figure 2 – Deflection of thin-shell ferrocement cover under load a/ constrained at edge b/ unconstrained

Figure 3 – dial gauge in place to test deflection of cover under load

Figure 4 – Thin-shell cover under a load of 1000kg of bricks – an evenly distributed load

The mortar dome cover – guidelines for construction

(Taken form a DTU working by Terry Thomas, Ben McGeever and members of URDT, Uganda)

1. Introduction

The mortar dome cover was developed as part of a collaborative project between the Development Technology Unit and the Uganda Rural Development and Training Programme (URDT), Kampala, Uganda. The cover is being reported here as an example of very low-cost technology for Roofwater Harvesting. The cover was part of a design of tank for underground storage of rainwater. The cover is also suitable for use on above ground tanks.

The Cover is a dome of mortar (containing almost no reinforcement) connected to a reinforced 'ring beam' set into the ground. The mortar dome and the ring are made at the same time over a carefully shaped mound of earth. Set into the mound are a bucket and a large plastic bowl. The bucket is to create a way for the rainwater to enter. The bowl is to create a hole to hold the plug in which the pump is set. It has to be large enough (e.g. 0.45 meter diameter) for a man to enter through. The 5 steps in making the dome will now be explained in turn.

2. Construction steps

Step 1 - Making the 'template' for shaping the dome

The shape of the mortar dome comes from the shape of the mound of earth it is built on. We therefore need a template to accurately form that mound of earth. Before building the first tank it is necessary to cut this wooden template. Once made, the template becomes a tool that can be used for many more tanks. The template must be the right shape and also strong enough to carry around and use without getting broken. It therefore consists of a piece of plywood, or thin planks, cut to that shape and stiffened by strips of thicker wood.

The right shape for the dome is approximately a upwards 'catenary'. A downwards catenary is the shape taken by a chain hanging between two nails on a wall, so we mark the template out using such a chain (e.g. 1 or 2 lengths of bicycle chain) and then turn it upside down.

First cut the plywood so that it measures 125 cm by 100 cm and has square corners. Figure 3a shows 2 nails spaced 2.2 meters apart on a horizontal line drawn across a flat wall using a spirit level. Draw a vertical line down the wall from midway between these two nails and mark a short line (the 'mark') across it 80 cm below the horizontal line. Hang a light chain between the two outside nails and adjust its length until it just reaches down to this mark. (If you do not have enough chain to do this, see the alternative below.) Slide the thin plywood behind the chain without touching it, so that the long top of the plywood touches the left-hand nail and the right side of the plywood lies along the vertical line. With a pen, copy the shape of the hanging chain onto the plywood, remove the plywood from the wall and saw along the line you have just marked. (Using planks instead of plywood, first nail them rigidly to their

stiffening bar so that they can be placed behind the hanging chain; then continue as for plywood).

Although it is easiest to make the catenary with two bicycle chains joined end to end, it can also be done with only one. This has to be hung so that it forms just over half the full U-shaped catenary: one end of the chain is attached to the left-hand nail, the other end is held low and pulled until the lowest point of the chain falls exactly over the ‘mark’. You can now drive in another nail (‘alternative nail position’ in Figure 1) to attach the chain to, while you are copying the chain’s shape onto the plywood.

It is necessary that the chain has no twists and that it hangs freely, otherwise it might take up the wrong shape. The right shape ensures that the mortar dome is strong (by being everywhere ‘in compression’). Rope is not usually suitable instead of chain, because most ropes twist and are not heavy enough to hang properly.

To finish the template, stiffen it with good wooden strips. Now turn the template over so that the long straight side is on top and write the word ‘TOP’ next to it. Smooth the sharp corners to make it safer to carry.

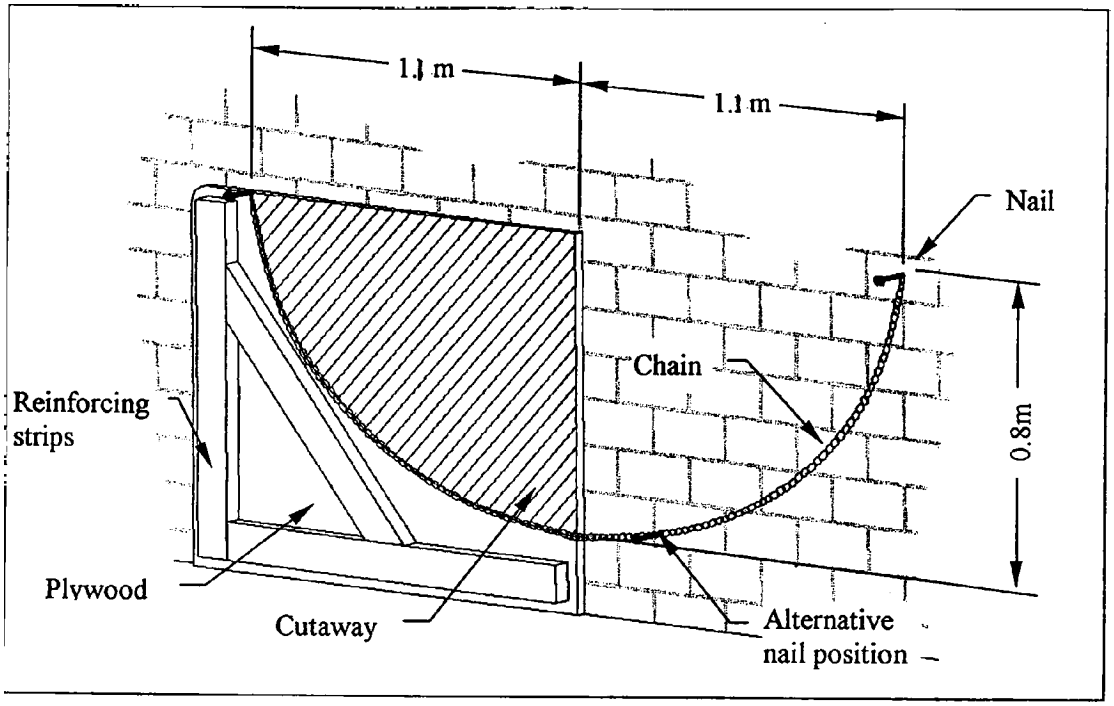

Figure 1 Making the template

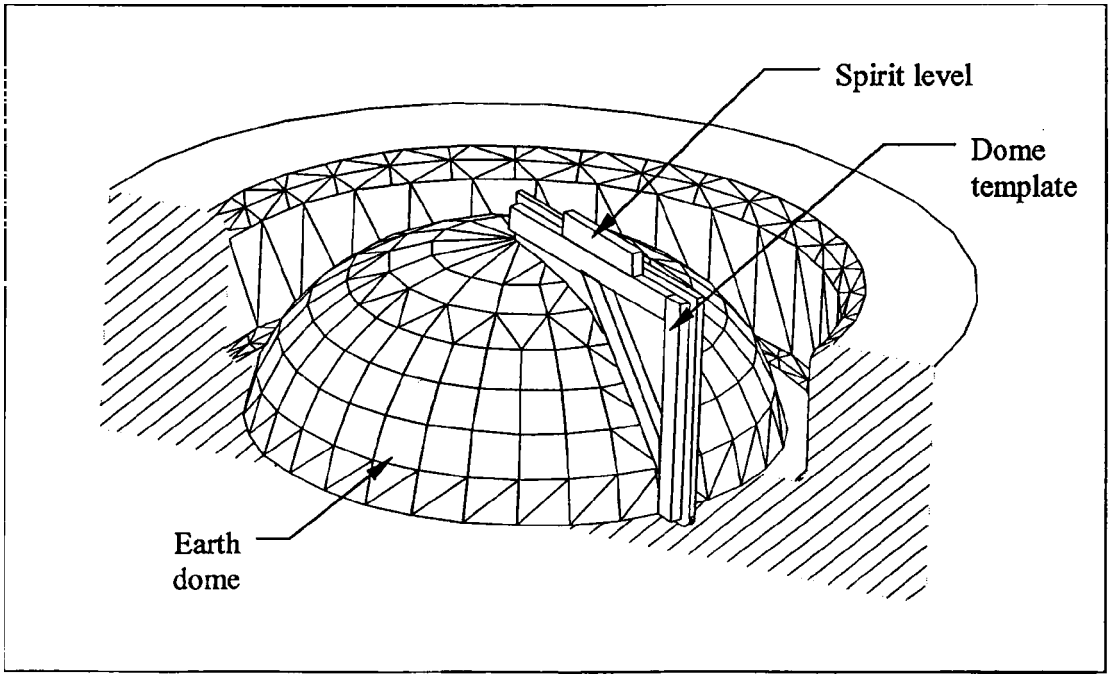

Figure 2 Forming the earth mound

Step 2 Marking out and making the trench and earth mound

The centre of the cover should be marked by a firm and vertical (use a spirit level) thin stake. Make a clear ink mark or cut a ring round the stake about 30 cm above the ground. Using a string 110 cm long looped once round the stake, mark out a circle of diameter 220 cm on the ground. This circle marks the inside edge of the trench in which the ring beam will be cast.

Dig a narrow trench (one hoe's width) outside this circle and throw some of the soil into the centre round the pole. The idea is to dig down 50 cm leaving a mound of firm soil inside the ring rising up to the ring round the stake. The shape can constantly be checked using the template - now with 'TOP' at the top - placed against the stake and rotated like a scraper. The template should be kept level by means of a spirit level and at the right height with its lower corner touching the ring marked on the stake. This is shown in Figure 2.

If the mound is rough or loose or fissured by drying, it can be plastered with more mud and wooden 'floated' to make it smooth and firm.

Chicken mesh can be fixed in the trench so that later on it can be used to improve the joint between the mortar lining the tank wall and the mortar of the ring beam. Make a single strip of mesh by cutting a 1.5 meter length into 5 strips each about 18 cm wide and twist joining them end to end - the final strip should be adjusted to fit round the inside face of the trench like a ring. This ring should now be folded longwise into the vee-shape shown in Figure 3 and the inside half buried in the earth of the dome. To do this you will have to cut out some earth from the inside of the trench, place the chicken mesh then plaster back the earth again.

The trench is now too wide for the ring beam, so fill back a step 10 cm high round its outside so that its bottom becomes only as wide as your foot - about 10 cm. (You will need to walk round this slot when you are plastering the dome). This too is shown in Figure 3. The bottom of the earth dome that faces into the trench should be grooved with a trowel or stick: these grooves will be ‘copied’ onto the inner edge of the ring beam and will later help ‘key’ the plaster joint to be formed there.

Finally place the bucket and the basin on the dome as shown in Figure 4. The bucket (the inlet) should be on the side nearest the house, with its edge touching the stake. The large basin (for the excavation access and later the pump hole) should be on the other side of the stake and with its edge 25 cm from the stake. Weight down the bucket and basin with stones and push them into the soil mound so that they do not rock; local excavation will allow the bucket to be sunk a desirable 20 cm into the soil. Put a small fillet of mud round each bowl as shown.

Pull out the stake without disturbing the mound.

Step 3 Preparing the reinforcing bars

Use 6 mm bar; it does not matter whether it is round or knobbly. Make a ring whose diameter is 230 cm, folding over and linking the ends and hammered the link tight so that there is no play in the joint. This ring will take about 8 meters of bar. Test that the ring will sit in the middle of trench without getting close to either its inner or outer edge.

Make two further such rings but much smaller, one each for the bucket and the bowl. Each ring should have a diameter bigger than its bucket/bowl so as to leave a clearance of 3 cm all round it where it enters the soil dome.

Step 4 Casting the ring beam and the pierced dome

The dome and the ring beam that forms its bottom edge are made of strong mortar in the manner shown in Figure 5. The mix is 1:3 (cement : sand) and 2 bags of cement should be ample. Concrete, mixed 1:4:2 (cement : sand : small sharp aggregate), is an alternative where such aggregate is available or can be made; a concrete dome needs only 1.5 bags of cement. (Concrete is more difficult to place as a plaster than is mortar and the surface finish achievable is not so good.) The ring beam is about 10 cm x 10 cm, while the rest of the dome is covered with 2 cm of mortar. However round the bucket and bowl this depth is increased locally to about 8 cm to make a good lip to hold the bucket/bowl and to cover the reinforcing rings there. As usual all three rings of reinforcing bar must be in the middle of the mortar with several centimetres of cover on all sides. So they must be placed as the mortaring progresses. The big ring, in the ring beam, is therefore placed only after 5 cm of mortar is already in the trench.

It is important to check the mortar thickness nowhere gets less than 2 cm as you work up the dome. There should be no joints in the mortar: the whole dome and ring beam should be made (plastered) in a single session with a mix that is dry enough not to slump. As the soil dome may suck water out of the mortar or concrete applied on top of it, it should be thoroughly wetted before plastering the dome starts. Moreover in a

hot climate it is wise to do this plastering early in the day so that the new dome can be covered with wet straw before the sun gets very hot.

Step 5 Curing the dome

As soon as the mortar is firm, gently remove the bucket and basin from the top of the dome.

Once the dome is cast it needs to cure under moist conditions for 14 days to develop a high strength. The simplest way to ensure it is kept moist is to cover it with plenty of grass and douse this with a jerrycan of water every morning and afternoon.

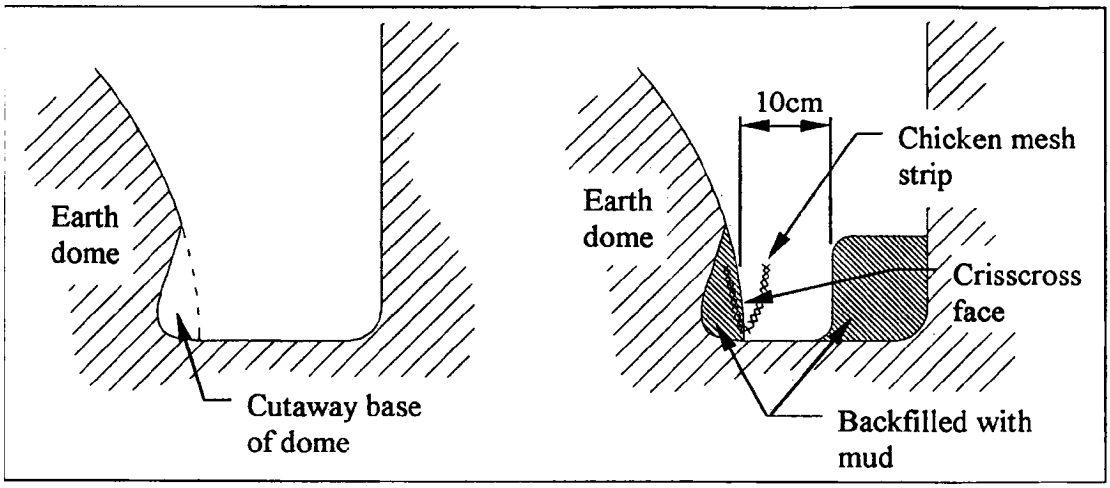

Figure 3 Details of trench (mesh is optional)

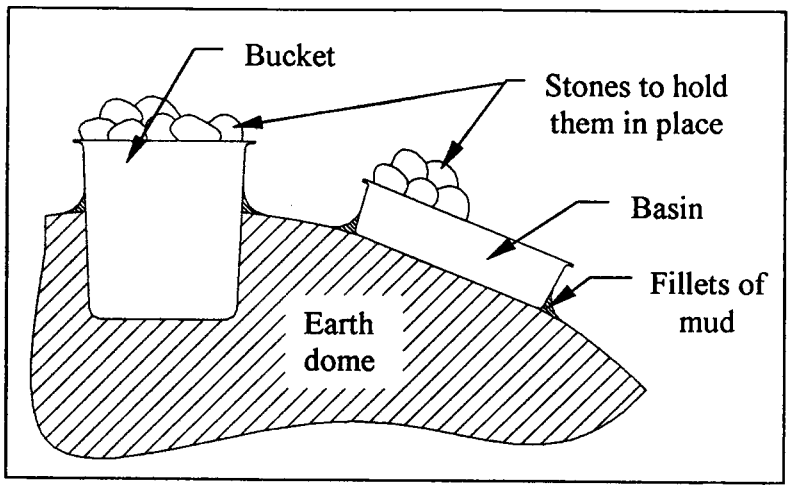

Figure 4 Basin and bucket on mound

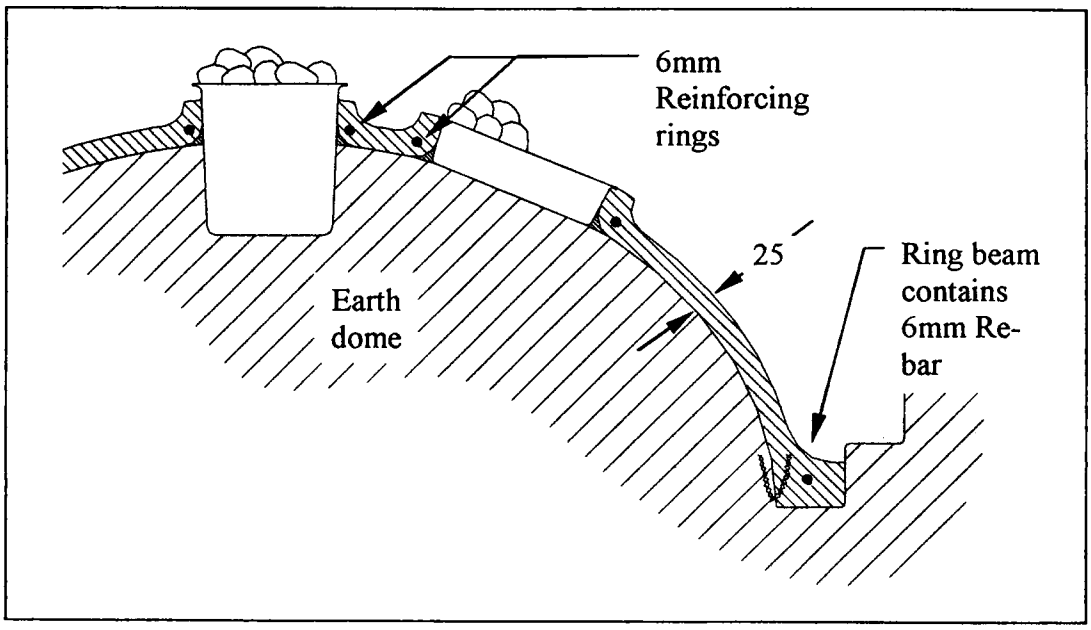

Figure 5 Completed dome

Report A3

Stabilised Soil Tanks for Rainwater Storage

Development Technology Unit

University of Warwick

Prepared by Mr. D.G. Rees

September 2000

This report is submitted as Milestone A5 under EU Contract ERB IC18 CT98 0276 : "Domestic Roofwater Harvesting in the Humid Tropics". That Milestone, under Task A – Technology, was originally to have been a report on the performance of underground tanks. Due to a re-sequencing of the research programme this Report A3 "Stabilised Soil Tanks for Rainwater Storage" has been substituted as the Milestone.

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1. Introduction

The present cost of roofwater storage tanks is too high for many potential users. Warwick University, under an EU contract with three other partners, is investigating ways of reducing it within the specific context of the contract title above.

One cost-reduction strategy is to employ cheaper materials than hitherto. Soil 'as dug' is certainly cheaper than the metal, mortar or plastic commonly used for tank building. Stabilised soil *may* be cheaper provided not much stabilising additive is used. Although soil-based walling is widely used in housing, water tank walls pose special problems. They require of their materials two extra attributes, namely waterproofness and *tensile* strength that are only of minor importance in housing. Since soil is not impermeable and wet soil has no tensile strength, a process of material adaptation is required before soil can be recommended for tank construction.

Sections 2 to 4 of this paper review the various techniques of soil selection, stabilisation and construction. Section 4 addresses tank design using this material. Two promising technologies are identified, namely construction using stabilised soil blocks (SSB) and construction using stabilised or even unstabilised rammed earth (RE). Section 6 describes the theory, design, prototype manufacture and Ugandan field testing of SSB rainwater tanks. Section 7 covers the same sequence for RE tanks, but also includes the results of laboratory trials.

The paper finishes with conclusions and the identification of further work required to confirm the initial promise of SSB and RE construction. Four appendices cover cost comparisons, test data and detailed construction guidelines. (The guidelines are in the form of a free-standing Technical Release designed for use in mason training.)

Note on units: Both imperial (foot=0.3 m and inch=25 mm) and metric units are used in this report, reflecting the predominance of the former amongst builders in Equatorial countries and the greater ease of the latter for calculations.

2. Soil/earth building technology

Almost a third of the world's population lives in unbaked earth housing. The technology used varies from country to country and region to region, and sometimes even from house to house. A wide variety of earth construction technologies are known to exist and a few are listed below.

- Adobe – sun-baked earth bricks
- Wattle and daub – a wooden lattice with daubed earth in-fill
- Compressed earth blocks – using a ram (of which there are many designs)
- Direct shaping – hand shaped earth
- Cob – coarse fibre reinforced balls of earth stacked and compacted lightly
- Dug-out – dwellings excavated from earth
- Rammed earth – earth compacted between shutters with a tamper

Of these seven variants, only two appear at all suitable for constructing (above-ground) tanks, namely stabilised soil blocks and rammed earth.

Figure 2.1 Buildings (a clinic and a latrine under construction) made from stabilised soil blocks in Tanzania

All the technologies mentioned above are ancient techniques that have been passed on from generation to generation. Many have only lost favour within the last century with the advent of modern building materials, particularly brick, cement and steel. They are still used widely in many developing countries where cement is prohibitively expensive for the poorer sections of society (see the map in Figure 2.2). In some cases cement is used in small quantities to 'stabilise' the earth, giving extra strength and impermeability. Earth building technology is seeing something of a revival in the West amongst groups keen to maintain traditional techniques and those who appreciate the superior properties of earth as a building material e.g. its thermal, aesthetic, environmental and cost advantages. Improved techniques have been developed by architects and engineers over the years.

Stabilised soil block (SSB) technology that has received a great deal of attention over the last few decades and is now seen as a mature technology with a good future in the building industry world-wide. It is a technology particularly suited to drier climates, although it is practised in many humid areas. Suitable earth is mixed with a small percentage (typically 5 – 10%) of cement and is compacted using a manual or hydraulically assisted ram or press (Figure 2.3). The compaction process can be static (slow squeezing) or dynamic (impactive), but the static process is more common.

Static compaction pressure ranges from 2 MPa in manual lever machines up to 10MPa or more in machines with hydraulic assistance.

Figure 2.2 Map of the world showing areas where earth construction technologies are, or have been, widely used

Figure 2.3 A CinvaRam press being used to produce stabilised soil blocks in Africa

Rammed earth (RE) is a technique whereby earth is rammed, using a rammer or tamp, between two shutters. The shuttering is removed to reveal the wall, usually constructed in sections of a few feet long by a foot or two deep. The shuttering is then moved along and the next section of wall is rammed to form a continuous wall. The shuttering is then raised and placed on top of the first 'lift' to construct the subsequent

'lifts' (see Figure 2.4). Unlike SSB production, the RE wall is built in situ. Wall thickness for a typical two-storey house is in the region of 12 to 24 inches. Curved walls of rammed earth are not common, but are found occasionally where the technique is more developed. The curved sections are usually for decorative purposes.

Typically rammed earth has been used for the construction of housing. The technique has been used to successfully construct buildings of several stories that have lasted for centuries.

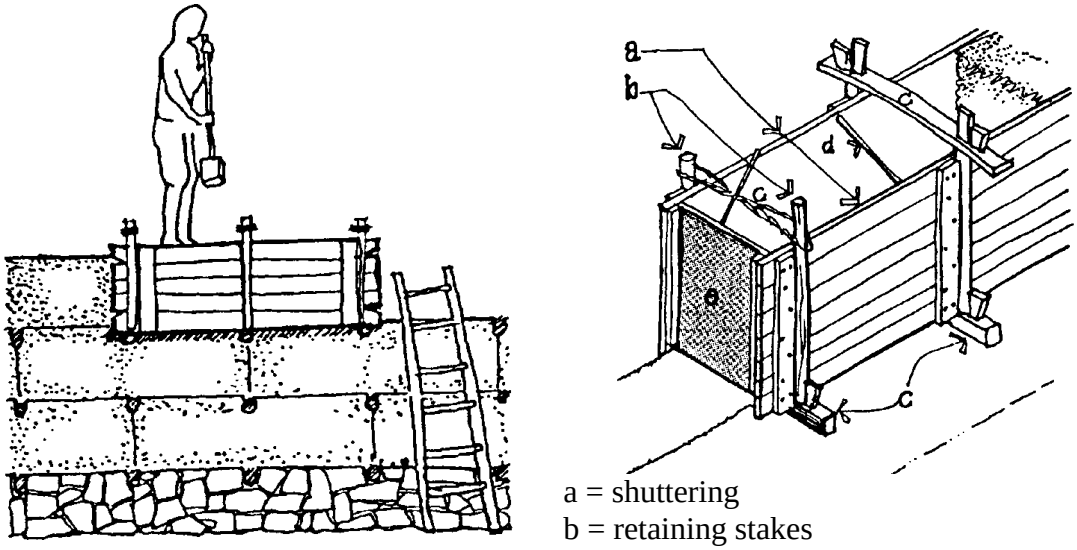

Figure 2.4 (i) rammed earth as practised in Morocco and (ii) basic elements of formwork or shuttering (from Norton[1997])

3. Soils - identification, classification and testing (field and laboratory methods)

3.1. Characteristics of soils

Not all soils are suitable for construction and methods have been developed for identifying those that are. For rammed earth (RE) construction a soil should be a mix of fine gravel, sand and silt with a small clay content. There should be no organic material present. Soil for stabilised soil block (SSB) construction needs to be of a higher fines content. However the actual soil used for either technique varies widely. Norton [1997] suggests the figures shown in Table 1 as suitable for rammed earth construction. The clay content should be sufficient to allow the soil to bind without causing excessive shrinkage. Soil varies widely in quality and content and so experimentation is required to find a suitable soil.

Table 3.1 – showing suitable values for soil particle distribution for rammed earth structures (Norton[1997])

Sand / fine gravel	45 – 75%
Fine sand / silt	15 – 30%
Clay	10 – 25%

Soil is generally characterised by 4 fundamental properties: texture, plasticity, compactibility and cohesion. These properties are described briefly below.

Determining the soil texture involves passing the material through a series of standard sieves and observing the fraction retained by each sieve, thus determining the grain size distribution. Further analysis is usually required to determine the fines content i.e. the make-up of the silt and clay passing through the finest practical (0.063 mm) sieve. Graph 3.1 shows the acceptable range for soil that is to be used for rammed earth structures. The ASTM-AFNOR standards and the decimal system standard for grain size distribution can be found on page 32 of Houben [1989].

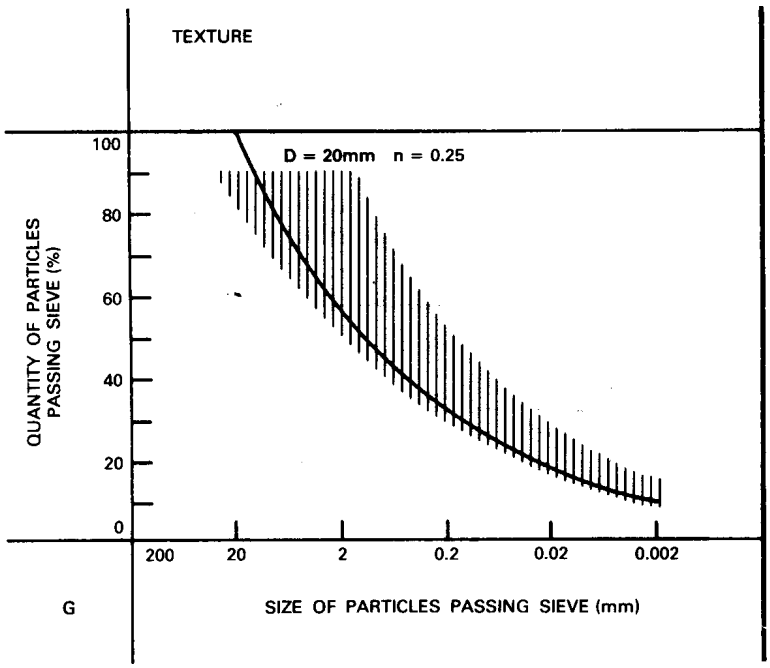

Graph 3.1 Showing the acceptable particle distribution for a soil used for Rammed Earth construction (Houben [1989])

The Plasticity Index (PI) is an indicator of the plasticity of the soil. The PI is a function of the Liquid Limit (LL) and the Plastic Limit (PL) of the soil (together known as the Atterburg limits) and is a measure of the likelihood of the material to deform. LL is the % of water in a soil when it is changing from being 'plastic' to being 'liquid'. PL is the water % at the boundary between solid and plastic behaviour. Numerically PI = LL – PL. There are agreed definitions of these transition points. Figure 3.1 shows on an Atterburg limits chart the type of stabiliser to be used with any particular soil.

The **compactability** of a soil defines its ability to be compacted to a maximum for a given compaction energy and degree of humidity {Houben 1994}. The compactability of a soil is measured by the Proctor compaction test (see Section 3.3).

Cohesion is a measure of the ability of a rammed soil to remain together when under tensile load. Cohesion is a function of the moisture content and the clay content (or other cementitious material) of the soil. Cohesion is higher when the moisture content is less than the PL. Cohesion increases with clay content, but so unfortunately does shrinkage.

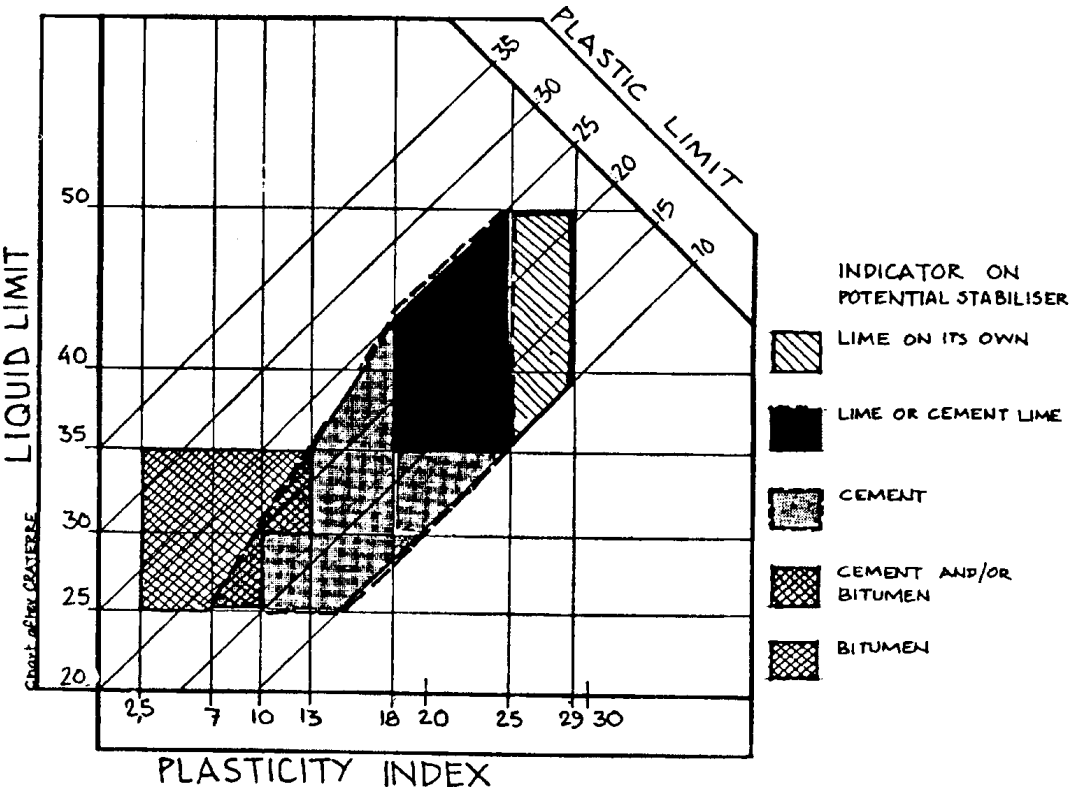

Figure 3.1 – The Atterburg limits chart (Norton[1997])

3.2. Soil suitable for rammed earth structures

A sieve analysis should indicate the ranges shown in Table 3.1 if a soil is to be used for earth construction.

Soil for use with rammed earth structures should be humid, i.e. not too dry and not too plastic, say in the region of 4% to 15% moisture content. The optimum moisture content (OMC) is defined later in this document and a method shown for determination of OMC.

3.3. Soil identification and classification

The suitability of a soil for building with is often established via three sorts of test – field tests, laboratory tests and construction trials.

Field tests

These are cheapest and come first. There are numerous initial sensory observations that can be made to help classify the soil in the field. These include:

- visual and tactile observation to analyse particle distribution
- sedimentation test to give more detailed particle distribution
- there are a number of tests to gauge (very roughly) clay content, including a simple test whereby a roll of clay is pushed over the edge of a table until it breaks - the length of the broken part gives an indication of the clay content
- drop test to determine optimum water content
- the smell of soil can sometimes give an indication of the presence of organic matter

More detail on these tests can be found in the relevant literature, especially Keable[1996], (Rammed Earth Structures – A Code of Practice).

Laboratory tests.
British Standard BS 1377 and corresponding standards in other countries cover the tests suitable for soils used in construction work. The tests are used to determine the main characteristics and suitability of the soil in question, as well as to give an initial idea of the performance of the material. The main tests that are used are described very briefly below:

A *'classification test'* is performed to determine the particle distribution of the soil. The test is carried out by passing the soil through a set of standard sieves (Figure 3.2). Material passing through the smallest sieve in the set is deemed to be a mix of clay and silt: these two components cannot be separated by further sieving.

Figure 3.2 – Wet sieving is the standard soil classification method

To determine the *'clay to silt ratio'*, the fraction of the soil passing through the last (0.063 mm) sieve is analysed using a hydrometer. The specific gravity of the liquid with its suspended particles, indicates its clay content. An alternative simpler test takes advantage of their different sedimentation rates to distinguish between clay and silt.

The compaction of a soil is dependent upon its moisture content. A *'compaction test'* is used to determine the maximum density of the material and the moisture content at which it occurs – called the optimum moisture content OMC. At maximum density the compressive strength of the soil will be greatest. To find the OMC a test is carried out using a simple compaction apparatus (see Proctor compaction test in Box 3.1) to compact a number of samples with different moisture contents. The samples are

weighed and measured. The dry weight is then found after drying the compacted sample in an oven and the OMC is that moisture content which has produced the sample of greatest density.

Box 3.1 BS Ordinary Test (or the Proctor test) for compaction

This test uses a 2.5kg metal rammer with a 50mm diameter face that falls into a cylindrical mould of 105mm diameter. The drop height is kept at a constant 300mm to ensure consistent energy transfer between blows. The blows follow a pattern over the face of the sample to ensure repeatability and consistent compaction of the entire sample. Each sample made up of three layers of soil that has passed through a 20mm sieve and each layer is given 27 blows of the rammer. After compaction the sample is trimmed off to a set height that gives a constant volume of 1000cm³. This is then weighed and the density can be calculated.

In the previous section we touched briefly on the consequences of shrinkage. The *'shrinkage box test'* measures this property and is simple to carry out. It involves measuring the shrinkage of a sample that is allowed to dry naturally over a period of 14 days. In practice, if the walls of a tank are constrained, say at the base, then cracking will take place if shrinkage is significant. Conversely, where a tank's cylindrical wall is free to shrink without constraint no cracking will take place. If shrinkage is found to be too great, due to an excess of clay, the soil will have to be either modified or rejected.

'Liquid and plastic limit tests' can be carried out either in the field, although it is preferably to perform them in a laboratory. Some equipment is needed. See section 3.1 for more detail.
A *'normal moisture content test'* is used to determine the normal moisture content of the material to be used. An oven and accurate scales is required.
To measure the rate at which water passes through a material requires a *'permeability test'*. Sophisticated equipment is required.
For many applications of rammed earth walls (i.e. housing and larger buildings), it is the compressive strength that should be maximised, so *'compressive strength tests'* are commonly applied to the material. *Wet* compressive strength, which is invariably less than *dry* compressive strength, is most commonly measured. Unfortunately little consideration is given to the *tensile* strength of the material which concerns us more in water tank design. Confusingly we have four possible strength measures: *dry compressive, wet compressive, dry tensile* and *wet tensile*.

Although Houben and Guillaud [1989] indicate reasonably good values for dry tensile strength of rammed earth (0.5 –1 MPa), little work has been directed at further increasing its value. For the application being considered here, the tensile strength of the material is of paramount importance. The OMC considered earlier is the moisture content that will optimise dry density (we could call this the DOMC , after Montgomery [1999]), and hence compressive strength. It is unclear to the author if this DOMC can be used to optimise dry tensile strength. Further investigation is required to find the water content to maximise dry tensile strength, which we could call the Tensile OMC (or TOMC). We then need to consider the wet tensile strength of the materials as this has great implications on the design of tanks to hold water.

Performance tests.
Even where we have applied field and laboratory tests to the raw material (soil) or to specimens prepared from it, it is still desirable to test samples of the walling during construction. In this way we can pick up not only soil variations but also imperfections in the construction process (such a deviations from intended proportions or procedures). These performance tests are usually applied either to samples drawn from batches in the construction process (e.g. every 50th block made) or to specimens sawn out of larger components.

Some of the tests that may be applied are:

- Wet and dry compressive strength
- Wet and dry tensile strength (modulus of rupture)
- Wet and dry bending strength
- Permeability
- Adhesion of render to walls

More details is available in the literature – see Houben

3.4. Calculating the quantity of soil required for a tank

The quantity of soil required for tank construction is calculated below. The quantity of soil required for tank construction is based on tank size, wall thickness and the density of the compacted material.

Weight of soil required $W = \pi (r_o^2 - r_i^2) H \times \rho_c$ (equation 2.1)

where
r_o = external radius of tank
r_I = internal radius of tank
H = height of tank
ρ_c = density of compacted material

For laboratory and development tests approximately 150 kg of soil is required.

4. Stabilisation of soils – methods for improving soil characteristics

Frequently one finds that the most readily available soil is not suitable for construction purposes. In such cases the main options are to

- bring in a suitable soil from elsewhere
- blend together different local soils
- add some sort of stabiliser.

Which option is chosen will usually depend upon their relative costs. However if wet strength is required, no natural soil is adequate and stabilisation (e.g. addition of cement) is essential. The physical characteristics of soil can be improved in a number of ways. Usually, the main reason to improve soil is either to obtain a suitable physical grading for a poor soil or to improve some other physical characteristic such as the strength, stability or water resistance of the soil.

Soil suitable for soil construction should be well graded with a suitable content of fines and larger particles (see Table 3.1). For raw soil, this is often not the case and soils have to be modified such that their grading is suitable for use. This will involve adding a material that is lacking in the raw material, removing unwanted particles by sieving or mixing a number of soils to obtain a suitable blend.

4.1. Additives and composite materials

A large number of additives and composites are available for adding to rammed earth. Their purpose is improve the properties of the material in one of a number of ways: *Chemical stabilisers* are added to the soil to bind or alter the grain distribution characteristics of the soil and hence improve its cohesion and stability. Common stabilisers include cement and lime, which are added in small quantities, say up to 10%, and can improve material strength and stability several fold. There is a wide range of synthetic additives available from specialist suppliers in some countries (Texas, USA is a good example, where earth building is a commonly practised building technique). They are not, however, generally available in developing countries and so we will not consider them in this work.

Waterproofing agents are available that reduce the permeability of soil structures. A commonly used water repellent is bitumen, which is mixed with the soil in an emulsion form. The emulsion is made using a solvent such as gasoline or kerosene diluted sufficiently to be mixed with the soil (Norton[1997]). Many synthetic waterproofing additives are available. Most earth walls, bearing in mind that such walls are used for buildings, are given a waterproof render, or a sacrificial coating. Renders and linings will be discussed later in the document.

Fibres can be added to increase the tensile strength of the material and help prevent cracking during the curing process. Straw is a common fibre additive and it also helps to reduce the weight of the material. Unfortunately it is only durable in permanently dry conditions.

Reinforcement is widely used to create a composite in which the matrix (e.g. soil) provides some properties and the reinforcement (e.g. steel wire or polypropylene or hessian rope) provides much of the tensile strength.

Box 4.1 Discussion of the effects of soil shrinkage on tank design, and design implications.

Upon drying a rammed earth wall will shrink as the moisture is drawn out of the structure and the clay, which is expansive (different clays having differing degrees of expansivity), shrinks. If the structure is constrained in any way, say for example, at the base of the tank, then this could result in cracking. For an unreinforced tank such cracking would seriously reduce tensile strength and could cause sudden and catastrophic failure of the structure. This needs to be considered when determining the OMC (or TOMC) and the author suggests that this area of rammed earth tank design needs further work at present. It is for this reason that some form of reinforcing could be used to give additional tensile (hoop) strength to the structure. Possible forms of reinforcement include:

- Externally applied steel packaging strap (as demonstrated by the author {Rees, 1999} on single skin brick tanks)
- Hoop wire rammed into the structure – ideally barbed wire would be used as it is cheap, strong and the barbs offer resistance to 'pull-through'.
- Fibre such as straw or short lengths of polypropylene rope can offer localised strengthening

Box 4.2 Stabilisation of soils (Montgomery[1999])

Stabilisation techniques can be broken down into three categories, Houben (1994): Mechanical, Physical and Chemical. Mechanical stabilisation compacts the soil, changing its density, mechanical strength, compressibility, permeability and porosity. Physical stabilisation changes the properties of the soil by acting on its texture, this can be done by: controlling the mixture of different grain fractions, heat treatment, drying or freezing and electrical treatment. Chemical stabilisation changes the properties of the soil by adding other materials or chemicals. This happens either by a physico-chemical reaction between the grains and the materials or added product, or by creating a matrix which binds or coats the grains.

Stabilisation fulfils a number of objectives that are necessary to achieve a lasting structure from locally available soil. Some of these are: better mechanical characteristics (leading to better wet and dry compressive strength), better cohesion between particles (reducing porosity which reduces changes in volume due to moisture fluctuations), and improved resistance to wind and rain erosion. Using one or more of the stabilisation techniques listed above, many of these objectives may be fulfilled. Optimum methods depend greatly on the type of soil, and a careful study of the local soil is necessary to suggest an effective method of stabilisation. In the case of mechanical stabilisation, the soil is compacted to a greater density, and there will always be an improvement in its mechanical properties with virtually any soil type. This is not true however with other forms of stabilisation, where different soil mixtures can lead to better or worse properties using the same technique. In the majority of cases mechanical stabilisation is used in conjunction with a common chemical stabiliser, such as cement. If the stabiliser and the soil are mixed together thoroughly and there is a suitable clay fraction in the soil, the compaction process reduces the quantity of chemical stabiliser required in the block. The increased density also increases the effectiveness of the cement matrix, given that the cement is left in a moist environment (the hydration period to let the cement cure) for at least 7-14 days. For details on selection of soils for cement stabilisation see Gooding (1993 - B).More details on the process of cement stabilisation can be found in Houben & Guillaud (1994) and Spence (1983).
(Source: Montgomery, David,
http//:www.eng.warwick.ac.uk/DTU/buildingmaterials/index.html, 1999)

5. Tank design using stabilised soils

It is certainly inconvenient, and it can be dangerous, for a water tank to fail (because at some point in it the local stresses exceed that which the tank material can bear). We therefore need to be able to calculate the size and location of the peak stresses. Unlike

other areas of structural design, stretching does not need to worry us much unless it is severe enough to cause the cracking of a superficial waterproof coat.

Our general design objective is to produce a safe watertight tank. This we can do either by using a single walling material that is both strong (in tension) and waterproof or by combining a strong material with a waterproof one. A wall of unstabilised soil is not waterproof and (when wet) doesn't have any tensile strength either. We therefore have either to stabilise it or to keep it dry by applying a waterproof skin to its inside face. In the latter case we must allow for the possibility that the skin will be punctured during the life of the tank – including some sort of reinforcing that may not save the tank but will prevent it bursting suddenly and dangerously.

5.1. The theory of stresses in cylindrical tanks

Tall cylindrical tank walls experience a horizontal tensile 'hoop stress' which is proportional to the diameter *D* of the tank, the local pressure *p* on the walls of the tank and the thickness of the tank wall *t* (Equation 5.1). As *p* increases towards the bottom of the walls, so too does the hoop stress.

$$\sigma_t = \frac{pD}{2t} \qquad \text{(Equation 5.1)}$$

However the stress in a cylindrical tank wall near to its base is also be affected by the type of joint between the tank base and tank wall. There are two obvious cases to consider as illustrated in Figure 5.1 below. In Case 1, the tank wall is made so that is free to move slightly at its base and yet still maintain a watertight seal. The water pressure against the wall will cause the diameter of the tank to increase until the hoop stress is wholly taken up by tensile stretching of the wall. (In the figure the increase in diameter is exaggerated here for clarity: in practice it might be less than 1 mm). The maximum hoop stress will be experienced at the base of the wall and will decrease linearly with height to zero at the top of the wall.

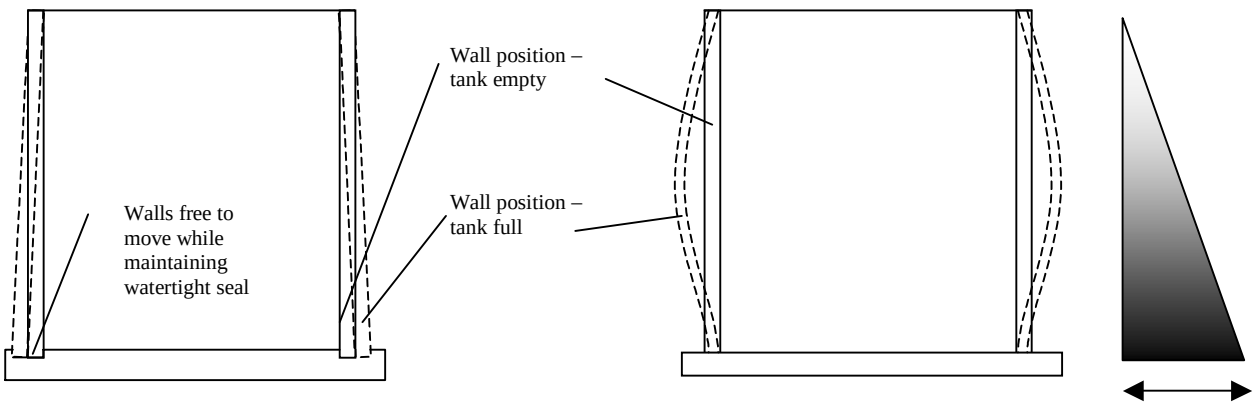

a/ **Case 1** – walls free to move relative to base

b/ **Case 2** – Walls joined to base

Figure 5.1 – The two cases for wall-to-base union in cylindrical tanks

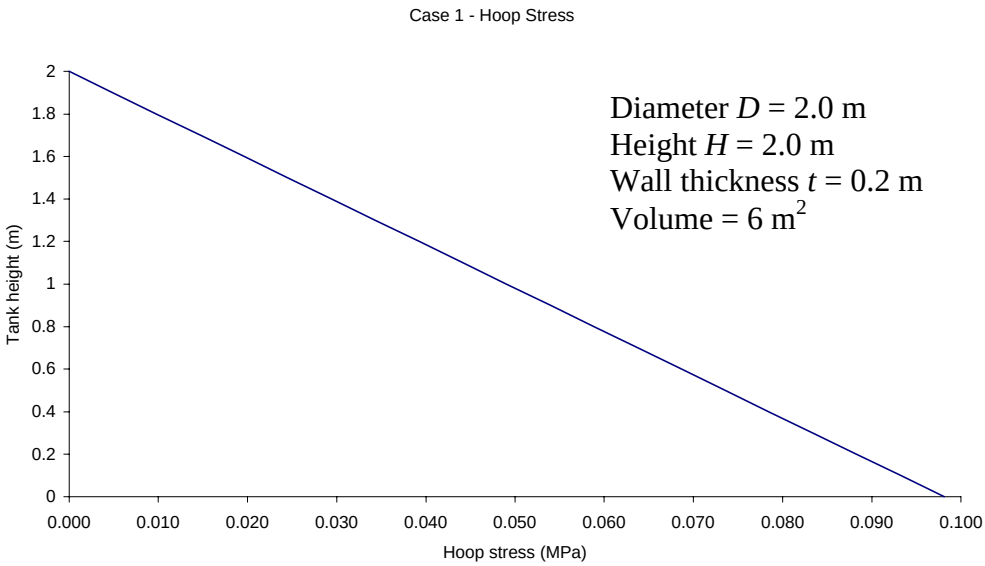

Figure 5.2 – Hoop stress in the tank wall for Case 1 (i.e. wall and base separate)

In Case 2, where the wall and base are monolithic i.e. the wall and base are continuous (and the base is assumed to be rigid), the situation becomes more complex. Bending and shear stresses are set up in the wall as a result of the restraining effect of the base slab. There now exists a combination of bending, shear and hoop stresses. The lower part of the wall is now constrained and is not free to move as in Case 1. The result is that a bending moment is generated in the wall that is a maximum at the joint of the wall and the base. This bending moment sets up vertical tensile stresses on the inner face of the wall of the tank that can be more than twice the magnitude of the horizontal hoop forces. Shear forces are also generated although these can generally be neglected as they are small in comparison the other induced forces. This is illustrated graphically in Figure 5.2

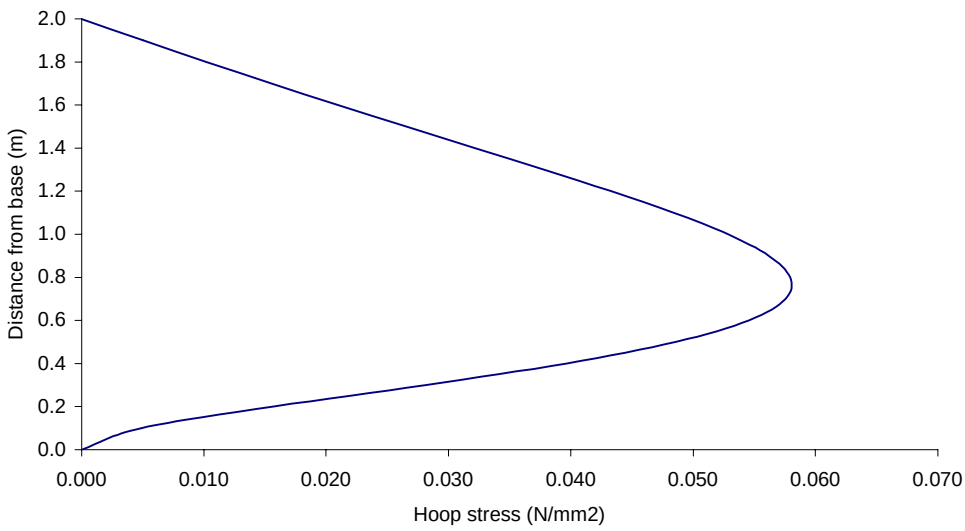

Figure 5.3 – Hoop stress for Case 2 (i.e. wall and base monolithic)
(D, H and t as in Figure 5.2)

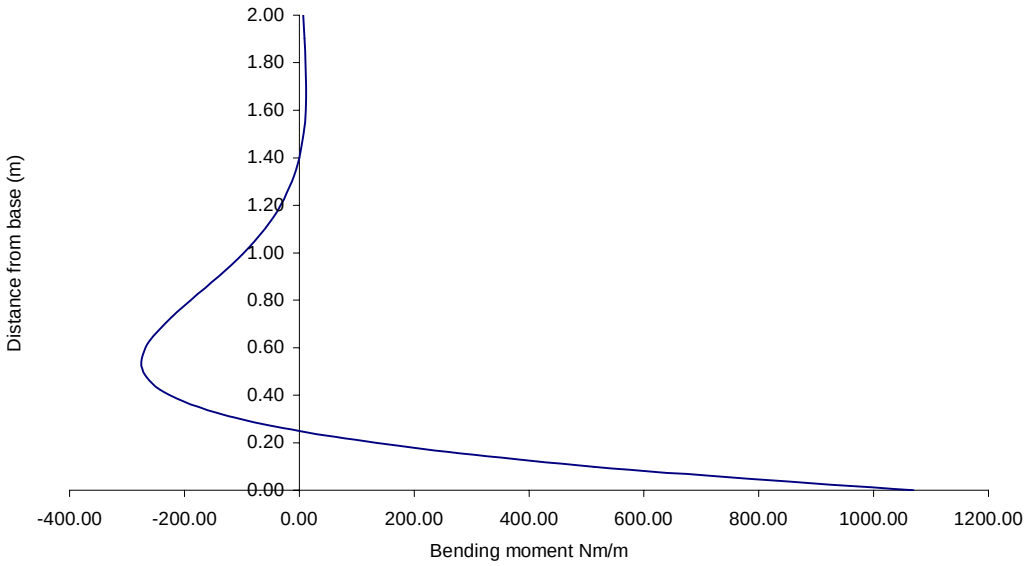

Figure 5.4 – Bending moment induced in tank wall for Case 2
(D, H and t as in Figure 5.2)

In Figure 5.2 we see that for Case 1 the hoop stress increases linearly from zero at the top of the tank wall to a maximum of 0.098 MPa at the base/ wall joint

In Figure 5.3 we see that for that Case 2 the hoop stress is a maximum of 0.058 MPa – less than in Case 1 – and occurs at 0.8m from the base (i.e. 0.4H). The hoop stress then drops off to zero at the base where the strain is zero. In Figure 5.4 we see the effect of the rigid constraint on the bending moment that is now induced in the wall. The maximum vertical tensile stress in the bottom of the inner face of the tank wall in Case 2 is 0.16 MPa, considerably more than the maximum hoop stress in either Case 1 or Case 2. So the tank is now vulnerable to cracking at the wall-base joint.

5.2. Conclusions from Section 5.1 and implied design considerations when using soil as a building material

Note:
Case 1 - wall is free to move at base (flexible joint)
Case 2 - wall and base are continuous (monolithic joint)
(assuming rigid base in both cases)

Table 5.1 Summary of conclusions from Section 5.1 and resulting design implications

Conclusions from Section 5.1	Design Implication
In Case 2 a bending moment is set up in the wall due to the constraint at the base of the tank. This is a maximum at the joint of the wall and the base and causes vertical stresses whose size is more than twice the maximum hoop stress. No bending moment is induced in Case 1.	Sliding base / wall joint are preferable to avoid complex stress regimes in the tank walls (see Box 4.1 below). These are difficult to achieve in practice.

The vertical stress cause by bending is very sensitive to changes in wall thickness as it is proportional to $1/t^{2;}$ thus halving wall thickness will multiply stress by four. The hoop stress is only proportional to $1/t$.	Where a monolithic base / wall joint is used it is wise to use a good safety factor when considering wall thickness or to thicken the wall near the joint.
The maximum hoop stress for Case 2 is always less than that of Case 1 (for an identical tank profile) and is experienced at some point above the joint of the base and wall, typically 0.3H to 0.6H, but lower for very thin walled tanks.	Do not design the wall thickness to decrease with height in the case of monolithic tanks.
For a tank of identical profile, the maximum bending moment set up in Case 2 will be of greater magnitude than the hoop stress set up in Case 1 or Case 2 (see Figure 5.5).	A greater wall thickness is required for Case 2 than for Case 1. This implies more material usage and hence higher cost. On this point, it is worth bearing in mind that many materials will have a greater tensile strength than bending strength and so the problem will be compounded.
Deflection is greater for Case 1, as there is no constraint at the base to restrict movement of the wall.	Strengthening at the base can help reduce deflection for Case 1. This is important where renders are used to help prevent cracking due to excessive strain.

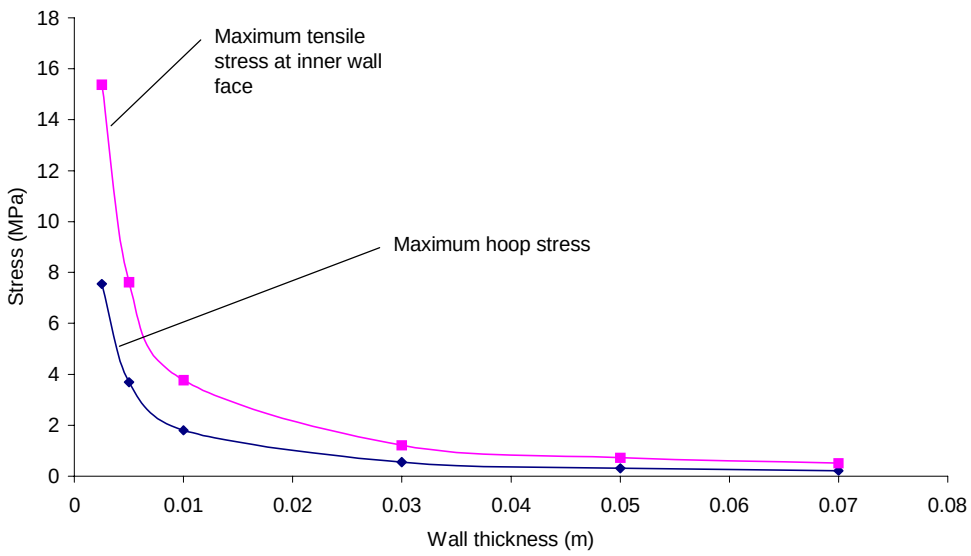

Figure 5.5 – The graph shows the relationship between hoop stress, maximum tensile stress due to bending and wall thickness. (*H* and *D* as for Figure 5.2) Note the significantly higher values for bending-induced tensile stress.

Box 5.1 Sliding / flexible base wall joints

Sliding of flexible joints between the wall and the base of a tank are common for large concrete storage. The reduction in stresses by using such a joint is well documented and the subsequent savings in materials well recognised. Such joints, in concrete structures, are usually effected using a bitumen layer between the base and the wall. The degree of movement in the wall is very small and the flexibility of the bitumen allows sufficient movement while maintaining impermeability.
The technique developed at the University of Warwick for work with soil tanks has been to lay two layers of polythene sheet beneath the wall of the tank. The sheets can have a smear of grease to help them slide across on another. The effect is to produce a 'sliding' joint that allows the wall and the base to act independently which, as pointed out in earlier, reduces stresses, simplifies tank design and leads to lower costs.

5.3. Spreadsheet design for rammed earth tanks

A spreadsheet has been developed at Warwick (Turner 1999) for aiding the design of cylindrical tanks. The spreadsheet allows the main variables to be entered and gives output in terms of design parameters. The main variables are tank diameter, tank height, material properties (or relative volumes in the case of composites), required safety factor and wall thickness. The outputs are given for both a tank with monolithic base and wall, and for a tank with separate base and wall. The outputs include maximum hoop stress, maximum bending moment, maximum deflection, maximum tensile stress on inside face of tank wall, maximum shear stress, tank volume and overall tank diameter. The spreadsheet allows the designer to play with the parameters until a satisfactory design solution is reached. Table 5.2 shows the general layout of the spreadsheet. The spreadsheet was used to design both the laboratory experimental tank and the field experimental tanks described and discussed in Section 7.

Table 5.2 Showing the input and output cells of the spreadsheet developed at Warwick to aid design of cylindrical tanks.

Data input section - click on boxes for data input instructions			
Parameter		**Value**	**Unit**
E (matrix)	e.g. soil	700	MPa
E (fibre)	e.g. steel	2.1E+5	MPa
po(matrix)		0.5	Poisson's ratio
po(fibre)		0.1	Poisson's ratio
thickness		0.20	m
tank rad		1	m
height		2	m
Vol. Fraction of fibre		0	0 – 1
po(total)		0.5	
E(total)		700	MPa
Volume		6.283	cubic metres

Output cells –for a Rammed Earth tank The output here is for a tank monolithic with base		
Tensile strength (of soil)	0.50	MPa
Safety factor required	4.00	
So design stress is	0.1250	MPa
Maximum hoop stress generated	0.0579	MPa
Position of max hoop force		m from base
Maximum bending moment	1069	Nm (always at base)
Maximum deflection	0.0033	mm
Position of maximum deflection		m from base
Maximum tensile stress on inner face of wall	0.16037	MPa (always at base)
Maximum shear stress	0.00021	MPa
Overall tank diameter	2.4	m

Output here is for tank wall unconstrained at base		
Tensile strength	0.50	MPa
Safety factor required	4.00	
Design stress	0.1250	MPa
Maximum hoop stress generated	0.098	MPa
Maximum deflection	0.1401	mm
No bending moment generated		

5.4. Construction principles when building with earth

There are several basic rules to follow when building with earth:

- The wall should be well protected from damp or wetness. Wet earth has less strength than dry and unstabilised earth will quickly become a mess of mud should it become saturated.
- Good foundations are used to protect the base of the wall from rising damp and often the first foot or two of wall above the foundation will be from stone or other impermeable material.
- Where a roof is fitted, the wall can be protected by using large overhanging eaves to prevent rain from hitting the wall directly.
- Renders or other coatings help to protect the wall from rain also. Practitioners colloquially use the phrase “good hat and boots” to describe the protection required – an overcoat doesn’t go amiss either!

The benefits of using earth as the construction material are numerous:

- low material cost (see cost comparison with ferrocement in Section 8)
- suitable material readily accessible locally in many parts of the world
- a well-known and widely-used technology in many parts of the world
- a simple technology that is easily taught to semi-skilled people

The drawbacks of using earth for tank construction are:

- not suitable for below-ground tanks or cisterns
- in the case of leaks serious problems can develop, especially if unstabilised earth is used
- high labour input – a problem where labour costs are higher

6. Stabilised soil block (SSB) tanks

6.1. Introduction

The work carried out on Stabilised Soil Block (SSB) tanks has been done in conjunction with Dr Moses Musaazi, a lecturer at Makerere University, Kampala and private entrepreneur working in the construction industry. Dr Musaazi also directs the Gatsby Trust in Uganda whose aim is to promote small-scale private enterprise through training. He has been working with SSB's for some time, both for low-cost housing and also for the construction of small too medium sized domestic rainwater storage tanks. Warwick University approached Mr Musaazi with the aim of working together to test the strength of the SSB tanks through practical experimentation.

A full report of the work that has been completed by Dr Musaazi is found in Appendix II.

6.2. The basic principles of SSB manufacture and construction

Stabilised, compacted, soil block technology is mature and widely used throughout the world. It involves compacting a suitable soil, which is often mixed with a small percentage (typically 5 – 10%) of cement, using a manual or hydraulically assisted ram or press. The compaction process can be static or dynamic, but the static process is most common. Static compaction pressure ranges from 2MPa (manual) up to 10MPa or more (hydraulic). This compaction reduces the voids in the material and hence it susceptibility to attack from water. Figure 2.3 shows a CinvaRam press being used on a building programme in Tanzania. Figure 6.1 shows some common press types.

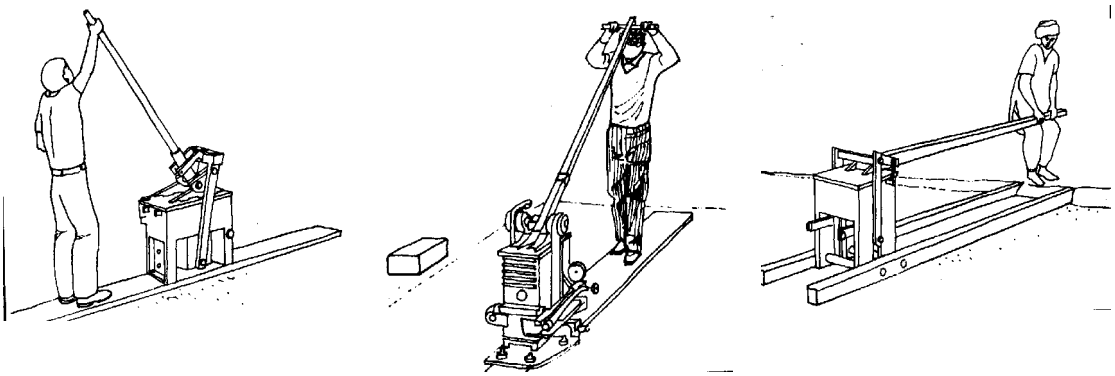

Figure 6.1 – A small selection of the many press types available for purchase (Houben[1994])

Special moulds can be manufactured to produce blocks required for special purposes. In the case of the cylindrical tanks manufactured in Uganda, curved blocks were produced using the mould shown in Figure 6.2.

(**Figure 6.2** – Mould for producing curved blocks)

(**Figure 6.3** – Curved blocks after curing)

For information about tank linings and water extraction for SSB tanks see Section 7.2. These principles are the same for RE and SSB tanks.

6.3. Field testing of SSB tanks in Uganda

Tests on SSB tanks started in March 2000 in Kampala. A small cylindrical tank (1.0m internal diameter, 2.1m height) was built and an attempt made to fit sealed covers to it. The tank was to have been pressurised by means of a header pipe fitted to the cover, however this proved impractical so it was simply subjected to the pressure (21 kPa) derived from its own height. The materials used are specified in the report in Appendix II. The soil used was stabilised with 5.25% OPC.

The experimental method was changed for subsequent tests and two tanks were built of the same curved end-interlocked SSBs. No reinforcing was included, but the tanks were rendered inside with a waterproof mortar. Details are:

Tank diameter (internal) in m	Tank Height in m	Code	% cement
1.67	3.8	SST1	5.25
1.00	5.2	SST2	3.27

SST1 was tested in July 2000 and failed dramatically when only part full. SST2 is still under test.

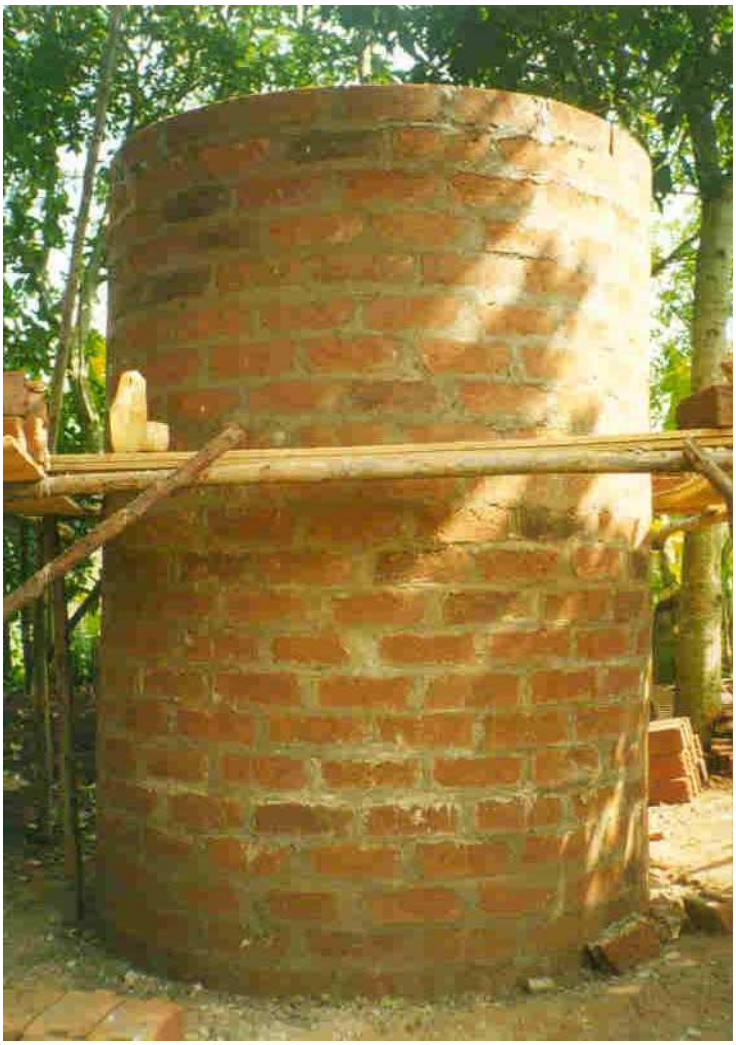

(**Figure 6.4** – A SSB tank of 1.67m diameter)

SST1, according to theory and using the *dry* tensile strength for the blocks from the literature, should have been able to withstand about 5 times the stress induced by the water pressure at which it burst (at 2.5m water pressure). There were, however, some irregularities:

- Some of the blocks analysed after the experiment seemed to have no wet strength and disintegrated completely in water.
- The tank was filled from a large water tanker. The waterproofing agent that was used in the cement render lining takes time to act and so water would have been passing through the tank lining and into the soil matrix. This would have reduced the strength to somewhere below the dry strength quoted in the literature.

SST2 by contrast was filled slowly by rainwater from a gutter and has sustained a pressure, 53 kPa corresponding to its full height, for many weeks despite being built with considerably less cement in the blocks than SST1. The peak stress in SST2 is 50% greater than that at which SST1 failed.

A further complication in the analysis of any tank made of blocks or bricks is uncertainty about how tensile forces travel from one block to the next. One route is via the mortar that separates blocks of the same course. Mortar does not have very high adhesion to blocks, although in this case the loose interlock between block ends would have provided some shear connection. The other route is via shear forces into, and then back out of, the overlapping blocks in the courses above and below the course of interest.

Three further but smaller SSB tanks have been built and sold.

6.4. Conclusions concerning SSB tanks

It is unclear exactly what was the failure mode of SST1. It appears that the lining was not sufficiently waterproof to prevent water passing to the stabilised soil matrix, causing the soil to rely solely on its wet strength. The maximum stress induced in the wall of the tank at 2.5m water pressure is 0.234 MPa. This is the maximum resultant tensile stress on the inner face of the tank wall due to both bending and hoop stresses (as calculated using spreadsheet by Turner [1999]).

If we look at Graph 6.1 we see that the 7-day wet compressive strength for the material (which has a 5.25% cement content and was compacted at about 2MPa, is about 1MPa. Similar figures are found in Houben for 28 day wet compressive strength – see Table 6.1. The usual rule of thumb for dry to wet strength ratio for soil is 5:1. So we see that the wet strength of the soil blocks would be in the region of 0.2 MPa, which is lower than the induced stress prior to failure. It could therefore be said that the tank performed better than might be expected.

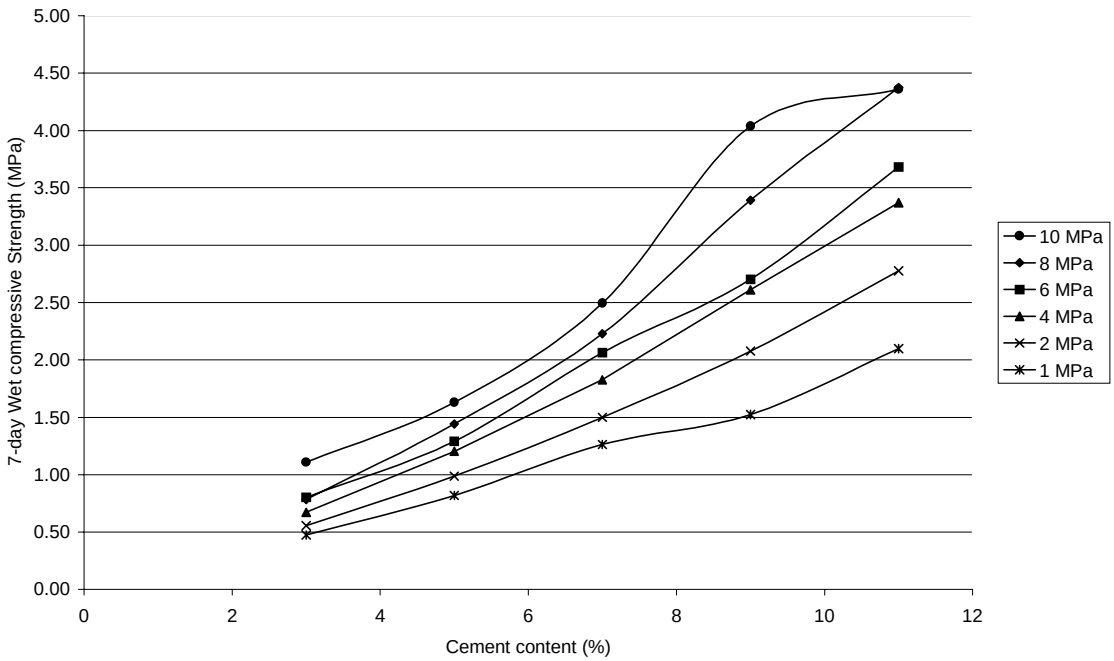

Graph 6.1 Graph showing variation of 7-day wet compressive strength with cement content for a number of compaction pressures (Gooding [1993]).
Cement content = 5.25% in our case.

So for this diameter tank (1.67m), using the construction method outlined in Appendix V, and with the standard 2.2m height, the dry strength would give a safety factor of approximately 5. However, if the tank lining should fail, or if the tank should become saturated for any other reason, then the tank would be on the border of failure as the wet strength (~0.2MPa) is approximately equal to the induced stress (0.2026MPa).

Table 6.1 Compressive and tensile strengths for SSB's. All the above assume 2MPa compaction pressure an assume tensile strength to 0.2 x compressive strength

Source	Compressive strength	Estimated tensile strength
Gooding (see Graph 6.1)	1MPa (7 day wet)	0.2MPa
Houben	1 – 2MPa (28 day wet)	0.2 – 0.4MPa (estimated by author)
Houben	5 – 12 MPa (28 day dry)	1.0 – 2.4MPa (estimated by author)

The analysis above would hold if the subsequent tests on the SSB's from the tank debris had not shown that some of the blocks had NO wet strength. The only explanation for this is that these blocks failed before their minimum strength was reached.

6.5. Further work with SSB tanks

Further suggested work on this area of work includes the following:
full laboratory analysis of the soil (the soil used in Kampala was somewhat pozzolanic and was assumed to be superior to standard lateritic soil there)

- development tests to determine the soil / block performance (however there is some suspicion that the blocks in SST1 had been starved of their proper cement allocation)
- further full-scale tank tests with some modifications to improve tank performance
- investigate methods for improving tensile strength e.g. reinforcing with barbed wire
- further work to investigate the relationship between wet and dry tensile strength of stabilised soils

7. Rammed earth (RE) tanks

7.1. Introduction to RE tank development

The general aims of the work carried out on rammed earth tanks (RE) are listed below:

- to set out the theory of RE tank design and to investigate the options available for RE construction
- to develop the specification for an experimental laboratory tank and two experimental field tanks
- to develop the skills required (within the research team) to analyse soils for building, in both the laboratory and in the field
- to investigate soil modification techniques and methods to develop a soil suitable for tank construction
- to develop the tools and equipment required for RE tank construction

- to develop a technique suitable for rammed earth tank construction
- to develop a technique for tank lining using plastic sheet
- to test a rammed earth tank under laboratory conditions to verify the theory
- to build a number of tanks in the field to test the feasibility of the technology and its suitability to LDC skills
- to test a tank under field conditions, again to verify the theory
- to carry out a cost analysis of a RE tank to allow comparison with other tank types
- to develop guidelines for the manufacture of RE tanks

Three (3) RE tanks have, to date, been designed and constructed:

- A tank of 1.4m diameter and 1m height was built at the University (RE-UK*). The tank was from unstabilised soil. The aim was to test the general principle of construction and to allow for initial tests to be carried out on earth tanks. The tank was completed in May 2000 and simple tests carried out, but full tests are yet be to be carried out on this tank. The simple tests include; fitting experimental linings, applying steel strapping and filling the tank a number of times to test strength. The full tests are to include a pressure test to ascertain the actual strength of the tank and to allow comparison with the theory.
- Two tanks of stabilised soil of 2m diameter and 2m height were constructed at Kyera Farm, Mbarara in June and July 2000. The first (RE1*) was constructed to a high specification (see Section 6.4.2) with concrete base and masonry wall section to 0.35m high. The second (RE2*) was designed to be very low cost using predominantly stabilised earth. Both were stabilised with 4% cement and reinforced with barbed wire hoops at 75mm intervals (see Appendix IV for Rammed Earth Tank Construction Guidelines)

** Note:*
For easy identification of the three tanks, they have been labelled as follows

RE-UK	- UK built tank
RE1	- Uganda high specification tank
RE2	- Uganda low specification tank

7.2. The basic principles of rammed earth construction

The general principles for building with earth are outlined in Section 5.4. and a full account of the rammed earth construction process used for the experimental tanks in Uganda is given in Appendix IV.

Some other points regarding RE construction are listed below:

- Availability of suitable materials is a key factor. If significant work is required in modifying the soil once it has been excavated, then the process can quickly become too costly.
- Wall thickness tends to be high, compared with modern materials. This is due to the relatively low compressive strength of the material and the variability in material quality. Compressive strength can be improved by using a small percentage (say 5% – 8% by weight) of cement mixed with the earth.

- Tensile strength is fairly low – in the region of 0.5 – 2.0 Mpa. The tensile strength can be improved by adding fibre or composite materials as well as by stabilisation with cement.
- The technique is characterised by high labour input and low material costs. This is well suited to many developing countries where labour is cheap and manufactured materials are costly.

The tools required for rammed earth construction can be few and of relatively low cost. In the West, sophisticated tooling has been developed, and sometimes costly pneumatic rams are used with steel shuttering, but in the less developed countries (LDCs) the tools have remained unchanged for centuries. Many designs of wood shuttering have been developed to meet the needs of the builder, but the principle actually varies little world-wide.

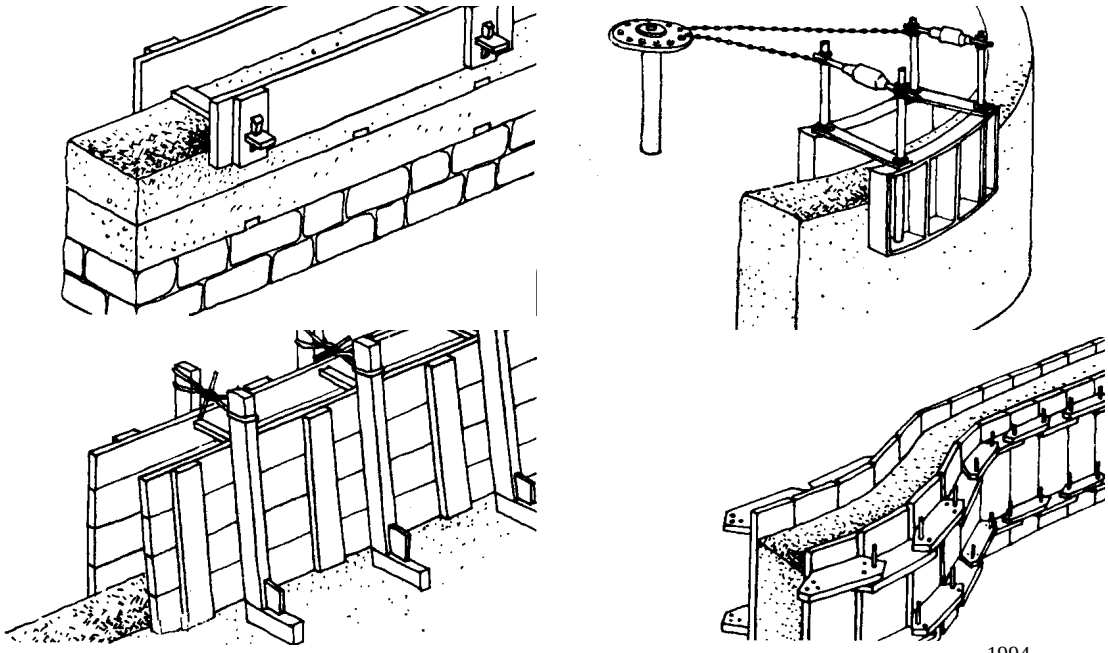

Figure 7.1 – Common types of shuttering used for RE construction (Houben[1994])

7.3. Equipment for making cylindrical RE tanks

Shuttering Most shuttering used for RE construction is designed to be used for the construction of straight walls. There are few examples of shuttering for curved walls, and those shown in the literature seemed to be unsuitable for cylindrical tank construction. The shuttering was, therefore, designed by the author and manufactured at the University workshops (RE-UK) and by local carpenters (RE1 and RE2) - see Figures 7.2 and 7.3. The UK shuttering required some subsequent strengthening to prevent deflection when compaction was taking place. The second set of shuttering was suitably strengthened during manufacture.

- *Shuttering fabrication methods used in UK*

The materials and techniques used for the shuttering construction varied slightly between the UK and Uganda. In the West, plywood is readily available, whereas in Uganda it is not. Plywood is well suited to forming curved surfaces through lamination and so 4mm plywood sheets were used to form the curved faces of the

mould – 3 layers glued together. Plywood (12mm – doubled up) was also used to form the main strengthening spines of the shuttering. The tie rods were from 12mm steel rod with T's welded on one end and threaded to sufficient length on the other. The nuts used were fitted with wings to make shuttering assembly easier. The end-stops were made for 12mm ply. The shuttering is shown in Figure 7.3.

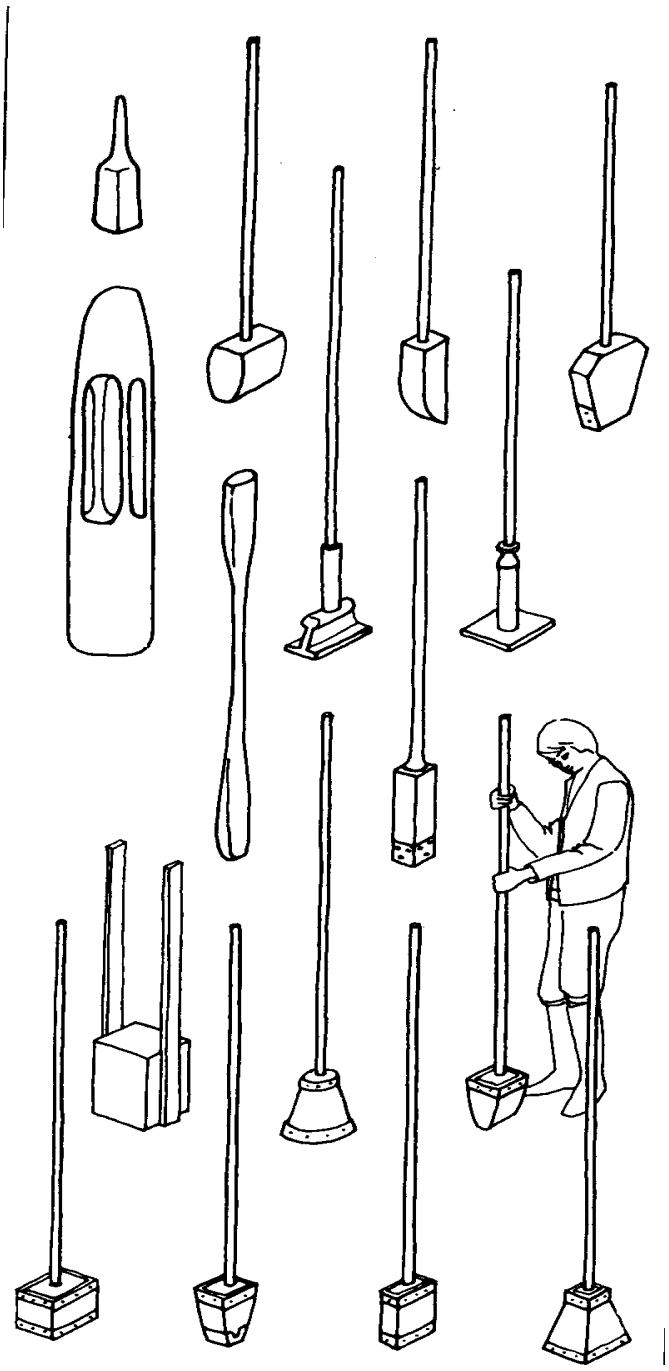

Figure 7.2 – Common types of rammers used for RE construction (Houben[1994])

- *Shuttering fabrication method used in Uganda*

In Uganda sawn hardwood timber is more commonly available and this was used for the construction of the shuttering. The curved faces of the mould were made using 25mm x 25mm strips of timber butted to one another and glued and nailed carefully to

each other and to the main spines. The spines and end-stops were from hardwood. The work was carried out at a local workshop and needed constant supervision to ensure that the work was done in accordance with the drawings. The workshop had few power tools and most of the work was done by hand. Again, the tie rods were of 12mm steel rod with T's and threaded section. The shuttering is shown in Figure 7.4. Design drawings for the shuttering are shown in Appendix V.

Figure 7.3 – Shuttering manufactured in the UK

Figure 7.4 Shuttering manufactured in Uganda

- *Test for shuttering strength*

The standard test for strength of shuttering is that the mid point deflection of the shuttering, when loaded with a 150 kg weight (e.g. 3 bags of cement) should less than 3mm. Loading is mid point between the vertical stays.

- *Expected useful life of Shuttering*

Based on the experience in Uganda, where the shuttering was used to make two tanks, it is estimated that well-made shuttering should be good for the construction of

between 15 and 20 tanks, with some maintenance required to repair any damage caused during ramming.

Rammers / tampers The tampers were manufactured at the University workshops and at a local workshop in Uganda. Drawings are shown in Appendix V. The handles were of hollow round section steel in order that the weight of the rammer can be adjusted by partially filling the handle with sand. The profiled 'V' rammer, used for creating a joint that helps prevent shear, was made using a piece of 50mm angle iron welded to the flat base of the rammer.

Covers The DTU ferrocement thin-shell cover was used on both RE1 and RE2 and a special sealed (pressure-resistant) cover is to be developed for RE-UK.

Tank linings
Experiments have been carried out with two types of tank lining:

- *Plastic lining*. Work on plastic linings has been underway for some time at the University by an MSc student. A technique has been developed for welding 250 micron construction or damp proof membrane (DPM) plastic sheet to make 'bags' (similar to large bin liners) that fit inside the tank structure to form a waterproof lining. The welding technique has been successfully developed but there are still problems to be overcome in relation to the quality of 'off-the-shelf' plastic sheet and failure of the lining due to abrasion.
- *Cement render lining with waterproofing agent*. This is a more traditional form of waterproofing for water storage tanks and was eventually used for both the field experimental tanks. Further investigation into the nature of render linings, with particular respect to permeability and the effects of waterproofing agents, is underway at the University.

7.4. Laboratory work on RE tanks

Aims of the laboratory experiments Between November 1999 and May 2000 laboratory tests were carried out at the University of Warwick. The work was carried out to allow the author to gain experience with earth building technology and to develop a technique suitable for building tanks from soil. The full aims of the work was as follows:

- to set out the theory of RE tank design and to investigate the options available for rammed earth tank construction
- to develop the skills required (within the research team) to analyse soils for building, in both the laboratory and in the field
- to investigate soil modification techniques and methods to develop a soil suitable for tank construction
- to develop the tools and equipment required for RE tank construction
- to develop a technique suitable for rammed earth tank construction
- to develop a technique for tank lining using plastic sheet
- to test a rammed earth tank under laboratory conditions to verify the theory with regard to:
    - hoop strength (reinforced and un-reinforced)
    - the effect of rain on stabilised soil
    - performance tests for soil:

- wet and dry tensile strength
- wet and dry bending strength
- wet and dry shear strength (all three to be carried out at experimental and applied levels)
- swell and shrinkage
- erosion
- abrasion
- passage of water
- compatibility (adhesion) with renders and mortars

Preparation for the laboratory experiments The test site was established in a disused water turbine testing sump in the university laboratory. The set up for the experiments was time consuming and the preparation of the site took several weeks, mainly fitting lighting and safety equipment to conform with university safety regulations

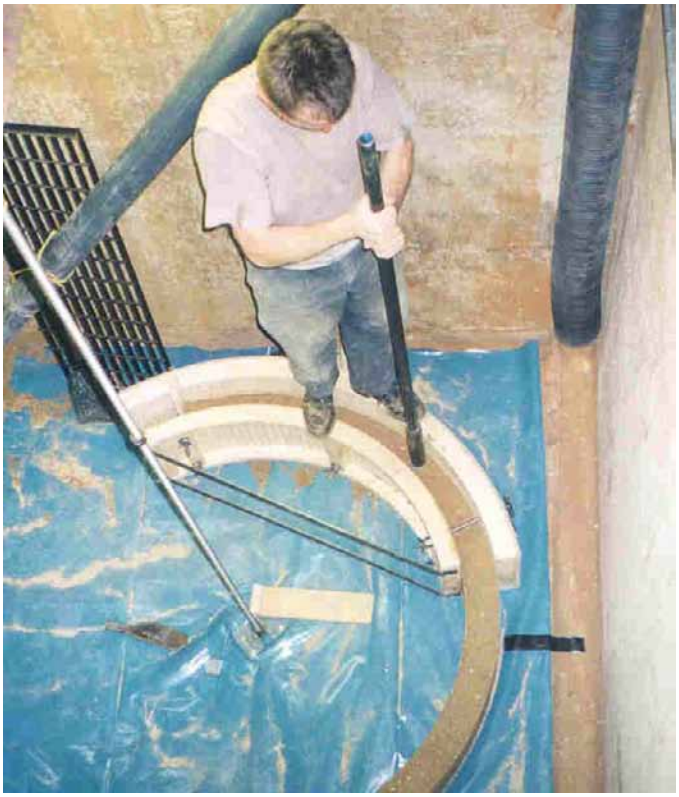

Figure 7.5 Showing tank test area at the university laboratory

Desk work to develop experimental tank specification
Sufficient deskwork was undertaken to formulate a specification for the RE tank. The theory of stresses in tanks is given in Section 4 along with detail of the spreadsheet used to analyse stresses and to develop the specification for the experimental tank. The specification is as given below:

Table 7.1 Specification for laboratory experimental tank

Tank internal diameter	1.40m
Depth	1.0m
Wall thickness	0.1m

Wall / base joint	'slippery' joint using plastic sheet
Section bonding	Polypropylene knotted rope to give tensile bond for vertical joints V channel ramming for better horizontal joints
Drying time	2 weeks in dry environment

Work carried out in the laboratory

Soil analysis What was thought to be a suitable soil was purchased from a local quarry and an analysis was carried out. The soil is known locally as 'Hoggin'The soil was analysed using the standard wet sieving technique and the following results were obtained:

Table 7.2 Soil classification for Hoggin from Husbands Bosworth, UK, December 1999. Sample size 1500g, oven dried for 24hrs, wet sieved

Sieve Size (mm)	Weight retained	% retained	Description
20.000	220.6	14.87	Pebbles
6.300	394.6	26.59	Gravel
2.000	379.8	25.60	Gravel
0.420	222.5	15.00	Coarse sand
0.063	146.3	9.86	Fine sand
<0.063	120.0	8.09	Silt, fine silt and clay

Table 7.3 Results of a sedimentation test carried out on particles passing through 0.063mm sieve (from Table 7.2 above).

Time elapsed since agitation	Settled depth (mm)	% of total settled depth	Description	%age of total soil sample
1min	18	56.25	Sand	18.46
30 min	25	21.875	Silt	7.18
24 hrs	32	21.875	Clay	7.18

The soil was assessed and it was noted that:

a) there were many large stones >30mm
b) there was an excessive amount of material over 6.3mm in size – about 40% of total
c) there was insufficient clay for binding the material (7.18% of total material content)
d) there was insufficient sand in the soil

Soil modification It was decided that the soil should be modified. Several experiments were carried out to formulate a suitable soil and the following procedure was developed to prepare the required soil:

a) all large stones >30mm were removed
b) the soil was sieved to remove all particles above 10mm
c) the soil was then sieved again to isolate all particles between 5mm and 10mm
d) kaolin (china clay) was purchased and used to make up the deficiency in clay content

e) concrete sand was acquired to make up the deficiency in sand in the original soil

The final mix was as follows:

Hoggin <5mm	- 30%
Hoggin 5mm – 10mm	- 20%
Concrete (builders) sand	- 35%
Kaolin	- 15%

No stabilisation was carried out at this point and the material could therefore be recycled during the early tests.

Table 7.4 The sieve analysis for the modified soil (now known as Soil 4)

Sieve Size (mm)	Weight retained	%age retained	Description
6.300	83.80	9.16	Coarse gravel
2.000	232.10	25.37	Gravel
0.420	274.45	30.00	Coarse Sand
0.063	160.70	17.57	Fine sand
<0.063	163.80	17.90	Silt and clay

Soil 4 was used for all subsequent construction work in the laboratory.

Compaction tests and Optimum Moisture Content Compaction tests were carried out (as described in Section 3.3.2) on Soil 4 to determine the Optimum Moisture Content (OMC). The results show a moisture content of 9% to be optimum. However, in practice a figure of 8% was used as soil with 9% moisture content was too 'sticky' and caused the soil to stick to the rammers.

Liquid limit and plastic limit tests – the Atterburg chart Tests to determine the liquid and plastic limits were carried out and the results shown below:

Table 7.5 – LL, PL and PI Figures

Liquid limit	14.80
Plastic limit	9.59
Plasticity Index	5.21

Figure 7.6 – Early experimentation with ramming wall sections

Initial ramming tests and developing the technique for RE tank construction The shuttering was developed in such a way that 3 sizes of wall thickness could be tried; 60mm, 80mm and 100mm. The reason for this was that it was doubtful if the smaller wall thickness (the lower lifts) would withstand the compaction blows of subsequent lifts.

Early tests showed a number of problems with the ramming technique:

- the shuttering was deflecting and causing the wall section geometry to loose its true curvature
- the 60mm thick wall showed signs of cracking when the shuttering was clamped to it for the subsequent section
- when ramming, a reaction caused the shuttering to bounce or lift slightly (see Figure 7.7)
- the geometry of the shuttering was crucial and problems were encountered due to slight irregularities in the geometry

These problems were overcome by some adjustments to the shuttering:

- strengthening was added to prevent deflection
- the wider setting was used to produce a wall of 100mm thickness
- radial arms were fitted to the shuttering to maintain centrality and to allow weights to be added to prevent 'bouncing' (see Figure 7.7)
- the geometry of the shuttering was corrected slightly as no allowance had been made for the width of the end stops

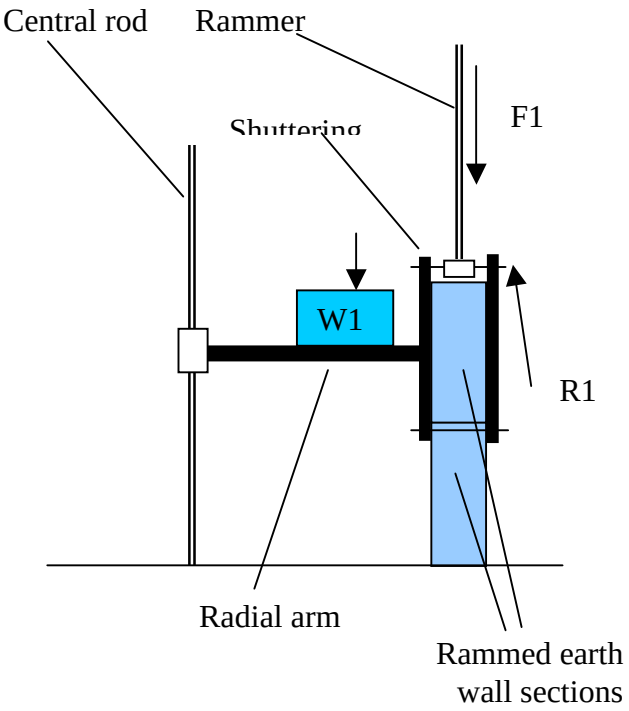

The ramming force, F1, causes a reaction in the shuttering, R1, which causes the shuttering to lift and hence cause deformation. The weight, W1 (two x 25kg bags of sand were used), counteracts R1 and prevents the deformation.

Figure 7.7 Showing the forces created through ramming and the measures taken to counteract these forces

Manufacture of experimental tank A tank of 1.4m diameter and 0.7m height was built in a disused turbine testing sump (see specification given in Section 6.3.3). The tank was built from Soil 4. The aim was to test the general principle of construction and to allow for initial tests to be carried out on earth tanks. The tank was completed in May 2000 and simple tests carried out, but full tests are yet be to be carried out on this tank The simple tests include fitting experimental linings, applying steel strapping and filling the tank a number of times to test strength. The fuller tests are to include pressure tests to ascertain the actual strength of the tank to allow comparison with the theory.

Figure 7.8 Showing the experimental tank in the sump at the university

Composite materials for added tensile strength Composite materials and reinforcement can be used to improve the strength of compacted soil. For improved tensile strength the added material should have good tensile properties and be malleable so that it can be rammed into the soil matrix. Some ideal materials include barbed wire, polypropylene fibre and straw.

External reinforcement for added tensile strength External reinforcement such as steel packaging strap, barbed wire, or plain fencing wire can be wrapped around the finished tank walls for added tensile strength.

Laboratory tests Due to time constraints and unforeseen problems with developing the technique for RE tanks, other planned laboratory tests have not yet been carried out. Tests are being undertaken at present to verify the theory with regard to:
hoop strength (reinforced and un-reinforced)
the effect of rain on stabilised soil

- performance tests for soil:
- wet and dry tensile strength
- wet and dry bending strength
- wet and dry shear strength (all three to be carried out at experimental and applied levels)
- swell and shrinkage
- erosion
- abrasion

- passage of water
- compatibility (adhesion) with renders and mortars

This work will be reported at a later date.

Conclusions and discussion concerning laboratory work on RE tanks Soil analysis was carried out for a locally sourced soil. The soil was modified to create a suitable soil for RE tank construction. The tools and techniques for RE tank construction have been developed.

Developing the technique for RE tanks proved to be more problematic and time-consuming than was originally thought, with much work needed to overcome geometry problems. The level of accuracy required, both in shutter manufacture and in the construction process, is higher than expected. Early tests show that the RE tank design has good potential.

Soil preparation time is high and so a suitable soil should be sought in the field that requires little preparation.

The problems encountered during the construction process meant that few further tests have yet been carried out.

Further laboratory work
Recommended further work is listed below:
- Manufacture of sealed cover and tank pressurisation equipment
- Pressure testing of the existing experimental tank
- Data logging to allow analysis of the stresses in the tank during pressurisation
- Performance tests to analyse the soils characteristics in use
- Experiments to determine the effects of cement content on stabilisation
- Experiments to determine the effect of cyclic loading on rammed earth tank walls (cracking, joint failure, etc.)
- Waterproof lining (resistance to penetration, fixing methods, liner penetration for off-take, etc)
- Wet strength tests of tanks

7.5. Field work

The principal aims of the field tests were:
- to test the technique developed in the laboratory for rammed earth tank construction
- to test the technique for tank lining using plastic sheet
- to build a number of tanks to test the feasibility of the technology and its suitability to LDC skills
- to test a tank under field conditions to verify the theory
- to carry out a full cost analysis of a RE tank to allow comparison with other tank types

Specification for 2 experimental field tanks

The specification for the two rammed earth tanks is given in the tables below. The specifications were drawn up using the results of the spread sheet analysis and with the specific aim of testing a) a tank using standard building guidelines for rammed earth construction (RE1) and b) a low-cost tank using predominantly stabilised earth and minimising the cement content (RE2).

High Specification RE Tank (RE1)

Tank internal diameter	2.0m
Tank external diameter	2.4m
Tank height	2.0m
Tank capacity	approximately 6 cubic metres
Concrete base thickness	100mm un-reinforced (on 100mm hardcore where ground is soft)
Concrete base diameter	2.8m
Soil wall thickness	0.2m
Soil make-up	10% clay, 15 – 30% silt, 50 – 70% sand, 10 – 20% garvel, 4% cement stabilisation
Reinforcement	barbed wire hoops at 50-60mm spacing in rammed earth sections steel reinforced cement hoops at spacing shown in drawing
Lower wall dimensions	350mm stone masonry, 0.2m thickness
Tank lining	waterproof render approx. 15mm thick (or plastic liner)
Cover	thin shell ferrocement cover
Water extraction	By gravity – washout also by gravity

Low Specification RE Tank (RE2)

Tank internal diameter	2.0m
Tank external diameter	2.4m
Tank height	2.0m
Tank capacity	approximately 6 cubic metres
Base	100mm stone with 50mm compacted stabilised soil, 2.8m diameter
Wall	Stabilised soil, 0.2m thickness
Reinforcement	barbed wire hoops at 50-60mm spacing in rammed earth sections
Soil make-up	10% clay, 15 – 30% silt, 50 – 70% sand, 10 – 20% garvel, 4% cement stabilisation
Tank lining	plastic liner
Cover	thin shell ferrocement cover
Water extraction	by handpump where plastic liner is used

Some of the design features and design considerations that were incorporated are outlined below:

- The wall sections were given a ‘V’ profile to prevent shear. The aim was to encourage better bonding and so reduce the likelihood of shear. The profile was achieved using a special ram with a V attached. See Figure 7.9.

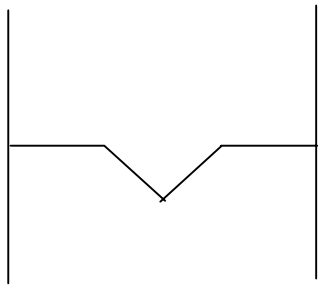

Figure 7.9 – Profile of the joint between 'lifts'

- The principle adopted for house construction of good protection at the base and overhanging eaves for protection from above were adopted, especially in the case of RE1
- The tank size is based on useful capacity and available catchment area
- Minimal cost – the general aim of this task is to reduce the cost of storage for rainwater
- The use of local materials as far as possible
- Durability – a minimum of 10 - 15 years life expectancy
- Easily constructed by local artisans in developing countries
- Foundations – these should be:
  - should be laid in a good sound soil
  - be protected against ingress of moisture
  - be protected against frost (not an issue in the Trpoics0
  - be protected from wind erosion – sand blasting in severe storms
  - be protected against animals, rodents, insects, etc
- Protection from surface water through good drainage (Houben pg 252) – ground to slope away from tank, ground gutters, moisture barriers,
- Foundations in unstable soils need to be considered – ground stabilisation may be needed

Work carried out in the field

The two tanks specified in the previous section were constructed at Kyera Farm. The procedure for their construction is outlined in Appendix IV. Each step of the work was carefully observed and monitored against the aims set out in Section 6.4.1. An initial field soil analysis was carried out to determine a suitable soil. Some modification was needed and then a full laboratory analysis was carried out on the modified soil.

Tests carried out in the field

Soil analysis – field tests

Three soils were analysed crudely in the field. The following tests were performed:

Sensory tests

The soil was analysed by feel, look and smell to test for initial suitability

Sedimentation test. The results are shown below:

Table 7.6 Results of the sedimentation test carried out in the field

Soil source	Soil code	T1	T2	T3	% sand	% silt	% clay
Murram from farm <4mm	S1	40	42.5	42.5	94	6	0
Anthill P <4mm	S2	22	53	53	37.7	62.3	0
RE2 excavation site <4mm	S3	53	59	59	89.8	10.2	0

Notes:
T1 = reading taken in mm, start time plus 1minute
T2 = reading taken in mm, start time plus 30 minutes
T3 = reading taken in mm, start time plus 24 hours
The murram has some organic material; good distinction between layers.
Anthill has little organic matter; poor distinction due to uniform colour.
RE2 excavation site high organic content; good definition.
Clay content is shown as 0% in each of the above. This is because further settling of the sand and silt after initial measurement caused final reading to be low.

A further sedimentation test was carried out to estimate the clay content. Tests were carried out on the murram and the anthill soil. Soil passing through a 0.075mm sieve was sedimented and readings taken at 20mins, 24hrs and 48hrs. From the readings obtained, the clay content was estimated to be:

Table 7.7 Results of tests to determine clay content of soils

Soil	Clay content	Comment
Murram from farm <0.075mm	4%	Again definition was difficult and the reading was not fully trustworthy
Anthill P <0.075mm	0%	Settling took place rapidly indicating little or no clay content

Soil modification

None of the three soils tested was fully suited to RE construction. However it was found that by mixing the larger particles of the murram (those retained on a 4mm sieve) with the crushed anthill soil, a suitable soil was developed. Stabilisation was provided by adding 4% cement. The cement percentage was kept deliberately low to save on cost. The final mix is shown in Table 6.8.

Table 7.8 Showing mix used for modified soil for RE tank construction

Material	Quantity
Crushed anthill soil	80%
Murram >4mm	16%
Cement	4%
Water	Added in sufficient quantity and checked using field test

Soil analysis – laboratory tests

An analysis of the modified soil was carried out at the Central Materials Laboratory, Ministry of Works and Housing, Kampala. The analysis is summarised below.

- *Sieve analysis*
  The full analysis is shown in Appendix III but a summary is given in Table 6.9

Table 6.9 Summary of sieve analysis for RE1 and RE2 tank soil

Classification	
Pebbles	0%
Gravel	21%
Coarse sand	17%
Fine sand	17%
Silts	10%
Fine silts	19%
Clays	16%

- *Other tests*

Table 7.10 Results from laboratory tests for construction soil

Test name	Testing for	Result
Hydrometer analysis	Specific gravity	Gs 2.65 (measured)
Atterburg limits(1)	Liquid limit	34
	Plastic limit	16
	Plasticity index	18
Normal moisture content	Normal moisture content	2%
Compaction and OMC(2)	Material density	1,930Kg/m^3 (Maximum dry density – MDD)
	Optimum moisture content	12%
Linear shrinkage	Linear shrinkage	10%
Permeability	Permeability	4.09 x 10^{-7} m/s
Unconfined compressive strength	Unconfined compressive strength	0.2MPa @ 95% MDD

Notes:
[1] Referring to the Atterburg Limits Chart in Figure 2.1, we can see that the ideal stabiliser for this soil is cement.
[2] A heavy compaction test was carried out to determine density and OMC:
The results are discussed in Section 6.4.7.

Water bearing test on finished tanks

RE2 was filled using a bowser. It was filled quickly using a motorised pump. The tank held water for about 8 hrs but damp patches appeared at the base of the tank. ‘Piping*’ caused loss of water which became critical after about 12hrs and there was a total loss of water after approximately 14hrs. As the wall became damper, 3 major cracks appeared in the tank wall. The possible reasons for the failure are discussed in Sections 6.4.7 and 6.4.8.

*Piping is a term used in the dam industry and is a mode of failure whereby water finds a path from one side of the dam wall to the other and the subsequent erosion of the wall causes failure.

Figure 7.10 The experimental rammed earth tank under construction at Kyera Farm, Mbarara, Uganda.

As a result of the failure of RE2, RE1 was relined and is awaiting slow filling by rain. RE1 has not yet be tested at full working water pressure.

7.6. Results of field and laboratory tests

Some observations regarding the laboratory tests:

- The results of the sieve analysis shows that the soil is suitable for RE construction.
- Referring to the Atterburg Limits Chart in Figure 2.2, we can see that the ideal stabiliser for this soil is cement.
- Compaction density (MDD) seems rather low – normally we would expect a MDD of at least 2000Kg/m^3.
- OMC seems rather high – this is normally in the range of 8 – 10%
- Permeability is high at 4.09 x 10^{-7}m/s. The norm for stabilised soil is 1 x 10^{-8}m/s.
- Unconfined compressive strength seems very low and this figure is not trusted.
- Linear shrinkage is also high.

The result of the water bearing test described in Section 7.4. was discouraging as far as the overall viability of RE tank technology is concerned. The failure highlighted a number of points:

- Soil tanks should have sufficient wet tensile strength to cope with total saturation in water. This has a strong impact on the design of such tanks and could result in excessive wall thickness.
- A tensile reinforcement should be included within the soil matrix to prevent catastrophic failure in the event of saturation.
- A good tank lining is critical. A poor leakage of the lining will cause rapid degradation of the wall.
- Where a waterproofing agent is used in a render lining it should be given adequate time to take effect. Follow the manufacturers instructions and where they are

lacking, fill the tank slowly, at no more than 200mm per day after 2 weeks of curing in a saturated environment.

7.7. Observations made regarding the RE tank construction technique and field tests

The construction technique developed in the laboratory was further refined in the field. The following observations were made:

- Soil preparation was initially very time consuming, until a groundnut sheller was acquired and modified to mill soil through a 4mm sieve (see Appendix IV). This reduced soil preparation time to about one tenth.
- RE construction is a time consuming process. The cost analysis in Section 6.5 shows how labour intensive the process can be.
- The shuttering used in the field had no radial arms and so the reaction discussed in Section 7.3 was dealt with by standing on the shuttering whilst ramming.
- The level of accuracy attained in the field was lower than in the laboratory. This was not a problem, however, as soil was cut away with a machete if the geometry was not perfect. This was more feasible in the field as the wall thickness of these tanks was higher.
- Some work was carried out to assess the feasibility of plastic liners for use with soil tanks. There were problems in a number of areas: finding good quality plastic sheet; finding plastic sheet of a suitable size; abrasion of liners when in use causing small puncture holes. The technique is not recommended for use at present.

Limitations of the field tests Time constraints were tight due the limited amount of time in-country. It was difficult to set up and execute proper tests during the limited time available, the construction process itself being very time consuming. The tests that were carried out were done so hurriedly and give only an indicative feel for the behaviour of the tank.

7.8. Conclusions, discussion and planned further work concerning RE tanks

Discussion The probable mode of failure of RE2 is outlined in this Section. It appears that water passed through the lining of the tank almost immediately the water was placed in the tank. It seems probable that the waterproofing agent had had insufficient time to act and that water was passing through the render under full water pressure. Alternatively, the lining was of poor quality and water passed through cracks in the lining. The water forced its way through the soil matrix under piping action until it emerged at the outer face of the wall, and the resultant erosion increased the ‘pipe’ area until the water could flow freely from the tank (see Figure 7.11).

The fact that cracks appeared in the tank wall mean that the wet strength of the soil was insufficient to withstand the forces exerted through normal working water pressure, which is not tolerable.

Figure 7.11 Failure of RE2 through 'piping' – this figure shows the leakage at the base of the tank and the crack running through the wall

Further work on RE Tanks A similar water pressure test will be carried out on RE1, as was carried out on RE2. This tank has been relined and will be filled with rain during the coming wet season (starting September 2000). Staff at Kyera Farm have been asked to observe the tank as it slowly fills.

The following is a list of further work that is recommended to clarify uncertainties regarding the technique:

- Performance tests on soil samples taken from field
- Further investigations into suitable levels of soil stabilisation
- Investigation of techniques for improving wet strength of stabilised soil
- Investigation of techniques for decreasing permeability of stabilised soil (e.g. inclusion of bitumen emulsion)
- Further field tests including destructive tank pressurisation tests
- Further work to develop suitable plastic or other flexible linings

8. Cost analysis

A cost analysis for an 11 cubic metre ferrocement tank and an 11 cubic metre rammed earth tank has been carried out

The bill of quantities for the ferrocement tank was taken from Gould and Nissen-Peterson, 1999. The rammed earth tank is an externally rendered tank fitted with a thin-shell ferrocement cover. It is also fitted with a plastic 'sock' lining as described later in this document. Hoop strength is augmented using barbed wire hoops spaced every 0.1m for the entire height of the tank. Cement content is 5% and moisture content of the soil is 8%. We have used material prices based on costs in Uganda as of August 1999. This allows us to make a realistic analysis using costs from a single location and an identical size of tank. We are therefore making a direct cost comparison. The cost comparison and relative benefits may change if the costing is repeated for a different location (with different prices). India, for example, has lower

cement prices, which would impact greatly on this comparison. One pound sterling is roughly equivalent to 2440 Ugandan shillings (UGX) as of January 2000. Transportation costs for materials (other than sand) are not included.

The costing figures are shown in the table in APPENDIX I and the table is self-explanatory. Some points to consider are:

- Cement is the major cost in the ferrocement tank. There is little means of reducing the cost without reducing wall thickness. Transportation of cement can be costly if the site is remote.
- The cost, including labour, of the thinner walled rammed earth tank is about 80% that of the ferrocement tank. Material costs are about 72%. This reflects the higher labour input required.
- If suitable soil is available on site then the material costs of the RET can be reduced significantly.
- The RET wall sits on a concrete ring rather than a concrete disc. The base of the tank is of compacted earth. This helps reduce costs as concrete raft bases consume significant quantities of material and are therefore expensive.
- The RET wall is stabilised. The wall would have sufficient strength without stabilisation and the cost could be reduced further. Stabilisation is desired however in case of wetting of the wall.
- If stabilisation and reinforcing is omitted, the cost of the (thinner-walled) RET drops to 697,000 UGX or £278.28, 58.5% that of the ferrocement tank cost (including labour).
- Tooling costs, shuttering and moulds in particular, tend to be higher for the ferrocement tank, although for both tanks the moulds / shuttering can be reused many times.

9. General conclusions, discussion and plans for further work

9.1. Discussion

A number of stabilised soil tanks have been constructed and tested, using two different soil construction techniques. Two tanks have failed under test and the failures have been analysed in the relevant sections of the report. Two further tanks are still under test. Some important lessons have been learned from the initial tests and these lessons will be used to guide further research. The main lessons learned are listed here:

- When designing stabilised soil tanks one should take into consideration wet tensile strength of the material. It is inappropriate to use the dry tensile strength as the design strength value unless it can be guaranteed that water will never reach the soil matrix.
- A composite tensile member is recommended to prevent sudden catastrophic failure of a tank.
- Tank linings should be fully impermeable to prevent water reaching the soil matrix.
- Plastic linings

9.2. Recommended further work

Stabilised soil block tanks

- Full laboratory analysis of the soil
- Performance tests to determine the soil / block characteristics
- Further full scale tank tests with some modifications to improve tank performance
- Investigate methods for improving tensile strength e.g. reinforcing with barbed wire

Rammed earth tanks - Laboratory work

- Manufacture of sealed cover and tank pressurisation equipment
- Pressure testing of the existing experimental tank
- Data logging to allow analysis of the stresses in the tank during pressurisation
- Performance tests to analyse the soils characteristics in use
- Experiments to determine the effects of cement content on stabilisation
- Experiments to determine the effect of cyclic loading on rammed earth tank walls (cracking, joint failure, etc.)
- Waterproof lining (cyclic loading with a variety of 'sharp' objects to test resistance to penetration, fixing methods, liner penetration for off-take, etc)
- Wet strength tests of tanks

Rammed Earth Tanks - Field work

- Performance tests on soil samples taken from field
- Further investigations into suitable levels of soil stabilisation
- Investigation of techniques for improving wet strength of stabilised soil
- Investigation of techniques for decreasing permeability of stabilised soil (e.g. inclusion of bitumen emulsion)
- Further field tests including destructive tank pressurisation tests
- Further work to develop suitable plastic or other flexible linings

Other work

- Render linings for tanks – permeability tests and effects of waterproofing agent on render (both in early stages and longer term)
- Methods for reducing permeability of compacted soils (e.g. treatment with bitumen emulsion)
- Further experiments on the relationship between wet and dry strength in tension
- Tank linings from plastics
- Termite attack on soil tanks
- Sliding joint at base of tank

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APPENDIX I - Cost comparison between 11 cubic metre ferrocement tank and two rammed earth tanks (of wall thickness 0.2m and 0.3m).

					11 cub m ferrocement (Nissen-Peterson, 6 cm wall thickness)		11 cub m rammed earth tank (wall thickness 0.2m)		11 cub m rammed earth tank (wall thickness 0.3m)	
Item	**Specification**	**Unit**	**Unit cost**		**Quantity**	**Cost**	**Quantity**	**Cost**		
Cement	50 kg	bag	15,500		22	341000	11	170500	15	232500
Lime	25 kg	bag	10000	*	1	10000				
Sand	coarse and clean	tonne	30000		5	150000	7	210000	11	330000
Crushed stones	10 to 20mm	tonne	40000		2	80000	2	80000	2	80000
Rubble stones	100 to 500mm	tonne	30000		1	30000				
Bricks	variable	number	70		50	3500	100	7000	100	7000
Water	200 litre	oil drum			15	0	5		7	
BRC mesh	No 65	m	6000		24	144000				
Chicken mesh	25mm, 0.9m	m	3000		38	114000				
Twisted iron	12mm	m	2000	*	3	6000				
GI wire	3mm	kg	1,250		10	12500				
GI Pipe	38mm	m	7000	*	0.9	6300	1	7000	1	7000
GI Pipe	18mm	m	5000	*	0.9	4500	0.3	1500	0.4	2000
Tap, elbow nipple and socket	18mm	unit	15000		1	15000	1	15000	1	15000
PVC pipe	100mm	m	5000		2.2	11000				
PVC pipe	50mm	m	3000		3	9000	2	6000	2	6000
Coffee mesh	galvanised	m	3000	*	1	3000	1	3000	1	3000
Mosquito mesh	plastic	m	2000	*	0.5	1000				
Lockable door	steel	0.9 x 1.5	20000	*	1	20000	1	20000	1	20000
Reinforcing steel	8mm	10m lngth	10000				3	30000	3	30000
Plastic liner	custom made	unit	20000	*			1	20000	1	20000
Barbed wire	galvanised	roll 50m	50000	*			2.5	125000	2.5	125000
Skilled labour	mason, supervisor	day	12,000		10	120000	12	144000	14	168000
Unskilled labour	assistants	day	4000		20	80000	24	96000	28	112000
Totals		Total minus labour			UGX	960,800		695,000		877,500
					£	393.77		284.83		359.63
* estimated cost		Total with labour			UGX	1,160,800		935,000		1,157,500
					£	475.73		383.19		474.38

APPENDIX II - REPORT ON WATER TANKS FROM STABILISED SOIL BLOCKS

(by Engineer Dr. M. K. Musaazi PhD DIC, August 2000)

Machinery

Manual Block Press (by ApproTec Kenya): Specially modified by authorized manufacture (Makiga Engineering Services, Kenya) to make curved interlocking blocks. There are two Block Presses designed so that 13 blocks interlock to make a 1.0m internal diameter circle or 17 blocks make a 1.5m internal diameter circle.

Material

Murrum (red) soil or volcanic soil and Ordinary Portland Cement (OPC)

Material Preparation

Sieve soil with a 5mm wire mesh. Mix while dry with OPC in the ratio.

Cement : Soil = 1: 19

i.e. 50kg(l bag) of OPC makes 110 SSB blocks each of about 9kg. A little water is added to make the mixer just damp.

Block Making

Prepared material compressed by 40% to make one block at a time.
Two men make 330 blocks/day.

Curing and Drying of Blocks

Blocks are cured under a black Polythene sheeting for five days if made from murrum and for 2 days if from volcanic soil. Dried for 5 days under direct sunshine, after curing, before used to make tanks.

Tank Building

A 150 mm concrete base is made and blocks laid the following day. Blocks interlock to form a circle desired internal diameter.

Experience has shown that the internal diameter can be increased from design by as much as 0.5m without any noticeable distortion of the circle.

The blocks are laid using a 1:4 cement to sand ratio. One bag (50kg) of OPC lays about 200 blocks. The inside of the tank is plastered with fine sand, OPC and water proof cement (I kg added to 50kg of OPC).

Block Size:

Length = 280 mm
Width = 140 mm
Height = 110mm

Hence the tank wall is 140 mm thick plus 10 mm of plaster.

Tank Sizes

The size of course depends on the internal diameter and height. The tanks that have NOT failed number five as tabled below:

TANK NO.	DIMENSIONS	CAPACITY (Litres)	WHEN MADE MONTH, 2000	REMARKS
1	Int diam – 1.0m Height - 5.2m Block layers – 13 Total blocks – 507	5,800	March	Full up to 3.5m as of 1st August 2000
2	Int diam – 1.24m Height - 2.12m Block layers – 15 Total blocks – 240	2,500	March	Full to capacity as of 1st August 2000
3	Int diam – 1.20m Height - 2.12m Block layers – 14 Total blocks – 210	2,400	April	Full to capacity as of 1st August 2000
4	Int diam – 1.20m Height - 2.12m Block layers – 14 Total blocks – 210	2,400	April	Full to capacity as of 1st August 2000
5	Int diam – 1.20m Height - 2.12m Block layers – 14 Total blocks – 210	2,400	May	Full to capacity as of 1st August 2000

One tank that ruptured when trying to fill it with water had the following dimensions:

Int. Dia = 1.67 m
Height = 3.80 m
Blocks/layer = 19
No. of layers = 28
Capacity = 8.324 litres

Tank ruptured when about 2.5m full.

Possible causes of tank failure:

(i) Diameter too large, hence insufficient hoop strength
(ii) Filled too quickly with a tanker – this does not give the waterproofing agent time to work properly

(iii) Blocks from volcanic soil seem not to have been stabilised – broken blocks disintegrated completely when soaked in water. This could be due to poor workmanship, although the building team are known and trusted.

(Figure AII.1 – Tank built for experimental tests in Uganda)

(Figure AII.2 – failure of the SSB tank was catastrophic – the debris remaining after failure is shown here)

APPENDIX III - Sieve analysis for soil used at Kyera Farm

mm	% passing	%retained	Classification
50.0000	100	0	Pebbles 0%
37.5000	100	0	
20.0000	97	3	Gravel 21%
10.0000	94	3	
6.3000	87	7	
5.0000	84	3	
2.0000	79	5	
0.6000	75	4	Coarse sand 17%
0.4250	73	2	
0.3000	68	5	
0.2120	62	6	
0.1500	52	10	Fine sand 17%
0.0630	45	7	
0.0600	43	2	Silts 10%
0.0579	42	1	
0.0411	40	2	
0.0258	38	2	
0.0202	35	3	
0.0148	25	10	Fine silts 19%
0.0107	23	2	
0.0076	22	1	
0.0054	22	0	
0.0044	20	2	
0.0038	20	0	
0.0034	19	1	
0.0031	19	0	
0.0028	18	1	
0.0027	16	2	
0.0016	15	1	Clays 16%
<0.0016		15	

APPENDIX IV – Rammed Earth Tank Construction Guidelines

Including Shuttering and Rammer Drawings

Milestone A4

Completion of three partially below ground tanks, 2 rammed earth tanks, eight cement jars and two stabilised soil block tanks.

(Originally titled 'Completion of 3 sets of 4 tanks and associated instrumentation')*

Development Technology Unit (DTU)

University of Warwick

April 2000

Milestone A4 - Table of Contents

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3. Construction of two rammed earth tanks.....6
4. Construction of eight cement jars for water quality experiments.....9
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Funded by the European Commission

*Please see the introductory section for an explanation of the change in the title of this report.

1. Introduction

As mentioned in the Milestone A3 Report, early in the programme, after the initial desk study had identified the areas where further research is required, it was decided to broaden the original scope of the water storage (technology) component of the programme to include above ground, free-standing water storage tanks as well as underground tanks. The focus of the work was, initially, broadened to look at tank covers and reinforced brick tanks. We have since moved forward with more radical cost reduction ideas and have been experimenting with two very low cost water storage ideas: the partially below ground tank and the rammed earth tank. We also carried out some water quality experiments in Uganda to test the acceptance of water from cement lined storage vessels. For these experiments we constructed eight 400litre cement jars. Finally, through our connections with Uganda we were asked to carry out some collaborative research with Mr Moses Musaazi of Makerere University into the use of cement stabilised soil blocks for the construction of above-ground water storage tanks.

The title of this Milestone has therefore been altered to reflect the practical research work that has actually been carried out under the programme.

A brief overview of the work that has been completed for this Milestone is given in this report. A fuller report of the work that has been carried out, including the experiments carried out and results obtained for each of the pieces of work mentioned above, will be presented in Milestone A5 (Report A3 '*Performance of Tanks for DRWH'*). This report will be submitted in the near future.

2. Construction of three partially below ground tanks

As reported in Milestone A3, work was started on the design of the Partially Below Ground (PBG) tank in Uganda last year. The work has still, to date, been primarily field based and three tanks have been built until now, in the vicinity of Kyenjojo, Kabarole District in Western Uganda. The tanks have been built by our partner organisation, ARUCED. ARUCED has also received orders for a number of these tanks to be built privately and to date eight tanks in all have been built.

The aim of the design of the PBG is to minimise the amount of material used by partially submerging the tank below ground – the major benefit of sub-surface tanks. The fact that approximately 1metre of the tank protrudes above the ground helps overcome some of the drawbacks normally associated with below ground tanks (see Table 1 below). The ground conditions in this part of SW Uganda are ideally suited to this kind of tank, being lateritic and highly stable.

	Above ground tank	Below ground tank
Pros	• Above ground structure allows for easy inspection for cracks or leakage • Many existing designs to choose from • Can be easily purchased 'off-the-shelf' in most market centres • Can be manufactured from a wide variety of materials • Easy to construct for traditional materials • Water extraction can be by gravity in many cases • Can be raised above ground level to increase water pressure	• Generally cheaper due to lower material requirements • More difficult to empty by leaving tap on • Require little or no space above ground • Unobtrusive • Surrounding ground gives support allowing lower wall thickness and thus lower costs
Cons	• Require space • Generally more expensive • More easily damaged • Prone to attack from weather • Failure can be dangerous	• Water extraction is more problematic – often requiring a pump • Leaks or failures are more difficult to detect • Contamination of the tank from groundwater is more common • Tree roots can damage the structure • There is danger to children and small animals if tank is left uncovered • Flotation of the cistern may occur if groundwater level is high and cistern is empty heavy vehicles driving over a cistern can cause damage

Table 1. Pros and Cons of Tanks and Cisterns

The design also tries to minimise the amount of cement used by employing a plastic liner to form the water proof lining for the tank. Until now the plastic liner has not, however, been fitted and the water proofing has been achieved by means of cement render. Further work in Uganda in the coming months will include the manufacture of plastic liners and these will be fitted to subsequent tanks.

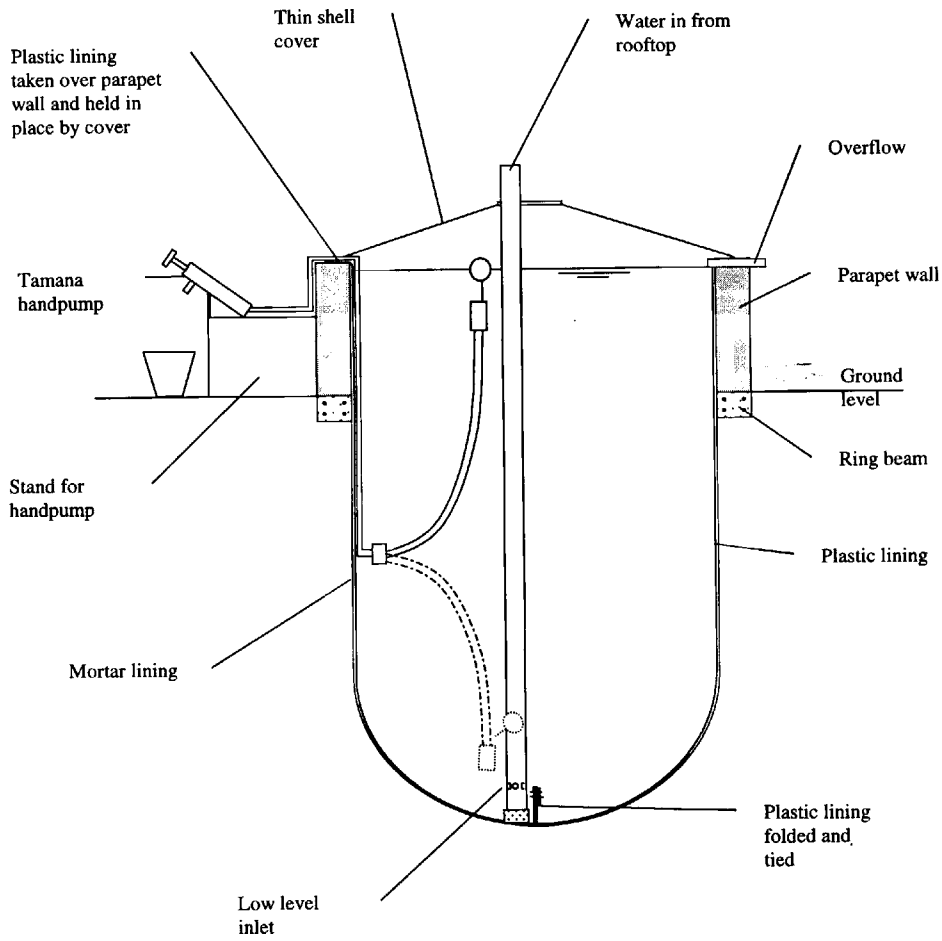

Figure 1 – Schematic drawing of the Partially Below Ground Tank

A costing exercise has been carried out to estimate the benefits of using the PBG tank against the traditional ferrocement tank (assumed to be amongst the cheapest options) and the rammed earth tank (described below). A brief summary is given Table 2.

	Ferro-cement tank	***Rammed earth tank***	***Partially below ground tank***
Material	394	179	107
Labour	81	98	90
Total cost	475	277	197

Table 2 - Comparison of costs between a ferrocement, rammed earth and PBG tank – all 11 cubic metres

Each of the PBG tanks was fitted with a thin shell ferrocement cover, described in a previous report and developed under this programme.

Figure 2 – A thin shell ferrocement cover near completion and ready for fitting to a PBG tank

Figure 3 - A completed PBG tank showing inlet pipe and handpump for extracting water

Initial leakage tests were carried out on a number of tanks using a device developed at Warwick (see Figure 4). These tests are continuing at present and will be reported later.

Figure 4 – Leakage test apparatus being tested in the field on a PBG tank

3. Construction of two rammed earth tanks

The direction of the experimental work at the University has shifted from reinforced brick tanks (reported in Milestone A3) to a more radical design of tank – the rammed earth tank. The aim is to adopt a low-cost technique commonly used for house building in areas of the world such as North Africa, North and South America and the Middle East. The technique uses a mixture of sand and clay, sometimes with a small amount of stabiliser such as cement, which is rammed, either manually or pneumatically, between wooden shutters. To use rammed earth as the structural material in a water storage vessel a waterproof liner is required. This can be provided by employing one of a number of possible options, such as cement render or a plastic sheet liner (as mentioned earlier, this latter is being developed for this application at the University). It is a technique that is relatively simple in essence and requires little in the way of imported material.

Figure 5 – A section of wall rammed between the wooden shuttering shown after removal of the shuttering

So far, the work that has been done on rammed earth tanks has been experimental, and mainly focused on adapting the basic technique (generally used for construction of straight walls in the building sector), to the construction of circular walls for water storage tanks. A 0.7m inner radius quadrant shuttering (see Figure 5) was manufactured and a number of test sections were rammed using a locally excavated soil (local to the University). The soil had to be modified somewhat to make it suitable in terms of cohesion. Wall thickness was increased gradually from a starting minimum of 60mm. We eventually opted for a 100mm wall thickness although even this is unsuitable for manufacture in the field. It is ideal, however, for testing purposes.

A tank, of radius 0.7m and depth 0.7m, has been constructed in a test pit at the University, and fitted with a plastic liner. The tank has been fitted with steel straps to give added hoop strength, but these will be removed after initial tests. The straps will be fitted with strain gauges and will be linked to computer data logging equipment. Measurements of strain, water depth, and temperature will be taken during tests. It is hoped that full-scale testing will take place within the coming month (May 2000). The aim is to seal the top of the tank with a large wooden disc, which will be pierced with a header pipe. The water pressure head will be gradually increased to a maximum of 5m while logging the variation in strain and water depth. The tank has been designed to fail at about 4m, so the test should be destructive, giving valuable information on the strength of rammed earth as a possible alternative to conventional building materials.

Figure 6 – Bird's eye view of the rammed earth tank under construction in the test pit at the University

Figure 7 – Revised shuttering arrangement shown during construction of the experimental tank

4. Construction of eight cement jars for water quality experiments.

There has been much discussion about the acceptability of water that is stored in vessels lined with cement mortar. Many users complain about the taste of the water, especially in the early days when the cement is still leaching calcium. An experiment was set up in Uganda, and carried out by the DTU's partner organisation, ARUCED. Eight small jars of 400 litres each were build and cured using different methods. The aim these experiments was to try to quantify the acceptability of water from cement lined vessels that were cured in a number of different ways. The experiment was designed to determine the efficacy of 8 different curing regimes in the search to find a regime that would minimise the taste problem. The experiment was also used to look at some technical aspects of small cement jars, as well as the user aspects of small rainwater jars and their benefits to users.

The outcome of the taste experiment has been unsatisfactory. There were a number of problems with the experiment, many of which were outside the control of the people involved, but some due to poor experimental procedure. They included:

- Key staff leaving the organisation during the experiments
- Failure of equipment that had been taken to Uganda from the UK
- Curing water being taken from an unknown source
- Poor siting of tanks which meant that sampling was difficult on a daily basis

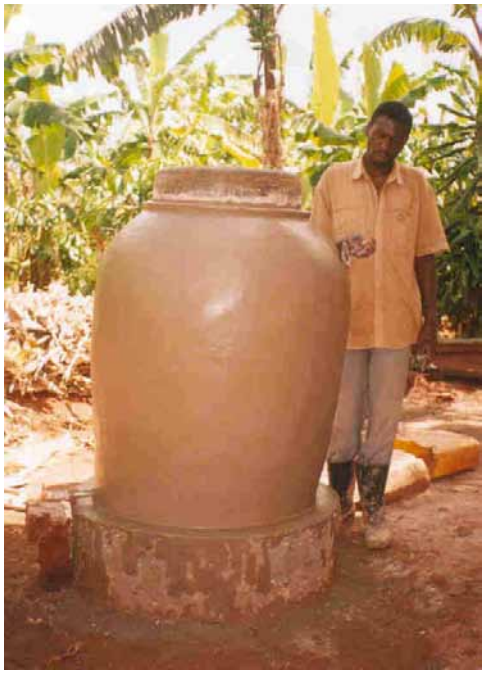

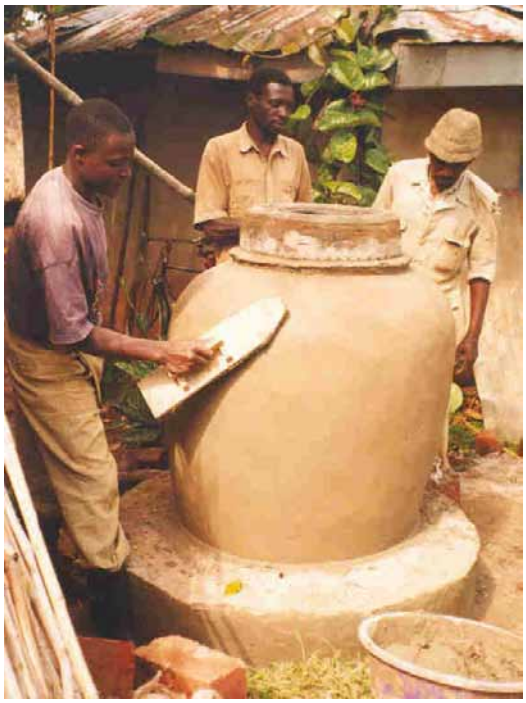

Figure 9 - 400 litre water storage jars being constructed as part of the water quality testing experiments in Uganda

A full report on the taste experiments will be presented later. The user studies are still underway. On a technical level, a number of findings have been made:

- Significant training is required to teach local masons the art of jar construction using this technique (the technique was taken directly from a classic ferrocement construction manual by S. B . Watt titled 'Ferrocement Water Tanks' [It Publications 1978]).
- Often the jars failed because the walls were of insufficient thickness – some method is needed of

5. Construction of two stabilised soil block tanks in Kampala, Uganda

In March 2000, two experimental cylindrical water tanks were built at Kawempwe, Kampala in collaboration with Dr Muses Musaazi, a lecturer at Makerere University. Both were built above ground of curved stabilised-soil blocks with end interlocking, 280mm x 140mm x 110mm high, made with an Approtec (Kenyan) manual block press. The soil used was a red somewhat pozzolanic local soil previously known to make strong blocks. The tanks were built on concrete plinths, lined with 'waterproofed' mortar (3 parts sand, 1 part cement and .02 parts 'Leak Seal' waterproofing compound). There was no metal reinforcing.

Figure 10 – Showing one of the stabilised soil block tanks under construction

Tank 1 is 2050mm high, has internal diameter 1300mm, wall thickness 140mm (+ 15mm render) and used 15 x 15 = 225 blocks incorporating 6% cement (100 blocks per 50kg bag). It has been filled with water and therefore has withstood a maximum head of 2.05m at the wall bottom. Volume = 2720 litres, max hoop stress = 0.19 MPa

Tank 2 is 1880mm high, has internal diameter 1000mm and the same wall thickness, but used 12 x 14 = 168 blocks with only 3% cement (180 blocks per 50 kg bag). It has been filled with water and therefore withstood a head of 1.88m at the wall bottom. Construction is continuing to extend its height up to 4m, testing its ability to resist

pressure forces at both 3m and 4m head. Volume = 1476 litres, maximum hoop stress (so far) = 0.13 MPa.

Materials use included 1 packet (50kg costing $\$_{US}11$) of cement for the render, 1 packet for a conical (reinforced) lid, 1 packet for mortar between the blocks and ½ packet in the foundation. Thus only $^{1}/_{5}$ to ¼ of the cement is in the blocks themselves. Experiments to achieve curved blocks with *vertical* interlocking, if successful, will significantly reduce the quantity of mortar needed for block-laying. The lid may well be made more cheaply, as that employed was designed to carry certain testing devices.

Figure 11 – Showing the interlocking blocks used for the tanks

Root cause analysis

From Wikipedia, the free encyclopedia

Root cause analysis (**RCA**) is a method of problem solving used for identifying the root causes of faults or problems.[1] A factor is considered a root cause if removal thereof from the problem-fault-sequence prevents the final undesirable event from recurring; whereas a causal factor is one that affects an event's outcome, but is not a root cause. Though removing a causal factor can benefit an outcome, it does not prevent its recurrence with certainty.

For example, imagine a fictional segment of students who received poor testing scores. After initial investigation, it was verified that students taking tests in the final period of the school day got lower scores. Further investigation revealed that late in the day, the students lacked ability to focus. Even further investigation revealed that the reason for the lack of focus was hunger. So, the root cause of the poor testing scores was hunger, remedied by moving the testing time to soon after lunch.

As another example, imagine an investigation into a machine that stopped because it overloaded and the fuse blew.[2] Investigation shows that the machine overloaded because it had a bearing that wasn't being sufficiently lubricated. The investigation proceeds further and finds that the automatic lubrication mechanism had a pump which was not pumping sufficiently, hence the lack of lubrication. Investigation of the pump shows that it has a worn shaft. Investigation of why the shaft was worn discovers that there isn't an adequate mechanism to prevent metal scrap getting into the pump. This enabled scrap to get into the pump, and damage it. The root cause of the problem is therefore that metal scrap can contaminate the lubrication system. Fixing this problem ought to prevent the whole sequence of events recurring. Compare this with an investigation that does not find the root cause: replacing the fuse, the bearing, or the lubrication pump will probably allow the machine to go back into operation for a while. But there is a risk that the problem will simply recur, until the root cause is dealt with.

Following the introduction of Kepner–Tregoe analysis—which had limitations in the highly complex arena of rocket design, development and launch—RCA arose in the 1950s as a formal study by the National Aeronautics and Space Administration (NASA) in the United States. New methods of problem analysis developed by NASA included a high level assessment practice called MORT (Management Oversight Risk Tree).[3][4][5] MORT differed from RCA by assigning causes to common classes of cause shortcomings that could be summarized into a short list. These included work practice, procedures, management, fatigue, time pressure, along with several others. For example: if an aircraft accident occurred as a result of adverse weather conditions augmented by pressure to leave on time; failure to observe weather precautions could indicate a management or training problem; and lack of appropriate weather concern might indict work practices. Because several measures (methods) may effectively address the root causes of a problem, RCA is an iterative process and a tool of continuous improvement.

RCA is applied to methodically identify and correct the root causes of events, rather than to simply address the symptomatic result. Focusing correction on root causes has the goal of entirely preventing problem recurrence. Conversely, RCFA (Root Cause Failure Analysis) recognizes that complete prevention of recurrence by one corrective action is not always possible.

RCA is typically used as a reactive method of identifying event(s) causes, revealing problems and solving them. Analysis is done *after* an event has occurred. Insights in RCA make it potentially useful as a preemptive method. In that event, RCA can be used to *forecast* or predict probable events even *before* they occur. While one follows the other, RCA is a completely separate process to incident management.

Rather than one sharply defined methodology, RCA comprises many different tools, processes, and philosophies. However, several very-broadly defined approaches or "schools" can be identified by their basic approach or field of origin: safety-based, production-based, assembly-based, process-based, failure-based, and systems-based.

- Safety-based RCA arose from the fields of accident analysis and occupational safety and health.
- Production-based RCA has roots in the field of quality control for industrial manufacturing.
- Process-based RCA, a follow-on to production-based RCA, broadens the scope of RCA to include business processes.
- Failure-based RCA originates in the practice of failure analysis as employed in engineering and maintenance.
- Systems-based RCA has emerged as an amalgam of the preceding schools, incorporating elements from other fields such as change management, risk management and systems analysis.

Despite the different approaches among the various schools of root cause analysis, all share some common principles. Several general processes for performing RCA can also be defined.

Contents

- 1 General principles
- 2 General process for performing and documenting an RCA-based corrective action
- 3 See also
- 4 References

General principles

1. The primary aim of root cause analysis is: to identify the factors that resulted in the nature, the magnitude, the location, and the timing of the harmful outcomes (consequences) of one or more past events; to determine what behaviors, actions, inactions, or conditions need to be changed; to prevent recurrence of similar harmful outcomes; and to identify lessons that may promote the achievement of better consequences. ("Success" is defined as the near-certain prevention of recurrence.)
2. To be effective, root cause analysis must be performed systematically, usually as part of an investigation, with conclusions and root causes that are identified backed up by documented evidence. A team effort is typically required.
3. There may be more than one root cause for an event or a problem, therefore the difficult part is demonstrating the persistence and sustaining the effort required to determine them.
4. The purpose of identifying all solutions to a problem is to prevent recurrence at lowest cost in the simplest way. If there are alternatives that are equally effective, then the simplest or lowest cost approach is preferred.
5. The root causes identified will depend on the way in which the problem or event is defined. Effective problem statements and event descriptions (as failures, for example) are helpful and usually required to ensure the execution of appropriate analyses.
6. One logical way to trace down root causes is by utilizing hierarchical clustering data-mining solutions (such as graph-theory-based data mining). A root cause is defined in that context as "the conditions that enable one or more causes". Root causes can be deductively sorted out from upper groups of which the

groups include a specific cause.
7. To be effective, the analysis should establish a sequence of events or timeline for understanding the relationships between contributory (causal) factors, root cause(s) and the defined problem or event to be prevented.
8. Root cause analysis can help transform a reactive culture (one that reacts to problems) into a forward-looking culture (one that solves problems before they occur or escalate). More importantly, RCA reduces the frequency of problems occurring over time within the environment where the process is used.
9. Root cause analysis as a force for change is a threat to many cultures and environments. Threats to cultures are often met with resistance. Other forms of management support may be required to achieve effectiveness and success with root cause analysis. For example, a "non-punitive" policy toward problem identifiers may be required.

General process for performing and documenting an RCA-based corrective action

RCA (in steps 3, 4 and 5) forms the most critical part of successful corrective action, directing the corrective action at the true root cause of the problem. Knowing the root cause is secondary to the goal of prevention, as it is not possible to determine an absolutely effective corrective action for the defined problem without knowing the root cause.

1. Define the problem or describe the event to prevent in the future. Include the qualitative and quantitative attributes (properties) of the undesirable outcomes. Usually this includes specifying the natures, the magnitudes, the locations, and the timing of events. In some cases, "lowering the risks of reoccurrences" may be a reasonable target. For example, "lowering the risks" of future automobile accidents is certainly a more economically attainable goal than "preventing all" future automobile accidents.
2. Gather data and evidence, classifying it along a timeline of events to the final failure or crisis. For every behavior, condition, action and inaction, specify in the "timeline" what should have been done when it differs from what was done.
3. In data mining Hierarchical Clustering models, use the clustering groups instead of classifying: (a) peak the groups that exhibit the specific cause; (b) find their upper-groups; (c) find group characteristics that are consistent; (d) check with experts and validate.
4. Ask "why" and identify the causes associated with each sequential step towards the defined problem or event. "Why" is taken to mean "What were the factors that directly resulted in the effect?"
5. Classify causes into two categories: causal factors that relate to an event in the sequence; and root causes that interrupted that step of the sequence chain when eliminated.
6. Identify all other harmful factors that have equal or better claim to be called "root causes." If there are multiple root causes, which is often the case, reveal those clearly for later optimum selection.
7. Identify corrective action(s) that will, with certainty, prevent recurrence of each harmful effect and related outcomes or factors. Check that each corrective action would, if pre-implemented before the event, have reduced or prevented specific harmful effects.
8. Identify solutions that, when effective and with consensus agreement of the group: prevent recurrence with reasonable certainty; are within the institution's control; meet its goals and objectives; and do not cause or introduce other new, unforeseen problems.
9. Implement the recommended root cause correction(s).
10. Ensure effectiveness by observing the implemented solutions in operation.
11. Identify other possibly useful methodologies for problem solving and problem avoidance.
12. Identify and address the other instances of each harmful outcome and harmful factor.

See also

- A3 problem solving
- Barrier analysis
- Eight Disciplines Problem Solving
- Factor analysis
- Failure mode and effects analysis
- Fault tree analysis
- Forensic engineering
- Multiple regression and multivariate linear regression
- Orthogonal Defect Classification
- RCASE

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Root cause

From Wikipedia, the free encyclopedia

A **root cause** is an initiating cause of either a condition or a causal chain that leads to an outcome or effect of interest. Commonly, **root cause** is used to describe the depth in the causal chain where an intervention could reasonably be implemented to improve performance or prevent an undesirable outcome.

In plain English a "root cause" is a "cause" (harmful factor) that is "root" (deep, basic, fundamental, underlying, initial or the like).

The term **root cause** has been used in professional journals as early as 1905.[1]

Paradies (2005) has defined a root cause as follows: "The most basic cause (or causes) that can reasonably be identified that management has control to fix and, when fixed, will prevent (or significantly reduce the likelihood of) the problem's recurrence." [2]

Fantin (2014) describes the root cause as the result of the drill down analysis required to discover which is the process that is failing, defining it as "MIN Process" (meaning a process that is Missing, Incomplete or Not followed)[3]

About Root-Cause discovery, see Root cause analysis.

See also

- Causation
- Forensic engineering
- Proximate and ultimate causation
- Root cause analysis
- RPR Problem Diagnosis
- Three Unwholesome Roots

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Root cellar

From Wikipedia, the free encyclopedia

A **root cellar** is a structure built underground or partially underground and used to store vegetables, fruits, and nuts or other foods.

Interior of a large Wyoming root cellar with crops

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- 2 Construction
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A pair of modern potato cellars in southeastern Idaho

Function

Root cellars are for keeping food supplies at a low temperature and steady humidity. They keep food from freezing during the winter and keep food cool during the summer months to prevent spoilage. Typically, a variety of vegetables are placed in the root cellar in the autumn, after harvesting. A secondary use for the root cellar is as a place in which to store wine or home-made alcoholic beverages.

Two traditional sod-covered potato cellars in southeastern Idaho

Vegetables stored in the root cellar primarily consist of potatoes, turnips, and carrots. Other food supplies placed in the root cellar over the winter months include beets, onions, jarred preserves and jams, salt meat, salt turbot, salt herring, winter squash, and cabbage.[1] A potato cellar is sometimes called a potato barn or potato house.

Separate cellars are occasionally used for storing fruits, such as apples. Water, bread, butter, milk, and cream are sometimes stored in the root cellar also. In addition, items such as salad greens, fresh meat, and jam pies are kept in the root cellar early in the day to keep cool until they are needed for supper.[2]

Construction

Common construction methods are:

1. Digging down into the ground and erecting a shed or house over the cellar (access is via a trap door in the shed).
2. Digging into the side of a hill (easier to excavate and facilitates water drainage).

3. Building a structure at ground level and piling rocks, earth, and/or sod around and over it. This may be easier to build on rocky terrain where excavation is difficult.

Most root cellars were built using stone, wood, mortar (cement), and sod. Newer ones may be made of concrete with sod on top.[2]

See also

- Basement
- Spring house
- Canning
- Larder
- Refrigeration
- Storage clamp
- Underground living
- Wine cellar

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Categories: Agriculture | Rooms | Food preservation | Semi-subterranean structures

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Root Crop Processing

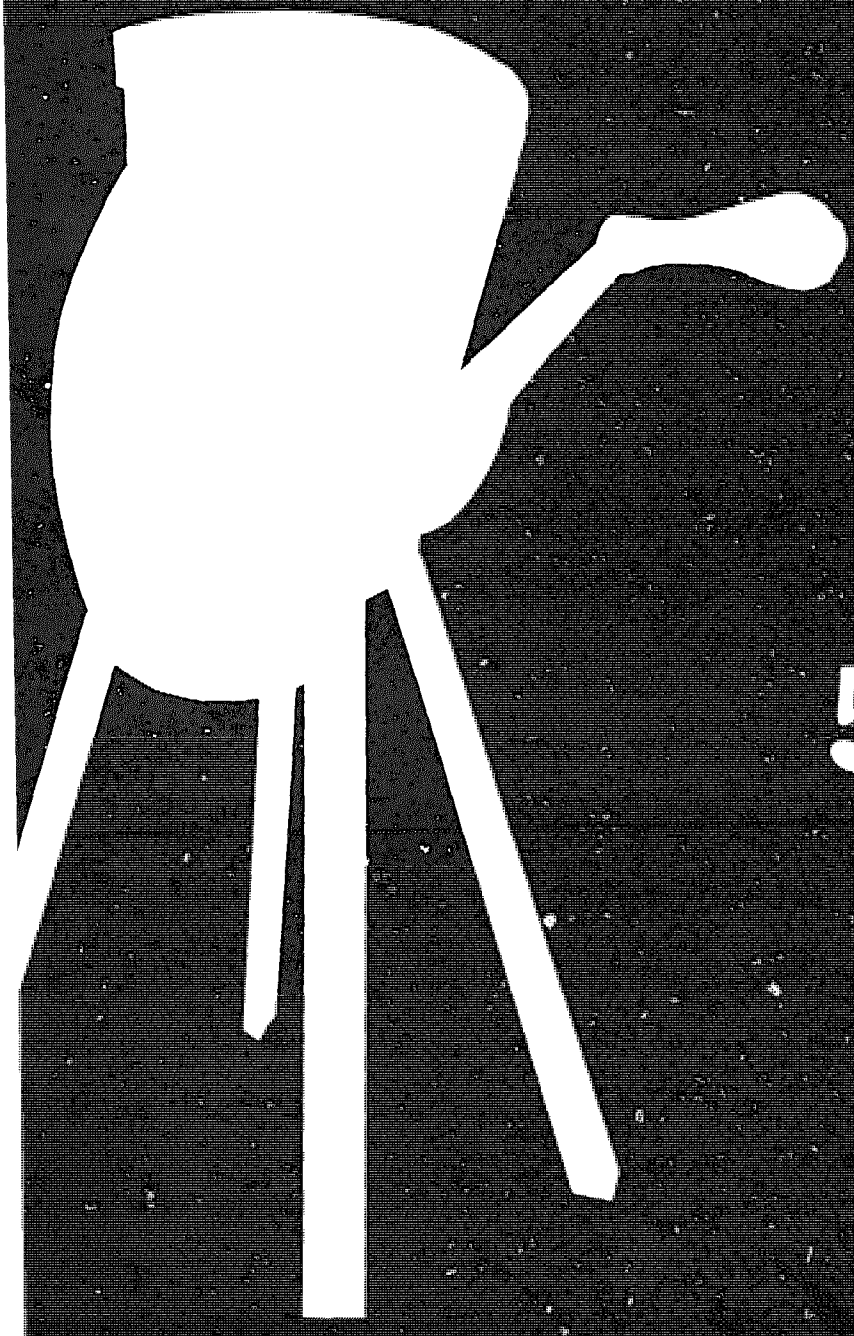

5 FOOD CYCLE TECHNOLOGY SOURCE BOOK

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FOOD CYCLE TECHNOLOGY SOURCE BOOK NO. 5

Root Crop Processing

UNIFEM

THE UNITED NATIONS DEVELOPMENT FUND FOR WOMEN

PROJECT GLO/85/WO2 - WOMEN AND FOOD CYCLE TECHNOLOGY (WAFT) AND PROJECT RAF/86/WO3 - TRANSLATION AND PUBLICATION OF FOOD CYCLE TECHNOLOGY SOURCE BOOKS

With the collaboration of the

INTERMEDIATE TECHNOLOGY DEVELOPMENT GROUP
United Kingdom

1989

PREFACE

UNIFEM AND THE FOOD CYCLE TECHNOLOGY PROJET (WAFT)

The United Nations Development Fund for Women (UNIFEM) was established in 1976, and is an autonomous body associated, since 1985, with the United Nations Development Programme. UNIFEM seeks to free women from under-productive tasks and augment the productivity of their work as a means of accelerating the development process. It does this through funding specific economic projects which yield direct benefits and through actions directed to ensure that all development policies, plans, programmes and projects take account of the needs of women producers.

In recognition of women's special roles in the production, processing, storage, preparation and marketing of food, UNIFEM initiated in 1985 a Food Cycle Technologies project with the aim of promoting the widespread diffusion of tested technologies to increase the productivity of women's labour in this sector. While global in scope, this five-year project is initially being implemented in Africa in view of current concerns over food security in many countries of the Region.
The eventual aim of the project is to increase indigenous capacity to respond to the technology needs of women producers and to inform and influence the decision makers who can create the correct policy environment for this to happen. This will be achieved by providing appropriate technical assistance relating to the process of technology development and diffusion.

This source book is one of a series being compiled as part of the preparatory phase of the Food Technology project. UNIFEM hopes that the widespread distribution of these sourcebooks will increase awareness of the range of technological options and sources of expertise, as well as indicating the complex nature of designing and successfully implementing technology projects and diffusion programmes.

Titles in this series include: Oil Extraction, Fruit and Vegetable Processing, Cereal Processing, Root Crop Processing, Fish Processing, Packaging, Drying and Storage. Source books will also be available in French and Portuguese.

ACKNOWLEDGEMENTS

This initial series of food cycle technology source books has been prepared at the Intermediate Technology Development Group (ITDG) in the United Kingdom within the context of UNIFEM's Women and Food Cycle Technologies (WAFT) specialization. During the preparation process the project staff have contacted numerous project directors, rural development agencies, technology centers, women's organizations, equipment manufacturers and researchers in all parts of the world.

UNIFEM and ITDG wish to thank the several hundred agencies and individuals who have contributed to the preparation of the source books. Not all can be mentioned by name, but special thanks are owed for their major contributions to the International Labour Organization (ILO), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Children's Fund (UNICEF), the Economic Commission for Africa (ECA), the German Appropriate Technology Exchange (GATE/GTZ) in Eschborn, the Groupe de Recherche et d'Echanges Technologiques (GRET) in Paris, the Royal Tropical Institute (KIT) in Amsterdam, the International Development Research Centre (IDRC) in Ottawa, the Tropical Development Research Institute (TDRI) in London, Appropriate Technologies International (ATI) in Washington, the Institute of Development Studies, Sussex University (IDS), and the Save the Children Fund.

The preparation of the source books has been funded by UNIFEM with a cost sharing contribution from the Government of The Netherlands.

UNIFEM is particularly grateful to the Government of Italy for providing the funds for translation and printing of the source books and to the Italian Association for Women in Development (AIDOS) for implementing this phase of the project.

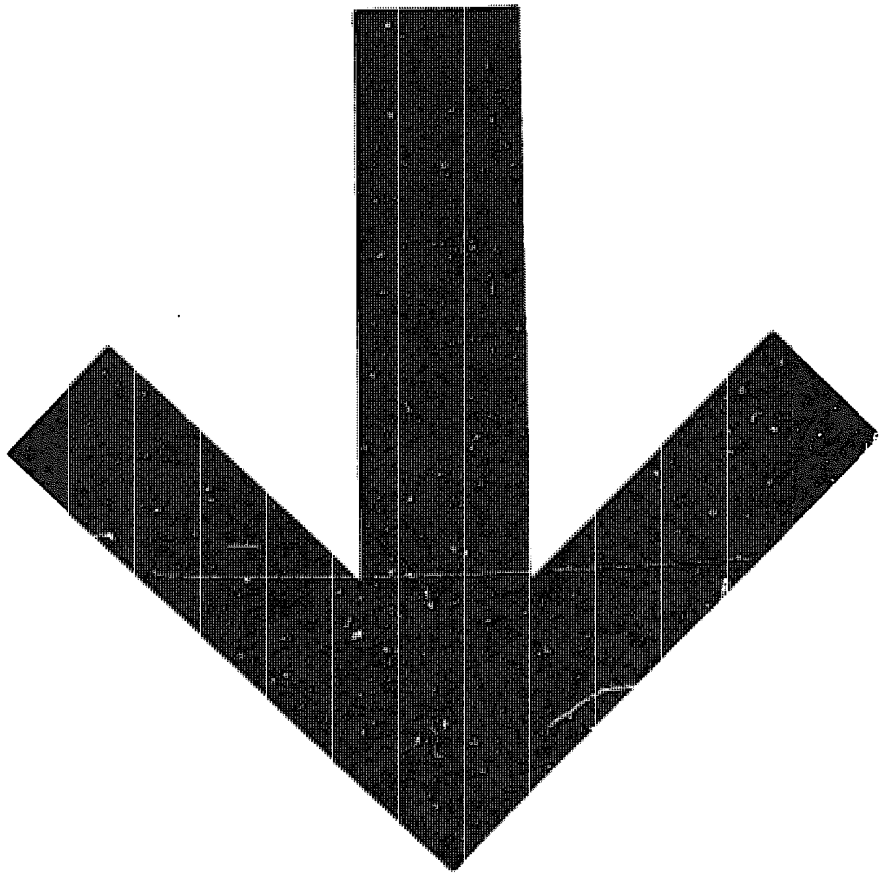

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This book will cover the small scale processing of tropical root crops in developing countries with the intention of providing UNIFEM consultants with technical understanding of traditional and improved technologies for use in these countries.

An illustration of the wider context into which such projects are found (in terms of socio-economic issues) is also given. This will enable the consultants to see any merits and/or problems of introducing technologies to different groups in various developing countries. In developing countries the family meals are usually prepared by women who are therefore involved in the various stages of processing the raw material for consumption. Root crops are a staple and hence are often the main part of the meal, especially where cereals are unavailable. Village scale processing of root crops is therefore an important part of womens' daily work. A substantial effort has been made to upgrade local processes but many communities still only have access to traditional methods which although appropriate are laborious.

Large scale production of starches, glucose syrups, animal feeds, gari etc from root crops is a commercial venture involving substantial capital investment. For direct human consumption, the processing of root crops is mainly at small scale, often at household level.

It would be impossible to cover all the root crops and processing techniques in a document of this size, so the more common methods of processing the more important root crops; cassava, yam, sweet potato, potato and edible aroids are discussed.

Emphasis is placed on cassava throughout this manual for several reasons. Even though the total world production for sweet potato may perhaps be greater, cassava's prime importance as a food in Africa, and the fact that it often requires special treatment to make it fit for human consumption, means that there are a greater variety of processing methods Finally small-scale cassava processing in developing countries has been researched and developed to a greater degree than any other root crop. This document is divided into several sections covering basic food science principles; traditional and improved small scale processing methods and equipment relevant to rural women: case studies illustrating the merits and problems of introducing improved technologies into a particular existing socio-economic framework; a list of summarising questions placing processing in the wider context of village situations, and a list of institutions to contact for information. It is important to realise that although a technology may be improved and tested technically in a research laboratory, workshop or field situation outside any community, it may prove to be inappropriate for the intended social setting. Although it is realised that one can only predict an outcome of introducing a technology trying it, it should be born in mind that assumptions can be made more accurately if consideration is given to the reality - that is, that rural women need recognition and access to relevant institutions, infrastructural support, extension workers and formal lines of credit.

Importance of root crops

The most important root crops in terms of tonnage production in developing countries are cassava, potato and sweet potato. There seems to be some disagreement over which is the most important, some sources favouring sweet potato (table 1), others cassava, but this is a

point of academic interest. While other major root crops such as yams and cocoyams are important foods in certain areas, their levels of production are considerably less.

It is estimated that 65% of cassava produced is for direct food use, the remainder being used in animal feed (30%) or processed into industrial products (5%). Reliable data on the ratios of other major root crops used for food and industrial uses are not readily available. Root crops are a cheap, available and essential energy source for many poor people who face problems of food availability. Although they contain little protein or fat, some, particularly potato and yam, are a source of vital vitamins (A and C).

Over half of the world's total cassava production is in Africa (table 2) and it has been estimated that 37% of the energy in the diet in tropical Africa comes from cassava. In the Americas and Asia the contribution is estimated to be only 12% and 7% respectively. Tropical rootcrops are mainly consumed and, where necessary processed at the village and household level. The relative importance of individual root crops varies both by region and country. Yams are a major food crop in West Africa, the Caribbean, the South Pacific Islands, Southeast Asia, India and parts of Brazil. Cassava is particularly important in South America, West, East, Central and South Africa, and Oceania. Taro plays an important cultural role in the diet of the people of the Pacific Islands, as does sweet potato in part of West Africa, Oceania and the West Indies. Potato, requiring a more temperate climate, is more important in highland areas of the tropics such as the Andean regions of Peru and Bolivia. The main advantages of root crops as a staple compared to cereals is that they are a cheaper source of energy, can be cultivated easily and provide more dietary energy per hectare at a lower cost to the farmer (principally because of reduced labour inputs). They generally require a comparatively low level of husbandry, especially cassava which can grow in very dry and nutrient-deficient soils, albeit with lower yields.

Some root crops have a production cycle which is continuous or semi-continuous, in contrast to cereal production, where harvesting is highly seasonal. Taro and cassava, for example, are grown in the tropics all year round. This can avoid storage problems and can provide increased food security for the poor, especially during periods of food shortage. The continuous cropping of root crops to act as a reserve food buffer allows many poor people to survive better the problems of seasonality and shortages of other food items. It should be noted, however, that the practice of only partially harvesting certain root crops and relying on their natural underground storage can create a problem of land availability for subsistence farmers.

The pre-harvest period of, for example, cereals is often the most difficult time for poor people. Not only can it be a 'hungry' period, but food prices are generally higher, food intake is at its lowest and labour requirements on the farm are rising in anticipation of harvest. The role of root crops at such times is thus of prime importance.

Women's role in processing

The majority of the labour required for the processing of all rootcrops is provided by women. It must be remembered, however, that the simple provision of labour does not ensure that women derive the benefits from a particular process. That depends much more on who controls the process — who makes the decisions on time allocation and the distribution of benefits gained. This control

Table 1

Value of production of ten principal food crops in all developing countries

	Number of producing countries	Production (million t)	Producer price ($t)	Value (billion $)
Rice	97	383	170	65
Wheat	69	162	148	24
Maize	119	154	119	18
Potatoes	98	91	142	13
Sweet potatoes	100	137	89	12
Cassava	95	127	70	9
Banana/plantain	119	62	107	7
Sorghum	69	44	123	5
Groundnuts	92	17	297	5
Millet	53	27	144	4

Source: De Horton, Fano, H CIP 1985

Table 2

Cassava: area and production in selected countries

	Area harvested ('000)			Production ('000 t)		
	1974-76 average	1983	1984	1974-76 average	1983	1984
World	12207	13489	14151	107679	123048	129020
Africa	6438	7191	7482	43300	48593	51002
Angola	121	130	130	1710	1950	1950
Ghana	253	210	250	1773	1729	1900
Mozambique	533	500	550	2600	3150	3150
Nigeria	1043	1150	1250	10467	9950	11800
Tanzania	707	450	450	5053	5400	5600
Zaire	1687	2086	2150	11734	14600	14800
South America	2549	2500	2311	30587	26878	26861
Brazil	2047	2023	1817	254[illegible]	21569	21275
Colombia	247	207	210	19[illegible]	2000	2100
Asia	3048	3615	4171	32713	46450	50000
China	197	252	252	2416	3880	4067
India	383	302	305	6462	5341	5800
Indonesia	1424	1242	1420	12589	12229	14000
Thailand	538	1018	1335	7855	18989	19985
All developing countries	12207	13489	14151	107679	123048	129020

Source: FAO Production Yearbook, 1984

can sometimes lie with the grower of the crop rather than the processors or those who market the final product.

In some countries production and processing of a root crop is under women's control (eg cassava in West Africa), while in other regions it is a male prestige crop and taboo for women to cultivate it (as for example, with certain yams in Nigeria and a specific variety of swamp taro in the Pacific Islands).

It is important to take these considerations of control into account in any project. Let us imagine, for example, a situation where the man grows a crop on land he controls, while women process the produce of that land. If the man invests in a labour-saving process so that he can re-deploy his wife in the fields, saving him time, who has really benefitted? The community as a whole, yes, if the men can use their freed-up time productively; but the women have not benefitted at all, at least not directly.

In the case where the land, labour and material inputs are sufficiently under the woman's control, labour-saving technological improvements may have more direct impact on her own and her family's livelihood. It has been seen that even when women farmers control these inputs, they can suffer displacement with the introduction of mechanisation. For example, in parts of West Africa the introduction of motorized cassava graters has greatly improved the productivity of gari processing, making this an attractive economic activity to both men and women. It has been known to happen that cassava, once a 'women's crop', has been taken over by male members within a household, with the females having to look for alternative income opportunities once the production became mechanized.

It is vital that the women processors themselves are included in project design and implementation. Women producers are always trying to maximize their limited resources. It is vital to understand how they value these resources and the trade-offs they are willing to make in their distribution. Experience has shown that some technologies have not been accepted because they have not taken into account the perceived needs and priorities of the user.

Project design, therefore, should look beyond the immediate confines of the 'project'. The processing activity should be seen as part of a number of systems: firstly, a food production system of growing, processing and marketing; secondly an economic system of production and exchange, and thirdly, a social system of interactions between members of the same family, between families, sexes and clans, in the same community and between communities. Only then can a reasonable assessment of the likely distribution of benefits of introducing an improved technology be made.

SECTION 1

Pre-Processing and Processing Considerations

It is important to have a basic understanding of the physiology of any crop in order to be able to predict its post-harvest behaviour. This, together with a knowledge of certain essential food science principles and the chemical composition of the crop will put the consultant in a far better position to study and adapt a given processing system.

In this book, it will only be necessary to describe the general composition of root crops together with basic food science principles relevent to their processing. Socio-economic aspects of tropical root crops will also be discussed.

Raw Materials

Root crops, as the name implies, are plants that develop starchy roots, tubers, stems, bulbs or corms that act as a food store for the plant. Chemically, they are mainly composed of water and starch with minor amounts of protein, fibre, minerals, vitamins and, very importantly in some cases, toxic components.

The term 'root crops' can be somewhat misleading and, in this publication will cover commodities such as cassava, yams, potatoes, sweet potatoes and certain aroids all of which are staple food crops of high starch content. Aroids, such as taro, and tannia (known collectively as cocoyams in Africa), in which the starch is deposited in swollen stems are included for convenience with root crops. Bananas, plantains and other staple starchy fruits, while processed in ways very similar to root crops are not covered in this publication but rather in the relevant fruit and vegetable volume.

After the plant has finished growing and the foliage dies away, the 'food store' of many root crops survives by going into dormancy, the duration of which depends on both the crop type and variety. Cassava is the exception having no natural dormancy period.

The post-harvest storage life of a root crop thus depends on the type of crop as well, of course, as the conditions of storage. The end of post-harvest storage is signalled by sprouting and the removal of the sprouts can, in many cases, increase the storage period. This is particularly true of yams.

In addition to the main chemical components, such as starch, root crops contain important minor components. One of these is an enzyme called polyphenyloxidase, which causes the well-known effect of darkening of fresh cut surfaces on exposure to air. This effect, which can be controlled by the use of chemicals, or blanching in hot water or steam, needs to be taken into consideration in certain processing systems. Also, as previously mentioned, several root crops contain toxic substances, the most important being a cyanide-containing glycoside in cassava, and solanins in some varieties of potato. The presence of such toxic factors demands special processing procedures to make the product safe for human consumption. The cyanogenic glycoside complex of cassava can produce extremely toxic hydrogen cyanide through the action of natural enzymes in

the root. Levels of hydrogen cyanide range from 10 to over 450mg/kg of fresh root depending upon variety. In many countries consumers often distinguish between sweet (of low toxicity) and bitter (of high toxicity) cassava. It is important to realize that although many sweet varieties do have lower levels of cyanide there is no well-defined correlation between the sweet/bitter taste and toxicity (Cooke, 1978). Considerable care should thus be taken when introducing unfamiliar varieties of sweet cassava to be sure that it is indeed a low cyanide variety.

Should cassava containing cyanide be consumed, the body will attempt to detoxify it. This puts the body system under great strain and can pose a serious health problem.The problem is particularly serious in areas with a low intake of dietary iodine (in which case goitre can develop) and for consumers with a low protein intake.

The toxic glycosides of cassava are reduced to safer levels during traditional processing.

Toxicity is initially considerably reduced by peeling. The roots are then grated breaking down the internal cells and so releasing the enzyme which starts to break down the cyanogenic glycoside complex. This releases hydrogen cyanide. During the subsequent fermentation stage, almost total breakdown of the glycoside occurs and the final frying, roasting or boiling step drives off the hydrogen cyanide, leaving a safer, edible product.

Toxicity problems have also been mentioned with regard to certain varieties of potato. This is of less importance on a worldwide basis and traditional methods have been developed to make the product safer for human consumption. Toxic varieties of potatoes are most commonly grown at high altitudes, particularly in the Andes. After harvesting they are soaked in water which removes the toxic components. The leached potatoes are then suitable for further processing, most commonly into a dried potato product. This process is described in more detail in the relevent section of this book.

Principles of Processing Techniques

A number of operations are commonly used in the processing of root crops and a brief summary of them is included in the following section. The descriptions are not intended to be crop specific and fuller details will be found in the relevant sections on traditional and improved root crop processing.

Peeling

This involves the removal of the indigestible outer layers of the root and is traditionally carried out by hand although mechanical and chemical peelers are available for larger scale operations.

Drying

It has been noted that root crops have a high moisture content. The preservation of almost all processed rootcrop products depends on reducing the moisture to a level which prevents the growth of micro-organisms. Drying is a very simple, inexpensive and common method to remove water in root crops and so extend their shelf-life. A brief summary of the principles involved is included here. Specific drying technologies are

covered in later sections of this book.
Drying requires the transfer of moisture from the product to the air around it. Clearly both the quantity (air flow) and moisture content (relative humidity) of the air will affect the rate at which a product dries, as will the nature of the product itself.
It is important to realize that there are two stages in the drying process;
(1) removing 'surface moisture'.
(2) removing 'internal moisture' from within the material.
The relative humidity of air decreases rapidly as its temperature is raised and at the same time its water-absorbing capacity increases.
The rate of drying during the first stage is dependent solely on the ability of the air passing over the material to absorb and remove moisture.
Air flow-rate is more important than temperature but in areas of high relative humidity the air may need heating to lower its humidity to a level that allows it to absorb significant amounts of water. In general, air with a relative humidity of 75% or more, is not able to effect drying except in the earliest stages when the root is very wet.
The surface area of food exposed to the air is also very important. Slicing or chipping of the root crop will increase the surface area, and thereby reduce the drying time.
Once the surface water is removed, a second stage of drying begins in which water is removed from the interior of the material. The rate of drying in this second stage is dependent on the rate at which moisture can migrate through the tissue to the surface where it evaporates to the passing air. The migration is a slow process, so drying rates are lower than in the first stage of drying. The drying rate is dependent on the moisture content, and on temperature, rather than air flow.

Boiling and steaming

Root crops are often cooked by boiling or steaming either for direct consumption or as one step in a processing system. This does not preserve the crop, which is usually eaten soon afterwards, unless it is further processed. Boiling and steaming are also important in cassava processing to partially detoxify the material.

Frying and roasting

Many types of root crops are commonly prepared by frying in hot oil or roasting. Roasting is widely practised throughout Africa where traditional techniques include burying the whole root in hot ashes or holding it in front of a fire. In gari processing, proper roasting is important to ensure a good quality product. Both frying and roasting enhance the flavour of the root crop and most importantly reduce its moisture content - so extending its shelf-life.
When packaged properly, fried, crisp products can have a shelf-life of several months.

Grating

The action of grating into fine shreds is a step common to the processing of many root crops and facilitates other later steps in a process, for example, de-watering, drying or pulping. The process alters the texture of the raw material. Grating methods range from simply rasping the roots on the trunk-spines of palms as practised in the Amazon basin of South America, through simple hand graters to mechanized graters.

Pounding

Pounding changes the texture of the previously prepared root crop to a more palatable, paste-like consistency. The root is first peeled and softened by boiling or soaking. Traditionally a large pestle and mortar is used.

De-watering

De-watering as the name implies, involves the removal of internal liquid from the root crop by pressing. This process is most common in cassava processing being an important method of reducing toxicity. Traditionally, heavy weights are placed on the prepared root crop and the expelled liquid is allowed to drain away. In other traditional methods a squeezing process is involved.

Starch extraction

While starch can be extracted from any root crop the most common starting materials are potato and cassava. Industrially, starch is extracted by a combination of wet milling, sieving and either settling or centrifuging. Starch can also be extracted by more simple methods. The juice draining from cassava, for example, during de-watering may be collected and left to stand allowing the starch to settle. After decanting the liquid layer the remaining starch may be rinsed and further processed into flour by pounding or grinding and drying.

Grinding, milling and sieving

After preliminary processing, including slicing or shredding and drying, most root crops can be ground to a flour. Of all root crops cassava is most commonly processed in this way, the flour being used in many traditional dishes such as 'fufu'. Traditionally pestles and mortars are used for pulverization but on a larger scale, hand or mechanical plate or disc mills are more appropriate. After grinding, the coarse flour is sieved, with any large particles returned for further grinding.

Fermentation

Fermentation is a most important step in the processing of cassava and certain high alkaloid-containing varieties of potato. In both cases fermentation results in a reduction in the levels of the toxic components. In the case of cassava two methods are commonly practised, which may be conveniently considered as the 'dry' and 'wet' methods. The dry method is used in the production of 'gari' and is essentially fermentation in the presence of air. The grated cassava passes through a two stage fermentation. During the first phase, starch is broken down and acids are produced. Subsequently, breakdown in the cyanide containing toxic component occurs by the action of naturally occuring enzymes in the root so releasing hydrogen cyanide. The conditions at the end of this first stage then allow the growth of a range of micro-organisms that produce compounds that give gari its characteristic flavour. Much of the cyanide is lost during fermentation, the remainder being largely driven off during the final roasting step.

The simple 'wet' method of fermentation is carried out in certain areas of Africa and Latin America and is sometimes referred to as 'retting'. Wet fermentation takes place in the absence of air. Cassava roots, either peeled or entire, are soaked under water for several

days until they have softened. The material is then broken up, sieved and finally squeezed to remove water. Although culturally acceptable in many areas, cassava processed in this way has a somewhat unpleasant odour and the waters used in the process can be a source of pollution in streams.

Socio-Economic Considerations

In general, traditionally processed root crops are low-value products which do not normally justify improved technologies with higher capital costs unless losses can be greatly reduced or higher-value products made. When considering establishing or improving a root processing system a decision on the production scale and technology used must be made.

This decision will depend on:

- economic status of members of the community
- supply of raw materials
- labour requirements
- cultural obstacles
- organisational and management capabilities
- availability of markets, both local and distant

Economic status

It is a truism that no-one can control a technology they don't own. This is, however, often forgotten in project work, when technologies are introduced that could not possibly be afforded by the groups being worked with.

This economic status is not simply the money people have to spend but also their access to credit. Most people can obtain access to credit, of a sort, but usually at extortionate interest rates. Any economic calculations must take this into account. Commercial interest rates (eg, the bank rate in the capital) should not be used in calculations of rates of return unless the processors can really have access to money at those rates.

At the village level, payback periods of more than one agricultural cycle or year may be unrealistic because it means scarce cash resources will be unavailable for other, possibly more immediate needs.

Lengthy payback periods may prove to be an effective obstacle for poorer, more vulnerable households.

Raw materials

The supply of raw materials is particularly important. Technological improvements which require a high capital investment such as a motorized cassava grater, will necessitate relatively high and stable crop production levels in order to pay for themselves within a reasonable time period.

Local land ownership patterns may preclude the establishment of a sufficient area under root crop cultivation. For example, in parts of West Africa, the community is traditionally the owner of the land with the Chief allocating parcels of land to households as needed. In Sierra Leone, lack of regular access to fertile land to produce the necessary cassava supplies for a women's cassava grater group proved to be a major hindrance for expansion. In this case, competing requests for land needed to cultivate cash crops by their male counterparts resulted in the women's group receiving lower priority.

Labour considerations

Labour requirements must be considered when choosing a technology as they can vary for different crops at pre-harvest and post-harvest production time. When comparing expected labour demands for root crops like cassava and yams, cassava requires little labour and is very easy to cultivate whereas yams require considerable effort in such tasks as, for example, staking and drainage preparation. In terms of post-harvest production needs, cassava processing is perhaps the most demanding of all the root crops as it requires detoxification before becoming edible. Much less effort is required in processing yams, for example, which also have the advantage of being a relatively hardy crop that can be stored for several months before any processing is required.

Cultural obstacles

Group ownership and operation needed to share investment costs and make maximum use of a higher capital cost technology may meet local cultural obstacles. Women may need to ask their husband's permission to participate in work efforts outside the household. If the husband feels threatened by his wife's participation in an income-generating project or feels that her labour may be better used to support his cash activities, then this permission may not be granted.

In some areas or countries, women have a tradition of working co-operatively, but not of dividing tasks between themselves. The introduction of a technology that requires group co-operation may result in increased suspicion over pooled finances and fear of unequal compensation for labour input.

Organizational and management capabilities

If a new technology requires group organisation, then there are several key questions that the members of the group must address themselves to:

- how will decisions be made
- who will have access to the technology and on what terms
- how will the group be managed from day to day
- who will look after the money
- who will operate and maintain the equipment
- how to control misuse of funds or machinery.

As well as deciding on the constitution, the group will have to choose a manager, and she will have to be trained in her responsibilities and relevant skills. She must also be ready for much suspicion and must, therefore, be scrupulously honest. It is usual, and often unwise, that a village leader is chosen. She, or sometimes he, is often tempted to abuse his/her position, since no-one will speak out until it is too late.

Marketing potential

Processed root crop products such as cassava flour, flaked instant yam, breakfast and weaning foods, chip and snack products have been developed in response to an expanding demand from urban-based populations in developing countries. This has offered new opportunities for rural people to earn cash incomes from processing their root crops. These new products, however, while having great potential for adding value to rootcrops and providing income to rural producers, often have very limited

markets. Any introduction of a new product must be accompanied by market research and consumer testing.

Along with these changes in consumer preference by an emerging middle class, there are growing health dangers as a result of rising demand. For example, in Nigeria, increased demand for the fermented cassava product, gari, has resulted in less careful processing. The fermentation period in certain zones is usually two to three days which allows sufficient time for breakdown of toxic elements within the cassava. Some commercial processors have reduced this period to one day and have added lime juice to produce the preferred sour taste instead of allowing the production of the natural fermented taste to occur in the detoxification process.

Traditional Processing Techniques and Equipment

Traditional processing of root crops has developed to suit local situations. A whole range of processing techniques, equipment and products have been developed which vary not only from country to country but also within individual countries. It would not be feasible to describe all the variations that exist, so in this section we shall look at typical processing systems used in Africa, Asia and Latin America. A description of some traditional equipment is followed by an account of traditional processing methods covering the more common products in areas of the three regions. The products described are arranged by crop type. In view of the emphasis on cassava so far in this document this section will start by looking at some of the other important root crops. Prior to recommending methods for improving traditional processing systems it is essential to understand fully how and why they have developed, how they fit into local social conditions and the relevent food science principles outlined earlier. Simply being aware of traditional practices is not enough.

Traditional Equipment

The items described below are very simple, low in cost and available locally. These important factors determine the suitability of equipment to local processors. Most of the items have been designed for cassava processing because of the more elaborate procedures involved to make this crop safer to eat.

Peelers

Peeling of roots is commonly carried out using knives made of bamboo, flint or metal.

Graters

Examples of the wide range of traditional graters used particularly for cassava, include, in South America, rough stone, the prickly trunk of palms and shells. A stone or piece of wood covered with shark skin or sharp stones set in basketwork has been used in the West Indies. Graters made from flat pieces of wood into which splinters of thorn, teeth or fishbone are driven or embedded in a wax coating are used in Venezuela, parts of the Amazon and Brazil.
In Ghana, Nigeria and Sierra Leone graters are made from sheets of tin or iron which have been pierced with nails on one side in order to produce a rough surface on the other.

Presses

The 'Tipiti' is used in Latin America, particularly in Brazil, for de-watering cassava. It is a complex cylindrical basket press which is diagonally woven such that it can be stretched lengthwise to squeeze its contents. It is suspended from a beam or tree while the lower loop is weighted down with a stone, or a pole is inserted so that one can exert pressure by pulling. More simply, strips of bark are spirally wrapped around the grated cas-

sava and twisted to squeeze the contents.
Such devices are not found in Africa where bags filled with cassava pulp are commonly pressed with heavy stones.

Sieves

Woven baskets or suspended cloth pieces holding the mash are used to allow the liquid to drain away or separate excess fibrous material.

Pounding/Grinding equipment

In South America and Africa pestles and mortars made of heavy wood are used to pound both fresh roots prior to processing and also to produce flours. Some of these may be large enough to require as many as eight women pounding simultaneously.

Roaster

A whole range of systems are used to roast root crop products over a fire. Examples include pans, oil drums cut in half and specially constructed raised clay semi-circles common in Nigeria. As the material is roasted it is continuously turned with a wooden spoon or calabash.

Potato

Potatoes, unlike the other root crops covered in this sourcebook, grow best at temperates below 20°C. Production in developing countries is therefore concentrated in highland areas where the soil temperature is cool enough. Potatoes and their processed products are one of the staple foods of highland peoples such as those of the Andean areas of Peru and Bolivia.
Generally, potato is consumed fresh, that is to say by cooking the fresh tuber. However, this crop is seasonal and for supplies to be available out of season, it is necessary either to store fresh or to process it into a stable product. Dehydrated products such as 'papa seca' and 'chuño' which can have a storage life of several years have been traditionally made for centuries in the Andean areas of Peru and Bolivia.
Potato is more difficult to cultivate than cassava because a live tuber, or seed, is required for planting the following season's crop. This seed potato thus has to be carefully stored and is more perishable than the stick, or stem used for cassava cultivation.
As has been mentioned in the section on food science potatoes contain toxic complex alkaloids, termed solanines. The amount of solanine present depends on variety. Levels are higher in immature potatoes and particularly high in active growing parts of the plant such as sprouts. Bitter potatoes, with high levels of solanines are grown in the high areas of the Andes and these are made safer for eating by processing into products such as chuño, tokosh and tunta.
To summarize, the main constraints facing potato production and marketing in developing countries are its irregular yields, seasonality, availability of live tubers for planting and the perishability of the fresh tuber in normal tropical temperatures.

Traditionally Processed Products

Product	Chuño
Region	South America
Country	Peru
Equipment	Straw, rocks, sacks or pails
Process	Process requires particular climatic conditions with very low night temperatures (-10 to -20°C), high day temperatures (20-25°C) and low relative humidity. Many variations in technique exist, the following is a typical method.
Raw material	Usually bitter varieties of potato
Prepared	Laid on straw bed for 1 day.
Frozen	Potatoes laid out to freeze at night time.
Defrosted	The following day they are allowed to thaw and may be covered wth straw to prevent blackening. This freezing thawing process is repeated several times and causes rupturing of cells.
Treading	The potatoes are trampled so squeezing out liquid from the broken cells and removing the skin.
Soaking	Placed in a running stream for several days.
Dried	In sun for 27 - 30 days (10% maximum moisture)
Product	Chuño is consumed by soaking in water and then cooking in soups, or eaten with meat, cheese etc.
Advantages	Long storage life of up to 3 - 4 years. The process has the great advantage of not requiring fuel, a very scarce commodity in these high areas.
Disadvantages	Product dependent on climatic conditions (frost, cold running water, sun). Considerable loss of nutrients particularly protein and vitamin C.

SECTION 2

Product	Papa Seca (Dried Potato)
Region	South America
Country	Andean highlands in Peru and Bolivia
Equipment	Cooking pot, tin sheet or sack
Process	Essentially partial cooking followed by sun drying.
Raw material	Potatoes.
Prepared	Boiled and peeled by hand then sliced or broken into small pieces.
Dried	Sundried on tin sheets or sacks.
Product	The product is used in many traditional dishes.
Advantages	Useful method of utilizing smaller second grade potatoes. Has considerably more market acceptability than chuño, higher value product than chuño.
Disadvantages	Fuel is required for boiling.

Product	Potato Starch
Region	South America
Country	Peru
Equipment	Grinder, large jars, cotton cloth
Process	Pulping, washing and sun-drying
Prepared	The potatoes are peeled.
Pulped	Ground into a pulp, thereby breaking down the cell walls and releasing the starch. The resulting milk contains mainly starch together with minor amounts of skin and fibre particles. If the latter are not removed by washing and sieving a brown-coloured starch which has a lower market value will result.

Settling The ground pulp is diluted with water and left to settle in large containers. The starch settles to the bottom. After the liquid above the starch has been poured off the starch is re-slurried in water and again allowed to settle. This washing process is repeated several times until a clean white product results.

Drained The starch is drained by squeezing in a cotton cloth.

Dried Placed in the sun to dry.

Note: Very little traditional starch processing is now carried out at household level, having largely been replaced by maize and potato starch imported from Europe and the USA.

Yam

Yams are an important staple food in West Africa, the Caribbean, parts of Southeast Asia and the Pacific. In West Africa the yam 'zone' principally covers the Ivory Coast, Ghana, Togo, Benin and Nigeria with the last being the world's largest producer.

Traditionally, yams have an important cultural role. In the yam 'zone', it is commonly forbidden to eat the first yams of the new harvest until the annual New Yam Festival occurs. There is also a gender division associated with the handling of the crop. Generally, in West Africa and Melanesia, men control the growing and storing of the crop. Some women, especially widows, may grow and store yams. This is advantageous to women in West African communities where a well-built and stocked yam barn is considered prestigious. However, in Melanesia, the gender taboo is stronger, and women are excluded from all cultivation stages of one particular yam species (*Dioscorea alta*), but are allowed to cultivate other less important species. This particular species may have been designated the man's crop and attained ritual importance because of the high labour and financial investment required for its cultivation. Another cultural belief common in West Africa is that small tubered species are thought to produce an inferior 'fufu', and thus considered an inferior gift.

When compared to cassava, yam is a more difficult and expensive crop to cultivate. Labour inputs and material costs are higher as not only does a yam crop require more husbandry but also greater soil fertility. It is a seasonal crop and part of a live tuber is required as planting material for the next season. Because of the perishable nature of the planting material the farmer does not necessarily have the next season's crop secured. This means that the producer requires a well managed store and may on occasions have to purchase suitable planting material from elsewhere.

Some varieties of yams will store up to 6 months. There are well developed traditional storage systems in the major yam-growing regions. These may involve leaving the tubers in the ground or heaping freshly harvested tubers underneath rock outcrops, on household

floors, inside huts, underneath houses built on stilts or underneath soil and humus. Under these conditions the rate of deterioration is reduced by curing, which is described later under the relevant heading. In parts of West Africa special structures are built for the storage of tubers. These 'yam barns' consist of a vertical framework of timbers with cross pieces of bamboo or the ribs of palm leaves. Tubers are fastened individually to the structure using raffia.

Yams are usually prepared for eating using simple cooking such as boiling, baking, roasting, steaming or frying.

Throughout the West African yam zone fufu is the most popular processed yam product.

Certain varieties are preferred for fufu production as they form a stiffer dough.

In the Pacific Islands yams are wrapped in green leaves with other ingredients such as coconut cream and chicken or fish and roasted in ovens.

Although there are about 600 species of yams, only about 10 are edible, and many contain toxic alkaloids. Some toxic varieties are traditionally processed as in the Philippines where for example, the following technique is used:

- thin slices of peeled tuber are placed in a basket and submerged in the sea or a solution of salt water for 2-3 hours;
- the slices are removed and squeezed under weights for a few hours;
- the material is replaced in the basket and left in a running stream for 36-48 hours with occasional stirring.

Traditionally processed products

Fufu is one example of a whole range of sticky dough or porridge-like foods.

The name is often applied to any such product made from starchy material such as cassava, yam, cocoyam or plantain, either singly or in combination. It is also sometimes used to describe similar doughs made from cassava starch, cassava flour or grated cassava. Numerous local variations and methods of preparation thus occur. For interested readers an excellent survey is included in the *Further Reading* list (Lancaster, *et al.*, *Traditional Cassava Based Foods: Survey of Processing Techniques*.)

Product	Fufu
Region	West Africa
Equipment	Pestle and mortar, sieve, raffia or cotton bags
Process	Raw material pounded or mashed to make a heaqvy dough.
Raw Material	Yam, cassava, cocoyam or plantain or blends of these.
Prepared	Peeled and cut into smaller pieces.
Cooked	Boiled or steamed till soft.

Pounded In a pestle and mortar with a little water until a smooth, sticky dough forms, which is then ready for consumption.

Product A heavy dough.

Note: The preparation of fufu from 'bitter' cassava will differ: unpeeled roots are placed in streams or in large earthenware pots for 3-5 days for soaking and fermenting. The roots soften and the peel and central fibres may then be removed after which the product is ground or pounded in a mortar until a smooth soft mash results.

Product Yam Flour

Region West Africa

Country Togo, Ghana, Ivory Coast, Benin, Nigeria

Equipment Pestle and mortar, sieve, knife

Prepared Tubers are peeled and sliced to about 1 cm thickness and parboiled in water.

Dried After cooling, the pieces are sun-dried until hard. In this chip form, the product is referred to as 'elubo' in Nigeria.

Ground Ground into coarse flour with pestle and mortar although mills are used where available.

Sieved To produce a finer flour. Grinding and sieving is repeated until product is satisfactory.

Note: The flour can be rehydrated with water to form a dough as needed, but considered an inferior substitute for fufu.

Advantages:

(1) Flour can be prepared from damaged tubers, thus limiting crop and storage losses.

(2) Can be stored for several months provided that the moisture content is sufficiently low and the product is protected from insect and rodent attack.

(3) The dry chips can also be stored and ground to flour as required. This has the added advantage of giving greater stability to moisture absorption.

(4) Stable product allows for reduction in marketing and transport costs.

Disadvantages:

(1) Certain varieties of yam turn black or brown and can be extremely hard when dry. This has met with consumer resistance.

(2) 'Elubo' is very hard and difficult to grind using conventional milling machines and causes machine wear.

Edible Aroids

Aroids are physiologically similar to root crops, although they do not yield edible roots but swollen starchy stems. They are cultivated, processed and consumed as a dietary staple in a similar way to root crops. Many aroids contain irritant crystals of oxalic acid and special cooking methods have been developed to make them safe and palatable. Within the edible aroid group, taro and tannia species are the main food crops used for direct human consumption and will therefore be the subject of this section. Tannia, taro and allied species are often collectively known as cocoyams.

Cocoyam cultivation and processing for direct consumption is a subsistence activity. Again, the crop requires high labour and material inputs compared to cassava. Traditional processing methods are limited to boiling, mashing, drying and fermentation. Commercial production includes products such as weaning foods, flakes, breakfast foods, noodles, canned and frozen goods. Such activities which require cultivation to be on a larger scale are concentratd in Hawaii, the Philippines, the Caribbean Islands and Egypt. Although taro and tannia appear similar they have developed in different hemispheres. Both crops are important staples in West Africa, while in Oceania taro is preferred. Taro requires more careful processing than tannia to eliminate the larger amounts of oxalic acid present.

In West Africa, tannia is commonly boiled and pounded with other root crops into fufu, or eaten boiled, fried, or roasted. In Hawaii and southern China, taro is fermented to make a purplish - grey paste known as 'poi'.

Traditionally Processed Product

Product	Poi
Region	Pacific
Country	Hawaii
Equipment	Knife, grater, sieve
Process	Cooking and grating
Prepared	After cooking, taro is peeled, washed and grated.

Fermented	The resulting liquid mass is kept at ambient temperatures for several days to ferment, during which time lactic acid is produced.
Product	When fermentation has produced the desired taste the poi is ready for eating.

Sweet Potato

The sweet potato originated in Latin America and is now widely grown throughout tropical and sub-tropical regions, particularly in the Pacific, Carribean, East Asia and New Zealand. It is not generally eaten as a main dietary staple in the same way as cassava, maize or rice; that is to say with almost every meal. The research that has been carried out on sweet potato is mainly in connection with processed products for the crop in the developed world. In the U.S.A. it is canned, frozen, dehydrated or used in pie fillings, candied pieces and baby foods. This suggests that its potential in developing countries as an important processed food has perhaps not been fully realized. Sweet potatoes are comparatively easy to grow and have a high consumer acceptability. However, they have a short storage life, generally less than four weeks in the tropics. Their thin skin is easily damaged during harvest and post-harvest handling leaving the crop highly perishable. It is therefore usually consumed soon after harvesting. Alternatively curing, drying and fermentation are traditional preservation methods, some of which are illustrated below.

Traditionally Processed Products

Product	Chips
Region	East Africa, Asia (India)
Process	Slicing and drying
Prepared	Tubers are peeled and sliced
Dried	The pieces are placed in the sun to dry and can then be stored. When the product is needed for consumption the dried slices are washed and boiled or ground into flour for making local dishes.

Product	Flakes

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Region	South East Asia
Country	Philippines
Process	Drying, pounding
Prepared	The tubers are peeled and flaked.
Dried	Placed in the sun to dry and then stored. When needed for consumption the dried flakes are pounded into a flour and either made into gruel by mixing with water and sugar, or formed into small balls of a dough consistency which are wrapped in sugarcane leaves and boiled.

Product	Flour
Region	South America
Country	Peru
Process	Drying, milling
Prepared	The tubers are peeled and sliced.
Dried	Placed in the sun to dry
Milling	The dried slices are milled and sieved to produce a flour.

Product	Fermented Sweet Potato 'Poi'
Region	Asia
Process	The tubers are baked or steamed.
Prepared	After cooking the tubers are peeled and pounded with a stone pestle in a long shallow bowl of wood or stone.
Fermented	The sticky dough is mixed with water and left in a calabash to ferment for several days (depending on local tastes).

Product	Futali
Region	Africa
Country	(Malawi)
Process	Cooking, pounding
Cooked	Boiled or roasted.
Prepared	Pounded together with peanuts to form a paste.

Cassava

The majority of the total world production of cassava is processed for direct human consumption in Africa and South America. In Asia, Thailand produces cassava chiefly for industrial purposes and export. Such industrial applications include animal feed, alcohol, starch and food products such as tapioca and 'instant' mixes. Cassava processing is not only important for preservation of the product which, as has been mentioned, must be used quickly after harvesting but also to reduce its toxic components. The toxicity of cassava has been covered in the sections of this book on basic food science and technology.

Traditionally Processed Products

Product	Gari
Region	Africa
Country	Nigeria, Ghana
Equipment	Grater, roasting pan, sieve, jute or fibre bag
Process	Fermentation, roasting
Prepared	Washed, peeled and grated roots are placed in large cloth bag in the sun and left to ferment for 3-4 days. Weights are placed on top of the bag to press out the liquid which drains away.
Sieved	When sufficiently dry (about 50% water content) the pulp is removed from the sack and sieved to remove fibrous material.

Roasted	Small amounts are constantly stirred in a shallow pan over heat until cooked. Palm oil is sometimes added to prevent burning and to impart a yellow colour.
Cooled	Spread out to dry further and cool.
Product	A light, crisp, free-flowing granular powder which is creamy white in colour. Shelf life: few weeks or months to more than one year depending on packaging and moisture content. For safe storage, moisture content must be below 12%. Also known as "Farinha de mandioca" in Brazil which is somewhat different in that its fermentation and pressing time (due to use of the Tipiti press) is much shorter. The product also has a different taste.
Advantages	Usually eaten as a convenience food and is therefore attractive to urban markets. When packaged properly has a good shelf life.
Disadvantages	Grating and peeling are time-comsuming; frequent cuts on the hands with hand-graters. Constant stirring of gari over a fire requires processor to endure heat and smoke and exposure to an atmosphere of cyanide gas for lengthy periods of time.

Product	Landang or Cassava Rice
Region	Asia
Country	Philippines
Raw material	Cassava
Equipment	Grater, jute sacks, winnowing basket, sieve, mat.
Process	The following are two common methods used to prepare this traditional Philippine dish:
Method 1	
Prepared	Freshly harvested roots are peeled, grated, and placed in jute sacks.
De-Watered	The sacks are pressed between two wooden blocks to squeeze out the juice.

Pelleted The pulp is put into winnowing baskets and whirled until pellets form (size depends on speed of motion and moisture content).

Sieving Pellets of more or less uniform size are isolated by sifting — those too big to pass through the sieve are broken, put back in and whirled again.

Steamed The pellets are steamed on a screen mesh placed over a vat of boiling water.

Dried After being separated by hand while still wet, the pellets are finally sun-dried on mats.

Method 2 Peeled roots are soaked in water in earthenware jars or wooden containers (contact with metal should be avoided) until they begin to soften (5-7 days). The contents are macerated and fibres removed by hand. The mass is air-dried, before making the pellets as described before. In both methods the pellets are thoroughly sun-dried for 3-5 days before storage. The product can be eaten without further cooking, or can be soaked, mixed with coconut milk, reboiled and served.

Advantages If placed in a cool, dry place, the storage life is 3 -6 months. Considered ideal for fishermen and others on trips as it stores well and can be eaten without cooking.

Product Gaplek (Cassava Chips)

Region Southeast Asia

Country Indonesia

Equipment Jute Mats

Process Drying

Prepared Peeled and cut into thin slices.

Dried Spread on woven mats or hung on fences to sun-dry. The drying time varies with the amount of sunny weather, but it is normally 2-3 days. The chips are sometimes steamed before drying, which it is reported prolongs the storage life.

Product Cassava chips are usually further processed as needed for consumption: boiled, fried in oil, or ground into flour.

Note: Preparation of cassava into dried chips followed by further processing into flour when needed is widely practised in Asia.
In Thailand and Indonesia cassava chip production is also carried out at the commercial level, being a primary export.
In India the chips are parboiled before drying. Storage life can be up to one year compared to 3-6 months without parboiling.
In Ghana, the smaller whole roots which might otherwise be discarded are peeled and left in the sun for approximately 10 days to dry. This product is known as 'Kokonte'.

Product Cassareep (West Indies)
Tucupy (Brazil)

Region South America and West Indies

Equipment Grater, press or "Tipiti"

Process Extraction, concentration

Prepared Roots are peeled and freshly grated.

De-watered Pressed to obtain juice which is collected.

Evaporated The liquid obtained is boiled down and concentrated by evaporation until it reaches a dark, syrupy consistency. The long heating destroys the toxins in the juice.

Product A thick syrupy sauce.

Note: Along the Caribbean coastal areas, cassareep is the basis of the traditional dish 'pepper pot' in which all kinds of meat, fish and vegetable leftovers from meals can be placed and cooked. Cassareep is said to be a meat preserver and pepper pots can be kept for many years by adding further ingredients as necessary and bringing to the boil daily. Bitter varieties of cassava are considered to give the best quality cassareep.

Advantages Long-storage life

Product Cassabe. This one example of the many types of cassava bread traditionally produced in many countries.

Region South America

Country Venezuela

Equipment Tipiti press, sieve, iron plate or griddle, trays

Process Grating, drying, baking.

Prepared Two methods are used depending upon whether the roots are subjected to a soaking fermentation stage or simply peeled and grated.

De-watered The juice is squeezed out from the mash using a Tipiti. The resulting 'press cake' is left for several hours or overnight until it becomes quite solid.

Sieved The cake is broken up and rubbed or sifted through a coarse sieve to separate out extraneous fibres.

Dried The dough is pressed down to a thickness of 1 cm in wide trays made of woven palm fibre and left in the sun until completely dry and hard.

Baked The press cake is either sun-baked or baked over a fire. Alternatively, the sifted pulp is spread into thin flat cakes and cooked on a hot griddle, turning to cook both sides to produce a hard cake. The cakes are then dried in the sun on the roofs of houses until they become hard. The cakes so produced can be 2 to 3 feet in diameter; pieces are broken off and dipped in gravy and soups.

Note: Cassabe or cassava bread is the staple diet of the Amazonian Indians. Bitter cassava is preferred as it has a higher starch content which makes the product less brittle and better to store.

Advantages The hard, brittle cake keeps in good condition for easy storage for several months, a convenient food to carry on extended trips such as when hunting.

Disadvantages A laborious process which can take up to 2 days

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Product Cassava Beer

Region Widespread, including Central and East Africa and Latin America.

Equipment Earthenware jars

Process Kasiri is one example of a common fermented alcoholic beverage based on cassava.

Method 1

Prepared Fresh tubers are left up to a week in a flowing stream until detoxified by fermentation.

Fermented The fermented cassava is removed from the stream, put into a jar and water is added leaving it to stand for another 3 days after which the mass is heated. In some cases yeast is then added before allowing the fermentation to continue.

Method 2

Prepared This process is widely used throughout Central and South America, and the West Indies. Cassava bread is chewed up, mixed with water, and fermented for 2-3 days. The natural enzymes of the saliva speed up fermentation by initiating the breakdown of starch to sug ar. Traditional customs require that only young girls chew the cassava in some areas while only the oldest women are permitted to do so in others. Without chewing, fermentation takes 4-5 days.
The drink has ritual importance for some tribes in the Brazilian tropical forest.

Product Starch

Region South Pacific

Country Tonga and Western Samoa

Equipment Knife, bucket, grater, strainer, mats

Process Extraction, drying

Prepared Fresh roots are washed, peeled and grated into coarse meal.

Extracted Grated cassava is washed with water, strained through a cloth bag which is squeezed by hand to extract starch

milk. This is then poured into a bucket or basin. The process is repeated until the squeezed liquid is no longer white.

Decanted After standing for several hours the starch will settle to the bottom.

Washed The starch is washed and the procedure repeated until the liquid poured off is clear.

Dried The white starch remaining at the bottom of the basin is removed and spread out on mats to dry in the sun.

Product When almost dry it is pressed into balls or dried completely and pounded into powder.

Note: Traditionally, starch was made from arrowroot, or sago palm. Since cassava is cheaper it has tended to replace these starches.
The most common use is to add to puddings or mix with fruit. Cassava starch can be stored as needed. It is baked into cakes in the Caribbean, Pacific Islands and Jamaica. Cassava starch can be further processed into tapioca: wet starch is heated in a pan stirring continuously until the grains burst and gelatinize into globules.
In West Africa starch is traditionally processed, dried, rehydrated later and eaten as pap or porridge.

Traditional Curing Methods

The purpose of curing is to increase the storage life of the tuber. During curing, conditions of increased temperature and humidity encourage growth of the outer layers of the tuber's skin. Existing wounds are thus sealed preventing entry of micro-organisms thereby helping to inhibit deterioration. Curing is practised with cassava, sweet potato and especially with yams. Several curing methods are described below.
In Papua New Guinea the tubers are stacked on platforms in a dark area of the house where heat and humidity from the cooking area can cure them. On the other hand, the Maoris of New Zealand practise pit storage as a method of curing sweet potatoes. Here, underground storage pits are dug into the side of a hill and the floor of the pit is covered with a layer of gravel and soft packing.
The seed stock is placed in first to fill the back of the pit while the tubers for consumption are stacked at the front, being separated by fern leaves. The store is sealed to allow a build up of heat and humidity inside for curing (owing to the natural respiration of the tubers).
Pit storage is also practised in Zimbabwe and Malawi. Yams are usually cured by covering the tubers with earth.

Improved Processing Equipment and Products

Many of the traditional processing systems outlined in the previous section have been improved and in many cases mechanized.

When considering upgrading traditional methods or introducing improved technologies, it is important to be sure

- that the need is correctly identified
- that appropriate expertise (including technical, socio-economic, marketing etc.) is available.

The introduction of improved technologies for root crop processing has met with varying degrees of success. Mechanical peelers, for example, have in some cases resulted in higher wastage than hand peeling and in general have not proved acceptable in small processing units. Graters on the other hand seem to have met with wider acceptance being able to take over what is seen as a very laborious task.

Complete 'packages' of equipment, of various scales are available for processing several rootcrops. Comparatively small packages exist for example for carrying out all the process steps in the production of gari and secondary cassava products such as chips, instant mixes and breakfast foods. Some of these products are not part of traditional local foods and are too expensive for most villagers.

They therefore have little or no readily available rural market.

Most small rural villages do not have the facilities to meet the necessary requirements of high capital investment; a regular and formal labour force; access to, and a regular supply of production materials and management abilities necessary to operate larger scale plants. For this reason package systems available will not be covered in this text. There appear to be few, if any, cottage or small-scale mechanized 'packages' for processing a particular rootcrop.

This section will describe improved technologies by processing methods and will include:

- Peeling and Washing
- Grating and Rasping
- Pounding
- Pressing and De-watering
- Sieving
- Roasting
- Drying
- Milling and Grinding
- Chipping and Slicing

As it is not known which pieces of equipment used in these processes are still prototypes, have been tested in the field, or are actually being used by rural women at village level, the names and addresses of the equipment suppliers and appropriate institutions are given in section 7 as a first contact point.

It should be stressed that before considering obtaining any equipment it would be beneficial to consult appropriate institutions (listed in the Contacts section), especially those who have had previous experience in introducing the equipment.

The introduction of an improved technology or process may benefit a community both economically and socially.

Increasing the efficiency of a process by making it more cost effective with the aim of increasing incomes will also result in social change, which will have to be acceptable to those involved. Both economic and social factors therefore need to be considered, ie:

A. Economic

1. Availability of local workshop facilities to produce or maintain the improved production system.
2. Labour requirements and availability.
3. Raw material supply.
4. Scale of production desired.
5. Production and product cost. The product may have to competeeconomically with traditional products made using uncosted or low-costed family labour.
6. Potential consumer markets.
7. Access to credit at local interest rates.

B. Social

1. Family needs and capacity for labour and/or capital investments.
2. Existing infrastructural support i.e. transport and credit conditions.
3. Cultural restrictions - gender divisions, local preferences in taste, texture, colour and odour of food, taboos, social structures.

Consumer acceptability is vital for a food processing operation to market its products. It is necessary then to examine and compare any change in terms of flavour, colour, texture and odour that might have occurred with the introduction of an improved technology.

Peeling and Washing

While equipment for washing and peeling root crops is commercially available its cost and throughput is generally too high for small rural projects.

Washing machines generally consist of a cylinder fitted with paddles and brushes that can be rotated while a stream of water is played over the rootcrop as it passes through the unit.

Mechanical peelers operate by rubbing the roots against a rotating abrasive surface. They are best suited to raw materials of regular shape. Irregular materials either have high losses on peeling or require final hand peeling. The use of mechanical peelers is dependent on the throughput required and local wage rates. In Europe, with its high hourly labour costs for example, the cost of hand peeling would far excede any losses of yield through mechanical peeling. It should be noted that in some cases abrasive peelers may offer a reduction in losses compared to hand peeling, especially when used for small roots or tubers.

A description of a simple washer and peeler that could be constructed locally together with a commercial peeler are included together with an outline of a chemical peeling process.

CIP Manual Potato Washer

The International Potato Centre (CIP) in Peru has designed a simple, hand-operated potato washer. A 55 gallon oil drum is cut lengthwise and paddle wheels equipped with brushes are fixed on an axle with wooden dowels. A handle is fixed to the axle in order to rotate the paddles and so agitate the potatoes. The washer has a capacity of 25 Kg of potatoes and requres 150 litres of water per batch. After a few minutes the drum is turned on its side to empty the potatoes and dirty water.

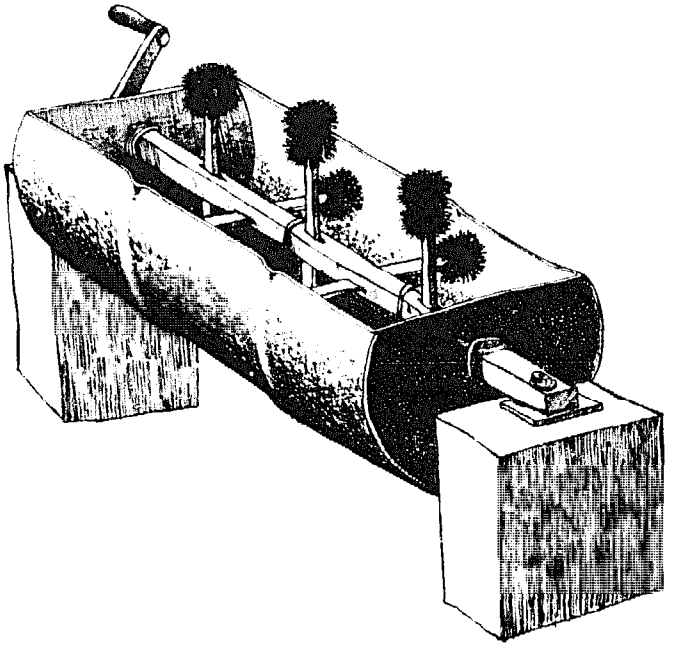

CIP Belt-Driven Motorized Peeler

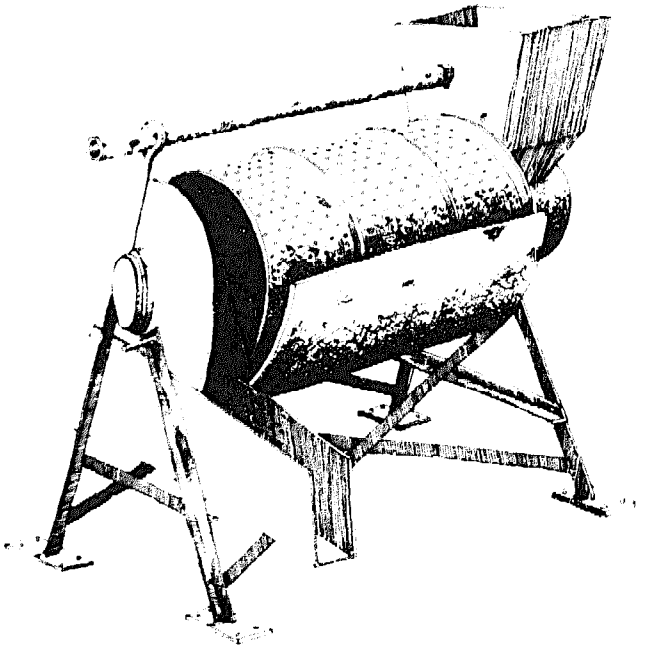

A sheet-metal cylinder or 55 gallon drum whose surface has been punched from the outside to create an abrasive surface internally, is mounted on a horizontal axle. The drum is rotated via a belt-drive from a motor. Potatoes are fed into the drum from the top, and as the cylinder rotates the protruding holes scrape the skin from the surface of the potatoes. Each end of the cylinder is fitted with a small door so that the potatoes may enter at one end and leave from the other when peeling is complete. A perforated metal pipe set above the cylinder sprays water over the rotating drum. 20 Kg of potatoes can be peeled in 4 minutes. Final trimming and peeling is necessary. A smaller hand operated peeler can be constructed using a similar design.

Abrasive Plate Peeler

The 'Crypto Peerless' abrasive plate peeler is an example of a typical commercial machine in which a rotating abrasive plate rubs the skin from the material passed through. It is most commonly used to peel potatoes. Various sizes of such machines are available from as small as 13 kg/batch. They are powered by electric motors.

Lye Peeling

Hot solutions of sodium hydroxide (lye) can be used to loosen skin of many rootcrops to facilitate later peeling, such as removal by water spray or scrubbing with brushes. A combination of chemical reaction and thermal shock aid in softening and loosening the skin. The desired effect can be obtained by selecting the combination of lye concentration, temperature and immersion time. Generally, lye acts more vigorously at higher temperatures. Technical advice should be sought if lye peeling is being considered, as problems can occur. For example, partial cooking and gelatinization of the outer layers of the root may, cause too much lye absorption. In addition, sodium hydroxide is a very dangerous chemical to handle and workers need to be properly trained and protected. In addition the used lye solution is a potential source of pollution and can corrode equipment. The following table shows suitable combinations found for the lye peeling of yam:

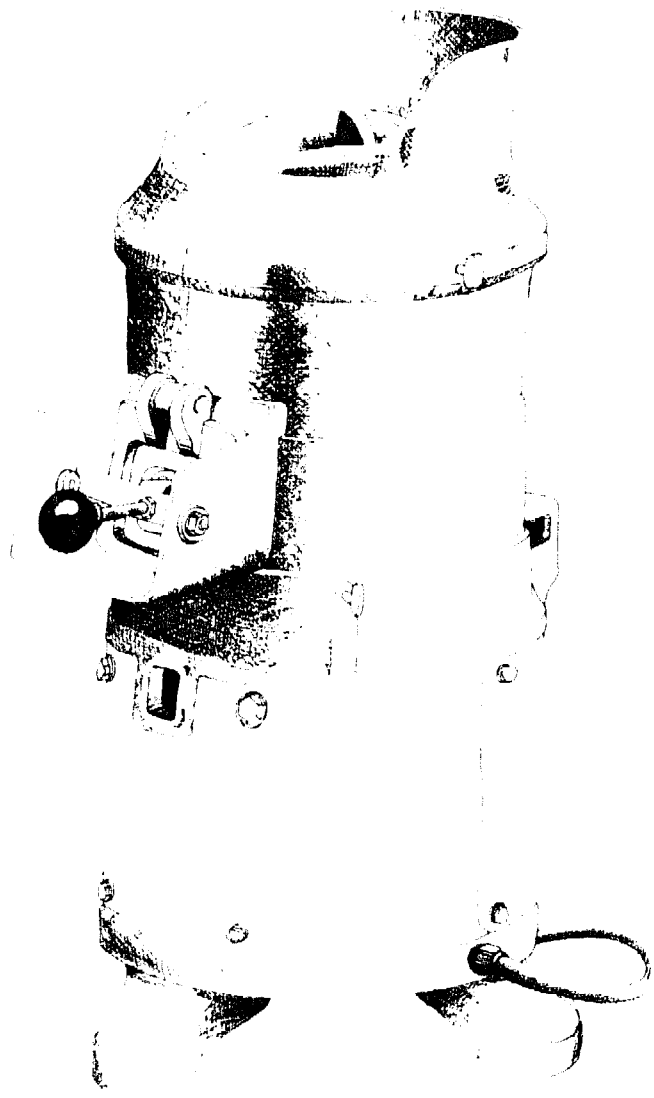

Lye Peeling of Fresh Yams

Table 3

Relation between immersion time and lye concentration on the efficiency of the lye peeling operation

Lye concentration Percent by weight	Time of immersion Minutes	Visual evaluation (1)	Loss in weight of lye-peeled tubers (2) Percent
10	2	Questionable	5.6
	3	Questionable	11.11
	4	Questionable	12.78
	5	Good	14.44
	6	Very Good	17.50
15	2	Questionable	7.22
	3	Questionable	11.11
	4	Good	13.33
	5	Very Good	16.11
20	1	Questionable	6.67
	2	Questionable	8.89
	3	Good	12.21
	4	Very Good	13.33

(1) *Questionable*: Tubers retained large patches of peel or many small patches.
Good: Tubers with one or two small patches of peel which can be removed easily by trimming.
Very Good: Tubers completely peeled.

(2) Average of three runs.

Source: Journal of Agriculture of University of Puerto Rico.
Lye Peeling of Fresh Yam, J.M. Rivera-Ortiz and M.A. Gonzales, 1972, 56 (1), Page 59.

Grating and Rasping

Grating and rasping are common steps in the processing of cassava and are time consuming and hard work. A considerable number of graters exist which range from simple hand graters through pedal operated units to motorized versions. Many are based on a rotating horizontal disc or vertical drum grating surface against which the root is held. Care should be taken when introducing any powered device that injuries do not occur: for example loose clothing becoming tangled in the drive, or fingers being caught in the rotating disc.

Hand Graters

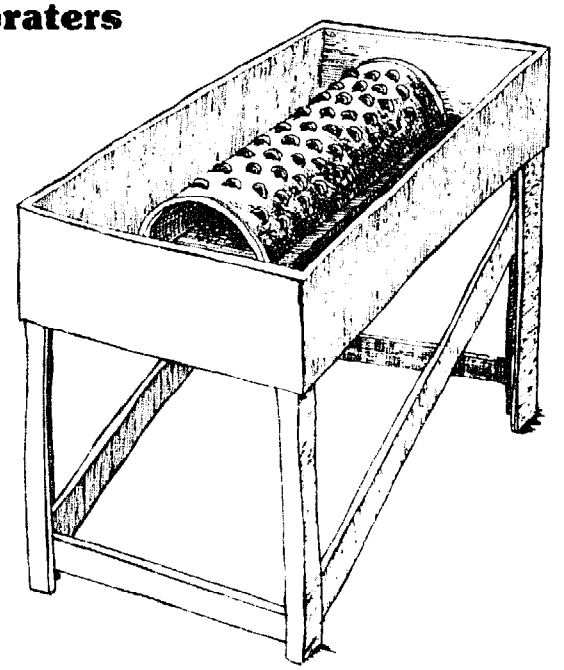

The two selected designs of hand graters shown here are both low-cost and can be constructed of tin or galvanized mild steel. The grating surface is created by puncturing the surface with holes, as in traditional construction. Both models need only one operator and are probably most suitable for an individual family or to be shared amongst a few families.
This design is essentially an upgraded traditional technology, with the grating surface horizontal instead of at a downward slant, often supported against the processor's legs. The elevated grater is now supported on a table.

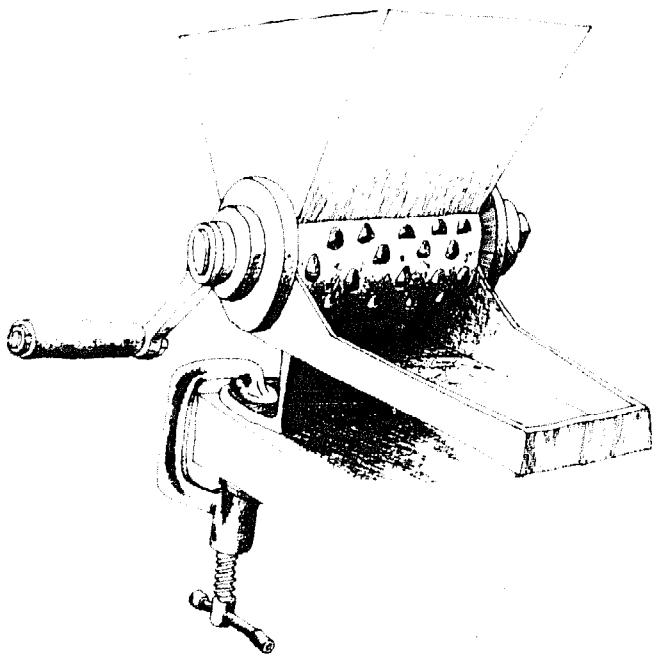

This hand-operated machine incorporates a rotating cylindrical grater against which the root is pressed. Note that only one tuber can be inserted at a time.

ITDG Pedal-Operated Cassava Grater

In the early 70's, an engineer at the Intermediate Technology Development Group's (ITDG) workshop in Zaria, Nigeria developed a cassava grater made from galvanised iron tubing, spare bicycle parts, hacksaw blades and sheet metal. Cassava is fed in the hopper and a vertical disc with grating slits fixed to a frame is rotated by pedal power.

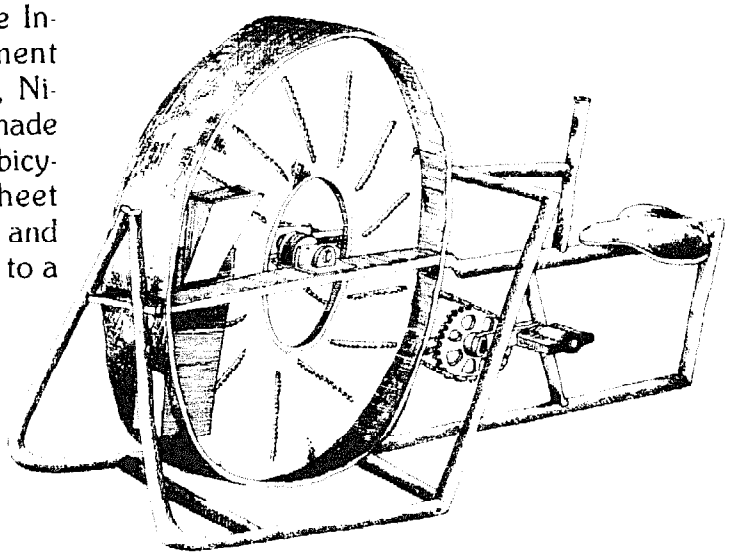

Wadwha Disc Grater

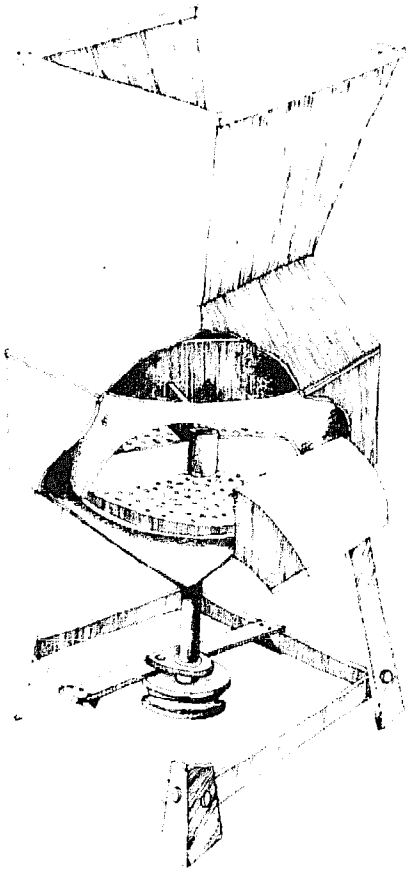

This grater, developed in Ghana, consists of a disc-shaped wooden block to which is nailed a perforated metal sheet. The perforated disc is rotated by a belt drive from a 5 h.p. diesel engine. The throughput is one tonne of cassava per hour.

TAEC Vertical Drum Grater

This drum grater was developed by T.A.E.C. (Tikonko Agricultural Extension Centre) in Sierra Leone. The surface of the drum is covered with a sheet of perforated metal which rotates across the base of the feed hopper The cassava is pressed against the grating surface by a wooden block inserted in the throat of the hopper. The drum is rotated by belt drive from a 4 h.p. diesel or electric motor. The hopper, drum, and frame can be made from timber or scrap metal.

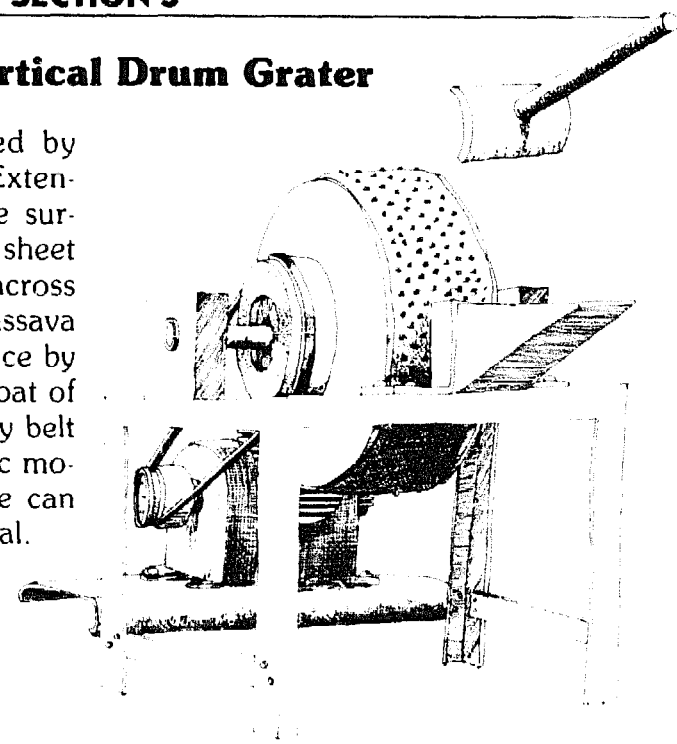

Pounding

The pounding of fufu from yams and cassava to produce a gelatinous, sticky product can take up to one hour using a traditional pestle and mortar.

Attempts to produce pounded yam products by rehydrating yam flour have proved unpopular because both the texture and taste were inferior to traditionally-pounded yam.

Motorized Pounding Machine

A machine for pounding yam and similar foods has been developed at the Department of Agricultural Engineering, University of Ife in Nigeria. It consists of a beater and bowl which operates in a manner rather similar to a heavy dough-mixer. The leading edge of the beater was sharpened to provide an additional chopping effect, with further beating producing a soft consistency characteristic of pounded foods. As in the traditional process water is added as necessary during the process. The unit is powered by a 1.75 h.p. motor and can produce enough fufu for eight adults in 45 seconds.

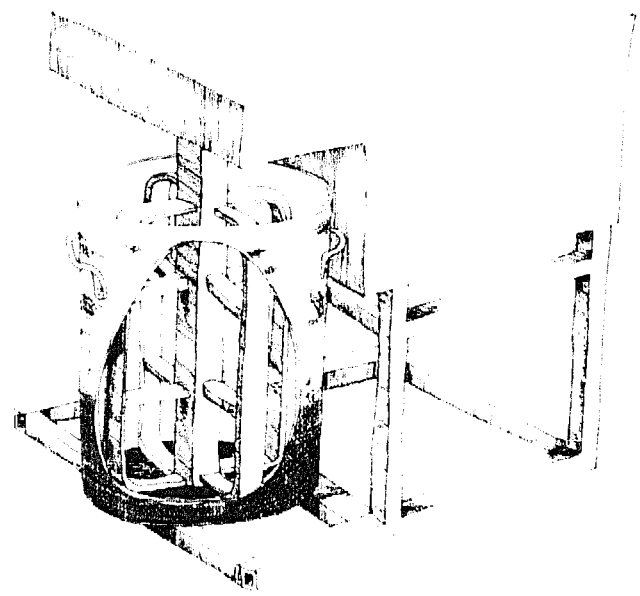

Pressing and De-watering

The common pressing step that occurs in several traditional root crop processing systems can remove up to 50% of the water present. Several press designs exist ranging from the simple, easily constructed parallel press board, press frame or wedge press to more sophisticated screw and hydraulic presses. The later clearly require access to better equipped workshops.

TAEC Upgraded Traditional Press

The traditional sticks-and-rope press has been upgraded by the Tikonko Agricultural Extension Centre in Sierra Leone. Two wooden frames are placed below and above the sacks filled with cassava mash. Half a dozen threaded rods pass through the bottom frame to fit holes in the top frame. Tightening exerts pressure on the sacks by pressing the frame closer together. The actual pressing time is not reduced but rather the time and labour necessary to either gather and heap heavy stones or to assemble and tie up the sticks around the sacks is reduced. Only wood, bolts and threaded rods are needed.

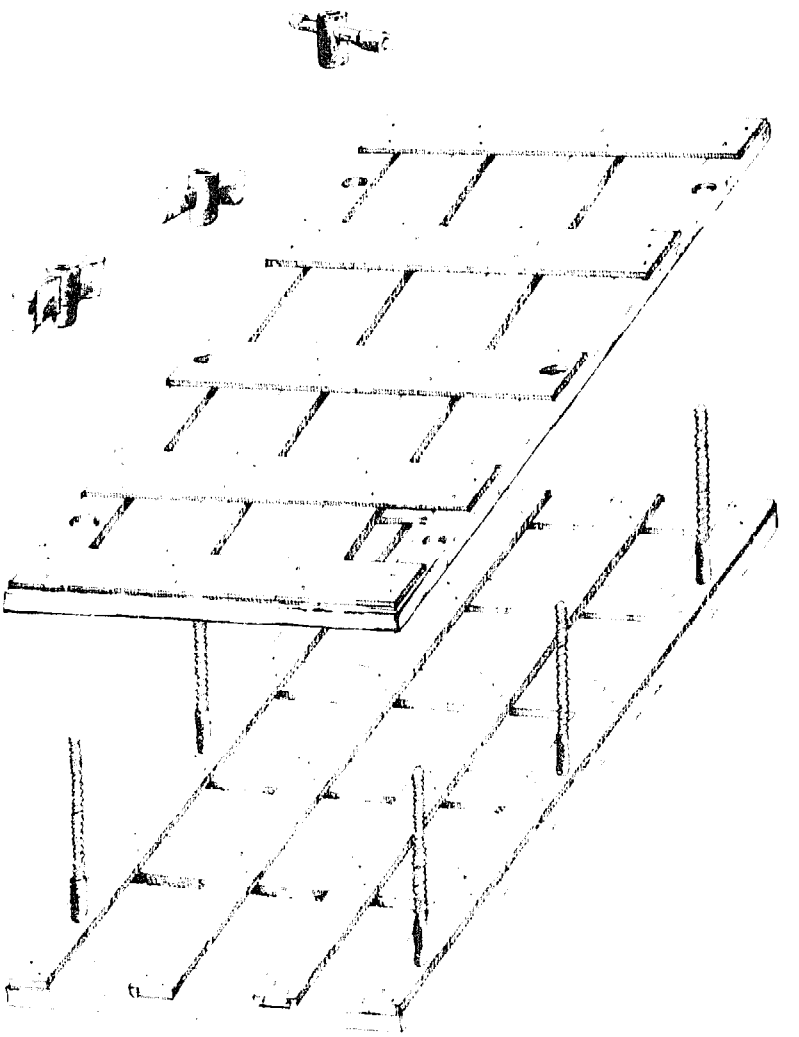

TCC Parallel Board Press

The Technology Consultancy Centre (TCC) in Ghana has developed a parallel board press which provides uniform pressure to pulp-filled sacks placed between them. Instead of a wooden frame as in the TAEC upgraded traditional model, two solid parallel boards are screwed together to create the pressure on the sacks. It takes about 3 to 4 hours to de-water one bag (125 kg) of gari as opposed to 3 - 4 days needed by traditional presses.

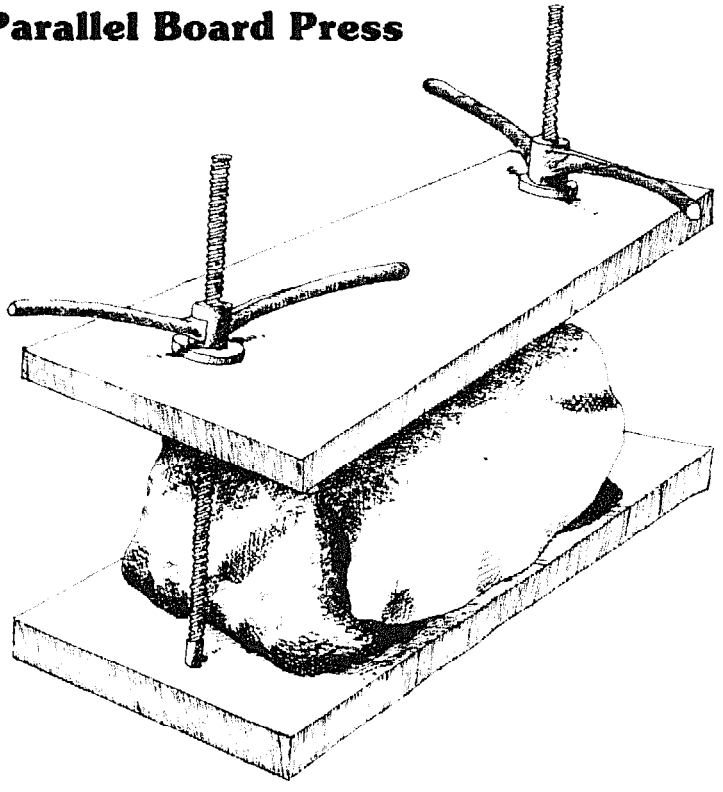

Wedge Press

The wedge press is an adaptation of a traditional Chinese press used to extract oil.

Tree stumps or wooden logs provide support for a wooden beam inserted in between them. Sacks of grated pulp are placed on the beam and pressure is applied when wooden wedges are hammered into the space between the sacks and tree stump.

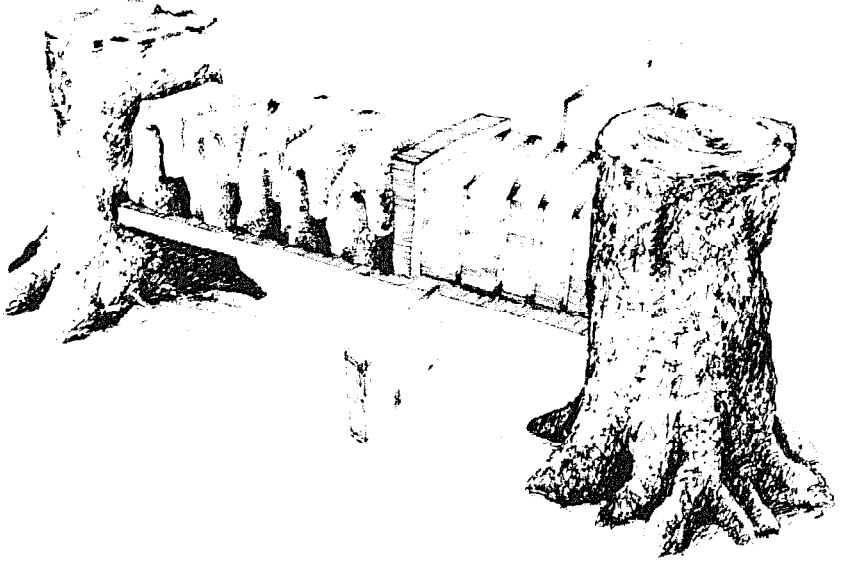

Screw Press

Screw-type cassava presses can either be in the form of a circular press cage holding the fresh pulp or a square frame exerting pressure on the sacks. Both types work by moving a heavy circular or square block which is lowered or raised by means of a threaded shaft. The press cage has a capacity of approximately one bag (125 kg) of cassava per batch whereas the other design can handle several sacks of pulp. A lathe is needed for cutting the screw thread as well as metal bending and cutting equipment.

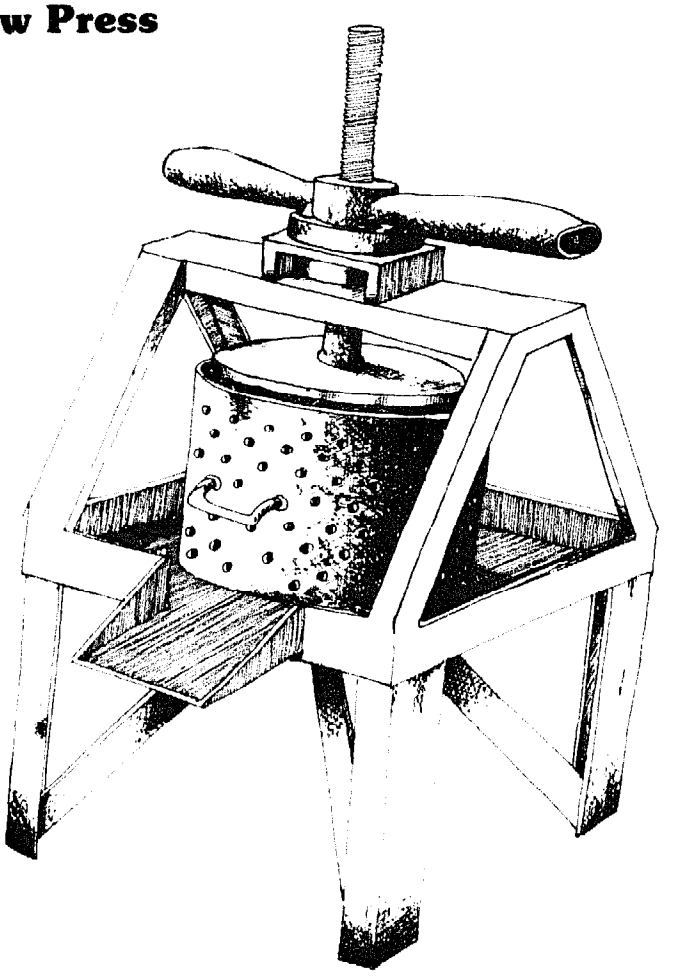

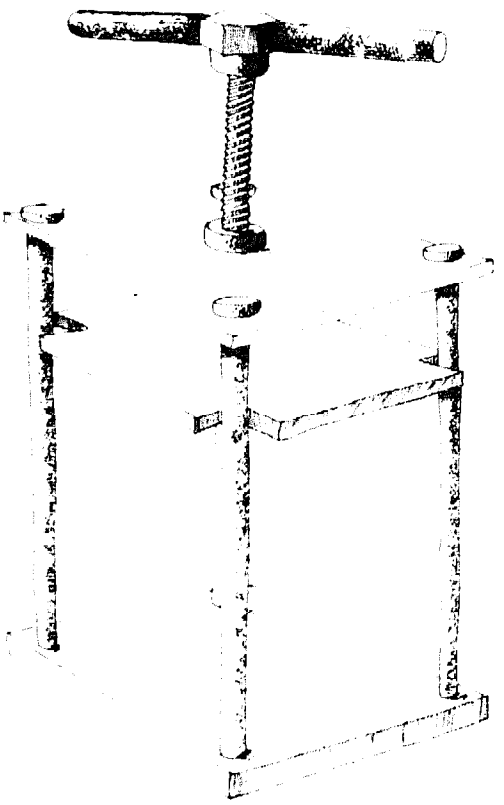

Hydraulic Press

Some designs of press use a hydraulic car or lorry jack to apply pressure to the material being dewatered, usually between pressing boards. If discarded car jacks are not available, the imported jack can make it an expensive piece of machinery to produce and maintain. Compared to the screw and other presses it requires the least amount of human effort to operate.

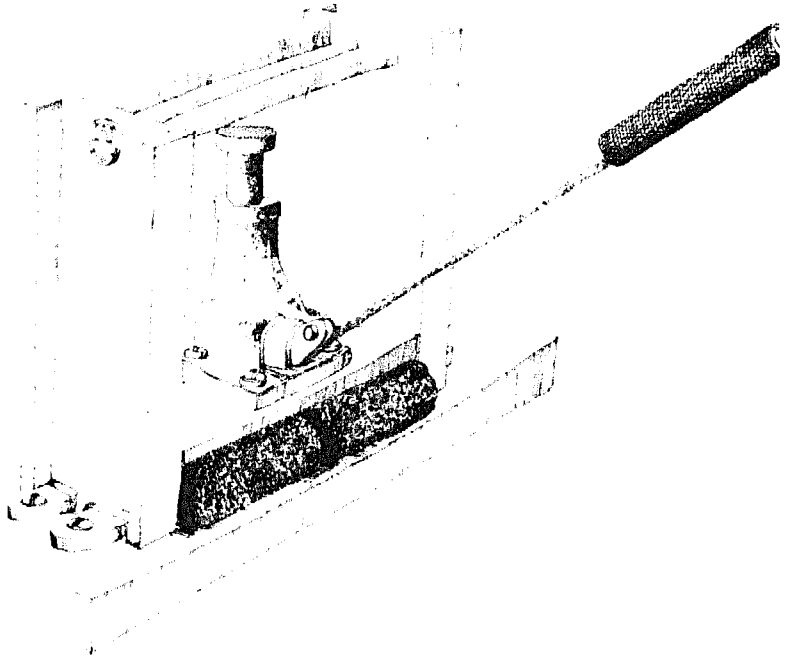

Sieving

After the pulp is de-watered by pressing the residual cake is traditionally broken up by manually rubbing it against wire mesh or raffia sieves. This process can be mechanized using either a vibrating or rotating sieve.

Improved Pulverizer and Sifter

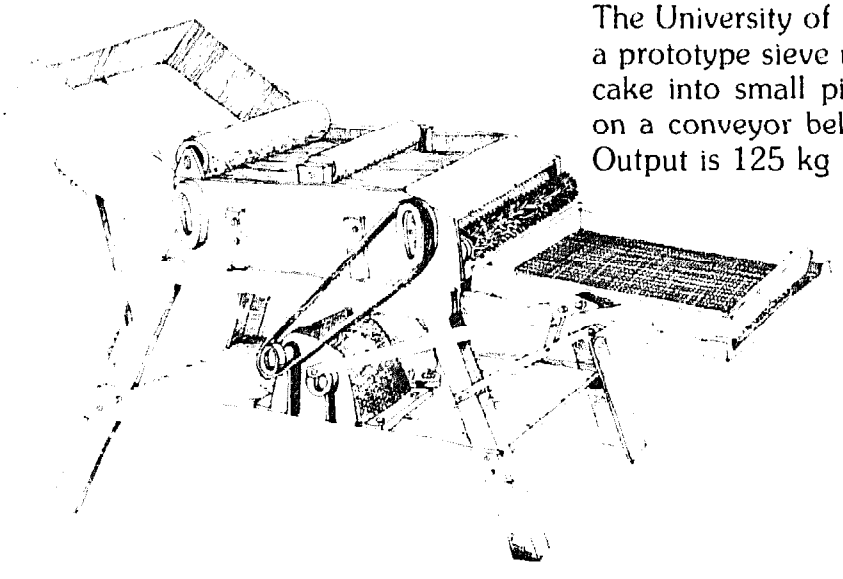

The University of Nigeria has developed a prototype sieve unit which cuts up the cake into small pieces which then pass on a conveyor belt to a vibratory sieve. Output is 125 kg per hour.

Rotating Drum Sieve

AGRICO Ltd in Ghana have developed a unit made from a 44 gallon drum fitted with a cylindrical sieve made of wire netting. The cake enters through a hopper and is then sifted when the drum is rotated, exiting from the bottom. A power-operated version has been developed by the same company which is driven by belt drive from a small motor.

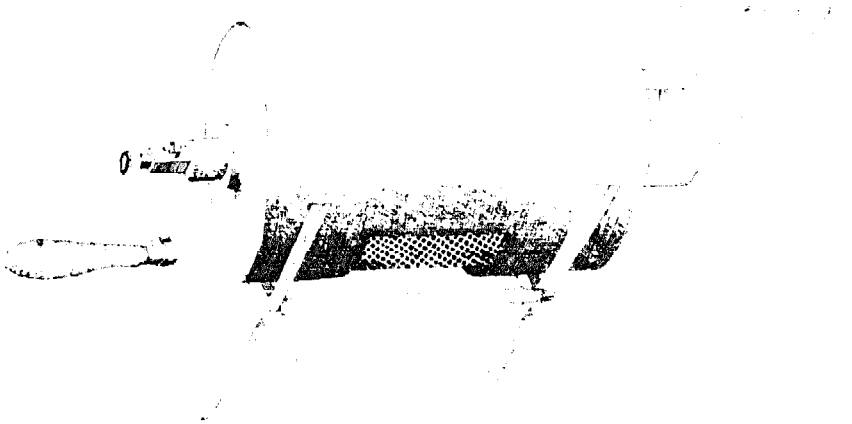

Roasting

Gari is traditionally heated in shallow cast-iron pans over a fire while being pressed and stirred against the hot surface with calabash pieces to prevent burning. Improvements have included either upgrading the traditional pan and wooden stirrer or development of a rotatable cylindrical roasting drum.

Upgraded Gari Roaster

One example is a rectangular tray roaster developed by The Rural Agro-Industrial Development Scheme (RAIDS) in Nigeria. A chimney helps to draw air which reduces the effects of smoke and heat on the processor. A long wooden stirrer or rake is used to turn the cake, preventing it from sticking and burning. This upgraded system improves the operators' health because the smoke is channelled away from the processor and the long stirrer allows her to remain some distance from the fire.

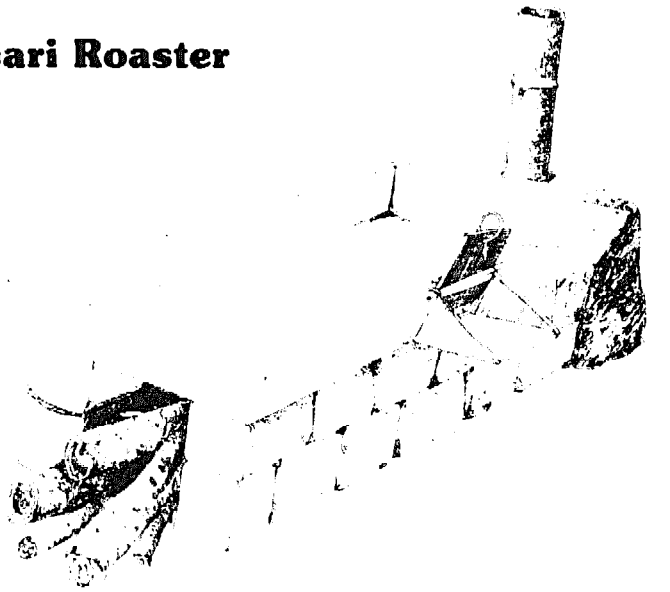

AGRICO Roaster

AGRICO in Ghana have developed a prototype cylindrical roaster containing paddles which continously stir the gari as the drum is heated. It can be hand or mechanically driven and heated by either wood or gas.

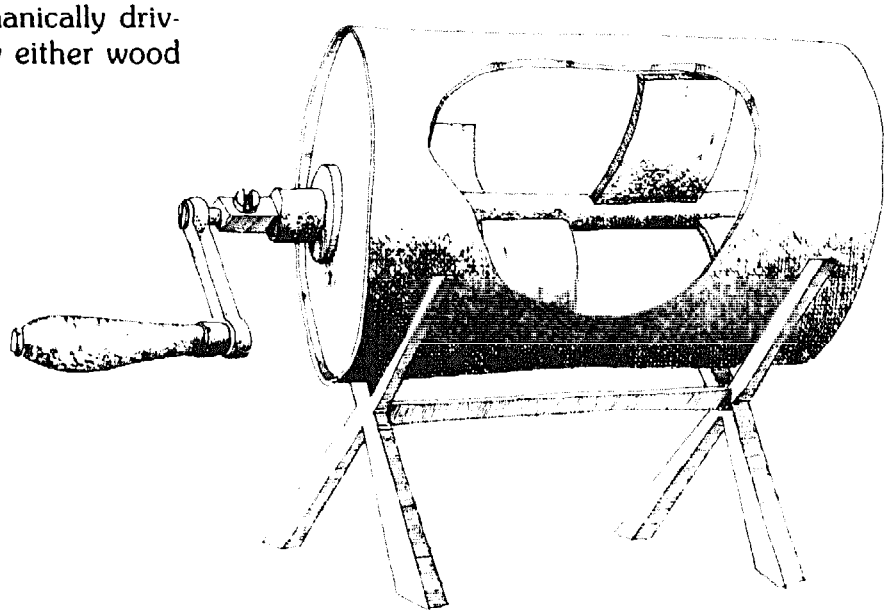

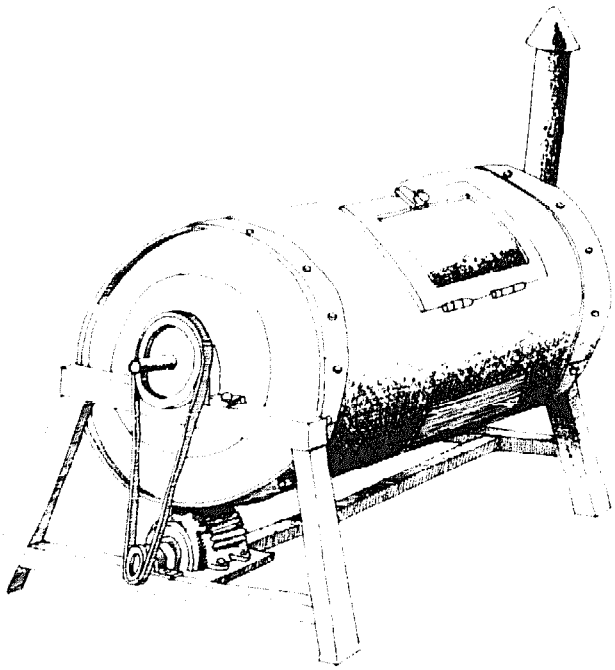

Drying

Technology choices exist for drying root crop products ranging from basic traditional systems which could consist of hanging the material from sticks right through to forced air driers. We have already seen, under Gari roasting, one traditional method of drying. This section will cover drying devices in the more accepted sense and include examples of solar, kiln-type and forced air driers in order of increasing sophistication, expense and drying capacity. Although these represent the range of drying technologies available, they have not been widely used for root crops. Root crops and their products are of fairly low value and it is doubtful that the use of artificial dryers would be economic, unless specialist comsumer markets exist requiring dry products with considerable value added eg, potato crisps or snack foods.

Solar Dryer

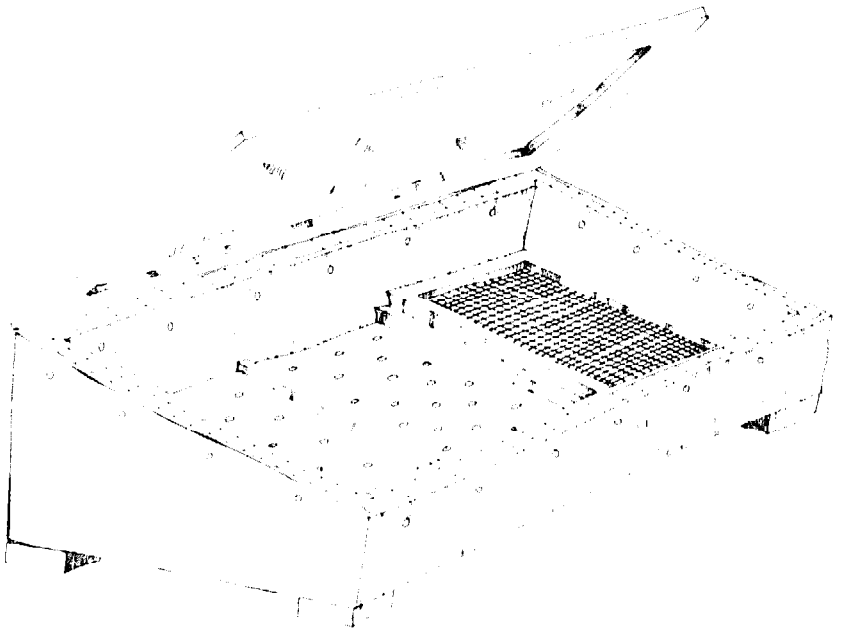

Simple solar dryers glazed with a transparent top and a system of air vents located at the bottom and top of the side are often referred to as Brace driers. The air in the chamber is heated by the sunlight passing through the transparent lid. The heated air rises and exits at the top of the dryer at the same time carrying away moisture from the product. An air flow develops with fresh air entering through the lower vents. While Brace driers are comparatively cheap and have been tried in many situations around the world they do not seem to have received wide acceptability.

Kiln Type Dryer

Two designs of simple wood fired driers are shown. In the first,sometimes known as a Brook Drier, a large tray is supported on a block or mud-brick base which has air entry holes in its sides. A flue passes under the tray through which hot air flows from a firebox to a chimney. Air entering the side vents is heated by passing over the flue. The McDowell drier is similar except that a transparent tent-like roof structure above the tray allows solar drying to be used when appropriate.

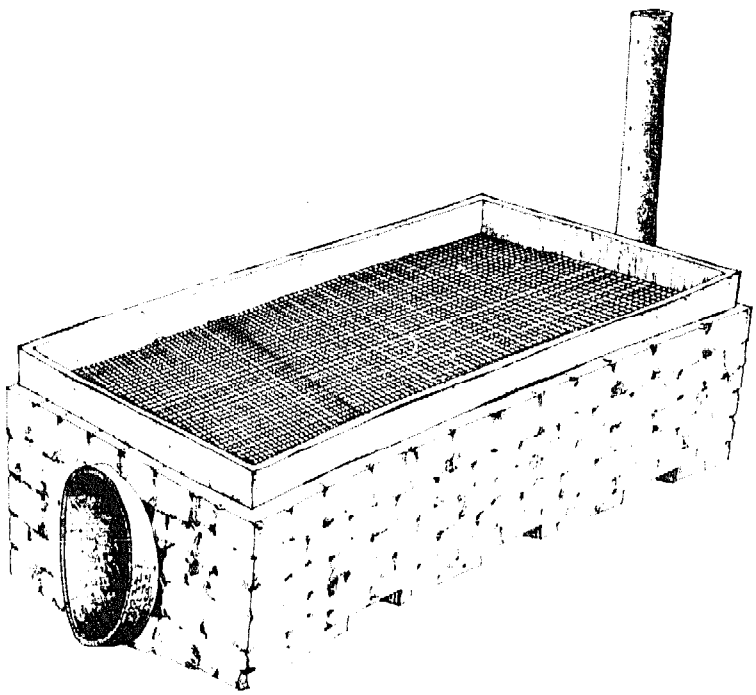

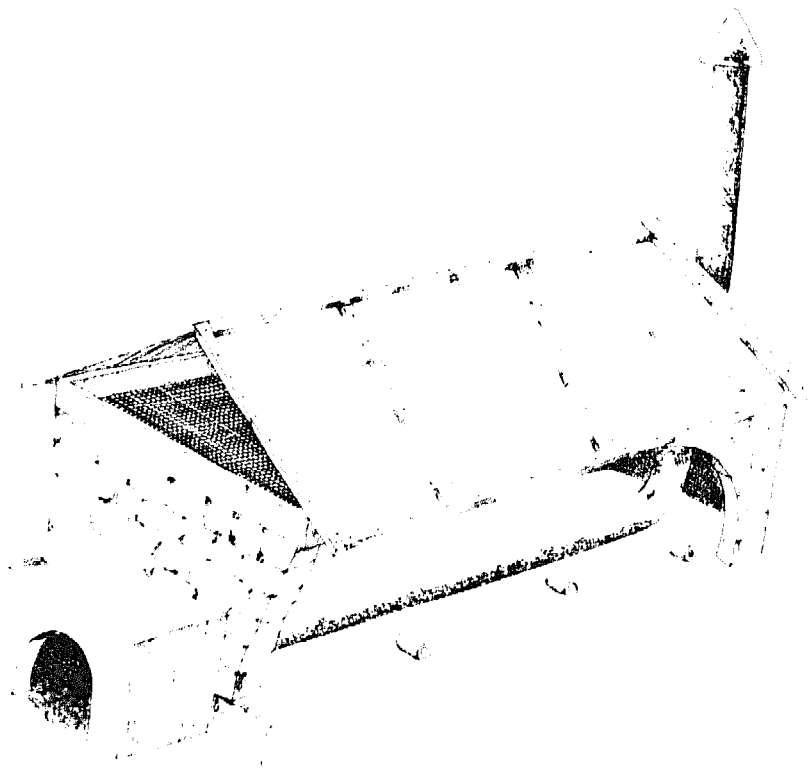

Milling and Grinding

Lumps often occur in gari if the heat is not distributed evenly during roasting. These large lumps will remain after traditional sieving process and are normally sold as animal feed. In order to reduce waste (losses of up to 10% can occur), roasted cassava can be milled in a conventional corn mill or hammer mill to reduce the lumps to a finer grade. An example of a hammer mill and a plate mill is shown below.

For further information on milling and grinding equipment, please refer to TOOLS FOR AGRICULTURE, ITDG.

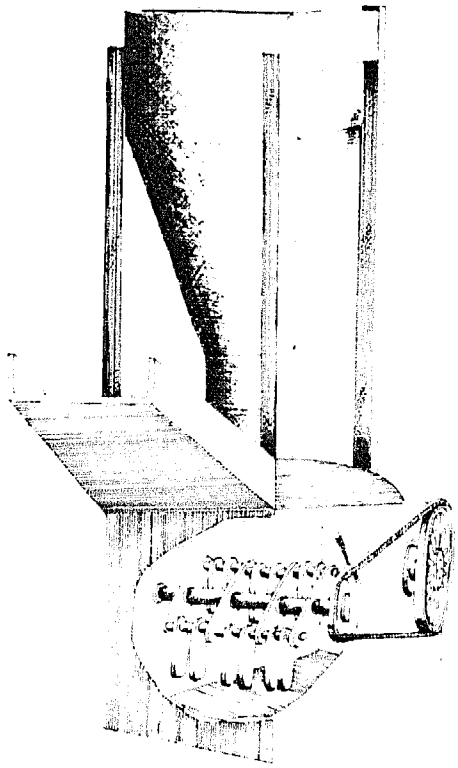

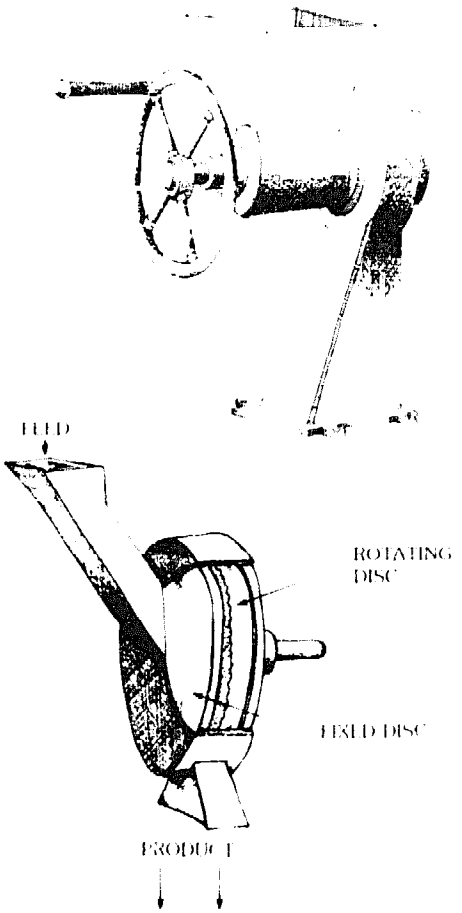

Plate Mill

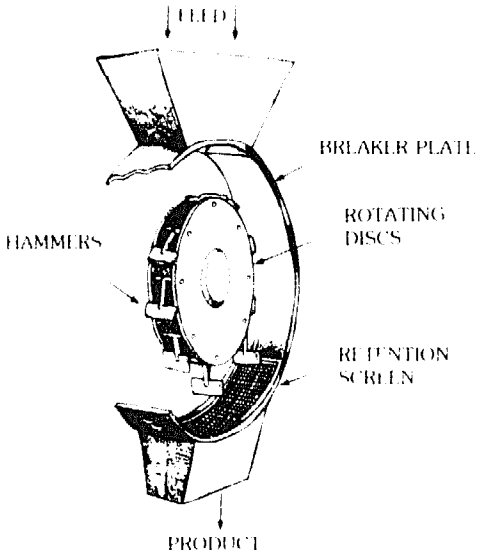

Hammer Mill

Chipping and Slicing

Slicing of root crops before drying reduces the drying time by exposing more surface area to the air. Slicing is also of course an important step prior to cooking root crops as it allows more rapid and even heat penetration.

DAC-FS Root Crop Slicer

The Department of Agricultural Chemistry and Food Science (DAC-FS) in the Philippines have designed a simple slicer which is said to cut sweet potatoes much faster than manual methods. The sweet potato is held on the cutting platform against a plate which controls the thickness of slice cut. Slices are then cut off with the hinged cutting blade. Capacity is 21 - 23 Kg/hour.

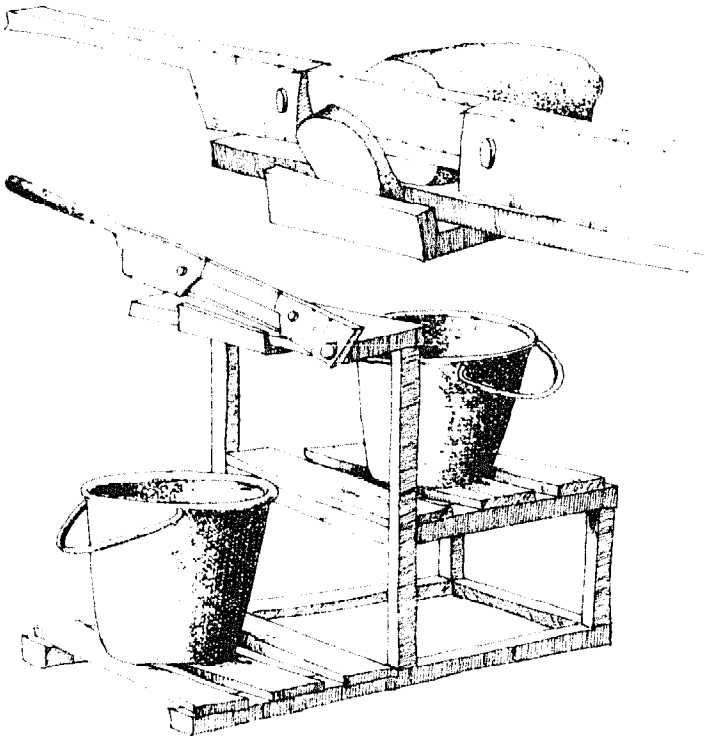

CIP Hand Operated Potato Cutter

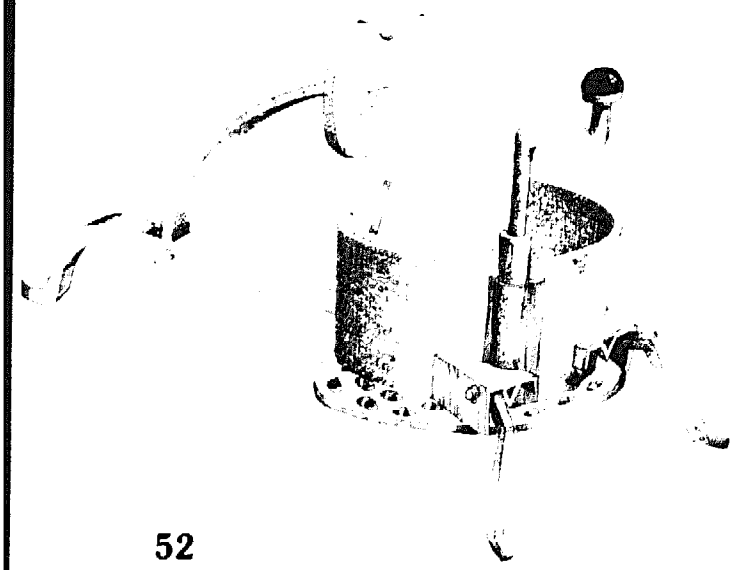

The International Potato Centre (CIP) have designed a cutter which consists of a horizontal rotating cutting disc. The potato is pressed down against the disc with one hand while the other hand turns a handle thus rotating the disc. This machine has been modified for motor drive with the disc running in a vertical plane. Cutting discs can be changed to alter cutting thicknesses if required. Crypto Peerless, (whose address is listed), supply a similar motorized machine with capacities up to 600 lb/hr which slices, dices, chips, grates and shreds.

Nardi Root Cutter

Nardi Francesco and Figli of Italy produce a manually operated root-chopper containing a rotating disc fitted with four blades.

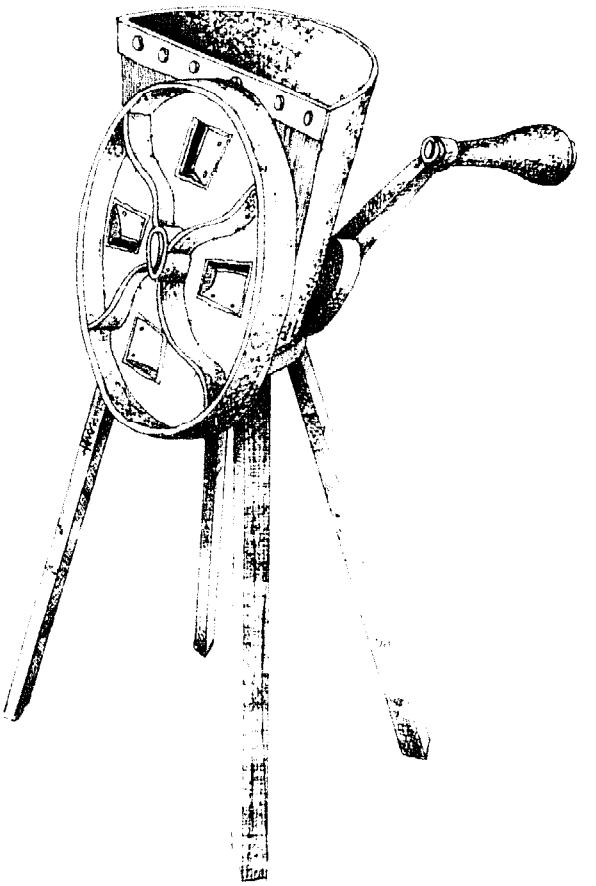

Pedal-Operated Cassava Slicer

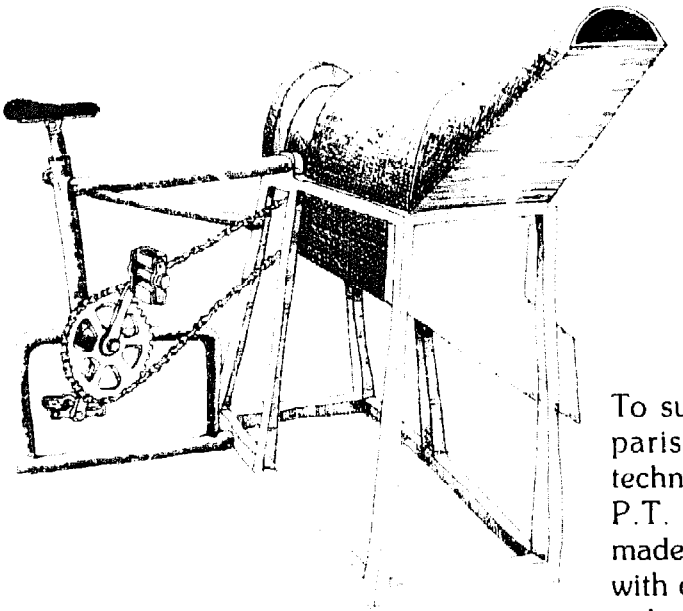

To summarize, Table 4 outlines a comparison of traditional and improved technologies for gari processing.

P.T. Kerta Laksana of Indonesia has made a pedal driven cassava slicer fitted with one large slicing blade. It is claimed to have a capacity of up to 500 kg/hour.

Table 4

A comparison of three technologies for the production of gari

Stage	Traditional Labour intensive	Post-traditional Intermediate	Modern Fully mechanised
1. Raw material production and supply	Small holder production Yield: c. 10 (t/hectare/yr) From traders	Smallholder production Yield: c. 10 (t/hectare/yr) From traders	Factory plantation and/or smallholder cooperative Yeld: c. 10-25 t/hectar/yr From purchasing agents on factory plantations.
2. Peeling and washing	Manual: 38 kg/man hour 25% raw material loss	Manual: 38 kg/man hour 25% raw material	Mechanical abrasive peeler, 30% raw material loss.
3. Size reduction	Manual: 23 kg/man hour Mechanical: 200 kg/hr	Manual: 23 kg/man hour Mechanical: 200 kg/hr	Mechanical: hammer mill (imported), 1500 kg/hour
4. Fermentation	Fermentation and dewatering in heavily weighted cloth or nylon bags	Batch fermentation in (aluminium) tanks	Batch fermentation in (aluminium) tanks
5. De-watering	See 4 above	Semi-mechanised: locally made hydraulic or mechanical press	Mechanised: hydraulic press
6. Screening	Manual: woven fibre screen	Semi-mechanised: locally made screen with hand or mechanically driven paddle	Mechanised: motorised rotary screen
7. Garification	Manual; cast iron pan over wood fire (combined stage with drying): 2.2 kh/man hr	Semi-mechanised: locally made wood-burning fryer (combined stage with drying): 70 kg/man hr	Mechanised: rotary kiln heated by oil burners 450 kg/hr.

Stage	Traditional Labour intensive	Post-traditional Intermediate	Modern Fully mechanised
8. Drying	See 7 above	See above	Mechanised: rotary drum drier
9. Milling and sieving	Not necessary Sieving: locally made	Milling: not required Sieving: vibrating hand or mechanical sieve.	Milling: disc mill Sieving: vibrating multi-deck sieve
10. Packaging	50 Kg jute sacks	50 kg heat sealed poly ethylene bags	50 kg heat sealed poly-ethylene bags
11. Material handling (all stages)	Manual	Manual, with trolleys	Belt conveyors, bucket elevators with trolleys.
12. Marketing and distribution	Through traditional gari trade system in local markets	Through traditional trade system and super markets	Through traditional trade system and supermarkets
13. Purchasers	All income groups, rural and urban	Mainly urban higher income groups and institutions (eg schools, army)	Mainly urban higher income groups and institutions (eg schools, army)
14. Buildings	600 m^2	200 m^2	650 m^2
15. Employees per shift			
total	234	45	28
unskilled	229 Predominantly female	40	9 Predominantly male

Source: Ngoddy, P. O. (1980): In Bruinsma et al (1983). *Selection of technologies for food processing in developing countries*.

Case Studies

Traditionally, the processing of root crops uses simple tools and methods, is highly labour intensive and has low labour productivity. It is not surprising that time is, therefore, a major constraint for women practising traditional technologies.

These case studies illustrate a number of the problems that can arise when trying to upgrade these traditional activities.

The case study from Sierra Leone illustrates that one must consider the entire system, from cultivation to processing, before attempting to introduce improvements at any one stage in the process.

A common problem arising in technology dissemination is that men often have more access to cash activities in rural communities than women. Unless a credit scheme is provided with the technology, its high purchase cost will provide an effective constraint on women benefitting. The case study from Ghana introducing gari-processing technology provides an example of this.

Mechanization can displace women from traditional income-earning activities. In Sierra Leone, the gari grater provided such an attractive new income source that the women's group lost control over the operation of the machine to the traditional village leader. This case study illustrates how vital it is to investigate the socio-political structures operating in a community when planning a project.

When considering ways to improve processing activities not only must the complex socio-economic environment be examined but also the infrastructure that may be needed to support the availability and diffision of improved technologies for women.

The case studies in this Section seek to provide an overview of the experiences gained in introducing improved root crop processing technologies.

Due to the lack of documentation on impact of projects introducing the full range of root crops and technoiogies, the case studies primarily cover cassava processing where the often high returns to gari production have encouraged technology innovation.

One case study from Papua New Guinea has been included which describes a sago palm processing project. Although sago palm is not a root crop, it is included because its lessons can be applied to many root crop processing activities. It shows clearly that introducing a new technology is not always necessary: transferring a traditional process from one area to another can work well given the availability of raw materials and markets.

1 Diesel-powered cassava grater - Sierra Leone

Summarized from:

Profile of Women in Farming Systems, Bo-Pujehun Rural Development Project Occasional Paper No. 4 February 1986, *"Gari Industry in Bo-Township"*, Bo-Pujehun Agricultural Programme, Report Series No. 23, Dec. 1984 and Private Communication (Linda Adams).

The Women's Programme of the Bo-Pujehun Rural Development Project operating in the Southern province of Sierra Leone introduced diesel-powered cassava graters on a pilot basis to selected villages beginning in 1984. The vertical drum graters were built locally at the Tikonko Agricultural Extension Centre (T.A.E.C.) in Bo using timber and scrap metal. The 4 h.p. diesel engines were imported from Germany and represented the most expensive part of the machine.

Gari processing is a highly profitable activity. In times of rice shortage (the staple food) and for urban populations which are dependant on village farms for their supplies of rice, gari is a popular food. Gari has a high value compared to fresh cassava because it has a considerably longer storage life and transport costs are a small proportion of the value of the final product.

In a pre-feasibility study conducted in Bo town in 1984 by the project, it was seen that 23% of the gari producers in the area were men. Normally, gari processing is considered a women's activity in rural villages and such a high percentage of men was seen to be due to the product's high profitability and the availability of improved technology in town centres.

Cassava processing in towns is usually done by hired motor-driven graters. Investment in a motor grater for the sole purpose of hiring it out is common. Given the domination of gari processing by women, it is ironic that only a small minority of women producers are owners of motorised graters.

This pattern of imbalance has been addressed by the Women's Programme by designing projects to improve women's access to improved technology, especially in the rural areas. A pilot project was initiated whereby motorised graters were introduced on a co-operative-ownership basis in rural areas. A revolving fund was set up by the Women's Programme at a national bank whereby women's groups could get loans with flexible repayments. The purchase price of the grater was also subsidised by the project.

The revolving fund system allowed village women greater access to formal banks in that the collateral of project funds made women to be seen as less risky borrowers to bank officials. In addition it gave the women an opportunity to learn about formal lending systems normally outside their experience. The flexibility of the payment schedule was adjusted to the seasonality of cassava production and the processors' other competitive labour obligations on the farm. This unique scheduling took into account the women's needs and was designed on a group by group basis.

The profitability of cassava products has led some farmers to shift production decisions in favour of cassava planting. In some villages located near to main roads allowing easy access to the capital city, almost the entire farm area was cropped with cassava and villagers used the proceeds from the sale of gari to buy rice and other staple foods. These changes have led to concerns over land being taken away from rice production in some areas and a general reduction of women's access to land for growing traditional food crops.

This interest in cassava has also led farmers to seek improved varieties. The women processors complained that the introduction of larger rooted improved cassava varieties with high water content resulted in an increased demand for fuelwood and subsequent processing time. Here is an example where the labour demands at different stages in the production cycle from cultivation to processed product were not taken into account by project planners and research stations. Although this particular

variety was higher yielding and therefore more productive at the cultivation stage, labour demands were increased at the processing stage as a result of its introduction.

Another environmental factor which affected the pilot groups was that competing development agencies operating on different terms were working in the same areas. This caused great confusion for villagers seeking access to the grater technology as the graters were offered at different subsidized rates and in one instance were given out free thereby discouraging self-sufficiency. One solution to this problem was that project managers met together and agreed on areas of operation.

Co-operation of group members was seen as critical to the success of the project. Before a loan could be applied for, adequate cropping areas of cassava had to be provided. In some cases this meant women farmers agreeing to put together their individual land holdings. In other cases it meant that the women in a village would organise a group together, request a piece of land from the chief, and agree to a communal work day each week on this land outside their individual household obligations.

Once the grater was set-up and in operation, decisions had to be taken as a group for new members who wanted to join or old members who wanted to leave and needed compensation. Other issues which arose included: on what terms members and non-members could have access to the machine; what penalties would be enforced for those not coming to group meetings, communal work days, or contributing membership dues/in-kind payments towards the loan. Such co-operation requires relatively high management capabilities within the group. It was observed that the profitability of gari resulted in women processors leaving cassava cultivation in some villages, as it was recognised as a new cash crop for their men. In such cases, these women returned to more intense cultivation of vegetables for their income source.

In other instances cassava cultivation was turned into a 'joint activity' with men controlling the proceeds. Women without husbands would cultivate cassava alone, that is if they had the cash resources to hire labour. In this area married women were usually not allowed to keep separate cassava farms, it had to be a joint activity. Men feared such independence would put women in a position to pay back their dowry and leave them.

The Women's Programme reviewed pilot villages in 1986 where graters had been installed. At least two of the original half dozen were removed as the original owners had lost control of the machine. In one village the chief had designated his son to be the sole operator who would hire out the machine to neighbouring villages.

2 Cooperative management of gari processing project Ghana

Summarized from:

"Technologies for Rural Women - Ghana", Technical Manual No. 4, ILO/National Council on Women and Development, Accra. January 1987.

Two pilot projects in Antoa and Damongo regions were initiated in northern Ghana under the guidance of the National Council on Women and Development (NCWD). Improved gari processing equipment consisting of a cassava grater, cassava press, gari roaster, and

a milling machine were installed. There were several reasons for locating the project at these sites. The proximity to Kumasi offered easy marketability. The area was already an important cassava producing region and thus offered employment for women engaged in the industry.

Both the NCWD regional representative and the village chief encouraged the women to organize themselves. The chief provided support by allocating land for a project site.

The original group consisted of 14 women and 1 man. All the women processed cassava into gari as a secondary occupation. Their primary activities included farming, selling cooked foods, clothes making and hiring out their labour to other farms.

Group members did not pay dues. They obtained the initial working capital from the Town Development Committee in order to purchase inputs such as sacks, metal basins, roasting pans and cassava. This loan has since been repaid.

Raw materials came from a variety of sources: purchased from other farms, harvested from group members' farms and the group-owned 10 acre farm.

The collection of firewood, harvesting, peeling, grating, roasting and bagging are done collectively as a group work effort. The gari is marketed in local villages and schools.

Group members have not shared the profits from sales amongst themselves but have chosen to use the funds to buy additional equipment. They feel they have benefitted from cooperative management in that they have received some of the product to supplement their families' diets. The group has expressed an interest in increasing their membership. Since many of the tasks require physical strength, they would like more men to join the group.

Several villagers had applied to join the group but the NCWD regional secretary insisted on limiting the number. Some disgruntled villagers complained that the cooperative had limited membership in order to be exclusive.

Clearly the members feel they have benefitted from pooling their labour resources. The husbands of the female members were happy about the project's existence in that they felt it reduced financial responsibilities at home.

3 Improved gari processing technologies - Nigeria

Summarized from:

C. E., Williams. "*The Effect of Technological Innovation among Rural Women in Nigeria: A Case Study of Gari Processing in Selected Villages of Bendel State, Nigeria*", Journal of Rural Development 5 (December 1982).

This case study relates to the introduction of improved gari processing technologies at an intermediate and industrial scale. In selected rural villages in Bendel State, where the processing and sale of gari is a predominant income source for women, the introduction of such technologies has had a profound effect on their income.

Traditionally, the ploughing, planting and weeding of cassava farms is done by men. There are few women who cultivate their own farms. More often, women buy the unharvested tubers from men and harvest the tubers themselves. The peeling and grating of cassava is done by hand. Gari pro-

cessing provides the main source of income for women in this area.

Diesel engine powered mechanical graters and hydraulic dewatering presses have replaced hand grating methods and reduced the time needed for pressing. The high purchase cost of these technologies has resulted in only men owning and operating these machines. All the men belonged to a union which fixed prices for operations and organised work schedules for members. These work schedules were determined by the number of machines available in any village and the length of market days. Such a system was intended to avoid conflicts and disagreements over indiviual economic gains.

The mechanical grater and press introduced at village level increased gari productivity. The time needed for grating, considered one of the most laborious steps in the process, was greatly reduced. The de-watering step, which normally took 5 - 8 days, was reduced to 1/2 an hour.

The introduction of the gari processing machinery also resulted in several adverse effects for the women in these areas. With the introduction of mechanical graters and presses, work traditionally done by women became the work of men. This transfer of control resulted in a transfer of income. Women lost an important income source. A set of four gari processing produced by a private Nigerian company were installed in one village in Bendel State. The system consisted of a cassava grater, dough sifter, mechanical press and garifier. Another component of the system, the peeler, was not bought.

The factory employed 48 workers to operate the machinery. Eleven of these were women whose tasks were to hand peel the cassava tubers and keep the factory clean. Gari produced from this factory was of very high quality and was only sold in the urban markets in places like Lagos and Ondo.

The sophisicated technology used by the factory was capable of producing very high quality gari. The garifier had a dual purpose of toasting as well as drying; heat supply could be regulated. The cylindrical machine fitted with prodders for stirring enabled the operator to avoid burns and eliminate contact with steam during stirring. It is interesting to note that the operations in the factory which were mechanised employed only male labour.

Female labour was minimal and was employed for a step in the process which was not mechanized.

Women were employed for this work because available peeling machines in Nigeria were seen to be ineffective and women's labour was less costly to employ.

From these experiences in Bendel State, the introduction of improved gari processing technologies were more beneficial to the men in the area than the women. At an intermediate level, the high capital cost of the machinery made it unavailable to the women while at the same time pushing them out of this economic activity altogether.

4 Transfer of Traditional Technologies - Papua, New Guinea

Summarized from:

Rashimah New. "*The Development of*

Sago Products in Papua New Guinea", Appropriate Technology Development Institute, Lae, Papua New Guinea, 1986.

Although sago is not a root crop, it plays a similar role to root crops in the diets of people in Papua New Guinea. Processed sago serves as an important starch-based carbohydrate.

The Appropriate Technology Development Institute undertook a sago product development programme in order to re-establish sago as a valuable resource, develop sago-based products and to assist small scale enterprises, at village level.

Traditional sago preparation methods were investigated in Papua New Guinea and in neighbouring countries. After research and testing, 'Sago Pops' were introduced to women's groups in the Sepik River Basin. 'Sago Pops' are a snack product made from sago slices which are first steamed, dried and finally fried in hot oil to produce a ready to eat food. This region was identified because sago was plentiful.

The women were initially reluctant to accept a sago product which was processed in a way they were unaccustomed to. After seeing that sago could be made into attractive products that could compete with imported foods, they became interested to learn these new processing techniques.

A year later it was found that 'Sago Pops' had become well known in the region and that several village-level enterprises had developed. This case study is cited in order to highlight the possibilities of transferring traditional processing technologies from one country to another. However, before pursuing such an approach, it is vital that local consumption habits and taste preferences be thoroughly investigated.

A Checklist of Questions to Ask when Planning a Root Crop Processing Project/Enterprise

The following questions should be asked by project planners and by decision makers before proceeding with the implementation of a root crop processing project.

Traditional Root Crop Processing

1. What is the extent of traditional and small-scale processing in the area?
2. What does the traditional process for a given product consist of?
3. Does the processing method vary in different areas?
4. If several processed products are made in your area, how do the methods differ? (in labour requirements, as seasonal activities, shelf-life of end-products, equipment used)
5. What is the place of women in traditional processing?
   a) are the processors farmers or landless?
   b) are there cultural taboos which prevent women from processing specific root crops and/or varieties?
   c) from cultivation to actual processing of the crop, what is the social organisation within the production cycle?
   (are specific steps done individually or collectively?, what steps do women or men dominate?)
6. Who owns the root crop?
   a) do the roles women and men play in the production cycle vary with ownership patterns?
   b) do landless women purchase root crops for processing and sale?
   c) is there more raw material available than can be processed in the traditional manner? If so, what is the constraint?
   (water/fuelwood/labour availability, capacity of equipment, credit availability, markets)
   d) are there seasonal shortages of the raw material?
7. Do the women cultivate and/or process the root crop principally for home con-

sumption or is it an important income source?

8. If the sale of processed root crop products are an income source, what proportion of the income do women earn and keep?
   a) what arrangements exist between women and men for sharing the proceeds of the production?
9. What is the traditional marketing mechanism and who controls it? (e.g. do women have access to markets?)
10. What are the major problems and constraints perceived by women processors?

Effects of Improved Technology on Traditional processing

Technical considerations

1. What is the estimated amount of production of the root crop?
2. What is the capacity of the improved technology — will it match the quantity of raw materials available to the processors?
3. Does the proposed technology address the major problems/constraints, within the various processing stages, perceived by women? (e.g. grating, pressing, grinding, milling)
4. Will the use of the improved technology reduce labour input as compared with the traditional method? How?
5. Will the equipment produce a greater quantity and/or better quality of products?
   (will the product have a different colour, taste or texture, - if so, will it be acceptable?)
6. Can the market absorb an increased supply of products?
7. What are the energy (sun, biomass, diesel, electricity) requirements of the equipment?
8. Will the users be able to meet those requirements on a regular basis?
9. Can the equipment be produced and/or maintained using local resources?
   a) are there capable local artisans or do they need to be trained?
   b) are the raw materials necessary for construction and workshop facilities available?
10. If parts need to be imported, will the users be able to afford the costs?
11. Will the users of the equipment need to be trained?
    a) is there already some familiarity with this type of technology?
    b) is training locally available?

SECTION 5

Socio-economic

1. What is the cost of the machine and related equipment?
2. Is the cost manageable on an individual or community basis?
   a) if on a community basis, does the traditional social organisation/culture of the producers operate on a collective basis?
   b) is this co-operation normally restricted to within family, tribal identity or other distinctions?
3. How are investment decisions in the community made? eg Individual, family, community, men only, elders only?
4. How long will it take to pay back the investment? What will the monthly profits be? Is the payback period and future net profits considered to be worth the present initial investment by the users?
5. If credit is needed is it accessible, and at what interest rate?
6. Will the women be able to repay the loan? (does seasonal production, labour availability etc. allow it?)
7. Who would control the use of the machine?
   a) Would it be village controlled or would individual men or women manage it on a lease basis?
   b) if village controlled, who would have access to it and on what terms?
   c) Who would be responsible for maintenance?
8. Considering traditional ownership patterns of land, possible gender domination of a given crop, and marketing control in your area, do you expect that the introduction of improved equipment will bring about any change in the pattern of work and distribution of benefits? If so, how?
   a) would root crop processing remain a significant income source for women after introduction of the machine?
   b) what proportion of the income would women earn?
   c) would work traditionally done by women be taken over by men if mechanised? Would this work displacement also mean loss of income?
   d) would the mechanisation of one stage create additional work (e.g. a need for pre-processing) and who is expected to do this work?
9. If the new technology brings scaling-up of production will the users be able to cope with the associated requirements of large-scale production such as handling finances, market and price negotiations, organising and managing personnel, acquiring regular supplies of raw materials?

SECTION 5

10. If the product is intended for markets beyond the local vicinity such as urban centres and neighbouring countries,
    a) will the quality be acceptable for these new consumers?
    b) can the product's normal shelf-life and packaging permit the demands of extended transport?

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CONTACTS

The following can be contacted for further information on root crop processing, equipment and experiences in planning root crop processing projects. Some of these institutions have developed their own equipment which has been or is being used in the field.

Agriculture Engineering Department
University of Ife, Nigeria, West Africa

Agriculture Engineering Department
University of Science and Technology, Kumasi, Ghana, West Africa

AGRICO, Agricultural Engineers Ltd.
Ring Road Industrial Area, P.O. Box 12127, Accra-North, Ghana, West Africa

ATI
Appropriate Technology International,
1331 H Street N.W., Washington DC 20005, USA

CIAT
Centro Internacional de Agricultura Tropical,
Apartado Aereo 67-13, Cali, Valle del Caura, Colombia

CIP
The International Potato Center,
Apartado 5969, Lima, Peru, South America or
c/o Tropical Africa Region, P.O. Box 25171, Nairobi, Kenya

Crypto Peerless Limited
Bordesley Green Road, Birmingham, B9 4UA, U.K.

CTCRI
Central Tuber Crops Research Institute.
Sreekariyan, Trivandandrum, 695015 Kerala, India

Department of Agricultural Chemistry and Food Science
University of Philippines, Diliman, Q. C. 3004, Philippines

Department of Agricultural Engineering
Njala University College, Sierra Leone, West Africa

Department of Tropical Crop Science
P.O. Box 341, Wageningen 6700 AH, The Netherlands

CONTACTS

FAO
United Nations Food and Agricultural Organization,
Via delle Terme di Caracalla, 00100 Rome, Italy

FABRICO
The Fabrication and Production Company,
Asaba, S.W. Nigeria.

FIIR
The Federal Institute of Industrial Research,
Oshodi, Lagos, S.W. Nigeria

GATE/GTZ
German Appropriate Technology Exchange,
Postfach 5180, D-6236 Eschborn 1, West Germany

IDRC
International Development Research Centre,
60 Queen Street, Ottawa, Canada

IITA
International Institute of Tropical Agriculture,
PMB 5320, Ibadan, Nigeria

ITDG
Intermediate Technology Development Group
Myson House, Railway Terrace, Rugby CV21 3HT, U.K

Nardi Francesco & Figli
06017 Seici Lama, Perugia, Italy

ODNRI
Overseas Development National Resources Institute,
56-62 Gray's Inn Road, London, WC1X 8LU, U.K.

Philippine Root Crop Research and Training Centre
Visayas State College of Agriculture, Bay Bay, Leyte 7127 Philippines

PRODA
The Production Development Agency,
3 Independence Layout, P.O. Box 609, Enugu, Anambra State, Nigeria

P. T. Kerta Laksana
Jl Jenderal Sudirman 504, Bandung, Indonesia

Root Crop Research Institute
Umudike, Umuahia, Imo State, Nigeria

CONTACTS

(KIT) Royal Tropical Institute
Mauritskade 63, 1092 AD Amsterdam, Netherlands

Rural Agro-Industrial Development Scheme
11 University Crescent, P M B 5517, Ibadan, Oyo State, Nigeria, West Africa

TAEC
Tikonko Agricultural Extension Centre,
c/o Methodist Church Headquarters Office, Wesley House, P.O. Box 64, Freetown, Sierra Leone, West Africa

TCC
Technology Consultancy Centre
University of Science and Technology Kumasi, Ghana, West Africa

A range of hand and machine operated mills suitable for different scales of operation are available from:

Ndume Products Ltd.
P.O. Box 6, Gilgil, Kenya, East Africa

Rope bridge

From Wikipedia, the free encyclopedia

A **rope bridge** is a bridge constructed chiefly of rope. In its simplest form, it can be one or two ropes that bridge a river, enabling the traveller to be supported in their crossing and not be swept away. One rope above another, for feet and hands, may be referred to as a commando bridge.

More complicated rope bridges can involve the use of multiple ropes, and boards as footpaths. One of the most complex examples of a culture using these as permanent, rather than temporary crossings, is the Inca civilization.

An 1853 watercolor by Manuel María Paz shows two men crossing a rope bridge over the Igara Paraná River "made of wood and lianas".[1]

Rope bridge

A rope bridge in South America

Ancestor	None - this is a foundational type
Related	Inca rope bridge
Descendant	Simple suspension bridge
Carries	Pedestrians, livestock
Span range	short
Material	Grass or other rope, appropriate decking material
Movable	No
Design effort	low
Falsework required	No

Wikimedia Commons has media related to ***Rope bridges***.

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See also

- Inca rope bridge
- Simple suspension bridge

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Categories: Ropework | Simple suspension bridges | Bridges | Bridge (structure) stubs

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Rope-making list

Funem Habes? **Got Rope?**

Rope-making Step-by-step

Beginning to string up the yarn. Hold the end of the yarn with your thumb and bring it through the slot as shown. Take the yarn down to the jack and wrap it around the hook opposite the slot in the paddle.

The yarn will come back through the same slot and up and out the top center slot Again loop the yarn around the top center hook of the jack.

Bring the yarn back through the top center slot of the paddle down and out the final slot, out to the final hook and around the hook.

The rope jack should be strung up to look like this.

Bring the yarn from the third hook back through the third slot in the paddle and tie off. (If a thicker rope is wanted, simply go across the back through the 1st slot again and repeat the process with all three hooks and slots and then tie off).

To attach the swivel hook first put the two yarns from the top slot of the paddle into the hook, then bring the strands that are tied off onto the hook (the far right to far left slots)

Here we have a young 8 year old pulling back on the the swiveling hook as her 7 year old brother turns the handle on the jack. The strands are beginning to be formed.

When there is sufficient overtwist in the strands (when the strands are properly formed) you can begin to move the paddle forward. The swivel hook will start to turn, laying the rope up as you go. Make sure the person at the jack end continues revolving the hooks.

Remove the strands and place them on the top center hook in order (i.e. continue the direction of the twist with each strand) Once all three strands are on the top hook have the person at the jack turn the crank the opposite way while you hold the rope. Remove the free swiveling hook at the back end to make sure the rope tightens down on itself. This will set the rope.

The rope at the swivel hook end will not come unraveled, however it will unravel at the jack end. If you are doing a demonstration and making a couple hundred ropes a day you don't have time to do a crown and backsplice or whip the end of the rope. Insert a puller through all 3 strands as shown.

Insert a 6 to 8 inch piece of twine through the puller and draw it through the strands (A rug latch hook or crochet hook may also be used)

Tie the piece of twine using a square or surgeons knot and let the child who made the rope take it away.

If you have questions please feel free to let John know, or if you would like to see additional information here send a few bytes our way.

Email John Roper

Direct questions about rope making to John Nelson
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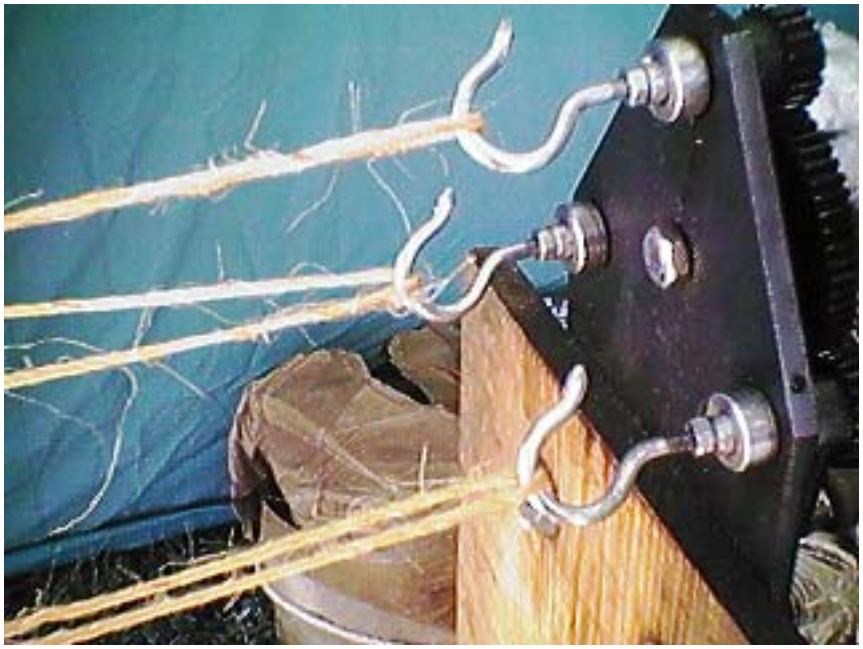

Rope pump

From Wikipedia, the free encyclopedia

A **rope pump** is a kind of pump where a loose hanging rope is lowered down into a well and drawn up through a long pipe with the bottom immersed in water. On the rope, round disks or knots matching the diameter of the pipe are attached which pull the water to the surface. It is commonly used in developing countries for both community supply and self-supply and can be installed on boreholes or hand-dug wells.

Rigid valve rope pump

Contents

- 1 Description
- 2 History
- 3 Construction
  - 3.1 Flexible valve rope pumps
  - 3.2 Rigid valve rope pump
  - 3.3 Valveless rope pumps
- 4 Intellectual Property
- 5 See also
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Description

A rope pump is a type of pump of which the main or most visible component is a continuous piece of rope, in which the rope is integral in raising water from a well. Rope pumps are often used in developing areas, the most common design of which uses PVC pipe and a rope with flexible or rigid valves. Rope pumps are cheap to build and easy to maintain. One design of rope pump using a solar-powered rope pump can pump 3,000 litres to 15 meters per day using an 80 watt solar panel .[1] Rope pumps can be powered by low speed gasoline/diesel engines, electricity,[2] human energy,[3] wind[4] and solar energy.[1]

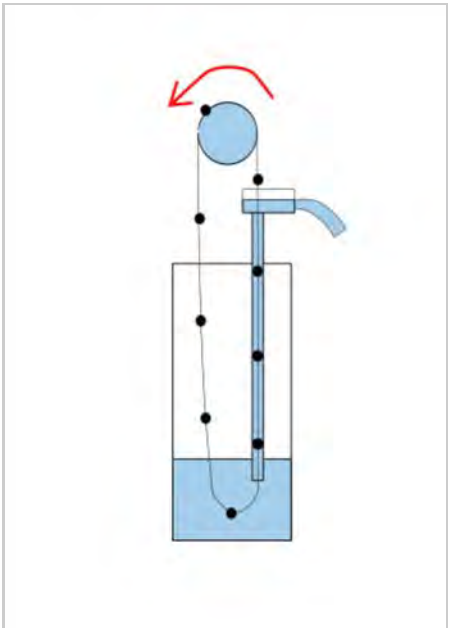

Rope pump schematic

History

Chain or washer pumps were used by the Chinese over 1000 years ago.[5] In the 1980s Reinder van Tijen an inventor and grass roots activist, with the support of the *Royal Tropical Institute* of Amsterdam, created and began instructing various communities around the world how to make a rope pump from simple available parts using PVC pipes and plastic moldings. He began at Burkina Faso in Africa, continued to

Tunisia, Thailand and Gambia among others.[6] In Nicaragua, the technology was rapidly disseminated over the whole country and 25% of the rural population in Nicaragua now use rope pumps. It is also used in other parts of Central America with over 25,000 pumps installed to date.[5] In Africa the rope pump is now being used with solar energy.[1] By the end of 2009 more than 4 million people in 20 countries worldwide were using rope pumps for domestic and irrigation water.

Construction

The original rope pumps used knots along the rope length but can be made with flexible or rigid valves on the rope instead of knots. Alternatively they may use only rope, simply relying on the water clinging to the rope as it is quickly pulled to the surface.

Flexible valve rope pumps

Flexible valves can be made from cut pieces of bicycle wheel tubing. The valves are positioned approximately 20 cm apart on the rope. One disadvantage of flexible valve rope pumps is that they must be appropriately sized and thickness for different types, sizes and length of pipes.[7]

Rigid valve rope pump

Rigid valves using plastic or metal washers that fit tightly into the PVC pipe as the rope is dragged through are also used. If the fit is tight, the washers can be spaced up to half a meter apart. The deeper the well, the smaller the pipe inner diameter must be, given the available power constraints. These rope pumps are often worked with a hand crank[8]

Valves can also be made from knots in the rope itself.[9]

Valveless rope pumps

Valveless pumps rely on friction with water clinging to the rope, which is moved at high speed, often using a bicycle to produce the required speed. It is a less efficient design but is simpler to construct than the other rope pumps.[3]

Intellectual Property

Rope pump technology is in the public domain and there are no patents pending on it.[5]

See also

- Chain pump
- Wind pump

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External links

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Rope splicing

From Wikipedia, the free encyclopedia

Rope splicing in ropework is the forming of a semi-permanent joint between two ropes or two parts of the same rope by partly untwisting and then interweaving their strands. Splices can be used to form a stopper at the end of a line, to form a loop or an eye in a rope, or for joining two ropes together.[1] Splices are preferred to knotted rope, since while a knot typically reduces the strength by 20–40%,[2] a splice is capable of attaining a rope's full strength.[3] However, splicing usually results in a thickening of the line and, if subsequently removed, leaves a distortion of the rope. Most types of splices are used on 3-strand rope, but some can be done on 12-strand or greater single-braided rope, as well as most double braids.

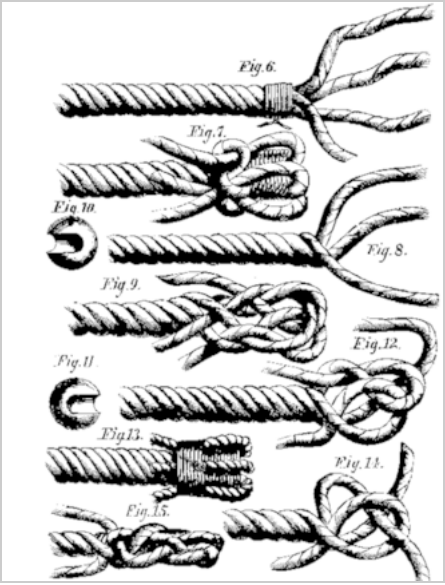

Stages in splicing the end of a rope, from *Scientific American*, 1871

Contents

- 1 Types of splices
- 2 Splicing tools
- 3 See also
- 4 References
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Types of splices

- **back splice** (also called an **end splice**) – A splice where the strands of the end of the rope are spliced directly back into the end without forming a loop. It is used to finish off the end of the rope to keep it from fraying. The end of the rope with the splice is about twice the thickness of the rest of the rope. With nylon and other plastic materials, the back splice is often no longer used; the rope strands are simply fused together with heat to prevent fraying.[4]

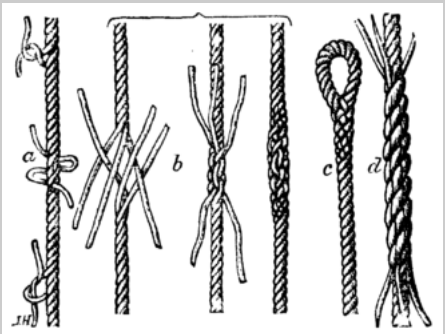

Examples of splices in different stages of completion, from the *Nordisk familjebok*: a) long splice b) tapered short splice c) eye splice d) short splice

- **cut splice** (originally called **cunt splice**) – A splice similar to the eye splice. It is typically used for light lines (e.g., the log-line) where a single splice would tend to come undone, the rope being frequently wet.[5] It makes a very strong knot. A cut splice is a join between two ropes, made by side splicing the ends slightly apart, to make an eye in the joined rope which lies shut when the rope is taut. Its original name was bowdlerised to "cut splice".
- **eye splice** – A splice where the working end is spliced into the working part forming a loop.

- **ring splice** – Attached the working end of a rope to a ring or clew.[6]
- **chain splice** – Attached the working end of a rope to a chain.[7]
- **figure-eight "splice" knot**- A splice-like bend knot used for joining two ropes.
- **horseshoe splice** – A cut splice where the two sides of the loop are of unequal length.
- **long splice** – A **splice** used to join two rope ends forming one rope the length of the total of the two ropes. The long splice, unlike most splice types, results in a splice that is only very slightly thicker than the rope without the splice, but sacrifices some of the strength of the short splice. It does this by replacing two of the strands of each rope end with those from the other, and cutting off some of the extra strands that result. The long splice allows the spliced rope to still fit through the same pulleys, which is necessary in some applications.[8]
- **short splice** – Also a splice used to join the ends of two ropes, but the short splice is more similar to the technique used in other splices and results in the spliced part being about twice as thick as the non spliced part, and has greater strength than the long splice. The short splice retains more of the rope strength than any knots that join rope ends.[9]
- **Soft shackle** – Dyneema soft shackles are strong, light and safe and are increasingly replacing stainless steel shackles.

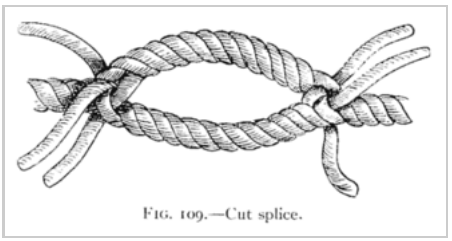

An unfinished cut splice

A line eye-spliced to a snap shackle.

A short splice, with ends whipped

[10]

Splices are often **tapered** to make the thicker splice blend into the rest of the line. There are two main types of tapering, the standard and the "West Coast Taper".

- **Standard tapers** progressively remove a portion of each remaining strand—one-third at a time is typical, resulting in a taper of two additional tucks beyond the splice—thus making each successive tuck produce a narrower splice. This is only practical with laid-lines, i.e., those made up of numerous strands laid side by side.
- **West Coast taper** (also known as a Fisherman's Taper) is effected by extra-tucks of entire strands, such that the second strand is interweaved one more time than the first and the third is interweaved an additional time after the second.

Splicing tools

A fid is a hand tool made from wood, plastic, or bone and is used in the process of working with rope. A variety of fid diameters are available depending on the size of rope being used. Styles of fid designs include:[11]

- **Swedish fid** is conical instrument with a somewhat long taper.
- **Tubular fid** aid in splicing double-braided rope.

- **Uni-fid** needed to splice braid with a parallel core.

A Marlinspike is a tool, usually made of steel and often part of a sailor's pocketknife, which is used to separate strands of rope from one another. They can range in size anywhere from 3 inches to 5 feet long, with a round or flattened point.[12]

A pulling fid is often used for smaller diameters of braided ropes. Also a Softfid is a great tool when dealing with tightly braided ropes.

See also

- Eye splice
- Whipping knot
- Western Union splice
- Nicopress Swaged Sleeve
- T-splice
- Talurit swaged sleeve
- Rat-tail splice

Wikimedia Commons has media related to ***splices***.

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Book:	Toolcare
Chapter:	7 Miscellaneous repairs
Section:	Ropes
Meta Data:	Details

Ropes used for tree work should be kept separate from ropes used for general work, which may include pond work, hauling wheelbarrows, towing vehicles and so on. Ropes can be distinguished by marking them with fabric dye. Mix up a quantity of cold water dye, suitable for the type of rope, and dip a section of rope into it.

Natural-fibre ropes are still available made of sisal or manila (hemp), but are generally less strong and more liable to rot than man-made fibre ropes. Ropes of man-made fibre are, in order of strength, made of nylon, polyester (Terylene) or polypropylene (see table below).

According to the way they are made, ropes are either hawser-laid (cabled) or kernmantel. Hawser-laid ropes have fibres twisted together to make strands, and then three strands twisted together to make the rope. They can easily kink and require careful coiling. Kernmantel ropes, made of polyester, have a large number of filaments running straight down the rope, encased in a braided sheath. They have a high tensile strength and are non-kinking. Kernmantel ropes for tree work have low stretch. Kernmantel ropes designed for rock climbing have very high stretch and should never be used for tree work.

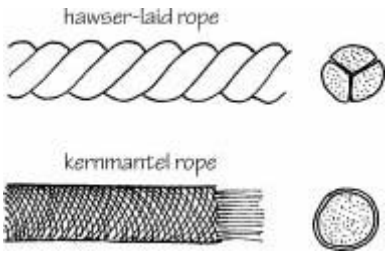

Hawser-laid polypropylene ropes are the type most commonly used for conservation work. Although these do not rot in water, they should still be stored dry and away from chemicals and batteries. Polypropylene ropes float, which is an advantage for pond work. Hawser-laid sisal or manila ropes will rot if kept damp.

If ropes are returned to the store very muddy, they should be washed, coiled loosely to dry and then coiled for storage. All ropes should be checked once a month for damage and wear by uncoiling them and making a careful visual check.

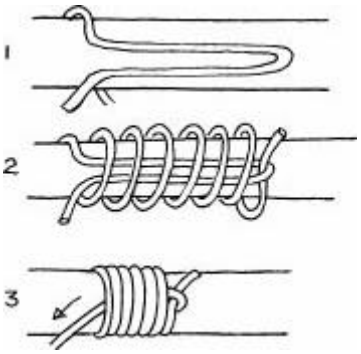

Very badly frayed or damaged ropes should be discarded. Ropes with one or more points of damage can be cut and the sound lengths kept for general purposes. Singe the ends of man-made fibre ropes to seal them. Use fine string (whipping twine) to whip the ends of natural-fibre ropes, as shown above.

The table below gives the breaking load and safe working load of various sizes and types of rope.

Rope (diam.)	Breaking load (kg)	Safe working load	
Sisal	8mm	480	80
Sisal	12mm	950	158

Sisal	16mm	1780	296
Sisal	24mm	4060	676
Manila	8mm	540	90
Manila	12mm	1070	178
Manila	16mm	2030	338
Manila	24mm	4570	761
Polypropylene	8mm	960	160
Polypropylene	12mm	2030	383
Polypropylene	16mm	3500	583
Polypropylene	24mm	7600	1266
Polyester	12mm	3000	500
Nylon	10mm	2080	346
Nylon	12mm	3000	500
Nylon	14mm	4100	683

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Rope water pumps

Lift Disk Pump

This type of pump uses flat disks (shown on edge in red here) attached to a chain or rope. The disks draw water up a tube.

This type of pump is probably thousands of years old. It is similar to a Rag Pump or Bucket Pump.

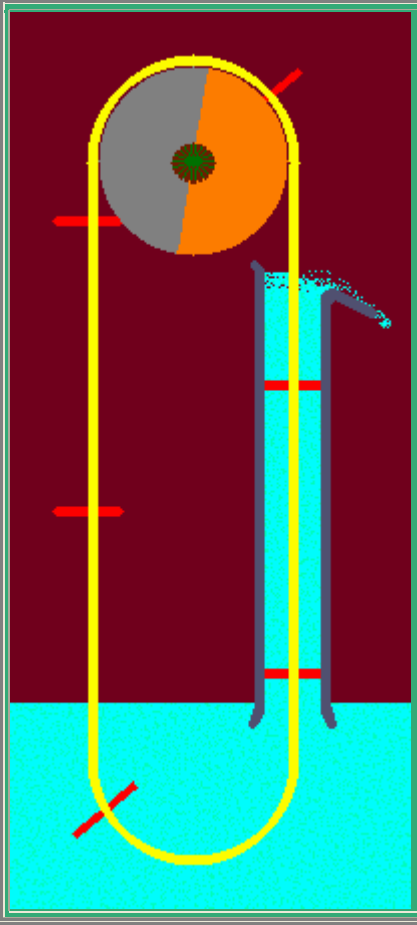

(This is a still representation and possibly also a low-resolution image of a pump which is fully animated in the CD-ROM version of this glossary.)

http://www.animatedsoftware.com/pumpglos/liftdisk.htm

Rag Pump

Rag Pumps have been used for at least 400 years and probably a lot longer.

Their use was widespread. Rag pumps were used aboard large sailing ships to bring salt water up for various uses and they were also used in wells. Horses, a water wheel, or "tramping men" all might have supplied the power to turn the wheel.

Cloth bundles, usually just rags, are tied in knots at intervals on a rope or chain. The chain is then hung around a wheel and through a tube that goes below water level. The base of the tube is flanged to prevent the rag balls from catching.

When the wheel rotates water is drawn up a tube.

This pump is very similar to a Lift Disk Pump and Bucket Pump.

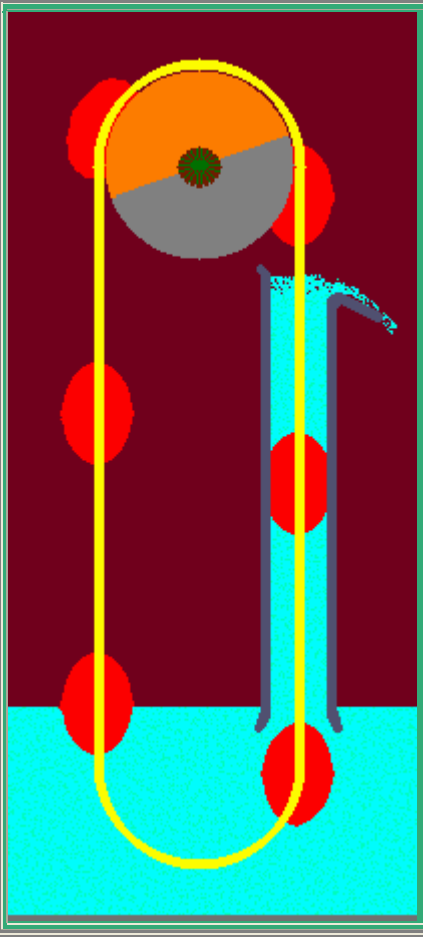

(This is a still representation and possibly also a low-resolution image of a pump which is fully animated in the CD-ROM version of this glossary.)

Bucket Pump

The Bucket Pump is similar to the Rag Pump and Lift Disk Pump but does not require a tube to draw the water up. It is not very common anymore, but can still be found occasionally.

One advantage of this pump is that the buckets don't turn upright until they are well below the surface of the water. They fill with clean water, and bring up less of the scum that often floats on the surface of a well.

Large old sailing ships sometimes used Bucket Pumps. They were also used on farms and many other places.

Of course, the length of the chain and the number of buckets can vary greatly.

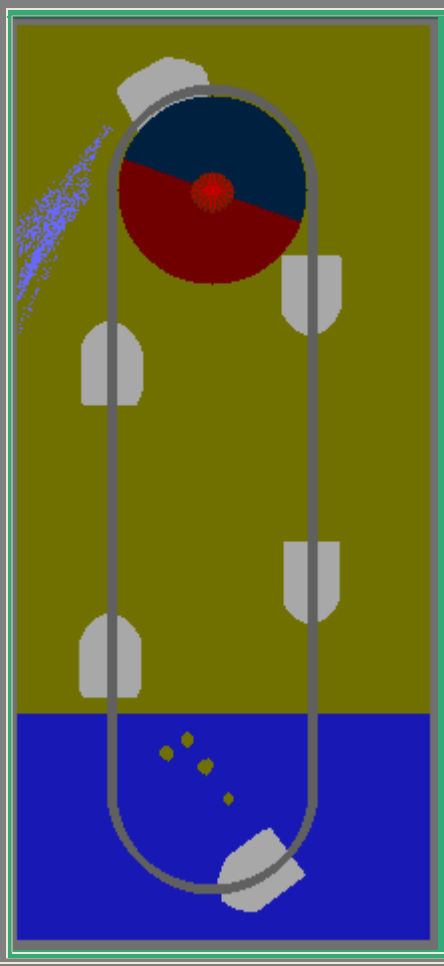

(This is a still representation and possibly also a low-resolution image of a fully animated pump.)

http://www.animatedsoftware.com/pumpglos/pumpglos.htm

Rope Water pump!
Made simpler every time you make one.

The WOT Rope pump with plastic discs in action.

Above a detail of the rope-pump, allowing a very low-cost installation for lifting water by hand or mechanical drive. Main advantage of the rope-pump is the continuous pumping action so minimal force is needed to lift water. When applying mechanical drive, the continuous force is also optimal, in contrast to most valve-pumps. (The constant force results in less wear and higher efficiency) I will add better pictures soon, to show how to assemble the pump parts easily.
Most critical part of the pump is the bottom turning-point of the rope. The wear can be minimised by use of a ceramic or glass cilinder (small bottle or jar) and the disks should enter the lifting tube easily by flanging (widening) the bottom end. Shown on the photos are two plastic/rubber fixtures of the PVC tubes, one already fixed into concrete. The thicker tube is used to guide the rope downward, the thinner one lifts water if the disks fit neatly inside. Note that one broken disk will not harm the pumping action, because a next disk will still lift the water. The number of disks is not critical, at least three are necessary but then the fit is very critical. More optimal is around 10 disks, also depending on the distance to lift the water. The disks should be at least half a meter apart.
At the top of the lifting tube, a widening and a T-joint are required to allow the water to be delivered smoothly. The rope can be driven by hand from a "wheel" which can be made from an old car type and four pieces of wood.
Cut the sides of the car tyre, resulting in circles approx 5 cm wide. Join the two sides by bolts & nuts or by driving nails through the two sides, approx 1 cm from the inner side.

The part of the nails sticking out can be bent to lock the two tyre sides together in a circular V-shape. The rope can be run through the bottom of the V, where it is caught, so the pulling force of a spinning wheel will result in the rope being pulled through the tube, it should not result in the rope slipping between the tyres. The V-wheel can be caught on the middle of four pieces of wood as shown on the last photo. No attachment is needed, except a tight fit. The pieces of wood are screwed on a square axis, which can turn by locally (at two places) rounding it. These parts are caught between two metal slabs at the top of two poles. One slab is bent and entered into a hole of the pole, made with a saw. The second slab is put on top of the first slab and the wooden axis laying in the first slab. Recently we made a bore-hole of only 8 cm (3 inches) wide, 7 meters deep and fitted a rope-pump on top. (Photos follow shortly) Ordinary nylon rope can be used, but regular maintenance/replacement is needed when the rope shows wear due to frequent use. Disks can be made from rubber (the inner tube of a tyre or from the soft side of the outer tyre) but can also be made from plastic. We (the WOT) are developing a machine to automate the production of plastic discs. One of them is shown on the first photo.

My notes – use a stationary bicycle mounted on supports to use the back wheel to drive a rope pump. Use rubber balls pushed onto rope with wire seat cover staples or coat hanger wire to hold on to the rope from slipping.

The WOT rope pump explained

The bottom picture shows the wheel, the axis and the top of the delivery tube. The working principle and the construction is explained to development workers, who actually are assembling and erecting a pump during our yearly training week.

Shopping List:
Follows shortly....

Last update: February 24, 2000
Webmaster: Cor van de Water

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The information is free of copyrights and fees (as far as we know) and can be used for private as well as commercial use. A notification of successful pump installation is appreciated. The WOT has a history of working on rope pumps. We have construction manuals, contact addresses and specialists that helped setting up pump projects in e.g. Nicaragua.

http://www.geocities.com/ResearchTriangle/System/7014/rope.html

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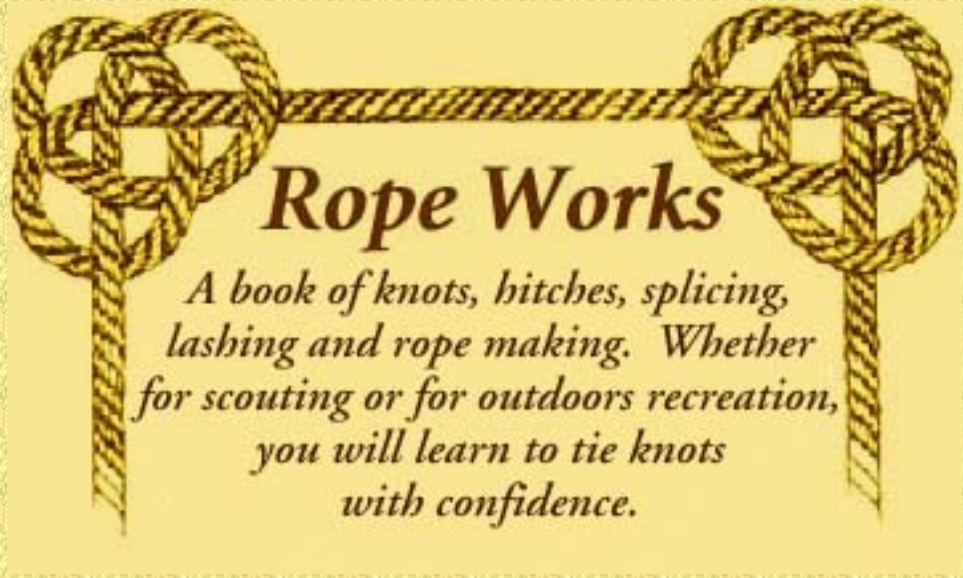

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"MONKEY'S PAW (Turh's Head Style)"

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"FOOTROPE KNOT"

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"MONKEY'S PAW (Coil Stile)"

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ANIMATED KNOTS

"(Animated) TURK'S HEAD"

"(Animated) BOATSWAIN'S WHISTLE KNOT"

"(Animated) CONSTRICTOR KNOT"

"(Animated) MOORING HITCH"

"(Animated) BELAYING TO A CLEAT"

"(Animated) FIGURE-EIGHT"

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ARTICLE OF THE MONTH

Each month there will be a new knot related article displayed on this page.

THIS MONTH'S IS THE :

<

ALAMAR KNOT

The alamar knot is a decorative knot related to the pretzel knot. The pretzel knot is tied in a single strand; the alamar knot is tied by doubling the strands as showwn in [Step 1]

[Step 1] Double the strand as shown.

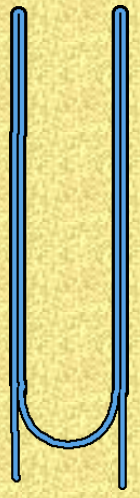

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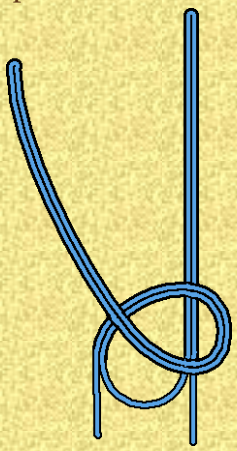

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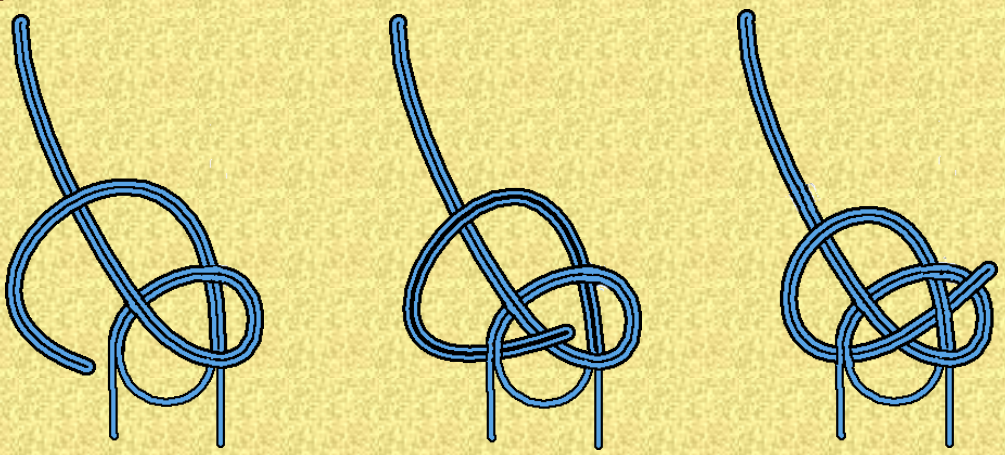

[Step 4]

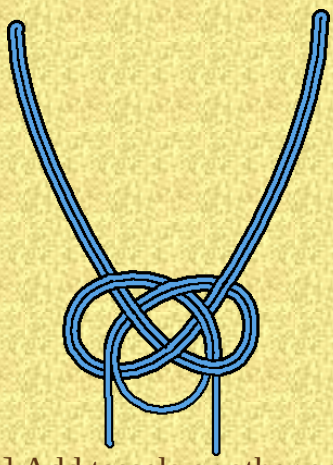

[Step 5] Add tassels or other end decorations.

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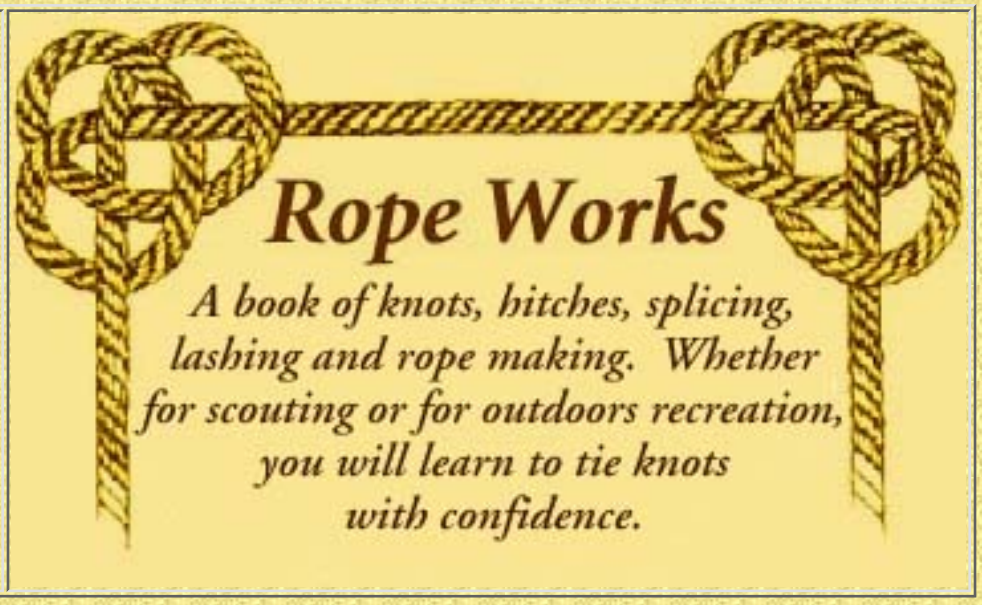

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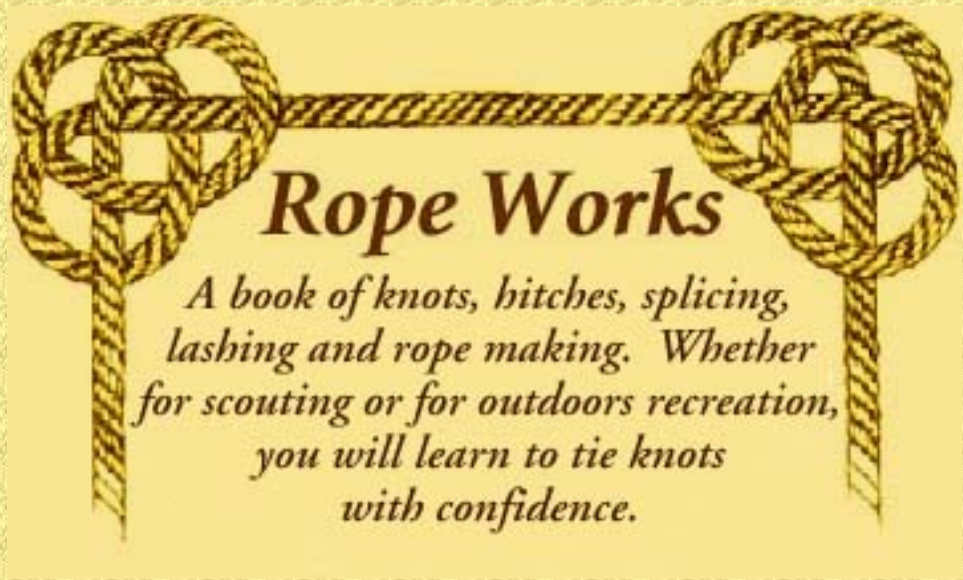

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KNOTBOARD OF THE MONTH

TURK'S HEAD:

Description ----

Three strand braid worked in a continuous circle.

Use ----

(1) As a decorative knot around a staff or railing.
(2) Worked tight around a checked or cracked tool handle or canoe paddle to reinforce them.
(3) As a neckerchief slide or wogal.

Comments ----

The form of Turks head shown here is a five crown Turk's head, this is only one of a group of knots that go by the name Turk's heads. The crown number is determined by counting the number of bights at the edge of the knot. To make a larger loop the, increase the size of the wraps made in steps 1 - 4 and then, at step 7 use three strand braiding to increase the number of crowns. The number of crowns can be increased by increments of three; so that the number of crowns in a larger loop can be 8, 11, 14, etc..The size of the finished Turk's head depends on the size of the rope used and the number of times the strand is chased.

Other Names ----

Three lead by five bight Turk's head, ordinary Turk's head.

Narration ------ (For Turk's head knotboard.)

(1) Start at the center of the line, by taking a

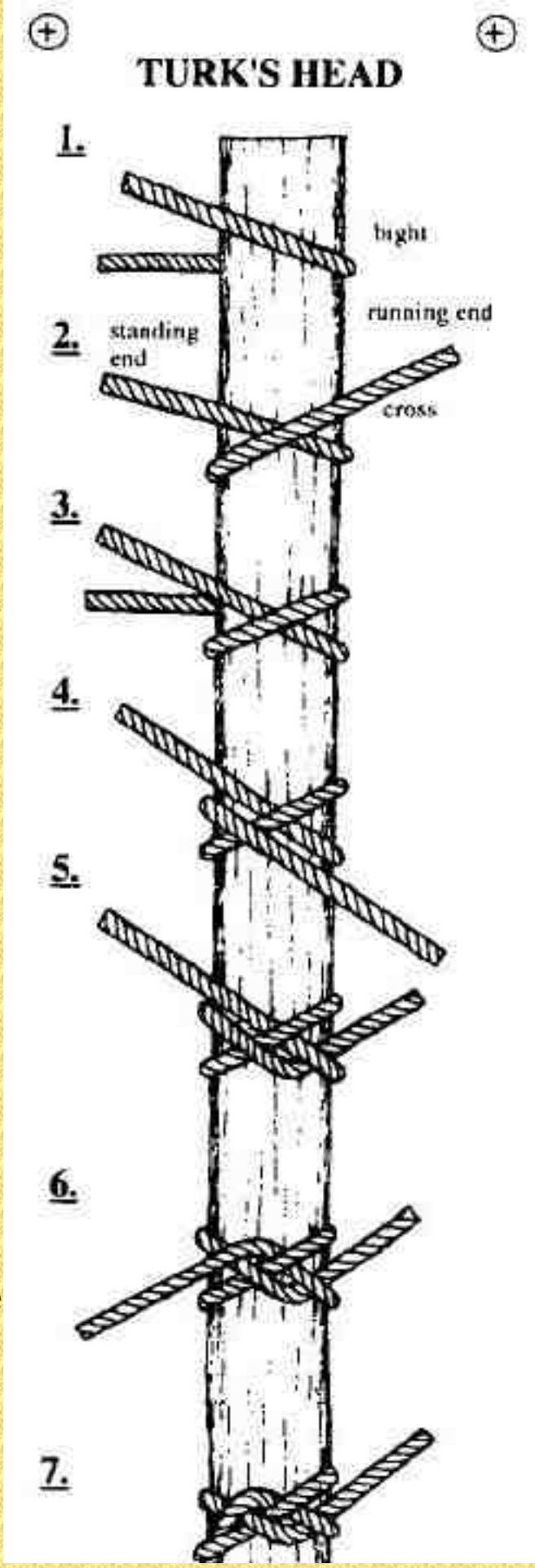

bight around an object (the fingers of the left hand work well) (2) Complete the round turn and cross the running end over the standing end. (3) Take a second bight around the object so that the running end is between the standing end and the first wrap. (4) Lay the running end across the first wrap then (5) tuck the running end under the standing end. (6) lay the standing end across the second wrap and (7) tuck it under the first wrap. (8) rotate the knot around the object so that you are looking at the opposite side. (9) Cross the second wrap over the first wrap. (10) Reeve the standing end through the eye formed between the two wraps. (11) Reeve the running end through the eye between the two wraps so that the ends are in opposite directions. (12) Chase, follow, the strand of the knot two or three times. Cut off and secure the ends.

[NOTE] To determine the length of line to use, wrap the line around the object four times for a single strand knot. Add three and one half wraps for each time you intend to chase the original strand.

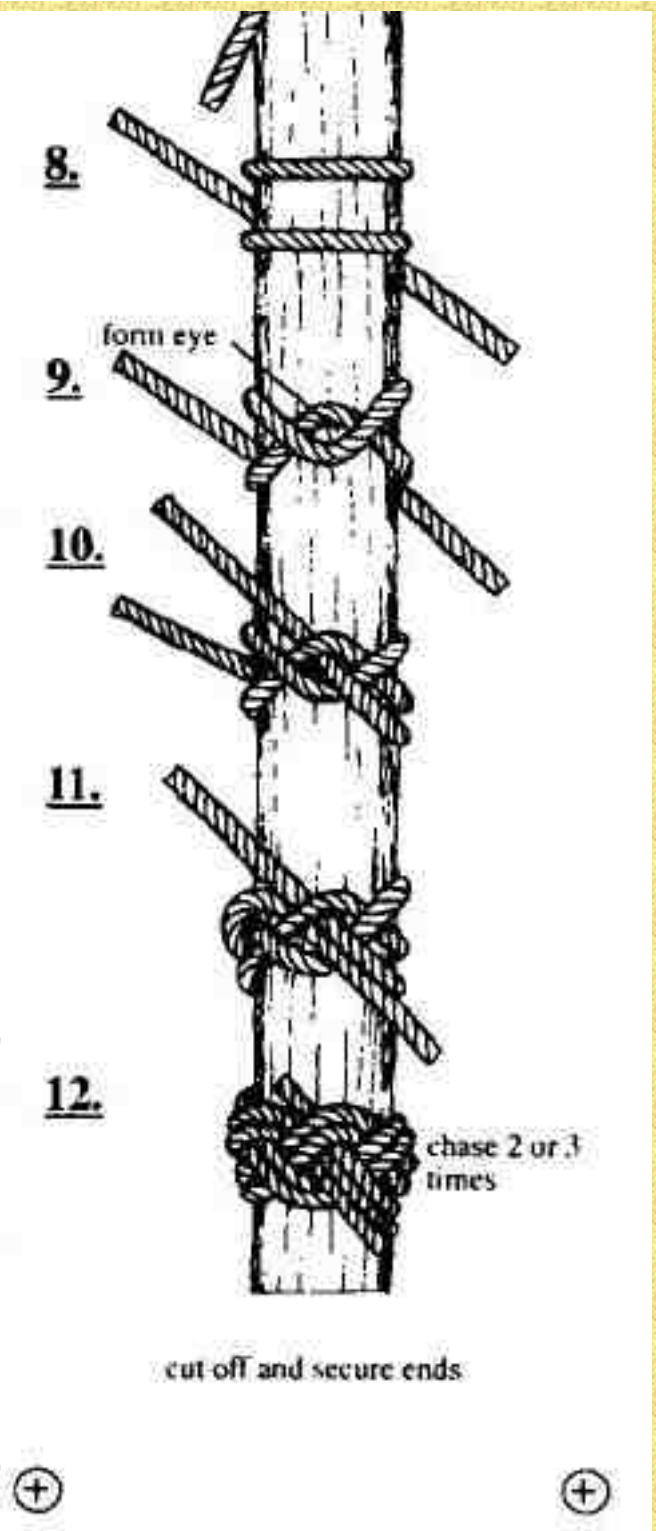

ANIMATED KNOT

TURK'S HEAD KNOT

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KNOTBOARD OF THE MONTH

RINGBOLT HITCHING:

Description ----

A series of interlocking lark's head knot that form a ridge around the outside of a ring or loop.

Use ----

To prevent chafing; as a decoration.

Comments ----

There are many forms of ringbolt hitching, the form shown here is one of the simplest and does not require the use of a needle as many other forms do. Ringbolt hitching was used to prevent chafing of ropes that were reeved through hand forged iron rings and to keep them from clanging against objects around them. In the present,

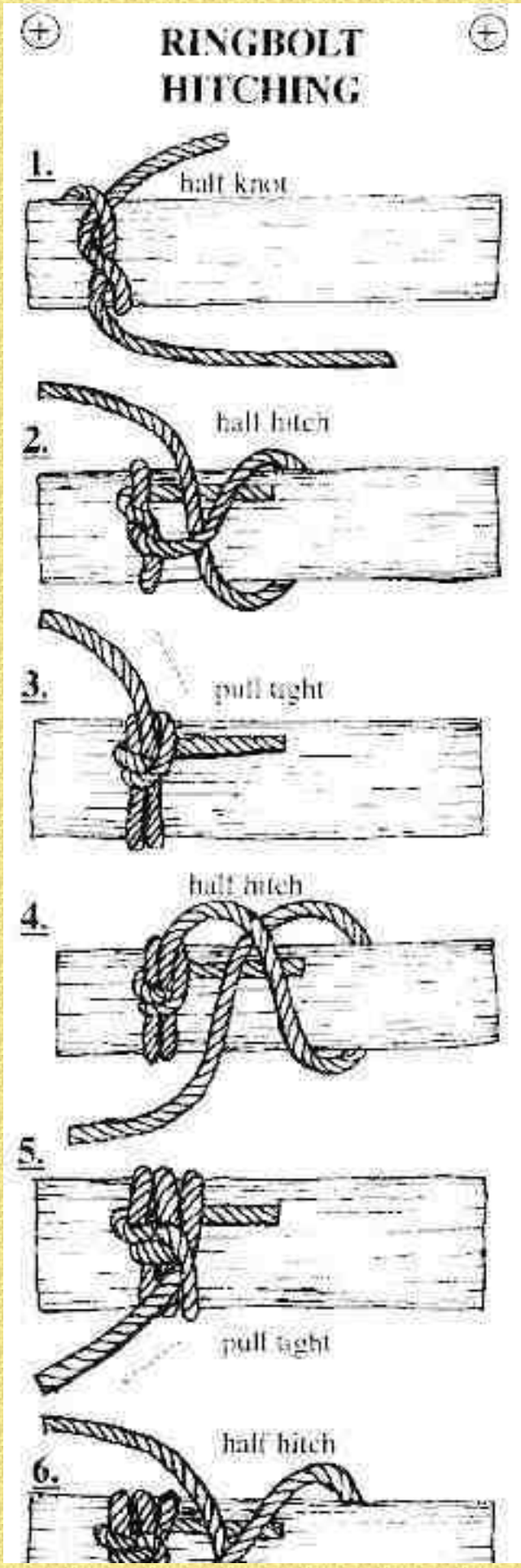

ringbolt hitching can be used to protect synthetic ropes that are easily chafed by a applying a layer of material that is not easily chafed.

Other Names ----

Platted Ring; Hog Backing; Cockscombing.

Narration ------ (For Ringbolt Hitching knotboard.)

(1) Start the ringbolt hitching by tying a half knot around the object. (2) Tie a half hitch around the object so that the standing end is trapped under the half hitch. (3) pull the half hitch tight. (4) Tie the next half hitch in the opposite direction around the object. (5) Pull the half hitch tight. (6) Tie another half hitch in the opposite direction around the object; the same direction as the first half hitch. (7) Pull half hitch tight. (8) When the length of the ringbolt hitching is within 5 or 6 half hitches of being long enough; form a bight in the a short piece of twine so that the eye of the bight is toward the end of the work. (9) Continue to add half hitches until the ringbolt hitching is completed; reeve the running end through the eye of the bight. (10) Use the short piece of twine to pull the running end under the half hitches. (11) Cut off the end of the twine.

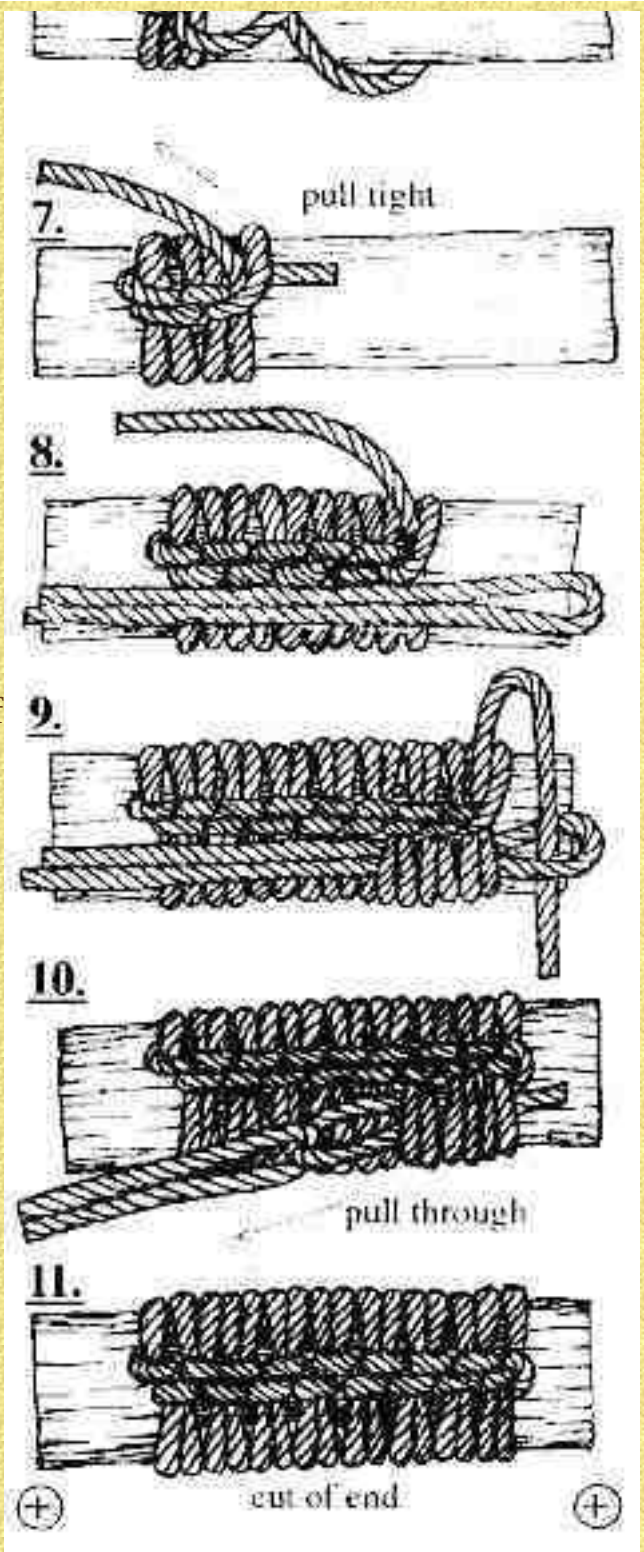

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KNOTBOARD OF THE MONTH

BOATSWAIN'S WHISTLE KNOT:

Description ----

A two lead knot that is built up from two interlocking underhand loops to looks like a turk's head knot when it is worked tight.

Use ----

As a decorative knot to attach a whistle or a knife to a lanyard ---- to form a toggle or button.

Other names ----

Sailor's knife lanyard knot, marlingspike lanyard knot, single-strand diamond knot, two strand diamond knot ---- pipe lanyard knot.

Narration -- (For

Boatswain's Whistle Knot knotboard.)

((1) Use the left hand to hold the middle of a strand of rope so that the loop of the bight is to the back of the hand and the two leads are between the fingers and hanging down across the palm. (2) Use the bottom lead, to lay an underhand loop over the standing end of top lead. (3) Form a bight in the bottom lead so that its running end is under the running end of the top lead. (4) Weave the running end of the bottom lead over the right edge of the top underhand loop, then under the standing end of the bottom lead, and over the left edge of the top underhand

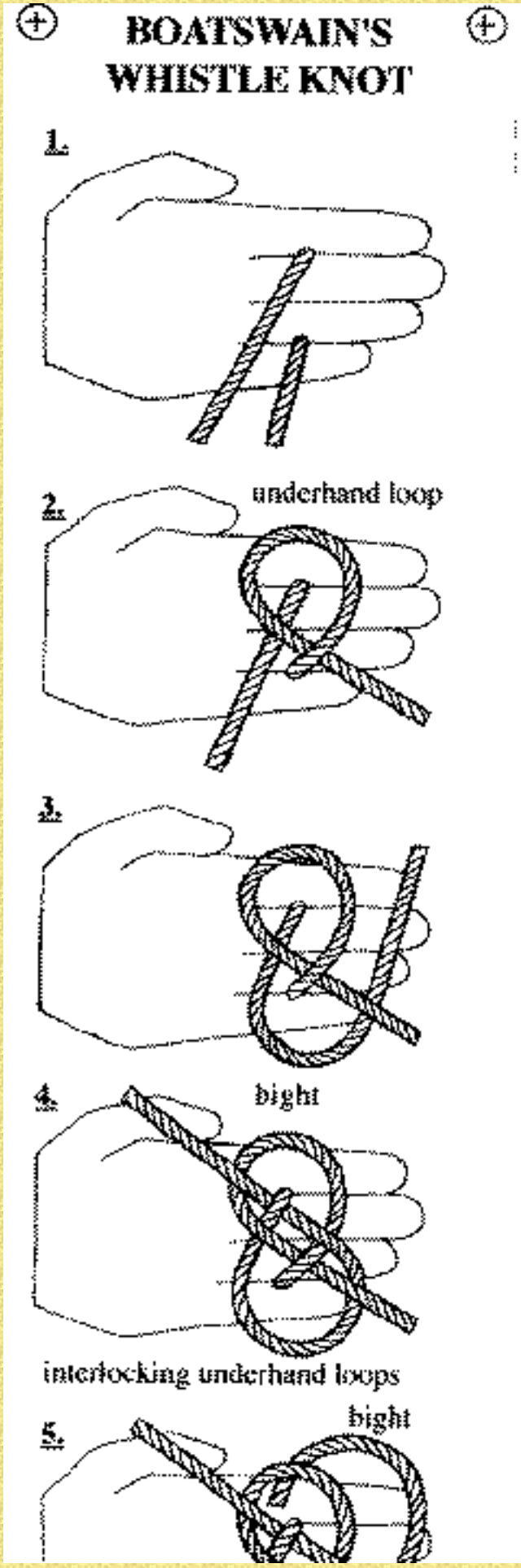

hand loop. This forms two interlocking underhand loops. (5) Form the next bight by placing the running end of the top lead under the top edge of the top underhand loop. (6) Reeve the running end of the top lead to the outside of the standing end of the bottom lead and up through the middle of the interlocking underhand knots. (7) Form the next bight by placing the running end of the bottom lead under the bottom edge of the bottom underhand loop. (8) Reeve the running end of bottom lead to the outside of the standing end of the bottom lead and up through the middle of the interlocking underhand knots. (9) Work the knot tight.

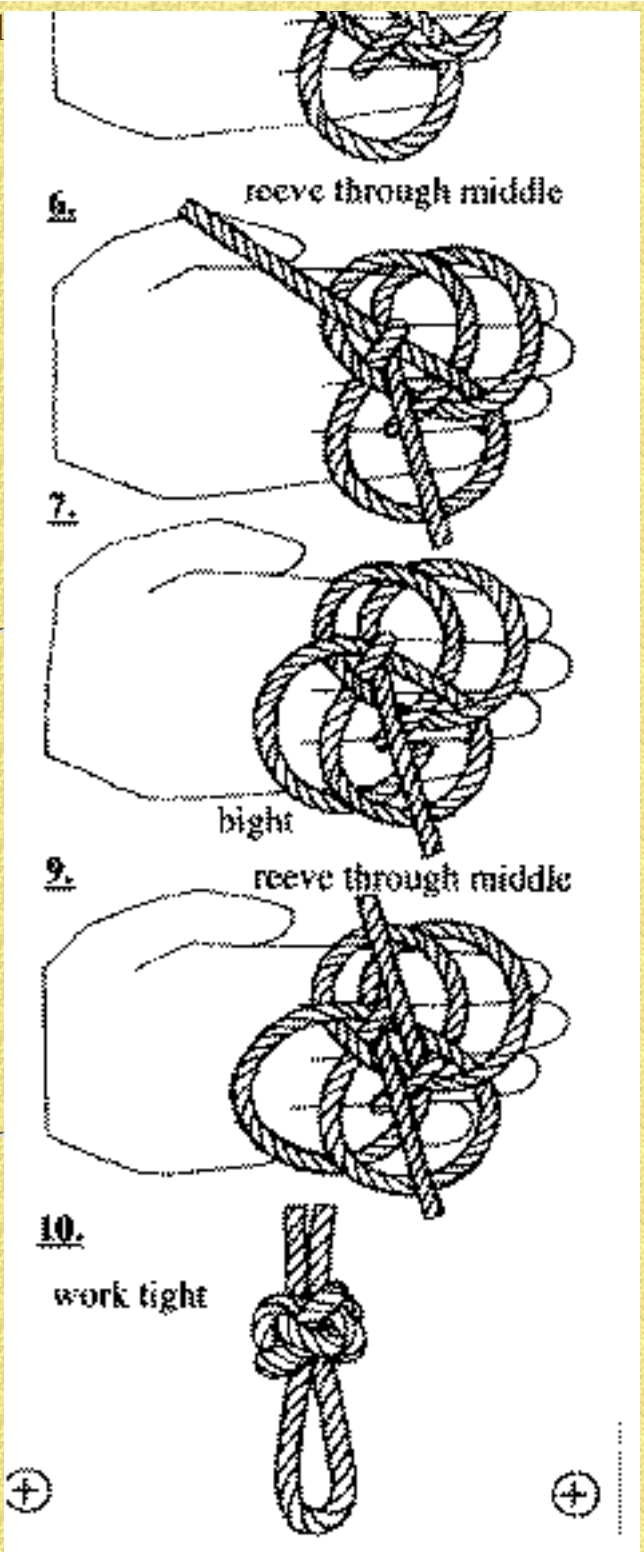

ANIMATED KNOT

BOATSWAIN'S WHISTLE KNOT

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KNOTBOARD OF THE MONTH

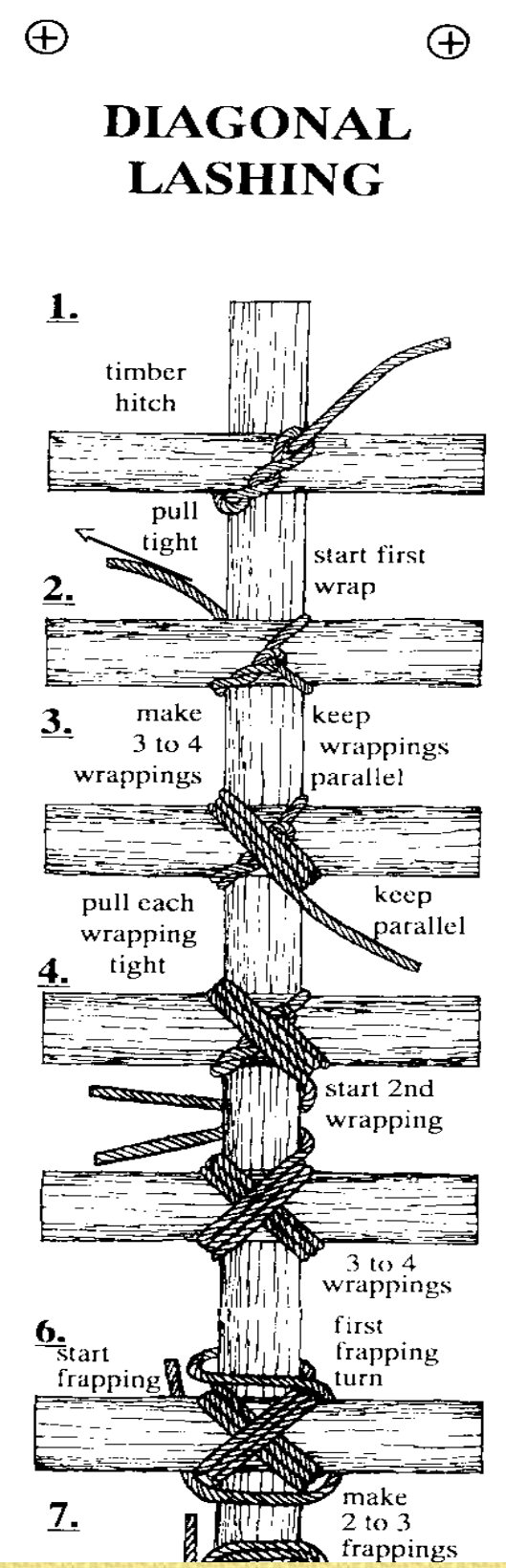

DIAGONAL LASHING:

Use ----

Diagonal lashing is used to bind poles together that cross each other but do not touch when their ends are lashed in place in a structure.

Comments ----

The diagonal lashing gets its name from the fact that the wrapping turns cross the poles diagonally.

The diagonal lashing can be used to bind poles that cross each other from 90o to 45o. If the angle between the poles is less than 45o a shear lashing should be used.

The diagonal lashing makes use of the timber hitch to pull poles together that are not touching each other. The timber hitch allows the poles to be drawn together without changing the relative positions of the poles. [NOTE] If a square lashing were used to bind poles that do not touch, the beginning clove hitch would pull the cross pole toward the clove hitch causing unnecessary bowing of the cross pole and could also produce a force that would act along the length of the pole to which the clove hitch is tied. These additional force, if strong enough, can place unnecessary strain on other lashing within the structure causing the structure to twist and fail.

Narration ------ (For Diagonal Lash knotboard.)

(1) Tie a timber hitch diagonally around both poles. (2) Start the wrapping turns on the opposite diagonal to the timber hitch, by pulling the rope tight so that the poles contact each other. (3) Take 3 to 4 wrapping turns; keep

the wrapping turns parallel; pull each wrapping turn tight. [NOTE] If the wrapping turns are allowed to cross, the increased friction between the strands of the rope will make it difficult to tighten the wrapping turns. (4) Start the second set of wrapping turns by going past and around the vertical pole. [NOTE] Going around the pole the rope allows the direction of the rope to be changed without crossing the first set of wrapping diagonally. (5) Take 3 to 4 wrapping turns; be sure to keep the wrapping turns parallel; pull each wrapping turn tight. (6) Start the frapping turns by going past and around one of the poles. [NOTE] Going around the pole with the rope allows the direction of the rope to be changed without crossing the wrapping turns diagonally. (7) Take 2 to 3 frapping turns; keep the frapping turns parallel. Be sure to pull each turn tight. (8) End the lashing with a clove hitch. Take the first half hitch of the clove hitch by going past and then around one of the poles. Lock the half hitch tight against the lashing by working it tight. (9) Take a second half hitch around the pole. (10) Work the second half hitch tight against the first half hitch so that the clove hitch is locked against the lashing.

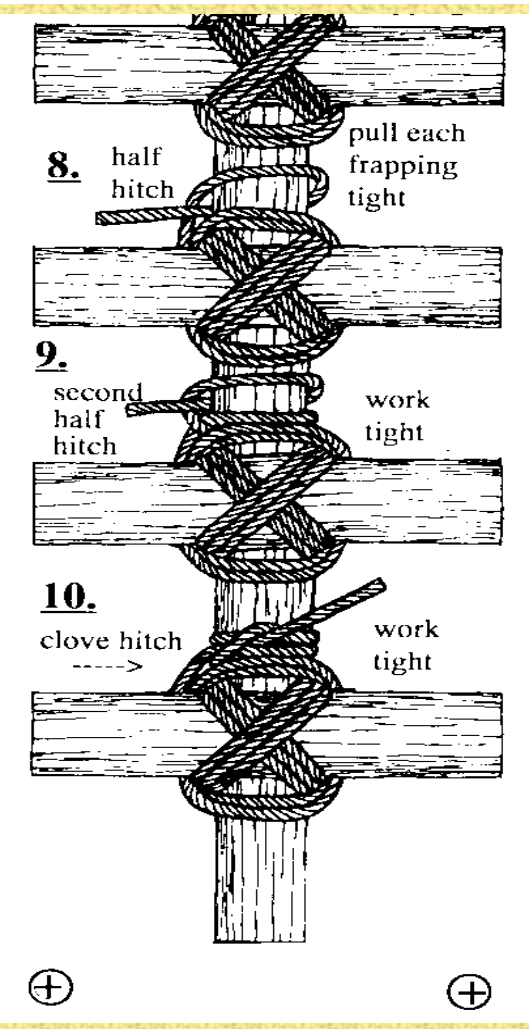

[NOTE]

If very smooth rope is used, the lashing can be made more secure by adding a third or forth half hitch to the clove hitch.

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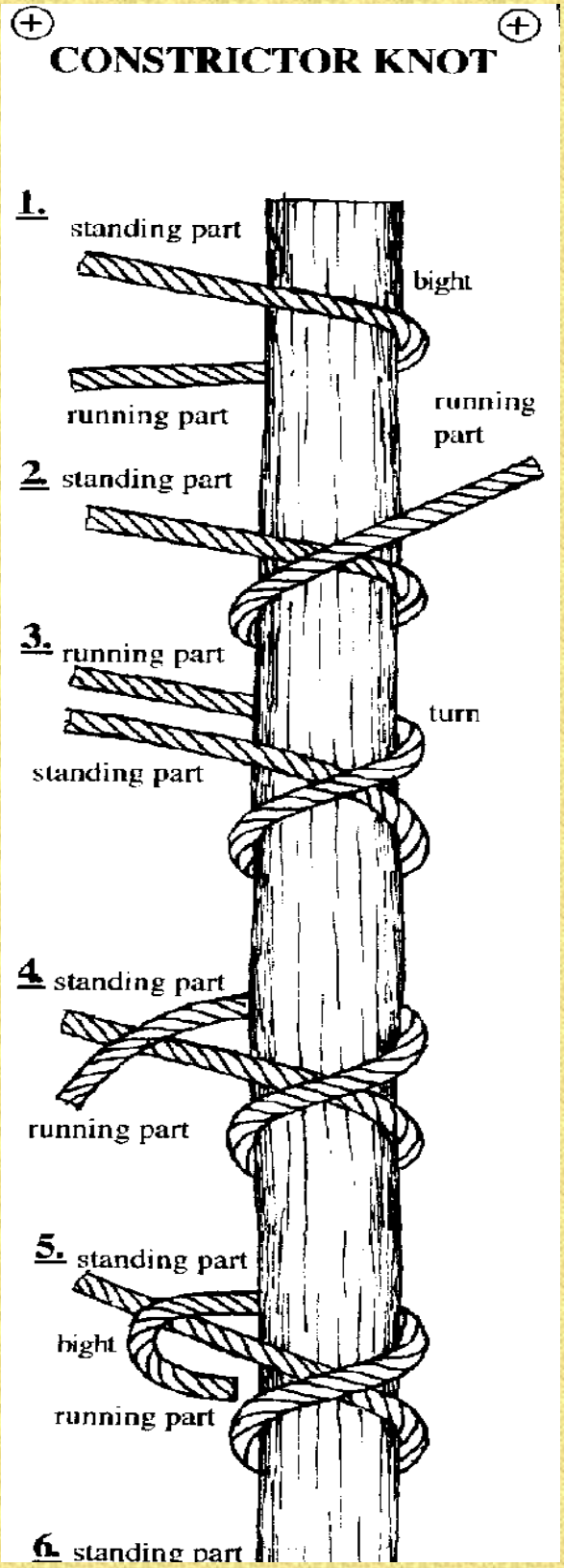

KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

CONSTRICTOR KNOT:

Dscription ----

A clove hitch with a half knot under the cross-point.

Use ----

To tie a smaller rope to a larger one, or to tie a rope to a stake or pole; a substitute for whipping; as a lashing for light construction ; as a hose clamp.

Comments ----

A secure nonslip knot ; difficult to untie without cutting.

[NOTE]

Use this method of tying the constrictor knot on either side of where you intend to cut a rope. This is a fast and easy way to prevent a rope from unlaying when it is cut.

Narration ------ (For Constrictor Knot knotboard.)

((1) take a bight around an pole. (2) Continue wrapping the running part around the pole so that the running part crosses over the standing part. (3)

Complete the turn around the pole. (4) Cross the running part over the standing part so that (5) a bight is formed around the standing part. (6) Reeve the running part under the cross part of the loop in the standing part to form a half knot under the cross-point. (7) Pull the standing tight. (8) Lock the knot tight by pulling hard on both the standing part and the running part.

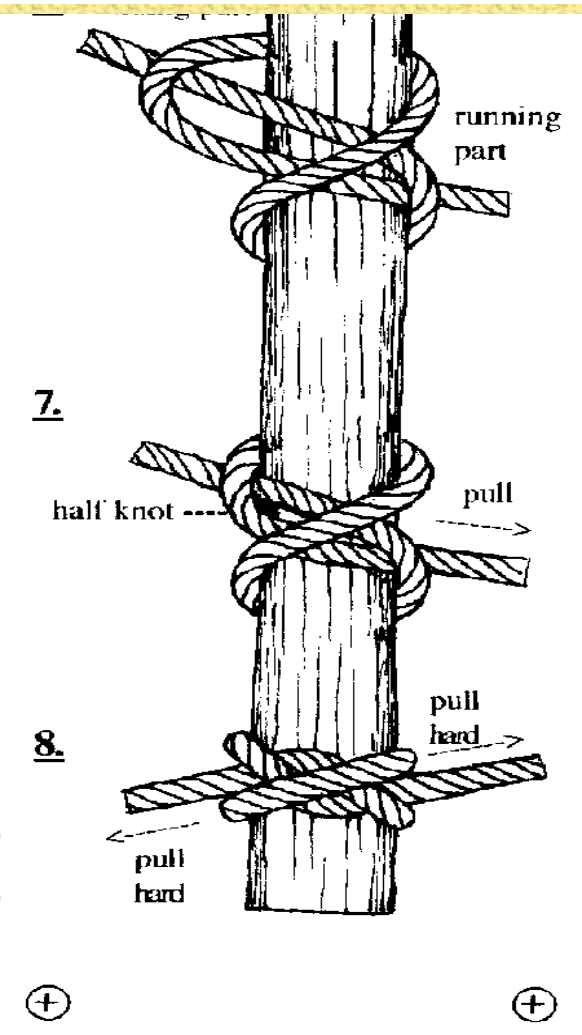

ANIMATED KNOT

BOATSWAIN'S WHISTLE KNOT

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KNOTBOARD OF THE MONTH

MONKIE'S PAW:

Dscription ----

Two forms of the monkey's paw are sown here the first is formed from four interlocking loops: a four crown turk's head; the second is constructed from three interlocking coils.

Use ----

The core determines what the monkey's paw can be used for. When tied over a stone or heavy ball, the monkey's paw can be used to add weight to a heaving line. If tied over a cork ball with small cord the monkey's paw makes a good float for boat keys or other small items used around a water front. Tied over a ball of twine or other soft material, the monkey's paw can be used as weight on the end of a rope for the game jump the shot. A Monkey's Paw can also be used as a toggle..

Comments ----

Neither form of the Monkey's Paw has an advantage over the other. Which one you choose to use is a matter of personal preference.

Core Size -----

The diameter of the core should be between three and four diameters of the rope being used..

Narration ------ (For Monkey's Paw Turk's Head knotboard.)

(1) Form an overhand loop (2) Form a second

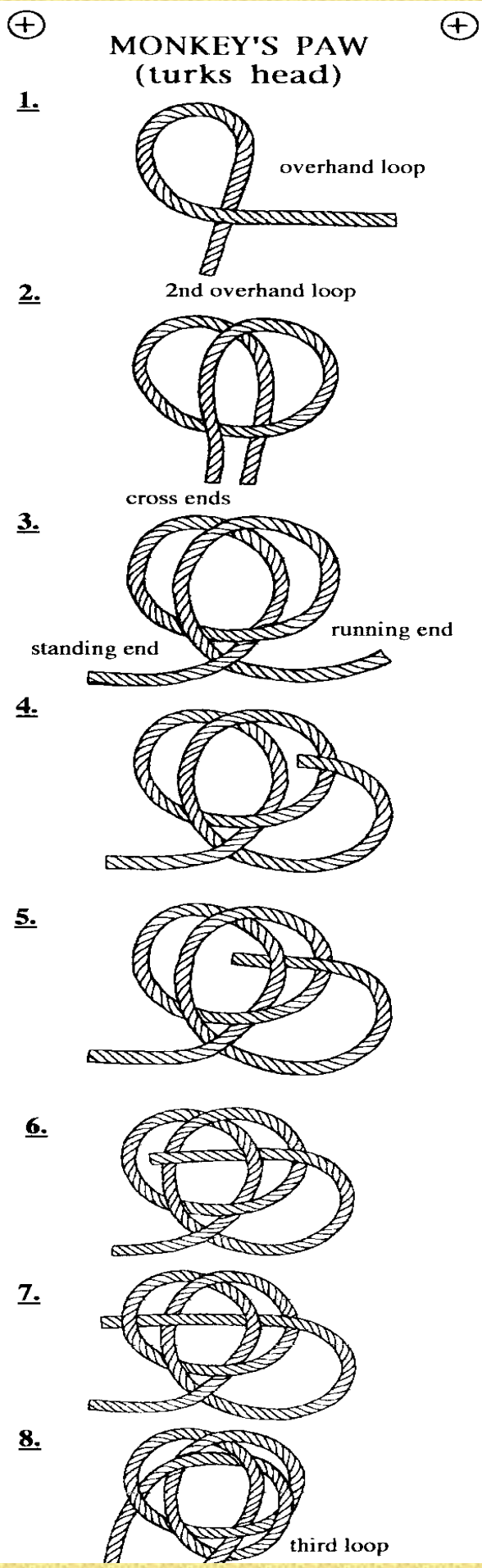

overhand loop over the left edge of the first overhand loop . (3) Cross the standing end over the running end. (4) Weave the running end across the loops by placing the running end over the right side of the top loop (5) then under the right side of the bottom loop (6) next, over the left side of the top loop (7) and finally under the left side of the of the bottom loop. (8) Pull the running end through until a third loop equal in size to the first two loops. (9) Add the fourth loop by placing the running end parallel to the standing end. (10) Chase the original pattern 2 to 3 times. (11) Work tight over the core.

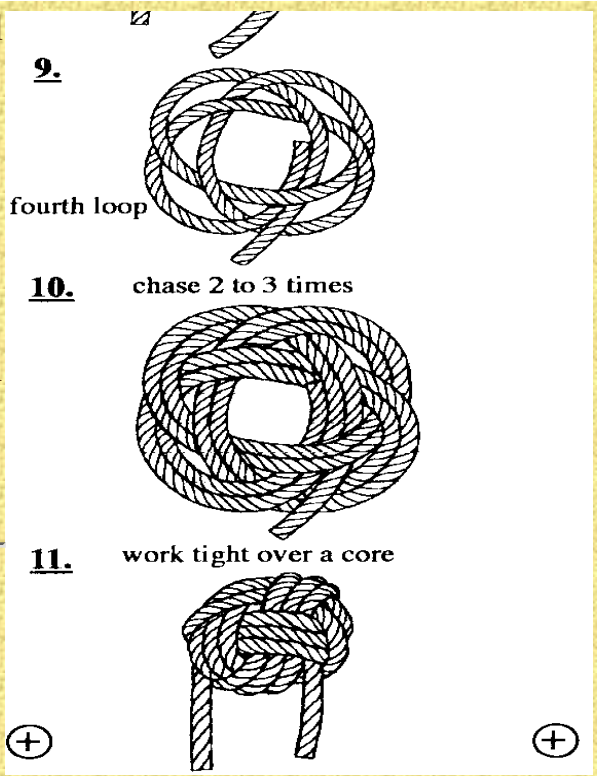

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

MOORING HITCH:

Dscription ----

An underhand loop toggled to the standing part with a bight made in the running end.

Use ----

To securely tie off a rope so that it can be quickly untied, especially a small boat to a dock or piling.

Comments ----

A secure knot that is easily tied or untied in wet or dry rope; when properly tied a non closing loop is formed, this allows the hitch to move up or down a piling as the water level changes.

Narration ------ (For Mooring Hitch Knotboard.)

(1) Take a bight around an object. (2) Form an underhand loop in the running part. (3) Place the eye of the underhand loop over the standing part. (4) Pull a bight of the standing part through the eye of the underhand loop. (5) Pull the underhand loop tight around the bight. (6) Place the running part under the eye of the bight that was pulled through the underhand loop. (7) Pull a bight of the running part through the eye of the standing part bight. (8) Pull on

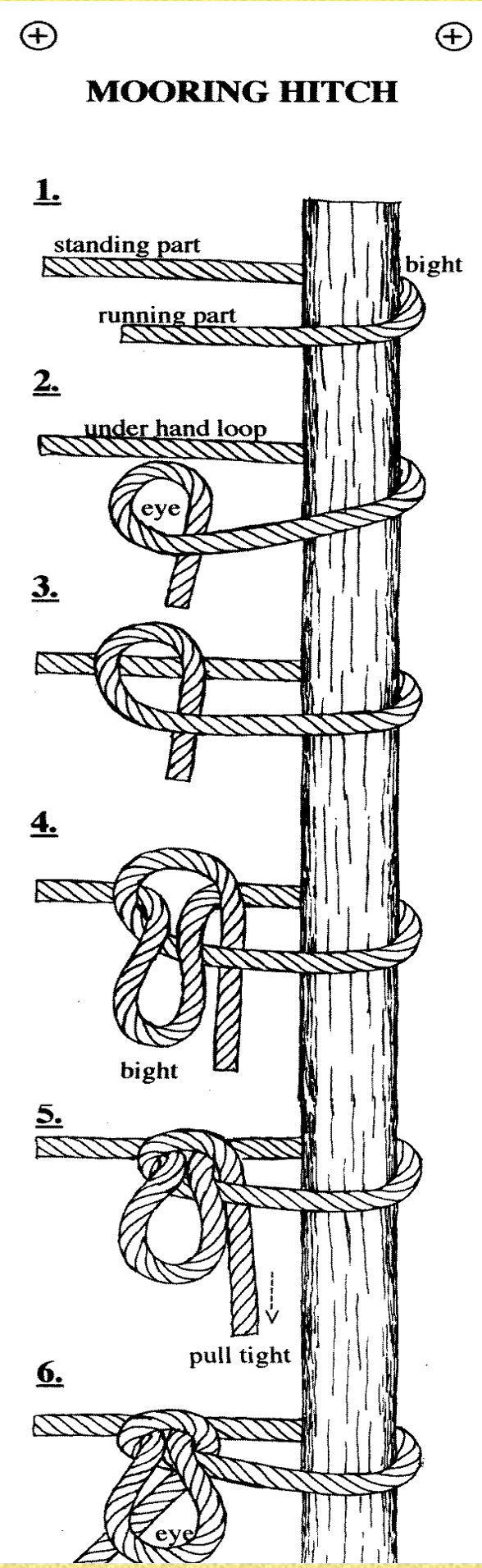

the standing part to tighten the standing part bight around the running part bight.

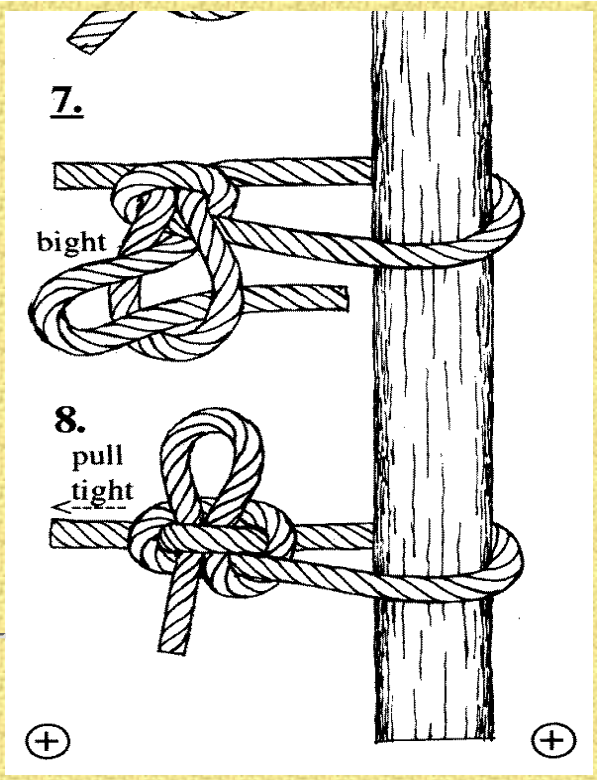

ANNIMATED KNOT

MOORING HITCH

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

JUG KNOT:

Use ----

- to provide a convenient carrying handle for jug or bottle ---- to attach a tool, such as a hammer to a security line to prevent accidental dropping --- to add a wrist loop to a walking staff --- to attach a safety line to a canoe paddle ..... use your imagination, but be sure that you keep safety in mind.

Other Names ----

Jar knot, moonshiner's knot, hackamore, bridle knot..

Comments ----

The most common use is to provide a loop handle attached to the neck of a bottle. The loop handle makes it easy to carry several bottles with one hand. If a toggle or a two strand button knot such as boatswain whistle knot is added to the free end of the rope, The loop of the jug knot can be use to toggle the bottle to a belt so that the bottle can be use as a canteen.

Plastic bottles with screw-on lids such as soda, sport drink, and mineral water bottles make strong,

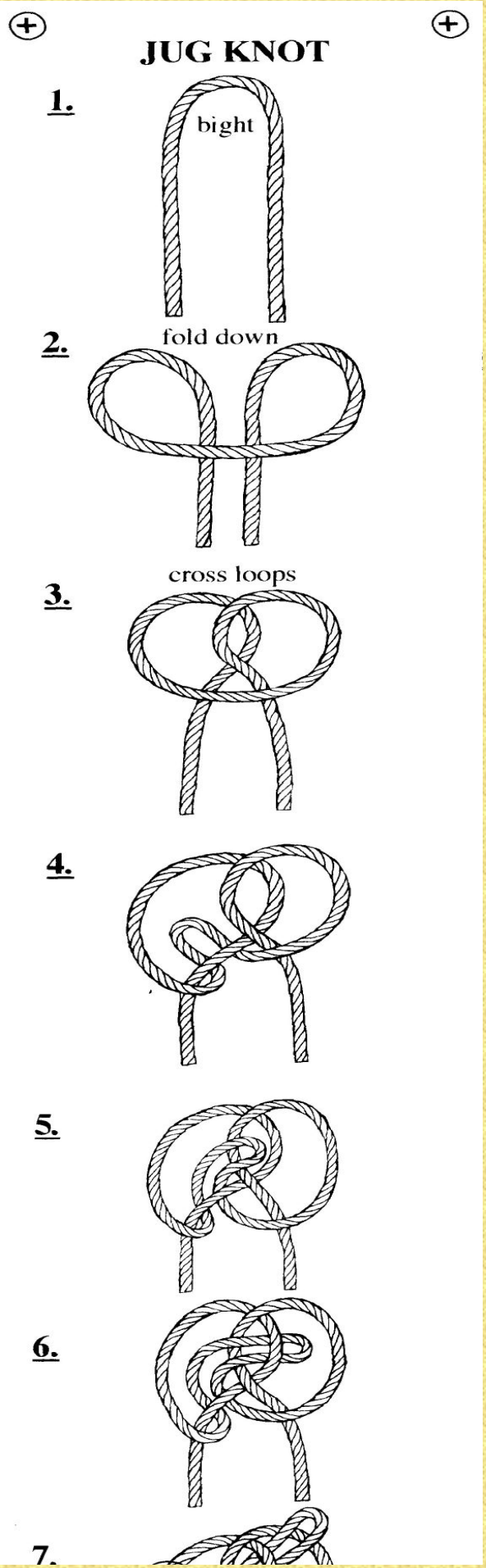

lightweight containers for carrying water on hikes and camp outs. 2 and 3 liter soda bottles are large enough to use as water containers around the camp kitchen. Smaller bottles (8 to 16 oz.) can be used as personal water bottles or canteens. These bottles can be made even more convenient by using a jug knot to attach a loop handle.

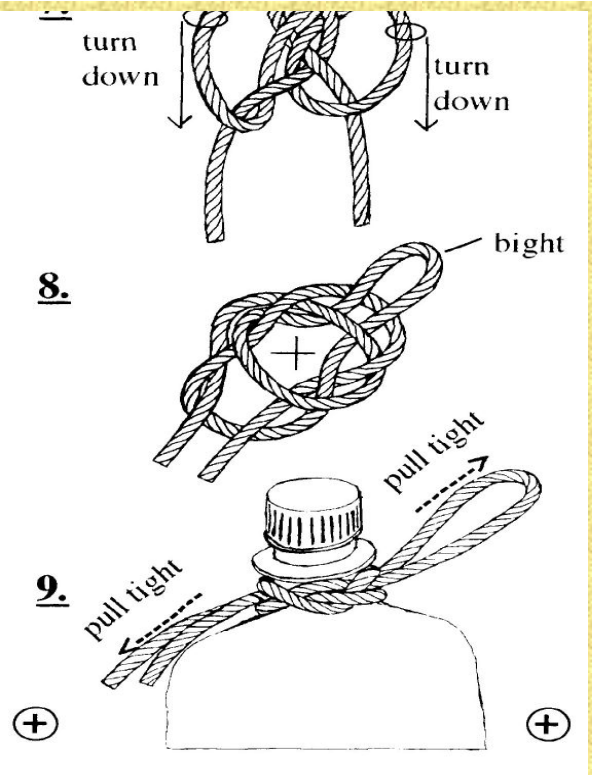

To help keep your water cool and refreshing in hot weather, place a sock over the bottle, wet the sock when you fill the bottle, evaporation will do the rest.

In cold weather, carry your water bottle under your coat. A dry sock placed over the bottle will help keep the water from freezing. In cold weather, carry your water bottle under your coat. A dry sock placed over the bottle will help keep the water from freezing.

In cold weather, carry your water bottle under your coat. A dry sock placed over the bottle will help keep the water from freezing.

Narration ------ (For Jug Knot Knotboard.)

Narrative ---- (For jug knot knotboard) (1) Form a bight in the middle of a 24 to 30 inch long by 3/16 inch diameter rope. (2) Fold the bight down over the standing ends to form two loops. (3) Place the right loop over the side of the left loop. (4) Weave the middle of the bight under the standing end; then over the left edge of the right loop; (6) next go under the right edge of the left loop; (7) finally pass the bight over the right side of the left loop. (8) Turn the tops of the original loops down over the knot. (9) Place the knot over the neck of a bottle and work the knot tight so that the bight forms a 4 to 5 inch loop handle and the loose ends are even.

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

BELAYING TO A CLEAT:

Use ----

To secure a flag lanyard, to moor a boat to a dock.

Comments ----

Belaying to a cleat is a fast non-jamming method of securing a rope anywhere along its length without reeving any part of the rope through or around anything.

Narration ------ (For Belaying to a CleatKnotboard.)

(1) Take a turn around the cleat and pull the line tight. (2) Complete a round turn around the cleat . (3) Place the line across the cleat. (4) Take a bight around one horn of the cleat. (5) Place the line across the cleat a second time. (6) Take a bight around the other horn of the cleat to form a figure eight around the horns of the cleat. (7) Repeat steps 3 through 6. (8) Form an underhand loop. (9) Place the eye of the underhand loop over the horn of the cleat. (10) Pull the underhand loop tight to form a half hitch around the horn of the cleat, this locks the rope in place.

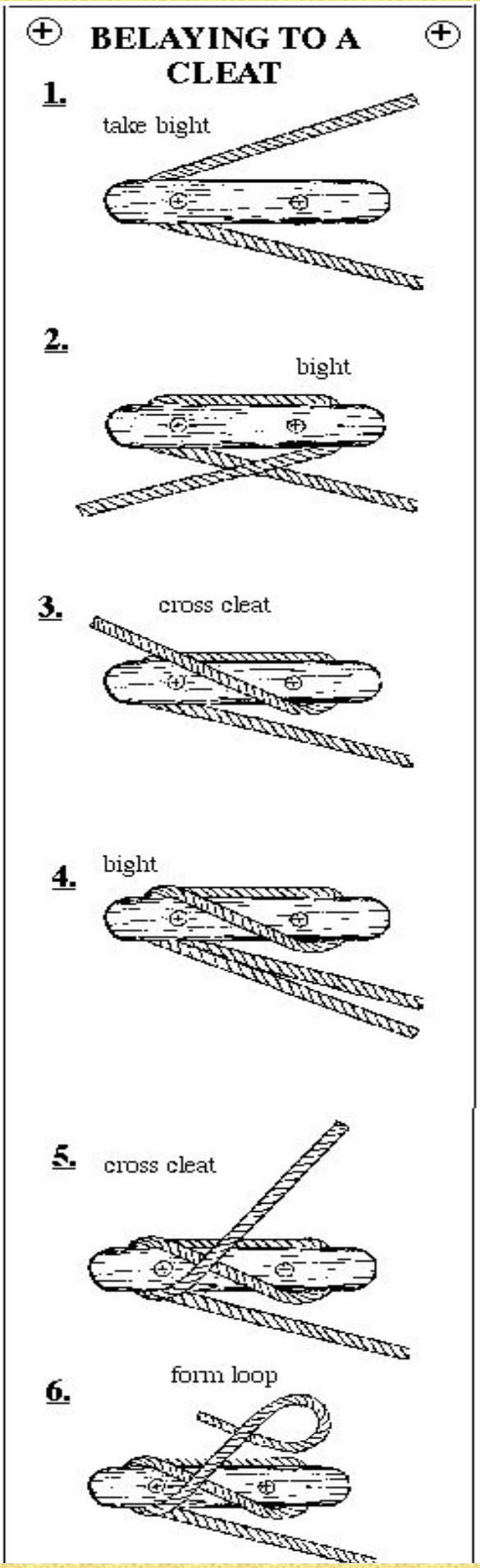

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BELAYING TO A CLEAT

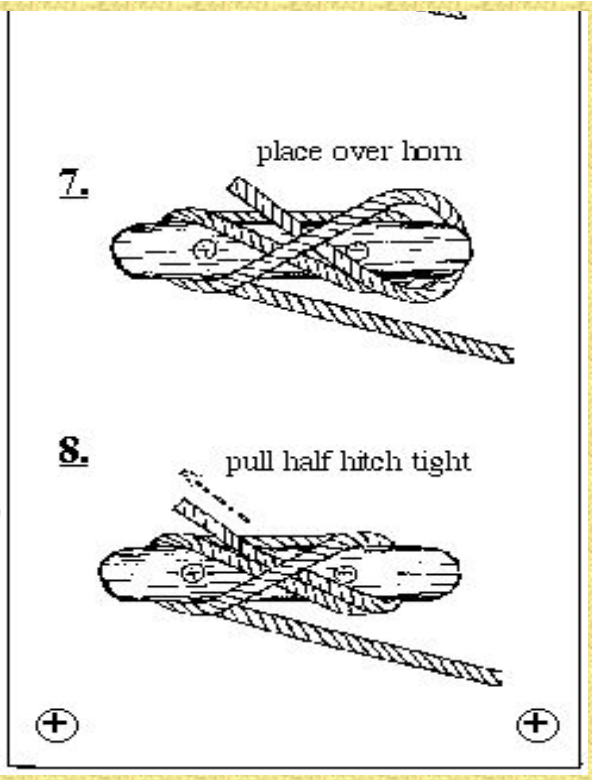

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Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

WHIPPING:

Description ----

Twine wrapped and secured to the end of a rope.

Use ----

To prevent the fraying of the end of a rope.

Comments ----

Even though "whipping" is done in several different ways, the finished "whippings" have similar appearance: the ends are secured under the turns, the length of the whipping is equal to the diameter of the rope, and all turns are parallel. Synthetic rope, rope made of plastic, should be whipped and fused to prevent the rope from fraying. Fusing helps to hold the whipping in place and the whipping helps to prevent the fused rope strands from braking apart.

Narration ------ (For Whipping Knotboard.)

(1) Take a turn around the cleat and pull the line tight. (2) Complete a round turn around the cleat . (3) Place the line across the cleat. (4) Take a bight around one horn of the cleat. (5) Place the line across the cleat a second time. (6) Take a bight around the other horn of the cleat to form a figure eight around

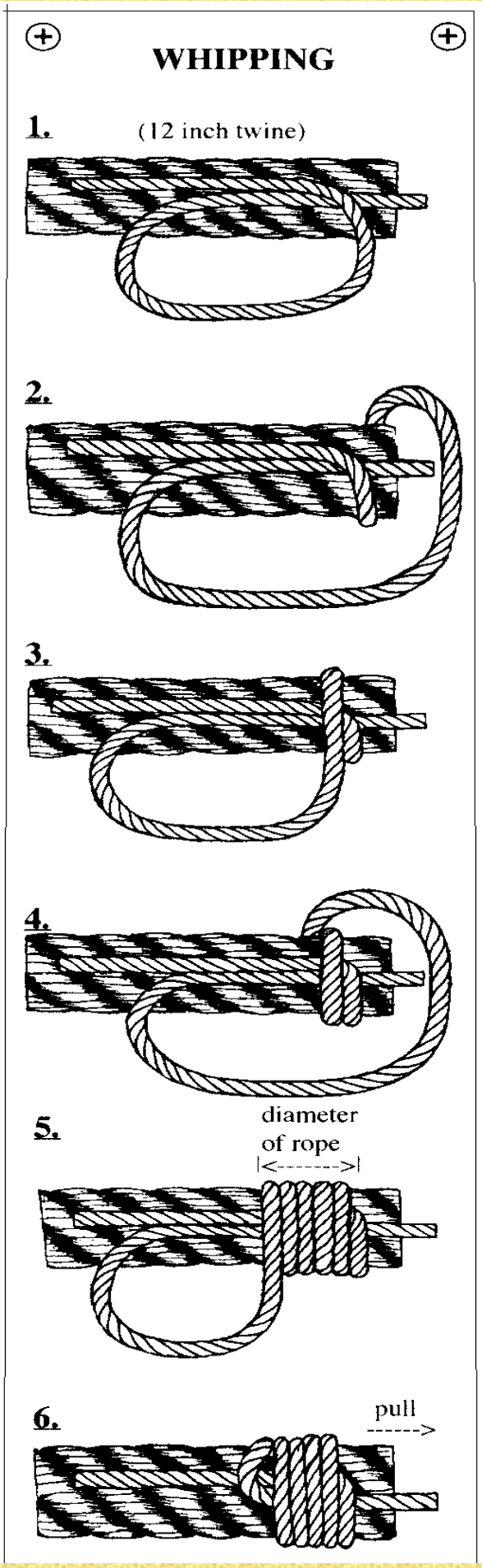

the horns of the cleat. (7) Repeat steps 3 through 6. (8) Form an underhand loop. (9) Place the eye of the underhand loop over the horn of the cleat. (10) Pull the underhand loop tight to form a half hitch around the horn of the cleat, this locks the rope in place.

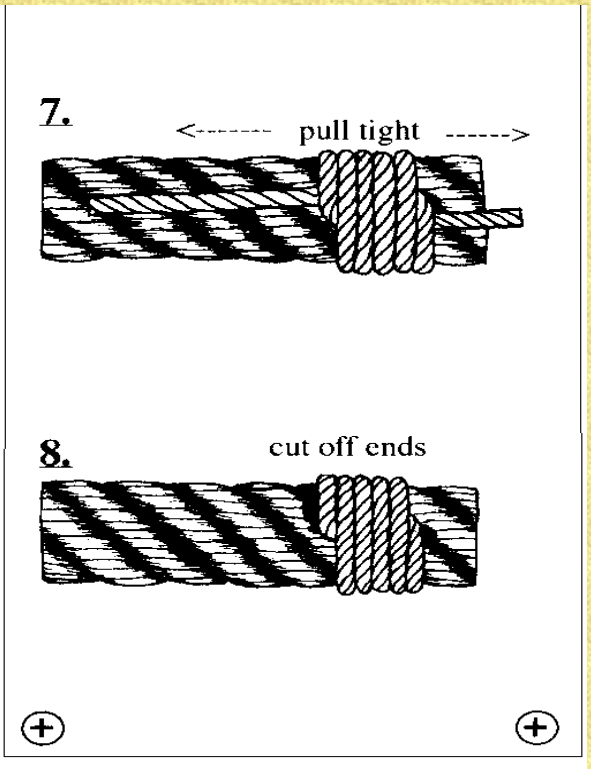

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

FIGURE-EIGHT KNOT:

Description ----

Interlocking overhand loops, the running part goes through the eye of one loop and the standing part goes through the eye of the other loop.

Use ----

(1) As a stopper knot; to keep a rope from unreeving from a pulley block; to prevent a rope from unlaying. (2) When tied on a bight, makes a reliable loop for rescue work and mountaineering.

Comments ----

Easier to tie and untie than an overhand knot; does not damage the rope fiber or jam like an overhand knot.

Narration ------ (For Figure-eight Knotboard.)

(1) Form an overhand loop. (2) Take a bight around the standing part. (3) Form the second overhand loop by bring the running part over the top edge of the firs overhand loop. (4) Complete the knot by reeving the running part through the eye of the first overhand loop (5) and pull tight.

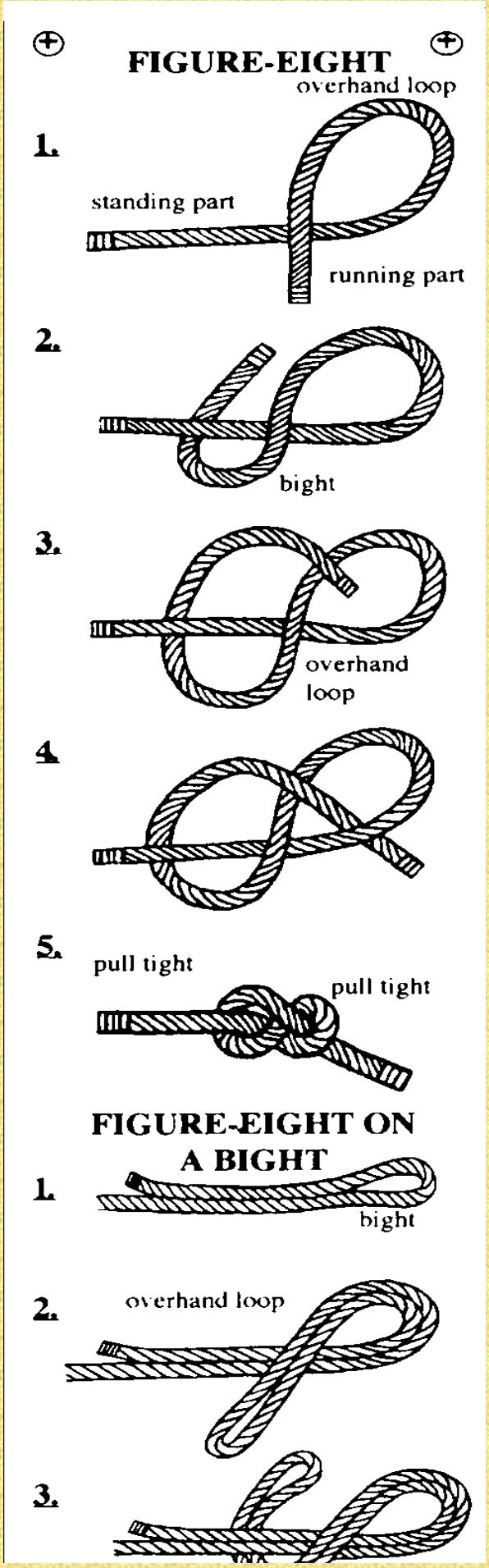

FIGURE-EIGHT ON A BIGHT:

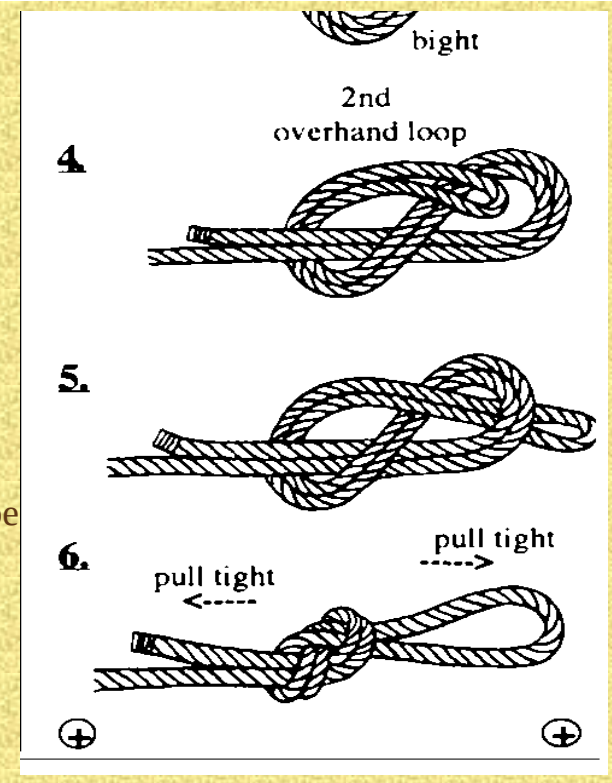

Description ----

Interlocking overhand loops tied on a bight in the running part (the bight is used as the running part); the running part goes through the eye of one loop and the standing part goes through the eye of the other loop.

Use ----

(1) Makes a reliable loop for rescue work and mountaineering. (2) As a stopper knot; to keep a rope from unreeving from a pulley block; to prevent a rope from unlaying.

Comments ----

Easier to tie and untie than an overhand knot; does not damage the rope fiber or jam like an overhand knot on a bight.

Narration ------ (For Figure-eight on a Bight Knotboard.)

(1) Form a bight in the rope. [NOTE] Treat the two strands of the bight as a single strand as the rest of the knot is tied. (2) Form an overhand loop. (3) Take a bight around the standing part. (4) Form the second overhand loop by bring the running part over the top edge of the firs overhand loop. (5) Complete the knot by reeving the running part through the eye of the first overhand loop (6) and pull tight.

ANNIMATED KNOT

BELAYING TO A CLEAT

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

TRIPOD LASHING:

Description ----

A shear lashing around 3 poles.

Use ----

To bind three poles together, for the construction of a tripod. ---- To bind three poles together that contact at the same point in a structure

Comments ----

The tripod lashing is a shear lashing that binds three poles together at the same point. ---- The tripod lashing gets it name from the fact that its most common use is the construction of a tripod. ----The tripod lashing can be used just about any where in a structure that three poles cross each other at the same point and the same time in the sequence of construction. ---- Tripod lashing takes two main forms; with racked wrapping turns (the rope is woven between the poles) and with plain wrapping turns (the rope is wrapped around the poles without weaving the rope between the poles). When the lashing is made with racking turns the rope contacts each pole around its entire circumference ; this

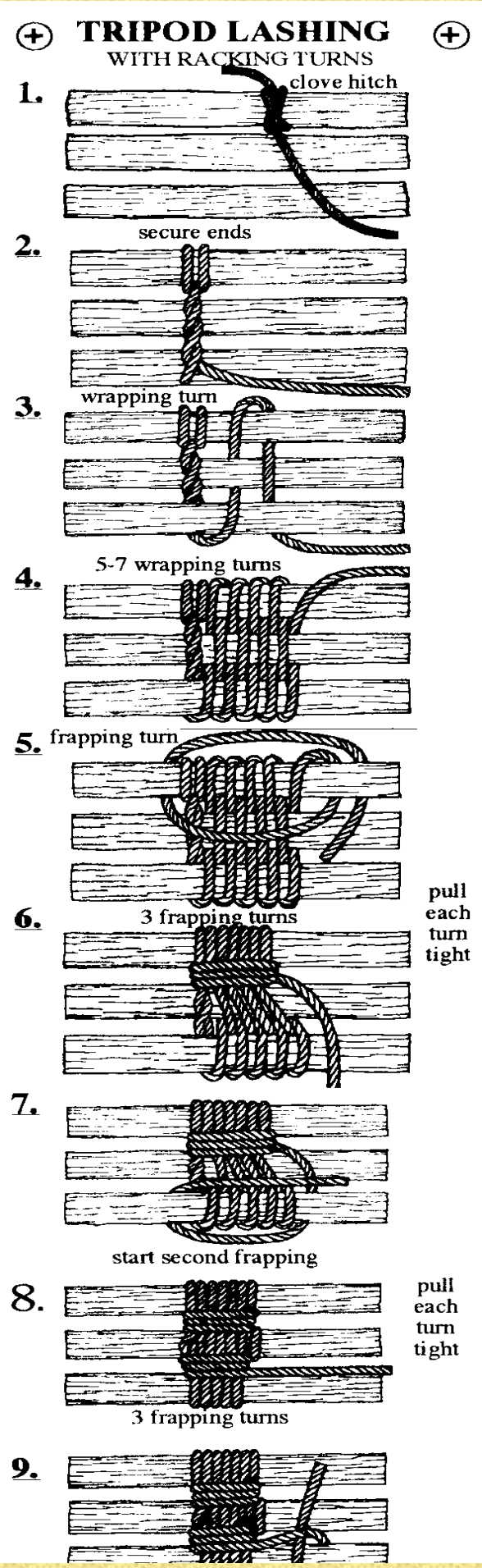

contact makes the tripod lashing with racking turns the most secure form of tripod lashing: therefore tripod lashing with racking turns should be used when safety is important. However, for light structures where there would be no danger if the lashing slipped, the faster to tie tripod lashing with plain wrapping turns may be used.

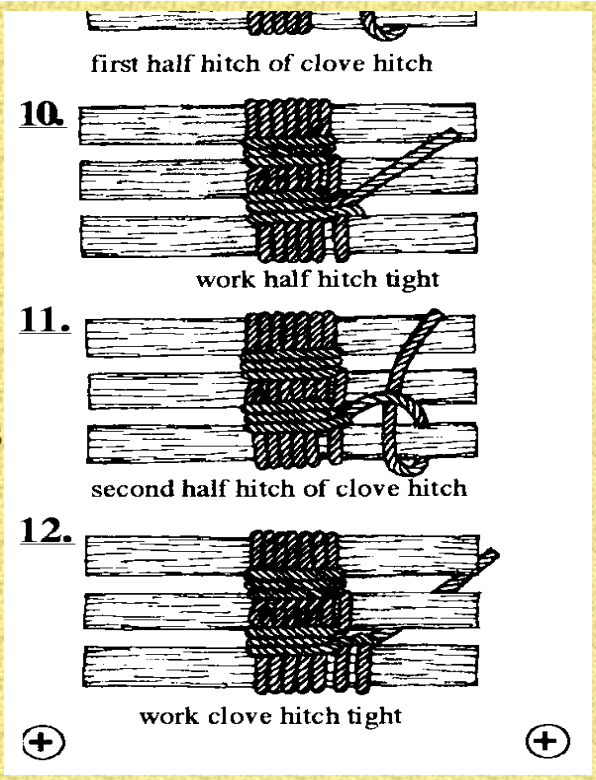

Laying Out The Poles ----

For most tripod lashings, lay the pole side by side with the butt ends aligned. The alignment of the butts of the pole insures that the tripod legs are the desired length.

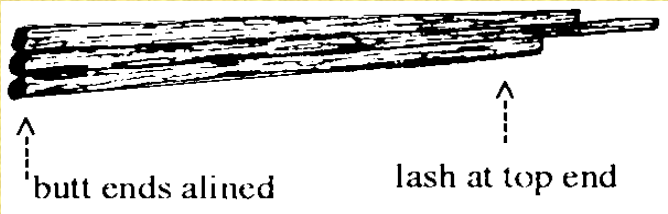

[NOTE]

The practice of laying the center pole in the opposite direction to the outside poles creates several problems. When the poles are laid in opposite directions the wrappings must be put on loosely so that when the center pole is rotated to its proper position the lashing is tightened around the poles. If the wrappings are put on to tight, the rope is stretched causing damage to the rope fibers, therefore weakening the lashing. On the other hand, if the rope is wrapped two loosely, the lashing will not tighten enough when the center pole is rotated and the lashing will be able to slip along the length of the pole. Either way, the rope to loose or the rope to tight, a dangerous situation is created.

Setting Up A Tripod -----

Set up the tripod by crossing the outside poles so that the cross point of the poles is under the center pole. Crossing the outside poles under the center pole causes part of the load that is placed on the tripod to be taken up by the wood to wood contact of the poles.

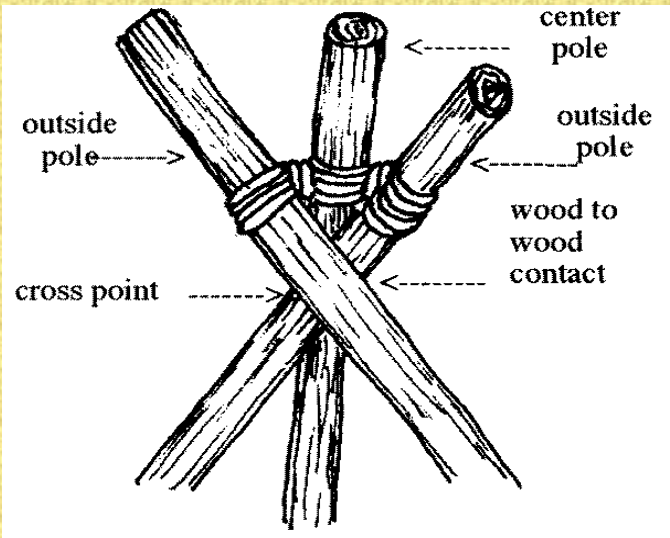

Narration ------ (For Tripod Lashing Knotboard.)

(1) Tie a clove hitch around one of the outside poles. (2) Secure the standing part by wrapping it around the running part. [NOTE] Wrapping the standing part around the running part prevents the clove hitch from slipping around the pole. If the clove hitch slips the lashing will loosen up from the inside. (3) Start the racked wrapping turns by weaving the rope between the poles. (4) Take a total of 5 to 7 wrapping turns. Pull each wrapping turn tight as it is made. [NOTE] The stiffness of the tripod lashing depends on the number and tightness of the wrapping turns. As the tightness of the wrapping turns or the number of wrapping turns increases, the stiffness of the tripod will increase. (5) Take the first frapping turn by taking the rope around the pole that the clove hitch was tied to, then between the outside pole and the center pole. (6) Take 3 frapping turns. Pull each frapping turn tight as it is made. (7) Start the second set of frapping turns by taking the rope across the center pole and reeving it between the second outside pole and the center pole. Take the second set of frapping turns in the opposite direction to the first set of frapping turns. [NOTE] Taking the second set of frapping turns in the opposite direction to the first set of frapping turns prevents the rope from crossing the wrappings at a diagonal. Unnecessary crossing of the rope increases friction between the strands of the rope making it difficult to tighten the lashing properly. (8) Take a total of 3 frapping turns. Pull each turn tight. (9) Take the first half hitch of the ending clove hitch around the second outside pole by taking the rope past the pole and then around the pole. (10) Work the half hitch tight so that it is locked against the lashing. [NOTE] See the narration for square lashing for instructions on working the half hitch tight. (11) Take the second half hitch of the ending clove hitch. (12) Work the half hitch tight to complete the ending clove hitch. [NOTE] If the clove hitch is not worked tight so that it is locked against the lashing the clove hitch will slip around the pole allowing the lashing to loosen. [NOTE] If very smooth rope is being used, a 3rd half hitch should be added to the clove hitch to insure that the lashing will stay in place.

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

SHEET BEND:

Description ----

An interlocked bight and half hitch.

Use ----

To temporarily join two ropes, especially if the ropes are of different sizes.

Comments ----

The sheet bend is a secure but easily untied knot. ---- When tying the sheet bend the running parts should be left long because there is some initial slip in the knot when the knot is first brought under tension. ---- The proper and more secure way to tie the sheet bend is so that the two end the rope are on the same side of the knot.

Other Names ----

Weavers knot

Related Knots ----

Bowline; becket hitch; these knots share the same form but are tied in a different way or have a different use.

Narrative ---- (For sheet bend knotboard.)

(1) Form a bight in the running part of the

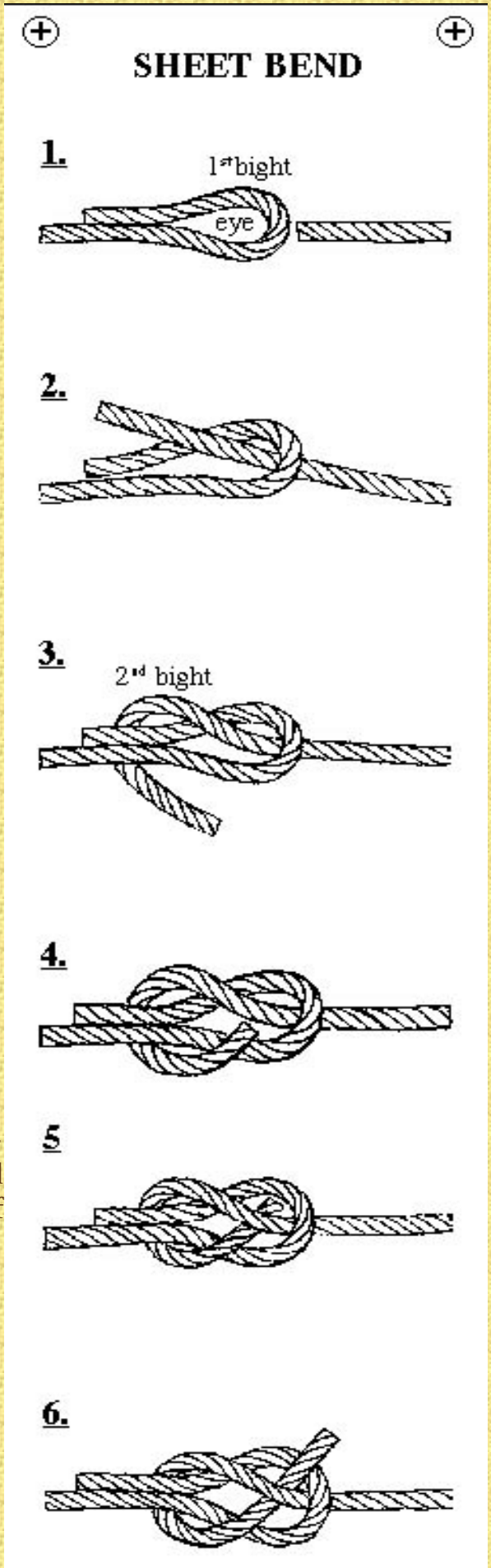

left-hand rope. (2) Reeve the running part of the right-hand rope through the eye of the bight in the left-hand rope. (3) With the right-hand running part take a bight around the running part and the standing part of the left-hand rope. (4) Pass the right-hand running part over the left-hand standing part, (5) under the right-hand rope, and (6) over the standing part of the left-hand rope. (7) Pull tight.

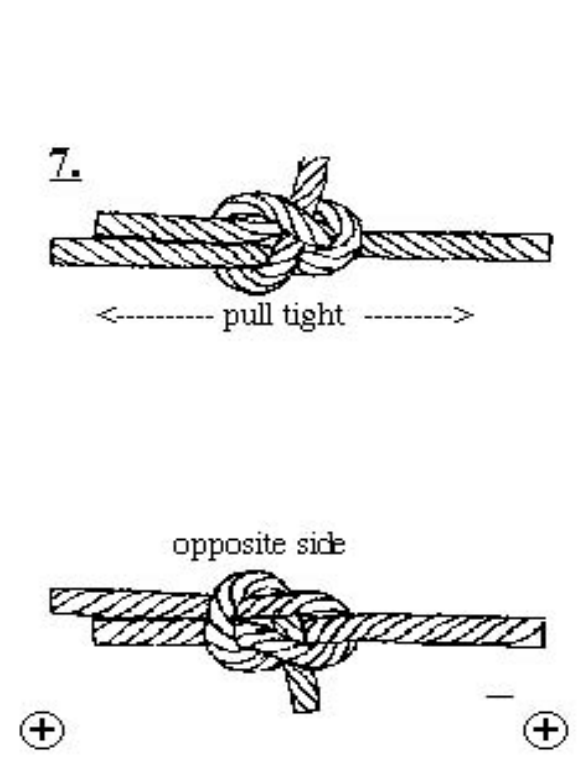

ANNIMATED KNOT

SHEET BEND

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Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

MASTHEAD KNOT:

Description ----

A multiple loop knot formed by reeving the loosely made loops of two over hand knots through each other and then securing the knot to a mast (pole).

Use ----

On board ship, a masthead knot was used to rig a temporary mast if the mast was lost in battle or during a storm. On land a masthead knot can be used to rig a gin pole or a flag pole.

Comments ----

There are several forms of the Masthead Knot. This form of the Masthead Knot was chosen for its symmetry and the ease of transition to the running half hitches used to secure it to the pole.

Other Names ----

Jury mast knot, pitcher knot.

Narrative ---- (For masthead knot knotboard.)

(1) Loosely tie two over hand knots. (2) Place the loop of one overhand knot on top of the loop of the loop of the other over hand knot. (3&4) Reeve the

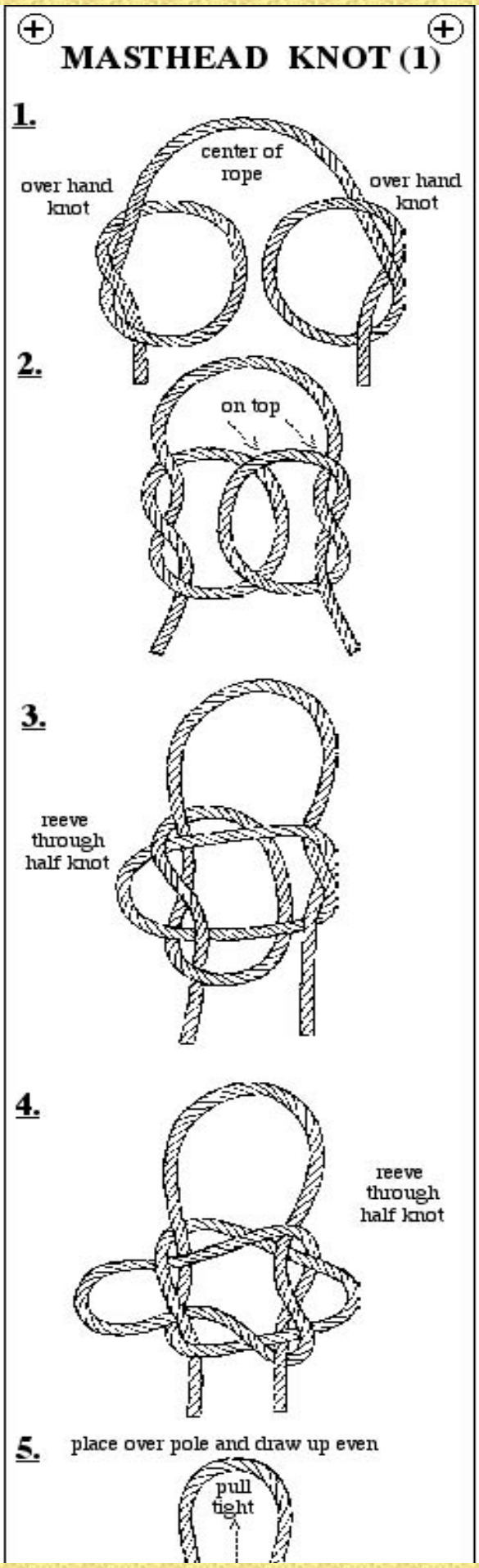

loops of the overhand knot through the half knot part of the opposite overhand knot. (5) Place over a pole and draw the three loops up even. (6) Secure to the pole with a series of running half hitches above and below the mast head knot.

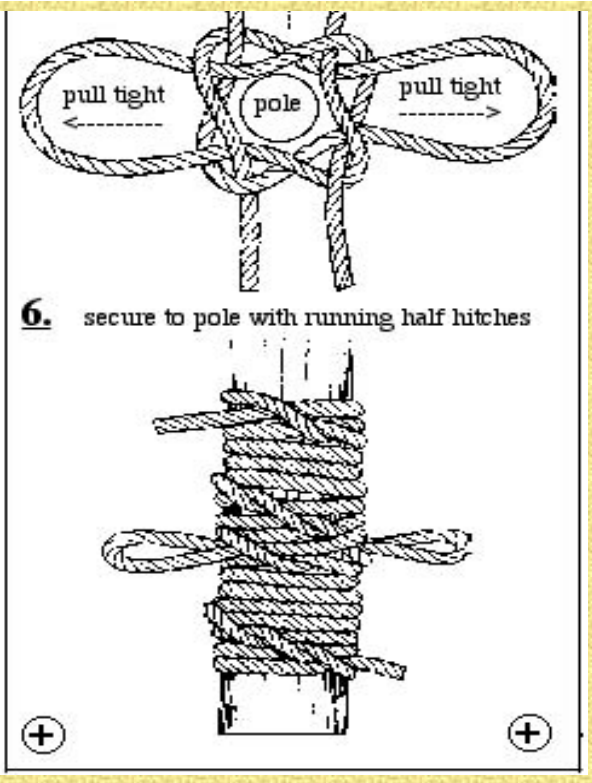

[NOTE]

A forth loop my be formed by tying or splicing the ends together. If a fourth loop is made, nail a cleats to the pole to prevent the mast head knot from slipping.

[NOTE]

Attach the guy lines to the loops with becket hitches.

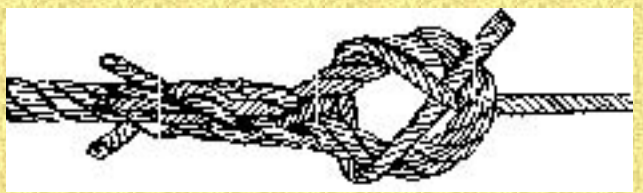

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Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

FLOOR LASHING:

Use ----

to lash a series of poles to a set of stringers to form a flat surface such as a deck, a table top, or a road way.

Comments ----

When using a floor lashing, both ends of the decking poles must be lashed at the same tine to insure a firm even surface.

When placing the decking poles on the stringers, lay the decking poles so that their butt end are in alternating direction. Alternating the but ends of the decking poles will compensate for the natural taper of the poles so that the length of the decking along each stringer will be equal.

Narrative ---- (For floor lashing knotboard)

(1) Tie a clove hitch around each stringer. (2) Secure the short end of the rope by wrapping it around the running end (wrap with the lay of the rope). (3) Place the decking poles on the stringers and take a bight around the first pole. (4) Next, on the inside of the stringer, pull a bight up between the first decking pole and the next decking pole. (5) Place the eye of

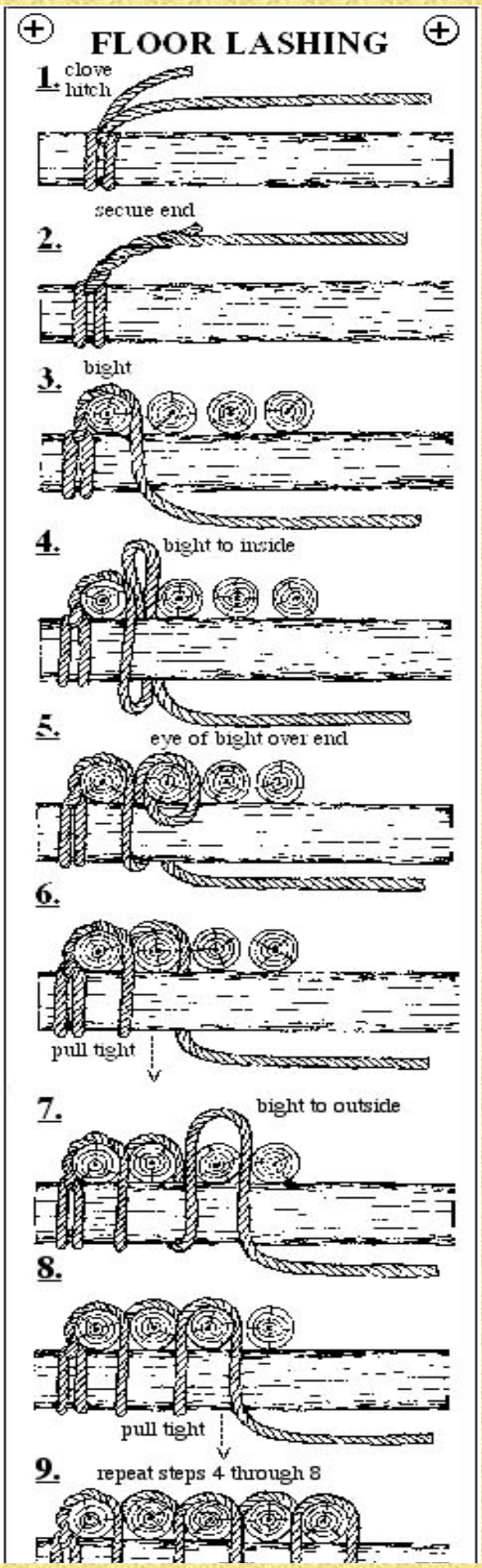

the bight over the end of the decking pole. (6) Pull tight. (7) On the outside of the stringer, place a bight over the next decking pole. (8) Pull tight. (9) Repeat steps 4 through 8 until all decking poles are lashed in place. (10) Tie the first half hitch of the ending clove hitch. Work half hitch tight. (11) Tie the second half hitch of the ending clove hitch. Work half hitch tight (12) to form clove hitch.

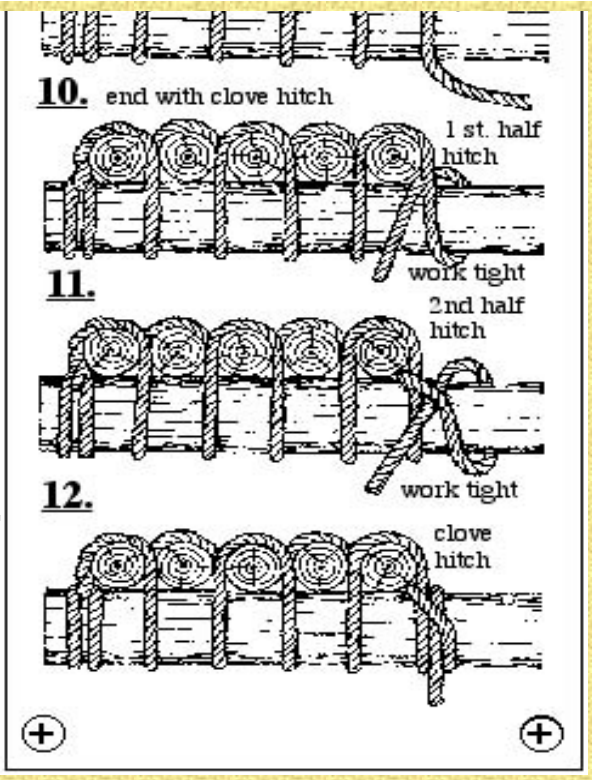

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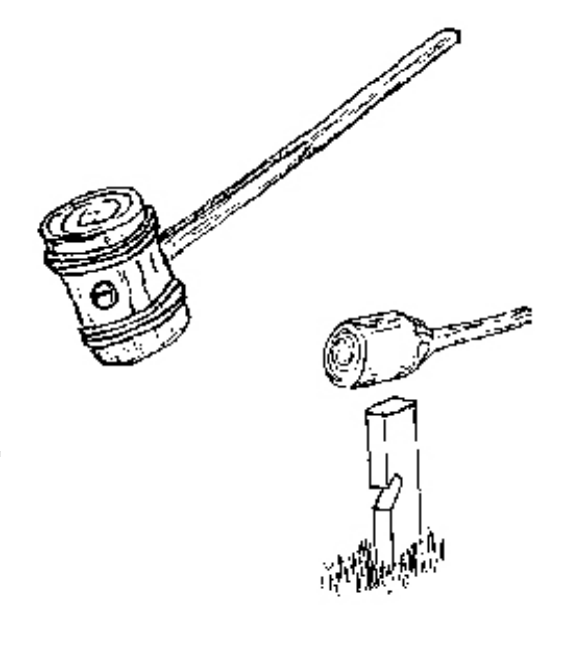

ARTICLE OF THE MONTH

Each month there will be article on this page.

THIS MONTH'S IS THE :

MAULS:

A maul is a wooden club or hammer that is used for driving stakes or wedges and for safety reasons should be used instead of an ax.
Using an ax instead of a maul exposes the user to the danger of being cut by its sharp edge. Even if the edge is covered by a sheath, a glancing blow can cause the sheath to be ripped off or to be cut through.
The pole of an ax serves as a counterweight to the blade. This counterweight adds to the balance of the ax head and helps to control and increase the force of momentum delivered to the bit. The ax head is shaped in such a way that the momentum of the ax head is delivered through the thin walls of the eye. However, when an ax is being used as a hammer, this same shape causes the eye of the ax head to spread and the handle to loosen.
The flat surface and angular edges of an ax pole makes it difficult to strike a stake squarely. This difficulty in striking a square blow results in most blows delivering some there force sideways, causing the end of the wooden stake to flare and split very quickly. In addition, when the pole of an ax contacts a stake, the metal surface of the pole lacks the ability absorb any of the force of the impact this contributes to the destruction of the stake. A wooden maul, on the other hand, absorbs some of the impact of the initial contact and a maul has no angular edges. Therefore, more of the force of the maul is used to do useful work and less of the force is used up in deforming or splitting the stake.

FOR MORE INFORMATIOM GO TO "MAULS"

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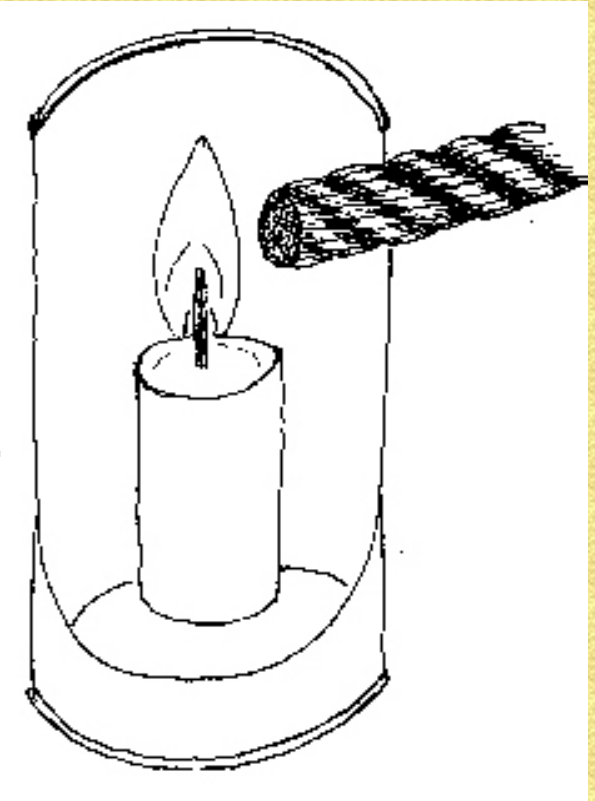

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Each month there will be an article on this page.

THIS MONTH'S IS THE :

FUSIING:

Use ----

To prevent a rope from fraying.

Comments ----

The ends of a synthetic rope can be fused to prevent the rope from fraying. This is done by heating the end of the rope so that the ends of the rope fibers melt together.

The fusing can be done by holding the end of the rope to the side of a candle or other small flame. If the end of the rope is placed in the flame or held too close to the flame, the plastic will ignite causing the end of the rope to turn black. Burning plastic can also give off toxic fumes . If the end of the rope is held above the flame, unburned carbon particle will be deposited on the melted plastic causing it to turn black. A candle flame will generate enough heat to fuse the end of a rope up to about one inch in diameter. If the rope is larger than one inch, a propane torch will work better .

FOR MORE INFORMATIOM GO TO "FUSING"

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Each month there will be article on this page.

THIS MONTH'S IS THE :

TAUT-LINE HITCH:

Description ----

Two half hitches with an extra turn.

Use ----

To adjust the tension on guy lines.

FOR MORE INFORMATIOM GO TO "TAUT-LINE"

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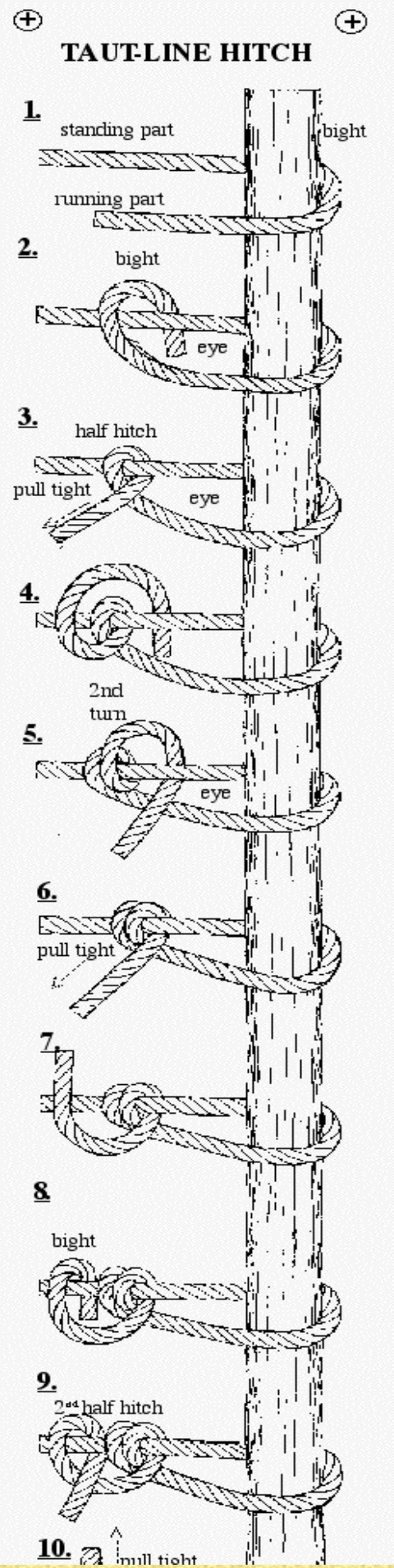

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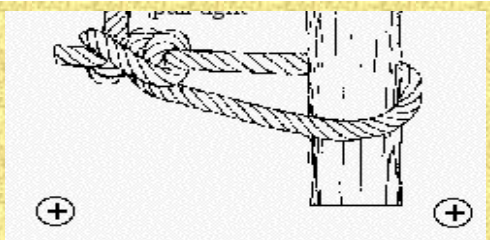

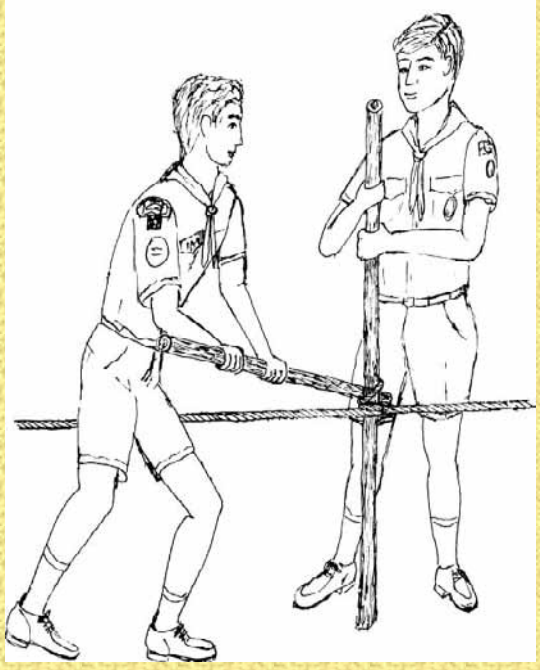

ARTICLE OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

SPANISH WINDLESS:

Description ----

A Spanish windless is a device for moving heavy loads such as rocks and logs.

[WARNING]

When setting up a Spanish Windless do not use nylon or other synthetic fiber ropes that stretch under a load. If you slip or let go of the poles the energy you used to stretch the rope will be released as the rope returns to its original length. This release of energy could cause the poles of the windless to spin around causing injuries to any one near by. Natural fiber ropes, such as sisal, have little stretch; therefore are much safer to use.

MATERIALS:

1 - 8 foot * 3 inch pole
1 - 5 foot * 3 inch pole
1 - 3/4 inch * 50 foot (natural fiber)

SETUP:

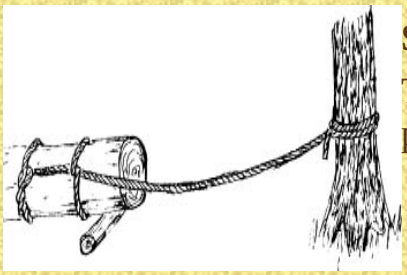

STEP 1:

Tie one end of the rope to the load and the other end to a secure anchor point. Leave some slack in the rope so that the windless can be rigged.

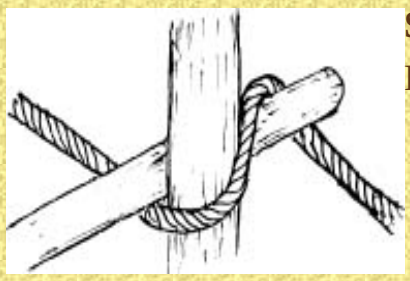

STEP 2:

Follow the diagrams to set up the poles at the mid point of the rope.

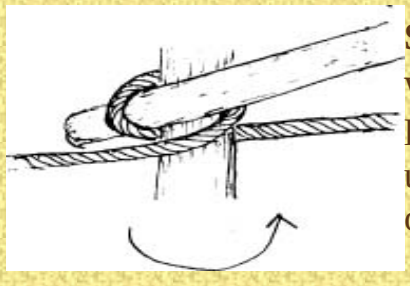

STEP 3:

While one person holds the up right pole, a second person rotates the longer pole around the upright so that the rope begins to wrap around the upright pole. Adjust the height of the rope so that it can be easily stepped over.

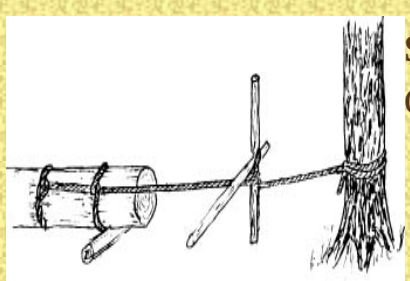

STEP 4:

Continue to rotate the longer pole around the upright.

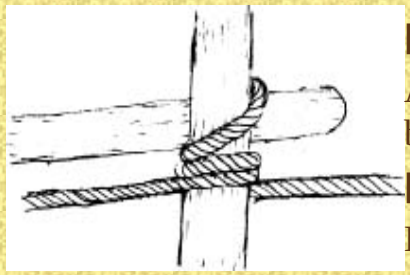

[NOTE]:

As the rope wraps around the upright it will be necessary to move the base of the upright to keep it vertical.

[NOTE]:

Be careful that the two ends of the rope are kept at the same level on the upright.

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Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

ROPE HALTER

Start with an eye splice.
(The Eye splice will form one end of the nose piece of the halter)

Decide how long the nose piece must be then tie a quick eye into the rope.

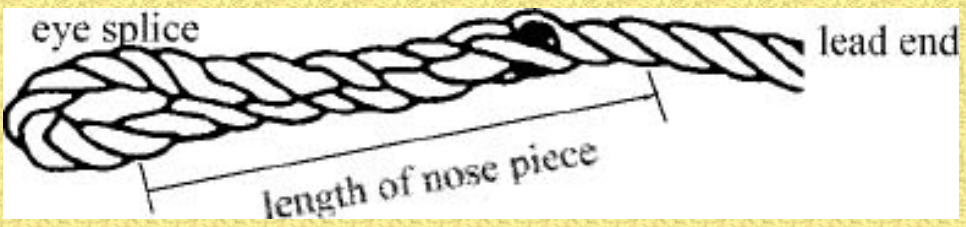

Quick Eye STEP1

Decide where the quick eye must be. Then reeve the lead end through the lay of the rope as shown. (Slightly larger than the diameter of the rope)

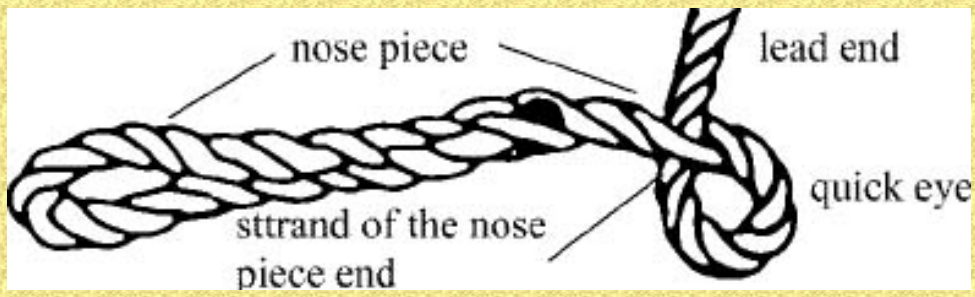

Quick Eye STEP 2

Observe which strand of the lead end is directly under the strand of the nose piece end. Reeve the eye splice under that strand.

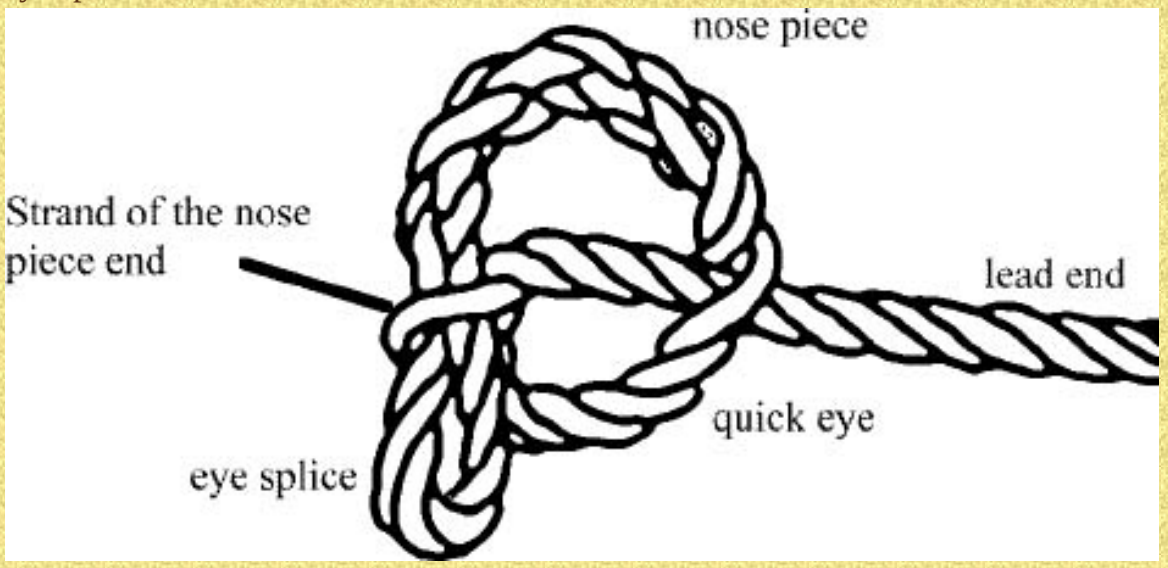

Quick Eye STEP 3

Work the eye into shape. (Do not just pull on the ends this will distort the eye.) When the eye is in shape, the strands of the rope should lay even showing little or no distortion.

Finnish the halter by reeving the lead end through the two eyes as shown.

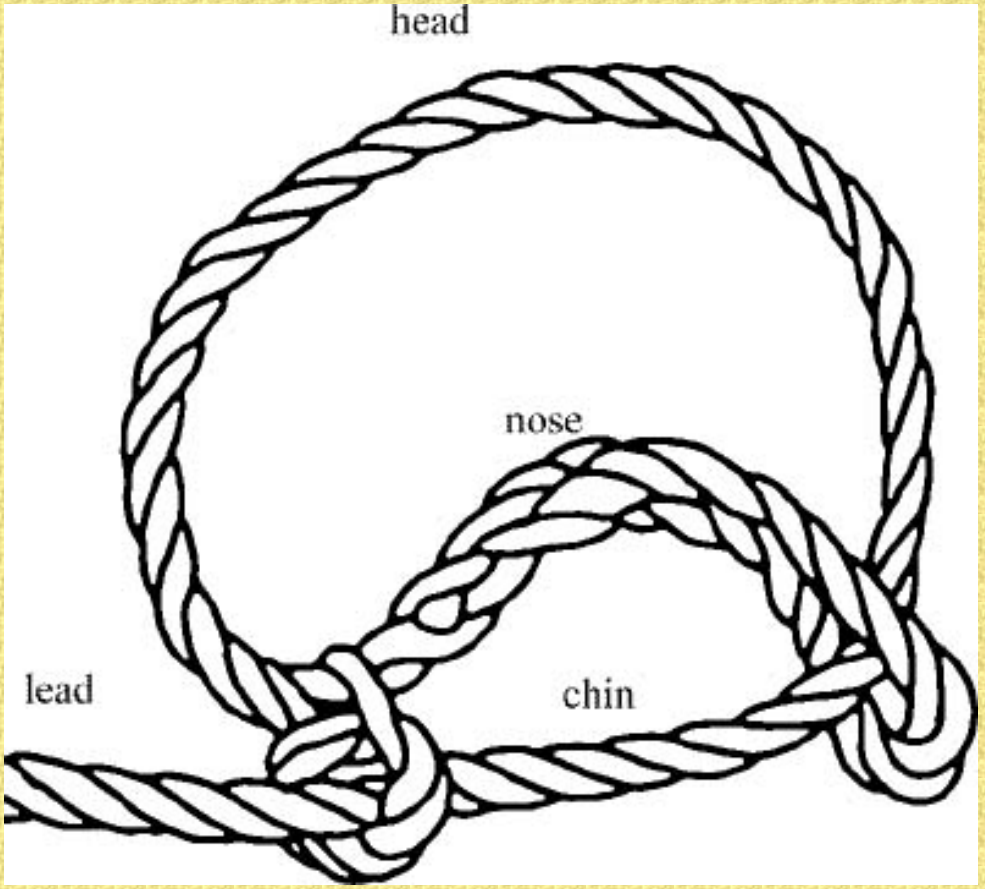

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LADDER LASHING:

Comments:

Ladder lashing allows for a quick and secure method for constructing a ladder or for constructing a decking with evenly space decking pieces.

This form of lashing has several advantages over the traditional floor lashing. Less material is required because unlike floor lashing a space can be left between each piece of the decking. Also, each rung is securely lashed in place by several loops of rope in much the same way as a square lashing; with the traditional floor lashing only a single loop of the rope holds each end of the decking in place, therefore if one piece loosens, the entire deck loosens.

The ladder lashing has two forms; left and right, each is a mirror image of the other.

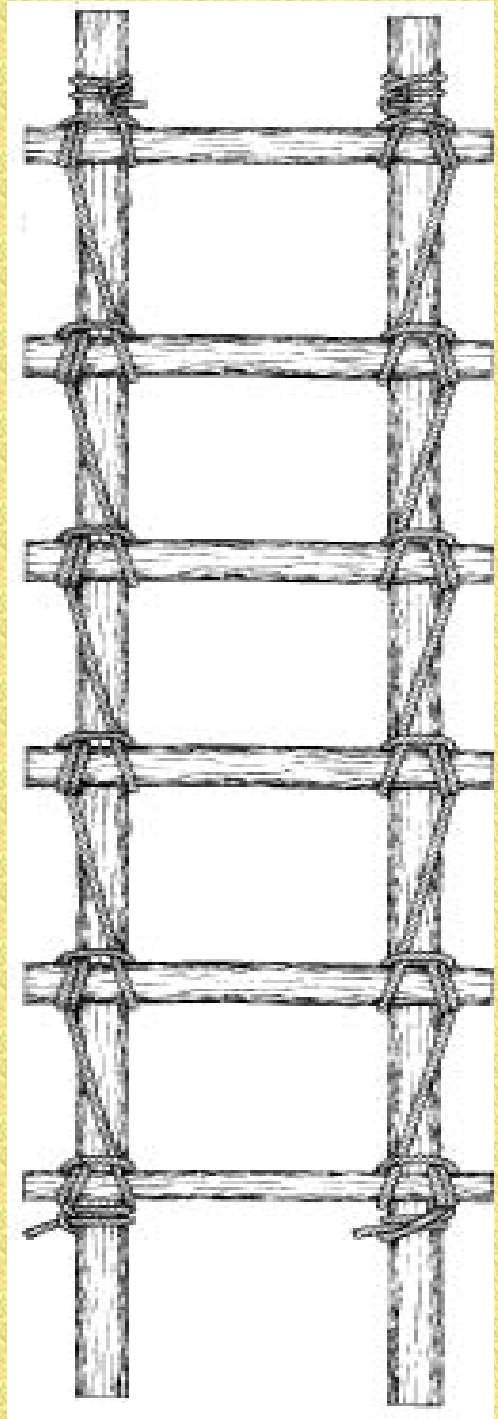

START: The ladder lashing is started by using a clove hitch stopped with two half hitches to secure a rope to the top end of each rail.

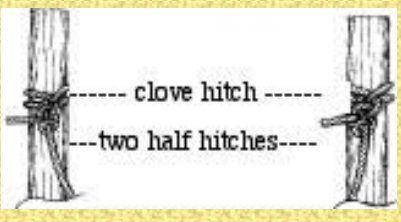

STEP 1: Lay an overhand loop over each side rail so that the running end of each loop is to the outside.

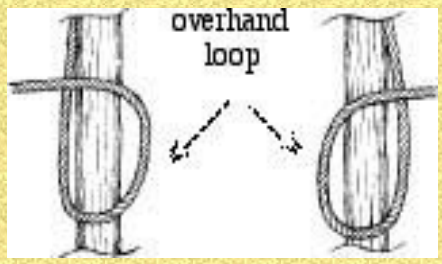

STEP 2: Place a rung across the rails so that the standing part of each overhand loop is over the end of the rung and the running part of each overhand loop is under the rung.

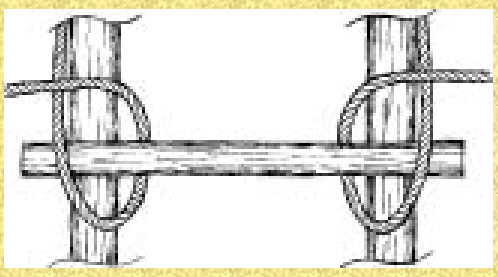

STEP 3: Pull the running part side of each overhand loop behind and to the outside of each rail.

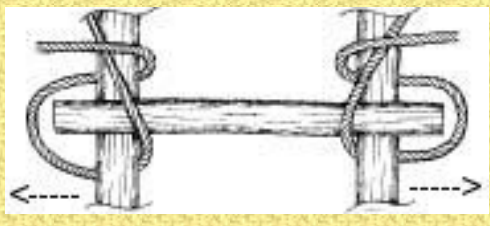

STEP 4: Then pull the loop over the end of the rung.

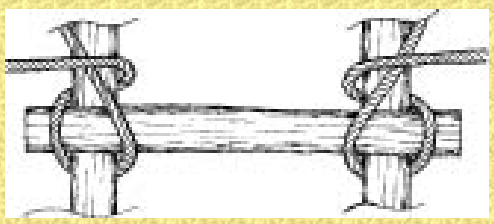

STEP 5: Work each rope until it is tightened around the rung and the rung is in its desired position.

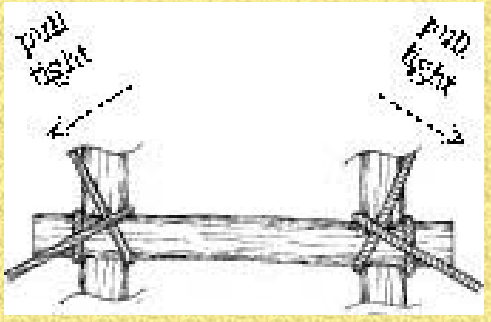

STEP 6: Form an overhand loop in each running part.

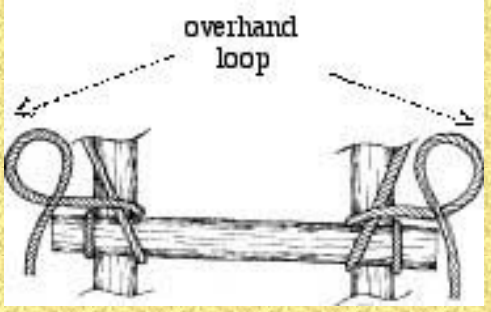

STEP 7: Place an overhand loop over each end of the rung to form a half hitch around each end of the rung.

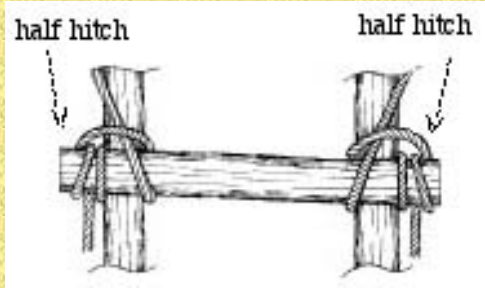

STEP 8: Work the half hitch tight.

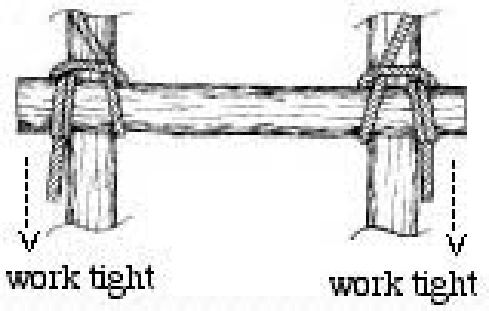

STEP 9: Repeat steps 1 through 8 for each additional rung.

END: Finnish the lashing by tying a clove hitch around each rail so that the clove hitch is directly under the bottom rung.

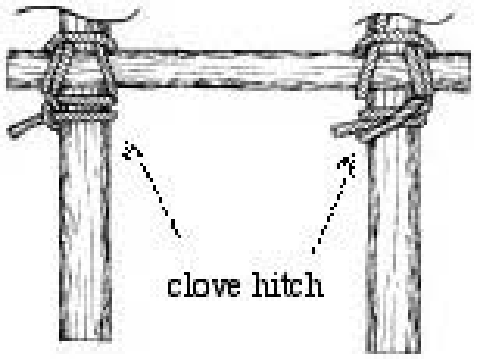

Quick Eye STEP 3

Work the eye into shape. (Do not just pull on the ends this will distort the eye.) When the eye is in shape, the strands of the rope should lay even showing little or no distortion.

Finnish the halter by reeving the lead end through the two eyes as shown.

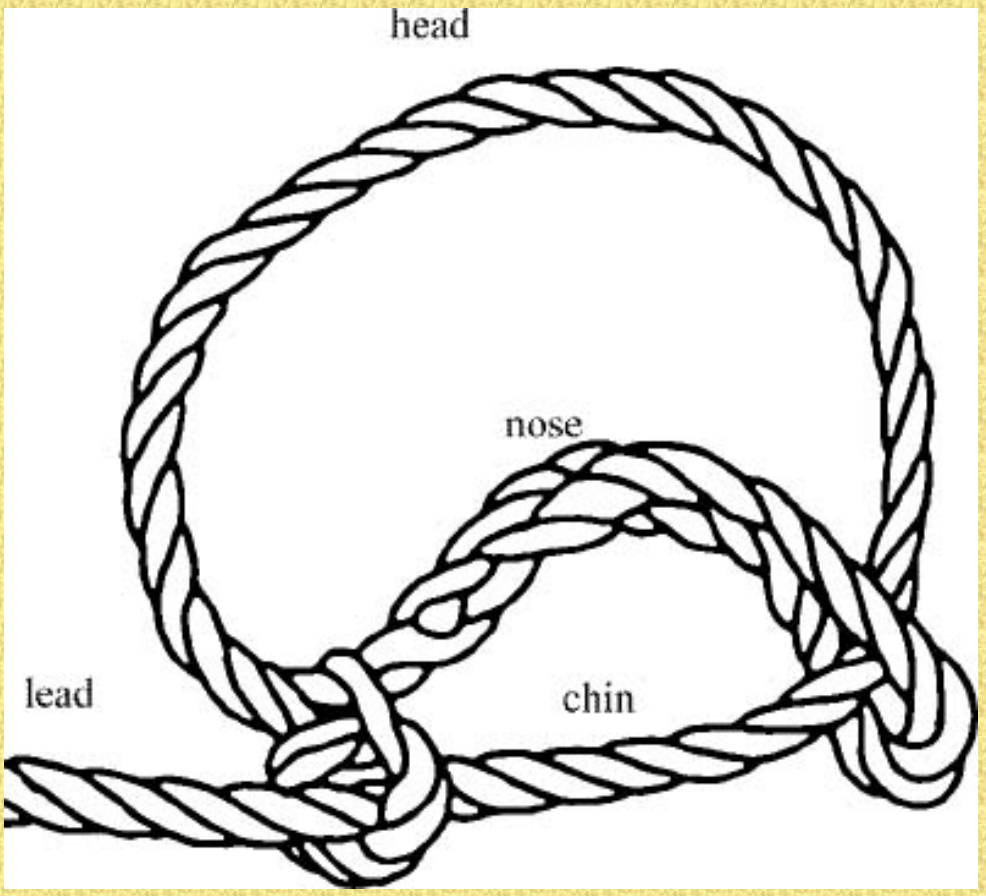

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SEIZING:

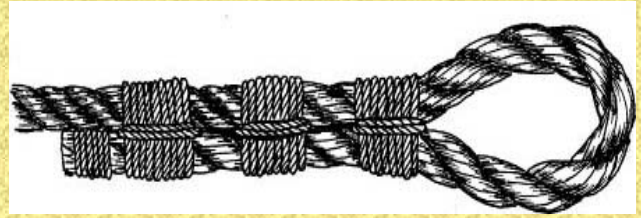

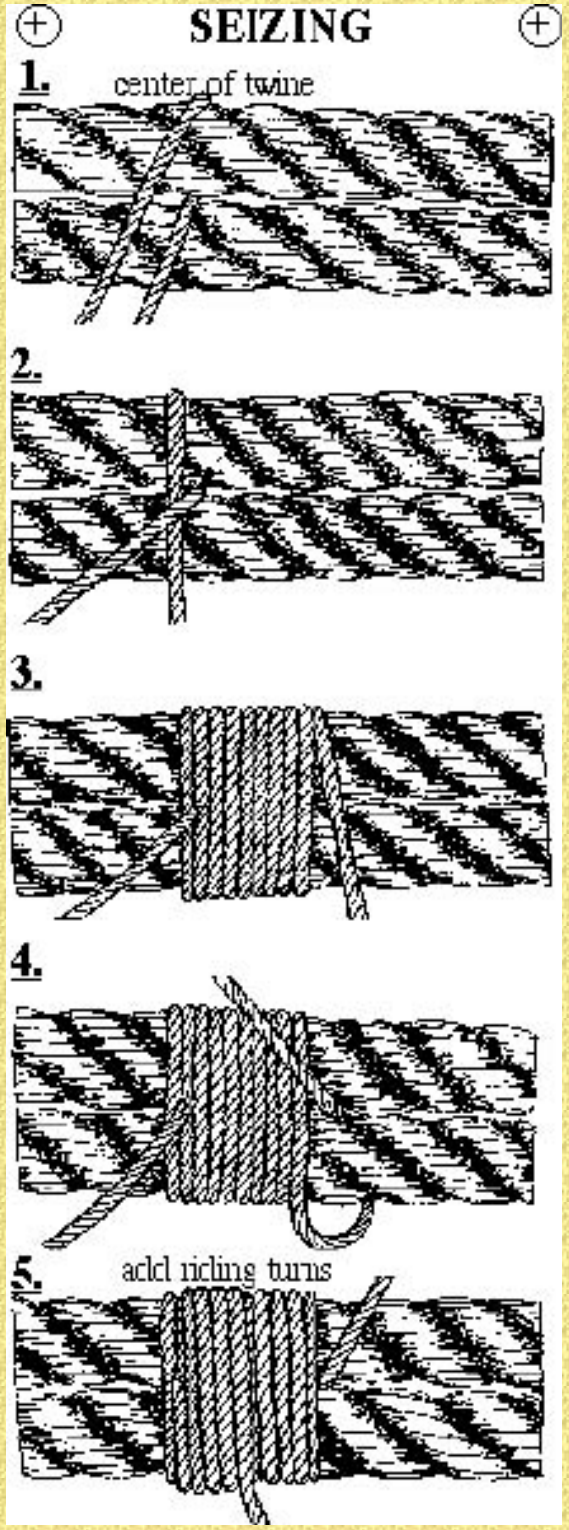

Use ---- To bind ropes together or to bind a rope to an object. Sometimes used to bind the running end of a rope to the standing end of the rope to prevent a knot from spilling.

Comments ---- Seizings do not use as much material and are not as bulky as a knot or a splice; nor does the seizing damage the fiber of the rope. The fibers of a rope do not need to be bent or separated to be seized as they do when a knot is being tied or a splice worked. If the seizing is no longer needed, the seizing can be cut away and the rope is undamaged.

The seizings shown here can be worked with out the use of a needle. However there are many forms of seizing that require the use of a needle to apply them to a rope.

To form an eye, 3 to 4 seizing should be used. This ensures that the eye will safely remain in place even if one of the seizings is damaged.

If there is additional strain on the ropes,

such as at the first seizing of an eye, racked turns should be used.

Materials ---- The diameter of the "twine" that is being used to do the seizing should be 1/8 to 1/12 the diameter of the rope being seized. The length of the "twine" should be about 3 feet for each 1 inch of diameter of the rope.

Narration ---- (For **seizing** knotboard.) **(1)** Fold a piece of twine in half over one strand of the rope. **(2)** Start the first layer of wrapping turns by laying the end of the twine that is between

---

the ropes over the other end. **(3)** Wrap the outside strand around the ropes so that so that the wrapping turns are parallel to each other; pull each wrapping turn tight. **(4)** When the width of the wrapping is equal to the diameter of the rope, end the first layer of wrapping turns by reeving the twine between the ropes; pull tight. **(5)** Add a layer of riding turns; the riding turns are laid in the grove between the wrapping turns and pulled tight but not so tight as to separate the wrapping turns of the first layer. **(6)** When the riding turns have been completed, end the riding turns by reeving the end of the twine between the ropes so that it is in the opposite direction to the other end of the twine. **(7)** Add frapping turns; reeve the end of the twine between the ropes at the other end of the wrappings; pull tight. **(8)** Use a square knot to end the frapping turns: reeve the ends of the twine between the

ropes again; tie a half knot; pull the half knot and the frapping turns tight. **(9)** Reeve the ends of the twine between the ropes again; tie the second half knot of the square knot. **(10)** Pull the second half knot tight so that the square knot is between the strands of the rope. Cut of the ends of the twine.

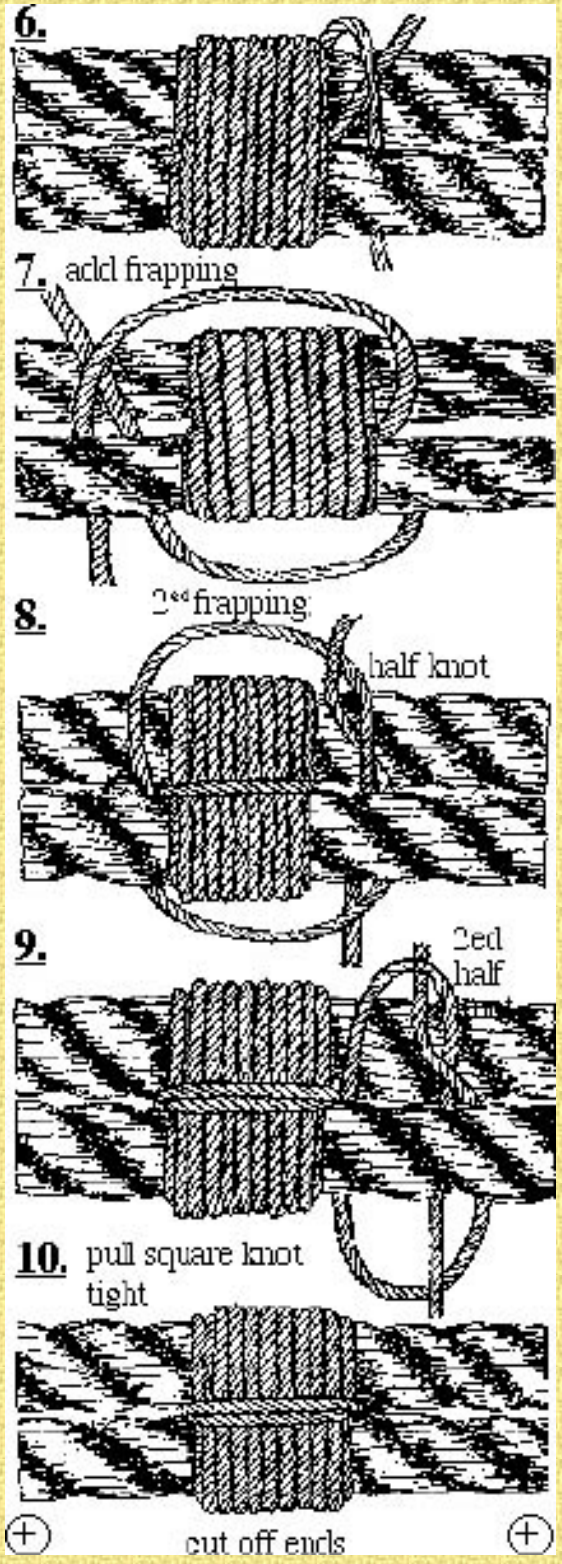

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FIDS:

A fid is a tool that is used to open the lay of a rope when working a splice or to loosen knots.

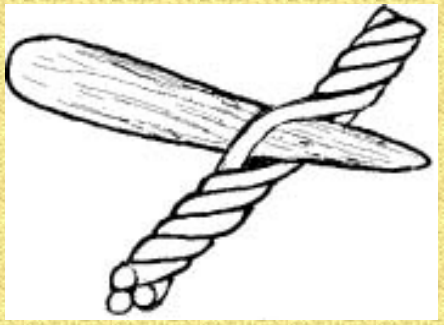

MAKING A WOODEN FID:

Split out an 8 inch by 3/4 inch piece of close grained, smooth, hardwood. Carve and smooth the piece to the shape shown in the diagram.

MAKING METAL FIDS:

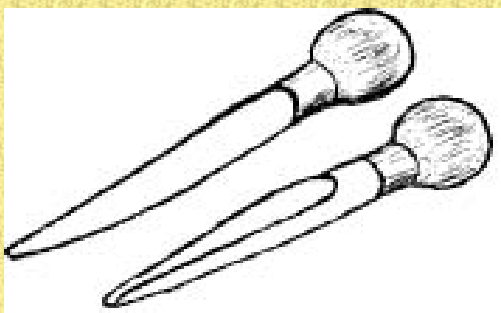

Materials:

1 --- 8 inch * 1/2 inch copper tubing or steel electrical conduit.

2 --- 1 inch diameter * 3 inch long piece of smooth grained hardwood.

2 --- 4D finishing nails.

Construction:

Cut the tubing diagonally into two pieces as shown in the diagram (Use a hacksaw).

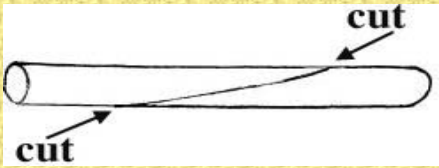

Making a Closed Fid:

STEP 1: Use a triangular file to enlarge the diagonal opening in one of the halves of the tubing. File the opening to the shape indicated by the dotted lines in the diagram.

STEP 2: Close the diagonal opening. Using light taps with a hammer gently roll the two edges toward each other to form the tubing into a cone. (When the two edges of the opening meet the seam in the tubing should be straight).

STEP 3: Solder the edges of the opening together.

3A] Clean the edges of the opening with steel wool.

3B] Spread soldering paste along the cleaned edges.

3C] Solder the seam. Use a propane torch to apply heat to the side of the fid that is opposite the seam. (Heating the tube from the opposite side, will ensures that metal is heated all the way through so that the solder will flow into the seam and not just spread out on the surface.) As you heat the tubing test the seam for the proper temperature by touching the solder to the seam. When the solder starts to melt and flow into the seam, move the solder along the seam until the entire seam is filled with solder.

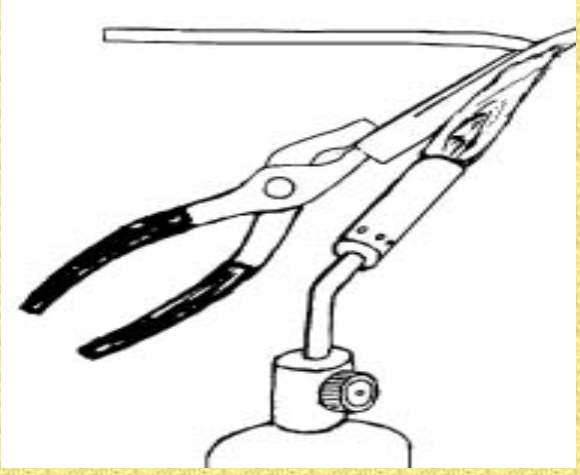

STEP 4: Cleanup the seam with steel-wool and a file. Make sure that there are no sharp edges to catch or cut the rope fibers when the fid is being used.

Making an Open Fid:

STEP 1: Enlarge the diagonal opening of the other piece of tubing by setting the tubing on end and forcing a rod into the opening. When the rod is forced into the opening, the cross section of the tubing should become "U" shaped.

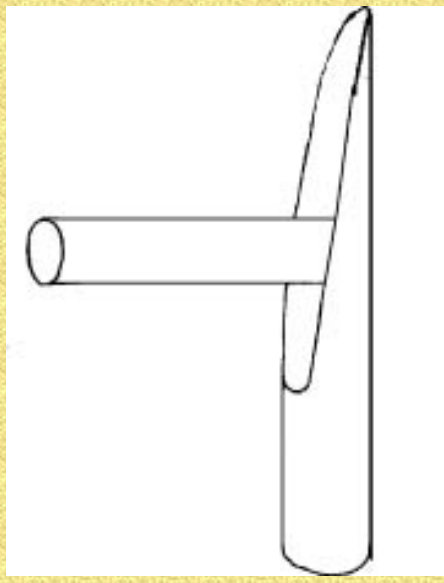

STEP 2: With a round file, enlarge the diagonal opening to the shape shown by the dotted line.

STEP 3: Smooth all rough and sharp edges with a file and steel-wool.

STEP 4: Gently tap the edges of the opening toward each other so that a cross section anywhere along its entire length will be "U" shaped.

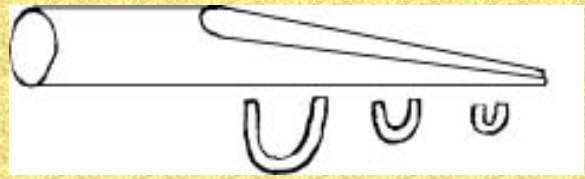

Making Handles For Fids:

STEP 1: Carve one end of a 1 inch diameter * 3 inch long piece of wood so that it will fit snugly into the end of the fid.

STEP 2: Attach handle to fid.

2A] Drill a small hole into the side of the fid about 1/2 inch from the end.

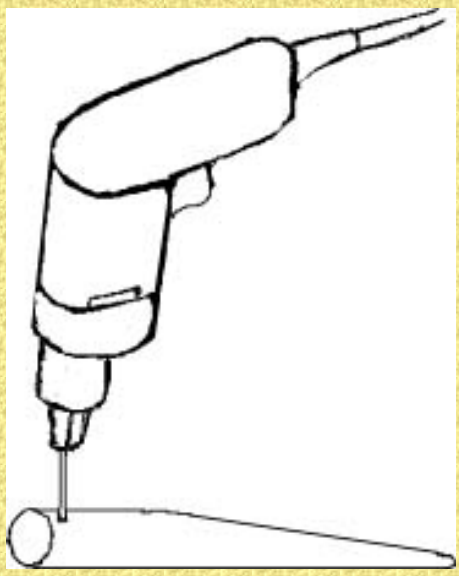

2B] Insert the handle into the end of the fid. Then drive a finishing nail through the hole into the wood of the handle.

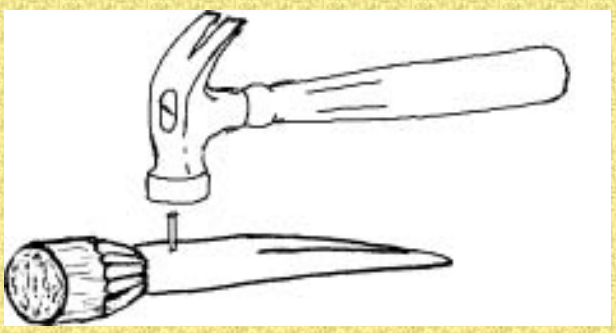

2C] Cut the nail off close to the side of the fid. Then file the nail down so that it is smooth and even with the surface.

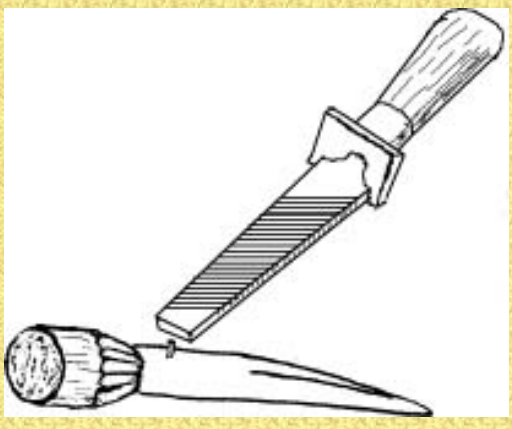

STEP 3: Finish the handle. Here is a chance to be creative. You can carve a simple rounded handle or let your imagination take over.

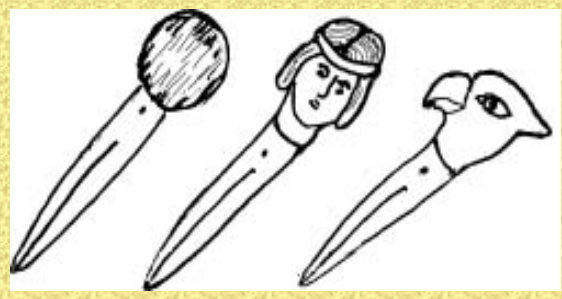

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MARLIN SPIKE HITCH:

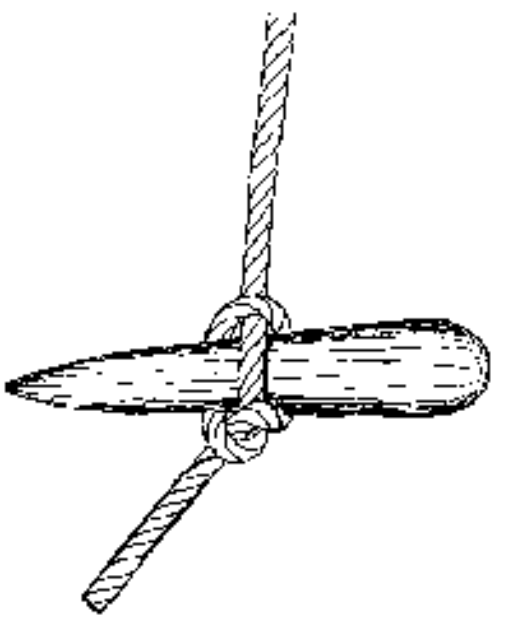

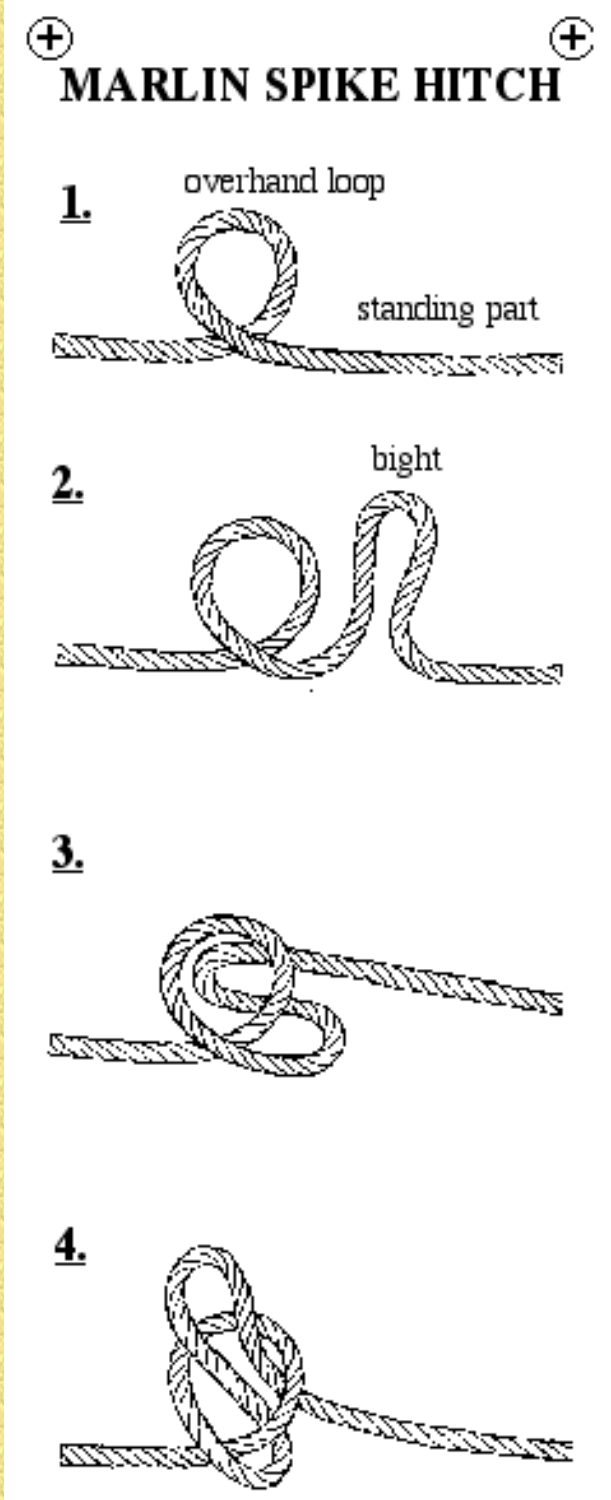

Description A loop formed by a half hitch around a bight in the standing part of the rope.

Use To temporarily hold a toggle (a Marlin Spike) so that a rope can be pulled tight; as a mooring hitch that can be dropped over the end of a stake or pole; to hold the rungs of a rope ladder.

Comments A secure temporary hitch that can be easily spilled by removing the toggle. The Marlin Spike Hitch gets it name from the practice of using it around a Marlin Spike or similar tool to tighten knots and servicing,

Other Names Slip Noose; especially when the half hitch is pulled closed around the bight.

Narrative ---- (For **marlin spike** knotboard) **(1)** Form an overhand loop. **(2)**

Then form a bight in the standing part. **(3)** Place the bight under the overhand loop. **(4)** Then reeve the bight through the underhand loop. **(5)** Pass a toggle

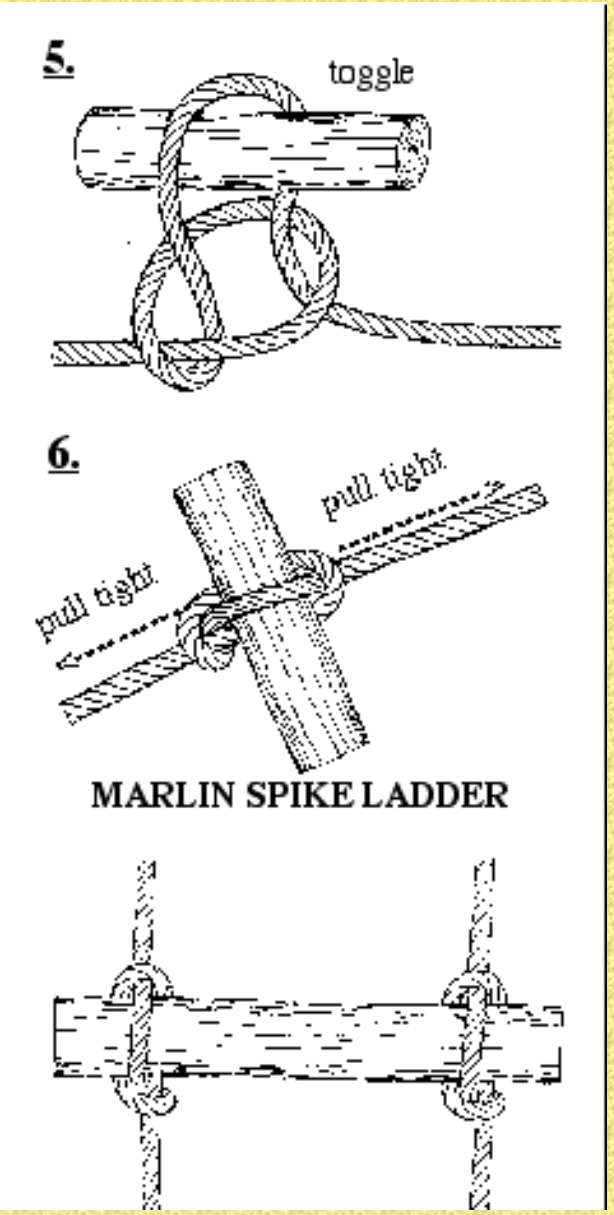

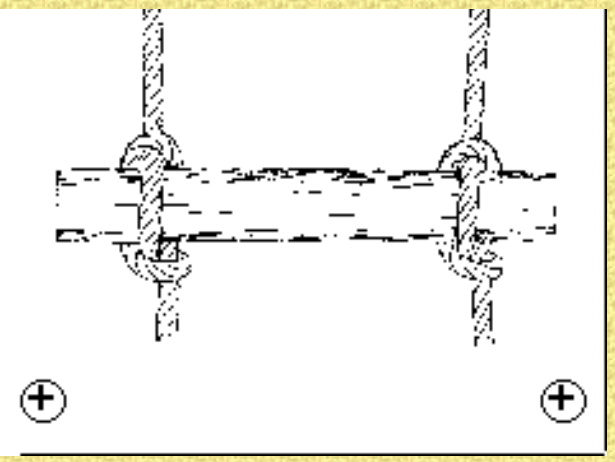

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FOOTROPE KNOT

Description: a three strand knot that looks somewhat like a turk's head knot.

Comments: This knot was tied in the "footrope" (the rope that was tied under the yard arm for the sailors to stand on when they were setting the sails) to prevent the sailors' feet from slipping along the footrope.

Use: as a stopper knot in the end of a rope.

STEP 1: Unlay 4 to 5 turns of the lay.

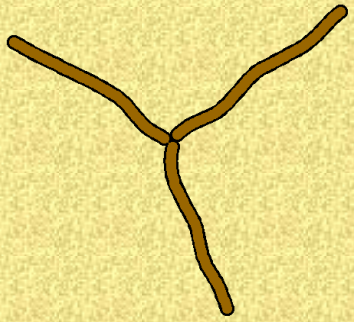

STEP 2: Tie a loose crown knot.

STEP 3:

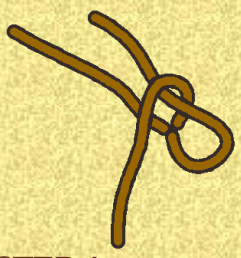

STEP 4:

STEP 5:

STEP 6:

STEP 7: Tie a wall knot under the crown knot but tuck the strands up through the center of the crown knot.

STEP 8:

STEP 9:

STEP 10:

STEP 11:

STEP 12:

STEP 13: Work tight and finish by combing out the fibers to form a tassel of relay the strand and whip the end of the rope.

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Each month there will be new knotboard and descriptive text displayed on this page.

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CAMP STOOL:

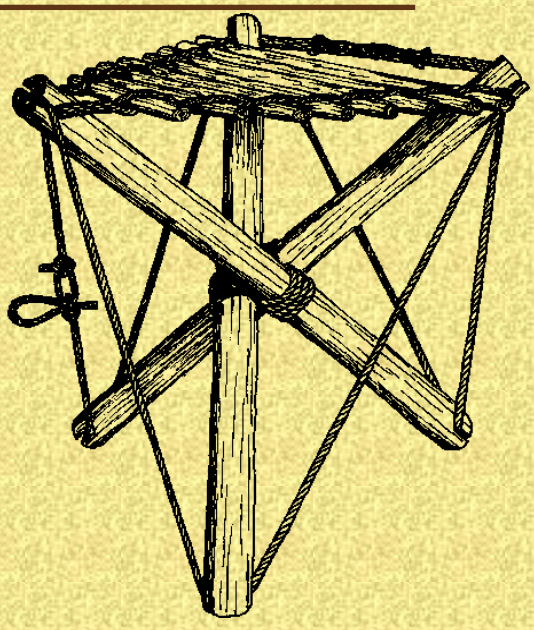

MATERIALS:

3 --- 2 Foot * 2 inch poles

20 --- 1/2 inch diameter sticks (various lengths)

1 --- 3/8 inch * 5 foot rope

1 --- 1/4 inch * 12foot rope

CONSTRUCTION:

STEP 1: Cut a grove 1 inch deep and 3/8 inch wide in each end of the 2 foot poles. Be sure that the groves are in the same direction.

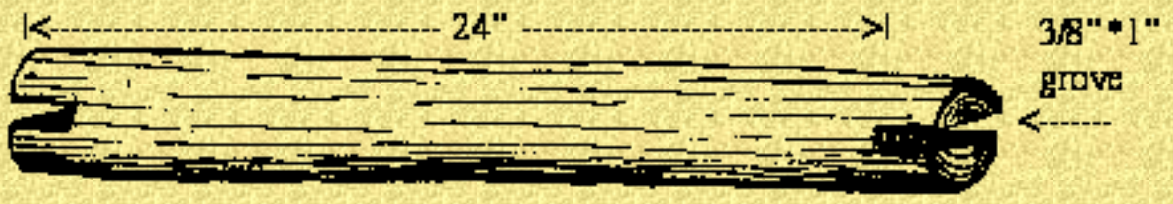

STEP 2: Lash the 2 foot pole together at their centers with the 1/4 inch * 12 foot rope. Use the **equal shear tripod lash** shown here.

2A] Tie a clove hitch around one of the poles; secure the end by wrapping it around the standing end.

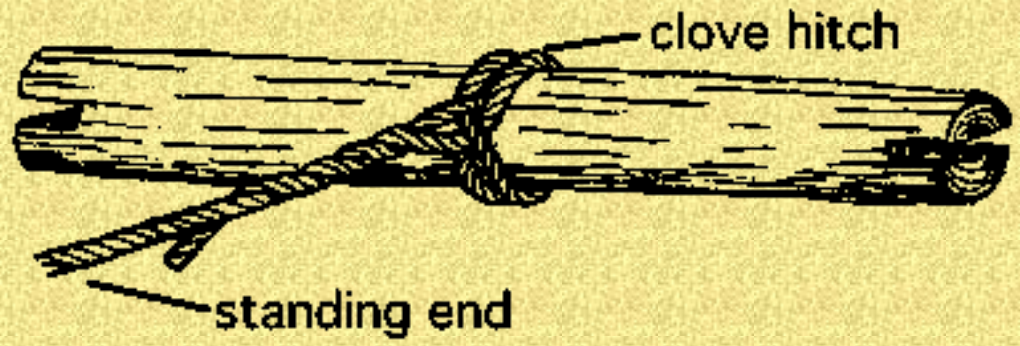

2B] Take 4 wraps around the 3 poles; follow the pattern shown for each wrap.

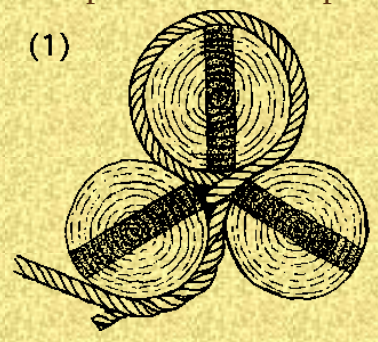

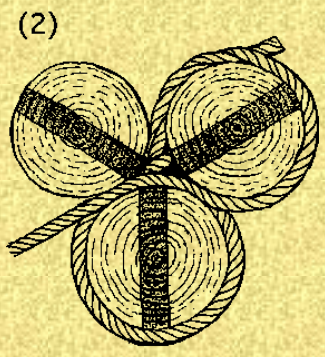

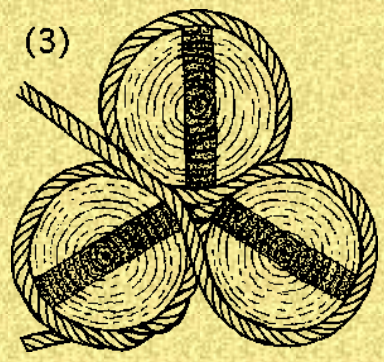

2C] Take 2 frapping turns behind each pole.

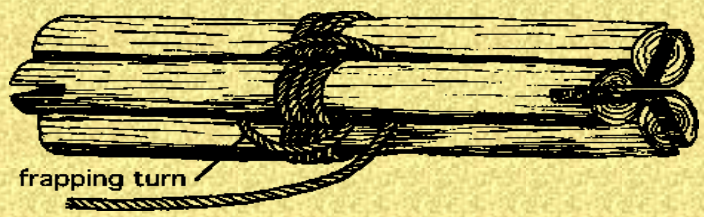

2D] End the lashing with a clove hitch around one of the poles.

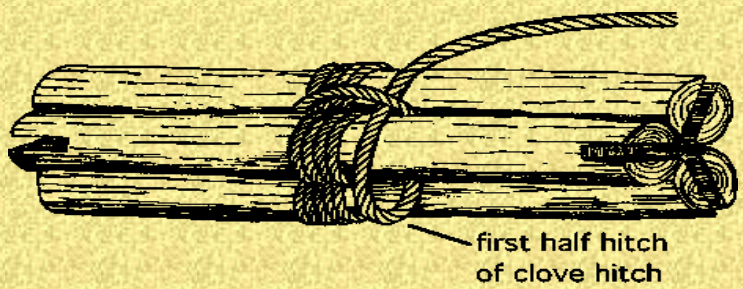

2E] Set the tripod up by rotating each leg

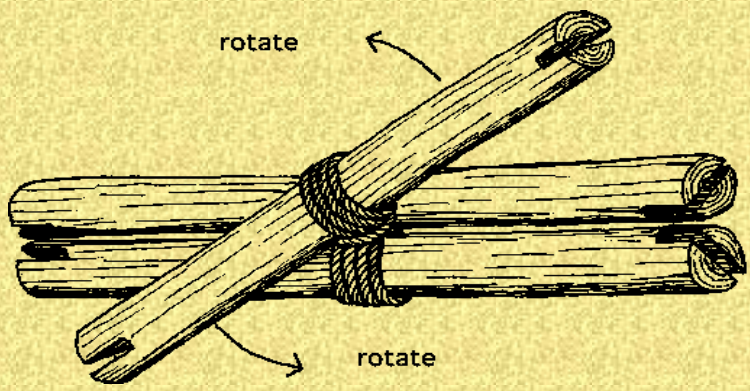

STEP 3: Prepare the seat support rope by marking the middle of the 3/8 inch * 5 foot rope by tying a piece of twine around it. Then form a loop that has a 42 inch circumference by temporarily tying the ends of the rope together.

STEP 4: Place the seat support rope in the groves at the top of the poles so that the middle of the rope is in one of the groves. Adjust the ends poles so that they are evenly spaced around the loop.

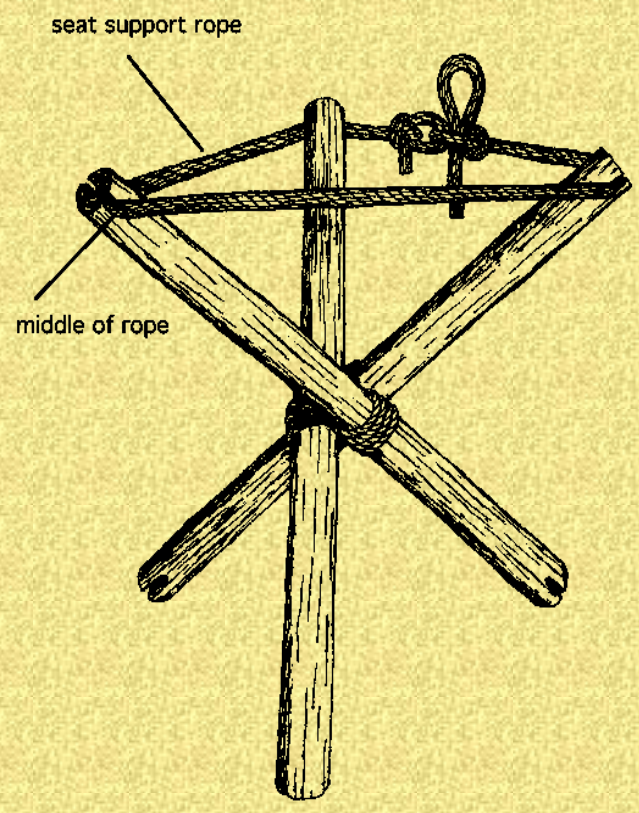

STEP 5: Add the bracing rope. Tie a bowline into one end of the 1/4 inch * 10 foot rope. Then weave the rope back and forth between the ends of the tripod poles; follow the pattern shown in the diagram. End by tying a slippery half hitch through the eye of the bowline.

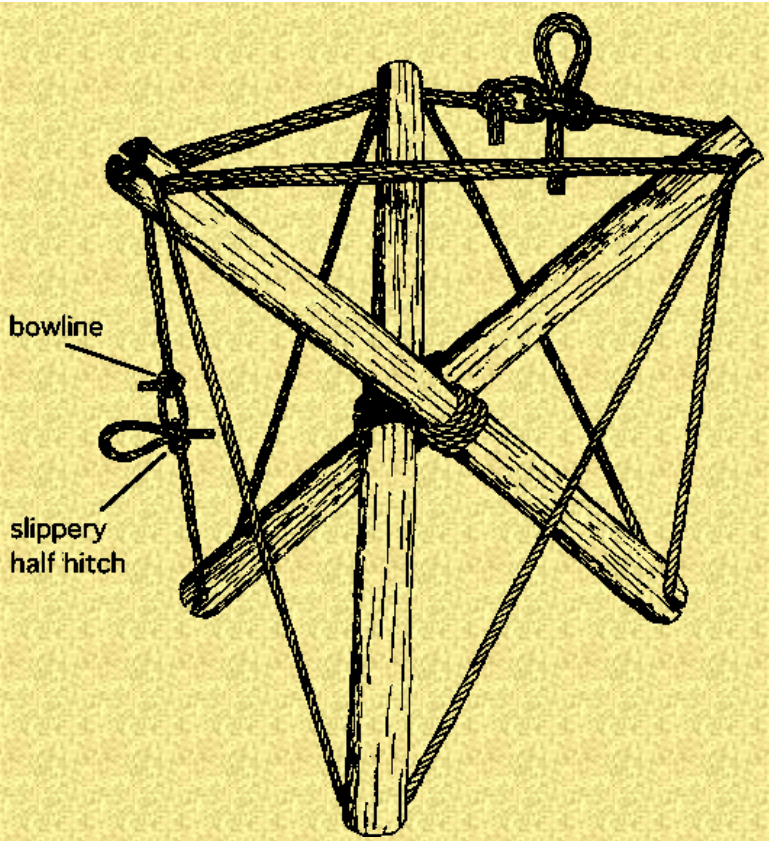

STEP 6: Assemble the seat.

6A] Lift one strand of the lay of the seat support rope on either side of the pole that is at the midpoint of the rope loop.

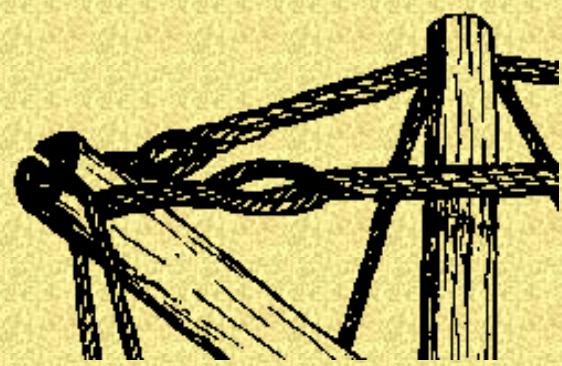

6B] Slide the ends of a 1/2 inch stick under the lifted strands of the seat support rope

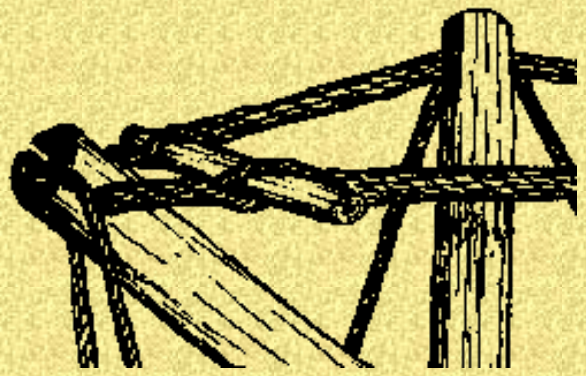

6C] Lift the next strand of the lay of the rope on either side of the pole that is at the midpoint of the seat support rope

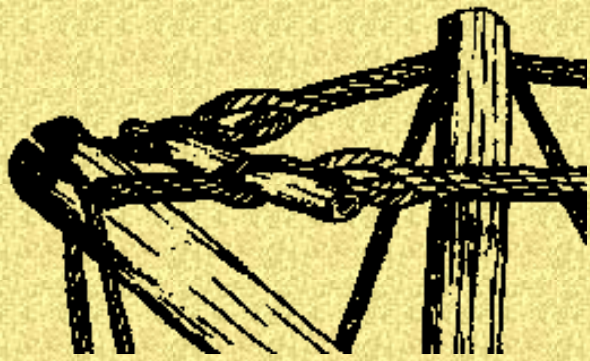

6C] Insert the next 1/2 inch stick**.**

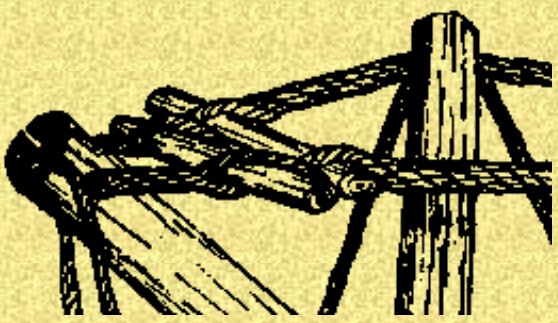

[NOTE] To keep the ends of the tripod poles at a equal distance from each other as the seat is being constructed, the temporary knot that joins the two ends of the seat support rope will need to be retied several times.

6E] Continue in this manner until the seat is the desired size.

6F] Permanently join the 2 ends of the rope loop with a short splice.

6G] Trim the ends of the 1/2 inch sticks so that they extend about 2 1/2 inches beyond the rope.

[NOTE] By removing the 1/4 inch brace rope, this stool can be folded for transport and storage.

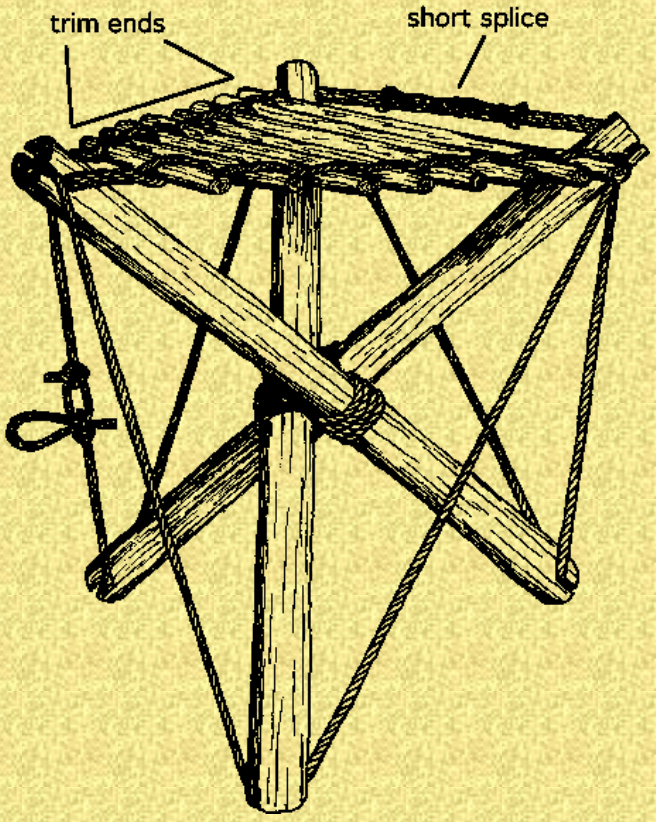

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MONKEY'S PAW

(coil style)

(1) Form the first coil by stacking three loop on top of each other.

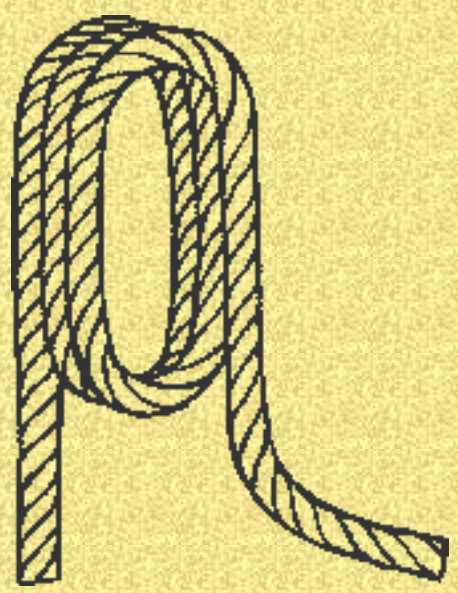

(2) Insert core into center of coil.

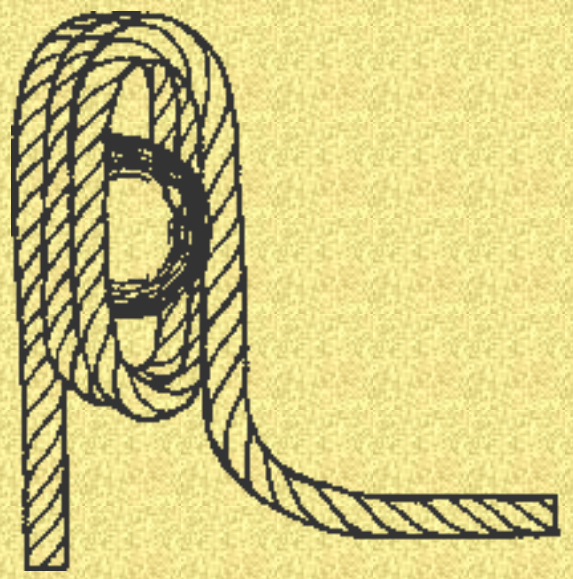

3) Start second coil by forming a small loop at the bottom of the first coil.

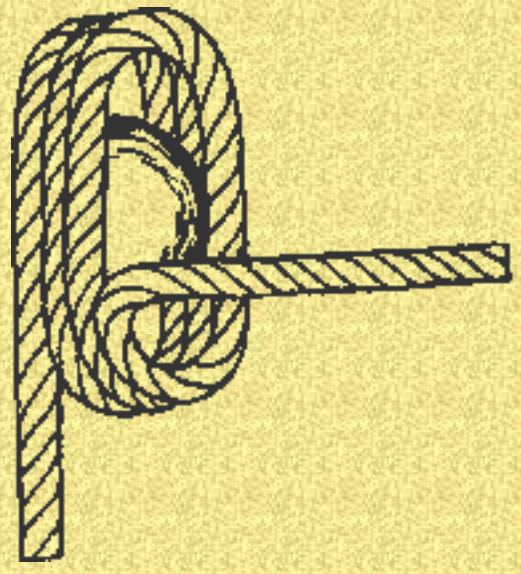

(4) Pass the running end behind and

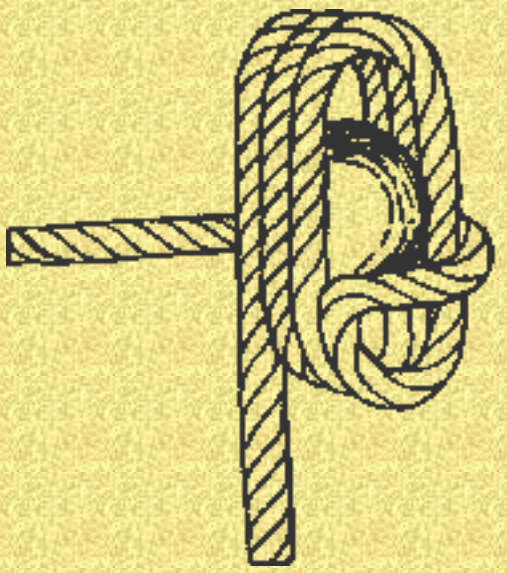

(5) across the front to for the first loop of the second coil

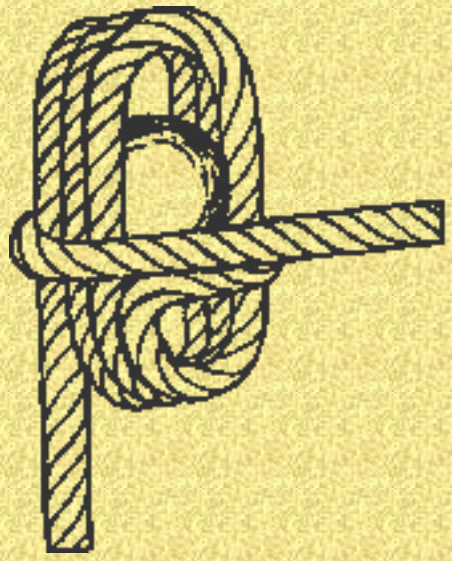

(6) Add the second and third loops of the second coil.

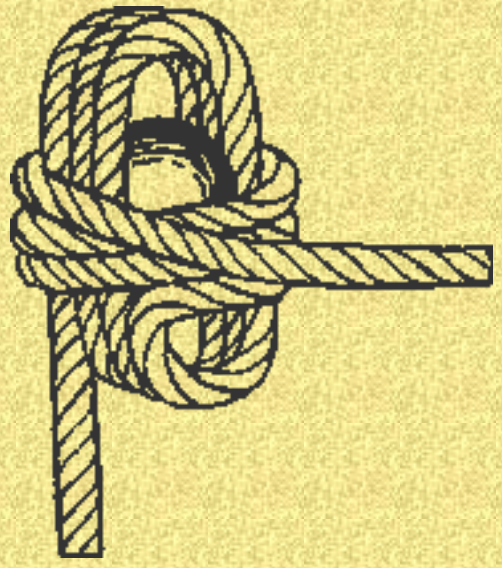

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(7) Start the third coil by reeving the running end through the top of the first coil and

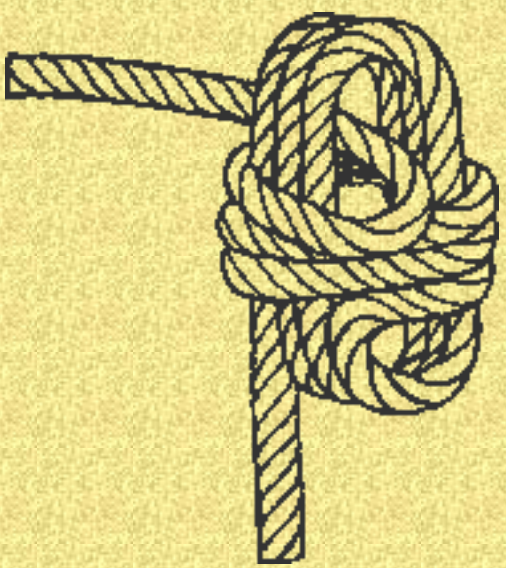

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(8) then reeve the running end through the bottom of the first coil.

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(9) Add the second and third loops of the third coil.

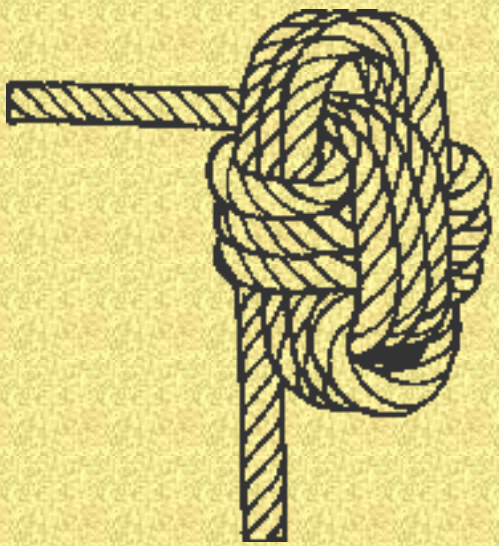

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(10) Work all coils tight over the core.

EXPLORE ROPEWORKS

Flag Pole Cleat:

A cleat is a device used to temporarily secure a line. When valuable equipment such as boat is being tied off, a commercially made cleat should be used. However, when a rustic appearance is desired a temporary cleat can be made with rope and wood.

Green Stick Cleat:

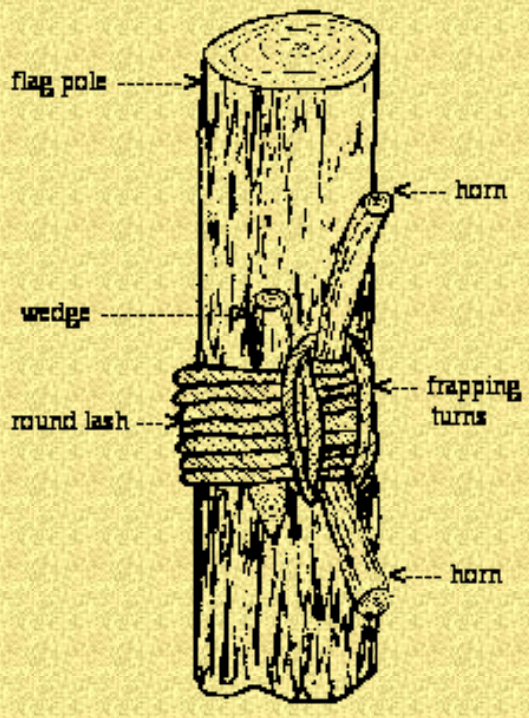

[Step 1] Round lash a piece of flexible green wood or a naturally curved piece of wood to the flag pole to make the horns of the cleat.

[Step 2] Tighten the round lashing by driving a small wedge on either side of the cleat.

[Step 3] Use frapping turns to raise the horns of the cleat.

Dry Wood Cleat:

Suggestion 1 ----

If only dry wood is available a cleat can be made as shown in the following diagrams:

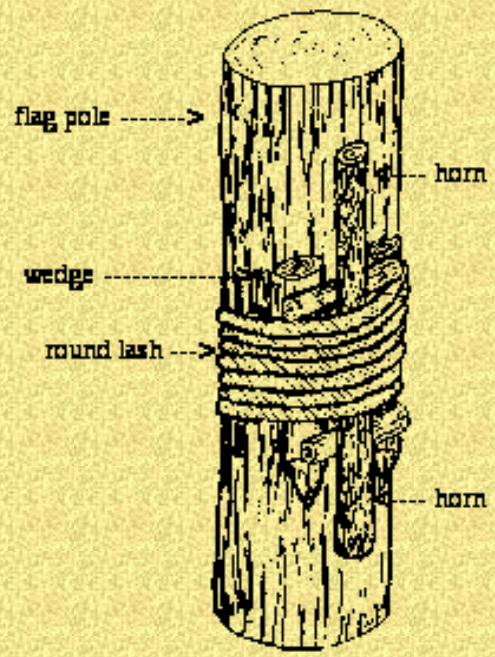

[Step 1] Round lash a stick of suitable size to the flag pole to make the horns of the cleat.

[Step 2] Raise the horns by forcing short risers under each horn.

[Step 3] If needed tighten the round lashing by driving a small wedge on either side of the cleat.

Suggestion 2 ----

Preshape the cleat from a piece of limb wood .
[Step 1] Split a 3 inch diameter by 8 inch piece of limb wood in half.

[Step 2] Use an ax and knife to shape the horns on either end of split piece of wood.

[Step 3] Round lash the cleat to the flag pole.

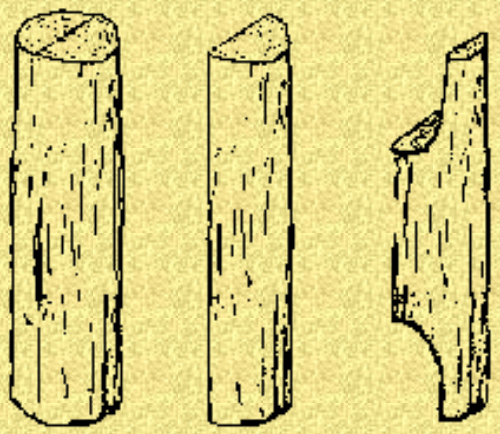

[Step 4] Tighten the round lashing by driving a small wedge on either side of the cleat.

Precut Cleats:

A cleat can be made from hard wood lumber by sawing it to the desired shape and then round lashed to the flag pole. Small wedges are used on either side of the cleat to tighten the round lashing and to stabilize the cleat.

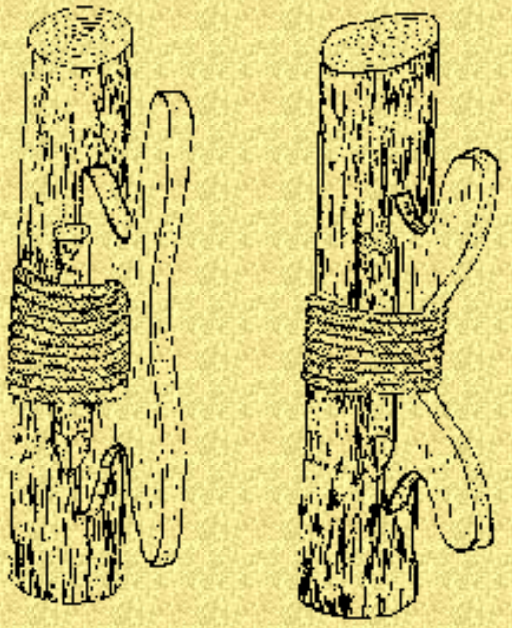

Making Wedges:

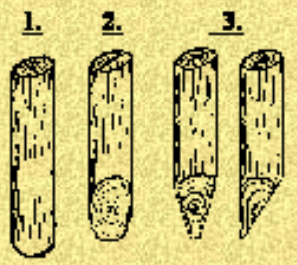

[Step 1] Cut to size. Length --- slightly longer than the width of the round lashing. Diameter --- slightly larger than the gap formed between the rope, the flag pole, and the cleat.

[Step 2] Cut one end off at an angle.

[Step 3] Taper the sides of the point so that the point of the wedge is on one side.

EXPLORE ROPEWORKS

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ROPE WRENCH:

A rope wrench is a simple tool that can be used to tighten the ropes of a lashing. Use a crochet stick that is about 18 inches long and 1 1/2 inches in diameter; the crotch should be about 6 inches from the end.

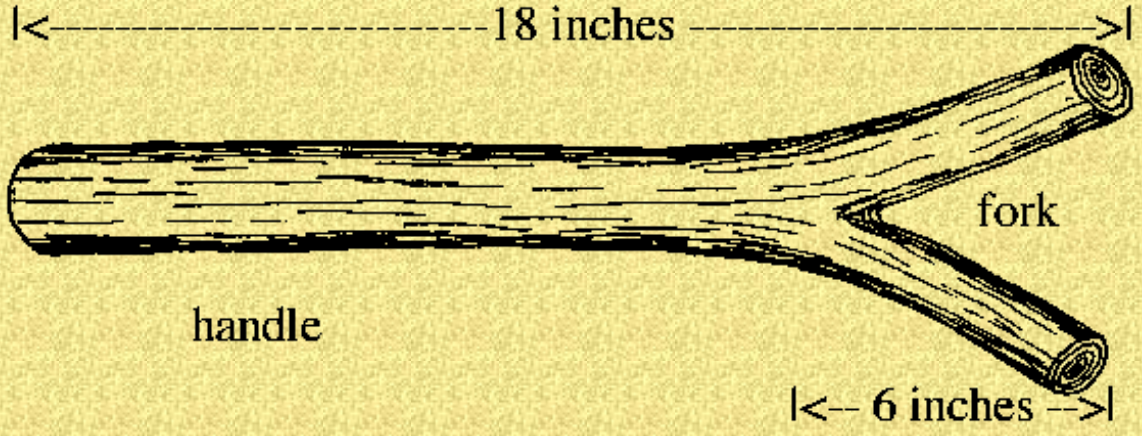

Using A Rope Wrench:

[STEP 1] Use the rope wrench by placing it over the pole next to the rope that is to be tightened.

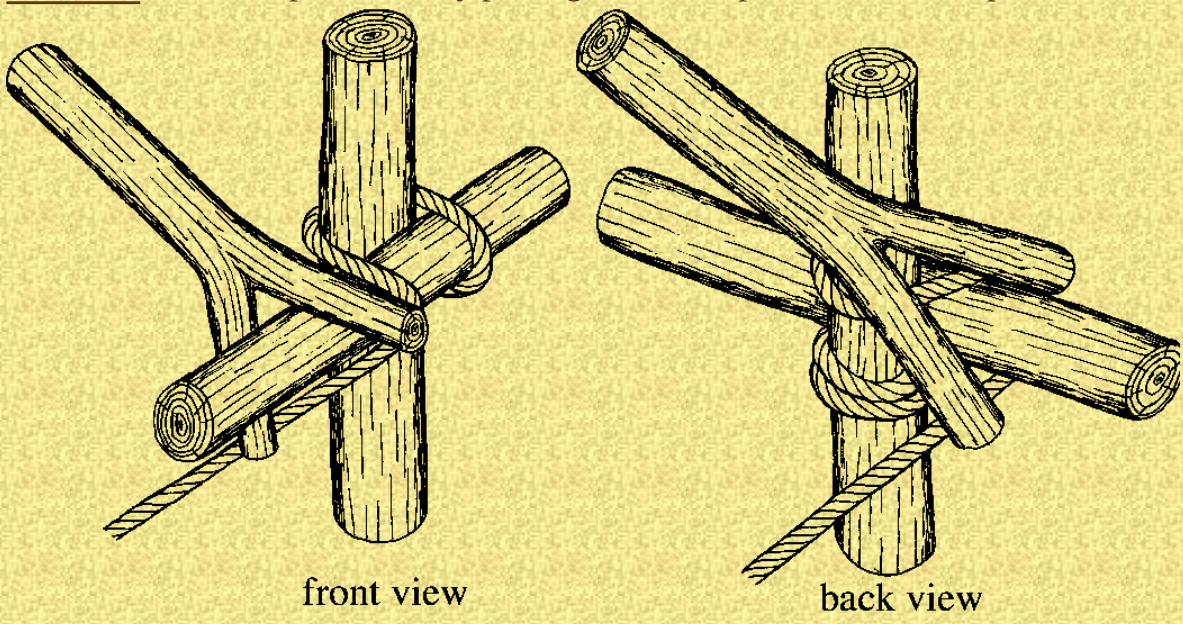

[STEP 2] Wrap the rope around the fork of the wrench.

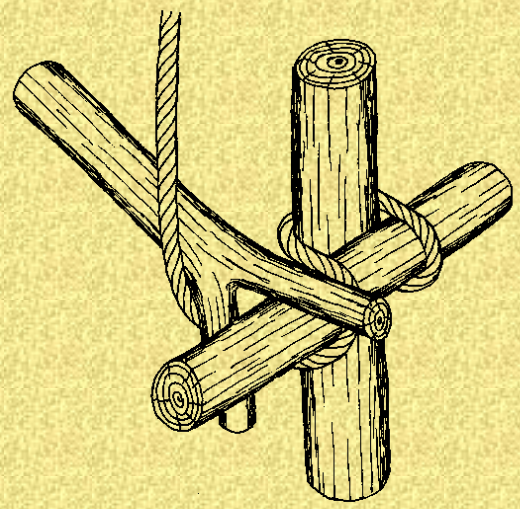

front view

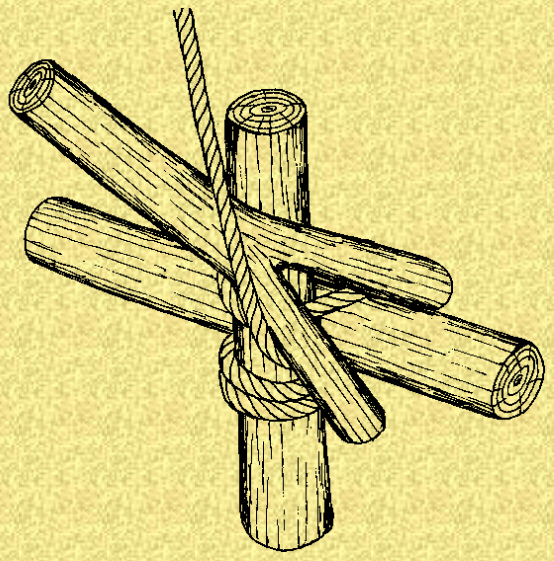

back view

STEP 3] Make one or two wraps around the handle of the wrench.

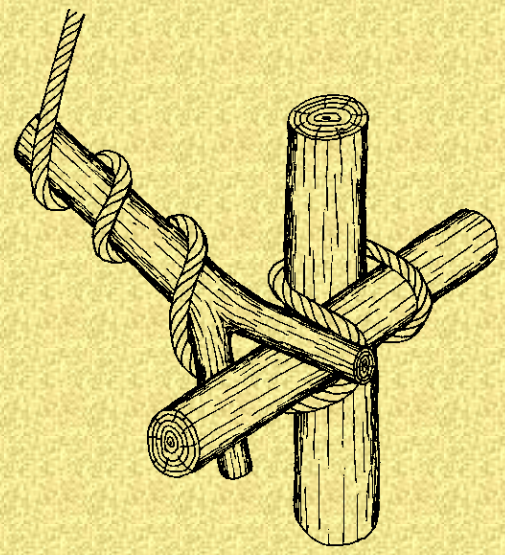

front view

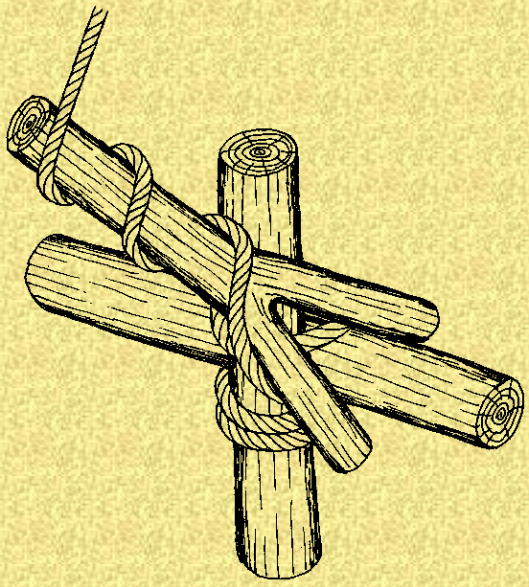

back view

[STEP 4] Grasp the handle so that you are holding the rope firmly to the handle; then rotate the wrench around the pole.

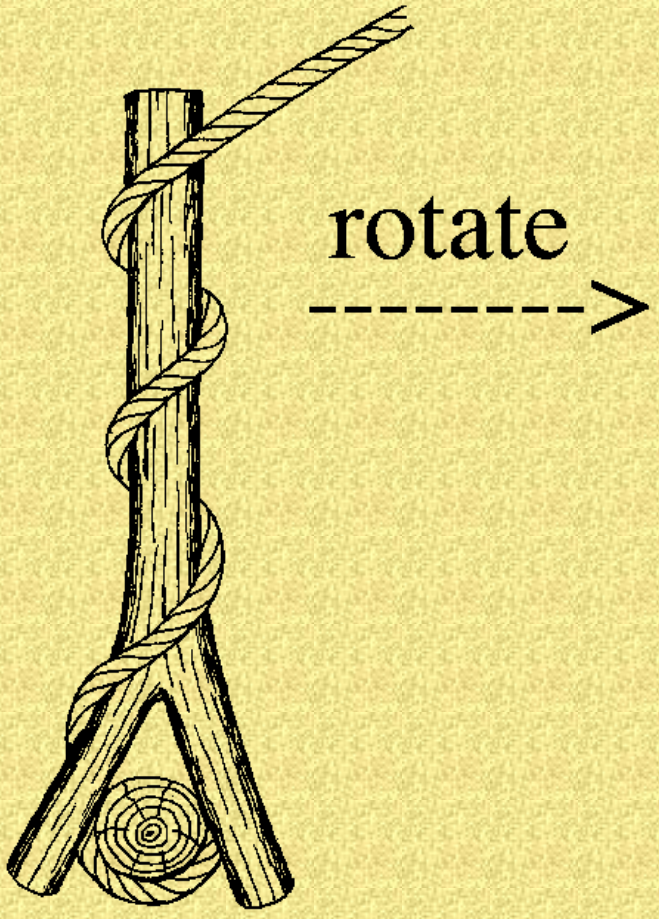

[NOTE] Tighten each turn of a lashing as it is made. The friction between the rope and the pole is too great to tighten more then one turn at a time.

Maintain the tightness of the rope by keeping a small amount of tension on it or by pressing the rope firmly against one of the poles while taking the next turn around the poles.

Be careful that the rope is not tightened so tight that the fibers of the rope begin to break.

NETTING:

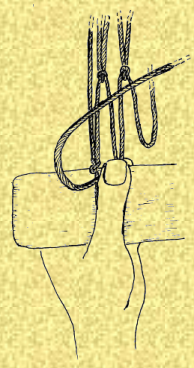

The making of netting is an ancient craft. Many prehistoric cultures used netting for a verity of uses, storage bags, fencing, hammock, just to name some and of course the obvious use as a fish net. No matter what the netting was used for, the knitting of the mesh was done by tying a series of loops in some type of twine.

In one method, the basic knot used was the sheet bend. To form and tie the loops a knitting shuttle and a spacer (gauge) were used.

NETTING TOOLS:

The size of the shuttle and gauge that is needed will depend on the project that you are working on. The size of the shuttle and gauge given in the following directions is a convenient size for many projects and is also a good size to use for practicing the craft of netting. Shuttles and gauges of different sizes can be made by changing the size of the materials used.

Knitting Shuttle:

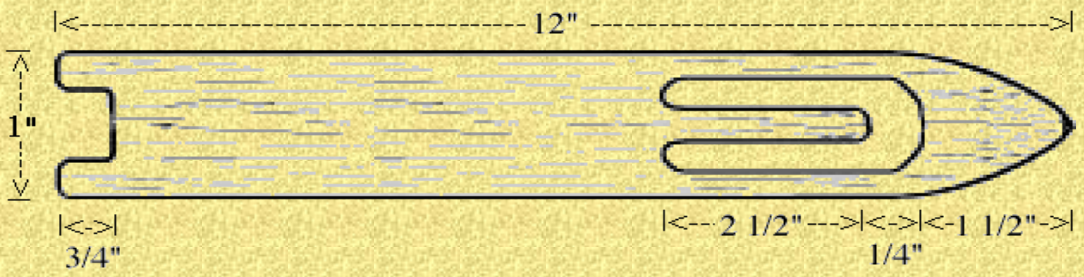

cross
sections

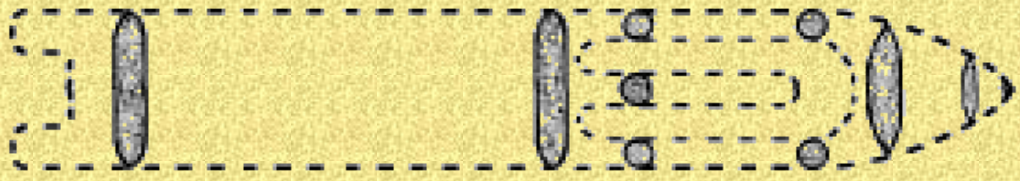

Make the knitting shuttle from a 1/4 inch * 1 inch * 12 inch piece of smooth grained hard wood. Carve and sand the shuttle to the shape shown in the diagram. Leave the shuttle unfinished; varnish or paint has a tendency to become sticky.

Knitting Gauge:

Make the knitting gauge from a 1/4 inch * 1 1/4 inch * 12 inch piece of smooth grained hard wood. Carve and sand the gauge to the shape shown in the diagram. Leave the gauge unfinished; varnish or paint has a tendency to become sticky.

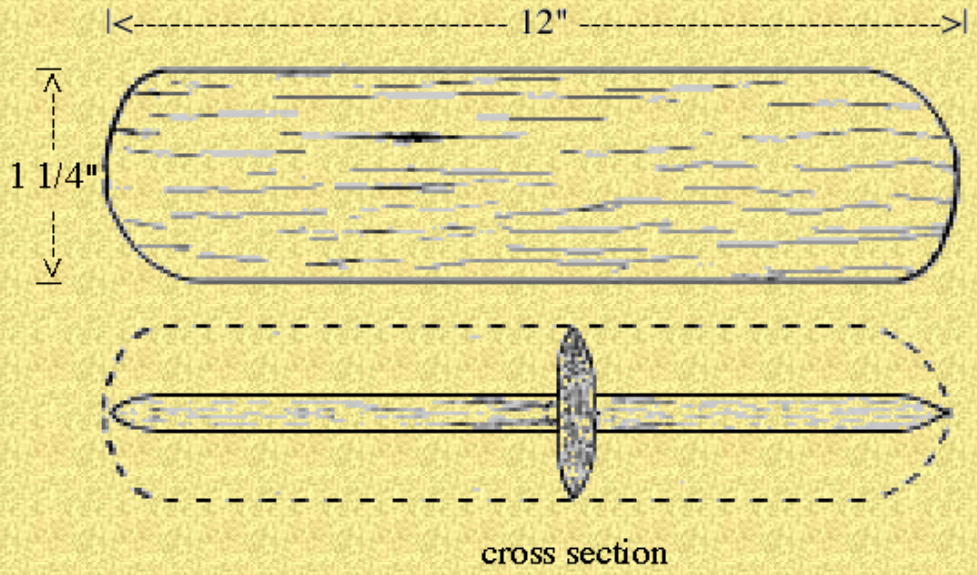

Filling The Knitting Shuttle:

STEP 1: Fill the shuttle with twine. Start by tying a single hitch around the tongue of the shuttle and then pass the twine through the notch.

STEP 2: Turn the shuttle over, loop the twine around the tongue and then through the notch.

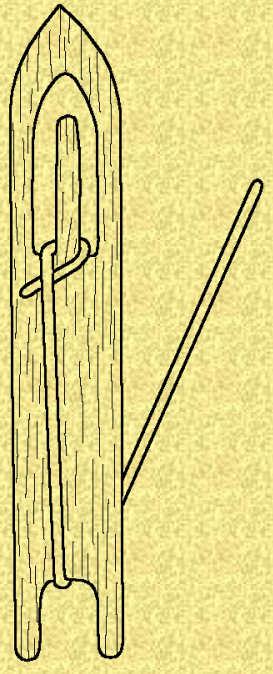

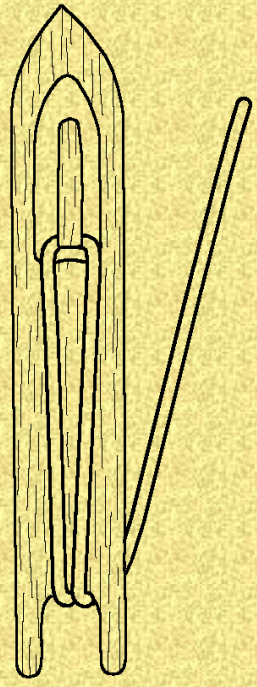

STEP 3: Continue turning the shuttle from side and looping the twine around the tongue until the shuttle is filled.

[NOTE] To prevent synthetic twine from fraying, use a candle flame to cut and fuse the ends.

[WARNING] Using a butane cigarette lighter to cut or fuse synthetic rope or twine may cause the lighter to over heat and explode.

DIAMOND MESH NETTING:

Diamond mesh netting is the easiest of the two forms of mesh to make. Square mesh netting will be dealt with latter.

Casting On: To start diamond mesh netting the first row of mesh loops is cast on to a loop of some kind. The kind of loop used depends on the project; a ring, grommet, frame, or loop of twine may be used. The following directions are for casting on to a ring but the same steps may be used for any starting loop.

STEP 1: Tie the end of the twine to the ring with a clove hitch stopped with two half hitches.

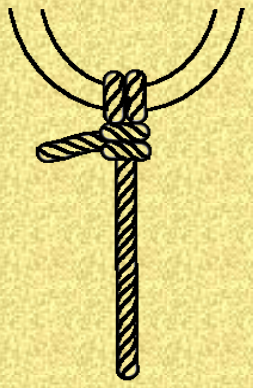

STEP 2: Place the twine behind the gauge then bring the twine in front of the gauge and to the right.

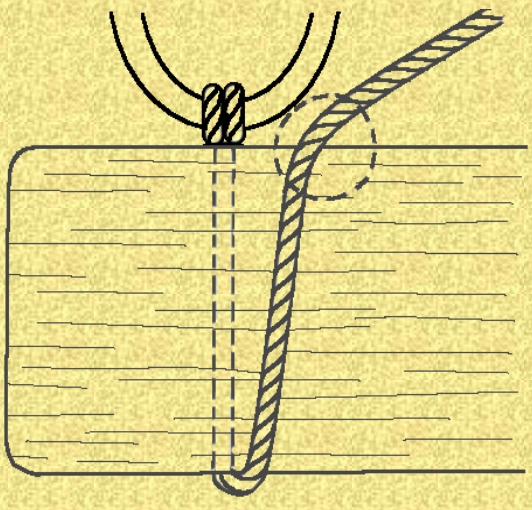

[NOTE]: The dotted circles in each of the diagrams is used to show the position of the thumb and finger of the left hand.

STEP 3: Reeve the twine through the ring from the front to the back so that an overhand loop is formed.

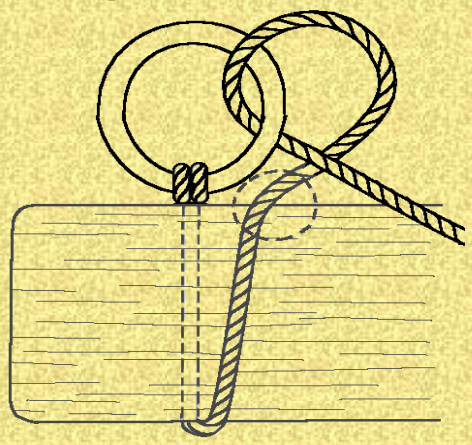

STEP 4: Pull the twine to the left to tighten the twine around the ring and the gauge.

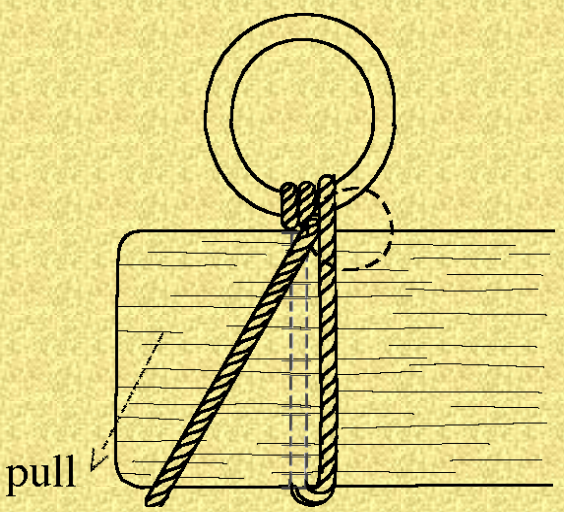

STEP 5: Lay the twine across the ring from left to right.

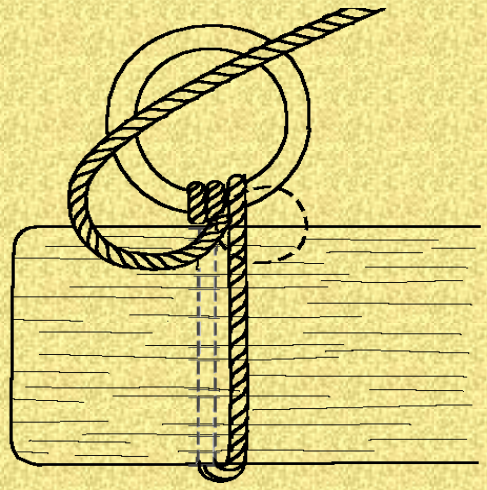

STEP 6: Reeve the twine through the ring from the back to the front.

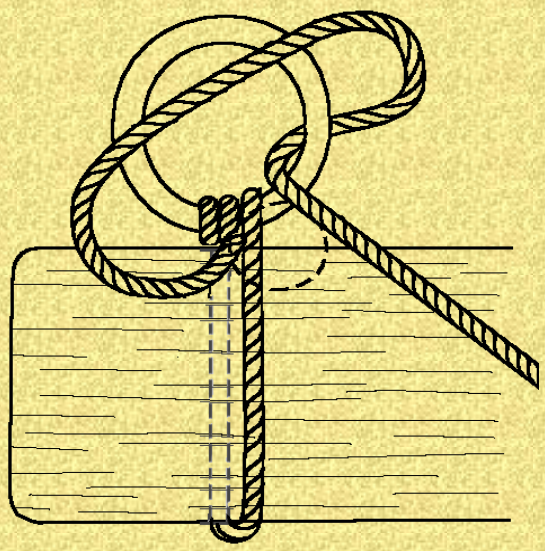

STEP 7: Place the twine behind the gauge; then pull the twine downward to tighten the twine around the ring. This forms a lark's head knot around the ring.

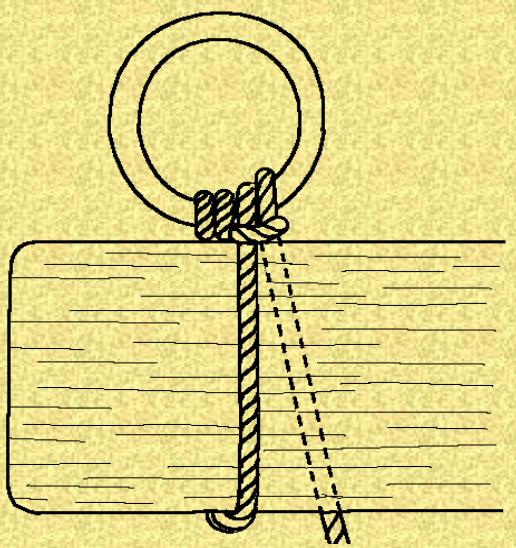

KNITTING A ROW OF MESH:

Netting is made by knitting roes of mesh using a shuttle and a gauge. The gauge is used to determine the size of the mesh, and the shuttle is used to hold the twine and form and tie the mesh loops. The basic knot used in netting is the sheet bend. The following diagrams illustrate the tying of the sheet bend as it is used for knitting a net.

STEP 1: Bring the twine down and up the back of the gauge. Then pick up the next loop by passing the shuttle through the loop from front to back.

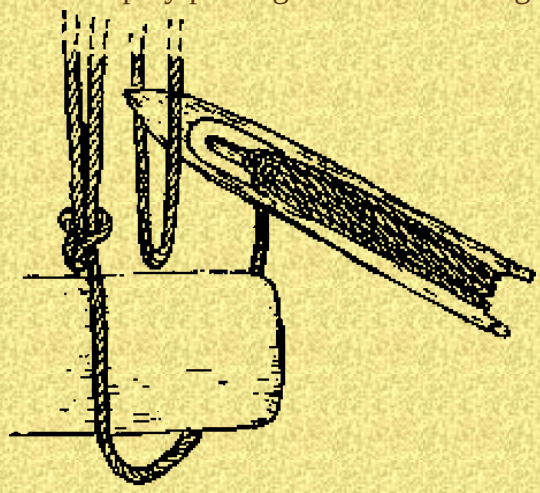

STEP 2: Pull the twine to the left to tighten the twine around the gauge. Use the thumb and finger of the left hand to hold the twine in place.

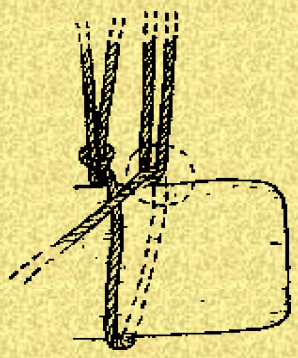

STEP 3: Lay a loop of twine over the loop just picked up.

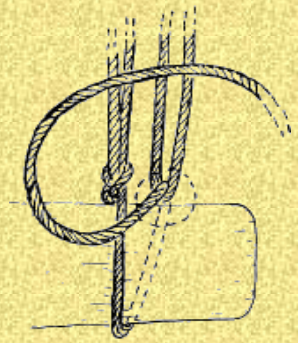

STEP 4: Pass the shuttle in back of the picked up loop and the through the loop that was laid on top.

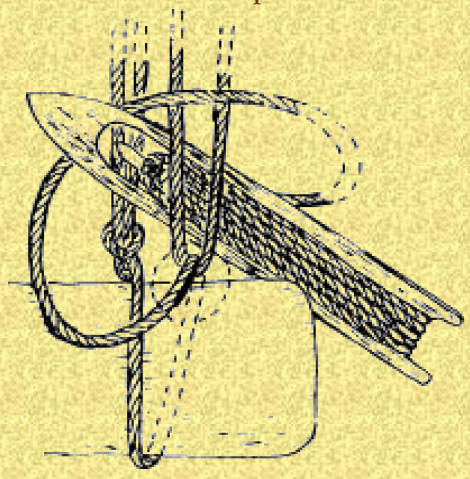

STEP 5: Pull the twine downward and slightly to the right to tighten the knot.

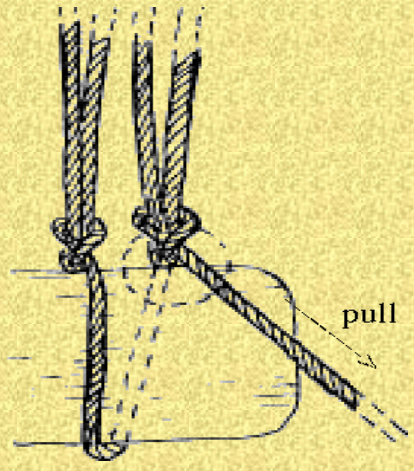

STEP 6: Repeat steps 1 through 5 for each loop in the row.

STARTING A NEW ROW:

STEP 1: When the end of a row of mesh is reached, slide the accumulated loops off the gauge, turn the work piece over so that the running end of the twine is on the left side of the work piece.

STEP 2: Wrap the twine around the gauge from front to back; pick up the first loop by passing the shuttle through the loop from back to front.

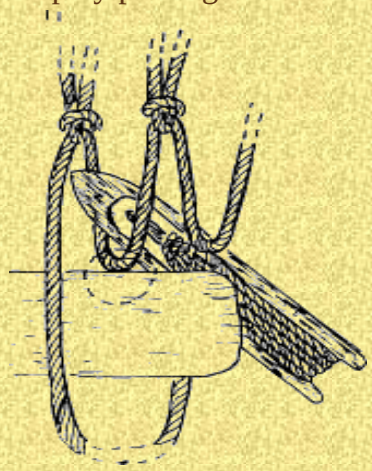

STEP 3: Knit the loop in place by following the directions for knitting a row of mesh.

ADDING A LOOP:

For some projects it is necessary to increase the width of the netting part way through the project. The width of the netting is increased by adding loops of mesh.

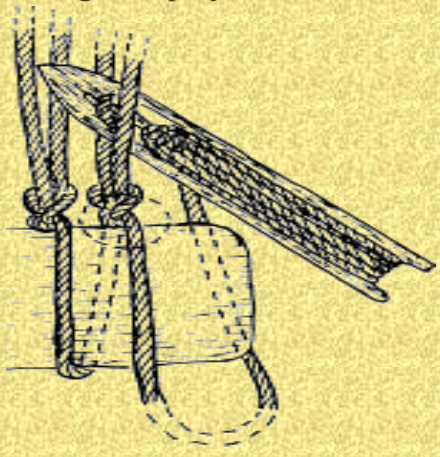

A loop is added by picking up the same loop a second time so that two loops are formed in the new row of mesh are tied to the same loop in the previous row of mesh.

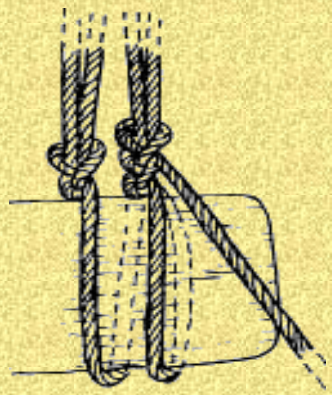

PROLONG KNOT

DESCRIPTION:

A flat knot that is made by interweaving two strands of rope.

USE:

As stair tread, mat, or chafing gear; also as a decorative knot in a two strand lanyard.

COMMENTS:

The prolong knot gets its name from the fact that it can be extended to any length.

TYING:

STEP 1:

Place the center of the rope over a peg or hook and tie a loose half knot.

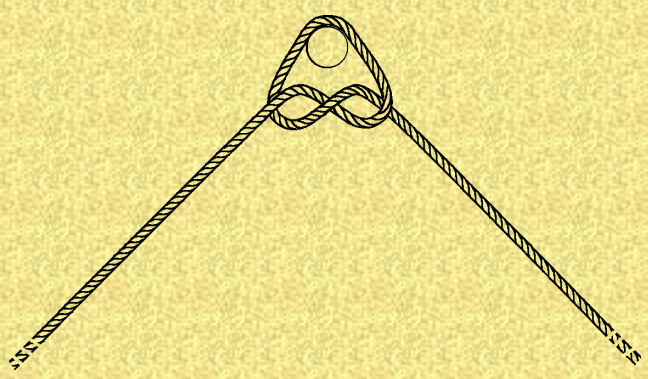

STEP 2:

Extend the half knot as shown.

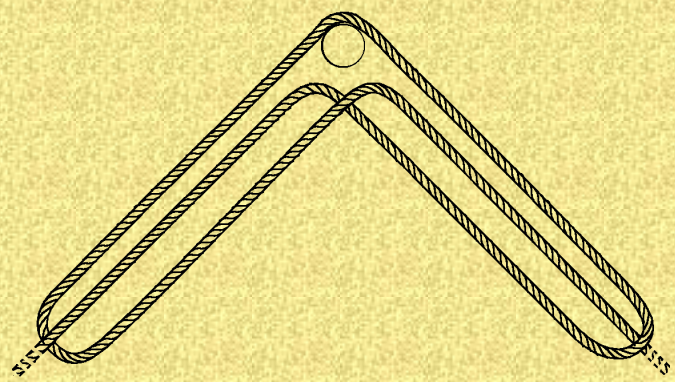

STEP 3:

Twist the left loop and extend it to the right side.

[NOTE] This will start the over under pattern

of the weaving.

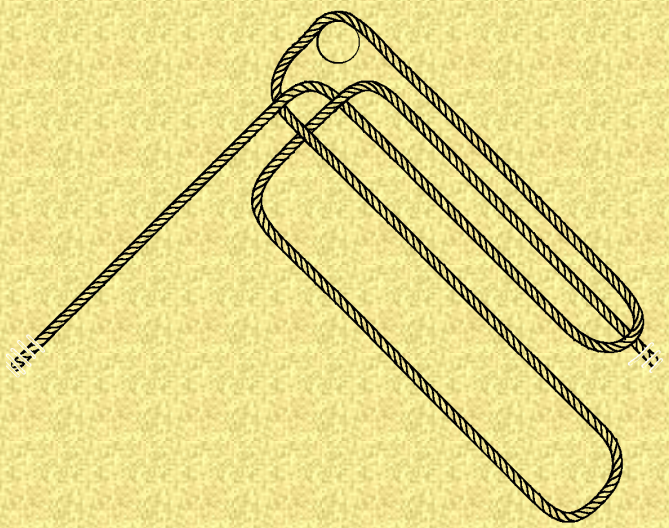

STEP 4:

Twist the right loop and extend it to the left side so that it is over the first extended loop.

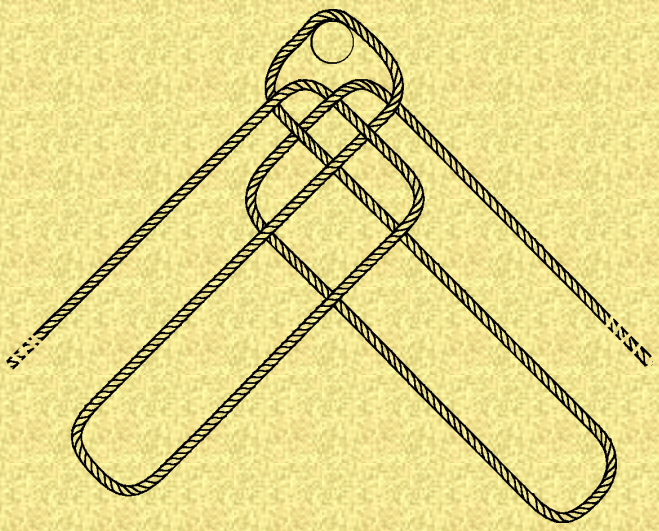

STEP 5:

Weave the left strand to the right in the pattern shown.

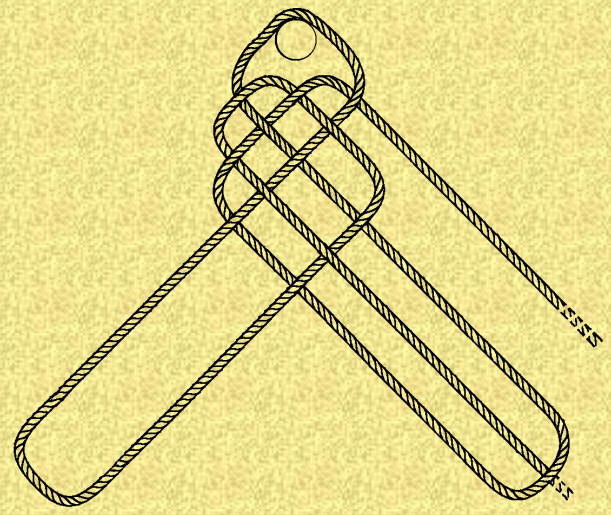

STEP 6:

Weave the right strand to the left in the pattern shown.

[NOTE] This completes the four bight prolong knot. At this stage it may be ended and worked firm (over tightening distorts the knot) or the strands my be doubbled as shown in later diagrams.

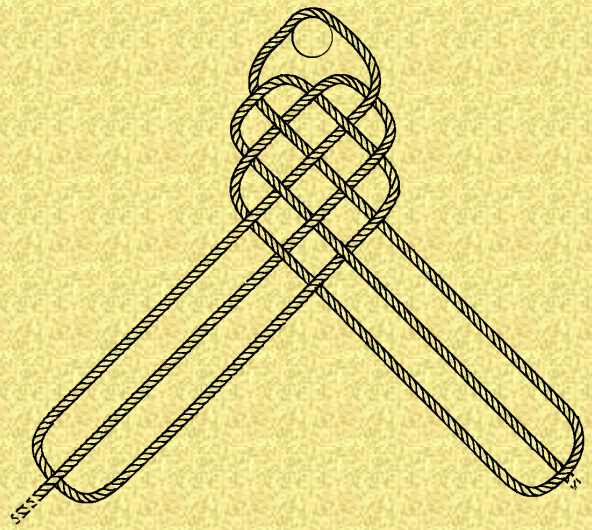

STEP 7:

Twist the left loop and extend it to the right side.

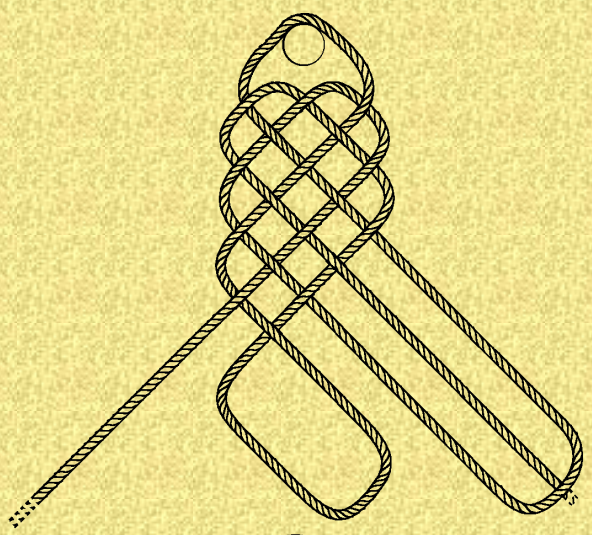

STEP 8:

Twist the right loop and extend it to the left side so that it is over the first extended loop.

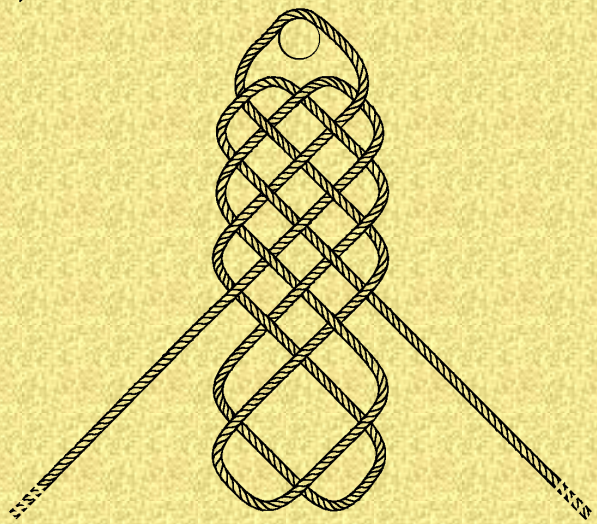

STEP 9:

Weave the right strand to the left in the pattern shown.

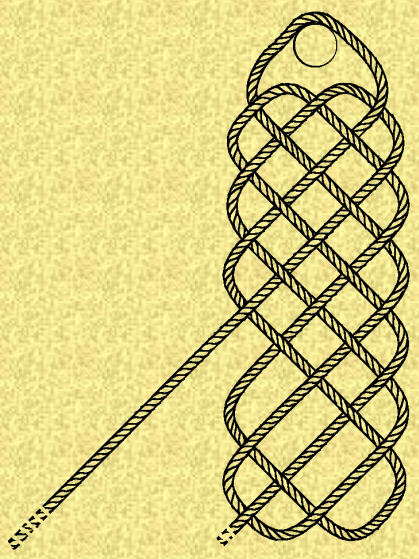

STEP 10:

Weave the left strand to the right in the pattern shown. This completes the 7 bight form of the prolong knot.

[NOTE] The prolong knot can be extended three bights at a time by repeating steps 7 through 10 for each extension.

STEP 11:

Start doubling the strands by chacing (following) the opposite strand.

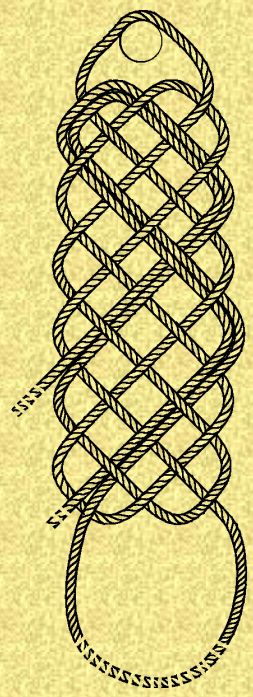

STEP 12:

Complete doubling the strands. Then work the knot into a firm mat . Do not over tighten the strands as this will distort the mat.

[NOTE] The ends of the strands can be hidden by sewing them to the adjacent strand on the underside of the mat.

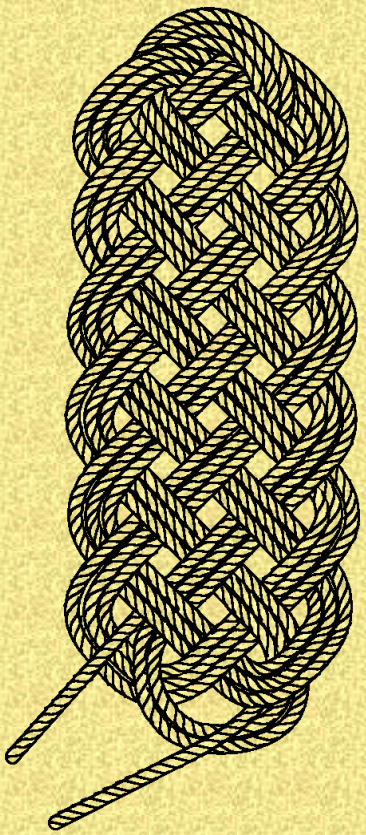

1996, Gerald L. Findley

LIFE BASKET:

Description ---- A body harness made by combining a bowline on a bight and a french bowline.

Use ---- To lower a severally injured person when a life threatening situation exists.

Comments ---- The life basket is a secure harness that can be used to move an injured person that is weakened or unconscious. However, unless there is a life threatening situation, such as a burning building or immediate danger of avalanche, you should wait for a trained rescue team.

If you attempt to use the life basket, do not allow the rope to slide through your hands as you lower the injured person . The friction caused by the sliding rope can cause severe painful rope burns and loss of control of the rope. The rope must be let out in a hand over hand manner to insure a safe, controlled descent.

1.

Narration ---- (1) Tie a bowline on a bight. Place one loop of the bowline on a bight around each leg. [NOTE] (The bowline on a bight should be large enough so that when it is in place the knot should be close to the victims belt buckle. Be sure to leave the running part of the rope extending about 3 feet beyond the knot.)

2.

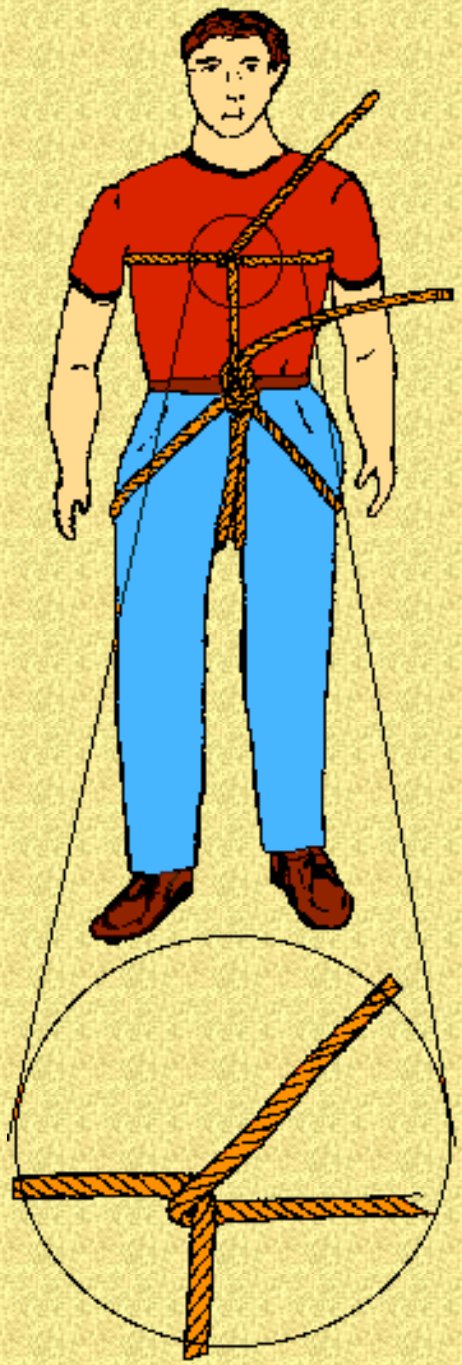

(2) Take a half hitch around the victims chest.

(3) Form a bight in the standing part by pulling it under the right hand part of the half hitch so that an underhand loop is formed around the cross point of the half hitch.

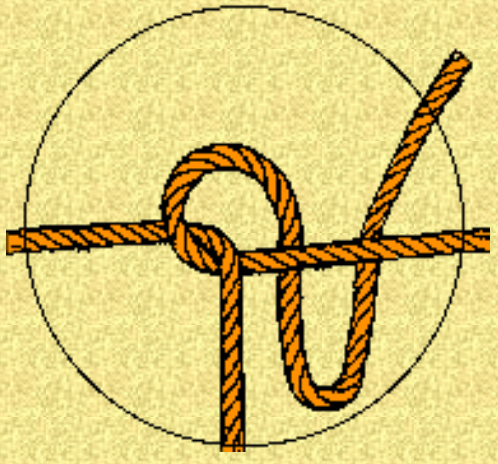

(4) Fold the bight around and reeve it through the eye of the underhand loop.

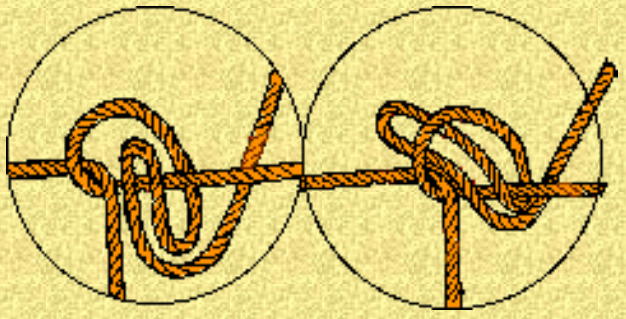

(5) Reeve the running part of the rope through the bight.

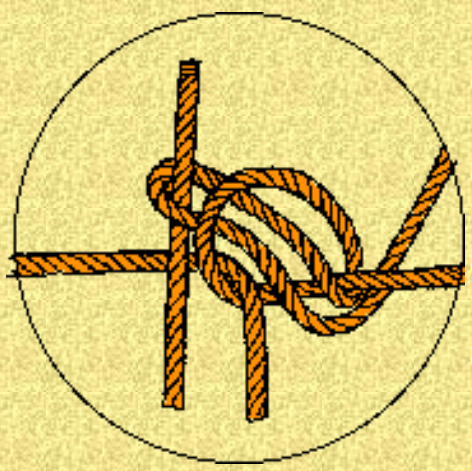

(6) Take the slack out of the running part of the rope and fold the it over to form interlocking bights.

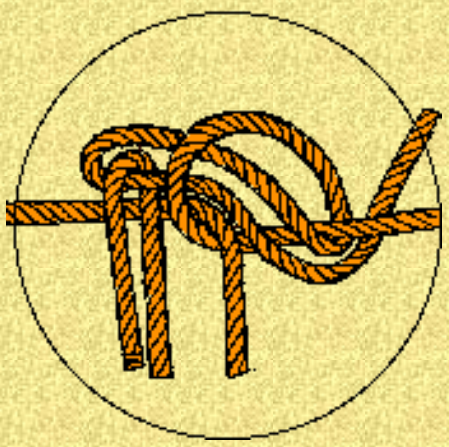

(7) Pull on the standing part so that the bight in the running part of the rope is pulled through the eye of the underhand loop and the underhand loop flips over and tightens around the bight to form a French Bowline.

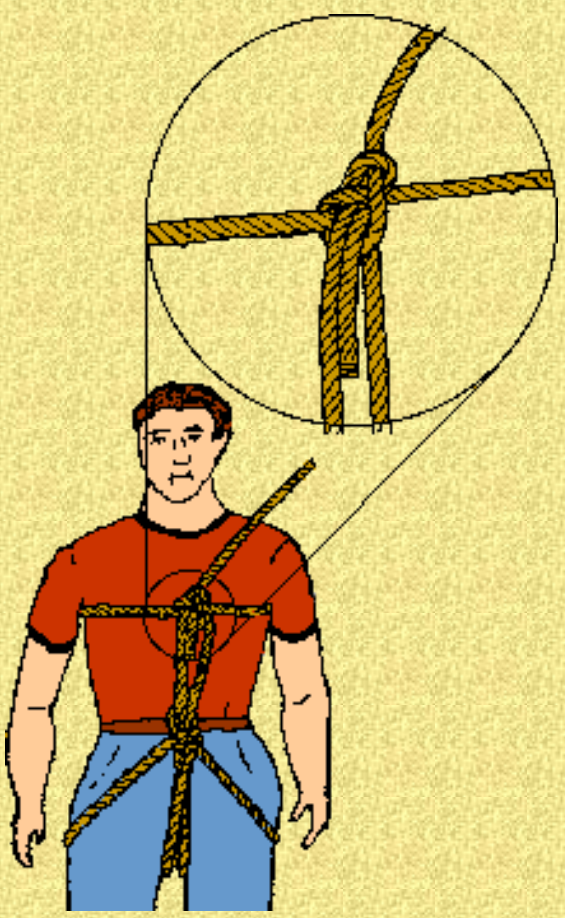

SPHERICAL KNOB COVERING

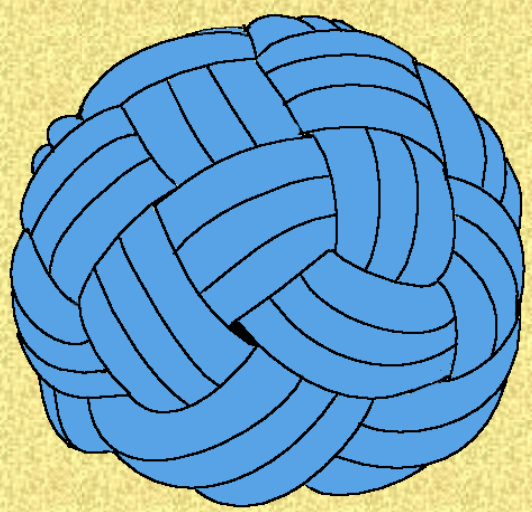

This knot is used to cover knobs. One example would be to cover a knob at the end of a walking stick.

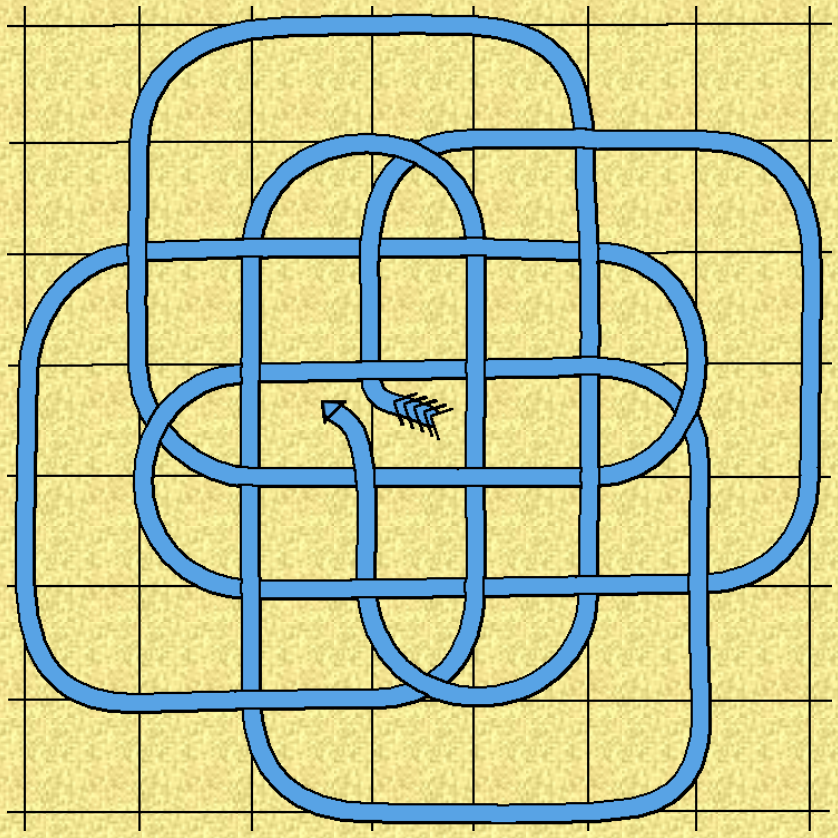

The length of cord needed to tie the knob covering knot depends on the size of the cord and the number of times the pattern is to be chased. A good length to start with is 8 times the circumference of the knob for each time the pattern is to be chased. [Example: a one inch knob has a circumference of a little over 3 inches. To cover a one inch knob it would require about 25 inches of cord for each time the pattern is chased. The pattern should be chased at least 2 times.

This means that about 50 inches of cord would be used to cover a 1 inch knob.

The knob covering knot is difficult to tie "in hand" the easiest method of tying it is to make a copy of the diagram and fasten the diagram to a work board. Start by pinning the middle of the cord to the feathered end of the arrow in the diagram. Then following the path indicated, pin the cord to the diagram. Be sure to follow the over/under pattern indicated in the diagram. Studying the following partial diagrams may help.

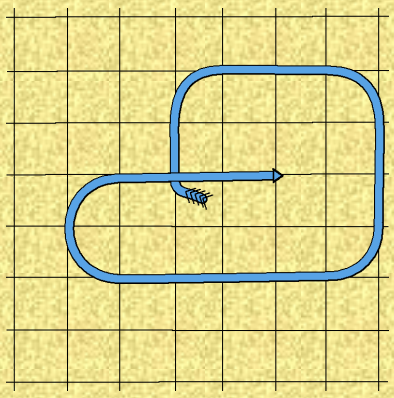

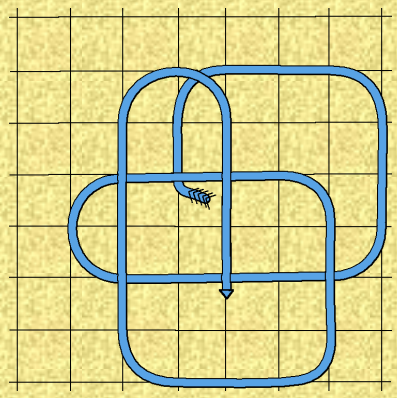

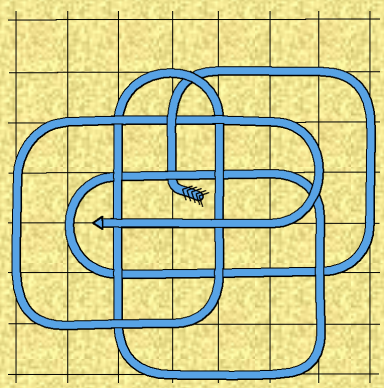

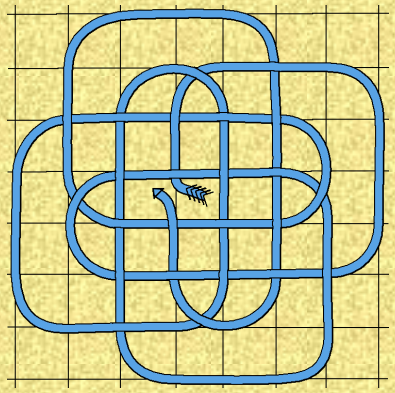

After the knot is tied on the work board unpin it and work it loosely into shape over the knob. Then chase the pattern the required number of times. Next work the knot tight around the knob. Do not rush this stage. When the knot is tight cut off the ends of the cord and push the ends into the knot.

To preserve the knot, it may be varnished or painted.

Walking Stick:

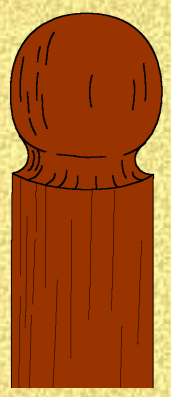

Carve a knob on the end of the walking stick.

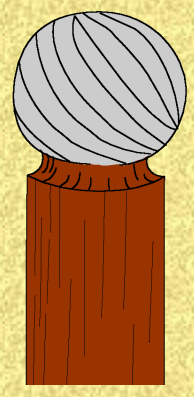

If desired, the size of the knob can be increased by wrapping it with tape.

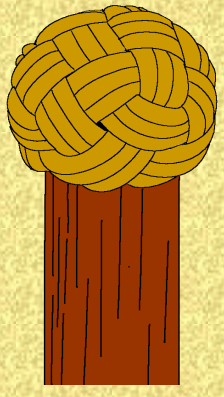

Tie the covering knot and work it tight over the knob.

CROWN KNOT:

Use ---- To tie of the end of a rope so that it does not unlay. ----- To begin a back splice. ---- As part of several multiple strand knots.

---

(1) Tie off the rope 6 complete lays from the end.

(2) Unlay the rope to the tied off point.

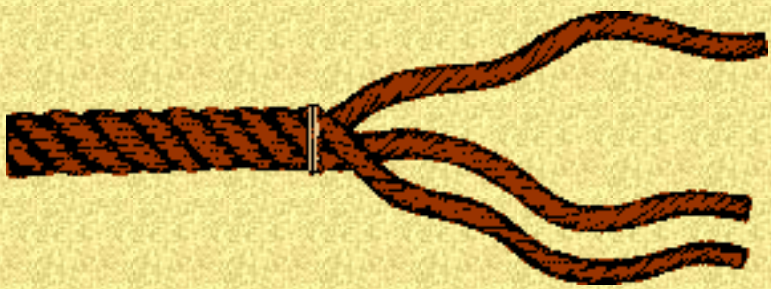

(3) Place the end of one of the unlayed strand between the other two unlayed strands;

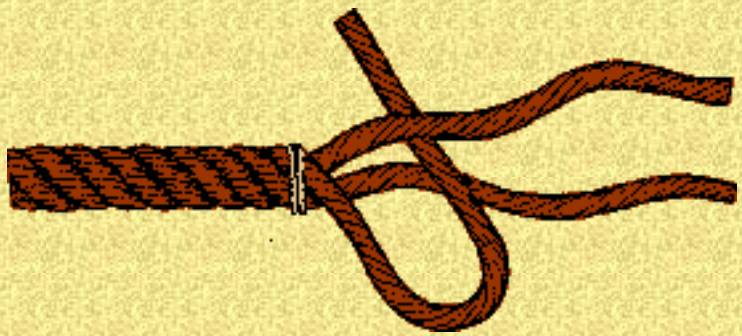

(4) press the strand firmly between the strands so that a loop is formed. **[NOTE]** As you are looking at the end of the rope work counterclockwise around the rope .

(5) Fold the second strand over the first strand. **[NOTE]** This will hold the loop in the first strand in place.

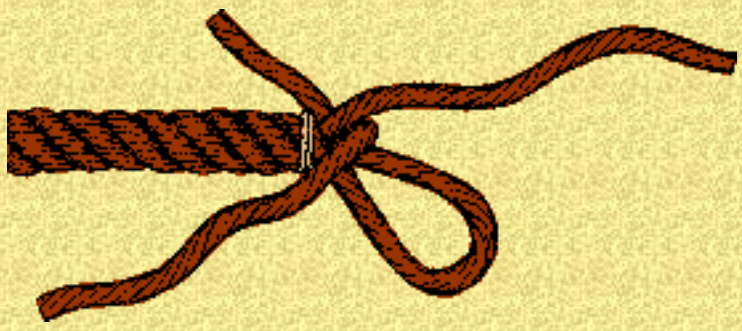

(6) Reeve the end of the third strand through the eye of the loop.

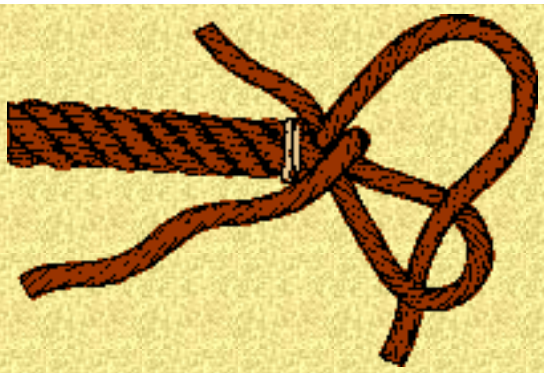

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(7) Fold the third strand over the second strand. **[NOTE]** This will hold the second strand in place.

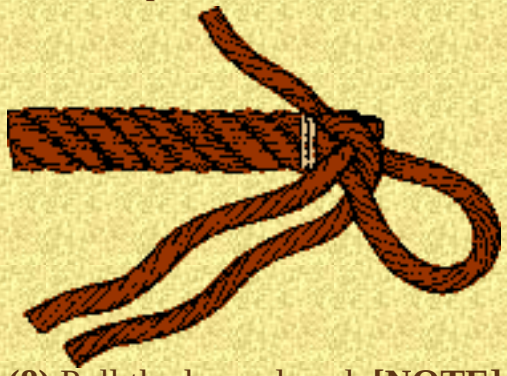

(8) Pull the loop closed. **[NOTE]** Work and pull all three strands until the knot is even and symmetrical.

EXPLORE ROPEWORKS

TABLE BORDER=0 CELLSPACING=0 CELLPADDING=0 LANG=en DIR=LTR WIDTH="500" COLS="5">

WALL KNOT

Use ---- To tie of the end of a rope so that it does not unlay. ---- As part of several multiple strand knots.

---

(1) Tie off the rope 6 complete lays from the end

(2) Unlay the rope to the tied off point.

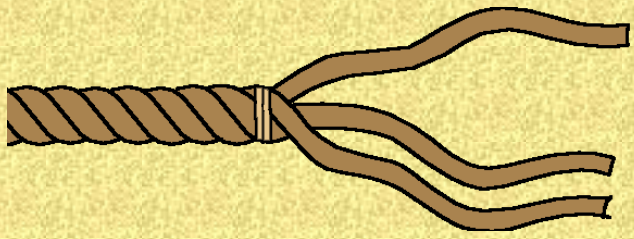

NOTE: work the knot in a counterclockwise direction as you look at the end of the rope.

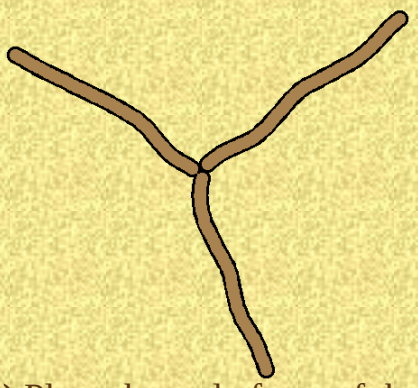

(3) Place the end of one of the unlayed strands under the strand to its left. (Hold the loop open as you work the knot).

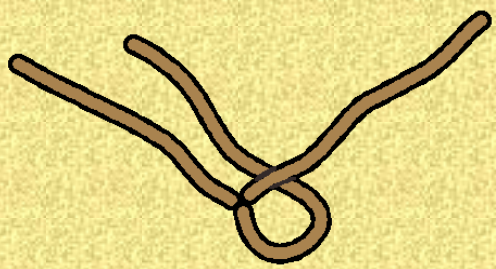

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(4) Place the second strand under the first and tthird strand.

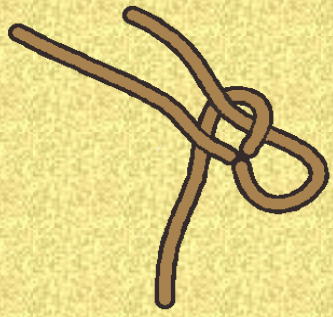

(5) Placce the third strand under the second strand.

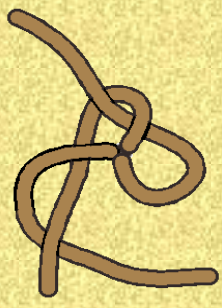

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(6) Reeve the end of the third strand up through the loop formed in the first strand.

[A]

[B]

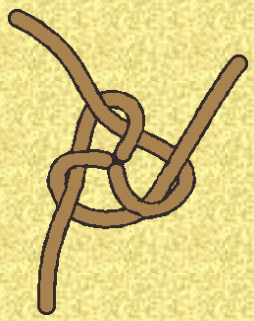

---

(7) work tight.

EXPLORE ROPEWORKS

ALAMAR KNOT

The alamar knot is a decorative knot related to the pretzel knot. The pretzel knot is tied in a single strand; the alamar knot is tied by doubling the strands as showwn in [Step 1]

[Step 1] Double the strand as shown.

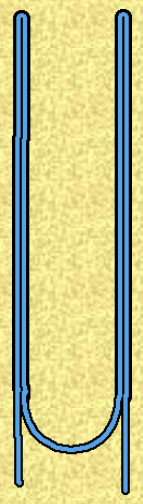

[Sterp 2]

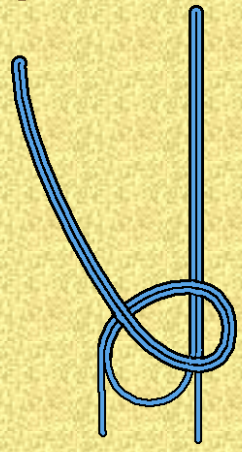

[Sterp3]

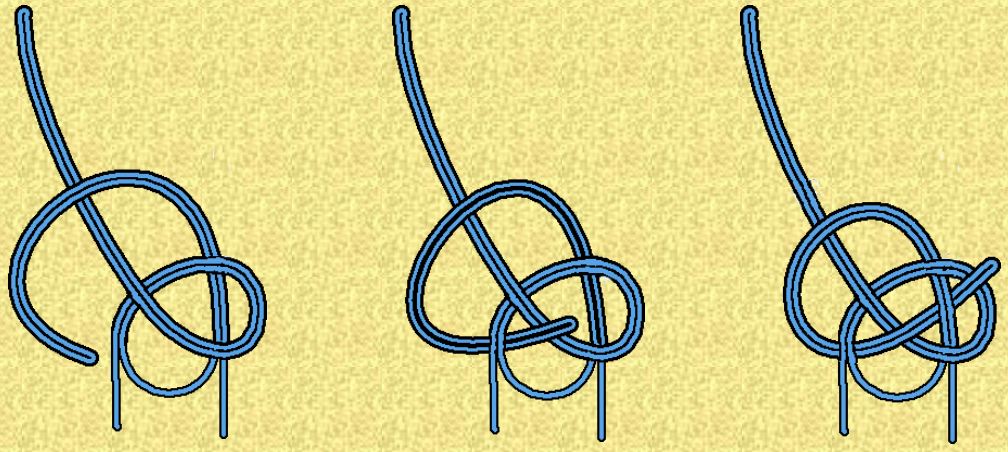

[Step 4]

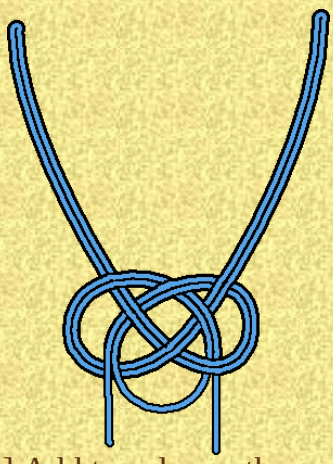

[Step 5] Add tassels or other end decorations.

TURK'S HEAD KNOT

RERUN ANIMATION

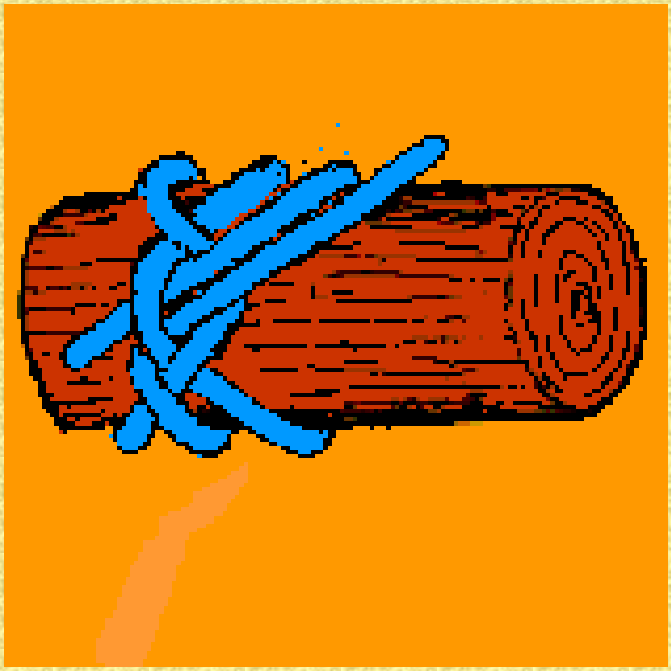

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BOATSWAIN'S WHISTLE KNOT

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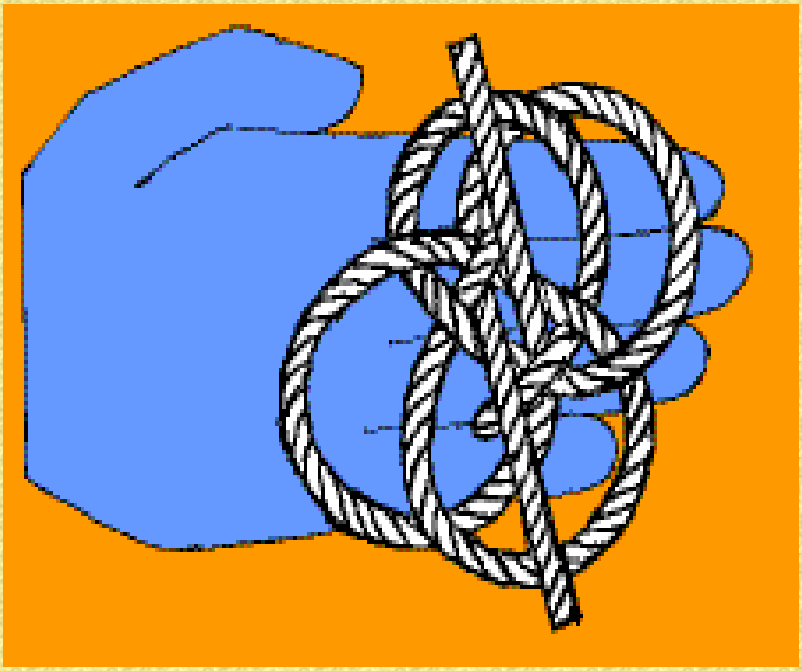

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CONSTRICTOR KNOT

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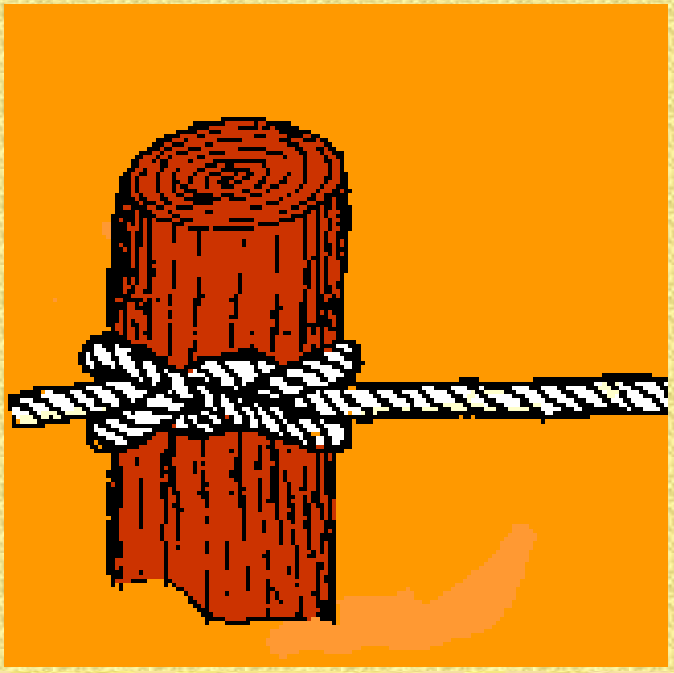

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MOORING HITCH

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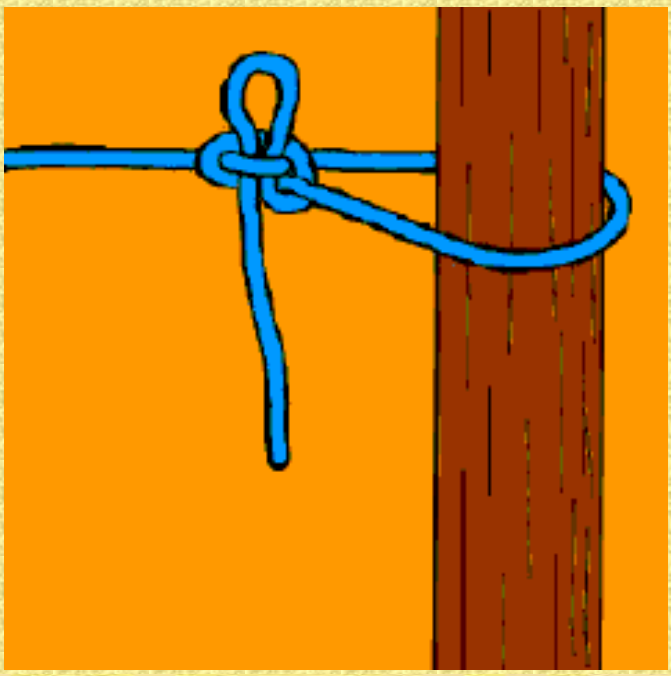

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BELAYING TO A CLEAT

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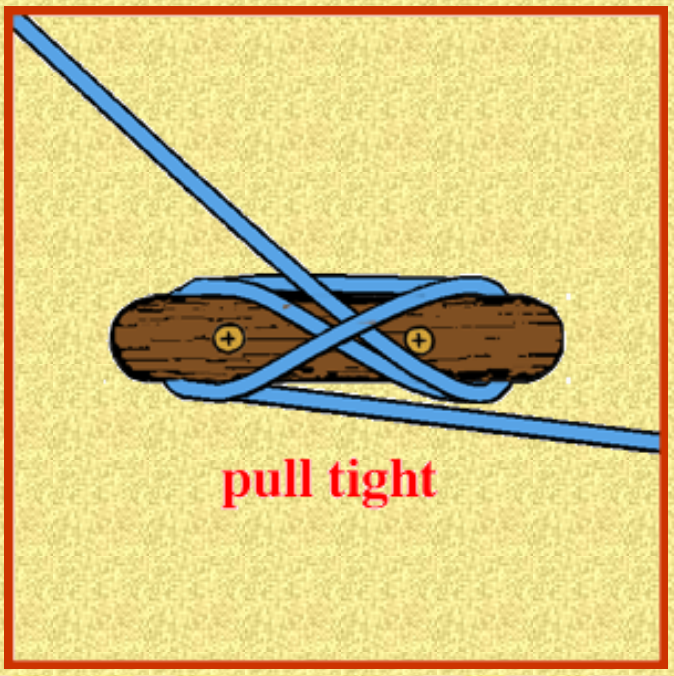

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FIGURE-EIGHT KNOT

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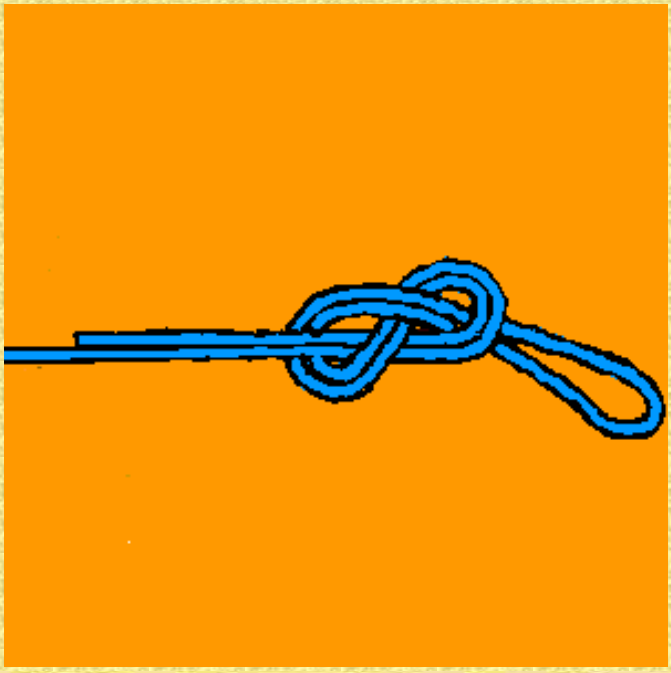

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WHIPPING

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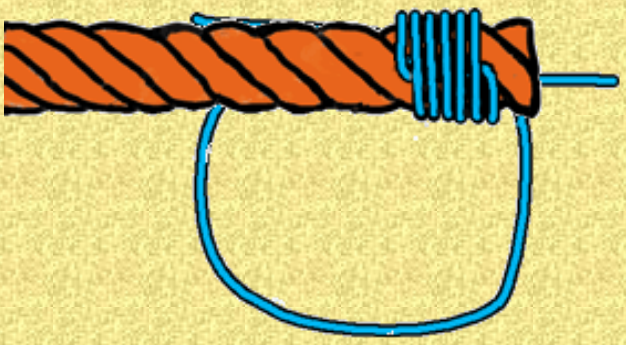

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BOWLINE

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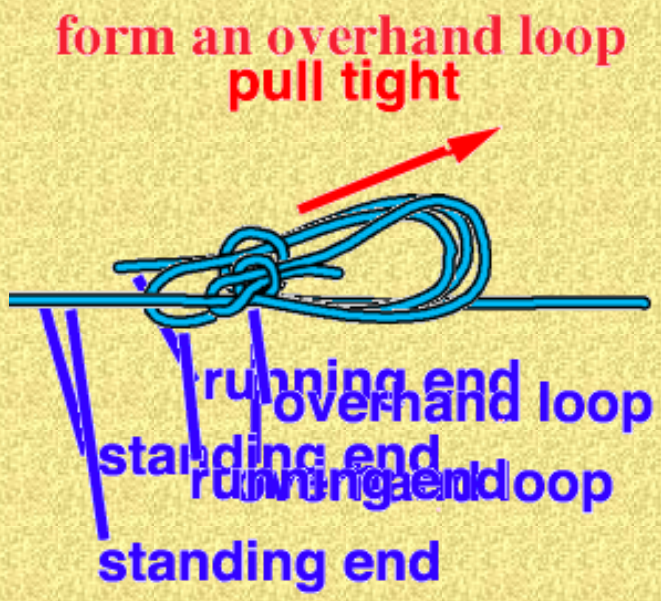

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BOWLINE ON A BIGHT

RUN ANIMATION WITH TEXT

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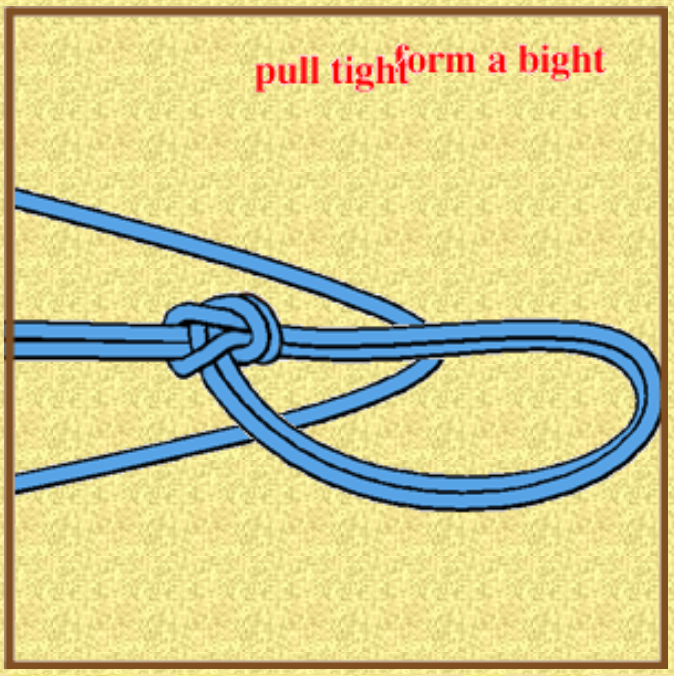

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CROWN KNOT

RUN ANIMATION WITH TEXT

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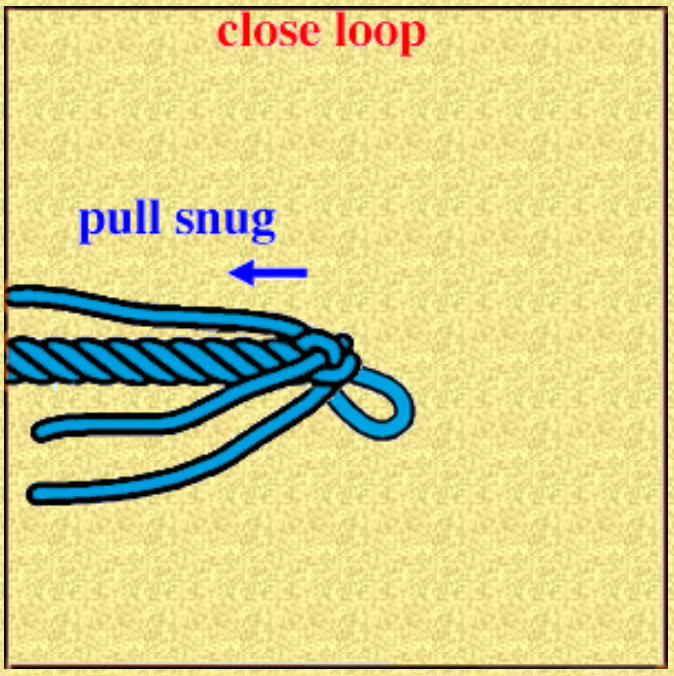

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BOWLINE ON A BIGHT:

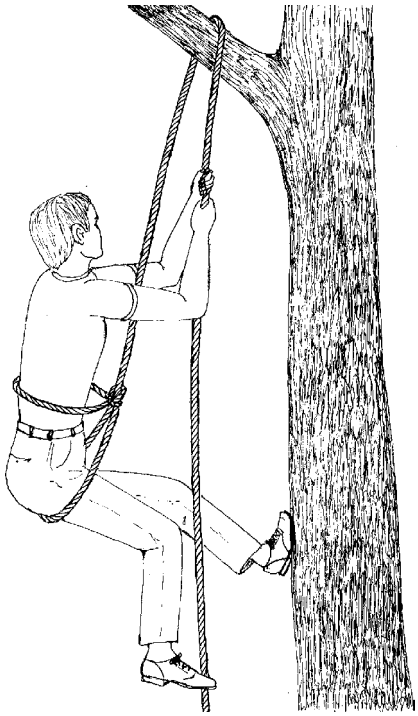

Description ---- A double loop bowline Tied by interlocking a doubled half hitch and a bight.

Use ---- As a nonslip double loop; as a loop any where along the length of a rope; as secure loop for rescue work; as the start of a life basket harness; as a emergency boatswain chair.

Comments ---- The bowline on a bight is a secure double loop that can be tied anywhere along the length of a rope. Several can be used as a "dead eyes" for tightening a rope when securing a load or guy line.

Narration ---- (For **bowline on a bight** knot-board.) **(1)** Take a bight in the rope. **(2)** Using the bight as the running part, make a double strand overhand loop. **(3)** Take the running part under the overhand loop. This forms a double strand bight that will become the eye of the knot. (4) Reeve the running part through the eye of the overhand loop. **(5)** Spread the eye of the running part (bight). **(6)** Pull the running part (bight) through the overhand loop

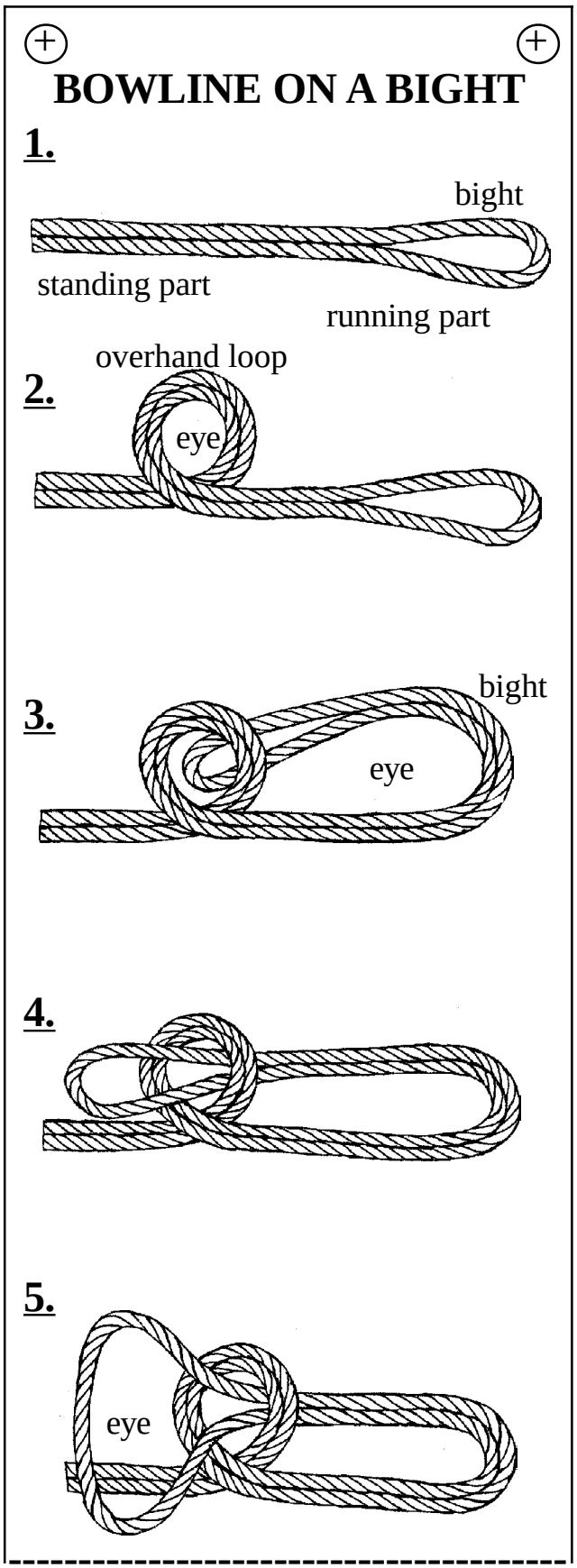

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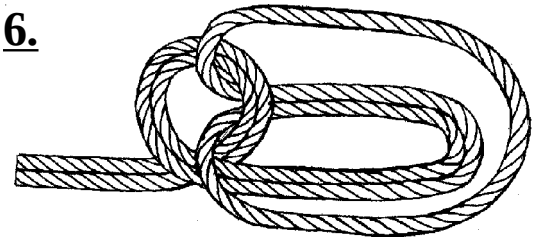

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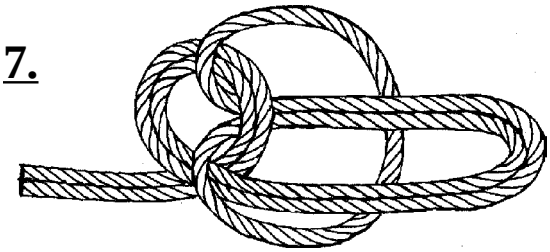

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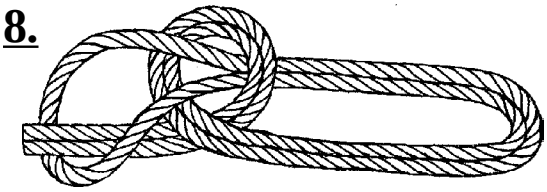

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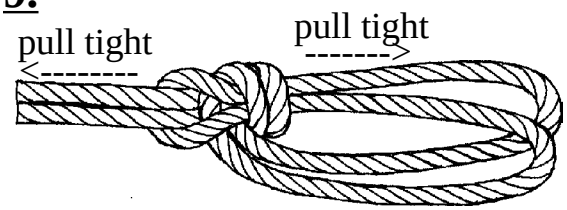

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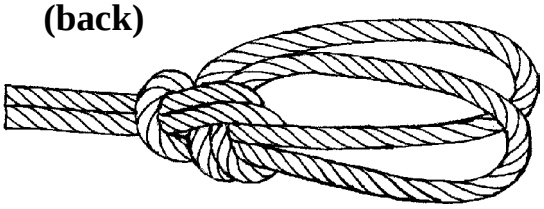

until you can enlarge it enough **(7)** to pass it over the double strand bight. **(8)** When the eye of the running part (bight) is around the standing part, **(9)** Grasp the double loop bight and the standing part and pull the knot tight.

[NOTES]

CLOVE HITCH:

Description —- Two single hitches (half hitches) tied in the same direction around an object.

Uses —-To secure a line to a post or pole; to start and end most lashings.

Comments — Can be untied (spilled) by pulling on the standing part so that it rotates the cross point in the knot until it goes over the end of the rope.

The length of the standing part can be adjusted by rotating the loops of the knot around the pole. To shorten the standing part, pull on the running end so that it rotates the cross point toward the standing end . To lengthen the standing part, pull on the standing part so that the cross point is rotated toward the running part.

Because the clove hitch can be spilled by rotating the standing part against the cross point, the clove hitch will spill itself if it is tied so that standing part moves back and forth in such a way that it cause the loops of the knot to slide around the pole. To prevent the clove hitch from spilling, 'stop' it by tying two half hitches around the standing part.

STOPPED CLOVE HITCH

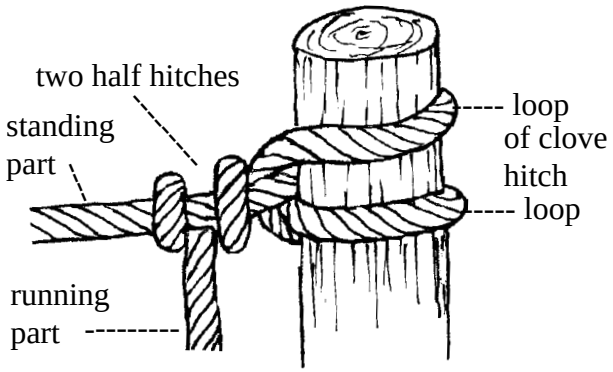

When under constant tension the clove hitch has little tendency to slide along the length of the pole even if the tension is nearly parallel to the pole.

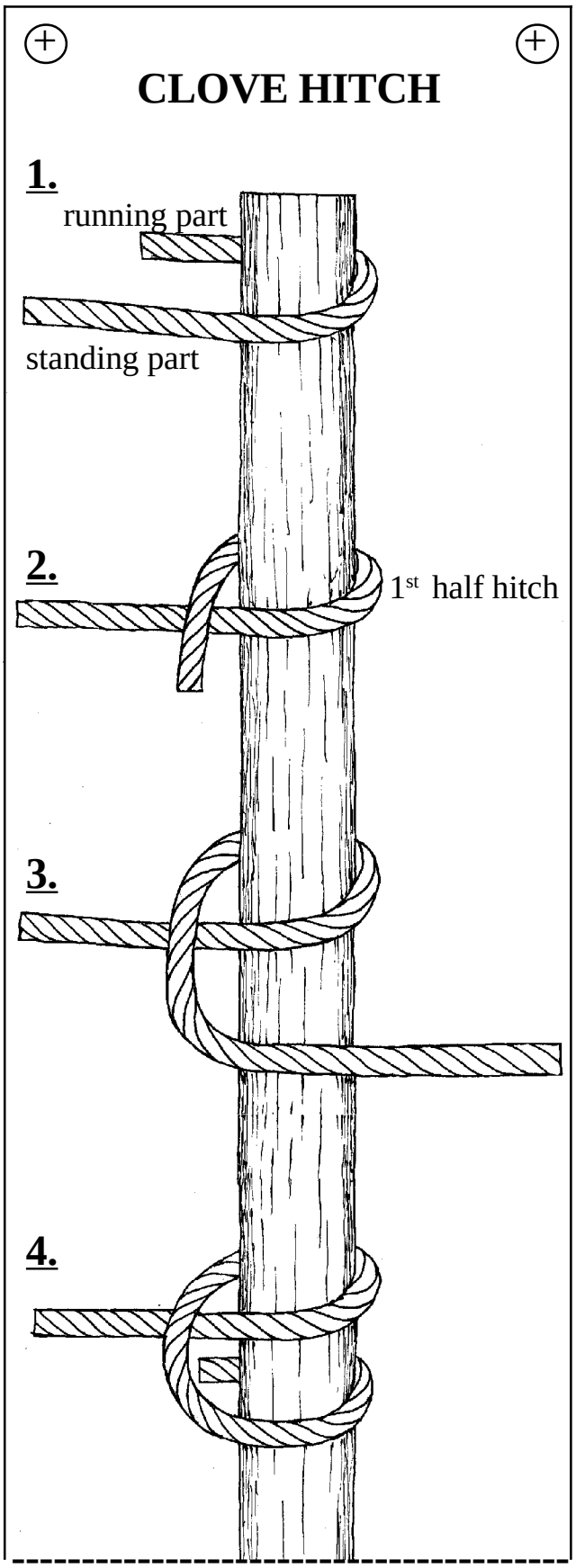

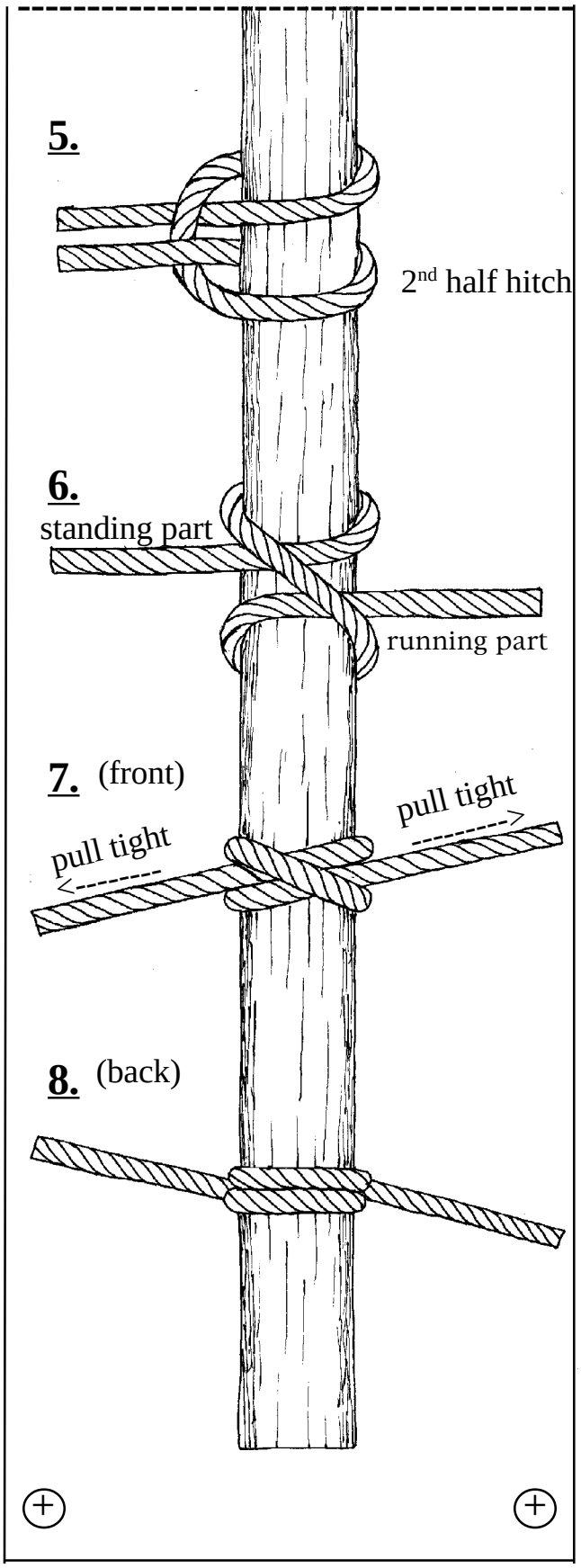

Narrative ---- (For **clove hitch** knotboard.) **(1)** Start the clove hitch by taking a bight around an object with the running part. **(2)** Cross the running part over the standing part to form a half hitch. **(3)** Start the second half hitch by continuing to wrap the standing part around the object in the same direction as the first half hitch. **(4)** Form a second bight around the object. **(5)** Finish the second half hitch**. (6)&(7)** Grasp the standing part and the running part: pull tight the clove hitch tight.

CLOVE HITCH; OVER AN END:

A clove hitch can be tied over the end of a pole or stake by using this method.

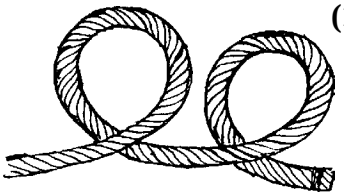

(1) Form two underhand loops in the running part of the rope.

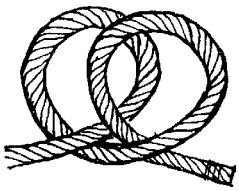

(2) Place the right underhand loop on top of the left underhand loop.

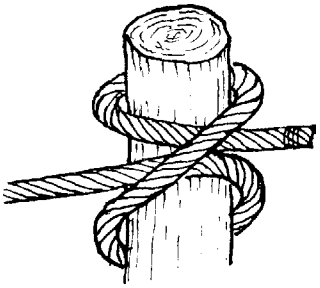

(3) Drop the loops over the end of the pole.

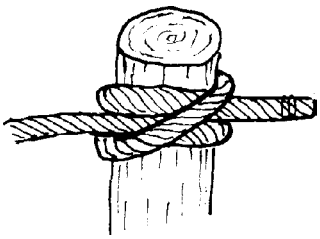

(4) Pull tight.

SQUARE LASHING:

Use ---- To bind poles that are in contact and cross each other at any angle from 45° to 90°.

Comments ---- The square lashing gets it name from the fact that the wrapping turns are at 90° or "square" to the poles.

Traditional square lashing is the most frequently used and the most secure form of lashing. If tied properly, the square lashing will remain tight and secure, but, as with all lashings, if any steps are omitted or done carelessly, the lashing will loosen and create a dangerous situation.

The square lashing can be used to bind poles together that cross and contact each other at any angle from 45° to 90°. If the angle of contact is greater than 45°, a shear lashing should be used.

When tying a square lashing, the poles and the rope must be positioned properly to achieve the maximum strength. The cross pole should

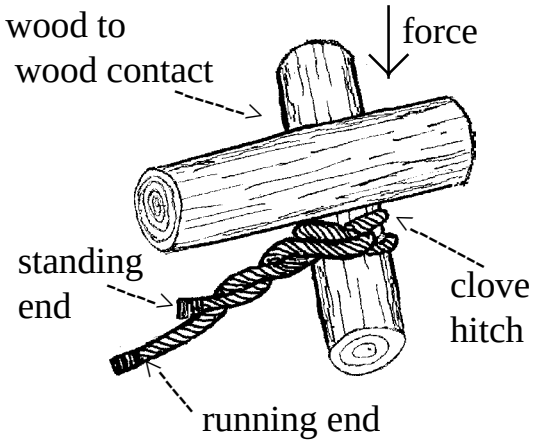

be position so that the force applied to the cross pole is directed toward the pole it is lashed to; this allows the wood to wood contact to bare part of the lode; if the force tends to separate the poles, only the rope will be supporting the load. The beginning clove hitch should be tied to the pole that is closest to parallel to the direction of the force and to the side of the cross pole that is opposite to the direction of the force. In most cases the force applied to a structure is due to gravity, therefore downward, this means that the beginning clove hitch is usually tied to the vertical pole, and under the cross pole. The standing end of the rope is secured by wrapping it around the running end.

Narration ------ (For **square lash** knotboard.) **(1)** Tie a clove hitch to the vertical pole. **(2)** Wrap the standing end of the rope around the running end **[NOTE]** The wrapping of the standing part around the running part is to secure the clove hitch so that it will not slip around the pole and loosen the lashing from the inside. **(3)** Bring the running end up and over the cross pole; then around the vertical pole; and back down over the cross pole. **(4)** Pass the rope behind the vertical pole and back up in front of the cross pole; this completes the first wrapping. **[NOTE]** Notice that the rope goes around the pole perpendicular, at 90°, to the length of the pole. This 90° angle gives the square lashing its name. **(5)** Take two more wrapping turns for a total of three wrappings: pull each turn tight. **[NOTE]** When the wrappings are taken around the vertical pole the rope should be to the inside of the previous wrapping turn; and the wrappings around the cross pole should be to the outside of the previous wrapping turn. When this pattern of taking the wrapping turns is followed the rope strands remain parallel; this insures the maximum contact between the wood and the rope. Also if the strands are not kept parallel, the additional friction between the crossed strands will make it difficult to properly tighten the wrapping turns. **(6)** Start the frapping turns by taking one

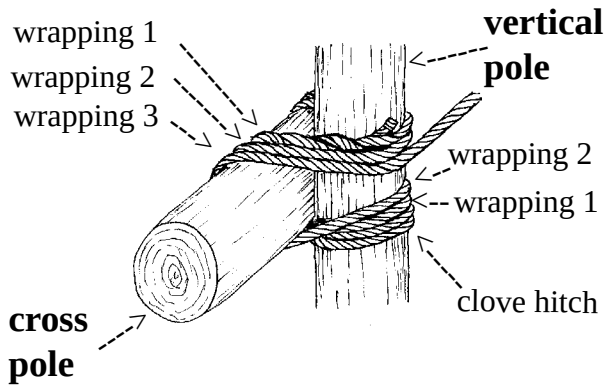

complete turn around the cross pole; **[NOTE]** The turn around the cross pole prevents the rope from crossing the wrapping turns on a diagonal. If the change of direction between the wrapping turns and the frapping turns is made by passing the rope diagonally across the wrapping turns, the increased friction between the rope strands will make it difficult to pull the wrapping turns tight. A diagonal across the wrapping turns will also allow unnecessary movement within the completed lashing, which could cause chaffing of the rope. **(7)** Take at least two frapping turns; keep the turns parallel to each other; pull each turn tight as it is made. **[NOTE]** Keeping the frapping turns parallel prevents unnecessary friction between the turns making it easier to tighten the frapping turns. **(8)** When the last frapping turn is in place, take a half hitch around the cross pole, work the half hitch tight. **[NOTE]** To prevent the rope from crossing the wrapping turns diagonally when tying the half hitch, take the rope past the cross pole on the same plain as the frapping turns, then around the cross pole. **[NOTE]** To work the half hitch tight, first pull the running end toward the standing end. This will tighten the frapping turns. Next, while keeping tension on the running end pull it in the opposite direction so that the loop of the half hitch will slip around the pole. This takes up any slack left in the rope. Work the running end back and forth in this way until the half hitch is locked tight against the lashing. If this half hitch is not locked against the lashing the ending clove hitch can slip around the pole allowing the lashing to loosen. **(9)** Add a second half hitch to form a clove hitch around the cross pole; work half hitch tight.

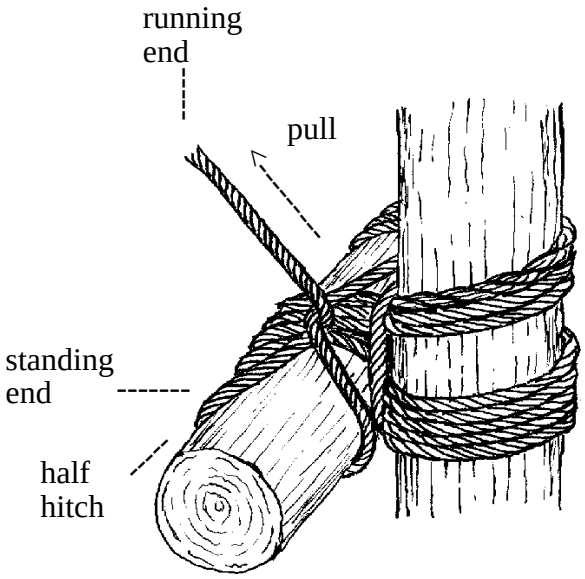

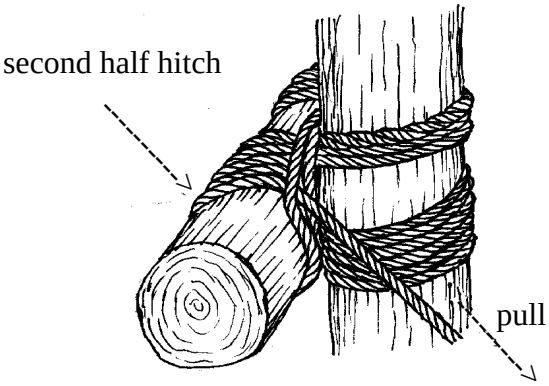

[NOTE] If smooth rope is being used a third half hitch added to the clove hitch will help insure that the lashing will stay securely in place.

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SQUARE LASHING

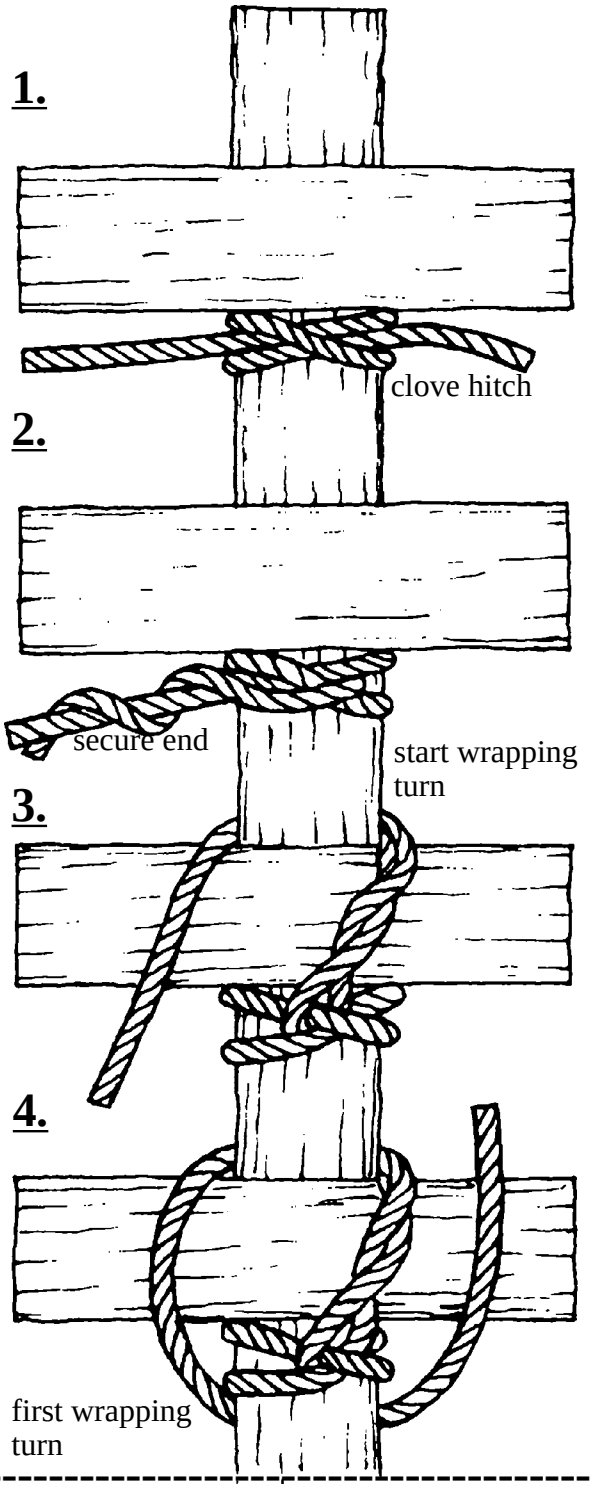

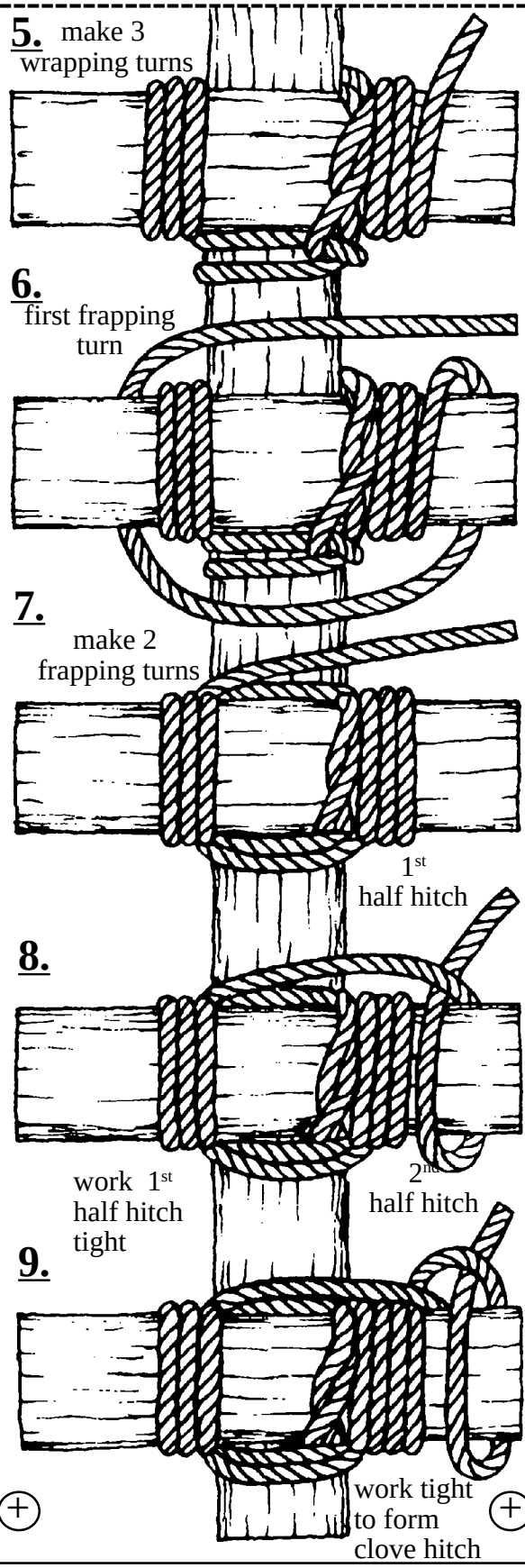

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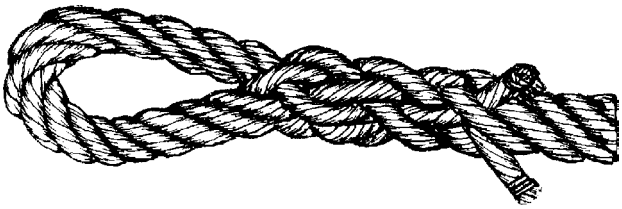

Use ---- To form a permanent loop or eye in the end of a rope.

Comments ---- The loop formed by a well made eye splice maintains 85% or more of the original strength of the rope; this makes the eye splice the preferred way to form an permanent loop in the end of a rope. However if the eye is to be subjected to repeated chafing, such as a rope being pulled through it, the eye should be serviced with a wear resistant twine.

Narration ---- (For **eye splice** knotboard) **(1)&(2)** Count back and unlay 5 rounds of the lay of the rope. **(3)** Fan the unlayed end of the rope and place it over the standing part of the rope. The strand to the inside of the eye must look like it is coming out from under the other two strands and the other two strands must be fanned in such a way that they do not cross each other. **(4)** While holding the inside strand in place, stick the middle strand under one of the strands of the standing end of the rope.

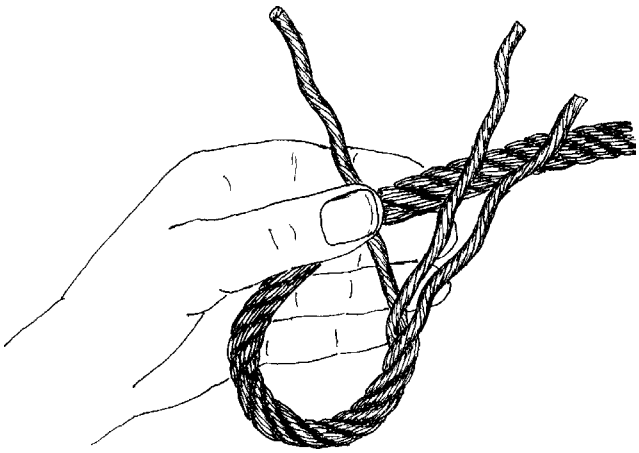

EYE SPLICE

1.

2.

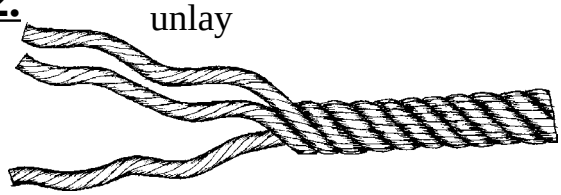

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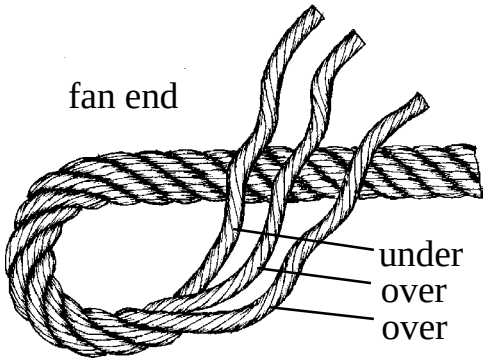

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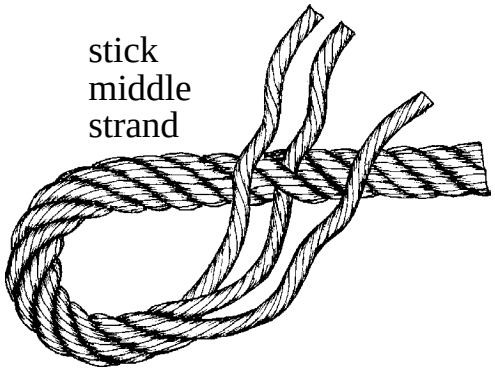

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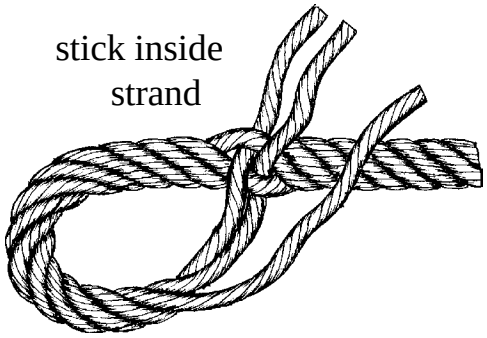

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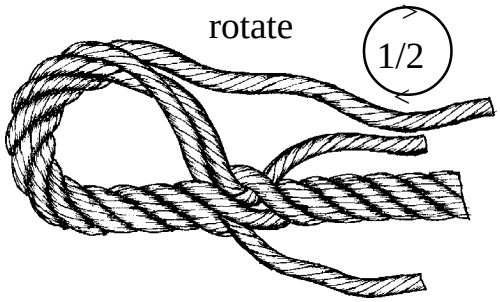

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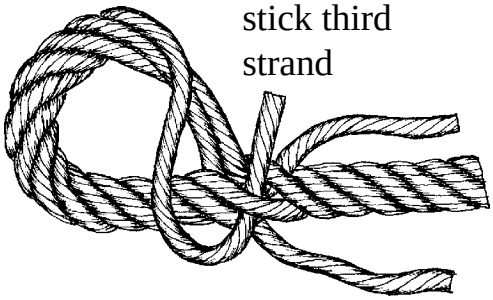

8B.

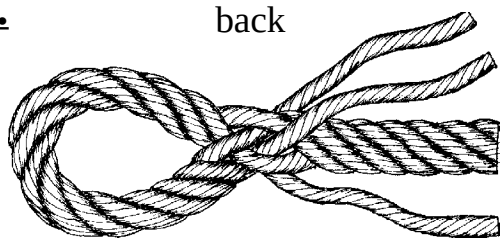

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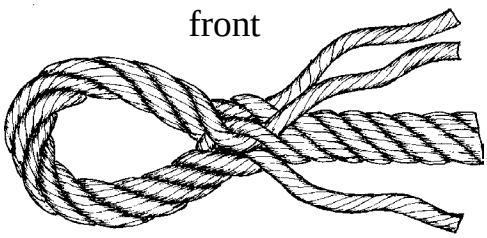

(5) Pass the inside strand over the standing end strand and stick it under the next standing end strand. **[N0TE]** The second strand goes in where the first strand came out. **(6)** Turn the splice over. (**7)** Stick the third strand under the remaining strand of the standing end. **[NOTE]** The third strand is stuck in where the second strand came out and comes out where the first strand went in. **[NOTE]** When the third strand is stuck it appears to go backward but when it is examined closely you will see that it is stuck in the same direction as the other two strands. **(8B) & (8F)** Complete the splice by working the strands snug and adding 3 to 5 50unds of tucks.

[NOTE] When the strands are folded back over the eye, you will notice that there is one strand going in and one strand coming out between each of the strands of the standing end.

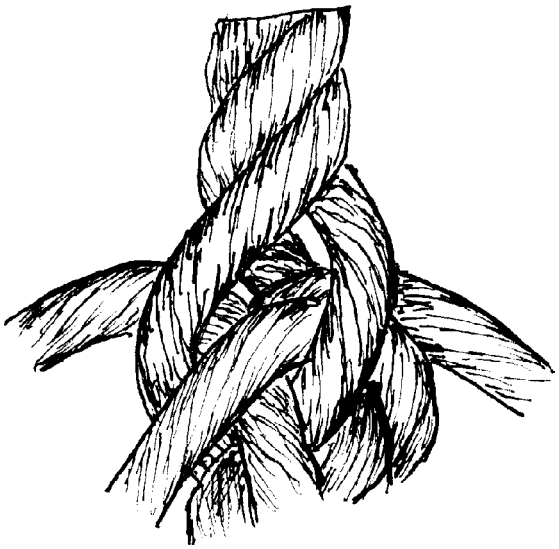

TURK'S HEAD:

Description ---- Three strand braid worked in a continuous circle.

Use ---- **(1)** As a decorative knot around a staff or railing. **(2)** Worked tight around a checked or cracked tool handle or canoe paddle to reinforce them. **(3)** As a neckerchief slide or wogal.

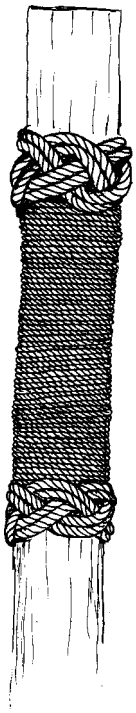

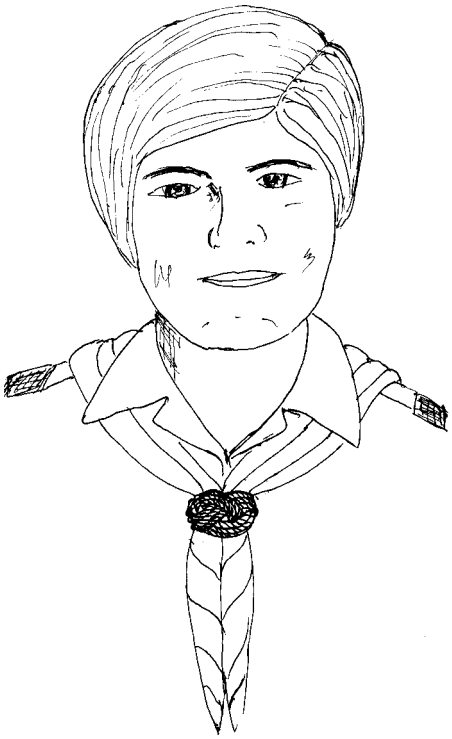

Comments ---- The form of Turks head shown here is a five crown Turk's head, this is only one of a group of knots that go by the name Turk's heads.

The crown number is determined by counting the number of bights at the edge of the knot. To make a larger loop, increase the size of the wraps made in steps 1 - 4 and then, at step 7 use three strand braiding to increase the number of crowns. The number of crowns can be increased by increments of three; so that the number of crowns in a larger loop can be 8, 11, 14, etc..

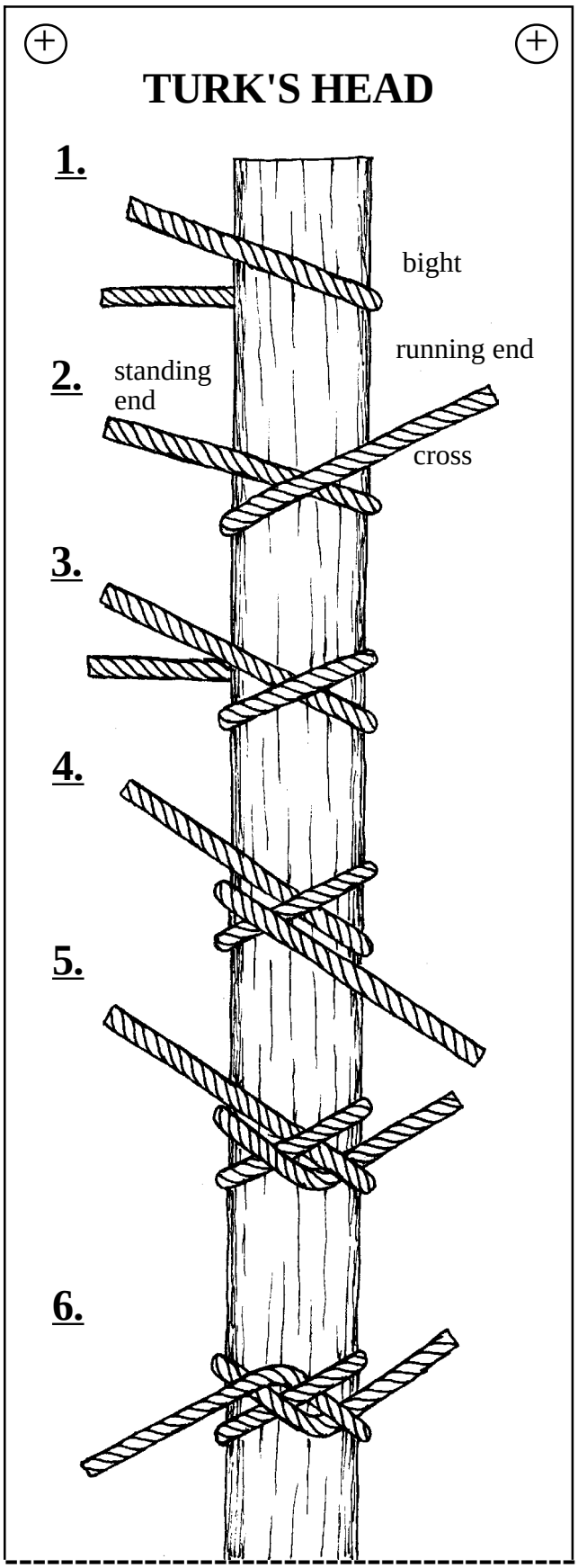

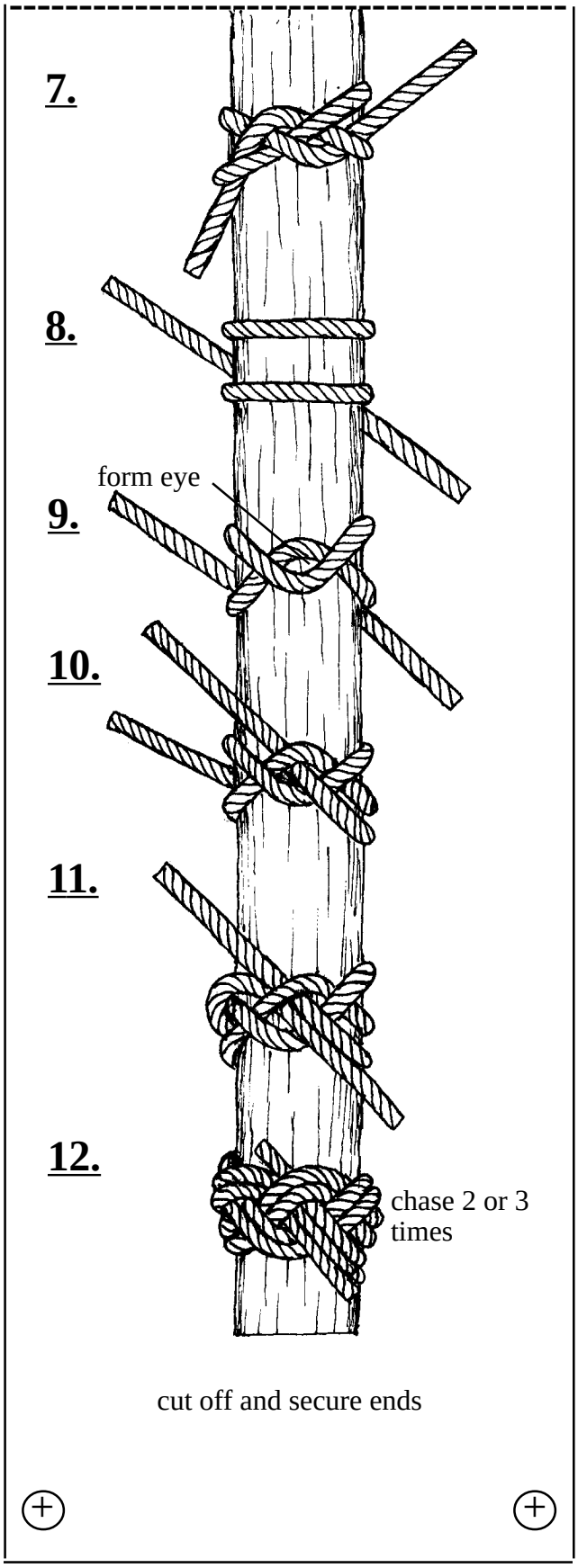

The size of the finished Turk's Head depends on the size of the rope used and the number of times the strand is chased.

Other Names ---- Three lead by five bight Turk's head, ordinary Turk's head.

Narration ------ (For Turk**'s head** knotboard.) **(1)** Start at the center of the line, by taking a bight around an object (the fingers of the left hand work well) **(2)** Complete the round turn and cross the running end over the standing end. **(3)** Take a second bight around the object so that the running end is between the standing end and the first wrap. **(4)** Lay the running end across the first wrap then **(5)** tuck the running end under the standing end. **(6)** lay the standing end across the second wrap and **(7)** tuck it under the first wrap. **(8)** rotate the knot around the object so that you are looking at the opposite side. **(9)** Cross the second wrap over the first wrap. **(10)** Reeve the standing end through the eye formed between the two wraps. **(11)** Reeve the running end through the eye between the two wraps so that the ends are in opposite directions. **(12)** Chase, follow, the strand of the knot two or three times. Cut off and secure the ends.

[NOTE] To determine the length of line to use, wrap the line around the object four times for a single strand knot. Add three and one half wraps for each time you intend to chase the original strand.

RINGBOLT HITCHING:

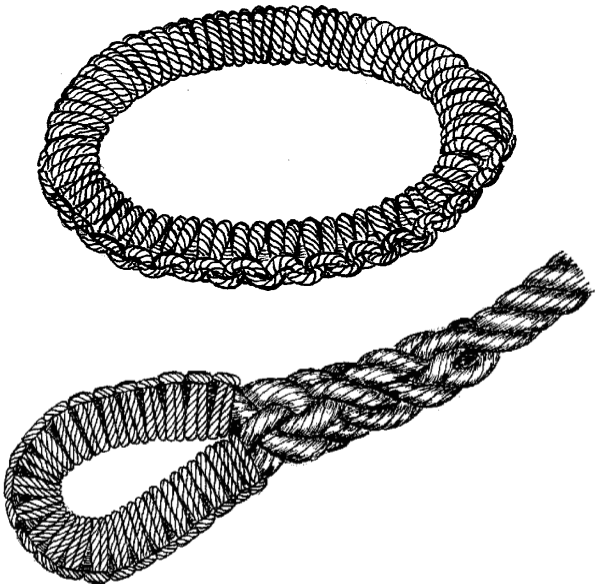

Description ---- A series interlocking lark's head knot that form a ridge around the outside of a ring or loop.

Use ---- To prevent chafing; as a decoration.

Comments ---- There are many forms of ringbolt hitching, the form shown here is one of the simplest and does not require the use of a needle as many other forms do. Ringbolt hitching was used to prevent chafing of ropes that were reeved through hand forged iron rings and to keep them from clanging against objects around them. In the present, ringbolt hitching can be used to protect synthetic ropes that are easily chafed by a applying a layer of material that is not easily chafed.

Other Names ---- Platted Ring; Hog Backing; Cockscombing.

Narration ----- (For **ringbolt hitching** knotboard.) **(1)** Start the ringbolt hitching by tying a half knot around the object. **(2)** Tie a half hitch around the object so that the standing end is trapped under the half hitch. **(3)** pull the half hitch tight. **(4)** Tie the next half hitch in the opposite direction around the object. **(5)** Pull the half hitch tight. **(6)** Tie another half hitch in the opposite direction around the object; the same direction as the first half hitch. **(7)** Pull

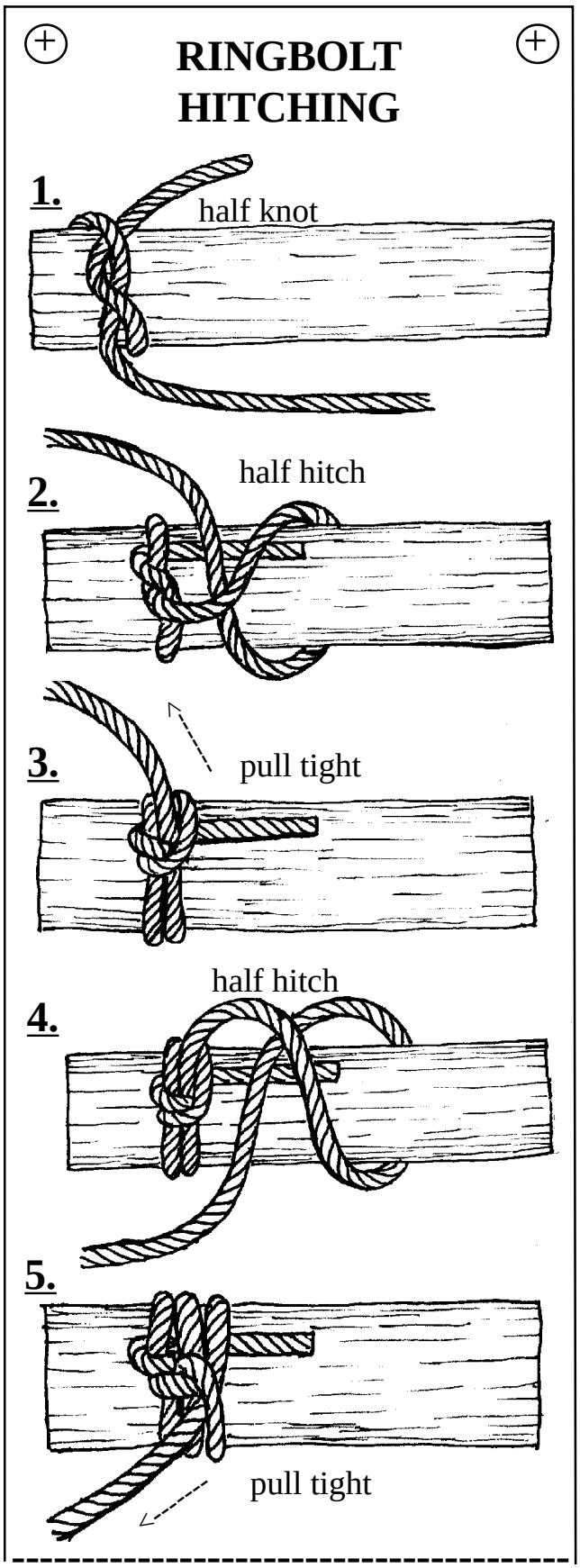

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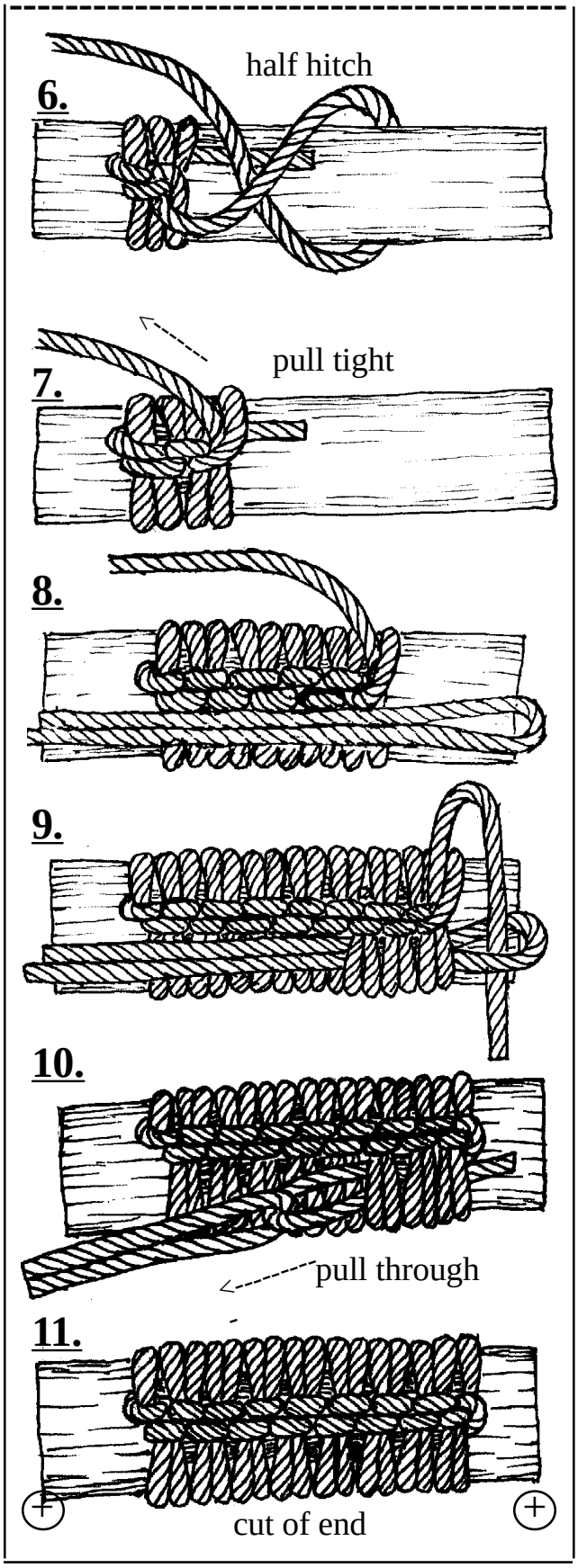

half hitch tight. **(8)** When the length of the ring-bolt hitching is within 5 or 6 half hitches of being long enough; form a bight in the a short piece of twine so that the eye of the bight is toward the end of the work. **(9)** Continue to add half hitches until the ringbolt hitching is completed; reeve the running end through the eye of the bight. **(10)** Use the short piece of twine to pull the running end under the half hitches. **(11)** Cut off the end of the twine.

[NOTES]

BOATSWAIN'S WHISTLE KNOT

Description ---- A two lead knot that is built up from two interlocking underhand loops to looks like a turk's head knot when it is worked tight.

Use ---- As a decorative knot to attach a whistle or a knife to a lanyard ---- to form a toggle or button.

Other names ---- Sailor's knife lanyard knot, marlingspike lanyard knot, single-strand diamond knot, two strand diamond knot ---- pipe lanyard knot.

Narration ----(For **boatswain's whistle knot** knot-board.) **(1)** Use the left hand to hold the middle of a strand of rope so that the loop of the bight is to the back of the hand and the two leads are between the fingers and hanging down across the palm. **(2)** Use the bottom lead, to lay an underhand loop over the standing end of top lead. **(3)** Form a bight in the bottom lead so that its running end is under the running end of the top lead. **(4)** Weave the running end of the bottom lead over the right edge of the top underhand loop, then under the standing end of the bottom lead, and over the left edge of the top underhand hand loop. This forms two interlocking underhand loops. **(5)** Form the next bight by placing the running end of the top lead under the top edge of the top underhand loop. **(6)** Reeve the running end of the top lead to the outside of the standing end of the bottom lead and up through the middle of the interlocking underhand knots. **(7)** Form the next bight by placing the running end of the bottom lead under the bottom edge of the bottom underhand loop. **(8)** Reeve the running end of bottom lead to the outside of the standing end of the bottom lead and up through the middle of the interlocking underhand knots. **(9)** Work the knot tight.

Doubling:

Doubling the Boatswain's Whistle Knot increases its size. The increase in size makes it more effective as a toggle or button. Doubling also gives a variation in appearance when doing decorative work.

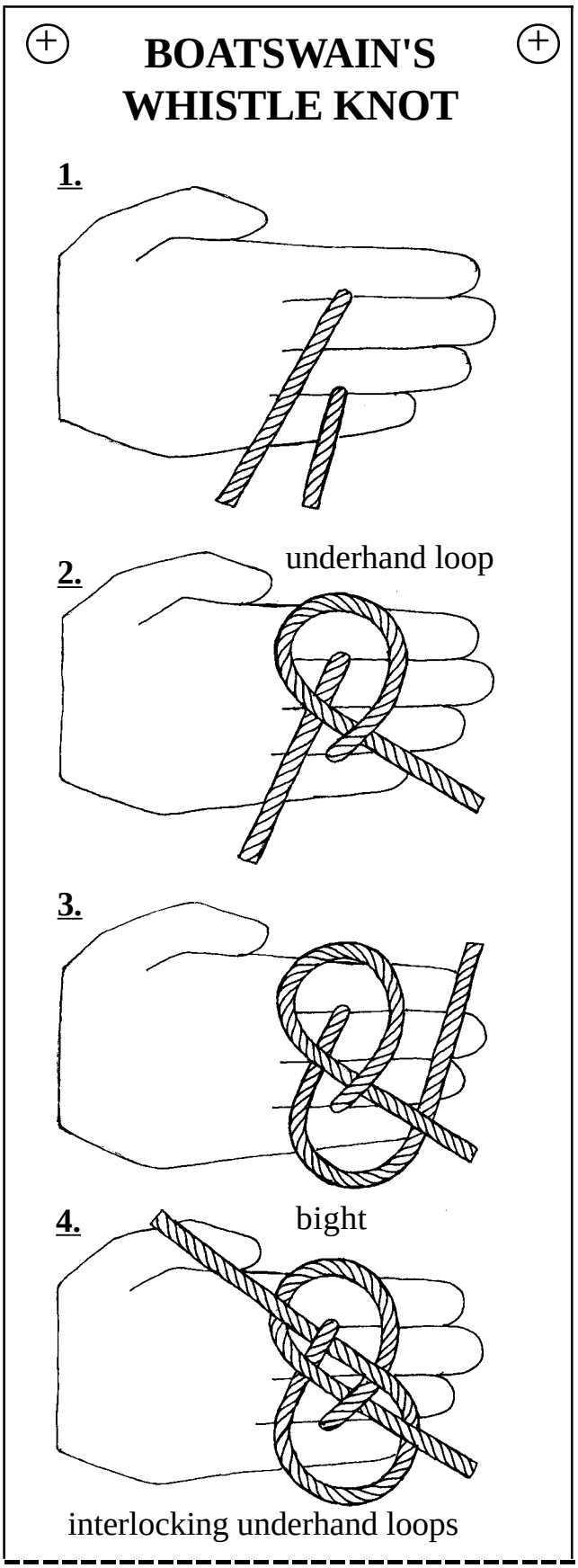

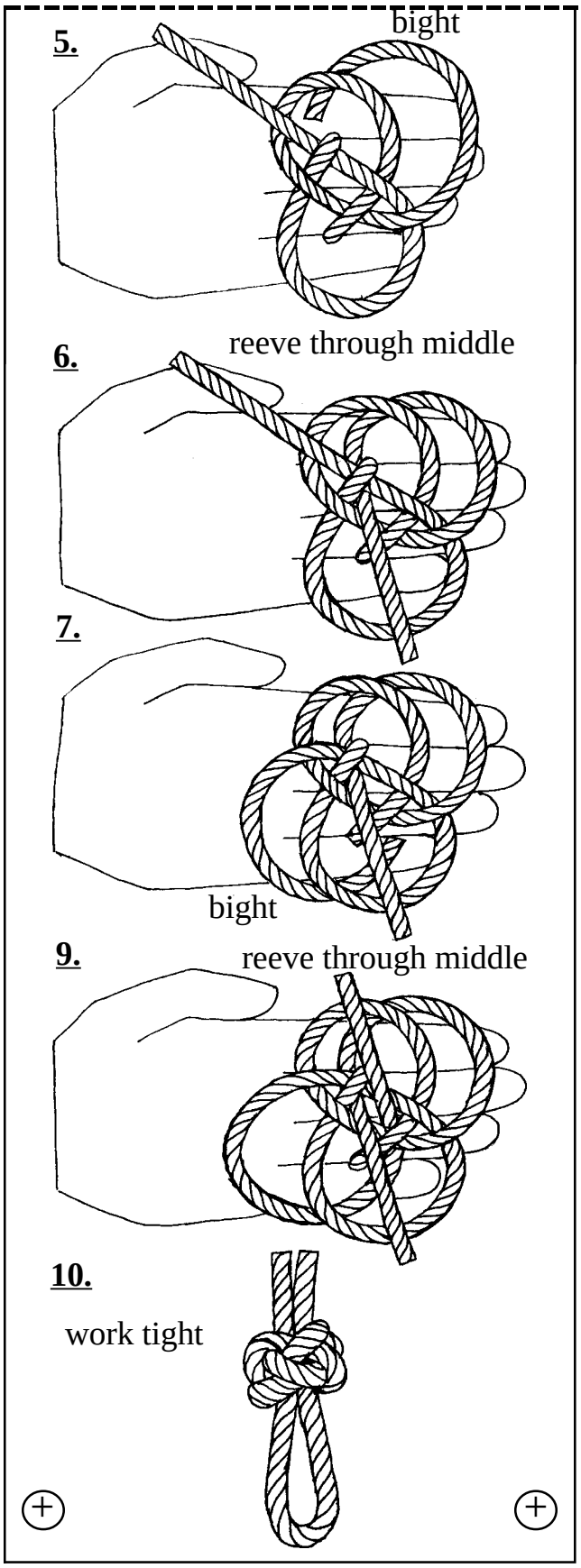

Doubling Continued:

Narrative ---- (For **Doubling** knotboard.) **(1)** Follow steps 1 --- 4 from the knot board for the BOATSWAIN'S WHISTLE KNOT. (**2**) Form the next bight by placing the running end of the top lead under the top edge of the top underhand loop. **(3)** weave the running end of the top lead to the inside of the standing end of the bottom lead and across the middle of the interlocking underhand knots. **(4)** Form the next bight by placing the running end of the bottom lead under the bottom edge of the bottom underhand loop. **(5)** Weave the running end of bottom lead to the inside of the standing end of the bottom lead and across middle of the interlocking underhand knots. **(6)** Chase the top lead with the bottom lead; end by bringing the top lead up through the middle. (7) Chase the bottom lead with the top lead; end by bringing the bottom lead up through the middle. **(8)** Work the knot tight.

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BOATSWAIN'S WHISTLE KNOT (DOUBLED)

1.

Follow steps 1 -- 4 from the knot board for the BOATSWAIN'S WHISTLE KNOT

2.

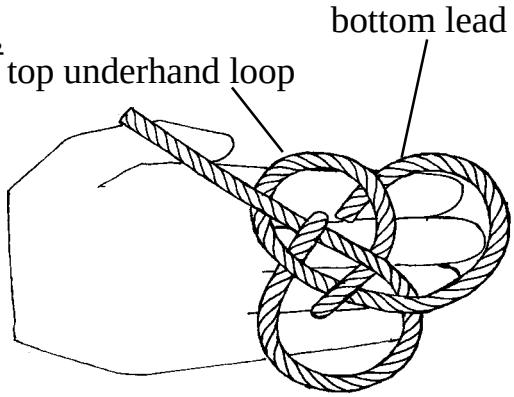

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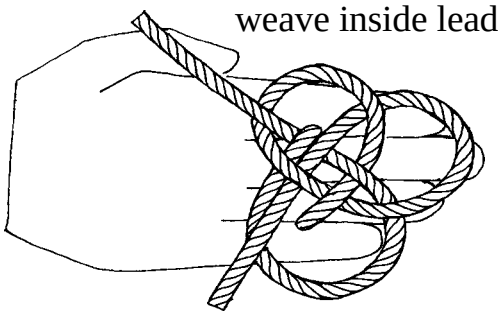

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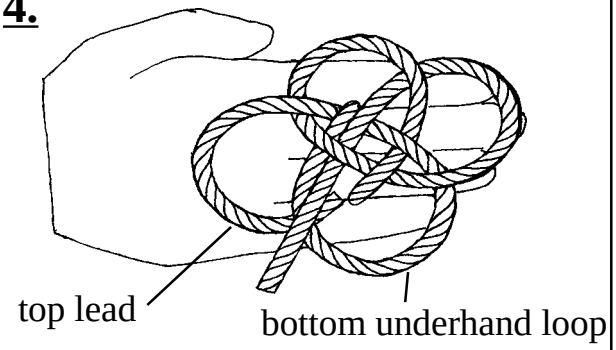

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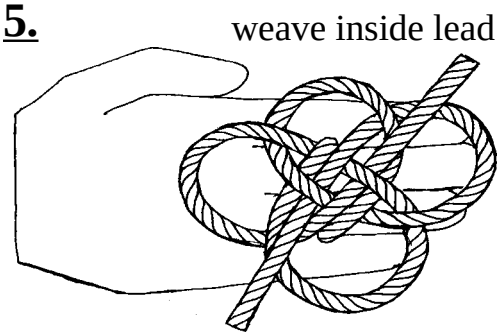

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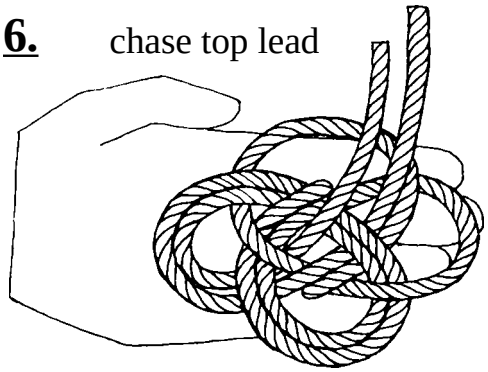

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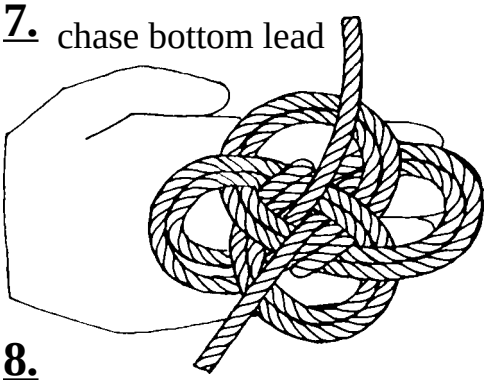

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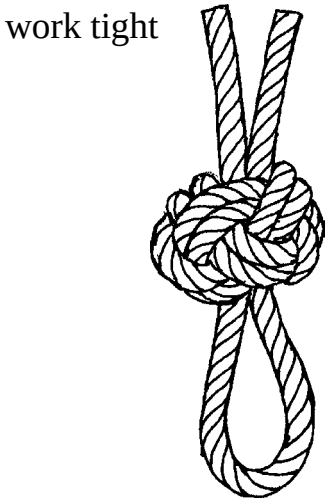

DIAGONAL LASHING:

Use ---- Diagonal lashing is used to bind poles together that cross each other but do not touch when their ends are lashed in place in a structure.

Comments ---- The diagonal lashing gets its name from the fact that the wrapping turns cross the poles diagonally.

The diagonal lashing can be used to bind poles that cross each other from 90° to 45°. If the angle between the poles is less than 45° a shear lashing should be used.

The diagonal lashing makes use of the timber hitch to pull poles together that are not touching each other. The timber hitch allows the poles to be drawn together without changing the relative positions of the poles. **[NOTE]** If a square lashing were used to bind poles that do not touch, the beginning clove hitch would pull the cross pole toward the clove hitch causing unnecessary bowing of the cross pole and could also produce a force that would act along the length of the pole to which the clove hitch is tied. These additional force, if strong enough, can place unnecessary strain on other lashing within the structure causing the structure to twist and fail.

Narration ---- (For **diagonal lash** knotboard.) **(1)** Tie a timber hitch diagonally around both poles. **(2)** Start the wrapping turns on the opposite diagonal to the timber hitch, by pulling the rope tight so that the poles contact each other. **(3)** Take 3 to 4 wrapping turns; keep the wrapping turns parallel; pull each wrapping turn tight. [NOTE] If the wrapping turns are allowed to cross, the increased friction between the strands of the rope will make it difficult to tighten the wrapping turns. **(4)** Start the second set of wrapping turns by going past and around the vertical pole. **[NOTE]** Going

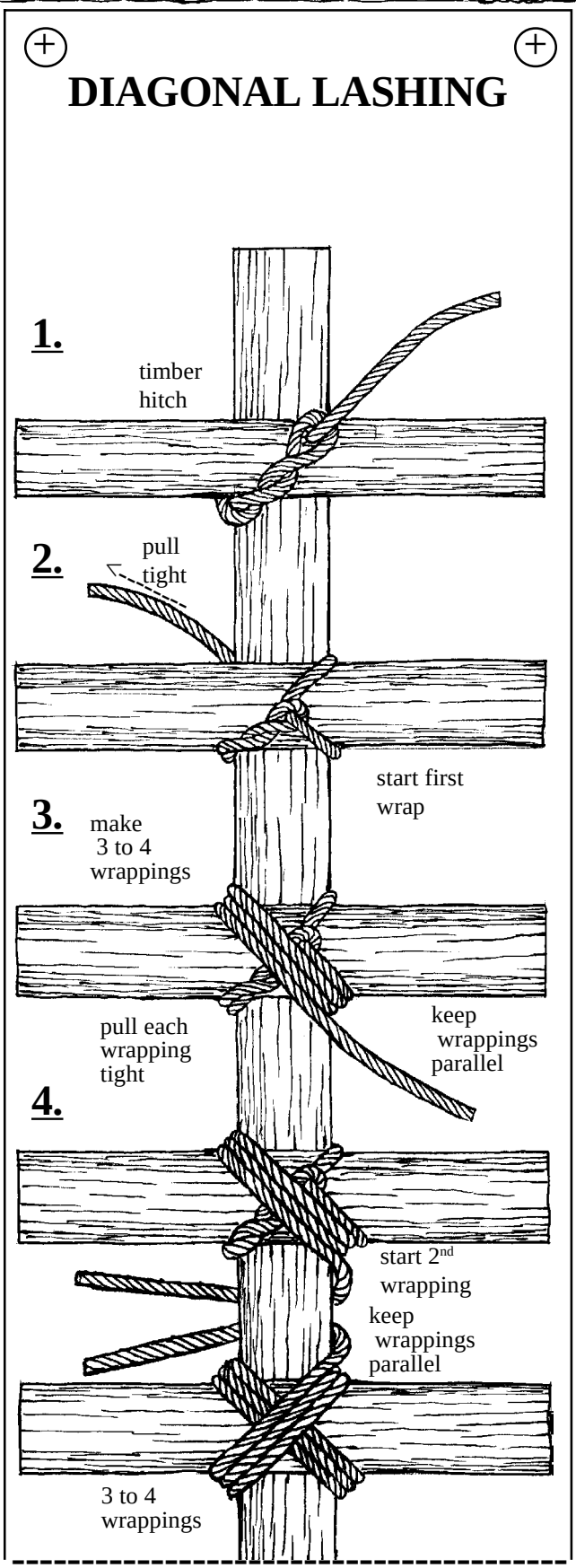

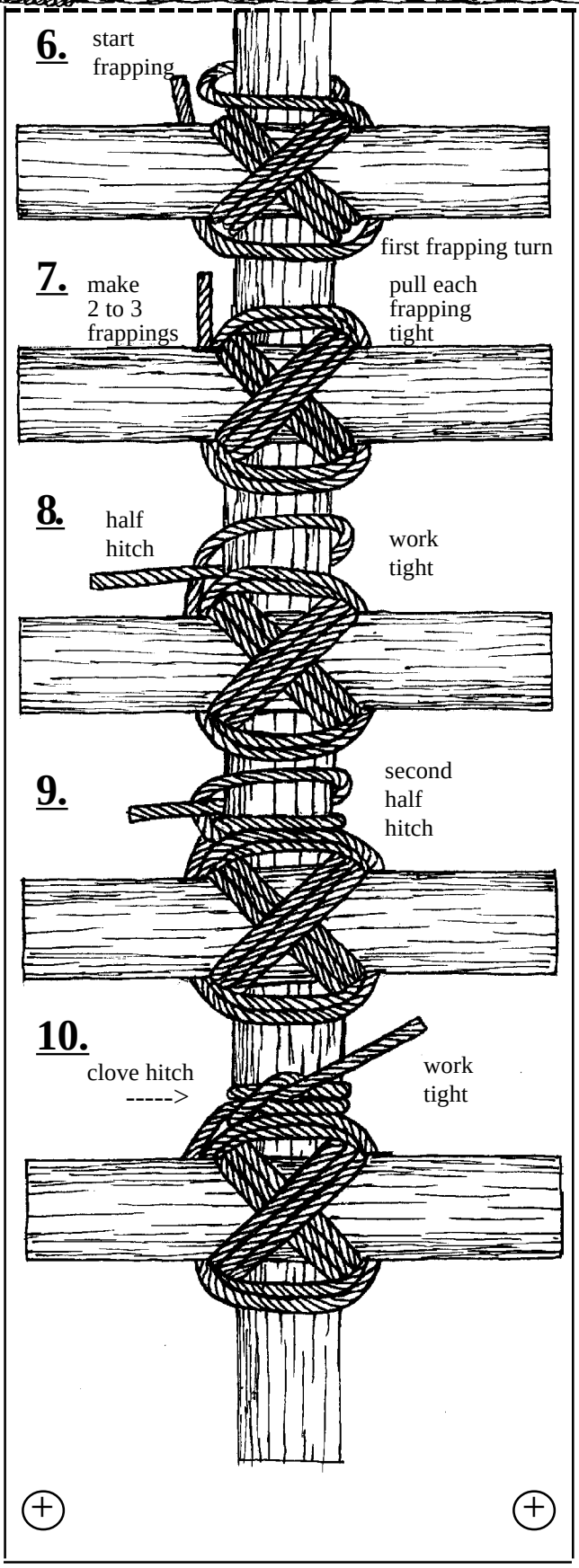

around the pole the rope allows the direction of the rope to be changed without crossing the first set of wrapping diagonally. **(5)** Take 3 to 4 wrapping turns; be sure to keep the wrapping turns parallel; pull each wrapping turn tight. **(6)** Start the frapping turns by going past and around one of the poles. **[NOTE]** Going around the pole with the rope allows the direction of the rope to be changed without crossing the wrapping turns diagonally. **(7)** Take 2 to 3 frapping turns; keep the frapping turns parallel. Be sure to pull each turn tight. **(8)** End the lashing with a clove hitch. Take the first half hitch of the clove hitch by going past and then around one of the poles. Lock the half hitch tight against the lashing by working it tight. **(9)** Take a second half hitch around the pole. **(10)** Work the second half hitch tight against the first half hitch so that the clove hitch is locked against the lashing.

[NOTE] See the directions for square lashing for instructions on working the half hitches tight.

[NOTE] If very smooth rope is used, the lashing can be made more secure by adding a third or forth half hitch to the clove hitch.

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CONSTRICTOR KNOT:

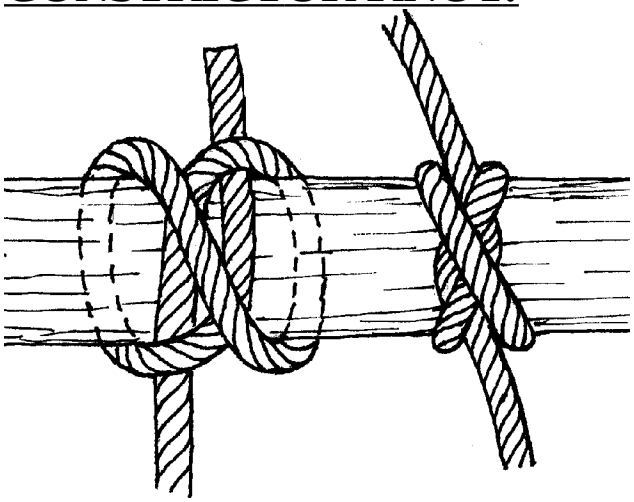

Description ---- A clove hitch with a half knot under the cross-point.

Use ---- To tie a smaller rope to a larger one, or to tie a rope to a stake or pole; a substitute for whipping; as a lashing for light construction ; as a hose clamp.

Comments ---- A secure nonslip knot ; difficult to untie without cutting.

METHODS OF TYING:

Method # 1:

[NOTE] Use this method of tying the constrictor knot on either side of where you intend to cut a rope. This is a fast and easy way to prevent a rope from unlaying when it is cut.

Narration ---- (For **constrictor knot (method #1)** knotboard.) (1) take a bight around an pole. **(2)** Continue wrapping the running part around the pole so that the running part crosses over the standing part. **(3)** Complete the turn around the pole. **(4)** Cross the running part over the standing part so that **(5)** a bight is formed around the standing part. **(6)** Reeve the running part under the cross part of the loop in the standing part to form a half knot under the cross-point. **(7)** Pull the standing tight. **(8)** Lock the knot tight by pulling hard on both the standing part and the running part.

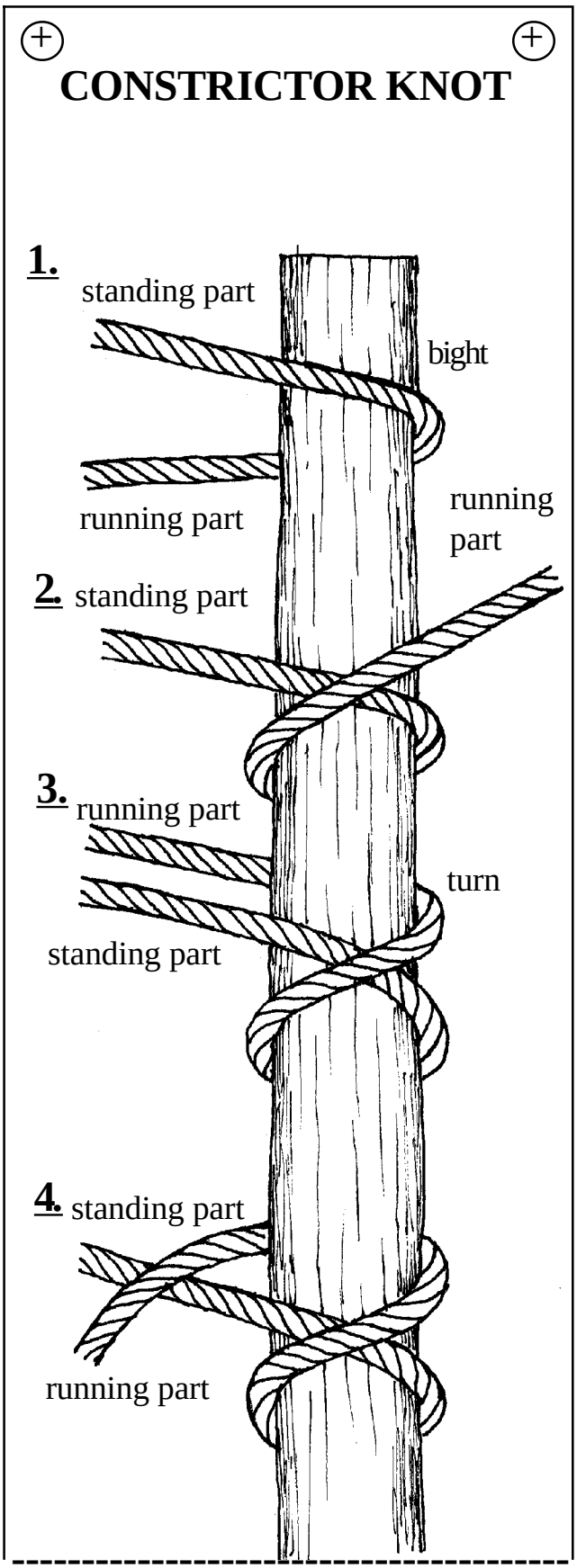

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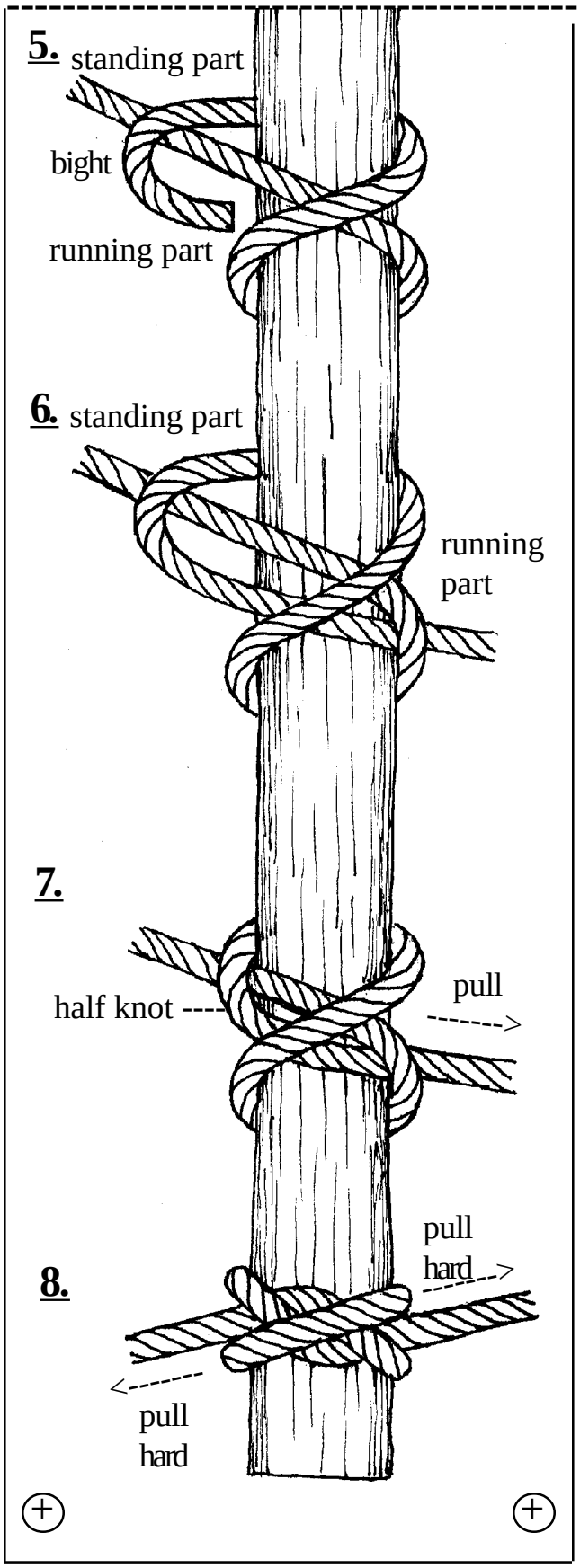

METHODS OF TYING:

Method # 2: Over the end of a pole or rope.

[1] Start with an underhand loop laid on the pole.

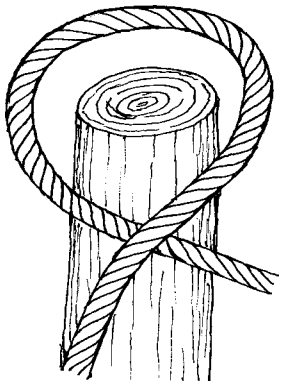

[2] Place the loop over the end of the pole.

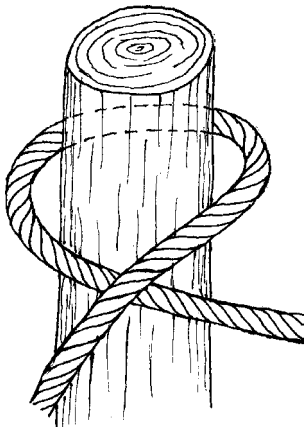

[3] Pull the opposite side of the loop down and under the cross point of the underhand loop

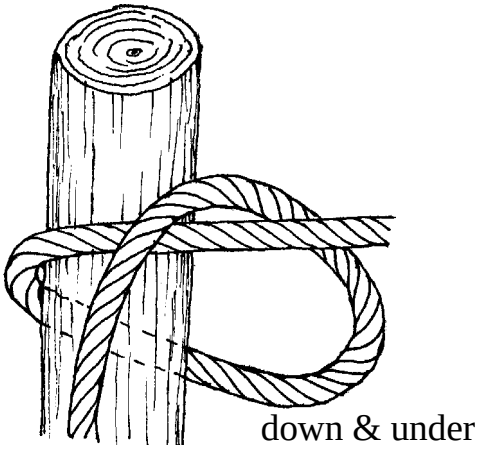

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[4] ..... then pull it up and over the end of the pole .....

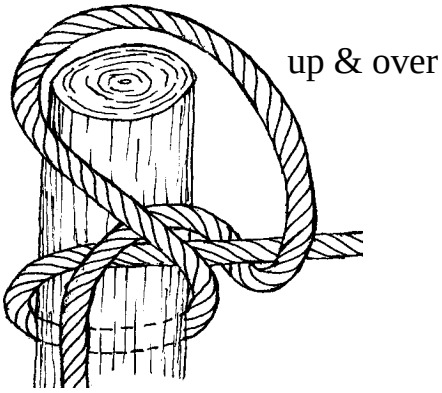

[5] ..... to form a second loop around the pole and a half knot under the cross point of the knot.

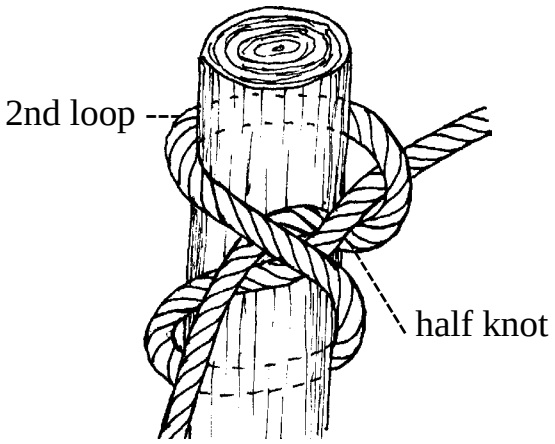

[6] Pull the two ends tight. The harder you pull the tighter the knot.

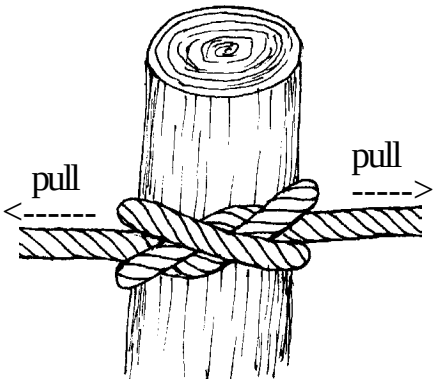

Method # 3: Slippery constrictor knot.

[NOTE] This method of tying the constrictor knot allows it to be untied quickly and easily.

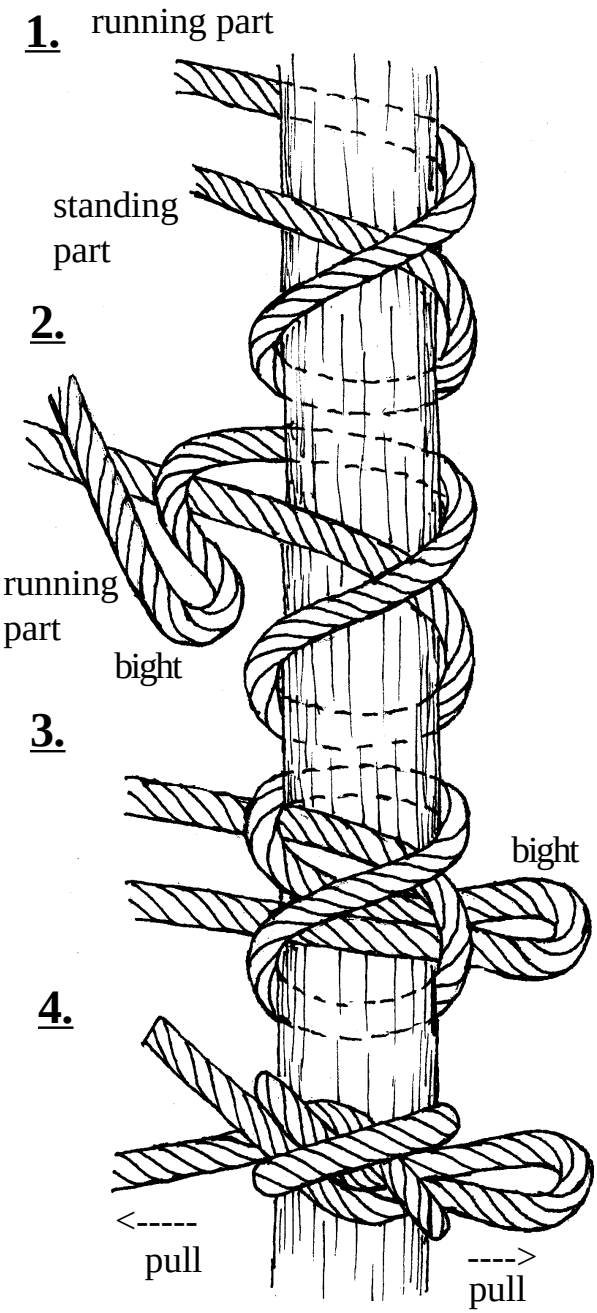

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Narration -----(For **slippery constrictor knot** knotboard.) **(1)** Tie the slippery constrictor knot the same way as a regular constrictor knot but **(2)** form a bight in the running end before it is **(3)** reeved under the cross part of the loop in the standing part. Pull the standing tight. **(4)** Lock the half knot tight by pulling hard on both the standing part and the running part.

Method # 4: As a lashing.

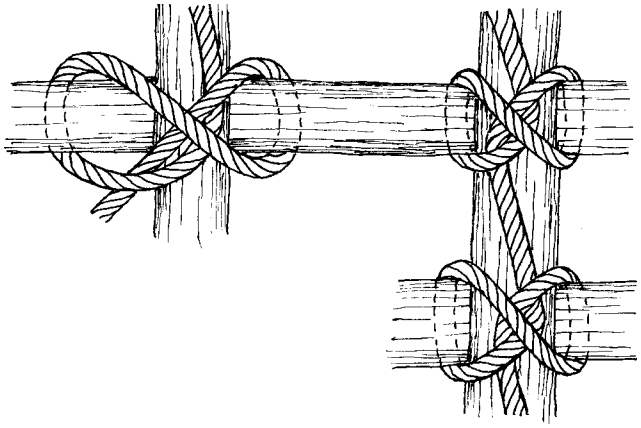

SUGGESTED USES: For the constrictor knot.

whipping

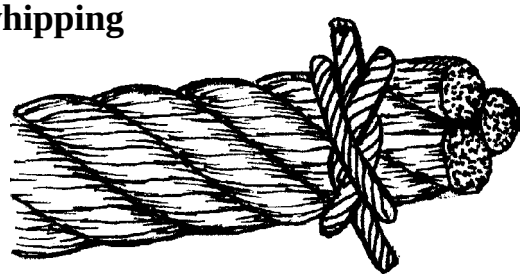

spaced rungs

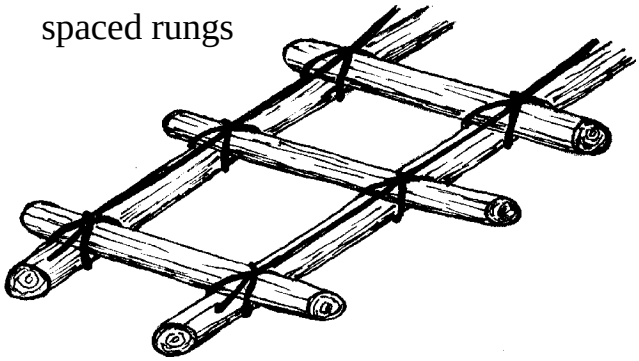

tying to a stake or pole

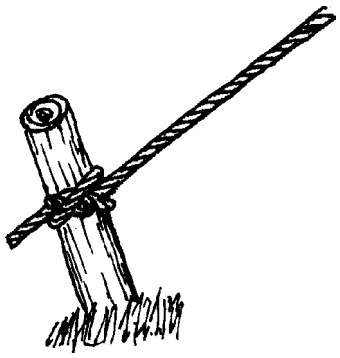

round lashing

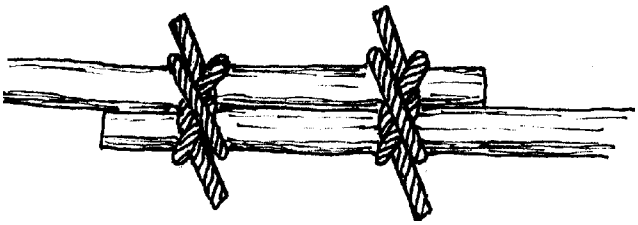

[NOTES]

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MONKEY'S PAW:

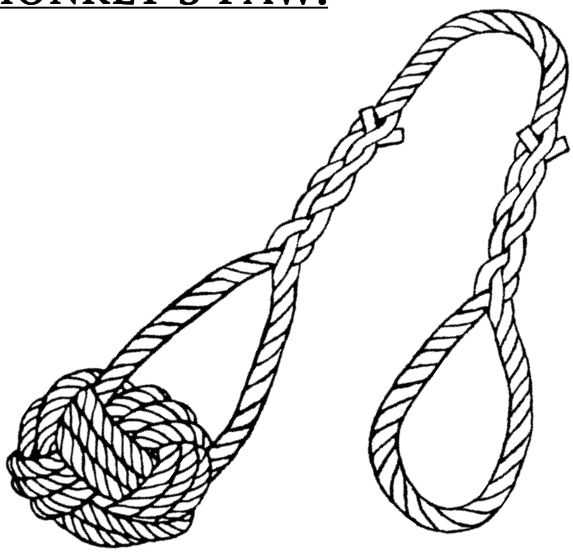

Description ---- Theform of the monkey's paw sown here is formed from four interlocking loops: a four crown turk's head.

Use ---- The core determines what the monkey's paw can be used for. When tied over a stone or heavy ball, the monkey's paw can be used to add weight to a heaving line. If tied over a cork ball with small cord the monkey's paw makes a good float for boat keys or other small items used around a water front. Tied over a ball of twine or other soft material, the monkey's paw can be used as weight on the end of a rope for the game jump the shot. A Monkey's Paw can also be used as a toggle.

Core Size ----- The diameter of the core should be between three and four diameters of the rope being used.

MONKEY'S PAW TURK'S HEAD

Narration ---- (For **monkey's paw turk's head** knotboard) **(1)** Form an overhand loop **(2)** Form a second overhand loop over the left edge of the first overhand loop . **(3)** Cross the standing end over the running end. **(4)** Weave the running end across the loops by placing the running end over the right side of the top loop **(5)** then under the right side of the bottom loop **(6)** next, over the left side of the top loop **(7)** and

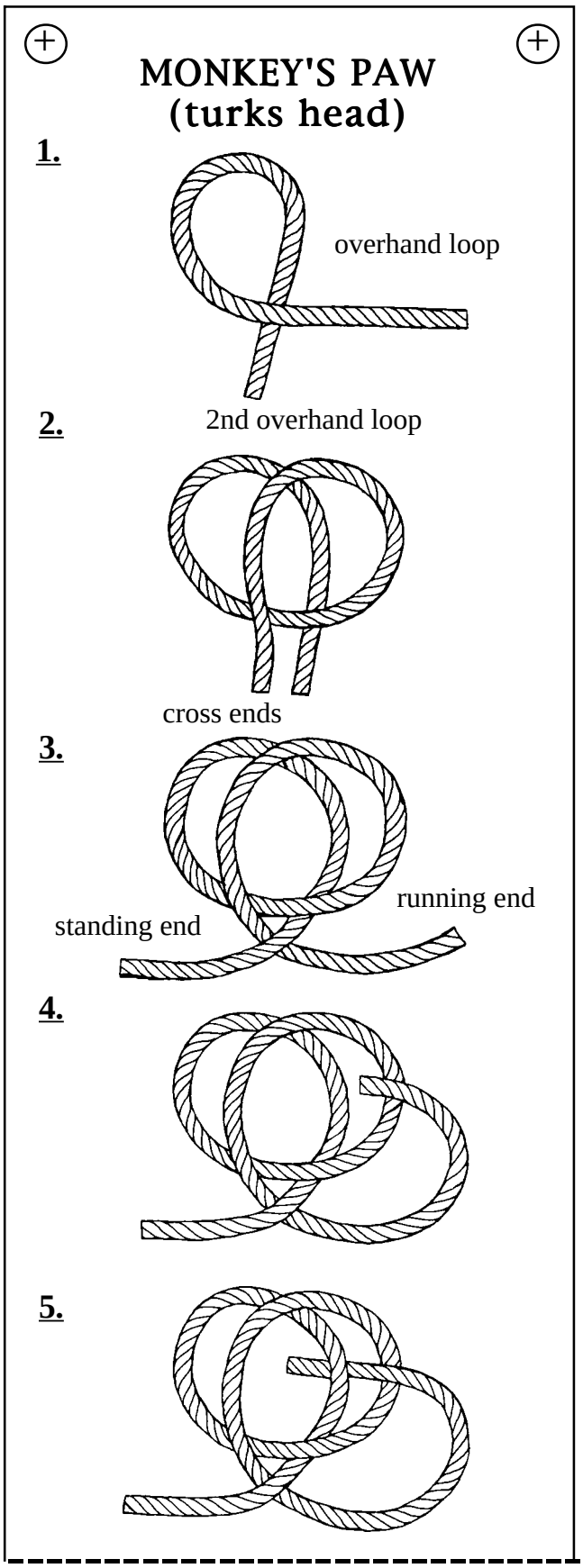

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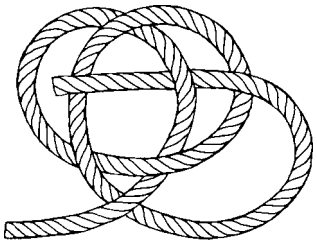

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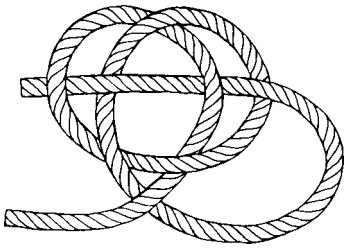

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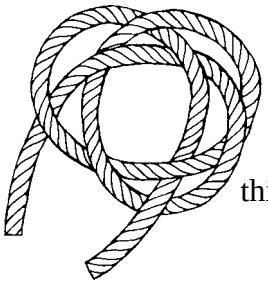

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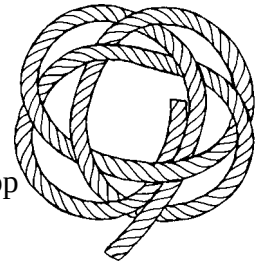

10. chase 2 to 3 times

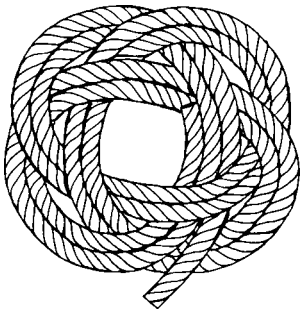

11. work tight over a core

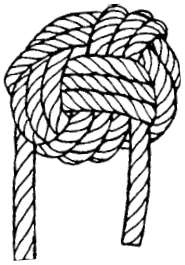

finally under the left side of the of the bottom loop. **(8)** Pull the running end through until a third loop equal in size to the first two loops. **(9)** Add the fourth loop by placing the running end parallel to the standing end. **(10)** Chase the original pattern 2 to 3 times. **(11)** Work tight over the core.

[NOTE] Join the two ends of the monkey's paw with an eye splice, a short splice, or a seizing.

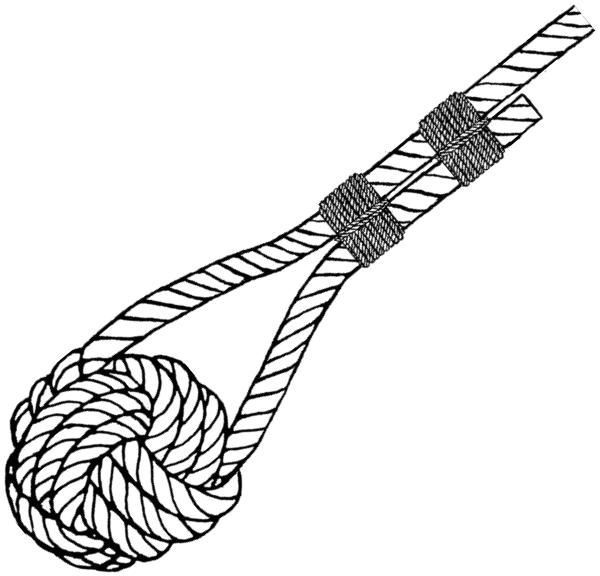

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MOORING HITCH :

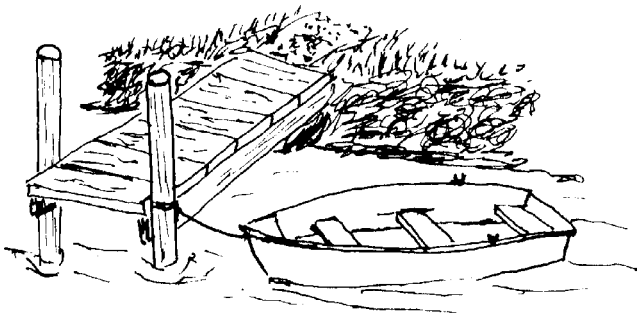

Description —— An underhand loop toggled to the standing part with a bight made in the running end.

Use —— To securely tie off a rope so that it can be quickly untied, especially a small boat to a dock or piling.

Comments —— A secure knot that is easily tied or untied in wet or dry rope; when properly tied a non closing loop is formed, this allows the hitch to move up or down a piling as the water level changes.

Narrative ——(For **mooring hitch** knotboard.) **(1)** Take a bight around an object. **(2)** Form an underhand loop in the running part. **(3)** Place the eye of the underhand loop over the standing part. **(4)** Pull a bight of the standing part through the eye of the underhand loop. **(5)** Pull the underhand loop tight around the bight. **(6)** Place the running part under the eye of the bight that was pulled through the underhand loop. **(7)** Pull a bight of the running part through the eye of the standing part bight. **(8)** Pull on the standing part to tighten the standing part bight around the running part bight.

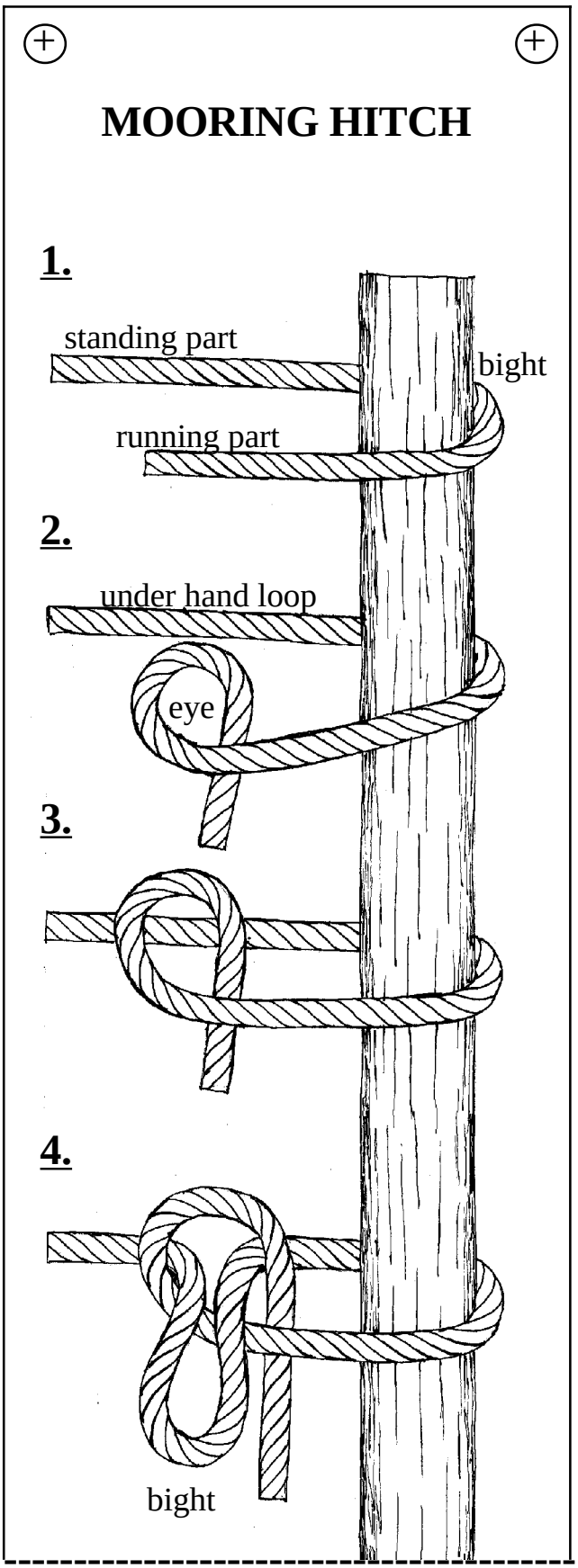

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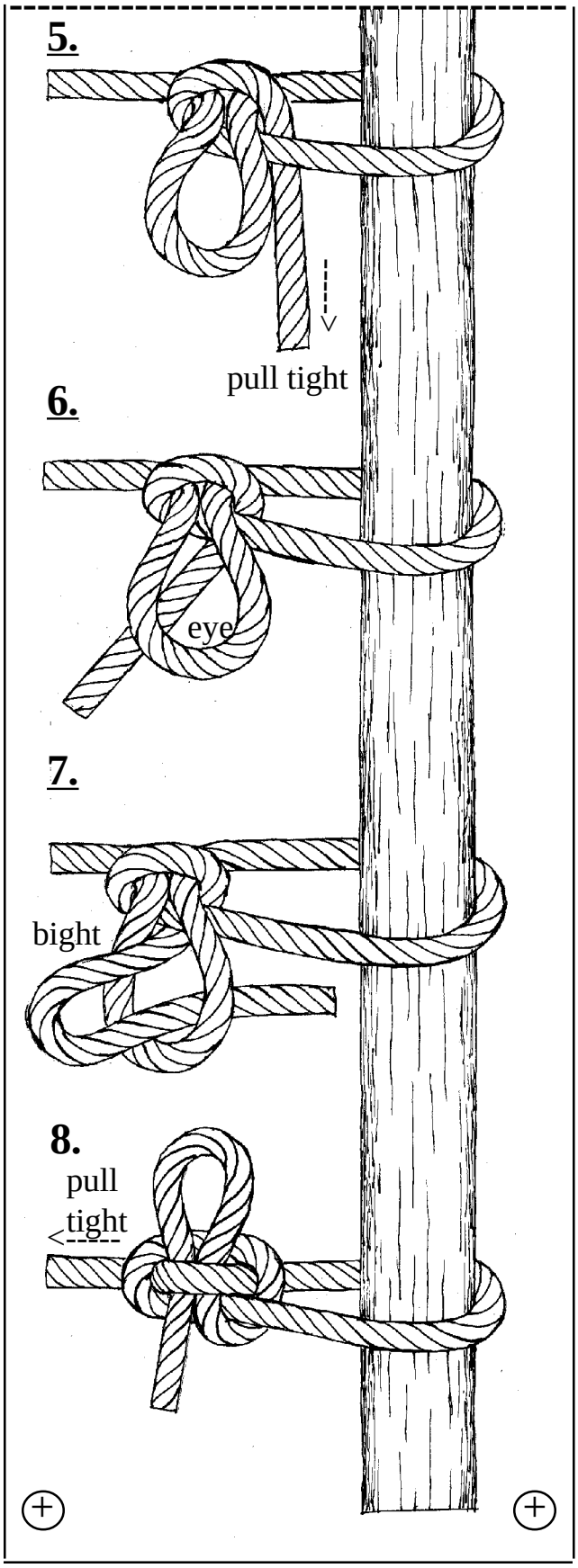

[NOTES]

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JUG KNOT:

Use ---- to provide a convenient carrying handle for jug or bottle ---- to attach a tool, such as a hammer to a security line to prevent accidental dropping --- to add a wrist loop to a walking staff --- to attach a safety line to a canoe paddle ..... use your imagination, but be sure that you keep safety in mind.

Other names ---- Jar knot, moonshiner's knot, hackamore, bridle knot.

Comments ---- The most common use is to provide a loop handle attached to the neck of a bottle. The loop handle makes it easy to carry several bottles with one hand. If a toggle or a two strand button knot such as boatswain whistle knot is added to the free end of the rope,

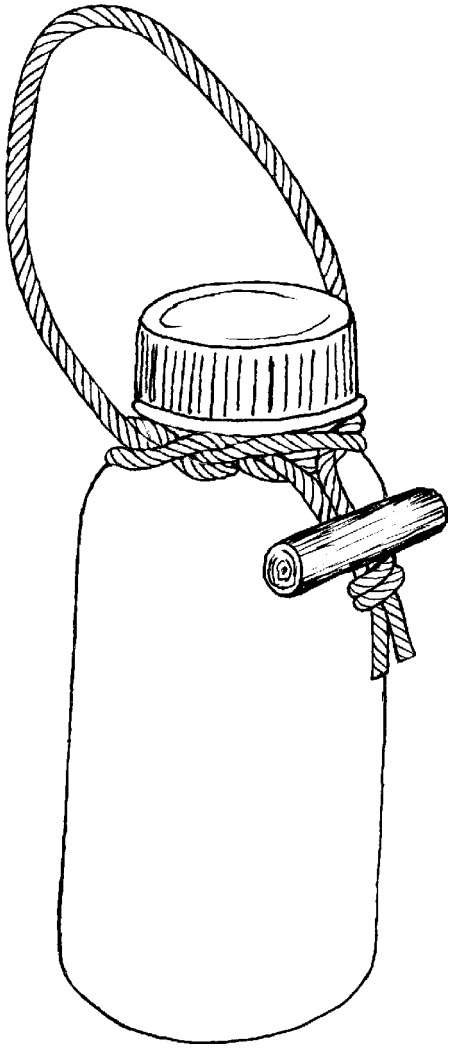

JUG KNOT

1.

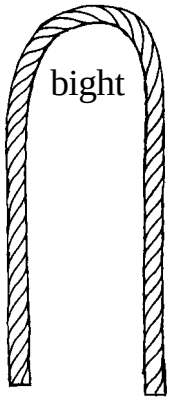

2.

fold down

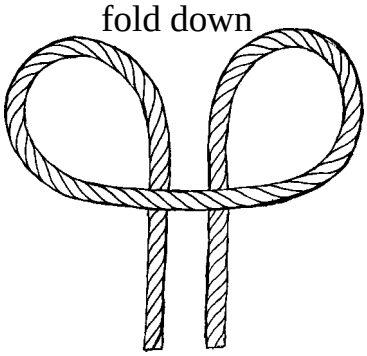

3.

cross loops

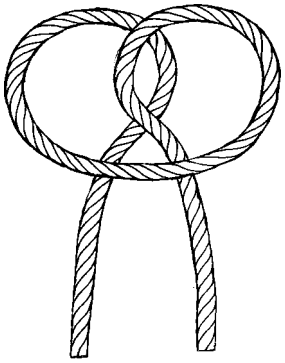

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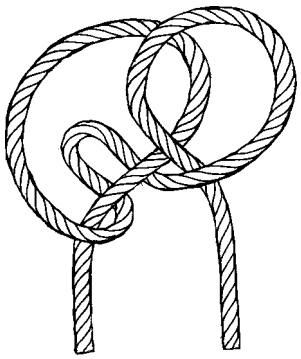

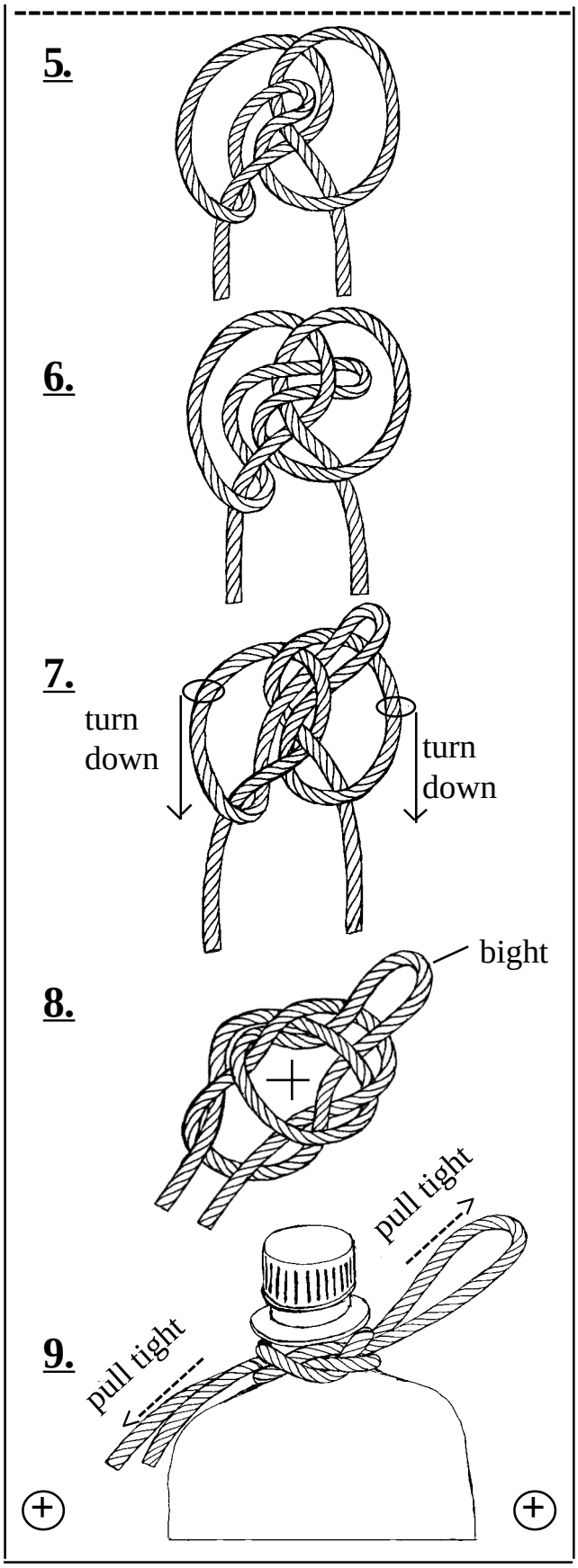

The loop of the jug knot can be use to toggle the bottle to a belt so that the bottle can be use as a canteen.

Plastic bottles with screw-on lids such as soda, sport drink, and mineral water bottles make strong, lightweight containers for carrying water on hikes and camp outs. 2 and 3 liter soda bottles are large enough to use as water containers around the camp kitchen. Smaller bottles (8 to 16 oz.) can be used as personal water bottles or canteens. These bottles can be made even more convenient by using a jug knot to attach a loop handle.

To help keep your water cool and refreshing in hot weather, place a sock over the bottle, wet the sock when you fill the bottle, evaporation will do the rest.

In cold weather, carry your water bottle under your coat. A dry sock placed over the bottle will help keep the water from freezing.

To protect your health, wash and disinfect your water bottle with a chlorine bleach solution and don't share your water bottle with others; show them how to make a water bottle of their own.

Narrative ---- (For **jug knot** knotboard) **(1)** Form a bight in the middle of a 24 to 30 inch long by 3/16 inch diameter rope. **(2)** Fold the bight down over the standing ends to form two loops. **(3)** Place the right loop over the side of the left loop. **(4)** Weave the middle of the bight under the standing end; then over the left edge of the right loop; **(6)** next go under the right edge of the left loop; **(7)** finally pass the bight over the right side of the left loop. **(8)** Turn the tops of the original loops down over the knot. **(9)** Place the knot over the neck of a bottle and work the knot tight so that the bight forms a 4 to 5 inch loop handle and the loose ends are even.

BELAYING TO A CLEAT:

Description ----- A turn secured to a cleat with a figure eights and locked in place with a half hitch.

Use ---- To secure a flag lanyard, to moor a boat to a dock.

Comments ---- Belaying to a cleat is a fast non-jamming method of securing a rope anywhere along its length without reeving any part of the rope through or around anything.

Narration ----(For **belaying to a cleat** knotboard.) **(1)** Take a bight around the the first horn of the cleat and pull the line tight. **(2)** Take a bight around the second horn. **(3)** Place the line across the cleat. **(4)** Take a second bight around the first horn. **(5)** Place the line across the cleat a second time. **(6)** Form a loop so that its running end is under its standing end. **(7)** Place the eye of the loop over the second horn of the cleat. **(8)**Pull the loop tight to form a half hitch around the horn of the cleat, this locks the rope in place.

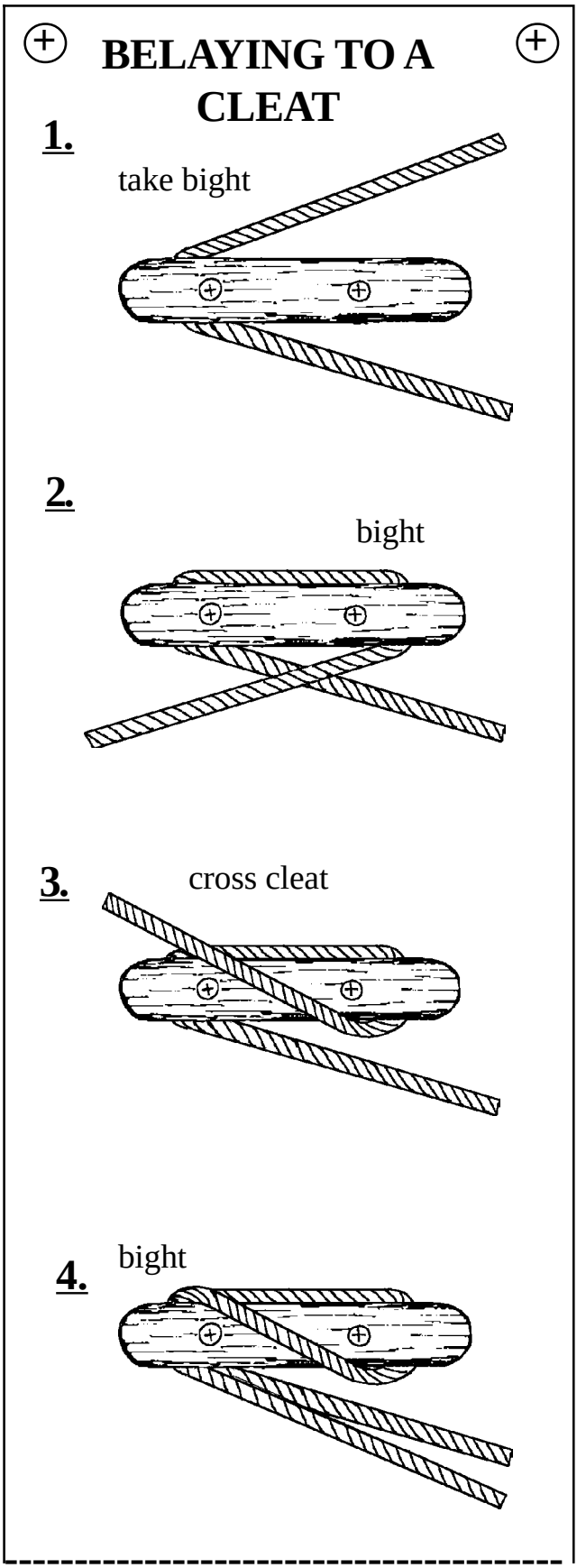

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5. cross cleat

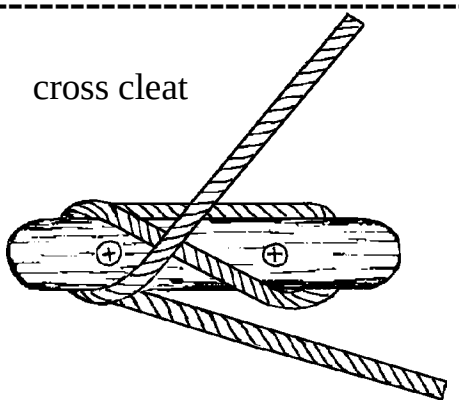

6. form loop

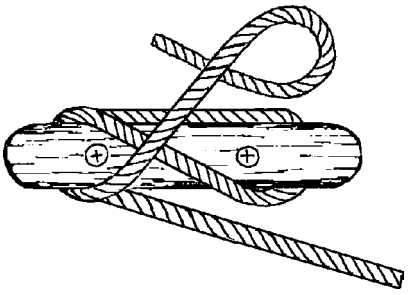

7. place over horn

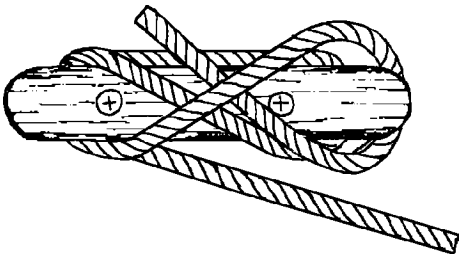

8. pull half hitch tight

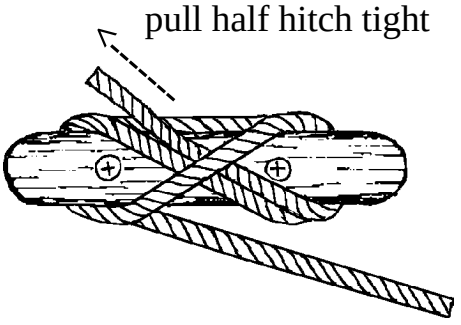

KNOTBOARD CLEAT PATTERN:

Use this pattern to make 8 hardwood cleats. Attach the cleats to the knotboard with 1 1/2 inch number 8 round head wood screws.

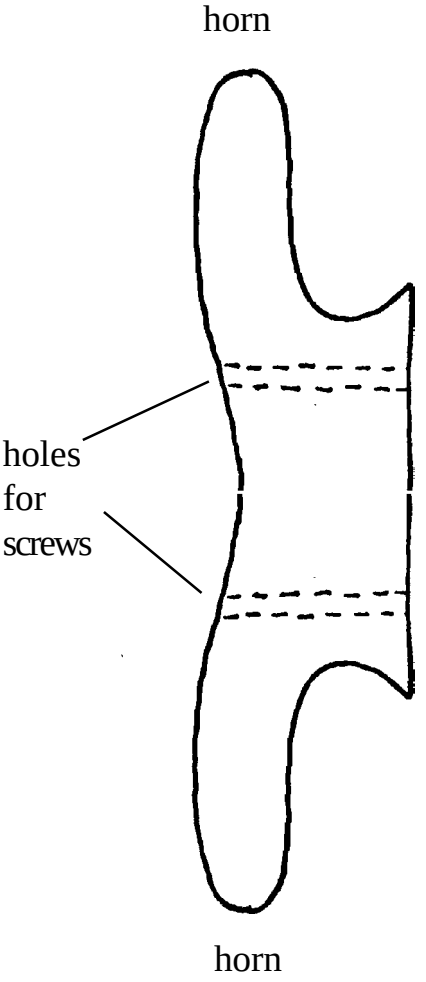

WHIPPING:

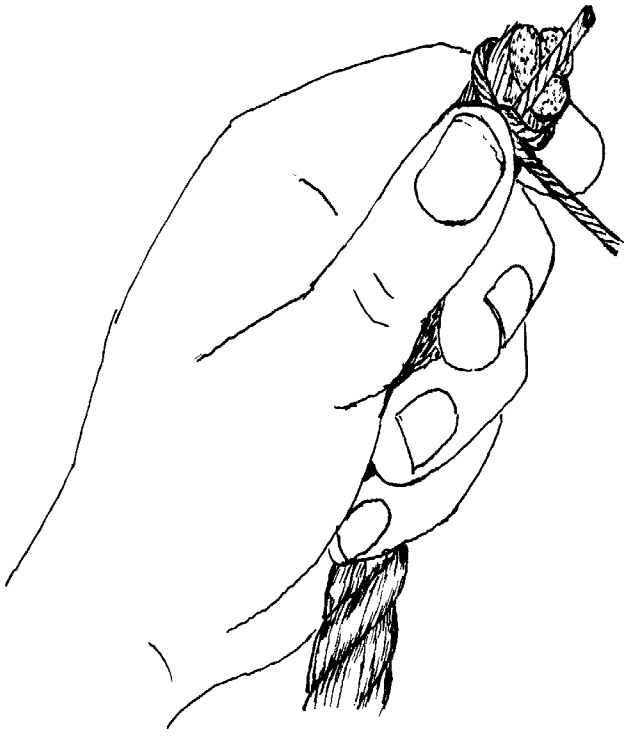

Description ---- Twine wrapped and secured to the end of a rope.

Use ---- To prevent the fraying of the end of a rope.

Comments ---- Even though "whipping" is done in several different ways, the finished "whippings" have similar appearance: the ends are secured under the turns, the length of the whipping is equal to the diameter of the rope, and all turns are parallel.

Synthetic rope, rope made of plastic, should be whipped and fused to prevent the rope from fraying. Fusing helps to hold the whipping in place and the whipping helps to prevent the fused rope strands from braking apart.

Other Names ---- Serving: When a rope is wrapped with twine to prevent chafing or wearing; the wrapping is done using the similar methods to whipping. ---- **Seizing:** When twine is wrapped around two or more strands of rope to hold the rope in place; the wrapping is done using methods similar to shear lashing.

Materials ---- The twine that is used for whipping should be tightly spun or braided twine that is less then 1/8 the size of the rope to be whipped. Twine made of synthetic material should be used to whip synthetic rope, if natural fiber twine is used, the capillary action along the fibers of the rope draw water under the whipping causing the whipping to remain damp, so that rot quickly sets in. Likewise, natural fiber twine should be used to whip natural fiber rope, the poor wicking action of synthetic fibers allowing the whipping to trap moisture in the natural fiber rope, causing the rope to rot.

WHIPPING: METHOD 1:

Narration ----- (For **whipping [method 1]** knotboard.) **(1)** Form a loop in a 12 inch piece of twine so that the ends of the twine are parallel and in opposite directions. Lay the loop on the end of the rope so that the ends of the twine and the rope are all parallel and one end of the twine is extending beyond the end of the rope. **(2)** While holding the twine in place between the thumb and forefinger, pass the loop of twine around the end of the rope so that the wrap is with the lay of the rope. **(3)** To finish the wrapping, pull the twine under the thumb so that the twine is wrapped toward the standing part of the rope, pull the twine tight. **(4)** While holding the last wrapping in place between the thumb and forefinger, add additional wraps by passing the loop of twine around the end of the rope and pulling the wrap tight under the thumb for each wrap. **(5)** Continue to add wraps until the length of the whipping is equal to the diameter of the rope. **(6)** While still holding the last wrap tight between the thumb and forefinger, pull the loop closed by pulling on the end of the twine that is sticking out past the end of the rope. **(7)** Tighten the whipping by pulling on both ends of the twine. **(8)** Finish the whipping by cutting off the ends of the twine.

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WHIPPING

1. (12 inch twine)

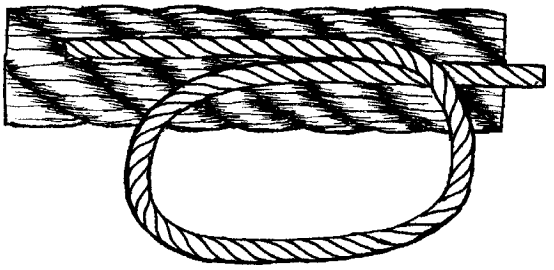

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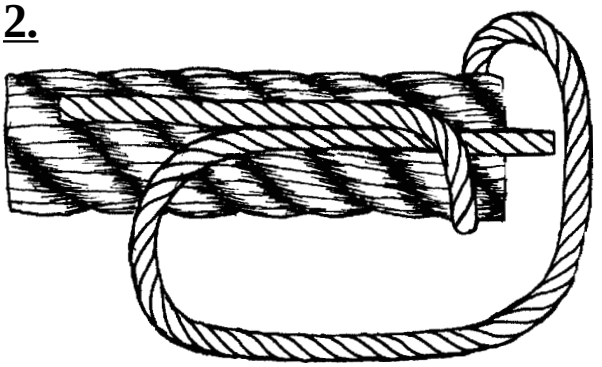

3.

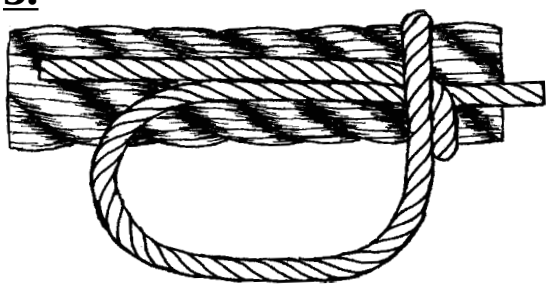

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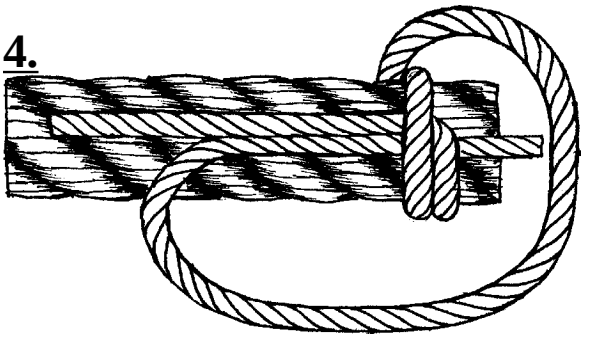

5. diameter of rope |<-------->|

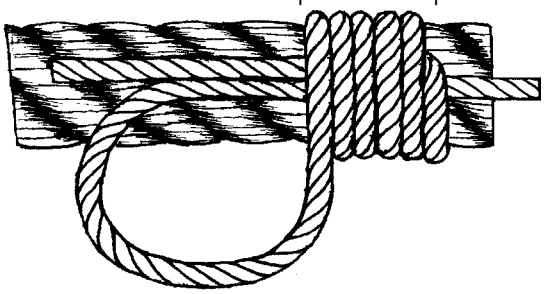

6. pull ------>

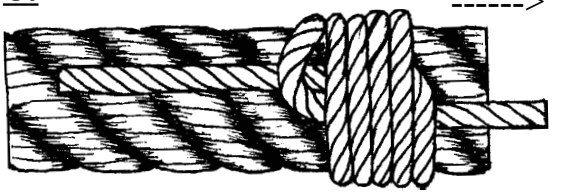

7. <------- pull tight ------>

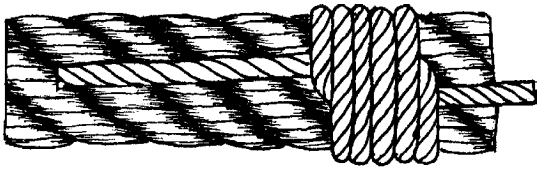

8. cut off ends

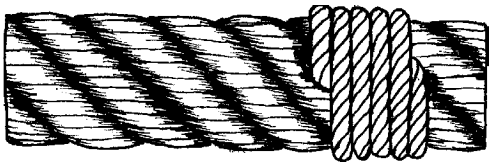

WHIPPING: METHOD 2:

Narration ----- (For **whipping [method 2]** knot-board.) **(1)** Form a bight in the end of a 24 inch piece of twine and lay it parallel to the end of the rope so that part of the short side of the bight is extending beyond the end of the rope. **(2)** Take a wrap around the end of the rope; hold the bight and the wrap in place with the thumb and forefinger; pull wrap tight. **(3)** When the length of the whipping is equal to the diameter of the rope, reeve the end of the twine through the eye of the bight. **(4)** Pull wrappings tight. **(5)** Pull on the end of the twine that is extending beyond the end of the rope until a bight of the free end of the twine is pulled under and to the mid point of the wrappings. **(6)** Finish the whipping by cutting off the ends of the twine.

WHIPPING
METHOD 2

1.

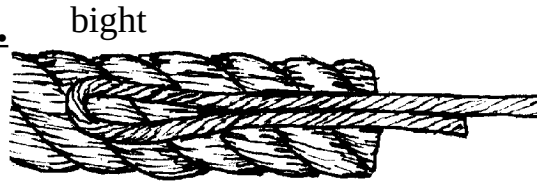

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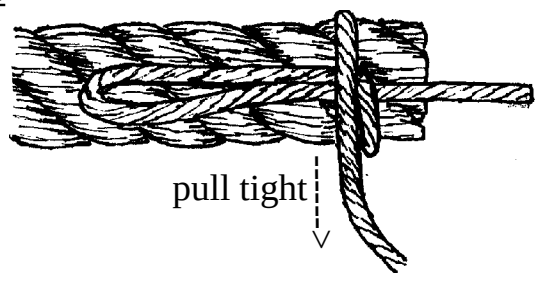

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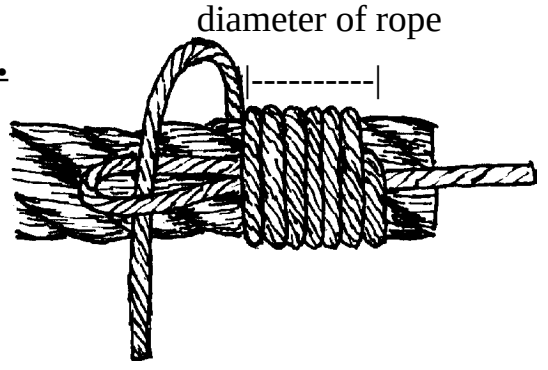

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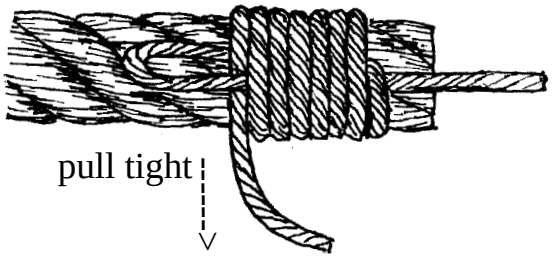

5.

pull to center

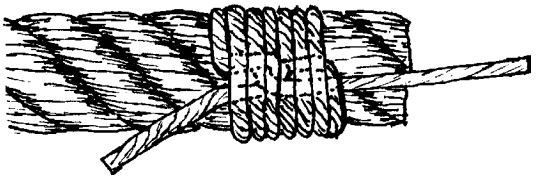

6.

cut off ends

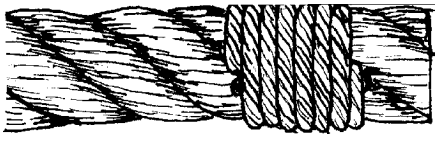

WHIPPING

METHOD 3

1.

short bight

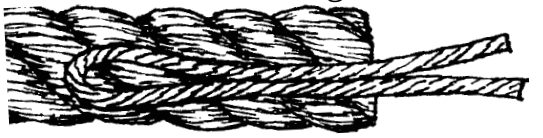

2.

12 inch twine

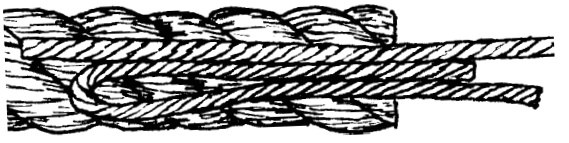

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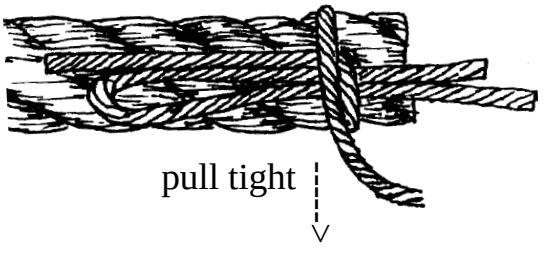

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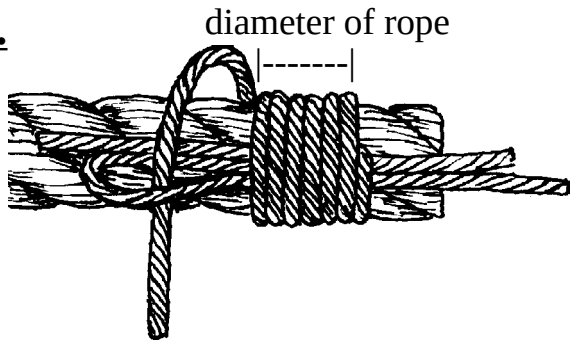

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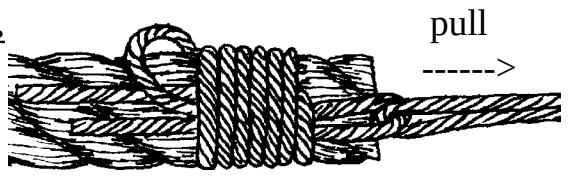

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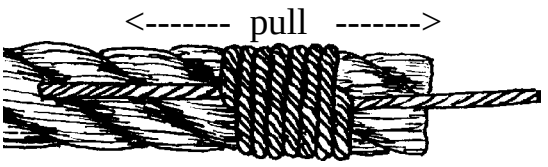

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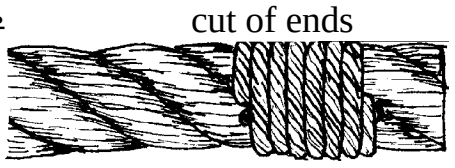

WHIPPING: METHOD 3

Narration ----(For **whipping [method 3]** knot-board.) **(1)** Form a bight in a 6 inch piece of twine; lay the bight parallel to the end of the rope with the ends of the twine extending past the end of the rope. **(2)** Lay the end of a 24 inch piece of twine next to the loop with the long end extending past the end of the rope. **(3)** Take a wrap around the end of the rope; hold the bight and the wrap in place with the thumb and forefinger; pull wrap tight. **(4)** When the length of the whipping is equal to the diameter of the rope, reeve the end of the twine through the eye of the bight. **(5)** Use the bight to pull the free end of the twine under the wrappings. **(6)** Tighten the whipping by pulling on the ends of the twine. **(7)** Finish the whipping by cutting off the end of the twine.

BOUND WHIPPING:

Description ---- A whipping with strands across the wraps.

Use ---- As a secure permanent whipping.

Comments ---- Bound whipping secures the wrapping turns by adding frapping turns to a standard whipping.

Other Names ---- Sailmaker's Whipping, (usually done with a needle).

Tying a Bound Whipping:

STEP 1: Lay a loop formed from a 24 inch piece of twine in one of the grooves between the strands of the rope. The end of the twine toward the standing part of the rope should be about 3 inches long.

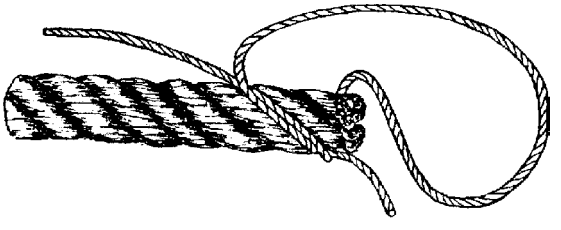

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STEP 2: Wrap the twine around the end of the rope, work toward the standing part of the rope.

STEP 3: When the length of the whipping is equal to the diameter of the rope, close the loop by pulling on the end of the twine that extends beyond the end of the rope.

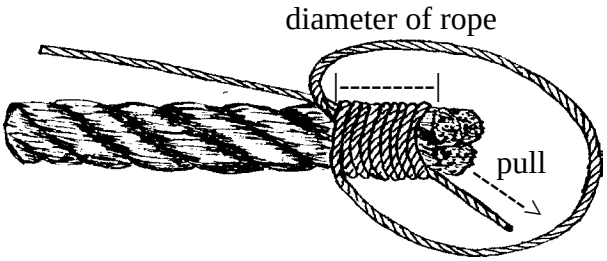

STEP 4: Pull on both ends of the twine to tighten the whipping around the rope.

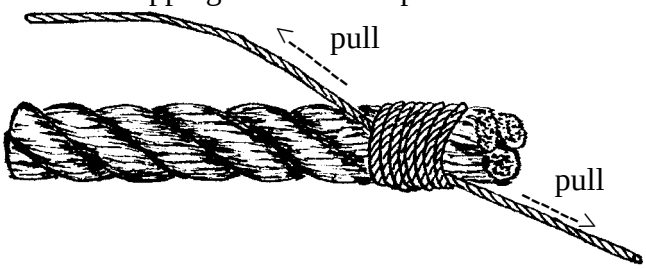

STEP 5: Separate the ends of the rope strands, pull the twine between the strand to the right of the groove that the twine was originally laid in and the other two strands.

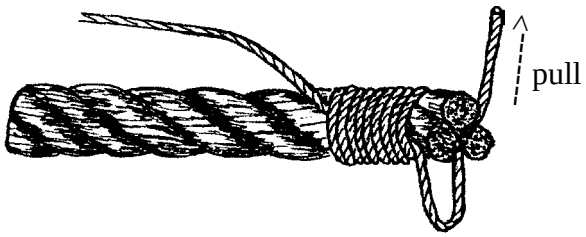

STEP 6: Use a fid to lift the strand of the rope as shown in the diagram (this is the same strand that the twine went around at the end of the rope), reeve the twine under the strand; pull twine tight.

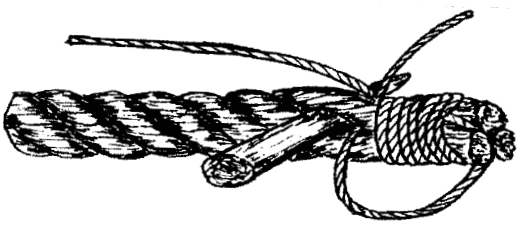

STEP 7: Lay the twine over the original groove and then pull the twine between the ends of the rope strands so that the twine is around the rope strand to the left of the original groove; pull twine tight.

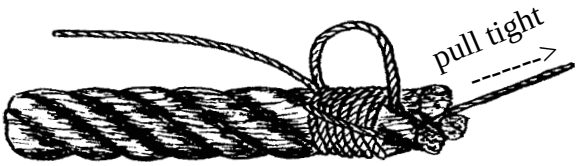

STEP 8: Use a fid to lift the rope strand as shown in the diagram (this is the same strand that the twine went around at the end of the rope); reeve the ends of the twine through the opening and tie a half knot as shown in the diagram; pull twine tight.

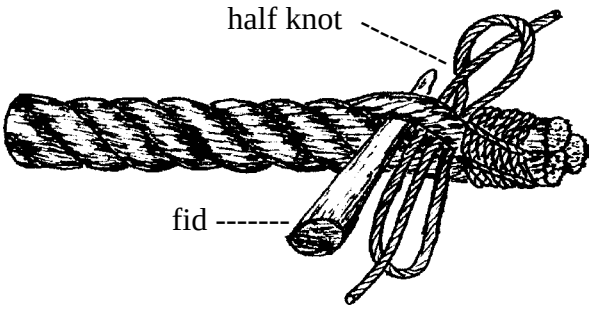

STEP 9: Reeve the ends of the twine through the opening again; tie a second half knot in the opposite direction as shown in the diagram; pull twine tight to form a square knot.

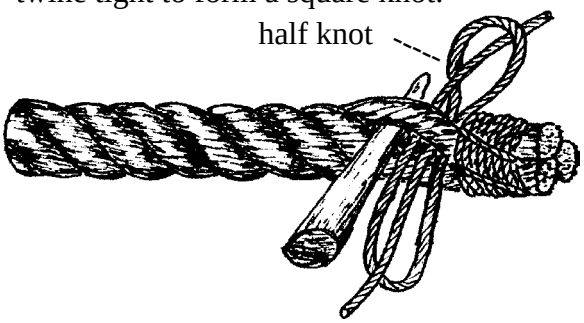

STEP 10: Remove the fid and trim the ends of the twine close to the surface of the rope.

[NOTE] If synthetic rope and twine were used the ends of the rope and the twine may be fused.

FIGURE-EIGHT KNOT:

Description ---- Interlocking overhand loops, the running part goes through the eye of one loop and the standing part goes through the eye of the other loop.

Use ---- (1) As a stopper knot; to keep a rope from unreeving from a pulley block; to prevent a rope from unlaying. **(2)** When tied on a bight, makes a reliable loop for rescue work and mountaineering.

Comments ---- Easier to tie and untie than an overhand knot; does not damage the rope fiber or jam like an overhand knot.

Narration ---- (For **figure eight** knotboard.) **(1)** Form an overhand loop. **(2)** Take a bight around the standing part. **(3)** Form the second overhand loop by bring the running part over the top edge of the firs overhand loop. **(4)** Complete the knot by reeving the running part through the eye of the first overhand loop **(5)** and pull tight.

FIGURE EIGHT ON A BIGHT:

Description ---- Interlocking overhand loops tied on a bight in the running part (the bight is used as the running part); the running part goes through the eye of one loop and the standing part goes through the eye of the other loop.

Use ---- (1) Makes a reliable loop for rescue work and mountaineering. **(2)** As a stopper knot; to keep a rope from unreeving from a pulley block; to prevent a rope from unlaying.

Comments ---- Easier to tie and untie than an overhand knot; does not damage the rope fiber or jam like an overhand knot on a bight.

Narration ---- (For **figure eight on a bight** knotboard.) **(1)** Form a bight in the rope. **[NOTE]** Treat the two strands of the bight as a single strand as the rest of the knot is tied. **(2)** Form an overhand loop. **(3)** Take a bight around the standing part. **(4)** Form the second overhand loop by bring the running part over the top edge of the firs overhand loop. **(5)** Complete the knot by reeving the running part through the eye of the first overhand loop **(6)** and pull tight.

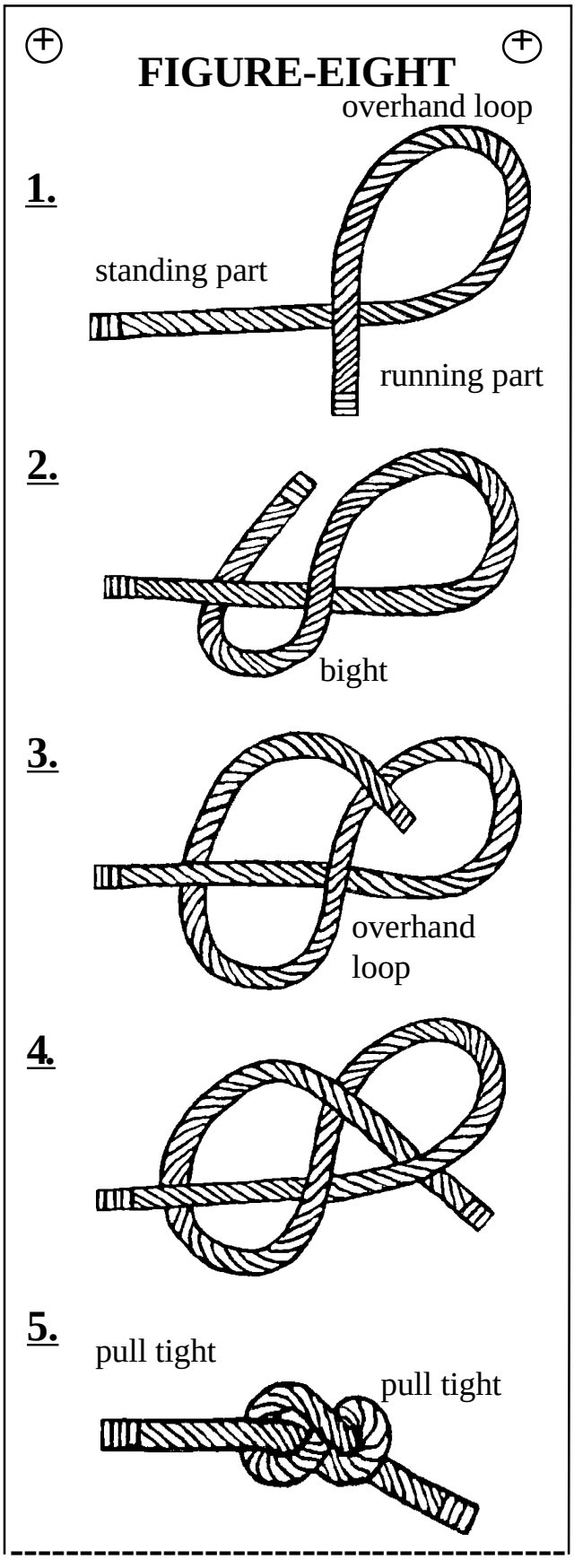

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FIGURE-EIGHT ON A BIGHT

1.

2.

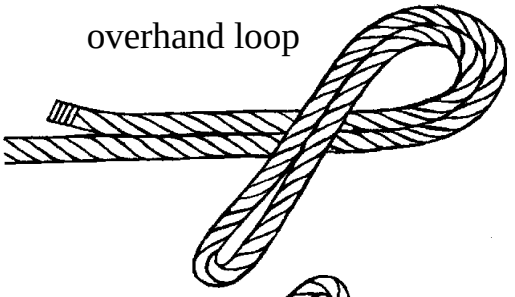

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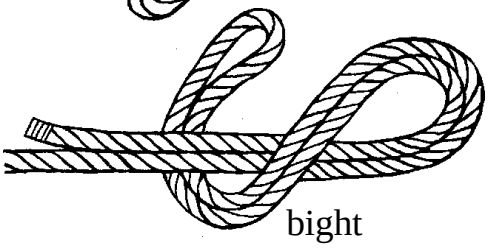

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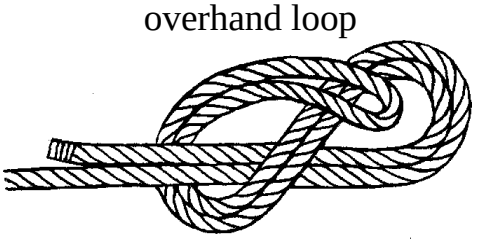

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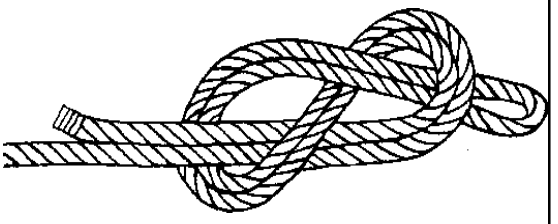

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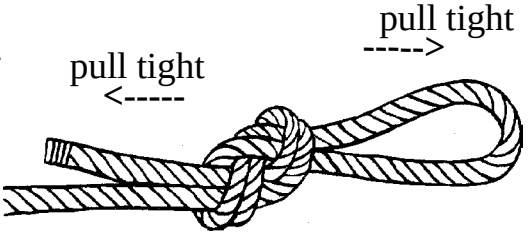

[NOTE]

TRIPOD LASHING:

Description ---- A shear lashing around 3 poles.

Use ---- To bind three poles together, for the construction of a tripod. ---- To bind three poles together that contact at the same point in a structure.

Comments ----The tripod lashing is a shear lashing that binds three poles together at the same point. ---- The tripod lashing gets it name from the fact that its most common use is the construction of a tripod. ----The tripod lashing can be used just about any where in a structure that three poles cross each other at the same point and the same time in the sequence of construction. ---- Tripod lashing takes two main forms; with racked wrapping turns (the rope is woven between the poles) and with plain wrapping turns (the rope is wrapped around the poles without weaving the rope between the poles). When the lashing is made with racking turns the rope contacts each pole around its entire circumference ; this contact makes the tripod lashing with racking turns the most secure form of tripod lashing: therefore tripod lashing with racking turns should be used when safety is important. However, for light structures where there would be no danger if the lashing slipped, the faster to tie tripod lashing with plain wrapping turns may be used.

Laying Out The Poles ---- For most tripod lashings, lay the pole side by side with the butt ends aligned. The alignment of the butts of the pole insures that the tripod legs are the desired length.

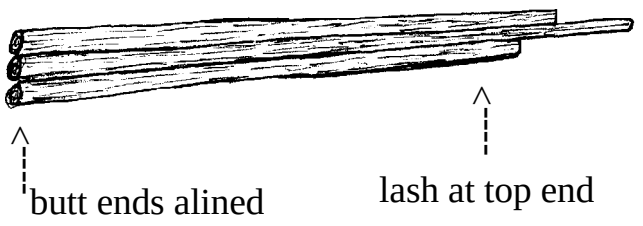

[NOTE] The practice of laying the center pole in the opposite direction to the outside poles creates several problems. When the poles are laid in opposite directions the wrappings must be put on loosely so that when the center pole is rotated to its proper position the lashing is tightened around the poles. If the wrappings are put on to tight, the rope is stretched causing damage to the rope fibers, therefore weakening the lashing. On the other hand, if the rope is wrapped two loosely, the lashing will not tighten enough when the center pole is rotated and the lashing will be able to slip along the length of the pole. Either way, the rope to loose or the rope to tight, a dangerous situation is created.

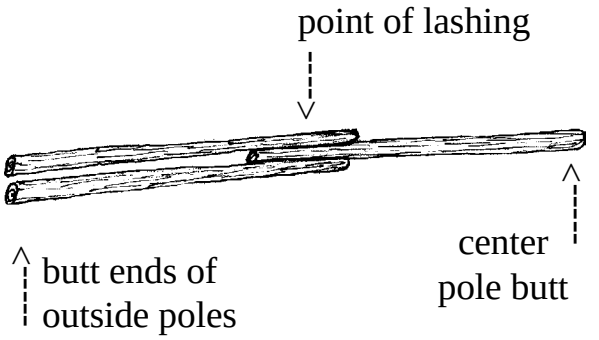

However, if the tripod is to be part of a structure and the center pole will be at an angle greater then 90° to the outside poles, lay the center pole in the opposite direction to the outside poles so that the rotation of the poles at the lashing is less then 90°. See gate way below for an example.

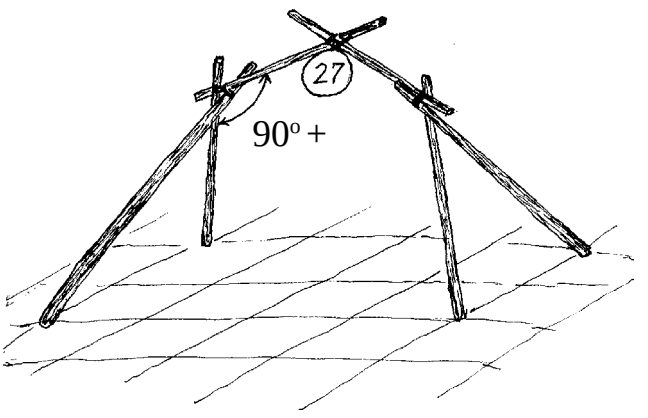

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Setting Up A Tripod ----- Set up the tripod by crossing the outside poles so that the cross point of the poles is under the center pole. Crossing the outside poles under the center pole causes part of the load that is placed on the tripod to be taken up by the wood to wood contact of the poles.

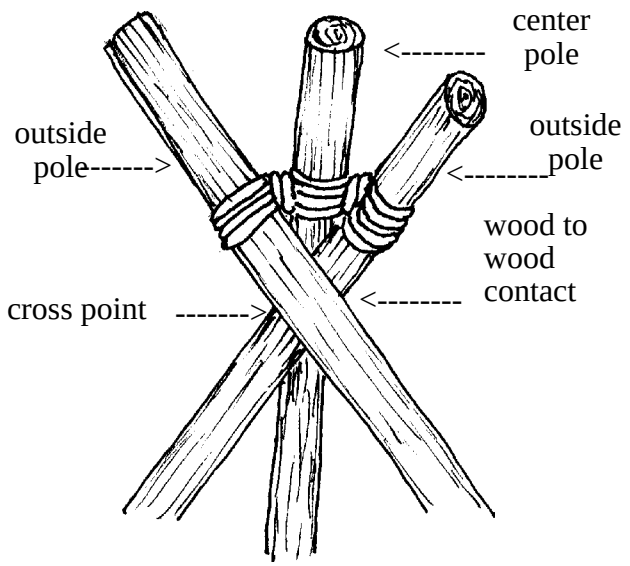

If the outside poles are crossed above the center pole, the rope of the lashing will be required to support all or most of the load; therefore the tripod will not be as strong as when the outside legs are crossed under the lashing.

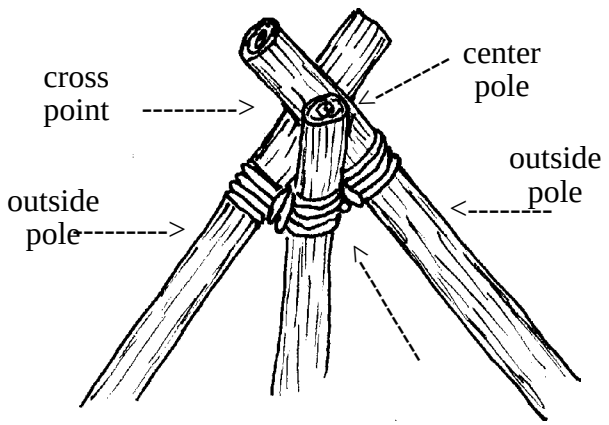

no wood to wood contact, rope supports load

If a symmetrical arrangement of the poles is needed within a structure, the tripod can be set up by rotating the poles around the lashing. This rotation cause the loss of the wood to wood contact so that the load is supported only by the ropes, and the joint between the poles becomes very flexible; therefore the tripod may be unstable.

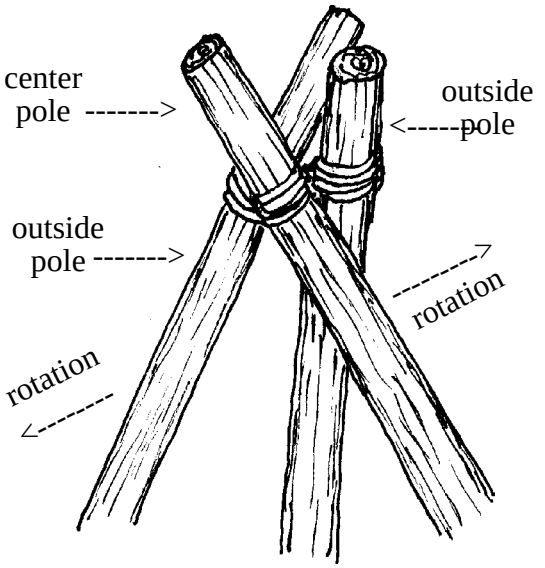

TRIPOD LASHING: (With Racking Turns)

Narration ---- (For **tripod lashing with racking turns** knotboard.) **(1)** Tie a clove hitch around one of the outside poles. **(2)** Secure the standing part by wrapping it around the running part. **[NOTE]** Wrapping the standing part around the running part prevents the clove hitch from slipping around the pole. If the clove hitch slips the lashing will loosen up from the inside. **(3)** Start the racked wrapping turns by weaving the rope between the poles. **(4)** Take a total of 5 to 7 wrapping turns. Pull each wrapping turn tight as it is made. **[NOTE]** The stiffness of the tripod lashing depends on the number and tightness of the wrapping turns. As the tightness of the wrapping turns or the number of wrapping turns increases, the stiffness of the tripod will increase. **(5)** Take the first frapping turn by taking the rope around the pole that the clove hitch

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TRIPOD LASHING

WITH RACKING TURNS

1.

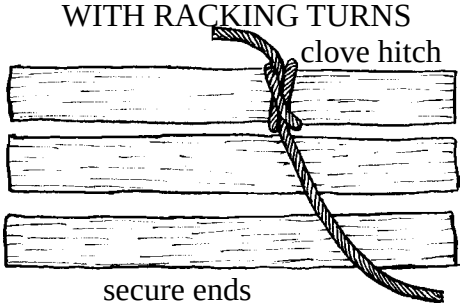

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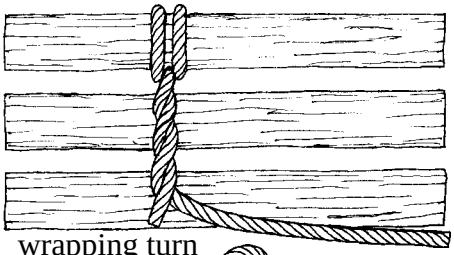

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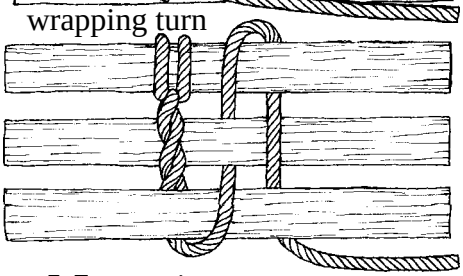

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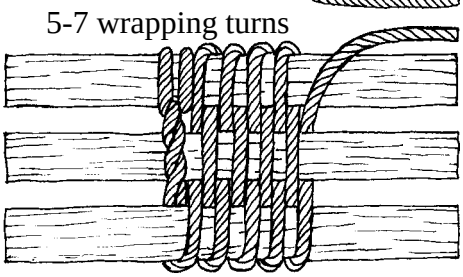

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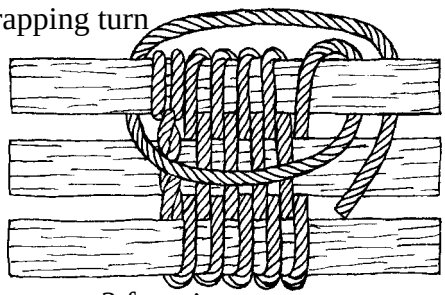

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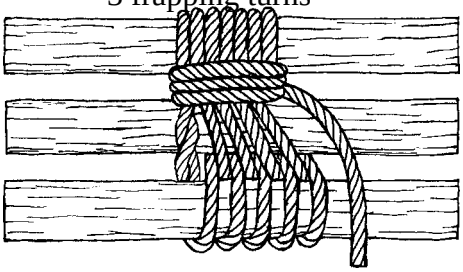

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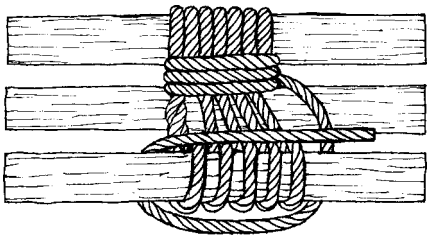

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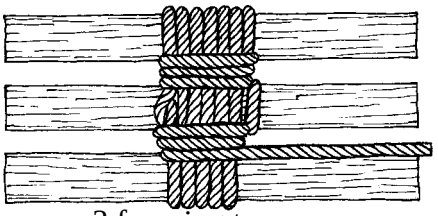

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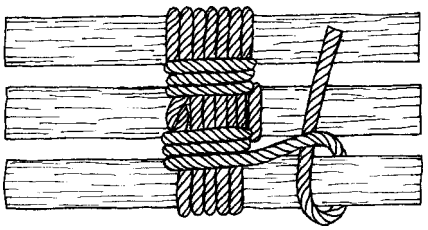

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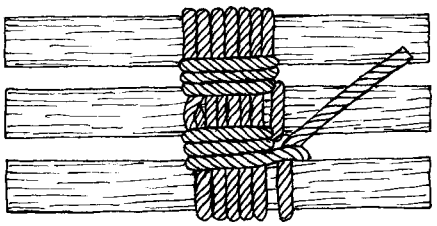

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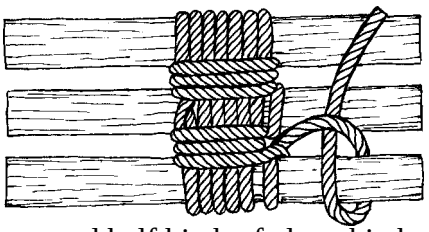

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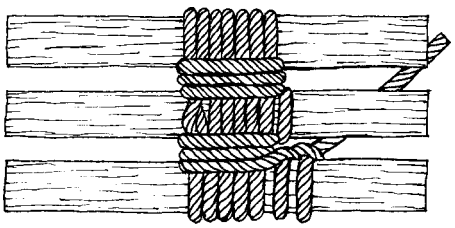

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was tied to, then between the outside pole and the center pole. **(6)** Take 3 frapping turns. Pull each frapping turn tight as it is made. **(7)** Start the second set of frapping turns by taking the rope across the center pole and reeving it between the second outside pole and the center pole. Take the second set of frapping turns in the opposite direction to the first set of frapping turns. **[NOTE]** Taking the second set of frapping turns in the opposite direction to the first set of frapping turns prevents the rope from crossing the wrappings at a diagonal. Unnecessary crossing of the rope increases friction between the strands of the rope making it difficult to tighten the lashing properly. **(8)** Take a total of 3 frapping turns. Pull each turn tight. **(9)** Take the first half hitch of the ending clove hitch around the second outside pole by taking the rope past the pole and then around the pole. **(10)** Work the half hitch tight so that it is locked against the lashing. **[NOTE]** See the narration for square lashing for instructions on working the half hitch tight. **(11)** Take the second half hitch of the ending clove hitch. **(12)** Work the half hitch tight to complete the ending clove hitch. **[NOTE]** If the clove hitch is not worked tight so that it is locked against the lashing the clove hitch will slip around the pole allowing the lashing to loosen. **[NOTE]** If very smooth rope is being used, a 3rd half hitch should be added to the clove hitch to insure that the lashing will stay in place.

TRIPOD LASHING: (WITH PLAIN TURNS)

Narration ---- (For **tripod lashing with plain turns** knotboard.) **(1)** Tie a clove hitch around one of the outside poles. **(2)** Secure the standing part by wrapping it around the running part. **[NOTE]** Wrapping the standing part around the running part prevents the clove hitch from slipping around the pole. If the clove hitch slips the lashing will loosen up from the inside. **(3)** Start the wrapping turns by wrapping the rope around the poles. Take a total of 4 to 6 wrapping turns. Pull each wrapping turn tight as it is made. **[NOTE]** The stiffness of the tripod lashing depends on the number and tightness of the wrapping turns. As the tightness of the

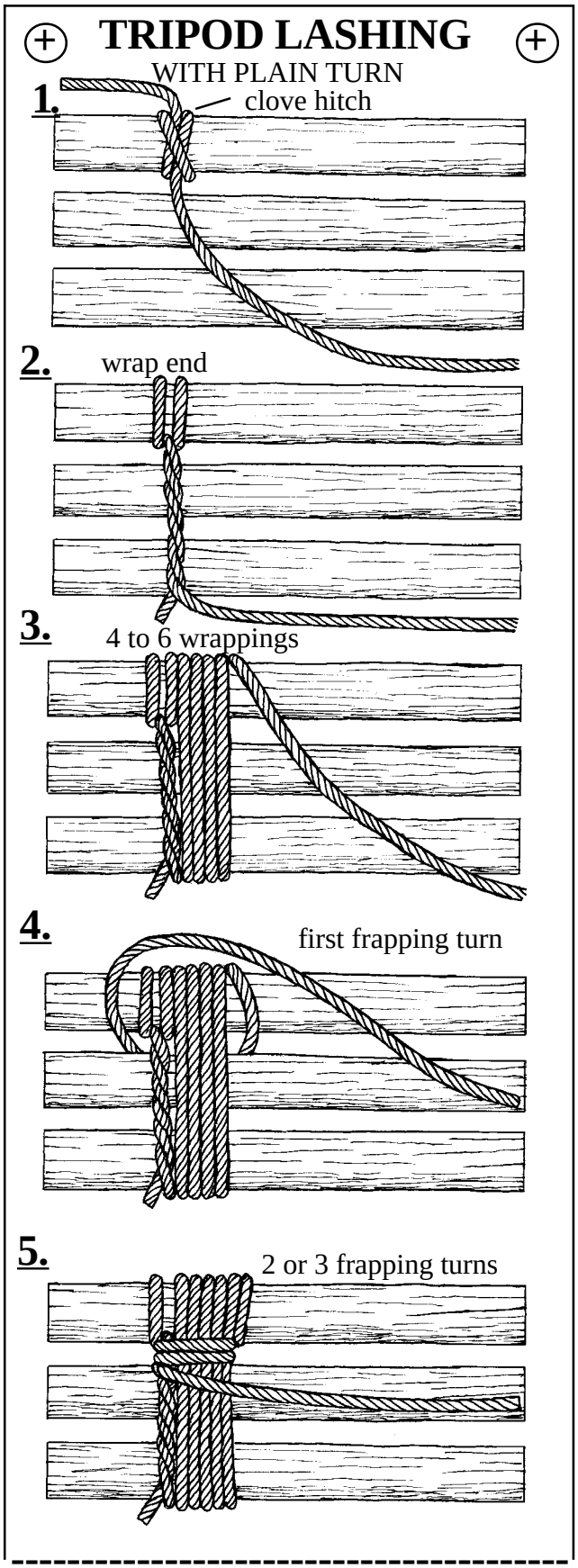

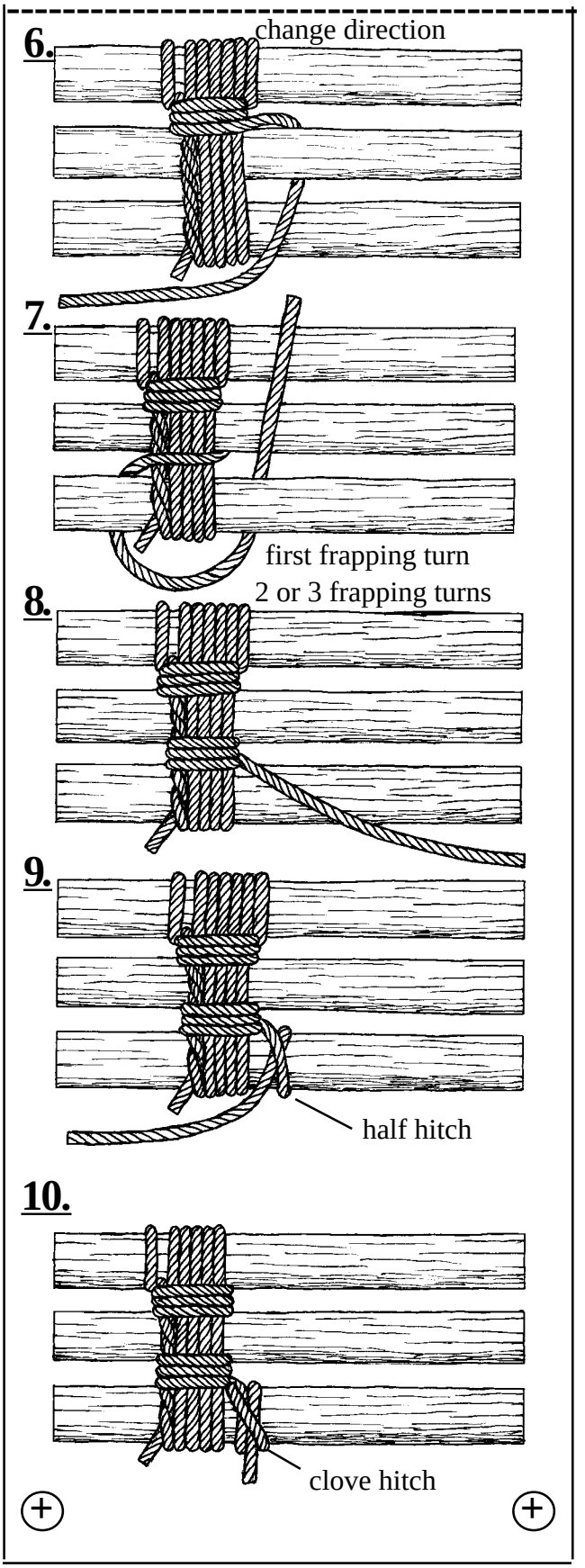

wrapping turns or the number of wrapping turns increases, the stiffness of the tripod will increase. **(4)** Take the first frapping turn by passing the rope around the pole that the clove hitch was tied to, then between the outside pole and the center pole. **(5)** Take 2 or 3 frapping turns. Pull each frapping turn tight as it is made. **(6)** Start the second set of frapping turns by taking the rope around the center pole and reeving it between the second outside pole and the center pole. **(7)** Take the second set of frapping turns in the opposite direction to the first set of frapping turns. **[NOTE]** Taking the second set of frapping turns in the opposite direction to the first set of frapping turns prevents the rope from crossing the wrappings at a diagonal. Unnecessary crossing of the rope increases friction between the strands of the rope making it difficult to tighten the lashing properly. **(8)** Take a total of 2 or 3 frapping turns. Pull each turn tight. **(9)** Take the first half hitch of the ending clove hitch around the second outside pole by taking the rope past the pole and then around the pole. Work the half hitch tight so that it is locked against the lashing. **[NOTE]** See the narration for square lashing for instructions on working the half hitch tight. **(10)** Take the second half hitch of the ending clove hitch. Work the half hitch tight to complete the ending clove hitch. **[NOTE]** If the clove hitch is not worked tight so that it is locked against the lashing the clove hitch will slip around the pole allowing the lashing to loosen. **[NOTE]** If very smooth rope is being used, a 3rd half hitch should be added to the clove hitch to insure that the lashing will stay in place.

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QUICK TRIPOD LASHING:

Comments ---- The tripod quick lash is one of the fastest ways to construct a tripod. However the tripod quick lash is not as secure as the more conventional methods, therefore the tripod quick lash tripod should not be use for heavy loads.

Directions -----

STEP 1] Lay the poles side by side with the with the butt ends alined. Wrap 5 to 8 wrappings around all three poles.

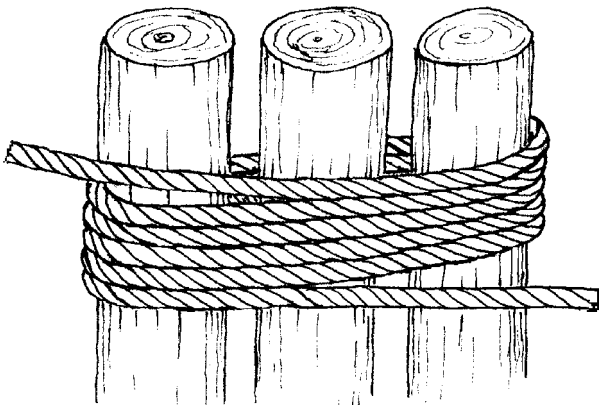

STEP 2] Start the frapping turn by taking each end around an outside pole and then between the outside pole and the center pole.

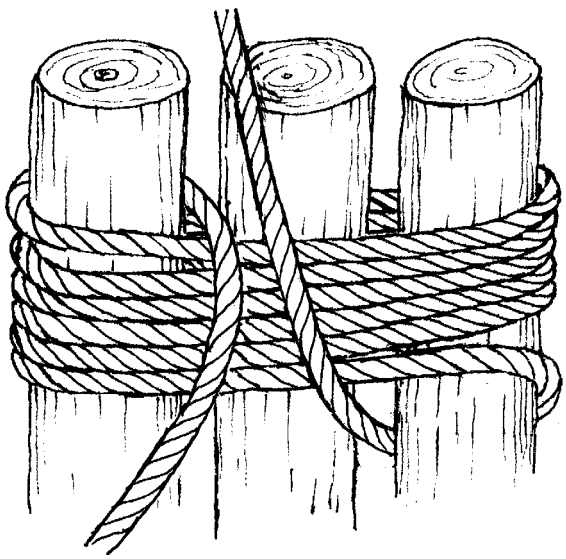

STEP 3] Take 1 or 2 frapping turns with each end. Pull the frapping turns tight; this will also tighten the wrappings.

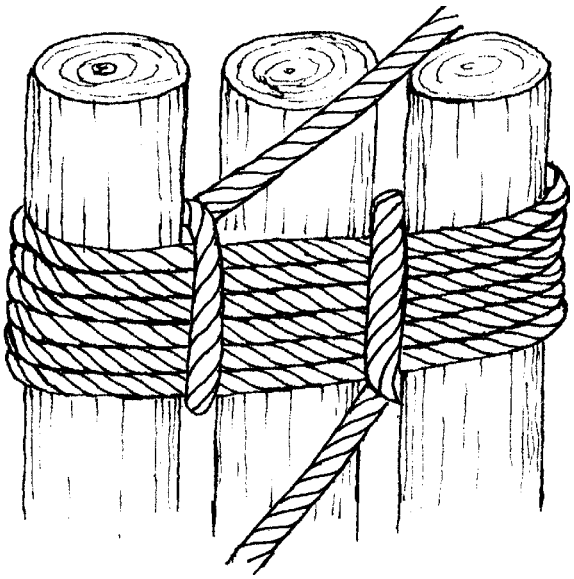

[NOTE] The frapping turns are taken in opposite directions.

STEP 4] End the lashing by tying the ends of the rope together with a square knot.

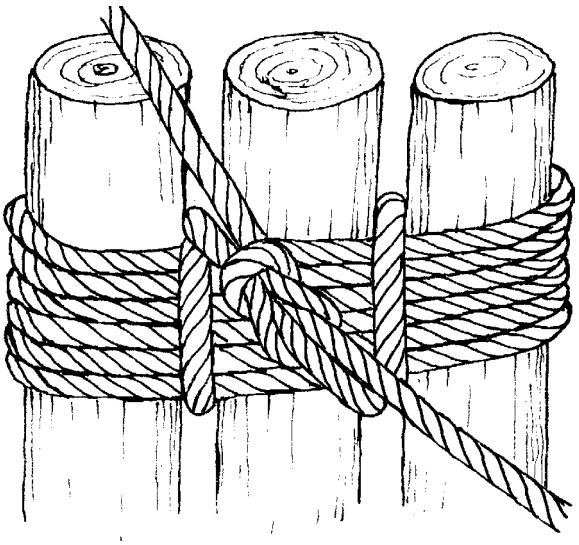

[WARNING]

If one end of the square knot is pulled it can be up set into a lark's head knot. When this happens the knot will slip causing the entire lashing to loosen and fail.

SHEET BEND:

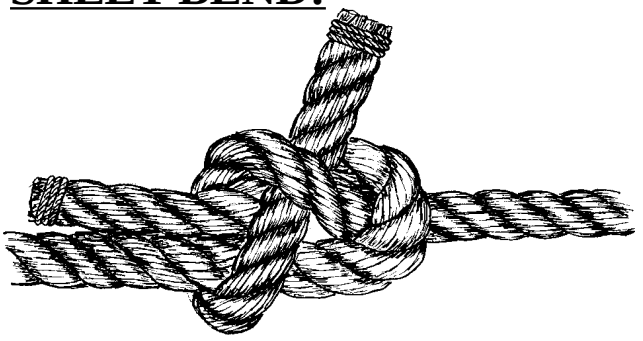

Description ---- An interlocked bight and half hitch.

Use ---- To temporarily join two ropes, especially if the ropes are of different sizes.

Comments ---- The sheet bend is a secure but easily untied knot. ---- When tying the sheet bend the running parts should be left long because there is some initial slip in the knot when the knot is first brought under tension. ---- The proper and more secure way to tie the sheet bend is so that the two end the rope are on the same side of the knot.

Other Names ---- Weavers knot

Related Knots ---- Bowline; becket hitch; these knots share the same form but are tied in a different way or have a different use.

Narrative ---- (For **sheet bend** knotboard.) **(1)** Form a bight in the running part of the left-hand rope. **(2)** Reeve the running part of the right-hand rope through the eye of the bight in the left-hand rope. **(3)** With the right-hand running part take a bight around the running part and the standing part of the left-hand rope. **(4)** Pass the right-hand running part over the left-hand standing part, **(5)** under the right-hand rope, and **(6)** over the standing part of the left-hand rope. **(7)** Pull tight.

SHEET BEND

1.

2.

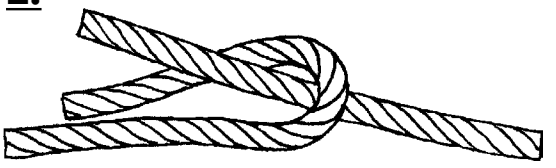

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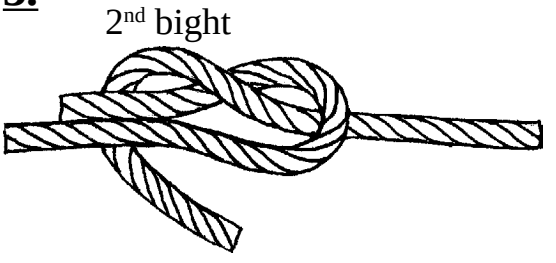

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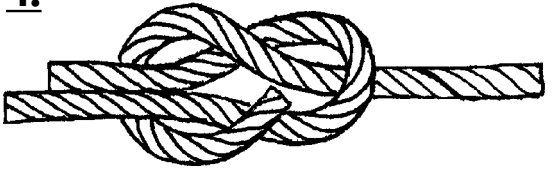

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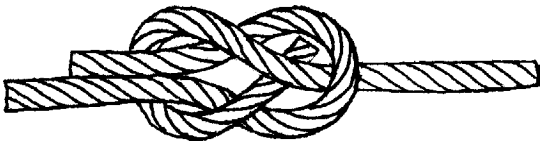

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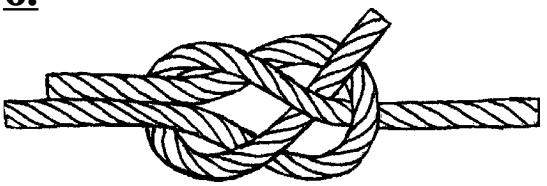

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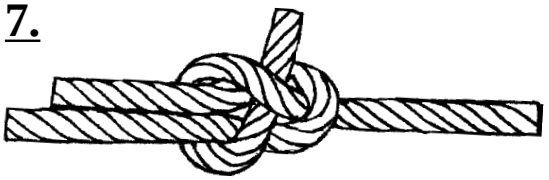

<---------- pull tight ---------->

opposite side

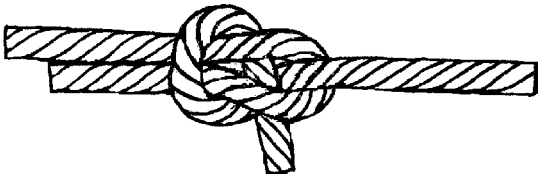

WEAVER'S KNOT:

Description ---- A different method of tying a sheet bend.

Use ---- For joining light twine and yarn together, especially by weavers.

Comments ---- This method of tying the sheet bend is faster then the usual method

.

Narration ------ (For **weaver's knot** knotboard.) **(1)** Cross the left-hand running part over the right-hand running part. Hold this cross point together between the thumb and first finger of the left hand. **(2)** With the right hand, grasp the right-hand standing part and make a loop over the thumb and **(3)** between the standing parts so as to form a half hitch around the left-hand rope. **(4)** Fold the running part of the left-hand rope back along itself to form a bight around the standing part of the right-hand rope. **(5)** Reeve the running part of the left-hand rope through the eye of the half hitch and pull the knot tight to complete the knot.

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WEAVER'S KNOT:

1.

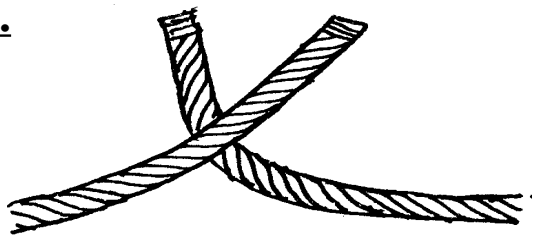

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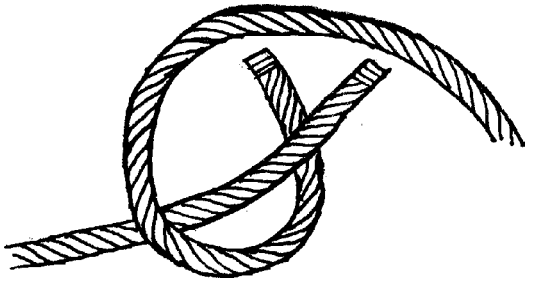

3.

half hitch

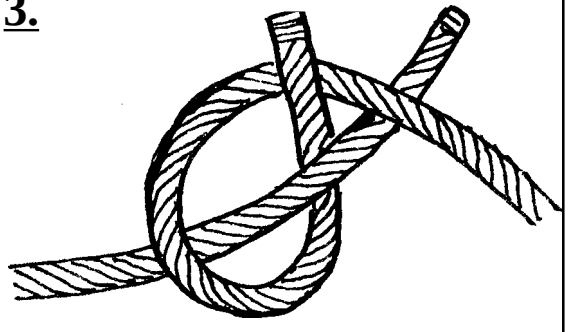

4.

bight

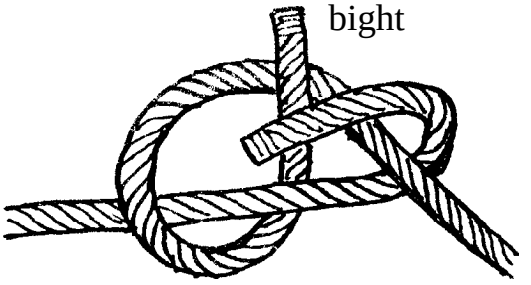

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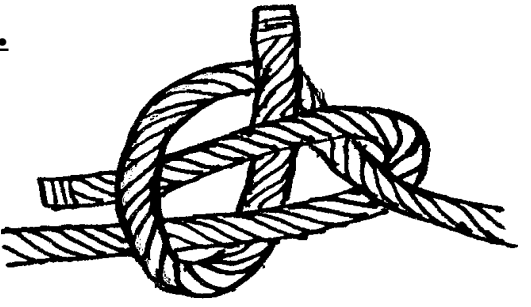

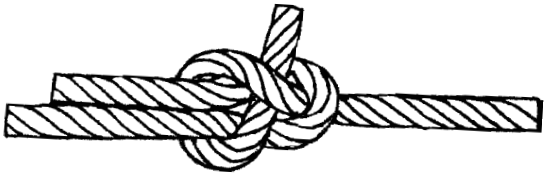

<----------- pull tight ---------->

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BECKET HITCH:

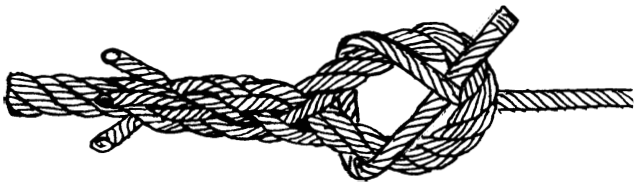

Description ---- A half hitch tied around a permanent eye, such as the eye of an eye splice or a hook.

Use ---- To tie a rope to an eye splice, a hook or a ring.

Comments The becket hitch has the sane form as the sheet bend but is used to tie a rope to an eye or hook, whereas the sheet bend is used to join two ropes.

DOUBLE SHEET BEND:

Comments ---- This method of tying the sheet bend is the most secure form of the sheet bend and should be used if there is a significant difference in the sizes of the two ropes that are being used.

Narrative ---- (For **double sheet bend** knotboard.) **(1)** Form a bight in the larger of the two ropes. **(2)** Reeve the smaller rope through the eye of the bight. **(3)** Then take a bight around the part of the larger rope; be sure to take the bight from the standing part side to the running part side. **(4)** Bring the running part of the smaller rope over the larger rope and **(5)** under the smaller rope to form a half hitch around the two parts of the bight in the larger rope. This forms the first turn. **(6)** Take a second bight around the larger rope. **(7)** Again bring the smaller rope over the larger rope and under the smaller rope to complete the second turn. **(8)** Pull tight.

[NOTE] If the difference in the sizes of the ropes is significant or the ropes are very smooth, additional turns of the smaller rope will help to prevent the ropes from slipping.

DOUBLE SHEET BEND

1.

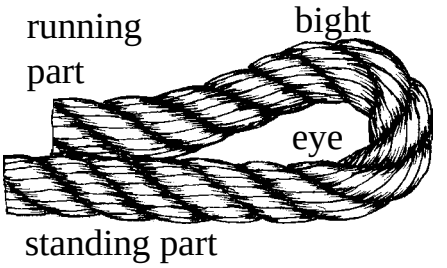

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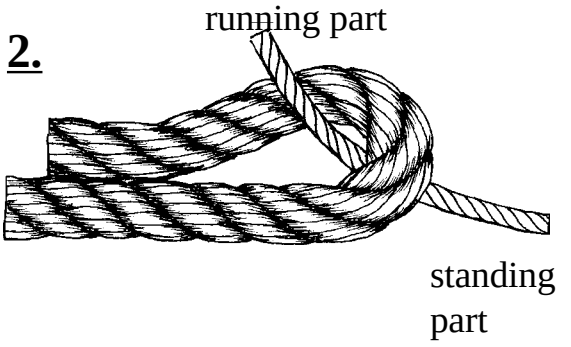

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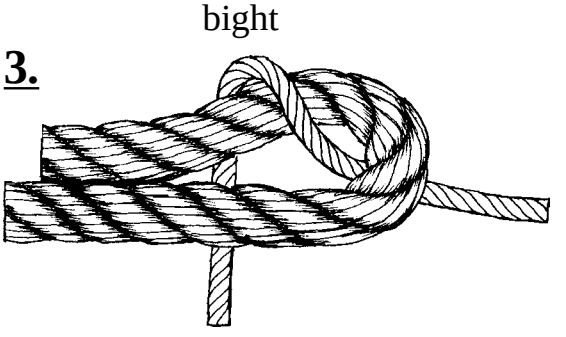

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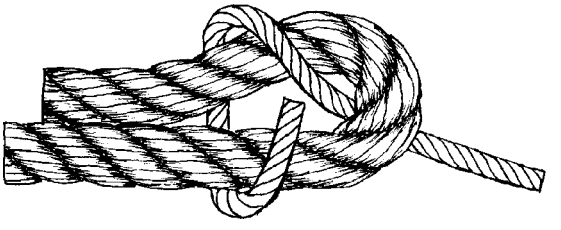

5.

half hitch

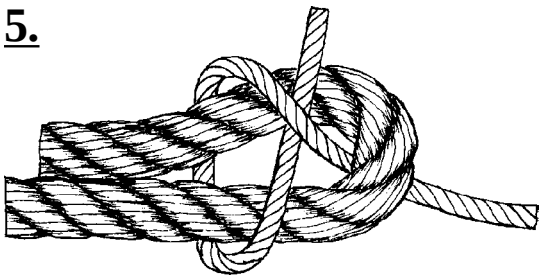

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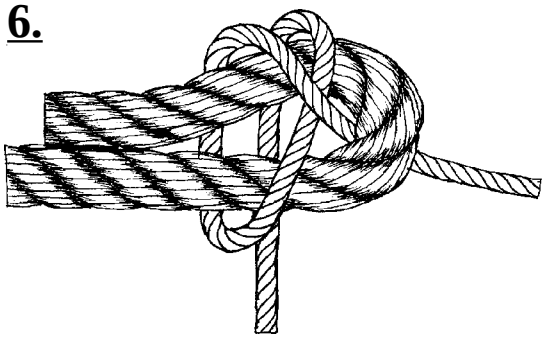

7.

second turn

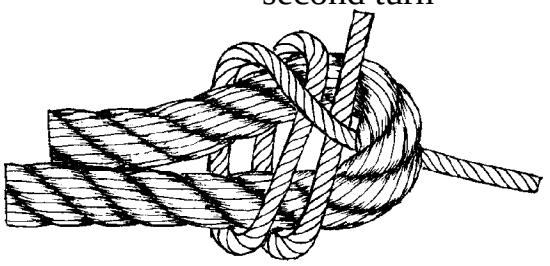

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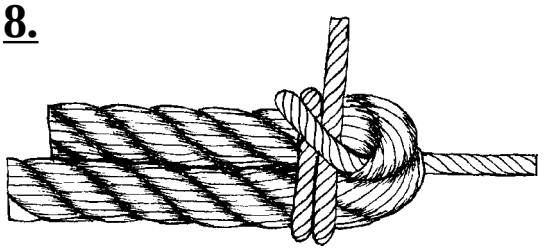

<----- pull tight ------->

SHEET BEND ON A SHORT END:

Use ---- For joining light rope, twine, thread, and yarn.

Comments ---- This method of tying the sheet bend is useful for tying a piece of rope onto another rope when the end of the rope is very short.

Narrative ---- (For **sheet bend on a short end** knotboard.) **(1)** Form an overhand loop. **(2)** Fold the loop over onto its standing part. **(3)** Pull a bight of the standing part through the loop to form an overhand knot in the running part. **(4)** Pull on the standing part and the running part of the overhand knot to close the eye around the standing part to form a slip noose. **(5)** Place the eye of the slip noose over the running part of the second rope. **(6)** Pull on the running part of the first rope and push on the overhand knot to upset the slip noose so that a bight of the second rope is pulled through the overhand loop to form the sheet bend. **(7)** Pull on the standing parts of each rope to tighten the sheet bend.

[NOTES]

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SHEET BEND (SHORT END)

1.

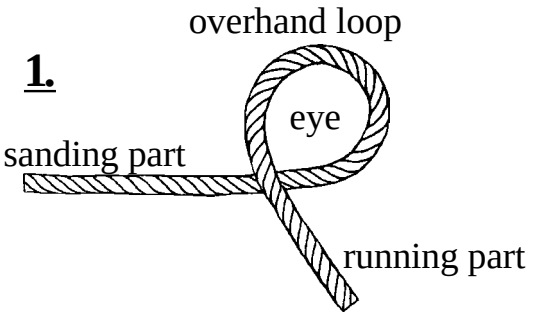

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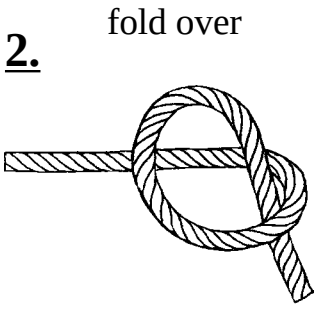

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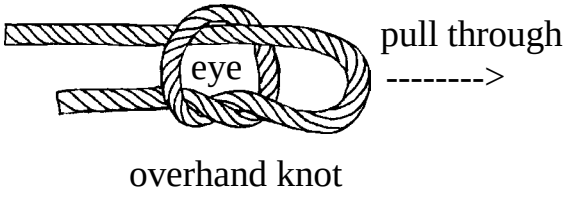

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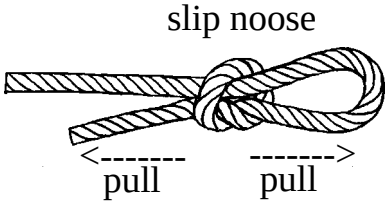

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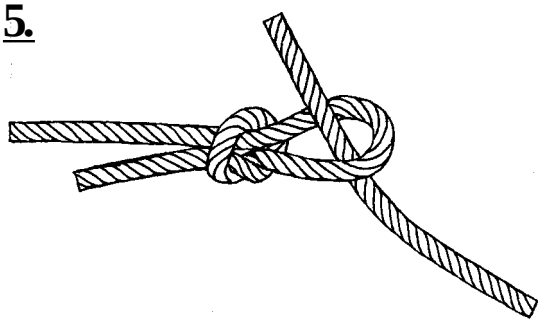

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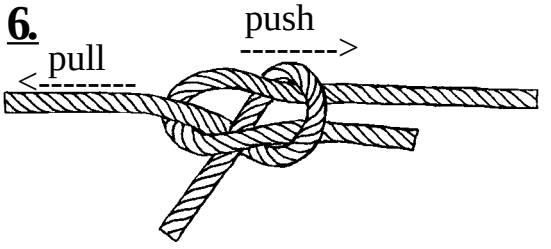

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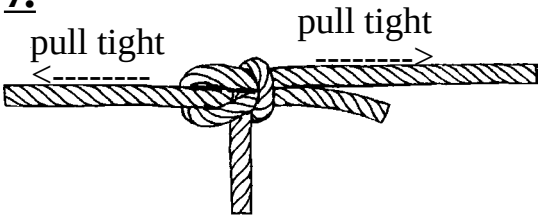

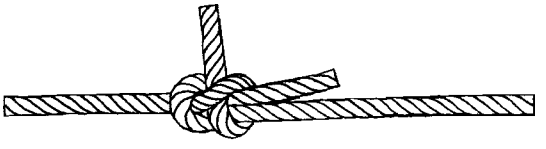

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MASTHEAD KNOT:

Comments ----There are several forms of the Masthead Knot, two of which are shown here. The first form of the Masthead Knot was chosen for its symmetry and the ease of transition to the running half hitches used to secure it to the pole. The second form was chosen for the ease with which it can be tied.

Use ----On board ship, a masthead knot was used to rig a temporary mast if the mast was lost in battle or during a storm. On land a masthead knot can be used to rig a gin pole or a flag pole.

Other names ---- Jury mast knot, pitcher knot.

MASTHEAD KNOT (1):

Description ---- A multiple loop knot formed by reeving the loosely made loops of two over hand knots through each other and then securing the knot to a mast (pole).

Narration ----- (For **masthead knot (1)** knotboard.) **(1)** Loosely tie two over hand knots. **(2)** Place the loop of one overhand knot on top of the loop of the loop of the other over hand knot. **(3&4)** Reeve the loops of the overhand knot through the half knot part of the opposite overhand knot. **(5)** Place over a pole and draw the three loops up even. **(6)** Secure to the pole with a series of running half hitches above and below the mast head knot.

[NOTE] A forth loop my be formed by tying or splicing the ends together. If a fourth loop is made, nail a cleats to the pole to prevent the mast head knot from slipping.

[NOTE] Attach the guy lines to the loops with becket hitches.

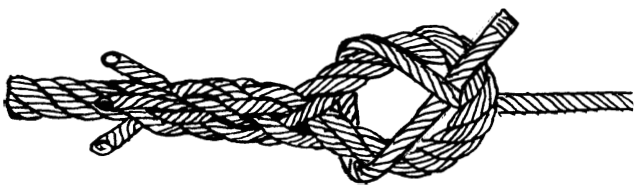

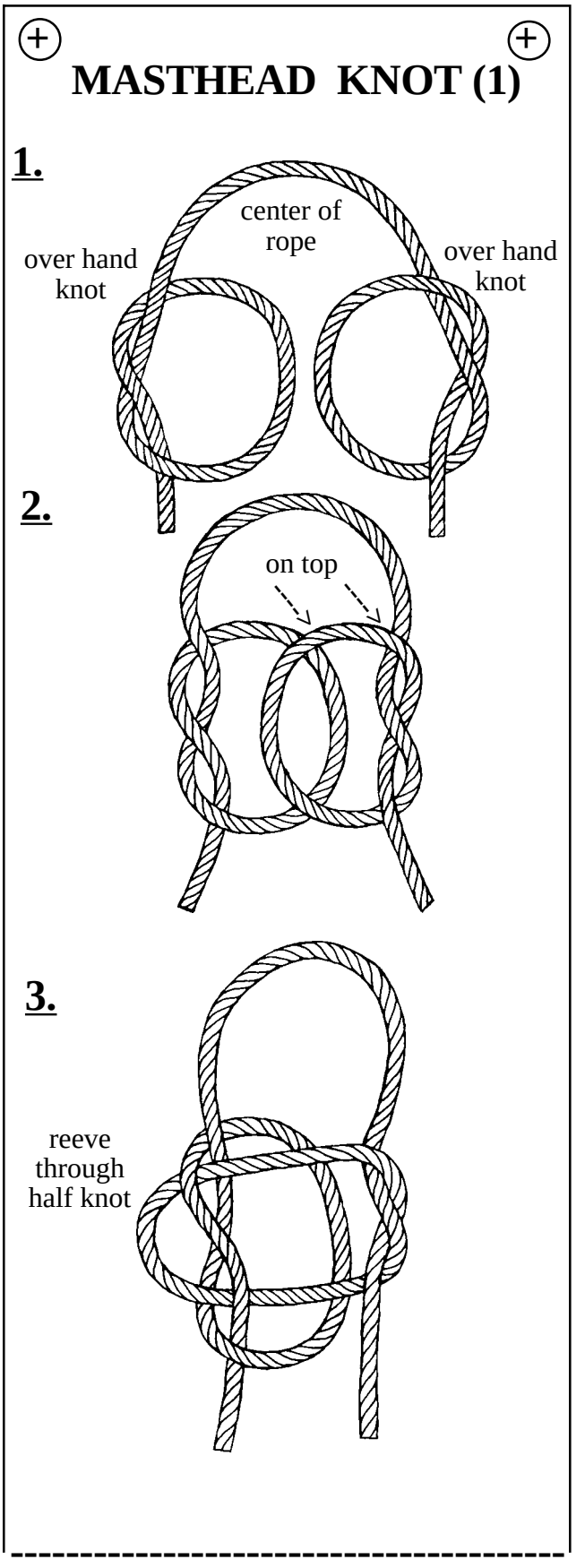

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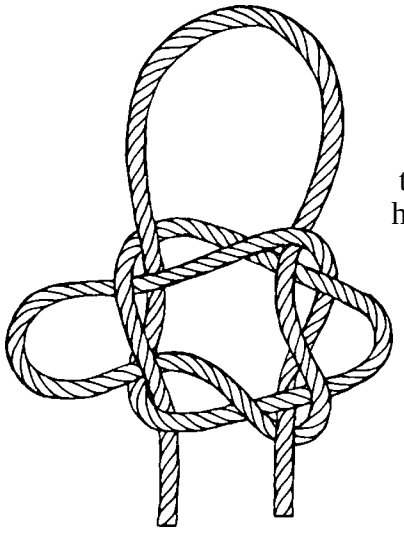

5. place over pole and draw up even

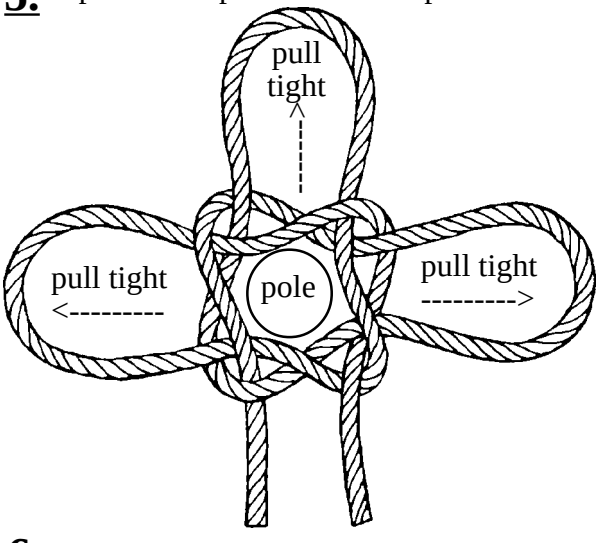

6. secure to pole with running half hitches

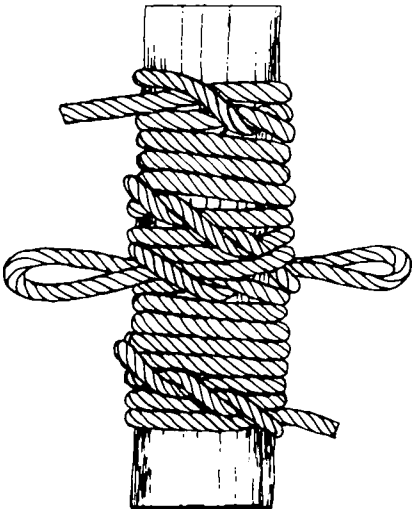

MASTHEAD KNOT (2):

Description ---- A multiple loop knot formed by weaving three overlapping over hand loops together and then securing the knot to a mast.

Narration ----- (For **masthead knot (2)** knotboard.) **(1)** Form an over hand loop near the center of the rope. **[NOTE]** The size of the loop is determined by the size of the pole that the finished knot is to be placed over. **(2)** Form a second larger overhand loop at the center of the rope. **(3)** Place the left edge of the second overhand loop under the right edge of the first overhand loop. **(4)** Form a third overhand loop. **(5)** place the left edge of the third overhand loop under the right edge of the second over hand loop. **(6)** Start weaving the over hand loops together by placing the left edge of the right overhand loop on top of the right edge of the left over hand loop. **(7)** Continue the weaving by placing the right edge of the left overhand loop over the right edge of the center overhand loop and by placing the left edge of the right overhand loop under the left edge of the center overhand loop. **(8)** Finish the weaving by placing the right edge of the left overhand loop under the right edge of the right overhand loop and by placing the left edge of the right overhand loop over the left edge of the left overhand loop. **(9)** Place over pole and work tight. The knot is prevented from slipping down the pole by nailing cleats to the pole or by cutting a grove for the knot to rest in. **(10)** Secure the ends of the rope by seizing them to the adjacent loop; two half hitches my also be used.

[NOTE] A forth loop my be formed by tying or splicing the ends together.

[NOTE] Attach the guy lines to the loops with becket hitches.

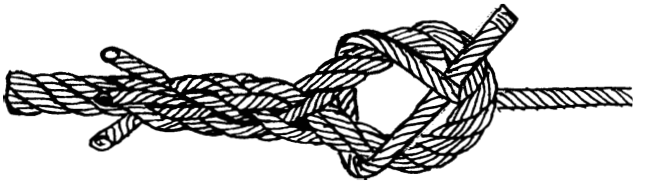

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MASTHEAD KNOT (2)

1. over hand loop

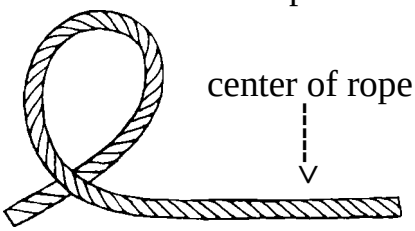

2. 2nd overhand loop

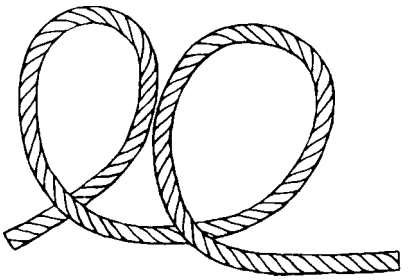

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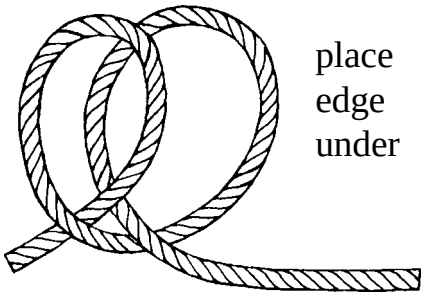

4. 3rd overhand loop

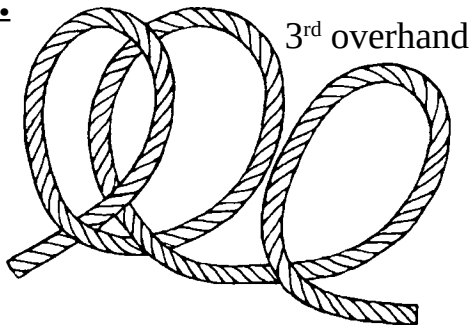

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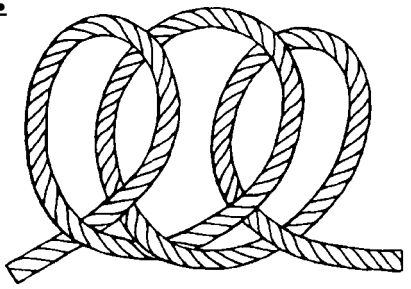

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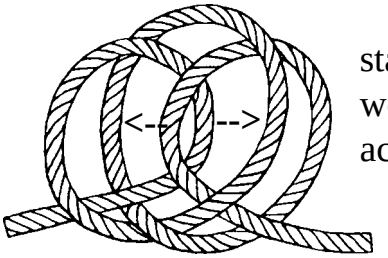

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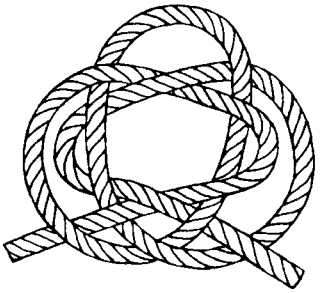

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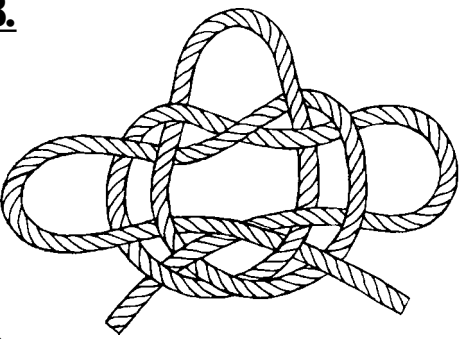

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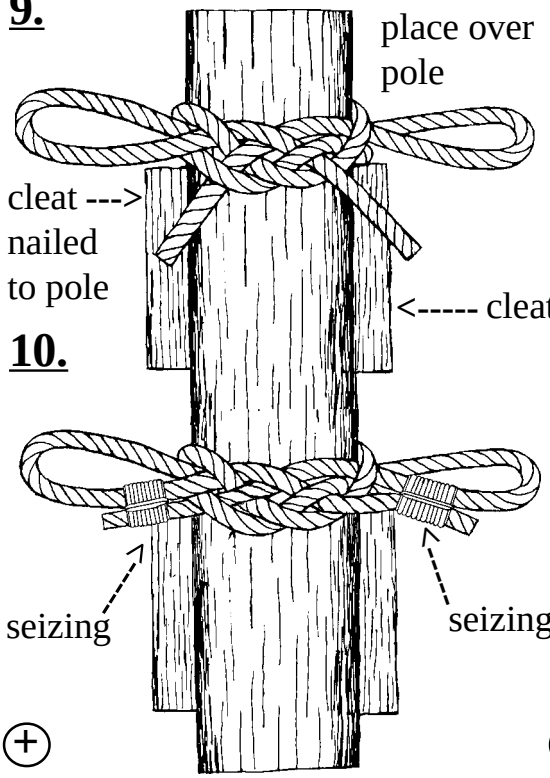

10.

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FLOOR LASHING:

Use ---- to lash a series of poles to a set of stringers to form a flat surface such as a deck, a table top, or a road way.

Comments ---- When using a floor lashing, both ends of the decking poles must be lashed at the same tine to insure a firm even surface.

When placing the decking poles on the stringers, lay the decking poles so that their butt end are in alternating direction. Alternating the but ends of the decking poles will compensate for the natural taper of the poles so that the length of the decking along each stringer will be equal.

Narration ---- (For **floor lashing** knotboard) **(1)** Tie a clove hitch around each stringer. **(2)** Secure the short end of the rope by wrapping it around the running end (wrap with the lay of the rope). **(3)** Place the decking poles on the stringers and take a bight around the first pole. **(4) Next,** on the inside of the stringer, pull a bight up between the first decking pole and the next decking pole. **(5)** Place the eye of the bight over the end of the decking pole. **(6)** Pull tight. **(7)** On the outside of the stringer, place a bight over the next decking pole. **(8)** Pull tight. **(9)** Repeat steps 4 through 8 until all decking poles are lashed in place. **(10)** Tie the first half hitch of the ending clove hitch. Work half hitch tight. **(11)** Tie the second half hitch of the ending clove hitch. Work half hitch tight **(12)** to form clove hitch.

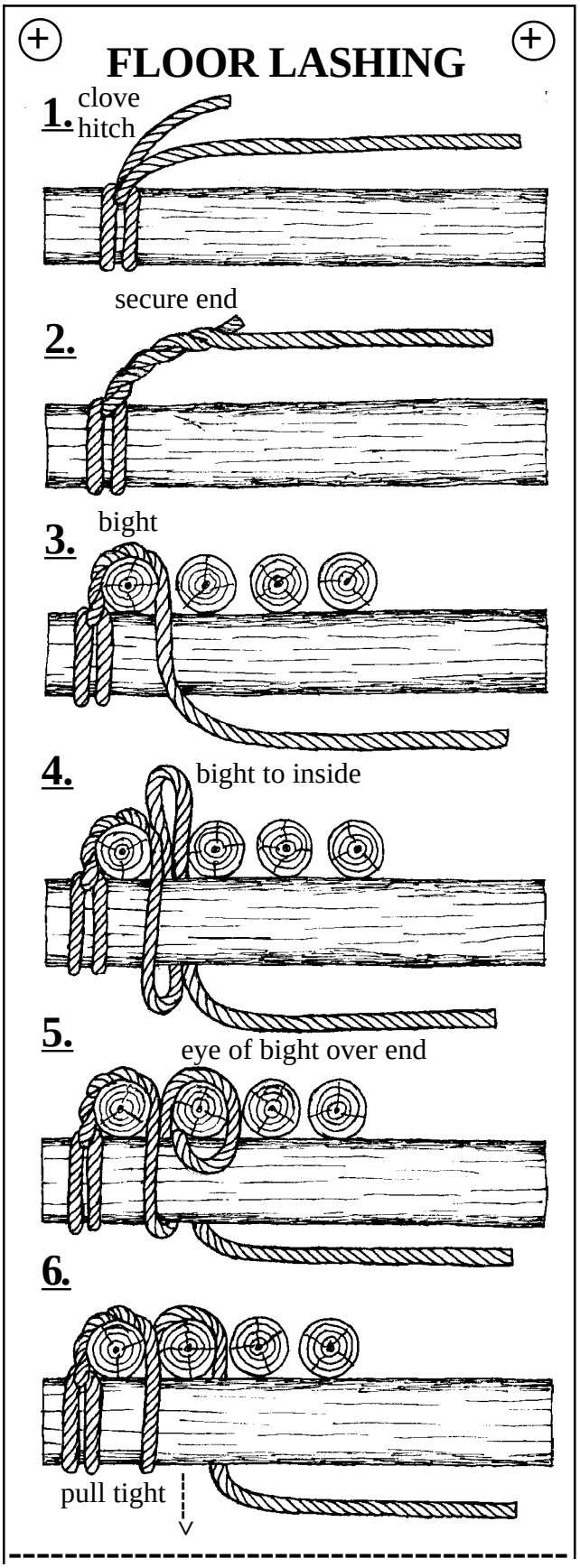

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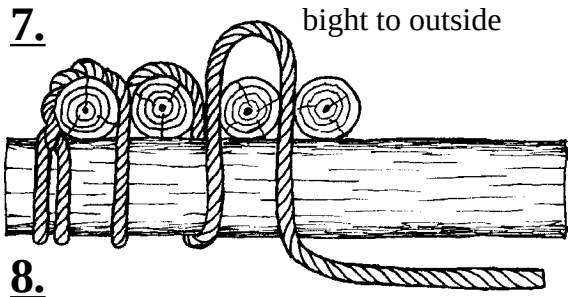

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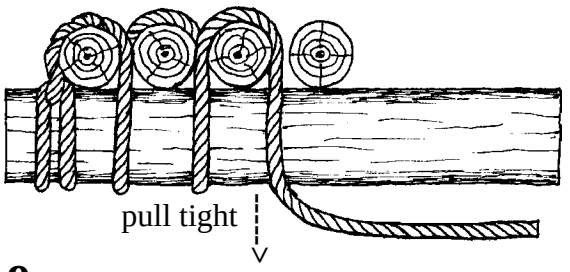

9. repeat steps 4 through 8

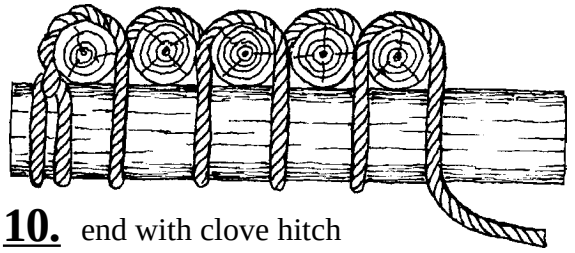

10. end with clove hitch

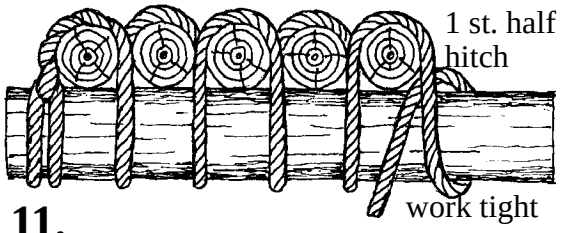

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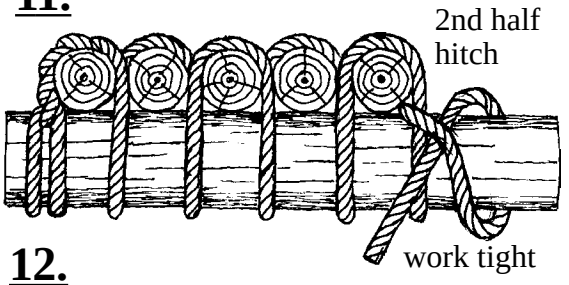

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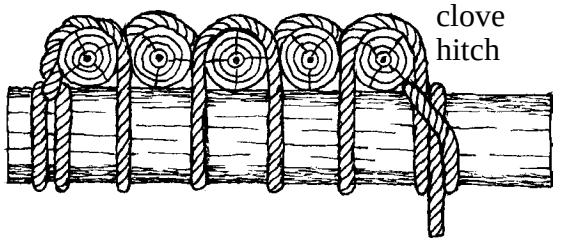

[NOTES]

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Mauls:

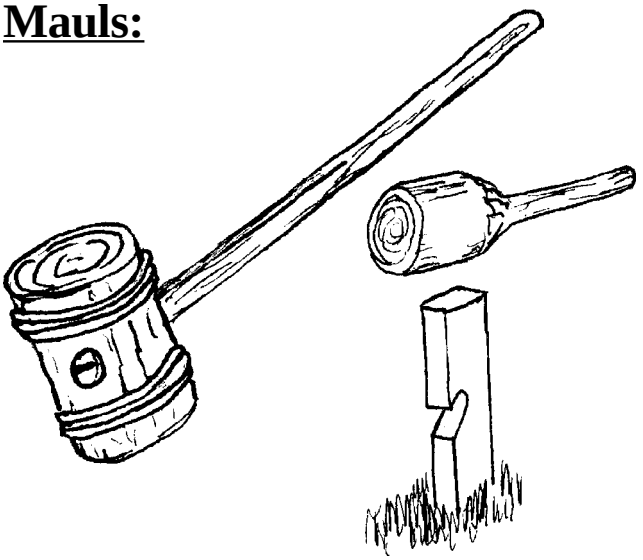

A maul is a wooden club or hammer that is used for driving stakes or wedges and for safety reasons should be used instead of an ax.

Using an ax instead of a maul exposes the user to the danger of being cut by its sharp edge. Even if the edge is covered by a sheath, a glancing blow can cause the sheath to be ripped off or to be cut through.

The pole of an ax serves as a counterweight to the blade. This counterweight adds to the balance of the ax head and helps to control and increase the force of momentum delivered to the bit. The ax head is shaped in such a way that the momentum of the ax head is delivered through the thin walls of the eye. However, when an ax is being used as a hammer, this same shape causes the eye of the ax head to spread and the handle to loosen.

The flat surface and angular edges of an ax pole makes it difficult to strike a stake squarely. This difficulty in striking a square blow results in most blows delivering some there force sideways, causing the end of the wooden stake to flare and split very quickly. In addition, when the pole of an ax contacts a stake, the metal surface of the pole lacks the ability absorb any of the force of the impact this contributes to the destruction of the stake. A wooden maul, on the other hand, absorbs some of the impact of the initial contact and a maul has no angular edges. Therefore, more of the force of the maul is used to do useful work and less of the force is used up in deforming or splitting the stake.

Making a Club Maul:

A club maul, for driving tent pegs and other light work, can be made from a piece of hardwood that is about 3 inches in diameter and 18 to 24 inches long.

|----------18" to 24" ----------|

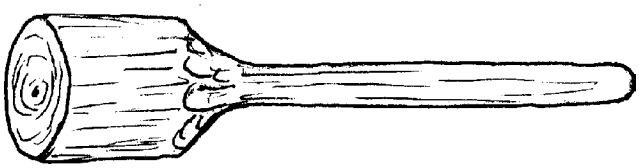

|---- 4" to 5" ---|

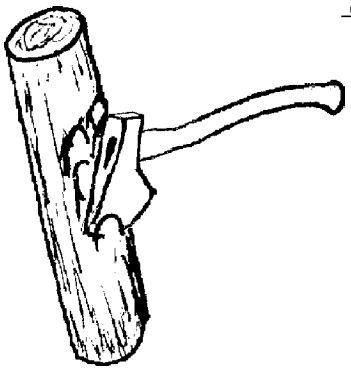

STEP 1: Use an ax to rough out the maul. Form a handle by cutting away one end of the piece of wood so that it is about 1 1/4 inches in diameter. Leave 4 to 5 inches of the other end at its original diameter to form the head of the maul.

STEP 2: Smooth the handle with a knife.

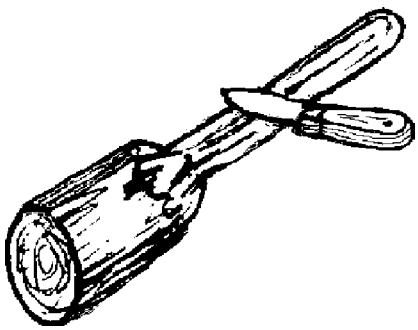

MAKING A HAMMER MAUL:

Materials:

To make the head of a hammer maul you will need a 4 inch diameter, 10 inch long piece of hard, dense, unchecked, well seasoned, hardwood such as elm, black gum or hophornbeam.

For the handle you will need a piece of well seasoned ash, hickory, or similar straight grained wood; 1 1/2 inch diameter and 3 to 4 foot long.

Making a Maul:

STEP1: Square the ends of the head with a saw.

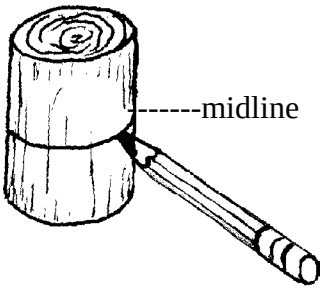

STEP 2: Find and mark the midline between the two ends.

STEP 3: Locate the center of the handle hole on each side of the maul head.

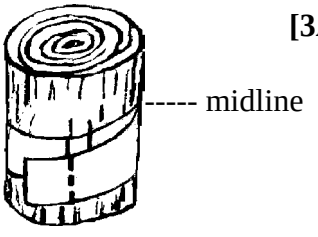

[3A] Wrap a strip of paper around the maul head. Cut the strip of paper off so that the two ends just meet.

[3B] Locate handle hole by folding the strip of paper in half to mark its mid point, then unfold it and wrap it around the maul head again. Mark the midline at the fold and at the ends of the strip of paper.

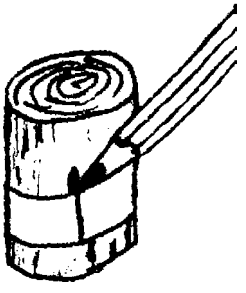

STEP 4: Drill handle hole in head. Use a 1 1/4 inch drill bit to drill a hole halfway through the head from one side, then finish drilling the hole from the other side of the maul head.

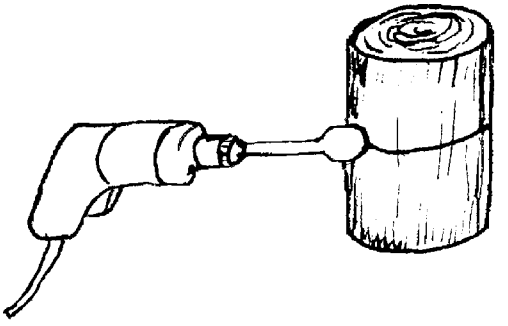

[NOTE] If the holes do not lineup in the middle use a chisel or wood rasp to cut away some of the excess wood.

STEP 5: Make maul handle.

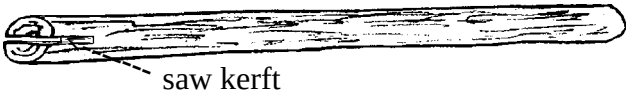

5A] Cut a saw kerft in the one end of the handle. The depth of the kerft should be equal to 1/2 the diameter of the maul head.

5B] Use a knife to shave the end of the handle down until it can be easily driven through the head with light blows with a light wooden block.

STEP 6: Attach the maul head to the handle.

6A] Make a hardwood wedge that is 1 1/4 inch wide, 3 inches long, and 1/4 inch thick at its large end.

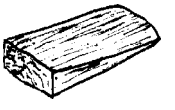

6B] Drive the handle into the maul head, make sure that the saw kerft is lined up across the maul head.

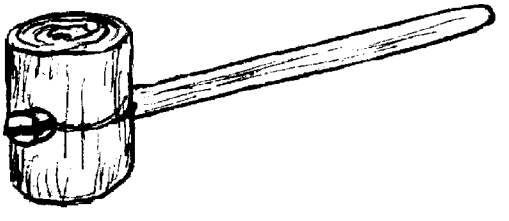

6C] Then drive the wedge in place.

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STEP 7: Reinforce the maul head to keep it from splitting by wrapping several turns of rope or wire around each end of the maul head. These can be held in place with staples.

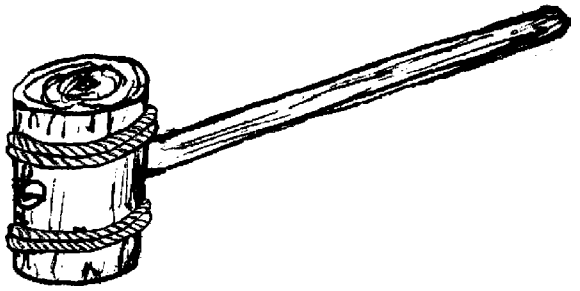

Another method of reinforcing the head would be to drive a braided ring or a grommet over each end of the head.

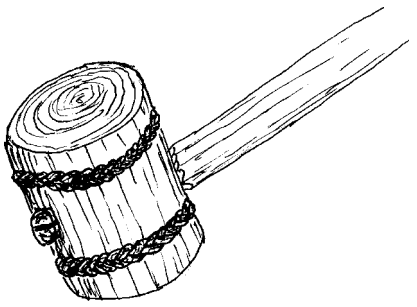

[NOTES]

MAUL --- DOVE TAIL HANDLE:

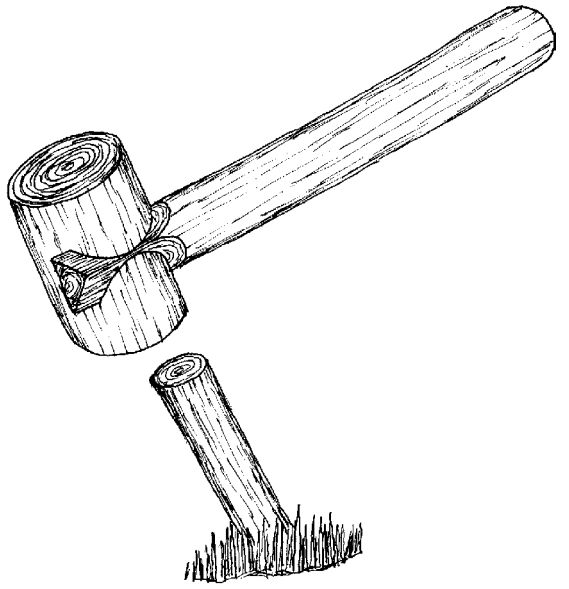

MATERIALS:

1 ----- Piece of seasoned hardwood that is 2 2/2 to 3 inches in diameter and 5 to 7 inches long for the head.
1 ----- piece of seasoned hardwood that is 1 1/2 inches to 2 inches in diameter for the handle.

CONSTRUCTION:

STEP 1: With a saw, cut 3 kerfts as shown at the center of the side of the head.

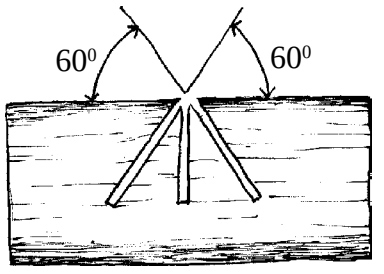

|----------|
Less than the diameter of the handle

[NOTE] The width of the bottom of the dovetail notch must be less than the diameter of the handle.

STEP 2: Use a knife or chisel to remove the wood to form the dovetail notch.

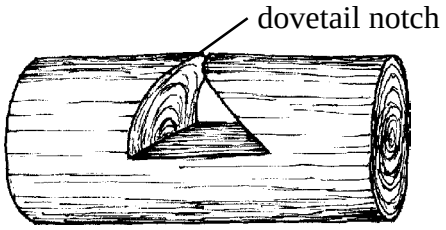

STEP 3: Shape and fit handle to head.

3A] Flatten one side of the end of the handle.

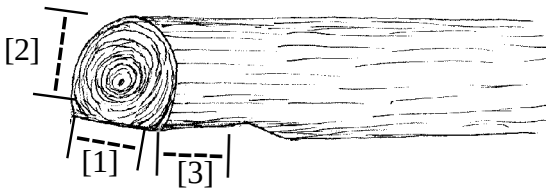

[1] Equal to or greater than the width of the bottom of the dovetail notch.

[2] Equal to or less than the depth of the dovetail notch.

[3] Equal to the diameter of the head.

3B] Fit the handle to the bottom of the dovetail notch. Gradually remove the surplus wood until the flattened part of the handle is the same width as the width of the dove tail notch.

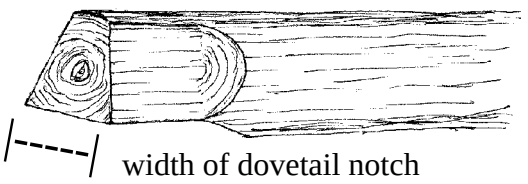

3B] Flatten the remaining two sides of the handle. Gradually remove the surplus wood until the handle fits snugly into the dovetail notch in the head.

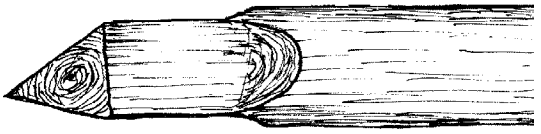

3A] Tap handle firmly into dovetail notch.

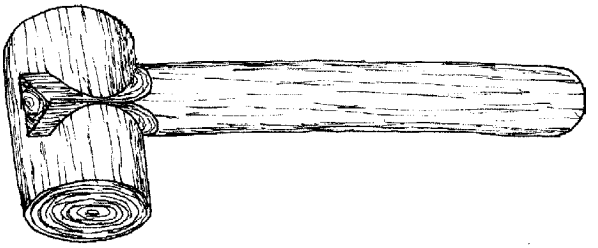

ROPE WRENCH:

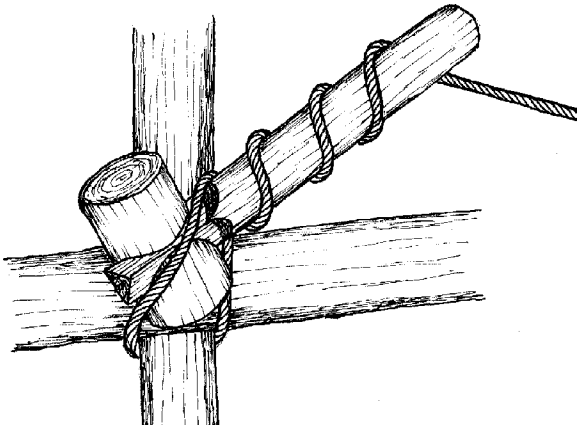

The dovetail maul makes a good rope wrench. Pass the rope over the head of the maul and then take several wraps around the handle. The rope is then tightened by rotating the maul so that the rope wraps part way around the head of the maul.

FUSING:

The ends of a synthetic rope can be fused to prevent the rope from fraying. This is done by heating the end of the rope so that the ends of the rope fibers melt together.

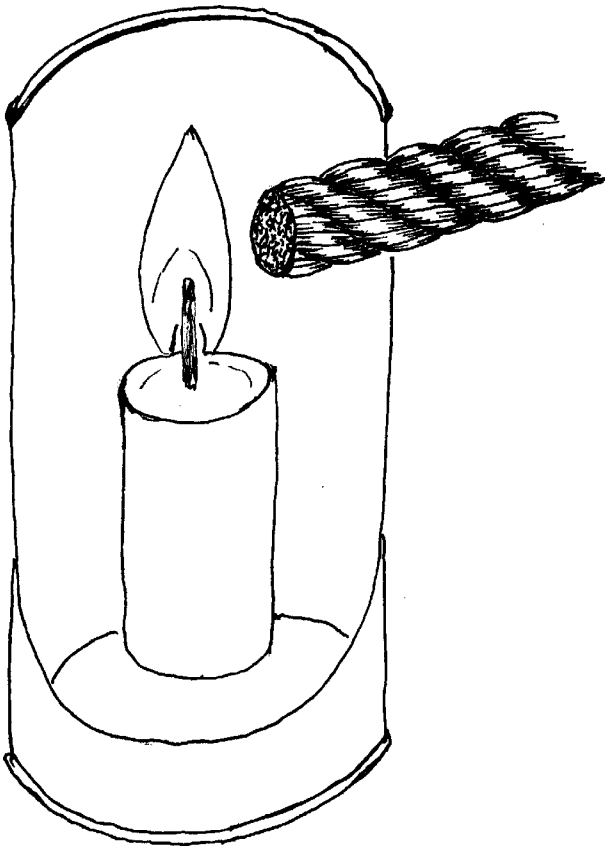

The fusing can be done by holding the end of the rope to the side of a candle or other small flame. If the end of the rope is placed in the flame or held too close to the flame, the plastic will ignite causing the end of the rope to turn black. Burning plastic can also give off toxic fumes . If the end of the rope is held above the flame, unburned carbon particle will be deposited on the melted plastic causing it to turn black. A candle flame will generate enough heat to fuse the end of a rope up to about one inch in diameter. If the rope is larger than one inch, a propane torch will work better .

[WARNING] Do not use a butane cigarette lighter to fuse rope. A butane lighter can explode if it is permitted to burn too long.

[NOTE] If the rope is cut to length with a soldering iron or other hot cutting tool, the ends of the rope will be fused as the rope is being cut to length.

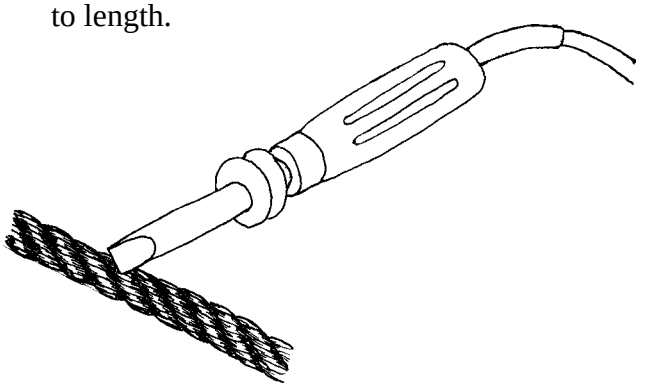

A small lamp such as an alcohol lamp or a small oil lamp works very well for fusing rope.

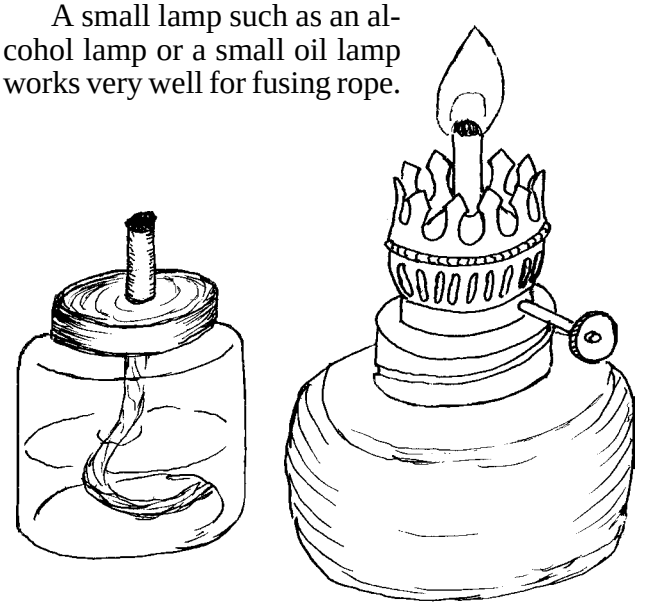

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TAUT-LINE HITCH:

Description —— Two half hitches with an extra turn.

Use —— To adjust the tension on guy lines.

Comments —— The tension is adjusted by sliding the knot along the standing part of the rope.

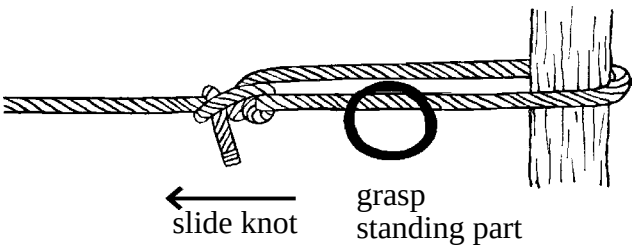

To decrease the tension on a guy line, grasp the standing part just out side the loop, then slid the knot away from your hand.

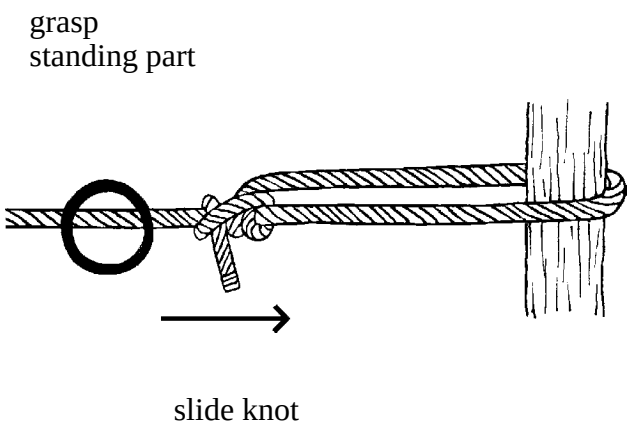

Other Names —— There are several other names that are used interchangeable for the taut-line hitch and several related knots. The midshipman's hitch, rolling hitch, and magnus hitch. The following seems to be the most common usage of these name:

When tied around its own standing part ----**taut line hitch**.

rolling hitch

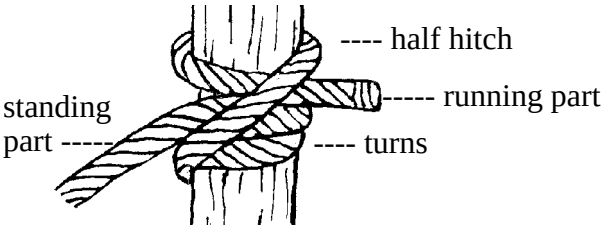

When tied around an object other then its own standing part ---- rolling hitc**h, magnus hitch.**

midshipman's hitch

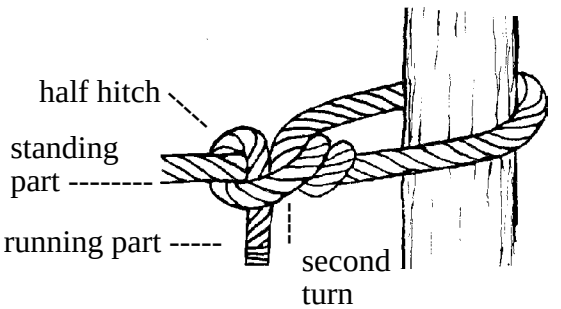

When tied so that the second turn is between the first turn and the standing part ---- **midshipman's hitch** (see direction for midshipman's hitch).

adjustable jam hitch

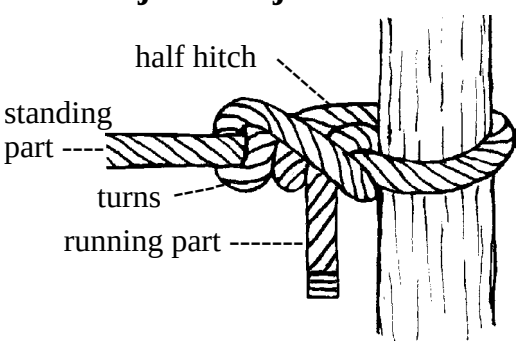

When tied with the two turns outside the loop and the half hitch inside the loop ---- **adjustable jam hitch.**

Use --- To tie-up a bundle so that the knot can be tightened by sliding the knot toward the bundle and loosened by sliding the knot away from the bundle.

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TAUT-LINE HITCH

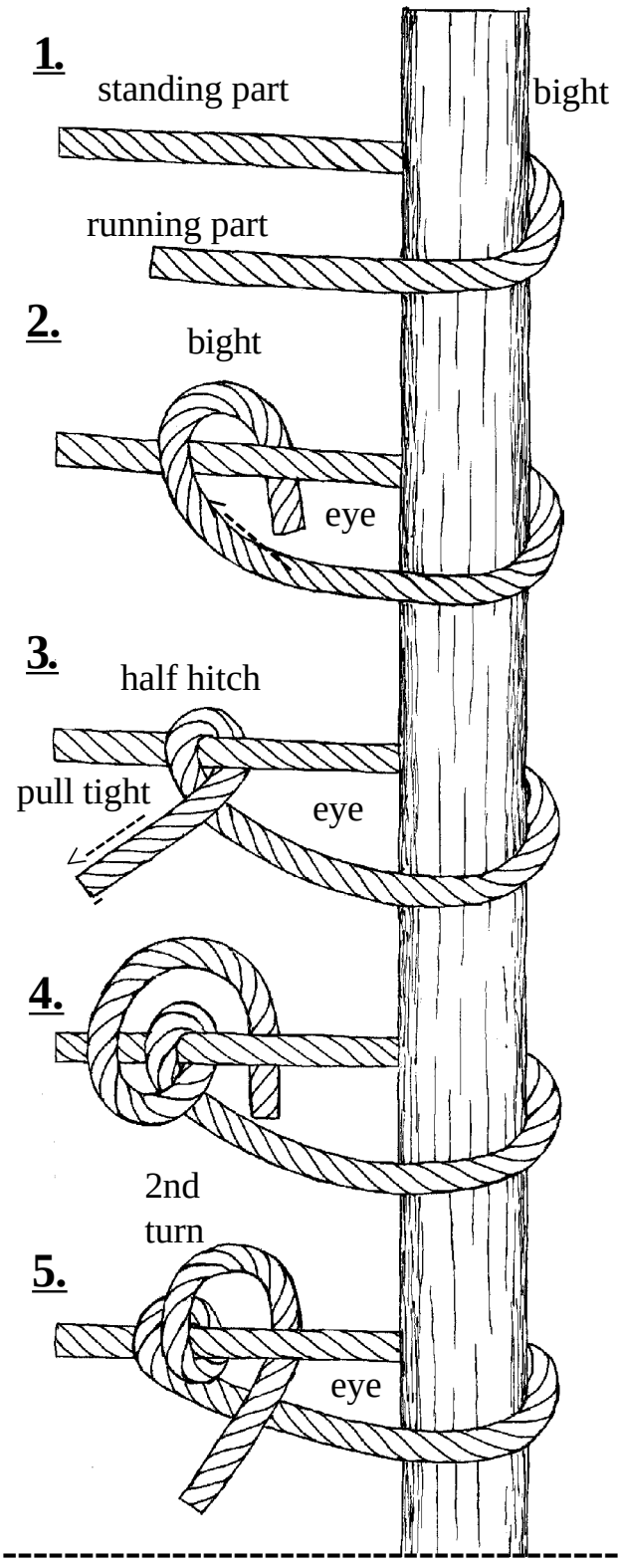

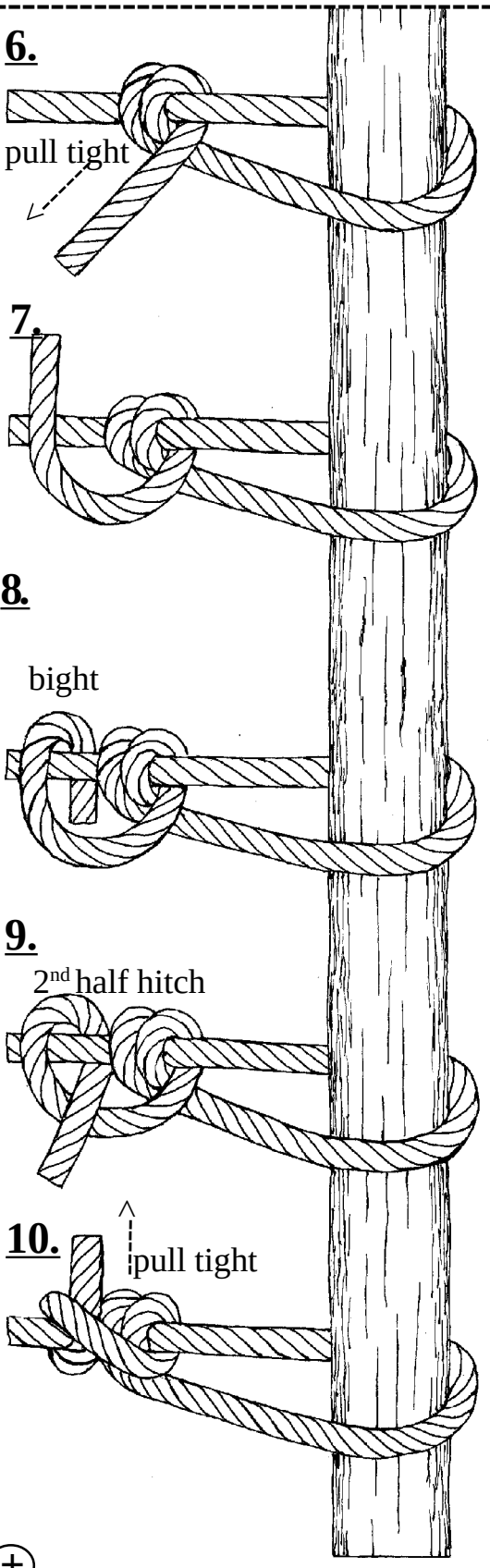

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Narrative ---- (For **taut-line hitch** knotboard.) **(1)** Take a bight around the pole. **(2)** Take a bight around the standing part. **(3)** (The eye of the bight becomes the eye of the taut-line hitch) Pass the running part through the eye of the aut-line hitch (between standing part and the pole) this forms a half hitch around the standing part**;** pull tight **(4)** Take a second bight around the standing part in the same direction; **(5)** this results in two complete turns around the standing part. **(6)** Pull tight. **(7)** Go to the outside of the loop. **(8)** Take another bight around the standing part; pass the running part between itself and the first half hitch, **(9)** this forms the second half hitch, **(10)** Pull tight.

[NOTES]

MIDSHIPMAN'S HITCH:

Description ---- Two half hitches with an overlapping extra turn.

Use ---- To adjust the tension on a guy line when very smooth rope is being used.

Comments ---- The midshipman's hitch is harder to adjust then the taut-ine hitch, therefor it is the ideal knot for adjusting the tension on synthetic rope guy lines.

Narrative ----

(1) After taking a bight around an object, take a turn around the standing part so that the turn is inside the loop.

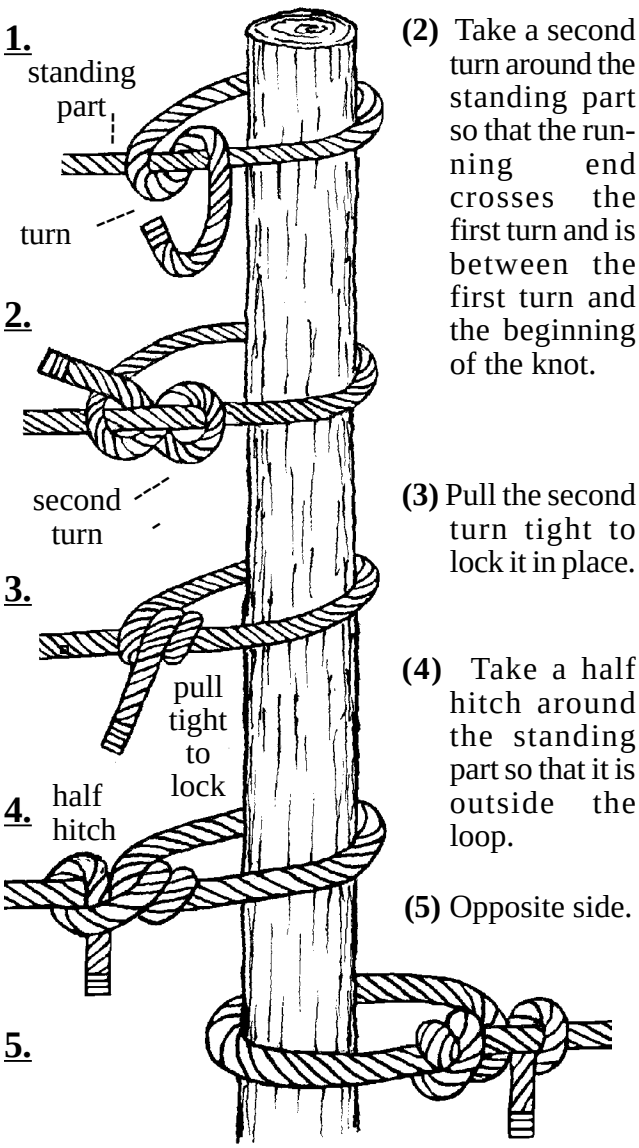

(2) Take a second turn around the standing part so that the running end crosses the first turn and is between the first turn and the beginning of the knot.

(3) Pull the second turn tight to lock it in place.

(4) Take a half hitch around the standing part so that it is outside the loop.

(5) Opposite side.

SPANISH WINDLESS:

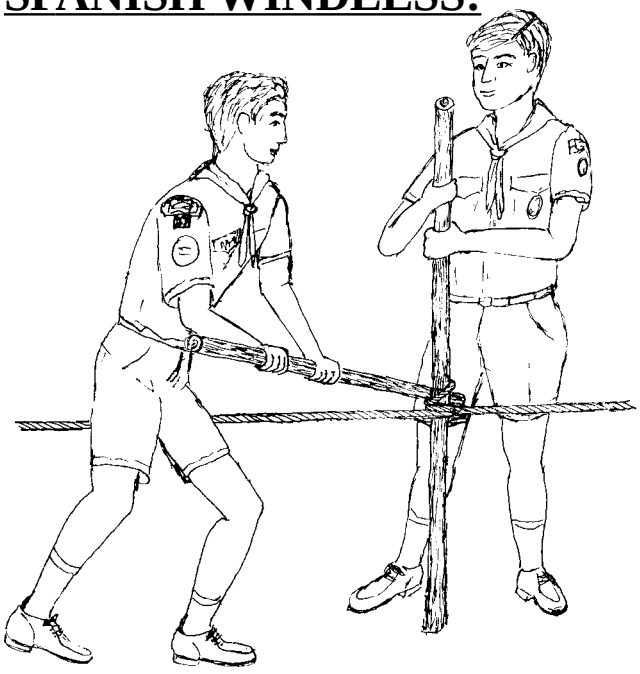

A Spanish windless is a device for moving heavy loads such as rocks and logs.

[WARNING] When setting up a Spanish Windless do not use nylon or other synthetic fiber rope that stretch under a load. If you slip or let go of the poles the energy you used to stretch the rope will be released as the rope returns to its original length. This release of energy could cause the poles of the windless to spin around causing injuries to any one near by. Natural fiber ropes, such as sisal, have little stretch; therefore are much safer to use.

MATERIALS:

1 — 8 foot * 3 inch pole
1 — 5 foot * 3 inch pole
1 — 3/4 inch * 50 foot (natural fiber)

SETUP:

STEP 1: Tie one end of the rope to the load and the other end to a secure anchor point. Leave some slack in the rope so that the windless can be rigged.

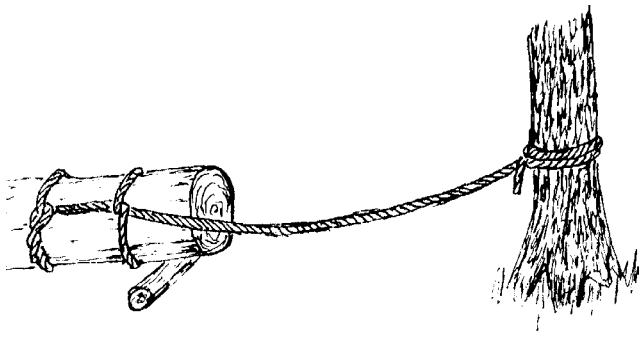

STEP 2: Follow the diagrams to set up the poles at the mid point of the rope.

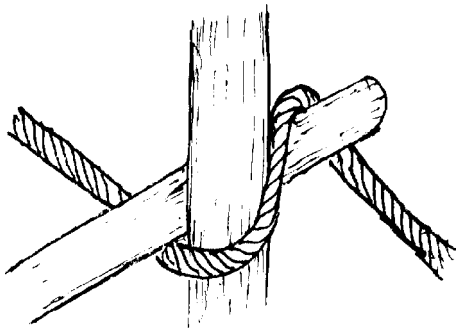

STEP 3: While one person holds the up right pole, a second person rotates the longer pole around the upright so that the rope begins to wrap around the upright pole. Adjust the height of the rope so that it can be easily stepped over.

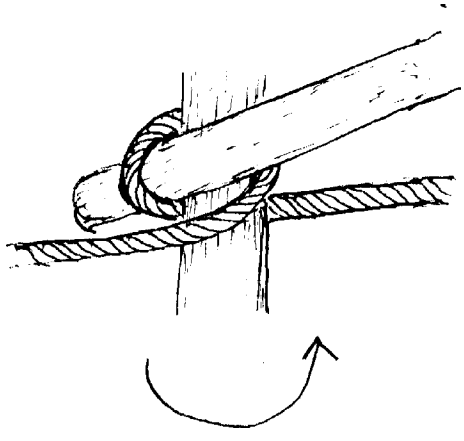

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STEP 4: Continue to rotate the longer pole around the upright.

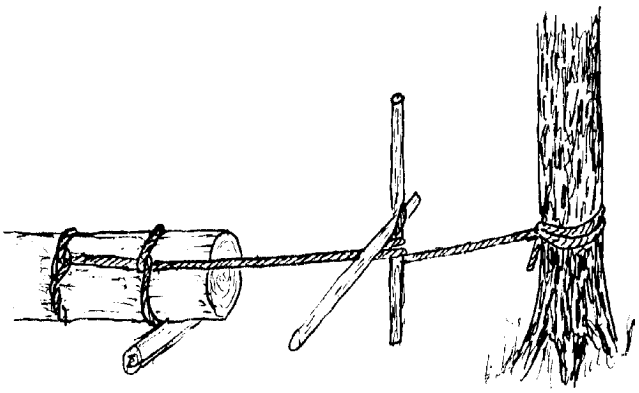

NOTE] As the rope wraps around the upright it will be necessary to move the base of the upright to keep it vertical.

NOTE] Be careful that the two end of the rope are kept at the same level on the upright.

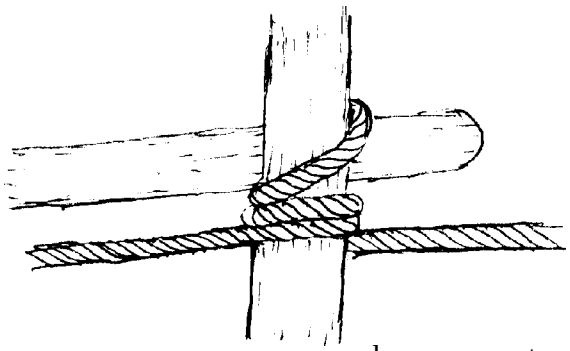

keep rope at
same level

[NOTES]

ROPE HALTER

Start with an eye splice.

(The Eye splice will form one end of the nose piece of the halter)

Decide how long the nose piece must be then tie a quick eye into the rope.

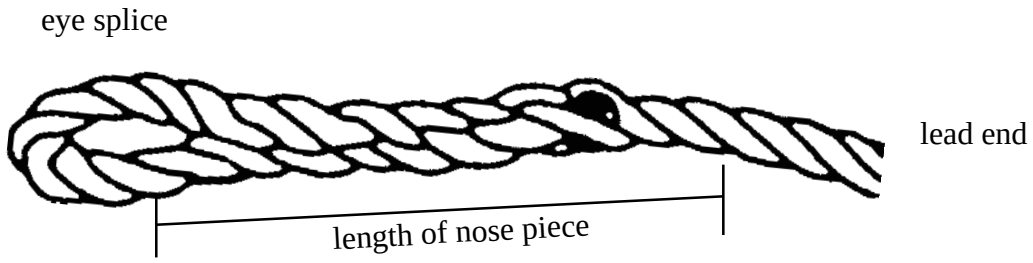

Quick Eye STEP1

Decide where the quick eye must be. Then reeve the lead end through the lay of the rope as shown. (Slightly larger than the diameter of the rope)

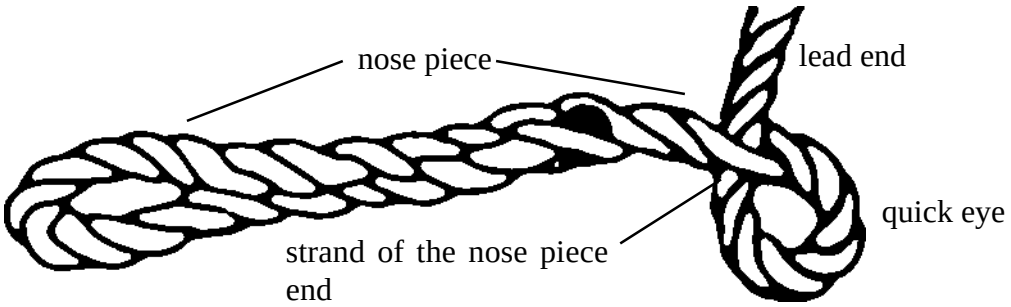

Quick Eye STEP 2

Observe which strand of the lead end is directly under the strand of the nose piece end. Reeve the eye splice under that strand.

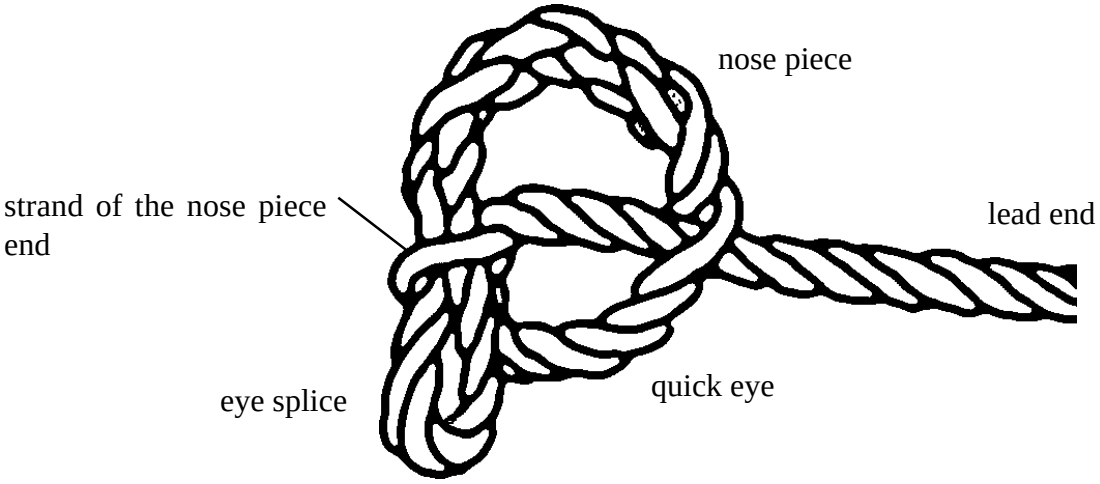

Quick Eye STEP 3

Work the eye into shape. (Do not just pull on the ends this will distort the eye.) When the eye is in shape, the strands of the rope should lay even showing little or no distortion.

Finnish the halter by reeving the lead end through the two eyes as shown.

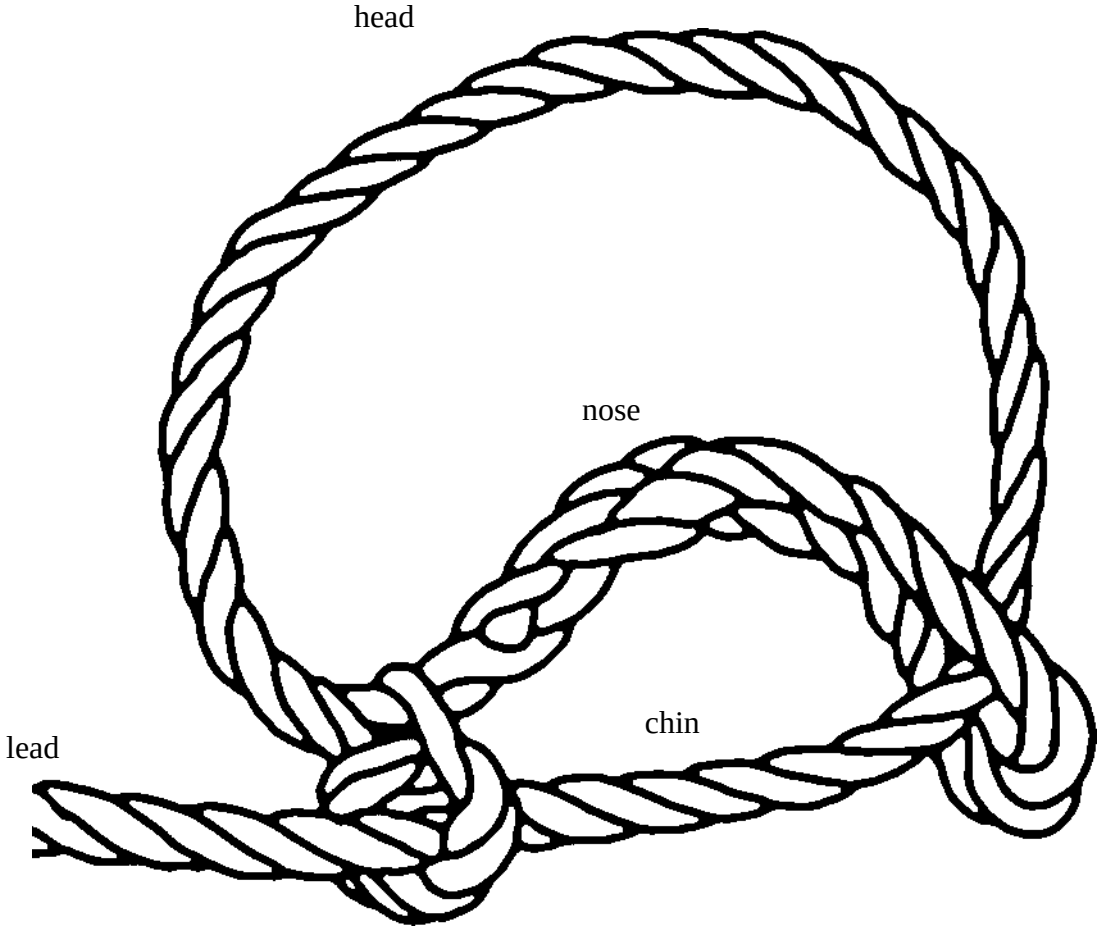

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LADDER LASHING:

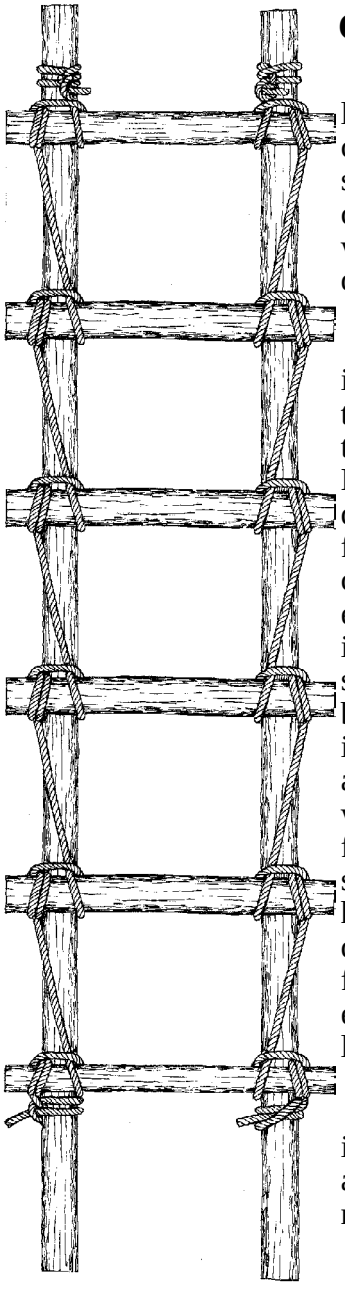

Comments:

Ladder lashing allows for a quick and secure method for constructing a ladder or for constructing a decking with evenly space decking pieces.

This form of lashing has several advantages over the traditional floor lashing. Less material is required because unlike floor lashing a space can be left between each piece of the decking. Also, each rung is securely lashed in place by several loops of rope in much the same way as a square lashing; with the traditional floor lashing only a single loop of the rope holds each end of the decking in place, therefore if one piece loosens, the entire deck loosens.

The ladder lashing has two forms; left and right, each is a mirror image of the other.

START: The ladder lashing is started by using a clove hitch stopped with two half hitches to secure a rope to the top end of each rail.

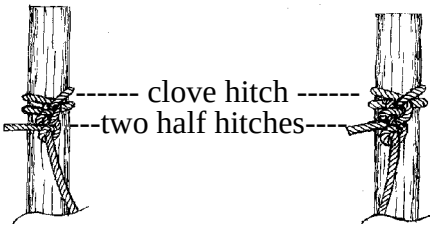

STEP 1: Lay an overhand loop over each side rail so that the running end of each loop is to the outside.

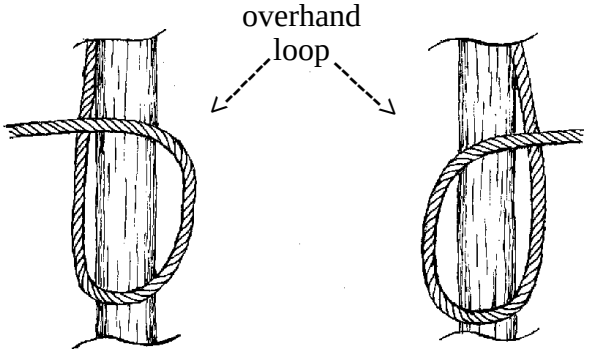

STEP 2: Place a rung across the rails so that the standing part of each overhand loop is over the end of the rung and the running part of each overhand loop is under the rung.

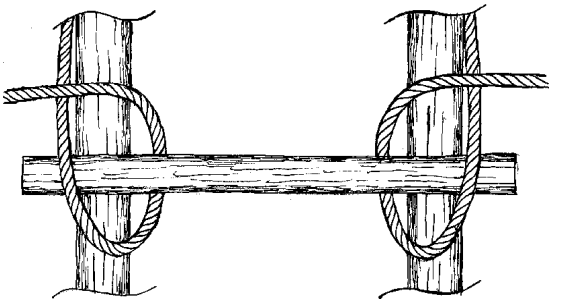

STEP 3: Pull the running part side of each overhand loop behind and to the outside of each rail.

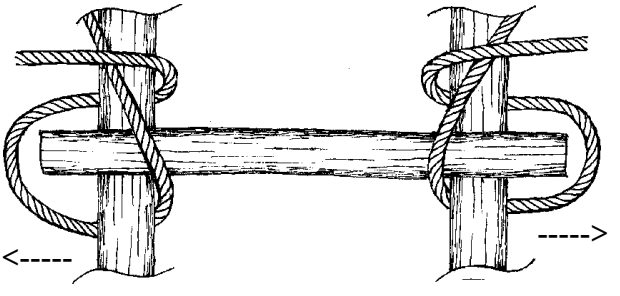

STEP 4: Then pull the loop over the end of the rung.

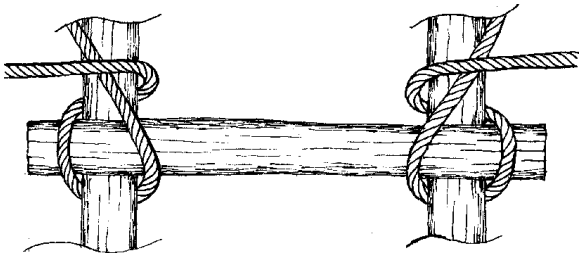

STEP 5: Work each rope until it is tightened around the rung and the rung is in its desired position.

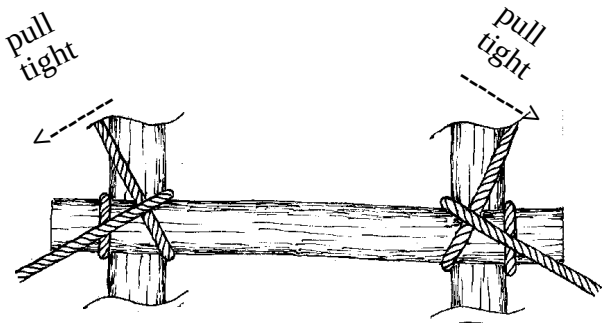

STEP 6: Form an overhand loop in each running part.

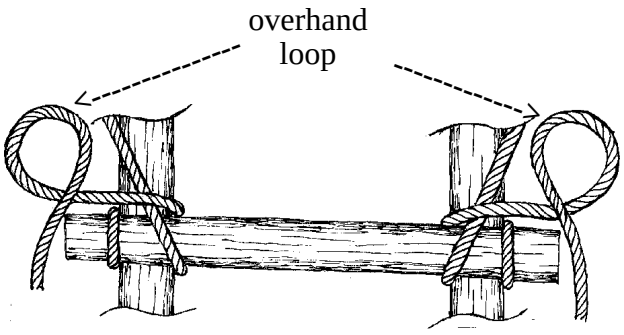

STEP 7: Place an overhand loop over each end of the rung to form a half hitch around each end of the rung.

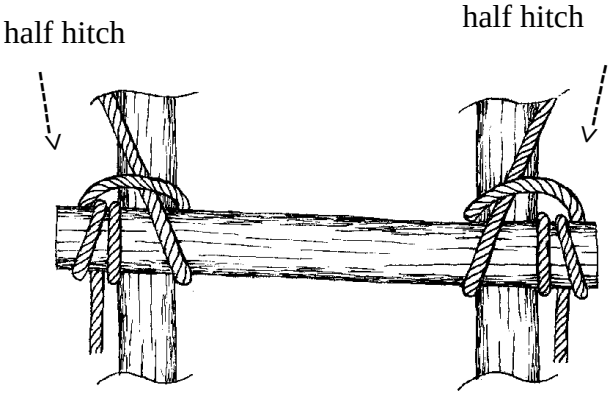

STEP 8: Work the half hitch tight.

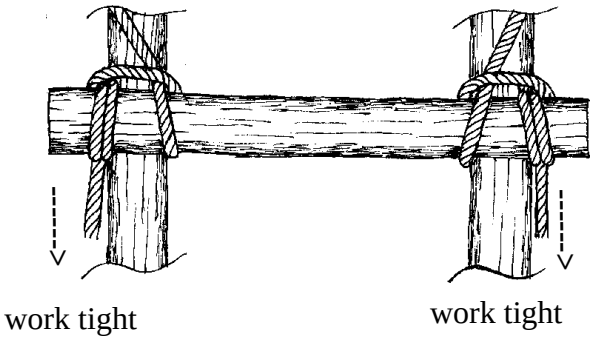

STEP 9: Repeat steps 1 through 8 for each additional rung.

END: Finnish the lashing by tying a clove hitch around each rail so that the clove hitch is directly under the bottom rung.

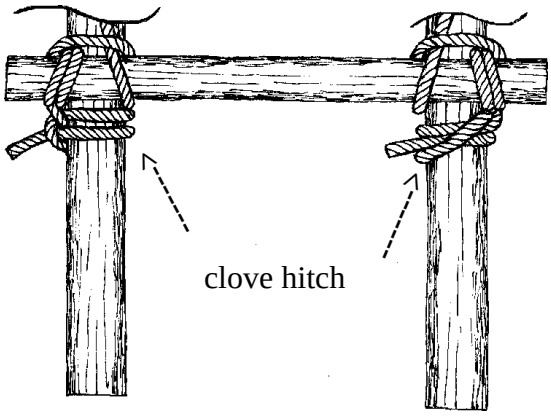

SEIZING:

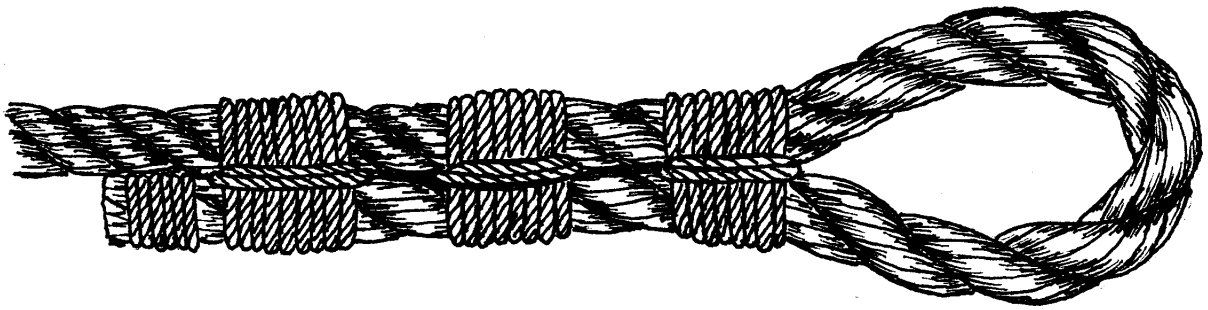

Use ---- To bind ropes together or to bind a rope to an object. Sometimes used to bind the running end of a rope to the standing end of the rope to prevent a knot from spilling.

Comments ---- Seizings do not use as much material and are not as bulky as a knot or a splice; nor does the seizing damage the fiber of the rope. The fibers of a rope do not need to be bent or separated to be seized as they do when a knot is being tied or a splice worked. If the seizing is no longer needed, the seizing can be cut away and the rope is undamaged.

The seizings shown here can be worked with out the use of a needle. However there are many forms of seizing that require the use of a needle to apply them to a rope.

To form an eye, 3 to 4 seizing should be used. This ensures that the eye will safely remain in place even if one of the seizings is damaged.

If there is additional strain on the ropes, such as at the first seizing of an eye, racked turns should be used.

Materials ---- The diameter of the "twine" that is being used to do the seizing should be 1/8 to 1/12 the diameter of the rope being seized. The length of the "twine" should be about 3 feet for each 1 inch of diameter of the rope.

Narration ---- (For **seizing** knotboard.) **(1)** Fold a piece of twine in half over one strand of the rope. **(2)** Start the first layer of wrapping turns by laying the end of the twine that is between the ropes over the other end. **(3)** Wrap the outside strand around the ropes so that so that the wrapping turns are parallel to each other; pull each wrapping turn tight. **(4)** When the width of the wrapping is equal to the diameter of the rope, end the first layer of wrapping turns by reeving the twine between the ropes; pull tight. **(5)** Add a layer of riding turns; the riding turns are laid in the grove between the wrapping turns and pulled tight but not so tight as to separate the wrapping turns of the first layer. **(6)** When the riding turns have been completed, end the riding turns by reeving the end of the twine between the ropes so that it is in the opposite direction to the other end of the twine. **(7)** Add frapping turns; reeve the end of the twine between the ropes at the other end of the wrappings; pull tight. **(8)** Use a square knot to end the frapping turns: reeve the ends of the twine between the ropes again; tie a half knot; pull the half knot and the frapping turns tight. **(9)** Reeve the ends of the twine between the ropes again; tie the second half knot of the square knot. **(10)** Pull the second half knot tight so that the square knot is between the strands of the rope. Cut of the ends of the twine.

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SEIZING

1. center of twine

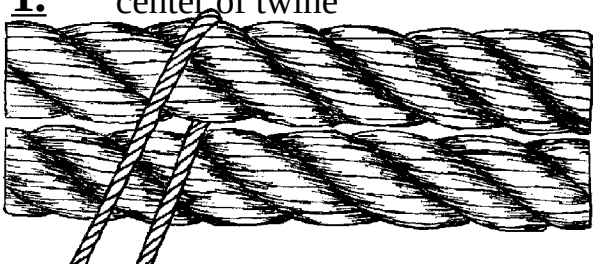

2.

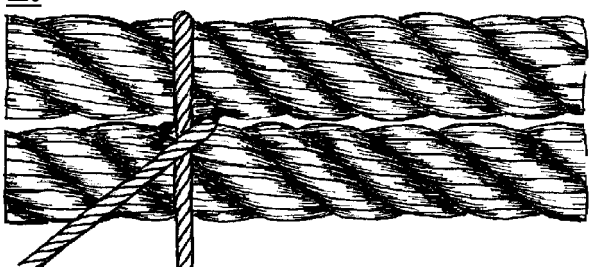

3.

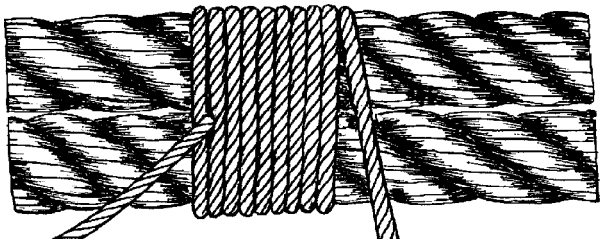

4.

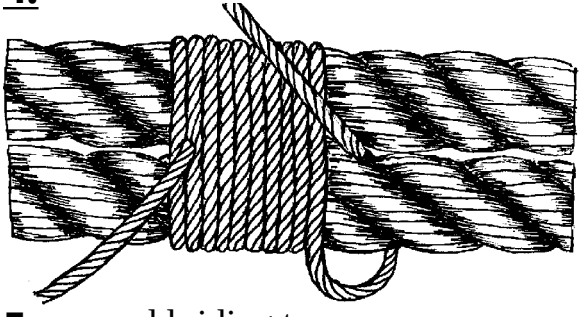

5. add riding turns

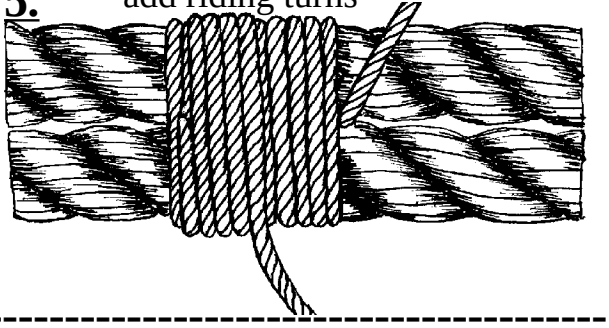

6.

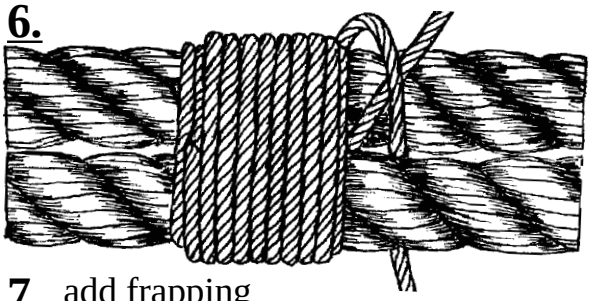

7. add frapping

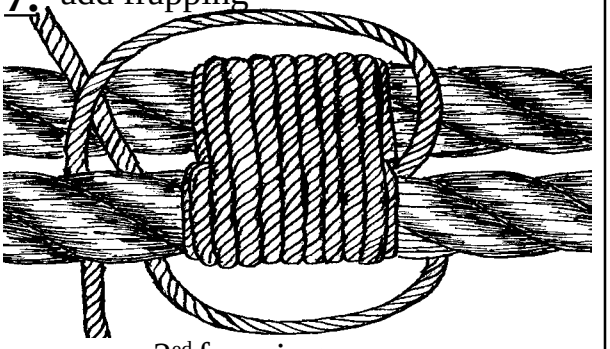

8. 2ed frapping; half knot

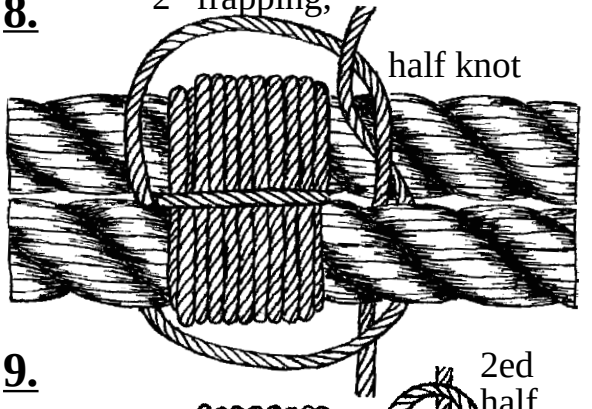

9. 2ed half knot

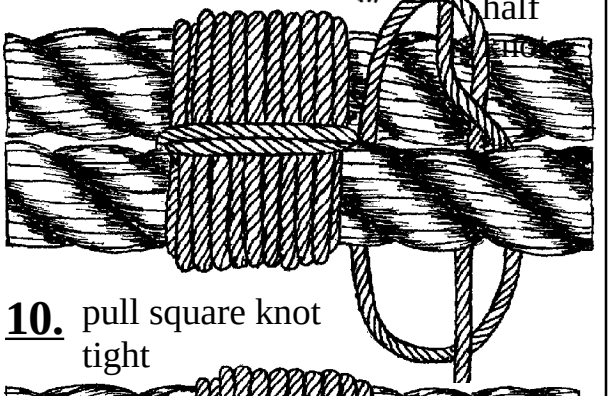

10. pull square knot tight

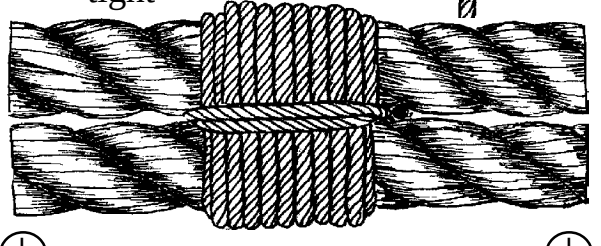

cut off ends

SEIZING:
WITH RACKING TURNS

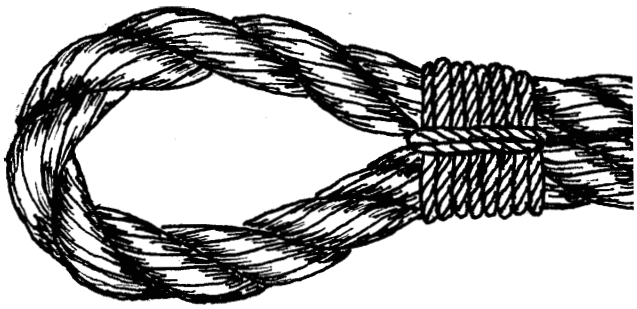

Narration ---- (For **seizing with racking turns** knotboard.) **(1)** At the center of a piece of twine, tie a half knot so that the twine is around the first rope and the half knot is between the ropes. **(2)** Take racking turns with the twine by taking a bight around the second rope and reeving the twine between the ropes; **(3)** then take a bight around the first rope and reeve the twine between the ropes again. (each racking turn forms a figure "8" around the rope. **(4)** When the length of the layer of racking turns is equal to the diameter of the rope, end the layer of racking turns with a half hitch around the second rope. **(5)** work half hitch tight. **(6)** Add a layer of riding turns; the riding turns are laid in the grove between the wrapping turns and pulled tight but not so tight as to separate the wrapping turns of the first layer. **(7)** Add frapping turns; reeve the end of the twine between the ropes at the other end of the wrappings; pull tight. **(8)** Use a square knot to end the frapping turns: reeve the ends of the twine between the ropes again; tie first half knot of the square knot; pull the half knot and the frapping turns tight. **(9)** Reeve the ends of the twine between the ropes again; tie the second half knot of the square knot. **(10)** Pull the second half knot tight so that the square knot is between the strands of the rope. Cut of the ends of the twine.

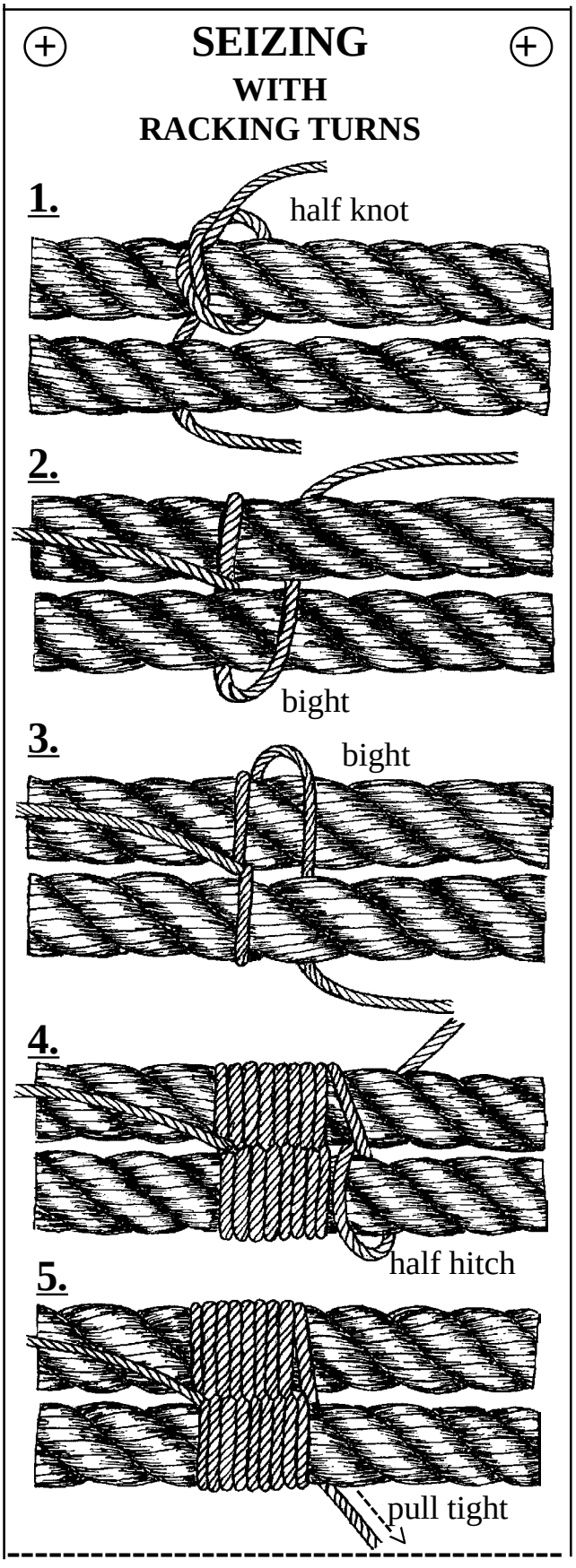

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6. riding turns

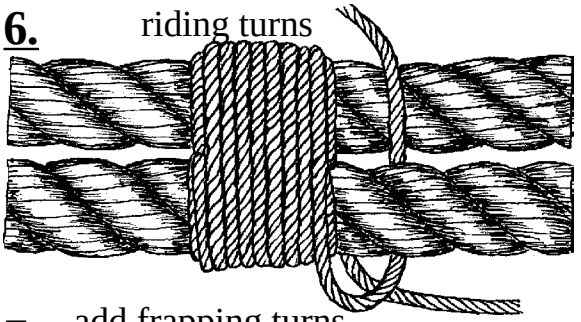

7. add frapping turns

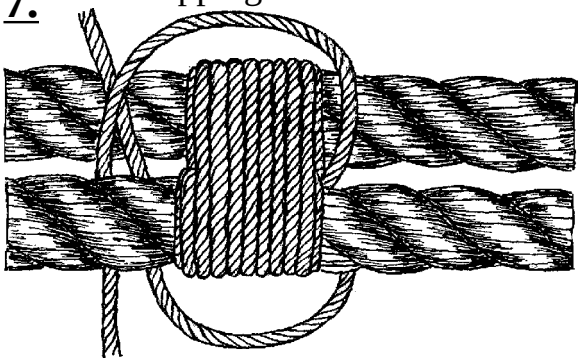

8. tie square knot

half knot

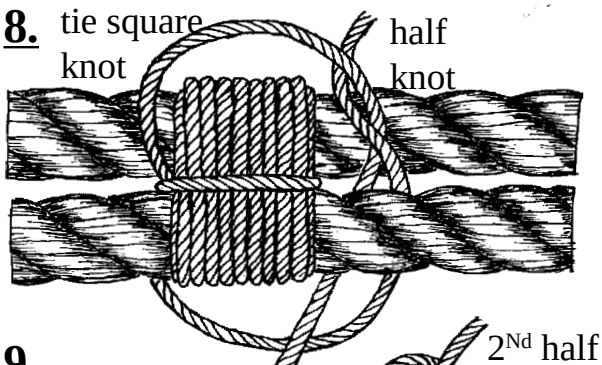

9.

2Nd half knot

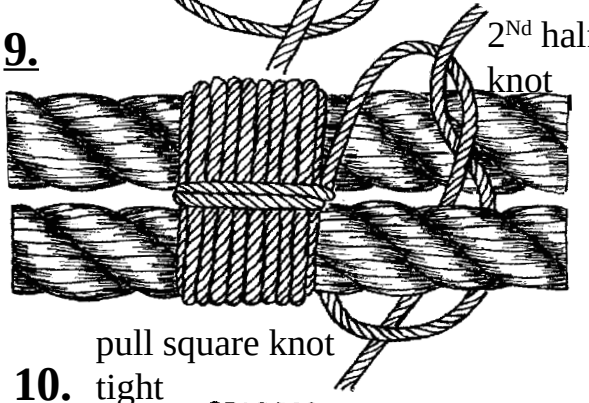

pull square knot tight

10.

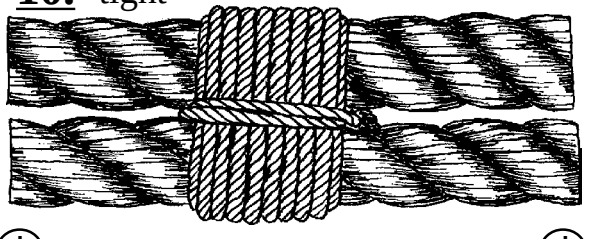

and cut off ends

[NOTES]

FIDS:

A fid is a tool that is used to open the lay of a rope when working a splice or to loosen knots.

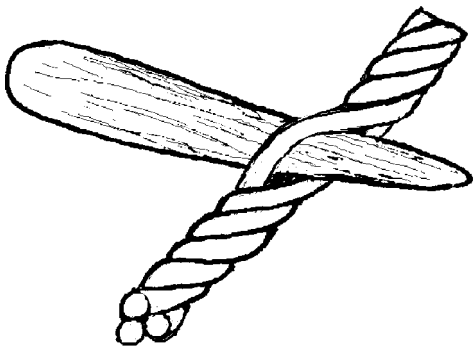

MAKING A WOODEN FID:

Split out an 8 inch by 3/4 inch piece of close grained, smooth, hardwood. Carve and smooth the piece to the shape shown in the diagram.

MAKING METAL FIDS:

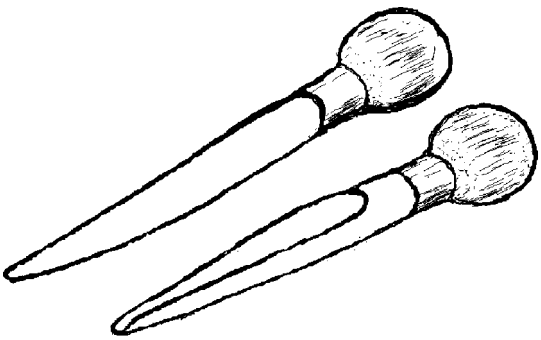

Materials:

1 --- 8 inch * 1/2 inch copper tubing or steel electrical conduit.
2 --- 1 inch diameter * 3 inch long piece of smooth grained hardwood.
2 --- 4D finishing nails.

Construction:

Cut the tubing diagonally into two pieces as shown in the diagram (Use a hacksaw).

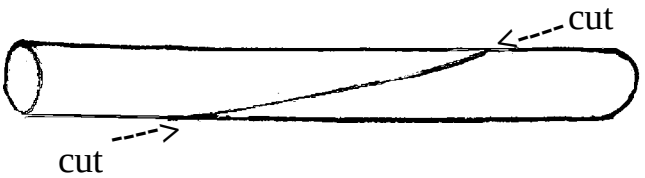

Making a Closed Fid:

STEP 1: Use a triangular file to enlarge the diagonal opening in one of the halves of the tubing. File the opening to the shape indicated by the dotted lines in the diagram.

STEP 2: Close the diagonal opening. Using light taps with a hammer gently roll the two edges toward each other to form the tubing into a cone. (When the two edges of the opening meet the seam in the tubing should be straight).

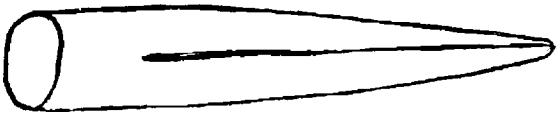

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STEP 3: Solder the edges of the opening together.

3A] Clean the edges of the opening with steel wool.

3B] Spread soldering paste along the cleaned edges.

3C] Solder the seam. Use a propane torch to apply heat to the side of the fid that is opposite the seam. (Heating the tube from the opposite side, will ensures that metal is heated all the way through so that the solder will flow into the seam and not just spread out on the surface.) As you heat the tubing test the seam for the proper temperature by touching the solder to the seam. When the solder starts to melt and flow into the seam, move the solder along the seam until the entire seam is filled with solder.

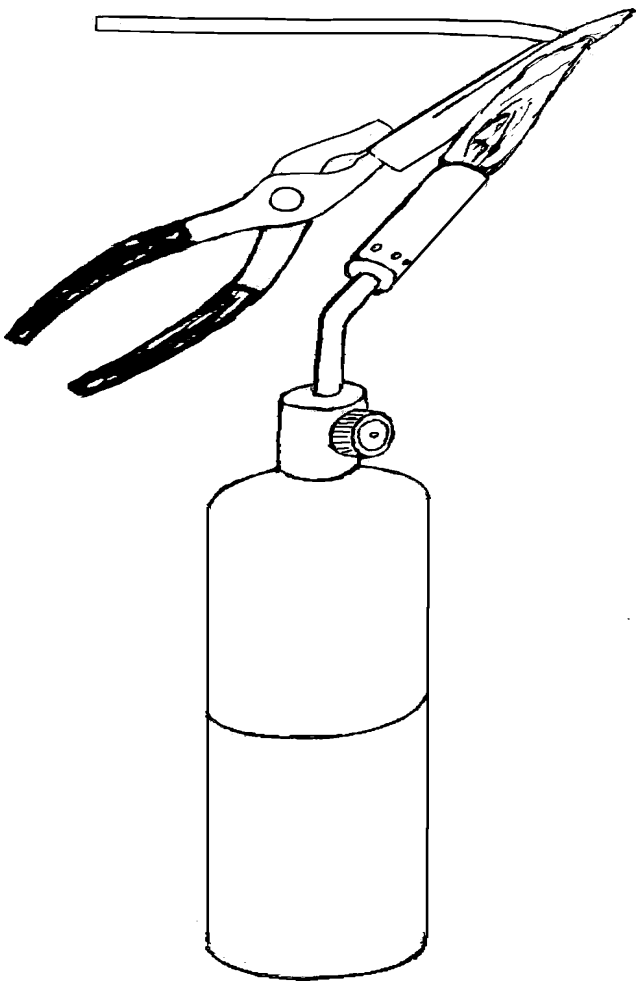

STEP 4: Cleanup the seam with steel-wool and a file. Make sure that there are no sharp edges to catch or cut the rope fibers when the fid is being used.

Making an Open Fid:

STEP 1: Enlarge the diagonal opening of the other piece of tubing by setting the tubing on end and forcing a rod into the opening. When the rod is forced into the opening, the cross section of the tubing should become "U" shaped.

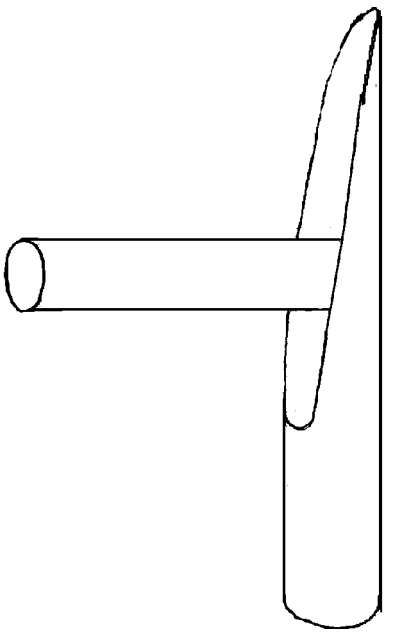

STEP 2: With a round file, enlarge the diagonal opening to the shape shown by the dotted line.

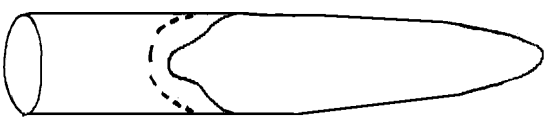

STEP 3: Smooth all rough and sharp edges with a file and steel-wool.

STEP 4: Gently tap the edges of the opening toward each other so that a cross section anywhere along its entire length will be "U" shaped.

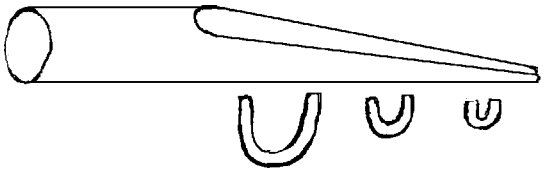

Making Handles For Fids:

STEP 1: Carve one end of a 1 inch diameter * 3 inch long piece of wood so that it will fit snugly into the end of the fid.

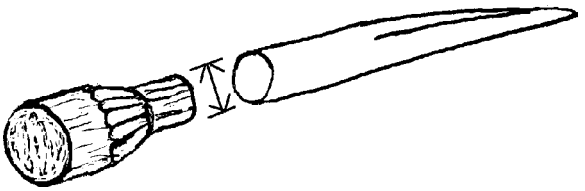

STEP 2: Attach handle to fid.

2A] Drill a small hole into the side of the fid about 1/2 inch from the end.

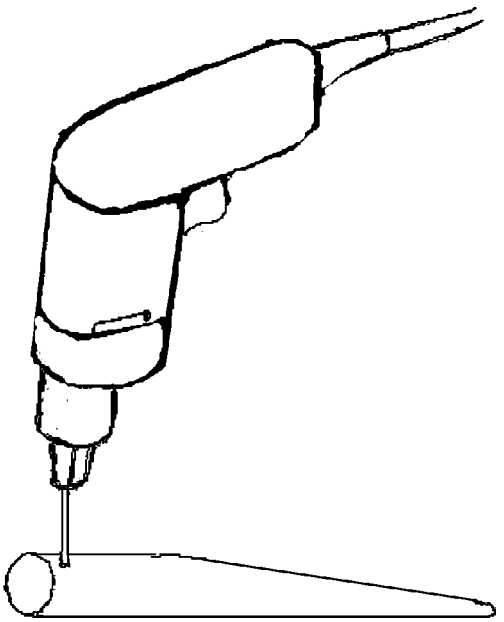

2B] Insert the handle into the end of the fid. Then drive a finishing nail through the hole into the wood of the handle.

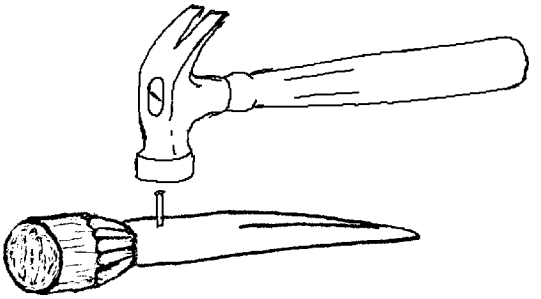

2C] Cut the nail off close to the side of the fid. Then file the nail down so that it is smooth and even with the surface.

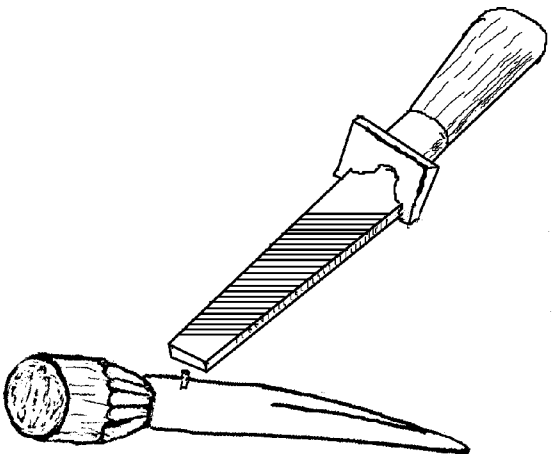

STEP 3: Finish the handle. Here is a chance to be creative. You can carve a simple rounded handle or let your imagination take over.

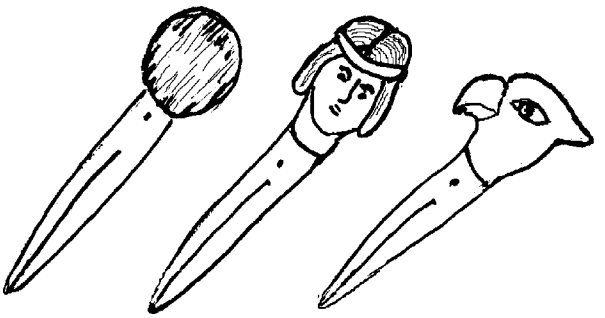

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JAPANESE SQUARE LASHINGS:

Comments —— The Japanese Square Lashings are a group of similar lashings that are all tied in a similar manner. The main difference is in the way each lashing is started.

The simplest and easiest form of the Japanese square lashing is tied by looping the center of the rope around the vertical spar and carrying the stands parallel to each other while taking the wrapping turns. The frapping turns are taken by separating the ends of the rope and taking them in opposite directions.

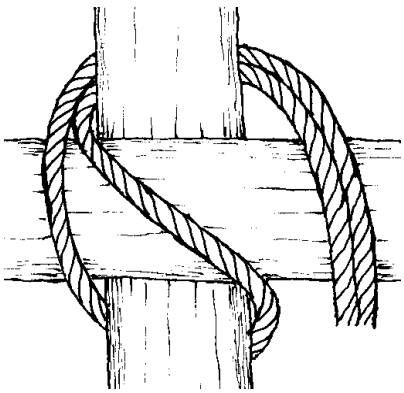

The MarkII Japanese Square Lashing is tied by looping the center of the rope of the upright spar and than forming the wrapping turns by taking the ends of the rope in opposite directions.

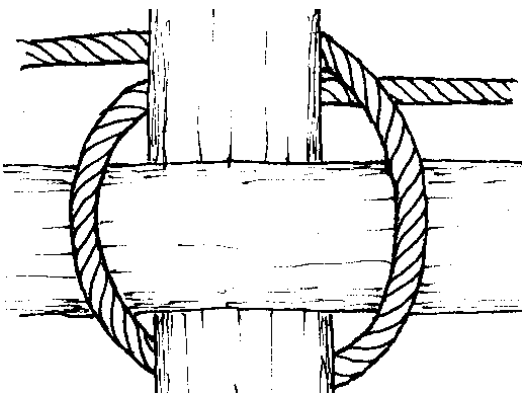

The Mark III is the same as the Mark II but a clove hitch is tied around the up right spar when starting the lashing.

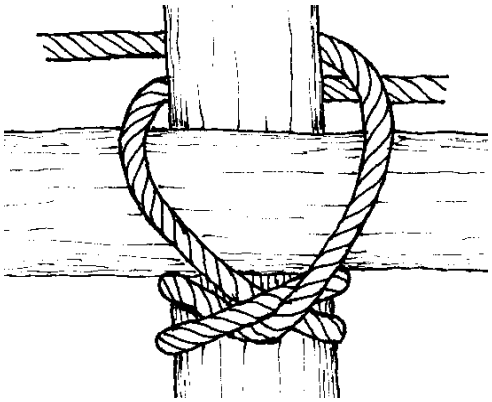

The Mark III is the most secure of the three Japanese square lashings because the clove hitch helps to prevent the lashing from shifting along the vertical spar.

Narration -----(For **Japanese square lash** knotboard.) **(1)** Start the lashing by looping the center of the rope around the vertical spar so that the loops under the horizontal spar. **(2)** Start the wrapping turns by leading the ends around the spars so that the two strands of the rope are parallel to each other. **(3)** When making the wrapping turns the two strands of the rope are lead around the spars at 90^0 to the spars; do not allow the strand to cross, be sure to keep the strands parallel. **(4)** Complete the wrapping turns by leading the rope strand around the vertical pole. **(5)** Start the frapping turns by separating the strands so that one strand is above the horizontal spar and the other strand is below the horizontal spar. **(6)** Lead the frapping strands in opposite directions. **(7)** Make two complete frapping turns; pull each turn tight as it is made; tie the first half knot of the ending square knot. (8) Tie the second half knot of the square knot to complete the lashing. **(9)** For safety add half hitches; The half hitches prevent the square knot from upsetting.

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JAPANESE SQUARE LASHING

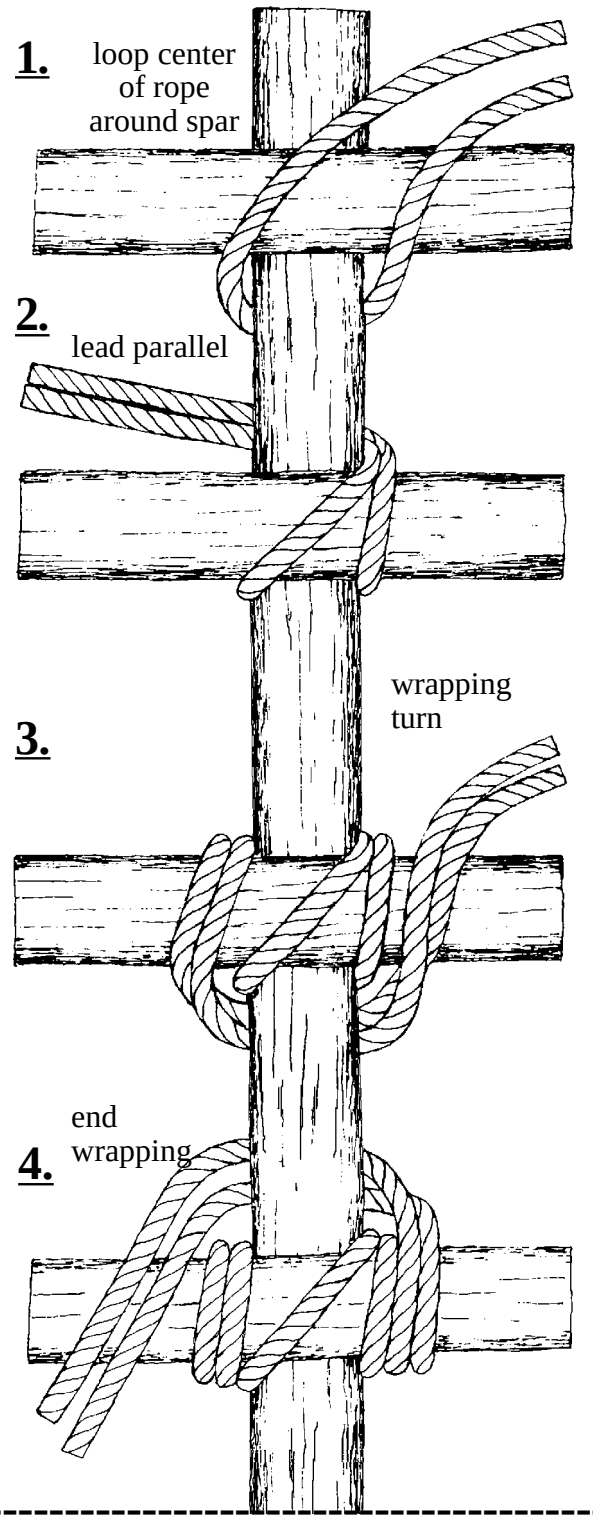

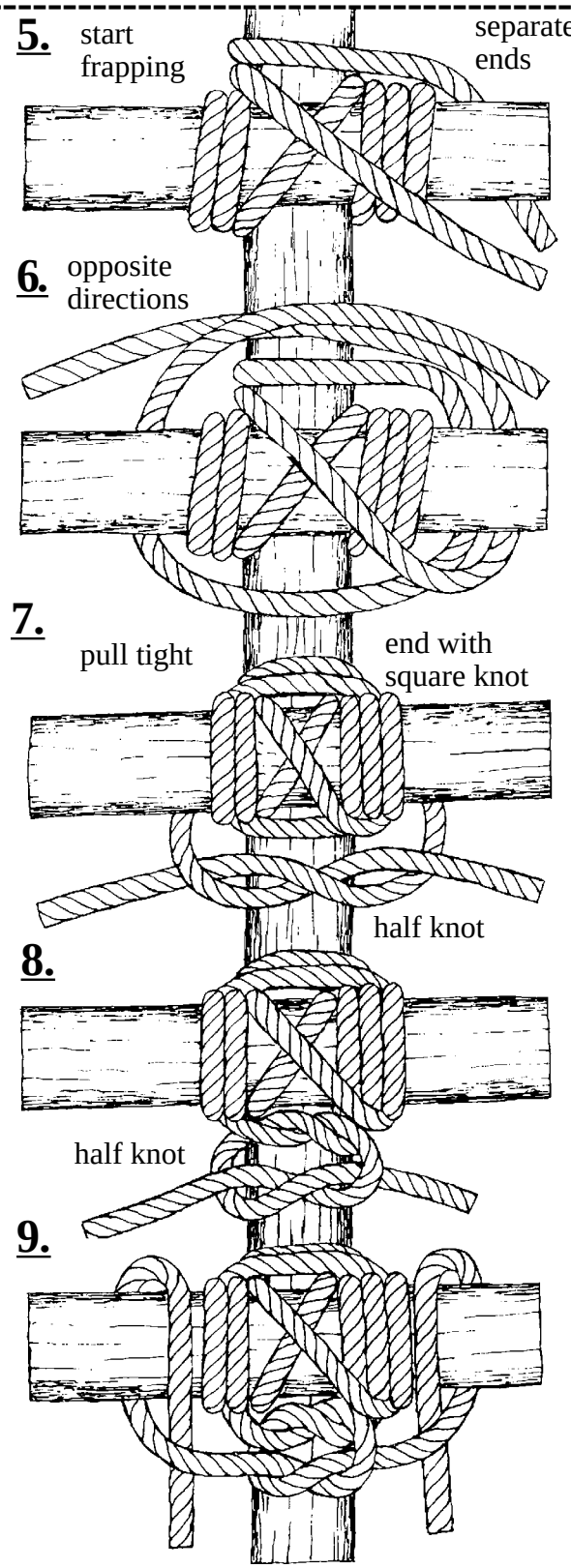

for safety add half hitches

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JAPANESE SQUARE LASHING MARK II

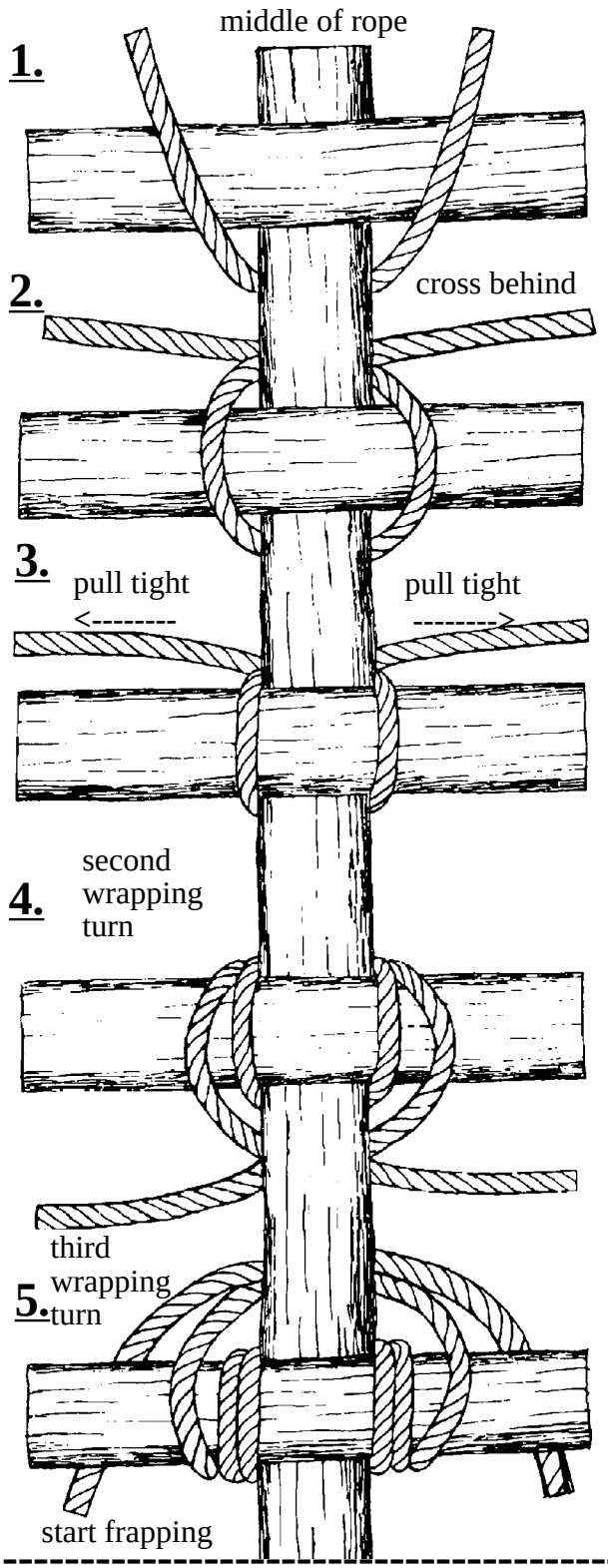

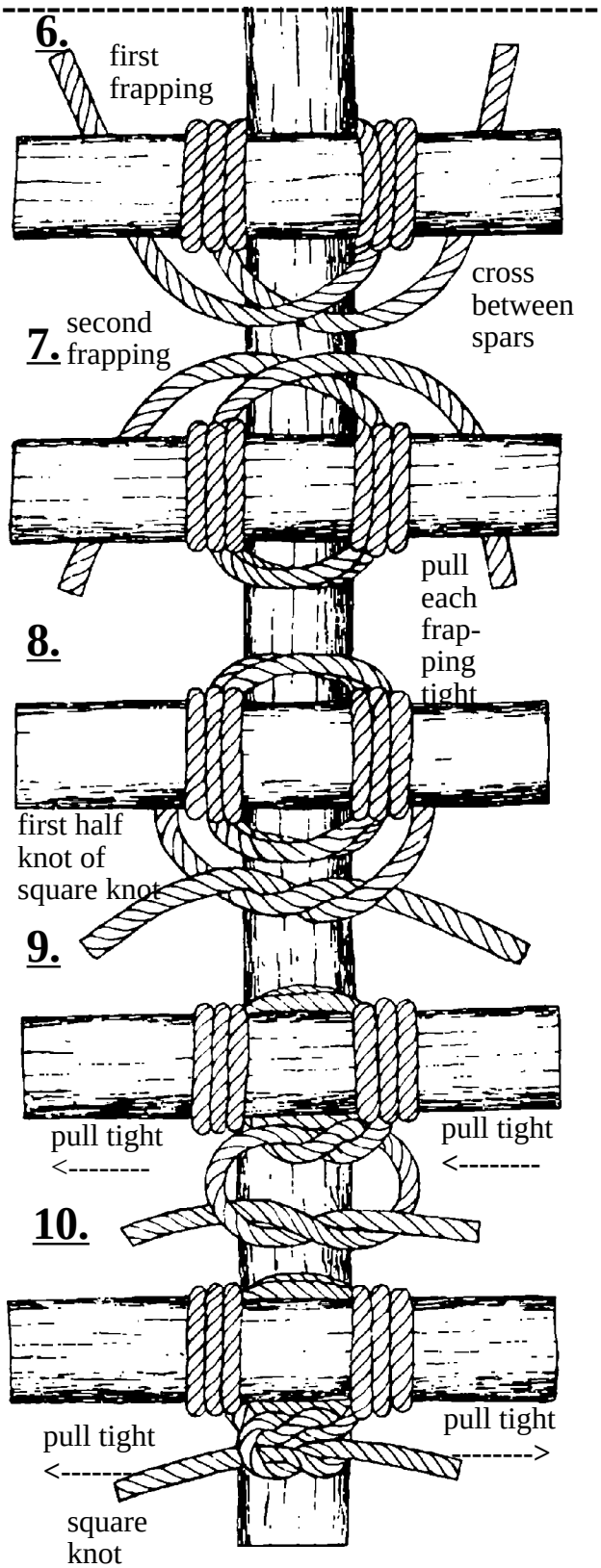

Narration ---(For **Japanese square lash, mark II** knotboard.) **(1)** Start the lashing by tying the center of the rope around the vertical spar with a clove hitch so that the clove hitch is under the horizontal spar. **(2)** Make the first wrapping turn by leading the ends up over the front of the horizontal spar and then in opposite directions behind the vertical spar. **(3)** Pull the strands tight but do not allow them to cross each other. **(4)** Add the second wrapping turn by leading the ends of the rope down over the front of the horizontal spar and then in opposite directions behind the vertical spar. **(5)** Complete the frapping turns by leading the ends of the rope up over the front of the horizontal spar and then in opposite directions behind the vertical spar. Position the strands of rope for starting the frapping tuns by leading them behind the horizontal spar. **[NOTE]** When pulled tight the strands will cross behind the vertical spar.

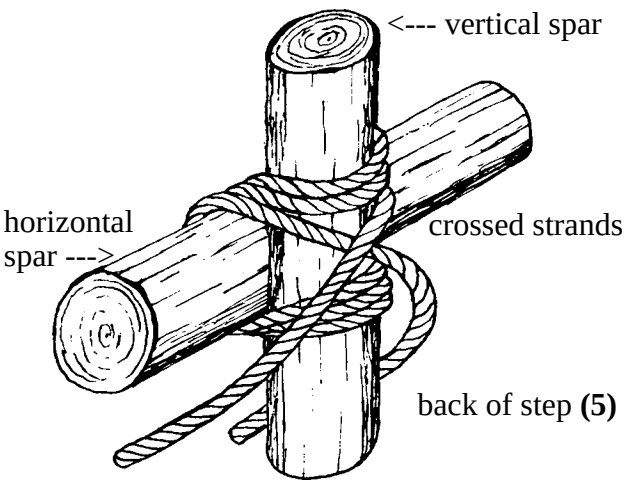

(6) Lead the frapping strands in opposite directions below and in front of the vertical spar and then behind the horizontal spar. **(7)** Make the second frapping turn by leading the ends above and in front of the vertical spar and then behind the horizontal spar; pull each turn tight as it is made. **(8) End** the second frapping turn by tying the firs half knot of the ending square knot. **(9)** Complete the ending square knot by adding a second half knot. **(10)** Pull the square knot tight **[NOTE]** For safety add half hitches around the horizontal spar to either side of the square knot; The half hitches prevent the square knot from upsetting.

MARLIN SPIKE HITCH:

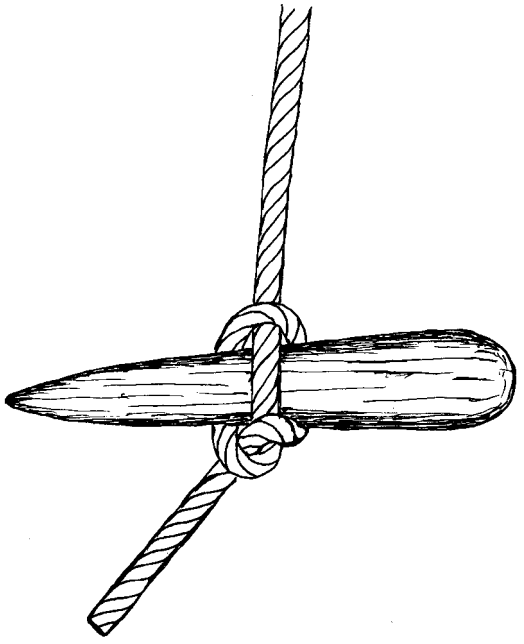

Description —— A loop formed by a half hitch around a bight in the standing part of the rope.

Use —— To temporarily hold a toggle (a Marlin Spike) so that a rope can be pulled tight; as a mooring hitch that can be dropped over the end of a stake or pole; to hold the rungs of a rope ladder.

Comments —— A secure temporary hitch that can be easily spilled by removing the toggle. The Marlin Spike Hitch gets it name from the practice of using it around a Marlin Spike or similar tool to tighten knots and servicing,

Other Names —— Slip Noose; especially when the half hitch is pulled closed around the bight.

Narrative ---- (For **marlin spike** knotboard) **(1)** Form an overhand loop. **(2)** Then form a bight in the standing part. **(3)** Place the bight under the overhand loop. **(4)** Then reeve the bight through the underhand loop. **(5)** Pass a toggle through the eye of the bight **(6)** and pull tight.

MARLIN SPIKE HITCH

1.

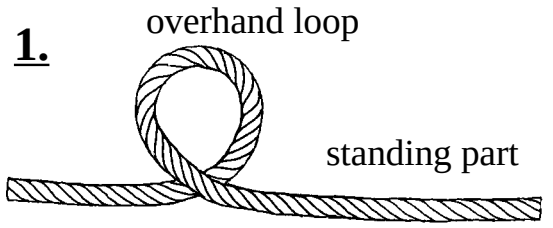

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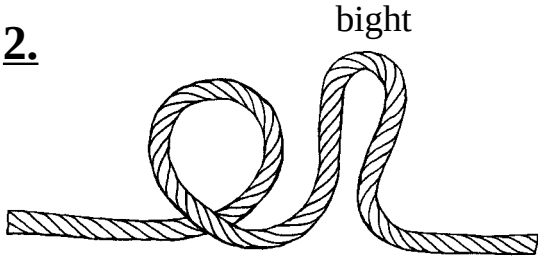

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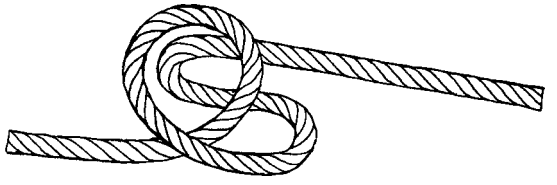

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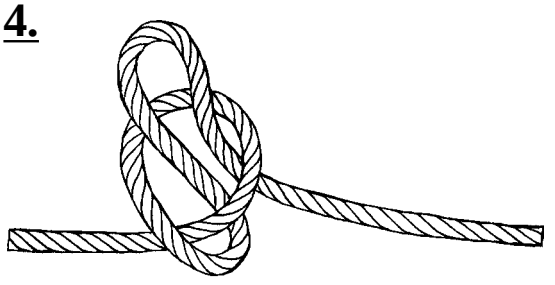

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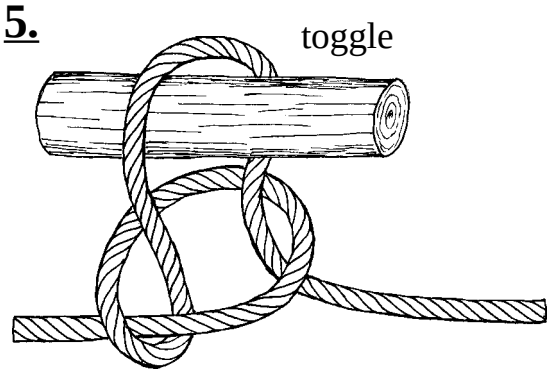

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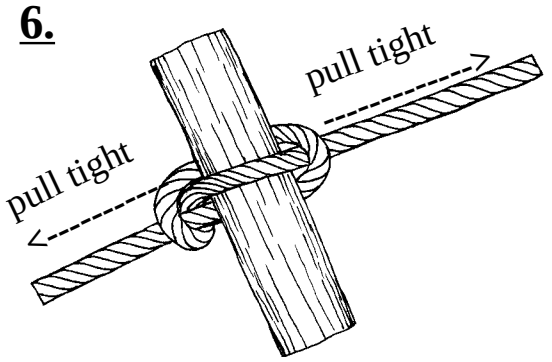

MARLIN SPIKE LADDER

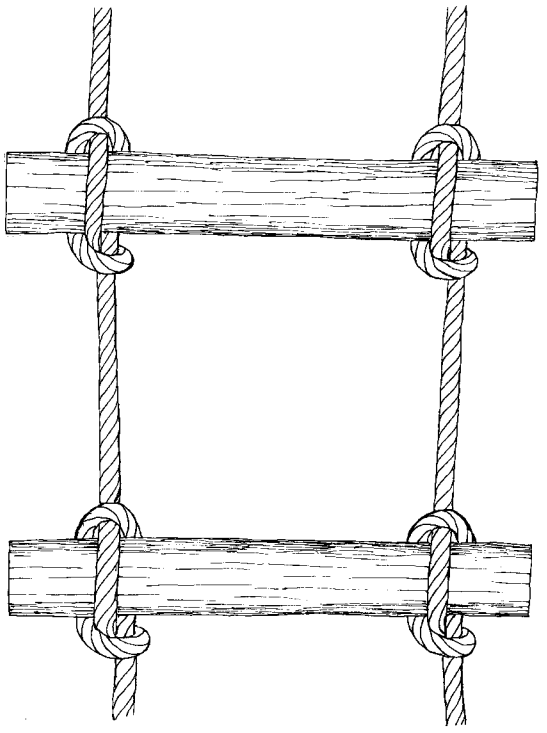

SLIP NOOSE:

Description ----- An overhand knot tied around its standing part.

Use ---- As a sliding loop for a snare; as a toggled stopper knot.

Comments ---- Related to the overhand knot. Often confused with the slip knot.

Narrative ---- Tie by folding an overhand loop over the standing part and pulling a bight of the standing part through the eye of the overhand loop. (See marlin spike hitch.)

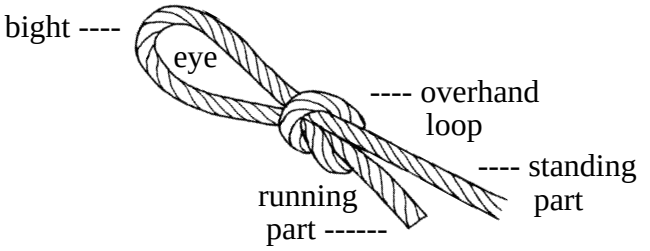

SLIP KNOT:

Description ----- An overhand knot tied around its running part.

Use ---- As a stopper knot.

Comments ---- Related to the overhand knot. Often confused with the slip noose.

Narrative ---- Tie by folding an overhand loop over the running part and pulling a bight of the running part through the eye of the overhand loop. (See marlin spike hitch.)

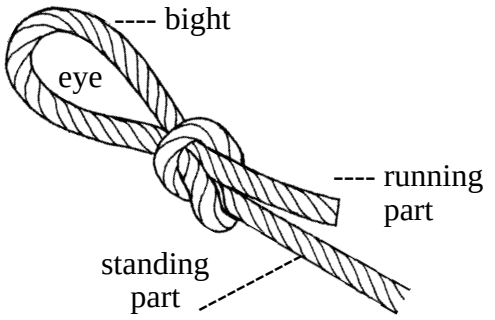

FOOTROPE KNOT

Description: a three strand knot that looks somewhat like a turk's head knot.
Comments: This knot was tied in the "footrope" (the rope that was tied under the yard arm for the sailors to stand on when they were setting the sails) to prevent the sailors' feet from slipping along the footrope.
Use: as a stopper knot in the end of a rope.

STEP 1: Unlay 4 to 5 turns of the lay.

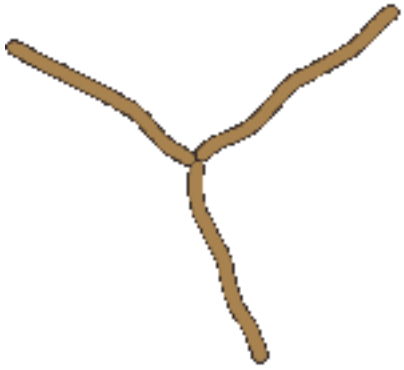

STEP 2: Tie a loose crown knot.

STEP 3:

STEP 4:

STEP 5:

STEP 6:

STEP 7: Tie a wall knot under the crown knot but tuck the strands up through the center of the crown knot.

STEP 8:

STEP 9:

STEP 10:

STEP 11:

STEP 12:

STEP 13: Work tight and finish by combing out the fibers to form a tassel of relay the strand and whip the end of the rope.

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CAMP STOOL:

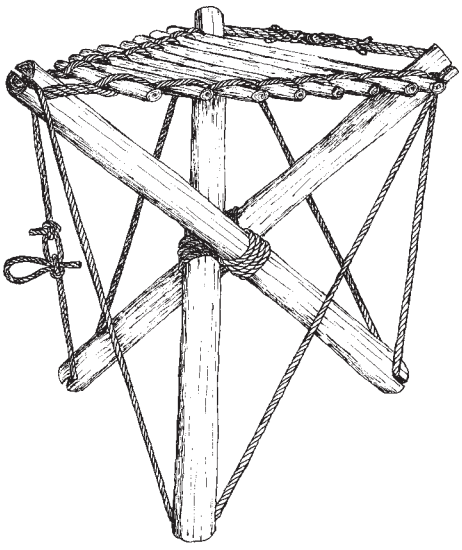

MATERIALS:

3 — 2 Foot * 2 inch poles
20 — 1/2 inch diameter sticks (various lengths)
1 — 3/8 inch * 5 foot rope
1 — 1/4 inch * 12 foot rope

CONSTRUCTION:

STEP 1: Cut a grove 1 inch deep and 3/8 inch wide in each end of the 2 foot poles. Be sure that the groves are in the same direction.

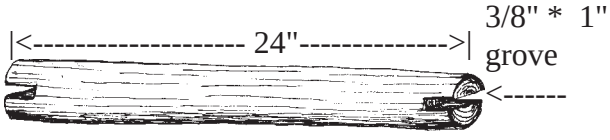

STEP 2: Lash the 2 foot pole together at their centers with the 1/4 inch * 12 foot rope. Use the **equal shear tripod lash** shown here.

2A] Tie a clove hitch around one of the poles; secure the end by wrapping it around the standing end.

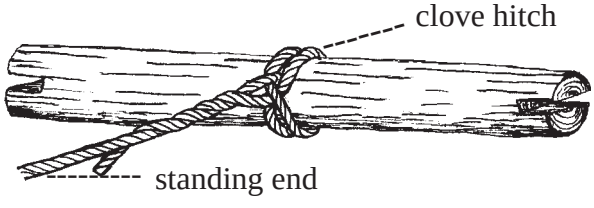

2B] Take 4 wraps around the 3 poles; follow the pattern shown for each wrap.

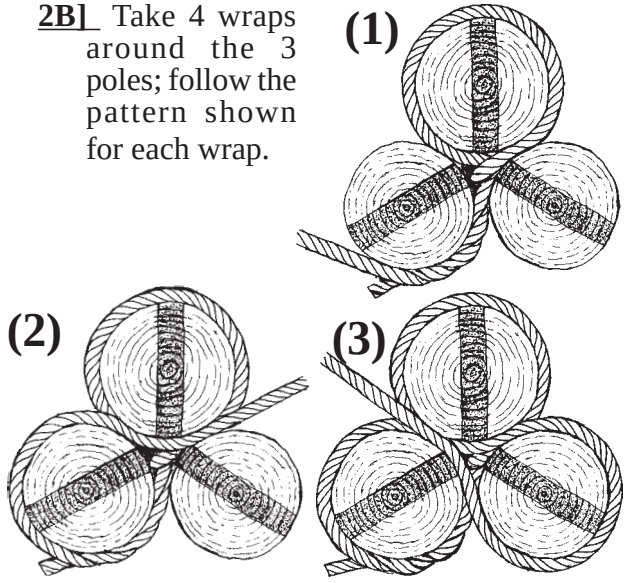

2C] Take 2 frapping turns behind each pole.

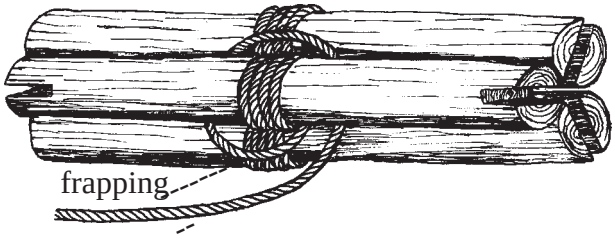

2D] End the lashing with a clove hitch around one of the poles.

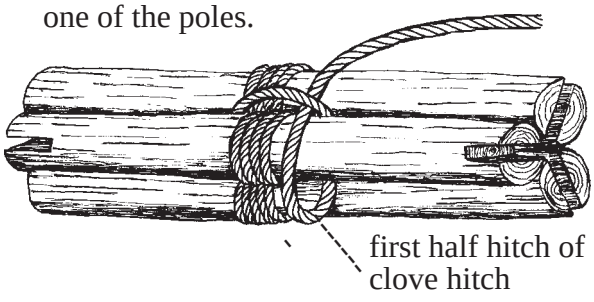

2E] Set the tripod up by rotating each leg.

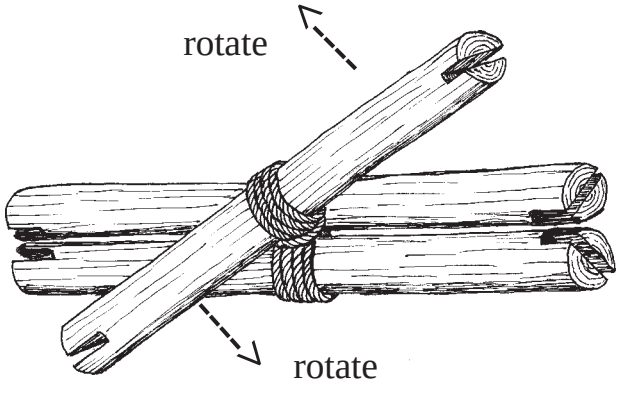

STEP 3: Prepare the seat support rope by marking the middle of the 3/8 inch * 5 foot rope by tying a piece of twine around it. Then form a loop that has a 42 inch circumference by temporarily tying the ends of the rope together.

STEP 4: Place the seat support rope in the groves at the top of the poles so that the middle of the rope is in one of the groves. Adjust the ends poles so that they are evenly spaced around the loop.

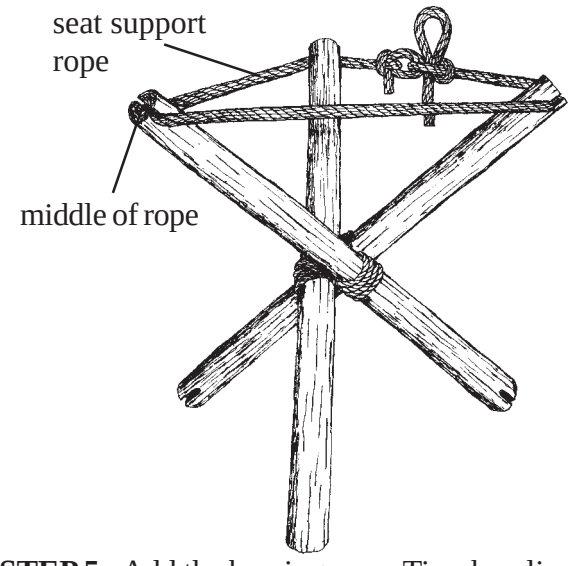

STEP 5: Add the bracing rope. Tie a bowline into one end of the 1/4 inch * 10 foot rope. Then weave the rope back and forth between the ends of the tripod poles; follow the pattern shown in the diagram. End by tying a slippery half hitch through the eye of the bowline.

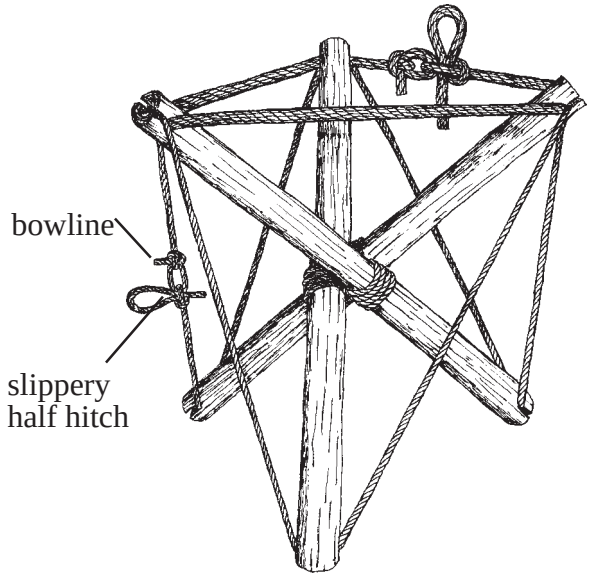

STEP 6: Assemble the seat.

6A] Lift one strand of the lay of the seat support rope on either side of the pole that is at the midpoint of the rope loop.

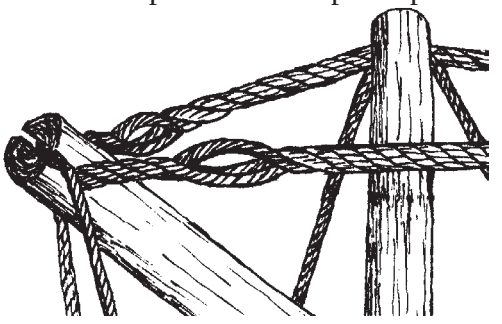

6B] Slide the ends of a 1/2 inch stick under the lifted strands of the seat support rope.

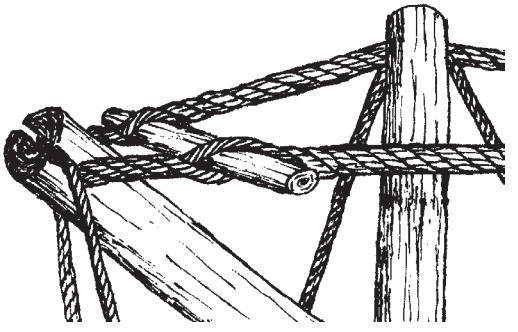

6C] Lift the next strand of the lay of the rope on either side of the pole that is at the midpoint of the seat support rope .

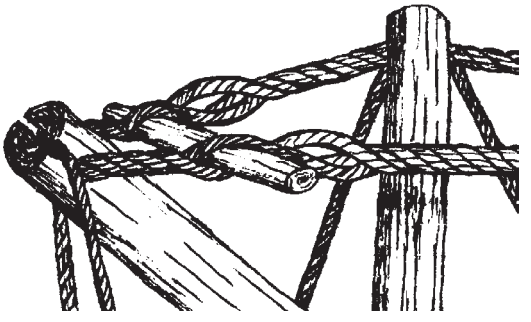

6C] Insert the next 1/2 inch stick**.**

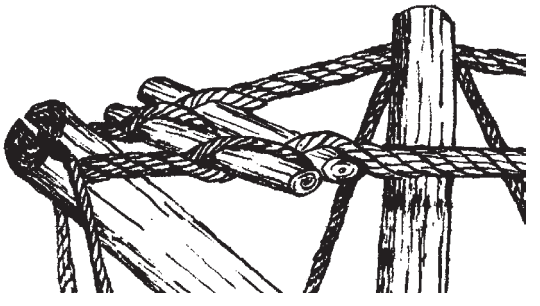

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[NOTE] To keep the ends of the tripod poles at a equal distance from each other as the seat is being constructed, the temporary knot that joins the two ends of the seat support rope will need to be retied several times.

6E] Continue in this manner until the seat is the desired size.

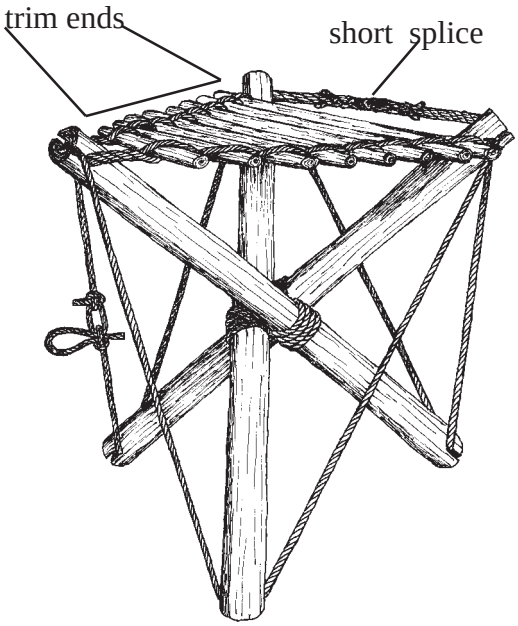

6F] Permanently join the 2 ends of the rope loop with a short splice.

6G] Trim the ends of the 1/2 inch sticks so that they extend about 2 1/2 inches beyond the rope.

[NOTE] By removing the 1/4 inch brace rope, this stool can be folded for transport and storage.

[NOTES]

MONKEY'S PAW: COIL STYLE

Narration ---- (For **monkey's paw coil stile** knot-board.) **(1)** Form the first coil by stacking three loop on top of each other. **(2)** Insert core into center of coil. **(3)** Start second coil by forming a small loop at the bottom of the first coil. **(4)** Pass the running end behind and **(5)** across the front to for the first loop of the second coil. **(6)** Add the second and third loops of the second coil. **(7)** Start the third coil by reeving the running end through the top of the first coil and **(8)** then reeve the running end through the bottom of the first coil. **(9)** Add the second and third loops of the third coil. **(10)** Work all coils tight over the core.

[NOTE] Join the two ends of the monkey's paw with an eye splice, a short splice, or a seizing.

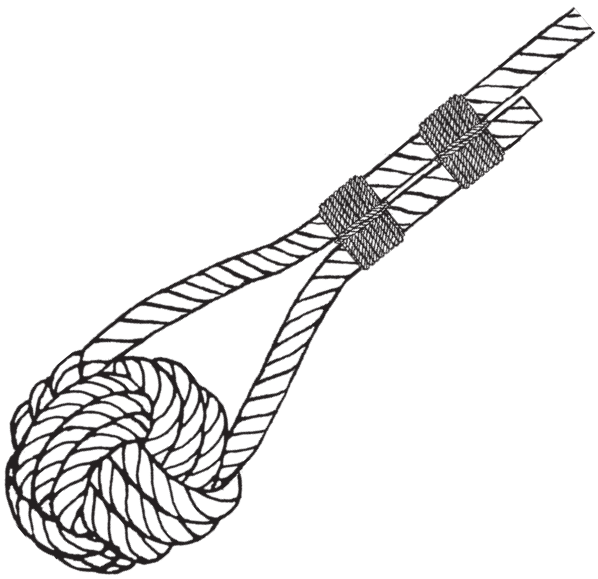

MONKEY'S PAW
(coil style)

1,

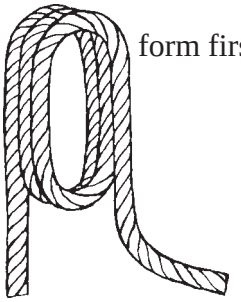

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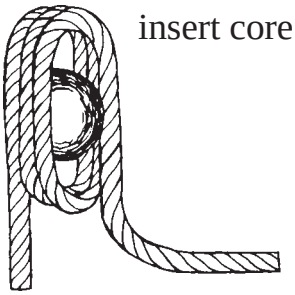

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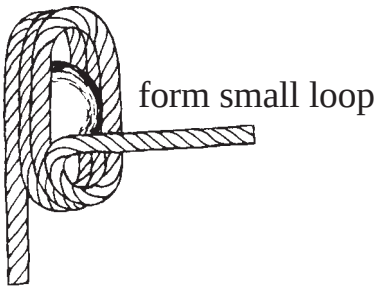

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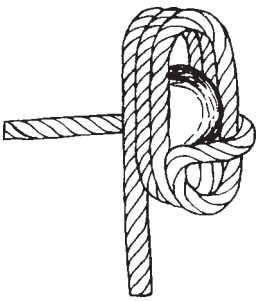

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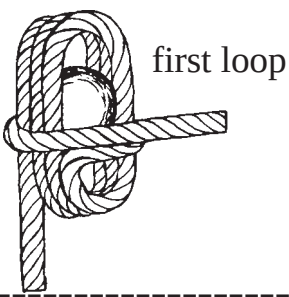

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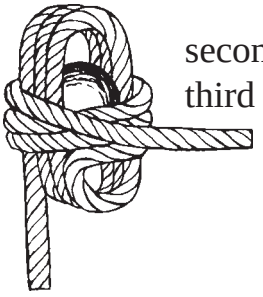

second and
third loops

7.

start third coil

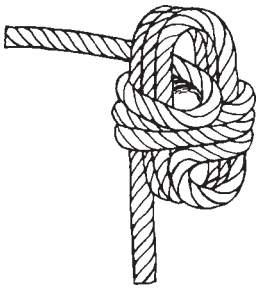

reeve through

8.

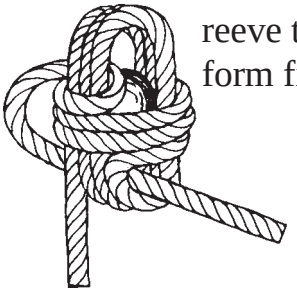

reeve through to
form first loop

9.

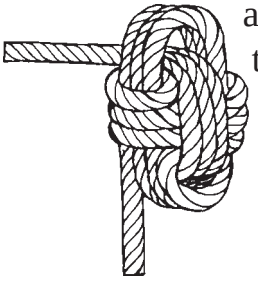

add second and
third loops

work tight over core

10.

[NOTES}\]

Flag Pole Cleat:

A cleat is a device used to temporarily secure a line. When valuable equipment such as boat is being tied off, a commercially made cleat should be used. However, when a rustic appearance is desired a temporary cleat can be made with rope and wood.

Green Stick Cleat:

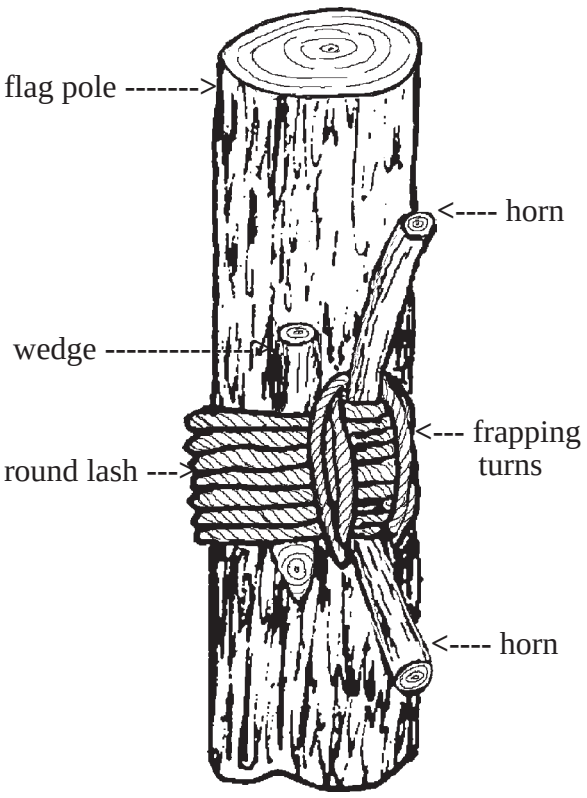

[Step 1] Round lash a piece of flexible green wood or a naturally curved piece of wood to the flag pole to make the horns of the cleat.

[Step 2] Tighten the round lashing by driving a small wedge on either side of the cleat.

[Step 3] Use frapping turns to raise the horns of the cleat.

Dry Wood Cleat:

Suggestion 1 ----

If only dry wood is available a cleat can be made as shown in the following diagrams:

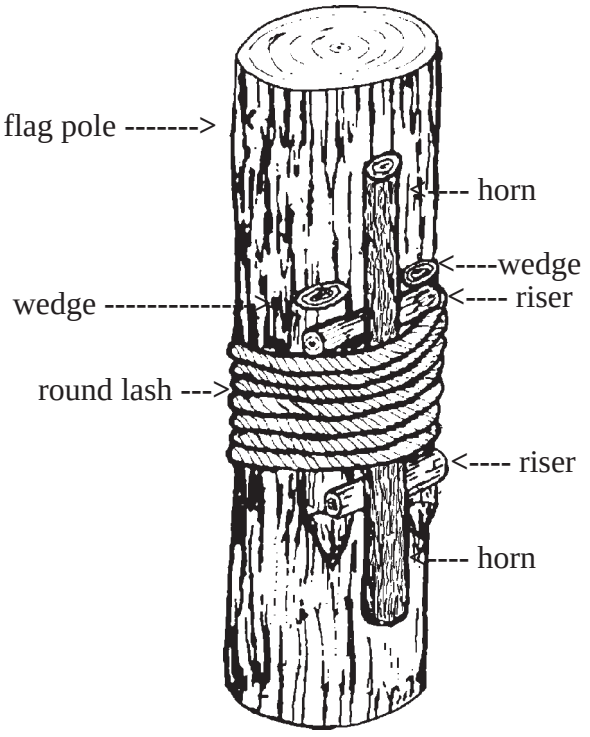

[Step 1] Round lash a stick of suitable size to the flag pole to make the horns of the cleat.

[Step 2] Raise the horns by forcing short risers under each horn.

[Step 3] If needed tighten the round lashing by driving a small wedge on either side of the cleat.

Suggestion 2 ----

Preshape the cleat from a piece of limb wood .

[Step 1] Split a 3 inch diameter by 8 inch piece of limb wood in half.

[Step 2] Use an ax and knife to shape the horns on either end of split piece of wood.

[Step 3] Round lash the cleat to the flag pole.

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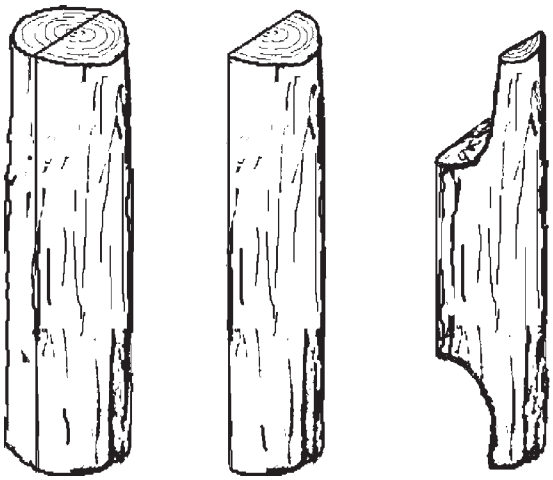

[Step 4] Tighten the round lashing by driving a small wedge on either side of the cleat.

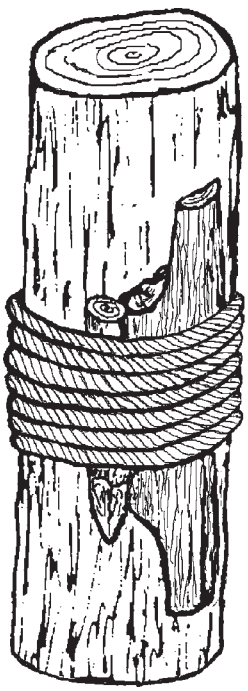

Precut Cleats:

A cleat can be made from hard wood lumber by sawing it to the desired shape and then round lashed to the flag pole. Small wedges are used on either side of the cleat to tighten the round lashing and to stabilize the cleat.

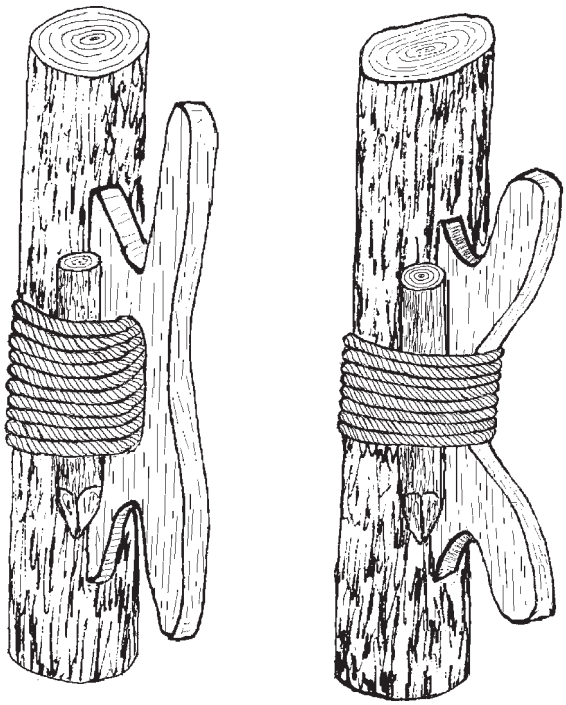

Making Wedges:

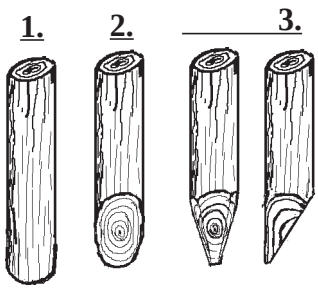

[Step 1] Cut to size. Length --- slightly longer than the width of the round lashing. Diameter --- slightly larger than the gap formed between the rope, the flag pole, and the cleat.

[Step 2] Cut one end off at an angle.

[Step 3] Taper the sides of the point so that the point of the wedge is on one side.

ROPE WRENCH:

A rope wrench is a simple tool that can be used to tighten the ropes of a lashing. Use a crochet stick that is about 18 inches long and 1 1/2 inches in diameter; the crotch should be about 6 inches from the end.

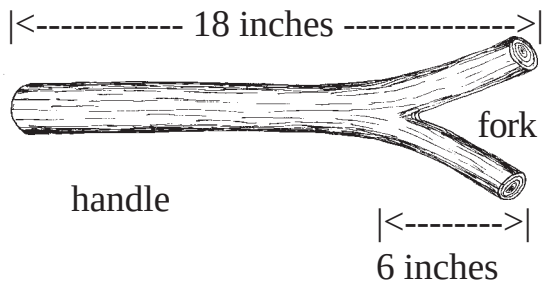

Using A Rope Wrench:

[STEP 1] Use the rope wrench by placing it over the pole next to the rope that is to be tightened.

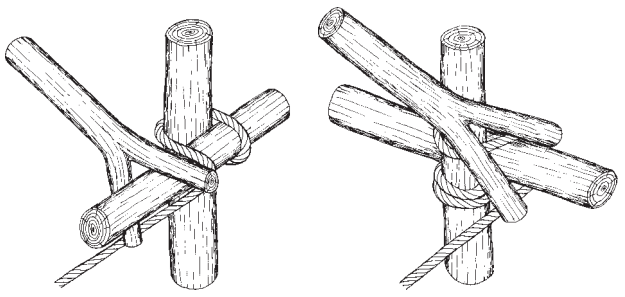

front view back view

[STEP 2] Wrap the rope around the fork of the wrench.

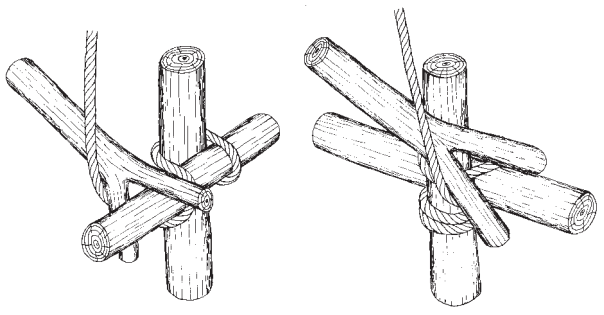

front view back view

STEP 3] Make one or two wraps around the handle of the wrench.

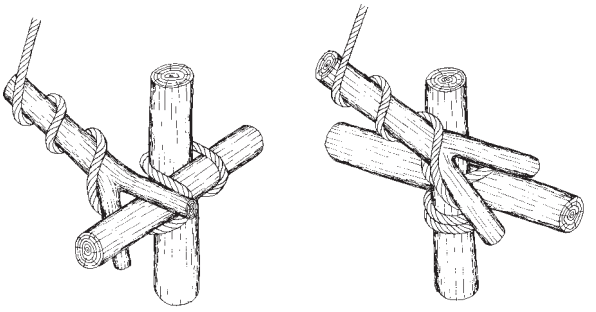

front view back view

[STEP 4] Grasp the handle so that you are holding the rope firmly to the handle; then rotate the wrench around the pole.

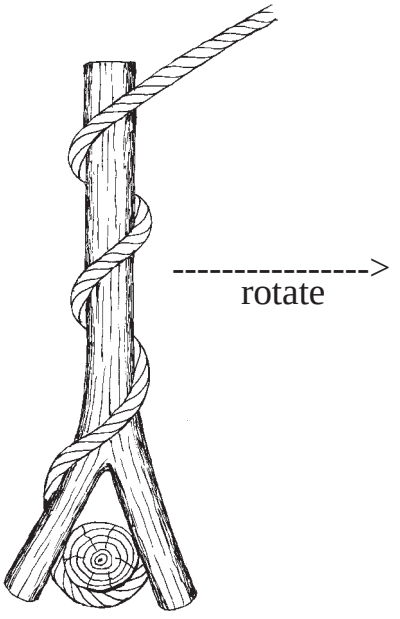

[NOTE] Tighten each turn of a lashing as it is made. The friction between the rope and the pole is too great to tighten more then one turn at a time.

Maintain the tightness of the rope by keeping a small amount of tension on it or by pressing the rope firmly against one of the poles while taking the next turn around the poles.

Be careful that the rope is not tightened so tight that the fibers of the rope begin to break.

NETTING:

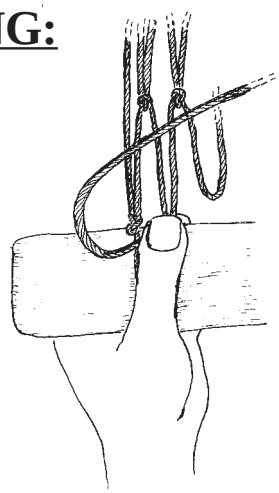

The making of netting is an ancient craft. Many prehistoric cultures used netting for a verity of uses, storage bags, fencing, hammock, just to name some and of course the obvious use as a fish net. No matter what the netting was used for, the knitting of the mesh was done by tying a series of loops in some type of twine.

In one method, the basic knot used was the sheet bend. To form and tie the loops a knitting shuttle and a spacer (gauge) were used.

NETTING TOOLS:

The size of the shuttle and gauge that is needed will depend on the project that you are working on. The size of the shuttle and gauge given in the following directions is a convenient size for many projects and is also a good size to use for practicing the craft of netting. Shuttles and gauges of different sizes can be made by changing the size of the materials used.

Knitting Shuttle:

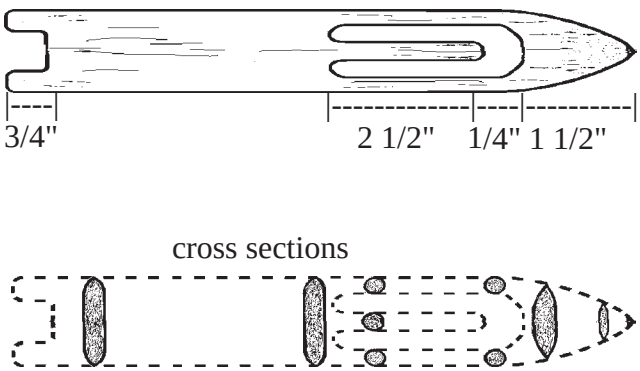

Make the knitting shuttle from a 1/4 inch * 1 inch * 12 inch piece of smooth grained hard wood. Carve and sand the shuttle to the shape shown in the diagram. Leave the shuttle unfinished; varnish or paint has a tendency to become sticky.

Knitting Gauge:

Make the knitting gauge from a 1/4 inch * 1 1/4 inch * 12 inch piece of smooth grained hard wood. Carve and sand the gauge to the shape shown in the diagram. Leave the gauge unfinished; varnish or paint has a tendency to become sticky.

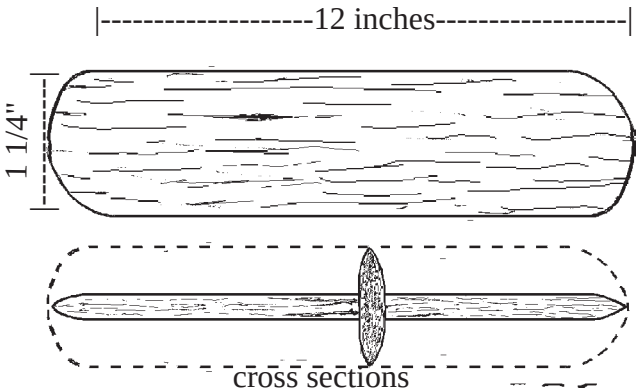

Filling The Knitting Shuttle:

STEP 1: Fill the shuttle with twine. Start by tying a single hitch around the tongue of the shuttle and then pass the twine through the notch.

STEP 2: Turn the shuttle over, loop the twine around the tongue and then through the notch.

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STEP 3: Continue turning the shuttle from side and looping the twine around the tongue until the shuttle is filled.

[NOTE] To prevent synthetic twine from fraying, use a candle flame to cut and fuse the ends.

[WARNING] Using a butane cigarette lighter to cut or fuse synthetic rope or twine may cause the lighter to over heat and explode.

DIAMOND MESH NETTING:

Diamond mesh netting is the easiest of the two forms of mesh to make. Square mesh netting will be dealt with latter.

Casting On: To start diamond mesh netting the first row of mesh loops is cast on to a loop of some kind. The kind of loop used depends on the project; a ring, grommet, frame or loop of twine may be used. The following directions are for casting on to a ring but the same steps may be used for any starting loop.

STEP 1: Tie the end of the twine to the ring with a clove hitch stopped with two half hitches.

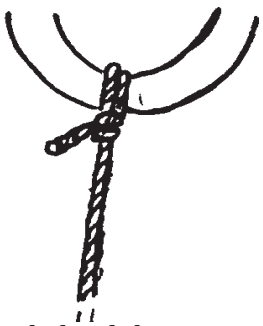

STEP 2: Place the twine behind the gauge then bring the twine in front of the gauge and to the right.

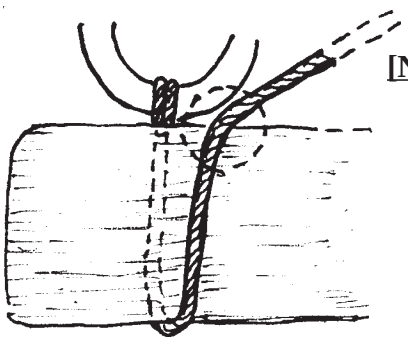

[NOTE]: The dotted circles in each of the diagrams is used to show the position of the thumb and finger of the left hand.

STEP 3: Reeve the twine through the ring from the front to the back so that an overhand loop is formed.

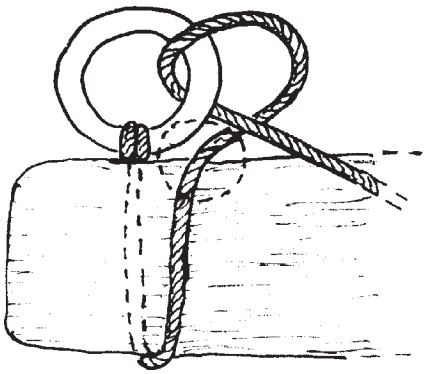

STEP 4: Pull the twine to the left to tighten the twine around the ring and the gauge.

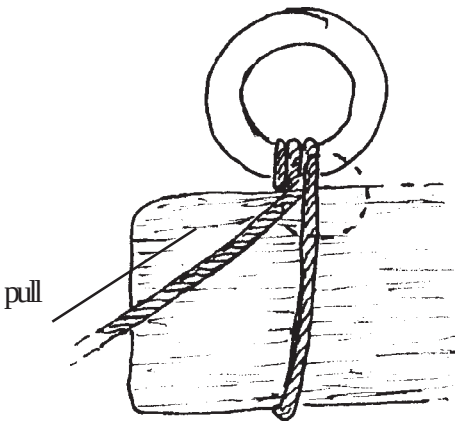

STEP 5: Lay the twine across the ring from left to right.

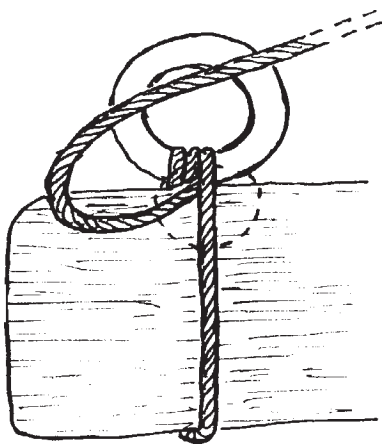

STEP 6: Reeve the twine through the ring from the back to the front.

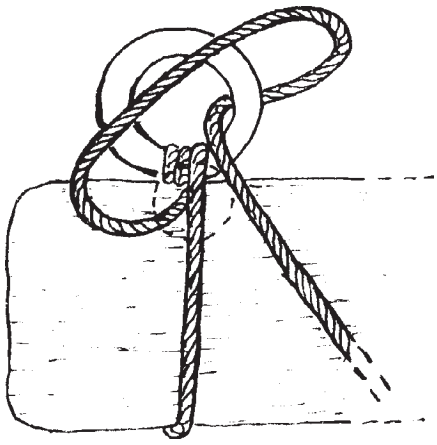

STEP 7: Place the twine behind the gauge; then pull the twine downward to tighten the twine around the ring. This forms a lark's head knot around the ring.

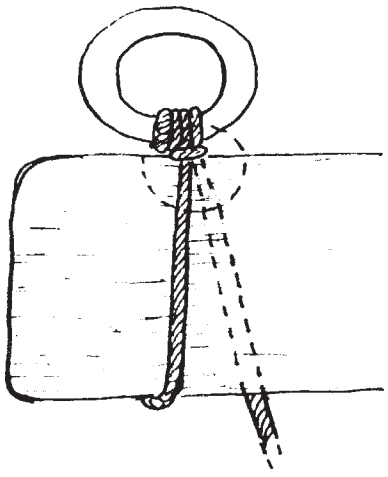

STEP 8: Repeat steps 2 through 7 for each additional loop required for the project.

KNITTING A ROW OF MESH:

Netting is made by knitting roes of mesh using a shuttle and a gauge. The gauge is used to determine the size of the mesh, and the shuttle is used to hold the twine and form and tie the mesh loops. The basic knot used in netting is the sheet bend. The following diagrams illustrate the tying of the sheet bend as it is used for knitting a net.

STEP 1: Bring the twine down and up the back of the gauge. Then pick up the next loop by passing the shuttle through the loop from front to back.

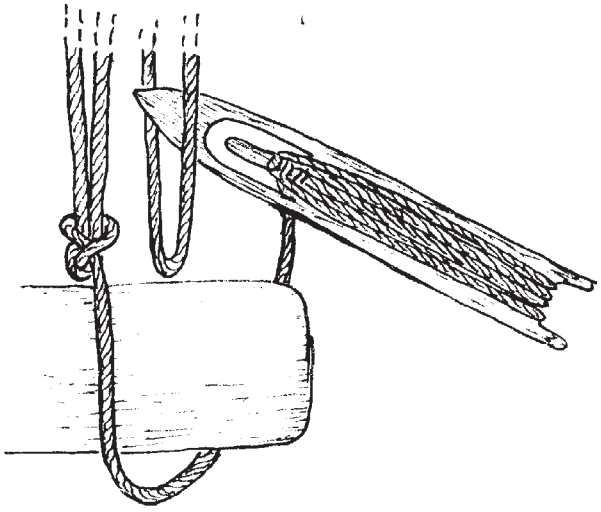

STEP 2: Pull the twine to the left to tighten the twine around the gauge. Use the thumb and finger of the left hand to hold the twine in place.

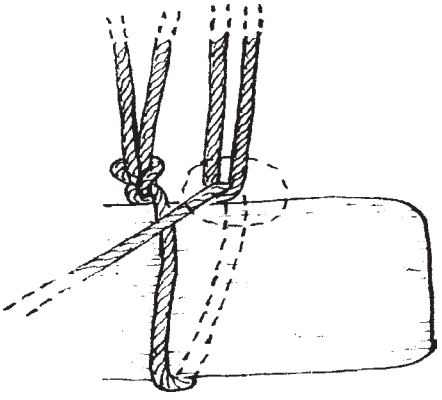

STEP 3: Lay a loop of twine over the loop just picked up.

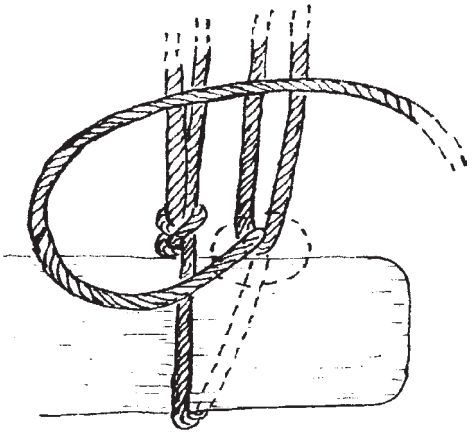

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STEP 4: Pass the shuttle in back of the picked up loop and the through the loop that was laid on top.

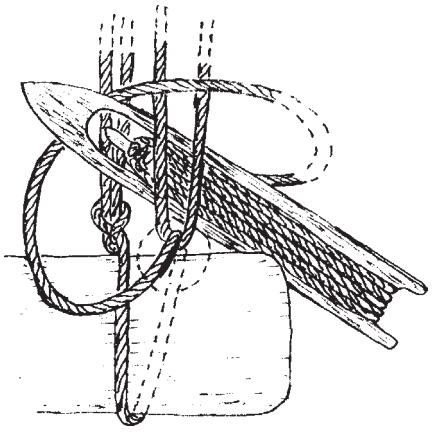

STEP 5: Pull the twine downward and slightly to the right to tighten the knot.

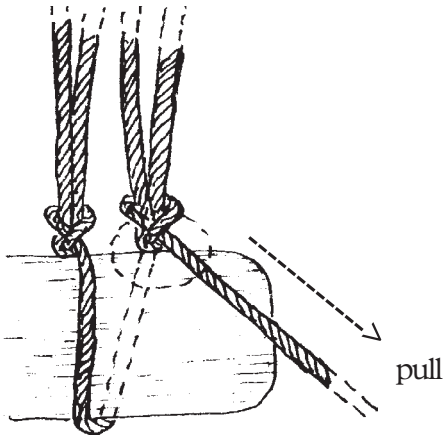

STEP 6: Repeat steps 1 through 5 for each loop in the row.

STARTING A NEW ROW:

STEP 1: When the end of a row of mesh is reached, slide the accumulated loops off the gauge, turn the work piece over so that the running end of the twine is on the left side of the work piece.

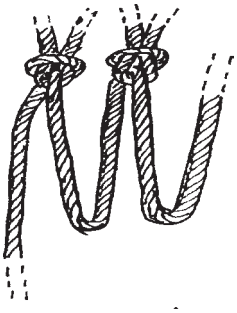

STEP 2: Wrap the twine around the gauge from front to back; pick up the first loop by passing the shuttle through the loop from back to front.

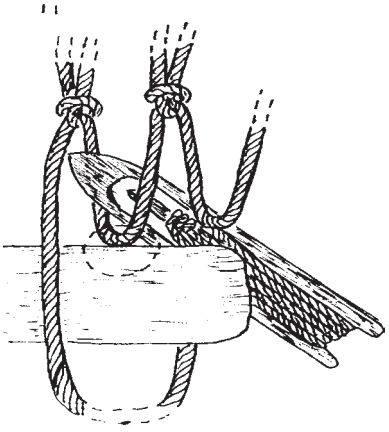

STEP 3: Knit the loop in place by following the directions for knitting a row of mesh.

ADDING A LOOP:

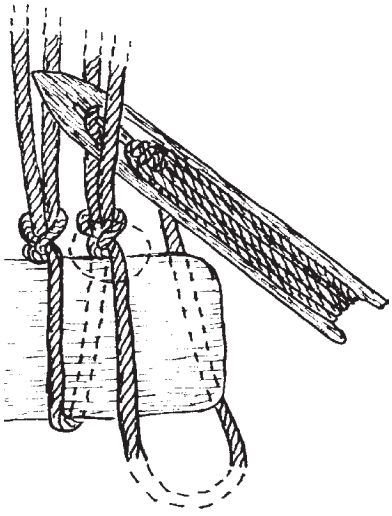

For some projects it is necessary to increase the width of the netting part way through the project. The width of the netting is increased by adding loops of mesh.

A loop is added by picking up the same loop a second time so that two loops are formed in the new row of mesh are tied to the same loop in the previous row of mesh.

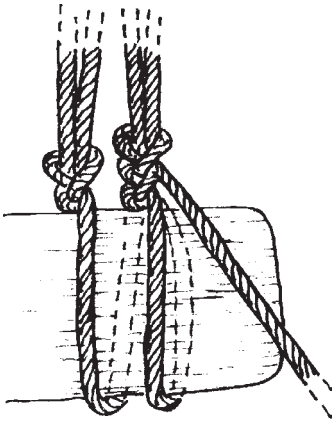

PROLONG KNOT

DESCRIPTION:

A flat knot that is made by interweaving two strands of rope.

USE:

As stair tread, mat, or chafing gear; also as a decorative knot in a two strand lanyard.

COMMENTS:

The prolong knot gets its name from the fact that it can be extended to any length.

TYING:

STEP 1:

Place the center of the rope over a peg or hook and tie a loose half knot.

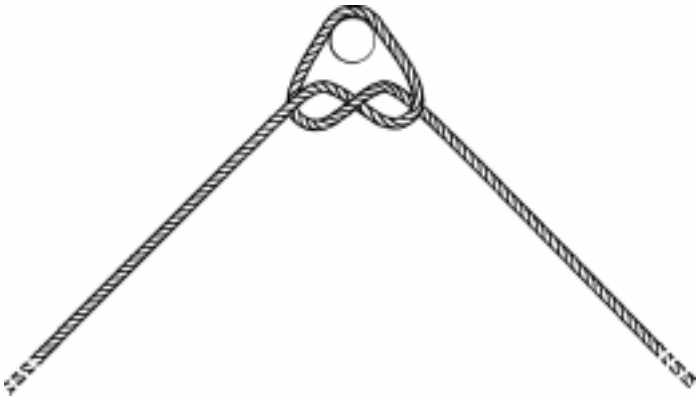

STEP 2:

Extend the half knot as shown.

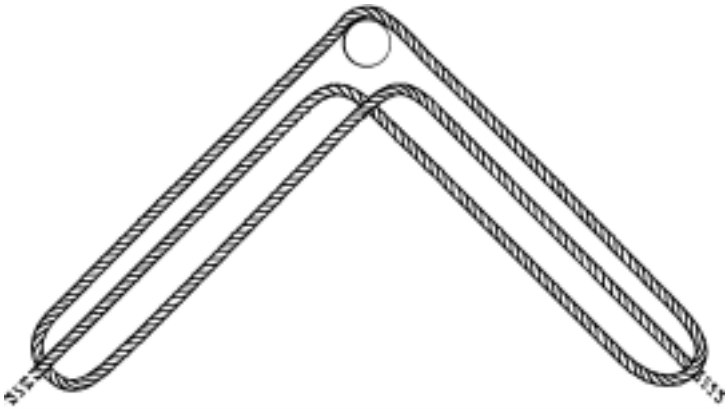

STEP 3:

Twist the left loop and extend it to the right side.

[NOTE] This will start the over under pattern of the weaving.

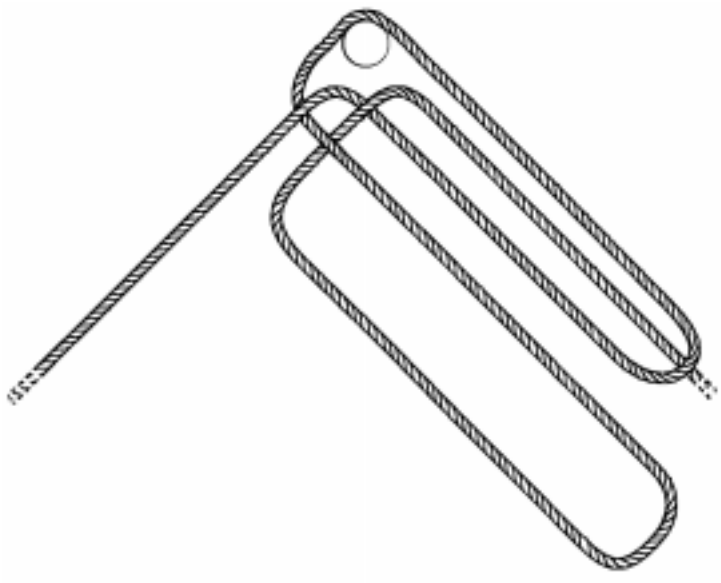

STEP 4:
Twist the right loop and extend it to the left side so that it is over the first extended loop.

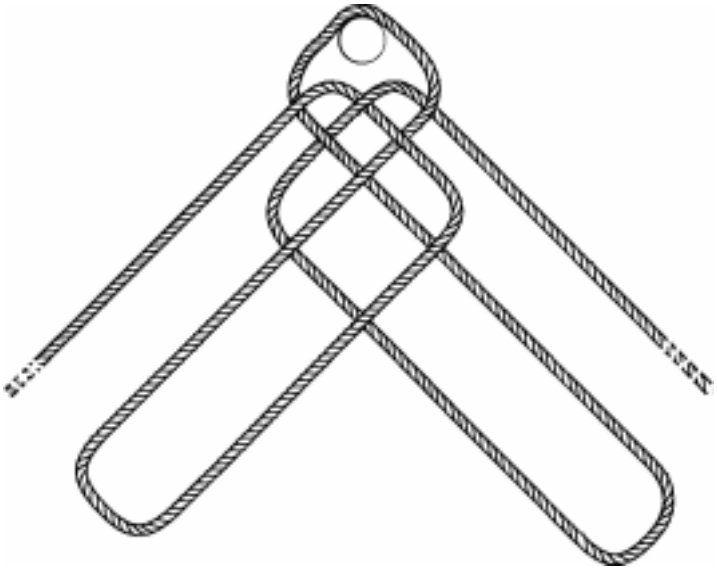

STEP 5:
Weave the left strand to the right in the pattern shown.

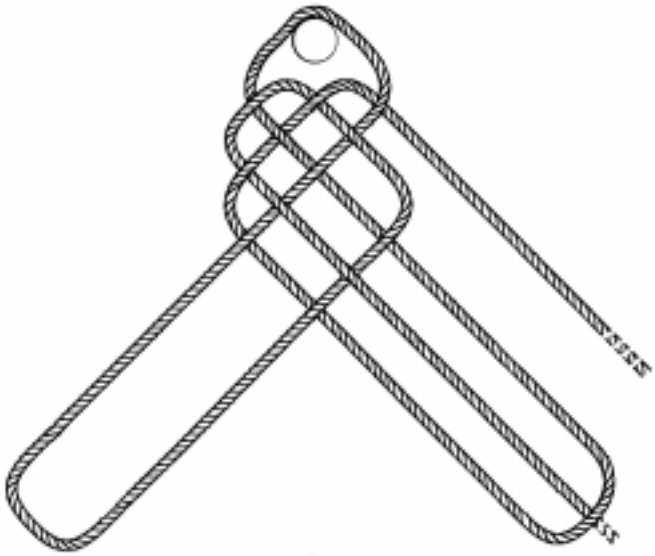

STEP 6:
Weave the right strand to the left in the pattern shown.

[NOTE] This completes the four bight prolong knot. At this stage it may be ended and worked firm (over tightening distorts the knot) or the strands my be doubbled as shown in later diagrams.

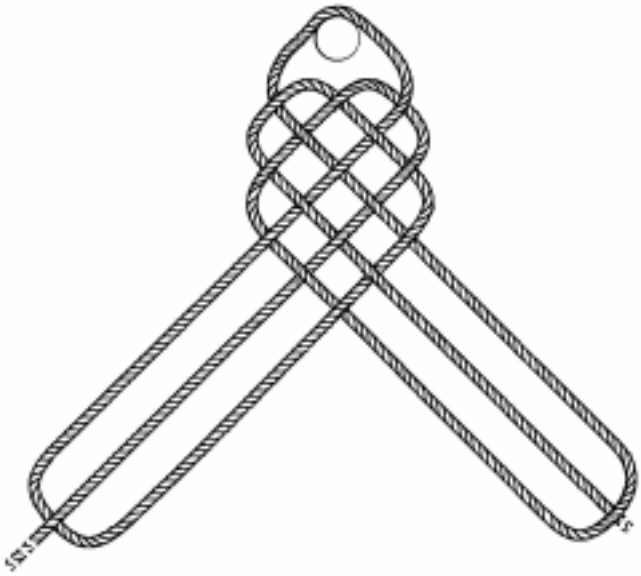

STEP 7:
Twist the left loop and extend it to the right side.

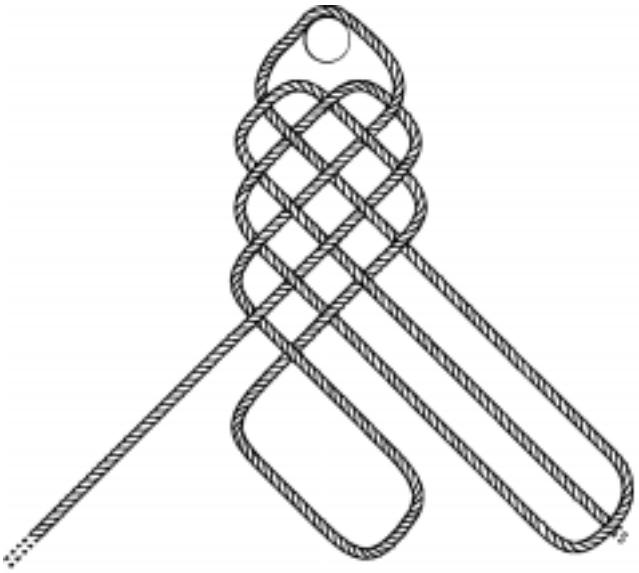

STEP 8:
Twist the right loop and extend it to the left side so that it is over the first extended loop.

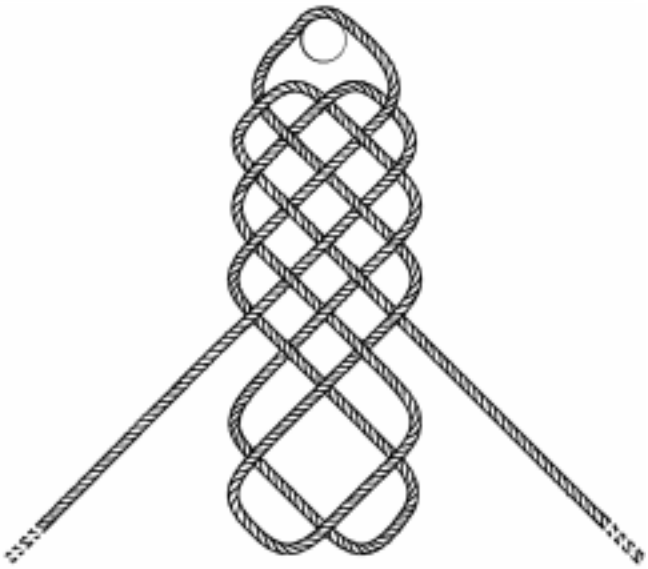

STEP 9:
Weave the right strand to the left in the pattern shown.

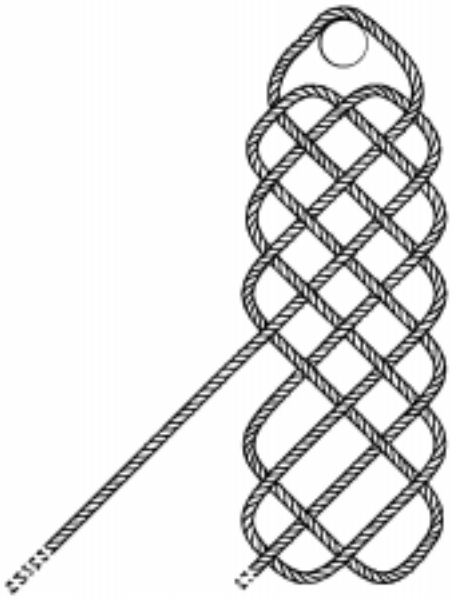

STEP 10:

Weave the left strand to the right in the pattern shown. This completes the 7 bight form of the prolong knot.

[NOTE] The prolong knot can be extended three bights at a time by repeating steps 7 through 10 for each extension.

STEP 11:

Start doubling the strands by chacing (following) the opposite strand.

STEP 12:

Complete doubling the strands. Then work the knot into a firm mat . Do not over tighten the strands as this will distort the mat.

[NOTE] The ends of the strands can be hidden by sewing them to the adjacent strand on the underside of the mat.

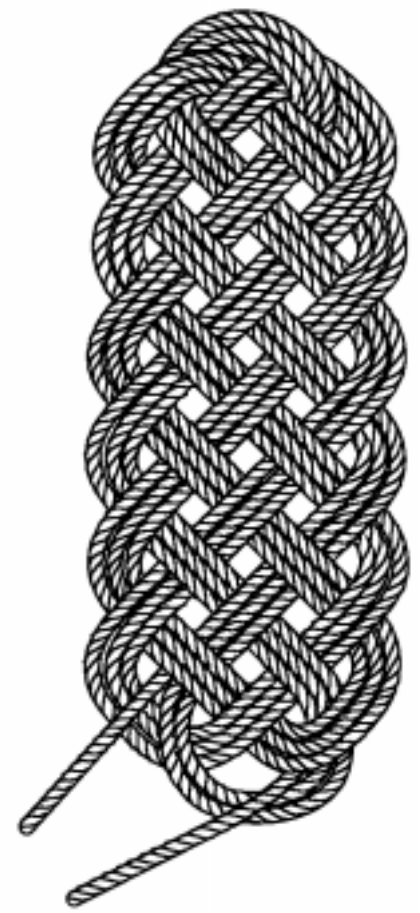

LIFE BASKET:

Description ---- A body harness made by combining a bowline on a bight and a french bowline.

Use ---- To lower a severally injured person when a life threatening situation exists.

Comments ---- The life basket is a secure harness that can be used to move an injured person that is weakened or unconscious. However, unless there is a life threatening situation, such as a burning building or immediate danger of avalanche, you should wait for a trained rescue team.

If you attempt to use the life basket, do not allow the rope to slide through your hands as you lower the injured person . The friction caused by the sliding rope can cause severe painful rope burns and loss of control of the rope. The rope must be let out in a hand over hand manner to insure a safe, controlled descent.

1.

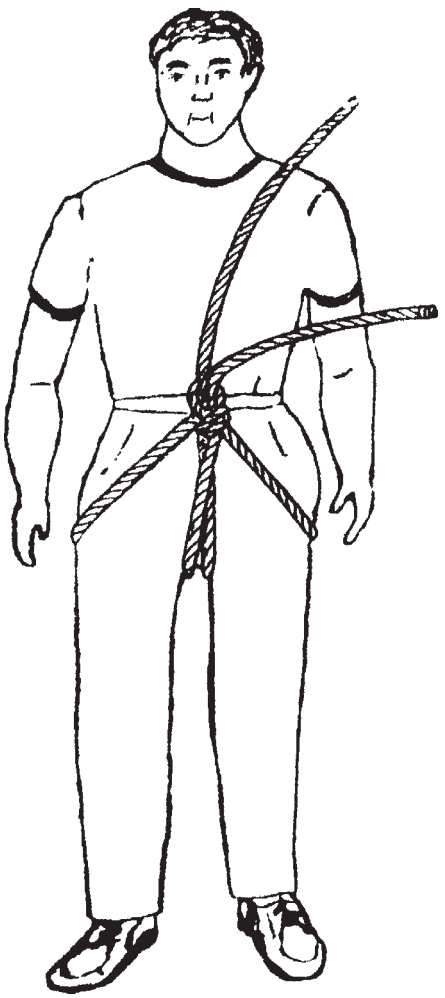

Narration ---- (1) Tie a bowline on a bight. Place one loop of the bowline on a bight around each leg. [NOTE] (The bowline on a bight should be large enough so that when it is in place the knot should be close to the victims belt buckle. Be sure to leave the running part of the rope extending about 3 feet beyond the knot.)

2.

(2) Take a half hitch around the victims chest.

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(3) Form a bight in the standing part by pulling it under the right hand part of the half hitch so that an underhand loop is formed around the cross point of the half hitch.

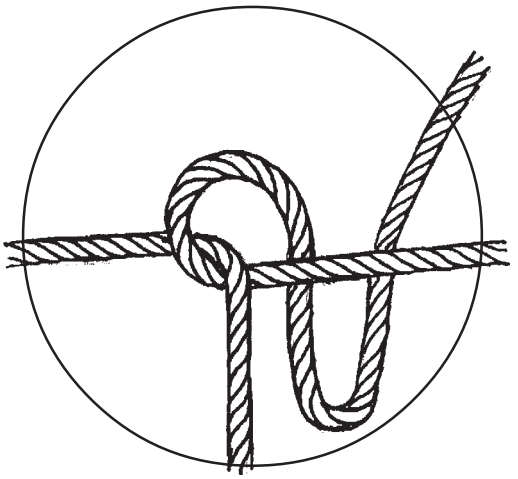

(4) Fold the bight around and reeve it through the eye of the underhand loop.

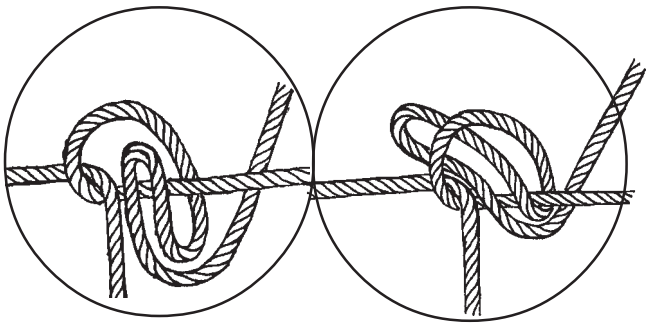

(5) Reeve the running part of the rope through the bight.

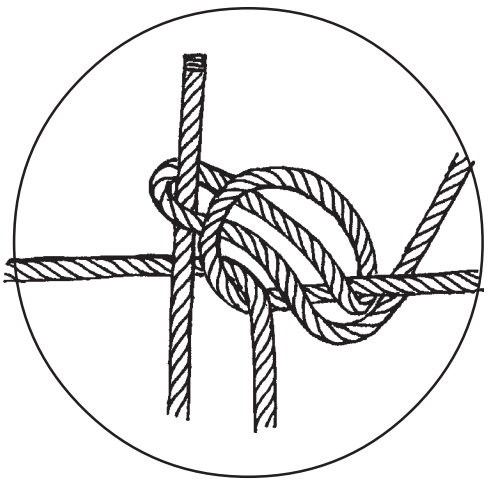

(6) Take the slack out of the running part of the rope and fold the it over to form interlocking bights.

(7) Pull on the standing part so that the bight in the running part of the rope is pulled through the eye of the underhand loop and the underhand loop flips over and tightens around the bight to form a French Bowline.

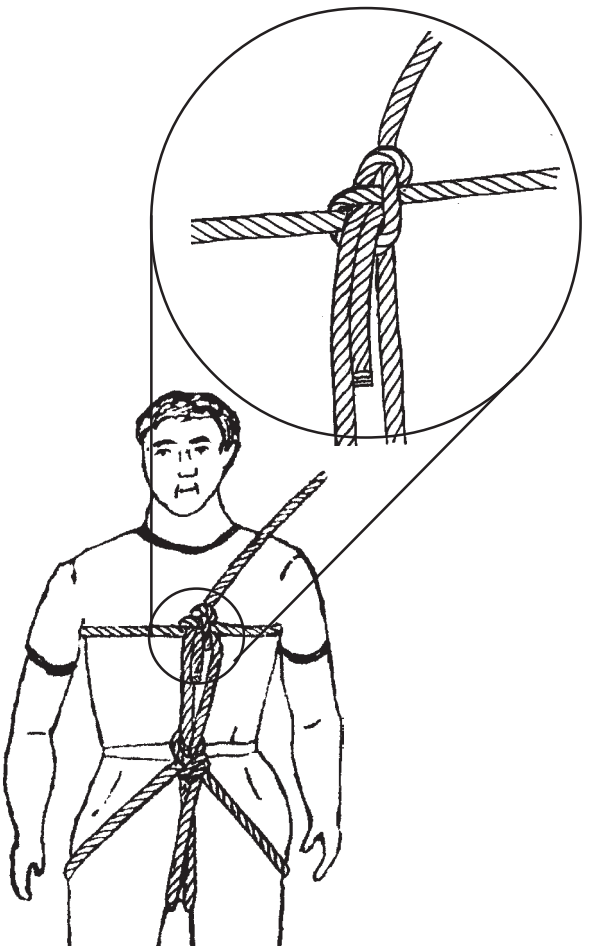

SPHERICAL KNOB COVERING

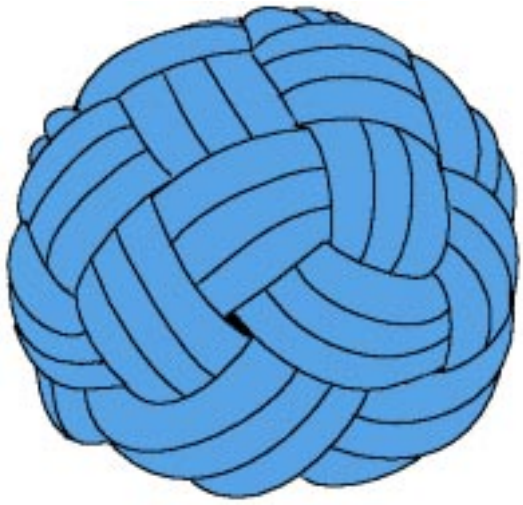

This knot is used to cover knobs. One example would be to cover a knob at the end of a walking stick.

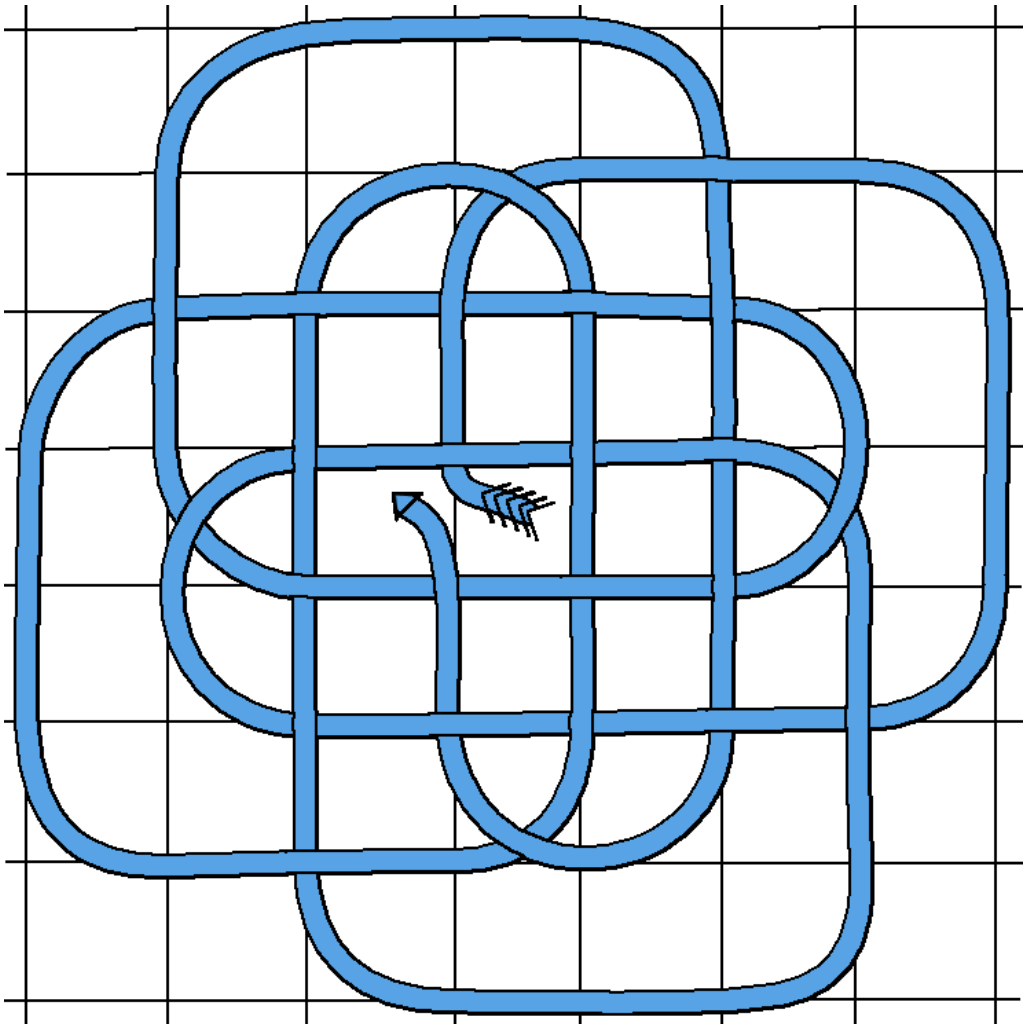

The length of cord needed to tie the knob covering knot depends on the size of the cord and the number of times the pattern is to be chased. A good length to start with is 8 times the circumference of the knob for each time the pattern is to be chased. [Example: a one inch knob has a circumference of a little over 3 inches. To cover a one inch knob it would require about 25 inches of cord for each time the pattern is chased. The pattern should be chased at least 2 times. This means that about 50 inches of cord would be used to cover a 1 inch knob.

The knob covering knot is difficult to tie “in hand” the easiest method of tying it is to make a copy of the diagram and fasten the diagram to a work board. Start by pinning the middle of the cord to the feathered end of the arrow in the diagram. Then following the path indicated, pin the cord to the diagram. Be sure to follow the over/under pattern indicated in the diagram. Studying the following partial diagrams may help.

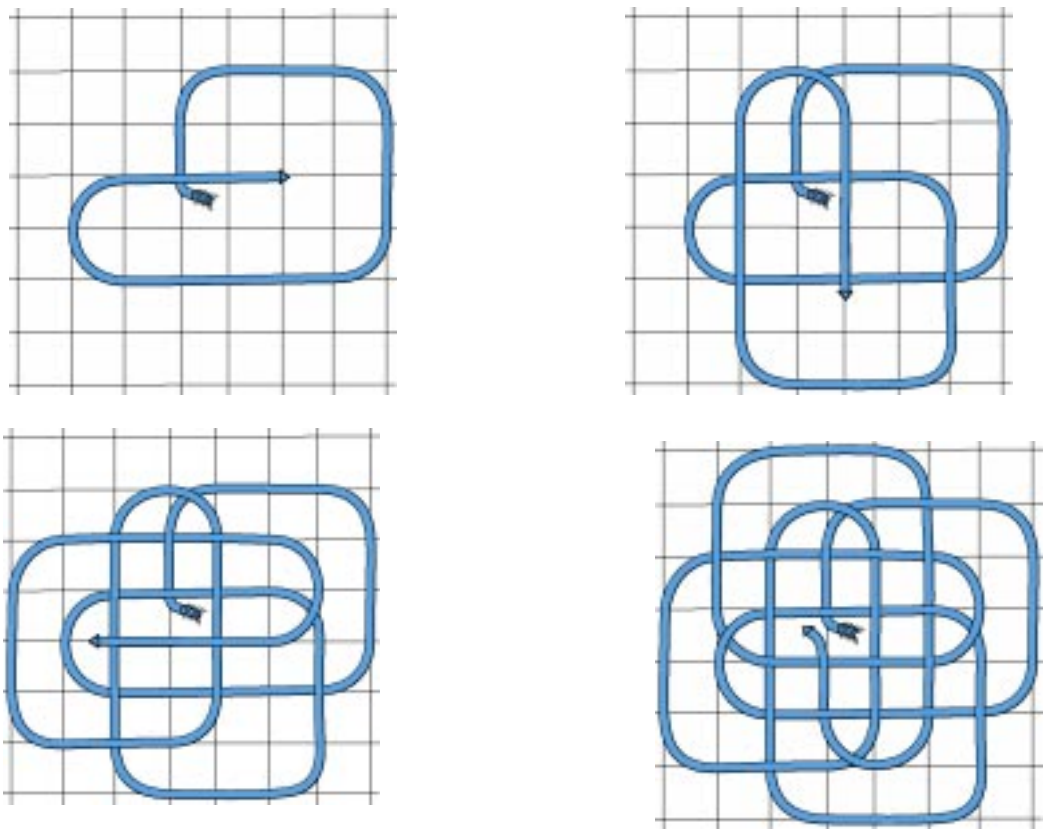

After the knot is tied on the work board unpin it and work it loosely into shape over the knob. Then chase the pattern the required number of times. Next work the knot tight around the knob. Do not rush this stage. When the knot is tight cut off the ends of the cord and push the ends into the knot.

To preserve the knot, it may be varnished or painted.

Walking Stick:

Carve a knob on the end of the walking stick.

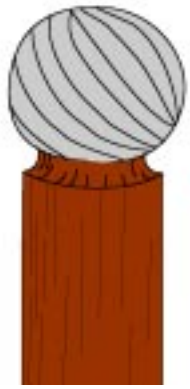

If desired, the size of the knob can be increased by wrapping it with tape.

Tie the covering knot and work it tight over the knob.

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CROWN KNOT:

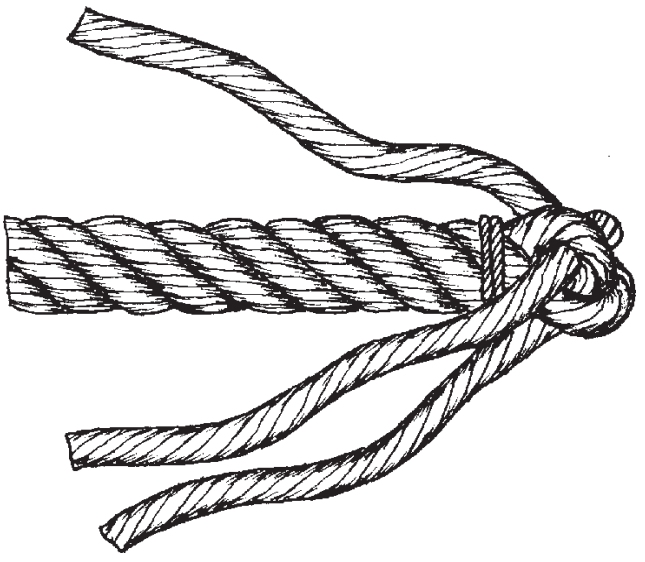

Use ---- To tie of the end of a rope so that it does not unlay. ----- To begin a back splice. ---- As part of several multiple strand knots.

Narration ---- (For **crown knot** knotboard.) **(1)** Tie off the rope 6 complete lays from the end. **(2)** Unlay the rope to the tied off point. **(3)** Place the end of one of the unlayed strand between the other two unlayed strands; **(4)** press the strand firmly between the strands so that a loop is formed. **[NOTE]** As you are looking at the end of the rope work counterclockwise around the rope . **(5)** Fold the second strand over the first strand. **[NOTE]** This will hold the loop in the first strand in place. **(6)** Reeve the end of the third strand through the eye of the loop. **(7)** Fold the third strand over the second strand. **[NOTE]** This will hold the second strand in place. **(8)** Pull the loop closed. **[NOTE]** Work and pull all three strands until the knot is even and symmetrical.

CROWN KNOT

1.

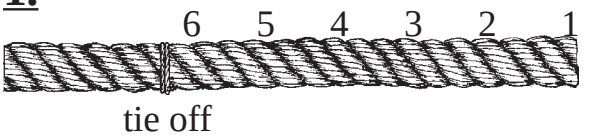

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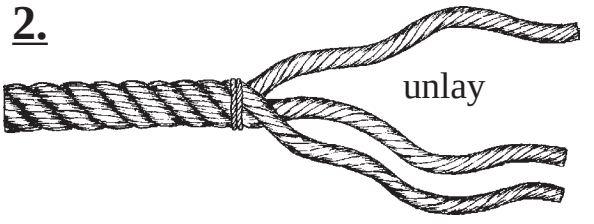

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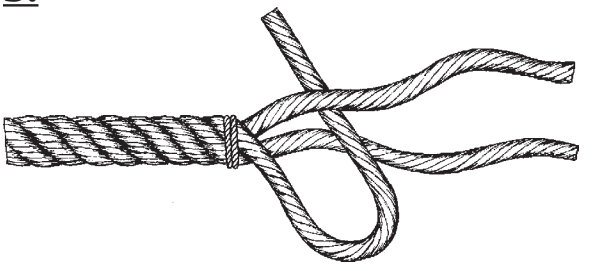

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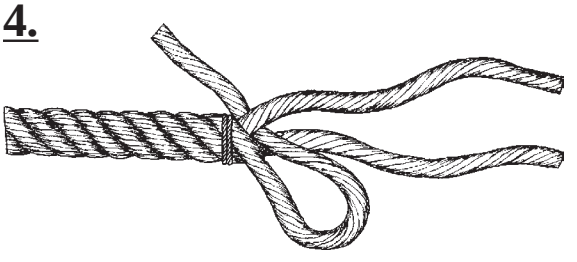

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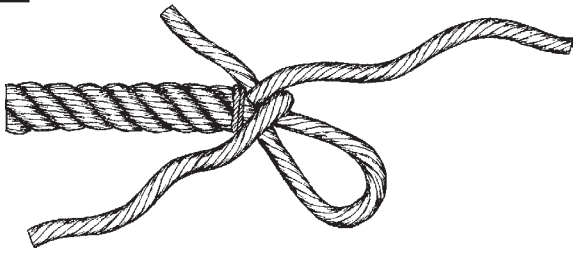

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6.

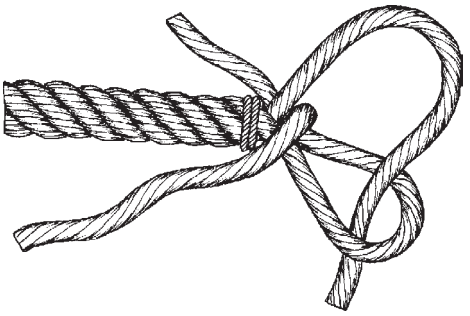

7.

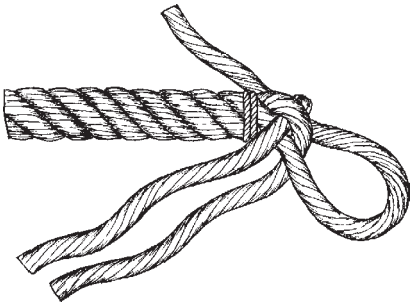

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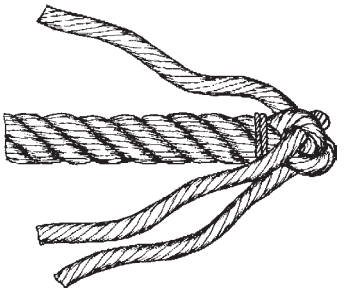

pull all strands snug and even

[NOTE]

WALL KNOT

Use ---- To tie of the end of a rope so that it does not unlay. ---- As part of several multiple strand knots.

(1) Tie off the rope 6 complete lays from the end

(2) Unlay the rope to the tied off point.

NOTE: work the knot in a counterclockwise direction as you look at the end of the rope.

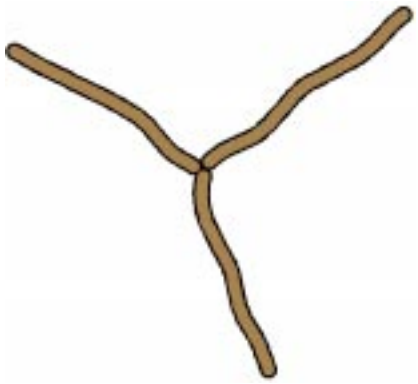

(3) Place the end of one of the unlayed strands under the strand to its left. (Hold the loop open as you work the knot).

(4) Place the second strand under the first and tthird strand.

(5) Placce the third strand under the second strand.

(6) Reeve the end of the third strand up through the loop formed in the first strand.

[A]

[B]

(7) work tight.

ALAMAR KNOT

The alamar knot is a decorative knot related to the pretzel. The pretzel knot is tied in a single strand; the alamar knot is tied by doubling the strands as showwn in [Step 1]

[Step 1] Double the strand as shown.

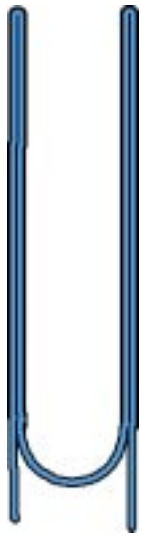

[Sterp 2]

[Sterp3]

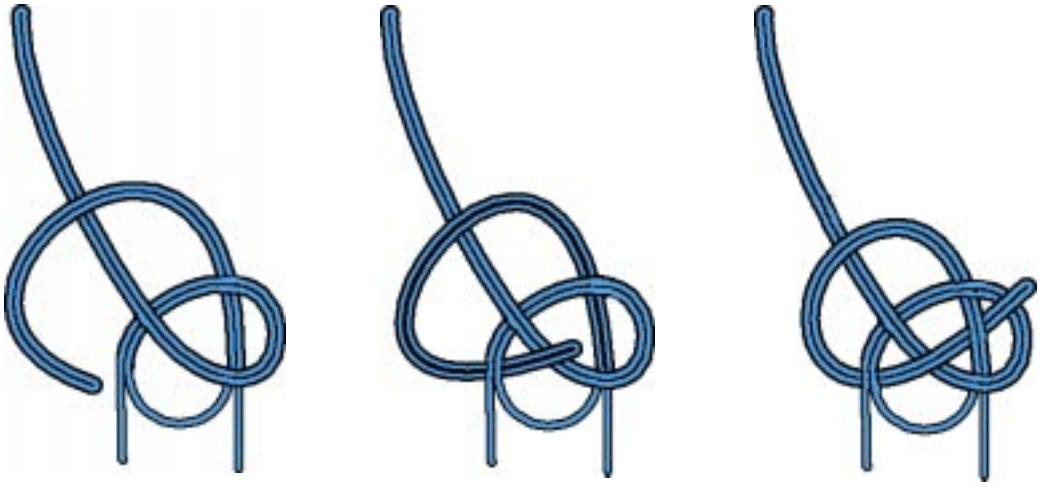

[Step 4]

[Step 5] Add tassels or other end decorations.

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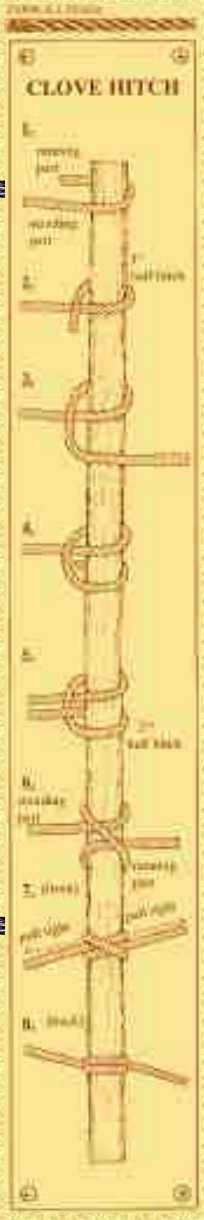

LINKS

The International Guild of Knot Tyers

The International Guild of Knot Tyers, Texas Branch

Knots on the Web

U.S. Scouting Service Project

The MacScouter

Welcome to Scouting Resources Online

U.S. MACSCOUTER

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The following topics about rope making are covered in :

ROPE WORKS

MATERIALS:

Any of the following materials may be used to make rope: binder twine, bailer twine, plastic twine, jute twine, yarn, string, or plastic bags. Just about any material that is made up of long flexible strands or that can be cut into strands can be used to make rope. However, only twines of proven strength should be used to make rope that will be expected to carry a load or lash a structure.

TYPE OF ROPE:

The type of rope that is explained in this book is three strand laid rope. This type of rope is made by twisting three strands of fiber in one direction and then laying the three strands together by allowing the strands to twist together in the opposite direction.

A SIMPLE ROPE MACHINE:

The twisting and laying can be done by hand but this takes a long time. To speed up the operation a machine is needed.

A rope machine consists of two devices; one that twists the three strands, the twisting end; and one that is used to lay the twisted strands together, the laying end.

ROPE WORKS has a set of diagrams showing a simple machine that can be made from scrap lumber and coat hanger wire.

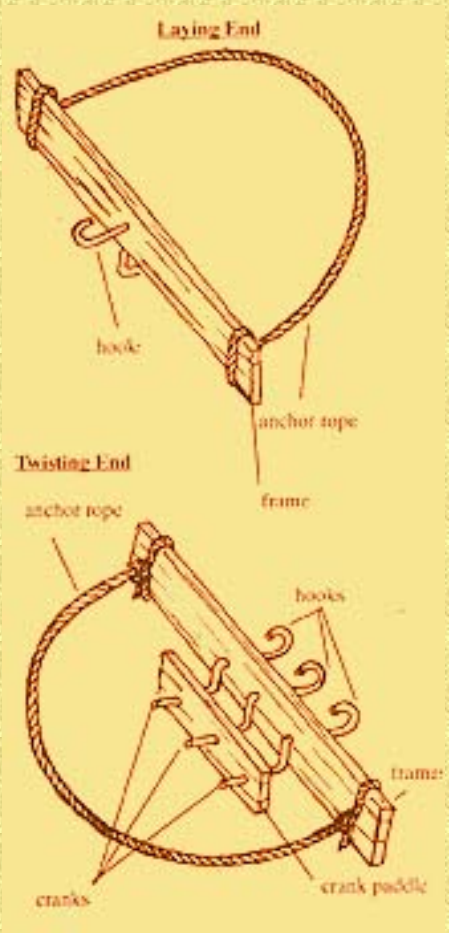

SETTING UP A ROPE MACHINE:

After the two ends of the rope machine are positioned, tie the end of the twine to the laying end hook. Then hook the twine over one of the hooks on the twisting end, then back to the laying end hook. Continue back and forth until each of the three hooks on the twisting end have two lengths of twine on it. Be careful to keep the tension equal on all lengths of twine.

TWISTING THE STRANDS:

After the machine is set up, turn the cranks on the twisting end so that the cranks are turning clockwise as you are looking at the crank handles. It Is a good idea to mark this direction on the frame of the machine.

Twist the strands until they become firm and resist further twisting. If the strands are not twisted tight enough the rope will be loose. On the other hand if you twist the strands too tight the strands will kink. Kinked or loose strands will weaken the rope. Experience will teach you when the amount of twist is just right.

[NOTE] During the twisting the laying end must not be turned.

[NOTE] While twisting and laying a modest amount of tension must be kept on the rope.

LAYING THE ROPE:

To lay the rope a rope-wrench will be needed. A rope-wrench can be made from a crotched stick.

The actual laying of the rope is done by turning the laying end crank in a counterclockwise direction and moving the rope-wrench toward the twisting end.

MAKING A GEARED ROPE MACHINE:

A geared rope machine not only speeds up the process of making rope but can also be used to make rope several inches in diameter.

The patterns and instructions included in ROPEWORKS are for building a wooden geared rope machine that has a 3:1 gear ratio. This rope machine can be constructed with hand tools.

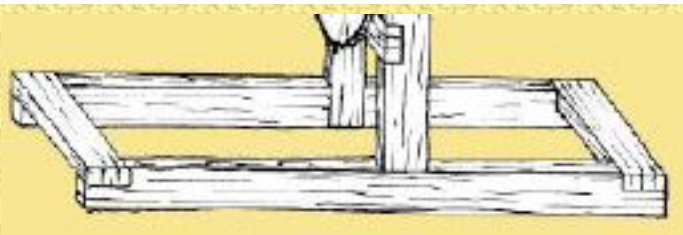

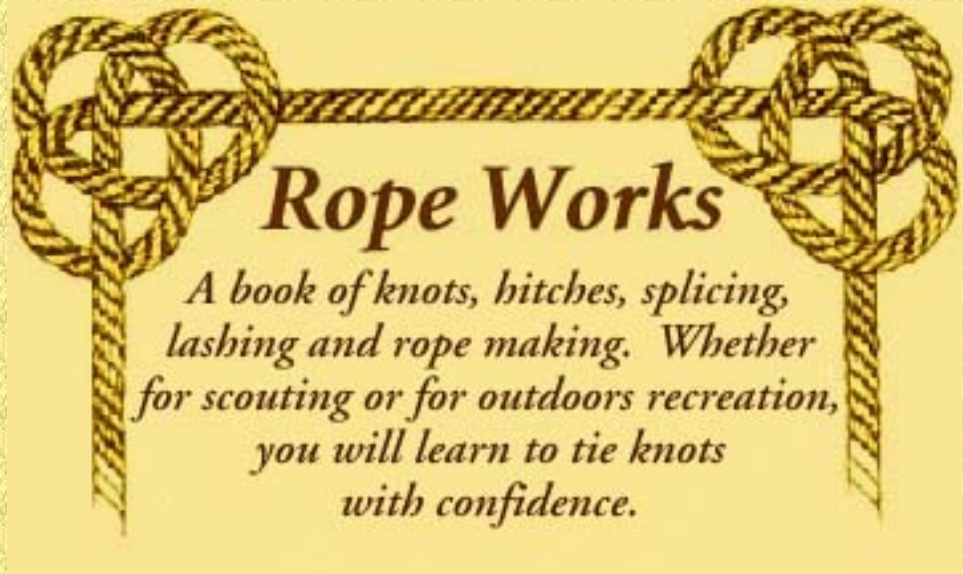

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Lashing

Lashings are used to join poles or spars when building pioneering structures. These structures can be functional, such as tables, bridges, and towers or decorative such as gateways. The only limit as to the type of structure is the imagination of the builder.

Correctly tied lashings in pioneering structures are essential for safety. When young people see an interesting structure they charge up and over with no thought as to the soundness of the structure. This places the responsibility for a safe structure directly on the builder.

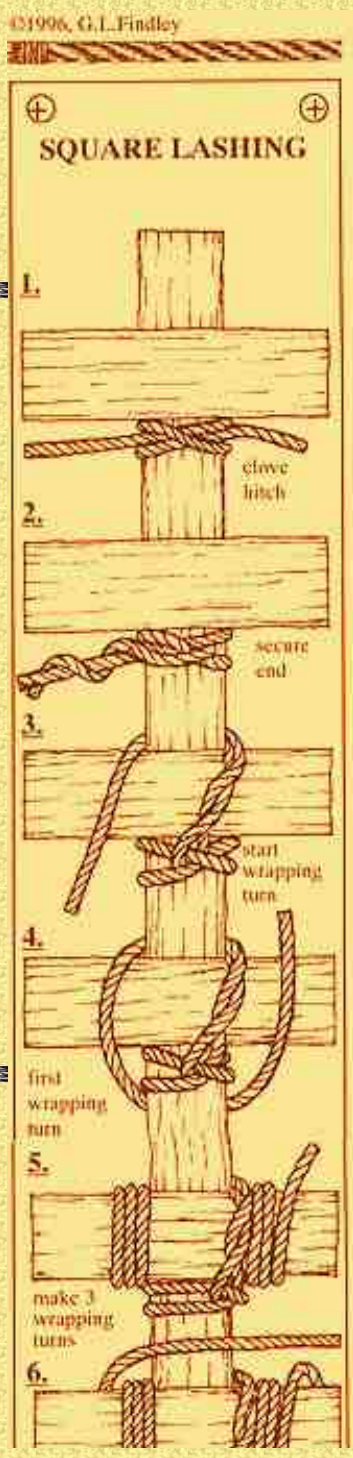

The following topics about lashing are covered in :

ROPE WORKS

Square Lashing
Diagonal Lashing
Tripod Lashing With Racking Rurns
Tripod Lashing With Plain Turns
Shear Lashing With Racking Turns
Shear Lashing With Plain Turns
Shear Lashing Quick
Round Lashing
Round Lashing West Country
Floor Lashing

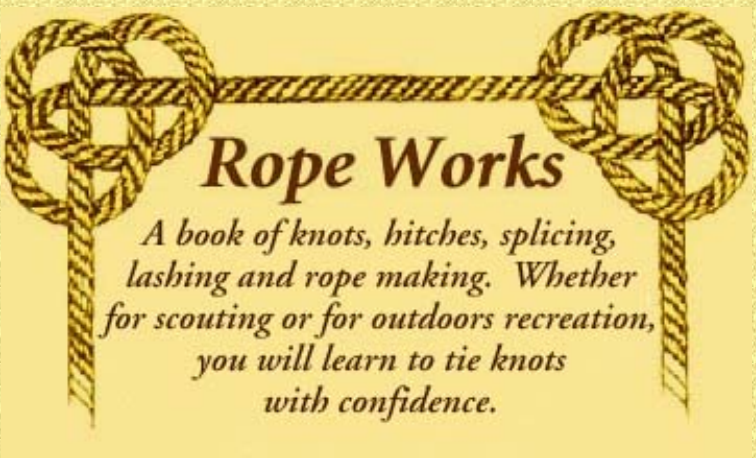

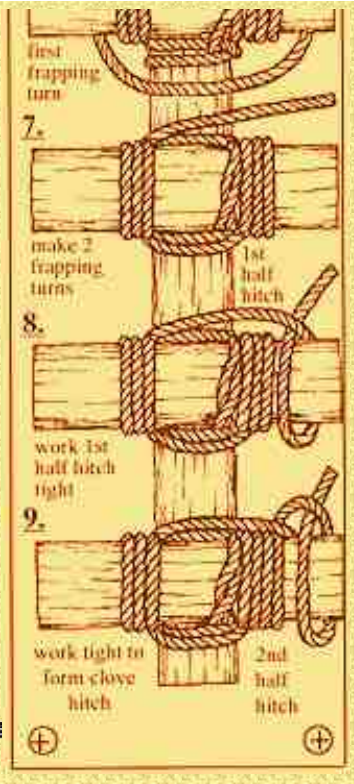

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Splicing

Splicing is used to join ropes together by interweaving the strands of the rope. Splicing is the safest way to fasten two ropes together or to form a loop. Knots could also be used to do these jobs but knots weaken the rope by as much as 30 to 55 percent of the original strength of the rope. However, with a splice the rope is 85 to 90 percent as strong as the original rope. Splicing should be used whenever there is a concern about safety or when the loop or joint is going to be left in the rope.

[NOTE] After a splice is started or after each round of tucks, fold the strands back over the work. You will notice that there is one strand going in and one strand coming out between each of the strands of the standing end. If this configuration does not exist you have made a mistake; trace the strands back and correct the mistake or pull strands out and start over.

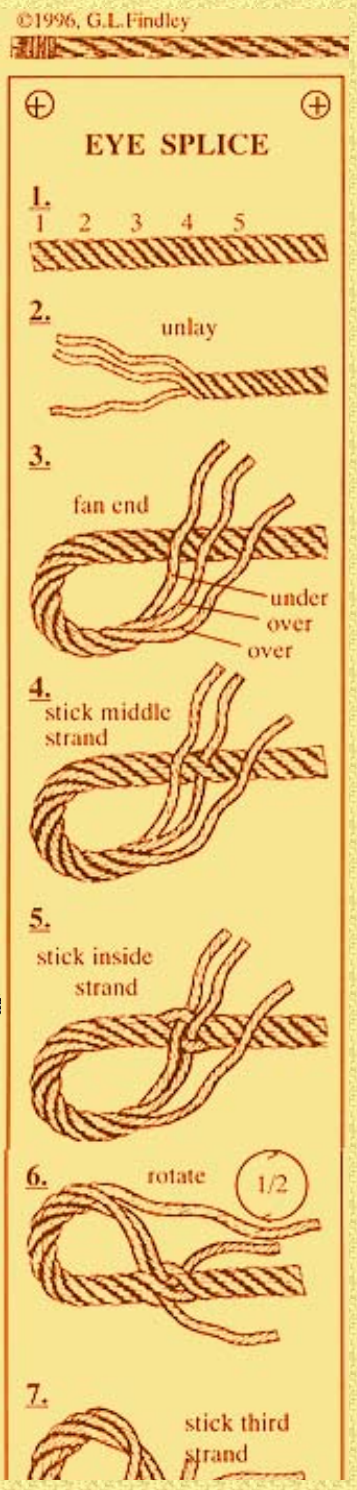

The following topics about splicing are covered in :

ROPE WORKS

Crown Knot
Back Splice
Eye Splice
Short Splice
Adding A Round Of Tucks
Ending A Splice

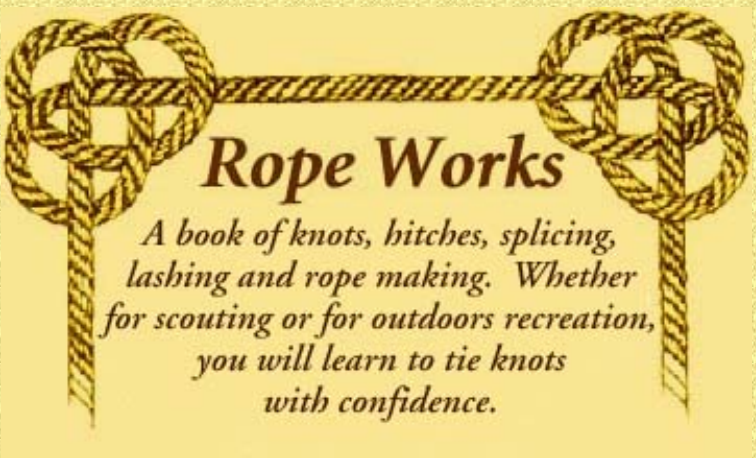

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Knots

The use of rope in the workplace was common practice until the midpoint of this century. At that time, modern materials handling techniques started to be used and the use of ropes declined. Along with this decline in the use of ropes in the work place there was also a decline in the knowledge of how to use rope safely.

The more common uses of rope by the average person is the securing of a load to a personal vehicle or for recreational purposes. Both of these uses require a knowledge of how to choose and tie safe, secure knots. If this knowledge is not available, the consequences can be devastating, resulting in personal injury or the loss of personal equipment.

For the last 35 years I have been learning and teaching about rope. My experience in teaching about rope has shown me that most people must be shown how to tie a knot in small, sequential steps, and they must be shown many times before they can tie a knot with confidence.

In preparing this book I have attempted to design a set of teaching aids that present each selected knot, splice, or lashing in small, sequential steps. These teaching aids enable the learner to study each step and to duplicate it with a length of practice rope.

The knots, splices and lashings presented in this book were selected because of their use by the Boy Scouts of America and others who are interested in outdoor recreation.

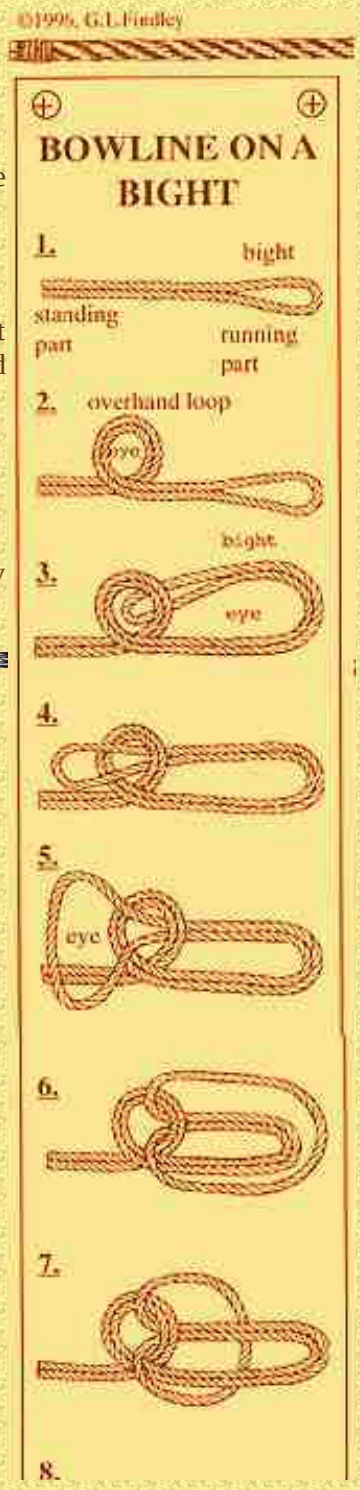

The following knots and hitches are covered in :

ROPE WORKS

Whipping (3 methods)
Service
Grapevine Service
Ringbolt Hitching
Sezing
Sezing With Racking Turns
Figure Eight
Figure Eight On A Bight
Stevedore Knot
Stopper Knot
Square Knot
Water Knot
Sheet Bend
Double Sheet Bend
Sheet Bend (Short End)
Bowline
Bowline On A Bight

French Bowline
Lineman's Loop
Sheepshank
Trumpet Knot
Sheepshank (Quick)
Clove Hitch
Constrictor Knot
Monkey's Paw
Turk's Head
Two Half Hitches
Taut-line Hitch
Timber Hitch
Mooring Hitch
Marlin Spike Hitch
Marlin Spike Ladder
Anchor Bend
Belaying To A Cleat
Jug Knot

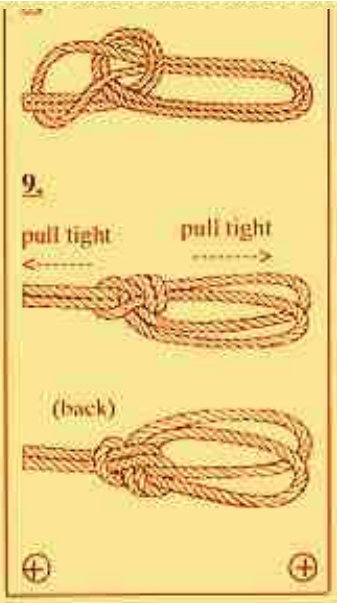

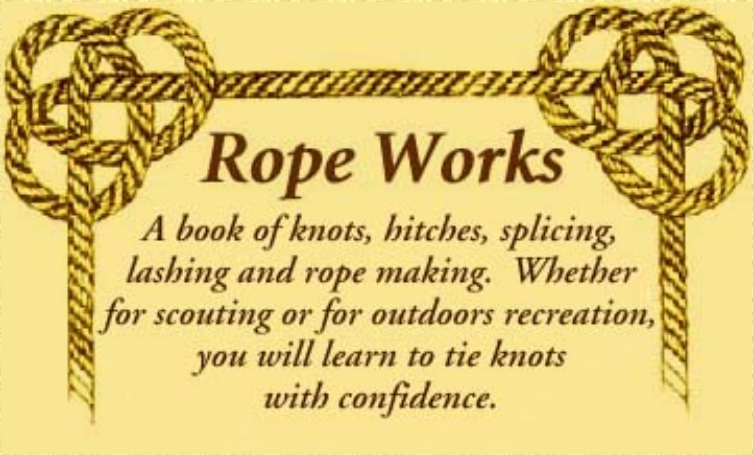

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INTRODUCTION

ROPE WORKS is a book that evolved to meet the needs of Scouts and Scouters. R0PE WORKS' 97 pages are bound in a plastic comb binding that allows it to lay flat while in use. Its 6 inch by 8 1/2 inch size makes it convenient to carry as a reference source. ROPE WORKS provides detailed step by step illustrations in a knot board layout. The knot board layout clearly shows each step required to tie a knot. The detailed steps allows the user of ROPE WORKS to learn the art of **knot tying**, **splicing**, and **lashing** without the constant supervision of an instructor. The table of contents, glossary of terms and complete index will help you find and tie the knots you need.

Twenty-two pages of ROPE WORKS are devoted to **rope making** and the building of a **geared rope machine.**

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KNOT SAFETY

If a knot is improperly tied or a wrong knot is used, an unsafe condition is created. Therefore it is not just enough for the teacher to teach someone how to tie a knot correctly, but it is also necessary to teach them how to use the knot correctly. Likewise it is the student's responsibility to learn how to correctly tie and use the knot. If either the teacher or the student does not accept their responsibility they are endangering themselves and others.

The most commonly used rope is right hand-lay rope; that is as you are looking at the rope, it appears to twist to the right and away from you. Because of the right-hand lay of most rope, the majority of knots hold best when tied in a right hand manner. If the knot is tied in a left-hand manner or the mirror image of its usual form, the knot may fail because the right-hand twist of the rope may cause the knot to loosen or spill more easily. This is especially true if the tension on the rope is repeatedly changed.

Thanks and safe tying.

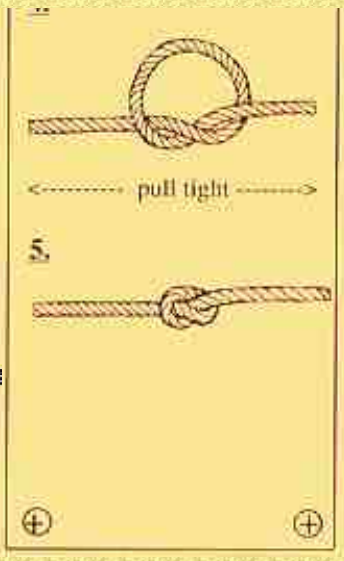

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Rope

From Wikipedia, the free encyclopedia

A **rope** is a group of yarns, plies, or strands that are twisted or braided together into a larger and stronger form. Ropes have tensile strength and so can be used for dragging and lifting, but are too flexible to provide compressive strength. As a result, they cannot be used for pushing or similar compressive applications. Rope is thicker and stronger than similarly constructed cord, line, string, and twine. Fiber rope is made from fiber, whereas wire rope is made from wire.

A coil of rope

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- 2 Usage
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Construction

Rope may be constructed of any long, stringy, fibrous material, but generally is constructed of certain natural or synthetic fibres. Synthetic fibre ropes are significantly stronger than their natural fibre counterparts, but also possess certain disadvantages, including slipperiness.

Common natural fibres for rope are manila hemp, hemp, feathers, linen, cotton, coir, jute, straw, and sisal. Synthetic fibres in use for rope-making include polypropylene, nylon, polyesters (e.g. PET, LCP, Vectran),

polyethylene (e.g. Dyneema and Spectra), Aramids (e.g. Twaron, Technora and Kevlar) and acrylics (e.g. Dralon). Some ropes are constructed of mixtures of several fibres or use co-polymer fibres. Wire rope is made of steel or other metal alloys. Ropes have been constructed of other fibrous materials such as silk, wool, and hair, but such ropes are not generally available. Rayon is a regenerated fibre used to make decorative rope.

Three-strand twisted natural fiber rope

The twist of the strands in a twisted or braided rope serves not only to keep a rope together, but enables the rope to more evenly distribute tension among the individual strands. Without any twist in the rope, the shortest strand(s) would always be supporting a much higher proportion of the total load.

Usage

Rope is of paramount importance in fields as diverse as construction, seafaring, exploration, sports, theatre, and communications; and has been used since prehistoric times. To fasten rope, many types of knots have been invented for countless uses.[1] Pulleys redirect the pulling force to another direction, and can create mechanical advantage so that multiple strands of rope share a load and multiply the force applied to the end. Winches and capstans are machines designed to pull ropes.

Mooring and rope

Rock climbing ropes

The modern sport of rock climbing uses so-called "dynamic" rope, which stretches under load in an elastic manner to absorb the energy required to arrest a person in free fall without generating forces high enough to injure them. Such ropes normally use a kernmantle construction, as described below. "Static" ropes, used for example in caving, rappelling, and rescue applications, are designed for minimal stretch; they are not designed to arrest free falls. The UIAA, in concert with the CEN, sets climbing-rope standards and oversees testing. Any rope bearing a GUIANA or CE certification tag is suitable for climbing. Despite the hundreds of thousands of falls climbers suffer every year, there are few recorded instances of a climbing rope breaking in a fall; the cases that do are often attributable to previous damage to, or contamination of, the rope. Climbing ropes, however, do cut easily when under load. Keeping them away from sharp rock edges is imperative.

Dynamic Kernmantle rock climbing rope with its braided sheath cut to expose the twisted core yarns and core yarn plies.

Rock climbing ropes come with either a designation for single, double or twin use. A single rope is the most common and it is intended to be used by itself, as a single strand. Single ropes range in thickness from roughly 9mm to 11mm. Smaller ropes are lighter, but wear out faster. Double ropes are thinner ropes, usually 9mm and under, and are intended for use as a pair. These ropes offer a greater margin or security against cutting, since it is unlikely that both ropes will be cut, but they complicate belaying and leading. Double ropes are usually reserved for ice and mixed climbing, where there is need for two ropes to rappel or abseil. They are

also popular among traditional climbers, and particularly in the UK, due to the ability to clip each rope into alternating pieces of protection; allowing the ropes to stay straighter and hence reduce rope drag. Twin ropes are not to be confused with doubles. When using twin ropes, both ropes are clipped into the same piece of protection, treating the two as a single strand. This would be favourable in a situation where there was a high chance of a rope being cut. However new lighter-weight ropes with greater safety have virtually replaced this type of rope.

Section through the same rope

The butterfly coil is a method of carrying a rope used by climbers where the rope remains attached to the climber and ready to be uncoiled at short notice. Another method of carrying a rope is the alpine coil.

Aerial rope

Rope is also an aerial acrobatics circus skill, where a performer makes artistic figures on a vertical suspended rope. Tricks performed on the rope are, for example, drops, rolls and hangs.They must also be strong [2] *See also Corde lisse*.

History

The use of ropes for hunting, pulling, fastening, attaching, carrying, lifting, and climbing dates back to prehistoric times. It is likely that the earliest "ropes" were naturally occurring lengths of plant fibre, such as vines, followed soon by the first attempts at twisting and braiding these strands together to form the first proper ropes in the modern sense of the word. Impressions of cordage found on fired clay provide evidence of string and rope-making technology in Europe dating back 28,000 years.[3] Fossilized fragments of "probably two-ply laid rope of about 7 mm diameter" were found in one of the caves at Lascaux, dating to approximately 15,000 BC.[4]

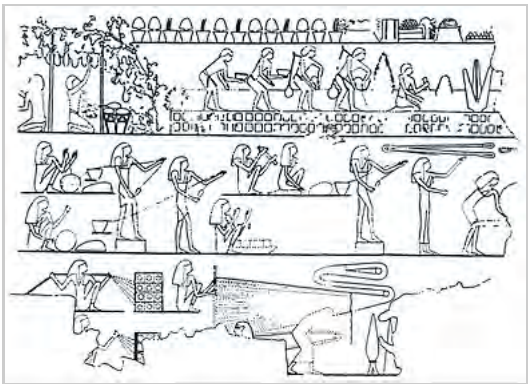
Ancient Egyptians were the first to document tools for ropemaking

The ancient Egyptians were probably the first civilization to develop special tools to make rope. Egyptian rope dates back to 4000 to 3500 B.C. and was generally made of water reed fibres.[5] Other rope in antiquity was made from the fibres of date palms, flax, grass, papyrus, leather, or animal hair. The use of such ropes pulled by thousands of workers allowed the Egyptians to move the heavy stones required to build their monuments. Starting from approximately 2800 B.C., rope made of hemp fibres was in use in China. Rope and the craft of rope making spread throughout Asia, India, and Europe over the next several thousand years.

In the Middle Ages (from the 13th to the 18th centuries), from the British Isles to Italy, ropes were constructed in ropewalks, very long buildings where strands the full length of the rope were spread out and then *laid up* or twisted together to form the rope. The cable length was thus set by the length of the available rope walk. This is related to the unit of length termed *cable length*. This allowed for long ropes of up to 300 yards long or longer to be made. These long ropes were necessary in shipping as short ropes would require splicing to make them long enough to use for sheets and halyards. The strongest form of splicing is the short splice, which doubles the cross-sectional area of the rope at the area of the splice, which would cause problems in running the line through pulleys. Any splices narrow enough to maintain smooth running would be less able to support

the required weight.

Leonardo da Vinci drew sketches of a concept for a ropemaking machine, but it was never built. Nevertheless, remarkable feats of construction were accomplished without advanced technology: In 1586, Domenico Fontana erected the 327 ton obelisk on Rome's Saint Peter's Square with a concerted effort of 900 men, 75 horses, and countless pulleys and meters of rope. By the late 18th century several working machines had been built and patented.

Some rope is still made from natural fibres, such as coir and sisal, despite the dominance of synthetic fibres such as nylon and polypropylene, which have become increasingly popular since the 1950s.

A ropemaker at work, c. 1425

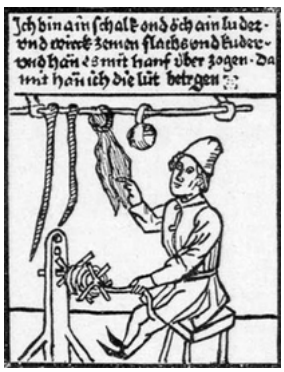

A German ropemaker, around 1470 AD

Public demonstration of historical ropemaking technique

A piece of preserved rope found on board the 16th century carrack *Mary Rose*

A ropewalk in Karlskrona, Sweden

Styles of rope construction

Laid or twisted rope

Illustration of the S and Z naming convention

Laid rope, also called twisted rope, is historically the prevalent form of rope, at least in modern western history. Common twisted rope generally consists of three strands and is normally right-laid, or given a final right-handed twist. The ISO 2 standard uses the uppercase letters **S** and **Z** to indicate the two possible directions of twist, as suggested by the direction of slant of the central portions of these two letters. The handedness of the twist is the direction of the twists as they progress away from an observer. Thus Z-twist rope is said to be right-handed, and S-twist to be left-handed.

Twisted ropes are built up in three steps. First, fibres are gathered and spun into yarns. A number of these yarns are then formed into strands by twisting. The strands are then twisted together to lay the rope. The twist of the yarn is opposite to that of the strand, and that in turn is opposite to that of the rope. It is this counter-twist, introduced with each successive operation, which holds the final rope together as a stable, unified object.[6]

Traditionally, a three strand laid rope is called a *plain-* or *hawser-laid*, a four strand rope is called *shroud-laid*, and a larger rope formed by counter-twisting three or more multi-strand ropes together is called *cable-laid*.[7]

Rope making using the twisted rope method on a 1928 Metters Rope Making Machine

One property of laid rope is partial untwisting when used. This can cause spinning of suspended loads, or stretching, kinking, or hockling of the rope itself. An additional drawback of twisted construction is that every fibre is exposed to abrasion numerous times along the length of the rope. This means that the rope can degrade to numerous inch-long fibre fragments, which is not easily detected visually.

Twisted ropes have a preferred direction for coiling. Normal right-laid rope should be coiled clockwise, to prevent kinking. Coiling this way

imparts a twist to the rope. Rope of this type must be bound at its ends by some means to prevent untwisting.

Braided rope

While rope may be made from three or more strands,[8] modern braided rope consists of a braided (tubular) jacket over strands of fiber (these may also be braided). Some forms of braided rope with untwisted cores have a particular advantage; they do not impart an additional twisting force when they are stressed. The lack of added twisting forces is an advantage when a load is freely suspended, as when a rope is used for rappelling or to suspend an arborist. Other specialized cores reduce the shock from arresting a fall when used as a part of a personal or group safety system.

A rope braiding machine at the Arbetets Museum (Museum of Work) in Norrköping, Sweden

Braided ropes are generally made from nylon, polyester, polypropylene or high performance fibers such as high modulus polyethylene (HMPE) and aramid. Nylon is chosen for its strength and elastic stretch properties. However, nylon absorbs water and is 10-15% weaker when wet. Polyester is about 90% as strong as nylon but stretches less under load and is not affected by water. It has somewhat better UV resistance, and is more abrasion resistant. Polypropylene is preferred for low cost and light weight (it floats on water) but it has limited resistance to ultraviolet light, is susceptible to friction and has a poor heat resistance.[9][10][11][12]

Braided ropes (and objects like garden hoses, fibre optic or coaxial cables, etc.) that have no *lay* (or inherent twist) uncoil better if each alternate loop is twisted in the opposite direction, such as in figure-eight coils, where the twist reverses regularly and essentially cancels out.

Single braid consists of an even number of strands, eight or twelve being typical, braided into a circular pattern with half of the strands going clockwise and the other half going anticlockwise. The strands can interlock with either twill or plain weave. The central void may be large or small; in the former case the term **hollow braid** is sometimes preferred.

Double braid, also called **braid on braid**, consists of an inner braid filling the central void in an outer braid, that may be of the same or different material. Often the inner braid fibre is chosen for strength while the outer braid fibre is chosen for abrasion resistance.

In **solid braid** the strands all travel the same direction, clockwise or anticlockwise, and alternate between forming the outside of the rope and the interior of the rope. This construction is popular for general purpose utility rope but rare in specialized high performance line.

Kernmantle rope has a core (kern) of long twisted fibres in the center, with a braided outer sheath or mantle of woven fibres. The kern provides most of the strength (about 70%), while the mantle protects the kern and determines the handling properties of the rope (how easy it is to hold, to tie knots in, and so on). In dynamic climbing line, core fibres are usually twisted, and chopped into shorter lengths, which makes the rope more elastic. Static kernmantle ropes are made with untwisted core fibres and tighter braid, which causes them to be stiffer in addition to limiting the stretch.

Other types

Plaited rope is made by braiding twisted strands, and is also called *square braid*. It is not as round as twisted

rope and coarser to the touch. It is less prone to kinking than twisted rope and, depending on the material, very flexible and therefore easy to handle and knot. This construction exposes all fibres as well, with the same drawbacks as described above. **Brait rope** is a combination of braided and plaited, a non-rotating alternative to laid three-strand ropes. Due to its excellent energy-absorption characteristics, it is often used by arborists. It is also a popular rope for anchoring and can be used as mooring warps. This type of construction was pioneered by Yale Cordage.

Endless winding rope is made by winding single strands of high-performance yarns around two end terminations until the desired break strength or stiffness has been reached. This type of rope (often specified as cable to make the difference between a braided or twined construction) has the advantage of having no construction stretch as is the case with above constructions. Endless winding is pioneered by SmartRigging and FibreMax.

Gallery of µCT/micro-CT images and animations

2D images / sections

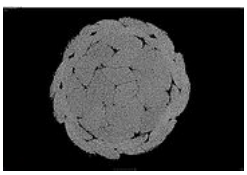
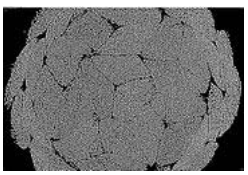
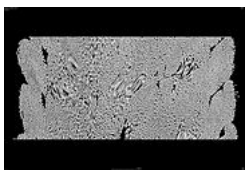
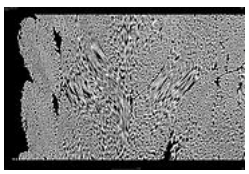

2D flight-throughs/sections

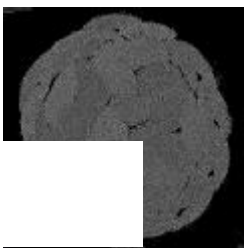
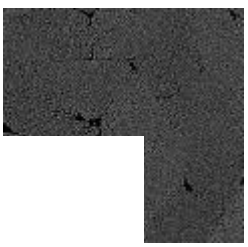

3D renderings

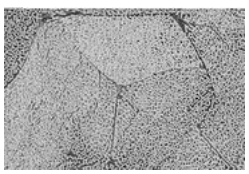

3D flight-throughs/sections

Safe and proper rope handling

Rope made from hemp, cotton or nylon is generally stored in a cool dry place for proper storage. To prevent kinking it is usually coiled. To prevent fraying or unravelling, the ends of a rope are bound with twine (whipping), tape, or heat shrink tubing. The ends of plastic fibre ropes are often melted and fused solid; however, the rope and knotting expert Geoffrey Budworth warns against this practice thus:[13]

> *Sealing rope ends this way is lazy and dangerous.* A tugboat operator once sliced the palm of his hand open down to the sinews after the hardened (and obviously *sharp*) end of a rope that had been heat-sealed pulled through his grasp. There is no substitute for a properly made whipping.

Cordage aboard the French training ship *Mutin*

If a load-bearing rope gets a sharp or sudden jolt or the rope shows signs of deteriorating, it is recommended that the rope be replaced immediately and should be discarded or only used for non-load-bearing tasks.[14][15]

The average rope life-span is 5 years. Serious inspection should be given to line after that point. However, the use to which a rope is put affects frequency of inspection. Rope used in mission-critical applications, such as mooring lines or running rigging, should be regularly inspected on a much shorter timescale than this, and rope used in life-critical applications such as mountain climbing should be inspected on a far more frequent basis, up to and including before each use.

When preparing for a climb, it is important to stack the rope on the ground or a tarp and check for any "dead-

spots".

Avoid stepping on rope, as this might force tiny pieces of rock through the sheath, which can eventually deteriorate the core of the rope. Ropes may be flemished into coils on deck for safety and presentation/tidiness as shown in the picture.

Many kinds of filaments in ropes are weakened by acids or other corrosive liquids or solvents, and high temperatures. Such damage is treacherous because it often is hard to tell by eye.[16] Rope damaged in such ways is dangerous to use. Ropes therefore should be kept away from all kinds of solvents and from corrosive acids, alkalis, and oxidising agents.[17]

In addition, ropes should avoid sudden load, as a shock load can destroy a rope easily.[18] Any operation of ropes should obey the principle of safe working load, which is usually much less than its ultimate strength. The rope should be replaced immediately if any evidences of shock load have been found.

A rope under tension — particularly if it has a great deal of elasticity — can be very hazardous if it should part, snapping backward and potentially causing grave or lethal injury to people, or damage to objects, in its path. There are occasions when it is proper to cut a taut rope under load, but this should be done *only* when necessary and *only* with great forethought and preparation for the potential consequences.

Line

"Rope" refers to the manufactured material. Once rope is purposely sized, cut, spliced, or simply assigned a function, the result is referred to as a "line", especially in nautical usage. Sail control lines are mainly referred to as sheets (e.g. jibsheet). A halyard, for example, is a line used to raise and lower a sail, and is typically made of a length of rope with a shackle attached at one end. Other examples include clothesline, chalk line, anchor line ("rode"), stern line, fishing line, marline and so on.

See also

- Cordage Institute
- Fid (splicing tool)
- Flogging
- Physical restraint
- Hanging
- Hawser
- International Year of Natural Fibres 2009
- Jump rope or *rope skipping*
- Knot
- Rigging
- Rope bondage
- Rope bridge
- Rope lock (in theatre fly system)
- Rope splicing
- Ropework
- Sheet (sailing)
- Single rope technique
- Tight-rope walking
- Whipped rope

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External links

- Ropewalk: A Cordage Engineer's Journey Through History (http://www.StoryOfRope.org) History of ropemaking resource and nonprofit documentary film
- Watch *How Do They Braid Rope?* (http://www.nfb.ca/film/how_do_they_braid_rope)

Wikimedia Commons has media related to ***Rope***.

Look up ***rope*** in Wiktionary, the free dictionary.

Retrieved from "https://en.wikipedia.org/w/index.php?title=Rope&oldid=755154924#Styles_of_rope_construction"

Categories: Ropes | Climbing equipment | Mountaineering equipment | Primitive technology

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~ SSRsi's Rope & Net Making Page ~
We tend to take alot of things for granted in the modern world. Ropes - from twine to cables - and nets are a couple of them. But when you can't visit the local hardware store for more, you'd better know how to make some cordage yourself! .

Intuition ~ Creativity ~ Adaptability

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Miscellaneous

KNOTS: A knowledge of knots has saved many a life in storm and wreck, and if everyone knew how to tie a knot quickly and securely there would be fewer casualties in hotel and similar fires where a false knot in the fire escape rope has slipped at the critical moment and plunged the victim to the ground. Many an accident has occurred through a knot or splice being improperly formed. Even in tying or roping a trunk, few people tie a knot that is secure and quickly made and yet readily undone.

Knots & Hitches Part I Basics By Jaden, 17 July 2003. Knowing how to tie some very easy and basic knots and hitches might just come in very handy someday. I've used 2 different color ropes to help enhance the detail.

Nets & Net Making Forum discuss fancy knots and especially pineapple knots! ...a place to find those hard-to-find knot tying tools, cords, hardware, etc. ...a place to sell your knots and display your work! ***Link fixed, 09/14/08 - sorry 'bout that.***

La Riata - The Lariat. ~ Making & Throwing the Lariat Excerpt from the: "The Outdoor Handy Book ... for Playground, Field & Forest" By D.C. Beard, 1914; Chapter XXXIII: Properly speaking, there is no such thing as a "lasso." You may lasso things with la riata, but you cannot carry a "lasso," because lasso is a verb, and no cow-boy carries a verb coiled at his saddle-bow though he may have strings of forcible adjectives under his tongue...

Some animated knots

Cordage

Some plants used for cordage:

- Agave (Agavaceae) dead leaves cut, beaten.
- Basswood (Tilia americana) inner bark peeled and retted.
- Bull Thistle twist together the tough fibers of the stalk
- Cedar (Cupressaceae)bark
- Cattail (Typha) leaves, shredded
- Cedar pull strips of bark off trunk
- Cottonwood Shred the inner bark for fibers
- Dogbane or Indian Hemp(Apocynaceae) root, bark, inner fiber, or vines, with leaves removed, pounded
- Day Lily (Hemerocallis) leaves dryed, soaked, mellowed.
- Elm Bark (Ulmus americana) inner bark.
- Flax (Linum Usitatissimum) bast fiber, retted and scutched.
- Hickory Shred the inner bark for fibers
- Iris (Iridaceae) leaves, harvest green or browned, dried, soaked, mellowed.
- Juniper Fiber may be obtained from roots and inner bark
- Linden Shred the inner bark for fibers
- Milkweed (Asclepiadaceae) stem fiber or decayed stem fiber, bark.
- Mulberry Shred the inner bark for fibers
- Nettles (Laportea canadensis)stem fiber
- Red Osier Dogwood (Cornaceae) bark
- Sagebrush (Asteraceae) bark
- Sedge (Cyperaceae) roots, leaves

Video
(Click Picture)

Rope 101 - Pt 1

By Hand

Bushcraft Cordage

Survival Moss String

Cordage Fiber Extraction

Handcuff Knot

Rope

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Monte Burch (Ha...
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H. R. Carter (Pa...
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Survival Skills...
Peter Goodchild ...
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Making rope ...
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Charlie Wing (Pa...
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Steven Watts (P...
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P. Kilgour (Paper...
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Primitive Fire ...
(DVD)
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- Spider Plant (Chlorophytum)dry leaves soaked, mellowed
- Sweetgrass (Hierochloe odorata) leaves, dried, soaked, mellowed
- Tule (Scirpus) leaves, dried, soaked, mellowed
- White Oak Shred the inner bark for fibers
- Willow (Salix) bark
- Yucca (Yucca) harvest green, pound and wash, or ret and wash

Making Traditional Cordage in North America, by Ron: This article is about cordage, one of the most used and necessary items for day-to-day life. Other than sinew, catgut, and rawhide, early man made his rope and string from more readily available plant material. Certain plant fibers were able to stand up to water emersion and made excellent nets and fishing line. Animal fibers, such as sinew and catgut, would stretch or unravel when wet and were more difficult to procure. Plant fibers were so much more abundant and easier to process; this left sinew and catgut for sewing, bow backing, arrow making and other arts requiring a strong, longer lasting material. **Article (all text) also has a much longer list of North American plants used for making cordage.**

Cordage Fiber Shredder Made From Bone by Dick Baugh: This little device arose from two situations. I had some left over bone pieces from a knife handle project and I use a lot of cattail leaves for cordage in grade school projects. Cattail leaf cordage is stronger and more flexible when it is finely shredded. In the past I have shown students how to shred the leaves by pulling them apart by hand while holding the base of the leaf with their feet. The ultimate way to shred the leaves is with a florists frog but that isn't very aboriginal...

Making Cordage By Hand by Norm Kidder: Cordage (rope and string) can be made from many different fibers including (Bast) Dogbane, Milkweed, Nettles, Hemp, Flax; (Leaves) Cattail, Yucca, Agave, Douglas Iris; (Bark) Willow, Maple, Basswood, Cedar; (Root) Leather Root, Beach Lupine; (Whole stem) Tule, straw, Juncus. Each material has specific requirements for extracting and preparing the fibers, but there are only two basic ways for using the fibers to make a cord: braiding (or plaiting) and twining. Braiding was usually done with flat, split materials such as cattail or flattened straw...

Probably the best Cordage site on the net. Includes a variety of materials, an .avi to view making cordage, an animated gif, and some links! Courtesy of NativeTech. Good work, folks!

Making Cordage ~ Once the plant and sinew fibers had been prepared, the making of cordage could actually be done. There are two methods for making the fibers into cordage... Learn About Finger Twining | Learn About Leg Rolling Method | Learn About Splicing

Cordage, or twine, was made in a variety of ways and from a variety of materials. For my experiment with cattail mats, nettle and basswood were used to make cordage. Milkweed, dogbane, slippery elm bark, cedar bark strips, shredded cattail, sinew, hide, and many other fibrous materials can also be used to make cordage.

EXPERIMENTAL ARCHAEOLOGY: MAKING CORDAGE ~ In this lesson students will become experimental archaeologists and make cordage from native plant fibers or craft items. Cordage artifacts are seldom found in North Carolina sites because the region's wet, humid climate and acidic soils cause them to decay. However, cordage was an important part of earlier tribes' technology, and indirect evidence exists for how people used it.

MAKING NATURAL CORDAGE [Mother Earth News] Cordage — that is, thread, string, or rope — is all but indispensable in a survival situation. It can be used for (among other things) bowstrings, fishing lines, trap triggers, snares, and lashings. Most people would likely despair if forced to make their own rope or string. However, the materials needed to do so are plentiful in most places (you'll find a list of possible options accompanying this article), and the techniques required are actually quite simple to master. Also available HERE: Wildwood Survival - Making Natural Cordage

AVI Movie of Thigh Rolling Cordage by Tara Prindle

YouTube - Bushcraft Cordage Making and Making Bushcraft Survival String

Cattail Cordage

Making Bark Cordage

Extracting Pulpy Fibers

Yucca Cordage

Net Knot

Handbook of ...
H.A. McKenna, J...
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Primitive Wild...
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A Text-Book ...
B Collard (Paper...
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How to Make ...
J. Garner (Paper...
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T. Dahlem (Pape...
$6.95

Cordage is the term used for any type of rope or string made by twisting fibers together. This was an invaluable tool for Native Americans and it had a major impact on their daily lives. The manufacturing of cordage by Native Americans has changed very little over the many years of its use.

Skill: Making Yucca Cordage: Cordage (rope, string, etc.) is a very useful thing to have in a survival situation. You can use it for making shelter, snares, bowstrings, tools for making fire and bundling things together just to name a few things. The yucca plant is one of the best plants for making cordage. Here are three reasons why...

Making Cordage From Natural Fibers ~ Adapted from Participating in Nature: Thomas J. Elpel's Field Guide to Primitive Living Skills: Cordage, or string, is one of those simple little things which we seldom think about but use every day and take for granted. It is only when we need a piece of cordage and do not have any that we begin to notice just how handy it is. In primitive living cordage is an integral part of many other skills. Primitive peoples used cordage for such diverse projects as fish nets and fishing line, rabbit nets, hammocks, bow and bowdrill strings, woven bags, trap strings and snares, lashing, sewing, and for just tying things up.

Making Cordage by Scott Stoddard (American Survival Guide) March 1995: In the hierarchy of tools, rope and cordage must be near the top. A good knife is probably more important, as well as flint and steel for starting fires, but cordage has got to be right up there. It can hunt for you, help shelter you, and with sufficient strength, cordage can even save your life.

Cordage Plants Twig bark is available year-round, but fall is the time to harvest the stems of fibrous plants for making cordage, otherwise known as string.

How to Make Cordage Once you have collected stalks of milkweed or dogbane, or twigs of basswood or elm, you must detach the bark, since the fibrous inner bark will be used to make string.

Native American Cordage Technology Here is a wonderful summary article on how to produce cordage by using authentic Native American Techniques. A list of possible cordage plants is included.

Netting

Pomo Netting (As learned from Craig Bates) by Norm Kidder

Fishing For Change Pretty good article on net usage followed by small segment on net making and patching.

Basic Netmaking, How To Make Nets

Netting: Concepts in Shaping a Net: Once you learn how to make a basic knot for netting, making your net the shape you want it becomes the next big challenge. It is especially confusing since in most cases you will be making the net as a series of diamonds, but want the end result to be viewed as squares. To gradually get used to the concept, we will first work on shapes that stay diamonds (like tubular netting) and then learn how to form flat shapes.

NETTING: The making of netting is an ancient craft. Many prehistoric cultures used netting for a verity of uses, storage bags, fencing, hammock, just to name some and of course the obvious use as a fish net. No matter what the netting was used for, the knitting of the mesh was done by tying a series of loops in some type of twine.

A Heavenly Hammock [Mother Earth News] There are few experiences more restful than relaxing on a summer's afternoon — while the sun bakes well-being into your soul — in the cradling arms of a good hammock. Of course, the swinging lounges can be very expensive ... but if you can scrounge some 10 to 20 hours of work time and about $20 for materials, you might well be able to tie a netted slumber nest of your own. Here's how.

MAKE YOUR OWN NETS! [Mother Earth News] In many parts of the world, fisherfolk have been making their own nets for generations! It's an enjoyable and productive pastime ... and —with some knowledge, a supply of string, and a couple of handmade tools—you can start tying your own meshwork right in your living room or back yard.

How to make a fishing net (Doing the knot) Tying 2 knots in a fishing net, (so you can see how its done)

Rope

Making & Using the "Lassoo": A Wanderer should be his own Manufacturer — The Way to Make a Lassoo and a Cabresto — Lassooing, Saddling, Mounting, Roping Wild Cattle. *Excerpt from: "At Home In The Wilderness" By John Keast Lord, 1876; Chapter 14*

Rope-making Step-by-step The art of rope making was one of the secret guilds of the Middle Ages. So successful were they in keeping their secrets, that even today there is little written about the craft.

Rope Making from Natural Fibers for Kite Tail Trailing Lines ... It's alot more detailed than the header makes it sound.

Royal Botanic Gardens, Kew: Information Sheets: Rope-making

The Incredible Rope-Making Machine The secret of the Incredible Rope-Making Machine is nothing but a few hooks (we like three, but you can use as many or as few as you like) that can be turned at the same time . . . at the same speed . . . and all in the same direction. This isn't nearly as difficult to accomplish as it might sound.

Rope Making A pictorial and text history

Rope Making - Plants & Textiles - A legacy of technology - Cornell ... This PDF book tells all and has plans for rope machine.

Eye Splicing 3 Strand Rope By Eli. 15 May 2003. I'm going to splice an eye (loop) into the end of a piece of rope. Once you've done it a couple of times it's easy. I'm going to try to explain this the best that I can. It's hard to explain to somebody. It's a lot easier to actually physically show you.

The Rope Works. The whole site is worth spending a couple hours in.

Rope Making. Pretty good article, but not exactly crystal clear.

Rope Works Web Page. Has short articles on knots, hitches, splicing, lashing and rope making. Worth a browse.

Building a Rope Making Machine And Making Rope

The Incredible Rope-Making Machine [Mother Earth News] The secret of the Incredible Rope-Making Machine is nothing but a few hooks (we like three, but you can use as many or as few as you like) that can be turned at the same time, at the same speed and all in the same direction. This isn't nearly as difficult to accomplish as it might sound.

ROPE AND ROPE-MAKING. All varieties of cordage having a circumference of an inch or more are known by the general name of " rope." Twisted cordages of smaller dimensions are called cords, twines and lines, and when the sectional area is still smaller, the article is known as thread or doubled yarn. All these varieties of cordage are composed of a number of separate yarns, each of which is made from some kind of textile fiber by preparing and spinning machinery. The number of separate yarns which ultimately form the rope or cord depends upon the fineness of the yarn, and also upon the circumference of the finished article.

Making Rope Making rope out of yarn. You can use any type of string to do this. I recommend using three different colors of yarn/string to really show the construction of the

finished rope. All three yarns/string should be the same diameter.

Rabbit Stick 2007 rope machine A rope machine for making reverse twist rope really fast and easy...Rabbit Stick 2007 rope primitive skills gatherings

Boy Scouts - Making Rope 1 and Boy Scouts - Making Rope 2

Pieter's Rope Making 101 7/8/07 Pt.1 Djuma Game Reserve...WildEarth wildlife Djuma Safari Africa nature

sisal rope making

Necessary Items for Rope Making

The STORY of HOME MADE -- HAND MADE ROPE (Dann Johnson)

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Pomo Netting

(As learned from Craig Bates)

by Norm Kidder

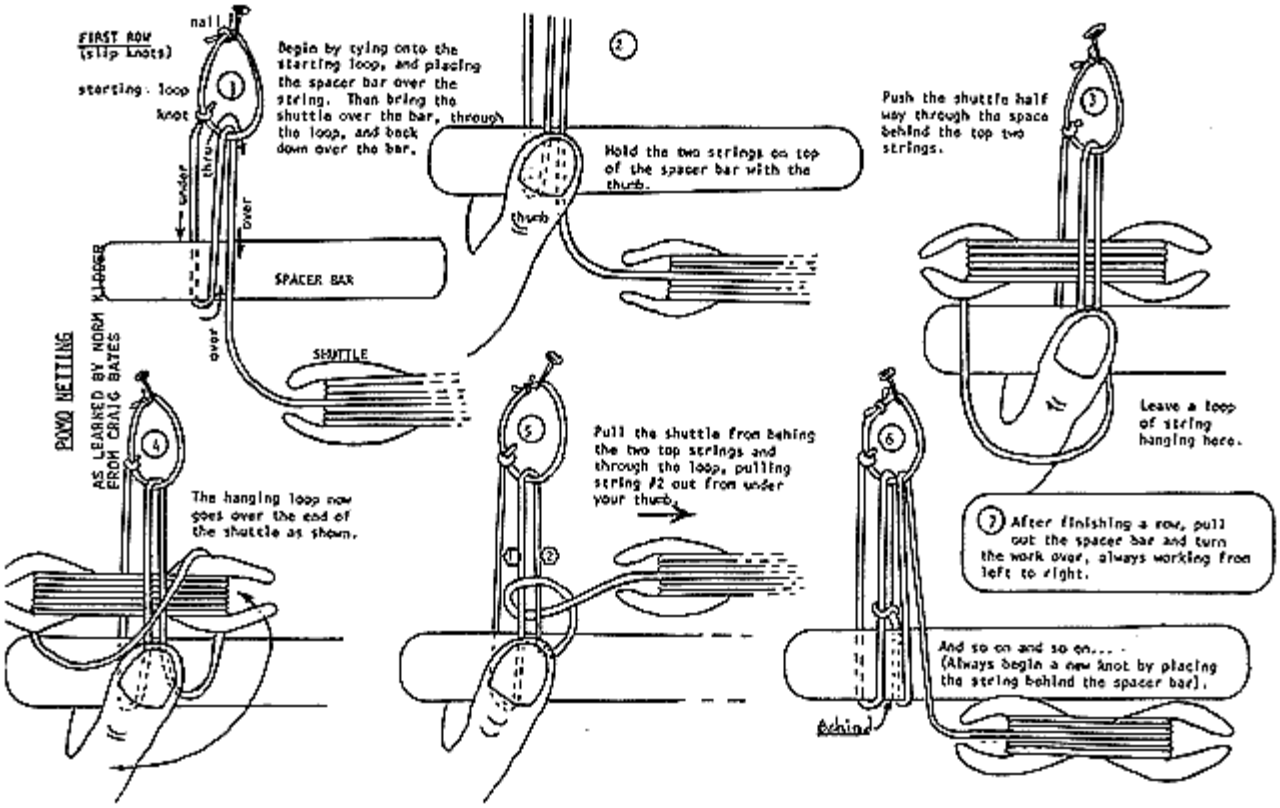

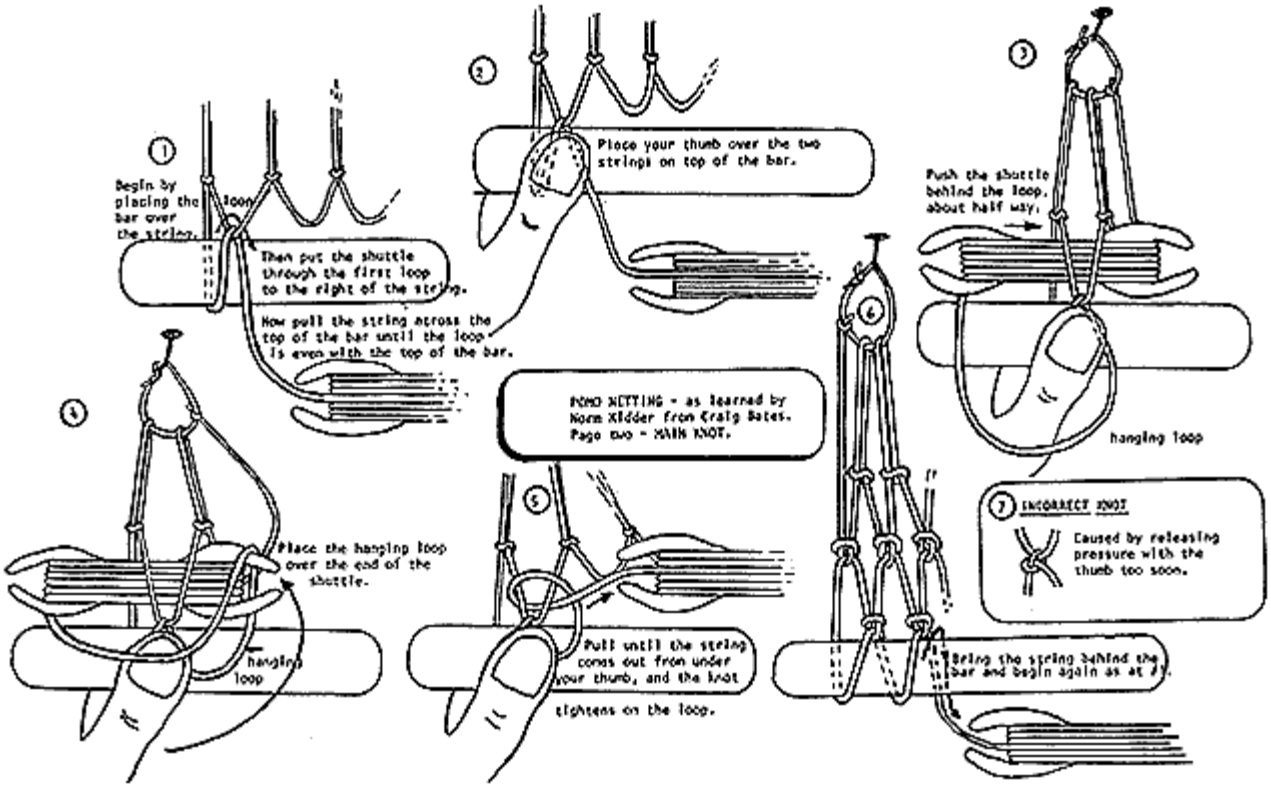

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E-mail your comments to "Norm Kidder " at atlatl1@aol.com

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NETTING:

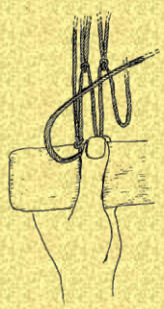

The making of netting is an ancient craft. Many prehistoric cultures used netting for a verity of uses, storage bags, fencing, hammock, just to name some and of course the obvious use as a fish net. No matter what the netting was used for, the knitting of the mesh was done by tying a series of loops in some type of twine.

In one method, the basic knot used was the sheet bend. To form and tie the loops a knitting shuttle and a spacer (gauge) were used.

NETTING TOOLS:

The size of the shuttle and gauge that is needed will depend on the project that you are working on. The size of the shuttle and gauge given in the following directions is a convenient size for many projects and is also a good size to use for practicing the craft of netting. Shuttles and gauges of different sizes can be made by changing the size of the materials used.

Knitting Shuttle:

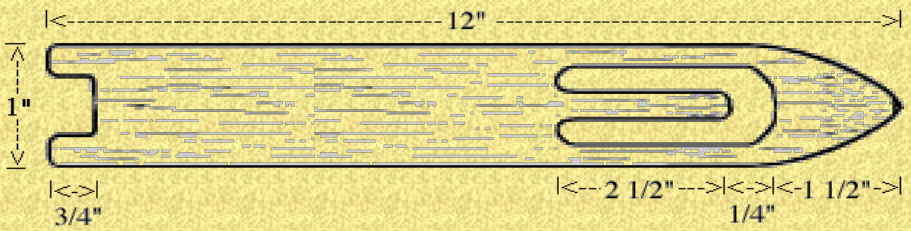

cross
sections

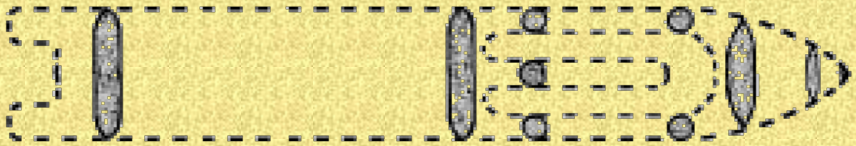

Make the knitting shuttle from a 1/4 inch * 1 inch * 12 inch piece of smooth

grained hard wood. Carve and sand the shuttle to the shape shown in the diagram. Leave the shuttle unfinished; varnish or paint has a tendency to become sticky.

Knitting Gauge:

Make the knitting gauge from a 1/4 inch * 1 1/4 inch * 12 inchpiece of smooth grained hard wood. Carve and sand the gauge to the shape shown in the diagram. Leave the gauge unfinished; varnish or paint has a tendency to become sticky.

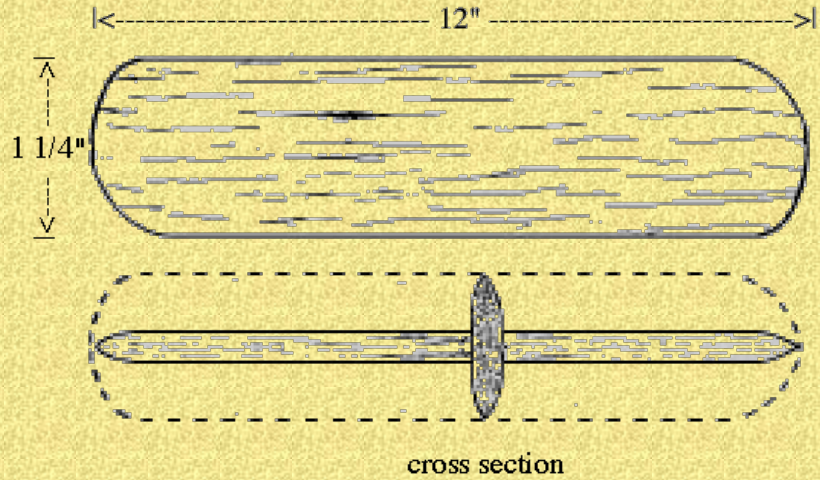

Filling The Knitting Shuttle:

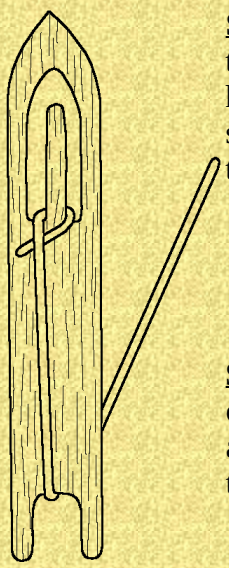

STEP 1: Fill the shuttle with twine. Start by tying a single hitch around the tongue of the shuttle and then pass the twine through the notch.

STEP 2: Turn the shuttle over, loop the twine around the tongue and then through the notch.

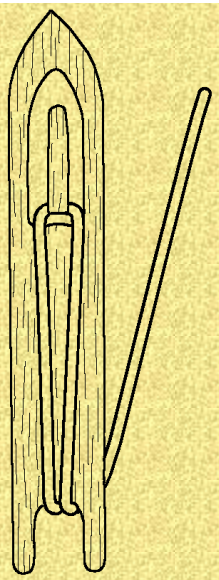

STEP 3: Continue turning the shuttle from side and looping the twine around the tongue until the shuttle is filled.

[NOTE] To prevent synthetic twine from fraying, use a candle flame to cut and fuse the ends.

[WARNING] Using a butane cigarette lighter to cut or fuse synthetic rope or twine may cause the lighter to over heat and explode.

DIAMOND MESH NETTING:

Diamond mesh netting is the easiest of the two forms of mesh to make. Square mesh netting will be dealt with latter.

Casting On: To start diamond mesh netting the first row of mesh loops is cast on to a loop of some kind. The kind of loop used depends on the project; a ring, grommet, frame, or loop of twine may be used. The following directions are for casting on to a ring but the same steps may be used for any starting loop.

STEP 1: Tie the end of the twine to the ring with a clove hitch stopped with two half hitches.

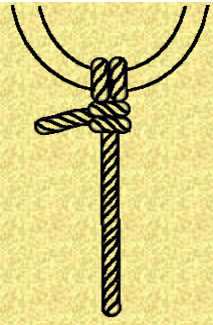

STEP 2: Place the twine behind the gauge then bring the twine in front of the gauge and to the right.

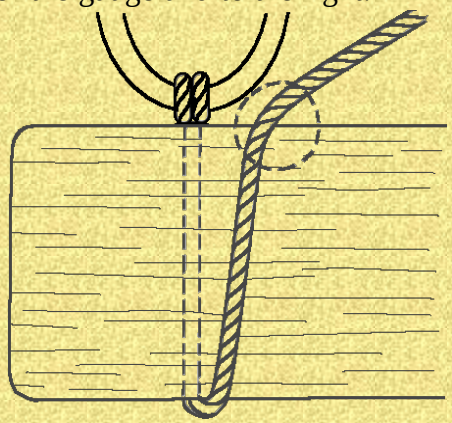

[NOTE]: The dotted circles in each of the diagrams is used to show the position of the thumb and finger of the left hand.

STEP 3: Reeve the twine through the ring from the front to the back so that an overhand loop is formed.

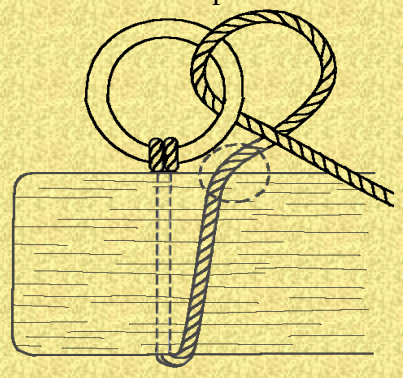

STEP 4: Pull the twine to the left to tighten the twine around the ring and the gauge.

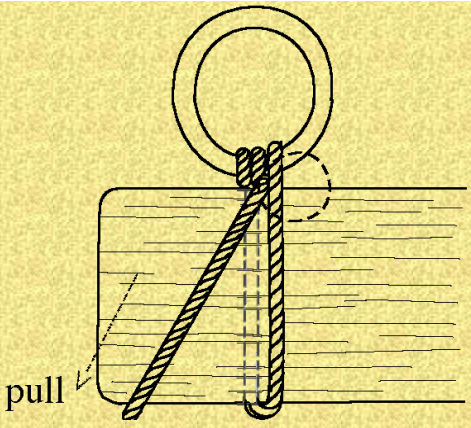

STEP 5: Lay the twine across the ring from left to right.

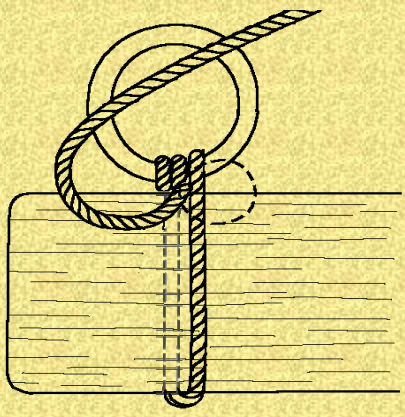

STEP 6: Reeve the twine through the ring from the back to the front.

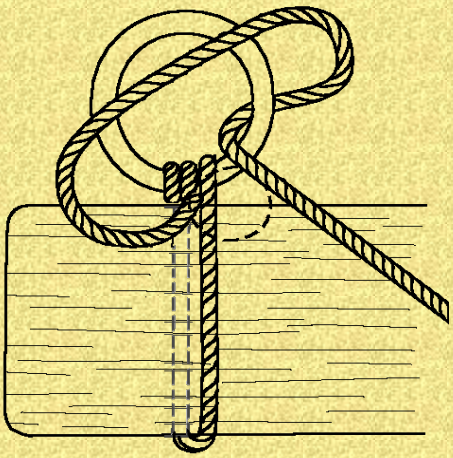

STEP 7: Place the twine behind the gauge; then pull the twine downward to tighten the twine around the ring. This forms a lark's head knot around the ring.

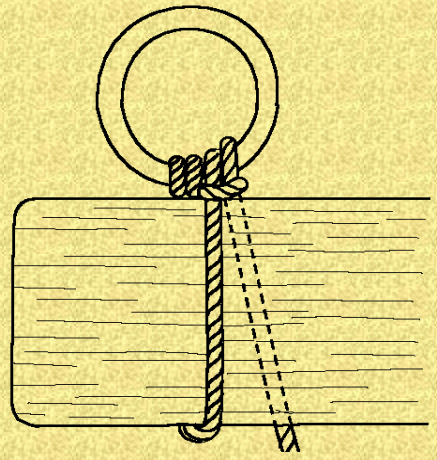

KNITTING A ROW OF MESH:

Netting is made by knitting roes of mesh using a shuttle and a gauge. The gauge is used to determine the size of the mesh, and the shuttle is used to hold the twine and form and tie the mesh loops. The basic knot used in netting is the sheet bend. The following diagrams illustrate the tying of the sheet bend as it is used for knitting a net.

STEP 1: Bring the twine down and up the back of the gauge. Then pick up the next loop by passing the shuttle through the loop from front to back.

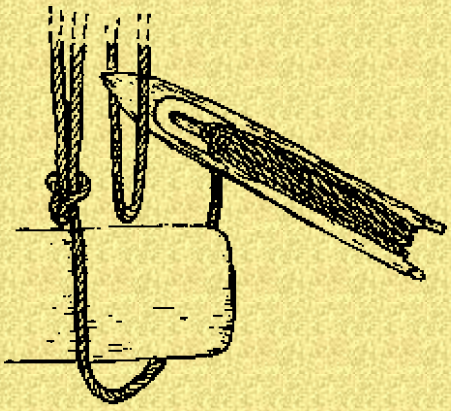

STEP 2: Pull the twine to the left to tighten the twine around the gauge. Use the thumb and finger of the left hand to hold the twine in place.

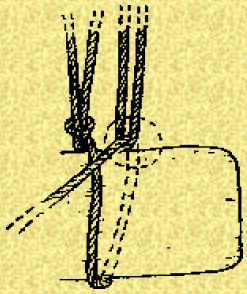

STEP 3: Lay a loop of twine over the loop just picked up.

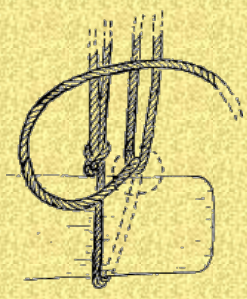

STEP 4: Pass the shuttle in back of the picked up loop and the through the loop that was laid on top.

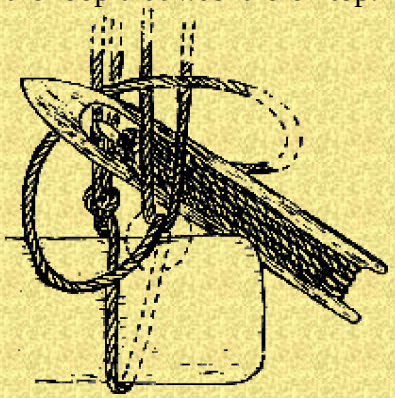

STEP 5: Pull the twine downward and slightly to the right to tighten the knot.

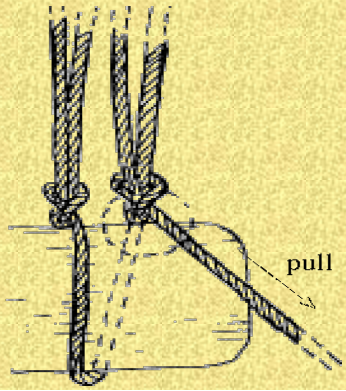

STEP 6: Repeat steps 1 through 5 for each loop in the row.

STARTING A NEW ROW:

STEP 1: When the end of a row of mesh is reached, slide the accumulated loops off the gauge, turn the work piece over so that the running end of the twine is on the left side of the work piece.

STEP 2: Wrap the twine around the gauge from front to back; pick up the first loop by passing the shuttle through the loop from back to front.

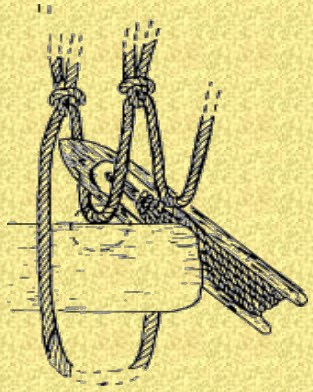

STEP 3: Knit the loop in place by following the directions for knitting a row of mesh.

ADDING A LOOP:

For some projects it is necessary to increase the width of the netting part way through the project. The width of the netting is increased by adding loops of mesh.

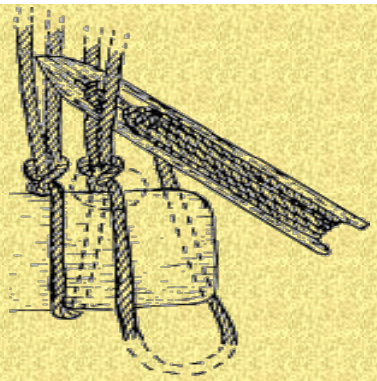

A loop is added by picking up the same loop a second time so that two loops are formed in the new row of mesh are tied to the same loop in the previous row of mesh.

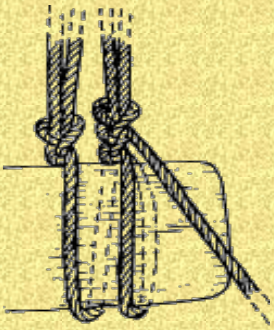

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A Heavenly Hammock

Our illustrated guide to weaving a homemade hammock.

By the Mother Earth News editors - May/June 1982

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Image Gallery

There's nothing better than lounging outdoors in a comfy hammock.

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There are few experiences more restful than relaxing on a summer's afternoon — while the sun bakes well-being into your soul — in the cradling arms of a good hammock. Of course, the swinging lounges can be very expensive ... but if you can scrounge some 10 to 20 hours of work time and about $20 for materials, you might well be able to tie a netted slumber nest of your own. Here's how.

Preliminaries

To make a one-person hammock, you'll need about two pounds (three, if you want a two-person sling) of seine twine, No. 40 to No. 46; two metal rings 2 to 3 inches in diameter (use welded steel or brass); two hardwood support bars measuring 1 1/2-by-1 1/2-by-33 inches each (make them 48 inches long for the double hammock); a smooth gauge stick that's about 3/4-by-1 1/2-by-12 inches; and a netting shuttle.

Now, check the accompanying sketches (Fig. 1) in the Image Gallery to be sure you know how to tie a square knot, a weaver's knot, a half hitch, a lark's head knot, and a plain overhand knot. Then find yourself a comfortable spot with a handy hook, nail or knob to hang your work on, and begin.

Casting On

You'll first want to cut a 3-foot length of twine, and square-knot its ends together. This is called the starter loop. Hang it from that handy nail or knob, then wind the netting shuttle full of twine (as depicted in Figs. 2-5 in the Image Gallery), and tie the free end of the shuttle cord to the starter loop, using an overhand knot.

Next, take the gauge stick in your left hand (unless you're a southpaw, in which case, simply reverse all the directions given here), and place it behind the shuttle cord, right up against the starter loop. Draw the shuttle up in back of the stick, pass it through the starter loop (Fig. 6, see Image Gallery), then bring it back down in front of the stick. Pull the twine taut, and pinch it against the stick with your left thumb to hold it in place (Fig. 7, see Image Gallery).

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Raise the shuttle again — still in front of the stick — and make a half hitch around both strands of the starter loop (Fig. 8, see Image Gallery). Now, pull the twine down in front of the gauge stick, letting go with your left thumb and tightening the half hitch as you do so. Congratulations, you've just completed your first cast-on "stitch"!

Go on to repeat the same process by bringing the shuttle around and up in back of the stick, passing it through the starter loop, etc. (Fig. 9, see Image Gallery). Continue this procedure until you've made 20 snug and even loops around the gauge stick (you'll need 30 for the two-person hammock). Incidentally, be sure you make your half hitches in the same direction each time (that is, so that the "over" strand is always taken from the same side) so your work will lie smooth (Fig. 10, see Image Gallery).

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MAKE YOUR OWN NETS!

Building a fishing net including techniques, know examples, pictures, diagrams, gauging.

by Tom Hamn - May/June 1983

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Image Gallery

Two netting shuttles(one wound with twine) and two sizes of gauge block are shown.

In many parts of the world, fisherfolk have been making their own nets for generations! It's an enjoyable and productive pastime ... and—with some knowledge, a supply of string, and a couple of handmade tools—you can start tying your own meshwork right in your living room or back yard. I learned the art from old-timers, who taught me to "knit" a net ... that is, to build a series of "meshes" to create an overall pattern. I also learned that netmaking can be a great family activity ... especially when everyone keeps in mind the delicious fresh fish that will soon be landed in those interlocking strands and brought to the dinner table.

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STRING ALONG

Nets don't *have* to be used for fishing, of course, but whether you make one to catch walleye or to serve as a decorative wall hanging, you'll have to knit it from some type of string. Kite line, baling twine, upholstery sewing thread, package cord, and even crochet yarn are all good candidates for webbing, although the intended *use* of the finished net will eliminate some choices and recommend others. (For good-quality, lightweight, strong, kink- and rot-resistant cord, however, Dacron or polypropylene are likely the best bets.)

You'll also have to decide the actual *size* of whatever twine you pick: just remember, when doing so, that while thinner cords tend to cost less ... they also have less durability and strength. If you plan to land lunker bass, for example, you wouldn't make your net out of crochet yarn! (On the other hand, if that's the only sort of cordage you have available at the moment, why not use it to *practice* the skill for a while?)

Besides string, you'll need a gauge block or stick, and a netting needle or shuttle (shown ABOVE). You can purchase these tools from most craft

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outlets, or you can make them from hardwood scrap (see the accompanying sidebar to learn how).

LET'S TAKE A DIP

The types of fishing equipment you can make using the block, shuttle, and string include such relatively large-scale harvesting devices as gill nets, hoop nets, and trammel nets ... and the same technique can produce good cargo nets, throw nets, hammocks, and even wall decorations. In order to master the basic method, however, it's best to start with a relatively simple (and very useful) project: producing a webbing tube that can be transformed into a dip—or landing—net. Naturally, this device also needs a *frame* ... *so,* in addition to your string and tools, you'll want either a commercially made landing-net frame (an old one that needs new netting would be fine), an adaptable existing frame (such as a discarded badminton or tennis racket), or a homemade "hoop" (perhaps fashioned from wire, or from springy or steamed wood).

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How to make a fishing net (Doing the knot)

DUN1066 39 videos

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DUN1066 | October 18, 2006

Tying 2 knots in a fishing net, (so you can see how its done)

Uploader Comments (DUN1066)

Jman999000
1 year ago

whats the best string to use for making the net (i dont want it to rot by the way)

> Can't really help you with this as I don't know the propertys of modern synthetic fibres.
>
> I use hemp as it is idea for my re-enactment., modern net makers seem to use modern materials probably due to their strength and durability.
>
> Is nylon the best or is it their somethink better that that? ANYONE?
>
> DUN1066 1 year ago

drunkass77
1 year ago

i see, you go around the big knitting needle thing and through top loop then around through the loop you just made and then make a knot. I bet after a ten minutes a person could do it without thinking. where did you get the two things at or did you make them?

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see all

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july3717
1 year ago

can i use yarn and somehow turn these in arm warmers?

ashiz777
1 year ago

can we people have it in detail and complete equipment how it works and how to make all it in similar measurment,

hope you will post it with a planned programe soon waiting for that anxiously

thanks for this

bum8576
1 year ago

i think i might have found what i have been looking for. thanks!

DUN1066
1 year ago

Hope fully between family/work commitments I will find more time to spend reenacting this summer and then I may be able to produce some more detailed videos. I am unable to record any video during the core day whilst reenacting due to authenticity. I hope this explains.

DUN1066
1 year ago

I would love to be able to produce a set of more comprehensive tutorial videos. Collecting the equipment needed to make a net, Making tools for net making, How to start making a net & to redo the video I have previously thrown together. But finding the time has been a problem for me. This video was recorded on the spot with no planning, mainly for my benifit & I am pleased that some people have found it useful.

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The newsgroup **rec.crafts.knots** is on line. And (perhaps also thanks to your support) I am able to join this news group!

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If you like it you can subscribe to mail notification on major changes. (about once a fortnight.)
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For the next year (or two) there will be no fancy knotting in the instruction part of Ropers Knot Site.
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Safe site rated by RSACi In August 97.

Rating 3 (of 5) from and reviewed by Web-magazine In December '97

A review from the New York Times A Virtual Helping Hand For Tying Up Loose Ends . July ´98

Any comment, suggestions, anything mail me: ***qqqq at realknots.com*** *with subject "**question**"*
All mail without thr right subject is flussed unred. automaticly.
I am sorry I had to remove the mail link. The mailgrabbers and spammers won. But.... I have a few hidden mail address for them to mail to each other after they grabbed it.

I can and will not allow junk mail nor spam. Therefor commercial, non-personal and bulk mail will be charged with handling costs of $100 per mail.

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Search the Helpware Member

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I am sorry to state the mail addresses in words. Automated mailgrabbers made this neccesserry. So if I state to mail to a at b you mail to a@b. All mail with other subjects as stated in the pages will be flusshed unred.

Return to Ropers Knot Page

Touwslager's Knopen Pagina (🇬🇧)

De knopen site met echte knopen.

Wat zijn de meest recente wijzigingen op deze site ??

De engelse knopen index

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Knopen aan een eind
Overhandsknoop, (Vlaamse)acht

Knopen om touwen aan elkaar te knopen
Platte Knoop, Schootsteek, Karaak steek, Zoeteliefjes en meer...

Knopen om touw aan iets anders vast te maken
Mastworp, Constrictor, De acht, en meer..

Enkele Lussen
Paalsteek, Boogpees knoop, en meer..

De Schuifknoop
De lopende paalsteek, beulsknoop, en meer..

Links naar andere knopen-sites
.

Books on Knots on the Web
Ashley, Klutz en meer

Links naar pagina's met links naar (Touwslager's) Roper's pagina's
.

Nieuws uit de knopen wereld

De nieuwsgroep **rec.crafts.knots** is on line.

Ik heb weer hulp van een corrector. De nederlandse versie van de site zal daarom weer groeien.

Over Touwslagers Knopen site.

Als je wilt kan je je abonneren op een mailbericht na wezenlijke wijzigingen in deze site. (ongeveer eens per veertien dagen.)
Touwslagers Knopen Site is geoptimaliseerd om snel te laden, ook op niet al te beste verbindingen. Dit maakt het voor iedereen mogelijk om van deze knopen te genieten.
Niet alle knopen zijn veilig voor kinderen om mee te spelen. Daarom heeft bonus.com deze site voor kinderen opgenomen. Alle "gevaarlijke" links zijn daarin geblokkeerd. Helaas heb je daar wel een krachtige processor en snelle verbinding voor nodig.
De komende paar jaar zullen er geen sierknopen worden opgenomen in het instructie deel van Touwslagers Knopen Site.
Andere knopen sites zijn te vinden via **Roper's Link Page.** Als je wat gevonden hebt wat daarin thuis hoort terwijl het er niet staat, laat het even weten.

Als je hier je e-mail adres registreert krijg je bericht per mail telkens als er een update van deze site geweest is.
(De URL minder vraagt nogmaals om je e-mail adres ter verificatie.)
Je complete Internet e-mail adres (user@domain):

Klik hier voor registratie

Commentaar, ideeen, sugesties mail me: ***qqqq at realknots.com*** *with subject "**question**"*
Alle mail zonder het juiste onderwerp worden automatisch, ongelezen weggemikt..
Het spijt me dat ik de mail link weg heb moeten halen. De Mailgrabbers hebben gewonnen.
Maar.... Ik heb een paar verborgen mail adresjes opgenomen zodat ze elkaar plat kunnen spammen nadat ze mijn "junk"gegrabbed hebben....

Omdat dit een niet commerciële site is kan en wil ik geen junk-mail of "spam" behandelen. Daarom behoud ik mij het recht voor om voor niet persoonlijke mail, bulk-mail en andere reclame uitingen f250,- afhandelings-kosten PER mail in rekening te brengen.

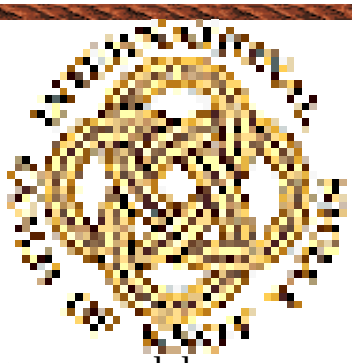

Deze Site wordt gesponsord door: even nog door niemand

(96/02/02)

Breast Plate Designs

to make and wear .. ..

Brian E.Fields made a booklet : "Breast Plate designs." Because I liked it and because there was a great demand for fancy knots I aksed and got permission to publish a part of this work on the WEB.
If you like it and want the complete booklet you can find detailed information on how to buy it on The IGKT store
In the booklet you will find about 20 breast plates and about 5 mats. On this page you find a sample of 5 breastplates from his booklet.

These breastplates are small enough to be tied in the hand, but if you have ten thumbs, by all means use a board and pins.
A nine feet, three meter, fathom and a half lenght of two mm line is sufficient to make and double all these designs and form the neck loop. When tieng a knot start in the middle of the line and work with one end and then the other.

The Bell

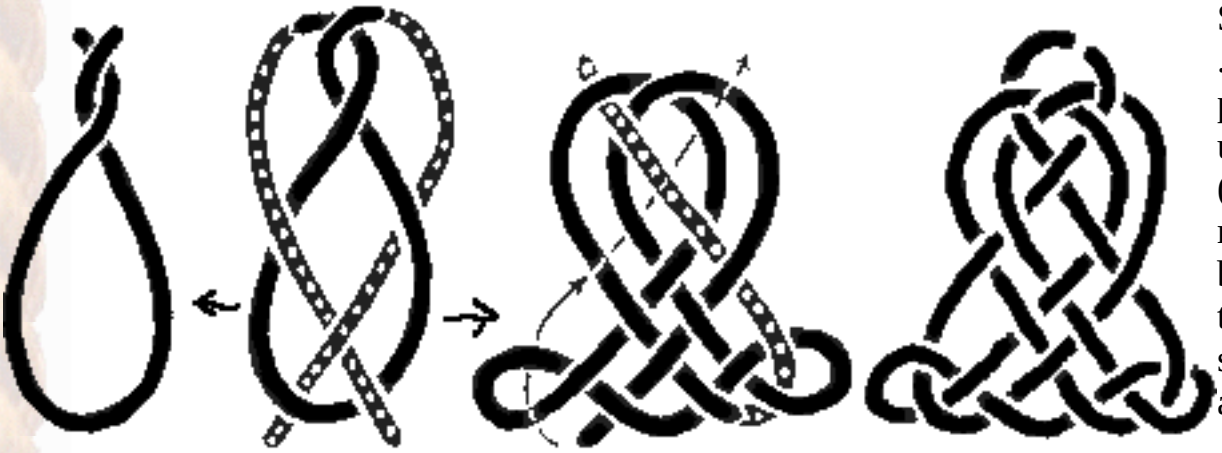

Start with a twist .. and lock it in position aby using the ends (see diagram right). Extend the bottom loop in the directions shown by the arrows.

The extended bottom loop is twisted to produce a locked bight on either side and these bights are held in position by passing the right side end as shown and then using the left end to lock and finish the knot.

Double Headed Carrick

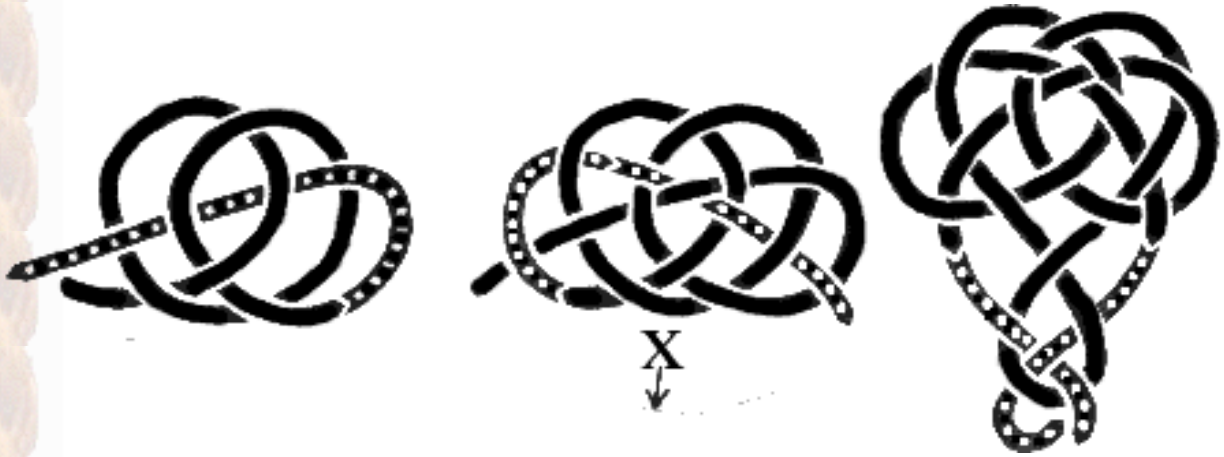

Start with two in terlinked half hitches and pass one end as shown.

The second end may now be passed in a regular over and under weave to complete the first part of the knot. Next work slack around the to extend bight x which is then twisted to lock.

The working ends are then used to lock the twisted bight in position and the knot is ready for doubling.

Handcuff Hitch Breasplate

Start with a half knot and lengthen the two bights. Twist the bights to lock them (this will produce a regular over and under weave). Lay one bight over the other (check that the sequence is correct by examining the rectangle r) Take one end and lock the bights as shown. Arrange the doubling so that both ends finish at x ~ this is the top loop of the knot.

The finished design is small but does form a basis for other patterns such as the design on the right. How to develop one from the other is your problem! (Solved on the next page in the booklet.)

Mors du Cheval (second Method)

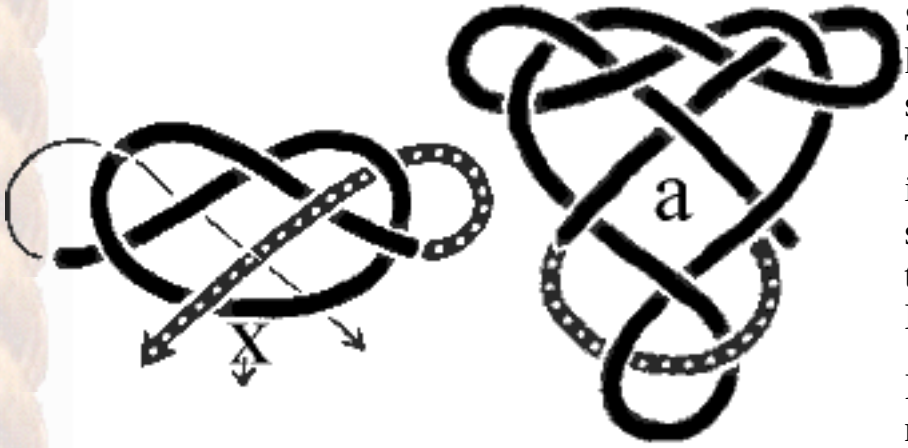

Start with two bights (unlocked half knot) and lock by passing the ends as shown. Extend bight x.
Twist the extended bight so as to lock it, (check the rectangle a. just to make sure the twist was correct), and pass the end as shown to complete the knot. Double (or preferably treble).

I believe this must have been the method used by the Viking who made the Bornhol pendant (dated 800ac-100 ac). He worked with three strands of wire rather than face the problems of trebling, and the work hardening that would inevitably affect the wire when bent as often as required by the tripling technique.

D-N

Start with Mors du Cheval (see previous knot) and extend the two center bottom bights. Twist these extended bights to lock them and place one over the other, as shown.

The working ends are then pased as shown n a regular over and under weave to lock and complete the knot.
Its not quite a ´Tribulation´,but it was still a d--- n--- work out ~ hence the title.

Any comment, suggestions, anything mail me: ***qqqq at realknots.com*** *with subject "**question**"*
All mail without thr right subject is flussed unred. automaticly.
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A

A B C D E F G H I J K L
M N O P Q R S T U V W
X Y Z

Back To

Ropers Knot Page

- Adjusible bend
  - 22nd Farnworth Scout Group(Right part need correction.)

- The Adjusable Hitch Also called the Jamming Hitch.
  - 22nd Farnworth Scout Group

- Albright Knot A Fishermans knot, used for joining lines of different diameter to line or wire
  - On the Fishernet.

- Alpine Butterfly See Butterfly

- Anchor hitch or Anchor bend See Fishermans bend (The bend that is a hitch)

- Arbor Knot A Fishermans knot, used to tye a line to a reel
  - On the Fishernet.

- The Artillary loop. A usefull temporary loop for carrying things.

To=>B

A<=To

B

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

Ropers Knot Page

- Bachman climbing knot
  - On a Climbing Knot Dictionary (Among others in)

- Back Splice.
  - On The Scout Association Of Australia page.

- Barrel Knot. A Fishermans knot. Also called "the Blood knot" Used to join lines of different diameter, as in fly fishing.
  - On the Fishernet.
  - On another Fishernet.
  - The fishing knots.
  - BRMRG Knot Primer Good Picture But this is the fishermans bend..on mountain site

- Bao knot.
  - The Bao Knot. A fancy chineese knot

- Boatswain's Whistle Knot
  - Northnet Ropeworks Clear instruction.
  - Northnet Ropeworks Excelent Animation

- The Bimini-twist. a fixed loop in fishline.
  - Link lost

- Bindary Knot. How to tye a pakkage
  - Link Lost

- Blackwall Hitch.

  Blackwall Hitch on Forty Boy Scout Knots

- Blood Knot. A stopper knot. Also called the dubble overhand
  - Blood Knot. (Fisherman) Also called "Barrel Knot".
  - Blood Bight Knot. A fixed loop for fishline.
  - The fishing knots.

- Bow Knot.
  - Bow Knot on Forty Boy Scout Knots

- Bög = Overhand knot.
  - Csomók.

- Bowline. A famous fixed loop.
  - How is the bowline called in other languages?
  - Bowline Game (for scouting 8-10 y)
  - Csomók.
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - On The Scout Association Of Australia page
  - In climbing. A climbing knot Among others in the Climbing Knot Dictionary
  - Animated Knots Requires plugin
  - Canoe Certificate Course Session 4 - Ropes & Lines
  - NautBob's Knots 4 well known copies of knots.
  - Animated Knots for Scouts No plugin needed
  - one of Forty Boy Scout Knots

- Bowline on the Bight.
  - Ropework Exelent instruction
  - one of Forty Boy Scout Knots

- The Bowstring knot. A permanent loop at the end of a rope.
  - Bowtie Knot.
    - A Tie Knot amongs a view others..
  - The Brubakker Loop knot. A fishermans loop
  - The Buntline Hitch.
    - How is the buntline called in other languages?
  - The Butterfly An Excellent loop in the middle of a rope.

    Link lost

To=>C

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C

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To
Ropers Knot Links

- Carrick Bend. The nearest thing er have to the perfect bend. Also called the Josephine Knot when used in macrame.
  - A poet on this famous knot.

- Cat's Paw.
  - one of Forty Boy Scout Knots
  - Website Gert Animated

- Cleath knot. Or How to belay a cleath
  - Northnet Ropeworks Clear instruction.
  - Northnet Ropeworks Excelent Animation

- Clinch Knot. A fishermans knot. Terminal to a tackle
  - On the Fishernet (Improved) ???.

- The Clove Hitch.
  - How is the clove hitch called in other languages?
  - On the Scout Association Of Australia page.
  - On the Yachtnet = Beautyfull but large page..
  - Website Gert Animated
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - Lehigh Samson (among other drawings with small description)
  - Quick Clove Hitch Good instruction for one way of tying.

- Animated Knots Requires plugin
- Canoe Certificate Course session 4 - ropes & lines
- NautBob's Knots 4 well known copies of knots.
- Animated Knots for Scouts No plugins needed
- one of Forty Boy Scout Knots
- Clovehitch Relay (game for youg scouts)

- The Constrictor Hitch.
  - Northnet Ropeworks Clear instruction.
  - Northnet Ropeworks Excelent Animation

- The Cow Hitch

- Csónak~ = Slip Knot
- Csomók.

To=>D

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D

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Diagonal Lashing.
  - Northnet Ropeworks Clear instruction.

- Double Carrick Bend.

  on of Forty Boy Scout Knots

- Double Constrictor Hitch.

  Probably the strongest hitch. Best use for temporary whipping.

- Double Eight. Probably the strongest 'double-stopper' knot
  -

- Double Figure-of-eight loop.
  - one of Forty Boy Scout Knots

- Double Fisherman's Knot. A Fishermans knot. Used to join lines of different diameter, as in fly fishing.
  - On the Fisher net. Used to join lines of different diameter, as in fly fishing.
  -

- Double Marline Hitch.

- Double Overhand Knot. Stopper.
  - On the Climbing Knot Dictionary (Among others)
  - one of Forty Boy Scout Knots
- Double Turle Knot. To Tye a hook with eye on a line
  - The fishing knots.
- Doubled Overhand.
  -
- Double sheetbend
  - Animated Knots for Scouts
  - Website GertAnimated
  - one of Forty Boy Scout Knots
- The Dropper Loop. A loop in fishline.
  - The fishing knots.
- The Dutch Marine Bowline.

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

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- Eye Splice.
  - Ropework Exelent instruction
  - On the Scout Association Of Australia page.

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- Farmers hitch.
  -
- Fiador.
  - Tie a First Class Rope Halter With Fiador Knot
- Figure eight knot. Stopper.
  - On the Scout Association Of Australia page.
  - On the Yachtnet. A beautifull but large page
  - Website GertAnimated
  - A short climbing page on this knot.
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - climbing knot Among others in the Climbing Knot Dictionary
  - Library of knots.(among other drawings)
  - Canoe Certificate Course Session 4 - Ropes & Lines
  - Knots, Bends and Hitches Between 4 other knots.
  - on Animated Knots for Scouts
  - on of Forty Boy Scout Knots
  - BRMRG Knot Primer Good Picture on mountain site
  - Northnet Ropeworks Clear instruction.
  - Northnet Ropeworks Excelent Animation

- Figure eight Lashing.
  - On the Scout Association Of Australia page.

- Figure eight Loop
  - Northnet Ropeworks Clear instruction. In the Bight

- Figure-of-nine knot.
  -

- Filipino Lashing.
  - On the Scout Association Of Australia page.

- Fisherman's Bend. The Hitch wich is called a bend and is (K)not.
  - Lehigh Samson (among other drawings with small description)
  - Knots,Bends and Hitches Between 4 other knots.

- Fisherman's knot= True Lovers Most common 'double-stopper' knot
  - How is the fisherman's knot called in other languages?
  - Website GertAnimated
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - On the Scout Association Of Australia page.
  - climbing knot Among others in the Climbing Knot Dictionary
  - on Animated knots for Scouts
  - on of Forty Boy Scout Knots

- Fisherman's Loop.
  - How is the fishermans loop called in other languages?

- Flamish Eight = Eight.

- Flower knot.
  - The flower Knot. A fancy chineese knot

- Four-In-Hand Knot
  - A way to tye your tie. A page with four knots
  - On a fashion site. (Same drawings as previous link!)

- The Float Stop. A knot ON a fishline.
  - The fishing knots.

- Floor Lashinhg
  - Northnet Ropeworks Clear instruction.

- French knots
  -

- Frost knots
  - BRMRG Knot Primer Good Picture on mountain site

- French Prussic
  - climbing knot Among others in the Climbing Knot Dictionary

- Frendship Knot
  - Jazzman site!

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

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- Gallow Knot.
  - Lehigh Samson among other drawings with small description
- Girth Hitch
  - BRMRG Knot Primer Good Picture on mountain site
- Granny. Do not forget to forget this knot
  - on of Forty Boy Scout Knots
- Gordian Knot
  -

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- The Half Hitch
- Halász = Fisherman's knot= True Lovers Most common 'double-stopper' knot
  - Csomók.
  - on of Forty Boy Scout Knots
- Halyard knot
  - on of Forty Boy Scout Knots
- Half-Windsor A Tie Knot.
  - A page with four Tie knots
  -
- Hangman.
  - Lehigh Samson among other drawings with small description
  - The fishing knots. Drawn as Scaffold...
- Harvester Hitch A truckers knot.
  - Canoe Certificate Course Session 4 - Ropes & Lines
- Hedden knot.
  - On a caving page.

- Highwayman's Hitch climbing knot
  - On Climbing Knot Dictionary Among others
  - Canoe Certificate Course Session 4 - Ropes & Lines

- Hunters Bend. = Zepplin Knot
  - On the Scout Association Of Australia page.

- Huffnagle knot.
  - Tying the Huffnagle for heavy shock leaders to class tippets.

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Improved clinch knot A fishersknot.
  -
  -
  - NautBob's Fishin' Knots between 5 other knots.

- Italian/Munter Hitch.
  -

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- The Jamming Hitch Also called the Adjusible Hitch.
- The Jansik. For connecting a hook to a fishline.
  - The fishing knots.
- Japanese Square Lashing.
  - On the Scout Association Of Australia page.
- The Josophine Knot A Macrame knot same as the Caric Bend
- Jug Sling Hitch.
  - How is the Jug Sling Hitch called in other languages?
  - Northnet Ropeworks Clear instruction.

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- King Sling A fishermans knot. Allows you to make a nutaral presentation.
  - On the fisher net.
- Kleimheist climbing knot
  - On the Climbing Knot Dictionary (Among others)
- Kreuzklem climbing knot
  - On the Climbing Knot Dictionary (Among others)

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- The Lap-Knot. Excelent 'native' knot.
- Lark's head.
  - How is the Lark's head called in other languages?
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
- Lark's Food climbing knot
  - On the Climbing Knot Dictionary (Among others)
- The Lineman's Loop = The Butterfly An Excellent loop in the middle of a rope.
- The Lobster Buoy Hitch

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Manharness Knot.
  - On the Scout Association Of Australia page.
- Marline Hitch. Also called the marling hitch
  - Knots, Bends and Hitches Between 4 other knots.
- Masthead Knot
  - Northnet Ropeworks Clear instruction.
- Mauls
  - Northnet Ropeworks Clear instruction.
- Monkey Fist. The nice knot used as ropers logo.
  - Klabautermann Knotentafel Excelent
  - Northnet Ropeworks Excelent "alternative" way.
  - Knot of the month June 97 Animanted two steps.
- Mooring Hitch
  - Northnet Ropeworks Clear instruction.
  - Northnet Ropeworks Excelent Animation
- Multiple Overhand Knot. Stopper

- Munter/Italian Hitch.

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

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- The Noose.

- Nyolcas = Figure eight knot.
  - Csomók.

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Overhand knot. Stopper
  - Ropework Exelent instruction
  - insigne District award of merit van BSA. a small gif picture.
  - Library of knots. (among other drawings)
  - BRMRG Knot Primer Good Picture on mountain site

- Overhand Loop climbing knot
  - On the Climbing Knot Dictionary (Among others)

- Orvis knot A fishersknot.
  - NautBob's Fishin' Knots between 5 other knots.

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Palomar knot A fishersknot.
  - On the fisher net.
  - The fishing knots.
  - Why KNot. Fisher knots
  - NautBob's Fishin' Knots between 5 other knots.

- The Pendant-Hitch. A Knot for breas-plates and necklace's

- Pile Hitch.
  - How is the pile hitch called in other languages?

- Pizen Knot A fishersknot.
  - On flyfishing sub-page.
  - On another flyfishing sub-page.

- Pratt Knot A Tie knot

- Prussic Knot. A very important climbing knot, also written as prussik prusik prusick
  - How is the Prussick called in other languages?
  - On the Scout Association Of Australia page.
  - On the Climbing Knot Dictionary (Among others)
  - Prusik Rappel "Safety" No picture,No drawing, but a plain tekst rappel for safety.

To=>Q

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

I am still looking for a knot with a Q on the web...

To=>R

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R

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Back To

- Reefknot = Square Knot.
  - Ethicon Knot Tying Manual How Surgeons Tie the reefknot.
  - How is the Reefknot called in other languages?
  - On the Scout Association Of Australia page.
  - Website Gert Animated
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - On the yachtnet. A beautyfull but large page
  - insignes van BSA. a 32k gif immage with all BSA insignes.
  - Lehigh Samson (among other drawings with small description)
  - Library of knots. (among other drawings)
  - First Aid Book.
  - Animated KnotsRequires plugin
  - NautBob's Knots4 well known copies of knots.
  - Knots, Bends and HitchesBetween 4 other knots.
  - BRMRG Knot Primer Good Picture on mountain site

- Reverse Eight noose.

- Reversed Half Hitches

- Ringbold Hitching
  - Northnet Ropeworks Clear instruction.

- Rolling Hitch. Also called the Magnus Hitch
  - Best description on the WEB of the Rolling Hitch (probably gone...)
  - On the Scout Association Of Australia page.
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - Library of knots. (among other drawings)
  - Canoe Certificate Course Session 4 - Ropes & Lines

- Round Lashing.
  - On the Scout Association Of Australia page.

- Round Turn.
  - How is the Round Turn called in other languages?

- Round Turn and two half Hitches
  - On the Scout Association Of Australia page.
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - On the yachtnet. Beautyfull but large page.
  - Animated Knots Requires plugin

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- Scaffold Knot.A Noose.
  - The fishing knots.Drawn as double marline.

- Sheep Shank.
  - On the Scout Association Of Australia page.
  - Website GertAnimated
  - Picture from http://genius.tttk.bme.hu/MuszPed/Cserk/hir1.htmlA moving gif-picture from a hongarian page. Probaly gone..

- Sheetbend.
  -
  - On the Scout Association Of Australia page.
  - On the yachtnet = Beautyfull but large page
  - climbing knot Among others in the Climbing Knot Dictionary
  - Lehigh Samson (among other drawings with small description
  - Library of knots. (among other drawings)
  - Website GertAnimated
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - Animated Knots Requires plugin
  - Canoe Certificate Course Session 4 - Ropes & Lines
  - NautBob's Knots 4 well known copies of knots.
  - Northnet Ropeworks Clear instruction.

- (Tucked) Sheetbend.

- The fishing knots.

- Single Hitch

- Simple Noose.

- Snelling Knot.
  - The fishing knots.Snelling a hook
  - Fisherman's Knots A page on 7 knots

- Spanish Windlass
  - Northnet Ropeworks Clear instruction.

- Spider hitch.A fishing knot
  - Why KNot. Fisher knots

- Square Lashing.
  - Ropework Exelent instruction
  - On the Scout Association Of Australia page.

- Square Knot = Reef Knot.

- Strangle Knot.

- Strangle-snare.

- Srugeon Knot.(Realy used by surgeons!)
  - USSC Sutures -- Knot Tying -- TOC Best site on the Surgeon Knot.(How can I

improve this??)

- Ethicon Knot Tying Manual How surgeons tie it..
- Lehigh Samson (among other drawings with small description)
- The fishing knots.
- Why KNot. Fisher knots

- Srugeon End Loop.
  - The fishing knots.

- The Swivel Knot.For attatching a swivel to a fishline.
  - The fishing knots.

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- Takács~ = Reefknot = Square Knot.
  - Csomók.

- Tape KnotClimbing knot
  - On the Climbing Knot Dictionary (Among others)

- The Tautline Hitch Alse called the Midshipmans Hitch
  - Animated Knots Requires plugin
  - Northnet Ropeworks Clear instruction.

- The Thief knot
  - 42nd Brighton (Saltdean) Scout Group, UKAnimated

- Timber Hitch.
  - How is the Timber Hitch called in other languages?
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  - 42nd Brighton (Saltdean) Scout Group, UKAnimated
  - Lehigh Samson (among other drawings with small description)
  - Library of knots. (among other drawings)
  - Animated Knots Requires plugin

- Toldó1~ = Carrick Bend. The nearest thing er have to the perfect bend. Also called the Josephine Knot when used in macrame.

- Csomók.

- The Transom knot A perfect cross knot for your kite.

- True Lovers = Fisherman's knot/bend

- Trilene KnotA fishersknot.
  - NautBob's Fishin' Knots between 5 other knots.

- Truckers Hitch
  - Canoe Certificate Course Session 4 - Ropes & Lines

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- TRIPOD LASHING
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- Two Half Hitches
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  - How is the Water Knot called in other languages?
  - BRMRG Knot Primer Good Picture on mountain site

- What Knot A trick knot.

- The Weaver-EightThe waevers 'heavline knot'.

  The best weavers knot I know.

- The Weaver Knot The waevers 'sheetbend'.

  The most common weavers knot.

- Whipping.
  - How is the Whipping called in other languages?
  - On the Scout Association Of Australia page.
  - Northnet Ropeworks Clear instruction.

- Woggle.
  - 41 steps over 4 pages. Clear instructions on how te make a woggle.

- Windsor Knot
  - A way to tye your tie. A page with four Tie knots
  - Hoe knoop je je stropdas. Een Nederlandse Stropdas pagina.

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- Yosemite Bowline.
  - On a caving page. Link probaly lost...

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- Zászló~ = Sheetbend.
  - Csomók.

- Zeplin knot. by exident also called the Hunters bend
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Stoppers ( )

Knots on the end.

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Knots on the end of a rope or yarn. There are a lot of situations where you need a knot like this. Every application has its own special demands for knot properties. So you have to choose carefully. You can use a stopper to prevent a rope or yarn from unfolding, but please do that only in cheap rope/yarn. Use a proper whipping in all other cases.

The Overhand Knot

The Overhand Knot or Half Knot

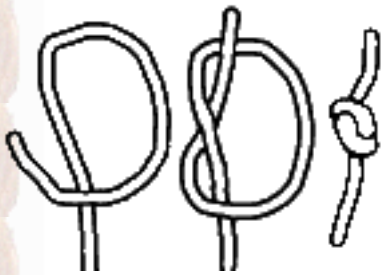

This is the simplest knot. Therefore probably the most used. The knot is very useful to support knots in yarns. The loose ends become a bit thicker. When this support makes the total bend too bulky you have to look for another bend. The overhand knot is not strong, so it is not used in situations where you might expect great force. It also reduces the strength of the rope or yarn by about 50%. But as an "anti-slip-knot" it does not have to withstand a lot.

This knot on the WEB.

The Double Overhandknot

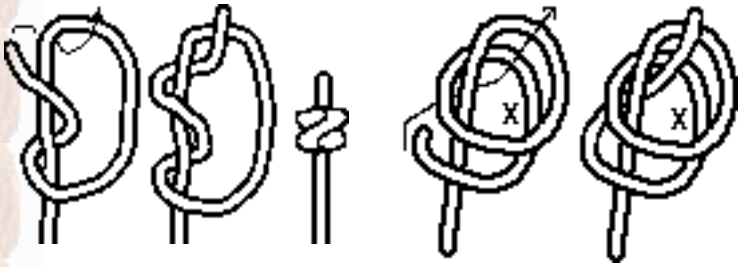

The double overhand knot is beautiful, thicker than the common overhand knot, but not any stronger. But use it with caution. The double overhand knot is also called the bloodknot when it is used at the end of a whip. This knot has several ways of tying and in principle two ways of working up. Both ways of tying shown here also show both results. The bloodknot shown in the middle is the preferred way of working up the second way of tying marked with the crosses. The bloodknot is very hard to untie after it has been under stress. If you put an object through the cross-marked hole the knot will work up as the strangleknot. It is usefull to practice this way.

This knot on the WEB.

the Multifold-Overhand-knot

If you make more than two turns in the overhand knot it wil be fatter. (But hardly stronger.) In twined rope it is important to work up the knot very carefully. (It will not only look neater, it wil prevent 'kinking' which will weaken the rope even more!)
This knot on the WEB.

The (Flemish) Eight

This knot is larger, stronger and more easy to untie than the overhand knot. It does not harm your rope as much as the overhand knot does. So therefore sailors use this knot in most cases. (! not for bend support, where the smaller overhand is used, or in rope, a permanent small stopper)
This knot on the WEB.

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Bends ( )

To 'unite' two ropes.

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The reef-knot

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The reef-knot is only useful in simple applications. Ashley says "it is a true Binder Knot, for which it is admirable, but under no circumstances should it be used as a bend." It is easy tied and will not jam, so it is always easy to untie. It is used to tie packages, and as a base for he shoe-bow. Sailors used it for binding rolled sails or better reefed sails. And that is where it got its english name from. Americans call it the square knot. Probably because it looks square, or because it was much used on square-rigged-ships, but that is a total guess of me.
Its relatives, the granny, the thief-knot and the what-knot all have their purposes, but not as a trustful knot.
For more information on the reef-knot-family you may visit the Reef-knot Family.

The Sheet Bend

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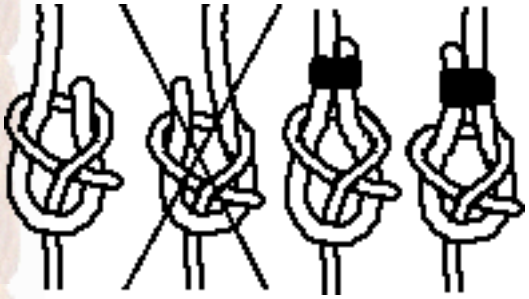

The sheet bend is my favorite bend. Be careful. With the loose end on the wrong side you have an other, weaker knot (Left-hand sheetbend). If the knot is well seized it does not matter if it is tied right or left handed
For more information on the reef-knot-family you may visit the Sheetbend Family.

The Carrick Bend / The Josephine Knot

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Also known as Full carrick Bend, Sailor's Knot and Anchor Bend. Beware! There are not many knots with so much wrong drawings as this bend. The ends have to be on opposite sites and the crossings always are alternating up/down/up/down... The Carrick Bend is one of the best knots. Ashley states it is possible the nearest thing we have to a perfect bend. It does not easily slip, not even if the rope is wet. And it is always easy to untie, also after a heavy load. If used as a Hawser bend in heavy material it is always seized and parceled to save wear.

The Josephine Knot

In the Macrame this knot is called the Josephine Knot. It is self evident the Josephine knot is not seized nor pulled tight.

The True Lovers or Fishermans's Knot

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The True Lovers, or Fisherman's Knot may be laid in two different ways. Which of both the is the stronger, I do not know.
With two equal overhandknots it is symmetrical. This is probably the most used variant.

With two different overhand knots you get the most beautiful version (always work it up neatly!)
Only ... The double eight is stronger, easier to untie after use and as decorative from all sides as the true lovers at best.

The Weavers-Eight

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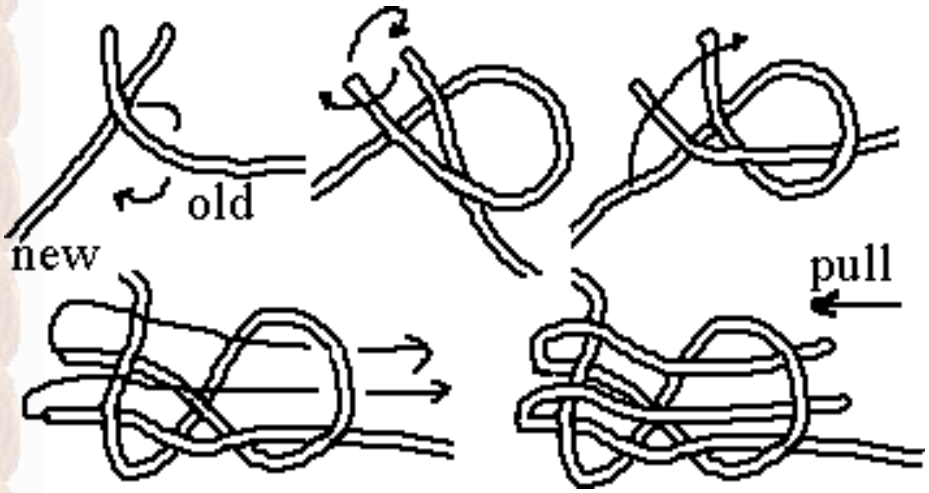

This is the best weaver knot I know. Although it looks difficult to tie, it is actually very easy. Fast to tie with small material, and reliable for wool, linen and most other weaver materials. Because both loose ends fall back over the standing part, it has an almost perfect lead.
Hold both threads together on the crossing between your thumb and finger. (first drawing)
Twist both threads together while you hold the cross in two simple movements. (first/Second

drawing)
Now, you pull over the standing part of the line you tie on, (third drawing)
And put both loose ends over the line you tie on through the loop you just created.
Now let loose the cross and hold the loose ends fixed to the standing part of the line you tie with and pull the knot tight.
This knot is related with The (Flemish) Eight. You can observe this by removing the thread you tied the knot with, leaving the thread you tied the knot on unchanged. If you have difficulties in learning this knot, you can start by practicing the flemish eight in the thread you want to tie on, using an imaginary thread to tie with.

For the other direction

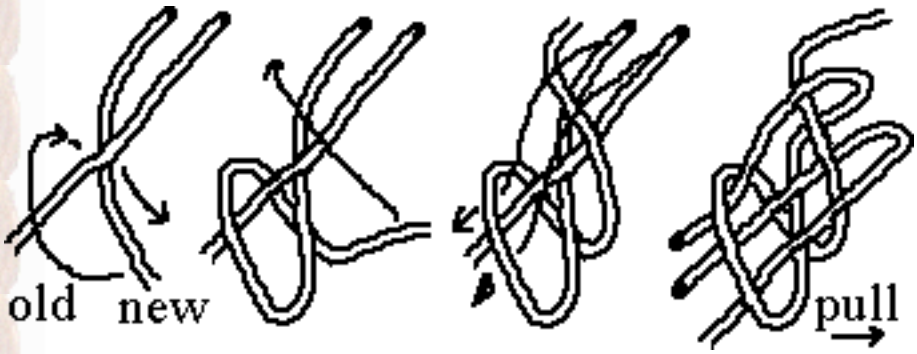

A weaver on a traditional weaving loom never knows in advance in what direction the next line has to be tied. Therefore he has to know two ways of tying the weaver knot. One for each direction. This is the same Weavers-Eight but tied different. Tied this way the knot points to the other direction.

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Forward To Hitches

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The Bends

Hitches ( )

Knots to tie a rope on ... something.

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'Elementery' Hitches

In this table you find the most elementary hitches. The hitches in each column are closely related. The top hitch is tied round a pole or other object. I will refer to them as primary-elementary Hitches. The hitches there under are 'the same' but tied round the standing part of the rope. I will refer to them as secondary-elementary Hitches. But beware, the application of the variants are very different. The primary-elementary Hitches will spill if the object is removed. The secondary-elementary hitches will not. Some of the secondary-elementary hitches are 'capsized' bindery knots. As for all knots working the knot well is for these knots extremely important. Work it wrong and you might end up with another (probably unwanted) knot. For example, capsizing the two half hitches might end up in a granny knot, one of the worst of all knots. On the other hand if you know what you are doing, you might tie the wrong knot on purpose and capsize it to the hitch you want. Take care!

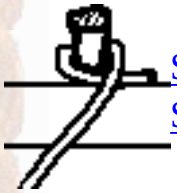
Single Simple

Clove

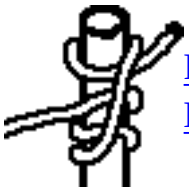
Rolling Magnus

Cow

Half

Two Half

Midshipmans Tautline

Reversed Half

Buntline

Adjustable Jamming

Lobster Buoy

The Single Hitch

(also called **The Simple Hitch**)

Although this is probably the simplest knot of all, you have to be a skilled knot-tyer to know how to tye and use it in a safe way. The loose end of the rope is nipped against the object and the standing part. The best nip is obtained against an edge or shoulder. If the load is released and the standing part shaken, the hitch is spilled instantly.

It is used to attatch rope to a belay-pin, a weaver needle or even to a tree branch, to start belaying, to start winding or as a temporary easy to spill made-fast.
The Single Hitch on the WEB.

The Half Hitch

This is the capsized overhand knot. It is very useful to carry light loads which have to be removed easily. Ashley recommends it to use it for hanging store to out of reach for mice. It should not be disturbed.
The Half Hitch on the WEB.

The Clove Hitch

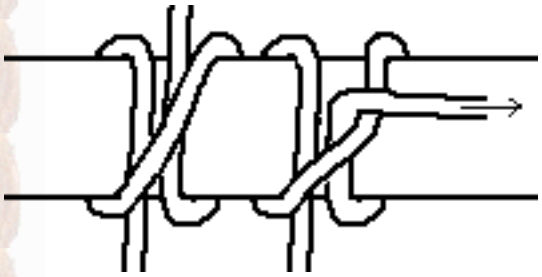

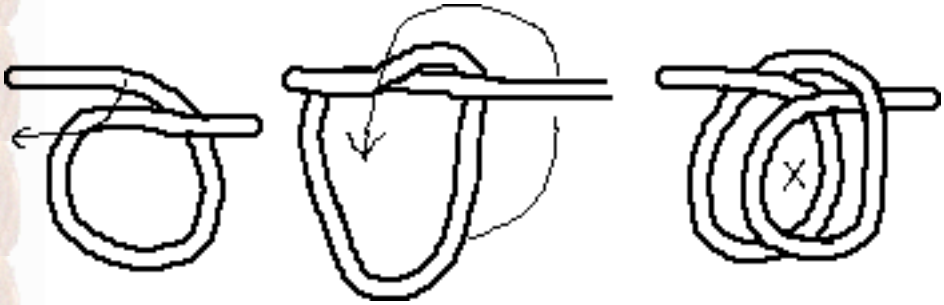

This is a very important knot of only theoretical value. Without extra support, it is untrustworthy in any situation, except as a crossing knot. You have to learn it for scouting and at sailing schools. If you have to use it, work it up properly; pull length-wise only at both ends before you load the working end. It is better to use The Rolling Hitch instead.
The Clove Hitch on the WEB.

Two Half Hitches

The two half hitches is used for tieing a rope with a right-angle pull to a pole or ring. It should be constant under load. (Not under constant load). It does not jam. If the object you tye it on has a small diameter it is better to use the "Round Turn with Two Half Hitches". This is the same knot but with an extra turn round the object.
The Two Half Hitches on the WEB.

Buntline Hitch

The Buntline Hitch is (was) used to tie a buntline to a square sail. It is a secure knot, but it tends to jam, so it is not easy to untie. Therefore, it is useful for work that will be left unattended for longer periods, since it will not untie suddenly.
The Buntline Hitch on the WEB.

The Rolling Hitch or Magnus and Magner's Hitch

The best simple hitch for lengthwise pull. It needs to be laid very carefully and pulled firmly before loading. Never use it for right angle pull, for it will spill.
The Rolling Hitch on the WEB.

Midshipmans Hitch Or Tautline Hitch

This is a remarkably useful knot. It is adjustable AND trustworthy.
Each sailor should know how to tye this knot in any circumstance. Especially to tye himself to a rescue rope thrown to him in the water. On the lifeline he has to hold the loose end securely to the standing part. This gives a good grip and a useful goal in this critical situation (HOLD!)
Anyone who uses a tent should know this knot. It is the best way to adjust your lines to the tent-poles.
It is the most simple of the adjustable knot family.
The Tautline Hitch on the WEB.

Adjusible or Jamming Hitch

This brother of the midshipmans Hitch is just a bit less important. This is because it tends to jam. When jamming is desirable, this knot is o.k., as when work will be left unattended. Ashley states it was used by cotton brokers in New Bedford to tye their cotton samples they took from mill to mill. The packages could be opened and closed at will, and still be secure when left alone at travel.
The Adjusible or Jamming Hitch on the WEB.

The Cow Hitch

This hitch is really useful for tieing a cow to a pole so it can graze round it. I myself would add an overhand knot at the loose end as a stopper. But I am not a farmer. Sailors use it to secure a lanyard to a shroud.
The Cow Hitch on the WEB.

Reversed Half Hitches

This knot is used to tye guy-ropes to tent-poles. But is is inferior to the Tautline Hitch The only reason I have included it in the elementary hitches is because its topology places it there. I see no use for it. (Please let me know if you know an application where this knot is the best knot to use.) A keen eye will recognize a capsized Reefknot in it.
The Reversed Half Hitches on the WEB.

Lobster Buoy Hitch

The Lobster Buoy Hitch is almost as secure as the Buntline Hitch, but more easy to untie. It is used to tie timber.
The Reversed Half Hitches on the WEB.

Marline Hitch or Single Hitch

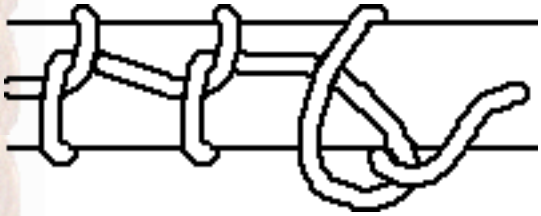

This hitch is very practical to lash long objects. The working end needs only one tug and will not slip easy. Before the 'tiewrap' (or how are they called) this hitch was used by electrical engineers to tye 'wiring-trees' A row marlshitches is best started en ended with a double marlshitch.

The Marline Hitch on the WEB.

The Strangle Knot or Double Marline Hitch

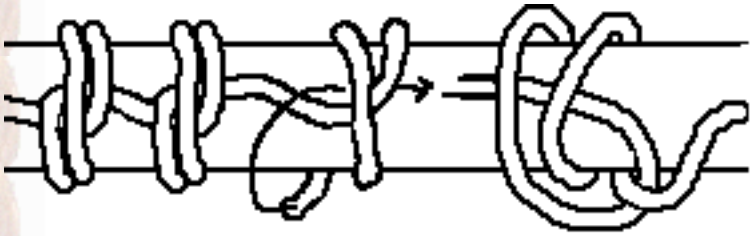

The strangle knot is important as temporary whiping and as permanent binding from which you need more in line. Laid well it is virtually impossible to untie without tools (needle or knife). So never use it if you need to untie. Used as marlhitch it is best used as first and last in a row. Or when a row becomes 'dangerously' long this hitch is used as ensurance between shorter rows.
Be careful!. Tied in this way the working end (or the bundle) needs only one tug, but it is not enoug to pull once, it needs to be worked up properly!
The Strangle Knot on the WEB.

The Constrictor Hitch

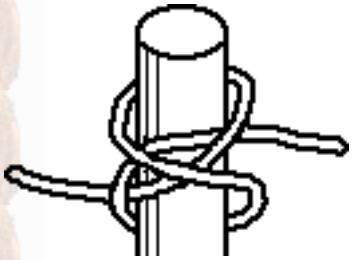

The constrictor knot is important as temporary whipping and as permanent binding from which you need more than one in a row, but not in line (when you should use the strangle knot). Laid well, it is virtually impossible to untie without tools (needle or knife). Never use it if you need to untie it. It is almost the strongest among the 'simple' hitches. Only the double constrictor is stronger. Because the constrictor may be tied in a bight, it is often preferred over the strangle knot.
For more information on the constrictor-knot-family you may visit the Constrictor-knot Family.

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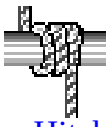
The Hitches

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Single loops ( )

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The Bowline

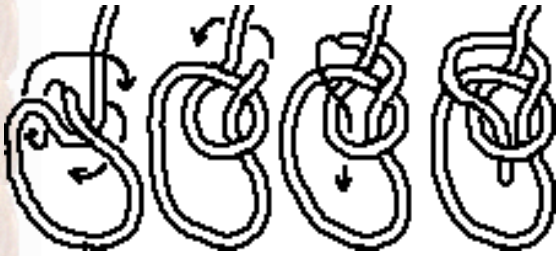

The Bowline Knot is one of the most used loop knots. This variant is most used in the world. Probably due to its simplicity, security, and its relationship with the Sheet bend. Keep the cross point in step A between a finger and thumb and make a clock-wise turn with your wrist. Without the loop in between, it is the same knot.
If the loop is expected to be heavily loaded, the bowline is, in fact, not secure enough. There is a rule of thumb which states that the loose end should be as long as 12 times the circumference for the sake of safety.

The Bowline
"Lay the bight to make a hole
Then under the back and around the pole
Over the top and thru the eye
Cinch it tight and let it lie"

The Dutch Marine Bowline / or The Cowboy Bowline

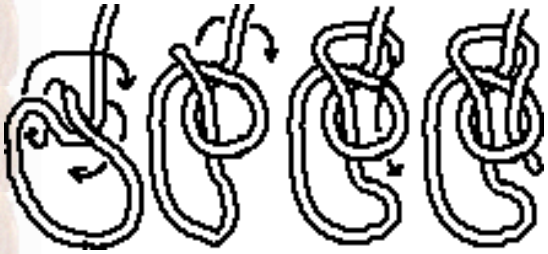

The Dutch Navy uses this variant of the bowline. And, of course, the Dutch sailor says this one is superior. The working end is not so easy pushed back by accident, they say. I think it is just a difference in culture.
There is a rule of thumb which states that the loose end should be as long as 12 times the circumference for the sake of safety.

Double Figure-of-eight loop.

The double eight is a knot used by climbers. It is easy to tie and safer as the bowline. There is a discussion whether there should be a stopper at the end of the loose end or not. Speed of (un)tying is a safety factor itself.
The first way of tying is equal to the way of tying the flamish eight, but now in a double rope. The 'loose-end' is the loop. This way is only applicable when the loop is 'empty' during tying.

If the loop is to be tied round something (round "your waist" for instance) you first tie an eight then lay the loop and double the eight. It is important to have enough rope for the loop. It requires experience, so start practicing.
The Double Figure-of-eight loop on the WEB.

The Bowstring Knot

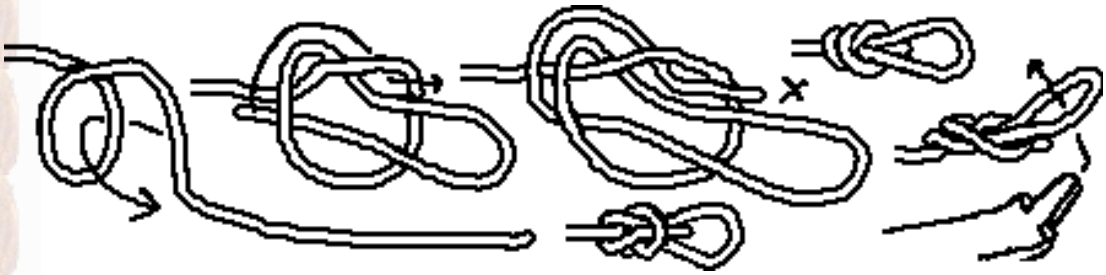

The Bowstring Knot is an ancient knot that is used as an eye for bowstrings. The knot is simple and strong. Once tied and pulled firmly, you do not want to untie it: you might call it a good 'tie-once' loop knot.
The bowstring knot is appreciated because it is small, strong, secure, and easy to tie. It's neat because it does not have loose ends.
Modern archers prefer fixed spliced loops.
If the loose (cross marked) end is not secured within the loop between the bow and loop, it is wise to add a small overhand knot as stopper.
The Bowstring Knot on the WEB.

The Tucked Double Overhand

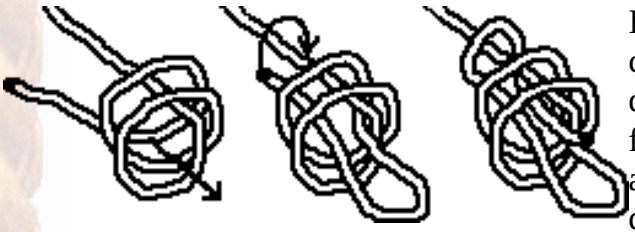

If you need a good looking and strong loop this is a good candidate. The Loose end must be at least two to three rope diameters long. But if you make the loose end inflexible with for instance glue, resch or by melting and you can hide it almost completely inside the two round turns. The "tucked double overhand" is a permanent loop. It jams badly, but that´s what it is made for.

The Butterfly or Lineman's Loop

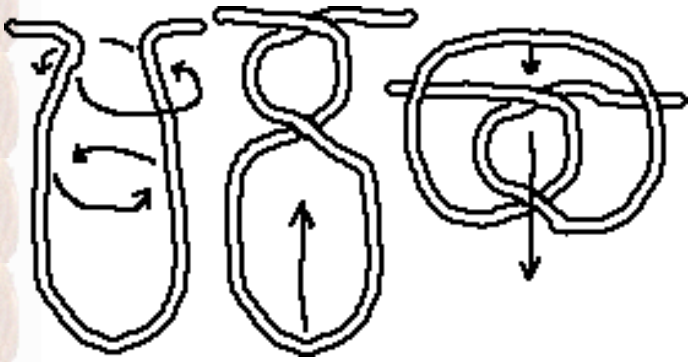

An excellent easy to tie loop for applications needing a loop in another place than the rope-end, but somewhere in the middle. It has an excellent lead, and is secure even if the forces on both ends are stronger than the load in the loop.
The Butterfly loop on the WEB.

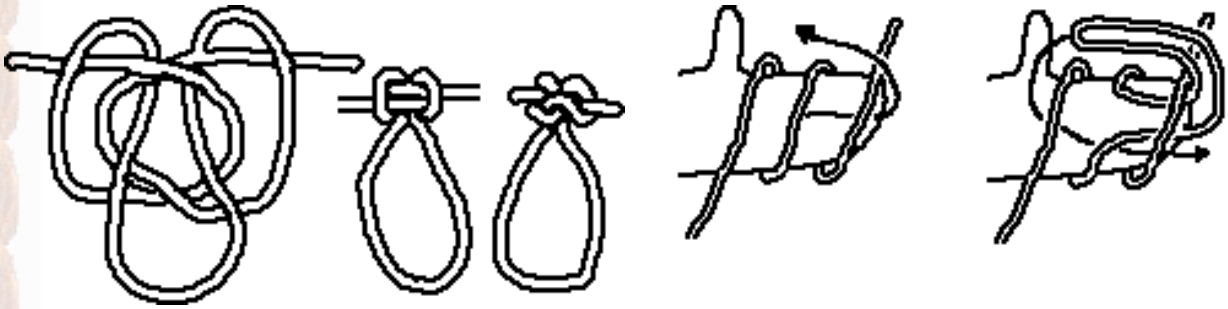

The Artillery Loop

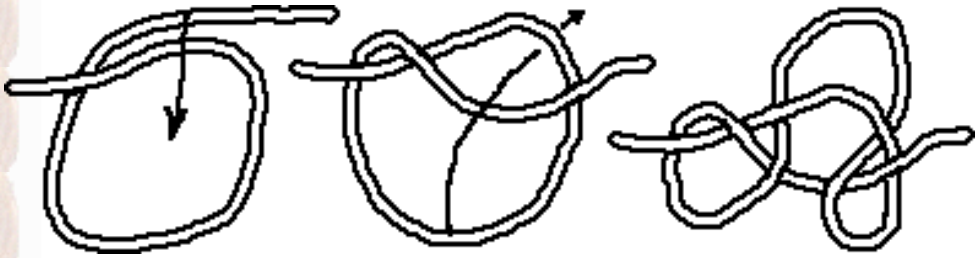

A practical and easy to tie loop for applications needing a loop in another place than the rope-end but somewhere in the middle. It is not as strong as the butterfly but is a bit faster to tie and untie. As the name already suggests it was used by the artillery (for carrying their guns over the shoulder.) Do not pull the rope too hard when the loop is not loaded. It is best used as temporary knot for carrying things. As always, work up the knot neatly!
The Artillery loop on the WEB.

The Pendant Hitch

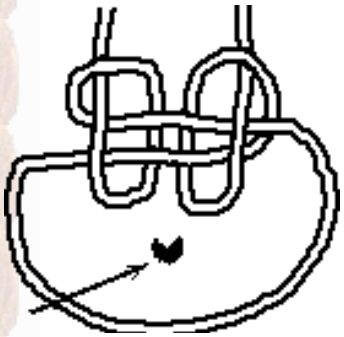

A hitch to tie a pebble or a breastplate to a necklace. You have to make sure the object is secured in the loop. If you use a loop (this loop) to tie a pebble or other nice stone to a neck loop without extra (visible) support it is wise to use a leather neck loop. Make a cut in the length of the inside of the loop. Not too deep; it is only to roughen the surface to improve the grip of the knot. And last but not least..... use a good shoemakers glue. The result is surprising.
The pendant hitch is closely related to the The True Lovers or Fisherman's Knot.

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All mail without thr right subject is flussed unred. automaticly.
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The Noose

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The Loops

The Noose ( )

Nooses, snares and lasso's.

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Ropers Knot Page

The Noose in General

WARNING!! The noose is not a knot to play hangman with. Too many accidents already killed children who thought they could release it in time. Even not strong pulled nooses can be dangerous round your neck.

There are three basic ways to make a noose. The first way is running the 'tail' of rope through a fixed loop on the end of that same rope. This may be a spliced-loop or a knotted-loop like the bowline. (In fact the bowline is used very often as the running loop by sailors.) The simple noose itself is used as a running knot for swift running loops.

The second way to make a noose is to tie a running knot (a simple knot or hitch) round the standing part of the rope in a way that pulling on the knot-side closes the loop. This is the most common way for making nooses. It makes the loop to close almost as easy as a noose using a fixed loop as a running knot.

The third way is to tie a running knot in a way that pulling the knot is opening the loop. I only know one practical application for this way of tieing this noose: for tying the rope to a yo yo, with the eight as running knot. But in packing bags and loads you will find it sometimes as an intermediate loop. It is also often the result of tying the running knot the wrong way.
The noose on the WEB.

The Simple Noose

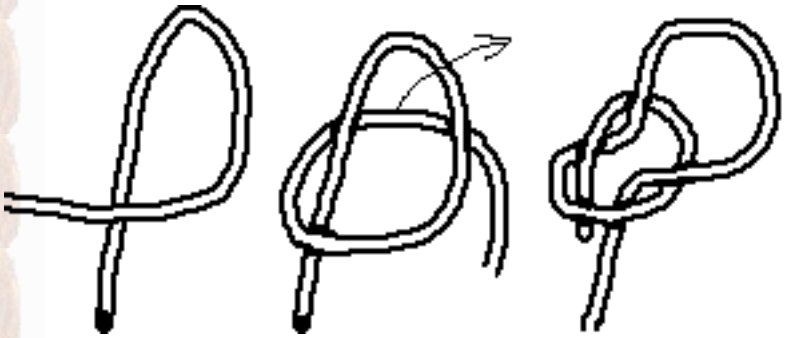

This is the simplest of the nooses. Its used mostly as a base for further work. It is a close relative of the overhand-knot and the Marline Hitch or Single Hitch If used as noose it is best to add an overhand-knot in the end. This noose is used as a poor snare for catching small birds.
The noose on the WEB.

The Strangle-Snare

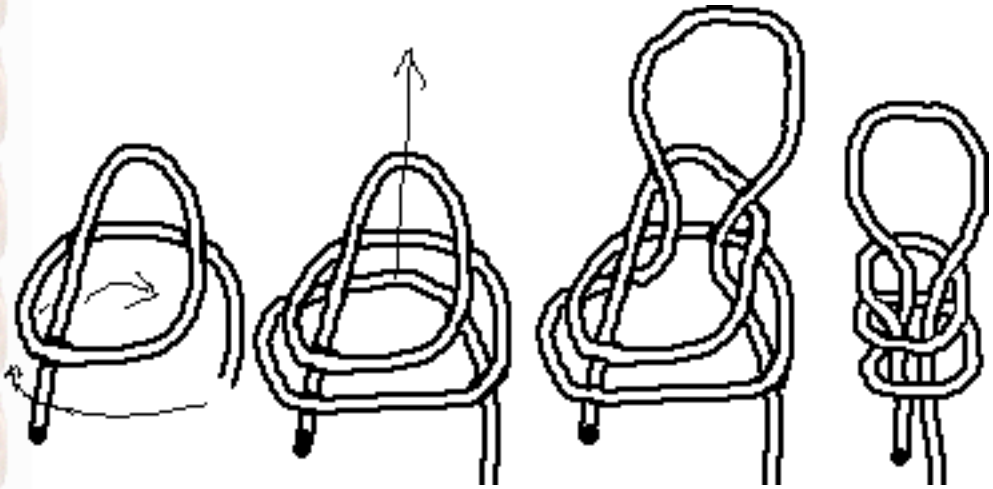

The strangle-knot is an excellent knot to be used a running knot for a snare. The pull is easy adjustable. The more force is applied from inside the loop the more firmly the running knot prevents opening of the loop.
The Strangle-Snare on the WEB.

The Scaffold knot or Gallows Knot.

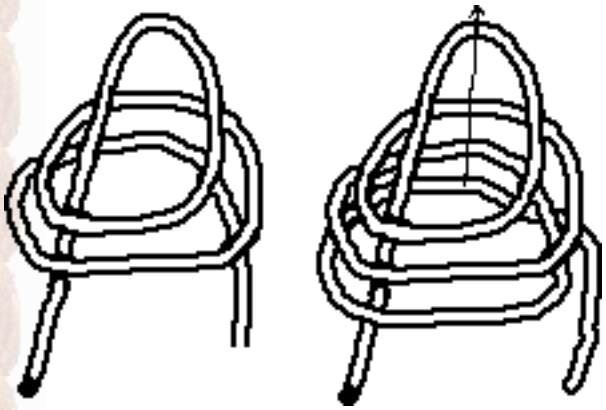

The third noose is based on the the Multifold-Overhand-knot. As its second name already suggests it has a dark history.
It is also used as a knot to tie angling-rods to fishline.

Never play hangman. It can really kill.
The Scaffold knot or Gallows Knot the WEB.

The Hangman's Knot.

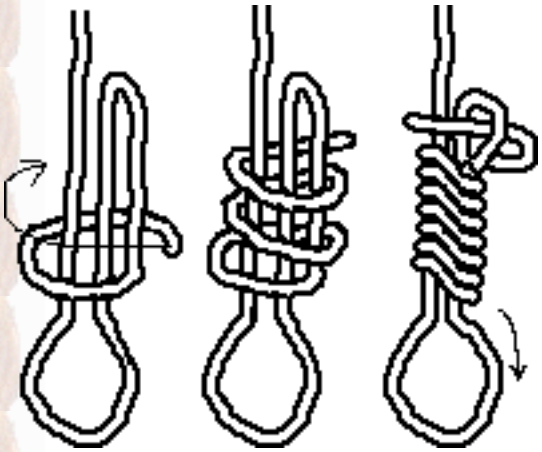

This knot is used for the gallows-tree as well. The force to close it is adjusted better than with the gallows knot. And because it is bigger in the neck it is believed to break the neck more easy. That would make it more mercy-full as the gallows-knot which kills by strangeling.
The Hangman is also used as a knot to tie angles to fishline.

Never play hangman. It can really kill.
The Hangman's Knot the WEB.

The Reverse Eight-noose.

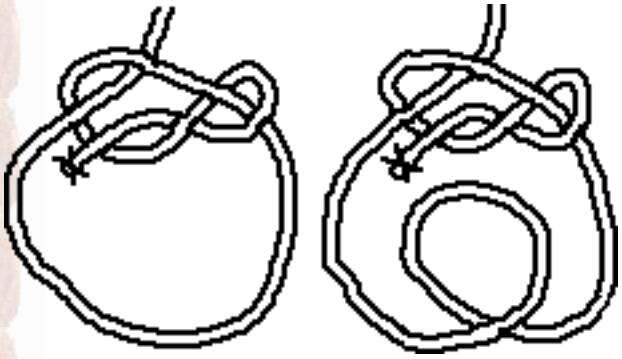

This is (so far) the only 'wrong' running noose I know applications for. It to tie a package and ... for tieing YoYo's. Experts use one loop to make it possible to let the yoyo spin on the end and to call it up with a little firm pull. The yoyo has to spin fast and the noose has to be trimmed carefully.
Starters use two loops and tie it firmly.
Use eventually an overhand-knot on the cross-marked ends.
(This is not the best way to fasten your YoYo. If you want to use the best thechnique you have to un-twine a line with two yarns and re-twine one of the yarns by doubling it with the YoYo in the middle. Free-spinning the YoYo my wear out the loop.) The Reverse Eight-noose the WEB.

Any comment, suggestions, anything mail me: ***qqqq at realknots.com*** *with subject "**question**"*
All mail without thr right subject is flussed unred. automaticly.
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FAK

frequently Asked Knots.

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Following knots were asked for very often last year. For frequently asked questions on knots also try: rec.crafts.knots FAQ
This page is more or less made to publish these "FAQ-knots" so I can add them in the knot index.

The Monkey Fist

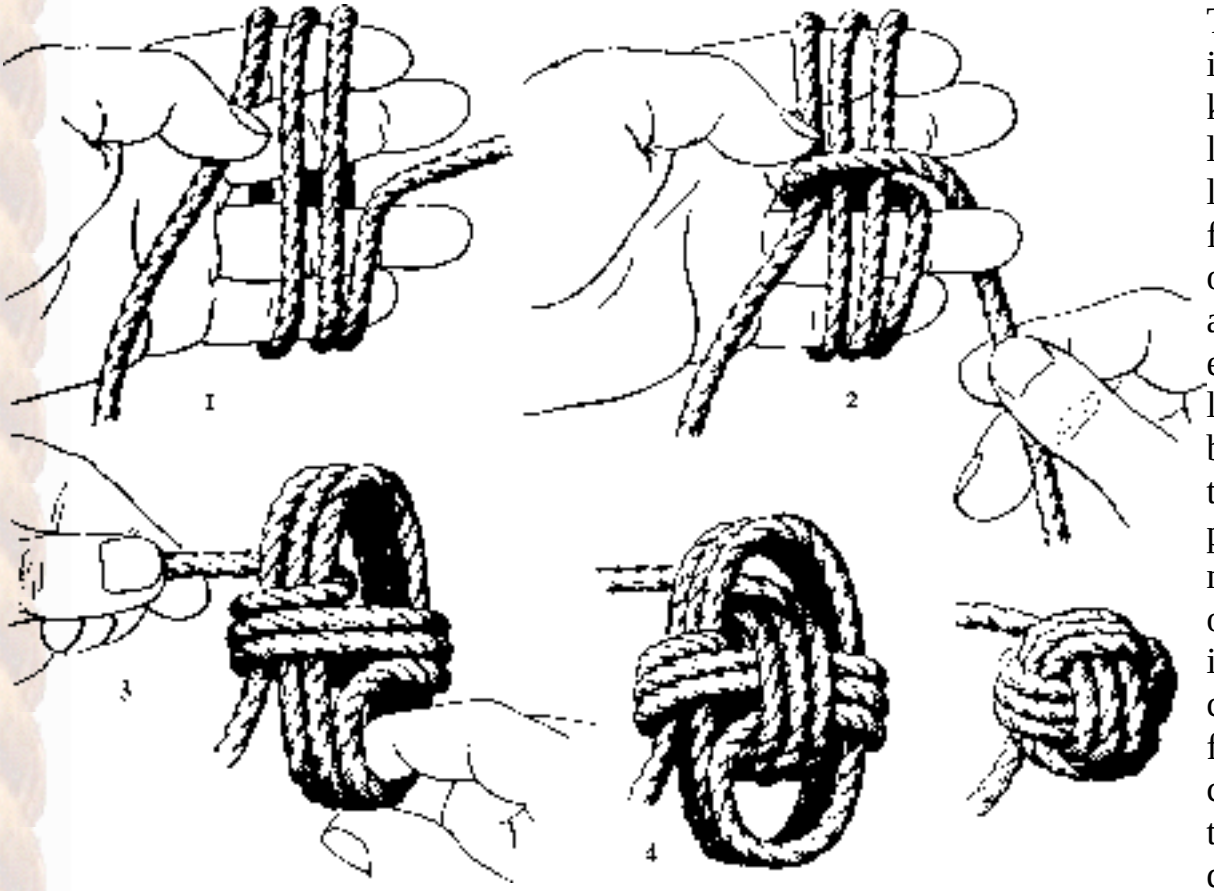

The Monkey Fist is used as an end knot for a heaving line. A heaving line is a line used for throwing from one location to another. This enables a larger line that could not be thrown over the distance to be pulled over. The most common use of a heaving line is at sea, to pull a cable to shore from a ship. A cable is not easily thrown over a distance of 10m [ft]or more, so instead one throws a heaving line. The line is tied to the cable and when it has been received the cable can then be pulled over. To make it easier to throw one needs to connect a weight on the end of the line - usually a stone, lead-ball or a small bag of sand is connected to the end. Better still a small rope ball is tied on the end. It is neat, it will endure many tosses last long and it is easily thrown. That is what the monkey fist is was originally used for. Now it is also used as fancy knot for key-rings, necklaces and so on. The knot can be done with or without a central

core (i.e. a round stone or ball bearing) to add extra weight but it is recommended to use extra loops depending on the size of the object.

The instruction drawing is made by Hervey Garrett Smith and copied from the dutch translation of his book **"The Marlinespike Sailor".** I got permission of "International Marine/Ragged Mountain Press" to use the instruction drawing on my site.
(I got 3 to 5 requests a week for this knot. That is why I am sure it is most wanted.)

The Dolly

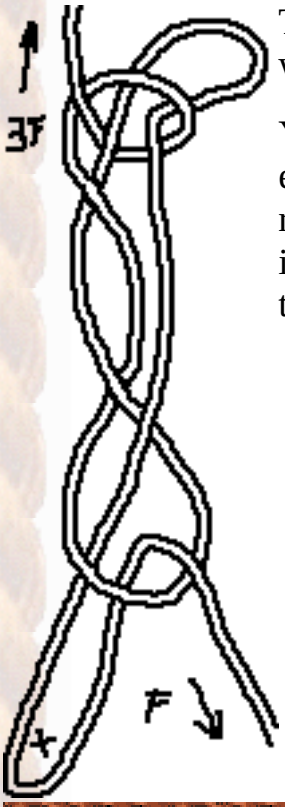

This is probably the most famous truckers knot. I never realized it was so wanted. I got 2 to 4 requests per month for it.

You need to hook in the cross marked place. The force F you apply at the loose end is multiplied by (almost) 3 on the standing part. You may say it is only a rope tackle. Beware, it wears out your precious rope fast, so if you use it often it is wise to use a form of protection in the bight where the loose end is pulled through. A folded paper will do, a smooth piece of leather is much better.

I do not have experience with this knot myself. But I have been told it will hold as long as the force is applied. And because that is also the case with its closest relative, the sheep shank, I think it will.

Any comment, suggestions, anything mail me: ***qqqq at realknots.com*** *with subject "**question**"*
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Ropers Knots Page

The knot site on real knots in rope.

What are the recent changes of the Roper Site ??

The Web Knot index

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

The Roper's Knot Pages

Ropers Knot Page The English 'root' of this knot-site.

Touwslagers knopen pagina De Nederlandse 'root' van deze site.

The WEB's Knot Index (All the knots I found on the web)

Books on Knots on the Web

Reverse Links Links To Pages with links to Roper's

Page's

International Guild Of Knot Tyers

The International Guild of Knot Tyers

Texas Branch

North American Branch

Other Knot (link) pages.

Klabautermann Knotentafel

Frequently Asked Questions

Knot KnowledgePhoto-Illustrations

Knot Knotes Great site, Knots and links.

Knots on the Web (Peter Suber) An other (GOOD) site. Differently orderd than this one.

The Art of Knot Tying

RopeCraft

The Argus Clearinghouse Knots (vanity) Peter and me.

Knot Tying Resources

FUN WITH KNOTS

Knopar på svenska och engelska

Knots in Rope

FM 5-125, Rigging Great site, but o so large, Not always "on line".

Get Knotted! Animated Knots for Scouts 42nd BRIGHTON (Saltdean)

Six Exploding Knots. Fast untieing slipknots.

Some useful knots mpeg! 4 'movies' three ok, the sheetbend wrong.

Lehigh Samson (among other drawings with small description)

S.A.Kids knots Requires netscape 3.0 with plugin.

Ropeworks Clear instructions, A sample taste of a book.

Marlinspike Knot of the Month A new knot each month

The BRMRG knot review

Josella's 2. HomePage A few great knot pictures.

Välkommen till Monicas Hemsida Knopar och Macrame. 4 great pictures.

Marlinspike Knot of the Month Animated. b u t s__l__o__w.

Programs Knots Examples of knot instruction programs.

Knot Some nice drawn interweaved knots.

Troop 480 knots Lots of Knots, indexed by name an use.

Sailing

Baidarka Instruction Manual Halfway the document a pipe lashing.

Nós de Marinheiro

Marine news: Knots 7 sailors knot

Boating knots 4 essential well known knots.

Scouting

Australian Scouts- Index of Knots

Index to Troop 24 Graphic Images

Canoe Certificate Course Redcliffe Scout District

Knots, Bends and Hitches Instruction on 4 knots.

Knots From a BSA group

Canoe Certificate Course session 4, Ropes and Lines

Fishing

Fishing Knots A great sample of important knots.

Useful Knots.

Dave Whitlock-- Knots: Putting it All Together

Fishing Knots Grant's Guide - by Ern Grant

Fishing In Early Medieval Times A bit of history.

Knots Good fish knots

Climbing And Caving

The Alpine Butterfly With an animated gif

The Prusik Knot

Caving Knots [More Like This]

Math.

The KnotPlot Site An entry to wonderfull pictures.

Tie me up, tie me down Great site.

Knots and Braids (and) Links a math index to other sites

The Knot Square

Knot--from Eric Weisstein's World of Mathematics

Pictures from knots and links

Math art gallery

A math page

Flaming Pear:Products:KnotAdvertizing page for a knotdrawing program

Design Any Knot from DNA A trefoil knot

Celtic Knots

Celtic Knot Construction#1

Computer Drawn Celtic Knotwork

Celtic Knot Puzzle This knot's not right, fix it!

Celtic Design Series A Home page on Celtic knots.

Celtic Knots A Celtic Knot Home Page.

Knot Art

Chineese Knotting Some Fancy knots

No Title Some Artistic knots

Not Knot A light sculpture by Scott Kim

Fair Winds design Woven Jewelry - Turksheads - Celtic Knots

Hand-crafted Knot Jewelry: Decorative Marlingspike Seamanship.

Art of Braiding Beautiful pictures of braiding work.

Poetry

Single Carrick Bend A poem on this famous knot.

The Tie

Marvin Minsky Rope Tie How to Tie A Tie

MBA Style magazine Realy a Tie of rope

The world headquarters for ties...X

Tie Yourself in Knots More than only tie knots.

Div.

Forensic Knot Analysis

The Sword Knot Collection

Gimp YES! a site on fancy knotting!!

Amaze Your Frends A 'magic' trick

Teach yourself knots and splices. A 60 minutes video.

Riggers Page

Splicing a Rope on a 30 hour Longcase Clock Splicing woven rope

How to Count Rug Knots.... Tapis/carpet knots

Types of Knots

The ins and outs of shoelace tying!

The Better Bow

Ian Fieggen's Site: How to tie an "Ian Knot"

About knots.(texts)

Knot So Fast. A proposal for regulating the world knot tying speed record.

Knots, Bends, and Hitches A great tekst on knots.

Knot Shops

MARLINESPIKE, LTD

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Knots&Splices I can not beat this excellent list!

Series on Knots and Everything is a book series polarized around the theory of knots.

Celtci Bibbliography

The Ashley Book of Knots

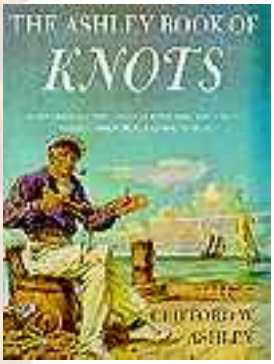

By: Clifford W. Ashley

Publisher: Faber and Faber, London & Boston.

ISBN: 0-385-04025-4

The book on knots. About 3800 different knots, 7000 drawings. It covers almost every practical knot and gives clear instructions on how to tie them. It gives some history from the knots and tells you where the author found them.

The Basic Essentials of KNOTS FOR THE OUTDOORS

By: Cliff Jacobson

Publisher: ICS Books

Online Sports
Mountain Zone Bookstore

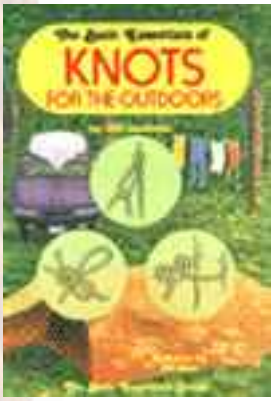

ISBN: 0-934802-57-2

Is unusual, if not unique, in having knot-tying instructions for lefthanders as well as righthanders. Table Of Contents

The Book of Outdoor Knots

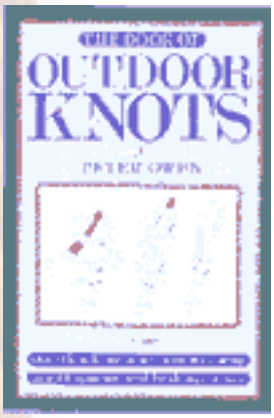

By: Owen, Peter

Publisher: Lyons & Burford

Mountain Zone Bookstore
The Adventurous Traveler Bookstore

ISBN: 1-55821-225-6

This book illustrates in a simple handbook format seventy of the most common knots for the outdoors. Table Of Contents

Celtic Ropework

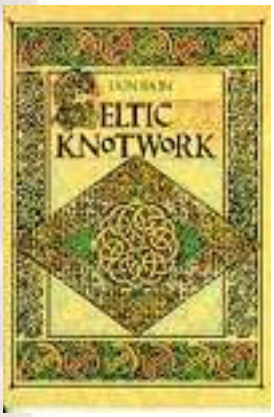

By: Iain Bain

Publisher: Sterling Publishing Co., Inc., New York

Danno's Celtic Site

ISBN: 0-8069-8638-7

The Essential Knot Book

By: Colin Jarman

Publisher: International Marine/Ragged Mountain Press, A Division of the McGraw-Hill Companies

Red Sky at Night

ISBN: 0-87742-221-4

Here are the 43 most important knots and splices you need to use aboard your boat.

History and Science of Knots

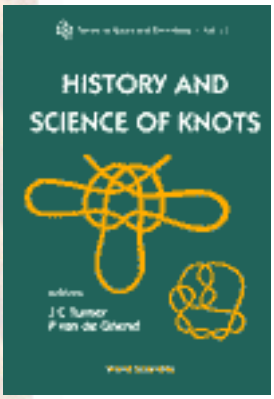

By: J C Turner & P van de Griend

Publisher: World Scientific

singnet
Series on Knots and Everything, Volume 11

ISBN: 981-02-2469-9

This book brings together twenty essays on various topics in the history and science of knots. It is divided into five parts, which deal respectively with knots in prehistory and antiquity, non-European traditions, working knots, the developing science of knots, and decorative and other aspects of knots.

How to Rock Climb, Knots for Climbers

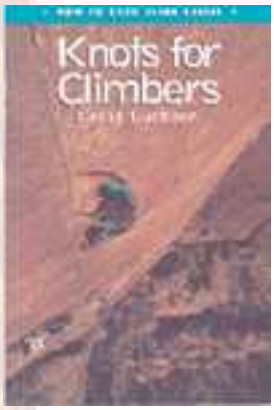

By: Luebben, Craig

Publisher: Chockstone Press

Online Sports
Mountain Zone Bookstore

ISBN: 0-934641-58-7

This book is from the popular series on How to Rock Climb. In this book you will find detailed information with illustrations on the most popular knots used by rock climbers. A chapter in the book is also devoted to some of the equipment used by rock climbers. Table Of Contents

The Klutz Book of Knots

By: John Cassidy

Publisher: %%

ISBN: %%

Knots and Lines Illustrated

By: Paul Snyder

Publisher: %%

ISBN: %%

Knots and Splices

By: Jeff Toghill

Publisher: Fernhurst Books, Duke's Pat

ISBN: 0 906754 11 9

A booklet on all the common knots and splices with their uses and applications.
I got complaints having this book on my page. The first edition should contain too much errors.

The Marlinespike Sailor

By: Hervey Garret Smith

Publisher: International Marine, division of McGraw-Hill, Inc.

ISBN: 0-87742-412-8

Knots & Marlinspike
Three books on knots

A reprinted/revised version of a popular book on knots. With sections on basic knot tieing, decorative rope-work, canvas-work and wood carvings.

The morrow guide to Knots

By: Mario Bigon, Guido Regazzoni

Publisher: William Morrow Company, New York

ISBN: 0-668-01225-4 (paper)
0-668-01225-6

Mountain Zone Bookstore

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Rigger's Locker

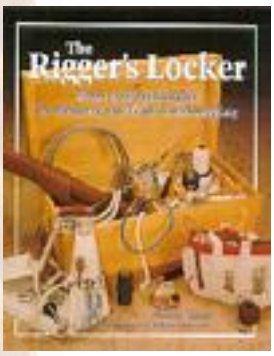

By: Brion Tos

Publisher: International Marine

ISBN: 0-87742-961-8

Rope Works

By: Gerald L. Findley

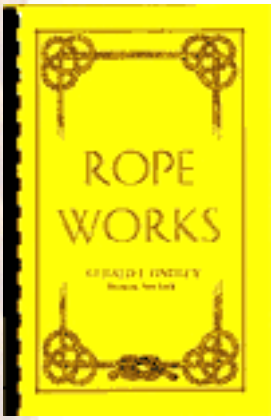

Rope Works

Publisher: Gerald L. Findley

ISBN: ????????

A book of knots, hitches, splicing, lashing and rope making. Whether for scouting or for outdoors recreation, you will learn to tie knots with confidence.

Symmetric Bends How to Join Two Lengths of Cord

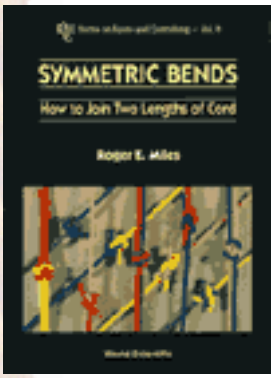

By: Roger E Miles

Publisher: World Scientific Publishing Co. Pte. Ltd.

Series on Knots and Everything, Volume 8

ISBN: 981-02-2194-0

Sufficiency: The Elementary Symmetric Bends; Necessity: Geometry and Planar Representations; Topological Considerations and a Theorem; Practical Considerations and Triple Symmetry; Sixty Symmetric Bends (Includes 16-page colour section); Miscellany; How to Invent Symmetric Bends.

World's Best Fishermans's KNOT BOOK

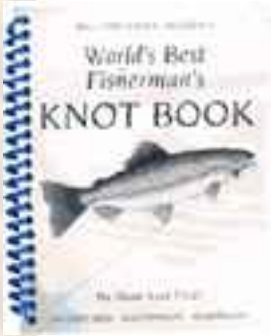

By: Bill Nelson

Publisher: ????

ISBN: ????

This is a pocket size, waterproof, tearproof book that shows the 11 knots and 5 loops every fly fisherman needs to know.

No Junk Mial

Any comment, suggestions, anything mail me:
mai *question@realknots.com*
All knot Ropers Web Site related mail and questions are answered for free!

No Junk Mail

Because this is an non-comercial site I can and will not allow junk mail nor spam. therefor commercial, non-personal and bulkmail will be charged with handling costs of $100 per mail.

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home
Ropers Knot Page

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Ropers Knot Page

Here are the links to pages I found (or that are told to me) with a link to **Ropers Knot Page** -(The knots home page) or one of the other page's of the virtual knot site, and not concerning knots directly. (Otherwise you find them on my Roper's Link Page. Still these pages might be interesting because they all have at least one thing in common... They are interested in knotting (for whatever reason.) If you have a link to one of the Roper's Knot Pages, and there is no reverse link to your page here you can always let me know. *question@realknots.com*

revlinks

All references without a flag are in english/american

General

Crafts,Skills and Hobbies Internet Sites

Scouting

The Scout Association of Hong Kong

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Cub Scout Arrow of Light Board

Cub Scout Pack 46, Sam Houston Area Council

Cubitems's Home Page

Scouting Tips and Info Bits

Grupo Escoteiro Pingo D'Água - 126 / PR

Hawk Patrol Cool Web Sites

Internet Resources for Scouts, Golden Arrow District

Jim Speirs' Scouting Page

Joti 98 The Scout Association of Hong Kong

Junior Forest Wardens

Links naar andere scouting sites

Mõningaid linke nii huviks kui kasuks:

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Nerd World : SCOUTING

Open Directory - Recreation: Scouting: How_To's

Pacific Skyline Council

PHGSC - Inside our Cottage

PVGSC - Getting Connected! Just for Girls!

Royal Rangers ... A Ministry to Boys

Royal Ambassadors Campcraft

Scouting and Other Web Sites

Scouting by Nerd world media(TM)

Scouting Links to the Web

Scouting on the net

Scouting op het internet

Scouting skills and activities

Speider relaterte linker

Spy scout Alguns Links Interessantes.

en The NetCommish ©1997-2000 M.F. Bowman - Knots & Ropes

The Scouting JumpStation

TROOP 237's WEBPAGE

What's new on the InterNETional Scouting Pages

Troop 8 BSA Favorite Links

User Homepages

VVKSM - Links - Hoofdpagina

Climbing

Climbing gyms

Free Climbing A climbing search engine

Jim Frankenfield - Climbing Page

RockList

TMRU Links

VER Sales Cable Rigging & Supply

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Sailing / Boating

Buzzards Bay Home Page Sailing

Chelmarsh Sailing Club

Das HochSeilNest

De Boot

Hot Marine Links

Jumbo

J30 "Awesome" Lake Michigan Sailboat Racing

Links

links

Links des DK-Yacht-Service

Links to other interesting web sites for sailors and rope users

NauticalNet -- Nautical Links

Open Directory - Recreation: Boating: Sailing: Education

Randy's Links - sailing;boating;marine;weather;knots - PART 2

Sailing-Links

Sailors Choice : Seamanship and Navigation

Seattle Times: Want to build a boat? Go sailing? Go online

Usefull Links for classic boating

VAART! F L I T S - wekelijks E-zine over Scheepvaart & Internet

Varazze Club Nautico

Ventura County Boating - Home Page - Sailing - Marine Weather - Directory - Race Results - Motoryachts

Yacht: Links - Tips

Outdoor sport

Ask the Chief Links

Camping/ Instruction and Training

Cadedian Outdoor Technologies

Homestead.org - Crafts, Skills and Hobbies Internet Sites

I.A.T.S.E. Local #21 Home Page

PE253

ReelOutdoor Adventure & Recreation--ROAR!!! !Under construction !

Wrolin Camping 'Round the World's Special Sites

Yahooligans Sports and Recreation

Fishing

Courtesy Web Links Resource

Living and working at sea

The Great Fly Fishing Page

Kiting

InfoJump : Web Directory/Recreation/Kites

Kite info on the Internet

Math

Pri..a o ..vorovima

Div

"A Pirate's Life for Me!!"

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Curriculum Connections

Educational links

Harris Diving Links

IRM Zuerich - Forensische Internet-Ressourcen

IOWA CITY FIRE DEPARTMENT

Links from the Club

sailordaveQ&A School Project on ship wreks

Web Site of the Day - Archives North High School Library

Cool link sites

±âÅ¸

Cool Sites

FLATTY'S_HOT-SPOTS

FreeLinks - editie1.14

Harris (a.k.a. River Rat) dive links

The junkie.com -- eclectic junkie resources

Länkar - Linkkejä - Links

My Cool Site

munford.com's Best of the Web Hobbies

Online Infoage / Internet magazine

Uncle Al's Search Engines - 3.72

Private Bookmarks

Adrenalin T..rman.... ve Do..a Sporlar.. - Do..a sporlar.., da..c..l..k, seyahat ve kamp

Bob & Geri's home page

Brand's Links

Christina's Homepage!

Folie One -- Links

Henscon - Links, links, links

Heimdahl9's Home Page

Junioravd Odjuren

Kirres hemsida

Mark L. Hessenflow Vanity Page

Merenkulku ja veneily

Michel T. Talbot's Bookmarks

Oh no, not another Home Page!

Other Stites

Rickards hemsida

SchoonerMan Rope Locker

Stephen Jones's Bookmarks

Unols Rvtec Link-O-Rama

Just Fun

Engines

Any comment, suggestions, anything mail me:

question@realknots.com

All knot Ropers Web Site related mail and questions are answered for free!

Because this is an non-comercial site I can and will not allow junk mail nor spam. therefor commercial, non-personal and bulkmail will be charged with handling costs of $100 per mail.

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Ropers Knot Page

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knots

Guide Information

Guide Information

http://www.realknots.com/knots/index.htm

Keywords

knots

Compiled by

Ed Prins (erpprs@dds.nl)

Rating

Overall: ✓✓✓✓✓

Resource Description: **2**

Resource Evaluation: **2**

Guide Design: **5**

Organization Schemes: **5**

Guide Meta-information: **3**

(Rated 11/2000)

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June 24, 2000

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NOW AVAILABLE!

Doug Ritter designed Pocket Survival Pak 3.9 oz LIFE SAVER

NEW: BUY NOW!

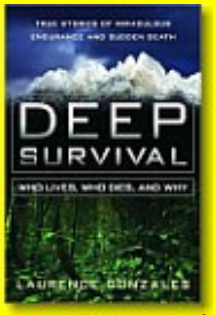

Doug says "a must read..."

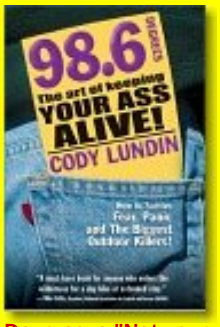

Doug says "Not your father's survival manual..."

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Equipped To Survive™

The Definitive Source for Independent Reviews & Information on Outdoors Gear and Survival Equipment and Techniques

Chance favors only the prepared and equipped.™*

Equipped To Survive™ is the most comprehensive online resource for independent reviews of survival equipment and outdoors gear, as well as survival and Search and Rescue information. Equipped To Survive™ will help you determine the best choices to prepare for anything from a hike in the park to a life threatening emergency or disaster. **Please note that this is not a *"survivalist"* site.** The Equipped To Survive™ Web site is supported by the non-profit 501(c)(3) Equipped To Survive Foundation and edited by noted survival authority, Douglas S. Ritter.

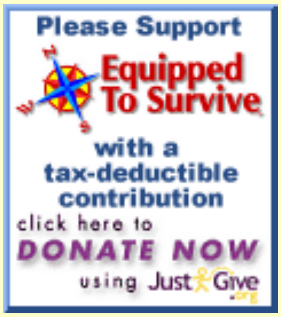

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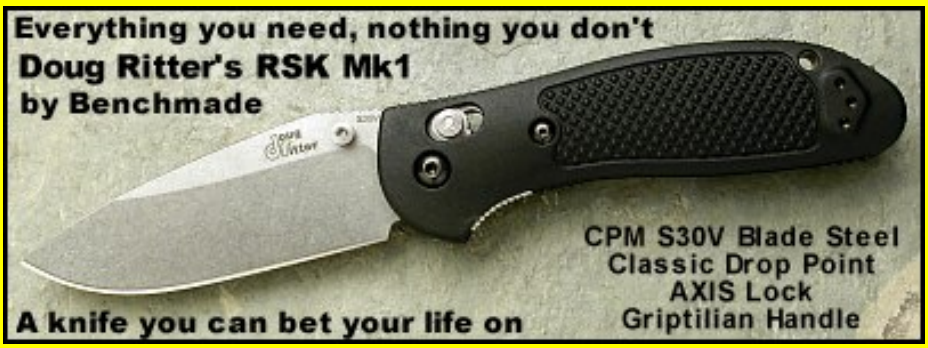

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***Mini*-RSK Mk1™ NOW AVAILABLE!**

Doug Ritter has designed an extraordinary new utility/survival folding knife with every feature you need—and it's affordable!

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The Survival Forum™ offers you a place to ask questions about emergency preparedness, survival equipment and outdoors gear. Whether you are experienced or just starting, we welcome you to our community.

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We rated with RSAC

Equipped Briefings

A Quick Look At New Gear: Triple Aught Design Gear Life Capsule Alpha • Water Storage Alternatives for PSKs

If McMurdo Calls, Will Rescue Come?

UPDATED! 7/13/2004

All GPS-equipped 406 MHz Emergency Beacons are not created equal. ETS has completed an extraordinary ground breaking evaluation of these beacons under real-world conditions. A 200+ page report details the findings of tests of six GPS-enabled EPIRBs and PLBs from three manufacturers. Excerpts from this report and details of the testing and results are now available on ETS, along with the 17 critical Conclusions about what works and what doesn't and 23 Recommendations for action to address the problems uncovered. Equipped To Survive™ once again takes the lead exposing deficiencies in lifesaving products. UPDATED! McMurdo advisories and press release on their own test results added.

AMK Introduces Pocket Survival Pak by Doug Ritter

It's been two and a half years in the making, but Adventure Medical Kits is finally shipping the Pocket Survival Pak designed by Doug Ritter. After a decade of evaluating others' kits and hoping someone would do an affordable kit that would be worth trusting your life to, Doug hooked up with AMK to develop this kit.Finally, an affordable pocket survival kit that really could save your life.

Second Edition of *ETS Survival News* Published

ETS Survival News is an irregularly published compendium of news related to survival, survival gear and search and rescue. Please check out ***ETS Survival News***

SHOT Show 2004 Review

The first installment of our SHOT Show review for 2004 is available. In this portion we take a look at the sharp stuff--knives and multi-purpose tools.

PLB Wars Heat Up With ACR TerraFix Intro

FIRST LOOK! The 2004 Outdoor Retailer Winter Market saw the introduction of ACR Electronics' next generation 406 MHz Personal Locator Beacon (PLB), the TerraFix 406 GPS. The TerraFix is quite a departure from ACR's utilitarian-looking designs of the past and is available in both external and external/integral GPS models. Combined with agressive pricing, this is the opening salvo of the next battle in the PLB wars and we take a first look at this new PLB.

First PLB Save in Contiguous U.S. Credits Equipped To Survive™

A Cleveland, Ohio, man is the first to be rescued using a 406 MHz Personal Locator Beacon (PLB) since they became legally available for use in the contiguous U.S. on July 1, 2003. Carl J. Skalak, Jr. credits Equipped To Survive™ for his having the PLB in the first place. The ACR Electronics 406 PLB worked exactly as designed using the COSPAS-SARSAT satellite alerting system to assure a quick rescue.

SafeSurf Rated
Family Friendly Site™ Recognized and Respected on the World Wide Web
American Library Association 700+ Great Sites!
Book Links ALA
USA TODAY BEST BET Education
Great Web Sites for Kids
KinderStart KID FRIENDLY SITE
TheHomeschoolMom A++ Featured Site
Yahoo! You Are Here AS FEATURED IN KIDS & FAMILY INTERNET GUIDE
editor's choice BONUS.com the SuperSite for Kids
Wolf Aviation Fund 2001 Grant Award

Online initiatives ETS visitors may find of interest:

Take Back Your Mailbox www.cauce.org

Lessons Learned: Surviving The Hurricane

Members of The Survival Forum discuss their experiences, what worked and what didn't and the valuable lessons learned from this relatively mild hurricane. The best way to prepare is to learn from those who have been there already. Please join the discussion, or just stop by and learn something for next time.

Tarp-Shelters - An Introduction

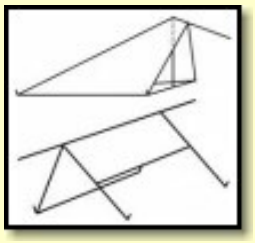

The tarp is the epitome of a basic shelter, but that hardly means it is limited in how it can be used. David B. Macpherson provides an excellent introduction to the subject. There's a wealth of information on their use and construction, covering everything from the most basic immediate action shelter to sophisticated multifaceted structures. Review the multitudes of shelters that can be created from a simple tarp.

NOAA Opens Online 406 MHz Beacon Registration

NOAA's online United States 406 MHz Beacon Registration Database is finally operational. This online registration capability will be a boon to both 406 MHz PLB, ELT and EPIRB owners and to the SAR forces that go out to rescue them. Read about the many advantages online registration offers..

Lights Out Wake Up Call

The recent blackout to hit the Eastern U.S. and Canada served as a wake up call for many. A little emergency preparedness effort can go a long way towards illuminating the darkness. Let Equipped To Survive™ guide you in preparing for these sorts of widespread, short term urban emergencies. Review our Disaster Preparedness section today.

Ultimate Personal Locator Beacon FAQ

Personal Locator Beacons, also known as PLBs, are finally here and everyone seems to have questions. We've got your answers with the most complete FAQ on PLBs you will find anywhere. Everything you always wanted to know about Personal Locator Beacons (PLBs), including some answers to question you maybe didn't even know to ask.

PLBs Finally Approved for U.S. UPDATED! 6/28/2003

You'll finally be allowed to legally purchase and use a 406 MHz PLB (Personal Locator Beacon) in the U.S., but not until July 1, 2003. So, make sure you don't need one to save your life until then. PEPIRBs (Personal EEPIRBs) are also on the near horizon for boaters. Get the details on relatively affordable technology that could save your life.

Survival Stories Are Key To ETS Goal - Saving Lives

The recent brouhaha involving Aron Ralston serves as a reminder as to why Equipped To Survive™ exists. Damn near anything can happen out there and survival stories are a big part of how we learn and how we encourage people to be Equipped To Survive™ Doug shares a few thoughts on the subject of survival stories.

Blue Ribbon Campaign
for online freedom of speech, press and association

Awards

Selected as a USA TODAY Education Best Bet Web Site

Evaluations of Eight Personal Survival Kits

It is spring cleaning time and we've cleared the desk, adding eight new commercial personal survival kit (PSK) reviews, including some of the best we've seen to date:

- There are five new reviews of Personal/Pocket Size Survival Kits.
- There are three new reviews of One-Person Belt Pouch/Cargo Pocket Size Survival Kits.

Care Package and Equipment Suggestions for Deployed Military

Doug Ritter has been asked what our deployed service members would find useful in a "Care Package" or as better-than-issued equipment. Here's an annotated list of what will be most appreciated, gleaned from those who have "been there, done that," as well as better gear recommendations.

Doug Ritter's Evaluation of READY.GOV

Now that the government's Department of Homeland Security has made its terrorism preparedness suggestions on their READY.GOV Web site, Doug Ritter has evaluated their preparedness checklists. You might not be too surprised to learn that Doug has found them wanting in some respects.

Travel Safe - Travel Smart

Canadian outdoorsman Bill Layman is plenty upset at those who abuse the Cospas-Sarsat emergency beacon system and cost taxpayers plenty for no good reason. In this opinion piece Bill offers up some suggestions that could reduce or eliminate the problem. With the coming availability of PLBs, you decide if his cure is worth it.

WSI Gold Label and Mini Survival Kits

We launch a new section on larger personal or "one-person" survival kits, large/cargo pocket or pouch size, with reviews of two kits by World Survival Institute's Chris Janowsky. These personal kits will generally provide more gear, or more capable gear, than the traditional everyday carry PSK.

Ranger Rick's Special Ops Survival Necklace

A different approach to the concept of a personal survival kit; you wear this kit around your neck. It is also unique in that it doesn't come ready to use--"assembly & modifications required." It's unique, but is it any good?

Water Or Trees?

Given the choice in a forced landing, is it better to choose trees or water? Paul Bertorelli has the answer, and it might not be as clear cut as you expect. See what Paul's research turned up.

Innovative Rescue Laser Flare Reviewed

UPDATED! 4/2/2002

When we first saw Greatland Laser's prototype "Rescue Laser Flare" in 1999 we were greatly impressed as it seemed to herald a significant improvement in nighttime signaling. Nearly three years later we have finally had an opportunity

to test the recently released first production model. Read our exclusive review to see if the Rescue Laser Flare lives up to expectations.

Barry Schiff Takes Ditching Lessons

Thirty years ago Barry Schiff ditched a Super Cub in Alaska. Back then he was ill-prepared to get out of the aircraft when it flipped. Still, like most, he managed. Join Barry as he visits Aircraft Egress Systems in Canada and learns the right way to egress a ditched aircraft. No muss, no fuss.

LifePac Survival Kit In A Sardine Tin

We seem to be awash in personal size survival kits. The LifePac, also marketed as Survival Kit In A Sardine Can, aims to provide for your survival in an inexpensive sealed package. Should you trust your life to the LifePac? See what we discovered when we opened it up.

Bob Cooper's Australian MkIII Survival Kit

Yet another personal/pocket size survival kit, this time from down under. This kit has attained a reputation of almost mythical proportions it seems. It's taken a while for us to get one, but it's now here and you can see for yourself if it lives up to its rep.

The Life Raft: Don't Leave Your Ship Without It

Renowned marine survival authority and author Steven Callahan, a survivor of 76 days adrift himself, shares some insights about what to expect from a life raft. All life rafts are a compromise, Callahan offers some thoughts on these compromises from his unique perspective.

Lessons Learned: So Near, Yet So Far

You don't need to be stranded a hundred miles from civilization to find yourself in a survival situation. Chris Kavanaugh found himself stranded on an island within view of one of the largest metropolitan areas in the world. Chris tells the story of how he and four others were stranded and how he relied on basic survival skills and equipment to survive and signal for rescue. Doug Ritter analyzes how Chris and his companions did and the lessons learned.

LED Flashlight Review

We gathered up all the white LED flashlights we could find, and some other colors as well, and now present Equipped To Survive's™ humongous LED Flashlight Review. You'll find both single and multi-LED lights, from pocket size on up to 24 LED monsters. Read all about the the best and the worst in this hot new product category.

Lessons Learned: Sailing to Hawaii...The First Attempt

After two years' fastidious preparations, he thought he was prepared. Arnold Rowe recounts the story of his ill-fated voyage to Hawaii, replete with equipment failures, medical problems and a helicopter rescue by the Coast Guard. Images from video clips of the rescue included! Doug Ritter analyzes what went right and what went wrong. Rowe's real life experience also validates some findings from the Marine Life Raft Tests.

Survival Gear For An Air Race

Simon T was entered in the London To Sydney Air Race. ETS Editor Doug

Ritter's job was to make sure he was Equipped To Survive. With weight a major concern and diverse environmental requirements, that made for quite a challenge. Read all about Simon's custom built and assembled survival gear and supplies.

Stay Alive™ Survival Simulator

ETS is pleased to present this innovative Survival Simulator that was developed as an independent student project for the ThinkQuest competition. While somewhat simplistic, it does get you thinking about a myriad of survival issues and it is entertaining. Have a go at it and see if you know how to Stay Alive™.

Aviation Life Raft Review 2000

This is the most comprehensive review of aviation rafts ever published. Check out the life rafts: The Good, The Bad & The Ugly.

Doug Ritter's Personal Mini Survival Kit

ETS Editor Doug Ritter has repacked and updated his personal mini survival kit. Small enough to fit in a pocket, check out this latest version.

Lessons Learned: A Long Wet Night

It was nighttime and raining when Ray Clamback successfully ditched 300 miles northeast of Hawaii. But for some extraordinary good luck they might well have perished. This narrative, based on interviews with the survivors and U.S. Coast Guard pilots, tells the story of that ditching and survival experience and analyses the lessons learned.

Abandon Ship Bag Recommendations UPDATED!

ETS takes a detailed look at what equipment and supplies should be included in an Abandon Ship Bag. More than just a list, this article provides the information you need to set priorities and make decisions about what to include.

"A Question Of Survival"

Two wilderness aircraft crashes. The pilots in both survive the crash. But, two very different endings--one lives, the other dies. William Waldock examines the question: Why the difference?

Multi-Media International Plagiarises ETS Material

Multi-Media International of New York City has plagiarized significant amounts of copyrighted work from the Equipped To Survive™ Web site; click for more information on this theft

Click here for More Features, Notable Additions, Updates & Changes

Click here for Trade Show Reports

Equipped To Survive™ used to be a member of a large number of Web Rings related to the content on this site. The take over of these Web rings by Yahoo! Web Ring resulted in unacceptable requirements and problems, so we were forced to drop all Yahoo based rings. These remaining Web Rings will take you to other sites which relate to that Web Ring's subject matter:

Emergency & Survival Web Ring **SurvivalRing Web Ring** **Emergency 911 Web Ring**

ISSN 1526-212X
Executive Publisher and Editor: Doug Ritter
Email: Doug Ritter
Survival Forum™ Adminstrator and Sysop: Chris Kavanaugh

Equipped To Survive Foundation, Inc.
Publisher of Equipped To Survive
Executive Director: Doug Ritter
Email: Doug Ritter

Equipped To Survive™ is always interested in submissions of articles for publication. Please review our Submission Guidelines before making a submission or query.

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Revision: 251 August 31, 2004

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Survival Links

This list of Survival related sites is hardly comprehensive in and of itself. However, within this list are a number of sites which focus purely on links to other survival resources and taken together they catalog just about everything worthwhile on the Web about the subject of survival, in all its variations.

Inclusion in this listing does not infer an endorsement of any survival concepts, techniques, products, services or other information on or linked to the site. Nor is it an endorsement of any philosophies that may be espoused by the operator of the site or in any files located on the site or linked to the site. **The ratings are for the quality of the information on and presentation of the Web site and have nothing whatsoever to do with the organization that may operate the site.**

Links open in new browser window.

★★★ **Pack Light, Eat Right**

Published by a backpacking dietitian who holds a Ph.D. in Biochemical Nutrition, this site is aimed at backpackers who must travel light and sustain their body while enduring rigorous exercise. There's a good deal of practical nutritional information, backed by understandable technical explanations for those interested, that could also be of use to those preparing for an emergency situation.

★★★ **Primitive Skills Network Links**

A group of primitive skills and wilderness survival enthusiasts and instructor links.

★★★ **Primitive Skills Group Archives**

An archive of messages from the Primitive Skills Group mailing list, organized by survival topic. More than just "primitive skills," it includes plenty of excellent general survival information.
(Information on subscribing to the Primitive Skills Group mailing list)

★★★★ **Primitive Technology Home Page**

Excellent link page to primitive technology resources. Included are links to Web sites and subscription information for a number of primitive technology related Email subscription groups.

★★★★ **Red Hot Dot Children's Fire and Kidnapping Safety**

A commercial site selling children's fire safety books and pamphlets with good online content on the subject of fire safety and kidnapping prevention and escape.

★★★★ **Rocky Mountain Survival Group**

Billed as "A Survival Information Clearinghouse," it does indeed gather together a huge amount of valuable information on survival of all kinds and descriptions, with both articles on-site and many more links to articles and pages on other sites. A large and growing treasure trove of interesting and useful information on all aspects of survival.

★★★★ **Roper's Knot Page**

Excellent site with all you ever wanted to know about knots. Included are diagrams and instructions for many useful knots. Many have links to other sites with additional illustrations and instructions, including some with animated GIFs demonstrating how to tie them. A very comprehensive link page to just about anything having to do with virtually every kind of knot.

★★★★ **SafetyAlerts.com**

The most comprehensive and up to date source for food contamination alerts and faulty product warnings, recalls, etc. Email notification of the latest alerts available.

★★★ **Simply Survival**

Small, but growing, another site that's a work in progress with lots of potential. Survival instructor Greg Davenport is adding more good stuff on survival techniques and "The Art of Adapting" on a regular basis.

★★★ **The Survival Bible 2001**

Richard Perron's large files contain a compendium of survival information on many subjects from many sources. Ranges from excellent to poor. Not very well organized, nor particularly scintillating prose, but there is **lots** of it. However, well worth the effort if you're seriously interested in the subject. Be warned that this site includes some "survivalist" materials that some may find objectionable.

★★★★ **United States Coast Guard (USCG)**

"They have to go out; they don't have to come back." Sadly, sometimes they don't. Every hour of every day the USCG rescues survivors who are in peril, unfortunately, more often than not, due to their own stupidity. In my estimation, the USCG probably has the highest proportion of true heroes of any of our military services. There's some valuable information here, and a lot of other stuff that's just plain interesting.

★★★★ **U.S. Rescue & Special Operations Group**

Aimed at military operators with advice covering all aspects of survival, most of the information will be useful to anyone interested in the subject. The recommendations for technique and equipment are based on the cadre's real life experiences fighting and survival around the world. Includes tests with answers.

★★★ **Wilderness Way Online**

Wilderness Way is a primitive survival magazine. The site contains articles and a section of user submitted Survival Tips.

If the information here helped you, won't you please help us with a tax-deductible contribution?

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Revision: 039 November 6, 2003

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★★★★ **American Red Cross Disaster Services - Being Prepared**

Information on basic disaster preparedness, from soup to nuts.

★★★ **Captain Dave's Survival Center**

This site covers a lot of ground including survival equipment lists from a variety of sources, some equipment reviews, survival techniques and general articles relating to the subject of long term survival. Dave's "Survival Guide" is a survival handbook work in progress.

★★ **Civil Air Patrol**

CAP performs over 90% of all aerial search and rescue for missing aircraft in the U.S. They also participate in other SAR operations, disaster relief and assist national, state and local emergency services in many other ways. The official auxiliary of the U.S. Air Force, many unfortunately take this military relationship a little too seriously.

If you have large reserves of patience, like paperwork as much as flying and have an extraordinarily high tolerance for B.S., then CAP may be for you. When all is said and done, the bumbling organization succeeds in spite of itself and does a pretty damn good job.

★★ **Colorado Firstrax - Winter Survival**

Tips for survival in winter snow and mountainous conditions.

★★★ **Common Sense Survival Guides**

A collection of advice on a wide variety of survival and disaster scenarios from the author's book of the same name.

★★★★ **Disaster! Finder**

Links dealing with disaster related information and an included search engine by the NASA Solid Earth and Natural Hazards Program.

★★★★ **DonRearic.com**

Focus on rational and practical self defense techniques, along with reviews of self-defense related products including knives, lights, impact weapons, etc.

★★★ **Earthquake Preparation Advice**

Some good, basic and sensible advice on disaster preparedness, with the focus on earthquakes, from The American Rescue Team International.

★★★★ **FEMA - Preparing For A Disaster**

FEMA (Federal Emergency Management Agency) is the government agency that's supposed to organize help after any widespread natural or man-made disaster in the U.S. While they are often criticized for being unprepared, slow and even incompetent at times, this site offers a lot of very good suggestions and advice about preparing for a disaster. Additional useful emergency preparedness information can be found perusing the virtual shelves of the **FEMA Library**.

★★★★ **Frugal Squirrel's Home Page**

The grandaddy of survival archival sites. Like any good squirrel, he's stashed away an abundance of good stuff. Includes one of the Web's best survival links page. Be warned that this site contains "survivalist" sort of materials and links that some may find objectionable.

★★★★ **The Gear Addict**

A great commercial site focused on outdoor gear with reviews submitted by users. Good links to manufacturers sites.

★★★ **The Gear Page**

Outdoor gear reviews, searchable by manufacturer and category

★★★ **Hoods Woods**

Ron Hood, a survival instructor, provides useful information on wilderness survival. His on-line survival manual, "Survival, The Last Laugh," is a work in progress and contains much useful and practical information written in an engaging manner. Navigation of the site is a bit rough, but well worth the effort.

★★★★ **Hug A Tree**
★★★★ **Hug A Tree and Survive - Coloring Book - Survival Training for Children**

The "hug a tree" program has proven very successful in imparting important survival information to children who are often inclined to do exactly the wrong thing when they get lost in the wilds. This program teaches them to stay put, "hug a tree," until they are rescued. If you have a child, this program could prove to be a lifesaver.

★★ **Hurricane Preparations**

Some common sense basic advice about how to prepare for a hurricane. Much is equally applicable for any similar natural disaster for which you have time to prepare.

★★★ **Lightweight Hiking & Backpacking**

Commercial site, lots of useful information, especially for those with weight or volume restrictions. Good links.

★★ **Modern Survival Magazine (ModernSurvival.net)**

A subscription online-only magazine (sample articles each issue freely available) from Jim Benson, former editor of *American Survival Guide*, that covers a wide range of survival issues and equipment. Be warned that this site has a "survivalist" bent that some may find objectionable.

★★★ **Mountain Rescue Association**

A volunteer organization dedicated to saving lives through rescue and mountain safety education. Don't let "volunteer" confuse you, these are serious professionals who rank among the best in the world in what they do, mountain rescue.

★★★★ **Air Cavalry - Survival**

The survival section of the site provides a complete survival manual based on the USAF and U.S. Army survival manuals. A very good primer on survival and survival techniques with U.S. Army Air Cavalry specific information (such as kits).

Recreational Software Advisory Council

RSAC

RSAC no longer exists. In 1999 it was "folded into" a new organization, the Internet Content Rating Association (ICRA). The original aims of RSAC, to protect children from potentially harmful content while preserving free speech on the internet, continue to provide the cornerstone for ICRA's work, backed by the biggest names online.

Please follow the links to the ICRA website below to find the information you're looking for:

- For general information about ICRA, please click here.
- For information about labelling your website, please click here.
- If you are looking for **technical support**, particularly with Microsoft Internet Explorer's Content Advisor, please note that we are not responsible in any way for this software, however, we are able to offer advice on its use. The most frequently asked of frequently asked questions (Content Advisor's "Missing information" error message) is answered in FAQ 3.3. For ICRA's support pages, please click here.

We rated with RSAC ICRA

EVERY DAY

CAMPAIGN 2004
The New York Times
nytimes.com

July 16, 1998

A Virtual Helping Hand For Tying Up Loose Ends

By MICKEY MEECE

You're stranded on a mountain. You have the handheld computer you brought to do some writing, a cellular phone and a few emergency supplies. You're lost, and it looks as if rain is on the way.

To make a shelter, you pull some rope and a poncho out of your pack. But after a few feeble attempts to tie a simple but secure knot to a tree, you turn to the Internet, of course.

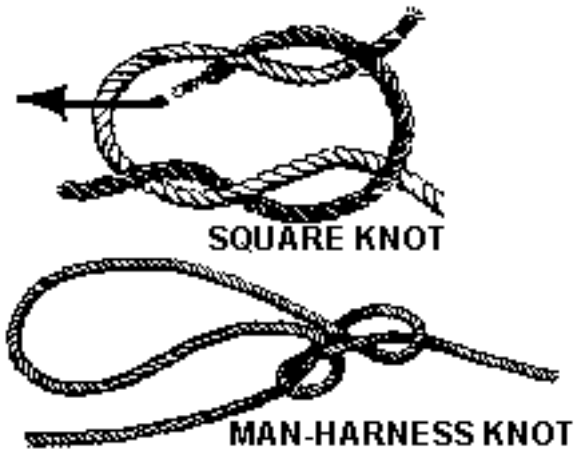

Knot Tying for Fun

You connect the computer to the phone (which has a wireless modem) and go on line. A Metacrawler search using "ropes and knots" calls up a number of promising sites, including the Ropers Knots page.

Whether you're lost on a mountain or sitting comfortably at home in front of a PC, the Ropers Knots page is a good primer on rope tying. Ed Prins, 43, of Delft, the Netherlands, set up the page in February 1996 in Dutch and English.

"One of my great hobbies is knots," Prins said in a phone interview. "I like more of the technical side: how I can join two knots together, why a knot is good in one application and not in another."

Prins, who works as an information specialist at the Schiphol Airport in Amsterdam, said he had built the site with sailors, climbers, scouts and novices in mind. "Most people can find what they want," he said, and if not, there are plenty of links for more specific information.

The Ropers Knots page takes a minimalist approach. Prins said he kept images simple so people with slow modems could load his site without delays. For animation or gimmicks, you have to go elsewhere.

For example, the Ropers Knots page is linked to a site created by the 42d Brighton Scout Group of East Sussex, England.

There, under Animated Knots, are a number of knots shown in two dimensions. In the clove hitch, a red rope slithers around a brown post over and over.

The simplicity of the Ropers Knots page, which is divided into sections with -- what else? -- a rope, both appealed to and frustrated Celina Monte, 17, a senior Girl Scout who knows a little something about knots. Celina is a summer intern at the Girl Scout Council of Greater New York on West 23d Street in Manhattan. With a rope in hand, she sat in front of a computer in the council's office recently to check out the site.

"A big Girl Scout knot is the clove hitch," she said. The diagram she found looked complicated, but she was able to produce a clove hitch.

"I think that this page is for people who already know about knots," she said.

In addition to the links, Prins maintains a Books on Knots page, where he reviews a number of books.

While children can access the Ropers Knots page, there are areas they shouldn't see, like the section on the hangman's noose. Prins put in red a warning: "The noose is not a knot to play hangman with. Too many accidents already killed children who thought they could release it in time."

The Ropers Knots site in English gets about 200 hits a day, while the Dutch site gets about 20, Prins said. He tries to answer each question he gets via E-mail, which keeps him busy. "If you're not stimulated," he said, "you end up with a rope in front of you, and for what?"

Related Sites

Following are links to the external Web sites mentioned in this article. These sites are not part of The New York Times on the Web, and The Times has no control over their content or availability. When you have finished visiting any of these sites, you will be able to return to this page by clicking on your Web browser's "Back" button or icon until this page reappears.

- Ropers Knots page
- 42d Brighton Scout Group of East Sussex, England
- Books on Knots page
- Knot Tying for Fun

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- How
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Ropers Knot Page - (Clubs and societies)

3 September 2004 07:24

Summary	
Measuring since …	29 July 1996
Total number of page views up till now	1356881
Busiest day so far	20 August 2003
Page views	1511

Forecast for today

On average 31 percent of the daily visits are made before 7:24. Based on the number of visitors of 211 today so far, today your site may have 661 page views (+/- 31).

Last 10 visitors

1.	3 September	06:54	America Online, United States
2.	3 September	06:54	Comcast Communications, Beech Grove, United States
3.	3 September	06:55	Genuity/ BBN Technologies, United States
4.	3 September	06:56	Genuity/ BBN Technologies, United States
5.	3 September	07:06	Comcast Communications, Beech Grove, United States
6.	3 September	07:07	Road Runner, United States
7.	3 September	07:18	Singapore (any.sg)
8.	3 September	07:22	Internode, Australia
9.	3 September	07:23	Videon.ca, Canada
10.	3 September	07:23	Genuity/ BBN Technologies, United States

Klik hier!

Page views per day

Page views per day	
7 August 2004	789
8 August 2004	718
9 August 2004	835
10 August 2004	878
11 August 2004	886
12 August 2004	950
13 August 2004	781
14 August 2004	738
15 August 2004	769
16 August 2004	882
17 August 2004	829
18 August 2004	855
19 August 2004	780
20 August 2004	837
21 August 2004	704
22 August 2004	730
23 August 2004	855
24 August 2004	883
25 August 2004	910

26 August 2004	899
27 August 2004	857
28 August 2004	737
29 August 2004	730
30 August 2004	797
31 August 2004	967
1 September 2004	853
2 September 2004	753
3 September 2004	211
Total	22413

Country of origin			
1.	United States	516540	38.1 %
2.	US Commercial	130904	9.6 %
3.	Network	102651	7.6 %
4.	Canada	69957	5.2 %
5.	Netherlands, The	58211	4.3 %
6.	United Kingdom	55000	4.1 %
7.	Australia	33922	2.5 %
8.	Germany	24186	1.8 %
9.	US Educational	20727	1.5 %
10.	Belgium	19879	1.5 %
	Unknown	142812	10.5 %
	The rest	182092	13.4 %
	Total	1356881	100.0 %

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Terug naar:

Touwslagers Knopen Pagina

Stoppers(🇬🇧)

Knopen aan een eind.

Terug naar:

Touwslagers Knopen Pagina

Knopen aan het uiteinde van een touw. Er zijn vele toepassingen waarin je zoiets gebruikt. Iedere toepassing stelt zijn eigen eisen en kent daarvoor een beperkt aantal knopen die het best geschikt zijn. Je kunt een stopper gebruiken om te voorkomen dat een touw of garen gaat rafelen. Doe dat echter alleen in goedkoop touw/garen. Gebruik anders een echte takeling.

De Overhandknoop

De Overhandknoop of de Halve Knoop

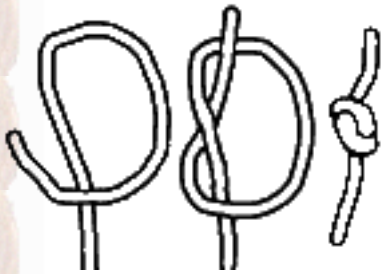

De eenvoudigste knoop die er bestaat, en daarom waarschijnlijk het meest gebruikt. De overhandknoop is goed bruikbaar om knopen in garens en snaren te ondersteunen. Losse tampen worden dan met een overhandknoop iets verdikt. Wanneer dat te rommelig wordt moet worden omgezien naar een betere verbindingsknoop. Er mag geen grote kracht op een overhandknoop worden uitgeoefend. De knoop halveert ongeveer de sterkte van het touw/garen ter plaatse. Als 'anti-slip-stopper' is dat niet erg want dan wordt hij nauwelijks belast.

De Dubbele Overhandknoop

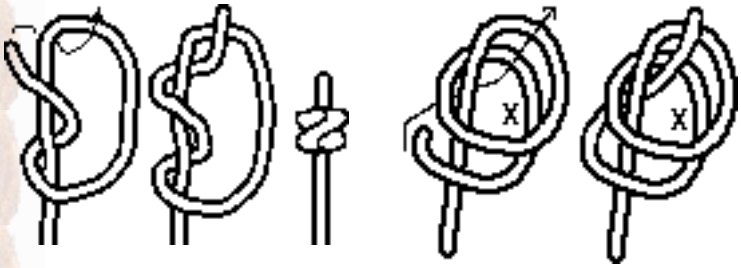

De dubbele overhandknoop is mooi, dikker dan de gewone overhandknoop, maar nauwelijks sterker. Dus hij kan alleen maar gebruikt worden als er maar weinig belasting te verwachten is. De dubbele overhandknoop wordt ook wel de bloedknoop genoemd als hij gebruikt is als zweeptop. De knoop kan op meerdere manieren worden gelegd en in principe op twee manieren worden afgewerkt. De twee manieren van leggen die hier getoond worden geven ook beide afwerkingen aan. De in het midden getoonde bloedknoop is de voorkeurs-afwerking van de tweede met kruisjes gemerkte knoopwijze. De bloedknoop is na belasting zeer moeilijk weer los te krijgen. Wanneer er een object door het met het kruisje gemerkte gat gestoken wordt trekt de knoop samen tot de wurgknoop. Daarom is het de moeite waard deze manier te leren.

De Meervoudige Overhandknoop

Wanneer de overhandknoop meer dan twee interne rotorns heeft wordt hij dikker. (Echter nauwelijks sterker.) Bij geslagen touw is het van groot belang dat de knoop netjes wordt aangetrokken (opgewerkt) anders hebben de losse strengen sterk de neiging te kinken.

De Vlaamse Acht

Dit is de stopper die volume, sterkte en eenvoud van leggen/losmaken in de optimale balans samen brengt.
Deze knoop op het WEB.

Commentaar, ideeen, sugesties mail me: ***qqqq at realknots.com*** *with subject "**question**"*
Alle mail zonder het juiste onderwerp worden automatisch, ongelezen weggemikt..
Het spijt me dat ik de mail link weg heb moeten halen. De Mailgrabbers hebben gewonnen.
Maar.... Ik heb een paar verborgen mail adresjes opgenomen zodat ze elkaar plat kunnen spammen nadat ze mijn "junk"gegrabbed hebben....

Terug naar:

Touwslagers knopen pagina

Door naar

De Verbindingsknopen

Terug naar:

De Stoppers

Verbindings Knopen(🇬🇧)

Knopen om twee touwen aan elkaar te binden.

Terug naar:

Touwslagers Knopen Pagina

De Platte knoop

De platte knoop is slechts bruikbaar voor het eenvoudige werk. Hij is eenvoudig te leggen en beklemt zich niet waardoor hij altijd makkelijk los te krijgen is. De toepassingen variëren van het vastzetten van opgerolde zeilen, het dichtbinden van pakjes, tot de basis van de schoenstrik. Zijn naaste verwanten, het ouwe-wijf, de dievenknoop en de what-knoop hebben zo hun eigen toepassingen, maar die hebben niets met een betrouwbare verbinding te maken.
Voor een uitgebreidere beschrijving van deze interessante knopen-familie kan je terecht bij de Platte-knopen Familie.

De Schootsteek

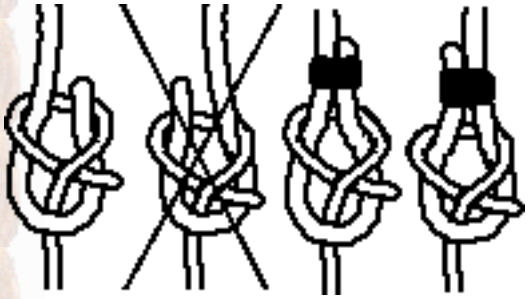

De Schootsteek is mijn favoriete verbindingsknoop. Pas op, wanneer het gekruiste tamp aan de verkeerde kant zit heb je een andere, zwakkere knoop. (In moderne materialen maakt het niet veel meer uit, maar in rechts geslagen touw is de foutieve schootsteek zwakker. Leer daarom de goede.)
Voor een uitgebreidere beschrijving van deze interessante knopen-familie kan je terecht bij De Schootsteek

De karaaksteek

Ook wel karaak hieling genoemd. Pas op! Er zijn maar weinig knopen die zo vaak verkeerd getekend worden als de karaaksteek. De einden moeten diagonaal tegenover elkaar uitkomen en de kruisingen moeten om en om onder- en bovenlangs

uitkomen. De karaaksteek is een van de beste steken. Ashley stelt dat het mogelijk het dichtst bij de perfecte steek komt. Hij slipt niet, zelfs niet als het touw nat is, en bovendien is hij altijd los te krijgen, ook na zware belasting. Als hieling voor zwaar materiaal wordt hij altijd afgebonden om slijtage te minimaliseren.

De Zoeteliefjes

Eigenlijk leg je twee halve steken om de staande einden van beide touwen.
Je kunt de zoeteliefjes op twee manieren leggen. Welke van de twee varianten het sterkst is weet ik niet. Met twee gelijke overhandknopen is hij symmetrisch. Dit is waarschijnlijk de meest gebruikte variant.

Met twee verschillende overhandsknopen krijg je de mooiste (Altijd netjes afwerken!)

Alleen ... de dubbele acht is zeker sterker, makkelijker los te krijgen na belasting en van alle kanten net zo decoratief als de zoeteliefjes op hun best.

De Dubbele Zoeteliefjes

Dit is de dubbel-stopper knoop met als basis de Dubbele Overhandknoop. Eigenlijk leg je twee wurgknopen om de staande einden van beide touwen. Het is het best om de knopen tegengesteld te leggen. Bij gelijke knopen is het lastiger ze goed tegen elkaar aan te sluiten.
Deze knoop wordt door klimmers veel gebruikt om twee touwen aan elkaar te knopen. Hij is sterk, betrouwbaar, maar is nogal lastig weer los te krijgen. Wanneer deze knoop in het midden van een klimtouw terecht komt is het verstandig om aan het hangend eind een vaste lus te maken om als zekering te gebruiken bij het passeren.

De Dubbele Acht

Dit is voor mij de universele dubbele-stopper-knoop. Hij is sterk, mooi, beknelt niet, dus wat wil je nog meer. Het is de verbindingsknoop variant van de Vlaamse Acht

De Wevers Acht

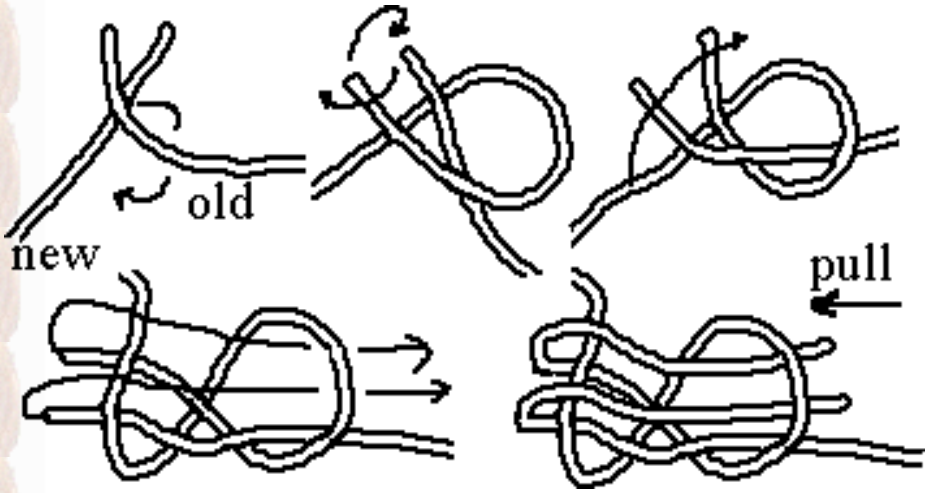

Dit is de beste wever knoop die ik ken. Hoewel het lijkt of hij moeilijk te leggen is blijkt hij juist erg makkelijk te leggen in klein materiaal en is betrouwbaar in wol, linnen en vele ander weef-materialen. Omdat beide losse einden terugvallen op het staande part heeft hij een bijna perfecte geleiding door het werk en over de machine-onderdelen. Houd beide einden op de kruising tussen duim en wijsvinger. (eerste tekening)
Draai beide draden terwijl je het kruis vast blijft houden in twee eenvoudige bewegingen (tekening twee en drie)
Nu leg je het staande eind van de draad waar je wilt aanhechten over de nieuwe draad die je wilt aanhechten.
Ten slotte stop je over de lijn waar je aanhecht door de loep die je net gemaakt hebt.
Nu laat je het kruis los en hou de losse eindjes tegen het staande part van de nieuwe draad en trek de knoop aan.
Deze knoop is gerelateerd aan De (Vlaamse) Acht Dat kan je goed waarnemen als je deze knoop legt zonder nieuwe draad. (Je doet net alsof.) Je zult zien dat je de acht knoopt.

Voor de andere richting

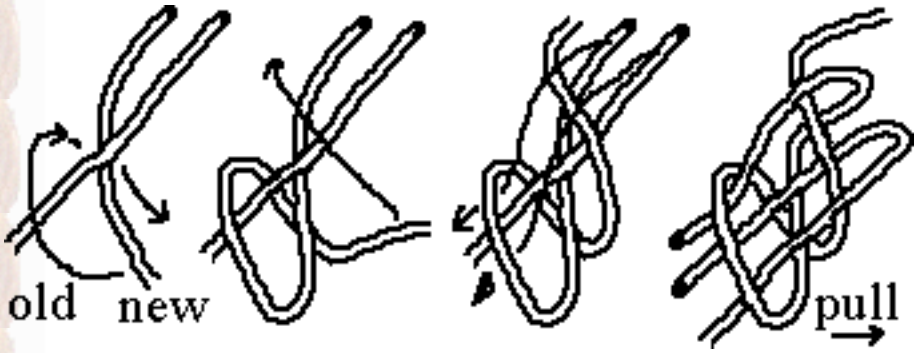

Een wever op een traditioneel weefgetouw weet niet van te voren in welke richting de volgende lijn aangehecht moet worden. Daarom moet hij de weverknoop in twee richtingen kunnen leggen. (Lang niet iedere wever/weefster kan dat en dat kost tijd of netheid.) Dit is de zelfde als de hierboven beschreven knoop, alleen dan anders gelegd. Op deze manier gelegd kan de draad de andere kant op getrokken worden.

Commentaar, ideeen, sugesties mail me: ***qqqq at realknots.com*** *with subject "**question**"*
Alle mail zonder het juiste onderwerp worden automatisch, ongelezen weggemikt..
Het spijt me dat ik de mail link weg heb moeten halen. De Mailgrabbers hebben gewonnen.
Maar.... Ik heb een paar verborgen mail adresjes opgenomen zodat ze elkaar plat kunnen spammen nadat ze mijn "junk"gegrabbed hebben....

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Terug naar:

Touwslagers knopen pagina

Door naar

De Steken

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Terug naar

De verbindingsknopen

Steken (🇬🇧)

Knopen om en touw aan ... iets te steken (verbinden)

Terug naar

Touwslagers Knopen Pagina

'Elementaire' Steken

In deze tabel staan de elementaire steken. De steken in iedere kolom zijn "familie" van elkaar. De bovenste steek wordt rond een paal of ander object geknoopt. Ik zal ze primaire elementaire steken noemen. De steken er onder zijn 'het zelfde' maar rond het eigen staande part gebonden. Ik zal ze verder de secundaire-elementaire steken noemen. Pas op! De toepassingen van de verschillende variaties zijn zeer verschillend. De primaire-elementaire steken "verdwijnen" als het object verwijderd wordt. De secundaire-elementaire steken doen dat niet. Sommige secundaire-elementaire steken zijn "gekapseisde" bindings knopen. Hoewel het eigenlijk voor alle knopen geldt is het goed afwerken van deze knopen extreem belangrijk. Verkeerd afwerken kan leiden tot een totaal andere en vaak zelfs gevaarlijke variant van de gewenste steek. Als je bijvoorbeeld de twee-halve-steken kapseist zit je met het "oud-wijf", een van de beroerdste knopen die je je maar kunt voorstellen. Aan de andere kant kan je als je weet wat je doet met opzet een "verkeerde" knoop leggen en die kapseizen tot de gewenste. Maar pas daar voor op en wees voorzichtig.
Helaas zijn de nederlandse namen die ik vond lang niet zo sprekend als de engelse.

Enkele Simpele

Mastworp

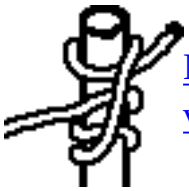

Mw met voorslag

Koe

Halve

Twee Halve

Scheerlijn

Twee verkeerde halve

"Buntline"

Verschuifbare

"Lobster Buoy"

De enkele steek

(ook wel **De Simpele Steek.**)

Hoewel dit waarschijnlijk de meest eenvoudige knoop is die je kunt verzinnen moet je een vaardig knoper zijn om hem op een veilge manier te leggen en toe te passen. Het losse eind van het touw moet worden afgeknepen tegen een object of tegen het staande part. De beste kneep krijg je tegen een rand of riggel. (Daar zit hem de kneep! En daar komt ook deze zegswijze vandaan.) Als de steek wordt ontlast en het staande part geschud dan lost de steek direct.

Hij wordt gebruikt bij het beleggen om een kikker, een wevers-naald of zelfs aan een boomtak, als begin voor het beleggen, als start voor het opwinden of als tijdelijke, snel los te maken "steek".

De Halve Steek

Dit is de "gekapseisde" overhandknoop. Het is een bijzonder bruikbare steek om lichte lasten te dragen die snel los te maken moeten zijn. Ashley raadt hem aan voor het ophangen van voorraden buiten het bereik van muizen. Je moet hem echt met rust laten.

De Mastworp

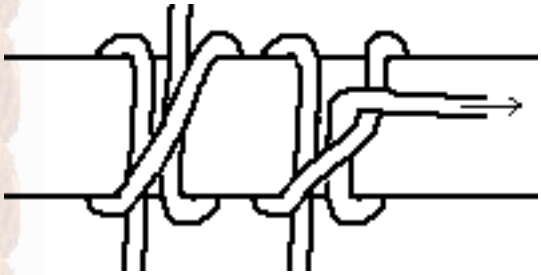

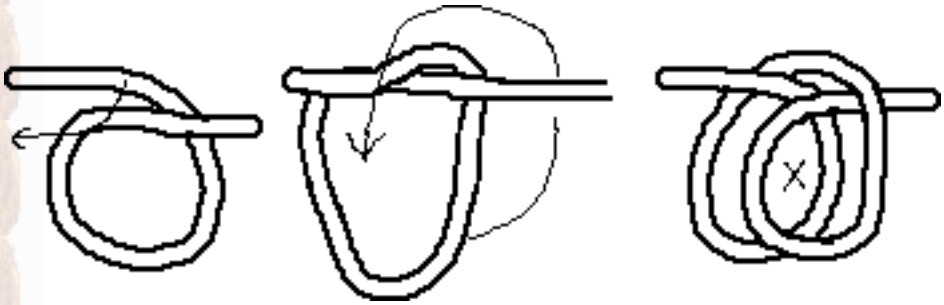

Deze belangrijke knoop heeft alleen theoretische waarde. Zonder extra ondersteuning is hij onbetrouwbaar in iedere situatie, behalve als kruisknoop. Je moet hem kennen voor de padvinderij en op zeilscholen. Als je hem toch moet toepassen werk hem dan netjes af. Trek beide einden stevig aan voor je hem belast, en dan nog alleen in de lengte-richting. Beter nog, gebruikde mastworp met voorslag als alternatief.

Twee Halve Steken

De twee halve steken worden gebruikt om een touw te knopen aan een ring of paal met een haakse belasting. Het moet constant belast blijven. (Hoeft niet onder een constante belasting.) Hij beknelt zich niet. Als het object een kleine diameter heeft is het verstandig om een extra rotorn te nemen.

De "Buntline" Steek.

De "Buntlijn" steek werd gebruikt om de "buntlijn" van een vierkant getuigd schip vast te zetten. Het is een veilige knoop, maar heeft nijging zich te beknellen. Hij is daarom niet eenvoudig los te krijgen. Daarom is hij geschikt voor werk dat langer zonder toezicht gelaten moet kunnen blijven.

Mastworp met voorslag

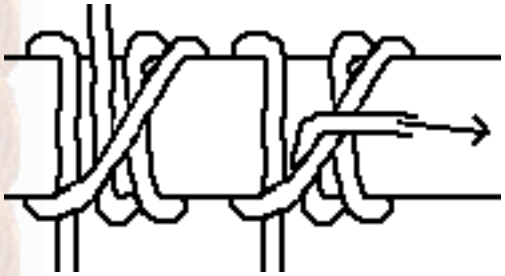

De beste knoop voor belasting in de lengterichting. Het is belangrijk hem goed af te werken en goed aan te halen voordat hij belast wordt. Gebruik hem nooit voor haakse belasting want dan schiet hij echt los.

Scheerlijn-steek

Dit is een bijzonder nuttige steek. Hij is verstelbaar EN betrouwbaar.
Iedere zeiler zou deze steek onder iedere omstandigheid moeten kunnen leggen. In het bijzonder om zichzelf te redden met het touw dat hem in het water is toegeworpen. Hij moet de lijn rond zich leggen, de scheerlijn-steek voor zich en zich tot doel stellen het losse eind tegen het staande part te houden. Dat geeft hem veiligheid en een doel in deze kritieke situatie: VASTHOUDEN!
Iedere kampeerder moet deze knoop ook kennen. Het is de beste knoop om je scheerlijn aan een haring te bevestigen.
Het is het eenvoudigste lid uit de verstelbare knopen familie.

Verstelbare steek.

Dit is de "broer" van de scheerlijn-steek en slechts een beetje minder belangrijk. Dat komt omdat hij zich eerder beknijpt. Als dat de bedoeling is, is dat natuurlijk prima zoals bijvoorbeeld voor werk dat lang zonder toezicht moet kunnen blijven. Ashley beschrijft een toepassing voor katoen-makelaars in New Bedford die hun monsterpakjes, die ze van molen tot molen namen, er mee sloten. De pakjes konden naar believen worden geopend en weer gesloten. Ze bleven veilig gesloten onderweg.

De Koe-steek.

Deze steek is zeer bruikbaar om een koe aan een paaltje vast te zetten. Zelf zou ik een overhand knoopje in het losse eind toevoegen, maar ik ben geen boer. Zeelui gebruiken hem om een koord aan een lijkwade te bevestigen bij een zeemans uitvaart.

"Verkeerde" halve steken

Deze steek wordt ook gebruikt om scheerlijnen vast te zetten, maar is daar veel minder goed voor als de Scheerlijn Steek. De enige reden dat ik hem hier noem is omdat zijn topologie hem hier plaatst. Ik zie er geen gebruiksmogelijkheden voor. (Laat me weten als je er een kent.) Een geoefend oog zal er de gekapseisde platte knoop in herkennen.

Lobster Buoy Steek

De Lobster Buoy Steek is ongeveer even veilig als de Buntline steek, maar veel makkelijker los te krijgen. Hij wordt gebruikt om houtbundels vast te zetten.

Marlsteek of Halvesteek

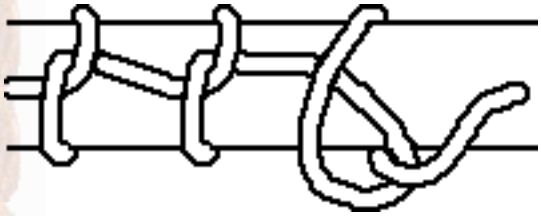

Deze steek is bijzonder praktisch als je een bos wil binden of een rol bij elkaar wil houden. Het werkend eind hoeft maar eenmaal doorgehaald te worden en toch schiet dit bindsel niet echt snel los. Voor de beroemde 'tie-wraps' (of hoe heten die plastic snelbinders) werd deze steek ook op technische scholen aan elektrotechnici geleerd voor het binden van draadbomen. De reeks steken wordt altijd begonnen en beëindigd met een dubbele marlsteek.

Dubbele Marlsteek of Wurgknoop

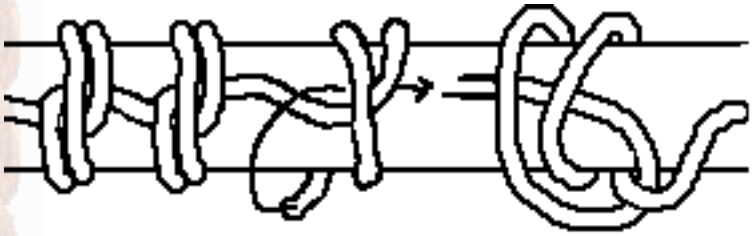

De wurgknoop is belangrijk als tijdelijke takeling, en als permanente binding waarvan er een aantal in elkaars verlengde moeten worden gelegd. Eenmaal goed gelegd is losmaken zonder hulpmiddelen (priem of mes) bijna onmogelijk. Gebruik hem dus nooit voor iets dat snel weer los moet. Als marlsteek wordt hij altijd als eerste en laatste in een rij gebruikt. Ook als een rij marlsteken 'gevaarlijk' lang wordt, pas je de dubbele marlsteek toe als 'tussenzekering', Let op! Op deze manier gelegd hoeft het werkend eind (of het 'klosje') maar één maal doorgehaald te worden. Je moet de knoop daarna wel even netjes afwerken. Gewoon aantrekken is daarbij niet voldoende!

De Constrictor

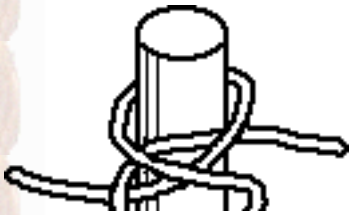

De constrictor is belangrijk als tijdelijke takeling. En ook als permanente binding waarvan je er meerdere naast elkaar nodig hebt. Eenmaal goed gelegd is losmaken zonder hulpmiddelen (priem of mes) bijna onmogelijk. Gebruik hem dus nooit voor iets dat snel weer los moet. Omdat de constrictor "in de bocht" gelegd kan worden wordt hij

vaker gebruikt dan de wurgknoop.
Voor meer informatie over de constrictor-knoop familie kun je terecht bij de Constrictor-knoop Familie.

Commentaar, ideeen, sugesties mail me: ***qqqq at realknots.com*** *with subject "**question**"*
Alle mail zonder het juiste onderwerp worden automatisch, ongelezen weggemikt..
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Maar.... Ik heb een paar verborgen mail adresjes opgenomen zodat ze elkaar plat kunnen spammen nadat ze mijn "junk"gegrabbed hebben....

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Terug naar

Touwslagers Knopen Pagina

Verder naar

De Vaste Lussen

Terug Naar
De Steken

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Enkele Lussen ( )

Terug Naar
Touwslagers Knopen Pagina

De Paalsteek

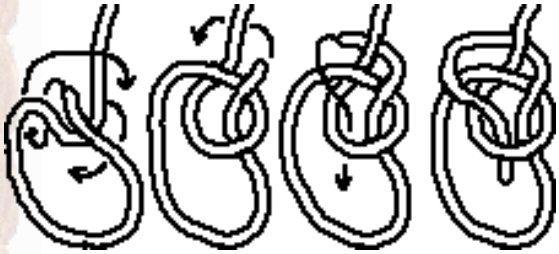

De Paalsteek is de meest gebruikte lus-knoop. Dat komt voornamelijk door de eenvoud, de betrouwbaarheid en waarschijnlijk ook de verwantschap aan de schootsteek. Houd in stap A het kruispunt tussen duim en wijsvinger van de rechterhand en draai vervolgens de pols met de klok mee. Wanneer je de lus weglaat heb je de schootsteek. Kan iemand me vertellen waarom ik in alle boeken deze paalsteek vind, behalve in de helft van mijn nederlandse boeken waarin de zwakkere linkse-paalsteek (met het losse eindje aan de verkeerde kant...) staat 'aangeprezen'???.

Gedubbelde Acht lus

De gedubbelde 8 is een door klimmers veel gebruikte knoop. De knoop is snel te leggen en is veiliger dan de paalsteek. Er is veel discussie of het losse eind nog een stopper behoeft of niet. Snelheid van leggen/losmaken is ook iets waar je voor veiligheid rekening mee moet houden. De eerste wijze van leggen is gelijk aan het leggen van de Vlaamse acht, maar dan met een dubbel touw. Het "losse-end" vormt de lus. Deze wijze van leggen is alleen toepasbaar als de lus pas na het leggen ergens om of in gelegd wordt.

Wanneer de lus ergens om gelegd moet worden, (om jezelf bijvoorbeeld) dan wordt eerst een enkele losse vlaamse acht gelegd die vervolgens gedubbeld wordt. Het is hierbij belangrijk dat er ruimte genoeg is voor de lus. Dat vraagt enige ervaring. Oefenen dus!

De boogpees knoop

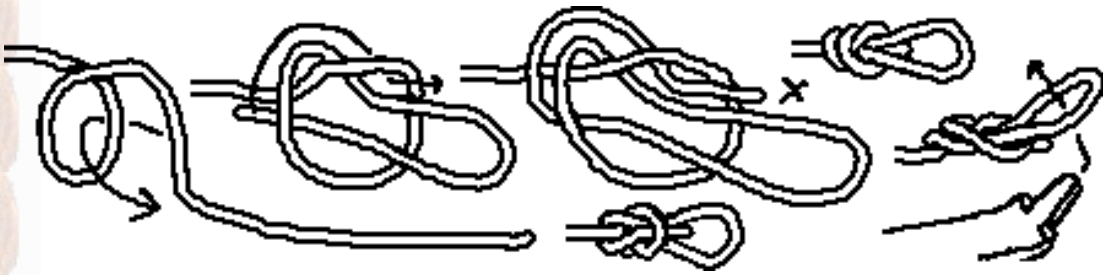

Dit is een zeer oude knoop die gebruikt werd als oog voor boogpezen. De knoop is eenvoudig en sterk. Eenmaal gelegd en stevig aangetrokken, wil je hem niet meer los knopen: je zou het een goede permanente lus kunnen noemen.
De boogpees knoop is geliefd omdat hij klein, sterk, veilig en eenvoudig te leggen is. Hij is netjes omdat er geen losse eindjes uitsteken.
Moderne boogschutters geven de voorkeur aan ingesplitste ogen.
Als het losse eind (gemerkt met een kruisje) niet tussen de boog en de loop gezekerd zit is het aan te bevelen om een extra overhand knoopje als stoppertje te leggen.

Het middenmannetje

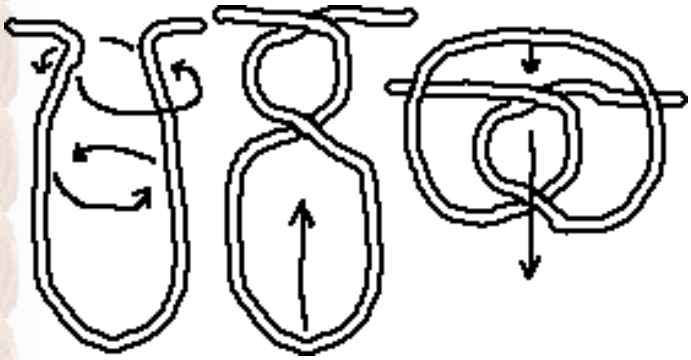

Een eenvoudig te leggen prima lus voor toepassingen waar de lus niet aan het uiteinde maar ergens in het werkend eind gelegd moet worden. Deze lus is in alle richtingen belastbaar. Dat is belangrijk voor toepassingen waarbij de spanning aan de einden groot is ten opzichte van die in de lus zelf.

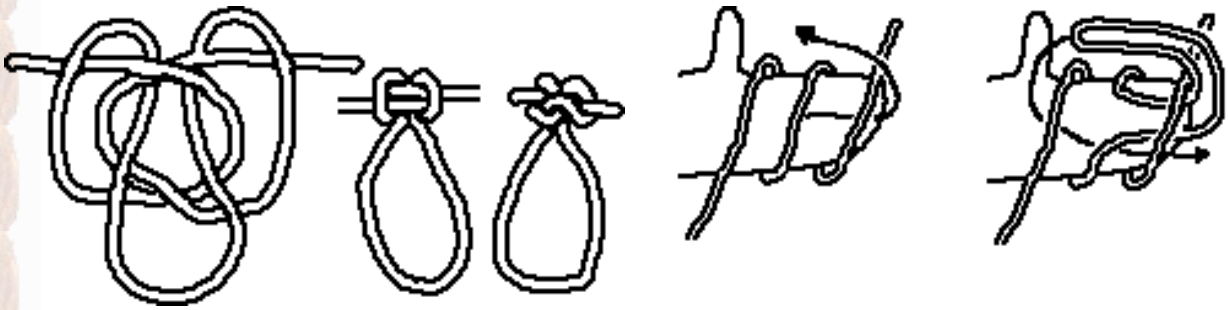

De Artillerie Lus

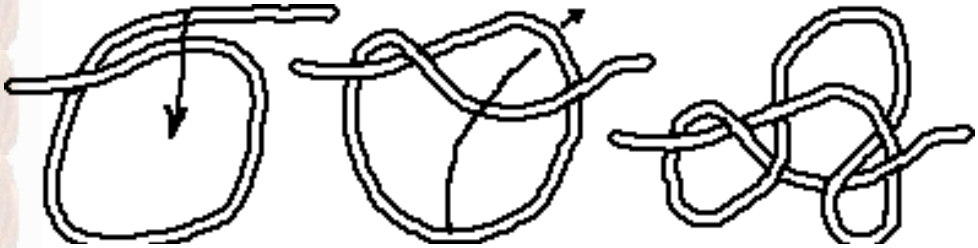

Een praktische en eenvoudig te leggen lus voor het midden van het touw. Hij is niet zo sterk als de middenman maar is iets sneller te leggen en weer los te maken.

Zoals de naam al aangeeft werd hij door de artillerie gebruikt (voor het dragen van het geweer over de schouder). Belast het touw niet te zwaar zolang de lus niet belast wordt. Hij is het best toepasbaar als tijdelijke knoop om dingen te dragen of op te hangen. En zoals altijd, netjes afwerken!

De Pendant Steek

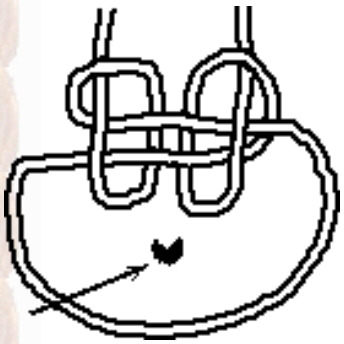

Een steek om een steentje in een amulet te binden. Zorg ervoor dat je het object goed in de lus zekert. Als je een lus (deze lus) gebruikt om een steentje of ander mooi object in een hanger te bevestigen is een leren veter de beste keuze. Maak een ondiep sneetje in de binnenkant van de lus. Precies diep genoeg om het oppervlak te vergroten zodat het beter grip heeft. En, zeker niet onbelangrijk, gebruik een goede schoenmakers-lijm (bijvoorbeeld bizon-kit.) Het resultaat is verrassend.
"De pendant steek is een naast familielid van de zoeteliefjes. Zoeteliefjes.

Commentaar, ideeen, sugesties mail me: ***qqqq at realknots.com*** *with subject "**question**"*
Alle mail zonder het juiste onderwerp worden automatisch, ongelezen weggemikt..
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Terug naar
Touwslarges Knopen Pagina

Verder naar
De Schuifknoop

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Terug naar

De Lussen

Schuifknopen ( )

Lopende-lussen, strikken en lasso's.

Terug naar

Touwslagers Knopen Pagina

De Schuifknooop algemeen

WAARSCHUWING!! De schuifknoop is geen speelknoop om galgje mee te spelen. Er zijn te veel kinderen per ongeluk gedood omdat ze dachten dat ze de knoop nog wel op tijd los zouden kunnen krijgen. Ook een niet strak aangehaalde schuifknoop is uiterst gevaarlijk rond je hals!

Er zijn drie basismethoden om een schuifknoop te maken. Bij de eerste wordt het staande part door een vast oog aan het einde van het touw genomen. Dit kan een ingesplitst oog zijn maar ook een geknoopte zoals de paalsteek. (De paalsteek wordt feitelijk veel door zeilers als lopend-oog gebruikt.) Ook de enkelvoudige schuifknoop zelf wordt wel gebruikt als soepel lopend-oog.

Bij de tweede manier knoop je een lopend oog rond het staande part, (een simpele knoop of steek) zodanig dat de lus sluit als aan het lopend eind getrokken wordt. Dit is de meest gebruikte manier om een schuifknoop te maken. Het zorgt ervoor dat de lus makkelijk sluit (maar vaak moeilijk opent.)

Bij de derde manier leg je een knoop andersom rond het staande part, zodat als je aan het lopend eind trekt de lus opent.
Ik ken maar één praktische toepassing van zo een schuifknoop: het aanbinden van een yoyo aan het touwtje. Met de achtknoop als lopende knoop.
Maar bij het opbinden van balen en pakketten worden ze regelmatig onbewust gelegd. Ook tijdens het oefenen van het leggen van schuifknopen eindig je in het begin met dit soort lussen.

De enkelvoudige Schuifknoop

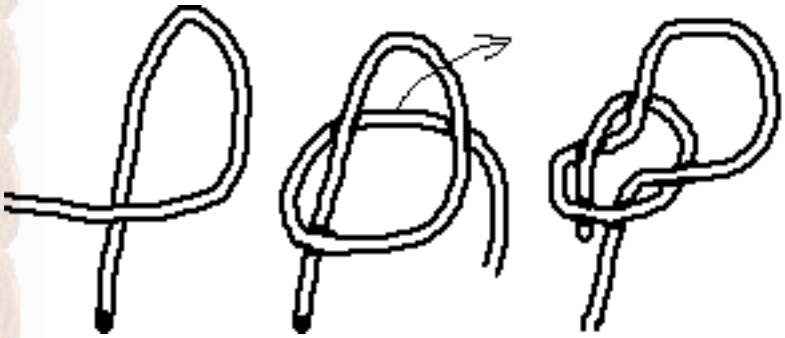

Dit is de eenvoudigste schuifknoop. Hij wordt meestal gebruikt als basis voor verder werk en is nauw verwant aan de overhandknoop en de Marlsteek Als hij als schuifknoop gebruikt wordt is het verstandig een stoppertje te leggen in het losse eindje (de overhandknoop). Hij wordt wel als stropers-strik voor kleine vogels gebruikt.

De Wurg Strik

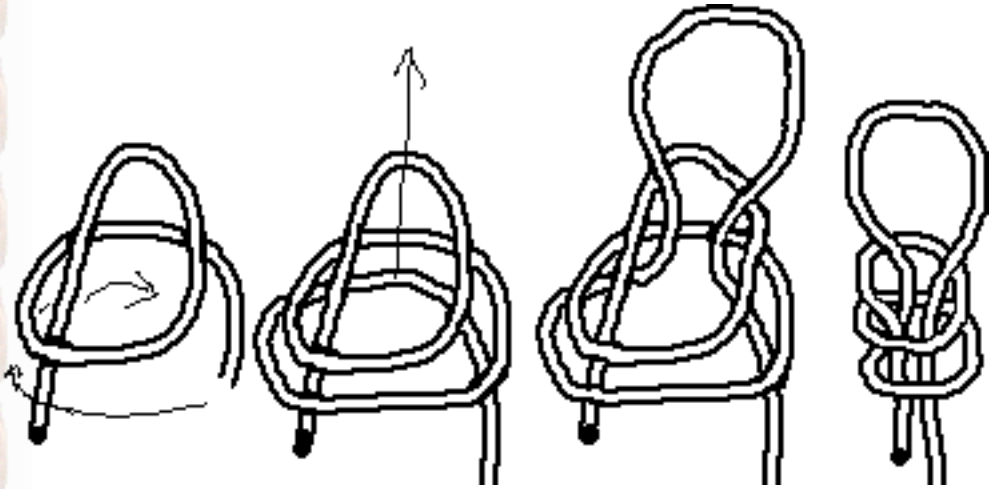

De wurgknoop is een uitstekende knoop om als lopende knoop voor een schuifknoop te gebruiken. Je kunt de kracht die nodig is voor het sluiten van de lus prima regelen. Hoe meer kracht er van binnen de lus wordt aangewend om los te komen, hoe sterker de wurgknoop zich hiertegen zal verzetten. Geen wonder dat deze knoop veel voor strikken gebruikt wordt.

De Galgen Knoop.

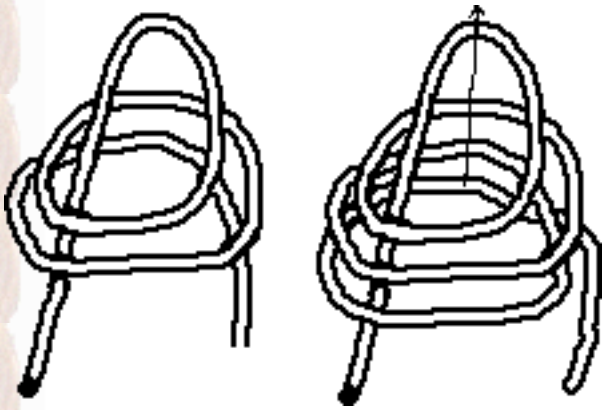

De meervoudige overhand knoop. Zoals de naam al aangeeft een knoop met een duister verleden.

Speel nooit 'Galgje'. Het is werkelijk dodelijk.

De Beulsknoop.

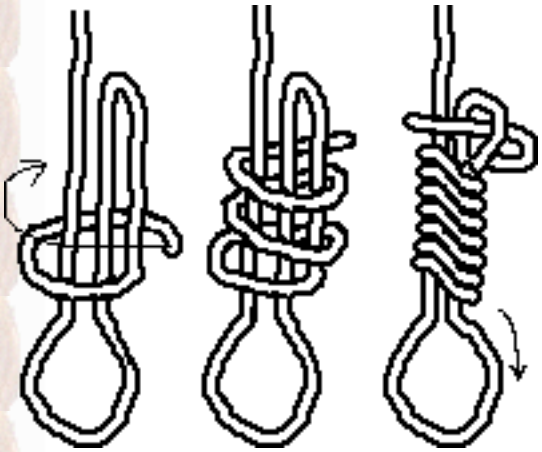

Deze knoop werd ook aan de galg gebruikt. De kracht om te sluiten is beter regelbaar dan bij de galgenknoop. En omdat hij groter is in de nek neemt men aan dat hij de nek eerder breekt. Dat zou 'menselijker' zijn dan het gebruik van de galgenknoop dit meer wurgde.

Speel nooit 'Galgje'. Het is werkelijk dodelijk.

De reverse acht schuifknoop.

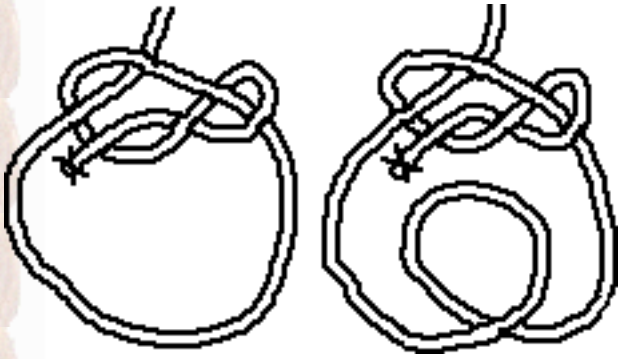

Dit is (tot nu toe) de enige 'verkeerd' lopende schuifknoop waarvoor ik toepassingen ken. Hij wordt gebruikt voor het binden voor pakjes en ... voor het vastmaken van het touwtje aan een YoYo. Gevorderde YoYo'ers doen de lus maar één maal om de yoyo. Zo kunnen ze de yoyo draaiend beneden houden (slippend) en met een klein rukje weer naar boven roepen. Hiervoor moet de yoyo zeer snel draaien en de lus goed getrimd zijn. Beginners willen de yoyo gewoon vast hebben. Zij slaan de lus er een keer extra om en trekken alles goed aan.
Leg eventueel een overhand knoopje in de tampjes. (gemarkeerd met kruisje).

Commentaar, ideeen, sugesties mail me: ***qqqq at realknots.com*** *with subject "**question**"*
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.....

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Terug naar

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Blood Knot

Blood Knot

Knot Tying Instructions

Last modified: Thu Nov 16 08:28:07 1995

Fishing Knots

A Grant's Guide By Herron Publications

The average angler needs perhaps no more than three or four basic knots, but these knots relate directly to his mode of fishing. The game fisherman need have little interest in the knots used by the trout fisherman, who, in turn, uses knots that are not necessarily suitable for the bream fisherman.

Each knot dealt with in this book has its own definite and prescribed purpose. When properly tied, or formed, then worked or drawn up into shape, the knot can make all the difference between boating a big fish, or losing it.

I suggest that you select only those few knots that are of the greatest use to you, and practise, practise, practise tying them until they become second nature to you. It is most important that you use knots that can be tied in an easily remembered manner. There is little point using a knot that can only be tied by reference to a book - even this one. You'll be astonished how a few hours practice with a knot will make for perfection.

Ern Grant, Author "Grant's Guide - Fishing Knots & Rigs"

Find out more about fishing knots and rigs....

This fishing knot guide is brought to you by Fishing Cairns - *If You Can't Catch It In North Queensland, It's Probably Not Worth Catching*.

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Web Site By Port Douglas Internet Services

Barrell Knot

Start with a two ends pointing towards each other and overlap them ~ 1 foot. Pass the Right hand rope (the one pointing away from you) over the other and back under

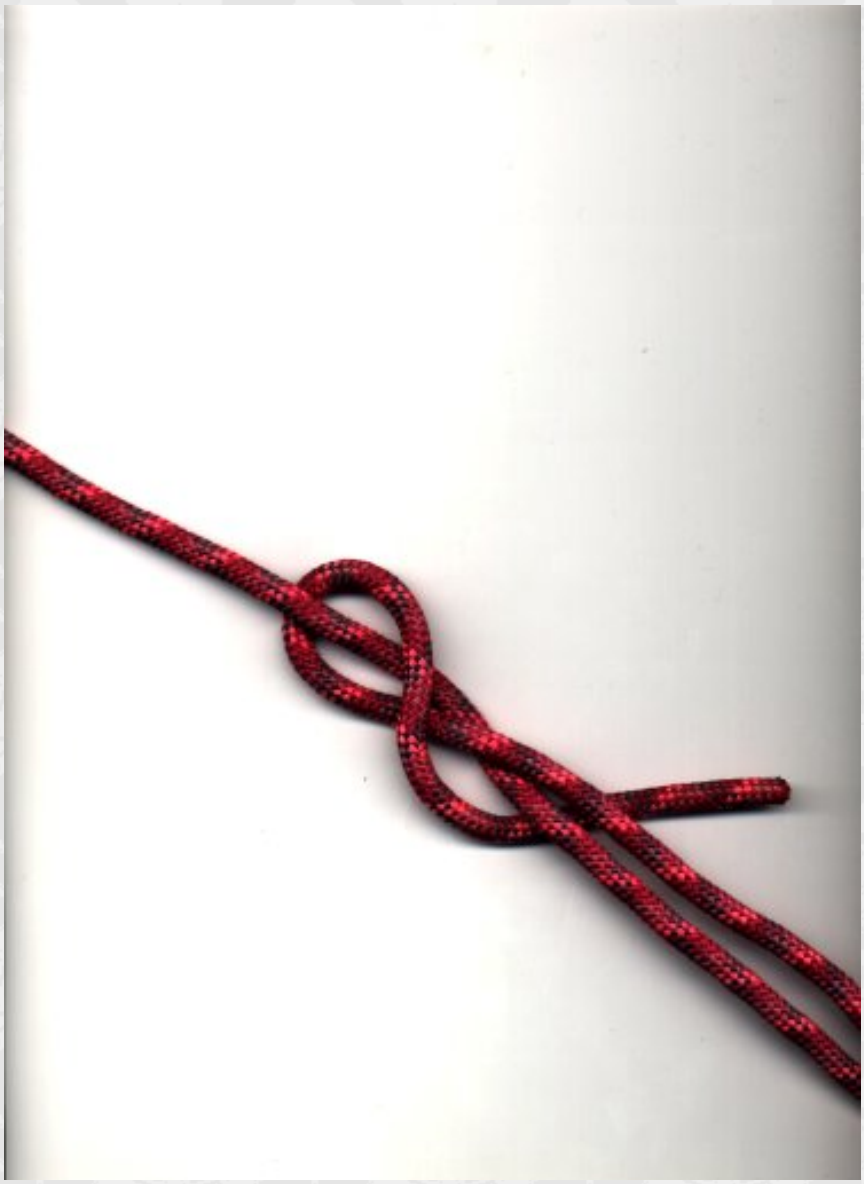

Cross the same end over itself making an X

Pass the end UNDER the X and pull tight

Flip the entire works around and do the same thing on the other side. When you're done, you should have two sliding knots like these.

The finished knot.
Pull the outside ropes, and the two knots should slide together and the X's should mesh. If they don't the knot is wrong and you should start over.

Back to Main Knot Page

Chinese Knotting: The Treasure Knot

Generalities

I came by the instructions for this particular family of knots from a single book, which is why I have classified them all together, despite there being what seems to be 2 distinct knot groups here. I may at some future date split this page, but until then... Only Ashley's #2463 bears any resemblance to any of this family of knots, so I have named the first one *bao* (a romanization of the Chinese name of the book in which I first found the instructions), the second type I am having great difficulting in executing (the instructions are quite sparse), but may end up being the *treasure knot* by default). In any case, it should be named by the time the instructions are completed.

The construction of the double bao knot is symmetrical in nature, so you will only be able to make knots with an even number of ears.

Nomenclature

The Treasure Knot: Double Bao (2), Triple Bao (3), Quadruple Bao (4), etc.
Ashley's: #2463 (Two part Quadruple Bao, Bao4x2)

Similar Knots

- Flower Knot
- Star Knot

How To

Bao 2x: 4. 6. 8. ***n***.

General Tips

- **be very clear on which loops are part of the central structure of the knot and which loops are ears as you are tightening the knot.** With the bao knot it is very easy to get confused and it's just a few tugs from finished construction to irretrievable mess, although, it is actually easier to distinguish ears from knot loops the larger (more ears) the knot.

2x4 Bao

The 2x4 bao is the smallest of the double bao knots. See the detailed instructions for construction information.

2x6 Bao

As previously mentioned, the construction method is symmetrical, so there are no odd numbered bao knots. The next larger bao knot after 2x4 is the 2x6 bao.

n Bao

Tie the 2x4 bao knot, then tie the 2x6 bao knot. The pattern for making as large a double bao knot as desired (even as large as 12, 14 or more) should become clear.

CLW

Creation Date: Mon Sep 21 12:06:36 PDT 1998
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KNOTBOARD OF THE MONTH

RINGBOLT HITCHING:

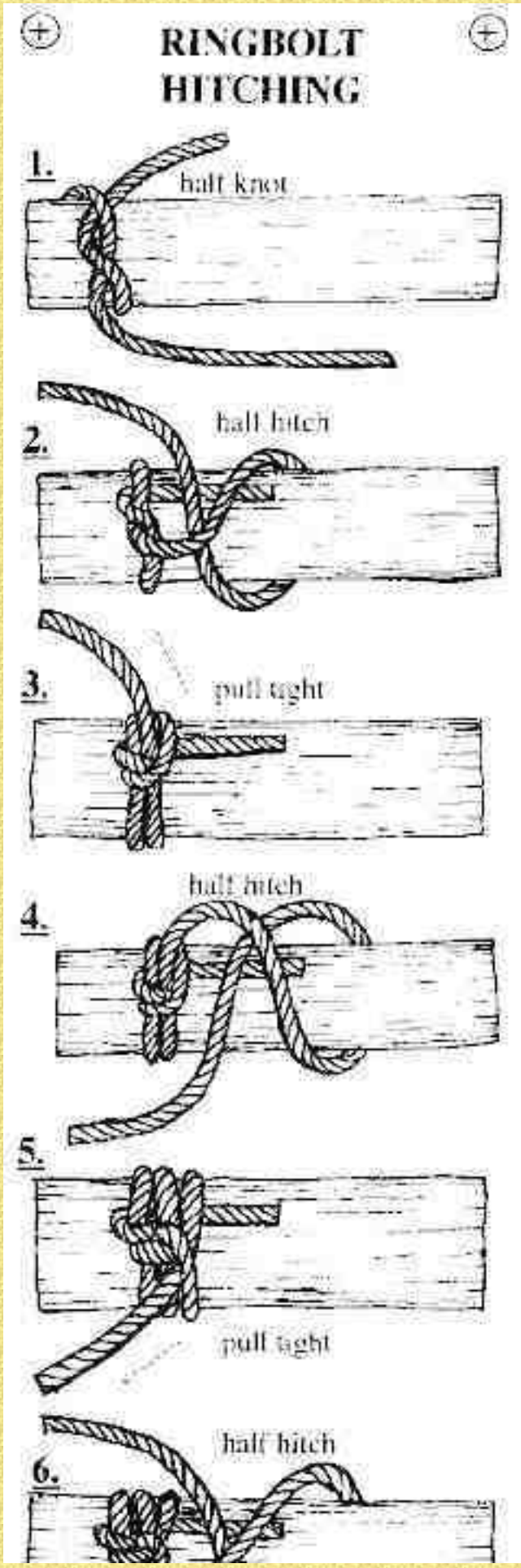

Description ----

A series of interlocking lark's head knot that form a ridge around the outside of a ring or loop.

Use ----

To prevent chafing; as a decoration.

Comments ----

There are many forms of ringbolt hitching, the form shown here is one of the simplest and does not require the use of a needle as many other forms do. Ringbolt hitching was used to prevent chafing of ropes that were reeved through hand forged iron rings and to keep them from clanging against objects around them. In the present,

ringbolt hitching can be used to protect synthetic ropes that are easily chafed by a applying a layer of material that is not easily chafed.

Other Names ----

Platted Ring; Hog Backing; Cockscombing.

Narration ------ (For Ringbolt Hitching knotboard.)

(1) Start the ringbolt hitching by tying a half knot around the object. (2) Tie a half hitch around the object so that the standing end is trapped under the half hitch. (3) pull the half hitch tight. (4) Tie the next half hitch in the opposite direction around the object. (5) Pull the half hitch tight. (6) Tie another half hitch in the opposite direction around the object; the same direction as the first half hitch. (7) Pull half hitch tight. (8) When the length of the ringbolt hitching is within 5 or 6 half hitches of being long enough; form a bight in the a short piece of twine so that the eye of the bight is toward the end of the work. (9) Continue to add half hitches until the ringbolt hitching is completed; reeve the running end through the eye of the bight. (10) Use the short piece of twine to pull the running end under the half hitches. (11) Cut off the end of the twine.

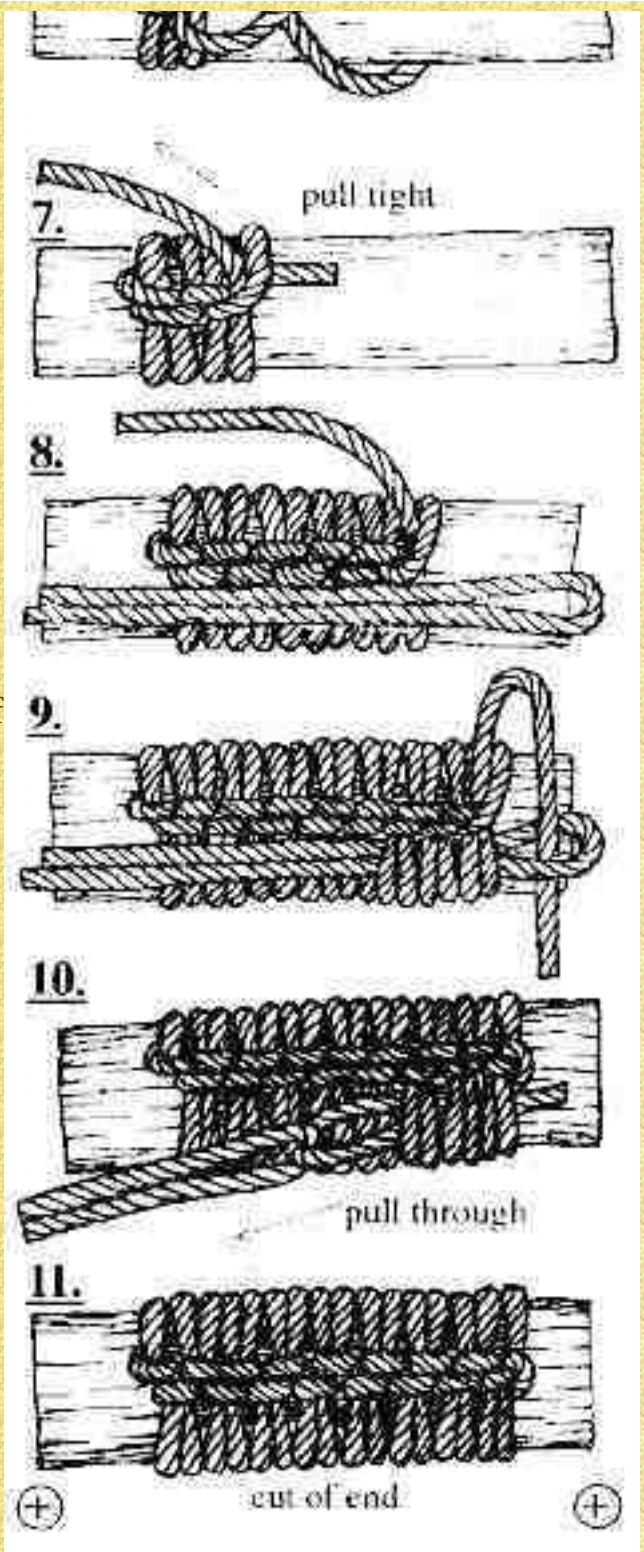

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BOATSWAIN'S WHISTLE KNOT

RERUN ANIMATION

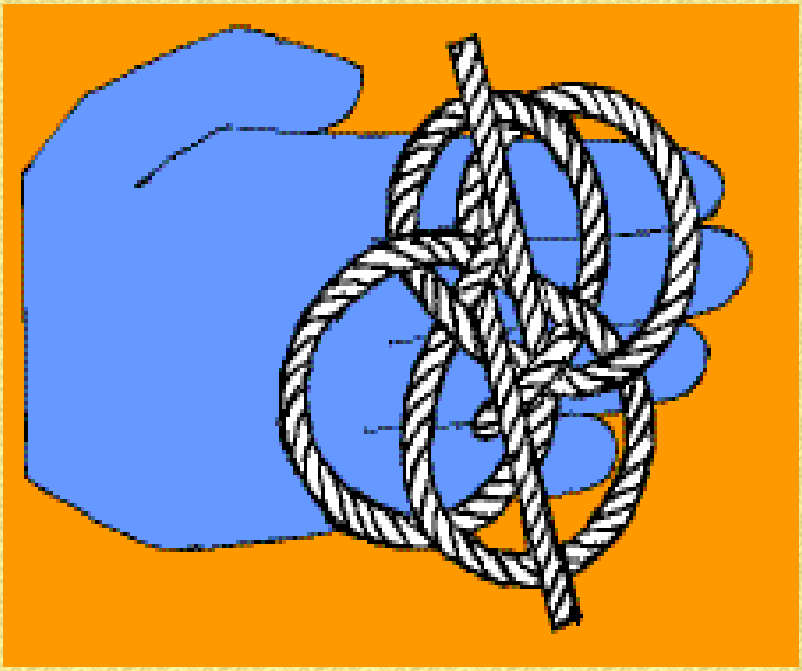

MORE ANNIMATED KNOTS

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Bög

Kötélvég kibomlása ellen, más csomóknál a szabad végek kicsúszásának megakadályozására.

<< | #eleje | index | levél | Dupla bög >>

Utolsó módosítás: 2002.09.26 23:41:34 CEST

Bowlin

Állóhurok. Eleg jól tart. Még akkor is viszonylag egyszerû kibontani, ha megszorul és vizes. Ui. a szár körüli kis fül nem feszül meg. (Persze ha uszályt vontatsz vele, akkor úgymarad.) Más néven paalsteek. Le kell biztosítani a kötélvéget.

<< Zászló~ | #eleje | index | levél | Dupla bowlin >>

Utolsó módosítás: 2002.09.26 23:41:34 CEST

Bowline

- A commonly used knot to tie a loop in the end of a rope. It has the advantage of not jamming, compared to some other loop forming knots (for example when using an overhand knot on a large bight to form a loop).
- Form a small loop (the direction is important), and pass the free end of the knot up through the loop, around behind the standing part of the rope, and back down through the loop.
- A chant used by many to remember this knot is "The rabbit comes out of the hole, round the tree, and back down the hole again", where the hole is the small loop, and the rabbit is the running end of the rope.
- In the same way that a Left Handed Sheet bend is a Sheet bend that has the running end of the rope coming out of the wrong side of the knot, a cowboy bowline is a bowline that also has the running end of the rope coming out of the wrong side of the knot. It suffers the same problems as the left handed sheet bend.

- Tip. Don't be afraid to use this knot to form a loop of any size in rope.
- Tip. To quickly identify if you have tied the Bowline normal or left handed, check to see that the running end exits the knot on the inside of the loop.
- Tip. For added security, finish the knot with a stop knot such as a Figure of Eight knot to remove any possibility of the Bowline slipping.
- Tip. If you use this knot in a man carrying situation - perhaps a rescue where a harness is unavailable - then you MUST use a stop knot as mentioned above.

Return to Knot Menu

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Campcraft Badge - Explorer Level - Knots and Lashings

Round Turn and Two Half Hitches
Sheep Shank
Bowline
Diagonal Lashing
Figure of Eight Lashing
Whipping of your choice

---

1. Round Turn and Two Half Hitches

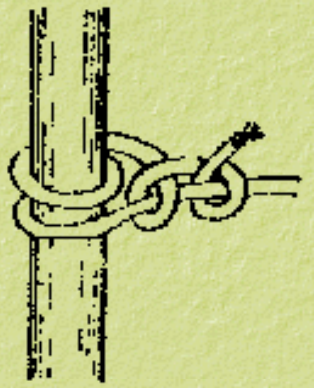

This knot is used to make fast a rope to an anchorage. It can be tied while the standing part is under strain. This is a good knot to attach your rope to an anchor for a flying fox or a bridge.

2. Sheep Shank

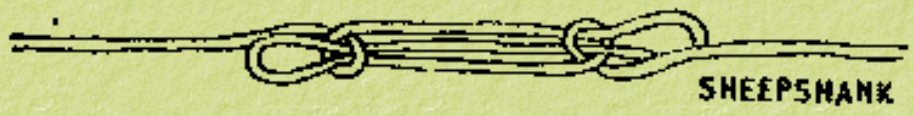

A knot tied in the bight for shortening a rope or taking up the slack, without cutting it. It can also be used to protect a weak damaged, or frayed section of the rope.

3. Bowline

The most useful and one of the simplest ways of putting a fixed loop in the end of a rope. It is easy to tie and untie, it never slips nor jams and has a high breaking strength.

4. Diagonal Lashing

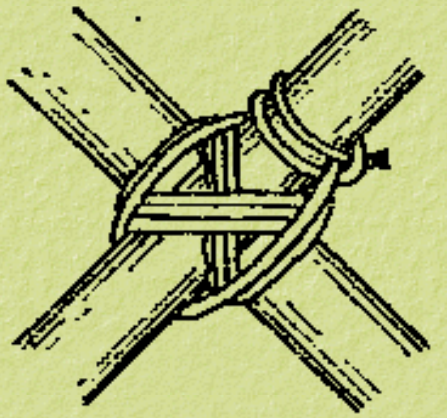

Used when two crossing spars tend to spring apart. Commonly used for the centre lashing on the diagonal braces of a trestle.

- Begin with a timber hitch.
- Do three diagonal turns across one way.
- Then three across the other way.
- Pull the lashing together with about three frapping turns
- Finish off with a clove hitch.

5. Figure of Eight Lashing

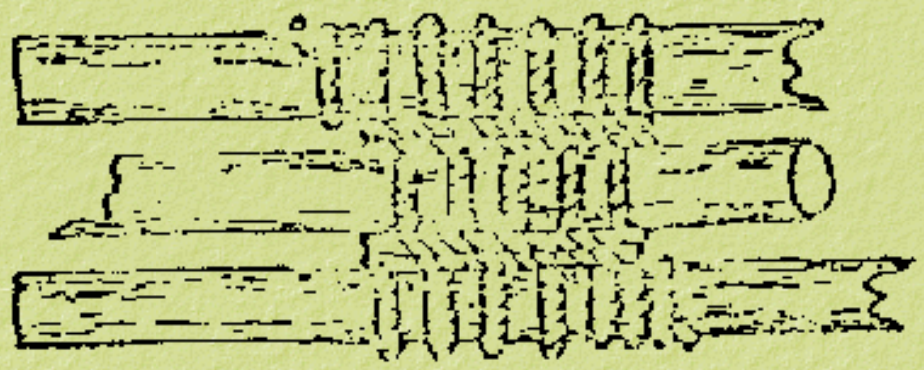

Used to make tripods. Lay spars with two running one way and the thrid in the other. Start with a clove hitch on one outer spar then take turns over and under. Make frappings between spars. End with a clove hitch on opposite spar to start.

6. Whipping of your choice

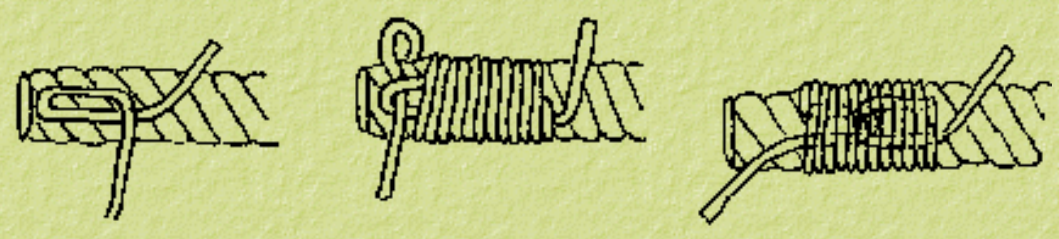

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EXPLORE ROPEWORKS

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Knots

The use of rope in the workplace was common practice until the midpoint of this century. At that time, modern materials handling techniques started to be used and the use of ropes declined. Along with this decline in the use of ropes in the work place there was also a decline in the knowledge of how to use rope safely.

The more common uses of rope by the average person is the securing of a load to a personal vehicle or for recreational purposes. Both of these uses require a knowledge of how to choose and tie safe, secure knots. If this knowledge is not available, the consequences can be devastating, resulting in personal injury or the loss of personal equipment.

For the last 35 years I have been learning and teaching about rope. My experience in teaching about rope has shown me that most people must be shown how to tie a knot in small, sequential steps, and they must be shown many times before they can tie a knot with confidence.

In preparing this book I have attempted to design a set of teaching aids that present each selected knot, splice, or lashing in small, sequential steps. These teaching aids enable the learner to study each step and to duplicate it with a length of practice rope.

The knots, splices and lashings presented in this book were selected because of their use by the Boy Scouts of America and others who are interested in outdoor recreation.

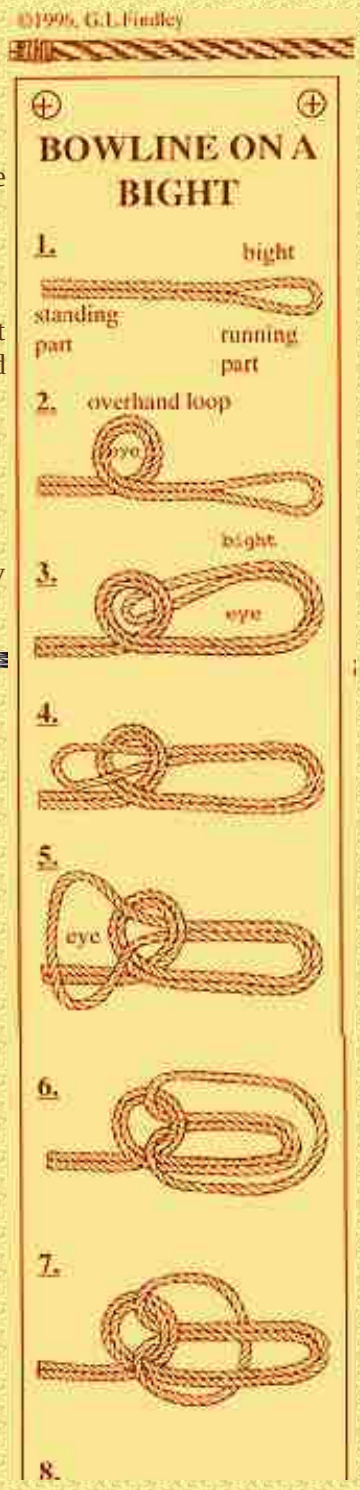

The following knots and hitches are covered in :

ROPE WORKS

Whipping (3 methods)
Service
Grapevine Service
Ringbolt Hitching
Sezing
Sezing With Racking Turns
Figure Eight
Figure Eight On A Bight
Stevedore Knot
Stopper Knot
Square Knot
Water Knot
Sheet Bend
Double Sheet Bend
Sheet Bend (Short End)
Bowline
Bowline On A Bight

French Bowline
Lineman's Loop
Sheepshank
Trumpet Knot
Sheepshank (Quick)
Clove Hitch
Constrictor Knot
Monkey's Paw
Turk's Head
Two Half Hitches
Taut-line Hitch
Timber Hitch
Mooring Hitch
Marlin Spike Hitch
Marlin Spike Ladder
Anchor Bend
Belaying To A Cleat
Jug Knot

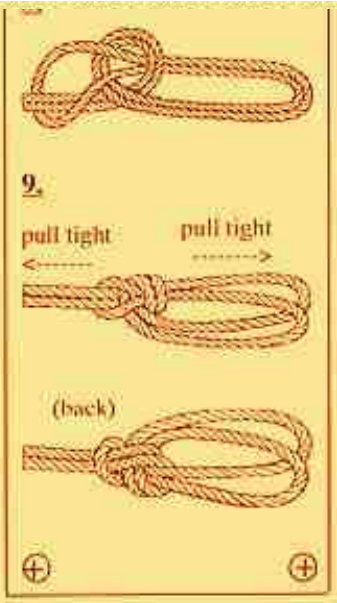

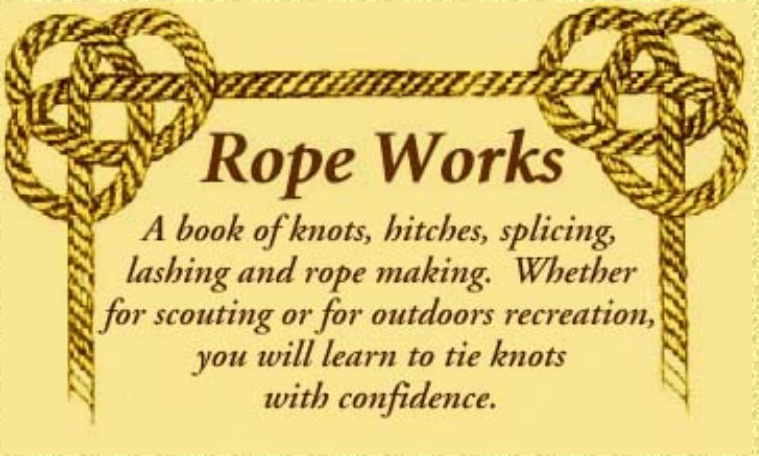

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ScoutDB.org presents *"How To Tie A Tie"*

As a service to the more fashion challenged (like me) ScoutDB presents the following primer on how to tie a tie. And be sure to check out what others are saying about ScoutDB's H2TaT.

Note that all images below are mirror images. That is, it is what you would see when looking into the mirror.

The Windsor Knot

Wide and triangular - for wide spread shirt collars

1. Start with wide end of the tie on your right and extending a foot below narrow end.
2. Cross wide end over narrow and bring up through loop.
3. Bring wide end down around behind narrow and up on your right.
4. Then put down through loop and around across narrow as shown.
5. Turn and pass up through loop and...
6. Complete by slipping down through the knot in front. Tighten and draw up snug to collar.

The Half-Windsor Knot

Medium symmetrical triangle - for standard shirt collars

1. Start with wide end of the tie on your right and extending a foot below narrow end.
2. Cross wide end over narrow and turn back underneath.

3. Bring up and turn down through loop.
4. Pass wide end around front from left to right.
5. Then up through loop...
6. And down through knot in front. Tighten carefully and draw up to collar.

The Four-In-Hand Knot

Long and straight - to complement a standard shirt collar

1. Start with wide end of the tie on your right and extending a foot below narrow end.
2. Cross wide end over narrow and back underneath.
3. Continue around passing wide end across front of narrow once more.
4. Pass side end up through loop.
5. Holding front of knot loose with index finger, pass wide end down through loop in front.
6. Remove finger and tighten knot carefully. Draw up tight to collar by holding narrow end and sliding knot snug.

The Bow Tie

For the man who dresses with a certain flair

1. Start with end in left hand, extending 1.5 inch below that in right hand.
2. Cross longer end over shorter and pass up through loop.
3. Form front loop of bow by doubling up shorter end (hanging) end placing across collar points.
4. Hold this front loop with thumb and forefinger of left hand. Drop long end down over front.

5. Place right forefinger pointing up on bottom half of hanging part. Pass up behind front loop and...
6. Poke resulting loop though knot behind front loop (see illustration). Even ends and tighten.

Bob Baggerman
bob.public@mindspring.com

ScoutDB Home

6/21/2003
http://www.scoutdb.org/h2tat/

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ARCHIVE

KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

BELAYING TO A CLEAT:

Use ----

To secure a flag lanyard, to moor a boat to a dock.

Comments ----

Belaying to a cleat is a fast non-jamming method of securing a rope anywhere along its length without reeving any part of the rope through or around anything.

Narration ------ (For Belaying to a CleatKnotboard.)

(1) Take a turn around the cleat and pull the line tight. (2) Complete a round turn around the cleat . (3) Place the line across the cleat. (4) Take a bight around one horn of the cleat. (5) Place the line across the cleat a second time. (6) Take a bight around the other horn of the cleat to form a figure eight around the horns of the cleat. (7) Repeat steps 3 through 6. (8) Form an underhand loop. (9) Place the eye of the underhand loop over the horn of the cleat. (10) Pull the underhand loop tight to form a half hitch around the horn of the cleat, this locks the rope in place.

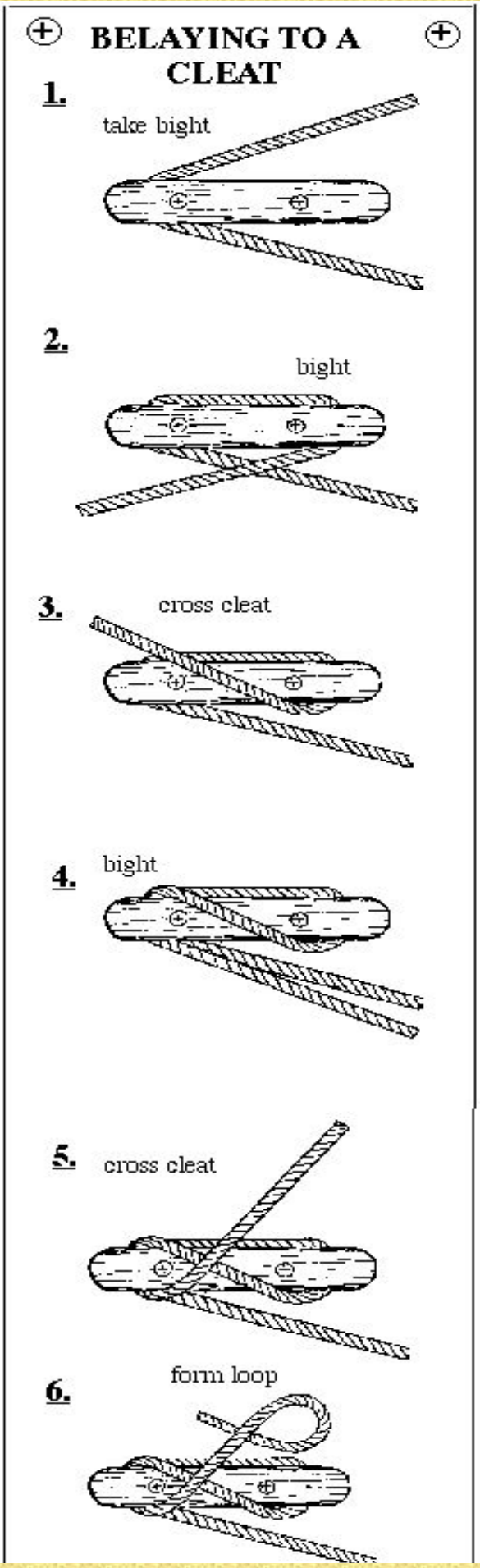

ANNIMATED KNOT

BELAYING TO A CLEAT

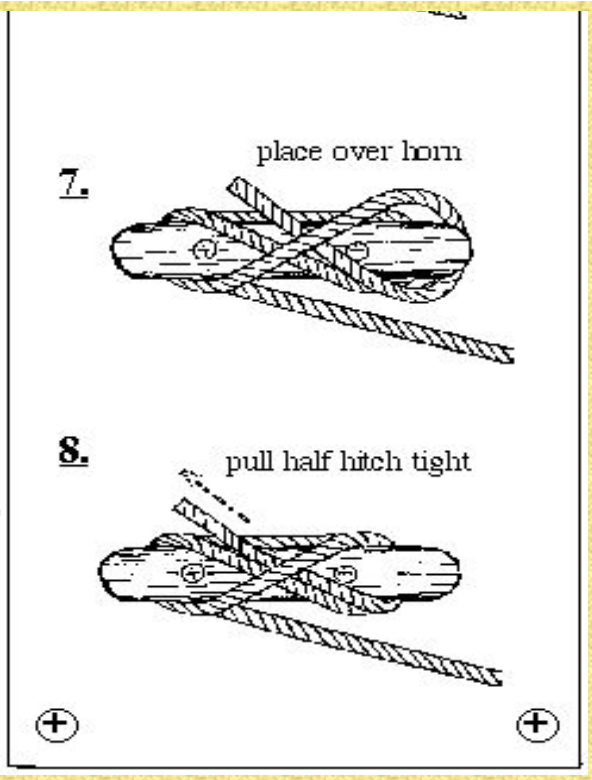

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BELAYING TO A CLEAT

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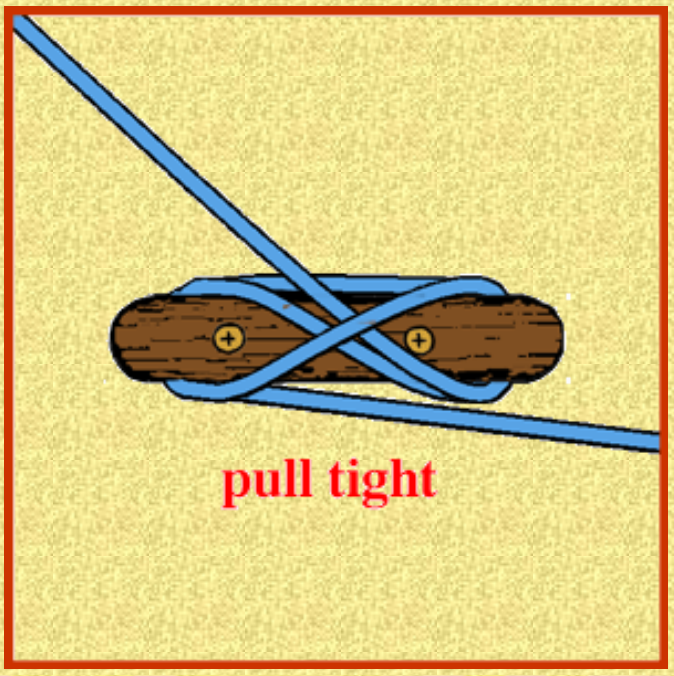

MORE ANNIMATED KNOTS

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Campc Badge - Pioneer Level - Knots and Lashings

Reef Knot
Sheet Bend
Clove Hitch
Rolling Hitch
Square Lashing
Round Lashing

1. Reef Knot

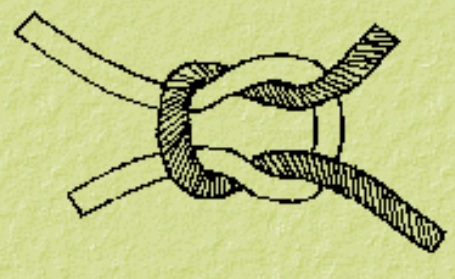

Used to join the two ends of the same rope or bandage. ("Right over left - left over right")

2. Sheet Bend

The Sheetbend is a knot that you use to tie two ropes together. Good both for thick and thin ropes. Easy to untie. It gets its name from the rope attached to the corner of a sail. This rope is called the sheet.

3. Clove Hitch

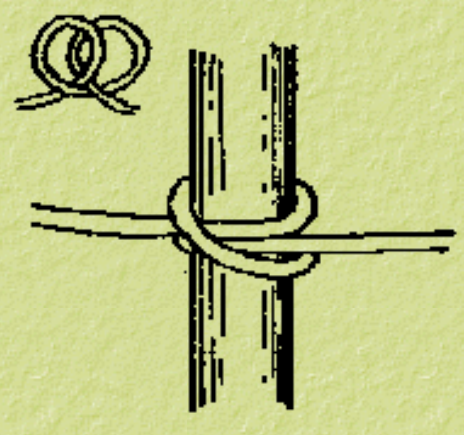

The nearest there is to a general utility hitch. It is easy to tie in a number of different ways and to untie.

4. Rolling Hitch

The rolling hitch allows you to slide the knot up and down the running part of the rope. It can be used on tent ropes, as a strainer for a bridge, in fact anywhere you want to be able to loosen or tighten a rope quickly.

5. Square Lashing

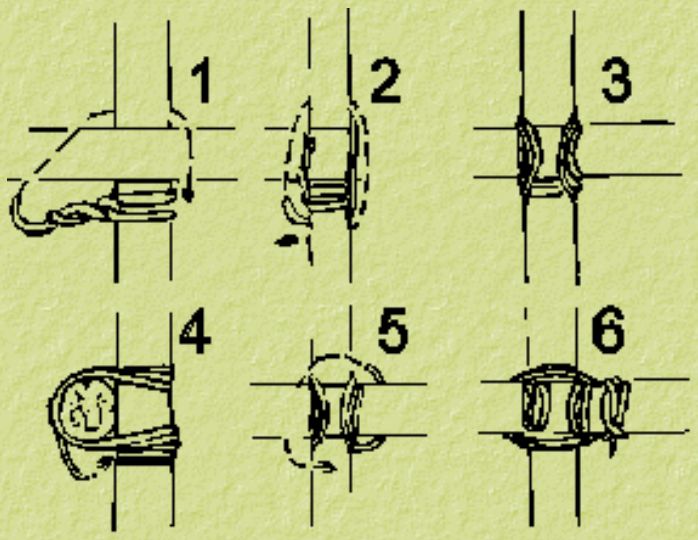

Used to fasten two spars or poles together

Begin with a clove hitch round the upright and tuck the end in neatly. Pull the clove hitch very tight, and take the long end over the crossbar, round the back of the upright, and over the crossbar again. Follow the same course, being careful to lay each cord alongside the one before and to pull tight all the time, until you have been round each part three times. Then take two or three frapping turns behid the crossbar and in front of the upright. Finish off with a clove hitch, puuled very tight, round the crossbar.

6. Round Lashing

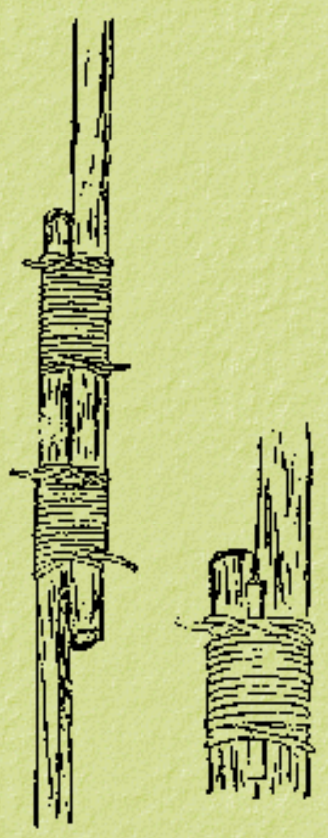

Used to lash two poles together (constructing a flagpole)

1. Tie a clove hitch round the bottom pole
2. Wind the rope around both six or seven times
3. Finish with two half hitches round both poles.
4. The lashing can be tightened by driving a small wooden peg between the poles

---

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Clove Hitch

- Use to attach a rope to a pole, this knot provide a quick and secure result. It rarely jams, and can in fact suffer from the hitch unrolling under tension if the pole can turn. Often used to start and finish lashings.
- With practice, this can be easily tied with one hand - especially useful for sailors!

- Tip. If you are in a situation where the clove hitch may unroll, add a couple of half hitches with the running end to the standing end of the knot, turning it into a "Clove Hitch and Two Half Hitches"!
- Tip. When pioneering, use the Round turn and two half hitches to start and finish your lashings instead of the Clove Hitch. It won't unroll, and is easier to finish tying off. It just does not look so neat!

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Which is the best rope for the job? See rope properties.
What is the safe working load of my rope? See safe working loads.
Can the elements affect my rope? See proper use and care of rope.
How do I splice rope? See rope splicing techniques.

THREE USEFUL AND POPULAR MARINE KNOTS

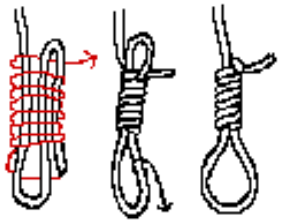

Hangman's Knot

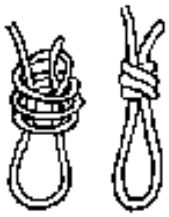

Scaffold Knot

Gallows Knot

Fisherman's Bend

An important knot because of its strength and simplicity, and becomes more secure when end is seized as shown.

Surgeon's Knot

This knot is usually tied with twine. The Surgeon's Knot is a modified form of the reef knot, and the extra turn taken in the first tie prevents slipping before the knot is completed.

Sheet Bend

Also known as Weaver's Knot, and is used aboard ships for joining small or medium sized ropes.

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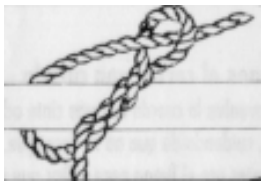

Timber Hitch
This knot is very useful for hoisting and towlines, and holds well without slipping or jamming.

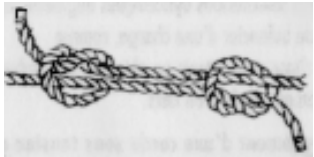

Fisherman's Knot
The Fisherman's Knot is probably the strongest known method of joining fine lines, such as fishing lines.

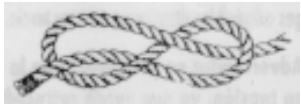

Figure-Eight Knot
This knot is used at the end of a rope to temporarily prevent the strands from unlaying.

Clove Hitch
Also known as Builder's Hitch because of its wide use by builders in fastening staging to upright posts.

Reef Knot (or Square Knot)
If tied with two ends of unequal size, or if one end is stiffer or more slippery than the other, it is bound to spill. Under no circumstances should it be used as a bend. (A bend is tying two ropes together.) There have probably been more lives lost as a result of using a SQUARE KNOT as a bend.

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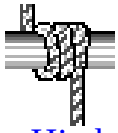
the Hitches

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The Constrictor Knot Family ( )

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The Constrictor Hitch

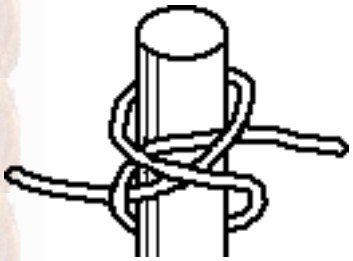

The constrictor knot is important as temporary whipping and as permanent binding from which you need more than one in a row, but not in line (when you should use the strangle knot). Laid well, it is virtually impossible to untie without tools (needle or knife). Never use it if you need to untie it. It is almost the strongest among the 'simple' hitches. Only the double constrictor is stronger. Because the constrictor may be tied in a bight, it is often preferred over the strangle knot.

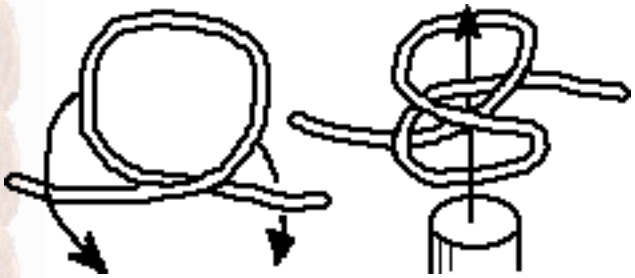

Lied in the bight, it is possible to use the constrictor virtually everywhere where a permanent hitch is needed. In fact, it is my favorite permanent hitch.

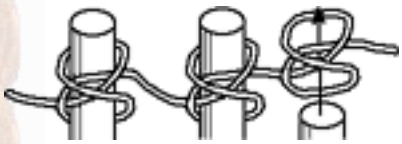

One of the best applications for this knot is the temporary whipping of ropestrands during marlinspiking. With one yarn, you can easily whip more than one strand at the time. Once tied, you pull them firmly all at once.

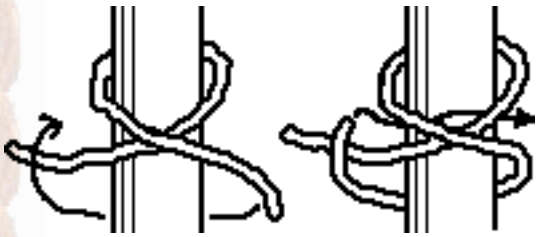

When you cannot place the knot around the object after the knot is formed, you have to tie it round the object. This may be difficult if you did not leave enough room to put the end through.

For tieing a fence rope, you can tie the constrictor in this interesting way. It allows working it up to

one end while you maintain a limited force on the other end. So, you easily make a straight rope fence (As long as your posts stand firm)
The Constrictor Knot on the WEB.

The Transom Knot

The Transom Knot (Constrictor)

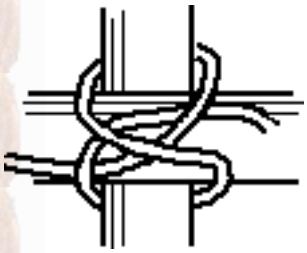

Tied this way the constrictor is an excellent cross knot, called the Transom Knot. (I used it for my kite when I was a kid). If you want to secure it, use two closely laid overhand knots in both ends, or simply use a good kit or glue. An extra knot above this knot does not have much effect. If more strength is required, tie another Transom Knot on the back.

The Transom Knot (Marlin)

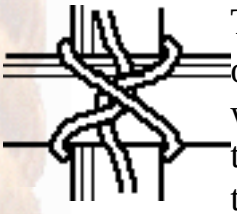

Tied this way the Marline Hitch is an even better cross-knot as the previous version of the Transom. It is not possible for the half-knot to work itself between both rods where it is not held by the overlaying rope. Therefore, it is a better cross knot than the constrictor-version of the Transom. (Thanks for the comment! I wish I knew this as a kid. On the other hand I did not have any trouble with the constrictor version. But I argree this is better.)
The Transom Knot on the WEB.

The Double Constrictor

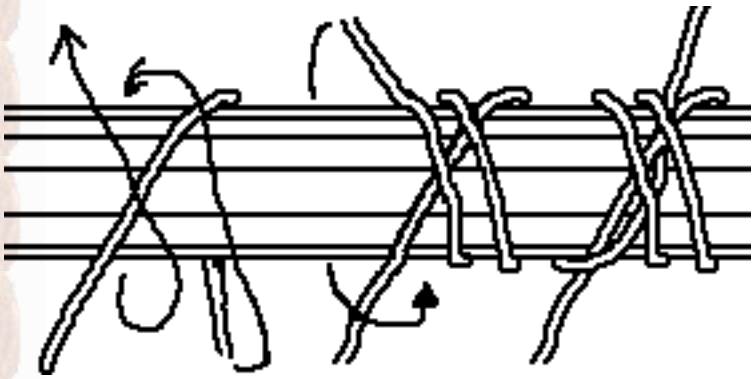

This is the strongest and most secure simple hitch. If the single constrictor does slip (on very slippery material) you can try this knot. If you make more turns round the enclosed half knot or if you twine the half knot one wrap extra it makes the total result weaker. That is probably because it makes it impossible to pull the knot as tight as this one. I always use the double constrictor to "strangle" tubes tight on a pipes. Tubes are often made from "slippery" materials.

The Double Constrictor tied in the bight.

If the end of the object which

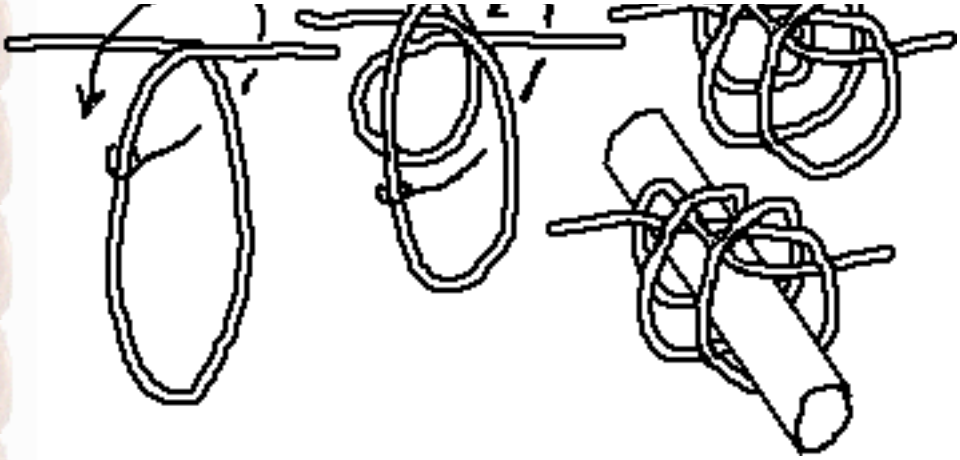

you want to lay the double constrictor on is free, it is best to tie the knot in the bight. If you master this technique it is much faster. Practice and check yourself after the first turn. If that resulted in the single constrictor instead of the clove hitch you started the wrong way.

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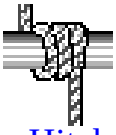

the Hitches

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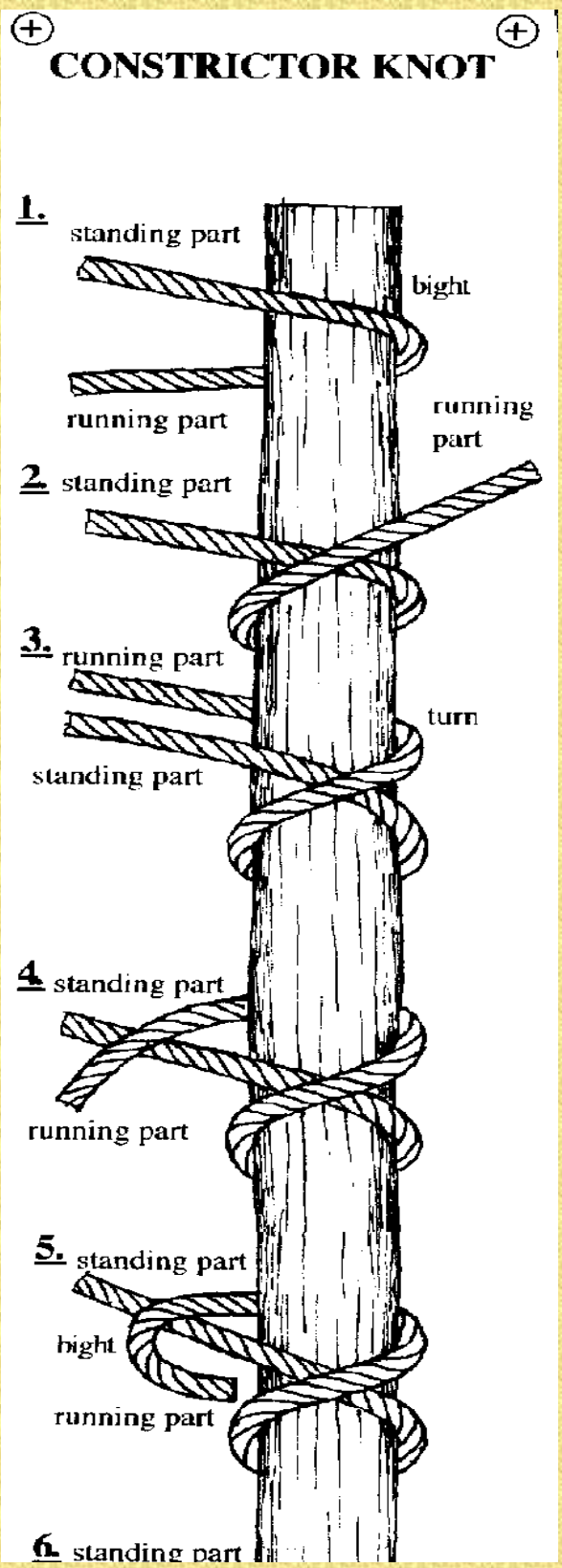

KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

CONSTRICTOR KNOT:

Dscription ----

A clove hitch with a half knot under the cross-point.

Use ----

To tie a smaller rope to a larger one, or to tie a rope to a stake or pole; a substitute for whipping; as a lashing for light construction ; as a hose clamp.

Comments ----

A secure nonslip knot ; difficult to untie without cutting.

[NOTE]

Use this method of tying the constrictor knot on either side of where you intend to cut a rope. This is a fast and easy way to prevent a rope from unlaying when it is cut.

Narration ------ (For Constrictor Knot knotboard.)

((1) take a bight around an pole. (2) Continue wrapping the running part around the pole so that the running part crosses over the standing part. (3)

Complete the turn around the pole. (4) Cross the running part over the standing part so that (5) a bight is formed around the standing part. (6) Reeve the running part under the cross part of the loop in the standing part to form a half knot under the cross-point. (7) Pull the standing tight. (8) Lock the knot tight by pulling hard on both the standing part and the running part.

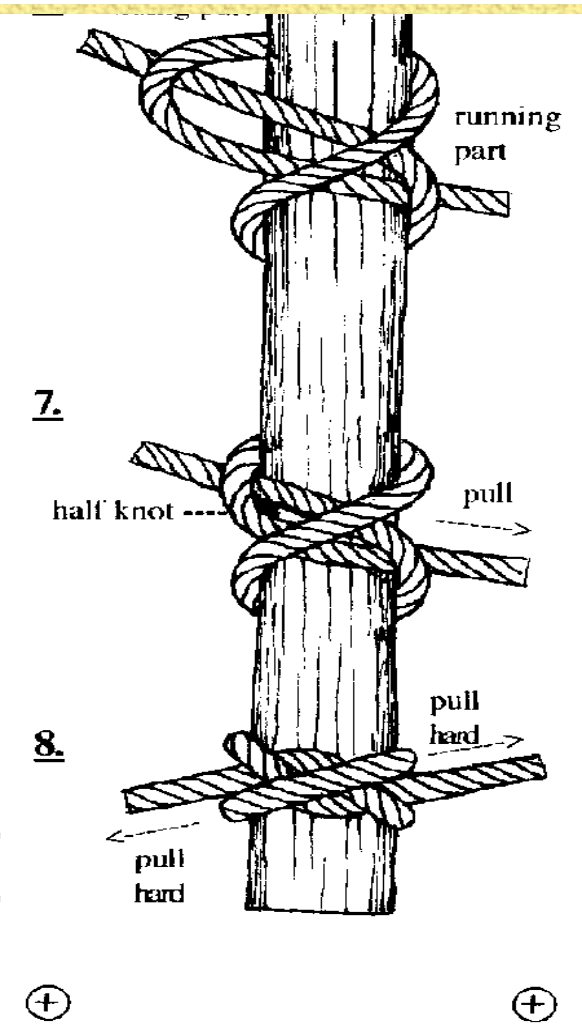

ANIMATED KNOT

BOATSWAIN'S WHISTLE KNOT

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CONSTRICTOR KNOT

RERUN ANIMATION

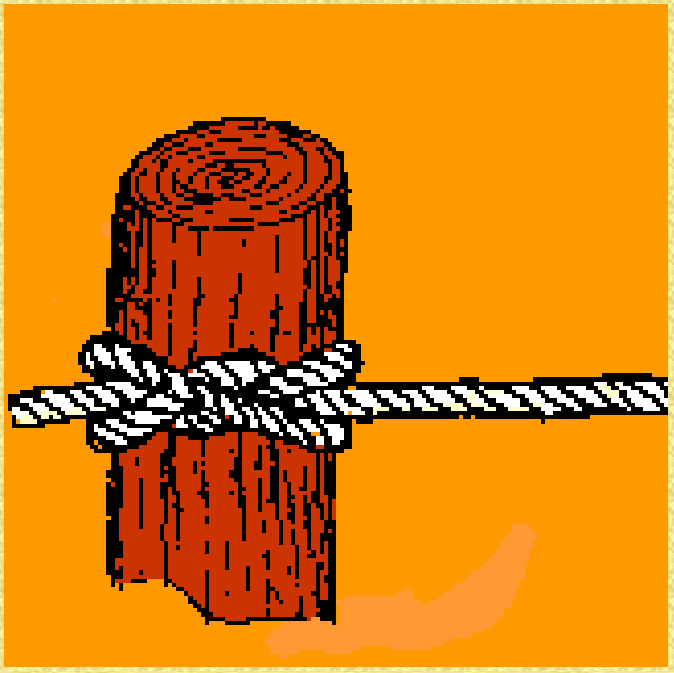

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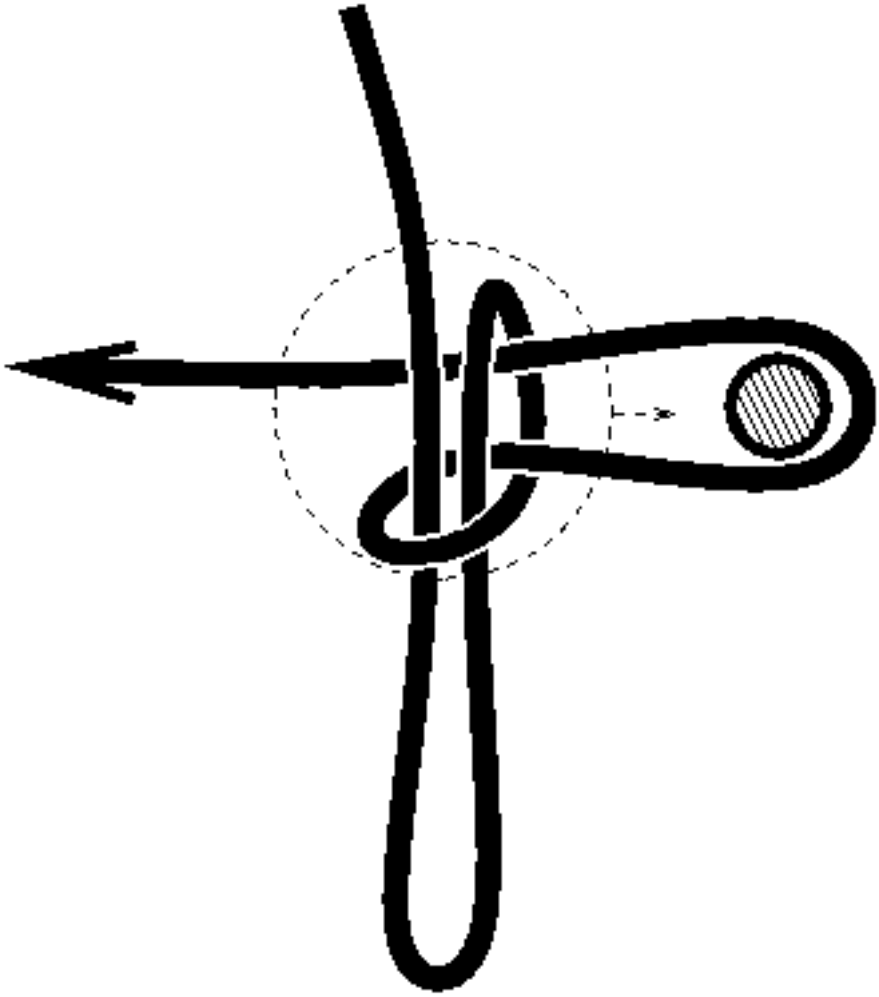

Gyorsan oldható csomó. Pl. csónak ideiglenes kikötésére gyûrûhöz. Elõször meg kell húzni a bekarikázott részt, aztán ütközésig eltolni a száron a nyíl irányába. Oldáshoz egyszerûen a szabad véget kell megrántani.

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The Bends

The Fishermans Bend Family

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The "Fishermans bend" is a bend. There is a page on bends.

The True Lovers or Fishermans's Knot

The True Lovers, or Fisherman's Knot may be laid in two different ways. Which of both the is the stronger, I do not know.
With two equal overhandknots it is symmetrical. This is probably the most used variant.

With two different overhand knots you get the most beautiful version (always work it up neatly!)
Only ... The double eight is stronger, easier to untie after use and as decorative from all sides as the true lovers at best.

Related knots

Double Fisherman's Knot

This is the double-stopper knot with the Double Overhandknot as a base. In fact you tie two strangle knots round the standing parts of both ropes. It is best to tie two counter-image strangle knots. With equal knots it is far more difficult to fit them close to eachother.
This knot is used by climbers to tie two ropes together. It is strong and releyable, but difficult to untie where this knot ends up in the middle of a climbing rope (and it will if you used it to tie two ropes together!) it is wise to tie a fixed loop in the loose end of the falling part as a security by passing the knot.

Double Fisherman's Knot

This is for me the universal 'double-stopper-bend'. It is strong, beautiful, it does not jam, so what do you want more... It is the bend-variant of the flemish Eight

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The Bends

Double Sheet Bend

- The Double Sheetbend is a more secure form of the Sheetbend.
- The thicker rope of the two is used to form a bight, and the thinner rope is passed up through the bight, around the back of the bight, around again before tucking under itself.

- Tip. It is particularly useful when the thickness of the two ropes varies considerably, or when a more secure Sheetbend is required.

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Splicing

Splicing is used to join ropes together by interweaving the strands of the rope. Splicing is the safest way to fasten two ropes together or to form a loop. Knots could also be used to do these jobs but knots weaken the rope by as much as 30 to 55 percent of the original strength of the rope. However, with a splice the rope is 85 to 90 percent as strong as the original rope. Splicing should be used whenever there is a concern about safety or when the loop or joint is going to be left in the rope.

[NOTE] After a splice is started or after each round of tucks, fold the strands back over the work. You will notice that there is one strand going in and one strand coming out between each of the strands of the standing end. If this configuration does not exist you have made a mistake; trace the strands back and correct the mistake or pull strands out and start over.

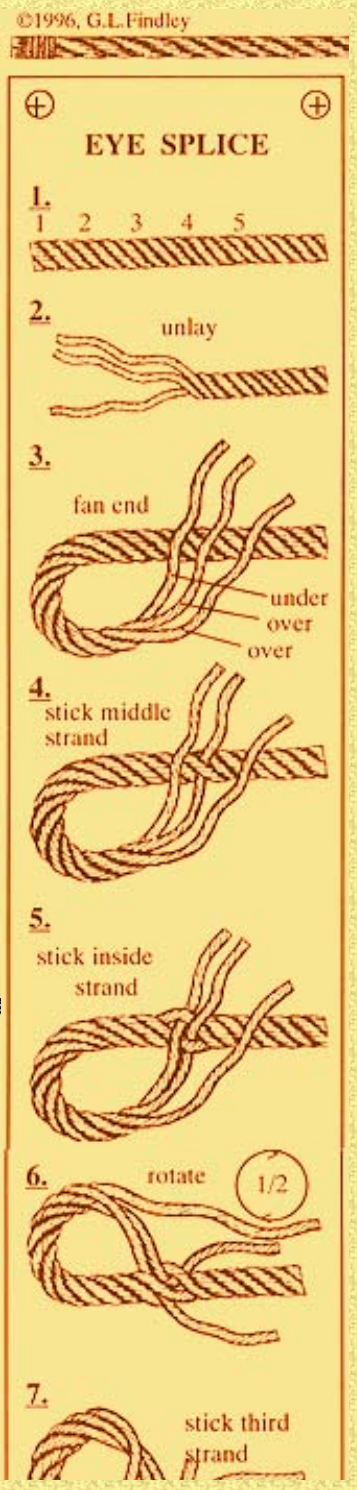

The following topics about splicing are covered in :

ROPE WORKS

Crown Knot
Back Splice
Eye Splice
Short Splice
Adding A Round Of Tucks
Ending A Splice

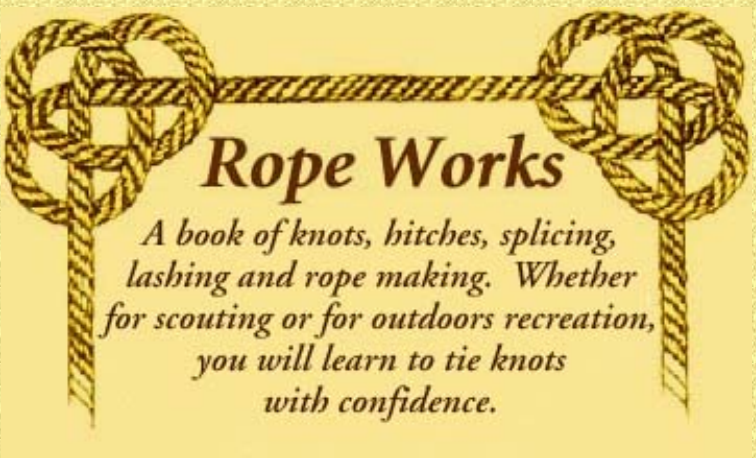

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Badge - Adventurer Level - Knots and Lashings

Fishermans Knot
Manharness Knot
Hunters Bend
Back Splice
Eye Splice
Japanese Square Lashing
Filipino Lashing
Prussic Knot

1. Fishermans Knot

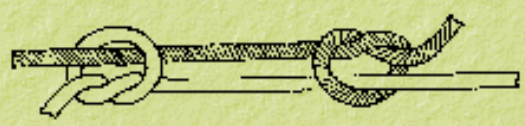

For stiff ropes and cords use the Fisherman's Knot. Easy to make, difficult to untie, so don't use it on a good rope, especially if there is a lot of strain on it.

2. Manharness Knot

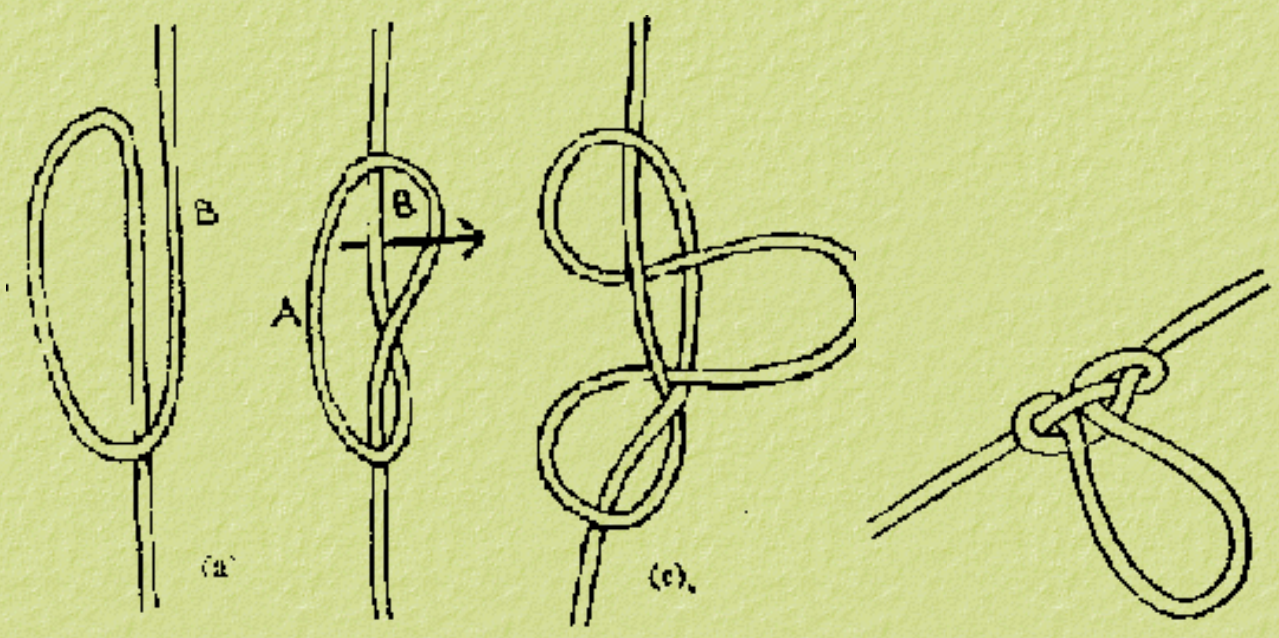

Also called the Artillery Knot and Diagonal Figure of Eight. A loop knot tied in the bight through which an arm can be put up to the shoulder to assist in hauling, while leaving the hands free.

Formerly used on gun carriages, one end of the rope being fastened to a ring on the end of the axle. Good for tying a 2nd boat/raft into the painter of a boat already tied to the only decent point on shore.

3. Hunters Bend

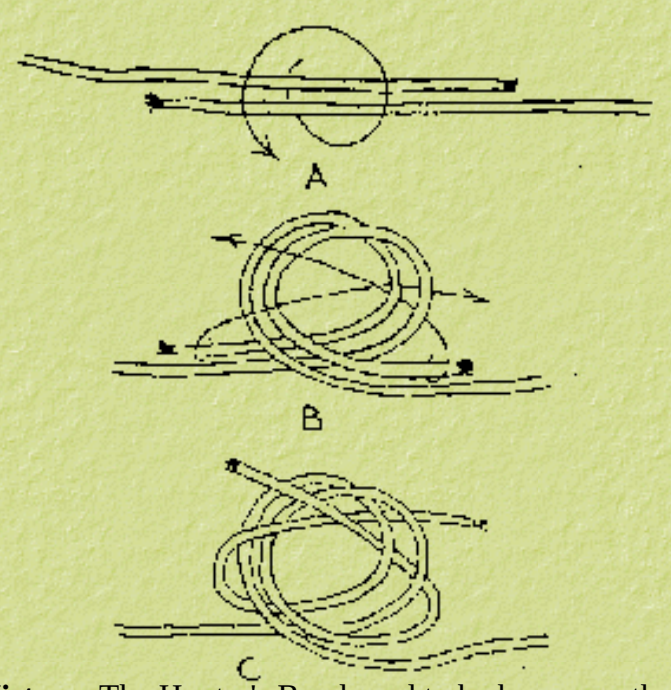

History: The Hunter's Bend used to be known as the Rigger's Knot. When it appeared on the front page of the The London Times in 1978 it was credited to Dr Edward Hunter. This led to much publicity for a knot and also to the foundation of the International Guild of Knot Tyers

4. Back Splice

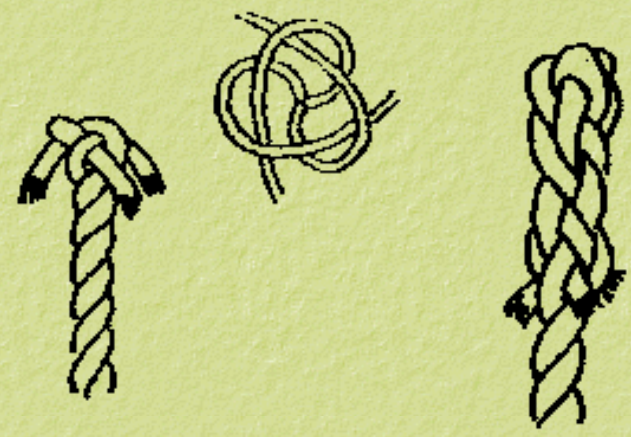

A simple and effective method of finishing the end of a rope in which a crown knot is made with the strands at the end which are then spliced back into the rope.

5. Eye Splice

A method of putting a permanent eye in the end of a rope. The strands are unlaid, a loop of suitable size formed and the three strands are spliced or worked in and out of the rope, usually under and over. Three "tucks" are normally taken.

6. Japanese Square Lashing

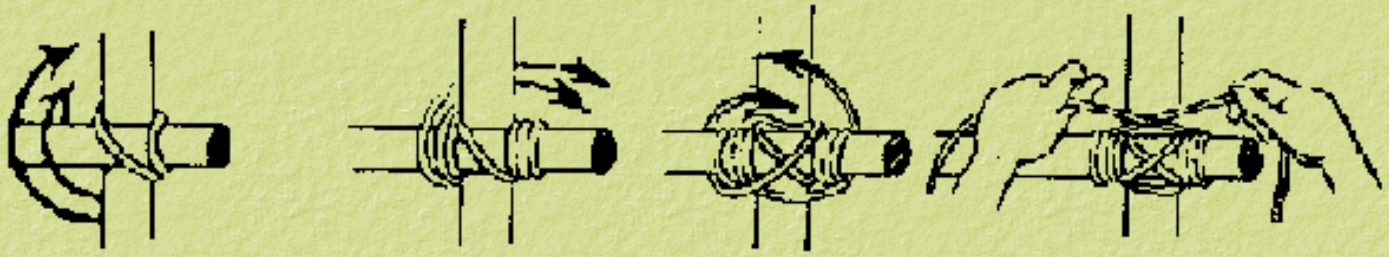

A lashing used in lightweight construction work.

6. Filipino Diagonal Lashing

A lashing used in lightweight construction work.

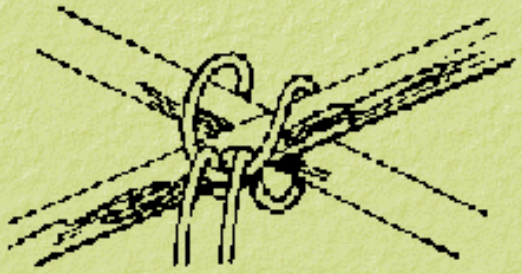

1. Start with the middle of the rope, tucking the running ends through the middle "loop" after going round both spars. Use the "loop" to pull the spars together.

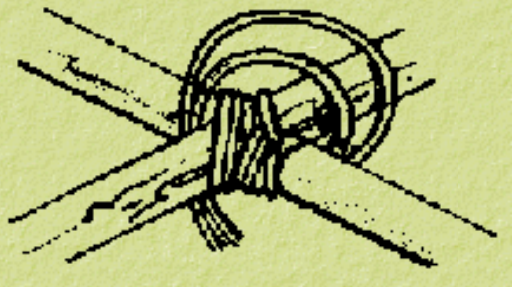

2. Now proceed as for a diagonal lashing taking the running end round both spars, keeping both ends together.

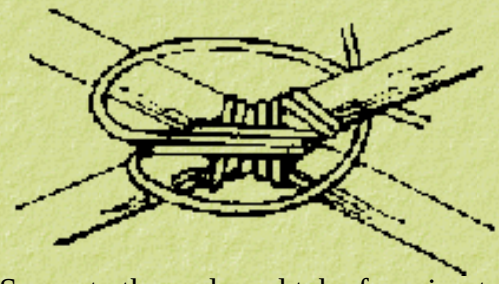

3. Separate the ends and take frapping turns between the spars, pulling the rope tight as you do so.

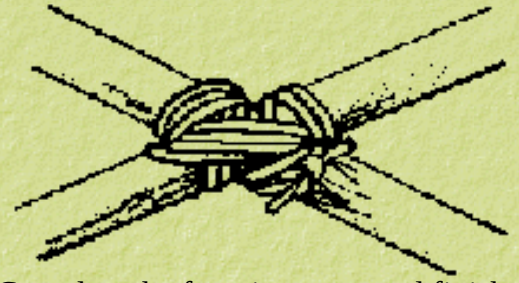

4. Complete the frapping turns and finish off with a square knot.

7. Prussic Knot

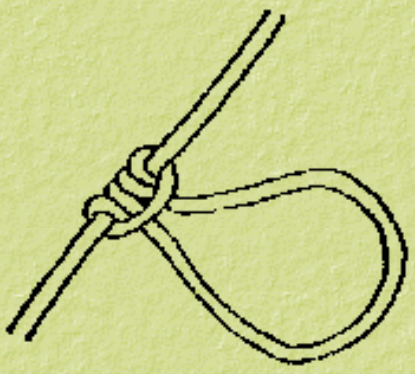

A knot used by climbers. It is made with a strop (endless loop, either spliced or tied) round the main climbing rope. It can be loosened and slid along the rope to vary its position on the rope.

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Figure of Eight Knot

(Flemish Knot, Savoy Knot)

- A useful "Stop" knot to temporarily bulk out the end of a rope or cord, the finished knot looks like its name. It is superior to using a Thumb Knot, because it does not jam so easily.
- Tip: The Figure of Eight is useful to temporarily stop the ends of a rope fraying, before it is whipped.

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Figure Eight Knot

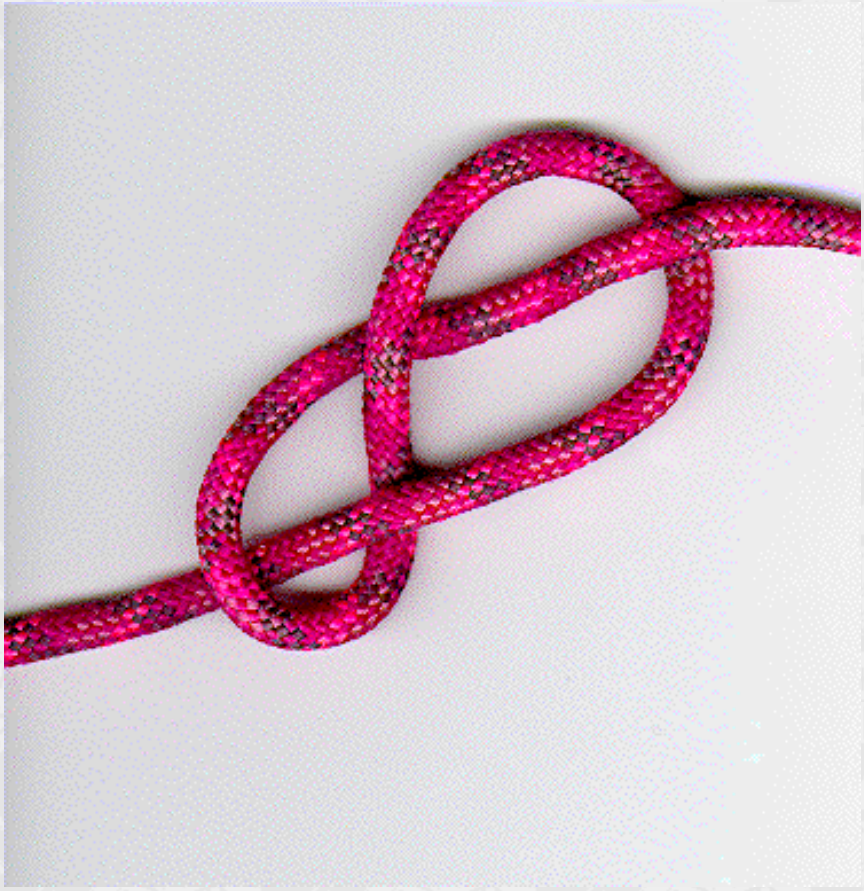

This knot is part of some other FTM knots we will learn and is used to tie them.

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

FIGURE-EIGHT KNOT:

Description ----

Interlocking overhand loops, the running part goes through the eye of one loop and the standing part goes through the eye of the other loop.

Use ----

(1) As a stopper knot; to keep a rope from unreeving from a pulley block; to prevent a rope from unlaying. (2) When tied on a bight, makes a reliable loop for rescue work and mountaineering.

Comments ----

Easier to tie and untie than an overhand knot; does not damage the rope fiber or jam like an overhand knot.

Narration ------ (For Figure-eight Knotboard.)

(1) Form an overhand loop. (2) Take a bight around the standing part. (3) Form the second overhand loop by bring the running part over the top edge of the firs overhand loop. (4) Complete the knot by reeving the running part through the eye of the first overhand loop (5) and pull tight.

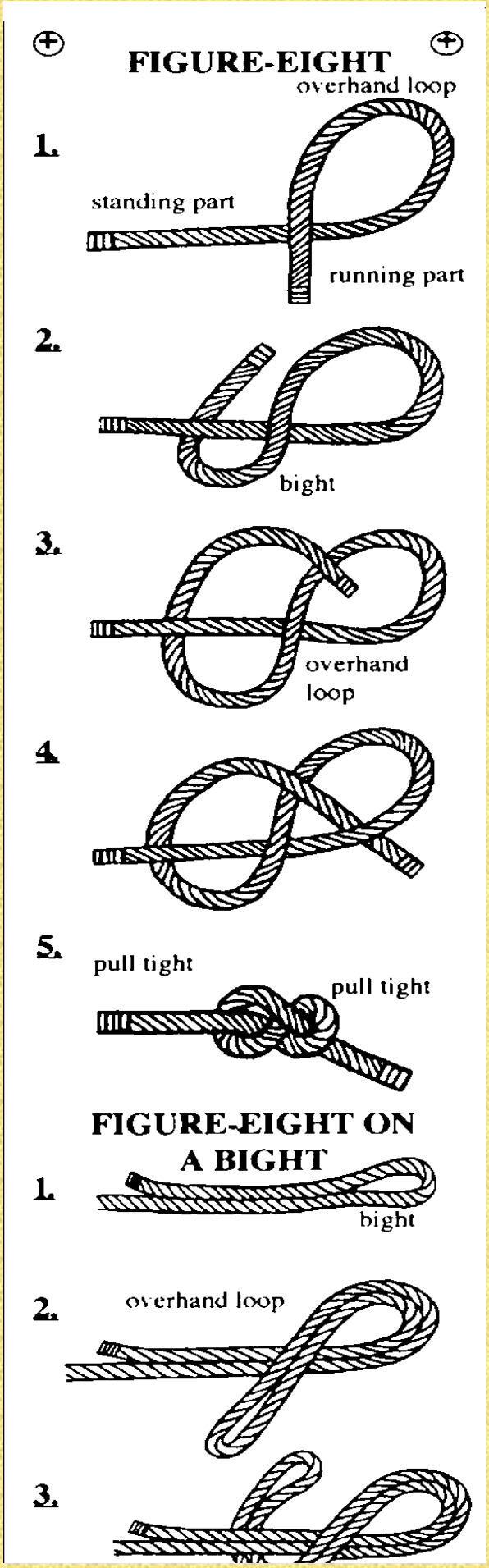

FIGURE-EIGHT ON A BIGHT:

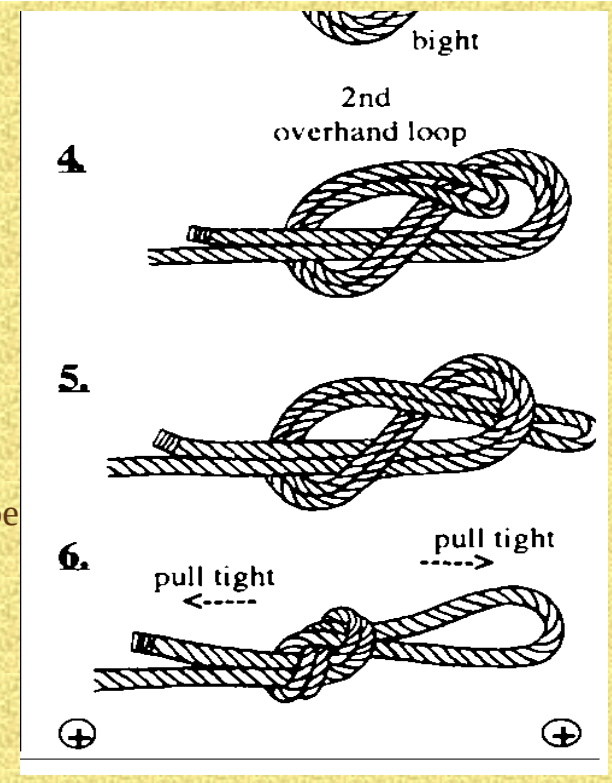

Description ----

Interlocking overhand loops tied on a bight in the running part (the bight is used as the running part); the running part goes through the eye of one loop and the standing part goes through the eye of the other loop.

Use ----

(1) Makes a reliable loop for rescue work and mountaineering. (2) As a stopper knot; to keep a rope from unreeving from a pulley block; to prevent a rope from unlaying.

Comments ----

Easier to tie and untie than an overhand knot; does not damage the rope fiber or jam like an overhand knot on a bight.

Narration ------ (For Figure-eight on a Bight Knotboard.)

(1) Form a bight in the rope. [NOTE] Treat the two strands of the bight as a single strand as the rest of the knot is tied. (2) Form an overhand loop. (3) Take a bight around the standing part. (4) Form the second overhand loop by bring the running part over the top edge of the firs overhand loop. (5) Complete the knot by reeving the running part through the eye of the first overhand loop (6) and pull tight.

ANNIMATED KNOT

BELAYING TO A CLEAT

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FIGURE-EIGHT KNOT

RERUN ANIMATION

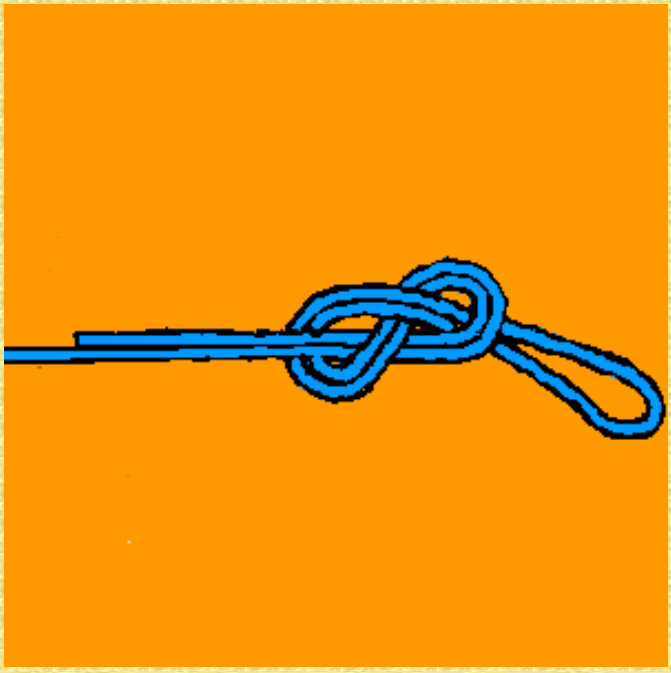

MORE ANNIMATED KNOTS

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Fisherman's Knot

(Angler's knot, English knot, Englishman's bend, Halibut knot, True Lover's bend, Waterman's knot)

- The Fisherman's knot is used to tie two ropes of equal thickness together. It is used by fishermen to join fishing line, and is very effective with small diameter strings and twines.
- Tie a Thumb knot, in the running end of the first rope around the second rope. Then tie a thumb knot in the second rope, around the first rope. Note the Thumb knots are tied such they lie snugly against each other when the standing ends are pulled.
- When tying knots in monofilament line, moisten the line before pulling the knot tight. This helps to stop the line heating up with friction, which weakens it.

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Chinese Knotting: The Flower Knot

Generalities

This particular knot has many names and seems to be a sequential variation from a number of different families of knots. I've chosen to give it the name of *flower knot* because I've always thought of its basic shape and ordinal variations as flowers.

Nomenclature

Chen 1: Cloverleaf Knot (3, 4), Round Brocade Knot (6)
Korean: Ginger Knot (4)
Owen: Butterfly Knot (3)
Hensel: Dragonfly Knot (4)
TAoCaWK: Double Loop Shamrock Knot (3), Shamrock Knot (4), Petal Knot (5-10), Ruyi Knot (3(1)x4)

Similar Knots

- The Treasture (Bao or Star) Knot

How To

3. 4. 5. 5o2. 6. 7. 8. 9.

General Tips

- **keep the loops that form the centre of the knot similarly oriented.** That is to say, as a general rule keep the part of the loop that leads from the already completed body of the knot aligned to the top of the knot and the part of the loop that is closer to the free working end aligned to the bottom of the knot. You can reverse this orientation if you wish, as long as you are consistent with all the loops.
- **keep the centre loops as short as will still allow you to work**, the petals will take care of themselves. Keeping the centre short and tidy will be closer to the final structure of the knot

and easier to control than if the centre loops are allowed to get long.

- you'll find that if you pull hard enough, that you can take up slack from one petal to another. **This is not recommended** because the larger the knot, the more this type of activity will deform the central structure of the knot. Also, you may find that you are tightening the knot *too much*, so that when it is time to adjust and fine tune the final structure of the knot (or take it apart because you made a mistake in design) that it is exceedingly difficult to do so.

4 Flower

The 4 flower is probably the most common of the flower knots, especially since it is easy to combine many of them into a single design. For this reason, detailed instructions are given for this particular flower.

3 Flower

The procedure to make 3 flower is exactly the same as the 4 flower except that you do step 1, skip step 2 and go directly to step 3.

5 Flower

The procedure to make 5 flower can be exactly the same as the 4 flower except that you add an extra loop between step 2 and step 3. As you can see from this illustration, however, the centre is already getting quite large and loose, and if the centre doesn't hold the whole knot will fall apart. A modification that will be introduced for 6 flower can also be used for 5 flower. As always, the option is yours.

5 Flower with Overlap of 2

This variant of the 5 flower is made with the same centre doubling strategy as is used in making the 6 flower except, of course, leaving out step 3 so that you only have 5 petals.

6 Flower

As the flower knots get larger, the centers become larger and looser, holding together more poorly. With the 6 flower knot, we introduce the construction variations that can be used to remedy this problem.

7 Flower

This 7 flower is made with the same centre doubling strategy as is used in the making of the 6 flower.

8 Flower

As the 6 flower is constructed with a "doubled" centre, so the 8 flower is constructed with a "tripled" centre.

9 Flower

This 9 flower is made with the same centre tripling strategy as is used in the making of the 8 flower.

n Flower

As you progress from the 4 flower through to the 8 flower, the pattern of how to make a flower as large as one has the patience for should become clear. Make as many loops as you want. Increase the overlapping of the centre loops as the centre becomes larger/looser than you want.

CLW

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

FLOOR LASHING:

Use ----

to lash a series of poles to a set of stringers to form a flat surface such as a deck, a table top, or a road way.

Comments ----

When using a floor lashing, both ends of the decking poles must be lashed at the same tine to insure a firm even surface.

When placing the decking poles on the stringers, lay the decking poles so that their butt end are in alternating direction. Alternating the but ends of the decking poles will compensate for the natural taper of the poles so that the length of the decking along each stringer will be equal.

Narrative ---- (For floor lashing knotboard)

(1) Tie a clove hitch around each stringer. (2) Secure the short end of the rope by wrapping it around the running end (wrap with the lay of the rope). (3) Place the decking poles on the stringers and take a bight around the first pole. (4) Next, on the inside of the stringer, pull a bight up between the first decking pole and the next decking pole. (5) Place the eye of

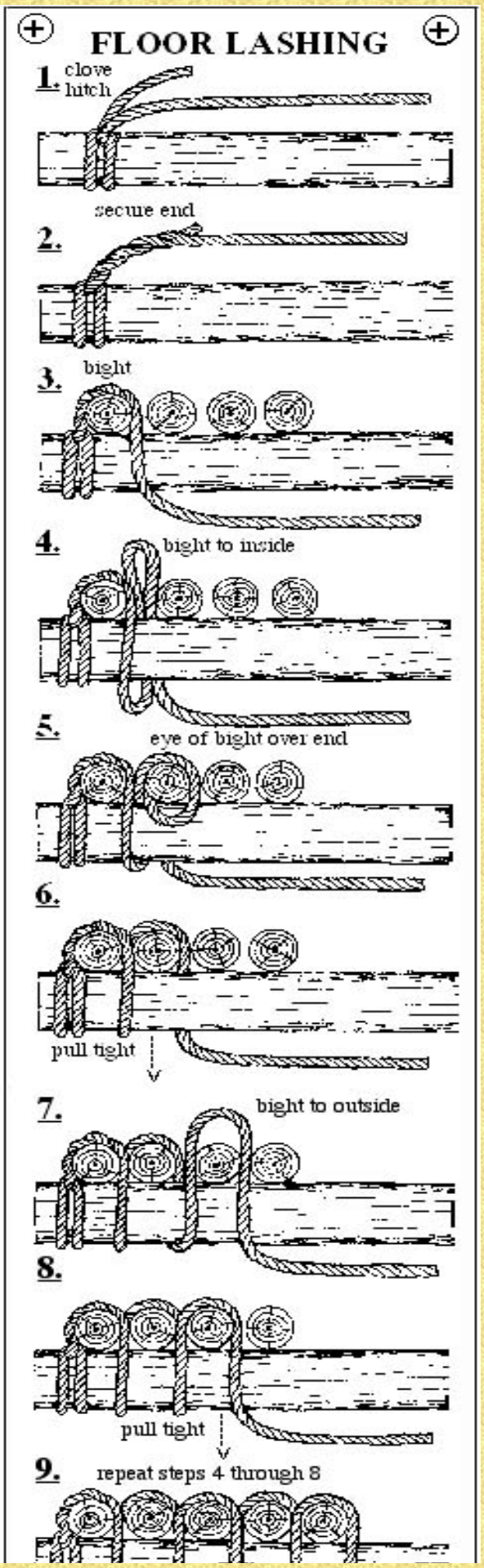

the bight over the end of the decking pole. (6) Pull tight. (7) On the outside of the stringer, place a bight over the next decking pole. (8) Pull tight. (9) Repeat steps 4 through 8 until all decking poles are lashed in place. (10) Tie the first half hitch of the ending clove hitch. Work half hitch tight. (11) Tie the second half hitch of the ending clove hitch. Work half hitch tight (12) to form clove hitch.

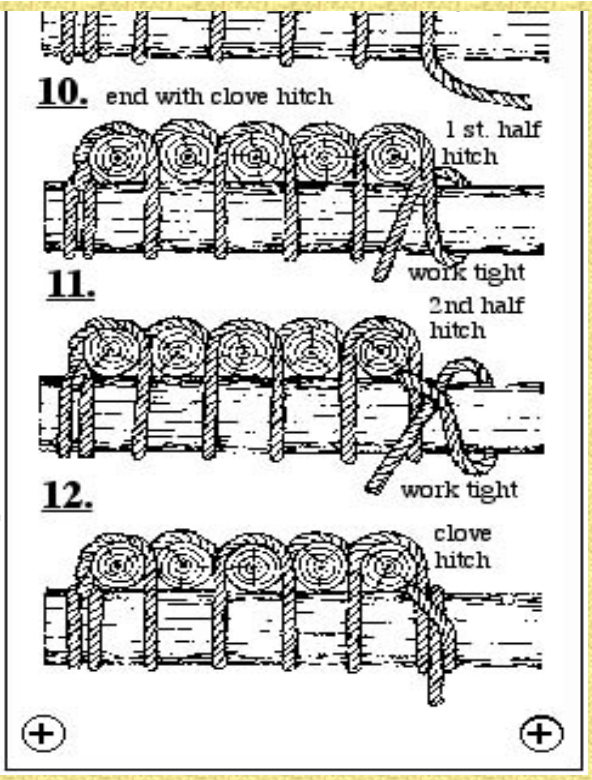

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Frost Knot

First place one end of webbing within a bend in the other end. NB: the diferent colors here are to illustrate technique, this knot is most often tied with one length of webbing.

Tie an overhand (see FTM knots) with the folded ends.

This will result in a loop with the short free end inside it.

The frost knot is used to tie an etrier (ay-tree-ay). A completed etrier is pictured below.

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The Friendship Knot

The knot frequently referred to as the Friendship Knot is illustrated below. This illustraion is modified from The Ashley Book of Knots by Clifford W. Ashley (p. 141 # 787). It is in the category of Two Strand Lanyard Knots. It is often given as token of friendship or recognition by Scouts and Scouters to be worn from the shirt pocket button.

It is also known as the Sailor's Knife Lanyard Knot, Marlingspike Lanyard Knot, Single Strand Diamond Knot, Two Strand Diamond Knot, and Bosun's Whistle Knot.

The version used as a friendship knot can be tied in about 9 inches of small cord about the first two fingers of the left hand . Start with a longer piece to work out the concept using the whole hand as a tying fixture.

The following sequence illustrates the steps.

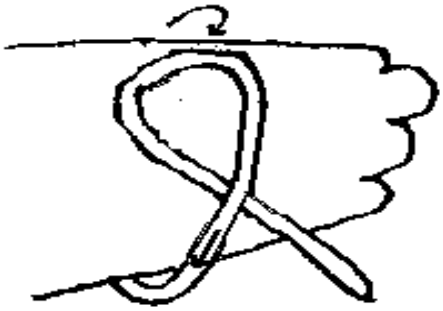

I - underhand loop in palm

II- bring end around back hand and under first loop as shown
Dash line shows next step.

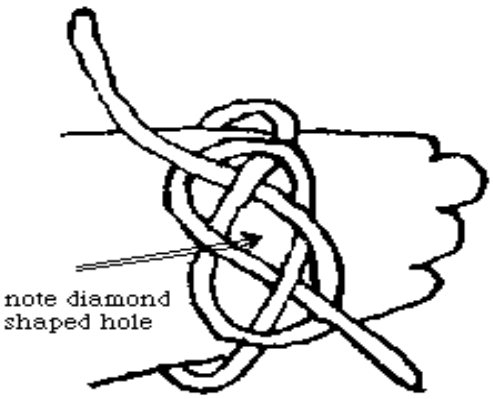

III - work end through as shown and you will have a full Carrick Bend with a diamond hole in the middle

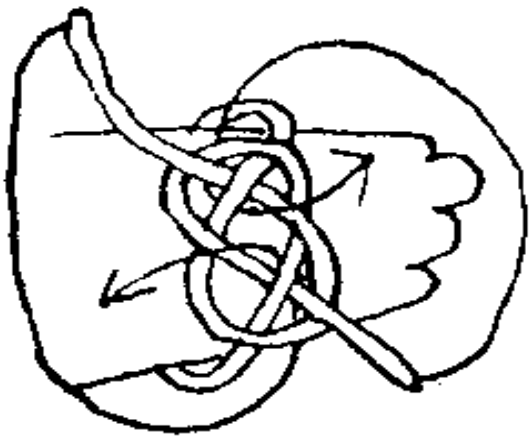

IV- this is the trick getting the ends in the right hole (the diamond)

After completing this sequence remove the knot from the fingers or hand and grasp the open loop left by the cord from around the fingers with one hand and using the other hand gently tighten the knot by a slight pull on the two loose ends. Slack within the knot can be worked through to improve the uniformity of the knot.

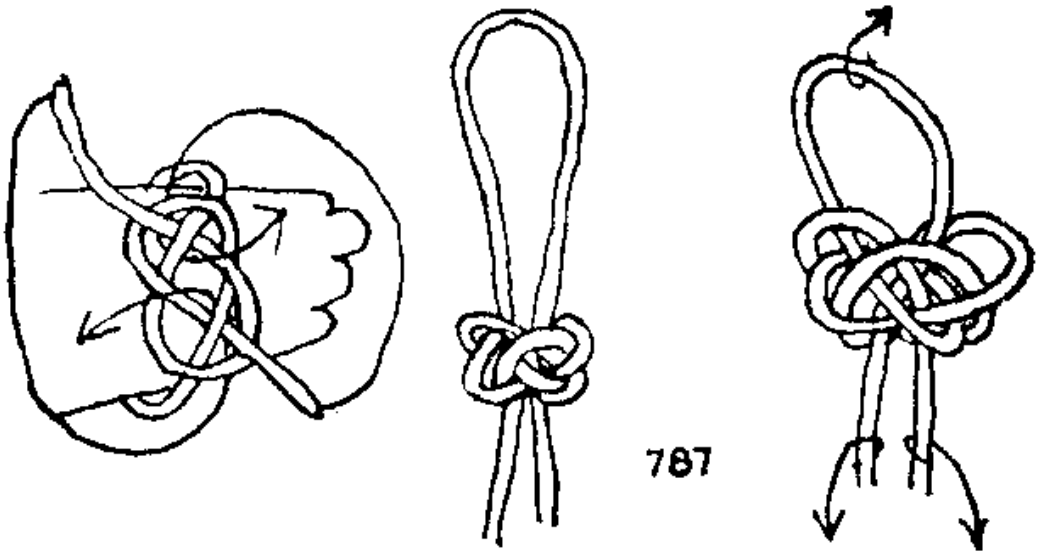

jk95

Girth Hitch

This hitch is primarily used to attach yourself to a litter during Semi-Tech.

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The Bends

The Reef Knot Family

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Ropers Knot Page

The reef-knot is a bend. There is a page on bends.

The Reef Knot or Square Knot General

The reef-knot is only useful in simple applications. Ashley says "it is a true Binder Knot, for which it is admirable, but under no circumstances should it be used as a bend." It is easy tied and will not jam, so it is always easy to untie. It is used to tie packages, and as a base for he shoe-bow. Sailors used it for binding rolled sails or better reefed sails. And that is where it got its english name from. Americans call it the square knot. Probably because it looks square, or because it was much used on square-rigged-ships, but that is a total guess of me.
Its relatives, the granny, the thief-knot and the what-knot all have their purposes, but not as a trustful knot.
The reef-knot on the WEB.

Related knots

The Granny.

This knot is dangerous, and untrustful. One moment is slips the other it jams. It is best to ban it out from your habits.
The granny on the WEB.

The Thief Knot.

The story goes sailors used this knot on their bags for they did not trust landsman. If a thief closed the bag after his theft, he would close it with a reef-knot, which is detectable by the sailor.
The thief-knot on the WEB.

The What Knot.

It is said to be used in a magic trick. Don't ask me how.
The what-knot on the WEB.

Any comment, suggestions, anything mail me: ***qqqq at realknots.com*** *with subject "**question**"*
All mail without thr right subject is flussed unred. automaticly.
I am sorry I had to remove the mail link. The mailgrabbers and spammers won. But.... I have a few hidden mail address for them to mail to each other after they grabbed it.

Because this is an non-comercial site I can and will not allow junk mail nor spam. Therefore comercial, non-personal and bulkmail will be charged with handling costs of $100 per mail.

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The Bends

Halász~

Hasonló kötelek végleges összekötésére való. Ui. ha jól megszorul, nagyon nehéz kibontani.

<< Takács~ | #eleje | index | levél | Toldó1~ >>

Utolsó módosítás: 2002.09.26 23:41:34 CEST

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

JUG KNOT:

Use ----

- to provide a convenient carrying handle for jug or bottle ---- to attach a tool, such as a hammer to a security line to prevent accidental dropping --- to add a wrist loop to a walking staff --- to attach a safety line to a canoe paddle ..... use your imagination, but be sure that you keep safety in mind.

Other Names ----

Jar knot, moonshiner's knot, hackamore, bridle knot..

Comments ----

The most common use is to provide a loop handle attached to the neck of a bottle. The loop handle makes it easy to carry several bottles with one hand. If a toggle or a two strand button knot such as boatswain whistle knot is added to the free end of the rope, The loop of the jug knot can be use to toggle the bottle to a belt so that the bottle can be use as a canteen.

Plastic bottles with screw-on lids such as soda, sport drink, and mineral water bottles make strong,

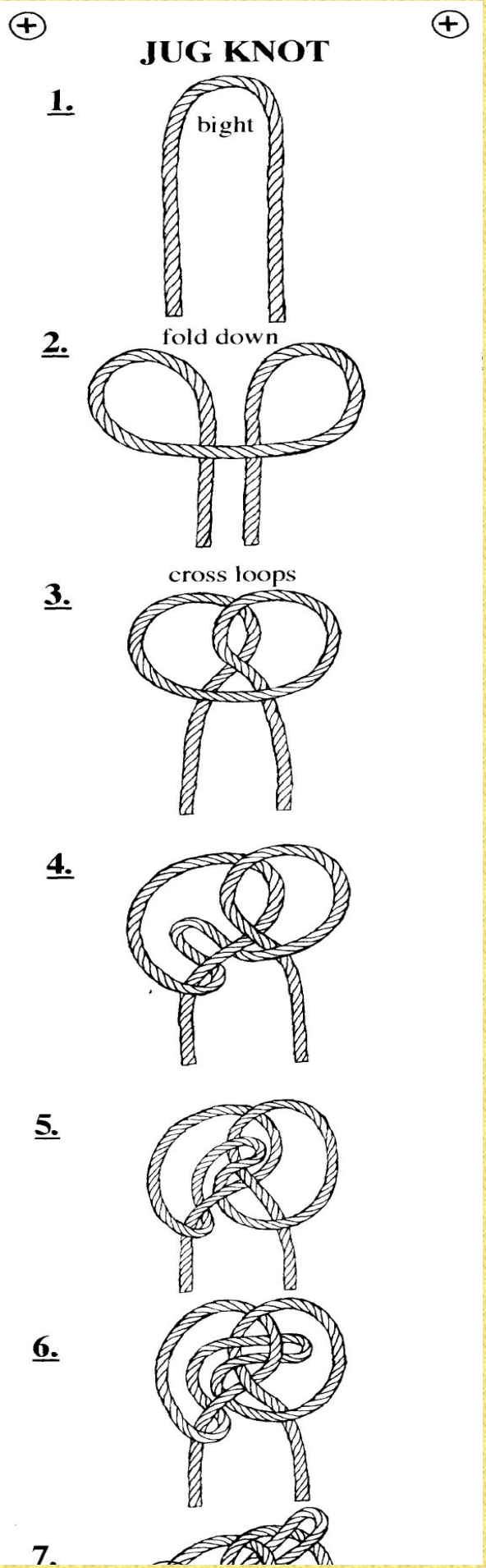

lightweight containers for carrying water on hikes and camp outs. 2 and 3 liter soda bottles are large enough to use as water containers around the camp kitchen. Smaller bottles (8 to 16 oz.) can be used as personal water bottles or canteens. These bottles can be made even more convenient by using a jug knot to attach a loop handle.

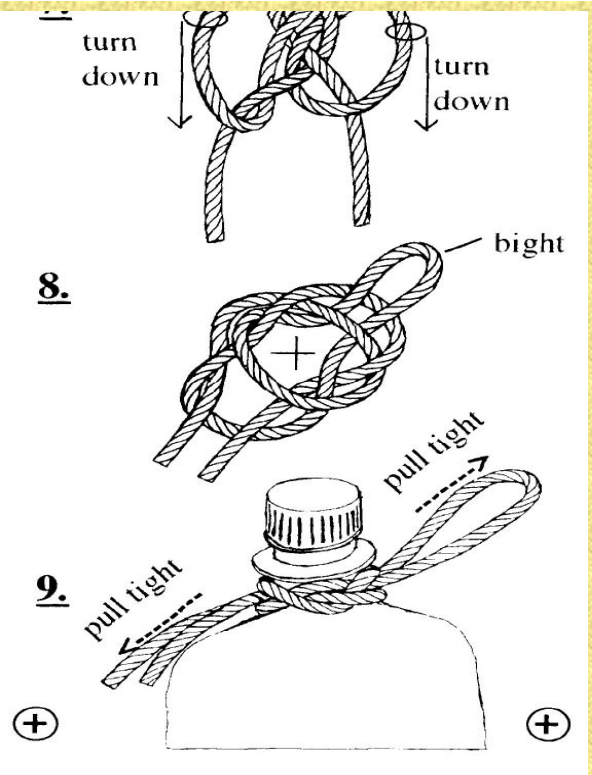

To help keep your water cool and refreshing in hot weather, place a sock over the bottle, wet the sock when you fill the bottle, evaporation will do the rest.

In cold weather, carry your water bottle under your coat. A dry sock placed over the bottle will help keep the water from freezing. In cold weather, carry your water bottle under your coat. A dry sock placed over the bottle will help keep the water from freezing.

In cold weather, carry your water bottle under your coat. A dry sock placed over the bottle will help keep the water from freezing.

Narration ------ (For Jug Knot Knotboard.)

Narrative ---- (For jug knot knotboard) (1) Form a bight in the middle of a 24 to 30 inch long by 3/16 inch diameter rope. (2) Fold the bight down over the standing ends to form two loops. (3) Place the right loop over the side of the left loop. (4) Weave the middle of the bight under the standing end; then over the left edge of the right loop; (6) next go under the right edge of the left loop; (7) finally pass the bight over the right side of the left loop. (8) Turn the tops of the original loops down over the knot. (9) Place the knot over the neck of a bottle and work the knot tight so that the bight forms a 4 to 5 inch loop handle and the loose ends are even.

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The Sheetbend Family ( )

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The sheetbend is a bend. There is a page on bends **The Sheet Bend, general.**

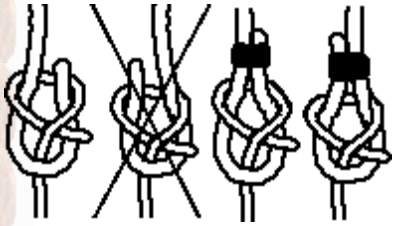

The sheet bend is my favorite bend. Be carefull. With the loose end on the wrong side you have an other, weaker knot (Left-hand sheetbend). If the knot is well seized it does not matter if it is tied right or left handed
The sheetbend on the WEB.

The Sheet Bend

This way of tieing is for connecting equally sized ropes to each other. When the ends are connected you have the Bowline Knot. You have to try to take the first 'steps' as one simple clockwise turn of your wrist. So practice...

The wever_sheetbend

If you want to tie two thin yarns to each other you use a wever-knot. The one shown here is the same as the Sheet Bend. If the yarn is slippery use an Overhandknot on the ends before tying this knot. If this ends up into a to bulky knot you need an other wever_knot.

Sheet Bend for a (to) short end.

With the simplest noose you can catch an end and capsize the knot to a sheed bend. Be careful. without practicing you have a 50% change of catching it wrong. Also, (as always) working up the knot properly is important.

The Lap-Knot

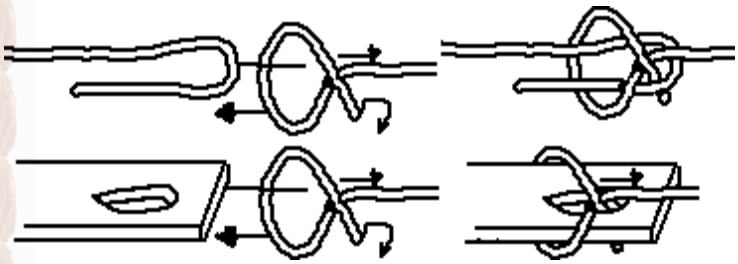

The Lap Knot sometimes is called the false sheetbend. But false knots do not exist. The Lap knot has been in use for ages by many civilisations. I use the name Lap knot because that is the name Robert Pont used in his description of this knot. He found it was used in Lapland in a lot of applications. Especially in lether, it is very suitable, just as secure as the sheetbend, but even more easy to untie. That is important, especially when your fingers are cold.

The Lap Knot is the knot to tie a rope to a strap. If the strap is hard to bend and the rope is slippery,

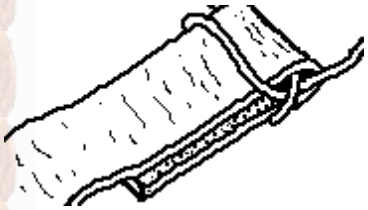

it is advisable to add an overhand knot at the end. Robert Pont thinks it is the best solution for this special situation. He tested it with a many heavy loads under hard conditions. Every time with the same strap, and the same rope. It did not slip a bit, in rain,sun, and snow during several months.

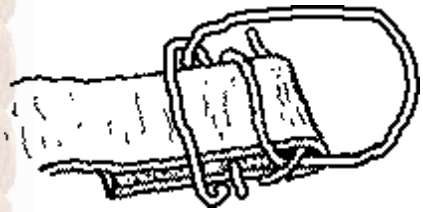

If the Lap Knot is the knot for tieing a rope to a strap it is certainly the knot to make a rope loop at the end of a strap. With a bit of practice, you can enjoy its usefulness.

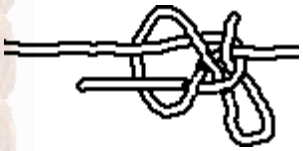

Ever needed a slipped knot which holds secure and releases instantly when pulled? tie the slipped version of the Lap-knot. You will be surprised. I saw this knot for the first time observing a man who hung sausages on a line. He knitted the line into a small noose and shifted the slipped loop over it making a slipped Lap knot. When he needed a sausage he simply grabbed an end and pulled. No scissors, no tools.

The sheetbend is a bend. There is a page on bends

Any comment, suggestions, anything mail me: ***qqqq at realknots.com*** *with subject "**question**"*
All mail without thr right subject is flussed unred. automaticly.
I am sorry I had to remove the mail link. The mailgrabbers and spammers won. But.... I have a few hidden mail address for them to mail to each other after they grabbed it.

Because this is an non-comercial site I can and will not allow junk mail nor spam. Therefore comercial, non personal and bulkmail will be charged with handling costs of $100 per mail.

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Lark's Head

(Cow Hitch, Lanyard Hitch)

- The Lark's Head knot is used to loosely attach a rope to a spar or ring. The knot has two redeeming features, it is easy to tie, and it does not jam. However, it will slip fairly easily along the spar, and may slip undone when tied using man made fibre ropes.
- Tip. This is a knot to be avoided when a secure attachment is required. The Round turn and two half hitches, and the Clove hitch are far more secure.

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ARCHIVE

KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

MASTHEAD KNOT:

Description ----

A multiple loop knot formed by reeving the loosely made loops of two over hand knots through each other and then securing the knot to a mast (pole).

Use ----

On board ship, a masthead knot was used to rig a temporary mast if the mast was lost in battle or during a storm. On land a masthead knot can be used to rig a gin pole or a flag pole.

Comments ----

There are several forms of the Masthead Knot. This form of the Masthead Knot was chosen for its symmetry and the ease of transition to the running half hitches used to secure it to the pole.

Other Names ----

Jury mast knot, pitcher knot.

Narrative ---- (For masthead knot knotboard.)

(1) Loosely tie two over hand knots. (2) Place the loop of one overhand knot on top of the loop of the loop of the other over hand knot. (3&4) Reeve the

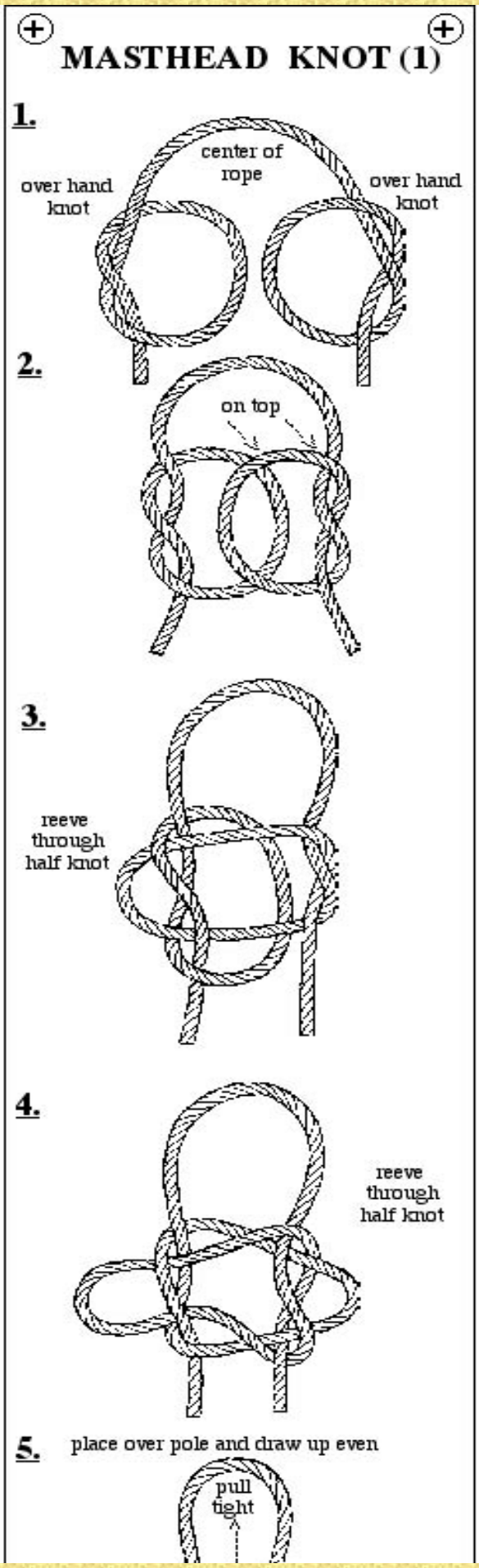

loops of the overhand knot through the half knot part of the opposite overhand knot. (5) Place over a pole and draw the three loops up even. (6) Secure to the pole with a series of running half hitches above and below the mast head knot.

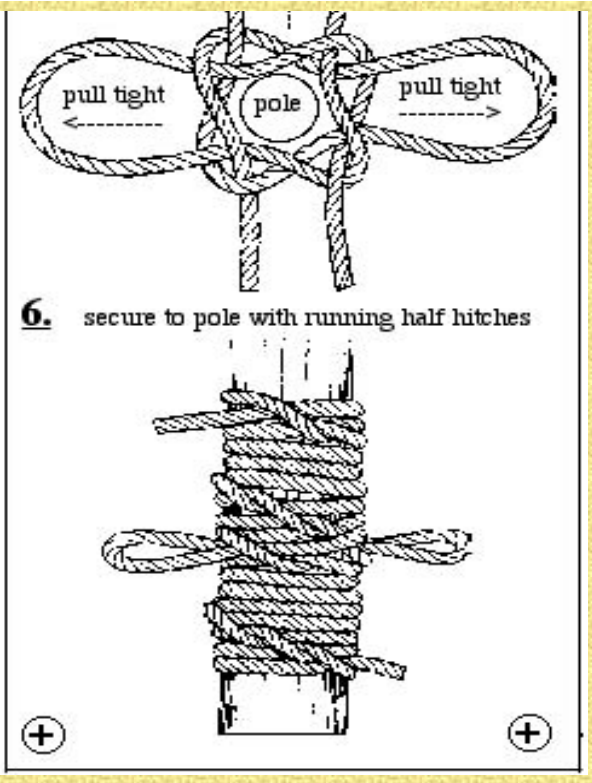

[NOTE]

A forth loop my be formed by tying or splicing the ends together. If a fourth loop is made, nail a cleats to the pole to prevent the mast head knot from slipping.

[NOTE]

Attach the guy lines to the loops with becket hitches.

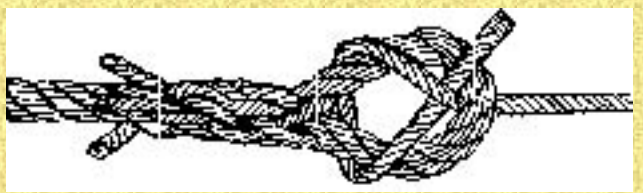

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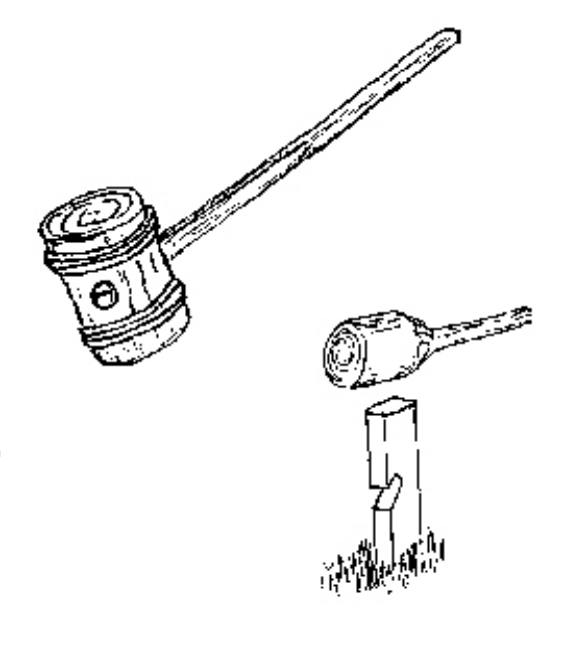

ARTICLE OF THE MONTH

Each month there will be article on this page.

THIS MONTH'S IS THE :

MAULS:

A maul is a wooden club or hammer that is used for driving stakes or wedges and for safety reasons should be used instead of an ax.
Using an ax instead of a maul exposes the user to the danger of being cut by its sharp edge. Even if the edge is covered by a sheath, a glancing blow can cause the sheath to be ripped off or to be cut through.
The pole of an ax serves as a counterweight to the blade. This counterweight adds to the balance of the ax head and helps to control and increase the force of momentum delivered to the bit. The ax head is shaped in such a way that the momentum of the ax head is delivered through the thin walls of the eye. However, when an ax is being used as a hammer, this same shape causes the eye of the ax head to spread and the handle to loosen.
The flat surface and angular edges of an ax pole makes it difficult to strike a stake squarely. This difficulty in striking a square blow results in most blows delivering some there force sideways, causing the end of the wooden stake to flare and split very quickly. In addition, when the pole of an ax contacts a stake, the metal surface of the pole lacks the ability absorb any of the force of the impact this contributes to the destruction of the stake. A wooden maul, on the other hand, absorbs some of the impact of the initial contact and a maul has no angular edges. Therefore, more of the force of the maul is used to do useful work and less of the force is used up in deforming or splitting the stake.

FOR MORE INFORMATIOM GO TO "MAULS"

"MAULS"

ARTICLE OF THE MONTH

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Die Affenfaust

Ursprünglich als Wurfleinenknoten benutzt, wird er heute fast nur noch als Zierknoten verwendet.

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KNOTBOARD OF THE MONTH

MONKIE'S PAW:

Dscription ----

Two forms of the monkey's paw are sown here the first is formed from four interlocking loops: a four crown turk's head; the second is constructed from three interlocking coils.

Use ----

The core determines what the monkey's paw can be used for. When tied over a stone or heavy ball, the monkey's paw can be used to add weight to a heaving line. If tied over a cork ball with small cord the monkey's paw makes a good float for boat keys or other small items used around a water front. Tied over a ball of twine or other soft material, the monkey's paw can be used as weight on the end of a rope for the game jump the shot. A Monkey's Paw can also be used as a toggle..

Comments ----

Neither form of the Monkey's Paw has an advantage over the other. Which one you choose to use is a matter of personal preference.

Core Size -----

The diameter of the core should be between three and four diameters of the rope being used..

Narration ------ (For Monkey's Paw Turk's Head knotboard.)

(1) Form an overhand loop (2) Form a second

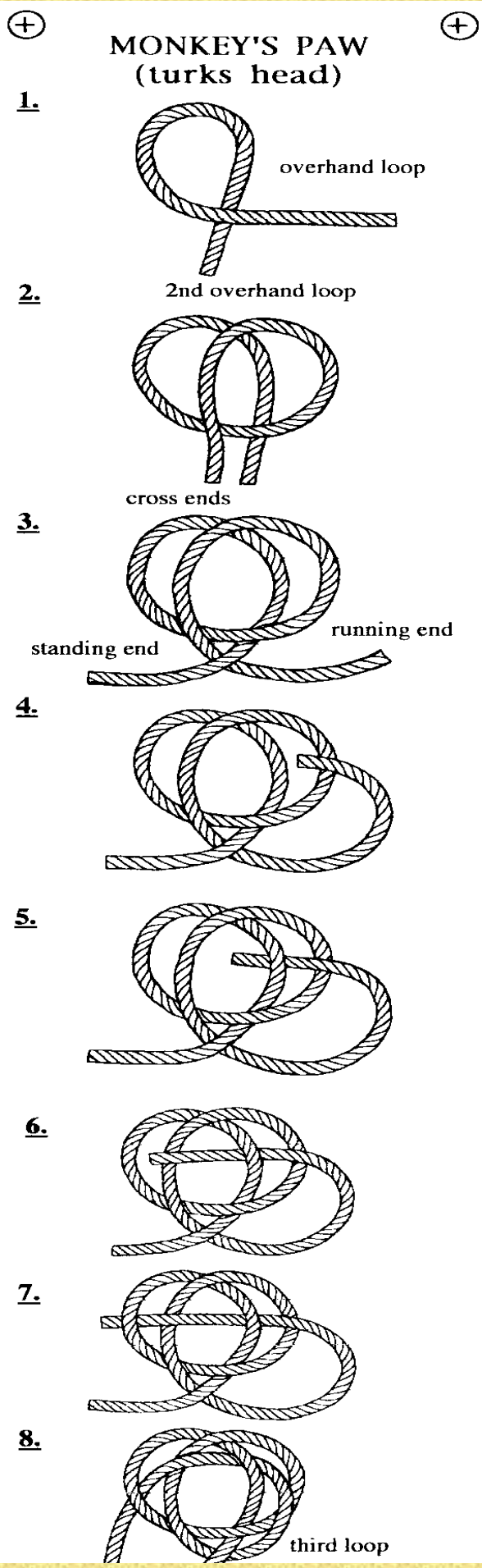

overhand loop over the left edge of the first overhand loop . (3) Cross the standing end over the running end. (4) Weave the running end across the loops by placing the running end over the right side of the top loop (5) then under the right side of the bottom loop (6) next, over the left side of the top loop (7) and finally under the left side of the of the bottom loop. (8) Pull the running end through until a third loop equal in size to the first two loops. (9) Add the fourth loop by placing the running end parallel to the standing end. (10) Chase the original pattern 2 to 3 times. (11) Work tight over the core.

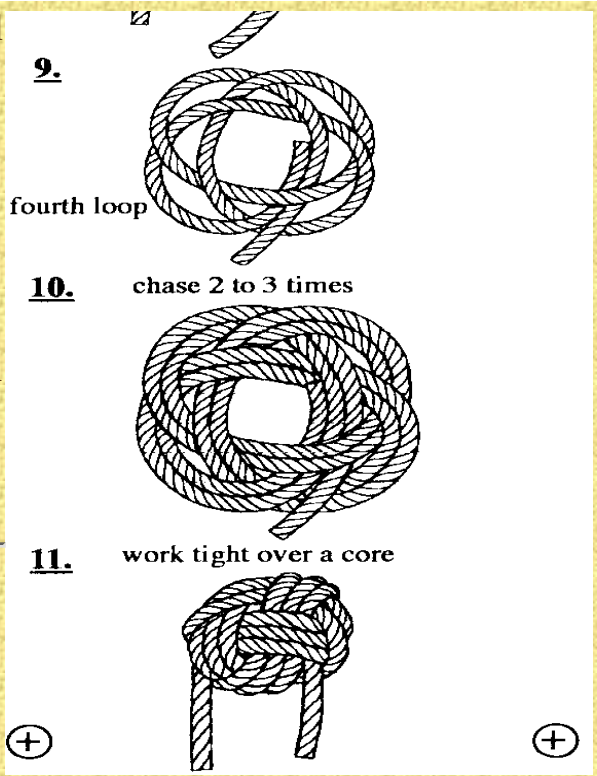

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Knot of the Month - June '97
The Monkey's Fist

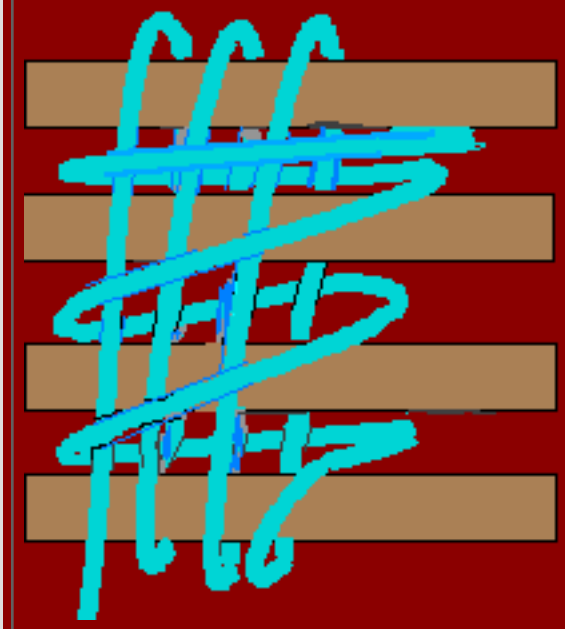

To tie a Monkey's Fist:

- Begin with three LOOSE parallel loops around the spread fingers of your left hand, Leave about 18 inches hanging at the beginning. We will call this set of loops "A loops."
- Start a forth loop, only this time, come between your little and ring fingers.
- Now, work the end of the line back between the little and ring fingers close to your palm to "capture" the A loops. Also keep these loops loose.
- Next, pass the line over, between your ring and middle fingers, and come back through these same fingers.
- Repeat this process going between your middle and index fingers. We will call this second set of loops the "B loops."
- Continue to part B.

Return to the Monkey's Fist beginning.

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

MOORING HITCH:

Dscription ----

An underhand loop toggled to the standing part with a bight made in the running end.

Use ----

To securely tie off a rope so that it can be quickly untied, especially a small boat to a dock or piling.

Comments ----

A secure knot that is easily tied or untied in wet or dry rope; when properly tied a non closing loop is formed, this allows the hitch to move up or down a piling as the water level changes.

Narration ------ (For Mooring Hitch Knotboard.)

(1) Take a bight around an object. (2) Form an underhand loop in the running part. (3) Place the eye of the underhand loop over the standing part. (4) Pull a bight of the standing part through the eye of the underhand loop. (5) Pull the underhand loop tight around the bight. (6) Place the running part under the eye of the bight that was pulled through the underhand loop. (7) Pull a bight of the running part through the eye of the standing part bight. (8) Pull on

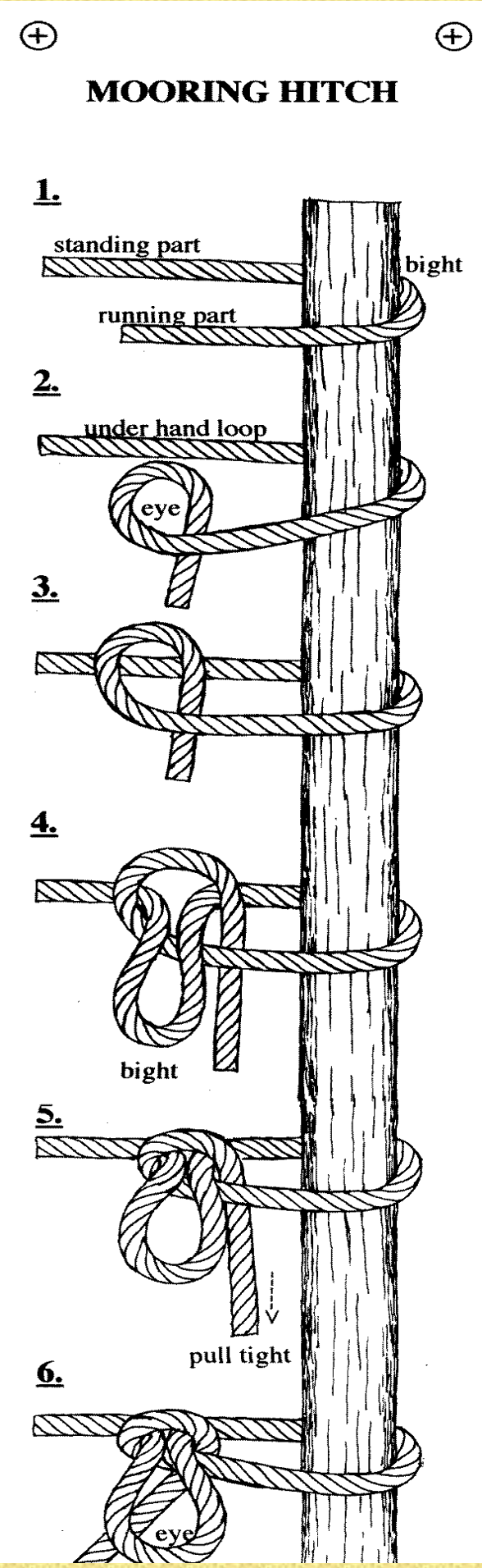

the standing part to tighten the standing part bight around the running part bight.

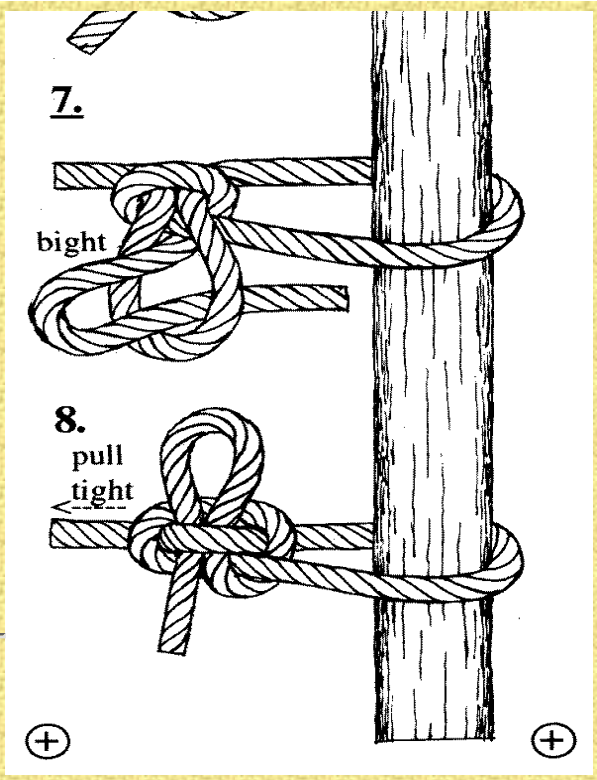

ANNIMATED KNOT

MOORING HITCH

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MOORING HITCH

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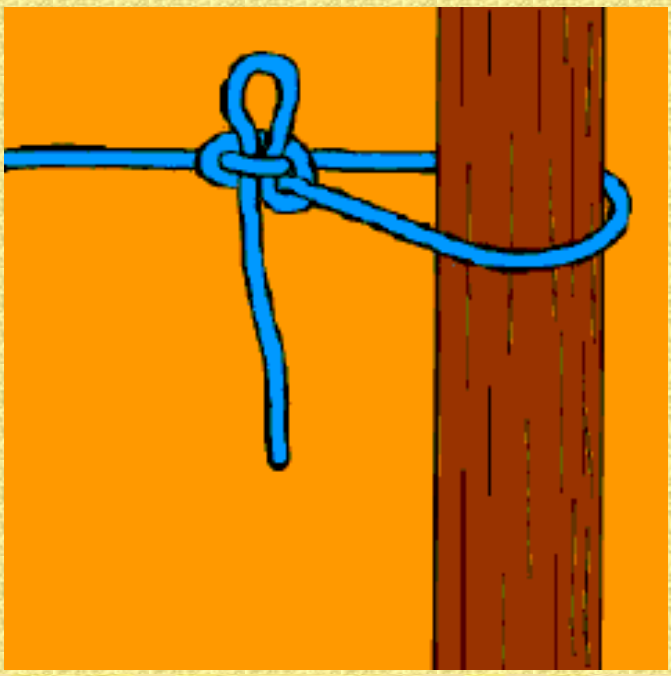

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Kötélvégek csigából való kicsúszásanak elkerülésére, más csomóknál a szabad végek kicsúszásának megakadályozására.

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Utolsó módosítás: 2002.09.26 23:41:34 CEST

EXPLORE ROPEWORKS

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INTRODUCTION

ROPE WORKS is a book that evolved to meet the needs of Scouts and Scouters. R0PE WORKS' 97 pages are bound in a plastic comb binding that allows it to lay flat while in use. Its 6 inch by 8 1/2 inch size makes it convenient to carry as a reference source. ROPE WORKS provides detailed step by step illustrations in a knot board layout. The knot board layout clearly shows each step required to tie a knot. The detailed steps allows the user of ROPE WORKS to learn the art of **knot tying**, **splicing**, and **lashing** without the constant supervision of an instructor. The table of contents, glossary of terms and complete index will help you find and tie the knots you need.

Twenty-two pages of ROPE WORKS are devoted to **rope making** and the building of a **geared rope machine.**

View our sample illustrations to see what we are talking about. Then order your copy of Rope Works today by using the handy mail in **order form** found at our Ordering Information button.

KNOT SAFETY

If a knot is improperly tied or a wrong knot is used, an unsafe condition is created. Therefore it is not just enough for the teacher to teach someone how to tie a knot correctly, but it is also necessary to teach them how to use the knot correctly. Likewise it is the student's responsibility to learn how to correctly tie and use the knot. If either the teacher or the student does not accept their responsibility they are endangering themselves and others.

The most commonly used rope is right hand-lay rope; that is as you are looking at the rope, it appears to twist to the right and away from you. Because of the right-hand lay of most rope, the majority of knots hold best when tied in a right hand manner. If the knot is tied in a left-hand manner or the mirror image of its usual form, the knot may fail because the right-hand twist of the rope may cause the knot to loosen or spill more easily. This is especially true if the tension on the rope is repeatedly changed.

Thanks and safe tying.

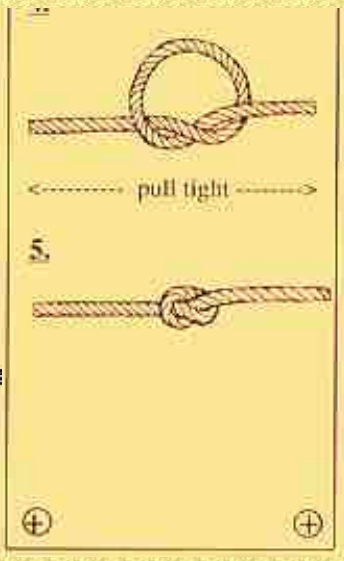

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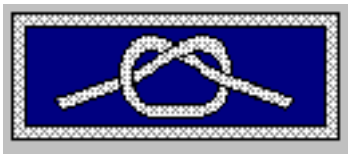

Overhand Knot

This simple knot and its cousin the barrell knot can be used to back up another knot. All knots should be backed up.

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The Pitzen Knot

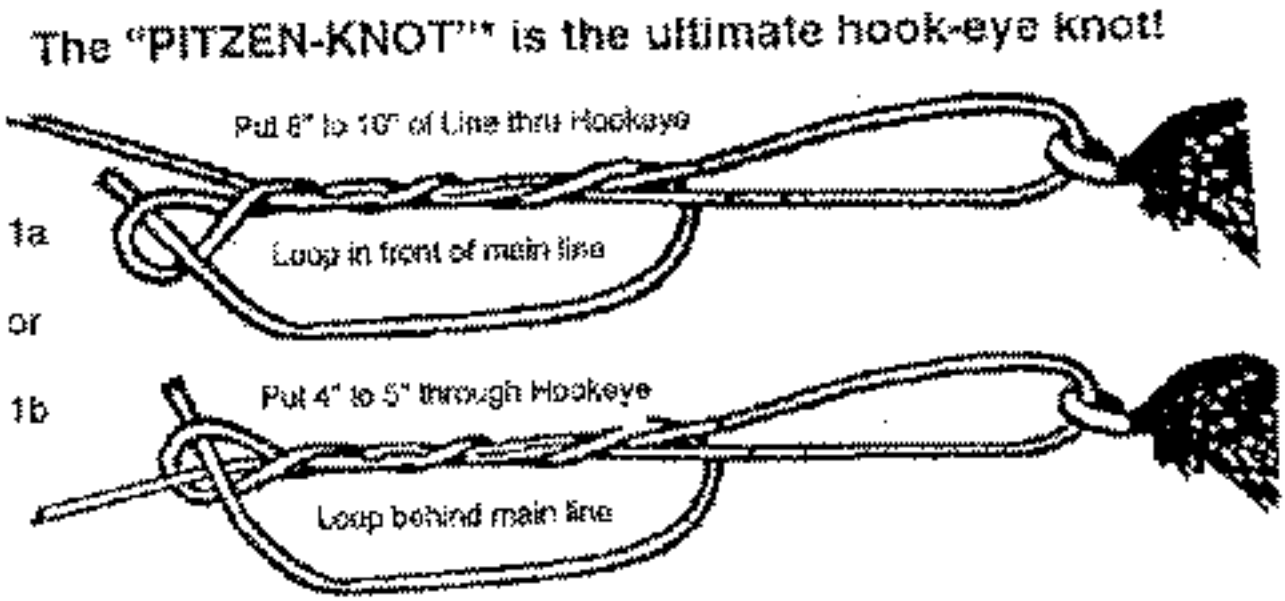

You can start with either 1a or 1b to tie this knot, which has a breaking strength close to 100% of the tippet rating.

1a -- position the fly to the right as shown!
2 -- Thread 8-10" of tippet through the hook eye. Hold the looped tippet line and tag end with your left thumb and finger. The tag end behind your fingers should be about 4" long. Leave a loop as illustrated. Let the fly hang!
3 -- Make 3 twists ONLY as shown, insert the tag end through the loop.
4 -- pull the tag end with the left hand so the twist close up loosely toward the loop. Now pull the tippet (not the tag) so the twists slide up toward the eye. Lubricate, and pull steadily until you feel the knot set into place.

1b -- The main difference is that you thread only 4-5" through the hook eye, and use hackle pliers or similar to hold the fly, rather than holding it in the palm of your hand.

The Pitzen knot, invented by Edgar Pitzenbauer of Germany is easy to tie with a little practice, and results in a knot the retains 95-100% of the tippet's rated strength as opposed to 65% for a Clinch knot. The Pitzen knot is also smaller by about 40%.

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PITZEN KNOT

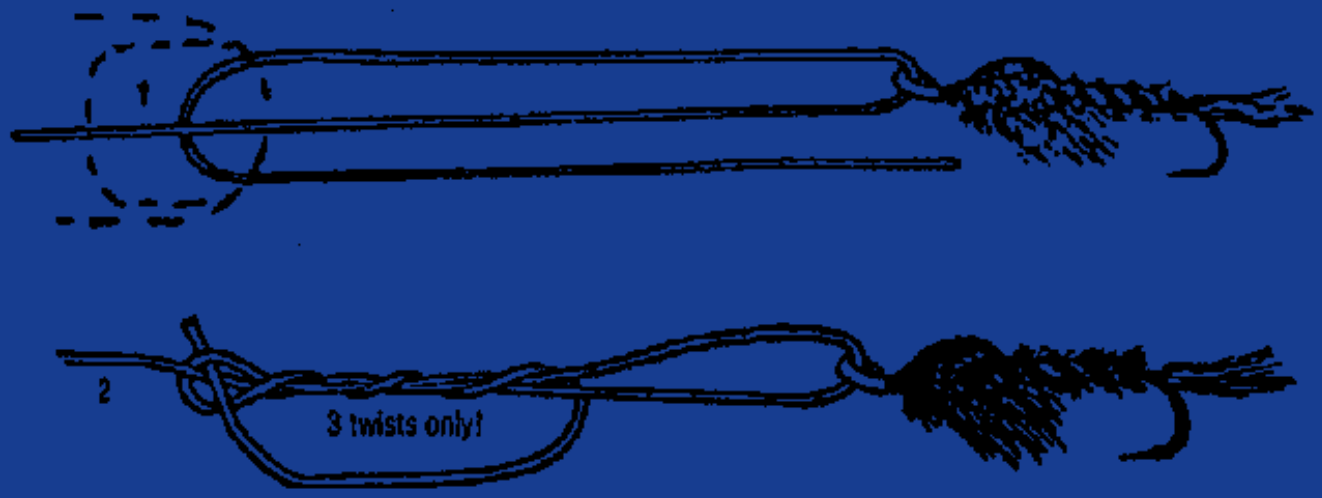

Knot Tying Instructions

1. Position fly to the right as shown.
2. Thread 3" to 4" of tippet through the hook-eye and loop as shown. Hold in place between your left thumb and finger. Now let the fly hang.
3. Make 3 twists (only) as is illustrated leaving a loop through which you thread the tag-end *exactly* as shown...(i.e. 'in' topfront and 'out' back of loop!)
4. Pull the tag-end with the left hand so twists close up loosely, not firmly! Now pull the tippet line (not tag-end) so that the knot slides to the hook-eye; do this steadily and then *firmly* until you feel the knot set

With repeated ties you will feel the knot set; pull it a second time as sometimes you may fell a second smaller 'knot-set'. Retie if you do not feel at least one 'knot-set'. This knot is as easy to tie as a Clinch-knot but it tests, on average, an incredible 95% to 100% of straight-line strength of *our* tippets verses as little as 65% for the Clinch-knot. The "Pitzen-knot" is so simple; it's a small knot, not at all bulky and you can snip the tag-end close!

Last modified: Wed Nov 15 17:26:47 1995

Reef Knot

(Square Knot)

- An excellent *general purpose* knot for tying two pieces of string or twine together, the reef knot is possibly the most commonly used knot for the job, and is easy to learn. However, it cannot be overly stressed that the Reef knot is not a long term or secure knot, and it should only be used to finish parcels or bindings. In other cases, use a more secure method of bending two ropes together, such as a Sheetbend, a Double Sheetbend, or a Fisherman's Knot.
- Unfortunately, the Reef knot can easily change into a slipping Lark's Head (see below), so it should *never* be used where life or limb are at risk.
- Holding one end of each rope in each hand, pass the left rope over the right, and tuck under. Then pass the same rope, now in the right hand, over the left rope, and tuck under.
- It is common to chant "Left over Right and Under, Right over Left and Under" when tying the knot. (This can also be performed as "Right over Left and Under, Left over Right and Under".)
- The reef knot can easliy be undone by gripping one loose end, and pulling it back over the knot, in the opposite direction, thus straightening the rope which is pulled. The other rope forms a Lark's Head knot, and slips off the tugged rope.
- The knot gets its name from its use on sailing ships, when the sails were "reefed" - rolled up and tied to the cross spar with a reef knot. To release the sail, the sailors would climb the rigging, and work their way along the cross spar, pulling the top end of the reef knot down. They only had to use one hand, holding on with the other. The weight of the sail would cause the reef knot to slip, and the sail would be released.

- Tip. If you want to tie two ropes together of similar thickness then never use a Reef knot. Only use it with string and twine when tying parcels, whippings and bindings.
- Tip. Never use this knot to join ropes of two different thicknesses.

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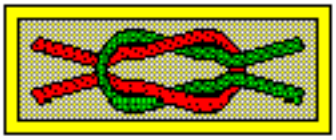
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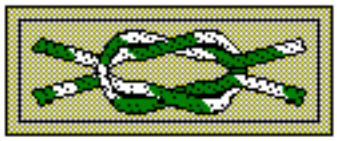
HORNADAY AWARD

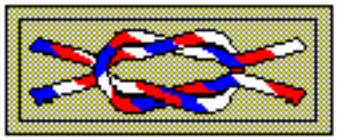
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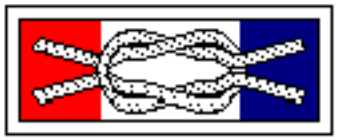
EXPLORER ACHIEVEMENT AWARD

QUARTERMASTER AWARD

LEADERSHIP AWARDS

CUB SCOUTER AWARD

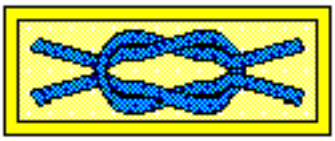
CUBMASTER AWARD

DEN LEADER COACH AWARD

WEBELOS DEN LEADER AWARD

DEN LEADER AWARD

TIGER GROUP ORGANIZER AWARD

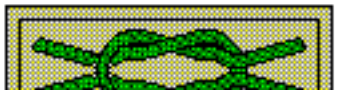
SCOUTER TRAINING

RELIGIOUS EMBLEMS

RELIGIOUS EMBLEM (YOUTH)

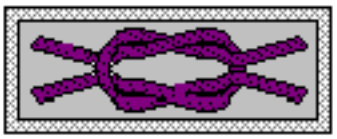
RELIGIOUS AWARD (ADULT)

BRAVERY AWARDS

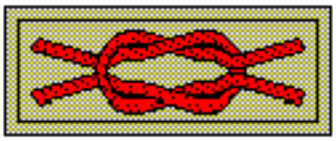
HONOR MEDAL

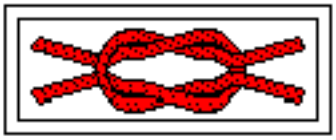
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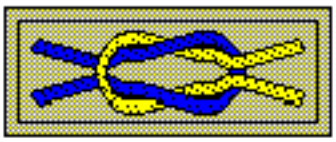
MEDAL OF MERIT

HONOR AWARDS

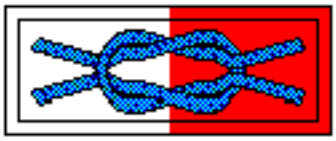
GEORGE MEANY AWARD

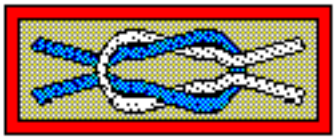
WHITNEY YOUNG, JR. AWARD

WILLIAM H. SPURGEON AWARD

ORDER OF THE ARROW DISTINGUISHED SERVICE AWARD

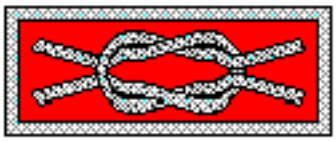
DISTINGUISHED COMMISSIONER SERVICE AWARD

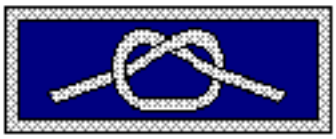
DISTRICT AWARD OF MERIT

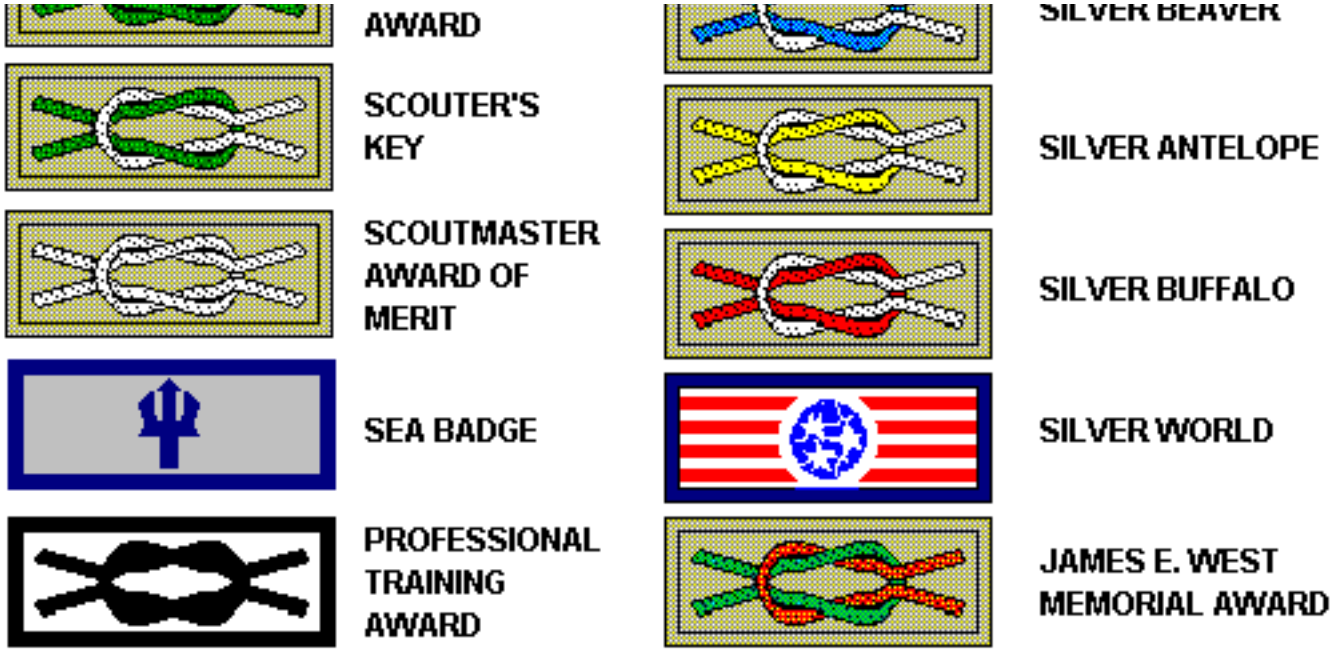
AWARD
SCOUTER'S KEY
SCOUTMASTER AWARD OF MERIT
SEA BADGE
PROFESSIONAL TRAINING AWARD
SILVER BEAVER
SILVER ANTELOPE
SILVER BUFFALO
SILVER WORLD
JAMES E. WEST MEMORIAL AWARD

Square Knot

This knot is used in the ASRC seat harness. Be careful to tie it correctly and not wind up with a "Granny knot"

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Rolling Hitch

(Magner's Hitch, Magnus Hitch)

- One of the most underated knots in Scouting and Guiding, the Rolling hitch is used to attach one rope to a second, in such a manner that the first rope can be easily slid along the second.
- The knot can be considered a Clove hitch with an additional turn.
- When tension is applied and the ropes form a straight line, the rolling hitch will lock onto the first rope. When the tension is released, the hitch can be loosened and slid along the first rope to a new location.
- The tension must be applied on the side of the knot with the extra turn.

- Tip. Use this knot if you have a guy rope with no adjuster. Create a loop on the end of a second rope which is slipped over the peg. Use a rolling hitch to attach the second rope to the guyline. Alternatively, take the guyline around the peg and tie the Rolling hitch back onto the standing part of the guyline, above the peg, thus forming an adjustable loop. This is known as the Tautline Hitch in America.
- Tip. Use this knot when constructing camp gadgets such as a suspended table. A Rolling hitch in each suspension rope will allow easy adjustment and a level table!
- Tip. When adjustments are complete, lock the rolling hitch into place by using a stop knot such as a Figure of Eight in the first rope, below the Rolling hitch, to stop it slipping.

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Round turn and two half hitches

- Used to secure a rope to a pole, or to start or finish a lashing. Pass the running end of the rope over the pole twice. Then pass the running end over the standing part of rope, and tuck it back up and under itself, forming a half hitch. Repeat this for a second half hitch.
- This knot has a redeeming feature - it rarely jams!

- Tip. Superior to a Clove Hitch for starting and finishing a lashing as the half hitches prevent this knot from unrolling, as they have the effect of locking the knot. The Clove Hitch looks neater (!) but it has a tendancy to unroll, and can be difficult to tie tightly when tying off.

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Sheet Bend

(Flag Bend, Common Bend)

- The Sheetbend is commonly used to tie two ropes of unequal thickness together. The thicker rope of the two is used to form a bight, and the thinner rope is passed up through the bight, around the back of the bight, and then tucked under itself.
- The knot should be tied with both ends coming off the same side of the bend, as illustrated here. However it can easily be accidentally tied with the ends coming off opposite sides of the bend, when it is known as the Left Handed Sheet Bend. The Left Handed Sheet Bend is to be avoided as it is less secure.

- Tip. If the ropes are of very unequal thickness, or placed under a lot of tension, use a Double Sheetbend.

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

SHEET BEND:

Description ----

An interlocked bight and half hitch.

Use ----

To temporarily join two ropes, especially if the ropes are of different sizes.

Comments ----

The sheet bend is a secure but easily untied knot. ---- When tying the sheet bend the running parts should be left long because there is some initial slip in the knot when the knot is first brought under tension. ---- The proper and more secure way to tie the sheet bend is so that the two end the rope are on the same side of the knot.

Other Names ----

Weavers knot

Related Knots ----

Bowline; becket hitch; these knots share the same form but are tied in a different way or have a different use.

Narrative ---- (For sheet bend knotboard.)

(1) Form a bight in the running part of the

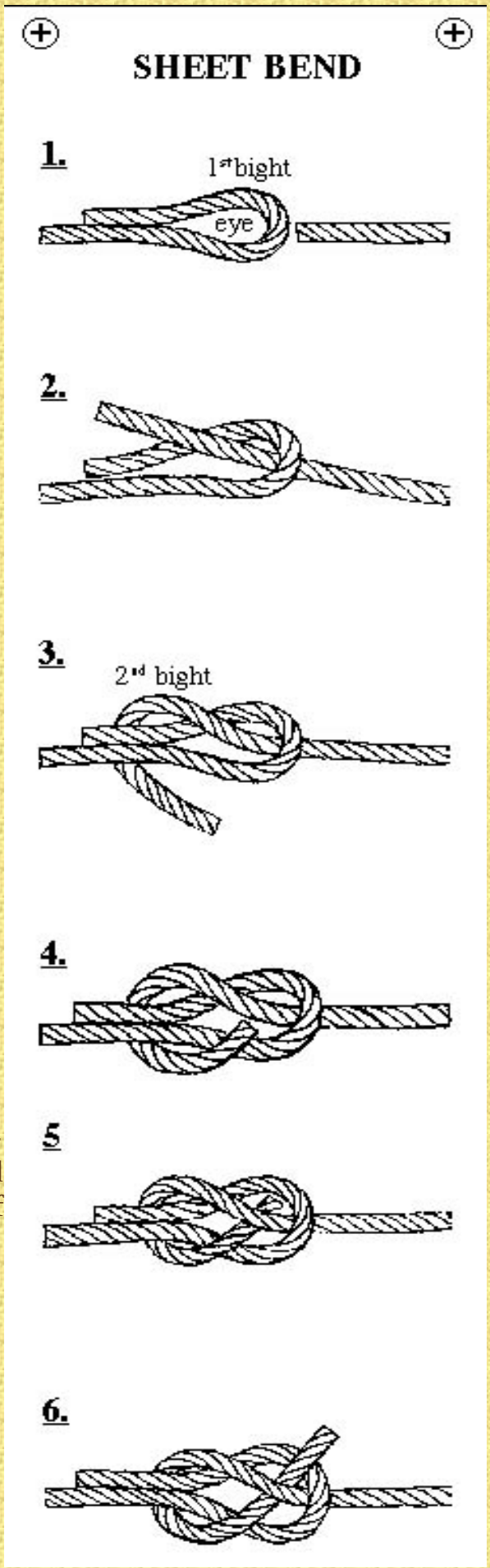

left-hand rope. (2) Reeve the running part of the right-hand rope through the eye of the bight in the left-hand rope. (3) With the right-hand running part take a bight around the running part and the standing part of the left-hand rope. (4) Pass the right-hand running part over the left-hand standing part, (5) under the right-hand rope, and (6) over the standing part of the left-hand rope. (7) Pull tight.

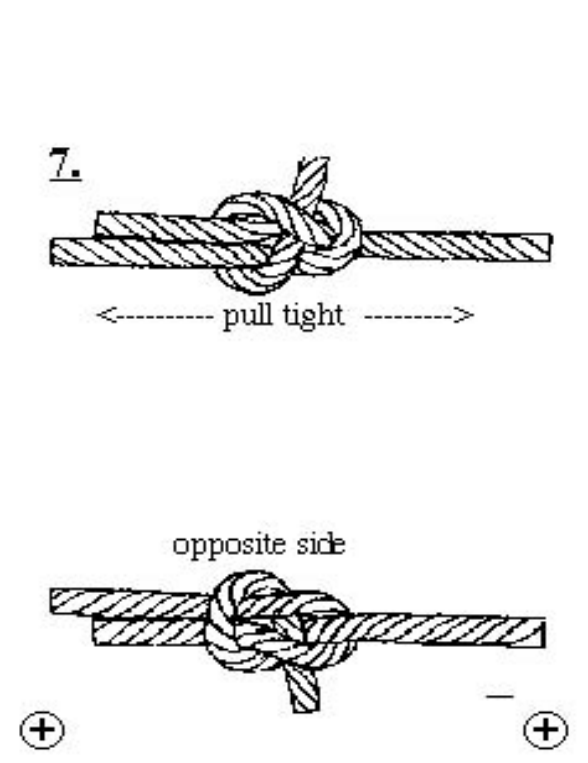

ANNIMATED KNOT

SHEET BEND

KNOTBOARD OF THE MONTH

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linknet.net
The top LINKS resources on the net

Main Categories

- Business
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- Insurance
- Internet
- Legal
- Shopping
- Travel

More Categories

- Link
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- Search Engine Listing
- Build A Web Site
- Web Page Design
- Dns Server
- Cheap Internet
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- Domain Name System
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Popular Searches

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- Site
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- Internet Computer
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Search:

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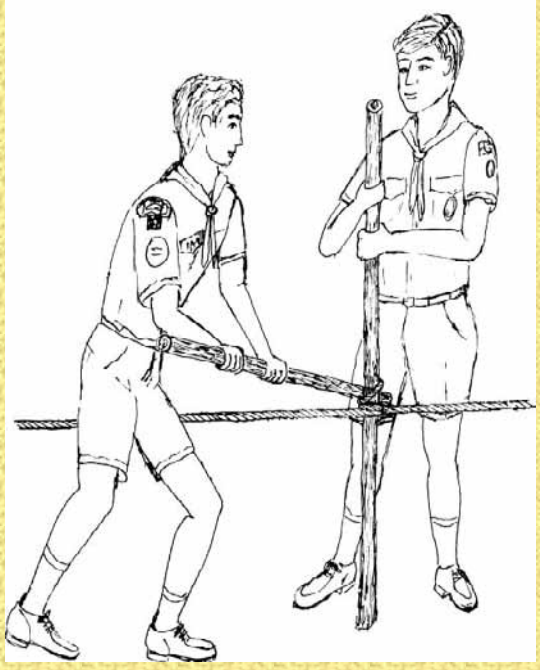

ARTICLE OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

SPANISH WINDLESS:

Description ----

A Spanish windless is a device for moving heavy loads such as rocks and logs.

[WARNING]

When setting up a Spanish Windless do not use nylon or other synthetic fiber ropes that stretch under a load. If you slip or let go of the poles the energy you used to stretch the rope will be released as the rope returns to its original length. This release of energy could cause the poles of the windless to spin around causing injuries to any one near by. Natural fiber ropes, such as sisal, have little stretch; therefore are much safer to use.

MATERIALS:

1 - 8 foot * 3 inch pole
1 - 5 foot * 3 inch pole
1 - 3/4 inch * 50 foot (natural fiber)

SETUP:

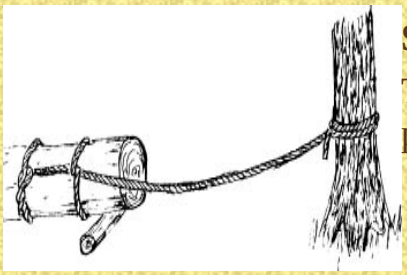

STEP 1:

Tie one end of the rope to the load and the other end to a secure anchor point. Leave some slack in the rope so that the windless can be rigged.

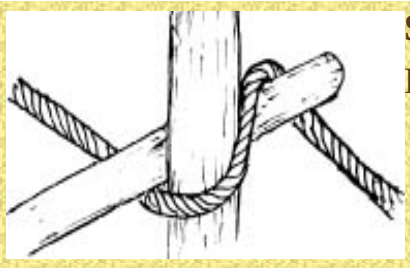

STEP 2:

Follow the diagrams to set up the poles at the mid point of the rope.

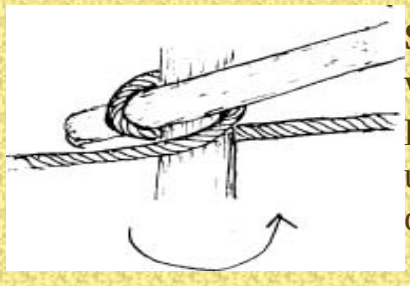

STEP 3:

While one person holds the up right pole, a second person rotates the longer pole around the upright so that the rope begins to wrap around the upright pole. Adjust the height of the rope so that it can be easily stepped over.

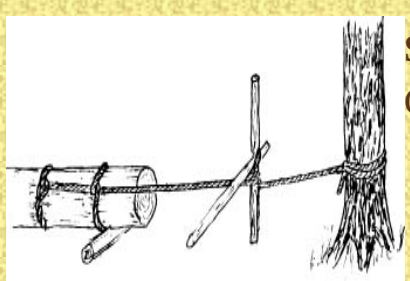

STEP 4:

Continue to rotate the longer pole around the upright.

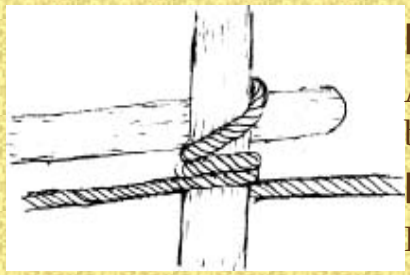

[NOTE]:

As the rope wraps around the upright it will be necessary to move the base of the upright to keep it vertical.

[NOTE]:

Be careful that the two ends of the rope are kept at the same level on the upright.

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EXPLORE ROPEWORKS

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Lashing

Lashings are used to join poles or spars when building pioneering structures. These structures can be functional, such as tables, bridges, and towers or decorative such as gateways. The only limit as to the type of structure is the imagination of the builder.

Correctly tied lashings in pioneering structures are essential for safety. When young people see an interesting structure they charge up and over with no thought as to the soundness of the structure. This places the responsibility for a safe structure directly on the builder.

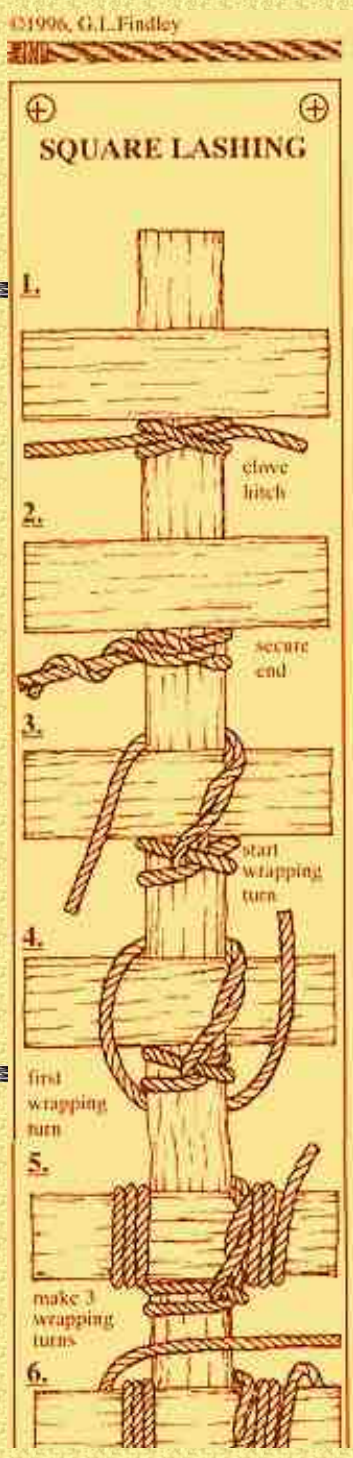

The following topics about lashing are covered in :

ROPE WORKS

Square Lashing
Diagonal Lashing
Tripod Lashing With Racking Rurns
Tripod Lashing With Plain Turns
Shear Lashing With Racking Turns
Shear Lashing With Plain Turns
Shear Lashing Quick
Round Lashing
Round Lashing West Country
Floor Lashing

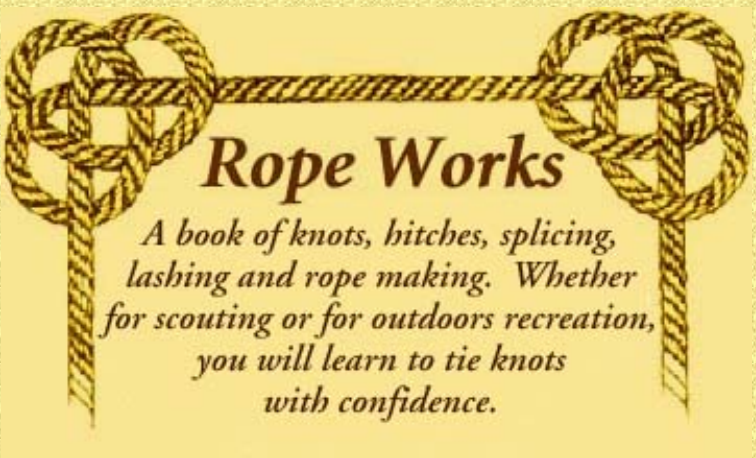

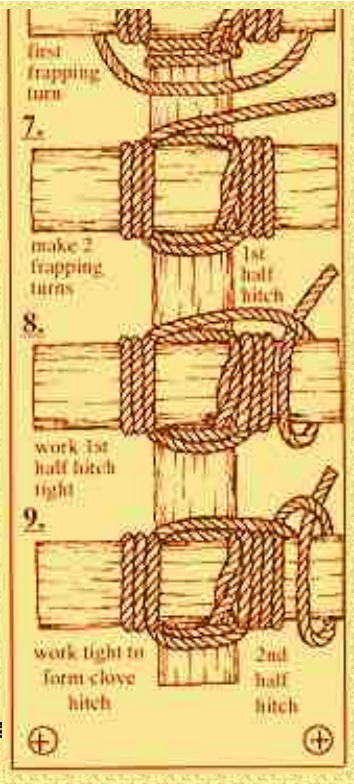

Order a copy of RopeWorks now !

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Takács~

Hasonló kötelek összekötésére. Pl. takácsok a felvetõfonal toldására használták (van jobb is). Ha nem szorult meg nagyon, akkor az egyik kötélvéget az ellenkezõ szár felé rántva egyszerûen lehúzható róla. Van aki ezt használja a reffzsinórokon is.

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ARTICLE OF THE MONTH

Each month there will be article on this page.

THIS MONTH'S IS THE :

TAUT-LINE HITCH:

Description ----

Two half hitches with an extra turn.

Use ----

To adjust the tension on guy lines.

FOR MORE INFORMATIOM GO TO "TAUT-LINE"

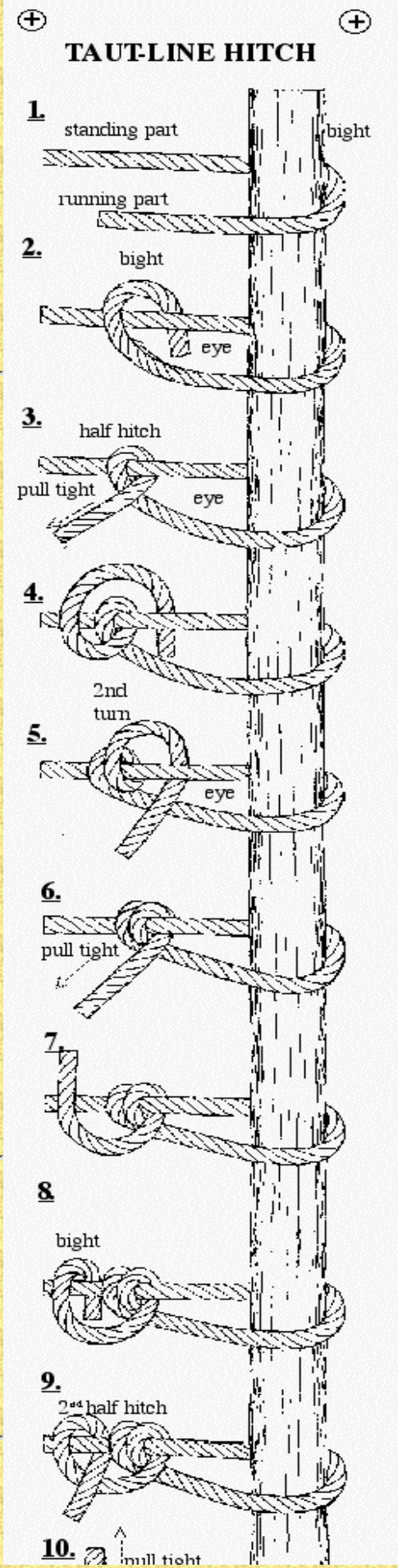

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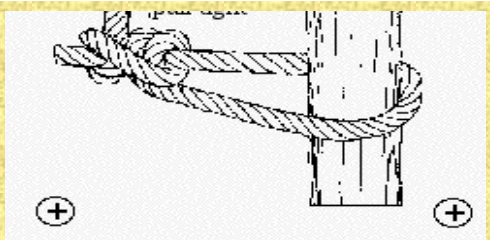

Thief Knot

- The Thief knot resembles the Reef knot at a casual glance. Note that the ends of the Thief Knot come off opposite sides of the knot. In the Reef knot, they come off the same sides.
- However, the Thief knot has no strength whatsoever, and will slip under tension.
- Try it and see!

- Tip. Only use this knot for tricks. NEVER use it where life and limb are at risk.

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Timber Hitch

- Used to attach a rope to a log, or where security is not an issue. This knot tightens under strain, but comes undone extremely easily when the rope is slack.
- Wrap the rope around the log, then pass the running end around the standing part of the rope. Finally twist the running end around **itself** three or four times. (Note: this is only shown twice in the animation.)

- Tip: Jolly useful for dragging logs back to the camp fire!

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Toldó1~

Ennek nem tudom a nevét. Kedvelt díszítõelem giccses trikókon. Hasonló kötelek összekötésére való. Meghúzáskor kifordul. Könnyen bontható.

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

TRIPOD LASHING:

Description ----

A shear lashing around 3 poles.

Use ----

To bind three poles together, for the construction of a tripod. ---- To bind three poles together that contact at the same point in a structure

Comments ----

The tripod lashing is a shear lashing that binds three poles together at the same point. ---- The tripod lashing gets it name from the fact that its most common use is the construction of a tripod. ----The tripod lashing can be used just about any where in a structure that three poles cross each other at the same point and the same time in the sequence of construction. ---- Tripod lashing takes two main forms; with racked wrapping turns (the rope is woven between the poles) and with plain wrapping turns (the rope is wrapped around the poles without weaving the rope between the poles). When the lashing is made with racking turns the rope contacts each pole around its entire circumference ; this

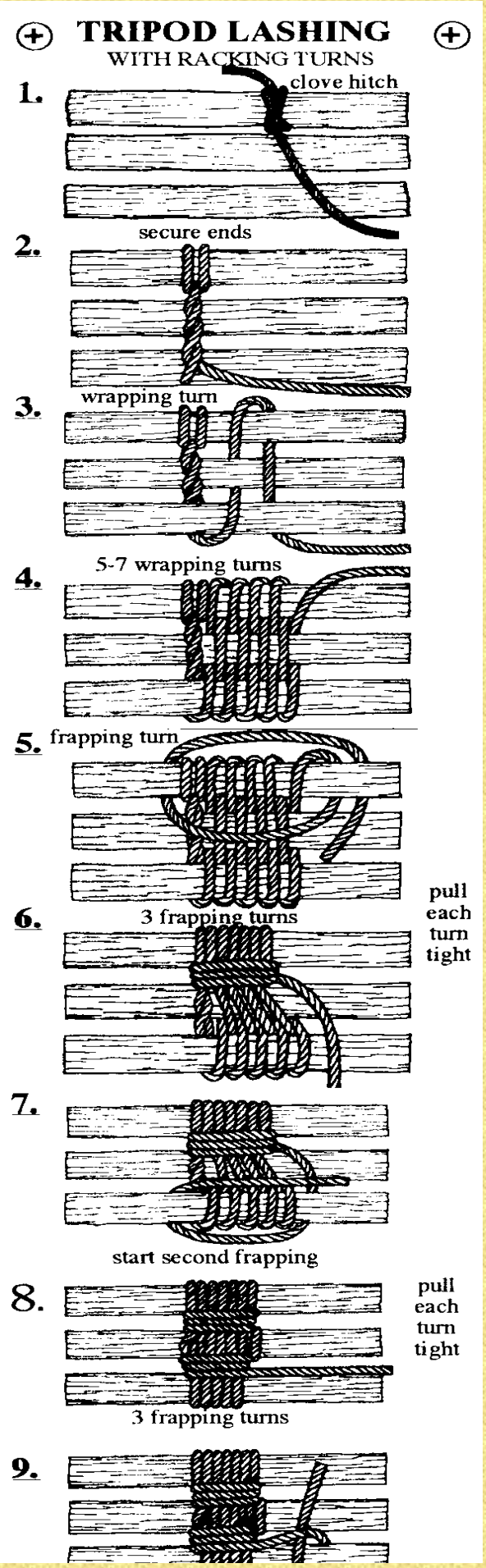

contact makes the tripod lashing with racking turns the most secure form of tripod lashing: therefore tripod lashing with racking turns should be used when safety is important. However, for light structures where there would be no danger if the lashing slipped, the faster to tie tripod lashing with plain wrapping turns may be used.

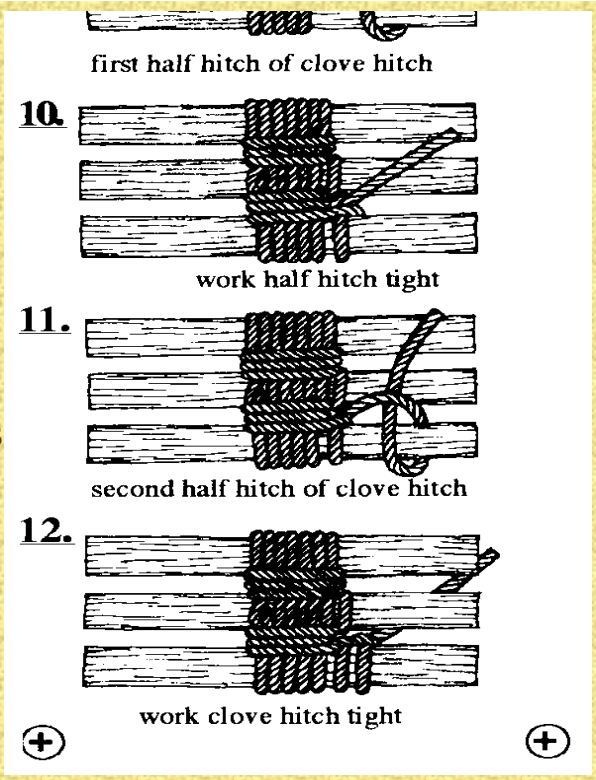

Laying Out The Poles ----

For most tripod lashings, lay the pole side by side with the butt ends aligned. The alignment of the butts of the pole insures that the tripod legs are the desired length.

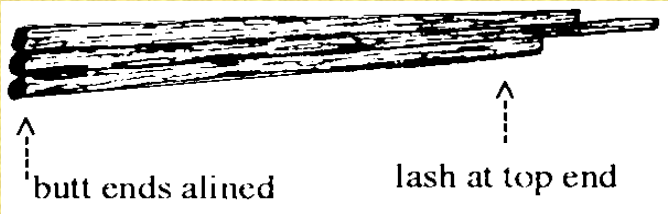

[NOTE]

The practice of laying the center pole in the opposite direction to the outside poles creates several problems. When the poles are laid in opposite directions the wrappings must be put on loosely so that when the center pole is rotated to its proper position the lashing is tightened around the poles. If the wrappings are put on to tight, the rope is stretched causing damage to the rope fibers, therefore weakening the lashing. On the other hand, if the rope is wrapped two loosely, the lashing will not tighten enough when the center pole is rotated and the lashing will be able to slip along the length of the pole. Either way, the rope to loose or the rope to tight, a dangerous situation is created.

Setting Up A Tripod -----

Set up the tripod by crossing the outside poles so that the cross point of the poles is under the center pole. Crossing the outside poles under the center pole causes part of the load that is placed on the tripod to be taken up by the wood to wood contact of the poles.

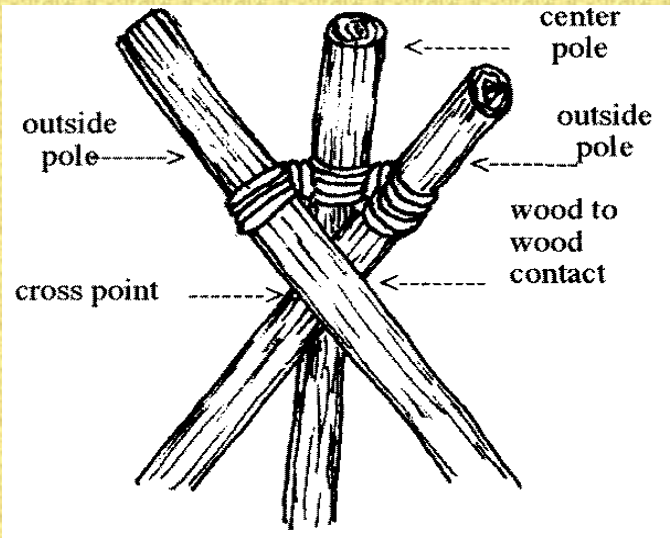

Narration ------ (For Tripod Lashing Knotboard.)

(1) Tie a clove hitch around one of the outside poles. (2) Secure the standing part by wrapping it around the running part. [NOTE] Wrapping the standing part around the running part prevents the clove hitch from slipping around the pole. If the clove hitch slips the lashing will loosen up from the inside. (3) Start the racked wrapping turns by weaving the rope between the poles. (4) Take a total of 5 to 7 wrapping turns. Pull each wrapping turn tight as it is made. [NOTE] The stiffness of the tripod lashing depends on the number and tightness of the wrapping turns. As the tightness of the wrapping turns or the number of wrapping turns increases, the stiffness of the tripod will increase. (5) Take the first frapping turn by taking the rope around the pole that the clove hitch was tied to, then between the outside pole and the center pole. (6) Take 3 frapping turns. Pull each frapping turn tight as it is made. (7) Start the second set of frapping turns by taking the rope across the center pole and reeving it between the second outside pole and the center pole. Take the second set of frapping turns in the opposite direction to the first set of frapping turns. [NOTE] Taking the second set of frapping turns in the opposite direction to the first set of frapping turns prevents the rope from crossing the wrappings at a diagonal. Unnecessary crossing of the rope increases friction between the strands of the rope making it difficult to tighten the lashing properly. (8) Take a total of 3 frapping turns. Pull each turn tight. (9) Take the first half hitch of the ending clove hitch around the second outside pole by taking the rope past the pole and then around the pole. (10) Work the half hitch tight so that it is locked against the lashing. [NOTE] See the narration for square lashing for instructions on working the half hitch tight. (11) Take the second half hitch of the ending clove hitch. (12) Work the half hitch tight to complete the ending clove hitch. [NOTE] If the clove hitch is not worked tight so that it is locked against the lashing the clove hitch will slip around the pole allowing the lashing to loosen. [NOTE] If very smooth rope is being used, a 3rd half hitch should be added to the clove hitch to insure that the lashing will stay in place.

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TURK'S HEAD:

Description ----

Three strand braid worked in a continuous circle.

Use ----

(1) As a decorative knot around a staff or railing.
(2) Worked tight around a checked or cracked tool handle or canoe paddle to reinforce them.
(3) As a neckerchief slide or wogal.

Comments ----

The form of Turks head shown here is a five crown Turk's head, this is only one of a group of knots that go by the name Turk's heads. The crown number is determined by counting the number of bights at the edge of the knot. To make a larger loop the, increase the size of the wraps made in steps 1 - 4 and then, at step 7 use three strand braiding to increase the number of crowns. The number of crowns can be increased by increments of three; so that the number of crowns in a larger loop can be 8, 11, 14, etc..The size of the finished Turk's head depends on the size of the rope used and the number of times the strand is chased.

Other Names ----

Three lead by five bight Turk's head, ordinary Turk's head.

Narration ------ (For Turk's head knotboard.)

(1) Start at the center of the line, by taking a

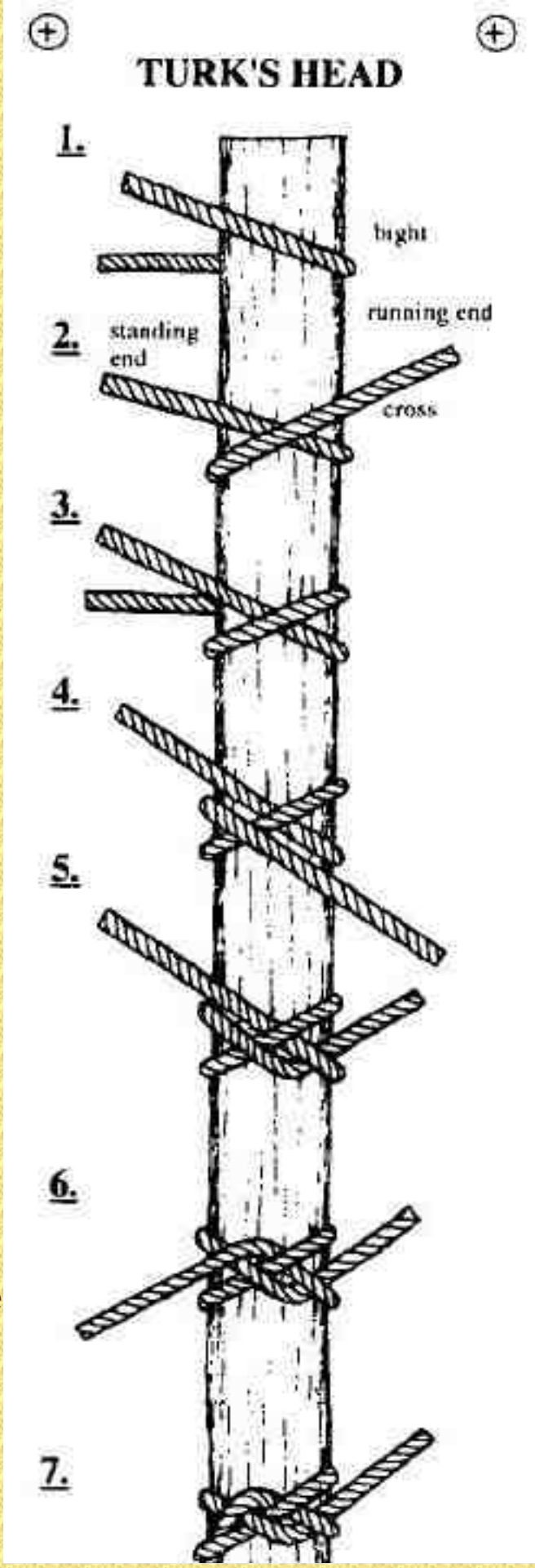

bight around an object (the fingers of the left hand work well) (2) Complete the round turn and cross the running end over the standing end. (3) Take a second bight around the object so that the running end is between the standing end and the first wrap. (4) Lay the running end across the first wrap then (5) tuck the running end under the standing end. (6) lay the standing end across the second wrap and (7) tuck it under the first wrap. (8) rotate the knot around the object so that you are looking at the opposite side. (9) Cross the second wrap over the first wrap. (10) Reeve the standing end through the eye formed between the two wraps. (11) Reeve the running end through the eye between the two wraps so that the ends are in opposite directions. (12) Chase, follow, the strand of the knot two or three times. Cut off and secure the ends.

[NOTE] To determine the length of line to use, wrap the line around the object four times for a single strand knot. Add three and one half wraps for each time you intend to chase the original strand.

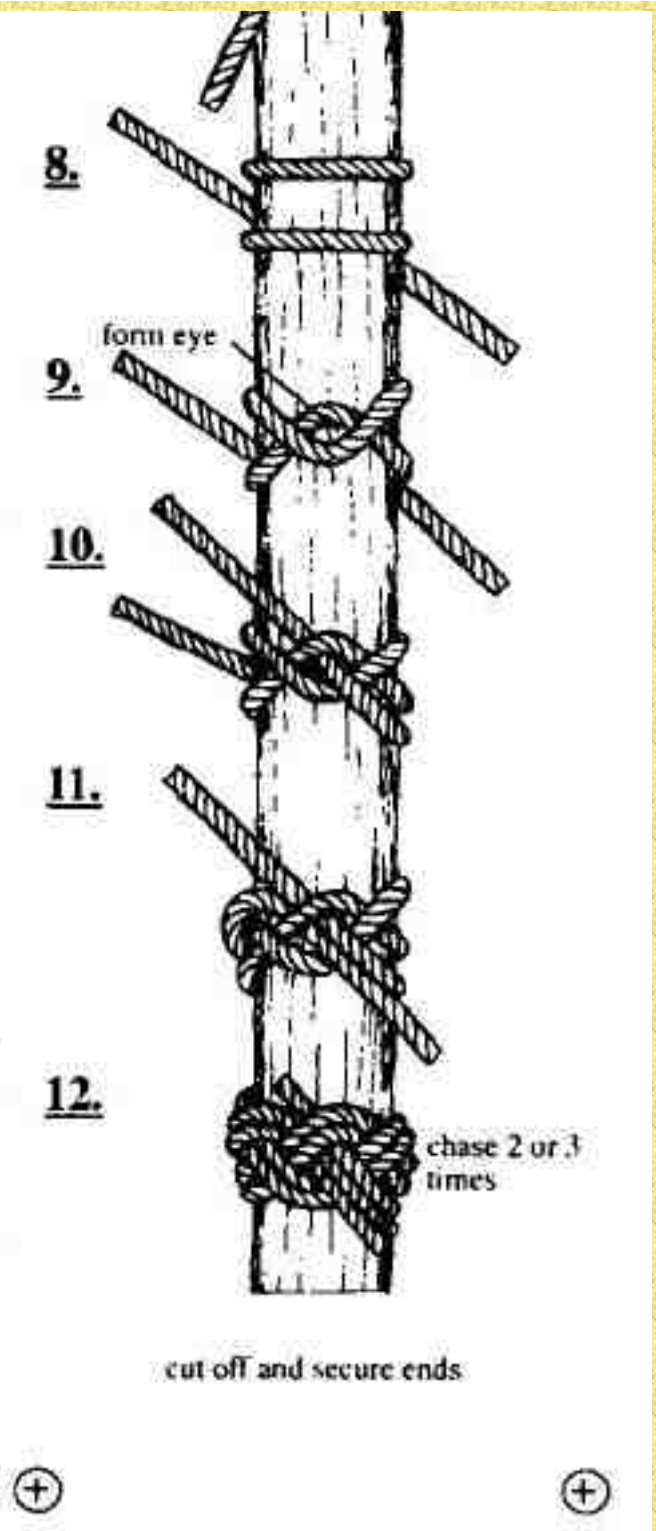

ANIMATED KNOT

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TURK'S HEAD KNOT

RERUN ANIMATION

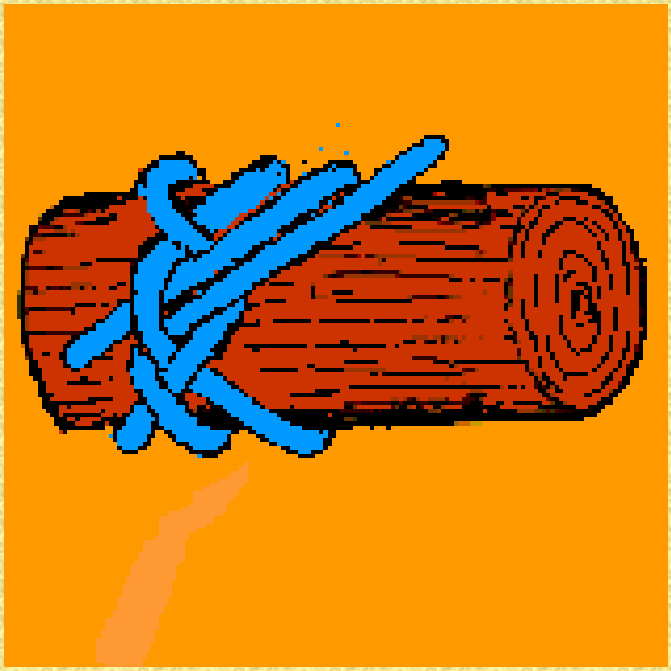

MORE ANNIMATED KNOTS

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Water Knot

The water knot is arguably the strongest knot you can tie in webbing. It is essentially an overhand follow-through.

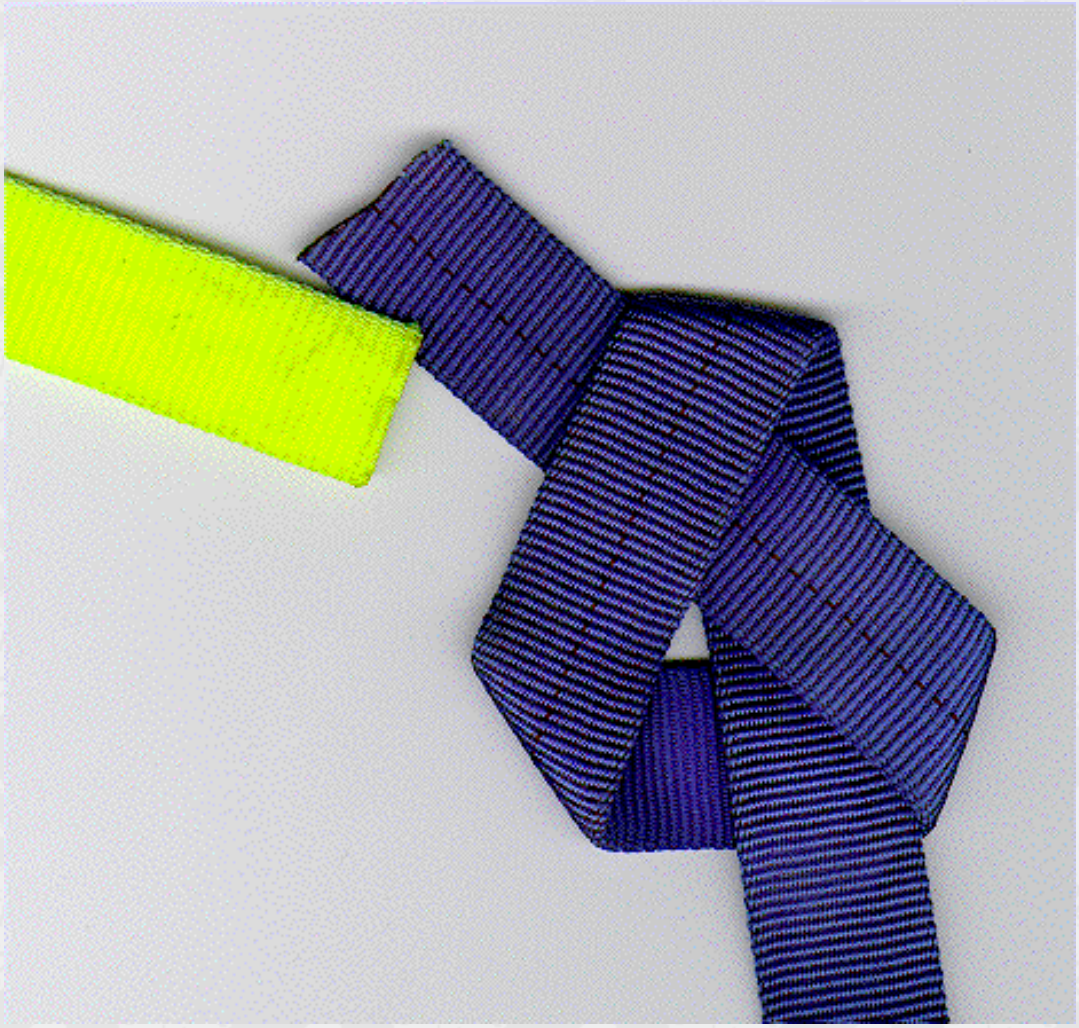

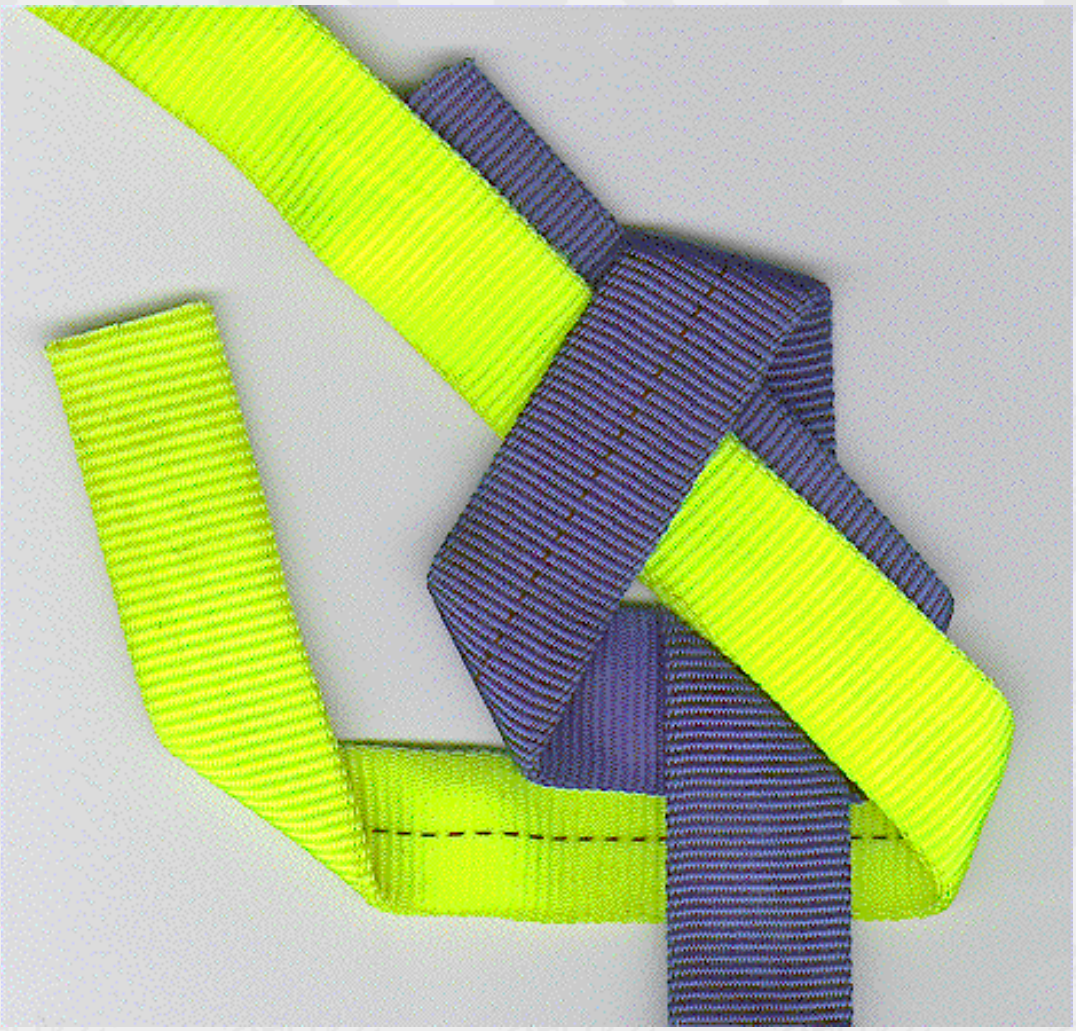

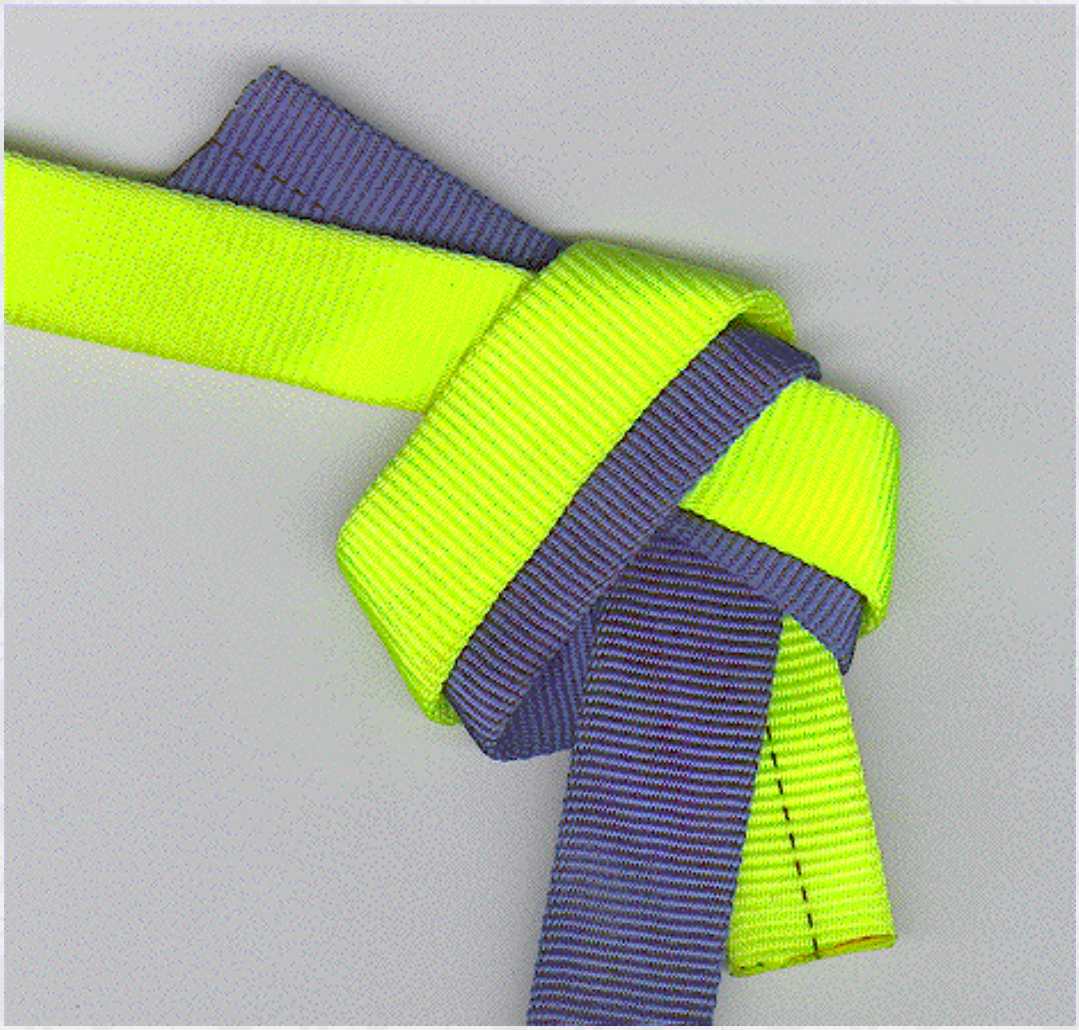

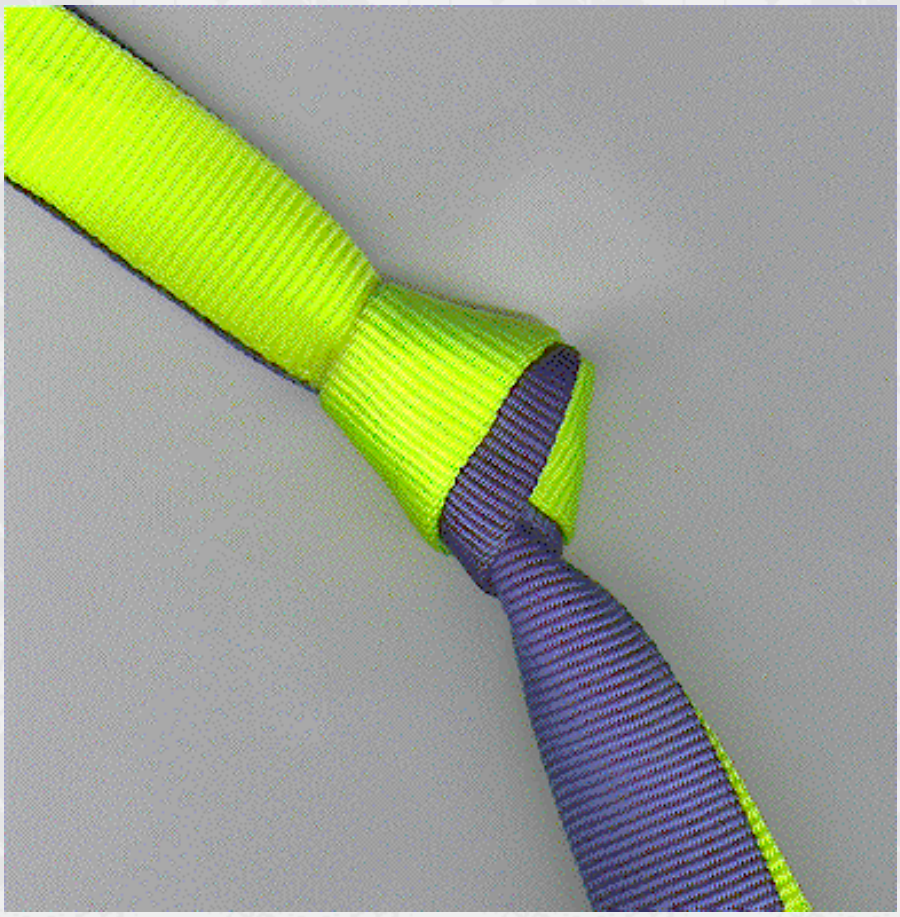

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KNOTBOARD OF THE MONTH

Each month there will be new knotboard and descritive text displayed on this page.

THIS MONTH'S IS THE :

WHIPPING:

Description ----

Twine wrapped and secured to the end of a rope.

Use ----

To prevent the fraying of the end of a rope.

Comments ----

Even though "whipping" is done in several different ways, the finished "whippings" have similar appearance: the ends are secured under the turns, the length of the whipping is equal to the diameter of the rope, and all turns are parallel. Synthetic rope, rope made of plastic, should be whipped and fused to prevent the rope from fraying. Fusing helps to hold the whipping in place and the whipping helps to prevent the fused rope strands from braking apart.

Narration ------ (For Whipping Knotboard.)

(1) Take a turn around the cleat and pull the line tight. (2) Complete a round turn around the cleat . (3) Place the line across the cleat. (4) Take a bight around one horn of the cleat. (5) Place the line across the cleat a second time. (6) Take a bight around the other horn of the cleat to form a figure eight around

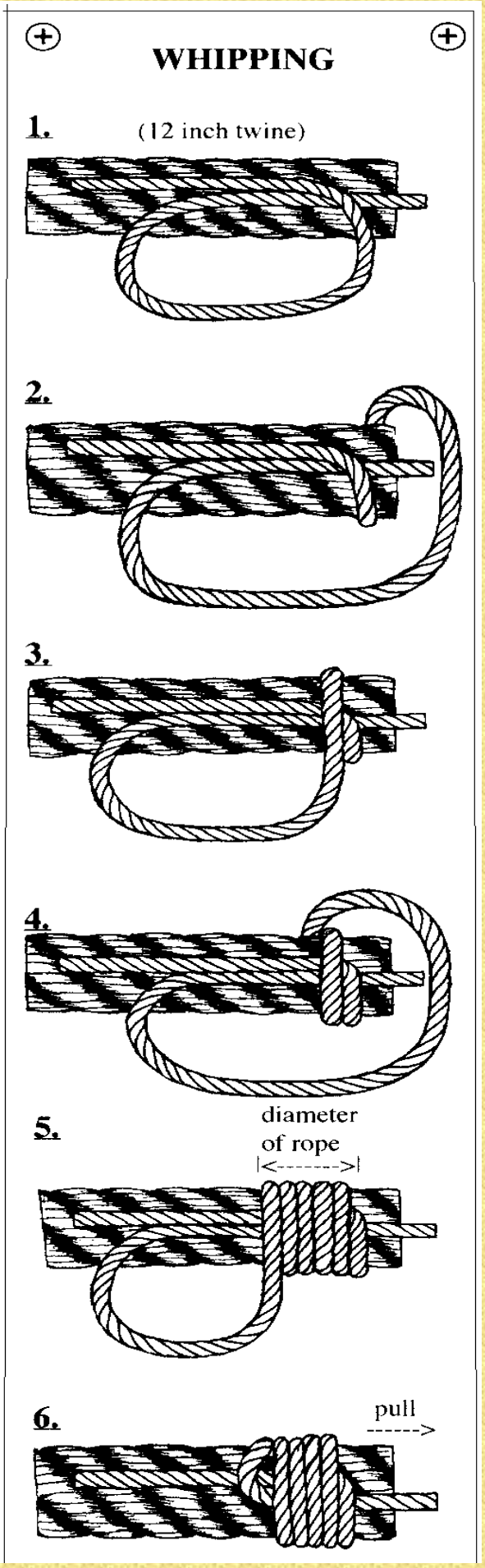

the horns of the cleat. (7) Repeat steps 3 through 6. (8) Form an underhand loop. (9) Place the eye of the underhand loop over the horn of the cleat. (10) Pull the underhand loop tight to form a half hitch around the horn of the cleat, this locks the rope in place.

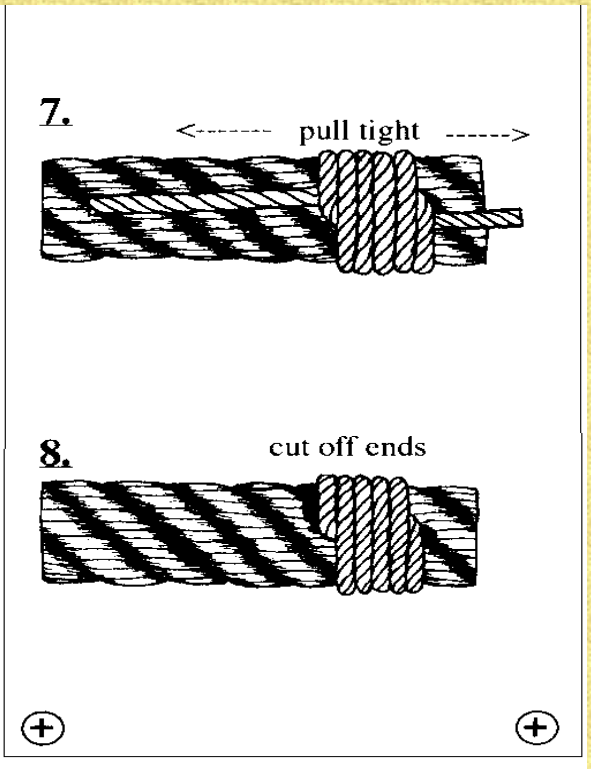

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Turk's Head Woggle, Page 1.

Turk's Head Woggle

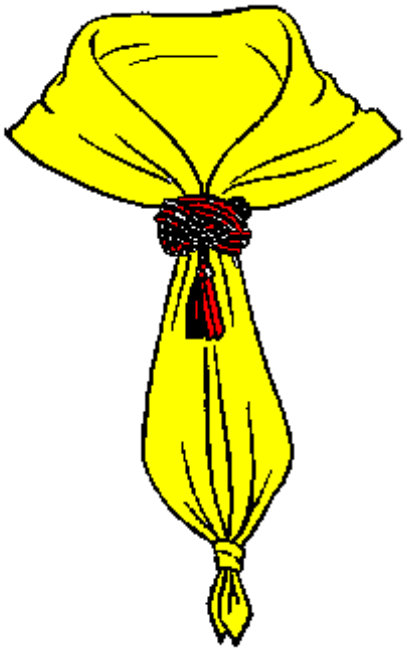

made with plastic craftstrip

Here it is . . . the classic Turk's Head neckerchief slide! I made 3 or 4 of these during my youth. I used small rope and leather when I made mine. You could use plastic craftstrip to make one as well.

The directions on the following pages are from the BSA Craftstrip Braiding Projects pamphlet, available at your Scout HQ or through the BSA catalog. The instructions work for either rope, leather, or craftstrip.

If you intend to make the Turk's Head out of craftstrip, you'll need to create a craftstrip "braid" first. This involves another 15 steps and 20 figures. I don't have that kind of space on this home page. You'll need to purchase the Projects pamphlet for the detailed instructions.

Go to Turk's Head Woggle, page 2.

Zászló~

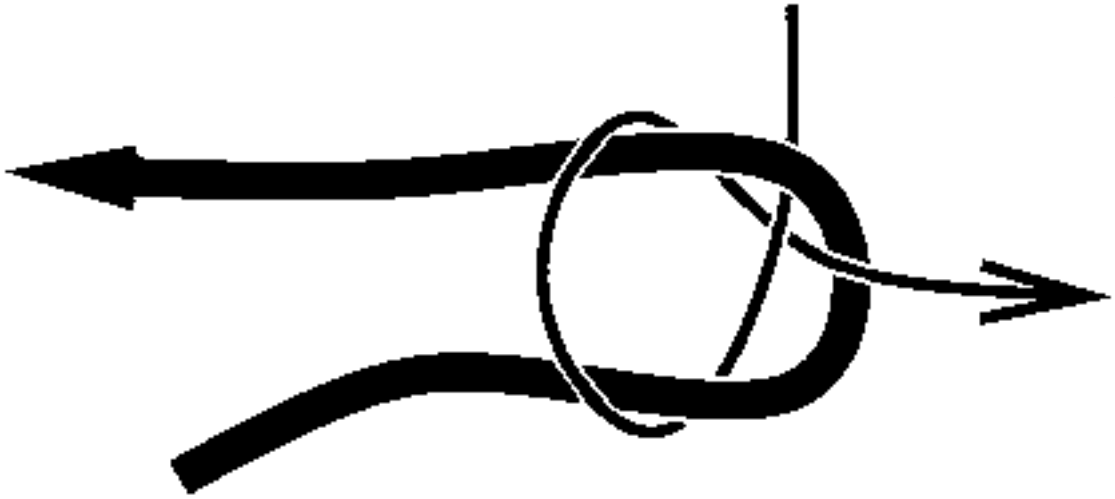

Kötelek összekötése, különbözõ vastagságúaké is. Jónéhány más csomóban felismerhetõ egy-egy változata.

<< Toldó1~ | #eleje | index | levél | Bowlin >>

Utolsó módosítás: 2002.09.26 23:41:34 CEST

rec.crafts.knots FAQ

"to me the simple act of tying a knot is an adventure in unlimited space. a bit of string affords a dimensional latitude that is unique among the entities. for an uncomplicated strand is a palpable object that, for all practical purposes, possesses one dimension only. if we move a single strand in a plane, interlacing it at will, actual objects of beauty and utility can result in what is practically two dimensions; and if we choose to direct our strand out of this one plane, another dimension is added which provides opportunity for an excursion that is limited only by the scope of our own imagery and the length of the ropemaker's coil."
From The Ashley Book of Knots
by Clifford W. Ashley (see in books below)

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1. Netiquette
2. Books
3. Periodicals
4. Organizations
5. Internet Resources
6. Sources for things
7. Where can I find...?
8. Miscellaneous questions
9. Contributors

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1. Netiquette in rec.crafts.knots (r.c.k)

The usual standards of newsgroup netiquette apply in rec.crafts.knots. We suggest reading the group for a while before your first posting to see what sort of posts are common here. The usual rule of no-binaries (picture files, programs, etc.) applies. If you have a graphic file to share with the group, place it at a FTP or WWW (Web) site available to you and post an article in the group that describes where interested people may look for it. As a last resort, post it to one of the alt.binaries... groups (there **are** some general purpose a.b... groups) and post your pointer in r.c.k; we suggest putting 'KNOT' in the Subject to enable others to find it easily.
If you are **unable** to place a graphics file related to a posting in rec.crafts.knots at your own or a friend's Web or FTP site, you may be able to arrange temporary hosting from some other person who has an interest in knots. See Resources below.

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2. Books

Please send entries

1. The Ashley Book of Knots by Clifford W. Ashley
   Doubleday (1944) $45; in its 35th printing
   This is the "must-have" book of knotting. Ashley's lucid style, clear drawings, background materials, and comprehensive coverage make this the book from which to learn knot tying. [pwm]

2. Symmetric Bends: How to Join Two Lengths of Cord by Roger Miles, Autumn 1995, 150 pages (16 pages of color photos) US$32, £22 World Scientific Publishing Co., Inc., http://www.wspc.co.uk 1060 Main Street, River Edge, NJ 07661, USA FAX: 201-487-9656 Phone 800-227-7562

   This book received a well-deserved glowing review by Lester Copestake in the Dec issue of Knotting Matters. I haven't finished reading it as yet, but have spent several happy hours confirming his lattice diagrams. Some of the topics covered by Roger Miles are: Elementary Symmetric Bends, Geometry and Plannar Representations, Topological Conciderations and a Theorem, Practical Considerations and Triple Symmetry, Sixty (60!) Symmetric Bends (diagrams and colored photos of each) and How to Invent Symmetric Bends.

   The book provides a layman's window into the mind-bogling mathematics that has evolved out of knot theory (and won a Field's Medal (Nobel-eqiv) in 1990 for Vaughan Jones). Dyslectic knot tyers will love this book, as the diagrams and photos are word-less.[dbl] Additional description is at: http://www.wspc.com.sg/books/mathematics/2686.html.[pg]

3. Forget Me Knots by Karl Rohnke, 1992, ISBN 0-8403-7138-1
   Kendal/Hunt Publishing Company
   2460 Kerper Blvd.
   P.O. Box 539
   Dubuque, IA 52004-0539

   This 67 page, spiral-bound handbook is designed for aspiring young climbers: "a gentle reminder of the knots, ropes and lore used on a challenge rope course." Safety and security are the theme in this fun-book. The illustrations by Plynn Williams include a couple of corner-series which animate the rope on its way to becoming a knot as you riffle through the page corners (a poor man's Quick-time movie for the computer-deprived). Interestingly, this book says nothing about bends, probably because of legal implications.[dbl]

4. The History and Science of Knots edited by J C Turner (Univ. Waikato) & P van de Griend (Aarhus Univ.); May 1996; ISBN 981-02-2469-9; US$78 / £54
   A collection of essays with sections on the prehistory and antiquity, non-European traditions, working knots, the developing science of knots, and decorative and other aspects of knots. A more complete description is at:
   http://www.wspc.com.sg/books/mathematics/2940.html. [pg]

5. The Klutz Book of Knots by John Cassidy; 1985; ISBN 0-932592-10-4
   Klutz Press, Palo Alto, California [rp]
   This spiral bound book shows step by step how to tie 24 useful hitches, ties, wraps and knots. It comes with practice cord and has thick stiff pages with holes and slots for practicing the knots right next to its drawings.

6. The Knot Book by Geoffrey Budworth; 1985; ISBN 0-8069-7944-5
   Published by Sterling Publishing Co., Inc. New York
   This is a paperback book of about 100 knots chosen for their usefulness. This book is distinguished by its well drawn illustrations, well conceived text and scarcity of errors. Although the author is one of the foremost authorities on knots, he also includes knowledge from other high achievers on this subject. [rp]

7. The Morrow Guide to Knots by Mario Bigon and Guido Regazzoni, translated by Maria Piotrowska; 1982; ISBN 0-688-01226-4
   William Morrow and Company, Inc. (American edition; Italian original 1981).
   This 255 page paperback contains about 80 knots covering a variety of uses. Its unique features include 647 color photographs, multiple ways to tie the bowline and various gems not usually found in a book this size. The photos are laid out with great care to illustrate the knot tying process. [rp]

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3. Periodicals

1. Het Knoopeknauwertje -- a Dutch knotting magazine. For more details e-mail: Pieter van de Griend <vdgriend@euronet.nl>
   An online, English language version of Het Knoopeknauwertje [pg]
2. The Australian Whipmaker -- Australian; AU$36 for overseas members; see AWPO under Organizations for address. [pg]

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4. Organizations

1. IGKT -- International Guild of Knot Tyers
   (need detailed info for this item)
2. IGKT:NAB -- International Guild of Knot Tyers: North American Branch
   - International Guild of Knot Tyers: North American Branch - info [pwm]
   - International Guild of Knot Tyers: North American Branch - application [pwm]
3. AWPO -- The Australian Whipmakers and Plaiters Organization [pg]
   12 Faireyland Road
   Kuranda
   Queensland 4872 Australia
   phone: (070) 937474
   fax: (070) 514484

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5. Internet Resources

1. International Guild of Knot Tyers (these don't seem to be getting updates) [dbo]
2. International Guild of Knot Tyers: North American Branch (these don't seem to be getting updates) [dbo]
3. International Guild of Knot Tyers: North American Branch - info [pwm]
4. International Guild of Knot Tyers: North American Branch - application [pwm]
5. International Guild of Knot Tyers: Texas Branch [gcs]
6. Army Field Manual on rigging; in-progress (sometimes not available); contains sections on ropes, knots, splices and more; opening page is reasonably sized, but chapters are large. [ep]
7. Knot Books on the Web: WWW references to books. [ep]
8. Ropers Knot Page [ep]
9. Ropers Knot Links [ep]
10. Suber's Knots on the Web [ps]
11. Animated Knots -- from a UK Scout troop [df]
12. International String Figure Association -- from cat's cradle on up [pg]
13. Jack Keene's list of links to web pages with Rope and Knot Strength information. [jk]
14. If you are **unable** to provide a web or FTP site for a graphics file related to a posting in rec.crafts.knots, you may be able to arrange for temporary hosting from someone listed here. Send them mail to ask how they want to set it up.
    - Peter Suber <peters@earlham.edu>

have a look at Peter's Gallery to find out how to submit an image file.

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6. Sources

1. The Knot Shoppe Supplies: para cord in different colors.
2. Foodrope Knots: Books on knotting. [ep]
   Des & Liz Pawson
   501 Wherstead Road
   Ipswitch, Suffolk, IP2 8LL

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7. Where Can I Find...?

1. What are the best sources/references for engineering data on ropes and knots?
   For several years, I have been looking for raw data on breaking strengths and creep rates under steady and cyclic loads. There must be a government agency (or several) concerned with rope and knot standards (e.g., parachute bureau), but I haven't found one.[dbl]
2. Where can I find a particular knot on the Web Ropers Knot Index [ep]

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8. Miscellaneous Questions

I've heard that many knot books have errors in them. Why is that and how do I find a book without errors?

Knot books sometimes have errors because the books the author referenced have errors. The most common error is misnaming, though sometimes the illustrations or the recommended uses are incorrect, which can be dangerous. The books reviewed on this page are generally reliable, and other knotting web sites sometimes include book reviews.[rp]

I keep seeing ABOK mentioned. What does that mean?

Ashley Book Of Knots. It is usually followed by a number to indicate a particular knot in his book.[rp]

What is a good book for beginners to learn knotting who don't want to learn a squizzilion knots?

The Klutz book of Knots reviewed in this FAQ is an excellent book with only 24 knots.[rp]

I have heard that the square knot (also called the reef knot) can be dangerous, is that true?

Yes, It should never be used as a bend (to connect two pieces of rope for the purpose of making a longer rope). This knot often slips when used this way and has caused injuries and deaths.[rp]

Why would someone want to learn knots when bungee cords and straps are so easy to use?

A length of rope and the knowledge of a few knots make for infinitely versatile connections and lashings. It's never a bad idea to have some around to fill in for when the bungees and straps are too awkward or wrong for the job.[rp]

Why would someone want to learn to put whipping on a rope when you can just use tape?

There are many activities where it helps to know whipping, like the increasingly popular practice of making and fixing your own fishing poles, or for decorative reasons.[rp]

Why do I always see fishing knots include their strength, but not other knots?

Fishing is usually done with line of very limited strength (especially in competitions) and the goal is to use knots that weaken it as little as possible. For most non fishing uses, a few percentage points of strength is not as important as security, being untied easily or whatever else your job may require.[rp]

How can you get a knot to hold in these new slippery synthetic ropes? Don't they just come undone?

Sometimes knots come loose because they were not worked down correctly. All knots must be worked down snug and proper for maximum reliability. It is also important to choose the correct knot for the job. Knots should be tested to see when they hold, slip

or jam when tied in different ropes. Other options include securing the working end with a half hitch, overhand or multiple overhand knot, or seizing.[rp]

What does IGKT mean?

The International Guild of Knot Tyers. The IGKT is open to anyone interested in knotting (whether expert or simply hoping to learn from others). For more information see their web pages in the Internet resources section above.[rp]

I sometimes see safety warnings about some knots, especially concerning children, why is that?

Loop knots that slip make dangerous nooses. Children like to play hangman with slip loops. There have been many deaths as a result. Toddlers like to put things around their neck and have even died from playing with mini blind cord. Many parents cut mini blind cords short so that young children cannot reach them.[rp]

When I was young I remember a relative who used to tie a really useful knot. Is there anyway I could find out what that was?

Many knot books organize the knots by use, or include a table listing them that way. If you can remember how or what the knot was used for that might help your search.[rp]

I know there is more than one way to tie a tie, but where do I find out how?

The general knot pages listed above have a number of links to instructional pages for tying ties.[rp]

Every time I try and carry furniture or boxes on the top of my car, they have to call out the national guard to help clean up the mess on the highway. Is there a good way to secure something like that?

Though it is never recommended to carry items on top of a car with no roof rack, many people do it. (I have, but don't tell anybody.) The way it's usually done is to make a small loop in one end of a rope and run the other end through the inside of the car while the doors are open (but not through the windows) , and then over the items on top and back through the small loop. If the resulting wrap is pulled tight with a truckers hitch the items on the roof will be pulled tightly down on the roof (though not necessarily securely). You may want to run more than one of these loops. When the doors are closed the lines will be pulled even tighter. The cargo should also be secured with ropes to the front and back bumpers if possible.[rp]

Half the time I see someone using a tarp on the highway, it looks like a wreckage scene from the movie Waterworld. Why is that?

A tarp under wind pressure suffers the forces of a net, airplane wing and a whip all at once. Care should be taken to keep it from behaving like a flag or a kite. All the corners should be tied down so that it cannot be move in any direction. Extra crossing ropes would not be a bad idea, and all cargo underneath should be secured independently of the tarp, to keep the tarp from having to do the job of a net. Since it is easy to underestimate the forces of wind on a tarp, highway travelers will continue to entertain (or frighten) us.[rp]

Why does it seem that for some knots nobody can agree on a name?

Use by different hobbies, professions, languages and cultures make multiple names for some knots inevitable. Some people use the number of the knot in Ashley's book (ABOK ###) to clarify communications.[rp]

How can I tell if a knot is safe and can hold a load?

Always practice with and test a knot before trusting it. Working a knot down to its proper snug form is just as important as tying it correctly. Also, remember that many knots will reduce the breaking strength of rope to about 40% to 60%. [rp]

How long have people been using knots.

Egyptians used them, Vikings used them, and according to knot historian and researcher Pieter van de Griend, they are "man's oldest technological achievement, possibly even predating the discovery of fire."[rp]

How many knots are there and can you patent them?

Many books say there are about 4000 in the literature, probably because Clifford Ashley has nearly that many in his knot book. There are actually infinitely many variations. You can't patent a knot but Clifford Ashley said he patented # 3028 in his book, which is a sinnet (braided cordage).[rp]

If you think you have discovered a new knot but you are not sure, how do you find out?

Because so much knotting knowledge is lost to history, you may never know for sure.

But the first step for most people is to see if it is in Ashley's book (See book review section above). If it isn't and you're still curious, post a link to a picture of it on this newsgroup. Their are some very knowledgeable knot tyers who monitor rec.crafts.knots. Also, one of the reasons for the establishment of the International Guild of Knot Tyers is to serve as an authoritative body for consulting purposes. [rp]

What is the best knot?

People can be very opinionated about knots. But it's good to remember that a knot that is good for one purpose is not necessarily good for another. Many experienced knot tyers never cease to try out new discoveries and update their repertoire.[rp]

What is the worst knot?

There are many opinions about this too so here's mine; use a square knot to hang your bait bucket over the pier and you will be watching it float away.[rp]

I get lost half the time when I am trying to follow a knot diagram, what can I do?

Some people work better from written directions than from diagrams, so you might try that. Here are some other tips: try a different book, try a different web page, try making other knots of similar type, try different rope or cord, try pinning the rope on a cork board, try photocopying and enlarging the diagram, try turning the diagram in a different direction, try drawing it yourself, ask someone to help you in person and last but not least -- ask for help from rec.crafts.knots. [rp]

Does it take 4 years of post doctorate work to learn how to do a good looking splice like you see on dock ropes?

Eye splicing is simple but some book diagrams and descriptions are tricky to learn from. Try some of the tips from the previous question. [rp]

If a rope has a sheath, how can you tell if the center might be damaged?

There is no easy way to be sure so if you suspect it is damaged it should never be used for climbing or rescue. One test is to tie its length under tension and feel for defects.[rp]

What ever happened to cotton rope and where can I find some?

Many of the uses for cotton rope are being handled admirably by synthetic ropes. Still it is the rope of choice for magicians and horseman, so you might try their shops. Magicians remove the core of cotton braid to facilitate sliding knots. Cotton rope is less likely to "burn" when pulled through the hands and prevents rope burns if a horse should get tangled when tied. It also makes a spiffy dog chew.[rp]

I've heard that some animals can tie knots, is that true? And if so, are any of them members of the IGKT.

Gorillas tie grannies and square knots to hold saplings down in their nests. The hagfish ties itself in an overhand knot, and the weaver bird ties a number of knots. I didn't see any animals listed in the membership handbook, but the IGKT is open to anyone interested in knotting (whether expert or simply hoping to learn from others). [rp]

A neighbor of mine puts half a dozen extra twists and loops and half knots on his knots when he secures gear in his pickup. He says that it is necessary to make it secure. Is that true?

No. It will just make it impossible to untie in a hurry if he needs to. The same applies to people who "bury the cleat" when docking a boat; they must assume there will never be a dock fire.[rp]

A friend of mine always pulls out a lighter and starts torching whenever he finishes a knot. Is that necessary?

Some people like to flame the working end of a knot after it is finished to swell up the end in the hope that it won't pull back into the knot. It is more important to use the correct knot and work it down properly. If that's not enough maybe another knot should be used.[rp]

Nylon 3-strand rope unravels at just short of the speed of light. What gives?

Nylon is a slippery material and although it's stable in 3-strand form, it will unravel easily if the ends are not whipped, taped or otherwise secured. One trick for cutting it neatly is to tape the spot you want to cut first, and then cut in the middle of the tape. Then you will automatically have two taped ends.[rp]

I am usually concerned about knots being secure but I have heard that some knots are stronger than others. Is that important?

Synthetic ropes are very strong. It's common to use a rope much stronger than needed

just to be thick enough to "get a grip." If you are using a knot that is correct for a given purpose then other knots will probably not be more than 10% or 20% stronger. Splicing however can be 40 to 100% stronger than some knots.[rp]

Every time I put a knot under a load, I can never get the *!! thing untied. Isn't their a better way?

Knots vary in how easily they untie after being stressed. For example; the bowline unties easily after a load, but the double half hitch can be ornery. Many knots are still secure when the last tuck is with the end folded over, like in shoelaces. This can make release much easier. Many knots known for their quick release abilities behave poorly under a load -- the highwayman's hitch can give way, the mooring hitch can jam. [rp]

I found your FAQ page, but I can't find your newsgroup on my server. What gives?

Different systems need different solutions. Some people have attained access through DejaNews at http://www.dejanews.com/ [rp]

I have heard that there is a computer program that makes knots. Is that true?

Yes, it's called KnotPlot and it makes astounding images and performs many mathematical operations on knots. There are several links to it on pages referenced from this page.[rp]

A friend told me that nobody uses knots on a sailboat anymore, is that true?

No, there are four or five knots that are used regularly plus many more for special tasks and emergencies.[rp]

In a recent, informal survey on the newsgroup rec.boats.cruising, asking about the necessary knots for the recreational sailor, boaters submitted 20 useful knots.

By far the most frequently mentioned (3 to 5 responses each) were the square (reef) knot, clove hitch, figure 8, bowline, sheet bend, and rolling hitch. Buntline hitch, alpine butterfly, and round turn and two half hitches each got 2 votes, while mentioned only once were Ashley's bend, overhand, constrictor, carrick, monkey chain, cleat hitch, monkey's fist, prusik, bowline on a bight, double sheet bend, and trucker's hitch.

(Amazing, not one anchor bend or becket bend, yet virtually every book of boater's knots features these!)[dh]

How do you get out a knot that is jammed?

I have leveraged some open with a Marlinespike, but if all else fails, try rec.knives.[rp]

I know that I am tying my fishing knots right, but they still break too often. What's happening?

When a knot is pulled down in fishing line it saws harshly against itself. If it is not wetted it will cut itself badly and then break under light strain. Also, you might want to test if the line is brittle by tying an overhand knot in it and seeing how easy it breaks (if the line is OK it should hold to about 50% line strength).[rp]

Where can I find some games for my boy scout troop to play that involves knots?

Many knot books have a recreational section in them. There are also many scout links on some of the pages referenced on this page.[rp]

I can read postings on the newsgroup, but I can't seem to post anything.

DejaNews has a search engine for computer and technical questions at: http://www.dejanews.com/[rp]

I was reading a message on the rec.crafts.knots newsgroup, but now it won't show it.

Some news browsers will not show a message again after it has been marked "read". In Netscape 2 and 3, you can chose "show all messages" from the Options menu. Also, see question above. Sorry Peter, I haven't had a chance to look up the menu Items on MSIE yet.[rp]

I'm concerned that if I post to a newsgroup, I will get a lot of junk mail. Is that true?

I received a couple of junk emails (spam) soon after joining rec.crafts.knots, but not enough to be a bother. The worst newsgroup for getting spam is news.admin.net-abuse.email ...since the spammers troll it for revenge. Some people put the letters NOSPAM in their return email address. That way other newsgroup members can still contact you by taking out these letters, but some automatic engines for collecting email addresses from newsgroups will be fooled.[rp]

I heard that everybody likes knot puns. If I hear a new one should I post it?

Try alt.humor.puns. But if you think it is so good that knot tyers MUST see it, then maybe post a link to it instead of posting it directly so there will not be any unintended victims (no pun intended).[rp]

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9. Contributors to the FAQ

[dbl]

Dick Blackmer <easy@wizvax.net>

[dbo]

David Bowie <dbowie@webshirt.com>>

[df]

Doug Fry <br816@freenet.toronto.on.ca>

[dh]

Dwight Hall <dwihall@ix.netcom.com>

[ep]

Ed Prins <erpprs@dds.nl>

[gcs]

Gary Sessions <gcsessions@netgazer.net>

[jk]

Jack Keene <knotter@juno.com>

[pg]

Pieter van de Griend <vdgriend@euronet.nl>

[ps]

Peter Suber <peters@earlham.edu>

[pwm]

Peter W. Meek <pwmeek@mail.msen.com>

[rp]

Randy Penn <rlpenn@gte.net>

Table of Contents

Suggestions for entries needed

I can always use suggestions for entries in all of the sections, especially 'Books', 'Periodicals' and 'Organizations'. Please include e-mail and surface-mail addresses, phone/fax numbers, dues or subscription costs, and anything else pertinant. Please also include which information about yourself to include in the contributors list.
Send suggestions to <pwmeek@mail.msen.com>

Created: Fri 7-Feb-1997
Modified: 12/29/98 12:40:06 PM
By: Peter W. Meek <pwmeek@mail.msen.com>
Send comments or suggestions

"Tying a knot is an adventure in unlimited linear space." Clifford W. Ashley

The Author is a Member of

September 28, 1997

This Yosemite's Scouting Jamboree site is owned by Rags

[Previous 5 Sites | Previous | Next | Next 5 Sites | Random Site | List Sites]

Are you a Scouting Website in GeoCities' Yosemite neighborhood

	and interested in joining this webring? Contact RingMaster.

Not Found

The requested URL was not found on this server.

Apache Server at webshirt.com

Startseite
Begriffe
Knoten & Steke
Festmacherknoten
Zierknoten
Spleisse
Krawatten
Knotenindex
Bücher
Fanshop
Forum
andere Knotenseiten
Links >>>

Klabautermanns Knotentafel

Die letzten Artikel:

Knoten:
neuer Knotenspass mit Scoubidous
27.07.04
Ausstellung geht nach Hamburg
12.07.04
Ausstellung in Flensburg
01.07.02
Knotentafel in Englisch
01.06.02
In eigener Sache
15.01.02

IGKT:
4. Gildentreffen in Bremen
10.05.04
IGKT Treffen in Bremen
01.03.04
Grosses Interesse in Duisburg
11.04.03
IGKT Treffen in Duisburg
20.03.03
IGKT Treffen in Flensburg
16.07.02

Aktuelles auf den Knotentafeln

[Knotentafel] [Knoten-Archiv]

neuer Knotenspass mit Scoubidous

Knoten

27.07.2004 Früher nannte man es Fancywork, heute Scoubidous. Früher knotete man mit Flechtschnüren und Seilen, heute knüpft man mit Plastikbändern. Wie auch immer man es nennt, Knoten knüpfen war schon lange nicht mehr so aktuell wie heute. >> weiterlesen

geändert am 15.08.2004 von Matthias Böving

Matthias Böving

Aktuelles von der 'International Guild of Knot Tyers'

[IGKT-Home] [IGKT-Archiv]

4. Gildentreffen in Bremen

IGKT

10.05.2004 IGKT Mitglieder aus 5 Nationen trafen sich vom 7.5-9.5.2004 auf der "Segelschulschiff Deutschland" in Bremen-Vegesack. >> weiterlesen

geändert am 10.05.2004 von Webmaster

Webmaster

Werbung
Yacht-Tauwerk seil-frey

Gästebuch
eintragen
anschauen

This IGKT--KnotTyers site owned by Matthias Boeving.
[Previous 5 Sites | Previous | Next | Next 5 Sites | ListSites]
Find out how to join this ring. Go to the
IGKT--KnotTyers Ring Homepage

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www.klabautermann.de

ausschluss

Impressum

KNOT KNOWLEDGE

PHOTO-ILLUSTRATIONS

Twenty-three practical knots are presented with photographs of the steps involved in tying each knot. Every step is also described in text. It is not the function (yet) of Knot Knowledge to teach how to use these knots, so please do not use friction hitches for dangerous activities like climbing rope unless you have been properly trained. Knot Knowledge provides in its lexicon definitions of the few knot tying terms used in the text descriptions.

Clicking on a category shows all the knots within that category on one page. Clicking on the name of a knot shows just that knot.

- **Single Loop Knots Page** (272K)
  - **Bowline**
  - **Figure 8 Loop**
  - **In Line Figure 8 Loop**
  - **Butterfly Knot**
- **Double Loop Knots Page** (297K)
  - **Spanish Bowline**
  - **"A Rigid Double Splayed Loop in the Bight" (ABoK #1100)**
  - **Triple Crown Knot**

- Bowline on a Bight

- Hitches Page (324K)
  - Clove Hitch
  - Constrictor Hitch
  - Anchor Bend
  - Bunt Line Hitch
  - Highwayman's Hitch

- Stopper Knots Page (108K)
  - Figure 8
  - Heaving Line Knot
  - Double Overhand Knot

- Bends Page (118K)
  - Sheet Bend
  - Full Carrick Bend

- Friction Hitches Page (552K)
  - Blake's Hitch
  - Kreutzklem
  - Prusik
  - Kleimheist

- Tautline Hitch (aka Rolling Hitch)
- Sliding Sheet Bend

Links:

- **If you didn't find the knot you wanted on Knot Knowledge, try Peter Suber's Knots on the Web. It's the most complete index of knot-related web sites on the web.**
- **Roper's Knot Page is Ed Prins' knot-related website index, which also has an instruction section.**
- **Want to tie a rope halter for your horse? The Fiador (aka Theodore) knot can be found on Part II of Connie Nygard's Rope Halter website.**
- **The trucker's hitch is a frequent request. It can be found on NetKnots.com's Outdoor Knots page.**
- **For information on using the Blake's Hitch in recreational tree climbing, check out Peter Jenkins' Tree Climbers International website.**
- **See the *NEW* knots on the contributions page.**

Knot Knotes

--This page is moving. Please update your bookmarks to **KnotKnotes**--

"Every Scout ought to be able to tie a knot. To tie a knot seems a simple thing, and yet there are right and wrong ways of doing it, and Scouts ought to know the right way. Very often it happens that lives depend on a knot being properly tied." -- Baden- Powell .

The business of rope and cordage represents one of humankind's oldest technical accomplishments. This skill coupled with the knots that hold it all together are part of the building blocks of civilization. Even in these times of bungee cords and Velcro a bit of cord tied properly can do a better job.

While this might seem a trivial pursuit to some, this knowledge is shared and prized among Scouts, campers, sailors, climbers, craftsmen and many more in their own special applications. There are knots for both function and decorative needs.

STATISTICS Since 19APR97

Page updated 29SEP02

Dragonfly Challenge

<< What's newest?

If you have comments and links you want to share with other knotters... please sign my guestbook.

View My Guestbook

Sign My Guestbook - Comments and Questions

For no frames follow the links below

Home KnotKnotes Knot Knotes II Knot Funny Links & Resources Comments? Me?

Visit the
Museum of Fancy Knots

Site Meter

and 160,000 or so before that since 1997.

Home Knotes Knotes 2 Knotfun Mail ?

Knots on the Web

Artwork credits

Unfortunately I'm much too busy with real, paying work nowadays to update *Knots on the Web* as often as I used to. Consequently, it has far too many dead links and omits far too many good, new sites. I wish I could say that this will change soon, but it won't. Until it does, please use what is still useful here and forgive the weak spots. If you have a specific knot need or question, and the surviving links here don't help you with it, then try posting your question to rec.crafts.knots or running a search on Google. —Peter.

Welcome to my collection of knotting resources.

My major sections are on **Knot Tying**, **Knot Theory**, and **Knot Art**. But knot lovers will understand that these distinctions are artificial. For example, a good practical knot is both a nugget of hard-won technology and a thing of beauty. Decorative knotting can be useful, and in any case requires uncommon dexterity and practical tying ability. Software developed to help mathematical knot theorists has produced some of the most beautiful knot images ever seen. So look at all three sections even if you think your interests are narrow. You might become happily entangled.

My fourth section is on **Knot Discussion**. Use these discussion forums to find answers to your knotting questions and to help others who know less than you do.

My fifth section is on **Knot Software**. You'll be surprised at how knotting software can make it easier for you to learn to tie knots, to explore the mathematical properties of knots, and to create stunning images of knots, including knots never seen on Earth.

My sixth section is on **Knot Videos**. If written instructions and still photos don't explain the intricacies of knotting well enough for you, try some of these videos (or some instructional software).

My seventh section is on **Knot Books**. Click on these links to buy knotting classics from Amazon.com. I've designed this section to aim for excellence, not completeness. It's limited to books I can personally recommend.

My eighth section is a **Knot Gallery** to display the images from rec.crafts.knots, the only usenet newsgroup devoted to knots.

To find something in particular, wait for the whole page to load and then use the search function on your browser. This will cover all my sections except the Knot Gallery, and my site awards, which are in separate files.

☐ Open links in new windows.

Stuck in a frame? Click here to escape.

If you are a frequent visitor, then press **reload** (on Netscape) or **refresh** (on Explorer) to make sure you get the latest version of the page, not the version cached on your hard drive from your last visit.

Table of Contents
Major Sections

	Knot Tying	Knot Theory	Knot Art
Links			
Discussion			
Software			
Videos			
Books			

These links will only work when the corresponding section of the file has loaded, which may take a minute.

All sections

- **Knot tying**
  - General
  - Animal-handling knots
  - Climbing and caving
  - Craft knots
  - Fishing knots
  - Necktie knots
  - Not knots
  - Rope and cordage
  - Rope rescue

    - Sailing and boating
    - Scouting
    - Suppliers
    - Surgical knots
- **Knot theory**
    - General
    - Biblographies
    - Glossaries
    - Journals
    - Primers
    - Tables
- **Knot art**
    - General
    - Celtic knotwork
    - Fancy and decorative knots
    - Metalwork knots
    - Related arts
- **Knot discussion**
    - Discussion of knot tying
    - Discussion of knot theory
    - Discussion of knot art
- **Knot software**
    - Software for knot tying
    - Software for knot theory
    - Software for knot art
- **Knot videos**
    - Videos on knot tying
    - Videos on knot theory
    - Videos on knot art
- **Knot books**
    - Books on knot tying
    - Books on knot theory
    - Books on knot art
- **Knot gallery**
- **Awards**

Knot Tying

Knot Tying Sub-Sections (more to come)
General | Animal-handling knots | Climbing and caving knots | Craft knots | Fishing knots | Necktie knots | Not knots | Rope and cordage | Rope rescue | Sailing and boating | Scouting | Suppliers | Surgical knots

General. Also see the discussion forums, software, videos, and books on knot tying.

- The International Guild of Knot Tyers. This is the organization to join if you are a serious knot tyer. Its journal, *Knotting Matters*, is the only English-language print journal devoted exclusively to knots.
  - The North American Branch has its own web page. The NAB publishes the InterKnot newsletter. (Interknot was formerly on the web, but the link is now dead. Does anyone know whether it's gone for good?)
  - The Pacific Americas Branch has its own own page.
  - The Texas Branch also has its own page.
  - There are many other branches without their own web sites.
- Het Knoopeknauwertje. The English-language International Edition of the Dutch knotting journal. *Apparently defunct. I'm still investigating what happened to it.*
- Nylon Highway. The magazine of rope, climbing, and cave exploration. From the Vertical Section of the National Speleological Society. The back issues do not exist in electronic form. Recent issues are online but only accessible to paying subscribers
- Ropers Knots Page. Maintained by Ed Prins. The most thorough page of links to knot sites, except possibly mine; but he includes some sites I omit and *vice versa*. Also available in Dutch. Now contains an ambitious Knot Index, an alphabetic list of links to every distinct knot discussed or illustrated on the web.
- Brion Toss Rigging. The professional site of Brion Toss, the leading authority on ship rigging alive today. (I sell his knotting and rigging books in my book section, below.) Includes a catalog, news, links, and Spar Talk, his wonderful discussion board.
- The Knotting Dictionary of Kännet. Maintained by Jan Korpegård. Under each knot, Korpegård gives the knot's name in 10 languages, and asks readers of other languages to send him the names of the same knots in their languages; he even provides the form for submitting the names electronically. Also available in Swedish.
- Knot Knotes. A knot miscellany from Jack Keene that includes illustrations, instruction, links, lore, and a cartoon.
- Knot Tying Resources. From Martin Combs. On request he'll send you an email with his list of sources for materials, tools, and books for knot tying. Also see his very good page of books on knots and tall ships.
- Folsom's Knots and Knotting Page. A strong and interesting page of knots and knot

links. Covers the basic knots, 50 more advanced knots, animations, Turk's Heads, and knot knives, knot books, and more. From Alan Folsom.

- Notable Knot Index. Thirteen knots, well-illustrated, and lots of useful related information. The site author wishes to remain anonymous except for his email address, which is on the front page.
- NudosA very large number of well-illustrated knots, with their names in Spanish. From Hernan Murno. *This site has disappeared and Google can't find it. Does anyone know where it went?*
- Splicing Guides. Select the kind of rope you want to splice, click, and follow the detailed, illustrated directions. From New England Ropes.
- Rigging. An enormous, illustrated work in progress. The U.S. Army Engineer School is putting full-text of the Army Field Manual of Rigging on the web. You'll have to download large files, but it's worth it. An earlier edition.
- NetKnots.com. A fairly large collection of knots for camping, fishing, and boating. Well-organized and well-illustrated.
- Knots Online. From Northern Mountain Supply. Sixteen illustrated knots for camping and climbing.
- Knot Tying Notation. A "programming language" to record the steps in a knot tying method. Not for everyone, but the only notation of its kind for those who need one. From the Suberian knot labs.
- Six Exploding Knots. Some of my own knot work.
    - One of my exploding knots, under the name *Exploding Hitch*, was featured as the Knot of the Month in the October 1999 issue of *Boating Magazine* (p. 64). Unfortunately, the magazine is not on the web.
    - Two of them have been re-drawn by David Blume. One has been illustrated in a series of eleven photographs by an anonymous fan.
- Knot So Fast. A proposal for regulating the world knot tying speed record. Another of my contributions.
- Notes on Clinton Bailey Sr. Notes on the world speed record-holder based on my conversation with his son in April 1998.
- World Record Six Knot Challenge. Photographs and drawings of the six knots used in the world record. From Daniel Callahan.
- Knot. A sort of online knotting journal in which the author reflects on new knots and knot tying and illustrates his reflections with very clear drawings. From Paul Shin-Hong Hahn.
- Some useful knots. Has links to some MPEG knot movies. Better than *Knot's Landing*.
- Knots and Hitches. Two elementary knots. Anonymous.
- Love Those Crazy Knots. JAVA-animated Turk's Head and Ocean Plain. From Thomas McClain.
- Klabautermanns Knotentafel. Animated knotting instructions from Matthias Böving.
- Knot Page of Mac Stevens. Superb knot animations. Temperamental, but when they are working, they are the best on the web.
- S.A. Kids Knots. A small number of knots but with stylish multimedia presentation. Requires Netscape 3.0 and the Shockwave plug-in; both may be downloaded from the

site. Beware, the bowline is the less safe "left-handed" bowline, and some of its crossings are incorrect.

- Knots. Project ideas for kids. From 42eXplore.
- Learn2 Tie Basic Knots. Eight elementary knots fully explained and illustrated for the novice. From Learn2.com.
- Ropes and Knots. From the Arboriculture homepage. One knot so far (Cat's Paw), otherwise just links to other, knot-related sites.
- Rope Tips. Eleven basic knot illustrations from Lehigh Samson, a rope manufacturer. Also see its page on splicing.
- Rope Works. Generous excerpts from the book of the same name, by Gerald Findley. Very good illustrations.
- Flip Flop Winch. Winding cord around a winch log to aid in flipping it, from John Goude (based on an idea by Mors Kochanski).
- Hojojutsu. Japanese rope restraint for prisoners.
- Nunchaku Tying. Tying in to this Japanese martial arts weapon. From Sei Shin Kan, Inc.
- Tsukamaki. How to tie the knots on a traditional Japanese samurai sword. From Thomas L. Buck.
- How to Tie a Figure-8 Knot. Remarkable only because it is animated. From the Nathan Lowe Memorial Climbing Wall Network.
- GORP Knot of the Week. Knots useful for camping described and illustrated. From GORP (Great Outdoor Recreation Pages).
- The Art of Marlinspike. Elementary.
- Splicing a Rope on a 30 hour Longcase Clock. Instructions for splicing woven, synthetic cord. From George Aldridge.
- Forensic Knot Analysis. The only site of its kind on the web. From J.J. Van Tassel.
- Knots for Bondage. 14 basic knots, illustrated (but not in their application to bondage). From Slakker. Probably the only major knotting application neglected by Ashley.
- Square Knot. From an online First Aid manual. Any paramedic who needs four illustrations to learn to tie a square knot should lie down and wait for help. *This site has disappeared and I can't relocate it. Can anyone help?*
- Talking Knots of the Inka. Abstract of an article by Viviano and Davide Domenici on the use of Peruvian quipus to designate syllables of words, not numbers. No knot illustrations. From the journal Archaeology, Vol. 49, No. 6 (November/December 1996).
- The Quipucamayu. An article on the Inca quipu by Madge Miller.
- Knots and twists. Part of a display on pre-historic knotting and weaving at the Pecos Rio Grande Museum of Early Man.
- Knotscape. Links to other knotting sites including pictures of some of the author's knots. From Starknot.
- The Turk's Head. Twelve illustrations to help you tie a Turk's Head (or as this site calls it, a WoodBadge Woggle).
- Tying a Five-Lead by Four-Bight Turk's Head. Part of Loren Damewood's site on

knotted jewelry.

- The Better Bow. Anonymous. A improvement over the standard bow for shoe-laces, well-illustrated, but not as good a bow as variations with two ripcords where this has only one.
- How To Tie an Ian Knot. A well-illustrated, symmetrical, two-ripcord shoelace bow with a very rapid method of tying. A real improvement over the standard bow. From Ian Fieggen.
- How I Tie My Shoes. A simple shoelace knot from Howard Cheng.
- The Sling, Ancient Weapon. History and use of slings. The author, James Burdine, sells hand-tied slings but does not give tying instructions on the site.
- Des noeuds en Jèrriais. The basic knot names in English and Jèrriais [Jersey], a dialect of French. From Geraint Jennings.
- How to amaze your friends in seven easy steps!. Guess what? A knot trick.
- Security was a knotted rope. First chapter in the Schlage History of Locks, implying that knotted ropes are obsolete now that metal locks have arrived. Schlage executives probably wear tassle loafers at work so that the steel hasp locks on their cross-trainers don't clank during meetings.
- Kaylee, the Knot-Tying Parrot. With photographs of a few of Kaylee's creations. From Doug and Shelly Lane.
- Knot Natural. Photograph of a knotted live cactus cultivated by sculptor Denny North by growing it on its side and upside down.
- The Legend of the Gordian Knot
- Should You Secure Wire Rope With Knots? The U.S. Occupational Safety and Health Administration (OSHA) says "no" in this memorandum opinion interpreting federal regulations. This site has made me realize that the federal government regulates almost every aspect of rigging in the name of workplace safety. One day I'll find all the relevant parts of the Code of Federal Regulations and link to them here. (Although the CFR is searchable, don't naively search for "rigging" or you'll get 150,000 hits on bid-rigging.) Here are some of the more salient sections of the CFR to get you started.
    - 29 CFR Sec. 1915.112, Ropes, chains, and slings
    - 29 CFR Sec. 1919.24, Limitations on use of wire rope
    - 29 CFR Sec. 1926.251, Rigging equipment for material handling
    - 33 CFR Sec. 401.42, Passing hand lines
    - 46 CFR Sec. 91.37-50, Use of wire rope and chains.
- All About Knots. From Dick Chisholm. Contains excerpts from Chisholm's writings about knots (full-text is available only for a fee) and describing his forthcoming book.
- The Clifford W. Ashley Commemorative Stamp Project. News of the effort to commemorate Ashley plus general knotting news especially about meetings and conferences. From Dick Blackmer.
- The Gospel According to Ashley. An article by Steve Knauth, in Soundings, on the effort to persuade the U.S. Post Office to issue a stamp honoring Clifford Ashley, author of *Ashley's Book of Knots*.
- Clifford Warren Ashley. A short biographical note from the New Bedford Whaling Museum.

- Ties That Bind. An article by Steve Knauth, in Soundings, on knots and the International Guild of Knot Tyers.
- Knotted Word Worms. A word puzzle by Mike Keith in which the challenge is to find words that trace a knot on a three dimensional grid.
- Knot Calendar. Twelve photos for twelve months, sinuous curves for your wall. From the Ink Group, calendar series.
- Knots & Splices (a bibliography). Maintained by Lars Bruzelius for the The Maritime History Virtual Archives.

Animal-handling knots. Other than fishing knots.

- Falconer's Knot. (Note that this is the knot, not the net. Nyet?) Scroll to the sixth topic. The illustrations are probably too small to teach this knot to newcomers, but large enough to remind those who once knew it.
- Making a Falconer's Net. Detailed instructions and illustrations for making a Dho-gazza. *This site seems to have disappeared without a trace. Can any readers help locate it?*
- Making Your Own Ganglines. If you need to ask what ganglines are (harnesses for sled dogs), then you don't need to make your own. Otherwise, these clear instructions should help. From Stephen Lee.
- Tie a First-Class Rope Halter. By Connie Nygard. Detailed directions for the series of knots needed to make a horse's halter out of rope. See especially her diagram on the Fiador knot.
- Horse Knots. Different methods for tying a fiador and links to others. From Jef Vandenberghe.
- Rope Halter. Detailed instructions for tying a rope halter from the Pony Club Association of Victoria.
- Halter Tying Instructions. From David Dill.
- Tying Horse Knots. Instructions for the fiador, mecate, and a halter. From Cynthia Cavanaugh.
- The Hackamore. Illustrated instructions for tying and using this headstall for a horse or mule. From Sue King.
- Hackamores. Hand-braided leather hackamores for sale, made by Ed Pass, Sara Hagel, and Ray Huffman.

Climbing and caving knots. Also see the books on climbing knots in the Book section.

- Animated Knots. Several well-done animations by "rhinckle". From New England Climbing.
- Belaying Guide. From the Outdoor Action Program at Princeton. Instruction on harness knots.
- Caving Knots. Good selection and graphics. From Sherry Mayo.
- Freeclimbing. The best climbing site on the web. I've linked to a search for knots.
- http://www.climbing.ie/knots.html">Climbing Knot Dictionary. 20 knots, mostly for climbing, well-illustrated in three colors. From Dave Hunt and Irish Climbing On-line.
- Knot Knowledge. 23 knots, mostly for climbing, clearly illustrated with 4-6

black-and-white photographs each. Anonymous.

- Noeuds Spéléos. Two illustrated caving knots. From Manuel du Secouriste.
- Nudos en Espeleología. Clear illustrations of some caving and climbing knots.
- Prusik Rappel "Safety". An article by Dr. Gary D. Storrick, arguing against the use of the Prusik knot at least in caving.
- The Prusik Knot. From Geoff Kuenning and Marc Anderson. On use of the Prusik in place of ascenders for climbing the mast of a ship.

Craft knots. Also see fancy and decorative knots.

- Beading Knots. Four knots for beading. From Maxine.
- The Bindery Knot. A knot for tying packages. From Donna Ashley for the benefit of MIT librarians.
- The Clones Knot. An Irish crochet knot, illustrated with eight photographs.
- French Knot. An illustrated cross-stitch knot. From Debbie Wilcock.
- Hammock Instructions. From Rita Barthelomew's larger site on netting.
- Making a Netted Hammock. Adequate but minimal instructions. From Earth Guild.
- Hammock Pattern. Scanned from an uncited printed source. Slow-loading. From Pu Bear's Collectibles. *This site has also disappeared without a trace. Does anyone know where it went?*
- Hammock Instructions. Minimal but helpful. From Earth Guild.
- Hammock Kits. If you want to make your own but don't want to start from scratch. From Hammocks from Bougainville.
- Kite Flier's Knot Gallery. Four knots, well illustrated.
- Netting. A comprehensive site. From Rita Bartholomew.
- Knotcraft. Excerpts from a book by Stuart E. Grainger. Useful for netting.
- Slatt's Rescue Belt. Instructions for making a woven belt which instantly unweaves when you need an emergency length of cordage. From Philip Sinnet-Slattery.
- Some Weaving Knots. Two clear photographs.

Fishing knots

- The Best Knots. Advice on fishing knots. No illustrations. From Fly Fisherman Magazine.
- Fishing Knots. Chapter 1 of Ern Grant's book, *Grant's Guide: Fishing Knots and Rigs*. Many knots and good illustrations. One of the better sites on fishing knots.
- Fishing Knots. Eight fishing knots, well-illustrated. From High Sierra Fly Casters.
- Fishing Knots. Seven knots, each with multiple, clear illustrations. From Grays of Kilsyth, a Scottish fly maker.
- Fishing Knots and Rigging. Twenty-two knots, animated illustrations. From Marinews.
- Fisherman's Knots. Seven knots illustrated. From the Toledo Bend Reservoir.
- Killroy's Knots. Ten fishing knots, well-illustrated. From Killroy's Fly Tying and Fly Fishing. Knotting instructions and illustrations courtesy of The Orvis Co.
- Knots and Connections [for Fishing]. For these Danish fisherfolk, a "connection" is a

bend.

- Useful Fishing Knots. Three knots from the Bass Fishing Home Page.
- Knots. Five fishing knots, three illustrations each. From New York Bass.
- Knots. Three fishing knots, 4-5 illustrations each. From Backwater Tackle.
- Flyfishing knots. Illustration from online ad for FlyTy software.
- Knots for the Flyfisher. From Bruce Harang.
- The Bimini Twist. From WorldWideAngler.com. There are many other fishing knots at this site. Just use their search engine to find them. Unfortunately there doesn't seem to be a page collecting them all together.
- Knot Tying Overview. Six fishing knots from High Country Flies.
- Knots. From The Fishernet.
- Three Fishing Knots. Text and illustrations poorly scanned.
- Knots for the Flyfisher. Knot links from elsewhere on the web.
- Knots: Putting It All Together. Knots for flyfishing by Dave Whitlock.
- Davy's Knot. A fishing knot by Davy Wotton.
- Tying the Huffnagle. One (fishing) knot illustrated with seven photographs.
- Knots and Fishing Knots. Animated knot-tying software for Windows by Frank Cooke. A large number of knots, taught with great clarity. View the tying process step by step, forwards and backwards. Better instruction than books or videotape. The web site now has a sample animation.
- The Nail Knot. One (fishing) knot illustrated with three line-drawings.
- Knots. Nine fishing knots illustrated. From The HorseMinnow fishing site.
- Knot Tying Page. Five fishing knots. Poor illustrations.
- Fisherman's Ty-All. Ad for a fishing knot tool.
- Rudy's Snell Tyer. Ad for a fishing knot tool.
- EZKnot. Ad for fishing knot tool.
- Fishing Fool Tool. Ad for a fishing knot tool. With RealVideo instruction for two fishing knots (Nail Knot, and Snell knot) and instructions and illustrations for another nine fishing knots.
- Knot-Tying Aids. Manufacturers of various fishing knot tools.
- The Needle Knot. From Saltwater Fishing in New Jersey.
- The Rapala Knot. From Rapala Corp., a fishing supplies company.

Necktie knots. Look how many sites there are on necktie knot compared to (say) climbing or fishing knots. This shows you what men care about these days —vanity and conformity even at the price of discomfort. Men of the world, awaken! This is the age of the internet. If your boss makes you wear a tie, leave your boss. Start your own company. Telecommute. Tie the knots you want to tie and no others.

- How to Tie a Tie. From BizWeb. The classical necktie knots.
- Four Ways to Tie a Tie. More classical necktie knots, from FashionMall.
- Knots Etc.. More classical necktie knots, from Knots Etc. Ties and Apparel).
- How to Tie a Necktie. More classical necktie knots, with some variations, from MBA

Style Magazine

- Necktie Repository. More classical necktie knots, from Jim Scarborough.
- Online Ties. Illustrations for eight different necktie knots.
- Tie Yourself in Knots. From Jim Landman. Landman's page of necktie-related links, including necktie knot links, is the best I've seen.
- Learn2.com has clear illustrations of the 4-in-hand and bowtie knots.
- Animated necktie knot. The instructions are in Dutch but the picture is self-explanatory. *This site seems to have disappeared. Can anyone help relocate it?*
- McSea necktie knot page. Illustrates the windsor and half-windsor. *This site seems to have disappeared. Can anyone help relocate it?*
- The Pratt Knot. From The Fashion Page.
- Tiecrafter's necktie knot page. Collecting links to several necktie pages.
- Tying the Knot. A book of instructions by Andrew Cochran.
- Five scarf-tying knots. Accompanied by Rush Limbaugh's demonstration, in which this sartorial authority misperceives which knot the world would like to see him tie around his neck.
- Tie Master. A device to help you tie a necktie knot. "A simple solution to an age old problem." Not quite as simple as an unassisted knot —or as giving up neckties.
- See how Marvin Minsky improvised a necktie with climbing rope —and no knots— in his Original Rope Tie.
- You've probably heard about Yong Mao and Thomas Fink, the two physicists from Cambridge's prestigious Cavendish Laboratory who turned from physics, even from respectable knot theory, to necktie theory. Because they published their mathematical analysis of necktie knots in the equally prestigious journal Nature (vol. 398, pp. 31-32, March 4, 1999), their new knots have become the biggest knot story in the mainstream press since the supposed discovery of the Hunter's Bend in 1978. But while the Hunter's Bend is a useful knot, this is just a pain in the neck. Here are some details.
    - Solving a Knotty Problem. From the BBC. Contains links to video demonstrations (require a RealPlayer plugin).
    - Telling a Fink From a Pratt. From the London Telegraph.
    - Physicists Tie the Knot. From Reuters, presented by Wired News.
    - Physicists' Work is All for Knot. From the Dallas Morning News.
    - An HTML version of the Fink & Mao Article. From Fink's home page, not Nature. Also see their page of instructions for the four traditional necktie knots (not for any of their own).

Not Knots. Products which make knots unnecessary, mostly for shoelaces. I don't plan to link to all sites for buckles, velcro, hooks, carabiners, nails, staples, glue, and so on. Hey, I'm a partisan. But these Anti-Knot sites can be helpful to parents of very young children, boaters with arthritic fingers, and those turning to the dark side.

- Con-Ferr Rope Locks. For cargo lashing and boat lines.
- Flip Lacer. Flipping plastic toggle for shoelaces.
- Lazy Lock. Adjustable, sliding lock for shoelaces.

- Safety Plus Rope Lock. For closing bags like laundry bags.
- Y * Ties. Curly elastic shoelaces tangle together to make tying unnecessary.
- Zip-A-Rope. The ad inconsistently appeals to "anyone who enjoys the outdoors" but who hates "to fight with stubborn knots."

Rope and cordage

- Basic Ropework Test. Test yourself with this exam designed for Australian rescue workers.
- Cordage. Lots of useful information from the SailingProShop.
- Rope-Making Machines. Choose from the Bradshaw Rope Maker and the Leonardo Rope Machine (and formerly Apollo Cord Winder). Described, illustrated, and ready to order. From the Textura Trading Company. Textura also sells all kinds of fiber supplies for textile artists.
- Bradshaw's Rope Machine. From the Bob Patterson Company. A one-person machine powered by a variable speed, reversible hand drill.
- Cordage. Data on strength, elasticity, tenacity, weight, and so on, of common synthetic ropes. From Allied Signal Fibers.
- Cordage Fibre Characteristics. Strength, weight, elasticity, coefficient of friction, critical temperature, and so on. From Layline.
- The Cordage Institute. A non-profit association of manufacturers which works toward voluntary technical standards for cordage, rope, and twine.
- Making Rope. See Jack Keene's instructions for making laid rope without a machine.
- Native American Cordage. An excellent, illustrated compendium of Native American cordage technology. Part of the larger NativeTech site.
- New England Ropes. A cordage manufacturer's home page.
- Pelican Rope Works. A cordage manufacturer's home page.
- Rope and Gear Testing. One of the most thorough rope-testing pages I've seen. From Tom Moyers.
- Rope Basics. From Boy Scout Troop 940.
- Rope Care. Excerpts from a Samson Rope brochure.
- Rope Care. A page from Jimmy Green Marine Ropes and Rigging.
- Rope Care. A page from Marlowe Ropes.
- Rope Data. Weight per meter, elongation, mantle shifting, and so on, for climbing ropes. Anonymous.
- Rope Data. Breaking strength, linear density, working load, and so on. From United States Rope Company.
- Rope Locker. Good collection of links to sites on rope, rigging, knots, and block and tackle systems. A page within the larger SchoonerMan site.
- Rope Making. A Yahoo discussion group on the craft.
- Ropes and Cords. From Merv Martin. Very thorough and well-illustrated. Also see his recipe for a rope stretcher.
- Strength of Rope. Incorrectly asserts that "knotted rope" (regardless of the knot)

reduces strength by 15%. From Diver's Datalog.

Rope rescue. Here I only include rope rescue sites which include some knot-related instruction online. Also see the books on rope rescue in the Book section, the section on suppliers, and the knot discussion forums.

- Basic Knots. Not rescue-specific knots, but I put it here because it's published in a search and rescue newsletter. Illustrated with color photos of colored cord.
- The Blue Ridge Mountain Rescue Group Knot Review. Good collection of knots, well-illustrated with color photographs.
- Considerations for Technical Rope Rescue. From Kenneth N. Laidlaw. Thorough text, very clear illustrations.
- Herschel Rope Rescue Training Systems. From Herschel Rescue, Toronto.
- MUEMS Rope Rescue Team. From Marshall University. Contains a large number of illustrated knots.
- River Rescue. Many useful links. From otterman.
- Rope Rescue. From the Mountain Ambulance Service (Mountain, Wisconsin). Contains some very clear knot illustrations.
- Rope Rescue Page. Tips and discussion from the Search and Rescue Society of British Columbia.
- Ropes, Webbing, and Knots. An outline of a search and rescue training course. No illustrated knots.

Sailing and boating knots

- Boating Knots. Seven elementary boating knots. From Black Lake, a fishing site.
- Boating Knots. Five elementary boating knots. From OnWater, a boat store.
- Boating Rope Knots. Seven elementary boating knots. From Marinews, an Australian boating site.
- Burglar-Proof Knot. For $9.95 this company will sell you the secret for tying up your dingy with a "burglar-proof knot". The ad ends with a joke (if you have thievery in your heart, they'll send you a fake knot), so it may be a hoax. Of course, every knot that can be tied can be untied with time and a fid —even the Gordian knot. If anyone learns what you get for your $9.95, please let me know.
- Common Boating Knots. Ten common knots, described and illustrated. From New England Ropes.
- Commonly Used Boating Knots. From Suncoast Boating. Elementary.
- How To Tie One On. Tips on tying up canoes and kayaks. Good text but no illustrations.
- Knots, Hitches, and Splices. Elementary knots for sailing, no illustrations.
- Knots To Know [for sailing]. The knots are elementary, but their illustrations are animated.
- Line Handling and Marlinspike. Five boating knots each illustrated with three still drawings and one animation. From BoatSafe.com.
- Marlinspike Knot of the Month. Over a dozen common boating knots. Now animated GIFs being converted to Java scripts that permit stopping and reversing. From the

Shooting Star Boating Safety Page.

- Marlinespike Learning Guide. Advertisement for a course and booklet. From United States Power Squadrons.
- NautBob's Knots. Elementary boating knots. Also a page of fishing knots.
- Nós de Marinheiro. Illustrated sailing knots. Instructions in Portuguese. From the Associação Nacional de Cruzeiros (Lisbon).
- Rigging for Windsurfers. From Easy Riser, Inc.
- Rope Loop. Illustrated instructions for tying a "handle" into loop to ease the pressure on your hand. From Paul.

Scouting

- Animated Knots. From Boy Scout Troop 700. These pages require the Microsoft PowerPoint Animation Player, a browser plug-in you can download from the site.
- Basic Knots in Outdoor/Adventure Awards. Includes bends and lashes, loops, hitches, and stopper knots. From the Boys' Brigade Australia.
- Boy Scouts of America Knot Designs for Awards and Badges. Thirty ways to color a square knot.
- Get Knotted! Animated Knots for Scouts. Clear animations of 15 useful knots, with helpful comments on each. From the 42nd Brighton Scout Group, East Sussex.
- Knot Diagrams. Four elementary knots. From Brad Pozarnsky.
- Knotmasters. A knot-learning program for scouts in England's North Star District.
- Knots. A large site on knots for scouts. The most useful feature is an alphabetical guide to 130+ common knots.
- Knots! Knots! Knots!. Animated instructions from Troop 72.
- Knots and Scouting. From André van der Salm. Jump to his main knot page. In English and Dutch.
- Knotting. From the 22nd Farnworth Scout Group. Includes an impressively large knot index, organized both alphabetically and by use. Each knot indexed is illustrated with very clear drawings.
- Knot Tying. Five elementary knots for sea scouts.
- Lashing Projects. A large number of clear drawings of lashing projects built by scouts.
- Learn to Tie a Few Knots!. Three basic knots. Aims at beginners yet uses words more than pictures. From the Royal Ambassadors of Kennesaw, Georgia.
- Pictures of Scouting Knots. Apparently scanned from a book, including the accompanying text.
- Royal Rangers Ropecraft. Requirements for the "advanced merit" level, no illustrations.
- The Scout Association of Australia, Index of Knots and Lashings.
- Scouting Knots. A collection of common knots (still growing) illustrated with photographs and demonstrated with effective animations. From Bob Gibson and the Montana Council's Troop 9.
- Cub Scout Knot Quiz. *This page seems to have disappeared without a trace. Can any readers help locate it?*

- Boy Scout Knot Quiz. What knots would you use for various common applications?
- Know Your Knots?. Another scouting knot quiz. From the boy scouting section of About.com.
- Commonly Used Rope and Knot Terms. Another scouting knot quiz (well done). Also contains animated instructions for six basic knots. From Troop 222, Belaire Texas.

Suppliers

- American Hemp. Twine, yarn, cordage, rope, and webbing, but wholesale only. Seattle, Washington.
- Custom Cords. Multi-colored braided cords for purchase and special order. In cotton and synthetic fibers. From D. Booker and Associates.
- Fid-O / McGrew Splicing Tool. You may not think you need this, but can you splice braided to twisted cord? If not, see the MPG at the site of Jim McGrew, the inventor, showing how it's done.
- Footrope Knots. Des Pawson's cordage and knot-tool shop, now with a web site.
- Hempland's Twine and Rope. Hemp twine, cord, and yarn in many sizes.
- Jimmy Green Marine Ropes and Rigging. Mail order chandlery in Beer, East Devon. Large inventory.
- The Knot Shoppe. Purveyor of fancy knots and supplies for fancy knotwork. See his online store. From "knot tyer" in Anchorage, Alaska. Also see the proprietor's Museum of Fancy Knots, and knots for sale at eBay.
- Macramé cord. Synthetic, 16 colors available. From Pu Bear's Collectibles.
- Marlowe Ropes. Many varieties. In East Sussex.
- Osborne Marlinspikes. From C.S. Osborne and Co., Harrison, NJ.
- Petzl. Suppliers for climbers and rope rescue e.g. cordage, harnesses, helmets, carabiners, etc. Crolles, France (with offices around the world).
- The Rescue Source. Specializing in water rescue equipment, including cordage.
- Rock-n-Rescue. Supplies for climbers and rope rescue teams, e.g. cordage, ascenders, pulleys, carabiners, etc. Valencia, Pennsylvania.
- Rope Magic. Supplies for rope magic from Denis the Magician.
- Scientific Nature Hemp Emporium. Twine, yarn, cordage, rope, and webbing. Bellingham, Washington.
- Brion Toss's Catalog. Knotting tools (plus Brion's books and videos).
- U-Braid-It Braiding Supply Co. Synthetic cord, leather, and mohair supplies for making horse tack. The site also includes some lessons.
- Urban H.A.R.T. Rescue Training. Buy rescue equipment from the site, including rope and harnesses.
- For suppliers without web sites, see Martin Combs' good list.

Surgical knots. If you go to PubMed and enter the search string, **knot* OR sutur*** , then you'll get a huge list of citations to surgical knotting (more than 2200 articles in January 2001). Unfortunately, PubMed searches don't have unique URLs so I can't link to such a search for you.

- Arthroscopic Knot Tying. From Don Johnson. Illustrated with nine photographs or in an animation (which is really a slide show of the nine still photos).
- Arthroscopic Knot Tying. From Robert K. Lieurance and Wesley M. Nottage. Detailed descriptions of many techniques, with thumb-nail and enlarged illustrations.
- Ethicon Knot Tying Manual. Another detailed and well-illustrated, professional manual for surgeons. From Ethicon Inc., which is a division of Johnson and Johnson.
- Excision: Knot Tying. Surgical knot tying. Click the "next" and "previous" buttons at the bottom of the screen for more detail and context.
- Interactive Suturing. The front page contains an alert service to recently published papers on suturing. Visit regularly to stay up to date. From InteractiveSuturing.com.
- Intracorporeal Knot Tying with the Endo Stitch. Text and illustrations. Part of a larger site on the Stringer laparoscopic suturing technique.
- Med I.A. Knot Tying and Suturing. Multimedia instruction for surgeons. This content was formerly on the web, but its producers evidently decided to make some money by pulling it off and selling it as a CD. The link takes you to an ad for the CD with a tiny bit of content.
- Surgical Knot Tying Manual. Detailed and well-illustrated. By pros for pros. From Richard F. Edlich of the University of Virginia School of Medicine.
- Vesalius Clinical Folios on Surgical Technique. Another detailed, well-illustrated, professional manual for surgeons. Don't overlook the "next" and "back" buttons at the bottom of the screens. There are several pages of instruction in each folio. From Vesalius.
    - One-Handed Surgical Knot.
    - Two-Handed Surgical Knot
    - Basic Surgical Hand Ties. Instruction in the basic surgical knots tied by hand.
    - Basic Instrument Tie. Instruction in tying knots with surgical instruments rather than fingers.

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Knot Theory

Knot Theory Sub-Sections (more to come)
General | Bibliographies | Glossaries | Journals | Primers | Tables

General. Also see the discussion forums, software, videos, and books on knot theory.

- MathSearch Knot Pages. Clicking on this link will initiate a search for knot-related pages on MathSearch, the dedicated mathematical search engine.
- The KnotPlot Site. Information on the fabulous knot-projection graphic software written by Rob Scharein, with stunning examples, one of which I use at the top of this page; see *Artwork credits*. Essentially the same as The Knot Square site, which I've listed under Knot Art below.
- International Knot Theory Meeting, August 7-15, 1998.
- The Geometry Junkyard Page on Knot Theory. An excellent page of links to web sites on knot theory, maintained by David Eppstein.
- Knot Theory. From Mark Brittenham. Good collection of links.
- Entrance to WWW on Knot Theory. From Masakazu Teragaito. Selected links to knot theory sites.
- Yahoo Guide to Knot Theory. Not very extensive but will probably grow.
- Knot Theory. Course and lectures by Brian Sanderson.
- Knot Theory. From Mouse Bousfield. Hand-outs and links for a course on knot theory.
- Knot Theory. An excellent collection of links from Icarus Research Data Centre Math Bookmarks.
- Knot Theory: Project Suggestions. Ideas for student projects. From Paul J. Kapitza.
- Knot Theory Lab. Apparently in Korean. But even if you don't read the language, there are some great graphics, including a nice table of prime knots. *These pages seem to have disappeared without a trace. Can anyone help find them again?*
- Knot Theory at Liverpool. From the University of Liverpool Department of Mathematical Sciences.
- Knots and Templates. Part of larger book on nonlinear dynamics and chaos by Nicholas B. Tufillaro, Jeremiah Reilly, and Tyler Abbott.
- Knots. Some basic concepts of knot theory, with some links to related topics. From Alexander Bogomolny.
- The Unknotting Number of a Knot. February 1997 cover story for What's New in Mathematics.
- Modularity in Art and Mirror Curves. Two unique and beautiful sites that would belong under Knot Art below but for their unusual combination of beauty and mathematical explanation. From Slavik Jablan.
- Ordering Knots. Another beautiful and lucid site from Slavik Jablan.
- Knot Theory Puzzles. Excerpts from a forthcoming book (sept 99); from Heather McLeay.
- Les Noeuds. French edition of *Scientific American*, issue devoted to knots.
- UMass GANG Knot Library. Contains links to a large number of knot diagrams, which require a PostScript viewer.
- Knot images. Beautiful, computer-generated images by Tom Longtin.
- Knot Gallery. Beautiful, complex knots from Milana Huang.

- Math Art Gallery. Many beautiful images of knots.
- Geometry and the Imagination in Minneapolis. Handouts for a two-week seminar led by John Conway, Peter Doyle, Jane Gilman and Bill Thurston at the Geometry Center in Minneapolis, June 17-28, 1991. Many pertain to knots.
- Knots and Links. Nine elegant knot and link graphics generated by Mathematica, with accompanying instructional text. From Leo Piilonen.
- Square Knots. An article by Brian Hayes in American Scientist on knots conceived as self-avoiding walks in 3-dimensional space.
- Ideal knots. An online catalogue of knot images and coordinates. From Ben Laurie, author of the Apache-SSL web server.
- Global curvature, ideal knots and models of DNA self-contact. An article by Oscar Gonzales.
- Ming. Knot software, plus neat illustrations, by Ying-Qing Wu.
- Scott Carter. Home page of a knot theorist.
- Morwen Thistlewaite. Home page of a knot theorist. Many beautiful knot graphics.
- Piotr Pierañski. Home page of a knot theorist, with links to several papers, including In Search of Ideal Knots, which has wonderful illustrations.
- On Composite Twisted Unknots. An article by Chaim Goodman-Strauss.
- Is A Knot Classification Possible?. An article by Charilaos Aneziris. Also see his The Problem of Knot Classification.
- Knots and Knotwork. From a site on Mathematics and the Liberal Arts. Summarizing articles on the mathematics of Celtic, Islamic, and Moorish knot designs.
- Design Any Knot From DNA. From Ned Seeman.
- Mathematics and Origin of String Figures. Taking string figures seriously. From Martin Probert.
- Jason's Favorite Knot. Borromean rings, with a brief introduction to knot theory, from Jason Cohen.
- Loops, Knots, Gauge Theories and Quantum Gravity. An article by Rodolfo Gambini and Jorge Pullin.
- Knots and DNA. An article using knot theoretic topology to explore the action of enzymes, by De Witt Summners.
- *Knots and Everything* Book Series from World Publishing. Edited by Louis Kauffman.

Knot theory bibliographies

- Knots, Braids, and Links. A list of online papers on knot theory, especially in physics rather than pure mathematics.
- A Bibliography of Literature on Knots and Braids. A very comprehensive list by Joyce A. Riley. Because of its size, slow-loading.
- Bibliography of Knot Theory. Another bibliography, not as good as Riley's. Anonymous.

Knot theory glossaries

- Glossary of Terms. Part of the excellent Knot Theory from High School students Jason Alonso (team leader), Andrei Garcia, and Stefan Nagey.

- Knot Glossary. Part of the excellent Mathmania knot theory site for kids. Apparently this supersedes the "Erdös For Kids" glossary of knot theory, made by the same folks, still on the web.

Knot theory journals

- Journal of Knot Theory and Its Ramifications.

Knot theory primers

- Knot Theory. From Bryson R. Payne. An introduction for students. Uses animation to advantage.
- Knot Theory. From John Starrett. Brief introduction and collection of links under construction.
- Knot Theory. Clearly written, handsomely illustrated. From a team of high school students at the Severn School: Jason Alonso (team leader), Andrei Garcia, and Stefan Nagey.
- Knot Theory. Part of Eric Weisstein's larger World of Mathematics. Very thorough, clear, and well-illustrated.
- A Knot Theory Primer. By Charilaos Aneziris. Essentially an online textbook which treats a very large number of subtopics. Admirable thoroughness and clarity.
- Mathmania Knot Theory. A primer for kids, with challenging problems. One of four branches of mathematics covered at Mathmania. From Day Kirby.
- Mathematics and Knots. Online catalog of an exhibition at the School of Mathematics of the University of Wales, Bangor, sponsored by the London Mathematical Society. This site has grown over time to become a very good general introduction to knot theory.
- Tie Me Up, Tie Me Down. Handsome primer on knot theory. Anonymous.
- Untangling the Mathematics of Knots. A useful tutorial in knot theory for children from MegaMath, a group trying to bring mathematical ideas to elementary school classrooms. Written by Nancy Casey. Among its subsections, Knots, Links and Other Mathematical Tangles introduces the basic notions with illustrations, and Activities with Knots suggests project ideas for teachers and students. Nancy has a follow-up site called New Ideas about Knots, with additional puzzles and exercises.

Knot tables

- Atlas of Oriented Knots and Links. From Corinne Cerf. An extremely useful reference.
- Knot Table. From Charilaos Aneziris. All distinct knots up to 12 crossings. Notation only, no projections.
- Knot Tables. Amazing work from 1992 done by the Claremont High School Supercomputing Club. Unfortunately, apart from this description, there is little to read directly on the web. Instead there are several files of prime knot tables to download by FTP (notation only, no projections).
- Knot Tables. Tables in English and Portuguese. Each knot in table is manipulable with the mouse; users may rotate them in any direction, even "throw" them into a spin. Both high-res (bigger download) and lower res (smaller download) availalbe, but even low res is stunning. Anonymous, using routines by Victor Sousa.

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Knot Art

Knot Art Sub-Sections (more to come)
General | Celtic knotwork | Fancy and decorative knots | Metalwork knots | Related arts

General. Also see the sections on software for knot art and books on knot art.

- The Knot Square. More on KnotPlot, the incredible knot-projection graphic software written by Rob Scharein, with stunning examples. Essentially the same as The KnotPlot Site, which I've listed under Knot Theory above.
- The Elegantly-Contrived Knot Page. Beautiful knot graphics from *Knot*, software written by Lloyd Burchill. I use an example on my Nomic page; see *Artwork credits*. Mac users: download the program!
- Knotology. Folding and tying strips of paper into elegant mathematical sculptures. Art by Heinz Strobl, text by Paula Versnick.
- The Knot Room. An elegant collection of animated graphics, many based on knots. From Staceyjoy.
- Knot That Small. Poster of a 2001 exhibition of fiber art objects built up by tying many small knots.
- Jaskets. Knotted fiber baskets by Tony Stubblefield.
- Chinese Knotting Home Page. An ancient art (Jai Yie), almost destroyed by the Cultural Revolution, now revived by a few books and this web site. Maintained by Carol Leon-Yun Wang.
- Chinese Decorative Knotting. Thorough and well-illustrated. Now in English. From Yvonne.
- Rough Art. Bold paintings of working knots. From Bruce Blanford. *This page has disappeared without a trace. Does anyone know where it went?*
- The Salomon's Knot. A knot depicted in early Christian mosaics and Roman petroglyphs. From Umberto Sansoni.
- Kuba Cosmology and Crafts. On the knot motif in the designs of the Congolese culture.
- How To Tie An Orthodox Prayer Rope Knot. Written instructions by Martin Watt and an ad for a video from Firebird Video. (The video links are dead. If anyone can help relocate the video, I'll add a link to the video collection.)

- Endless Knot Carpet. From Rupert Smith Textiles. *Temporarily off-line.*
- Decorations from Andrew Birrell's Home Page. Intricate and attractive. I use two of his copyrighted knot keys on this page, with permission; see *Artwork credits*.
- Math art gallery. Contains "Singularity Knots" and "Singularity Knot Animations".
- MATLAB Gallery. Contains a nice 10.9K knot image by Rouben Rostamian.
- Artesanía Mediterránea. Knot boards for sale.
- Mariyo Yagi's Rope Art. Making a huge rope as an art event.
- Knot Images. Images created by Steven Abbott and Jon Hawkes using Visual Basic Graphics Programming.
- Solmuja Sipoosta. Knot art by Kari Nikrus.
- Solmuja. Knot art by Hannu Keskitalo. Also available in Finnish.
- PB-Takilapaja Oy. Knot art from Paavo Broström. The text is in Finnish.
- Torus Knots. Handsome graphics linked to an image of a handsome sculpture by John Robinson.
- Not Knot. An image by Scott Kim.
- The Endless Knot. A nine-crossing knot projection which this site is pushing as "the peace sign for the next millenium". It's a nice knot, but its advocates do not apparently realize that all knot projections are "endless" in the same way.
- The Rope Show. An original play featuring human beings and cordage by the Chicago troupe, Local Infinities. It premiered 1/30/99 at Chicago's Museum of Contemporary Art.
- Wooden Knot Puzzles. From Interlocking Puzzles. Not very knotty.

Celtic knotwork. For Celtic knotwork jewelry and related 3D art, see the section on Metalware knots, below.

- Aon Celtic Art. Celtic knotwork by Cari Buziak. The site includes instruction, clip art, cross-stich patterns, cards, and much more. Extensive and beautiful.
- The Art of Keltia. Celtic knotwork by Vitor Gonzalez. Beautiful images.
- Calamity's Celtic Page. On Celtic knots.
- The Celtic and Heraldic Center. The gallery contains Celtic knot artwork in copper by Gerry and Sean Forde.
- Celtic Art. Large, detailed, classy. From A. Reed Mihaloew.
- Celtic Clip Art. Many knot designs. From the House Ravenscroft Scriptorium.
- Celtic Clip Art at Ceolas. Some very nice examples. From Gerard Manning.
- Celtic Computer Art. Intricate and precisely rendered Celtic knotwork. Images plus advice on drawing them with graphic software. From A. Reed Mihaloew.
- Celtic Desktop Icons. Free for downloading. Some based on knots.
- Celtic Knot Graphics. From Jason Gabler. Scanned from original sources.
- The Celtic Knot Page. By Danno. Elegant pencil drawings. There are a few more designs at his home page.
- Celtic Knot Tattoo. Part of a larger (Leprechaun) site unrelated to knots.

- Celtic Knot Webring. Hundreds of participating sites.
- Celtic Knots. Mostly original designs by the anonymous page author.
- Celtic Knots. Designs by Frederick Cooper. Not in the same league as most of the other knotmeisters in this list.
- Celtic Knots. By Marc Wallace.
- Celtic Knotwork. Striking, original knot graphics from Andrew Glassner. (Although Glassner works in computer graphics professionally, these images are entirely hand-designed and hand-rendered.)
- Celtic Knotwork Images. By John Williams. Beautiful works of art, including 3D Celtic knot animations, and Celtic fractals.
- Celtic Mandalas. Complex, knotwork mandalas by Courtney Davis.
- Celtic Page. Includes a Celtic knot tattoo. From Twistress.
- Celtic Stone. Not your father's Celtic knotwork site. Includes a 3D virtual reality Celtic knotwork chat room and instructions for designing Celtic knots. From Celtic One Design. Celtic Knotwork. Computer-generated celtic knotwork images as if in stone. Very nice images. From Celtic Stone.
- Celtic Triple Knot. By Michael Dunn. Handsome bronze sculpture.
- Celtic Web Art. Buttons, bullets, clip art, animated GIFS, and so on. All designs by Karen Nicholas.
- Celtic Wood Sculpture. From Celtic Carver Woodworks.
- Computer Drawn Celtic Artwork. From Steven Abbott. If you run Windows, downloaded the program from the site.
- Cours d'enluminure celte à base d'entrelacs. An online course in designing Celtic knots, in English and French, by Christian Mercat.
    - See Mercat's Java applet for making Celtic knots in your browser.
    - Thomas Guionnet has implemented Mercat's algorithm in software for Windows. The screen shots are stunning.
- Craig's Knot Page. Apart from two Celtic knot graphics, not related to knots.
- Dave's Cave. Elegant and precise Celtic artwork from Dave Hall. He wrote the program (for Windows) on which he produced the designs, and sells it at the site.
- Pat Fish's Tattoo Santa Barbara. Photos of several Celtic knotwork tattoos.
- Fractals. Includes many Celtic knotwork images. From Jos Leys.
- Get Knotted. Beautiful Celtic knotwork from Bernadette Bultman-Fenlon.
- Gruhn's Knots. Celtic knot designs from Peter Gruhn.
- How to Draw Your Own Celtic Knots. By Drew Ivan. Clear and helpful instructions; great examples, one of which I use at the bottom of this page; see *Artwork credits*.
- Knots. A downloadable decorative font from Emerald City Fontwerks.
- Knot Fonts. Three knot fonts for Windows by Jack Keene.
- The Celtic Knot Font. Available in three styles (outline, filled, inverse) for both the Mac and PC. From ClanBadge.
- Knot Magic. A painting with Celtic motifs by Freya Owlsdottir. Not about magic tricks with knots, but casting spells. That kind of magic.

- Aidan Meehan's Celtic Design Series. Stunning. Not limited to Celtic knot designs. Public Domain Knotwork Graphics. Very nice Celtic knotwork by Josh Mittleman, including one I use on this page; see *Artwork credits*
- Bradley W. Schenck's Art. A very handsome site by a graphic artist. Contains some striking Celtic knot images and Celtic knot clip art and borders.
- Threads of Time. Clothing with stitched Celtic knotwork.
- Celtic Knot Design Chart. For making cross-stich patterns. From Stephanie Peters.
- Vintage Type Celtic Knot Font. A font for Mac and Windows of elegant Celtic knot designs to decorate a page, by Susan Townsend.
- Victoria Griebel Wright's Watercolors. Celtic knot paintings in a more florid style.

Fancy and decorative knots. Also see the discussion forums, software, videos, and books on knot art.

- The Art of Decorative Ropework. A brief, illustrated history of fancy knotting. From Richard Phelan. Also see some of Phelan's decorative knots (stills from his video).
- Dave Does Knot Work. Decorative knotting for sale from Dave Hedgepeth. No illustrations on the web site.
- Home Page for Fancy Knot Tyers. From Daniel Callahan. Also see his Museum of Fancy Knots, Fancy Knots From Around the World and knots for sale at eBay.
- Knot Swap. A site allowing artistic knotters to display and trade their creations. View the guestbook to see the action. From Martin Combs.
- Knots of Monicas Hemsida. Fancy knotting and macrame. Text in Swedish.
- Marlinespikes and Monkey's Fists. An exhibit of "Traditional Arts and Knot-Tying Skills of Maritime Workers" at the Michigan State University Museum. This is a traveling exhibit which your own local museum can rent (details on the site).
- Neat Knotwork. From Guy Lautard.
- A Perpetual Account of the International Knot Expo in Weert, Belgium. From Het Knoopeknauwertje, the Dutch knotting journal. The Expo opens Easter, 1999.
- Rope Art By Chief Charles Haywood. Decorative knotting, some for sale, by a man who calls himself the world's best (which may or may be true), and who thinks of himself as alone in his art (which is fortunately false). *This link is now defunct, and the site does not seem to have reappeared at another URL. Can any readers help locate it?*
- Some of My Knotwork. Fancy knotwork from S. Goodwin.
- Sword Knots. Like minature bell pulls, tied in fancy ribbon, leather, or cord hanging from the sword's sheath. From The Discriminating General.

Metalwork knots

- Turk's Head Rings Knots in precious metal by Loren Damewood.
- Celtic Knot Jewelry. Earrings, pendants, and rings from Talisman Jewelers and Metalsmiths.
- Celtic Jewelry. Pendants, earrings, brooches, and hairslides, from Triplemoon Witchware. The same site sells Celtic knotwork boxes, clocks, flasks, and frames.
- Fair Winds Design. Nautical and Celtic knots in precious metal and pottery from Grey Chisholm.

- Fisherman's Knot Ring. Ring by Ed Levin.
- Hayman Celtic Jewelry. Amulets, necklaces, torcs, earrings, brooches, and rings. From Michael Hayman.
- Knot Sculptures by Carlo H. Séquin. Elegant metal sculptures, mathematically inspired.
- The Lover's Knot Collection. Necklace, brooches, and earrings from Sheila Fleet, a Scottish jeweler.
- Nantucket Knot Bracelets. From Nantucketer.com.
- Symbolic Sculpture. Photograph of John Robinson's sculpture of a trefoil knot in a band of shining brass.
- Topological Sculptures. Knot theorists will enjoy thinking about how these intriguing sculptures are related to knots. By Brent Collins. Here's a second page of his work.
- Turk's Head Jewelry. Turk's Head rings, bracelets, brooches, earrings, and cuff links in gold, from A.G.A. Correa and Son.

Related Arts. I only want to list a couple of links for each of these arts, to get you going. Please let me know about web pages on knot-related arts that I don't already cover. But for those that I do already cover, I'd only like to hear about pages that surpass those I list at introducing or organizing the field. Sorry, I don't pursue any of these arts or crafts and cannot answer questions about them. Alphabetical by art.

- **Basketry** Information. From Alan Beebe.
- **Braiding**. Especially leather braiding for horse tack. From Gail.
- **Braids** and **Weaves**. From Lenny Henderson.
- The Pine Needle Group (on the art of **coiling**). From Pamela Zimmerman.
- **Crochet**. From Sandi Marshal for About.com.
- The Art of **Gimp**. Anonymous.
- Alissa's **Lace** Links. From Alissa.
- Victoria's **Knitting** Page. From Victoria Palay.
- **Kumihimo**. Japanese braiding. Anonymous.
- The **Lace** Ring. Links to the major sites in lacing. Anon.
- Lori's **Lace** Fairy Lace Pages. Very thorough. From Lori Howe.
- **Macramé**. From tses.
- Amanteca Artisans **Macrame**. Native American macramé. From Stephanie Stoermer.
- Chinese **Macramé**. From the Taiwan Government Information Office.
- The Craft of Echizen **Mizuhiki**. The Japanese art of making paper cordage for tying ceremonial knots in hair or gifts. Another Mizuhiki site.
- Iida **Mizuhiki** Association. Many color photos of stunning projects.
- **Rugmaker**'s Homestead. From Rafter-four Designs and Diana Blake Gray.
- International **String Figure** Association. From Mark Sherman.
- **String Figures** From Around the World. From Richard Darsie.
- WWW Collection of Favorite **String Figures**. Anonymous.

- Tattle Tales: The **Tatting** Newsletter. From Teri Dusenbury.
- **Tatting** and **Lacemaking** Page. From trix.

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Knot Discussion Forums

Discussion of knot tying

- CMC Rescue Forum. On rope rescue and related rigging issues. From CMC Rescue. First-time users must register but there is no charge.
- The Guild's Knot Forum. From the International Guild of Knot Tyers. Covers all knotting topics. Apparently an email forum.
- KnotTyers. A Yahoo Club and discussion forum set up by the North American Branch of the International Guild of Knot Tyers. Supports graphics and email notification. Covers all knotting topics.
- Rec.crafts.knots is the only usenet newsgroup devoted to knots. An unmoderated group approved by voters on May 5, 1997. Covers all knotting topics.
    - This group does not allow the posting of graphics files. See my Knot Gallery for the images that accompany the discussion.
    - Rec.crafts.knots FAQ. Maintained by Peter W. Meek, who welcomes contributions. Under construction.
- Rope Making. A Yahoo discussion group on the craft.
- Rope Rescue Discussion. From the Search and Rescue Society of British Columbia (SARBC). Mostly on rope rescue. See the SARBC's page of related discussion forums.
- Spar Talk. From Brion Toss Rigging. Mostly on ship rigging, often with comments and answers from Brion Toss.

Discussion of knot theory

- The High School students who built the award-winning ThinkQuest website on Knot Theory originally had a discussion forum on the site. They have since closed it, perhaps from lack of traffic. There's a niche here, knot theorists.

Discussion of knot art

- Fancy Knots Forum. From Delphi. Mostly on fancy knots. First-time users must register but there is no charge. *This forum has disappeared. Does anyone know whether it relocated?*
- The Knot Board. Administered by Daniel Callahan. Mostly on fancy and decorative knots. Supports the use of graphics.

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Knot Software

Some of these programs are also listed in my sections on knot tying, knot theory, and knot art. This increases the size of my file, but it also makes these programs easier to find for those who want them. If one day there is a much larger array of knot software, I may give up the double listing and index them only in this section.

Software for knot tying

- 33 Knots. Illustrated tying instructions for 33 knots. From Dmitry Nikolayev. For the Palm Pilot. (Is there really knot tying software for Palm and not for Mac or Unix? I guess we know what OS will dominate in the 21st century.)
- Knots and Fishing Knots. Animated knot-tying software for Windows by Frank Cooke. A large number of knots, taught with great clarity. View the tying process step by step, forwards and backwards. Better instruction than books or videotape. The web site now has a sample animation.

Software for knot theory

- KED. A Knot Editor for Windows by Kenny Hunt. Downloadable.
- KnotSolver. Software by Lars Gilson. Platform unknown. Downloadable.
- KnotTheory. Software by Mitsuyuki Ochiai and Earl Fife. For the Mac. Downloadable.
- KnotPlot. The most flexible and elegant knot theory software. By Rob Scharein. I use a few graphics from KnotPlot with Rob's permission on this page.
- Knotscape. Software by Jim Hoste and Morwen Thistlethwaite. For Linux, Sun, and Alpha. Downloadable.
- Knot Thickness. Some graphical output from a program by Eric Rawdon for maximizing the thickness of a given knot. Rawdon's program is a descendant of Ying-Qing Wu's Ming (see below).
- LinkTool. Anonymous software for mathematical knot theory. (It might not be anonymous for those who download the source code, but I haven't done that.) For NeXT machines. Downloadable.
- Maple-Generated Knot. An elegant trefoil graphic generated by the mathematical software, Maple. Programmed by ijmcgee.
- Ming. Software by Ying-Qing Wu.
- Programs and Procdures. Programs for mathematical knot theory, collected by the Liverpool University Knot Theory Group.
- SnapPea. A program for creating and studying hyperbolic 3-manifolds. For Windows,

the Mac, and soon for Linux. Downloadable.

- Snap Pea. *Not* the same as the previous program. Sofware by Jeff Weeks. For the Mac. Downloadable.
- Surface Evolver. Software by Kenneth Brakker. Downloadable source code for DOS, Windows, Mac, and Unix.

Software for knot art

- Celtic Assistant. Freeware for the Mac by James Walker. Downloadable.
- Celtic Designer. For Windows. Free trial version, but the main version costs $28.00. Anonymous.
- A Celtic Doodler. A Java applet which lets you make Celtic knots. The applet was written by "Thau". Also see the author's article about the applet.
- Celtic Knot Draw. Software by Saul Scudder. For Windows. Downloadable.
- Celtic Knot Software. Mostly screen savers and desktop icons.
- Celtic Knot Thingy. Freeware for Windows, Linux, and probably the Mac, by Douglas Zongker. Downloadable.
- Celtic Knots Designer. Software for Windows, apparently by Rita Godfrey. Free trial version downloadable.
- Excel spreadsheet implementing some Andy Sloss algorithms for designing Celtic knot images. From Jos Leys.
- Knot. Software by Lloyd Burchill. For the Mac. (A Windows version is coming.) Downloadable.
- Knots3D. Software by Steve Abbott. For Windows. Downloadable.
- KnotTyer3D. Another knot program by Steve Abbott. Lets you design knots in 3D, view the knot from any 3D angle, and watch an animation of it tie from any 3D angle. For Windows. Downloadable.
- Knotware. Software for Celtic knotwork by Chaz Boston Baden. The program is written in Perl and operates from the web site through interactive forms (simple form to start, more complex forms to refine).
- KnotWorker. A Celtic knotwork design tool for Windows, from Goldcup Software and Design. A free trial version is available for downloading.
- L'Art Celtique. Software for Celtic knot art by Thomas Guionnet, apparently for Windows. Described in French.
- Square Knots. A Java applet for making Celtic knots in your browser. Click to lay down basic shapes, then click over the shapes to alter them. By Christian Mercat.
- Thomas Guionnet has implemented Christian Mercat's Celtic knot algorithm in software for Windows but does not apparently make the software available to others.

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Knot Videos

Knot Videos Sub-Sections
Videos on knot tying | Videos on knot theory | Videos on knot art

When I started this guide, I disregarded web pages advertising knotting videotapes, because I linked only to knotting content, not to ads for knotting content. I've slowly and selectively changed this policy over the years, and have now (9/2000) begun to collect links to knotting videos. I wish I had URLs for all the video sites I once visited and ignored. I hope to bring this section up to date over the next few revisions of the page. If you know of videos I've overlooked, please drop me a line.

If a knotting video doesn't have its own web site, but is for sale from Amazon.com, then I have not made its title into a link. For these videos, I only know what Amazon.com has dislosed in its video catalogue.

Videos on knot tying

- The Art of Knot Tying. A 60 minute video on fishing knots. I can't tell from the ad who made the video, but it's sold by Sportsman's Mall.
- Basic Knots. Sorry, I don't have any more information on this video.
  - Buy this video from Amazon.com
- Brion Toss Videos. Look down the left-hand column of this page for Brion's four videos. Mostly on rigging, though one is on rope magic and one is on decorative knots. From Brion Toss.
- Bush Knots. From Randall Breeuwsma. Sorry, I don't have any more information on this video.
  - Buy this video from Amazon.com
- Fishin' Knots. From Les Igoe. Sorry, I don't have any more information on this video.
  - Buy this video from Amazon.com
- Fishing Knots. Sorry, I don't have any more information on this video.
  - Buy this video from Amazon.com
- Hooked On Fly Fishing: Fishing Knots for Fresh & Saltwater. Twenty-one fly-fishing knots taught by Jim and Kelly Watt.
  - Buy this video from Amazon.com
- How to Tie Fishing Knots. Sorry, I don't have any more information on this video.
  - Buy this video from Amazon.com
- Instructional Video of Fishing Knots & Rigs Volume I. Sorry, I don't have any more information on this video.
  - Buy this video from Amazon.com
- Just Knots and a Few Splices. Two hours of clear instructions on 47 knots and 6

splices. Also see the companion video, Why Knot?, which covers the same knots but "in the field" with commentary on how to use them. Which 47 knots and 6 splices? The web site has a nice page of stills previewing each one. From iKnots.

- Knots. From Robert Koester. Sorry, I don't have any more information on this video.
  - Buy this video from Amazon.com
- Knot Tying: The Basic Knots. A CD-ROM covering 21 basic knots, taught by Dave Gulden. There are two additional volumes in the series, one on advanced knots and one on splicing, though they don't yet have their own web pages. As you watch a video of a knot being tied, you can pause or start over at any point. Stills of the major tying stages moved to a different part of the screen for review. Useful. From Beutner Multimedia.
- Teach Yourself Knots and Splices. A 60 minute video on seven elementary knots. Includes a section on tying methods for lefties. From Bennett Marine Videos.
  - Buy this video from Amazon.com
- Useful Knots for Boatmen. Sorry, I don't have any more information on this video.
  - Buy this video from Amazon.com

Videos on knot theory

- MSRI Knot Theory Videos. Videotaped lectures given at MSRI (Mathematical Sciences Research Institute, Berkeley, California) between 1995 and 1997. More recent lectures are on streaming video. Not all on knot theory. When the page loads, use your browser to search for "knot".
- Not Knot. A 1991 knot theory video from the Geometry Center. The web site also contains a good number of stills from the video. The distributor, A. K. Peters, also has a page on Not Knot.

Videos on knot art

- Martin Combs' Decorative Knotting Videos. One on making a bellrope and one on boatswain pipe lanyard. The web page shows stills of the finished products.
- Dave Does Knot Work Videos. Two videos for sale, one on Monkey's Fists, and one on Turk's Heads, each two hours long. From Dave Hedgepeth.
- KnotsCD. Instructions for 64 knots. Available on a CD or as a huge downloadable MPG. I can't tell whether the MPG is all or part of the CD and I'm not going to download the file and buy the CD in order to find out.
- Knots Made Easy. A 94 minute video on decorative knotting. From Richard Phelan. The web site contains a nice history of fancy knotting. Although priced in pounds, knotters outside England will apparently pay in their own local currency if they order by credit card.

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Knot Books

Knot Books Sub-Sections
Books on knot tying | Books on knot theory | Books on knot art

Here are some of my favorite knotting books and an easy method to buy them at a discount. This service is offered in association with Amazon.com.

With a few exceptions, I've listed books alphabetically by author's surname within each category. Because retail prices and the Amazon.com discounts are subject to change, I no longer list them. For prices, click through on a title of interest.

Here in the book section, the New flag means that a book is new to my page, not that it is newly published.

Books on Knot Tying

- **The Alternative Knot Book**, by **Harry Asher**, Sheridan House, 1989. Instead of simply giving instructions on the basic knots, Asher offers a theory of knot classification based on the similarities of knots to one another, and teaches the knots in their natural order. Paperback.
    - The only other book of this kind that I know is, unfortunately, not available from Amazon.com. It is **A Fresh Approach to Knotting and Ropework: Knots Arranged According to Their Structure**, by **Charles Warner**, published by Charles Warner (Picton, Australia), 1992. Of the two, Asher's is shorter and simpler; Warner's more extensive and sophisticated. Paperback.
- **The Ashley Book of Knots**, by **Clifford W. Ashley**, Doubleday, 1944 (reissued 1993). If you are interested in practical knots and knot tying, this is the one book to own. Ashley collected knots from every occupation, illustrated them by hand, and described them in his concise and salty prose. His collection of 3,900 knots and 7,000 illustrations is unrivaled for scope and utility, even today. All knotting literature refers to it. Unusual knots without names are typically cited by their Ashley number. To make a *prima facie* case that a knot is a new creation, one need only show that it does not appear in Ashley. It makes a great read for the knotting lore interspersed among the technical

instructions and the window it provides onto many fascinating past forms of manual labor. Because the knots for (say) square-rigged sailing ships, stevedores, steeplejacks, and draymen have been made obsolete by modern tecchnologies, the book is of immense historical value, even if these knots were not transferable to other applications. Ashley has his weaknesses, but these quickly become part of the charm of the book. For example, are some of his instructions confusing, or is he simply overestimating our intelligence and experience? Hardback only.

  - My views are clear. If you can only buy one knotting book, buy Ashley's. There are a hundred knotting primers and collections shorter and less interesting than Ashley's. Most of them are not worth buying if you already own Ashley. But the best of them, while less comprehensive than Ashley, have their own advantages which make them useful even alongside Ashley. In this select company, I would put Bigon and Regazzoni (1982), Budworth (1997), Budworth (1999), Fry (1996), Pawson (1998), Toss (1990), and Toss (1998), all of which are listed below.

- **The Art of Rigging**, by **George Biddlecombe**, Dover Publications, 1990 (original 1925). If you think you know knots but can't tell your keckling from your kevels, your jiggers from your jib-guys, your gammoning from your gripes, or your catheads from your catherpins, then you need this book. It's the first I've seen that doesn't presuppose that you already know. Paperback.
- **The Morrow Guide to Knots**, by **Mario Bigon and Guido Regazzoni**, translated by Maria Piotrowska, William Morrow & Co., 1982 (Italian original 1981). A first-rate book, one of the best for the 70 knots it covers. Unusually clear illustrations, using color photographs of colored cord. Contains some rare and useful knots hard to find elsewhere, such as a bowline when the standing part is under tension (pp. 80-81) and the self-locking Poldo tackle (p. 118). One of the best collections after Ashley. Paperback.
- **The Knot Book**, by **Geoffrey Budworth**, Sterling Publishers, 1985. More comprehensive than most of the general collections of useful knots, with exceptionally clear descriptions and illustrations, by one of the greatest living experts on knotcraft. But for even better books by the same author, see the next two titles. Paperback.
- **The Complete Book of Knots**, by **Geoffrey Budworth**, Lyons & Burford, 1997. This is an elegant and useful book. The word "Complete" in the title is the only false note. It covers all the well-known knots and an unusually large number of lesser-known knots, new knots, and knot tricks. (He is the only major knot compiler who acknowledges that new knots are still being discovered.) The instructions and illustrations are very clear. Budworth

includes a brief historical note on each knot, and a useful table on the best knots for different spheres —sailing, fishing, climbing, and so on. One of the best collections after Ashley. Paperback.

- **The Ultimate Encyclopedia of Knots and Ropework** by **Geoffrey Budworth**, Lorenz Books, 1999. How do you top the misnamed Complete Book of Knots? With the misnamed Ultimate Encyclopedia of Knots. This book is the first lush, coffee-table book of knots ever published. It's not as comprehensive as it appears, with 256 pages (to Ashley's 620) and roughly one knot per page (to Ashley's 5-7). The large, color photographs are more beautiful (for knot fanciers) than instructive. The knots are well-chosen from all fields and are marked with icons for their common applications. A worthy collection, but Budworth is starting to repeat himself. Hardback.
- **The Forensic Analysis of Knots and Ligatures**, by **Robert Chisnall**, Lightning Powder Co., 2000. If you're reading this page, then you're probably among the top knotting experts in your town. Hence, you may eventually be asked by police to help analyze knots and ligatures left at crime scenes to learn what they reveal about the person who tied them. Chisnall's book is the best ever written on the subject and the only one still in print. Knotting experise is not enough to do well in this field. You need Chisnall's many years of experience dealing with murder, suicide, and accident, working with police, preserving evidence, and testifying in court. Hardback.
- **Climbing knots**. Also see the rope rescue books.
    - Climbing is too dangerous for you to rely on your knotting common sense. Many classic knots that work beautifully in fiber rope, with its high friction, slip in modern synthetic climbing rope. Some useful climbing knots, like the Munter Hitch and Klemheist, simply aren't known in other domains like sailing or fishing. Carabiners make some knots unnecessary and at the same time give rise to the need for creative new knots. Finally, climbers often tie in with flat nylon webbing, which raises new knotting challenges not always covered by the knots evolved for leather straps. These are the main reasons why climbing-specific knot books are useful.
    - **Knots for Climbers**, by **Craig Luebben**, Chockstone Press, 1995. Short, clear, and well-illustrated. Paperback.
    - **Climbing Knots For Lefties and Righties**, by **John McMullen**, ICS Books, 1997. Not only one of the most thorough and best-illustrated of climbing knot books, but the only knot book of any kind I've seen that gives more than a passing nod to left- and right-handed versions of practical knots. Paperback.
    - **Knots and Ropes for Climbers**, by **Duane Raleigh**, Stackpole Books, 1998. Roughly as thorough as Luebben, less thorough than McMullen. Has longer prose commentaries on each knot than either of the other books. Clear illustrations. Paperback.
- **The Art of Knotting and Splicing**, by **Cyrus L. Day**, Naval Institute Press, 4th ed., 1987 (first edition, 1947). A jumbo knotting guide illustrated with black and white photographs, brought up to date (especially for synthetic cord) by Ray O. Beard, Jr. and M. Lee Hoffman, Jr. Large enough to contain tips and tricks the ordinary primers and manuals cannot include. Paperback.
- **Knots and Splices**, by **Cyrus L. Day**, International Marine, 1953. A thin, short classic. Combines a good selection of knots with black and white photographs. The photographs are not as clear as those in contemporary books, but are clear enough. Still worth buying if you need to fit your knotting manual into your pocket. Paperback.
- **The Complete Book of Knots and Ropework**, by **Eric C. Fry**, David and Charles, 1996. Another good book by a knotter who knows better than to use the word "Complete" in the

title (see Budworth 1997 above). Ninety-five knots well-illustrated with black-and-white photographs. Unlike other general knot manuals, this one gives half its space (as opposed to a quarter or less) to decorative knots. This book reprints Fry's *Knots and Ropework* and *Practical and Decorative Ropework* in a single volume. Paperback.

- **The Complete Guide To Knots and How To Tie Them**, by **Walter F. Gibson**, Lifetime Books, 1997 (original 1961). Gibson is yet another knowledgeable knottist who doesn't know what "complete" means. More inclusive than the run-of-the-mill collections I omit from my book list, but not as thorough or well-illustrated as most that I do list. About a third of the book is devoted to magic tricks.
- **Stage Rigging Handbook**, by **Jay O. Glerum**, Southern Illinois University Press, second ed., 1997 (original, 1987). Detailed instruction in all the knots, ropework, and hardware needed to rig a theatrical stage, plus the mathematics for calculating loads and forces. The definitive handbook for this field. Paperback.
- **KnotCraft: The Practical and Entertaining Art of Tying Knots**, by **Allan and Paulette Macfarlan**, Dover Publications, 1967 (original 1967). What sets this book apart from other short collections of useful knots is the well-researched introductory chapter on the history of knotting, many illustrated applications for different knots (as opposed to the knots themselves), and sections on knot games and magic. Paperback.
- **The Handbook of Knots**, by **Des Pawson**, DK Publishing, Inc., 1998. An excellent handbook by one of the co-founders of the International Guild of Knot Tyers. A very wide selection of knots, very well-illustrated with color photographs of colored cord. Each knot is described and photographed in several steps. One of the best knot collections after Ashley. Bound in stiff, flexible covers to withstand wear and tear. (For a while my link took you to the wrong book in Amazon.com. I've fixed it. My apologies to Des Pawson and those who wanted to buy his book.)
- **Rope magic**
  - If you are reading this, then you probably carry a hank of cord in your pocket wherever you go. If you do, you might as well know a few tricks. But even if you don't like to astound your friends, there are some nice tricks in these books that have helped me in my (pathetically unsuccessful) assault on the world knot tying speed record.
  - **Fun With String**, by **Joseph Leeming**, Dover Publications, 1974 (original 1940). Most of the "fun" is rope magic, but some is ordinary knotting and knot crafts. Paperback.
  - **Self-Working Rope Magic**, by **Karl Fulves**, Dover Publications, 1990. More illustrations per trick than other magic books. Paperback.
  - **Abbott's Encyclopedia of Rope Tricks for Magicians**, by **Stewart James**, Dover Publications, 1975 (original 1945). Named "Abbott's" after the original publisher. At 400 pages, this is the most thorough collection of rope tricks I've seen. Paperback.
  - **Magic with Rope, Robbon, & String**, by **Bill Severn**, Stackpole Books, 1982. Clear and well-illustrated. Paperback.
  - Some of the other books I list in the Knot Tying section (notably, **Ashley**, **Gibson**, and the **Macfarlans**) also contain a good selection of knot tricks.
  - By the way, the single best knot trick I've ever found is at pp. 98-99 of Louis Kauffman's **On Knots**, a mathematical treatise listed below with the books on knot theory. I'm sure you've seen the trick in which someone ties an overhand knot by crossing their arms before picking up the cord, and then uncrossing them. Kauffman shows you how to do the same trick without crossing your arms first. The version of

this trick in Ashley #2576 and Budworth 1977 [p. 151] is not nearly as good.

- **Rope rescue**. Also see the climbing knot books.
  - Books on rope rescue contain ordinary knots, climbing knots, some knots rarely used elsewhere, and comprehensive coverage of harnesses, anchors, and rigging for rescues under many different circumstances. Unlike most knot books, which simply show the tying steps for a selection of knots out of context, these books show the knots and rigging procedures in action, with tips on safety, alternatives, and when to apply what. As in climbing, this is an area where the stakes are high and learning from the experience of others can make the difference between life and death.
  - **Engineering Practical Rope Rescue Systems**, by **Michael G. Brown**, Delmar, 2000. A large book (322 oversized pages) on the full-scope of rope rescue, emphasizing the practical. It avoids asserting that there is just one way to rig a given rescue, and shows the safety and speed issues which would help you choose among alternatives. It is one of the few books willing to disclose mistakes in earlier books, and to go beyond the basics on some technical subjects, e.g. the metallurgy of rescue hardware, legal and professional regulations, and highlines. Illustrated with black-and-white drawings and photographs. Paperback.
  - **CMC Rope Rescue**, edited by **James A. Frank**, CMC Rescue Inc., 1998. A large book (208 oversized pages) on rope rescue in nearly all settings. This makes it more general than the specialized works below, which is a plus if you want orientation or flexibility, a minus if you work in a special field of rope rescue. Black-and-white drawings. Paperback.
  - **Swiftwater Rescue: A Manual for the Rescue Professional**, by **Slim Ray**, CFS Press, 1997. A large book (243 oversized papges) covering its special topic, rescue from whitewater rivers and floods, in great detail. Many black-and-white drawings and a few photographs. Paperback.
  - **Confined Space and Structural Rope Rescue**, by **Michael Roop, Thomas Vines, and Richard Wright**, Mosby-Year Book, 1998. Color drawings and photographs illustrate this large book (384 oversized pages), focused on rescues from confined spaces and other difficult locations. Paperback.
  - **On Rope: North American Vertical Rope Techniques**, by **Bruce Smith and Allen Padgett**, National Speleological Society, new edition, 1996. A large book (382 oversized pages) on rope techniques for vertical ascents and descents, for example in "caving, search and rescue, firefighting, rope rescue, mountaineering, window cleaning, river runners, rock climbing, aborists, event riggers, military operations, challenge courses, nautical applications, and rappellers" —to quote the title page. Numerous black-and-white drawings and a few photos. Very detailed text. (The "new edition" of 1996 and the "second edition" of 1997 are apparently the same; at least they have the same ISBN.) Hardback only.
- **Nautical Knots and Lines Illustrated**, by **Paul and Arthur Snyder**, International Marine, 1997. A short book with some material not covered in longer books on the standard knots. Clear black and white photographs, several per knot to show successive stages. Paperback.
- **Knowing the Ropes: A Sailor's Guide to Selecting, Rigging, and Handling Lines Aboard**, by **Roger C. Taylor**, International Marine, second edition, 1993. Goes well beyond the basic boating knots. Covers essentially all the applications for rope on shipboard, with abundant detail on technique, efficiency, and safety. Clear black and white drawings. Paperback.
- **Chapman's Nautical Guides: Knots**, by **Brion Toss**, Hearst Marine Books, 1990. A

remarkably clear and useful handbook of boating knots, more comprehensive than other knotting books limited to one domain (more than 100 knots covered). Bound in flexible covers to stand up to the wear of a working life. Lucid illustrations by Gae Pilon. One of the best collections after Ashley. For Toss's *magnum opus*, see the next entry.

- **The Complete Rigger's Apprentice**, by **Brion Toss**, International Marine, 1998. Toss's *Rigger's Apprentice* and *Rigger's Locker* reprinted (and synthesized) in a single volume. Toss is the only contemporary writer who can compare to Clifford Ashley and Hervey Garrett Smith in technical knowledge, literary skill, and nautical authenticity. These very recent books are already classics. Loaded with knowledge and lore one fears is slipping away, even if elegantly preserved in books like this one. Illustrated with wit by Robert Shetterly. One of the few must-have books after Ashley. Hardback only.

Books on Knot Theory

- **The Knot Book: An Elementary Introduction to the Mathematical Theory of Knots**, by **Colin C. Adams**, W.H. Freeman and Co., 1994. One of the two best introductions to mathematical knot theory (with Livingston, below). Introduces all the basic terms and concepts, with well-designed exercises. Also includes open questions to challenge advanced readers. Hardback only.
- **Knots and Surfaces**, by **N.D. Gilbert and T. Porter**, Oxford University Press, 1997 (original 1994). An introduction to knot theory and the topology of surfaces, showing their connections to one another and to such related fields as graph theory and group theory. Clearly written and illustrated. Presupposes no knot theory and only undergraduate mathematics. Paperback.
- **On Knots**, by **Louis H. Kauffman**, Princeton University Press, 1987. A serious treatise that I recommended above for a great knotting magic trick at pp. 98-99. Not an introduction to knot theory, except for the mathematically able. If you've read one of the good introductions (by Adams or Livingston, for example) and want more, this is a good book to try. Wonderfully apt and playful illustrations. Hardback only.
- **Knot Theory**, by **Charles Livingston**, Mathematical Association of America, 1993. One of the two best general introductions to mathematical knot theory (with Adams, above). Illuminates the field from the perspectives of geometry, combinatorics, and algebra. Hardback only.
- **Symmetric Bends: How to Join Two Lengths of Cord**, by **Roger E. Miles**, World Scientific Publishing Co., 1995. A fascinating mix of mathematics and practical knot-tying. Miles gives the mathematics of the symmetric bends (like the Hunter's bend and the Zeppelin bend), sixty variations on the theme, and instructions for inventing new ones. Hardback only.
- **Knots and Links**, by **Dale Rolfsen**, Publish or Perish, Inc., 1976. One of the classic textbooks in the field. Clear and thorough, but (like Kauffman) not an introduction except for those with a mathematical background. Especially helpful is the appendix (by James Bailey and Ali Roth) on prime knots and links. Paperback.
- **Knots**, by **Alexei Sossinsky**. The most readable introduction I've seen. What it lacks in thoroughness, it provides in clarity. Very readable introductions to a miscellany of knot theory topics from the elementary to the somewhat advanced. If it were more thorough or systematic, I'd rank it among the best introductions to the field. Hardback.
- **History and Science of Knots**, edited by **J. C. Turner and P. Van De Griend**, World Scientific Publishing Co., 1996. This is the most gratifying book on knots to be published in a long time. It proves that knotting by prehistoric peoples can be studied. It proves that knotting can be regarded as one of the earliest and most widespread technologies on which civilization

depends. It's expensive ($78) and only available in hardback. But if you always knew that there was more to the study of knots than either the knot-tying manuals or the mathematical treatises let on, but didn't know where to put your hands on it, here it is. Hardback only.

Books on Knot Art

- **Celtic Knotwork**, by **Iain Bain**, Sterling Pub. Co., 1992. A step-by-step guide for beginners, emphasizing the construction of grids to fit the shape in which you'll be working. Lovely drawn illustrations of the techniques, photographs of historical specimens. Becomes quite advanced by the end. Paperback.
- **The Complete Book of Decorative Knots**, by **Geoffrey Budworth**, The Lyons Press, 1998. A thorough guide to decorative knots with sections on lanyard knots, button and globe knots, Turk's heads, mats and hitching, and plaits and braids. (Thorough does not mean "complete", as Budworth and his publisher should know.) Clear drawings, usually many per knot. In addition to instructions, each knot is accompanied by a few words on its applications and history. Paperback.
- **Chinese Knotting**, by **Lydia Chen**, Echo Books, n.d. An ancient and beautiful art, almost destroyed by the Cultural Revolution. Lydia Chen has done more than anyone else to preserve and revive it. Stunning color photographs of classical and contemporary examples, many of the best by the author herself. Distinctively Chinese and quite different from Western decorative knotting. This is the book that persuaded me that "decorative knotting" is a true art, not mere decoration. Hardback only.
    - If you like Chen's book, you will also like **Hanamusubi: Traditional Japanese Flower-Knots** by **Toshiko Tanaka**, Kyoto Shoin Co., Ltd., 1993. Paperback. Unfortunately, Tanaka's book is not available from Amazon.com.
- **Encyclopedia of Knots and Fancy Rope Work**, by **Raoul Graumont and John Hensel**, Cornell Maritime Press, 4th ed., 1952. Over 700 pages of knot descriptions and photographs. There are better books for practical knots, but for decorative knots it is unrivaled in its scope and detail. Hardback only.
- **The Book of Ornamental Knots**, by **John J. Hensel**, Cornell Maritime Press, 1990 (Original, 1973). Hensel is the co-author of the *Encyclopedia of Knots and Fancy Rope Work* (above). While the larger work is more like a museum, this one is much more a primer. A good introduction to large knotting projects (belts, mats, wall hangings) by one of the masters. Illustrated with black and white photographs. Paperback.
- **Celtic Design: Knotwork: The Secret Method of the Scribes**, by **Aidan Meehan**, Thames and Hudson, 1991. A step-by-step guide for beginners. Elegant illustrations and calligraphy by the author. Builds up to some complex designs. Paperback.
- **The Book of Decorative Knots**, by **Peter Owen**, Lyons & Burford, 1994. This is the best introductory book I've seen on decorative knots. It's not encyclopedic, it's not intimidating, and it presupposes no knotting sophistication. Short with clear black and white line drawings and concise descriptions. (Having said that, it wouldn't take much practice for the beginner to outgrow this book.) Paperback.
- **How to Draw Celtic Knotwork**, by **Andy Sloss**, Blandford Books, 1995. Unlike the other Celtic knotting books listed here (by Bain, Meehan, and Sturrock), Sloss breaks Celtic knotting designs down into the distinct lines and square modules which may be combined to make complex designs. Because each line and module can be named, he produces a notation for arbitrary patterns. The modules are illusrated for hand-drawing and computer graphics. Paperback.

- **The Arts of the Sailor**, by **Hervey Garrett Smith**, Dover Publications, 1990 (original 1953). This book is about half and half practical knots and sailors' knot art. I've arbitrarily decided to list it with the art books. Smith is like Ashley in that he draws his own, very clear illustrations, and writes with the authentic saltiness of an old sailor. This is one of the few knot books that is as enjoyable to read as it is to use. Smith wrote a subsequent book, **The Marlinspike Sailor** (International Marine, 1993, original 1960) that covers much the same ground as **Arts of the Sailor**, but with a slightly greater tilt toward artful knotting. It also has a useful appendix on splicing woven, synthetic cord. Both are paperbacks.
- **Celtic Knotwork Designs**, by **Sheila Sturrock**, Guild of Master Craftsman Publications, Ltd., 1997. A step-by-step guide for beginners. Handsome illustrations. Paperback.

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See my policy on dead links.

Last revised June 2, 2004.

Peter Suber, Department of Philosophy, Earlham College, Richmond, Indiana, 47374, U.S.A.
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RECYCLE-A-BIKE BIKE SALE

KNOT TYING RESOURCES

(This is one of my recently made bellropes, it is made out of several sizes of cotton cord and contains a core made frome scraps from other bellropes) I think it came out pretty good, one of these days I'll have to get me a bell.

I have had a lot of requests about instructions to construct a bellrope like the one in the photo so I purchased a good tripod and have put togeather a video showing how I put one togeather step by step so if you would like a copy contact me and I'll give you more info.

ONE OF MY GOALS WITH MY BELLROPES: I would really like to have one of my bellropes make it to the silver screen as one of the props in a movie, so if any producers, directors, prop suppliers, whoever, anyone in the business that might be able to use a bellrope in some of their scenes, just let me know.

"NEW" Check out the E-Bay link in the links, a very easy to use tool for looking for knot items for sale in the e-bay online auctions, use it to find

Martin Combs

roundturn@hotmail.com
PO Box 9573
Chesapeake, Virginia 23321
United States

KNOT INFO

INTERNATIONAL GUILD OF KNOT TYERS: A good organization if you are interested in knots, and knotwork.
THE PACIFIC AMERICAS BRANCH OF THE INTERNATIONAL GUILD OF KNOT TYERS:
ONLINE KNOT MUSEUM: The only photos of knotwork on the net that I know of. (The knot photos are under the poetry)
"FID-O": If you are going to be doing some splicing you might want to have a look at some of these cool spliceing tools.
BOOKS ON KNOTS AND TALL SHIPS: Also a good video on decorative knotwork and a good book on the U.S. Lifesaving Service, and a couple of knot tying materials sources. And for the bellrope makers the elusive brass thimble.
KNOTS ON THE WEB: An excellent site with lots of links to other knot sites, nice artwork also.
ROPERS KNOT LINKS: Another excellent website with catagories (sailing, climbing, fishing, etc.) take a look you'll like it.
KNOT TYING VIDEOS BY MARTIN COMBS: A couple of videos for sale that will assist you in making a bellrope and also boatswain pipe lanyards.
ANDERSON LEATHER: Check out the photo's of the Corvette (the other photos are good also)
DIETZ LANTERNS FOR SALE: My favorite brand of kerosene lantern, good to have onhand for emergencies, I used mine for 7 days after Hurricane Isabel
DAVID GOODCHILDS BOOK SITE: A good source for nautical classics a few good knot books also.
TOMMY COMBS CARVINGS: My Dads page with his waterfowl carvings. (If the link dosen't work you can use this address and type it in: http://www.freeyellow.com\members2\ladybug1998\index.html
NIKI'S MACRAME PAGE: Info on macrame and links ot other macrame sites
Turks Heads and Mats By T J Bartruff : Turkshead Information
DAVID MORGAN BRAIDING SUPPLIES: Looking for a source for Kangaroo leather in the USA they have it. Other good braiding supplies also.
Marlinespike.com: Tim Whittens Knotwork: Great examples of bellropes and chest beckets and he sells them also, excellent knotwork.
KNOT TYING COMPUTER PROGRAMS: By Frank in Sisters Oregon, have a look in there he has some demos and a screen saver.

books, knotted items, tools, etc. (You can pick up some pretty good deals in here sometimes and you can also sell some of your own things)

CARRICK BEND PATTERNS: I am looking for different carrick bend type patterns anchors, crosses, mats, whatever, (they could be any design) if you are interested in this area of knot tying please let me know and maybe we can trade ideas and swap around some information.

KNEW KNOT KNEWS (If you have heard something new in the knot tying world let me know and I might be able to post it)

I'm no longer in Coos Bay, I now reside in Chesapeake Virginia, my e-mail address is still the same so keep in touch.

JUST REPUBLISHED: A. Hyatt Verrills, "Knots, Splices and RopeWork: A Practical Treatise" First published in 1912 with a second edition in 1917. It contains all the usual knots (well drawn) along with some other more unusual ones such as the "French Shroud Knot", the "Alternative Eye" and the "Flemish Eye", etc. For information on obtaining a copy contact David Goodchild see the link for David Goodchild in the links section.

(I recieved a copy of this book recently, it had a few things in there that I hadn't seen before, even a section in the back on rope halters for horses. It's hardback and has a classy look about it there on the bookshelf, it's a must if you are a knot tying enthuseist and knot book collector.)

NEW WEBSITE: THE KNOT BOARD a bulletin board for the knot tying community. (just look over in my links section)

I've created this web page to assist in gathering information on sources for knot tying information and sources for knot tying materials. I've been fooling around with knots for the past 17 years and I have found that it is not easy to find a lot of materials used in knot tying and fancy ropework (especially here in Alaska) If you are interested in finding sources for information in knot tying check out my links section. If you are interested in finding sources for knot tying materials drop me an e-mail and I'll send you a copy of the e-mail message that I keep on file with a list of sources for materials, tools, books, etc. (After some suggestions I have gone ahead and posted my list of sources at the bottom of this web page)

Also if you are looking for information on a specific topic send me an e-mail and I might be able to tell you where to find the information you are looking for or I might be able to put you in contact with someone that knows more about it.

Also I'm always looking for sources so if you know of any let me know and I'll add them to my list.

Sources: THIS IS MY CURRENT LIST THAT I UTILIZE IF YOU KNOW OF ANY OTHER SOURCES FOR SUPPLIES LET ME KNOW AND I'LL INCLUDE IT.

1. LEE VALLEY TOOLS 12 EAST RIVER ST. OGDENSBURG, NY, 13669 USA TELE:1-800-871-8158 in CANADA also LEE VALLEY TOOLS P.O. BOX 6295, Stn J OTTAWA, ONTARIO K2A 1T4 CANADA

CARRIES A GREAT VARIETY OF TOOLS FOR JUST ABOUT EVERYTHING THEY HAVE AN ITEM CALLED JAPANESE GARNISH AWLS THAT MAKE VERY GOOD PRICKERS, THEY ALSO CARRY WAXED POLYESTER SAIL TWINE, AND A NICE SELECTION OF KNIVES. (THEY HAVE A VERY GOOD CATALOG WITH LOTS OF NEAT STUFF)

2. THE KNOT SHOPPE PO BOX 202607 ANCHORAGE, AK 99520

KNOT KNOTES: A good website by another fellow knothead has some links to some good animations.
BOOKERS CUSTOM CORDAGE: Some interesting patterns in braided cords, they might even be able to do made to order patterns of your own design.
DAVE DOES KNOT WORK: A fellow knot artisian that offers his work for sale he also offers an instructional video on how to make the mysterious monkeyfist.
CALLAHAN'S KNOT PHOTO ALBUM: Some great photos of knotwork, (you got to have a look at these)
KNOT CHAT (Most of the time on sunday at 6PM Pacific) :

This page has been visited times.

TELE: (907)274-2321 E-MAIL: the_knot_shoppe@prodigy.net

GOOD FOR JUST ABOUT ANY KIND OF CORD, A VERY GOOD SELECTION OF GOOD QUALITY PARACHUTE CORD, IN JUST ABOUT EVERY COLOR YOU COULD ASK FOR. SCREW THREADED NEEDLES ALSO THAT ARE JUST ABOUT THE NEATEST TRICK TO COME ALONG IN YEARS FOR KNOT TYERS. JUST TELL HIM WHAT YOU ARE LOOKING FOR AND HE'LL TELL YOU IF HE'S GOT IT OR CAN GET IT. (HE'S GOT BEADS, SPLIT RINGS AND LOTS OF OTHER THINGS THAT YOU WOULDN'T THINK OF USING FOR KNOT TYING TILL HE TELLS YOU ABOUT THEM)

3. FOOTROPE KNOTS 501 WHERESTED ROAD IPSWICH, IP2 8LL UNITED KINGDOM

LOTS OF STUFF, WRITE TO THE OWNER DES PAWSON HE'LL SEND YOU A NICE LITTLE CATALOG WITH JUST ABOUT EVERYTHING FOR KNOT TYING IN IT. THEY DO CUSTOM WORK ALSO, KNOTBOARDS, FENDERS, BELLROPES, ETC.

4. S-T LEATHER COMPANY P.O. BOX 78188 ST. LOUIS, MO 63178-8188 TELE: (314) 241-6009

THESE FOLKS CARRY THAT OLD TIME WAXED LINEN SAIL TWINE, THEY HAVE A GOOD CATALOG ALSO WITH GOOD LEATHER WORKING SUPPLIES THAT MIGHT BE USED WITH KNOT TYING.

5. MYSELF: MARTIN COMBS PO Box 9573 Chesapeake, Virginia 23321 E-MAIL: roundturn@hotmail.com

IF YOUR LOOKING FOR SOME OF THE HARD TO FIND KNOT BOOKS FROM OVERSEAS (ENGLAND, SCOTLAND, AUSTRALIA) (check out my books on knots and tall ships in the links section of my web page) I have a couple of materials that I use myself that I am now offering, including good quality 3 strand cotton cord in 5 sizes, and also solid brass thimbles like the one in the eye of the bellrope in the picture above.

6. TANDY LEATHER PO Box 791, Fort Worth, TX 76101 USA http://www.tandyleather.com/

LOTS OF LEATHERWORK SUPPLIES THAT YOU MIGHT BE ABLE TO USE FOR KNOT TYING WORK

7. R&W Enterprises 404 Nash Road P.O. Box 50420 New Bedford, MA 02745-0014

Tel. 508/997-3933 Fax 508/997-9990 Lots of different lines to use .

8. Wrisco Industries Inc. 6075 W 115th St Alsip, IL 60803 (708)385-7000 This source was suggested to me by Mr. Jackson as a source for venitian blind cord (says they have every color under the sun) $51.36 / 1000 yard spool 1.4mm nylon cord Part # 160080

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FUN WITH KNOTS

or...I'm at the end of my rope

I found these links on Scouts_L

Animated knots for Scouts and Guides
http://www.mistral.co.uk/42brghtn/knots/

Australian Scouting Knotting Index
http://www.scouts.asn.au/knot_idx.html

Best Knot Site on the Web
http://www.earlham.edu/suber/knotlink.htm

Knot Knotes
http://dfw.net/~jazzman/knotter/knot.htm

Knotting programs for Windows
http://members.aol.com/idfrank/knots.html

Learning to tie knots
http://www.bsw.net/~bgibson/knots/ [with animations]

Rope making instructions
http://www.northnet.org/ropeworks/

Rope making page
http://www.northnet.org/ropeworks/text/r.html

Ropers Knots Page
http://ww.realknots.com/knots (with lots of further links]

Turk's Head woggle
http://www.ccil.org/~dkohn/woggle.html

Woggle World, the Neckslide Nook
http://members.tripod.com/~cubclub/

WWW Knotking Index
http://www.realknots.com

Knot quiz
http://www.erols.com/astro/knotquiz.htm

Return to Applegate Way

Knopar på svenska och engelska

Råbandsknop

Reef Knot (Square Knot (A.E.))

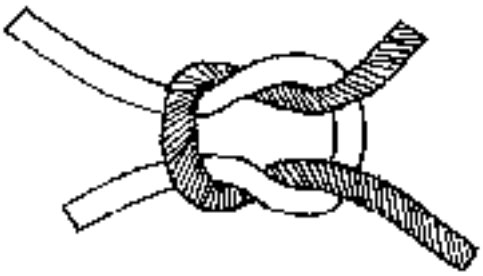

Fiskarknop

Fisherman's Knot

Vattenknop

Water Knot

1.

2.

Skotstek

Sheetbend

Normal

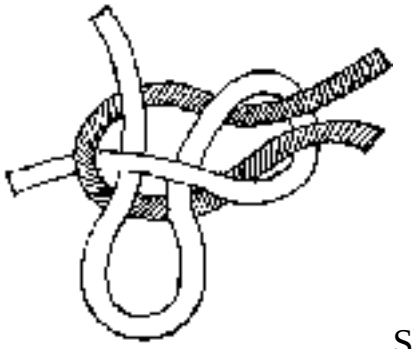

Skotstek med bukt

Lärkhuvud

Lark's head

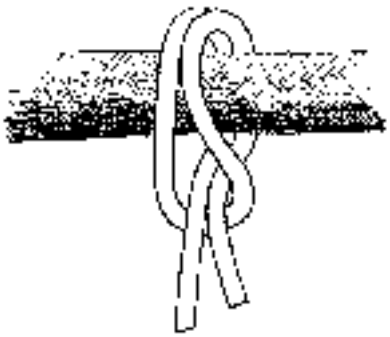

Nyckstek

Round Turn

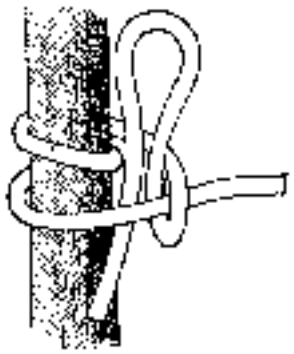

Timmerstek

Timber hitch

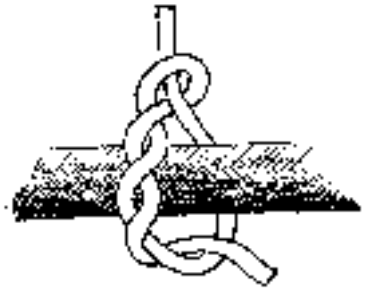

RÄTT!

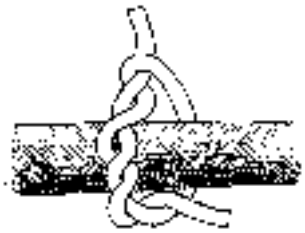

FEL!!!

Kärleksknop

Fisherman's Loop

1. 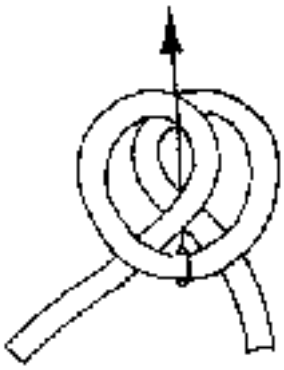

2.

Pålstek

Bowline

1. 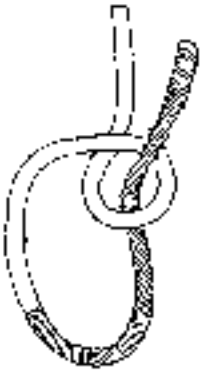

2.

Prusik

Prussick

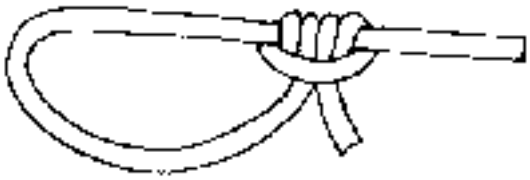

Dubbelt halvslag

Clove hitch

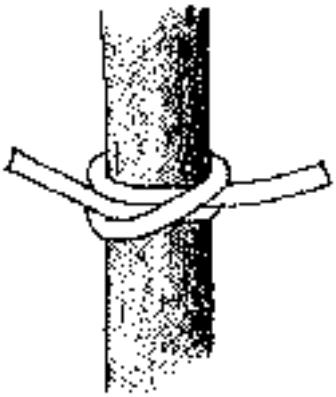

Trumpetstek

Sheepshank

1. 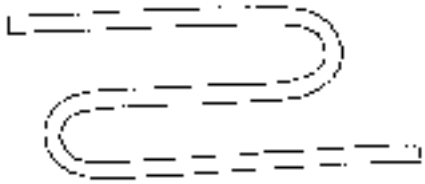 or

2. 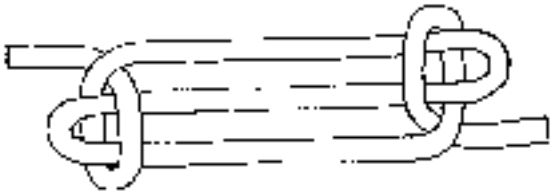

Engelsk säckknop

Jug Sling Hitch

1. 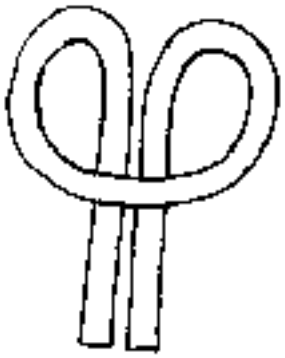

2. 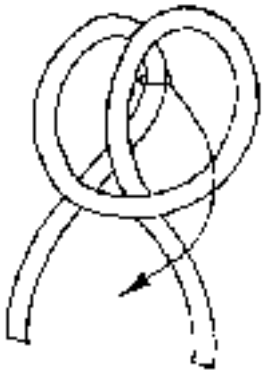

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4. 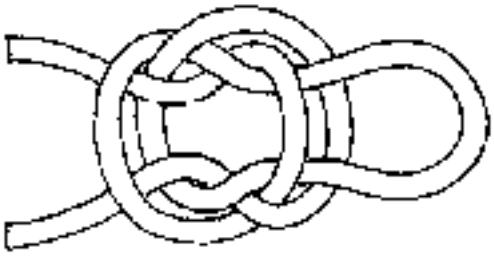

Tagling

Whipping

1. 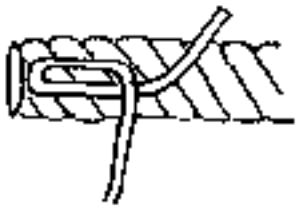
2.
3.

Fiskarstek

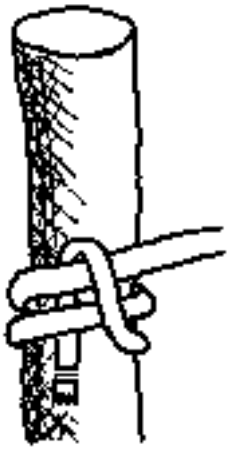

Fiskarstek med bukt

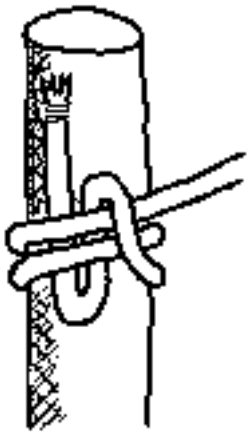

Pollarstek

Pile Hitch

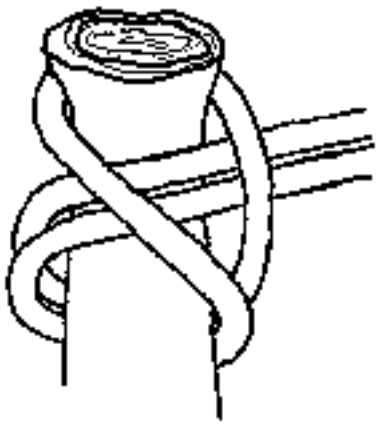

Flaggbänd

Buntline Hitch

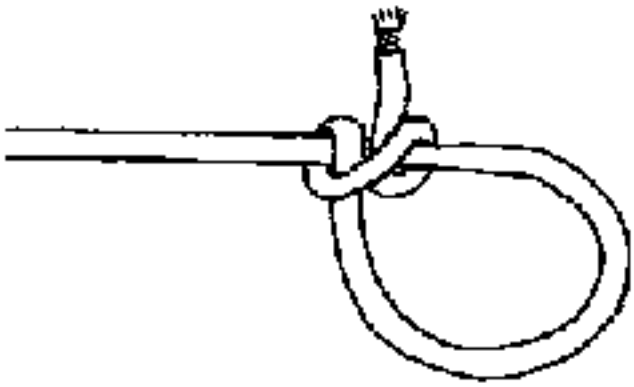

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Six Exploding Knots

- Clove hitch biting a bight
- Figure-eight biting a bight
- Sliding butterfly
- Sliding sheet bend
- Sliding Chinese crown
- Double Carrick bend
- Table of types

Overview & Quick Start

- I call these six hitches "exploding" knots because they untie easily and completely with one tug of the ripcord. Unlike slipped knots that untie with a ripcord, these knots leave absolutely no tangle. Yet they give up nothing in strength or ease of tying.
- To learn to tie them, jump to the illustrations and skip the commentary.
- In each illustration, the line labelled "R" is the ripcord ("running part"). The line labelled "S" is to be attached to the load ("standing part"). Tighten the knot with the "S" line.
- To decide which of these knots is best for which application, see the table at the end, which presupposes some of the text you might have skipped.
- After learning to tie the knots from the illustrations, read the text if only for safety issues.
- These knots are "probably original" in Clifford Ashley's sense of this phrase.

If you've ever tried to untie a taut-line hitch on a cold morning, then you know why slipped and exploding knots are a good idea. If the knot is tight, especially if the cord is also wet or thin or both, then fingernails will tear on it. Teeth might work, even if you were foolish enough to use them, but most people can't put their mouths the six or seven feet off the ground where the taut-line hitch often resides. If the cord is thin, the knot cannot be worked with gloves on, and if the morning is cold, the knot cannot be

worked with gloves off. If you have to cut your knots, then you don't belong in the wilderness.

Slipped and Exploding Knots

A *slipped*, *slipping* or *slippery* knot is one that replaces the end of the cord with a bight (the end doubled over itself) at the last step, to stick through the last opening before tightening. Just yank the *ripcord*, the end that hangs free, to undo the knot. This is a vast improvement over unslipped knots.

Don't mistake a slipped knot for a *sliding* knot. A knot slides if it moves over the cord, like a noose. Bowlines don't slide, for example. A taut-line hitch should slide; it would be nice if it also slipped. Most knots designed for strength should not slide.

The only trouble with slipped knots is that, after slipping, the cord is usually tangled and must be untangled. Certainly untangling the kind of tangle we're talking about is always easier than untying, and one is lucky to have grievances so small when one is cold, hungry, tired, wet, and bug-bitten. But it would be elegant and desirable to overcome this little problem. The *exploding* knot is a refinement of the slipped knot that does just that. When you pull the ripcord of an exploding knot, the ends fly apart, leaving no tangle at all.

Exploding knots are not merely elegant and fun, as you will see in the field. If exploding knots save your cord, or your fingernails (or teeth!), your time, or your temper, they can save your trip.

We need a few more terms before we begin. The *standing part* of a cord is the end attached to the load. The *running part* (or *the bitter end*) is the other end. The running part "runs" because it is the end in motion when the knot is tied. With exploding knots, however, just as much of the action takes place on the standing part, as we'll see. In the illustrations below, "S" stands for the standing part, "R" for the running part. Don't mix these up! With most exploding knots, if you mistake the running and standing parts, then the load will be attached to the ripcord. Ouch!

A *bight* is technically distinct from a *loop*. But any of these knots can be tied with loops instead of bights if you wish. Technically, a loop allows the ends of a doubled section of cord to cross, while a bight does not.

A sliding knot *locks* if some simple tug will tighten its grip on the standing part so that it will no longer slide. Another simple bend or twist should unlock it.

Exploding with a Bang or with a Whimper

Exploding knots require a balance of opposites: the knot must be tight enough to hold its load securely, but loose enough to let the ripcord slide through. A well-tied exploding knot will achieve this balance. The load on the standing part will always tighten the knot while preserving an island of relaxation somewhere inside where the ripcord lies like a sleeper in a tent in a thunderstorm. Learning to tie them so that they

achieve this balance is the most difficult aspect of exploding knots.

A general tip for achieving this balance is to tighten these knots flat (except #1). Don't let them curl up into balls or cubes. If they are kept flat while tightened, then the further tightening that comes from the load will not cause them to curl up.

If the knot is overtight, the ripcord may become too tightly bound inside the knot to pull. If the knot is well-tied, this overtightening will never arise from the tug of the load on the knot. But imperfect tying, combined with the added friction on the cord from rain or dew, may occasionally clutch the ripcord. Even with a clutched ripcord, however, an exploding knot is much easier to release than a non-exploding knot.

For all the knots presented here, the problem of tight ripcords can be cured either by *unlocking* in the usual way (described for each locking knot), or by an alternate kind of exploding release we may call *whimpering*. If the knot is grabbed like a knob, and pulled in a certain direction, then the bight that composes the ripcord will simply pull out, freeing the knot in a quiet explosion --not a bang, but a whimper.

Sliding knots will not whimper. When you pull a sliding knot, it will either slide or tighten. Whimpering knots, essentially, have two ripcords, one hanging free and one running around a spar or attached to the load. Hence, even though the two non-sliding, whimpering knots here (knots #1and #2) tighten as the load pulls, it is possible to whimper the knot if the load pulls in the "right" direction. So whimpering knots should not take critically heavy loads.

The advantage of non-whimpering knots, then, is strength in unpredictable situations (moving or jerking loads). The advantage of whimpering knots is convenience of release when the primary ripcord is seized by moisture or overtightening. After a whimpered release, you still have all the advantages of an explosion, with no winding to unwind.

If you didn't follow a point or two of this "knot theory," don't worry. Practice the knots, and you'll see what's going on.

These Six Knots

Of the exploding knots I've developed, these six fall into a natural family (they are all hitches with various properties), they are the most versatile and easy to tie, and they have undergone the most refinement and testing. Three slide and three don't. All the sliding knots lock and unlock. Two of the three non-sliding knots whimper, one doesn't. In every case, the knots explode by pulling the ripcord, which is always the end of the running part. A table to help you pick the knot just right for your application follows at the end.

The three sliding knots (knots #3, #4, #5) are named after traditional non-sliding knots that they resemble. The resemblance, obviously, has a limitation, since these knots slide (and explode) while their namesakes do not. The names are a convenience for remembering these knots, but should not confuse you about their functions or the

situations in which they might be useful or dangerous.

I describe the knots as if they were to be used to tie a load (pack, horse, canoe, clothesline, tarp) to a fixed object (spar, bollard, tree), but all of them have other applications.

I believe that the first five of these knots are original. The sixth is original only in its exploding form. None of them appears, for example, in the 600 pages of Ashley's encyclopedic *Book of Knots* (Doubleday, 1944). I say "original" but not "new," for it is impossible to say whether crafty sailors, cowboys, climbers, loggers, surgeons, quilters, or embroiderers have stumbled across them before.

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1. Clove hitch biting a bight (exploding, whimpering, non-locking, non-sliding).

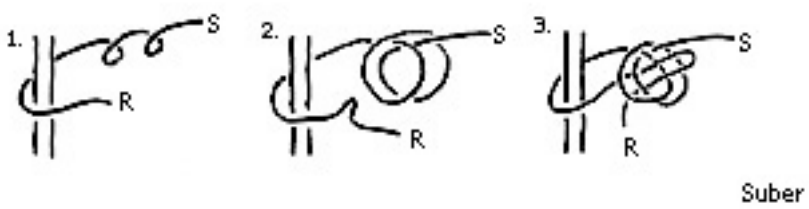

This and the sliding sheet bend (knot #4) are the easiest to tie of the six knots presented here, which makes it the easiest of the non-sliding knots. It is so easy that even when I have the time for something fancier, I will often tie this knot. It has the advantages and disadvantages of whimpering.

Start a clove hitch on the standing part. Instead of popping it over a fence or dock post, however, pop it over a bight from the running part. Tighten by pulling the standing part. Don't let the two "coils" of the clove hitch drift too far apart while tightening. There is no need to worry about tightening this knot flat; there's only one way to tighten it, and it's the right way. Whimper by pulling the knot away from the cord that forms the bight inside the clove hitch. (If the standing part came into the spar from the right and running part from the left, as in the illustration, then whimper by pulling the knot out from the spar and to the right.)

> This knot, under the name **Exploding Hitch**, was featured as the Knot of the Month in the October 1999 issue of *Boating Magazine* (p. 64).

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2. Figure-eight biting a bight (locking, exploding, whimpering, non-sliding).

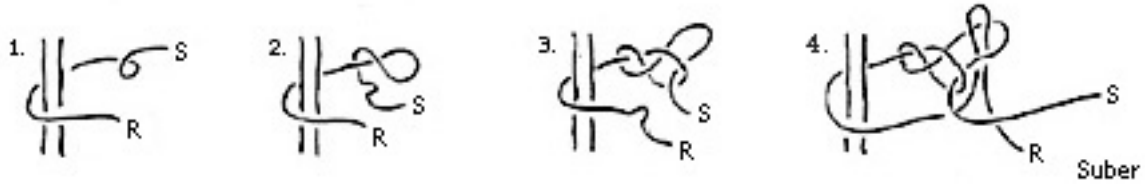

This is easy knot to tie that also has the advantages and disadvantages of whimpering. Tie a figure-eight on the standing part, and stick a bight of the running part through it at the last moment. Tighten it flat so that it will not curl up and lock the ripcord. Whimper by pulling the knot away from the cord that forms the bight inside the figure-eight. (If the standing part came into the spar from the right and running part from the left, as in the illustration, then whimper by pulling the knot out from the spar and to the right.) Lock by holding the knot and pulling the non-whimpering cord (the line from the knot to the spar on the right on the right side of the spar). Unlock by flattening the knot.

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3. Sliding butterfly (sliding, locking, exploding, non-whimpering).

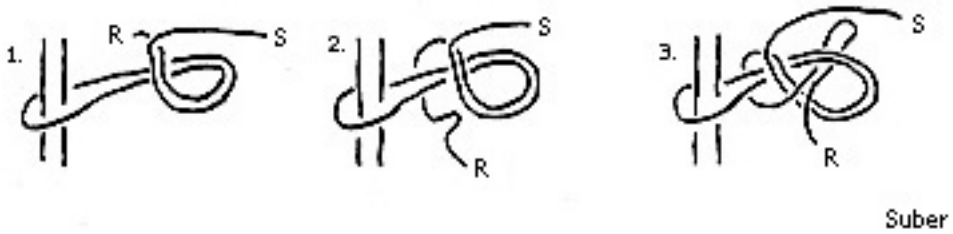

I call this knot a sliding butterfly because it looks like a butterfly knot, not because it acts like one. It can even fool knot-so-smart climbers momentarily into thinking it is a butterfly, until you slide it for them. (Don't expect it to make a secure loop as a real butterfly does.)

After the running part wraps around a tree or post, lay it alongside the standing part. Grab the two lines as if they were one, and make a loop by twisting counterclockwise. Take the running part alone now, without the standing part, and wrap it over the doubled lines and stick a bight of it through the doubled loop. Tighten by pulling the standing part.

Tightening this knot proceeds in two stages. First, the slack is taken up, then the knot capsizes. "Capsize" is the nautical term for the sudden twist or transformation that takes place in some knots when they are tightened. For example, sailors start a bowline by capsizing a half-hitch. For this knot, however, we should say that it "metamorphosizes," since it is only after the transformation that it looks like a butterfly.

Lock by holding the knot and pulling on the non-sliding line. Unlock by putting your thumbs on the butterfly's "wings" and bending up and down, or by pulling the sliding ends apart hard, or by flattening the knot.

4. Sliding sheet bend (sliding, locking, exploding, non-whimpering).

This knot has to be studied closely to see its kinship to the sheet bend. If you don't see the resemblance, don't bother; just enjoy it. (It should not be used like a regular sheet bend to join two different lengths of cord.) This is my favorite sliding exploding knot.

When mastered, this knot is not only very easy, but enjoyable to tie, leading the hand into unusual, efficient hand-gestures. A few twists, with almost no pokes or pulls, and you are done. Until mastered, however, it will often fall apart in your hands before it is finished. Tighten flat, not in a ball. It can make so tight a grip on the standing part that you may have to unlock it a bit before it slides. That should give you some comfort if you use it as a taut-line to hold your clean wet clothes. For a variation of this knot for heavier taut-line applications, see the sliding Chinese crown (#5).

Make a bight in the standing part between the spar and your load. Grab the running part (already wrapped around the spar) and make a loop in it by twisting counterclockwise. Slide the original bight through this loop, making a new loop on the other side. (With practice, this step can be done in the same counterclockwise twist that created the loop.) Stick a bight of the running part through this new loop, and tighten by pulling on the standing part.

Lock by holding the knot and pulling on the non-sliding line. Unlock by pulling the two sliding ends apart hard, or by flattening the knot.

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5. Sliding Chinese crown (sliding, locking, exploding, non-whimpering).

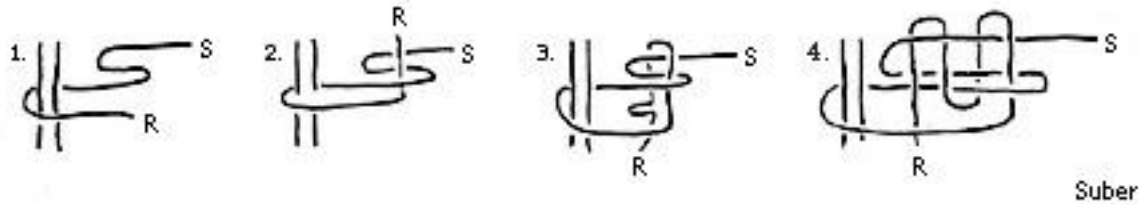

This may be the hardest to tie of the knots presented here, although it can be tied in three or four seconds with practice. The slide is controlled by one more bend in the rope than the sliding sheet bend (knot #4) which makes it stronger when locked. For taut-line applications meant to hold heavier loads, like wet tarps, it is better than the

sliding sheet bend. But don't let its "difficulty" stop you from trying it even for light loads, like a sliding "buckle" belt. (Slide it tight around your waist, then lock; explode when diarrhea attacks.) Like the sliding sheet bend, it can grip the standing part so hard that you may have to unlock it a little before you can slide it.

This knot is a sliding and exploding variation on the Chinese crown (Ashley #808, #1032). It also bears a certain resemblance to a non-sliding double Carrick bend (see knot #6). You could use it to amaze your friends who know that double Carrick bends don't slide, if you had any friends like that. Like the double Carrick bend, this knot should be tightened flat, otherwise it will become a cube that will neither slide nor explode. Because it slides, do not use it like an ordinary double Carrick bend to join two lengths of cord together.

Make an S-shaped curve in the standing part, with the bottom of the "S" toward the spar and the top of the "S" toward the load. Stick the running part up through the lower right-hand curve of the "S" from behind. Wrap the running part over the top of the "S" and when it emerges at the bottom of the "S" stick a bight of the running part through the upper lefthand curve from the front. Hold the new loop that results as you tighten by pulling the standing part.

Lock by holding the knot and pulling the non-sliding line. Unlock by pulling the sliding ends apart hard or by flattening the knot.

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6. Double Carrick bend (locking, exploding, non-sliding, non-whimpering).

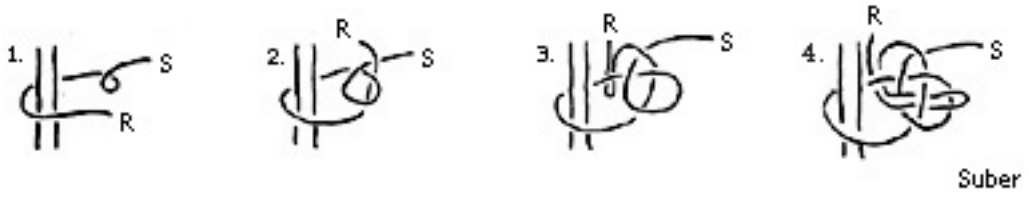

Make a loop in the standing end by grabbing it and twisting counterclockwise. Pass the running part under this loop (not through it yet) and over the top of the standing part. Then pass it under the next length of standing part. Make two bights at this point: (1) find the running part that passed under the original loop, and pull it up through that loop into a bight, and (2) take the end of the running part and make a bight of it. Pass the second of these through the first of these, and tighten by pulling the standing part. For best results (cleaner explosions) the ripcord should lie under the standing part it faces, not over.

This knot can be tightened into a cube, which locks the ripcord. Tighten it slowly so that it remains flat instead. Lock by holding the knot, and pulling the entire bight that holds the ripcord, or by pulling either of the non-ripcord lines. This knot has the advantages and disadvantages of non-whimpering.

The traditional (non-exploding) double Carrick bend is rated the strongest known bend (knot for tying two cords together). The variation that makes it explode should not affect its strength, although it will increase the chances of misadventure from another cause. To use it as a bend, follow the same directions, but treat the two ends of cord that come around the spar as if they were the ends of two distinct cords.

Do not use any of the other five knots as bends (for tying two cords together). Either one cord will be the ripcord for the knot, or it will slide through it. (I have another, more original, exploding bend that I'll put on the web soon.)

Despite its unmatched strength, the double Carrick bend is seldom used by mountaineers because it has been difficult to tie. I'd like to think that this version, with or without the exploding variant, might revive its use.

Six Exploding Knots					
Sliding			Non-Sliding		
Strength (2 bend)	Convenience (1 bend)		Strength (non-whimpering)	Convenience (whimpering)	
Sliding Chinese crown (#5)	Sliding butterfly (#3)	Sliding sheet bend (#4)	Double Carrick bend (#6)	Clove hitch biting a bight (#1)	Figure-eight biting a bight (#2)

This article has been translated into Dutch by Pieter van de Griend, "Zes Exploderende Knopen," *Het Knoopeknauwertje*, 9 (December 1997) 8-13.

Also see my page of **Knots on the Web**.

Peter Suber, Department of Philosophy, Earlham College, Richmond, Indiana, 47374, U.S.A.
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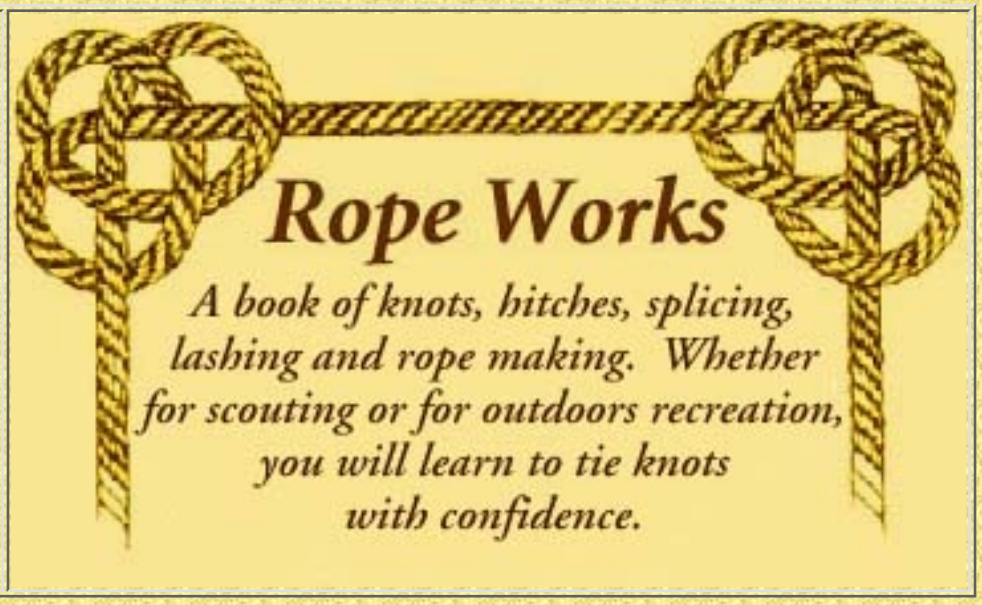

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  - The Rolling Hitch
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- Bends -- Tieing lines together
  - The Sheet Bend, and a modification:
    The Becket Bend on a Bight as a towline towing bridle connection.
  - The (Full) Carrick Bend
  - The Anchor Bend Technically a Hitch.
- Stopper Knots -- making a stop in the bitter end of a line
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The BRMRG Knot Review

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Written and developed by Jason Dalton 1995-1999

This Web page is for the training and reference of the ***Blue Ridge Mountain Rescue Group Inc.*** *It is not intended to replace competent training on how to safely and correctly tie knots used for Wilderness Search and Rescue. Please seek instruction if you are interested in learning to tie these knots, and use this resource as a practice and refresher aid..*

Click on a knot and you will get an illustrated tutorial on how to tie it and the usage for each knot. Memorize all of this information.

FTM Knots

- overhand
- square knot
- figure-8
- figure-8 bend
- figure-8 loop
- bowline
- taut-line hitch
- girth hitch
- prüssik
- water knot
- barrell knot
- ASRC triple redundant seat harness

FTL Knots

- sheet bend
- frost knot
- butterfly knot
- one-way knot
- bowline-on-a-coil
- load-releasing hitch
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Josella Simone Playton

Seit dem Merger zwischen GeoCities und Yahoo! haben sich dort die BenutzungsBedingungen in **unakzeptabler Weise** geändert. Deshalb haben wir alle GeoCities-Seiten rausgerissen. Diese WebSite sollte jetzt in sich leidlich konsistent sein.

Die Entsprechung der alten EingangsSeite bei GeoCities wird http://www.Josella-Simone-Playton.de/index.html sein.

Die GeoCities Sites bleiben zunächst stehen, werden aber **in keiner Weise mehr gewartet**. Die Josella Simone Playton HomePage ist **hier**. Ob es woanders noch eine Mirror-Site geben wird ist noch nicht entschieden. Hier einige weitere Links:

Zum HochSeilNest (Deutsch)

Zum HochSeilNest (Bilder - (das ist hier))

In die WeltHöhle (Deutsch, kapitelweise, HTML)

HomePage English

HauptSeite Deutsch

Andere HomePages

Zum WebRing WebFehler

Web-Site Pflege

Andere Websites vom selben WebMaster:

Die QuantenRente

Das HochSeilNest und die meisten in der C´T veröffentlichte Story sind schon umgezogen, ebenso das alte GästeBuch von GeoCities, welches nicht mehr weitergeführt werden kann. Die WeltHöhlenTrilogie ist ja sowieso schon hier.

Der Roman Deadlock ist bei TelePolis, wird aber ebenso bald hier zu finden sein.

Die Photos vom HochSeilNest auf dieser Seite werden demnächst in eine eigene Seite ausgelagert.

Ältere Eintragungen:

Seit 1998-11-07: Die WeltHöhlen-Trilogie-Mirror-Site.

Am 1998-04-14: Ich habe das Material etwas umgeordnet, damit nicht immer alle Bilder gleichzeitig geladen werden. Außerdem habe ich Hinweise über das eingefügt, was inzwischen nicht mehr existiert.

Weil die Telekom am 1998-11-01 ein Einsehen hatte und nun jedem MitBenutzer 10 MegaByte WebSpace ermöglicht, spiegele ich hier die WeltHöhlen-Trilogie.

Vorübergehend parke ich hier zwei Stories, die in Arbeit sind: PiceaAbies und Die andere Seite des Himmels. Beide Stories haben noch Defizite.

Weiterhin definieren wir gerade ein Universelles PartitionsSystem, das seit dem 9. Dezember 1997 in Arbeit ist. Das unfertige Papier erscheint hier - der flüchtige Leser wird eine rudimentäre Ähnlichkeit mit dem PartitionsSystemen auf PC bemerken - das UPS ist aber einfacher. Es soll keine Einführung sein, eher ein 'RFC'.

Hier also die Photos:

Zum Bild

Die Achtschlaufe - Variationen des AchtKnotens (und des Webleinensteks) sind die am häufigsten eingesetzten Knoten am HSN.

Zum Bild

Der AchtKnotenStopper (Gut) und der ÜberhandKnotenStopper (PfuiBähBäh).

Zum Bild

Der Palstek.

Zum Bild

Für den HochSeilNestBau weniger wichtig: Der HenkersKnoten.

Zum Bild

Eine von meinen 3_600 'versehentlich' gesähten SonnenBlumen (1997).

Belichtung 1/78 Sekunde

Zum Bild

Im unteren Teil des Bildes das 6 Meter Sisal Nest, im oberen Teil das 12 Meter Nest mit meiner SchlafStätte - Die Decken sind gerade gegen Regen in PlastikFolie gut eingepackt, was man auf dem Bild aber nicht erkennen kann.

Das 6 Meter Sisal Nest existiert seit dem 1998-03-30 nicht mehr.

Zum Bild

Die AnlegeLeiter, an einem der tragenden Bäume mit zwei Ketten und zwei Vorhängeschlössern gesichert.

Seit dem 1998-03-30 wird die Leiter woanders aufbewahrt.

Belichtung 1/29 Sekunde

Zum Bild

Perfekte Tarnung - Das HSN ist in der von der 'Wibke' gerissenen Lücke. Man sieht es in Wirklichkeit kaum, auf diesem Photo gar nicht.

Belichtung 1/205 Sekunde

Zum Bild

So sieht eine StrickLeiterSprosse aus der Nähe aus (PolyHanf 12 mm, gedreht).

AufnahmeZeitPunkt 97-09-17 12:38:38 Belichtung 1/8 Sekunde

Zum Bild

Der Schatten links von der BildMitte ist von meiner SchlafStätte auf dem 12 Meter Nest.

AufnahmeZeitPunkt 97-09-17 13:18:56 Belichtung 1/75 Sekunde

Zum Bild

Aussicht vom Nest nach NordWesten.

Zum Bild

Die halbabgeschlossene AnlegeLeiter.

Dieses ist die unsichere Aufbewahrung der AnlegeLeiter, die die beiden Teenager am 2000-07-12 überwunden haben.

Zum Bild

Die entsicherte AnlegeLeiter.

Im VorderGrund ist die SisalSchlinge zu erkennen, auf der die halbabgeschlossene Leiter ruht.

Zum Bild

Höchster Sonnenstand.

Dieses Bild ist am 22. Juni aufgenommen und zeigt den Schatten des HängeBrückenBettes etwa zur MittagsZeit.

Zum Bild (200 kB)

Das neue HängeBrückenBett.

Der LattenRost ist länger als 2 Meter, und er ist durch GewindeStanden, die man hier nicht sieht, versteift. Die TrageSeile sind nicht mit dem LattenRost verbunden, sondern führen unter ihm durch.

AufnahmeZeitPunkt 00-06-28 13:20:28 MESZ

Zum Bild (200 kB)

Blick nach Süden unten.

Über den SüdRand des Nestes hinweg sieht man in den niederen Buchen- und BirkenWald. Bei Regen ist es im Sommer ein dampfender Dschungel. Im VorderGrund eines der TrageSeile des

HängeBrückenBettes, das ein niedriges Geländer bildet.

AufnahmeZeitPunkt 00-06-28 13:21:55 MESZ

Zum Bild (200 kB)

Blick nach Süden.

In der Ferne ist irgendwo die BenediktenWand.

AufnahmeZeitPunkt 00-06-28 13:22:05 MESZ

Zum Bild (200 kB)

Das Trocknen der Decken.

Nach dem heftigen Regen vom 1. auf den 2. Juli ist unser Nest voll mit zum Trocknen aufgehängten Decken, wie ein altes SegelSchiff.

AufnahmeZeitPunkt 00-07-02 15:56:49 MESZ

Zum Bild (200 kB)

Die beiden westlichsten Bäume.

Hier zeigt sich, wer wirklich schwindelfrei ist.

AufnahmeZeitPunkt 00-07-02 15:57:50 MESZ

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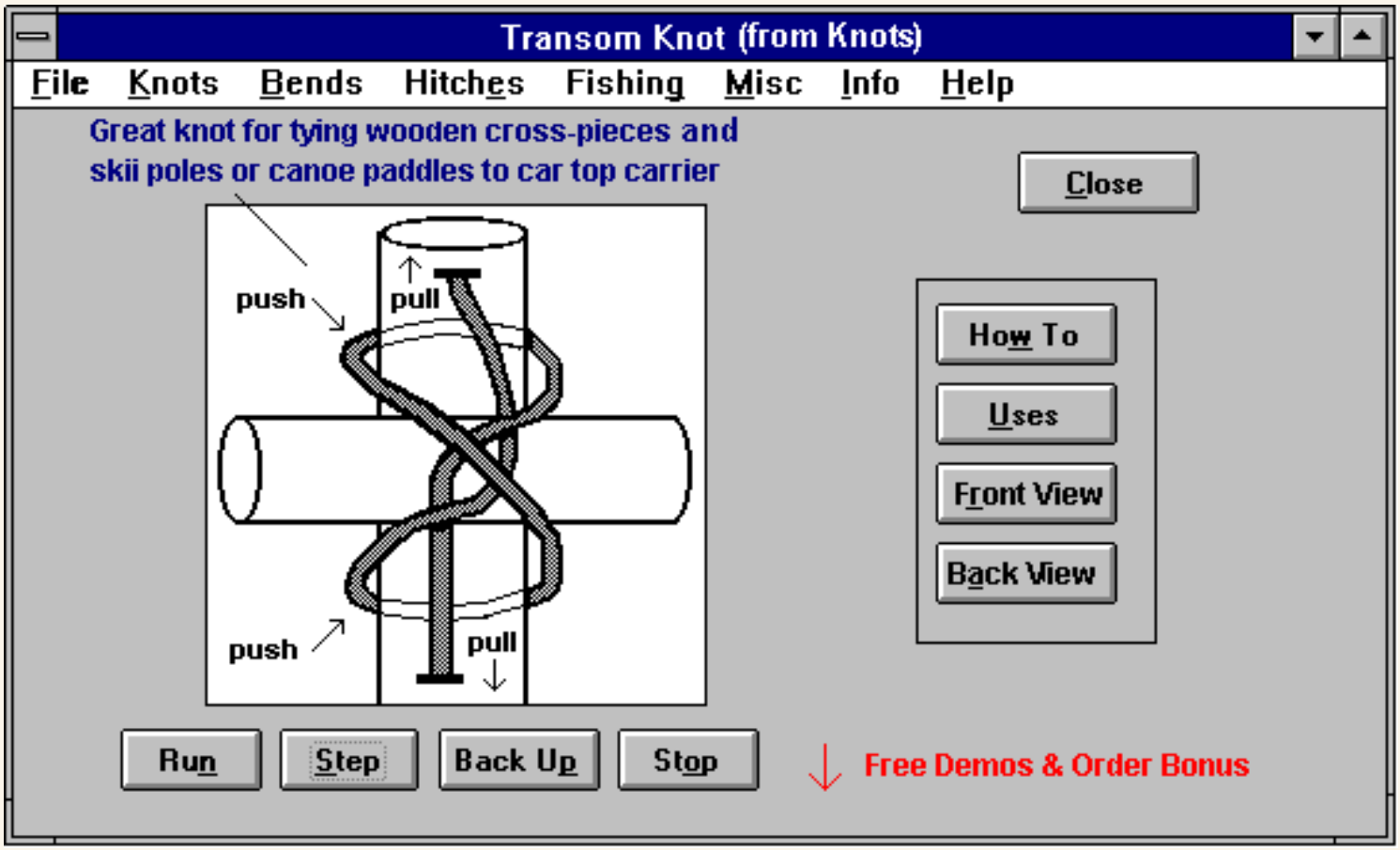

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Knot

Yes, I know that some of the graphics on this page are broken. Restoring them from backup will be something of a hassle and, frankly, is not that high on my list of priorities, so don't count on it getting fixed very soon. --pH

Bends

[Graphic of Basketweave Bend]

[Added 12/14/97] This knot is a sort of compromise between the Double Harness Bend [Ashley 1421] and the Barrel Knot [Ashley 1413], though I find it easier to untie than either. Others may disagree, however. I developed it mainly to satisfy my (perhaps irrational) preference for what Ashley calls "cruciform" bends, bends from which the bitter ends emerge at opposing right angles.

[Alternate graphic of Basketweave Bend]

[Added 12/22/97] Although the first graphic above gives a (slightly) better idea of the shape of the knot, it can actually be drawn with fewer crossings (10 vs. 12) as in the second illustration.

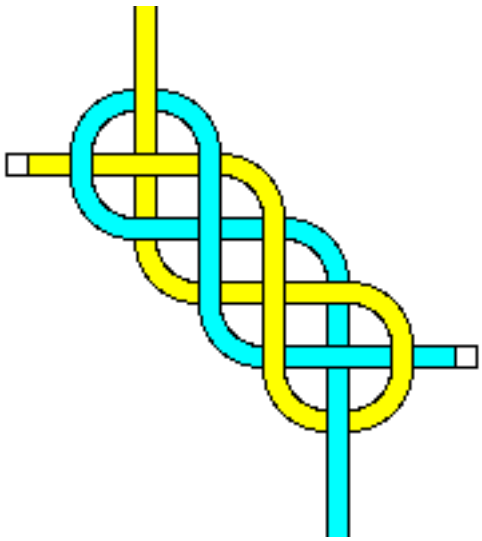

[Added 3/13/98] This version, although it has even more crossings (14), gives a very good idea of the final shape of the knot, and of its attractive appearance.

[Added 12/30/97] To point out some other relatives of this knot: it bears a certain resemblance to the Surgeon's Knot [Ashley 1209], but the knot it actually resembles most closely is Ashley 1450, which Ashley developed as a hawser bend; the above is essentially a symmetrical version of that knot.

[Added 1/13/98] Though I realize that it may turn out that this knot is not original to me, in the meantime, to have a more convenient method of referring to it I tentatively dub it the "Basketweave Bend", because of the appearance of the back face of the knot. It, too, can be tied (in

loop form) to a ring without first knotting the rope (see below). Perhaps I'll add a graphic showing the method for that.

[Added 1/26/98] If loosened sufficiently, then capsized by pulling on the bitter ends, Basketweave transforms into Ashley 1451, another excellent bend related to the Full Carrick.

[Added 3/2/98] I was told a week or two ago that Basketweave is described in the latest issue of *Knotting Matters*, which (shame on me) I don't get since I haven't joined the IGKT yet.

[Added 3/16/98] There are essentially two ways to generalize this knot if the resulting bend is to remain symmetrical. If one thinks of the tying method as twisting the ends together twice as for a Surgeon's Knot, then tucking the ends (this can be best seen from the topmost illustration), one can increase the number of twists and then either:

1. tuck the ends at the center still, which preserves the basketweave appearance but makes the knot much more difficult to undo, or
2. tuck the ends at the same distance from the ends (as if finishing a sheet bend), which preserves the liftable loops at the ends of the knot which make the original Basketweave so easy to untie. The result is shown below, with the number of twists increased to three. (Four or more seems to be overkill, in my estimation. Perhaps in fishing line they might be needed--haven't tried it yet.) As the knot is tightened the added twist transfers itself to the outside of the knot, which results in less basketweaviness, but also an attractive corkscrew appearance.

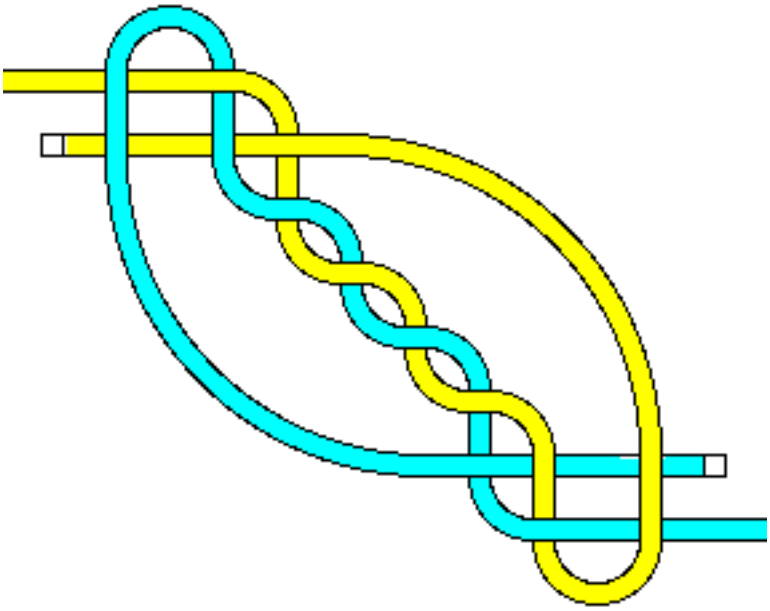

I believe this knot to be nearly as secure as the Barrel Knot, slightly bulkier, but much easier to untie.

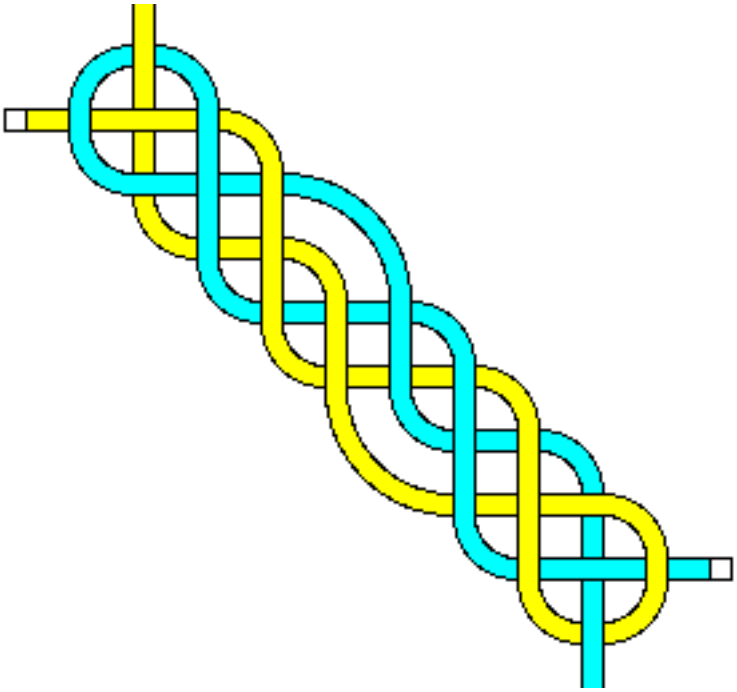

[Added 3/21/98] This shows the Double Basketweave Bend after the twist has been transferred to the outside.

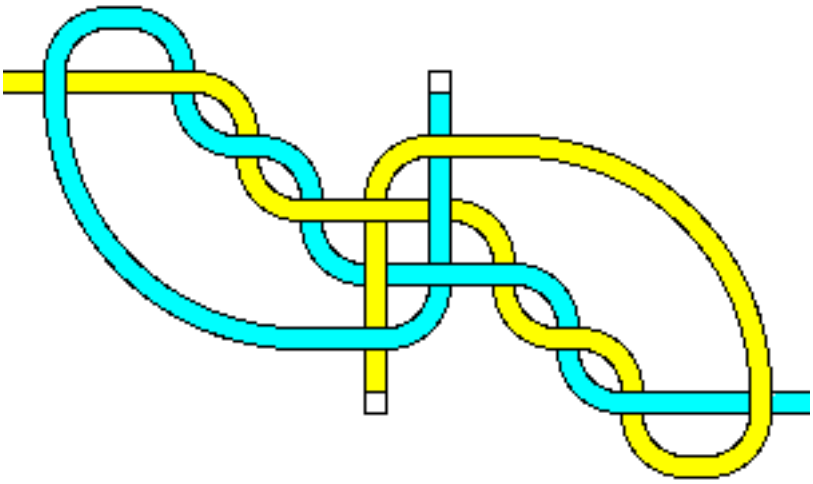

[Added 3/27/98] This shows option 1 above, which I think of as the "Barrel-Weave" bend, as it shares characteristics of both the Basketweave Bend and the Barrel Knot. It seems to work well even with four twists, although here it is only drawn with three.

[Added 4/9/98] I have received the following from Brian A. Glennon, rigger:

> In reference to you new knot, the "Basket Weave Bend", I believe you have re-discovered the SENNIT BEND first developed by two mountain climbing enthusiasts: C.E.I. Wright and J.E. Magowan in 1928 and a current diagram of this bend may be found in the book: 'The History and Science of Knots' by Turner & Van de Griend (1996) page 159.

[Graphic of Chicago Bend]

[Knot posted 10/26/97] This knot, which I (briefly) believed original (see below), bears the same relationship to Hunter's Bend as Ashley 1452 (Ashley's Bend) does to Ashley 1408 (note: *not* Ashley 1409!), i.e. similar in structure (and therefore in method of tying), but with the direction of the final tuck of the ends through the central nip of the knot reversed, which makes it more easily untied.[1] Hunter's Bend is depicted below.

[Graphic of Hunter's Bend]

Another way of thinking about this knot, or rather the relationship between this one and Hunter's Bend, is that each is formed by taking one of the differing sides of a Lineman's Loop (Ashley 1043) and duplicating it symmetrically.

[1][Added 10/30/97] To amplify on this comment: this depends partly on how the knot is drawn up. If it is tightened primarily with tension on the standing parts, the knot is very easily untied by pulling on the outer loops, though still not as easily as Ashley's Bend with its "unwinding" action. If drawn up firmly by the bitter ends as well as the standing parts, it assumes a shape whose cross-section is smaller than that of Hunter's Bend (which might be advantageous in certain conditions) but becomes more difficult to untie than before.

[Added 11/23/97] Yet another way of thinking about this knot: it is quite similar to a Full Carrick Bend With Diagonal Pull, Capsized (Ashley 1439). The two knots differ only by two crossings, as can be seen by comparing the above graphic with the Carrick Bend, below:

[Graphic of Carrick Bend]

[Added 3/19/98] An aside about the Carrick Bend: by following this diagram (or the one below for the Carrick Loop(s)) one can tie the Carrick Bend "pre-capsized", which might be preferable to the usual method of tying it as two overlapping loops, then capsizing it by pulling on the standing parts. If not sufficiently loose, the knot fails to capsize completely, and the intermediate form is not as strong as when completely capsized, which is according to Ashley "one of the strongest of bends".

[Added 12/10/97] Yet *another* way of thinking about this knot: it is quite similar to Ashley 145*3*, an asymmetrical but easily untied bend. The two knots differ only in the way one end is tucked. I'll add a graphic illustrating this as soon as I get the time.

[Graphic of Ashley 1453]

[Added 12/11/97] As promised, here is the new graphic: just tuck the upper end as indicated by the arrow, and "my" bend is converted to Ashley 1453. A slight correction to the above paragraph: although it appears asymmetrical when tied this way, or for that matter by following Ashley's diagrams, Ashley 1453 *can* be manipulated into a symmetrical form.

[Added 12/22/97] It turns out that this knot *is* pretty new, but it is *not* original to me. Robert M. Wolfe first brought it to the attention of the knotting community in 1996. He has dubbed it the "Chicago" bend, or simply the "C-bend".

Darn.

Loops

[Added 12/22/97] Here is my latest idea: The Angler's Loop [Ashley 1035] is strong, secure, and easily tied, even in the bight. Its only disadvantage is that it is difficult to untie. Why not therefore add a twist so that its "core" (highlighted in yellow) is a figure-eight instead of an overhand knot? This makes it easier to untie. The original Angler's Loop is below on the right, my proposed variant on the left. It remains to be seen, however, whether there is any reason to prefer this variant when one could use Ashley 1043 (the second graphic), which has essentially the same virtues and is even easier to untie. Ashley 1043 is more lopsided, but the lines running together around the top make it more attractive, at least to my eye. The greater lopsidedness *may* make it weaker, but I have yet to test that hypothesis.

[Angler's loops, modified and original] [Ashley 1043]

[Added 01/11/98] One disadvantage of the above loops (and other popular loops such as the figure-eight loop) is that if they are used as hitches to a ring or other such object, they require one to tie an overhand knot or figure-eight in the rope before reeving the end through the ring, unlike the dependable old bowline, which does not. Of course one is not supposed to depend on a bowline anymore in these days of synthetic line, so I began experimenting with tying the Carrick Bend as a loop knot. (I know about the double bowline, but that's too easy. Quit spoiling my fun. 8-)>)

In the following diagram, option 1, in yellow, yields a straightforward Carrick loop. Option 2, in cyan, is a variation which should be more secure, but may be slightly less strong. It is sort of half Carrick, half Chicago. Option 3 (green) might be a reasonable compromise between the previous two in strength and security. (Note: these strength and security rankings are guesses based on the geometry of the knots; I need to get going on my stress tests.)

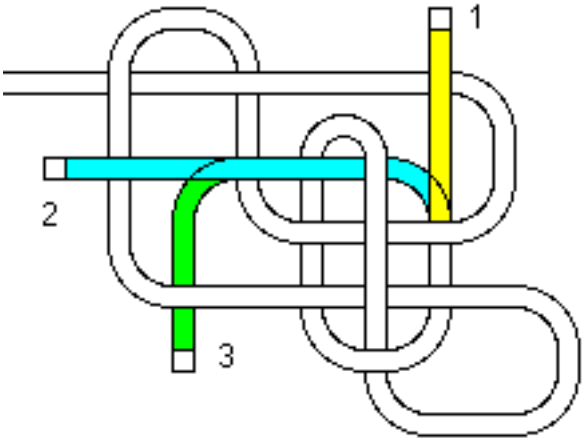

[Added 3/19/98] I still haven't done rigorous stress testing, but I must admit that of these three variants I am most fond of option 2.

Binder Knots

[Added 12/30/97] A thought about binder knots: Ashley neglects to point out that the Constrictor With an Extra Turn [Ashley 1252] can also be tied in the bight; his method of tying the Constrictor by taking a round turn, lengthening a bight, and lifting it over with a twist (described at Ashley 1188) produces it, if one starts with a clove hitch instead of a round turn.

Ashley 1201 can also be tied in the bight, at least in principle (when lifted off the post, it capsizes to nothing without access to the ends), but puzzling out the exact method eludes me so far and may not be worth the trouble. As Ashley says, it is rather ponderous.

[Added 3/2/98] I've discovered the method, after some time away from this subject. Diagrams will follow as soon as I get the time.

[Added 3/3/98] Here we go. First throw two bights of opposite handedness:

Lap one over the other:

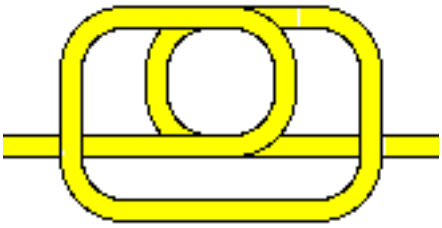

Twist the combined loops into a figure eight, and insert whatever the knot is to be tied around as shown by the arrow.

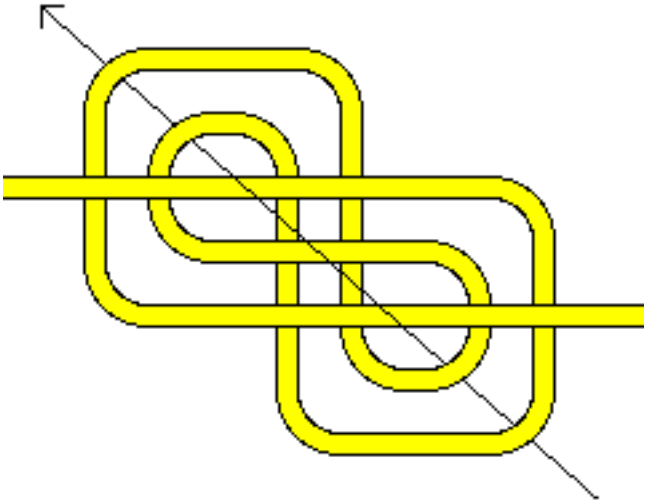

Finally, tighten and adjust to smooth out the extra crossings.

This knot is very similar to a recently discovered knot called the *Boa knot*; in fact, if the bight on the left in step one, above, were of the opposite handedness, a Boa knot would result. However, as best I can tell the Boa knot is inferior to this one; it is harder to draw up, no more secure (possibly less so), and less attractive in appearance.

[Added 7/29/98] One slight advantage that the Boa Knot seems to have over Ashley 1201 is that it introduces no twist into the rope when tied in the bight, while 1201 does; thus, if one tied a series of such binder knots in succession in the bight of a single rope whose ends were fixed, the rope would eventually start to kink using 1201, but not the Boa. However, it is difficult to imagine a situation in which this one point would outweigh the other ways (described above) in which 1201 seems superior to the Boa.

For comparison, the Constrictor knot also introduces no twist, but the Constrictor With an Extra Turn [Ashley 1252] produces even more than 1201. The Clove Hitch produces the same amount of twist as 1201.

More on (possibly) new ways to tie old knots

[Added 3/4/98] The Flemish/Figure-eight bend and loop are popular for their strength, but much is made of how time-consuming they can be to tie. While this is true of the loop in cases where one can't just tie a figure-eight in a doubled end (as when hitching to a ring, say), it needn't be true of the bend form. Much easier than tying a figure eight in one end and following it back with the other (the standard method) is this: tie a Thief's Knot with long ends, then wrap each end around and tuck it through again. I'll make up diagrams when I have time, but the method should become clear if you just tie a Flemish bend by whatever method you know, then untuck each end once.

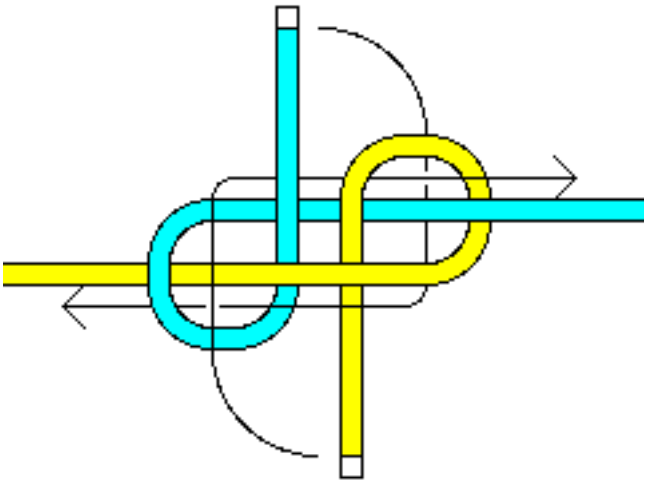

[Added 3/13/98] Here's the diagram. I think it pretty much explains itself.

[Added 3/19/98] Just a brief comment: this is exactly analogous to Ashley's method of tying a Ring Knot (Ashley 1412).

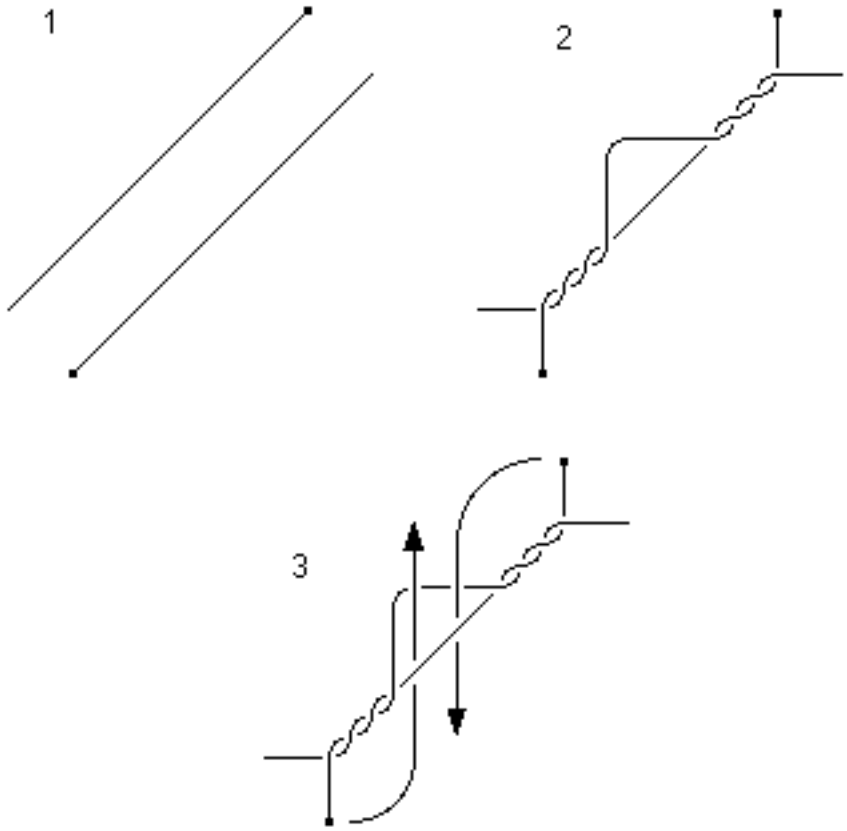

[Added 3/26/98] A simple method of tying a Barrel Knot (Ashley 1413, except this results in the ends opposite instead of parallel). With fewer twists this yields a Double Harness Bend (Ashley 1420), or with even fewer a Thief's Knot (this is how I begin the Flemish Bend, above).

Miscellaneous Notes

[Added 6/30/98] I recently, at a friend's request, created some new knot graphics to illustrate the IGKT's six-knot challenge.

[Some material relating to Desmond Mandeville's *Neat and New Bend*, previously presented on this page, was removed on 12/14/97.]

Please email me, Paul Hahn, at manynote@library.wustl.edu, if you have any comments regarding the above.

Campfire (Home)

Troop 480 Information

The 1923 Scout Creed

Links Relative to Scouting

Links to other Troops across America

Troop 480 Calendar

Here's a Jerky Recipe

Some Basic Knots

Our Album

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What a knot page! This is not to say that this is not a page, but a knot page. If you enjoy tying knots, visit these sites:

GORP - Knot of the Week-good all-around outdoor site.
42nd Brighton (Saltdean) Scout Group UK-many animated knots for Scouts.
Knots on the Web (Peter Suber)-incredibly vast list of knot resources.

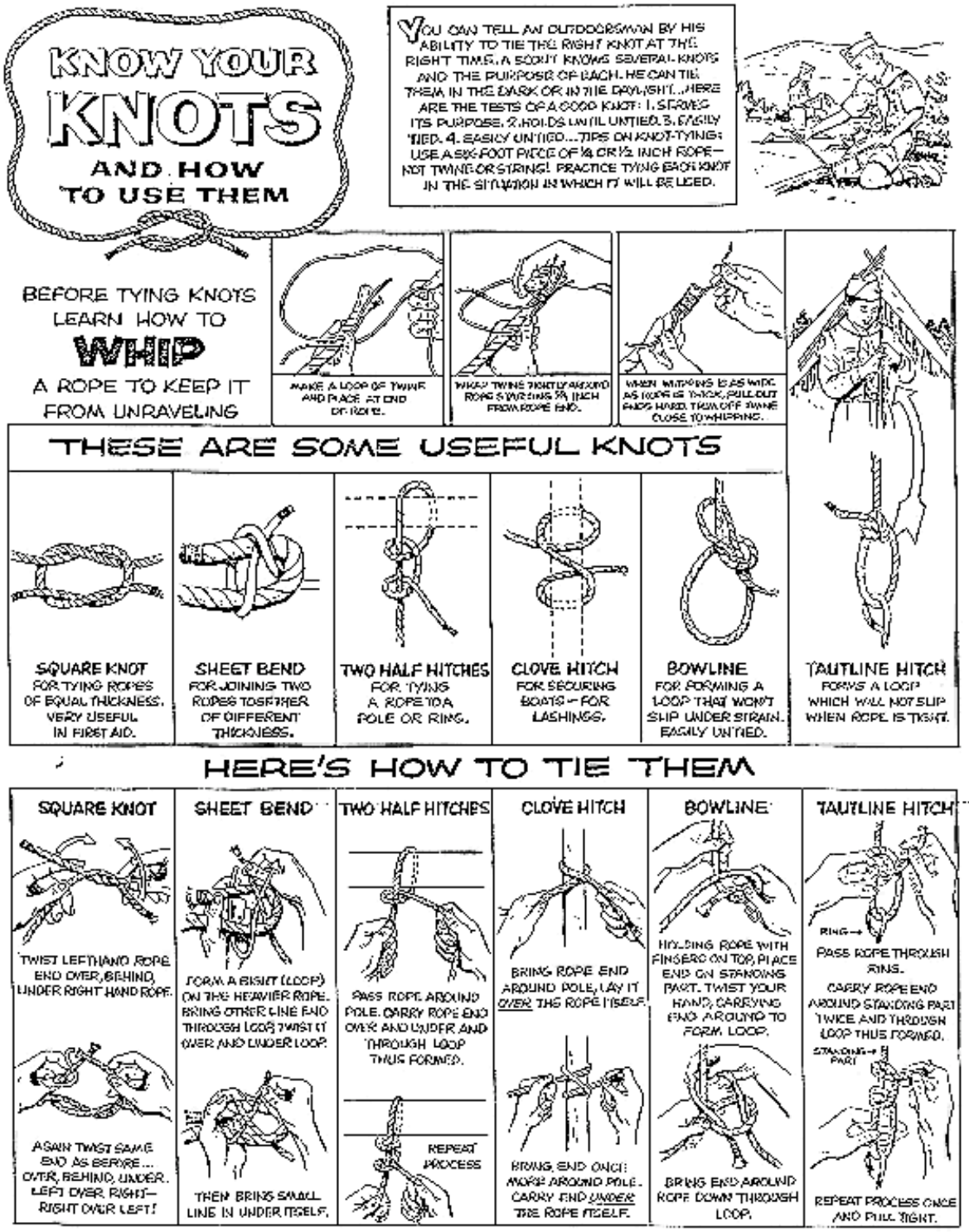

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Baidarka Instruction Manual

Building the 6.6m and 5.28m

Dyson Baidarka

*(**Editor's Note**: Craig nicely sent me a stack of photo's to scan in. In the interest of disc space I did not include all of them. For some I substituted pictures I already had for Tom Clark's article. Nick)*

You are about to build one of the lightest, fastest, most comfortable and most seaworthy kayaks available. This 2000 year old design will be a delightful surprise on your maiden voyage.

What type of boat should I build?

My first skin boat was the 6.6 Meter 2 hatch design with rudder and sail. What a gorgeous craft..... I could not believe how well it paddled and sailed my first time out. Great primary stability, (so good that secondary stability has fortunately not yet been experienced). It handles well in rough seas and is quite speedy in calm water. Depending on crew -- expect 3.5 -- 4.5 knots average over all.

I included 1/2" X 3" ship's teak battens in my first kayak which ran the length of inside deck. These 4 strips definitely added to the appearance of the craft's interior, but after some time I found that the extra weight (15lb) was not worth the trade off in weight and foot room. I then removed these wood battens and found car top loading and unloading to be much easier.

The finished 6.6m Baidarka weighed 86lb with the wood battens and 71lb without the battens. This was with the 26 oz. skin. The construction time was approximately 200 hours. I would expect the same finish time from a first time builder with moderate mechanical ability.

The 6.6m Baidarka also paddles reasonably well solo from the rear seat. Be sure to put a cover over the front hatch. Paddling the 6.6 by yourself is a good work out. It is not difficult to make above 3 knots.

Sailing the 6.6m Baidarka is exhilirating. The sail rig (for down wind sailing only) can be made for about $30 to $50 but I decided to have the mast made for the Baidarka on a large wooden lathe at a cost of $47.00. The sail was made by a local sail maker for $150. I later put windows in the sail as this helps the pilot see where he is going. Of course a wind at your back is best as there is no center or side board to keep you from slipping side ways. Experimenting with different wind directions is a lot of fun. But be very careful as a strong side wind will capsize you. I also attached cleats (need picture??) and reinforced them with stainless steel braces running forward and attached to station #4. Be careful not to position anything on deck where it might interfere with your paddling stroke or bang up your knuckles.

For the rudder system I used the designed set up and attached "Necke" steering pedals to aluminum sheet metal brackets sewn to the stringers. Cabling was easily run through plastic tubing and affixed with plastic wire ties (see pic 1). To draw and lower the rudder I tried many different approaches and found that the rigging (see pic ??) worked best. The rudder sometimes needs a tap from your paddle if you have pulled it to the full up position. This is especially true if there is sand in the mechanism.

The 5.28m (17.32 ft.) is also a wonderful craft. It weighs less (38lb) with the 14 oz skin, is a single and doesn't have a sail. Also, at George's urging I am trying this Baidarka without a rudder and find it very stable and tracks well.

I am very pleased with the 5.28m Baidarka's performance in calm water as well as a rough confused sea. It is wonderful to be able to toss this boat on your shoulder and just walk down to the shore. As opposed to needing a set of wheels or a strong partner (see pic ??) which are necessary with the 6.6m Baidarka.

Construction time of the 5.28m Baidarka is less than 100 hours depending on your experience. I purchased the tubing already bent for this craft and saved at least 15 hours work. Bending tubing can be difficult and wasteful the first time around as it takes a "special touch" to get it right. Although it is fun to learn this technique.

USEFUL TOOLS

- Band saw or saber saw. I prefer a 1/4" wide blade with 16 teeth per inch (TPI
- Bic lighter
- Clamps ("C", handy, spring type)
- Deburring tool
- Drill press or hand drill. A small drill press is almost a necessity.
- Files (1/2" round, 3/4" round, flat)
- Grinder or belt sander (optional)
- Hand sander (optional)
- Hemostats

- Leather glove. See pictures for various themes on this item. Cut and modify to suit yourself.
- Metric tape measure (24 ft.). This may be hard to find but it is convenient when laying out the stations.
- Net needle
- Respirator mask (for coating and cutting fabric)
- Seam ripper (optional)
- Sewing Needles. Sail makers needles both straight and curved are a must.
- Small tube cutter
- Soldering iron with flat cutting tip
- Spring loaded center punch
- Tube bender 1/2"
- Vise
- Wire cutters
- Work bench

Tubing Bender

Assorted Tools

Modified Gloves

I understand that it is possible to mount the station supports on a shop wall and build outward instead of upward. Good Luck

SUPPLIES NEEDED

- Acetone (less toxic than Xylene)
- Contact cement (not water soluble type)
- Cutting lubricant
- Electrical ties
- Fine tip marker for layout
- Foam blocks (for holding kayak while painting)
- Foam plugs (for tubing ends)
- Nylon washers (for tie down points)
- Paint brushes
- Ply-wood for tube bending patterns
- Silacone sealant (for tubing ends)
- Steel "tie" wire (for holding frame parts in place)
- Tubing splices (if susing short tubing length)
- Vaseline (for bending tubing)
- Xylene

Materials from the kit

SHEET METAL PARTS

At first one might be a bit over taken by the massive number of holes (6.6 m = 1,730 and 5.28m = 1,300) that must be drilled but I have found with proper center punching they go rather quickly.

The burnished combing

First of all, don't bother laying everything out with dye and scribing cutting lines. It is faster and much cleaner to cut out the part patterns from the blueprints and then glue them in place with rubber cement, wall paper glue or double sided tape. Be sure to leave 1/2 inch border around the cutting lines. This way you have a better view of where you are cutting.

Hole drilling started with an automatic or self loading spring type center punch. I have found it best to center punch all the holes after taping the blueprints to the aluminum. This way if your pattern moves while you are working you can realign easily on the center punch marks.

Drill the 1/2" and 3/4" holes, in the bulkhead pieces, which end up being cut in half when you band saw the outside of the pieces. If you don't drill these holes first you will have to hand file them later.

An adjustable hole cutting bit "fly cutter" is the only economical way of cutting the large diameter holes. Be very careful to hold the metal tightly in place and use the right speed on the drill press. Look out for the spinning arbor it is a real knuckle buster. Be sure to use a wood backing plate when cutting these holes. A good tip when using the "fly cutter" is to cut half way through the metal and turn it over and finish your cut from the other side. Somehow this just works better.

Some have used a saber saw to cut the larger holes.

Most of the sheet metal cutting is done with a band saw or saber saw. (stop picture) Practice with scrap to be sure you have the right blade. I use a 1/4" 16 TPI blade for this. Some suggest 18 TPI, 3/8-1/2 inch blade.

After all the cuts are finished file and deburr the edges. The deburring tool pictured (pic #) is a wonderful and cheap tool for this operation. Otherwise you can simply use a hand file.

Drill the small lacing holes and use a single flute counter sink on both sides of the hole. Be sure to visually re-inspect each hole for a clean counter sink otherwise you will end up breaking your lashings. This inspection can be done also by feel. Running your fingers over the holes. The ideal counter sink would be as follows.

Insert picture of counter sink

Clean all pieces with Acetone, solvent or soap and water. This is done so that later the epoxy will stick to the lashings and aluminum. You might also burnish these flat parts to make them look better. Scotch Brite works well.

LACING THE STEM (BOW) AND STERN

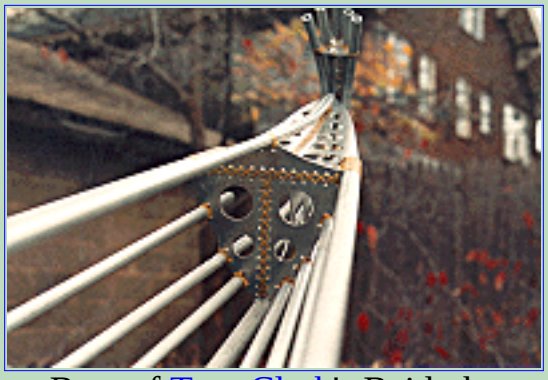

Bow of Tom Clark's Baidarka

Note: discuss types of thread etc. I have no input on this....

Lacing all the pieces to together is a simple task but takes a bit of time and concentration. Use steel wire or electrical ties and bind all pieces together in place. Use a single length of the nylon thread and a straight needle.

George sells good needles, straight and bent, but you can get all kinds of other sizes and shapes at your local sewing shop.

The stern top piece is called out to be pre-bent in between the center line of holes. I have done this and the bend tends to follow either one set of holes or the other and thus becomes off center. So be careful. I have also just pulled this piece in place and lashed it down. This works well.

Start your lashing wherever you please but be sure to hide any knots so you can't see them.

Also, be sure to position knots where the skin won't later touch them and create a lump.

TIP: It is best to use thread length of no more than twice the width of your arm span otherwise you will spend a lot of time untangling unwanted knots and snarls.

CORROSION:

Corrosion is a problem when using any type of metal for construction. The most important thing to consider is not to have more than one type of metal in contact with another, i.e. aluminum tube with a brass plug or stainless steel bolts. This combination will create a very accelerated corrosion situation. Many thoughts have been considered regardin the frame corrosion problem including anodizing and coating the frame parts. Both solutions have their own adverse effects. For example, anodizing makes the metal more brittle and will wear off in areas of friction. This will then concentrate any corrosion. Another problem is that coatings and anodizing will crack when flexed. As this craft is built to flex the problem of cracking is obvious.

The best solution so far is to simply use the tubing and sheet aluminmum as supplied and keep your kayak well flushed with fresh water.

After a time you will notic some corrosion but don't be too concerned as it will eventually cover itself with a white film and thus slow down it's sewn progress. Eventually, your frame will become structually impaired but this happen to all types of craft as well as our own bodies. How you take care of your craft and body dictates how long it will last.

TUBE BENDING AND CUTTING

A Hi-Tech vise

I have found that cutting tubing with a band saw leaves a cleaner edge then a tube cutter. This is important when you are using tube splices. Be sure to have a square cut so the butt joints match well. If this cannot be done on the band saw then use a tube cutter.

Tubing can be purchased in three different configurations. The best is full lengths, but UPS does not ship packages over nine feet. Therefore you can either pick up full lengths or pay for extra shipping.

I have found that splicing the tubing after it has been cut to 9 ft. lengths is satisfactory but be careful to have the splices fully inserted into each piece.

The third way to purchase the tubing is to have it cut and bent by George. Pre-bent tubing is well worth the added cost. You might be able to purchase lengths locally but I have not had much success finding the right wall thickness. I think the local salespeople put it to those of us who only purchase small amounts at a time.

Note: That lengths in cm on the plans are for finished lengths.

Do not cut your rib tubing exactly to length before bending. It is best to leave 2-4 inches on each side of the tube so that you can cut to length, matching the blueprint, after the bend is done. You will see the wisdom in this after you do your first bend. Installing splices to connect the tubing is a little tricky. I have experimented with different ways of inserting splices including heating the tubing (not recommended). The best way is to mark the center of each splice for reference as to how much splice goes into each tube. Without this reference you may end up with a short piece of splice in the tube, thus creating a weak spot.

Note: Be sure that all the ends of the tubing are cut flush.

Be sure ther are no burrs on the ends of the tubing or else the splices will gall (bind). Next compress the splices with vice grips or a vice and slide the splice into the tubing as far as possible

do the same on the other end of the splice. At this poing you must hold one piece of the tubing in a jig or some other type of contraption. I simply held the tubing flat and secure by screwing a piece of wood to my work bench with the tubing in between. This holds the tubing streight and secure. I then hammer the two pieces together using a piece of wood to protect the end of the tubing. Keep an eye on the center of the splice. If one side is going in to the tube too fast use vice grips to hold it in place until the other end catches up. If a splice is lose expand it by putting a screw driver blade into the slot and twist.

Note: The cut and bent tubing that George sells come with a set of plans and markers on each cut tubing. Be sure to follow this direction.

I used 2 sheets of 3/4" pressed board (ply-wood is better) screwed together as my jig for bending. I then used 2" X 3/8" aluminum doweling for positioning pegs. You will be well served to look carefully at the pictures and read the text in the book Baidarka regarding tube bending.

Note: You will only need to purchase a 1/2" tube bender as sends the 3/4" tubing already bent and slotted.

Be sure to practice a few bends before you work with the final parts.

The blue prints have pivot points plotted where you place the tube bender alignment dowel. As with the flat metal parts, glue, tape or paste the blueprints to the jig board, and work from the print. You may use the same board for different tubes. I got a bit mixed up with drilling all those holes in one board. It may be better to can flip the board over and start again on the back side. Be sure that any subsequent hole layouts do not come near previously drilled holes, otherwise your new hole might drift into another hole used on a previous bend. I used a hand drill for most of the holes.

I used a dowel jig attachment on a hand drill to make my holes were perpendicular to the flat surface of the board. The size of the hatch coaming can be changed to accommodate different sized paddlers. It can be made wider or longer depending on your needs. If you have long legs you may want to make this part longer. If you have a large bum you may want to make this part wider. I would suggest going to your local kayak shop and trying different size hatches then build yours to fit your needs. A spacer in the hatch coaming sheet metal part should make up for any added length due to your modification. SHOW PICTURE FOR LOCATION

In bending the hatch coaming tubing... I made it match the drawing which was pasted to a bending jig. The upward bend of the tubing was done by putting plywood over the coaming ring and having my son stand on it, then slowly bending it upward a little at a time till it met the drawing....

As for bending the hatchway tube, there are no bending centers on the drawing because it is an incremental bend, you just walk the bender around the tubing following over the pattern. A symmetrical job is possible by starting in the middle of the tube, (clamp the beginning solidly to your table) and bend one half of the coaming, then flip it over and bend the same half again (same goes for ribs). This way you are infinitely more likely to end up with two halves that mirror each other than trying to bend the whole thing from one end to the other. Getting a good hatchway on the first try is tricky but not impossible. Take your time...

ASSEMBLING THE FRAME

The most critical part of this operation is to have the frame supports cut out and precisely placed on the strong-back (work bench)

I built a work bench (see Pic) out of 3/4" pressed board and 2X4's. This made a nice flat surface on which to work. My frame supports were made from 3/4" pressed board and were attached to the bench with dry wall screws. (see pic). Any old scrap from 1/4" on up will make good frame supports.

Alignment of the frame supports is done by running a piece of nylon thread through each frame support and then centering the supports on the thread. Attaching the top portion of each station is done by sewing in place a gussett or knee. You will find that there are three different types knee design for this area.

1. The insert design.
Where the knee is inserted into a slot made in the tubing. This is the strongest support but is time consuming to do and some think it is over engineered for the strength needed. 2. The bent tab design
This design is very strong but incorporates two pieces for each joint. It too is a bit over engineered.
3. The simple design
The simple design is the one that comes with the plans as of today. It is very easily cut out and installed but does not provide rigidity until the ridge beam is installed.

I have used all three types of installation and found each to be acceptable. I will stick with the simple design as it takes less time.

Once the knees have been cut out and holes drilled, assembly takes place in a large vice or calmping device (pic). The two pieces of tubing must be held flat and in place while the knee is sewen in place. A tight lashing does the trick. Don't forget to put plugs in the ends of the tubing.

Putting the frame together is a matter of simply starting at the bow and working aft. Be sure to check and double check alignment of each station as well as being sure that all ribs are vertical. George suggests marking each rib from the blue print as to where each stringer goes later on.

Don't forget to file the 3/4" groove in each station before attempting to put the frame together.

As each part goes into place, tie it with either wire or plastic ties. Then remove them as you do your lashing.

LASHING THE TUBING

Lashings will show through the skin so don't be concerned. Knots tied in the wrong place will also show. You might want to put a small piece of fabric over the lashings and inside the outer skin to protect against chaffing in the stem and stern areas where the gunwale terminates.

Note: You might want to put a piece of fabric over the lashings which attach the gunwales to the stem and stern. These areas are somewhat sharp. This application will prevent the skin from chaffing.

I have also found that there are only two basic knows used in lashing the kayak together. The overhand loop and the half hitch. The overhand loop (see pictures) is used to start or anchor the lashing and the half hitch is used for finishing the lashing. In the case where you run out of thread, I do not try to attach two lengths together, instead I simply start again with another knot.

Lashing the tubing is simple but tedious. Be sure to use the half hitch tie off method in the diagram. This will pull the lashing tight and hold it in place. It is also a good idea to melt the ends of the lashings with your Bic lighter. An alternative is to leave the lashings ends long and burn them off later with a soldering iron.

You will want to use a net needle (see Pic) for this operation as well as have your hand or hands covered with leather gloves with all but the little fingers removed.

You might turn the frame upside down for tying the lower lashings. This makes it easier on your back. the frame regains its shape when reattached to the frame.

EPOXYING THE LASHINGS

After the frame is lashed together and aligned leave it attached to the frame supports. This will keep it in shape during the epoxy.

I have used West Systems epoxy and found it to be very easy to work with. Any "laminating or coating" epoxy will do. The thinner the better. INSERT CANANDIAN BRAND OF EPOXY

Be sure to read and understand the instructions on the epoxy. Otherwise you may end up with a coating that doesn't dry properly.

Clean all surfaces with Acetone.

Lightly brush on a coat of epoxy to all lashings. Look out for drips and do not try to do the under side of the lashings. Reinspect for drips frequently.

After the first coat dries (per the instructions) remove the frame from the supports and turn it over. Now coat the bottom of the lashings. A second coat may be applied over the first coat.

This operation will increase the stiffness of the frame.

ATTACHING THE SKIN

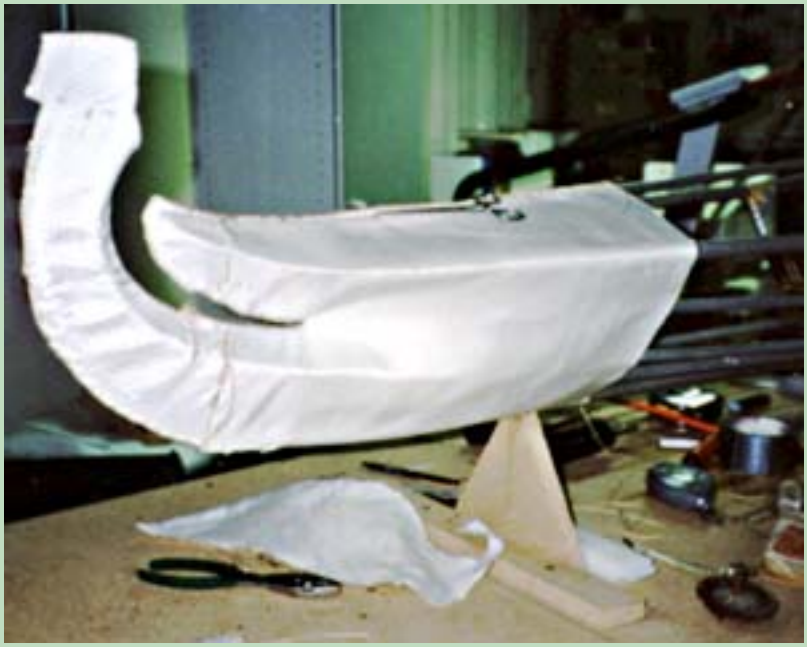

You'll probably be so excited at this point that you will want to rush. DON'T... This is a very important phase of construction and should be done with care to provide a pleasing look. It also doesn't take that long, so take your time. Mistakes made here can be irreversable. You may want to install carrying handles prior to attaching the skin. I used 1/4 inch nylon rope with 3/4 inch PVC handles. Attaching these in the vicinity of the aluminum sheet stations is a good idea as this is a very strong area. (see picture)

I would suggest that you use the 14 or 15 oz skin for most applications. For the double 15oz X 72" wide skin is OK. I used the 26 oz skin on my 6.6 and found it to be nice looking, easy to work with, but very heavy and overkill as to puncture resistance. The 24 oz skin also soaks up a lot of Hyplon. On the 6.6, I would have saved about 12 pounds if I had used the lighter skin.

Nylon shrinks. This is very important as you do not want to make your initial fitting too tight. One's tendency is to pull the skin too tight. I found while constructing my second boat that you can leave the skin fairly wrinkled and still end up with a tight fit after shrinking is complete.

Notes on shrinking:

1. Even a heavy fog in the air will shrink your boat's skin noticeably.
2. It only necessary to use a fine mist from a spray bottle.
3. Don't bother putting your boat in the sun to dry, it will shrink
4. in the shade.
5. Nylon shrinks 10%, hence, so you will see a tighter fit around the midsection of the boat as there is more material in this area. Leave this area really loose.
6. Even 6 months after you boat is finished you will still notice shrinkage and expansion due to water inside your boat and the ambient temperature.

What we are trying to do is find a middle ground on the tightness issue. The stringers and gunwales of my 6.6 Baidarka bend and release due to temperature even after 2 years.

How lose is too lose before you shrink? Be able to easily put your thumb in between the fabric and deck stringer. DO NOT USE A HEAT GUN TO SHRINK THE FABRIC except in very small defined areas such as around the hatch coaming or to take out specific wrinkles.

The first step is to turn your frame upside down and rest it on a few of the station supports. Snap a center line on the cloth and center the cloth on the keel.

Be sure to ask George to ship you 1 foot of extra cloth if this is your first boat. You'll find out why later. I held my material in place with easy clamps. 3 or 4 should do the job nicely. Now stitch a single running stitch along the gunwales to hold the fabric in place.

Use a large curved needle and don't be afraid to make this a tight stitch. 3" upholstry needles work well also.

Turn the boat over and cut away all fabric not needed with a hot knife. Be sure to leave an over lap of at least 2 inches on the deck stringers. Do not cut fabric away from the stem, stern or hatch coaming yet.

Now start in the middle of the kayak and work outward fore or aft. Run a basting stitch (single line with curved needle) along the deck stringer. This will hold the fabric in place while you sew and

cut the final seam.

I have in the past cut through the deck stringer lashing with the hot knife during this operation. In subsequent cutting and sewing operations I have taken a piece of 1/2" PVC pipe and cut it in half on the band saw. I then place this over the deck stringer and use it to back up my hot knife cuts. When finished with the cutting and sewing I simply remove this spacer. In addition, this extra spacer allows for a loser fabric.

I use two needles to sew this deck seam. I start by marking each side of the fabric with sewing marks (1cm apart) and then proceed by using a cross stitch.

IXIXIXIXIXIXIXIXIXIXI (X on top I under the skin)

Use a single thread. Cut away about 6 inches of the fabric then sew with one needle and then the other. Be sure to keep the seam straight. Use a hot knife to smooth rough edges on the fabric before you sew. When finished this seam is extremely strong. Don't be concerned about the seam unraveling as Hyplon seals this area well.

Once you have reached the stem area be sure to baste enough extra fabric in the (inside mouth area) of the jaw.

Start sewing along the top of the stem, up around and into the mouth area. Continue sewing and cutting fabric until the end of the mouth area is reached then start going forward toward the Horn or Prow area. Stop about 3 inches before the top of the prow. Now turn the kayak upside down and make your bottom cut starting at the point where the fabric begins to be lose. Cut away excess fabric and start sewing up the prow and stop about 3 inches before the top of the prow.

The top of the prow is finished at your own discretion. I have done a (dart) type of inverted peace sign and also a (cap) type of seam. (see Pics). As discussed previously, practice will reward you with a better job.

The stern area is also a little tricky in that as you approach the narrow stern the seam tends to pull off center. In order to reduce this tendency, alternate from side to side every 2 inches or so. Camp the opposing side as you go aft.

The vertical stern stitching is done after folding the fabric inside of itself about 1/2 inch then working up and down the vertical stern sewing holes.

The fabric around the aft keel area must be lashed and sewn to make a water tight seal.

Attaching the skin to the hatch coaming is not tricky although it is a bit time consuming.

First, sew the lower part of the skin to the bottom of the hatch coaming. When sewing a long seam like the hatchway circumference, you can save time (and a knot or two) by starting with (about) 3 circumferences of twine, use half the length going clockwise, then the other half counterclockwise, you'll meet back where you started. The two stitches are out of phase, so combined they give a

very neat stitch. Hide any knots under the tubing on the inside.

Next cut the fabric at the top of the hatch coaming with a hot knife. Make it level with the top of the coaming. (some people fold it over to the inside of the coaming and sew it there). I cut it at the top and then attach the rope around he hatch coaming with a barber poll type stitch using the top holes of the coaming and putting the fabric in between the metal and rope. Be sure to stretch the fabric as you go in order to take the wrinkles out.

The butt joint of the hatch coaming rope can either be sewn in place or covered with a piece of fabric. I have found that this section looks more finished with a cover piece sewn in place. You might try to leave enough fabric (from the verticle covering of the hatch coaming) in place to pull over this joint.

When the skin is in place and finished take a misting type spray bottle and mist the outside of the skin and let it dry. Be sure to keep the seams straight as this process proceeds. A properly tight skin should feel less taught than a bongo drum and tighter than a well maid bed. Kind of like the skin on your forehead. Try to take additional small wrinkles out with more misting.

KEEL WEAR STRIP

The keel wear strip is very critical to long term use of your Baidarka, especially in the areas of the bow and stern. These areas are exposed to a great deal of wear.

After the skin in installed and shrunk into place cut the wear strip to length and round the edges at each end. Rounding the edges will help keep the strip from coaming loose. Use contact cement to attach the strip to the skin. I have found a solvent based product such as DAP Weldwood to work effectively.

I tried a water based cement and found that it did not hold well. Use at least 2 coats on each surface for a tight bond. Be sure to center the strip and run it from the stern all the way up the stem (front).

Do not mask off the area to be cemented as it will leave an ugly line where the glue is not in contact with the wear strip.

After attaching the strip iron it down with a roller device such as a wall paper seam roller.

Note: The material sold by George adheres to the curved section of the Prow well on the 6.6 but wrinkles a bit on the 5.28. You might want to make a few small cuts in this area to make the strip lay down.

Any 1.5 inch webing should also work for this application but it should be flexible enough to mold to the keel. Some have used additional (left over) nylon material but this is difficult to cut straight.

REPAIRING THE SKIN.

As you might already know, many kayakers of old were able to make repairs while in the water. This was done by rafting a few boats together and flipping the injured craft upside and making the repair right on the spot. How novel.

The only repair I have had to make so far was when I split the seam on between the two hatches on my 6.6 meter Baidarka. I did this because the skin was too tight and was bending the stringers. I had to release the tension. The repair process in this case was as follows:

Remove all frayed or bulky material with a soldering gun cutting tip. Use a double length of nylon line and a very long needle or curved needle depending on the type of blind sewing needed. Make pilot holes with a hot nail for each stitch opening. This is necessary on the thick fabric but might not be needed on the 14 oz fabric. Sew up the "wound" as well as possible making sure that locking stitches are used so that the seam will not unravel if one stitch gives way.

Next, glue a piece of fabric over the stitches and coat with Hyplon. Minimum of 3 coats. This will hold very well and look fairly good if done with care and attention to detail.

Note: Should the hull of your craft need replacing for any reason, think about cutting a line at the gunwale and removing the old hull. Then sew a new piece of fabric to the hull and cover the seam with webbing. This will save a lot of work, fabric and Hyplon.

DECK ATTACHMENTS

Deck attachments should be firmly sewn to the ridge beams or deck stringers. A rule of thumb should be that the empty kayak should be able to be supported by a single attachment.

I have used nylon washers purchased at the hardware store. These washers are 1/16 inch thick and are 1/2 inch O.D. X 3/8 inch I.D.. George uses a PVC tubing ? X ?. One of the problems is that it is hard to blind stitch these pieces in place. George uses a curved needle for this purpose. I have used a small person inside the kayak to feed the needle back and forth.

Three or four stitches will hold the rings in place and the knot is terminated by using a double half hitch. I mask the rings and then apply Hyplon around the area covering the stitching.

HYPLON COATING

Hyplon is a brain burner so be sure to wear OSHA approved breathing mask otherwise you will have problems with mentation during the final stages of the project.

Xylene is the only thinner to use with Hyplon.

DO NOT USE Xylene SUBSTITUTES as they do not mix.

Before you put your first coat on be sure to burn off all fuzz balls on the fabric. this is done with a blow torch or lighter. Without this procedure those little fuzz balls will look like golf balls when filled with Hyplon

Hyplon is very forgiving as it dries out. I was very disappointed with drips and runs during my first boat. But later found that as the material dries out that drips and runs seem to shrink.

My experience with coats of Hyplon has been best with the following formula. First coat mix 50/50 and re-thin during initial application if necessary. Second coat 40% thinner 60% Hyplon Subsequent coats 30% thinner 70% Hyplon

Always thin as you apply to keep an easy flowing coat.

Be sure to build a well padded support platform for both the top and bottom of the kayak. Or use foam blocks (see pic) I tried using clearwrap over foam blocks and found that even the clearwrap left wrinkles in the skin. Be very careful in this respect as wrinkles cannot be removed.

I have tied down my boat after more than a month of cure time and found that the tie-down straps left marks in the skin. During each application I would suggest that you start at one end or the other and proceed toward the other end switching sides each 2 feet.

My suggestion regarding coats would be to apply 2 or 3 coats in one day, allow to dry, flip the boat over and do 2 or 3 coats and so on. Try to feather the coats at the gunwales.

OUTFITTING

A drain plug

Seats are a very personal accouterment of the finished craft. I have tried every conceivable type of seat from regular open cell upholstery foam to Spenco jelly (used on bicycle seats). I have found a closed cell, molded seat sold by Southwind Kayak (So. California) to be very comfortable on the bum during long trips. I also carry along two self inflating camping pillows for comfort. One for my back and one for under my knees. I also pad the knee braces on the 5.26 meter, which are built into the hatch coaming, with 1/2 inch closed cell foam.

Regarding foot peddles, I suggest using rigid peddles in the front cockpit on the 6.6 meter Baidarka and steerable foot peddles on the rear seat. My preference is the fixed pedals be supplied by George and Necke adjustable peddles for the rudder system.

In the single 5.28 meter I have installed Necke adjustable peddles and have tied them off to keep them stable. I may need them later if I decide to install a rudder.

Floatation is also a consideration. I am using beach balls currently but would suggest investing in a good set of puncture resistant floats. Floats are necessary in case your boat fills with water. Be sure to have floats in both ends of your kayak, otherwise it may end up looking like a channel buoy.

Regarding foot peddles, I suggest using rigid peddles in the front cockpit on the 6.6 meter Baidarka and steerable foot peddles on the rear seat. My preference is the fixed pedals supplied by George (Yakima made by North West Design works) and the Necke adjustable peddles for the rudder system.

In the single 5.28 meter I have installed Necke adjustable peddals and have tied them off to keep them stable. I may use them later if I decide to install a rudder.

Floatation is also a consideration. I am currently using a good set of puncture resistant floats. Floats are necessary in case you flip and your boat fills with water. Unless you have a good amount of boyancy you will not be able keep ahead of water sloshing over the hatch coaming. This is a very real senario. Be sure to have floats in both ends of your kayak, otherwise it may end up looking like a channel buoy.

I had my foot pedals poke holes in on of my float bags so be careful not to pinch the bag when adjusting the pedals.

GENERAL NOTES: Most hull damage is encountered while transporting the kayak. Roof racks come in many different configurations (see Pic) but it is very important to support the bow of the kayak. A flag on the rear is also important to attract the attention of other dirvers and to remid you of your rear backing limit.

Be careful not to bend your boat when it is filled with water.

MODIFICATIONS:

Hull modifications are possible but not desirable below the waterline as changes in length or width will greatly change the craft's performance.

It is also possible to change the height of the foredeck (for more leg room). This is accomplished by increasing the height of the deck stringer supports.

One of the most popular changes of the design is to either lengthen or widen the cockpit opening to accommodate wider and taller people. This is done by simply changing the size and shape of the

hatch coaming tubing, the coaming flatware and rope. Be sure to order more material if you are contemplating a change.

SUPPORT:

- FIRST: Locate a fellow Baidarka builder in your area For names and phone numbers call Dyson Baidarka & Co. or contact the Baidarka Historical Society
- SECOND: Join the Baidarka mailing list on the Internet and post questions there. To join the mailing list send an email item with the following text in the body of the message to majordomo@imagelan.com "subscribe baidarka"
- THIRD: Phone George Dyson at (206) 734-9226 (probably only fair if you are buying supplies from him.)

GOOD LUCK

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Back to Kayak building page

High Performance Wooden Sea Kayak Designs
Send snail-mail to:

Guillemot Kayaks
824 Thompson St, Suite I
Glastonbury, CT 06033

Phone/Fax: (860) 659-8847
Email Guillemot Kayaks
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Associação Nacional de Cruzeiros

Edifício Álvares Cabral - Cais da Rocha Conde de Óbidos - 1350-352 Lisboa - Portugal
tel.: +351 21 3958910 / fax.: +351 21 3955117 / email: geral@ancruzeiros.pt

Arte de Marinheiro

A arte de marinheiro consiste em saber aparelhar um navio a preceito. No tempo da navegação à vela, saber esta arte equivalia possuir um diploma de instrução profissional. Ao contrário dos dias de hoje não havia marinheiro que não soubesse todos os segredos sobre cabos e nós.

A bordo de uma embarcação só existem duas cordas: a do badalo do sino de bordo e a corda do cronómetro. O resto são cabos, qualquer que seja a bitola ou o material de que são feitos.

Básicamente existem 3 tipos de cabos. Os de fibra vegetais (linho, pita, cairo, cânhamo, sisal, algodão, manila) designando-se por enxárcia branca ou alcatroada, os compostos por fios metálicos (arame zincado ou aço inoxidável) e os de fibras sintéticas (nylon, perlon, dacron, kevlar, spectron, etc) mais usados na marinha de recreio.
Os de fibras vegetais não são tão fortes como os de fibras sintéticas e decompõem-se quando molhados. As fibras sintéticas por sua vez detrioriam-se com os raios ultra-violetas do sol, mas a sua variedade e resistência faz com que sejam as mais preferidas na marinha de recreio. Os cabos em aço, por não serem tão flexiveis, não são usados senão no aparelho fixo.

O aparecimento de nós iguais em partes diferentes do globo leva-nos a concluir que alguns deles foram descobertos isoladamente. Julga-se que já eram usados na pré-história pelos homens das cavernas. O nó mais antigo que se conhece foi descoberto em 1923 numa turfeira na Finlândia e científicamente datado de 7.200 AC.
Também se sabe que os antigos Gregos, Egípcios e Romanos usavam nós com alguma complexidade nas construções de edifícios, pontes e fortificações pelo que não é lícito julgar que apenas os marinheiros são detentores desta arte.

No que respeita ao seu uso na marinha existem registos escritos pelo menos desde o séc.XVII, mas desenhos e figuras mostram que o seu uso é muito anterior a este periodo.

Nós, voltas, falcaças, mãos, costuras, botões, pontos, pinhas, gachetas e cochins, são trabalhos da *arte de marinheiro*. Os nós são usados quando se pretende unir um cabo a outro, ligar os chicotes do mesmo cabo ou fixar um cabo a qualquer objecto (ex: cabeço, cunho, etc.). Nem sempre se aprendem pelos livros: fazem-se, desfazem-se e tornam a fazer-se sempre que seja possível.
A maioria destes trabalhos não tem actualmente utilização práctica sendo usados hoje em dia com fins decorativos. Outros porém continuam a ser essênciais em qualquer manobra onde se usam cabos, e por isso tão actuais como sempre o foram.
Um bom exercício consiste em fazê-los com as mão atrás das costas ou de olhos fechados.

Nós
(Simples, Oito, Frade, Direito, Ladrão, Escota, Pescador, Lais de Guia)

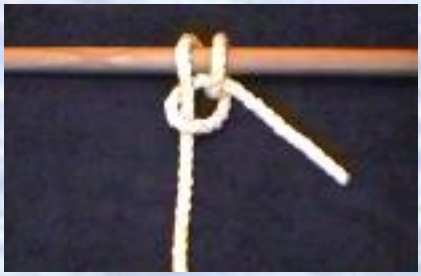

Voltas
(Fiel, Anete, Redonda, Cunho)

Outros
(Alça, Falcaças, Pinha)

Glossário

Abotoar - Amarrar ou ligar fortemente dois objectos com botões.
Alar - Puxar cabos.
Alça - aselha feita no chicote ou num seio de um cabo para receber um trambelho ou passar outro cabo.
Bitola - diametro de um cabo.
Chicote - extremidade de um cabo.
Cochim - entrelaçado de cabos com diversas aplicações a bordo, como defensas, capachos, etc.
Costura - trabalho feito nos chicotes de dois cabos para os unir definitivamente ou num cabo apenas para fazer uma *mãozinha*.
Cote - volta que se dá como a laçada, mas, depois em vez de o chicote ficar na posição que permite apertá-lo, se puxa por ele na direção do vivo do cabo, ficando assim mordido.
Descochar - separar os cordões de um cabo para o desfazer.
Embotijar - Cobrir completamente um cabo com um entraçado de fio ou merlim.
Emendar - Acrescentar cabo.
Esganar - Dar voltas em cruz, comprimindo ouitras já dadas em botão, cosedura, etc.
Espicha - instrumento para trabalhar cabos. Usa-se para alargar os cordões.

Falcaça - trabalho feito nos chicotes dos cabos para não descocharem.
Forrar - Cobrir completamente um cabo com uma camada de voltas redondas de fio ou merlim.
Gacheta - Entrelaçado de cabo, com vários aspectos usado em trabalhos de adorno.
Gornir - Enfiar o cabo pelo gorne (abertura).
Mão ou **Mãozinha** - espécie de alça num chicote.
Meia Volta - cabo que circunda uma única vez.
Morder - Entalar ou apertar o cabo para impedir que corra.
Nó - entrelaçamento de cabos, quer para os unir, quer para os ligar a um objecto.
Pinha - espécie de cabeça de cordões entrelaçados geralmente nos chicotes.
Recorrer - Deixar correr as voltas dadas sem as desfazer, folgando-as ou aliviando-as.
Sapatilho - aro em meia-cana de forma oval para reforço das alças.

Seio - a parte de um cabo que fica entre os chicotes.
Socar - Apertar com força e bem, um nó ou uma volta.
Urdir - Construir uma pinha.

Página principal da **A.N.C.**

Coloque aqui o seu correio, sugestões, ou informações.

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Home

Boating

Rope Knot

We have 7 knots within this category from which you may choose

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Bowline

Creates a loop for purposes such as slipping onto a bollard. Quick and will not slip, kink or pinch. Easy to undo.

Cleat Wind

The recognised way to secure your boat to a cleat. When half formed it presents a holding or adjusting position. Whilst secure, it can still be released very quickly.

Clover Hitch

A quick way to temporarily secure to a pile or bollard. Handy in that it can be preformed and 'thrown' over a pile.

Double Half Hitch

Just a quick simple way to secure to a bollard or staunchion in a temporary situation.

Fisherman's Bend

Usually used for making fast to a buoy or spar.

Reef Knot

(Figure 8 or Square Knot) - The simplest of knots that will not slip and as easy as the 'granny' anyway. Use only on similar rope thickness. Under stress it can jam and prove difficult to undo.

Wagoner's Hitch

(Truckies Knot) - Handy for 'strapping' boats to trailers. Advantages are its ease of adjusting and the pull down pressure that can be exerted.

Click Here to Break out of a Frame

BLACK LAKE

Boating Knots

Knowing how to tie a few basic knots is essential to a boater's security. The art of knot tying is known as "Marlinspike." Good sailors take pride in their ability to chose and tie knots. Below are 7 Basic Knots you should know....If you master these knots, you'll be way ahead of most recreational boaters in your knowledge of marlinespike. For practice, a section of rope six feet long with a diameter of 3/8" is a good size. Tie each knot several times to make a mental picture of the sequence. With practice you'll be able to tie each knot without thinking about it.

NOTE: The end of the line that you work with in tying knots is called the "Bitter End." The main length of line is the "Standing Part."

Two Half Hitches

This reliable knot is quickly tied and is the hitch most often used in mooring. To tie:

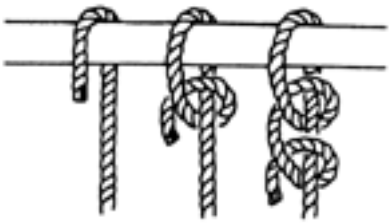

1. Pass end of rope around post or other object.
2. Wrap short end of rope under and over long part of rope, pushing the end down through the loop. This is a half hitch.
3. Repeat on long rope below first half hitch and draw up tight.

Bowline

This knot doesn't jam or slip when tied properly. To tie:

1. Make the overhand loop with the end held toward you, then pass end through loop.
2. Now pass end up behind the standing part, then down through the loop again.
3. Draw up tight.

Figure Eight

This knot is ideal for keeping the end of a rope from running out of tackle or pulley. To tie:

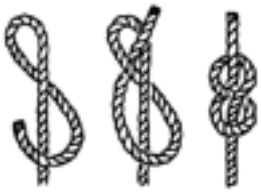

1. Make underhand loop, bringing end around and over the standing part.
2. Pass end under, then up through the loop.
3. Draw up tight.

Square Knot

This knot is used at sea in reefing and furling sails. To tie:

1. Pass left and over and under right end. Curve what is now the left end toward
   the right and cross what is now the right end over and under the left.
2. Draw up tight.

Anchor Bend

This knot is used to secure a rope or a line to an anchor. To tie:

1. Pass two loops through ring.
2. Place free end around standing line.
3. Pass free end through loops.
4. Complete by making half hitch.

Clove Hitch

This knot is the "general utility" hitch for when you need a quick, simple method of fastening a rope around a post, spar or

stake. To tie:

1. Make a turn with the rope around the object and over itself.
2. Take a second turn with the rope around the object.
3. Pull the end up under the second turn so it is between the rope and the object. Tighten by pulling on both ends.

Cleat Hitch

In order to secure the boat to a dock or secure a line to the boat you will probably use the cleat hitch.

1. Take the line to the ear of the cleat furthest from where the line comes from the boat (or load).
2. Take one wrap around the base of the cleat and then start a figure eight across the top of the opposite ear.
3. Finish with a half hitch turned under so that the line is coming away from the cleat in the opposite direction from which it came in.

Black Lake

Index of Knots and Lashings

Back Splice
Bowline
Clove Hitch
Diagonal Lashing
Eye Splice
Figure of Eight Lashing
Filipino Lashing
Fishermans Knot
Hunters Bend
Japanese Square Lashing
Manharness Knot
Prussic Knot
Reef Knot
Rolling Hitch
Round Lashing
Round Turn and Two Half Hitches
Sheep Shank
Sheet Bend
Square Lashing
Whipping of your choice

Other Knotting Resources

- Knots & Fishing Knots - Animated Knot Tying Programs for Windows
- Animated Knots for Scouts provided by 42nd BRIGHTON (Saltdean) Scout Group, East Sussex, UK

WebSpace Donated Courtesy of ARCON Web Services

Guide to

The BSA Knots

Thanks to Michael F. Bowman, the NetCommish, *(mfbowman@usscouts.org)*, for sharing the artwork displayed here.

Thanks also to Randy Spradling, Simon Kenton Council, *(freemason@aol.com)*, for his exposition on How to Wear These Knots, from rec.scouting.

Full page display of the knots (39K)

See also Mike Walton's Knot Page and his instructions for wearing Devices & Eagle Palms in conjunction with the knots..

Youth Achievement Awards Worn as Adults

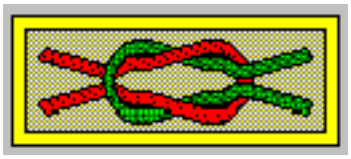

Arrow of Light

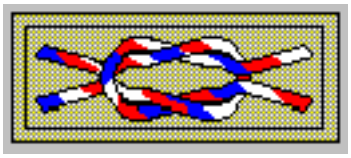

Eagle

Quartermaster Award

Youth Achievement Awards Which May Be Worn as Youth and as Adult

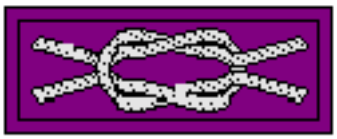

Religious Award (Youth)

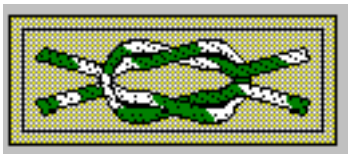

Hornaday Award

Lifesaving Awards

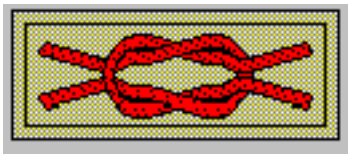

Honor Medal

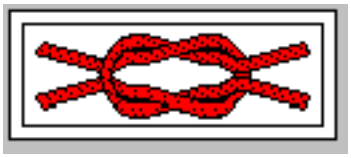

Heroism Award

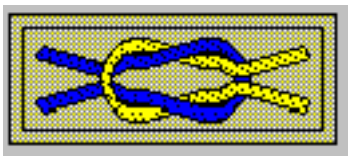

Medal of Merit

Leader Training Awards

Caution: These are the latest requirements, sometimes patched from several different sources, that I have at hand and are presented as a guide. To earn any of these awards, you should contact your District or Council Training Committee for the current requirements.

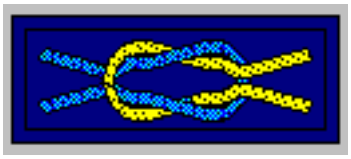

Cub Scouter Award

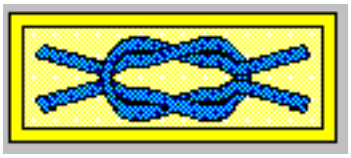

Cubmaster Award

Den Leader Award

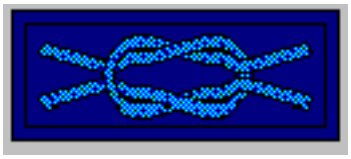

Den Leader Coach Award

Professional Training Award

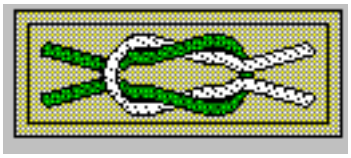

Scouter's Key

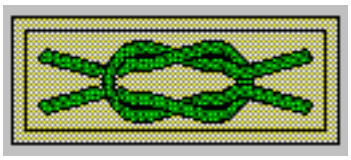

Scouter's Training Award

Sea Badge

Tiger Cub Group Coach Award

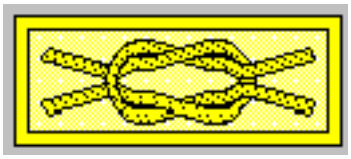

Webelos Den Leader Award

Honor Awards

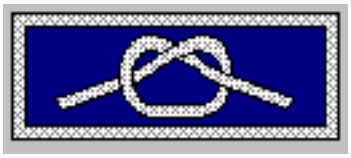

Award of Merit

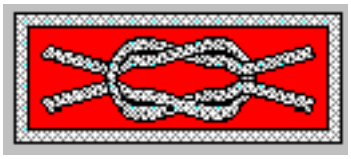

Distinguished Commissioner Service Award

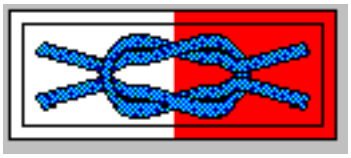

George Meany Award

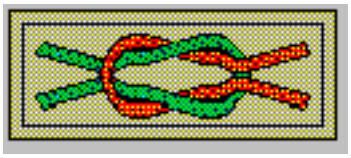

James E. West Award

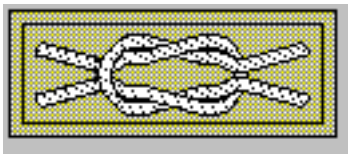

National President's Scoutmaster Award

of Merit

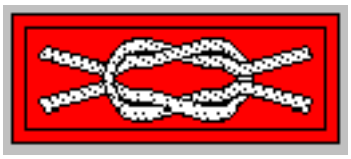

Order of the Arrow Distinguished Service Award

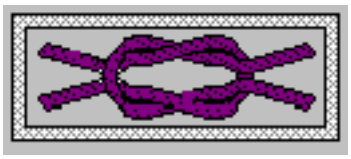

Religious Award (Adult)

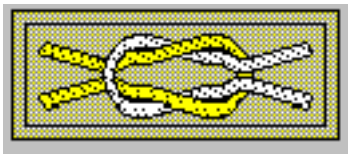

Silver Antelope

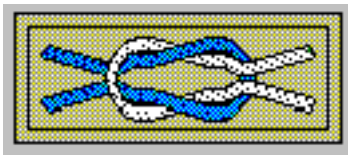

Silver Beaver

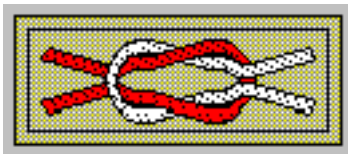

Silver Buffalo

Silver World

Spurgeon Award

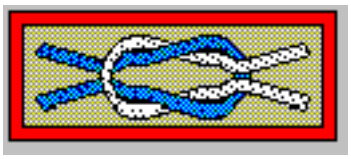

Whitney M. Young, Jr., Award

Return to the Requirements Page.

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http://www.emf.net/~troop24/reqs/knots.html

To:
Troop 24
Berkeley CA

Lots About Knots!

Learn to tie these knots!

Courtesy of Boy Scout Troop 9, Billings, Montana					
	Bowline Knot		Clove Hitch		Figure 8 Loop Knot
	Sheep Shank		Sheet Bend		Square Knot
	Tautline Hitch		Timber Hitch		

Animated knots for Scouts and Guides

The World Wide Web's Knotting Index - More knot tying information

Back to the Scouting Resources Page

Return to the Pack 982 Home Page

Ropes course

From Wikipedia, the free encyclopedia

A **ropes course** is a challenging outdoor personal development and team building activity which usually consists of high and/or low elements. Low elements take place on the ground or only a few feet above the ground. High elements are usually constructed in trees or made of utility poles and require a belay for safety.

Example of a high ropes course at night

Contents

- 1 Terminology
- 2 History
- 3 Modern courses
- 4 High course
- 5 Low course
- 6 Purpose
- 7 Research
- 8 See also
- 9 References

Rope climbing at the Alpine Center Bottrop, built by insight-out, Germany

Terminology

Ropes courses are referred to using several different names, including Challenge Courses, Ropes Challenge Courses, Teams Course, and Low Ropes, as well as more idiosyncratic names such as the Challenging Outdoor Personal Experience (Project COPE) course (used by the Boy Scouts of America).

An Aerial Adventure Park (or "European-Style" Adventure Park, Tree-Top Adventure course) has a more recreational purpose.

Other related terms include Obstacle Courses, Assault Courses and Commando Courses, although these terms also have slightly different meanings, often more associated with military training than with education and training for the general public.

Adventure Park in a forest

History

It is unclear where and when the first ropes course was created. Obstacle courses have been used by the military to train soldiers as far back as the ancient Greeks. Those courses, however, were primarily used for the training of extremely fit individuals and not necessarily aimed at the development of unremarkable persons as is common practice on ropes courses today. The use of belay and risk management systems on such courses was limited or often non-existent.

Many practitioners cite Georges Hébert as the originator of the "modern" ropes course. A French naval officer in the early 1900s, Hébert developed his own method of physical education, apparatus, and principles to train in what he called the “Natural Method,” which included the development of physical, moral, and “virile” qualities in an outdoor environment. Drawing from his naval background, Hébert patterned some of his obstacles on obstacles found on the decks of ships. “Hébertism” grew during and between the World Wars, becoming the standard for physical education training for the French military. Many ropes courses and challenge course programs in French Canada and Europe are still known as Hébertism courses today.

Two boys climbing on the Palisades Climb Adventure, an indoor rope course at Palisades Mall, West Nyack, New York.

Marble, Colorado, the site of the first Colorado Outward Bound course, has been cited as the location of the first ropes course in the USA, although this is highly unlikely. Patterned after a military obstacle course and similar to the course in use at the Outward Bound school in Aberdyfi, Wales, the course was constructed of hemp ropes. Belay systems were minimal or non-existent.[1]

Modern courses

Since the 1980s, ropes course sophistication has evolved considerably. Modern ropes courses incorporate sophisticated belay and safety systems using wire rope, friction devices, and climbing harnesses to manage what before were unmanaged risks. Recent technological advances in pole hardware and climbing equipment along with industry-accepted installation and design practices have greatly reduced the risk to end users and to the natural environment. Modern courses make use of a variety of materials other than trees, including utility poles and steel structures. Today’s courses can be found in a variety of locations, including wooded areas, open fields, or inside heated buildings.

A recent trend of themed courses (e.g. ropes course meets Disney World) has created a whole new genre of challenge course aimed at recreational pay-to-play users. New, mobile high ropes courses (originally designed by Jim Liggett of Ropes Courses, Inc.) and climbing walls built on flat bed trucks have made challenge courses more readily available to the public for recreational purposes and are generating increased publicity. Recent estimates by builders on the ropes-online listserv estimate that there are more than 7,500 challenge courses in the USA and that an additional 200 to 400 are built each year.

Adventure Parks with a more recreational-orientation are booming in Europe and awake a great interest in the USA and around the globe. They are usually designed for a larger volume of visitors and the Forest Adventure Park is very popular. They do not follow a specific educational concept, but see the individual, physical and mental challenge as a predominantly recreational activity. Neither climbing techniques nor special/specific physical fitness experience are necessary. Typical slogans are: Have fun, Test your Courage and Overcome your Own Fears. In an Adventure Park, the participants independently run a variety of trails of increasing difficulty levels. Each trail consists of several poles or trees that are connected by different acrobatic elements.

Adventure Park in Bali

High course

A high course can be a pre-fabricated, professionally installed course, built of

utility poles, cables, and bolts, or it can be a course that is hand-built in a wooded area, where ropes and wire are attached to different trees.

An alpine tower at Warren Wilson College.

Ropes courses can be described as static, dynamic, vertical, and M-Belay. With a static course, participants are attached to an upper wire, belay cable, with lanyards (ropes and carabiners) for safety. If the participant dangles, they will be caught by the wire. Advantages of a static course include needing fewer facilitators, being able to get more participants up on the course at one time, and allowing participants to do multiple elements without having to be lowered and climb back up after each. On a dynamic course, participants are connected to a rope, which someone on the ground will be holding onto and belaying the participant on the course. Participants on a dynamic course remain on a belay the entire time: climbing up to the element, doing the activity, and being lowered to the ground after. A vertical course is very similar to dynamic, except that the element is the climb up. Vertical courses can be: vertical obstacle courses with hanging logs, ladders, and tires or alpine towers with their unique hour-glass shape of activities. The M-Belay is the most complicated of the two, and involves to separate belays. Otherwise, it is very similar to a dynamic course.

Usually participants must sign a waiver before being allowed to participate on the course, because of the high risk of injury. Some participants may have a hard time completing the course due to its height and the physical challenge. Courses usually range from 25 feet through 50 feet tall, though some elements can reach upwards of 150 feet plus (as in the redwoods and some jungle courses). In order to climb up onto the course participants usually must climb, such as by using a cargo net or Jacob's Ladder, which could be made of rope, or an artificial climbing wall.

Low course

Low ropes courses consist of a series of real and imaginary obstacles designed to challenge groups and individuals to work together to accomplish a task. The classification of low ropes courses can be further broken into several types of activities:[2]

- *Cooperative Game, Socialization Activity, Ice-Breaker:* a fun activity designed to reduce inhibitions and break down barriers. These activities are often not based on a defined task but on a sequence of events. Users are often placed in positions where they are encouraged to try new things that may place them outside their normal comfort zones. Examples include: name games, people to people, raccoon circle...
- *Group Initiative:* problems involving real and imaginary ground-based obstacles (either natural or constructed) that challenge a group to pool their resources and work together to find solutions. Success is achieved only when all members have contributed to the outcome. Examples include: The Muese, Spider's Web, Carpet Maze, Crocodile Pit, Whale Watch, Peanut Butter River, Ragging River, T.P. Shuffle, Nitro Crossing, and Group Wall
- *Trust-building games*: activities designed to provide members the opportunity to demonstrate their trust in other members of the group through a series of sequenced actions. Examples include: Willows in the Wind and Trust Fall.
- *Low Ropes Elements*: a series of cables, ropes, and obstacles strung between trees or poles, 12 to 18 inches above the ground, low rope elements present tests of physical strength, stamina, agility, balance, and flexibility, and invite participants to confront such emotional issues as the fear of falling, the fear of failure, and the fear of losing control. Risk is managed by group members who assume critical

spotting roles. Examples include: Swinging Balance Beam, Triangle Traverse, Tire Swings, and Mohawk Walk.

Zig Zag

Mohawk Walk

The Wall

Purpose

Ropes course advocates claim that they meet a number of educational, developmental, and recreational goals. High ropes course and climbing programs generally focus on personal achievements and ask participants to confront their personal fears and anxieties. Challenges may be physical and/or emotional. In certain cases, high element programs involve the development and mastery of technical skills to manage rope belay systems used to secure other climbers as they move through the course. In such cases, outcomes often include exploring the fundamentals of trust, craftsmanship, and coaching. Programs using low ropes course elements or group initiatives are most often designed to explore group interaction, problem-solving, and leadership. Some of the commonly claimed outcomes include enhancement of cooperation, decision making, self confidence, positive risk taking, social cohesion, trust, self esteem, leadership, goal setting, and teamwork. In addition to these commonly cited benefits, a study published in 2000 in the Journal of Leisure Research found that ropes courses also demonstrate higher-level outcomes, including increases in effectiveness and efficiency, building relationships, developing understanding, setting goals, brainstorming ideas and task accomplishment.[3]

The British Royal Marines have an extremely difficult ropes course dubbed the 'Tarzan Assault Course'. To pass the Commando Course, recruits must complete this and other arduous tests consecutively under a strict time limit.

Research

Despite the rapid development of ropes course programming during the latter part of the 20th century and the increasing sophistication and professionalism in ropes course construction, there remains a lack of clear scientific consensus about the many claimed psychosocial training benefits of ropes course participation. A key resource is Aram Attarian's 88 page annotated bibliography of research on ropes challenge courses.[4]

See also

- Adventure park
- Aerial adventure park
- Climbing
- Group-dynamic games, Playground

- Karl Rohnke
- Outdoor education, Outward Bound
- Project Adventure
- Adventure therapy

References

1. Rohnke, Wall, Tait, & Rogers, 2003, p. 4
2. *A Facilitator's Guide to Adventure Challenge Programming* by Mike Smith and David Brassfield
3. Goldenberg, Marni A. (Spring 2000). "A means-end investigation of ropes course experiences.". *Journal of Leisure Research*. Retrieved 19 August 2015.
4. The Research & Literature on Challenge Courses (http://acct.affiniscape.com/associations/5266/files/attarian_bibliography.pdf) compiled by Aram Attarian PhD, North Carolina State University, 2005-02, 88p 540kb pdf

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Categories: Alternative education | Outdoor education | Types of climbing

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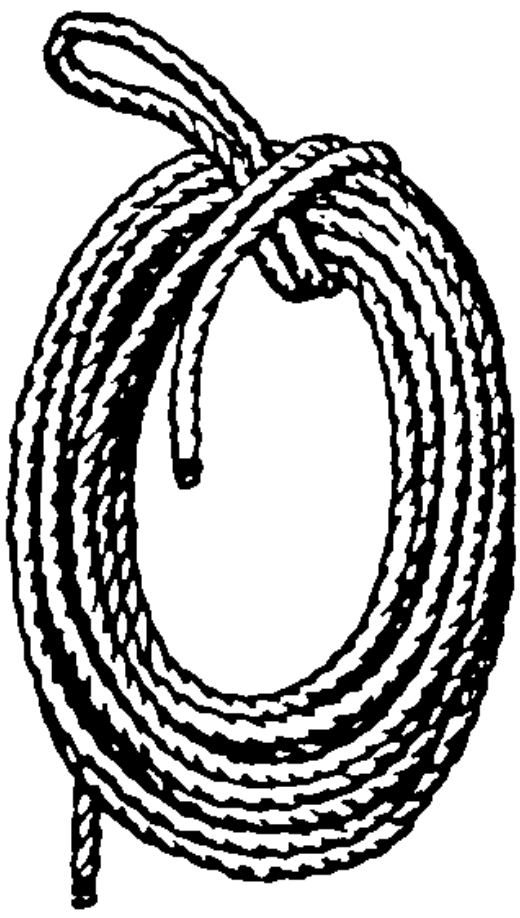

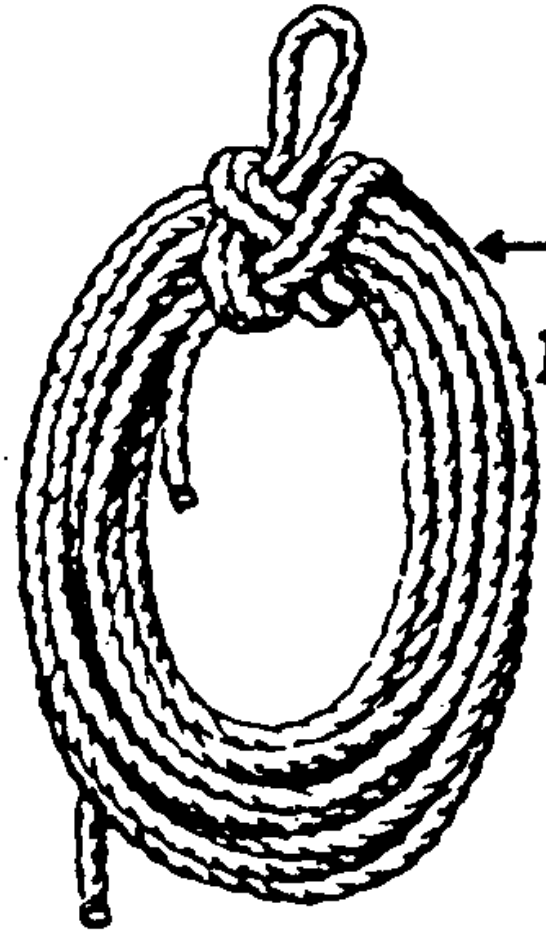

← A Coil made up for stowing

143. To break a heavy cord or string, take a turn of the cord around the left palm. Revolve the left hand so the cord is twisted in front of the palm, and wind the standing part several times around the fingers. Wrap the end (which is longer than illustrated) several times around the right hand; hold everything firm and jerk stoutly.

In each of the two methods given the string crosses itself at right angles, one part being held rigidly while the other part is strongly jerked.

My first impression was that the weakening effect of this harsh crossing was the important factor in causing the string to break invariably at this point. One of the "laws" quoted in dictionary and encyclopedia knot discussions is that "the strength of a knot depends on the ease of its curves," and of course a right-angle crossing provides the uneasiest curve that is possible within a knot.

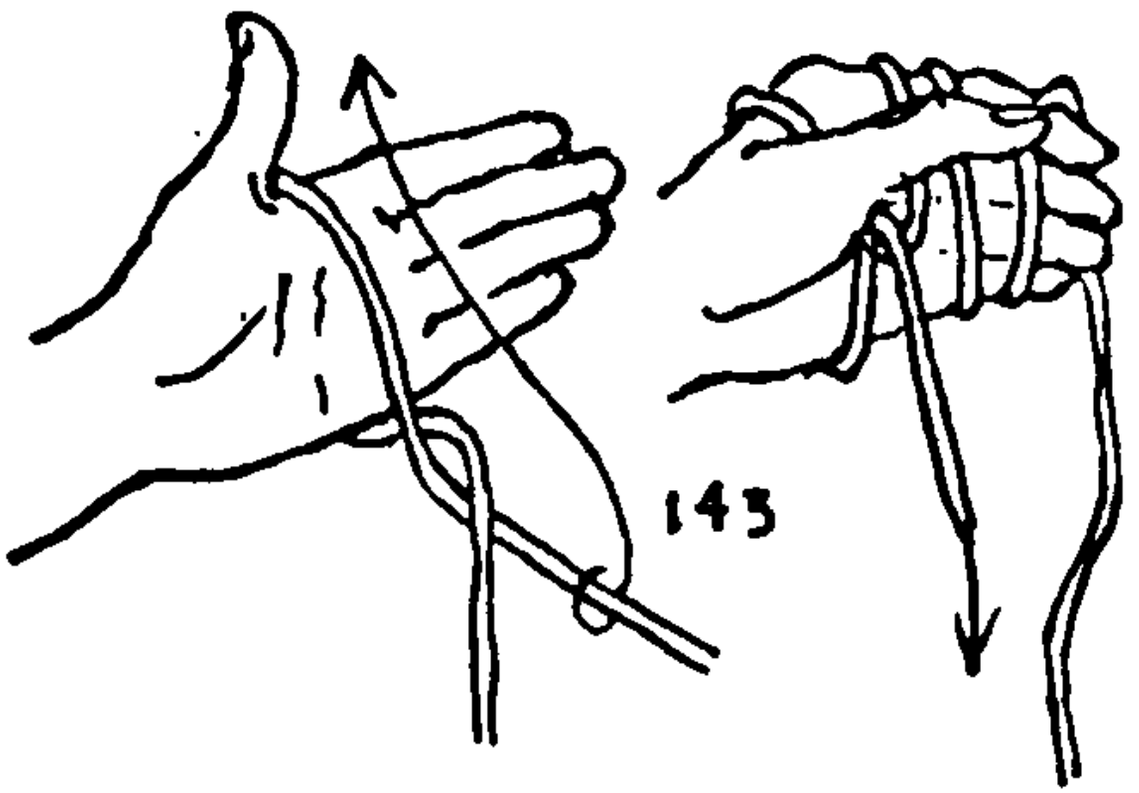

For joining structural members that will receive constant wear, use synthetic ropes such as Nylon or Dacron, since they are strong and rot resistant. Nylon is best for making lashings to a tree, because it has some elasticity. One synthetic rope to avoid is polypropylene, which degrades in the sun, makes slippery knots, and in time produces tiny sharp "whiskers" that can cut your hands. Also, be careful about using manila rope. Although it is made of natural fibers, manila hemp has a tendency to rot from within, making the user unaware of its defects until a load is applied and it's too late!

Overhand knot
Sometimes used as a stop knot or to keep the end of a rope from unraveling

Square knot
Most popular knot — used for tying everything from packages to payloads

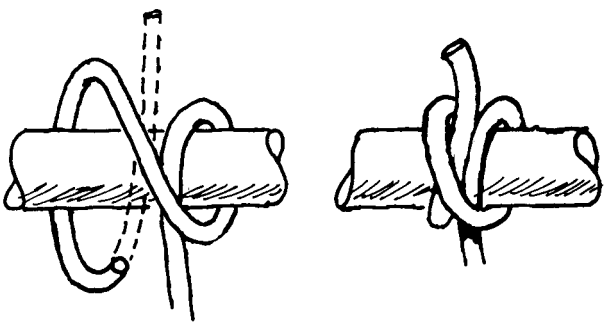

Clove hitch
Gets tighter as you pull on it, but comes apart easily when the pressure is released

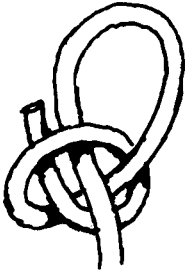

Slip knot
Constricts around the object it is tied to

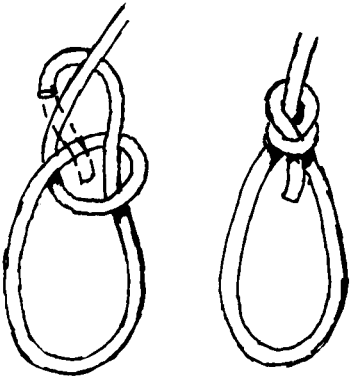

Bowline
A very secure seaman's knot used for slipping over pilings and posts

KNOTS

It is important to select the right knot for the task in hand. You never know when you may need to tie a knot, so learn their uses and how to tie – and untie – each one.

In the instructions for individual knots that follow the end of the rope or cord being used to tie the knot is referred to as the 'live end' to distinguish it from the other end of the rope, or 'standing part'.

Reef knot: Use to tie ropes of same thickness. Holds firm under strain, yet is easily untied. It is not reliable for ropes of different diameters, nor for nylon. Can be tied in other materials – use in first aid. It will lie flat against the patient.

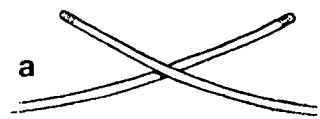

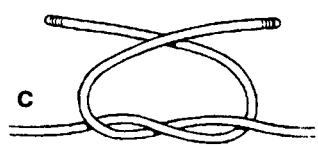

Pass right end over left (a) and then under it (b). Take left over right (c) and under it (d).

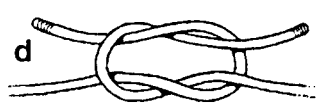

Check – the 2 loops should slide on each other. Tighten by pulling both strands on each side (e). To be doubly sure, finish by making a half-hitch with the live ends on either side of the knot (f).

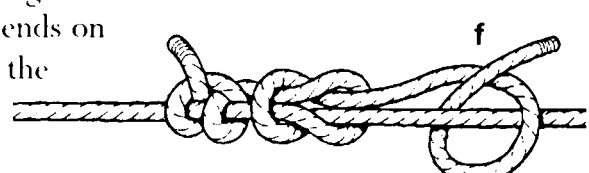

Simple knots

These knots are quickly made and will help you understand the more complicated knots that follow.

Overhand knot: Make a loop and pass the live end back through it.

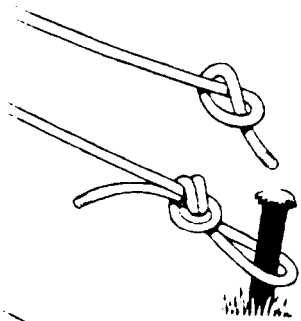

Overhand loop: Fixed loop for throwing over a projection. Double the end of rope and tie overhand knot with the loop.

Figure-of-eight: An end-stop. Make a loop. Carry live end first behind, then round, standing part. Bring it forward through the loop.

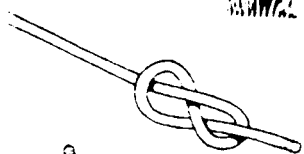

Figure-of-eight loop: Made in the same way as the figure-of-eight, but with line doubled, using loop as the live end. Can be used over a spike anchor for a belaying rope.

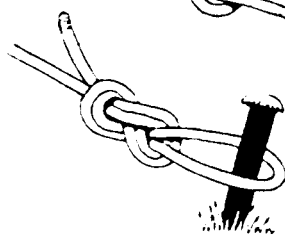

Rewoven figure-of-eight: Use when top end of a projection is out of reach. Make loose figure-of-eight along the rope. Pass live end round anchor and feed it back round the figure-of-eight, following exactly. Ease tight.

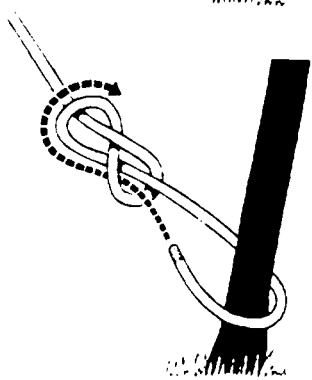

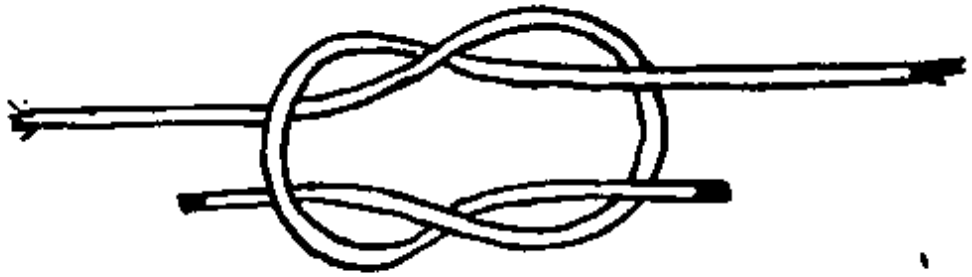

Square Knot

Clove Hitch

~KNOTS & HITCHES~

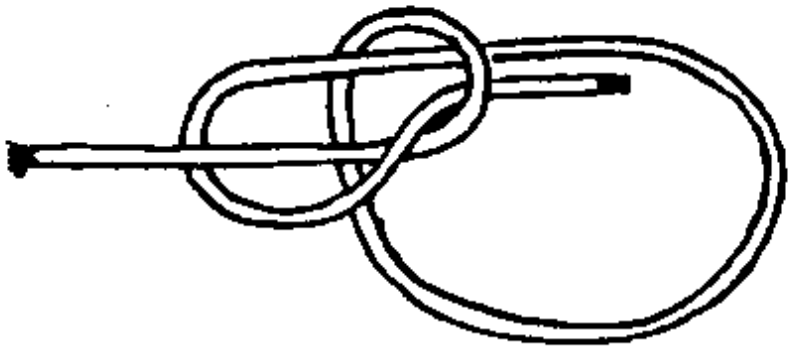

Bowline

Half Hitch

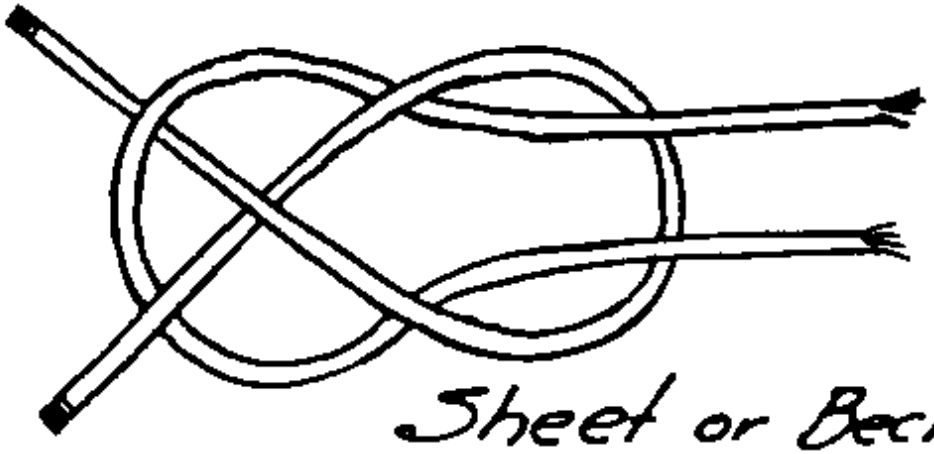

Sheet or Becket Bend.

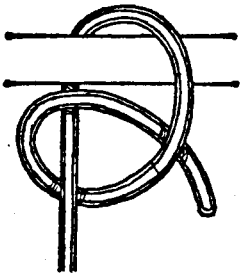

(a) half-hitch

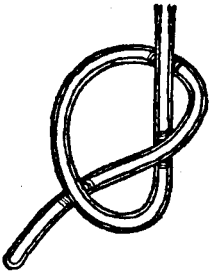

(b) overhand

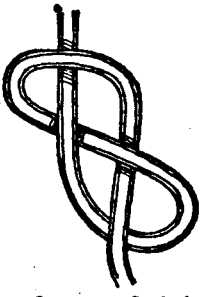

(c) figure-of-eight

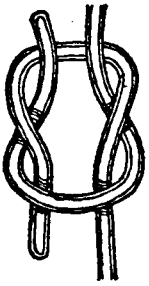

(d) reef knot

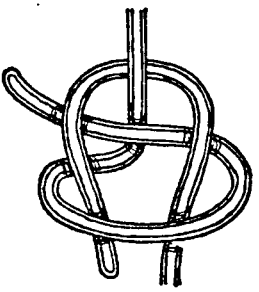

(e) weaver's knot

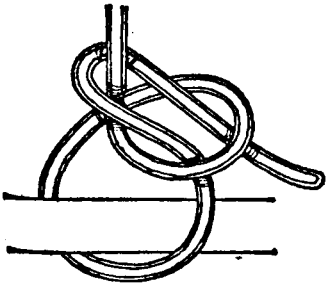

(f) bowline

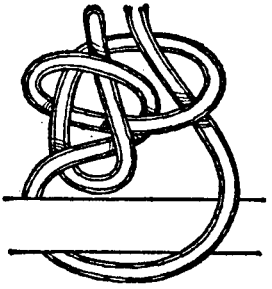

(g) running bowline

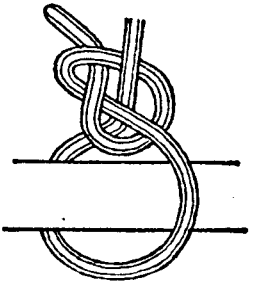

(h) running knot

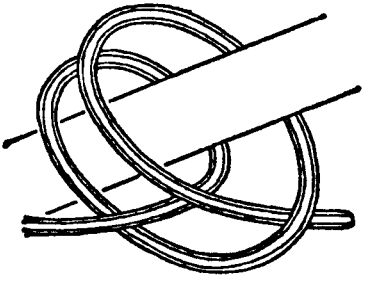

(i) clove hitch

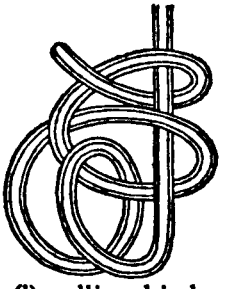

(j) rolling hitch

weaver's knot

(A) overhand knot

(B) slipknot

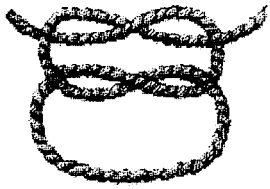

(C) square knot

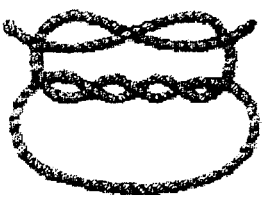

(D) surgeon's knot

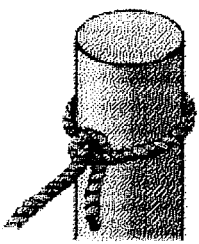

(E) half hitch

(F) Blackwall hitch

(G) cat's-paw

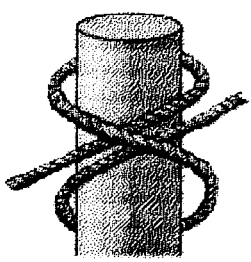

(H) clove hitch

(I) sheet bend

(J) fisherman's bend

(K) sheepshank

(L) bowline

BASIC KNOTS

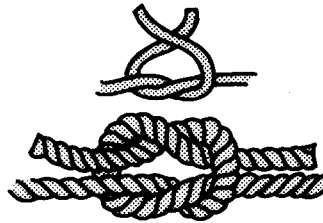

SQUARE KNOT: The basic tie for joining two ropes, also called a *reef knot*. Make by forming first a right and then a left overhand knot. Much easier to untie and far superior in holding strength than the granny knot, which it closely resembles.

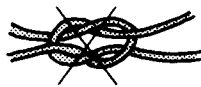

GRANNY KNOT

BOWLINE (above): This knot will not slip and is ideal for tying two ropes together, for fastening a rope to a pole and for rescue operations. Form closed loop in rope, bring end of line up through loop, around standing end of rope and back down through loop. Pull tight.

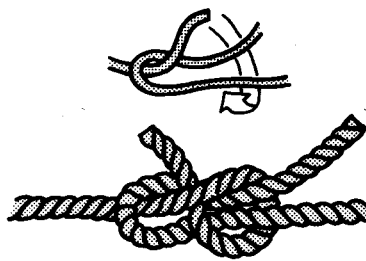

SHEETBEND: The best knot for joining two ropes, especially when they differ in size. Form a blight (loop) in the larger line. Bring the smaller through the blight, eround the doubled heavier cord and back under itself.

CLOVE HITCH: Easy to tie and untie. Holds well. This is one of the most useful of all hitches for fastening tent ropes and guys to stakes or poles.

OUTDOOR KNOTS

HALF HITCH: For temporarily fastening a line to a pole (Fig. 1).

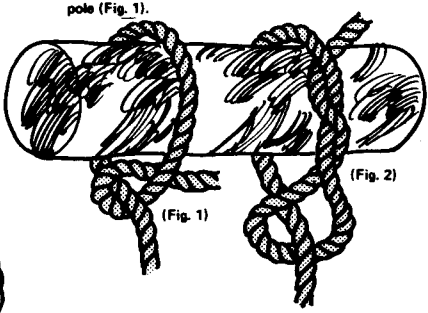

TIMBER HITCH: A half hitch modified to hold more securely (Fig. 2).

COMBINATION HALF AND TIMBER HITCH: Ideal for applying a straight end pull to a pole or pipe. Tie the half hitch first, timber hitch second.

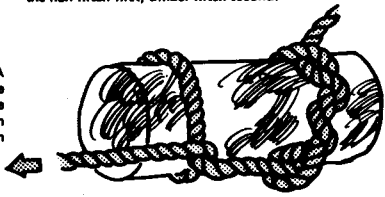

CAT'S PAW (above): A good way to secure a rope to a hook. Throw a double loop in the line, twist both ends twice and slip them over the hook.

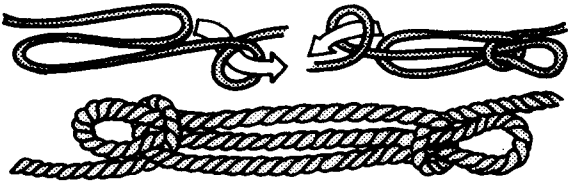

SHEEPSHANK: Downright handy for shortening a line without untying it. Follow the diagrams and you can't go wrong. The hitch may be fastened permanently by passing the ends of the rope through the loops.

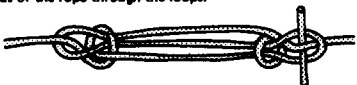

BOATING KNOTS

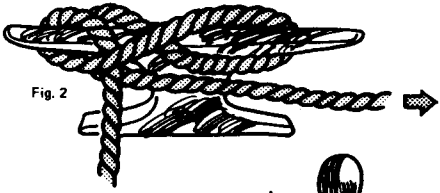

Fig. 2

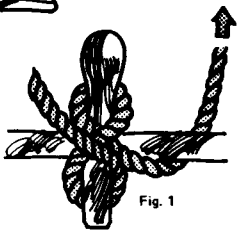

Fig. 1

BELAYING TO A PIN OR CLEAT: It's always best to make a first turn to take the strain before making one or two figure eight turns to temporarily hold the load (Fig. 1). For more permanent fastening, finish with a half hitch (Fig. 2).

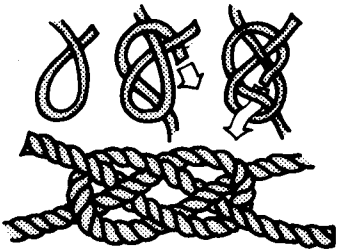

CARRICK BEND: A strong joining knot. Cross a blight on one rope and work the end of the second line around it in a regular under-and-over manner. Note that at no time does a line pass through a loop.

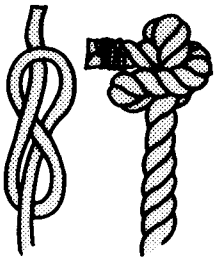

FIGURE EIGHT: Useful as a convenient handhold and for preventing ropes from running through a hole or pulley. Form by throwing a loop near the end of a line, bringing the short end completely around the standing part of the rope and back through the loop. Pull tight.

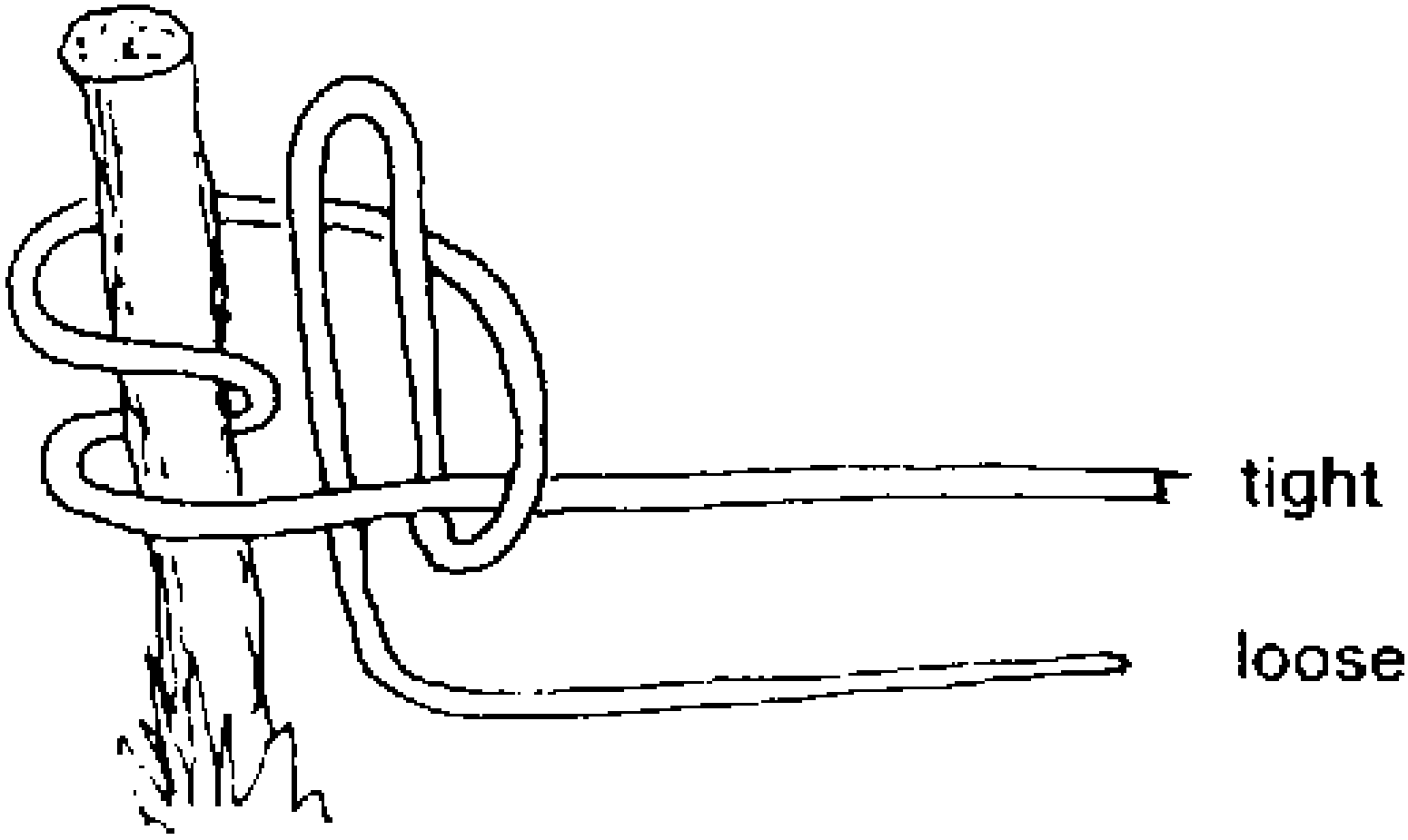

a round turn and a slipped half-hitch.

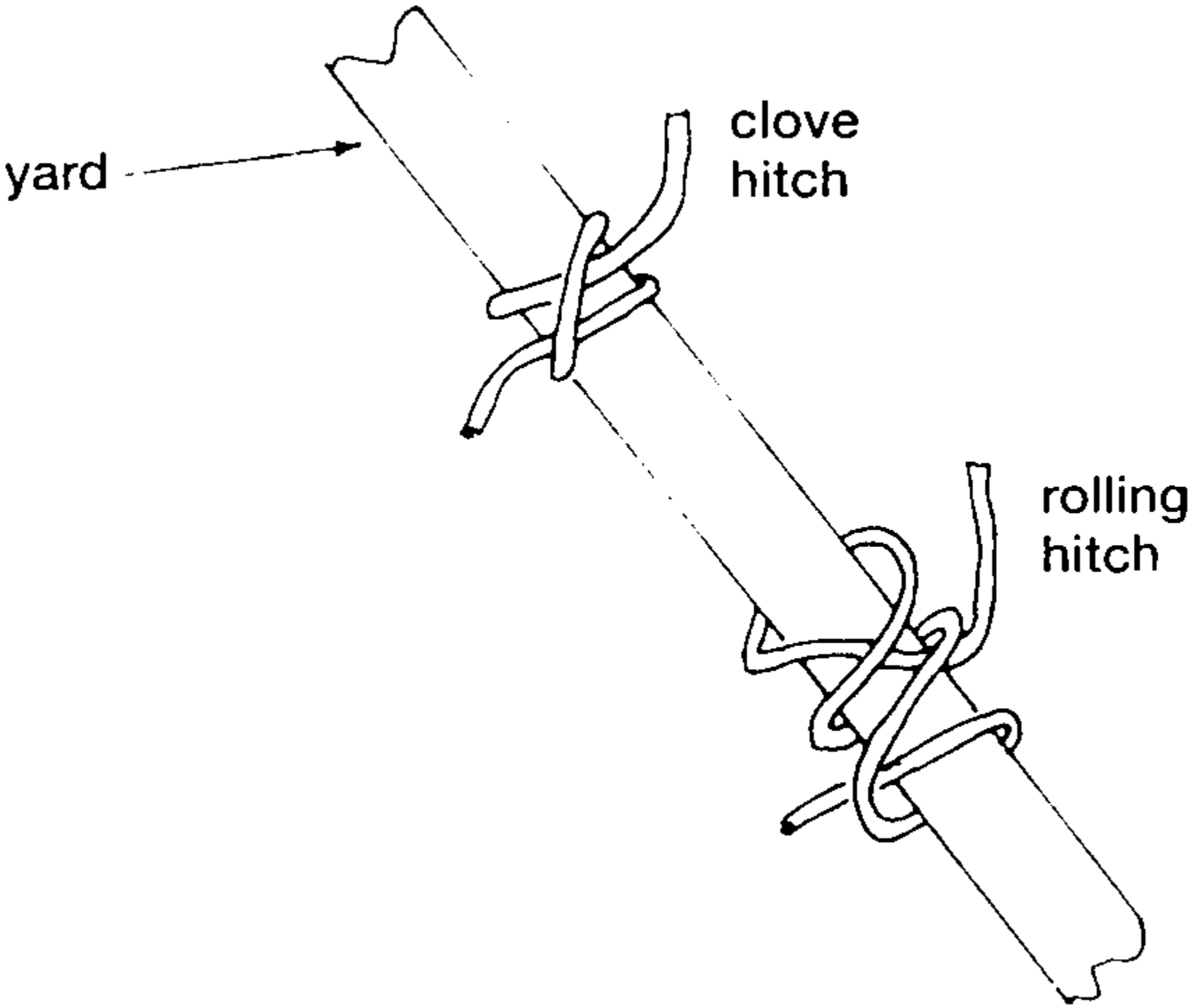
yard
clove
hitch
rolling
hitch

Joining ropes

SHEET BEND: If correctly made and strain is not erratic this won't slip.
1 Make a loop in one rope. Take live end of the other (a) right round behind loop to the front, carry it over itself and then tuck down through loop. 2 Draw it tight and ease into shape as strain is increased.

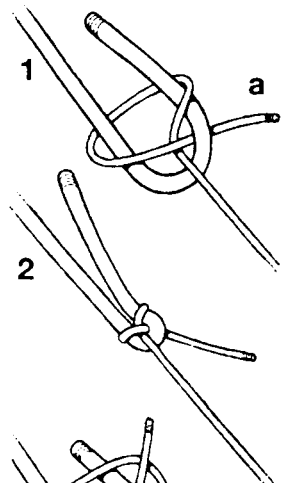

DOUBLE SHEET BEND: More secure variation of sheet bend use on wet ropes and where strain is not constant.
1 Make a loop in the thicker rope. Take live end of thinner rope (a) through loop, beneath thicker live end and then forward on outside of loop and right round it. Bring thin live end back between itself and outside of thick loop. 2 Take thin live end completely round the loop again and back through same place on outside of thick loop.
3 Draw tight and ease into shape.

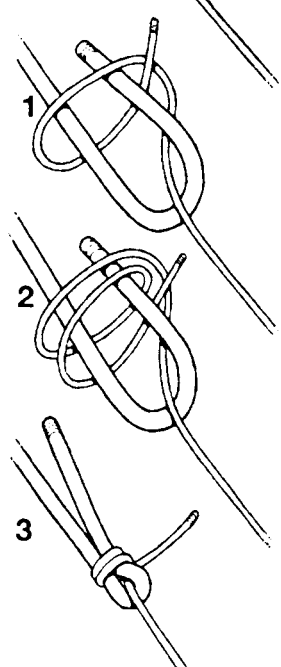

If not tightened these knots tend to work loose. Do not use with smooth lines, e.g. nylon fishing line.

Fisherman's knot: Ideal for joining springy vines, wires, slippery lines and gut fishing line (soak gut first to make it pliable). Very secure but hard to untie. Not recommended for bulky ropes or nylon line.
1 Lay lines beside each other, the ends in opposite directions. Carry live end of one line round the other and make a simple overhand knot. **2** Repeat with live end of other line.
3 Partially tighten knots and slide towards each other. Ease them to rest against one another, completing tightening process.

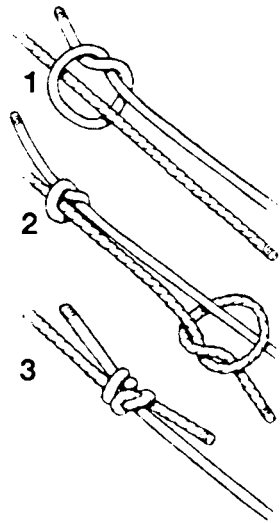

Double fisherman's: Stronger version of the above. Do not use for nylon fishing lines, nylon ropes, or bulky ropes.
1 Carry live end of one line round the other, then round both. **2** Carry live end back through the two loops.
3 Repeat with the end of the other line. **4** Slide the 2 knots together and tighten, easing them to rest well against each other. Apply strain gradually.

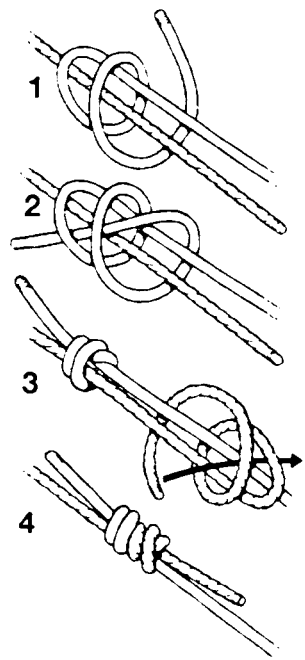

TAPE KNOT: Use to join flat materials, e.g. leather, webbing, tape and sheets or other fabrics. 1 Make an overhand knot in the end of one tape. Do not pull it tight. 2 Feed the other tape through it so it follows exactly the shape of the first knot. 3 Live ends should be well clear of the knot so that they will not slip back when you tighten it.

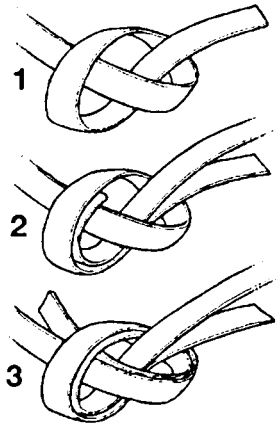

Loop making

BOWLINE: A fixed loop that will neither tighten nor slip under strain. Use at the end of a lifeline. 1 Make a small loop a little way along the rope. 2 Bring live end up through it, round standing part and back down through loop. 3 Pull on live end to tighten, easing knot into shape. Finish with a half-hitch.

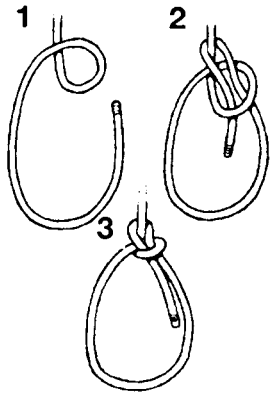

RUNNING BOWLINE: A loop which tightens easily. Make a small bowline and pass long end of rope through loop.
Never tie a running bowline round the waist, it acts like a hangman's noose and could kill.

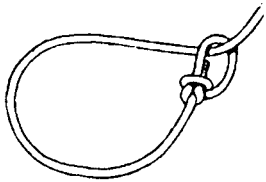

Triple bowline: A bowline made with a double line. Form a loop, pass doubled live end through loop, behind standing part and back through loop. This produces 3 loops which can be used for equipment haulage, or as a sit-sling or lifting harness with one loop round each thigh and the other round the chest. It takes practice – learn it before you need to use it.

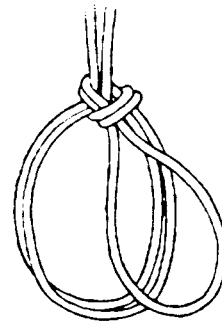

Bowline-on-the-bight: To support or lift someone from a crevasse. The loops will neither tighten nor jam, forming a bosun's chair, one loop fitting round buttocks, the other round upper body. Practice before you need to use it. **1** Using doubled line, form a loop and pass the live end through it. **2** Bring this end down (a) and over the end (b) of the larger double loop now formed. Ease it back up to behind the standing part (c). Pull on the large double loop to tighten (d).

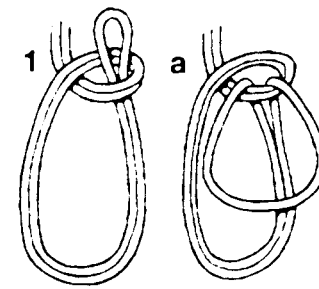

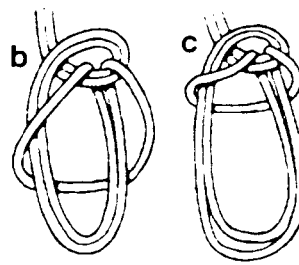

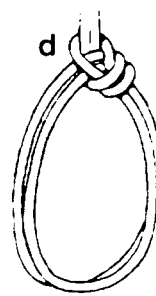

Anchor bend ■ 210

To connect a warp with a ring or anchor.

Bowline ■ 211

Wherever a bight is needed.

See: Bowline – for a one-handed method.

■ 210 *Anchor bend*

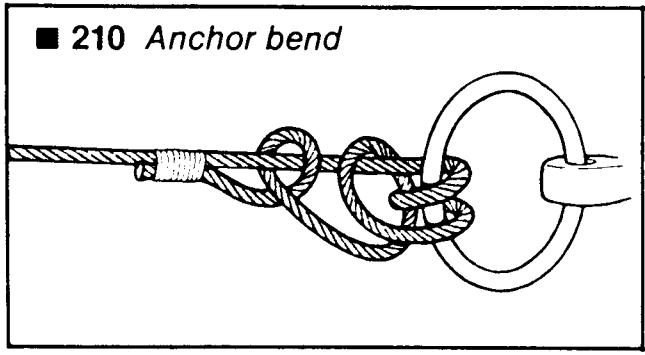

■ 211 *Bowline*

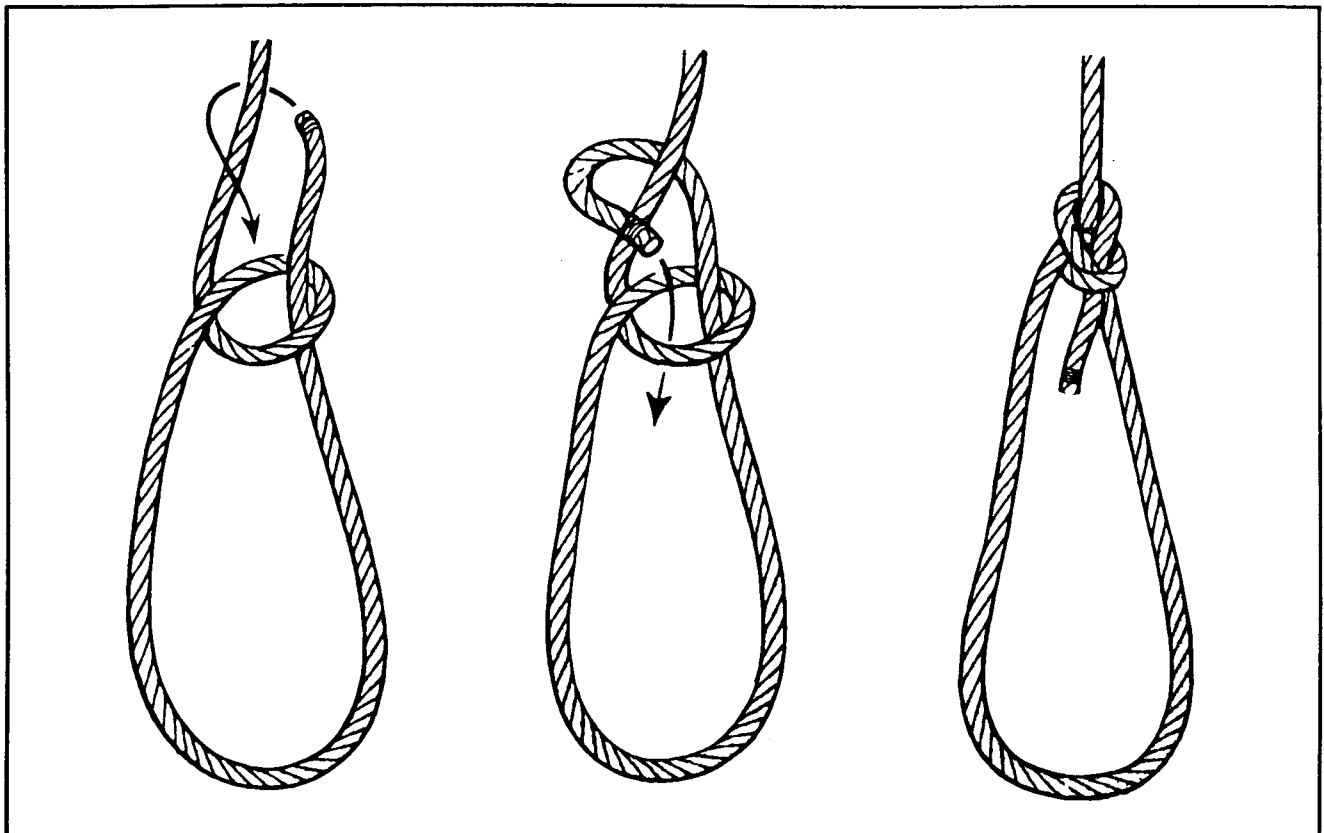

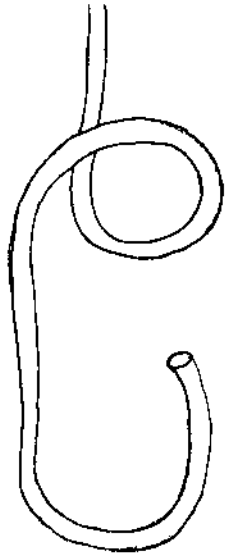

ONCE THERE WAS A SNAKE WHO LIVED IN A HOLE BY A TREE...

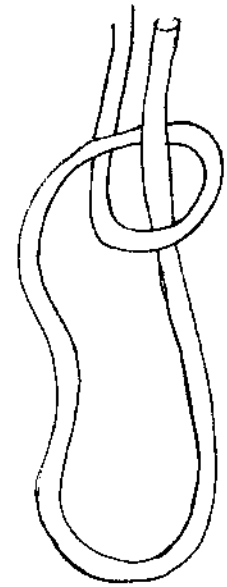

ONE DAY THE SNAKE PUT HIS HEAD OUT OF THE HOLE...

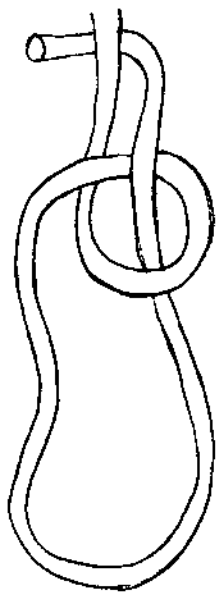

AND LOOKED ALL AROUND THE TREE BUT HE SAW NOTHING INTERESTING...

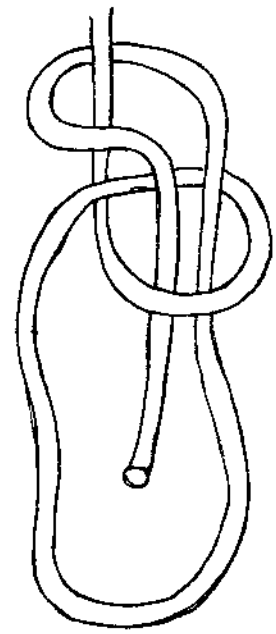

SO HE SLID BACK DOWN INTO HIS HOLE

THE BOWLINE KNOT

■ **56** *Tying a one-handed bowline*

A

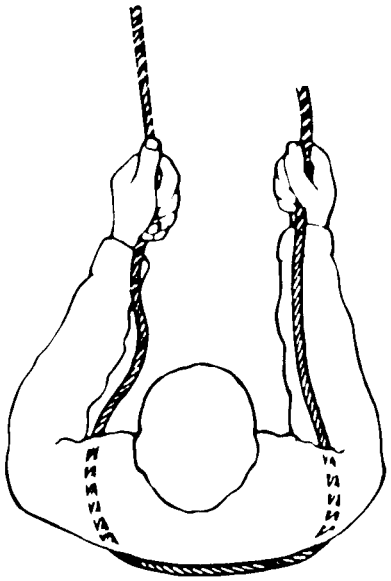

B

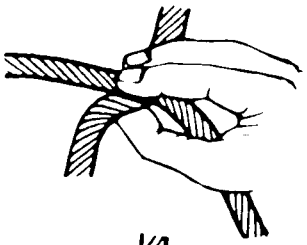

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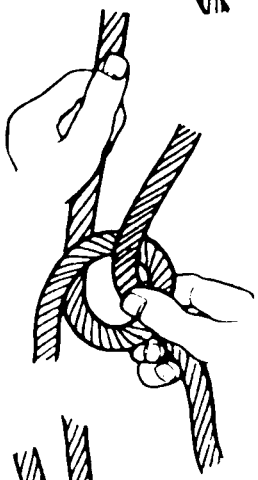

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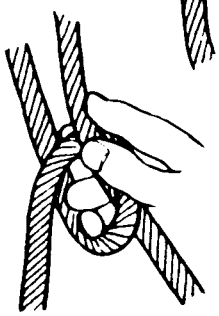

With your *left hand*, grasp the long end firmly to hold the tension

Pass the short end around you ■ **56A**.

Take the tip of the short end in your *right hand* and bring it up to the slack portion of the line ■ **56B**.

Grasp the slack and twist it into a loop so that the tip of the short end passes through it ■ **56C**.

Pull a bit of line through the loop ■ **56D**, then pass it underneath the slack ahead of the loop ■ **56E**.

Pull the line back through the loop and tighten the knot ■ **56F**.

E

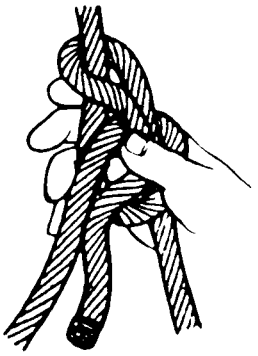

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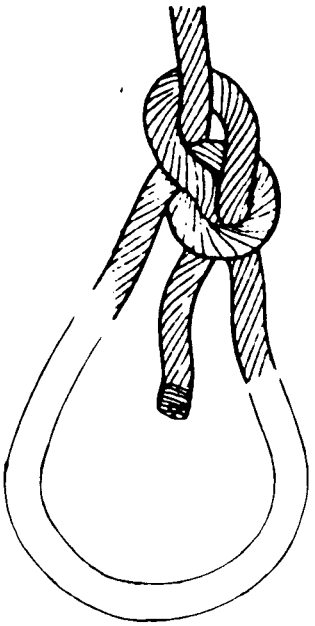

WARNING:

Do not use two bowlines to join lines together as this reduces their strength by about 50%.

Carrick bend ■ 212

To join heavy warps or lines of unequal size.

NOTE:

The ends can be tucked either over or under several times or bound to the line.

■ 212 *Carrick bend*

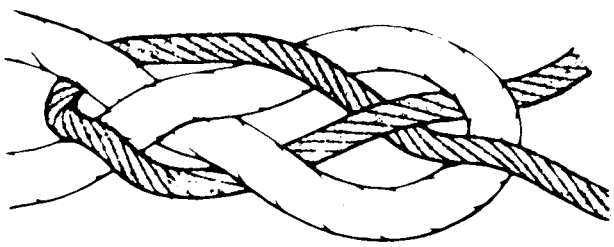

■ 213 *Sheet bend*

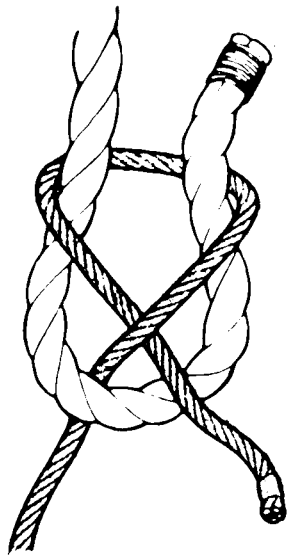

Sheet bend ■ 213

To join a line to a bight or two lines of unequal size.
When joining two lines an extra turn should be taken making the knot into a double sheet bend.

Stopper knot or rolling hitch ■ 214

To make a line fast to a shroud, stay or spar which will not slip when pulled in the opposite direction from the knot.

■ 214 *Stopper knot or rolling hitch*

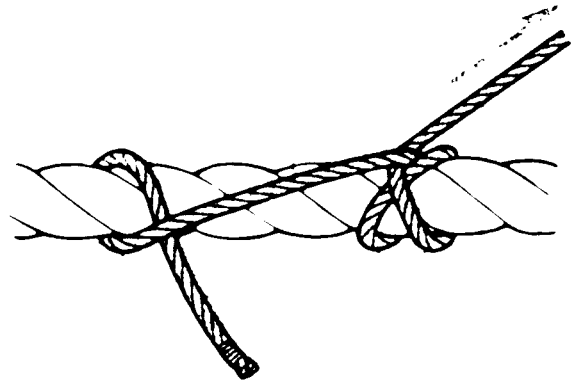

Tugboat hitch ■ 215

To attach a warp to a samson post or bollard.

■ 215 *Tugboat hitch*

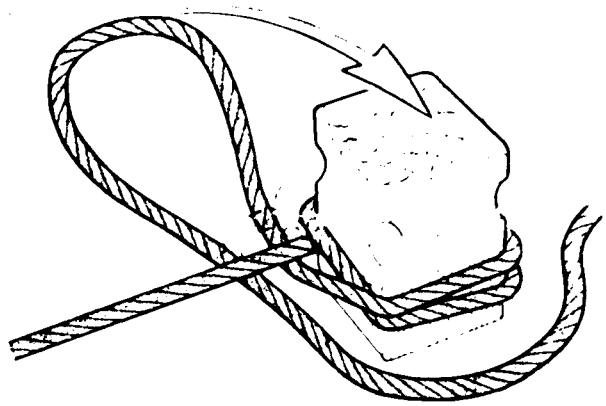

For lifelines or lashings with a pull in only one direction ■ 218

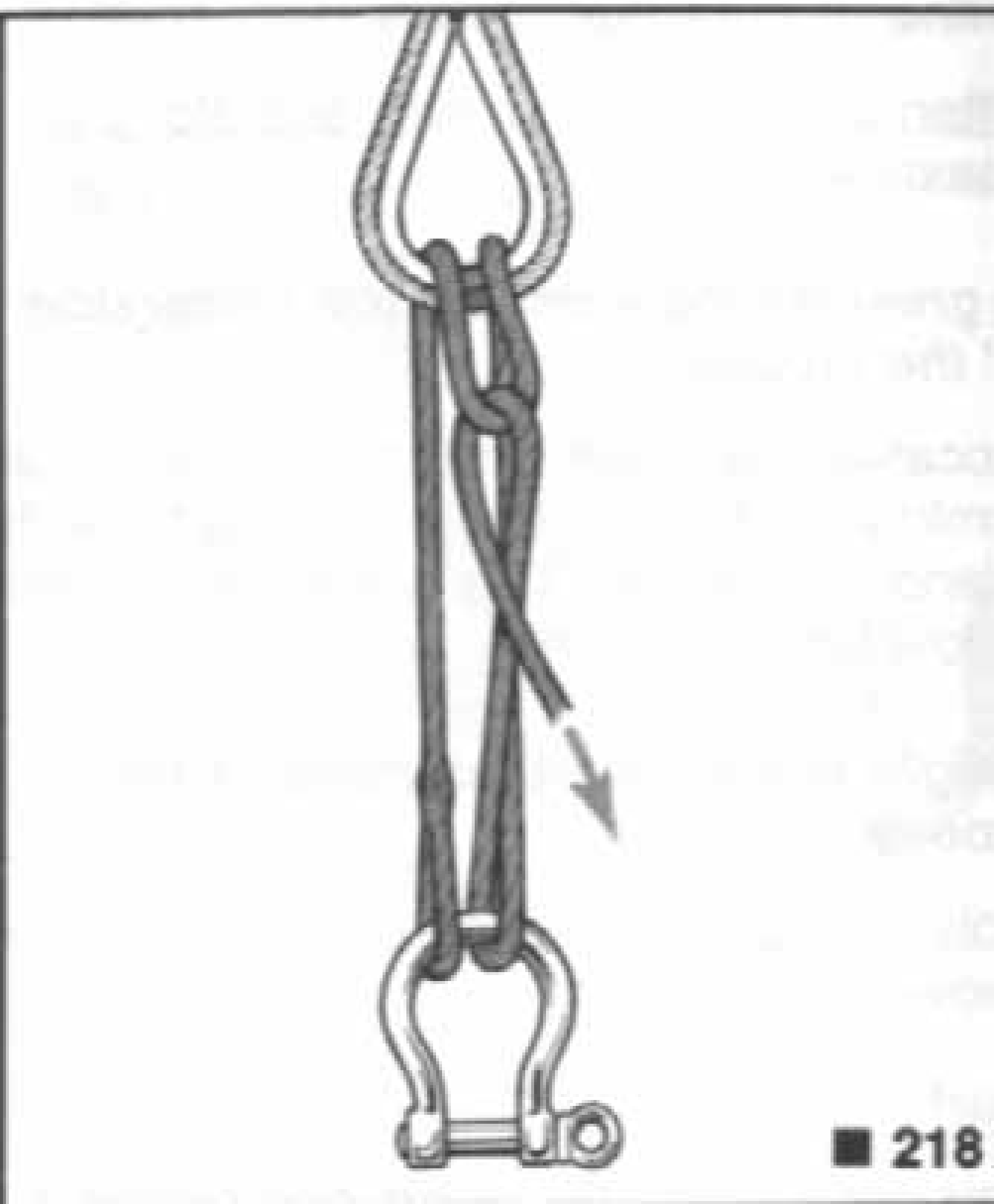

■ 218

MANHARNESS HITCH: A non-slip loop. It can be made along the length of the rope, but does not require access to an end. Several loops can be put on a rope for harnessing people together. Also a good way of preparing a rope for climbing. Toes and wrists can be put into the loops to carry weight allowing you to take a rest.
1 Make a loop in rope look closely at the drawing.
2 Allow left side of rope to cross over loop. **3** Twist loop. **4** Pass it over left part of rope and through upper part of original loop. **5** Pull knot gently into shape, ease tight and test carefully.

Note: If not eased tight correctly loop may slip.

Different ways of making this knot may be found where the loop is not twisted at **3**. The final strength of the loop does not appear to be affected either by making this twist or not, nor if the twist should straighten out in use.

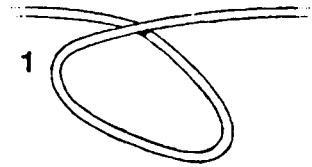

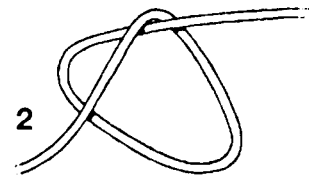

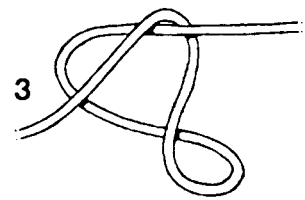

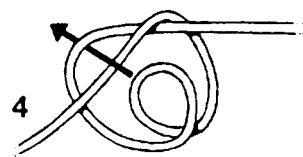

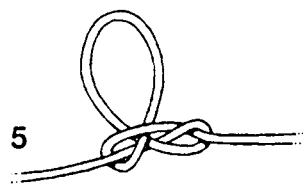

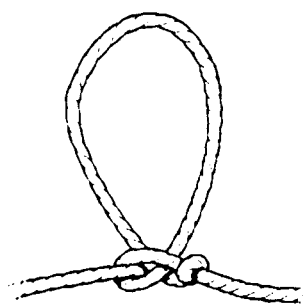

Ladders

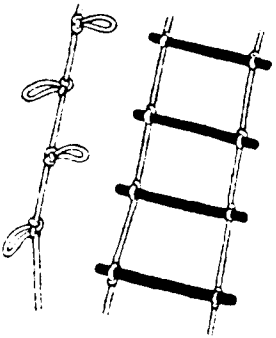

Tie as many manharness hitches in a rope as you need hand and foot holds. Rungs may be added, using strong sticks or pieces of wreckage.

Use 2 ropes or a long rope, doubled, with manharness hitches placed equally along both sides to make a rope ladder. As you make loops, pass sticks through the corresponding loops and ease tight to hold sticks firmly. Allow sticks to project a few inches on either side of the ropes and test for strength.

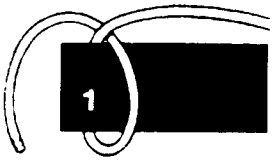

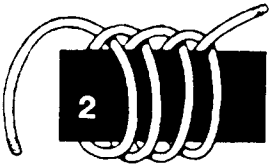

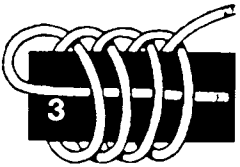

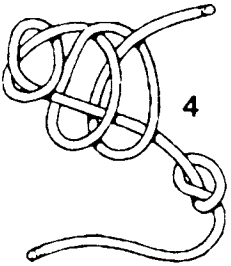

Ladder of knots: A series of overhand knots tied at intervals along a smooth rope will make climbing it much easier.
1 Leaving a reasonably long free end, make a half-hitch near the end of a short piece of log. **2** Continue making loose half-hitches along the log the diameter of which will fix the spacing of the knots. **3** Pass start end back through all the loops and then slide them all off the end of the log. **4** As each turn of rope comes through, the centre of the half-hitch loops to the other end. Shape and tighten each knot.

If no bosun's chair is on board, one may be improvised from:

A tubular fender ■ **71.**

A boarding ladder ■ **72.**

A bowline on the bight ■ **73.**

If no winch is available ■ 74

Attach one halyard to the bosun's chair.

Tie the end of a *second* halyard into a loop, which can be used as a stirrup.

While the climber supports himself on the stirrup, the bosun's chair is hoisted half a metre at a time.

Then climber transfers his weight to the chair, in order that the stirrup can be raised another half a metre.

NOTE:

This method is slow, safe, and requires little physical effort of the person on deck.

■ **74** *Climbing the mast without a winch*

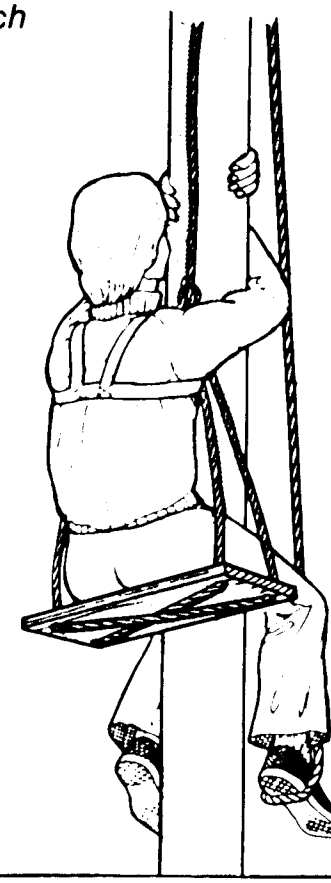

Emergency bosun's chair

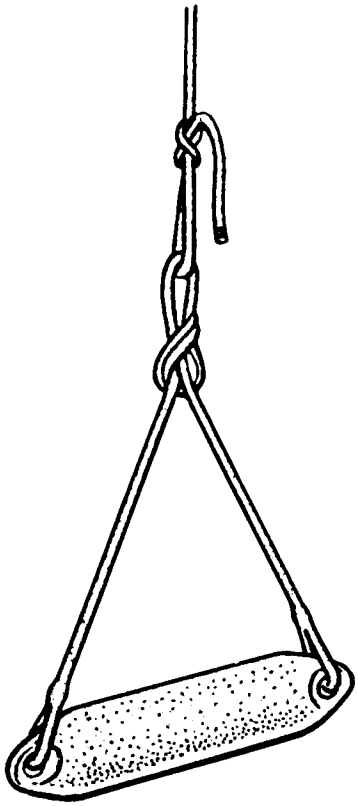

■ **71**

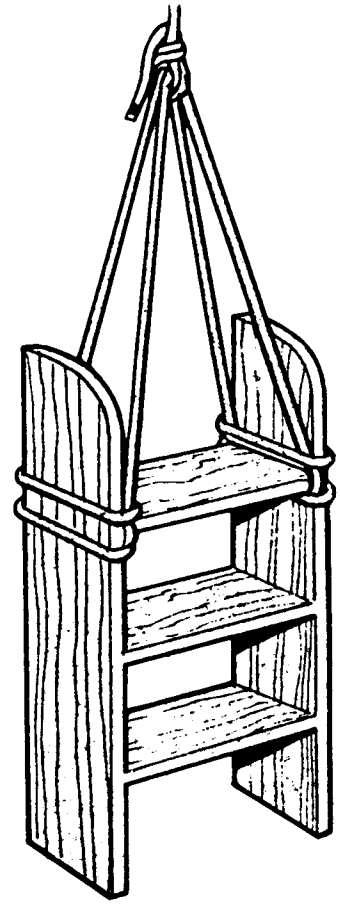

■ **72**

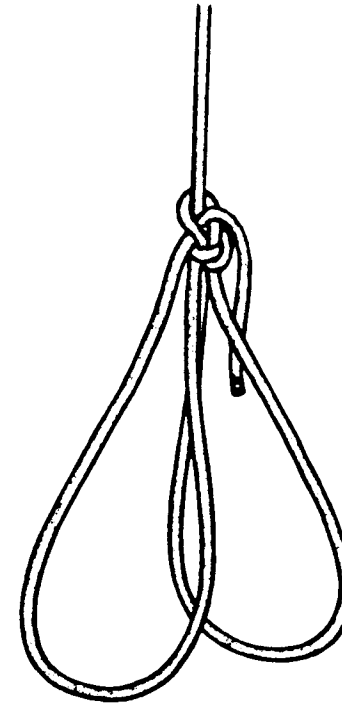

■ **73**

METHOD 1 ■ 75, 76

Lay a length of stiff rope, such as a warp, on the deck, and at one foot intervals, tie large overhand knots to form stirrup-like bights.

Hoist the chain of loops aloft on a halyard, twist it several times around the mast to prevent it from swinging, then secure it tightly to a pin or cleat.

NOTE:

If the ladder is not long enough, the climber can secure himself to the cross-trees. The ladder can be unwound, hoisted to the masthead, then re-spiralled for the next stage of the climb.

METHOD 2 ■ 77

Lay a length of line on the deck – about three times the height of the ladder required – double it, then tie sheepshanks to form the steps.

Hoist the ladder aloft on a halyard and secure the end to the base of the mast.

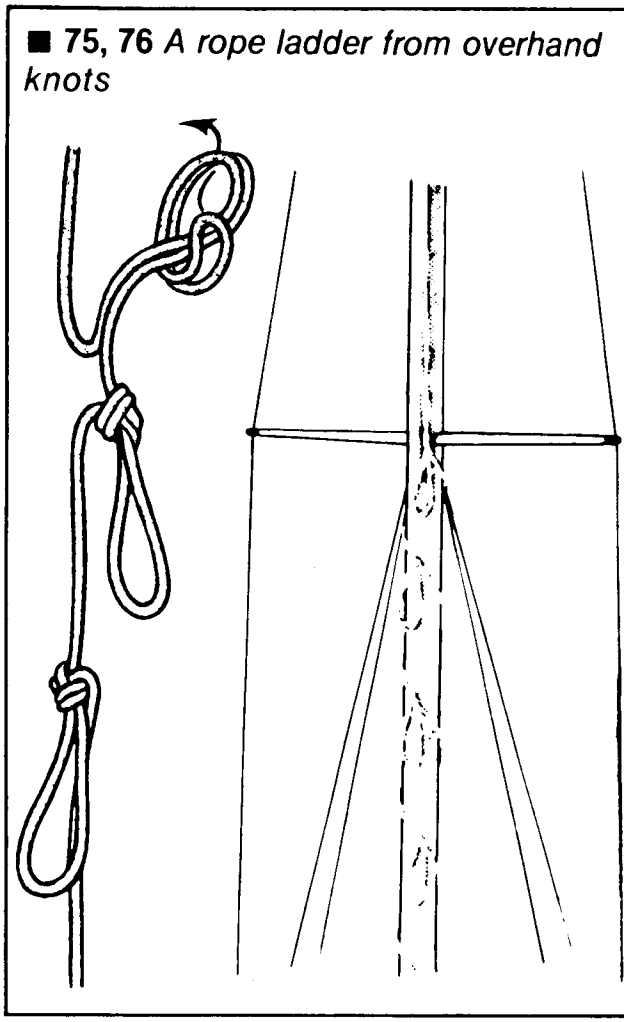

■ **75, 76** *A rope ladder from overhand knots*

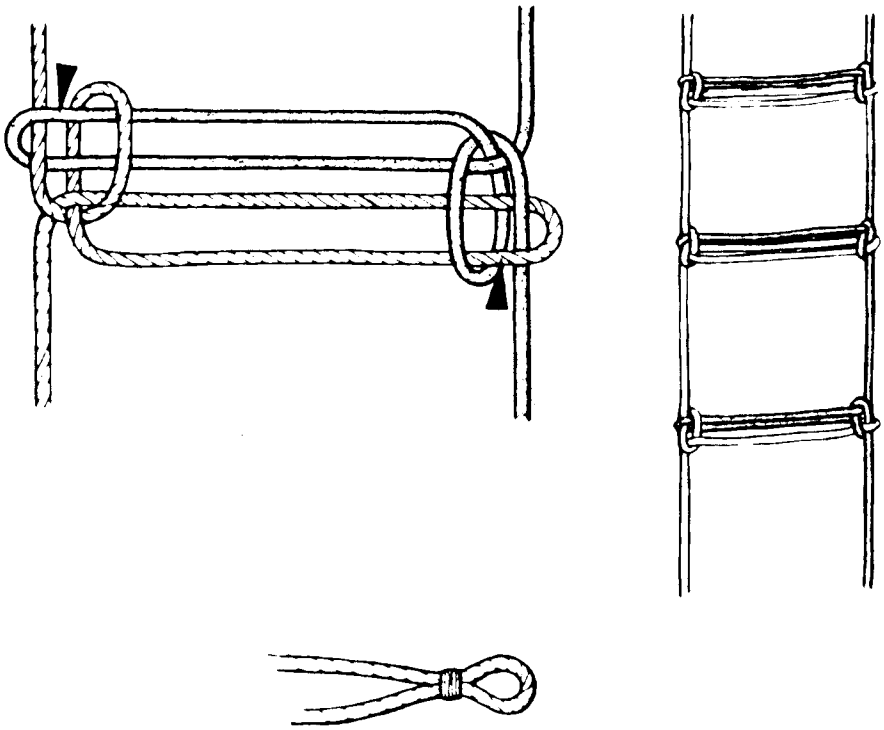

■ **77** *A rope ladder from sheepshanks*

METHOD 3 ■ 78

Using lengths of heavy cord, attach temporary ratlines to the shrouds with stopper knots (rolling hitches). **See: Knots**

With a little practice, these knots can be tied with one hand, leaving the other free to hang on with. If the lengths of cord are pre-cut, they can be tied in place, one by one, as an ascent is made.

On an average-sized yacht, 8–12 lines should be enough to reach the cross-trees. Above that, if necessary, a web of ratlines can be tied between the upper shrouds, the mast and/or the forestay.

NOTE:

If the knots are being tied on stainless steel wire, a few turns of tape just below each knot will help it gain purchase.

METHOD 4 ■ 79

Short lengths of wood, for example cut from a boat hook, are tied with marlin spike hitches between two spare sheets to form a Jacob's ladder.

The ladder is tied to the main halyard, hoisted aloft, then cleated securely to the base of the mast.

METHOD 5 ■ 80

If the sail slides and their lashings are sufficiently strong, the mainsail can be slightly lowered and the slack in the sail used as ladder steps.

■ **78** *Ratlines*

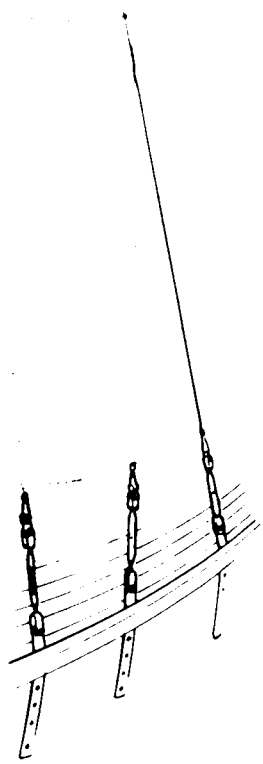

■ **79** *Jacob's ladder*

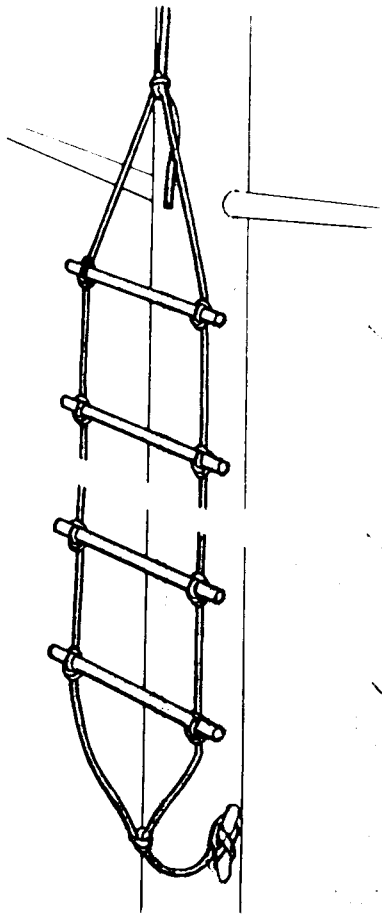

■ **80** *Climbing the sail*

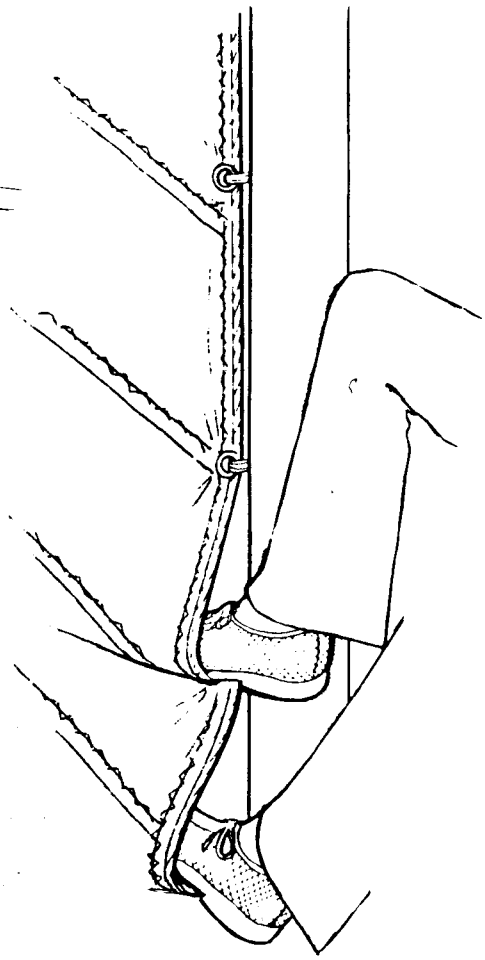

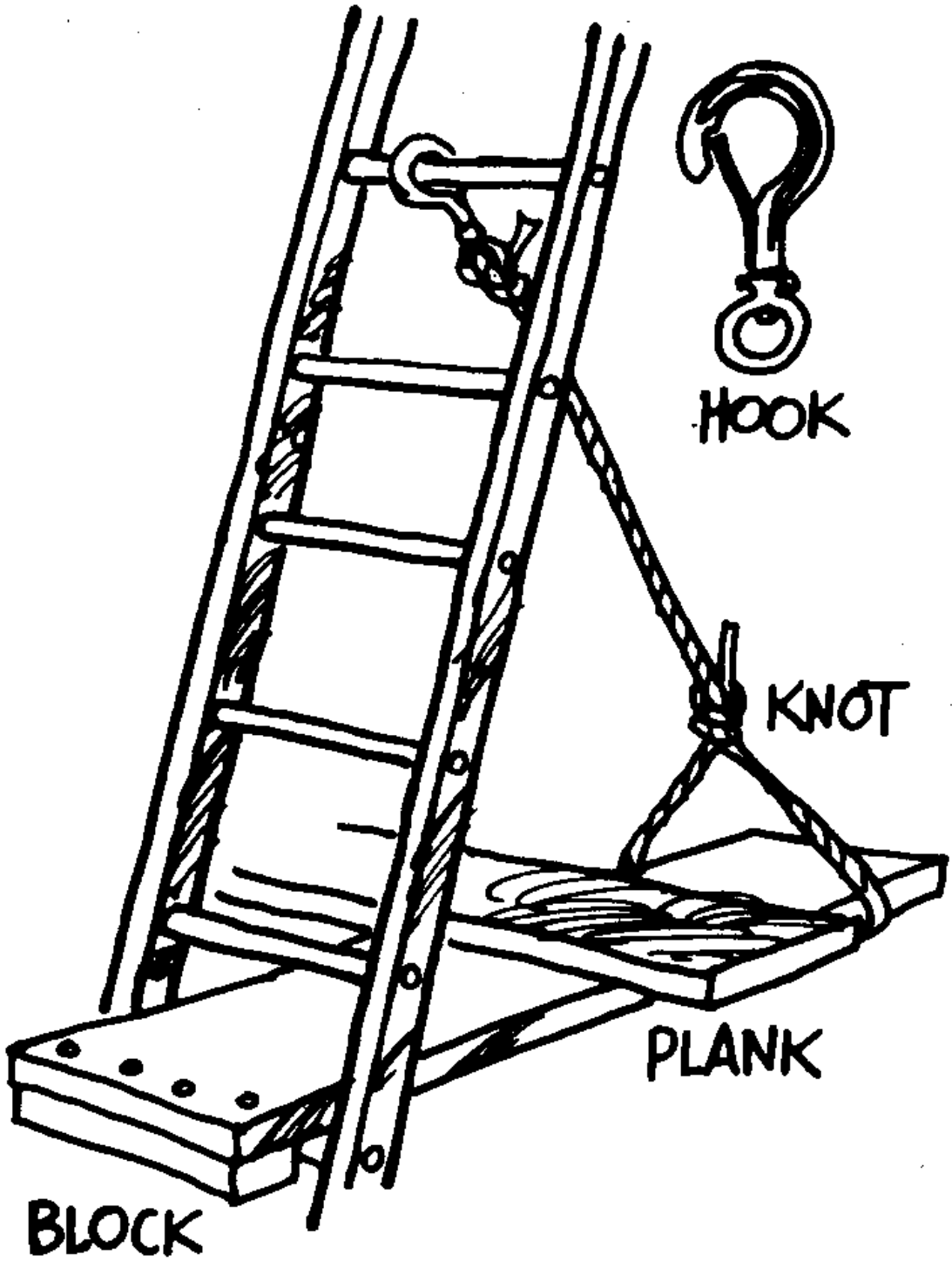

Everybody needs a good scaffold occasionally but nobody seems to know a handy way to put one together. Here, then—once and for all—is an extremely simple manner in which an ordinary ladder can be rigged to support one end of a plank. Set up a second ladder in the same way to hold the other end of the board and move the whole assembly as desired.

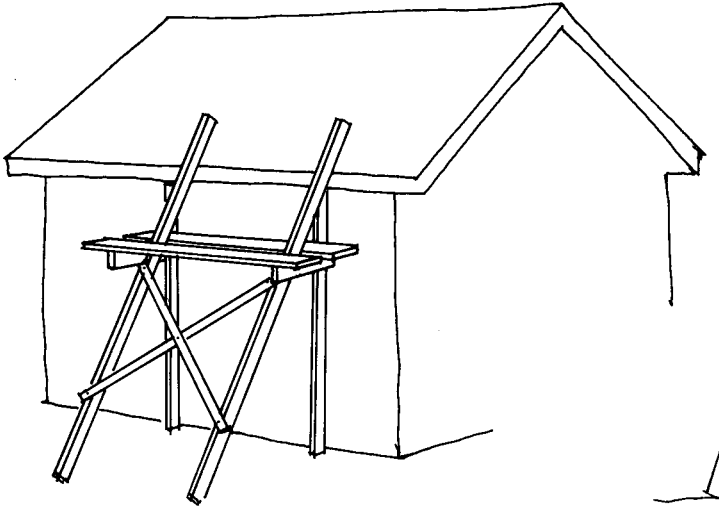

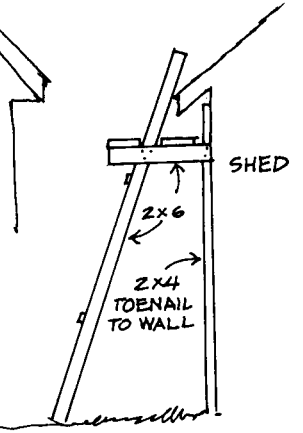
SHED
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TOENAIL
TO WALL

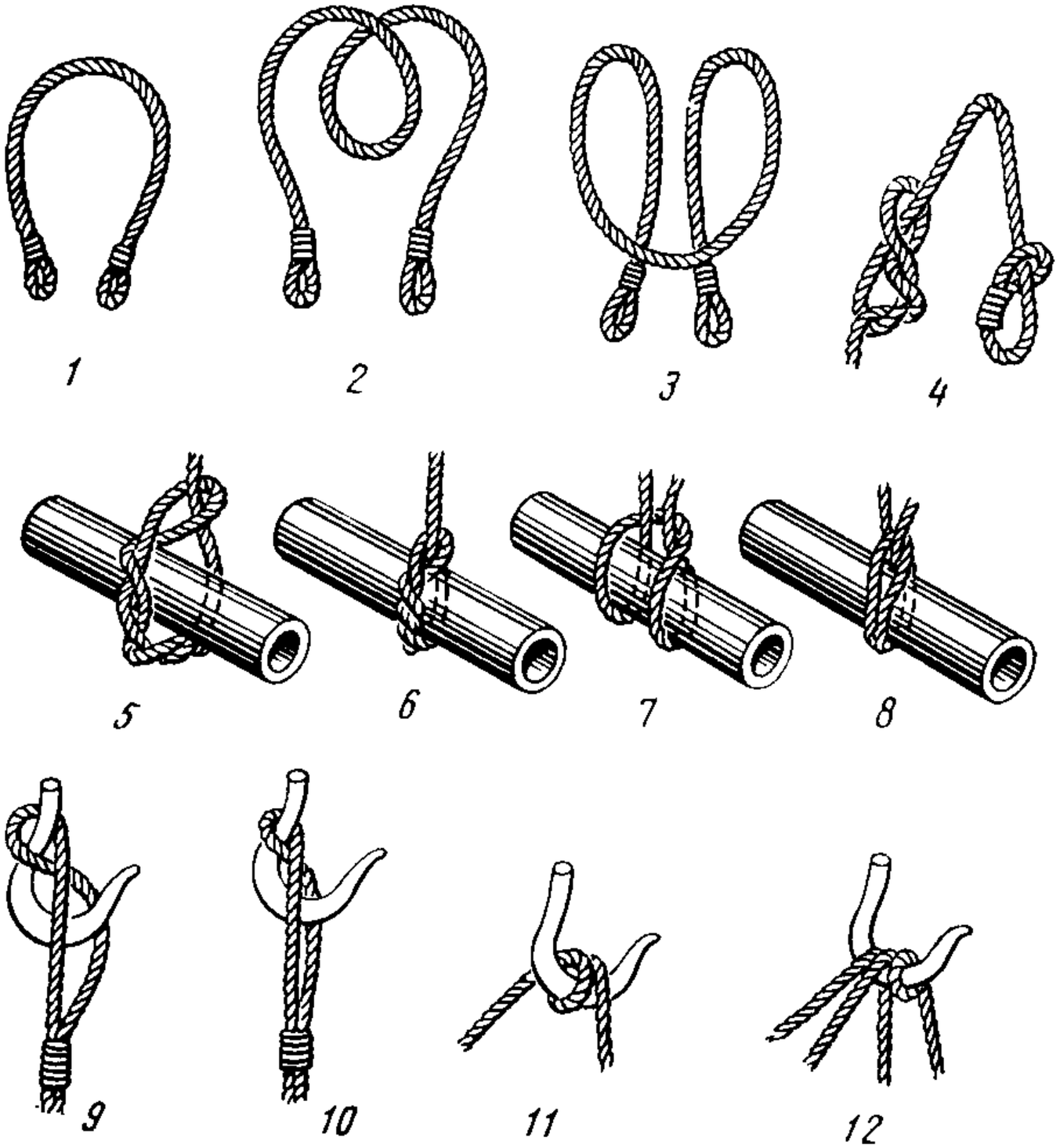

Fig. 230. Hoisting slings and knots

1, *2*—sling with two loops; *3*, *4*—slings with one loop; *5*, *6*—timber hitch before and after tightening; *7*, *8*—clove hitch; *9*, *10*—blackwall hitch before and after tightening; *11*, *12*—tying slings with one and two lengths of rope to lifting hook

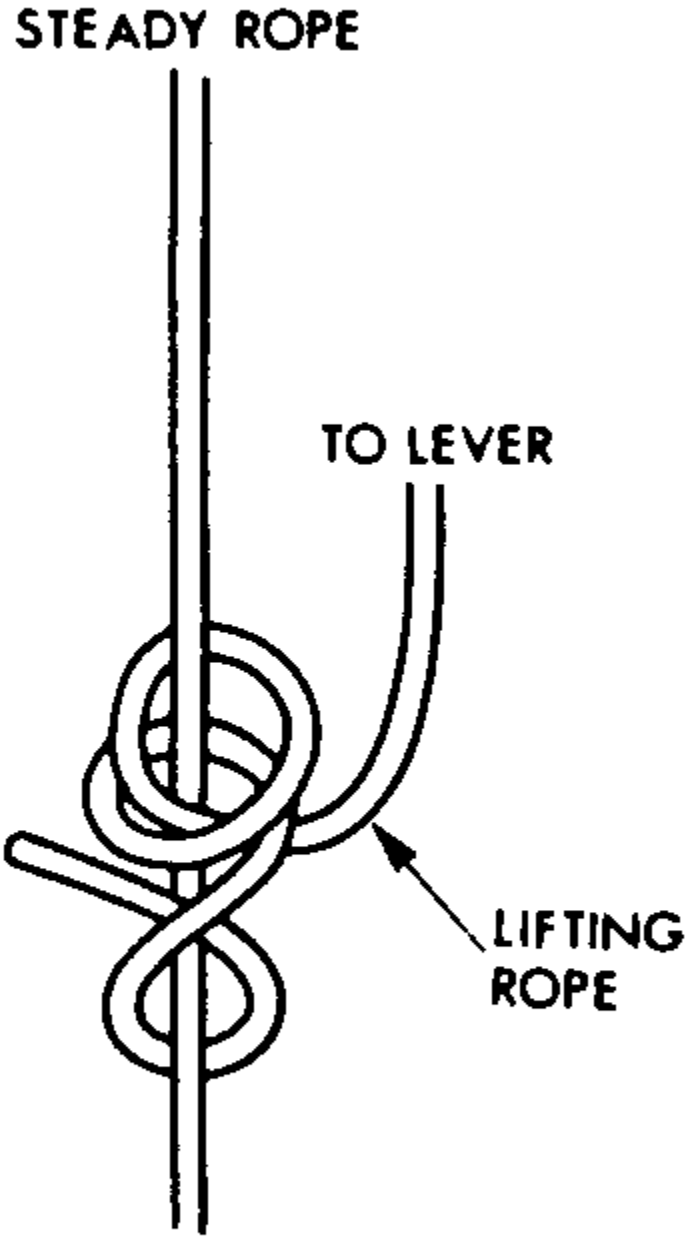

ROLLING HITCH CONSTRUCTION

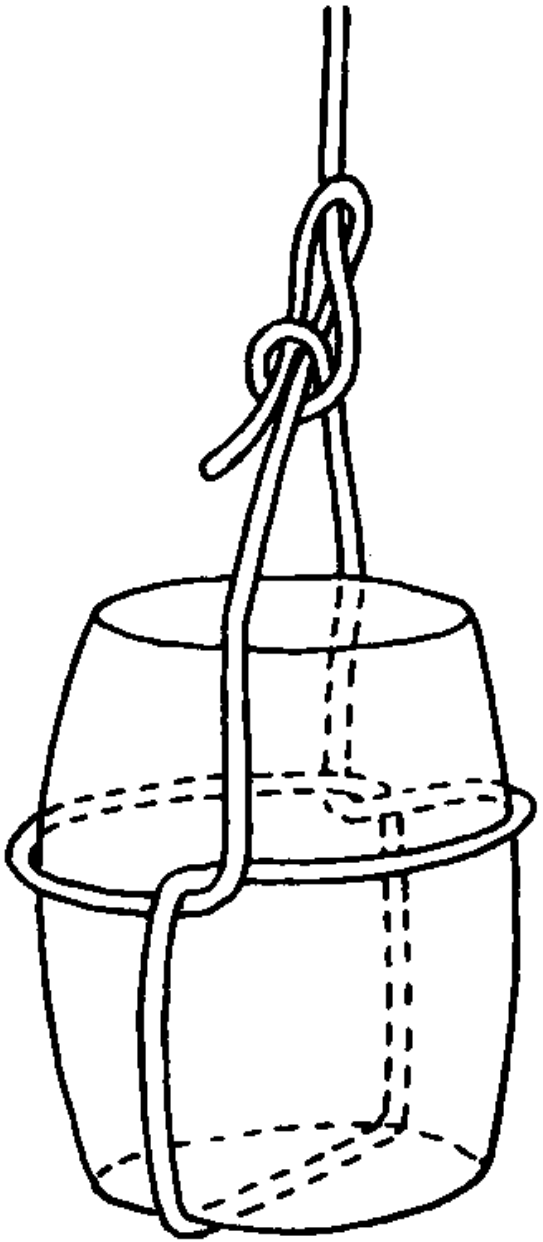

Tøndestik og Pælestik.

Fig. 40.

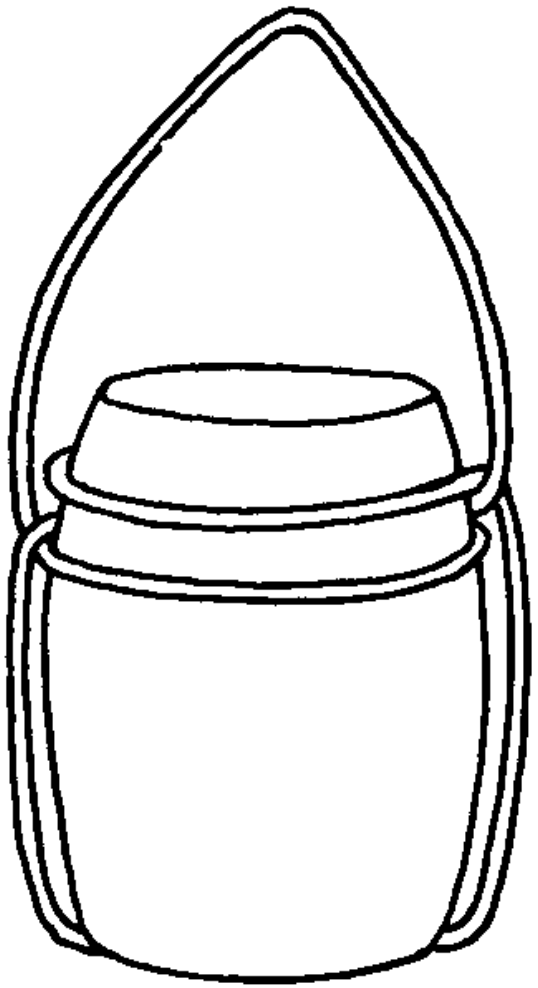

Tøndestik med en Strop eller en Bugt.

Fig. 41.

A very useful variation of the figure eight knot is the *packer's knot*, which the man behind the counter uses to tie up your parcel. It is a slip knot which can be pulled tight and locked. A figure eight knot is made with the end around the standing part. Take care that this finishes with the end standing up, and not the other way. The line is tightened by pulling on the standing part, then a little loop, called a *half hitch*, is made with the standing part over the end projecting from the figure eight knot.

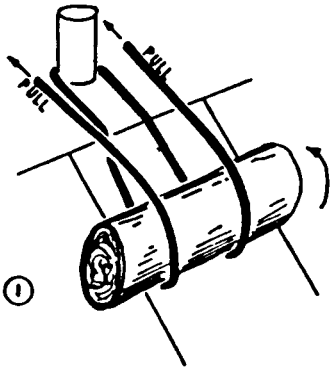

Parbuckling

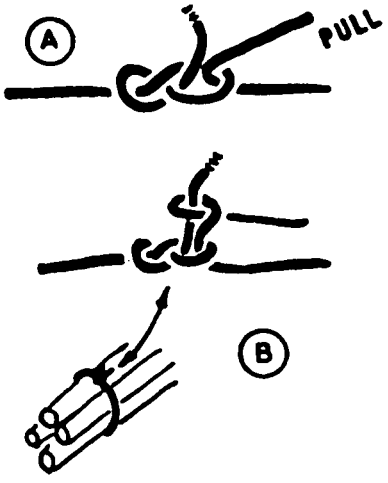

Packer's knot

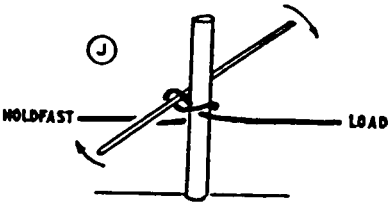

Spanish windlass

Weights are moved by tackle which gives the operator an advantage, but there are two simple ways of shifting weights which do not need special apparatus. An article which is round and can be rolled may be *parbuckled*. The center of the rope must be anchored to a holdfast, the two parts go under the object and the ends to the operator. Pulling on the ends gives him a two-fold advantage, except for slight frictional losses. A *Spanish windlass* may be used to shift a load horizontally. A rope from the load to a holdfast is looped with a short stick around a pole being held upright. If the stick is turned around the pole, considerable leverage can be applied.

HONDA KNOT: A free-running noose with a circular loop which is ideal for lassoing. If you have only one rope, don't use it as a lasso – this causes wear and damage to rope.

a Start with an overhand knot.
b Form a loop further down the rope.
c Double rope into a bight between loop and knot.
d Pass bight through loop.
e Tighten loop round bight.
f Pass long end of rope through new eye formed by bight.

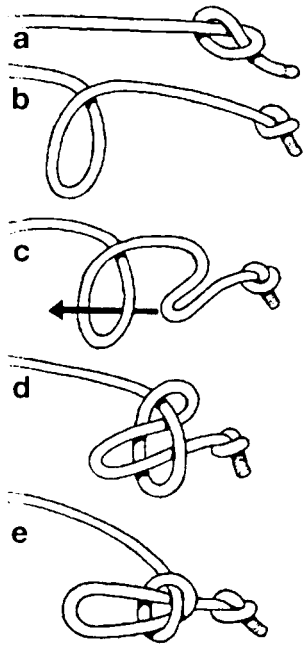

Before lassoing an animal, consider its strength. A big animal may wrench the rope away, depriving you of a meal and a rope. If the rope is anchored to you, you may be dragged along and injured. Instead, use a firm anchor – a tree or rock – to take the strain.

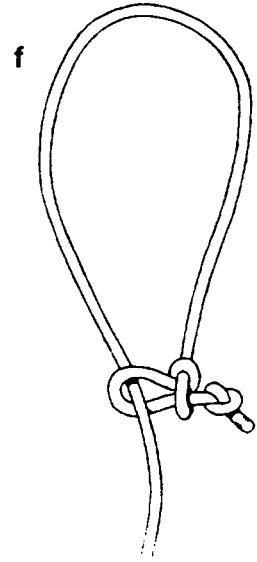

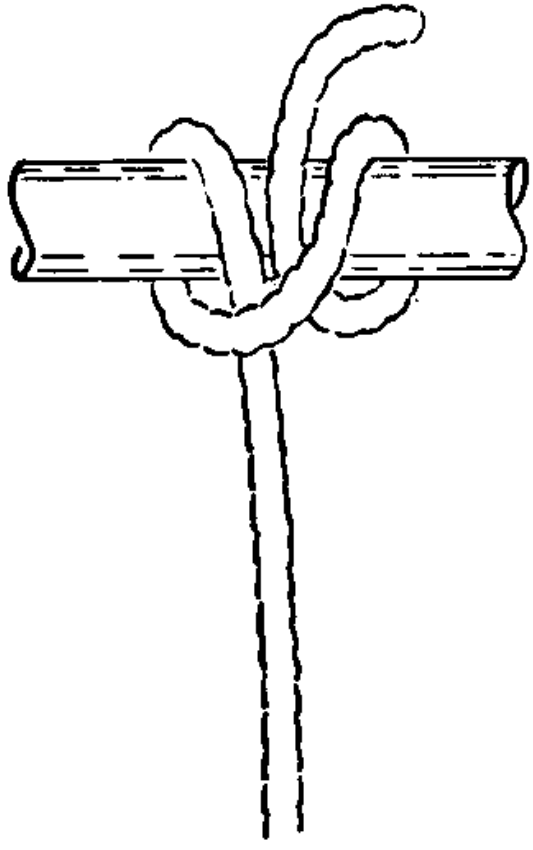

Dobbelt halvstik
omkr. rør ell. lign.
Fig. 15.

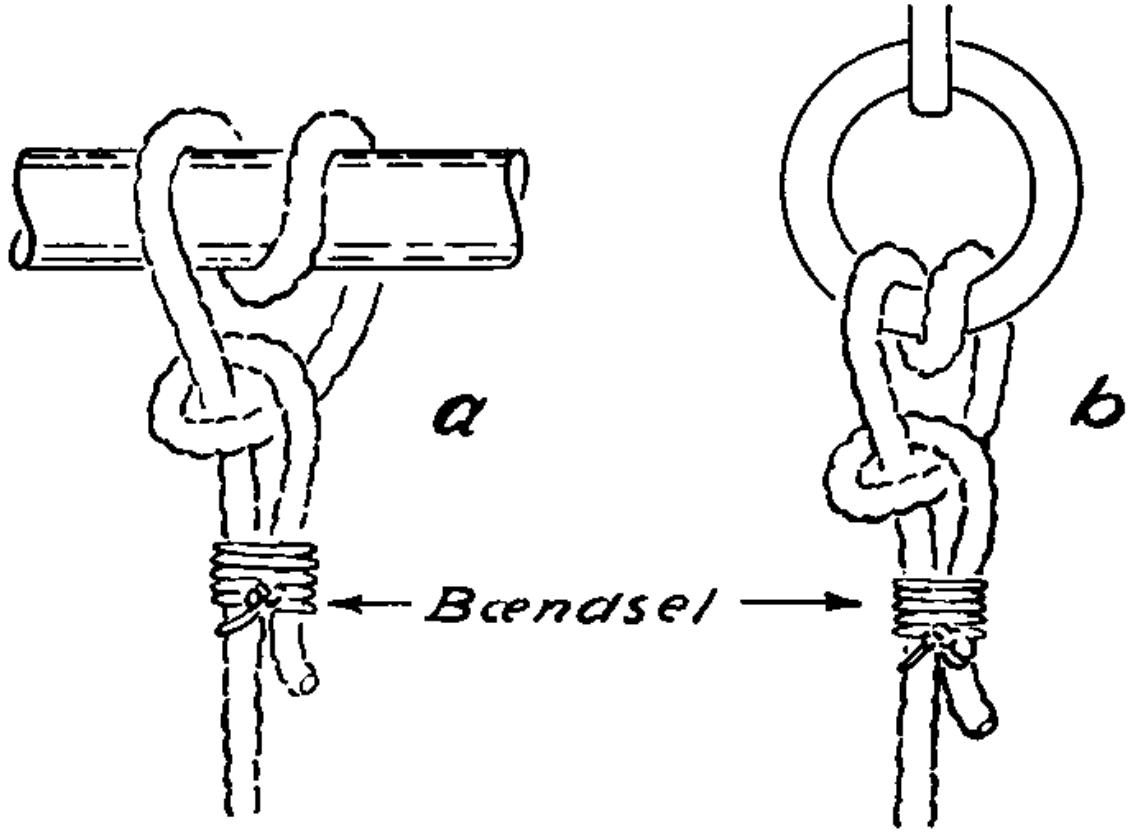

Rundtørn om fast konstruktion og
derefter enkelt halvstik med bændsel.
Fig. 16.

Hitches

Use to attach ropes to posts, bars and poles.

Round turn and two half-hitches: The best way to secure a rope to a post. Can take strain from any direction. Carry rope behind post, then round again. Bring live end over and back under standing end and through loop thus formed. Tighten and repeat half-hitch to make knot secure.

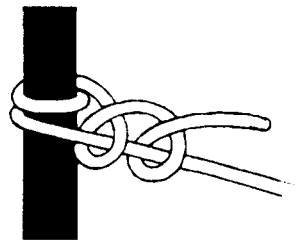

Clove hitch: Effective when strain is perpendicular to the horizontal. Not so good when the strain comes at an angle or is erratic.

1 Pass live end over and round bar. **2** Bring it across itself and round the bar again. **3** Carry the live end up and under itself, moving in the opposite direction to standing end.
4 Close up and pull tight.

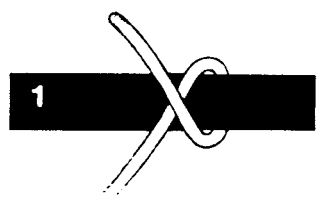

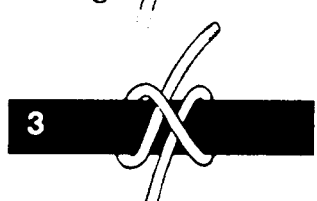

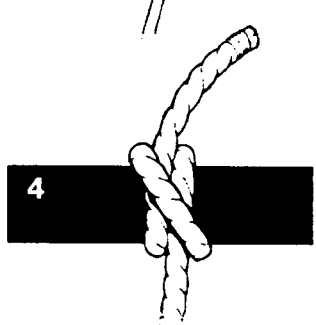

Timber hitch: Use as a start knot for lashings and for hoisting and for dragging or towing heavy logs.
1 Bring live end round bar and loosely round standing end.
2 Carry forward and tuck beneath rope encircling bar. Twist round as many times as comfortably fit. Tighten knot by gently pulling on standing end until a firm grip is achieved.

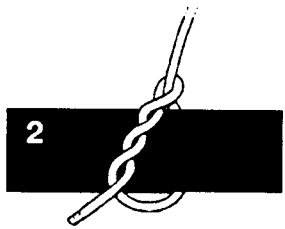

Killick hitch: To secure a line to an anchoring weight, make a timber hitch round one end of weight and tighten. Carry line along weight and make a half-hitch.

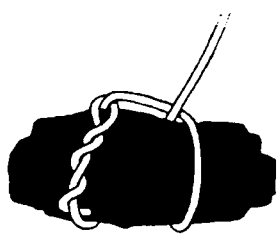

Marlin spike hitch: A temporary knot for securing a mooring line to a post, or for dragging over the top of an upright peg. By attaching a short, stout stick to the line it is possible to gain extra purchase for a firmer pull.
1 Form a loop in the rope – study drawing carefully. 2 Bring one side of loop back up over standing end. 3 Drop this over the pole – the pole coming between extended loop and standing part. Pull live end to tighten.

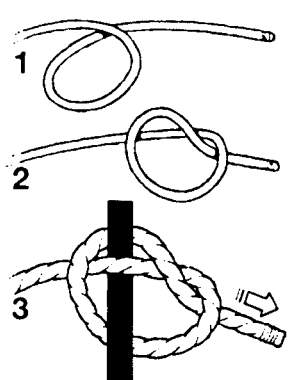

Quick-release knot: A secure knot, but will come untied with a single sharp tug on the live end. Recommended for temporarily anchoring lines. **1** Carry a bight round a post or rail. **2** Bring a bight from the standing end through the first bight. **3** Form live end into a further bight and push doubled end through loop of second bight. Pull on standing end to tighten knot. **4** To release pull sharply on live end.

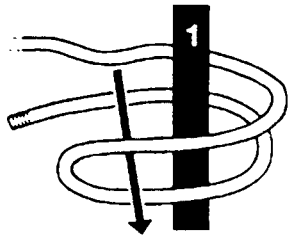

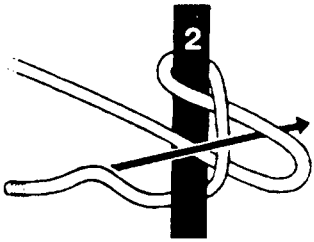

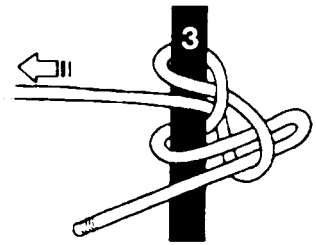

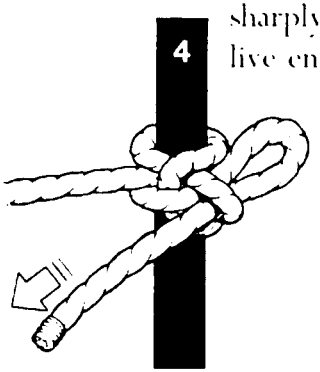

Shortening rope

Sheepshank: Treble the line. Form half-hitches in outer lengths and slip over adjoining bends. Or, instead of half-hitches, when a loop is formed in the standing part, pull a bight through it and slip this over bend in rope. Tighten as you gradually increase tension.

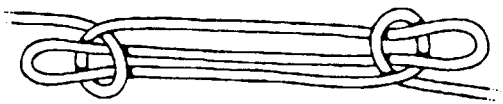

Make a sheepshank more secure by passing a stick through the bend and behind the standing part (a). Or, if you have access to the rope's end, pass that through the bight (b). A stick would make this more secure.

Never cut a rope unnecessarily: a joined rope has only half the strength of a continuous one. Use sheepshank to shorten it or to exclude a damaged section.

Securing loads

WAKOS TRANSPORT KNOT: Use to secure a high load or to tie down a roof. For maximum purchase, pull down with all your weight then secure with 2 half-hitches. If it comes loose, undo the hitches, retighten and secure. **1** Make a loop in rope. Further down, towards end of rope, make a bight. **2** Pass bight through loop. **3** Make a twist in the new lower loop. Pass end of rope round securing point and up through this twist. **4** Pull end to tighten. **5** With end make two half-hitches round lower ropes to secure. Undo these to adjust and retighten.

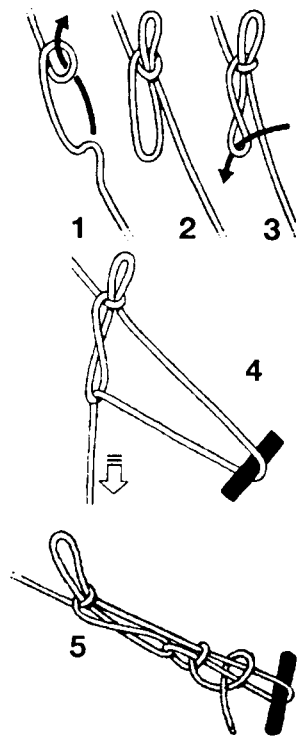

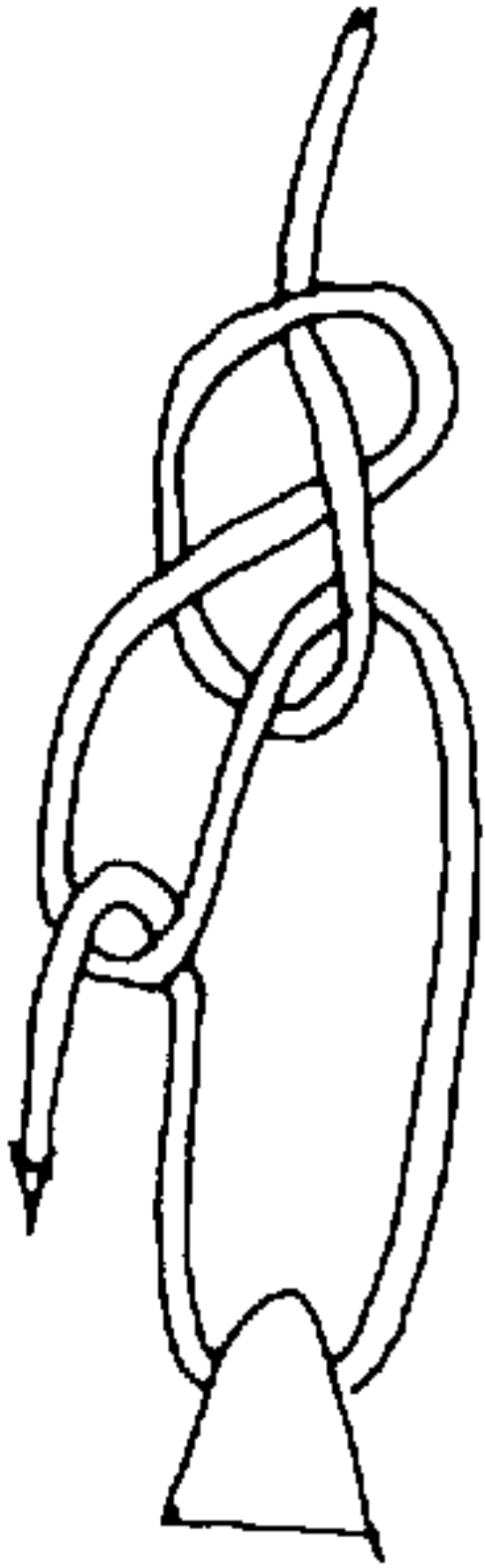

The trucker's hitch, a useful hitch for tightening down a lashing.

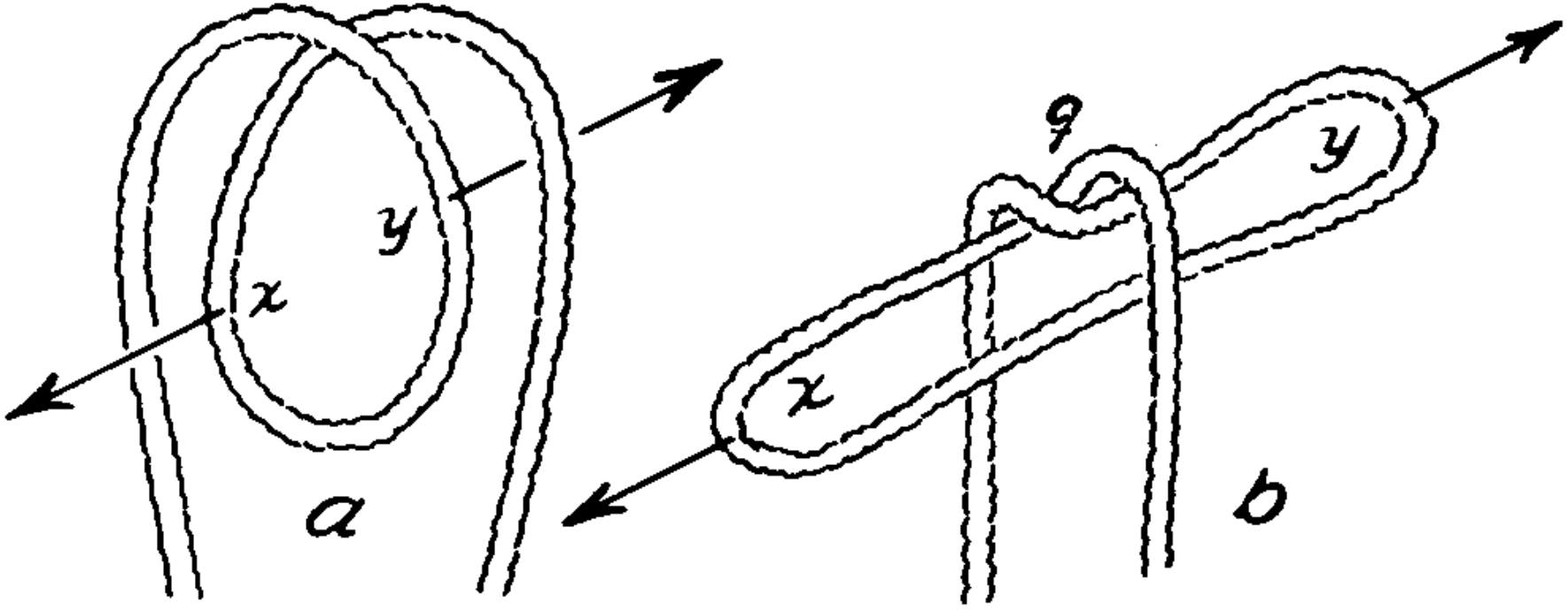

Fig. 43.

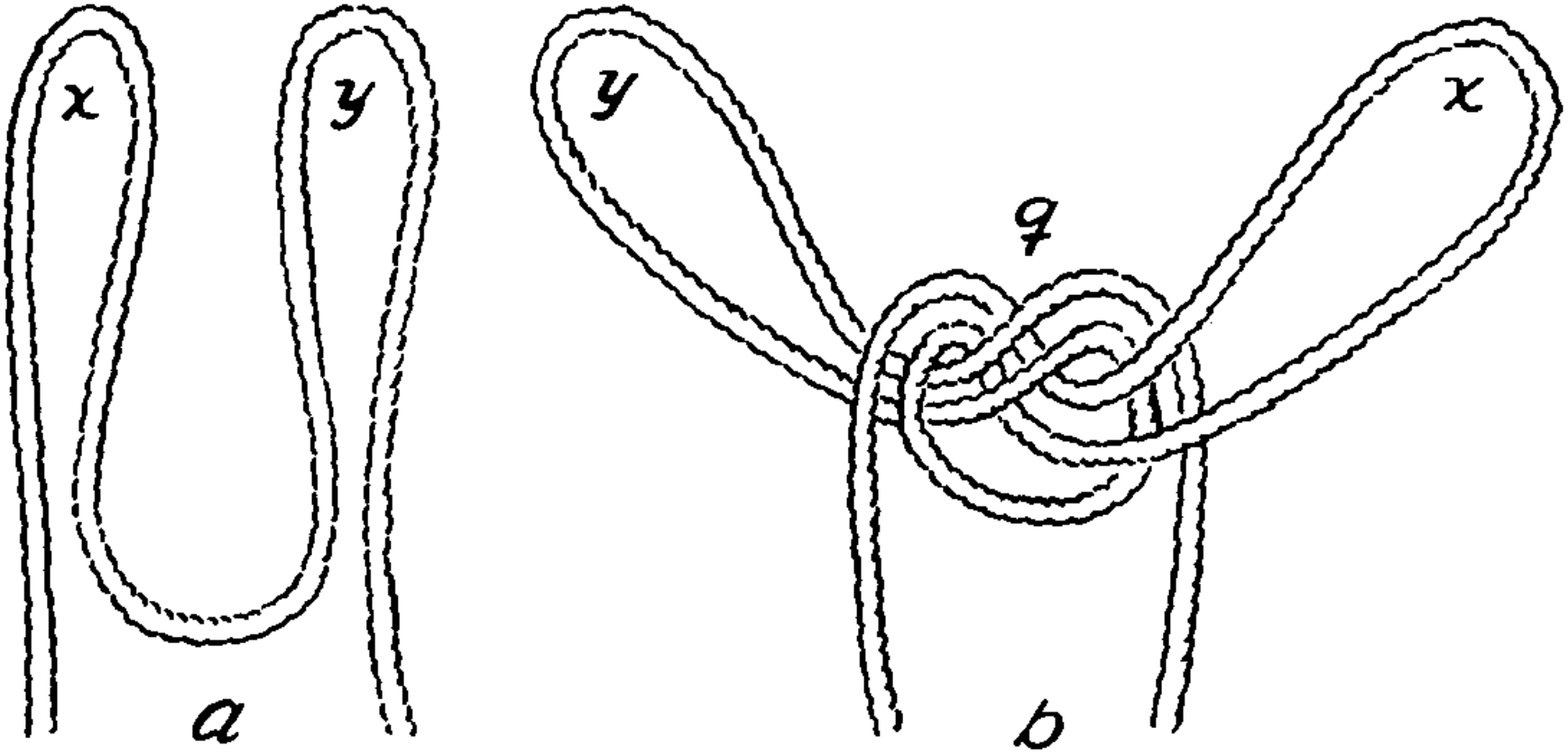

Fig. 44.

Prusik knot: A sliding loop. It will not slip under tension, but will slide along when tension is released. A pair of prusiks provide hand and foot holds for climbing or for swinging along a horizontal line. Slide them along main rope as you proceed. Also good for tent guylines.

1 Pass a bight round main rope, pull ends through. Keep loose.

2 Take ends over again and back down through loop. Ease tight. Do not allow circuits to overlap.

3 This gives the appearance of four turns on the main rope (a). Mountaineers take ends round and back through loop to give the appearance of six turns on main rope (b). **4** A prusik knot can be made using a fixed spliced loop: pass bight over main rope and back through itself, and repeat.

5 For use as a tensioning line attach along the guy rope etc., and secure ends (a) to an anchor.

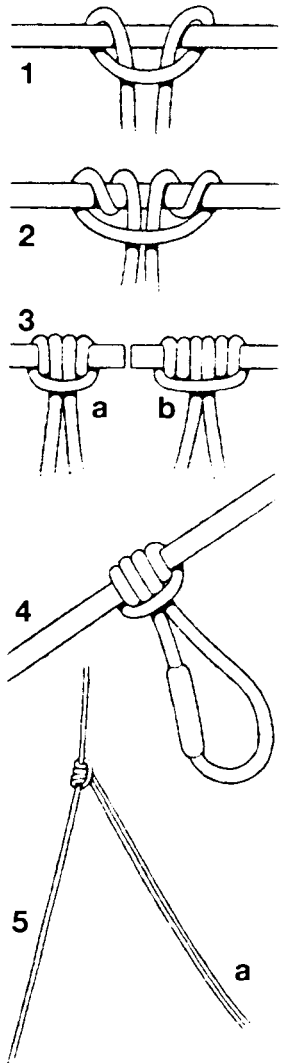

When used for climbing, or travelling along a rope, a spliced loop (4) is safest. If you have no spliced loop, join ends after knot is made. Test joins rigorously before use.

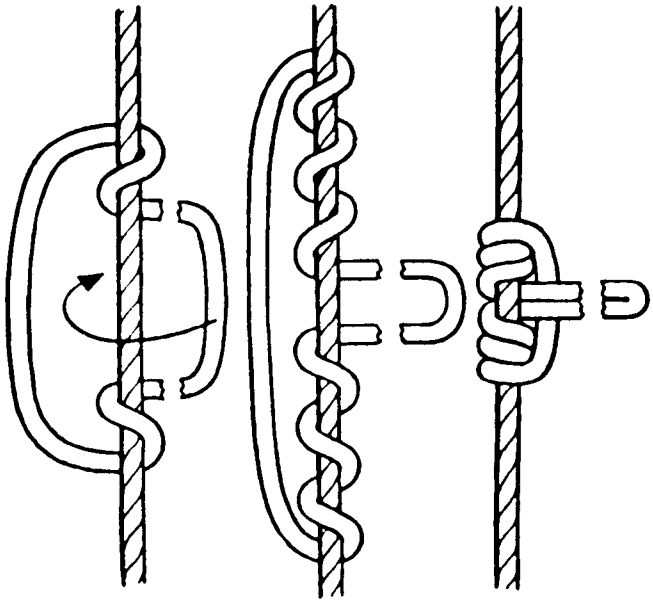

Fig. 4.8. The Prusik Knot.

Fig. 4.9. Use of Prusik Knot to Climb a Rope.

Prusik Knot. The Prusik knot is a valuable means of saving yourself if you fall into a crevasse, or in climbing up a rock face. The knot will hold tightly when weight is applied, but it will slide easily when unweighted. The method of tying is shown in Fig. 4-8. Take a bight of line and turn it twice around the rope, then pull the loose ends of the line through the loop.

You can also use the Prusik knot for climbing a rope. Use three slings fashioned from lengths of line. Make two stirrups and a chest loop fastened by Prusik knots to the climbing rope, as in Fig. 4-9. There should be about five feet between the stirrup and the knot in order to have the knot in front of the chest in an easy handling position. Then, by moving first one stirrup and then the other, it is possible to climb the rope. At the same time, by pushing up the chest loop, the victim is secured against loss of balance and can take a rest by leaning back at any time.

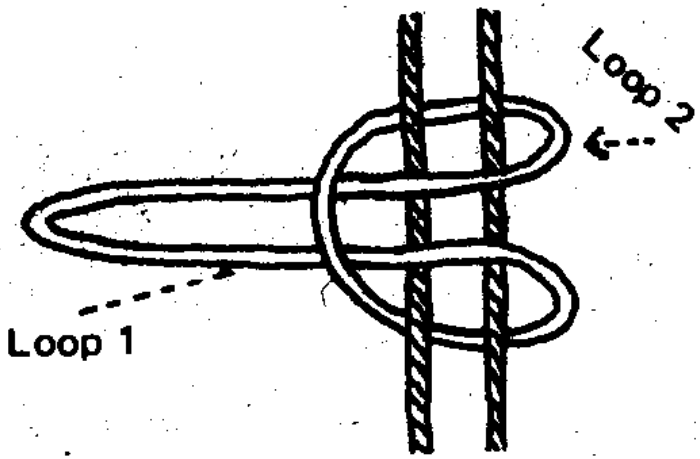

It's best to take loop one around again and come through loop two again—for double protection. This knot will slide when no pressure (weight) is placed on it, but will tighten, and hold you as soon as you put your weight on it.

Carabinier with safety lock:

Harness: You can buy a ready-made harness or make one out of about two yards of nylon strap from a mountain climbing shop. The ends are tied to make a continuous loop. To get into it, hold the entire loop horizontally behind your ass and bring the loop ends together in front of your crotch. Hold them with one hand and reach back between your legs with your other hand to grab the lower line. Pull this line between your legs to meet with the other loops in front. Hook the carabinier through all three loops and wiggle the whole business up to waist level.

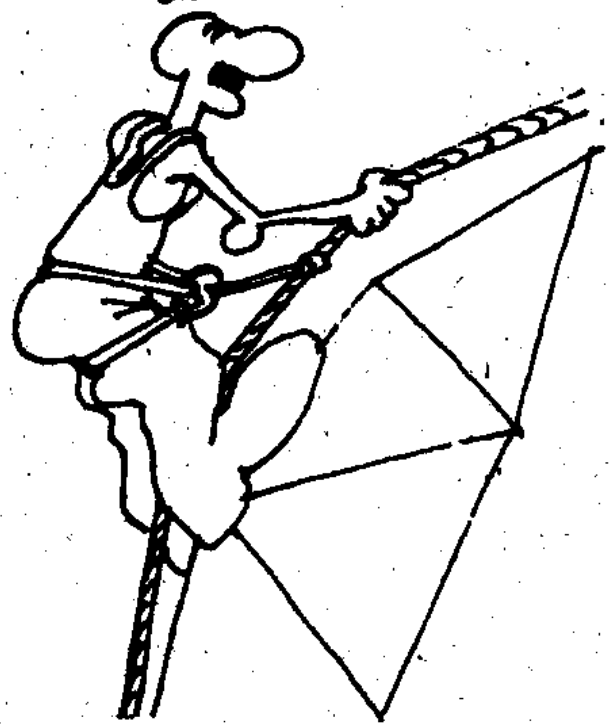

When you lean back, the knot holds. To move, you take weight off the knot. When you get to desired position, lean back, and you can work with both hands free. It's a strange sensation—you'll gradually learn to trust the rig. It works best to start at top, and work your way down: you get so you learn the amount of relief needed to descend, and soon you're walking up and down on the domeskin. Have care not to slip feet up-head down; you'll fall out of the harness.

Lashing Together Two Poles

1. Start with a clove hitch.

2. Loop the rope over and under the poles twice.

3. Loop the rope under and over the poles twice.

4. Tighten the loops by wrapping the rope around the midsection several times, as shown in the illustration. Finish with a clove hitch.

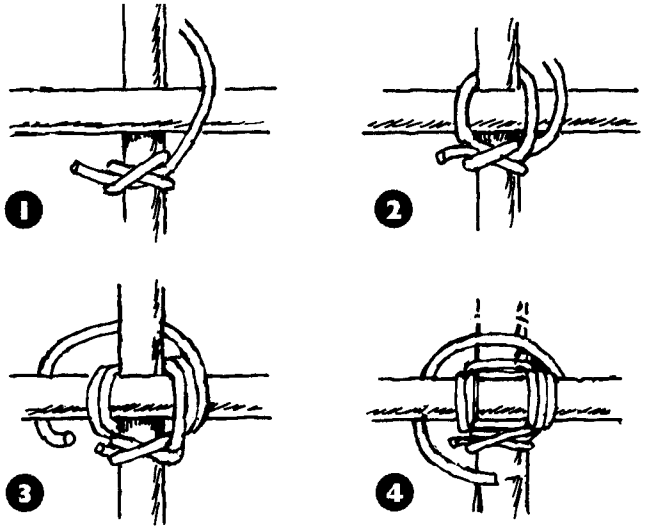

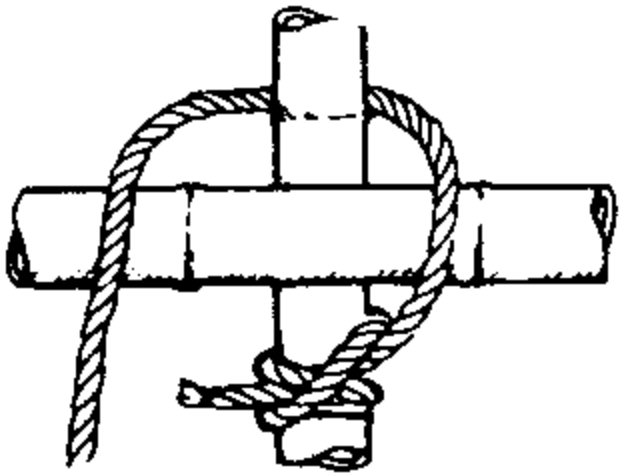

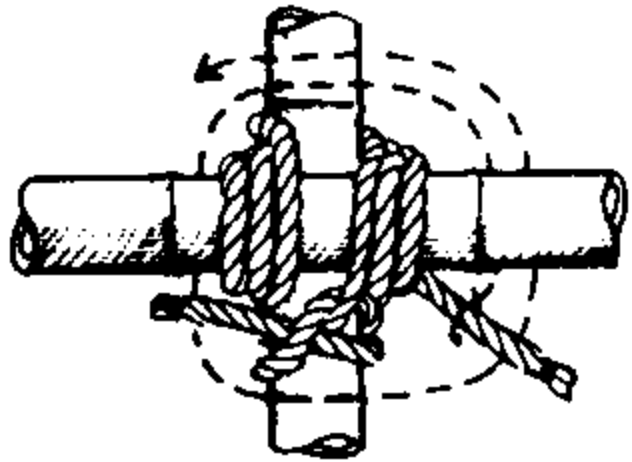

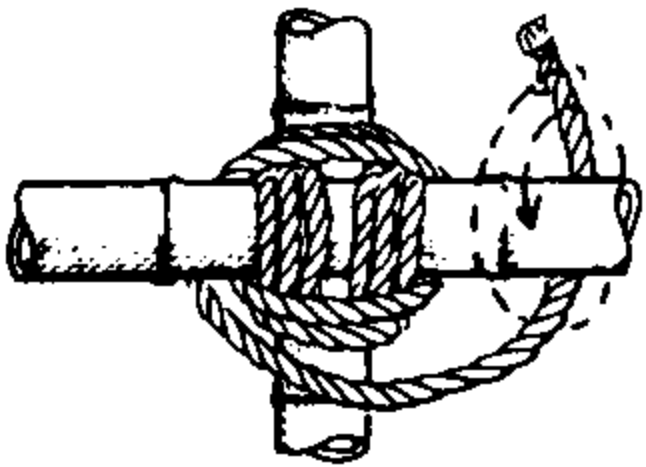

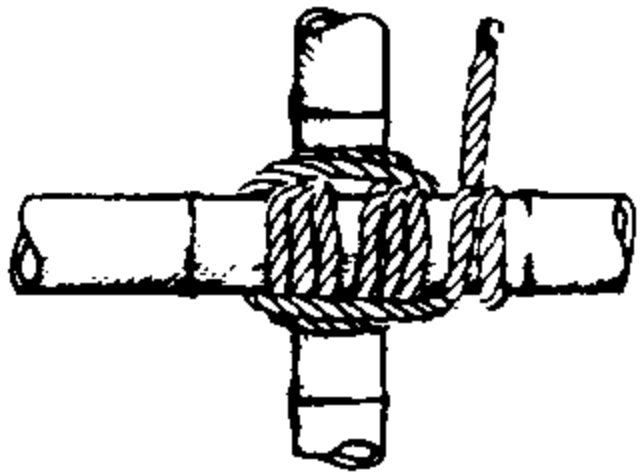

Lashings

Methods of lashing differ according to the position of the components. These techniques are invaluable in making rafts, shelters, etc.

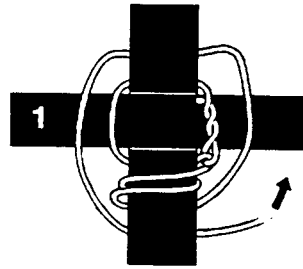

SQUARE LASHING: For lashing spars which cross at right angles. **1** Make a timber hitch carrying line alternately above and below both spars in a complete circuit before securing it. Then carry rope anti-clockwise over and under both spars. **2** After three or four circuits make a full turn round a spar and circuit in the opposite direction. **3** Complete circuits with a half-hitch round one spar and secure with a clove hitch on a spar at right-angles.

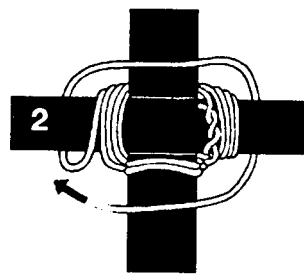

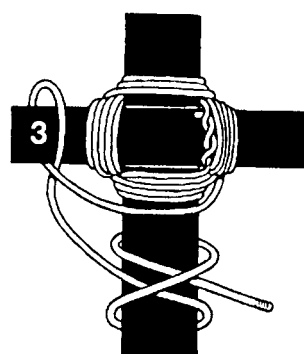

ROUND LASHING: Use to lash spars alongside each other or to extend length of a spar. Begin with a clove hitch round both spars (a), then bind rope round them. Finish knot with a clove hitch at other end (b). Force a wedge under lashings to make them really tight. If spars are vertical bang the wedge in downwards.

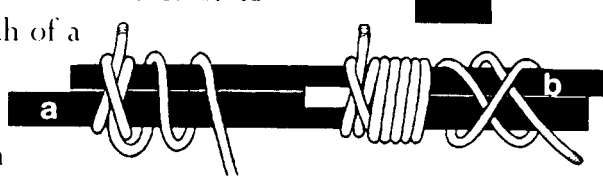

Diagonal lashing: Use when spars do not cross at right-angles, or when spars need to be pulled towards one another for tying.
1 Begin with a timber hitch round both spars, placed diagonally.
2 Frap (lash) both spars with a few turns of rope over a timber hitch, then make a full turn under the bottom spar. **3** Frap across other diagonal, then bring rope back over one spar and make two or three circuits above upper spar and below lower. **4** Finish with a clove hitch on a convenient spar.

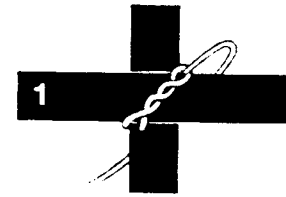

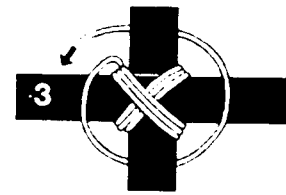

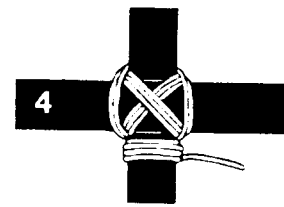

Shear lashing: To tie ends of two spars at an angle, e.g. for an A-frame. Begin with a clove hitch (a) round one spar. Bind, not very tightly, round both. Bring rope between spars and frap a few times round binding. Finish with a clove hitch round other spar (b). Tighten by opening up shears (c). A similar method can be used round three poles to make a tripod. Make turns round all three legs and frappings in the two gaps. The feet of A-frames and tripods should be anchored to stop them spreading.

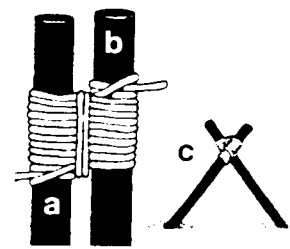

Lashing two spars together ■ 219, 220

Begin with a clove hitch.

Tuck the short end under the long one as you make the first turn.

Make at least two complete turns, pulling the line taut after each one.

End with a clove hitch or two half-hitches.

NOTE:

Whether lashing two spars together or at right angles to each other, the method is the same.

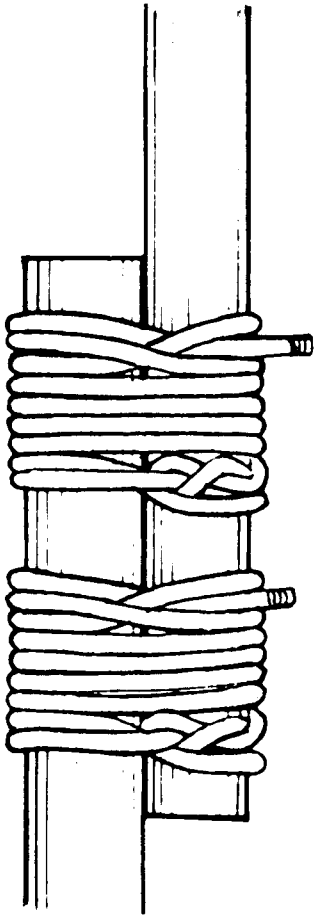

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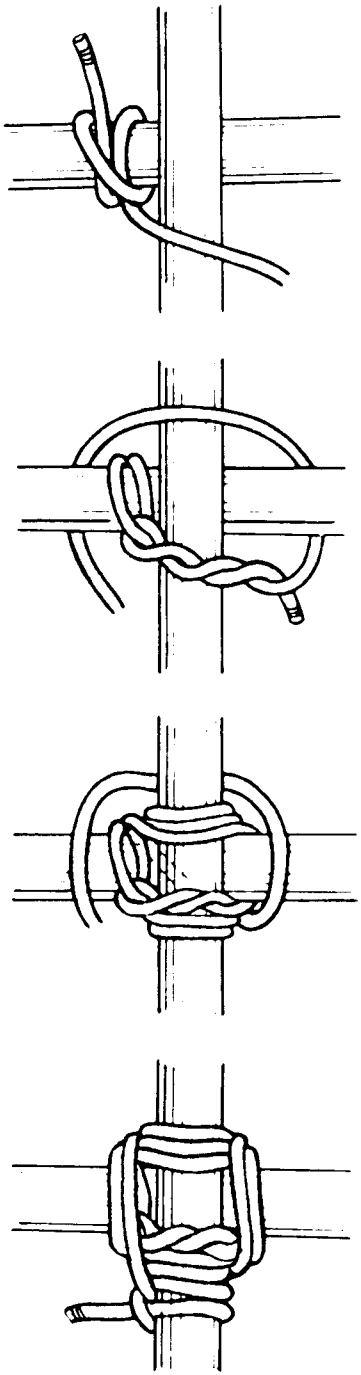

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18 A guide to anchorages

Anchorages are needed in a variety of situations – for example, bridging, lifting, vehicle recovery, and stabilizing sheer legs and structures. The following is a guide to anchorages which can be improvised in the field.

Natural or structural anchorages

A tree can be strengthened as an anchorage by tying it back to another tree or to a picket holdfast. Two trees close together can be used with a stout timber log between them to spread the load. Always try to spread loads taken on stone masonry and brickwork. The pull should be taken as close to the ground as possible.

Picket holdfasts

A picket is a stout pole up to about 1.5m long. One end is pointed for driving into the ground. Pickets are used singly or in groups lashed together. Various combinations are shown in Figure A18.1.

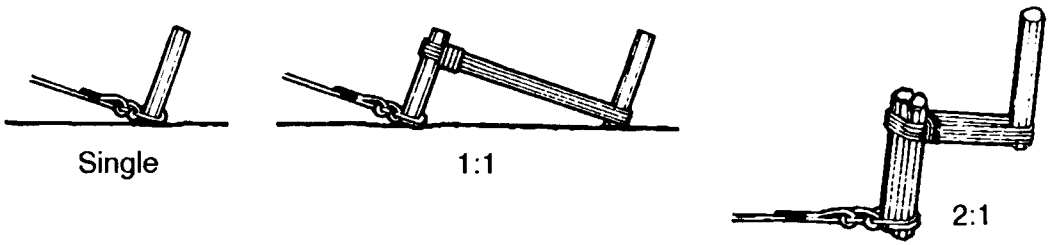

Figure A18.1 Combinations of picket holdfasts

Key points when using picket holdfasts in normal ground:

- pickets should be driven at least a metre into the ground at right-angles to the line of pull
- the lashings connecting the pickets should be at right-angles to the pickets
- lashings should come from the head of the picket in front to the bottom of the back-up picket
- there should be no slack in the lashings.

Holdfasts can be used in rock by chiselling holes with a 'jumper bar' and jamming steel crowbars or angle iron into the holes. Wire ties can be used for back-up lashings.

Withdraw pickets in the same line as they were driven in or they may break.

Baulk anchorage

This anchorage uses a log or stout timber (a baulk), held by a series of picket holdfasts (Figure A18.2). Use for loads of 2 to 10 tonnes.

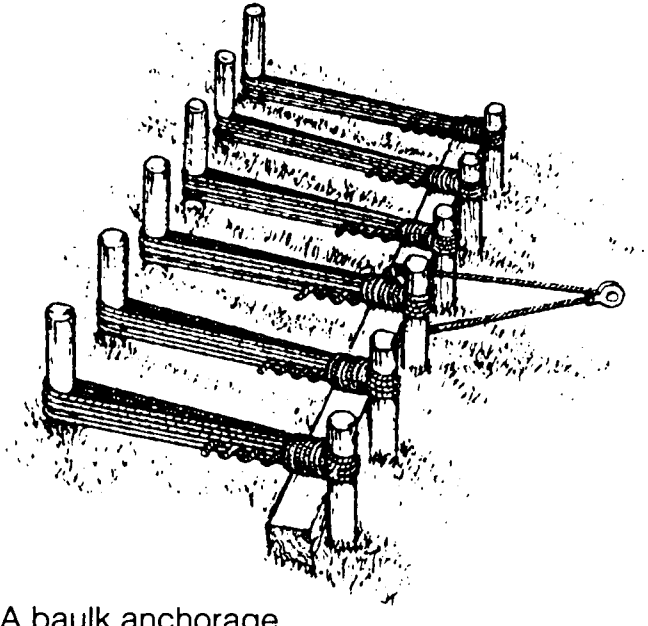

Figure A18.2 A baulk anchorage

Key points when using a baulk anchorage:

- there should be the same number of holdfasts either side of the pull
- holdfasts should not be less than 0.5 metres apart
- the log must bear evenly on all the pickets
- the log should rest on the ground and soil removed for the rope to pass around the log
- square section timber must be bedded into the ground so that a flat face bears evenly on all pickets.

Buried log anchorage

A buried log anchorage is used for pulls above about 10 tonnes. A log, or several logs, are buried horizontally in a trench (Figure A18.3).

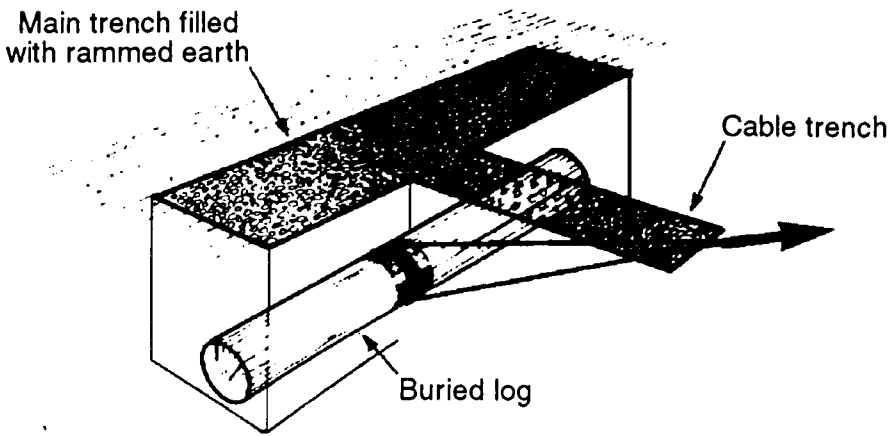

Figure A18.3 A buried log anchorage

Key points when using a buried log anchorage:

- the log, timber or steel pipe must be chosen to resist failure due to shear or bending
- the trench is dug with a vertical face at right-angles, in the horizontal plane, to the direction of pull
- the optimum burial depth is half the length of the log
- the trench for the cable is dug as narrow as possible
- the main trench is filled and rammed with earth; the cable trench is left open for the inspection and adjustment of cable and fastenings.

(Adapted from MoD, 1981a)

19 A guide to sheers and gyns

Sheers

A sheer is a hoisting apparatus of two poles or spars tied together at the top and with the feet separated. To assemble the sheer, the spars are laid on the ground and the bark stripped away at the point of the lashing. Lash the spars together while they are side-by-side so that when they are opened out the lashing will be tight. If the spars are large they may need to be opened some distance before lashing. A typical arrangement is shown in Figure A19.1. Note that the guy ropes are arranged so that they draw the spars together when loaded. The load sling is passed over the fork formed by the spars.

Sheers can be used to move a load in a straight line swung between the legs until the sheers lean at a limiting slope of 3:1. In this case the base of the spars must be well anchored.

General rules for loads:

- sheer legs made of 4in. spars are suitable for lifting up to 4 tonnes
- sheer legs made of 6in. spars are suitable for lifting up to 10 tonnes

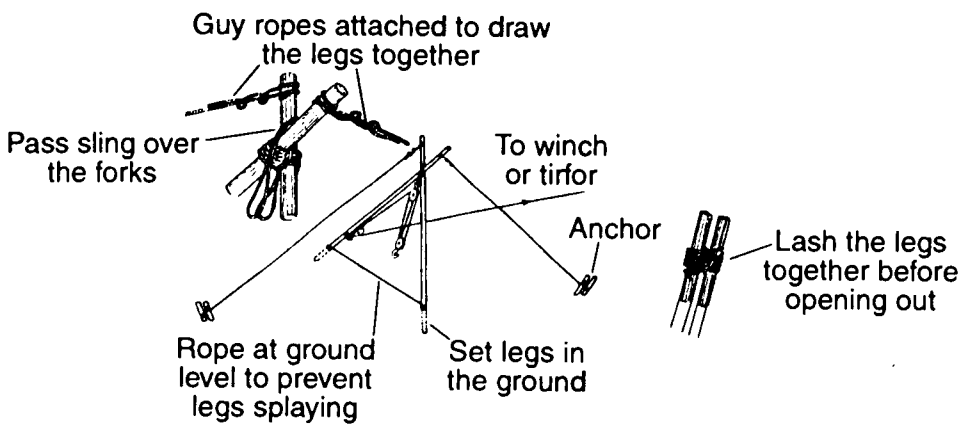

Figure A19.1 Sheers

Gyns

A gyn is shown in Figure A19.2. Gyns can only be used to lift vertically or to support a vertical load. A gyn occupies little space and no guys are required. To erect the gyn, lay two spars in one direction and the middle spar in the other direction as shown in Figure A19.2. Lash the three spars together before crossing the two outer spars until the feet of the spars are a distance apart of about half the length of the spars. Lash poles between the feet of the spars to fix their distance apart. Place the load sling across the top lashing and lift the spars. Push the middle spar into the triangle formed by the other two spars and the bottom pole until an equilateral triangle is formed on the ground by the feet of the spars. The top lashing can be

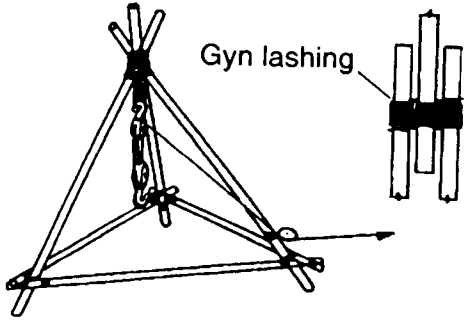

Figure A19.2 Gyn

prevented from slipping during lifting by a nail driven into the middle spar just below the lashing. Anchor the feet of each spar to prevent movement when loaded. The head of the gyn should be placed above the load to be lifted. Guy ropes should be fixed if there is a chance of a load moving sideways.

(Adapted from MoD, 1981a)

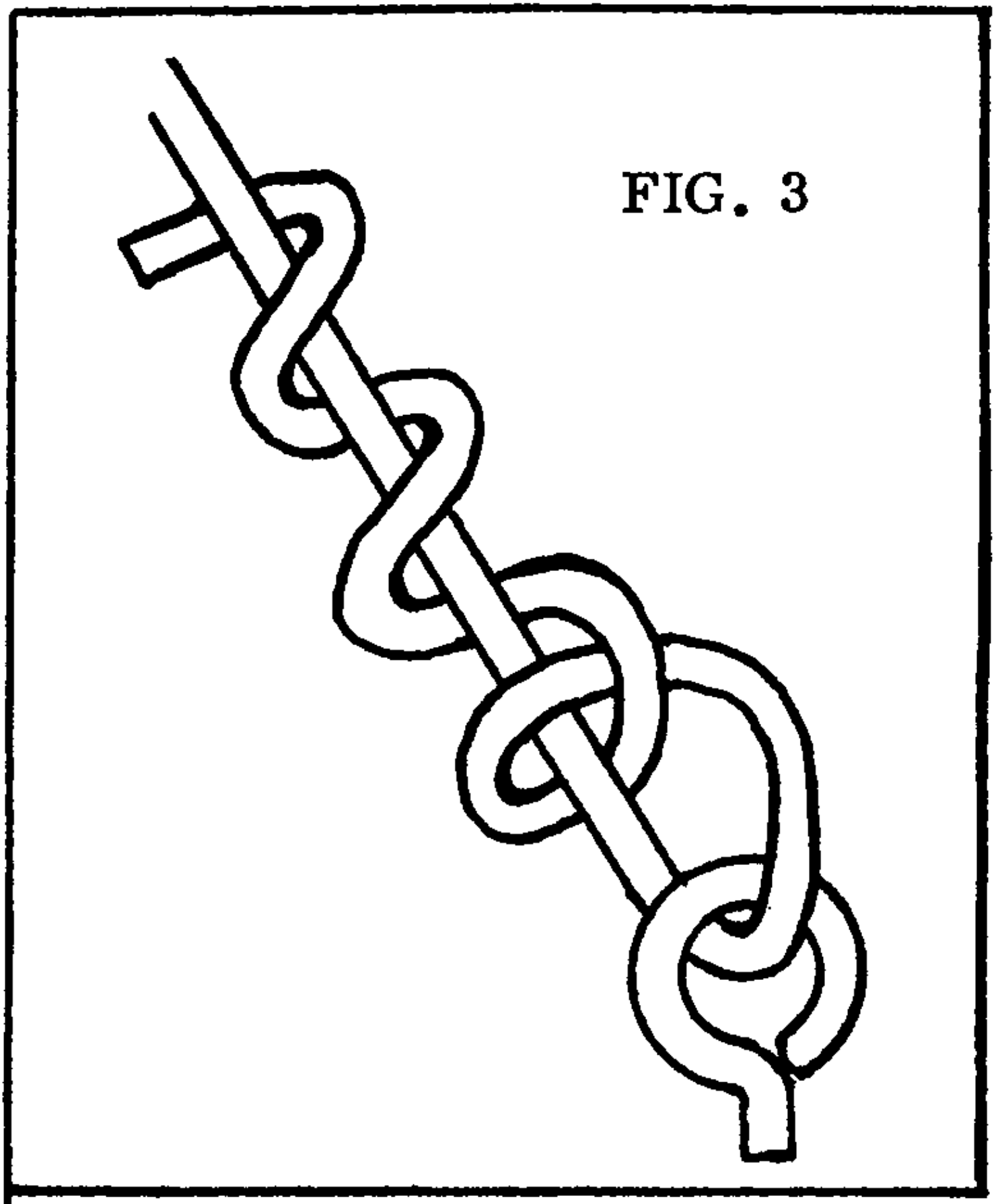

FIG. 3

Guy wires should be tied

The sketches below show the lashing techniques for both gable and hipped roof structures. They are both 12'-6" long, 10'-3" wide, 8'-6" high. The lashing material was generally a three-ply braid of *'uki'uki* grass. "They make little use of these dwellings, except to protect their food and clothing," wrote a member of Cook's expedition in describing the small (4'-6' high) houses of Hawaii, "and most generally eat, sleep and live in the open air, under the shade of a *kou*, or breadfruit tree."

THE GABLE

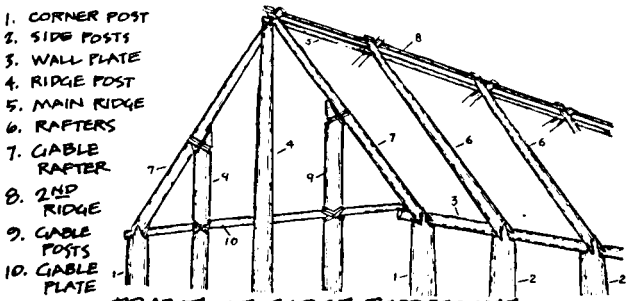

FRAME OF GABLE END HOUSE.
SIDE POSTS WERE ABOUT 4' HIGH AND 6"-8" IN DIAMETER.
POSTS WERE HARDWOOD (UHIUHI, NAIO, PUA, OTHERS).
SET POSTS IN HOLES, MAKE FIRM WITH STONES.

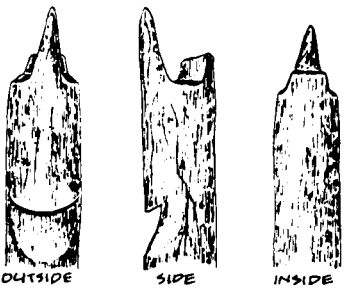

LASHING WAS DONE WITH A 3-PLY BRAID OF 'UKI'UKI GRASS. COCONUT FIBER WAS RARELY USED.

TOP OF WALL POSTS

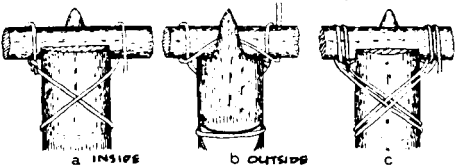

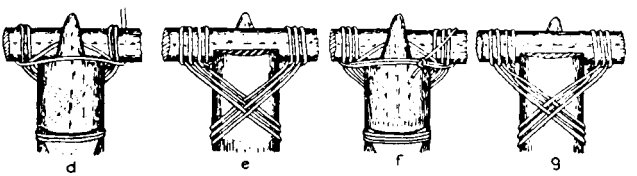

LASHING WALL PLATE TO WALL POST

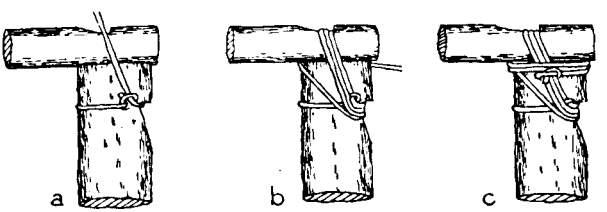

RIDGEPOLE TO RIDGEPOST

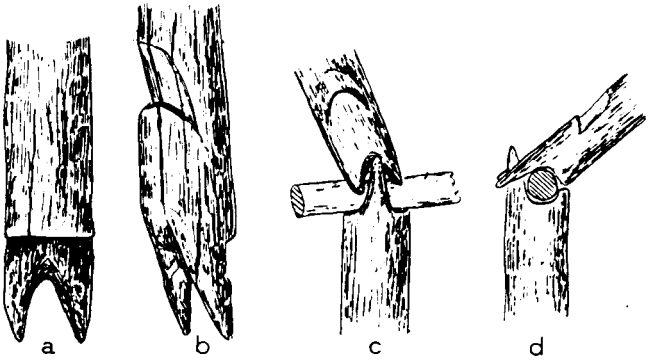

RAFTER END POST, WALL PLATE, RAFTER

LOWER RAFTER END, AT POST AND WALL PLATE

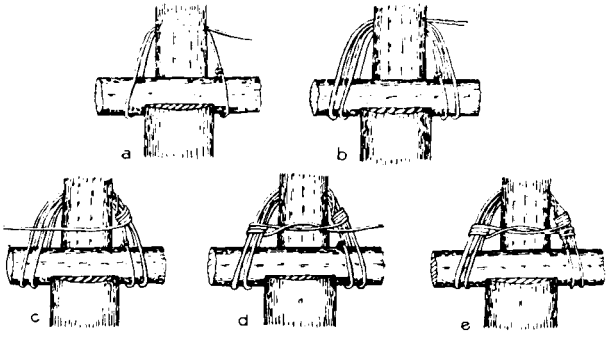

LASHING RAFTER TO WALL PLATE

AT (d), PULL TAUT BEFORE KNOTTING (e)

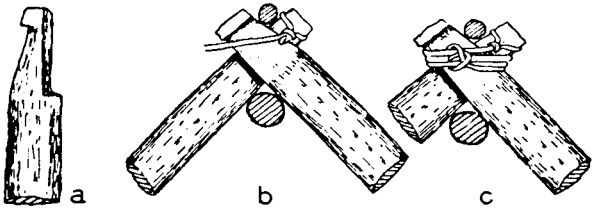

LASHING RAFTERS AT RIDGE

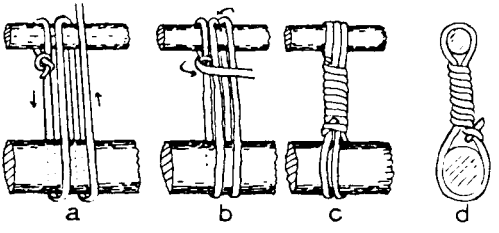

LASHING RIDGEPOLES TOGETHER

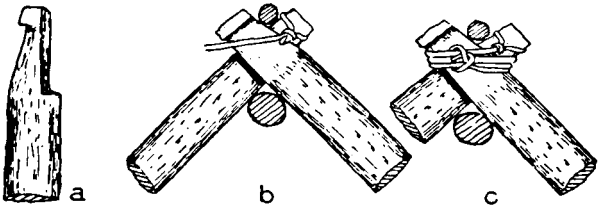

LASHING RAFTERS AT RIDGE

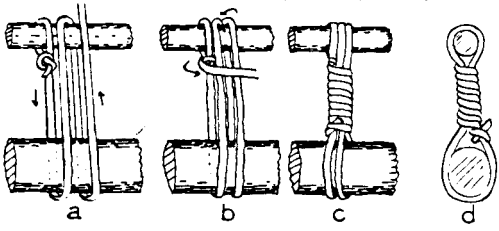

LASHING RIDGEPOLES TOGETHER

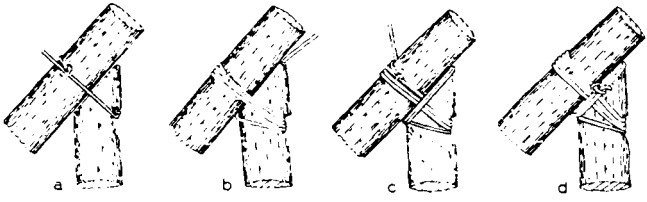

LASHING GABLE POSTS TO GABLE RAFTERS

NOW BASIC FRAME IS COMPLETED. THE PURLINS ARE ADDED TO THE FRAME TO ATTACH THE THATCHING. SEE THE DRAWINGS AT THE ABOVE RIGHT FOR LOCATION OF PURLINS.

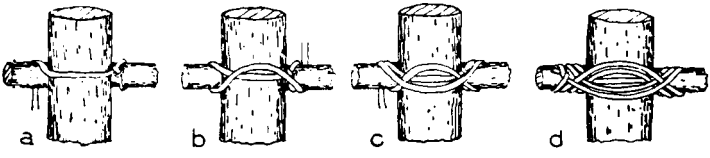

LASHING MAIN PURLINS TO RAFTERS AND POSTS

ORNAMENTAL LASHING VIEWED FROM INSIDE.

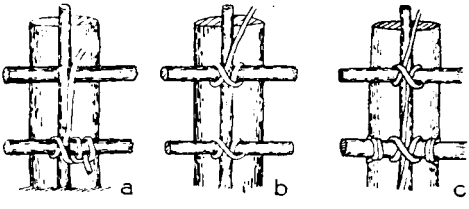

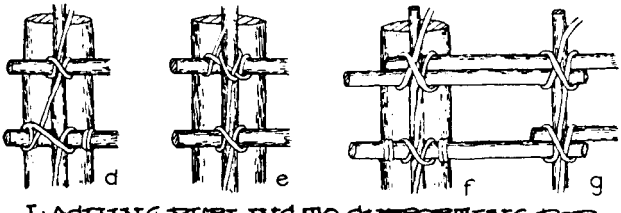

LASHING PURLINS TO SUPPORTING ROD

Lashing purlins to supporting rod: main purlins ¾-1" thick; thatch purlins, ½-¾" thick go between main purlins on both roof and wall. They are not lashed directly to rafters or posts but to ½" vertical rods.

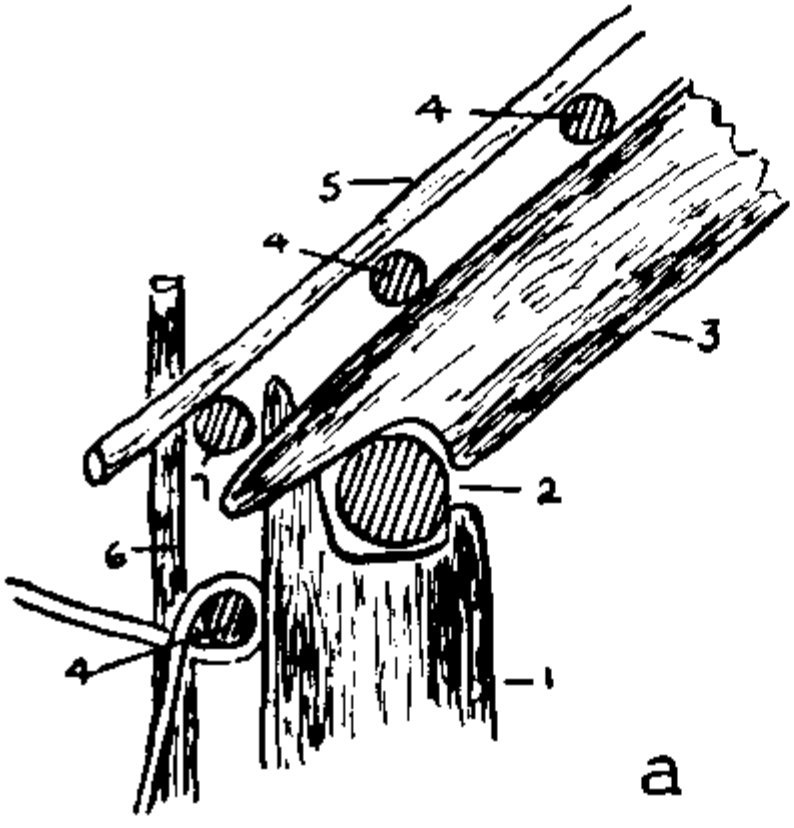

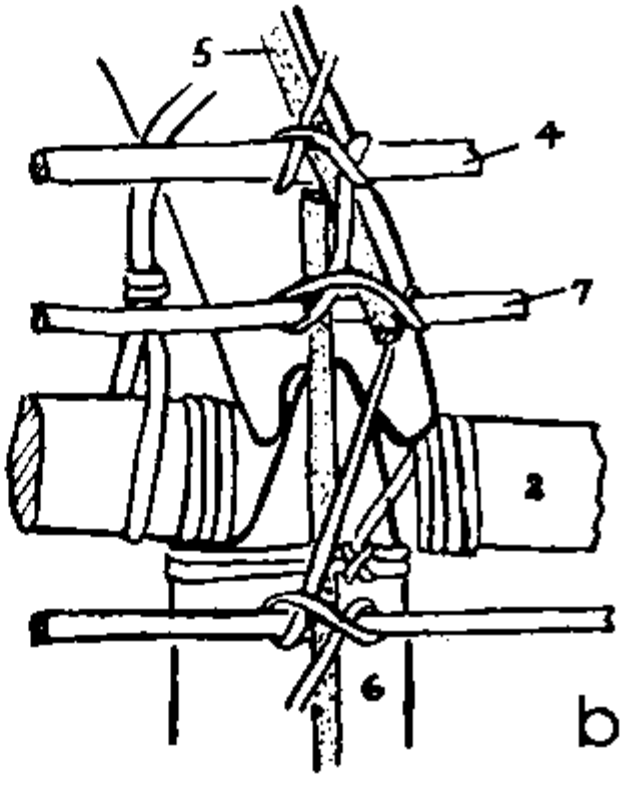

Junction of roof and wall rods: a, side view of junction between roof rod (5) and wall rod (6) with extra purlin (7); b, continuation of clove-hitch lashing down over extra purlin (7); c, close-up of junction join with wall rod (6) on right; d, junction join with wall rod (6) on left.

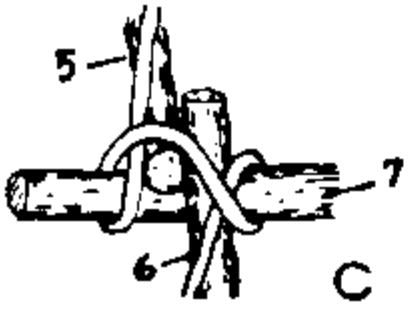

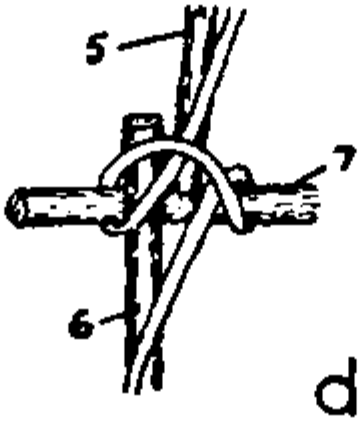

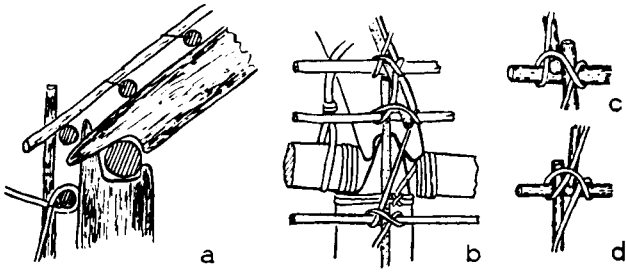

JUNCTION OF ROOF AND WALL RODS

HAWAIIAN NAMES: *
POU KIHI : CORNER POSTS
POU KUA : WALL POSTS, BACK
POU ALO : WALL POSTS, FRONT
LOHELAU : WALL PLATE
POU HANA : RIDGE POSTS
HALAKEA : TEMPORARY RIDGE POSTS
KAUHUHU : RIDGEPOLE, ALSO KAUPAKU
O'A : RAFTERS
KAUPAKU 'IOLE : 2ND RIDGEPOLE
KUKUNA : GABLE POSTS
'AHO PUEO : MAIN PURLINS
'AHO : THATCH PURLINS
'AHO HUI : THATCH PURLINS SUPPORTS.

* PRONOUNCE EACH SYLLABLE EVENLY. 'AHO SOUNDS LIKE HAHO.

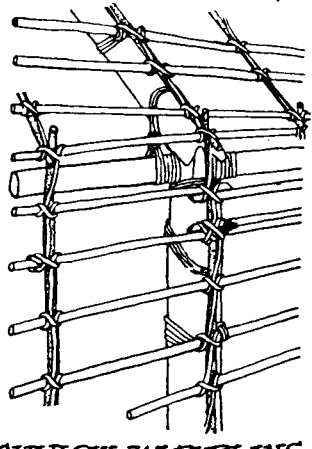

CLOVE HITCH TECHNIQUE W/ PURLINS

THE HIP

The hipped roof differs from the gable roof in that the triangular section above the wall plate slopes inward and upward instead of being vertical. The hipped roof house did not appear in the Islands until after European contact.

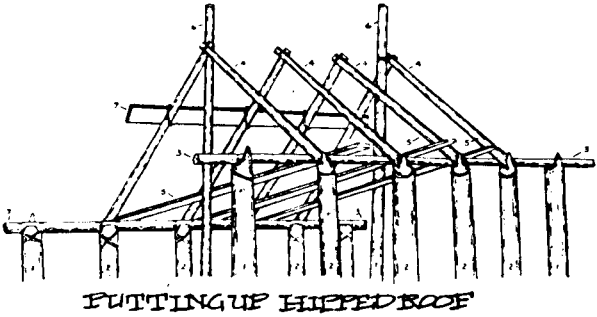

PUTTING UP HIPPED ROOF
INTERIOR POSTS ARE TEMPORARY

1. CORNER POSTS
2. SIDE WALL POSTS
2'. END WALL POSTS
3. WALL PLATE
3'. END WALL PLATE
4. MAIN RAFTERS
5. MAIN RIDGE POLE
6. 2ND RIDGEPOLE
7. HIP RAFTERS
8. MEDIAN END STRUT
9. LATERAL END STRUTS

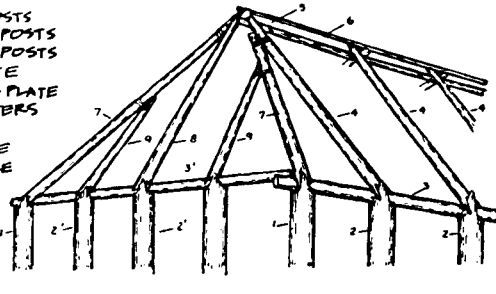

FRAME

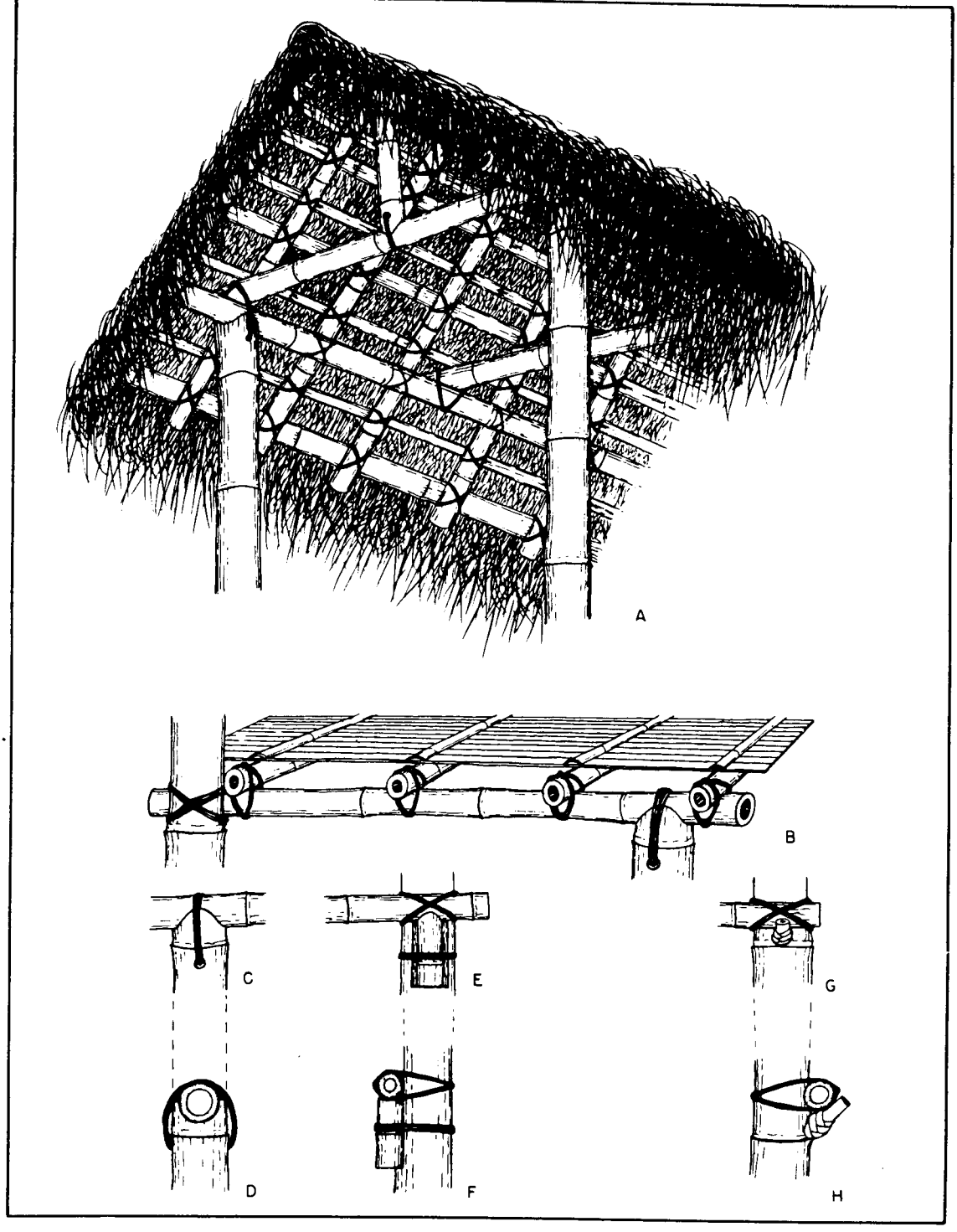

Figure 10 --Details of bamboo construction: A, fitting and binding culms at joints in roof and frame; B, fitting and securing bamboo boards of floor; C and D, saddle joint; E and F, use of inset block to support horizontal load-bearing elements; G and H, use of stump of branch at node of post to support horizontal load-bearing elements.

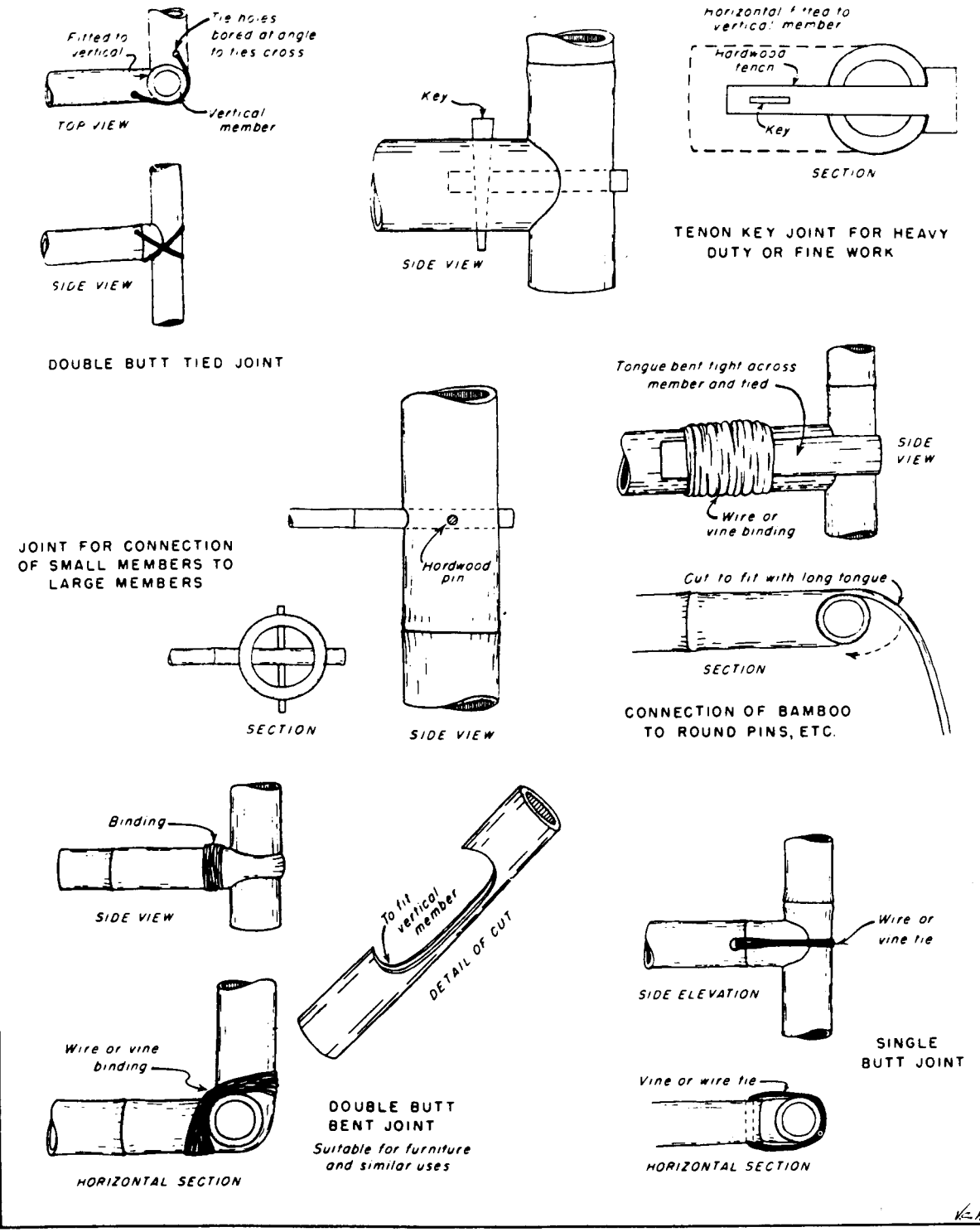

Figure 11 --Joints used in building with bamboo.

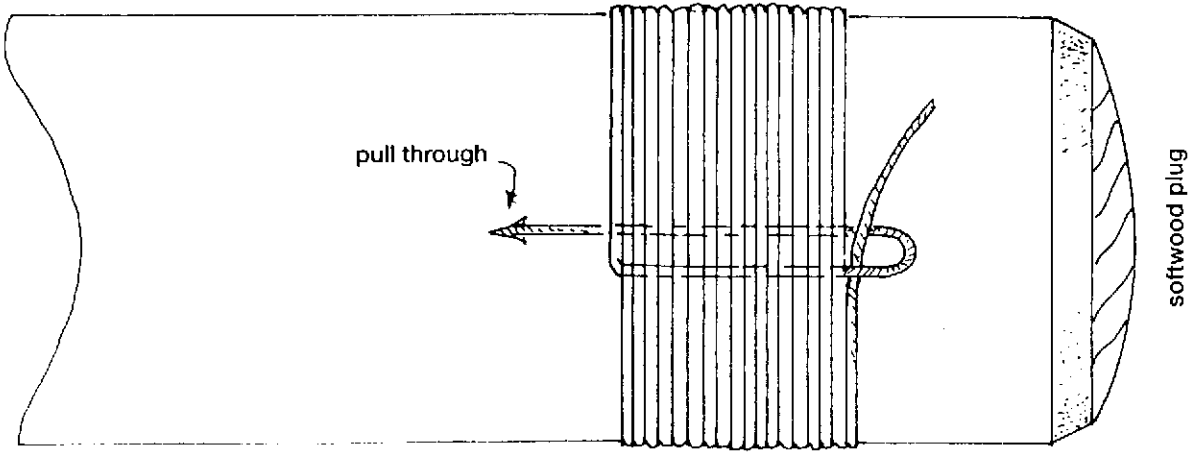

Fig 54 Common whipping at the top of a bamboo pole.

Fishing knots

Hook on to gut: Turl knot. Soak gut. Thread through eye of hook. Make overhand loop and pass a bight through it (a) to form a simple slip knot (b). Pass hook through slip knot (c) and pull tight round shank.

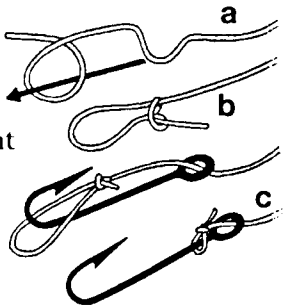

Hook on to nylon I: Half blood knot. Thread end through eye. Make 4 turns round standing part. Pass live end through loop formed next to hook (i). Pull taut and snip off fairly close to end (ii).

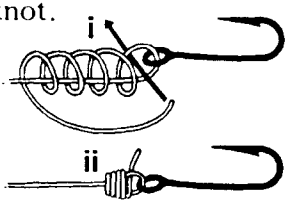

Hook on to nylon II: Two turn turl knot. Thread hook. Pass live end round standing part to form a loop and through it. Twist live end twice round side of loop. Hold loop and pull twists tight. Pass hook through loop (1). Pull on standing part to tighten loop on hook (2).

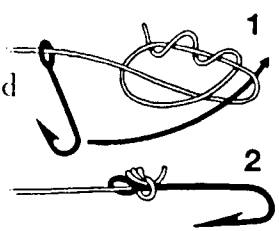

Jam knots: To secure improvised hooks to gut or cord. With an eye: thread gut. Make two turns round hook and bring live end up through turns (a). Ease tight and test for strength. Without an eye: make loop round lower part of shaft. Make two half-hitches from upper end downwards and pass live end through lower loop (b). Pull on standing part to tighten.

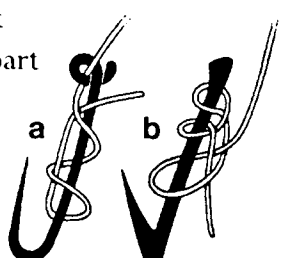

Loop in nylon I: Double overhand loop. Double line to make a bight. Tie an overhand in it (a). Twist end through again (b). Pull tight (c) and snip off end.

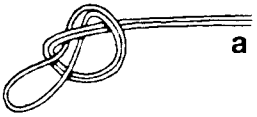

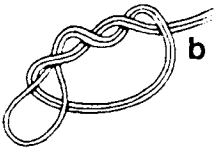

Loop in nylon II: Blood bight. Form a bight. Twist the end of it back round the standing part (i). Bring end back through new loop (ii). Pull tight and snip off loose end.

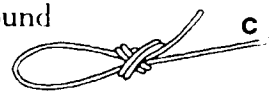

Joining loops: With free ends: pass each line through the other loop (1) and pull tight (2). With only one end free: make loop on one line. Take live end of other line through loop, round it and back through and then tie off with either of the knots for hooks on to nylon.

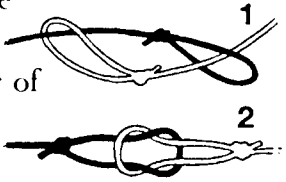

Joining nylon: Double three-fold blood-knots. Place ends alongside and twist one three times round the other. Bring live end back and pass it through the space where the two lines cross over the other line and under its own standing end (a). Repeat in the opposite direction with the other line. Live ends then point in opposite directions (b). Ease tight.

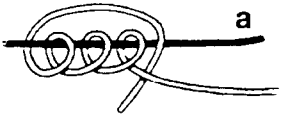

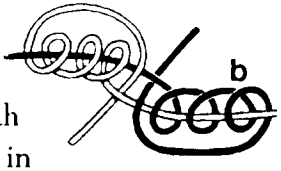

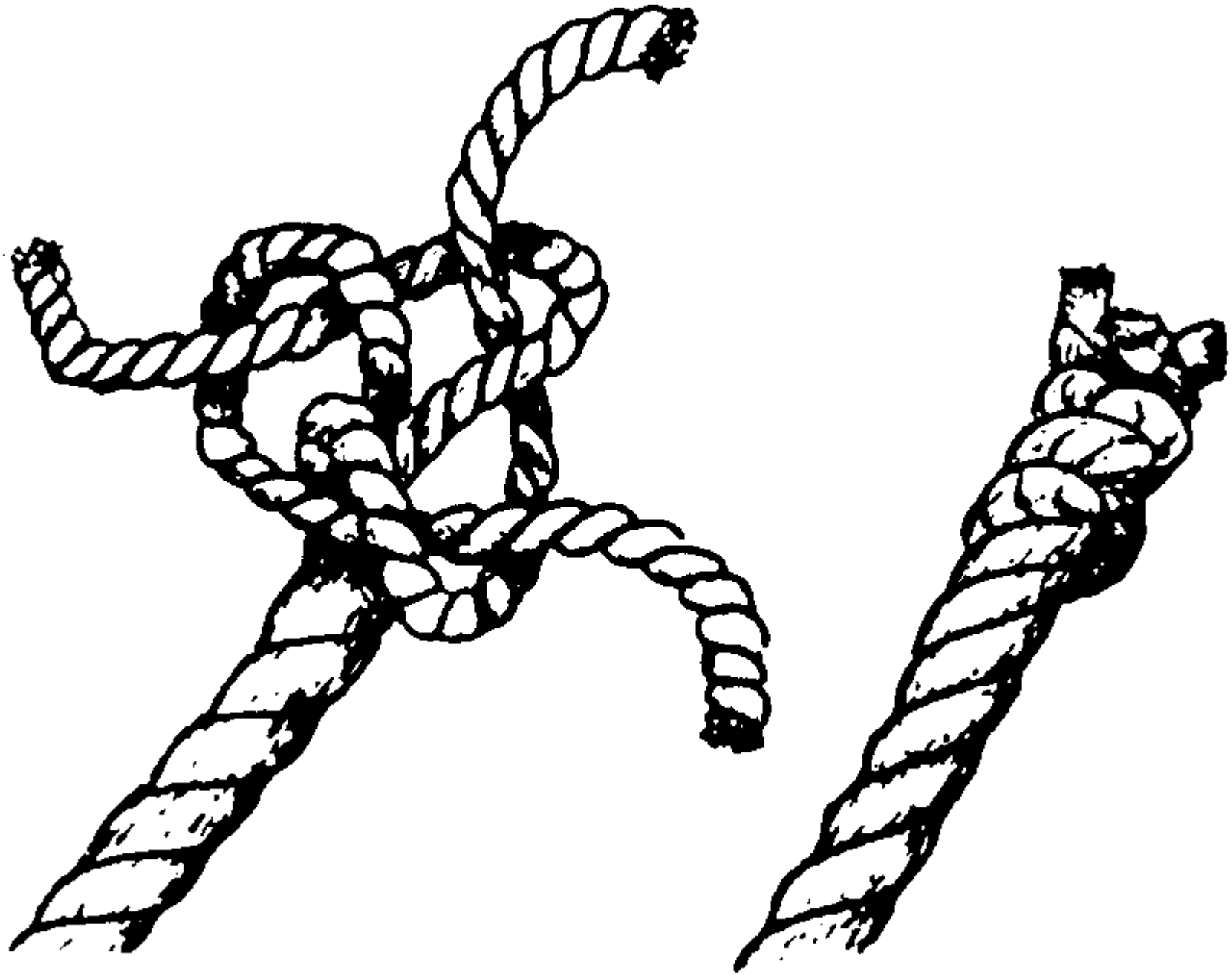

Stopper Knot

SPLICING & WHIPPING

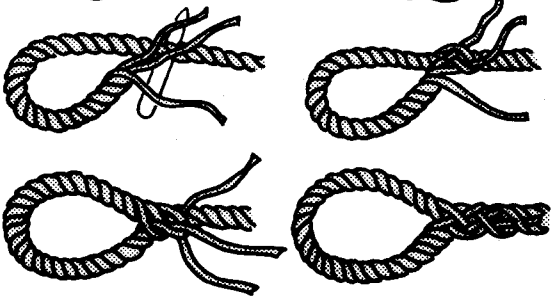

EYE SPLICE: Useful for putting a permanent loop in the end of a rope and for splicing one line, at right angles, into another. First unlay the rope about five turns and bend it back upon itself to form the desired loop. The two outer strands should straddle and the central strand lie on top of the line. Second, raise a strand in the main line and pass the middle loose strand under it, over the second main line strand, under the third, etc. Weave the two outside loose strands in *over* the first main line strand, *under* the second, etc. The finished splice will look like the final drawing above.

THE ESSENTIALS OF A GOOD SPLICE: A good splice must be strong and durable, it must carry the same load as any other part of the rope and—when made out in the middle of a line—it must not increase the rope's diameter enough to bind up in a pulley. Basically, splicing consists of three steps: (1) unlaying the strands of the ends to be joined, (2) fitting the ends together and interlocking their strands and (3) relaying and weaving the strands into a smooth piece of rope. The splice shown above illustrates all three steps and is an exceptionally handy one to know for making lariats, cinch lines for heavy loads, etc.

WHIPPING: To prevent a rope from unraveling, form a blight in a piece of twine and hold it 1/4" from the rope's end. Wrap the other end of the twine around the rope until the length of whipping equals the larger line's diameter. Place end of twine through the exposed loop, pull the loop under the whipping and trim loose end.

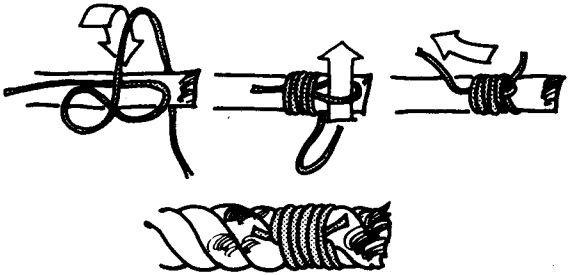

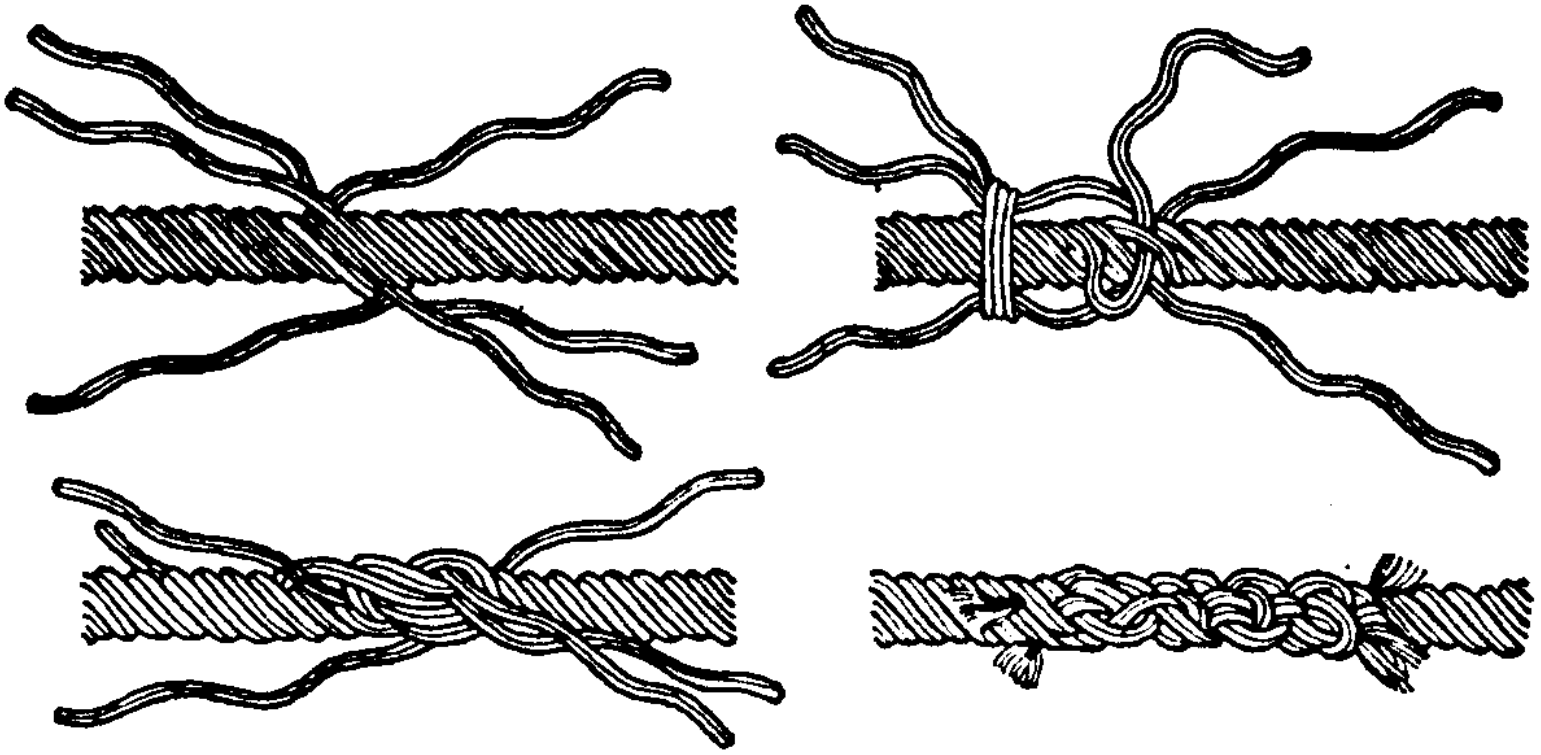

(k) short splice

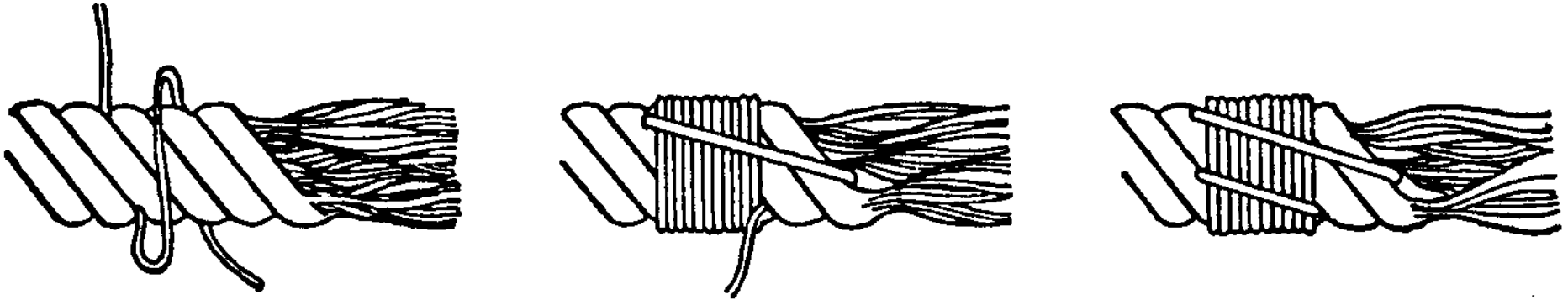

(l) palm and needle whipping

ROPE SPLICING. When two pieces of rope are joined by unlaying the strands and weaving or intertwining the strands of one end with those of the other, the operation is known as *splicing*. Ordinarily the object of splicing is to join the rope ends without increasing the size at the joint, as when a knot is employed. There are two kinds of splices in common use which are known as the "short splice" and the "long splice." The short splice may be made more rapidly than the long one, but the joint or

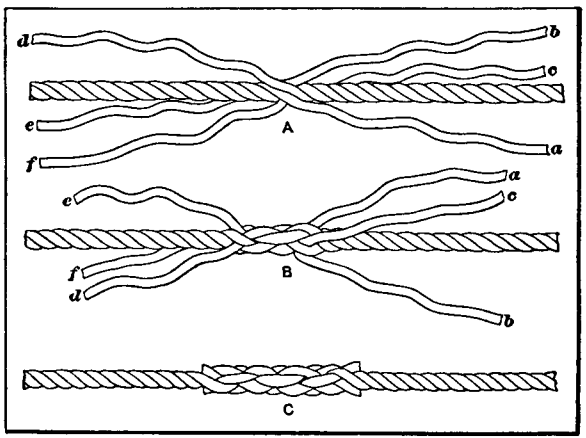

Fig. 1. Method of Making a Short Splice

splice is somewhat larger in diameter than the rest of the rope, whereas, a long splice, if properly made, can scarcely be detected.

Making a Short Splice. — The first step in making a short splice is to unlay or untwist the strands at the end of each rope. The two ends are then placed together as indicated at *A* in Fig. 1, so that each strand lies between two strands of the other rope. The distance that each end should be unlayed, or the length of the untwisted strands, depends upon the diameter of the rope, but the proportion should be about as indicated in the illustration. It is better to have a little extra length, since the projecting ends, in any case, are finally cut off. After the ropes are placed together, as shown at *A*, the strands on one side, as shown at *d*, *e*, and *f*, are either held together by the left hand or are fastened together with twine, in case the rope is too large to be held by the hand. The splicing operation is started by taking one of the strands as at *a*, and passing it across or over the adjacent strand *d* and then under the next strand *e*, after having made an opening beneath strand *e*. The strands *b* and *c* are next treated in the same manner, first one and then the other being passed over its adjoining strand and then under the

next successive one. These same operations are then repeated for the strands *d*, *e*, and *f* of the other rope. The splice will now appear as shown at *B* in the illustration. In order to make it stronger and more secure, the projecting strands of each rope are again passed diagonally over the adjoining strands and under the next successive ones. The splice should then be subjected to a strong pull, in order to tighten the strands and make them more compact. The projecting ends of the strands should then be cut off,

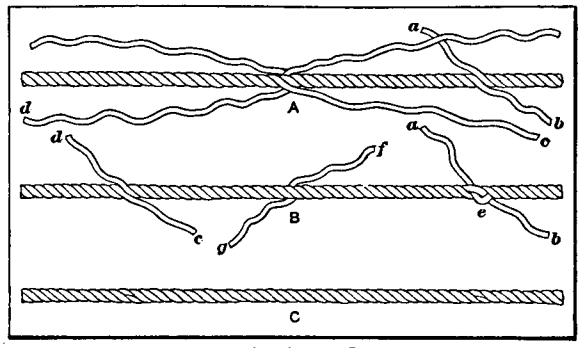

Fig. 2. Views illustrating how a Long Splice is made

thus completing the splice as shown at *C*. For making the openings beneath the strands on the rope, what is known as a *marlin spike* is generally used. This is merely a tapering, pointed pin made of wood or iron.

Making a Long Splice. — When a rope has to pass through pulley blocks, or in case any increase in the size of the rope would be objectionable, the short splice is not suitable and the long splice should be employed. The diameter of a long splice is the same as that of the rope and, if the work is done carefully, the place where the ends are joined can scarcely be distinguished from the rest of the rope. The ends of each rope are first unlaid or untwisted the same as when making a short splice, but for a distance about three times as long. These ends are then placed together so that each strand lies between two strands of the other rope, the same as shown at *A*, Fig. 1, for a short splice. One of the strands is next unlaid and then a strand from the other rope is curled around into the groove thus made, as indicated at *A* in Fig. 2, strand *a* having been unlaid and strand *b* from the other rope end, put into its place. Care should be taken to twist strand *b* so that it will lie in its natural position into the groove previously occupied by strand *a*, as the neatness of the splice will depend partly upon the care with which this part of the work is done. This operation is then repeated in connection with strands *c* and *d*, strand *c* being unlaid and strand *d* twisted around to occupy the groove thus made. The splice will now be as shown at *B*, and the next step is that of disposing of the protruding ends of the strands. After these strands have been cut to about the length shown at *B*, two of the strands, as at *a* and *b*, are first reduced in size by removing about one-third of the fiber; these ends are then tied by an overhand knot as shown at *e*. After tightening this knot, the protruding ends may be disposed of the same as when making a short splice, or by passing them over the adjoining strand and through the rope, under the next one. By gradually removing the fiber each time the end is passed across an adjoining strand, the enlargement of the rope at this point may be made very slight and scarcely noticeable. The strands *f* and *g* which remain in their original positions in the center of the splice, and also the strands *c* and *d* are disposed of in a similar manner, thus completing the splice as shown at *C*.

Making an Eye-splice. — When a loop is formed at the end of a rope by splicing the free end to the main or standing part of the rope, this is known as an *eye-splice*. The end of the rope is first unlaid about as far as it would be for making a short splice. After bending the end around to form a loop of the required size, the middle strand *a* (Fig. 3) is tucked under a strand on the main part of the rope, as illustrated at *A*. The strand *b* is next inserted from the rear side under the strand on the main part which is just above the strand under which *a* was inserted. Since strand *b* is pushed under the strand on the main part from the rear side, it will come out at the point where strand *a* went in, as illustrated at *B*. The third strand *c* is now passed over the strand under which strand *a* was inserted, and then under the next successive one, as illustrated at *C*. These three strands are next pulled taut and then about one-third of the fiber should be cut from them; they are next tucked away the same as when making a short splice, that is, by passing a strand over its adjoining one and under the next successive strand. The reason for cutting away part of the fiber or yarns is to reduce the size of the splice and give it a neater appearance. By gradually thinning out the fiber, the overlapping strands may be given a gradual taper, as indicated at *D*, which shows the completed eye-splice.

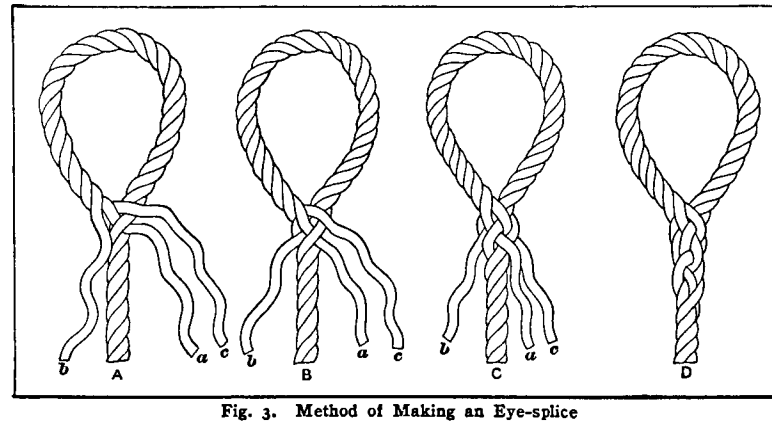

Fig. 3. Method of Making an Eye-splice

Splicing Transmission Rope. — The splice in transmission rope must be of the same diameter as the original rope and it should be smooth and free from lumps. What is known as the *English transmission splice* will be described, the rope selected being a four-strand Manila rope $1\frac{3}{4}$ inch in diameter, which is to be spliced on the sheaves such as are used with the multiple system of rope transmission. The rope is first placed around the sheaves and with tackle it is stretched and hauled taut. The ends should pass each other from 6 to 7 feet, the passing point being marked by tying twine around each rope. The rope is then removed from the sheaves and allowed to rest on the shaft so that there will be sufficient slack for making a splice.

First unlay the strands in pairs as far back as the pieces of twine *a* and *b* (see diagram *A*, Fig. 4). The ends of the rope are now placed together, as at *A*, and the cores which pass through a rope of this kind are drawn out together on one side. After having removed the marking twine, unlay the two strands *i* and *j* back for a distance of two feet or to a point *k* (see diagram *B*). The pair of strands *c* and *d* should be carefully laid in the place of strands *i* and *j*. Next unlay the strands *g* and *h* back for a distance of two feet or to point *l* and replace them with strands *e* and *f*. The rope is now as shown at *B*.

The pair of strands *i* and *j* are next separated and *j* is unlaid back a distance of four feet to point *m* which is six feet from the center. (See illustration *C*.) The strand *i* is left at *k*. The pair of strands *c* and *d* are next separated and *d* is left at point *k* with strand *i*, whereas strand *c* is carefully laid in place of strand *j* until they meet at point *m*. The two pairs of strands *e* and *f* and *g* and *h* are now separated and laid in the same manner, care being taken to maintain the original twist and lay of each strand. The protruding cores that extend through the center of the rope are cut off so that the ends, when pushed back into the rope, butt together. The rope now appears as shown at *C*, and after the eight strands have been cut to convenient working lengths (about two feet) the companion strands, such as *c* and *j*, *d* and *i*, etc., are ready to be fastened together and tucked. This operation will be described for strands *e* and *h*, the method being identical for the other three pairs. Unlay strands *e* and *h* for a length of about from 12 to 14 inches and divide each strand in half by removing its cover yarns as indicated at *D*. Whip or bind with twine the ends of the interior yarns of *e* and *h*; then, leaving the outer cover, re-lay strand *e* until it is near strand *h* and then join these strands with a simple knot, as indicated at *E*. Next divide the cover yarns of strand *h* and pass *e* through them, as at *F*, continuing on through the rope under the two adjacent strands, avoiding the core.

The half strand *h* is now taken care of as follows: At the right of the knot made with strands *e* and *h*, strand *e* is raised slightly by using a marlin spike and *h* is passed or tucked around *e* two or three times so that these two half strands form a whole strand. Half strand *h* is tucked until the cover of *e* is reached, which is shown at the right in diagram *F*; the yarns of this cover are then divided and strand *h* is passed through them and drawn under the two adjacent strands, thus locking it the same as was done with strand *e*. Both of these strand ends are now cut off leaving about two inches so that the yarns may draw slightly without unlocking. This completes the joining of one pair of strands as indicated at *G*. The three remaining pairs are joined in the same manner. After the transmission rope has been in service for a few days, the projecting ends at the locks wear away, and if the tucks have been made carefully and the original twist of the yarns preserved, the diameter of the rope will not be increased appreciably, nor can the splice be located when the rope is in motion.

Splicing Wire Rope. — The following directions for splicing wire rope are given by the American Steel & Wire Co. It is first necessary to determine the length of the splice. The allowance depends upon the rope diameter and should be about as follows: For diameters of $\frac{3}{8}$ or $\frac{1}{2}$ inch, 16 feet; $\frac{5}{8}$-inch diameter, 20 feet; $\frac{3}{4}$-inch, 24 feet; $\frac{7}{8}$-inch, 28 feet; 1-inch, 32 feet; $1\frac{1}{8}$-inch, 36 feet; $1\frac{1}{4}$-inch,

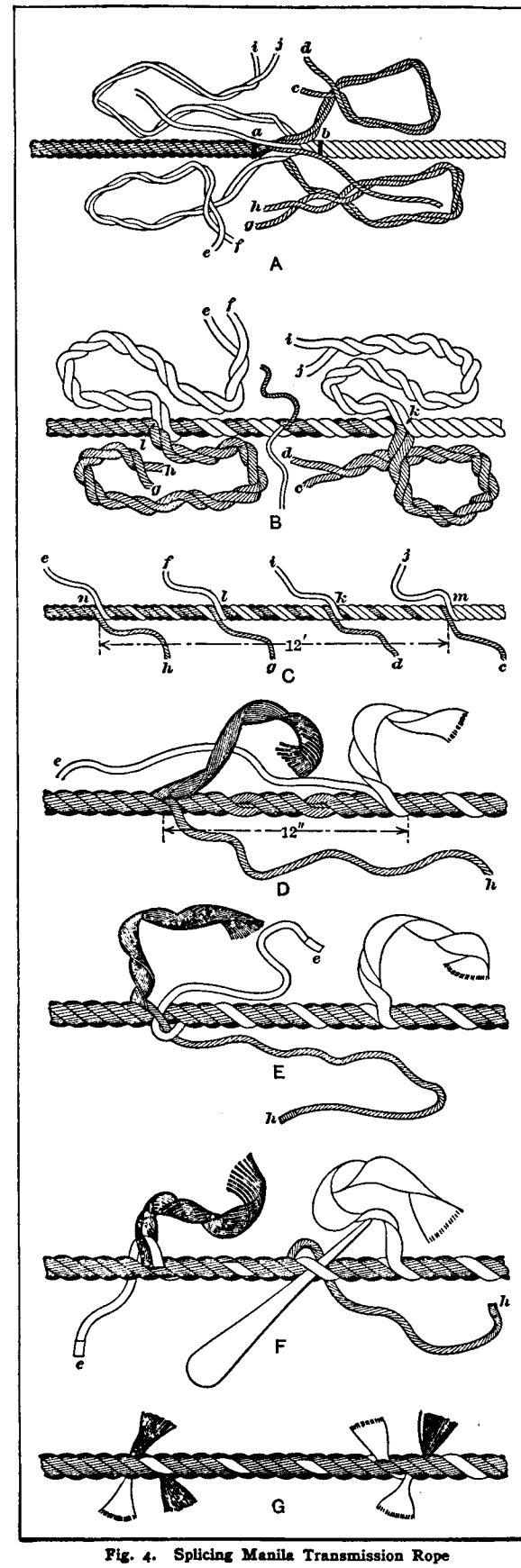

Fig. 4. Splicing Manila Transmission Rope

40 feet; 1½-inch, 44 feet. This extra length is equal to the distance *a–b* (see Fig. 5). Before making a splice, the required length of the rope after splicing should be carefully measured and marked at the points *c* and *d*. The strands are next unlaid from each end *a* and *b* as far as the marks *c* and *d*. There are usually six strands in wire rope, and these are laid together around a hemp center or core. After the strands have been unlaid, the projecting hemp centers should be cut off at *c* and *d*. The two rope ends are next placed together so that a strand of each rope is between two other strands and the marks *c* and *d* meet, as indicated at *B*. Next unlay a strand from one end and follow by laying the strand opposite and belonging to the other rope into the seam or groove thus formed; this operation should be continued until there remains a length of strand having a length in inches approximately equal to the total length of the splice in feet. For instance, if the splice were 16 feet long the following strand or the one that is inlaid should have a projecting end about 16 inches long. The strand which was unlaid to form a groove for the inlaid strand should be cut off to about the same length at the point where the two strands meet. An adjacent strand is next unlaid in the opposite direction from the center of the splice and the corresponding opposite strand is laid in its place, after which the two ends are cut off as previously described. As this is a six-strand rope, four of the strands now terminate at *e* and *f*, as illustrated at *C*, and eight strands remain in the center of the splice. It is advisable after laying each pair of strands as previously described to tie them temporarily at the points *e* and *f*.

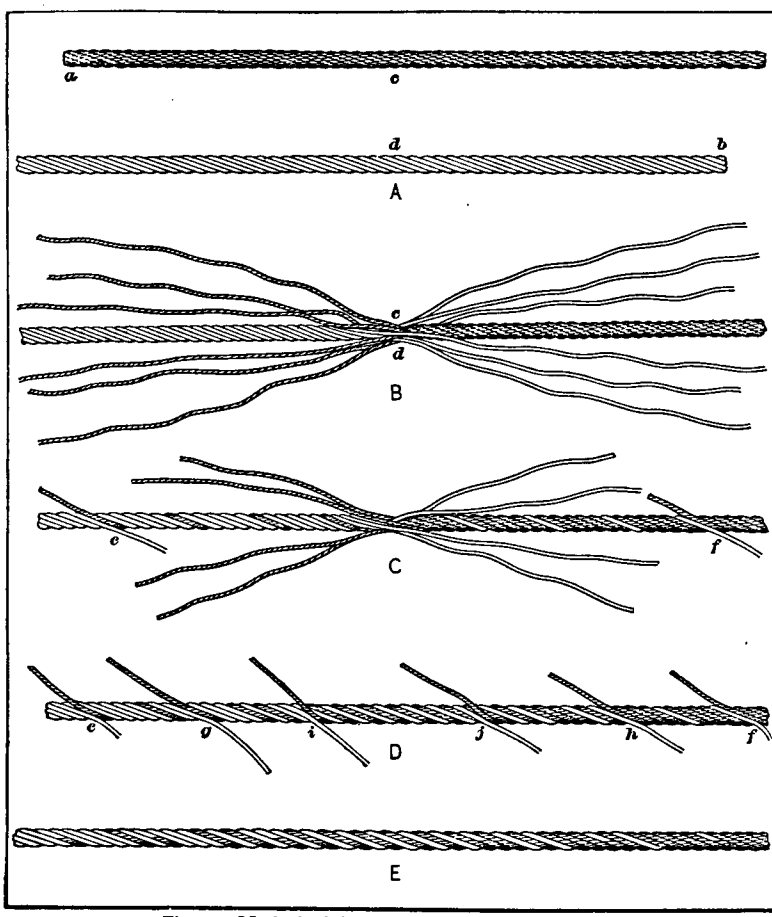

Fig. 5. Method of Splicing a Six-strand Wire Rope

This process of unlaying one strand and replacing it by a corresponding strand from the opposite side is repeated for each of the remaining four pairs of strands in the center; one pair should be carried back to a point *g*, another to a point *h* on the opposite side of the center, and the two remaining pairs should be stopped at points *i* and *j* in order to divide the space between *e* and *f* into approximately five equal parts, as shown at *D*. The ends in each case are cut off so that the strands extend beyond the main part of the rope a distance in inches equal to the length of the splice in feet.

Securing the Ends of the Strands. — Up to this point, all methods of making long splices are practically the same. They differ, however, in regard to the method of securing the ends of the strands. One good method is to insert the ends into the center of the rope after removing part of the hemp center or core. The rope is first clamped in a vise at a point to the left of the two strands (as at the left of *e*), and, by means of a hand clamp applied near *e*, the rope should be opened up by untwisting it sufficiently to permit cutting the hemp core which is then seized with nippers and a short length drawn out. The two nearest strands should then be opened up by inserting a marlin spike, after which the loose strand is started into the open space left vacant by the hemp center. By rotating the marlin spike, the projecting end of the strand may be placed completely in the center. After cutting the hemp core where the strand ends, the core should be pushed into place. The clamps are next removed, thus allowing the rope to close around the core. The hemp core is now drawn out in the opposite direction and the other strand is laid in the center of the rope in the same manner. After repeating this operation at the five remaining points *g*, *i*, *j*, etc., the rope should be hammered lightly at these points with a small wooden mallet, which completes the splice. A rope spliced by this method will be nearly as strong as the original rope and after it has been in use a few days, the splice, if carefully made, can scarcely be detected. If a clamp and vise are not available for this work, two rope slings and short wooden levers may be used to untwist and open the rope.

Rosacea

From Wikipedia, the free encyclopedia

Rosacea is a long term skin condition characterized by facial redness, small and superficial dilated blood vessels on facial skin, papules, pustules, and swelling.[2] Rosacea typically begins as redness on the central face across the cheeks, nose, or forehead, but can also less commonly affect the neck, chest, ears, and scalp.[3] In some cases, additional signs, such as semipermanent redness, dilation of superficial blood vessels on the face, red domed papules (small bumps) and pustules, red gritty eyes, burning and stinging sensations, and in some advanced cases, a red lobulated nose (rhinophyma), may develop.

Rosacea affects all ages and has four subtypes, three affecting the skin and the fourth affecting the eyes (ocular rosacea). It primarily affects people of northwestern European descent and has been nicknamed the "curse of the Celts" by some in Britain and Ireland, although such a connection has been questioned.[4] Rosacea is almost three times more common in women. It is commonly found in people between the ages of 30 and 50, and is more common in Caucasians.[2]

Treatment has typically been with doxycycline, tetracycline, or metronidazole.[5] Other treatments with tentative benefit include brimonidine cream, ivermectin cream, and isotretinoin.[5]

Rosacea

An Old Man and His Grandson by Domenico Ghirlandaio (ca. 1490) shows skin damage from rhinophyma.[1]

Pronunciation /roʊˈzeɪʃiə/

Classification and external resources

Specialty	Dermatology
ICD-10	L71 (http://apps.who.int/classifications/icd10/browse/2016/en#/L71)
ICD-9-CM	695.3 (http://www.icd9data.com/getICD9Code.ashx?icd9=695.3)
DiseasesDB	96 (http://www.diseasesdatabase.com/ddb96.htm)
MedlinePlus	000879 (https://medlineplus.gov/ency/article/000879.htm)

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eMedicine	derm/377 (http://www.emedicine.com/derm/topic377.htm)
MeSH	D012393 (https://www.nlm.nih.gov/cgi/mesh/2017/MB_cgi?field=uid&term=D012393)

Signs and symptoms

Signs include facial redness, small and superficial dilated blood vessels on facial skin, papules, pustules, and swelling.[2]

Erythrotelangiectatic rosacea

Erythrotelangiectatic rosacea (also known as "Erythematotelangiectatic rosacea"[6] and "vascular rosacea"[6]) is characterized by prominent history of prolonged (over ten minutes) flushing reaction to various stimuli, such as emotional stress, hot drinks, alcohol, spicy foods, exercise, cold or hot weather, or hot baths and showers.[7]

Glandular rosacea

In glandular rosacea, men with thick sebaceous skin predominate, a disease in which the papules are edematous, the pustules often 0.5 to 1.0 cm in size, with nodulocystic lesions often present.[7]

Cause

The exact cause of rosacea is unknown.[2] Triggers that cause episodes of flushing and blushing play a part in its development. Exposure to temperature extremes, strenuous exercise, heat from sunlight, severe sunburn, stress, anxiety, cold wind, and moving to a warm or hot environment from a cold one, such as heated shops and offices during the winter, can each cause the face to become flushed.[2] Certain foods and drinks can also trigger flushing, such as alcohol, foods and beverages containing caffeine (especially hot tea and coffee), foods high in histamines, and spicy foods.[8]

Medications and topical irritants have also been known to trigger rosacea flares. Some acne and wrinkle treatments reported to cause rosacea include microdermabrasion and chemical peels, as well as high dosages of isotretinoin, benzoyl peroxide, and tretinoin. Steroid-induced rosacea is caused by the use of topical or nasal steroids.[9] These steroids are often prescribed for seborrheic dermatitis. Dosage should be slowly decreased and not immediately stopped to avoid a flare-up.

Cathelicidins

In 2007, Richard Gallo and colleagues noticed that patients with rosacea had high levels of the antimicrobial peptide cathelicidin[10] and elevated levels of stratum corneum tryptic enzymes (SCTEs). Antibiotics have been used in the past to treat rosacea, but they may only work because they inhibit some SCTEs.[10]

Demodex mites

Studies of rosacea and *Demodex* mites have revealed that some people with rosacea have increased numbers of the mite,[8] especially those with steroid-induced rosacea. On other occasions, demodicidosis (commonly known as "mange") is a separate condition that may have "rosacea-like" appearances.[11]

A 2007, National Rosacea Society-funded study, demonstrated that *Demodex folliculorum* mites may be a cause or exacerbating factor in rosacea.[12] The researchers identified *Bacillus oleronius* as distinct bacteria associated with Demodex mites. When analyzing blood samples using a peripheral blood mononuclear cell proliferation assay, they discovered that *B. oleronius* stimulated an immune system response in 79 percent of 22 patients with subtype 2 (papulopustular) rosacea, compared with only 29 percent of 17 subjects without the disorder. They concluded that "[t]he immune response results in inflammation, as evident in the papules (bumps) and pustules (pimples) of subtype 2 rosacea. This suggests that the *B. oleronius* bacteria found in the mites could be responsible for the inflammation associated with the condition."[12]

Intestinal bacteria

Small intestinal bacterial overgrowth (SIBO) was demonstrated to have greater prevalence in rosacea patients and treating it with locally acting antibiotics led to rosacea lesion improvement in two studies. Conversely in rosacea patients who were SIBO negative, antibiotic therapy had no effect.[13] The effectiveness of treating SIBO in rosacea patients may suggest that gut bacteria play a role in the pathogenesis of rosacea lesions.

Diagnosis

Most people with rosacea have only mild redness and are never formally diagnosed or treated. No test for rosacea is known.

In many cases, simple visual inspection by a trained health care professional is sufficient for diagnosis. In other cases, particularly when pimples or redness on less-common parts of the face is present, a trial of common treatments is useful for confirming a suspected diagnosis.

The disorder can be confused or co-exist with acne vulgaris or seborrheic dermatitis. The presence of rash on the scalp or ears suggests a different or co-existing diagnosis because rosacea is primarily a facial diagnosis, although it may occasionally appear in these other areas.

Classification

Four rosacea subtypes exist,[14] and a patient may have more than one subtype:[15]:176

1. Erythematotelangiectatic rosacea exhibits permanent redness (erythema) with a tendency to flush and blush easily.[8] It is also common to have small, widened blood vessels visible near the surface of the skin (telangiectasias) and possibly intense burning, stinging, or itching.[8] People with this type often have sensitive skin. Skin can also become very dry and flaky. In addition to the face, signs can also appear on the ears, neck, chest, upper back, and scalp.[16]
2. Papulopustular rosacea presents with some permanent redness with red bumps (papules); some pus-filled pustules can last 1–4 days or longer. This subtype is often confused with acne.
3. Phymatous rosacea is most commonly associated with rhinophyma, an enlargement of the nose. Signs include thickening skin, irregular surface nodularities, and enlargement. Phymatous rosacea can also affect the chin (gnathophyma), forehead (metophyma), cheeks, eyelids (blepharophyma), and ears

(otophyma).[17] Telangiectasias may be present.

4. In ocular rosacea, affected eyes and eyelids may appear red due to telangiectasias and inflammation, and may feel dry, irritated, or gritty. Other symptoms include foreign body sensations, itching, burning, stinging, and sensitivity to light.[18] Eyes can become more susceptible to infection. About half of the people with subtypes 1–3 also have eye symptoms. Blurry vision and vision loss can occur if the cornea is affected.[18]

Zones

Variants

Variants of rosacea include the following:[19]:689

- Pyoderma faciale, also known as rosacea fulminans,[19] is a conglobate, nodular disease that arises abruptly on the face.[6][19]
- Rosacea conglobata is a severe rosacea that can mimic acne conglobata, with hemorrhagic nodular abscesses and indurated plaques.[19]
- Phymatous rosacea is a cutaneous condition characterized by overgrowth of sebaceous glands.[6] *Phyma* is Greek for swelling, mass, or bulb, and these can occur on the face and ears.[19]:693

Treatments

Treating rosacea varies depending on severity and subtypes. A subtype-directed approach to treating rosacea patients is recommended to dermatologists.[20] Mild cases are often not treated at all, or are simply covered up with normal cosmetics.

Acne rosacea on face.

Therapy for the treatment of rosacea is not curative, and is best measured in terms of reduction in the amount of facial redness and inflammatory lesions, a decrease in the number, duration, and intensity of flares, and concomitant symptoms of itching, burning, and tenderness. The two primary modalities of rosacea treatment are topical and oral antibiotic agents.[21] Laser therapy has also been classified as a form of treatment.[21] While medications often produce a temporary remission of redness within a few weeks, the redness typically returns shortly after treatment is suspended. Long-term treatment, usually one to two years, may result in permanent control of the condition for some patients.[21][22] Lifelong treatment is often necessary, although some cases resolve after a while and go into a permanent remission.[22] Other cases, left untreated, worsen over time.

Behavior

Avoiding triggers that worsen the condition can help reduce the onset of rosacea, but alone will not normally lead to remission except in mild cases. Keeping a journal is sometimes recommended to help identify and reduce food and beverage triggers.

Because sunlight is a common trigger, avoiding excessive exposure to the sun is widely recommended. Some people with rosacea benefit from daily use of a sunscreen; others opt for wearing hats with broad brims. Like sunlight, emotional stress can also trigger rosacea. People who develop infections of the eyelids must practice frequent eyelid hygiene.

Managing pretrigger events such as prolonged exposure to cool environments can directly influence warm room flushing.[23]

Medications

Medications with good evidence include ivermectin and azelaic acid creams and brimonidine, doxycycline, and isotretinoin by mouth.[24] Lesser evidence supports metronidazole cream and tetracycline by mouth.[24]

Metronidazole is thought to act through anti-inflammatory mechanisms, while azelaic acid is thought to decrease cathelicidin production. Oral antibiotics of the tetracycline class such as doxycycline and oxytetracycline are also commonly used and thought to reduce papulopustular lesions through anti-inflammatory actions rather than through their antibacterial capabilities.[8]

Using alpha-hydroxy acid peels may help relieve redness caused by irritation, and reduce papules and pustules associated with rosacea.[25] Oral antibiotics may help to relieve symptoms of ocular rosacea. If papules and pustules persist, then sometimes isotretinoin can be prescribed.[26]

The flushing and blushing that typically accompanies rosacea is typically treated with the topical application of alpha agonists such as brimonidine and less commonly oxymetazoline or xylometazoline.[8]

Laser

Dermatological vascular laser (single wavelength) or intense pulsed light (broad spectrum) machines offer one of the treatments for rosacea, in particular the erythema (redness) of the skin.[27] They use light to penetrate the epidermis to target the capillaries in the dermis layer of the skin. The light is absorbed by oxyhemoglobin, which heats up, causing the capillary walls to heat up to 70 °C (158 °F), damaging them, and causing them to be absorbed by the body's natural defense mechanism. With a sufficient number of treatments, this method may even eliminate the redness altogether, though additional periodic treatments will likely be necessary to remove newly formed capillaries.[21]

Laser treatment for rosacea using a V-Beam laser

CO_2 lasers can be used to remove excess tissue caused by phymatous rosacea. CO_2 lasers emit a wavelength that is absorbed directly by the skin. The laser beam can be focused into a thin beam and used as a scalpel or defocused and used to vaporize tissue. Low-level light therapies have also been used to treat rosacea. Photorejuvenation can also reportedly be used to improve the appearance of rosacea and reduce the redness associated with it.[28][29][30]

Epidemiology

Women, especially those who are menopausal, are more likely than men to develop rosacea.[31]

See also

- Keratosis pilaris

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External links

- Rosacea photo library at Dermnet (http://www.dermnet.com/rosacea)
- Questions and Answers about Rosacea (http://niams.nih.gov/Health_Info/Rosacea/default.asp), from the US National Institute of Arthritis and Musculoskeletal and Skin Diseases

Wikibooks has a book on the topic of: ***Rosacea***

Wikimedia Commons has media related to ***Rosacea (disease)***.

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Categories: Acneiform eruptions

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Rotavirus

From Wikipedia, the free encyclopedia

Rotavirus is the most common cause of diarrhoeal disease among infants and young children.[1] It is a genus of double-stranded RNA viruses in the family *Reoviridae*. Nearly every child in the world is infected with rotavirus at least once by the age of five.[2] Immunity develops with each infection, so subsequent infections are less severe; adults are rarely affected.[3] There are eight species of this virus, referred to as A, B, C, D, E, F, G and H. *Rotavirus A*, the most common species, causes more than 90% of rotavirus infections in humans.

The virus is transmitted by the faecal-oral route. It infects and damages the cells that line the small intestine and causes gastroenteritis (which is often called "stomach flu" despite having no relation to influenza). Although rotavirus was discovered in 1973 by Ruth Bishop and her colleagues by electron micrograph images[4] and accounts for approximately one third of hospitalisations for severe diarrhoea in infants and children,[5] its importance has historically been underestimated within the public health community, particularly in developing

Rotavirus

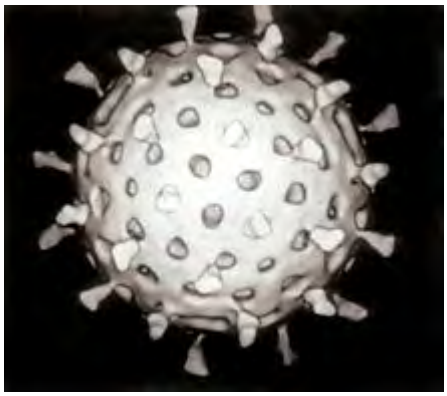

Computer–aided reconstruction of a rotavirus based on several electron micrographs

Virus classification

Group:	Group III (dsRNA)
Order:	*Unassigned*
Family:	*Reoviridae*
Subfamily:	*Sedoreovirinae*
Genus:	***Rotavirus***

Type species

Rotavirus A

Species

countries.[6] In addition to its impact on human health, rotavirus also infects animals, and is a pathogen of livestock.[7]

- *Rotavirus A*
- *Rotavirus B*
- *Rotavirus C*
- *Rotavirus D*
- *Rotavirus E*
- *Rotavirus F*
- *Rotavirus G*
- *Rotavirus H*

Rotavirus is usually an easily managed disease of childhood, but in 2013, rotavirus caused 37 percent of deaths of children from diarrhoea and 215,000 deaths worldwide,[8] and almost two million more become severely ill.[6] Most of these deaths occurred in developing countries.[9] In the United States, before initiation of the rotavirus vaccination programme, rotavirus caused about 2.7 million cases of severe gastroenteritis in children, almost 60,000 hospitalisations, and around 37 deaths each year.[10] Following rotavirus vaccine introduction in the United States, hospitalisation rates have fallen significantly.[11][12] Public health campaigns to combat rotavirus focus on providing oral rehydration therapy for infected children and vaccination to prevent the disease.[13] The incidence and severity of rotavirus infections has declined significantly in countries that have added rotavirus vaccine to their routine childhood immunisation policies.[14][15][16]

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Signs and symptoms

Rotaviral enteritis is a mild to severe disease characterised by nausea, vomiting, watery diarrhoea and low-grade fever. Once a child is infected by the virus, there is an incubation period of about two days before symptoms appear.[17] The period of illness is acute. Symptoms often start with vomiting followed by four to eight days of profuse diarrhoea. Dehydration is more common in rotavirus infection than in most of those caused by bacterial pathogens, and is the most common cause of death related to rotavirus infection.[18]

Rotavirus A infections can occur throughout life: the first usually produces symptoms, but subsequent infections are typically mild or asymptomatic,[19][20] as the immune system provides some protection.[21][22] Consequently, symptomatic infection rates are highest in children under two years of age and decrease progressively towards 45 years of age.[23] Infection in newborn children, although common, is often associated with mild or asymptomatic disease;[3] the most severe symptoms tend to occur in children six months to two years of age, the elderly, and those with immunodeficiency. Due to immunity acquired in childhood, most adults are not susceptible to rotavirus;

gastroenteritis in adults usually has a cause other than rotavirus, but asymptomatic infections in adults may maintain the transmission of infection in the community.[24]

Transmission

Rotavirus is transmitted by the fæcal-oral route, via contact with contaminated hands, surfaces and objects,[25] and possibly by the respiratory route.[26] Viral diarrhea is highly contagious. The faeces of an infected person can contain more than 10 trillion infectious particles per gram;[20] fewer than 100 of these are required to transmit infection to another person.[3]

Rotaviruses in the faeces of an infected child

Rotaviruses are stable in the environment and have been found in estuary samples at levels up to 1–5 infectious particles per US gallon, the viruses survive between 9 and 19 days.[27] Sanitary measures adequate for eliminating bacteria and parasites seem to be ineffective in control of rotavirus, as the incidence of rotavirus infection in countries with high and low health standards is similar.[26]

Disease mechanisms

The diarrhoea is caused by multiple activities of the virus. Malabsorption occurs because of the destruction of gut cells called enterocytes. The toxic rotavirus protein NSP4 induces age- and calcium ion-dependent chloride secretion, disrupts SGLT1 transporter-mediated reabsorption of water, apparently reduces activity of brush-border membrane disaccharidases, and possibly activates the calcium ion-dependent secretory reflexes of the enteric nervous system.[28] Healthy enterocytes secrete lactase into the small intestine; milk intolerance due to lactase deficiency is a symptom of rotavirus infection,

[29] which can persist for weeks.[30] A recurrence of mild diarrhoea often follows the reintroduction of milk into the child's diet, due to bacterial fermentation of the disaccharide lactose in the gut.[31]

Electron micrograph of a rotavirus infected enterocyte (top) compared to an uninfected cell (bottom). The bar = approx. 500 nm

Diagnosis and detection

Diagnosis of infection with rotavirus normally follows diagnosis of gastroenteritis as the cause of severe diarrhoea. Most children admitted to hospital with gastroenteritis are tested for rotavirus A.[32][33] Specific diagnosis of infection with rotavirus A is made by finding the virus in the child's stool by enzyme immunoassay. There are several licensed test kits on the market which are sensitive, specific and detect all serotypes of rotavirus A.[34] Other methods, such as electron microscopy and PCR, are used in research laboratories.[35] Reverse transcription-polymerase chain reaction (RT-PCR) can detect and identify all species and serotypes of human rotavirus.[36]

Treatment and prognosis

Treatment of acute rotavirus infection is nonspecific and involves management of symptoms and, most importantly, management of dehydration.[13] If untreated, children can die from the resulting severe dehydration.[37] Depending on the severity of diarrhoea, treatment consists of oral rehydration therapy, during which the child is given extra water to drink that contains small amounts of salt and sugar.[38] In 2004, the WHO and UNICEF recommended the use of low-osmolarity oral rehydration solution

and zinc supplementation as a two-pronged treatment of acute diarrhoea.[39] Some infections are serious enough to warrant hospitalisation where fluids are given by intravenous therapy or nasogastric intubation, and the child's electrolytes and blood sugar are monitored.[32] Probiotics have been shown to reduce the duration of rotavirus diarrhoea,[40] and according to the European Society for Pediatric Gastroenterology "effective interventions include administration of specific probiotics such as *Lactobacillus rhamnosus* or *Saccharomyces boulardii*, diosmectite or racecadotril." [41] Rotavirus infections rarely cause other complications and for a well managed child the prognosis is excellent.[42]

Epidemiology

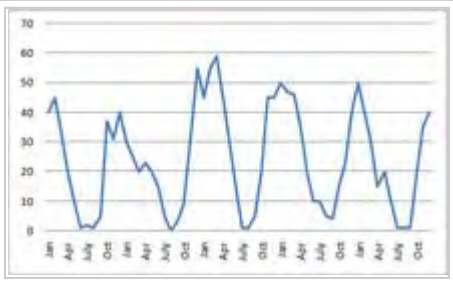

The seasonal variation of rotavirus A infections in a region of England: rates of infection peak during the winter months.

Rotavirus A, which accounts for more than 90% of rotavirus gastroenteritis in humans,[43] is endemic worldwide. Each year rotavirus causes millions of cases of diarrhoea in developing countries, almost 2 million of which result in hospitalisation.[6] In 2013, an estimated 215,000 children younger than five died from rotavirus, 90 percent of whom were in developing countries.[8] Almost every child has been infected with rotavirus by age five.[44] Rotavirus is the leading single cause of severe diarrhoea among infants and children, is responsible for about a third of the cases requiring hospitalisation,[11] and causes 37% of deaths attributable to diarrhoea and 5% of all deaths in children younger than five.[45] Boys are twice as likely as girls to be admitted to hospital for rotavirus.[46][47] Rotavirus infections occur primarily during cool, dry seasons.[48][49] The number attributable to food contamination is unknown.[50]

Outbreaks of rotavirus A diarrhoea are common among hospitalised infants, young children attending day care centres, and elderly people in nursing homes.[51] An outbreak caused by contaminated municipal water occurred in Colorado in 1981.[52] During 2005, the largest recorded epidemic of diarrhoea occurred in Nicaragua. This unusually large and severe outbreak was associated with mutations in the rotavirus A genome, possibly helping the virus escape the prevalent immunity in the population.[53] A similar large outbreak occurred in Brazil in 1977.[54]

Rotavirus B, also called adult diarrhoea rotavirus or ADRV, has caused major epidemics of severe diarrhoea affecting thousands of people of all ages in China. These epidemics occurred as a result of sewage contamination of drinking water.[55][56] Rotavirus B infections also occurred in India in 1998; the causative strain was named CAL. Unlike ADRV, the CAL strain is endemic.[57][58] To date, epidemics caused by rotavirus B have been confined to mainland China, and surveys indicate a lack of immunity to this species in the United States.[59]

Rotavirus C has been associated with rare and sporadic cases of diarrhoea in children, and small outbreaks have occurred in families.[60]

Prevention

Rotavirus is highly contagious and cannot be treated with antibiotics or other drugs. Because improved sanitation does not decrease the prevalence of rotaviral disease, and the rate of hospitalisations remains high despite the use of oral rehydrating medicines, the primary public health intervention is vaccination.[2] Two vaccines against Rotavirus A infection are approved for global use and are safe and effective in children:[15] Rotarix by GlaxoSmithKline[61] and RotaTeq by Merck.[62] Both are taken orally and contain attenuated live virus.[15] Three vaccines are licensed for use in national

markets only: ROTAVAC®, licensed in India in 2014; Motavin-M1™, licensed in Vietnam in 2007; and Lanzhou Lamb Rotavirus Vaccine, licensed in China in 2000.[63] Additional rotavirus vaccines are under development.[64]

In 2009, the World Health Organisation (WHO) recommended that rotavirus vaccine be included in all national immunisation programmes.[65] The incidence and severity of rotavirus infections has declined significantly in countries that have acted on this recommendation.[14][15][16] A 2014 review of available clinical trial data from countries routinely using rotavirus vaccines in their national immunisation programs found that rotavirus vaccines have reduced rotavirus hospitalisations by 49-92 percent and all cause diarrhoea hospitalisations by 17-55 percent.[66] In Mexico, which in 2006 was among the first countries in the world to introduce rotavirus vaccine, diarrhoeal disease death rates dropped during the 2009 rotavirus season by more than 65 percent among children age two and under.[67] In Nicaragua, which in 2006 became the first developing country to introduce a rotavirus vaccine, severe rotavirus infections were reduced by 40 percent and emergency room visits by a half.[68] In the United States, rotavirus vaccination since 2006 has led to drops in rotavirus-related hospitalisations by as much as 86 percent. The vaccines may also have prevented illness in non-vaccinated children by limiting the number of circulating infections.[69] In developing countries in Africa and Asia, where the majority of rotavirus deaths occur, a large number of safety and efficacy trials as well as recent post-introduction impact and effectiveness studies of Rotarix and RotaTeq have found that vaccines dramatically reduced severe disease among infants.[16][70][71][72] In September 2013, the vaccine was offered to all children in the UK, aged between two and three months, and it is expected to halve the cases of severe infection and reduce the number of children admitted to hospital because of the infection by 70 percent.[73] In Europe, hospitalisation rates following infection by rotavirus have decreased from 65% to 84% following the introduction of the vaccine.[74] Rotavirus vaccines are licensed in over 100 countries, and more than 80 countries have introduced routine rotavirus vaccination, almost half with the support of Gavi,

the Vaccine Alliance.[75] To make rotavirus vaccines available, accessible, and affordable in all countries—particularly low- and middle-income countries in Africa and Asia where the majority of rotavirus deaths occur PATH, the WHO, the U.S. Centers for Disease Control and Prevention, and GAVI, the Vaccine Alliance have partnered with research institutions and governments to generate and disseminate evidence, lower prices, and accelerate introduction.[76]

Other animals

Rotaviruses infect the young of many species of animals and they are a major cause of diarrhoea in wild and reared animals worldwide.[7] As a pathogen of livestock, notably in young calves and piglets, rotaviruses cause economic loss to farmers because of costs of treatment associated with high morbidity and mortality rates.[77] These rotaviruses are a potential reservoir for genetic exchange with human rotaviruses.[77] There is evidence that animal rotaviruses can infect humans, either by direct transmission of the virus or by contributing one or several RNA segments to reassortants with human strains.[78][79]

Virology

Types of rotavirus

There are eight species of rotavirus, referred to as A, B, C, D, E, F, G, and H.[80] Humans are primarily infected by species A, B and C, most commonly by species A. A–E species cause disease in other animals,[81] species E and H in pigs, and D, F and G in birds.[82][83] Within rotavirus A there are different strains, called serotypes.[84] As with influenza virus, a dual classification system is used based on two proteins on the surface of the virus. The glycoprotein VP7 defines the G serotypes and the protease-sensitive protein

VP4 defines P serotypes.[85] Because the two genes that determine G-types and P-types can be passed on separately to progeny viruses, different combinations are found.[86]

Structure

The genome of rotavirus consists of 11 unique double helix molecules of RNA which are 18,555 nucleotides in total. Each helix, or segment, is a gene, numbered 1 to 11 by decreasing size. Each gene codes for one protein, except genes 9, which codes for two.[87] The RNA is surrounded by a three-layered icosahedral protein capsid. Viral particles are up to 76.5 nm in diameter[88][89] and are not enveloped.

Proteins

There are six viral proteins (VPs) that form the virus particle (virion). These *structural* proteins are called VP1, VP2, VP3, VP4, VP6 and VP7. In addition to the VPs, there are six *nonstructural* proteins (NSPs), that are only produced in cells infected by rotavirus. These are called NSP1, NSP2, NSP3, NSP4, NSP5 and NSP6.[81]

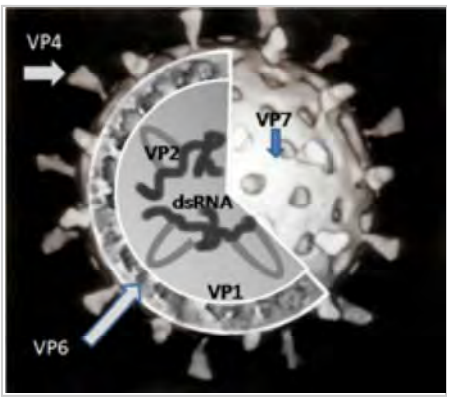

A simplified diagram of the location of rotavirus structural proteins

At least six of the twelve proteins encoded by the rotavirus genome bind RNA.[90] The role of these proteins play in rotavirus replication is not entirely understood; their functions are thought to be related to RNA synthesis and packaging in the virion, mRNA transport to the site of genome replication, and mRNA translation and regulation of gene expression.[91]

Structural proteins

VP1 is located in the core of the virus particle and is an RNA polymerase enzyme.[92] In an infected cell this enzyme produces mRNA transcripts for the synthesis of viral proteins and produces copies of the rotavirus genome RNA segments for newly produced virus particles.

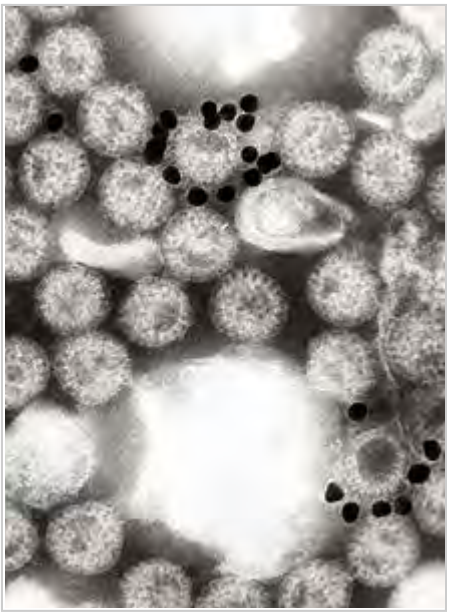

Electron micrograph of gold nanoparticles attached to rotavirus. The small dark circular objects are gold nanoparticles coated with a monoclonal antibody specific for rotavirus protein VP6.

VP2 forms the core layer of the virion and binds the RNA genome.[93]

VP3 is part of the inner core of the virion and is an enzyme called guanylyl transferase. This is a capping enzyme that catalyses the formation of the 5' cap in the post-transcriptional modification of mRNA.[94] The cap stabilises viral mRNA by protecting it from nucleic acid degrading enzymes called nucleases.[95]

VP4 is on the surface of the virion that protrudes as a spike.[96] It binds to molecules on the surface of cells called receptors and drives the entry of the virus into the cell.[97] VP4 has to be modified by the protease enzyme trypsin, which is found in the gut, into VP5* and VP8* before the virus is infectious.[98] VP4 determines how virulent the virus is and it determines the P-type of the virus.[99]

VP6 forms the bulk of the capsid. It is highly antigenic and can be used to identify rotavirus species.[20] This protein is used in laboratory tests for rotavirus A infections.[100]

VP7 is a glycoprotein that forms the outer surface of the virion. Apart from its structural functions, it determines the G-type of the strain and, along with VP4, is involved in immunity to infection.[88]

Nonstructural viral proteins

NSP1, the product of gene 5, is a nonstructural RNA-binding protein.[101] NSP1 also blocks the interferon response, the part of the innate immune system that protects cells from viral infection. NSP1 causes the proteosome to degrade key signaling components required to stimulate production of interferon in an infected cell and to respond to interferon secreted by adjacent cells. Targets for degradation include several IRF transcription factors required for interferon gene transcription.[102]

NSP2 is an RNA-binding protein that accumulates in cytoplasmic inclusions (viroplasms) and is required for genome replication.[103][104]

NSP3 is bound to viral mRNAs in infected cells and it is responsible for the shutdown of cellular protein synthesis.[105] NSP3 inactivates two translation initiation factors essential for synthesis of proteins from host mRNA. First, NSP3 ejects poly(A)-binding protein (PABP) from the translation initiation factor eIF4F. PABP is required for efficient translation of transcripts with a 3' poly(A) tail, which is found on most host cell transcripts. Second, NSP3 inactivates eIF2 by stimulating its phosphorylation. Efficient translation of rotavirus mRNA, which lacks the 3' poly(A) tail, does not require either of these factors.[106]

NSP4 is a viral enterotoxin that induces diarrhoea and was the first viral enterotoxin discovered.[28]

NSP5 is encoded by genome segment 11 of rotavirus A. In virus-infected cells NSP5 accumulates in the viroplasm.[107]

NSP6 is a nucleic acid binding protein[108] and is encoded by gene 11 from an out-of-phase open reading frame.[109]

Rotavirus genes and proteins

RNA Segment (Gene)	Size (base pairs)	Protein	Molecular weight kDa	Location	Copies per particle	Function
1	3302	VP1	125	At the vertices of the core	<25	RNA-dependent RNA polymerase
2	2690	VP2	102	Forms inner shell of the core	120	Stimulates viral RNA replicase
3	2591	VP3	88	At the vertices of the core	<25	Guanylyl transferase mRNA capping enzyme
4	2362	VP4	87	Surface spike	120	Cell attachment, virulence
5	1611	NSP1	59	Nonstructural	0	5'RNA binding
6	1356	VP6	45	Inner Capsid	780	Structural and species-specific antigen
7	1104	NSP3	37	Nonstructural	0	Enhances viral mRNA activity and shut-offs cellular protein synthesis
8	1059	NSP2	35	Nonstructural	0	NTPase involved in

						RNA packaging
9	1062	VP7[1] VP7[2]	38 and 34	Surface	780	Structural and neutralisation antigen
10	751	NSP4	20	Nonstructural	0	Enterotoxin
11	667	NSP5 NSP6	22	Nonstructural	0	ssRNA and dsRNA binding modulator of NSP2

This table is based on the simian rotavirus strain SA11.[110][111][112] RNA-protein coding assignments differ in some strains.

Replication

Rotaviruses replicate mainly in the gut,[113] and infect enterocytes of the villi of the small intestine, leading to structural and functional changes of the epithelium.[114] The triple protein coats make them resistant to the acidic pH of the stomach and the digestive enzymes in the gut.

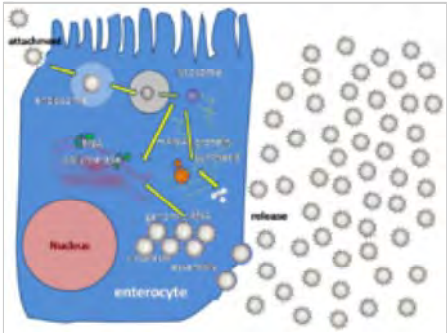

A simplified drawing of the rotavirus replication cycle

The virus enter cells by receptor mediated endocytosis and form a vesicle known as an endosome. Proteins in the third layer (VP7 and the VP4 spike) disrupt the membrane of the endosome, creating a difference in the calcium concentration. This causes the breakdown of VP7 trimers into single protein subunits, leaving the VP2 and VP6 protein coats around the viral dsRNA, forming a double-layered particle (DLP).[115]

The eleven dsRNA strands remain within the protection of the two protein shells and the viral RNA-dependent RNA polymerase creates mRNA transcripts of the double-stranded viral genome. By remaining in the core, the viral RNA evades innate host immune responses called RNA interference that are triggered by the presence of double-stranded RNA.

During the infection, rotavirus produces mRNA for both protein biosynthesis and gene replication. Most of the rotavirus proteins accumulate in viroplasm, where the RNA is replicated and the DLPs are assembled. Viroplasm is formed around the cell nucleus as early as two hours after virus infection, and consists of viral factories thought to be made by two viral nonstructural proteins: NSP5 and NSP2. Inhibition of NSP5 by RNA interference results in a sharp decrease in rotavirus replication. The DLPs migrate to the endoplasmic reticulum where they obtain their third, outer layer (formed by VP7 and VP4). The progeny viruses are released from the cell by lysis.[98][116][117]

History

In 1943, Jacob Light and Horace Hodes proved that a filterable agent in the faeces of children with infectious diarrhoea also caused scours (livestock diarrhoea) in cattle.[118] Three decades later, preserved samples of the agent were shown to be rotavirus.[119] In the intervening years, a virus in mice[120] was shown to be related to the virus causing scours.[121] In 1973, Ruth Bishop and colleagues described related viruses found in children with gastroenteritis.[4]

One of Flewett's original electron micrographs

In 1974, Thomas Henry Flewett suggested the name *rotavirus* after observing that, when viewed through an electron microscope, a rotavirus particle looks like a wheel (*rota* in Latin);[122][123] the

name was officially recognised by the International Committee on Taxonomy of Viruses four years later.[124] In 1976, related viruses were described in several other species of animals.[121] These viruses, all causing acute gastroenteritis, were recognised as a collective pathogen affecting humans and animals worldwide.[122] Rotavirus serotypes were first described in 1980,[125] and in the following year, rotavirus from humans was first grown in cell cultures derived from monkey kidneys, by adding trypsin (an enzyme found in the duodenum of mammals and now known to be essential for rotavirus to replicate) to the culture medium.[126] The ability to grow rotavirus in culture accelerated the pace of research, and by the mid-1980s the first candidate vaccines were being evaluated.[127]

In 1998, a rotavirus vaccine was licensed for use in the United States. Clinical trials in the United States, Finland, and Venezuela had found it to be 80 to 100% effective at preventing severe diarrhoea caused by rotavirus A, and researchers had detected no statistically significant serious adverse effects.[128][129] The manufacturer, however, withdrew it from the market in 1999, after it was discovered that the vaccine may have contributed to an increased risk for intussusception, a type of bowel obstruction, in one of every 12,000 vaccinated infants.[130] The experience provoked intense debate about the relative risks and benefits of a rotavirus vaccine.[131] In 2006, two new vaccines against rotavirus A infection were shown to be safe and effective in children,[132] and in June 2009 the World Health Organization recommended that rotavirus vaccination be included in all national immunisation programmes to provide protection against this virus.[133]

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External links

Wikimedia Commons has media related to ***Rotavirus***.

Rotaviral Gastroenteritis

Classification and external resources

Specialty	infectious disease
ICD-10	A08.0 (http://apps.who.int/classifications/icd10/browse/2016/en#/A08.0)
ICD-9-CM	008.61 (http://www.icd9data.com/getICD9Code.ashx?icd9=008.61)
DiseasesDB	11667 (http://www.diseasesdatabase.com/ddb11667.htm)
MedlinePlus	000252 (https://medlineplus.gov/ency/article/000252.htm)
eMedicine	emerg/401 (http://www.emedicine.com/emerg/topic401.htm)
MeSH	

D012400 (https://www.nlm.nih.gov/cgi/mesh/2017/MB_cgi?field=uid&term=D012400)

- WHO Rotavirus web page (http://www.who.int/topics/rotavirus_infections/en/)
- Rotavirus (http://www.cdc.gov/rotavirus/) on Centers for Disease Control and Prevention (CDC) site
- Viralzone: Rotavirus (http://www.expasy.org/viralzone/all_by_species/107.html)
- Vaccine Resource Library: Rotavirus (http://www.path.org/vaccineresources/browse.php?e=12)
- DefeatDD.org (http://www.defeatdd.org)
- Centers for Disease Control and Prevention (2012). "Ch. 18: Rotavirus". In Atkinson W, Wolfe S, Hamborsky J. *Epidemiology and Prevention of Vaccine-Preventable Diseases* (12th ed.). Washington DC: Public Health Foundation. pp. 263–274.
- 3D macromolecular structures of Rotaviruses from the EM Data Bank (EMDB) (http://www.pdbe.org/emsearch/rota*%20AND%20comp_type:virus)
- ROTA Council (http://rotacouncil.org/)

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Categories: Rotaviruses | Gastroenterology | Pediatrics | Species described in 1973

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Rotenone

From Wikipedia, the free encyclopedia

Rotenone is an odorless, colorless, crystalline isoflavone used as a broad-spectrum insecticide, piscicide, and pesticide. It occurs naturally in the seeds and stems of several plants, such as the jicama vine plant, and the roots of several members of Fabaceae. It was the first described member of the family of chemical compounds known as rotenoids.

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Discovery

The earliest record of the now-known rotenone-containing plants used for killing leaf-eating caterpillars was in 1848, and for centuries, the same plants were used to poison fish.[3] The active chemical component was first isolated in 1895 by a French botanist, Emmanuel Geoffroy, who called it *nicouline*, from a specimen of *Robinia nicou*, now called *Lonchocarpus nicou*, while traveling in French Guiana.[4] He wrote about this research in his thesis, published posthumously in 1895 after his death from a parasitic disease.[5] In 1902 Japanese chemist Nagai Nagayoshi isolated a pure crystalline compound from *Derris elliptica* which he called rotenone, after the Japanese name of the plant, *roten*. By 1930, nicouline and rotenone were established to be chemically the same.[6]

Uses

Rotenone is used as a pesticide, insecticide, and as a nonselective piscicide (fish killer).[7]

It is commercialized as *cubé*, *tuba*, or *derris*, in single preparation or in synergistic combination with other insecticides.[8] In the United States and Canada, all uses of rotenone except as a piscicide are being phased out.[9][10]

Rotenone has historically been used by indigenous peoples to catch fish. Typically, rotenone-containing plants in the Fabaceae family of legumes are crushed and introduced into a body of water, and as rotenone interferes with cellular respiration, the affected fish rise to the surface in an attempt to gulp air, where they are more easily caught.

Rotenone has been used by government agencies to kill fish in rivers and lakes in the United States since 1952.[11]

Rotenone

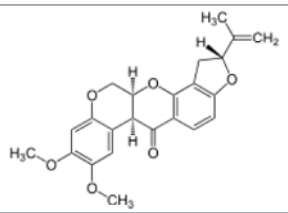

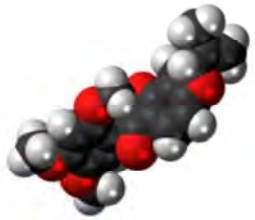

Names	
IUPAC name	(2*R*,6a*S*,12a*S*)-1,2,6,6a,12,12a-hexahydro-2-isopropenyl-8,9-dimethoxychromeno[3,4-*b*]furo(2,3-h)chromen-6-one
Other names	Tubatoxin, Paraderil
Identifiers	
CAS Number	83-79-4 (http://www.commonchemistry.org/ChemicalDetail.aspx?ref=83-79-4) ✓
3D model (Jmol)	Interactive image (http://chemapps.stolaf.edu/jmol/jmol.php?model=CC%28%3DC%29%5BC%40H%5D1CC2%3DC%28O1%29C%3DCC3%3DC2O%5BC%40%40H%5D4COC5%3DCC%28%3DC%28C%3DC5%5BC%40%40H%5D4C3%3DO%29OC%29OC)
ChEBI	CHEBI:28201 (https://www.ebi.ac.uk/chebi/searchId.do?chebiId=28201) ✗
ChEMBL	ChEMBL429023 (https://www.ebi.ac.uk/chembldb/index.php/compound/inspect/ChEMBL429023) ✗
ChemSpider	6500 (http://www.chemspider.com/Chemical-Structure.6500.html) ✗
ECHA InfoCard	100.001.365 (https://echa.europa.eu/substance-information/-/substanceinfo/100.001.365)
KEGG	C07593 (http://www.kegg.jp/entry/C07593) ✓
MeSH	Rotenone (https://www.nlm.nih.gov/cgi/mesh/2014/MB_cgi?mode=&term=Rotenone)
PubChem	6758 (https://pubchem.ncbi.nlm.nih.gov/compound/6758)
UNII	03L9OT429T (http://fdasis.nlm.nih.gov/srs/srsdirect.jsp?regno=03L9OT429T) ✓
InChI	
SMILES	
Properties	
Chemical formula	$C_{23}H_{22}O_6$
Molar mass	394.42 g·mol^{-1}
Appearance	Colorless to red crystalline solid[1]
Odor	odorless[1]
Density	1.27 g/cm^3 @ 20 °C
Melting point	165 to 166 °C (329 to 331 °F; 438 to 439 K)
Boiling point	210 to 220 °C (410 to 428 °F; 483 to 493 K) at 0.5 mmHg
Solubility	Soluble in ether and acetone, slightly soluble in ethanol
Vapor pressure	<0.00004 mmHg (20°C)[1]

Small-scale sampling with rotenone is used by fish researchers studying the biodiversity of marine fishes to collect cryptic, or hidden, fishes, which represent an important component of shoreline fish communities. Rotenone is the most effective tool available because only small quantities are necessary. It has only minor and transient environmental side effects.[12]

Rotenone is also used in powdered form to treat scabies and head lice on humans, and parasitic mites on chickens, livestock, and pet animals.

Rotenone has been used as an organic[13] pesticide dust for gardens. Unselective in action, it kills potato beetles, cucumber beetles, flea beetles, cabbage worms, raspberry beetles, and asparagus beetles, as well as most other arthropods. It rapidly biodegrades under warm conditions, so harmful residues are minimal. A light dusting on the leaves of plants will control insects for several days.

Hazards	
Lethal dose or concentration (*LD*, *LC*):	
LD_{50} (median dose)	60 mg/kg (oral, rat) 132 mg/kg (oral, rat) 25 mg/kg (oral, rat) 2.8 mg/kg (oral, mouse)[2]
US health exposure limits (NIOSH):	
PEL (Permissible)	TWA 5 mg/m^3[1]
REL (Recommended)	TWA 5 mg/m^3[1]
IDLH (Immediate danger)	2500 mg/m^3[1]
Except where otherwise noted, data are given for materials in their standard state (at 25 °C [77 °F], 100 kPa). ✗ verify (what is ✓✗ ?) Infobox references	

Mechanism of action

Rotenone works by interfering with the electron transport chain in mitochondria. It inhibits the transfer of electrons from iron-sulfur centers in complex I to ubiquinone. This interferes with NADH during the creation of usable cellular energy (ATP).[8] Complex I is unable to pass off its electron to CoQ, creating a back-up of electrons within the mitochondrial matrix. Cellular oxygen is reduced to the radical, creating a reactive oxygen species, which can damage DNA and other components of the mitochondria.[14]

Presence in plants

Rotenone is produced by extraction from the roots and stems of several tropical and subtropical plant species, especially those belonging to the genera *Lonchocarpus* and *Derris*.

Some of the plants containing rotenone:

- Hoary pea or goat's rue (*Tephrosia virginiana*) – North America
- Jícama (*Pachyrhizus erosus*) – North America
- Cubé plant or lancepod (*Lonchocarpus utilis*) – South America[15]
  - The root extract is referred to as cubé resin
- Barbasco (*Lonchocarpus urucu*) – South America[15]
  - The root extract is referred to as cubé resin
- Tuba plant (*Derris elliptica*) – southeast Asia and southwest Pacific islands
  - The root extract is referred to as derris or derris root
- Jewel vine (*Derris involuta*) – southeast Asia and southwest Pacific islands
  - The root extract is referred to as derris or derris root
- Common Mullein (*Verbascum thapsus)* according to Peterson Field Guides Eastern/ Central Medicinal Plants
- Cork-bush (*Mundulea sericea*) – southern Africa[16]
- Florida fishpoison tree (*Piscidia piscipula*) – southern Florida, Caribbean[17]
- Several species of *Millettia* and *Tephrosia* in South-east Asian regions[18]

Toxicity

Rotenone is classified by the World Health Organization as moderately hazardous.[19] It is mildly toxic to humans and other mammals, but extremely toxic to insects and aquatic life, including fish. This higher toxicity in fish and insects is because the lipophilic rotenone is easily taken up through the gills or trachea, but not as easily through the skin or the gastrointestinal tract. Rotenone is toxic to erythrocytes *in vitro*.[20]

The lowest lethal dose for a child is 143 mg/kg. Human deaths from rotenone poisoning are rare because its irritating action causes vomiting.[21] Deliberate ingestion of rotenone can be fatal.[22]

The compound decomposes when exposed to sunlight and usually has an activity of six days in the environment.[23] It oxidizes to rotenolone, which is about an order of magnitude less toxic than rotenone. In water, the rate of decomposition depends upon several factors, including temperature, pH, water hardness and sunlight. The half-life in natural waters ranges from half a day at 24 °C to 3.5 days at 0 °C.[24]

Parkinson's disease

In 2000, injecting rotenone into rats was reported to cause the development of symptoms similar to those of Parkinson's disease (PD). Rotenone was continuously applied over a period of five weeks, mixed with DMSO and PEG to enhance tissue penetration, and injected into the jugular vein.[25] The study does not directly suggest rotenone exposure is responsible for PD in humans, but is consistent with the belief that chronic exposure to environmental toxins increases the likelihood of the disease.[26]

In addition, studies with primary cultures of rat neurons and microglia have shown low doses of rotenone (below 10 nM) induce oxidative damage and death of dopaminergic neurons,[27] and it is these neurons in the substantia nigra that die in Parkinson's disease. Another study has also described toxic action of rotenone at low concentrations (5 nM) in dopaminergic neurons from acute rat brain slices.[28] This toxicity was exacerbated by an additional cell stressor – elevated intracellular calcium concentration – adding support to the 'multiple hit hypothesis' of dopaminergic neuron death.

The neurotoxin MPTP had been known earlier to cause PD-like symptoms (in humans and other primates, though not in rats) by interfering with complex I in the electron transport chain and killing dopaminergic neurons in the substantia nigra. However, further studies involving MPTP have failed to show development of Lewy bodies, a key component to PD pathology. Therefore, the mechanism behind MPTP as it relates to Parkinson's disease is not fully understood.[29] Because of these developments, rotenone was investigated as a possible Parkinson-causing agent. Both MPTP and rotenone are lipophilic and can cross the blood–brain barrier.

In 2010, a study was published detailing the progression of Parkinson's-like symptoms in mice following chronic intragastric ingestion of low doses of rotenone. The concentrations in the central nervous system were below detectable limits, yet still induced PD pathology.[30]

In 2011, a US National Institutes of Health study showed a link between rotenone use and Parkinson's disease in farm workers.[31]

Notable administrations

Rotenone was implemented in 2010 to kill an invasive goldfish population present in Mann Lake, with the intention of not disrupting the lake's trout population. Rotenone successfully achieved these aims, killing nearly 200,000 goldfish, and only three trout.[32]

Beginning May 1, 2006, Panguitch Lake was treated with rotenone, to potentially eradicate and control the invasive population of Utah chub. which were probably introduced accidentally by anglers who used them as live bait. The lake was restocked with 20,000 rainbow trout in 2006; as of 2016, the lake's fish population has recovered.

In 2014, Rotenone was used to kill all remaining fish in San Francisco's Mountain Lake, which is located in Mountain Lake Park in order to rid it of invasive species introduced since the migration of European settlers to the region.[33]

Deactivation

Rotenone can be deactivated in water with the use of Potassium Permanganate to lower toxicity back down to acceptable levels.

See also

- Fenpropathrin
- NADH dehydrogenase

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External links

- Rotenone (http://www.chm.bris.ac.uk/motm/rotenone/startpageh.htm), Molecule of the Month at chm.bris.ac.uk (http://www.chm.bris.ac.uk/motm/motm.htm)
- Compendium of Pesticide Common Names at alanwood.net (http://www.alanwood.net/pesticides/rotenone.html)
- Cornell University. Rotenone. Resource Guide for Organic and Disease Management. (http://www.nysaes.cornell.edu/pp/resourceguide/mfs/11rotenone.php)
- Rotenone. ARS Pesticide Properties Database (http://www.ars.usda.gov/SP2UserFiles/ad_hoc/12755100DatabaseFiles/PesticidePropertiesDatabase/IndividualPesticideFiles/ROTENONE.TXT)
- Rotenone use in research on the biodiversity of marine fishes (http://striweb.si.edu/rotenone_and_marine_research)
- Rotenone Factsheet (http://www.pan-uk.org/pestnews/Actives/rotenone.htm)
- Rotenone registration at US Environmental Protection Agency (http://www.epa.gov/oppsrrd1/reregistration/rotenone/)
- CDC – NIOSH Pocket Guide to Chemical Hazards (http://www.cdc.gov/niosh/npg/npgd0548.html)
- Rotenone at Bioblast (http://www.bioblast.at/index.php/Rotenone)
- Chemical Description (http://www.ebi.ac.uk/chebi/searchId.do?chebiId=CHEBI:28201)

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Categories: Rotenoids | Phenol ethers | Isoflavones | NADH dehydrogenase inhibitors | Plant toxin insecticides

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Rotor Design for Horizontal Axis Windmills

by: W.A.M. Jansen and P.T. Smulders

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May 1977

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and collaborates with other interested parties.

The S.W.D. tries to help governments, institutes and private parties in the Third World, with their efforts to use windenergy and in general to promote the interest for windenergy in Third World countries.

ROTOR DESIGN FOR HORIZONTAL AXIS WINDMILLS

by

W.A.M.Jansen*)
and
P.T.Smulders*)

MAY 1977

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*) Wind Energy Group, Laboratory of Fluid Dynamics and Heat Transfer, Department of Physics, Eindhoven University of Technology, Eindhoven, The Netherlands.

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INTRODUCTION.

This publication was written for those persons who are interested in the application of wind energy and who want to know how to design the blade shape of a windmill rotor. We have received many requests on this issue from parties inside and outside the Netherlands. In writing this booklet we were uncertain as to the level at which it should be written. So some might find it too easy, others too difficult.

We would like to emphasize that the design procedure, as given in one of the chapters, is very simple. It is important however that a number of basic ideas and concepts are well understood, before an attempt is made to design a rotor. Therefore quite a lot of attention is given to explaining lift, drag, rotor characteristics etc. So we ask the reader to be tolerant and patient. Those who are not familiar with the basic concepts we urge to go on and not to be afraid of the first formulas and graphs presented here.

Although a good rotor can be designed with the procedure as presented here, a few things should be noted. In the selection of a rotor type, in terms of design speed and radius, the load characteristics and wind availability must be taken into account. We have seen various good rotors coupled to wrong types of loads or to too high loads. Although it is possible to change the number of revolutions per minute with a transmission, this will not solve the problems that may arise when the selected design figures are basically incorrect. A second remark is that rotors can be very dangerous. No strength calculations are given in this book, but remember that the centrifugal forces can make a rotor explode if it is not strong enough. Touching a rotor during operation will lead to serious injury.
The availability of certain materials and technologies can be taken into account in the earliest stages of the design. We therefore hope that, with this book, the reader will be able to design a rotor that can be manufactured with the means and technologies as are locally available.

LIST OF SYMBOLS

a_n	constant	
A	area	m^2
B	number of blades	-
c	chord	m
C_d	drag coefficient	-
C_l	lift coefficient	-
C_P	power coefficient	-
C_Q	torque coefficient	-
d	diameter	m
D	drag	N
E	energy	J
E_v	energy per volume	Jm^{-3}
f	plate bending of arched steel plate	m
L	lift	N
m	mass	kg
n	number of revolutions per second	s^{-1}
P	power	W
Q	torque	Nm
R	rotor radius	m
r	local radius	m
Re	Reynolds number	-
Re_n	Re for $B = C_l = r = V_\infty = 1$	-
u	tangential blade speed at radius r	ms^{-1}
V	velocity, speed	ms^{-1}
V_∞	undisturbed windspeed	ms^{-1}
W	relative velocity to rotor blade	ms^{-1}
α	angle of attack	-
α_c	design value for angle of attack	-
β	blade angle, blade setting	-
η_B	factor for blade number effect on C_P	-
λ	tip-speed ratio	-
λ_o	design value for tip-speed ratio	-
λ_r	local speed ratio at radius r	-
ν	kinematic viscosity	m^2s^{-1}
ρ	density	kgm^{-3}
Φ_v	volume flow	m^3s^{-1}
ϕ	angle between plane of rotation and relative flow velocity at the rotor blades	-
Ω	rotor angular velocity	s^{-1}

UNITS OF MEASURE.

The units used in this publication belong to, or are based on the so-called Système International d'Unités (SI).
Those who are not familiar with these units or who have data given in units of other systems (for example windspeed in mph), we here give a short list with the conversion factors for the units that are most relevant for the design of windmill rotors.

length	1 m	= 3.28 ft
area	1 m^2	= 10.76 ft^2
volume	1 m^3	= 35.31 ft^3=264.2 gallons
speed	1 ms^{-1}	= 2.237 mph
	1 knot	= 0.5144 ms^{-1} = 1.15 mph
mass	1 kg	= 2.205 lb
force	1 N	= 0.225 lbf = 0.102 kgf
torque	1 Nm	= 0.738 ft lbf
energy	1 J	= 0.239 calories = 0.2777* 10^{-6} kWh=1Nm
power	1 W	= 1 watt = 1 Js^{-1} = 0.738 ft lbf s^{-1}=1Nms^{-1}
	1 hp	= 0.7457 kW
	1 pk	= 0.7355 kW

1. WIND ENERGY - WIND POWER.

Wind is air in motion. The air has mass, but its density is low. When mass is moving with velocity V it has kinetic energy expressed by:

$$E = \tfrac{1}{2}mV^2 \qquad [J] \qquad (1\text{-}1)$$

If the density of the flowing air is ρ , then the kinetic energy per volume of air, that has a velocity V_∞, is:

$$E_v = \tfrac{1}{2}\rho V_\infty^2 \qquad [Jm^{-3}] \qquad (1\text{-}2)$$

If we consider an area A perpendicular to the wind direction (see fig. 1.1), then it may be seen that per second a volume V_∞ A flows through this area. V_∞ is the undisturbed wind velocity.

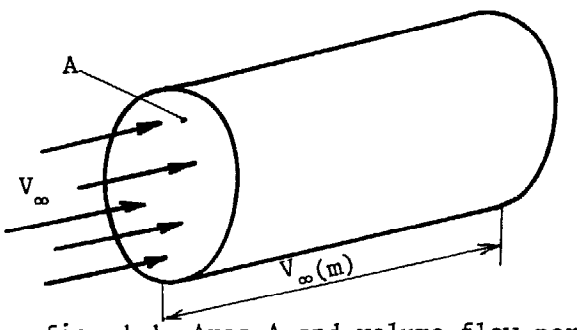

fig. 1.1 Area A and volume flow per second V_∞ A.

So the flow per second through A is:

$$\Phi_v = V_\infty A \qquad [m^3s^{-1}] \qquad (1\text{-}3)$$

The power that flows with the air, through area A, is the kinetic energy of the air that flows per second through A.

Power = Energy per second.

Power = Energy per volume * Volume per second.

Equations (1-2) and (1-3) combined give:

$$P_{air} = \tfrac{1}{2}\rho V_\infty^2 \; * \; V_\infty \, A \qquad [Js^{-1} = watt]$$

$$\boxed{P_{air} = \tfrac{1}{2}\rho V_\infty^3 \, A} \qquad [W] \qquad (1\text{-}4)$$

This is the power available in the wind; as will be seen, only a part of this power can actually be extracted by a windmill.
The above derived relation for the power in the wind (1-4) shows clearly that:

- the power is proportional to the density ρ.
  This factor can not be influenced and varies slightly with the height and temperature (For 15^oC at sea level $\rho = 1.225\ kgm^{-3}$).
- in case of horizontal axis windmills the power is proportional to the area $A = \pi R^2$ (area swept by the blades) and thus to R^2. Radius R is chosen in the design.
- the power varies with the cube of the undisturbed windvelocity V_∞. Note that the power increases eightfold if the windspeed doubles.

2. HORIZONTAL AXIS WINDMILL ROTOR.

To extract the power from the wind, several devices have been used and are still in use throughout the world. Examples of such devices are sailboats and windmills.
This book deals only with the design of rotors for horizontal axis windmills, which are rotors with the axis of rotation in line with the wind velocity. The rotor rotates because forces are acting on the blades. These forces are acting on the blades because the blade changes the air velocity. The next paragraph deals with the relations between the velocity at the rotor blade and the forces acting on the blade.

2.0 Airfoils.

The rotor of a windmill consists of one or more blades attached to a hub. The cross sections of these blades can have several forms, as illustrated in fig. 2.1 and we call these cross sections airfoils.

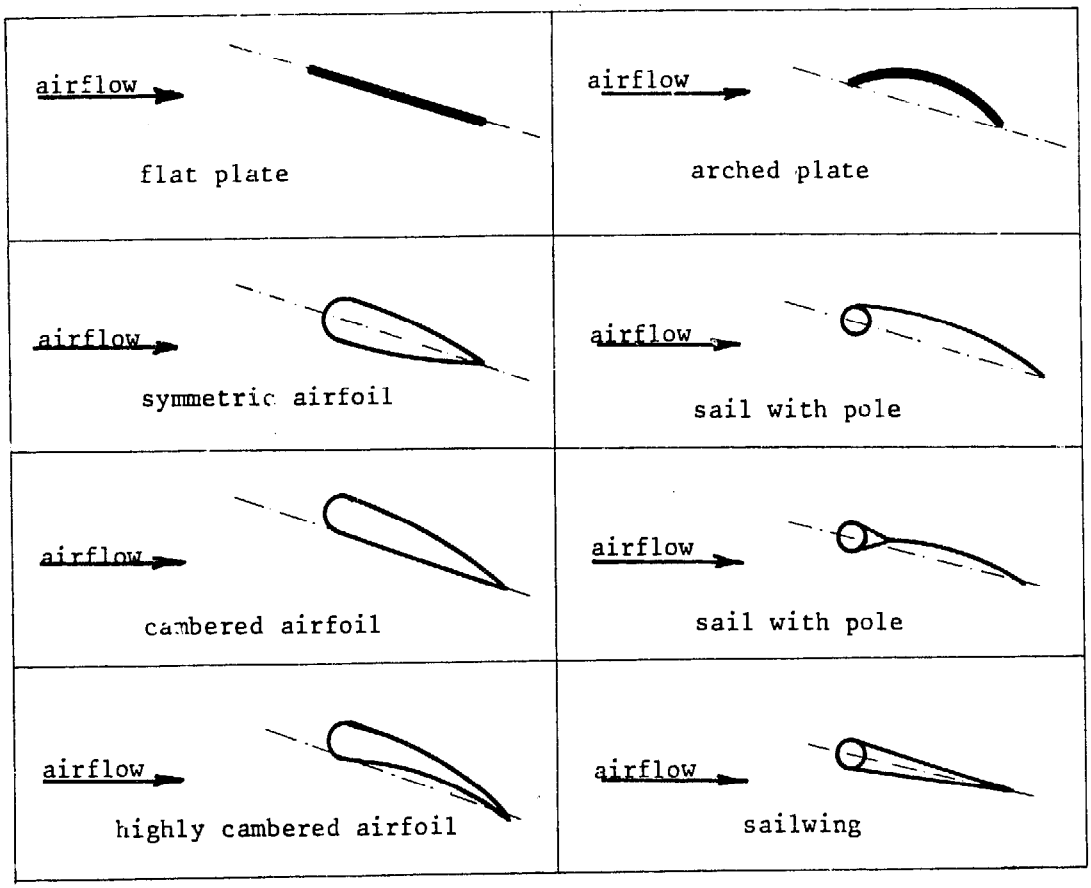

fig. 2.1 Types of airfoils.

An airfoil is a surface over which air flows. This flow results in two forces: LIFT and DRAG. Lift is the force measured perpendicular to the airflow - not to the airfoil! Drag is measured parallel to the flow. See fig. 2.2.

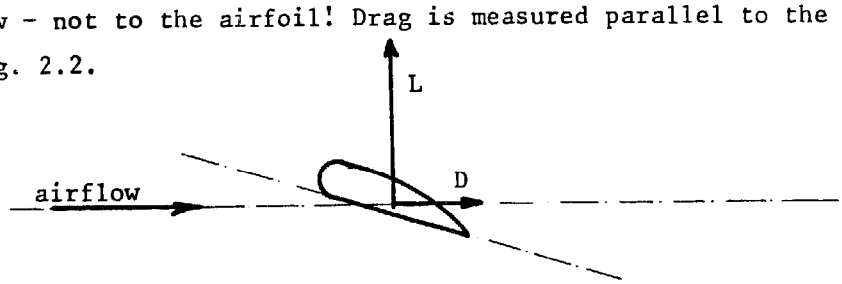

fig. 2.2 Lift and drag.

All airfoils require some angle with the airflow in order to produce lift. The more lift required, the larger the angle.
The chord line (fig. 2.3) connects the leading edge and the trailing edge of the airfoil.* The angle required for lift is called angle of attack α. The angle of attack is measured between the chord line and the direction of the airflow. See fig. 2.3.

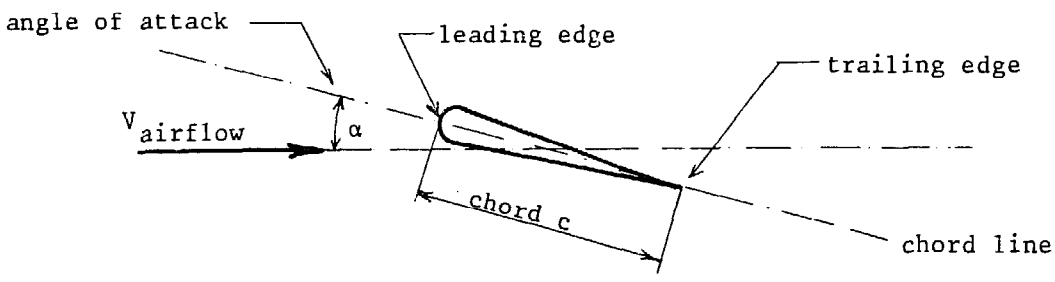

fig. 2.3. Chord line and angle of attack.

We want to describe the performance of an airfoil independent of size and airflow velocity. Therefore we divide lift L and drag D by $\frac{1}{2}\rho V^2 A$ where

ρ = air density	$[kgm^{-3}]$
V = flow velocity	$[ms^{-1}]$
A = blade area (= chord * blade length)	$[m^2]$

The results of these divisions we call lift coefficient C_l and drag coefficient C_d

$$C_l = \frac{L}{\frac{1}{2}\rho V^2 A} \quad [-] \qquad (2\text{-}1)$$

$$C_d = \frac{D}{\frac{1}{2}\rho V^2 A} \quad [-] \qquad (2\text{-}2)$$

As stated before, the amount of lift and drag that is produced, depends on the angle of attack. This dependence is a given characteristic of an airfoil and is always presented in C_l-α and C_l-C_d graphs. See fig 2.4.

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* For some airfoils the chord line is defined otherwise.

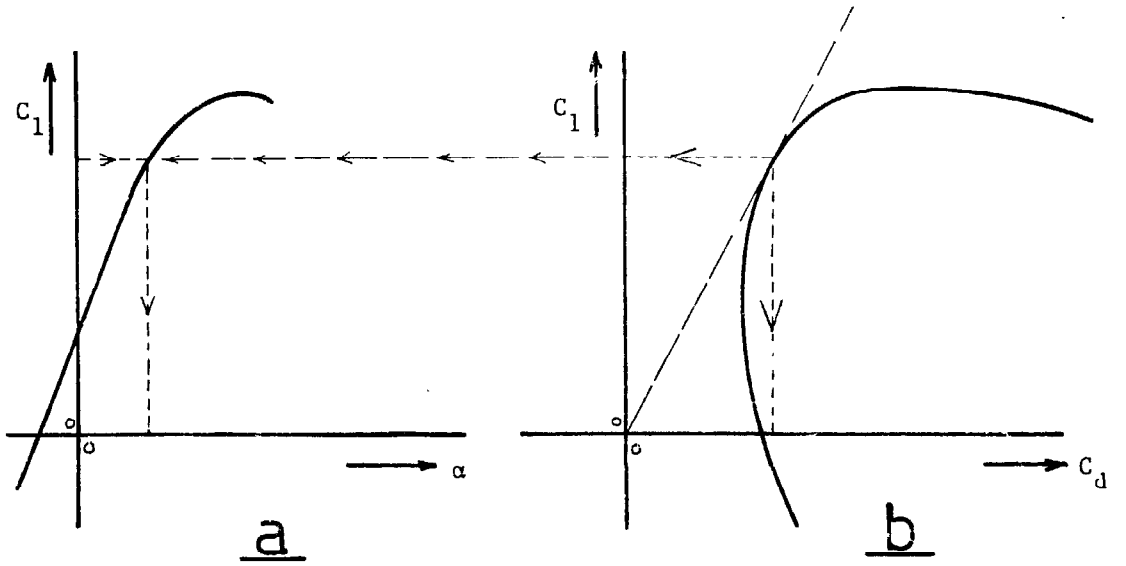

fig 2.4. Lift and drag characteristics.

In Appendix II C_l-α and C_l-C_d characteristics of a series of NACA airfoils is presented as an example. For the design of a windmill it is important to find from such graphs the C_l and α values that correspond with a minimum C_d/C_l-ratio.*) This is done in the following way:
In the C_l/C_d graph a tangent is drawn through C_d=C_l=0. See fig 2.4.b.
From the point where the tangent touches the curve, we find C_d and C_l. From fig. 2.4.a we find the corresponding angle of attack α.
The C_l and α values that are found in this way we call C_l-design and α-design and the division of C_d by C_l is the minimum C_d/C_l-ratio: $(C_d/C_l)_{min}$.
Table 2.1 on p. 10 gives these design values for several airfoils.
Note that it is not important for the behaviour of the airfoil whether it is standing still in an airflow with velocity W or that it is moving with velocity W in air that is at rest; what matters is the relative velocity that is "seen" by the airfoil. See fig. 2.5.

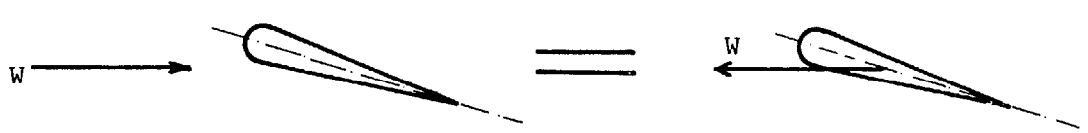

fig 2.5 Relative velocity.

A blade element of a windmill rotor "sees" a relative velocity that results from the wind velocity in combination with the velocity with which the blade element moves itself. See fig 2.6.

---

*) We will see on p.11 that a maximum power is obtained when the drag to lift ratio is as small as possible.

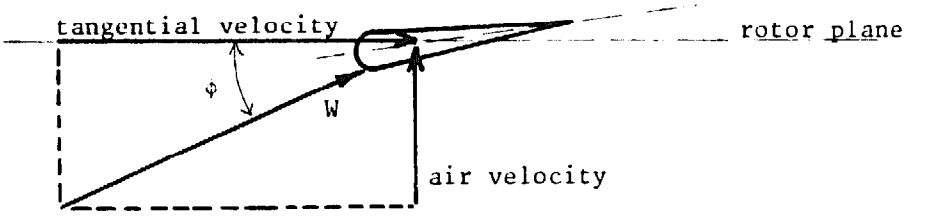

Fig.2.6 Relative velocity on rotor blade

ϕ is the angle between the relative velocity W and the rotor plane.

TABLE 2.1

airfoil name	geometrical description	$(C_d/C_l)_{min}$	α^o	C_l
sail and pole	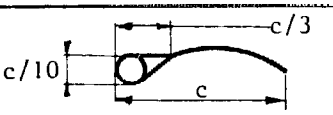	0.1	5	0.8
flat steel plate		0.1	4	0.4
arched steel plate				
	f/c=0.07	0.02	4	0.9
	f/c=0.1	0.02	3	1.25
arched steel plate with tube on concave side	d<0.1c			
	f/c=0.07	0.05	5	0.9
	f/c=0.1	0.05	4	1.1
arched steel plate with tube on convex side	f/c=0.1	0.2	14	1.25
sail wing	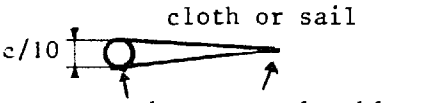	0.05	2	1.0
sail trouser f/c=0.1 d_{tube}≈0.6f	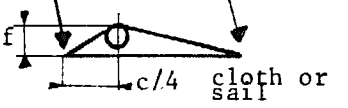	0.1	4	1.0
NACA 4412	see appendix II	0.01	4	0.8
NACA 23015	see Lit(1) in appendix I	0.01	4	0.8

2.1 Torque and power characteristics.

The components in the plane of rotation of the lift forces result in a force working in tangential direction at some distance from the rotor center. This force is diminished by the component of the drag in tangential direction. The result of these two components is a propelling force in tangential direction at some distance from the rotor center.

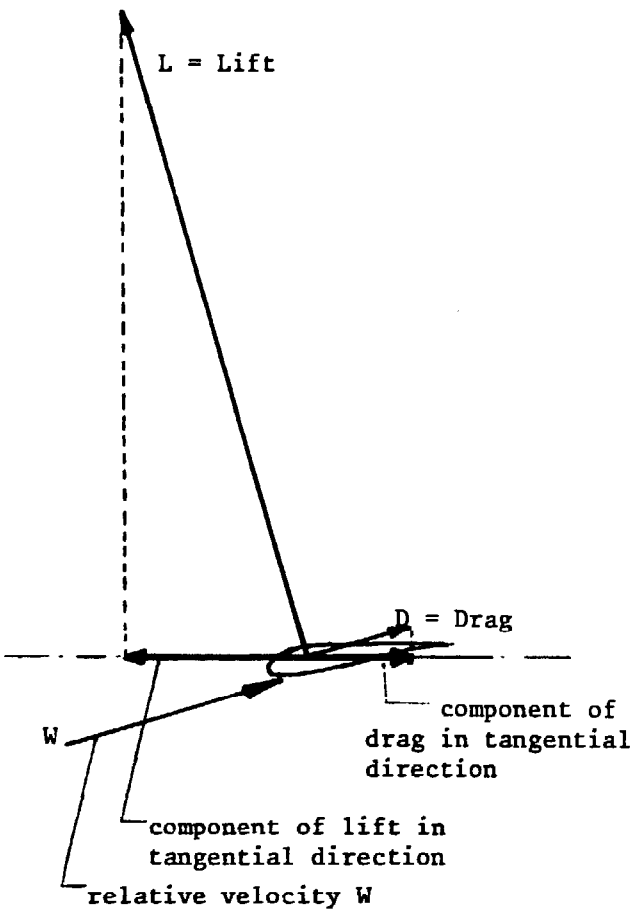

The product of this propelling force and its corresponding distance to the rotor center is the contribution of the blade element under consideration to the torque Q of the rotor. The rotor rotates at an angular speed Ω (= $2\pi *$ number of revolutions per second).

$$\Omega = 2\pi n \quad [\text{rad sec}^{-1}] \qquad (2\text{-}3)$$

The power that such a rotor extracts from the wind is transformed into mechanical power. This power is equal to the product of the torque and the angular speed.

Q = torque	[Nm]
Ω = angular speed	[rad s^{-1}]
$\boxed{\text{power } P = Q * \Omega}$	[W] (2-4)

A windmill of given dimensions transforms kinetic energy from the wind into a certain amount of power. Equation (2-4) clearly shows that a windmill for a high torque load (for example a piston pump) will have a low angular speed; a high speed design will only produce a small amount of torque (for example for a centrifugal pump or an electricity generator).
We call a graph, that shows the dependance of the windmill torque on the angular speed, a windmill torque characteristic. Fig.2.7.a shows torque characteristics of two different windmills designed for the same power but for different angular speeds. The windmill torque characteristic depends on wind speed V_∞, so we have many curves in one characteristic.

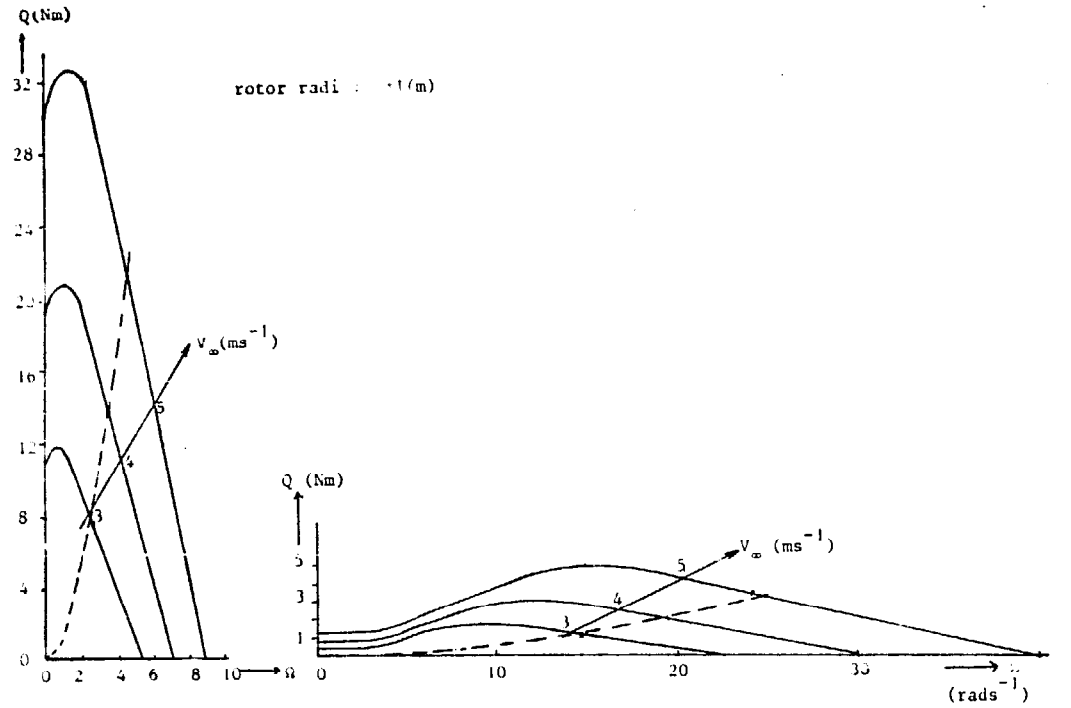

fig. 2.7.a. low speed windmill torque characteristic

high speed windmill torque characteristic

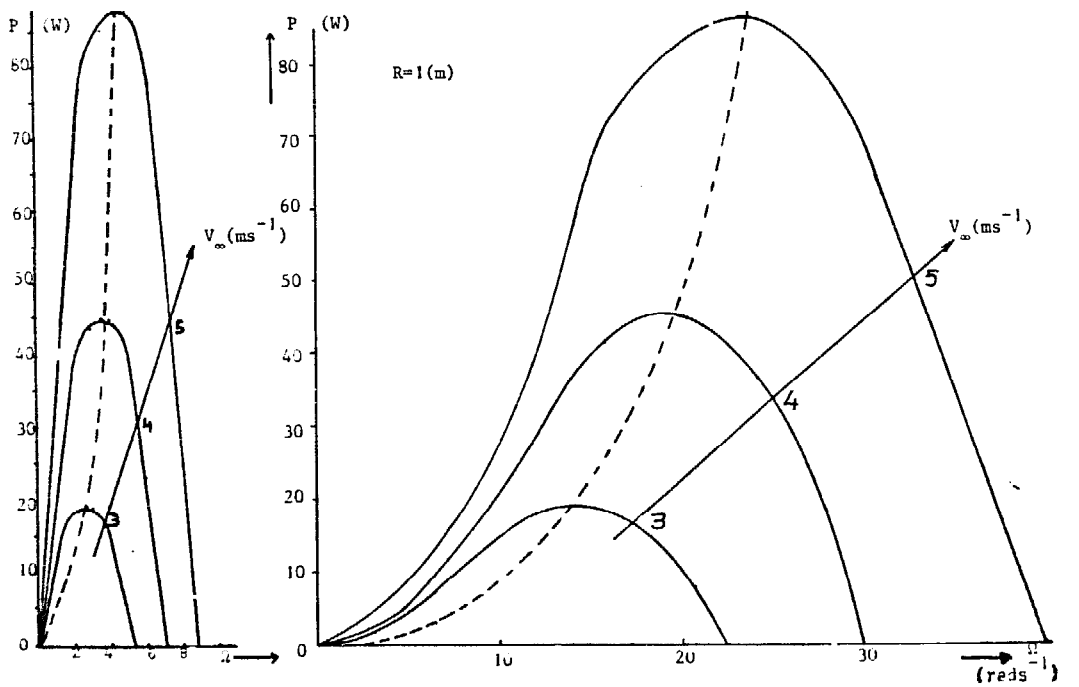

fig. 2.7.b. low speed windmill power characteristic

high speed windmill power characteristic

With relation (2-4) it is very simple to derive from the torque characteristics the corresponding power characteristics. See fig. 2.7.b, where the power-angular speed curves, belonging to windmills of fig. 2.7.a, are shown.

Note: 1) The power of the two windmills is the same, but is delivered at different angular speeds Ω.

2) The maximum power is delivered at a higher angular speed than the maximum torque.

3) The maximums of the power curves in fig. 2.7.b. vary with the cube of the angular speed Ω:

$$P_{max} \sim \Omega^3 \qquad (2\text{-}5a)$$

while the corresponding torque values vary with the square of the angular speed Ω:

$$Q_{(at\ P = P_{max})} \sim \Omega^2 \qquad (2\text{-}5b)$$

4) The starting torque, i.e. the torque at zero revolutions per second, is considerably lower for high speed than for low speed windmills.

Before selecting the speed of the rotor to be designed, the designer must compare the torque characteristic of the load with the torque characteristic of the rotor.

For a proper match of a load to a windmill rotor it is important that both load and windmill operate at angular speeds where their efficiencies are maximum. The angular speed at which the rotor has its maximum efficiency is not always equal to the angular speed at which the load has its maximum efficiency. In that case we need a transmission. It is in most cases not difficult to determine the transmission factor needed for the optimum angular speeds of both load and rotor, but remember that a transmission also changes the torque. In practice this means that the transmission factor cannot be chosen on the basis of angular speeds only.

2.2 Dimensionless coefficients.

In order to be able to compare the properties and characteristics of different windmill designs under different wind conditions we write the mechanical power as the power in the air multiplied by a factor C_p

$$P_{mech} = C_p * P_{air} \qquad (2\text{-}6a)$$

C_p is called power coefficient and is a measure for the success we have in extracting power from the wind. With relation (1-4) we may write

$$\boxed{C_p = \frac{P_{mech}}{\frac{1}{2}\rho V_\infty^3 \pi R^2}} \qquad (2\text{-}6b)$$

For the same reasons we divide the speed u of the rotor at radius r by the windspeed. See fig. 2.8

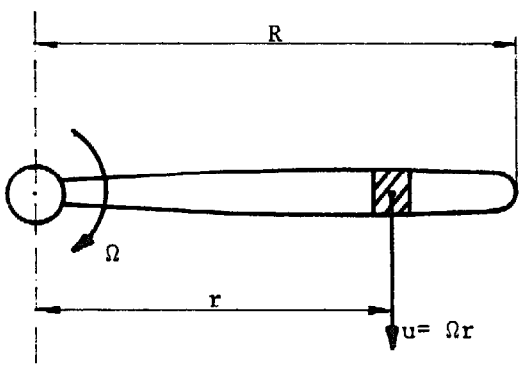

fig. 2.8 Definition of speed ratio.

The result $(\frac{u}{V_\infty})$ we call local speed ratio and is noted

$$\boxed{\lambda_r = \frac{u}{V_\infty} = \frac{\Omega r}{V_\infty}} \qquad (2\text{-}7)$$

The speed ratio of the element of the rotor blade at radius R we call tip-speed ratio:

$$\boxed{\lambda = \frac{\Omega R}{V_\infty}} \qquad (2\text{-}8)$$

Note: Later it will be shown that a windmill has one value of λ at which the power coefficient is maximum. This λ is often called 'the tip-speed ratio of a windmill ' or 'the speed ratio of a windmill'.

There is of course a direct relation between λ and λ_r. Relations (2-7) and (2-8) together give

$$\lambda_r = \frac{r}{R} * \lambda \qquad (2\text{-}9)$$

From relation (2-4) we know that

$$Q = \frac{P}{\Omega} \qquad (2\text{-}10)$$

With this relation we define a dimensionless torque coefficient in the following way:

$$\left.\begin{aligned} P &= C_p \tfrac{1}{2}\rho V_\infty^3 \pi R^2 && (2\text{-}6b) \\ \Omega &= \frac{\lambda V_\infty}{R} && (2\text{-}8) \\ Q &= \frac{P}{\Omega} && (2\text{-}10) \end{aligned}\right\} \longrightarrow$$

$$\longrightarrow \quad \frac{C_p}{\lambda} = \frac{Q}{\tfrac{1}{2}\rho V_\infty^2 \pi R^3}$$

We define:

$$\boxed{C_Q = \frac{Q}{\tfrac{1}{2}\rho V_\infty^2 \pi R^3}} \qquad (2\text{-}11)$$

Note that in this way relation (2-4) is still valid but now in dimensionless form:

$$\boxed{C_p = C_Q * \lambda} \qquad (2\text{-}12)$$

2.3 Basic form of a windmill characteristic.

The power coefficient C_p in equation (2-6) is not an efficiency but may be interpreted as a measure of the success that a windmill has in transforming wind energy into mechanical energy. For one specific windmill C_p varies with the tip-speed ratio of the windmill. In dimensionless form this is shown in a so-called $C_p - \lambda$ characteristic based on formulas (2-6) and (2-8).
See fig. 2.9 where one curve now represents all the curves for different V_∞ of fig. 2.7.b.

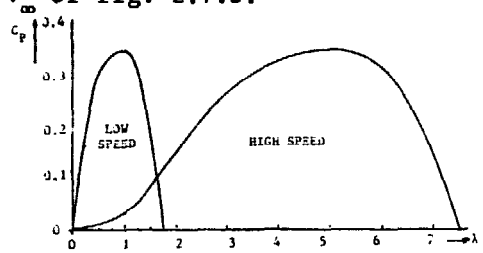

fig 2.9 $C_p - \lambda$ characteristic.

This characteristic is independent of air density ρ, windspeed V_∞ and radius R.
Using relation (2-12) we may derive from fig 2.9 a dimensionless form of the torque-speed characteristic of the windmill: C_Q-λ curve; see fig 2.10. Also here one curve represents all curves of fig 2.7.a.

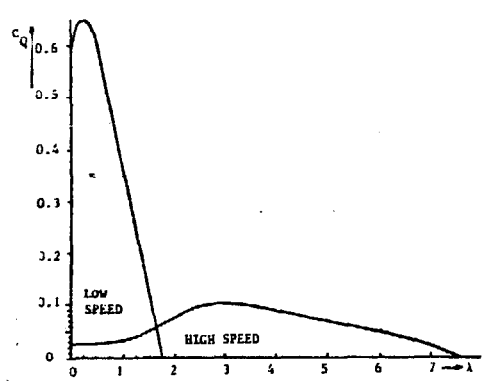

fig 2.10 C_Q-λ characteristic.

Note that the power is zero if $\lambda = 0$ but that the torque is not.
See relations (2-4) and (2-12).

2.4. Maximum power coefficient.

The power coefficient C_p as defined with relation (2-6) describes how much power we get from the wind with a windmill. The power in the wind is given by relation (1-4). We are of course very interested in how much wind power we can transform into mechanical power with a windmill. In other words, we want to know what the highest power coefficient C_p is for a given windmill that is designed for a certain tip-speed ratio. Betz was the first one to show that the theoretically maximum attainable power coefficient is 0.593. This result will be clarified in the next paragraph. Three other effects cause a further reduction of the maximum power coefficient. How to find the maximum power coefficient that takes these effects into account will be explained in the next four paragraphs:

2.4.0 Betz coefficient
2.4.1 Effect of wake rotation on maximum power coefficient
2.4.2 Effect of C_d/C_l-ratio on maximum power coefficient
2.4.3 Effect of number of blades on maximum power coefficient

2.4.0 Betz coefficient

It is not possible to transform all the wind energy that flows through cross sectional area A (fig 1.1) into mechanical energy. If we could transform all the energy in the air this would mean that we could extract all kinetic energy from the air; the air velocity behind the rotor would then be zero and no more air would flow through the rotor. The process of extracting kinetic energy from the wind will stop and no more power will be transformed. If on the other hand the air velocity behind the rotor is equal to the wind velocity, no kinetic energy has been extracted and also in this case no power will be transformed. In this way it may be understood that, if the flow velocity behind the rotor is either zero or equal to the wind velocity V_∞, in both cases the mechanical power is zero. Between these values there is an optimum value of the wind velocity behind the rotor.
Betz found this value to be $\frac{1}{3} V_\infty$ and calculated the maximum power coefficient (Betz coefficient).

$$C_{P_{max}} = \frac{16}{27} = 0.593 \qquad (2\text{-}13).$$

This value is however only valid for a theoretical design for a <u>high tip-speed ratio</u>, with an <u>infinite number of blades</u> and a <u>blade drag equal to zero.</u> The effect of deviations from these three assumptions will be shown one by one in the next three paragraphs.

2.4.1 Effect of wake rotation on maximum power coefficient.

The Betz coefficient suggests that, independent of the design tip-speed ratio λ_o, we may expect a maximum power coefficient C_P of 0.593. Relation (2-13) is however only valid for high tip-speed ratios and for low tip-speed ratios considerable deviations exist. This can be explained in the following way:
The power is: torque * angular speed. The torque is produced by forces acting on the blades in tangential direction, multiplied by their corresponding distances to the rotor center. These forces are the result of velocity changes of the air in tangential direction (action = reaction; force = mass * velocity change per unit of time). The direction of the velocity change in the air is opposed to the direction of the forces acting on the blades. Since the air has no tangential velocity before passing the rotor, the velocity change means that behind the rotor the wake rotates in a direction opposite to that of the rotor. This wake rotation means a loss of energy because the rotating air contains kinetic energy (see relation 1-1). Since a certain amount of power is to be transformed, we know from relation (2-4) that a low tip-speed ratio (= low angular speed Ω), means that the torque Q must be high. High torque means large tangential velocities in the wake; the consequence is a loss of energy and a lower power; the more so if the design tip-speed ratio is lower. The result is shown in fig. 2.11.
The graph presented in fig. 2.11 shows the collection of maximum obtainable power coefficients of ideal windmills i.e. wir ·lls with an infinite number of blades without drag.

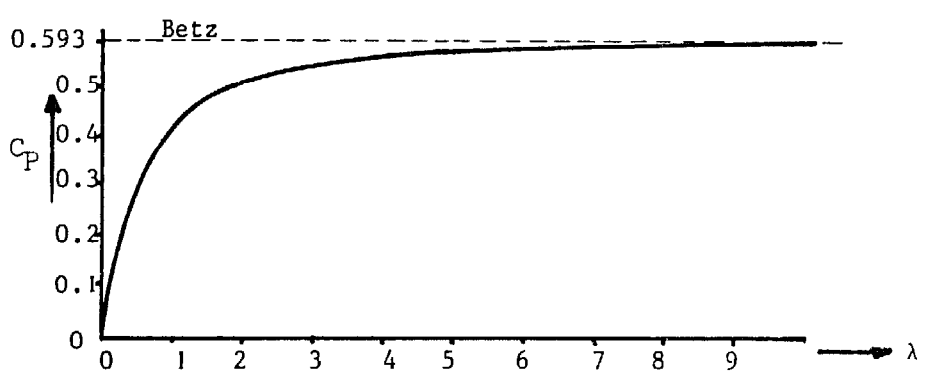

fig. 2.11 Collection of maximum power coefficients of ideal windmills.

2.4.2 Effect of C_d/C_l-ratio on maximum power coefficient.

The factor C_d, as defined in par. 2.0, is a measure for the resistance of the blades against moving through the air. The C_d/C_l-ratio determines the losses due to this resistance. These losses are calculated and included in the collection of maximum power coefficients of fig. 2.11. The results are shown in fig. 2.12.

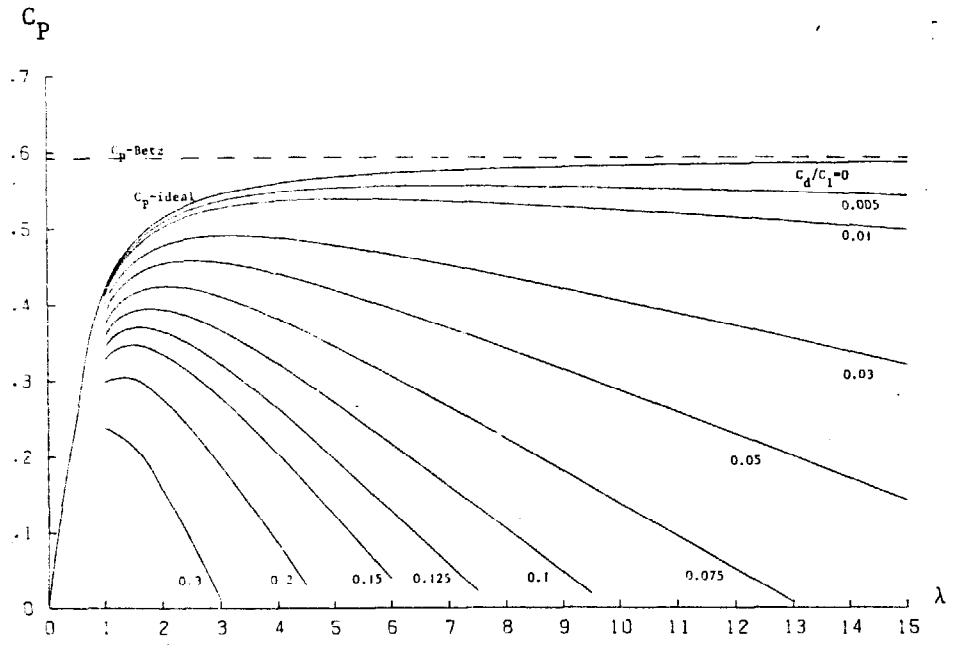

fig. 2.12 Effect of C_d/C_l-ratio on C_p-max for a rotor with an infinite number of blades.

Fig. 2.12 shows that a rotor, designed for a tip-speed ratio $\lambda = 2.5$ with airfoils having, for example, a minimum C_d/C_l-ratio of 0.05, will have a maximum power coefficient $C_p = 0.46$. If the rotor is designed for $\lambda = 10$, at the same C_d/C_l value, the C_p value at $\lambda = 10$ will have a maximum of 0.3.

Note that from fig. 2.12 it is clear that it is useless to design a rotor for $\lambda = 10$ with airfoils that have $(C_d/C_l)_{min} = 0.1$.

2.4.3 Effect of number of blades on maximum power coefficient.

The number of blades also affects the maximum power coefficient. This is caused by the so-called "tip-losses" that occur at the tips of the blades. These losses depend on the number of blades and the tip-speed ratio. The losses have been calculated and as example are included in the collection of maximum power coefficients for $(C_d/C_l)_{min} = 0.03$ of fig. 2.12. The results are shown in fig. 2.13.

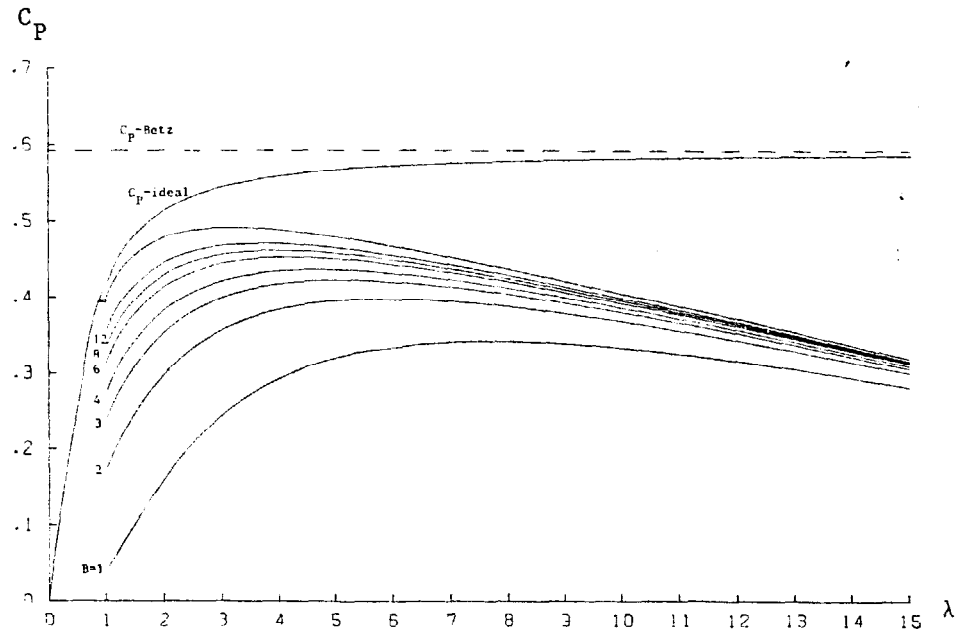

fig. 2.13 Influence of number of blades B on C_P-max for $C_d/C_l = 0.03$.

In appendix III graphs like fig. 2.13 are shown giving the maximum expected power coefficient for λ-design between 1 and 15.
The first group of graphs shows $C_{P_{max}}$ for constant number of blades B while the C_d/C_l-ratio is varied. The second group gives $C_{P_{max}}$ for constant C_d/C_l-ratio while B is varied.
Conclusion: If design figures for tip-speed ratio λ, number of blades B and C_d/C_l-ratio have been chosen, the expected power coefficient C_p may be read from the graphs in appendix III.

3 DESIGN OF A WINDMILL ROTOR.

3.0 Calculation of blade chords and blade setting.

In chapter 2 it was shown that the selection of the number of blades B affects the power coefficient. Although B has no influence on the tip-speed ratio of a certain windmill, for the lower design tip-speed ratios, in general, a higher number of blades is chosen (see table 3.1). This is done because the influence of B on C_p is larger at lower tip-speed ratios. A second reason is that choice of a high number of blades B for a high design tip-speed ratio will lead to very small and thin blades which results in manufacturing problems and a negative influence on the lift and drag properties of the blades (this problem will be dealt with in chapter 4).

λ_o	B
1	6-20
2	4-12
3	3-6
4	2-4
5-8	2-3
8-15	1-2

table 3.1 Selection of number of blades.

A second important factor that affects the power coefficient is the drag. Drag affects the expected power coefficient via the C_d/C_l-ratio. This will influence the size and, even more, the speed ratio of the design.
In paragraph 2.0 a list is shown with several airfoil types and their corresponding minimum C_d/C_l-ratios (table 2.1 on p. 10). Promising airfoils in this table have a minimum C_d/C_l-ratio between 0.1 and 0.01.

A large C_d/C_l-ratio restricts the design tip-speed ratio. At lower tip-speed ratios the use of more blades compensates the power loss due to drag. See Appendix III. In this collection of maximum power coefficients it is seen that for a range of design speeds $1 \leq \lambda_o \leq 10$ the maximum theoretically attainable power coefficients lie between $0.35 \leq C_{P_{max}} \leq 0.5$.
Due to deviations, however, of the ideal geometry and hub losses for example, these maximums will lie between 0.3 and 0.4. This result shows that the choice of the design tip-speed ratio hardly effects the power output. Two other factors, however, limit the choice of the design tip-speed ratio. One is the character of the load. If it is a piston pump, scoop wheel or some other slow running load, that in most cases will require a high starting torque, the design speed of the rotor will usually be chosen low; this allows the designer to use simple airfoils like sails or steelplates. If the load is running fast like a generator or a centrifugal pump, then a high design speed will be selected and airfoils with a low C_d/C_l-ratio will be preferred. The second factor is that the locally available technologies will often restrict the possibilities of manufacturing blades with airfoils having low C_d/C_l-ratios. But even in the case of a high speed design, simple airfoils like arched steel plates, can give very good results.

We will pass over in silence the problems related to starting torque and optimum angular frequency of the load. Now we can design a windmill rotor for a given windspeed V_∞ and a power demand P. Selecting in table 2.1 an airfoil in terms of a minimum expected C_d/C_l-ratio, we can choose a design tip-speed ratio λ_o with the help of appendix III. With table 3.1 a number of blades B is chosen and, returning to appendix III we can find the maximum power coefficient $C_{P_{max}}$ that may be expected.

example: design rotor with 7% arched steelplates.

	Table 2.1	– $(C_d/C_l)_{min} = 0.02$
Appendix III	*Page 48*	– $1 < \lambda_o < 8$; *we choose* $\lambda_o = 4$.
	Table 3.1	– $B = 4$
Appendix III	*Page 43*	– $C_{P_{max}} = 0.48$

With relation (2-6) we can now calculate the desired radius R of the rotor. For conservative design we take $C_p = 0.8 * C_{P_{max}}$.

$$R = \sqrt{\frac{2P}{\pi \rho V_\infty^3 C_p}} \qquad (2\text{-}6)$$

example: the rotor to be designed must deliver 1100 Watts of mechanical power (P = 1100 Watt) in a wind with V_∞ = 8 [ms^{-1}].

$$R = \sqrt{\frac{2*1100}{\pi*1.225*8^3*0.8*0.48}} = 1.7 \text{ [m]}$$

Design of the blades.

We need the following data:

rotor radius	R	[m]
number of blades	B	[-]
design tip-speed ratio	λ_0	[-]
airfoil data:		
design lift coefficient	C_{l_o}	[-]
corresponding angle of attack	α_o	[-]

Airfoil data may be found in table 2.1, Appendix II and literature (1), (5), (6) and (12).

Once these data are known, it is now very simple to calculate the blade geometry; i.e. the chord c of the blade and the blade angle β, the angle between the chord and the plane of rotation, fig. 3.1.

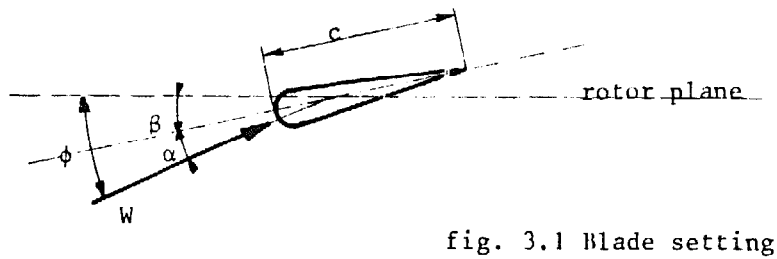

fig. 3.1 Blade setting β.

Only three simple formulas are needed and one graph

$$\lambda_r = \lambda_o \times r/R \tag{2.9}$$

$$c = \frac{8\pi r}{BC_l} (1 - \cos \phi) \tag{3.1}$$

$$\beta = \phi - \alpha \tag{3.2}$$

and graph $\lambda_r - \phi$ (appendix V)

The underlying theory is too complicated to be explained here (see appendix IV and the literature references appendix I). The reader who is primarily interested in the design of the rotor, can do without this theory.

Now the design procedure is as follows:
Divide the blade with radius R in a number of parts of equal length. In this way we find cross sections of the blade. Each cross section has a distance r to the rotor center and has a local speed ratio λ_r, according to (2.9).
In appendix V we can find the corresponding angle ϕ (see fig. 3.1) for each cross-section. ϕ is the angle of the relative air velocity W that meets the blade section at radius r. We now calculate the chord with relation (3.1). (For ease, $(1 - \cos \phi)$ has been added in the graph of appendix V). The blade angle at the corresponding radius is found with (3.2).

example: We continue our design of a rotor with

$R = 1.7$ [m]

$B = 4$

$\lambda_o = 4$

airfoil = 7% arched steel plate

table 2.1 gives for this airfoil:

$C_{l_o} = 0.9$ *(i.e. the value for minimum* C_d/C_l*)*

$\alpha_o = 4°$ *(i.e. the corresponding angle of attack).*

With equations (2-9), and (3-1), (3-2) we can now compute the values of the following table:

Table 3.2

cross section number	r(m)	λ_r	ϕ^o	α_o^o	β^o	c(m)
1	0.2125	0.5	42.3	4	38.3	0.386
2	0.4250	1	30.0	4	26.0	0.398
3	0.6375	1.5	22.5	4	18.5	0.399
4	0.8500	2	17.7	4	13.7	0.281
5	1.0625	2.5	14.5	4	10.5	0.236
6	1.2750	3	12.3	4	8.3	0.204
7	1.4875	3.5	10.6	4	6.6	0.177
8	1.7000	4	9.4	4	5.4	0.159

The result is the blade chord c and the blade setting β at various stations along the blades. Plotting the chords (fig 3.2) gives the blade form and plotting β shows the desired twist of the blade.

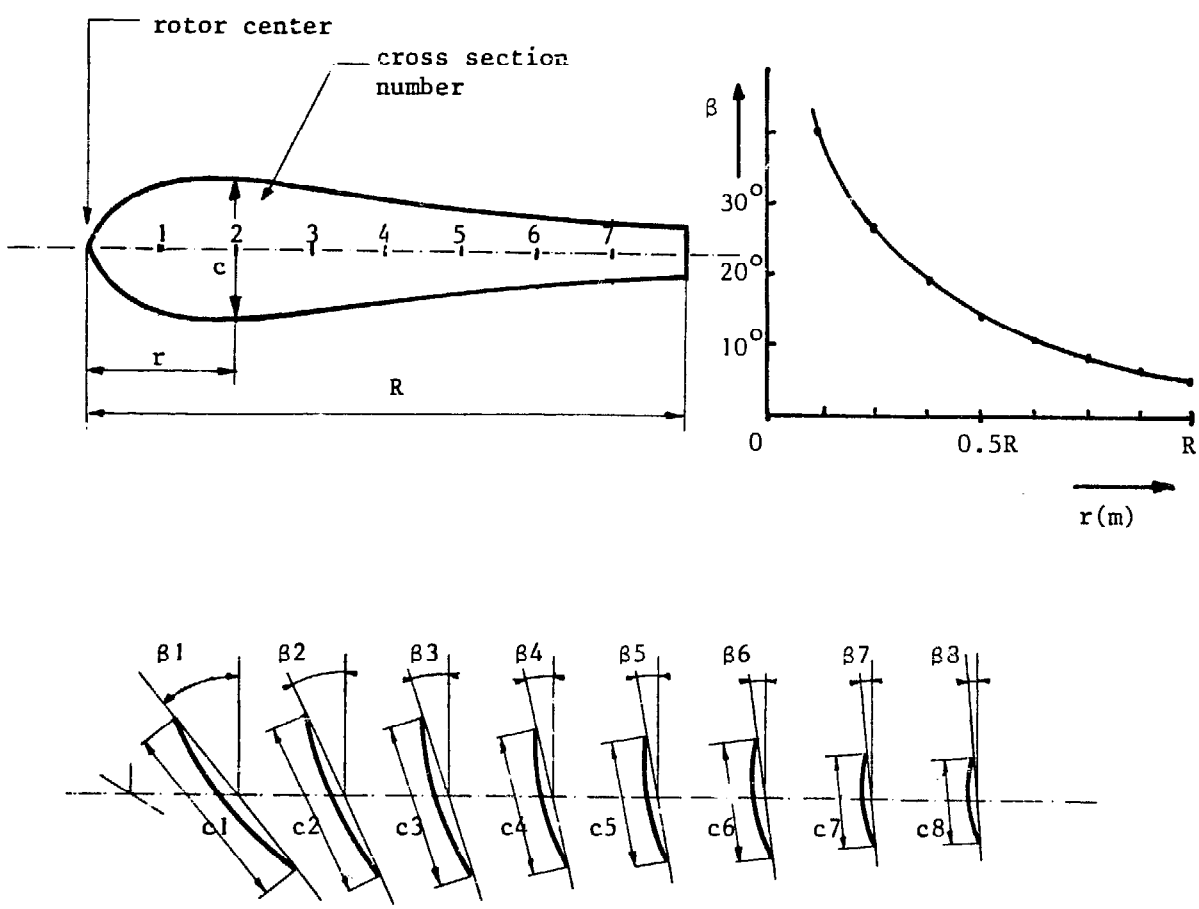

Fig. 3.2 Blade form, twist and cross sections of the blade.

3.1 Deviations from the calculated chords and blade setting.

In the last paragraph we showed how to calculate the ideal blade form. The chords as well as the blade angles as calculated in par. 3.0 vary in a non-linear manner along the blade. Such blades are usually difficult to manufacture and lead to an uneconomic use of materials. In order to reduce these problems it is possible to linearize the chords and the blade angles. This results in a small loss of power. If the linearization is done in a sensible way the loss is only a few percent.
In considering such linearizations it must be realized that about 75% of the power that is extracted by the rotor from the wind, is extracted by the outer half of the blades. This is because the blade swept area varies with the square of the radius; also the efficiency of the blades is less at small radii, where the speed ratio λ_r is small. On the other hand, at the tip of the blade the efficiency is low, due the so-called tip losses discussed in par. 2.4.3.
For the reasons mentioned above, it is advised to linearize the chords c and the blade angles β between r = 0.5R and r = 0.9R.

example: we linearize the blade chords c and angles β as calculated in table 3.2 of par. 3.0.

The nearest value of r to 0.5 R in table 3.2 is r = 0.85 (= 0.5 R).
The nearest value of r to 0.9 R in table 3.2 is r = 1.4875 (= 0.875 R).
In table 3.2 for these values of r the following values of c and β were calculated:

r [m]	*c [m]*	β^o
0.85	*0.281*	*13.7*
1.4875	*0.159*	*6.6°*

We can now linearize the chords and blade angles by writing c and β in the following way:

$$c = a_1 r + a_2$$

$$\beta = a_3 r + a_4$$

With the values of c and β at r = 0.85 and r = 1.4875, the constants a_1, a_2, a_3 and a_4 are found.

$$c = -0.191\ r + 0.444$$

$$\beta = -11.14\ r + 23.17$$

Suppose we have a hub for the rotor and the hub has a radius r = 0.17 [m] then we can calculate the chords and blade angles at the foot and at the tip of the blade:

$$c_{foot} = -0.191 * 0.17 + 0.444 = 0.412\ [m]$$
$$c_{tip} = -0.191 * 1.7 + 0.444 = 0.119\ [m]$$
$$\beta_{foot} = -11.14 * 0.17 + 23.17 = 21.3^{o}$$
$$\beta_{tip} = -11.14 * 1.7 + 23.17 = 4.3^{o}$$

The result of the linearizations is shown in fig. 3.3 where blade form and twist in the blade are shown and compared with the blade form of fig. 3.2.

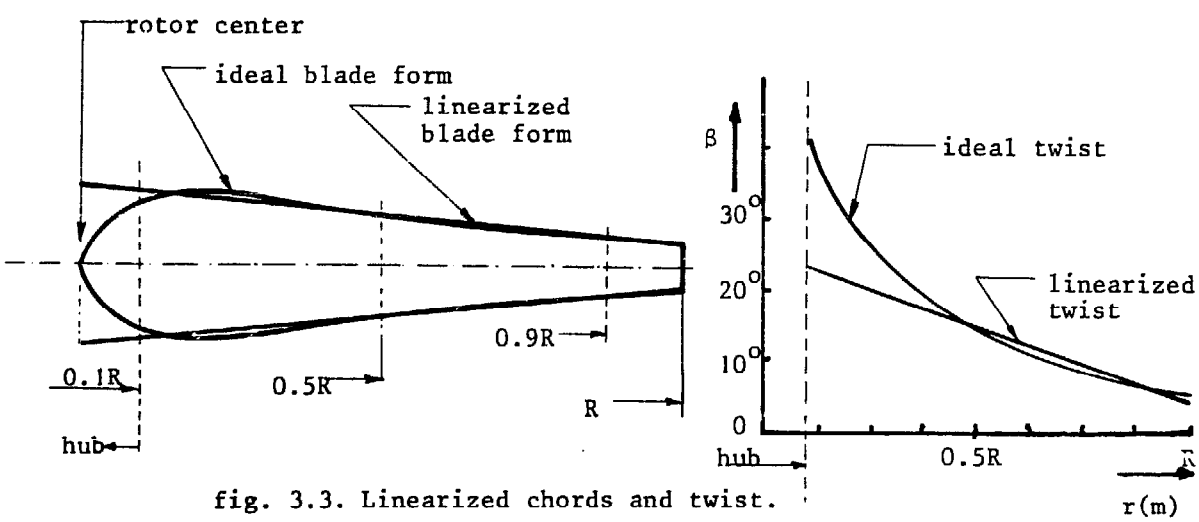

fig. 3.3. Linearized chords and twist.

As may be seen from fig. 3.3 the changes in chords and blade angles are very small at the outer half of the blades. At the inner half the chords also remain almost unchanged. A rather large change is found in the blade angles for $r < 0.5$ R. For reasons as stated on the first page of this chapter, this will not lead to any significant power loss but may have a considerable effect on the torque that is produced at low angular speeds. In general the starting torque will be less and in cases where the starting capacities of the windmill are very important, this effect should not be forgotten. An example of a load that demands a high starting torque is the single stroke piston pump. For this load, the size of the windmill is often determined by the demanded starting torque.

4. EFFECT OF THE REYNOLDS-NUMBER.

4.0 Dependance of airfoil characteristics on the Re-number.

The airfoil characteristics depend on the so-called Reynolds-number (Re) of the flow around the airfoil. For an airfoil Re is defined as $Re = \frac{W.c}{\nu}$, where W is the relative velocity to the airfoil, c is the chord and ν is the kinematic viscosity (in our case that of air).
All airfoils have a critical Re-number. If the Re-number of the flow around the airfoil is less then this $Re_{critical}$ then the C_l-value is lower and the C_d-value is higher; above this $Re_{critical}$ the performance is considerably better. See for example fig. 4.1 where the effect of the Re-number on $(C_d/C_l)_{min}$ is shown.

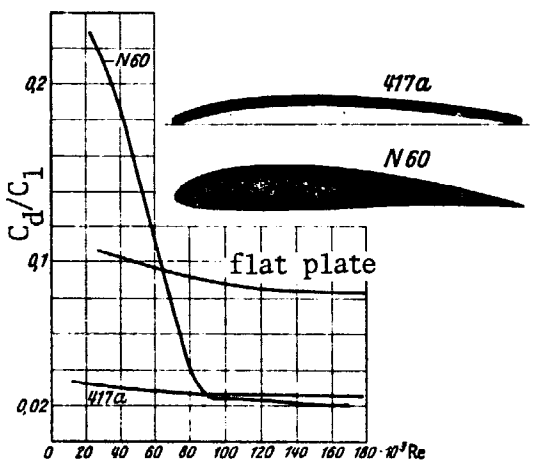

fig. 4.1. Effect of Re-number on $(C_d/C_l)_{min}$-ratio for three different airfoils.

In general the critical Re-number for airfoils with a sharp nose will be 10^4 while for the more conventional airfoils like NACA the critical Re-number is about 10^5; some of the very modern airfoil types have a critical Re-number of about 10^6.
Fig. 4.2 shows the inverse value of the C_d/C_l-ratio of various airfoils as f (Re).

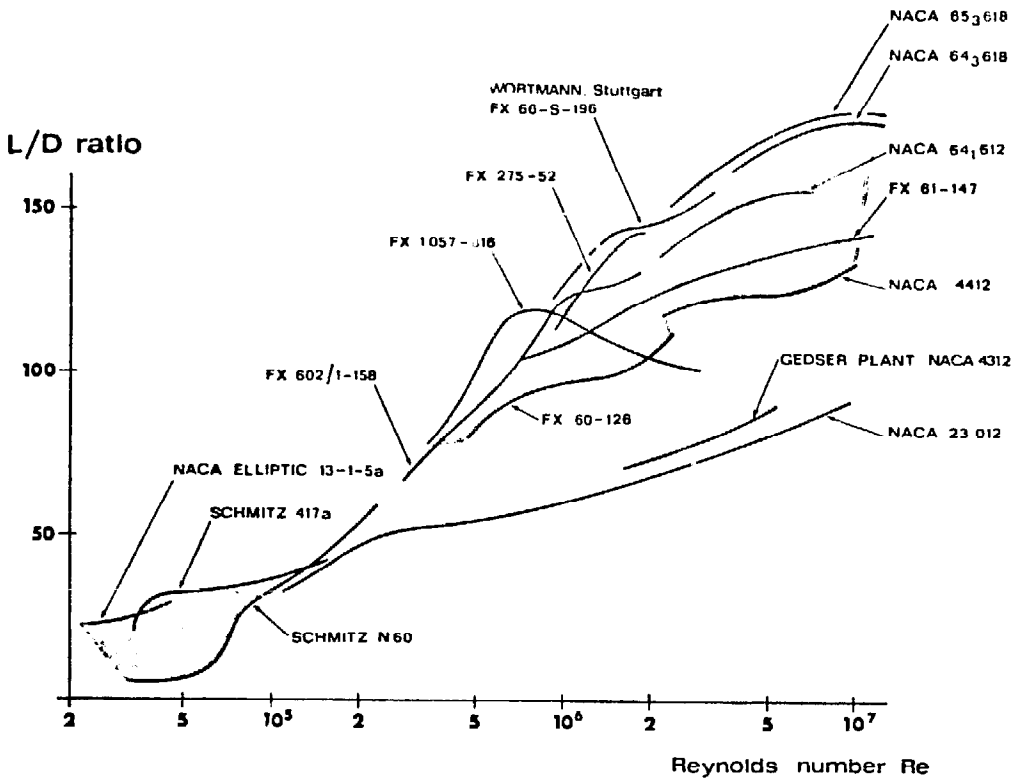

fig. 4.2. Inverse value of minimum C_d/C_l-ratio as function of the Re-number for several airfoils. From lit(5).

4.1 Calculation of the Re-number for the blades of a windmill rotor.

For the condition that the rotor runs at $\lambda=\lambda_{optimum}$ the Re-number of the flow around the airfoil can be determined with fig.4.3 in the following way:

if B = number of blades

r = radius = distance to rotor center of blade element under consideration

λ_r = speed ratio of blade element under consideration

C_l = design lift coefficient of blade element under consideration

V_∞ = undisturbed windspeed

the Re-number is:

$$Re = \frac{V_\infty * r}{B * C_l} * Re_N$$

Re_N may be read from the graph presented in fig. 4.3 (valid for air: kinematic viscosity $\nu = 15 * 10^{-6}$ $[m^2 s^{-1}]$)

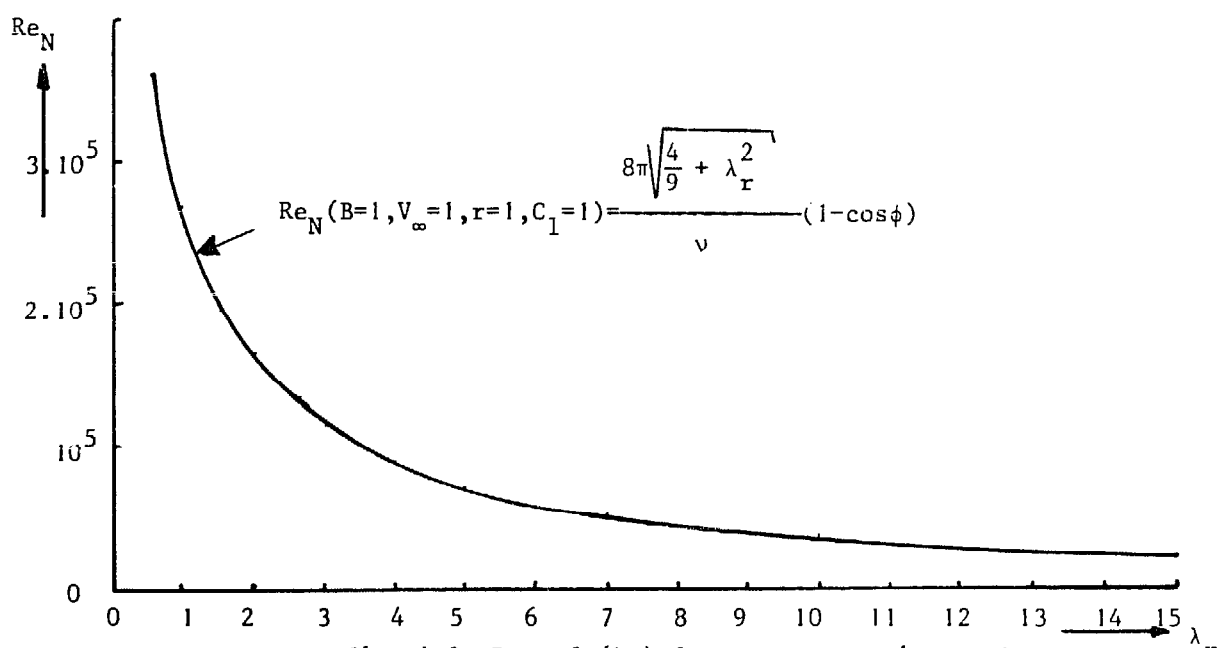

fig. 4.3. Re = f (λ_r) for rotors running at $\lambda_{optimum}$.

example: we will check the Re-number for the rotor as designed in chapter 3.

airfoil: 7% arched steel plate
radius : R = 1.7 [m]
tip-speed ratio: $\lambda_o = 4$
C_l*-design = 0.9*
Number of blades B = 4.

1) at the tip $\lambda_r = \lambda_o = 4.$
$r = R = 1.7$ [m]

fig 4.3 - $Re_N \approx 9*10^4$

$$Re_{r=R} = Re_N * \frac{R * V_\infty}{B * C_l} = \frac{9 * 10^4 * 1.7}{4 * 0.9} V_\infty$$

$$Re_{r=R} = 4.25 * 10^4 V_\infty$$

2) at $r = 0.5\ R$ $\lambda_r = 2;\ r = 0.85$

$$Re_{r=0.5R} = \frac{17 * 10^4 * 0.85}{4 * 0.9} V_\infty = 4 * 10^4 V_\infty$$

3) at $r = 0.2\ R$ $\lambda_r = 0.8$ $r = 0.34$

$$Re_{r=0.2R} = \frac{28 * 10^4 * 0.34}{4 * 0.9} = 2.6 * 10^4 V_\infty$$

Conclusion: for the whole blade, the Re-number is, even for very low windspeeds, higher than the critical Re-number for steel plates (= 10^4*).*
Thus the assumed minimum C_d/C_l*-ratio is correct.*

APPENDIX I.

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NACA 4412

(Stations and ordinates given in per cent of airfoil chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0	0	0	0
1.25	2.44	1.25	− 1.43
2.5	3.39	2.5	− 1.95
5.0	4.73	5.0	− 2.49
7.5	5.76	7.5	− 2.74
10	6.59	10	− 2.86
15	7.89	15	− 2.88
20	8.80	20	− 2.74
25	9.41	25	− 2.50
30	9.76	30	− 2.26
40	9.80	40	1.80
50	9.19	50	− 1.40
60	8.14	60	− 1.00
70	6.69	70	− 0.65
80	4.89	80	− 0.39
90	2.71	90	− 0.22
95	1.47	95	− 0.16
100	(0.13)	100	(− 0.13)
100	.....	100	0

L.E. radius: 1.58
Slope of radius through L.E.: 0.20

NACA 4415

(Stations and ordinates given in per cent of airfoil chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0	.....	0	0
1.25	3.07	1.25	− 1.79
2.5	4.17	2.5	− 2.48
5.0	5.74	5.0	− 3.27
7.5	6.91	7.5	− 3.71
10	7.84	10	− 3.98
15	9.27	15	− 4.13
20	10.25	20	− 4.15
25	10.92	25	− 3.98
30	11.25	30	− 3.75
40	11.25	40	− 3.25
50	10.53	50	− 2.72
60	9.30	60	− 2.14
70	7.63	70	− 1.55
80	5.55	80	− 1.03
90	3.08	90	− 0.57
95	1.67	95	− 0.36
100	(0.16)	100	(− 0.16)
100	.....	100	0

L.E. radius: 2.48
Slope of radius through L.E.: 0.20

NACA 4418

(Stations and ordinates given in per cent of airfoil chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0	.....	0	0
1.25	3.76	1.25	− 2.11
2.5	5.00	2.5	− 2.99
5.0	6.75	5.0	− 4.06
7.5	8.06	7.5	− 4.67
10	9.11	10	− 5.06
15	10.66	15	− 5.49
20	11.72	20	− 5.56
25	12.40	25	− 5.49
30	12.76	30	− 5.26
40	12.70	40	− 4.70
50	11.85	50	− 4.02
60	10.44	60	− 3.24
70	8.55	70	− 2.45
80	6.22	80	− 1.67
90	3.46	90	− 0.93
95	1.89	95	− 0.55
100	(0.19)	100	(− 0.19)
100	.....	100	0

L.E. radius: 3.56
Slope of radius through L.E.: 0.20

NACA 4421

(Stations and ordinates given in per cent of airfoil chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0	.....	0	0
1.25	4.45	1.25	− 2.42
2.5	5.54	2.5	− 3.48
5.0	7.82	5.0	− 4.78
7.5	9.24	7.5	− 5.62
10	10.35	10	− 6.15
15	12.04	15	− 6.75
20	13.17	20	− 6.98
25	13.88	25	− 6.92
30	14.27	30	− 6.76
40	14.16	40	− 6.16
50	13.18	50	− 5.34
60	11.60	60	− 4.40
70	9.50	70	− 3.35
80	6.91	80	− 2.31
90	3.85	90	− 1.27
95	2.11	95	− 0.74
100	(0.22)	100	(− 0.22)
100	.....	100	0

L.E. radius: 4.85
Slope of radius through L.E.: 0.20

NACA 4424

(Stations and ordinates given in per cent of airfoil chord)

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0	0	0	0
0.530	3.964	1.970	− 3.472
1.536	5.624	3.464	− 4.656
3.775	7.942	6.225	− 6.066
6.153	9.651	8.847	− 6.931
8.611	11.012	11.389	− 7.512
13.674	13.045	16.326	− 8.169
18.858	14.416	21.142	− 8.416
24.111	15.287	25.889	− 8.411
29.401	15.738	30.599	− 8.238
40.000	15.606	40.000	− 7.606
50.235	14.474	49.765	− 6.698
60.405	12.674	59.595	− 5.562
70.487	10.312	69.513	− 4.312
80.464	7.447	79.536	− 3.003
90.320	4.099	89.680	− 1.655
95.196	2.240	94.804	− 0.964
100.000	.....	100.000	0

L.E. radius: 6.33
Slope of radius through L.E.: 0.20

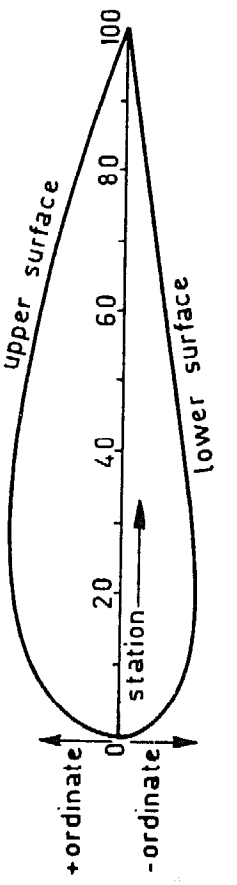

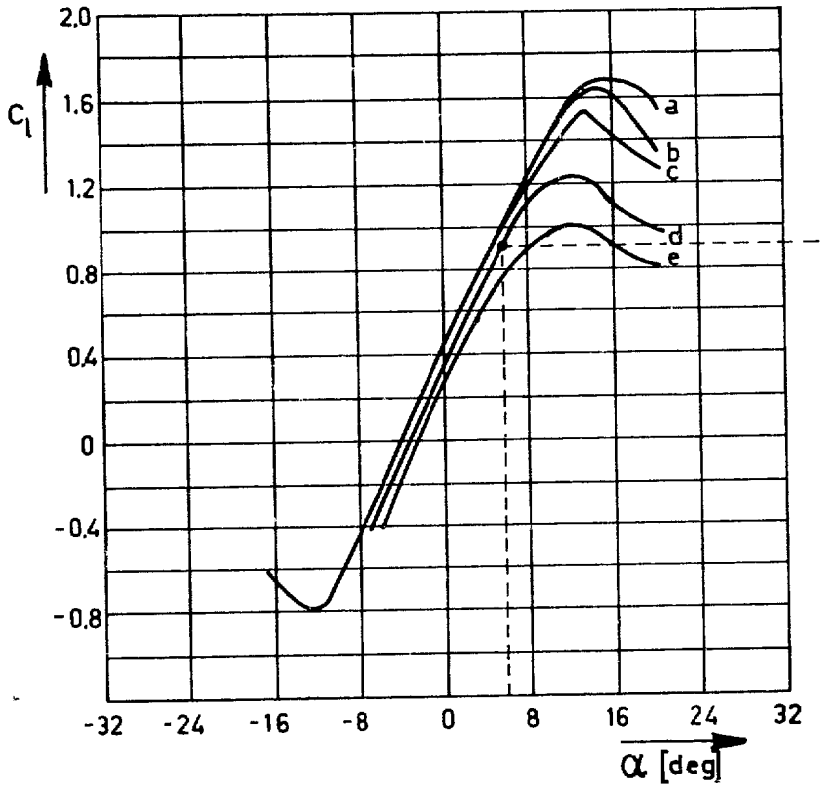

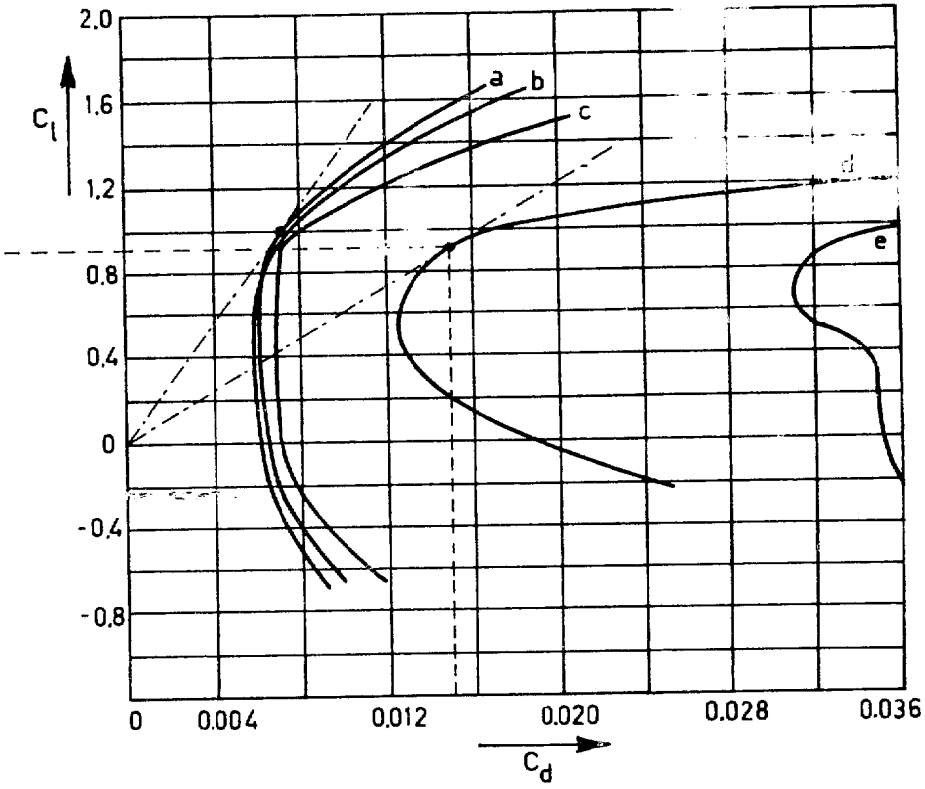

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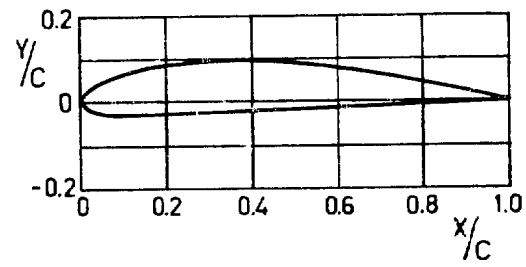

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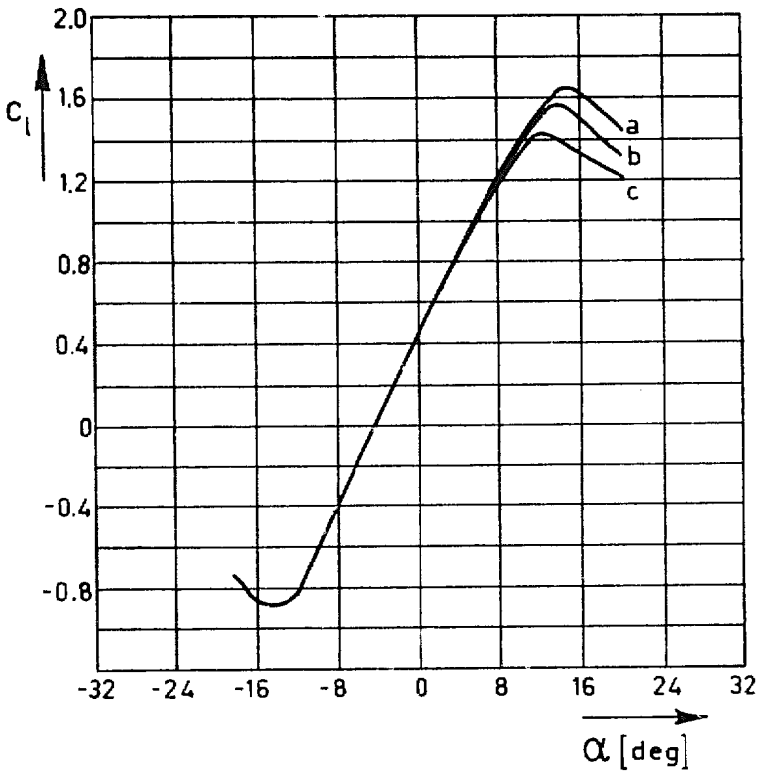

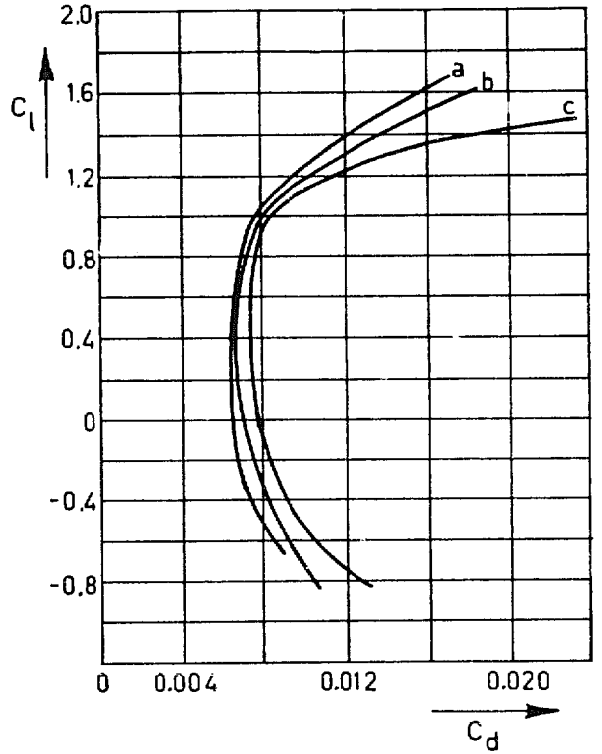

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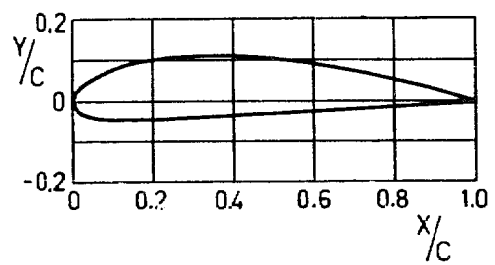

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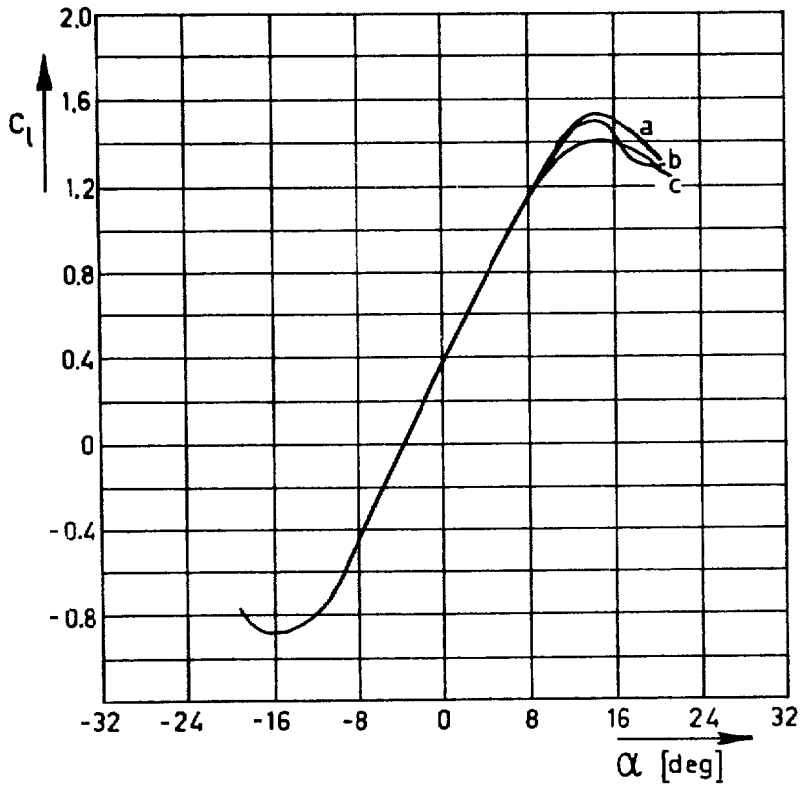

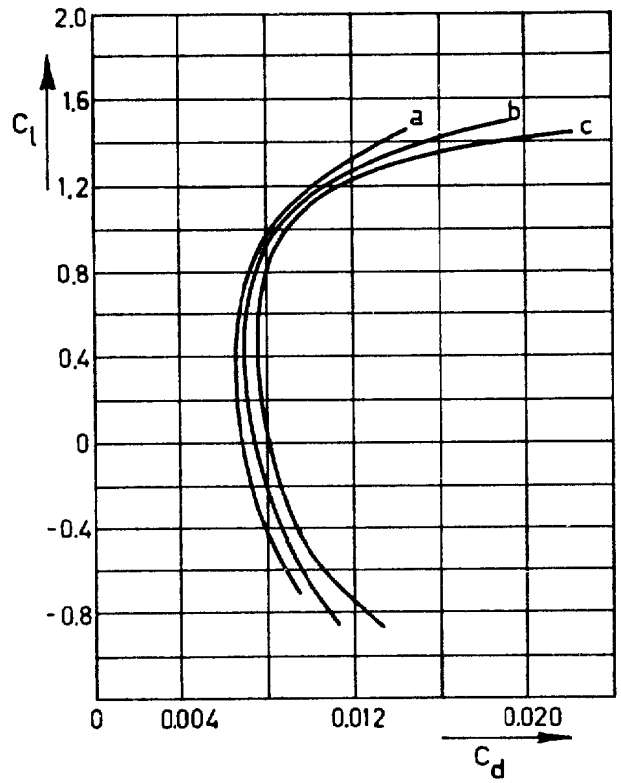

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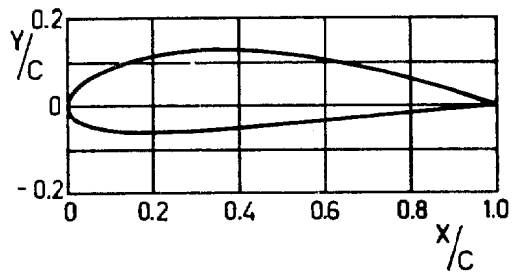

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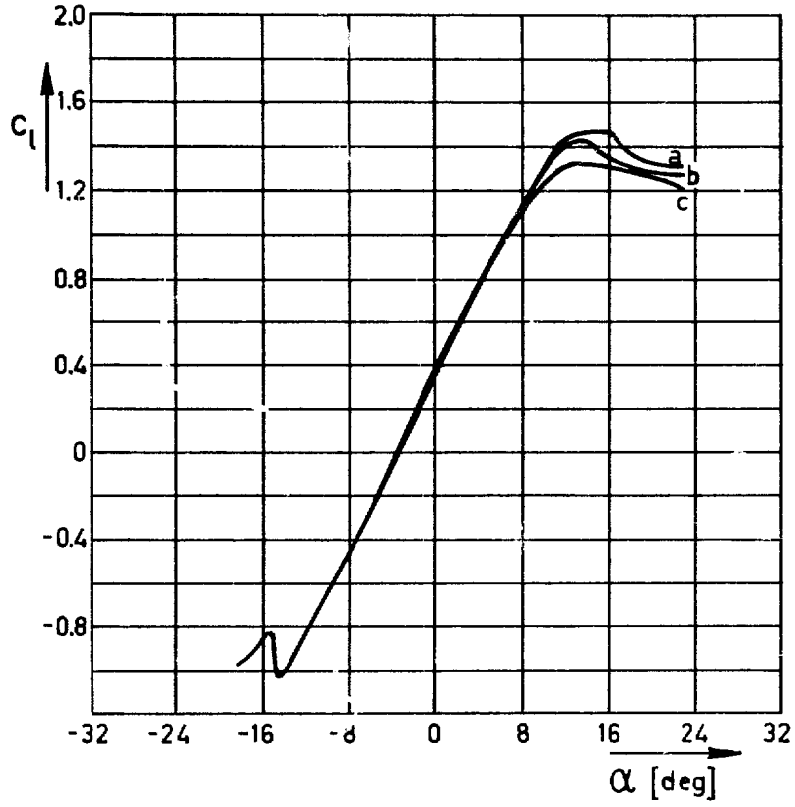

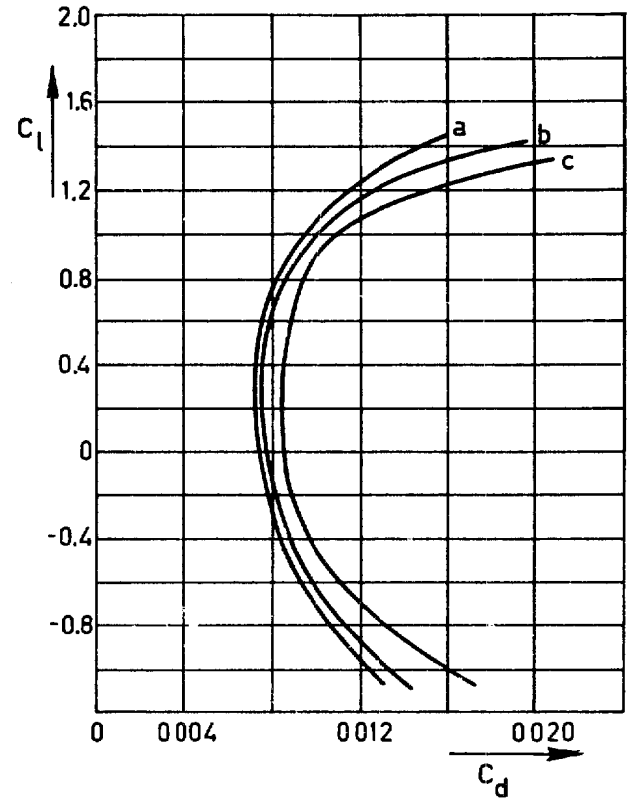

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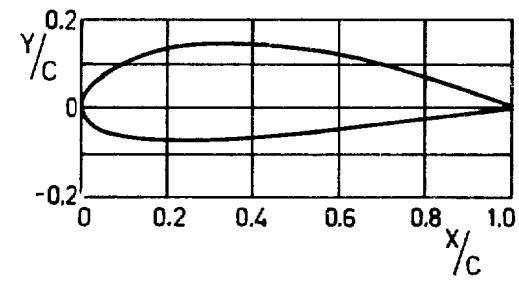

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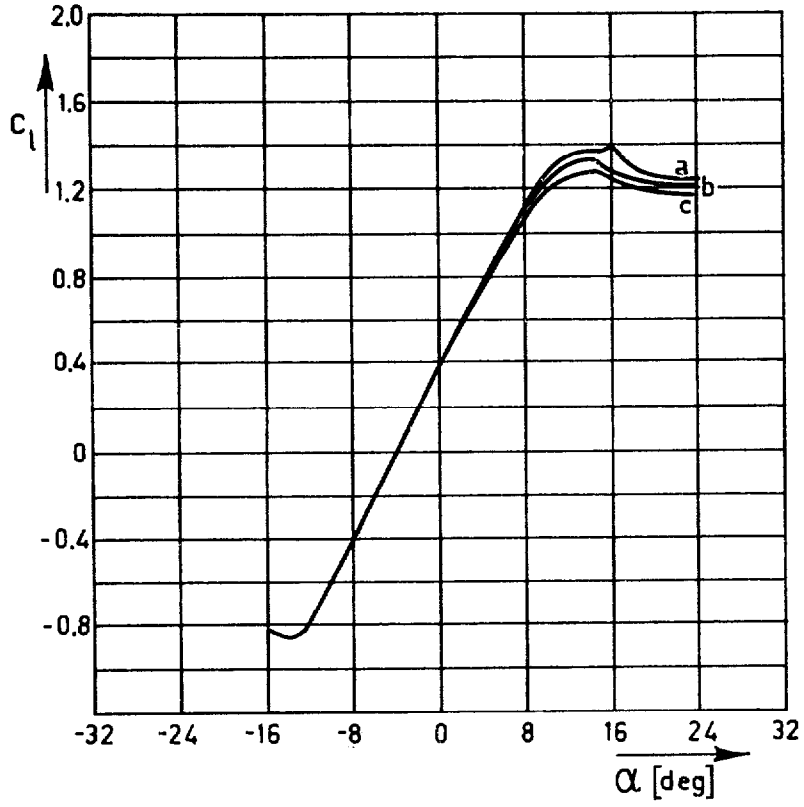

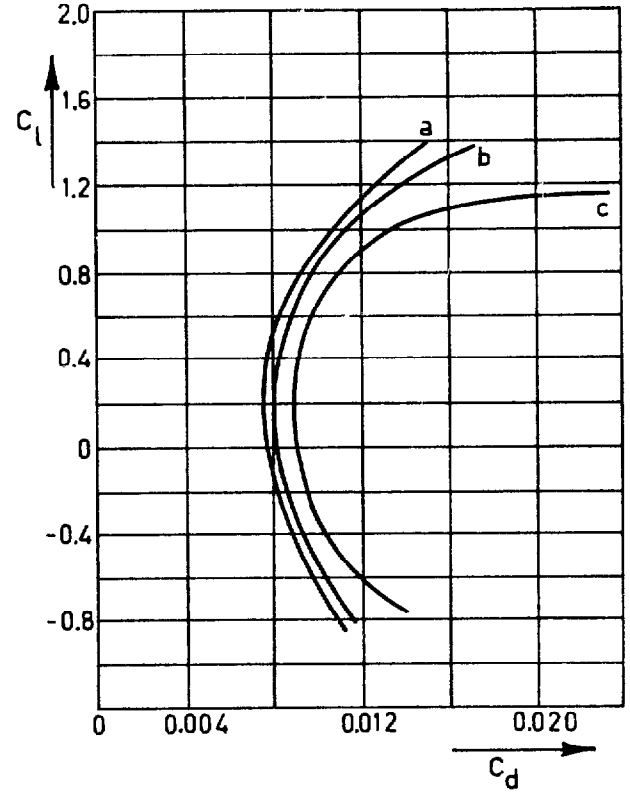

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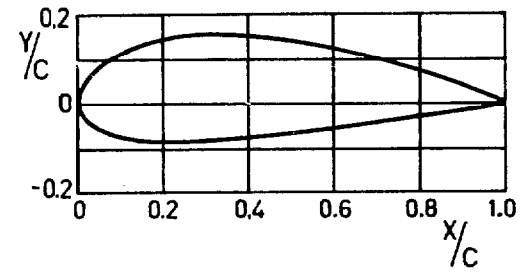

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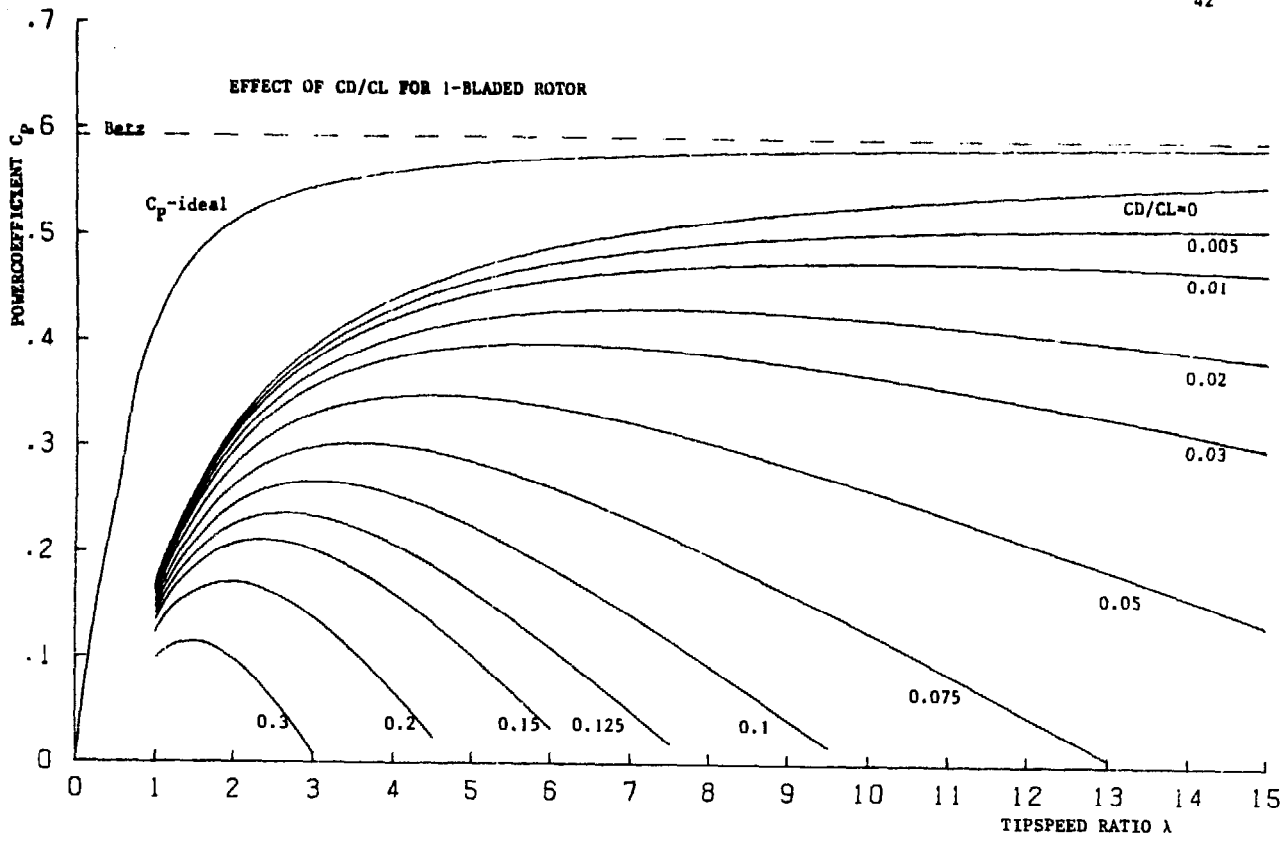
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Betz
C_P-ideal
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0.15
0.2
0.3
TIPSPEED RATIO λ

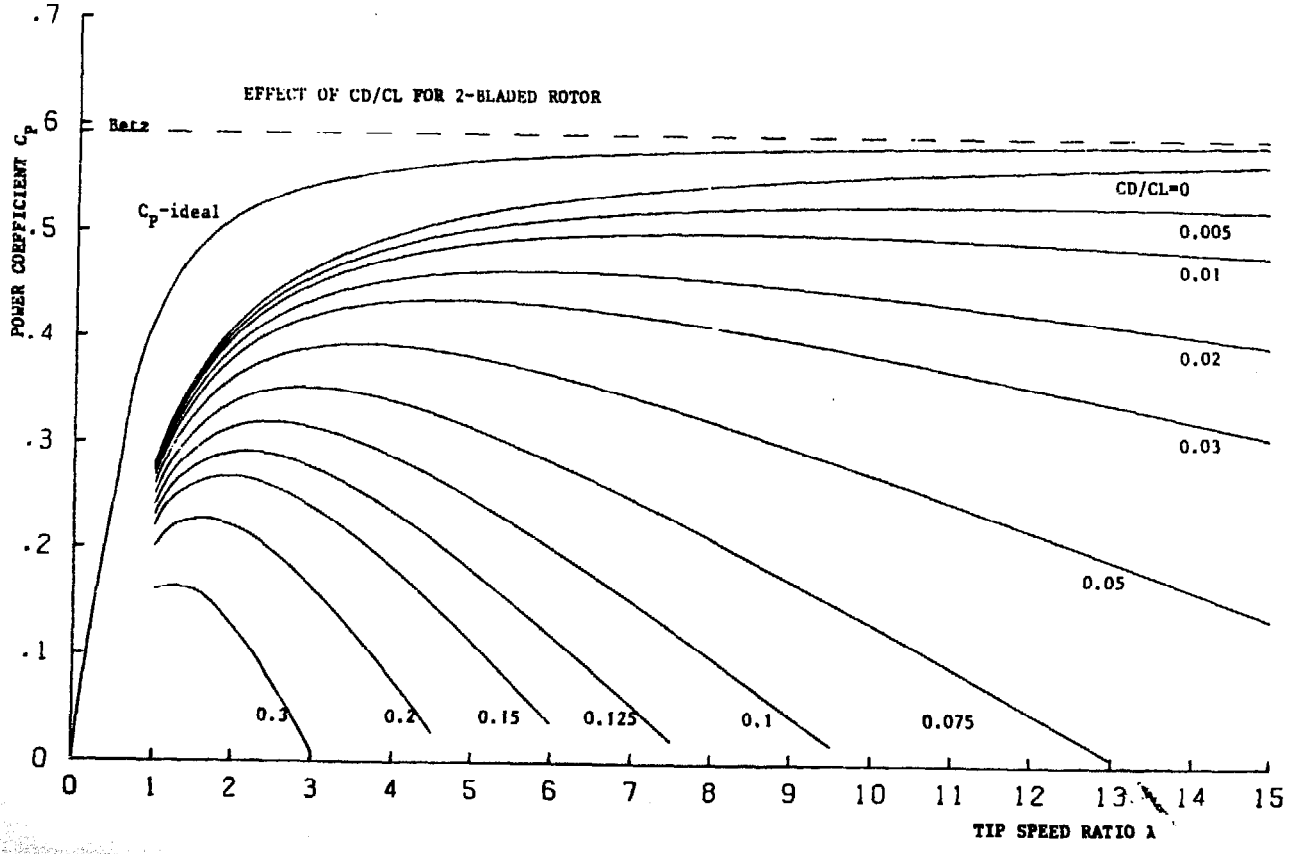
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TIP SPEED RATIO λ

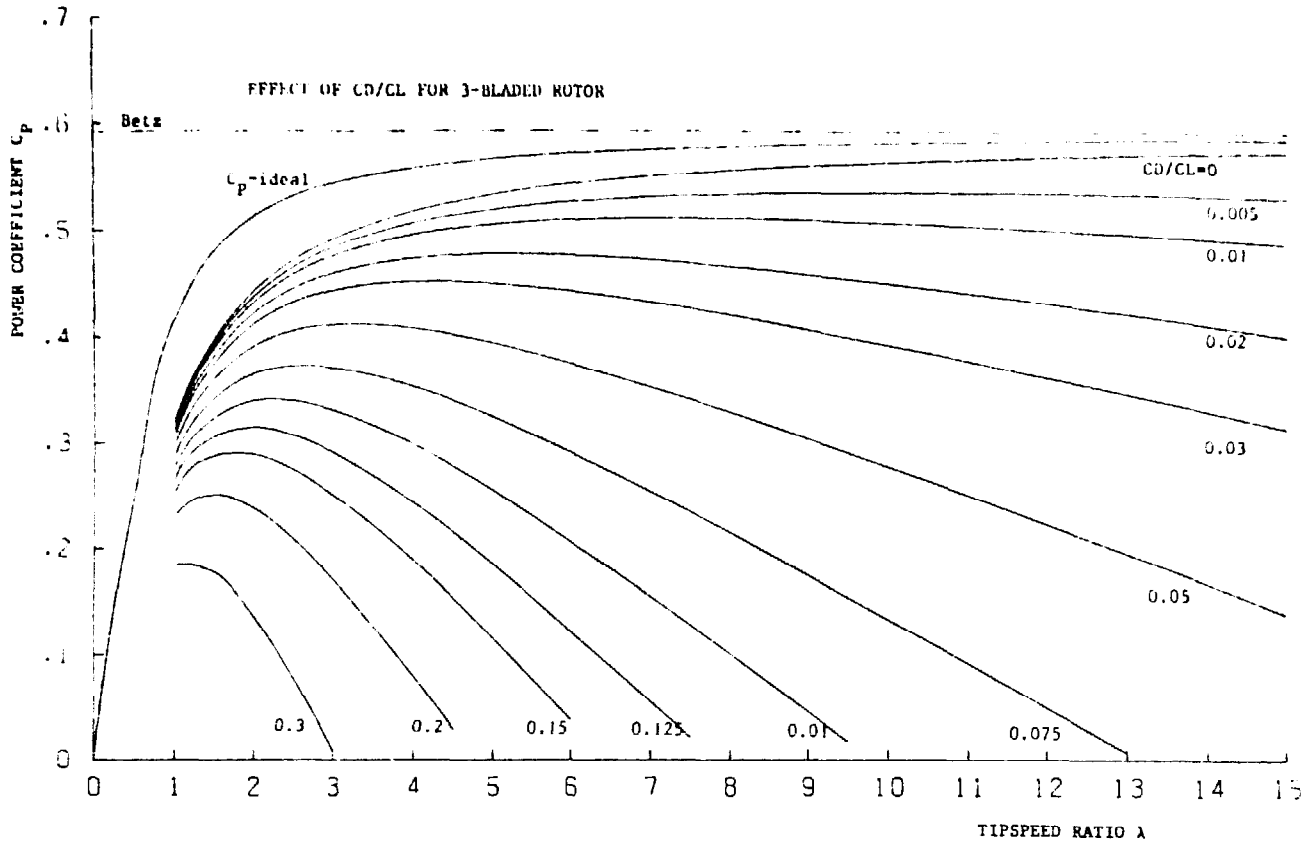
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POWER COEFFICIENT C_p
TIPSPEED RATIO λ

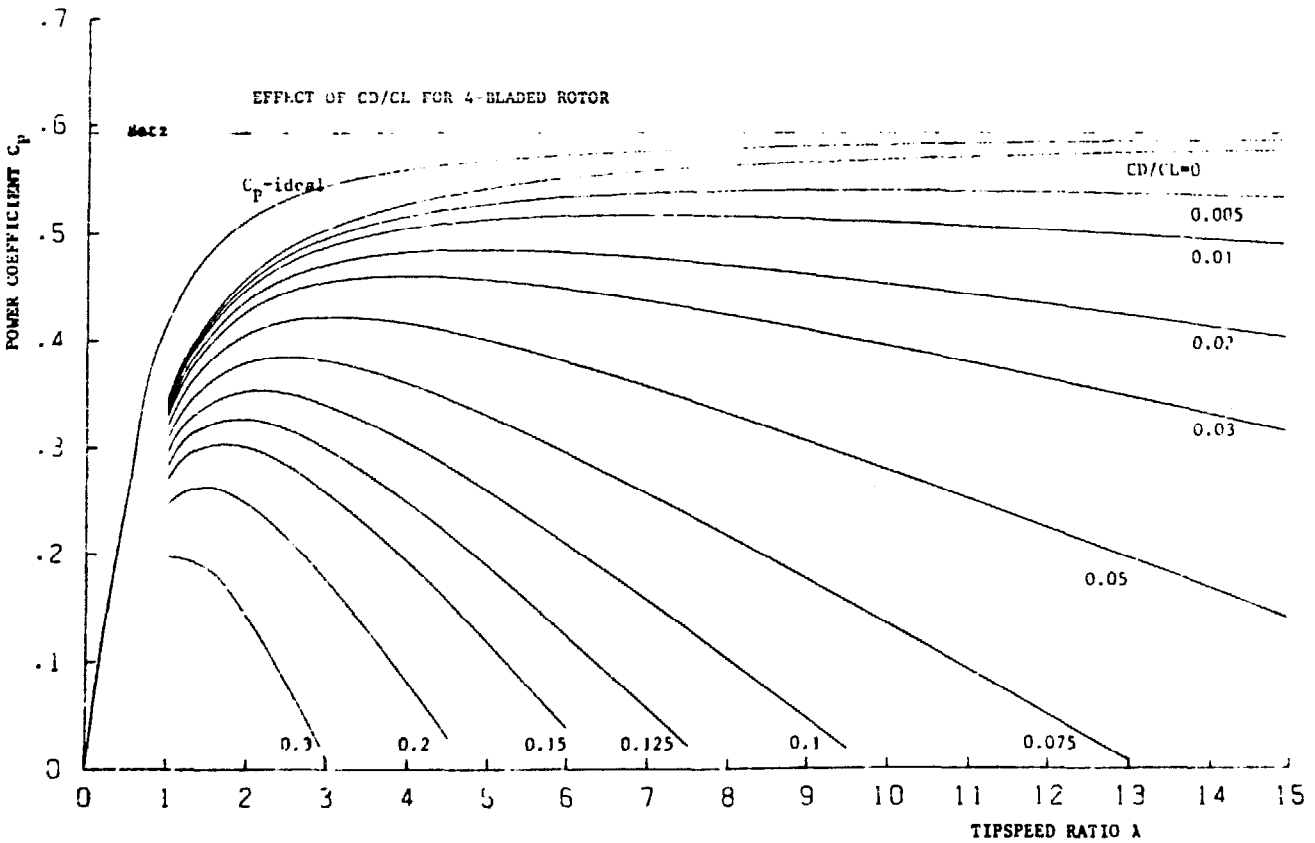
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POWER COEFFICIENT C_p
TIPSPEED RATIO λ

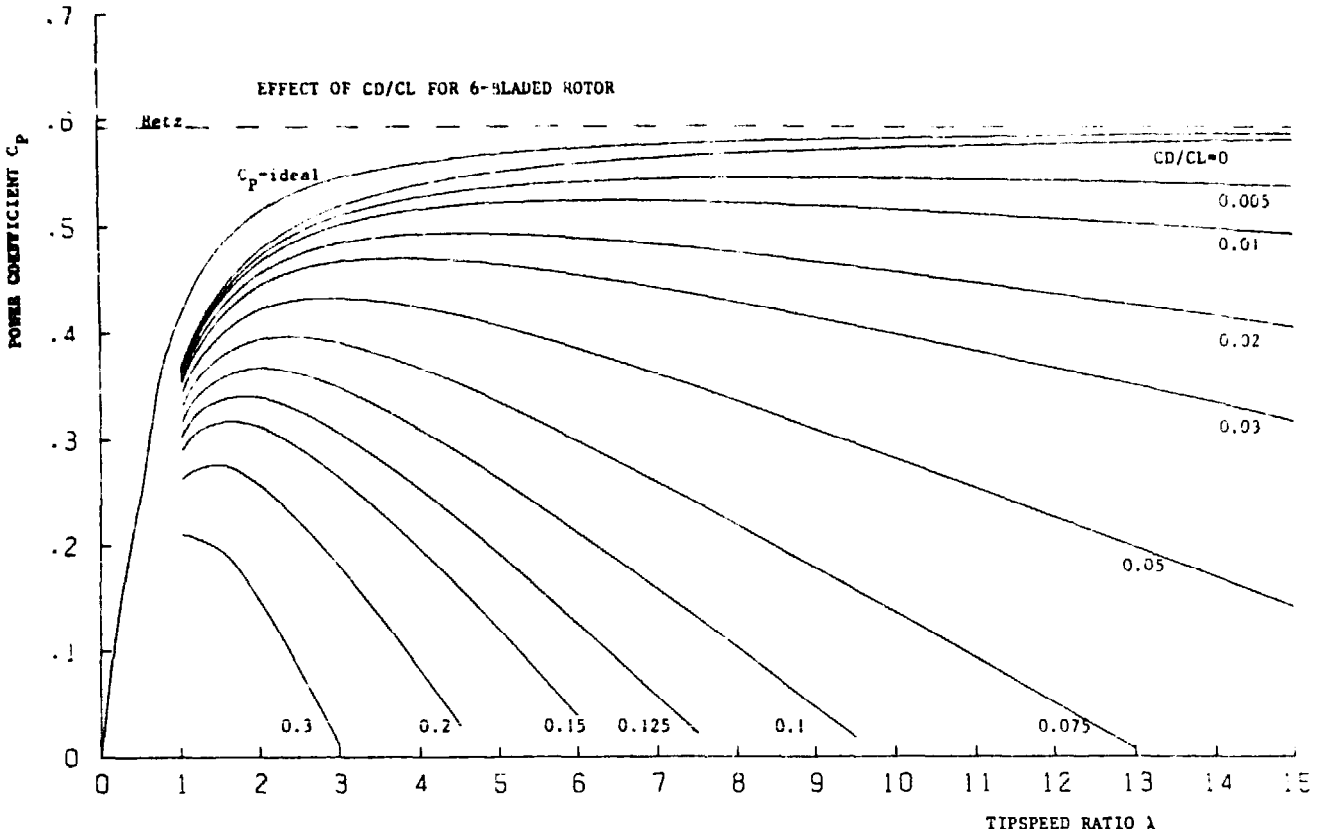
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TIPSPEED RATIO λ

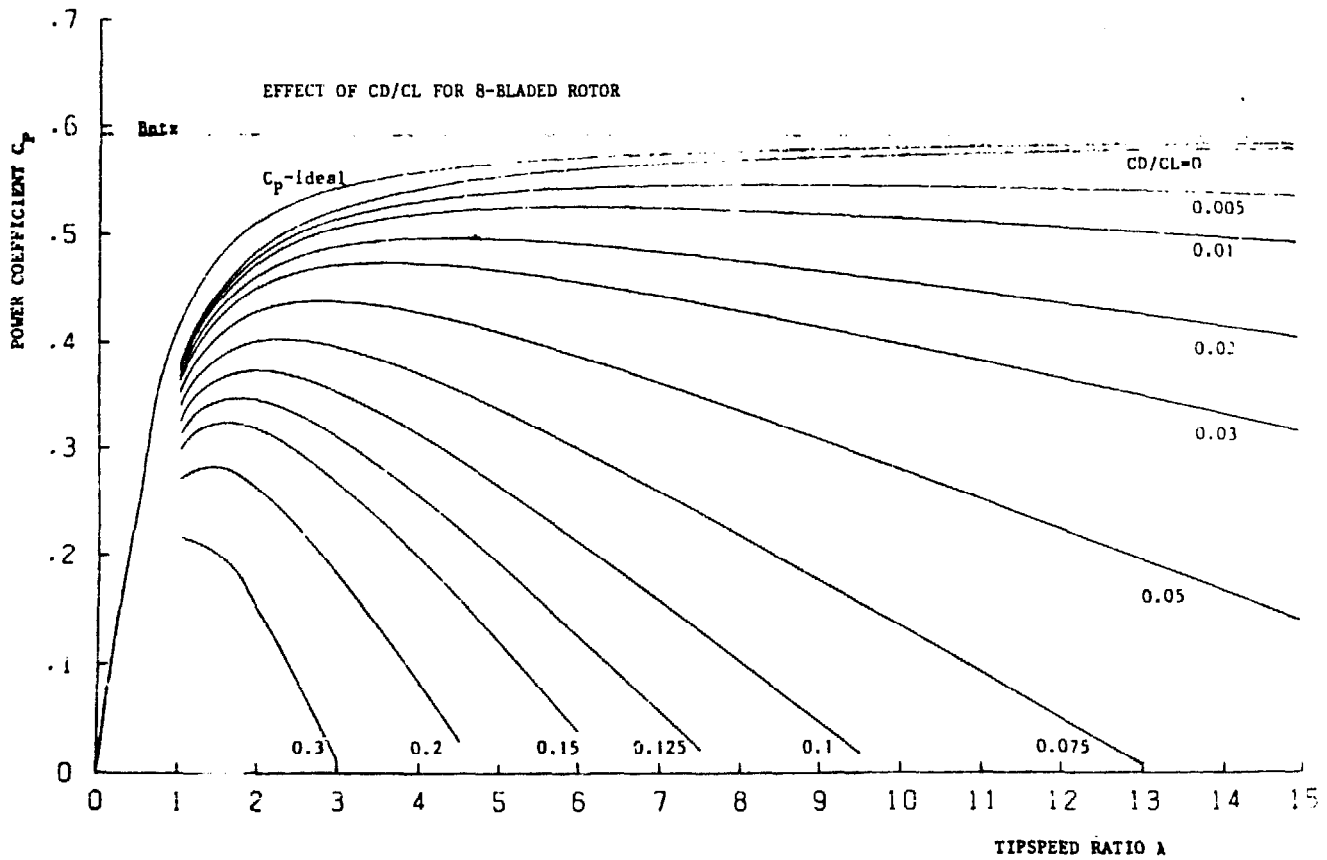
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POWER COEFFICIENT C_p
TIPSPEED RATIO λ

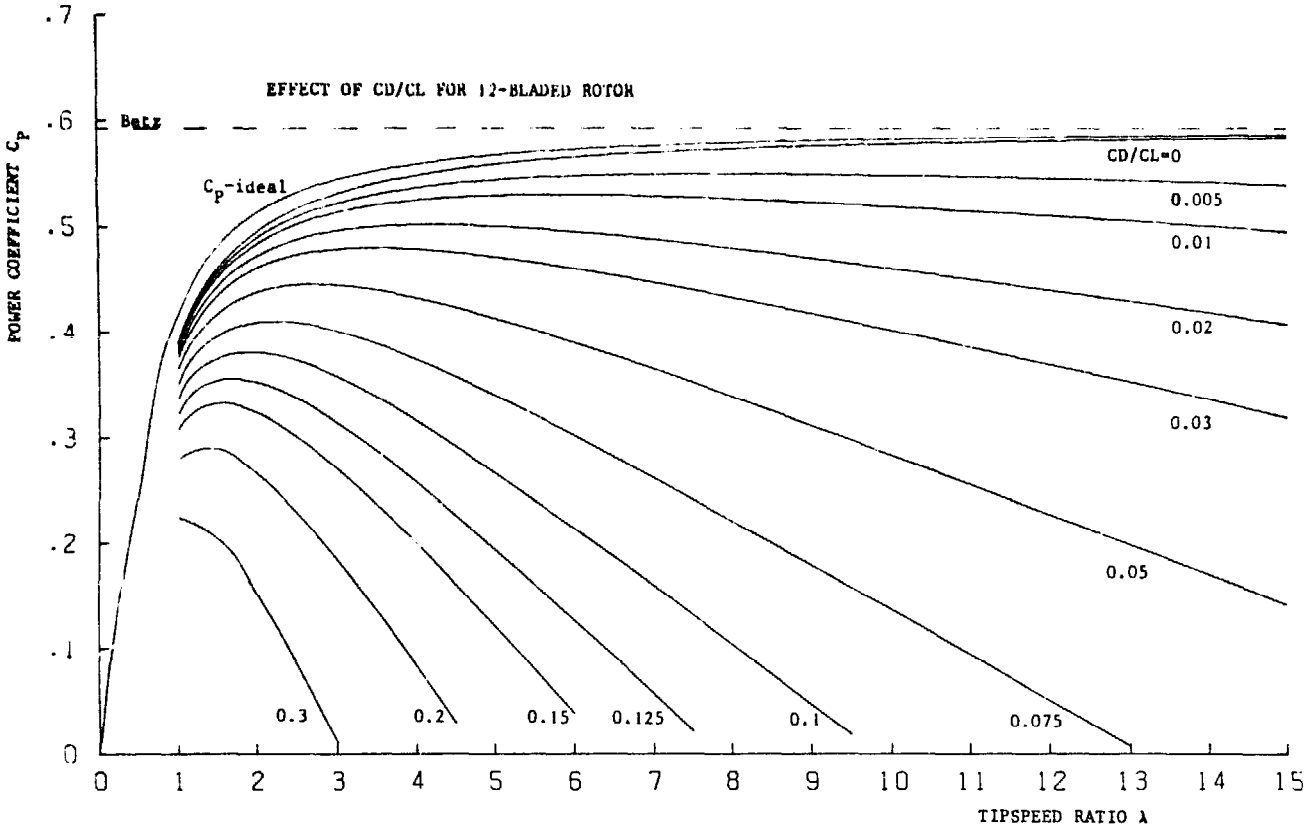
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C_P-ideal
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0.03
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0.075
0.1
0.125
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0.2
0.3
TIPSPEED RATIO λ

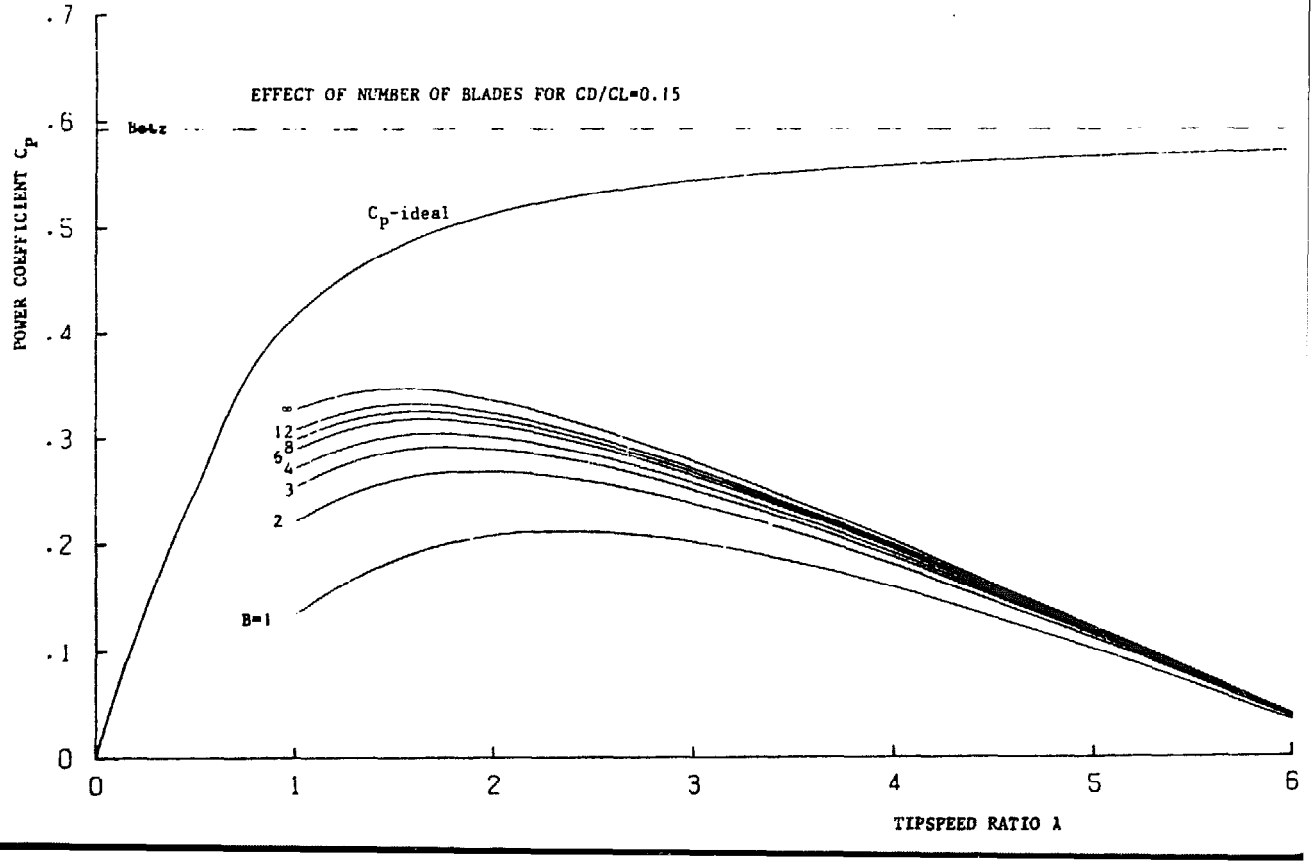
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TIPSPEED RATIO λ

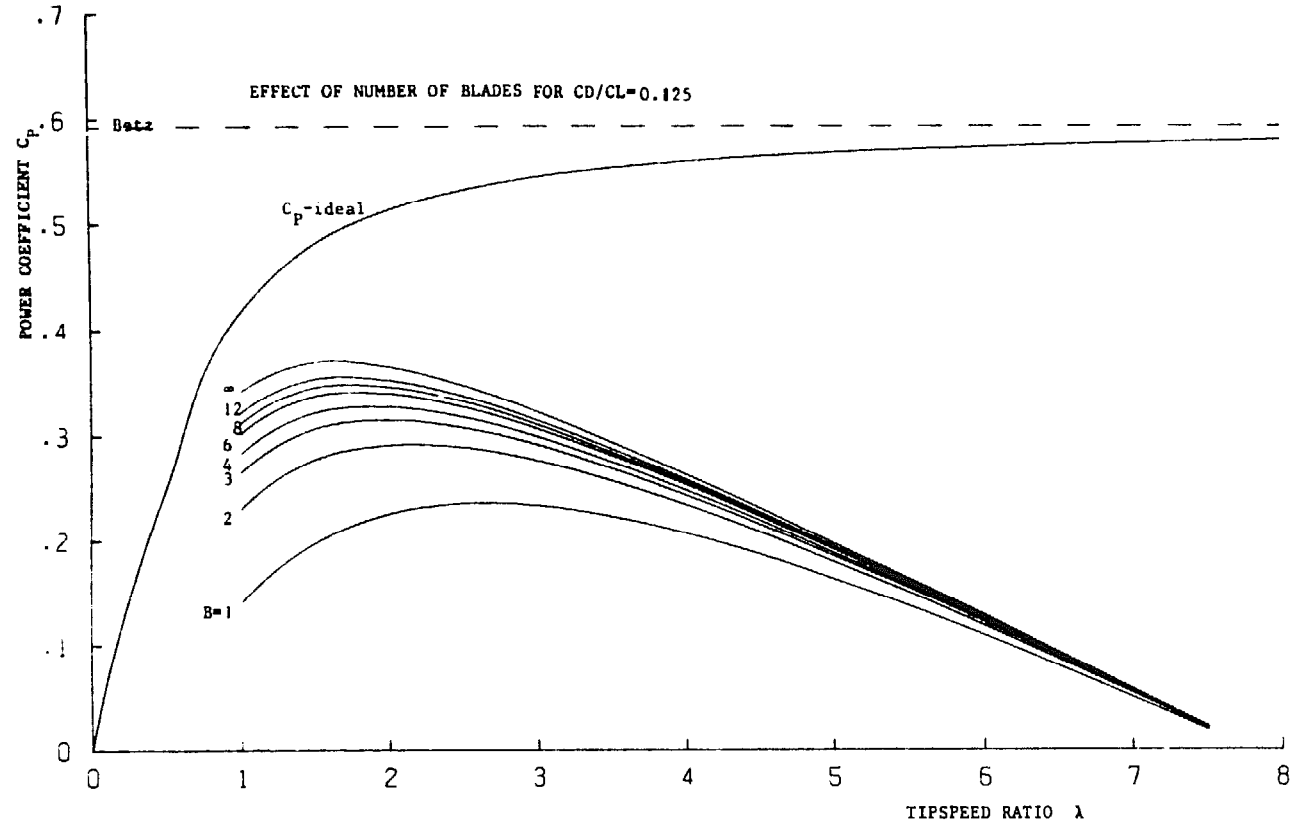
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4
3
2
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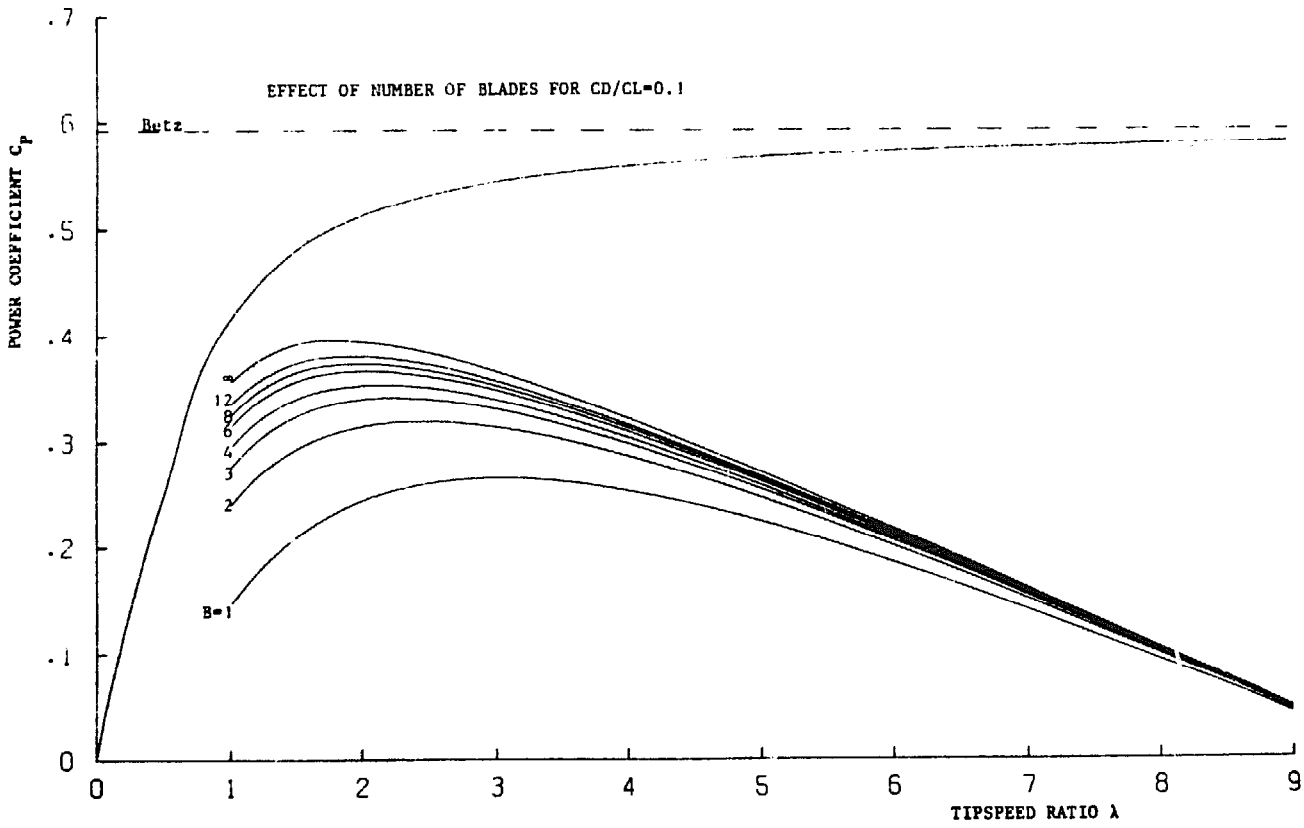
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POWER COEFFICIENT C_P
TIPSPEED RATIO λ
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B=1
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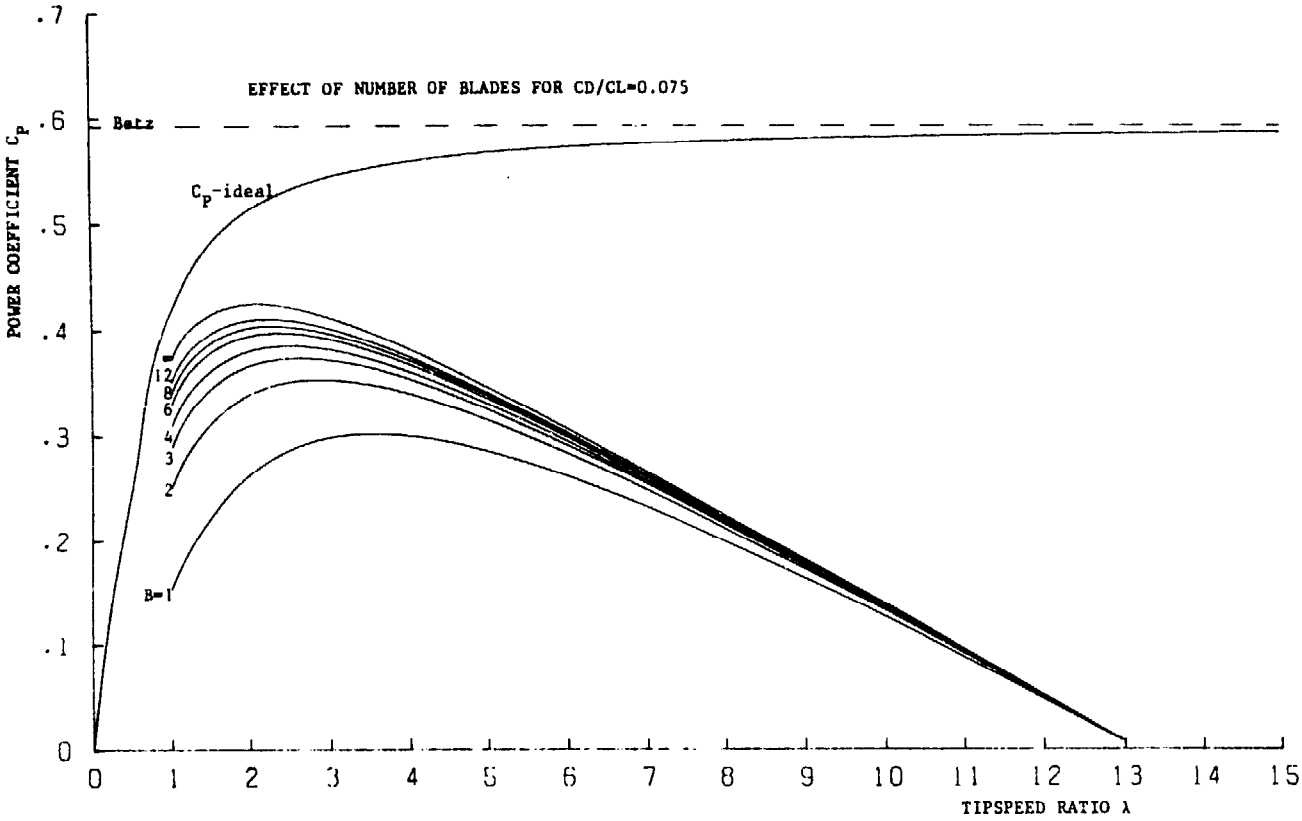
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TIPSPEED RATIO λ
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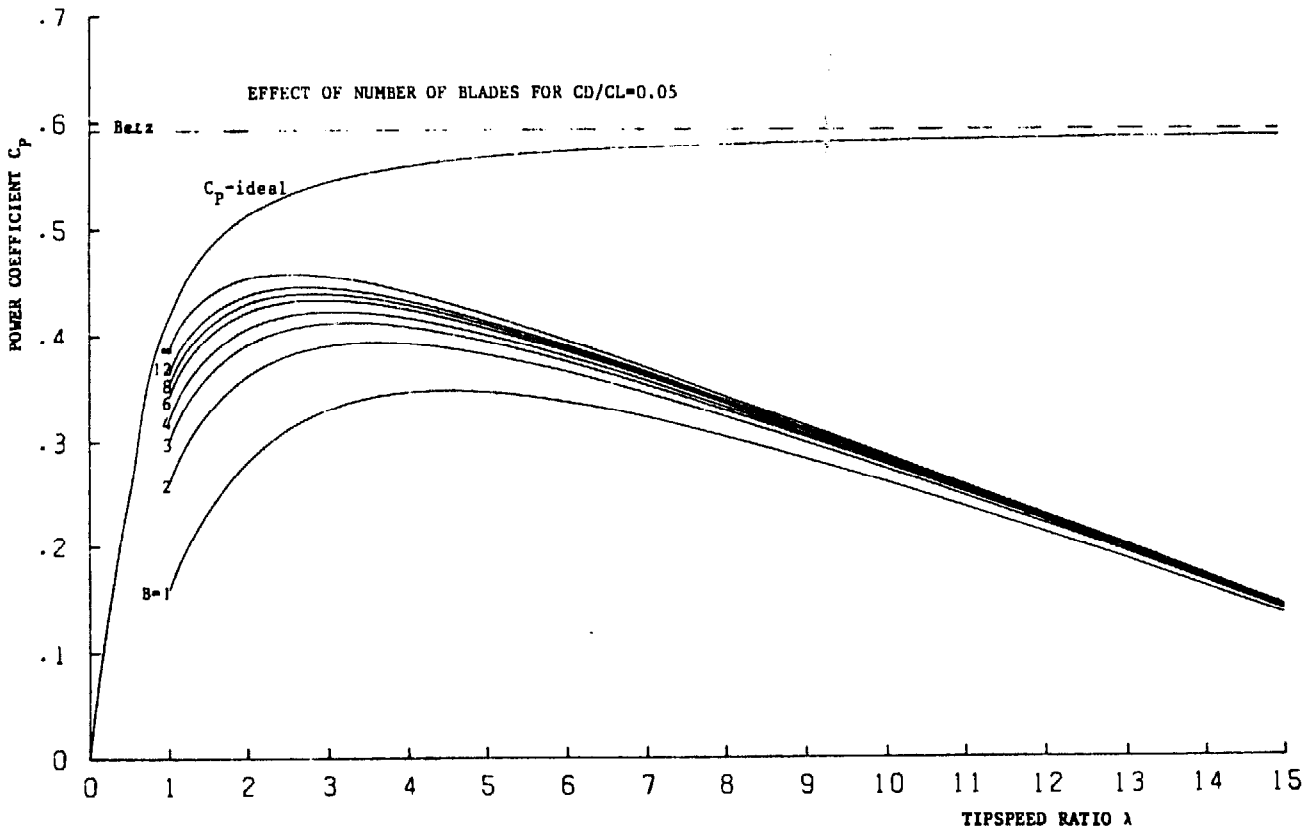
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∞
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TIPSPEED RATIO λ
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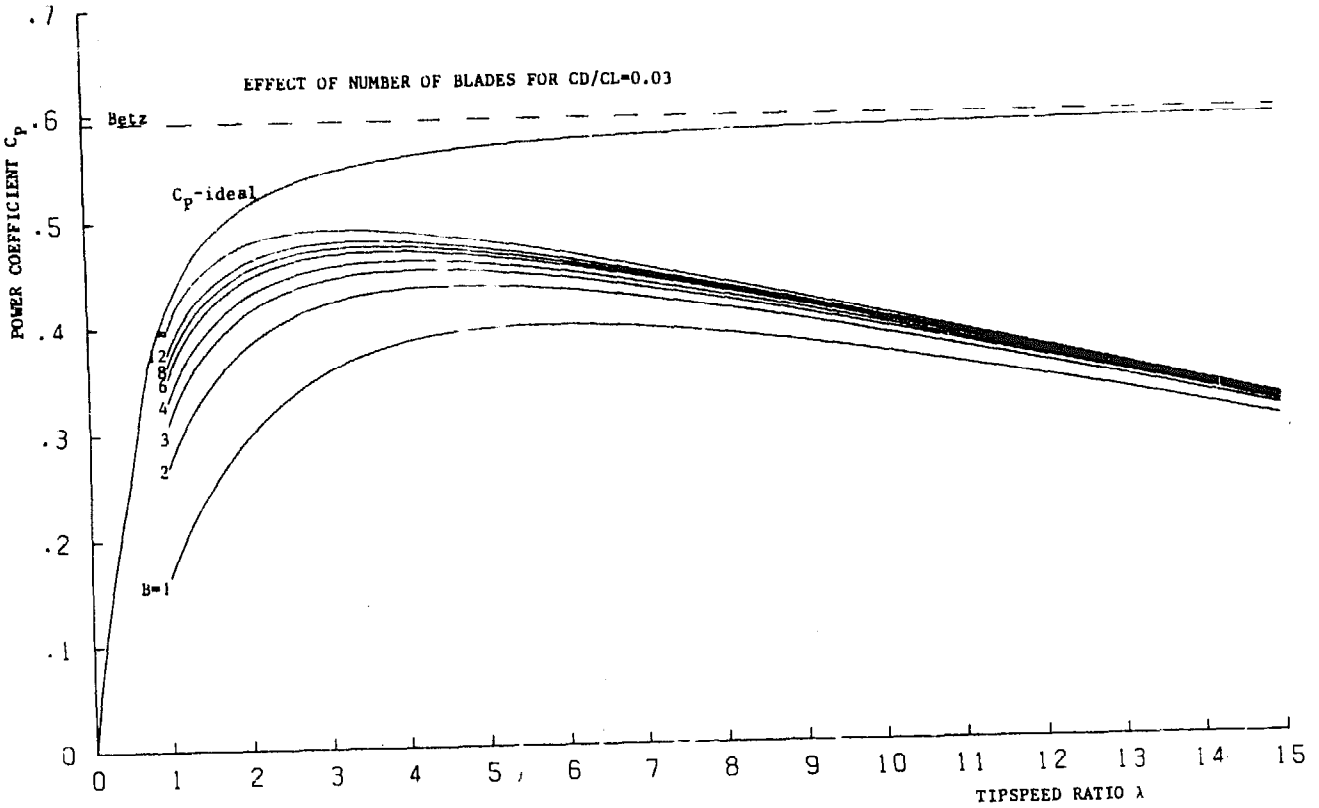
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4
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POWER COEFFICIENT Cp
TIPSPEED RATIO λ
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.3
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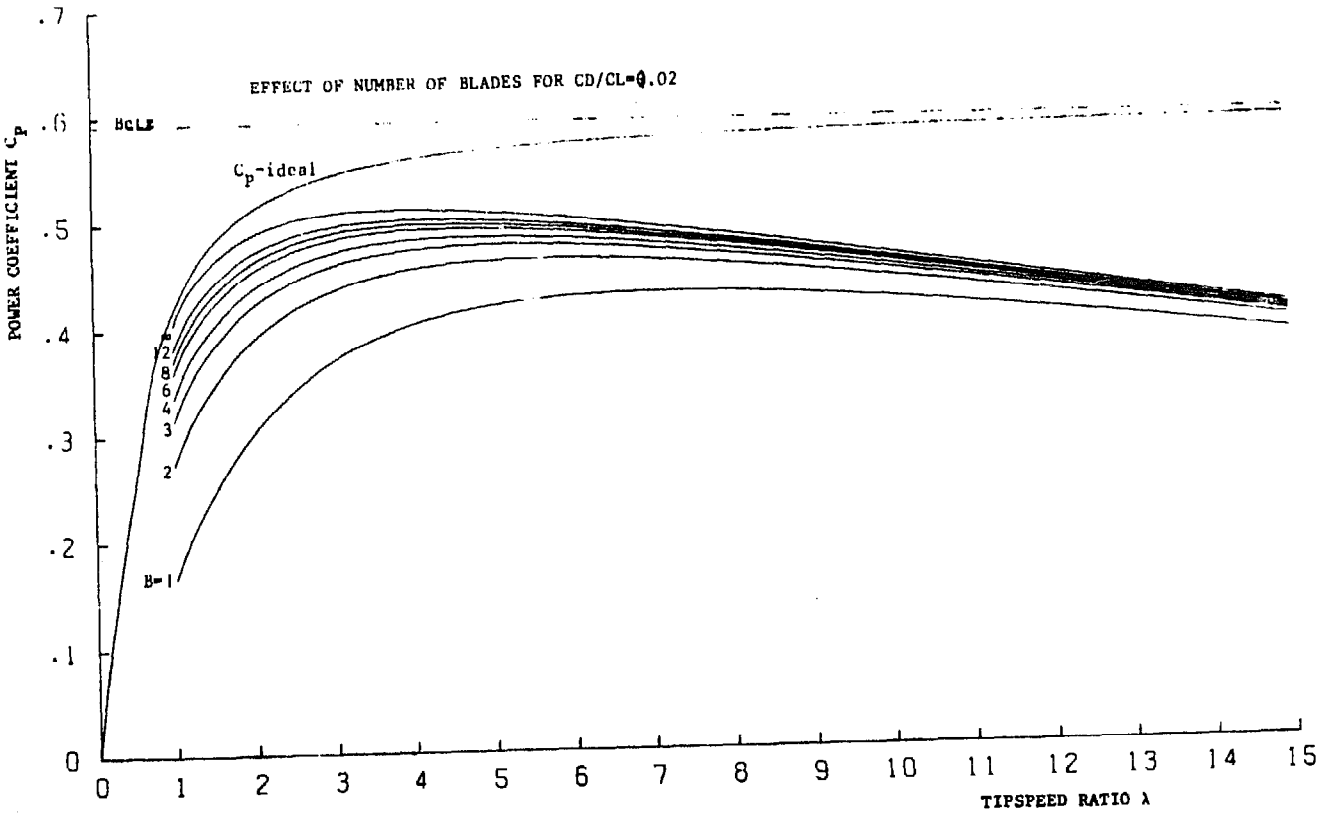
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TIPSPEED RATIO λ
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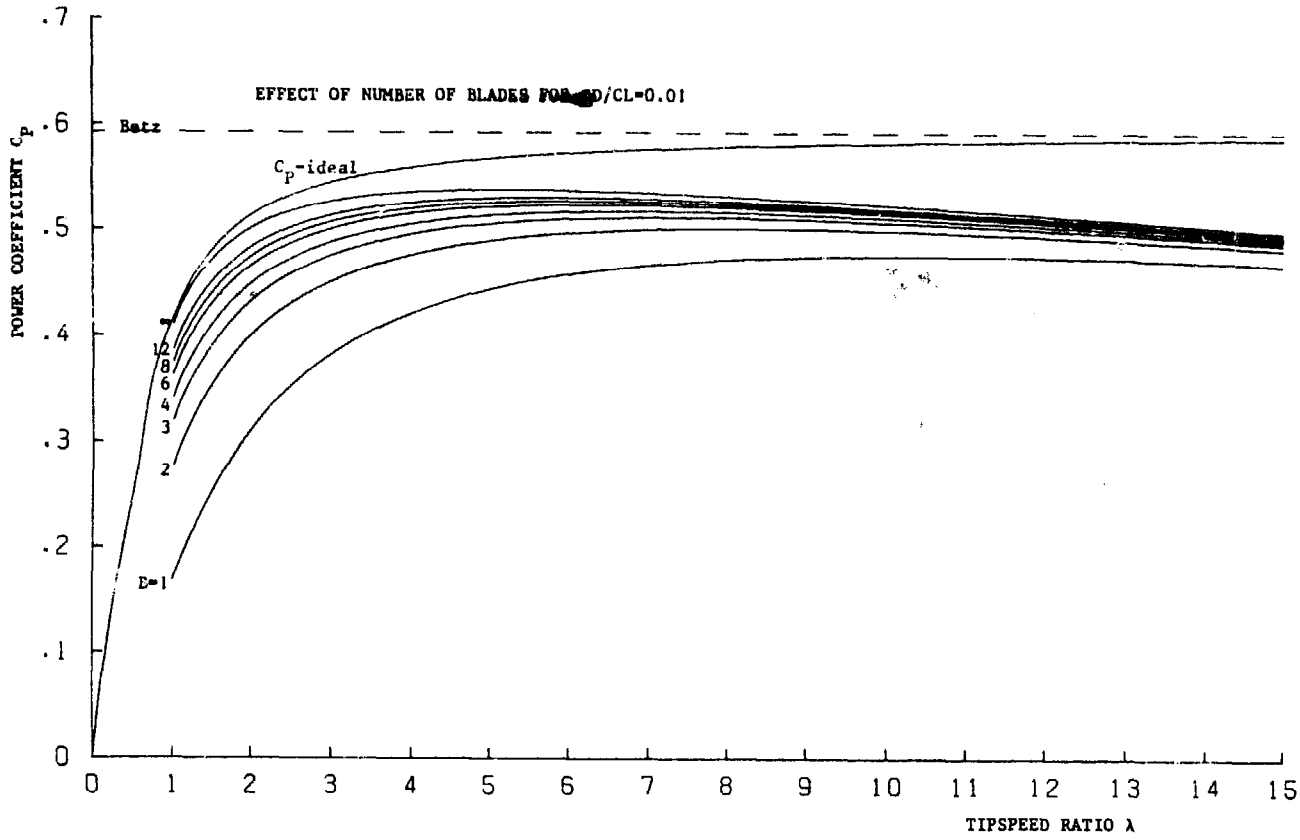
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POWER COEFFICIENT C_P
TIPSPEED RATIO λ

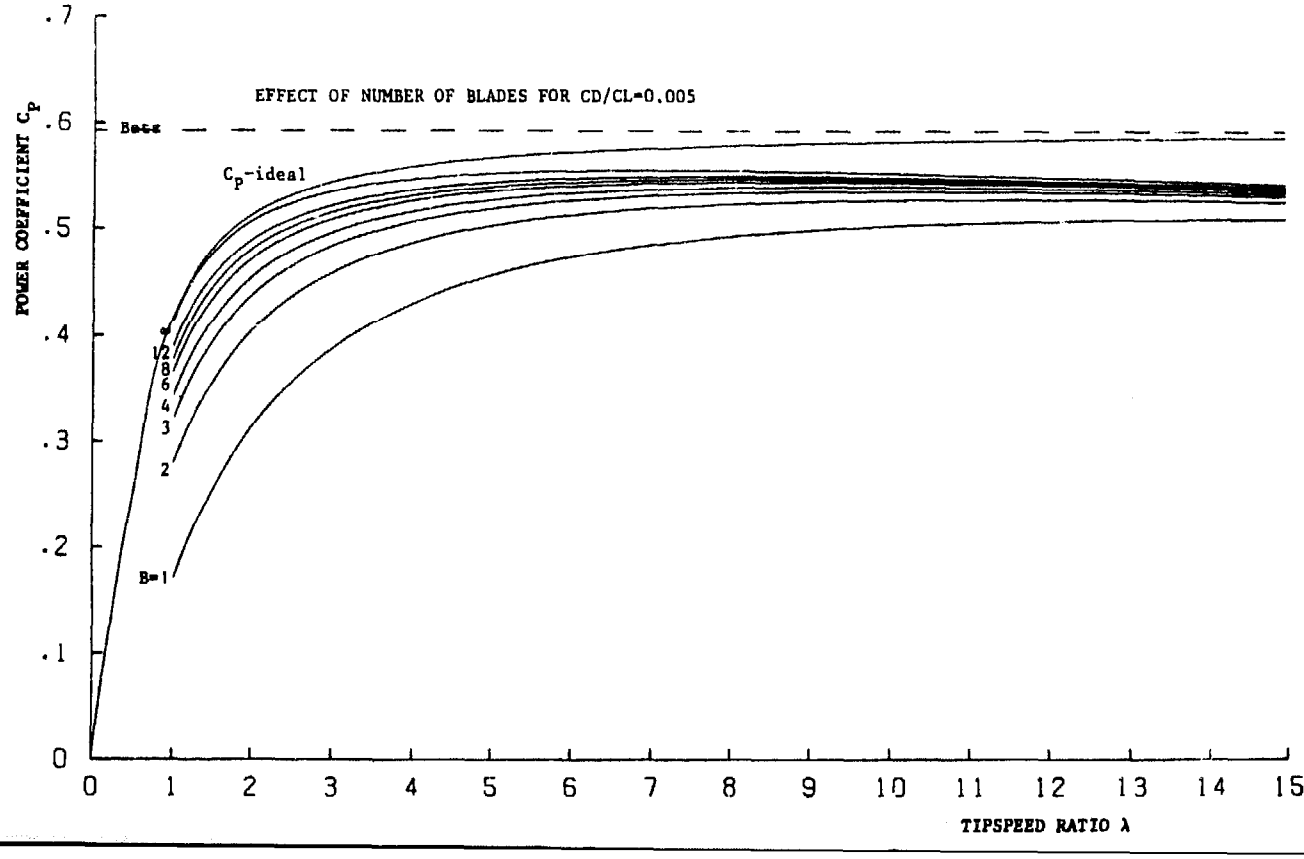
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2
B=1
POWER COEFFICIENT C_P
TIPSPEED RATIO λ

Note on the theoretical assumptions on which the design method is based.

The design procedure presented in this publication is based on general momentum theory and blade element theory as can be found in for example lit (2-3-6-10). This simple design procedure ignores tip effects as mentioned in paragraph 2.4.3. In the collection of maximum power coefficients given in AppendixIII, however, the tip losses are included.

As described in paragraph 2.4.0 - 2.4.3, the attainable power coefficient can be described with the following effects:

1) Betz coefficient $C_{P_{Betz}} = \frac{16}{27}$
2) wake rotation
3) blade drag
4) tiplosses due to finite number of blades

Effects 1) and 2) can be described with the following approximation (error ≤ 0.5 percent for $\lambda \geq 1$):

$$C_{P_{ideal}} = \frac{16}{27} = e^{-0.35\lambda^{-1.29}}$$

with $\lambda=\lambda_{optimum}$.

Effect 3) can be described by reducing $C_{P_{ideal}}$ with an approximation for power loss due to drag (max error = 2 percent for $\lambda=1$; error ≤ 0.1 percent for $\lambda > 2.5$)

$$C_{P_{drag}} = \frac{16}{27} \frac{C_d}{C_l} \lambda$$

with $\lambda=\lambda_{optimum}$ and $\frac{C_d}{C_l}$ is $\frac{C_d}{C_l}$ at $C_{l_{design}}$

$C_{P_{max}}$ including drag is:

$$C_{P_{max}} = C_{P_{ideal}} - C_{P_{drag}} = \frac{16}{27}\left(e^{-0.35\lambda^{-1.29}} - \frac{C_d}{C_1}\lambda\right)$$

Effect 4) can be included by multiplying $C_{P_{max}}$ with factor η_B:

$$\eta_B = \left(1 - \frac{1.386}{B} \sin\frac{\phi}{2}\right)^2$$

B = number of blades; ϕ is found in Appendix V with $\lambda_r = \lambda_{tip}$

Thus $C_{P_{max}}$ is:

$$C_{P_{max}} = \eta_B \left(C_{P_{ideal}} - C_{P_{drag}}\right)$$

$$C_{P_{max}} = \left(1 - \frac{1.386}{B} \sin\frac{\phi}{2}\right)^2 \frac{16}{27}\left(e^{-0.35\lambda^{-1.29}} - \frac{C_d}{C_1}\lambda\right).$$

APPENDIX V

$$\lambda_r = \frac{\sin\varphi(2\cos\phi-1)}{(1-\cos\phi)(2\cos\phi+1)}$$

λ_r	ϕ	$(1-\cos\phi)$
10.00	3.807	0,00220
9.75	3.904	0,00232
9.50	4.006	0,00244
9.25	4.113	0,00258
9.00	4.227	0,00272
8.75	4.347	0,00288
8.50	4.473	0,00305
8.25	4.607	0,00323
8.00	4.750	0,00343
7.75	4.902	0,00368
7.50	5.063	0,00390
7.25	5.236	0,00417
7.00	5.420	0,00447
6.75	5.618	0,00480
6.50	5.831	0,00517
6.25	6.060	0,00559
6.00	6.308	0,00605
5.75	6.577	0,00658
5.50	6.870	0,00718
5.25	7.190	0,00786
5.00	7.540	0,00865
4.75	7.926	0,00955
4.50	8.353	0,01061
4.25	8.827	0,01184
4.00	9.357	0,01336
3.75	9.954	0,01505
3.50	10.630	0,01716
3.25	11.402	0,01774
3.00	12.290	0,02292
2.75	13.322	0,02691
2.50	14.534	0,03200
2.25	15.975	0,03862
2.00	17.710	0,04739
1.75	19.830	0,05930
1.50	22.460	0,07585
1.25	25.773	0,09948
1.00	30.000	0,13397
0.75	35.420	0,18507
0.50	42.290	0,26025
0.25	50.642	0,36584
0.00	60.000	0,5

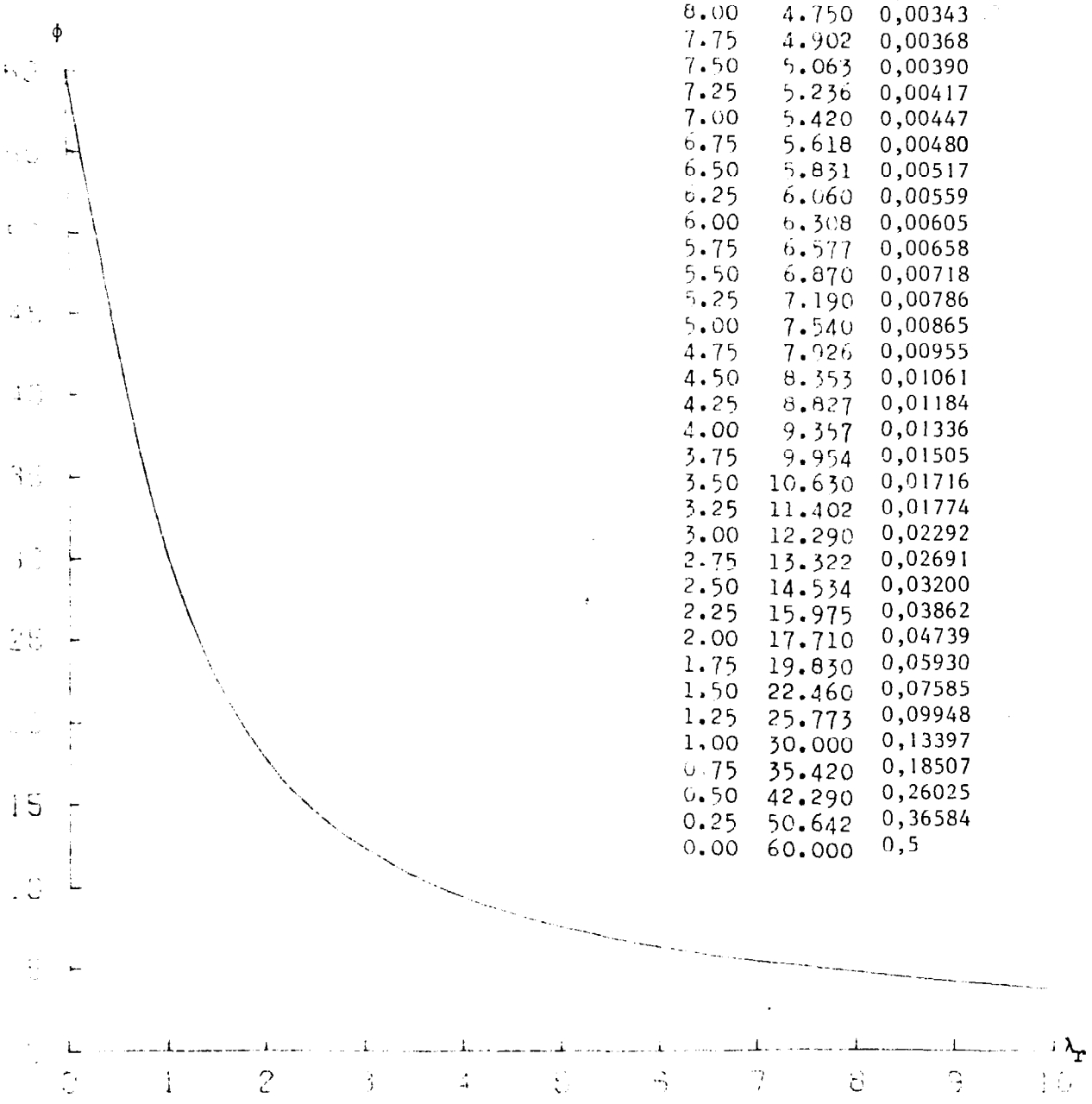

Angle ϕ between relative velocity and plane of the rotor versus the speed ratio of an element at radius r for a windmill with a flow equal to the flow of an ideal windmill.

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DISCOVER MORE

Everywhere you look you can see the fruits of scientific effort and technological innovation — from mobile phones to medicines, from the clothes we wear to the foods we eat. In the natural world, science has shed much light on the value and function of plants and animals and the interplay of various life forms and habitats. Scientists have opened our eyes to a startling, exciting and occasionally bewildering universe.

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A Brief History of Science
What is Science all About?
The Art of Science

Create Your Own Rough Science Adventures

Targeted to educators, museum professionals, parents and the general public, these science and technology activities are similar to thise faced by the scientists in the series. They are designed to encourage collaborative learning and experimentation in an informal setting after viewing each episode.

Download the Rough Science Adventure Activities Guide
(2.7MB PDF, requires Acrobat Reader)

Water Quality Control Center
Weather Station
Island Power Plant
Island Observatory
Island General Store
Island Restaurant
Tropical Island Day Spa
Tropical Island Party

National Science Education Standards: Grades 5-8
National Science Education Standards: Grades 9-12

Additional Resources

Rough Science Metric Converter
Books
Web Sites
Scientific Supply Companies

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ROUGH SCIENCE

DISCOVER MORE

Water Quality Control Center

That tropical water really looks inviting! Looks can be deceiving. Before you jump in for a swim, do a little rough science to check if that water's as pure as it looks.

The Challenges!

- To determine if the water is polluted, **test the acidity of the water**.
- To determine if the water has a high or low mineral content, **test the hardness of the water in a soap solution**.
- To see what organisms are in the water, **make a microscope**.
- To make sure that your drinking water is safe, **design and build a water filter**.
- To help you to keep an eye on the time, **make a water clock**.

Test the Acidity of Water

We want to know if the water on your island is acidic or basic (alkaline). Strongly acidic or strongly alkaline water can be a sign of pollution and can be harmful to plants and animals and hazardous to drink. Carry out the following test to check your water.

You'll need:

- a red cabbage
- medium-size bowl
- grater
- strainer
- small plastic or glass pitcher
- 5 clear plastic cups
- baking soda
- lemon juice
- vinegar
- cola
- distilled water
- "island" water (spiked with something acidic like vinegar)
- teaspoon

What you do:
Grate one cup of red cabbage into a medium-size bowl and cover it with 1/2 cup cold distilled water. Let it sit for 45 minutes. When the water turns red, strain the cabbage juice into a plastic pitcher. Use the cabbage juice to test for acids or bases. Acids will make the cabbage juice turn different shades of red, and bases will make it turn different shades of blue.

Pour an equal amount of cabbage juice into five plastic cups. Add 1 teaspoon of baking soda (which is

a base) to four of the cups.. The stronger the acid, the less liquid you'll use to get the original color back. The fifth cup is your control. The color of the juice in the cup with just the baking soda is the color that you want to get all of your mixtures to match.

Add the lemon juice, 1 teaspoon at a time, to your first cup. How much lemon juice did you have to add to get the cabbage juice back to its original reddish color? In the second cup repeat for vinegar, and cola in the third cup. The liquids you need to use the least of are the most acidic. The liquids you need to use the most of are the least acidic. The liquids that don't change the color at all are bases. Now that you have a range of reactions for comparison, test island water in the fourth cup. What is your conclusion? Is it acidic or basic?

What's going on?
Red cabbage juice is an indicator. When it comes into contact with a base, like baking soda, it turns blue/purple. When it's mixed with an acid, like vinegar, it stays red/pink. Pure water is neutral — neither acidic nor basic.

For more information, see **Rough Science** episode 1: "Mapping it Out"

Test the Hardness of Water

Water can be "hard," even though it's a liquid. Hard water contains lots of minerals (such as magnesium and calcium) that leave deposits in pans and water pipes. Hard water also makes it difficult to lather up with soap. Are you concerned about the lack of lather when you soap up on the island? Test your water to see how hard it is.

You'll need:

- "island" water
- two screw-top jars
- teaspoon
- eye dropper
- small open jar
- tall drinking glass
- distilled water
- liquid soap
- Epsom salts
- measuring cup

What you do:
In the small jar mix a teaspoon of the liquid soap with ½ cup of the distilled water to make a soap solution. In the tall glass dissolve 1 teaspoon of Epsom salts in 2 cups of distilled water to make hard "island" water. Pour distilled water into one screw-top jar and the same amount of "island" water into the other. Use the dropper to put one drop of soap solution into the jar of island water. Screw the lid on tight and shake. If the water doesn't foam, add another drop of soap solution, screw on the lid, and shake it again. Repeat until the water foams. Count how many drops of soap solution you need. Repeat the experiment using the screw-top jar of distilled water. Which water needed more drops of soap solution to make it foam?

What's going on?
Distilled water is "soft." We can use it as a measure of the hardness-the mineral content-of the "island water." In hard water the salts (magnesium and calcium) interact with soap to form a scum that will not form bubbles (soap foam). Therefore, the amount of lather is related to the hardness of the water.

For more information, see **Rough Science** episode 10: "Sustenance and Sayonara"

Make a Microscope

Water is full of plants and animals that are too small to see with the naked eye. Make a simple microscope to see if you can detect any tiny organisms swimming around in the water.

You'll need:

- empty matchbox
- piece of thin, transparent plastic (e.g., from a plastic bag or plastic wrap)
- matchstick
- petroleum jelly or lip balm
- dropper
- scissors
- transparent tape
- water samples (e.g. from an "island" pond)

What you do:
Cut out most of one of the large sides of the matchbox sleeve. Be careful not to cut it all out since the sleeve still needs to hold together. Next cut a piece of thin, transparent plastic the same size as the end of the sleeve (where the tray slides in). Tape the plastic across the end of the sleeve, taking care to keep the tape right to the edges. Cut a hole in the side of the sleeve to allow light to enter. With the plastic-covered end up, slide the sleeve onto the tray of the matchbox (as if to close the matchbox) with the hole on the open side. Using the matchstick, draw a circle of petroleum jelly on the plastic. Use the dropper to place a single drop of water in the circle. Put another drop of water (pond water) on the end of the tray and look at it through your magnifying water drop. Very carefully, slide the sleeve up or down to focus your microscope. This matchbox setup can also be used to view other items like small insects.

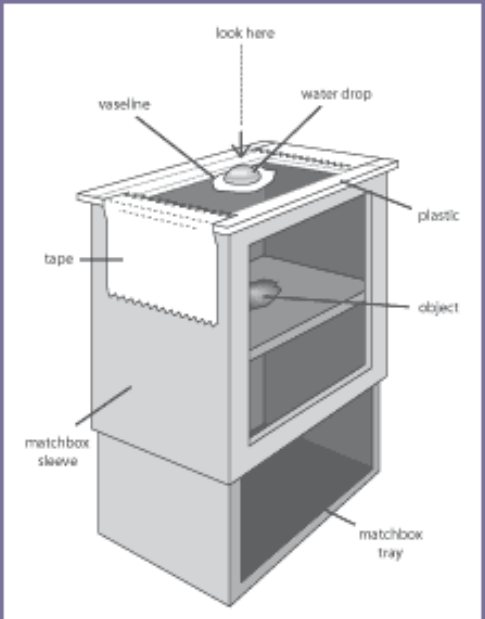

Microscope

What's going on?
This is a simple type of light microscope that bends light reflected by an object to make a larger magnified image.

Activity adapted from "How to Build a Mini Microscope" at http://physics.about.com.

For more information, see **Rough Science** episode 2: "Bugs and Barometers"

Build a Water Filter

Worried about the quality of drinking water on the island? Filtering is one of the best methods of making water safe to drink. This filter will remove small particles from dirty water. Make your own filtered water using this method.

You'll need:

- 2-liter soda bottle with cap
- serrated knife
- napkins or paper towels
- gravel, sand, charcoal, and cotton balls for the filter
- dirty water (if your "island" water looks too clean, add cooking oil, food coloring, pieces of

paper, or tiny pieces of Styrofoam)

What you do
Remove the plastic sheath from the outside of the soda bottle and screw on the cap. Cut the bottle in half. Put the top half of the bottle upside-down (like a funnel) into the bottom half. Line the upside-down half-bottle with a napkin or paper towel. Put layers of gravel, sand, charcoal, and cotton balls inside the top half of the bottle. (Ask participants to predict what they think each of the filter materials will remove from the water.) Remove the bottle cap. Pour the dirty water through the filter. (Ask participants to comment on any changes they notice and how their observations fit with their predictions.) Now scoop out each layer of the filter and examine what each layer has taken out of the water. Experiment by putting the filter materials into the bottle in a different order each time. What difference does the order of the layers make? Clean the bottle halfs thoroughly before you use them again.

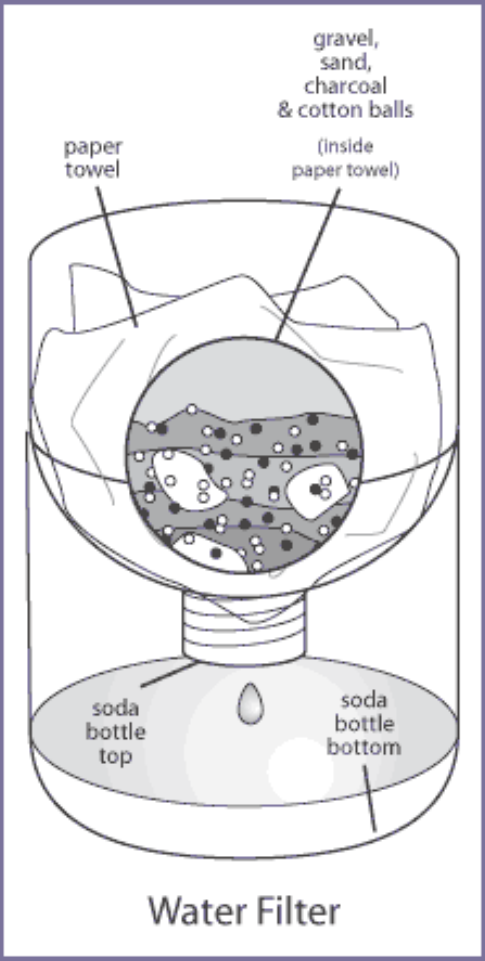

What's going on?
Different materials filter different substances from the water. The slower the water travels through a material, the more impurities are removed. Here the cotton fibers and sand create a longer path for the water and impurities to pass through and solids get trapped. Charcoal particles are charged (like a glass rod rubbed with a silk cloth) and they attract oppositely charged impurities.

For more information, see **Rough Science** episode 2: "Bugs and Barometers"

Make a Water Clock

The island sundial relies on the sun. So how will we know the time after dark or on a cloudy or rainy day? This water clock, based on an ancient Chinese design, will keep you on schedule. It marks time every 5 minutes. Use it to keep your water treatment activities on schedule.

You'll need:

- sundial or kitchen timer or alarm watch
- 5 paper cups (all one size)
- clear glass jar at least as big as the cups
- 5 thumbtacks
- transparent tape
- pencil
- strip of heavy cardboard
- strip of paper
- water

What you do:
Prick a hole in the bottom of each cup with a thumbtack. Pin the 5 cups to the cardboard with the thumbtacks, one cup above the other. Tape the strip of paper vertically on the glass jar; place the jar beneath the bottom cup. (Test the apparatus: fill the top cup with water and make sure the water drips smoothly through each cup down to the glass jar, then empty the water from the cups and jar.) Fill the top cup. Using your sundial or other timepiece, every 5 minutes mark the water level in the glass jar on the strip of paper. When the glass jar is full, you will know how much water represents a five-minute interval. Now you can use the water clock to keep track of time.

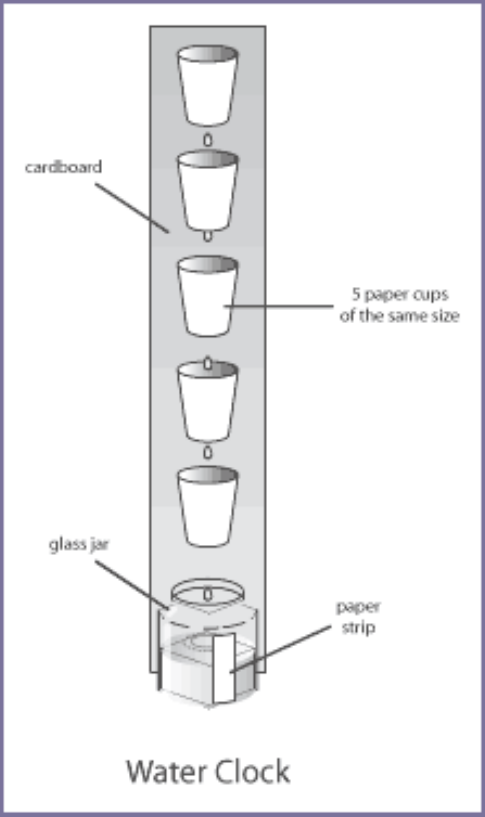

What's going on?
The water clock measures time against a known scale of five-minute intervals. This not unlike a sand timer that has been calibrated to take a period of time to move from the top to the bottom.

For information on making other types of water clocks, see http://nationalgeographic.com/world/trythis/try10.html.

For more information, see **Rough Science** episode 3: "Time and Transmitters"

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ROUGH SCIENCE

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Weather Station

The weather in the tropics can be unpredictable. And there's no radio or TV station to turn on and get a reliable forecast. That's why you'll need a weather station to figure out what changes lie ahead. You'll want advance warning if that big storm is on the way. And you'll want to know which direction it's coming from.

The Challenges!

- To calculate the moisture content of the air, **find the dew point**.
- To predict changes in the weather, **make a barometer**.
- To find out which way is North, **construct a compass**.
- To determine the wind direction, **build a wind vane**.

Find the Dew Point

The island climate is completely different from the one you're used to. How do you avoid getting caught in a torrential storm or a thick fog? The dew point is the temperature at which moisture in the air begins to form dew. It is a way of gauging the air's humidity. Here's a way to calculate it.

You'll need:

- tin can
- thermometer
- tablespoon
- ice cubes
- paper towel
- bowl
- water

What you do:
Crush the ice cubes in the paper towel using the back of the tablespoon. Fill the bowl halfway with crushed ice. Make sure the outside of the tin can is completely dry. Fill the can with cold water. Place the thermometer in the can. Add one tablespoon of crushed ice and stir. Continue adding ice until a layer of dew is visible on the outside of the can. Immediately read the thermometer to find the dew point temperature. If it's high, beware! The humidity is high also.

What's going on?
All air contains water vapor. As air cools (when it comes in contact with the cold can), the water vapor begins to condense. This is why glasses holding cold drinks "sweat" in the summertime. The dew point is the temperature at which moisture in the air begins to form dew. The higher the dew point temperature, the higher the moisture content of the air at a given temperature.

Activity adapted from Robert Wood. Science for Kids: 39 Easy Meteorology Experiments. *TAB Books, 1991.*

For more information, see **Rough Science** episode 2: "Bugs and Barometers"

Make a Barometer

A barometer shows changes in air pressure. High pressure indicates good weather, low pressure indicates possible storms. By consulting your barometer every day, you'll be able to make predictions about weather changes. (This can be a multi-day activity to compare the daily differences in air pressure.)

You'll need:

- tall glass or jar
- bowl
- 4 paper clips
- pen
- water

What you do:
Slide the paper clips onto the rim of the glass and space them equally around the rim. Fill the glass about two-thirds full with water. Place the bowl upside down over the glass. Carefully turn the bowl and the glass over so that the glass sits upside down in the bowl. Some of the water will run out of the glass but most will stay inside it. With a pen mark the level of the water in the glass at the beginning of the activity. Take your barometer outside into the open air. Look for changes in the water level in the glass over time. (This may take several hours or even longer than a day.)

What's going on?
When the atmospheric pressure of the air rises, the water in the bowl will be forced downwards by the weight of the air on the water. This, in turn, will cause the water in the glass to rise. A barometer measures the weight of the amount of air between the surface of the earth (the water in the bowl) and the top of the atmosphere.

Activity adapted from Robert Wood. Science for Kids: 39 Easy Meteorology Experiments. *TAB Books, 1991.*

For more information, see **Rough Science** episode 2: "Bugs and Barometers"

Make a Compass

Make a compass to determine the different directions: North, South, East, and West.

You'll need:

- needle
- magnet
- plastic container
- a cork (1/4" to 1/2 " thick)
- pen
- water

What you do:
Fill the plastic container with water. Stroke one end of the magnet along the needle in one direction at least 50 times to magnetize the needle. Lay the needle on the cork, with one end of the needle in the center. Tape the needle down. Float the cork in the container of water. The needle will bob around until it points North, towards the Earth's magnetic north. When the needle settles in position, mark North on the side of the container. Now you can determine the other directions and label them East on the right, South on the bottom and West on the left.

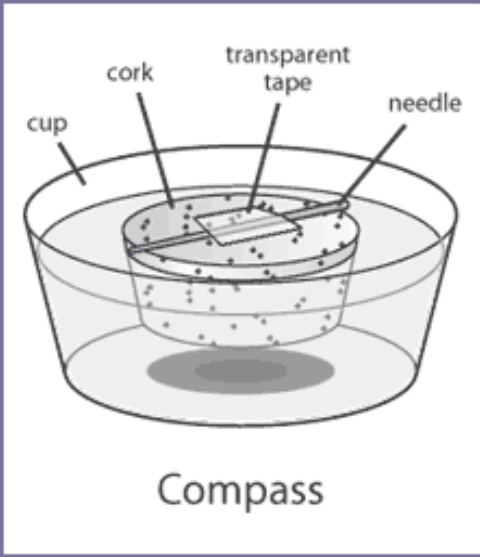

What's going on?
The Earth's core is thought to consist largely of molten iron, which crystallizes into a solid. Convection caused by heat radiating from the core, along with the rotation of the Earth, causes the liquid iron to move in a rotational pattern. It is these rotational forces in the liquid iron layer that lead to weak magnetic forces around the axis of spin. The magnetized needle in a compass can detect very slight magnetic fields. No matter where you stand on Earth, you can hold a compass in your hand and it will point toward the North. This is amazingly helpful because you can tell which way to go no matter what the weather or time of day.

For more information, see **Rough Science** episode 3: "Simmering Shutterbugs"

Build a Wind Vane

A change in wind direction often indicates an imminent change in the weather. Be prepared for sudden change by making this wind vane. (You can also use the compass you made in the previous activity to identify the direction of the wind.)

You'll need:

- a long tack
- scissors
- modeling clay
- a plastic pot or container, e.g., from take-out food
- ruler
- glue stick
- thin, colored card
- drinking straw
- 2 pencils with eraser
- compass

What you do:
Turn the plastic container upside down. Make a hole in the center by inserting the pencil, sharp end first. Make sure that it is firmly in place. With another pencil and a ruler, draw two large triangles and four small ones on the colored card. Then cut out the shapes. Glue the small triangles to the base of the plastic container at equal distances and on opposite sides from each other as on a compass. One point of each small triangle should overlap the edge of the pot, with the pencil in the middle. Cut short slits in each end of the straw and insert one large triangle in each end to make an arrow-shaped "vane." Push the tack through the center of the straw and into the eraser on the pencil sticking out of the pot. Secure the other end of the pot to a surface with a ring of modeling clay. Take the vane outside or to a simulated windy weather area and watch it swing in the wind. Finally, use your compass to determine East, West, North and South, and then label the small triangles accordingly. Now you can tell which direction the wind vane is pointing.

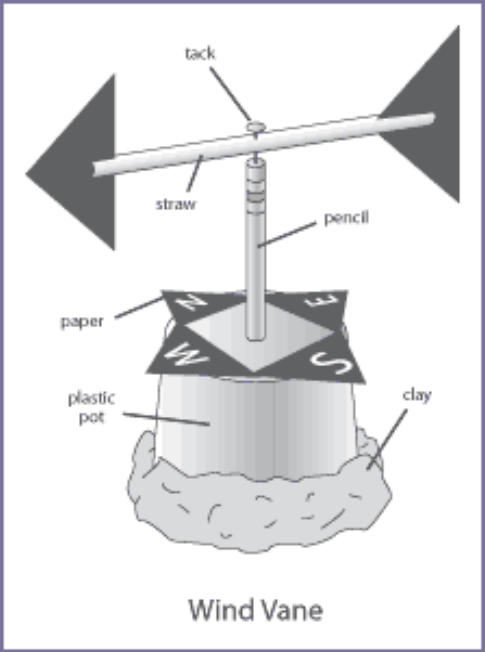

Wind Vane

What's going on?
The direction in which the vane points indicates the direction from which the wind is blowing. For instance, in a westerly wind, the vane points "West."

Activity adapted from Neil Ardley. 101 Great Science Experiments. *Dorling Kindersley, 1993, pp. 14-15.*

For more information, see **Rough Science** episode 2: "Bugs and Barometers"

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ROUGH SCIENCE

DISCOVER MORE

Island Power Plant

Once you've taken care of basics like food and water, you'll want to experiment with ways to create your own electricity and electrical gadgets. Why don't you employ a little rough science to create a power plant on your island?

The Challenges!

- To power things, **make your own battery**.
- To drive a paper windmill to create a breeze, **build an electric motor**.
- To see things at night, **make your own flashlight**.
- To warn others of potential danger, **create a buzzer**.

Make a Battery

Some kinds of batteries produce electricity by a chemical reaction between two different metals (electrodes) immersed in acid (electrolyte). Figure out how to make your own batteries in case the limited supply on the island runs out.

You'll need:

- two wires with the ends stripped off
- aluminum foil
- scissors
- small bowl
- warm water
- salt
- tape
- 6 pennies (copper coins)
- paper towels
- 1.5 volt penlight light bulb
- a paper plate

What you do:
Partially dissolve 1 tablespoon of salt in 1 cup of warm water. Some salt should still be evident in the bottom of the bowl. Place a penny on the aluminum foil and draw around it. Repeat five times. Do the same thing with the paper towel. Cut out the circles. You should have six foil circles and six paper ones. Tape the end of one wire to a foil circle. Dip a paper circle in the warm, salty water. Place the foil circle with the wire on the plate, and put a wet paper circle and a penny on top of it. Using all the foil, pennies, and paper circles, build alternate layers. Then tape the other end of the wire to the last coin and put it on top. This is your battery.

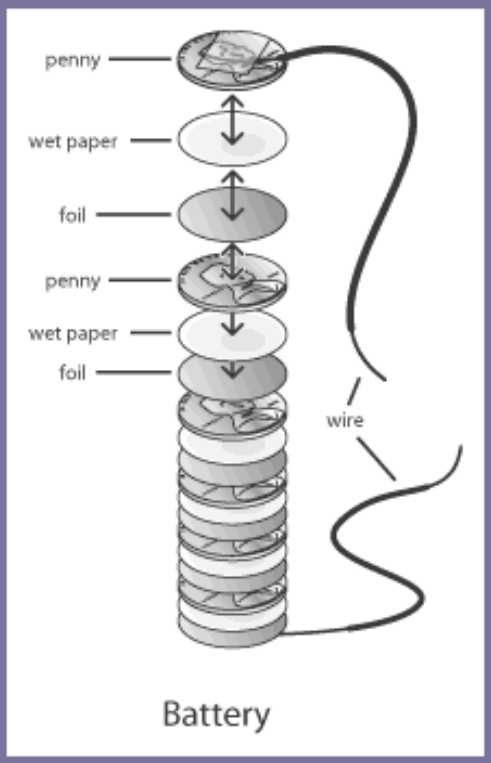

Test the battery with the light bulb. Attach the end of one wire to the metal terminal end of the light bulb. Wrap the end of the other wire around the metal shaft of the light bulb. Can you see the bulb light up?

What's going on?
The metal atoms in the foil dissolve into the electrolyte (the warm, salty water) and electrons are left behind. Electricity is created when the electrons flow through a circuit (the foil circles and paper circles soaked in warm, salty water). When the metals eventually dissolve completely into the electrolyte, no more electrons are formed and the battery stops working. The first battery (Volta's Pile) was developed about 1860 by Alessandro Volta. He stacked discs of copper, zinc, and cardboard soaked in salty water in alternate layers and measured an electronic current.

Activity adapted from Neil Ardley. 101 Great Science Experiments. *Dorling Kindersley, 1993. For instructions on creating a similar battery, see http://www.exploratorium.edu/snacks/hand_battery.html.*

For more information, see **Rough Science** episode 5: "Sun and Sea"

Build an Electric Motor

It's hard to sleep at night because of the heat. How would you go about building a simple motor to turn a paper windmill and create a breeze? When a current passes through a coil of wire it turns the wire into an electromagnet which interacts with a permanent magnet to make the coil spin. The spinning coil is a basic motor.

You'll need:

- 5 small magnets (available at electronics stores)
- 2 large paper clips
- plastic, paper, or foam cup
- 2 feet of solid insulated 20-gauge copper wire (non stranded)
- masking tape
- a 1.5 volt D cell battery in a battery holder
- 2 alligator clip leads (available at electronics stores)
- wire strippers
- broom

What you do:

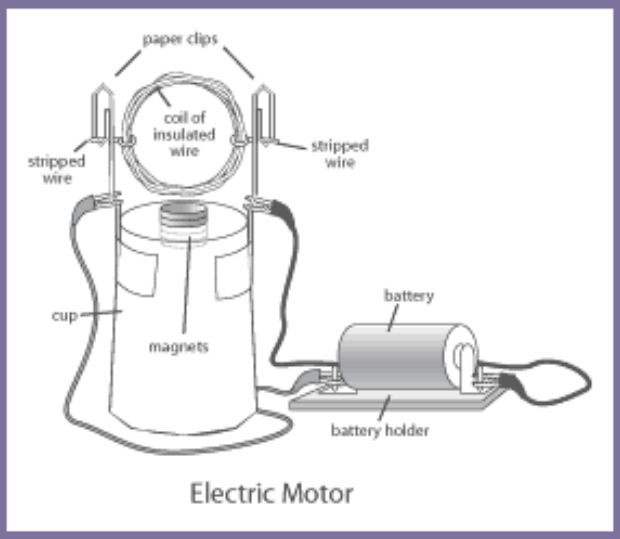

Wind the copper wire around the end of a broom handle to create a coil with a 1-inch diameter. Take each end of the wire and wrap it around the coil to hold the coil together. Leaving about 2 inches of wire sticking out from each end, strip the insulation off these two ends using wire strippers. Attach three magnets to the bottom of the cup with masking tape. Turn the cup upside-down and lay two magnets on top. (The magnets underneath create a strong magnetic field and keep the magnets on top in place with no tape.) Unfold one end of a paper clip and tape it to one side of the cup so that the rest stands up above the cup. Unfold the other paper clip, and tape it to the other side of the cup. The paper clips will form a cradle for the coil. Attach one end of the coil to one paper clip and the other end of the coil to the other paper clip. Spin the coil and adjust the height of the paper clips to make sure that there is around 1/16 of an inch between the coil and the top of the magnets. Adjust the clips to make sure the coil stays balanced and centered. Put the battery and battery holder beside the cup. Attach one end of an alligator clip to a battery terminal and the other to a paper clip. Attach the other alligator clip to the other battery terminal and the other paper clip. Spin the coil to start it turning.

What's going on?

The current running through the coil of wire creates an electromagnet. What does this mean? As with a bar magnet, one end of the coil has become a North Pole, and the other a South Pole. Each of the three magnets attracts its opposite pole and repels its like pole of the coil, causing the coil to spin.

For more information, see **Rough Science** episode 5: "Sun and Sea"

Make a Flashlight

When you're on the island, you can't just flick a switch and turn on a light. There isn't a constant electricity supply. But with a flashlight, you'll be able to see around your room at night and even venture outside for a walk — moonlight or no moonlight.

You'll need:

- 2 batteries with 1.5 volts each
- 2 brass paper fasteners
- sharp pencil
- screwdriver
- aluminum foil
- plastic tape
- a light bulb in a bulb holder
- 3 pieces of wire with bare ends
- paper clip
- cotton
- empty dishwashing liquid bottle
- scissors

What you do:

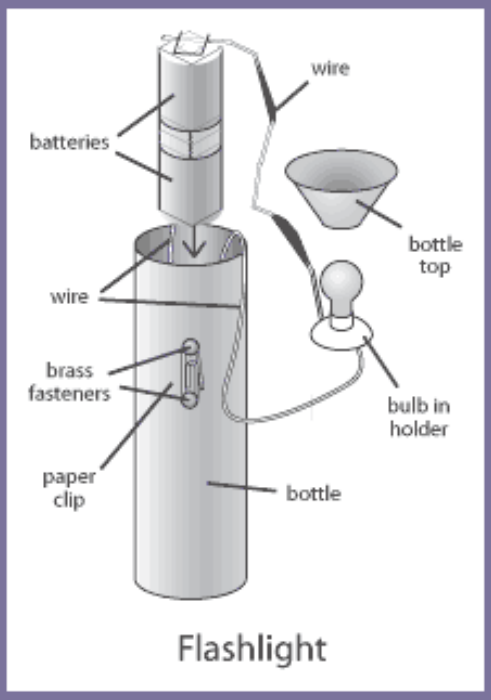

Cut the top off the empty dishwashing liquid bottle. Tape foil shiny side up to the inside of the bottle top. Use the pencil to make two small holes in the side of the bottle near the bottom. One hole should be about an inch below the other. Firmly attach two pieces of wire to the bulb holder. Tape the top of one battery to the bottom of the other to make one long battery. Tape the third piece of wire to the bottom of the battery. Tape one of the wires from the bulb-holder to the exposed terminal on the battery. Put the long battery in the bottle, carefully threading the wire from the bottom battery through the lower hole. Stuff cotton in the space between the batteries and the walls of the bottle to keep the batteries in place. Thread the wire from the bulb-holder through the top hole in the bottle. Attach paper fasteners to the two wires poking through the holes and push in the fasteners. Put the bulb-holder on top of the battery and tape the center of the bottle top over the bulb. In other words, put the bottle top on back-to-front so that the aluminum foil is visible. Bend the paper clip and fit one end under the lower paper fastener to make a switch. (When the switch is turned, current flows from the battery along the wires to the bulb.) Press the other end of the paper clip against the top fastener and see the flashlight light up.

What's going on?

There is a thin wire (a filament) inside the bulb that glows white-hot when current flows through it. The light reflects off the foil to produce a bright beam of light.

For more information, see **Rough Science** episode 5: "Sun and Sea"

Create a Buzzer

The island can be a spooky place, especially at night. Since there is no phone system, you can't call for help if there's a problem. You can, however, create your own alarm system. Try using an electromagnet to make a buzzer!

You'll need:

- 9 feet of PVC-covered wire with both ends stripped
- iron or steel bolt
- modeling clay
- an empty thread spool
- steel nail file
- rubber band
- scissors
- plastic tape
- thick cardboard
- soda can
- switch
- 4.5 volt battery

What you do:
Firmly wrap the wire around the bolt 200 times (leaving both ends of the wire loose). Use the clay to fix the bolt to the cardboard. Turn the spool on its side and attach the handle of the nail file to it with the rubber band. Using the scissors, scrape away the paint at the base of both sides of the can. Tape one end of the wire to the metal part of the nail file, and attach the spool to the cardboard with clay. Cut the two wires. Attach one end to the battery and the scraped part of the can, and the other to the battery and the switch. Stick the can to the cardboard with modeling clay and touch the other scraped part of the can with the nail file. Connect the switch and press it. The can gives off a loud buzz. The vibrating nail file repeatedly strikes the can. Both the buzz and the nail file stop when you release the switch.

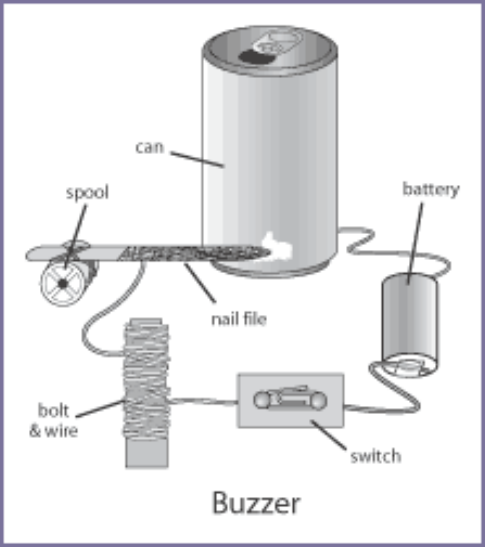

What's going on?
The buzzer uses magnetism to make a loud sound. Electricity flows from the battery through the can and into the nail file. Every time the nail file hits the can, electricity flows through it to the electromagnet formed by the bolt and wire, through the switch, and back to the battery. The electromagnet pulls the file away from the can. As a result, the electricity stops, and the nail file springs back, striking the can again and setting everything in motion once more. It's the movement of the electromagnet that makes the buzzing sound.

For more information, see **Rough Science** episode 5: "Sun and Sea"

Suggestions for other activities:

- To communicate with other people, make a telegraph.
- To see how much power you have, build a charge detector.
- To check for materials that act as conductors, create an electricity probe.

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Island Observatory

On the island, far away from polluting lights and smog of the city, you check out the spectacular night sky. Using a little rough science, study the solar system while you enjoy the solitude.

The Challenges!

- To calculate time at night, **make a star clock**.
- To identify what's in the night sky, **make a telescope**.

Make a Star Clock

It's night and you want to figure out the time by reading the positions of the stars. Before the invention of clocks, people told the time by the movement of the stars across the night sky. You can do the same using your star clock.

You'll need:

- star clock template
- scissors
- brass paper fastener
- sharp pencil

What you do:
Carefully cut around each star clock circle and poke a hole through the middle of each one. Place the small circle on top of the large circle. Push a paper fastener through the holes in both circles and spread the fastener open on the back of the clock. Go outside, look up at the sky, and using your star clock find the Big Dipper and the North (or Pole) Star. Face the North Star. Put your thumb over the current month. Slide the outer circle around so that your thumb is at the top. Turn the smaller disc carefully until its stars line up with those in the sky. You can now read the time in the window. (If you are on Daylight Savings Time, add one hour.) Compare the time with your wristwatch to see how close you get. It's better to do this activity when the moon is not full. A full moon is so bright that it becomes difficult to see the stars.

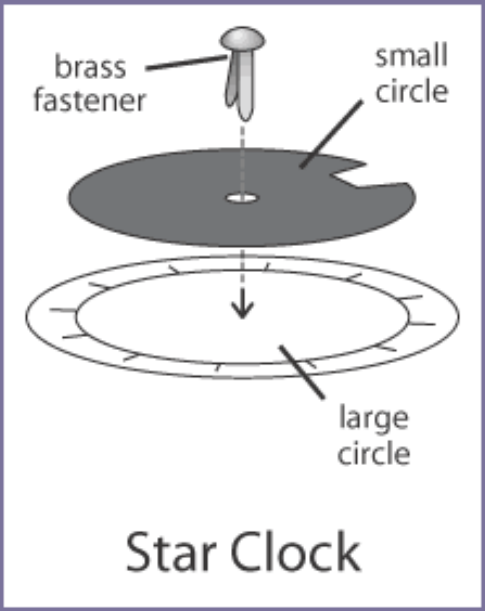

What's going on?
The North Star never appears to move because the Earth's axis, the imaginary line drawn from pole to pole through the center of the Earth, points almost directly to the North Star. The stars that appear to revolve around the North Star are known as circumpolar stars. In mid-northern latitudes, these stars appear to circle around the North Star without rising or setting. The star clock estimates the time based on where the stars appear relative to the North Star.

Activity adapted from Lawrence Hall of Science. Earth, Moon, and Stars. *Regents of the University of California, 1986.*

For more information, see **Rough Science** episode 7: "Mediterranean Mystery"

Make a Telescope

When you first look up to find the Big Dipper to orient your star clock, you may have trouble seeing it. Why don't you make sure you'll find it by making your own telescope? Even if you find the Big Dipper and the North Star with ease, your telescope will help you to see the moon and thousands of other stars in much greater detail.

You'll need:

- 2 convex lenses of different focal lengths (e.g., use 2x and 4x lenses from drugstore reading glasses)
- a cardboard tube at least as long as the sum of the two focal lengths of the lenses
- pen
- tape

What you do:
Fix one lens to each end of the tube with tape. Take care not to obscure the view through the tube. Mark the end of the tube with the shorter focal length lens. This will help you figure out which way round your telescope is. Look through this end.

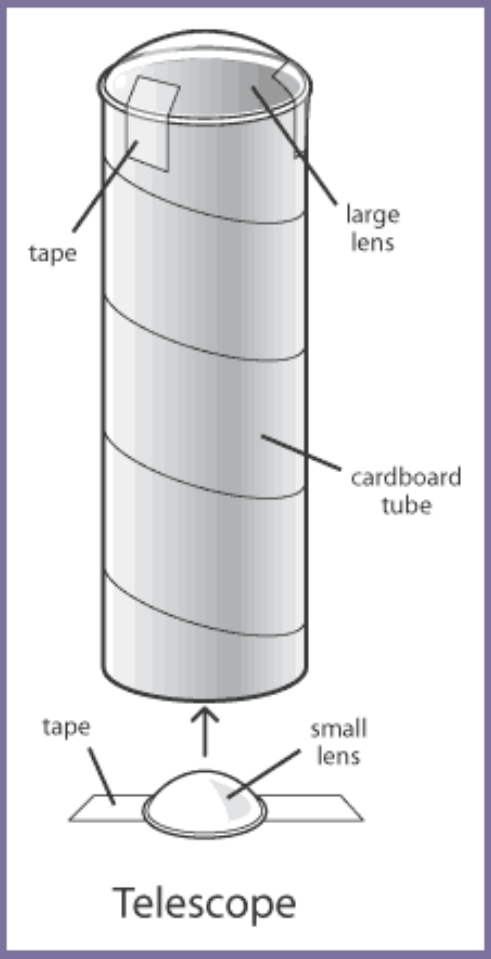

What's going on?
Telescopes use lenses to bend the incoming light. The first lens (objective lens) gathers light and bends it into focus and provides a small, upside down image of the object you're looking at. The second lens (the eyepiece) then magnifies the object so that you can see it better. When the two lenses are combined, you have a telescope that magnifies the image.

For more information on how telescopes work, see www.howstuffworks.com.

Suggestions for other activities:

- To understand the position and distance of different planets and the sun, make a model of the solar system.
- To understand the rising and setting of the sun at different points on the Earth, make a solar calculator.
- To measure the height of celestial objects in degrees, make a clinometer.
- To track the stars that you see, make a constellation chart.

For more information, see **Rough Science** episode 7: "Mediterranean Mystery"

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ROUGH SCIENCE

DISCOVER MORE

Island General Store

Every tropical island needs a general store. This one is stocked with lots of useful items to help you and your customers have fun in the sun and enjoy yourselves after dark. Everything on the shelves is a rough science product.

The Challenges!

- To set the mood for meals and have light when there is no electricity, **make your own candles**.
- To keep island visitors' teeth white and their breath fresh, **concoct homemade toothpaste**.
- In case things come unstuck, **make rough science glue**.
- To keep insect pests at bay, **make some insect repellent**.

Make Candles

If you didn't build a flashlight in the Island Power Plant scenario, you'll still be able to function in the dark if you make some candles — for yourself and the general store customers.

You'll need:

- paraffin wax or beeswax
- colored crayons or dye
- powdered stearin
- wick
- wide, shallow pan
- two tall cans
- thermometer
- paper towel
- waxed paper
- pencil
- metal washer
- newspaper
- essential oil or perfume
- water

What you do:
Spread the newspaper over your work area. Heat water in the pan. Cut the wax into small chunks and add them to one of the tall cans. Set the can in the warm-water pan. Heat slowly, adding more chunks as the wax melts. When the wax has melted, stir in about 3 tablespoons of stearin for each pound of wax. For color, melt in the wax crayons or add dye. Use the thermometer to maintain the temperature of the molten wax between 150 and 180°F. Prepare the wick by cutting it into lengths 5 inches longer than the candle you want to make. Attach a metal washer to one end of the wick to weight it, and tie the other end to a pencil. Dip the wick into the molten wax, lift it up, and let the wax drip along the

wick. Dip the coated wick into the second tall can, filled with cool water. Lift the wick out, and use some paper towels to remove excess water. Place your candle on waxed paper for 30 seconds and then repeat the dipping process. Dip each candle 40 to 50 times until your candle is about 1 inch. As the size of the candle increases, you may need to straighten it by rolling it on waxed paper. When the candle is about 1 inch thick, add a tablespoon of stearin to the wax for one final dip. The added stearin will make the final wax coating of your candle dripless. If you want to make scented candles, add a few drops of essential oil or perfume.

What's going on?
The Romans used beeswax to make candles, but modern candles are made from a mixture of hard paraffin and stearin (added to increase the melting point and to prolong burning time). Stearin is a substance that changes the melting point of the wax. This allows the candle to harden faster. Stearin also makes candles firmer, dripless, and brighter burning. It is harder than tallow. Wicks must be naturally absorbent to absorb liquid wax and move it upward while the candle is burning. The heat of the flame vaporizes the wax, and it is the wax vapor that burns. The wick does not burn because the vaporizing wax cools the exposed wick and protects it.

For other candle-making activities, see:

- http://www.howstuffworks.com/question267.htm
- http://www.hollyhobby.com
- http://www.make-stuff.com

For more information, see **Rough Science** episode 10: "Sustenance and Sayonara"

Concoct Homemade Toothpaste

Fail to pack for your island vacation? Don't panic. Toothpaste doesn't have to come in a tube. You can make it from a few simple ingredients if you know the basic principles.

You'll need:

- baking soda
- water
- calcium carbonate
- peppermint oil, mint, or lemon juice
- glycerin (optional)
- teaspoon
- a bowl

What you do:
In the bowl, add 3 parts of baking soda to 1 part calcium carbonate. Add 2 teaspoons of glycerin and 5 to10 drops of peppermint oil. Test for taste. If you like your toothpaste to tingle, add a bit more oil. Mix all of the ingredients thoroughly and add enough water to give a smooth, toothpaste consistency. You could use other flavorings, such as mint or lemon juice.

What's going on?
Baking soda causes dirt and grease to dissolve in water. This cleansing action combines with the abrasive calcium carbonate (chalk) to produce an effective cleaning agent. The glycerin thickens the mixture to give it a paste consistency. The peppermint oil is for flavor.

For more information, see **Rough Science** episode 10: "Sustenance and Sayonara"

Make Glue

Even island dwellers must make simple repairs. You never know when one of your customers might break something. Making this glue is so easy, you'll never run out.

You'll need:

- 1/2 cup warm milk
- 1/4 teaspoon baking soda
- 2 tablespoons vinegar
- water
- saucepan
- cup
- cheesecloth or coffee filter

What you do:
Slowly heat the milk until it is hot. Remove it from the heat and add 4 teaspoons of vinegar for every cup of milk. Place the curds in cheesecloth and then squeeze out the water. Rinse the curds with cool water. Squeeze out all the water and put the curds in a cup. Add a pinch of baking soda and mix with a little water to make the glue smooth.

What's going on?
When vinegar is added to milk, the acetic acid in the vinegar causes thick lumps (curds) of casein to develop and coagulate from the proteins in the milk. The acid separates the milk into curds and whey. The acid causes constituents of the proteins (amino acids) to react with each other, resulting in adhesion. Also the fibers in paper or other objects attract the casein that makes them stick together.

Activity adapted from Lawrence Hall of Science. Secret Formulas. *Regents of the University of California, 1996. See also http://www.howstuffworks.com.*

For more information, see **Rough Science** episode 10: "Sustenance and Sayonara"

Make Insect Repellent

Insects are everywhere in the tropics and some carry diseases. You need to stock an effective insect repellent. This one really works. Watch it fly off the shelves!

You'll need:

- 1/4 cup denatured alcohol (available from scientific supply companies)
- 1 1/2 teaspoons camphor (available from scientific supply companies)
- 1 1/2 teaspoons calcium chloride (available from scientific supply companies)
- bowl
- spoon

What you do:
Mix all the ingredients together in the bowl. Stir thoroughly until everything has dissolved. Before you go outside, apply the repellant to your skin but avoid getting any lotion near your eyes. Be sure to discontinue use at the first sign of an allergic reaction.

What's going on?
Camphor is a powerful natural repellent. It is an extract from the camphor laurel tree. Insects don't like the smells of the volatile oils (vapors) in the camphor.

For more information, see **Rough Science** episode 7: "Mediterranean Mystery"

Suggestion for other activity:

- Make your own filtered water and bottle it for sale. See the Water Quality Control Center scenario for directions on how to make a water filter.

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ROUGH SCIENCE

DISCOVER MORE

Island Restaurant

If you're on a tropical island, it's great to know there is a restaurant where the food is fresh and the mood is mellow. After you're through with your rough science, don't forget to make a reservation!

The Challenges!

- To cook meals for your guests, **make a solar oven**.
- To grow herbs and spices, **build a terrarium**.
- To provide warm water, **build a solar water heater**.

Make a Solar Oven

Nothing beats home cooking! It's your restaurant and you're the chef. Get creative with the menu. In fact, get creative with the oven. Make your own solar oven to prepare exquisite meals for your guests.

You'll need:

- a box with a lid, e.g. a pizza box
- black construction paper
- aluminum foil
- heavy plastic laminate
- glue
- transparent tape
- scissors
- ruler
- magic marker
- straw

What you do:
Draw a square on the lid of the box and cut along three sides of it. Fold back along the uncut side to form a flap that opens and shuts. Line the inside of the flap with aluminum foil, smoothed over and glued into place. Cut a piece of plastic to fit very tightly over the hole you created in the lid of the box by forming the flap. Use enough plastic to overlap the underside of the flap. Seal the plastic by taping it to the underside of the flap. (The plastic has to be tightly sealed to make sure that no air can escape from the oven.) Line the bottom of the box with foil, and glue it into place. Again, take care to smooth out all wrinkles. Cut out a piece of black construction paper to fit on the bottom and tape it in place. Close the lid (including the plastic window) and prop the flap open, facing the sun. Move the box around to get the maximum amount of sun into your oven. Try cooking something like s'mores. Compare the solar oven with the solar water heater.

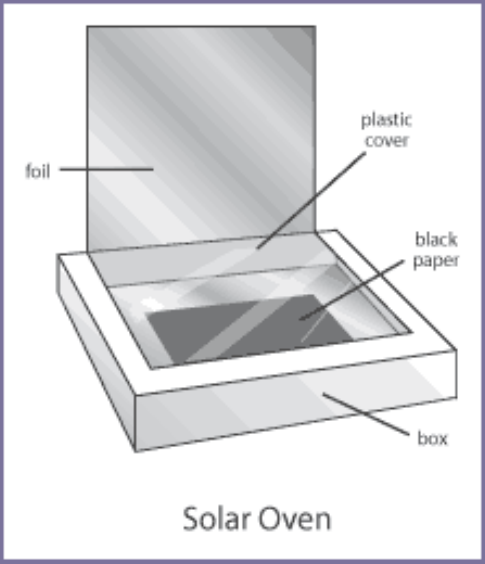

What's going on?
Energy, radiating from the sun, reflects off the foil. This heat energy is then stored in the oven.

For more information on solar-powered technology, see http://www.solarnow.org/pizzabx.htm.

For more information, see **Rough Science** episode 9: "Power Supplies"

Make an Herb Terrarium

Spice up your food and garnish dishes with herbs and spices grown in an herb terrarium (herbarium). Your restaurant will become an instant hit once customers realize that their palates will be pampered with subtle flavors. Building a terrarium is much easier than tending a garden, and it's low maintenance.

You'll need:

- a glass or plastic container, such as a candy jar or pickle jar, with a wide mouth and tight-fitting lid
- potting soil
- potted herbs
- colored stones
- shells
- water
- soap
- paper towel

What you do:
Do some research to select herbs that need similar conditions (soil, light, water) for growth. Take care to choose plants that will not outgrow the container. After cleaning, rinsing, and drying the container thoroughly, fill it ¼ full with potting soil. Place the plants in the soil at a depth similar to that in their pots and press the soil down around them. Squeeze water from wet paper towels to moisten the soil around the plants, but do not overwater or you will kill them. (If you need to, you can add more water at a later date.) Decorate your terrarium with colored stones and shells. Close the lid tightly and place the terrarium where the plants will receive the light they need. You have created a self-sustaining ecosystem.

What's going on?

The lid traps air inside the terrarium. Plants use carbon dioxide and sunlight during the day to produce food and oxygen through photosynthesis. At night, they use the oxygen to create more carbon dioxide. The water trapped inside the terrarium is absorbed through the roots of the plants. It moves up through the stems and evaporates through the leaves. Like rain, the water will condense on the top of the terrarium and drip back down to the bottom. The oxygen, carbon dioxide, and water are therefore constantly being recycled by the plants.

For more information, see **Rough Science** episode 10: "Sustenance and Sayonara"

Make a Solar Water Heater

Wash the sand off after a dip in the ocean with a relaxing warm shower hooked up to a solar water heater. All it takes is a few simple objects and plenty of sunshine!

You'll need:

- water jug
- large fish tank with a lid
- aluminum foil
- transparent tape
- cardboard, with an area greater than the base of the fish tank
- thermometer
- black paint
- paintbrush
- water

What you do:
Line the sides of the tank with aluminum foil, inside and out, and tape the foil firmly in place. Paint the bottom of the inside of the tank black. Place the cardboard in a spot that is in the sun all day. Place the tank squarely on the cardboard. Once the paint is completely dry, fill the tank with water. Put the lid on the tank. Use the thermometer to test the temperature of the water every half hour. If it gets too hot for a comfortable shower, remove the lid until the water equilibrates with the outside temperature.

What's going on?
Sunlight (infrared energy) passes through the glass and is absorbed by the water. Water has a high heat capacity (able to absorb and hold heat). A black surface absorbs some of the light (sunlight). If trapped, as it is in this case by the insulation (the foil), the heat (energy) accumulates and is reflected into the water so it gets warmer. The heat energy cannot escape as easily back through the glass so the water stays warm.

For more information, see **Rough Science** episode 9: "Power Supplies"

Suggestions for other activities:

- To make the ice cream taste better, add flavors or fruit.
- So patrons can be notified when their table is ready, make a buzzer for the maitre d' of the hotel. (See the Island Power Plant scenario.)
- Make butter, popcorn, and peanut butter, and soda.

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ROUGH SCIENCE

DISCOVER MORE

Tropical Island Day Spa

Hot and sweaty from the tropical sun? What better way to recover than a luxurious day in a spa? Before you slather on that facemask and kick back in the sauna, you're going to have to figure out how to create the essentials for a day of pampering yourself! Discover the rough science behind what happens in a day spa.

The Challenges!

- To remove some of those layers of grime, **make scented and textured soap**.
- To clean those pores and keep your skin hydrated and beautiful in the sun, **create a facial mask**.
- To protect your lips from the sun, **make a lip balm**.
- Leave that astringent cucumber mask on too long and you'll look like a prune! On an island you won't have a watch or clock so **construct a sundial**.
- To discover just how bad the humidity really is, **build your own humidity indicator or hygrometer**.

Add Scent and Texture to Your Soap

Soaps are made by boiling oils and fats with an alkali. Because this takes a long time and can be dangerous, we're going to use shredded olive oil soap as our base and add oils and flowers for scent and texture. For safety, ask the soap makers to tie back long hair and roll up their sleeves. Supervise young participants. To dry the soap quicker, place it in the sun or in a low oven for 15 minutes.

You'll need:

- 2 saucepans, 1 large, 1 small
- 1-lb. bar of olive oil soap
- grater
- plastic or glass droppers
- a selection of herbal tea bags (chamomile, green tea, fruit flavors)
- teapot or pitcher
- essential oils such as lavender, geranium, vanilla, sweet almond oil (You can buy herbal teabags and essential oils in health food stores.)
- dried flowers
- oatmeal
- tiny squares of candied fruit
- a blunt object such as a butter knife
- a cookie tray

What you do:
Shred a bar of soap using the grater. Place the large pan on a burner and fill the bottom with enough

water to cover the bottom of the small pan that you place inside the large pan. Take care to make sure that the inside of the small pan stays completely dry, and that there's always water in the large pan. Place the grated soap in the small pan. Heat the large pan slowly on a medium flame till the soap melts. Add 1/4 of a cup of strong tea (that you have made) to the soap, mixing it in thoroughly. Spoon the soap mixture onto a cookie tray in six equal measures. Knead, or mill, each soap mixture with a knife. When the soap firms up, add your choice of essential oils using the droppers. Continue to knead until the soap is hard enough to pick up. Form it into a shape, then roll your bar of soap in dried flowers, oatmeal, or candied fruit. Allow the soap to dry completely before you use it.

What's going on?
Soap molecules have both fatty acid and salt-like properties. The latter allow the soap to dissolve in water, while the fatty acid properties allow the soap to dissolve dirt and oils. The combination of the two sets of properties gives soap its ability to dissolve grease in water.

For more information, see **Rough Science** episode 10: "Sustenance and Sayonara"

Create a Facial Mask

Whether your skin is oily or dry, it can benefit from a facial mask. Mixing eggs with mint and honey will make masks suited to oily skin; yogurt and cucumber will help rehydrate dry skin. Put slices of cucumber over your eyes while your mask is drying.

You'll need:

- eggs, cucumbers, instant nonfat dried milk, plain yogurt, chamomile flowers, fresh mint, and honey
- small bowls
- whisks
- graters

What you do:
In a small bowl, mix grated cucumber, yogurt, and dried milk with a whisk to create a moisturizing mask for dry skin. Mix egg, chamomile flowers, fresh mint, and honey with a wisk in another bowl to produce an astringent mask that will tighten pores in oily skin. Apply the mask that matcher your complexion to your face for 15 minutes, and then rinse it off with warm water.

What's going on?
The yogurt mask increases the flow of sebum (oil produced by glands in your skin) by causing your skin tissue to expand. The astringent (an agent that contracts tissue to reduce secretions) mask made from mint shrinks skin tissue and reduces the sebum flow.

For more information, see **Rough Science** episode 10: "Sustenance and Sayonara"

Make Lip Balm

Do your lips feel dry and burned from exposure to the tropical sun? What can you do to protect them? Let's make a scented lip balm using a mixture of beeswax and almond oil.

You'll need:

- 1/4 cup sweet almond oil
- 1/4 oz. beeswax
- metal spoons
- tropical fruit-flavored oils, such as mango, pineapple or coconut
- small jars for lip balm

- saucepan
- small metal container
- water

What you do:
Put a saucepan with a small amount of water on a low burner. Place the almond oil in a small metal container and place it in the water in the pan. When the oil warms up, add the beeswax to the container. Stir the mixture with a metal spoon until the beeswax is completely melted. Add drops of flavored oil and mix some more. Remove the mixture from the heat. Collect some in the spoon and put it in a cool place. When the spoonful hardens, test it with your finger. If your balm is too hard, add more oil. If it's too soft, add more beeswax. If the flavor is weak, add more drops of oil.

What's going on?
Lip balms and lip glosses contain oils and waxes that protect the lips and therefore act like a water repellent.

For more information, see **Rough Science** episode 10: "Sustenance and Sayonara"

Construct a Sundial

You have to watch how long you wear that facial mask. So let's make a timepiece for the spa.

You'll need:

- sundial template
- a magnetic compass
- card stock
- elastic string with metal ends
- atlas

What you do:
Copy the sundial template onto card stock. Fold the tabs to an angle that corresponds to your latitude, as shown on an atlas. Then fold down both tabs to form the base of the sundial. Open your sundial to form a 90-degree angle and fold in the supporting tabs. To finish the dial, attach the elastic string through the holes at the top and bottom at the points where all the hour lines converge. This string is the gnomon (pronounced no-mun) and casts the shadow to indicate the time. To provide accurate time, the sundial (1) must be orientated with the gnomon pointing North/South; (2) must be located where a shadow will be cast by the gnomon most of the day. (Note: one can move the dial from window to window as the day progresses.) For greater accuracy, see the Equation of Time chart on the upper face of the sundial. A magnetic compass may be used to determine the North/South line. Because of the difference between magnetic North and true North, the sundial reading could be off by an hour or more. The variation will depend on the local difference between magnetic and true North.

What's going on?
Your location on Earth in relation to the sun determines the time where you are. Because the Earth rotates as it travels round the sun, the date is also very important. Compare 5 o'clock in the afternoon in July with the same time in December. Your watch or clock measures standard time. Your sundial records solar time, which is not the same. According to solar time, noon is when the sun is directly overhead. Even though noon in Boston, New York and Miami happens at the same moment in standard time, there would be noticeable differences if you measured noon at all three locations in solar time.

Activity adapted from Sun Sculpture & Sundial-Making Kit. *New York Hall of Science, 2002. For information on making other sundials, see Liftoff to Space Exploration: A Space Sciences Project.*

For more information, see **Rough Science** episode 7: "Mediterranean Mystery"

Make a Humidity Indicator

Is the tropical humidity giving you another "bad hair day"? Let's figure out how to determine how high the humidity is.

You'll need:

- aluminum foil
- newspaper
- tape
- pencil
- scissors
- empty spool

What you do:
Cut a strip of aluminum foil (10" x 4") and a strip of newspaper (10" x 10"). Tape the edges of the aluminum strip to the middle of the newspaper. Tape one end of the newspaper-aluminum strip to the top of the pencil and carefully and tightly wind the rest of it around the pencil. Place the pencil in the spool. If the weather is humid, the strip will unwind in the moist air. If the air becomes dry again, the strip will wind closed.

What's going on?
The paper expands when it absorbs moisture. The aluminum foil, a metal, doesn't absorb moisture. The tension between the two causes the strip to unwind and wind according to the amount of moisture in the air.

For more information, see **Rough Science** episode 2: "Bugs and Barometers"

Suggestions for other activities:

- To make body paint, extract dye from plants, fruits, vegetables and flowers.
- To make hair gel and aromatherapy shampoos, use plants.
- To make henna tattoos, use henna (a natural dye that dates back to the ancient Egyptians) to produce a deep red/orange/brown color.
- To make a perfume, blend natural oils.

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DISCOVER MORE

Tropical Island Party

On vacation let your hair down. What better place for a party than a tropical island paradise? But who would have thought that rough science could help make you the perfect host?

The Challenges!

- For original invitations, **make your own paper**.
- To wake up the party poopers, **create botanical noisemakers**.
- For refreshments, offer homemade **ice cream** and **soda**.

Make Paper

You need to let people know when and where to come to the party. But first you'll need some paper to write your invitations.

You'll need:

- plain office paper, newspaper, magazines, egg cartons, toilet paper, paper bags, old cards, nonwaxed boxes pre-soaked in warm water, tissue paper, napkins, or construction paper (any of these types of paper or a mixture)
- sponge
- screening from a window or door
- an old picture frame or other wooden frame
- plastic tub large enough to accommodate the wooden frame
- blender or food processor
- white felt or flannel fabric
- staples or tacks
- liquid starch
- 2 cookie sheets

What you do:
Rip the paper into small pieces and place it in a blender until half full. Fill the blender up with warm water. Blend slowly until there is no trace of paper and the pulp is smooth. Staple the screen to the frame as tightly as possible to make a deckle. Fill half the basin with water and add 3 blenders-full of pulp. (For thicker paper, add more pulp.) Stir well and add 2 teaspoons of liquid starch. Submerge the deckle in the pulp and gently shake it until you have an even covering on top of the screen. Lift the deckle above the water level and let it drain off. (If the new paper on top of the screen is too thick, take some pulp out of the tub. If the paper is thin, add more pulp and re-stir.) When the deckle stops dripping completely, carefully place one edge along an edge of fabric and gently ease the paper out of the deckle on top of the fabric. Press out as much water as possible with the sponge. Make sure the paper has come apart completely from the deckle. Stack the fabric and paper pieces on a cookie sheet. Put a piece of fabric on top of the top sheet of paper and cover the pile with another cookie sheet. Press well to remove any remaining water. Gently separate the sheets of paper and hang them in the

sun, or lay them on sheets of newspaper, until they are dry.

What's going on?
Paper is made from plant fibers — old rags, trees. By chopping up the paper, you are recycling the fibers in the old paper to make new paper. The liquid starch helps to prevent inks from soaking into the paper fibers.

For more information on making paper, see http://www.pioneerthinking.com.

For more information, see **Rough Science** episode 1: "Mapping it Out"

Make Botanical Noisemakers

You don't want anyone to miss the fun! Let everyone know where the party is with some rattles, shakers, and other noisemakers.

You'll need:

- dried beans, peas, rice, nuts in shells, or other dry seeds
- 2 aluminum pie plates
- empty film canisters and lids
- empty plastic bottles and lids
- craft sticks
- tape
- scissors

What you do:
Place a handful of beans, peas, nuts, or seeds between two pie plates and then tape the plates together around the edges. Use a pair of scissors to make small slits in the bottom of the canisters, and insert craft sticks through the holes. Put different amounts of rice inside the film canisters and put on the lids. Put other plant materials inside the plastic bottles. Shake them to different rhythms.

What's going on?
Sounds come from vibrations. Shaking the noisemakers causes the beans, rice, or other plant materials to hit against the pie plates and vibrate, thus creating sound.

Activity adapted from Jill Frankel Hauser and Loreta Trezzo Brare. Kid's Crazy Concoctions. *Williamson Publishing, 1998.*

For more information, see **Rough Science** episode 6: "The Science of Celebration"

Make Ice Cream

What's a tropical party without ice cream? Take the temperature down a degree or two by making your own chocolate ice cream.

You'll need:

- cream
- milk
- ice cubes
- dish towel
- cocoa powder
- tablespoon
- salt

- glass
- large bowl

What you do:
In the glass, mix one spoon of cocoa powder, two spoonfuls of milk, and one spoonful of cream. Put some ice in the bowl and cover it with lots of salt. Put the glass on top of the ice and pack ice around the glass. Cover all the ice with salt. Place the dish towel over the bowl and leave the ice cream mixture to set for an hour. Voilá — delicious chocolate ice cream!

What's going on?
The salt lowers the freezing temperature of the ice. This actually makes the ice colder. The ice absorbs heat from the ice cream mixture. The ice cream gets colder and colder until it eventually freezes.

How about using flavors other than chocolate? Lemon, vanilla, orange, or raspberry?

For more information, see **Rough Science** episode 10: "Sustenance and Sayonara"

Make Lemon or Orange Soda

Throwing a party is thirsty work! You'll need something to quench your thirst and give you the energy to keep dancing all night. Make a refreshing soda from a few simple ingredients.

You'll need:

- a lemon or orange
- a glass
- water
- sugar
- 1 teaspoon baking soda

What you do:
Squeeze a lemon or orange and put the juice in the glass. Add an equal volume of water and some sugar till your drink tastes sweet enough. Stir in the baking soda and stand back as your drink fizzes.

What's going on?
Baking soda is a chemical compound called a carbonate. Lemon and orange juices contain acids. When a carbonate and an acid are mixed, they produce a salt. Baking soda is a buffer. In the presence of an acid, carbon dioxide gas is released, producing the bubbles in your drink. A similar reaction, producing carbon dioxide, is used in certain fire extinguishers.

For more information, see **Rough Science** episode 10: "Sustenance and Sayonara"

Suggestions for other activities:

- To make sounds like a horn, recorder, drum, and whistle, make musical instruments from natural materials (willow sticks, vines, tree branches, shells, blades of grass).
- To have neat jewelry to wear, make bracelets and rings from plants.

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ROUGH SCIENCE

EXPLORE THE CHALLENGES

Sound Recording | Scale Map | Paper and Ink | Weather
Antibacterial Cream | Microscope | Transmitter and Receiver | Clocks | Kite
Ice | Thermometer | Sunblock | Recharge a Battery | Solar Distillation
Underwater Flashlight | Fireworks | Musical Instruments | Find Latitude and Longitude
Saucepan Radio | Camera | Generate Electricity | Soap

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SOLVE THE WEB CHALLENGE

Mike Bullivant needs your help! He's in danger on the other side of Carriacou. Can you use your knowledge of science to rescue him?

This adventure requires the Flash player.

GET macromedia FLASH PLAYER

Once you have Flash, start the Web Challenge.

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ROUGH SCIENCE

SITE MAP

The Challenges

Explore the Challenges

Sound Recording
Scale Map
Paper and Pen
Weather
Anti-bacterial cream
Microscope
Transmitter
Clocks
Kite
Ice
Thermometer
Sunscreen
Recharge Battery
Solar Distillation
Underwater Torch
Fireworks
Musical Instruments
Latitude and Longitude
Radio
Camera
Generate Electricity
Make Soap

Web Challenge

Solve the Web Challenge

The Scientists

Meet the Rough Scientists

Mike Bullivant
- Carriacou Diary
- Capraia Diary
- Carriacou Interview
- Capraia Interview

Vanessa Griffiths
- Capraia Diary
- Capraia Interview

Jonathan Hare
- Carriacou Diary
- Capraia Diary
- Carriacou Interview
- Capraia Interview

Mike Leahy
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- Capraia Diary
- Carriacou Interview
- Capraia Interview

Anna Lewington
- Capraia Interview

Ellen McCallie
- Carriacou Diary
- Carriacou Interview

Kathy Sykes
- Carriacou Diary
- Carriacou Interview

TV Series

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Host Kate Humble
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Local Airdates
Production Credits
About Open University
About NSF
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What is Science All About?
The Art of Science
Create Your Own Rough Science Adventure
Rough Science Museum
Adventures
Rough Science Metric Converter
Books
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Feedback

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Message Boards

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ROUGH SCIENCE

EXPLORE THE CHALLENGES

The Challenge: Make Paper and Ink

Many different plants and materials have been used to make paper and ink over the centuries. What would our scientists use from the island to make theirs and would they be able to produce a clean sheet and colored inks in just three days?

What is paper and how is it made?

Paper is made from cellulose. All plant matter is composed in part from cellulose fiber but the amount varies between plants. The reason why plant material is so suitable for making paper lies in the molecular structures of cellulose and water. Water molecules are made up of one oxygen atom and two hydrogen atoms. The hydrogen atom on one molecule can chain onto the oxygen atom of another molecule causing an effect called 'surface tension'. This chaining process is the key to making paper.

Water Molecule

How chaining works

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ROUGH SCIENCE

EXPLORE THE CHALLENGES

The Challenge: Make an Antibacterial Cream

Time to get thinking.

An antiseptic is a substance that destroys, or stops the growth of, germs on living tissue. They must be strong enough to fight germs but mild enough not to irritate sensitive tissues. Antiseptics should not be confused with disinfectants and antibiotics.

An antiseptic cream that causes the death of bacteria is called a bactericidal cream or antibacterial cream and is useful for preventing cuts, scratches and insect bites from becoming infected.

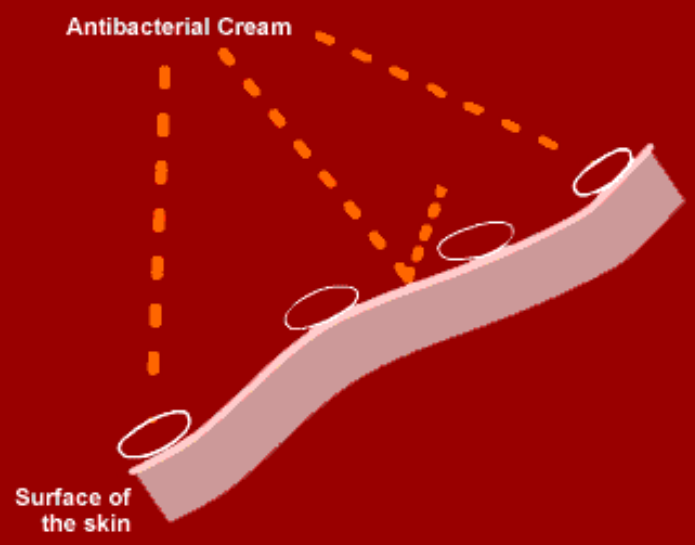

What are bacteria?

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ROUGH SCIENCE

EXPLORE THE CHALLENGES

The Challenge: Make a Microscope

Would it be possible to make a microscope on the island using just a basic array of wire, glassware, kitchen utensils and a car battery but not a clean glass lens in sight?

How does a microscope work?

Essentially, a microscope is just a lens. You can see the principle quite easily by looking through a tiny drop of water. Try balancing a water droplet on a 2mm (.078 in.) hole made in cardboard and looking through it. You'll have to get your eye very close — and the object you're looking at very close too — but it magnifies surprisingly well.

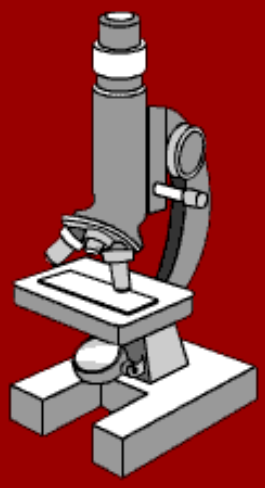

Why use glass?

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The Challenge: Make a Transmitter and Receiver

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WARNING: Most unlicensed radio broadcasts are illegal in the U.S. The following is for informational purposes only.

With just a basic tool kit, some copper wire, a piece of coke, a car battery, a bottle of rum, and some old kitchen pots and pans would we be able to transmit a signal across the island and successfully decipher the message?

What sort of signal are we going to transmit?

Since the beginning of time, people have been trying to communicate over distances greater than the human voice can travel. More rudimentary attempts included the use of smoke, fires and waving flags. Mirrors were also used to flash the image of the sun to distant objects.

After the discovery of electricity, a revolution in communication took place. Wires were stretched from one point to another and an electric current passed through them, controlled by a switch called a telegraph key. A light or buzzer could be turned on and off over great distances and using a simple code, such as the Morse system, people were able to communicate almost instantly over distances that had previously required days or weeks by horse or train.

In 1901, Marconi sent a signal across the Atlantic using the recently discovered radio waves. It paved the way for today's complex wireless communications systems such as satellites and mobile phones.

What is a transmitter?

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ROUGH SCIENCE

EXPLORE THE CHALLENGES

The Challenge: Make a kite from natural products

How does a kite fly?

Most people associate kite flying with a strong wind to get the kite into the air but most kites are designed for light breezy conditions. Although you do not need to know anything about aerodynamics to fly a kite, it helps you control your kite if you understand basic wind flow and lift. There are two main principles involved in the aerodynamics of a kite:

The first is Newton's Third Law of Motion and the second is Bernoulli's Theorem.

Newton's Third Law

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ROUGH SCIENCE

EXPLORE THE CHALLENGES

Explore the Challenges
Solve the Web Challenge
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The Challenge: Measure Latitude and Longitude

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To pinpoint your position on a map of the world you need to work out your co-ordinates, known as latitude and longitude. Latitude is your position north or south of the Equator. Lines, or parallels, are drawn around the Earth at intervals. The North Pole is assigned the latitude 90° north and the South Pole latitude 90° south.

Lines of longitude, or meridians, are drawn a little differently. The line of longitude corresponding to 0°, which passes through Greenwich in London, is called the Prime (or Greenwich) Meridian. Longitude lines run along the Earth's surface in a north-south direction, and unlike latitude lines, they divide the globe into segments like those of an orange, rather than regular strips.

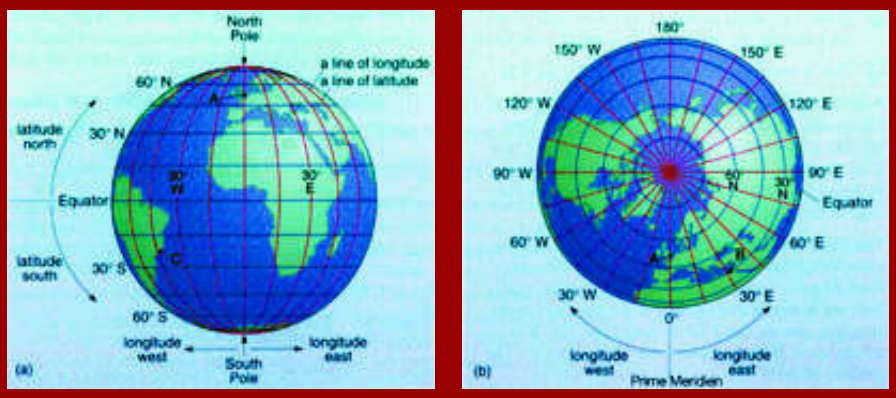

A geographical globe (a) viewed from above the Equator; (b) viewed from above the North Pole

Measuring latitude

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EXPLORE THE CHALLENGES

The Challenge: Build accurate clocks, construct a timepiece that chimes and make a portable 'watch'

To tell the time in a Rough Science environment — where we only have access to a tool kit, rope, buckets, hoses and old scrap — it is probably easiest to use the sun, a local ingredient which was thankfully in plentiful supply. The one point that is relatively easy to determine by using a sundial is local noon. But how do we make the sundial tell the time accurately, how do we get a clock to chime, and with the rough components on the island, how will we ever make a wristwatch?

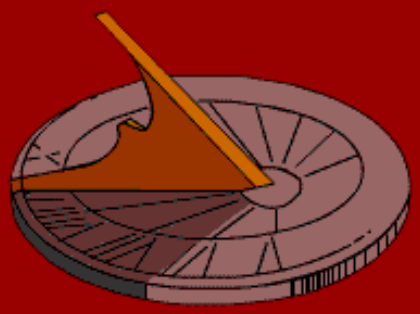

How does a clock work?

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ROUGH SCIENCE

EXPLORE THE CHALLENGES

The Challenge: Recharge a Battery

Batteries store electrical energy. Some, like conventional flashlight batteries, are used then thrown away. Others are rechargeable. On the island, we had a car battery which was used to power various pieces of Rough Science apparatus but over time the battery became discharged. We were given the challenge of recharging it.

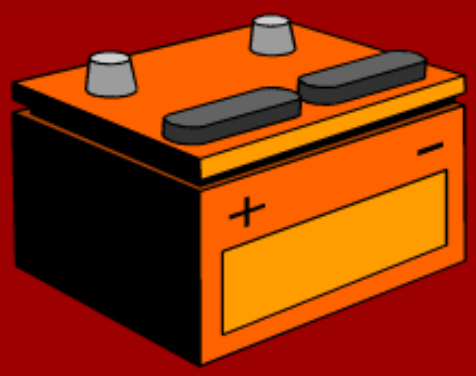

How does a battery work?

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ROUGH SCIENCE

EXPLORE THE CHALLENGES

The Challenge: Make an underwater flashlight

With access only to a basic tool kit, some reels of wire, pots and pans, rusting kitchen equipment and a car battery would we be able to make a light at all, let alone a flashlight that worked underwater?

How is light created?

Whether using fire, electricity or even a chemical reaction, you are essentially doing the same thing: giving atoms energy and getting them 'excited'. The energy absorbed by the atoms is taken up by the electrons that surround an atom's nucleus. The energy carries the electrons further away from the nucleus than normal and the atom is in an 'excited' state. When the electrons fall back to their ground state, closer to the nucleus, energy is radiated away again.

Electrons can give off different kinds of electromagnetic radiation when they fall back to their ground state but we're particularly interested in getting them to emit radiation within the visible spectrum.

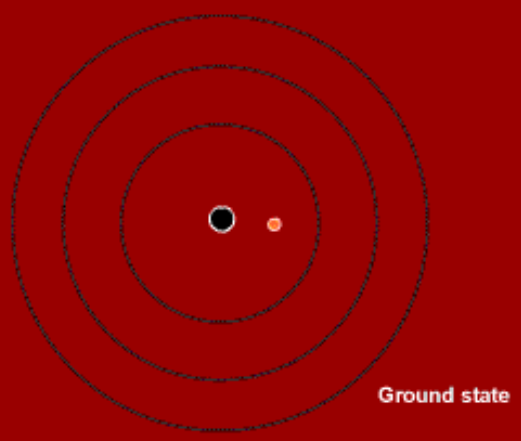

Key

Energy

Photons

Exciting the atoms

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EXPLORE THE CHALLENGES

The Challenge: Make a radio from a saucepan

Radio waves fill the space around us every second of the day. They emanate from local radio stations, mobile phones, short-wave radio transmitters around the world, and some even from satellites 36,000km (about 22,000 miles) out in space.

Radio is fundamentally about electricity and magnetism. Every time an electric current is turned on or off it creates electricity and magnetism in the form of radio waves. That's why you often hear a click on the radio when a nearby light switch is turned on or off. The radio waves radiate from the switch much like the ripples formed when a stone is dropped into a pond. Radio waves, like visible light, X-rays and microwaves, are all forms of electromagnetic radiation travelling at the speed of light — an incredible 300,000,000 meters per second (186,000 miles per second)!

A radio transmitter is simply a device that continuously produces radio waves. It uses an electric circuit that causes a current to oscillate. By varying the strength of this oscillation according to, say, the loudness of a piece of music, you can encode information about the music onto the radio waves. These encoded waves are then transmitted from an antenna and picked up by a receiver that decodes the signal so that you can hear the music again.

How a radio works

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ROUGH SCIENCE

EXPLORE THE CHALLENGES

The Challenge: Generate electricity

A generator is simply a device that converts mechanical energy (itself derived from coal, oil, natural gas, wind, water, nuclear reactions or other sources) into electrical energy. Here, we describe how to use readily available materials to make a simple generator. Although it will only be powerful enough to light a small torch bulb, it works on the same basic principles as the power station generators that supply domestic electricity.

How a Generator Works

When an electric current flows through a wire, it generates a three-dimensional magnetic force field around the wire, similar to that surrounding a bar magnet. Magnets are also surrounded by a similar three-dimensional field. This can be "seen" in two dimensions if iron filings are sprinkled on a sheet of paper placed over the magnet. The filings align themselves along the lines of magnetic force surrounding the magnet.

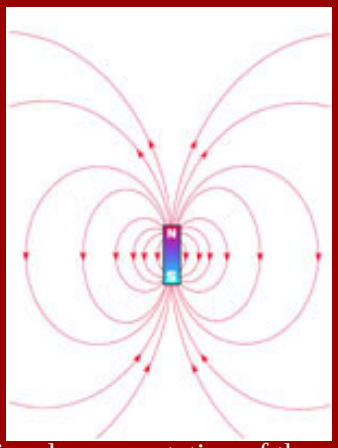

Two-dimensional representation of the magnetic field around a bar magnet. The arrows indicate the direction of the lines of magnetic force. The N (north) and S (south) indicate the poles of the magnet, where the lines of force are focused. The north pole of the magnet will repel the north pole of a compass or another bar magnet, while its south pole will attract the north pole of a compass or another bar magnet.

The simplest generator consists of just a coil of wire and a bar magnet. When you push the magnet through the middle of the coil, an electric current is produced in the wire. The current flows in one direction as the magnet is pushed in, and in the other direction as the magnet is removed. In other words, an alternating current is produced. If you hold the magnet absolutely still inside the coil, no current is generated at all. Another way of producing the current would be for the magnet to be rotated inside the coil, or for the coil to be rotated round the magnet.

This method of generating electricity, called induction, was discovered by Michael Faraday in 1831. He found that the stronger the magnets were, the more turns of wire in the coil, and the quicker the motion of the magnet or coil, the greater the voltage produced. Faraday also observed that it was more efficient if the coil was wound around a metal core, as this helped to concentrate the magnetic field.

The Rough Science generators

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EXPLORE THE CHALLENGES

The Challenge: Make Soap

In theory, you can make soap by treating almost any fat or oil with sodium hydroxide or potassium hydroxide (for a 'soft' soap). Some recipes use animal fats like tallow (from beef) or lard (from pork). Others use vegetable oils, like coconut or olive oil. Soapmaking (or saponification as the chemical reaction is called), like any chemical experiment, is sensitive to the purity of the reactants, the reaction conditions used and the care with which you carry it out.

Making soap on Capraia

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Ascariasis

From Wikipedia, the free encyclopedia

Ascariasis is a disease caused by the parasitic roundworm *Ascaris lumbricoides*.[1] Infections have no symptoms in more than 85% of cases, especially if the number of worms is small.[1] Symptoms increase with the number of worms present and may include shortness of breath and fever in the beginning of the disease.[1] These may be followed by symptoms of abdominal swelling, abdominal pain, and diarrhea.[1] Children are most commonly affected, and in this age group the infection may also cause poor weight gain, malnutrition, and learning problems.[1][2][3]

Infection occurs by eating food or drink contaminated with *Ascaris* eggs from feces.[2] The eggs hatch in the intestines, burrow through the gut wall, and migrate to the lungs via the blood.[2] There they break into the alveoli and pass up the trachea, where they are coughed up and swallowed.[2] The larvae then pass through the stomach for a second time into the intestine, where they become adult worms.[2] Ascariasis is classified as a neglected tropical disease as it is a type of soil-transmitted helminthiasis. These diseases are in turn part of a group of diseases called helminthiases.[4]

Prevention is by improved sanitation, which includes improving access to toilets and proper disposal of feces.[1][5] Handwashing with soap appears protective.[6] In areas where more than 20% of the population is affected, treating everyone at regular intervals is recommended.[1] Reoccurring infections are common.[2][7] There is no vaccine.[2] Treatments recommended by the World Health Organization are the medications albendazole, mebendazole, levamisole, or pyrantel pamoate.[2] Other effective agents include tribendimidine and nitazoxanide.[2]

About 0.8 to 1.2 billion people globally have ascariasis, with the most heavily affected populations being in sub-Saharan Africa, Latin America, and Asia.[1][8][9] This makes ascariasis the most common form of soil-transmitted helminthiasis.[8] As of 2010 it caused about 2,700 deaths a year, down from 3,400 in 1990.[10] Another type of *Ascaris* infects pigs.[1]

Ascariasis

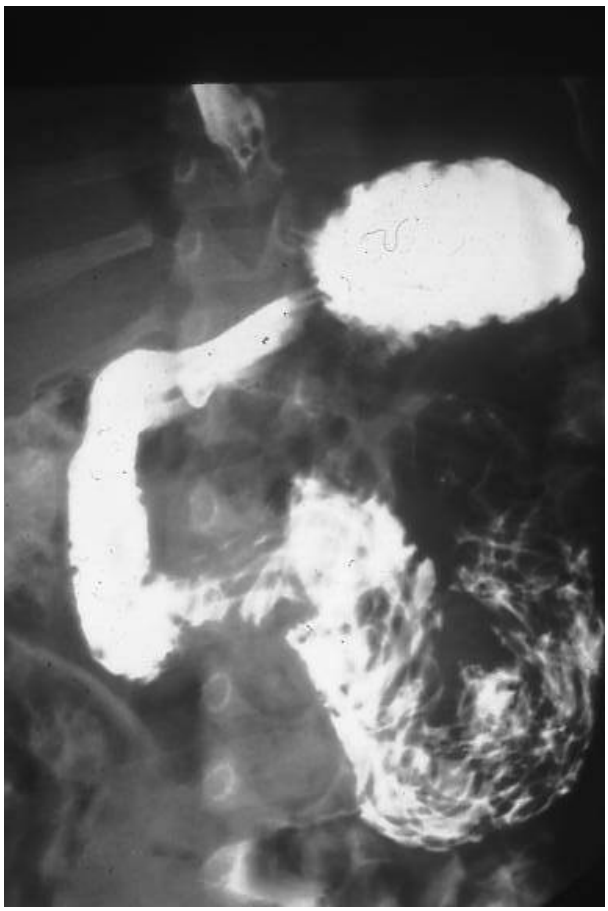

High number of ascaris worms – visible as black tangled mass – are filling the duodenum, the first portion of the bowel after the stomach, of this South African patient (X-ray image with barium as contrast medium)

Classification and external resources

Specialty	Infectious disease
ICD-10	B77 (http://apps.who.int/classifications/icd10/browse/2016/en#/B77)
ICD-9-CM	127.0 (http://www.icd9data.com/getICD9Code.ashx?icd9=127.0)
OMIM	604291 (https://omim.org/entry/604291)
DiseasesDB	934 (http://www.diseasesdatabase.com/ddb934.htm)

MedlinePlus	000628 (https://medlineplus.gov/ency/article/000628.htm)
eMedicine	article/212510 (http://emedicine.medscape.com/article/212510-overview)
MeSH	D001196 (https://www.nlm.nih.gov/cgi/mesh/2017/MB_cgi?field=uid&term=D001196)

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Signs and symptoms

Most people who are infected with only a small number of worms have no symptoms. It is common to find that most people are infected by a small number of worms, while a small number of people are heavily infected, something that is characteristic of many worm infections.[1][11] Clinical features depend on the affected body site.

Migrating larvae

As larval stages travel through the body, they may cause visceral damage, peritonitis and inflammation, enlargement of the liver or spleen, and an inflammation of the lungs. Pulmonary manifestations take place during larval migration and may present as Loeffler's syndrome, a transient respiratory illness associated with blood eosinophilia and pulmonary infiltrates with radiographic shadowing.[12]

Intestinal blockage

The worms can occasionally cause intestinal blockage when large numbers get tangled into a bolus or they may migrate from the small intestine, which may require surgery. More than 796 *A. lumbricoides* worms weighing up to 550 g [19 ounces] were recovered at autopsy from a 2-year-old South African girl. The worms had caused torsion and gangrene of the ileum, which was interpreted as the cause of death.[14]

Piece of intestine, blocked by worms, surgically removed from a 3-year-old boy in South Africa.[13]

Bowel obstruction

Bowel obstruction may occur in up to 0.2 per 1000 per year.[1] A worm may block the ampulla of Vater, or go into the main pancreatic duct, resulting in acute pancreatitis with raised serum levels of amylase and lipase. Occasionally, a worm can travel through the billiary tree and even into the gallbladder, causing acute cholangitis or acute cholecystitis.

Allergies

Ascariasis may result in allergies to shrimp and dustmites due to the shared antigen, tropomyosin; this has not been confirmed in the laboratory.[15][16]

Malnutrition

The worms in the intestine may cause malabsorption and anorexia which contribute to malnutrition.[17] The malabsorption may be due to a loss of brush border enzymes, erosion and flattening of the villi, and inflammation of the lamina propria.[18]

Others

Ascaris have an aversion to some general anesthetics and may exit the body, sometimes through the mouth, when an infected individual is put under general anesthesia.[19]

Cause

Transmission

The source of infection is from objects which have been contaminated with fecal matter containing eggs.[2] Ingestion of infective eggs from soil contaminated with human feces or contaminated vegetables and water is the primary route of infection. Infectious eggs may occur on other objects such as hands, money and furniture.[2] Transmission from human to human by direct contact is impossible.[20]

Transmission comes through municipal recycling of wastewater into crop fields. This is quite common in emerging industrial economies and poses serious risks for local crop sales and exports of contaminated vegetables. A 1986 outbreak of ascariasis in Italy was traced to irresponsible wastewater recycling used to grow Balkan vegetable exports.[21]

The number of ova (eggs) in sewage or in crops that were irrigated with raw or partially treated sewage, is a

measure of the degree of ascariasis incidence. For example:

- A 1978 study showed about 75% of all sewage sludge samples sampled in United States urban catchments contained *Ascaris* ova, with rates as high as 5 to 100 eggs per litre.
- In Frankfort, Indiana, 87.5% of the sludge samples were positive with *Ascaris*, *Toxocara*, *Trichuris*, and hookworm.
- In Macon, Georgia, one of the 13 soil samples tested positive for *Ascaris*.
- In a study published in 1992, municipal wastewater in Riyadh, Saudi Arabia detected over 100 eggs per litre of wastewater[22] and in Czechoslovakia was as high as 240–1050 eggs per litre.[23]
- In one field study in Marrakech, Morocco, where raw sewage is used to fertilize crop fields, *Ascaris* eggs were detected at the rate of 0.18 eggs/kg in potatoes, 0.27 eggs/kg in turnip, 4.63 eggs/kg in mint, 0.7 eggs/kg in carrots, and 1.64 eggs/kg in radish.[24] A similar study in the same area showed that 73% of children working on these farms were infected with helminths, particularly *Ascaris*, probably as a result of exposure to the raw sewage.

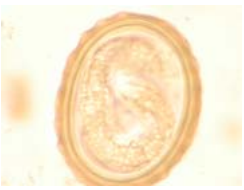

The larva of Ascaris lumbricoides developing in the egg

Ascaris lumbricoides adult worms (with measuring tape for scale)

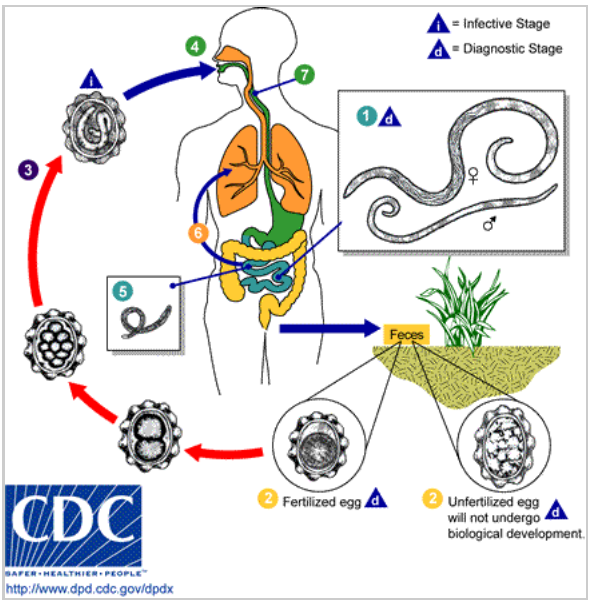

Ascaris life cycle: Adult worms (1) live in the lumen of the small intestine. A female may produce approximately 200,000 eggs per day, which are passed with the feces (2). Unfertilized eggs may be ingested but are not infective. Fertile eggs embryonate and become infective after 18 days to several weeks (3), depending on the environmental conditions (optimum: moist, warm, shaded soil). After infective eggs are swallowed (4), the larvae hatch (5), invade the intestinal mucosa and are carried via the portal, then systemic circulation and/or lymphatics to the lungs . The larvae mature further in the lungs (6) (10 to 14 days), penetrate the alveolar walls, ascend the bronchial tree to the throat, and are swallowed (7). Upon reaching the small intestine, they develop into adult worms (8). Between 2 and 3 months are required from ingestion of the infective eggs to oviposition by the adult female. Adult worms can live 1 to 2 years.

Ascaris lumbricoides adult worms

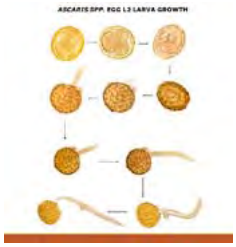

Ascaris egg, incubation process: The Ascaris egg incubation process consists in placing the egg in a controlled environment, at 26°C during 28 days, in acidic conditions. This process allows for evaluation of an egg to determine if it is viable or not, by watching the bipartition of the nucleus, and the growth of the larva.

Lifecycle

The first appearance of eggs in stools is 60–70 days. In larval ascariasis, symptoms occur 4–16 days after infection. The final symptoms are gastrointestinal discomfort, colic and vomiting, fever, and observation of live worms in stools. Some patients may have pulmonary symptoms or neurological disorders during migration of the larvae. There are generally few or no symptoms. A bolus of worms may obstruct the intestine; migrating larvae may cause pneumonitis and eosinophilia. Adult worms have a lifespan of 1–2 years which means that individuals may be infected all their lives as worms die and new worms are acquired.[11]

Eggs can survive potentially for 15 years and a single worm may produce 200 thousand eggs a day.[2] They maintain their position by swimming against the intestinal flow.[25]

Diagnosis

Most diagnoses are made by identifying the appearance of the worm or eggs in feces. Due to the large quantity of eggs laid, physicians can diagnose using only one or two fecal smears.

The diagnosis is usually incidental when the host passes a worm in the stool or vomit. The eggs can be seen in a smear of fresh feces examined on a glass slide under a microscope and there are various techniques to concentrate them first or increase their visibility, such as the ether sedimentation method or the Kato technique. The eggs have a characteristic shape: they are oval with a thick, mamillated shell (covered with rounded mounds or lumps), measuring 35-50 micrometer in diameter and 40-70 in length. During pulmonary disease,

larvae may be found in fluids aspirated from the lungs. White blood cells counts may demonstrate peripheral eosinophilia; this is common in many parasitic infections and is not specific to ascariasis. On X-ray, 15–35 cm long filling defects, sometimes with whirled appearance (bolus of worms).

Mechanism

Ascaris takes most of its nutrients from the partially digested host food in the intestine. There is some evidence that it can secrete anti-enzymes, presumably to protect itself from digestion by the hosts' enzymes. Children are often more severely affected.[1]

Prevention

Prevention is by improved access to sanitation which includes the use of properly functioning and clean toilets by all community members as one important aspect.[1] Handwashing with soap may be protective; however, there is no evidence it affects the severity of disease.[6] Eliminating the use of untreated human faeces as fertilizer is also important.

In areas where more than 20% of the population is affected treating everyone is recommended.[1] This has a cost of about 2 to 3 cents per person per treatment.[1] This is known as mass drug administration and is often carried out among school-age children.[26] For this purpose, broad-spectrum benzimidazoles such as mebendazole and albendazole are the drugs of choice recommended by WHO.[27]

Treatment

Medications

Medications that are used to kill roundworms are called ascaricides. Those recommended by the World Health Organization for ascariasis are: albendazole, mebendazole, levamisole and pyrantel pamoate.[2] Other effective agents include tribendimidine and nitazoxanide.[2] Pyrantel pamoate may induce intestinal obstruction in a heavy worm load. Albendazole is contraindicated during pregnancy and children under two years of age. Thiabendazole may cause migration of the worm into the esophagus, so it is usually combined with piperazine.

Piperazine is a flaccid paralyzing agent that blocks the response of Ascaris muscle to acetylcholine, which immobilizes the worm. It prevents migration when treatment is accomplished with weak drugs such as thiabendazole. If used by itself, it causes the worm to be passed out in the feces and may be used when worms have caused blockage of the intestine or the biliary duct.

Corticosteroids can treat some of the symptoms, such as inflammation.

Surgical intervention

In some cases with severe infestation the worms may cause bowel obstruction, requiring emergency surgery.[28] The bowel obstruction may be due to all the worms or twisting of the bowel.[28] During the surgery the worms may be manually removed.[28]

Alternative medicine

- Hexylresorcinol effective in single dose[29]
- Santonin, more toxic than hexylresorcinol[29]
- Oil of chenopodium, more toxic than hexylresorcinol[29]

Santonin is often only partly effective.[30]

Prognosis

It is rare for the infections to be life-threatening.[1]

Epidemiology

Regions

Ascariasis is common in Africa and in Southeast Asia. It also occurs in the United States including Gulf Coast.

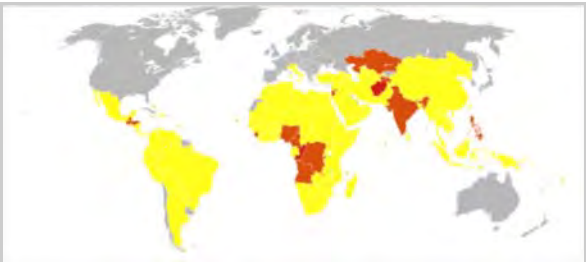

Ascariasis deaths per million persons in 2012

0-0 1-1 2-2

Infection estimates

Roughly 0.8-1.3 billion individuals are infected with this intestinal worm, primarily in Africa and Asia.[1][2][9] About 120 to 220 million of these cases are symptomatic.[1] One study indicated that the prevalence of ascariasis in the United States at about 4 million (2%).

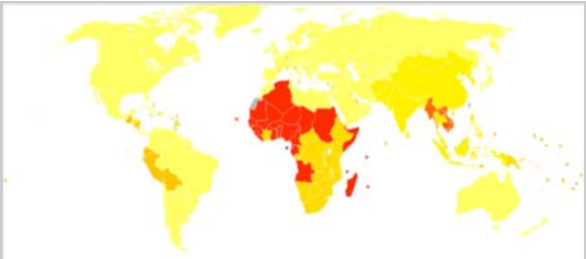

Disability-adjusted life year for ascariasis per 100,000 inhabitants in 2004.

no data
less than 10
10-20
20-30
30-40
40-50
50-60
60-80
80-100
100-120
120-140
140-150
more than 150

Deaths

As of 2010 Ascariasis caused about 2,700 directly attributable deaths, down from 3,400 in 1990.[10] The indirectly attributable deaths due to the malnutrition link may be much higher.

Research

There are two animal models, the mouse and pig, used in studying *Ascaris* infection.[31][32]

Other animals

Infections in pigs leads to poor weight gain and thus financial losses for the farmer.[1] In pigs the infection is due to *Ascaris suum*.[1] In horses and other equines, the equine roundworm is *Parascaris equorum* and the parasites are colloquially called Ascarids. A problem for young animals more than for mature ones, clinical signs include unthriftiness, potbelly, rough hair coat, and slow growth.[33]

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External links

- Image (warning, very graphic):Image 1 (http://www.sp01.com/micro/worms/imagepages/image1.htm)
- CDC *DPDx Parasitology Diagnostic Web Site* (http://www.dpd.cdc.gov/dpdx/)
- Ascariasis: Radiology (http://rad.usuhs.mil/medpix/medpix_cow.html?mode=quiz&pt_id=12877&quiz=yes#top) and color pathology pictures (http://rad.usuhs.edu/medpix/medpix_cow.html?mode=quiz&quiz=no&map=&imid=48240&page=#top) from MedPix
- Discussion of Ascaris (http://www.microbeworld.org/index.php?option=com_content&view=article&id=854:twip-21-the-giant-intestinal-worm-ascaris-lumbricoides&catid=99:this-week-in-parasitism&Itemid=259) on the "This week in Parasitism" Podcast (http://itunes.apple.com/podcast/this-week-in-parasitism/id340512495)

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Categories: Helminthiases | Foodborne illnesses | Ascaridida | Neglected diseases | Conditions diagnosed by stool test

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Strongyloides stercoralis

From Wikipedia, the free encyclopedia

Strongyloides stercoralis is a human pathogenic parasitic roundworm causing the disease strongyloidiasis. Its common name is **threadworm**. In the UK and Australia, however, the term *threadworm* can also refer to nematodes of the genus *Enterobius*, otherwise known as pinworms.[1]

The *Strongyloides stercoralis* nematode can parasitize humans. The adult parasitic stage lives in tunnels in the mucosa of the small intestine. The genus *Strongyloides* contains 53 species,[2][3] and *S. stercoralis* is the type species. *S. stercoralis* has been reported in other mammals, including cats and dogs. However, it seems that the species in dogs is typically not *S. stercoralis*, but the related species *S. canis*. Non-human primates are more commonly infected with *S. fuelleborni* and *S. cebus*, although *S. stercoralis* has been reported in captive primates. Other species of *Strongyloides*, naturally parasitic in humans, but with restricted distributions, are *S. fuelleborni* in central Africa and *S. kellyi* in Papua New Guinea.

Threadworm

First stage larva (L1) of *S. stercoralis*

Scientific classification

Kingdom:	Animalia
Phylum:	Nematoda
Class:	Secernentea
Order:	Rhabditida
Family:	Strongyloididae
Genus:	*Strongyloides*
Species:	***S. stercoralis***

Binomial name

Strongyloides stercoralis

Bavay, 1876

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Geographic distribution

S. stercoralis has a very low prevalence in societies where fecal contamination of soil or water is rare. Hence, it is a very rare infection in developed economies. In developing countries, it is less prevalent in urban areas than in rural areas (where sanitation standards are poor). *S. stercoralis* can be found in areas with tropical and subtropical climates.[4]

Strongyloidiasis was first described in the 19th century in French soldiers returning home from expeditions in Indochina. Today, the countries of the old Indochina (Vietnam, Cambodia, and Laos) still have endemic

strongyloidiasis, with the typical prevalences being 10% or less. Regions of Japan used to have endemic strongyloidiasis, but control programs have eliminated the disease. Strongyloidiasis appears to have a high prevalence in some areas of Brazil and Central America. It is endemic in Africa, but the prevalence is typically low (1% or less). Pockets have been reported from rural Italy, but current status is unknown. In the Pacific islands, strongyloidiasis is rare, although some cases have been reported from Fiji. In tropical Australia, some rural and remote Australian Aboriginal communities have very high prevalences of strongyloidiasis.[5]

In some African countries (e.g., Zaire), *S. fuelleborni* was more common than *S. stercoralis* in parasite surveys from the 1970s, but current status is unknown. In Papua New Guinea, *S. stercoralis* is endemic, but prevalence is low. However, in some areas, another species, *S. kellyi*,[6] is a very common parasite of children in the New Guinea Highlands and Western Province.[6]

Knowledge of the geographic distribution of strongyloidiasis is of significance to travelers who may acquire the parasite during their stays in endemic areas.

Because strongyloidiasis is transmittable by textiles, such as bedclothes and clothing, care must be taken never to use hotel bed sheets in endemic areas. Personal sleeping bags and using plastic slippers when showering are very important when travelling in tropical regions.

Life cycle

The strongyloid's life cycle is heterogonic—it is more complex than that of most nematodes, with its alternation between free-living and parasitic cycles, and its potential for autoinfection and multiplication within the host. The parasitic cycle is homogenic, while the free-living cycle is heterogonic. The heterogonic life cycle is advantageous to the parasite because it allows reproduction for one or more generations in the absence of a host.

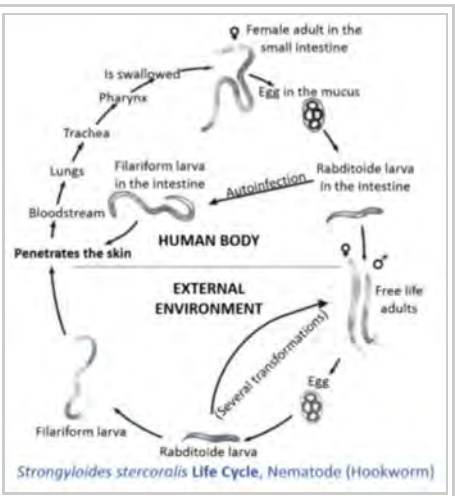

Life Cycle of *Strongyloides stercoralis* inside and outside of the human body

In the free-living cycle, the rhabditiform larvae passed in the stool can either molt twice and become infective filariform larvae (direct development) or molt four times and become free-living adult males and females that mate and produce eggs from which rhabditiform larvae hatch. In the direct development, first-stage larvae (L1) transform into infective larvae (IL) via three molts. The indirect route results first in the development of free-living adults that mate; the female lays eggs, which hatch and then develop into IL. The direct route gives IL faster (three days) versus the indirect route (seven to 10 days). However, the indirect route results in an increase in the number of IL produced. Speed of development of IL is traded for increased numbers. The free-living males and females of *S. stercoralis* die after one generation; they do not persist in the soil. The latter, in turn, can either develop into a new generation of free-living adults or develop into infective filariform larvae. The filariform larvae penetrate the human host skin to initiate the parasitic cycle.

The infectious larvae penetrate the skin when it contacts soil. While *S. stercoralis* is attracted to chemicals such as carbon dioxide or sodium chloride, these chemicals are not specific. Larvae have been thought to locate their hosts via chemicals in the skin, the predominant one being urocanic acid, a histidine metabolite on the uppermost layer of skin that is removed by sweat or the daily skin-shedding cycle.[7] Urocanic acid concentrations can be up to five times greater in the foot than any other part of the human body. Some of them

enter the superficial veins and are carried in the blood to the lungs, where they enter the alveoli. They are then coughed up and swallowed into the gut, where they parasitise the intestinal mucosa of the duodenum and jejunum. In the small intestine, they molt twice and become adult female worms. The females live threaded in the epithelium of the small intestine and, by parthenogenesis, produce eggs, which yield rhabditiform larvae. Only females will reach reproductive adulthood in the intestine. Female strongyloids reproduce through parthenogenesis. The eggs hatch in the intestine and young larvae are then excreted in the feces. It takes about two weeks to reach egg development from the initial skin penetration. By this process, *S. stercoralis* can cause both respiratory and gastrointestinal symptoms. The worms also participate in autoinfection, in which the rhabditiform larvae become infective filariform larvae, which can penetrate either the intestinal mucosa (internal autoinfection) or the skin of the perianal area (external autoinfection); in either case, the filariform larvae may follow the previously described route, being carried successively to the lungs, the bronchial tree, the pharynx, and the small intestine, where they mature into adults; or they may disseminate widely in the body. To date, occurrence of autoinfection in humans with helminthic infections is recognized only in *Strongyloides stercoralis* and *Capillaria philippinensis* infections. In the case of *Strongyloides*, autoinfection may explain the possibility of persistent infections for many years in persons not having been in an endemic area and of hyperinfections in immunodepressed individuals.

Morphology

Whereas males grow to only about 0.9 mm (0.04 in) in length, females can grow from 2.0 to 2.5 mm (0.08 to 0.10 in). Both sexes also possess a tiny buccal capsule and cylindrical esophagus without a posterior bulb.[8] In the free-living stage, the esophagi of both sexes are rhabditiform. Males can be distinguished from females by two structures: the spicules and gubernaculum.

Autoinfection

An unusual feature of *S. stercoralis* is autoinfection. Only one other species in the *Strongyloides* genus, *S. felis*, has this trait. Autoinfection is the development of L1 into small infective larvae in the gut of the host. These autoinfective larvae penetrate the wall of the lower ileum or colon or the skin of the perianal region, enter the circulation again, travel to the lungs, and then to the small intestine, thus repeating the cycle. Autoinfection makes strongyloidiasis due to *S. stercoralis* an infection with several unusual features.

Persistence of infection is the first of these important features. Because of autoinfection, humans have been known to still be infected up to 65 years after they were first exposed to the parasite (e.g., World War II or Vietnam War veterans). Once a host is infected with *S. stercoralis*, infection is lifelong unless effective treatment eliminates all adult parasites and migrating autoinfective larvae.

Symptoms

Many people infected are asymptomatic at first. Symptoms include dermatitis: swelling, itching, larva currens, and mild hemorrhage at the site where the skin has been penetrated. Spontaneous scratch-like lesions may be seen on the face or elsewhere. If the parasite reaches the lungs, the chest may feel as if it is burning, and wheezing and coughing may result, along with pneumonia-like symptoms (Löffler's syndrome). The intestines could eventually be invaded, leading to burning pain, tissue damage, sepsis, and ulcers. Stools may have yellow mucus with a recognizable smell. Chronic diarrhea can be a symptom.[9] In severe cases, edema may result in obstruction of the intestinal tract, as well as loss of peristaltic contractions.[10]

Strongyloidiasis in immunocompetent individuals is usually an indolent disease. However, in

immunocompromised individuals, it can cause a hyperinfective syndrome (also called disseminated strongyloidiasis) due to the reproductive capacity of the parasite inside the host. This hyperinfective syndrome can have a mortality rate close to 90% if disseminated.[11][12][13]

Immunosuppressive drugs, especially corticosteroids and agents used for tissue transplantation, can increase the rate of autoinfection to the point where an overwhelming number of larvae migrate through the lungs, which in many cases can prove fatal. In addition, diseases such as human T-lymphotropic virus 1, which enhance the Th1 arm of the immune system and lessen the Th2 arm, increase the disease state.[12] Another consequence of autoinfection is the autoinfective larvae can carry gut bacteria back into the body. About 50% of people with hyperinfection present with bacterial disease due to enteric bacteria. Also, a unique effect of autoinfective larvae is larva currens due to the rapid migration of the larvae through the skin. Larva currens appears as a red line that moves rapidly (more than 5 cm or 2 in per day), and then quickly disappears. It is pathognomonic for autoinfective larvae and can be used as a diagnostic criterion for strongyloidiasis due to *S. stercoralis*.

Diagnosis

Locating juvenile larvae, either rhabditiform or filariform, in recent stool samples will confirm the presence of this parasite.[14] Other techniques used include direct fecal smears, culturing fecal samples on agar plates, serodiagnosis through ELISA, and duodenal fumigation. Still, diagnosis can be difficult because of the day-to-day variation in juvenile parasite load.

Treatment

Ideally, prevention, by improved sanitation (proper disposal of feces), practicing good hygiene (washing of hands), etc., is used before any drug regimen is administered.

Ivermectin is the drug of first choice for treatment because of higher tolerance in patients.[5] Thiabendazole was used previously, but, owing to its high prevalence of side effects (dizziness, vomiting, nausea, malaise) and lower efficacy, it has been superseded by ivermectin and as second-line albendazole. However, these drugs have little effect on the majority of these autoinfective larvae during their migration through the body. Hence, repeated treatments with ivermectin must be administered to kill adult parasites that develop from the autoinfective larvae. This means at least two weeks treatment, then a weeks pause, then again treatment. Follow-up treatment and blood tests are necessary for decades following infection.

In the UK, mebendazole and piperazine are currently (2007) preferred.[15] Mebendazole has a much higher failure rate in clinical practice than albendazole, thiabendazole, or ivermectin.[16]

Chemoattractant

This parasite depends on chemical cues to find a potential host. It uses sensor neurons of class AFD to identify cues excreted by the host.[17]*S. stercoralis* is attracted to nonspecific attractants of warmth, carbon dioxide, and sodium chloride. Urocanic acid, a component of skin secretions in mammals, is a major chemoattractant. Larvae of *S. stercoralis* are strongly attracted to this compound.[7] This compound can be suppressed by metal ions, suggesting a possible strategy for preventing infection.

See also

- Larva currens
- List of parasites (human)

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External links

- Overview of taxonomy of *Strongyloides* genus (http://www.jcu.edu.au/school/phtm/PHTM/ss/speare-taxonomy-1989.pdf).

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Categories: Rhabditida | Parasitic nematodes | Parasites of mammals | Conditions diagnosed by stool test

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Trichinella

From Wikipedia, the free encyclopedia

Trichinella is the genus of parasitic roundworms of the phylum Nematoda that cause trichinosis (also known as trichinellosis). Members of this genus are often called **trichinella** or **trichina worms**. A characteristic of Nematoda is the one-way digestive tract, with a pseudocoelom (body cavity made up of only an ectoderm and endoderm).

The genus was first recognised in a larval form in 1835. The L1 larvae live in a modified skeletal muscle cell. The adult worms occupy a membrane-bound portion of columnar epithelium, living as intramulticellular parasites. Infections with this genus have been reported from more than 150 different naturally or experimentally infected hosts. It has been shown to have a worldwide distribution in domestic and/or sylvatic animals.

Trichinella is known as the smallest human nematode parasite, yet it is also the largest of all intracellular parasites.

Oral ingestion of larvae-contaminated tissue is the usual route of infection, but congenital and mammary transmission can occur in rats.[1]

Trichinella

Scientific classification

Kingdom:	Animalia
Phylum:	Nematoda
Class:	Adenophorea
Order:	Trichocephalida
Family:	Trichinellidae
Genus:	***Trichinella*** Railliet, 1895

Species

Trichinella britovi
Trichinella murrelli
Trichinella nativa
Trichinella nelsoni
Trichinella papuae
Trichinella pseudospiralis
Trichinella spiralis
Trichinella zimbabwensis

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- 2 Prevalence in animals and humans
  - 2.1 Treatment
  - 2.2 Prevention
- 3 References

Phylogenetics

Eight species are currently recognized. Four additional genotypes require adequate description before they can be recognized as valid species.

Two main clades are recognized in the genus: one group (*T. britovi*, *T. murrelli*, *T. nativa*, *T. nelsoni*, *T. spiralis*) that encapsulates in host muscle tissue and a second (*T. papuae*, *T. pseudospiralis*, *T. zimbabwensis*) that does not.

The nonencapsulated group infects saurians, crocodilians, and other nonavian archosaurs (*T. papuae*, *T. zimbabwensis*) and birds (*T. pseudospiralis*). The encapsulated group infects synapsid and mammalian hosts. *T.*

spiralis and *T. nelsoni* appear to be basal in the encapsulated group and *T. murrelli* and *T. nativa* the most recently evolved.

Prevalence in animals and humans

Trichinella species can infect swine, horses, wild animals (foxes, wolves, bears, skunk, raccoons, rats, and other small mammals), and humans.

A microscope for *Trichinella* detection (from 1847).

In swine, the prevalence varies from country to country, and regionally. Long-standing meat inspection programs in some European countries have drastically lowered prevalence rates among domestic swine. Domestic swine can be exposed to the parasite by:

- Feeding of animal waste products or other feed contaminated with *Trichinella*
- Exposure to infected rodents or other infected wildlife
- Cannibalism within an infected herd

In wild animals, *Trichinella* infection rates vary from region to region and seem to increase in colder climates. Foxes, wolves, and bears have the highest infection rates, but small mammals, such as skunks, raccoons, and rats, provide the highest risk to infecting the domestic pig. In horses, natural infections are rare; however, infected horses from Mexico and Romania have been identified.

Human infection caused by the domestic pig varies from country to country. While some countries do not report any human infection, other countries in Eastern Europe and Asia report hundreds or thousands of cases annually.

The United States reported 25 cases per year from 1991–1996, with few implicating raw or undercooked pork. Documented sources of human infection have also included game meats, such as wild boar, bear, walrus, fox, and cougar. During 1997–2001, meats other than pork were the most common source of infection, with more cases associated with home-raised pork than commercial. The decreased incidence of trichinellosis in the United States has resulted from changes in pork industry management standards and government regulations.[2]

In Finland, meat inspection revealed a small but worrisome number of swine infections in the early 1980s, peaking in 1996. However, due to the swine industry's modernization process, the number of cases decreased, with the last infected swine diagnosed in 2004. As of 2005, only eight known human infections were reported in Finland since the 1800s, with the last one more than three decades ago.[3]

A study of the sera from 197 wild boars from 25 farms slaughtered in Finland between 2007 and 2008 found four (2.0%) of the sera, originating from three (12.0%) farms, to be *Trichinella*-seropositive.[4]

Trichinosis is often diagnosed in humans once the larvae invade the muscle tissue. Some symptoms include fever, myalgia, malaise, and edema. Trichinosis treatment focuses on reducing inflammation, and corticosteroids are usually administered. This treatment often leads to complete recovery, but muscle pain and weakness may persist.

Treatment

Treatment is by either thiabendazole or mebendazole.

Prevention

Cooking pork meat properly or by freezing pork, *Trichinella* infection can be prevented. However, freezing pork is not an effective method for killing larvae.

One way to prevent trichinellosis is to cook meat to safe temperatures (145 °F and a three-minute rest for fresh pork).[5] A food thermometer should be used to measure the internal temperature of cooked meat. Do not sample meat until it is cooked.

To help prevent *Trichinella* infection in animal populations, do not allow pigs or wild animals to eat uncooked meat, scraps, or carcasses of any animals, including rats, which may be infected with *Trichinella*,[6] which helps break the oral ingestion route of infection.

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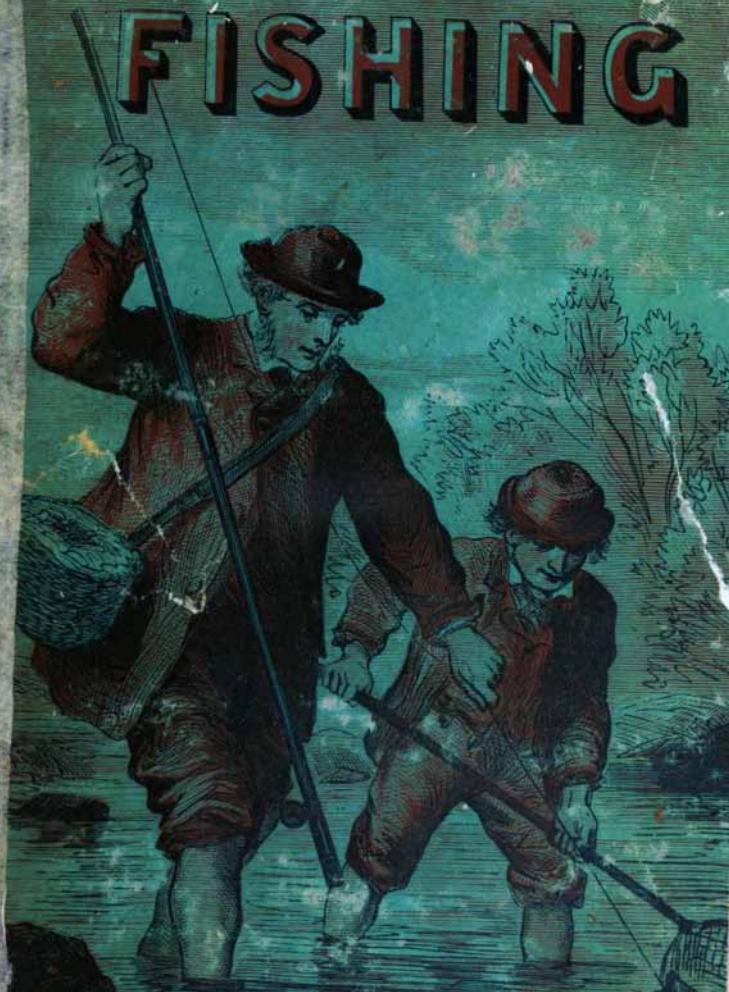

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A Monthly Magazine.

"Where sticklebacks and minnows
Each day I caught in store,
With stone-roaches and miller's thumbs;—
These brooks afford no more.

"But I a little angler,
With crooked pin for hook,
Would shun each noisy wrangler,
To fish the little brook."

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WHAT can be more delightful than angling? Not indeed so much on account of the fish we may catch, but for the pleasantness of the recreation itself, for the cool streams, the shady trees, the little sunny nooks, the tiny or gigantic cascades, the meandering rills, the still pools, "with sedges overhung;" the picturesque mill-wheels, the deep mill-ponds, "smooth sheeted by the flood;" and above all, for the hair-breadth escapes, for the duckings, for the hazards, for the triumphs. Ah, I do not wonder at boys being fond of angling, it is almost an instinct with them, and has long been a favourite amusement with boys of all degrees, ages and constitutions. Therefore we shall be somewhat comprehensive in our notices of this

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interesting sport, that every boy who can bait a hook and hold a line may be an angler if he will.

A WORD ABOUT FISH.

First, however, let us say a word about fish in general, before we come to fish in particular. Fish or fishes are, to speak scientifically, a class of vertebrated animals (*i.e.*, having a backbone) inhabiting the water; which breathe through the medium of that fluid by means of branchiæ or gills, instead of lungs; which swim by means of fins, and are mostly covered with scales. They are also generally furnished with a white membraneous bag close to the backbone, called the air bladder, by the dilatation or compression of which it is supposed they can rise or sink in the water at pleasure. All parts of their bodies seem to aid them in swimming in the water; their fins, their tails, and the undulation of their backbones assist progression, and their whole structure is as much adapted for swimming as that of a bird is for flight.

The fins of fish consist of thin elastic membrane, supported by bony rays, and are denominated according to their position—*dorsal* on the back, *pectoral* on the breast, *ventral* near the vent, *anal* that between the vent and the tail, and *caudal* the tail fins. The dorsal and ventral fins appear to balance the fish, and the pectoral to push it forward; while the tail fins are the grand instruments of motion, and enable the creature to dart forward almost as rapidly as the bullet from a gun.

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With regard to the senses of fishes, the eye holds the first place; but this is best adapted for seeing under water. Of the organ of hearing there is no outward sign. The organ of taste is thought to be very unsensitive, and the power of touch but slightly developed. To preserve their own existence, and to transmit it to their posterity, seems to be their only enjoyment; and they move forward in pursuit of whatever they can swallow, conquer, or enjoy, and their insatiable appetite impels them to encounter every danger, and to their rapacity there seems to be no bound. A single pike has been known to devour a hundred roaches in three days. The fecundity of fish is prodigious. The number of eggs in the codfish often amounts to more than three millions; those of flounders above a million, of the mackerel 500,000, of the sole 100,000, and of the lobster 20,000; but the salmon is far more productive than any of these, as it has been known to have more than twenty millions of eggs!

Without saying any more about "Fish in the abstract," as the angler called his "catch," when he returned without one, we must go to the art of "catching fish;" and the first thing to be attended to is the necessary fishing apparatus, which may be increased to any extent; but the *young* angler would be wise to limit his stock as much as possible. I have fished many hundred miles of water, and killed many a thousand of fish, with no better equipment than this:—One rod of about fourteen feet long, with three tops—one stiff top, for bottom fishing and trolling, and

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two for fly-fishing. Two reels or winches, one holding a silk and hair line of thirty-five yards in length for fly-fishing, and the other holding a similar line of forty yards, but much stronger, for bottom fishing, trolling, &c. One moderate-sized creel, or fishing-basket. One oblong tin box, about eight inches long, four inches deep, and six inches wide, divided into two compart-

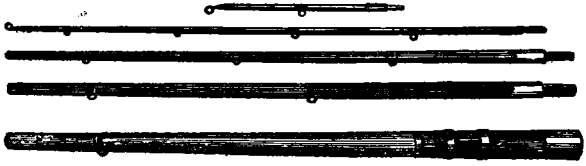

ments at the centre, the lids opening each way, and pierced with holes, which serves to carry dead minnows and ground bait. A landing net; some shoemakers' wax in a piece of soft leather; a large clasp-knife; a pair of sharp-pointed scissors; a pocket-book, the centre filled with leaves of flannel to hold flies, and the remainder fitted up with gut, hooks, silk, baiting needles, a pair of small pliers, split shot, floats, &c.

ABOUT THE ROD.

The angle rod is a material article in the young angler's catalogue, and much care should be taken to procure a good one. The fishing-tackle shops keep a great variety, made of bamboo cane, hazel, hickory, and other kinds of wood. Rods are of different lengths, some fitted as walking-canes, and others are

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made to pack in canvas bags; the latter are to be preferred, because you may have them of any length, and they are made more true. Those made of bamboo cane are best for angling near towns. But the rods made of the white cane are much superior for fine fishing, particularly for roach, being very light in weight, but stiff.

CHOOSING THE ROD.

In choosing a rod (not a school rod, for no one likes to choose that), observe that it is perfectly straight, when all the joints are put together, and that it gradually tapers from the butt to the top, and is from twelve to sixteen feet long. A bad rod is likely to snap in striking a heavy fish. Rods fitted with several tops all packing together, are at once the best and most convenient. Some anglers have one rod for trolling, another for barbel, perch, or other heavy fish, as well as those for fly-fishing—which boys may have when they become men—but a thoroughly good rod will suit the juvenile for all purposes. I have now one with which I can fish from a bleak to a pike, by only changing the top and second joints.

A good trolling rod should be made of the choicest stout and well-seasoned bamboo cane, about sixteen feet in length. When trolling with the gorge or live-bait fishing, a long rod is necessary, to enable the angler to drop in his baited hook over high sedges, rushes, &c., as also when the water is bright, for he should then keep as far away from it as he can, which

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a long rod enables him to do while dipping, casting, or spinning his bait. If either a jack or pike see him, it is very rare, indeed, that he will take the bait; and again, with a long rod you will be able to drop your baited hook in some very likely place for jack or pike, such as a small hole, division or clear place among a bed of weeds, in a river or any other water where there are many weeds.

There is some difference of opinion among anglers about the number of rings necessary for *trolling rods:* those who have their line on a thumb winder, or on a bank runner, seldom place more than two or three rings on their rod, and others have only one large ring at the top; but if a winch is used, there should be a ring to every joint except the butt,—that is, fasten the winch to the butt about a foot from the bottom, and let that joint be without a ring—each ring made of double twist wire, fixed so as always to stand out, and nearly large enough to admit the top of your little finger; the top joint should have two rings, the top one nearly three times the size of the others; this prevents any obstruction of the line running, which is of material consequence. When not in use, rods should be kept nicely stowed in a moderately dry place, and they ought to be well scraped and re-varnished every three years; should the joints become loose by shrinking, they should be slightly moistened. Should any accident befall a rod while fishing, and should you not have a spare top with you, your only remedy will be to splice your rod. To do this the broken pieces must be cut in a slanting direction, so

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as to fit each other, then stuck together by a thin coating of the marine glue, and tightly wrapped round with waxed silk, or very strong yellow hempen twine.

LINES OR BOTTOMS.

Next to the rod the line is of the utmost importance. Good lines should be well twisted. The twisted lines should be made wholly of silk, or silk and hair, but those made of gut are the strongest and best for young anglers; the twisted hair are the cheapest, and the single horsehair the finest. The young angler will find a line of about four yards in length the most useful. A single hair line, with a small porcupine float, is commonly used for general fishing; the plaited silk lines are the best for trolling, and are less inclined to break or tangle than the twisted.

SHOTTING THE LINE.

The line must be shotted, that the float may partially sink in the water; and in putting on the shots, place them all together within three inches of the bottom loop of the line; to which loop fix the loop of the hair or gut to which the hook is tied. Place two small shots, the smaller the better, about two inches from the hook, which will cause the bait to swim well and steadily, and the rest above the first loop. When you place shot on the line, do it with a pair of pliers, which is the best and easiest method; some boys fasten them with their teeth, which is a bad and ungentlemanly practice, and they often bite the gut

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through, which causes delay and vexation. When you make a line of silk, gut, or hair, remember it must be always finest at the bottom, where the hook is fastened, very gradually increasing in thickness to the top.

THE FLOAT.

There are various kinds of floats, each adapted for different kinds of fishing. The principal are: 1. Tip-capped floats; 2. Cork floats; 3. Plugged floats. The tip-capped floats are made of several pieces of quills, or of reed for the middle, and ivory or tortoise-shell for the top and bottom, and narrow at each end, gradually increasing in circumference to the middle. They are superior to all others for angling in waters which are not very rapid, particularly in roach fishing, as the least movement or fine bite sinks it below the water. The tip-capped float is also best for pond fishing for carp and trench, as it requires but few shot to sink it, and consequently disturbs the water but little when cast. The young angler should note that the caps which fix the lines to the float are not rough at the edge, as this roughness chafes and weakens a fine line; should this be the case, he should smooth them before use.

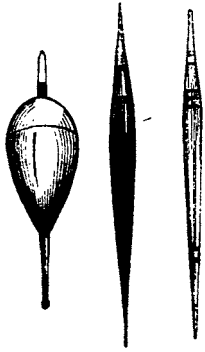

Cork Floats are generally made of quills at the top, with a piece of cork, which is burned or bored in the

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middle to admit the quill, and then filed or ground down smooth and painted. The bottom is plugged with wood, and has a ring to let the line pass through. Cork floats are well calculated to fish in heavy or rapid streams, as they require a great many shot to sink them, which weight of shot prevents the baited hook from passing too rapidly over the bottom. Cork floats are made of various sizes and forms; instead of common quills, some introduce the quills of the porcupine, which make an excellent strong float.

Plugged Floats.—These kind of floats are the cheapest, and made of indifferent quills, some of them of one goose quill with a wooden plug at the bottom, from which they take their name; they are very apt to loosen by the plug coming out. They are often used by the young angler, because they are cheap; but we may say in the words of the ancient Roman "Bad is the best."

REELS, OR WINCHES.

A reel, or winch, is a most necessary addition to the rod and line, as it enables you to vary the length of your line at pleasure, and to play your fish. The best winches are those to fix in a groove on the rod, and are fastened with brass ferrules made for the purpose on the butt, because you can fasten such a winch to any sized joint.

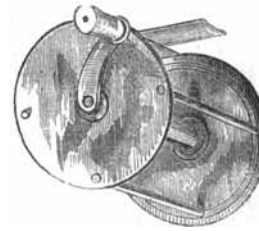

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There are two kinds of winches, multipliers and plain : the multiplying winch is the most useful, as long as it lasts, but is apt soon to get out of order, unless carefully used and constantly oiled, and care be taken that no sand or gravel is allowed to get into it ; but as young anglers are seldom very careful in such points as these, I would recommend them at first, to purchase a plain and strong winch, which will answer every purpose, and be much less expensive.

REEL LINES

Are mostly made of silk and horsehair, twisted or plaited together, but some are made entirely of silk. I prefer, however, a *plaited* silk and hair line, as it is less likely to twist, runs more freely, and is less likely to rot. The length of lines vary from fifteen to eighty yards ; but for general purposes twenty or five-and-twenty yards is quite long enough, The line should always be unwound after a day's fishing, as, if it is allowed to remain wet on the reel, it soon rots.

HOOKS.

Hooks are to be bought at the "angling shops," of all sizes, and suitable for the kind of fish to be caught. There is a great controversy among adept anglers about hooks, which is sometimes as violent as those upon politics or religion. Some anglers prefer what are called the Limerick hooks, some the Kendal ; while others again prefer the Kirby or Sneckbend. We are hooked to the Kirby, as we consider those to

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be best for holding the fish—a most important particular. The hooks found most suitable for the following fish are these :—

Barbel, 1, 7, 8, 9.
Bleak, 11, 12, 13.
Bream, 10.
Carp, 7, 8, 9.
Chub, 8, 9.
Dace, 10, 11, 12.
Eels, 8.
Flounders, 3.
Grayling, 10, 12.
Gudgeon, 9, 10.
Loaches, 13.
Miller's Thumb, 13.
Minnow, 13.
Perch, 7.
Roach, 10, 11, 12.
Rudd, 10.
Ruffe, 10.
Smelt, 9, 10.
Tench, 9, 10.
Trout, 6, 10.

HOW TO BAIT A HOOK.

To bait a hook with a worm, use the following method : First enter the point of the hook close to the top of the worm's head, and carry it carefully down to within a quarter of an inch of its tail ; to do which you must gently squeeze or work up the worm with your left thumb and finger, while with your right you are gradually working the hook downwards. The small lively piece of the worm at the point of the hook moving about will entice the fish ; but mind, if too much of the worm hangs loose, though it may entice fish to nibble, yet they will seldom take the whole in their mouth, so as to enable the angler to hook them ; on the contrary, he is frequently tantalized with a bite, and, when he strikes, finds part of his worm "bolted," the hook "innocent," and the fish "non est." Therefore, to bait a hook well with a worm is necessary to insure hitting a fish when you strike ; and it consists in drawing the worm without injuring it (use him as you would a friend, Walton

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says) quite over and up the shank of the hook, leaving only a small lively part of the tail below. If you bait with half a worm, prefer the tail end, and enter the point of the hook into the top part of it, and bring it down nearly to the end of the tail, leaving only a very small piece of it loose. If you bait with two worms on the same hook, draw the first up above the shank, while you put the second on in the same manner as directed with one worm, but enter the hook near the tail of the second worm; then draw the first one down on the second over the shank of the hook, and all will then be well covered, and will be a very *bon-bon* for perch, chub, carp, barbel, and all large fish; but when angling for gudgeon, and other small fish, half a red worm is sufficient, and the tail end is best. If blood-worms are used, put on two or three, in doing which be tender, or you will burst them.

BAITS.

The principal baits are—

1. The Lob-worm.
2. The Brandling.
3. The Marsh-worm.
4. The Tagtail.
5. The Ash-grub.
6. Cowdung Bait.
7. Caterpillars.
8. Cabbage-worms.
9. Crab-tree-worms.
10. Gentils.
11. Cad-worms.
12. Flag-worms.
13. Grasshoppers.
14. Wasp-grub.
15. Beetles.
16. Salmon Spawn.
17. Bread Paste.
18. Cheese Paste.
19. Wheat Paste.
20. Ground Bait.

1. *Lob-worms* are found in gardens or churchyards, late in the evening; they have a red head, a streak

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down the back, and a broad tail. This is a good worm for salmon, chub, trout, barbel, eels, and large perch.

2. *Brandling* is found in old dunghills, rotten earth or cowdung, and the best in tanners' bark. It is a good bait for any kind of fish.

3. The *Marsh-worm* is found in marshy grounds, or on the banks of rivers; and is a good bait for trout, perch, gudgeon, grayling, and bream.

4. The *Tagtail* is found in marly lands or meadows, after a shower; and is a good bait for trout when the water is muddy.

5. The *Ash-grub* is found in the bark of trees. It is a good bait for grayling, dace, roach, or chub.

6. *Cowdung-bait* is found under cowdung, from May to Michaelmas; and is a good bait for grayling, dace, roach, or chub.

7. *Caterpillars* can be found on almost every tree or plant. Almost any small caterpillar will answer.

8. The *Cabbage-caterpillar* is found on cabbages.

9. The *Crabtree-worm* can be taken by beating the branches of the crab-apple.

10. *Gentils.* These are bred in putrid liver, or may be obtained from the butchers. They are an excellent bait for all kinds of fish.

11. *Cad* is found in the ditches, or on the sides of stony brooks. It is an excellent bait for trout, grayling, roach, dace, or chub.

12. *Flag-worms* are found among flags in old pits or ponds, and are good bait for grayling, tench, bream, carp, roach, and dace.

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13. *Grasshoppers*, found in sun-burnt grass, and are good bait for various kinds of fish.

14. *Wasp-grubs* are to be obtained from wasps' nests, and are a good bait for most fish that will take gentils.*

15. *Beetles* are found everywhere, and sometimes in cowdung. They are a capital bait for chub.

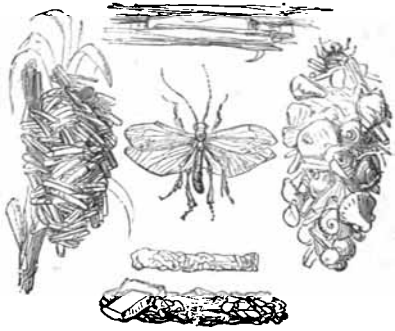

THE CADDIS FLY.

16. *Salmon-spawn* is a good bait for trout, chub, and other fish; but must be prepared in a peculiar way before it can be used.

17. *White-bread Paste* is prepared by dipping white bread in honey, and working it in the palm of the hand. It is a good bait for carp, tench, chub, or roach.

18. *Cheese Paste* is made with rotten cheese and

* Wasp-grubs will keep better and be easier to fit on the hook, if they are baked for half an hour.

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bread, worked up in the hand. It is a good bait for chub.

19. *Wheat Paste* is made by bruising wheat and working it with milk, and makes a good ground bait.

20. *Ground Bait* should be used in the spot about to be fished, and, if possible, the night before, and should be fresh. For carp, chub, roach, or dace, use white bread soaked in water, and mixed with bran and pollard. For roach, dace, and bleak, mix clay and bran together in balls the size of a pigeon's egg. For barbel, chandler's greaves, boiled and worked up into a ball with clay. For carp, tench, and eels, malt soaked in water is good; or gentils may be thrown in.

TO BAIT A HOOK WITH GENTILS.

To bait a hook with gentils, enter the point of the hook into the gentil near either end, and bring it out at the other end; then draw the point back again just within the gentil, enough to hide it. The best way to bait with a gentil whose skin is somewhat tough, especially in cold weather, is by piercing the skin in the first instance.

TO BAIT WITH GREAVES.

First select the whitest pieces from those you have soaked, and put four or five of them upon your hook, or as much as will cover it from the bend to and over the point; these pieces should not be bigger than a pea, and should be put on the hook separately, one after the other—not a large piece doubled, as some

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slovenly boys will do, for then the hook is prevented from entering firmly the fish you may strike. These little particulars of baiting are of considerable advantage to young anglers, who ought to remember also that it is a bad practice to soak greaves in hot water, for it makes them rotten, and they in consequence soon fall off the hook.

TO SCOUR AND PRESERVE WORMS.

To do this, the young angler should provide himself with a quantity of fresh moss. Wash out all the earth and squeeze it, but not too dry; then put it into a jar and squeeze it tightly down: throw in the worms upon it. The jar ahould be kept in a cool place in summer, and the moss changed once in three or four days. Gentils should be thrown into a mixture of damp sand and bran to scour them, and will be ready in two or three days.

THE PLUMMET.

Plummets are used by anglers for sounding the depth of a stream or hole. They are of two kinds, either the folding plummet or the common plummet. The folding plummet, which is the better, is made of a slip of sheet lead, folded up; and this the young angler should never be without.

PLUMBING THE DEPTH

Is performed in the following manner: If a folding

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plummet, unfold about two inches of it, pass the hook over its side, and then fold the plummet up again: your hook is now secured from drawing away from the plummet. As success depends much in angling at a proper depth, the young angler should take due pains, and measure the depth accurately before he begins fishing. When the plumb-lead touches the bottom, and the top of the float is even with the surface of the water, you will have the true depth.

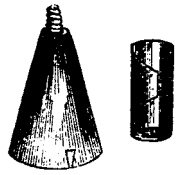

LANDING-HOOK AND LANDING-NET.

The landing-hook or gaff is a large hook, which is sometimes barbed like a fish-hook, and sometimes plain, fastened on one end of a rod; this rod is occa-

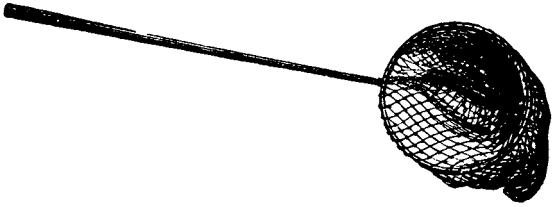

sionally composed of several pieces, which run one into another, like the slides of a telescope. A landing-net is a small net mounted on an iron ring, which is fastened, like the landing-hook, to the end of a pole.

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CLEARING-RING AND LINE.

The clearing-line is made of several yards of strong small cord, to the end of which is fastened a heavy ring of lead or brass. If the hook should get fast in a heavy weed, post, or anything else, this ring is put over the rod, and suffered to go down to the hook. The rod should be held in the right hand, the top pointing downwards, and the clearing-line in the left, the ring falling on the hook, which, from its weight, generally clears the hook from what it may have struck against. If not, the angler should hold the rod firmly, and draw the line sideways, and break away. In this case, the angler seldom loses more than a hook, if he acts as above directed; but without the assistance of a clearing-line he frequently loses his float as well as his hook and line, and sometimes breaks his top joint. The brass clearing-rings are to be preferred, because they are jointed, and in consequence can be used when the angler has a winch in his rod, in which case the leaden ring could not be passed over the winch.

DRAG-HOOK.

The drag is a piece of iron with three or four stout wire hooks without barbs, placed back to back, which is fastened to a strong cord line, which is used to draw away weeds. The landing-hook is, however, infinitely preferable, and not so troublesome. We therefore advise the angler not to use the drag-hook

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at all, and merely describe it, that he may know the use of every angling implement.

BANK-RUNNER.

The bank-runner is mostly used in the day-time, when the angler is fishing for roach, barbel, &c. It is stuck in the bank, the bottom being strong turned wood, sharpened for the purpose, with a winder at the top for the line, which should be from sixteen to twenty feet long, made of silk trolling-line, thin cord, or plaited Dutch twine. But there should be a cork and bullet to the line, and the bait a dace, which should swim a foot or two from the ground, as it will by the aid of the cork.

When you use the rod, hold the line with your left hand, and with your right pass the forked end under the line, just above the bullet; you may then place the baited hook in the water where you please by a jerk of the rod, at the same time letting the line go from the left hand.

LIVE-BAIT KETTLE.

This should be of an oblong form, and not round; white inside, and brown out. In getting out the bait, never put your hand into the water, which frightens the fish, and, by heating the water, makes them sickly and dull; but make use of a small net, which is easily carried in the fish-kettle, by having a piece of the lid cut away in one corner.

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DISGORGER.

This is an instrument with a forked top, about six inches long, made of iron, brass, or bone. Its use is to get the hook from a fish when swallowed; and in using it, the forked end is thrust down upon the swallowed hook with one hand, while the line is held tight with the other, which disgorges the hook, and it is then easily drawn out. In attempting to get a gorged hook from a fish without this instrument, you run a hazard of breaking the hook and hurting yourself. When the fish is hooked through the lip, the angler has only to hold the fish steadily in one hand, while with the other he carefully takes away the hook.

RULES FOR ANGLERS.

1. Never fish any water without leave from the proprietor, unless it be water that is free to all comers.
2. Never use unfair bait, or attempt to take fish in any but a fair and sportsmanlike manner.
3. Never start on a day's fishing without first considering the wind, weather, and water.
4. Never let your shadow fall on the water.
5. Use the finest tackle of which your fishing will admit.
6. Strike a fish with the *wrist*, not with the arm.
7. Never begin bottom fishing without first plumbing the depth.
8. Don't spare ground-bait.
9. Never intrude upon another fisherman's water.
10. Always remember, nothing is lost by politeness.

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Accounts of the various Fresh-water Fish, with their Habits, Haunts, Seasons, and the Methods of Taking them.

THE SALMON.

THE Salmon is the king of fresh-water fish. It is handsome in form, its head is small, its nose pointed, its back and sides grey, the belly silvery, and its flesh the well-known salmon-colour. The female

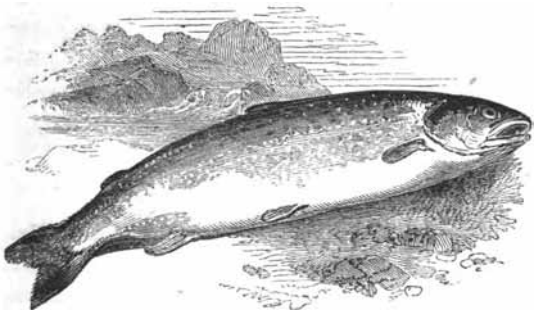

may be distinguished by having a longer snout than the male fish.

Salmon bite best from six till eleven in the forenoon, and from three in the afternoon until sunset, especially when there is a moderate breeze upon the water. The chief months to angle for them are March, April, May, and June. They are to be fished for with lob-

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worms or minnows, but a large artificial fly is the most killing bait. The rod should not be less than fifteen feet long, with a good running line, and the reel should contain at least threescore yards. The hook must be large and long in the shank, with a very small one fixed above at nearly the distance of the length of the fish baited with. In fishing for salmon with lob-worms the trolling tackle is to be used, and two of these worms well scoured put upon the hooks.

In the large streams of Scotland, salmon are caught in various ways :—by the stake-net, an artificial space or dyke in a river; by burning the water, as it is called; *i. e.* holding a torch above the stream and driving the fish into nets; also by spearing, which is, however, considered illegal. Few of our young readers will be able to go salmon fishing till they have reached maturity, and, therefore, to give the various modes of attacking the fish would be superfluous.

THE TROUT.

This beautiful fish is much prized. Izaak Walton says of it, "It is more sharp-sighted than any hawk, and more watchful and timorous than your high-mettled merlin is bold." In its habits it is a very solitary and predaceous fish. Its general length is from twelve to sixteen inches, its weight quite uncertain.

The trout are found in lakes and rivers and minor streams, and are finest in appearance from the end of March to the end of July or middle of August: their

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spawning time is from November to January. The most brilliant and beautiful trout are generally found in streams that flow rapidly over rocky bottoms. They feed upon worms, minnows, and other small fish, but their most favourite food is the fly, upon which they thrive and fatten prodigiously.

In angling for the trout we must have a stout rod, running tackle, and a cork float; his bait is the minnow, small frogs, snails, caddis grubs, and artificial flies.

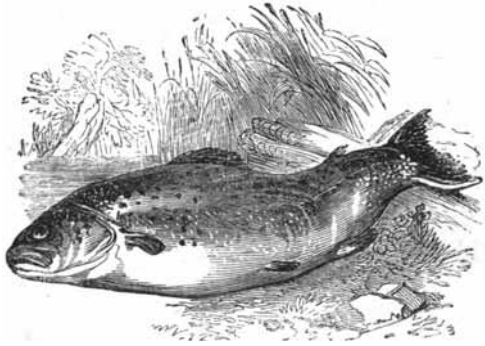

The minnow is, however, the most taking bait, which should be cast lightly on the water, and drawn trippingly against the current. The angler must not be in too great a hurry to strike, as the trout is very apt to nibble at his bait before swallowing it; rather let him try once or twice and then nick him. The favourite haunts of the trout are mill tails, deep dark holes and eddies, pools, the roots of trees, and the "nethers" of bridges and weirs.

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THE JACK, OR PIKE.

The mighty luce, or pike, says Walton, is taken to be the tyrant, as the salmon is the king, of the fresh waters. His aspect is repulsive. He is a rag ed, savage, ugly-looking fish. His teeth are very sharp and very numerous, being upwards of seven hundred, and his voracious appetite is such that nothing comes amiss to him. He has been known to swallow the plummet, and the clay and bran balls of ground bait of the angler, and he will prey upon "rats and mice and such small deer," with ducks, geese, and even

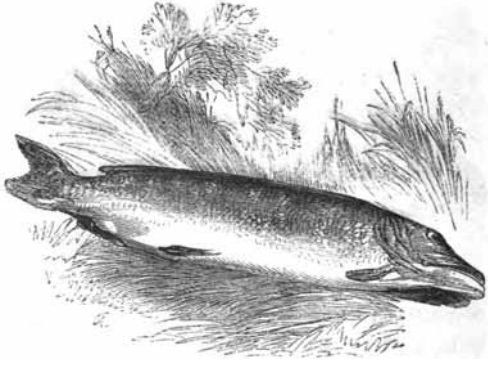

swans, which he has been known to pull under water. He often grows to an enormous size (no wonder), and has been taken upwards of thirty pounds in weight.

Pike are fond of dull, shady, and unfrequented waters, with a sandy, chalky, or clayey bottom. In summer they are found among or near flags, bulrushes, or water docks. They seldom seek a rapid stream,

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their favourite retreat being in the vicinity of a whirlpool, or a sharp bend of the stream. In winter they retire into the depths, under clay banks, or under a projecting stone or stump of a tree.

The pike is in its prime during September and October, but is in season from May to February; the baits used for it, gudgeon, minnows, chub, bleak, and young frogs, and should be about three or four inches in length; and trolling for them is "excellent sport." The rod should be strong; the line of silk, at least thirty yards long, wound upon the winch already described. Hooks for trolling, called dead gorges, and other sorts for trolling, snap and trimmer, and baiting-needles, are to be bought at every shop where fishing tackle is sold; in the choice of the first, let them not be too large, nor their temper injured by the lead on the shanks, nor the points stand too proud; and although usually sold on wire, it is recommended to cut off the wire about an inch from the lead, and with a double silk well waxed fasten about a foot of good gimp to the wire, with a noose at the other end of the gimp large enough to admit the bait to pass through to hang it upon the line. The best baits are gudgeon and dace of a middling size; put the baiting-needle in at the mouth and out at the middle of the tail, drawing the gimp and hook after it, fixing the point of the hook near the eye of the fish; tie the tail to the gimp, which will not only keep it in a proper position, but prevent the tail from catching against the weeds and roots in the water; thus baited, the hook is to be fastened to the line and dropped gently in the water

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near the sides of the river, across the water, or where it is likely pike resort; keep the bait in constant motion, sometimes letting it sink near the bottom and gradually raising it. When the bait is taken, let the pike have what line he chooses. It will be soon known

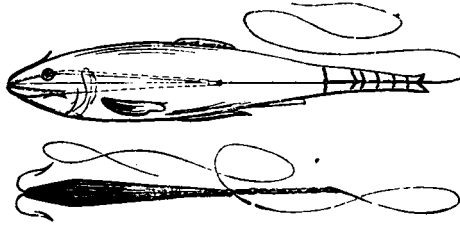

when he has reached his hole, which he always flies to, by his not drawing more. Allow him ten minutes for gorging the bait, wind up the line gently till you think it is nearly at its stretch, and then strike. Manage him with a gentle hand, keeping him, however, from roots and stumps, which he will try to fasten the line upon. In clear water veer out line till he is sufficiently tired, and a landing net can be used; but by no means, however apparently exhausted he may be, attempt to lift him out with the rod and line only, for the moment he quits the water he will open his mouth, and from his own weight tear the hook from his stomach, and he will be lost.

In trolling, the bait hook should never be thrown too far; in small rivers the opposite bank may be fished with ease, though the violence of its falls upon the water in long throws soon spoils the bait by rubbing off its scales. The lead hook is used by putting

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the lead into the mouth of the live bait, and sewing it up; the fish will live some time, and, notwithstanding the lead, will continue to swim. In angling for this fish always prefer a rough wind, and when the stream is clear for trolling. Pike never bite in white water after rain, &c. If a pike goes slowly up a stream, after taking the bait, it is said to be the sign of a good fish.

THE GUDGEON

Is one of the most delicious fish for eating, although small in size. It bites freely from the latter end of spring until autumn, in gloomy warm days, from an

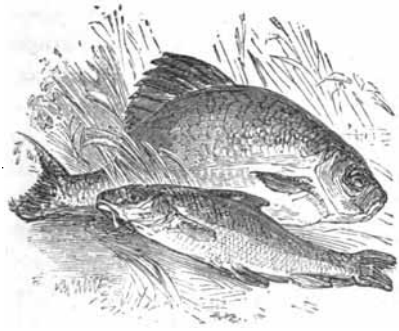

GUDGEON AND BREAM.

hour after sunrise to within the same space of its setting; and during the rest of the year, in the middle of the day, when it is warmest.

In angling for gudgeon the tackle must be very fine, a single hair or fine gut line, a hook, No. 8 or 9, a

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short rod and line, and a small porcupine float. They will take the small red-worm greedily, and blood-worms—the first is perhaps the best—and a rake or the boat-hook should be kept frequently stirring the bottom. To the spot so stirred gudgeon assemble in shoals, expecting food from the discolouring of the water; and by now and then throwing in a handful of gravel mixed with dead gentils, they are also kept together, and sometimes great quantities are taken. They are apt to nibble at the bait; the angler ought not, therefore, to strike at the first biting.

Should any young angler desire a good day's fishing for gudgeon, and a pleasant walk into the bargain, he should seek out some sequestered gravelly stream, and providing himself with a rake, he may have sport till he is tired of it. He will find them scattered up and down every river in the shallows during the heat of summer, but in winter they get into deeper water, and are to be fished for there with your hook always touching the ground, if fished for with a float. Some persons, however, prefer fishing for them with a running line upon the ground without a cork, but this requires a gentle rod and a gentle hand.

THE ROACH.

The roach is a handsome fish either in or out of the water. It inhabits many of our deep still rivers, delighting most in quiet waters. It is gregarious, keeping in large shoals. It delights in gravelly, sandy, or a kind of slimy marl bottom, under a deep

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gentle running stream; in summer they often frequent shallows near the tails of fords, lie under banks among weeds, under the shades of boughs, and at or opposite the mouth of a rivulet or brook, that empties itself into a large river. In winter they like to get into clear, deep, and still waters.

The tackle for roach must be fine and strong, a six-feet rod and a five-feet line, a porcupine float, and hooks No. 11 or 12. The bait, gentils, red paste, boiled wheat or malt. The ground bait should be boiled malt or bran mixed with clay, in which are a few dead gentils. In fishing for roach in ponds, chew and throw in white bread, baiting with one large gentil. The hook should be No. 6, and the bait either touch the bottom or lie within one inch of it.

The season for roach fishing in the Thames begins

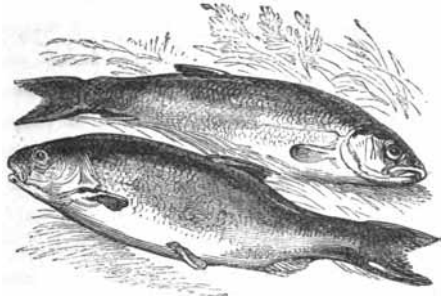

ROACH AND DACE.

about the latter end of August and continues through the winter. To London Bridge and among the shipping below it, numbers of roach return in June

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and July, after having been up the river to spawn, and many of them are taken by means of a strong cord, to which is fastened a leaden weight, more or less, according to the strength of the current; a foot above this lead a twine twelve feet long is joined to the cord, and to this twine at convenient distances are tied a dozen hair links, with roach hooks at the ends; these are baited with white snails or periwinkles, the fisherman holds the cord in his hand, and easily feels the biting of the fish, which is a signal to pull up, and frequently five or six are taken at a haul.

THE DACE.

Dace are gregarious—are great breeders—very lively—and during summer fond of playing near the surface. Their haunts are deep water, near the piles of bridges, where the stream is gentle, and has a sandy or clayey bottom. They like deep holes that are shaded by water-lily leaves, and under the foam caused by an eddy; in the warm months they are to be found in shoals on the shallows near to streams.

The baits for dace are the red worms, brandling, cowdung, and earth bob, and, indeed, any worm bred on trees and bushes, and almost every kind of fly and caterpillar not too large. In angling for dace, with worms, maggots, &c., the tackle cannot be too fine, the float small, the hook No. 9, the shot a foot from it; by baiting the place with a few maggots before fishing, the diversion will be increased. If you angle in an eddy between two mills-treams, and the water is

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only two or three feet deep, there will be a greater chance of success than where it is deeper; take a cork float, bait with three large gentils, and strike at the first nibble. If there are large dace in the mill pool they will resort to this eddy.

In bottom fishing for dace, let the ground bait be bread soaked an hour in water; put an equal quantity of bran, knead it to a tough consistence, and make it into balls, with a small pebble in the middle, to sink them; throw these balls a little up the stream from the spot where it is proposed to angle, that the current may not drive them beyond the reach of the line. Fish for dace within three inches of the ground, especially where the ant fly is the bait under water. We have more than once caught dace upwards of a pound in weight upon night-lines baited with minnow for eels. In fishing take advantage if you can of a still, warm, gloomy day, or go in a summer's evening to the smooth part of the end of a mill-stream from seven to eight, and as long as the light continues the dace will yield diversion.

THE PERCH.

"Perch feed on perch," is an old maxim; the perch being the only one of all fresh-water fish that feeds on its own kind. His excuse is a prodigious appetite, like that of Saturn, who ate his own offspring. Notwithstanding this wicked propensity, the perch is a beautiful fish, the back and part of the sides being a deep green, marked with broad black bars, pointing

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downwards; the spaces between are golden, the belly white, tinged with red, and the ventral fins tinged with scarlet. They vary greatly in size. The largest perch we ever caught weighed three pounds twelve ounces, and was taken with a roach bait near Richmond. Their general length is about ten or twelve inches.

Perch are found in clear swift rivers with pebbly, clayey, or sandy bottoms. They are fond of water moderately deep, and frequent holes near to gentle streams where there is an eddy, the hollows under banks, among weeds and roots of trees, piles of bridges, or in ponds which are fed by a brook or rivulet. The perch is a bold biter in the summer, but scarcely ever

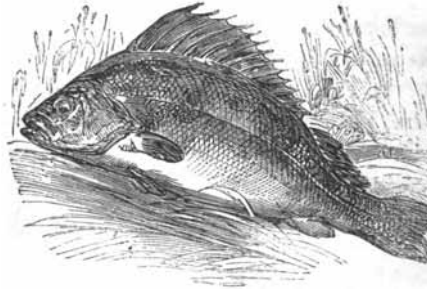

in the winter. In the middle of a warm sunshiny day, you are sure to have him with a proper bait. He bites best in the latter part of the spring, from seven till eleven in the forenoon, and from two to six in the afternoon, except in hot and very bright weather; and then from sunrise to six in the morning, and in the evening from six till sunset.

The baits for the perch are various, as well as the

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manner of using them. Of worms, the best are small lob-worms, which have no knot; brandlings, and red dunghills, or those found in rotten tan, all well scoured. The hook may be varied from 2 to 6, being well whipped to a strong silkworm gut, with a shot or two a foot from it. Put the point of the hook in at the head of the worm, out again a little lower than the middle, pushing it above the shank of the hook upon the gut; take a smaller one, beginning the same way, and bring its head up to the middle of the shank only; then draw the first worm down to the head of the latter, so that the coils may hang one above the other, keeping the point of the hook well covered. This is the most enticing method that can be adopted in worm-fishing. Use a small cork float to keep the bait at six or twelve inches from the bottom, or sometimes about midwater; in angling near the bottom, raise the bait very frequently from thence almost to the surface, letting it gradually fall again. Should a good shoal be met with, they are so greedy that they may be all caught, unless one escapes that has felt the hook; then all is over, the fish that has been hooked becomes restless, and, somehow or other, the whole shoal leave the place.

Other baits for the perch are, roach, sticklebacks with the spines cut off, miller's-thumbs, horsebeans boiled, cadbait, lobs, and gentils; but the best and most enticing bait is a live minnow. To draw the fish together, three or four balls of stiff clay should be procured, and holes made in them; one end of a lob-worm should be put into each hole, and the clay closed

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fast upon them, and these, a yard or two apart, thrown into the angling place. If you find the fish shy, try not long in one spot. In baiting your hook with the minnow, fix your hook through his back fin, and use a small reel with your rod. Your hook should be No. 5, fastened to a link of gimp.

THE GRAYLING.

The grayling is a fish of elegant form; the back is of a dusky green, inclining to blue; the sides of a fine silvery grey (from which the fish derives its name), marked with black spots, irregularly placed; and

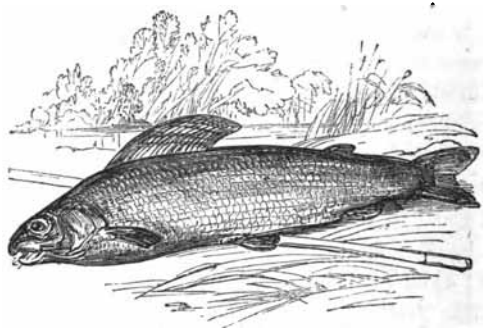

when first taken, this fish seems to glitter with spangles of gold. It is rather a hog-backed fish; and, from the nose and belly touching the ground together, is supposed to feed mostly at the bottom. In length it seldom exceeds sixteen inches, but some have been caught upwards of five pounds in weight.

The haunts of the grayling are in rapid, clear streams, particularly such as flow through mountainous

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countries.* They are usually taken in the same manner as the trout, and with similar baits. They do not bite freely till late in August or early in September, and may be found at the tails of sharp streams and in deep water. They rise more boldly than the trout, and if missed several times will still pursue the bait. They will bite during the whole of the cold cloudy days; but the preferable time to look after them is between eight and twelve o'clock in the morning, and from four in the afternoon till after sunset. Grasshoppers, wasp-grubs, maggots, brandling-worms, and the artificial fly, are the most killing baits.

THE CHUB.

This fish takes its name from the shape of the head, not only in our own, but in other languages. He much resembles the carp, but is of a larger form; the head and back are of a deep dusky green; the sides silvery, but in the summer yellow. The tail is forked, and of a brownish hue; and altogether the chub is rather a handsome fish, although its flesh is not in much esteem.

The haunts of the chub are in rivers whose bottoms are of sand or clay, or which flow over a rocky bottom, in deep holes, under hollow banks; in summer particularly, where, shaded by trees, weeds, &c., they frequently float on the surface, and are sometimes found in streams and deep waters, where the currents are strong. In ponds fed by a rivulet they grow to a large size.

* I have taken tolerably large graylings in the little brooks that flow into the Dove, in Derbyshire.—Ed.

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To fish for chub, you should have a stout long rod, a strong line (and if you use a reel, you will be the better able to fish under bushes), with a yard or more of the best silkworm gut at bottom; a hook proportionate to the bait used; a swan-quill float, and the line so shotted, eight or ten inches from the hook, as to sink the float to a quarter of an inch above the surface. The same groundbait is to be used as for carp, and the hook backed with a sufficient quantity of salmon's roe to fill the bend properly: this, rightly managed, is a tempting bait.

By daybreak the young angler should be at the

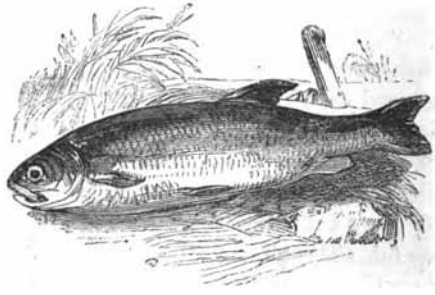

river; and, after baiting his hook with a cockchafer let him move it two or three times near the surface, as in the act of flying; then let him drop it in the water, tapping the rod gently, which will cause the appearance of its struggling to escape. This attracts the chub, who are so fond of this bait, that they will rise two or three at a time to seize it. But mind and be ready with your landing-net.

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The chub will take a grub, wasps, maggots, paste of fine new bread worked in the hand, and tinged with vermilion, to make it look like salmon-roe; but the best bait for bottom or float-fishing for the chub is old Cheshire cheese, worked with the crumb of a new roll, or the pith from the backbone of an ox. In baiting with the cheese, put a round lump the size of a cherry on a large hook, so as to cover the bend, and some way up the shank; fish six inches from the bottom, or in cold weather the bait may lie on the ground. When there is a bite, the float will be drawn under water: strike immediately, and give him play, holding a tolerably tight line, to keep the fish clear from weeds and stumps.

The best time for fishing for chub is chiefly before sunrise to nine in the morning, and from four till after sunset in the summer; but, in winter, the middle of the day is best. In hot weather, the chub is to be fished for at or near the top of the water, and not deeper than midwater; and in cold weather, close to or near the bottom; and the main point on taking the fish is for the angler to keep himself out of sight.

THE CARP.

Carp are esteemed among the richest fresh-water fish we have in the kingdom, and are as cunning as foxes. The angler, therefore, must be "wide-awake" to catch him, and also as patient as a saint. He may, however, fish for him at any time in the day during warm weather. The bait may be either worms or

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paste. Of worms, the bluish marsh or meadow is the best; but a red-worm, not too big, will do, or a large gentil: of paste, the best is made of bread and honey; and the spot intended should be well baited beforehand. In a large pond, to draw them together, throw in either grains, or blood mixed with cowdung, or bran, or any kind of garbage; follow this with some of the small baits you intend to angle with.

If you fish for carp with gentils, put on your hook a small piece of scarlet cloth, about the bigness of a

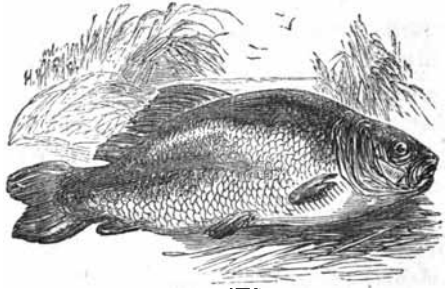

pea, soaked with oil-of-peter (by some called oil-of-the-rock), and keep your gentils for two or three days in a box smeared with honey; and while you are fishing, chew a little bread, and throw it in about the place where your float swims. In this way, with due patience, you will prove a match for these crafty fish.

THE TENCH.

The tench is one of our most useful fresh-water fishes, for the ease with which it may be preserved and

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its increase promoted, and the goodness of its flesh. It is very usual to breed it in ponds, but naturally, like many others of the carp tribe, it is generally found in lakes and still waters; its favourite haunts are in places well shaded with bushes or rushes. In standing waters, it lies under weeds, near sluices, and at pond-heads.

To fish for tench, make up some paste of brown bread and honey; and you may use a marsh-worm, but he will

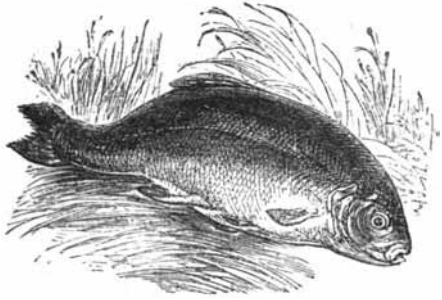

take the bread in preference, particularly if you add to it a little tar. He will also take a small red-worm, the head nipped off, and a cad-worm put on the hook first; but he will only feed in the three hot months. He will likewise bite at a lob-worm, or a green gentil; but the pastes are by far the most killing baits.

THE POPE, OR RUFF,

Is something like a perch in shape, but more bluff and bulky. He is found principally in slow, deep, quiet rivers, which have a loamy bottom. The spawning

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time is in April. The best baits for him are red-worms and brandlings. The places where he is to be had are where the water is deep and still; and these places should be baited with some clay-balls, with which worms are mixed. Should the water be muddy, worms will do alone; but if clear, clay must be used to render it opaque before you fish. The fish will

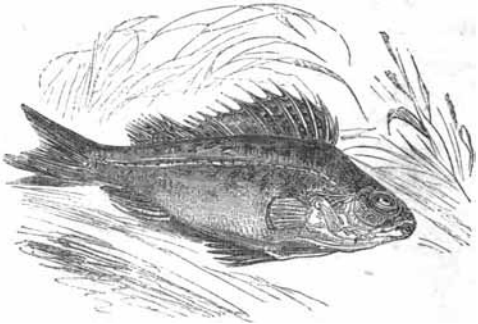

bite at any time of a warm summer's day, when the sky is cloudy. In angling use a No. 8 or 9 hook, with a quill float; and the moment you feel a bite, strike, without allowing much line.

THE BREAM.

The bream, at full growth, is a large and stately fish, and is oftentimes as fat as a hog. He is principally found in large ponds or in lakes, and in still rivers where the waters are deep and shaded by weeds; and may be taken in summer from May to the end of September; and in these months from sunrise

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to eight o'clock in the morning, and from five o'clock till twilight in the evening.

The baits are many: paste made of brown bread and honey, gentils, wasp-grubs, flag-worms, and brandlings. Use lob-worms, cut in pieces, and grains as groundbaits in the places where you intend to angle. Use a gut line, quill float, and No. 10 hook. Sound the bottom, which should be eight or ten feet deep, and stand at least two yards from the bank from which you fish. Strike as soon as you feel a bite.

THE FLOUNDER.

The flounder is a well-known flat-fish very common about our own coasts; and should any of our young

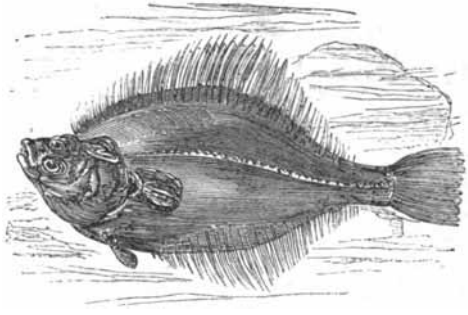

friends be at the seaside, it is well that they should know how to take flounder. They are also found in rivers, at some distance from the sea. They may be taken in May, July, and August,—not in June, as that is their spawning time. The best baits are red-

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worms and marsh-worms, on a No. 6 hook; and you should fish at the bottom, trailing the bait gently along.

EELS.

Eels are denizens of the mud; but they are fond of clean, not foul mud, and ought never to be sought after in filthy places. There are many modes of taking them: by rod and line, by dead line, by sniggling, by

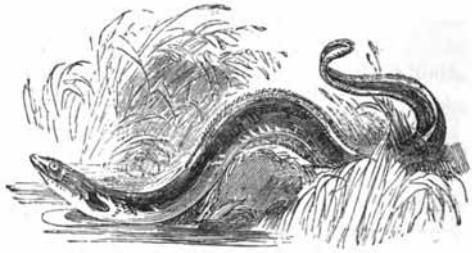

bobbing, and by spearing. When a rod is used, you should put a maggot or red-worm on a No. 8 hook; the bait should touch the bottom; and, when you have a "bite," the float should be drawn quite under water before you strike.

The dead line is a line of whipcord, with hooks about six inches asunder, baited with lob-worms or small fish. You should also have a bank-runner—a reel on a pin or stake stuck into the ground on the edge of the bank; the line and baits should be thrown

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in, and left for the eels to *amuse themselves* with,—looked to, and drawn up at *your leisure.*

In sniggling, a lob-worm is put upon a stout worsted needle; the line is on a winder; and the fish will be found near flood gates, wharfings, bridges, piles, holes in the banks of rivers, ponds, and canals. The bait should be put into the lurking-places of the eel, by means of a stick with a forked head; and when the bait is taken, which will easily be known by the pull of the string, strike.

Bobbing for eels.—In this process long red-worms are strung on threads of worsted, until a bunch as large as the two fists is formed around a piece of lead. The whole is sunk to the bottom, or nearly so, then raised a little, then depressed, so as to induce the eels to bite. When this occurs, heave up without hurry. The number of eels taken in this way is often prodigious.

In spearing eels, the spearer usually goes into the mud in a pair of pants or mud pattens, pieces of square board fastened into the heel to prevent sinking. He takes an eel-spear in his hand, something like Neptune's trident, and progs the mud all under (not all over), and the eels are caught between the forked blades of the spear. Great numbers of eels are taken in this way on the muddy ooze of salt or fresh-water rivers.

THE STICKLEBACK AND MINNOW.

The stickleback is a dark-coloured little fish, found in ditches and ponds. They are best caught with a

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small hand-net, and are used as bait for perch. The minnow is very beautiful in appearance, being of a rose colour underneath, and may be taken with a worm

and a No. 13 hook at any time of day; but more easily with a small hand-net. They are commonly found in little rivulets, rills, or small sandy streams, and are highly prized by the angler as baits for many kinds of fish.

THE BARBEL.

The barbel is a bold, sturdy, handsome-looking fish, although its flesh is coarse to the eater; but he is a rare fellow for sport, and often affords great amusement as well as chagrin to the angler by his bolting off with the line by a "coup de barbel," and breaking it with his tail. Izaak Walton says, that barbel "flock together like sheep."

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Barbel are to be found in the strongest runs of water. In summer, they love the shallowest and sharpest streams, and will lurk under weeds, and will root and dig in the sand like pigs. Sometimes he retires to deep and swift bridges, or to flood-gates or weirs, and will rest himself against piles or hollow places. In winter, he gets into deep water.

In fishing for barbel in large streams, you should go

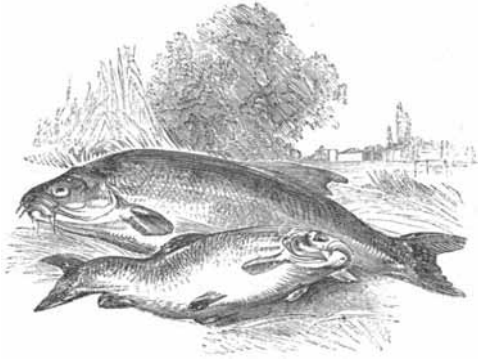

BARBEL WITH GOLD CARP.

out in a boat provided with greaves, gentils, and red-worms; and, before you begin fishing, you should throw in plenty of groundbait—such as soaked greaves, bran and clay made into small balls, maggots, and a paste made of sheep's suet, cheese, and honey compounded together. They may be angled for with a stout rod, strong running-line, cork float, and No. 7 or 8 hook, baited with marsh-worms or greaves. The

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barbel being a sharp biter, strike the moment you feel a nibble. He may be caught from May to October all day, but best in the morning and evening. After he is struck he will frequently make a run, but you must play him gently; keep him clear of weeds, and try to get him into deep water; in hauling him to land mind what you are about, or you will be sure to lose him; and when you have him, mind he does not bounce out of your hand and drop down the stream again.

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Natural Fly-fishing, or Dipping.

FISHING with a fly may be practised either with the natural fly, usually called "dipping," or with the artificial fly; in which latter case the sport is called "fly-fishing," or sometimes "whipping." Dipping requires a moderately long and *stiff* rod, of about twelve or thirteen feet. The line should not be above a yard in length from the end of the rod, but the reel should contain sufficient to play the fish if necessary. When the river is much overhung with bushes, it is a good plan to wind the line round the end of the top joint, leaving only a few inches dependent; and then having thrust the rod through some small opening in the bushes, gradually to unwind the line by turning the rod in the hand, so as to drop the fly on the water in the most gentle manner. In this insidious way large fish are often taken with any of the flies which are in season and found at the time on the banks of the river which is fished, especially if they are only just coming out, and the fish are not yet satiated with them. It is quite needless to give a list of the natural flies which are likely to prove serviceable to the fisherman, because he has only to look for those which *at the time* are tempting the fish, and then to find them on the banks, and at once to try their

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19. *Stone fly.*—Wings of a dusky-blue cock's hackle, or a mottled feather from a hen pheasant, the body of dark-brown and yellow camlet mixed, and a grizzled hackle for legs; the wings should be flat.

20. *Black silver palmer.*—The body of black ostrich harl, ribbed with silver twist, and wrapped with black cock's hackle.

21. *Willow fly.*—The wings of dark grizzled cock's hackle, the body of blue squirrel's fur, mixed with yellow mohair.

22. *Yellow palmer.*—The wings of white hackle, dyed yellow, the body of yellow silk.

23. *Black palmer.*—The body of black ostrich's harl, wrapped with a black cock's hackle.

24. *Black palmer, ribbed with gold.*—The body of peacock's harl, wrapped with a black cock's hackle, and ribbed with gold twist.

25. *Marlow Buzz or Cock-a-Boundhu.*—This is one of the most killing flies known, and should never be off the line during the trout season. The body of peacock's harl, ribbed with gold twist and a dark-red cock's hackle over all.

26. *The Grouse Hackle.*—This is also a very killing fly, especially late in the evening, during June, July, and August. Body of brown fur, ribbed with gold twist, and a grouse hackle over all; hook No. 10.

The foregoing list comprises twenty-six of the most killing flies, and the following are the months in which they will be found to kill best.

February, red cowdung fly, blue dun; *March* brown; *April,* black gnat, stone fly, gravel or spider

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fly, the green tail, March brown, blue dun; *May*, green drake, grey drake, oak fly, hazel fly, little iron blue, and yellow sally; *June*, hare's ear, cock-tail, whirling dun, marlow buzz, bee fly, kingdom fly, white gnat, blue gnat, blue dun, governor, fern fly, gold spinner; *July*, red ant, red spinner, yellow dun, coachman, fern fly; *August*, whirling blue, red spinner, pale yellow dun; *September*, willow fly, silver twisted blue, whirling blue.

It would of course be impossible, in a work of this description, to give a list of all the artificial flies used by experienced fishermen, but the above are a few of the most killing. For bleak, dace, roach, chub, &c., a piece of a maggot, or a small piece of white leather, should be placed at the end of the hook.

Having thus given the "order of flies," natural and artificial, we may imagine the young fly-fisher, with rod in hand, proportionate to his strength and the breadth of the stream, ready to throw his fly; but let his rod and running tackle be in good order, and the idea of the coachman's whip out of his mind. He is not to flog the water, but to tickle it. The novice should teach himself to handle the line, by beginning with it alone (*i. e.* without flies or hook), trying a short length first, and lengthening it gradually. In using the rod, it should be drawn gently back without force, and thrown forward again when the line has reached its full extent behind him. Take care in doing this, that the fly be not whipped off. When tolerably expert, put on one fly, and try awhile with

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that, adopting two or three when able to use them properly.

In fly-fishing keep as far from the water as possible, especially if fishing for trout. Let only the fly touch the water, and keep moving it gently and slowly on the surface. When a fish rises, let a moment elapse before you strike, and then do it sharply. If your tackle be sufficiently strong, take your fish out at once; but, if fishing from a bridge or high bank, it may be necessary to play him.

When you have two flies on your line, you must try to throw your line so that the bottom fly shall reach the water first; it must be done always as lightly as possible, so that it may resemble a natural fly settling upon the water. You must suffer the line to float gently down the stream, at the same time dragging along towards you to the left hand.

The best time for angling with the fly is when there is a gentle breeze upon the water; south and west winds are to be preferred, when the water has been disturbed by heavy rains and is just resuming its natural colour, or when the day is dull and cloudy after a moonlight night. The best time, morning and evening. In cold weather the fish bite deeper, and you should then let the fly sink a little. Take care to have the wind in your back, and the sun in your face, if possible.

When you see a rise, throw your fly about half a yard above the fish's nose, and let it fall down with the stream; watch it narrowly, and strike as the fish rises, giving him an "infinite little moment" to taste.

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When you have hooked, play your fish carefully, keeping up his head and running him down the stream, at the same time driving him towards you. If you see a fish rise at a natural fly, throw your bait a little before him, so that he may take it as "one of the number."

To know what flies the fish are most likely to take, observe what natural flies are about the water, or on the grass, trees, or bushes in the vicinity of the river; and take that fly which is the most in abundance, either natural or artificial, at your discretion.

Such are, my young friends, a few practical particulars concerning angling and fly-fishing, sufficient to enable any young angler to begin. For more abundant information, we refer him to old Izaak Walton, Stoddart, Ephêmera, and Salter; our parting advice is to him, never to forget humanity, and to inflict as little pain and torture upon God's creatures as possible.

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Material List:

A. **Black Poly Pipe** (3/4",80psi)

B. **Snap Clamps** (at least three per hoop. More may be needed if windy.)

C. **Covering Material**
- Shade Cloth
- Clear Plastic
- Bird Netting
- or other material

Assembly Steps:

1. Push ends of Items "A" (poly pipe hoops) approx. 6" into soil. Fig. 1

2. Lay Item "C" (covering of choice) over hoops.

3. Attach Items "B" (snap clamps) as needed. Fig. 2

Fig 1.

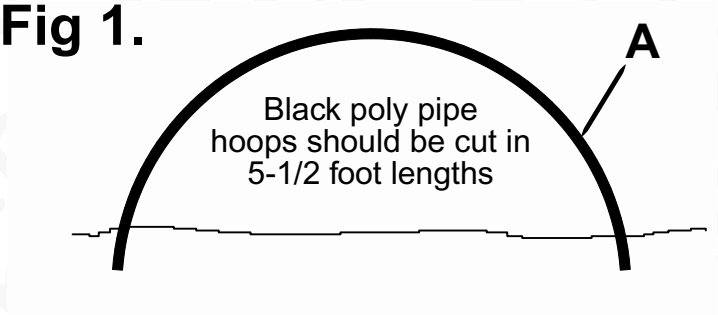

Fig 2.

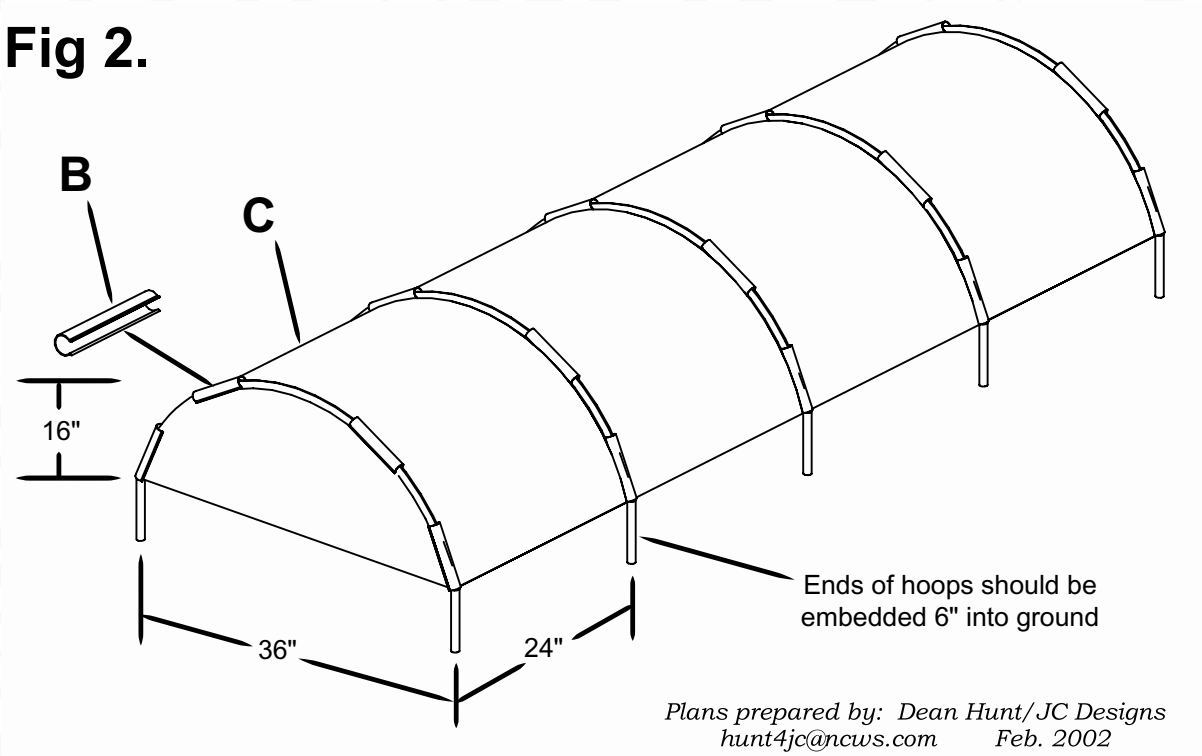

Plans prepared by: Dean Hunt/JC Designs
hunt4jc@ncws.com Feb. 2002

Rowing

From Wikipedia, the free encyclopedia

Rowing is the act of propelling a boat using the motion of oars in the water. The difference between paddling and rowing is that rowing requires oars to have a mechanical connection with the boat, while paddles are hand-held and have no mechanical connection.

Typical Finnish rowing boats on the shore of Palokkajärvi, Jyväskylä

This article deals with the more general types of rowing, such as for recreation and transport rather than the sport of competitive rowing which is a specialized case of racing using strictly regulated equipment and a highly refined technique.[1]

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- 2 Ancient Rowing
- 3 Venetian Rowing
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Rowing in the Amstel River by a student rowing club.

Types of rowing systems

In some localities, rear-facing systems prevail. In other localities, forward-facing systems prevail, especially in crowded areas such as in Venice, Italy and in Asian and Indonesian rivers and harbors. This is not strictly an "either-or", because in different situations it's useful to be able to row a boat facing either way. The current emphasis on the health aspects of rowing has resulted in some new mechanical systems being developed, some (such as the Rantilla rowing method) very different from the traditional rowing systems of the past.

Rearward-facing systems: This is probably the oldest system used in Europe and North America. A seated rower pulls on one or two oars, which lever the boat through the water. The pivot point of the oars (attached solidly to the boat) is the fulcrum. The motive force is applied through the rower's feet. In traditional rowing craft, the pivot point of the oars is generally located on the boat's gunwale. The actual fitting that holds the oar may be as simple as one or two pegs (or thole pins) or a metal oarlock (also called rowlock - "rollock"). In performance rowing craft, the rowlock is usually extended outboard on a "rigger" to allow the use of a longer oar for increased power.

Sculling involves a seated rower who *pulls* on two oars or *sculls*, attached to the boat, thereby moving the boat in the direction opposite that which the rower faces. In some multiple-seat boats seated rowers each pull on a single "*sweep*" oar, usually with both hands. Boats in which the rowers are coordinated by a coxswain are referred to as a "coxed" pair/four/eight. Sometimes *sliding seats* are used to enable the rower to use the leg muscles, substantially increasing the power available. An alternative to the sliding seat, called a *sliding rigger*, uses a stationary seat and the rower moves the oarlocks with his feet. On a craft used in Italy, the catamaran *moscone*, the rower stands and takes advantage of his body weight to increase leverage while sculling.[2]

Forward-facing systems: *Articulated* or *bow facing* oars have two-piece oars and use a mechanical transmission to reverse the direction of the oar blade, enabling a seated rower to row facing forward with a pulling motion. *Push rowing*, also called *back-watering* if used in a boat not designed for forward motion, uses regular oars with a pushing motion to achieve forward-facing travel, sometimes seated and sometimes standing. This is a convenient method of manoeuvring in a narrow waterway or through a busy harbour. The "Rantilla" system of frontrowing oars uses *inboard mounted oarlocks* rather than a reversing transmission to achieve forward motion of the boat with a pulling motion on the oars.

Another system (also called *sculling*) involves using a single oar extending from the stern of the boat which is moved back and forth under water somewhat like a fish tail, such as the Chinese *yuloh*, by which quite large boats can be moved.[3]

Ancient Rowing

In ancient times, rowing vessels, especially galleys, were extensively used in naval warfare and trade, in particular in the Mediterranean from classical antiquity onwards. Galleys had advantages over sailing ships; they were easier to maneuver, capable of short bursts of speed, and able to move independently of the wind. Galleys continued in use in the Mediterranean until the advent of steam propulsion. Their use in northern Atlantic waters was less successful, finishing with their poor performance with the Spanish Armada.

A French galley and Dutch man-of-war off a port

The Classical trireme used 170 rowers; later galleys included even larger crews. Trireme oarsmen used leather cushions to slide over the seats, which allowed them to use their leg strength as a modern oarsman does with a sliding seat. Galleys usually had masts and sails, but would lower them at the approach of combat. Greek fleets would also leave their sails and masts on shore (as being unnecessary weight) if possible.[4]

Venetian Rowing

In Venice, gondolas and other similar flat bottomed boats[5] are popular forms of transport propelled by oars which are held in place by an open wooden fórcola.[6] The Voga alla Veneta[7] technique of rowing is considerably different from the style used in international sport rowing, due to the oarsman facing forward in a standing position. This allows the boat to manoeuover very quickly and with agility - useful in the narrow and busy canals of Venice. Competitive regattas are also held using the Venetian rowing technique, using both gondolas and other types of vessels.

A Gondola in Venice

There are three different styles of Venetian rowing:

1. Single oarsman with one oar, standing near the stern of the boat (the oar also acts as a rudder)
2. One or two oarsman each with two crossed oars (known as *a la valesàna*)
3. Two or more oarsmen, rowing on alternate sides of the boat

Whitehall rowboats

The origins of this distinctive and practical craft are unclear. In earlier times, however, builders were often sailors or seafaring men. Successful designs for large and small craft alike evolved slowly and as certain desirable qualities were attained and perfected they rarely changed.

Some hold that the Whitehall rowing boat design was introduced from England. However the famed nautical historian Howard I. Chapelle, cites the opinion of the late W. P. Stephens that in New York City there is a Whitehall Street and this was where the Whitehall was first built. Chapelle, Stephens and others agree that the design came into existence some time in the 1820s in New York City, having first been built by navy yard apprentices who had derived their model to some extent from the old naval gig.

In Wooden Boats to Build and Use (1996), John Gardner of Mystic Seaport describes a 25-foot (7.6 m) racing Whitehall, named American Star, which triumphed in an 1824 race in New York Harbor that according to newspapers of the time drew 50,000 spectators, more than any American sporting event ever until then. The following year the boat was gifted to an aging General Lafayette, hero of the American Revolution, during his tour of the U.S. The American Star returned to Lafayette's estate in France where it was displayed in a specially constructed gazebo. During the mid 20th century the boat was rediscovered in storage there, and its lines have be preserved at Mystic Seaport where an exact replica was built in 1974–75, and still rows at Seaport events.

Design factors of rowing boats

Many considerations go into selecting a good rowboat. A well designed rowboat will perform well in trying conditions. The classic shapes of rowboats reflect an evolution of hundreds of years of trial and error to get a good shape. Some factors to be considered are waterline length, speed, carrying capacity, stability, windage, weight, seaworthiness, cost, waterline beam, the fullness or fineness of the ends and trim .

Design details are a compromise between competing factors. If the waterline beam (width) is too narrow the boat will be tender and the occupant at risk of falling out, if the beam is too wide the boat will be slow and have more resistance to waves. If the freeboard (height of the gunwale above the waterline) is too high then windage will be high and as a result the boat will be caught by the wind and the rower will not be able to control the boat in high winds. If the freeboard is too low, water will enter the boat through waves. If the boat is designed for one person then only a single rowing position is required. If the rower is to carry a passenger at the stern then the boat will be stern heavy and trim will be incorrect. To correct this a weight can be added in the bow, alternatively the boat can supply a second rowing position further forward for this purpose. For a boat to have three separate thwarts and have adequate space for each occupant then the boat has to be of a certain minimum size. A 2.4-meter (8 ft) pram dinghy can carry 4 passengers on 3 thwarts in flat seas. The ideal size of a good row boat intended for distance rowing is 5 m (16 ft).

Overall beam (width) is important. If the rowlocks are too close together the oars will be difficult to use. If the rowlocks are too far apart then the boat will be overly large and rowing will be inefficient, wasting a rower's effort. Sometimes on narrow, faster rowboats for protected waters outriggers are added to increase rowlock separation. Many traditional rowboats have a beam of about 135 cm ($4\frac{7}{16}$ ft). Most modern rowboats between 2.4 m (8 ft) and 4.6 m (15 ft) have a maximum beam of 1.2–1.3 m (4–$4\frac{5}{12}$ ft). Waterline beam is important for stability. Most general purpose rowboats' water line beams are 0.9–1.2 m (3–$3\frac{11}{12}$ ft). Stability is much influence by seat height as the rower makes up a big percentage of the total weight. Most general purpose rowboats have a main thwart height of 25 cm (10 in) above the keel. Wider boats can have higher seats. Older rowers with stiff or sore backs benefit from 28 cm (11 in) high seats. The Finnish Savonian type rowboat is very narrow and fast, having very sharp bow and stern, with beam around 110 cm (3.6 ft), but also dangerously tender and prone to capsize easily in unexperienced hands. Most modern style rowboats are considerably lighter than traditional clinker-built style. Many 3.7–4.6-meter (12–15 ft) row boats are about 32–45 kg (70–100 lb). A pure rowing boat built for speed will have a narrow transom 61–84 cm (2–$2\frac{3}{4}$ ft) and be very narrow at the stern waterline, while a rowboat intended to use a small outboard motor of 2–5 hp (1.5–3.7 kW) needs a wider transom to support the weight of the engine and operator in the stern. Small short shaft outboards need a transom height of 38 cm (15 in). Often the aft thwart is moved forward 30–36 cm (12–14 in) from the stern to give better weight distribution and balance if the boat is being operated solo with an outboard.

Spring in the keel or rocker influences how a rowboat performs. Longer, slender race boats have less rocker of about 7.6 cm (3 in). A short 2.4-meter (8 ft) pram dinghy has a rocker of 15–18 cm (6–7 in). Boats with less rocker are easier to row and faster in flat or nearly flat water. However, in any waves a boat with 13–15 cm (5–6 in) of rocker will be more seaworthy—rising over waves rather than going through them. A boat with more rocker can change direction easily whereas a straight keel boat will track well in a straight line but resist turning. High sided and fine-ended boats, such as dories, are affected by wind. Their trim can be altered by using a plastic container of water attached to a rope that can be moved to the bow or stern as need be. Long-distance rowers can keep up a steady 20 strokes per minute compared to a racing shell which can be rowed at 32–36 strokes per minute by fit athletes. A rower can maintain 40 strokes per minute for only a brief period. Longer, narrower rowboats can reach 7 knots (13 km/h; 8.1 mph) but most rowboats of 4.3 m (14 ft) can be rowed at 3–4 knots (5.6–7.4 km/h; 3.5–4.6 mph).[8]

Many old rowboats have very full ends (blunt ends); these may appear at first glance to be bad design as it looks slow, not fast. However a full-ended rowboat will rise to a sea and not dig in as a finer hulled boat might do, thus a compromise needs to be made between the factors of speed and of seaworthiness. This style of rowboat was designed to carry a bigger load and the full sections gave far more displacement. Also older boats were often very heavily constructed compared to their modern counterpart, hence weighed far more. A rowboat designed as a tender carrying occupants to a boat on a mooring might tend to be short, whilst a rowboat for use on rivers and to travel long distances might be long and narrow.

Oars

A *Sunnmørsfæring*; a Norwegian four-oared rowing boat, from the region Sunnmøre (Herøy kystmuseum, Herøy, Møre og Romsdal, Norway)

The position and length of oars is critical to rowboat performance. Generally, short boats have short oars. A 2.4-meter (8 ft) dinghy uses oars about 2 m ($6\frac{1}{2}$ ft). A short oar makes quick but short strokes possible. A short oar is easier to use in a narrow creek or a crowded anchorage. This is important in a small tender which may be heavily laden with passengers, limiting the swing of the oars. A short, quick stroke prevents the bow being driven under in choppy waters while heavily laden. Longer oars can be used to produce longer, slower strokes, which are easier to maintain over long distances. Designers may match oar length to the amount of space provided for oar storage in the boat. Wooden oars are generally made of a light, strong wood, such as fir or ash. The blades can either be flat for general use, or spooned for faster propulsion. Utility oars are often unbalanced. Rowers looking for performance and ease of use over long distances often use balanced oars, where the inboard (handle) end uses either heavy shoulders(button/collar) or lead weights inside the handle. Generally the oar is weighted so it is balanced about 28 cm (11 in) outboard of the rowlock in a 2.1 m (7 ft) oar so the oar is slightly blade heavy. Most designers position rowlocks about 30 cm (12 in) aft of the rowing thwart and about 15 cm (6 in) above the thwart. Short rowers—1.73 m (5 ft 8 in) and under—can shorten these distances by 2.5 cm (1 in) and taller rowers—1.88 m (6 ft 2 in) plus—can extend the distance 2.5–5.1 cm (1–2 in). In a short rowing boat the distance is often shortened to 23 (9) and 10 cm (4 in). The height of the rowlock plate is adjusted by the height of the wooden spacer block. Rowboat used as tenders should have U shaped rowlocks so oars can quickly be unshipped when coming alongside.

See also

- Rowing exercise
- Rowing (sport)
- Ocean rowing
- Coastal and ocean rowing
- Sculling

- Racing shell
- Row bar
- College rowing

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External links

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Categories: Watercraft | Rowing

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Royal jelly

From Wikipedia, the free encyclopedia

Royal jelly is a honey bee secretion that is used in the nutrition of larvae, as well as adult queens.[1] It is secreted from the glands in the hypopharynx of worker bees, and fed to all larvae in the colony, regardless of sex or caste.[2]

Developing queen larvae surrounded by royal jelly

When worker bees decide to make a new queen, because the old one is either weakening or dead, they choose several small larvae and feed them with copious amounts of royal jelly in specially constructed queen cells. This type of feeding triggers the development of queen morphology, including the fully developed ovaries needed to lay eggs.[3]

Royal jelly has long been sold as both a dietary supplement and alternative medicine. Both the European Food Safety Authority and United States Food and Drug Administration have concluded that the current evidence does not support the claim of health benefits, and have actively discouraged the sale and consumption of the jelly. In the United States, the Food and Drug Administration has taken legal action against companies that have used unfounded claims of health benefits to market royal jelly products. There have also been documented cases of allergic reactions, namely hives, asthma and anaphylaxis, due to consumption of royal jelly.

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- 2 Composition
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- 4 Uses
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Cultivation

Royal jelly is secreted from the glands in the heads of worker bees, and is fed to all bee larvae, whether they are destined to become drones (males), workers (sterile females), or queens (fertile females). After three days, the drone and worker larvae are no longer fed with royal jelly, but queen larvae continue to be fed this special substance throughout their development.

It is harvested by humans by stimulating colonies with movable frame hives to produce queen bees. Royal jelly is collected from each individual queen cell (honeycomb) when the queen larvae are about four days old. It is collected from queen cells because these are the only cells in which large amounts are deposited; when royal jelly is fed to worker larvae, it is fed directly to them, and they consume it as it is produced, while the cells of queen larvae are "stocked" with royal jelly much faster than the larvae can consume it. Therefore, only in queen cells is the harvest of royal jelly practical. A well-managed hive during a season of 5–6 months can produce approximately 500 g of royal jelly. Since the product is perishable, producers must have immediate access to proper cold storage (e.g., a household refrigerator or freezer) in which the royal jelly is stored until it is sold or conveyed to a collection center. Sometimes honey or beeswax is added to the royal jelly, which is thought to aid its preservation.

Composition

Royal jelly is composed of 67% water, 12.5% crude protein, including small amounts of many different amino acids, and 11% simple sugars (monosaccharides), also including a relatively high amount (5%) of fatty acids. The main acid is the 10-hydroxy-2-decenoic acid (10-HDA) (about 2 - 3%). It also contains many trace minerals, some enzymes, antibacterial and antibiotic components, pantothenic acid (vitamin B_5), pyridoxine (vitamin B_6) and trace amounts of vitamin C,[2] but none of the fat-soluble vitamins, A, D, E and K.[4]

Royalactin

The component of royal jelly that causes a bee to develop into a queen is said to be a single protein that has been called royalactin. Jelly which had been rendered inactive by prolonged storage had a fresh addition of each of the components subject to decay and was fed to bees; only jelly with an addition of royalactin caused the larvae to become queens.[5] The effect seems to be mediated by epidermal growth factor receptor (Egfr). Royalactin also induced similar phenotypical change in the fruit fly (Drosophila melanogaster), marked by increased body size and ovary development. However, there is a debate on the reproducibility of this function of Royalactin.[6]

Epigenetic effects

The honey bee queens and workers represent one of the most striking examples of environmentally controlled phenotypic polymorphism. In spite of their identical clonal nature at the DNA level, they are strongly differentiated across a wide range of characteristics including anatomical and physiological differences, longevity of the queen, and reproductive capacity.[7] Queens constitute the sexual caste and have large active ovaries, whereas workers have only rudimentary, inactive ovaries and are functionally sterile. The queen/worker developmental divide is controlled epigenetically by differential feeding with royal jelly; this appears to be due specifically to the protein royalactin. A female larva destined to

become a queen is fed large quantities of royal jelly; this triggers a cascade of molecular events resulting in development of a queen.[3] It has been shown that this phenomenon is mediated by an epigenetic modification of DNA known as CpG methylation.[8] Silencing the expression of an enzyme that methylates DNA in newly hatched larvae led to a royal jelly-like effect on the larval developmental trajectory; the majority of individuals with reduced DNA methylation levels emerged as queens with fully developed ovaries. This finding suggests that DNA methylation in honey bees allows the expression of epigenetic information to be differentially altered by nutritional input.

Uses

Royal jelly is collected and sold as a dietary supplement for humans, but the European Food Safety Authority has concluded that the current evidence does not support the claim that consuming royal jelly will give health benefits in humans.[9] In the United States the Food and Drug Administration has taken legal action against companies that have used unfounded claims of health benefits to market royal jelly products.[10][11]

Adverse effects

Royal jelly may cause allergic reactions in humans ranging from hives, asthma, to even fatal anaphylaxis.[12][13][14][15][16][17] The incidence of allergic side effects in people who consume royal jelly is unknown. The risk of having an allergy to royal jelly is higher in people who have other allergies.[12]

See also

- royal jelly acid
- Bee propolis
- 3-Hydroxydecanoic acid
- 3,10-Dihydroxydecanoic acid
- 3,11-Dihydroxydodecanoic acid

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Ruminant Feeding Strategies for Sustainable Agricultural Production in Upland Mixed Farming Systems of Indonesia

J.C. Tanner (1), E Owen (2), M. Winugroho (3) and M. Gill (4)
(1) International Livestock Research Institute, PO Box 30709, Nairobi, Kenya
(2) Department of Agriculture, The University of Reading, Earley Gate, PO Box 236, Reading, RG6 6AT, UK
(3) Balai Penelitian Ternak, PO Box 221, Ciawi-Bogor, Indonesia
(4) NR International, Chatham Maritime, Kent ME4 4TB, UK

Abstract
Ruminants are an integral part of smallholder farming systems in Indonesia. However the extent and continuous nature of cropping on densely populated islands such as Java leaves little land available for grazing. Most livestock are therefore permanently housed and fed indigenous forages cut from field margins and roadsides. Cut-and-carry feeding is labour-intensive and the supply of forage is often the most expensive input to ruminant production. Surprisingly, farmers collect quantities of forage greatly in excess of the appetites of their livestock. In Experiment 1, indigenous forage dominated by *Axonopus compressus*, was offered to sheep at increasing rates: 25, 50 or 75 g DM/kg liveweight (W) daily (d). The results showed that although DM intake and W rose with increasing offer-rate, the incremental improvements from 50 to 75 were non-significant (P>0.05) and less than from 25 to 50. Rice bran is a cheap and readily available feed. It could be used to substitute for a large proportion of the expensive forage on offer. In Experiment 2, rice

bran was fed to sheep at 0, 15 or 30 g DM/kg W0.75.d in combination with indigenous forage offered at 30 or 60 g DM/kg W.d. Sheep fed the lowest cost 30/30 (forage/rice bran) diet achieved similar total DM intakes as those receiving the 60/0 diet and W gains as those receiving the 60/15 diet (P>0.05). Even when using supplements Javanese farmers persist in offering excess levels of forage to their livestock. It is unlikely that they justify this excess feeding on the basis of marginal gains in animal productivity alone. The rationale for excess feeding may lie in greater yields of manure-compost produced from a mixture of refused forage and excreta which accumulates in pits beneath the slatted floors of their animal barns.

KEY WORDS: Excess feeding, cut-and-carry, ruminant, manure, compost, Indonesia

Introduction

Over 60% of Indonesia's 194 million people live on the island of Java which occupies only 7% of the country's total land area. Half of Java's population are farmers (Biro Pusat Statistik, 1991) cultivating less than 0.5 ha per household (Booth, 1988). Cropping is continuous. Java is thus not only one of the most densely populated areas of the world with around 800 person/km2 , but one of the most intensively cultivated (Kepas, 1985).

Ruminant livestock are an integral part of these intensive farming systems. In 1991, over 30 and 60% of Indonesia's large and small ruminant populations respectively were located on Java despite intensive cropping leaving little land for grazing (Direktorat Jendral Peternakan, 1992). Ruminants are instead permanently housed (around two large ruminants and/or up to five small ruminants per household) in backyards and cut-and-carry fed indigenous grasses and broadleaves collected from roadsides and field margins. Cut-and-carry feeding is labour intensive making forage the most expensive input to livestock production.

Surprisingly, farmers collect large quantities of forage, often greatly in excess of the appetites of animals (Mathius & van Eys, 1983) with as

much as 400 g/kg DM of that offered being refused (Little, Petheram & Boer, 1988).

The forage refusals are not wasted, they combine with faeces and urine falling through the slatted floors of the animal barns into pits where they decompose to produce manure-compost. High forage offer-rates maximise manure-compost yield. It is possible that farmers adjust their feeding rates to optimise total output from the livestock enterprise i.e. including manure-compost, as opposed to animal production per se. Manure-compost is ranked by Javanese farmers alongside offspring as the most important outputs from livestock production (Ifar, 1996).

It is hypothesized that livestock integration into Javanese agriculture is essential to the sustainability of some of the most intensive cropping cycles in the world. As intensive smallholder agriculture expands onto more marginal soils world-wide there is urgent need for developing strategies for closer integration of crops and livestock. Excess-feeding, an effective means of improving intake and productivity of ruminants fed low quality forages by providing greater opportunity for selective feeding (Osafu, Owen, Methu, Abate, Tanner & Aboud, 1996) and also generates high quality composts, may be one such strategy. The biological and economic relationships between excess-feeding, animal productivity and manure-compost production are reported in this paper.

Experiments Undertaken

Experiment 1: Effect of Quantity of Indigenous Forage Offered on Intake and Growth by Sheep and Manure-compost Yield.

Materials and methods:

Thirty Javanese Thin-tailed rams (aged 18 months, mean W 29.1 kg, s.e. 0.3) were blocked according to initial W and then randomly allocated to one of three forage offer levels: 25, 50 or 75 g DM/kg W.d. Indigenous forage, cut each morning from roadsides and field margins, comprised largely of grasses (71% of fresh weight offered) dominated by *Axonopus compressus*, with the remainder as sedges, broadleaved plants and dead plant material. The daily ration was split into two equal meals offered at

8.00 h and 12.00 h, salt licks and water were freely available. The feeding trial lasted 70 days during which intake was measured daily and W changes weekly.

Refused forage, faeces and urine were collected daily from three rams per diet, mixed and stored in slat-sided composting bins measuring 1.5x1.5x1.5m. The waste materials were collected in this manner for the last 50 days of the feeding trial and then left to compost for a further 50 days, turning every 3 days to assist aeration, before weighing and sampling for DM content.

Experiment 2: Effect of Quantity of Indigenous Forage and Rice Bran Offered on Intake and Growth by Sheep and Manure- compost Yield.

Materials and methods

Thirty-six Javanese Thin-tailed rams (aged 30 months, mean W 28.8 kg, s.e. 0.03) were blocked according to initial W and then randomly allocated to one of six feeding regimes in a 2x3 factorial design: 30 or 60 g DM/kg W.d or indigenous forage in combination with either 0, 15 or 30 g DM/k gW0.75.d of rice bran. The diets were coded as follows (forage/rice bran): 30/0, 30/15, 30/30, 60/0, 60/15 and 60/30. The daily ration of indigenous forage (of similar species composition to that fed in Experiment 1) and rice bran was again split into two meals and fed at 8.00h and 12.00h. Water and salt licks were freely available. The feeding trial lasted 42 days during which intake was measured daily and W changes weekly.

Refused forage, faeces and urine were collected from three different pairs of rams per diet over three 14-day periods. Accumulated waste materials from each pair of rams were mixed at the end of each 14-day period and composted for 50 days, turning every 3 days as described above. A quantity of forage equivalent to that which would be fed to two, 30 kg W rams on the 60/0 diet was also collected over each 14 day period to assess the profitability of composting grass directly in the absence of livestock.

Results

Table 1 shows that the DM intake and growth rate of the rams in Experiment 1 improved with offer-level but that the incremental improvement from 50 to 75 g DM/kg W.d was non significant ($P<0.05$) and less than that from 25 to 50. The quantity of grass refused increased substantially as a proportion of that offered from 0.109 to 0.526 by raising the offer level from 25 to 75. Allowing the rams greater opportunity for selective feeding by raising the offer-level improved the estimated N content of the diet consumed from 21.2 to 22.5 and 23.8 g/kg DM. Not surprisingly, manure-compost production rose with forage offer-level.

Table 1: Effects of increasing forage offer level on intake, ram growth rate and manure-compost yield.

Quantity of forage offered (g DM/kg W.d)	25	50	75	s.e.d
Number of rams	10	10	10	
Initial W (kg)	29.2	29.1	28.9	0.33
Growth rate (g/d)	-16.5	25.8	28.5	4.73
Intake:				
Forage offered (g/d)	3627	7772	11616	
Forage offered (g DM/d)	671	1438	2149	
Forage refused (kg DM/kg DM offered)	0.109	0.359	0.526	
Forage intake (g DM/d)	598	922	1019	
Forage intake (g DM/kg W.d)	22.1	31.7	34.9	1.16
Manure-compost yield (g/ram.d)	540	1620	2320	

In Experiment 2 (Table 2), forage and rice bran offered both had significant effects upon forage DM intake, total DM intake and forage refused as a proportion of that offered (P<0.05). Increasing the level of rice bran on offer increased bran intake but as a consequence substituted for forage intake. Increasing the rice bran offered caused a significant (P<0.05) rise in W gains at each level of forage on offer. It should be noted that rams fed the 30/30 (forage/rice bran) diet grew faster but produced less manure compost than those fed the 60/0 diet.

Table 2: Effects of increasing forage and rice bran offer levels on intake, ram growth rate and manure compost yield.

Forage offered (g DM/kg W.d)			30			60	
Rice bran (g DM/kg W0.75.d)	0	15	30	0	15	30	s.e.d
Number of rams	6	6	6	6	6	6	
Initial W (kg)	28.9	29.7	28.8	28.9	28.4	28.9	0.73
Growth rate (g/d)	-21.0	13.2	37.5	-2.4	34.5	53.6	22.8
Intake:							
Forage offered (g DM/d)	810	853	848	1702	1683	1750	
Forage refused (kg DM /kg DM offered)	0.174	0.246	0.277	0.463	0.516	0.539	
Forage intake (g DM/d)	670	644	616	909	815	804	51.6
Forage intake (g DM/kg W.d)	24.3	22.3	21.3	31.6	28.5	27.1	0.62
Rice bran intake (g DM/kg W0.75.d)	-	13.7	25.4	-	14.4	23.5	
TOTAL INTAKE (g DM/kg W.d)	24.3	28.2	32.3	31.6	34.7	37.2	1.49
Manure-compost yield (g/ram.d)	607	964	1107	2750	3071	3357	

In Experiment 1, although the high feeding levels produce the best W gains and manure-compost yields these benefits must be offset against the extra time required to supply the feed (Table 3). The most profitable ration would be that which yields the highest returns to labour (calculated as: [Value of outputs - Non labour costs]/hours of labour). The financial analysis reveals that feeding at 50 gDM/kg M.d was most profitable irrespective of whether manure-compost was considered as an output or not. The lowest level of feeding was unprofitable with the costs of production alone (excluding labour inputs) exceeding the value of growth and manure-compost production.

Table 3: Estimated cost of production (Rp1/ram.d), value of outputs (Rp/ram.d) and returns to labour (Rp/hour) when feeding indigenous forage to rams at increasing levels of offer.

	COSTS		OUTPUTS		RETURNS TO LABOUR	
Offer -rate	Labour*2 (h)	Other*3 (Rp/d)*1	Compost*4 (Rp/d)	Weight*5 (Rp/d)	Including compost (Rp/h)	Excluding compost (Rp/h)
25	0.42	18.6	18	-50	-120	-163
50	0.83	18.6	54	77	135	70
75	1.2	18.6	77	86	120	56

*1: USD 1 = Indonesian Rupiah (Rp) 2110 (1993 rate)
*2: The lowest cost of forage input corresponds to the lowest forage offer level (25 g DM/kgW.d) and the highest forage cost to the highest forage offer level (75 gDM/kgW.d) assuming it takes 5.9 minutes to cut 1 kg of grass (derived from van Eys *et al.*, 1984 and Amir *et al.*, 1985).
*3: Non-labour costs, in decreasing order of magnitude, including depreciation on the sheep barn, minerals, anthelmintics and miscellaneous expenses on ropes etc.
*4: On average, a 30 kg sack of manure-compost fetches Rp 1000 (Holden *et al.*, 1993),equivalent to Rp. 33/kg.
*5: Assuming a sale price of Rp. 3000/kg (or Rp 3/g) (Biro Pusat Statistik, 1991).

In Experiment 2, feeding unsupplemented forage diets gave negative returns to labour when outputs did not include manure-compost. Supplementing rams improved profitability through higher animal growth rates. Including manure-compost as an output substantially improved the profitability of all diets. However, it should be noted that it is more profitable to compost forage directly than to feed that quantity to an animal. Greater returns could however be achieved through supplementation. At the highest rate of supplementation (Diet 60/30) a farmer could increase returns to labour by around 50% compared with composting the same quantity of grass directly.

Conclusions

Excess-feeding strategies have been demonstrated to be an effective means of improving intake and productivity of small ruminants and cattle fed low nutritive value fodders such as cereal crop residues (Osafo, Owen, Methu, Abate, Tanner & Aboud, 1996). Offering excessive levels of feed inevitably produces large quantities of refusals which appears wasteful. In many smallholder situations excess-feeding may only be economically rational if other uses can be found for refusals.

Excess-feeding indigenous forages led to higher intakes and growth rates which raised returns to labour (Experiment 1). It was demonstrated that the profitability of the livestock enterprise could be significantly improved however by using the refusals and excreta to produce compost. Although, feeding at the highest offer-level yielded a positive return to labour, the calculated 'hourly wage rate' was 11% less than that obtained from feeding the 50 g DM/kg W/day diet where compost is included in the total output and 20% less where compost is excluded from outputs. A cheaper alternative to feeding high levels of expensive cut-and-carry forage might be to replace part of the diet with rice bran. In Experiment 2, feeding rams the 30/30 diet resulted in better returns to labour than the 60/0 diet. However, the most expensive diets, 60/15 and 60/30, where rice bran is fed in addition to excess levels of forage, turned out to be the most profitable. This suggests that even in circumstances where Javanese farmers are feeding rice bran they will persist in offering high levels of forage to maximise not only W gain but also manure-compost output.

The need to maximise manure-compost output is particularly acute on smallholder farms in densely populated areas where intensive cropping patterns place heavy demand upon soil nutrient status. The research shows that excess-feeding represents a financially rational feeding strategy for such production systems permitting the optimisation of animal and fertiliser outputs.

As the price of inorganic fertilisers continues to rise beyond the means of smallholder farmers, greater reliance will be placed upon livestock wastes to maintain soil fertility. However, even when the yield of organic fertiliser outputs from livestock is maximised by excess-feeding for example, the quantity of plant nutrients may not be sufficient to totally replace artificial fertilisers in a manner which is economically viable. Animal scientists should be aware that excreta is often used in combination with inorganic fertilisers. There is a need to be able to predict the influence of diet upon excreta quality and the consequences of manure handling upon nutrient loss. A better understanding of the degree to which livestock management practices influence the plant nutrient contents of animal "wastes" would provide agronomists with greater confidence to make integrated fertiliser recommendations which could, for example, capitalise upon the reported synergy between limited quantities of inorganic and organic fertilisers. The development of livestock feeding strategies for mixed-farming systems should therefore take into account not only livestock requirements but also the nutrition of soils and crops.

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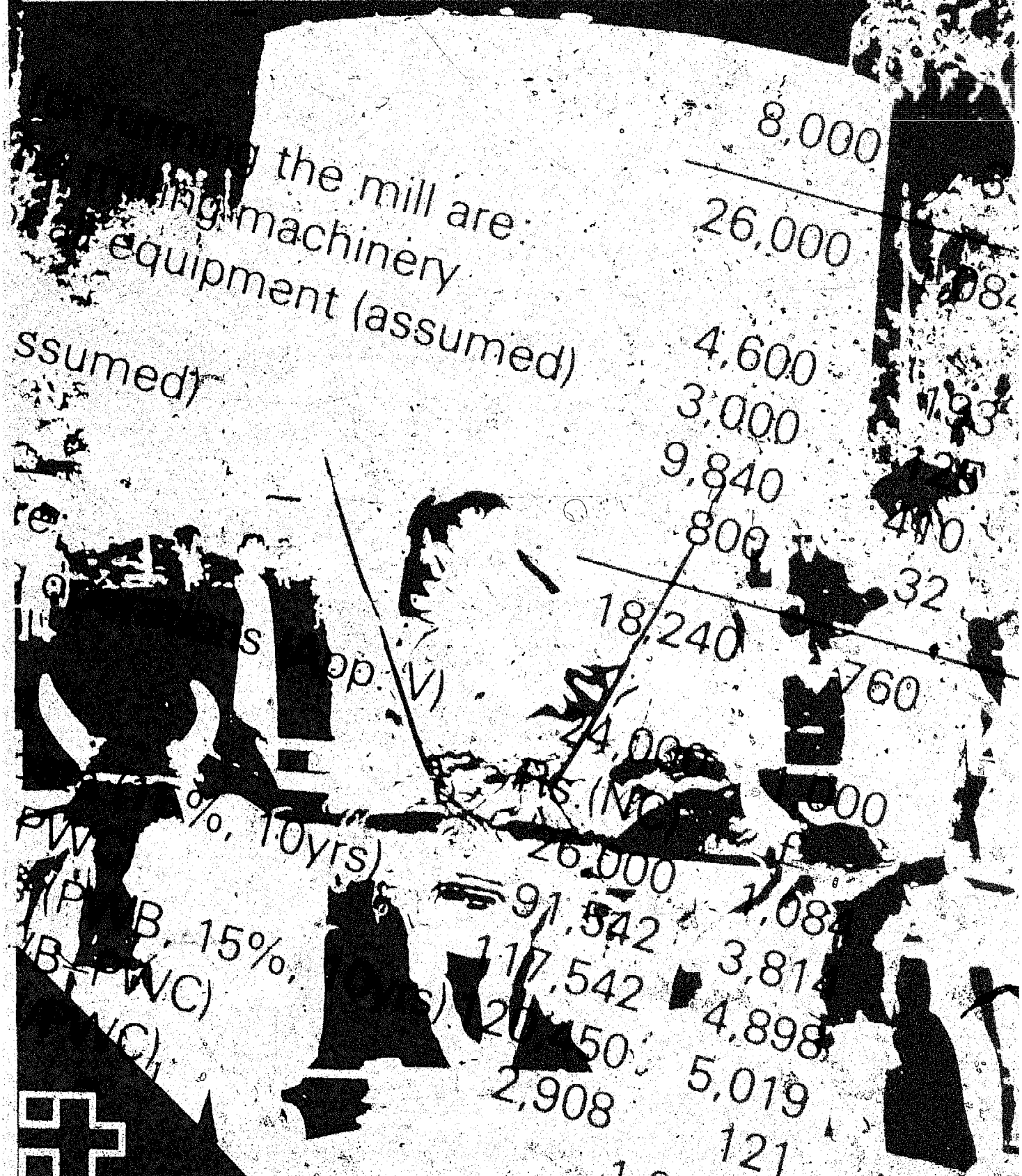

RUNNING A BIOGAS PROGRAMME

A handbook

DAVID FULFORD

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Notation used in Drawings

The notation used in the drawings and equations in the book follows international engineering practice as far as possible.

Almost all dimensions are in millimetres, so 1000 is 1 metre.

A few dimensions (such as GI pipe) are also shown in inches.

Tolerances are not usually shown on drawings. In general, masonry dimensions are rounded to the nearest 10 mm implying a tolerance of ± 10 mm. Machined parts (such as in gas stoves) are shown to the nearest 1 mm.

When a drawing is of the outside of an object, in elevation, only the outline is drawn. When an object is shown in section, cut across to show internal details, the sectioned parts are shaded or patterned to indicate the material from which they are made. A key to these patterns is given below.

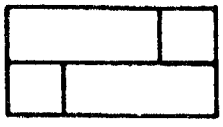
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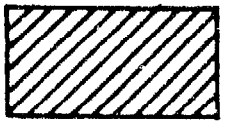
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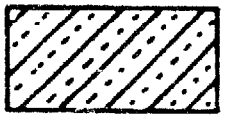
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Concrete

Plastic

Plaster or ceramic

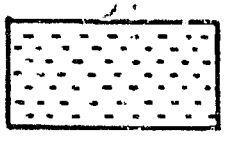
Liquid

The equations given in this book are designed to be used with a simple electronic calculator. A scientific calculator, with trigonometric functions, is most useful.

Logarithmic functions are used in some of the equations. Logarithms to base 10 are denoted by: 'log', while logarithms to base: e (2.71828) are denoted by: 'ln'. Most scientific calculators have both functions, but conversion from one to the other is given by: $\log(x) = \ln(x)/\ln(10)$.

CHAPTER 1
An Overview of Biogas

1.1 A world view of biogas

There are many advantages to biogas technology for people living in the rural areas of a developing country. A biogas plant can digest materials that are readily available on small farms, such as animal dung and crop wastes. Biogas digestion not only produces a clean, high-grade fuel gas, it also gives a residue that is a good fertilizer. The quality of this fertilizer is often higher than if the same materials were composted by more traditional methods.

Biogas is much more convenient to use than traditional fuels, such as firewood, dried dung and even kerosene. It gives a hot, clean flame that does not dirty pots or irritate the eyes, as does the smoke from other fuels. The compost from the plant does not smell or attract flies. Once it has been dried, it is easy to apply to the crops in the fields.

Biogas can be used in engines to drive machinery and water pumps. Groups of farmers can come together to buy and run a biogas plant with an engine and they will all benefit from the income earned from a cottage industry, such as a grain mill, or from the increased crop production resulting from pumped irrigation.

The concept of replacing wood fuel and petroleum oils by alternative fuels, such as biogas, has encouraged governments in various countries to set up biogas programmes. In India, for example, over 200,000 biogas plants were reported to have been completed by 1984, in a programme that started in the 1950s. In 1985 the government set a target for another 1,500,000 plants to be built in the five years to 1990. In China, the total claim for biogas plants built by 1985 was over 10,000,000 (including both Moulik's[1] and Cui's[2] totals for plants built before and after 1979).

Biogas programmes in other Asian countries have had erratic histories. Korea had 30,000 plants in 1979,[3] but problems with poor gas production in Korea's cold winters seem to have reduced the impetus.[4,5] Thailand has had a small biogas study programme for many years, but an adequate supply of other fuels has meant a slow growth in the extension to rural areas. The high cost of imported fuels and a high national debt have encouraged Brazil, along with other South American nations, to start biogas programmes. Between 1980 and 1985 Brazil built 7,530 plants.[6]

However, biogas technology does not always seem to have lived up to expectations. Despite government subsidies (25 per cent to 50 per cent for

family plants, 75 per cent to 100 per cent for community plants) and high-pressure salesmanship by extension agents the uptake of biogas technology in India is much slower than government targets (between 1975 and 1980, 5,000 to 6,000 plants were built per year, compared to the annual target of 20,000 plants.[7]) Biogas technology has only really reached one stratum in Indian society, the richer land-owners in the rural areas, because of the way the programme is approached. There are attempts to reach poorer people through the use of community biogas plants, but there are manv problems.[8]

After the initial enthusiasm for biogas in China inspired by Chairman Mao, the image of biogas technology has weakened, partly due to reports of a 40 per cent to 50 per cent failure rate.[9] Many of the plants built in the 1970s had short lives (less than five years).[2] The actual failure rate can be assessed from the claim in 1979 that China had 7,000,000 biogas units.[1] The 3,300,000 units built since 1980 are of much improved quality.[2] However, the total number of working plants in China in 1985 was claimed to be 4,480,000,[2] suggesting that few plants built before 1980 have survived, despite a reported government-sponsored repair programme.[1]

Western nations and development agencies have been much less enthusiastic about biogas technology. Being labour intensive, it does not fit well into mechanised Western farming techniques and automating a biogas plant appears expensive. Plants in Europe and in the more northerly states of America suffer from low winter temperatures, so must be well insulated and heated if they are to produce year-round gas.

In Britain and the USA especially, biogas also has an unfortunate political flavour. The early advocates of alternative energies included people from counter-cultures that rejected philosophies of fast growth and energy from nuclear fuel. The enthusiasm of these radicals for biogas technology was based on the work of a very few pioneers, such as L.J. Fry (South Africa and USA)[10] and Harold Bates (UK).[11] When the oil price rises of the 1970s made people take alternative fuels more seriously, the lack of adequate experience with biogas technology became apparent. Several attempts to commercialise biogas failed because of poor design work and weak economic analysis.[12]

During the 1980s biogas has developed a more acceptable, if more mundane, image. Much research has been done, in both Europe and USA, and many different designs and types of plant are now available.[13] The commercial application of biogas in the West is still very limited;[14] less than 100 farm-scale plants are reported in USA, although some of these are of a very large scale (up to 10,000 cu.m working volume).[15]

The atmosphere in Europe is also slowly changing. Agencies in places such as Sweden and Germany (such as the Beier Institute and BORDA) are keen to advocate biogas, especially in their programmes of aid to the Third World. In other countries, such as Belgium and France, concern

over pollution from farms has led to an improved economic climate for building biogas plants as a means of reducing the oxygen demand of animal wastes.[16]

In general, biogas technology faces the future from a weak base, but with increasing opportunities for its use. If planners are not to repeat the mistakes of the past as they attempt to fit biogas into development and aid programmes, they need to understand the limitations of biogas technology as well as its benefits. The economic, technical and organisational difficulties of setting up a biogas programme need to be faced and plans made to overcome them.

1.2 Biogas in Nepal

The biogas programme in Nepal is small, as befits a small developing country. Between 1974 and 1984, 1,400 plants were built and the extension programme moved from being a local test programme into one that sold plants over the whole country. The programme was launched by the Agricultural Department of His Majesty's Government of Nepal (HMG/N), but the responsibility of continuing it lies with Gobar Gas tatha Krishi Yantra Bikash (Pvt) Ltd. This private company was set up as a joint venture by the United Mission to Nepal (UMN) and the Agricultural Development Bank of Nepal (ADB/N), with the help of the Fuel Corporation of Nepal.[17]

The particular position of the Nepal programme, small enough to analyse easily, but national in scope, makes it a valuable base from which to consider biogas programmes in general. Our experience in this programme, with our understanding of some of the reasons behind both its successes and its failures, allows us to suggest guidelines that would help biogas programmes in other places.

1.3 Challenges of biogas

The challenges that face attempts to popularise biogas are not so much difficult as unexpected and complex. Biogas is very difficult to define as an academic subject, as it includes many different disciplines.

The process by which biogas is made is microbiological. The biochemistry of anaerobic fermentation is very complex. While the details are becoming clearer as a result of an effective research effort in many countries, such as USA and China,[18,19,20,21] the next step, to design microbiological systems that are more effective and efficient at biogas digestion, appears to be still in the future.[22,23]

The practical problem of making cheap but effective biogas plants is one of civil and mechanical engineering. Again, research effort has produced many different designs of plant.[15] The selection of the right plant for

the job requires well-informed and accurate technical judgement. Once biogas is produced, suitable, cheap biogas appliances must be designed and manufactured.

The economics of biogas are important; people will not use a new technology, however good, if it costs more than the alternatives. There are also sociological implications: biogas is called '*gobar gas*' in Nepal and India, as '*gobar*' is the word for cow dung. The cow is a holy animal to a Hindu, so gobar is an acceptable source of cooking fuel. Pig dung and human faeces are not acceptable feedstocks for a biogas plant for many Hindus, even though the gases produced from them are almost the same.

Since biogas technology uses animal dung and agricultural residues as feedstocks and produces a fertilizer as well as a fuel gas, it should belong to the subject of agriculture. The main users of the technology are farmers. The use of the effluent from a biogas plant brings in the subjects of soil science and horticulture. In China, where composting of all agricultural residues, including human faeces (night soil) is held in high esteem,[24,25] the use of biogas plants for producing good compost is often more important than the fuel gas.

The organisation of biogas programmes has proved difficult, particularly as there may be political dimensions. In India, the government gives large subsidies for the construction of biogas plants and annual construction targets are defined. In China, while biogas technology was given an initial impetus by Chairman Mao's Great Leap Forward, the ongoing incentive lay in biogas plants and pigs being owned privately, in the midst of a state-run economy.[9] In Nepal, the organisation was further complicated by making the extension work the responsibility of a commercial concern. This company was supposed to make a profit on the sale and construction of biogas plants. The Agricultural Development Bank was also involved in giving loans so that farmers could pay for their plants.

When a government department or an aid agency plan to start a biogas programme, they are faced with this set of closely related challenges that demand a very wide range of skills and experience. A biogas team cannot usually employ experts in every field, so people involved in biogas technology must be 'generalists' with skills in different fields.

1.4 Economic challenges

While the economics of biogas have received much attention,[26,27,28,29] the conclusions are not hopeful. The running costs of a biogas plant are low, but the capital costs per unit of energy produced are fairly high. This is a factor common to most alternative energy technologies, because the energy density in biomass, or wind or sunlight, is much lower than in coal, oil, nuclear energy or even hydro-power. The physical dimensions of a

plant to extract that energy must be larger per unit of energy produced than for conventional plants.

Conventional energy plants also rely on economies of scale to extract large amounts of energy in centralised units. Alternative energy technologies tend to be diffuse; plants are small and scattered, and this also increases the capital cost per unit of power produced.

Many analyses of the economics of biogas consider only its use as a domestic fuel, such as for cooking and lighting. The benefit: cost ratio is then very sensitive to the cost of alternative cooking fuels, usually firewood (see Chapter 9). If the cash cost of wood fuel is low, the savings made by replacing it with biogas appear to be financially unattractive. The original investment made on the purchase of a biogas plant may not be recovered from these savings for seven to ten years (based on figures from Nepal). The actual cash cost to many farmers of wood fuel is often zero, as they go to collect their own supplies from the forest, although this is illegal in many countries.

The environmental cost of wood fuel is often very high, as deforestation can result in land erosion, landslides and floods. Some governments try to prevent this by giving subsidies to people building biogas plants. Even with the 25 per cent to 50 per cent subsidies given by the government of India, it has been estimated that only 10 per cent of the population can afford domestic biogas units.[9]

Approximately 0.33 litres of oil are used to produce 1 kW.hr of electricity, either in a diesel generator or in an oil fired power station. The same energy requires 667 litres of biogas, produced from 60 kg of cattle dung (i.e. 120 litres of slurry when mixed with water). The biomass occupies 360 times the volume of oil for the same energy.

The cost of an oil-fired power station in 1982 was about £1,450 per kW for medium-scale units (around 5MW). A biogas unit, producing 2 m^3 of gas a day, cost around £530. If this amount of biogas were to be used to drive a generator set, it would produce about 3kW.hr per day. This gives a capital cost of £4,270 per kW, about three times higher. However, the cost of feedstock for a biogas plant is negligible, while the cost of oil (even at $18 per barrel in 1988), is of major concern for many governments.

Also, this example does not include the cost of distribution of power. Biogas plants can be built in villages, from which the supply of feedstock comes. The cost of power transmission to remote villages becomes very expensive, making the economics of biogas more attractive.[28,29]

Example 1.1 Economic considerations

Biogas can also be used to fuel engines, which can then earn an income for the owner. However this requires a larger plant, which uses feed from more than 20 cattle (if cattle dung is the main feed). Either dung must be bought in from outside suppliers or several farmers must co-operate to run such a plant. The economics of a group-owned plant running a grain mill look reasonable in Nepal (see Chapter 9). The group of farmers could recover the original investment within the period of the loan (seven years). Government subsidies help to increase the economic attractiveness of this approach.

In general, biogas technology is expensive. Further technical development work may reduce the capital cost, but the present economic viability of biogas programmes seems to depend mainly on the political commitment of national governments.

1.5 Technical challenges

Economics put a severe constraint on the technologies. It is relatively easy to make a biogas plant that will produce gas and fertilizer; there are many designs available.[30,31] The more difficult task is to design a biogas plant that is both effective and cheap enough for people to afford. It may be possible to make a few low-cost plants by using scrap materials, but the technology used in a national biogas programme must be reproduced for thousands of plants by workmen with suitable training.

Biogas plants designed in the developed world, especially in USA, Japan and Europe, tend to be fairly complex, with slurry pumps and temperature control systems and they use specialist materials, especially plastics. While some of these designs are specifically for research plants, in which different parameters need to be monitored, this whole design philosophy is clearly inappropriate to rural areas in developing countries.

Low cost, simplicity and the use of local materials are the priorities when designing biogas plants for rural farmers. These requirements pose special problems. In Nepal the materials available, such as cement and steel, are of undefined and variable quality, so can not be used in designs that demand accurate specifications. An over-emphasis on low cost, as in the late 1970s in China, can also cause problems. The plants did use local materials: lime and locally made cement, but they had short life-times and quickly failed.

Design data and principles learned in a developed country are often misleading. Techniques and design approaches need to be adapted to the local situation. Simple, appropriate technology often demands scientists and engineers with more skills and wider know ledge than does the sophisticated, but routine, technology of the developed world.

1.6 Organisational challenges

The advocates of appropriate technology tend to be engineers, so the technical side of a programme is often emphasised to the neglect of other areas, especially those of organisation and management. In the enthusiasm to develop a technology, management can be left to chance.

The result is 'crisis management', a series of decisions made to meet problems only as they arise. Since these problem-solving decisions are seldom well-planned, they give rise to further problems that need solutions. These crises become more difficult and frequent as the programme gets bigger and more complex. The neglect of well-planned decision-making in the early stages of a biogas programme can give rise to administrative problems that can slow, or even destroy, its progress.

A biogas programme must be well-planned from the beginning. The managers and senior technicians who are to be involved in the running of the programme should be appointed and trained early enough for them to be involved in the planning process. Technical and extension staff should be trained in administration, book-keeping and personnel management, so they can run their sections of the programme effectively.

CHAPTER 2
National Biogas Programmes

Biogas programmes in many countries have followed a similar pattern. Interest in biogas technology is first encouraged by a few entrepreneurs and enthusiasts. After some time (a decade or longer), the government, or a key figure in the country, takes up the idea and launches a biogas programme. A feature common to most government programmes in any country seems to be poor organisation, as government planners set high achievement targets without the skills, experience or resources to back them up. In time, the programme finds its own level, its progress relating more to political and socio-economic factors than planners' aims.

2.1 Biogas in China

Biogas technology was introduced into China by an entrepreneur, Lo Guorui, who set up a private company for the building of biogas plants in the 1930s. He developed the Chinese displacement digester principle, in which slurry is displaced from the digester pit into a reservoir as gas collects under the roof of the pit (see Chapter 5). Several hundred units were built, mainly for rich land-owners, of which about fifty survive and still work well.[1] Most of these plants had rectangular digester pits, although a few cylindrical designs were also made. Their sizes ranged from 6 to 108m^3 internal volume and they were made of brick or stone, with concrete roofs. While the quality of construction was very good, the cost of the plants was very high.

After the communist take-over, Chairman Mao introduced biogas as part of the Great Leap Forward in the 1950s.[2] Government cadres in the Communes mobilised local people to build their own biogas units. The Communes were set up as the basic administrative structure in rural China and would contain 4,400 to 5,800 households. Supplies of cement, bricks and reinforcement steel were obtained from new local factories set up under the same programme. People from a Production Team (30 to 80 households in size) would exchange 'work points' as a means of paying for each others' labour in building biogas plants, animal sheds and other projects.

A large number of plants were built, but their reliability was not good and many did not function for long. The basic design was poor, as it used a flat-roofed digester pit,[3] which was difficult to make gas-tight. The local

supplies of cement, brick and steel were of variable quality and there was a lack of trained masons who could guide the local people in their construction work.

The biogas programme was revived in the 1970s, apparently spontaneously, by local people's groups in Sichuan Province.[1] New designs appeared, such as plants with domed roofs, apparently as a result of peasant farmers' attempts to improve the technology. Its initial success attracted government attention, and the widespread use of biogas plants was again encouraged. As in the 1950s, the mistake was made of trying to expand the programme too fast, with inadequate resources and skills. Records suggest that about 1,600,000 plants were built each year at a very low cost (40 yuan, about £13, each), but after only a year or two problems began to appear.[4]

The Cultural Revolution created a further problem as it caused many people with technical expertise to be removed from universities and research institutions. Is is possible, of course, that technically trained academics, who were forced to work in the communes alongside peasant farmers, were able to suggest design improvements to biogas plants being built in their villages.

As the programme developed in the 1970s, support was required from higher political levels, such as provincial and national governments. Supplies of cement, bricks and lime (or coal with which to make them) had to be traded between communes. Many leading figures in China, including Chairman Mao, were keen supporters of the programme, so political pressure encouraged its continuation.

A national biogas organisation eventually grew out of the needs of the popular programme. As the demand for information and training increased, provincial governments had to set up their own biogas bureaux. As academic institutions were re-established after the effects of the Cultural Revolution had faded, they became interested in doing research on biogas, so became involved in the dissemination of information. By 1978 the Chinese national Ministry of Agriculture had set up a biogas office at Beijing in Sichuan. After several national biogas conferences to discuss the problems of the programme, especially the short life-times of the 'popular' design (less than five years,[4]) the Chinese government recognised that a nationally coordinated approach was required.

A 'Leading Group' was established to coordinate the biogas programme on a national level, with members from the Planning, Economic and Scientific Commissions.[5] At the time of writing their decisions are implemented by the National Biogas Extension Office (NBEO), coordinating the activities of 25 provincial extension centres. The Chinese Academy of Sciences was encouraged to become involved in research and development (R & D) work in fields related to biogas technology at some of its research institutes, such as the Chengdu Institute of Biology, the

Guangzhou Institute of Energy Conservation and the Beijing Energy Research Institute. Staff from these places work with the NBEO, helping solve some of the more difficult problems that arise from the extension work. Some provincial extension offices have also set up their own experimental stations.

Since 1979 standards have been issued for the construction of better quality biogas designs.[6] Only trained, certificated technicians are allowed to build plants and they are encouraged to join digester building teams (of which there were 7,000 in 1985). The teams are themselves being formed into biogas service companies (716 in 1985). These companies undertake contracts for digester building and management, are self-managed and funded and are as close to being private limited companies as present attitudes in China allow.[1]

The plants built by these teams cost much more than those that people built themselves (200 yuan, about £63, for a family unit), but they are expected to have much longer lifetimes.[4] The rate of construction has decreased, being around 20,000 per year during 1982/83, for the whole country.[5] An emphasis on the use of good designs, the employment of skilled workmen and effective quality control have ensured that the plants that people use are much more reliable than previously.

There is a growing interest in extending the scope of biogas technology; for example using the gas from sewage digesters and from plants using food processing waste to fuel power stations. In some places, central biogas plants supply gas to homes in the surrounding area, using wastes such as distillery dregs as the main feedstock. This is related to a growing concern to restrict pollution from the new industries that are being established in many parts of China.

2.2 Biogas in India

The Indian biogas programme was inspired by research carried out by the Indian Agricultural Research Institute at Delhi,[7] in connection with a sewage plant in Bombay. The idea was taken up by J.J. Patel of the Khadi and Village Industries Commission (KVIC) in 1951 and the commission set up its own national biogas programme. The KVIC was originally set up to encourage village industries, especially 'khadi'—hand-spun and woven cotton goods—along the lines inspired by Mahatma Gandhi. It has an effective team of extension agents, with good technical training, although there are not enough of these people to fulfil all the demands made upon them. KVIC is also involved in the extension of other technologies, such as soap-making and carpentry (up to 20 different rural industries).[8]

Various biogas plant designs were tested at the KVIC Biogas Centre near Bombay, but the choice of design for the extension work was unfortunate. Due to a misunderstanding of the results of the initial research

work done in Delhi (see Chapter 11), a design using a counter-balanced floating steel gas drum was used. This caused many problems for customers.[9] KVIC continued the research and development work, coming up with a better design which was called the 'Gramalaxmi III'. This still used a steel gas drum, but it was allowed to float on the surface of the slurry and was held upright by a central guide pipe (see Chapter 5).

Other groups became interested, such as the one led by Ram Bux Singh of the Planning, Research and Action Division of the State Planning Institute of Uttah Pradesh in Lucknow.[10] He set up a biogas research centre in the village of Ajitmal near Etawah. Some of his early plants were more successful and are still working, including some larger-scale ones (up to $100m^3$ working volume). By 1974 over 6,000 plants had been built in India, mainly in the Western states of Gujurat and Punjab and in Uttah Pradesh. Mr Patel started a private company himself, Patel Gas Crafters, to make biogas stoves and lights for the programme.

In 1975 the Department of Science and Technology of the Indian government decided that the biogas programme needed a broader scientific and organisational base.[11] Many more agencies became involved, including those in the local voluntary sector as well as academic institutions.[12] The All India Committee on Biogas (AICB) was set up in Delhi, with the aim of coordinating all the agencies involved in the programme and, especially, to encourage research institutions to consider problems relating to biogas technology. In all, 192 different organisations became involved, including government institutions such as the National Energy Board, the Indian Institute of Technology and the State Bank of India. As well as semi-government corporations, such as the Agro-industries Corporation, many state run groups are also involved, as are 30 private enterprises, including that Tata Energy Research Institute. The most effective sector for biogas extension seems to be the non-governmental organisations (NGOs), although they often lack technical skills and knowledge.

The committee put emphasis on the extension of the 'Janata' (people's) plant—a version of the Chinese fixed-dome design developed at PRAD. This design was supposed to be much cheaper than the floating drum design, as it did not require a steel gas holder. One voluntary organisation in particular, Action for Food Production (AFPRO), based in Delhi, has built over 1,000 plants to this design,[13] and has also trained many masons to be proficient in its construction.

The Structural Engineering Research Institute (SERI) at Roorkee developed a design of floating gas holder made of ferro-cement, where a thin layer of cement mortar is reinforced by wire mesh.[14] KVIC have been using this design in their extension work in some areas, such as Andra Pradesh and Madhya Pradesh in the south-eastern part of India.[15] By 1980, 80,000 plants had been built in India, although the reported failure rate was about 30 per cent.[16] Between 1980 and 1985 the Indian government

established a National Project on Biogas Development to build 400,000 family-sized biogas units at a cost of Rs.50 crores (about £33 million).[12] For the Seventh Development Plan (1985 to 1990), government planners have defined that another 1,500,000 plants should be built.[11]

The high cost of the National Project on Biogas is a result of the Indian government's policy of giving subsidies for biogas plants in many areas of the country. These range from about 30 per cent of the construction costs for most applicants to up to 55 per cent for scheduled tribes and for people in hilly areas where deforestation is becoming a problem.[12] Incentives are also paid to the agencies involved in constructing biogas plants as well as to extension agents whose job it is to persuade farmers to buy plants. The rest of the cost of a biogas plant can be borrowed from commercial banks.

Emphasis in both the Sixth and Seventh Development Plans has been laid on building biogas digesters for communities of farmers and for institutions, such as dairy schemes and agricultural colleges. Subsidies of up to 100 per cent are being made available for these projects. Ten such plants were to be built between 1980 and 1985, but this part of the programme has not been very successful. In 1986 about 25 community/institutional plants were being used in the whole of India, but many only survive through subsidies from groups such as KVIC and PRAD (see also Chapter 12).[11]

The Indian biogas programme is a massive one, involving many different organisations, including national and local government ministries and corporations as well as national and state banks and research institutions. It appears very successful on the surface, achieving its targets for the number of biogas plants sold and built. However the programme does have its weaknesses, especially at the local level, where lack of cooperation between the different agencies appears to be a major problem.[8]

Competition between different workshops to build biogas drums has led to state-run enterprises trying to put smaller private concerns out of business. Poor management and an over-emphasis on red tape has often led to long delays in obtaining finance and materials to allow plants to be built. A customer may have agreed to take a loan to buy a plant and his name entered into the statistics a year or more before his plant is actually built. In many cases these 'pending' plants may appear as 'plants sold' in more than one year's figures.[8]

Despite a high emphasis on research and development, the results of this work seem to take a long time to reach the extension workers. There is a lack of communication between research centres and the field that prevents an effective flow of experience and ideas between the two. Ideas that prove successful in one area of India are seldom used in another.

2.3 The biogas programme in Nepal

The pioneer of biogas in Nepal was B.R. Saubolle S.J., a Belgian teacher at St Xaviers school. He built a demonstration plant in 1955.[17] Two other

plants built in Kathmandu are still running. In 1968 KVIC built a plant for an exhibition in Kathmandu. In 1974, the Energy Research and Development Forum at Tribhuvan University recommended that biogas be considered as an alternative energy resource for Nepal.[18]

The Department of Agriculture planned a programme of biogas extension. The aim was to build 250 biogas plants during the 'Agricultural Year' of 1975/76. Several contractors were asked to make steel gas drums to the KVIC design, while the Department's local extension agents (Junior Technical Assistants, (JTAs)) were to sell plants and find local builders to make the brick-lined pits. The Agricultural Development Bank of Nepal (ABD/N) were to offer zero-interest loans for biogas plants during this first year.

In 1974, the Development and Consulting Services (DCS) (part of UMN) built four biogas plants to the KVIC design. The Butwal Engineering Works (BEW), then part of Butwal Technical Institute (BTI), made the welded steel drums. A small demonstration plant, built by BTI, was shown at an exhibition held at the coronation of King Birendra in 1974. BTI was asked to make steel gas drums for the agricultural-year programme, while DCS set up a programme to install the biogas plants.[19]

According to the records, 196 plants were built during this year. DCS built 95 of these and helped with the installation of 14 more. Four US Peace Corps volunteers also helped with the building of plants under a two year programme. However, the Agricultural Year was not as successful as the records imply. The JTAs had received little training on biogas and many plants had technical problems.[20] In some cases, loans were used for purposes other than building biogas plants.

The next year proved disappointing. DCS managed to build only half as many plants, while the rest of the national programme seemed to evaporate. The JTAs were required to put emphasis on other agricultural extension projects and the Peace Corps volunteers finished their contracts and went home.

The two groups still involved in biogas extension—DCS and ADB/N—decided to pool resources by setting up a commercial concern to sell biogas plants. The Gobar Gas Company was formed in 1978, with capital finance from UMN, ADB/N and the Fuel Corporation of Nepal, based on the DCS biogas extension organisation. UMN has a policy of setting up its development programmes as private limited companies; a model that allows more control to pass to local managers as they gain experience. Most of the staff of the new company were Nepali citizens, apart from an expatriate Executive Director. DCS retained the research and development side of the programme, offering technical back-up to the staff of the company. Responsibility for research and development passed to the Company in 1984.

The company set up branch offices in about nine strategic places in

Nepal, mainly on the Terai (the plains area). Transport was far more difficult in the hills and the higher ambient temperatures below 300 metres altitude allowed better year-round gas production. By the middle of 1987 the Company had built over 2,300 biogas plants in Nepal, including those built under DCS. The work of follow-up, started by DCS, has continued, ensuring that at least 95 per cent of these plants continue to work. For each plant built a seven-year guarantee is offered against design or construction faults; yearly visits are made by company staff to the owners for the period of the guarantee.[21] This approach was encouraged by ADB/N, mainly to safe-guard the repayment of loans.

Even after eight years of trading, however, the Gobar Gas Company had not made a profit. It was under-financed for the sudden expansion from a local extension programme to a national organisation, and this also put severe strains on staff and resources.[22] The follow-up programme means very high overheads, which cannot be fully financed from plant sales.

Sudden expansion resulted in technicians, who had only been trained to supervise the building of biogas plants, being promoted to area managers, with little management training. They were expected to look after their office accounts and stores inventories, act as salesmen to farmers, liaise between farmers and bank officials for loans, supervise the construction of plants and follow-up all their customers, all with no transport in a country that has few roads. Most were given motorbikes in 1983. These men have gained experience over time and received on-the-job training, so their weaknesses are being overcome.

Nepal is a difficult country in which to do business. It is landlocked and dependent on India for supplies of most materials. Shortages of basic commodities such as steel and cement in India mean that a quota and licence system operates. Very careful planning and management is required to ensure the correct quantities of materials are available at the right time, together with enough money to pay for them. Political disturbances, especially during the first five years of the Gobar Gas Company's trading, have caused problems for all commercial concerns in the country.

While there are biogas programmes in other countries,[23] they are less well documented than those in India, China and Nepal. Thailand had about 3,000 family-sized digesters in 1984[12] and a government programme for 25,000 more to be built by 1990. They had problems with the floating drum design and changed to the fixed dome design. The government of Taiwan is promoting the use of bag digesters using red mud plastic. In 1982, 1,200 of these plants had been built, but there is a lack of information on how successful they have been or how the programme is progressing.[12]

2.4 Lessons to be learned

While the Chinese and Indian programmes started very differently, the practicalities of building biogas plants for large numbers of customers has

meant that the organisational structures are becoming similar. The Chinese programme started as a 'people's movement'. In some ways the programme followed the 'ideal' model for the extension of an appropriate technology, with people discovering the benefits for themselves and making their own decisions. The economics of these plants looked very good, as people had to pay the production team for fuel, either firewood or crop stalks, but were paid for the composted fertilizer from the plant. Despite all these advantages, the Chinese programme up to 1979 was considered officially as a failure, mainly because of the short lifetime of the plants.[1] The Chinese government recognised the need for central coordination and planning, especially in the development of effective technologies and in providing standards for quality control.

The Indian programme started as a centrally planned operation, first by KVIC as a national organisation, then by the AICB. The main weakness of the programme appears to be at the local level, where the cooperation encouraged at national level does not seem to have penetrated.[8] The difficulties faced by a farmer attempting to set up a biogas plant include the paperwork required to obtain a loan and the subsidy, and the need to arrange for supplies of materials to be available at the correct time. Extension agencies, such as KVIC, are now employing 'supervisors' or 'motivators' to contact farmers and oversee all aspects of the project, assisting them through the bureaucracy involved.[13] The time required to get a plant built can be reduced from a couple of years to a few months.

So, while the emphasis in the Chinese programme has shifted away from a decentralised approach to one which has greater central control, the Indian programme has had to become less centralised.[2] The Nepal programme is directed fairly firmly from a single head office, although the control passed from a government agency to the Gobar Gas Company early in its history. The programme would probably be more effective if the managers of the local company offices had more autonomy in planning and decision-making.

2.5 Aspects of a biogas programme

A biogas programme is a complex operation, involving many components, such as extension, construction, publicity, finance and research and development. All these must work effectively, both individually and with each other, if the programme, as a whole, is to be successful. Each aspect of the programme usually involves a different organisation, each with its differing attitudes and approach, so careful coordination is required to ensure good cooperation.

The core of the biogas programme is the extension work. Salesmen must go to potential customers to persuade them to buy biogas plants. Once a customer has agreed to purchase a plant and loan finance (if necessary) has

been arranged through a bank, building materials must be supplied and masons and other technicians called in to build the plant. The building work must be supervised and the quality of work inspected. The farmer must be taught how to run his new technology. He should know to whom to go if something goes wrong. Technicians also need to be available to help the customer in follow-up and routine maintenance.

In India and Nepal it is the job of supervisors to do most of these tasks, from selling the plant through supervising the construction to follow-up. In India, the supervisors are paid by KVIC and other implementing agencies, funded by national or state governments. Only the wages of the construction workers form part of the cost of the plant paid by the customer. In Nepal the salaries of the supervisors are part of the overheads of the Gobar Gas Company, which is supposed to be self-supporting from its sales. In China in the 1970s 'selling' was done by Communist Party cadres, working in the communes, while customers were responsible for obtaining materials and doing most of the construction work themselves. Both selling and construction work are being taken over by the biogas construction teams, which are self-supporting at the local level. The provincial biogas offices are funded by central or provincial governments.

A key factor in reducing the rate of plant failure is that of follow-up. The Gobar Gas Company took over the guarantee and follow-up programme started by DCS and records indicate that 95 per cent of all plants built by the Company continue to work.[21] If plants fail because of poor workmanship, they are repaired by the Company free of cost. The biogas extension programme started in Brazil in 1980 uses a similar approach and can claim similar success rates (a failure rate of 7.5 per cent in the 7,530 units built between 1980 and 1985).[24] Follow-up is best carried out by construction staff and field staff from a national or regional office. Since the companies will be local, they will have close contact with their customers, who can come to a local office if they have problems. Follow-up by agents from a central biogas office provides quality control and the compilation of national (regional) statistics for on-going evaluation of the programme.

An effective extension programme is dependent on well tested and proven technology. The early biogas programmes in both India and China lost impetus when the technology they were using proved unreliable. On-going research and development is an essential part of such a programme from the early stages. The value of this research and development is only demonstrated when it is used by customers in the field. Close links between the research and extension staff are essential in a biogas programme. The research staff must have personal experience of work in the field, so they can relate their research to the problems there. They can assist in follow-up surveys, looking at wider questions than those usually considered by the extension staff, such as the socio-economic environment of the programme in different areas of a country. It is helpful for extension staff to make

regular visits to research centres to see new ideas and to receive training in new techniques, so that the results of research and development may be quickly applied in practice. Research and development originally inspired the Indian biogas programme and KVIC has continued the tradition with a research department attached to its Bombay office. However, the research work done at the centre does not seem to be very closely related to the needs of Indian villagers. The emphasis appears to be more on technical problems.[13]

The opposite extreme obtained in China, where the farmers themselves experimented with new ideas and designs. Many of these designs were imaginative and did work, the best ideas being shared with others through the Chinese propaganda machine. As academic research became acceptable again after the disruptions of the Cultural Revolution in the early 1970s, the Chinese government recognised the lack of scientific method in the peasants' work and set up biogas research centres. There were over 50 biogas research projects in different institutions in 1985.[1]

DCS in Nepal attempted to link the extension and research and development sides of their project from the start. The follow-up programme started as part of the research programme, as a series of surveys of how well the first 95 steel-drum biogas plants built by DCS were working. Several problems were identified during this survey, allowing the original KVIC design to be adapted to meet the needs of the people who were using the plants in the field. The research and development work continues in the Gobar Gas Company, the staff acting as trouble-shooters if extension staff discover problems with the plants they are building. They are also continuing more basic research projects, such as the use of alternative feed stocks in biogas plants.[21]

Another aspect needing early organisation is that of finance. Capital is required to set up the programme infrastructure, such as manufacturing facilities and research laboratories, and to obtain adequate stocks of materials. Few rural farmers can find enough cash to purchase a biogas plant outright, so loan finance is also required. Arranging loans and collection of repayments and interest is a specialised job, best done by banks or an agricultural credit scheme. If national subsidies are provided, government departments become involved, although money can be disbursed through the bank that provides the loans.

The banks are very involved in the Indian biogas programme, with the National Bank of Agricultural and Rural Development (NABARD) providing reserve financing to commercial banks to allow them to lend to farmers.[12] Commercial banks ask an interest rate of 11 per cent for a loan period of five to seven years, depending on the size of the plant. Bank officials have problems with loan security, as a biogas plant is a permanent installation and cannot be moved. Banks prefer the steel drum design, as at least the gas holder can be repossessed in case of non-payment of debts. In

Nepal, the Agricultural Development Bank (ADB/N) is deeply involved in the programme, both as the main source of loan finance and as a shareholder in the Gobar Gas Company. Loans are offered for 7 years at an interest rate of 11 per cent. The ADB/N, itself, is financed by soft loans from the Asian Development Bank as well as grants from groups such as UNDP.

Finance was not a key concern in the Chinese programme until recently. The early plants were considered to be so cheap that families could pay for them directly from their earnings, either in the form of cash or work credits. As the cost of biogas digesters has risen the provincial offices are having to make arrangements for loan finance and for subsidies.[6] The cost of loans from the Agricultural Bank of China is low (2.1 per cent interest).

If the idea of biogas is to be presented to potential customers publicity is required, through national newspapers and radio. The idea of biogas only became well-known in rural India after 1970, when the government of India made the subject newsworthy enough for the national media to take an interest.[8] While a national publicity campaign as such has not been organised in Nepal, certain civil servants and journalists have become interested enough in biogas technology for the subject to appear regularly in newspapers and on the radio. In communist China, a massive publicity campaign formed an important part of the 1970s biogas programme. The use of demonstration plants in strategic places formed the basis of this popularisation campaign which proved very successful.[2]

CHAPTER 3
Organisation and Management

One of the most important factors in ensuring that a biogas programme continues effectively is the way it is organised and managed. However good the ideas and technology may be, poor management can cause a programme to fail and lose credibility with the public.

A major mistake made at the start of the Nepal biogas programme was to try to set up a whole national programme in one go. With inexperienced staff and a lack of coherent infrastructure, the programme almost failed before it was properly started. The Gobar Gas Company was set up as an organisation that was able to rescue the programme and keep it going. In India KVIC already had an infrastructure of area offices and extension staff into which the biogas programme could fit. Even so, its programme has suffered from poor management, with too many decisions made at central offices.

This chapter is meant only as an introduction to the particular problems faced in the management of a biogas programme. Full information on the management of development projects can be found in other books.[1]

3.1 Starting a biogas programme

The initial priority of a new biogas programme, in either a country or a region which does not already have a programme, is good, well-proven technology. Staff who understand the technology and can test it are required. The second priority is staff training. People can only learn how to build a biogas plant, or to supervise the building or to manage the different aspects of the programme, by actually doing it.

These priorities can be covered by a pilot extension programme. A limited number of plants are built for customers in a defined geographical area. While the customers must pay the market price for the plants (less any subsidies that may be planned for the programme), adequate guarantees and compensation must be available in case of failures due to poor design or lack of skill in the builders. Any failures must be put right quickly, without argument, to ensure continued confidence in the programme. Funds must be set aside to allow for a 100 per cent guarantee for all the plants built under the scheme. Therefore this pilot programme will be relatively expensive, but it will provide much-needed data for the planning of the main programme, as well as giving staff on-the-job training.

The 95 floating drum biogas plants built by DCS for the Agricultural Year in Nepal acted as a pilot programme for the national programme under the Gobar Gas Company. Ninety-five proved too large a number for the limited resources of DCS, as finance was insufficient to cover the cost of the failures against which guarantees had been given.

As staff skills develop and technology becomes reliable, the pilot scheme will merge into an on-going extension programme. The temptation to expand too fast must be resisted. The rapid expansion of the 1970s' programme in China led to a high plant-failure rate. Similarly, when the Gobar Gas Company was formed from the local DCS programme, staff were not prepared for the sudden increase in work and responsibility.

Staff training must continue as the programme expands. In the early stages of expansion the programme will be overstaffed, with two people being trained for each job. This approach allows for drop-out of staff as well as for expansion. Some of the more able personnel will discover they can use their training in other areas which may pay more money than the biogas programme. Management staff are particularly important. DCS trained technical staff very effectively, but management skills were given a lower priority. The Gobar Gas Company therefore built good-quality plants, but was poorly administered.

An important factor at the start of a programme is research and development, so a research centre should be included early in the programme plans. Scientific and technical staff are required who can learn the basics of the technology and teach the extension staff. They are also required to monitor the progress of the pilot programme and to identify design and construction faults so they can be corrected quickly.

3.2 Coordination of the programme

The governments of India and China recognised in the 1970s that the way to make their programmes really effective was to set up a coordination committee composed of senior people from all the organisations involved in biogas technology. In Nepal one of the first moves of the government planners when setting up their biogas programme, was to appoint a Biogas Committee to supervise it. Such committees include representatives from government ministries, such as Agriculture, Energy, Industry and Finance, so that appropriate political decisions affecting the programme can be made. A weakness on the Nepal committee was lack of representation from the Ministry of Finance, which meant that decisions about subsidies and problems that the Gobar Gas Company had with tax payments took a long time to sort out.

This type of coordinating committee should be set up either before the programme starts or soon after. As well as civil servants, it needs to include senior managers of the banks involved in loan finance and the

senior people in the programme concerned with extension, manufacturing and research and development. The formation of a committee should mean that problems can be sorted out quickly at a high level.

It is also helpful to set up similar committees at the local programme level, to ensure local organisations are also working together effectively. Again, all those involved with the programme (at regional, state or provincial level) should be represented, together with bank managers, local government officials and politicians.

3.3 Programme structure

Under the coordinating committee, and responsible to it, the programme will have an Executive Director or General Manager and a full-time staff. In China this central administration is based in the National Biogas Extension Office, while in Nepal it consists of the management of the Gobar Gas Company. In India responsibility for the implementation of the biogas programme is divided between KVIC, government departments and corporations and many other organisations,[2] so the programme lacks full-time staff directly responsible to the coordinating committee.

The recent Chinese approach appears to be the most effective, with a central biogas office directly responsible for the planning and organisation of the national programme. The main job of such an office is to make yearly plans for the progress and expansion of the programme under the direction of the coordinating committee. It will also assign personnel and resources to meet these plans and evaluate the performance of the different aspects of the programme against the plans, making regular reports to the committee.

In a typical national or regional biogas programme, different functional managers in the central office would be responsible for the various aspects of the programme, such as finance, manufacturing, extension, research and development and publicity. Some of these activities may be carried out by groups directly employed by the central office. The Gobar Gas Company in Nepal, for example, relies on its own in-house manufacturing, extension and research facilities. Other activities may be done by outside organisations under contract to the central office, so it retains some control over what is done. In India there is very little effective direct central control over the different organisations involved in the different aspects of the programme, as they have independent management structures.

One of the major decisions to be made by the coordinating committee is the nature of the funding for the programme. The cost of a large extension programme is fairly high, particularly at the start, so budgets and sources of finance need to be carefully worked out before the programme begins. The process is straightforward if the programme is funded by a national or regional government, as the ministries involved would already have their

own budgeting systems. If a programme is being set up by a non-governmental organisation and finance is required from an outside funding group, such as an aid organisation, then programme plans must be made very carefully for several years in advance. In Nepal the central office is funded by the extension programme, adding high overheads on to the cost of biogas plants. This approach is not recommended: the central office should be funded from a source not dependent on plant sales; such as government funds or the profits of a bank. In practice in Nepal the biogas programme is being subsidised by the ADB/N.

An effective extension programme needs to be decentralised, with area offices running their own programmes under the direction of the central office. With communications being poor in China, India and Nepal, all these programmes have to have offices in different places within the country. An area office is set up in a similar way to the central office, with an area manager and staff under him responsible for the various aspects of the work. The main function of area offices will be extension work, with the area manager looking after teams of extension agents and construction workers. Some area managers may have additional responsibility for liaising with local manufacturing workshops or material suppliers in their area, on behalf of the central office. Others may have research laboratories or test sites in their area.

Responsibilities need to be carefully defined in written job descriptions, with lines being carefully drawn between the different geographical and functional areas for which different offices have oversight. Also clear lines of authority need to be defined by the central office, to ensure that every member of staff knows to whom they report. Such careful planning while the organisation is being set up saves a great deal of upset, worry and trouble later on.[3]

3.4 Programme planning and evaluation

One of the main functions of a biogas coordinating committee is that of planning the programme and evaluating its progress. The Indian programme is centrally planned with government planners defining how many plants should be built each year (300,000 between 1985 and 1990). This number is divided between the agricultural departments, Khadi Boards and NGOs in the different states of India. State government officials then assign construction targets for the different districts and blocks within the state, often in an arbitrary manner. Such an approach allows target allocation decisions to be based on relationships between officials rather than on the needs and resources of different areas. The result is that the actual number of plants built each year seldom comes close to the target (often being less than half). Such an approach to planning often hinders rather than helps a programme.

The approach in Nepal was similar, with senior staff in the Department of Agriculture and (later) in ADB/N making decisions about how many plants should be built in any year, with little reference to local conditions. The governing parameter seemed to be the amount of money available for loans for biogas plants.

When USAID gave a grant to the programme in 1979, they insisted on the proper use of planning procedures. With a better understanding of the process of planning, the Gobar Gas Company began to involve local supervisors in preparing targets for their own areas. They had become habituated to over-planning, so the yearly national target at the time of writing (1987) remains much higher than the Company is capable of achieving (typically, a target of 400 to 500 and an achievement of 200 to 250). This has the advantage that, while orders are based on the target figures, supplies of materials (such as cement and steel) tend to arrive late and in inadequate quantities, thus balancing out the over-ordering. However, income budgets based on the targets are never met, so the Company always makes a loss. More realistic and carefully designed plans and targets, taking into account the variability of supplies, would ensure a more effective and economic programme.

Effective planning takes place before the programme starts. A pre-planning stage is required when senior technical and management staff are hired and trained to allow them to be involved in planning the programme they are to administer. Plans must be based on accurate and up-to-date data, so this stage also involves market surveys and economic analyses. The lines of responsibility between the managers of the different aspects of the programme should be clearly defined at this point. Initial budgets should adequately cover every aspect of the programme, as funding agencies are more prepared to give money at the start of a programme than while it is running.

The plans should also include set times for programme evaluation. Several assumptions have to be made in order to design the plans and these assumptions should be identified, so they can be tested during the evaluation. If assumptions prove to be invalid, the approach to programme implementation may have to be changed to achieve the set goals of the programme. Evaluation also allows weaknesses in the programme to be highlighted, so that financial or staff resources can be diverted to strengthen these areas. Certain people may need further training or may need to be moved to jobs more appropriate to their skills.

Information from each geographical area and functional sector is required for a complete evaluation of the progress of the programme, identification of problem areas and for the drawing up of accurate plans for the following year. Good plans should include a list of measurable indicators of the progress of different parts of the programme, such as the number of plants built per month in a geographical area. Under-managers can simplify their

reports if they are given a list of definite questions related to these indicators to answer. Further detailed information is only required if any indicator deviates markedly from its planned value.

Planning and evaluation are effective tools that assist in the smooth running of a programme. However, the skills required are not well understood and many administrators feel threatened by the process. Further information on planning and evaluation is available in books on the subject.[4]

3.5 Extension work

While the central and area managers are responsible for coordinating the work of the programme, it is the extension agents who actually get the job done. They are the ones who visit a farmer to persuade him to have a biogas plant, make links with a bank for the farmer to receive a loan to pay for it, and arrange for the right materials to be delivered to the site. They also arrange for construction workers to be there at the same time to build the plant, check that the plant has been built to the correct standard and finally make follow-up visits at appropriate intervals to ensure the plant continues to work well. In Nepal these people had the additional task of supervising the building work to ensure it was done according to the plans supplied by the technical advisers. In many programmes all this work has to be done in remote rural areas where roads and communication facilities are minimal.

The training of extension agents in management as well as in the technical aspects of biogas is therefore crucial to the progress of a biogas programme. They need to know how to look for potential customers and how to persuade them to buy a biogas plant. Western approaches to hard-selling are unlikely to be effective in developing countries. Sales techniques need to be culturally appropriate to the people with whom the extension agents are working. They need to develop good relationships with bank staff and with the construction staff in their sales areas, as they will be working closely with both groups. Finally, the extension agents need a basic understanding of how biogas works and how a biogas plant is made, so they can explain the technology clearly to customers and be effective in quality control and follow-up work.

Travel in remote areas can add greatly to the cost of a programme. If extension agents are expected to use public transport and bicycles the travel cost per journey is reduced, but they can achieve far less work in a given time, because so much time is taken up in moving from place to place. They can be provided with motorbikes, which are expensive to run and maintain, but they achieve much more work each week. Jeeps or Landrovers are not usually economic for extension workers in remote areas. In the mountainous areas of Nepal, where roads were not built and even motorcycles were unable to go, it was found that there was no

alternative to walking. Horses and mules were too expensive to feed and look after.

The progress of each plant sale should be monitored at area office level, with periodic checks being carried out with bank offices that loan applications are being processed and with construction groups that sufficient staff are available for their side of the work. Area offices need to carry sufficient stocks of materials locally to ensure that all current orders can be supplied in good time. In Nepal customers are normally expected to collect their own materials from the area offices, as they often have a tractor and trailer or a bullock cart that can be used. Customers often arrange their own supplies of bricks directly from suppliers. Sand and aggregate can often be obtained from local riverbeds by farmers supplying their own transport and labour. As far as possible, customers are also asked to provide local labourers to dig the holes for the digester pits and to assist the skilled masons in mixing concrete and carrying materials on the site. The price paid by the customer for his biogas plant reflects the amount of work he is able to contribute towards the building of the plant.

An area office may employ several construction teams to build their plants. Each team would consist of a master mason with one or two assistants and labourers. A team may also include a specialist pipe fitter to connect up the gas pipe lines. These teams may be employed directly by the area office, as in Nepal. Alternatively, they may be employed by independent construction firms who build biogas plants under contract to the area office, as in India and China.

The use of small independent contractors has several advantages. Being local people, they are available to customers for repair work and maintenance of the plants they have built. They also have a motivation to sell biogas plants that is separate from that of the main programme and geared to the local situation. Their efforts to advertise biogas plants can reinforce those of the extension agents from the biogas programme.[5]

The use of larger national building firms as contractors may be less effective, as they do not have the local facilities and knowledge that smaller firms possess. National firms also have their own motivations and priorities that may conflict with those of the biogas programme. If the company is a large one, or has political influence, as with some Indian government corporations, it can influence the direction of the whole programme.[6]

Quality control is important, as contractors may try to cut corners to increase their profits. Contracts with construction firms should include provision for training their staff in the building of biogas plants, both at the beginning of the contract period and at regular intervals during the contract. Masons can be taught good building procedures and their skills can be assessed during these courses. Mechanisms to encourage good workmanship can also be devised. Extension agents need to check the plant for construction faults before it is filled with slurry, to approve it for payment.

A small percentage (e.g. 10 per cent) of the fee for the work can be withheld for a year, when it can be paid after the plant has been inspected to ensure it is still working. Further checks can be made during subsequent follow-up visits. Building contracts can be cancelled if there are too many faults in certain contractors' work.

3.6 Resource management

The biogas programme needs a yearly budget as well as a plan to which everyone can work. The allocation of personnel and finance, the effective use of technical services and the ordering of materials all depend on a projection of what the programme will require in the following year. In some countries, such as India and Nepal, the purchase of strategic materials, especially steel and cement, requires government licences and quotas which must be obtained in advance for a year, so careful planning is even more important.

The programme plan should be realistic. It needs to be based on the figures of previous years, as well as detailed projections made by each of the field staff as to what they consider is possible in their own areas. The projected growth rate of the programme, especially, needs to be based on feasible assumptions. The number of potential customers able to afford family biogas plants usually forms too small a proportion of the population to allow for an annual expansion rate for this section of the programme of more than about 10 per cent. The complexities of setting up group-owned biogas plants and the time they take mean that there is unlikely to be fast growth in this part of the programme either.

Large organisations, such as biogas programmes, tend to centralise the making of financial decisions. Money is controlled fairly strictly by accountants at the head office and area managers are very limited in the decisions they are allowed to make. This approach can stifle growth in the programme and can lead to the failure of area offices to perform well. The centralisation of financial decision-making can have a ruinous effect on special projects, such as community biogas and research and development.[7]

A much better approach involves the area and sector managers taking responsibility for their own financial planning and operation. Each area office should have its own detailed budget, devised by the area manager with the help of his extension agents and approved by the head office. The area budget would be closely based on the plan for that area and can be compared with previous years' budgets and performance and the budgets of all the other area offices. A cash-flow chart can be mapped out for each area office, indicating how much money is needed each month for salaries, purchase of materials, contract payments for construction work, etc. It would also include the money earned from plant sales, if this is regarded as an income for the programme and paid directly to the area offices. The

central office then provides finance (from grants and other income) to the area offices according to the cash-flow plans and the area managers are expected to keep their spending as close to their plans as possible.

The overall funding for the programme should come from government or aid agencies, as grants. If the programme is made self-financing, with all overheads paid out from the money earned by selling biogas plants, the cost of the plants to customers is artificially inflated. A customer should only pay the direct cost for his plant: materials, skilled labour and transport.

The question of subsidies for a biogas programme is a difficult one. In principle, subsidies do little to overcome the basic economic problems associated with biogas extension; they do little to make a bad programme better. However, most biogas programmes are giving subsidies for plant construction or are considering doing so. The argument for subsidies is based on the idea that a government benefits from the programme in reduced deforestation and lower import bills for oil-based fuels. These benefits are not seen by the consumer as lower prices for the fuel from their biogas plant, as wood fuel has a low market price and kerosene and diesel are usually subsidised by the government, anyway. Therefore, the best way to pass the national benefits of biogas technology to people who are prepared to buy a plant is to give government subsidies on the capital cost of the plant itself.

3.7 Communication

Personnel management depends on good communication between people belonging to the different sectors and levels of the administrative structure. Information should flow freely from the extension agents and construction staff to the head office, as well as the other way round. Central managers should know of the concerns and needs of the field staff and be able to respond quickly to them. This type of communication requires that head office staff spend time visiting the area managers. The area managers themselves should visit extension staff working in the field at regular intervals.

Extension staff are motivated by such visits, as they feel their work is being appreciated. This policy proved effective in Nepal, where regional and central managers made a point of visiting as many field staff as possible each year, despite the difficulties of travel. Lack of interest by the central office can quickly lead to reduced morale among the field staff and a high turnover of personnel (a problem faced by the PRAD programme in Uttah Pradesh in North India).[6]

Groups of staff, especially field staff, should meet together at intervals (perhaps once or twice a year) for training weeks. There are often times in the year when field visits are difficult (such as in the monsoon in South Asia), or when potential customers are very busy with agricultural work, so

training sessions need not adversely affect the progress of the programme. These times are also opportunities for administrative staff to discuss any changes in the procedures used by the programme and to listen to problems discovered by the field staff. They are also times when R & D and technical staff can present new ideas and train field staff in the use of new technology and equipment that is being made and sold. The main value of such meetings, though, is the exchange of ideas between field staff from different areas. They will all encounter similar problems, so they will be able to share their different ways of overcoming them. Much of this communication will take place over meals and during leisure activities, so the training weeks should not be too intensive.

These training weeks have been an important part of the Nepal biogas programme and they have enabled area managers to gain the management skills they lacked when first appointed. These meetings also proved a good time for writing area plans, as the process of planning could be taught to the managers in the context of their work. The different approaches adopted by the managers in their separate geographical areas could be compared and suggestions shared between them.

3.8 Management of technical projects

Most of the field and area staff will be expected to understand the basics of biogas technology, how it works and how to teach customers to use it. However, as the programme expands, especially in the use of community plants to run engines and cottage industries, more specialised technical staff will also be required. For example, if group-owned plants are to be used for grain milling and rice hulling, people with experience in setting up engines and milling equipment will be required. Help can be obtained from the company agents supplying the equipment, but the programme should also employ staff who can assist extension agents in this work, both in the setting-up and the follow-up. Another area where expert help is required is in irrigation projects.

Depending on the number of technical projects in the programme, specialist staff may need to travel from a base in the head office, or several such staff may be stationed at different area offices. If the biogas programme is linked up with other rural development programmes, then some of this technical help may be available from the area offices of these other programmes. For example, in Nepal help is available from the Small Farmers' Development Programme, which is also linked with ADB/N.

3.9 Management training

Management is a complex subject and there are many books about it. There are also many courses available to train managers, ranging from

short evening classes in colleges of further education to university B.Com. and M.Com. degrees. Many of the organisations involved in a biogas programme, such as banks and government departments, will already have schemes for training their own managers, often an arrangement with a local college. These schemes can be used by the biogas programme to train its managers, if allowance has been made in the budget. Experienced managers can be seconded from some of the organisations involved in the programme to run the central office, at least until people from within the programme have gained sufficient training and experience to do so. In Nepal, senior management for the Gobar Gas Company was provided first by DCS and later by ADB/N.

CHAPTER 4
How Biogas Works

Everybody involved in a biogas programme, especially the administrative and technical staff, should have a simple understanding of the biogas process. The details of anaerobic digestion are complex and require an understanding of biochemistry (see Gunnerson for a good introduction),[1] but a simplified account is useful.

Biogas is produced by certain types of bacteria: microscopic organisms that break down the complex molecules contained in the feedstock into simpler molecules in a way that releases energy and the chemicals they need for growth. The bacteria that are used in a biogas digester are the same or similar to those that live in the gut of ruminant animals, such as cattle. Cow dung is a good source of suitable bacteria. These bacteria are adapted to the conditions found inside a cow, so a biogas digester must have a similar environment. The key factors are the exclusion of air and light and a temperature close to blood heat (between 20°C and 40°C for the mesophylic bacteria used in rural plants).

These conditions can be met in a hole in the ground, lined with brick or cement to keep the mixture of bacteria, water and feedstock (called a 'slurry') from leaking out, with a suitable cover which excludes air and light and also collects the gas. In tropical and sub-tropical areas the ambient temperature is usually about right for biogas digestion during most of the year. In cooler climates, some method of insulating and heating the slurry is required.

4.1 The anaerobic process

Several different types of bacteria live in a biogas digester and do different jobs.[2,3] Bacteria are single-celled organisms surrounded by a membrane. They secrete chemicals, called *enzymes*, through the membrane into the food around them, to break it down into simpler substances. These substances will dissolve in water, so they can be absorbed and used by the bacteria.

There are several ways of classifying bacteria. Here it is useful to consider their response to oxygen. *Aerobic* bacteria require oxygen to survive, while anaerobic bacteria cannot function at all in the presence of oxygen (they do not die, they stop working until the oxygen is removed). *Facultative* bacteria are able to use oxygen if it is present, but can use alternative digestion processes if it is absent.

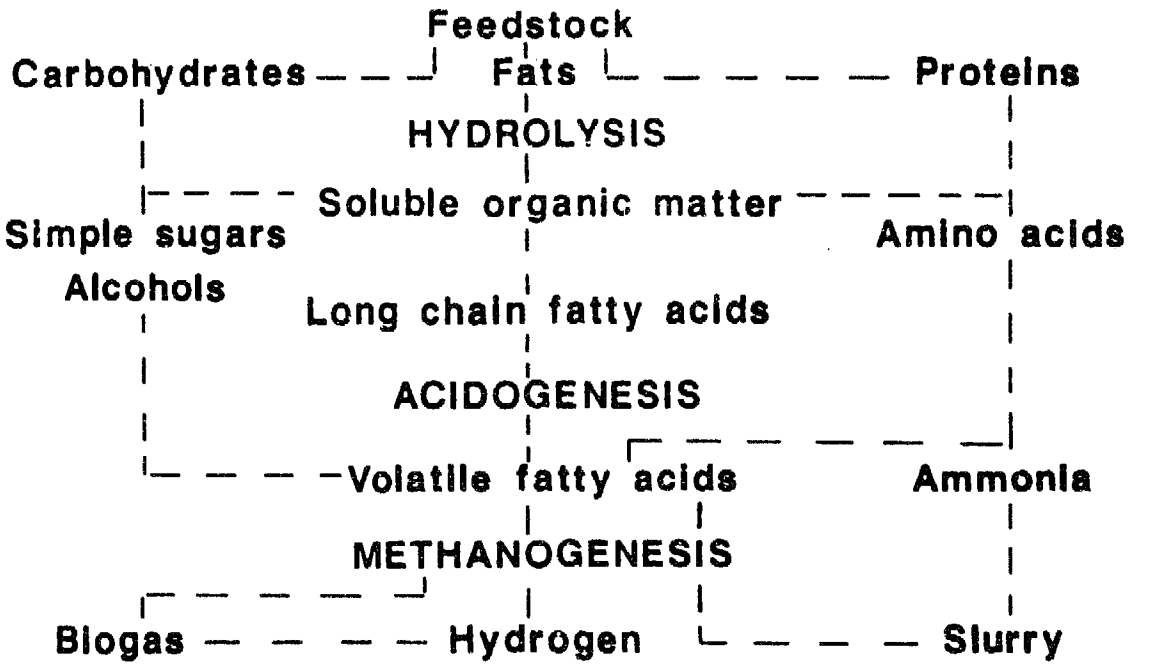

Figure 4.1 *The anaerobic process.*

When a feedstock is placed in an anaerobic digester the facultative bacteria begin to break down the complex molecules (Fig. 4.1), using up the oxygen in the feed. They will also use the oxygen in the air trapped inside the digester, thus lowering the gas pressure. These bacteria continue breaking down foodstuffs using oxygen from water once the free oxygen is finished, so this process is called *hydrolysis*.

The second stage (or the second half of the first stage, the *liquifaction* stage) is the formation of *volatile fatty acids* as well as carbon dioxide and some hydrogen. These acids are of low molecular weights and have low boiling points. Acetic acid (CH_3COOH), which is the major constituent of vinegar, is the commonest acid formed. If there is some air present the digestion process stops at this point, and the digester gives off the distinctive smell of these acids, usually associated with decaying food.

In an anaerobic digester (with no oxygen), the third stage, the *methanogenic* stage is continued by methanogenic bacteria which break down these fatty acids into even simpler molecules: water, carbon dioxide and methane (H_2O, CO_2 and CH_4), removing the smell and producing biogas. Methanogenic bacteria are *obligate anaerobes*; they cannot function if oxygen is present. Different methanogens are able to use a range of fatty acids as well as simple alcohols and even hydrogen and carbon dioxide to form methane. However, about 70 per cent of the methane in biogas is estimated to come from acetic acid ($CH_3COOH \rightarrow CH_4 + CO_2$).

The many different types of bacteria work together in a symbiotic relationship. The hydrolytic bacteria produce waste products that the

acid formers can use. The acid formers, in turn, produce acids that the methanogens use, giving biogas as their waste product. If all the bacteria are working in balance the acid level remains constant, the rate of production by the acid formers equalling the rate of use by the methanogens.

4.2 Effect of pH

The measure of acidity is called *pH* (the negative logarithm, base 10, of the concentration of hydrogen ions; see Fig. 4.2). A normal value for pH in a working biogas plant is between 7 and 8 (about neutral). When a biogas plant is newly started, the acid formers become active first, reducing the pH to below 7 (increasing the acid content). The methanogens then start using these acids, increasing the pH back to neutral.

A working biogas plant is *buffered*, in other words, the acid level is controlled by the process itself. Some of the carbon dioxide (CO_2) produced by the bacteria dissolves in the water to form bicarbonate ions (HCO_3^-) which cause the solution to become mildly alkaline. The amount of bicarbonate in solution depends on the concentration of carbon dioxide and the amount of acids in the slurry. The effect of this carbon dioxide passing in and out of solution acts as a buffer to balance out small variations in the acidity of the slurry.

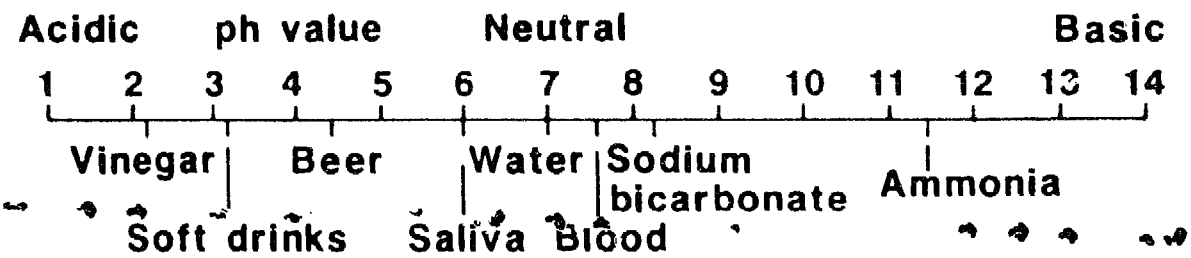

Figure 4.2 *The pH scale*

The pH of the slurry is easily measured using a pH meter or with suitable indicator papers. However, it is an insensitive measure of the way the digester is working, because of the buffering effect. If the pH of a digester drops it indicates the buffering mechanism has already failed and too much acid is being produced, usually because the methanogenic bacteria have stopped working for some reason.

A better measure of the stability of a digester is its *alkalinity*. The amount of bicarbonate in a sample of the slurry can be measured by titrating it against a known acid (see Appendix III).

4.3 Effects of temperature

Another way of classifying bacteria is according to their preferred temperature. *Cryophylic* bacteria work best at between 10°C and 20°C, *mesophylic* bacteria between 30°C and 40°C and *thermophylic* bacteria between 45°C and 60°C. While anaerobic digestion is very efficient in the thermophylic region, rural digestors use mesophylic bacteria because higher temperatures are difficult to maintain.

The gas production rate roughly doubles for every 10°C rise in temperature between 15°C and 35°C. The gas-production efficiency (the gas produced per kilogram of feedstock) also increases with temperature. A mesophylic digester works best at 35°C.

Methanogenic bacteria are sensitive to temperature changes. A sudden change of more than 5°C in a day can cause them to stop working temporarily, resulting in a build-up of undigested volatile acids: the plant goes 'sour'. This is less of a problem in large-volume digesters, where the high heat capacity of the slurry ensures that its temperature changes slowly.

4.4 Effect of toxins

The main cause of a biogas plant going sour is the presence of toxic substances. Antibiotics, disinfectants and pesticides are designed to kill bacteria and will stop a digester functioning, as will detergents. Chlorinated hydrocarbons, such as chloroform and other organic solvents, are particularly toxic to biogas digestion.

Care must be taken that the feedstock used in a biogas plant has not been affected by these chemicals and that the water used to mix the slurry is not polluted. The dung of any animals being given antibiotics should be kept separate and not added to the plant. If an animal shed is cleaned with detergents or disinfectants the washings must be directed away from the biogas plant. The chemicals used to clean the shed must then be washed away with plenty of water before the animals are allowed to return.

Methanogenic bacteria are not killed by toxins, but switch themselves into a non-working state.[4] Once this happens volatile acids build up and the plant begins to give off a bad smell. In principle, it is possible for a biogas plant to recover from this sour state if the pH is corrected using lime or chalk (calcium hydroxide or calcium carbonate) and the source of the problem is removed.[5] However, if the plant has been badly poisoned it may be difficult to remove the toxins without removing most of the bacteria. In this case, the digester must be emptied, cleaned with plenty of water and refilled with fresh slurry.

4.5 Properties of feedstocks

Any material containing food substances, such as fats, carbohydrates or proteins, can be digested in a biogas plant. However, the rate and efficiency

of digestion of the feedstock depends on its physical and chemical form. Raw plant material is bound up in plant cells, usually strengthened with cellulose and lignin, which are difficult to digest. In order to let the bacteria reach the more digestible foods the plant material must be broken down.

Cattle dung is the easiest feedstock to use for a biogas plant: it already contains the right bacteria and it has been ground up by the animal's teeth and broken down chemically by acids and enzymes in the animal's gut. Human, pig and chicken manure are also good, but need a 'starter', such as slurry from a working plant, if they are used to start a biogas plant, because these animals do not have all the right bacteria in their gut. Some animals, such as horses and elephants, are less good at breaking down fibrous material, so their dung contains more indigestible matter. This can be screened out or chopped mechanically. Goat and sheep dungs are rich in nutrients,[6] but they are in the form of pellets that must be broken up mechanically. These pellets are difficult to collect, so there are few reports of their use in the literature.[7]

Raw vegetable matter usually needs to be treated before it can be used. It can be physically chopped up or minced, or it can be treated chemically.[8] Some plants, such as water hyacinth, have little lignin, so are easier to use. One good method seems to be to compost vegetable matter for five days before adding it to the plant, as aerobic bacteria are better at breaking down cellulose.

There are several measurements that can be made to define the properties of the feedstock or the slurry (Appendix III):

1 Total solids (TS) is a measure of the dry matter (DM) left after the moisture has been removed (by heating to 105°C).
2 Volatile solids (VS) is a measure of the organic solids lost when the dry matter is burnt (at 500°C or 600°C).
3 Chemical oxygen demand (COD) is a measure of the degree of pollution of the slurry. It is determined by chemically oxidizing a sample.
4 Biological oxygen demand (BOD) is an attempt to measure the pollution more realistically. Aerobic bacteria are used to digest the sample and the oxygen required is measured.
5 Carbon to nitrogen ratio (C:N) is an important parameter as anaerobic bacteria need nitrogen compounds to grow and multiply. Too much nitrogen, however, can inhibit methanogenic activity.

Typical values for some of these parameters are given in Table 4.1. These results depend very much on the size of the animal, what it is eating, the weather, etc. Hot dry weather will cause water to evaporate from the dung before it is collected, giving an apparent increase in TS, while humid weather will have the opposite effect. Measurements should be made of the properties of locally available feedstocks that could be used in a biogas

Table 4.1 Properties of dung from typical animals[9,10,11]

Animal	*Wet Dung (kg/day)*	*Biogas (lit/day)*	*Total Solid (%)*	*Volatile Solid (%TS)*
Buffalo	14	450–480	16–20	77
Cow	10	280–340	16–20	77
Pig	5	280–340	25	80
100 hens	7.5	420–510	48	77
Human	0.2	11– 14	15–20	90

programme and these values considered when suitable biogas plants are designed.

The total solid content of animal dung varies between 15 per cent and 30 per cent (Table 4.1), while the recommended value for slurry is between 8 per cent and 12 per cent. This means that dung must be diluted with water before it is used in a biogas plant. A low solids concentration mean that the digester volume is used inefficiently. It can also lead to separation of the slurry, the heavier solids sinking to the bottom to form a sludge layer and the lighter solids floating to form a scum layer on top of the liquid (supernatant). The scum layer can dry out to form a solid mat, preventing gas release from the liquid and blocking pipes. This should not happen if the TS of the slurry is kept above about 6 per cent.

A slurry with a high solids concentration (greater than 12 per cent) does not easily flow through inlet pipes. If toxins are present, such as a high nitrogen concentration, bacteria are more likely to be affected in a thick slurry. However slurries of up to 30 per cent total solids can be digested in a dry fermenter.[12,13]

The volatile solid content of dung is usually around 80 per cent of the total solids (Table 4.1). The remaining ash (fixed solids) is composed of soil particles, inert portions of vegetable matter (some grasses, e.g. rice, concentrate silica in their stalks) and some solid carbon left from the decomposition of foodstuffs. VS is not an ideal measure of the digestibility of a feedstock. Lignin and other indigestible solids will burn at 500°C, while some digestible solids, such as sugars, leave a carbon deposit when heated. It is an easy measurement to make (Appendix III).

COD and BOD are also not ideal ways to predict whan proportion of the feedstock will be digested in an anaerobic digester, as they were designed as measures of the aerobic digestibility of materials. While they may give a more valid answer than VS, these measurements are much more difficult to make (Appendix III). The best way to determine the anaerobic digestibility of a feedstock is to digest it in small laboratory digesters (2 litres) in controlled temperature baths (see Appendix III).

COD is useful in that it is possible to define a value for methane. Using this figure, a digester should produce 350 litres of methane for each kg of COD digested.

The ideal C:N ratio is reported to be 25:1. The measurement of total carbon and nitrogen requires a well-equipped laboratory, but values of C:N are quoted in the literature for many feedstocks (Table 4.2) and the ratios for mixtures can easily be estimated from these values.[14] However, the values of total carbon can be misleading, as some of the carbon is bound up in indigestible lignin. The nitrogen content of plant materials varies with the age of the plant (e.g. barley straw contains 39 per cent protein at 21 days of growth, but only 4 per cent after 86 days).

Table 4.2 Carbon and nitrogen content of feedstocks

Material	*C:N*	*% N*	*% C*	*% Water*	*Comments*
Cattle dung	20–30	3–4	35–40	72–85	Grass/Grain fed
	25–35	1–2			Straw fed
Horse dung	25	2	58	70–75	
Sheep dung	20	3.8	75	68	
Pig dung	14	3–4	53	82	
Poultry dung	8	3.7	30–35	65	
Human faeces	6–10	4–6	40	75–80	
Human urine[15]	0.8	15–18	13	95	
Water hyacinth[16]	15–23	1–9	24–35	93–95	Dried
Rice straw[17]	47.2	0.6	40	5–10	

Notes: Data for fresh dung. All dung will lose water and nitrogen on keeping, especially if air humidity is low.

In general, the C:N ratio of dung from cattle fed with poor feeds, such as straw and dry grass, tends to be too high (up to 35 per cent). The values quoted in Western literature (20 per cent or less) are measured using dung from cattle that eat more protein-rich foods. If the C:N is high, then gas production can be enhanced by adding nitrogen in the form of cattle urine or urea, or by fitting a latrine to the plant. If the C:N ratio is low, for example if chicken manure is used as a feedstock, the addition of carbon, such as chopped grass or water hyacinth, can reduce the possibility of toxicity from too much nitrogen affecting the bacteria.

4.6 Types of digester

A biogas digester can be operated as a batch process or a continuous one. In a batch digester the waste is put into the plant, usually with a starter

(5 per cent to 30 per cent by volume), and the gas collected as it is given off. There is a lag time of between one and 14 days before the first gas is given off (depending on the slurry temperature and the amount of starter).[9] For the first day or two the gas will be mainly carbon dioxide. The gas production rate will rise to a peak and then fall off (Fig. 4.3). There may be subsidiary peaks in the gas-production rate as less digestible material becomes available to the methanogens.

The advantage of a batch reactor is that the feed can contain lignin and other indigestible matter, as it does not have to be fed through inlet and outlet pipes. A batch digester can be run at a high solids content (as a dry reactor), reducing the volume of water required. Since the gas production varies with time, several batch reactors are usually run together, started at different times, so that some are always producing gas.

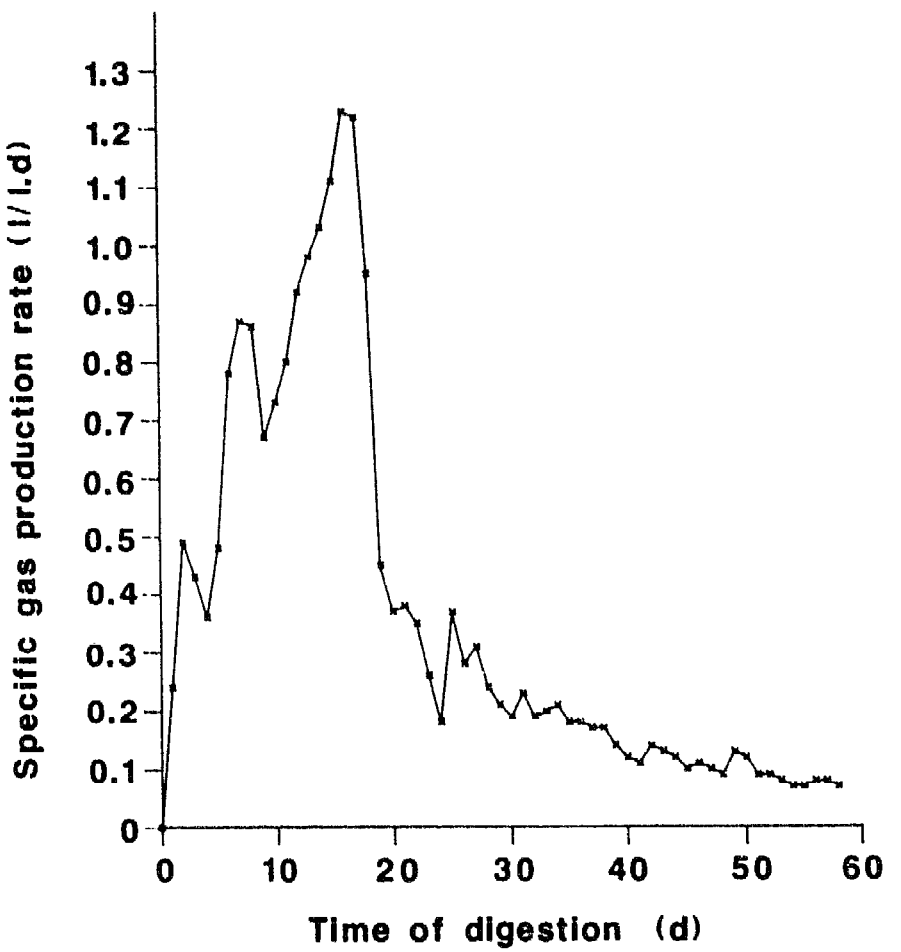

Figure 4.3 *Rate of gas production with time*

A continuous digester is fed regularly once it has been started. The feed is mixed with water outside the digester and fed through an inlet pipe. The outlet is arranged so that spent slurry either overflows into a collecting pond as new slurry is added, or it can be removed with a bucket. Once the

digestion process has stabilised, the gas production rate is fairly constant (with constant feed rate and temperature). Care must be taken that the inlet and outlet pipes are not blocked by indigestible matter.

Many digesters in China are run in a semi-batch mode. They are started as batch digesters and filled with vegetable matter, such as straw and garden wastes, and animal dung and a starter. However these digesters are also fed daily, with dung (usually from pigs and an attached latrine) and vegetable wastes. The gas production remains fairly constant, as the daily feed is digested, but it is enhanced by the slow degradation of the less digestible matter. The Chinese empty these plants once or twice a year, removing the undigested materials and using the slurry as fertiliser on their fields. The disadvantage of this approach is the break in gas production during the time the plant is being emptied and restarted.

4.7 Digester design parameters

When a biogas digester is designed the main variable to be defined is its internal volume. The amount of gas produced depends on the volume of slurry in the pit. The digester volume is related to two other parameters: the retention time (R, measured in days) and the feed rate. For a batch digester, the retention time is simply the time the slurry has been left in the pit. For a continuous digester, it is given by the volume of the digester pit (V, m^3), divided by the volume of the daily feed (V, m^3/day):

$$R = \frac{V}{v} \text{ days.} \tag{3.1}$$

The volume feed rate (v) is given by the mass of total solids (m, kg) fed daily, divided by the proportion of total solids in the mixed slurry (assuming the density of feed is 1000 kg/m^3):

$$v = \frac{m}{TS \times 1000} \text{ or } v = \frac{m}{TS\% \times 10} \quad m^3/\text{day} \tag{3.2}$$

The retention time is always a compromise between gas production rate and efficiency. If the supply of feed is limited and the temperature low (less than 20°C), the retention time should be as long as possible (up to 100 days) to get the maximum gas from the feed. Long retention times also allow less digestible materials in the feed to be broken down. The volume of the plant will be large, though, making the cost high. If the feed is in plentiful supply and the temperature can be kept high (30°C), a retention time of 10 days is possible, giving a high rate of gas production. Special high-rate thermophylic reactors can have retention times down to one or two days, but these are very expensive to build and operate.

At low temperatures it is important to keep the retention time long, as the bacteria grow more slowly. If the bacteria are removed with the spent slurry faster than they can replace themselves in the digester pit, 'wash-out'

occurs and the plant will fail. As the methanogens multiply more slowly than acid-forming bacteria, the main symtom of wash-out is the plant becoming sour. The plant may recover if feeding is stopped for a time.

The loading rate (r, kg.VS/m^3/day) of a digester is defined as the mass of volatile solids added each day per unit volume of digester. It is related to the mass feed rate:

$$r = \frac{m \times VS}{v} \text{ or } r = \frac{m \times VS\%}{v \times 100} \text{kg. VS/m}^3\text{/day} \qquad (3.3)$$

Typical values for the loading rate are between 0.2 kg.VS/m^3/day and 2.0 kg.VS/m^3/day.

4.8 Effluent slurry

Anaerobic digestion not only breaks down plant materials into biogas, it also releases plant nutrients, such as nitrogen, potassium and phosphorous and converts them into a form that can be easily absorbed by plants.[18] These fertiliser chemicals are not removed or created in a biogas plant, although the removal of carbon, oxygen and hydrogen as methane and carbon dioxide means that the concentration of these other chemicals is increased (Table 4.3). For example, protein and amino-acids in the feed-stock are converted into ammonia, which forms soluble ammonium compounds with the fatty acids.[19]

While the value of biogas effluent as a fertiliser is well-known to biogas workers, most biogas programmes have given it too little emphasis. Farmers tend to assume that the removal of one benefit (biogas) from the feed must reduce its effectiveness in other directions (as a fertiliser). This attitude prevails even in China, where the people have a long tradition of composting wastes (especially night-soil)—despite intensive propaganda on the benefits of biogas.[21,22] Few Indian and Nepalese farmers, are convinced of the fertiliser value of the effluent, except those who have tried it and have become impressed with the results. One such farmer claims to be saving 80 per cent of the urea he used to put on his crops. A few institutions in India run biogas plants purely for the fertiliser they produce.

Table 4.3 Plant nutrients in air dried manure and effluent measured in Nepal[20]

Material	*Nitrogen %*	*Phosphorous %*	*Potassium %*	*Indigestible ash %*
Buffalo dung	1.01	1.11	0.92	26.43
Biogas effluent	1.41	1.18	1.48	28.64

Biogas slurry must be used correctly for its full value to be realised. Preliminary trials of slurry in Kathmandu, at the Department of Soil Science and Agricultural Chemistry, suggested that the concentration of nitrogen in the slurry was too high for transplanted rice seedlings, which grew too fast and weakened. The presence of hydrogen sulphide may be toxic to some plants,[9] especially when pig dung is used as a feedstock. However, frogs were able to live happily in the slurry pits of Nepalese biogas plants using cow dung as feed, so this may not be a major problem.

If biogas slurry is used carefully it does make an excellent fertiliser and soil conditioner. It is free from odour and does not attract flies. Most of the harmful bacteria and parasites in the original feed are either killed or considerably reduced in number.[23,24] The benefits of slurry use build up over several years. Tests in China show a productivity increase in rice production of 11 per cent to 14 per cent after biogas slurry had been applied to the fields regularly for four years.[19,25]

The major problem with effluent slurry is transporting it to the fields as it is in liquid form. Chinese plant owners often collect the slurry daily in buckets and carry them to nearby vegetable plots. Slurry has a total solids content of about 8 per cent, so 92 per cent is water, which is bulky and heavy to carry over long distances. A large volume is required to get an adequate quantity of fertiliser.

The usual practice in India and Nepal is to collect the effluent in shallow ponds and allow it to dry in the sun. This reduces its weight and volume considerably. Any toxic substances, such as hydrogen sulphide, evaporate and any remaining harmful bacteria are killed. However, ammonia is also lost by evaporation into the air and by leeching, as water drains into the soil. The loss of nitrogen from dried slurry (7 per cent to 15 per cent)[26] appears to be less than from drying raw cattle dung (20 per cent to 45 per cent).[6] However, sun drying takes up a lot of space and is difficult in the rainy season.

Digested slurry can be introduced into irrigation canals, so the water washes it to the fields. This approach was used in a biogas irrigation scheme in Parwanipur, Nepal.[27] Unfortunately, more slurry was deposited near the sluices from the canal than reached the far ends of the fields. Slurry can be put in tanker trailers and pulled by animals or tractors. In some communes in China, the slurry is then sprayed onto the fields, using a small biogas-powered pump.[25] This approach requires machinery and is expensive.

Slurry can be added to dry plant material, such as straw or leaves.[26,28] The dry material absorbs the plant nutrients and water and conserves them. The slurry contains facultative bacteria that composts the plant material, increasing its fertiliser value.

4.9 Research on microbiology and slurry use

Since the anaerobic process is complex, a biogas extension programme needs to have available the skills of a qualified microbiologist or biochemist as well as the services of well-equipped laboratories and trained personnel to run them. The digestibility of different local feedstocks needs to be tested and the causes of any plant failures discovered. A large programme might have its own laboratory and staff, but most biogas programmes employ university or government research laboratories on a consulting basis, paying for research and test work as required. In India and China, as well as other countries such as Thailand, the Philippines and Brazil, there are many research institutions involved in biogas-related research projects. In less-developed countries, special research programmes may need to be funded to ensure that specialist help is available when needed by the extension programme.

Much more work needs to be done on the use of slurry as a fertiliser. For example, a low-cost appropriate technology is required that can separate the solid from the liquid fractions of effluent slurry. The liquid can be used on nearby vegetable plots, leaving the less bulky solids to be collected and used on crops in more remote fields.[29]

A biogas extension programme should also have land available, either its own or loaned by agricultural research stations, on which the use of biogas slurry on local crops can be tested. These plots would also serve as demonstration and training areas to teach local farmers to make the best use of the fertiliser from their plants.

CHAPTER 5
Biogas Plant Designs

A biogas extension programme must have at least one design of biogas plant that can be sold to customers and built by its staff. It must be possible to make it in a range of sizes, suitable for different applications. Both the Indian and Chinese programmes started badly because they used unreliable and unproven designs. A large number of failures at the start of a new programme can bring bad publicity and loss of public confidence. So the choice of the right design of plant with which to start a biogas programme is one of the most important decisions to be made during planning.

5.1 Digester design criteria

There are many different designs of biogas plant available.[1,2,3] Some have been made only as prototypes, to test an idea; others have been made in thousands in extension programmes. A biogas plant must perform a basic set of functions: it must contain the slurry for a suitable length of time; it must keep out air and light; it must keep the slurry at a reasonable temperature and it must collect and store the biogas until it is required.
There are several criteria against which different designs may be considered, when choosing one to act as the basis of an extension programme. A biogas plant should be:

1 Strong
2 Leak-tight
3 Built of local materials
4 Cheap to build
5 Easy to use
6 Easy to maintain
7 Easy to insulate and heat
8 Reliable

A large volume of slurry ($5m^3$ to $1000m^3$) exerts high pressure on the walls of its container, depending on the depth. The easiest way to support the container walls is to place them in a pit in the ground. The space between the walls and the undug earth must be filled with hard-packed earth for strength.

Some of the above criteria are linked; a plant built of local materials, such as those used to build local houses, will be much cheaper than one made from imported materials. Some are in conflict: a biogas plant built of welded steel sheet will be strong and leak-tight, but will be expensive. The cheapest building materials: mud, wood, bamboo etc. are not suitable, as slurry and biogas will leak through them. Mud can be used to add weight

to support a lighter material. Concrete and brick seem to be the best materials for building a digester, although care must be taken in the construction to ensure that it does not leak slurry or gas.

Rubber and plastic materials have also been used in biogas plants, as they are leak-proof. However, sheets of rubber and plastic are not strong and can be damaged by rodents and by sunlight. Great care must be taken during transport and construction that they are not damaged by sharp objects. In Nepal, where these materials are mostly imported, they can be as expensive as the steel required to do a similar job.

A farmer will not buy a biogas plant that is difficult to use. If a man has to carry buckets of slurry up a tall ladder each day to feed the plant, he will soon stop using it. The same is true if the plant fails frequently and is difficult or expensive to repair. Farmers are willing to do simple, regular maintenance work, as long as they understand what they must do and the work does not require expensive supplies. A biogas plant must be designed with maintenance in mind. For example, taps in a gas line must be fitted so they can be easily removed for repair if they become stuck or break.

In the tropics the slurry temperature in a plant should remain above 20°C for most of the year. In colder regions of the world, a biogas plant must be designed so it can be easily insulated and heated if biogas is required in winter.

The most successful biogas plant designs are shaped as a cylinder or as part of a sphere, as these shapes are stronger and easier to make leak-tight. Corners are very difficult to seal against slurry or gas leaks. If components, such as gas storage drums, are to be made in a workshop, the transportation of these components to a plant site must be considered.

5.2 Basic plant designs

While there is a wide range of plant designs available, only three will be considered for use in extension programmes: the floating drum, the fixed dome and the flexible bag digesters. These are the most used designs and many other plants are only variations of them. Both the floating drum and the fixed dome designs are built in Nepal and they are versions of the original designs adapted to local conditions. The Nepalese versions also incorporate improvements to the original designs that make them cheaper to build and easier and more reliable to use.

5.3 Floating drum design

The floating steel drum design has formed the basis of the Khadi and Village Industries Commission programme in India since the 1950s. It was originally developed in Bombay by Mr J.J. Patel, who called it the *Gramalaxmi III* design.[4] It is now more commonly called the *Indian* design.

The slurry is kept in a cylindrical pit in the ground. The pit is usually lined with brick masonry, similar to a dug water well. The soil around the pit supports the brick walls and allows them to take the hydraulic pressure. If the brickwork is made carefully, the walls should not leak. Small holes are filled by the slurry seeping through and drying out within them.

The gas is collected in a cylindrical steel gas drum that floats mouth downwards in the slurry. As gas collects in the drum, it floats higher in the liquid. As gas is used, the drum sinks back down. If the drum becomes full, the gas bubbles out around its sides and is lost into the air. The drum usually has a steel bar framework fixed inside it, so that when the drum is rotated by hand it stirs up the surface of the slurry and breaks up any scum formation. It often has handles fixed to the top with which it can be rotated and also carried, when it is being transported to or removed from a plant. The drum is usually made from mild steel sheet, welded around a light frame made of welded steel angle bars.

The gas drum is held in the right place by a central guide pipe running vertically through a second pipe at its centre. This system allows the drum to move up and down and to rotate about its central axis. It stops the drum moving sideways or toppling over and jamming on the walls of the digester pit.

The standard KVIC design uses a deep, straight-sided cylindrical digester pit,[5] the depth being two to three times the diameter (Fig. 5.1). This shape is not optimum as it requires a deep hole to be dug and does not

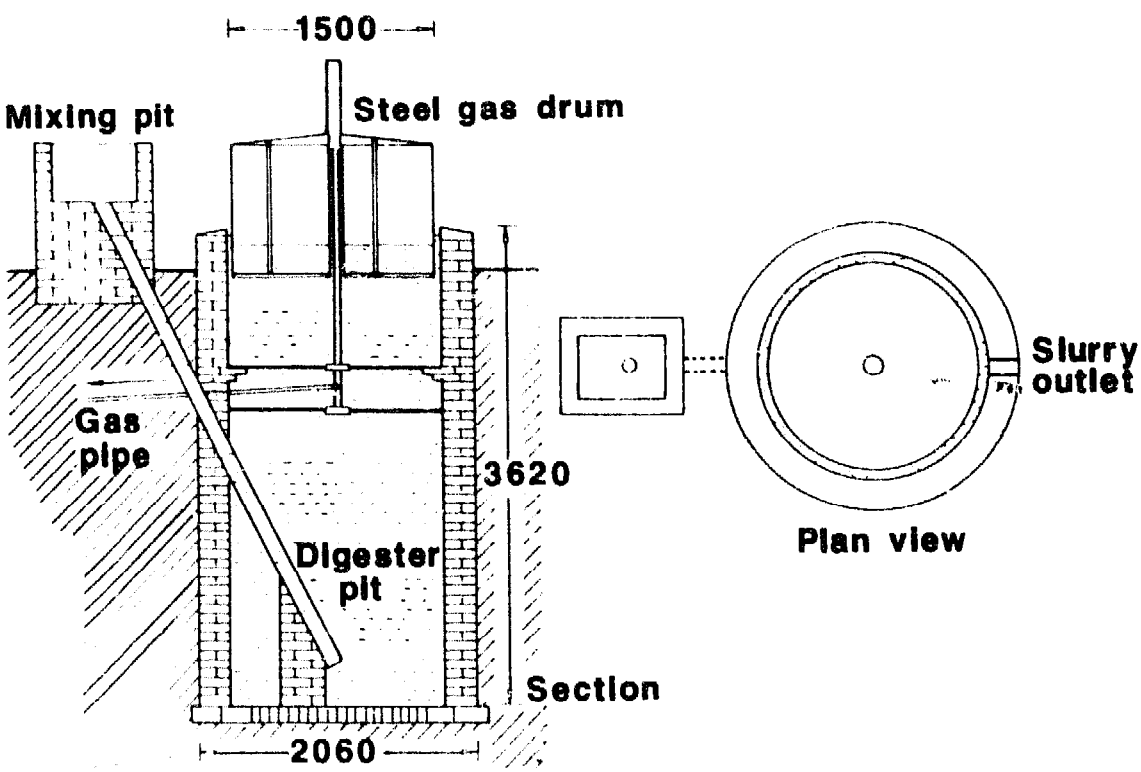

Figure 5.1 *Straight design of steel drum biogas plant*

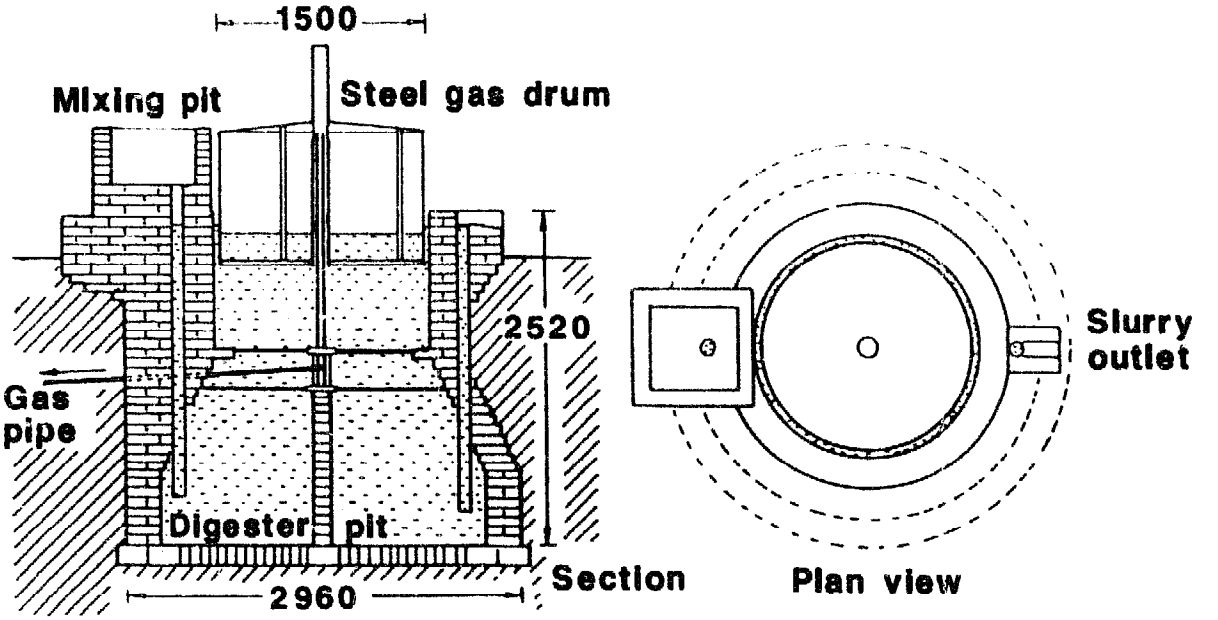

Figure 5.2 *Taper design of steel drum biogas plant*

make the best use of materials. A shallower, wider pit (the depth being about the same as the diameter) should be cheaper to build.[6] The problem of digging deep pits in the plains (Terai) of Nepal, where the underground water table is often near the surface, inspired the taper design (Fig. 5.2).[7] The internal volume of this plant is the same as the straight version of the corresponding size and both use the same number of bricks and size of gas drum (see Appendix I). The tapered version requires a much shallower hole. A central dividing wall is used to stop new feed slurry coming out of the outlet pipe before it is digested.

A second improvement made to the Nepal version by DCS is in the way the gas is removed. The KVIC design has a gas tap fitted to the top of the gas drum and a flexible plastic pipe hose links this to the permanent gas pipeline. This plastic pipe needs to be replaced regularly (once or twice a year) as it degrades in the sunlight, gets brittle and cracks. The drum used in Nepal has holes leading into the central guide-pipe, which is sealed to atmosphere. The gas is removed under the side of the drum (see Fig. 5.3). The drum can be rotated more easily and maintenance is reduced. As the central guide pipe is closed to the air, it is less likely to corrode than the KVIC version, which has a typical lifetime of only five years.[8]

Other versions of the floating drum design include rectangular digesters and drums (used in Korea and Taiwan), but these are more difficult to seal against leaks. KVIC have a shallow version of their design, which uses a rectangular slurry chamber built slightly inclined to the horizontal. The drum floats in a circular hole at the higher end of the chamber.

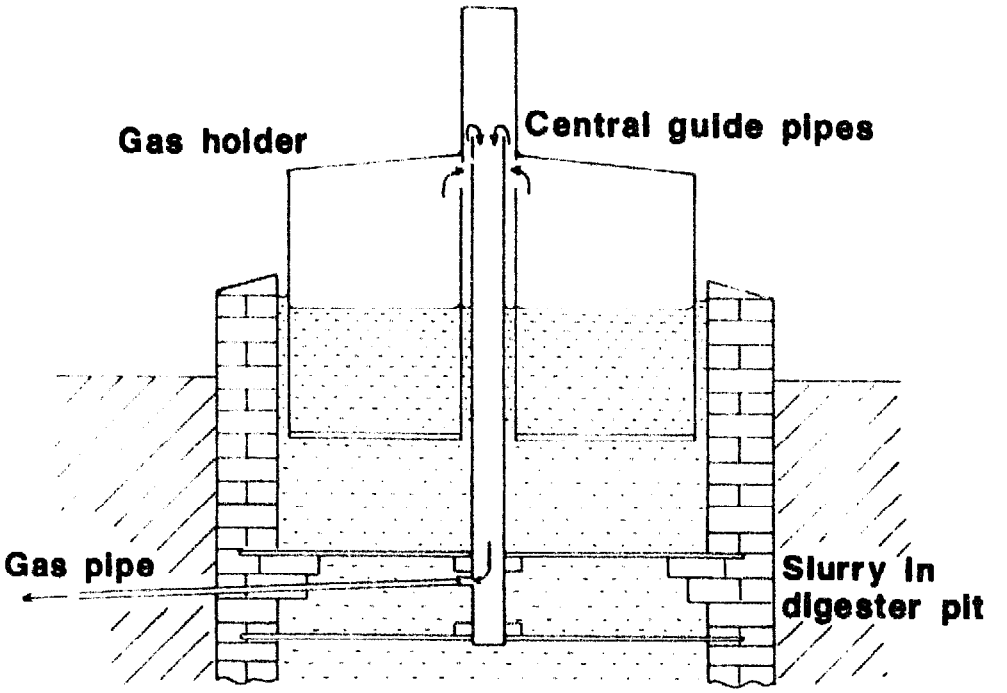

Figure 5.3 *Gas removal system for DCS drum design*

A standard digester can use floating drums built of different materials. KVIC have experimented with the use of drums made from HDPE (high density polyethylene), PVC and ferrocement.[9,10] DCS have also tested plastic and ferrocement drums, with little success. HDPE expands and contracts in the heat of the sun and quickly cracks. Ferrocement drums are very heavy and difficult to transport. Small hairline cracks easily occur and they are difficult to seal against gas leaks.

Galvanized steel (GI) sheet has been successfully used for gas drums. The seams must be sealed with solder or glue to ensure they are leak-tight. GI drums are very light, so require weights on top to give enough gas pressure. Any small scratches in the zinc coating can allow galvanic corrosion that quickly creates holes in the drum.

An early version of the KVIC design used a steel drum supported by ropes passing over pulleys and attached to counter-balance weights. The reduced gas pressure was supposed to improve gas production; but the extra 'biogas' was actually carbon dioxide coming out of solution. This design was very dangerous, as air could leak into the drum and form an explosive mixture with the biogas. Some of these plants have blown up. Other drums designs, without the counterweights, are much safer to use.

5.4 Practical aspects of the drum design

Over 800 plants to the DCS version of this design have been made in Nepal and many more have been made in India (over three-quarters of their

200,000 total). Follow-up surveys show several problems, especially that of corrosion of the steel drums.[11] Eighty-six of the first 95 built in Nepal showed signs of rust within a year of being installed. Although the chlorinated rubber paint was cleaned off and replaced with bituminous paint, 50 per cent of these drums needed total replacement within the next four years. An estimate of the life of KVIC drums is about seven years.[8] Cracks were reported in the walls of some of the digesters of these first plants in Nepal, but as masons learned their work this type of fault became rare.

Biogas slurry is corrosive to steel, so gas drums must be protected against it. Corrosion resistance is partly a matter of good design work; there must be no corners or ledges where slurry or rain water can sit and start rust formation.[12] It is also a matter of using an effective paint scheme. The finished drums must be carefully cleaned of welding slag, rust and mill scale (a blue oxide coating). Hand cleaning with wire brushes and sandpaper is hardly adequate, although it is the usual approach in many workshops in Nepal and India. Machine cleaning with rotary wire brushes and sanders is better. Sand or shot blast cleaning removes all corrosion and provides a good key for painting, but it is the most expensive and difficult approach.

The cleaned steel must quickly be primed with a metalised antisaline primer paint before rust can form again. Pressure spray painting gives the best results, but is expensive. Air spray painting is not appropriate for the thick paints that need to be used. The primer coat should be followed with a coat of bituminous paint (such as 'high-build black'). A second coat of this paint is required after the drum has been delivered to the plant site.

Steel drums should be painted each year they are in service, if they are to last. Some steel drums in India are over 30 years old, because they have been carefully looked after. The ones that failed within five years were poorly cleaned and painted at first and have been scratched and not regularly repainted while in service.

5.5 Fixed dome design

The fixed dome design is the basic design used in China. It is an underground digester pit, lined with brick or concrete, with a dome-shaped cover, also made from brick or concrete, placed over it. The cover is fixed and held in place with earth piled over the top to resist the pressure of the gas inside. A second pit, the slurry reservoir, is built above and to the side of the digester. As gas is given off by the slurry, it collects in the dome and displaces some of the slurry into the reservoir. As gas is used, the slurry flows back into the digester to replace it (Fig. 5.4). This system of gas storage is called the displacement principle.

The Chinese use a range of different shapes for their digesters ranging from a fully spherical container to a flat-roofed rectangular one.[13,14] The

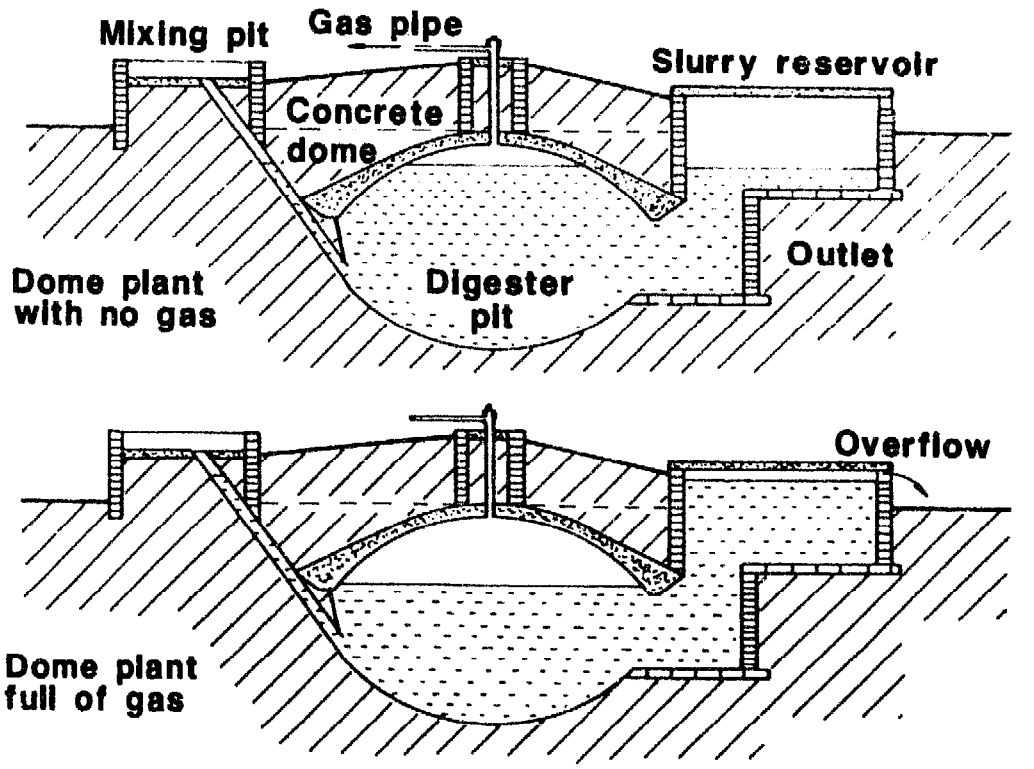

Figure 5.4 *Displacement principle for fixed dome plants*

rectangular shape was used early in the Chinese programme, but proved unreliable, as the corners were difficult to make leak-tight. The most commonly used shape has a roof and a floor made as segments of a sphere, joined by a cylindrical or conical section (Fig. 5.5). If the included angle at the centre of the spherical segment is less than 110° the material of the

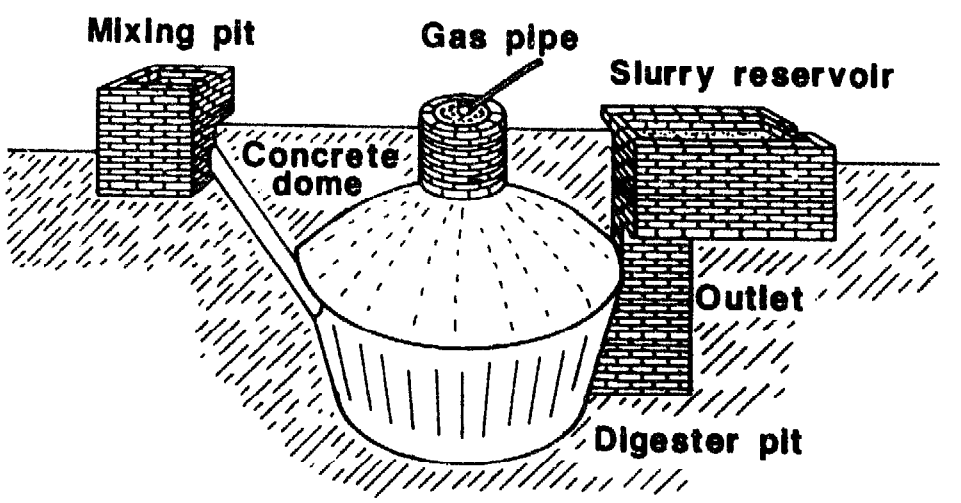

Figure 5.5 *Fixed dome design of biogas plant*

dome is always in compression and a minimum of steel reinforcement is required.

A version of this design is used in Nepal. It is made by first pouring a concrete dome over a mould shaped in mud in the ground. Once the concrete has set the digester pit is excavated from under the dome and lined with cement plaster applied directly to the mud walls. If the soil is weak or crumbly, the plaster can be reinforced with wire mesh, making ferrocement. The weight of the dome is taken by a thick collar formed around its perimeter that rests directly on the undisturbed soil around the edge of the digester.

The reservoir pit is made from brick or stone masonry. The gas is taken out from the centre of the dome, via a pipe which is supported by a small masonry turret. Access to the digester pit during building, and also if the pit needs cleaning, is through the slurry reservoir and outlet. (*Note*: For safety, no-one should enter a digester pit until every trace of biogas and slurry have been removed and flushed out, as it is possible to be suffocated by any biogas left in the pit.)

The gas pressure inside a dome plant can be as high as 1200mm of water and can exert a force of several tonnes upwards from under the dome. A mass of soil, about one metre deep, is placed over the dome to hold it down. Some of the Chinese versions have a man-hole in the centre of the dome, to allow the digester to be emptied easily: a concrete plug is sealed in the man-hole with thick clay which is kept moist with a pool of water. The plug must be held in place against the gas pressure with heavy rocks. If the plug leaks gas, bubbles can be seen in the pool above it.

PRAD in India also have a version of the 'Chinese design', called the *Janata* (people's) plant.[15] They claim it is much cheaper than the drum design, but gas leakage through the dome seems to be a problem.

5.6 Practical aspects of the dome design

At least 10,000 plants have been built to various versions of this design in China, but most have been of poor quality. The average lifetime has been less than five years. While the cost of the plant can be covered in less than this time, through the saving of other fuels and the sale of fertiliser,[16] a failed plant in the back garden brings loss of face and embarrassment to the owners. A biogas plant is not a throw-away item of consumer technology. The present approach in China puts emphasis on high quality, despite higher costs. The oldest Chinese plants have lasted 50 years, so long-lasting plants do have potential in China.

Over 1,100 plants have been made to the Nepal version of this design and surveys have shown few problems. However, masons need more careful training to make this design than the drum plants, especially in the shaping of the mud mould for the dome and in making a gas-tight plaster

seal inside it. The few plants that did fail in Nepal had faults caused by poor workmanship, such as the use of stale cement. Minor design changes made the shape of the plant easier to measure and check. The owner of one plant put slurry in the digester before the dome had been covered with soil. The dome rose out of the ground with the pressure of gas inside it. Once the slurry had been removed, the dome was put back in place, the cracks plastered over and the plant worked as well as any other.

The main problem with the dome design is that concrete and brick masonry are porous to biogas unless they are very carefully sealed. The Chinese biogas manufacturers mainly use a cement and lime plaster inside the dome,[13] although polymer-based paints such as vinyl emulsion are also recommended.[17,18] Coatings that are dissolved in a volatile solvent, such as chlor-rubber, epoxy and polyurethane paints, cannot be used in the enclosed space inside a digester, as the fumes are toxic, both to the painters and the methanogenic bacteria. Many paints cannot be applied until the inside of the dome is completely free of moisture.

In Nepal, the best coating was found to be an acrylic plastic emulsion mixed into a thin cement plaster applied to the inside of the dome. The cement provides strength, while the polymer paint fills in the pores in the plaster. The emulsion is water based, so there is no toxicity problem and the plaster layer can (and should) be applied over damp concrete. Acrylic emulsion is the most stable of the polymer paints (more so than vinyl), so this coating should have a long lifetime. The first plant built in Nepal using this technique is seven years old and is still working well.

5.7 Extended dome design

An adaptation of the basic dome design was developed by DCS in Nepal for larger plants.[19] The extended dome design looks like a tunnel closed at either end with half a dome (Fig. 5.6). The reservoir pit is usually dug first and lined with brick or stone masonry. The roof of the plant is then cast over steel moulds to give the correct shape. Excavation of large volumes of soil ($50m^3$ or more) through the slurry outlet was considered too time-consuming. If steel moulds are not available the digester pit can be covered with wooden boards and a mud mould made on top for the roof. The same system is used to make a roof over the slurry reservoir (Appendix I).

More than 18 plants to this design have been made in Nepal (most of $50m^3$ volume) and they work well. The manufacture and transport of the steel moulds is expensive, but the cost can be spread over several plants if they are made in the same area. Consideration has been given to the use of 'permanent formwork' sections made from lightweight, fibre-reinforced cement. These act as forms for the casting of the dome and are left in place. The insides of these sections are plastered with cement mortar mixed with acrylic emulsion as usual.

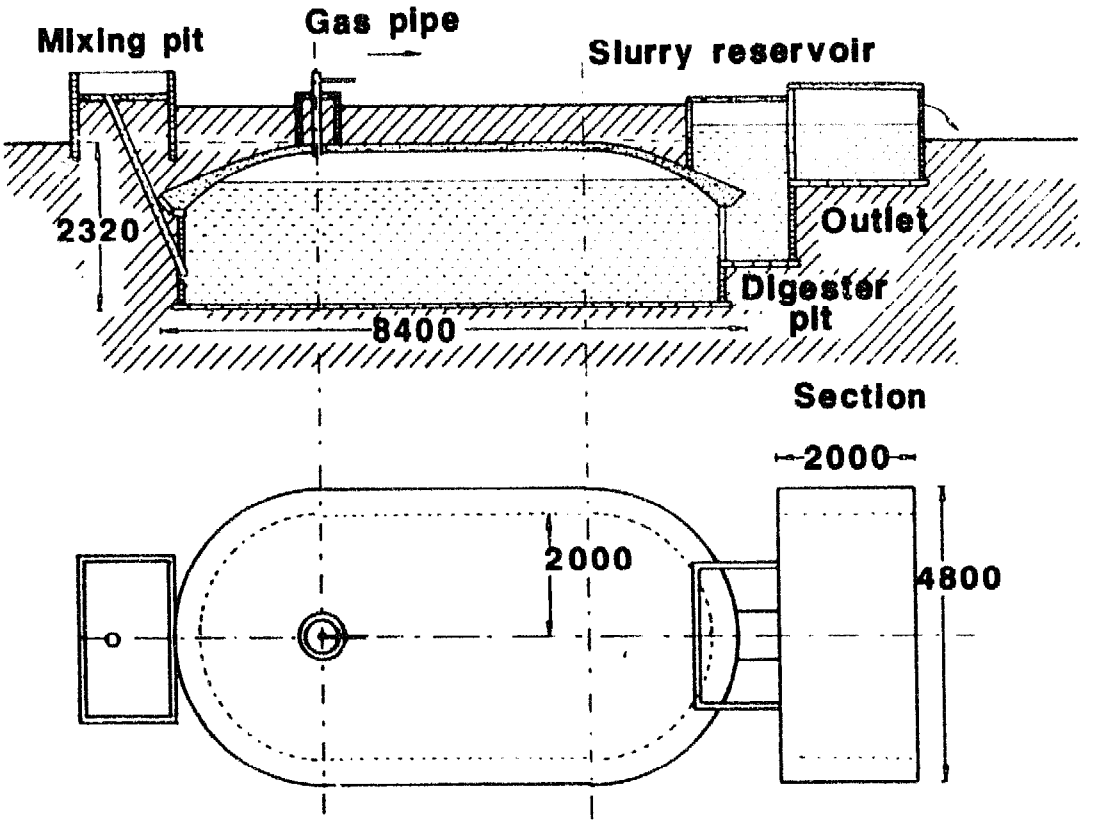

Figure 5.6 *Extended dome design of biogas plant*

5.8 Flexible bag digesters

The flexible bag digester was developed in Taiwan in the 1960s and is now creating interest in mainland China.[20,21] The original design uses a long cylindrical bag (shaped like a sausage) made of plastic, supported in a trench lined with masonry, concrete or compacted sand or mud. The slurry fills the lower two-thirds portion of the bag and the gas collects above it. As the biogas is used the bag collapses, like a balloon being emptied of air (Fig. 5.7.).

A variant uses a masonry or concrete-lined trench to contain the slurry, with a flexible tent-like roof. The edges of the roof are held down to the edges of the trench with clips or poles passing through loops in the plastic. This tent design has been exhaustively tested at Cornell University in USA.[22] It has been built for farmers in the Ivory Coast and is becoming more popular in Taiwan.[23]

The tunnel plant, which has been made and tested by DCS in Nepal, could be considered a version of the bag digester. It has a roof made of concrete arch pieces, lined with plastic sheeting. The gas storage system uses the displacement principle so the plastic lining is kept inflated against the concrete roof.

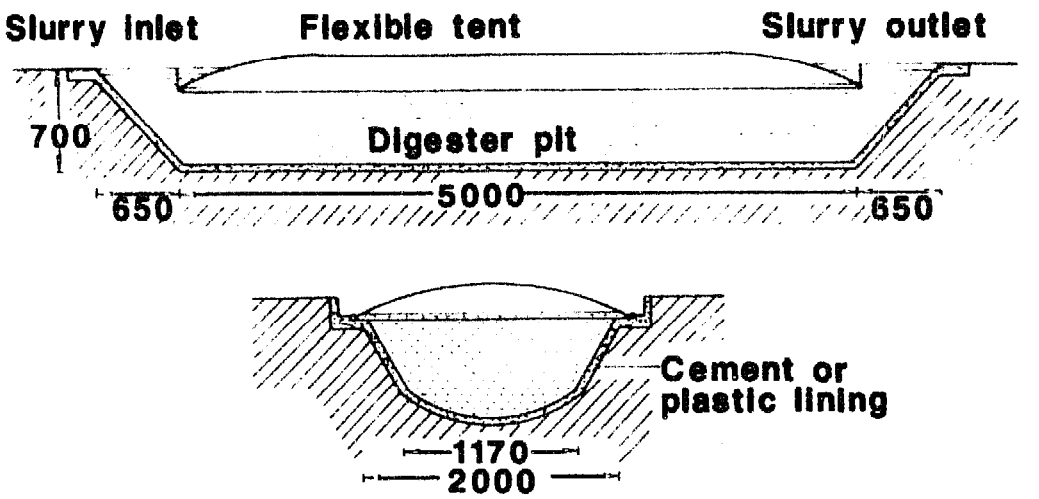

Figure 5.7 *Flexible tent design of biogas plant*

5.9 Practical aspects of the bag design

Over 2,000 bag digesters have been made in Taiwan, where manufacturers are selling bags and tents ready-made for installation in a trench. The original material used for this design was a nylon-reinforced neoprene rubber, but this proved expensive and did not last. The present success of the design depends on a new material: red mud plastic (RMP), a polyvinyl chloride (PVC) plastic which uses a byproduct from aluminium refining as a filler. It is a very strong and flexible material which is resistant to sunlight. The manufacturers claim a ten-year life-time.

Only six tunnel digesters have been made in Nepal for customers. They all work well, but the builders reported difficulties with the PVC lining. The black PVC lining used is stiff and brittle and the workers were afraid of cracking or puncturing it as it was put into the digester and fastened to the roof.

PVC, especially the RMP version, can be welded using a high-frequency, electronic plastic-welding machine. This is easy to use, once the operator has learnt the basic procedures. Manufacture of the bags or tents is similar to making fabric tents and other goods. Transport of the made-up parts is easy, as they are light and can be rolled to take up little space. If the bag is punctured a patch can be glued on, using PVC glue.

The main problem with bag digesters seems to be the removal of gas. A flexible PVC pipe coupling can be welded into the top of the bag or tent, but it must be capable of moving with the bag as it inflates and deflates. DCS had problems with sealing the connection between the gas pipe and the plastic lining of the tunnel plants, even though the plastic did not move. A fixed pipe can be fitted that passes through the bag underneath the surface of the slurry, where a seal is easier to make. However, this intro-

duces extra problems: the bag or tent can rub on this pipe when it deflates. In addition, slurry can easily enter this pipe and block it.[22]

5.10 Choice of plant design

The choice of design for a biogas programme depends on the cost of making the different designs in the locality. While an RMP bag or tent digester may be the cheapest design available in Taiwan, where they are made, transport costs may increase their price in other places (such as Thailand) to the point where other designs are cheaper.[23]

In Nepal the drum design was the most expensive, with the equivalent dome design costing about 25 per cent less. The price of a tunnel plant was even lower (about 64 per cent of the equivalent drum plant). A similar calculation for Thailand makes the tunnel plant more expensive than an equivalent dome plant;[23] illustrating the need to calculate the costs of different designs in the place where they are to be made. The cost of a bag digester in Nepal made from RMP would be relatively high, even if DCS were able to import one from Taiwan. Indian and Nepali import restrictions cause problems with the purchase of many materials from other countries.

A second consideration is the lifetime of the different plants. It is better for a farmer to spend more on a design that is longer-lasting, as a biogas plant is a substantial structure, than one which is cheaper, but has a shorter life. Loan schemes should reflect this emphasis, offering larger loans with longer pay-back periods (five to ten years). Unless a steel drum is regularly cleaned and painted, its life-time can be short (about eight years in India).[8] A steel drum can easily be replaced without affecting the rest of the plant, but it is a major extra expense (about one-third of the cost of a new plant).

The life-time of bag digesters has not been carefully studied. If they are well looked after and protected from damage, the manufacturer's claim of ten years is probably justified. On a typical village site, where there are small boys with sticks, goats with sharp hooves, pigeons that peck and other sources of damage, it is doubtful that an unprotected bag would last long. In Nepal, an experiment with a polythene tent over a gas plant lasted less than a week. In Brazil, bag digesters quickly fell from favour with customers because of the risk of damage.[24]

The life-time of a well designed, properly-made dome digester should be over twenty years, although the acrylic/plaster seal might need renewal after ten years. Some of the early Chinese biogas plants have lasted fifty years.

The gas pressures from the three designs of digester are different. The displacement principle means that a dome digester produces gas pressures up to 1000mm water gauge (the height of water in a pipe the pressure will support) or more, although it varies (down to about 200mm water) as gas is

used. This high gas pressure did not seem to cause owners in Nepal any problems when using biogas with conventional stoves, lights or engines. Many people prefer the higher pressures as they have a greater degree of control over the gas flow. Higher pressures also allow smaller pipes to be used in gas supply lines.

Drum digesters produce a fixed pressure, calculated by dividing the drum weight by its surface area ($1kg/m^2 = 1mm$ water pressure). A drum is usually designed to give a pressure of 100mm water, although the pressure can be increased by placing weights on the drum. No problems were encountered in Nepal with running biogas appliances with these pressures, apart from one gas light brought from China. It had been designed for use with displacement digesters, so did not work with biogas at lower pressures.

The pressures from bag and tent digesters are inherently low, unless weights are placed on the bags. The weights must be placed on a smooth plank in a way that does not allow the plastic sheet to be punctured. Care must be taken when designing the slurry inlet and outlet pipes for these digesters, to ensure that they are long enough, otherwise, slurry may come out of them when the gas pressure is increased. These plants can be used to supply biogas engines without the use of weights, as gas is drawn into the carburettor by suction.

Biogas plants do have to be cleaned, especially if woody material, such as straw, is added to them. Plants that are fed with vegetable wastes may need to be cleaned once or twice a year. If only dung is used and care is taken to remove most pieces of straw and other indigestible matter, a plant could be run for five years without cleaning. A floating drum can easily be removed from its digester to allow cleaning (unless it is made of ferro-cement). Tent digesters are also very easy to clean, as the plastic cover can be removed. Bag digesters can be more difficult, although solid matter can be washed out and dried deposits can be broken up by flexing the outside of the plastic film. Dome digesters are the most difficult to clean, as access is through a small opening in the slurry outlet or in the roof of the dome (in most of the Chinese dome designs).

The issue of stirring the slurry in rural digesters has concerned many designers. High-rate digesters do work better if they are stirred, but the gains in gas production from using a stirrer in rural digesters do not justify the extra cost. Steel drums usually contain stirrer bars, although only the surface of the slurry can be stirred in this way. Their main job is to break up any scum that may form on the surface.

Displacement digesters seem to suffer less from scum. The constant movement of the slurry surface in and out of the dome reduces the tendency for scum to form. Many of the early DCS dome digesters had scum breakers fitted, but owners did not find much benefit from their use. The motion of the slurry also ensures it is well mixed. Scum formation can be a

problem in bag and tent digesters, as they have a larger surface area to the slurry, which is fairly stagnant. One design of digester, which used a concrete 'bag' but which worked on a similar principle, suffered very badly from scum.[25]

In cold climates the insulation and heating of biogas digesters has to be considered. Drum digesters are very difficult to insulate, as the steel drum allows heat to escape. Some community plants in India have been enclosed in a plastic 'greenhouse' that improves solar heating and reduces heat loss;[26] but this is an expensive approach. Dome digesters can easily be insulated by placing a thick layer of straw on top. Storing straw or haystack over the roof of the digester during the winter should be recommended to owners. Bag and tent digesters could be covered with straw in a similar way, although the straw would tend to move as the plastic inflated and deflated.

5.11 Plant sizes

All these biogas plant designs are available in a range of sizes, chosen to supply gas for different purposes. The smallest units have a working volume of between $5m^3$ and $10m^3$ and supply between $1m^3$ and $2m^3$ of biogas each day from 8kg to 12kg of dry feed (40kg to 60 kg of wet cattle or pig dung). If dung is the main feed, this amount can be obtained from four to eight animals. $2m^3$ of gas is considered to be the amount required by a family of four to eight people each day for cooking.

In Nepal, the smallest drum plant (SD100) had a working volume of $7.1m^3$ (Table 5.1). For a drum plant, the working volume is the capacity of the digester pit. The plant produced enough gas in the summer (ambient temperatures between 30°C and 40°C) to run two cooking burners and two lights for a family (five to eight people). This plant had a retention time of 59 days. In the winter when gas production was reduced (temperatures down to 18°C), some owners complained of a lack of gas.

The working volume of a dome plant is more difficult to determine, as some of the slurry moves in and out of the digester. One definition is the volume of the 'permanent' slurry plus half the volume of the gas storage dome. A simple mathematical simulation of the average amount of slurry that is producing gas over a whole day confirms this assumption. DCS took account of the fact that owners need to have sufficient gas during the winter and made the smallest dome plant with a total volume of $10m^3$ (giving a working volume of $9m^3$ and a retention time of 75 days).

The working volume of a bag or tent digester is the amount of slurry that it will hold. This is normally about two-thirds of the total internal volume of a bag; or the total volume of the trench of a tent digester. The mechanism for gas production is slightly different for 'plug-flow' reactors, which are not stirred. The populations of bacteria in the slurry vary along the length

of the trench. The facultative bacteria are most active near the inlet end, while the methanogens predominate in a section from around the centre towards the outlet. The plug-flow principle is somewhat more efficient than a stirred reactor and should produce 15 per cent to 20 per cent more gas from the same input of feed with the same retention time.[27]

The tunnel digester is not a plug-flow reactor as the displacement principle for gas storage produces horizontal mixing in the slurry. Experiments in Nepal suggest that the gas production from drum, dome and tunnel digesters is very close, within the limits that can be accurately measured.

Table 5.1 Characteristics of plant designs used in Nepal

Plant Type	*Digester vol. m^3*	*Storage vol. m^3*	*Work vol. m^3*	*Dry feed kg/day*	*Retention time day*	*Gas Production m^3/day*		
						20°C	*25°C*	*30°C*
SD100	7.1	1.7	7.1	12	59	1.3	1.7	2.9
SD200	13.0	3.4	13.0	24	54	2.5	3.4	5.7
SD350	24.0	6.0	24.0	42	58	4.5	6.0	10.2
SD500	34.0	8.5	34.0	60	57	6.4	8.5	14.5
CP10	7.3	3.3	9.0	12	75	1.4	1.9	3.1
CP15	9.7	5.6	12.5	18	69	2.1	2.7	4.5
CP20	14.1	5.6	16.9	24	70	2.8	3.7	6.1
EP50	39.9	14.6	47.2	60	78	7.4	9.4	15.5
EP65	51.1	19.3	60.7	80	76	9.7	12.5	20.6
EP95	73.5	28.5	87.7	120	73	14.3	18.5	30.6

Notes: The feed is assumed to have a TS of 10 per cent.
The gas production is calculated using a model (Appendix IV)

Larger sized plants (30m^3 working volume and upwards) are required to provide enough fuel for engines. A SD500 plant, or its equivalent, should run a 3kW engine (5HP) for seven hours a day on 40kg to 60kg dry feed (250kg to 300kg wet dung from twenty to thirty animals), at summer temperatures (above 30°C).

While the largest drum plant made in Nepal was the SD500 (working volume 34m^3), much larger plants have been made in India, up to the equivalent of SD1500 (working volume 100m^3). A major problem with these larger plants is the transport and installation of the drums. Such a drum can be carried to the site in pieces and welded with a portable welding machine, but it would still need a crane or a large gang of labourers to lift it up and lower it on to the digester pit.

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SD200	13.0	3.4	13.0	24	54	2.5	3.4	5.7
SD350	24.0	6.0	24.0	42	58	4.5	6.0	10.2
SD500	34.0	8.5	34.0	60	57	6.4	8.5	14.5
CP10	7.3	3.3	9.0	12	75	1.4	1.9	3.1
CP15	9.7	5.6	12.5	18	69	2.1	2.7	4.5
CP20	14.1	5.6	16.9	24	70	2.8	3.7	6.1
EP50	39.9	14.6	47.2	60	78	7.4	9.4	15.5
EP65	51.1	19.3	60.7	80	76	9.7	12.5	20.6
EP95	73.5	28.5	87.7	120	73	14.3	18.5	30.6

Notes: The feed is assumed to have a TS of 10 per cent.
The gas production is calculated using a model (Appendix IV)

Larger sized plants (30m^3 working volume and upwards) are required to provide enough fuel for engines. A SD500 plant, or its equivalent, should run a 3kW engine (5HP) for seven hours a day on 40kg to 60kg dry feed (250kg to 300kg wet dung from twenty to thirty animals), at summer temperatures (above 30°C).

While the largest drum plant made in Nepal was the SD500 (working volume 34m^3), much larger plants have been made in India, up to the equivalent of SD1500 (working volume 100m^3). A major problem with these larger plants is the transport and installation of the drums. Such a drum can be carried to the site in pieces and welded with a portable welding machine, but it would still need a crane or a large gang of labourers to lift it up and lower it on to the digester pit.

The largest dome plant that can easily be made has an internal volume of $20m^3$ (CP20 with a working volume of $17m^3$). The extended dome design can be built with a working volume of $80m^3$, or even larger. The transport problem is much reduced, as there are no large components. Bag and tent digesters can be made to any size. A typical large-volume bag plant has a total volume of $100m^3$, but tent plants have been made with a working volume of $540m^3$.[22]

5.12 Site selection for biogas plants

Biogas salesmen and technicians who are responsible for installing plants need to be trained to select the right sites. The soil must be of good quality; if it is loose and sandy or water-logged, the digester pit may collapse while it is being dug. However, the Chinese do have a special spherical design that can be used in these conditions. If the ground is hard and rocky excavation will be time consuming and expensive.

There are several other factors that affect the choice of site, such as the length of the gas pipeline as gas pipe is expensive; and the distance dung and other feedstocks have to be carried. There must be room not only for the plant, but also for the mixing pit and slurry storage pits to be dug. If trees are too near the digester roots may grow into it and crack the walls. The digester must be at least 15m away from any drinking water source, in case of contamination.

The plant should be in a warm place, if possible. A location that is sheltered from the wind and heated by the sun is ideal. Finally, the site must be away from places that can be flooded, as flood water can dilute the slurry and damage the plant. A typical site plan is shown in Fig. 5.8.[27]

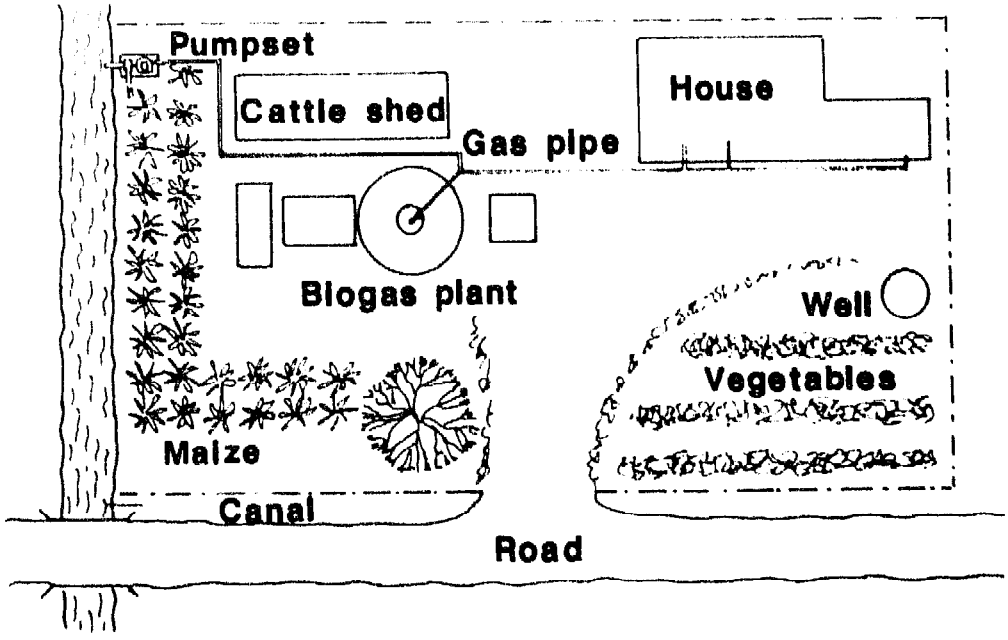

Figure 5.8 *Typical site plan for a biogas plant*

In China farmers are encouraged to link latrines to biogas plants.[14] Human night-soil has a high nitrogen content, so it improves the fertiliser value of the effluent. In many cases, where the C:N ratio of the feed is high, the extra nitrogen from night-soil will improve gas production.

The latrine can be connected to the digester using a second feed pipe between the pan and the pit. This approach has several disadvantages. The latrine floor must be at least 0.3 metres above the slurry outlet to avoid flooding, which usually means that access to the latrine is up a flight of steps. The night-soil is not broken up and mixed in the digester pit, so its digestion is poor. There is a risk of excess water entering the pit when the latrine is flushed or cleaned. An alternative approach is to connect the outlet of the pan to a settling pit. The solids can be pumped out of the pit with a slurry screw pump and the excess liquids allowed to drain into a gravel-filled soaking pit. However, this approach has not yet been tested in practice.

CHAPTER 6
Ancillary Equipment

Although the plant is the major part of a biogas system, it cannot exist by itself. A biogas plant must be fed, usually daily, with suitable feed, spent slurry must be removed and the biogas taken to where it is required. Suitable equipment must be provided to allow customers to use the gas, either in domestic appliances, such as stoves and lights, or in engines that drive useful machinery.

In Nepal and India a biogas plant is usually supplied as a 'package', which includes the appropriate ancillary equipment to fulfill the task for which it was purchased. When Chinese peasants were responsible for setting up their own plants, they usually had to make their own stoves and lights, often of poor quality and low efficiency. The present emphasis on higher standards means that designs for more efficient and reliable stoves are becoming available.[1]

6.1 Slurry handling

The feedstock must be mixed with water into a smooth slurry before it is put into the digester. The bacteria cannot easily reach foodstuffs at the centre of lumps of animal dung or vegetable matter. A masonry pit is usually provided at the entrance of the slurry inlet pipe, where this mixing can be done. A plug, made of wood or concrete, is used to close the pipe until the feed is ready.

In Nepal and India cattle dung is usually mixed with water by hand. This is a culturally acceptable practice, as a cow is a holy animal to a Hindu, but it is not recommended on health grounds. Animal dung often contains intestinal parasites, such as amoeba and giadia. A simple hand-mixing tool, shaped like a hoe with a blade made of wire mesh, was designed by DCS (Fig. 6.1) for use in Nepal.[2] It worked well, but was not for some reason popular with customers.

Larger biogas plants in Nepal and India use a mixing machine (Fig. 6.2), designed by KVIC, based on a machine used to break up pulp for paper making. It consists of an elliptical masonry trough with a paddle-wheel beater set in it. A coarse sieve removes straw and other fibrous material. The machine works fairly well and is popular, despites its tendency to splash slurry over the operator.[2]

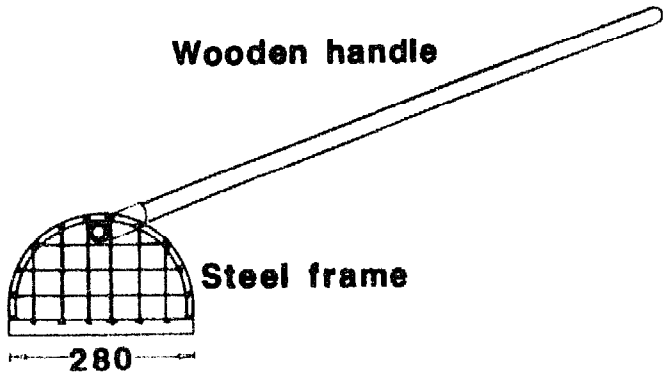

Figure 6.1 *Hand tool for mixing slurry in inlet pit*

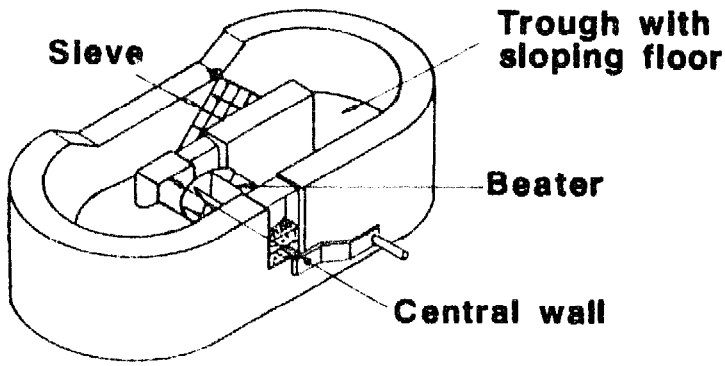

Figure 6.2 *Machine for mixing feed slurry*

Vegetable matter needs to be chopped up before being compressed into a biogas plant. It is best fed to the surface of the slurry, rather than to a position close to the floor of the digester, as is common with plants fed mainly on dung. A plunger can be used to push vegetable matter down the inlet pipe.[3] One suggestion, not yet tried, is to use a screw pump, similar to a large-scale domestic food mincer, both to chop fibres and to push them into a digester.

The effluent slurry is usually stored in shallow pits until it can be removed, usually for use on the fields as a fertiliser. The pits are usually left unlined, unless the soil is of poor quality, when walls can be made from masonry. The size of the pits depends on the daily output from the plant and the number of days for which slurry is to be stored. Deep pits are not recommended, as slurry then cannot dry effectively. They are also a danger to animals and children.

6.2 Gas piping

Pipes must be used to convey the biogas produced in the plant to where it is used. These pipes are often laid underground to be out of the way and also

for protection. Biogas contains moisture which condenses in the gas pipes and must be removed, or it blocks the gas flow. The pipes should be laid so they slope towards one or more drain points (Fig. 6.3). The slope should be at least 1:100.

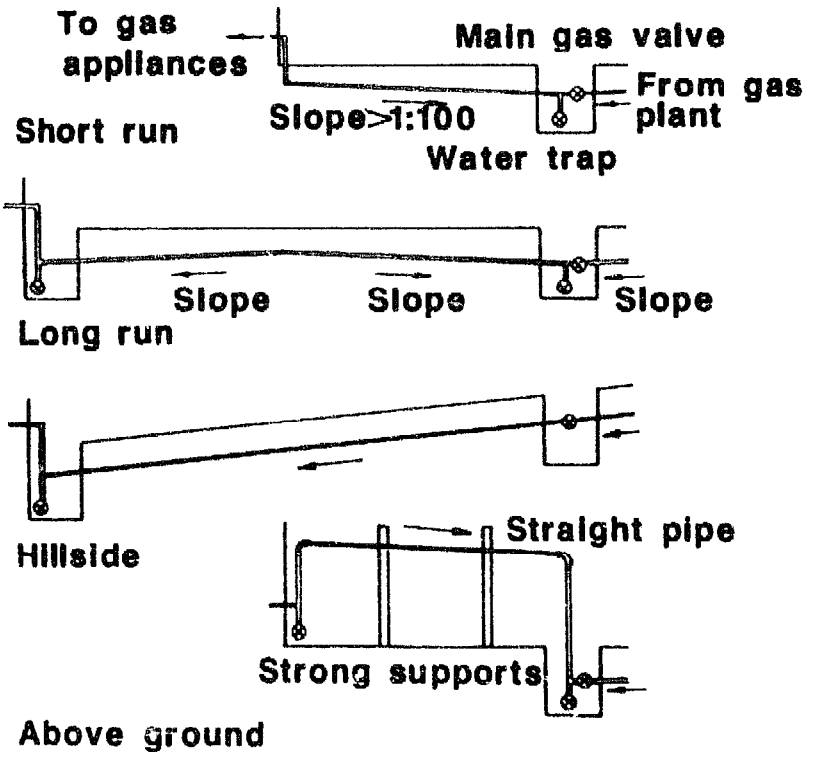

Figure 6.3 *Location of drain points in typical gas lines*

Galvanised steel gas pipe (GI pipe) is often used, as it is resistent to the corrosive effects of biogas, but it is expensive. It comes in straight lengths (2 metres) that are joined by screwing the threaded ends into sockets. Different types of fittings are available. The screwed joints must be sealed

Table 6.1 Pipe lengths used with drum plants

	Flow rate (litre/min)				
Maximum pipe length (m)	10	20	30	40	50
Gas pipe sizes					
16mm ID (½in. GI)	73	31	12	–	–
21mm ID (¾in. GI)	215	107	71	26	16
27mm ID (1in. GI)	589	294	196	100	59
35mm ID (1½in. GI)	1665	832	555	416	237

Note: Pressure drop is 10mm WG (water guage) in 60mm WG.

with paint or putty, with the help of a filler, such as string. Special tools are required to thread the pipes and to bend them.

Plastic pipe, made from HDPE (high density polyethylene) or PVC (polyvinyl chloride) can also be used. Low-quality plastic piping is not suitable as it can crack and leak gas. Plastic pipe is usually available in long rolls and joints can be made by heat welding. Pipe fittings are also available, which are pushed into the ends of the pipe after it has been softened by heating. Plastic pipe is more easily damaged than GI, but is often cheaper. It should be protected from sunlight if used above ground, and from sharp stones and heavy weights if used underground. A layer of sand around the pipe (about 300mm round) will protect it from damage by rodents (mice, rats, porcupines) which may gnaw it. Tools for heating and welding the pipe are required.

The size of pipe required in any installation depends on the length of the pipeline, the volume flow rate of the gas and the permissible pressure drop along the pipe. The pressure drop is caused by the friction of the gas flowing along the pipe and can easily be calculated (Appendix II). The gas pressure from a drum plant is low (40mm to 80mm water gauge) so only a small pressure drop is acceptable (10mm WG; Table 6.1). The higher pressure from a displacement digester (100mm to 1200mm WG) means a larger pressure drop can be allowed (50mm WG; Table 6.2), so longer lengths of smaller, cheaper pipe can be used.

Table 6.2 Pipe lengths used with dome plants

	Gas/flow rate (litre/min)				
Maximum pipe length (m)	10	20	30	40	50
Gas pipe sizes					
16mm ID (½in. GI)	361	54	60	33	22
21mm ID (¾in. GI)	1073	536	254	130	81
27mm ID (1in. GI)	2932	1466	977	497	295

Note: Pressure drop is 50mm WG in 100mm WG.

The maximum gas flow can be found by adding the gas consumption from all the appliances served by the pipe (Table 6.3). The pipe length is measured from the gas plant to the point the pipe divides to the different places where gas is used. In a simple system allowance can be made for pressure lost in gas fittings by adding 5 per cent extra to the length. The correct gas pipe size to use can be read from these tables or by using Appendix II.

Different water traps can be used to catch the water that condenses in the pipe. The simplest is a short length of pipe in a 'T' fitting at the lowest point of the line. A simple tap can be used to release water when required. Deeper pipe lines must be fitted with a 'U' tube and bucket arrangement to catch the water condensed in the pipe (see Appendix II).

Table 6.3 Gas consumption of various appliances at 75mm WG.

Biogas appliance	*Biogas consumption (75mm WG)*		
	litre/min	*m^3/hour*	*ft^3/hour*
Gas lamp (per mantle)	2.4	0.14	5
Refrigerator burner	2.4	0.14	5
Domestic burners (stoves)	4 to 15	0.2 to 0.9	8 to 32
Commercial burners	20 to 50	1 to 3	40 to 100
Dual fuel engines (per kW)	9	0.56	20
Spark engines (per kW)	11.5	0.7	26

6.3 Gas valves

Valves are used to turn the gas supply on and off. A main gas valve is needed near the plant, as well as gas taps for each appliance. Water taps (globe valves) are not suitable, as they require fluid pressure to lift the washer. Gate valves can be used, with a metal 'gate' that is pushed into a slot by a rotating spindle (Figure 6.4), but they are not reliable. Users can over-tighten and break them and the gate wears out and leaks.

Plug cocks, or quarter-turn gas taps (Figure 6.4), work well at low pressures. The tapered plug has a slot in it that can be aligned with the pipe. The plug can wear and become loose in the body, but a spring can be used to keep the fit tight. This design tends to leak when used with the higher pressures from displacement digester.[2]

The best design of tap is the ball valve (Fig. 6.4). This uses a ball with a hole in it, which can be aligned with the pipe. Round seals press against the ball and prevent gas leaks. This type of valve tends to be more expensive, as the ball is usually made from stainless steel.

Accessories for biogas systems, such as valves, need to be made from materials that are resistant to corrosion. Unprotected steel quickly rusts if it is used with biogas. Galvanised steel can be used, if the zinc coating is not rubbed off. Stainless steel is good, but expensive and difficult to machine. Brass is a suitable material, as long as the lead content is low (1 per cent). Plastic and aluminium are resistant to biogas, but are not usually strong enough to stand hard usage.

Casting is a quick and cheap way of making large numbers of small items, but it must be of good quality. A poor casting can be porous to biogas. Metal-to-metal seals are unreliable at higher pressures. Rubber or plastic seals such as 'O' rings are more reliable, as long as the metal parts are accurately made.

There are many other designs of gas taps available. Several designs were made and tested by DCS.[2] A biogas programme needs to find good valve

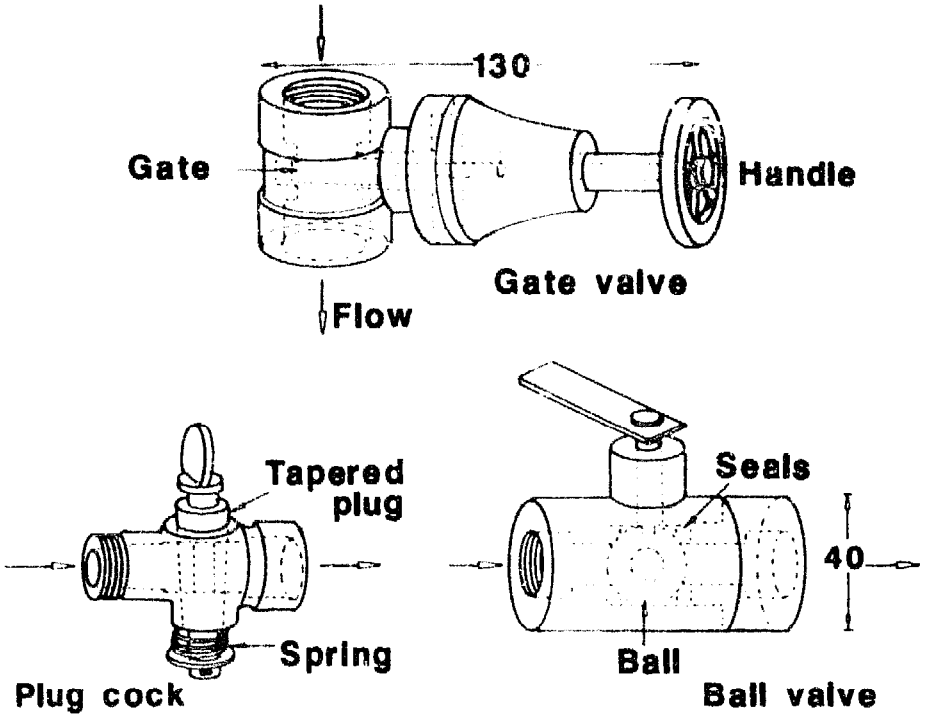

Figure 6.4 *Different types of gas valve.*

designs, as well as suitable manufacturers to ensure sufficient numbers are available.

6.4 Biogas stoves

There are many different designs of biogas stove available. Several manufacturers in India, such as Patel Gas Crafters (Pvt) in Bombay, are supplying stoves to the KVIC and other biogas programmes. The Chinese government has issued a set of standards for stoves made in China to ensure better quality ones are available for their programme.[1] A biogas stove was designed in DCS, which is now manufactured and sold by the

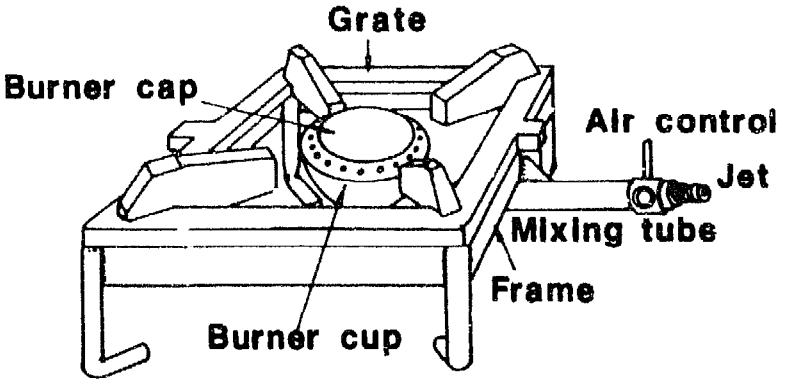

Figure 6.5 *Biogas stove designed in DCS.*

Gobar Gas Company for the Nepal biogas programme.[2] It works well and is about 55 per cent efficient, similar to the best of the Indian designs.

The DCS stove (Fig. 6.5) illustrates the different aspects of a stove that have to be considered when it is being designed (Appendix II) or when different stove designs are compared. A burner mixes gas and air in the correct proportions and feeds the mixture to a burner head, which supports the flame under the vessel to be heated. The flow of gas into the burner is controlled by the size of the main jet, as well as the gas pressure. Most stoves are designed for a standard pressure of 75mm WG, the pressure from a drum plant. The most popular size of domestic burners uses about 450*l* of gas per hour, at this pressure, giving a heat output of 9680kJ per hour. This would heat 1 litre of water from 20°C to boiling point in about four minutes, assuming a 55 per cent efficiency.

The 'primary' air supply that is drawn in by the jet is controlled by an air control. This can be opened or closed down, to adjust the efficiency of the burner. A 'lazy' flame, with reduced air supply, is easier to light and the flame can then be adjusted by opening the air supply to give maximum heat, once a pot has been placed on the stove. The mixing is done in the pipe that leads to the burner ports; the length of the pipe should be about ten times its diameter.

The burner ports are usually arranged in a circle, so that the underside of a pot is evenly heated. Free circulation must be allowed for the 'secondary' air that the flame requires and for combustion products to flow away from the flame. The cap containing the burner ports must be easy to clean, in case food and grease are spilled on it.

The distance between the burner ports and the bottom of the pot is important. If the pot is too low, the flame is 'quenched' and burns inefficiently. If the pot is too high, much of the heat is lost. The frame and grate of the stove must be carefully designed to ensure this height is correct. The DCS stove has a cast-iron grate that can be inverted for use with either round-bottomed or flat-bottomed pans, as both shapes are used in Nepal. The frame must be stable, so it does not wobble or fall over when food is being stirred during cooking.

Some stoves are supplied with a gas tap attached, while others use a gas tap fixed to the supply pipe at the wall. Usually a rubber tube is used to connect the stove to the supply. A wall-mounted tap is much safer, as it can be turned off if the rubber pipe pulls away or splits.

A much larger prototype biogas was also designed and made in DCS, which uses a 450*l*/hr burner at the centre, with a 900*l*/hr burner around it.[4] The two burners have separate jets and supply pipes, so can be operated independently to give good control over cooking large amounts of food.

Over 4,000 stoves to the DCS 450*l*/hr design have been made and sold in Nepal. The production from Patel Gas Crafters and other manufacturers in India is much larger. These stoves are now well-established technology,

although they are still fairly expensive, as they are usually made of a metal such as cast iron. Ceramic stove designs are also being made, although most are at a prototype stage, such as the one made at Reading University (Appendix II).[5]

An alternative approach adopted in China is to use a simple biogas burner in the grate of a traditional wood-burning stove. While the burner is less efficient than a well-designed biogas stove, much less heat is lost, as it is absorbed by the thick mud walls of the wood stove.

6.5 Biogas lights

Where there is no electricity, as in most parts of rural Nepal and many parts of India and China, biogas can be used to give light. While biogas lights are inefficient, expensive and need regular servicing, they give as good a light as a kerosene pressure lamp and are easier to use. A gas lamp gives the same illumination as a 40 to 60W electric light bulb and uses between 90*l* and 180*l* of gas an hour.

Different designs of biogas light are also available from manufacturers in India and China. The Indian designs are usually made mainly of metal, such as cast iron, brass, aluminium and enamelled steel, and are fairly expensive. The designs available from China are often made mainly of ceramic and are much cheaper. These designs are less reliable, however, and can be difficult to use.

An example of an Indian-made lamp (Fig. 6.6) can be used to illustrate how a biogas-powered lamp works. It uses incandescent mantles which glow brightly when heated. The gas supply is controlled by the size of the main jet and by the control valve. The Indian jet is of brass (it is made of glass in the Chinese lamp), with a steel needle partially closing it to adjust the gas flow. The primary air is drawn into a 'venturi', a tapered tube in which the gas and air mix. The air supply can be controlled by means of an

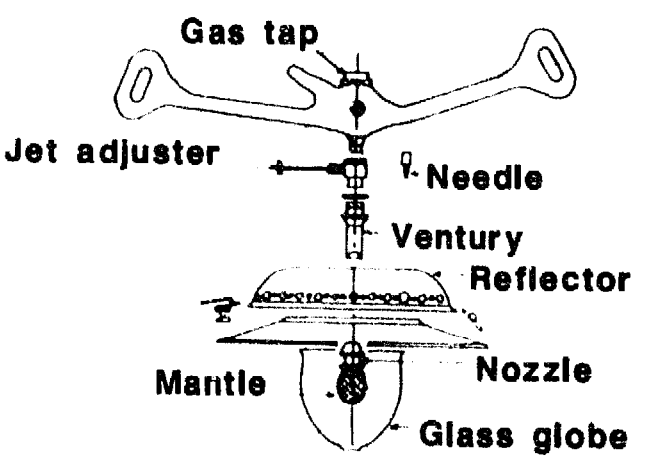

Figure 6.6 *Biogas light (made in India)*

air control or by moving the gas jet to the best position within the venturi (as in lamps made in China). The flame is supported on a 'nozzle', usually made of ceramic. This nozzle is usually composed of one main flame port, surrounded with a ring of much smaller ports, which give the flame stability (Appendix II).

The mantle is held around the nozzle in the hottest part of the flame. The mantle is made of a silk mesh soaked in a solution of rare earth salts (thorium and cerium).[6] When the mantle is first lit the silk burns away leaving a fragile matrix of these salts, which glow brightly in the flame. The flame must be carefully adjusted to give the best light. A 'reflector' above the mantle deflects the heat and burnt gases away from the air inlet and controls.

A glass shield (or globe) is usually supplied with many Indian-made lamps, to protect the mantle from draughts and insects. The mantle is very fragile and breaks if the lamp is knocked or if an insect flies into it. New mantles are fairly cheap. The most common problem with biogas lights is a blocked venturi. Insects make webs in the pipe, which collect dirt. The webs are easy to clean out, although the mantle is usually broken while it is being done.

6.6 Supply of ancillary equipment

Suppliers of these items of ancillary equipment must be found for a biogas programme. Suitable prototype designs must be purchased from manufacturers already making them or made by the programme technicians if suitable manufacturers are not already available. These prototypes should then be thoroughly tested. Manufacturers and suppliers must be found for the best designs, so that sufficient numbers will be available as required.

KVIC licenses manufacturers and suppliers of mixing machines, valves, stove and lights to supply the biogas programme in India. The Gobar Gas Company in Nepal either purchases these items from suitable suppliers in India or manufactures them in its own workshops. As the demand for higher standards for biogas equipment grew in China, entrepreneurs in several production brigades started making improved versions of the simple items that villagers had been making for themselves. The supply and use of these better designs of ancillary equipment (such as the Beijing-4 stove) is now being encouraged by biogas agencies in China.[1]

Using of local workshops to make biogas equipment encourages the growth of local businesses, although mechanics and fitters from the workshops may need to be properly trained to ensure good-quality workmanship. Careful inspection and quality control of these items is important to ensure that the biogas systems built by the extension programme continue to work well.

CHAPTER 7
Biogas in Engines

Biogas is a 'high-grade' fuel, because it burns at a fairly high temperature. Biogas can therefore be used for purposes other than just cooking and lighting, such as a fuel for running internal combustion engines for small-scale cottage industries.

Development depends partly on energy; people who want a more advanced life-styie than is available in a village tend to move to places where energy is available. These are usually areas such as main towns and cities, as energy is produced by large power stations, based on central supplies of coal, oil or natural gas. Electric lines and gas pipes are easy to install in factories and houses that are close together. It is much more expensive to supply the same sort of energy to villages that are widely scattered and distant from population centres.

Biogas offers a decentralised power supply. The energy is created in the villages, where the animals are kept and crops grown and harvested. Biogas can be used to supply energy for cottage industries in the villages themselves, so catalysing development away from the towns. Village people can begin to consider a slightly more advanced standard of living, as they become able to earn money in the place where they are already living. Biogas technology offers the rural areas of developing countries the possibility of increased self-sufficiency and reduced dependence upon supplies from the towns.

7.1 Running engines on biogas

Biogas is commonly used in dual-fuel engines; converted diesel engines in which biogas is introduced into the cylinder with the air supply. A small amount of diesel (about 20 per cent) is still required to ignite the mixture. Lubrication oil is also required, but the running costs of the engine are lower and the amount of diesel fuel that needs to be transported out to the village is reduced, compared to an engine that runs on diesel alone.

There are two types of internal combustion engine: the 'Otto' (the petrol or gasoline) engine and the 'diesel' engine. The Otto engine uses a spark to ignite the fuel, while the diesel cycle relies on the fuel being ignited by the high pressure and temperature in the engine, as the air is compressed (Fig. 7.1.). Biogas can only be used in four-stroke engines, as two-stroke engines rely on oil mixed with a liquid fuel for lubrication.

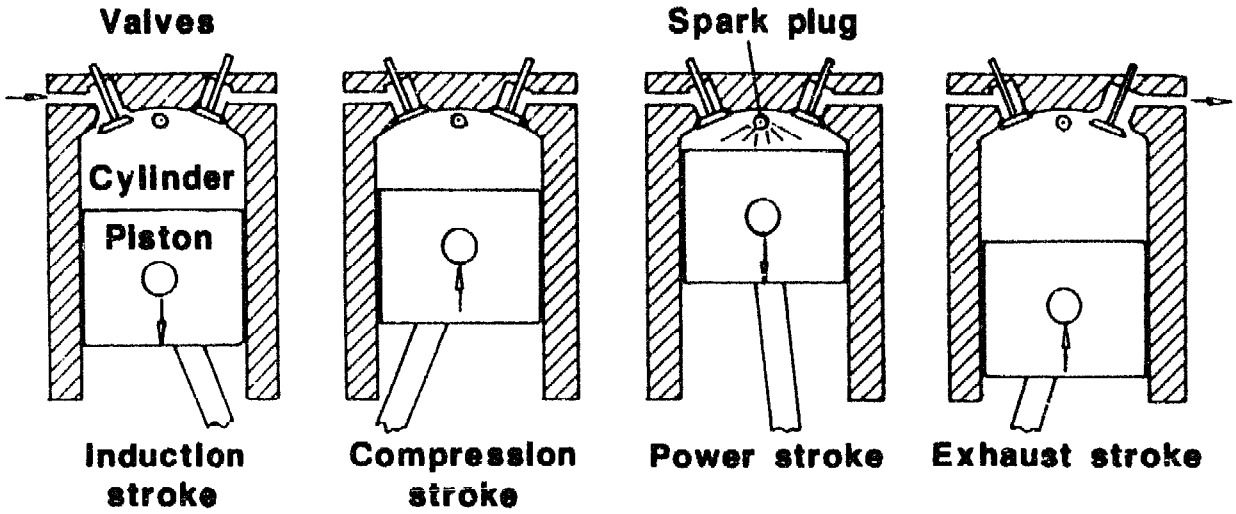

Figure 7.1 *4-stroke cycle for diesel (Otto) engine*

Biogas can be used directly in Otto engines, but it is not commonly done. Biogas is used inefficiently in such an engine, because of the low compression ratio (7:1 to 9:1) and it produces only 60 per cent of the power available when the engine is run on petrol (gasoline).[1,2] Hydrogen sulphide is burnt to sulphur dioxide in the engine and this tends to corrode the exhaust valves and manifold.

When biogas is used in a dual-fuel engine, based on the diesel cycle, the much higher compression ratio (14:1 to 21:1) means that the fuel is used more efficiently. The power loss is just 20 per cent of diesel-only operation, at full power. At other power levels there is little difference.[3] There seems to be much less corrosion in a dual-fuel engine, probably due to its far heavier construction. An advantage of the dual-fuel approach is that the engine can run on diesel alone if supplies of biogas are inadequate.

A third alternative is to adapt a diesel engine to work on an Otto cycle, by replacing the diesel injector by a spark plug.[4] This type of engine has the advantages of the high compression ratio, good efficiency and heavy construction associated with a dual-fuel engine, but no supplies of diesel are

have a relatively low compression ratio (17:1) and run at 1500rpm at normal load. The Gobar Gas Company has installed over 40 of these engines in Nepal and they have proved fairly reliable. They use a simple mixing chamber type of carburettor (Appendix II).

Other diesel engines can be adapted for dual-fuel operation. A Japanese Yanmar engine was fitted with a venturi type of carburettor by DCS (Appendix II). This engine had a higher compression ratio (23:1) and ran faster (2000rpm) than the Indian engines and it would not run with a simple mixing chamber. The key to adapting engines in this way is the correct choice of carburettor.[6]

Maya farms in the Philippines use Japanese spark-ignition car engines to generate electricity and to supply the power needs of their food-growing and processing complex.[1] Their system appears to work well, although reports suggest that the life-time of these engines is limited (about six months of continuous running). The system is only economic because the farm is able to obtain second-hand engines very cheaply from Japan.

Dual-fuel and spark-adapted diesel engines appear to have much longer lifetime when used with biogas (over five years). A dual-fuel engine is started on diesel and the gas valve is opened once the engine is running smoothly. The engine governor automatically closes the diesel control valve until the engine runs at the set speed, keeping the diesel:gas ratio to about 1:5. If too much gas is supplied the engine will begin to misfire.

Dual-fuel and spark-adapted engines run at a higher temperature when

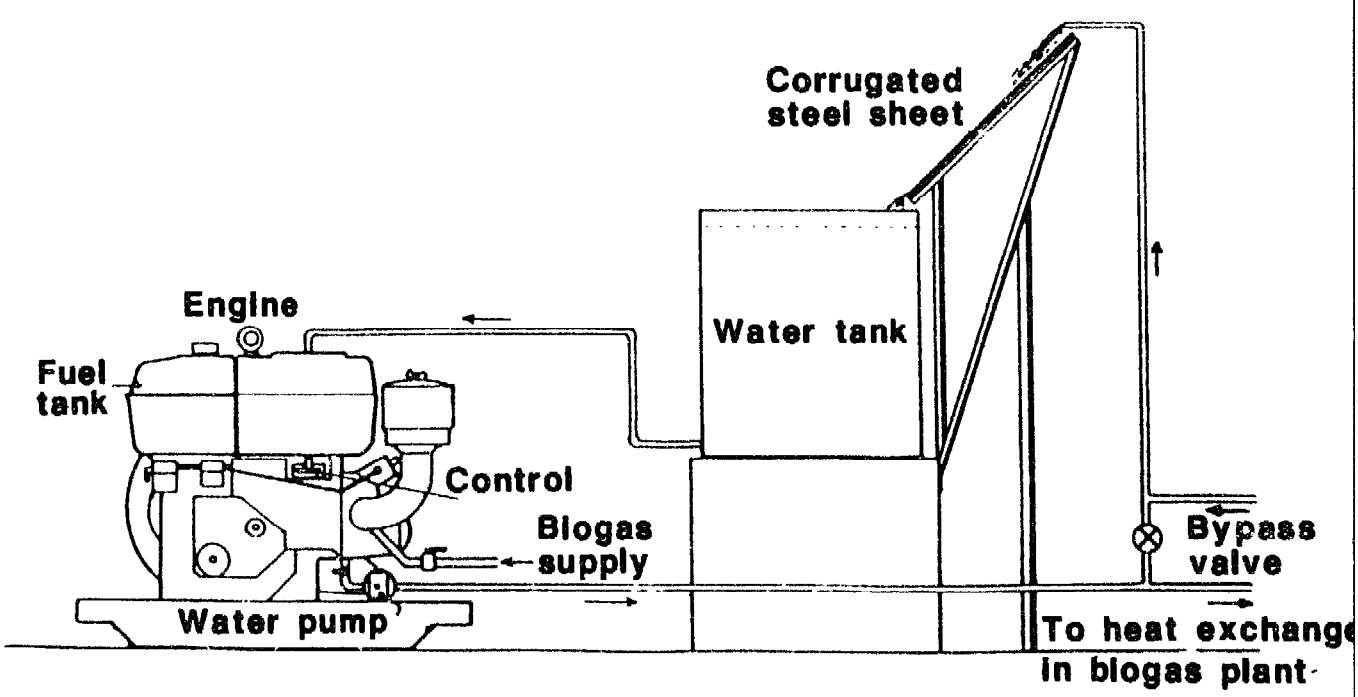

Figure 7.2 *Cooling system for a dual-fuel engine*

used with biogas, so the cooling system must be more effective. A circulation system is needed for cooling, such as the use of a water bleed from the outlet of an irrigation pump. If other machinery is being used a thermosyphon system may be used, with a water reservoir above and to the side of the engine, or a small water pump may be needed to circulate water through a radiator.

The hot cooling water from an engine can be pumped around a heat exchanger in the slurry pit, to warm the slurry to improve gas production. A by-pass valve and a water cooler must also be provided, to allow both the engine and biogas plant temperatures to be set correctly (Fig. 7.2).

If the use of engines is to be made part of a biogas programme then villagers must be trained to operate and maintain the engines that they buy. There must be trained mechanics available to visit the villages to service the engines and to make repairs. Most failures of engines in rural situations have simple causes. Operators forget to top-up or change the engine oil; bolts shake loose, allowing parts to crack or gaskets to blow; filters are not changed in time or are left out. If villagers are trained to recognise these simple faults and to put them right, engines should last much longer.

7.3 Use of engines in villages

The most popular use of a biogas-fuelled engine in Nepal is for food processing. People are usually willing to pay to have rice hulled, or maize, wheat and millet ground into flour: owners of rural mills can make a good living. The most profitable activity is the expelling of oil from mustard, sesame and other oil seeds. Hand milling is a very labour-intensive and time-consuming activity and machine milling is much more efficient. Up to 50 per cent more oil can be pressed from mustard seed with a good machine than is possible with simple hand tools.

A typical small mill, designed for these tasks, can use a 5kW dual-fuel engine using gas from an SD500 or ED50 biogas plant for five hours a day. The different milling tasks tend to be seasonal, so the engine would run one machine at a time, depending on the main task to be done. If cattle dung is used to run such a mill, the dung from thirty animals is required. Such a system could hull 750kg of paddy per day or process 450kg of flour or 150kg of oil seed. Several such systems have been installed in Nepal and India both for individual entrepreneurs and for groups of farmers.

The engine and milling machinery must be properly installed. It should be mounted on strong concrete foundations with wood or rubber mountings to absorb vibrations. Traditional mills in many countries use flat belt drives, which are inefficient and dangerous. 'V' belts are to be recommended. Again, operators must be trained to look after and maintain

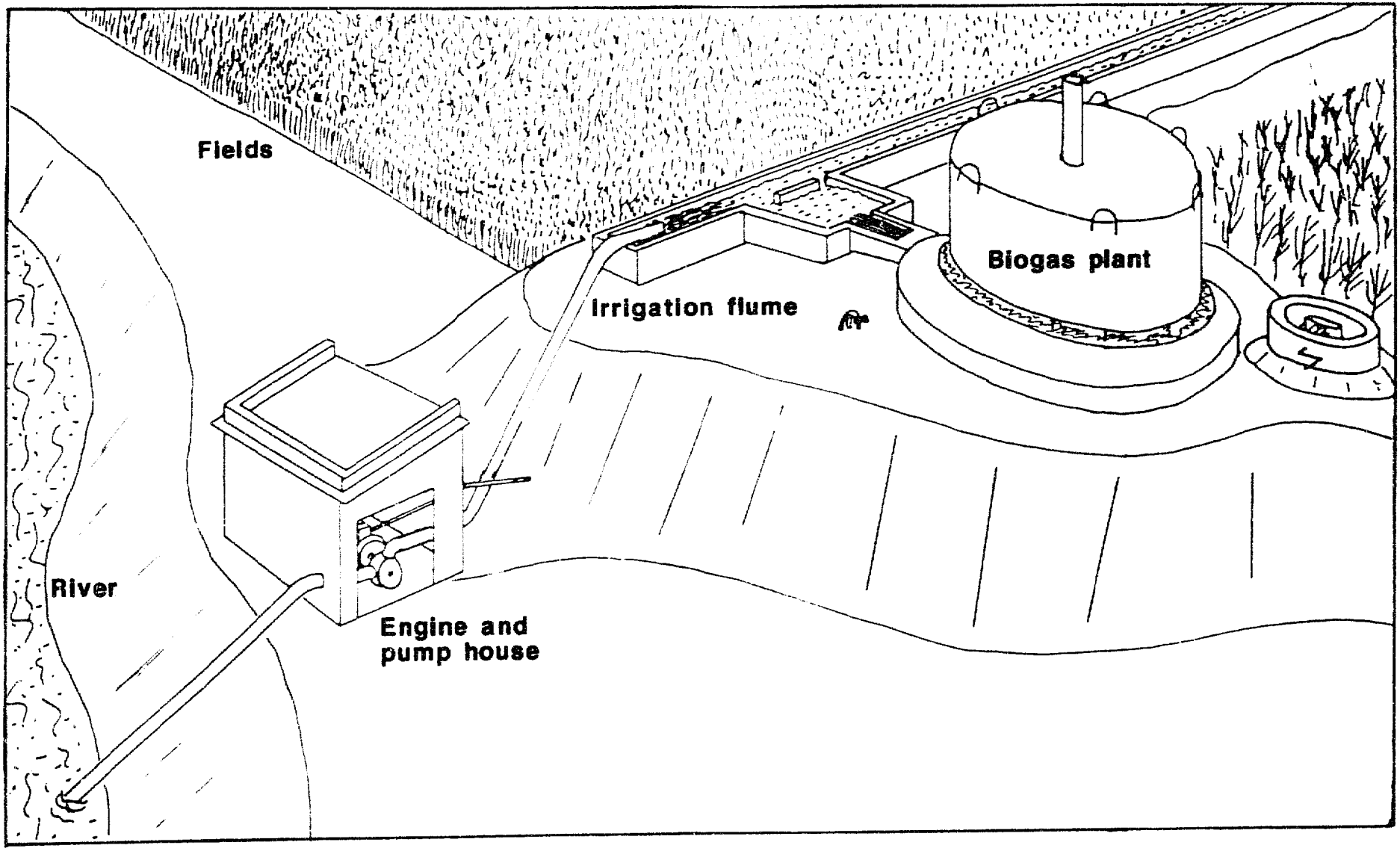

Figure 7.3 *Biogas irrigation scheme*

milling machinery and well-trained technicians must be available in the biogas programme to follow up systems that have been installed.

A second use for engines is to drive irrigation pumps. Kirloskar sells a series of dual-fuel pump-sets, using centrifugal pumps matched to the engines that drive them. One such system has been running for over six years near Birgunj in Nepal (Fig. 7.3). An SD500 plant, fed from the dung of thirty buffalo, fuels a 4kW engine that pumps 700m^3 of water from a stream 3.3m below, when used seven hours a day. The effluent from the biogas plant is fed into the irrigation flume and is washed to the fields by the irrigation water. The owner claims it is much cheaper and more reliable to use than an electric pump that is also available, as the local electricity supply is poor.

In this case, the cattle sheds, biogas plant, pump, stream and irrigation flumes have been arranged to be close together. In other places, one or more components of a biogas-fuelled irrigation system may be some distance from the rest. Feedstocks may need to be carried some distance to feed the plant; gas may need to be piped along a long pipe; a new canal or irrigation flume may need to be built. In many situations wells or bore holes may need to be made to exploit underground water tables. Advice must be sought from irrigation specialists on the most effective ways to obtain and use water. Close cooperation between biogas and irrigation extension programmes should prove fruitful.

Biogas engines have also been used to generate electricity. Many production teams in China have set up their own small (3kW to 15kW) biogas-fuelled generators to provide power for lights, radios, cassette players and even televisions.[7] It is much more efficient to use electricity for lighting than gas. 700 litres of biogas can generate 1kW.h of electricity to run sixteen 60Watt light bulbs; the same gas can only run five biogas lights for an hour.

Electricity generation must be regarded as a luxury, though, as it is uneconomic unless the power can be sold to hotels or government offices which are willing to pay for it. Apart from lighting and supplying power for electronic equipment, biogas can be used much more efficiently to give direct heat or mechanical power via a suitable engine, than if it were used to generate electricity to do the same job.

7.4 Biogas used in cottage industries

Biogas can also be used in cottage industries that require heat. Several such industries have been considered, such as making soap from vegetable oils and caustic soda, extracting medicinal oils such as menthol, making jam and other preserves and roasting coffee beans, but few have been set up. In Nepal a cheese plant was built by the Swiss Association for Technical Assistance (SATA), that was to be powered by a mixture of solar energy and biogas.[8]

The Pauwa cheese plant was at an altitude of 1800 metres in the Himalayas. Solar heaters preheated the water which was then made into steam in a biogas boiler. The biogas plants, also heated with solar energy, were fed with dung from pigs that were fed on the whey from the cheese plant. Local farmers supplied the milk and also owned the pigs. This approach proved very expensive. Ill-health among the pigs has been a recurring problem and the antibiotics used to cure them has resulted in poor biogas production.

Ideally, the cattle that provide the milk to process into cheese would also provide enough dung to give biogas to process the milk. However, the Dairy Development Corporation in Nepal tend to build centralised cheese plants that can process 1000*l* of milk a day. If such a plant were run on biogas the dung from 150 cattle would be required. While farmers are willing to carry milk to the cheese plant each day (often an hour's walk) they would not carry dung that far.

If biogas is to be used in this type of village industry a different approach must be used. Several very small processing units (such as cheese plants processing 100 or 200*l* of milk together with a biogas plant) should be sold or rented to farmers, who do the processing themselves. A central office would supervise the farmers and offer quality control, marketing and maintenance facilities. This approach, of using a service centre to help village-based industries and workshops, has proved successful in other contexts.[9]

The potential of biogas in a range of cottage industrial activities is immense. To realise this potential biogas programmes need to be linked to other rural development programmes in order to share expertise. The experience and skills to develop biogas-based rural industries already exist in organisations such as KVIC in India, ADB/N in Nepal and in many communes in China, as they are involved in a range of other rural development programmes alongside their work with biogas. All that is needed is a willingness on the part of specialists in the different programmes to discuss ideas together and to discover how biogas can be used as a rural energy resource within these other programmes.

7.5 Industrial uses of biogas

One of the earliest uses of anaerobic digestion was in the reduction of the pollution load of municipal wastes such as sewage. The scale of municipal plants is usually much larger than most rural digesters and the technology is well established. The Indian biogas programme was inspired by the building of such a plant in Bombay in the 1930s. Most builders of municipal waste digesters rely on specialists in the subject, but scientists from biogas extension programmes may be asked for advice. DCS was asked to build a nightsoil digester to cope with waste from latrines in a local jail in Nepal. The biogas programme in China, especially, has been involved in building small urban digesters.

Many industries, too, are concerned to reduce the pollutants produced by the waste products of their processes. Agro-industrial and other food-processing concerns are potential users of anaerobic digesters. The Maya farm complex in the Philippines[1] is run as an agro-industry using biogas as the main source of fuel for all its processes. A brewery in the Sichuan province of China digests all its waste products and uses the biogas produced to generate 340kW of electricity and to supply heating fuel.[7]. It also runs a small fleet of lorries on biogas, although the costs of the compressor and the storage cylinders required proved fairly high. If gas is to be stored under pressure the hydrogen sulphide and carbon dioxide needs to be removed by scrubbing, which also adds to the cost. Normally, biogas is used in engines without being scrubbed.

If some of the staff of a biogas extension programme are to become involved in municipal or industrial waste digesters, then they will need to study designs for medium- and high-rate digesters. Several new technologies have been developed for these types of waste, which are often more dilute than rural biogas feedstocks (less than 4 per cent total solids). Details of these technologies, for example the anaerobic filter and sludge blanket digesters, are available.[10] The application of these technologies to the needs of different industries offers many challenges to researchers in the biogas field.

CHAPTER 8
Operating a Biogas System

Once individual farmers or groups of farmers have had a biogas plant built, they need to be taught how to use both the plant and the equipment that was purchased with it. The technicians from the biogas programme need to visit new owners to train them in the use of their technology. Further follow-up visits in the first year of operation give the owner confidence in his equipment and allow the technicians an opportunity to put right any fault.[1]

8.1 Starting a digester

Most new owners will need advice on and help with starting their continuous digester, once it is complete. The digester pit (of a drum, dome or bag design) should be filled with digestible feedstock within as short a time as possible (usually within a week). Feedstuff can be collected before and while the digester is being built, but it must not be allowed to dry out. If cattle dung is used as the main feed the digestion process should start by itself within a few weeks (depending on temperature). If other feedstocks are used, such as pig or other animal dung, or vegetable matter, a starter is required. Between 5 per cent and 30 per cent by volume of effluent slurry from a working biogas plant should be mixed with the new feed. The more the starter, the faster the digestion process will start.[2] A starter can also be used to speed up the initial operation of cattle-dung digesters, especially if the temperature is low.

The feedstuffs should be mixed with water to give a total solids content of between 8 per cent and 12 per cent. The TS can be measured (see Appendix III) or it can be estimated from the slurry consistency. It should be as thick as possible, like a thick lentil soup, while allowing it to flow down the inlet pipe. Vegetable matter should be chopped as small as possible and any fibrous material, such as stalks, should be removed. Sawdust, rice husk, moss and pond weed tend to float on the surface of the slurry and cause scum, so they should be avoided.

The new feed can be put in a drum plant before the drum is placed on top. If this type of plant has a central wall, both sides of the wall must be filled equally, otherwise the wall might collapse. The gas outlet valves on dome and bag plants should be left open to allow air and initial gases to escape. They should not be overfilled; the reservoir pit of a dome plant should only just have its floor covered.

Once a plant is full of slurry it should be left until gas formation starts. The gas valves can be closed and the gas storage volume allowed to fill up. A floating drum will rise up out of the slurry until gas escapes under its sides. A full dome plant or bag is indicated by bubbles coming from the slurry outlet. The first two or three plant-fulls of gas must be allowed to escape into the air. While it is probably mainly composed of carbon dioxide, which will not burn, it also contains the air that was present in the plant while it was being filled. If enough methane were present it could form an explosive mixture with this air. For the same reason, all pipework must be flushed with gas before any light is applied to gas appliances. The gas can be detected by its 'bad eggs' smell.

The main tasks required to keep the digester running, after it has successfully started, are to feed it with the correct amount of mixed slurry each day (see Table 8.1) and to remove the water from the gas-line traps each week. It is important to be consistent in feeding a biogas plant. Sudden changes in feeding practice can unsettle the bacteria and cause reductions in gas production. If a change in the amount of daily feed or in the slurry consistency is to be made it should be done slowly, a bit at a time. It does seem possible, however, to reduce the feed to a plant, when less gas is required, and to add the stored feedstock when more gas is needed, as long as the changes are made slowly.

Table 8.1 Recommended feed for different biogas plants.

Plant type	*Work. vol. m^3*	*Retn. time day*	*1:1 Mix*			*1:½ Mix*		
			Dung kg	*Water lit*	*Gas m^3*	*Dung kg*	*Water lit*	*Gas m^3*
SD100	7.1	59	60	60	1.7	80	40	2.3
SD200	13.0	54	120	120	3.4	160	80	4.5
SD350	24.3	58	210	210	6.0	280	140	8.0
SD500	34.0	57	300	300	8.5	400	200	11.4
CP10	9.0	75	60	60	1.9	80	40	2.5
CP15	12.5	71	120	120	2.7	120	60	3.6
CP20	16.9	73	120	120	3.7	160	80	4.9
EP50	42.5	71	300	300	9.4	400	200	12.6
EP80	74.1	74	500	500	15.5	670	330	20.7
EP95	81.1	68	600	600	18.5	800	400	24.7

Notes: The daily gas production is calculated from a theory based on data from Nepalese trials (Appendix IV)[3]

In some cases, especially in plug-flow digesters, it is helpful to add effluent slurry (10 per cent to 30 per cent) to the daily feed, in place of the equivalent volume of water. This replaces some of the bacteria removed from the plant with the effluent.

8.2 Control of temperature

Since both the rate of gas production and the gas production efficiency are reduced at lower temperatures (less than 30°C), attention should be given to methods of insulating and heating biogas plants where the ambient temperature is low. While rural biogas plants in the tropics and sub-tropical areas of the world are seldom heated, records suggest that soil temperatures can drop during winter months (to 20°C in the plains of Nepal). In colder climates soil temperatures can go below freezing point, so the heating of biogas plants is essential in these places.

Dome and bag plants can be insulated and heated by covering them with a layer of composting straw and other vegetable matter. The compost heap needs to be more than 1m thick and raw cow dung and biogas plant effluent can be added. Facultative bacteria can produce heat by hydrolising food materials in the presence of oxygen. The compost must be kept slightly damp, but not too wet, to produce the right rate of heating. In rainy weather it should be covered with a plastic sheet.

Steel drum plants are more difficult to insulate. A woven straw mat may be made to cover the drum, although it would be wetted by the slurry. The whole plant can be enclosed in a plastic tent, like a greenhouse[4], but this is expensive and unlikely to last long.

The slurry temperature can be reduced if cold water is used to mix the input. The mixing water can be left in the sun for a few hours, in a black-painted drum, or else the slurry can be solar heated after it is mixed. If the slurry is held in a shallow mixing pit (about 70mm deep), which is covered by a plastic sheet during the hottest part of the day, its temperature can rise by as much as 9°C (4.5°C on a cloudy day).

The cooling water from an engine can also be used to heat a biogas plant (Fig. 8.1). A heat exchanger for an SD500 biogas plant was made from 10 metres of 35mm OD pipe. Water at 70°C was pumped round it at 1.2*l*/min. The heat exchanger was placed in the bottom of the digester pit, so that convective flow in the slurry would circulate the heat. Extra heat can be obtained from the engine by making another heat exchanger to absorb heat from the exhaust gases. Tests indicated that the heat available from such a system was adequate to heat the biogas plant: in warmer weather, it was excessive and a system for cooling the water had to be devised (see Chapter 7).

If the biogas is used for purposes other than fuelling engines, a separate heating unit and pump and required if the plant is to be run in cold weather. Where electricity is available, a domestic-type water heater and

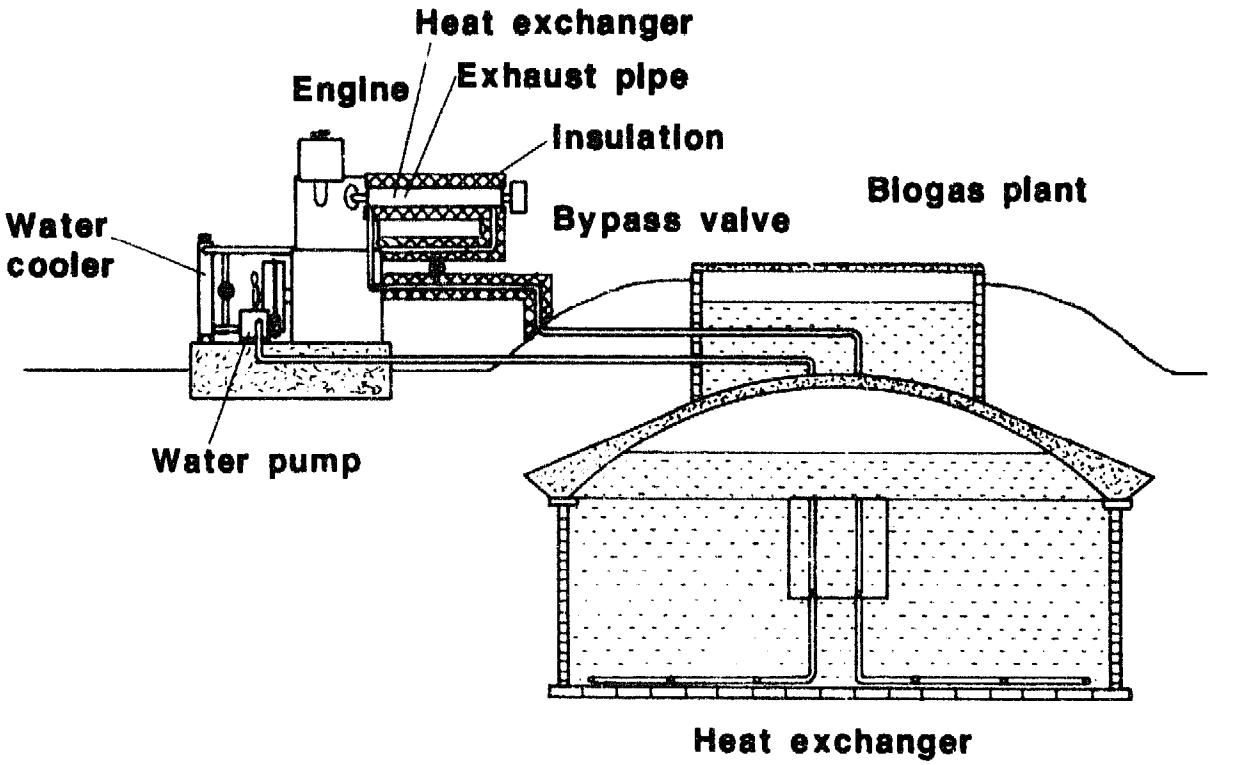

Figure 8.1 *Heating plant with engine water*

pump can be used, suitably adapted for biogas (by changing the size of the main jet and air ports). Domestic sensors and control valves can be used to regulate the water and slurry temperatures. If the plant is well insulated, about one-third of the gas production may be required to keep the slurry temperature between 30°C and 35°C at ambient temperatures below freezing.

A self-actuating steam displacement pump was developed at Leicester Polytechnic in Britain.[5] This can be used both to heat and pump water using a fuel gas such as biogas. As a pump it is not efficient, but the waste heat goes to heat the water, so the overall efficiency of the pump/heater is good. A secondary boiler, controlled by simple pressure-actuated control valves, can be used to ensure water and slurry temperatures are regulated.

If a biogas plant is being heated by any of these methods, more effective insulation than a compost or straw covering may be required. Blocks of polystyrene foam are fairly rigid and can be incorporated into the walls and roof of dome, extended dome and tent digesters. The tent plant tested at Cornell University was insulated in this way and produced plenty of gas even when covered with snow.[6]

8.3 Stirring biogas digesters

Stirring digester slurry has two functions: the breaking up of surface scum and the agitation of the bulk of the liquid to assist bacteria to reach

foodstuffs. Designers of high-rate digesters put a lot of emphasis on stirring, as methanogenic bacteria move very slowly. The value of bulk stirring for low-rate rural digesters is questionable, especially as they are expensive to make and give extra maintenance problems. Bag and tent digesters should not be stirred at all, as they are plug-flow digesters.

Gas drums of floating drum digesters usually have scum-breaker bars fitted inside them. The drum should be rotated for about five minutes each day to break up any scum that might be forming. This rotation will also cause a mild agitation of the bulk slurry. Displacement digesters are effectively self-stirring, since the slurry moves in and out of the slurry reservoir as gas is produced and used. Any scum on the slurry surface will be broken up as it moves within the domed roof. DCS did put stirrers into the first dome digesters made in Nepal, but owners saw little value in using them. They often broke and they caused a few gas leaks.

8.4 Solving digester problems

Biogas plants should have few problems if they are well made and run correctly. Most problems are caused by faults in construction, which should be discovered during the final inspection before a plant is filled or during the initial follow-up visit by programme technicians. Construction faults, such as cracks in digester walls, are the responsibility of the organisation building the plant and must be put right at its expense.

The most common fault in biogas digesters is gas leaks, either from the gas pipeline, especially around valves, or from the gas storage volume. All the joints in a gas pipeline should be checked before it is finally buried. Gas should be put in the line, usually from the plant once it starts working. Soap solution is then brushed around the joints and gas leaks show up as bubbles. Plastic pipe can be cracked where it goes round sharp corners and it can be cut or broken by ploughs and hoes or by animals and machines passing over it, so it must be carefully checked and protected where these things are likely to happen (see Appendix II).

Steel gas drums can leak gas through porous or cracked welds or through holes caused by corrosion. Small holes can be sealed with epoxy glue, but larger holes may need to be rewelded. Large areas of corrosion mean that the whole drum must be replaced. If the fault is due to bad workmanship, then the construction organisation must put it right at its expense. Some faults can arise from the owner's neglect: welds can crack if the drum is dropped and corrosion will occur if the paint is scratched. New owners need to be warned of the dangers of mishandling their drums.

Dome plants can leak gas through the dome, if it has not been properly plastered and sealed. Cracks or rough patches of plaster may be visible during the final inspection, but plaster leaks are not always easy to see. If a dome plant appears to produce little gas, despite careful checks that the

pipeline is leak-tight and the slurry is producing gas, then the plant will have to be emptied and the plastering redone. The use of acrylic plastic emulsion mixed with the final plaster layer improves its sealing properties.

Bag and tent digesters can leak gas through cracks or tears in the plastic. Small holes in PVC and RMP can be repaired by gluing patches over them with PVC solution, preferably on the inside of the digester. Larger tears may need to have a patch welded over them, using a high-frequency electronic welding machine. While the removal of the plastic cover from a tent digester is not a major job, a bag digester would need to be completely emptied and cleaned out before it could be welded.

A less serious problem is the leakage of slurry through the walls and floor of the digester pit, which can occur if the lining is porous to water. Poor quality bricks or cracks in cement mortar linings can cause leaks, especially in the reservoir pits of dome plants. Small leaks are often self-sealing, as the slurry dries within them. If leakage continues the plant must be emptied and the inside replastered with a good cement mortar.

Another cause of a sudden loss of gas supply is a blockage in the gas pipeline. As biogas flows through relatively cool pipes underground, water condenses out and can stop the flow if arrangements for its removal have not been made. All gas pipelines should slope (1:100) towards one or more water traps, from where condensate can periodically be removed.

Blockages can also occur in the gas outlets from dome, bag or tent digesters, if slurry, scum or froth enters this pipe. Dome plants can be overfilled if gas production is low or gas usage is high, so the dome never gets more than half full of gas. A screw top is often provided in the gas outlet, which can be removed to allow a rod to be pushed in to clear blockages. Care must be taken when cleaning the gas outlet of a dome plant as slurry can be ejected from the pipe under the relatively high gas pressure.

8.5 Microbiological problems

If the biogas plant is free from leaks and blockages a loss of gas production may be due to a failure of the bacteria in the digester. If the causes of these faults are to be fully tested the facilities of a small laboratory are required. Measurements of the parameters of slurries will need to be made and samples of slurry tested in small-scale temperature-controlled reactors to see if they are producing the expected amount of biogas (see Appendix III).

If a new digester fails to start at all, then the correct bacterial population may not be present. If the slurry temperature is reasonable (between 20°C and 35°C), the first response is to leave the plant, without feeding it, for another week or two. If gas is still not being produced, then a starter can be added: 10 per cent to 30 per cent of slurry from a working digester. If the

contents of the plant have become acidic (if the pH is below 6.5), then chalk or lime can be added as well. Tests should be done by titrating a small sample of slurry against the chalk or lime to determine the correct amount to add.

If the plant is still not producing gas a month later, then the slurry has probably been poisoned by a toxic substance. Samples of the slurry, the original feedstock and the source of mixing water should be tested in the laboratory. Attempts can be made to digest these samples in small bench reactors, while the samples can also be analysed to try to identify the poisons. The plant will probably have to be emptied and cleaned out thoroughly before being refilled with fresh feedstock, starter and water, all from sources that have been checked for freedom from contamination.

Problems with plant start-up are more likely to be encountered if unconventional feedstocks are used, such as different vegetable materials or food-process waste. Laboratory tests of the digestibility of these feedstocks should be made before they are used in full-scale plants. Some of these feedstocks may be more easily digested if a plant is started on animal dung and the new feedstock introduced with the dung in gradually increasing concentrations.

If a plant that has been working well suddenly fails the most likely reason is poisoning by toxic substances.[7] Sudden changes in temperature, feed rate or feed composition may cause a temporary reduction in gas production, but the plant should recover within a week or two, especially if the change is slowly corrected. A reduction in feed rate will help the bacterial population to stablise. A plant that is poisoned will fail and not recover. The pH will probably drop and the slurry will accumulate noxious-smelling fatty acids.

The source of the poison should be identified before the plant is restarted. Possible sources are: animals being given antibiotics, chemical sprays used on crops or in animal houses against insect pests or fungal infections, disinfectants being washed into the digester or pollutants in the water used to mix the slurry. Chlorinated hydrocarbons, found in many solvents, are particularly toxic to methanogens and could cause contamination by being spilled into rivers or irrigation canals. Heavy metal salts, such as copper, zinc, lead or nickel are toxic in high concentrations, such as may be found in wastes from some industrial processes like galvanising.

Attempts can be made to restart the plant, by adding chalk or lime to correct the pH and by adding a starter to provide the correct bacteria. However, if the poisons are still present in the plant it may not restart and the whole plant will have to be emptied, cleaned out and filled with slurry that is free from contamination.

This type of problem is not usual; it occurs less than once a year among the 2,000 plants that are being followed-up regularly in Nepal. It is more likely where the use of chemicals such as pesticides and fungicides is more

common, as in Europe and USA. The poisoning of a biogas plant is also more likely if a latrine is attached. People who are taking medicines may use the latrine, or even throw excess medicine into it. People may also use disinfectants to clean a latrine or throw water containing detergents or solvents into it. Plant owners should be warned of these dangers.

8.6 Servicing of biogas plants

Apart from the removal of dried effluent slurry from places where it tends to build up, there is little regular servicing necessary on most biogas plants. Gas valves should be oiled monthly to keep them from getting stiff.

Steel drums should be painted each year to prevent rust. The gas supply should be turned off for 24 hours, so the drum fills up and rises in the slurry. It should be carefully washed of dried slurry before a new coat of paint is applied. The same paint should be used as was applied during manufacture (usually a bituminous paint, such as high-build black). The paint needs to be dry before the supply valve is opened and the drum allowed to sink again.

Surface scum may build up in a digester, especially if the feeds contain straw or other vegetable matter. Animal hair and grease from dung can accumulate over several years. Mud and sand can also be introduced into the plant with the feed. They accumulate below the inlet pipe and reduce the digester volume. The interval between cleanings depends very much on the type of feed. Many Chinese plant owners use a lot of vegetable matter in their feed and clean their plants every six months to a year. Most Indian and Nepali owners do not clean out their plants for five years or longer.

Dome and bag plants will need to be emptied completely to remove both scum and dirt accumulation. The gas holders of drum and tent plants can be removed to allow access to surface scum, but they, too, will need to be emptied completely if dirt accumulation is to be removed. Great care must be taken during cleaning operations as biogas will escape. No naked flames or lighted cigarettes must be nearby, as there will be a risk of explosion.

When a biogas plant is emptied all the slurry should be removed from the digester pit before anyone attempts to enter, as it will continue to produce biogas. Removal can be done with a bucket on a rope, or a slurry pump can be used. The slurry can be stored in a pit in the ground or carried directly for use on the fields as fertiliser. Up to 30 per cent may be used as a starter to get the plant working again with a new feed, if the old slurry has not been poisoned.

Biogas is not poisonous, but it does not contain oxygen, so it can suffocate anyone trying to breath it. Biogas is heavier than air so it can remain in the digester pit even after the slurry has been removed. As biogas cannot be seen it is difficult to tell when it is safe to enter the pit. An animal (a rabbit or a chicken) can be lowered into the empty pit in a basket

to see if it has difficulty in breathing. The gas can be removed by using a fan or a winnowing machine or even bailed out with a bucket. If a person goes into a digester pit a friend must always be available outside, in case of trouble. A rope can be tied around the person entering the pit, so they can quickly be pulled out if they have difficulties in breathing.

In China, some of the new biogas building teams offer a digester cleaning service.[8] They have slurry pumps and air blowers driven by small two-wheeled tractors, so the slurry and remaining biogas can be removed quickly and easily. Many farmers are prepared to pay a fee to save themselves a tedious and messy job.

8.7 Safety of biogas

Biogas will only burn if mixed with air in the right proportions (between 10:1 and 5:1, biogas: air or 9 per cent to 17 per cent biogas in air). It is safer than most other fuel gases, which have wider flammability limits. Since the pressure of the gas in the pipeline is higher than atmospheric, there is little chance of air entering the line or the gas store to form an explosive mixture. The only times that this is possible is when a biogas plant is being started or after cleaning or repair work. Extra care must be taken at these times to ensure no flames are near while the pipes are flushed with gas. Flame traps in gas lines are considered unnecessary, although they are recommended by some extension groups.

Gas leaks during operation can be detected by the smell. Owners should be taught how to recognise leaks and to take the appropriate action. If a leak occurs within a confined space, such as a building, the risk of explosion is greater. Gas taps should be closed, all fires and flames extinguished and all doors and windows opened. The leak should be found using soap solution, and repaired.

CHAPTER 9
Economics of Biogas Systems

The primary reason that biogas technology is not more widely accepted in Nepal and India is economic.[1,2] A biogas plant demands a relatively high capital investment from a small farmer and he has to be convinced that it is worth it. The economics of various different alternatives available to the farmer need to be analysed, so that the best one can be chosen.[3] Under certain conditions, a farmer might expect a higher return on his investment if he uses a different system than one using biogas, such as using a diesel mill run on diesel alone, rather than going to the extra expense of a biogas plant. Economics are not the only factors to consider when making such decisions, but they are major ones.

There are many ways to approach economic analysis, depending on the point of view from which a plant is considered and the complexities that need to be introduced. The simplest approach is to look at the cash-flow position of the owner. If a farmer, or group of farmers, has taken out a loan to buy the system, he needs to save or earn enough each year to cover the repayments and interest over each year of the loan. While this is an important calculation to do for each individual project, it is not general enough to allow a comparison of the value of a biogas project with other possibilities. A more formal approach is to use 'cost-benefit analysis'.[4] This assumes a potential owner has capital to spend (either his own or borrowed) and that he can invest that money in a biogas system or in other ways, such as putting the money in a bank to earn a commercial rate of interest.

All the costs of a project must be defined; these will include the capital costs of purchasing a plant as well as the recurring costs of running and maintaining it. The costs of a project over its lifetime are calculated by defining a cost for each year and multiplying these by discount factors, obtained using a standard formula or tables (Appendix V). The 'present worth of the costs' (PWC) is the sum of these discounted values. Discounting is an attempt to allow for inflation and other decreases in the value of project work with time. The financial benefits, from savings and/or income, also need to be defined and discounted in the same way. The 'present worth of benefit' (PWB) is the sum of the discounted figures over the project lifetime.

Three indicators are used to measure the economic results of a project. The 'benefit: cost ratio' (B:C) is the present worth of benefit divided by the present worth of costs, while the 'net present worth' (NPW) is the difference

of these two values. The 'internal rate of return' (IRR) is the discount rate that must be applied to the benefits to give a PWB figure close to the PWC. It is an attempt to measure the earning power of the investment the owner made in the project. The calculation of IRR is usually done by trial and error, looking up different discount factors in the tables to multiply with the benefit figures. In order to use cost-benefit analysis, suitable values for a base discount rate and a project lifetime need to be chosen. In Nepal a discount rate of 15 per cent, spread over ten years, seemed to be reasonable.[5]

A more complex approach attempts to define the costs and benefits of a project to the society around the people who purchase biogas plants. These 'secondary' or 'social' costs and benefits must be given financial value. For example, the time employed by a family without a biogas system and by the same family with a biogas system can be estimated and costed. The value (at a suitable wage rate) of this saving on time, or the extra time required, can be included as a benefit or a cost.

Many secondary costs and benefits are very difficult to quantify.[6] For example, the use of a biogas-fuelled rice-hulling mill will save the women of a village from a very laborious job (taking perhaps an hour a day). The mechanical huller, though, may polish the rice, removing nutritious bran (with protein and vitamins), so introducing a secondary cost along with the secondary benefit of the women's time. Other secondary benefits, such as employment creation, building of community awareness, an increase in people's dignity, are very important, but very difficult to measure or to define in monetary terms.

9.1 Domestic biogas plants

There have been many economic analyses of domestic biogas plants, especially in India.[2,3,7] They all suffer from similar problems,[8] but all reach a similar conclusion: that domestic biogas is only marginally economic, especially for the owner. As in most economic analyses of rural activities, many assumptions have to be made to obtain useful figures. The accuracy of these assumptions is very difficult to test and some of the parameters, such as the cost of alternative fuels, are very variable, both with place and time of year.

If biogas is used for cooking and lighting in a rural area it replaces fuels such as firewood, crop residues and kerosene. The capital costs of building a family-sized digester can easily be defined, especially if figures are available from an on-going extension programme (see Example 9.1). The running costs are less easy to define: they include the labour required to collect and mix the dung each day and the cost of maintenance. Regular maintenance costs depend on the design of plant used: a steel drum plant needs a yearly coat of paint on the drum, while dome and bag plants have a lower yearly expense.

The benefits from biogas are much more difficult to define. Biogas as a fuel cannot be sold on the open market, so its value must be defined in terms of other fuels. If biogas is valued according to its replacement of commercial fuels, such as kerosene or coal, then its financial benefit is relatively high and the economics look very good.[8] However, it is usually used to replace firewood or crop residues, which have a much lower market value per kilojoule of energy produced (Appendix V).

Firewood is usually given a value related to its price on the open market (see Example 9.1). This price is very variable, as it is determined by the local pressures of supply and demand. On the plains of Nepal in the dry season, for example, the price is fairly low. There are forests within half a day's walking distance from most settlements, firewood is easy to collect (despite being illegal) and there is little other work for people to do. In the hills of Nepal, during the monsoon, the price is much higher. Deforestation has removed much of the tree cover from many hills, wood is much more difficult to collect in the rain and mud and most people are busy harvesting their maize and rice crops.

Many people who might purchase a biogas plant do not pay for fuel. They collect their firewood or crop residues themselves. The value of the fuels replaced might be calculated in terms of the labour and time required to collect them. Since most of the work of collection is done by the women and children it is difficult to place a value on their time. Some husbands may even regard the time their wives and children might save as a cost: 'You don't know what they could get up to.'[1]

The value of the fertiliser 'produced' by a biogas plant is even more difficult to define. Some analysts assume the dung would otherwise be burnt, so put a price on the total fertiliser value of the slurry.[10] Others try to assess the improvement of the fertiliser value of the slurry digested in a biogas plant and stored in pits with that of raw cattle dung stored in heaps until it is needed for the fields.[9] These assumptions depend very much on the practice of the local farmer. Some people, (especially in China) are used to composting wastes and can produce concentrations of available nitrogen close to those from anaerobic digestion.[1] Figures for the extra nitrogen available from digested slurry as compared with traditional composting techniques in China, range from 11 per cent to 100 per cent.[11] Other analysts ignore the improvement value in fertiliser completely,[5] as many farmers do not take this into account.

9.2 Milling systems

Mechanical milling of grain is becoming very popular in rural areas in most countries. The removal of the hull from grains of rice and the grinding of wheat and maize into flour using hand tools is very hard work and time consuming, so people are prepared to pay for it to be done by machine.

A CP15 biogas plant built in Butwal, Nepal in 1986 by Energy and Agro Developers (P) Ltd cost (£1 = Rs.24 Nepal Currency) as given by N.P. Pradhan, manager:

	Rs.(NC)	£
Materials (Cement, sand, bricks, gravel)	6 000	250
Fittings (Gas pipe, 2 stoves, 2 lights, mixer)	4 720	197
Labour (Skilled and unskilled)	4 050	169
Guarantee Fee	1 730	72
	16 500	688
The yearly costs for running the plant are:		
Labour (1 hour a day at Rs.10 per day)	456	19
Maintenance (assumed)	100	5
	556	23
The yearly benefits are:		
Saving in fuel wood (2578kg @ Rs 1)	2 578	107
Saving in kerosene (146/ @ Rs.6)	876	37
Saving in urea fertiliser (84kg @ Rs.4)	336	14
(see Appendix V)	3 790	158

Loan Repayment	Rs. (N/C)	£
Assuming 7 years' repayment and 11 per cent interest,		
Yearly cost of loan:	3 517	146
Savings each year:	3 234	135

which does not quite cover the loan repayments.

Cost: Benefit Analysis	Rs.(NC)	£
Capital cost of CP15 plant	16 500	688
Discounted running costs (15 per cent, 10 yrs)	2 790	116
Present Worth Costs (PWC)	19 290	804
Present Worth Benefits (PWB, 15 per cent, 10 yrs)	19 021	793
Nett Present Worth (PWB – PWC)	– 269	– 11
Benefit: Cost Ratio (PWB/PWC)	0.99	
Internal Rate of Return	15%	

The economics of this biogas plant appear to be marginal.

Notes

1. 15 per cent discount rate compares with the rate of inflation in Nepal.
2. 10 years' lifetime for a dome plant is short; it should last for 20 years.
   (giving: NPW = Rs.3 743, £156, B:C = 1.19, IRR = 18%)
   The lifetime of a drum plant is less: only 5 years for the gas

holder and central guide pipes.[2] The addition of Rs.2 500 after 5 years to the costs to allow for this make the economics look much worse.

3. The results are very sensitive to the cost of firewood:[2,5]

Firewood cost Rs/kg	*NPW Rs.(NC)*	*£*	*B:C*	*IRR %*
1.2	2 319	97	1.12	18
1.0	– 269	– 11	0.99	15
0.8	–2 857	– 119	0.85	11

Table 9.1 *Effect of firewood price on biogas economics.*

Example 9.1 ***Economic analysis of a domestic biogas plant.***

Mechanical milling is essential if grain excess to domestic requirements is sold. Most mills are driven by diesel engines, although water power is also becoming popular in hilly areas, especially in Nepal and parts of China. A small milling system can be run on biogas, which replaces up to 80 per cent of the diesel fuel required. There are many advantages in using less diesel fuel, if a mill owner or group of farmers can find enough dung to feed a biogas plant (see Chapter 7). There is also a financial benefit, which can be analysed.

The costs and benefits from using a biogas plant for fuelling a grain mill are much easier to define than those for a domestic biogas plant. Milling is done as a service to the neighbourhood and charges are made for the work done. A biogas-fuelled milling system therefore earns a cash income for the owner. The analysis (Example 9.2) is based on data from two 5kW biogas-fuelled mills in Nepal,[5] one at Tikuligarh (see Chapter 10). These surveys were made in 1983, but the figures have been adjusted to 1986 prices (assuming 15 per cent inflation per year). The mills are owned either by a single owner or a small group of farmers who share both the work and the benefits. The income may have been understated, as mill owners are cautious of giving accurate answers, in case they may be taxed on their profits. The milling work is seasonal, but the gas produced during the times when the mill is not employed can be used for domestic purposes.

The mill is assumed to have a 5kW engine to drive two machines, a rice huller and a flour mill. The engine can only drive one machine at a time. The economics of this system look fairly good and they can also be compared with a similar mill using only diesel as fuel (Appendix V). The capital costs are much reduced for a diesel mill, only Rs.26,000 as compared with Rs.76,760 for a biogas mill, but the returns on the investment are less.

The financial returns are very sensitive to the amount of grain brought

for milling, so a market survey needs to be done before such a project is set up. If there are other mills in the locality and competition brings the price for milling down, then a biogas mill may have a low return. However, if local people must take their grain some distance to get it milled they will be prepared to pay extra for the time and effort saved.

Both biogas and diesel systems look better if the volume of grain processed is increased. The mills considered in the survey were in areas where there was competition from both diesel and electric mills. Also, these mills do not use heat exchangers, so the gas production in winter is reduced, although this is the time when demand is highest. In more remote areas, without an electricity supply, and using a well-designed system (with a heat exchanger), the amount of grain processed could be higher and the financial return improved.

The conclusions of this analysis are supported by the attitude of villagers using biogas milling systems. The first one set up in Nepal (Tikuligarh) has run for seven years and the owners are still very keen on showing it off to visitors. Over forty more similar systems have been installed in Nepal (both family and group-owned),[12] despite the high capital cost, and interest seems to be growing in the idea. Greater profits can be earned from an oil-expeller, but the engine must be larger (10kW to 15kW), the mill must be sited in an area where oil-seed crops are grown and there must be a market for the oil.

9.3 Irrigation systems

In a monsoon climate, such as that of many parts of India and Nepal, crop production can be greatly increased using irrigation. During the dry season water is often available underground or in streams and rivers fed by snow melt and by springs of water from mountain aquifers. If this water can be pumped up on to villagers' fields a whole extra crop a year, such as wheat, can be grown. Also a pumped water supply allows crops grown during the monsoon season (especially early paddy and maize) to be irrigated at optimum times, especially if the rain fails to arrive as expected. Crops grown by irrigation allow food to be produced during the time of year when it is normally scarce, so it has a high market value.

A water pump can be driven by a dual-fuel engine, supplied with gas from a biogas plant, in the same way as the engines used in grain mills (see Chapter 7). The costs are similar to those for a grain mill, although the fuel use is even more seasonal, depending on when water is required for the different crops (Appendix V). The analysis (Example 9.3) is based on a survey done to study the feasibility of a community biogas irrigation system for Madhubasa village (see Chapter 10). The village is on the edge of the Terai (plains) of Nepal, near Janakpur, and underground water is available for pumping all the year round. The figures for the analysis have been adjusted to 1986 prices (assuming 15 per cent inflation per year).

An SD500 biogas plant with a 5kW engine, a rice huller and a flour mill, supplied in Butwal in 1986 would cost:

	Rs.(NC)	£
SD500 plant, with accessories	48 760	2 032
5kW dual-fuel engine (from India)	18 000	750
Rice huller (from India)	4 000	167
Flour mill (from India)	4 000	167
Heat exchanger (locally made)	2 000	82
	76 760	3 198
The yearly costs for running the mill are:		
Labour to run the biogas plant	475	20
Labour to run the milling machinery	4 600	192
Maintenance for all equipment (assumed)	3 000	125
Diesel used with the biogas (20%)	2 070	86
Lubricating oil (assumed)	800	32
	10 945	456
The yearly benefits are:		
Income from milling operations (App. V)	24 000	1 000
Saving from gas used domestically (App. V)	7 500	313
Saving in fertiliser (420kg @ Rs. 4)	1 120	47
	32 620	1 359

Loan Repayment	Rs.(NC)	£
Assuming 7 years' repayment and 11 per cent interest,		
Yearly cost of loan:	16 290	679
Savings each year:	21 675	903

which makes a profit of Rs.5385 (£224) per year for the owner or, alternatively, the loan could be paid off in 5 years.

Cost: Benefit Analysis	Rs.(NC)	£
Capital cost of Project	76 760	3 198
Discounted running costs (15 per cent, 10 yrs)	54 930	2 289
Present Worth Costs (PWC)	131 690	5 487
Present Worth Benefits (PWB, 15 per cent, 10 yrs)	163 712	6 821
Nett Present Worth (PWB – PWC)	32 022	1 334
Benefit: Cost Ratio (PWB/PWC)	1.24	
Internal Rate of Return	21%	

The economics of the project look fairly good.

Notes

1. A dual-fuel engine may not last 10 years in a village depending on how it is looked after. The drum of an SD500 plant may also rust out after about 5 years, if it is not painted every year. However,

an EP50 plant should last over 20 years, offsetting the shorter lifetime of the engine.

2. The results are very sensitive to the charges made for milling.
3. The result must be compared with a diesel-only mill doing the same business (see Appendix V):
   (giving: NPW = Rs.2 908, £121; B:C = 1.02; IRR = 16%)

Mill charge Rs/5kg rice	*NPW Rs.(NC)*	*£*	*B:C*	*IRR %*
6.0	56 112	2 338	1.43	25.5
5.0	32 022	1 334	1.24	21
4.0	7 932	330	1.06	16.5

Table 9.2 *Effect of milling charges on biogas economics.*

Example 9.2 *Economic analysis of a biogas milling system.*

The benefits of a biogas irrigation system depend on the crops that are grown. It is assumed that without irrigation the villagers' main crop is paddy, watered by monsoon rain and limited gravity irrigation (surface water is available for several days after a good monsoon downpour). While maize, vegetables and tobacco are also grown in the village, these are ignored in the analysis, as they normally use land which is not affected by the irrigation scheme. It is assumed that the availability of irrigation water allows higher yields from the paddy crop (from 2 tonnes per hectare to 3 tonnes), as water can be supplied at optimum times. Irrigation also allows higher yielding varieties of paddy to be grown, which may be more sensitive to a lack of water at critical times. These better strains of rice usually need more fertiliser, so this is added at a cost.

The main benefit from the scheme is the extra crop of wheat, grown in the dry season (December to January). This is valued at the appropriate market rate, as it can either be sold or used to replace other food which otherwise would have to be purchased. The analysis of the system (Example 9.3) suggests that the economics should be very good, with an internal rate of return of 29 per cent. The loan could be paid back within two years. The results are sensitive to the price of grain in the local market (Table 9.3), so a market survey needs to be done to check the up-to-date prices. The economics look fairly good, even when the rainfall fails, as long as the ground-water supply remains. This analysis, too, needs to be compared with one for a diesel-only irrigation system.

The economic analysis of irrigation schemes seems to be one in which the assumptions are not always valid in practice. There have been very few studies of the effectiveness of pumped irrigation as used by peasant farmers, whether these pumps are driven by diesel, electricity or biogas. Most trials

of water use and crop productivity are done in carefully controlled agricultural centres, such as the Japanese-funded Janakpur Agricultural Development Project near Madhubasa, which provided the pump-set and gave very valuable help and advice. Despite the apparent economic advantages of a biogas irrigation system the villagers in Madhubasa did not appear to be earning enough money from the sale of wheat to cover the cost of the loan repayments. They were rescued from potential economic problems by the decision to ask the village to set up a tree nursery. To grow well, tree seedlings need a constant supply of small amounts of water most of the year round. The irrigation system seems more able to supply this need, but it does not seem capable of providing the large quantities of water required by grain crops at critical times.

An SD500 biogas plant with a 4.5kW dual-fuel pump-set supplied in Janakpur in 1986 would cost:

	Rs.(NC)	£
SD500 plant, with accessories	48 760	2 032
5kw dual-fuel pump-set (from Japan Project)	16 000	667
Engine shed	7 500	312
	72 260	3 011
The yearly costs for running the pump-set are:		
Labour to run the biogas plant	475	20
Labour to run the pump-set	5 000	208
Maintenance for all equipment (assumed)	3 000	125
Diesel used with the biogas (20%)	785	33
Lubricating oil (assumed)	800	33
	10 060	419
The extra costs for the extra crops are:		
Seed for new crops	2 760	115
Fertiliser for improved productivity	13 970	582
Labour for extra crops	9 230	385
	36 020	1 501
The yearly benefits are:		
Income from sale of crops (App. V)	67 700	2 822
Saving from gas used domestically (App. V)	10 265	428
Saving in fertiliser (420 kg @ Rs.4)	1 120	47
	79 085	3 296
Loan Repayment	Rs. (NC)	£
Assuming 7 years' repayment and 11% interest,		
Yearly cost of loan:	15 335	639
Savings each year:	43 065	1 794

which makes a profit of Rs.27730 (£1155) per year for the owners or, alternatively the loan could be paid off in 2 years.

Cost: Benefit Analysis	Rs.(NC)	£
Capital cost of Project	72 260	3 011
Discounted running costs (15%, 10 yrs)	180 776	7 532
Present Worth Costs (PWC)	253 036	10 543
Present Worth Benefits (PWB, 15%, 10 yrs)	296 909	16 538
Nett Present Worth (PWB – PWC)	143 873	5 995
Benefit; Cost Ratio (PWB/PWC)	1.6	
Internal Rate of Return	29%	

The economics of the project look fairly good.

Notes

1. The remarks about lifetimes of project components in Example 9.2 also apply to this analysis.
2. The results may be compared to those for a diesel-only system irrigating the same areas of crops.
   (giving: NPW = Rs.122 120, £5088, B:C = 1.6, IRR = 29%)
3. The results are sensitive to the prices of grain in the local market (see Table 9.3)
4. The economics still look fairly good even in a drought year, where the natural rainfall is reduced (Appendix V). (where: NPW = Rs.96 190, £4008, B:C = 1.4, IRR = 25%), especially if the market price increases (eg. by 50%) (giving: NPW = Rs.239 551, £9981, B:C = 2.0, IRR = 39%

Grain price Rs/t. rice	*NPW Rs.(NC)*	*£*	*B:C*	*IRR %*
2 700	211 827	8 826	1.8	35
2 250	143 873	5 996	1.6	29
1 800	75 919	3 163	1.3	23

Table 9.3 *Effect of grain price on irrigation economics.*

Example 9.3 *Economic analysis on a biogas irrigation system*

The basic problem seems to be the amount of water supplied by the pump. The analysis assumes a 50 per cent efficiency for the pump, a fairly low figure compared to the laboratory efficiencies for typical centrifugal pumps. In practice, however, farmers often seem to use their pumps at much lower efficiencies. In Madhubasa the water flow seems to be limited to 10*l*/sec, as opposed to the theoretical flow of 46*l*/s (giving an efficiency of only 11 per cent). The flow appears to be even less in the dry season (3l/s).

Surveys in India suggest that many pump-sets there are also operated inefficiently (a 4.5kW engine is often used to irrigate only 2.4ha rice from a 5-metre-deep well, less than half the area suggested by this analysis).[13] Some farmers even find the use of diesel or electric pumps for irrigation results in an overall loss of income. In Nepal, despite the wide publicity for the Madhubasa community irrigation scheme (see Chapter 14), the idea has not attracted the keen interest that biogas milling has done. In contrast, one of the top businessmen in Nepal uses a biogas irrigation system on his land near Birgunj and has been impressed by its effectiveness and profitability. He can, however, afford to employ well-trained technicians and farm managers who know how to make the best use of the system.

The answer to the problem of including irrigation schemes in a biogas extension programme appears to be to link them into agricultural extension programmes, employing experienced agronomists and irrigation specialists who can advise on the best use of the water. A rotation of a wider variety of crops, ensuring a more even water demand throughout the year, allows a much more effective use of the system.[13]

9.4 Economic conclusions

Despite the many different approaches to the economics of biogas systems, a few overall conclusions can be drawn. Domestic biogas plants offer only marginal economic benefits, except where firewood prices are high. Even in this case it might be more economic for villagers to plant a firewood crop than invest in biogas.[5] The use of biogas for simple cottage industries, such as grain milling, looks much more attractive, especially in more remote areas, where there is little competition from conventional mills. There appears to be a good potential in the use of biogas to drive irrigation pumps, but very careful project design and planning is required for this potential to be realised.

A biogas programme needs to employ the services of economists, either full-time or on a consultancy basis. They would be responsible for checking the economic feasibility of particular community biogas projects, as well as monitoring the economic value of different approaches to the extension and use of biogas technology as circumstances in the programme and the country vary with time.

CHAPTER 10
Community Biogas

One of the main criticisms directed against biogas technology is that only the richer farmers can afford to use it. In Nepal and India, for example, between 10 per cent and 20 per cent of the population can afford to take a loan for a family biogas plant and to repay its cost, even with 50 per cent subsidy. The concept of community biogas is based on the idea that poorer farmers can come together and match in terms of money and lifestock what the rich can provide on their own.

This idea is based on three assumptions:

A larger biogas plant will mean that the effective cost per cubic metre of biogas is lower.

The biogas from such a plant can be used in such a way that all the people in the community will benefit from it.

The people in the community will be willing to cooperate with each other in order to share in these benefits.

These assumptions need to be tested in a real environment with real people. People tend to be self-interested and want to go their own way. They will only come together to make such a project work if they can see how each one of them can benefit from doing so.

Community plants have only been properly tested in India and Nepal. Despite the apparent attractions of the idea to a communist government, very few true community plants have been built in China.[1] In many communes there has been close cooperation in the building of individual plants: many people in a village helping each other build their own plants. There is also a growing interest in the idea of 'corporate' biogas: plants run by a specialist group on behalf of other people for a fee.[2] There appear to be no examples in China of a group of people jointly owning and successfully running a biogas plant for their mutual benefit.[1].

10.1 Community biogas in India and Nepal

The past success rate for jointly owned plants in India and Nepal has been low. Three such plants were built in 1979 by HMG, Nepal with the help of US Peace Corps volunteers. Within a year two plants had failed and the third was used by only five of the original twenty-six families for which it was built [Bulmer] In India, between 1981 and 1983, the Indian Institute of

Management (IIM) cooperated with KVIC and PRAD in setting up ten community plants all over India, following a survey of two others.[3,4,5]. Not one of these plants was working as expected by early 1984. Many of the plants had over-run on cost; some were being run (at a loss) by the implementing agency as a service to the community; three were not commissioned and one had failed completely.

A careful study of the causes of failure of these different projects indicates that most of the problems lay within the implementing organisations rather than in the communities within which they worked. One major failing was in communication, both betwen the organisations and the communities and within the organisations themselves. KVIC, for example, seemed to suffer problems in communicating between its different offices and with their site supervisors.

Poor communication often led to false expectations by villagers and a rejection of the project when these expectations were not fulfilled. In PRAD, dissatisfaction within the staff resulted in changes in the management team and a lack of continuity in the projects. Poor communication within both PRAD and KVIC meant that money was not available when needed, causing long delays in obtaining materials and paying workmen. This in turn resulted in a loss of interest by both the field staff and the villagers.

Several plants had technical problems. One of the plants built in Nepal used night-soil as a feedstock, from latrines serving 300 low-caste women. The gas would not burn, because the bacterial population, without a starter, lacked methanogens and the galvanised steel gas drum rapidly corroded. The latrines proved very popular at first, so they became quickly overloaded and dirty. The two systems built by PRAD in Uttah Pradesh used several $30m^3$ dome plants. These were larger than PRAD had attempted to build previously and the plans had not been properly prepared. The site surveys had also been inadequate and the builders discovered unexpected problems: a high water table on one site and a high level of vibration from a railway line on another. These technical difficulties quickly led to disillusionment by the field staff, who felt they were poorly supported by their engineers, and rejection by the villagers.

The relationships between the implementing organisation and the village community deteriorated with time. During the planning stage, the villagers were keen to cooperate and made many promises. However, they tended to see the biogas plant as the responsibility of the aid group who were paying for it. They demanded high wages for the labouring work and high prices for supplying dung, while expecting low fees for the gas and fertiliser produced. In many cases KVIC had to bring labour and dung in from outside the village to ensure the project worked. This in turn upset the villagers, who were expecting an immediate financial benefit from the project, so they became even less cooperative.

These attitudes were the result of a wrong approach: the villagers saw the community plants as projects set up by the implementing organisations. Therefore the people felt no commitment to the projects and were not interested in their success. Their only concern was to get as much out of the project for themselves as they could.

A further root cause of these problems appeared to be a lack of will to make decisions, both within the aid groups and the villages. The promises made by villagers to the staff who came to do surveys and make plans were not based on a careful consideration of the problems involved. Instead, they tended to give the answers they thought the planners wanted to hear. Within the organisations many decisions were passed up the line to the main KVIC office in Bombay or to the main PRAD office in Lucknow. This, together with poor communication, led to the many delays.[4]

Three of the Indian plants were built for employees of institutions, who lived in housing that was supplied for them. The implementing organisations only had to deal with the representatives of the institutions (two corporate trust farms and an agricultural college), who were supplying the biogas as a service to their employees. Therefore the problems of management and organisation should have been much less than in a community, where all members were supposed to be involved in decision making. That the same delays, disagreements, false expectations and lack of decision affected these plants too,[4] confirms the impression that the main causes of failure lay within the implementing organisations.

10.2 An approach to community biogas

When DCS and ADB/N agreed jointly that the Nepal biogas programme should include community biogas they carefully considered the sociological factors involved. Several questions had to be asked.

An important question involved the motives for considering community biogas. Such programmes tend to be fashionable and often attract funding, but both fashion and money can distort otherwise well-planned programmes. The main purpose had to be to help the people with whom DCS intended to work. They had to see things from the villagers' point of view, which meant DCS staff being prepared to stay with them, sharing their language, culture and food.

A project must belong to the people for whom it is intended. This means that the villagers need to have a financial commitment to the project, as well as supplying local materials (such as sand) and labour. Poor communities do not have the capital to pay for such a project, so they must take loans. The project, therefore, must generate enough income to cover loan repayments and interest. In Nepal ADB/N made a policy decision to give a 50 per cent subsidy towards community biogas projects, but to expect the groups of farmers involved in such projects to take loans for the rest. The

biogas was to be used to drive either grain mills or irrigation pumps. Careful economic analyses of such projects indicate that enough income could be earned from them to cover repayments (see Chapter 9).

The selection of the right communities with which to work is fundamental to the success of a project. The policy guidelines of the implementing and funding organisations need to be taken into account; they may direct attention to particular groups of people, such as the poor and disadvantaged. There may be geographical or environmental limitations. Implementing organisations usually require good communications which allow technical staff and visitors easy access to the project, while the poorest people are often the least accessible. In general, homogeneous communities, composed of people from the same tribe, racial group or caste, are more likely to work together than heterogeneous communities.[4]

People who have shown a cooperative spirit and who already have an interest in biogas technology are likely to have the highest motivation for such projects. When choosing an area and a community within it with which to work, advice should be sought from people already working there, such as agricultural extension agents and community health workers.

Once suitable communities have been chosen contact must be made with the people. Initial visits will be formal, but they should be low key. One person walking into a village is much less threatening than a team arriving by jeep or helicopter. Great care should be taken that the villagers are not given false expectations. They will be suspicious of a stranger asking questions and will often give misleading answers.

It is important to get to know whether a group of villagers can cooperate together before going too far with project planning with them. Questions must be asked about the village leadership, about any disputes and factions in the group and whether they have been previously involved in cooperative projects. More accurate information may be gained from neighbouring villages or local tea shops. If a village has already learnt to cooperate in building a road or a school, for example, they are more likely to be successful in a community biogas project.

The cooperative spirit of the members of a community can be tested by giving them a simple job that they must do together. They could be asked to repair a road, to allow access to the village, or to dig the first 2 metres of the digester pit. This test must be unsupervised and the group leaders should report to the implementing office when they have finished. If they do this the project can move into the next stage.

The people need to have their own decision-making mechanisms, so a management committee should be organised. This committee must have authority and be recognised by all the members of the community. It will probably include the natural leaders of the community, but representatives of the less advantaged groups, such as the women and the landless people, could also be members. While the implementors can offer advice and may

have to train people in committee procedures, all the decisions about the project should be made by this committee, with the agreement of the rest of the community.

The villagers must understand all the implications of the project. Members of the committee can be taken to visit other community biogas projects; pictures and models can be used for training courses for them. This process may take several months or even years, but it should not be rushed, otherwise the villagers may not be able to cope with the project.

10.3 Small farmers' development in Nepal

DCS and ADB/N cooperated in the second community biogas programme in Nepal, starting in 1981. The Small Farmers' Development Programme (SFDP), set up by ADB/N with the guidance of the Freedom from Hunger Campaign of the Food and Agricultural Organisation (FAO), had been working in Nepal for over ten years.[6] This programme helps small farmers (with less than a fixed land holding) to organise into groups which can obtain low interest loans from ADB/N for development projects, such as the breeding of improved livestock or pumped irrigation schemes.

The SFDP had gained valuable experience in working with these small groups of farmers (four to twenty families).[7] They had experienced motivators (GO/ARFs, group organisers/action research fellows) working in several areas in Nepal. These people were often well-educated local people using this work to gain material towards a thesis for a higher degree.[8] One such motivator encouraged four families in Tikuligarh Panchayat, near Bhairahawa, to take a joint loan for a community biogas plant. The SFDP found money to offer a 50 per cent subsidy. Initially, the biogas was to be used for domestic purposes only, but they were also asked to test the use of a dual-fuel engine fuelled by biogas, driving a rice-huller.

This first project proved very successful, so several others followed. By the beginning of 1984, eight others had been built and ADB/N had found money to launch a nationwide programme. By the middle of 1986 forty of these plants were working in Nepal, most used to drive small grain mills, and they appear to be successful. Most groups contain four to twelve families, although a project encouraged by the Resource Conservation and Utilisation Project (RCUP) of USAID involved twenty-two families.[8] The main motive for starting and continuing in these projects is that the mills earn a reasonable income for the people involved.

These were 'group' biogas projects, where a 'group' is self-selecting; people only join in the project if they are interested in it. They are free to leave, once they have fulfilled their commitments to the group. DCS also decided to set up a 'village' biogas project, which would include all the people living in a small natural community. This approach is more difficult, as it may include people who are less interested in the project.

Also past tensions and disputes within the village are brought into the project.[5]

10.4 Case study of a group-owned biogas plant

In 1980 the SFDP manager in Manigram (on the Terai in Lumbini zone) suggested to Group Number 36 that they set up a community biogas plant. They were having problems obtaining fuel wood and they had seen a family biogas plant nearby and were interested in it. DCS was asked to make a survey of the village.[3]

Five of the houses in the village of Kusongodai, in Tikuligarh Panchayat, were very close together, so the piping of biogas to these houses would be easy. All the people in the village were Brahmins and related to each other. They traditionally worked together and had been involved in the SFDP group for several years. In 1980 they were spending about Rs1,500 per household on wood and kerosene for cooking and lighting, and expected these prices to increase. Four of the families had similar land holdings and livestock and they were keen on the project. The head of the fifth family, a respected elderly priest, disagreed. The four families had twenty-seven cattle between them, just enough to feed an SD500 biogas plant.

An SD500 biogas plant was built for the four families in 1981. SFDP provided a 50 per cent subsidy and the villagers took a loan for the rest from ADB/N. Each of the houses was supplied with two ring burners and a biogas lamp. The farmers became concerned about repaying their loan to ADB/N. Early in 1982 they were persuaded to test the use of a 4kW dual-fuel engine with a rice-huller (supplied by DCS), using biogas from their plant. After six months, when the Gobar Gas Company removed the engine, the villagers took a second loan (without subsidy) from ADB/N to buy a 5kW engine and a flour mill. They later purchased the rice huller from DCS.

The villagers have carefully organised themselves to ensure that the biogas system works fairly. Each house sends a person to bring three buckets of cattle dung each day and to help mix the slurry. The main gas valve is opened at fixed times during the day, for cooking and lighting. The mill is used whenever there is a demand for its services. In winter, when there is less gas, the villagers must use firewood for cooking the evening meal. Customers come to the village to have their grain milled towards late morning. If all the gas has been used they will run the engine on diesel alone.

The effluent slurry is collected in pits at the edge of the village. Each household has its own storage pit and fills it from the central pit. They must count the number of buckets removed to ensure each household receives the same amount.

The mill is operated by two people. The driver is hired from outside the village and is paid a fixed salary of RS.300 (£14) per month, whether he works three hours a day in the slack season or eighteen hours a day after harvest. He collects diesel from a nearby town on a bicycle (20 litres a time from 7km away). He does all the repair and maintenance work required on the mill. Staff from the Gobar Gas Company are called in if there is a problem that he cannot solve.

The cashier is one the people from the four households. He issues slips of paper to the people waiting to have their grain milled. These indicate the order in which they are to be served and how much must be paid, in money or in grain. Records are kept of these amounts. The cashier's job is taken by each household in turn. House number four holds the register of income, while house number two keeps the money and grain received. The grain is sold to people who come to buy it; a person from another house must be present during the transaction.

The villagers seem to be very satisfied with the dual role of their biogas plant. They are able to use biogas for cooking and lighting, as well as earn an income from the mill. The close cooperation between the four house-holds is motivated by the benefits they see coming from the effective operation of their biogas system. The villagers will not give exact details of their income from the mill, as they are afraid they will be taxed on it. They claim that they are earning enough income to cover the repayments on their loan. The economic analysis of a dual-fuel mill (see Chapter 9) seems to be valid.

The villagers seem to be able to compete with other mills in their area: about five diesel mills within an hour's walk of their village. Their price has been lower and local people prefer to come to a small mill, which will process small quantities, than go to a larger one, where they may have to wait. As electricity comes to the area electric mills are being set up, which charge lower prices. This may have an effect on the profitability of the Tikuligarh mill in the future.

10.5 Case study of a village-owned biogas plant

The village of Madhubasa (on the Terai in Janakpur zone) had set up their own cooperative society in 1964. The village was chosen as a place for a SFDG in 1979 (number 37). There are thirty-seven families (187 people in 1983), all of whom belong to the Magar tribe and are farmers. The Magar tribe are noted for their community spirit and in Madhubasa this is combined with a strong but open leadership (also Magar) that enables the people to join in cooperative ventures. SFDP suggested the village as a site for a community biogas project and DCS did a survey in 1980.

The village lies at the base of the foothills of the Himalayan range, between two rivers. These rivers are usually dry, but they are subject to flash flooding in the monsoons, when water runs off the hills to the north.

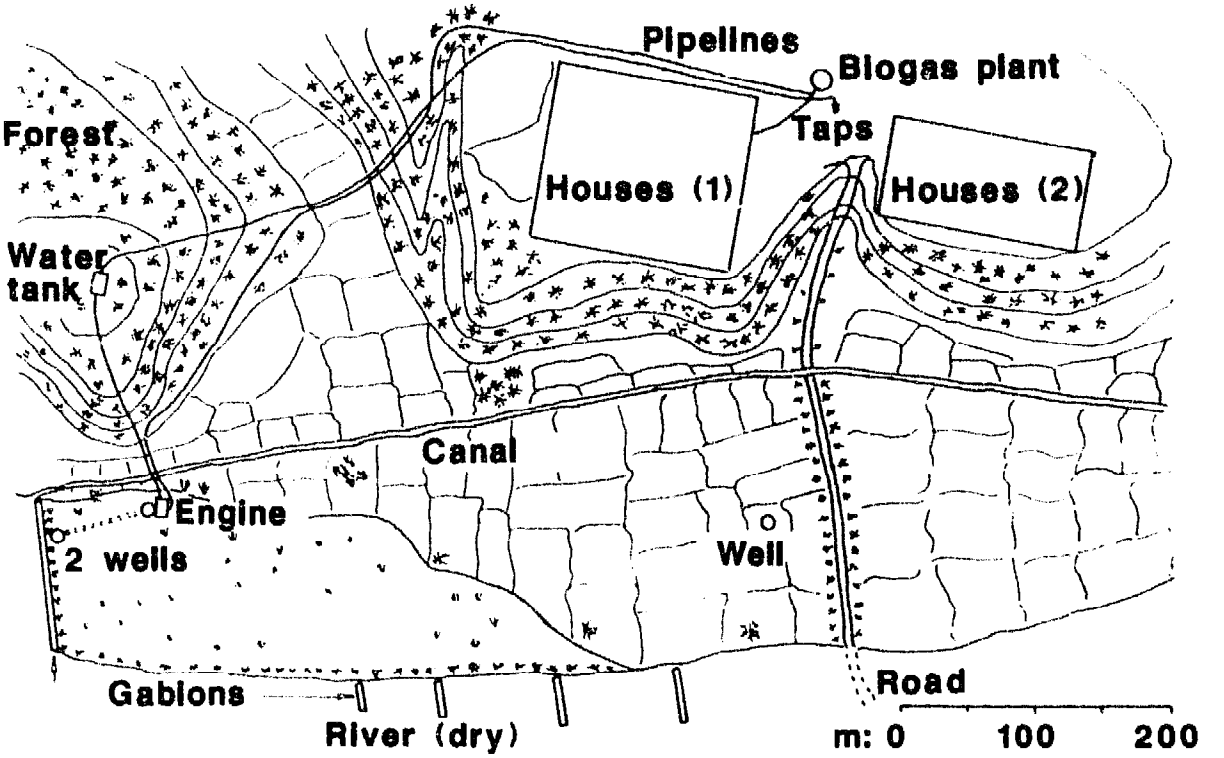

Figure 10.1 *Map of Madhubasa Project Site*

These flash floods are getting much worse, as deforestation and removal of soil cover mean that run-off is increased during rain.

The survey by DCS concentrated on the real needs of the villagers. They had little interest in domestic biogas technology: no-one in the village had seen a plant and they were close enough to the forest that fuel wood was not a problem. Their main concerns were that the flash floods were eroding their land each monsoon, and they wanted to irrigate part of their land to grow more crops. DCS decided to work in the village, with the idea of introducing a dual-fuel irrigation pump, fuelled mainly by biogas.

The land-erosion problem was urgent, so help was given to the villagers to build gabion barriers across the path of the flash floods, to deflect the water from the fields. They were taught to weave the wire baskets, using wire donated by Oxfam. Stone was brought from higher up the river with a tractor and trailer loaned by another agency. About 5.5 hectares of land were reclaimed from the riverbed. It was planted with mango and other fruit trees, to build up the soil and to provide a cash crop. This project acted as a test of the people's willingness to cooperate.

The biogas irrigation project first involved digging exploratory wells. A Japanese-funded irrigation project (JADP) became interested in the idea of biogas-fuelled irrigation pumps, so they offered much help, including expert technical advice and the loan of digging machinery. Eventually two

permanent wells, 80 metres apart, were constructed, connected by an underground plastic pipe.

The irrigation scheme was carefully planned. An economic feasibility study was encouraging (see Chapter 9).[9] A biogas committee was set up, the members being the office holders in the cooperative society, although no women were on this commitee. In spring 1982 six members of this committee were taken on a 'Biogas Tour'. Two of the young men of the village were sent on a course in engine operation and maintenance at JADP. The villagers were loaned a diesel engine, so they could become used to its operation.

While the biogas plant was seen as an answer to one of the villagers' felt needs, that for irrigation, other uses of the biogas were considered. The villagers wanted gas lamps, so they could hold village meetings by gas light. Two gas burners were placed in the community house, for use in making tea for meetings and for guests in the village. Irrigation is seasonal, so the gas can be used for other purposes at times of the year when water is not needed for the fields.

The Local Development Department of HMG/N had offered to pay for a drinking-water scheme, so a storage tank was built on a hill above the wells. A pump-set was chosen that could pump water up to this tank, from where it could be piped to the village. It was also able to pump irrigation water.

The site of the biogas plant was another issue. From a technical point of view the plant should have been near the pump-set, but the cattle dung would have had to be carried for 500 metres (300 or 400kg/day). The villagers wanted the biogas plant in the village, near the cattle sheds. They were also concerned about security, being as much afraid of attacks from evil spirits as of possible human interference. One of the village leaders contributed land for the plant. The gas was piped the 500 metres from the village to the pump by plastic pipe. Such a pipeline proved expensive and there were fears about the plastic being chewed by rats.

A 50 per cent subsidy for community biogas schemes is now government policy, so DCS made this available to the project. The rest of the cost had to be taken as a loan from ADB/N, and application was made in the name of SFDG number 37. Not all members of the cooperative society were members of this group; the two village leaders owned too much land to be considered as small farmers. These people would pay their contributions to the members of SFDG 37 when loan repayments had to be made.

The water was to be pumped from the wells into an existing irrigation canal that had been built to take water from the Jalad river, when it flows during the monsoon. Only twenty-two families had land in the area served by this canal. Another ten families had land in other places, while five households had no land at all. If the main benefit of the scheme came from the profit from the sale of a winter wheat crop, these fifteen families had to benefit, too.

Discussions took a year; the idea of 'gas rights', where the people using the gas paid a fee to those who did not, was rejected. Land was available for sale in the irrigated area, owned by an outsider, but no money could be found to buy it. The twenty-two land-owners were challenged about sharing their land, but the committee (ten of whom were land-owners) were not keen. After they were asked to imagine themselves in the role of those without land in the area, they agreed to lease a portion of their land on a 'Bathya' system. This traditional arrangement allows the farmer and the land owner to share the crop on a 50:50 basis. An agreement was drawn up and all parties signed it.

The biogas plant and engine shed were built in Madhubasa in 1983 and were running by early 1984. The rota system for putting cattle dung into the plant was slow to get going. The engine (purchased from JADP and adapted for dual-fuel use) runs well on biogas and is being used to pump water to the drinking water tank and for irrigating a winter wheat crop. The initial income from the sale of wheat proved disappointing: the crop yields were much lower than expected, mainly because the villagers were not used to growing wheat. However, the village has become involved in another development project: growing tree seedlings for a joint HMG/aid agency reafforestation project. Part of the water pumped for the drinking water supply is being used to irrigate these seedlings, which earn a good income for the village. There is enough money from the sale of these seedlings to repay the loan and interest as well as improving the living standard of everyone living there. Few people in the village now have to cut firewood to sell to gain extra income.

10.6 Conclusions about community biogas

While a larger biogas plant does give some economy of scale, it is insufficient to reduce the price per m^3 of biogas to that which a poor farmer can afford. Even with a 50 per cent subsidy the villagers of Tikuligarh were concerned about repaying their loan while they were only using biogas for domestic purposes. The real value of a community biogas plant comes when it is used to earn an income for the group or the village. Biogas used to fuel a dual-fuel engine offers real financial benefits, an important new dimension in the concept of community biogas.

People's commitment to a cooperative project depends on the benefit they receive from it. If the project is earning a cash income in which all the members of the community can share, they will work to keep the project going. The benefits from a domestic biogas plant are not valuable enough to offer a high incentive.

Once people discover the benefits they can gain from working together they are more likely to try other projects. Madhubasa was chosen as the village in which to set up a tree nursery because of the way in which

they had worked together on the biogas scheme. Both Madhubasa and Tikuligarh are places to which other groups are brought to demonstrate the idea of community biogas. The King of Nepal visited Madhubasa in 1985, (although he only had time to look at the project from a helicopter). All these things lead to a growth in people's status and confidence in themselves.

The second factor which encouraged success in the Nepal community biogas programme was the close cooperation of SFDP and JADP. Technical expertise was readily available to train villagers in the use and maintenance of engines, the most effective use of irrigation water and the best way to grow wheat. Mechanisms were also available for giving low-interest loans and subsidies for cooperative projects, and the villagers were used to using them. They had learnt to trust the officials of ADB/N and were prepared to take the risk of a much larger debt to pay for the biogas projects. This trust had been built up over several preceding years by the GO/ARFs, who had been trained and motivated through the FAO scheme.

The experience from Nepal demonstrates that community biogas can work if the right approaches are used within the biogas programme. An effective community programme demands involvement from people with many skills. A sociologist or anthropologist is needed to choose the area and communities within which to work, to make initial contacts with people and to train and motivate them in their working together. The selection of suitable technologies with which to use biogas will involve both engineers with suitable experience and economists to consider the economic feasibility. If biogas is used for irrigation, water engineers and agronomists are needed to advise on the best ways to find, supply and use the water. The staff of the biogas extension programme will be involved in the building of the plants and their on-going follow-up. Training and follow-up are also required for the engines used in the projects. A biogas programme should have its own technicians trained in the repair and maintenance of the engines used in these projects. Help can also be sought from local agents for the engine suppliers.

In Nepal most of these skills were already available in DCS, ADB/N, SFDP and JADP. In India KVIC, PRAD and IIM neglected some of these areas, especially those of sociology, management and economics, and discovered many problems. In other biogas extension programmes arrangements need to be made to ensure that people with these skills are employed by the project or are available as consultants from other cooperating agencies.

CHAPTER 11
Biogas Research and Development

Research and development is an important aspect of a biogas programme. Biogas plant and equipment designs need to be adapted to local conditions and resources. Biogas plants are generally considered expensive, so ideas for reducing costs without reducing reliability or effectiveness need to be tested. The digestibility of different feedstocks needs to be tested, so local people can be advised as to the best ones to use. Experts need to be available who can assist the extension programme to find out the reasons for any plant failures.

11.1 Biogas research and development in India, Nepal and China

The Indian biogas programme has always had a research and development dimension. The work at IARI, Delhi,[1] inspired the setting up of the KVIC Biogas Research Centre on the outskirts of Bombay,[2] and the PRAD test centre in Ajitmal (near Etawah, U.P.) in the 1950s.[3] After 1975 several other organisations were encouraged to get involved in biogas R & D, including ASTRA,[4] part of the Indian Institute of Science in Bangalore, the TATA Energy Research Institute in Bombay,[5] the Indian Institute of Management in Ahmedabad[6] and many others.[7,8]. There are a wide range of different problems identified within the Indian biogas programme and there appears to be a growing interest in them.[9]

In Nepal, too, there has always been a close connection between biogas R & D and extension. The original HMG/N programme was planned and organised by staff of the Soil Science and Agricultural Chemistry Laboratory (part of the Department of Agriculture) at Kumaltar, near Patan.[10] The Gobar Gas Company was formed around the staff of the Biogas Project in DCS, Butwal, in 1977. DCS continued the R & D part of this project for anover seven years, offering technical back-up to the staff of the company as well as testing improved designs of biogas plants and equipment. An R & D laboratory was set up within the Gobar Gas Company in 1983, with staff trained by DCS to continue this work.

In China the Cultural Revolution in the early 1970s inspired a reaction against academics, so there was little formal R & D work on biogas until after 1978. There are now over 1,000 scientific and technical personnel involved in biogas research as the leaders of the programme attempt to catch up for lost time.[11] Before 1978, though, many peasants themselves

were engaged in informal R & D, testing new ideas, especially better and cheaper designs of biogas plants. While this informal approach was inefficient and wasteful, with members of many different communes facing the same problems and making the same mistakes, it did work. Peasant farmers were able to make cheap biogas plants that produced sufficient gas to provide cooking fuel for a Chinese family.

11.2 Biogas plant development

The early Indian and Chinese approaches to biogas R & D were very different. The Indian approach started with institutions and moved via semi-government organisations to local labourers building plants for farmers. The Chinese approach started with the farmers, with research and extension organisations being formed to meet the needs of the farmers. Now, both programmes seem to be moving towards middle ways that are very similar.[12]

The Indian emphasis on institutions, meant that extension organisations took the results of the institutional R & D work without a clear understanding of their implications for the designs they were making. When local labourers started to build these designs for farmers in villages, they, in turn, did not understand what they were building or how the plants were supposed to work. A lack of effective communication between researchers, designers, builders and farmers meant that when problems occurred with new plants there was no-one available who could put them right. Also farmers were not trained in the correct use of their plants or in basic maintenance.

For example, an early Indian design used a counter-balanced gas drum,[9] to reduce the gas pressure to below atmospheric, as the R & D results suggested that reduced pressure increased gas production. A more careful examination of this result shows the extra 'biogas' was carbon dioxide coming out of solution from the slurry. This design was also very dangerous, as air could be drawn into the low pressure in the drum, making an explosive mixture. Poor communication also led to a single design (the KVIC floating drum design) being used for a wide range of different applications. There was very little flexibility in the system.

Once more research and extension organisations became involved in the biogas programme the approach became more flexible. The 'Janata' (fixed dome) plant was introduced into the extension programme (originally by PRAD) and taken up by these other organisations. Floating ferrocement drums (introduced by SERC) also became available.[13]

Poor communications with builders and owners leads to high failure rates for plants. Many biogas technicians are only taught to follow a set procedure, without being given an explanation of why the different tasks need to be done. Where conditions exist that are not normal, such as poor

soil or a high water table, the technician cannot adapt his approach to suit these conditions. If farmers do not have an understanding of the biogas process they are likely to make mistakes in operating the plant, such as introducing toxic substances (antibiotics, detergents, etc.) into the digester.

Again, since voluntary organisations, such as AFPRO (Action For Food Production, New Delhi) and Gandhian groups have been involved in biogas extension,[8] much more emphasis has been placed on training local biogas technicians and farmers in basic biogas technology.

The two main 'popular' thrusts in the Chinese biogas programme, in the 1950s and 1970s, were based firmly in Chinese village communes, with peasant farmers building (and often designing) their own biogas plants. Combined with strong government propaganda, this approach meant that a large number of people gained a basic understanding of biogas technology and could attempt innovations at a local level. However, this understanding was limited and many of the early designs had basic flaws. The design used extensively in the 1950s had a rectangular gas storage volume.[14] Attempts to duplicate this design in Nepal showed that the corners of the flat roof were sites of high stress.[15] When movement of the roof occurred (as the internal gas pressure varied) the plaster seal in these corners cracked and leaked gas.

The dome-shaped gas storage volume seems to be an idea that occurred to several different people in different communes, as there are now a number of different versions of it.[16] The shapes range from a completely spherical plant to a cylindrical digester pit with shallow domes top and bottom. Theoretical analysis suggests that the best shape for the gas storage volume is a spherical segment with an internal included angle of less than 100°.[15] If the spherical segment includes an angle larger than this parts of the shell are under tension. Unreinforced concrete only shows high strength when compressed.

The materials used in the Chinese biogas plants of the 1970s were often of poor quality. During this time emphasis had been placed on rural cement plants, using local supplies of coal and limestone, but the quality of the product was very variable. A cement made from lime (calcium hydroxide) and pozzolana (such as crushed brick or burnt rice husk) was also used. This is very dense, so reduces gas leakage, but makes concretes and mortars that are much weaker than those based on conventional cement.

Once the idea of formal R & D had again become acceptable to the Chinese authorities and central biogas organisations had been established, national standards were defined for biogas plants and equipment.[11] These are issued by the National Bureau of Standards and the Ministry of Agriculture, Animal Husbandry and Fishery and are based on scientific criteria.[16] The effective implementation of these standards is ensured by training

biogas technicians, incorporating them into biogas building teams and making it illegal for non-certified people to build biogas plants.[11]

The close link between R & D and extension enabled the Nepal biogas programme to avoid most of the expensive mistakes of others. DCS started their research and development work by doing detailed follow-up surveys on the first ninety-five plants built to the KVIC-style floating drum design. These surveys revealed several design weaknesses that only became obvious after the plants had been run by a farmer more than a year. For example, the flexible plastic pipe used to withdraw gas from the top of the drum had a short life-time (six to nine months) and many farmers had problems in replacing it. A different arrangement for removing the gas was designed. The high water table in the Terai of Nepal meant that much shallower pits had to be used, so the 'taper' design was made. The other major fault was that the gas drums rusted badly.

When alternative designs to the KVIC one were investigated DCS decided to use the same approach. Several innovative designs were built for farmers, such as plants with hemi-spherical ferrocement floating gas drums and a flat-roofed displacement digester.[15] An interesting design used a trapezoidal gas holder, hinged at one end to allow the other end to float up and down in the slurry. The customers were told of the experimental nature of the design and usually paid a reduced price for the plant. Unfortunately, most of these designs failed and the customers became upset. Eventually, most of the plants were replaced with conventional designs by DCS at their expense, although one owner insisted on receiving his money back.

This approach was not helpful to the reputation of biogas technology in Nepal. It is interesting, however, that one or two farmers, having seen these prototypes made of cement, wanted similar plants for themselves, despite knowing that the prototypes were not working. They instinctively trusted concrete rather than steel and were convinced that the biogas research group could make them work eventually. A test site was set up where new prototype designs could be built and thoroughly tested before field tests were undertaken. The Nepali version of the fixed dome design was first built on the test site and various systems tested for making a gas-tight seal over the gas dome, before the acrylic plastic emulsion approach was found.

Once the prototype fixed dome design had been proved on the test site field tests were undertaken. Twenty plants were built for customers of the Gobar Gas Company in one geographical area (around Pokhara). While the customers paid a market price for these plants, a guarantee fund was set up by the research group that would allow all of these plants to be replaced if they had failed. Detailed follow-up surveys were made of these plants and all problems were noted.[17] The main difficulties appeared to be leakage of gas from the main gas valves, blockages caused by slurry entering the gas outlet pipe and faults with the scum breaker mechanism.

A scum breaker is probably unnecessary for a fixed dome plant, as owners did not experience a loss in gas production after the mechanism broke. Minor design changes and a better design of gas valve were the answers to the other problems.

An effective approach to the development of biogas plant designs involves both a central research team and also the farmers using biogas systems. The central team must include people with good scientific and technical training and experience, who can analyse the problems and know how to look for solutions. Their work, however, must be done in the context in which the results are to be applied. They must seek to solve the real problems faced by the farmers using biogas technology. The answers devised by these scientists must be tested by normal biogas users in the field, to ensure they work well and do not introduce further problems.

11.3 Biogas equipment development

Biogas equipment, such as valves, stoves, lights and engines, is easier to test than biogas plants as it is small enough to be run in a laboratory. The approach to the development of biogas equipment has been very similar to that of biogas plants.

KVIC produced standard designs for biogas stoves, lights and valves, based on good town gas equipment, and licensed Patel Gas Crafters in Bombay to make them. Other companies also made their own, cheaper versions, which were used by other extension agencies, such as PRAD. Kirloskar Oil Engine Company,[18] Pune, produced a design of dual-fuel engine, based on their standard diesel engines with a mixing-chamber-type gas carburettor fitted to the air-inlet manifold. This engine was extensively tested in Kirloskar's own laboratories.[10]

In China the peasant farmers made their own gas stoves and lights, from tins packed with stones or using simple fired-clay designs.[14] The gas piping was made from soft PVC tube, closed off with simple clips that pinched the tube.[19] These designs were not very efficient, but they worked satisfactorily. Again, official standards have been issued for the design of stoves and lights, using the best of the peasant designs with improvements based on scientific principles.[11]

DCS was concerned about biogas equipment development from early in the biogas programme. Supplies could be obtained from India, but the designs were either expensive or unreliable. The standard plug cock, made in Calcutta, was adapted by fitting a tensioning spring to hold the plug tightly in the body even when it was worn down. Even this design leaked at the higher gas pressure from displacement digesters. Attempts were made to find better designs.[20] A cheaper, but reliable gas stove was developed by DCS and was made in workshops in Nepal. Attempts were also made to develop a cheap, reliable gas light.

The development of effective, low-cost biogas equipment is as important as the work on biogas plants. The research and development facilities of a biogas programme should include testing areas and equipment for valves, stoves, lights and engines.

11.4 Laboratory testing of biogas technology

The main job of a biogas laboratory is to check the digestibility of different feedstocks and to analyse samples brought in from the field. The feedstocks may be different farm residues or plants available to the local farmers. Digestibility testing is also important to check the reasons for failure of plants belonging to customers of the extension programme.

Laboratory biogas reactors are usually glass flasks of between 1 and 5*l* in volume. Plastic flasks could be used, but they are very difficult to make gas-tight. The reactors need to be kept at a constant temperature, either in a temperature-controlled room or in water baths. Water baths are usually cheaper and easier to set up as well as being more flexible, in that several small systems can be run at different temperatures at the same time (Appendix III).

Laboratory reactors can be either batch or semi-continuous, continuously or intermittently mixed. The biogas given off needs to be collected and measured and samples of slurry need to be removed so that parameters such as pH and volatile solids and COD content can be measured. Gas is usually collected in a bottle containing water that is displaced into a second bottle by the gas. The second bottle is usually placed higher than the first, allowing the gas to be collected under a positive pressure (Appendix III). The end of the sampling pipe, used to remove and add slurry, should dip well below the surface of the slurry to prevent air entering the gas space. The positive pressure also makes mixing difficult (Appendix III). If the reactors are used to simulate low-rate rural digesters, then an occasional shake by hand is sufficient.[23]

11.5 Test site and field tests

The monitoring of the performance of full-scale digesters, whether on a test site or using plants owned by customers, involves different problems to those met in the laboratory. While the temperature of the plant may not be controlled, it should always be monitored (Appendix III). Samples of slurry can be removed from the inside of the digester pit using a dipper bucket (Appendix III) passed through the slurry inlet or outlet.

Most rural plants are not heated if they are used in tropical or sub-tropical climates, so most plants, including test-site plants, do not have a temperature-control system. Heat losses in these plants can be reduced by placing straw or compost over the top in cold weather. The few test-site

plants that may be heated would be those which have been designed for cold-climate use and are being tested in a cold region.

There are two aspects to the measurement of the gas production from a full-scale biogas plant: the gas used and the gas remaining in the plant. When plants are run on a test site the gas is usually retained in the plant and released through a gas meter (Appendix III) twice a day. The gas is either lost or collected in a secondary store. The testing of plants on a customer's site means that the gas used each 24 hours, as measured by a meter, needs to be corrected according to the volume left in the plant at the beginning and end of each measuring period (Appendix III). Despite the greater difficulty of field tests the results are very valuable as a sample of different plants to the same design can be tested. The effects of peculiarities in individual plants and the ways different owners run them can be statistically removed. Operating mistakes by different owners can also be identified and the effects measured, so that advice on the best way to run plants can be given to all customers.

11.6 Gas and slurry analysis

An accurate assessment of the performance of a biogas system should include the volume of methane produced, so samples of biogas need to be analysed for content. Various devices are available to do this (Appendix III), some of which can be used in the field. The pH of the slurry is a measurement that is often made, because it offers a guide as to the health of a biogas plant. Measurements are most easily done in the field (Appendix III)

Slurry analysis must be done in the laboratory (Appendix III), although slurry samples collected in the field can be placed in sealed pots for later analysis. If the samples are to be kept for more than a few hours, they should be kept cool (eg. in a refrigerator). The measurement of total solids and volatile solids require a furnace that can be run at 100°C and 500°C.

COD and alkalinity measurements require the use of chemicals and glassware (Appendix III), so the facilities of a simple chemical laboratory and trained technicians are required. Gas burners are useful as the chemicals need to be boiled for COD measurement and biogas from a test site plant can be used to run them.

BOD, total phosphorous, potassium and nitrogen and C:N ratio measurements require more specialised apparatus and training. They are best done by university or government research laboratories specialising in soil science or waste disposal work.

11.7 Biogas plant modelling

The results of all the measurements on laboratory-scale, test-site and field digesters need to be analysed and interpreted. Although a detailed

investigation may result in thousands of different data points, these must be resolved into two or three figures that allow the performance of a plant design or the digestibility of a feedstock to be assessed and compared with others. Mathematical models—a simplified mathematical description of how a biogas plant works—provide a way of doing this.

The actual mechanism inside the plant, with many different types of bacteria all contributing to the production of biogas, is very complex and impossible to define, so any model must be a gross simplification of reality. The most effective models seem to be the simplest, mainly because they define clearly two or three parameters by which a plant design or a feedstock can be assessed. A good model should roughly predict how much gas a customer can get each day from his plant, given that it is a particular design and uses a particular feedstock under defined conditions.

Several different models have been suggested for biogas plants, many based on simpler biological systems.[23,24] The most effective seems to be the first order kinetic model in which it is suggested that the rate of substrate (feedstock) digestion is directly proportional to the substrate concentration (Appendix IV). The substrate concentration can be expressed as total solids, volatile solids, COD or BOD. This model was used by Pfeffer to analyse his data from continuous cattle dung digesters in USA.[21] It has been applied to both batch and semi-continuous systems by Lau-Wong in Nepal.[22]

The derived models for both batch and semi-continuous digesters attempt also to define a rate of gas production in terms of other parameters, particularly time (see Appendix IV). A yield constant is also defined: the gas production per unit mass of substrate. There are many ways of expressing this constant, which have been used by different workers. The substrate can be defined in terms of total solids, volatile solids, COD or BOD; the gas production can be defined in terms of the substrate added to the digester or that destroyed within the digester (input less output). The value of this constant is related to another constant used by some workers: the ultimate biodegradability of the substrate.[23] This is the theoretical gas production that could be achieved if the substrate could be left in the digester for a very long time.

11.3 Results of biogas modelling

There have been few studies of the kinetics of batch digesters using the first order model. Maramba noticed two regions in his cumulative gas production curves from the digestion of pig manure in the Philippines. They indicated a higher rate of gas production at short retention times (22 days at 31°C) than at longer times (32 days).[25]

Chowdhury, using a more analytical approach on her results from cattle dung, based on the first order model, also found two digestion rates.[23] She

suggested that the high rate was due to the break-down of easily digested material, and the low (background) rate from the digestion of materials, such as cellulose, for which the rate-limiting process is hydrolysis.[26]

Both Chowdhury and Maramba found that the lag time appeared to be very short (about one day), probably because they were both using a starter, so the bacteria were able to start biogas production immediately on encountering a new source of feedstock. Chowdhury also noticed sharp oscillations in the daily gas-production curve (Fig. 11.1).

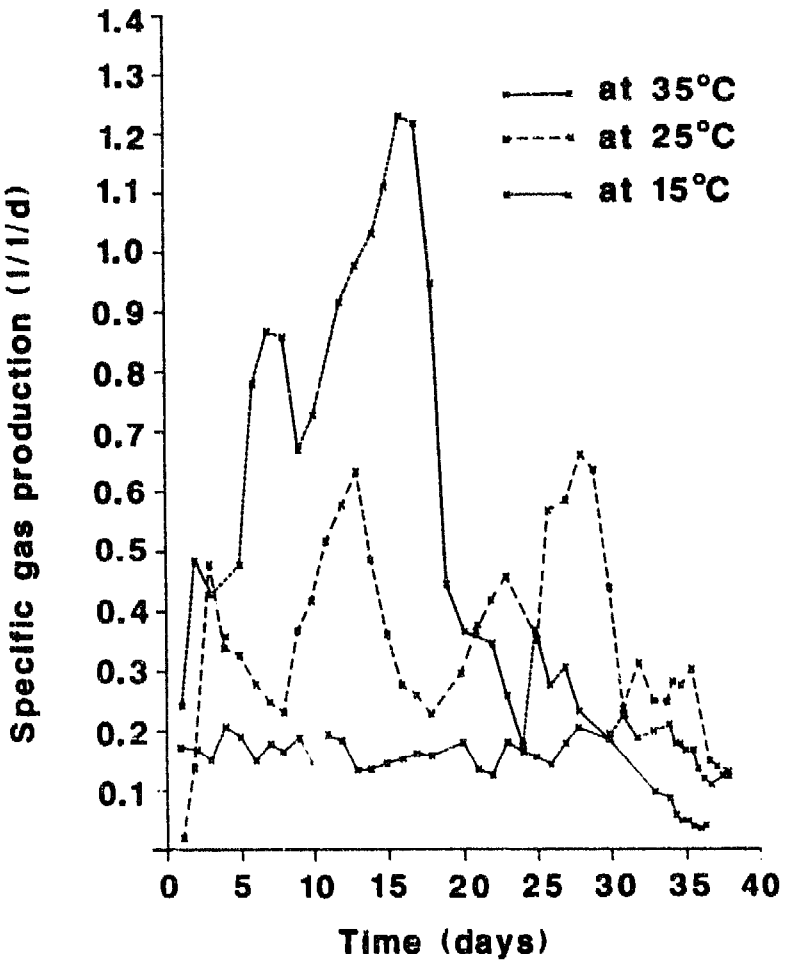

Figure 11.1 *Daily gas production curves at different temperatures*

More workers have looked at the kinetics of continuous biogas systems, although they have used a variety of models. Pfeffer used the first order model with his results from cattle dung reactors in USA, although he assumed that the yield constant was a constant (547*l*/kg.VS. digestible, based on the theoretical maximum).[21] Lau-Wong, using results from full-scale biogas plants fed mainly with cattle-dung in Nepal, found that both the yield constant and the rate constant varied with temperature.[22] The variation of the rate constant with temperature fitted an Arrhenius equation (Appendix IV).

Chowdhury found similar results to those of Pfeffer and Lau-Wong and demonstrated that the yield constant and the rate constant at three temperatures differed from those derived from the analysis of the results from batch reactors run in the same water baths.[23] Pfeffer found a second, lower-rate reaction at longer retention times and Chowdury's results indicated a possible similar conclusion.

Biogas modelling does offer a means of analysing and interpreting the results from measurements of solids degradation and gas production from biogas plants, both laboratory and full-scale. The results from such modelling can be used to predict the overall performance of a biogas plant, although it will not give a detailed description of the way the daily gas production may vary. A simple model, such as the first order model, will not predict phenomena such as 'wash-out', the failure of a continuous digester at very high loading rates.

The results from batch reactors cannot be used to predict the behaviour of continuous biogas plants. If laboratory trials of the digestibility of suitable feedstocks for use in semi-continuous digesters are to be undertaken, then semi-continuous laboratory-scale reactors should be used.

11.9 Staff for research and development

The collection of sufficient data from biogas reactors to give statistically meaningful results is very labour-intensive. Ideally, at least ten reactors should be run under the same conditions and the results averaged to remove the effects of random variations in feed composition and bacterial population. The collection of this data from laboratory reactors is a full-time job for at least one person. If results are required from field reactors, then two or more people may be required, depending on how far apart the chosen reactors are sited. Since reactors must be run for at least sixty days to give meaningful results (or two retention times for semi-continuous reactors), data collection is also very time-consuming. Semi-continuous laboratory and test-site reactors need to be fed daily, so rotas are required that ensure staff are available at week-ends and during holiday periods.

Planners for biogas programmes must therefore ensure that the research programme is given sufficient staff. As well as scientists and laboratory assistants, the research programme needs people to collect fresh feedstocks (daily if possible) and to visit field plants for taking measurements and doing follow-up surveys. This type of work is excellent training for extension staff, as it provides a basic understanding of how a biogas digester works. Trainee field supervisors should be given a chance to spend time on this type of work and staff can be rotated between the research and extension programmes as necessary.

CHAPTER 12
The Politics of Biogas

The sharp rise in the price of oil in the early 1970s brought energy suddenly into the realm of politics. Many of the less-developed countries had committed themselves to a process of development based on an increasing use of imported energy. They were faced with the choice of scrapping their plans and the investment they had already made or taking large loans to pay for the oil to run their new industries. Alternative fuels, such as biogas and alcohol technology, became politically important as leaders of many countries tried to discover if they could offer a way out of this dilemma. The United Nations and its specialist groups, such as ESCAP, FAO, UNDP and the World Bank, also became interested in alternative energy, as it appeared to offer the possibility of help towards the solution of these economic problems.[1]

Biogas technology was unable to provide an immediate answer as it was poorly developed and more related to the needs of rural families than to those of the new industrial areas that were demanding more energy. However, despite the fall in the oil price in the mid-1980s, biogas technology has remained, along with other alternative energies, on the agenda of government and United Nations' planners and in the political arena.

Planners and administrators in a biogas programme need to recognise the political influences on their programme, not only at the international and government levels, but also among the customers with whom the programme is working and the staff of the programme. The arguments for emphasising biogas technology over other demands need to be clearly defined, ready for use in applying for financial grants, subsidies and government help

12.1 National views of biogas technology

Biogas is a resource for rural areas, so does not have the immediate priority for government ministers demanded by other energy sources such as liquid fuels. Politically, the needs of the urban elite for fuel for transport and industry tend to gain precedence, as they have a powerful voice. Civil servants and journalists, especially, belong to this group and can make their needs known to politicians with a much greater urgency than the poor majority in their distant villages. Biogas cannot easily be used in urban areas as it requires space, which is expensive, and the transport of waste

products, such as night soil and animal dung, which are bulky and obnoxious to many urban people.

Biogas has found a place where governments have deliberately placed emphasis on the needs of the rural population. The large biogas programmes in both China and India came from the commitment to rural developments of leading political figures, notably Mao Tse-Tung and those in the Indian government who were concerned to respect the aims of Mahatma Gandhi.

In other developing countries, while biogas technology has been given an important place in national energy policy, it has never had a real priority. In Nepal, for example, biogas is seen by HMG/N to have an important part in their energy programme and planners have recognised the need for subsidies to allow more people to build plants. However, each year other needs seem to displace biogas plant subsidies in the national budget and they either do not appear in the list of priorities or are allocated at an inadequate level.

12.2 Biogas and the fuel crisis

The most important argument for the value of biogas technology is that of the crisis in domestic fuel supply. The world is facing an energy crisis that has nothing to do with the supply or price of oil. The drop in oil prices in the mid-1980s has not helped this second energy crisis at all, because it is to do with the supply and demand for firewood. As populations grow in most parts of the world, people need more wood to build houses and to cook food. They also need more land on which to grow food, so they clear forests and reduce the wood supply even further. As less wood is available, people begin to burn agriculural wastes, such as dried animal dung and crop residues, which could otherwise have been composted to make fertiliser. These fuels are also inefficient, giving smokey flames.

As forest cover is removed and land is impoverished by the growth of more food crops, with less and less fertiliser to replace the plant nutrients, soil erosion occurs. This problem is worst in mountainous areas, such as Nepal, where the monsoon rains quickly wash away unprotected top soil. As the soil cover is lost, the sides of the mountains become unstable and landslides can happen, destroying land, crops and homes. Increased water run-off on deforested slopes means floods downstream in the monsoon and less water absorbed by the mountain rock strata. Thus less water is stored underground in the mountains for the dry season, so springs and streams dry up earlier in the year. A natural cycle of flood and drought is therefore intensified and people are not only short of fuel, food and fertiliser, but water also.[1]

The attraction of biogas technology is that it offers a way of cutting across this vicious circle. A biogas plant can produce both fuel and a good

fertiliser from the same animal dung and crop residues. Because biogas is a high grade fuel and can be used in stoves of high efficiency, a fixed mass of residues will produce more usable energy if digested, than if it were dried and burnt on an open fire. The value of the fertiliser from a biogas plant is also higher than that produced if the same wastes were composted in traditional ways.

Biogas-fuelled irrigation schemes, where underground water is available, mean that crops can be grown in the dry season, without having to cut down forest to create more agricultural land. Cottage industries, powered by biogas, could also mean that fewer people would have to cut firewood to sell, as they could earn extra cash in other ways through village cooperatives. This would cause the price of firewood to rise, making domestic biogas plants look more economic.

Theoretically, biogas technology does have the potential for making an impact on these problems in a country such as Nepal. It has been calculated that three-quarters of the fuel wood used in Nepal could be replaced, if all the available cattle dung were digested to biogas.[2] However, such calculations ignore the cost of all these biogas plants and the resources, in manpower and materials, such as cement, that they would require. At the present rate of construction, it would take centuries before the biogas programme begins to make an impact on these problems. The problems themselves are likely to reach crisis dimensions within decades!

12.3 Local concepts of biogas technology

Biogas technology has an inbuilt advantage in the nations in which it has spread most rapidly, in that it has been culturally acceptable. The Chinese people seem to have always seen the benefits of composting residues to make fertiliser. The idea of a composting system that not only produces a good fertiliser, but also a fuel gas, is very attractive.

For Hindus in India and Nepal the cow is a holy animal and cattle dung is considered a ritually clean substance. Most village houses, and especially kitchens, have floors made from dried cattle dung and mud, which are replastered several times a week. Therefore the idea of cooking on 'gobar' (cow dung) gas is culturally attractive. Biogas has not had the same impact in Pakistan and Bangladesh, where Moslems do not have the same beliefs.

Socio-economic surveys suggest that people's motives for purchasing biogas plants are varied.[3,4] The economic argument for domestic plants is weak, the financial benefits are marginal (Chapter 9). Some of the more enlightened and better educated farmers recognise the problems of deforestation, so are motivated by a social conscience to build biogas plants. Others see biogas as a status symbol, wanting a plant because it is new and different. In some areas of India and Nepal, a biogas plant offers

advantages in marriage negotiations, as a new wife will not have to work so hard in her husband's home.

Once rural women get used to biogas and overcome their fear of a new technology, they usually like it very much. It saves them the hard work and time required to collect and prepare other fuels, such as cutting firewood or moulding cattle dung and crop wastes into lumps for drying. Biogas is also much cleaner to use: cooking utensils, clothes and the whole kitchen are free from soot and smoke and the smell of burning. A few people complain that some foods lack the characteristic flavour that is imparted when they are cooked over burning cattle dung,[3] but, in general, biogas technology is seen by rural women as a real benefit to them in their hard lives.

The main reason for many farmers wanting to build a biogas plant is persuasion by extension workers. In China, especially, many people had become so used to following the lead of the revolutionary cadres that they agreed to build biogas plants, too. In India, the biogas extension workers are often involved in other extension work. Many farmers wanting help in other areas, such as getting supplies of fertiliser or high-quality seed, agree to build a biogas plant to help the extension agent fulfil his quota for plant sales.

12.4 Staff motivation

One of the problems faced by extension agencies with staff working mainly in the field is the management of these people. Unsupervised young field agents can spend time sitting in tea shops rather than making the effort to go out to inaccessible villages to meet farmers, who are probably away working in their fields. Even highly motivated agents can achieve very little if they have to travel long distances to meet the relatively few people who are able to afford loans for domestic plants.

Many agencies have incentive schemes, such as the offer of a bonus for each biogas plant sold. These need to be carefully administered, especially to avoid jealousy between different groups of staff. Construction staff can also be offered incentives to sell plants to people coming to visit new plants out of curiosity. In Nepal, these bonuses were even extended to bank staff, as they often had to visit farmers in connection with loans for other projects.

Money should not be the only bonus for staff. Effective training in biogas should include all the arguments for the use of biogas technology, so that people are inspired by a concern for the environment and a conviction that their work could have a beneficial effect. The organisational structure should allow staff to see different aspects of the work and include prospects for advancement for those who work hard and effectively.

12.5 Political aspects of community biogas

The cooperative aspect of community plants should not be heavily emphasised in the publicity of a biogas programme. The idea of cooperatives has a political flavour: right-wing governments are suspicious of the concept and left-wing governments often have a fixed idea of how they should be organised. In Nepal, cooperative concept had a poor image because previous attempts had not been very successful, including the Farmers' Cooperative Bank, the forerunner of the ADB/N. The reasons for the failures were usually based on preconceived ideas of the way cooperatives should be organised. These ideas were applied to rural groups without adapting organisational structures to the cultural situations of the people involved.

When a community project is set up it is important to involve local politicians. As far as possible local decision-making structures should be used when making plans for the project. Community leaders can be given a place on planning committees, even though these positions may only be honorary, with little real influence. While the winning-over of local leaders may be a time-consuming task at the beginning of the project, their support may save time later. Other local people will be much less suspicious of requests made by staff involved in the project and many potential problems may be averted by local political support.

Successful projects attract a lot of interest and many people, especially the local politicians, try to take some of the credit for the success. The opposite is true for unsuccessful projects, where politicians try to find someone else to take the blame. The Madhubasa project in Nepal (Chapter 10) gained a great deal of interest, especially from the Department of Agriculture. The Minister of Agriculture became involved, resulting in visits by many high officials to the village. Articles about the project appeared in national newspapers and even the King of Nepal made a visit, hovering over the village in his helicopter. This type of interest and publicity can be used to encourage similar projects elsewhere.

The key person in a community project is the extension worker, who needs to be highly motivated to work with villagers and motivate them. Financial incentives are seldom enough to motivate these people; they need a philosophical or religious drive to make them leave the benefits that their education has given them to go and spend time in villages. The SFDP approach, inspired by FAO, of using community projects as the basis for the motivator to gain material towards a higher degree (eg. a Ph.D. in sociology) proved effective. Other rural workers have been inspired by the philosophies of Mahatma Gandhi or Mao Tse-Tung. People inspired by a Christian commitment to community and the sharing of resources have also proved good motivators. The right selection and training of these motivators is one of the most important factors in the success of a community projects.

APPENDIX 1
Basic Building Techniques

It is important to select a suitable site for a biogas plant (Chapter 5). Sufficient building materials should be available close to the site before work is started. The site is first cleared and levelled before the positions of the digester and slurry inlet and outlet are marked out with pegs in the ground. A datum level should be marked with pegs and string, in a way that allows measurements to be made from it during excavation and construction.

Excavating digester pits

Most biogas plants are built in a hole in the ground. If the soil is strong the digester pit can be dug and lined with masonry or cement plaster. Building gauges and templates are helpful to define the shape accurately. A simple building gauge to check the diameter of a circular hole is a length of rope looped around a pipe held in the centre of the hole with rope and pegs (Fig. I.1). Masonry walls need to be supported by packing the space between each course and the sides of the hole with earth and ramming it firm, dampening the soil with water if necessary.

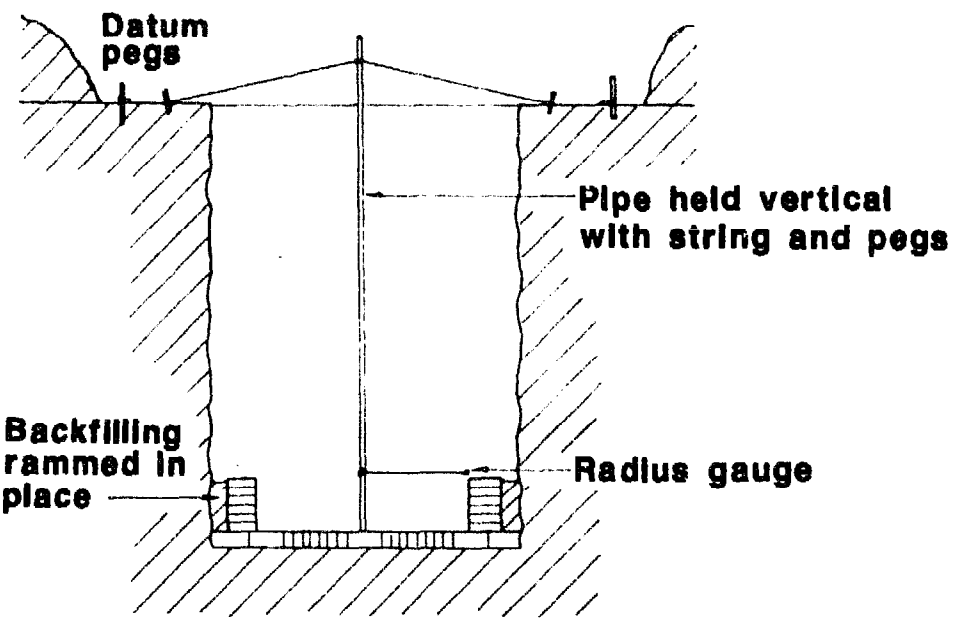

Figure I.1. *Building gauge used for cylindrical pit*

If the soil is weak and liable to fall into the hole the sides need to be supported as it is dug. A technique used in building wells can be adopted for floating drum and fixed dome plants. The lining of the pit is made close to where the pit is to be dug, usually of reinforced concrete or ferrocement rings. Alternatively spun concrete pipes can be purchased. These rings are placed, one by one, above the hole, which is excavated from within the lining. As earth is removed, the lining sinks into the hole, supporting the walls. Long troughs, for extended dome, bag and tent digesters could be made in a similar way, using precast concrete sections sunk into the ground to form walls. Internal struts of steel or reinforced concrete would be required to support these walls, when the earth is removed from inside the digester pit.

Building materials

The main building materials for a biogas plant are brick or stone masonry and concrete. Sheets of plastic or rubber are also used in bag and tent plants. Materials affected by moisture, such as unburnt brick and wood, are not suitable.

Bricks should be fired and of good quality. Porous bricks may leak slurry, so a wall built of them may need to be coated with cement plaster. Stone walls need more cement mortar, but can be used where bricks are not available. The stones should be free from soil.

Sand used in mortar and concrete must be free from vegetable matter and mud. Dirty sand can be washed before it is used. Each batch of sand is placed in a container (eg. a wheelbarrow) and water flushed through it. If the sand is fine, or has mica in it, more cement may have to be used to ensure a strong mortar. A 'bag' of sand (usually an empty cement bag) contains about 35*l* and weighs 50kg to 60kg.

The broken stones and gravel used as aggregate in concrete should be between 5mm and 25mm in size. They can be screened by passing them through wire netting with the appropriate sized holes. The stones should be free of soil and other matter.

The Portland cement used for mortar and concrete should be as fresh as possible. Cement that has become wet and lumpy is useless, so bags should always be stored in a dry place.

Cement mortar should be of the same strength as the bricks or stones it binds together. A ratio of 1:6 cement:sand is average, but the ratios can vary between 1:4 and 1:9. Ideally material quantities should be measured by weighing, using a bucket and a spring balance. In practice, measurement by volume is easier and is usually adequate. The density of cement is 1.44kg/*l* and that of sand, between 1.44 and 1.76kg/*l*.

Concrete used in these designs is normally a 1:2:4 mix of cement, sand and aggregate, although a 1:3:3 mix gives a more compact concrete for

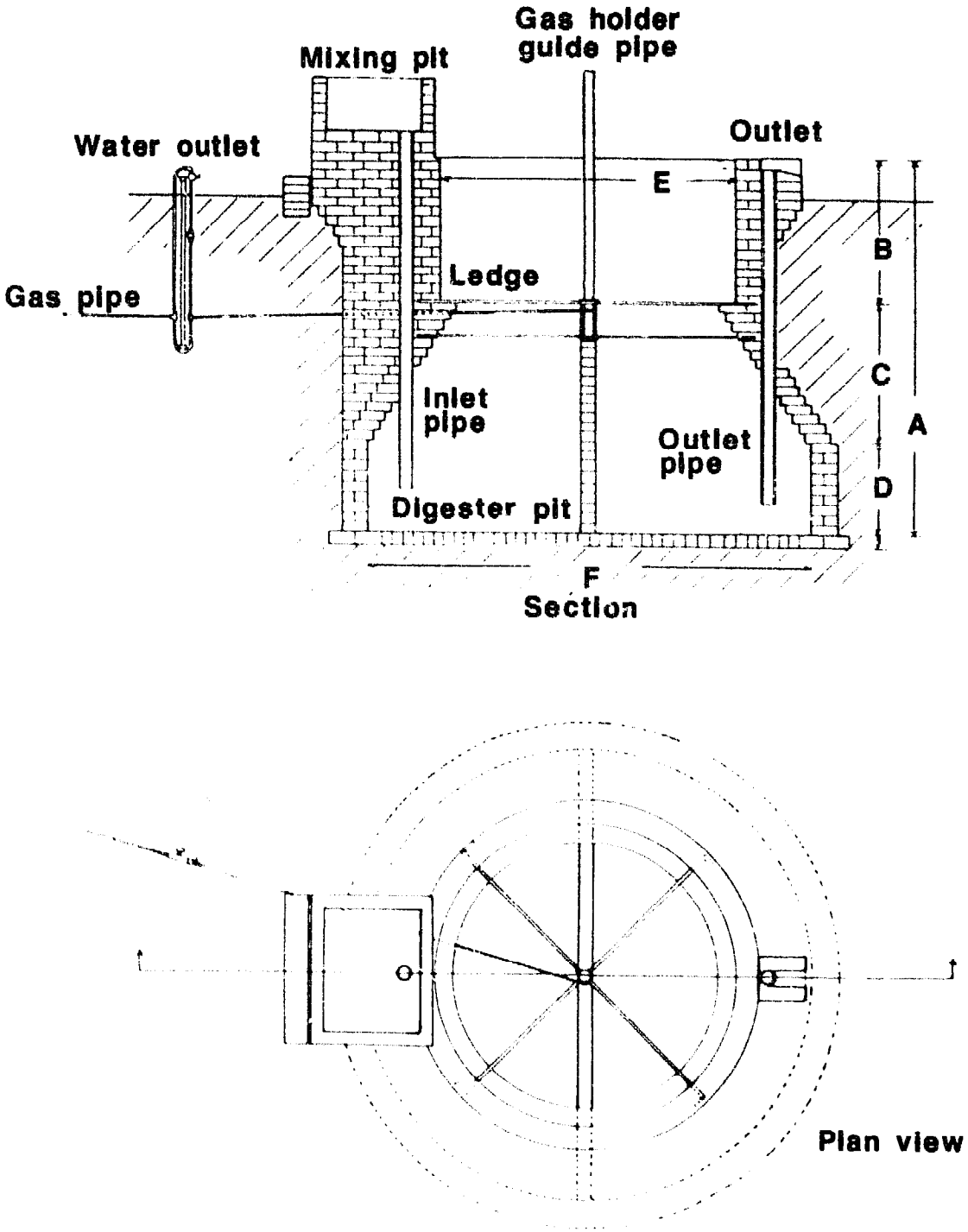

Figure I.2. *Floating drum design SD100, 200, 350 & 500 (Taper)*

cement dome plants. As the concrete is laid or put in a mould, it must be carefully compacted to avoid air pockets (6 per cent air voids in concrete means a 20 per cent loss in strength).[1] The concrete must be well mixed, with just enough water to give a good consistency. Once it is put in place the concrete should be cured in a damp atmosphere for seven days before any load is placed on it, by covering it with wet sacks or water. Small sections can be cured under water in a pond or stream.

Flat concrete pieces, such as reservoir covers, need reinforcement. 6mm steel rods, spaced at 120mm in 50mm-thick concrete are adequate. Transverse rods may be spaced at wider intervals (200mm to 300mm).

The plaster used to line digester pits is 25 to 30mm thick. It is usually applied in three layers, of 1:6, 1:4 and 1:3 cement to sand mixes, respectively.[2] If the soil is poor the first coat can be reinforced with wire mesh (as ferrocement). The mesh is held to the soil surface with wire staples, while the plaster is applied.

Details of the floating drum design

The floor of the floating drum design can be made of brick or concrete (Fig. 1.2). The inlet and outlet pipes (100mm diameter) are usually made from spun cement, reinforced with fibre, such as asbestos. A central dividing wall is often built between the inlet and outlet pipes to stop slurry passing directly between them. A ledge (300mm wide) is made below the gas drum to support it when it is empty and to deflect gas into the drum. Sizes and typical material quantities used in Nepali designs are given in Tables I.1 and I.2.[3]

The gas drum is made from steel sheet welded to a frame made from angle iron. The roof should slope outwards so rainwater does not collect. Handles around the drum make it easier to carry and to rotate when in place on the plant. The welds can be checked by filling the inverted drum with water and inspecting it for leaks. The completed drum should be carefully cleaned and painted to avoid rust. The black mill-scale on the steel sheets can be removed with rotary wire brushes or sand blasting. A coat of metallic anti-saline primer should be put on as soon as possible after cleaning, followed by two coats of bituminous paint. The top coat of paint

Table I.1 Dimensions of taper type drum plants

Dimension (mm)		*Let.*	*SD100*	*SD200*	*SD350*	*SD500*
Digester Volume	(m^3)		7.1	13.0	24.0	34.0
Drum Volume	(m^3)		1.7	3.4	6.0	8.5
Mixing Pit Volume	(m^3)		0.12	0.22	0.47	*
Depth of Digester		A	2 520	3 090	3 300	3 770
Depth Deflect. Ledge		B	1 030	1 270	1 270	1 500
Depth Taper Section		C	910	910	1 220	1 220
Depth Lower Section		D	580	910	810	1 050
Diam. Upper Section		E	1 600	2 000	2 600	2 900
Diam. Lower Section		F	2 500	2 900	3 900	4 230

Notes: * The SD500 plant usually uses a mixing machine.

can be applied after the drum has been transported to the site for the biogas plant, to cover any scratches.

Details of the fixed dome design

A pilot hole is usually first dug in the ground and covered with boards before the mud mould for the dome is made (Fig. I.3). A template made

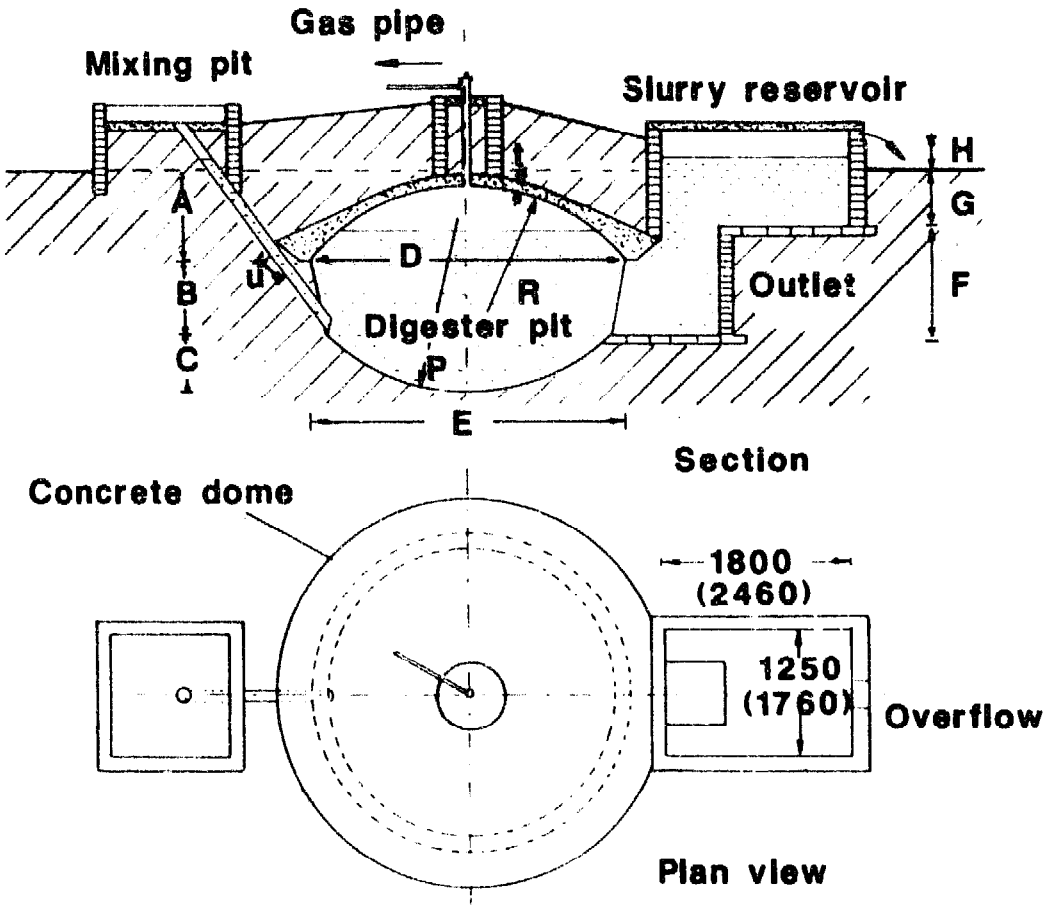

Figure I.3 *Details of fixed dome design*

from welded steel rod is used to shape the mould. If the soil is weak the foundations for the collar of the dome should be increased in area to spread the load. Sizes and typical material quantities used in Nepali designs are given in Tables I.3 and I.4.[3]

The radii of the dome and floor are chosen so that they can each be checked with a gauge made from a length of string attached at the centre of the other. The gas outlet pipe can have holes drilled in the bottom edge to allow this string gauge to be fastened to it.

The sizes and typical material quantities for extended dome plants are given in Tables I.5 and I.6 (Fig. I.4).

Table I.2 Material quantities for drum plants

Plant Type	*SD100*	*SD200*	*SD350*	*SD500*
Cement kg (bags)	630 (14)	990 (22)	1,530 (34)	2,025 (45)
Sand *l* (bags)	2,450 (70)	3,850 (110)	5,950 (170)	7,875 (225)
Bricks	3,000	5,000	7,500	10,000
Drum Weight (kg)	132	246	392	454
Cement Pipe (m)	4.8	7.1	5.4	7.4

Notes: If stone masonry is used, the quantities of cement and sand should be doubled.
The inlet pit should be 300 mm above the slurry outlet.
Space should be left at the bottom of the inlet and outlet pipes to allow debris (soil, stones) to collect.
The top of the plant should not normally protrude more than 500 mm above the ground level. It is possible to make the walls higher out of the ground, if the bricks are reinforced with bands of galvanised wire tightened around each course.

Table I.3 Dimensions of concrete dome plants

Dimension (mm)	*Let.*	*CP10*	*CP15*	*CP20*
Dome Volume (m^3)		3.3	5.6	5.6
Digester Volume (m^3)		7.3	9.7	14.1
Working Volume (m^3)		9.0	12.5	16.9
Reservoir Volume (m^3)		1.3	2.1	2.9
Mixing Pit (m^3)		0.22	0.34	0.43
Dome Outside Depth	A	800	920	920
Dome Inside Diameter	D	3,100	4,000	4,000
Dome Radius of Sphere	R	2,000	2,800	2,800
Dome Shell Thickness	t	60	80	80
Collar Thickness	u	250	300	300
Depth Conial Section	B	780	270	785
Depth Digester Floor	C	580	1,090	875
Radius Spherical Section	P	2,100	1,200	2,500
Inside Diameter	E	2,900	3,800	3,800
Res. Overflow to datum	H	240	160	120
Res. Datum to Floor	G	560	680	630
Res. Floor to Outlet	F	1,060	630	1,195

Note: The turret should be at least 750mm high to ensure enough earth is placed on the dome to hold it down against the gas pressure inside.

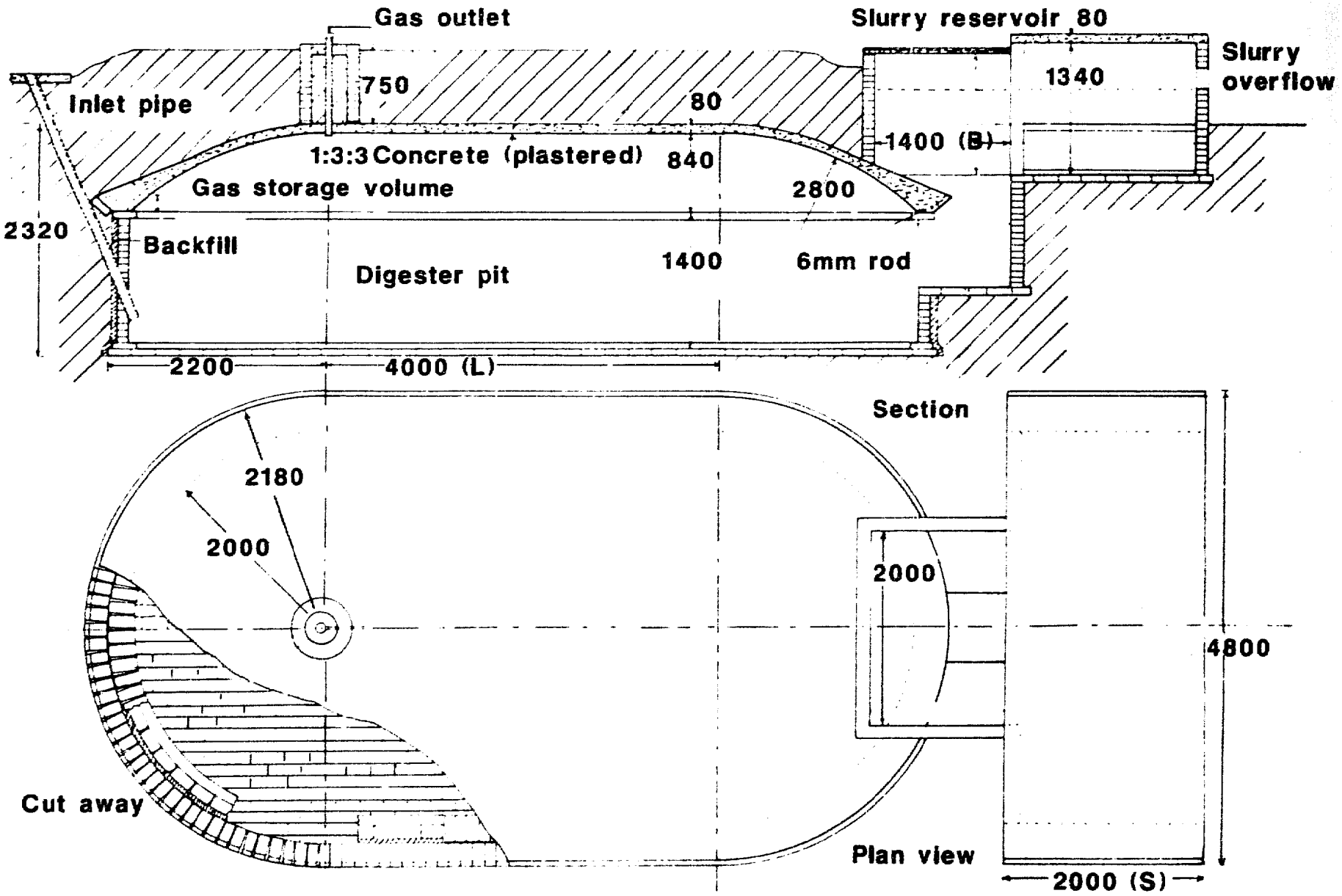

Figure I.4 *Extended dome biogas plant (EP50)*

Table I.4 Material quantities for concrete dome plants

Type of Plant		*CP10*	*CP15*	*CP20*
Cement	kg (bags)	690 (14.5)	1,130 (23.5)	1,180 (26)
Sand	l (bags)	1,630 (49)	2,490 (73)	1,830 (82)
Aggregate	l (bags)	640 (19)	1,300 (38)	1,380 (40)
Bricks		1,300	1,500	1,900
Cement Pipe	(m)	2.5	3.0	3.0
Steel Rod	(6mm)	40m	50m	75m
Acrylic Paint	(l)	2	3	3

Table I.5 Dimensions for extended dome plants

Plant Type	*L (m)*	*S (m)*	*B (m)*	*Dome Vol. (m^3)*	*Digester Vol. (m^3)*
EP20	0	0	2,320	5.4	17.5
EP35	2,000	1,000	1,800	10.0	28.7
EP50	4,000	2,000	1,400	14.6	39.9
EP65	6,000	3,000	1,400	19.3	51.1
EP80	8,000	4,000	1,400	23.9	62.3
EP95	10,000	5,000	1,400	28.5	73.5

The reservoir pit is large and deep enough for an animal or a child to drown in so it must be covered. Reinforced concrete pieces or wooden boards or slats can be used. These covers also prevent water evaporating from the slurry, which may otherwise become too dry.

Table I.6 Material quantities for extended dome plants

Materials		*EP20 Plant*	*2 m Tunnel (T)*	*EP50 (EP20 + 2T)*	*EP95 (EP20 + 5T)*
Bricks		3,000	1,100	5,200	8,500
Cement	kg	950 (22)	700 (16)	2,350 (54)	4,450 (100)
Sand	l	2,400 (70)	1,500 (44)	5,400 (156)	9,900 (285)
Aggreg	l	1,400 (41)	1,200 (35)	3,800 (110)	7,400 (212)
Steel Rod	m	130	0	100	100
Cement Pipe	m	2.7	0	2.7	2.7

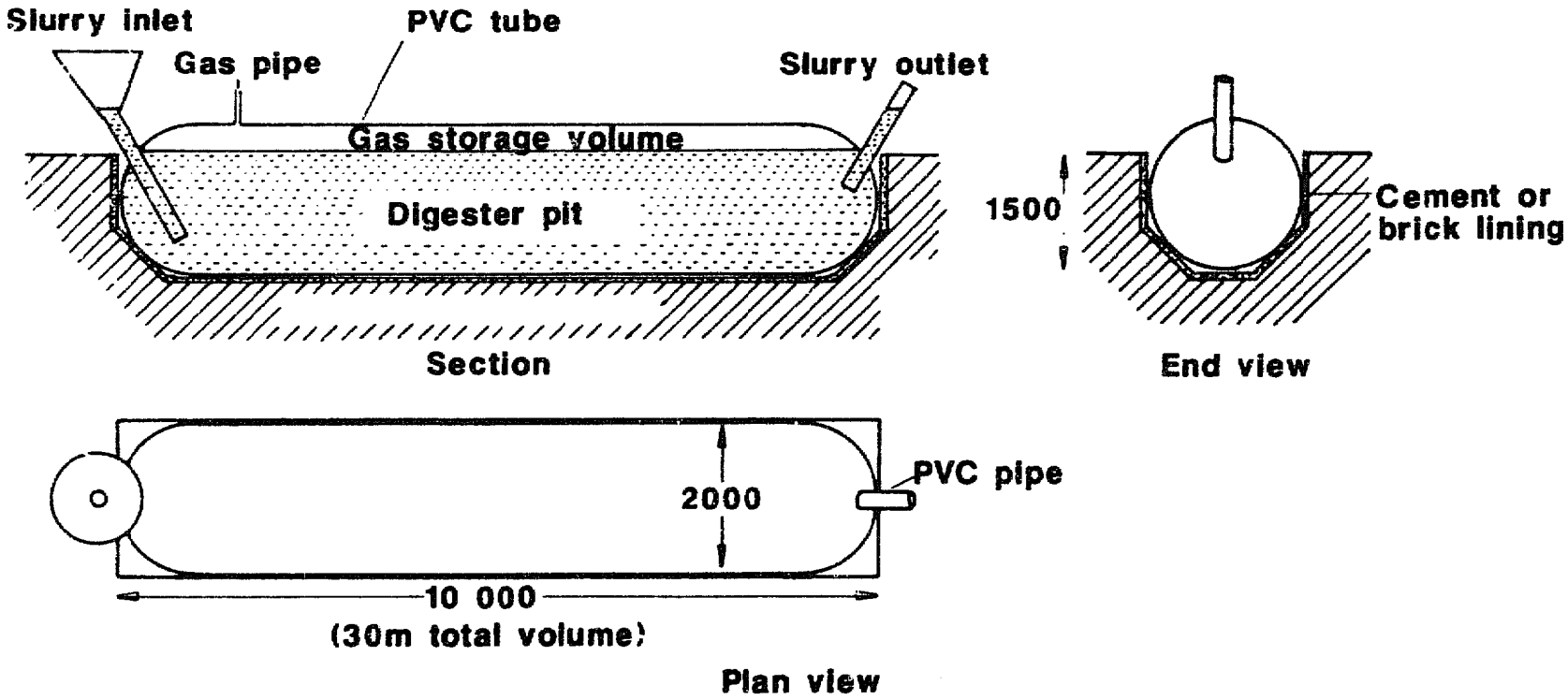

Figure I.5 *Bag digester details*

Details of bag and tent digesters

A bag digester needs a smooth trench in which to lie, that will support the sides of the bag and the weight of slurry within it (Fig. I.5). The walls of the trench should be free from stones or any sharp objects that may puncture the bag. A smooth cement-plaster-walled trench is suitable, although wire mesh reinforcement would be required if the soil were weak. The shape of the trench can be checked using a template made to the shape that the bag will form when full of slurry.

A tent digester needs a similar trench, although it must be made to a higher standard to ensure the slurry does not leak out. The edges of the trench need to be carefully shaped to suit the system adopted for attaching the edges of the plastic tent. There are many different ways in which the tent can be fixed down. One effective way is to fold the tent edges around metal or plastic pipes which are set into grooves in the digester wall and clamped in place (Fig. I.6). More details, such as typical material quantities and costs may be obtained from the manufacturers of the plastic sheeting.[4,5]

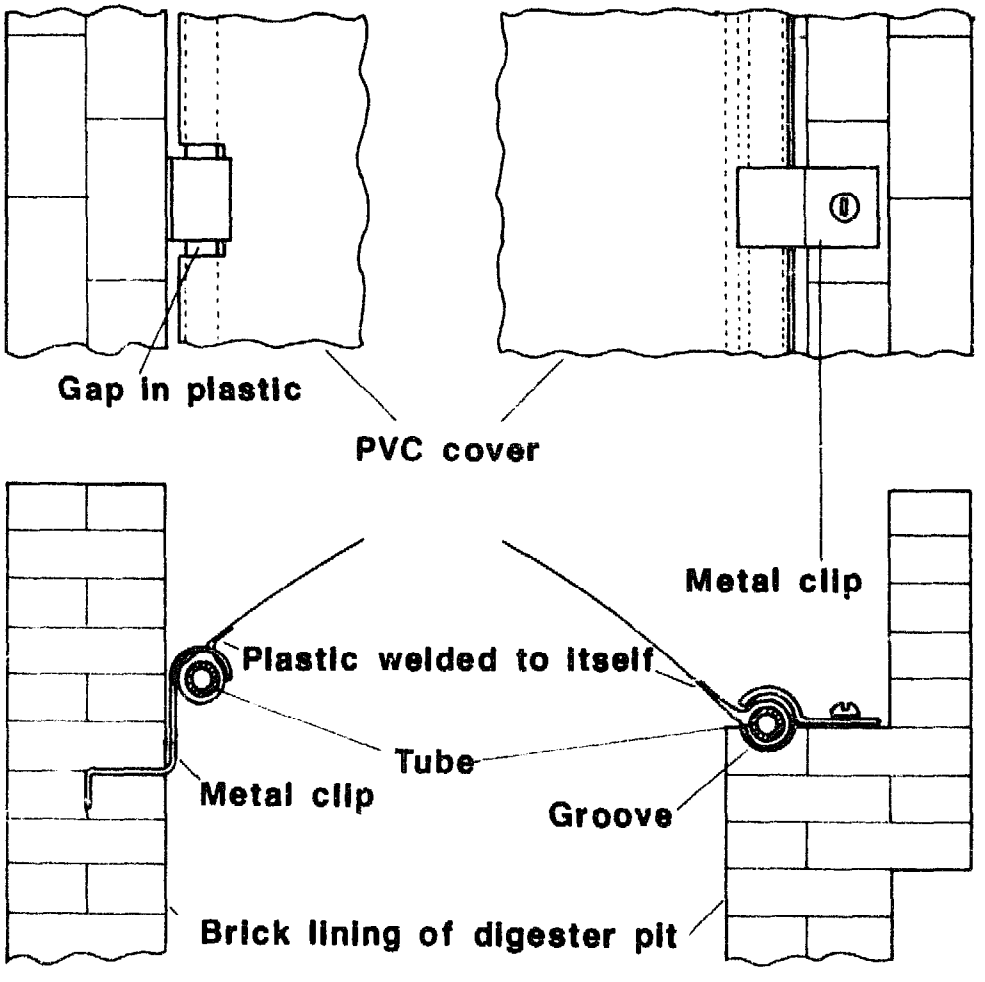

Figure I.6 *Clamps for tent design*[6]

APPENDIX 11
Gas Appliance Design

The design of systems to distribute and use biogas has received much less attention than the design of biogas plants in many biogas programmes. The layout and installation of pipework and the design and manufacture of effective and efficient stoves, lights and engines is important. An efficient stove, for example, allows a limited supply of biogas to be used to the best advantage.

Gas pipes

Gas lines need to be fitted with water drains at appropriate points (see Chapter 5). Two designs were used in Nepal, the 'T' trap (Fig. II.1) for shallow gas lines and the 'U' trap for pipes laid deeper in the soil (Fig. II.2)

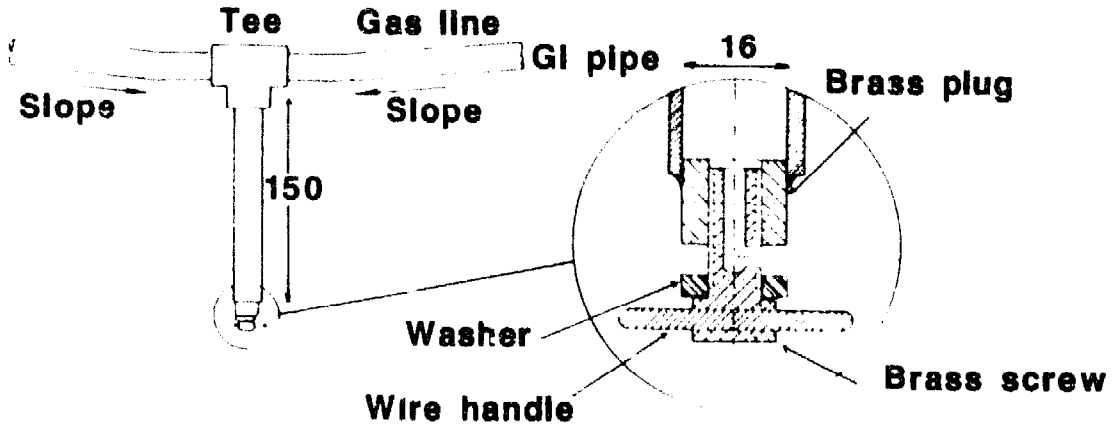

Figure II.1 *'T' Type water trap.*

The pressure drop along a gas line can be calculated using the following equations.[1] If a pipe of diameter: D (metres) has a gas flowing down it at a rate: Q (m^3/sec = *l*/min/60,000), the velocity of the gas (u, m/sec) is:

$$u = \frac{4.Q}{\pi.D^2} \text{ m/sec.} \qquad \text{(II.1)}$$

If the gas pressures at two points along the pipe (L metres apart) are: p_i and: p_z (mm WG), the pressure difference ($\Delta p = p_i - p_z$) is given by:

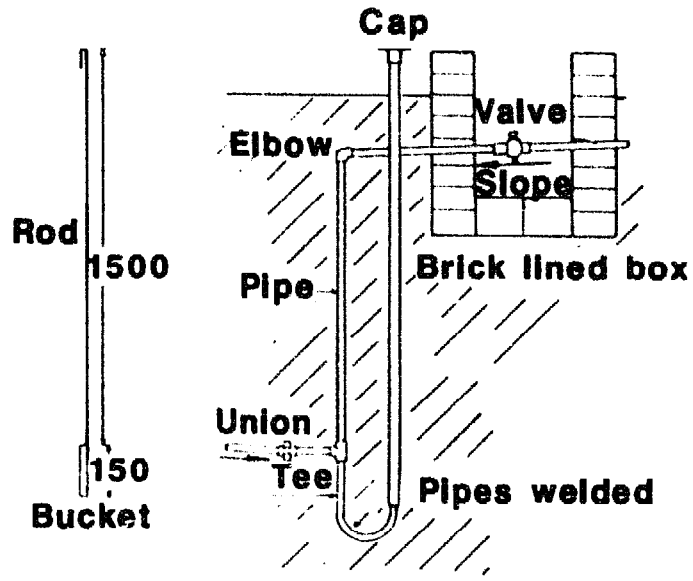

Figure II.2 *'U' type of water trap.*

$$\Delta p = \frac{f.L}{D.g.}.u^2.\rho \qquad \text{(II.2)}$$

where: f = the friction factor.

The friction factor (f) depends on the Reynolds number: Re:

$$Re = \rho.D.\frac{u}{\mu} \qquad \text{(II.3)}$$

where: ρ = the density of biogas (1.0994 kg/m^3 at 30°C)
μ = the viscosity of biogas (1.297×10^{-5} kg/m/sec)

If the Reynolds number is less than 2,000, the flow is laminar:

$$f = \frac{64}{Re} \qquad \text{(Hagen–Poiseulle formula)}^2 \qquad \text{(II.4)}$$

If the Reynolds Number is more than 4,000, the flow is turbulent:

$$f = \frac{0.316}{\sqrt{\sqrt{Re}}} \qquad \text{(Blasius formula).}^2 \qquad \text{(II.5)}$$

In the transition region, with a Reynolds number between 2,000 and 4,000, f has a value between those given above.

Graphs of flow for two values of Δp (10mm WG—for a drum plant—and 50mm WG—for a dome plant) are shown in Figures II.3 and II.4.

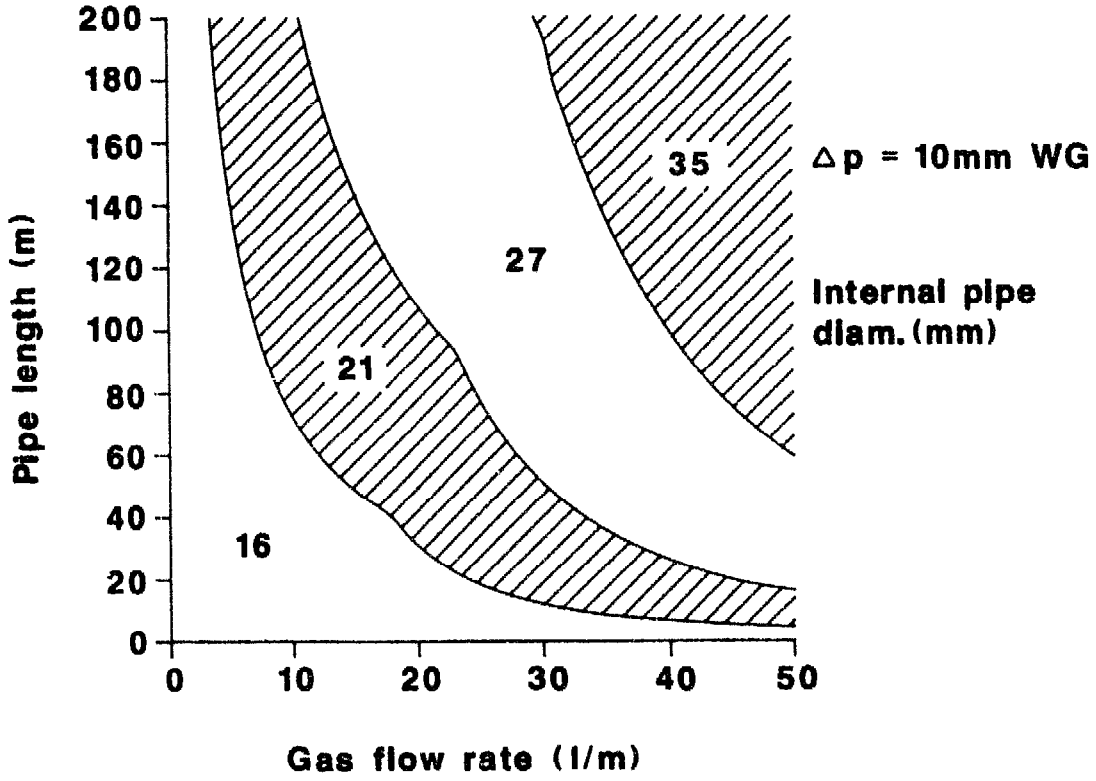

Figure II.3 *Gas flow rate verses pipe length for drum plants*

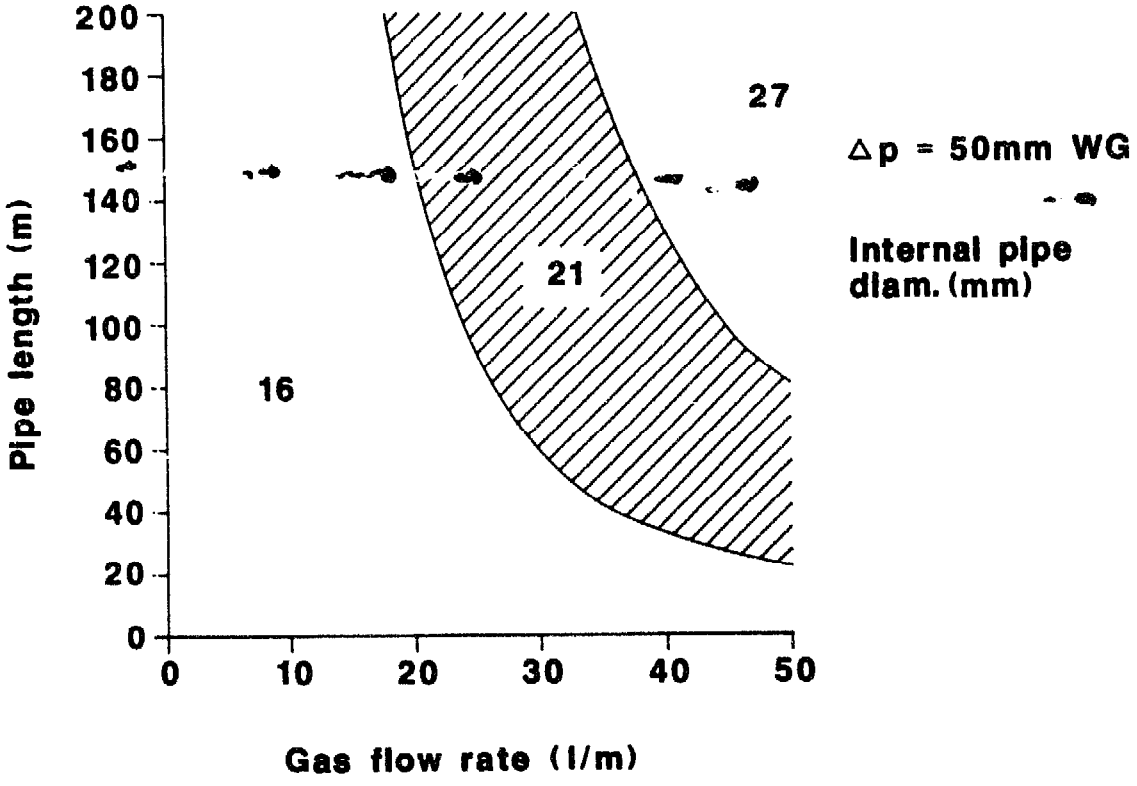

Figure II.4 *Gas flow rate verses pipe length for dome plants*

Biogas burner design

A gas burner supplies heat by burning a fuel gas in air, 4.184kJ of heat will raise the temperature of 1*l* of water 1°C. 1*l* of biogas, burnt with the optimum of air, will give 21.5kJ of heat, so a biogas burner using 7.5*l*/min would give 161kJ/min. This should heat 1 litre of water in 2 minutes from 20°C to 100°C. In practice, it takes 4 minutes, as some of the heat is lost. The DCS stove is about 55 per cent efficient, which means 45% of the heat is not used.

A medium-sized gas burner (7.5*l*/min) and two gas lamps (2 × 2.4*l*/min) are to be used in a house 38m away from a gas plant. The maximum flow rate is then 12.3*l*/min. Choosing a 16mm pipe:

$$u = \frac{4 \times 12.3 \times 10^{-3}}{n \times 0.016^2 \times 60} = 1.02 \text{ m/sec.}$$

Taking a drum plant, with pressure 70 mm WG, the maximum pressure loss (Δp) is 10 mm WG.

$$Re = \frac{1.099 \times 0.016 \times 1.02}{1.297 \times 10^{-5}} = 1412$$

$$Re < 2000, \text{ so } f = 64/Re = 0.045$$

$$L = \frac{2 \times 10 \times .016 \times 9.81}{.045 \times 1.02^2 \times 1.0994} = 61.0 \text{ metres}$$

Since 61m is longer than 38m, a 16mm pipe can be used for the pipeline.

Example II.1 Use of gas pipe formulae.

The rate at which gas is delivered to the stove (Q, *l*/min) depends on the size of the gas jet (Diameter: d_o, Area: A_o, m^2) and the gas pressure (p, mm WG) (Figure II.5):

$$Q = 3.90.C_d.A_o.\sqrt{\frac{p}{s}} \times 60{,}000 \qquad \text{(II.6)}$$

Where C_d is the discharge coefficient of the jet (0.73) and s is the specific gravity of the gas (0.94)

The rate at which heat is supplied to the burner (H, kJ/sec or kW) is:

$$H = 3900.\ C_d.A_o.W.\sqrt{p} \qquad \text{(II.7)}$$

where W is the Wobbe number for the gas (22.2kJ/*l*).[3]

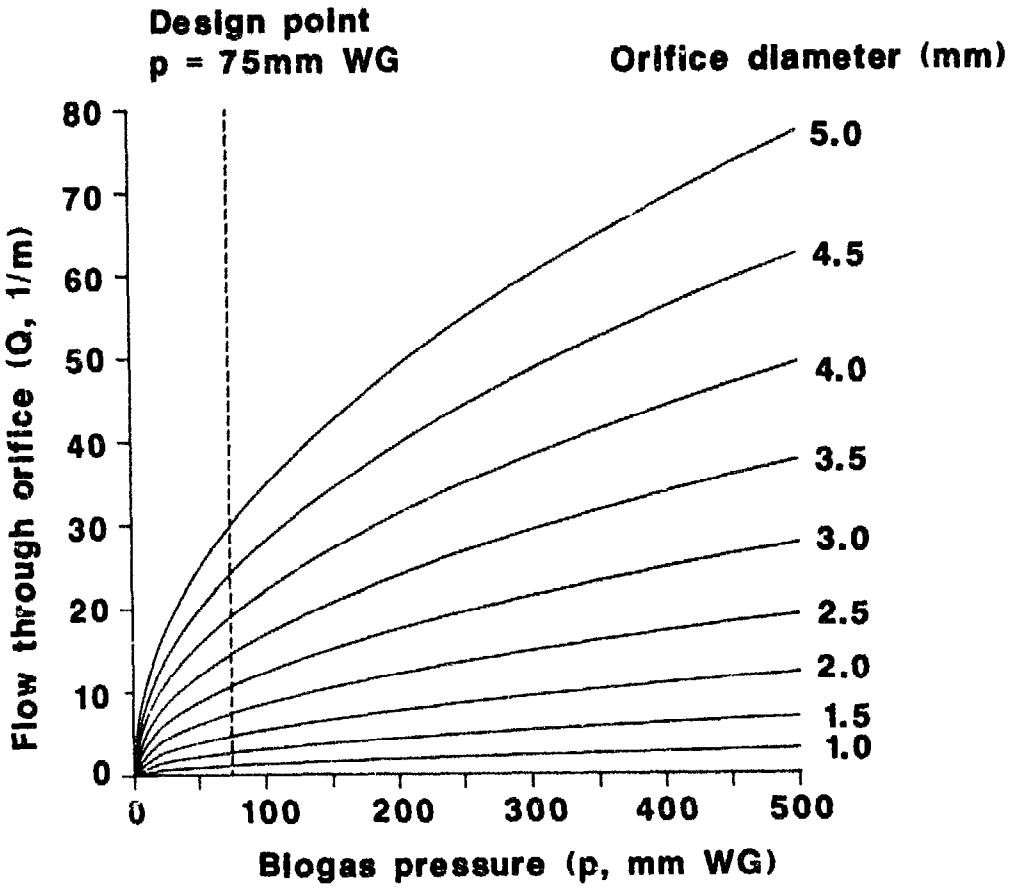

Figure II.5 *Gas flow vs gas pressure for various jets*

Table II.1 Properties of biogas.[3,4,5]

Biogas: assumed 58% CH_4 and 42% CO_2 saturated with water vapour at 30°C and standard pressure. (Range of values)

Calorific value	21.5kJ/l	(20.1 to 25.9)
Effective molecular weight	27.35/	(24 to 29)
Density	1.0994 kg/m^3	(0.96 to 1.17)
Specific gravity	0.94	(0.82 to 1.00)
Viscosity	1.297×10^{-5} kg/sec/m	
Optimum air to fuel ratio	5.5:1 (15% biogas)	
Flammability limits	9% to 17% biogas in air	
Wobbe number	22.2 kJ/l	
Burning velocity	0.25 m/sec in air	

The Wobbe number is a measure of the heating effectiveness of the gas. Biogas (22.2) is less effective than natural gas (50.7) and bottled gas (80) The heat available is the heat supplied times the efficiency of the stove. If a

stove designed for natural gas is to be used for biogas, the area of the jet must be almost doubled (50.7/22.2). A stove designed for bottled gas must have a jet area about 3.6 times (80/22.2) larger.

The DCS ring burner has a jet size (d_o) of 2.5mm.

$$A_o = \frac{\pi}{4} \times 0.0025^2 = 4.91 \times 10^{-6}\ m^2$$

$$Q = 3.9 \times 0.73 \times 4.91 \times 10^{-6} \times \sqrt{\frac{75}{0.94}} \times 6 \times 10^4$$

$$= 7.46\ l/min \text{ at 75mm WG pressure.}$$

$$H = 3900 \times 4.91 \times 10^{-6} \times 22.2 \times \sqrt{75}$$

$$= 2.69\ kW = 161\ kJ/min.$$

which is: 161 × 0.55 = 88.6 kJ/min available heat, since the stove is 55% efficient.

Example II.2 Gas and heat flow from DCS stove

The value for the discharge coefficient (C_d = 0.73) was found by experiment. This value may vary between different jets of the same design, if burrs and surface irregularities affect the shape of the hole.

Biogas must be mixed with air to burn. For complete combustion, the 'stoichiometric air requirement' is 5.5 volumes of air to one volume of biogas. One volume of methane requires 2 volumes of oxygen:

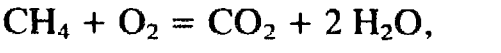

$$CH_4 + O_2 = CO_2 + 2\ H_2O,$$

and there is 58 per cent (approx) methane in biogas and 21 per cent oxygen in air.

The gas stream, as it comes from the jet, enters a 'throat', where it entrains primary air through the air holes. The 'entrainment ratio' (r), the number of volumes of air entrained by one volume of gas, is:

$$r = \sqrt{s}.\left(\sqrt{\frac{A_t}{A_o}} - 1\right) = \sqrt{s}.\left(\frac{d_t}{d_o} - 1\right) \qquad \text{(Priggs formula) (II.8)}$$

where A_t and d_t are the Area and diameter of the throat.[3]

Prigg's formula holds if the total flame port area (A_p) is between 1.5 and 2.2 times the area of the throat. This ratio is approximately independent of the gas pressure and the flow rate. The primary air supply is rarely enough to give a stoichiometric mixture.

The primary aeration (r) can be varied by altering the area of the jet orifice, the area of the throat or the area of the air inlet holes. The first option is used in lamp burners. The closing of the air holes means that the

The DCS burner has a throat diameter of 16mm, giving an area of 201 mm^2. There are 20 flame port holes of diameter 5mm giving a total area of: 393 mm^2, 1.95 times the throat area.

$$r = \sqrt{0.94 \times \left(\frac{16}{2.5} - 1\right)} = 5.2,$$

which is almost a stoichiometric mixture.

Example II.3 Entrainment ratio in DCS Burner.

entrainment ratio is not constant with gas pressure and flow. A better burner design uses a tapered throat (Fig. II.6), into which the jet can be moved to give a good flame.[6]

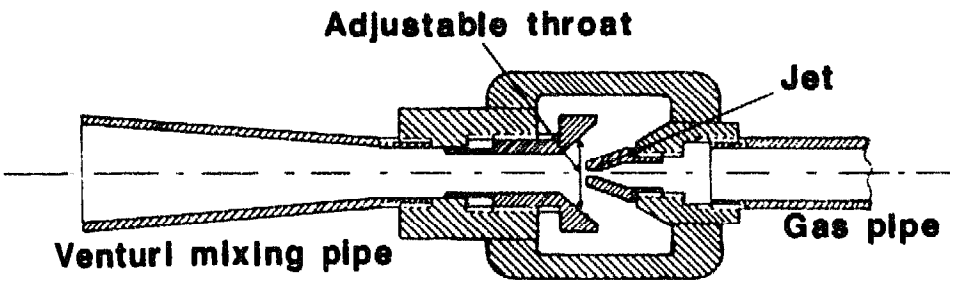

Figure II.6 *Tapered throat design of gas burner*

The mixing tube between the throat and the flame ports should be long enough to allow the gas and air to mix thoroughly (at least 10 times d_t). The mixing tube can taper outwards towards the flame ports, making a 'venturi', which can be shorter than a straight tube ($6 \times d_t$).

A gas flame consists of several regions (Fig. II.7). The preheat region,

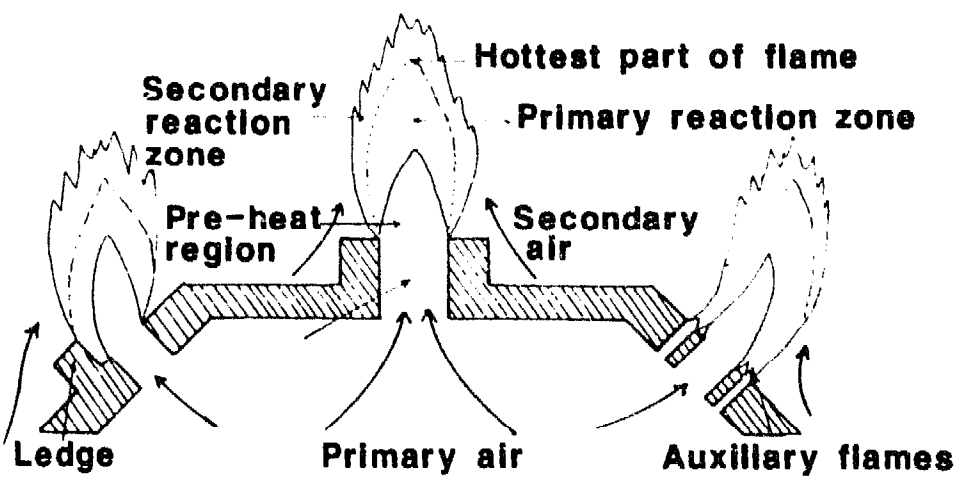

Figure II.7 *Details of gas flame and means of stabilisation*

where the gas and air are heated, is seen as a paler cone in the centre of the flame. The primary reaction zone is where gas burns with the primary air and the secondary reaction zone is where secondary air takes part in the reaction. Secondary air must have free access to the flame ports. The hottest part of the flame lies at the tip of the primary reaction zone, so the stove should be designed so the pots to be heated touch this point of the flames. If the cold surface of a pot touches the preheat region, the flame will be quenched and burn inefficiently.

Biogas has a low burning velocity (less than 0.25m/sec in air), so 'light back', the burning of the gas in the mixture tube, is almost impossible. Flame traps are therefore not needed. 'Blow off', the lifting of the flame from the ports, is a problem. The flame ports need to be close together (about 5mm apart) and be of a suitable size (5mm), so that the velocity of the mixture through the holes (v_g) is much less than the burning velocity:

$$v_g = Q_m/A_p << 0.25\text{m/sec}, \qquad \text{(II.9)}$$

where Q_m (m^3/sec) is the mixture flow rate (r.Q), and: A_p (flame port area) is in m^2.

The flame can be stabilised by surrounding the main flame port with a series of smaller holes, such as in a lamp nozzle. A second way is to provide a ledge that controls the flow of secondary air to the flame (Fig. II.7).

Gas lamp and stove parts can be made of ceramic materials such as fire-clay, fired in a kiln. One design of lamp made in China, uses a ceramic mixing tube and nozzle (Fig. II.8). Ceramic stoves have been designed and made in India. Another design was made and tested at Reading

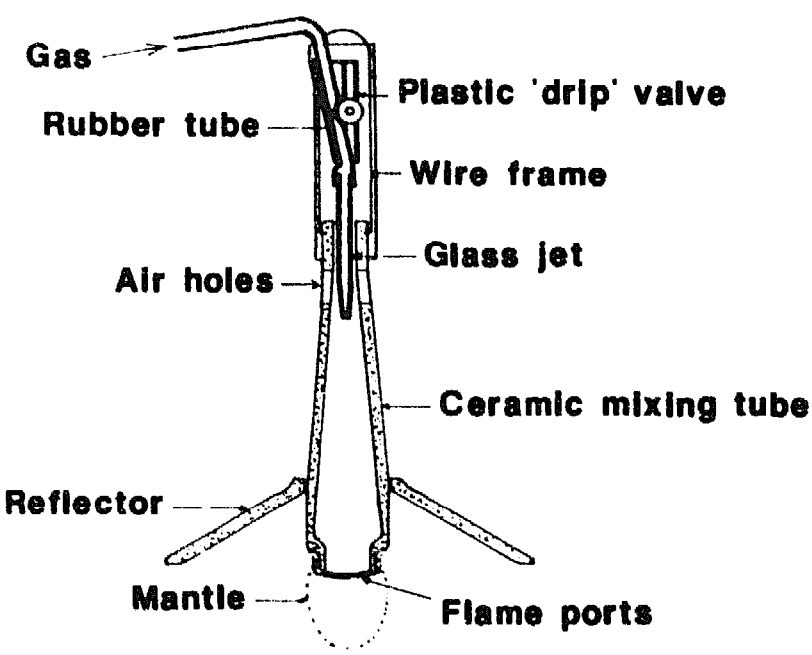

Figure II.8 *Ceramic gas lamp—made in China*

University (Figure II.9). It works well, although improvements could be made.

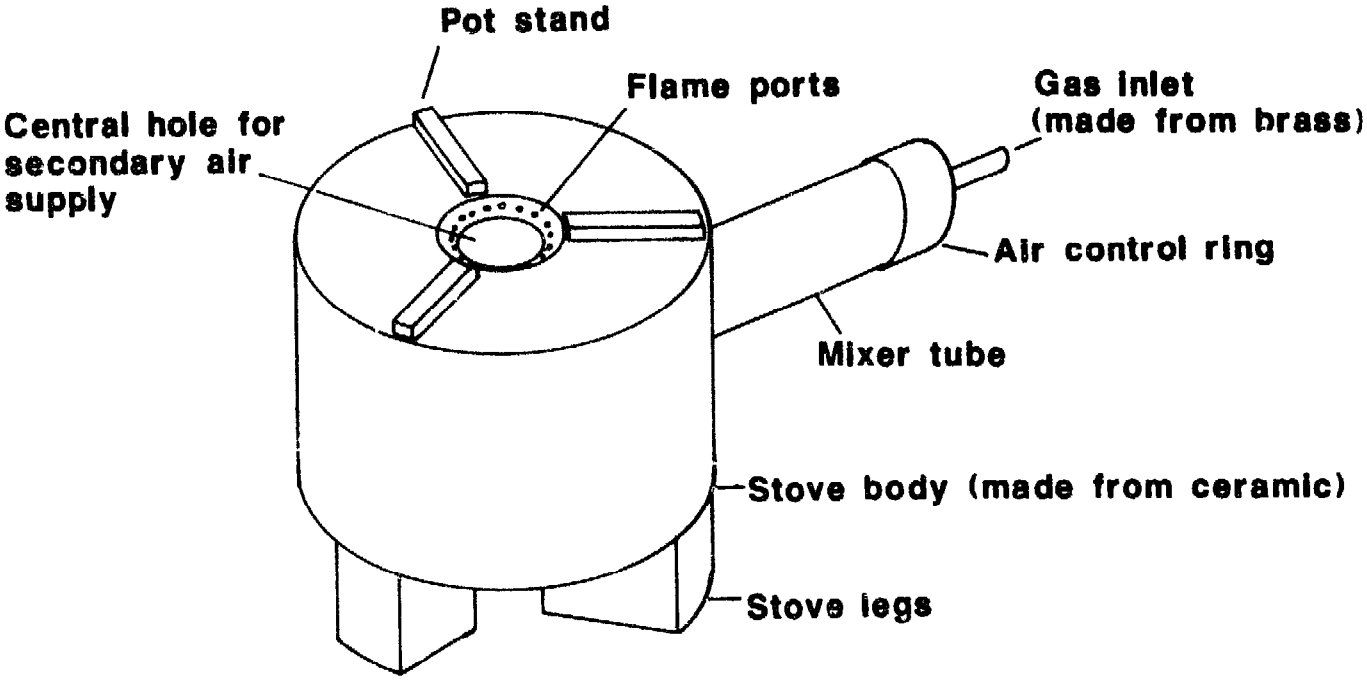

Figure II.9 *Ceramic gas stove*

Carburettors for mixing biogas and air

When a diesel engine is adapted to be a dual-fuel engine, the main alteration is the addition of a carburettor to mix the biogas and air in the correct proportions. The simplest type of gas carburettor is a mixing chamber (Fig. II.10). The pressure drop across a paper air filter sucks biogas through the gas valve during the intake stroke of the engine. This type of carburettor has been used with several types of Indian-made diesel engines and works well. Improvements could be made: for example, the engine performance could be adjusted by making the air orifice adjustable.[7]

This carburettor did not work with a Japanese engine that had a higher compression ratio than the Indian models (23:1 instead of 17:1). A paper air filter constricted the air supply to the engine; if this was replaced by an oil-soaked wire-mesh filter to improve the air supply, the pressure drop across it was too low to suck in sufficient biogas. A venturi type of gas carburettor was designed (Fig. II.11), which fitted between the air intake pipe and the air manifold in the cylinder head. As air is drawn through the ventury, the pressure at the centre is reduced, sucking biogas into the air stream.

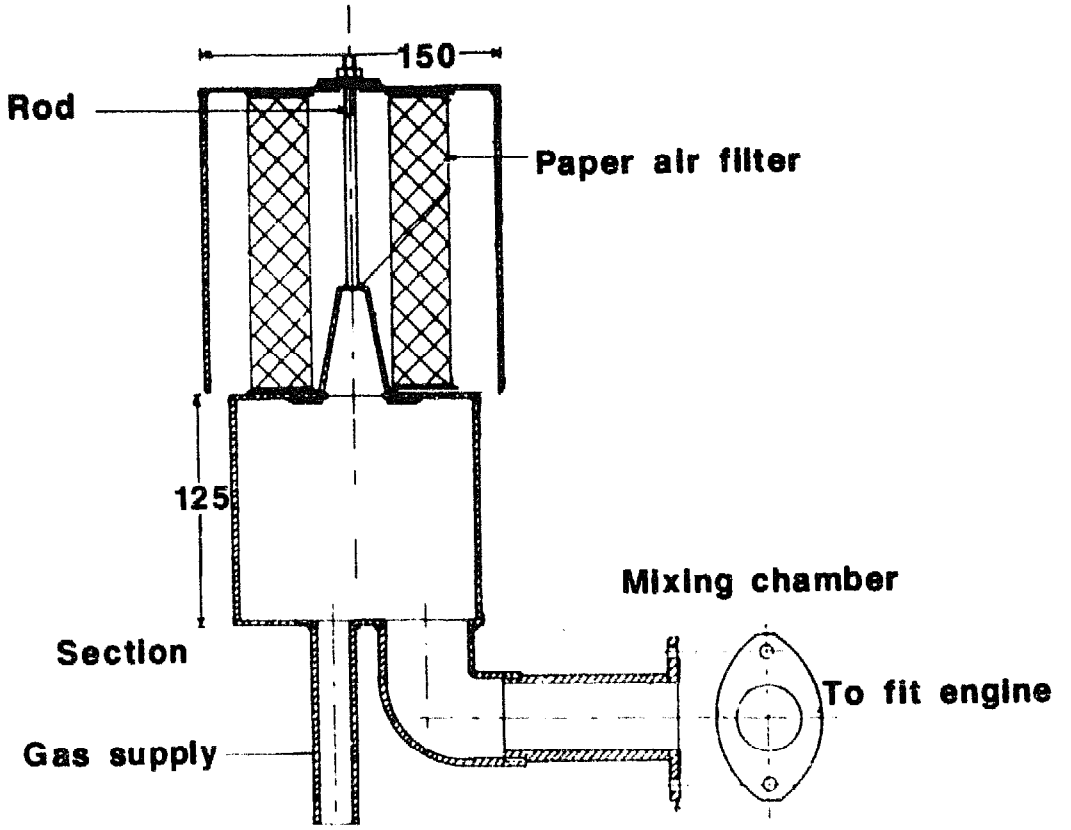

Figure II.10 *Mixing chamber type of carburettor*

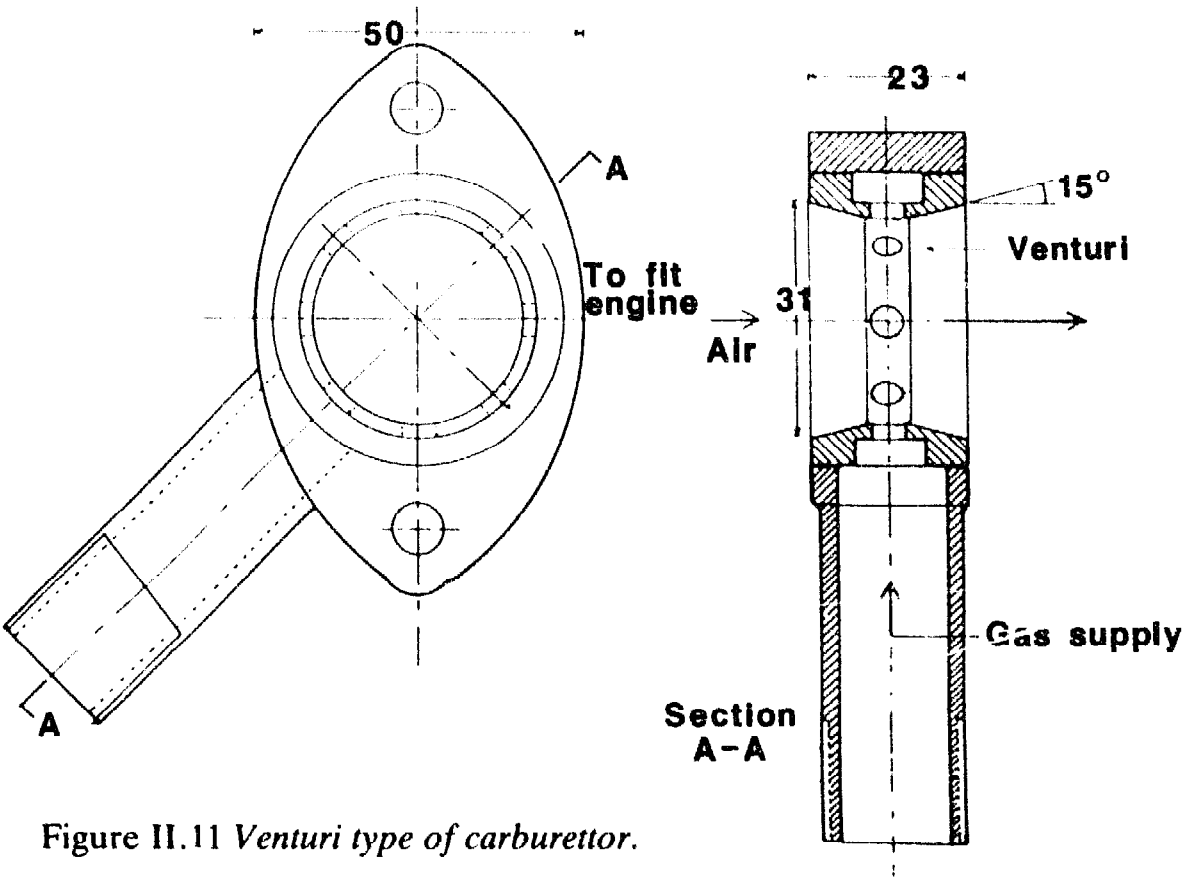

Figure II.11 *Venturi type of carburettor.*

Table II.2 Variables used in Appendix II.

A_o	—Area of gas jet	(m^2)
A_t	—Area of throat	(m^2
A_p	—Area of flame ports	(m^2)
a	—Atmospheric pressure	(10332 mm WG)
C_d	—Discharge coefficient for jet	(–)
D	—Pipe diameter	(m)
d_o	—Diameter of gas jet	(m)
d_t	—Diameter of throat	(m)
f	—Friction factor	(–)
g	—acceleration due to gravity (9.81)	(m/sec^2)
H	—Heat delivery rate for burner	(kW)
L	—Length of pipe	(m)
p	—Gas pressure at a point in the pipe	(mm WG)
Q	—Gas flow rate down pipe	(m^3/sec)
Q_m	—Flow rate of gas/air mixture	(m^3/sec)
Re	—Reynolds number	(–)
r	—Entrainment ratio for burner	(–)
s	—Specific gravity of biogas (wrt. air)	(–)
u	—Gas flow velocity	(m/sec)
v_g	—Velocity of mixture through flame ports	(m/sec)
W	—Wobbe number of gas	(–)
p	—Density of biogas	(kg/m^3)
μ	—Viscosity of biogas	(kg/m.sec)

APPENDIX III
Research Techniques

Apparatus for laboratory and full-scale tests on biogas reactors will often need to be purchased, although some can be made in local workshops. Some less-developed countries (such as India) do have their own scientific equipment suppliers, from which much of the apparatus is available. Other, more specialised, equipment must be obtained from a developed country, such as Britain or the USA.

Water baths

Suitable water baths for laboratory reactors are available from many scientific suppliers, but simple versions can be made in a local workshop.[1] Suitable containers are required in which to place the reactors: washing-up bowls are cheap and convenient. Pumps are required to circulate the water and heaters to raise the temperature (Fig. III.1). The heaters are switched on and off by thermostats, usually obtained from a developed country. A mercury-in-glass thermometer that has an adjustable wire that makes contact with the mercury to complete an electrical circuit is an effective and accurate device. An electronic amplifier and relay is required to allow the small current that can flow in the mercury to switch the power to the heater (usually around 1kW).

Most water-bath controllers (purchased or home-made) need a temperature difference of about 5°C between the water in the bath and the ambient temperature to work effectively. If the ambient temperature is high or tests are required at low temperatures, a water cooler is also needed. An old refrigerator is the best solution; the water can be circulated through the ice box, or the compressor and heat exchanges can be removed from the cabinet and used to cool the bath directly.

Laboratory-scale reactors

Laboratory biogas reactors are usually glass flasks of between 1 and 5*l* capacity. Plastic flasks can be used, but they are difficult to make gas-tight. Special digestion bottles are available from specialist suppliers, but these are expensive. Suitable conical flasks can be obtained from suppliers in many countries. The neck of the flask must be wide enough to allow at least two or three access pipes to pass through the bung closing it. A gas outlet is

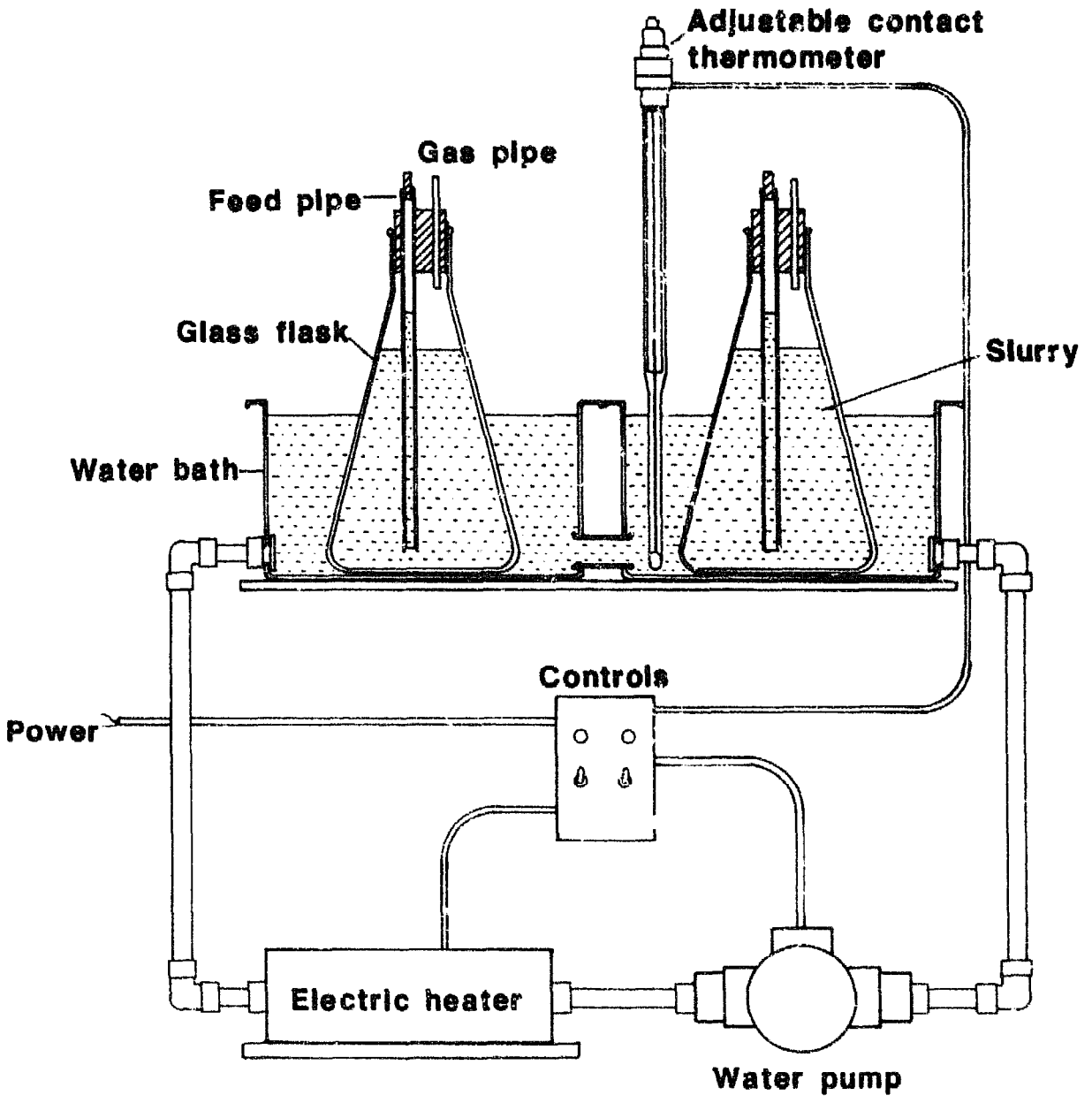

Figure III.1 *Schematic diagram of a temperature-controlled system*

required as well as a sampling tube through which to add and remove slurry samples. A third pipe is required if a mechanical mixer is to be used.

Gas is usually collected into a bottle over water that is displaced into a second bottle (Fig. III.2). The water should have added salt (sodium chloride) and acid (hydrochloric or sulphuric) to stop carbon dioxide dissolving. The gas-collecting bottles can each be graduated, but the usual practice is to connect the bottles from several reactors through a valved manifold to a single graduated cylinder (Fig. III.2). This is filled with acidulated brine via a pipe in the bottom connected to a reservoir bottle. The pressure of the gas in the cylinder can be adjusted by raising or

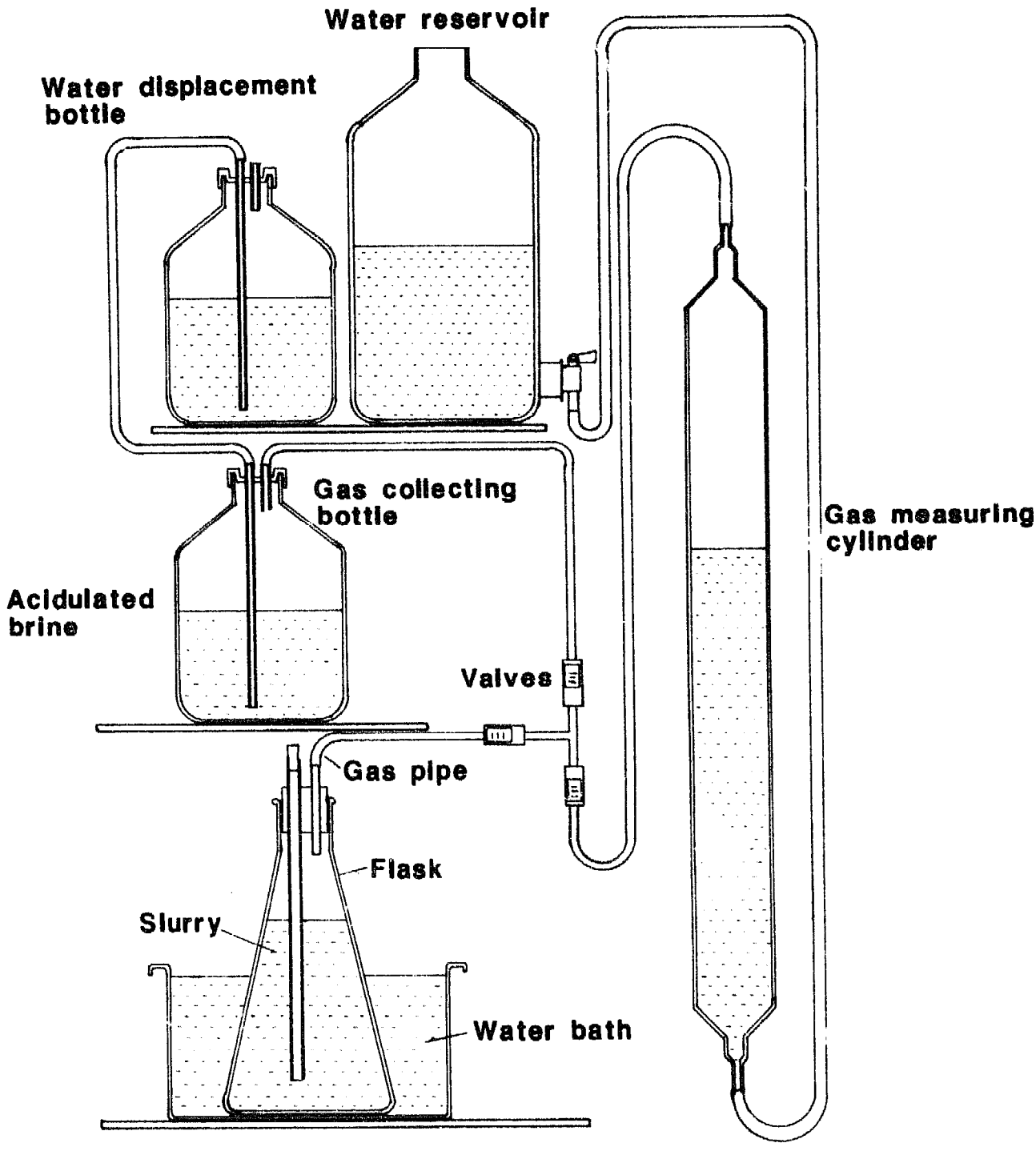

Figure III.2 *Schematic diagram of a digesting system.*

lowering this bottle. Volume readings should always be taken at zero gauge pressure, ie. with the level of water in the reservoir being held at the same level as the water in the cylinder.

Since the water-receiving bottle from each reactor is usually placed above its gas-collecting bottle, the gas is collected under a positive pressure

(200mm to 500mm water gauge). The pipe through which slurry samples are removed, and added in the case of semi-continuous reactors, should therefore be sealed against this pressure. Samples are taken or added when the pressure is removed, such as when gas measurements are taken. The end of this sampling pipe should dip well below the surface of the slurry to prevent air entering the gas space. For semi-continuous reactors it is usual to remove a fixed volume of slurry before replacing it with the same amount of fresh, the exact volume being related to the feeding rate and retention time defined for the reactor. If slurry samples are being regularly removed from a batch reactor the total volume of slurry in the reactor will obviously decrease and allowance for must be made for this in the calculations.

The positive pressure also makes mixing difficult. A stirrer driven by a rotating magnet is not very effective, especially if the slurry is thick and viscous. The shaft of a mechanical stirrer needs to be sealed against gas or slurry leakage. If the reactors are used to simulate low-rate rural digesters, then an occasional shake by hand is sufficient (2 to 3 minutes one to four times a day.[1]

At higher reactor temperatures (30°C and above) water vapour may be carried over with the gas. To ensure accuracy, this water may be absorbed (eg. in a tube of drying agent) and the same weight of fresh water added each day.

Temperature measurement in full-scale reactors

The most obvious way to measure the slurry temperature is to place a thermometer in a sample of slurry dipped from the digester pit. Samples of slurry can be removed from the inside of the digester pit usng a dipper bucket (Fig. III.3) passed through the slurry inlet or outlet. Unless a digester is being heated, the slurry temperature is very uniform and changes

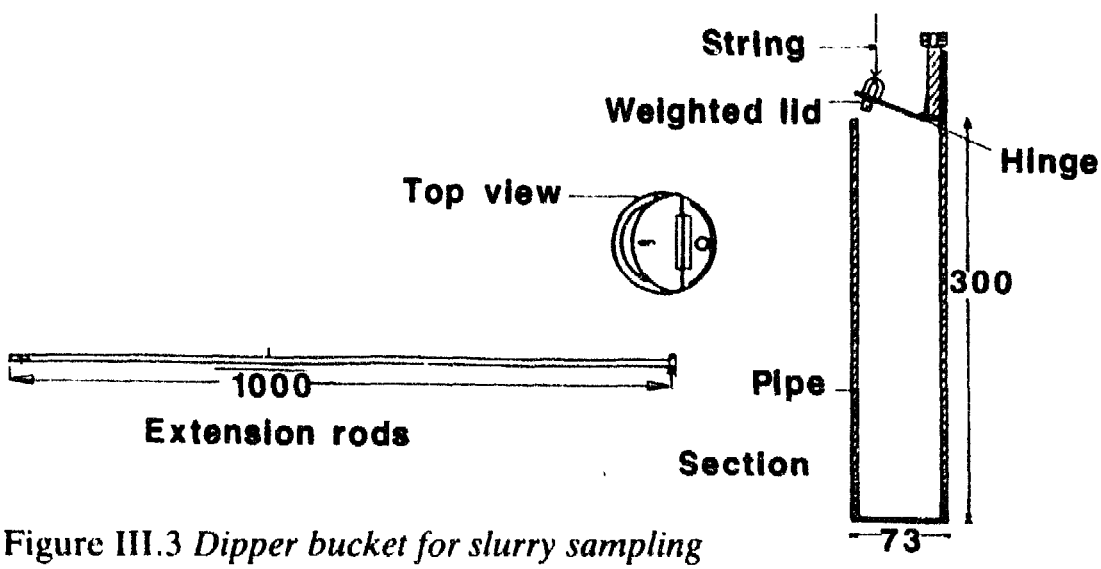

Figure III.3 *Dipper bucket for slurry sampling*

very slowly,[2] so a single daily reading is sufficient. An easier approach is to use a soil thermometer with a long temperature probe. The read-out can be a dial for single readings, although a recording thermograph will give a continuous plot of temperature for a week at a time. These machines can be powered by clockwork or batteries for operation in places remote from a power supply.

Gas production measurements

There are two aspects to the measurement of the gas production from a full-scale biogas plant: the gas used and the gas remaining in the plant. Cumulative wet-type gas meters are very accurate and can be made of materials that are unaffected by biogas (obtainable from suppliers in India and the developed world). Normal domestic gas meters usually contain parts made of plated steel, which are quickly corroded by the hydrogen sulphide in biogas. Most wet-type gas meters are not designed to cope with the higher pressures from a displacement digester. The gas may be passed through a pressure regulator before its volume is measured. DCS, in Nepal, designed their own gas meter, made from acrylic plastic (perspex or plexiglass) and capable of withstanding these pressures (Fig. III.4).[3]

The gas remaining in a drum plant is easy to measure: it is the height at which the drum is floating in the slurry times the cross-sectional area of the drum. The gas remaining in a dome plant can be estimated from its pressure and the position of the slurry surface in the reservoir (Figure III.5).[4] The determination of the gas in a bag plant is very difficult, unless the bag is full.

Gas analysis

Instruments for gas analysis are used extensively by the oil industry, so are available in many parts of the world. More sophisticated apparatus must be obtained from a supplier in a developed country.

The best way to analyse biogas samples is to use a gas chromatograph, although these are expensive and delicate instruments, accurate to better than 0.1 per cent. A column designed for the separation of permanent gases should be used with a thermal conductivity detecter. The supplier should be approached for advice about the correct column to use. A molecular sieve column will separate hydrogen, oxygen, nitrogen and methane, but is permanently contaminated if carbon dioxide and water pass through it. A 'Carbosieve' column will separate air, methane and carbon dioxide and even oxygen and nitrogen, if used carefully. Hydrogen or helium gas is used as a carrier.

A much less expensive device for gas analysis is the Orsat Apparatus,

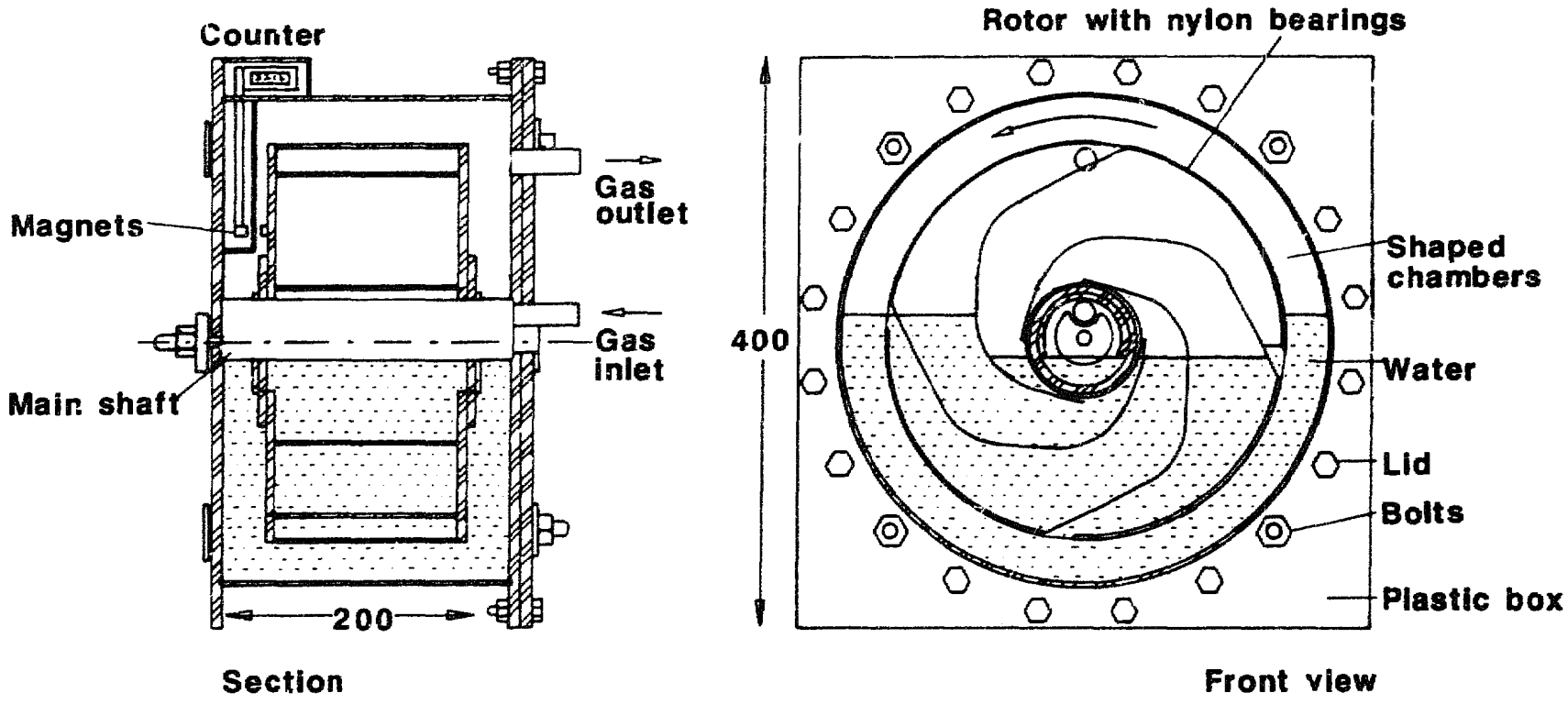

Figure III.4 *Plastic gas meter design*

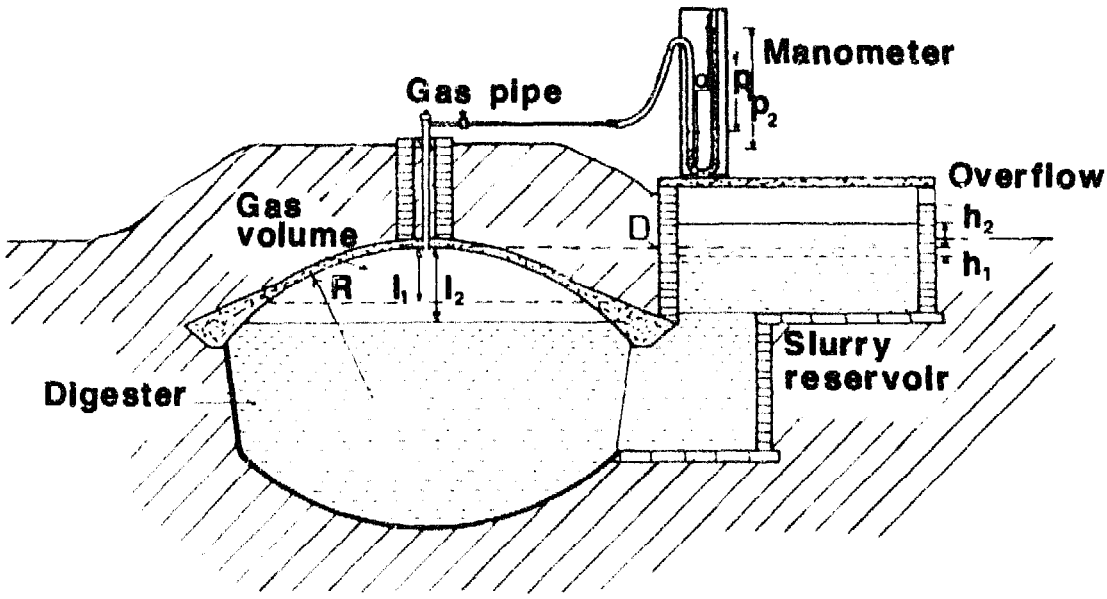

Change of volume of gas in dome = $\pi.(l_1^2 - l_2^2)\ R - \frac{1}{3}.(l_1^3 - l_2^2)$ where l_1 and l_2 are levels of slurry at two different times.
Slurry level: $l = p - h$
Where p = pressure of gas (measured in mm.H_2O by a manometer)
h = height of slurry in reservoir from datum point: D.
Figure III.5 *Measurement of gas left in a dome plant*

which consists of a series of bulbs, full of suitable solutions to absorb different gases. The volume of a sample of biogas is measured before and after it is passed into a bulb to absorb a constituent, such as potassium hydroxide to absorb carbon dioxide. Methane cannot be absorbed directly, so it is usually combusted over a catalyst (such as platinum) and the carbon dioxide produced measured. It is a laborious piece of equipment to operate,[5] but it can produce accurate results (around 1 per cent) if used carefully. This instrument can be obtained from manufacturers in India.

A simpler version of this apparatus is the carbon dioxide analyser, which only uses one bulb filled with potassium hydroxide solution. As the carbon dioxide is absorbed, a rubber diaphragm allows the liquid to rise up the bulb, giving a measure of the original proportion of carbon dioxide in the biogas. While being much less accurate (2 to 3 per cent), it is robust and could be used for field tests.

A fourth alternative is an electronic methane detector. This draws a sample of gas through a cell in which the thermal conductivity of the gas is measured. While these instruments are usually calibrated for a mixture of methane in air, they can be used for rough checks in the field. The instrument can be recalibrated with different known biogas mixtures, although an accuracy of better than 5 per cent cannot be expected.

pH measurement

The simplest way to measure pH is using indicator papers, which can be dipped into a sample of slurry removed from a digester. A set of papers for the region around neutral is very cheap and easy to use. However, slurry can cause discolouration of the paper and make the result difficult to see. A more accurate instrument is a pH meter, an electronic device that uses a glass probe dipped into the slurry. Most models are battery driven and robust enough to be used, with care, in the field.

Total solids and volatile solids analysis

The measurement of total solids involves placing a weighed sample in an oven and drying it for several hours at 105°C. The sample should be kept in a high-temperature glass or glazed ceramic container and care should be taken that the dried sample does not reabsorb moisture from the atmosphere before it is weighed. The proportion of total solids in the sample is given by the weight of the dried sample divided by the weight of the wet original.

Volatile solids content is measured by heating the dried sample at 500 or 600°C for several hours in a furnace and weighing the residue. The heating of animal dung to such high temperatures causes it to burn, so the furnace should be sited where the obnoxious smoke given off does not give offence. The volatile solids proportion is the difference between the weight of the dried sample before and after combustion, divided by its weight before.

COD and alkalinity measurements

Theoretically 1 gram of COD destroyed gives 0.35 litres of biogas, so COD is a useful measure of the concentration of the substrate available for digestion. A homogenised sample of slurry is diluted with water and boiled under reflux with known concentrations of mercuric sulphate, sulphuric acid and potassium dichromate for about 2 hours. After the solution has cooled, it is titrated against a reducing agent, ferrous ammonium sulphate, using a ferrion indicator to measure the concentration of unused oxidising agent.[6] A sample containing no slurry is treated in the same way to give a standard. The quantity of potassium dichromate required to oxidise the slurry sample is a measure of the COD.

Alkalinity is measured by titrating a sample of slurry against dilute sulphuric acid using either an indicator or a pH meter to show when the pH reaches 4.5. The alkalinity is a measure of the stability of the reactor and is measured in milligrammes of calcium carbonate per litre of slurry.

APPENDIX IV
Model for Biogas Digestion

The first order model for biogas digestion is based on two assumptions.[1,2]
1. The rate of substrate conversion to biogas is directly proportional to the substrate concentration:

$$\frac{dS}{dt} = -k.S \qquad \text{(IV.1)}$$

where t is time and k is the first order rate constant (measured in *l*/days). The substrate concentration (S) can be expressed as total solids, volatile solids, COD or BOD.
2. The volume of gas given off by the digester is proportional to the mass of substrate destroyed:

$$G = C.V.(S_o - S) \qquad \text{(IV.2a)}$$

$$g = C.v.(S_o - S) \qquad \text{(IV.2b)}$$

where G is the cumulative gas production from a batch plant and V is the volume of the reactor, while g is the daily gas production from a continuous plant and v is the daily feed rate. C is the yield constant for the substrate, S_o is the initial and S is the final substrate concentration.

For batch reactors, the substrate remaining in the reactor (S) is given by integrating expression (IV.1):

$$S = S_o.\exp\{-k.(t - t_o)\}, \qquad \text{(IV.3)}$$

where S_o is the initial substrate concentration (in kg.VS/*l*) and t_o is the 'lag time', the time for the gas production to reach its peak value. The model is obviously inadequate, as it suggests that the substrate concentration can be greater than the initial value when $t < t_o$, but it does offer a useful description of average reactor behaviour at longer times. For analysis, the results are best plotted on a straight line, by taking natural logarithms:

$$\ln(\frac{S}{S_o}) = -k.t + k.t_o. \qquad \text{(IV.4)}$$

A regression analysis on the data should give a slope of: $-k$ and an intercept on the 'y' axis of: $k.t_o$.

This equation can be extended (using equation 2a) to predict cumulative gas production:

$$G = C.V.(S_o - S)$$

$$= C.V.S_o.[1 - \exp\{-k.(t - t_o)\}], \qquad \text{(IV.5)}$$

Taking natural logarithms:

$$\ln\left(1 - \frac{G}{C.V.S_o}\right) = -k.t + k.t_o. \qquad \text{(IV.6)}$$

If the yield constant: C is known (see equation IV.15), a regression analysis g ves the kinetic constant: k and the lag time: t_o. In principle, the values for these constants should be the same as those found from the results for the substrate concentration data.

For continuous reactors, the rate at which the substrate is consumed by the bacteria depends on the volume feeding rate (v, l slurry per day). This is related to the retention time (R, days) and the loading rate (r, kg.VS./m^3/day):

$$R = \frac{V}{v} \text{ and } r = \frac{v.TS.VS.1000}{V} = \frac{TS.VS.1000}{R} \qquad \text{(IV.7)}$$

where V is the reactor volume and TS and VS are the total and volatile solid contents of the feed

$$v.(S_o - S) = k.S.V \text{ or } S_o - S = k.S.R,$$

$$\text{so: } S = \frac{S_o}{1 + k.R} \qquad \text{(IV.8)}$$

$$\text{and: } g = C.V.S_o.\frac{k}{1 + k.R} \text{ (from IV.2b)}, \qquad \text{(IV.9)}$$

where S is the effluent substrate concentration (eg. in kg.VS).

Rewriting these equations in a linear form:

$$\frac{S_o}{S} = k.R. + 1 \qquad \text{(IV.10)}$$

$$\text{and: } R = C.\frac{V.S_o}{g} - \frac{1}{k}. \qquad \text{(IV.11)}$$

Plotting substrate reduction data at various retention times as a straight line should give a slope of: k and an intercept of: 1. Similarly, a regression

analysis of retention time (R) plotted against ($V.S_o/g$) should give a slope of: C and an intercept of: – l/k/.

The values of k in the above equations should vary with temperature according to an Arrhenius equation:

$$k = A.\exp - \left(\frac{E}{RT}\right) \qquad \text{(IV.12)}$$

where A is a constant, E is the activation energy, R is the universal gas constant (= 8314 J/kg. K) and T is the temperature in K.

This equation, too, can be written in a linear form, by taking natural logarithms:

$$\ln(k) = -\frac{E}{RT} + \ln(A). \qquad \text{(IV.13)}$$

By plotting ln(k) against l/T, the constants ln (A) and E/R can be found.

The yield constant: C also appears to vary with temperature, but in a less predictable way.

In order to use the batch model, the gas production of a batch plant should be measured daily and the feedstock concentration at least once a week. The feedstock concentration can be measured in kg. TS, VS, COD or BOD, but the volatile solids measurement is easiest to use.

For batch reactors:

$$C = \frac{G}{(S_o - S).V} \qquad \text{...(IV.14)}$$

so a graph of cumulative specific gas production (G/V) against the concentration of feedstock digested ($S_o - S$) should give a straight line of slope: C. If this value for: C is used in equation IV.6, then values for rate constant: k and lag time can be found. In practice, there seem to be two values for rate constant depending on the length of time for which the reactor has been run. At short digestion times the rate appears to be defined by how fast simple molecules of feedstock can be turned into methane (methanogenisis is rate limiting). At longer digestion times, once the simple molecules in the feed are used up, the rate is limited by how fast more complex molecules can be hydrolised to compounds that can be utilised by acid-forming bacteria (hydroiysis is rate limiting). Typical values for yield constants and initial and final rate constants for cattle and pig dung are given in Table IV.1.

The cumulative gas production and the volatile solids and COD degradation curves with time are shown in Fig. IV.1 for data from the digestion of cattle dung at 33.5°C in the UK.[2] Fig. IV.2 shows the gas production against VS and COD digested, giving values of C_v of 828 //kg.VS digested and C_c of 578 //kg.COD digested (compared to the theoretical value of 583 //kg.COD digested, assuming 60 per cent methane in the gas). Fig. IV.3 gives the logarithmic plot of the gas production equation, showing the two rate constants at different times. The initial rate constant (k_i) is 0.00961 //day using the VS data between 0 and 34 days and the final rate constant (k_f) is 0.00239 //day between 35 and 90 days.

Example IV.1 Analysis of batch reactor results:

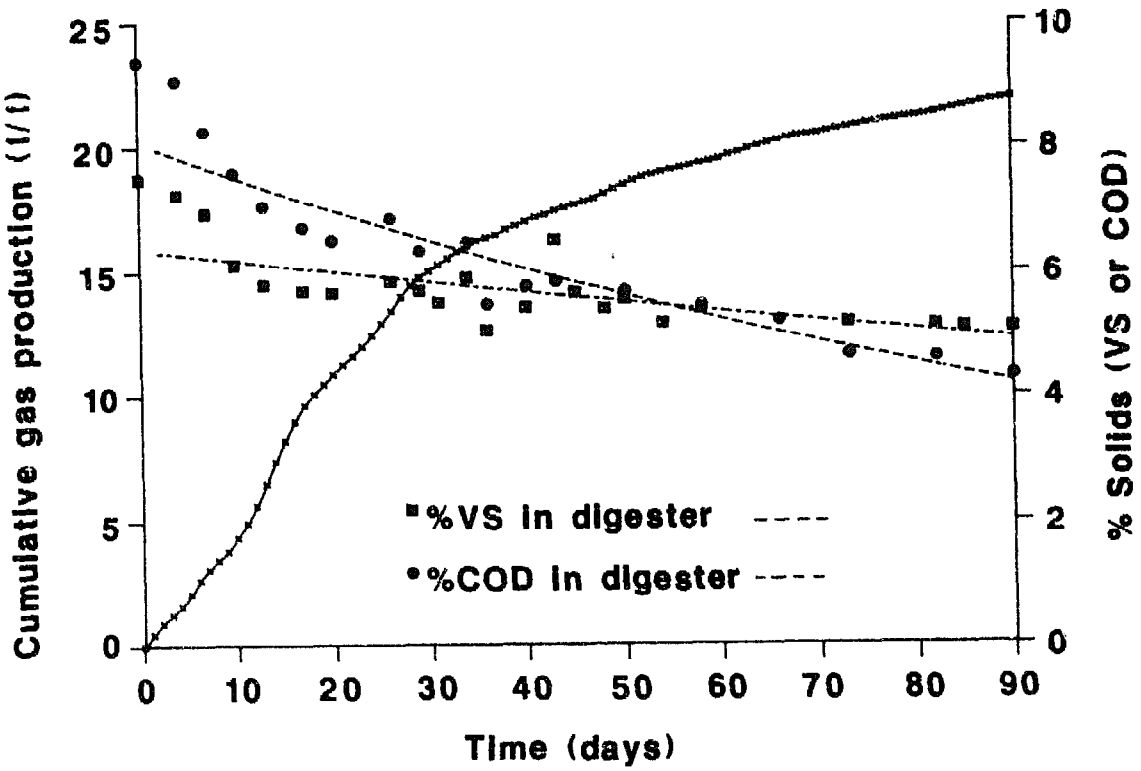

Figure IV.1 *Cumulative gas production, VS and COD degradation with time*

To use the semi-continuous model for biogas digestion a series of reactors must be set up, each with a different retention time. The reactors may have the same volume, but are fed at different rates with slurry from the same source. The daily gas production (g) and the substrate concentration in the influent (S_o) and effluent (S) are measured. After the reactor has become stable, ie. when the daily readings remain roughly the same for at least 5 days running, a series of readings is recorded.[2] This will take at least two retention times (2 × R) and may take longer (up to 4 × R) from the time the digester is started or a new set of running conditions have been established. Using equation IV.11, values for the yield (C) and rate (k) constants can be found for this series of reactors. Again,[3] there is evidence

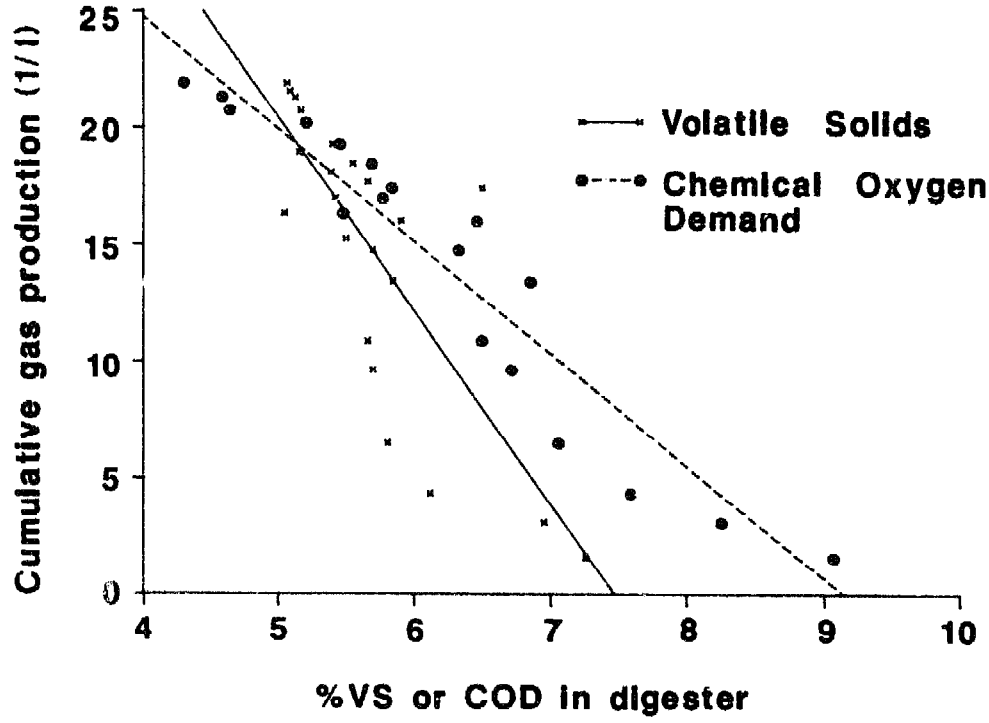

Figure IV.2 *Gas produced against substrate concentration*

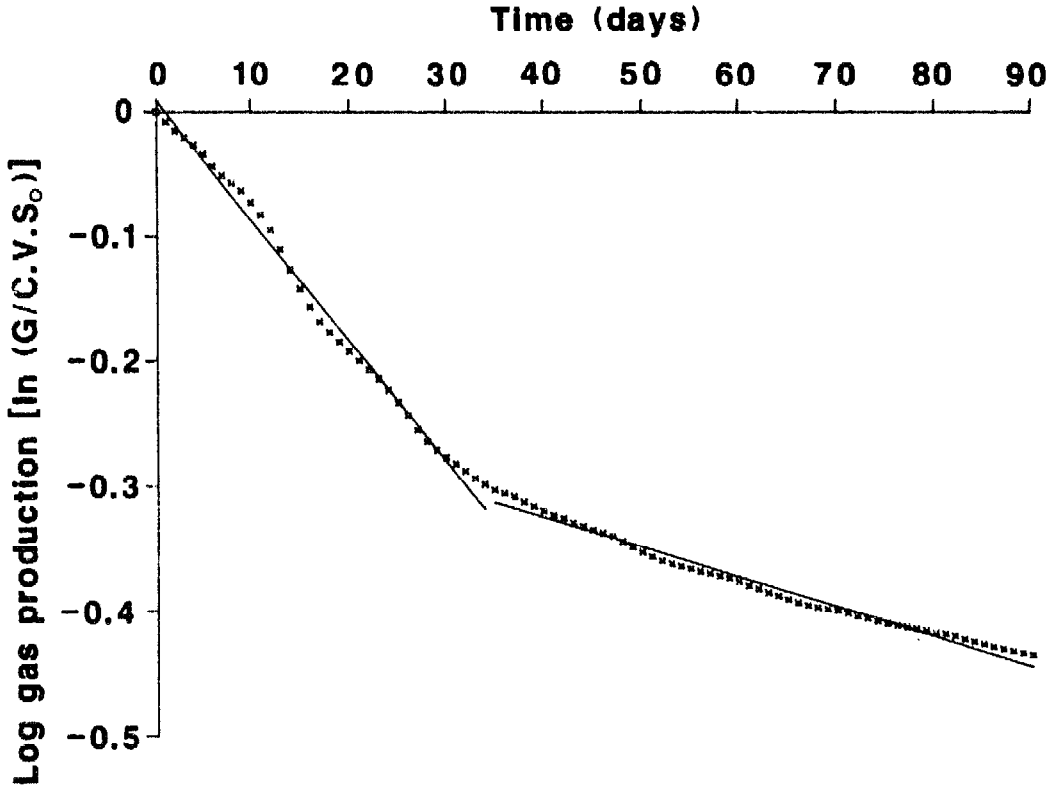

Figure IV.3 *Logrithmic plot of the gas production equation*

that lower-rate constants at longer retention times can be identified. Typical values for yield and rate constants for cattle dung in semi-continuous digesters are given in Table IV.2.

A plot of the data from a series of semi-continuous reactors using cattle dung at 33.5°C[2] is given in Fig. IV.4. The retention time (R) is plotted against the inverse specific gas production ($V.S_o/g$) for feedstock concentrations measured in terms of VS and COD. The slope of these lines gives a value for the yield constant (C = 402 //kg/VS or 347 //kg/COD) and the intercept gives the rate constant (k = 0.083 //day in terms of VS data and k = 0.083 //day based on COD data)

Example IV.2 Analysis of semi-continuous results.

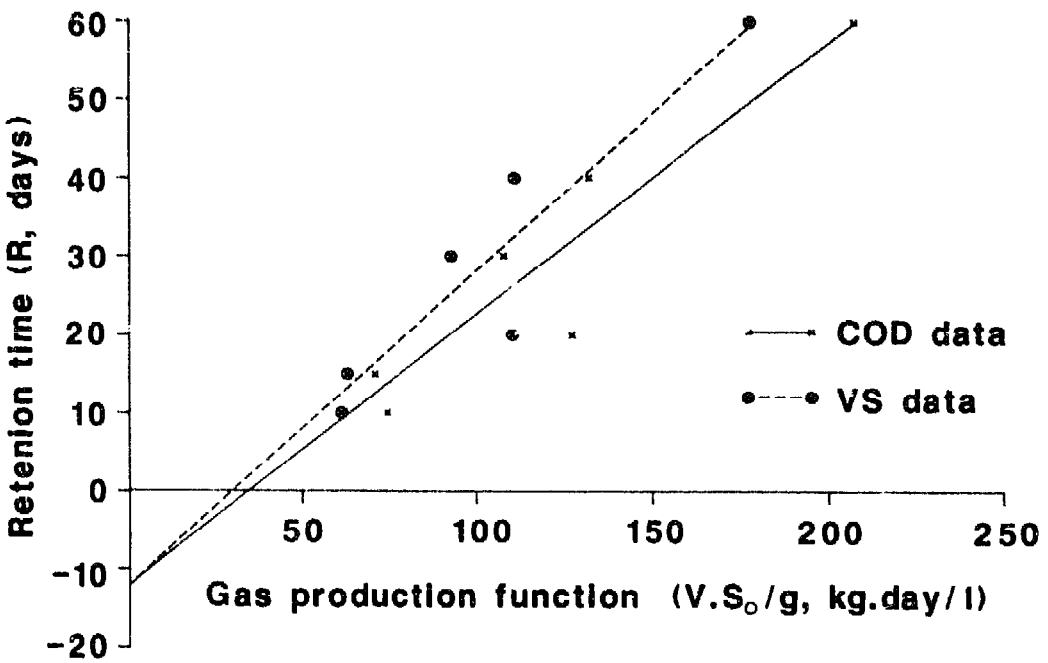

Figure IV.4 *Plot of semi-continuous digester data*

These equations and data can be used to predict the performance of full-size biogas digesters using the similar feedstocks to the experiments. A CD10 plant, run as a semi-continuous digester, is fed daily with 60 / of water mixed with 60 kg of cattle dung from the same source as the experiments in Example IV.2. If the slurry temperature is maintained at 33.5°C, the gas production can be calculated:

$$g = C.V.S_o.\frac{k}{1 + k.R}$$

The working volume (V) of a CP10 plant is 9 m^3 (Table I.3) so the retention time (R = V/v) is 9 m^3/.12 m^3/day = 75 days. The total solids content of cattle dung mixed 1:1 with water is usually around 9 per cent and the volatile solids content is 80 per cent of this, say 72 kg/m^3 (assuming the density of slurry is 1000 kg/m^3).
From Example IV.2: C = 402 l/kg.VS and k = 0.083, so:

$$g = 2.99\ m^3/day.$$

At 16°C: C = 178 l/kg.VS and k = 0.033, so:

$$g = 1.10\ m^3/day.$$

Example IV.3 Use of semi-continuous equation.

Table IV.1 Kinetic constants for batch digesters

Temp. (°C)	*Yield (l/kg)*		*Rate Constant (1.d)*				*Ref.*
	V.S.	*COD*	*VS:Init*	*Final*	*Cod:Init*	*Final*	
35	578	–	0.018	0.0022	–	–	4
33.5	895	513	0.0129	0.0033	0.0188	0.0054	1
25	829	525	0.0068	0.0023	0.0090	0.0031	1
16	–	514	–	–	0.0038	–	1

Notes: The yield constants are in terms of V.S. or COD destroyed.
The constants deprived from Maramba[4] are for pig dung, while those for Lau-Wong[1] are for cattle dung, from animals fed in the UK with maize silage and protein concentrates.

The values for these constants derived from semi-continuous results are not the same as those from batch results, even when fed from the same source used for both. The detailed mechanisms of digestion, especially the bacterial poulation balances, are likely to be different between the two modes of anaerobic digestion. Therefore results from laboratory tests on batch digesters should not be used for predicting performance of semi-continuous digesters and vice-versa.

Table IV.2 Kinetic constants for cattle dung in S-C digesters

Temp (°C)	*Yield Constant (l/kg)*		*Rate Constant (l/d)*		*Ref.*
	Vol.Sol.	*COD*	*Vol.Sol.*	*COD*	
33.5	402	347	0.083	0.081	2
30.1	450	–	0.052	–	1
27.5	310	–	0.044	–	1
25	289	237	0.069	0.078	2
24.4	250	–	0.036	–	1
20.3	310	–	0.022	–	1
16	178	164	0.033	0.026	2

Notes: The yield constants are in terms of V.S. or COD destroyed. The feedstock for Lau-Wong[1] was dung from buffalo in Nepal, fed on straw and dried grass, while that for Chowdhury[2] was dung from cattle in UK, fed on maize silage and protein concentrates.

Table IV.3 Constants used in Arrhenius Equation (IV.12)

Feed-stock	*Type*	*Frequ.Fact.(A)*	*Energy (E/R)*	*Ref.*
Cattle Dung (Nepal)	S-Cont	7.5×10^{9}	7780	1
Cattle Dung (UK)	S-Cont	3.6×10^{5}	4610	2
Cattle Dung (UK) V.S.	Batch	1.6×10^{7}	6430	2
Cattle Dung (UK) COD	Batch	1.8×10^{10}	8460	2

Table IV.4 Variables used in Appendix IV

A	– Frequency factor in Arrhenius equation	(–)
C	– Gas yield constant	(m^3/kg)
E	– Activation energy in Arrhenius equation	(J/kg)
g	– Daily gas production	(m^3/day)
G	– Cummulative gas production (over time)	(m^3)
k	– Rate of digestion	(l/day)
r	– Loading rate	(kg.VS/day)
R	– Gas constant (= 8314)	(J/kg. K)
S	– Substrate concentration	(kg/m^3)
S_o	– Initial substrate concentration	(kg/m^3)
t	– Time	(days)
t_o	– Lag time – time to peak gas production	(days)
T	– Absolute temperature (°C + 273)	(K)
v	– Volume feed rate to digester	(m^3/day)
V	– Volume of slurry in digester	(m^3)

Notes: S, S_o and C can be expressed in terms of kilograms of TS, VS, COD, or BOD, as long as one unit is used in all the equations consistently.

APPENDIX V
Economic Assumptions

Basic equations

The amortization factor (A) is used to calculate the yearly cost of a loan.[1] The total bill includes the repayments of capital plus interest. This is divided into equal yearly portions.

$$A = \frac{I \times (1 + I)^N}{(1 + I)^N - 1}$$

where: I = Annual interest rate (%/100)
N = Lifetime of loan (years)
If: C = Capital borrowed: the yearly repayment:
$R_y = A \times C$, and the total repayment:
$R_t = A \times C \times N$.

For a loan of Rs.10,000 at 11% annual interest over 7 years:
$A = 0.212$, R_y = Rs.2,120 and: R_t = Rs.14,840.

The discount factor (D) is used to calculate the 'worth' of benefits or costs,[1] accrued or paid over the lifetime of the project, assuming these are the same each year[1]:

$$D = \sum_{k=0}^{M} \frac{1}{(1 + J)^k}$$

where: J = Discount rate (%/100)
M = Project lifetime (years).
If: B = the Benefit or Cost per year, the Nett Present Worth (NPW) $= B \times D$.

For a discount rate of 15% and a project lifetime of 10 years:

D = 5.019. If B = Rs.1,000,
NPW = Rs.5,019 over 10 years.

If the benefits or costs change from year to year:

$$NPW = \sum_{k=0}^{M} \frac{B_k}{(1 + J)^k}$$

where: B_k is the Benefit or Cost for the Kth year.

Assumptions for domestic biogas

The biogas used from a plant is valued in terms of how much fuel wood and kerosene it replaces (Table V.1), using figures for cost and usage for a typical family living near Butwal, on the plains of Nepal, supplied by N.B. Pradhan. These show that 2,578kg of wood (120 bundles at 21.5kg/bundle) are used per year at a cost of Rs.1 per kg. (Rs.21.50 per bundle) plus 146 litres of kerosene at Rs.6 per litre, mainly for lighting.

The value of the fertilizer saved assumes that 44 per cent of the nitrogen available in raw dung is lost if the dung is stored in a pile (normal practice in Nepal). A second assumption is made that only 11 per cent of this nitrogen is lost if the dung is digested in a biogas plant (Table V.2).

Table V.1 Heating values of various fuels used by a family.

Fuel	*Heat Val. MJ*	*Burner Effic.*	*Fuel/ Year*	*Heat MJ/yr*	*Biogas Equiv.*	*Value £/yr.*
Biogas	19.4/m^3	55%	911m^3	9705	911m^3	144
Firewood	18.0/kg	15%	2,578kg	6956	653m^3	107
Kerosene	37.7/l	50%	146l	2749	258m^3	37

Running a biogas plant is assumed to take about an hour a day. This job is done either by a member of the household (unpaid) or by a domestic servant or a farm worker. A typical unskilled labourer's wage of Rs.10 per day is assumed. The maintenance cost of Rs.100 per year is arbitrary.

Table V.2 Value of fertiliser saved by using a biogas plant

Total dung fed to CP15 plant per year	(wet)	=	32,850kg
	(dry)	=	6,570kg
Nitrogen content of raw dung	(1.8%)	=	118kg
Nitrogen content of stored dung	(1.0%, 44% loss)	=	66kg
Nitrogen content of slurry	(1.6%, 11% loss)	=	105kg
Saving of nitrogen by use of biogas		=	39kg
Equivalent quantity of Urea saved (47% N_2)		=	84kg
Value of Urea saved (at Rs.4/kg)		=	Rs.332
			£14

Assumptions for milling systems

The milling year in Nepal is split into three main seasons: the rice hulling season (November to March), after the main rice crop is harvested, the

wheat milling season (April to July), and the slack season (August to October). During the last season, most people mill only enough stored grain to satisfy their domestic needs, although some early rice and maize is also milled. The income for these three seasons is given in Table V.3, which is based on the limited survey of two biogas mills near Butwal.

The amount and value of diesel used in both a 5kW diesel-only mill and a dual-fuel mill is given in Table V.4 for the same three seasons. It is assumed that only 20% of diesel is used in a dual-fuel engine, the rest of the fuel being biogas. In practice, mill drivers seem to often use less than the optimum of 80% biogas. Possibly the engine runs more smoothly with more diesel, or else the wives of the mill owners want enough biogas left to cook the evening meal. The analysis also assumes that, using the heat exchanger, the slurry can be kept at 30°C all the year round, so the maximum gas production (14.5m^3/day) is available from the feed of 300kg of cattle dung or equivalent per day. The spare gas (valued at Rs.3.8/m^3) is assumed to be used for domestic purposes.

Table V.3 Typical income for a 5kW mill

Months	*Days/ Season*	*Hrs/ Day*	*Quantity/day (kg)*		*Income*	
			Rice	*Wheat*	*Rs(NC)*	*£*
Nov/Mar	151	4	750	26	13,200	550
Apr/Jul	122	4	600	32	9,200	383
Aug/Oct	92	1	50	26	1,600	67
Total					24,000	1,000

Notes: Rice is hulled at 300kg/hr, at Rs5 per 50kg
Wheat is ground at 38kg/hr, at Rs1.5 per 3kg

Table V.4 Biogas and diesel usage in mills

Months of Seasons	*Diesel Used (lit)*				*Gas used m^3*		*Gas left m^3*	
	DO/day	*DF*	*DO/seas.*	*DF*	*/day*	*/se.*	*/day*	*/se.*
Nov/Mar	5.6	1.2	840	180	11.2	1,680	3.3	498
Apr/Jul	5.6	1.2	680	140	11.2	1,360	3.3	402
Aug/Oct	1.4	0.3	120	25	2.8	250	11.7	1,076
Totals			1,640	345		3,290		1,976
Values	Rs.(NC)		9,840	2,070		7,770		7,500
	£(UK)		410	86		324		313

Note: Do = Diesel Only, DF = Dual-Fuel Mill.

Costs for a diesel-only mill, 1986 prices in Butwal:		
	RS.(NC)	£
5kW diesel fuel engine (from India)	18,000	750
Milling machinery	8,000	334
	26,000	1,084
The yearly costs for running the mill are:		
Labour to run the milling machinery	4,600	193
Maintenance for all equipment (assumed)	3,000	125
Diesel used	9,840	410
Lubricating oil (assumed)	800	32
	18,240	760
The yearly benefits are:		
Income from milling operations (App. V)	24,000	1,000
Cost:Benefit Analysis	Rs.(NC)	£
Capital cost of project	26,000	1,084
Discounted running costs (15%, 10yrs)	91,542	3,814
Present Worth Costs (PWC)	117,542	4,898
Present Worth Benefits (PWB, 15%, 10yrs)	120,450	5,019
Nett Present Worth (PWB–PWC)	2,908	121
Benefit:Cost Ratio (PWB/PWC)	1.02	
Internal Rate of Return	16%	

Example V.1 Economic analysis of a diesel milling system.

Assumptions for irrigation systems.

The key to the analysis is the amount of water available.[2] Assuming a 4.5kW pump and a 5-metre-deep well, the water flow can be calculated:

$$P = \frac{H.Q.g.\rho}{\eta}$$

where P = the engine power (watts)
H = the pumping head (metres)
Q = the water flow (litres/sec)
g = the acceleration due to gravity ($9.81\ m/s^2$)
ρ = the density of water (1kg/*l*)
η = the pump efficiency.

Assuming a pump efficiency of 50 per cent, this formula suggests that 45.9 *l* per second is available, or $165m^3$ per hour. The biogas usage per hour is $2.52m^3$, plus 0.3 litres of diesel fuel. It is assumed that the limit to the area to be irrigated is defined by the water available, which, in turn, depends on

the biogas available. In Madhubasa, the biogas plant is sited about 500 metres away from the engine, so engine-cooling water cannot be used to heat the plant. This means the biogas production is limited during the winter months (Table V.5). The water requirement of the two crops is very variable during the growing seasons and is also influenced by the water available from rain (Table V.5). These water requirement figures are based on a study of crops on the Ganges plain in India,[3] assuming a normal year for rainfall. The critical month for rice is November, when the monsoons have finished, but water is needed to help the grains to fill. If all the available biogas is used to pump water in this month, then 5.2 hectares can be planted with paddy. For wheat, the critical month is February, allowing 8.3 hectares to be planted. The figures for water requirement are corrected for losses, such as water leaching out of the soil and through canal banks and evaporation (using a factor of 0.32 for rice and 0.55 for wheat).[3]

Table V.5a Water, biogas and diesel requirements

	Rice season (5.2ha)					
Months of the year	*June*	*July*	*Aug.*	*Sep.*	*Oct.*	*Nov.**
Water requ. (mm/day)	0	25.2	18.9	17.7	16.0	11.6
Rain average (mm/d)	9.3	21.6	24.2	16.5	6.0	1.0
Irrig. requ. (mm/d)	0	3.6	0	1.2	10.0	10.6
Water pump. (m^3/d)	0	18.7	0	62.4	520	550
Hours/day pumped	0	0.1	0	0.4	3.2	3.4
Biogas (m^3.day)	14.5	14.5	14.5	11.5	11.5	8.5
Biogas used (m^3/d)	0	0.3	0	1.0	8.1	8.5
Biogas left (m^3.d)	14.5	14.2	14.5	10.5	3.4	0
Diesel used (1/mon)	0	0.9	0	3.6	29.8	30.6
Diesel value (Rs/m)	0	5.4	0	21.6	179	184
Biogas value (Rs/m)	1,650	1,674	1,705	40	13	0

The crop production and value figures (Table V.6) are based on data[4] from the Janakpur Agricultural Development Project (JADP), a Japanese-funded programme, about 10km away from Madhubasa. An analysis can also be made for a drought year, when rainfall is much less (Table V.7). The area sown to crops is much reduced, but it can be assumed that the crop prices will rise. An analysis can also be made for a diesel-only system, providing irrigation for the same areas of land.

Table V.5b Requirements for irrigation scheme

	Wheat season (8.3ha)					
Months of the year	*Dec.*	*Jan.*	*Feb.**	*Mar.*	*Apr.*	*May*
Water requ. (mm/day)	3.0	4.8	8.0	3.0	0	0
Rain average (mm/d)	0.2	1.5	1.4	0.7	0.2	0.7
Irrig. requ. (mm/d)	2.8	3.3	6.6	2.3	0	0
Water pump. (m^3/d)	232	274	550	191	0	0
Hours/day pumped	1.3	1.7	3.4	1.2	0	0
Biogas (m^3/day)	8.5	8.5	8.5	11.5	11.5	14.5
Biogas used (m^3/d)	3.3	4.3	8.5	3.0	0	0
Biogas left (m^3/d)	5.2	4.2	0	8.5	11.5	14.5
Diesel used (1/mon)	12.1	15.8	28.6	11.2	0	0
Diesel value (Rs/m)	73	94.8	171.6	67.2	0	0
Biogas value (Rs/m)	613	495	0	1,001	1,311	1,705

Notes: Total value of diesel used: Rs.785 (£33)
Total value of biogas saved: Rs.10265 (£428)
*Critical month for crop.

Table V.6 Costs and income from use of irrigation system

Costs (in 1983 Rs(NC))	*Paddy (2.4ha)*	*Wheat (9.6ha)*	*Total*
Cost of seed (50kg/ha)	780	1,980	2,760
Cost of extra fertiliser	4,460	9,510	13,970
Cost of extra labour	780	8,450	9,230
Benefit (in 1983 Rs(NC))	3.0–2.0t/ha	2.5t/ha	
Income—sale of crop	11,700	56,000	67,700

Notes: The costs and profits for paddy are the extra ones resulting from an irrigated crop instead of a rain-fed one.

Table V.7a Water, biogas and diesel requirements in drought

	Rice season (4.4ha)					
Months of the year	*June*	*July**	*Aug.*	*Sep.*	*Oct.*	*Nov.*
Water requ. (mm/day)	0	25.2	18.9	17.7	16.0	11.6
Rain average (mm/d)	9.3	3.6	9.9	0.5	0	0
Irrig. requ. (mm/d)	0	21.6	9.0	17.2	16.0	11.6
Water pump (m^3/d)	0	950	396	757	704	510
Hours/day pumped	0	5.8	2.4	4.6	4.3	3.1
Biogas (m^3/day)	14.5	14.5	14.5	11.5	11.5	8.5
Biogas used (m^3/d)	0	14.5	6.0	11.5	10.8	7.8
Biogas left (m^3/d)	14.5	0	8.5	0	0.7	0.7
Diesel used (1/mon)	0	53.9	22.3	41.4	40.0	27.9
Diesel value (Rs/m)	0	324	134	248	240	167
Biogas value (Rs/m)	1,650	0	1,001	0	82	82

Table V.7b Requirements for irrigation scheme in drought

	Wheat season (7.0ha)					
Months of the year	*Dec.*	*Jan.*	*Feb.**	*Mar.*	*Apr.*	*May*
Water requ. (mm/day)	3.0	4.8	8.0	3.0	0	0
Rain average (mm/d)	0	0	0	0	0	0
Irrig. requ. (mm/d)	3.0	4.8	8.0	3.0	0	0
Water pump (m^3/d)	210	336	560	210	0	0
Hours/day pumped	1.3	2.0	3.4	1.3	0	0
Biogas (m^3/day)	8.5	8.5	8.5	11.5	11.5	14.5
Biogas used (m^3/d)	3.3	5.0	8.5	3.3	0	0
Biogas left (m^3/d)	5.2	3.5	0	8.2	11.5	14.5
Diesel used (1/mon)	12	19	29	12	0	0
Diesel value (Rs/m)	72	114	174	72	0	0
Biogas value (Rs/m)	613	412	0	966	1,311	1,705

Notes: Total value of diesel used: Rs.1,321 (£55)
Total value of biogas saved: Rs.7,822 (£926)

Glossary

Abbreviations

ADB Asian Development Bank, Head Office, Manilla, Philippines.

ADB/N Agricultural Development Bank of Nepal, Head Office, Ram Shah Path, Kathmandu, Nepal.

AFPRO Action for Food Production, C17 Community Centre, Safdarjang Development Area, New Delhi 110 017, India.

AICB All India Committee on Biogas, Dept. of Science and Technology, Delhi, India.

BORDA Bremen Overseas Research and Development Association, Hoffnungstrasse 30, D2800 Bremen 1, West Germany.

BTI Butwal Technical Institute, Butwal, Lumbini Zone, Nepal.

DCS Development and Consulting Services, PO Box 8, Butwal, Lumbini Zone, Nepal.

FAO Food and Agricultural Organisation of the United Nations, Head Office, Rome, Italy.

GO/ARF Group Organiser/Action Research Fellow—people employed by the SFDP as community motivators.

GOBAR GAS CO. Gobar Gas tatha Krishi Yantr Bikash (P) Ltd., Head Office, Kupondol, Kathmandu, Nepal.

HMG/N His Majesty's Government of Nepal (Nepal is a constitutional monarchy).

IIM India Institute of Management, Vastrapur, Ahmedabad 380 015, India.

JADP Janakpur Agricultural Development Project, Janakpur, Nepal.

JTA Junior Technical Assistant: extension workers for the Department of Agriculture in Nepal.

KVIC Khadi and Village Industries Commission, Head Office, Gramodaya Ida Road, Vile Parle (West), Bombay 400 056, India (and Gobar Gas Research and Development Centre, Kora Gramodyog Kendra, Borivli (West), Bombay 400 092, India).

KIRLOSKAR Kirloskar Oil Engines Ltd., Head Office, 13, Laxmanrao Kirloskar Road, Pune 411 003, India.

NBEO National Biogas Extension Office, Beijing, China.

NGO Non-Governmental Organisation.

NSPRC The National Standard of the People's Republic of China, San Li He, Fu Wai, Beijing, China.

PRAD Planning, Research and Action Division, State Planning Institute of Uttah Pradesh, Kalakankar, Lucknow (and Biogas Office, Ajitmal, near Etawah, U.P., India).

PEACE CORPS An organisation, based in USA, which sends short-term volunteers (usually for two years) to work in developing countries.

R & D Research and Development.

RCUP Resource Conservation and Utilization Project, run under the direction of USAID in Nepal.

RMP Red Mud Plastic, a PVC (Poly-Vinyl Chloride) plastic that uses a waste product from aluminium smelting as a filler.

SERC Structural Engineering Research Centre, Roorkee, U.P., India.

SFDP Small Farmers' Development Project, a programme set up by FAO, in co-operation with ADB/N in Nepal.

UMN United Mission to Nepal, PO Box 126, Kathmandu, Nepal.

UNDP United Nations Development Programme, Head Office, New York, USA.

USAID United States Agency for International Development, Washington, USA.

Specialist Terms

ACIDOGENESIS Production of acids by bacteria.

AEROBIC With oxygen.

ANAEROBIC Without oxygen.

AQUIFER Underground rock strata (layers) that carry water.

B:C Benefit:Cost ratio, the ratio of the financial benefits to costs of a project (PWB/PWC).

BACKFILLING Replacing soil behind a wall and ramming it firm.

BOD Biological Oxygen Demand, a measure of the polluting potential of a waste.

BUFFER To control the pH of a solution.

C:N Carbon:Nitrogen ratio—as measured in a feedstock.

COD Chemical Oxygen Demand, a measure of the polluting potential of a waste.

CP— Concrete Dome—the design of biogas plant that uses a fixed, partly spherical gas storage volume (the number refers to the total internal volume in m^3).

CARBURETTOR A device for mixing fuel and air in the correct proportions for combustion in an engine.

CRORE Indian rupees are expressed in lakhs and crores, a Hindi word meaning 'Ten Million' (and written 1,00,00,000). *See* lakh.

CRYOPHYLES Bacteria that operate best at low temperatures.

DATUM A fixed line from which measurements are taken.

DIGESTION Breakdown of foodstuffs to simpler chemicals by living organisms for their own use.

EP— Extended Dome—the design of biogas plant that uses a fixed gas storage volume made as a tunnel with domed ends (the number refers to the total internal volume in m^3).

EFFLUENT That which comes out—slurry that has given up its biogas.

ENTRAINMENT The drawing in of one fluid (air) by another (fuel gas), as it flows from a jet.

ENZYMES Organic catalysts that enable processes, such as digestion, to proceed.

FACULTATIVE Able to live with or without oxygen.

FERROCEMENT A building material made from cement plaster reinforced with wire mesh.

FIBRE-CEMENT A building material made from cement plaster reinforced with plastic or natural fibres.

FLUME A channel made for irrigation water, usually lined with concrete.

GAUGE A rod (or rope) of a fixed length, used to check the main dimensions of a construction.

GI Galvanised Iron—steel or cast iron coated with zinc as protection against corrosion.

GOBAR Hindi word meaning 'cattle dung'.

HDPE High Density Poly-Ethylene—a high-quality form of polythene plastic.

HYDROLYSIS The process of adding oxygen from water to a chemical.

IRR Internal rate of return—an economic assessment of the earning potential of a project.

JANATA Hindi word meaning 'of the people'.

KINETIC CONSTANT A measure of how fast a reaction (such as biogas digestion) proceeds.

LAKH Hindi word meaning 'One Hundred Thousand' (and written 1,00,000).

MESOPHYLES Bacteria that operate best at medium temperatures.

METHANO-GENESIS Production of methane and carbon dioxide by bacteria.

NPW Nett present worth—Difference between the economic benefits and costs of a project (PWB–PWC).

NIGHT-SOIL Human wastes, especially faeces.

OBLIGATE ANAEROBES Bacteria that cannot function in the presence of oxygen.

PH A measure of the acidity of a solution.

PWB Present Worth of Benefits, an economic valuation, in financial terms, of the benefits from a project.

PWC Present Worth of Costs, an economic valuation in financial terms of the costs of a project.

POZZOLANA A volcanic ash used as a mortar or hydraulic cement.

REACTOR A container in which a reaction (eg. biogas digestion) occurs.

REGRESSION ANALYSIS A mathematical technique used to find how closely data would fit a straight line when plotted on a graph.

RETENTION TIME Length of time a feedstock effectively remains in a digester.

SD— Steel Drum—the design of biogas plant that uses a floating gas holder (the number refers to the nominal daily gas production in ft^3).

SLURRY A liquid with finely divided solids dispersed in it.

STOCHIOMETRIC Optimum ratio of fuel gas to air for complete combustion to occur.

SUBSTRATE Feedstock for bacteria to use.

TS Total Solids—a measure of the dry matter in a slurry.

TEMPLATE A pattern or shape which can be used to check the dimensions and shape of a construction.

TERAI The plains area of Nepal, which used to be covered in thick forest. Many of the trees have been removed to make fertile fields to grow rice and wheat.

THERMOPHYLES Bacteria that operate best at high temperature.

THERMOSTAT A switch that operates at a pre-set temperature.

THROAT The region in the mixing tube of a gas burner with the smallest cross-sectional area.

TOXIC Poisonous to living things, such as bacteria.

VS Volatile Solids—an approximate measure of the organic content of a feedstock.

VENTURI A tube that tapers from both ends to a narrower region between them.

WORKING VOLUME The volume of slurry in a biogas digester that effectively contributes to gas production.

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By: John van Winden

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VOLUME 1

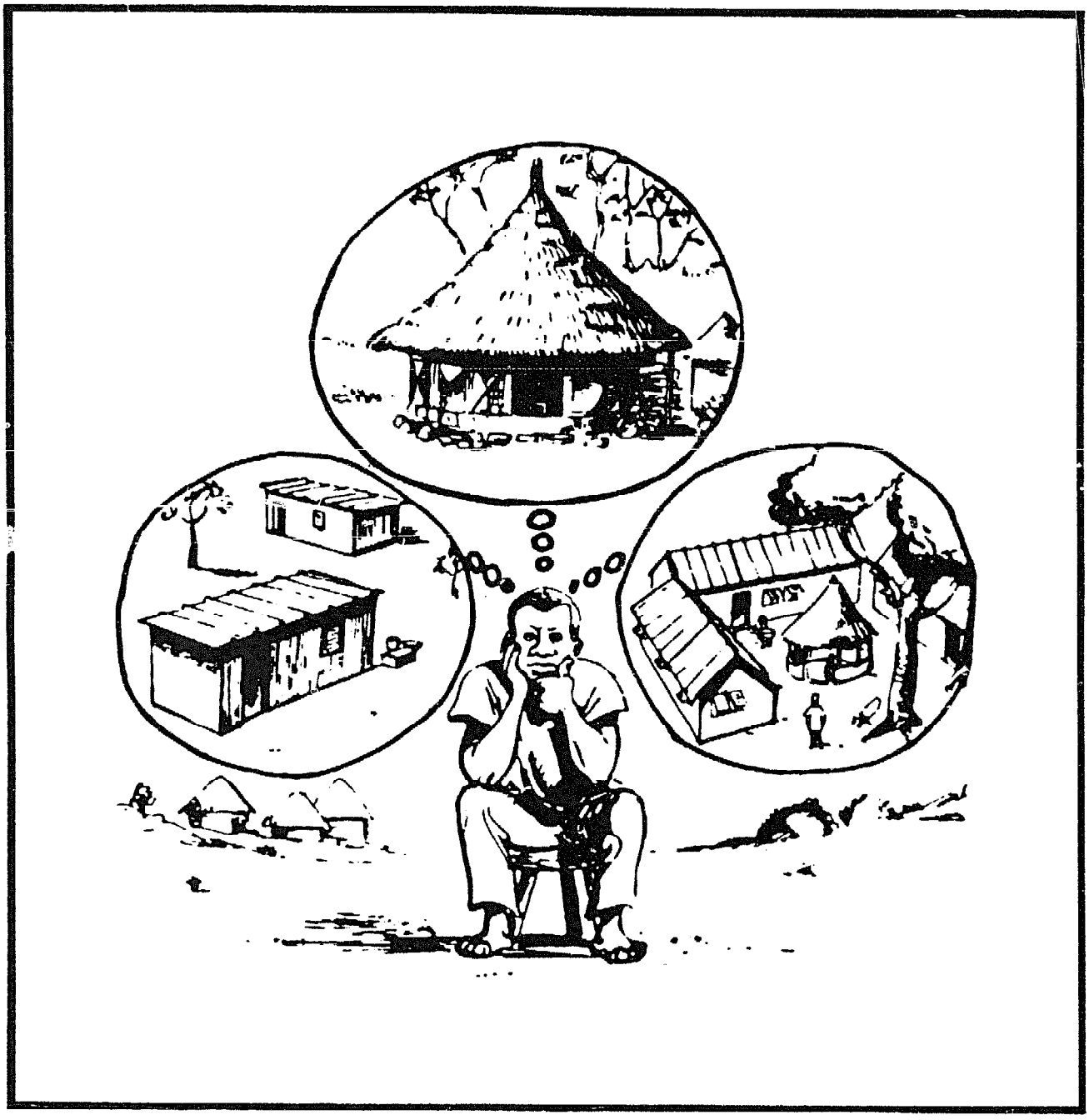

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PREFACE

In response to the many requests by people involved in technical vocational training and in general development work, we have decided to publish a second edition of the Rural Building Course.

The main aim of this set of books is still to provide technical training information in understandable language and with illustrations suited to the understanding of those involved.

Except for a few corrections, the text and illustrations are the same as in the first edition. The binding of the technical drawing book was revised and the size of the books reduced for economy reasons.

We are grateful to the Stichting Brothers F.I.C., Stichting CEBEMO and Mensen In Nood for their assistance in the re-printing of these coursebooks.

It is our sincere wish that the contents of these books may be of assistance to stimulate the use of appropriate techniques in Rural Building and General Development.

Bro. John van Winden F.I.C.

INTRODUCTION TO A RURAL BUILDING COURSE

Vocational training in Rural Building started in the Nandom Practical Vocational Centre in 1970. Since then this training has develcped into an official four year course with a programme emphasis on realistic vocational training.

At the end of 1972 the Rural Building Course was officially recognised by the National Vocational Training Institute. This institute guides and controls all the vocational training in Ghana, supervises the development of crafts, and sets the examinations that are taken at the end of the training periods.

The Rural Building programme combines carpentry and masonry, especially the techniques required for constructing housing and building sanitary and washing facilities, and storage facilities. The course is adapted to suit conditions in the rural areas and will be useful to those interested in rural development, and to farmers and agricultural workers.

While following this course, the instructor should try to foster in the trainee a sense of pride in his traditional way of building and design which is influenced by customs, climate and belief. The trainee should also be aware of the requirements of modern society, the links between the old and new techniques, between traditional and modern designs -- and how best to strike a happy medium between the two with regard to considerations like health protection, storage space, sewage and the water supply. The trainee should be encouraged to judge situations in the light of his own knowledge gained from the course, and to find his own solutions to problems; that is why this course does not provide fixed solutions but rather gives basic technical information. The instructor can adapt the course to the particular situation with which he and the trainee are faced.

This course is the result of many years of work and experimentation with different techniques. The text has been frequently revised to serve all those interested in Rural Development, and it is hoped that this course will be used in many vocational centres and communities. It is also the sincere wish of the founders of this course that the trainees should feel at the completion of their training that they are able to contribute personally to the development of the rural areas, which is of such vital importance to any other general development.

We are grateful to the Brothers F.I.C., the National Vocational Training Institute and the German Volunteer Service for their assistance and support during the preparation of this course.

Bro. John v. Winden (F.I.C.)
Wolfram Pforte (G.V.S.)
Fritz Hohnerlein (G.V.S.)

LAY-OUT OF THE RURAL BUILDING COURSE

The Rural Building Course is a block-release-system course, which means that the trainee will be trained in turn at the vocational centre and at the building site. The period of training at the centre is called "off-the-job" training, and the period on the building site is called "on-the-job" training. Each will last for two years, so that the whole course will take four years and will end with the final test for the National Craftsmanship Certificate.

BLOCK RELEASE SYSTEM

YEAR	TERM 1	TERM 2	TERM 3
1	X	X	X
2	O	O	O
3	O	X	O
4	X	O	X

X = OFF-THE-JOB TRAINING
O = ON-THE-JOB TRAINING

The total "off-the-job" training period is approximately 76 weeks, each week 35 hours. During this training about 80% of the time is spent on practical training in the workshop. The remaining 20% of the time is devoted to theoretical instruction.

The total "on-the-job" training period is approximately 95 weeks, each week 40 hours. During this period the trainee does full-time practical work related to his course work. In addition some "homework" is assigned by the centre and checked by the instructors.

A set of books has been prepared as an aid to the theoretical training:

A - Rural Building, Basic Knowledge (Form 1)
B - Rural Building, Construction (Forms 2, 3, 4)
C - Rural Building, Drawing Book (Forms 1, 2, 3, 4)
D - Rural Building, Reference Book

All these books are related to each other and should be used together. The whole set covers the syllabus for Rural Building and will be used in the preparation for the Grade II, Grade I, and the National Craftsmanship Certificate in Rural Building.

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BOOK INTRODUCTION

Rural Building Tools, Maintenance of Tools, Materials and Products is a reference book. This means that you should not read it through at once like a textbook, but use it when you need to look up information about certain tools, about the maintenance of a tool, or about a kind of building material or building product.

This book is divided into 4 parts:

PART 1: RURAL BUILDING TOOLS

This part of the book covers the basic tools needed in Rural Building and how to use them. It also treats a variety of site tools, site equipment and some optional tools.

PART 2: MAINTENANCE OF TOOLS

This section is about how to maintain the tools, so that they work better and last longer.

PART 3: RURAL BUILDING MATERIALS

This part deals with building materials; both the traditional ones and modern ones, that are used in Rural Building.

PART 4: RURAL BUILDING PRODUCTS

This part of the book covers the products such as reinforcement steel, blocks, paint, sheet materials, roofing sheets etc. used in Rural Building.

It is very important that you know all the technical terms, so if you come across a word or term that you don't understand you should look it up in the glossary at the end of this book, where most of the technical terms are e .plained. If you can't find the word in the glossary, write it down and ask your instructor to explain it.

The Tables of Figures in Appendix I are intended to help you to figure out the amounts of building materials that will be required for the planned building.

GENERAL RULES FOR SAFETY

1. Give all your attention to the job and don't distract others.
2. Be sensible in your behavior, don't play with tools or run about the building site or workshed.
3. Be alert, watch out for any dangerous situations, warn your colleagues, and report it to the person in charge.
4. If you are not sure of the correct way to use a tool, ask your instructor.
5. Make sure that your workpiece is safe and securely fastened in place before you start cutting or any work.
6. When cutting wood, guide the cutting tool in the correct way and keep your hands away from the cutting edge. Always cut away from yourself.
7. Wear safety goggles when cutting blocks, breaking concrete or grinding tools.
8. Carry tools with the pointed ends down.
9. When you finish working with a tool, clean it and return it to the toolbox.
10. Never throw or drop tools.
11. Keep the place tidy. A workplace scattered with tools is dangerous.
12. Maintain your tools, work only with clean and sharp tools.
13. A good quality, well maintained tool can do half the work for you .....

NOTES:

PART 1: RURAL BUILDING TOOLS

During thousands of years of development, people became aware that making certain things and doing certain jobs requires the use of special tools. Technical tasks could not be done with bare hands alone.

To make the things that they wanted, people were forced to design and make different tools for different jobs. For example, without tools like the plough, the farmer would not be able to feed his family. The plough was invented to make his work easier and to make sure that he could harvest a surplus of food for the benefit of the whole society. The plough was invented step by step and adapted to serve under different conditions.

In the same way, tools are very important in building. They enable people to shape all kinds of materials into useful articles and to make improved shelters to protect them from the weather and from enemies.

Early tools were the axe and the cutlass, which allowed men to cut wood for building instead of breaking it, and to make things like ladders, wheels and stools.

Now the Rural Builder uses more advanced tools and it is necessary for him to learn how to use and treat these tools well, because they are valuable. Even the most skilled craftsman can do little or nothing without the proper tools.

Since the Rural Building trade combines the crafts of carpentry and masonry, the Rural Builder's set of tools must also be a combination of masonry and carpentry tools.

This combined set of tools is limited and adapted for building in rural areas. It will enable the Rural Builder to construct perfectly well the kind of living quarters that are needed in the Northern and Upper regions of Ghana, starting from the foundation to the last nail of the roof construction.

Due to the structure of this course it is convenient to introduce the masonry tools first.

NOTES.

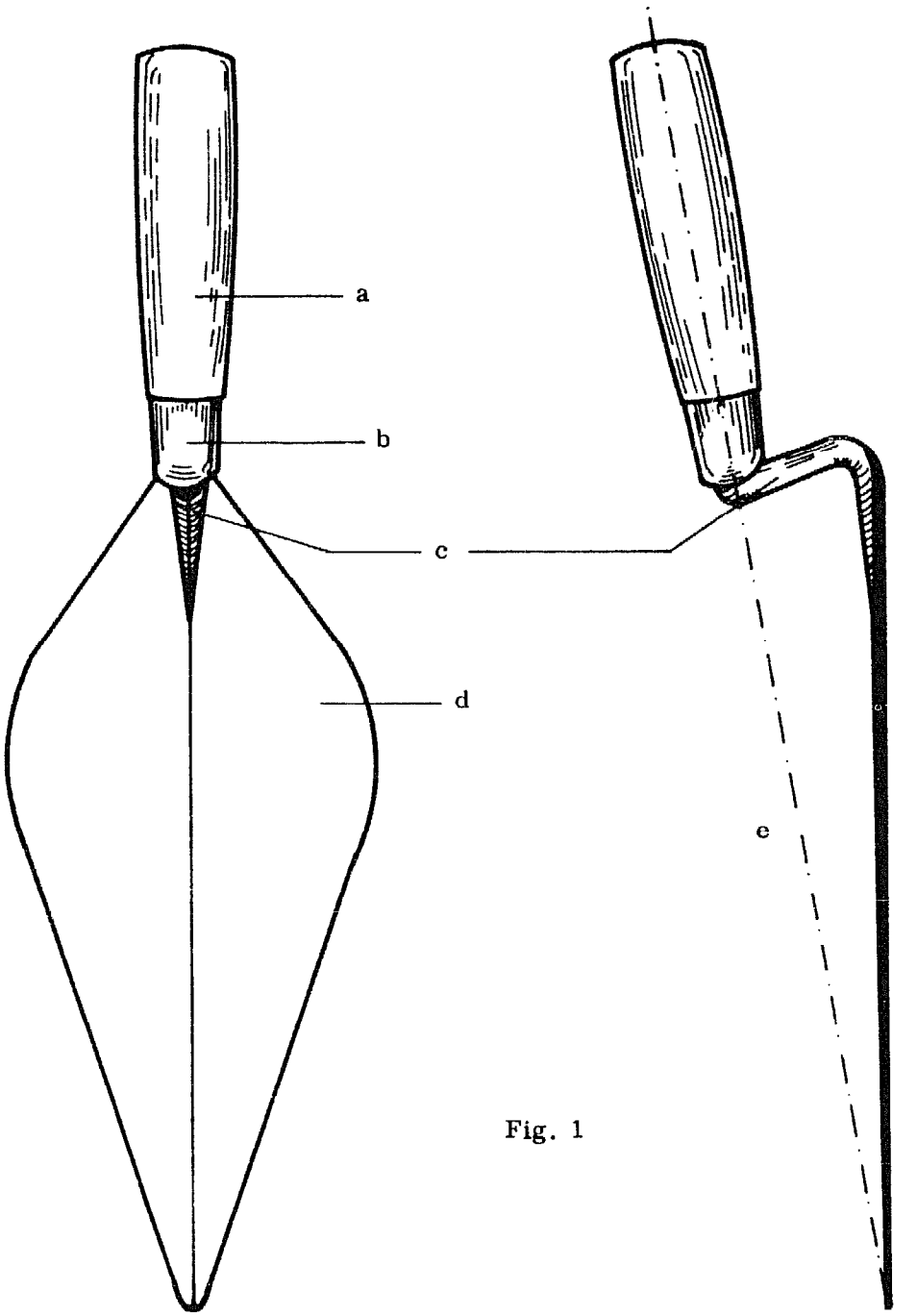

Fig. 1

FRONT VIEW

SIDE VIEW

NEVER CUT SANDCRETE BLOCKS WITH A TROWEL, AS THIS WILL DENT THE EDGE OF THE BLADE.

N P V C	LAYING TOOLS.
2 TOOLS	

LAYING TOOLS

THE TROWEL

Of all the tools that a blocklayer uses, the brick trowel is by far the most important one, for it is almost continuously needed during the building construction.

Its main function is to pick up the mortar and to spread it to an even thickness in preparation for laying the blocks. Apart from its use in the trimming of landcrete blocks, the trowel is needed for any work where mortar or concrete is worked up.

NOTE: Never cut sandcrete blocks with a trowel, as this will dent the edge of the blade.

The long narrow-bladed trowel shown in Fig. 1 is very popular in this country and it is most frequently used for laying blocks and trowelling floorscreeds.

This trowel consists of a wooden handle (a) connected by a ferrule (b) to the shank (c) which joins the steel blade (d). The size of the blade ranges from 23 to 36 cm in length; this dimension being measured from the back of the shank to the tip of the blade, while the width varies from 9 to 13 cm.

The extended axle line of the handle (e) should line up with the tip of the blade in order to provide the best handling. This applies to all types of brick trowels.

When you buy a trowel, make sure that the blade is of a good quality steel. You can judge this quality by knocking your fingernail on the blade. The higher the sound the harder the steel.

The blade should also be able to bend slightly and return to its original position. If not, the blade is too soft.

NOTES:

WOODEN SPIRIT LEVEL Fig. 1

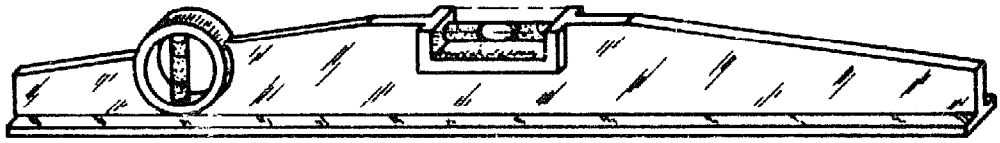

METAL SPIRIT LEVEL Fig. 2

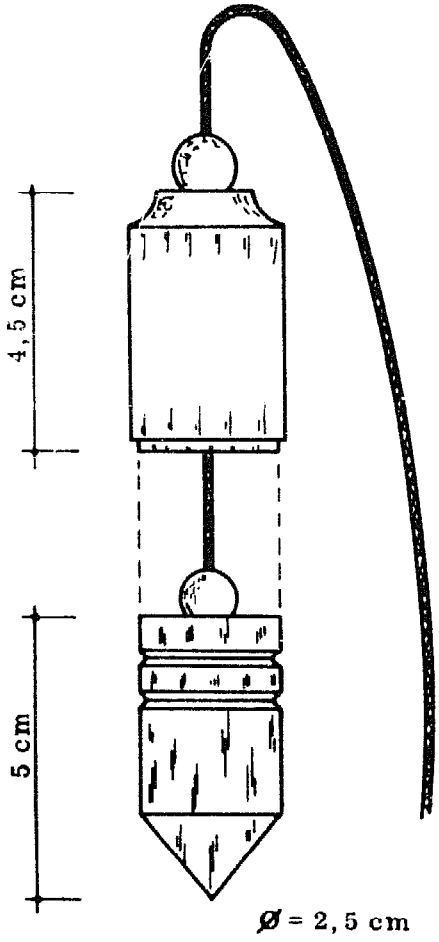

PLUMB BOB

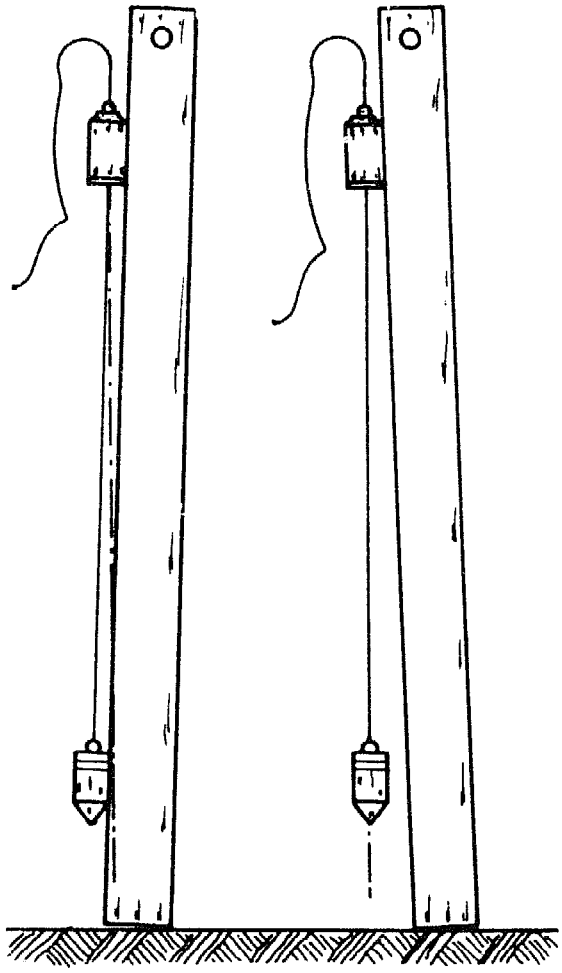

TOUCHING FLYING

N P V C	
4	TOOLS

STRAIGHTENING TOOLS.

STRAIGHTENING TOOLS

There are four main straightening tools.

SPIRIT LEVEL

These are wooden or metal straight edges specially fitted with plastic tubes containing spirit and a bubble of air.

These tubes are set into the straight edge so that when it is placed across two points which are level to each other, the air bubble will be exactly in the centre of the tube. This position is clearly marked with lines inside the tube (Figs. 1 & 2).

In a similar way, a tube is set in the straight edge to read with the level held vertically, which enables you to plumb members over short distances. If the level is used in conjunction with a straight edge you can plumb or level over a longer distance.

To level a longer horizontal distance you cannot use a straight edge with a level. Instead you have to use a water level which will be explained later. To level a vertical distance which is longer than your straight edge you can use your plumb bob.

PLUMB BOB

This tool consists of a solid brass or metal cylinder with a pointed end, which is attached to a suspending line so that its tip is always pointing vertically down. Its upper part is a small wooden block with a hole drilled in its centre so that the line with the cylinder on it can be pulled up or lowered down through the hole.

The diameter of the wooden block is slightly greater than the diameter of the cylinder, so that the cylinder can move freely up and down without touching the workpiece. The dimensions of the plumb bob are shown in Fig. 3.

The main use of the plumb bob is as a more accurate replacement for the vertical spirit level and also to transfer points down vertically in marking. Both methods will be described later.

NOTES:

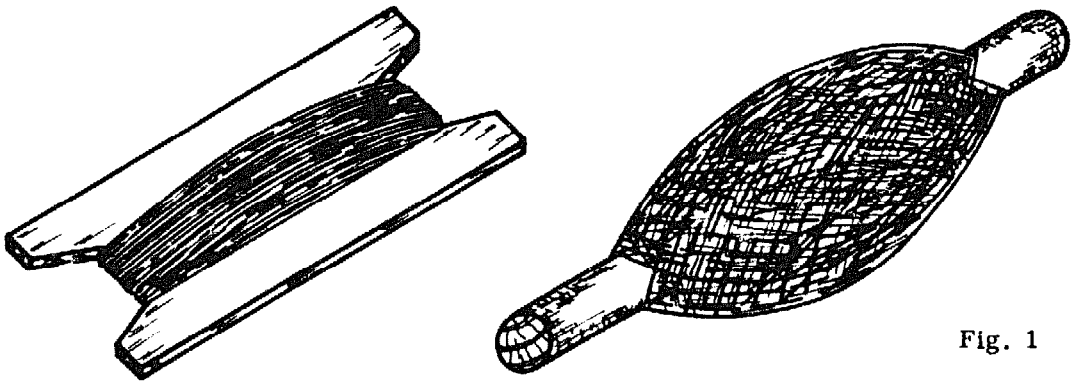

Fig. 1

MASON LINE

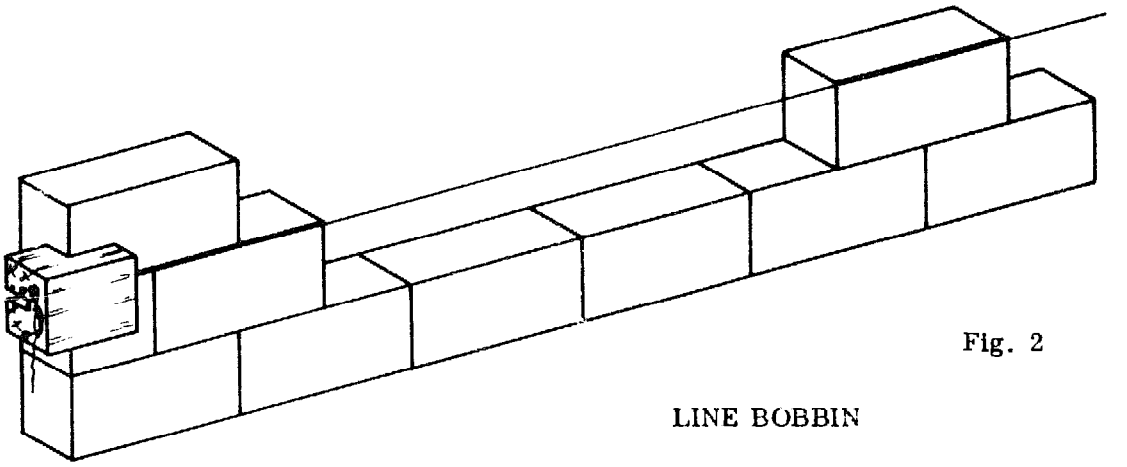

Fig. 2

LINE BOBBIN

There should be a trowel thickness
ALLOWANCE between line and wall.

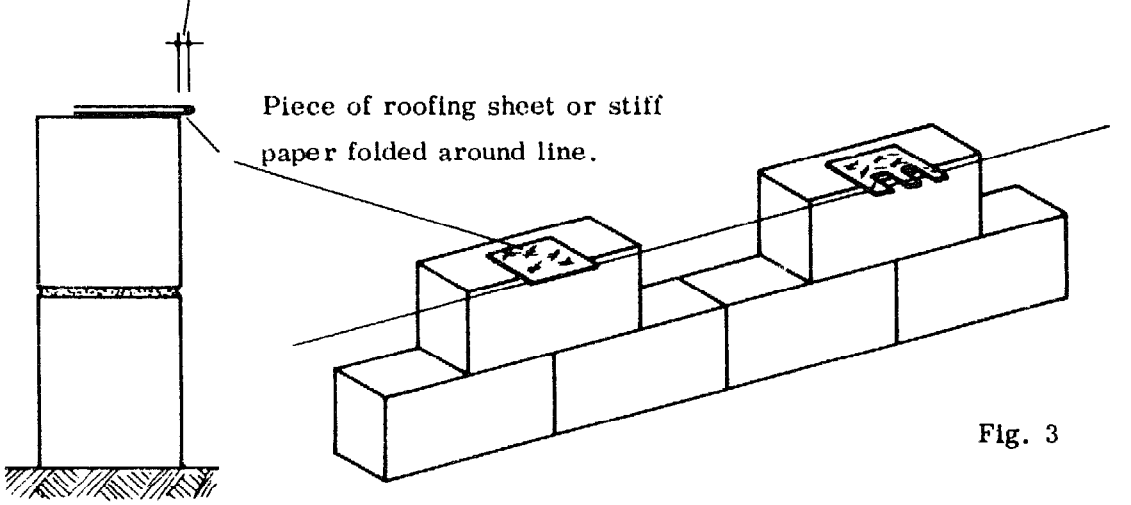

Fig. 3

TINGLE PLATE

N P V C		STRAIGHTENING TOOLS.
6	TOOLS	

MASON LINE

When building up walls between two quoins we employ the mason line, which is approximately 30 metres long, to ensure that the courses are straight and at the correct height (Fig. 1).

The line is tightened between two nails driven into the bed joints.

Mason lines are also used for setting out buildings, lining out frames for doors and windows and many other purposes where a straight line is needed for a guide over longer distances.

Instead of nails, so-called line bobbins may be used. These are hard wood blocks made to the size and shape indicated in Fig. 2. The line is stretched between opposite quoins, passed through the sawcut of each bobbin and wrapped around the projecting screws. Their uses will be explained later.

Line bobbins are preferred to nails, as they are easily adjusted to the required level and no holes need to be made in the bed joints.

In addition to the mason line, a tingle plate must be used if the distance between the quoins becomes too great and the line starts to sag. A tingle plate is made from thin metal and it is used to support the line in the middle to prevent sagging. The tingle plate must of course be set at the correct height (Fig. 3).

A tingle plate can easily be made from a piece of roofing sheet or any other sheet metal. Sometimes a piece of stiff paper is used for the purpose.

If the line breaks, it should be spliced and not tied with a knot, because a line full of knots will not be straight.

NOTES:

STRAIGHT EDGE

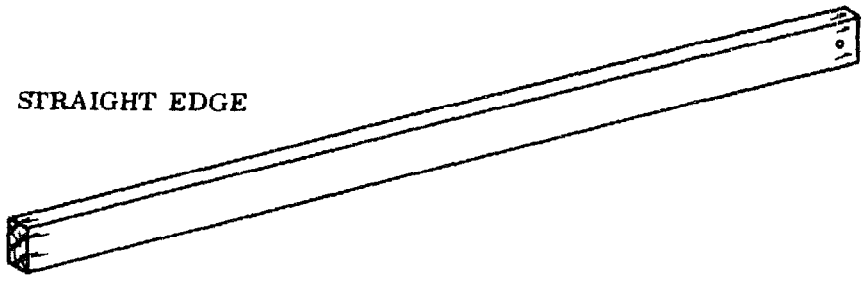

Fig. 1

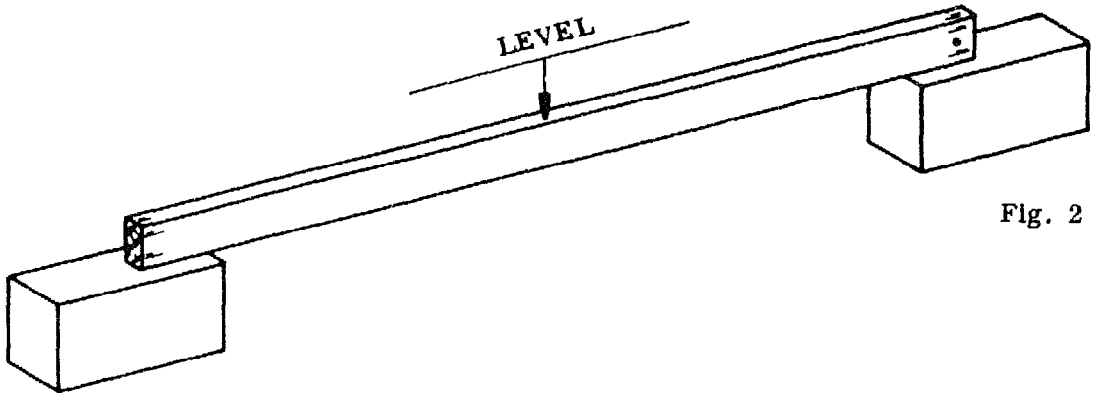

Fig. 2

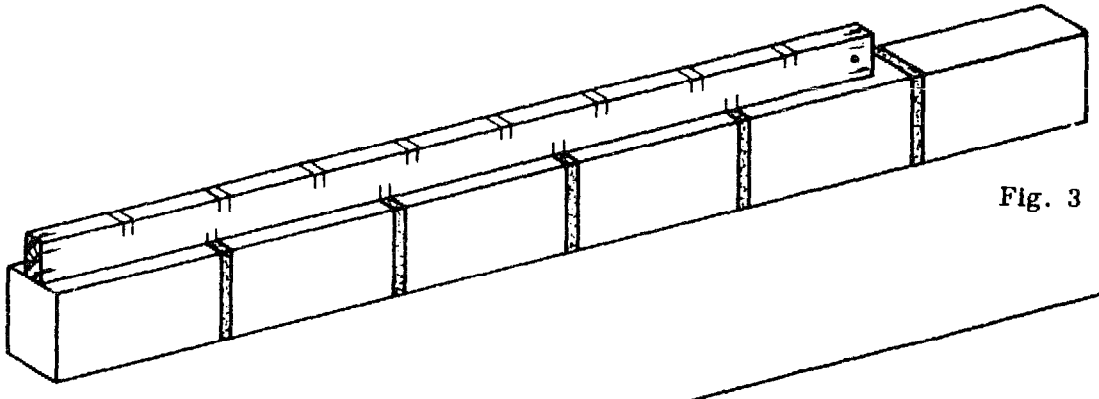

Fig. 3

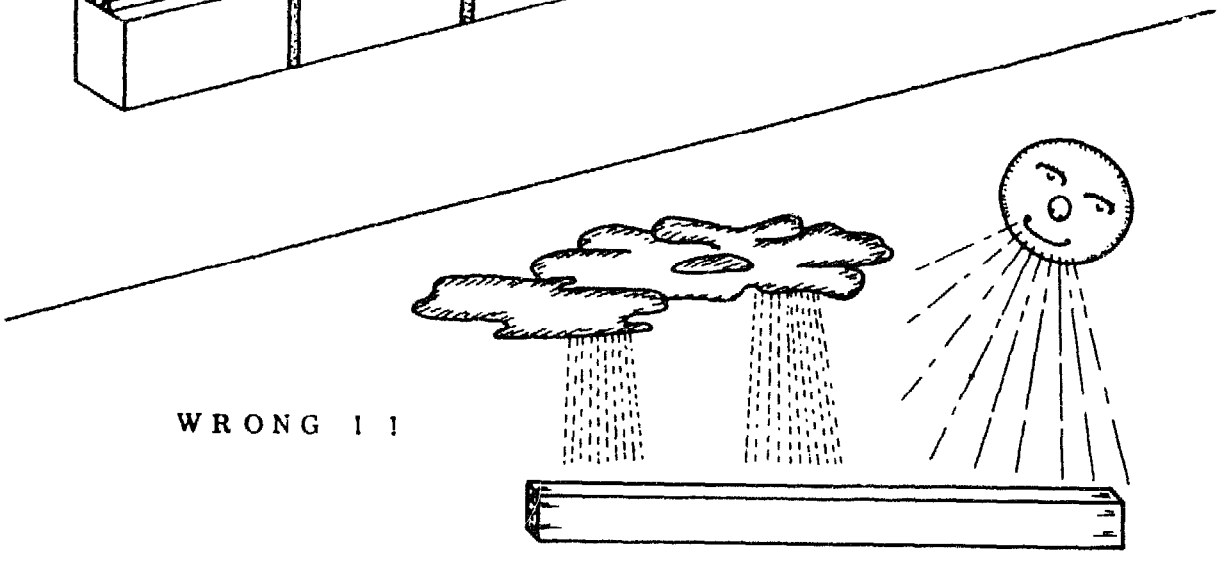

WRONG ! !

N P V C	
8	TOOLS

STRAIGHTENING TOOLS.

STRAIGHT EDGE

This is a planed piece of wood which should be well seasoned and dry to prevent it from bending and twisting. The dimensions of a straight edge are usually 2 to 2,50 m long, 7,5 cm wide and 2,5 cm thick; both edges must be perfectly straight and parallel (Fig. 1).

The straight edge is employed for testing masonry work either alone or in conjunction with the spirit level (Fig. 2).

Some straight edges are marked off with saw cuts to the required gauge; that is, one division is equal to the height of a block plus the joint; and, on the other edge, the length of a block plus the joint (Fig. 3).

Its wide range of further applications will be described as it is needed for certain constructions.

Do not allow a straight edge to dry out in the sun or to be soaked in water as this may cause it to bend or twist (Fig. 4). When you are finished using it, hang the straight edge in a protected place to keep it straight.

NOTES:

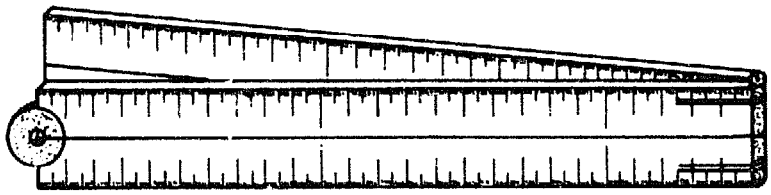

FOLDING RULE Fig. 1

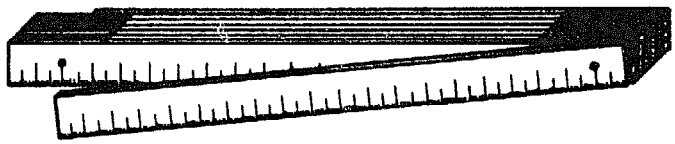

ZIG-ZAG RULE Fig. 2

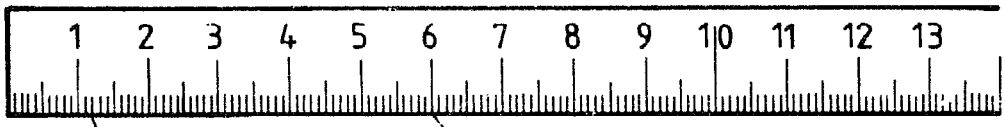

MILLIMETRE MARKS

CENTIMETRE MARKS

Fig. 3

PENCIL Fig. 4

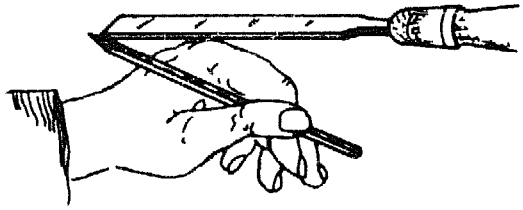

Fig. 5

N P V C	
10	TOOLS

MEASURING AND MARKING TOOLS.

MEASURING AND MARKING TOOLS

FOLDING RULE

The four-fold rule shown in Fig. 1 is made of four wooden, plastic or metal pieces which are held together by special hinges. It is one metre long and divided on both sides into millimetres and centimetres. It is used to find and check measurements as well as to mark out the work.

To make the rule operate more smoothly and last longer, put a drop of machine oil in the joints.

ZIG-ZAG RULE

A zig-zag rule is similar to a folding rule (Fig. 2). It is made out of the same materials but from pieces which are 20 cm long. As the hinges are different from those of the folding rule, be careful not to break it when opening and closing it. They come in lengths of 100 and 200 cm.

HOW TO READ RULES

The marks on a rule are of different lengths to make it easier to read accurately (look at the rule you use in class). The marks at each centimetre are the longest, the marks for 5 mm (1/2 cm) are medium long, while the millimetre marks are shortest (Fig. 3).

When measuring with the folding rule or the zig-zag rule, one must make sure that the rule is completely opened and straight. It is then held parallel to an edge, or at right angles to a face. If this is not done, the measurements you get will always be a little different from the correct ones.

PENCILS

For marking on wood, a hard lead pencil (H or 2H) is best (Fig. 4). The point should always be kept sharp, because using a blunt pencil can result in an inaccuracy of up to 2 mm.

Fig. 5 shows how to hold a pencil while sharpening it.

NOTES:

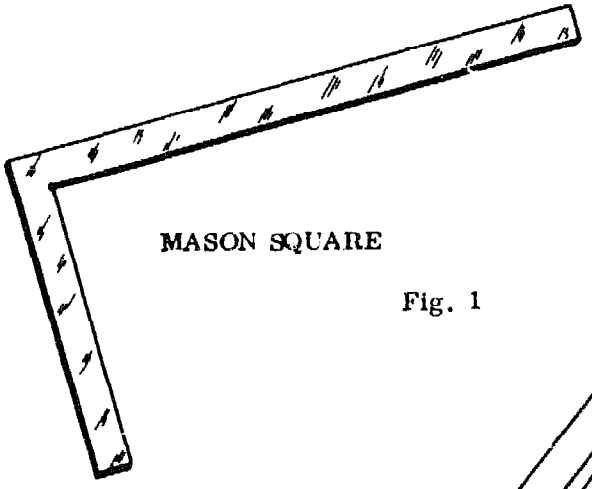

MASON SQUARE

Fig. 1

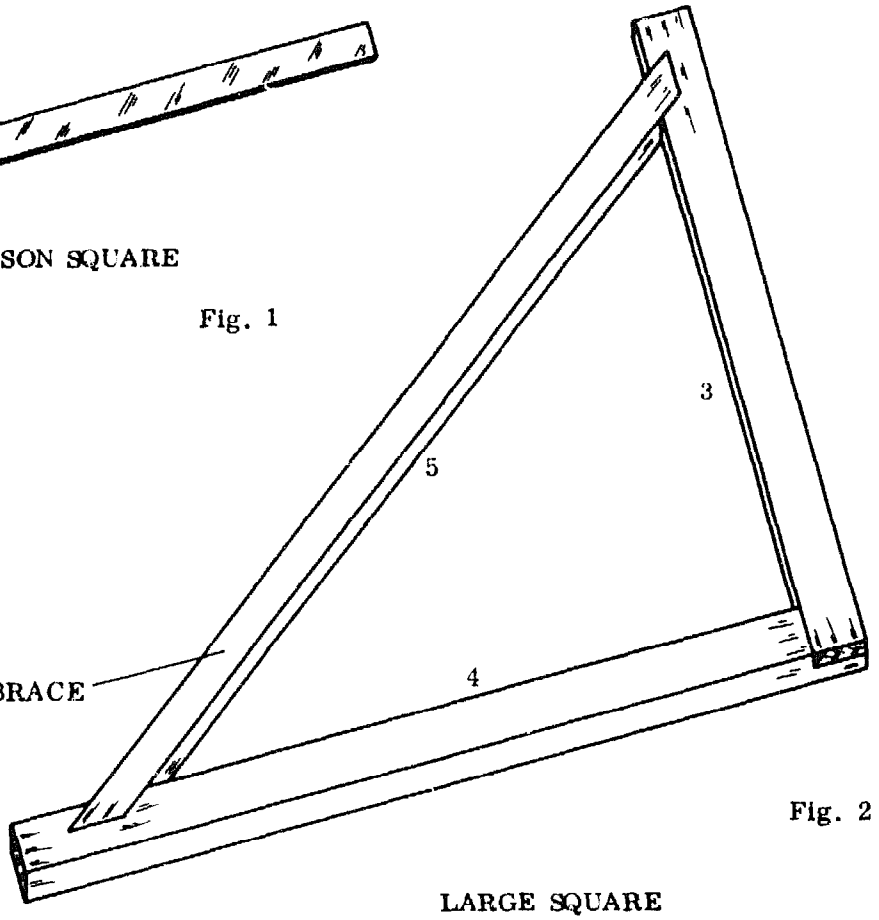

Fig. 2

LARGE SQUARE

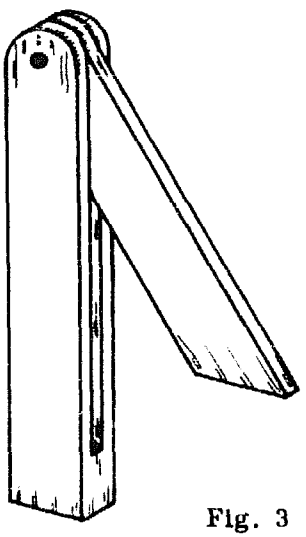

Fig. 3

SLIDING BEVEL

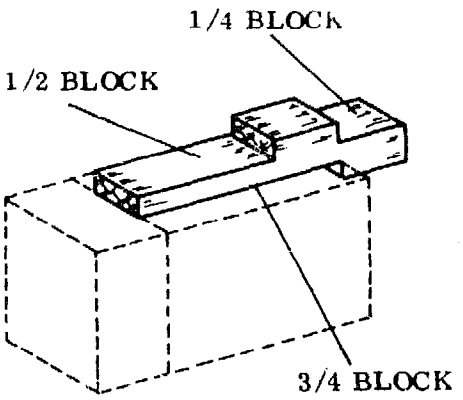

BLOCK GAUGE

Fig. 4

N P V C	MEASURING AND MARKING TOOLS.
12 TOOLS	

THE MASON SQUARE

The mason square is made from steel (Fig. 1). Measured along the outer edge, the short blade is 33 cm long and the long blade is 60 cm long. The blades are sometimes marked with millimetres, centimetres, and decimetres.

The mason square is used for setting out right angles as at quoins, and for testing corners during plastering.

When using the square, hold it either horizontally or vertically (not at an angle) to be sure of getting the correct angles.

THE LARGE SQUARE

This square is made entirely from wood (Fig. 2). To construct this large square which is made at the building site, use the 3-4-5 method and nail the boards together securely. A brace over the two legs ensures that the square remains at the correct angle. The square is used to test larger right angles.

THE SLIDING BEVEL

A sliding bevel (Fig. 3) can be made out of wood by the Rural Builder. The two legs are adjustable and held together by a small bolt with a wingnut to make it easy to adjust the bevel. It is used when you have to mark many blocks at a certain angle (also see page 78).

BLOCK GAUGES

These are pieces of wood cut to the size and shape indicated in Fig. 4. Block gauges may be used to mark off the sizes of 1/4, 1/2, or 3/4 blocks. Since the dimensions of landcrete blocks are different from sandcrete blocks, the trainee will make two different block gauges.

The gauges help the Rural Builder to work more efficiently when he is measuring blocks for cutting.

- NOTE: More tools for measuring and marking are included in the following sections with the carpentry tools.

NOTES:

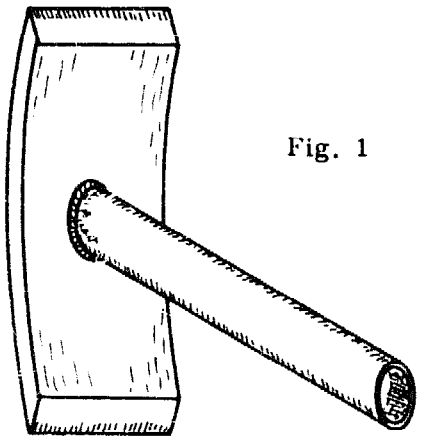

Fig. 1

BLOCK SCUTCH OR SCUTCHER

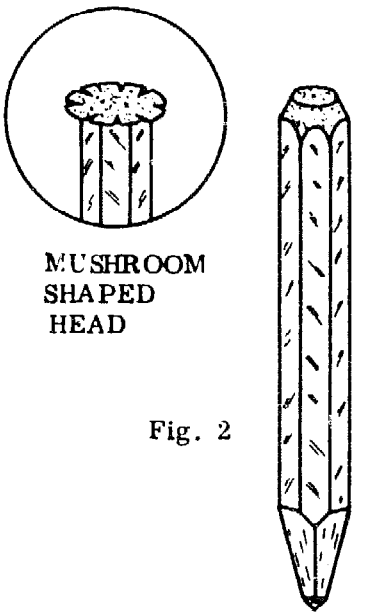

Fig. 2

POINTED CHISEL

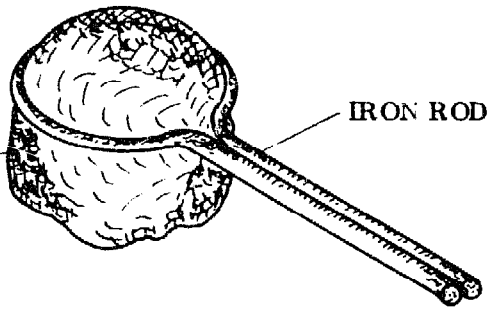

Fig. 3

STONE BREAKING TOOL

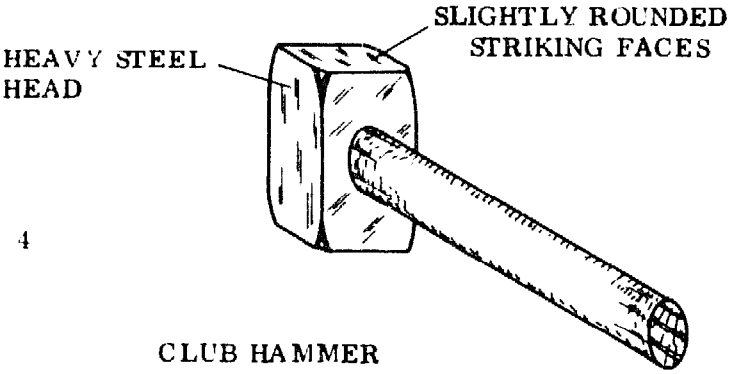

Fig. 4

CLUB HAMMER

N P V C		CUTTING TOOLS.
14	TOOLS	

CUTTING TOOLS

THE BLOCK SCUTCH

This tool consists of a hard steel blade with two cutting edges, welded to the handle which is made of iron pipe (Fig. 1). It is used for cutting all sorts of blocks and dressing cut surfaces. The angle between the blade and handle should be 75 to 80 degrees, which increases the effectiveness of the blow. The handle is oval shaped to provide a better grip.

THE POINTED CHISEL (COLD CHISEL)

This is a forged steel rod with a hardened cutting tip and striking end. It is octagonally shaped to provide a better grip for the hand (Fig. 2). Cold chisels are available in different sizes and are used together with a club hammer.

The end of the cold chisel should never be allowed to become mushroom shaped, as this may result in badly cut hands or in a piece of steel breaking off and piercing someone's eye. Always wear your safety goggles when you use the chisel.

THE STONE BREAKING TOOL

A device like the one in Fig. 3 is a useful tool on the building site. It can be made locally and is used to break stones into smaller pieces needed for concrete work. Place the device on top of the piece of stone and press it down during the hammer blow.

THE CLUB HAMMER

This hammer has a heavy steel head with slightly rounded striking faces and it can weigh from 1 to 2 kg.

The head is fixed on a wooden handle which is 15 to 20 cm in length. The hammer is used to strike cold chisels and to break stones into smaller sizes. When using the hammer, make sure that the wedge that holds the handle in the head is firmly in position (Fig. 4).

NOTES:

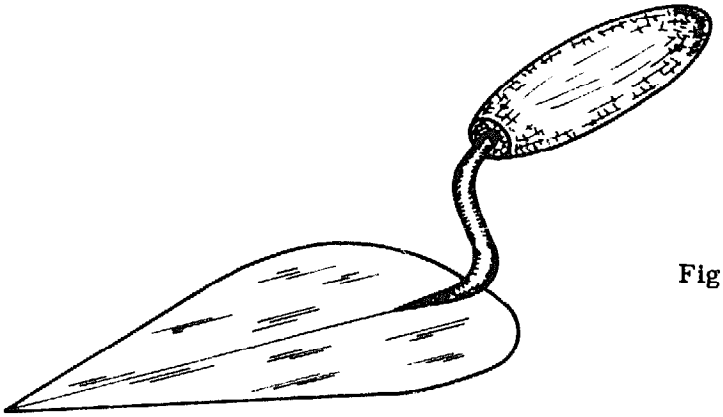

Fig. 1

POINTING TROWEL

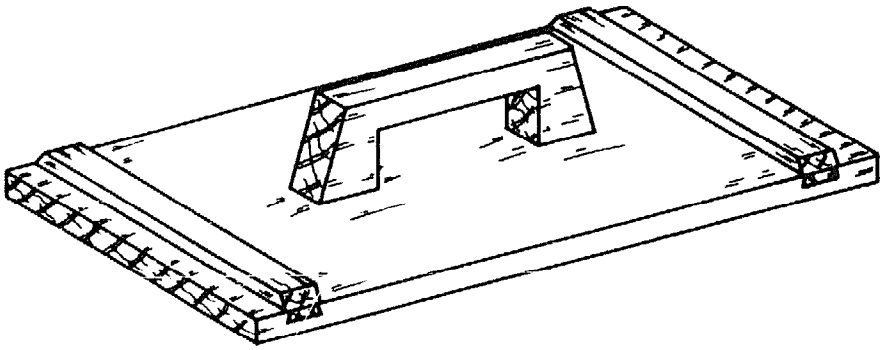

Fig. 2

BIG WOOD FLOAT

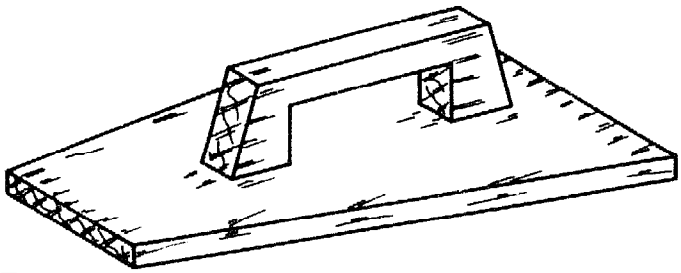

SMALL WOOD FLOAT

Fig. 3

N P V C	
16	TOOLS

FINISHING TOOLS.

FINISHING TOOLS

THE POINTING TROWEL

Fig. 1 shows a trowel of almost the same shape as the brick trowel mentioned earlier, but smaller in its dimensions.

This pointing trowel is chiefly used for precision work such as finishing in general and the dressing of corners and edges in particular.

THE BIG WOOD FLOAT

This tool has a blade made of a soft wood like Wawa. It measures approximately 40 cm long and 25 cm wide. A handle made from hard wood is fixed to it with screws so that the blade can be replaced when necessary (Fig. 2).

Its main uses are to distribute an even thickness of mortar during plastering and to flatten concrete surfaces during floor construction.

THE SMALL WOOD FLOAT

The small wood float is constructed in the same way as the big one but with smaller dimensions, being approximately 25 cm in length and 15 cm in width.

As it is used mainly to give the plaster and floor surfaces a smoother finish, its blade may be made from hard wood (Fig. 3).

Because the wood float is made from wood it absorbs water from the wet mortar or cement during use, and it tends to warp. To prevent it from warping, keep the float under water when it is not in use so that all the sides are wet and the wood swells evenly.

NOTES:

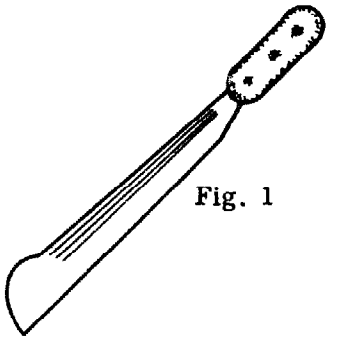

Fig. 1

CUTLASS

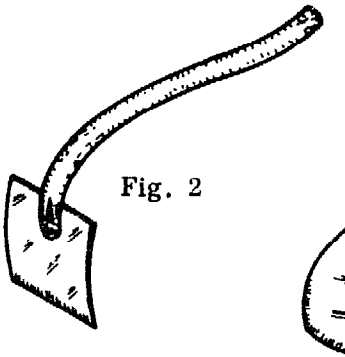

Fig. 2

HOE

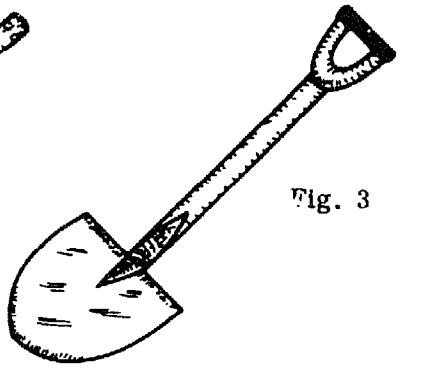

Fig. 3

SHOVEL

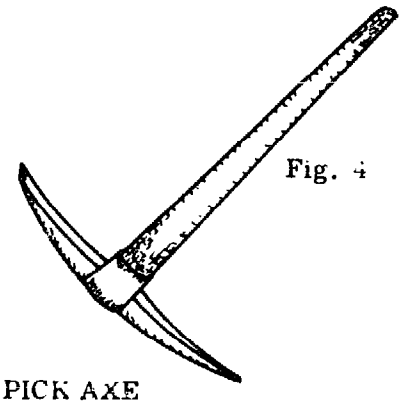

Fig. 4

PICK AXE

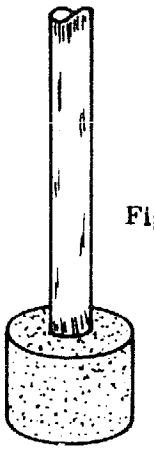

Fig. 5

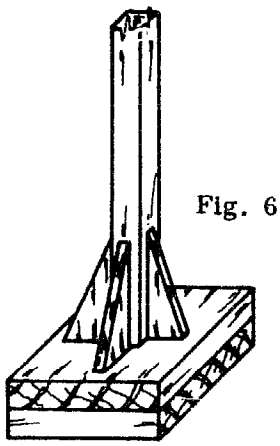

Fig. 6

RAMMERS

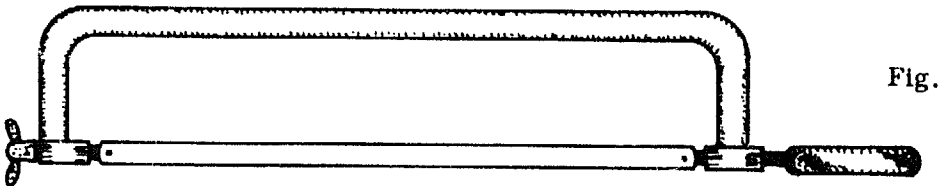

Fig. 7

HACKSAW

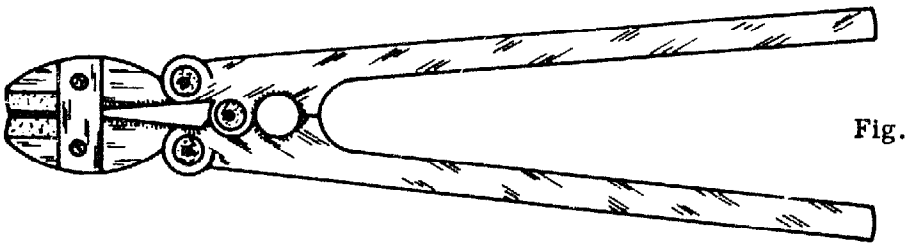

Fig. 8

BOLT CUTTER

N P V C	
18	TOOLS

SITE TOOLS.

SITE TOOLS

CUTLASS

The cutlass (Fig. 1) is used for clearing the site and other general cutting work.

HOE

This farming tool is often used in Rural Building to excavate top soil (Fig. 2).

SHOVEL

There are various types of shovel-like tools. The most common type is the one with a round-nosed steel blade of about 25 by 30 cm, connected to a short wooden shaft that has a "D" or "Y" shaped handle at the end (Fig. 3).

Whether the shovel has a short or a long handle is a matter of personal preference or local custom. It has been observed that the short-handled one is more suitable for filling purposes and for moving light soil, while the long-handled shovel with a square steel blade is better for loading sand and for mixing.

PICK-AXE

This digging tool consists of a heavy steel head with one pointed end and one end with a chisel edge. The head is connected to a wooden shaft (Fig. 4). The pick-axe is used during excavation to break up hard rocky soils or loosen laterite etc.

RAMMER

Rammers are either made entirely out of wood or they have a wooden handle attached to a metal or concrete head (Figs. 5 & 6). They are used to compact soil or concrete.

HACKSAW

A hacksaw is a handsaw used for cutting metal. It consists of a steel blade tightly stretched in a metal frame. The blade is removable and other blades can be fixed in the frame for cutting asbestos-cement or other materials (Fig. 7).

BOLT CUTTER

The bolt cutter is a tool which is used to cut steel reinforcing rods up to 19 mm in diameter (Fig. 8). Be careful when using the bolt cutter, one can easily damage the tool when cutting not perpendicular on the rod.

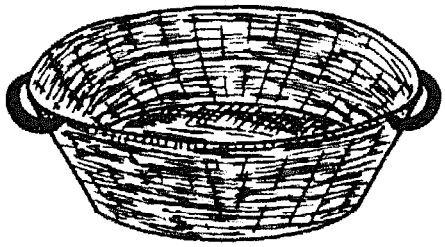

Fig. 1

METAL HEADPAN

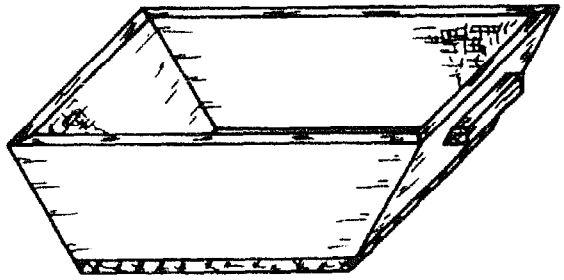

Fig. 2

WOODEN HEADPAN

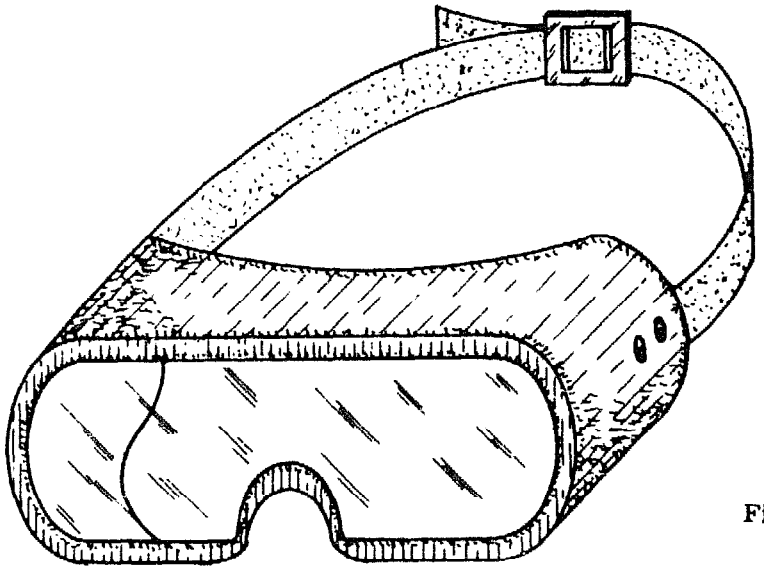

Fig. 3

SAFETY GOGGLES

N P V C	
20	TOOLS

SITE TOOLS & SAFETY GEAR.

HEADPAN

Smaller quantities of mortar and concrete are kept and transported in headpans. These are round containers shaped like bowls and made from mild steel or sheet metal (Fig. 1).

If made locally from wood, the headpan will be square with slanting sides (Fig. 2).

The common headpan has a holding capacity of about 15 litres for liquids, or half a bag of cement (slightly heaped up). These figures indicate that the headpan can also be used as a measure.

If you make your own headpan from wood or metal, be sure that it has the same capacity as other headpans so that you can measure accurately with it.

SAFETY GEAR

SAFETY GOGGLES

These are made from plastic and are designed to protect the eyes during all kinds of cutting or grinding operations and where there is a lot of dust in the air (Fig. 3).

NOTES:

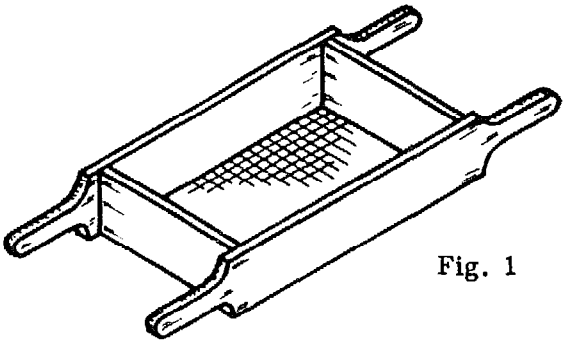

Fig. 1

SCREEN

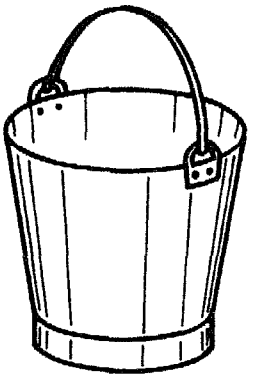

Fig. 2

BUCKET

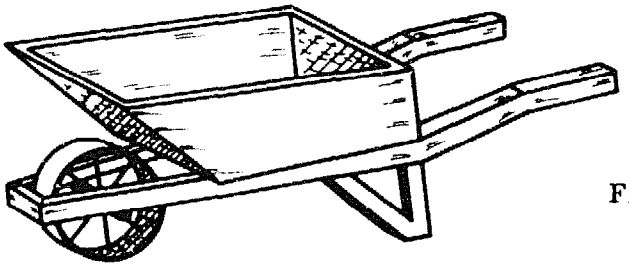

Fig. 3

WHEELBARROW

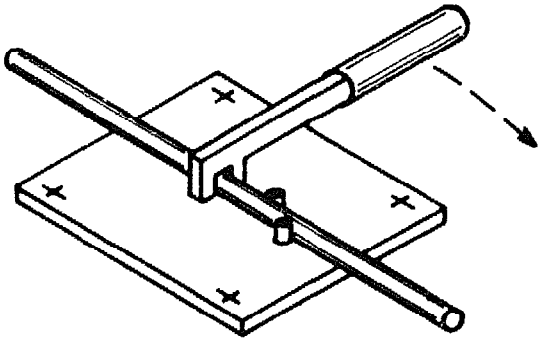

Fig. 4

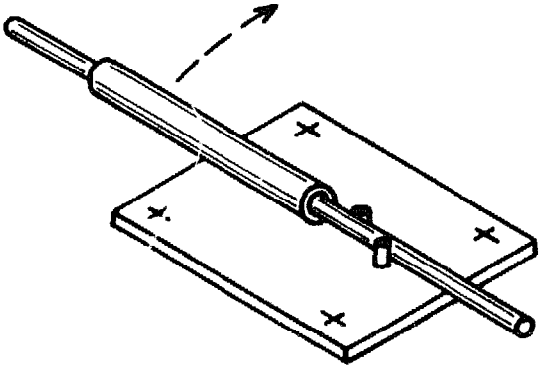

Fig. 5

BENDING PLATE

N P V C		SITE EQUIPMENT.
22	TOOLS	

SITE EQUIPMENT

SCREEN

A screen is a rectangular frame with a wire mesh built into it for separating impurities or stones from sand (Fig. 1). A well-equipped building site will have two different screens: a larger mesh to separate out stones of a convenient size; and a smaller one to sieve sand that will be used for plastering.

BUCKET

Buckets are open containers that can be made from different materials like rubber, plastic, or galvanized iron (Fig. 2). The average bucket (size no. 28) has a volume of 10 litres and is used mainly for carrying water.

ROPE

Ropes used on the building site are usually made from hemp or nylon. Nylon ropes have a tendency to stretch when they are under strain, and this must be taken into consideration when you use this kind of rope during construction work.

WHEELBARROW

The wheelbarrow is a steel or wooden container with a single steel or rubber-tyred wheel in front. It is lifted and pushed forward by means of two hand-holds attached to the frame (Fig. 3).

BENDING PLATE

Our Rural Building equipment for bending iron rods simply consists of a base-plate with two steel pegs which are spaced according to the diameter of the rod to be bent, and a bending bar (Fig. 4). The bending bar is used to do the actual bending. This is a key-shaped tool with a slot in one side into which the rod fits. Each different diameter of rod needs its own bending bar. If a suitable bending bar is not available, a pipe can be used to do the job (Fig. 5).

WATERING CAN

The watering can (not illustrated here) is a container with a pouring spout, used for watering plants. On the building site it is often used to wet down newly poured concrete or freshly made sandcrete blocks.

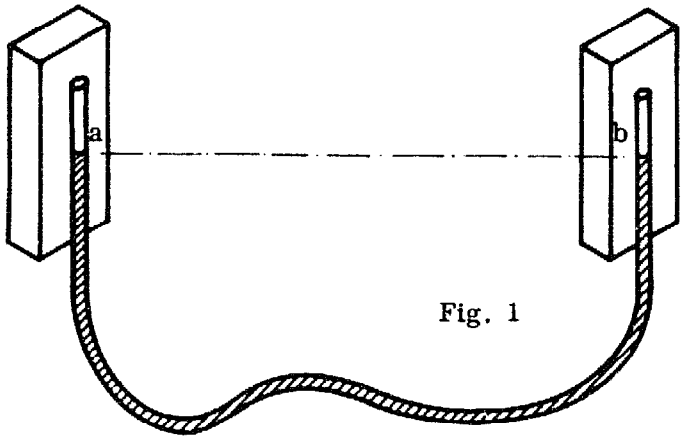

Fig. 1

Fig. 2

WATER LEVEL

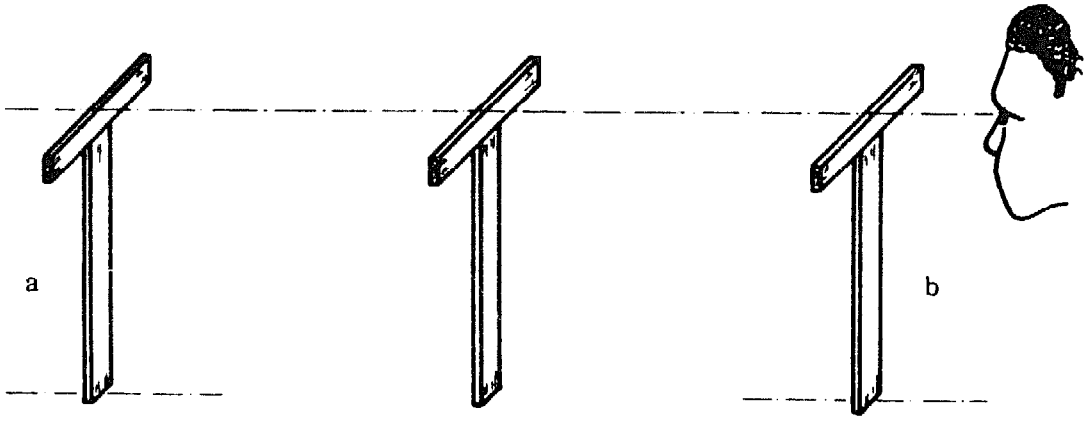

BONING RODS

Fig. 3

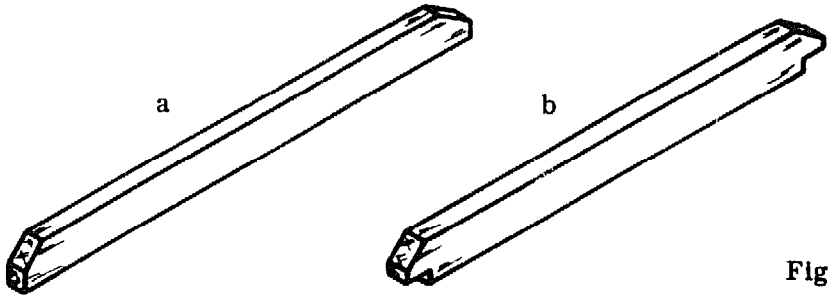

Fig. 4

STRIKE BOARD

N P V C		SITE EQUIPMENT.
24	TOOLS	

WATER LEVEL

This instrument is used for setting out levels on the site as well as to transfer and control levels over large distances. It consists of a transparent plastic tube filled with water (Fig. 1). The level of the water at one end of the tube (a) will be at exactly the same height as the level at the other end (b), provided that there is no air bubble in the tube and it is not buckled.

The water level enables us to level over large distances with a high degree of accuracy.

If there is no transparent plastic tube available and some rubber hose can be found, the Rural Builder can take two glass bottles, knock out the bottoms and fit the bottle necks to each end of the hose. This apparatus is then filled with water until the water is seen in the bottles. Levels can be read as easily with this device as with any other water level (Fig. 2).

BONING RODS

Boning rods are T-shaped wooden tools, usually 120 cm high and 20 cm wide at the top. They are used in sets of three to help the Rural Builder to level between two given points (Fig. 3).

Points a and b are marked with the water level and any point in between them can be obtained by using the third boning rod and sighting along the rods (Fig. 3).

STRIKE BOARD

Strike boards are made from well seasoned wood. They are similar to straight edges except that they are usually longer (Fig. 4).

Strike boards (a) are used to level off the screed on floors, or in the case of notched strike boards (b) to level off concrete before the screed is layed.

NOTES:

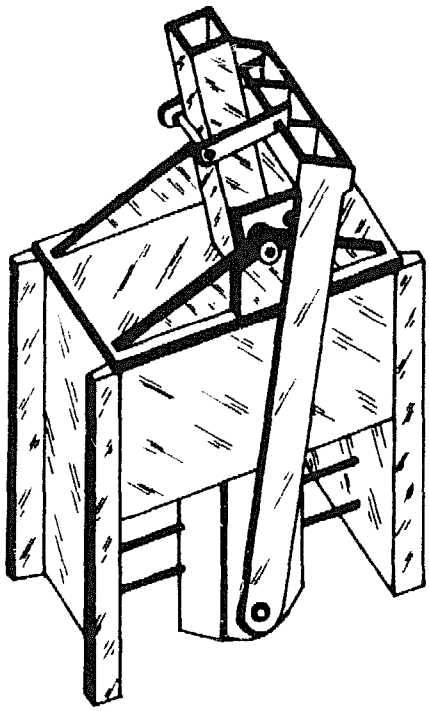

"CINVA RAM" BLOCK PRESS

Fig. 1

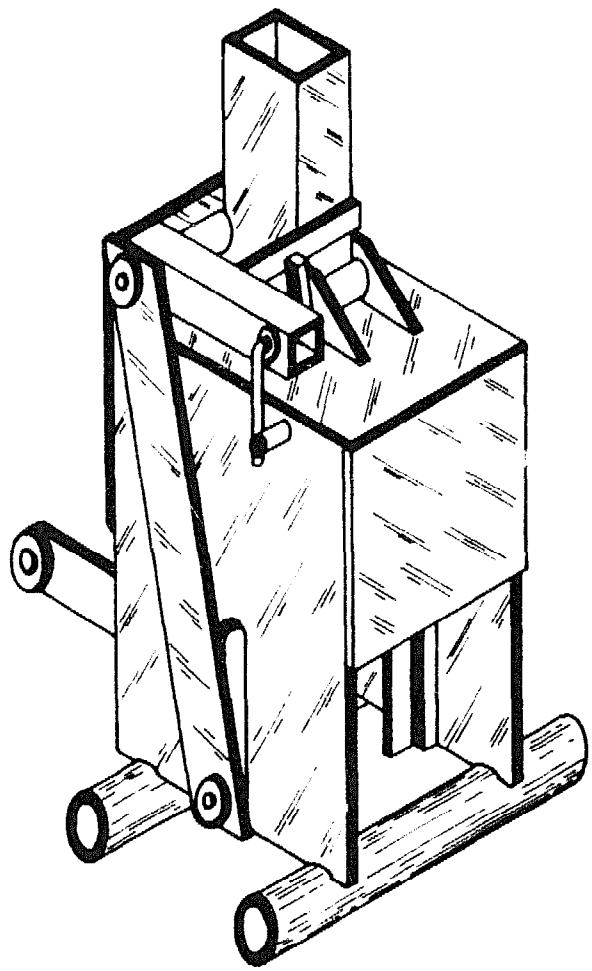

"TEK BLOCK" PRESS

Fig. 2

N P V C		SITE EQUIPMENT.
26	TOOLS	

"CINVA RAM" BLOCK PRESS

The Cinva Ram block press is a simple low-cost machine which produces building blocks from common laterite. It consists of a mould in which a slightly moist soil/cement mixture is compressed (packed down) by a hand operated piston and lever system (Fig. 1).

Unlike sand-cement blocks made with a similar press, these blocks can be removed immediately from the press and st[illegible]ed for curing without the use of a pallet underneath.

The machine is made from steel and it is tough, durable and will stand up to long and hard use. Little maintenance is needed except for oiling.

- SPECIFICATIONS: Size of blocks -- 10 x 15 x 30 cm
  Building unit -- 12 x 17 x 32 cm (2 cm joints).

"TEK" BLOCK PRESS

The Tek block press is similar to the Cinva Ram, except that this press produces blocks of larger dimensions (Fig. 2).

The Tek block press was designed at U.S.T. Kumasi and has been used successfully in the field for many years. The Tek block press can make blocks in any area where good laterite is available.

A moist soil/cement mixture is put into the steel mould box, pressed into a block and ejected (pushed out).

With the wooden handle, one man can put a lot of pressure on the block, so the blocks are very hard and long-lasting.

- SPECIFICATIONS: Size of blocks -- 14 x 22 x 29 cm
  Building unit -- 16 x 24 x 31 cm (2 cm joints).

- MAINTENANCE: Oiling the machine will make it work better and last longer. Oil or grease the moving parts at least twice a day when the machine is in use.

  Wipe the inside of the mould box with oil about every 10 blocks. This will make it easier to remove the blocks.

  If more than one man presses on the handle of the machine, the handle should break. If the handle is too big and strong, the machine will break instead of the handle. A broken machine is far more difficult to repair than a broken handle, therefore do not use any handle which is longer than 2,5 m.

  When the machine is not in use, paint it with oil to prevent rust.

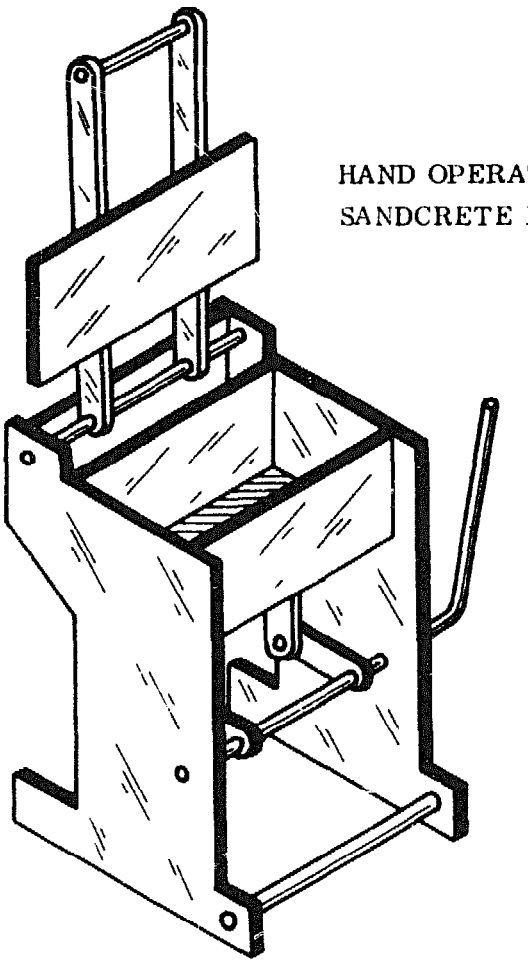

HAND OPERATED
SANDCRETE BLOCK MACHINE

Fig. 1

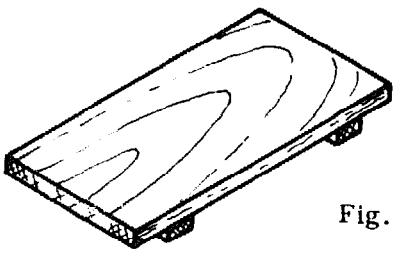

Fig. 2

PALLET

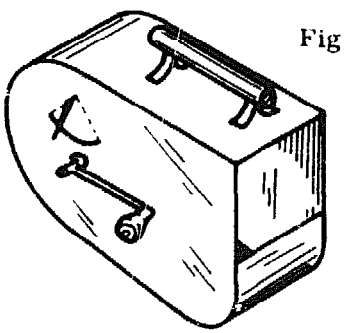

Fig. 3

SPATTERDASH APPARATUS

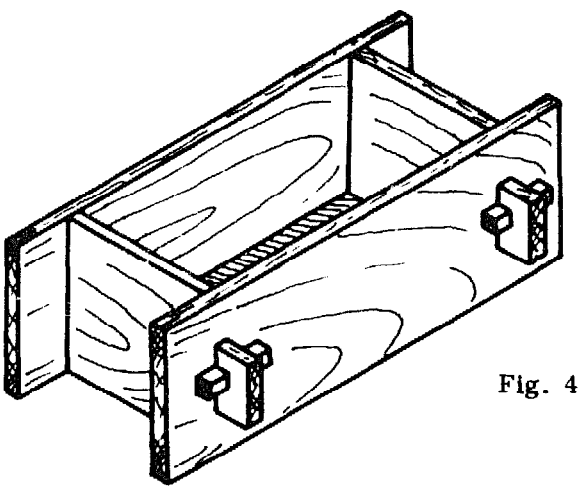

Fig. 4

WOODEN MOULD

N P V C		SITE EQUIPMENT.
28	TOOLS	

HAND OPERATED SANDCRETE BLOCK MACHINE

This type of block machine consists mainly of a mould box with a movable bottom plate mounted into a supporting frame. The bottom plate is connected to a handle so that it can be raised (Fig. 1).

The lid is made of heavy material so that it presses down to compact the sandcrete. Sometimes additional weights are attached to the top of the lid to make it press harder.

After it is compacted, the block is pushed out by means of the handle at the side of the machine.

Unlike landcrete blocks, sandcrete blocks must be made on pallets, as they are too soft to be carried when they are freshly made (Fig. 2).

The inside measurements of the mould box are approximately: 46 cm in the length, 23 cm in the width, and 28 cm deep. Blocks of various shapes can be made with this machine by changing the height of the pallet or by using inserts.

SPATTERDASH APPARATUS

The spatterdash apparatus is used to give plaster or concrete an attractive appearance without the use of paint.

A slurry of sand and cement is placed in the apparatus (Fig. 3); when the handle is turned, the mixture is thrown against the wall, giving the surface a textured effect. Another handle adjusts the texture of the spatterdash from rough to fine.

WOODEN MOULD

A specially made wooden mould can be used when unusual blocks such as arch-blocks are needed or when there is no block-making machine available.

To make work easier and more accurate, the wooden mould should be made so that the sides of the mould can be removed easily and fixed back together by using wedges through tenons (Fig. 4).

NOTES:

BULLOCK CART

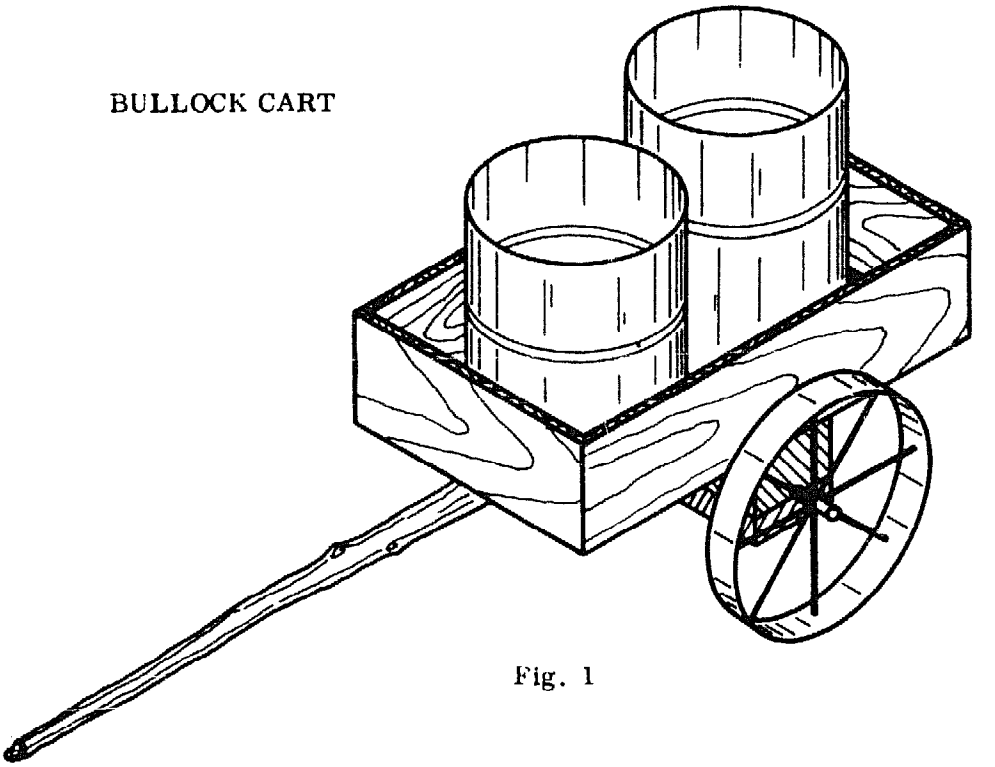

Fig. 1

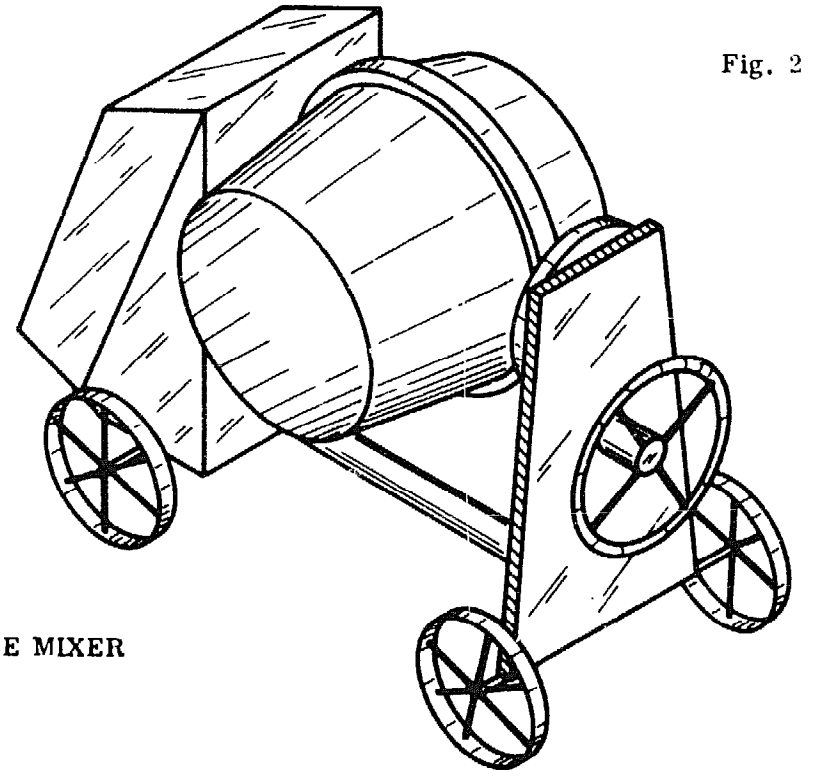

Fig. 2

CONCRETE MIXER

N P V C	
30	TOOLS

SITE EQUIPMENT.

BULLOCK CART

A bullock cart can transport water and limited quantities of building materials and it is therefore particularly useful at a Rural Building site. Bullock carts are made locally from wood and have steel rimmed wheels. The steel axles turn in wooden bearings which are soaked in oil. These bearings should be inspected and oiled regularly (Fig. 1).

CONCRETE MIXER

If there are few labourers and it is necessary to mix large amounts of concrete, a concrete mixer can be hired to do some of the work (Fig. 2).

The Rural Builder should know how to load the machine in the right sequence and make sure that the concrete is well mixed and has the correct content of water.

After the job is done the machine should be cleaned thoroughly with water and all sand and cement should be washed off from the drum and the frame of the machine.

A maintenance card will tell you how to maintain the machine and how often this needs to be done.

The engine needs special care and the Rural Builder should learn as much as he can about caring for it.

NOTES:

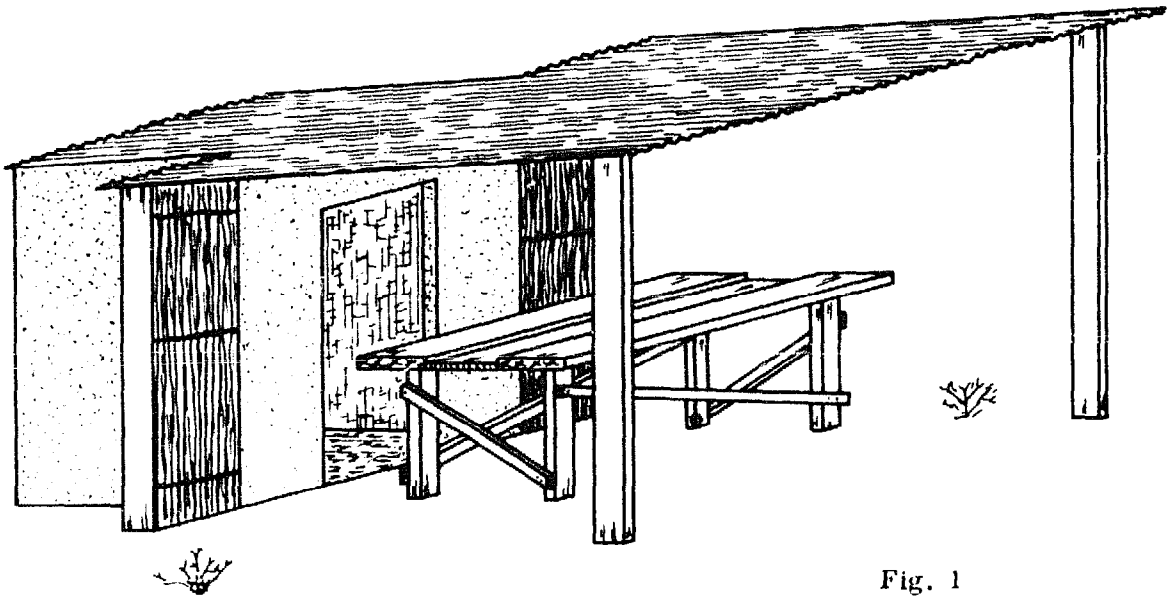

Fig. 1

THE WORKPLACE

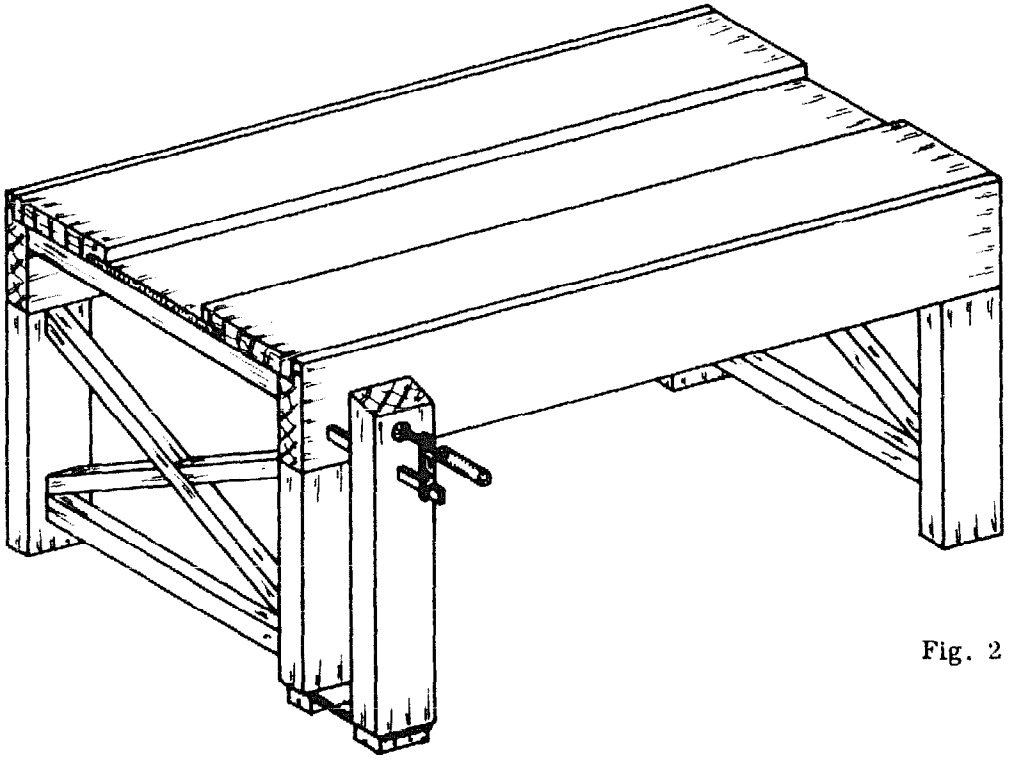

Fig. 2

THE WORK BENCH

N P V C		THE WORKPLACE & THE WORK BENCH.
32	TOOLS	

THE WORKPLACE

The ideal workplace (Fig. 1) will have a waterproof shed which is open on three sides. The fourth side should be arranged for laying out the tools and toolboxes. If possible there should be a lockable store for tools and materials next to the workshed. The workshed should be close to the timber pile.

THE WORK BENCH

The bench is used for supporting the workpiece while it is being marked and during the various operations of its construction. Therefore, the bench must be strong, rigid and made from good wood.

The top must be flat and it is constructed out of planks which are 5 cm thick and 30 cm wide. The length of the bench can be from 2 to 4 metres. The height of the bench can vary between 80 and 90 cm. The legs should be well braced.

There are single and double width work benches. The last type is commonly used at the building site. It must be wide enough to handle door and window frames and long enough (a full board length of 4 metres) to be used for bending concrete iron.

If the bench is built on the building site, it is not necessary to use extra timber. The timber used in the bench can be reused for some other workpiece after the carpentry work is finished.

Permanent work benches (Fig. 2) used in a workshop will be constructed slightly different from the types used at a construction site (Fig. 1). A wooden vice is used to hold the timber, with the help of a G-clamp (Fig. 2).

NOTES:

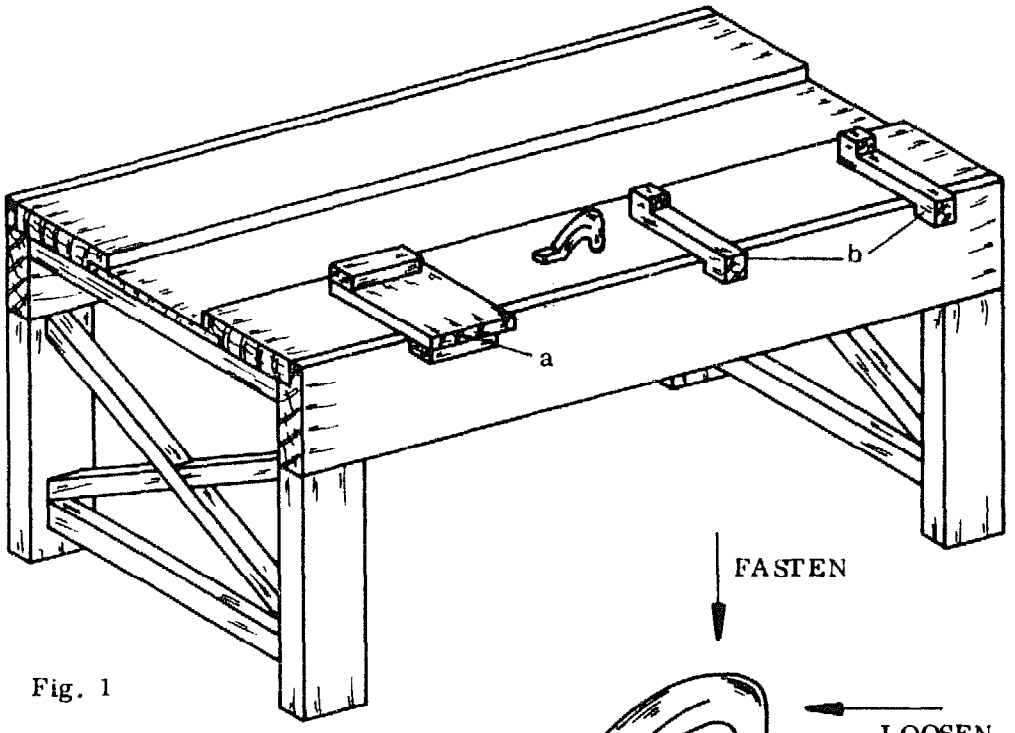

Fig. 1

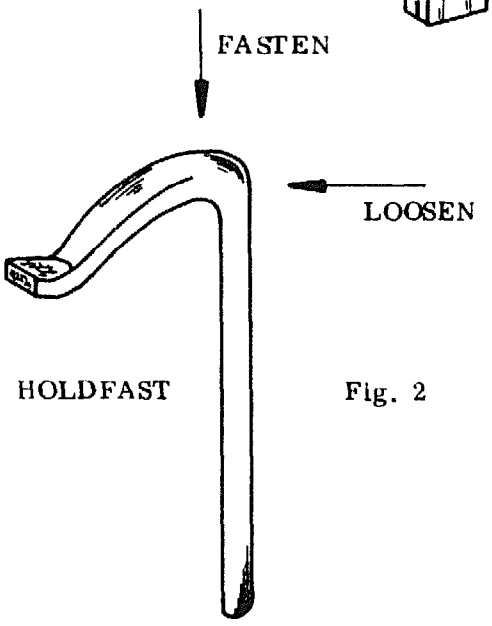

Fig. 2

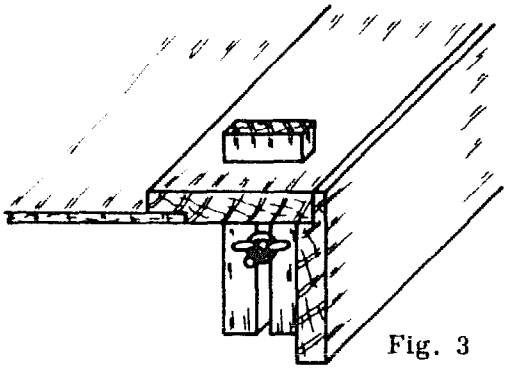

Fig. 3

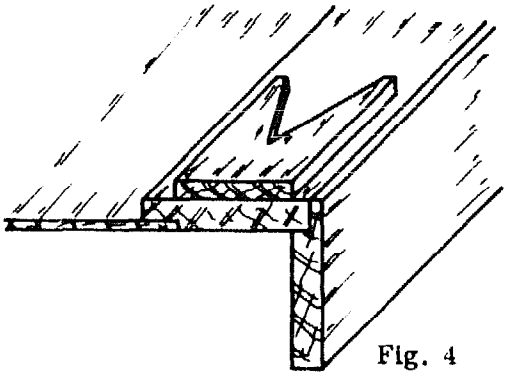

Fig. 4

BENCH STOPS

N P V C		THE WORK BENCH.
34	TOOLS	

BENCH HOOKS

When we have to cut a short piece of timber across the grain, we use a wide bench hook to support it. The bottom batten of the hook is held against the side of the bench and the work is pressed against the upper batten (Fig. 1a).

For long pieces of timber, we use small bench hooks for support (Fig. 1b).

Wide bench hooks measure approximately 15 x 25 cm; small ones about 5 x 25 cm.

THE HOLDFAST

A holdfast can be used to fasten wood firmly to the top of the bench. It is made tight or loosened by knocking it with a hammer (Fig. 2).

Holdfasts can be made locally from a piece of concrete iron, 2,5 cm in diameter, with a piece of a car spring welded to the top.

THE BENCH STOP

On the left side of the bench there is a bench stop made from hard wood, to support the timber during planing.

Some bench stops can be moved up or down. These are called adjustable bench stops (Fig. 3). Other bench stops are stationary (Fig. 4).

NOTES:

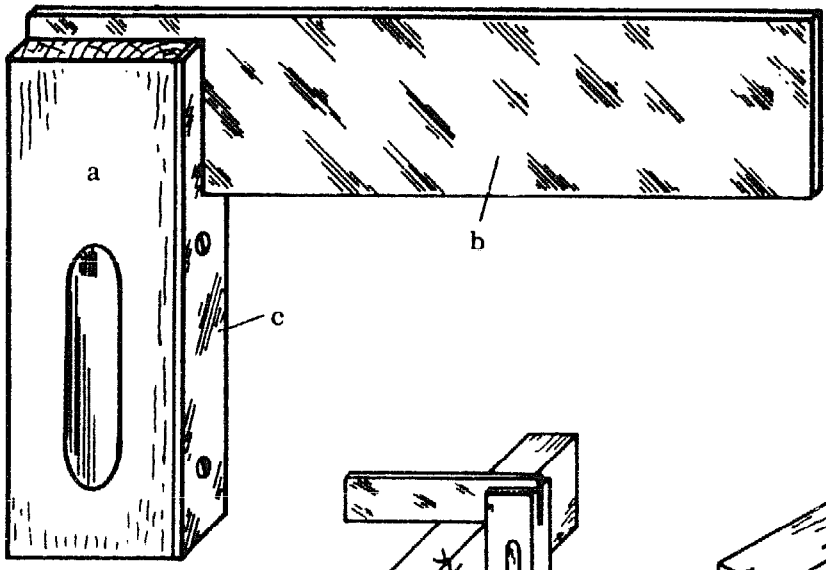

Fig. 1

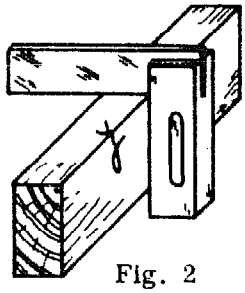

Fig. 2

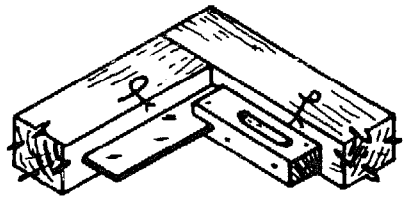

Fig. 3

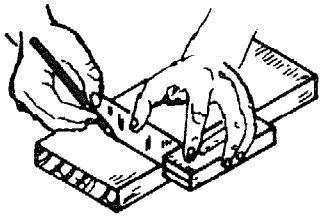

Fig. 4

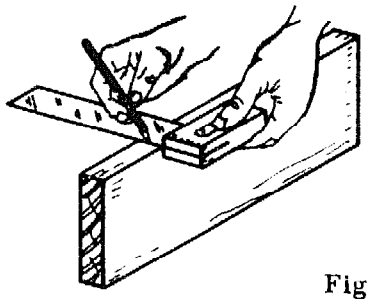

Fig. 5

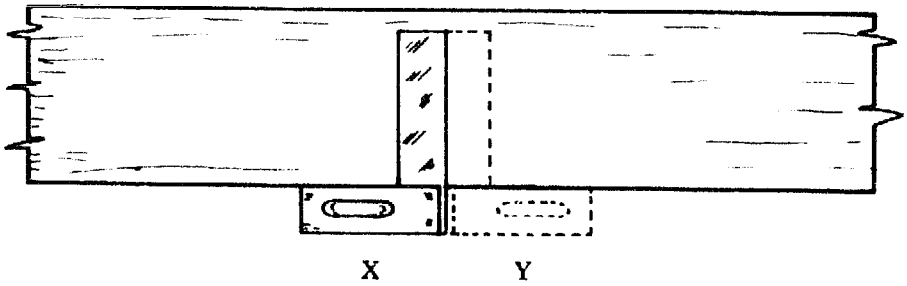

Fig. 6

N P V C	
36	TOOLS

THE TRY SQUARE.

THE TRY SQUARE

The try square is used for marking timber, and for testing right angles to make sure that they are correct.

Its parts are (Fig. 1): the stock (a), the blade (b) and the stockface (c). The stock can be all metal or it can be made of hard wood with a brass stockface. The blade is made of steel. The angle between the stockface and blade is exactly 90 degrees.

HOW TO USE THE TRY SQUARE

- To test the angles of workpieces and boards, place it as shown in the figures on the left (Figs. 2 & 3). Always use the try square with the stock against the face edge or the face side of the workpiece when you are squaring or testing angles.
- For marking timber, press the stockface against one edge or side of the workpiece and use the blade to guide your pencil (Figs. 4 & 5).
- Keep the pencil pressed to the blade, to avoid making double lines.
- Be careful not to drop the try square or use it carelessly. Any small movement of the blade will make it inaccurate.

HOW TO TEST THE TRY SQUARE

1. Select a board with a true edge.
2. Lay the blade in position "X" and draw a line along the blade (Fig. 6).
3. Turn the square over as shown by the dotted lines (position "Y"). If the line and the blade come together exactly, the angle of 90 degrees is true.

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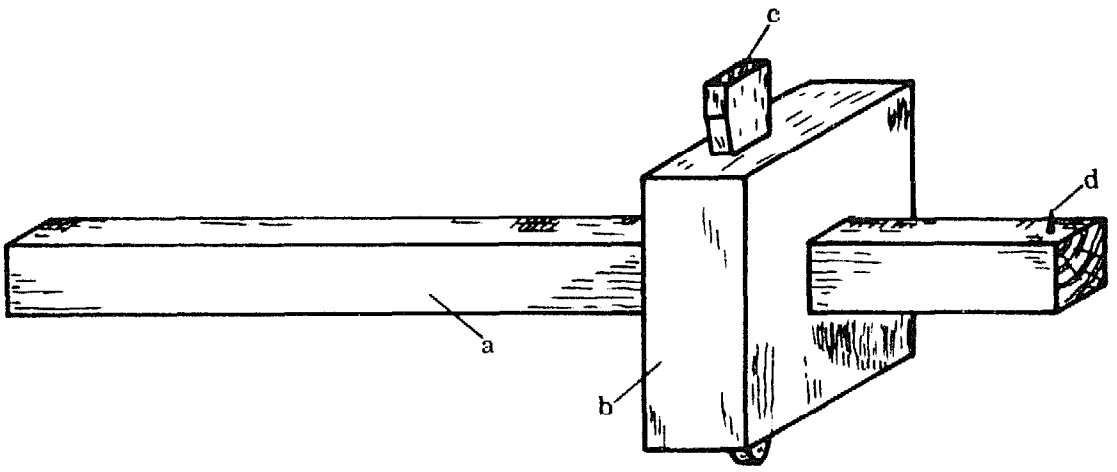

Fig. 1

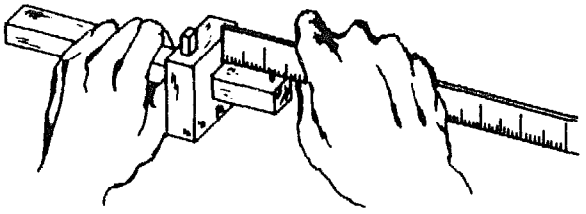

Fig. 2

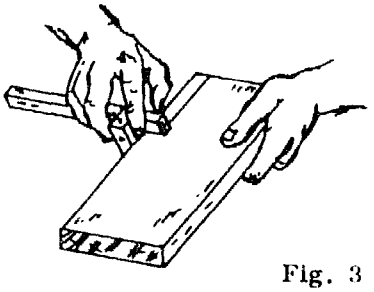

Fig. 3

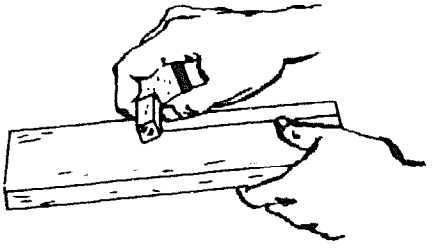

Fig. 4

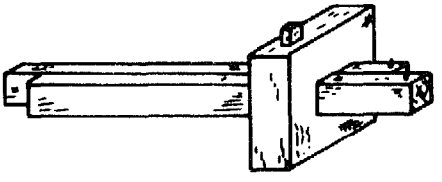

Fig. 5

N P V C	
38	TOOLS

THE MARKING GAUGE.

THE MARKING GAUGE

The marking gauge (Fig. 1) is used to make lines on timber, parallel to the edge of the timber; that is, the lines always continue at the same distance from the edge.

The parts of the marking gauge are: the stem (a), the stock(b), the wedge (c) and the spur or pin (d). Sometimes a screw is used instead of a wedge.

HOW TO SET THE GAUGE

1. Use a rule to measure and slide the stock along the stem until the stockface is at the required distance from the pin (Fig. 2).
2. Slightly tighten the wedge or screw.
3. Check the size once more and make any necessary adjustments by tapping the end of the stem on the work bench.
4. Finally, properly tighten the wedge or screw.

HOW TO USE THE GAUGE

- Hold it in your right hand, with the face side of the stock pressed against the edge of the wood (Fig. 3).
- Keep it tilted slightly forward, so that the pin drags lightly along the wood. Don't try to make a deep mark with the pin (Fig. 4).
- Push it away from you. The pin will trace a line on the wood (Fig. 4) parallel to the edge of the wood. The stock must be held firmly against the timber edge as you move the gauge along.
- The pin may be forced out of line by grooves in the wood structure; if that occurs, mark from the other direction.
- If the gauge is hard to use at first, steady it by holding one end of the wood against the bench stop or hook.

Sometimes, marking gauges with two stems are used for marking out mortices. They are called Mortice gauges (Fig. 5).

NOTES:

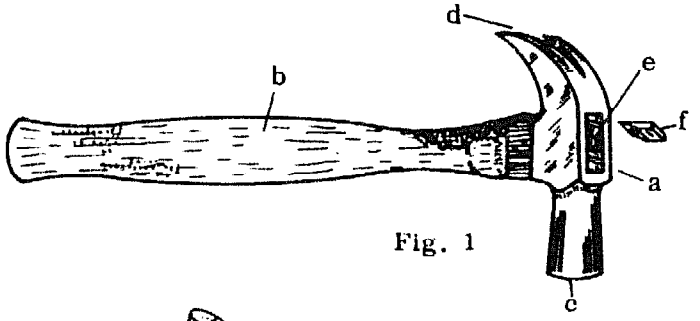

Fig. 1

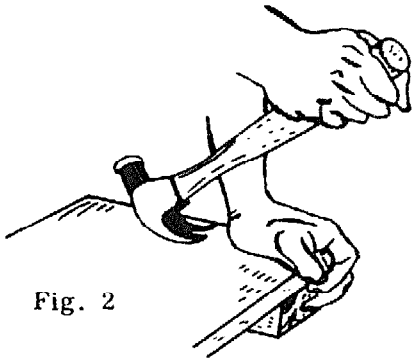

Fig. 2

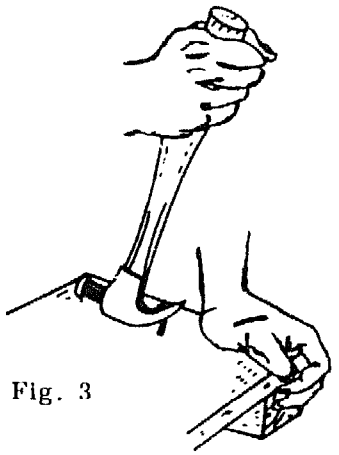

Fig. 3

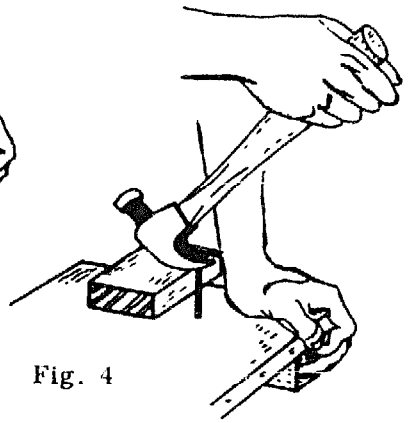

Fig. 4

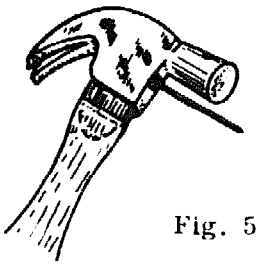

Fig. 5

Fig. 6

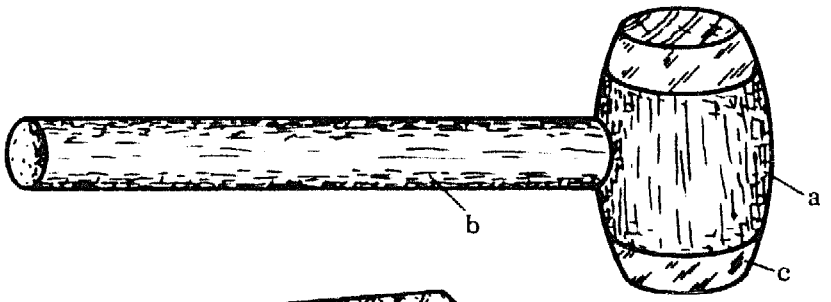

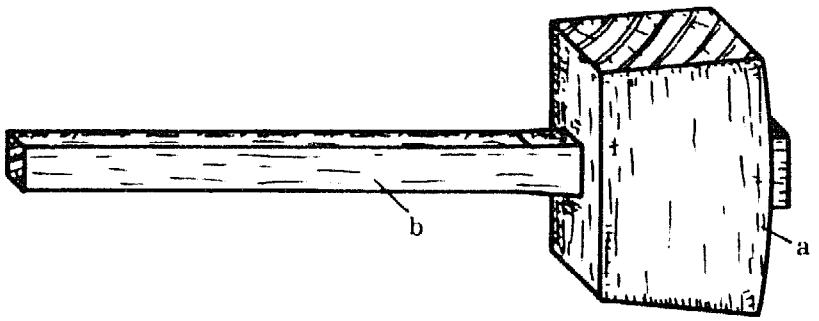

Fig. 7

N P V C	
40	TOOLS

THE CLAWHAMMER & THE MALLET.

THE CLAWHAMMER

The clawhammer (Fig. 1) is used in light or heavy carpentry work, for driving and extracting nails. Its size, determined by the weight of the head, can be from 350 to 650 gr.

A hammer has two main parts: the head (a) and the handle (b). The head is made of steel, with a hardened face (c) and a claw (d) for extracting nails. The wooden handle is held in the eye (e) by metal wedges (f). The handle is usually made of hard wood, which absorbs shock better than metal and keeps the arm from getting tired so quickly.

HOW TO PULL NAILS

To pull a nail, slip the claws under the nailhead and pull up and back on the hammer handle (Figs. 2 & 3). When the handle reaches the vertical position and the nail is not yet all the way out, use a block of wood under the hammer (Fig. 4) to help. Pulling the handle back too far may overstrain or possibly break it.

HOW TO DRIVE NAILS

Nailing is covered in detail in the Basic Knowledge book, pages 92 to 94.

- To drive nails when you have only one hand free, hold the nail on the hammer as shown in Fig. 5 and start it in the wood with one sharp blow.

THE MALLET

The mallet is used for driving chisels, assembling joints and knocking together pieces where the hammer would damage the wood or the chisel handle. The mallet (Figs. 6 & 7) has two parts: the head (a) and the handle (b), which passes through a tapered mortice in the head.

The head can be square or round in shape. The round type can be strengthened with a metal collar (c) to prevent it from splitting. This can be made from an old shock absorber mantle.

NOTES:

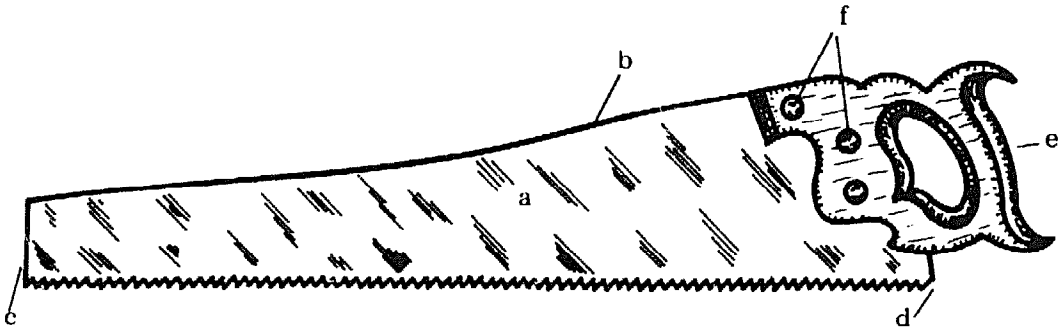

Fig. 1

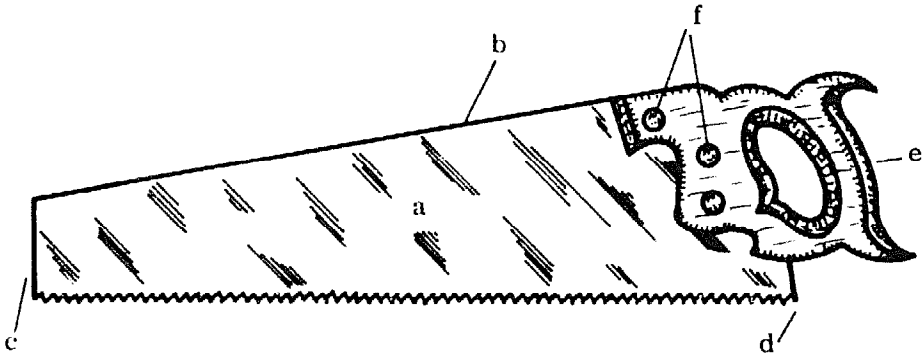

Fig. 2

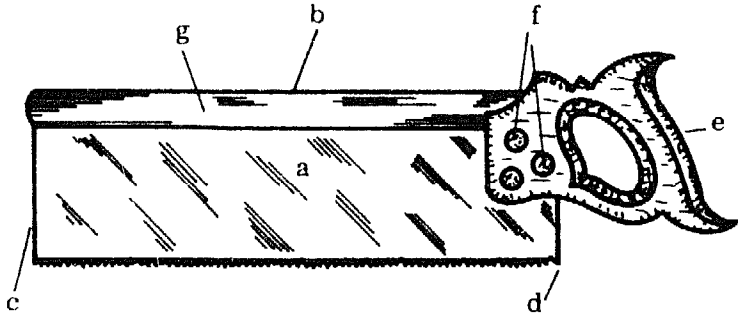

Fig. 3

N P V C		HANDSAWS.
42	TOOLS	

HANDSAWS

Saws are used for cutting timber to the required size and shape with a minimum of waste in materials and labour. The principal types used in Rural Building are handsaws.

The parts of the saw are (Fig. 1): the blade (a) which has a back (b), toe (c) and heel (d), the handle (e) and the sawscrews (f) which hold the handle to the blade.

Better quality saws are taper ground, that is, they are thinner towards the back of the blade than at the cutting edge. Such saws can run (move) more freely in the kerf (the saw cut).

A good sawblade makes a clear sound when it is slightly bent and struck on the back with a fingernail. The handle should be made of good hard wood and have a comfortable grip.

Manufacturers make saws in various grades of hard or soft steel, regular or light weight to suit any need. Depending on the kind of work we want to do, we use one of three types of handsaw: a ripsaw, a crosscut saw or a backsaw.

THE RIPSAW

The ripsaw (Fig. 1), because of the special shape of its teeth, is used only to cut with the grain of the wood. The length of the saw can vary from 66 to 71 cm. A long saw can cut faster, but it is harder to control.

THE CROSSCUT SAW

The crosscut saw (Fig. 2) is designed for cutting across the grain. Its length can vary from 51 to 66 cm.

THE BACKSAW

The backsaw (Fig. 3) is used to make fine and finished cuts. In general, the blade of the backsaw is thinner than that of a ripsaw or crosscut saw. The fold of steel that sits on the back of the blade (g) makes it stiff and it can be removed if necessary to make deep cuts.

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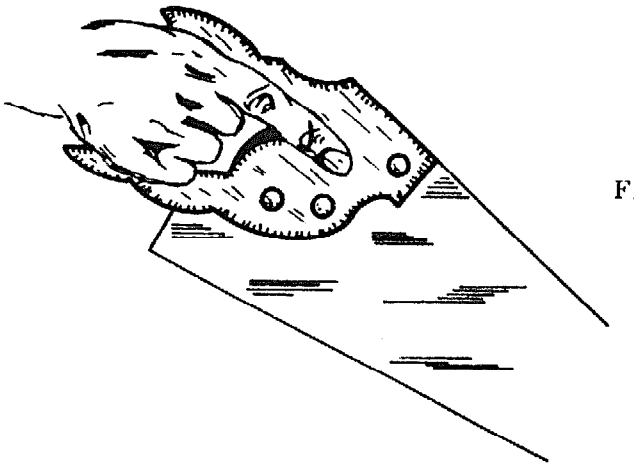

Fig. 1

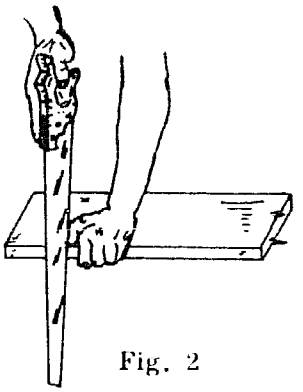

Fig. 2

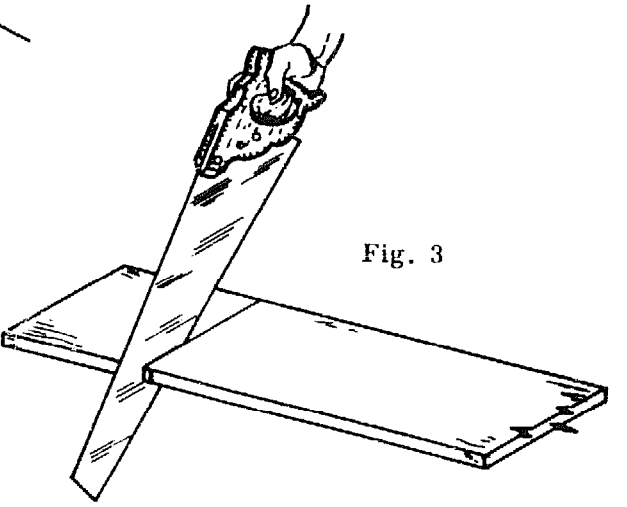

Fig. 3

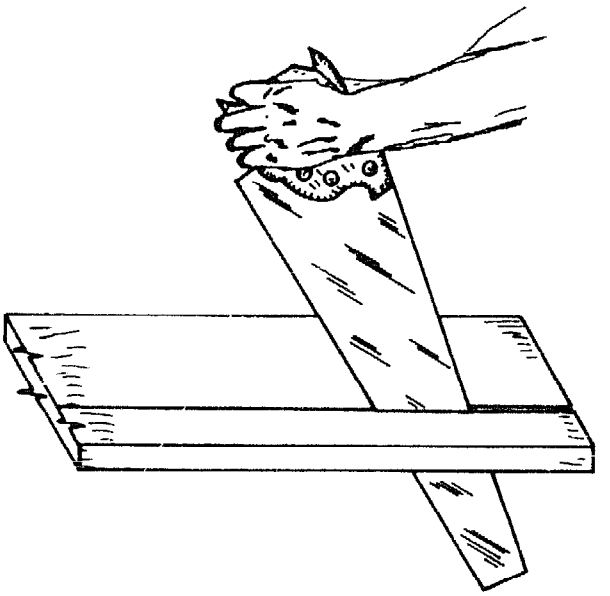

Fig. 4

N P V C	
44	TOOLS

HANDSAWS.

HOW TO USE A HANDSAW

- Grasp the handle of the saw firmly. Your index finger should point along the blade (Fig. 1). This gives maximum control of the saw and it is the rule for holding all the different kinds of handsaws.
- To start a sawcut, grasp the far edge of the wood with your left hand, using the thumb to guide the saw while starting the cut (Fig. 2). Make two or three backstrokes, lifting the saw on the forward strokes. Draw the saw slowly and carefully, exactly along the cutting line (Fig. 3).
- After the saw is started, push it forward and pull it back, using long, easy strokes and light pressure.
- Hold the saw at an angle of about 30 degrees to the board for rough work and almost flat to the board for fine cuts.
- If the saw tends to go to one side of the line, twist the handle slightly and gently to make it come back to the line gradually, as the sawing proceeds.

HOW TO RIP BOARDS

For ripping boards (cutting with the grain), you can use different methods. The most common method used in Ghana is known as overhand ripping.

- To do overhand ripping, hold the saw in both hands as shown in Fig. 4.

When cutting timber take care that you always watch the edge of the work bench, to avoid sawing into it.

NOTES:

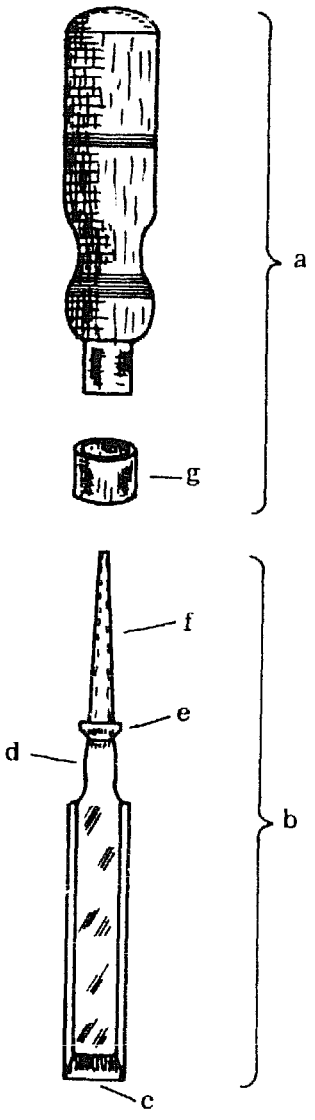

Fig. 1

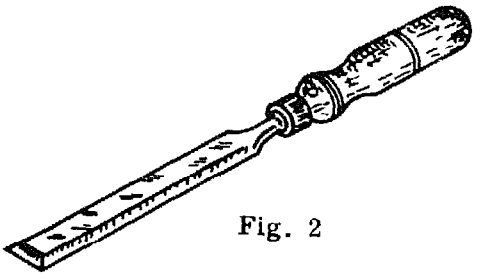

Fig. 2

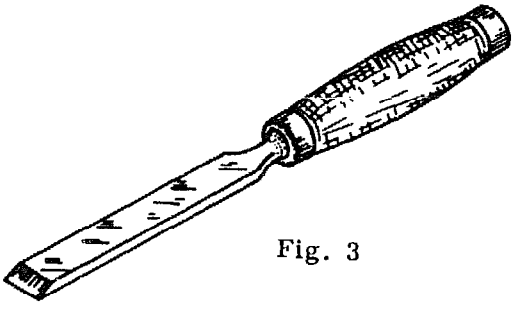

Fig. 3

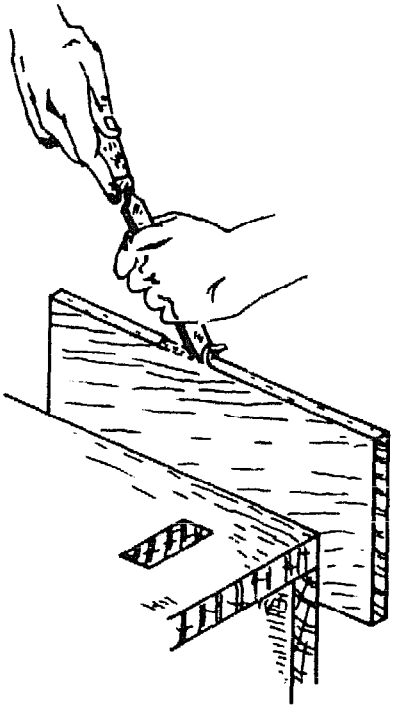

Fig. 4

NPVC	
46	TOOLS

THE CHISEL.

THE CHISEL

Chisels are used for shaping wood in places where the plane cannot be used.

They have two main parts (Fig. 1): the blade (a) and the handle (b). The blade is made of steel, with a cutting edge (c) which is 3 to 32 mm wide and ground at an angle of 25 degrees. The neck (d) is the narrow part at the top of the blade. The shoulder above the neck (e) is to prevent the blade from being driven too far into the handle and splitting it. The tang (f) is the end of the blade which fits into the handle and holds the two parts together.

The ferrule (g) at the bottom of the handle keeps the wood from splitting where the blade enters the handle. The handle itself is made from hard wood or plastic and it is slightly rounded on top to prevent splitting.

For the various tasks of carpentry work in Rural Building, there are different kinds of chisels. The two most common ones are the firmer chisel and the mortice chisel.

THE FIRMER CHISEL

Most of the firmer chisels (Fig. 2) are the type with a bevelled edge. The firmer chisel is normally driven into the wood by hand and is used only for light cutting and shaping work.

THE MORTICE CHISEL

The blade of the mortice chisel (Fig. 3) is thicker and stronger than that of the firmer chisel, as it is used for heavy work. This chisel is driven into the wood with a mallet (never with a steel hammer), so it is usually fitted with two ferrules, at the top and bottom of the handle, to prevent splitting.

NOTES:

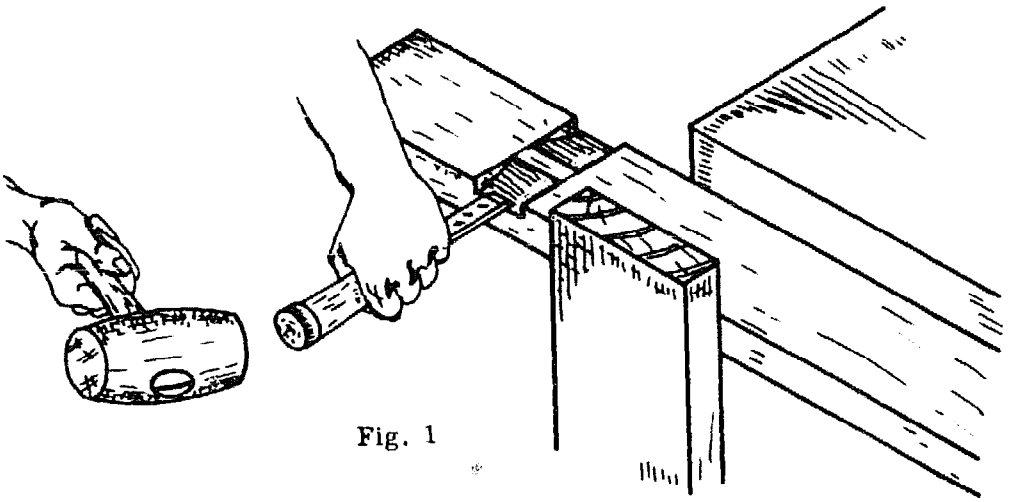

Fig. 1

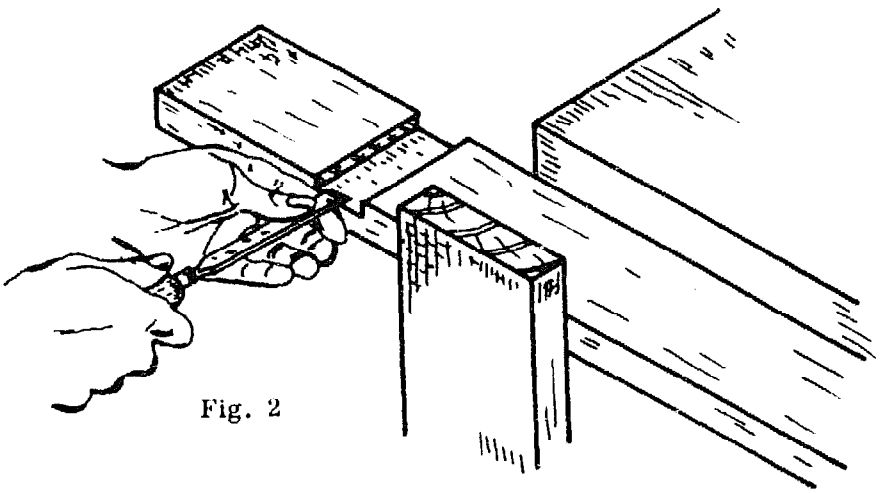

Fig. 2

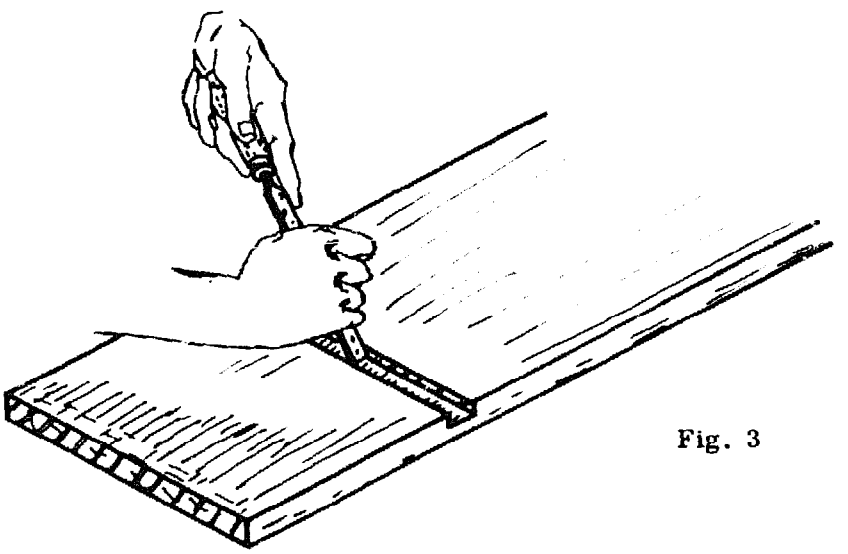

Fig. 3

N P V C	THE CHISEL.
48 TOOLS	

HOW TO USE THE CHISEL

To do good work, you need a sharp chisel. A dull chisel is hard to force through the wood and it is also hard to guide and control, making the resulting work rough and inaccurate. The time you use to stop and sharpen a dull chisel will soon be regained by better and faster work.

To prevent dulling the chisel, do not allow the cutting edge to touch other tools or the bench top. Always lay the chisel on the bench with the bevel side down.

CHISELLING WITH THE GRAIN

When chiselling with the grain, observe the following points (see Fig. 4 on the previous page):

- Always work with the grain, to avoid splintering or splitting the wood.
- Fasten the work securely so your hands are both free for the chisel.
- Always push the chisel away from yourself, keeping both hands behind the cutting edge.
- Use your left hand to guide the chisel, and your right hand to push on the handle.

CHISELLING ACROSS A BOARD

When chiselling across the grain, observe the following:

- Grasp the blade of the chisel between the thumb and forefinger of your left hand, to guide it and act as a brake, while the pushing is done with your right hand (Fig. 2).
- Cut with the bevel side up, raising the handle just enough to make the chisel cut. For heavier chiselling and for rough cuts, the mallet may be used as is shown in Fig. 1.
- When chiselling across wide boards, where the chisel cannot reach to the center of the board, work with the bevel side down (Fig. 3).

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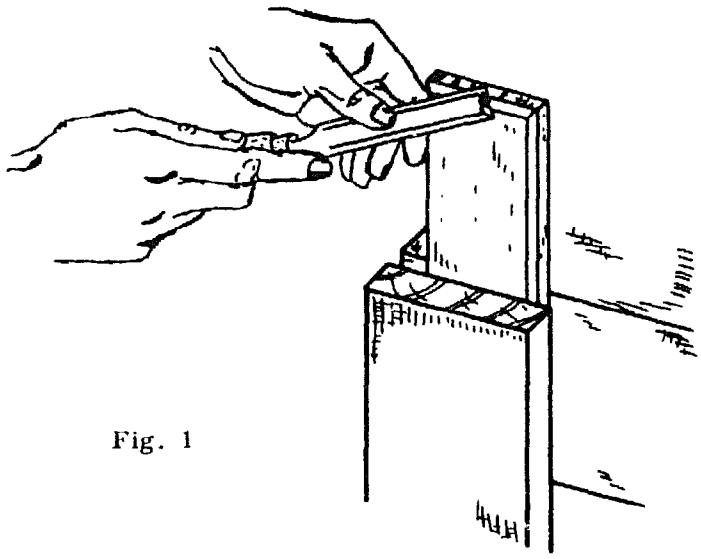

Fig. 1

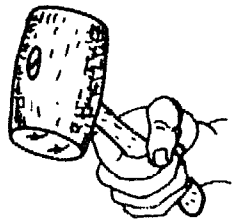

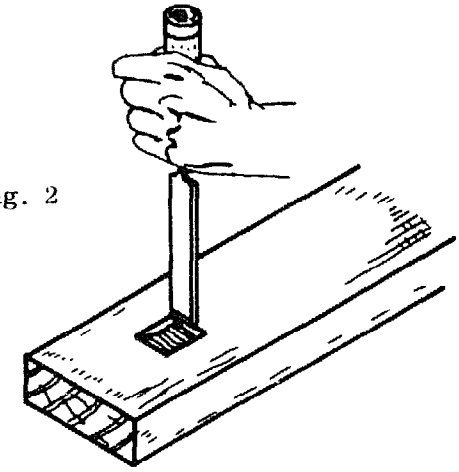

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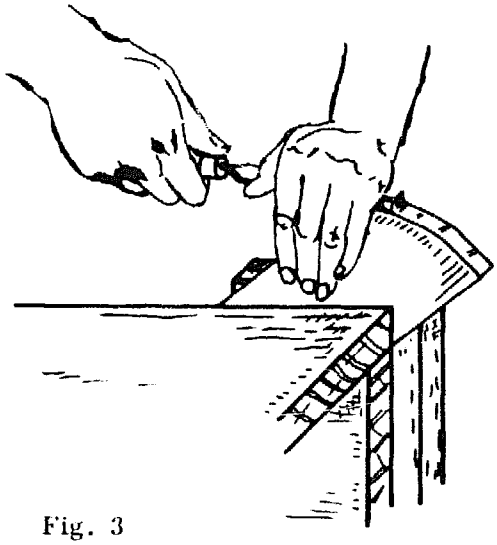

Fig. 3

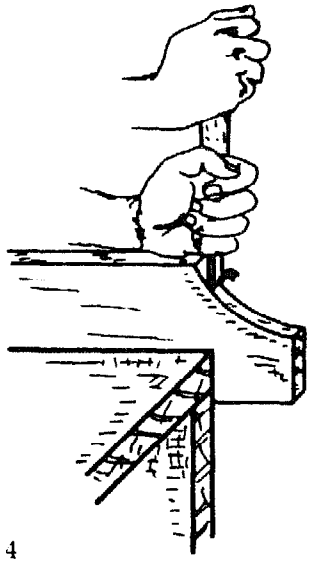

Fig. 4

N P V C	
50	TOOLS

THE CHISEL.

USING THE MALLET

Use a mallet to drive the chisel when force is required to make deep, rough cuts. Never use a steel hammer, it will soon damage the chisel handle.

- Make a series of light taps with the mallet instead of heavy blows, as light taps will give you better control.

CHAMFERING

The chisel may be used to make chamfers or bevels, with or across the grain.

- Keep the bevel up. As you push the chisel forward, move the handle slightly from side to side, so that the cutting edge works obliquely (at an angle) (Fig. 1).
- Prevent splintering in cutting end chamfers or bevels by working part way from one edge and part way from the other.

MORTICING

Morticing is done as shown in Fig. 2 on the left page.

CUTTING CURVES WITH THE CHISEL

Convex curves can be shaped with the chisel as shown in Fig. 3.

- Use the chisel with the bevel side up. Hold and guide it with your left hand while you push it forward with your right hand.

Concave or inside curves may also be finished with the chisel, as in Fig. 4.

- Use the chisel with the bevel side down.
- Guide it with your left hand, while your right hand pushes down and pulls backward at the same time.

NOTES:

PLANES

Together with the hammer, saw, try square and chisel, the plane is one of the principal tools used for carpentry work.

When timber comes from the sawmill, it is rough from the saw. Before rough-sawn timber or boards can be used for any finished work, they must be prepared so that all their sides and edges are square, flat and smooth. This preparation is done by planing them first and later smoothing them.

The tool used for the rough part of this work is called a jack plane (Fig. 1). It is used for planing the wood true and to reduce it to the correct size. The jack plane is used for general planing purposes, which is why it is called "jack", meaning generally useful.

After the board has been planed to a true surface, we use the smoothing plane (Fig. 2) to remove the rough marks of the jack plane, making a smooth surface on the board.

Other planes, used for special purposes, are discussed later in this book.

THE JACK PLANE

The jack plane (Fig. 3) consists of five main parts: the stock or body (a), the handle (b), the cutting iron (c), the cap iron (d) and the wedge (e).

The stock of the plane is made of hard wood which wears uniformly (doesn't get more worn out in some areas than in others), is tough, straight grained and keeps its shape. It is about 40 cm long. This long length lets the plane go over the low spots in the wood without cutting (Fig. 1), while it removes the high spots.

The stock holds the cutting iron, which takes off the shavings. The cutting iron sticks out through the mouth (f) on the bottom of the stock and the shavings leave the plane through the escapement (g) on top of the stock.

The bottom of the stock, which rubs along the wood during planing, is called the sole (h). The front part of the sole is called the toe (i) and the back part is the heel (j).

The cutting iron rests on the bed (k), at a 45 degree angle to the sole.

The front end of the stock is called the nose (l). To remove the cutting iron or to reduce the cut, the top of the nose is struck sharply with a hammer. In order to prevent the wood from being bruised, some planes have a small piece of metal

let into the nose, to take the blows of the hammer. This is called the striking button (Fig. 3, m, previous page).

The handle is morticed into the stock behind the escapement. It should have a comfortable grip to protect the hand.

The cutting iron is made out of steel. It has a slot in the centre which ends in a screw hole. The cutting edge is ground at an angle of 25 to 30 degrees (see Maintenance of Tools, pages 92 to 99). If there is any imperfection in the cutting edge you will see a mark from it on the wood after planing.

The cap iron is made from mild steel and is secured to the cutting iron by a cheese-head screw (holding screw) which passes through the slot in the cutting iron. The cap iron helps the cutting edge to plane smoothly, by breaking up the shavings before they split ahead and tear up the fibres of the wood.

It is essential that the back of the cap iron should bed perfectly on the face of the cutting iron when they are fitted together, for even the slightest gap between the two will allow a shaving to enter and the mouth of the plane will immediately become blocked (see Maintenance of Tools, page 104).

The wedge is made of hard wood and its function is to hold the irons in place. It fits into special grooves in the sides of the escapement.

It is a good idea to keep the wooden parts of the plane in good condition by occasionally rubbing some vegetable oil, like groundnut oil (not machine oil) on them.

NOTES:

THE SMOOTHING PLANE

The smoothing plane is constructed similarly to the jack plane. It is used to finish the surface of the wood.

The smoothing plane is about 20 cm long, so it is the smallest plane that a builder uses (Fig. 2, page 54).

The smoothing plane is not used to remove large quantities of wood or to plane the wood flat and true. It is set to remove only rather fine shavings, so we use it only to make a smooth surface on the wood.

The smoothing plane has a handguard rather than a handle like the jack plane and it has the striking button on the back end of the plane instead of on the nose.

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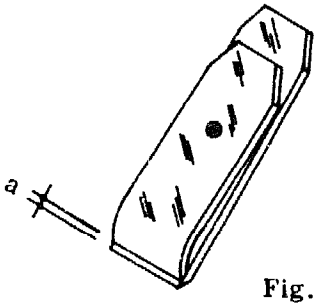

Fig. 1

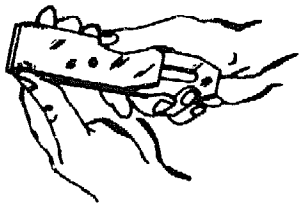

Fig. 2

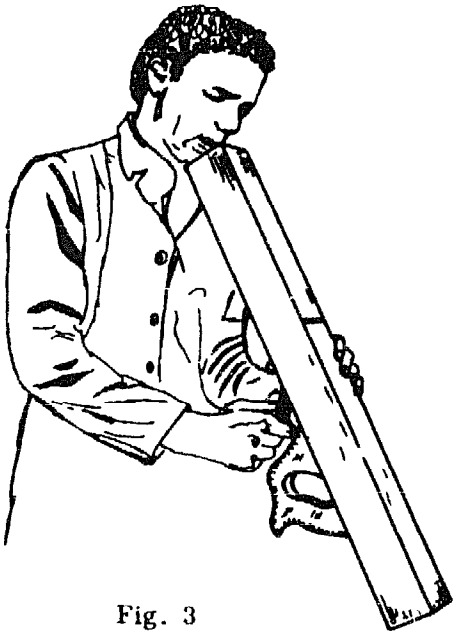

Fig. 3

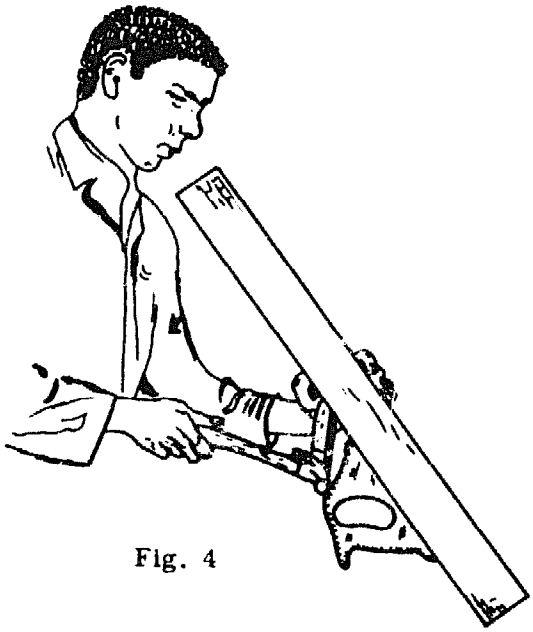

Fig. 4

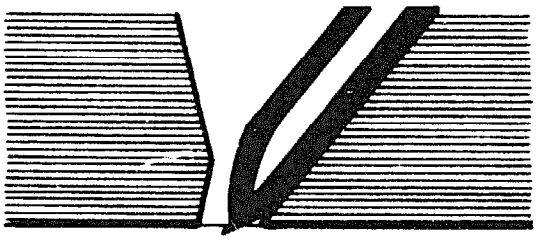

Fig. 5

N P V C	
56	TOOLS

PLANES.

HOW TO SET THE CAP IRON

The distance from the edge of the cap iron to the cutting edge is called the set (Fig. 1, a).

- The set for the jack plane should be:
  2 mm, when planing hard woods;
  3 mm, when planing soft woods.
- The set for the smoothing plane should be:
  1 mm or less.

In order to set the cap iron, first loosen the cheesehead screw which holds the two irons together; until the cap iron can move. Hold the irons as shown in Fig. 2 and be very careful that the cap iron does not touch the cutting edge as this will make it dull. Adjust the irons to the proper set and tighten the screw.

HOW TO SET THE CUTTING IRON

1. Hold the plane in your left hand and look along the sole while putting the irons in it (Fig. 3). Fix the wedge so that they are held in place lightly. Adjust them to roughly the correct position.
2. Adjust the cutting iron exactly by tapping with the clawhammer either on top of the iron (Fig. 4), so that it comes out more and takes off thicker shavings; or on the striking button to get thinner shavings.
3. After every adjustment, tighten the wedge slightly. Don't hit it too hard or you will damage the wedge.

The cutting iron should project as shown in Fig. 5 on the left page. It is important that the cutting iron projects evenly. For rough work, you will want the cutting iron to project more so as to take off thicker shavings. For fine work, where only a little wood will be planed off, the cutting iron should project less.

- After you finish using the plane, knock the cutting iron back so that it doesn't project out of the sole at all. This is to prevent damage to the cutting edge when the tool is not in use.

NOTES:

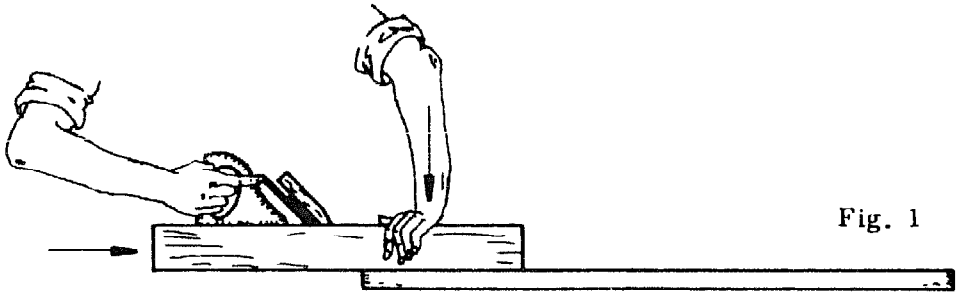

Fig. 1

PRESS, PUSH

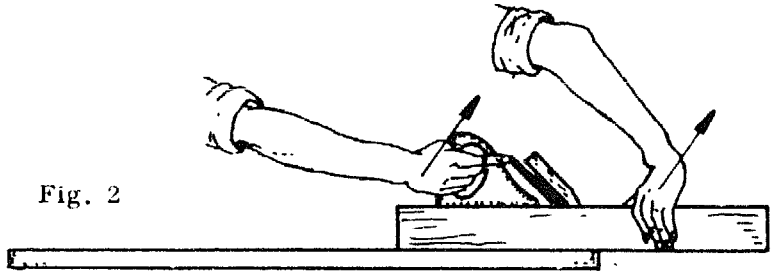

Fig. 2

AND LIFT

Fig. 3

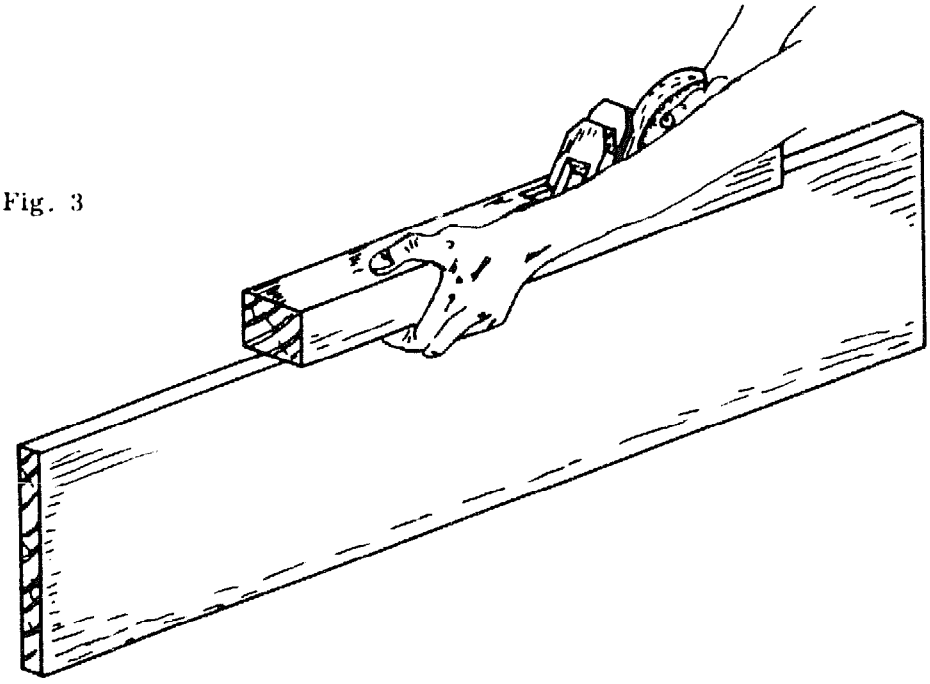

N P V C		PLANES.
58	TOOLS	

PLANING

- When you use the plane, try to put pressure on it in such a way that the part of the sole which is in contact with the wood is pressed firmly to the wood surface. At the start of the stroke when the cutting iron does not yet touch the wood, put pressure on the front part of the plane (Fig. 1). When the cutting iron comes to the end of the board, press down more on the heel of the plane (Fig. 2).
- Guide the plane when you plane on edges, by curling your fingers under the plane so that they contact the board (Fig. 3).
- To obtain a good surface, always plane with the grain. If the wood is cross-grained, it is best to hold the plane at an angle to the direction of the stroke.

STUFFING

Sometimes the plane won't take off shavings anymore, but just slips over the wood without cutting it. This happens when shavings have blocked up the plane: the plane is stuffed with shavings.

- The plane may stuff when the cap iron is not fitted well to the cutting iron. Shavings can enter the gap between the irons and block the mouth of the plane (see Maintenance of Tools, page 104).
- Another cause of stuffing may be an incorrectly made plane. If you make your plane by hand, be sure to make the mouth and the escapement large enough. The mouth must not be too big however, because then it will not give a good surface when it is used to plane.
- Make sure that the ends of the wedge are not projecting over the cap iron and blocking the shavings.

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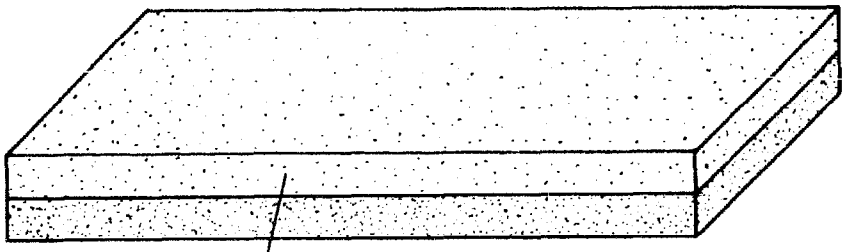

Fig. 1

SHARPENING STONE

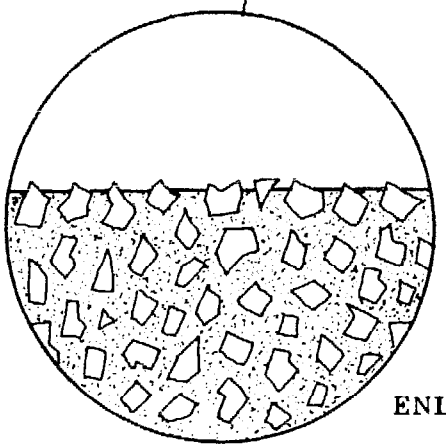

SHARP-EDGED GRAINS

BINDING MATERIAL

Fig. 2

ENLARGED DETAIL

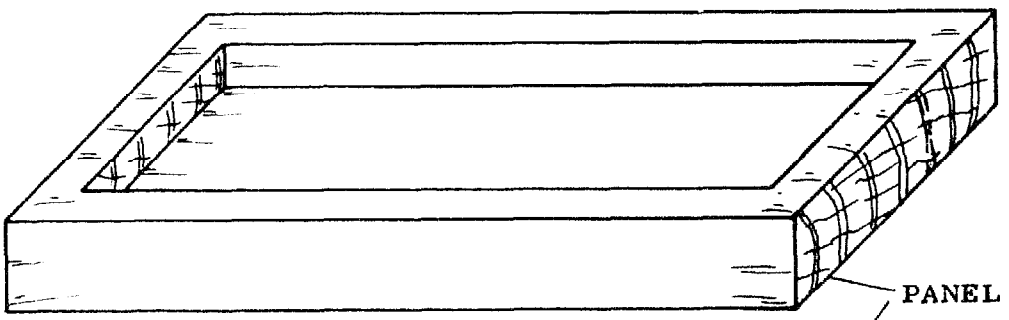

PANEL PIN

WOODEN BOX

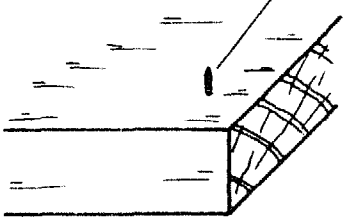

Fig. 3

N P V C		THE SHARPENING STONE.
60	TOOLS	

THE SHARPENING STONE

The sharp edges of plane irons and chisels are made with sharpening stones. The stone acts like a file to wear away the portion of the tool that is rubbed on it.

There are natural and artificial (man-made) stones. Nowadays we use mostly the artificial ones. The grit (rough surface) of the stone consists of hard, sharp-edged grains, embedded in a binding material (Fig. 2). The bigger the grains, the coarser the stone. Stones can be coarse, medium, or fine; in Rural Building we use a combination stone, one side of which is coarse and the other fine (Fig. 1). The coarse side cuts quickly, but does not give a very keen (sharp) edge. The fine grit cuts slowly and gives a keen edge.

Take very good care of your sharpening stone. House it in a solid wooden box. On each corner of the box, drive a panel pin almost home and file the heads to sharp points (Fig. 3). The pins will anchor the box and the stone to the bench when you are sharpening tools.

HOW TO USE THE STONE

- Before using the stone, soak it in water for a few minutes. Use water during the sharpening to wash away the metal particles. After use, clean the stone with water. The water keeps the stone from glazing (becoming clogged with small metal particles between the grains, which makes it smoother and less efficient to use).
- Try to keep the stone worn down evenly and flat by using the entire surface, not rubbing just in the centre.
- The end nearest you is less easy to use, so turn the stone around occasionally to let both ends wear down equally.
- If a stone is worn hollow, it can be made flat again by rubbing it on a flat stone or cement surface, using sand and water to grind it.

NOTES:

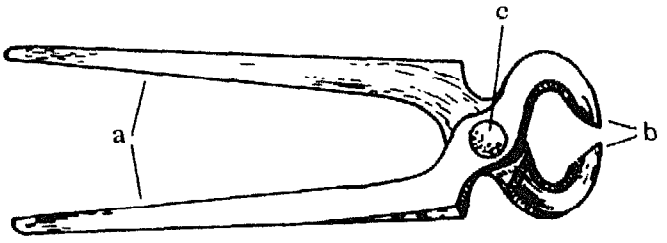

Fig. 1

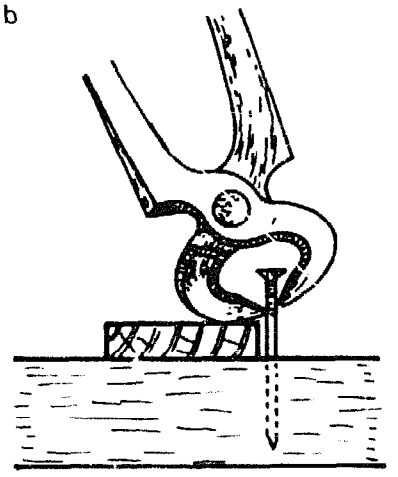

Fig. 2

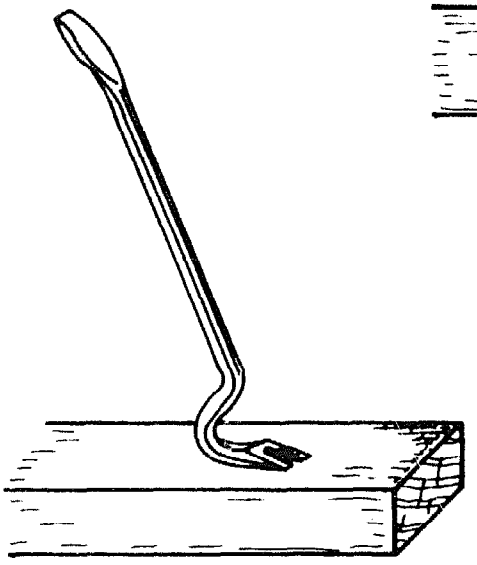

Fig. 3

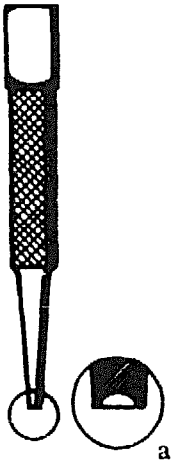

Fig. 4

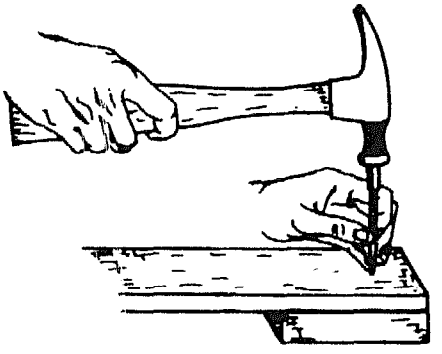

Fig. 5

N P V C	
62	TOOLS

OTHER TOOLS FOR EXTRACTING AND PUNCHING NAILS.

OTHER TOOLS FOR EXTRACTING AND PUNCHING NAILS

PINCERS

Pincers (Fig. 1) are used chiefly for extracting nails which have become bent in driving. When using the pincers, protect the wood surface from bruising by using a small piece of wood underneath (Fig. 2).

Pincers have three main parts: the arms (a), made of steel, the jaws (b), made of hardened steel and sharpened to grip nails etc. and the rivet (c) which connects the two arms.

THE CROWBAR

This is an iron bar with a forged end (Fig. 3) used for pulling big nails out of timber and as a lever to move heavy objects. Other uses are: to open crates, or to loosen boards of concrete forms.

When a lot of force is needed to get out a nail, you use a crowbar so as not to break the handle of your hammer.

For lifting very heavy objects, an iron bar should be used in place of the smaller crowbar.

THE NAIL PUNCH

The nail punch (Fig. 4) is used along with the hammer to drive the heads of nails below the surface of the wood and to clench nails that go through to the other side of the board and stick out.

Nail punches are generally cylindrical in shape, with concave points to keep the punch from slipping off the nailhead (Fig. 4a). If no punch is available, a large blunt nail can be used instead.

- To punch a nail under the surface of the wood, hold the punch in place on the nailhead, steadying your hand on the board (Fig. 5), and hit it with the hammer.

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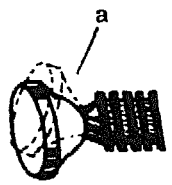

SWIVEL SHOE

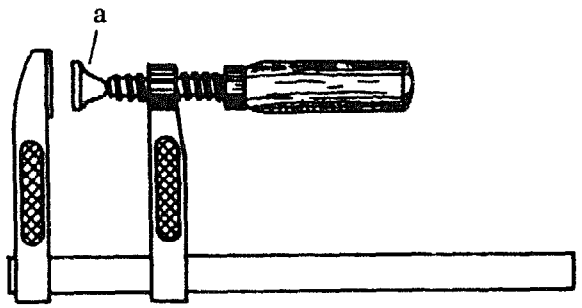

Fig. 1

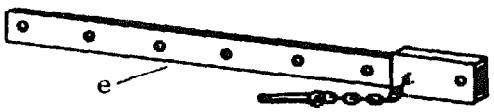

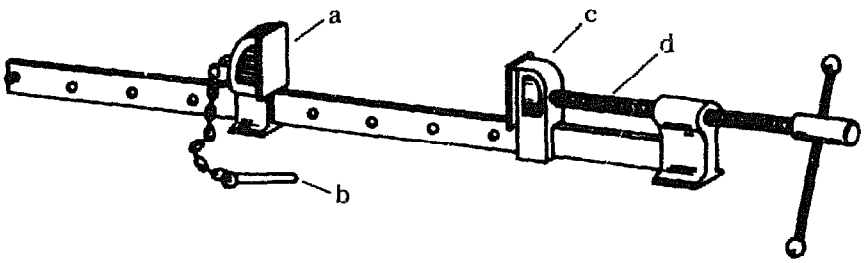

Fig. 2

Fig. 3

Fig. 4

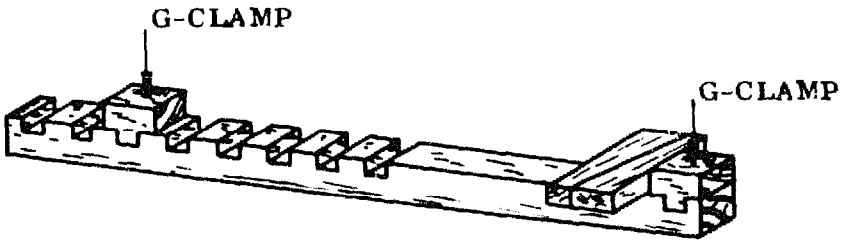

Fig. 5

N P V C		CLAMPS.
64	TOOLS	

CLAMPS

THE G-CLAMP

The G-clamp (Fig. 1) is used to hold the job under control while it is worked upon. It is used in the workshop as well as on the building site and can be used for holding small pieces together while they are being glued.

Except for the handle, which is made of wood, the parts are all steel. The shoe (a) is set on a swivel, which allows it to move and adapt to the surface of the job. These clamps are available in different sizes, up to 240 cm.

THE METAL SASH CLAMP

Sash clamps (Fig. 2) are used for pushing together joints and holding parts for glueing or nailing, or holding wood when making rebates.

The adjustable shoe (a) is fixed on the bar by the pin (b). The clamping shoe (c) is tightened against the job by the screw (d).

The length of the clamps can be between 100 and 200 cm, and they can be made longer by an extension bar (e).

- If more than one clamp is used on a piece, take care that they are set in line, so that they don't twist the piece.

THE WOODEN SASH CLAMP

Homemade clamps (Figs. 3, 4 & 5) can serve the same purposes as a metal one. The job is tightened by means of a wedge.

For quick jobs, a clamp can be made as shown in Fig. 3. Here the different members are nailed together according to the required size of the sash clamp.

If a more permanent, adjustable clamp is required, it can be made as shown in Figs. 4 or 5.

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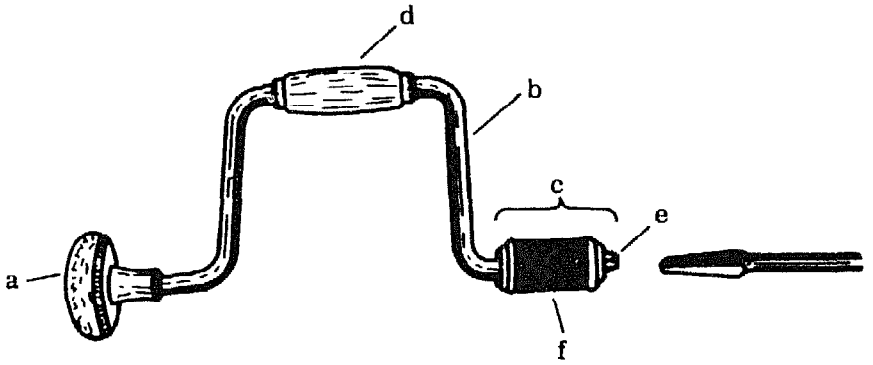

Fig. 1

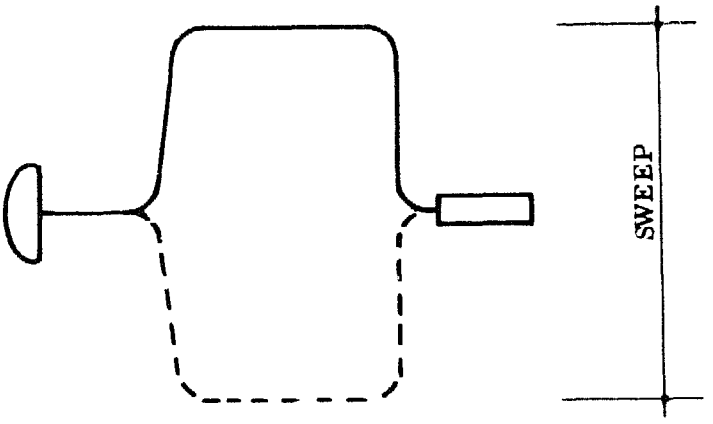

Fig. 2

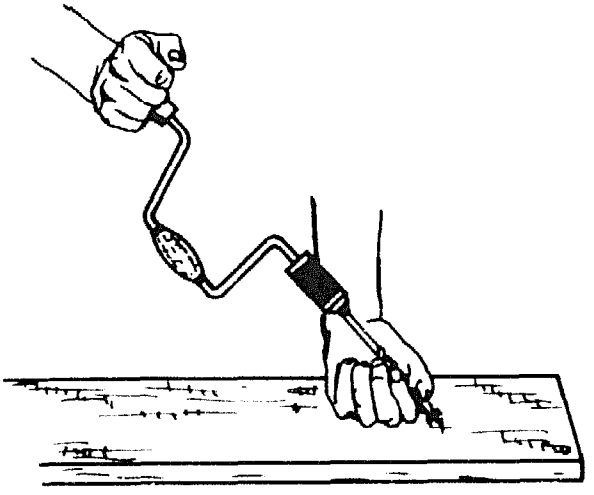

Fig. 3

N P V C		THE BRACE (PLAIN AND RATCHET).
66	TOOLS	

THE BRACE (PLAIN AND RATCHET)

This is a cranked tool used to turn drill bits and countersinks, thus making holes in wood.

Its parts are (Fig. 1): the head (a), the crank or bow (b), and the chuck (c).

The head is a hard wooden or plastic knob, which is fixed to the bow and turns on a ball bearing.

The crank, which is formed by the rectangular bend, can be 10 to 20 cm in width giving a sweep of 20 to 40 cm, which determines the size of the brace (Fig. 2).

The wider the brace, the more force you can apply with it, but also, the distance your arm must travel is longer and more tiring and the bit may be broken more easily.

A handle (d) is attached to the crank by steel collars. It should revolve freely.

The chuck holds the various bits (the drilling parts). The bits are gripped by jaws (e). There are different kinds of jaws. The square shank of the bit fits into the square opening of the chuck. When the socket (f) is turned, it tightens the jaws over the shank of the bit.

There is a more advanced type of brace available, which is the ratchet brace. The ratchet makes it possible to use the brace in places where it is impossible to make a complete turn of the crank with an ordinary brace.

HOW TO USE THE BRACE

1. For accurate boring, first mark the location of the centre of the hole with two lines crossing each other, or by making a small hole with a sharp tool (Fig. 3).
2. With the knuckles of one hand down against the board, guide the point of the bit carefully into place, while with your other hand you exert a slight pressure on the head of the brace (Fig. 3).
3. As the bit starts boring, be careful to keep it perpendicular to the surface (unless you want the hole to be bored at an angle).

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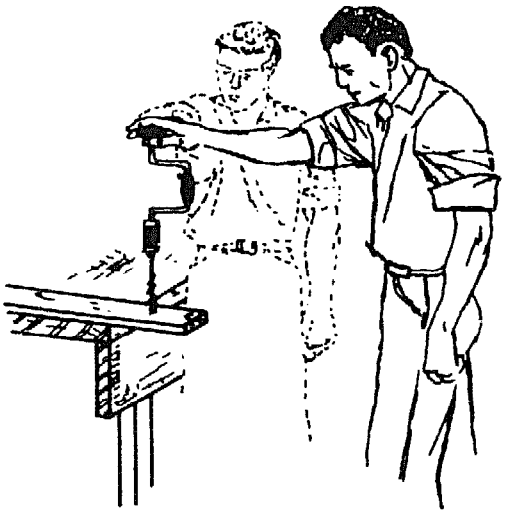

Fig. 1

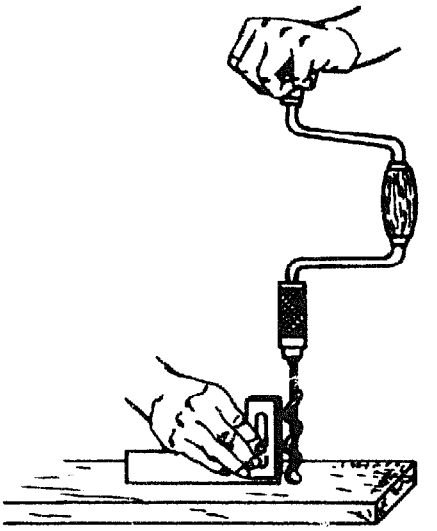

Fig. 2

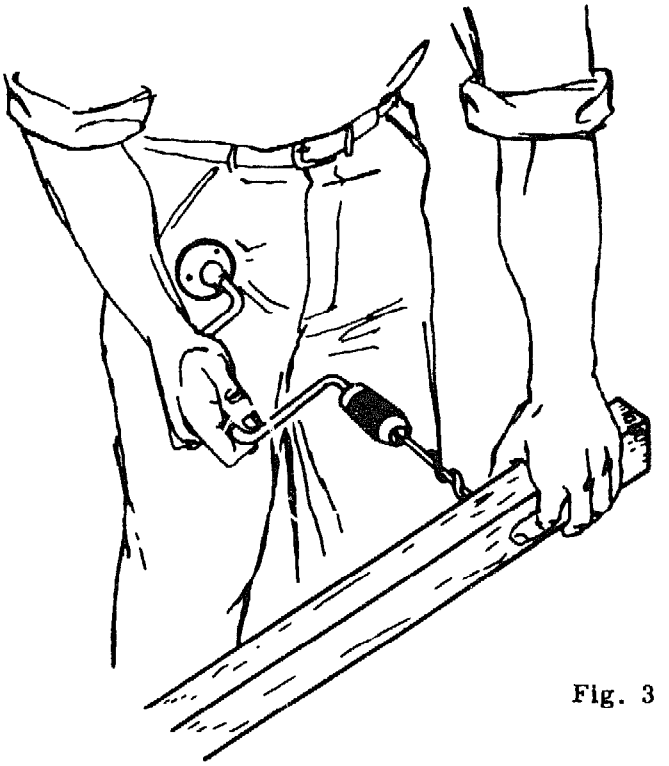

Fig. 3

N P V C		THE BRACE (PLAIN AND RATCHET).
68	TOOLS	

It is fairly easy to tell if the brace is leaning to the right or left, but difficult to know if it is leaning away from you or towards you.

- For jobs where this is important, it is best to ask another person to stand to one side and tell you whether you are holding the brace upright.
- Another way to see whether the brace is boring square to the surface is to step back a little, steadying the brace with one hand, and sight. Then move around and sight in the other direction, at about right angles to the first sighting (Fig. 1).
- A square can be used to check if the bit is boring straight (Fig. 2).
- If a hole is to be bored completely through a board, bore until the point of the bit can be felt on the other side (Fig. 3), then turn the board over and bore from the other side. This prevents splintering around the edge of the hole where the drill comes out.
- You can also prevent splintering by clamping a piece of waste wood on the other side of the board where the drill will come out. The drilling can then be done from one side only with no danger of splintering the wood.

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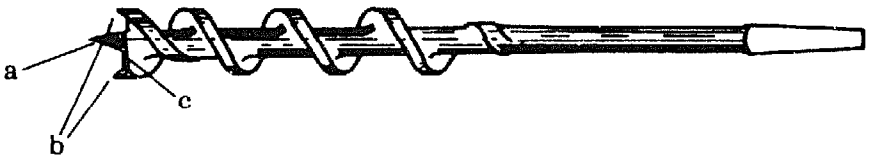

Fig. 1

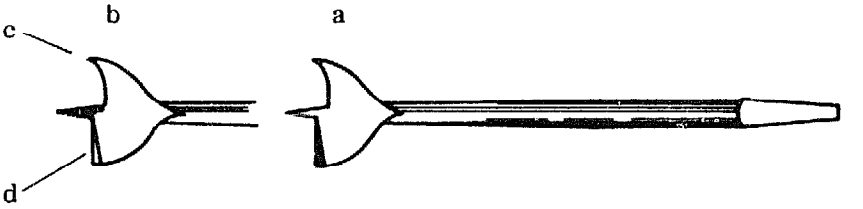

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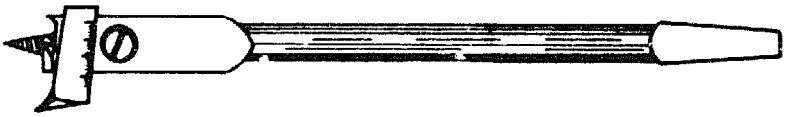

Fig. 3

Fig. 4

N P V C		BITS AND DRILLS.
70	TOOLS	

BITS AND DRILLS

Boring bits are used with a brace to bore holes in wood. They have a square-head shank, which fits the chuck of the brace. The shank below the head is cylindrical.

Boring drills usually have a cylindrical shank which fits into a special kind of hand operated drilling machine.

The size of the bit or drill is stamped on the shank, in mm.

AUGER BITS

The twisted part of the auger bit (Fig. 1) guides it and removes the waste. The screw-nose (a) draws the bit into the wood, the two spurs (b) scribe the diameter of the hole, and the cutter (c) cuts it.

Auger bits are used to drill deep holes. They come in sizes from 4 to 40 mm.

CENTRE BITS

The centre bit is used for boring holes in thin timber only, because it doesn't guide itself as the auger bit does.

Centre bits are available with either a point or a screw-nose (Fig. 2a or b). The screw-nose type is preferred over the type with a point, because it draws the bit into the wood.

The spur (c) cuts the rim of the hole and the router (d) removes the waste.

EXPANSION BITS

These bits are used for drilling large holes. The cutter is adjustable with a screw (Fig. 3). The size of the hole can range from 13 to 40 mm in diameter. Special types can expand up to 80 mm and more.

TWIST DRILLS

These drills have twisted flutes (Fig. 4) to bore clean holes in hard or soft woods. One of the main advantages of the twist drill is that it is available in sizes from 1 mm and up.

Besides the drill for wood, there are harder types which can drill holes in metal, stone and concrete. Even though they may look the same, you should never use woodworking drills for metal work.

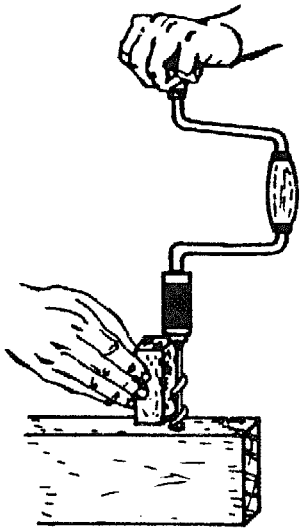

Fig. 1

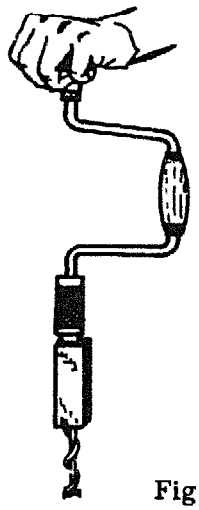

Fig. 2

Fig. 3

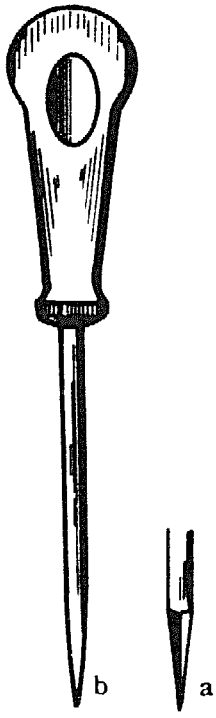

Fig. 4

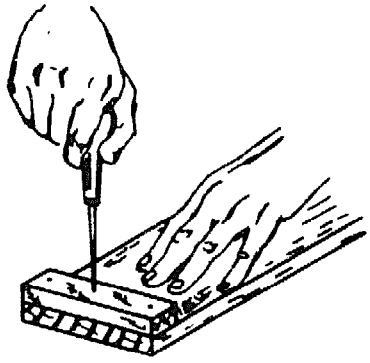

Fig. 5

N P V C	
72	TOOLS

BITS AND DRILLS.

DEPTH STOPS

If you are drilling a number of holes at the same depth, you can save time by cutting a wooden block to the correct size and using it as a gauge (Fig. 1), or boring a hole through the block and fitting it on the bit as shown in Fig. 2.

COUNTERSINKS

Countersinks are used to enlarge the top of a screw hole so that the screw head can fit below the surface of the wood. The most common type is the rosehead countersink (Fig. 3).

AWLS

An awl is a thin, pointed steel rod, which is fitted with a wooden or plastic handle.

Awls are used for marking or piercing holes in wood. The tip can be either square or rounded (Fig. 4a or b). Awls with square shaped tips are preferred for piercing holes for small screws or nails.

- Force the awl into the wood with a turning motion, left and right, so that it cuts its way through the wood (Fig. 5).
- An awl can easily be made from a thin steel rod, by hammering one end to a square shape and sharpening it, then fitting a handle to the other end.

NOTES:

Fig. 1

Fig. 2

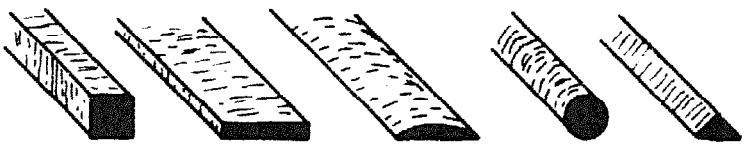

Fig. 3

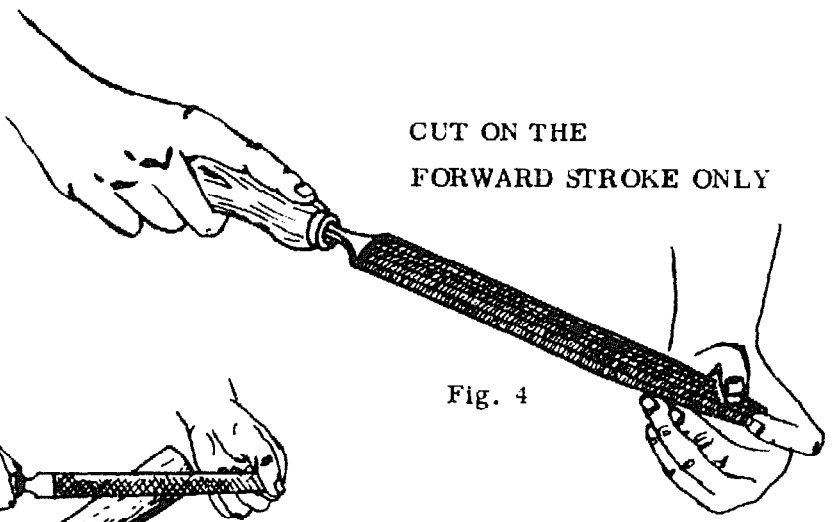

Fig. 4

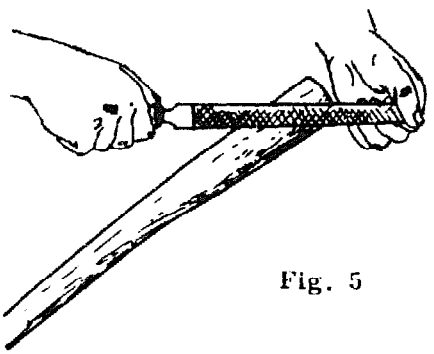

Fig. 5

N P V C		RASPS AND FILES.
74	TOOLS	

RASPS AND FILES

Rasps (Fig. 1) and files (Fig. 2) are used in woodwork for smoothing wood which cannot be worked easily with any other kind of cutting tool.

- NOTE: Special metalworking files are used to work metal and sharpen tools. Never use woodworking files on metal.

The difference between the rasp and file is in the cut. Files have a series of chisel cuts across their surface, while rasps have many separate small teeth. The rasp is more coarse and cuts faster and rougher than the file.

The handles on both rasps and files must be firmly seated.

Files and rasps are available in different grades of coarseness and in different shapes. Some common shapes for files are (Fig. 3): square, flat, half-round, round and triangular (sawfiles). Rasps are usually half-round or round in section.

HOW TO USE RASPS AND FILES

- Hold the tool at a slight angle to the direction of filing (Fig. 4). By doing this, you file over a wider area and avoid making a hollow spot in one place.
- The actual cutting is done on the forward stroke only.
- When you are filing a curved piece, give the file a sideways sliding motion at the same time as you move it forwards. This is so that the file follows the curve better and doesn't produce flat spots (Fig. 5).
- The rasp is used first, to get the rough shape as quickly as possible. Then the file is used to remove the coarse marks left by the rasp.
- Do not clean rasps or files with sharp tools or steel brushes. To clean them, scrub them with a hard-bristled brush.

NOTES:

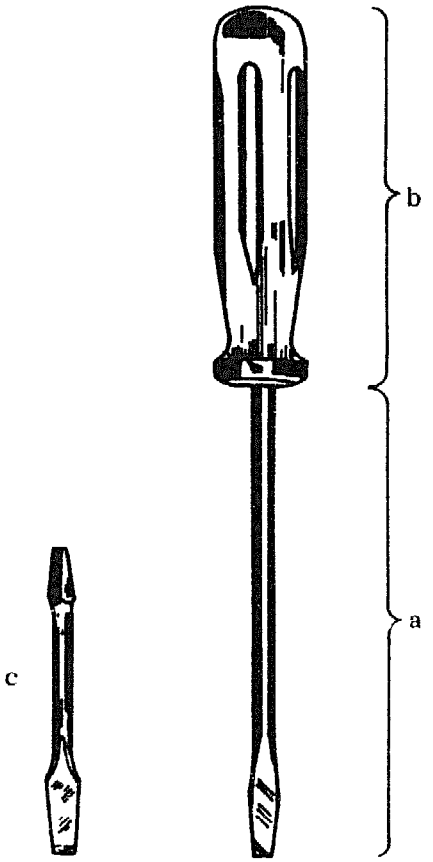

Fig. 1

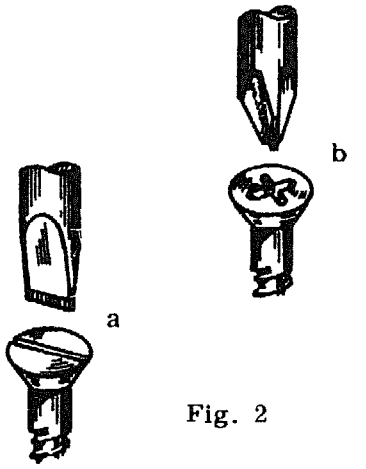

Fig. 2

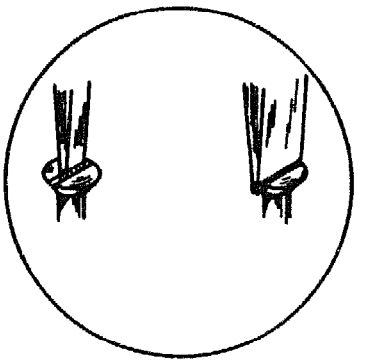

Fig. 3

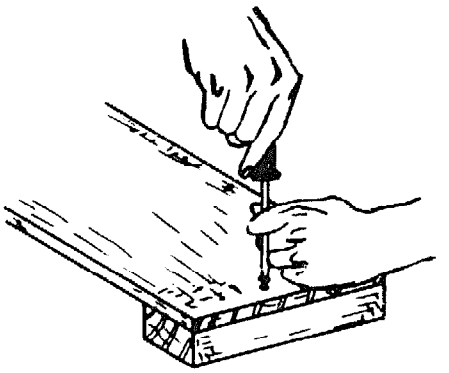

Fig. 4

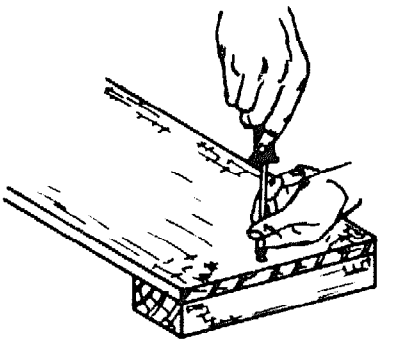

Fig. 5

N P V C	
76	TOOLS

THE SCREWDRIVER.

THE SCREWDRIVER

Screwdrivers are used for inserting and removing screws. Many different types of screwdrivers are available. There are also screwdriver bits (Fig. 1, c) to be used with a brace.

The parts of the screwdriver are (Fig. 1): the blade (a) and the handle (b). The blade is either flat or cylindrical and the tip is either ground to a flat straight edge (Fig. 2a) or has a Philips shape (Fig. 2b) to fit different screws. The other end of the blade is shaped to a tang to fit into the handle.

The handle is made out of tough wood or plastic and is sometimes fitted with a ferrule to prevent splintering and keep the blade from turning in the handle.

The size of the screwdriver is determined by the length of the blade from the tip to the handle and by the diameter of the blade.

In order to work efficiently and not damage the slots of the screwheads, select a screwdriver with a tip that is the same width as the slot of the screw. A tip which is too small can slip and damage the slot, while one which is wider than the screwhead can scrape and damage the workface around the screw (Fig. 3).

The screwdriver tip must be properly formed (see Maintenance of Tools). A badly formed tip will cause the screwdriver to slip out of the slot and damage it.

HOW TO USE THE SCREWDRIVER

- Grasp the handle firmly in your right hand with your palm resting on the end of the handle; the thumb and forefinger extend along the handle.
- While the right hand changes grips to turn the handle, the left hand steadies the tool and keeps it in the slot. Figs. 4 and 5 show two methods of using a screwdriver.

NOTES:

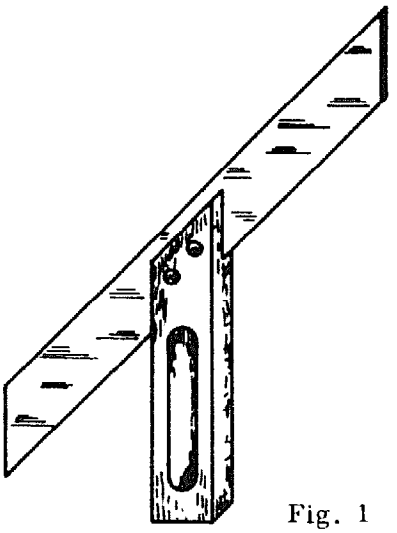

Fig. 1

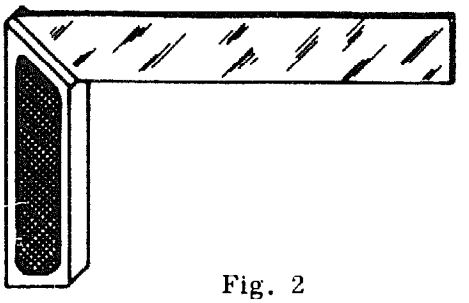

Fig. 2

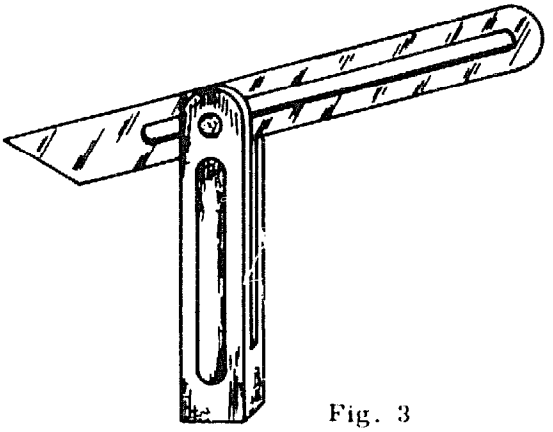

Fig. 3

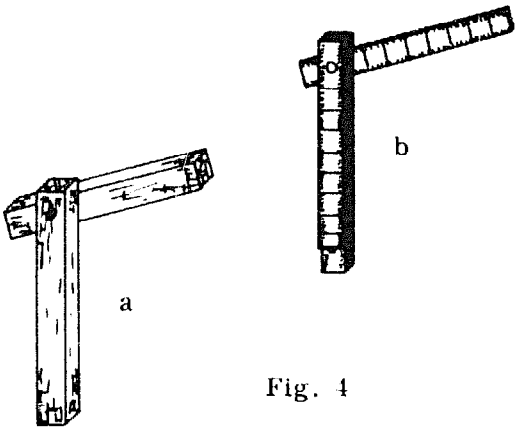

Fig. 4

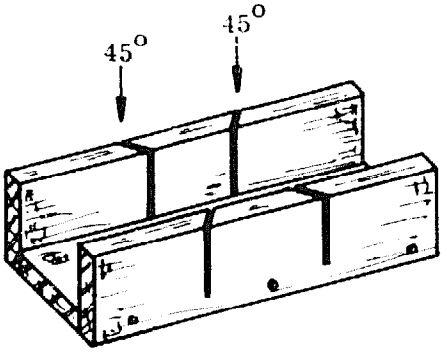

Fig. 5

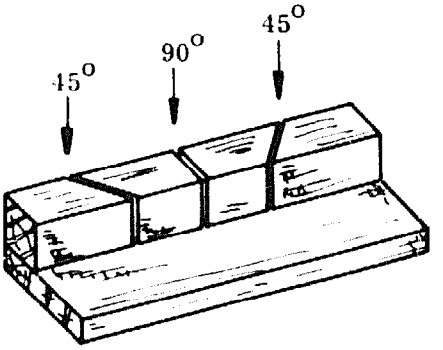

Fig. 6

N P V C	
78	TOOLS

TOOLS FOR MEASURING AND MITREING ANGLES.

TOOLS FOR MEASURING AND MITRING ANGLES

THE MITRE SQUARE

This is used to mark and test angles of 45 and 135 degrees. The blade is fixed at 45 degrees to the stock (Fig. 1).

THE TRY AND MITRE SQUARE

This is a combination of a try square and a mitre square. The end of the stock where it meets the blade is cut at 45 degrees (Fig. 2), so the square can be used for setting out and testing angles of 45 and 135 degrees, as well as 90 degrees.

THE SLIDING BEVEL

This is an adjustable square for marking out, testing and duplicating angles from 0 to 180 degrees. It has a stock and a slotted blade which can be adjusted to any angle and is held in place by a screw or a wing nut (Fig. 3).

A simple sliding bevel can be made by fixing two pieces of wood together with a nail or screw (Fig. 4a). Another method is to use the first section of a folding rule (Fig. 4b).

THE MITRE BOX

The mitre box (Fig. 5) is built of three pieces of wood, one forming the base and two parallel sides. It has saw kerfs in the sides at 45 degrees to the left and right to guide the saw in cutting mitres (cutting at a 45 degree angle).

THE MITRE BLOCK

This is used to mitre small sections of wood accurately. It is made of two pieces of wood with three cuts in the top piece; 45 degree cuts left and right and a 90 degree cut in the centre to help in sawing accurately square (Fig. 6).

- Mitre boxes and mitre blocks should be made of very hard wood and the saw cuts should be made with the same saw which will be used in them.

NOTES:

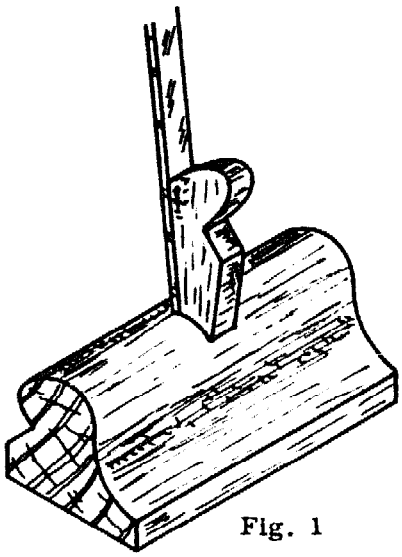

Fig. 1

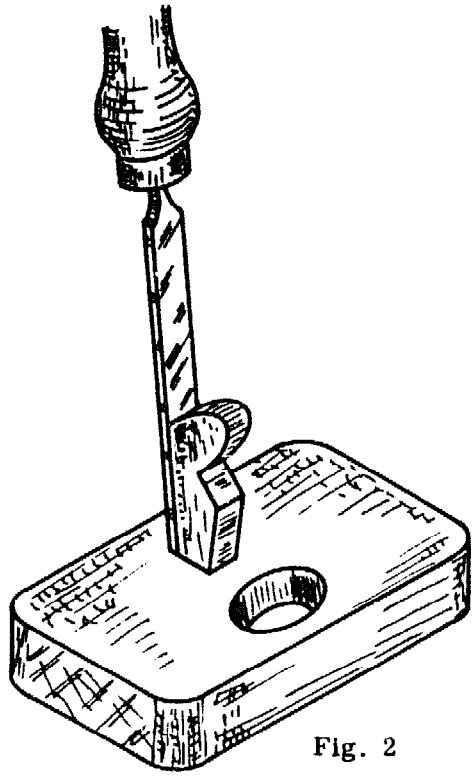

Fig. 2

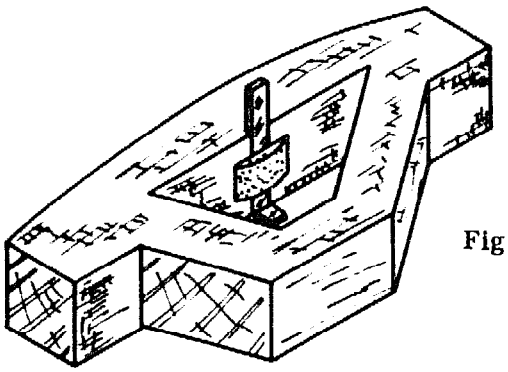

Fig. 3

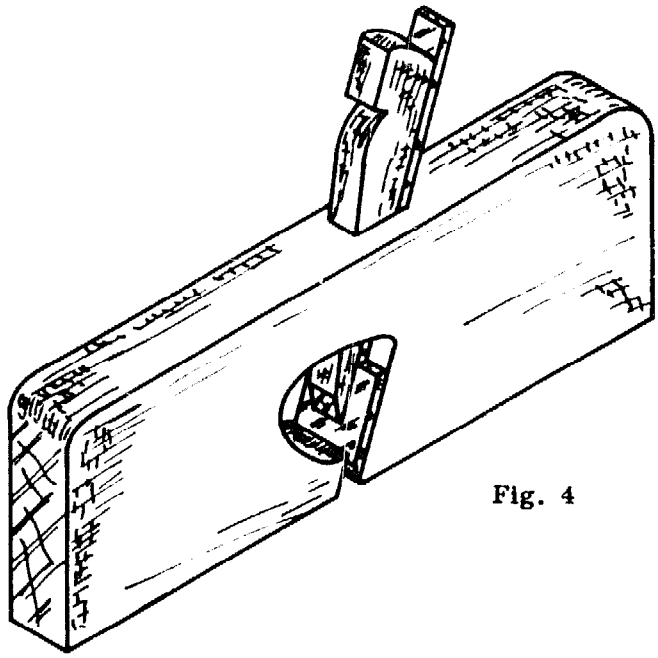

Fig. 4

N P V C	
80	TOOLS

ADDITIONAL PLANES FOR THE RURAL BUILDER.

ADDITIONAL PLANES FOR THE RURAL BUILDER

THE ROUTER PLANE

This is a tool adapted from the "old woman's tooth" (Fig. 1) shown on the left page. It is used for planing the bottoms of grooves, trenches, etc. after they have been chopped out with a chisel and mallet.

There is a wooden type as well as a metal type. The wooden type has the advantage that it can be made locally (Fig. 3).

For our Rural Building course, the old woman's tooth has the advantage that an ordinary chisel can be used as a cutting iron (Fig. 2), making it unnecessary to obtain a special iron.

THE REBATE PLANE

The rebate plane is used for working along the edge of timber. It is used for making rebates as well as for cleaning them up.

The use of the rebate plane is described in the section on Rebated Butt Joints, in Rural Building, Basic Knowledge, page 132).

NOTES:

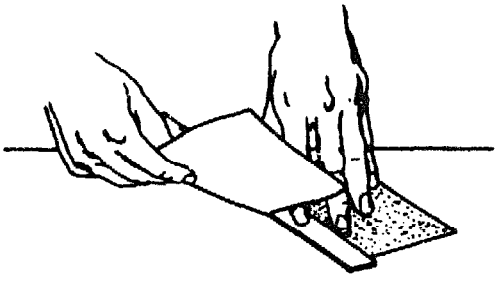

Fig. 1

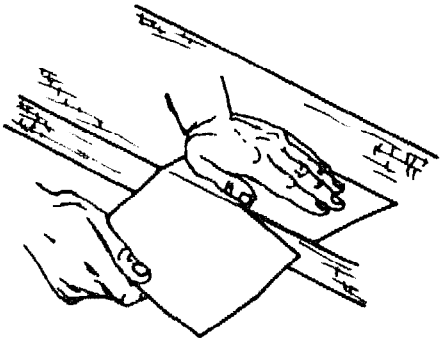

Fig. 2

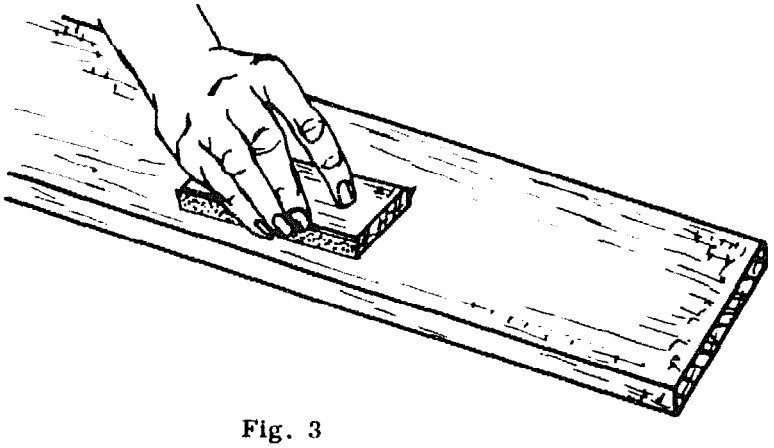

Fig. 3

N P V C		SANDPAPER.
82	TOOLS	

SANDPAPER

Sandpaper is used to smooth wood surfaces, remove old paint, etc. It is used after all the planing work is done; sandpaper cannot be used instead of the smoothing plane.

Sandpaper is made from grains of very hard material glued to paper. The sharp edges of the grains are what cut into the surface of the wood. The sharper the grains, the better the sanding effect.

Sandpaper is graded according to the space between the grains: the more widely spaced the coarser the grade. Use coarse grades for rough surfaces or for the first sanding and finer grades for the final sanding. The commonly used grades are from No. 00 (fine) to No. 2 (coarse). Usually No. 1/2 or No. 1 is satisfactory for coarse sanding on wood and No. 0 for the final or finished sanding.

HOW TO USE SANDPAPER

- Tear the paper to the right size by creasing it and then tearing it over the edge of a bench or ruler (Figs. 1 & 2).
- Wrap it part way around a flat block of wood (Fig. 3).
- For ordinary sanding, move the block back and forth with the grain; not in a circular motion or across the grain, which will roughen and scratch the wood instead of smoothing it (Fig. 3).
- If you are sanding off old paint, this may be done across the grain.
- Keep the block flat to the wood surface, particularly on narrow edges and be careful not to round the corners.
- Use only moderate pressure on the sandpaper block. Too much pressure may cause the paper to wrinkle or tear. Keep the sandpaper free of dust by knocking and shaking it out often.

NOTES:

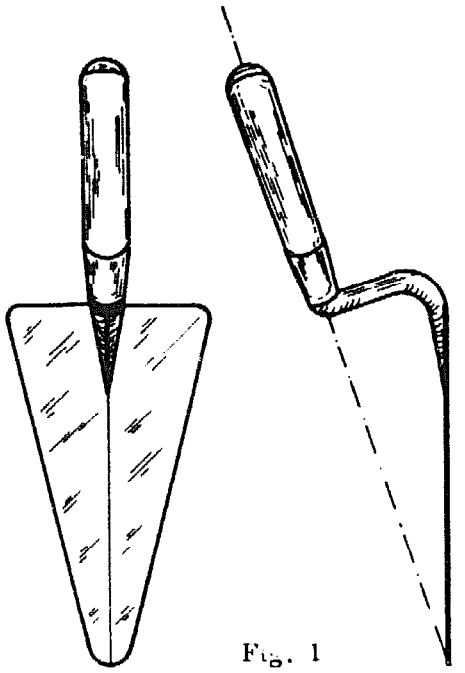

Fig. 1

TRIANGULAR TROWEL

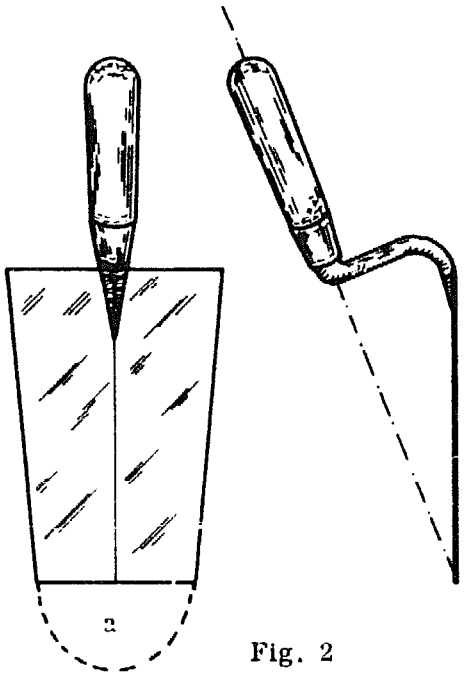

Fig. 2

RECTANGULAR TROWEL

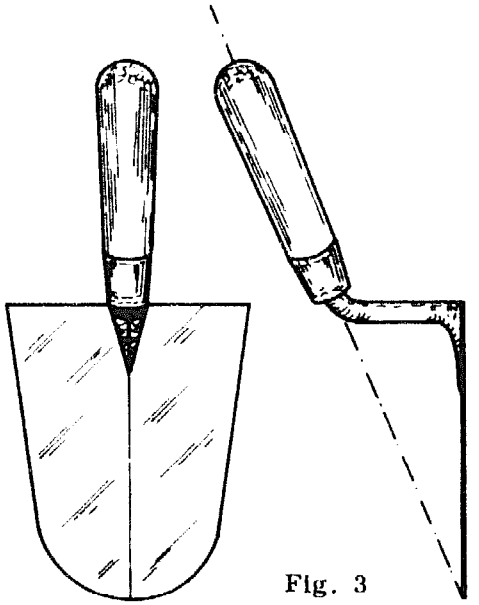

Fig. 3

HEAVY TROWEL

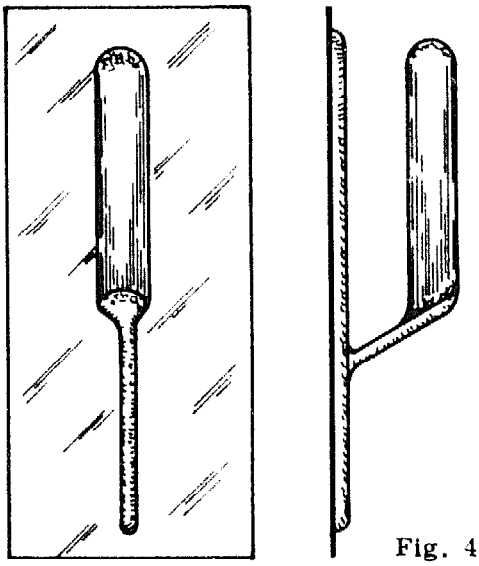

Fig. 4

STEEL FLOAT

N P V C	
84	TOOLS

OPTIONAL TOOLS.

OPTIONAL TOOLS

There are many useful tools which the apprentice will eventually come into contact with and which perhaps he would like to purchase.

Although the set of tools supplied to the Rural Builder will be adequate to do the work, a good craftsman will always try to improve upon his tool set.

Therefore, the purpose of the following introduction to some additional tools is simply to round out the apprentice's general knowledge about tools.

OTHER TYPES OF TROWELS

Fig. 1 shows a triangular trowel, while the one in Fig. 2 is almost rectangular. The rectangular type of trowel is also available with a rounded tip (Fig. 2a). All three types of trowel are useful in Rural Building and the decision of which one to use depends merely upon their availability and the Builder's personal preference.

Fig. 3 shows a heavier trowel designed specially for concrete work. The head is rounded to make it easier to pick up concrete. The blade is rather thick compared to other trowels and the straight shank is connected to the blade at a 90 degree angle to reduce the flexibility of the trowel.

STEEL FLOAT

The steel float consists of a thin rectangular blade about 12 cm wide by 28 cm long. There is a handle fitted to the back side of the blade (Fig. 4).

This is a finishing tool used for smoothing surfaces such as floors and plaster.

NOTES:

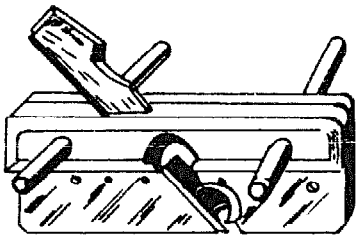

PLOUGH PLANE

Fig. 1

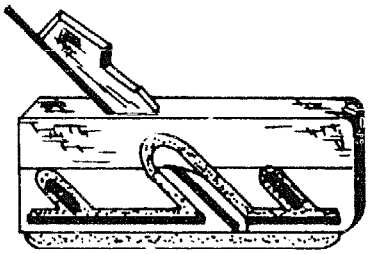

FILLISTER PLANE

Fig. 2

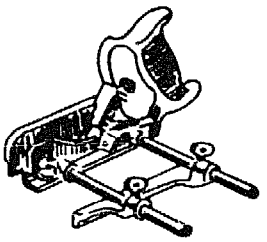

COMBINATION PLANE

Fig. 3

METAL PLANE

Fig. 4

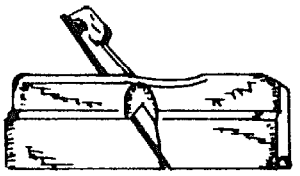

MOULDING PLANE

Fig. 5

SPOKE SHAVE

Fig. 6

N P V C		OPTIONAL TOOLS.
86	TOOLS	

OTHER PLANES

There are many varieties of planes available for different jobs. However, in Rural Building, we can do a good job with the four different planes we have and we will leave it to the future craftsman to decide if it is necessary to obtain any other plane in addition.

Below we describe briefly some other planes which might be a choice for the future builder. They are shown on the left page.

The plough plane (Fig. 1) is used to make grooves in wood.

The fillister plane (Fig. 2) is used for making rebates.

The combination plane (Fig. 3) is a combination of the fillister plane, plough plane and moulding plane.

There are various types of metal planes (Fig. 4) used for different purposes in furniture making.

The moulding plane (Fig. 5) resembles a rebate plane and it is used for making profiles.

The spoke shave (Fig. 6) is used to true and smooth edges after sawing.

NOTES:

NOTES:

PART 2: MAINTENANCE OF TOOLS

The importance of good tool maintenance is something which is readily appreciated by everyone; the beginner will quickly realize that without maintenance, the finest tools are no more useful than the most inferior ones.

Apart from their general maintenance in terms of cleanliness, rust prevention and avoidance of damage from rough handling, the most important aspect of maintaining tools is in the preparation and preservation of good cutting edges.

Until one has some experience in tool maintenance, one easily overlooks the fact that from the moment that a fine cutting edge is formed, it becomes the most delicate and easily damaged part of the tool. Even the lightest touch of another piece of metal can spoil the edge, wasting the work which has gone into making it.

Such damage can be avoided in commonsense ways such as:

- By keeping the bench clear of tools which are not in use.
- By laying planes down on their sides or keeping the toe raised on a wood support so that the plane iron does not touch the bench top.
- By keeping chisels and saws in the box when they are not in use.
- By keeping the bench clear of ironmongery such as nails, screws, hinges, etc.
- And by putting tools down on wooden surfaces only.

NOTES:

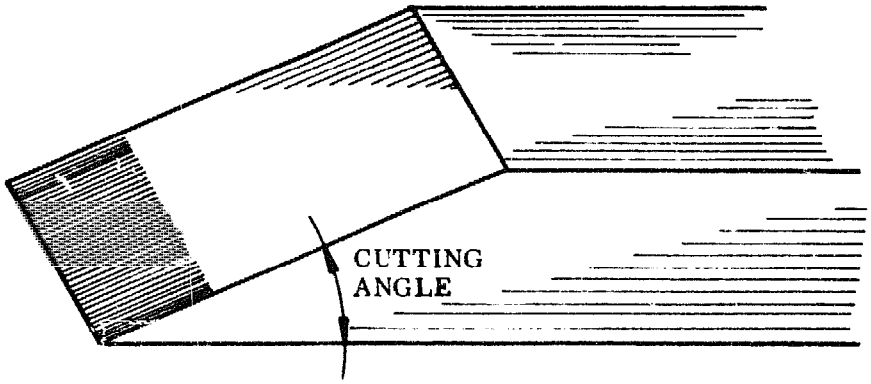

Fig. 1

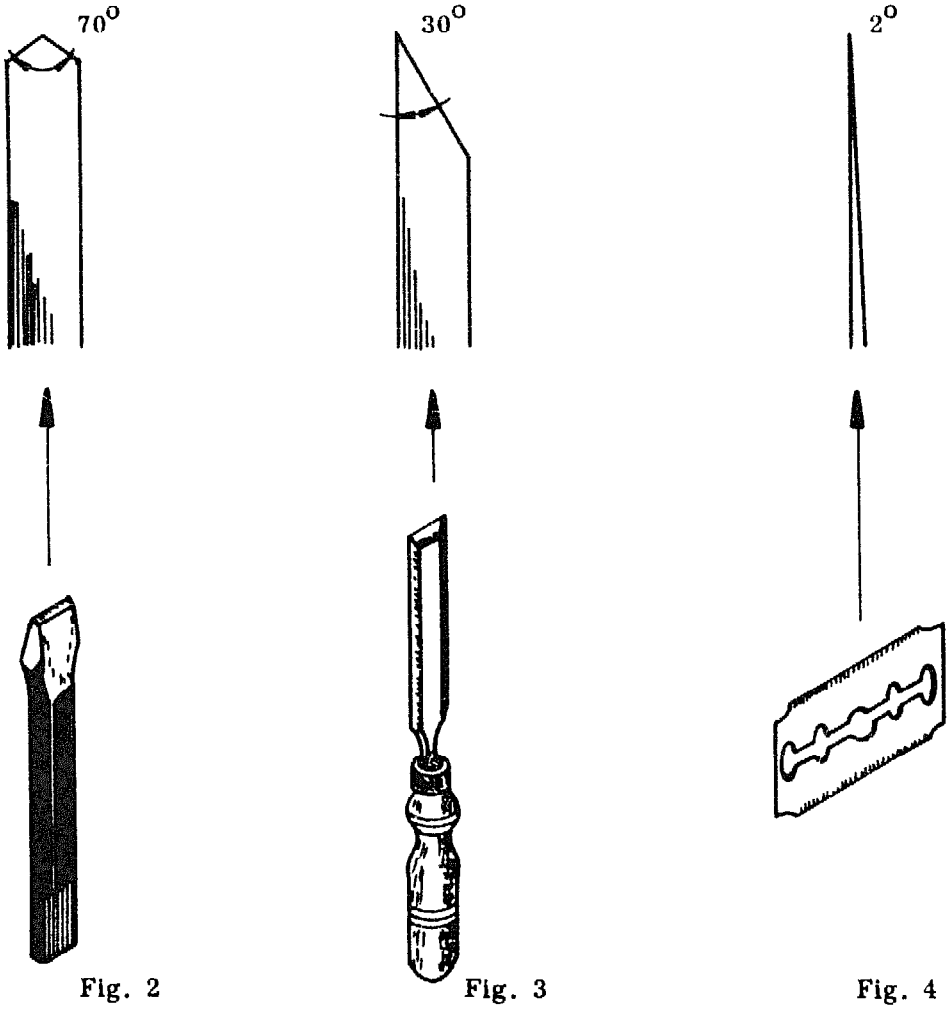

Fig. 2 Fig. 3 Fig. 4

N P V C	
90	MAINT.

CUTTING ANGLES.

CUTTING ANGLES

Before you can properly maintain your tools, you need to know something about the shape of the cutting edges on tools like plane irons and chisels. A cutting edge is formed where the two faces of a wedge come together at an angle, which is the cutting angle (Fig. 1).

In general, the harder the material that you want to cut, the larger the cutting angle you need. For example, to cut steel or stone you need a tool with a cutting angle of about 70 degrees, like the cold chisel (Fig. 2). To cut a soft material like leather, a knife or a razor blade with a cutting angle of only a few degrees (Fig. 4) will work efficiently. Of course, you would not be able to cut steel with a razor blade.

In both these cases, it is important that the cutting edge of the tools is sharp, although they have different cutting angles.

For cutting wood, we generally have one standard cutting angle for the tools like plane irons and chisels, although different kinds of wood can vary quite a bit in hardness. This standard angle of between 25 and 35 degrees is more or less suitable for all types of wood (Fig. 3). The craftsman will find with experience the right cutting angle for his needs.

Note that the smaller the cutting angle, the more easily the tool will cut and also the sooner it will become dull.

NOTES:

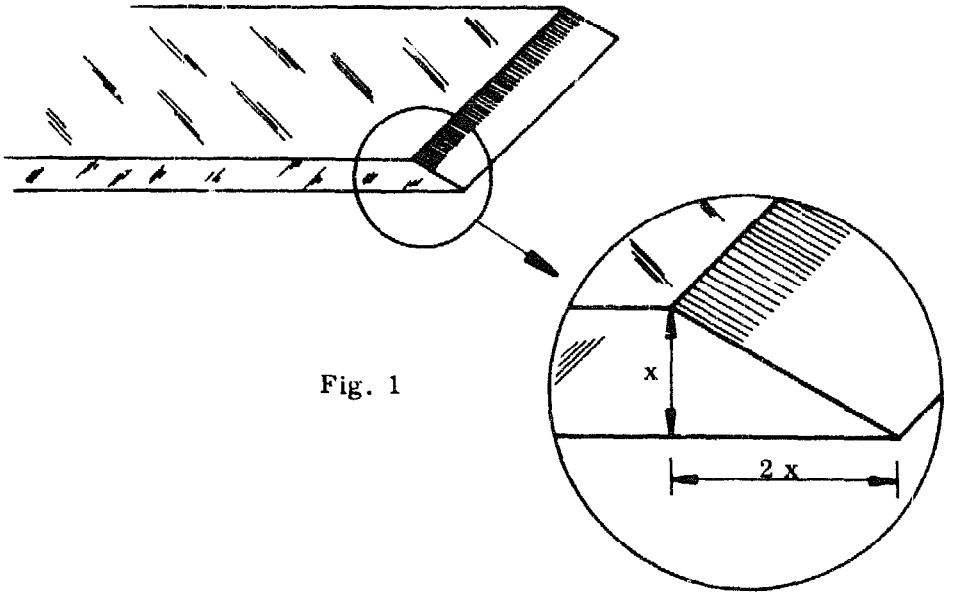

Fig. 1

ENLARGED DETAIL

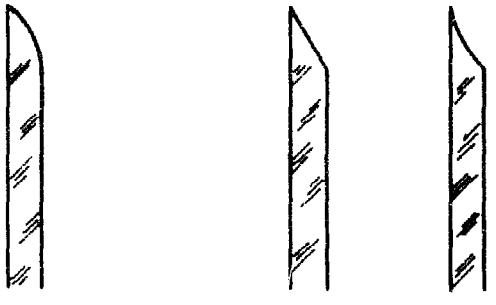

WRONG

RIGHT

Fig. 2

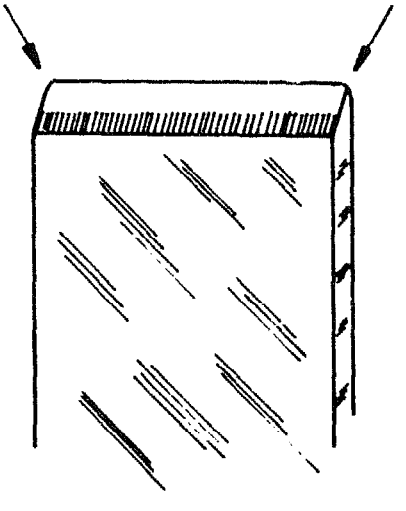

Fig. 3

N P V C	
92	MAINT.

SHARPENING PLANE IRONS AND CHISELS.

SHARPENING PLANE IRONS AND CHISELS

Two different operations may be needed to produce a keen edge on these tools: grinding and honing.

Simply honing tools on a sharpening stone is all that is needed to sharpen them if they are dull but undamaged.

If the edges have been damaged, or worn down by many honings, they will need to be ground first and then honed. The grinding step is done on the rough side of the sharpening stone, or if the damage is very bad, on the grinding wheel.

ANGLE AND SHAPE OF THE CUTTING EDGE

- For normal work, grind plane irons and chisels so that the length of the bevel is a little more than twice the thickness of the blade (Fig. 1). This gives an angle of 25 to 30 degrees.
- The bevel should be ground straight or slightly concave, not rounded or convex (Fig. 2).
- For jack planes it is desirable to grind the corners of the blade slightly rounded as shown in Fig. 3. This lets the iron cut thicker shavings without causing deep grooves or plane marks in the wood surface.
- The cutting irons of smoothing planes, rebate planes and chisels should not be rounded.
- When you sharpen the cutting iron of a plane, always remove the cap iron first.

NOTES:

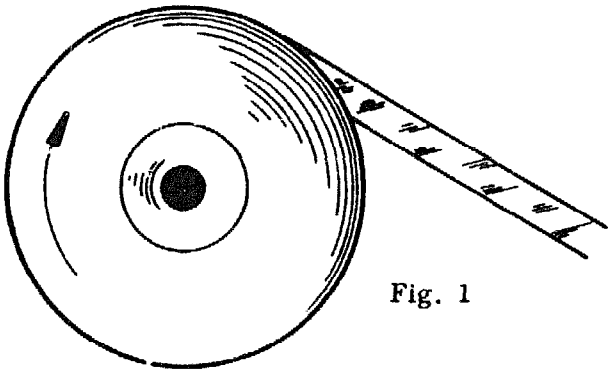

Fig. 1

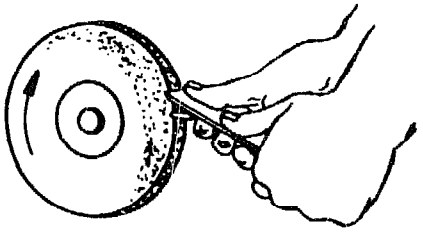

Fig. 2

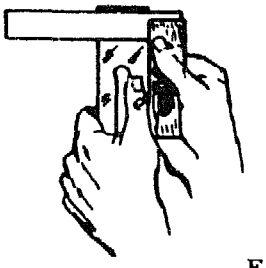

Fig. 3

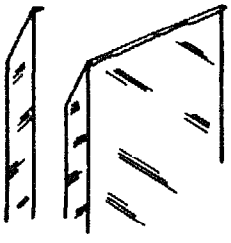

Fig. 4

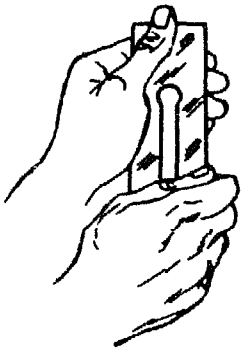

Fig. 5

N P V C	
94	MAINT.

SHARPENING PLANE IRONS AND CHISELS.

HOW TO GRIND PLANE IRONS AND CHISELS ON THE GRINDING WHEEL

When the cutting edge of a tool is badly damaged, it is ground on the grinding wheel. This is done by holding the tool at a constant angle to the rotating edge of the wheel (Figs. 1 & 2).

Each grinding makes the tool a bit shorter, and thus shortens its life. Use your tools carefully so that they don't need to be reground as often.

When you grind a plane iron or chisel on the grinding wheel, the following points are important to keep in mind:

- Before grinding, test the cutting edge for squareness. Put a try square on top of the chisel or plane iron, with the cutting edge projecting slightly past the try square blade (Fig. 3). Be careful not to touch the cutting edge with the square.
- Hold the tool against the wheel in a manner that will produce a smooth, even bevel, with the desired angle.
- If possible, adjust the work rest of the grinding wheel, so that when the tool is held firmly against the rest it will come into contact with the wheel at the correct angle (Fig. 2).
- Grasp the tool so that your first finger is against the work rest; this will enable you to replace the tool in the proper position after removing it for inspection or to dip it in water (Fig. 5).
- During grinding, a wire edge or burr is formed on the tool. You can feel this burr if you run your thumb across the edge at the back (Fig. 4).
- It is important that the grinding wheel always turns towards you (Fig. 1), so that the burr that is formed remains on the blade. If the wheel were rotating away from you the burr would tear off, leaving an uneven edge.
- Turn at a moderately fast speed, not so fast that the gears whine or the grinder vibrates.
- Always work with another person on the grinding wheel, so that he can turn the wheel while you do the grinding.
- Hold the tool against the wheel with a medium firm pressure.
- Move the tool from side to side across the face of the wheel.
- Take care that the cutting edge does not become overheated and thus softened during grinding. Prevent overheating by frequently dipping the cutting edge into a tin of water.

- Inspect the edge often, to see if the tool is being ground to the proper shape and angle.
- With a bit of practice, you can check the cutting angle by eye, remembering that the length of the bevel should be a little more than twice the thickness of the blade. Use a rule at first to check the length of the bevel and the thickness of the blade.
- Continue grinding until the dull edge is removed, all the marks are removed, the edge is straight and square and the bevel has the required angle. If the edge is not square, correct it during the grinding by pressing carefully more on one side than on the other.
- Remove the burr or wire edge left by the grinding wheel by honing the tool on a sharpening stone.

NOTES:

GRINDING ON THE COARSE SIDE OF THE SHARPENING STONE

If the tool has a cutting edge with only a few marks in it and no serious damage, it can be ground on the coarse side of the sharpening stone, instead of using the grinding wheel.

- Soak the stone in water and grind the bevel of the tool on the coarse side of the stone, until a slight burr or wire edge is formed.
- When grinding, place the cutting iron on the stone so that the bevel lies flat (Fig. 1) and rub it with circular movements. Do not rub it just back and forth, as this makes the stone wear unevenly.
- Be particularly careful to move your hands parallel to the surface of the stone and do not allow them to make a dipping movement, as this will round the cutting edge.

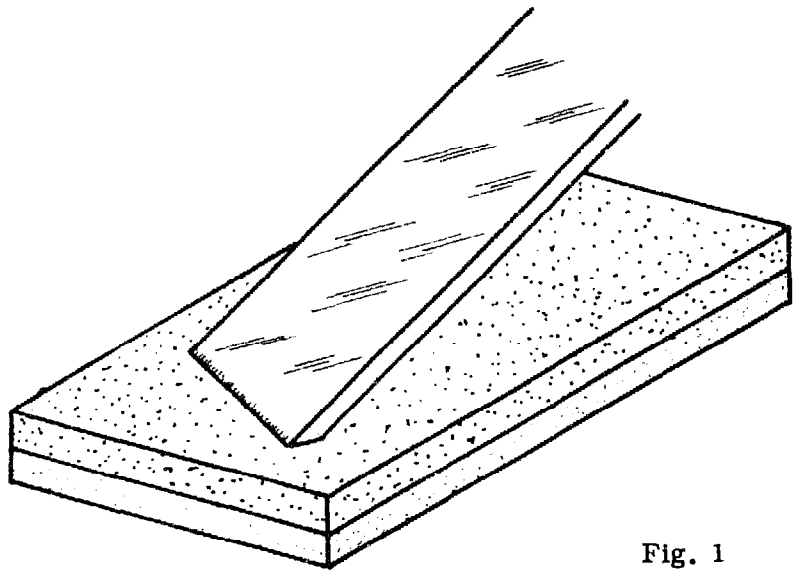

Fig. 1

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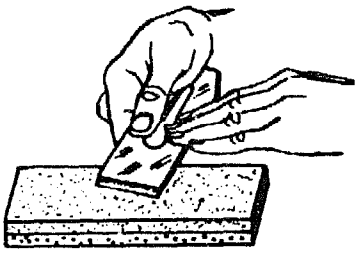

Fig. 1

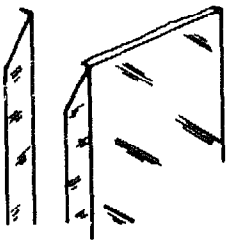

Fig. 2

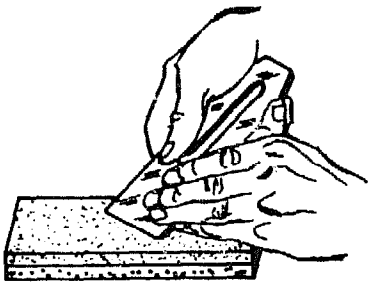

Fig. 3

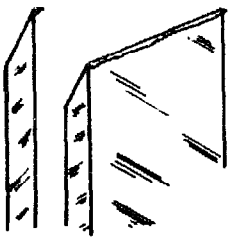

Fig. 4

Fig. 5

N P V C		SHARPENING PLANE IRONS AND CHISELS.
98	MAINT.	

HOW TO HONE PLANE IRONS AND CHISELS

Honing is done on the fine side of the sharpening stone. Honing produces a keen edge.

After a slight wire edge has been produced on the coarse side of the sharpening stone, or on the grinding wheel, it is removed by honing on the fine side of the stone.

- First, soak the stone in water. Place the tool perfectly flat on the stone with the bevel up and push it forward (Fig. 1). A few strokes will turn the burr from the flat side of the tool to the side with the bevel (Fig. 2).
- When the wire edge turns, turn the tool over so the bevel is flat on the stone and hone lightly on the bevel (Fig. 3).
- Then reverse the tool again and hone on the flat side.

If the honing is properly done, the wire edge will quickly become smaller and smaller (Fig. 4) and eventually disappear. The tool will then be sharp.

To check whether the tool is sharp, draw the nail of your thumb across the edge of the tool.

Marks, such as may have been caused by a nail, can be detected by holding the iron to the light. A sharp edge cannot be seen, while a dull one will show up in the light and appears as a narrow, shiny surface (Fig. 5).

If the tool is not held perfectly flat when the flat side is honed, a small bevel may be produced on the flat side and it will then be impossible to put the edge in good condition without regrinding it.

- In alternately honing the flat and bevelled sides, make sure that the wire edge is actually turned from the flat to the bevelled side before you reverse the tool for honing on the bevelled side (Figs. 2 & 4).
- To hone a slightly dull edge without grinding it, rub it on the sharpening stone in the same way, but only on the bevel side, not on the flat side.

Chisels are sharpened in the same way as cutting irons. Keep in mind that they are narrow and they should not be worked all the time in the centre of the stone, as this will quickly cause the centre of the stone to become hollow.

NOTES:

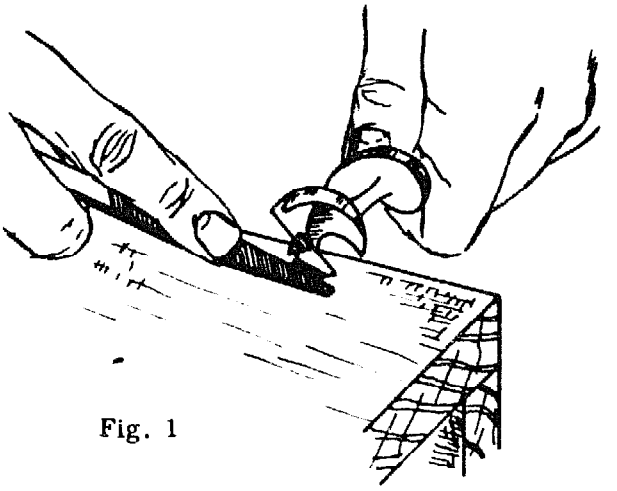

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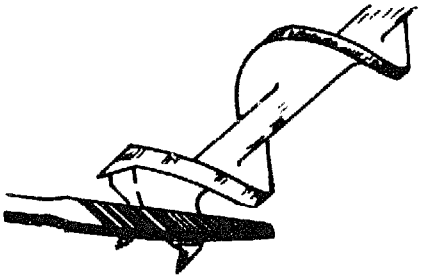

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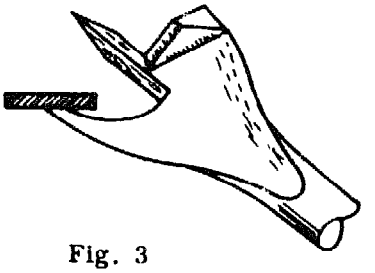

Fig. 3

Fig. 4

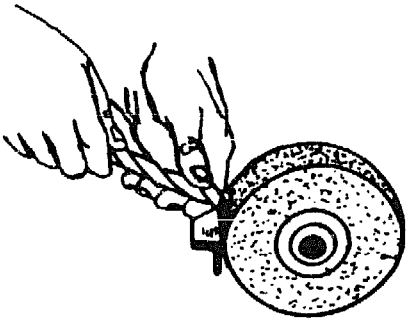

Fig. 5

N P V C	
100	MAINT

SHARPENING BITS AND DRILLS.

SHARPENING BITS AND DRILLS

Manual wood bits are usually sharpened with a small file. It is best to avoid too much sharpening. Your tools will last longer if you use them carefully and keep them in a good case, so they won't need sharpening so often.

SHARPENING THE AUGER BIT

Auger bits are sharpened as shown on the left (Figs. 1 & 2).

- For the spurs, use a small file and sharpen from the inside face only (Fig. 1). The spurs are never sharpened on the outer faces, as this would change their diameter.
- For the cutters, file from the top side (Fig. 2). Retain the original bevel and remove about the same amount of material from each side.
- Hold the bit firmly to the edge of the bench during filing.

HOW TO SHARPEN THE CENTRE BIT

- To sharpen the spur, file from the inside (Fig. 3). To sharpen the router, file the bevel from the top side (Fig. 4).
- When sharpening the centre point, take care that the point remains exactly in the middle between the spur and the outside of the router.

HOW TO SHARPEN THE TWIST DRILL

- Grind the nose from the bottom (Fig. 5). Keep the original shape and angles and remove the same amount from each side.
- Never file the flutes as this would change the diameter of the drill. If the drill is really out of shape, contact someone with metalworking experience.

HOW TO SHARPEN AWLS

- To sharpen an awl you can use the sharpening stone, or if it is damaged rub it down with a file. Pointed awls can be sharpened on a grinding wheel.

NOTES:

Fig. 1

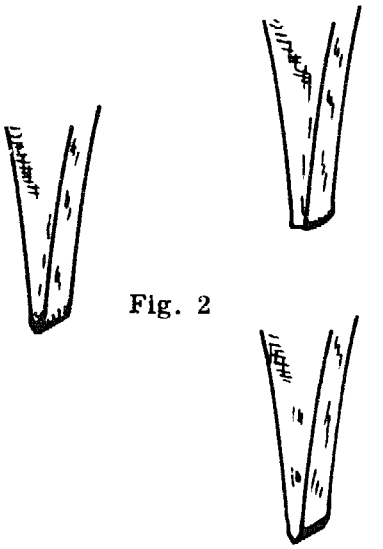

Fig. 2

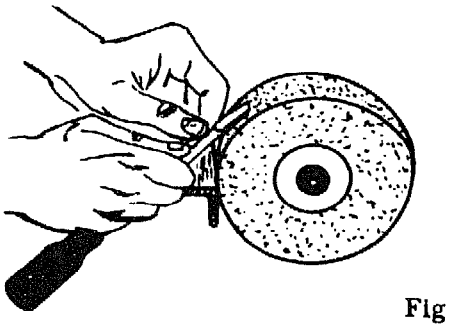

Fig. 3

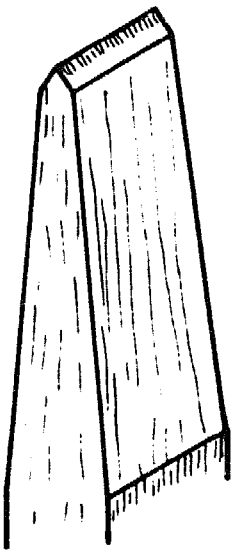

Fig. 4

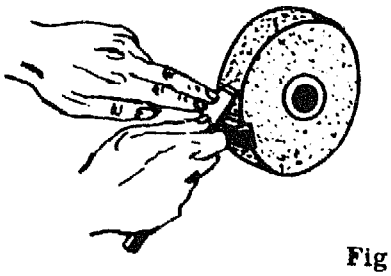

Fig. 5

N P V C	
102	MAINT.

SHAPING SCREWDRIVERS.

SHAPING SCREWDRIVERS

A screwdriver should be ground or filed to a very blunt end (Fig. 3). The two flat surfaces should be straight and parallel near the tip. The end should be square to the flat sides, and should be a little less thick than the width of a screw slot (Fig. 1).

If the end is rounded or sharpened to a knife edge, it will easily slip out of the screw slot and damage the slot (see Screwdrivers, page 77). In Fig. 2 there are some examples of badly shaped screwdriver tips.

SHAPING COLD CHISELS

Cold chisels should be ground or filed with the bevels on the cutting edge making an angle of about 70 degrees to each other (Figs. 4 & 5).

SHAPING BLOCK SCUTCHES

A block scutch should be shaped and filed to an angle of 70 degrees. Unlike the cold chisel, it is filed only from the inside (Fig. 6).

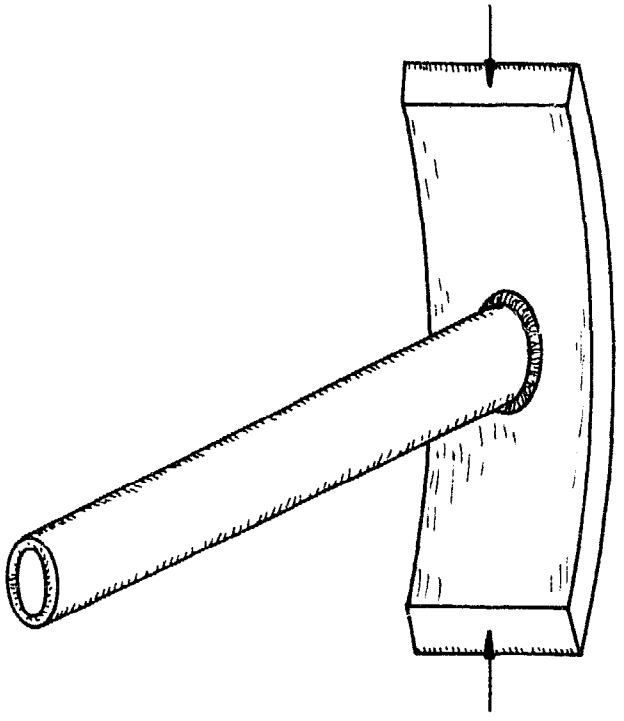

Fig. 6

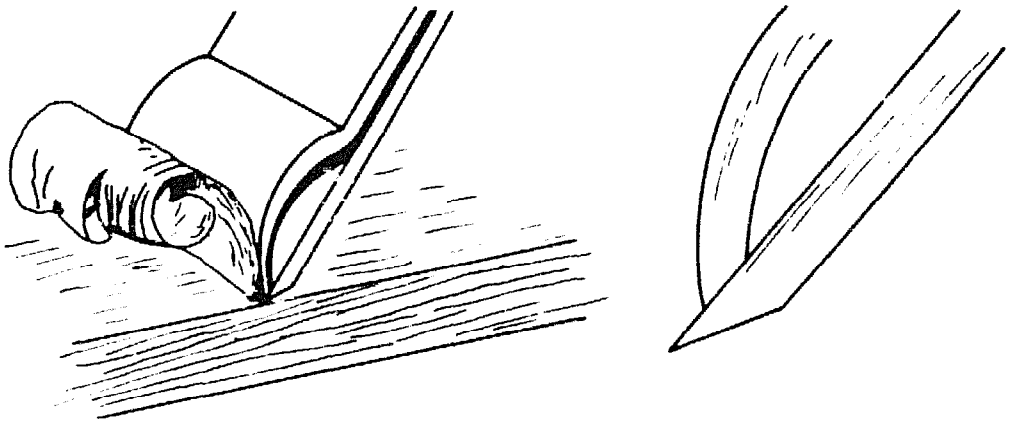

Fig. 1

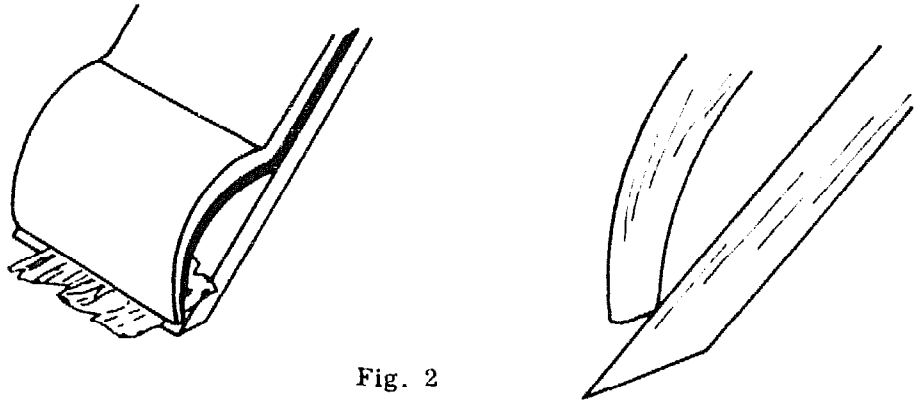

Fig. 2

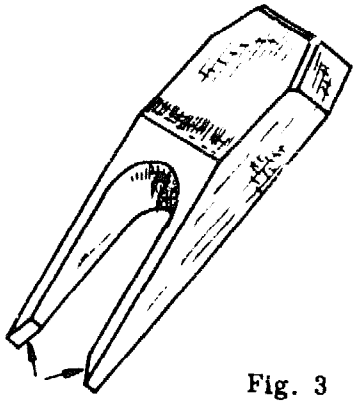

Fig. 3

N P V C		MAINTAINING WOODEN PLANES.
104	MAINT.	

MAINTAINING WOODEN PLANES

HOW TO REFACE THE SOLE

Whatever the quality of the wood stock, the soles of all wooden planes eventually wear and require refacing.

Refacing can be done on a large sheet of sandpaper, which is fastened to a true flat surface. The cutting iron of the worn plane is pulled inside the mouth, not removed, for it is best to have the stock held in the usual pressure by the wedge.

- Sand the surface down, test it with a straight edge and winding strips and oil the wood lightly.

ABOUT THE BEDDING OF THE CAP IRON

It is essential that the edge of the cap iron should bed perfectly on the face of the cutting iron when they are screwed together (Fig. 1). Even the slightest gap between the two will allow a shaving to enter and block the mouth of the plane (Fig. 2).

Usually this problem is caused by a fault in the cap iron. The cap iron should be rubbed on a sharpening stone or filed to restore the true edge. Keep the cap iron clean and shiny.

FITTING THE WEDGE

After much use, the wedge may no longer fit well into the stock. Heavy use of the hammer when knocking it in may cause the wedge to become misshapen because of the pressure.

When it becomes difficult to remove the wedge in the usual way (by hitting sharply on the striking button), the wedge should be removed, cleaned and filed or sandpapered to the correct fit again.

The ends of the wedge can become worn and cause the plane to stuff because they are too far inside the plane. If this happens, recut the ends of the wedge (Fig. 3).

NOTES:

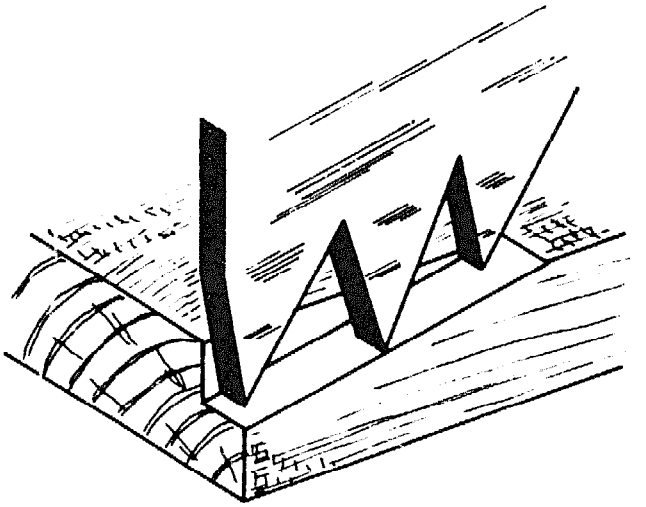

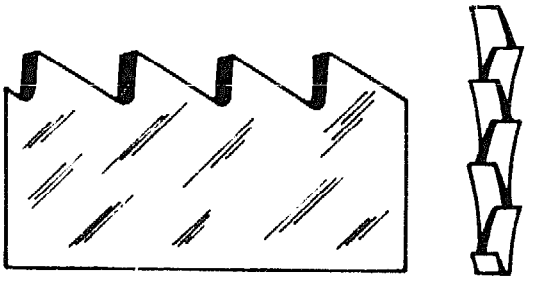

Fig. 1

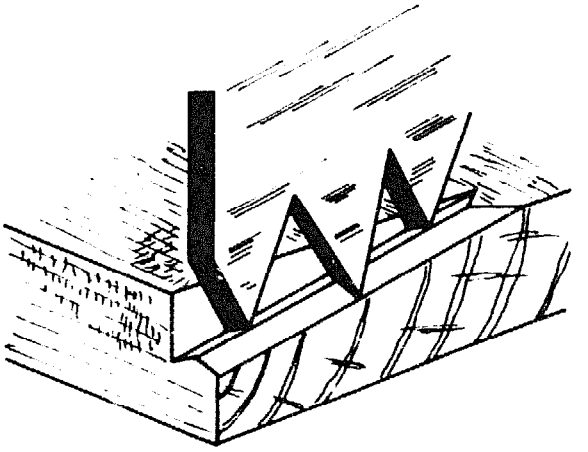

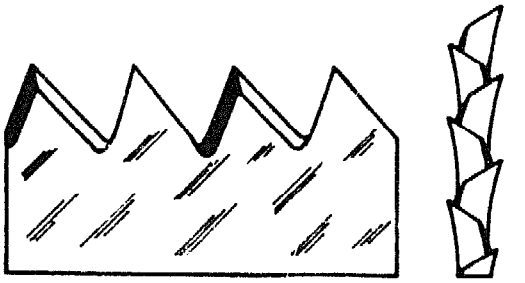

Fig. 2

N F V C	
106	MAINT.

MAINTENANCE OF SAWS.

MAINTENANCE OF SAWS

GENERAL MAINTENANCE

- Frequently give the saw a light coat of oil on the blade, to prevent rust. Keep the saw away from water.
- Keep the saw in the toolbox and be careful not to damage the blade by putting other tools on top of it.
- Keep the workbench uncluttered and be careful where you put the saw down.
- If the blade gets bent or buckled, straighten it at once.

THE ACTION OF THE TEETH

In order to properly maintain saws, it is necessary to understand how the teeth should look and how they work.

The ripsaw tooth resembles the cutting edge of the chisel. Its cutting edge strikes at practically a right angle to the wood fibres and the effect is as if a series of small chisels were set one behind another. Each tooth cuts out the full width of its edge and carries away the shaving (Fig. 1).

The teeth of the crosscut saw and the backsaw have a different shape, size and action from those of the ripsaw.

The form of the teeth is more like a series of knives that cut alternately on the two sides of the kerf (Fig. 2).

In sawing across the grain of the wood, the wood fibres must be cut on each side of the kerf so that a clean cut can be made. The teeth are therefore formed into sharp points on the outer side, so that they cut the fibres accurately.

The cut is started as the teeth make fine cuts, similar to the cuts of a knife, across the wood surface. Then as pressure is applied, the teeth go deeper and deeper, gradually bringing into action the full cutting edge of the teeth.

NOTES:

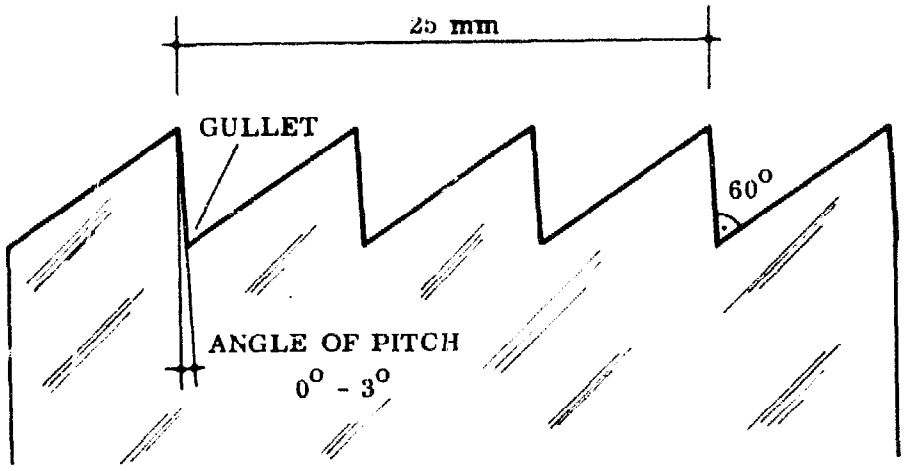

Fig. 1

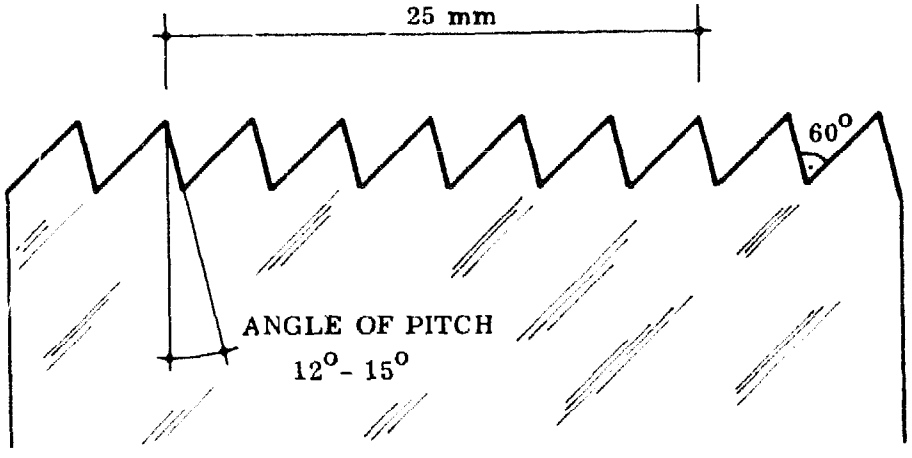

Fig. 2

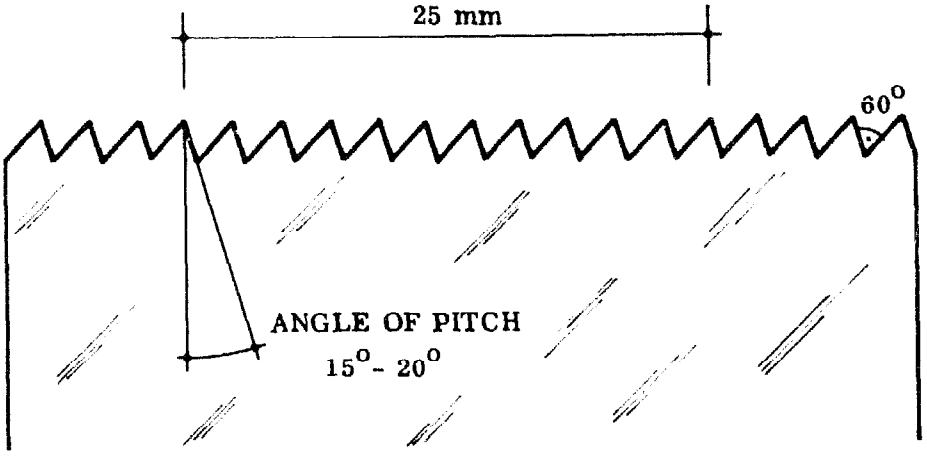

Fig. 3

N P V C		ANGLE OF PITCH, SHAPE AND NUMBER OF SAW TEETH.
108	MAINT.	

ANGLE OF PITCH, SHAPE AND NUMBER OF SAW TEETH

The angle of pitch of the saw teeth is important in the maintenance of the saw. This angle is the measure of how far the face of the tooth is leaning from the vertical. The angle of pitch for the different saws is shown on the left page.

The smaller the angle of pitch, the faster the saw will cut and the more often it will need resharpening. A large angle of pitch means a longer life for the blade, while a small angle means more frequent resharpening and thus a shorter life.

THE RIPSAW

The blade of the ripsaw has 4 points (teeth) per 25 mm. The teeth of the ripsaw are rather big (Fig. 1).

The angle of pitch of these teeth is very small, from 0 to 3 degrees. This small angle means that the ripsaw will not cut properly across the grain, because the teeth will tend to tear the fibres. This saw is used only for cutting with the grain, where there is not any danger of tearing the fibres.

THE CROSSCUT SAW

The blade of this saw has 6 to 8 points per 25 mm, so its teeth are smaller than those of the ripsaw. The angle of pitch of the teeth is greater in order to get cleaner cuts; this also makes the work slower. The angle is between 12 and 15 degrees for this kind of saw (Fig. 2).

Do not use this saw for cutting along the grain; it is not designed for that and it will not guide as well as the ripsaw.

THE BACKSAW

The blade of the backsaw has 10 to 15 points per 25 mm, so the teeth are still smaller than those of the crosscut saw. The angle of pitch is between 15 and 20 degrees (Fig. 3).

NOTES:

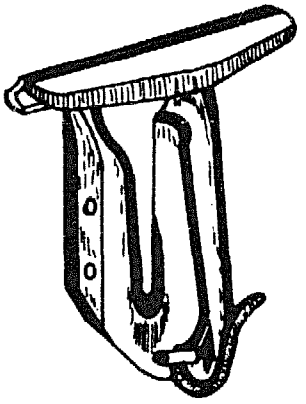

Fig. 1

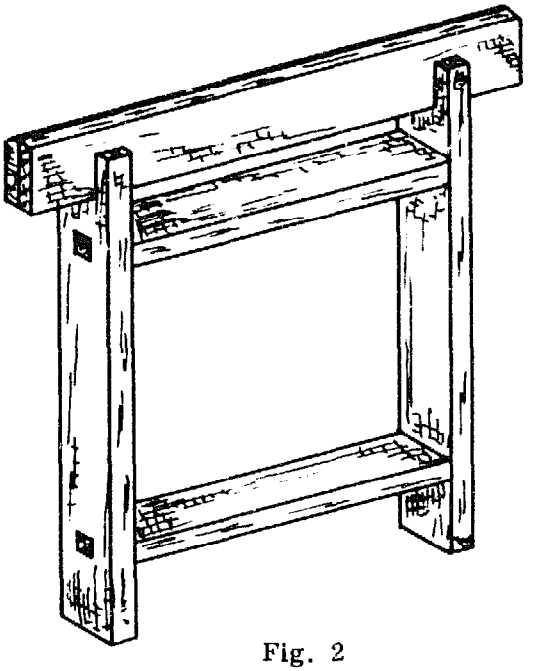

Fig. 2

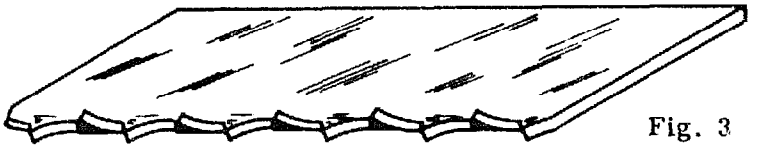

Fig. 3

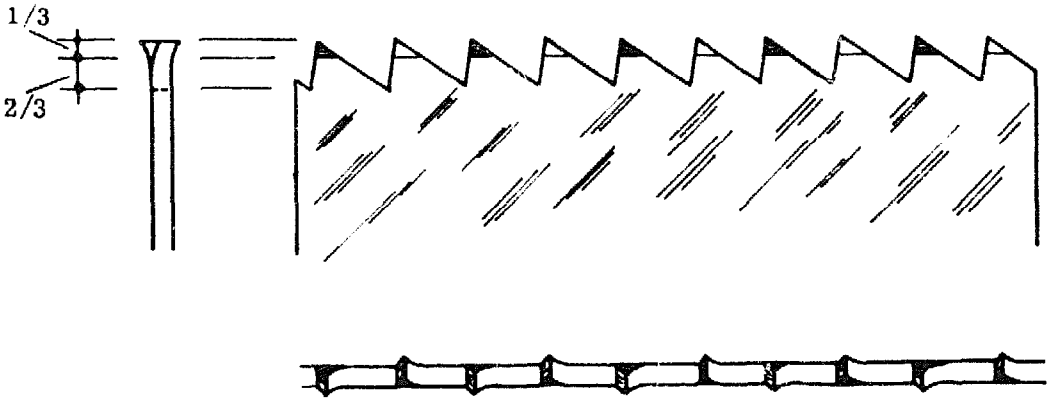

Fig. 4

N P V C		SETTING HANDSAWS.
110	MAINT.	

SETTING HANDSAWS

There are two main operations involved in sharpening a handsaw:

a. Setting
b. Filing

In order to make sure that the saw blade moves freely in the saw cut without any side friction, the saw teeth must be set. This is done by slightly bending the teeth at their tips (Fig. 3) to give more clearance in the kerf (saw cut). A saw should never be given more set than is necessary for the blade to move easily in its kerf. Too much set will cause the blade to wander out of line, too little set can cause the saw blade to buckle.

Only the tips of the teeth are set, never more than about 1/3 rd of the length of the tooth (Fig. 4). If you set the saw deeper than that you will buckle or crack the blade.

A saw need not be set every time it is filed, particularly if only a light filing is required. A saw can sometimes be filed two or three times before it needs to be reset and filed again.

- SAW VICE: During the maintenance of a saw, it must be securely fixed in position. A saw vice is used to hold it; either the wooden type (Fig. 2) called a horse, or the metal type (Fig. 1) which grips the blade more strongly but does not grip the whole length of the blade.

  Another type of wooden saw vice can be made by fixing the two wooden jaws to the handle of your toolbox.

NOTES:

Fig. 1

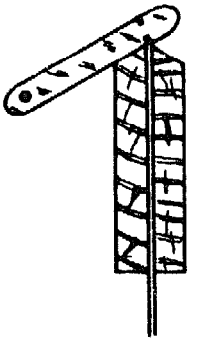

Fig. 2

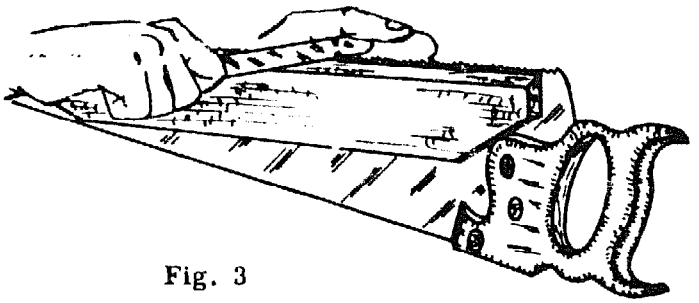

Fig. 3

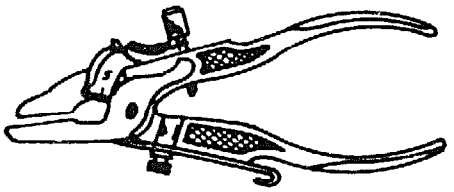

Fig. 4

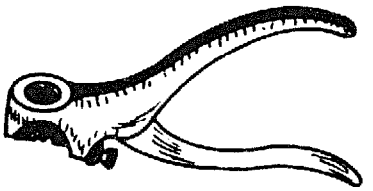

Fig. 5

N P V C		SETTING HANDSAWS.
112	MAINT.	

HOW TO SET A SAW

To do the setting, we use a setting tool. This can be a strip of metal with some cuts in it, the cuts being the thickness of the different saw blades (Fig. 1). Setting has to be done by eye, and practice is needed to get the right bend. The top of the saw vice can be bevelled to act as a guide for the setting tool (Fig. 2).

- Hold the saw firmly in a good position. When setting the first tooth, take care that you bend it to the same side that it was bent before.
- Start at the heel of the blade and bend every second tooth. When you finish one side, turn the blade around and do the other teeth (Fig. 3).
- It is important that the set is exactly the same on each side, otherwise the saw will run (saw out of line).

Instead of the setting tool mentioned above, pincer type sawsets (Figs. 4 & 5) are often used. You simply place the set over the tooth and squeeze the handles. These sawsets are adjustable, so when you use an unfamiliar one, it is best to set a few teeth and examine them before you set the whole saw. If the teeth are set too much or not enough, you can then adjust the sawset accordingly.

SETTING THE RIPSAW

When the saw cuts with the grain, like the ripsaw, the fibres of the wood don't tend to move back into the cut, so the ripsaw doesn't need a big set to have enough clearance between the blade and the kerf.

SETTING CROSSCUT AND BACKSAWS

Crosscut fibres tend to move back into the kerf, so these saws need a bigger set to get enough clearance.

It is important to note that the wider setting of these saws makes them unsuitable for cutting with the grain, because the kerf will be too wide to guide the saw.

NOTES:

Fig. 1

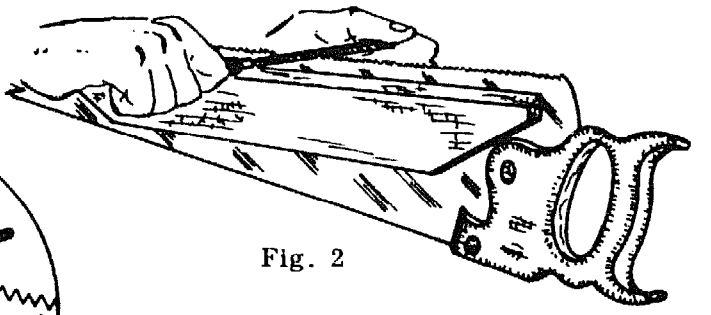

Fig. 2

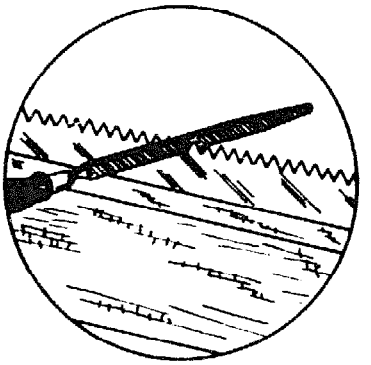

Fig. 3

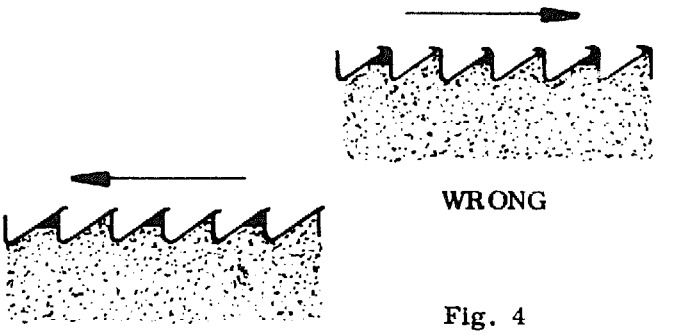

Fig. 4

N P V C		FILING HANDSAWS.
114	MAINT.	

FILING HANDSAWS

After the saw has been set it can be filed.

Secure the saw in a saw vice, with the teeth sticking out just a little way from the vice jaws. If the teeth stick out too far, the filing will cause a screeching sound.

The top of the saw vice should be at about the level of your armpits, or slightly below (Fig. 1). While filing, you must be able to constantly check the shape of the teeth and this rather high position enables you to see them properly.

In order to avoid eyestrain and ensure a good job of filing, it is essential to have good light. Work in front of an open window if possible, so that the light shines on the saw teeth.

USING THE SAWFILE

Small metalworking files with a triangular cross section are used for filing saws. The following points are important to remember in using the saw file:

- Hold the file handle in your right hand (Fig. 2).
- Hold the tip of the file gently between your thumb and forefinger of the left hand (Fig. 2).
- Exert pressure on the forward stroke only.
- Make long slow cutting strokes, not short fast ones.
- Keep the file level (Fig. 3).
- Use enough pressure to make the file cut, but no more.

During filing, a small burr is formed at the tip of the teeth. This burr can improve the cutting action of the saw when it is filed in the right direction. Therefore the saw must always be filed from toe to heel (Fig. 4).

NOTES:

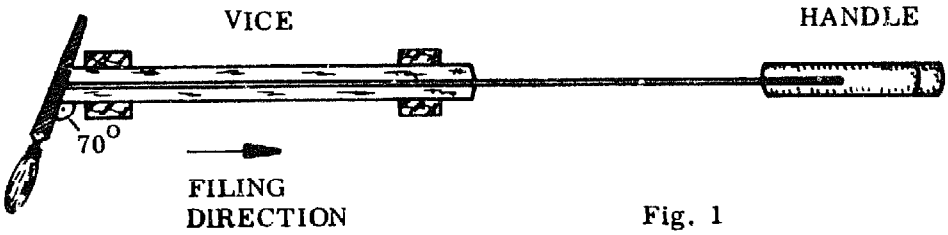

Fig. 1

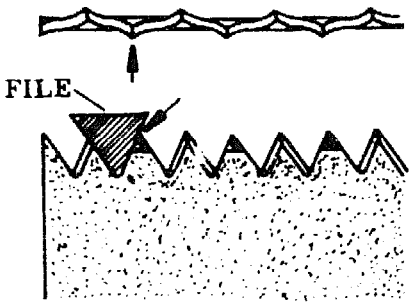

Fig. 2

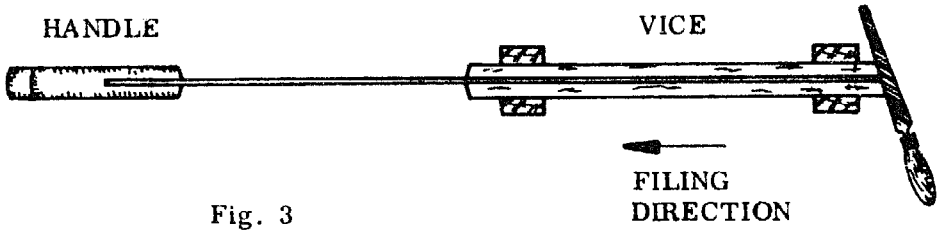

Fig. 3

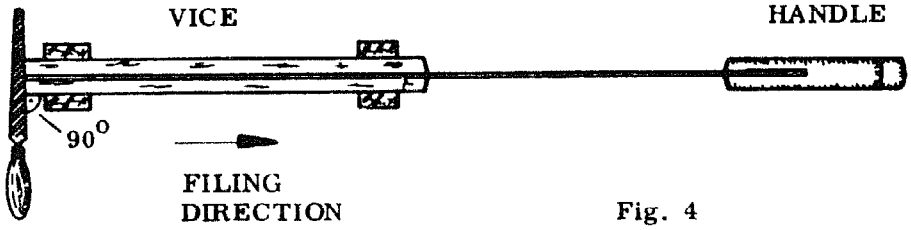

Fig. 4

N P V C		FILING HANDSAWS.
116	MAINT.	

HOW TO FILE THE CROSSCUT SAW

Study Fig. 1 very carefully to understand the proper starting position for filing this saw. Work according to the following sequence:

1. Place the toe of the saw in the saw vice with the handle to your right.
2. Find the first tooth in the toe that is bent towards you. Place the file in the first gullet (V-notch between the teeth) to the left of that tooth (Fig. 2, arrow).
3. Hold the file across the saw blade at an angle of about 70 degrees, with the point towards the saw handle.
4. If the teeth are of the proper shape (see section on Angles of Pitch) press the file gently into the gullet and let it find its own placement against the two teeth (Fig. 2). Remember to keep the file level.
5. Push the file forward, cutting the front surface of one tooth and the back surface of another.
6. Release the pressure on the file during the backstroke.
7. File every other gullet until you are about halfway through the saw, then make a pencil mark at this point.
8. Shift the blade in the vice until the head end is held more securely and continue filing every other gullet until you reach the handle.
9. When every other gullet has been filed from one side, turn the saw around in the saw vice so the handle is to the left (Fig. 3).
10. Find the first tooth in the toe of the saw that is bent towards you and put your file into the gullet to the right of that tooth.
11. Hold the file at an angle of about 70 degrees across the blade, with the point towards the saw handle.
12. File every other gullet as before, until you reach the saw handle.

- REMEMBER:
  - Inspect your work frequently to make sure that you are getting the teeth properly shaped. Remember that the angle of pitch must be correct.
  - Throughout the filing, give each tooth the same number of strokes with the file. This helps keep the teeth all the same size and shape.
  - If you get one tooth out of shape, don't be too concerned; it can be left as it is.

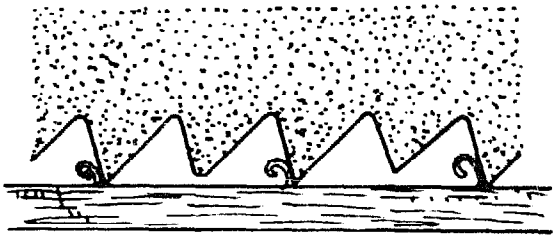

Fig. 1

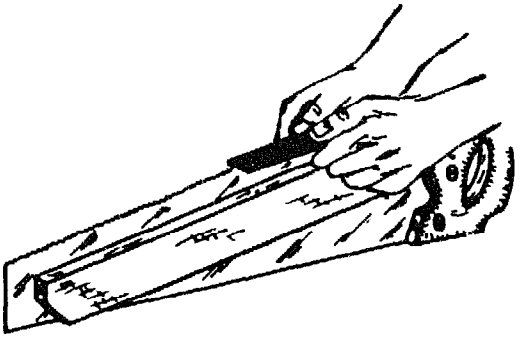

Fig. 2

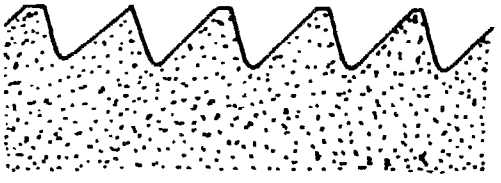

Fig. 3

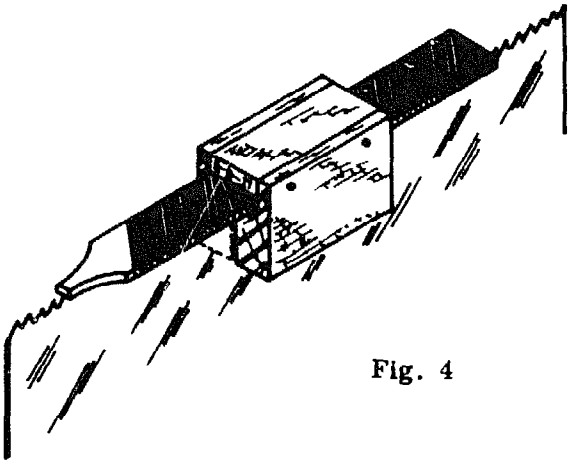

Fig. 4

N P V C		FILING HANDSAWS & TOPPING A HANDSAW.
118	MAINT.	

- Turn the file occasionally, so that it is used evenly.
- If you think you have lost your place or skipped a gullet, look for the last shiny tooth in the light.

HOW TO FILE THE BACKSAW

This saw is filed in the same way as the crosscut saw, except that the angle of pitch is different.

Be careful with the pressure you apply with the file, because the teeth are very small and are easily filed out of shape.

HOW TO FILE THE RIPSAW

The same general procedure is used for filing ripsaws as for crosscut saws. There are two important differences:

1. The angle of pitch is different.
2. The file is held at 90 degrees, not 70 degrees, to the blade (Fig. 4, previous page).

(Some people file the ripsaw from one direction only, filing all the teeth at once instead of filing every other tooth and reversing the saw).

TOPPING A HANDSAW

If you always file the saw correctly, without twisting the file or filing some teeth more than others, the teeth will always have the correct form and equal height.

When you make small mistakes in filing, or use the saw carelessly, the teeth will become out of line, different in height and irregular in shape. The result is that only some of the saw teeth can cut; the others don't touch the wood (Fig. 1). Topping is done to correct this problem.

WELL KEPT AND MAINTAINED SAWS NEVER NEED TOPPING!

HOW TO TOP A SAW

Topping must always be done before you set or file the saw.

- To top a saw, you run a flat metalworking file over the ends of the teeth, moving along the length of the saw. Be very careful to keep the file square to the saw blade and flat.

- One way to do this is to grasp the file in both hands by the edges, thumbs on top and the fingers under, touching the saw blade and guiding the file (Fig. 2, previous page).
- A wooden block may also be used to hold the file in the proper position (Fig. 4, previous page).
- File until there is a small shiny point on each tooth. When you have made two or three light strokes and there are still some teeth that have not been touched (Fig. 3, previous page), don't keep on filing. Too much topping will make it difficult to reshape the teeth.
- Next, file the teeth to the correct form again. This is called reshaping the teeth. When all the teeth have the same height and shape they are ready to be set and filed again after setting, to sharpen them.

NOTES:

PART 3: RURAL BUILDING MATERIALS

Man learned early to protect himself from the weather as well as from his enemies by making shelters of various kinds.

The type of structure he made depended on the locally available building materials, and on whether the shelter was meant to be permanent or not. Compare the sketches below, for example.

The extreme northwest of Ghana provides the inhabitants with such universally used building materials as sand, mud, stone, laterite, timber, grass and straw. However, the traditional way of building with these materials does not always produce a very permanent structure; with the result that almost every dry season the houses must be thoroughly maintained, repaired and even rebuilt. In order to make more durable structures, the Rural Builder should include in his technical knowledge the uses of local and modern materials, and of binding materials such as lime or cement. Building materials are described in the following chapters.

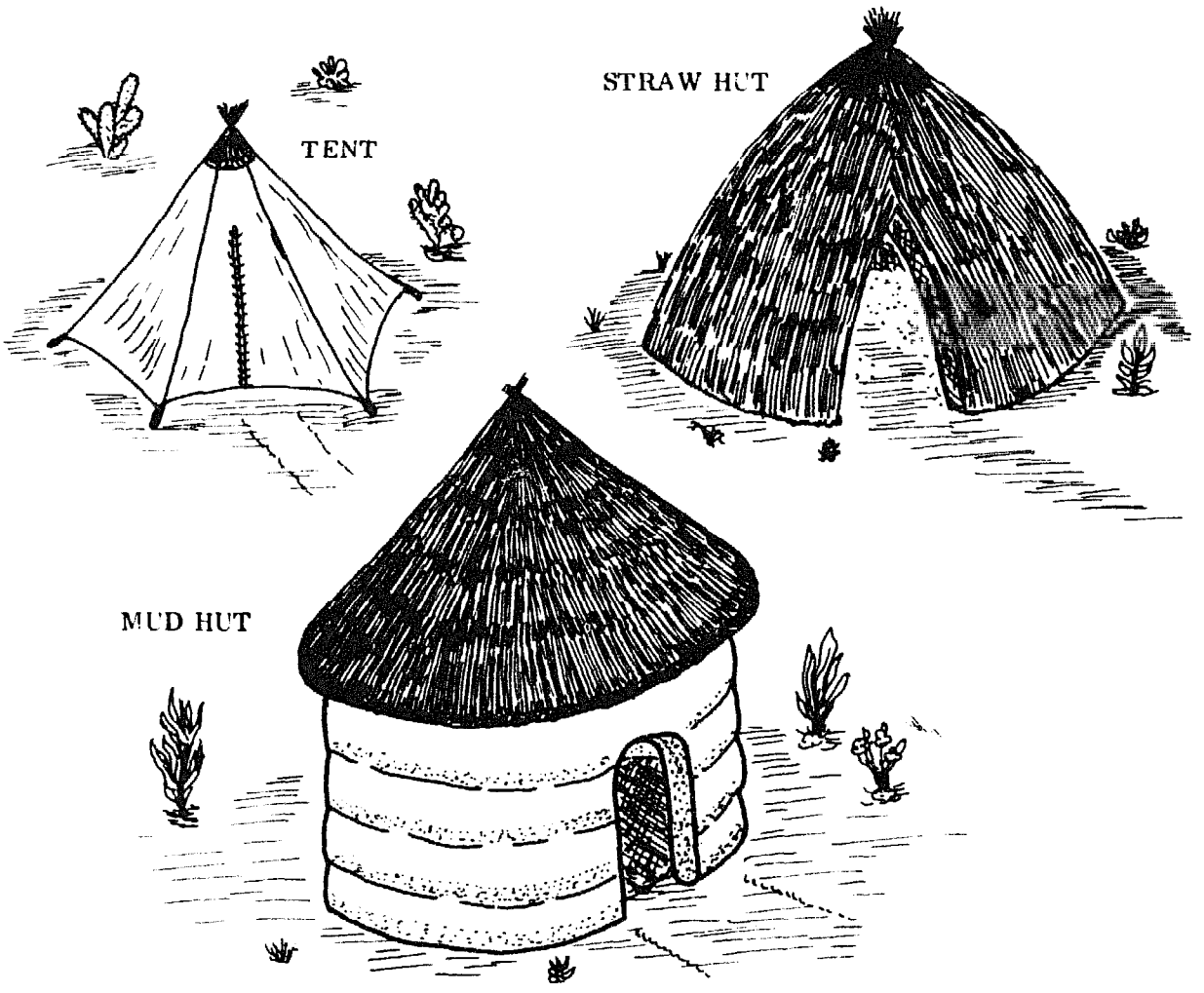

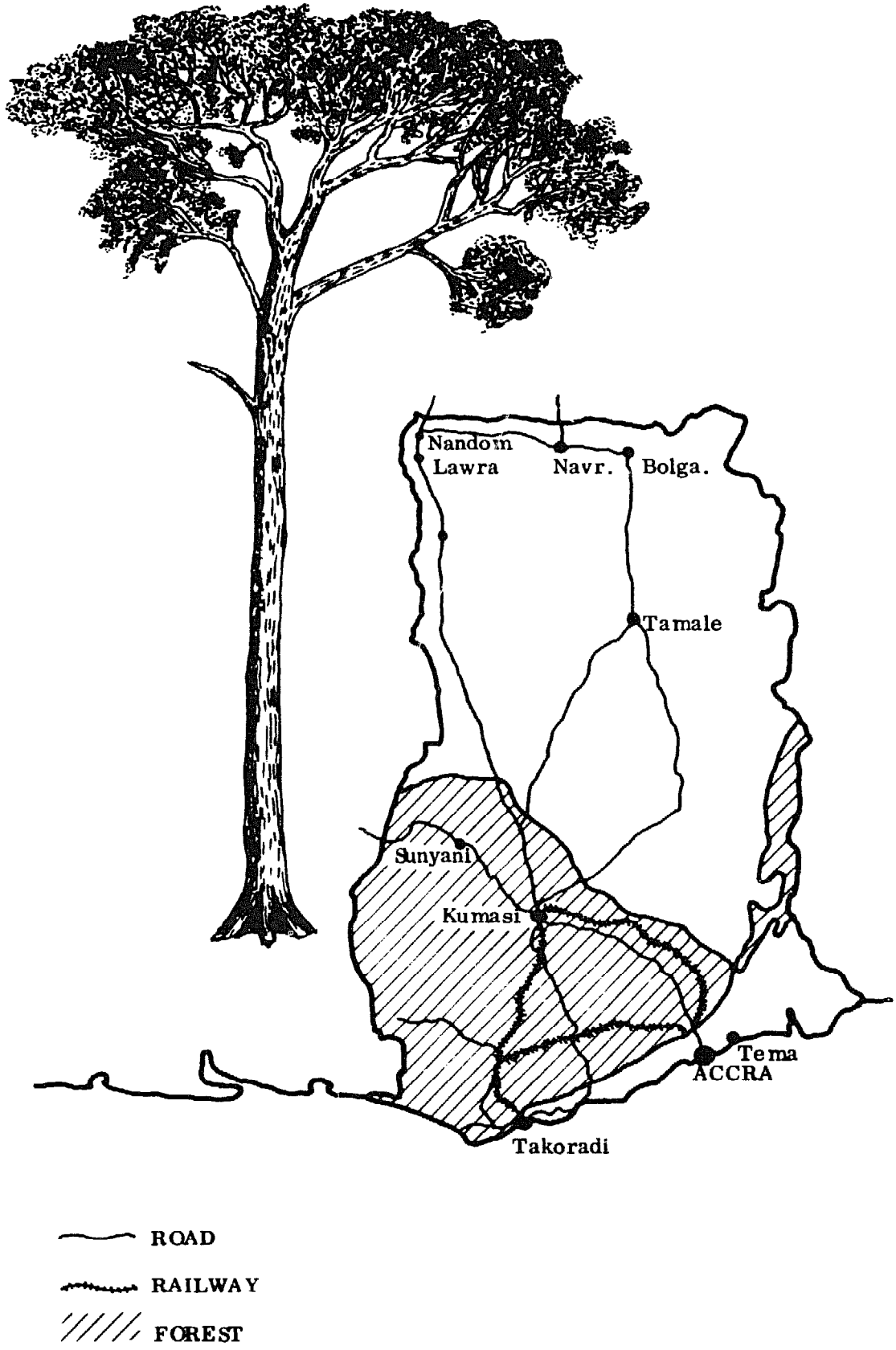

N P V C		ABOUT WOOD IN GENERAL.
122	MAT.	

ABOUT WOOD IN GENERAL

In Rural Building we work a great deal with wood. Wood has always served man for many different purposes: for tools (handles of hoes, knives and axes), for weapons (bows and arrows), for housing (ladders, doors and windows), furniture and firewood.

For traditional building purposes, nearby trees and bushes are cut and the branches as well as the trunks are used.

In Rural Building, we work with sawn timber. Sawn timber is cut from the trunks of very tall trees. Such trees are not common in the northern parts of Ghana. They are found in the rainforest areas of the south, where they are felled (cut down), sawn into boards and transported to the north and elsewhere.

The most common woods we use in northern Ghana are Wawa and Odum. Others, like Emire or Mahogany, are sometimes used.

There are 85.000 square kilometres of forest in Ghana, from which comes more than 200 different species of wood. Most of the wood that is cut is not used in Ghana but is sold to other countries to bring in money. It is one of the largest sources of income for Ghana. The principal kinds of wood that Ghana exports are Afromosia, Wawa, Utile, Sapele, Odum and Mahogany.

To make sure that these woods are available in the future, the cutting is controlled by Forestry Acts and efforts are made to reforest the cut areas. These new trees will not be ready to cut for a long time.

The map on the left page shows the areas where the trees are cut, the locations of the roads and railways that bring the wood into the harbours at Takoradi and Tema and the roads by which wood is exported to neighbouring countries. It is transported either as whole logs or as sawn timber and also as timber products made from waste wood or wood chips, like chip board or plywood. The mills that convert logs to sawn timber and timber products are located all over the forest.

THE STRUCTURE AND GROWTH OF THE TREE

A tree has three main sections: the roots, the trunk and the crown. The crown is made up of the branches, twigs and leaves (Fig. 1, next page).

In order to grow, the tree must have water and minerals from the soil. The water and minerals are taken out of the soil by the roots and brought to the

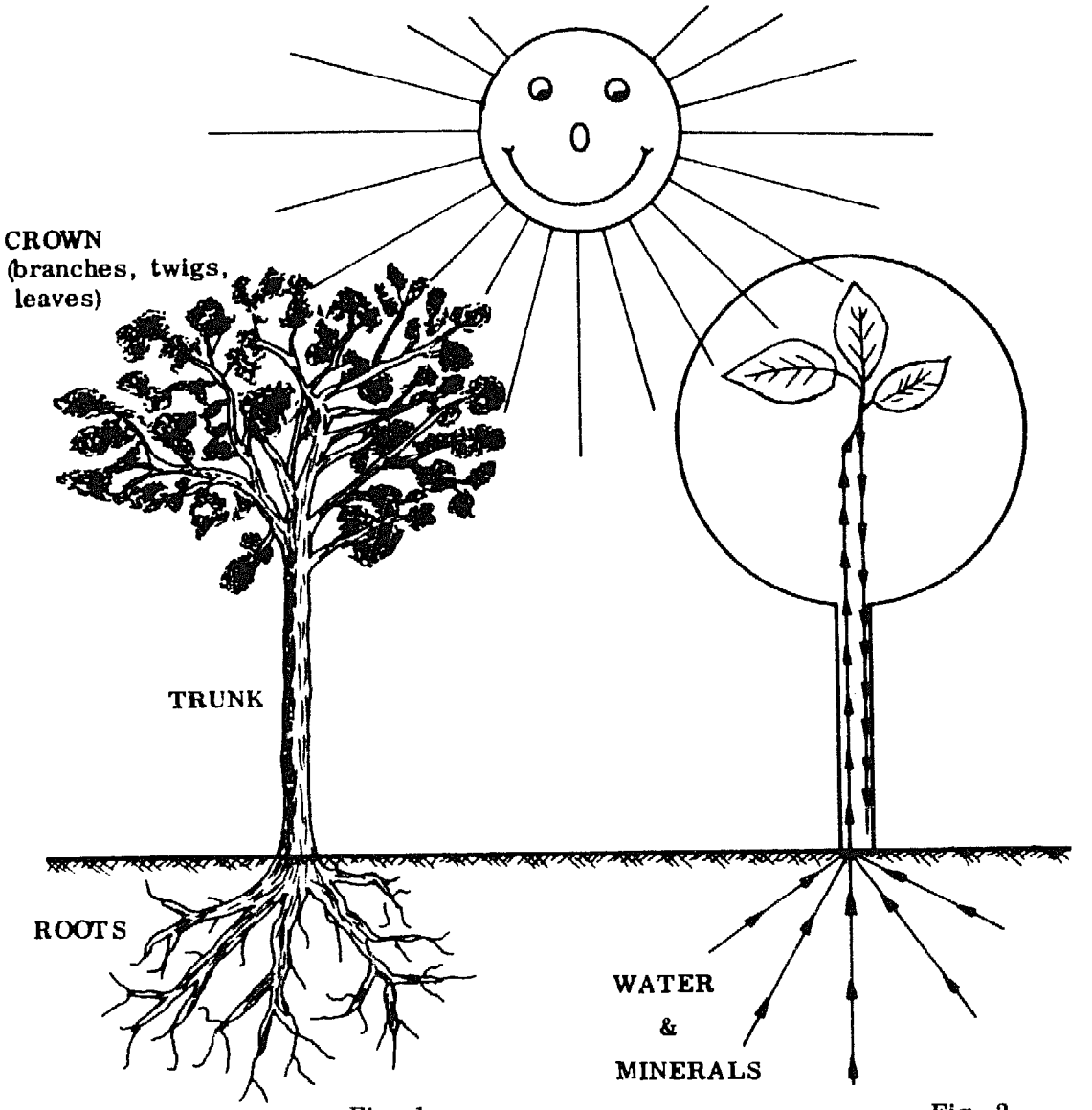

Fig. 1

Fig. 2

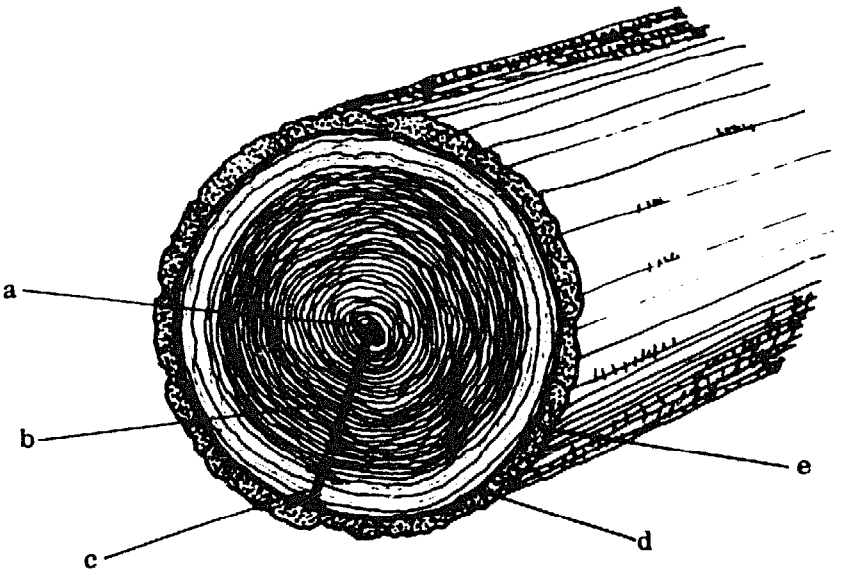

Fig. 3

N P V C	
124	MAT.

ABOUT WOOD IN GENERAL.

leaves through the outer layers of the sapwood (Fig. 2).

In the leaves, the sunlight acts on the water, minerals and air to make the materials that the tree uses to build new roots, wood and leaves.

The material made by the leaves is brought down to the roots and growing parts of the tree by the inner layers of the bark. If the bark is damaged by cutting or bush fire, the sap can't move up and down and the tree might die.

HARD AND SOFT WOOD

We talk about two main categories of wood: hardwoods and softwoods. These categories are only trade terms, they do not indicate that the wood itself is either hard or soft. The difference comes from the way of growth of the tree. Almost all the trees that grow in Ghana are hardwoods, but the actual wood itself may be hard or soft in character. For example Wawa, which is classed as a hardwood, is actually very soft in character and easily worked.

THE STRUCTURE OF WOOD

The tree trunk is made up of five layers (Fig. 3).

The pith (a) is the centre or heart of the tree.

The heartwood (b) is the fully developed mature wood which surrounds the pith. It is usually dark in colour and hard. The heartwood does not play an active part in the growth of the tree; it is only for strength, to support the tree.

The sapwood (c) is the layer around the heartwood which is lighter in colour and softer. Sapwood is immature wood, it will harden and darken and become heartwood as the tree grows. A new ring of sapwood is added every year on the outside of the older wood.

Sapwood should not be used for construction purposes, because it is soft and easily attacked by termites. It is always removed when wood is cut for construction purposes.

The cambium (d) is a soft, greenish layer between the sapwood and the bark. It is the "factory" of the tree, making new wood at the inside and new bark at the outer side. The cambium is fed by materials brought from the leaves by the inner layers of the bark.

The bark (e) protects the cambium from cold, fires, insects and animals, and it also transports food material from the leaves to the cambium and to the roots.

The annual rings are the rings you see (Fig. 3) in the heartwood and sapwood.

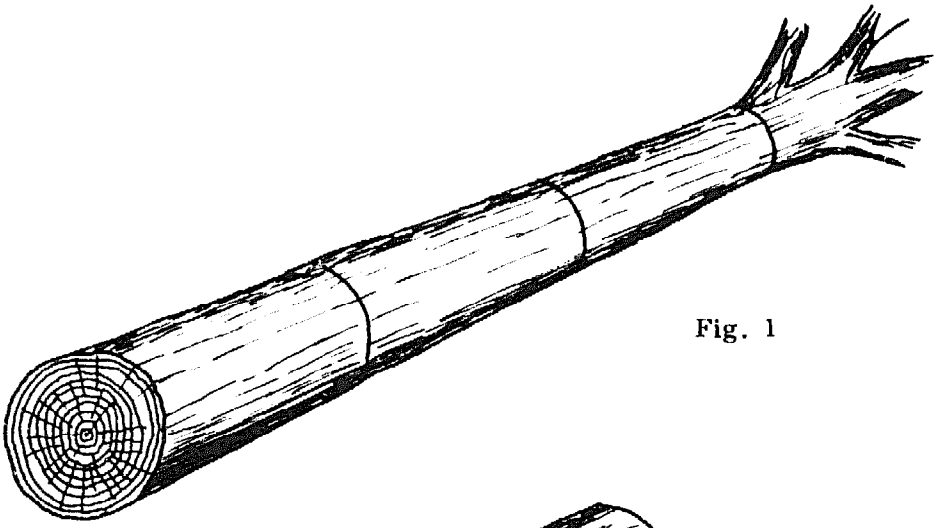

Fig. 1

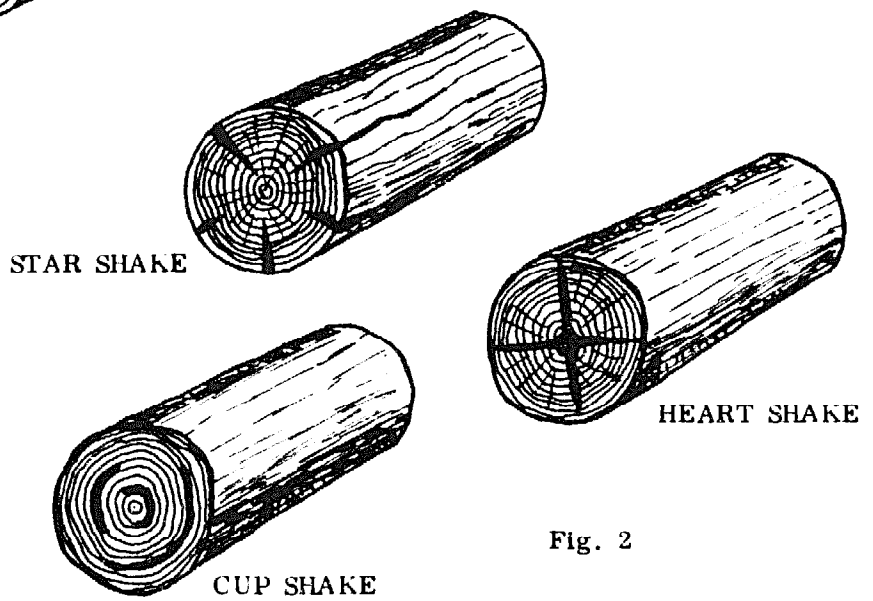

Fig. 2

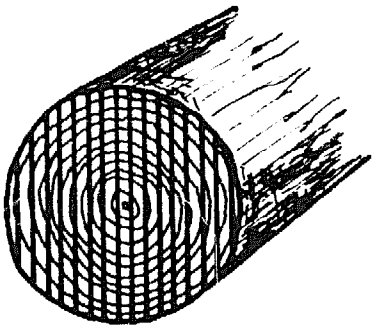

Fig. 3

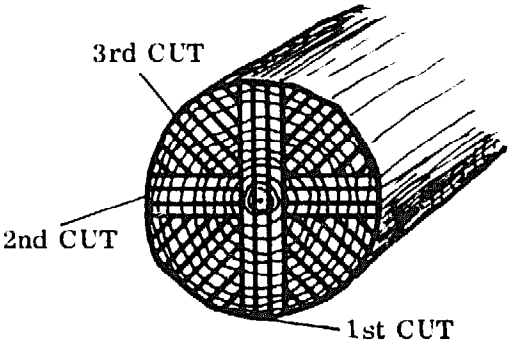

Fig. 4

N P V C	
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ABOUT WOOD IN GENERAL.

These are formed by the growth of the tree, by the layer of new wood that is added each year.

The tree grows all year long but in the rainy season, when it gets more water, it grows faster than in the dry season. The new wood formed in the rainy season is lighter in colour than the wood formed in the dry season, so they appear as light and dark rings in the wood. One light ring and one dark ring are formed each year; together they make an annual ring (annual means every year).

Don't forget: HARD WOOD is not the same as HARDWOOD is not the same as HEARTWOOD; they all mean different things.

THE PATH FROM STANDING TREE TO SAWN TIMBER

After the tree is felled, the crown is removed and the bark is taken off so no insects can hide in it. The trunk is cut into logs up to 12 metres long (Fig. 1) for transport and handling purposes. These logs are brought to the sawmill where they are converted to sawn timber. Converting the logs to timber means sawing them into boards, planks etc., which can be used for construction purposes.

If the logs cannot be converted immediately, they are kept in water to prevent the formation of shakes. These are long cracks in the unsawn log (Fig. 2). The most common ones are: cup shakes, which occur when the annual rings fail to grow together and star and heart shakes, which can occur in the growing tree or in the cut log as it dries.

There are different ways of converting logs. The method which is chosen depends on the thickness and species of the tree and the quality of the wood that is needed.

Plain sawing is the easiest, cheapest and most common way of converting tropical woods. It is also called the "through and through" method.

The log saw starts cutting from one side and continues, cutting off one board after another until the whole log is converted to timber (Fig. 3).

The second method, quarter sawing, requires better equipment and more work than plain sawing. With this method, almost all of the annual rings will be square to the surface of the board, which we will see later is an advantage over plain sawn boards (Fig. 4).

There are still other methods of conversion, but they are not important for us in this course.

CONVERSION TERMS FOR SOLID TIMBER

- Scantlings are pieces about 75 mm wide by 50 mm thick.
- Boards are pieces more than 150 mm wide and less than 50 mm thick.
- Planks are pieces above 200 mm wide and between 38 and 100 mm thick.
- Baulks are more square shaped pieces, about 100 mm wide and 50 mm or more thick.

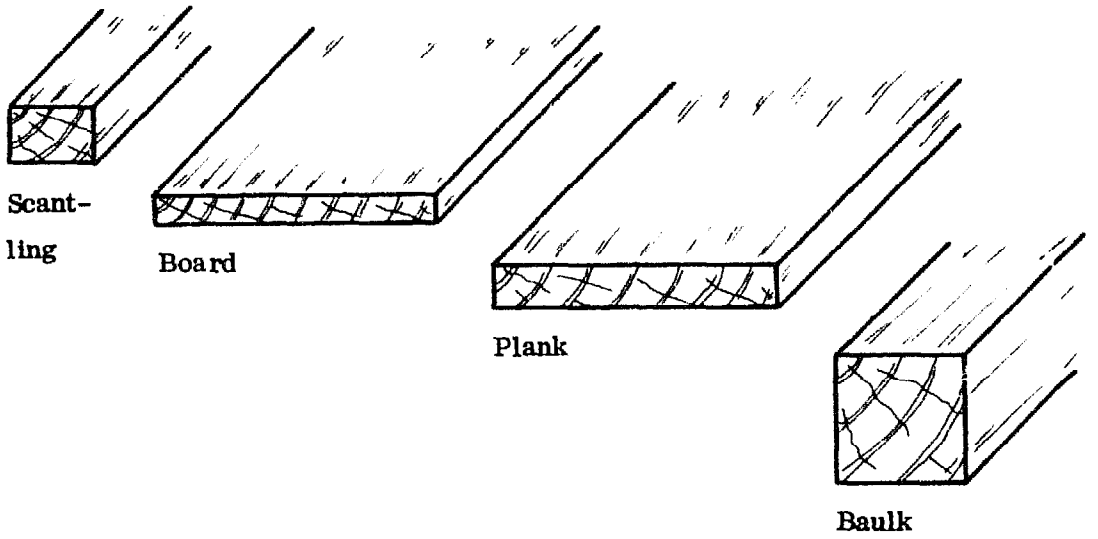

HOW TO ORDER TIMBER

Before you place an order for wood, make sure that you list the correct sizes, quantities and kinds of wood.

Boards are sold in different measurements. Very often the sizes are still given in the imperial system, but the metric system is becoming more common everywhere.

The surface of sawn timber is still rough, so you have to allow for planing the boards when you order timber (refer to Rural Building, Basic Knowledge, p. 90).

Example:

		Size		
No.	Kind of wood	Thickness	Width	Length
50	Odum	2,5 cm	30 cm	2,5 m up
40	Wawa	3,8 cm	30 cm	3,0 m up

If a minimum length of sawn timber is required, the word "up" is added. So "3,0 m up" would mean 3,0 m and longer.

THE PROPERTIES OF WOOD

To be able to use timber properly and store it in the correct way we need to have some knowledge about:

- the moisture content of wood, and
- wood shrinkage.

THE MOISTURE CONTENT OF WOOD

When a tree is cut down, the trunk still contains a large amount of water which has been stopped on its path through the trunk and remains trapped there. The weight of the water at this time is between 1/3rd to 1/2 the weight of the tree.

Thus the moisture content (amount of water remaining in the wood) is very high when the tree is freshly cut. Some of the water evaporates (dries off) as the logs are brought to the mill and more will evaporate after the logs are sawn into timber. Each time the moisture content changes, the size of the timber also changes.

SHRINKAGE

As the wood dries, it becomes smaller in size. This is what we mean by shrinkage. Because of the wood structure, it does not shrink equally in each dimension; shrinkage will be up to 10% along the annual rings, about 5% at right angles to the rings and no more than 0,5% in the length of the board.

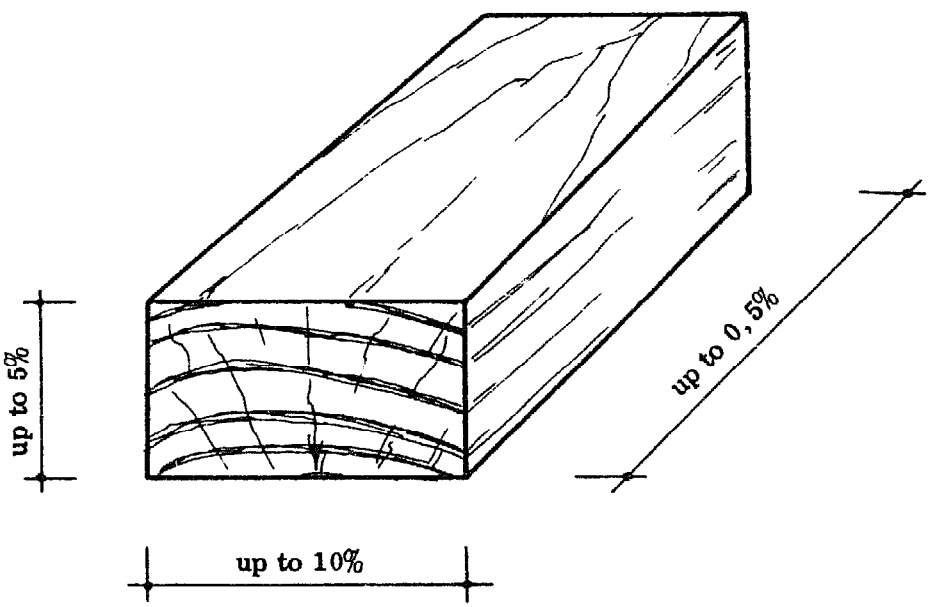

Here we can see the advantage of quarter-sawn timber, in which the annual rings are mostly at right angles to the width of the board. The biggest size change (10%) will be in the thickness of the board, where it usually doesn't matter so much. The shrinkage in the width will however still be up to 5%.

In plain-sawn boards, the rings lie mostly across the width of the board and the board will shrink more and also tend to get out of shape as it dries, because the rings change directions within the board.

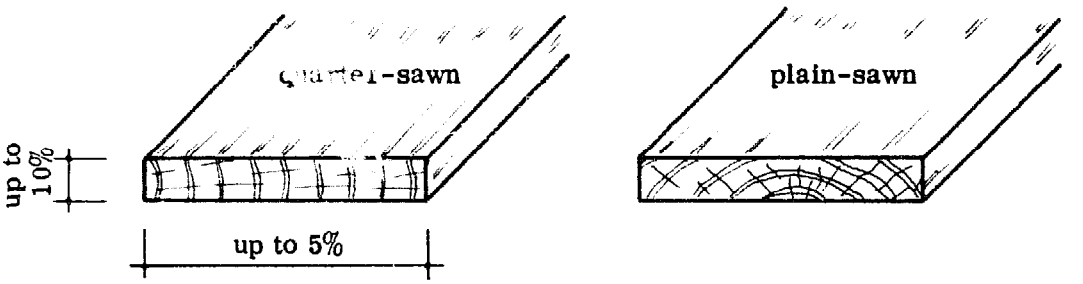

Shrinkage in the length of the timber can almost be ignored, and will only matter when you join boards together end to end over longer distances.

You should know that different woods shrink differently, for example Odum will shrink more than Wawa.

The weather has a great effect on the size of wood. In northern Ghana especially, the very great changes in the humidity (the moisture in the air) between the dry and rainy seasons result in a lot of problems for the builder.

The very dry air of the dry season and especially that of the harmattan causes wood to dry out too much and shrink. You will find that the boards easily crack or split when you work on them.

During the rainy season the humidity is very high and this results in a higher wood moisture content. This means that the wood actually expands quite a bit. The wood may feel wet to the touch. You might plane a board straight and true one day, and find the next day that it is bent again.

Keep the effects of the weather in mind when you construct anything out of wood. For instance, you want to build a solid door out of Odum. If you build it in the dry season it should not fit tightly into the door frame, so that it can still open when it swells in the wet season. If you build it in the wet season it should fit well, so that the gap between it and the frame is not too wide when it shrinks in the dry season.

NATURAL SEASONING

The builder should know that he must never use freshly sawn timber. The timber must first be seasoned, which means that it is dried to a certain moisture content which is most suitable for building work, so that it changes its size as little as possible after it is used in a piece of work.

The kind of seasoning we do in Rural Building is "natural seasoning", and it is done by storing the wood for some months.

After seasoning, the moisture content of the wood should be low enough to use it for building work. However, even well seasoned timber will still be affected due to the changes in humidity from the dry to rainy seasons.

Well seasoned timber will still shrink or expand up to 6% in the direction of the annual rings. For example, a board which is sawn in such a way that the annual rings are along the width (see plain sawing) might have a width of 30 cm during the dry season, while in the rainy season it can expand up to 31 1/2 cm wide. This means that whenever possible you should choose your boards in such a way that the changes in size don't cause problems in the finished piece.

NOTES:

WARPING

Seasoning can cause boards to bend. This happens because the moisture content differs from one part of the board to another, especially if one part gets more sun or rain, when it is stored improperly. The boards should be stored in such a way that air can reach every side of them and all sides are equally dry.

Wood that is not straight grained also tends to warp as it dries.

There are four different kinds of warping: bowing, cupping, springing and twisting. These are illustrated below.

Warping of boards can be partly avoided by proper storage of the wood, which we will discuss in the next section. To prevent warping of finished workpieces such as door and window frames, they should be installed as soon as possible after they are completed.

BOWING

CUPPING

SPRINGING

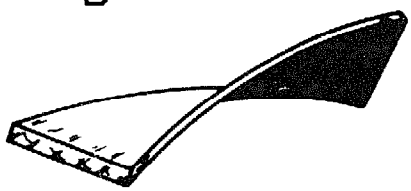

TWISTING

TIMBER PILING

In previous lessons, we learned about why seasoning is important to reduce shrinkage. Seasoning also helps to prevent decay and attack by insects and fungi. In natural or air seasoning, the wood is kept protected from sun, rain, and insects, but air is permitted to circulate freely around the wood.

The site where we put the wood to season is very important. It must be open and well drained; all weeds and grass should be removed and the base should be covered with gravel, or even better, with concrete, to prevent growth of new weeds under the stack. Ashes can also be spread around to keep away termites.

Strict cleanliness should be observed around the stacks. Sawdust and short pieces of wood left lying around can start rotting and attract termites or fungi, or they might even catch fire during the dry season and destroy the entire stock of wood. Take extra care with Wawa, as it is easily attacked by insects or fungi.

The entire pile should be shaded from the sun, to keep the timber from drying out too rapidly. The stack should be oriented with the length in the east-west direction, to minimize the effects of rain and sun.

LAYOUT OF THE WOOD STACK

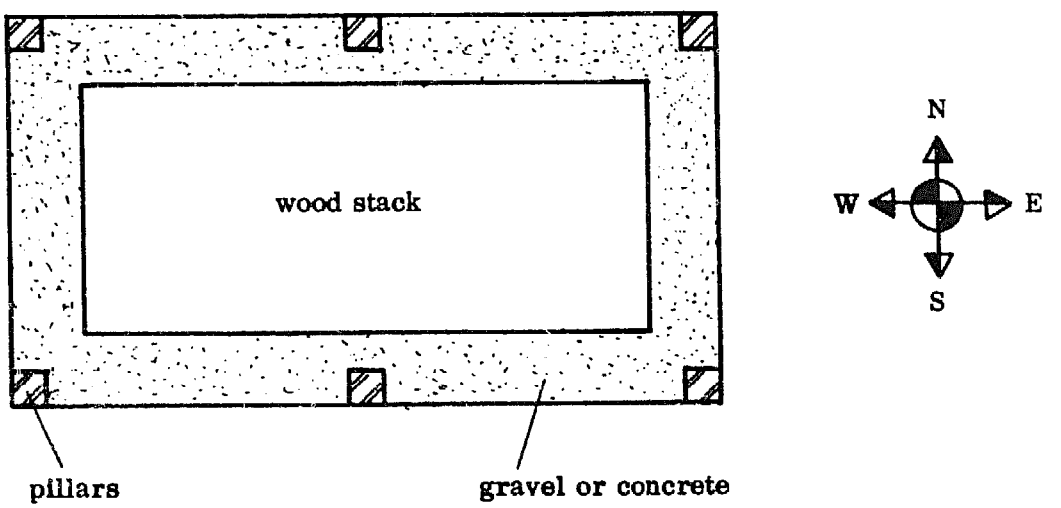

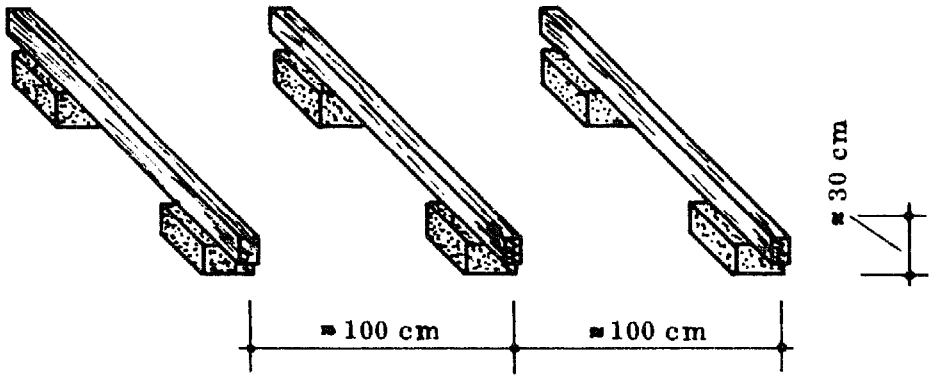

Fig. 1

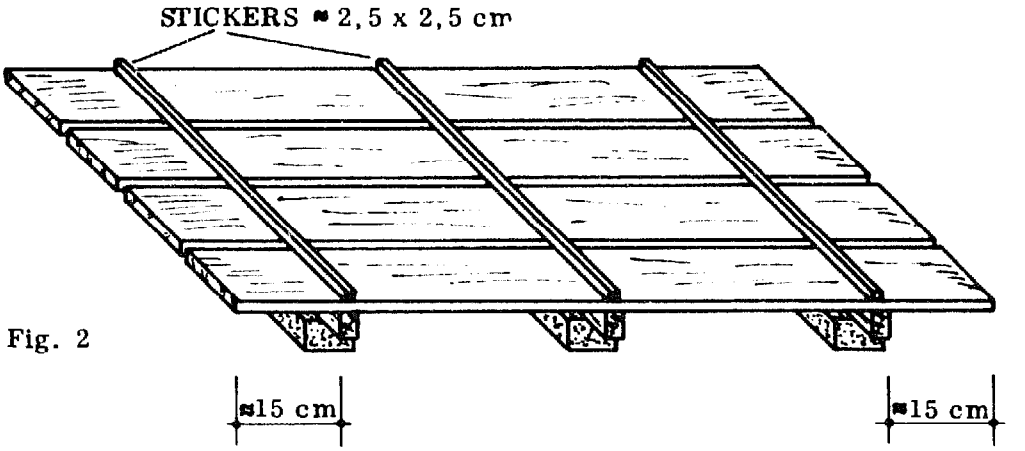

Fig. 2

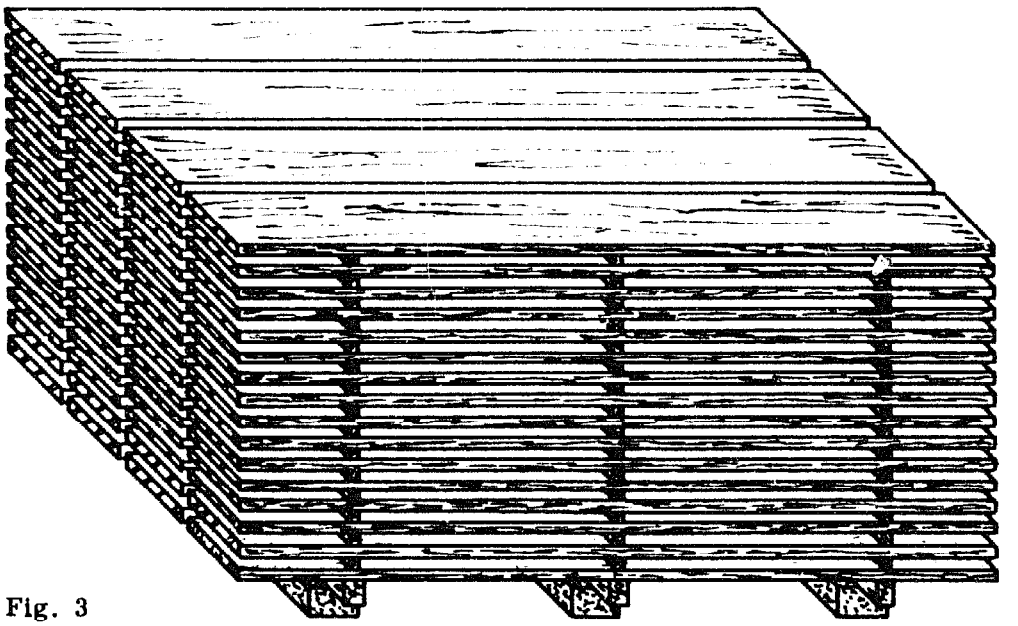

Fig. 3

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TIMBER PILING.

MAKING THE STACKS

The bases of the stacks are sandcrete blocks (not wood, which might be attacked by termites). On these blocks we set the cross pieces, which are straight baulks without any twisting, because they must carry the whole weight of the stack. The length of the cross pieces will be the width of the stack. They should be perfectly in line on top of the bases (Fig. 1).

The pile should be level from side to side, but may slope a bit lengthwise. Place the cross pieces about 100 cm apart. The end pieces should be about 15 cm from the ends of the boards (Fig. 2).

On top of the cross pieces, put the first layer of boards. Between the layers of boards, put wood strips (stickers) to allow air to flow between the layers (Fig. 2). The stickers should be all exactly above the cross pieces and each other as we build up the stack (Fig. 3). If this is not done correctly the boards may start bending.

The stickers should be square in section so you don't have to take care to put them all flat or all edgeways. They should be around 25 mm thick. All the stickers should have the same thickness, or they may cause the boards to bend or the stack to collapse.

Always stack the wood in such a way that the pieces you will need first are on top.

If you have some wood that you want to reserve for a special purpose, it may be secured by tacking a short stick across the end of the pile.

The stack should always be covered. Make sure that you leave the stack covered and in order after you take out wood.

NOTES:

SPECIFICATIONS OF WOODS WIDELY USED IN NORTHERN GHANA

ODUM

Local trade name: Odum
Standard (international) trade name: Iroko

The tree is up to 60 m high and 7 m in girth (circumference).

Wood characteristics:

The wood is hard and of medium weight.

It is variable in colour, from yellow to dark brown. When freshly felled, it is yellowish green.

The sapwood is paler, about 2,5 to 7,5 cm wide and it is quite distinct from the heartwood.

Durability:

Odum is very resistant to decay when kept dry but it is liable to be attacked by fungi in damp situations. The sapwood is often attacked by pin-hole borers and termites.

Seasoning:

It is easily naturally seasoned.

Working qualities:

It can be worked with moderate ease by most hand tools and it finishes well. Stonelike deposits are sometimes present and these may cause damage to cutting edges. The wood can be nailed, screwed or glued with no problems. When very dry it can be difficult to nail.

Uses:

Odum is probably the most generally useful tropical African hardwood and it is widely used locally for all kinds of construction work and carpentry.

WAWA

Local trade name: Wawa

Standard trade name: Obeche

The tree is up to 55 m high and 5,5 m in girth.

Wood characteristics:

The wood is soft and light in weight. It is nearly white to pale yellow in colour and there is no clear distinction between the sapwood and heartwood. The sapwood is about 7,5 to 10 cm wide.

Durability:

Wawa is not resistant to decay. Seasoned timber is liable to be attacked by powder post beetles and termites.

Seasoning:

Natural seasoning is rapid and satisfactory, with only very little warping and little inclination to split.

Working qualities:

It works easily with all hand tools. To avoid roughening the surface, use very sharp tools. The wood is rather soft and takes nails and screws easily, but it does not hold them well under hard use.

Uses:

It is used for formwork, scaffolding and furniture, where it is not exposed to attack by termites. It can be used only where it will be protected against moisture and rain.

NOTES:

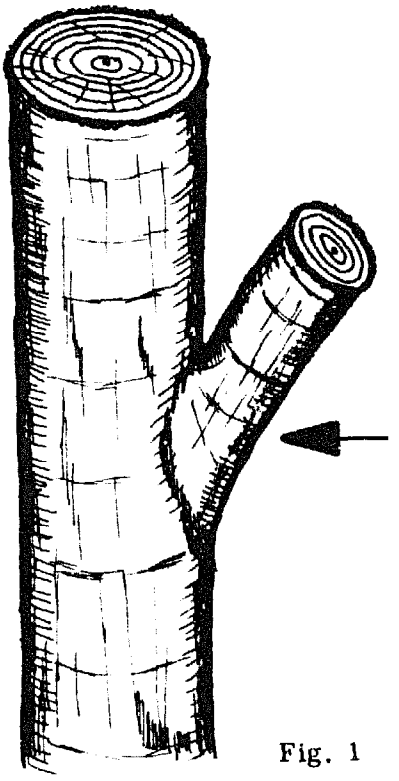

Fig. 1

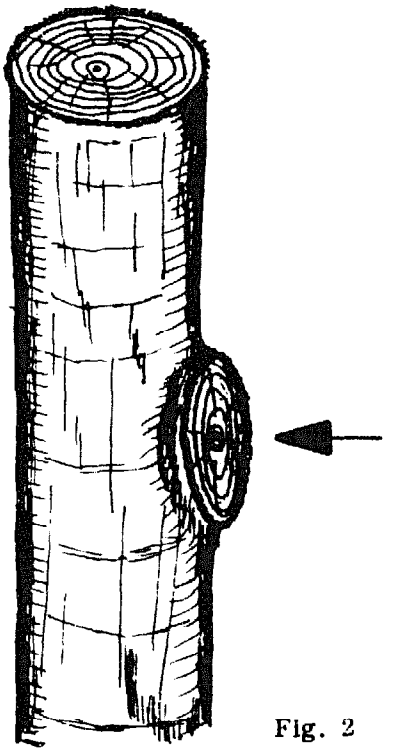

Fig. 2

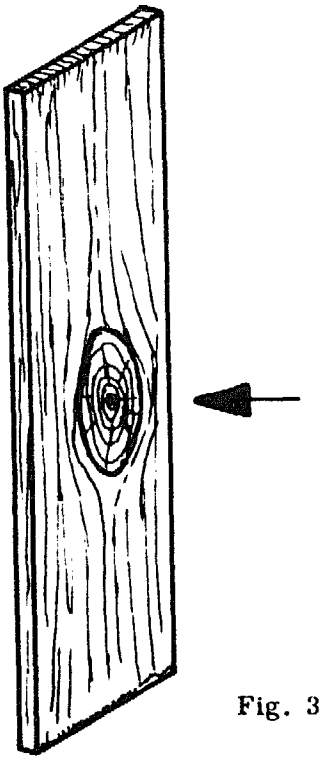

Fig. 3

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DEFECTS IN TIMBER.

DEFECTS IN TIMBER

In order to choose the right timber for the work, we need to have some knowledge about defects and diseases in timber. A defect is an irregularity or weakness in the wood which reduces its usefulness and suitability.

The common defects in timber are: knots, twisted grain, checks, wane or waney edge and deadwood.

KNOTS

The place in a tree trunk from which a branch has grown out is called a knot. Each knot marks the junction of a branch with the stem.

There are "live" and "dead" knots.

When a branch is broken off or damaged, a small piece is left attached to the tree. The tree continues to grow around the branch piece, eventually burying it in new wood. These dead pieces of branches are known as dead knots. They have no connection to the living wood, but they occupy a place in the tree, with living wood surrounding them. When the tree is converted to timber, these knots often fall out.

When a tree is felled, all the branches along the stem will be cut off (Figs. 1 & 2). They will leave a knot which is called a live knot (Fig. 3), because it comes from a living branch. Live knots are sound, healthy knots and are always firmly fixed in the wood.

Knots are more or less common in all timber. As long as they remain in place, the presence of a few knots will not harm a piece of timber. However, knots also weaken the wood in some ways and pieces with many knots should not be used for parts which carry heavy loads.

Trees grown in the forest are usually tall, with all the branches at the crown and not along the stem where they could leave knots. Trees which stand apart from other trees tend to have more branches lower on the stem, forming knots which appear when the log is converted.

NOTES:

TWISTED GRAIN

This defect occurs when the tree grows crookedly. The sawn timber tends to twist and it is difficult to plane and chisel because of the changing direction of the grain.

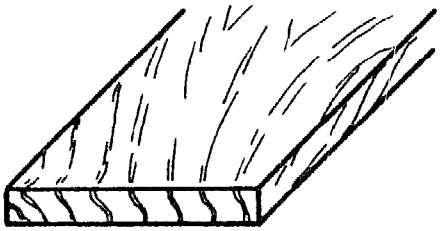

Twisted grain

CHECKS

Splits which occur during the seasoning of the wood are known as checks.

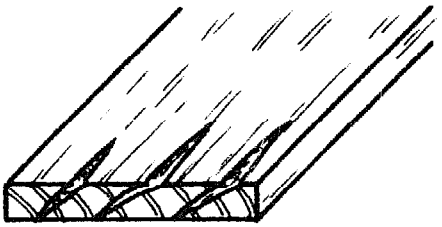

Checks

WANE OR WANEY EDGE

This defect is due to a lack of wood on the edge of the timber, from whatever cause.

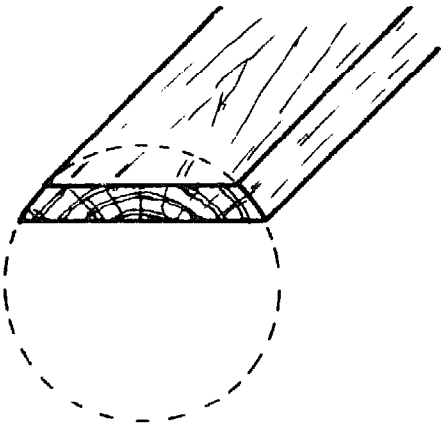

Wane or waney edge

DEADWOOD

Timber made from dead standing trees is called deadwood.

DISEASES IN TIMBER

Diseases in building timber are caused mainly by attacks from fungi and insects

FUNGAL DISEASES

A fungus is a kind of plant which is not able to make its own food from sunlight, air and water, as most plants make theirs. Instead, it must get food by breaking down dead matter such as wood.

The best places for fungi to grow are dark, damp, warm places with little air movement.

There are many kinds of fungal attack on wood. We will only deal with the most common ones, dry rot and blue stain.

Dry rot is the most common fungal disease of building timber. It spreads easily and since the fungus actually feeds on the wood, it can cause a tremendous amount of damage. Dry rot is especially a problem with built-in work such as frames or cupboards where the wood is in direct contact with masonry work, because there it is often damp.

The appearance of the infected timber depends on the age and the extent of the disease. In the early stages, it looks as if pieces of thread are hanging from the wood. These quickly develop into a network that looks like a spiderweb, gray in colour. If the wood is very damp, clumps like cotton wool may form and turn into brown or dark red sponge-like growths that often are greater than 30 cm in diameter. On the surface of the sponge-like mass, seeds are produced which spread the disease to the other parts of the building.

Blue stain is one of a few relatively harmless fungi which cause stains on wood. It appears as a light blue discolouration, usually in lighter coloured wood such as Wawa, in sapwood and sometimes in unseasoned timber. The strength of the timber is not affected by this stain.

NOTES:

PREVENTION OF FUNGAL DISEASES

It is always better to prevent disease in healthy wood than to wait until disease is present and then try to treat it. Infection of timber can be prevented by following some simple precautions:

- It is important to ensure that fungi cannot find the conditions that they need to live, namely warmth, dampness and poor air circulation. Therefore the places where timber is built-in should always be dry and well ventilated.
- Use only healthy, well seasoned timber.
- Workpieces should be designed and constructed so that water drains quickly away from the wood.
- Use paint or preservatives on the wood if possible.
- Wood should not be in direct contact with concrete or masonry. If that cannot be avoided, the wood must be treated with a preservative. It is best to also use tarred paper to separate the wood from the concrete or plaster.
- Good storage, especially of unseasoned timber, helps to prevent attack by fungi (see Timber Piling).

REMEDIES FOR FUNGAL ATTACKS

Dry rot is very difficult and expensive to get rid of, once the timber is infected.

- First find if the timber is still strong enough to serve its purpose, if not replace it.
- Cut off and burn the affected parts.
- Find the cause of the dampness and provide good ventilation to the area (for example, repair defective roofs). Repair the damaged areas with new timber.
- Apply preservative to the timber.
- For blue stain, simply remedy the damp conditions, and provide good ventilation to the wood.

NOTES:

INSECT ATTACK

Most damage to wood by insects is caused by members of the beetle family and by termites.

BEETLES

The eggs of the beetles are laid in cracks on the wood surface and they develop into grubs or larvae. The larvae damage the wood by making small holes in the surface and then digging tunnels into it. They chew the wood and convert it into powder. Small piles of wood powder are pushed out of the holes and these are the sign that the wood is infested. When the larvae have eaten their way through the wood, they will leave it and fly away as fully developed beetles.

PREVENTION OF BEETLE ATTACK

It is quite difficult to prevent attack by beetles, especially in Wawa wood, since most beetles can fly. Some simple precautions can help.

- Paint, varnish, wax or wood preservative should be applied on all surfaces. The smell often keeps insects away. Chemicals are available which protect the wood; you should always follow the manufacturer's directions in using these.
- Beetles usually attack the sapwood first, because it is softer than the heartwood. This is why the sapwood should always be cut off.
- If whole logs, poles or sticks are to be stored, remove the bark first. Insects quickly multiply in wood from which the bark is not removed.

REMEDY FOR BEETLE ATTACK

When you suspect an attack, immediately inspect the wood for beetles. Check whether the wood is still strong enough to serve its function. There are chemicals available to kill the insects. Use them carefully and follow the manufacturer's instructions, as most of them are poisonous.

TERMITES

The greatest damage to wood here in Ghana is done by termites. They build their tunnels from the soil into the timber, leaving the surface of the timber untouched, which makes it very difficult to detect an attack in the early stages.

PREVENTION OF TERMITE ATTACK

The best way to prevent termites from attacking wood is to make sure that they cannot reach the wood.

- The wood should never be in contact with the soil, it should always rest on concrete etc.
- All sapwood should be cut off, because that will be attacked first.
- Protect the wood with wood preservatives.
- Do not use Wawa for construction wood, because it is very likely to be attacked.
- When wood must be in contact with the ground, for example with fence posts, it can be partly protected by scorching it over a fire, or by adding ashes around it when you set it in the hole. Termites do not like scorched wood or ashes.
- When wood is stored for seasoning etc., the ground under the stack should be covered with ashes.

REMEDIES FOR TERMITE ATTACK

- Destroy the path of the termites from the soil to the wood.
- Check if the wood is still strong enough for its function.
- Apply a wood preservative or a chemical to kill the termites.

PRESERVATION AND PROTECTION OF TIMBER AND MASONRY

It is important for the Rural Builder to protect timber and masonry in some way, to make them last longer. There are two basic types of protection we use:

- timber preservatives
- protective finishes

Timber preservatives are used only for wood, and they penetrate into the wood. The deeper they penetrate the wood, the better they work.

Protective finishes are used for both timber and masonry. They work by covering the surface with a protective "skin". Protective finishes are discussed on pages 200 and 201.

NOTES:

TIMBER PRESERVATIVES

Wood used in construction is often destroyed by fungal diseases or insects, especially termites. It is very important for a builder to find ways to protect wood from these dangers.

Some methods of protection have already been discussed in the sections on fungal and insect attack. There we mentioned the uses of wood preservatives. Wood is food for fungi and insects. This food can be poisoned for them by wood preservatives. The wood absorbs these preservatives easily and the fungi and insects that try to eat the treated wood will die.

There are two classes of preservatives: waterborne preservatives and oil preservatives. The type we choose will be determined by the intended use of the wood and by what further surface treatment (painting, etc.) will be done.

- WATERBORNE PRESERVATIVES: These are usually available as powders which are dissolved in water and applied to the wood. Since water is the base the preservative can also be washed out again by water. This can happen if rain should reach the wood. For this reason use waterborne preservatives only under dry conditions and not for outside work where the rain can wash them out.

  Kinds of waterborne preservatives:

  - Aldrex 40 (mix 1 part of Aldrex 40 with 40 parts of water; use 1½ Ideal milk tins of the powder in a No. 28 bucket of water, which will give the correct proportions)
  - Any other chemical preservative which is mixed with water.

- OIL PRESERVATIVES: These have an oil base. They not only kill insects and fungi, but also keep water from penetrating the wood. They do not wash out with water, so they are useful for outside work.

  The most common oil preservatives are:

  - solignum
  - creosote
  - used engine oil
  - Aldrex 40 mixed with engine oil or kerosene; 1 part Aldrex to 40 parts oil or kerosene.

- NOTE: While it is possible to apply an oil preservative over wood that has already been treated with a waterborne type, paint or waterborne preservatives cannot be applied over oil preservatives because they cannot penetrate.

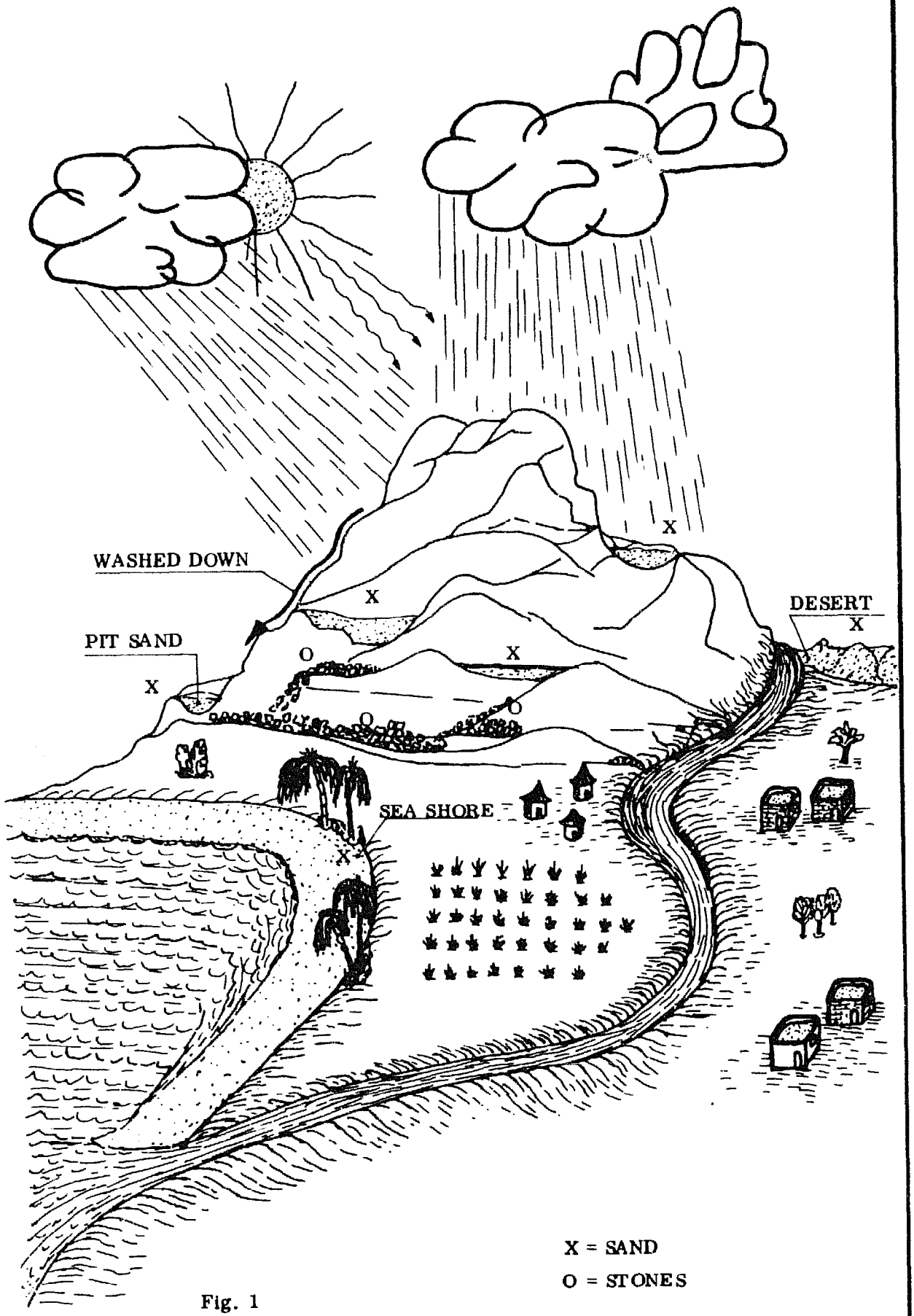

Fig. 1

N P V C		AGGREGATES.
146	MAT.	

AGGREGATES

"Aggregate" is the term used for the mixture of different sized stones that form the body of mortars and concrete. Ideally the stone should be graded so that the smaller sizes of stone fit exactly into the spaces between the larger ones and no gaps or holes are left in the mass of mortar or concrete.

SAND

Sand is a mass of finely crushed rock. It is either crushed naturally as seen on the sea shore, in river beds, or in deserts (Fig. 1); or it is artificially produced in crusher plants near rock quarries (where rock is dug out of the earth).

Sand is classified according to the shape of its particles (which differs depending on where the sand came from originally). It is also graded according to the size of its grains (the individual particles of sand).

GRAVEL

"Gravel" is the term commonly used for the larger sized stones of the aggregate. Originally, gravel meant an "all-in-one" aggregate, a mixture of sand and stones of all sizes which can sometimes be found all together in a natural deposit. The individual particles are rounded by the natural action of water and weather.

BROKEN STONES

These are the largest stones of the aggregate, they make up the bulk of concrete. They are found either in natural deposits or scattered on the ground surface; or they are artificially produced in crusher plants. The Rural Builder often must break up large stones with hammers, to make them a convenient size (see Tools, page 14).

- NOTE: These aggregates are the most common ones used for building in the Northern and Upper Regions of Ghana. Of course there are many other types of aggregates (chips, pebbles, rubble etc.), but as far as the Rural Builder is concerned they are of little importance.

NOTES:

QUALITY AND PROPERTIES OF AGGREGATES

Good mortar and concrete can never be made with poor materials. The cement, sand and stones must all be good quality and the correct types. Sand and stone (the fine and coarse aggregate) together make up more than four-fifths of the concrete mass, so there can be no doubt about their importance. It is not safe to take for granted that every load of sand or gravel brought to the site will be up to standard. Remember that aggregates are either dug from a pit or river bed or they are quarried, and although they may look the same there is a possibility of variation in the quality of different loads.

Particle sizes, the shape and texture of the particles and their surface areas are all important factors in the strength and durability of the concrete or mortar.

- GRADING: A graded aggregate is one that is made up of stones or particles of different sizes, ranging from large to very small. It sometimes happens that a load of sand will have too many coarse particles to make a good mortar, while another load will have too many fine particles. Depending on the job to be done, you might have to mix the two sands together in different proportions to get a suitable aggregate. If the sand contains too many bigger particles it may be necessary to sift these out before using the sand to make mortar, but it could work well for concrete.

  The idea is to come up with a "well graded" aggregate; which means that the smaller grains will fit in between the larger ones, leaving only small spaces to be filled with the cement paste. The result will be a good workable mix of adequate strength, using a minimum amount of cement (see sketches below).

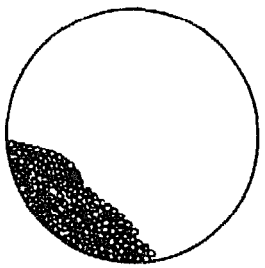

FINE UNIFORM

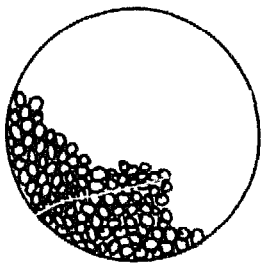

COARSE UNIFORM

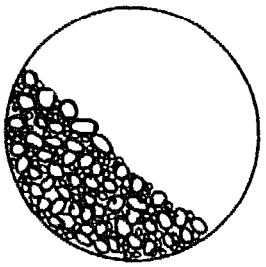

WELL GRADED

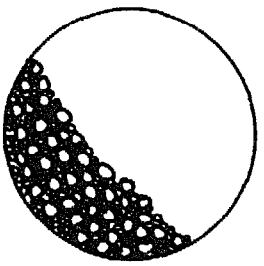

MIXED WITH CEMENT PASTE

- CLASSIFICATION OF AGGREGATES: For making concrete and mortar, the Rural Builder has two types of aggregate: the fine one which is sand; and the coarse one which is broken stones. Both aggregates are classified according to their grain size and are each divided into two main groups:

Fine sand -- from 0 - 1 mm	Fine broken stones -- from 5 - 25 mm
Coarse sand -- from 1 - 5 mm	Coarse broken stones -- from 25 - 50 mm

Another classification is made according to the shape and texture of the single particles. Some sands and stones have particles which are rounded, with relatively smooth surfaces. This sort of aggregate is found mainly in river beds, along the shores of lakes and coasts, and in deserts. This weather- and water-worn sand is called "river sand" or, because of its properties and workability, "soft sand" (Fig. 1).

The other type of sand has a fairly rough surface and it is found mainly in deposits close to hills and mountains. Artificially made sand made from crushed rock also comes under this classification. It is known as "pit sand" or else "sharp sand" (Fig. 2).

Whether the sand is soft river sand, or sharp pit sand; it will have various grain sizes and is classified as fine or coarse, as in the table above.

- NOTE: In the Northern and Upper Regions of Ghana, most sand is dug from river beds. This does not necessarily mean that the sand will be "soft". Often it is a sharp sand or between soft and sharp, because the particles don't get exposed long enough to weather and water to become rounded and smooth.

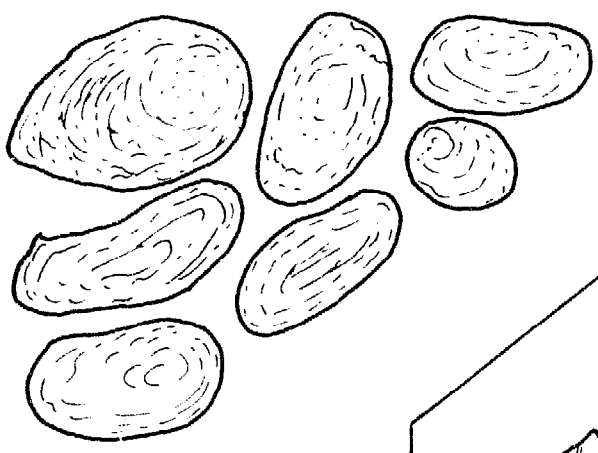

Fig. 1

SOFT SAND
(SMOOTH SURFACE)

Fig. 2

SHARP SAND
(ROUGH SURFACE)

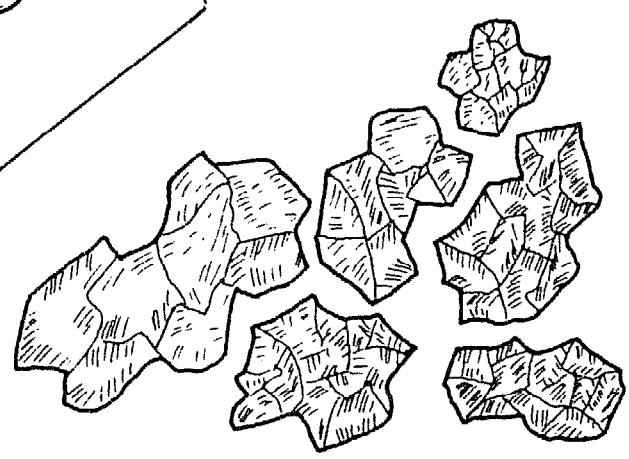

An important factor in the quality of an aggregate is its cleanliness. Clay, mud, or fine dust (known as silt) in the aggregate will weaken the concrete or mortar; while any rotting vegetable matter (organic impurities) like leaves, grass or roots may interfere with the setting of the cement.

- THE HAND TEST FOR SAND: As a first test for cleanliness, simply pick up a little sand and rub it between your hands. If your palms stay clean, the sand is clean enough. If not, the sand may contain too much silt.

- THE SILT TEST FOR SAND: You yourself can carry out a simple test to get an idea of the amount of silt in a natural sand (though not in an artificially crushed rock sand).

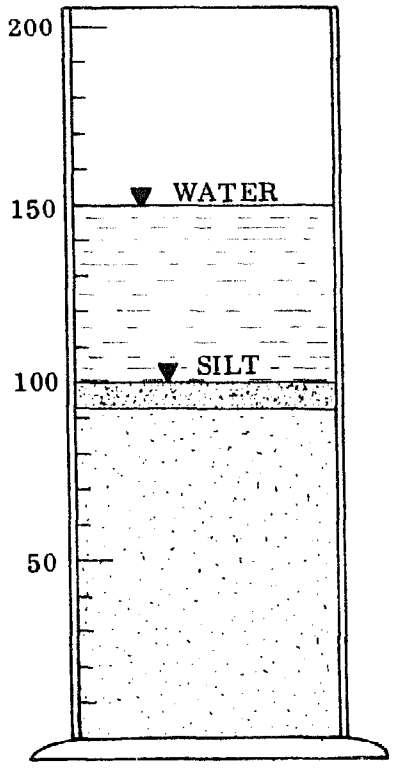

To test accurately you should have a measuring cylinder which is marked in millilitres, shown as "ml", usually up to 200 ml.

First make a salt-water solution by putting one teaspoon of salt into 1/2 litre of water. Fill this solution into the measuring cylinder, up to the 50 ml mark.

Next pour in the sand until the level of the sand is up to the 100 ml mark. Add more salt water until the water reaches the 150 ml mark, cover the cylinder and shake it well.

Stand the cylinder on a level surface and tap it gently until the top surface of the sand is level. Leave it to settle for 3 hours and then measure the height of the silt layer on top of the sand. This should be no more than about 6 ml, or about 6% of the total amount of sand.

- NOTE: If the sand contains more than 6% silt, you would have to use more cement and the concrete would shrink more during the hardening process, causing cracks in the product.

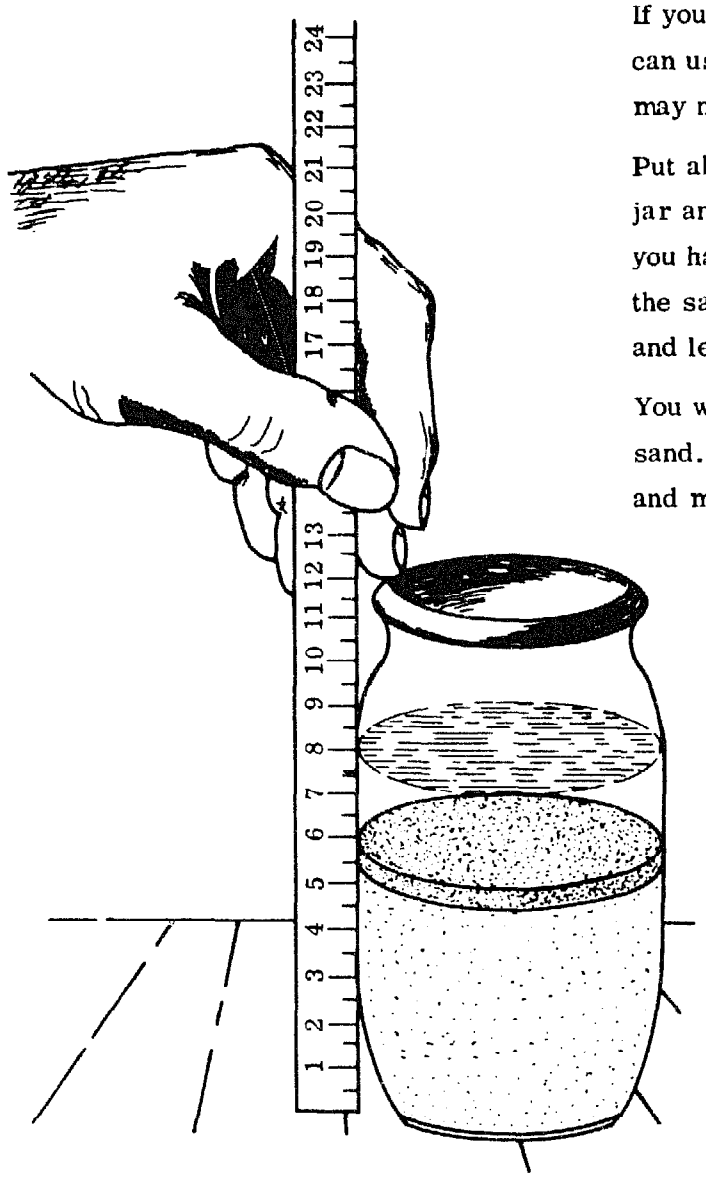

If you have no measuring cylinder, you can use a 0,5 kg jam jar, though this may not be quite accurate.

Put about 5 cm of sand loosely into the jar and pour some salt water on it until you have about 2,5 cm of water above the sand. Now cover and shake the jar, and leave it to stand for about 3 hours.

You will see a layer of silt on top of the sand. Measure the depth of the layer, and measure the sand below it. There should be no more than about 3 mm of silt, or about 6% of the amount of sand.

- ORGANIC IMPURITIES: The Rural Builder can carry out a test for organic impurities using a glass jar. Put sand into the jar and fill up the rest of the jar with water. Cover and shake the jar and leave it standing for some minutes. If the water above the sand is brown or very dirty, the sand contains organic impurities and cannot be used.

Better sand can be found by simply removing the top layer of sand, about 5 cm deep, before taking sand from a dry river bed. This top layer consists mainly of excessive silt as well as organic impurities such as vegetable matter and cow dung. None of this is wanted, because it would cause problems with the concrete or mortar.

- REMEMBER: Wherever your sand comes from, it must be clean and suitably graded. If you use dirty sand, you may find that it mixes very nicely, but you will find problems before the job is finished. The impurities in it may affect the rate of setting and hardening of the concrete or mortar, and decrease the final strength of the work. The fine appearance of the just finished work may be spoiled by cracking and flaking as it dries.

BINDING MATERIALS

LIME

Lime is a very fine white powder, used in mixes for mortar, plaster and render. It is made from limestone or chalk which is burnt in a kiln and becomes quicklime.

The quicklime is usually passed through a machine called a hydrator, where it combines with water and becomes hydrated lime. This is dried, crushed to a fine powder, then bagged and sold. Below is a diagram of the whole process.

Sometimes the lime is sold as quicklime, and the builder adds the water to it himself. This process is called "slaking" the lime or "running it to putty", and it is not described here.

Slaked lime and hydrated lime are chemically the same, but slaked lime has more water in it.

Hydraulic lime is made from limestone or chalk containing clay. It hardens when combined with water; and it also hardens well in damp places or even under water. It is stronger than other limes, although weaker than Portland cement.

Non-hydraulic lime comes from the purest limestones and chalks. It hardens by drying out and then slowly combining with the carbon dioxide in the air.

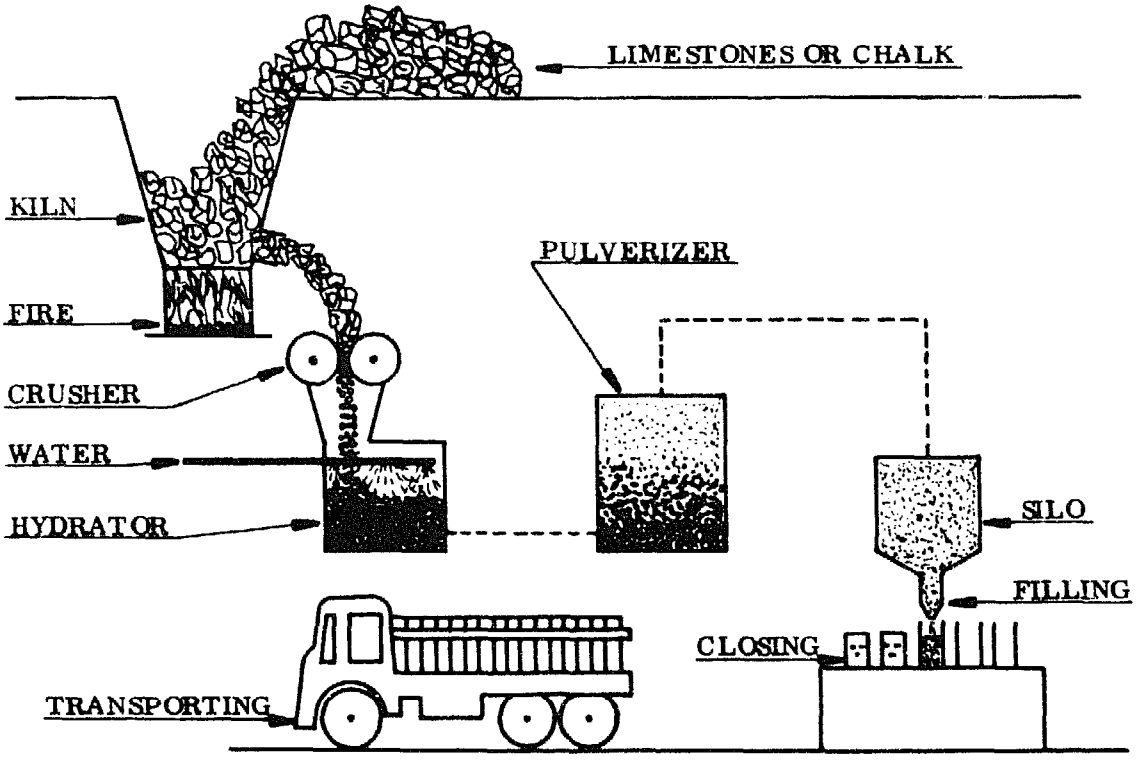

PORTLAND CEMENT

Portland cement is a fine grey powder. Among the various kinds of cements, it is the most commonly used as binding material. It is made of a mixture of chalk or limestone and clay.

The following description of the manufacturing process is illustrated below.

The limestone or chalk and the clay, in appropriate proportions, are fed into a "wet grinding mill" and reduced to a creamy substance known as slurry. The slurry is pumped to a large cylindrical "kiln" which is about 90 m long and 3 m in diameter. The slurry enters the kiln at its upper end while pulverized (crushed) coal, gas or other fuel is blown in at the other end. The temperature inside the kiln at the lower end is very intense, approximately 1500 degrees C; gradually decreasing towards the top end. So the slurry as it moves down the kiln is first dried, then heated, and then finally burnt. It leaves the kiln in the form of very hard "clinkers" shaped like small balls and of a dark brown to black in color. The clinkers are ground up to an extremely fine grey powder, which is the cement. The cement is packed in paper bags of 50 kg capacity.

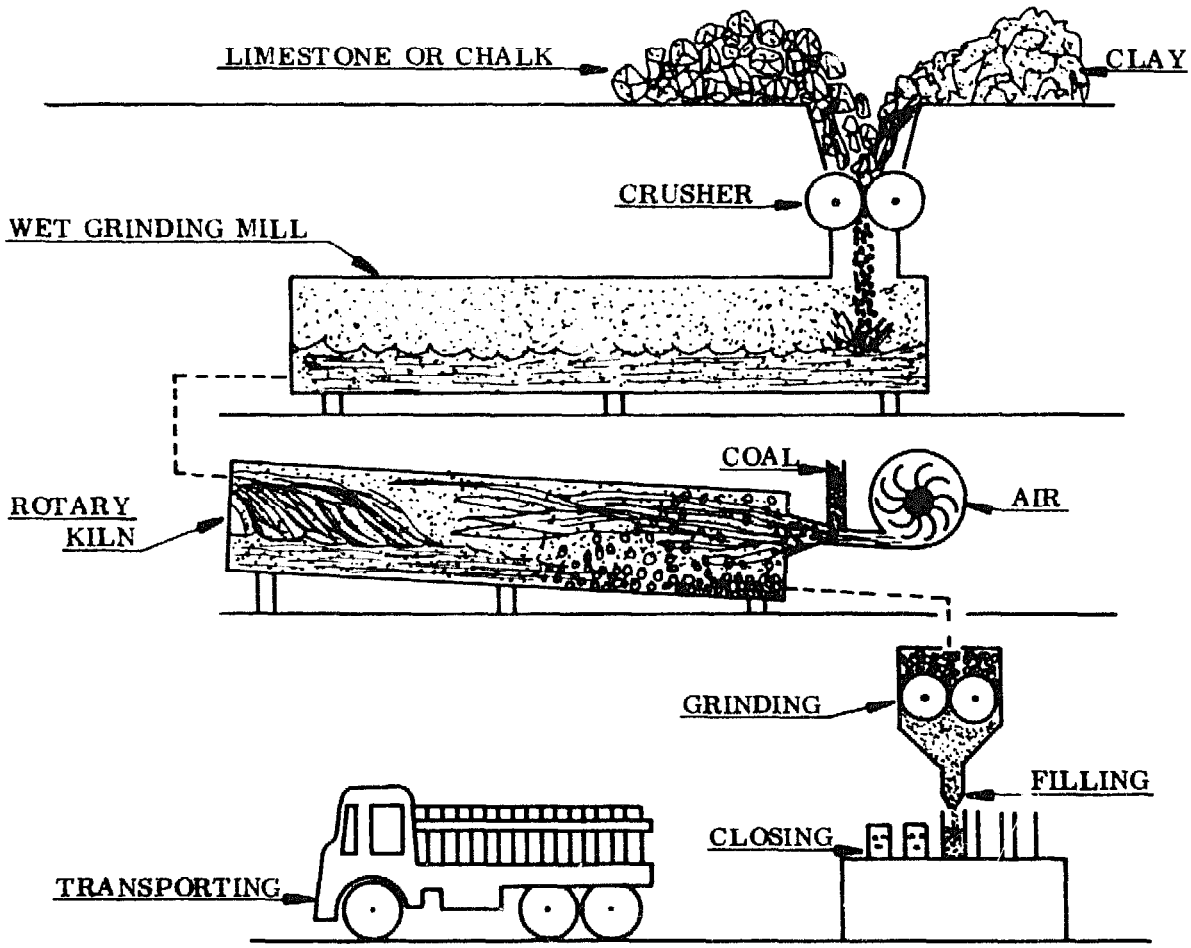

HYDRAULIC CEMENTS
HARDEN

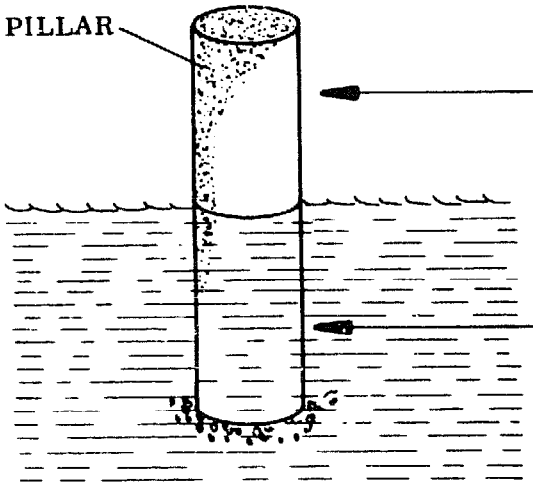

Fig. 1

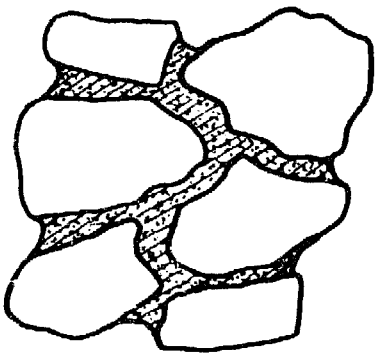

Fig. 2a

HARDENED CEMENT PASTE
BINDS STONES TOGETHER
AND FORMS A SOLID MASS

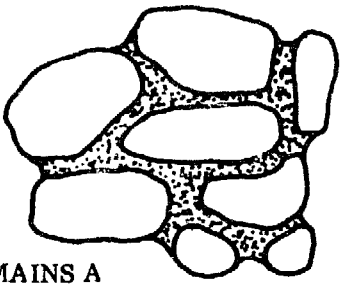

Fig. 2b

BITUMEN OR TAR
ALSO BINDS STONES
TOGETHER BUT REMAINS A
BIT SOFT (WATCH FOR EXAMPLE TARRED
ROADS IN THE HEAT)

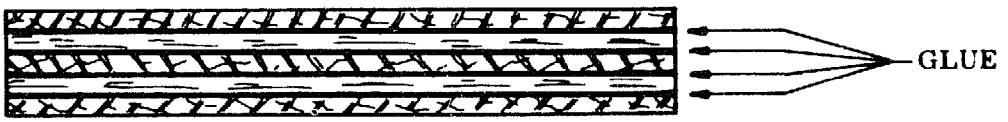

Fig. 2c GLUE HOLDS WOOD, PLASTIC, ETC. TOGETHER TO MAKE JOINTS OR SOLID PIECES, FOR EXAMPLE PLY-WOOD

N P V C		BINDING MATERIALS.
154	MAT.	

HISTORY OF CEMENT

Some sort of binding substance has been used since ancient times to hold together the stones, bricks etc. used in building. The earliest building cement was probably clay or ordinary mud. The Romans were master builders in brick and stone, and a large part of their success was because of their discovery of a cement that was made by mixing a volcanic ash with burned lime. The Romans also made pure lime mortars and gypsum plasters. These materials were the only building cements until modern times.

The modern era of building cements began about 1760, when an English engineer discovered the most suitable composition for hydraulic cements. These are cements which will harden even under water (Fig. 1). A few years later, in 1824, another Englishman invented Portland cement. He named it because of its similarity in appearance to a natural stone from Portland in England.

- DEFINITION: A cement is any material which attaches or unites two surfaces, or serves to combine particles into a whole.

- TYPES OF CEMENTS (Fig. 2):

  a - Building cements (eg. Portland cement and lime)

  b - Bituminous cements (eg. tar and asphalt)

  c - Adhesives (eg. animal glues and synthetic resins)

NOTES:

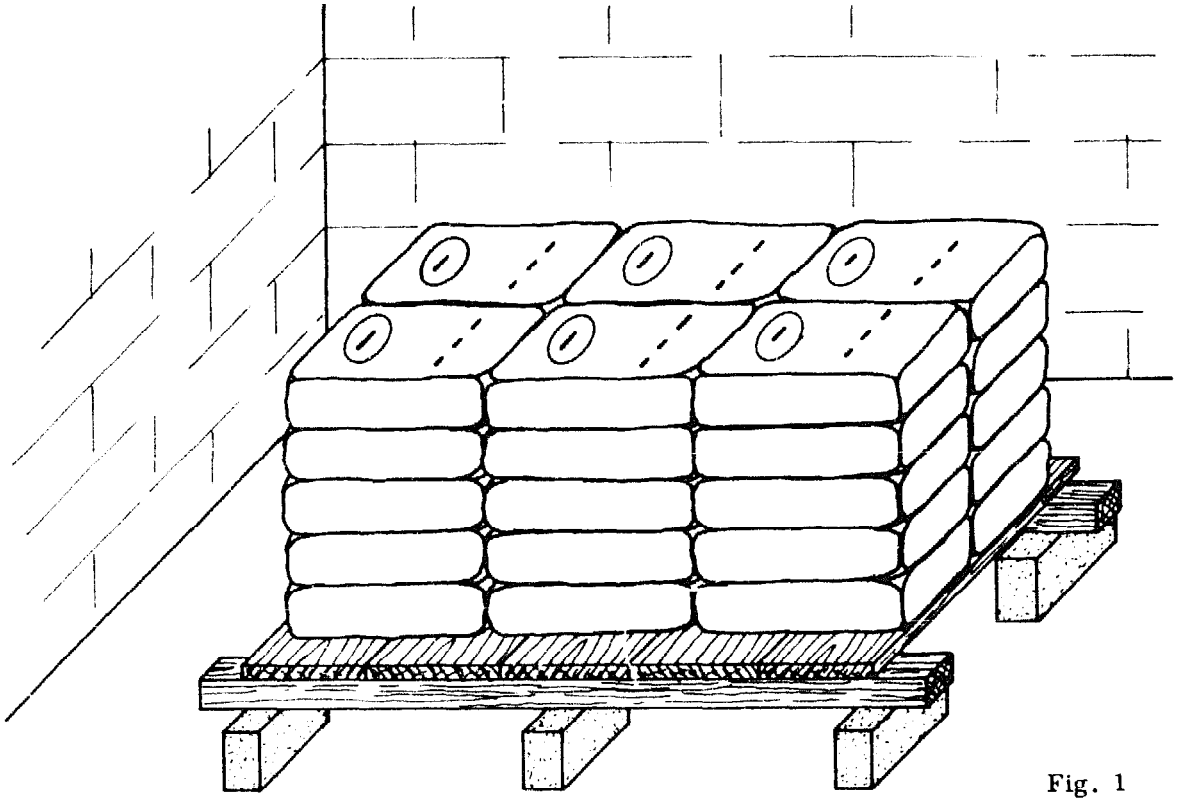

Fig. 1

HOW TO STACK BAGS OF CEMENT IN A STORE

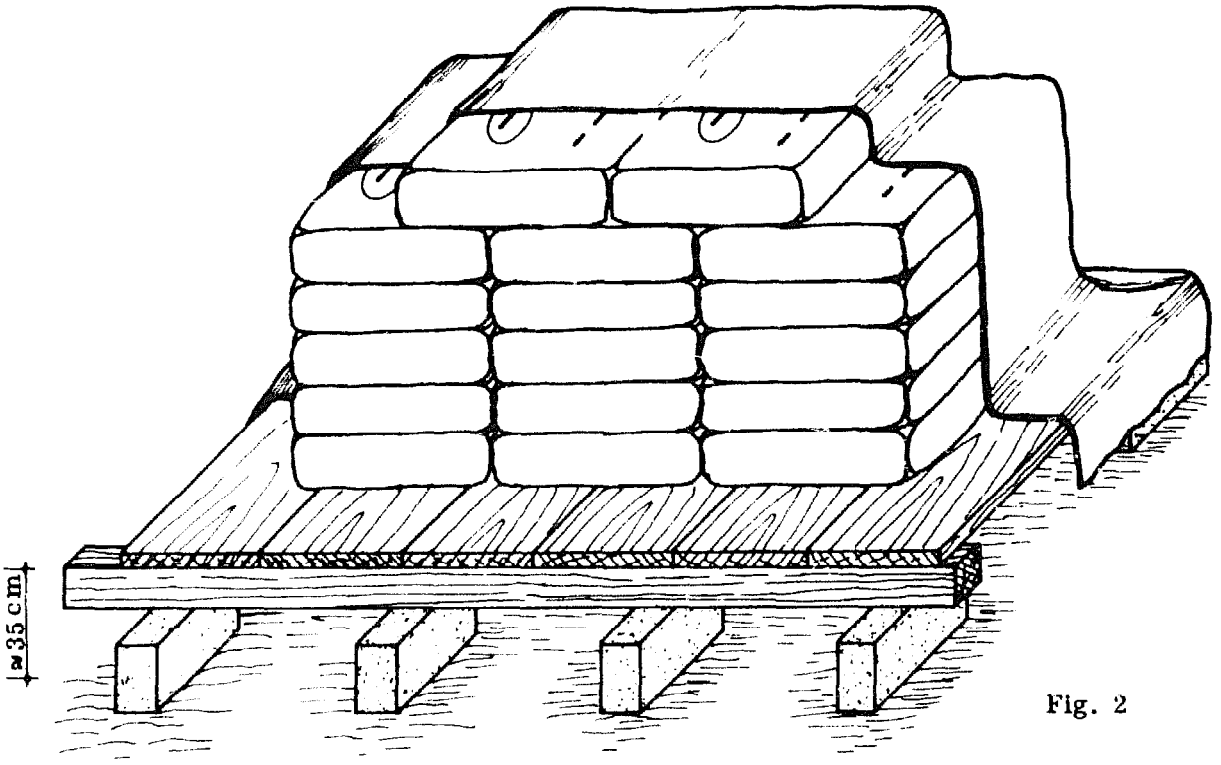

Fig. 2

HOW TO STACK BAGS OF CEMENT IN THE OPEN

N P V C		BINDING MATERIALS.
156	MAT.	

STORING BINDING MATERIALS

The quality of mortar and concrete depends on so many factors, but one of the most important of these is the cement. Cement must be stored properly, to prevent it from setting (hardening) before it is used. If the cement gets damp, it will become unusable. Everyone knows that cement should be kept dry, but they don't always realize that contact with damp air can do as much harm as direct contact with water. On all jobs where bagged cement is used, there should be a shed or room to store it.

- STORING IN A SHED: Make sure that the shed or room is water-tight and has a sound, dry floor. If the floor is not dry, make a platform out of boards set on blocks and timber, to raise the bags off the ground (Fig. 1). Stack the bags closely together to keep out air, and away from the walls so that they are not in contact with any dampness on the walls. In very large sheds it is better to cover the bags with plastic sheeting to keep out damp air, especially during the rainy season.

  Check the bags from time to time for termites: these may damage the bags and with them the cement. Check also that the roof doesn't leak and that the walls are waterproof.

- STORING IN THE OPEN: On some jobs, bags of cement may have to be stored in the open, with no more protection than a dry base and a covering of tarpaulins or plastic sheets. The sheeting must be properly overlapped to keep out the rain; and the top sheet should lay over all the ones below like a roof, so that the rain can run straight off without getting into the tarpaulin "tent" and wetting the cement.

  Even if the cement is to be stored in the open for only an hour or so, there must be a dry platform raised about 35 cm above the ground for the bags to lie upon (Fig. 2).

  Whether the cement is stored indoors or out, arrange the bags so that the first batch brought in can be the first ones used, and the old bags don't get left at the bottom of the stack and never used. Prevent accidents by keeping the piles to a height of about 1,20 m, and never stack them more than 10 bags high.

- REMEMBER: The important thing with cement is to always KEEP IT DRY! Cement starts to set about 30 minutes after mixing or coming into contact with water or moisture.

MORTAR

Mortar consists of the body or aggregate, which is fine sand; and the binding material, which is cement mixed thoroughly with water.

Mortar is used to bed blocks as well as for plastering. A good mortar should be easy to use and should harden fast enough that it does not cause delays in the construction. It must be strong enough, long lasting and weatherproof.

TYPES OF MORTAR

The best mortar for a particular job is not necessarily the strongest one. Other properties like workability, plasticity or faster hardening can be more important, though the strength of the mortar must of course be sufficient for the job.

Mortar should neither be much stronger or much weaker than the blocks with which it is used.

- CEMENT MORTAR: This sets quickly and develops great strength. It is used in proportions of one part cement to three parts sand (1: 3), which makes quite a strong and workable mix; down to a 1: 12 mix, a lean mix which will be rather harsh and difficult to use.
- LIME MORTAR: This is usually very workable and does not easily lose water to the blocks, but it is weaker than cement mortar and hardens slower. Lime mortars are nowadays largely replaced by cement mortars or combinations of lime and cement.
- CEMENT-LIME MORTAR: This combines the properties of cement and lime to give a workable and strong mortar. The cement makes the mortar stronger, denser, and faster setting; while the lime makes the mortar workable and reduces the shrinkage during drying, because it retains the water better.

In some areas, lime is not always available, so in this book we will concentrate on the use of cement mortars.

NOTES:

SELECTING THE RIGHT KIND OF SAND

Sand for plaster, mortar and renderings must always be chosen with care. The sand used to make mortar for blocklaying should be well graded, sharp and must not be too fine if a strong mortar is needed (eg. for footings).

The more fine particles the sand contains, the better its workability in the mix, but more cement paste will be needed to cover the surfaces of the particles. This means that in order to improve the workability while maintaining the same strength, more cement must be added which results in higher costs.

The Rural Builder is always faced with this problem and it takes a lot of experience to be able to find a good compromise.

If the sand is found to be too sharp so that it makes a mortar with poor workability, we suggest replacing about 1/3 of it with fine soft sand; but don't replace more than about 1/2 unless you add more cement.

We can do this because the common mix proportion of our mortar is 1: 6, while the sandcrete blocks are mixed in a proportion of 1: 8 (cement: sand). When the fine sand is added, the strength of the mortar is reduced to about the same as the strength of the blocks, which is acceptable.

The information above is meant to show the problems concerning the selection of the right sort of sand for a particular job. This book will address these problems repeatedly as we introduce the different kinds of blocks as well as the different jobs.

- REMEMBER: A good mortar should:
  - a - be easy to work with
  - b - harden fast enough not to delay the construction
  - c - stick well to the blocks
  - d - be long lasting and weatherproof
  - e - if possible, be as strong as the blocks.

NOTES:

STAGE 1

FILL FLUSH

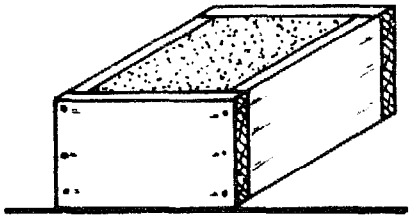

STAGE 2

LIFT UP

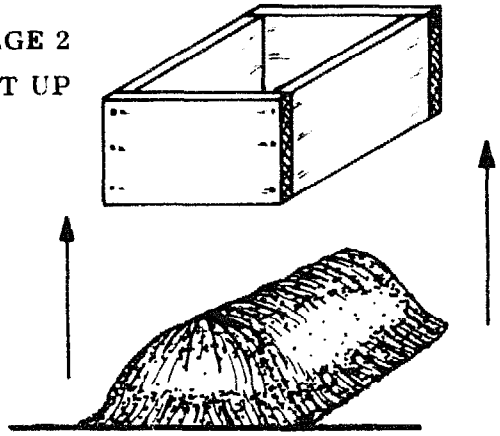

STAGE 3

FILL SECOND TIME

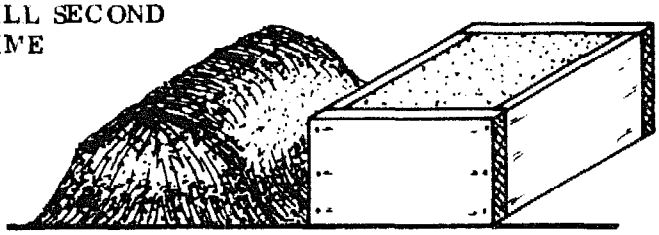

STAGE 4

FILL SMALLER BOX WITH CEMENT

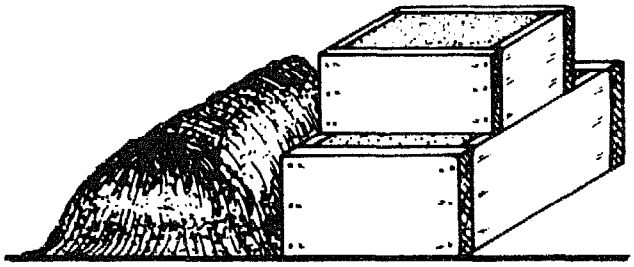

Fig. 1

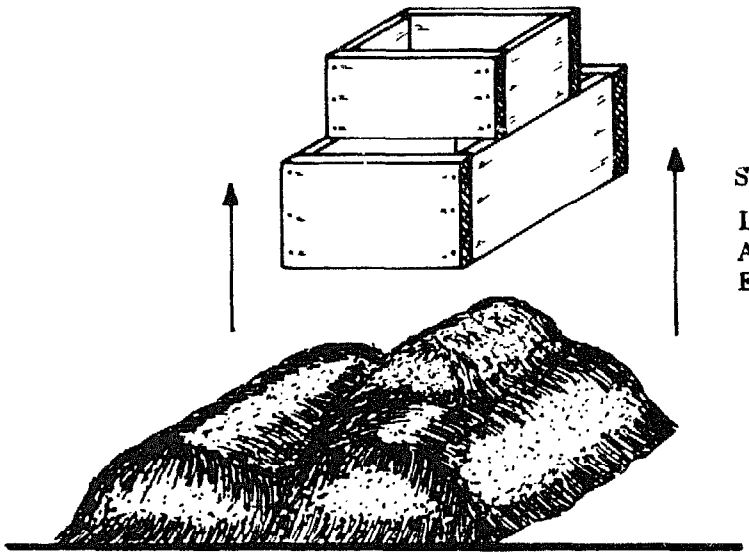

STAGE 5

LIFT UP BIGGER BOX AND EMPTY BOTH AT ONCE

N P V C	
160	MAT.

MORTAR.

BATCHING

By the term "batching" we mean that we measure the proportions of the various ingredients of a mix. We already know that the ingredients for a mortar should be mixed in certain proportions. To help us to obtain the correct amounts we can make boxes with the appropriate sizes; this method is known as "batching by volume".

Since a common mix proportion is 1: 6 and some special jobs require a mix of 1: 3, two batching boxes are made with corresponding measurements. The smaller one for cement measures 15 cm high, 30 cm wide and 38 cm long (inside measurements) giving a volume of 17,1 litres, which is about half a bag of cement or one slightly heaped headpanful (one bag of cement contains 34,1 litres or two slightly heaped headpans).

For the sand, a bigger box is made which must hold exactly three times as much as the smaller one. Therefore its inside measurements are: 30 cm high, 30 cm wide, and 57 cm long. This gives a volume of 51,3 litres, which is 3 x 17,1.

Both boxes are bottomless; they are only frames in order to make it easier to work.

- PROCEDURE: Before you start batching and mixing, it is advisable to make a mixing platform out of lean concrete for all future mortar and concrete work. This provides a firm and clean place so that your mix will not become dirty, no cement paste will be lost, and shovelling will be easier.

  For small jobs, the mixing platform can measure approximately 1,5 m by 2 m and may be 5 to 7 cm thick.

  For a 1: 6 mix, place the bigger box on the platform and fill it with sand flush to the top edge. Then lift it up and set it down again next to the first pile and refill it in the same way (Fig. 1, stages 1 to 3).

  Now put the small box on top of the sand-filled big one, and fill it with cement. It must be filled flush to the top edge in order to get the right proportions (Fig. 1, stage 4).

  Now lift up the lower box, taking the smaller one with it and emptying both at once. The result is a heap of sand (6 parts) covered with cement (1 part), ready to be mixed (Fig. 1, stage 5).

Fig. 1

SAND AND CEMENT

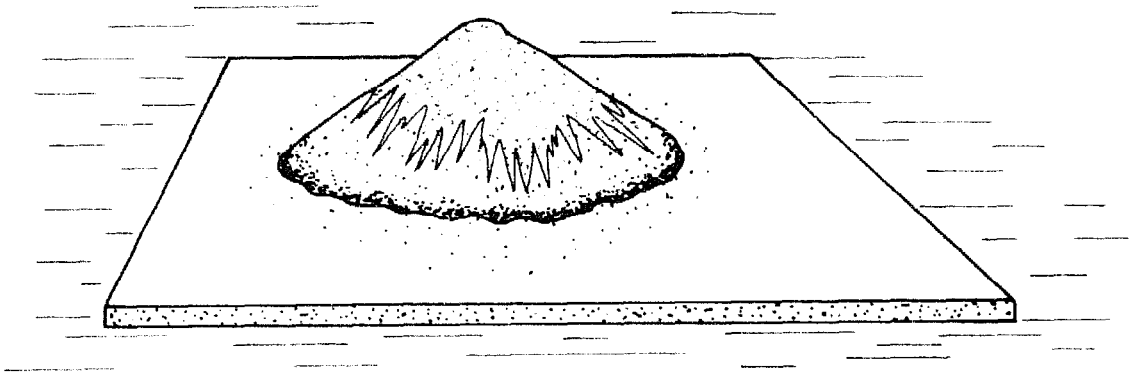

Fig. 2

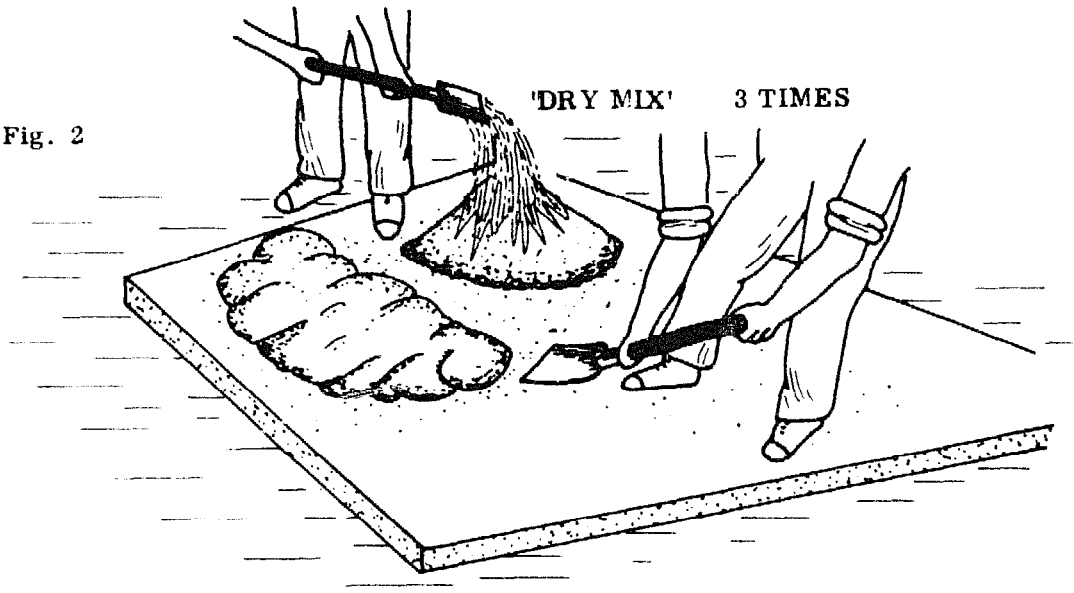

Fig. 3

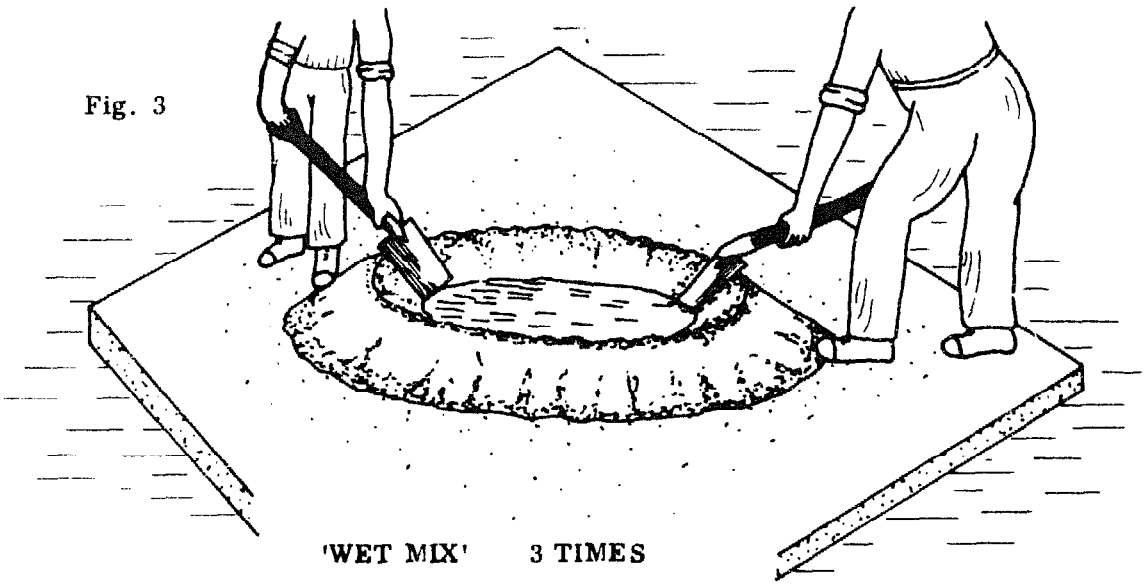

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MORTAR.

MIXING THE MORTAR

Mixing is one of the most important stages in the process of making mortar because the workability and strength of mortar depend so much on the way it is mixed and on the amount of water added to the mix.

- WHAT WATER DOES: Water in the mix does two things: it makes the mortar workable and it combines chemically with the cement to cause hardening. However, only about half the water is required for the chemical reaction and the rest will remain or evaporate slowly as the mortar hardens, leaving small holes or "voids" in the cement.

  Obviously, the more water there is in the mix, the greater will be the number of voids and the weaker the mortar.

  For your 1: 6 mixture, a maximum of 15 litres of water should be added (almost one headpanful); never any more than this even if the mix appears to be too dry, as sometimes happens in the first stage of mixing.

- THREE TIMES DRY: The sand and cement is measured on one end of the mixing platform. With two men facing each other across the pile and working their shovels together, turn the whole heap over once to form a pile at the other end of the slab (Figs. 1 & 2). This turning must be repeated twice and results in a so-called "dry mix".

  The correct method for turning over is to slide the shovel along the top of the platform, pick up a load and spill the load over the top of the new pile. The main point is that each shovelful runs evenly down the sides of the cone. This is the best and easiest way of mixing dry mortar and all other motions should be eliminated. When the dry mix is a uniform colour throughout, it is considered to be well mixed.

- THREE TIMES WET: Form the heap of dry mix into a crater or pool, with the sides drawn out towards the edges of the mixing platform. There should be no mixture left in the centre of the pool.

  Now gently pour about 3/4 of the total required water into the crater. Turn the shovel over and with the edge scraping along the platform, push some of the dry mix into the pool in such a way that it spreads out, without separating the sand and cement. Handle the shovel carefully so that no water can escape by breaking through the ring (Fig. 3).

  When all of the dry mix has been heaped up in the centre of the platform, it should have taken up all the free water and have a rather stiff consistency (earth-moist).

Now make a second pool, add the remaining water and repeat the rest of the mixing procedure. This will result in a mortar of a plastic consistency. To make sure the mixing is thoroughly done, turn the mortar over a third time.

- CONSISTENCY TEST: You can carry out a simple test to get a rough idea whether the consistency of the mortar is correct (this means the water content).

  Fill a headpan with mortar and smooth the surface (Fig. 1). With the blade of your trowel, make a straight cut clear through the mortar to the bottom of the headpan (Fig. 2). Now push the trowel flat under the mortar along the bottom of the headpan, so that the cut in the mortar centres the length of the trowel.

  When the trowel is lifted up 2 or 3 cm, the gap in the mortar must open into an oval shape along the outer edge but remain closed along the bottom (Fig. 3).

- NOTE: If you want to improve the workability of the mortar by adding water, remember that this will also decrease its strength. You are therefore strongly advised to add both cement and water in equal quantities (for example 1/2 bucket of water plus 1/2 bucket of cement).

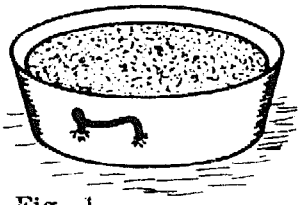

Fig. 1

FILL HEADPAN HALF FULL AND SMOOTH THE SURFACE

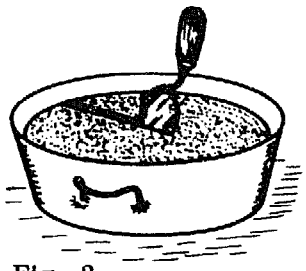

Fig. 2

MAKE A CUT WITH THE TROWEL

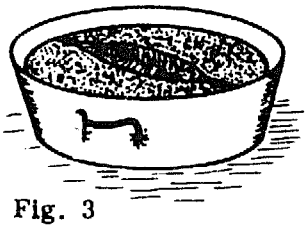

Fig. 3

- REMEMBER : Ready mixed mortar starts setting after only 30 minutes! Never prepare more mortar than you can use within this time.

  It is certainly better to mix smaller amounts more often than to allow mortar to spoil; or to do the work very quickly (and sloppily) in order to get rid of the mortar.

  Always cover freshly mixed mortar with empty cement bags to keep it from drying out.

NOTES:

CONCRETE

To concrete something means to form it into a mass, or to solidify it.

As far as building is concerned, the term concrete means an artificial stone made by mixing sand, stone, Portland cement and water. This mixture, cast into a form of the desired shape and size, hardens into a stone-like mass: the concrete.

There are basically three materials we start with to make concrete:

- The aggregate, which is made up of the fine and coarse aggregates together, ie. the sand and broken stones. The aggregate makes up the main mass of the concrete; its function is mostly just to add bulk.
- The water.
- The binding material, which is usually Portland cement.

When the three materials are mixed together, the cement and water combine chemically to make a cement paste, which surrounds the particles of the aggregate and holds them together.

NOTES:

CEMENT PASTE

The cement paste component of concrete is what causes it to harden, the aggregate simply remains passive (inactive).

Thus the cement paste must completely cover the surface of every single particle of the aggregate. This means that each stone, no matter whether tiny or big, must be covered all over by a thin layer of cement paste.

This is achieved by mixing all three components very thoroughly and in the correct proportions (see Batching, and Mixing The Mortar, pages 160 to 163).

The cement paste fills up all the spaces between the particles of the aggregate and bonds them firmly together as it hardens.

The hardening process requires a certain amount of water; how much depends on how much cement is added to the mix. The correct proportions can be found in the Tablas of Figures, page 234.

After it is set, the hardened cement paste cannot be dissolved again (except by the use of certain acids).

An undesirable further reaction of the cement paste is the drying shrinkage as it hardens. Because of the evaporation of the extra water, the volume of the concrete is gradually reduced. The concrete shrinks and develops cracks.

This reaction can be effectively reduced, if not prevented, by correct curing; as will be discussed later in this book.

Also to prevent cracking, large areas that are covered with concrete; such as floors, should be divided up into bays.

PROPERTIES OF CONCRETE

Concrete has many properties, but most of them are of little interest to the Rural Builder. Therefore this chapter deals only with the three most important properties:

a - Compression strength

b - Tensile strength

c - Protection against corrosion.

NOTES:

- COMPRESSION STRENGTH: It is commonly known that concrete becomes very hard and can withstand enormous pressures; a property which is called compression strength.

This compression strength depends mainly on the properties and quality of the cement paste and the aggregate.

- If the aggregate consists of a soft or weak material, the concrete will be weak also.
- If the aggregate is so dirty that there is no direct contact between the surface of the particles and the cement paste, the concrete will again be weak.

Provided that all the rules for producing a good concrete are observed, the strength of the concrete can be controlled by choosing the mix proportions. For example, a mix proportion of 1 : 10 is weaker than a 1 : 3 mix. This is because in a 1 : 10 mix the particles of aggregate are not completely coated with cement paste, but in the 1 : 3 mix they are fully embedded in it.

- If not enough water was added to the mix, the cement paste remains too dry and stiff and the concrete will be weak.
- If too much water was added, making the cement paste too thin, the concrete will again be weak.

Therefore the Rural Builder must always carefully follow the correct concrete recipe.

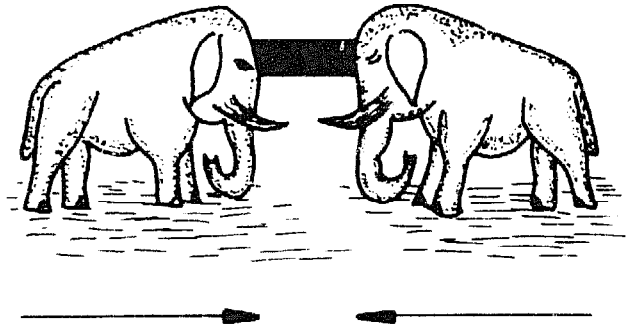

COMPRESSION STRENGTH

- TENSILE STRENGTH: The tensile strength of a material means its capability of being stretched to a certain extent without breaking.

Although concrete becomes very hard, its tensile strength is very limited. It is so low that in practice, the tensile strength of concrete is regarded as being non-existent. This is why sometimes concrete members of a structure must be reinforced by steel bars embedded in them.

Some types of wood, while they are softer and have a much lower compression strength than concrete, have a far higher tensile strength because of their fiber structure. The wood fibres act in a way like the reinforcement iron embedded in concrete.

Wood is a good building material because of its tensile strength. However, its flexibility makes it subject to bending under loads. Because of this problem, short-span constructions are chosen; or, among other possibilities, reinforced concrete can be used instead of wood.

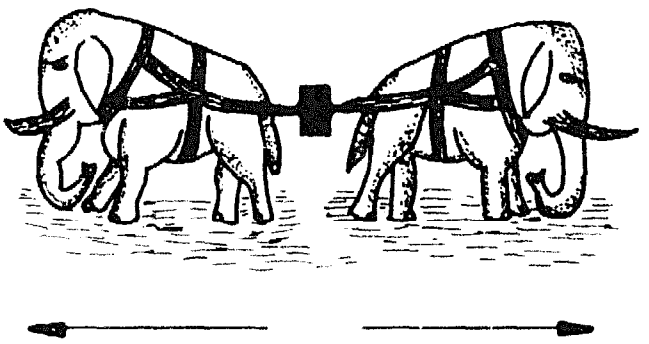

TENSILE STRENGTH

NOTES:

- PROTECTION AGAINST CORROSION: Corrosion means a wearing away, a slow destruction caused by a reaction with air, water or chemicals.

  Reinforcement iron which is left unprotected and exposed to air and humidity will eventually start to corrode on the surface and become rusty.

  If this process is not halted in time, the rust goes into the bar and it becomes too weak to be used.

  In order to maintain the strength of steel-reinforced concrete, the steel has to be protected from rust. This is partly done by the hardened cement paste and partly by structural means.

  Ideally, the hardened cement paste hermetically seals the iron so that direct contact with air and humidity is cut off. Even slight rust stains on the iron cannot do any harm because the cement paste protects it against further corrosion.

  The protection will not be enough however, unless the builder observes the following rules:

  - The reinforcement bars must be completely covered by concrete which is well compacted and without voids.
  - The concrete cover must be sufficiently thick, and without cracks.
  - In most cases ordinary Portland cement is used and the mix proportion should be no less than 1: 5 for reinforced concrete. (see Tables of Figures, page 234).

  Apart from these, all the other rules for producing a good concrete must be observed.

- NOTE: Quality concrete is not a brand. It does not have a trademark on it to say "This is quality concrete". Sometimes the concrete does not even look different from poor concrete, but it is different. This depends not only on the mix proportion, but on the awareness and skill of the builder.

NOTES:

REINFORCEMENT STEEL

To reinforce a material means to add something to it, in order to make it stronger.

One of the strongest reinforcement materials available is steel or iron. In reinforced concrete, a concrete member is strengthened with steel bars or metal netting embedded in it.

TYPES OF REINFORCEMENT STEEL

There are various types of reinforcement steel; how they are used depends on the function, shape and dimensions of the reinforced concrete member as well as on the required strength.

Reinforcement steel is classified according to its shape and surface texture. The most common reinforcement is single round bars which can have either a smooth or a ribbed surface.

- CIRCULAR BARS: Round, smooth bars are called circular bars and are available in diameters ranging from 5 mm to 28 mm (Fig. 1, next page). The four sizes most often used in Rural Building have diameters of 6 mm (1/4"), 10 mm (3/8"), 12 mm (1/2") and 18 mm (3/4").
- RIBBED BARS: The round bars with a ribbed surface are called ribbed bars and are available in diameters ranging from 6 mm to 40 mm, if the bar is cross-ribbed (Fig. 2, next page). For obliquely ribbed bars, the diameters range from 6 mm to 28 mm (Fig. 3, next page). This last type of reinforcement is also called "tentor bar" and it is the strongest reinforcement steel available.

The standard length of reinforcement bars is 9 m.

- ADVANTAGES / DISADVANTAGES: Although the strength of circular bars is sufficient for all Rural Building purposes, it is advisable to purchase ribbed bars if they are available in the market. Ribbed bars are preferred because their rough surface texture provides a better grip to the concrete. This, along with their greater strength, allows the Rural Builder to space the ribbed bars wider apart, thus saving materials and reducing the total weight of the member.

Fig. 1

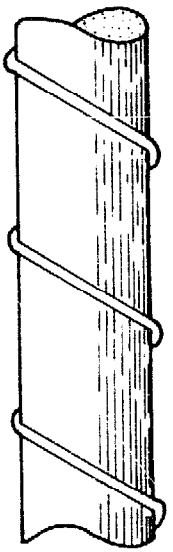

Fig. 2

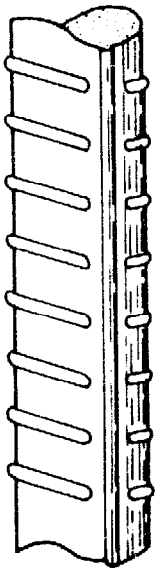

Fig. 3

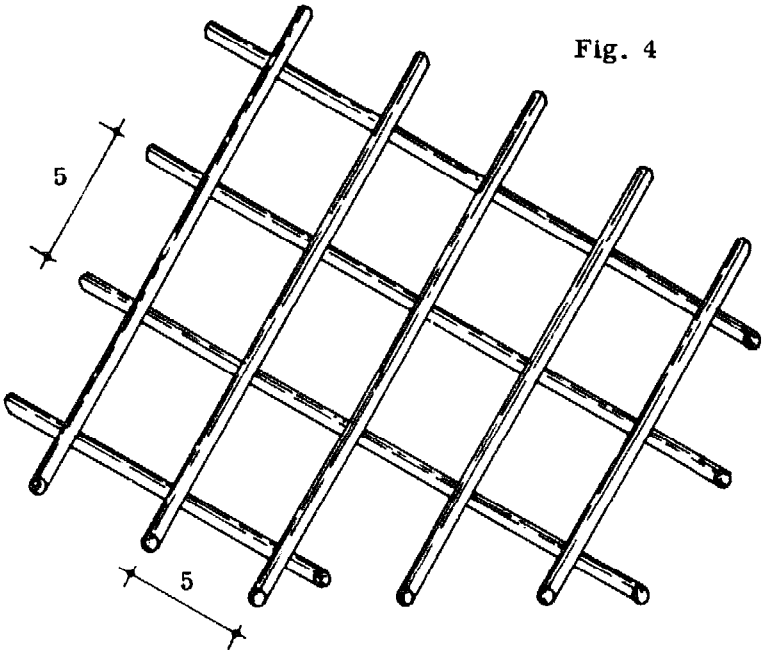

Fig. 4

STEEL WIRE NETTING

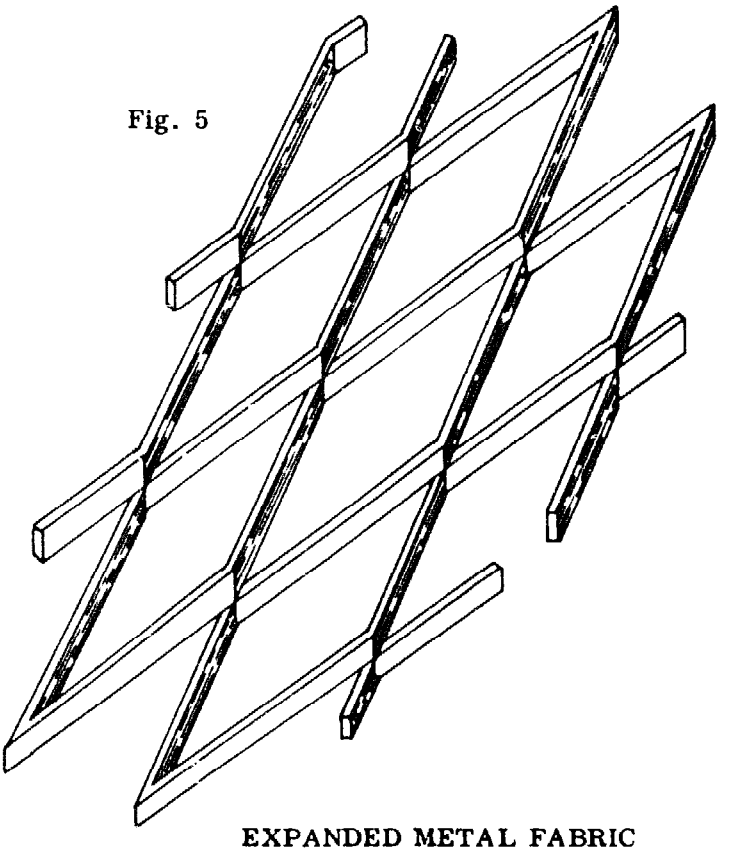

Fig. 5

EXPANDED METAL FABRIC

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REINFORCEMENT STEEL.

REINFORCEMENT MATS

A variety of reinforcement mats are available. They are usually made out of two layers of reinforcement bars laid across each other and secured together by welding.

The mats are either square or oblong in shape. They reduce the work needed to reinforce large members of the structure such as floors, walls, slabs, etc.

Regular reinforcement mats are hardly necessary in Rural Building, but two special kinds are frequently used for burglar proofing and to reinforce thin concrete slabs like manhole covers, draining boards in kitchens, and coping slabs.

These two are "expanded metal fabric" and "steel wire netting".

- STEEL WIRE NETTING: The most common steel wire netting (Fig. 4) has square meshes measuring 5 by 5 cm and is manufactured in the same way as reinforcement mats. The same kind of wire mesh can also have oblong meshes.
- EXPANDED METAL FABRIC: This is made by slitting metal sheets and then stretching them to form a diamond-shaped mesh (Fig. 5). Always wear leather gloves when working with expanded metal fabric, as the edges are very sharp.

Reinforcement mats are sold in sheets approximately 2,15 m wide and 5 m long.

Expanded metal fabric and steel wire netting can be purchased in sheets of about 1,5 m wide and 2,5 m long.

BINDING WIRE

This is a soft steel wire about 1 mm in diameter, used for binding reinforcement bars at the points where they cross each other. It is bought in rolls and may also be called lashing wire, annealed wire or tying wire.

NOTES:

LANDCRETE BLOCKS

One of the smallest but most important members of the structure is the block. Almost all walls in Rural Building are erected with blocks, preferable landcrete blocks.

- LANDCRETE: This word comes from the words laterite, land, and concrete.

  The land on which we live provides us with the laterite; the first syllable is a combination of the first two letters of laterite and the last two letters of land.

  Concrete as well as landcrete contains cement. In order to show this, the last syllable of the word concrete is used, making the word LANDCRETE.

Landcrete is a low cost, long-lasting and attractive building product. This chapter is about making landcrete blocks using a hand operated block press.

- LATERITE: This type of soil is found throughout the tropics. Its colour can vary from white-grey to a dark red, depending on the iron content. Laterite consists mainly of fine and coarse sand mixed with clay.

  Laterite has been used to make houses for a long time, but such walls break down easily and get washed away by rain. Pressing the soil into blocks makes it easier to build the walls, and they are stronger and more resistant to rain. By adding some cement to the laterite it is stabilized and makes even better blocks. The basic material, laterite, costs nothing and is usually found on the building site. It is easy to find good soil for building or to mix it with sand or clay to make it good.

The basic steps of the operation to make landcrete blocks are fairly simple: first good soil is found and tested; then it is prepared for the block press, with the addition of cement or lime if available. The soil or soil-cement is put into the press and compacted, raised out and removed for curing.

- NOTE: If the blocks do not contain cement they are not called landcrete; they are simply called "laterite blocks".

REQUIRED MATERIALS

a - Laterite soil: composed of sands, silt and clay

b - Water: to wet the soil; it should be clean

c - Cement: to stabilize the soil.

- NOTE: If you have no cement you can use lime (twice as much as the amount of cement recommended) or else just make plain laterite blocks.

REQUIRED EQUIPMENT

a - Block press with proper mounting rails and a wooden handle (2,5 m long)

b - Box for shrinkage test

c - Headpan, box or bucket for batching

d - Pick-axes and shovels for digging, mixing and filling.

TESTING AND CHOOSING THE SOIL

Most soil is suitable for making blocks, but it must be tested first to find out how much sand, silt and clay it contains.

Dig a small pit for testing. First remove and set aside the top soil where plants or grass may be growing (25 to 50 cm deep). This soil should not be used for blocks. Dig out the soil under the top soil. The deeper soil may be sandier, which is usually better for making blocks.

Now make three tests: a - Drop test b- Jar test c - Box test.

- DROP TEST: Take a handful of soil which is wet enough to form a ball, and squeeze it in your hand, but not so tightly that the water is squeezed out.

  Drop the ball from about one meter high onto hard ground. If it breaks up into only a few pieces, the block-making quality is good. If it breaks completely up, there is either not enough water in it or not enough clay, and the quality is bad.

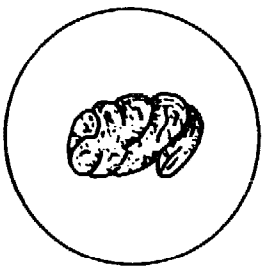

TOO WET

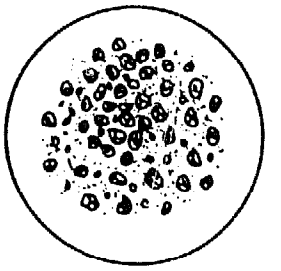

NOT ENOUGH CLAY

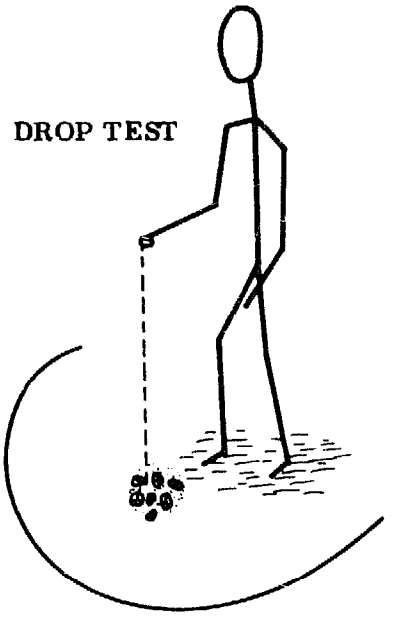

DROP TEST

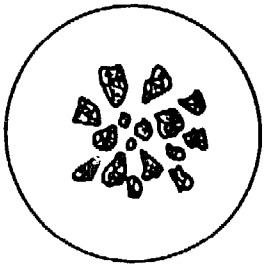

TOO DRY

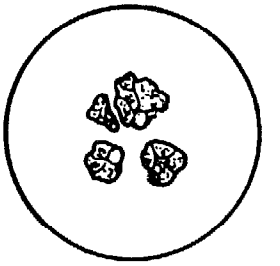

GOOD

Fig. 1

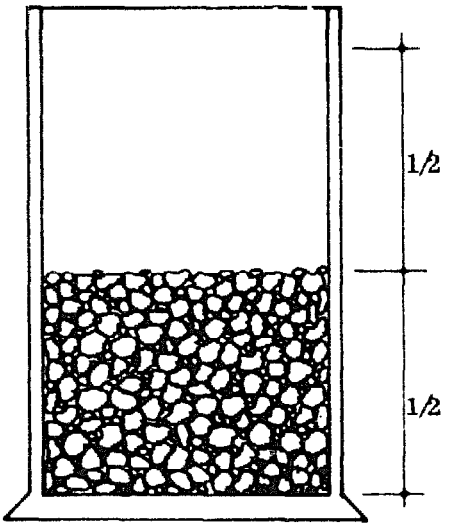

FILL GLASS JAR HALF FULL
WITH LATERITE SOIL

Fig. 2

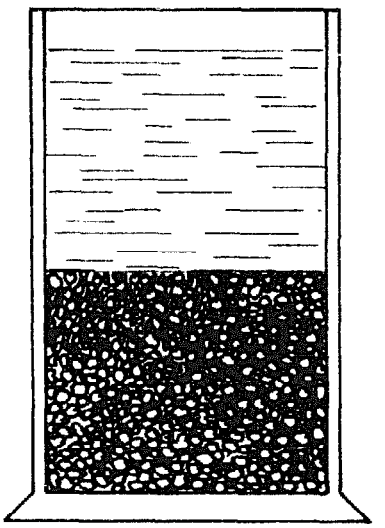

FILL WITH WATER AND ADD
A LITTLE SALT
SHAKE IT THOROUGHLY !

Fig. 3

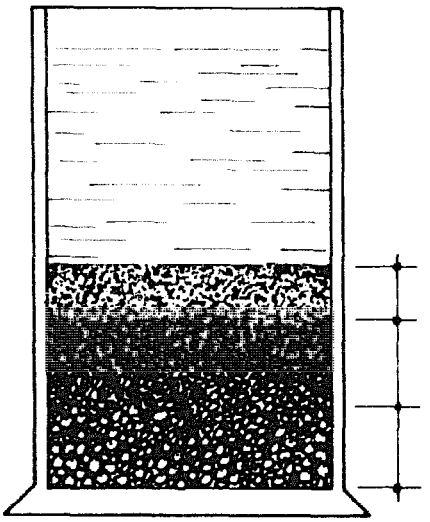

USE SOIL THAT CONTAINS:

5 - 30% CLAY AND SILT

AND AT LEAST 30% SAND

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LANDCRETE BLOCKS.

- JAR TEST: This test separates the sand from the clay and silt, so that we can measure the quantity of each.

First dig out some soil (not top soil). Fill a glass jar half-full with the soil (Fig. 1).

Fill the jar up with water and add two teaspoons full of salt, to make the particles settle faster (Fig. 2).

Cover and shake or stir the jar for two minutes to mix the water thoroughly with the soil.

Set the jar on a level surface and leave the soil to settle for several hours. Sand and gravel will settle to the bottom, leaving the silt and clay on top (Fig. 3).

Measure the height of each layer to find the total amount of sand and the amount of clay and silt, compared to the total amount of soil.

The soil you use should contain at least 30% sand (about 1/3), and between 5% and 30% clay and silt. If there is not enough clay add more or else find some better soil. You can also add sand if necessary.

NOTES:

Fig. 1

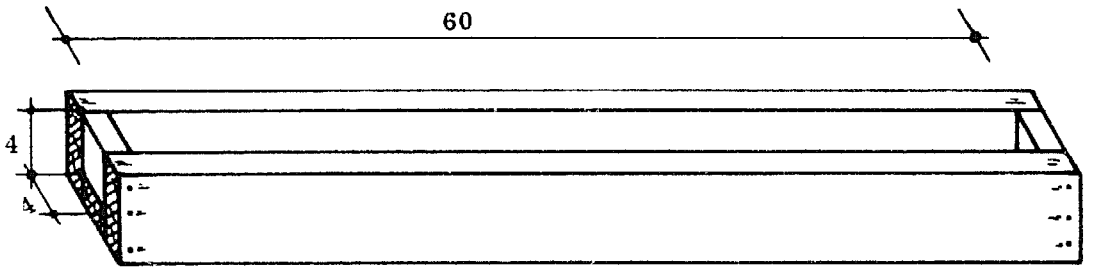

OIL THE INSIDE OF THE BOX

Fig. 2

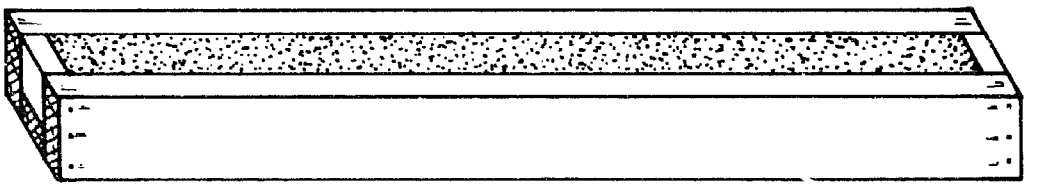

FILL WITH LATERITE

Fig. 3

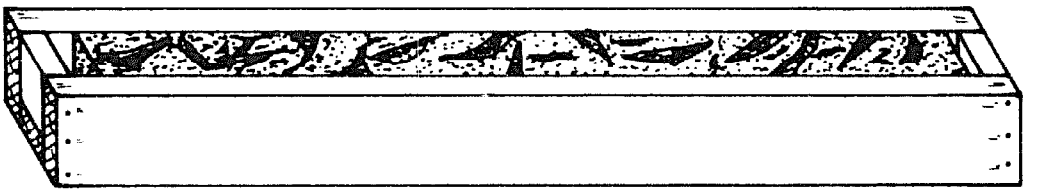

DO NOT USE THIS SOIL

Fig. 4

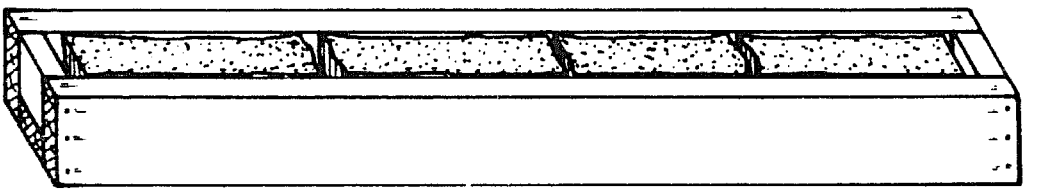

CRACKS OCCUR

Fig. 5

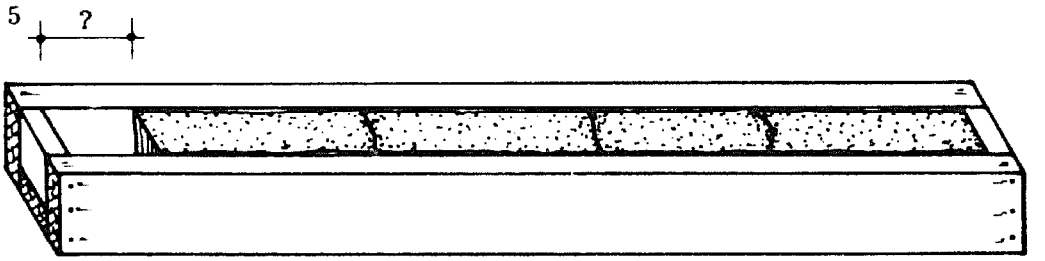

MEASURE THE SHRINKAGE SPACE

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- BOX TEST: This test shows the quality of the soil and allows you to determine the amount of cement you should use with it.

Use an open wooden box with inside measurements of 60 cm by 4 cm by 4 cm (Fig. 1). Oil or grease the inside of the box.

Fill the box with very wet soil. Compact it well, especially in the corners, and level off the top with a stick or the edge of your trowel (Fig. 2).

Put the box in the sun for three days to dry, or in the shade for seven days. It should be protected from rain.

The soil will shrink as it dries. Do not use soil for blocks if it has many cracks in it (Fig. 3) or if it has arched up out of the box. Don't use soil if it has shrunk more than 5 cm. Either find some better soil, or improve the soil by adding sand, since it is the clay which causes shrinkage.

Measure the shrinkage by tapping one end of the box on the ground so that all the soil slides down to one end (Fig. 4). The cracks will close and you can measure the shrinkage space at the top end (Fig. 5).

The amount of shrinkage tells you how much cement you should use. The more shrinkage, the more cement is needed. Use the table below as a guide for the amount of cement to be added to the laterite.

- TEST TABLE:

Shrinkage	Cement to soil
0 - 10 mm	1 : 35
10 - 20 mm	1 : 30
20 - 30 mm	1 : 25
30 - 40 mm	1 : 20
40 - 50 mm	1 : 15

NOTES:

Fig. 1

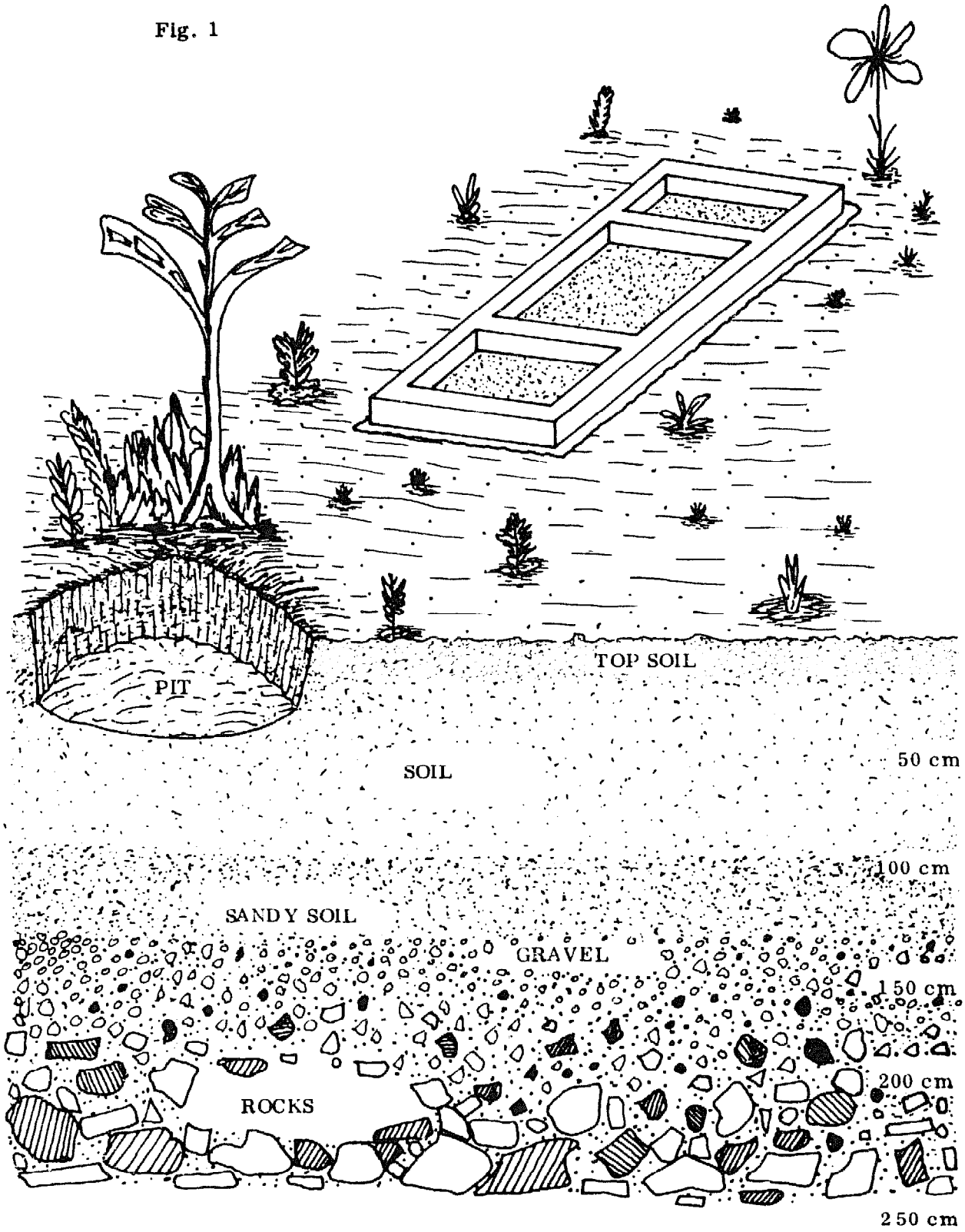

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LANDCRETE BLOCKS.

MAKING BLOCKS

- PREPARATION OF THE MIXTURE: After you have found good soil and the correct amount of cement to use with the help of the box test, the soil mixture must be prepared for the block press.

  If you have no cement and must make laterite blocks, you follow the same sequence as described below.

  a - Remove the top layer of soil (Fig. 1).

  b - Dig out the soil you want to use and pile it (Fig. 1).

  c - Measure the required proportions of laterite and cement.

  d - Make a dry mix of the batch.

  e - Add water and make a wet mix.

  f - Check the moisture content using the drop test.

  If you are making laterite blocks, steps c and d are of course left out.

  Before you start batching, the laterite must be broken up so that no lumps remain. This is usually done by beating the soil with the back of a shovel or with a piece of wood. Large stones are removed.

- MIXING: Use flat, hard ground for mixing. If no such place is available, prepare a mixing platform before you start working.

  Spread the laterite out until it is about 10 cm thick. Spread the cement evenly over all the soil. Mix the cement and soil with a shovel until the mixture is of an even colour throughout (about 3 times - see Rural Building Materials, page 163).

  Spread the heap again, sprinkle a little water over it and mix. At this point, test the mixture for moisture with the drop test. If it is too dry, spread it out again and add more water.

  The soil-cement mixture is now ready for the block press. There should be enough mix for about 7 or 8 blocks in one batch at a time.

- NOTE: Never prepare more than you can use up within 30 minutes (about three batches). It is better to mix small amounts more often.

NOTES:

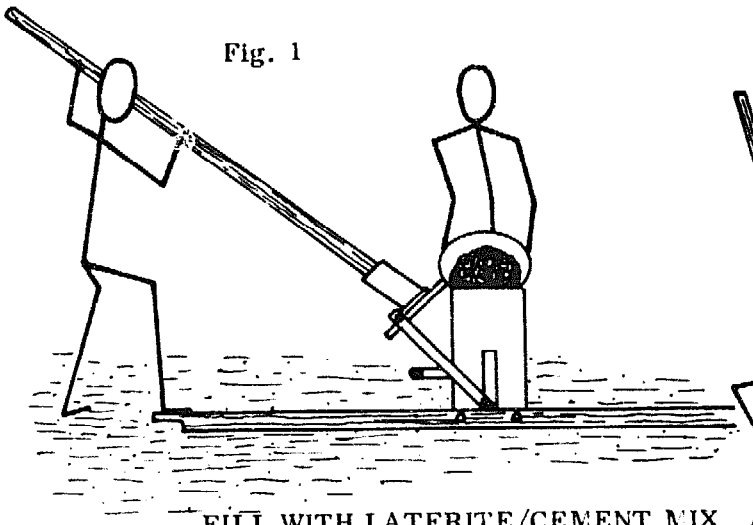

Fig. 1

FILL WITH LATERITE/CEMENT MIX

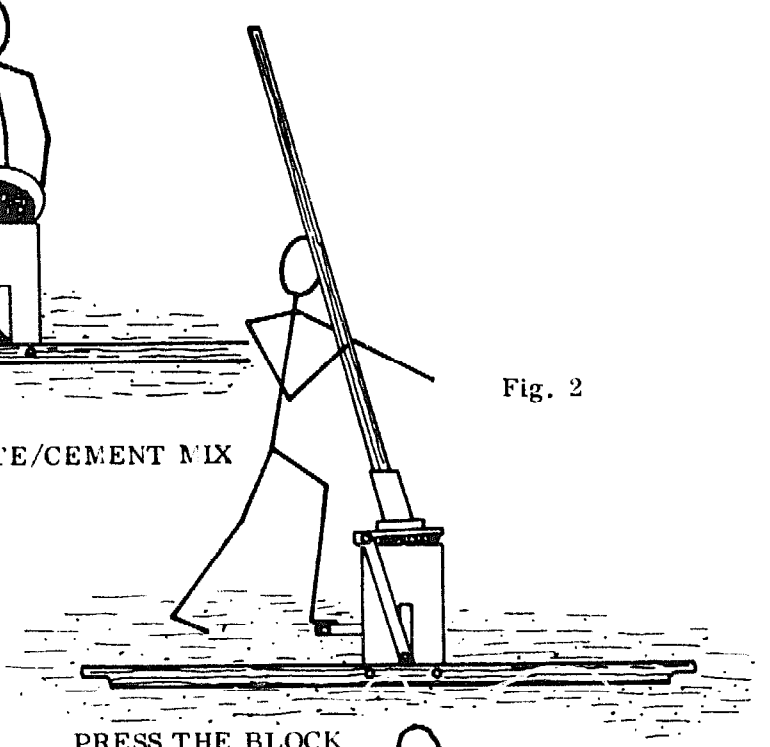

Fig. 2

PRESS THE BLOCK

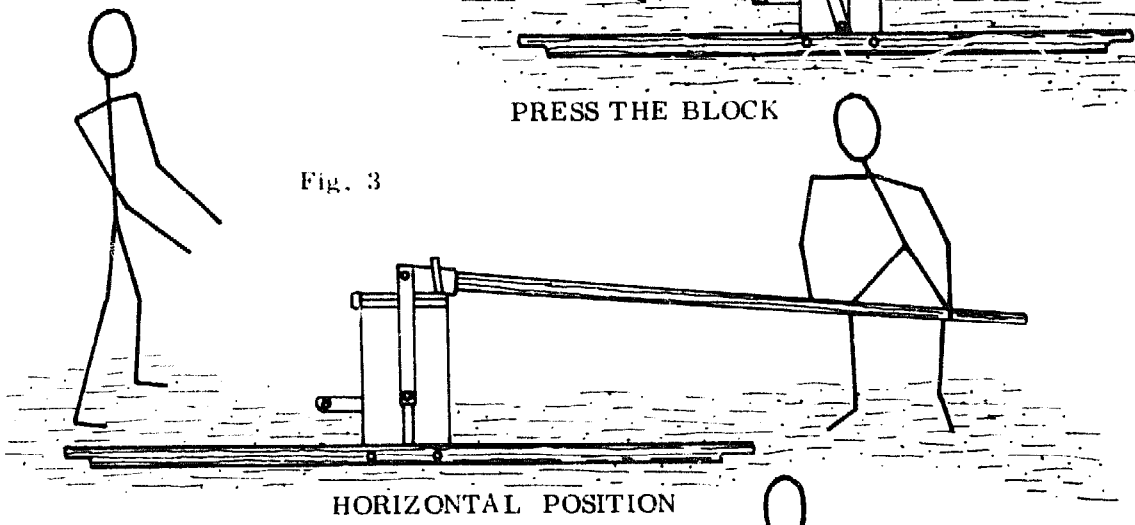

Fig. 3

HORIZONTAL POSITION

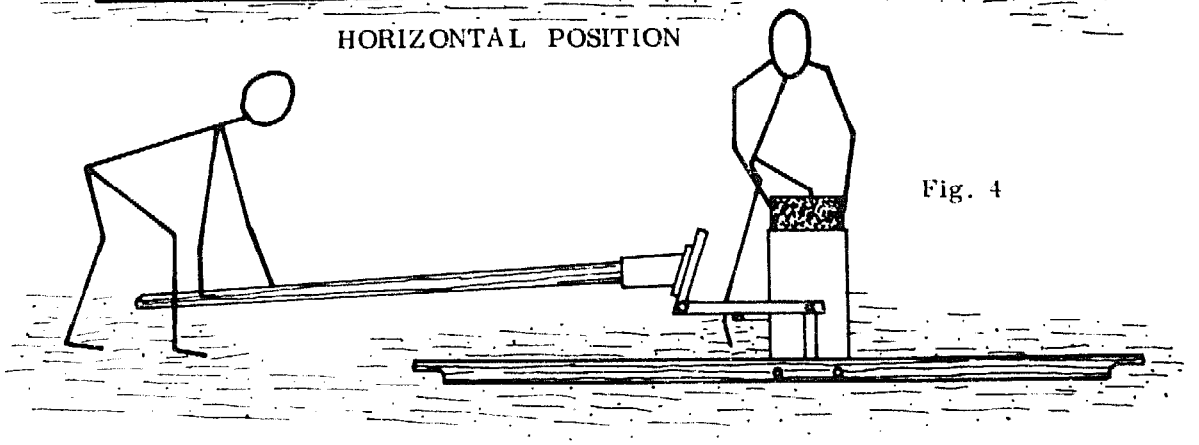

Fig. 4

RAISE THE BLOCK AND LIFT IT CAREFULLY

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- PRESSING THE BLOCK:

a - Place the block press in its rails on flat, solid ground near the mixing platform.

b - Open the mould box by swinging the handle down to the lower roller.

c - Half-fill the mould box with the laterite cement mix (Fig. 1).

d - Press the mix firmly into the corners with a piece of wood.

e - Fill the mould to the top and compact the corners again.

f - Add a little more so that the mould is filled flush to its top edge.

g - Swing the handle quickly over to the other side and press the block until the handle has reached a horizontal position (Figs. 2 & 3).

If the mix is too dry, the handle will not go all the way down to the horizontal position. In this case do not force it, as the handle may break.

Instead, eject the unfinished block so that you can refill the mould box after adding a little water to the mix.

On no account should more than one man at a time work the handle!

h - Raise the block out of the mould box by swinging the handle back against the lower rollers (Fig. 4).

i - Lift the block carefully off the machine and place it for drying.

The freshly made block is not strong yet. If it breaks or cracks very easily, the mixture is not correct. Try a different mixture.

Hold the block in such a way that your fingers are not caught under it when you put it down, so as not to crumble the edges.

NOTES:

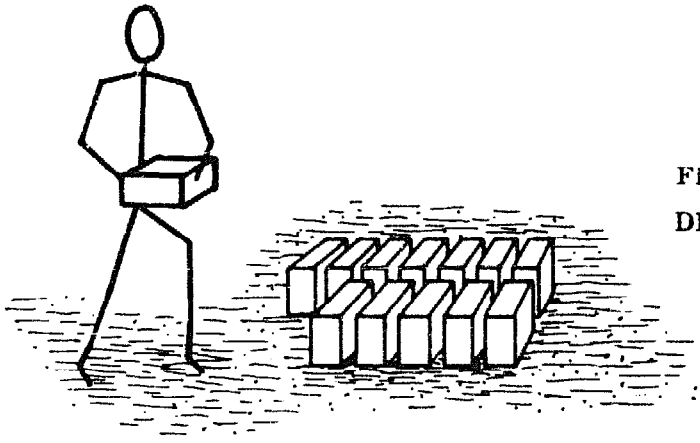

Fig. 1

DRYING FOR ONE DAY

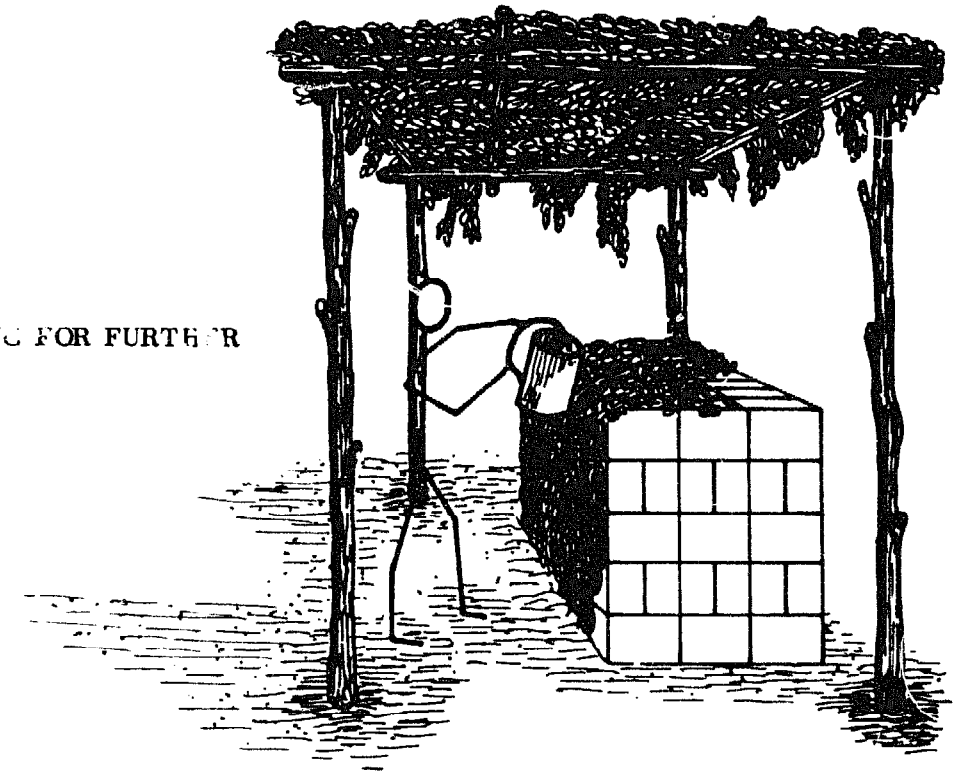

Fig. 2

STACKING FOR FURTHER CURING

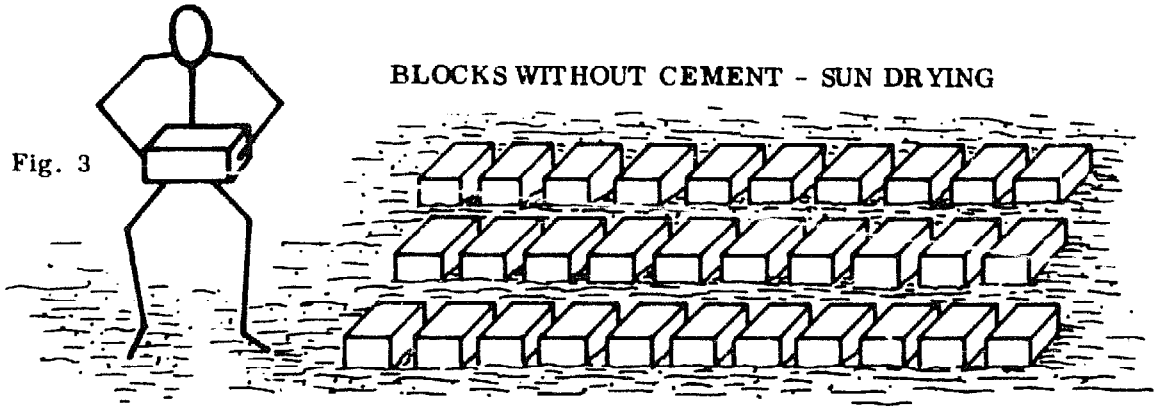

Fig. 3

BLOCKS WITHOUT CEMENT - SUN DRYING

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LANDCRETE BLOCKS.

- CURING: This is the term originally used to describe the chemical change in glues when they set, meaning when they become strong and hard.

As far as cement products are concerned, curing simply means the after-treatment of any of those products.

If the blocks contain cement, we talk about "curing". If the blocks don't contain cement, we talk about "sun-drying".

The blocks with cement must now be cured for about two weeks while the cement sets. It is important to follow the directions for curing. If you do not, the blocks may be weak and full of cracks, and therefore unusable for building.

a - Remove the block from the block press, holding it carefully.

b - Place it on leaves, grass or boards on flat ground. The block should not touch the ground (Fig. 1).

c - The blocks should be under shelter or covered with something so that they are out of the rain and sun for at least the first day.

d - Let the blocks dry like this for one day.

e - After one day the blocks are a little stronger so that they can be stacked for further curing.

Stack the blocks on boards or on very flat, hard ground up to five blocks high. Place them so that they touch each other. Make the stacks under a cover if possible, to keep them out of the sun (Fig. 2).

f - The blocks must be kept moist by sprinkling water on them twice a day. Put grass or leaves on top to help keep them moist (Fig. 2).

g - After two weeks of watering the cement has set properly and the blocks can dry completely. They are now ready for use.

Blocks without cement simply need to be dried in the sun. Let the blocks dry in the sun for two weeks; then they are ready for building (Fig. 3).

NOTES:

Fig. 1

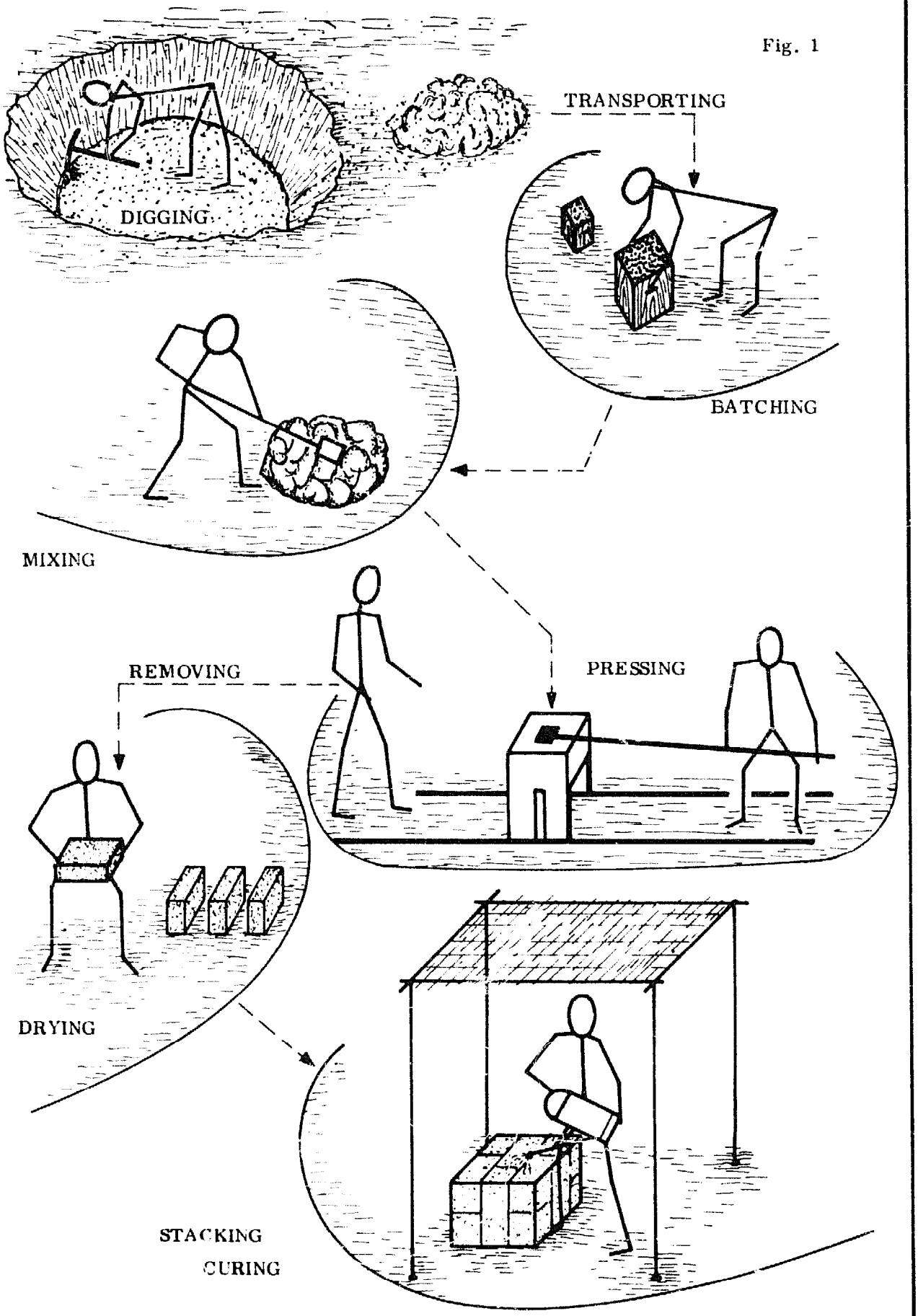

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LANDCRETE BLOCKS.

PLANNING THE WORK

- PLAN OF OPERATIONS: Good planning can make the work of block-making go faster and easier.

The places where the different steps are carried out should be as close to each other as possible, so that there is a continuous step by step flow of laterite from the soil pit to the finished wall. The soil and blocks should be transported as little as possible.

If there is more than one building to erect, some operations can be moved.

There should be a smooth flow (Fig. 1) of:

a - digging
b - transporting
c - batching
d - mixing
e - testing
f - filling
g - pressing
h - raising
i - removing/drying
j - stacking/curing
k - walling up

You can make a layout like the one in the picture (Fig. 1) or you can lay out the operations in a straight line; or anything in between, whatever suits you and the situation best.

Several factors can be important in deciding what sort of digging pits you will have. If the good soil goes deep, all the soil can come from one pit. However such a large pit might be ugly and undesirable; several small pits could be a better solution in some cases.

The possible future uses of the pits should also be considered. They could form a part of a drainage system, a water storage tank, a sewage pit, a soak-away, and so on. This of course, provided that the planning is done beforehand.

NOTES:

Fig. 1

NUMBER OF MEN							KIND OF ACTIVITY
ONE MAN ONLY	1	1	2	2	3	4	DIGGING
				2	2	3	TRANSPORTING
		1	2	2	2	1	BATCHING AND TESTING
						2	MIXING
				1	1	1	FILLING AND OILING
	1	1	2		1	1	PRESSING
				1		1	RAISING OUT
					1	2	REMOVING AND PLACING TO DRY
1	2	3	6	8	10	15	TOTAL MANPOWER

Stacking, curing and transporting the blocks tc the actual place of building can be done every morning by the soil diggers.

They can do this only if they have dug some soil in advance during the previous day, so that the rest of the workers have the materials to continue their operations of batching, mixing etc.

- LABOUR: From one to fifteen men can work on block-making. If there are plenty of workers, they should be organized to keep the block press going constantly, so it is used to maximum efficiency.

  To do this, there must be a steady supply of soil-cement mix ready to put into the machine. Make the mixing platform big enough so that there is room for one pile of already mixed landcrete and one pile which is being mixed.

  You can use the rough table at left as a planning guide to divide the labour, but experience will be the best guide (Fig. 1).

  In any case the work should be divided so that everyone is busy all the time. If the block press filling worker has to stop and wait for prepared landcrete, he or another man should be switched to doing soil preparation.

  Workers should relieve one another in their jobs every few hours to prevent boredom with the work. After a few days of such rotations, the workers will each become skilled and efficient at three or four of the different steps of block-making.

  It is important to share the work fairly to keep up the morale and enthusiasm among the workers.

- NUMBER OF BLOCKS: You should know from the start approximately the number of blocks that will be needed for the building. This is necessary to be able to schedule the block-making, curing and building.

  To find the approximate number of blocks to be made, you must know the size and plan of the building. Take measurements of the lengths of the walls and add these up to get a total. Multiply this wall-length by the total height from the plinth course to the top of the wall; this gives you the total wall area in square meters. This number, multiplied by 13,5 (the approximate number of blocks per square meter) gives you the total number of blocks to be made.

- REMEMBER: Wall area in square meters x 13,5 = Number of blocks. (Also, see the Tables of Figures, pages 237 and 238).

NOTES:

Fig. 1

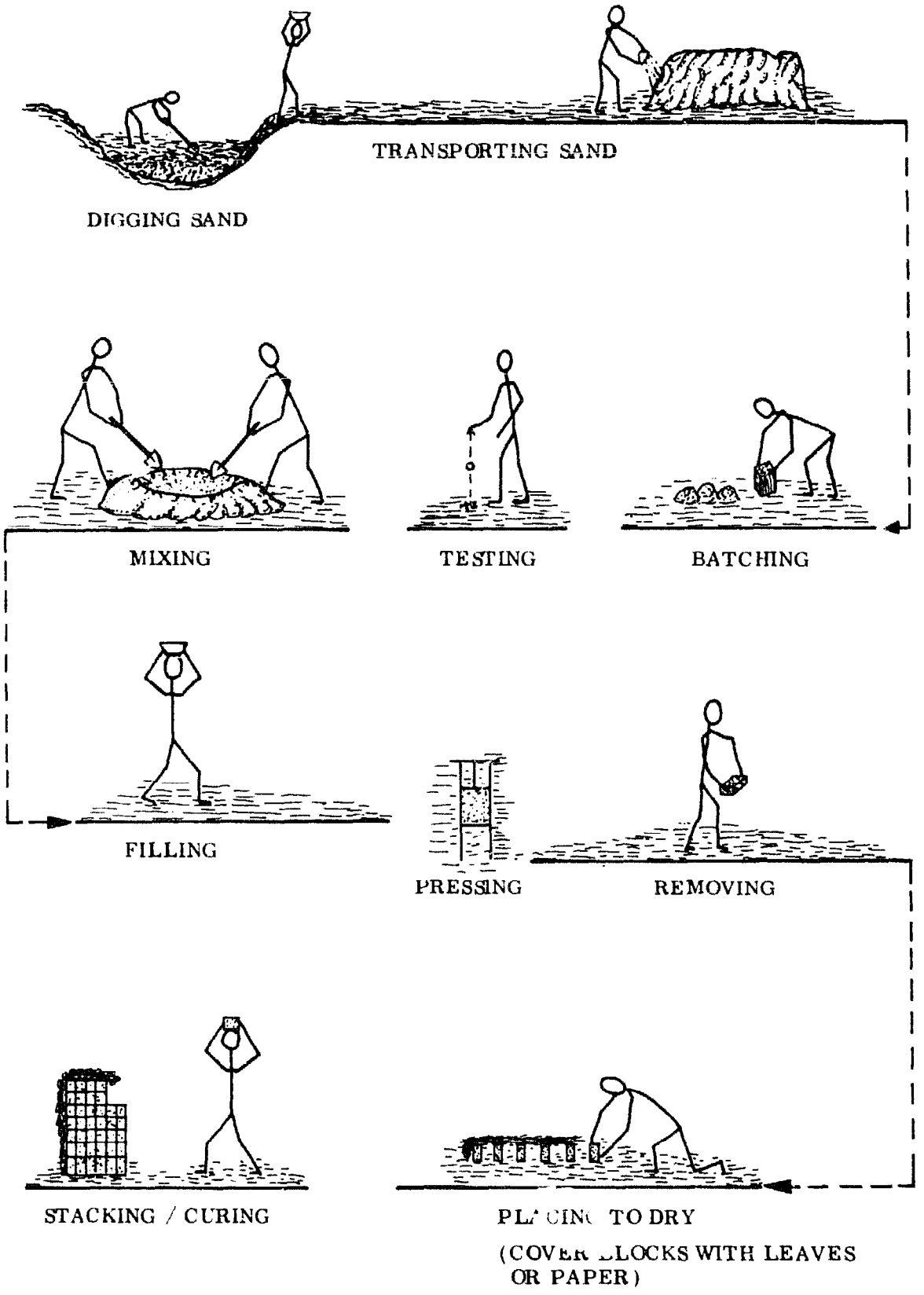

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SANDCRETE BLOCKS.

SANDCRETE BLOCKS

The term sandcrete comes from "concrete" by replacing the first syllable "con" with the word "sand". This is done to make it clear that this building product contains only sand as an aggregate, and no stones. It can also be called "fine-grained concrete" but the new term sandcrete is preferred as it corresponds to landcrete.

A pallet is put into the mould box of the machine (see page 29) and the box is filled with a mixture of cement and sand; then the lid of the machine is used to compact the material to the required size (for proportions of the mix, see the Tables of Figures, page 234).

Unlike landcrete blocks, sandcrete blocks have to be made upon a pallet, as they are too soft to be carried when freshly made. Differently shaped blocks can be made with this machine by changing the height of the pallet or by using inserts.

MAKING THE BLOCKS

Making blocks with this machine is similar to making landcrete blocks.

a. Put one or more pallets into the mould box, according to how thick you want the blocks.

b. Half-fill the mould box with the ready mixed sandcrete.

c. Compact the corners with a piece of wood.

d. Fill the mould box completely and again compact the corners. Add a little more if necessary to fill the box flush to the top edge.

e. Compact the sandcrete by repeatedly banging the heavy lid on it, until the lid fits exactly in its lowest position. Sometimes the lid does not close properly because the mould box is too full. In this case, scrape off a small amount of sandcrete with your trowel and repeat the compaction. If you fail to do this the block will be wedge-shaped and difficult to set in the wall.

f. Open the lid wide and pull the handle to push the block out.

g. Remove both pallet and block at the same time and set them in place for hardening and curing.

- NOTE: Before use, the pallets must be soaked in water thoroughly, to prevent them from bending during the drying process. If this is not done the pallets will probably bend and crack the blocks.

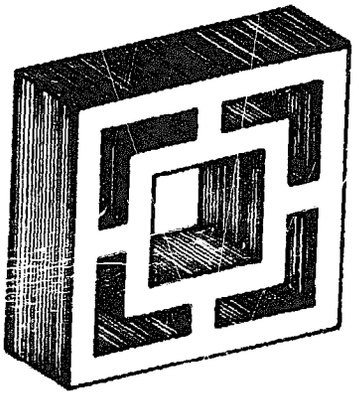

Fig. 1

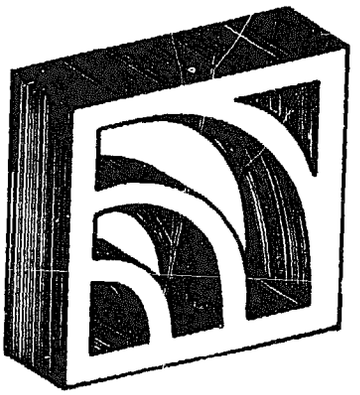

Fig. 2

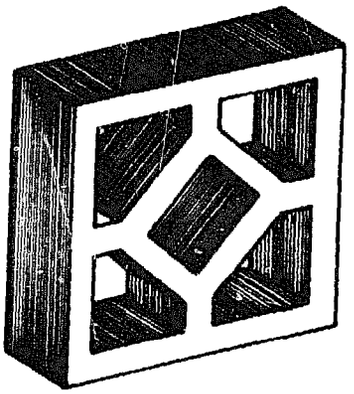

Fig. 3

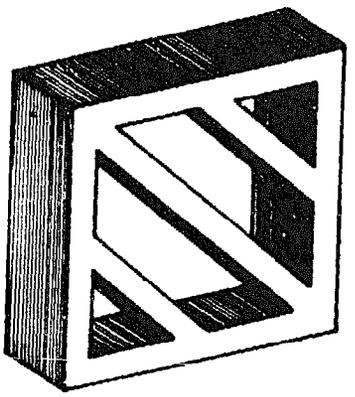

Fig. 4

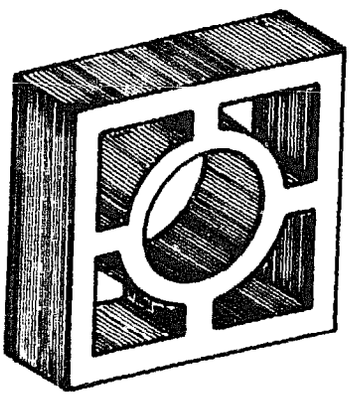

Fig. 5

N P V C	
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DECORATIVE BLOCKS.

PLANNING THE WORK

As in the plan of operations for making landcrete blocks (page 187), for sandcrete blocks also the speed and ease of the work depend on how well it is planned.

Fig. 1 on page 190 shows how the block-making can be planned.

DECORATIVE BLOCKS

Originally, a decorative block was understood to be a solid block with decorative textured faces. What we now commonly call decorative block is in fact part of a decorative openwork screen built into an opening. The correct term is "decorative grille" (also spelled "grill").

This kind of block is made in a special iron mould. It can serve several purposes:

- To give an attractive appearance
- To provide light without installing burglar-proofing or any kind of louvres, shutters, etc.
- To provide permanent ventilation without using ventilation blocks
- Or a combination of two or three of the above requirements.

The illustrations of blocks on the opposite page show that almost any design is possible, given a fertile imagination. Remember however that the strength of the blocks depends also on their shape (Figs. 1 to 5).

- NOTE: To make it easier to empty the mould, short pins can be welded onto each corner at the top of the mould. This allows you to tap the pins gently on a hard, level surface; thus loosening the block from the mould (Fig. 6).

  Drilling small holes into the bottom of the mould can also make it easier to remove the block. The holes allow air into the mould as the block comes out.

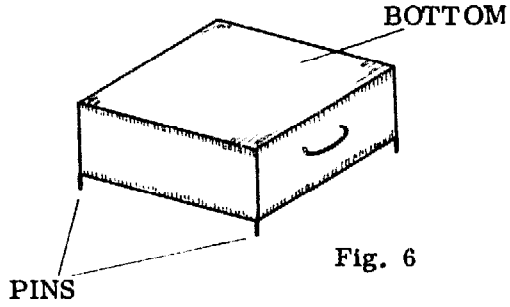

Fig. 6

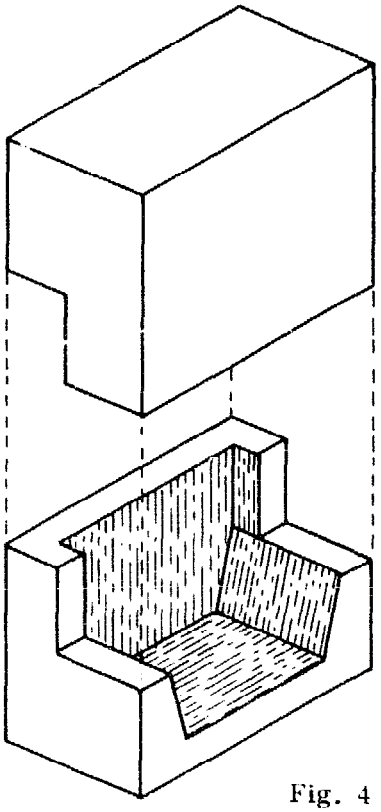

Fig. 4

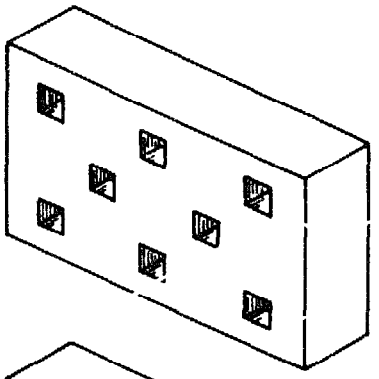

Fig. 1

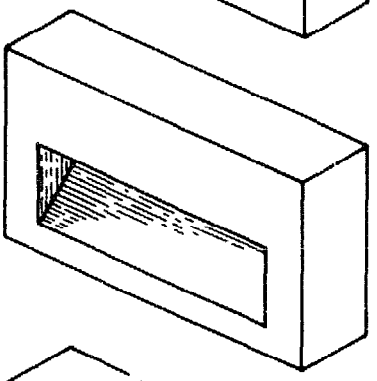

Fig. 2

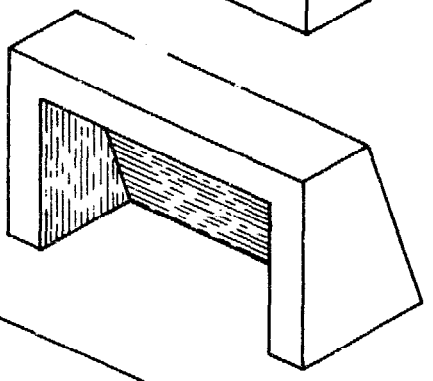

Fig. 3

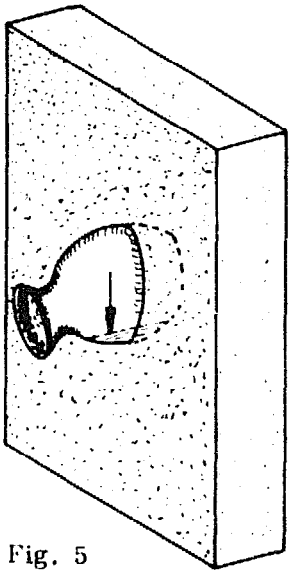

Fig. 5

INSIDE OF POT SHOULD BE HIGHER SO THAT NO WATER CAN BE TRAPPED INSIDE (SEE ARROW)

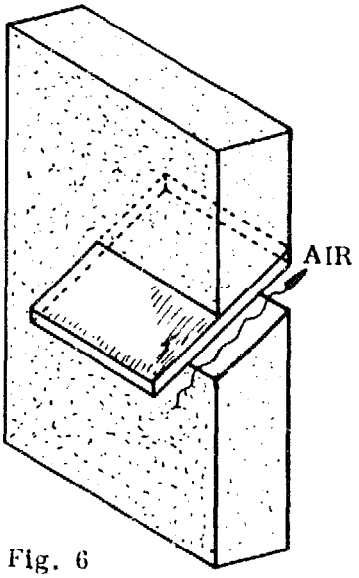

Fig. 6

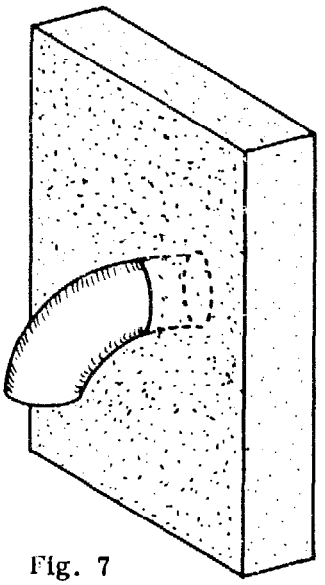

Fig. 7

N P V C	
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VENTILATING BLOCKS.

VENTILATING BLOCKS

These are blocks which have an opening (or several openings) in them. They are used to ventilate rooms, stores, the spaces above ceilings etc.

There are various types of ventilating blocks. Some are designed to keep out rain, others include mosquito-proofing or a decorative front face (Figs. 1, 2 & 3).

In cases where a maximum amount of ventilation is desired, it is advisable to make a ventilating unit which is constructed out of two identical halves (Fig. 4). The inside of this unit can be painted in a bright colour, to increase the amount of light inside the room.

Simply shaped blocks for ventilation can be made in the sandcrete block machine by inserting wooden blocks according to the desired shape.

More complicated designs usually require a specially made wooden mould. The advantage of this kind of mould is that any size and shape of block can be made.

Pre-cast sandcrete or concrete are not the only choices of materials for ventilating units. Local potters' skills in baking earthenware can be used and one can design ventilating units from clay. Existing clay shapes can be used, such as tiles and pots (Figs. 5 & 6) or new shapes can be invented (Fig. 7).

When designing these ventilating units keep in mind the direction of the driving rain. Make sure that the inside of the unit is higher than the outside, and that there is no place for water to become trapped inside the unit to make a breeding place for mosquitos (Fig. 5).

Apart from the above considerations, there is no limit to the imagination of the Rural Builder in designing different shapes and kinds of ventilating units.

NOTES:

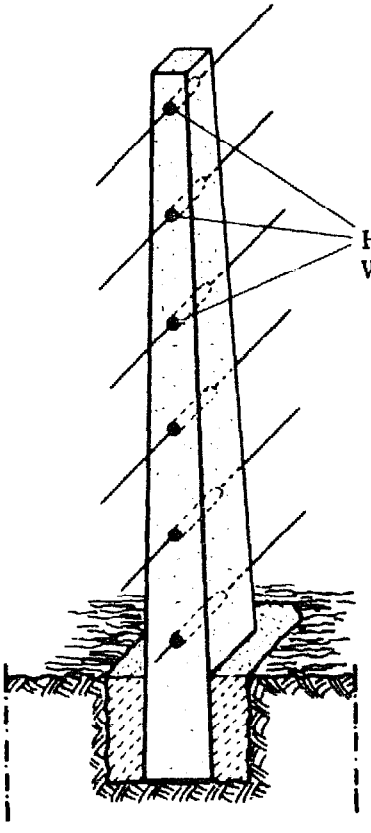

Fig. 1

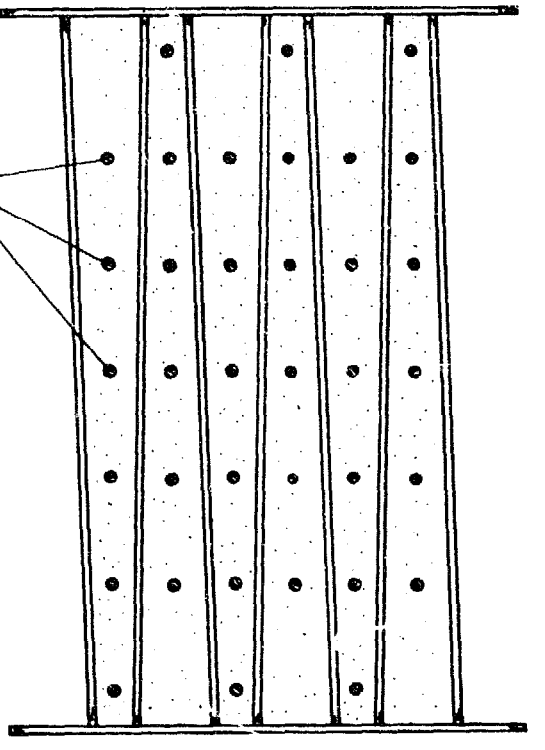

ARRANGEMENT OF SHUTTERING BOARDS

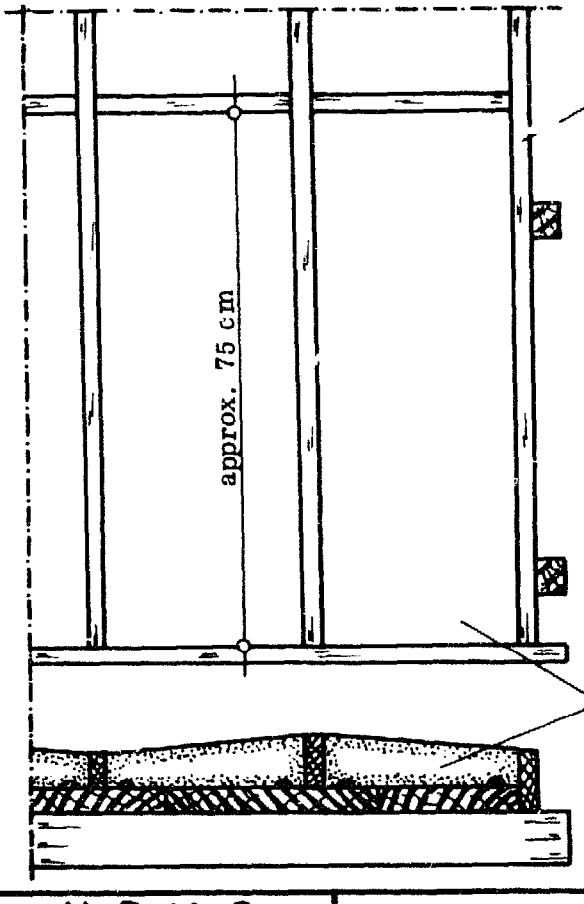

Fig. 2

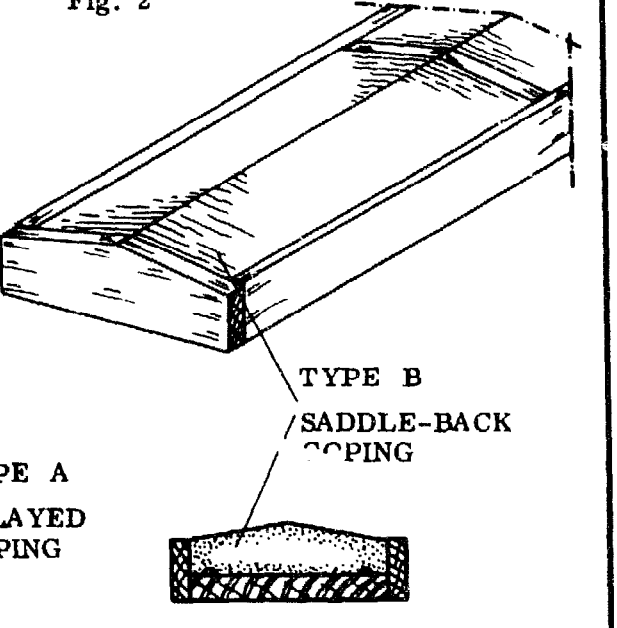

N P V C	
196	PRO.

PRECAST CONCRETE MEMBERS.

PRECAST CONCRETE MEMBERS

Many of the components of a building are prefabricated. This means that they are made in advance at any time and place, and can be used for any building. The most common examples are the various sorts of blocks, plywood, roofing sheets etc.

In the same way, many reinforced concrete members of the structure can be made well in advance so that they are ready to be used as the construction proceeds and they are needed. These are referred to as "precast" members, as opposed to the "cast-in-situ" members.

Generally speaking, prefabricated construction is divided into two classes with regard to buildings:

a - Prefabricated units produced in a factory and transported to the building site
b - Units produced by the contractor in a yard next to the building site.

Since Rural Building is understood to be conventional building and not factory production, the first method does not apply to us.

It is becoming more and more common however for the contractor to prefabricate members near the building site, although the possibilities of this method are limited to small-scale applications.

In Rural Building the most frequently made precast concrete members are:

- REINFORCED CONCRETE LINTELS: These cannot exceed 1.5 m in their length, as otherwise they will be too heavy and impossible to set in place without using a lifting device.
- REINFORCED CONCRETE POSTS: For fencing purposes (Fig. 1).
- REINFORCED CONCRETE PILLARS: These should not be too heavy to be set up under rural conditions.
- CONCRETE COPINGS OR CAPPINGS: These are of various shapes, with or without reinforcement (Fig. 2).
- REINFORCED CONCRETE SLABS: Of limited size and thickness, used to cover manholes or to serve as draining boards in kitchens, etc.

NOTES:

PLANNING THE WORK

All the plans and if possible, detailed drawings must be available before you start to make precast concrete members. Careful planning, supervision and performance are all necessary in order to obtain the desired product.

- SAVING TIME: As soon as the required materials are available, a group of the workers can start production of precast concrete members. The earlier they begin the better, because the concrete needs to be cured for some time before it is used in the building. By the time the precast member, for example a lintel, is needed the curing process will be complete and the lintel can simply be set into place.

  In contrast to the cast-in-situ method, this method allows construction to proceed without delays caused by waiting for concrete to harden; and without being hindered by shuttering and strutting. In this way the total construction time is shortened.

  This time-saving can become very important, for example if the wet season is approaching and the building has to be done before that time.

- SAVING MATERIALS: Since precast concrete members can simply be made on levelled ground, there is no need for poles and braces or other strutting to hold up the shuttering. Curing is also made much easier.

  In addition, the same formwork can be used repeatedly if several members of the same size and shape have to be made.

  If there is no proper storage space for the cement on a job, it is better to precast as many members as possible; thereby using up the cement before it gets spoiled.

- NOTE: The more time, materials and money you save, the happier your client will be. Not only that, but your reputation as a Rural Builder will grow in the eyes of the people around you and be appreciated in the society.

NOTES:

GLUE

Glue is a liquid which is used to stick materials together, particularly on wooden surfaces.

In Ghana's Upper Region, the Rural Builder cannot use glue very often, because of the problems caused by the difference in humidity between the dry and rainy seasons. Glue is sometimes applied to make joints stronger, but it should not be used alone. There must always be some additional fastening; either screws or nails. To rely on joints fastened simply with glue is asking for trouble.

Three points should be kept in mind when you use glue:

a - The parts to be glued have to be in close contact.
b - There must be a large area of contact for glueing.
c - End-grain does not glue well, so a joint which consists mostly of end-grain will be weak.

There are many different glues but in Rural Building we use only two kinds; synthetic glue and contact glue.

- SYNTHETIC GLUE: The most common synthetic glue is PVA (polyvinyl acetate) glue. It is a milk-white glue.

  The parts to be glued should be clean and well-fitting. The parts are squeezed together immediately after the glue has been applied, and clamped together until the glue has set hard. The joint will have considerable strength after the glue has set for one hour. PVA glue is not waterproof. If the joint must be waterproof, special kinds of glue have to be used.

- CONTACT GLUE: This glue is used primarily to glue laminated plastics such as Formica or similiar materials to sheet materials.

  The glue is spread evenly over both surfaces. A toothed spatula can be used for this purpose. After fifteen minutes the surfaces are pressed together. It is important to take care that the surfaces are exactly in the correct position when they are put together. Once the surfaces stick they cannot be separated again for adjustment.

  Take care that no air is trapped between the two surfaces when they are glued, because afterwards it will be impossible to get the air bubbles out.

PROTECTIVE FINISHES

In Rural Building we have the following finishes which are applied on wood or masonry work:

- Oil paint
- Synthetic paint
- White wash
- Cement paint
- PVA Emulsion paint
- Varnish

OIL PAINT

The traditional type of oil paint has a vegetable oil base (linseed oil) and a pigment which gives it colour.

Oil paint is usually applied in three coats. Each coat is of a different composition and they cannot be mixed.

- Priming coat
- Undercoat
- Finishing coat

Follow the directions on the tin when using these paints. Oil paints can be diluted only with thinners, such as turpentine.

SYNTHETIC PAINT

Synthetic paints have a chemical base and a pigment. These paints dry more quickly than oil paints and they are more weather resistant.

Read the directions on the tin before using the paint.

WHITE WASH

White wash is often used for interior work. It is composed of lime and water and it is not water resistant. Its lack of water resistance and its poor wearing qualities make it inferior to emulsion paint as a finish for outside surfaces.

White wash is often used as a priming coat for emulsion paints. It fills in the pores in cement or plaster and makes the surface smoother so that less emulsion paint is needed.

After mixing the lime with water it is advisable to leave the white wash for a day to stand, to be sure that no more chemical reactions are taking place. Follow the manufacturer's directions on the label when mixing the white wash.

CEMENT PAINT

Cement paints are often used externally. They contain white or coloured Portland cement and are sold in powder form. This paint should be made workable with water only; when dry it forms a waterproof seal on the concrete or masonry.

PVA EMULSION PAINT

Polyvinyl acetate emulsion paint has a latex (rubber) base and a pigment for the colouring. This paint is used mostly for internal and external masonry work.

The latex paint can be diluted with water if necessary to improve its workability. The paint should be applied in thin layers and the directions on the label should be followed. Read them before you start work.

VARNISH

Varnishes are used to protect wood. There are two kinds of varnish: oil or spirit. Oil varnish can be used for external work. It is diluted if necessary with turpentine.

Spirit varnish is only used for internal work such as for furniture. This varnish is not very strong or water resistant. Spirit varnish can be diluted with commercial alcohol.

PAINTS AND VARNISHES: PURCHASING

Paints and varnishes are sold in containers of one or more litres. On each container there should be a description of how to apply the paint or varnish. There should also be a date stamped on the container, to indicate how long the paint or varnish will last (when it will be too old to use any longer).

NOTES:

Fig. 1

PLYWOOD

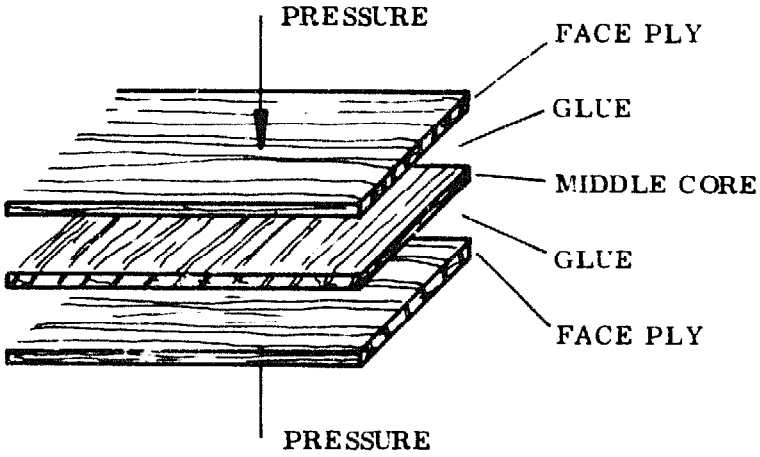

Fig. 2

3-PLY-BOARD

Fig. 3

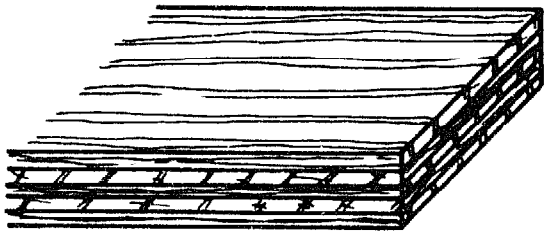

5-PLY-BOARD

Fig. 4

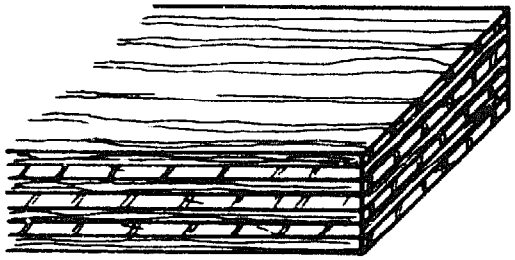

7-PLY-BOARD

Fig. 5

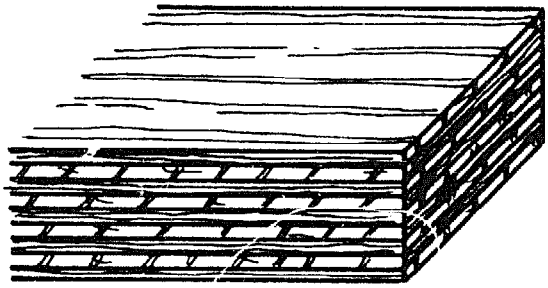

9-PLY-BOARD

N P V C		SHEET MATERIALS.
202	PRO.	

SHEET MATERIALS

Even as new and wonderful materials are becoming available to the Rural Builder, timber is still in very great demand. Wood is easy to work with, adaptable and durable when cared for properly.

Sheet materials manufactured from sawmill wastes are used more and more, both because they save money and because they do not have some of the problems with shrinking or splitting that affect natural materials.

The sheet materials we deal with in Rural Building are: plywood, blockboard, hard board, chip board and decorative laminated plastics.

PLYWOOD

Plywood manufacture is the oldest means of improving the properties of timber. Large sheets can be made, free from defects and unaffected by shrinkage and splitting.

The plywood is made by glueing together several thin layers, called plies or veneers, so that the grains of each run crosswise to its neighbours. There is always an odd number of plies so that the grains of the two outer layers run in the same direction. This is so that the plywood remains flat (Fig. 1).

Plywood is so useful because of its special properties:

- It is stable and will not expand or shrink like solid timber; however it will absorb moisture and may tend to curl as the surface layers expand a bit.
- It is very strong because of the crossed grain structure. Even the thinnest plywood cannot be split.

The number of plies can be from 3 to 9, making sheets which are 3 to 25 mm thick (Figs. 2 to 5).

NOTES:

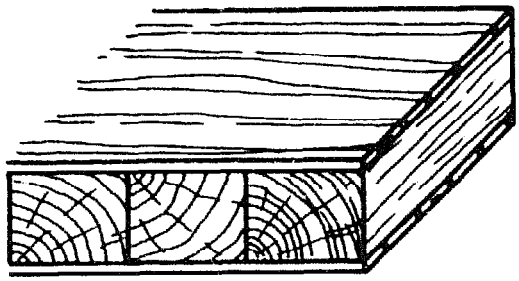

Fig. 1

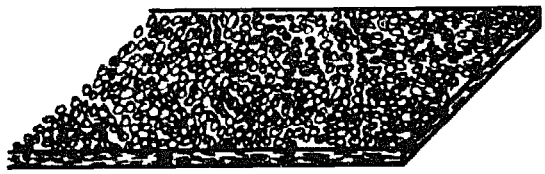

Fig. 2

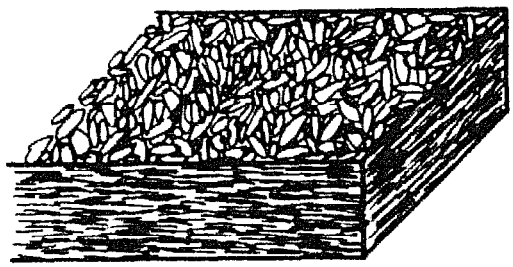

Fig. 3

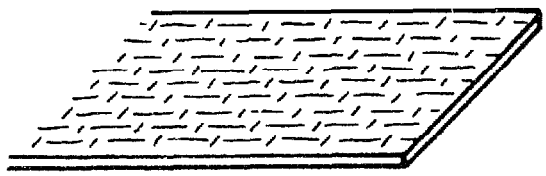

Fig. 4

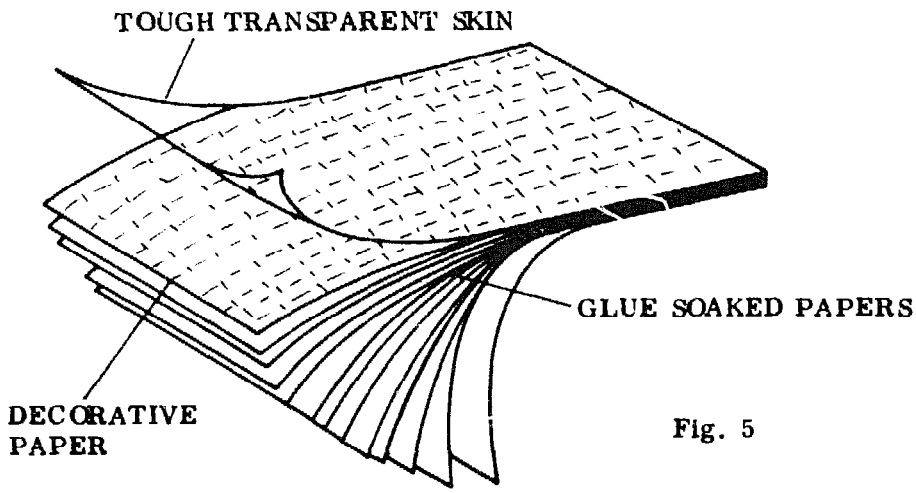

Fig. 5

N P V C	
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SHEET MATERIALS.

BLOCK BOARD

This is a variation of plywood. A core of wood strips is glued together and faced with one or more veneers on each side (Fig. 1).

HARD BOARD

Low quality wood and wood wastes are ground and combined with water and glue to form a pulp. This mixture is spread between smooth aluminium sheets under great heat, forming a board. Hard boards have a smooth surface and a coarse side. They are available in thicknesses from 3 to 6 mm (Fig. 2).

CHIP BOARD

This is made from wood chips bonded together with glue. The chips are sorted, dried and mixed with the glue. Then they are spread on a plate and bonded with great heat and pressure. Chip boards are made in thicknesses from 6 to 60 mm (Fig. 3).

The edges of chip boards should always be protected, as they tend to split. This is done by glueing wood strips around the edges.

DECORATIVE LAMINATED PLASTIC

Laminated means consisting of a number of thin layers. Laminated plastics such as Formica (Fig. 4) are made by assembling many paper sheets soaked in glue. A decorative paper, also soaked in glue, is laid on top and over this is laid a transparent paper soaked in a very hard transparent glue which gives a tough surface. The assembled layers are placed between polished steel sheets and pressed at a high temperature (Fig. 5).

Decorative laminated plastics are durable, clean looking, smooth and attractive. They are made in a variety of patterns.

NOTES:

Fig. 1

Fig. 2

Fig. 3

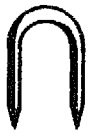

Fig. 4

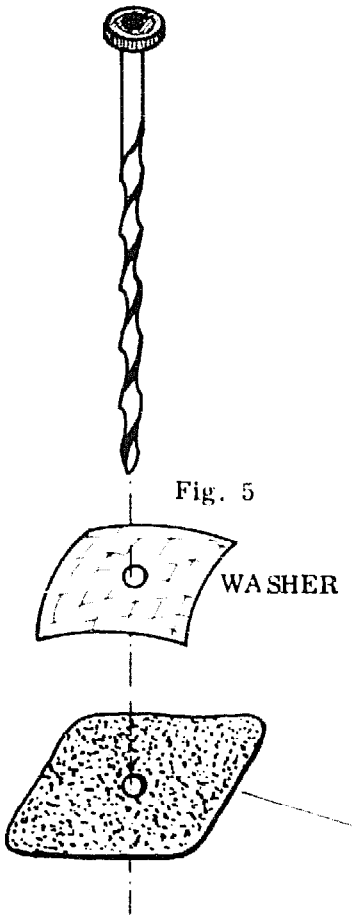

Fig. 5

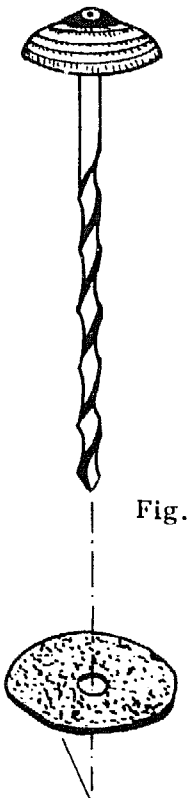

Fig. 6

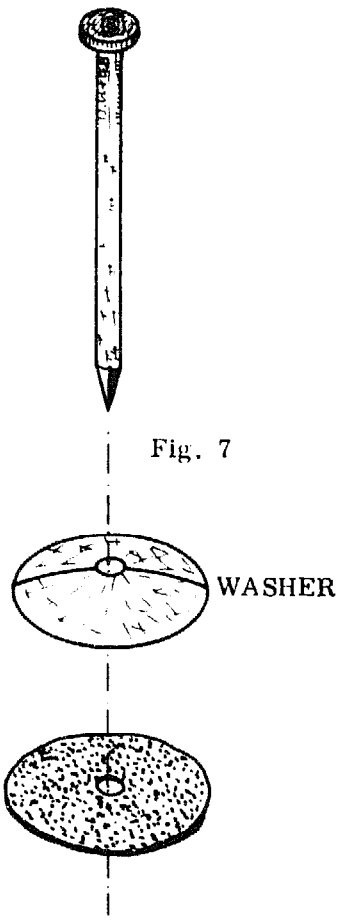

Fig. 7

ROOFING FELT

N P V C	
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WOOD FASTENINGS.

WOOD FASTENINGS

NAILS

Nailing is a fairly strong, cheap and quick method of fastening wood (see Rural Building, Basic Knowledge, page 92).

Nails have a head, shank and point and are usually made from mild steel wire. Galvanized, copper-plated or aluminium nails are used for work which will be in contact with water.

In Rural Building we use mostly wire nails. We group these into two classes: wire nails with flat heads and wire nails with very small heads, known as lost head nails. Some nails are used for special purposes, like staples, concrete nails and roofing nails.

- WIRE NAILS WITH FLAT HEADS: These are nails with large flat heads (Fig. 1). The head prevents the fastened member from being pulled off over the head of the nail.

  These nails are available in sizes from 7 to 310 mm long.

- WIRE NAILS WITH SMALL HEADS (LOST HEAD NAILS): These are wire nails with very small heads which can be punched or set below the surface of the wood and covered with putty. The disadvantage of this nail is that the nailhead can be easily pulled through the wood, so it cannot be used for heavy construction work (Fig. 2).

  These nails are available in sizes from 7 to 100 mm long. Small lost head nails are called panel pins.

- CONCRETE NAILS: These are hardened steel nails, available in different shapes and sizes. They are used to fix things to concrete or masonry (Fig. 3).

- STAPLES: These are U-shaped nails (Fig. 4) with two points. They are used to fasten wires and screens to walls or timber.

- ROOFING NAILS AND WASHERS: Special roofing nails are used for fixing corrugated sheet materials. They should be aluminium or galvanized metal to prevent rust, which could cause the nailhead to break off. The nails must be long enough to go at least 2 cm into the wood.

  Drive screws, or screw nails as they are sometimes called, are commonly used for roofing (Figs. 5 & 6) and they have largely replaced nails with plain shanks (Fig. 7). The drive screws are galvanized and the shank is 2 mm or more in diameter, with a steep thread around it.

Drive screws can be driven in with a hammer, but they are very difficult to pull out again.

There are different types: either with a metal washer already attached to the head of the nail (spring head roofing nail, Fig. 6, page 206), or with loose metal washers (Figs. 5 & 7, page 206)

The washers or the spring heads prevent the nails from being pulled through the roofing sheet. They should be thick and wide enough (at least 2 cm in diameter) so that they secure the sheets well.

Roofing felt is always used under the washer to prevent leaking. The felt should be larger in diameter than the washer. Place the washers correctly: the hollow side should face the roofing felt and the sheet.

ORDERING NAILS

When ordering nails, state the kind of nail; the thickness (in 1/10 mm) and the length (in mm). Also state the material of the nails.

Example: Lost head nails; 16 x 30; steel

NOTES:

SCREWS

After nails, screws are the next most common type of wood fastener used in Rural Building. Screws are superior to nails because:

- they have greater holding power,
- they cause less shock to the work when driven into it,
- and they are easily removed, without damage to the work.

Screws are made of mild steel, brass, copper or they are galvanized. Usually mild steel screws are used because they are stronger than the copper or brass ones.

The parts of a screw are: the head (a), the slot (b), the shank (c), the thread (d), the point (e) and the core (f) (Fig. 1, page 210).

Screws are classified according to the shape of their heads:

- Countersunk head screws (Fig. 1, page 210)
- Round head screws (Fig. 2, page 210)
- Raised countersunk head screws (Fig. 3, page 210)
- Coach screws (Fig. 4, page 210).

Posidriv or Phillips screws have a head which is not slotted across the full width like common wood screws. They have a cross-shaped recess into which a special screwdriver fits (see page 76).

- COUNTERSUNK HEAD SCREWS: The head of this kind of screw is flat on top and tapering underneath. The length is measured from the point to the top of the head (Fig. 1, page 210).

  These are general purpose screws, used where the head of the screw must be flush with or below the surface of the wood.

- ROUND HEAD SCREWS: The head of these screws is round on top and flat underneath, and the length is measured from the underside of the head to the point (Fig. 2, page 210).

  These are used only where the head can be visible and can project above the surface of the wood, and when fixing light metal, where the metal is too thin for countersinking.

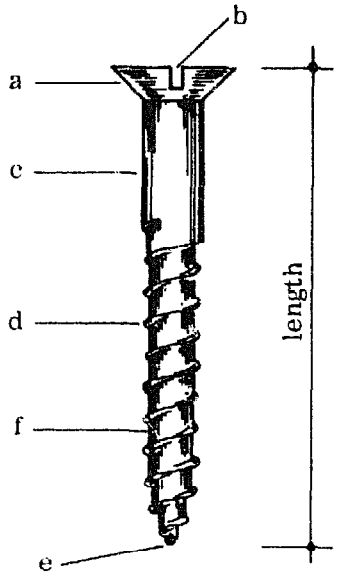

Fig. 1

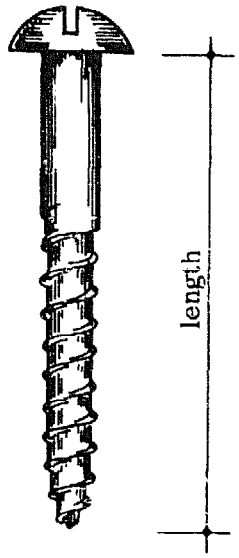

Fig. 2

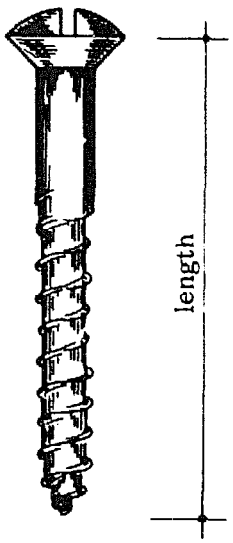

Fig. 3

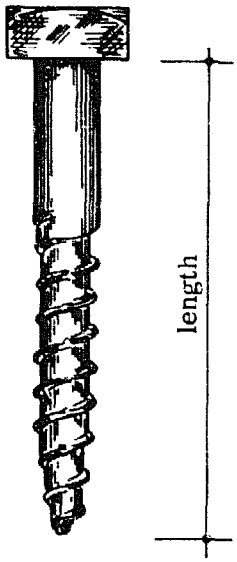

Fig. 4

N P V C	
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WOOD FASTENINGS.

- RAISED COUNTERSUNK HEAD SCREWS: The head of this screw combines the round and countersunk heads; round on top, tapering underneath. It is stronger than the round head screw because the head is less likely to break off. The length is measured as indicated in Fig. 3.

  These screws are used in fixing heavy fittings and thick sheet metal, where strength is needed.

- COACH SCREWS: This is a strong screw with a square head. Unlike other wood screws, it is turned with a spanner. Always put a metal washer under the head to prevent damage to the wood surface. The length is measured from the point to the underside of the head (Fig. 4).

  These are used for heavy construction work, for gate hinges, carriage work etc, where the head doesn't interfere.

ORDERING SCREWS

Screws are sold by number or in boxes containing a gross (144 screws). When ordering screws state the following in the order:

- thickness in mm
- length in mm
- kind of screw
- kind of metal
- amount needed

For example: 3 x 30; round head; brass screws; 3 gross or,
5 x 50; coach screw, mild steel with washers; 2 gross.

NOTES:

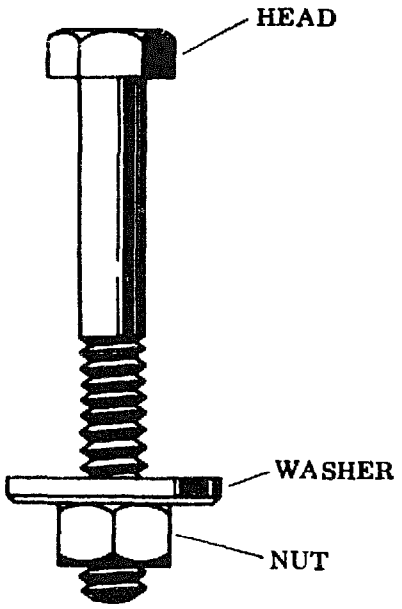

Fig. 1

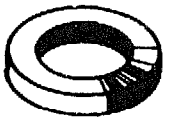

Fig. 3

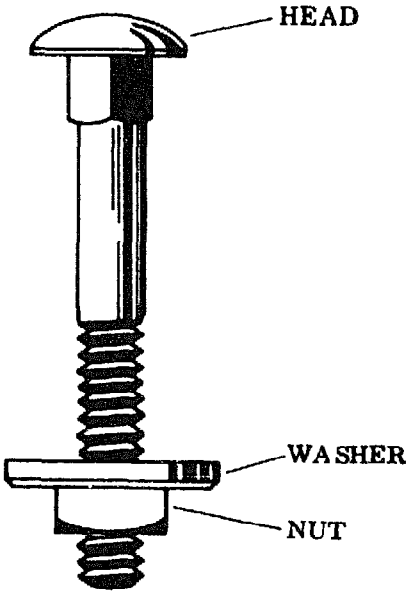

Fig. 2

Fig. 4

N P V C	
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WOOD FASTENINGS.

BOLTS AND NUTS

Bolts and nuts are yet another means of fastening two pieces together. Bolts have hexagonal heads and are tightened up with the nuts. Bolts and nuts are used for heavy construction work (Fig. 1).

If bolts are used in timber, washers must be laid under the nut to prevent it from sinking into the wood (Fig. 3).

COACH BOLT

These bolts have oval heads and a square shank just under the head. This is so that the bolt grips the wood and doesn't turn when the nut is tightened up (Fig. 2).

The advantage of these bolts is that the head doesn't project up, since it is rounded and pulled into the wood.

WASHERS

A washer must always be used under the nut with both coach and regular type bolts. Never put a washer under the head of a coach bolt.

Washers can be made locally from a square piece of metal with a hole drilled in it.

SPRING WASHER

To prevent the nut from loosening when it is fastening metal to metal, a spring washer can be put between the metal and the nut. (Fig. 4).

NOTES:

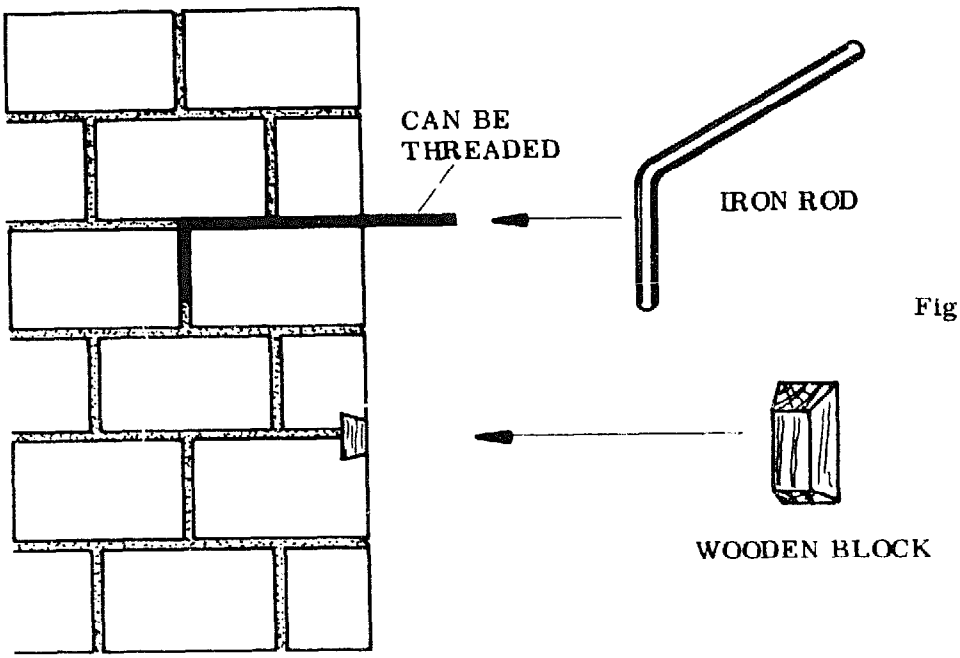

Fig. 1

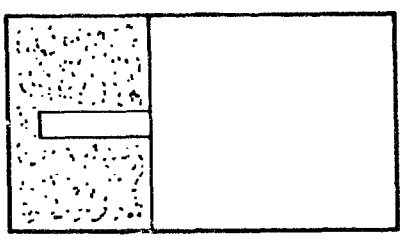

STEP 1

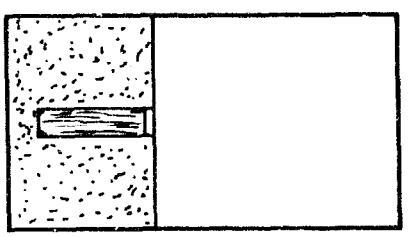

STEP 2

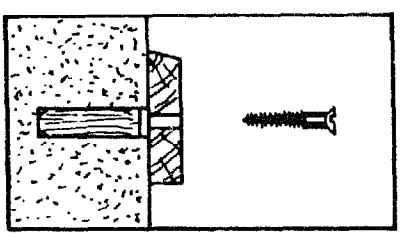

STEP 3

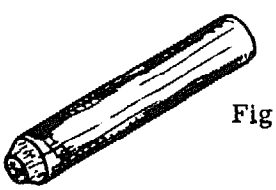

Fig. 2

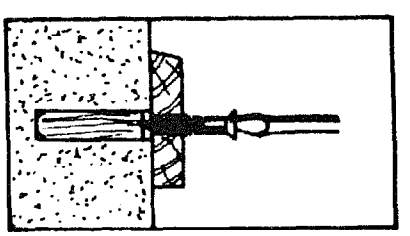

STEP 4

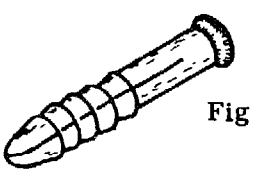

Fig. 3

N P V C		WOOD FASTENINGS.
214	PRO.	

ANCHORS

Fastening wood or other materials to concrete or masonry can be a problem. Often a screw will not hold in a landcrete block, or will not grip in concrete. Anchors can be used to solve this problem.

Anchors can be classed in two groups:
- anchors fixed during the initial construction and
- anchors which are fixed after the initial construction.

The first type of anchor can be an iron rod set into the wall during walling or casting, as is often done with the door frames. Threaded iron rods can be used, to receive a nut later (Fig. 1).

Another way is to insert wooden blocks in the masonry; into which screws, etc. can be driven later. For maximum strength the wooden block should be dovetail shaped (Fig. 1) and it should be cut and fixed in a way that its shrinkage will have as little effect as possible on the wall.

The second group are the devices used to fix a piece to an already existing masonry or concrete work. The most simple of these is a wooden plug. A hole is chiselled or drilled into the masonry and into that hole is inserted a cylindrical plug of wood, which has the same diameter as the hole. The length of the plug should be a little less than the depth of the hole. The plug is made out of hard dry wood and the end which enters the wall is chamfered to enter smoothly. When a screw is driven into the plug, the wood will expand or even crack and the screw is wedged into position (Fig. 2).

More complicated devices, all sharing the same principle of holding a screw or nail by expanding, are now available. The most common one is a plastic plug (Fig. ').

NOTES:

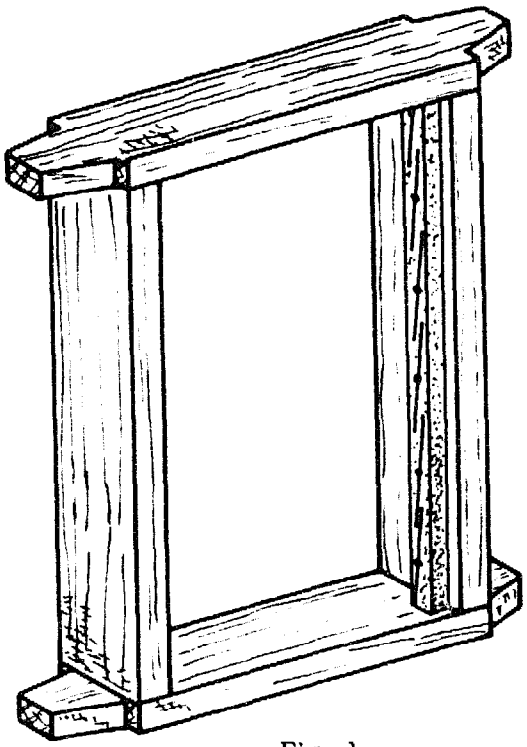

Fig. 1

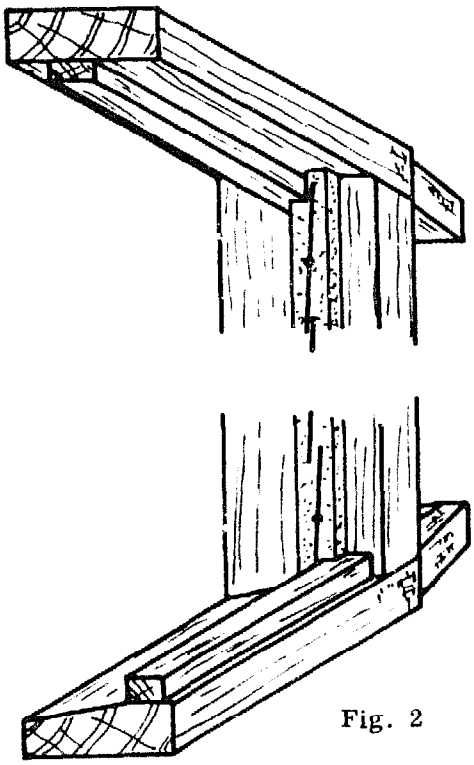

Fig. 2

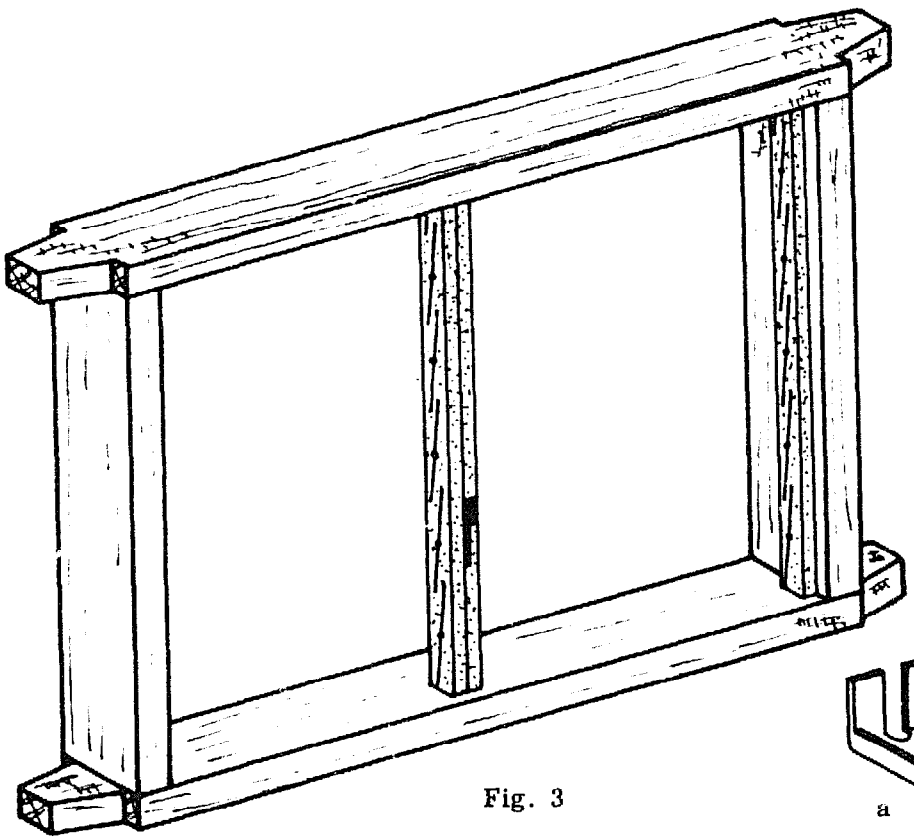

Fig. 3

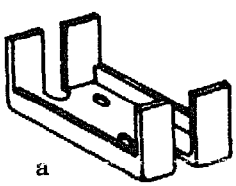

a

N P V C		DOOR AND WINDOW HARDWARE.
216	PRO.	

DOOR AND WINDOW HARDWARE

LOUVRE WINDOWS

Windows with glass louvres are often used in the tropics because of their various advantages: they can be opened without any waste of space in the room and in the closed position they still admit light to the room. Their disadvantage is that it is very difficult to make them water-tight.

Louvre windows are installed ready-made into the window frame (Fig. 1). When the glasses are inserted in the window, wooden beads or ready-made aluminium waterbars are fitted to the head and cill to keep out dust and rain (Fig. 2).

In wide windows where two sets of louvres are installed in the frame, the metal posts of the louvre frame are fixed together in the middle, forming a metal mullion (Fig. 3). A separate wooden mullion is therefore not necessary. We will learn more in the Construction book (windows) about the installation of a self-mullioning louvre frame. Specially made mullion connectors are sold in a separate set (Fig. 3a).

Louvre windows are available in mild steel or aluminium frames. The aluminium frames need very little maintenance, but they are more expensive and less strong.

The size of the window frame is determined by the size and number of the louvre glasses. The inside width is:

- the length of the glass plus 3,8 cm (the thickness of two frames).

If two or more louvres are set across the width of the window, then for each additional glass 3,8 cm, plus the glass length must be added to the inside width of the frame.

The inside height of the window frame is determined by the number of louvre glasses.

Inside height (in cm) of window frames according to the number of louvre glasses:

No.	2	3	4	5	6	7	8	9	10	11	12	13	14
Ht.	30,5	44,5	58,4	72,4	86,4	100,3	114,3	128,3	142,2	156,2	170,2	184,2	198,1

All the above measurements are for 6 in. (15 cm) glasses. If you have other sizes, follow the manufacturer's instructions.

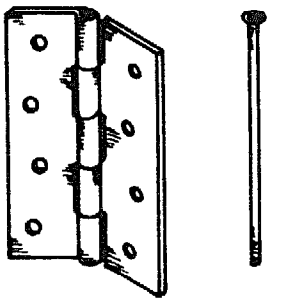

Fig. 1

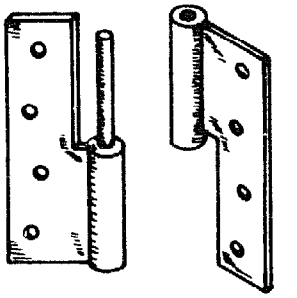

Fig. 2

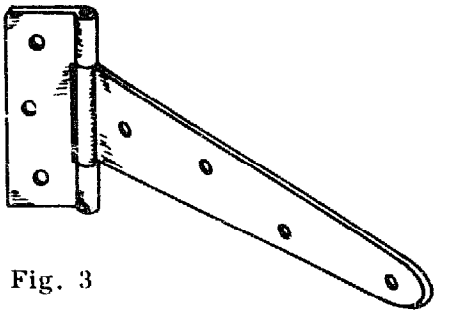

Fig. 3

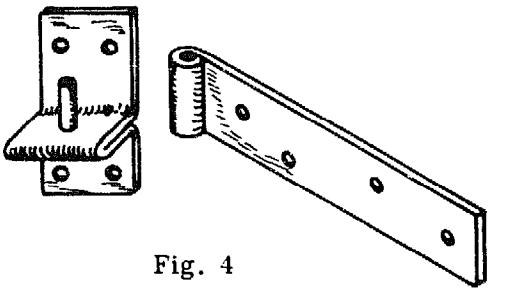

Fig. 4

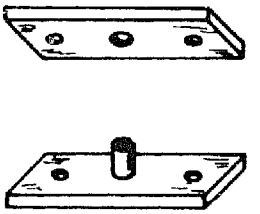

Fig. 5

N P V C	
218	PRO.

DOOR AND WINDOW HARDWARE.

HINGES

Hinges are available in almost countless different shapes, sizes and materials. The most common materials are steel, brass, and copper; or sometimes the hinge is only plated with brass or copper.

In Rural Building, we deal only with the most common types of hinges, which are butt hinges, H-hinges (Parliament hinges), T-hinges, band-and-hook hinges, and pivot hinges.

- BUTT HINGE: The ordinary steel butt hinge is cheap and durable, and it is the most common hinge for doors and casements (Fig. 1). It consists of two halves, also called leaves or flaps, held together by a pin. The pin may be removable or permanently fixed. If the pin can be removed from the outside when the door is shut and locked, the door is not burglar-proof.

  When the door is shut, the two leaves (one attaches to the door post and the other to the hanging stile of the door) are folded together. The leaves are usually set into recesses in the door and post.

- H-HINGE (PARLIAMENT HINGE): The H-hinge, sometimes called the Parliament hinge, is similar to the butt hinge. It consists of two leaves, each with a knuckle. The pin is set permanently into the knuckle of one leaf. The H-hinge is installed in the same way as the butt hinge (Fig. 2).

- T-HINGE: T-hinges are mostly used for large and heavy doors, gates and ledged and battened doors. They are available in different sizes.

  The hinge (Fig. 3) consists of a long mild steel strap, which is fixed to the outside of the door; and a cross bar which is hinged to the strap and attached with screws to the post of the door frame.

  For security reasons, the strap of the T-hinge should be fixed to the door with at least one coach bolt, so that no one can unscrew the hinge to enter the building.

NOTES:

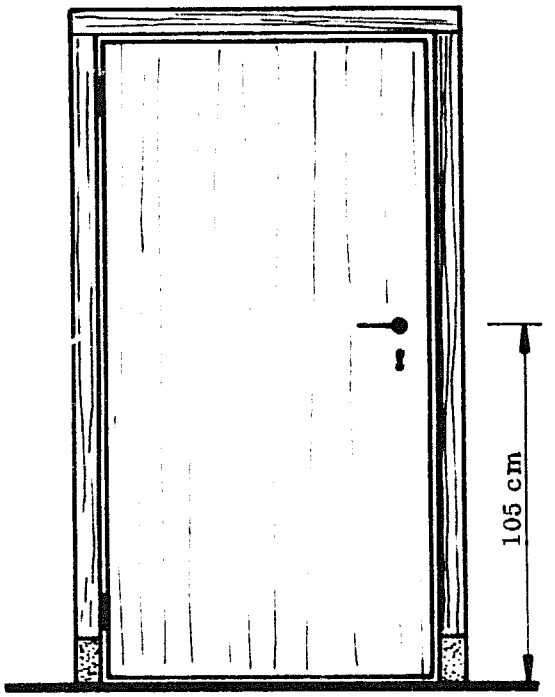

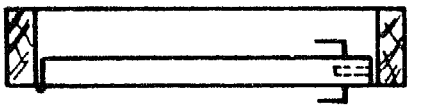

LEFT-HANDED

Fig. 1

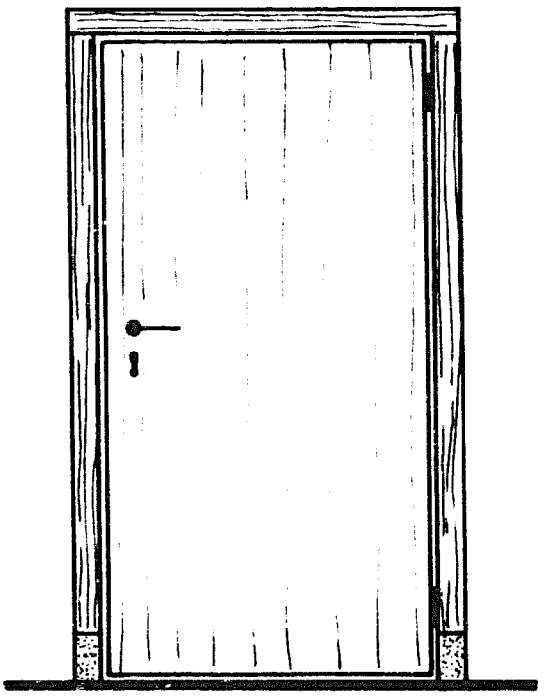

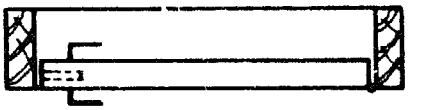

RIGHT-HANDED

Fig. 2

N P V C	
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DOOR AND WINDOW HARDWARE.

- BAND-AND-HOOK HINGE: The band-and-hook hinge is closely related to the T-hinge. It consists of an iron strip called the band, which drops onto a pin called the hook, which is attached to the frame of the door or window (Fig. 4, page 218).

  They are used and installed in the same way as T-hinges.

- PIVOT HINGE: For windows, we sometimes use pivot hinges. These consist simply of a plate with a pin, which fits into a hole in another plate (Fig. 5, page 218).

LOCKS AND FITTINGS

There are many kinds of locks and fittings available for doors and casements. The choice between them depends on the type of door or casement and its function.

Doors and casements may be either left or right-handed. When the door opens towards you with the hinges on the left, it is a left-handed door (Fig. 1); if the hinges are on the right, the door is said to be right-handed (Fig. 2).

Some types of locks can be used on only one type of door, either right or left-handed. Therefore, we have to know whether the doors are right or left-handed before we order the locks, so we can buy the correct ones. Some types of locks have a latch bolt which can be changed to work in either type of door.

The most common types of locks are:

- the mortice lock
- the rimlock
- the padlock

The most common types of fittings are:

- the hasp and staple
- the barrel bolt
- the tower bolt
- the casement fastener

Locks are normally fixed at a height of 105 cm, measured from the floor to the centre of the handle (Fig. 1).

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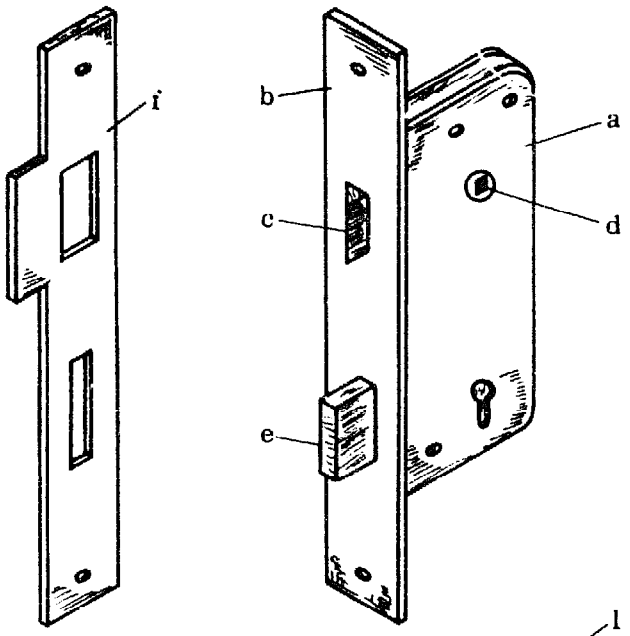

Fig. 1

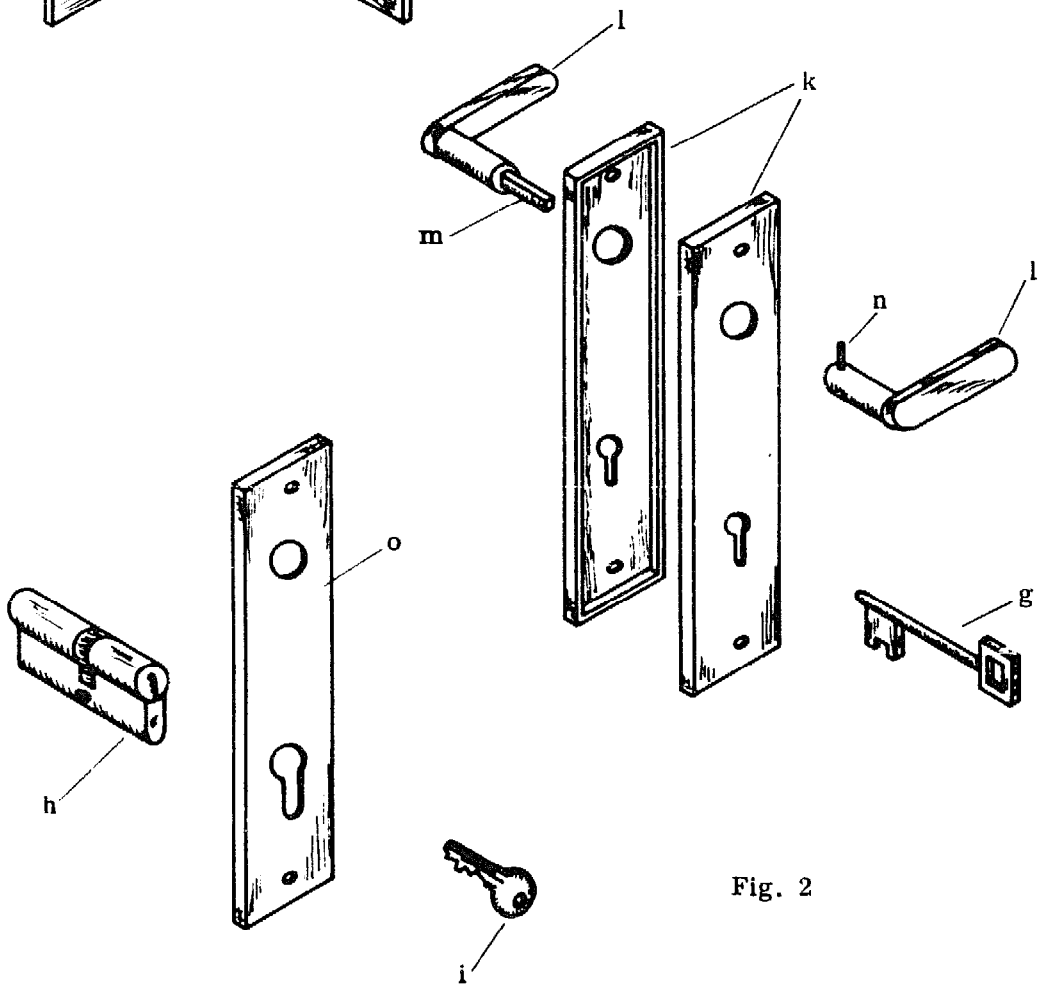

Fig. 2

N P V C		DOOR AND WINDOW HARDWARE.
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- MORTICE LOCKS: Mortice locks (Fig. 1) consist of a stock (a), faceplate (b) and the latch bolt (c) moved by the handle. The handle fits into the bush (d) and there is a lock bolt (e) moved by the key. The two bolts fit into holes in the striking plate (f) which is attached by screws to the door post.

  As the name suggests, the mortice lock fits into a mortice in the edge of the door. The stock should fit tightly against the sides of the mortice so that the door itself takes the strain, not the screws which only hold the lock in position.

  Mortice locks can only be installed in doors which are thick enough to receive a mortice. They are difficult to force open, since they are inside the door.

  Mortice locks are locked either with an ordinary key (g), which moves small levers inside the stock to push the lock bolt in and out, or with a locking cylinder (h), which operates the locking mechanism inside the stock. The advantage of the locking cylinder is that it is more secure, since a special key is needed to open and lock it (i).

- DOOR FURNITURE FOR MORTICE LOCKS: The door furniture (Fig. 2) consists of two leaf plates (k), two handles (l) and a spindle (m). The spindle is permanently fixed in one handle and secured in the other by a pin (n). The handle with the pin should always be inside the door, so that the pin cannot be loosened from the outside.

  The leaf plates are attached to both sides of the door with screws; or better, with specially made bolts which cannot be torn out easily. The leaf plates hold the handle in place and prevent damage to the keyhole. Sometimes separate leaf plates are used for the keyhole and the handle.

  The leaf plate for a mortice lock with a cylinder (o) has an opening into which the locking cylinder fits, instead of a keyhole.

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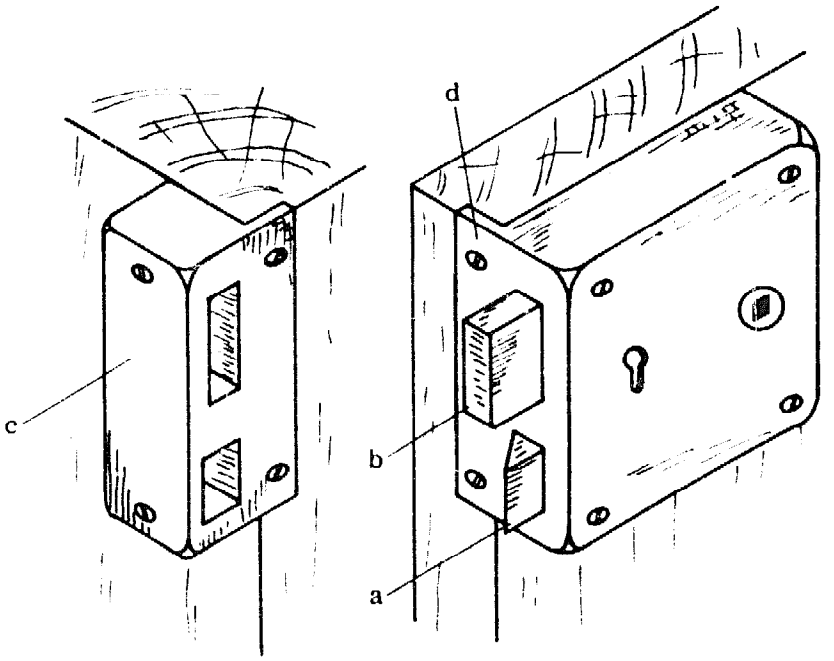

Fig. 1

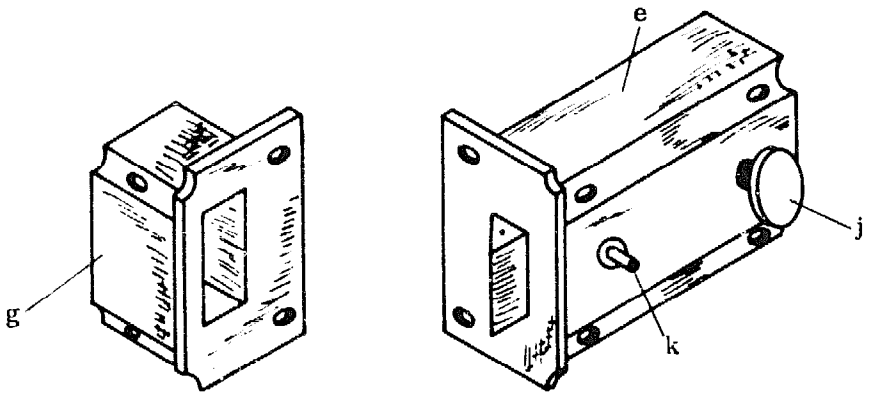

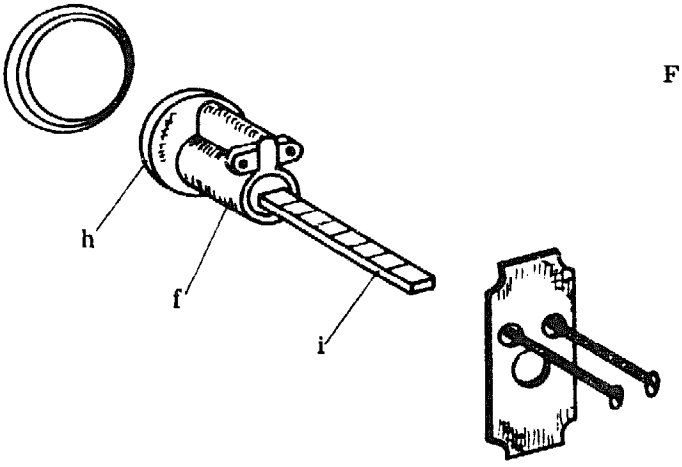

Fig. 2

N P V C	
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DOOR AND WINDOW HARDWARE.

- RIM LOCKS: Rim locks (Fig. 1) have a latch bolt (a) operated by a handle and a lock bolt (b) operated by a key from the outside or inside of the door. This kind of lock is attached with screws to the inside face of the door and the bolts shoot into a staple (c). There is a face plate (d) which is attached with screws to the door edge.

  On the outside of the door, two round plates are attached with screws, one to hold the handle and the other to cover the keyhole. The handles have a square spindle which fits into the bush of the lock.

  These locks are used on doors which are too thin to have mortice locks installed in them. Like the mortice lock, the rim lock is available with either an ordinary key locking system or with a locking cylinder.

- CYLINDER RIM NIGHT LATCH: This is a special kind of rim lock. It consists (Fig. 2) of a latch (e), a locking cylinder (f) and a staple (g). There is a face plate (h) which is part of the shell of the cylinder. The spindle (i) is fixed in the cylinder.

  The latch bolt is operated from the outside by a key which rotates the spindle. The spindle moves the bolt mechanism inside the latch.

  The bolt may also be shot back from the staple by turning the knob (j) of the latch from the inside. The locking arm (k) is used to fix the bolt in place, so that it cannot be operated from either side by the key or the knob, making the lock more secure.

- PADLOCKS: Padlocks have a ring which locks into a body. The locking mechanism can be either a lever mechanism or a locking cylinder, as with the mortice lock.

NOTES:

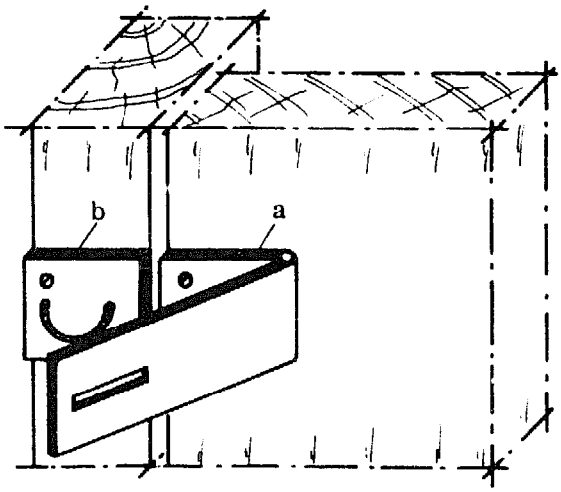

Fig. 1

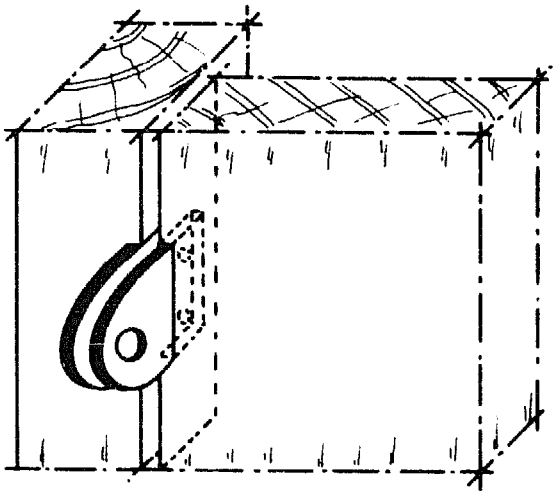

Fig. 2

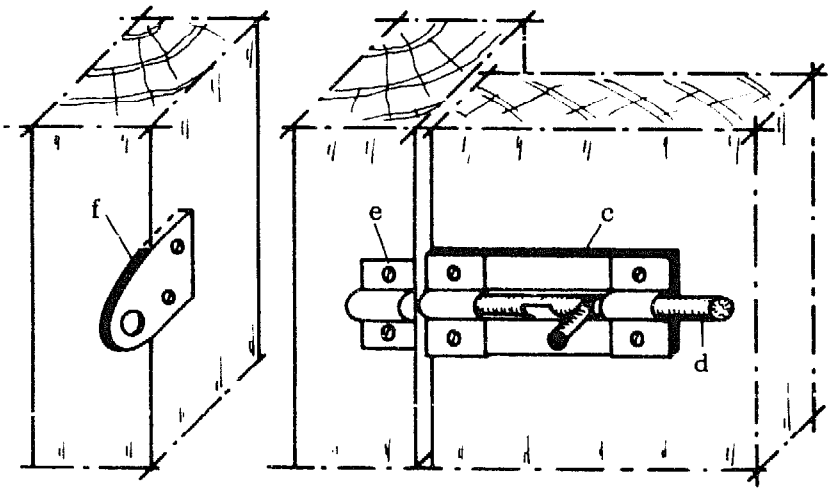

Fig. 3

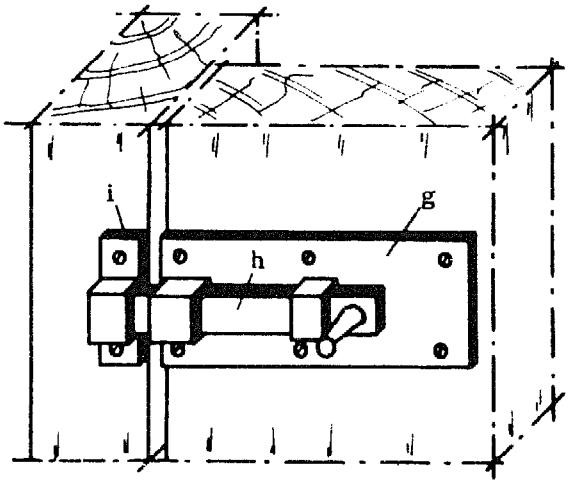

Fig. 4

N P V C

DOOR AND WINDOW HARDWARE

- HASP AND STAPLE: The hasp and staple (Fig. 1) is usually used in combination with a padlock. It is installed on doors which do not have to be opened very often, as it takes time to open it.

  The hasp (a) is screwed to the door or casement and the staple (b) to the frame. Some types of hasp and staple can be unscrewed from the outside. For security reasons, these types should be attached with bolts and nuts rather than with screws. The leaf of the hasp should be installed so that when closed it covers the screws.

  An alternative to the hasp and staple is the device shown in Fig. 2. This is an efficient way of locking doors with a padlock and the parts can be made by hand. Two small plates have holes drilled in them for the padlock and screws to pass through. The plates are attached with screws to the edge of the door and the post.

- BARREL BOLTS: The barrel bolt (Fig. 3) consists of a plate (c) with a round bolt (d). The bolt engages in a staple (e). The plate is attached with screws to the inside of the door or window and the staple is attached to the frame. Barrel bolts are often used to lock casements.

  A more effective staple can be made by hand (f), in the same way as the device in Fig. 2 above. It provides more security than the staple normally supplied with the barrel bolt since the screws are on the inside face of the post and cannot be so easily forced out. The bolt plate can also be attached with bolts and nuts to make it more secure.

- TOWER BOLTS: A tower bolt (Fig. 4) consists of a plate (g) with a flat bolt (h) fitted in it. The bolt engages in a staple (i) or in a striking plate in the frame. the plate and bolt are usually fixed on the door or casement.

NOTES:

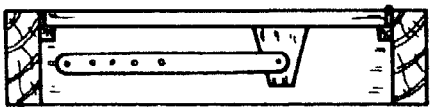

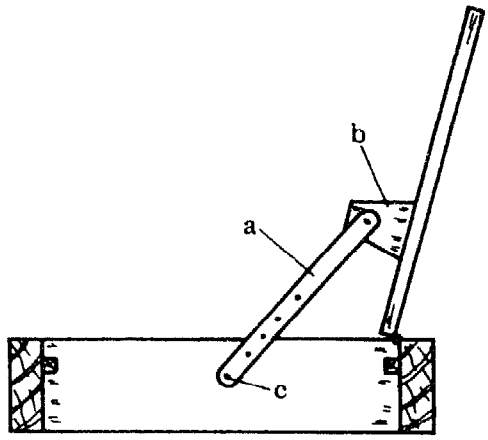

Fig. 1

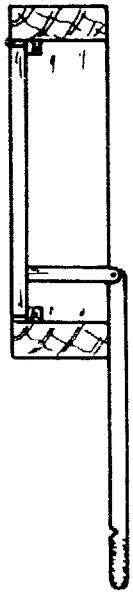

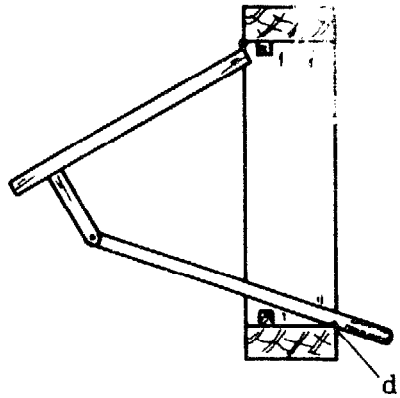

Fig. 2

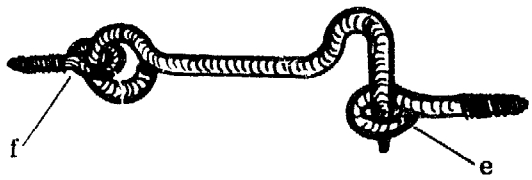

Fig. 3

N P V C		DOOR AND WINDOW HARDWARE.
228	PRO.	

- CASEMENT FASTENERS: Besides the barrel bolt and the tower bolt, there are some other methods for keeping casements in a closed or open position. These are the casement stay and the cabin hook.

  The casement stay serves to keep the casement in the open position. It consists of a handle (a), either wooden or metal, which is fixed onto a plate (b) screwed to the casement. A hole in the handle fits over a small pin in the cill of the frame when the casement is open and holds the casement in position (Fig. 1, c).

  If the casement opens upwards, the stay can be constructed so that it also serves as a lock when the window is closed (Fig. 2). A notch (d) holds the stay on the cill when the window is open.

  The cabin hook (Fig. 3) is used to hold the casement in the closed position. It consists of a hooked bar which fits into a screw eye (e). The other end of the bar is held by a second screw eye (f) which is fixed on the door or casement.

- LOCKING DEVICE FOR LARGE DOORS: The drawings below show a locking device used for large doors on stores etc, where trucks or other vehicles may have to enter to deliver goods (Fig. 4). It consists mainly of a long baulk (a) which can hold the two doors securely shut. The baulk is fixed with a coach bolt (b) onto one of the doors.

  Two wooden blocks (c) hold the baulk in position when the doors are closed and a catch (d) prevents the baulk from swinging open by its own weight or from a gust of wind (Fig. 5). A piece of flat iron (e) bent as shown in Fig. 4, keeps the baulk in the locked position. This iron should be firmly attached to the door.

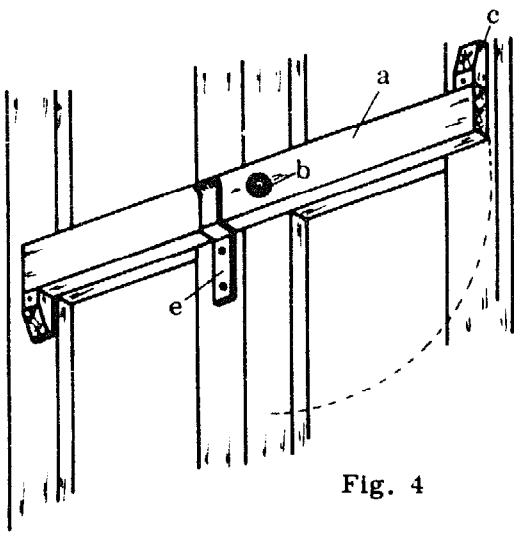

Fig. 4

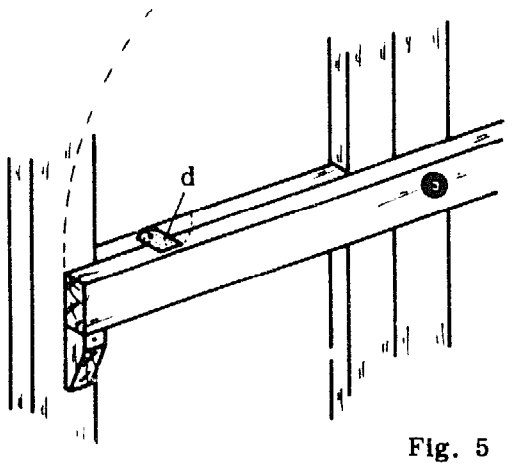

Fig. 5

ROOF COVERINGS

When we talk about roof covering, we mean the non-load-bearing clothing of the roof. In Rural Building, we deal with three different types of roof coverings. These are:

- corrugated aluminium sheets,
- corrugated galvanized iron sheets and
- corrugated asbestos cement sheets.

All of these sheets are corrugated because that makes them stiffer so that they can go across the gap between the purlins without sagging.

CORRUGATED ALUMINIUM SHEETS

This roof covering is lighter and far more durable than the other types. Lightness is important so that the sheets can be easily transported. Aluminium sheets are rust-proof, easily installed and have a bright reflective surface which helps to keep the building cool.

However, the thinner gauge sheets are especially vulnerable to being dented, punctured, or torn off by storms. The sheets also creak a lot when temperature changes make them expand or contract.

Aluminium roof covering is available in a variety of shapes and sizes. The sheets can be from 61 to 76 cm wide and 200 to 400 cm long. Sheets up to 18 metres in length can be ordered from the factory.

In Rural Building, we mostly deal with sheets which are 61 cm wide and 244 cm long. This size is the most commonly used and readily available.

The sheets are available in different thicknesses or gauges. The thinnest is 26 SWG (Standard Wire Gauge; 26 SWG = 0,446 mm) and the thickest is 18 SWG (= 1,22 mm).

Store the sheets in a dry place. Avoid putting them in contact with fertilizer, lime or cement.

Further details and instructions concerning aluminium sheets can be obtained from:

Ghana Aluminium Products Limited
P. O. Box 124
Tema

Also look at the Tables of Figures, pages 239 and 240, for more information.

CORRUGATED GALVANIZED IRON SHEETS

These are steel sheets which are corrugated and galvanized on both sides. They are usually thicker and heavier than aluminium sheets, so they lack some of the drawbacks of the aluminium, like being easily punctured or torn away in storms.

The most common size of these sheets is 61 by 244 cm.

CORRUGATED ASBESTOS CEMENT SHEETS

This kind of roofing sheet is also widely used. The disadvantage of these is that they are brittle and break easily if they are walked on or if a heavy object falls on them. They can also break if the roof construction warps due to the humidity changes in different seasons. Another problem is that they are heavy, and so they are difficult to transport.

The standard size is again 61 by 244 cm.

HOW TO ORDER SHEETS

When ordering sheets, you must keep in mind that the overlap of two corrugations on each sheet must be subtracted to find the effective width of the sheet.

RIDGE CAPS

Ready made caps for covering the ridge of the roof are also available. They are made from aluminium, galvanized iron or asbestos cement, to fit with the roofing sheet material.

Ridge caps can be made locally out of aluminium or galvanized iron sheets as will be explained when we come to roof construction.

The caps have to overlap the sheets on both sides of the roof. In the case of a roof which has the ridge along the direction of the prevailing wind (in northern Ghana, this is the east-west axis) the cap must overlap the sheets by 20 cm on each side. If the ridge lies across the direction of the prevailing wind (north - south) the cap has to overlap by 30 cm on each side (see Tables of Figures, page 239).

NOTES:

APPENDIX I : TABLES OF FIGURES

WEIGHT OF AGGREGATES

Dry sand weighs about 1800 kg per cubic metre, or 1,8 tons.

Broken stones weigh about 1700 kg per cubic metre, or 1,7 tons.

One slightly heaped headpanful of dry sand weighs about 30,5 kg.

One slightly heaped headpanful of broken stones weighs about 29 kg.

TABLE OF LOADING CAPACITIES FOR VEHICLES

Loading capacity	Maximum number of headpans	
	dry sand (fine and coarse)	broken stones (small and medium)
1 ton	33	34
1,5 tons	49	51
2 "	65	69
2,5 "	82	86
3 "	98	103
3,5 "	115	120
4 "	131	138
4,5 "	147	155
5 "	164	172
5,5 "	180	189
6 "	197	207
6,5 "	213	224
7 "	229	241
7,5 "	246	258

- REMEMBER: Never overload the vehicle! Observe the above quantities strictly.

NOTES:

TRANSPORTATION OF AGGREGATES

Supposing we have a 3,5 ton lorry available for transporting the aggregates, we can now figure out how many trips with the lorry will be necessary. If we know the total amount needed of each aggregate, we can find the number of lorry loads needed from the table on the left page.

For example, we need for the whole building: 429 headpans of fine sand;
152 headpans of coarse sand;
181 headpans of small broken stones;
165 headpans of medium broken stones.

The number of lorry loads required is found by dividing the number of headpans above by the number found in the table for the 3,5 ton lorry:

- Fine sand: 429 divided by 115 equals 3,73 or approximately 4 loads.
- Coarse sand: 152 divided by 115 equals 1,32 or approximately 1,5 loads.
- Small broken stones: 181 divided by 120 equals 1,5 loads.
- Medium broken stones: 165 divided by 120 equals 1,37 or approximately 1,5 loads.

- NOTE: It is always better to have a little extra material. Therefore, it is better to fill the lorry with every trip rather than take back a half-load. The cost of the transportation will be about the same anyway.

NOTES:

BUILDING MATERIALS REQUIREMENT FOR ONE CUBIC METRE CONCRETE

(approximation values)

USE	MIX	CEMENT		WATER		AGGREGATES (in headpans)			
codes (key below)	prop.	bags (50 kgs)	head-pans	buckets size no. 28	head-pans	fine sand	coarse sand	small broken stones	medium broken stones
1	1:15	2	4,5	4,5	3	21	19	23	21
1;4	1:12	2,5	5,5	5,5	3,75	21	18,75	23	21
1;4;5	1:10	3	6,75	6,75	4,5	20,5	18,5	22,5	20,5
2;4;5	1:9	3,25	7,5	7,5	5	20,25	18,25	22,25	20,25
2;3;4;5	1:8	3,5	7,75	10	6,5	20	18	22	20
3;4;5	1:7	4	9	11	7,5	19,5	17,5	21,5	19,5
3;4;5	1:6	4,5	9,5	12,5	8,5	19	17,25	21	19
3;5	1:5,5	5	11,25	13,75	9	19	17	21	19
6;7;8	1:5	5,5	12,5	14,5	10	18,75	22,50	33,75	---
6;7;8	1:4,5	6	13,5	16,5	11	18,25	22	33	---
6;7;8;9	1:4	6,5	14,5	18	12	18	21,5	32,5	---
8;9	1:3,5	7	15,75	20	13,5	17,25	20,75	31,25	---
8;9	1:3	8	18	22	14,5	16,5	20	30	---

KEY FOR USE CODES

1 = foundations

2 = sandcrete blocks*

3 = mortar*

4 = plaster/render*

5 = floors

6 = columns

7 = beams/lintels

8 = slabs

9 = screed mortar*

- NOTE: Any reinforced concrete member of the structure must contain at least 270 kg of cement per cubic metre; and must be free of medium and large sized stones. Therefore, the figures in the upper part of the table are never used in mixing reinforced concrete.

* The items marked with a star are those which contain only sand as an aggregate. The amount of sand required is obtained by adding together the amounts of all the aggregates: fine and coarse sand, small and medium broken stones.

HOW TO USE THE TABLE

When the plans for the building are completed, the builder can make calculations to find how much cement needs to be ordered. From the dimensions in the plan, the volume in cubic metres can be found for the various parts of the structure such as the foundation, floor, footings, etc. This is done by multiplying the width, length, and height of a part to get its cubic volume.

The examples below show how to calculate the cement required once you have found the volumes.

- FOUNDATIONS: Mix proportion = 1:10, volume = 5,75 cubic metres.
- FOOTINGS: Mix proportion of sandcrete blocks and mortar = 1: 8, volume = 3,3 cubic metres.
- FLOOR: Mix proportion = 1: 7, volume = 2,4 cbm.
- CALCULATION:

FOUNDATIONS: According to the table, the mix proportion of 1:10 requires 3 bags of cement per 1 cbm. Therefore, we multiply 5,75 cbm x 3 = 17,25 bags of cement.

FOOTINGS: The mix proportion of 1:8 requires 3,5 bags of cement per cbm. We multiply the volume of 3,3 cbm x 3,5 = 11,55 bags of cement.

FLOOR: The mix proportion of 1:7 requires 4 bags of cement per cbm. We multiply the volume of 2,4 cbm x 4 = 9,6 bags of cement.

We now add up the three results above and obtain a final result:

$$\begin{array}{r} 17,25 \\ +\ 11,55 \\ +\ 9,6 \\ \hline 38,40 \text{ bags} \end{array}$$

The total of 38,40 means that 39 bags of cement have to be ordered.

Do not forget to include all the members which contain cement in your calculations: landcrete blocks, mortar, lintels, concrete ring beam, etc.

The cement requirements for landcrete blocks varies according to the soil used. For approximate values see the table on page 179.

NOTES:

When the cement requirements have been determined, we can use the table to find the quantities of aggregates that are needed. This is done by multiplying the same volume measurement by the appropriate number in the table.

- FOUNDATIONS:

5,75 cbm x 20,5 equals approximately 118 headpans of fine sand.
5,75 cbm x 18,5 equals approximately 106 headpans of coarse sand.
5,75 cbm x 22,5 equals approximately 129 headpans of small broken stones.
5,75 cbm x 20,5 equals approximately 118 headpans of medium broken stones.

- FOOTINGS: Since the sandcrete blocks and the mortar require only sand, all four quantities under aggregates (fine sand, coarse sand, small and medium broken stones) are added together and the result is multiplied by the volume of the footings: 20 + 18 + 22 + 20 = 80; 80 x 3,3 cbm = 264 headpans of sand.

- FLOOR:

2,4 cbm x 19,5 equals approximately 47 headpans of fine sand.
2,4 cbm x 17,5 equals 42 headpans of coarse sand.
2,4 cbm x 21.5 equals approximately 52 headpans of small broken stones.
2,4 cbm x 19,5 equals approximately 47 headpans of medium broken stones.

NOTES:

HEIGHT MEASUREMENTS FOR WALLS

This table can be used to calculate the height of a wall (not including copings, tie beams, or foundations) or to calculate the number of courses in the wall in order to make it a certain height.

LC = Landcrete wall; NC = number of courses; SC = sandcrete wall.

EDGEWISE LAID		
LC	NC	SC
24	1	25
48	2	50
72	3	75
96	4	100
120	5	125
144	6	150
168	7	175
192	8	200
216	9	225
240	10	250
264	11	275
288	12	300
312	13	325
336	14	350
360	15	375

FLATWISE LAID BLOCKS					
LC	NC	SC	LC	NC	SC
16	1	17	256	16	272
32	2	34	272	17	289
48	3	51	288	18	306
64	4	68	304	19	323
80	5	85	320	20	340
96	6	102	336	21	357
112	7	119	352	22	374
128	8	136	368	23	391
144	9	153	384	24	408
160	10	170	400	25	425
176	11	187	416	26	442
192	12	204	432	27	459
208	13	221	448	28	476
224	14	238	464	29	493
240	15	255	480	30	510

USING THE TABLE

- FOR EXAMPLE: The walls of a common house (not including wall plate or ring beam) are supposed to reach a height of 3 m above the finished floor level. We find with the aid of the above table that the plinth course of sandcrete blocks must be followed by 12 courses of landcrete blocks to reach a height of: 0,25 m + 2,88 m = 3,13 m. The floor is 10 cm thick, so the height above the finished floor level will be 3,13 m - 0,10 m = 3,03 m.
- ANOTHER EXAMPLE: The bottom of a water tank must be at a height of 4 m above ground level. With the aid of the table, the Rural Builder can easily figure out that he needs to make 24 courses of flatwise sandcrete blocks to reach this height.

LENGTHS OF WALLS

LC = Landcrete blocks, length of wall (cm); No = number of blocks; SC = sandcrete blocks, length of wall (cm).

LC	No	SC	LC	No	SC	LC	No	SC	LC	No	SC
29	1	46	1114	36	1726	2199	71	3406	3284	106	5086
60	2	94	1145	37	1774	2230	72	3454	3315	107	5134
91	3	142	1176	38	1822	2261	73	3502	3346	108	5182
122	4	190	1207	39	1870	2292	74	3550	3377	109	5230
153	5	238	1238	40	1918	2323	75	3598	3408	110	5278
184	6	286	1269	41	1966	2354	76	3646	3439	111	5326
215	7	334	1300	42	2014	2385	77	3694	3470	112	5374
246	8	382	1331	43	2062	2416	78	3742	3501	113	5422
277	9	430	1362	44	2110	2447	79	3790	3532	114	5470
308	10	478	1393	45	2158	2478	80	3838	3563	115	5518
339	11	526	1424	46	2206	2509	81	3886	3594	116	5566
370	12	574	1455	47	2254	2540	82	3934	3625	117	5614
401	13	622	1486	48	2302	2571	83	3982	3656	118	5662
432	14	670	1517	49	2350	2602	84	4030	3687	119	5710
463	15	718	1548	50	2398	2633	85	4078	3718	120	5758
494	16	766	1579	51	2446	2664	86	4126	3749	121	5806
525	17	814	1610	52	2494	2695	87	4174	3780	122	5854
556	18	862	1641	53	2542	2726	88	4222	3811	123	5902
587	19	910	1672	54	2590	2757	89	4270	3842	124	5950
618	20	958	1703	55	2638	2788	90	4318	3873	125	5998
649	21	1006	1734	56	2686	2819	91	4366	3904	126	6046
680	22	1054	1765	57	2734	2850	92	4414	3935	127	6094
711	23	1102	1796	58	2782	2881	93	4462	3966	128	6142
742	24	1150	1827	59	2830	2912	94	4510	3997	129	6190
773	25	1198	1858	60	2878	2943	95	4558	4028	130	6238
804	26	1246	1889	61	2926	2974	96	4606	4059	131	6286
835	27	1294	1920	62	2974	3005	97	4654	4090	132	6334
866	28	1342	1951	63	3022	3036	98	4702	4121	133	6382
897	29	1390	1982	64	3070	3067	99	4750	4152	134	6430
928	30	1438	2013	65	3118	3098	100	4798	4183	135	6478
959	31	1486	2044	66	3166	3129	101	4846	4214	136	6526
990	32	1534	2075	67	3214	3160	102	4894	4245	137	6574
1021	33	1582	2106	68	3262	3191	103	4942	4276	138	6622
1052	34	1630	2137	69	3310	3222	104	4990	4307	139	6670
1083	35	1678	2168	70	3358	3253	105	5038	4338	140	6718

USING THE TABLE

Suppose you are planning a wall which is about 6 metres long, made from landcrete blocks. In this case it would be best to choose either 5,87 m or 6,18 m as the final length, so that it is not necessary to cut blocks to fit.

The table makes it simple to read off the number of blocks required per course, so it is easier to calculate the building materials that will be required. For example, a 34,70 m landcrete wall contains 112 blocks per course. The number of courses required to reach a certain height can be found in the table on page 237.

ROOFING SHEET REQUIREMENT

This table is to help you to find the number of roofing sheets that need to be ordered, according to the length of the planned building. The number of sheets in this table refers only to the sheets along one side of the ridge line; so if you want to make a gable roof you have to double this number to get the number of sheets that will cover both sides of the roof. In addition, if the building is wide, so that more than one sheet is needed to cover the distance between the ridge and the lower edge; then the number from the chart has to be multiplied by the total number of sheets across the whole width of the building (see the example given on the next page).

The figures below are for the most commonly used roofing sheet size, which is 61 cm by 244 cm. The effective width of the sheets (minus 2 corrugations overlap) is approximately 50 cm (see pages 230 and 231). The figures include an allowance of 20 cm extra at each gable end.

NS = Number of roofing sheets; L (m) = the length of the building in metres.

NS	L (m)
3	1,1
4	1,6
5	2,1
6	2,6
7	3,1
8	3,6
9	4,1
10	4,6
11	5,1
12	5,6
13	6,1

NS	L (m)
14	6,6
15	7,1
16	7,6
17	8,1
18	8,6
19	9,1
20	9,6
21	10,1
22	10,6
23	11,1
24	11,6

NS	L (m)
25	12,1
26	12,6
27	13,1
28	13,6
29	14,1
30	14,6
31	15,1
32	15,6
33	16,1
34	16,6
35	17,1

NS	L (m)
36	17,6
37	18,1
38	18,6
39	19,1
40	19,6
41	20,1
42	20,6
43	21,1
44	21,6
45	22,1
46	22,6

SHEET REQUIREMENT FOR RIDGE CAPS

When the ridge of the roof is oriented in the direction of the prevailing winds (the direction from which the wind usually comes; in northern Ghana this is the east) then the ridge cap has to overlap 20 cm on each side of the ridge. Thus a common roofing sheet (244 cm long) will provide 6 ridge caps, each 40 cm long. To find the number of sheets required for the ridge caps, use the figure you get from the table above and divide it by 6.

For example: The building will be 10 metres long; looking in the table you find the figure of 21 sheets. Divide 21 by 6; this gives 3,5 (or approximately 4) sheets

which are required for the ridge caps.

When the ridge of the roof is oriented across the direction of the prevailing winds (in northern Ghana this would be north-south), the ridge cap has to be wider so that the sheets are held better against the wind. In that case, the caps have to overlap each side of the ridge by 30 cm; therefore the roofing sheet can be cut into 4 pieces, each 60 cm long. To find the number of roofing sheets required for the caps, divide by 4 instead of by 6. Thus in our example, 21 divided by 4 gives 5,25 (or approximately 6) sheets required for the ridge caps.

ROOFING SHEET REQUIREMENT / WIDTH OF BUILDING

In order to avoid unnecessary waste, the Rural Builder should decide on the width of the building with the size of the roofing sheets in mind (see Construction, pages 158 & 159) The table below gives the span of the roof for a gable roof according to the number of sheets required to reach from ridge to eave level on each side of the roof. The sheets are standard 244 cm long roofing sheets, the roof has a 20 degree pitch, and there is an allowance of 50 cm extra on each side for the sheets to overhang (overhanging eave).

NS = Number of sheets; W (m) = Width (span) of the roof truss.

NS RIGHT	W (m)	NS LEFT
1	3,65	1
1	4,65	1½
1½	5,65	1½
1½	6,8	2
2	7,95	2
2	8,95	2½

NS RIGHT	W (m)	NS LEFT
2½	9,95	2½
2½	11,1	3
3	12,3	3
3	13,3	3½
3½	14,3	3½

- EXAMPLE: If the roof is to be 21 m long and 8 m wide (span of the truss), with a pitch of 20 degrees, and oriented with the prevailing wind, the number of sheets required can be figured as follows:

  From the table on the preceeding page, we see that 43 sheets will fit along the ridge line. The table above shows that 4 sheets are required to cover the width of the house. When we multiply both numbers, we get the total amount of sheets which is 172 sheets.

  We must also find the number of sheets required for the ridge caps. Dividing 43 by 6 gives approximately 8 sheets, making a total of 180 sheets to be ordered.

APPENDIX II : GLOSSARY

Most new terms are explained in the text as they come up, but after that they are used without explanation. To make it easier for you, the words which tend to come up again and again are explained here once more, and references are given when possible to more thorough explanations in one of the text books.

- NOTE: The other books referred to here are given as abbreviations: the Basic Knowledge book is referred to as "BK" and the Construction book is written as "Con". Where the page number only is given, it refers to the page in this book.

TERMS

- AGGREGATE: The sand, rocks or gravel which make up the greater part of concrete, sandcrete blocks, mortar, plaster or render (see page 147).
- ANCHORAGE: This refers usually to iron rods which are embedded in one part of the building and serve to hold another part in place, for example the roof anchorage which is embedded in the walls and holds the roof construction in place.
- ANGLE OF PITCH: This means the slope of the face of a saw tooth (see page 109; or else it refers to the slope of the roof construction (roof pitch), depending on the context where it is used (see page 158, Con).
- BATTEN: This usually refers to a small piece of wood that is used to help fix another piece, or it refers to the lengthwise boards of a battened door (see page 93, Con).
- BEVEL: A sloping edge; the edge of a piece which is cut off so the angle is no longer 90 degrees (see page 72, BK).
- BOND: This refers to the arrangement of blocks in a wall, in Rural Building usually a half-block bond (se page 8, BK).
- BRACE: A piece added to a construction to make it stronger or more stable.
- BUILDING UNIT: This is usually used with reference to blocks to specify the measurement of a block in the wall, including the thickness of one cross joint and the bed joint (usually 2 cm) (see page 4, BK).
- CAST: To pour concrete into a mould so that it hardens to a particular form.
- CAST-IN-SITU: This means that the concrete member is cast in its permanent position (page 170, BK).
- CHAMFER: An edge wich is cut to a 45 degree angle; this is a special kind of bevel (see page 72, BK).
- CLEARANCE: Free space; or space to allow movement between parts.

- CLENCH: To secure a nail by bending the point over where it comes through the piece of wood (see page 94, BK).
- CONCAVE: This describes a surface which is hollow or curved inwards.
- CONCRETE: This is a mixture of sand, stones, cement and water which hardens into a rock-like substance (see page 166).
- CONVEX: This means that a surface is curved outwards, like the outer surface of a ball.
- COUNTERSINK: This means to enlarge the top of a screw hole so that the head of the screw will be flush with the surface (see page 96, BK).
- COURSE: This refers to a horizontal layer or row of blocks in a wall, including the mortar bed (see page 2, BK).
- CROSS-GRAINED: The wood fibres do not run parallel to the length of the piece of wood, so it is difficult to work with the wood.
- CURING: This refers to the process of hardening for any product wich contains cement. The piece must "cure" for a period of days or weeks before it is ready to carry out its function.
- CUTTING ANGLE: The angle to which a cutting edge is shaped (see page 91).
- DIMENSIONS: The measurements of the length, width and height of an object.
- END GRAIN: The end surface which is exposed when wood is cut across the grain (see page 72, BK).
- FACE SIDE OR FACE EDGE: This is the first side or edge to be prepared when wood is planed for use in a work piece, usually the best side or edge (see page 84, BK).
- FLUSH: When we say that to surfaces are flush, we mean that they are in the same plane, they form one flat surface together.
- FOOTINGS: These are the first courses of flatwise blocks which are laid on top of the foundations (see page 36, BK; also page 43, Con).
- FORMWORK: This is the wooden structure which holds and supports the concrete pieces while they are being cast (see page 170, BK).
- FOUNDATIONS: The solid base, usually concrete, on which the building rests. It is the only part of the building which is in direct contact with the ground (see page 15, Con).
- GAUGE: A measure, a means of comparing sizes (for example, see pages 13 and 39).
- GRAIN: The natural arrangement of the wood fibres (see page 72, BK).
- GRIND: To polish or sharpen by rubbing on a rough hard surface (see page 95).
- HEADER: This is a block which is placed in a wall in such a way that the smallest face is exposed (see page 2, BK).
- HONE: To give a final polished keen edge to a tool by rubbing it on the smooth side of a sharpening stone (see page 99).

- KERF: The cut made by a saw blade.
- LANDCRETE BLOCKS: This is a mixture of laterite soil, cement and water which is pressed into blocks in a landcrete block machine (see page 2, BK).
- LEVEL: A line or surface which is parallel to the horizon; horizontal. This can also refer to the tool, the spirit level (page 5) which is used to determine whether a surface is level.
- LINTEL: The wooden or reinforced concrete member which bridges the opening of a door or window at the top (page 164, BK).
- MARKING OUT: This means to make marks on a surface to show where later operations have to be carried out; for example marking out joints on frames or marking out foundations on the ground.
- MILD STEEL: This is the same as iron. Hardened steel is iron which has been hardened by a special process.
- MITRE: This refers to a joint where the two pieces are cut at a 45 degree angle so that they form a corner where the connection between them bisects the angle of the corner (see page 98, BK).
- MORTAR: A mixture of sand, cement and water which is used to form the joints between blocks; or as plaster or render, depending on the proportions of the mix (see page 158).
- MORTICE: A hole which is cut in a piece to receive the end of another piece (see page 104, BK).
- PLASTER: The mortar layer which is applied to the inside walls of a building to make them smoother and more durable (page 174, BK).
- PLINTH COURSE: This is usually one course of edgewise laid sandcrete blocks which is laid on top of the footings (see page 36, BK).
- PLOT: An area limited by certain boundaries, it may contain one or more building sites (see page 140, BK).
- PLUMB: Vertically straight, perpendicular to the horizon.
- PRECAST: This means that the piece is cast beforehand and set into its permanent position after it is hardened (see page 170, BK).
- PREFABRICATED: This means that the piece or part of the building is made ready before it is installed in its final position in the structure. In Rural Building we usuallly mean those things which are manufactured on the site such as doors, casements or frames. We also call this "ready-made".
- QUOIN: The outside corner of a wall (see page 26, BK).
- REBATE: A step-shaped rectangular cut in the edge of a piece (see page 72, BK).
- REINFORCE: To make something stronger by adding another material, for example the iron rods which are sometimes used to make concrete pieces stronger (page 171).

- RENDER: The mortar layer which is applied to the outside of the building to make the walls water resistant so that the blocks are not destroyed by rain (see page 174, BK).
- RIGHT ANGLE: A 90 degree angle.
- RIPPING: This means cutting a board along the grain, using a saw (page 45).
- SANDCRETE BLOCKS: These are blocks made with sand, cement and water, shaped in a sandcrete block machine (see page 2, BK).
- SCALE: In a drawing, this means the relation between the size of the drawing and the actual size of the object which is drawn; for example a building may be drawn in a scale of 1:100 (cm), which means that 1 cm on the drawing represents 100 cm in the actual building.
- SCREED: This refers to a strip of mortar which is laid on the wall to act as a guide during plastering (see page 176, BK); we also talk about floor screeds, by which we mean the 2 cm mortar layer which is laid on top of the base layer during floor construction (see page 179, BK).
- SETTING OUT: Marking the dimensions of an excavation with pegs and lines, or marking the positions of the walls on the footings, etc., sometimes called lining out.
- SHUTTERING: This means the parts of the formwork which are in contact with the cement (page 170, BK).
- SITE: This is the piece of land on which a building is made; a plot of land can contain one or more building sites (see page 140, BK).
- SOFFIT: This refers to the under-surface of a piece; in a concrete form, the bottom board of the shuttering is called the soffit board.
- SPECIFICATIONS: This means a detailed description of something.
- SQUARE: By this we usually mean that a piece has all its sides at right angles to each other, or that all the angles are right angles; or it can mean a rectangular surface where all the sides have the same length.
- STRETCHER: This means a block which is laid so that one of the long faces is exposed (either the top face or a long side) (see page 2, BK).
- STRUTTING: These are the supports which hold the shuttering in place when the concrete piece is cast (see page 170, BK).
- TAPER: This means that something is thinner at one edge than at the other.
- TRUE: This is a description meaning that a surface is completely straight flat.
- VENTILATION: The air movement in and out of a room or area.
- WARP: This is any change of shape in a piece of wood which is caused by uneven shrinking or expansion (see page 132).
- WEDGE: A piece, usually V-shaped, which is used to hold other pieces under pressure, usually to hold pieces together as for example the handle and head of a hammer which are fixed together by wedges (see page 41).

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By: J. van Winden

Published by: Stichting Kongregatie F.I.C.
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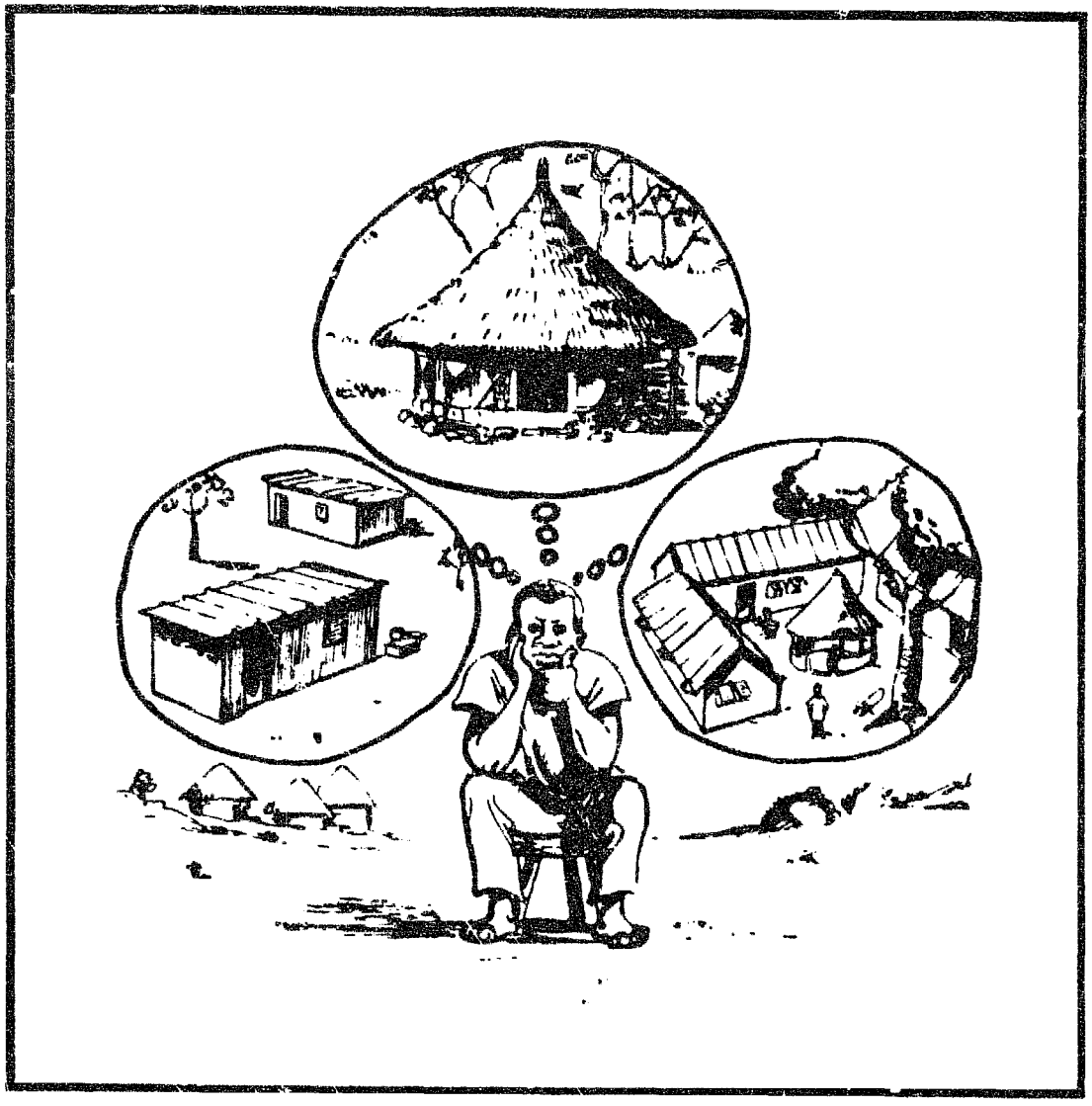

BASIC KNOWLEDGE

RURAL BUILDING

VOLUME 2

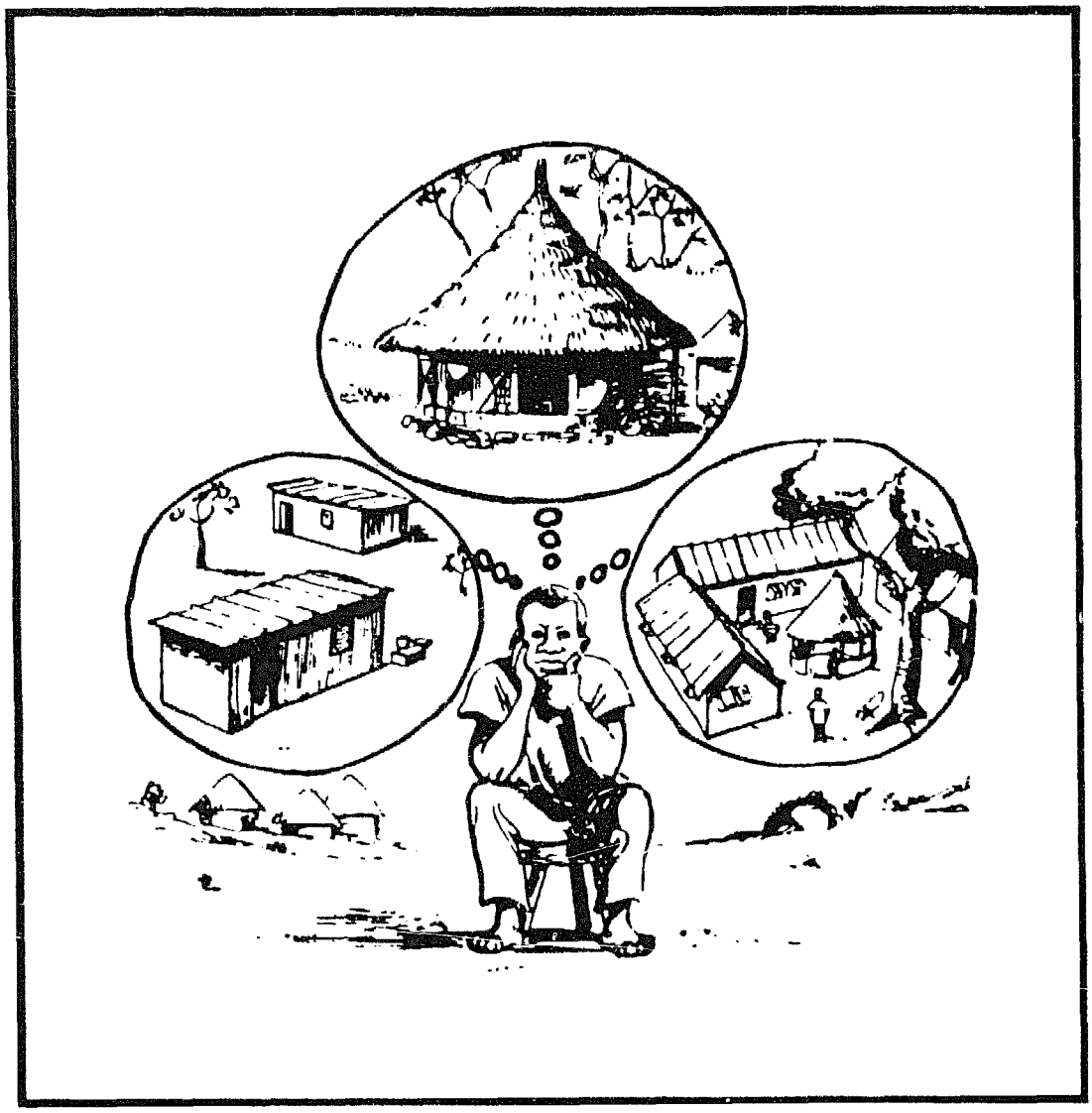

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PREFACE

In response to the many requests by people involved in technical vocational training and in general development work, we have decided to publish a second edition of the Rural Building Course.

The main aim of this set of books is still to provide technical training information in understandable language and with illustrations suited to the understanding of those involved.

Except for a few corrections, the text and illustrations are the same as in the first edition. The binding of the technical drawing book was revised and the size of the books reduced for economy reasons.

We are grateful to the Stichting Brothers F.I.C., Stichting CEBEMO and Mensen In Nood for their assistance in the re-printing of these coursebooks.

It is our sincere wish that the contents of these books may be of assistance to stimulate the use of appropriate techniques in Rural Building and General Development.

Bro. John van Winden F.I.C.

INTRODUCTION TO A RURAL BUILDING COURSE

Vocational training in Rural Building started in the Nandom Practical Vocational Centre in 1970. Since then this training has developed into an official four year course with a programme emphasis on realistic vocational training.

At the end of 1972 the Rural Building Course was officially recognised by the National Vocational Training Institute. This institute guides and controls all the vocational training in Ghana, supervises the development of crafts, and sets the examinations that are taken at the end of the training periods.

The Rural Building programme combines carpentry and masonry, especially the techniques required for constructing housing and building sanitary and washing facilities, and storage facilities. The course is adapted to suit conditions in the rural areas and will be useful to those interested in rural development, and to farmers and agricultural workers.

While following this course, the instructor should try to foster in the trainee a sense of pride in his traditional way of building and design which is influenced by customs, climate and belief. The trainee should also be aware of the requirements of modern society, the links between the old and new techniques, between traditional and modern designs -- and how best to strike a happy medium between the two with regard to considerations like health protection, storage space, sewage and the water supply. The trainee should be encouraged to judge situations in the light of his own knowledge gained from the course, and to find his own solutions to problems; that is why this course does not provide fixed solutions but rather gives basic technical information. The instructor can adapt the course to the particular situation with which he and the trainee are faced.

This course is the result of many years of work and experimentation with different techniques. The text has been frequently revised to serve all those interested in Rural Development, and it is hoped that this course will be used in many vocational centres and communities. It is also the sincere wish of the founders of this course that the trainees should feel at the completion of their training that they are able to contribute personally to the development of the rural areas, which is of such vital importance to any other general development.

We are grateful to the Brothers F.I.C., the National Vocational Training Institute and the German Volunteer Service for their assistance and support during the preparation of this course.

Bro. John v. Winden (F.I.C.)
Wolfram Pforte (G.V.S.)
Fritz Hohnerlein (G.V.S.)

LAY-OUT OF THE RURAL BUILDING COURSE

The Rural Building Course is a block-release-system course, which means that the trainee will be trained in turn at the vocational centre and at the building site. The period of training at the centre is called "off-the-job" training, and the period on the building site is called "on-the-job" training. Each will last for two years, so that the whole course will take four years and will end with the final test for the National Craftsmanship Certificate.

BLOCK RELEASE SYSTEM

YEAR	TERM 1	TERM 2	TERM 3
1	X	X	X
2	O	O	O
3	O	X	O
4	X	O	X

X = OFF-THE-JOB TRAINING
O = ON-THE-JOB TRAINING

The total "off-the-job" training period is approximately 76 weeks, each week 35 hours. During this training about 80% of the time is spent on practical training in the workshop. The remaining 20% of the time is devoted to theoretical instruction.

The total "on-the-job" training period is approximately 95 weeks, each week 40 hours. During this period the trainee does full-time practical work related to his course work. In addition some "homework" is assigned by the centre and checked by the instructors.

A set of books has been prepared as an aid to the theoretical training:

A - Rural Building, Basic Knowledge (Form 1)
B - Rural Building, Construction (Forms 2, 3, 4)
C - Rural Building, Drawing Book (Forms 1, 2, 3, 4)
D - Rural Building, Reference Book

All these books are related to each other and should be used together. The whole set covers the syllabus for Rural Building and will be used in the preparation for the Grade II, Grade I, and the National Craftsmanship Certificate in Rural Building.

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BOOK INTRODUCTION

Rural Building, Basic Knowledge is your first construction book. This book plus most of the Reference Book (Rural Building Tools, Maintenance of Tools, Materials and Building Products) will be treated in the first year of centre training.

This book is divided into three parts:

PART 1: BASIC MASONRY TECHNIQUES

This part covers the very basic techniques of masonry. These include the preparation of mortar, blocklaying, the proper arrangement of blocks, and building up walls. Some of the techniques mentioned in the section on the arrangement of blocks are techniques used mainly for bricklaying and therefore only apply to areas where bricks are available.

PART 2: BASIC CARPENTRY TECHNIQUES

The basic techniques covered here include planning construction pieces, preparing wood for construction pieces, ways of fastening the pieces and the important types of joints and how to construct them.

PART 3: PREPARATION FOR ON-THE-JOB TRAINING

This part is meant to be a preparation for the trainee's first year of on-the-job training. It should enable him to follow the basic procedures he is confronted with on a building site, and to understand the technical terms used there. This part of the book doesn't attempt to give detailed information about technical problems but merely to give an idea of them and to enable the trainee to understand the terms and deal with situations on the building site. Most of the procedures will be treated more intensively in the Construction and Drawing books.

At the beginning of both the carpentry and masonry sections there is a list of the terms you will need to know, together with explanations.

You will often be asked to refer to one of the supplementary books for additional information. Especially in the first part of the course, much of the basic knowledge you will need about tools and materials and products will be found in the other books.

You should prepare yourself for each lesson by reading the material before class and looking up the references given in the text for the Reference Book or Drawing Book. If you are not familiar with a tool that is mentioned, now is the time to look in the Reference Book and learn about the tool and how to use it.

There is ample space provided in the book for making notes and sketches.

SAFETY FIRST

When you first start doing construction work it is essential to realize the importance of being safety conscious. You must develop safe working habits in order to prevent injuries to yourself and others.

Accidents can generally be avoided by using ordinary care and skill. Most accidents are a result of thoughtlessness or carelessness on the part of some person.

To practise any kind of craftwork you need your hands, your legs and feet, a healthy body, and most of all your head.

Safety first means that you use your head and think out what you are going to do before going ahead with the job. By first thinking the operation through, you will discover that there is a correct way of doing the task, and some other ways of doing it that may cause danger to yourself and others. Look in the beginning of your Reference Book for a list of general safety rules.

Follow the safety rules, but also use your own sense. When you realize that certain actions can be dangerous, you can plan to prevent accidents and injuries. Look ahead to find the dangerous points of a task and plan to make them safe by taking proper precautions. We can make hundreds of safety rules, but they are useless unless we understand why they are needed and we all cooperate in following them.

One of the most important safety precautions is learning to use the right tool for the job, and in the correct way. The correct way is the safest way.

RESPECT OTHER PEOPLE: RESPECT YOURSELF!

Fig. 1

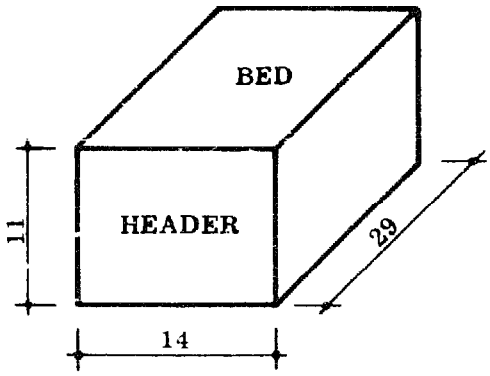

SUN-DRIED TRAINING BLOCK

Fig. 2

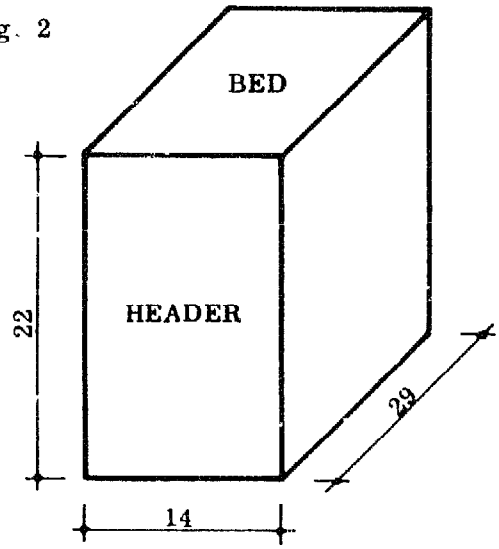

LANDCRETE BLOCK

Fig. 3

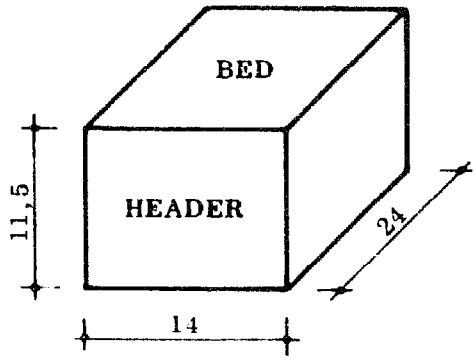

SANDCRETE TRAINING BLOCK

Fig. 4

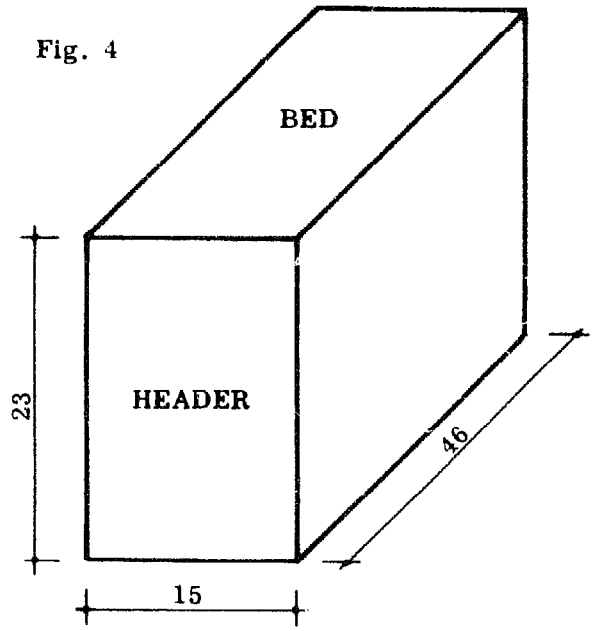

SANDCRETE BLOCK

Fig. 5

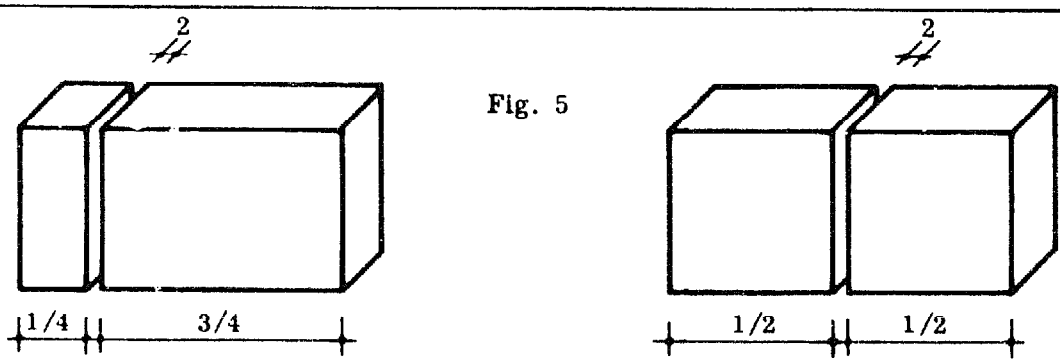

1/4 - 1/2 - 3/4 BLOCKS

N P V C		PART 1: BASIC MASONRY TECHNIQUES. TECHNICAL TERMS.
1	BASIC.	

TECHNICAL TERMS

Before describing the methods used in bonding it is necessary to briefly define and explain a few of the technical terms commonly used.

- SUN-DRIED TRAINING BLOCKS: These blocks, as the name implies, are dried in the sun, because they do not contain cement (Fig. 1). They are often used by beginners during their first terms of in-centre training, as they are easy to make and to handle.

  The dimensions of these blocks are approximately 29 cm x 14 cm x 11 cm, which allows us to construct complicated bonds with them. They can be used to make an excellent inside wall also, as the following chapters will describe.

- LANDCRETE BLOCKS: These are blocks used for actual building (Fig. 2).

- SANDCRETE TRAINING BLOCKS: These are specially made small sandcrete blocks with the approximate dimensions of 24 cm x 14 cm x 11,5 cm; so they can be used to teach the making of more complicated bonds (Fig. 3).

  Like the sun-dried blocks, they are often used in training because they are easy to handle. As they are made with cement they can be used for a long time before they wear out.

- SANDCRETE BLOCKS: This type of block is used for actual building (Fig. 4).

- 3/4 - 1/2 - 1/4 - BLOCKS: These are parts of blocks obtained by cutting a block through either the centre line or the quarter line, less half the thickness of the joint (Fig. 5). The cut is made along the width, not along the length. A special block gauge may be used for marking off the different sizes.

- HEADER: A block is known as a header when it is placed in a wall so that its smallest face is exposed (Fig. 1, next page).

- BED: The under-surface of a block, or the mortar on which the block is laid.

- STRETCHER: If the biggest face of a block is exposed, the block is called a stretcher (Fig. 1, next page). This is the way most blocks are laid in Rural Building, and we say that the block is laid edgewise. If a block is laid flatwise, so it is actually showing the top face, it is also called a stretcher (Fig. 1, next page).

- COURSE: This is the term applied to each layer or row of blocks, with the bed joint included (Fig. 1, next page).

Fig. 1

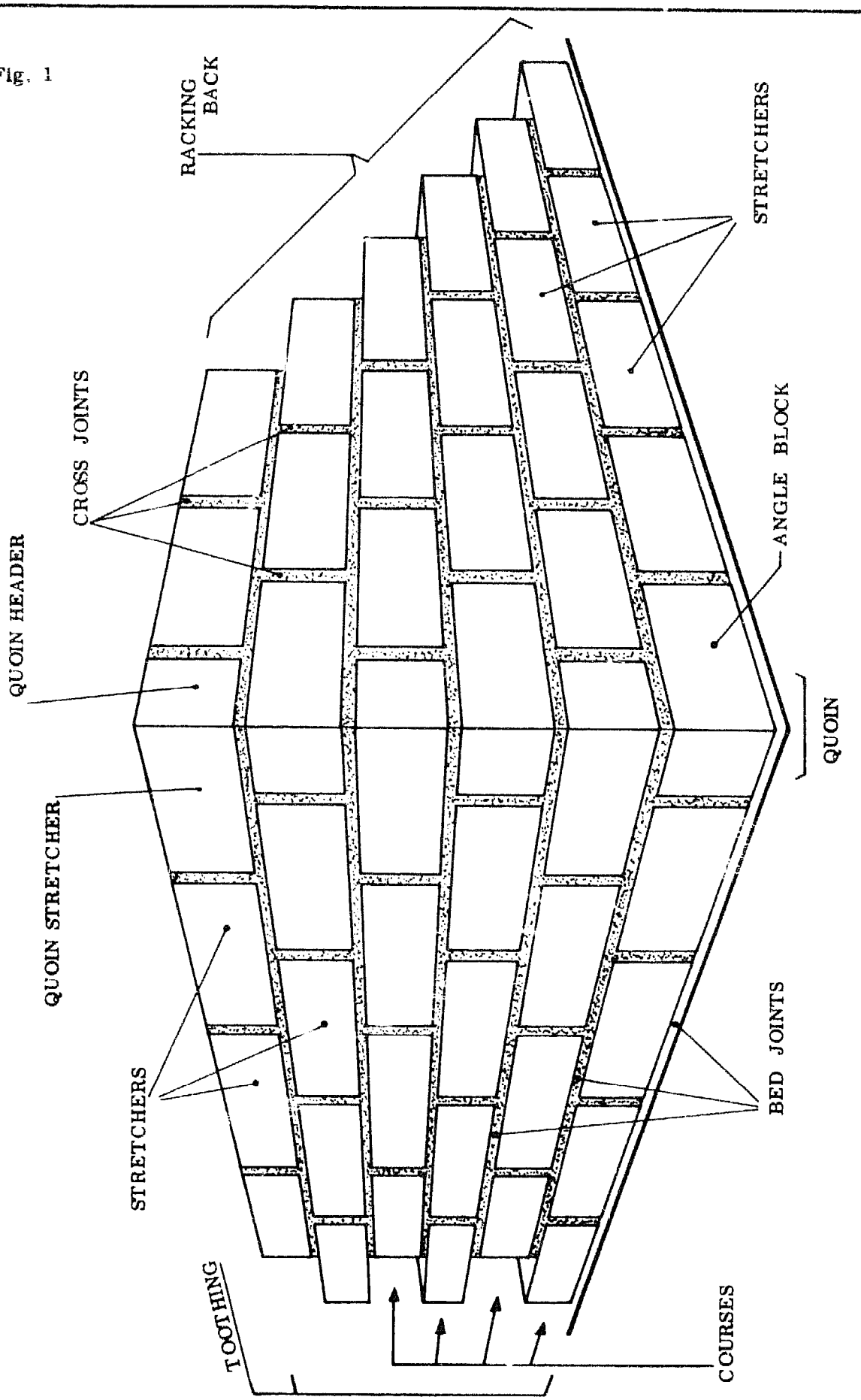

N P V C	
3	BASIC.

TECHNICAL TERMS.

- BED JOINT: This is the horizontal mortar joint between two courses (Fig. 1).
- CROSS JOINT: The vertical joints between the blocks (Fig. 1).
- QUOIN: The quoin is the outside corner of a wall or the external angle on the face side of the wall (Fig. 1).
- ANGLE BLOCK: This is the block which actually forms the corner in each course (Fig. 1).
- STOPPED END: A plain vertical surface which forms the end of a wall (see page 21).
- TOOTHED END OR TOOTHING: The form produced at the end of a wall by recessing every other course by half a block (Fig. 1) in order that the wall may be extended later using the same bond.
- RACKING BACK: As an alternative to toothing, the end of a wall may be set back half a block at each course (Fig. 1). This is also done so that the wall may be extended later using the same bond.
- BUILDING UNIT: This refers to the dimensions of a full block, plus one joint. For sandcrete blocks the building unit is 25 cm high by 48 cm long (2 cm joints).
- FOUNDATION: The base, usually concrete, on which the building rests. It is usually set below ground level, and is the only part of the building in direct contact with the ground.
- FOOTINGS: The courses laid directly on top of the foundations; usually three flatwise courses of sandcrete blocks (see page 35).
- PLINTH COURSE: The edgewise course of sandcrete blocks laid on top of the footings (see page 35).
- RISING WALL: The edgewise courses of sandcrete or landcrete blocks which build up the rest of the wall (see page 35).

NOTES:

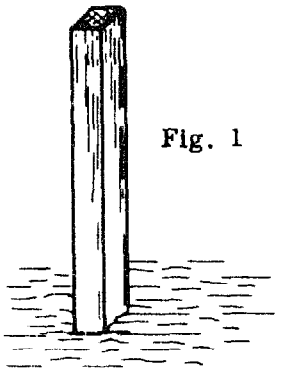

Fig. 1

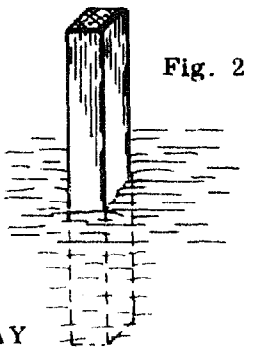

Fig. 2

POLE GIVES WAY
AND SINKS DOWN

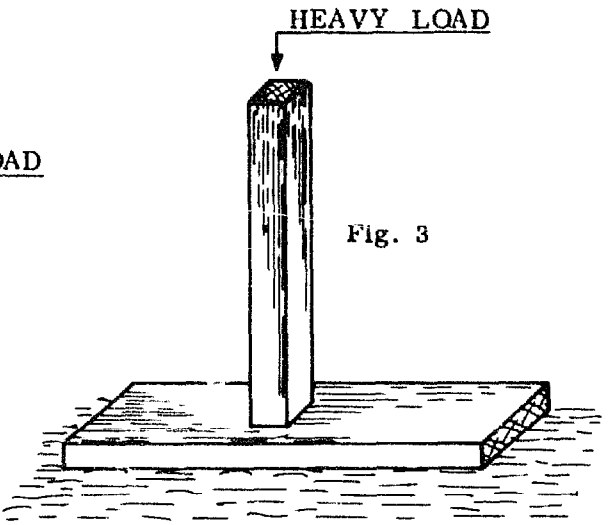

Fig. 3

LARGER AREA OF BOARD
PREVENTS POLE FROM
SINKING DOWN

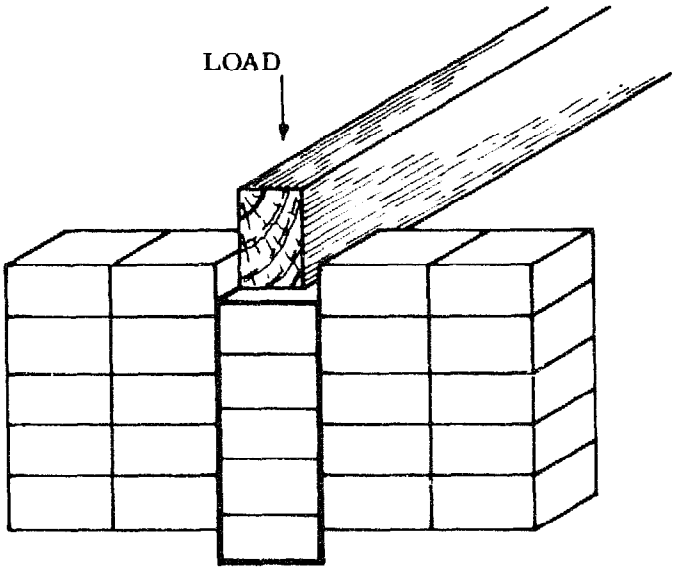

Fig. 4

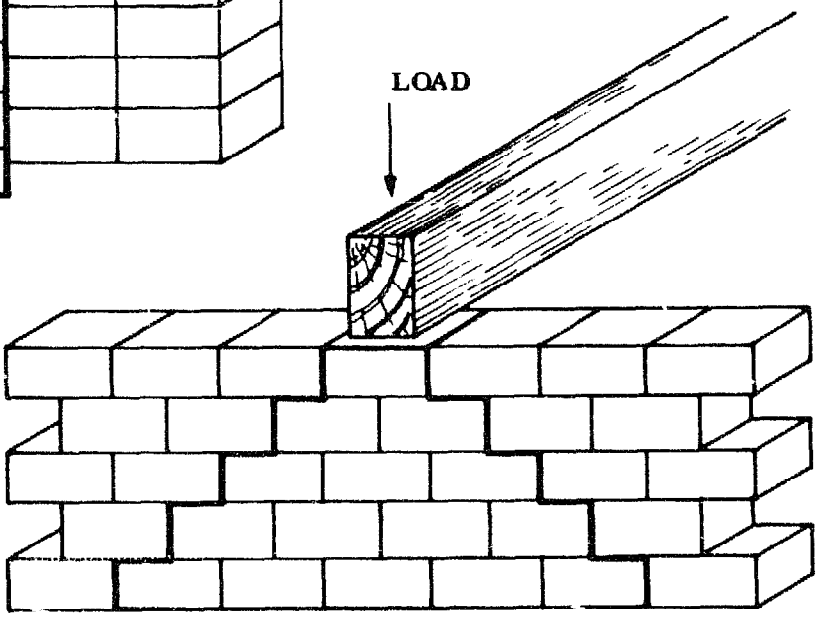

Fig. 5

N P V C	
5	BASIC.

BONDING OF WALLS.

BONDING OF WALLS

The practise of blocklaying requires a complete understanding of the correct arrangement of the blocks forming a wall. This correct arrangement of blocks, regardless of the method, is known as bonding.

The blocks are placed so that they overlap each other and care must be taken to ensure that as far as possible no vertical joint is immediately above another vertical joint in the course below.

GENERAL EFFECT OF BOND

Fig. 1 shows a wooden pole placed vertically on soft ground. If this pole has to carry a heavy load it will sink down into the soil, because the total area on which the pole rests on the ground is far too small to support it (Fig. 2).

A possible solution to the problem is shown in Fig. 3: a board is laid flat on the ground and it now carries the pole with the load. In this way the total load is distributed over a larger area of ground and it is impossible for the pole to sink down.

If a wall is built up by simply placing blocks directly above each other, we say the wall is built without bond. If a heavy load is put on top of this wall (Fig. 4) the column of blocks immediately under the load tends to give way and sink down.

In order to make the wall stronger in itself and able to distribute loads properly, the Rural Builder applies the so-called half-block bond.

A properly bonded wall which receives a heavy load will distribute the pressure over a large number of blocks and therefore over a much greater area (Fig. 5).

NOTES:

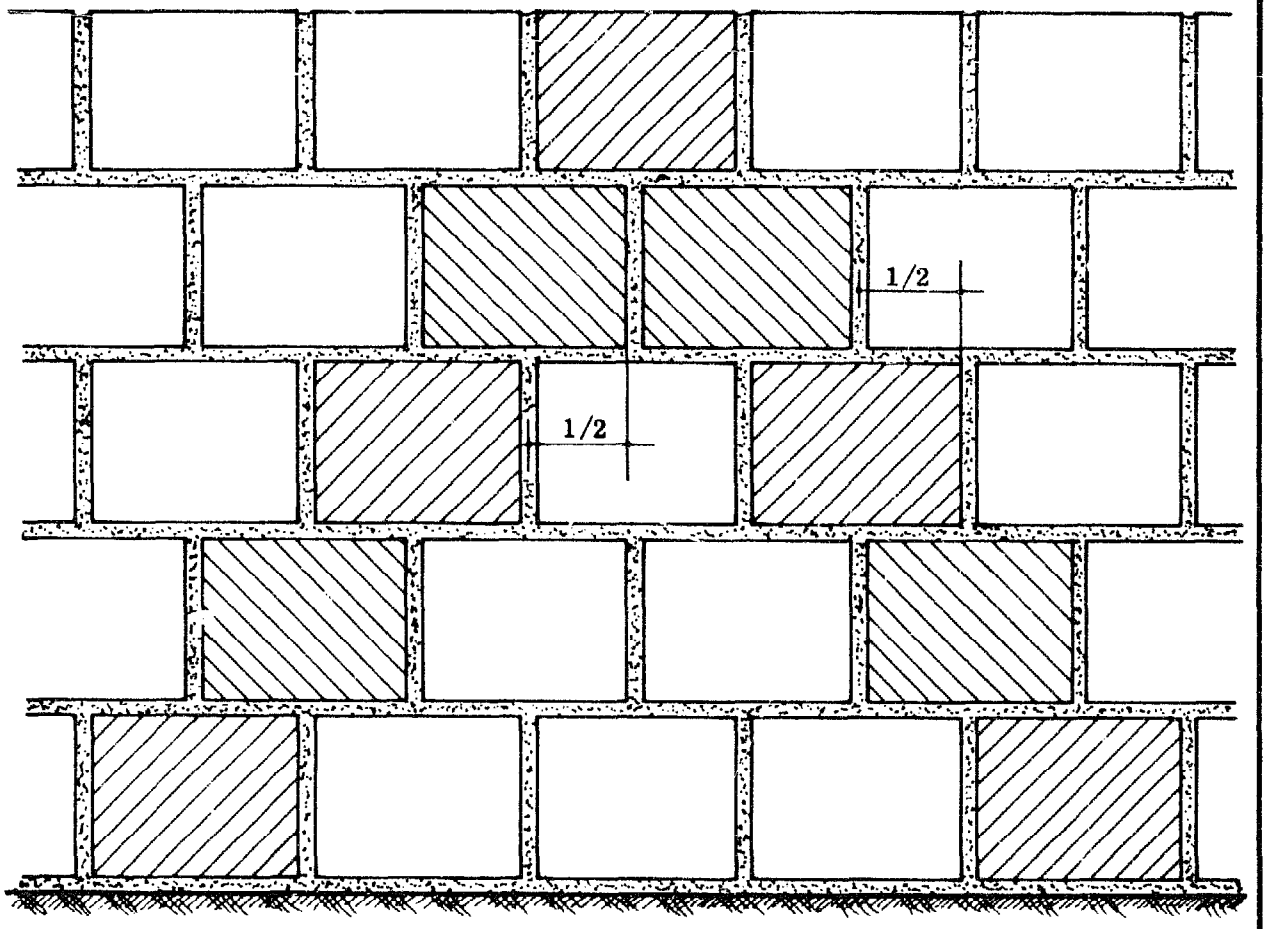

Fig. 1 HALF-BLOCK BONDING (LANDCRETE)

SCALE 1:10 (cm)

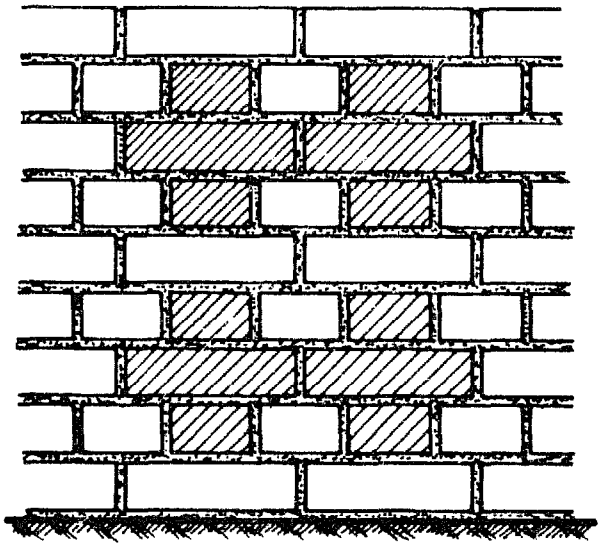

Fig. 2 ENGLISH BOND

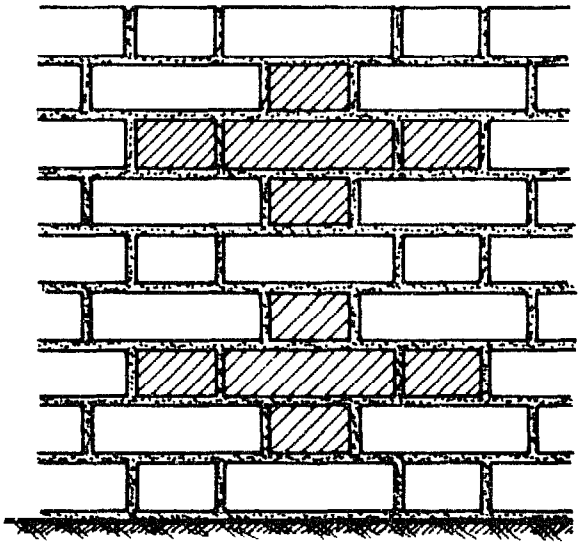

FLEMISH BOND Fig. 3

SCALE 1:10 (cm)

N P V C	
7	BASIC.

BONDING OF WALLS.

HALF-BLOCK BOND

The simplest form of bonding is that where all the blocks are laid down as stretchers, each block overlapping the one below by half its length (Fig. 1).

This form of bonding is only suitable where a one-block thickness of the wall is sufficient. In Rural Building the most common wall thickness is 14 cm when landcrete blocks are used and 15 cm when using sandcrete blocks; provided that they are laid edgewise.

If for some reason a thicker wall is required, the blocks may be laid flatwise. By doing this the wall thickness will be increased to 23 cm, 29 cm or even 46 cm depending on the type of block and the way the blocks are laid.

OTHER TYPES OF BOND

There are many types of bond in use, the two most common being the English Bond (Fig. 2) and the Flemish Bond (Fig. 3), both of which are used with bricks.

Bricks are smaller blocks with approximate dimensions of 24 cm x 11,5 cm x 7 cm.

- ENGLISH BOND: This bond consists of alternate courses of headers and stretchers. The centre of any stretcher is in line with the centre of the header in the courses above and below.
- FLEMISH BOND: This bond consists of alternate headers and stretchers in the same course. Again, the centre of any stretcher is in line with the centre of the header in the courses above and below.

NOTES:

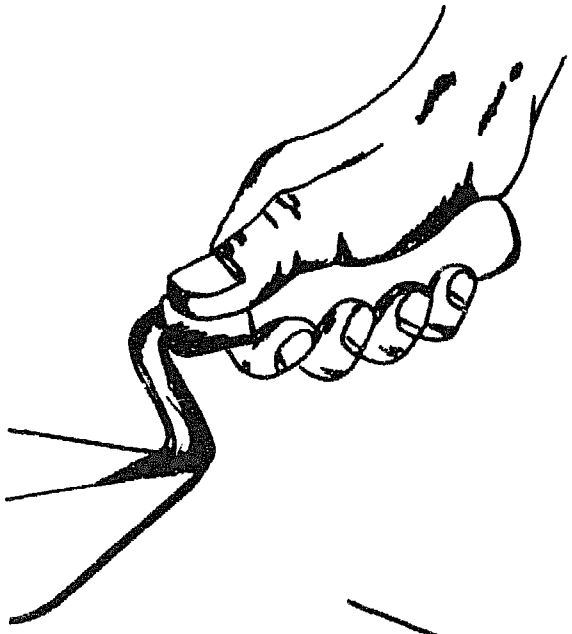

Fig. 1

CORRECT GRIP

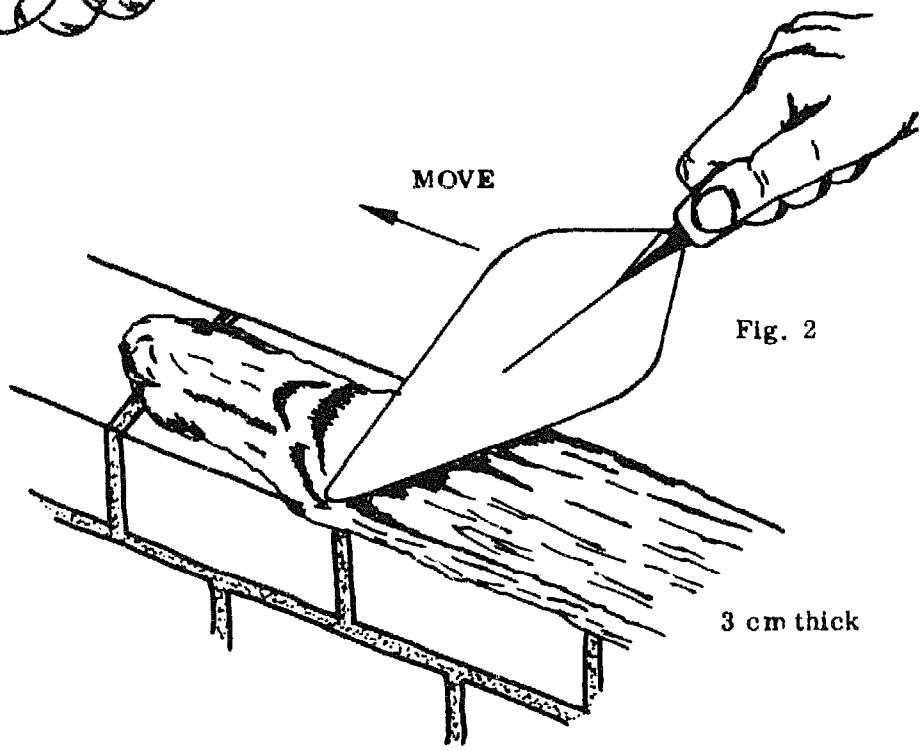

Fig. 2

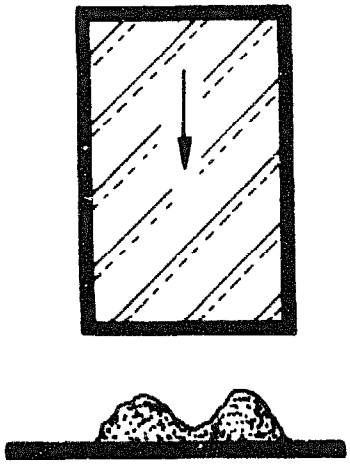

Fig. 3

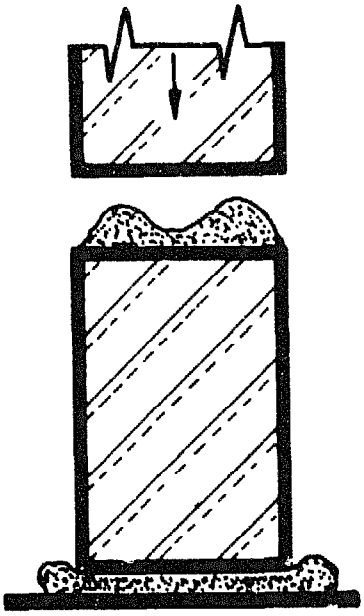

Fig. 4

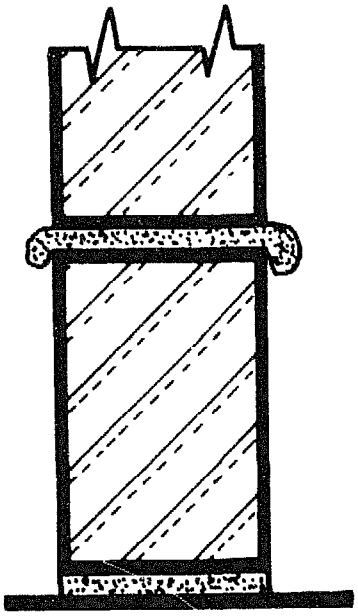

Fig. 5

N P V C	
9	BASIC.

HANDLING THE TROWEL.

HANDLING THE TROWEL

In the process of laying blocks, the brick trowel is used to perform a series of operations during which the trowel is seldom put down or changed from one hand to the other.

All operations require free and easy manipulation of the trowel from the wrist and it is therefore essential to master the correct handling of the trowel.

Fig. 1 illustrates the correct grip on the handle, with the thumb resting on the ferrule. The thumb must be in this position in order to manipulate the trowel skillfully.

The amount of mortar picked up from the headpan will depend on the nature of the job, but for the trainee it is advisable to pick up a sufficient amount to lay one training block, i.e. a heaped trowel. Later, when working with the common big blocks, it will become necessary to pick up two trowelfuls of mortar.

PREPARING THE BED JOINT

Place the mortar in the middle of the wall or the marked position of the first course and spread it out by a pushing movement with the back of your trowel, into a layer about 3 cm thick (Fig. 2).

Next draw the point of your trowel through the centre of the layer, making a mortar bed suitable for the block (Fig. 3).

A block laid on a bed prepared in this way will at first rest on the two outer edges, but when it is pressed down to its correct position it will not only squeeze mortar from the front and back of the block but will also squeeze it into the valley in the centre. In this way a solid bed is formed (Figs. 3, 4, & 5).

- NOTE: All the tools mentioned in this section on masonry techniques are described in the Rural Building Reference Book, pages 3 to 15.

NOTES:

Fig. 1

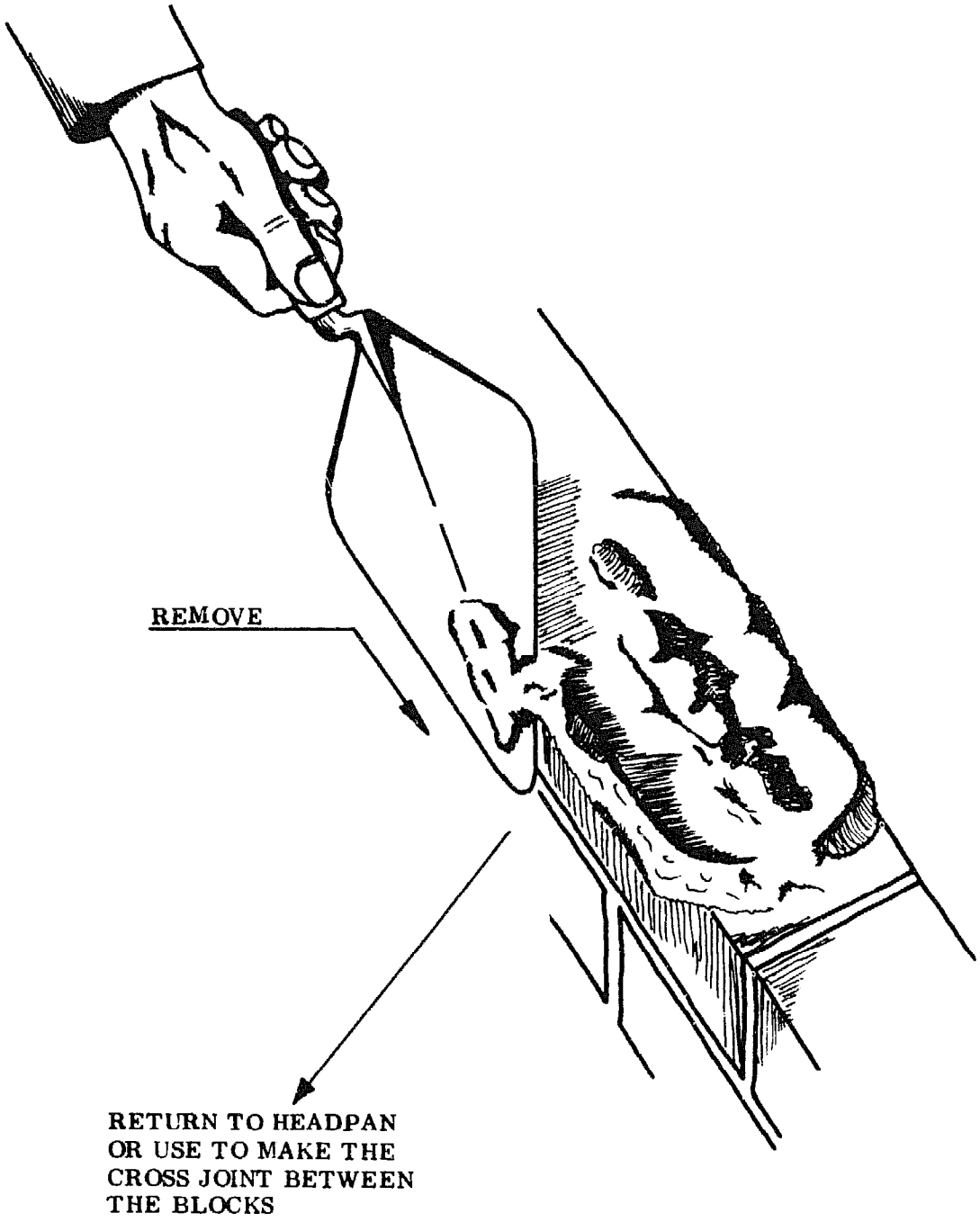

N P V C		HANDLING THE TROWEL.
11	BASIC.	

REMOVING SURPLUS MORTAR

Before and after the block is layed, a certain amount of mortar will project from both sides of the wall. This must be removed before it drops down, as one of the most important principles of the Rural Builder is to work as economically as possible. This means saving materials. Fig. 1 shows the position of the trowel for these operations.

The surplus mortar recovered on the trowel is usually taken to form the cross joint between the last laid block and the previous one, or it is returned to the headpan.

NOTES:

THE FIRST WALL

SETTING OUT

Before actual building operations are started, you must know the correct position and dimensions of all the parts of the building.

This information is given in the plan or drawing of the building, which of course must have been already prepared and at hand.

The positions of the walls, for instance, have to be marked on the ground according to the measurements given on the plan before any building operation starts.

This operation is called "setting out" and we will deal with it repeatedly here, because it is one of the most important preparatory steps in building.

ORGANIZING THE WORK

The workplace has to be well organized in order to operate smoothly and safely.

Building materials such as blocks and mortar should be neither too close nor too far away from the wall being erected. A working space of about 90 cm will usually be all right. The blocks should be neatly stacked, not just thrown in a heap; and there should always be an adequate supply available, so that work is not delayed by waits for materials.

Keep your tools together and near your workplace so they are within easy reach. When you use a tool, put it back immediately afterwards so that it cannot fall off the wall etc. and injure you or other workers. Make a habit of putting your tools down in a way that prevents accidents.

- NOTE: You cannot expect to produce a good job with your tools and materials always scattered around. Neatness and orderliness show the professional.

  Never throw, kick or drop tools as you might damage them.

  Work on one side of the wall only. As the wall becomes higher, you won't be able to move from side to side anyway.

NOTES:

PREVENTIVE MEASURES

Almost all of the building in the Northern and Upper Regions of Ghana is done during the dry season, with its high temperatures and low humidity. These conditions are important and our building procedures must take them into consideration to prevent problems with drying out.

Before you put the mortar down and spread it, thoroughly wet the top of the foundation or the already laid course.

Do the same thing with the block that you are going to lay next. This is to prevent the block from absorbing too much moisture from the mortar. The porous landcrete or sandcrete blocks quickly suck in any moisture they come into contact with. This process is known as absorption. If the blocks absorb too much moisture from the mortar, it will not be able to set properly, and the joints will be weak. By sprinkling sufficient water onto the blocks, we ensure that there will be enough moisture left in the mortar to allow it to harden properly.

It is also important to never spread too much mortar at one time. Some masons prepare the mortar bed in advance for five , six or even more blocks in order to speed up the work. This is wrong.

While the first blocks are placed, lined-out, and levelled, the rest of the mortar is exposed for too long to the sun and air.

Due to the high temperatures and the low humidity, the mortar dries out very fast. As a result the mortar becomes too stiff, making it difficult to lay the last blocks and weakening the grip between the mortar and the block. The end result is a weak wall.

The Rural Builder should always keep in mind the dry climate and never spread more mortar than is actually needed.

NOTES:

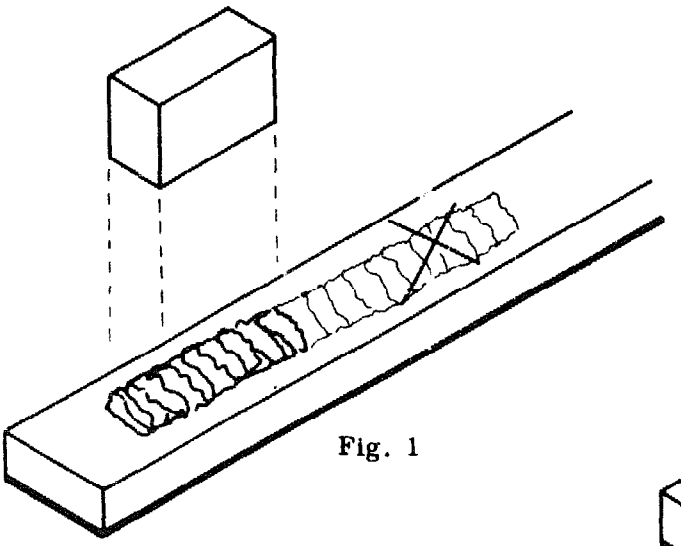

Fig. 1

SET THE BLOCK ON THE MORTAR

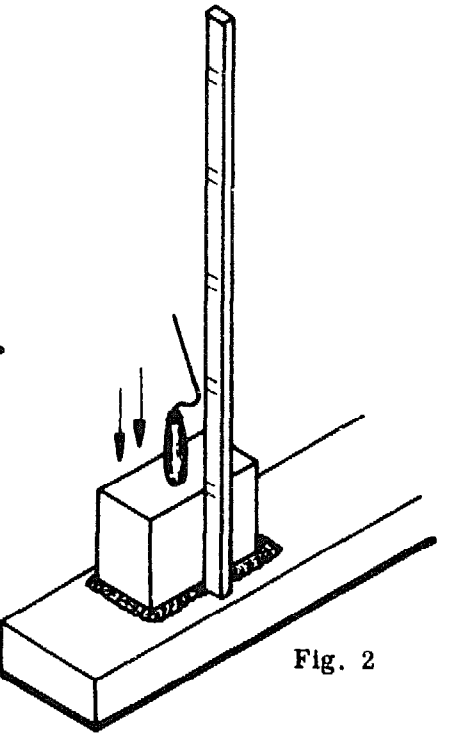

Fig. 2

CHECK THE HEIGHT

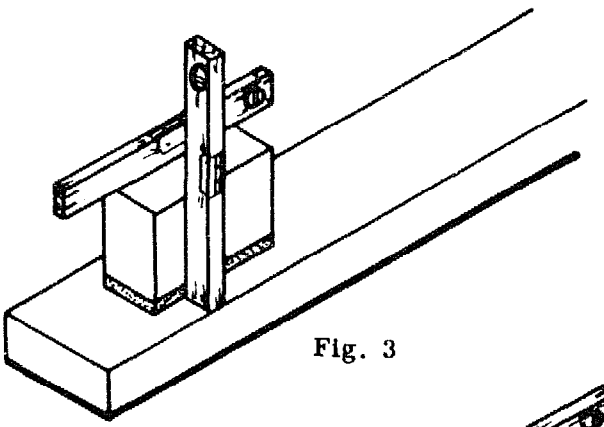

Fig. 3

PLUMB AND LEVEL THE BLOCK

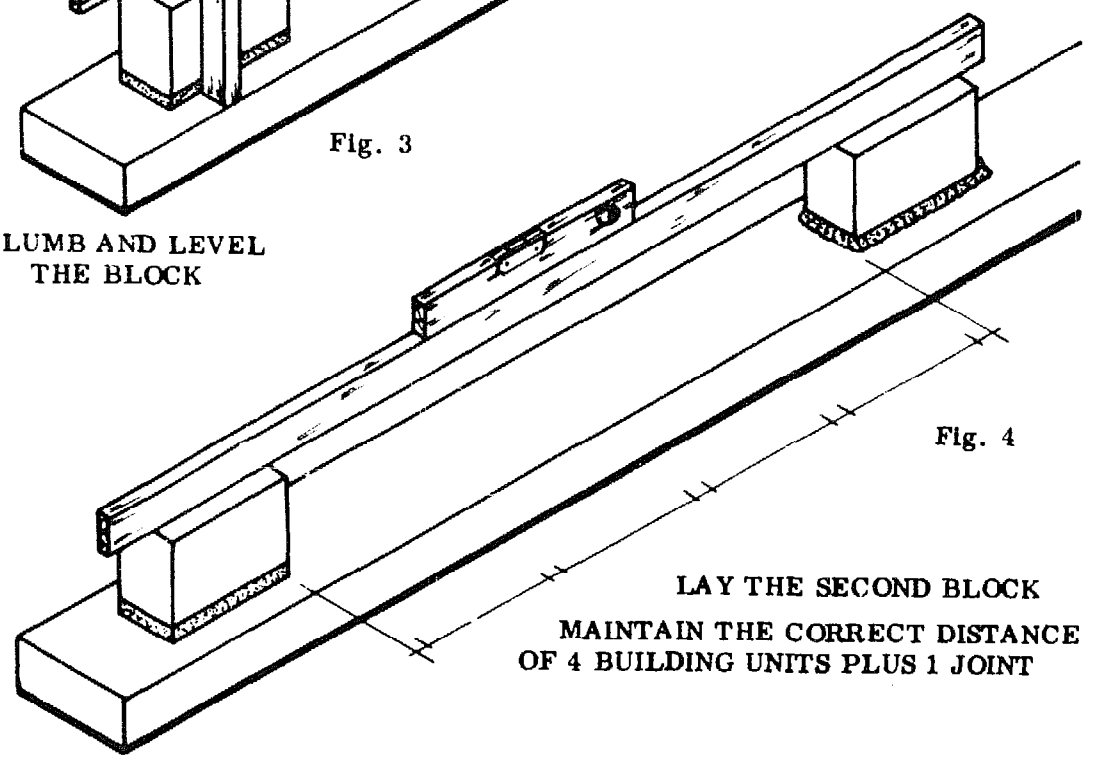

Fig. 4

LAY THE SECOND BLOCK

MAINTAIN THE CORRECT DISTANCE OF 4 BUILDING UNITS PLUS 1 JOINT

N P V C	
15	BASIC.

THE FIRST WALL.

THE FIRST BLOCKS

After you have wetted the block and the area where it is supposed to be set, spread the mortar according to the method described on page 12. Set the block immediately onto the mortar bed and press it down firmly and evenly (Fig. 1).

If the bed has been spread correctly, only a few taps with the handle of the trowel will be needed to adjust the height of the block. The height is checked by comparing the height of the block with the gauge marks on the straight edge (Fig. 2).

Next, plumb the block with the spirit level along the stretcher face and the header face as shown in Fig. 3. The pressure on the block will have squeezed out some of the mortar. Trim off this excess, collect it on the trowel and return it to the headpan.

If you don't use enough water to make the bed, the block will not come up to the required height; it will sit too low. If on the other hand too much mortar is used, the block will sit too high.

Do not try to correct problems like this by pushing some mortar from the edges towards the inside of the bed using your fingers; or by knocking hard on the top of the block to try and force it down. These are very poor practices. Instead, simply remove the block and re-spread the mortar.

At the beginning of the training you will have to re-lay blocks quite often. As you gradually gain experience you will be able to spread just enough mortar to lay one block, without any of the problems mentioned above.

Lay the second block at a distance of four building units and one joint away from the first block (Fig. 4). Hold the straight edge against the stretcher faces of the two blocks to make sure that they are in line.

NOTES:

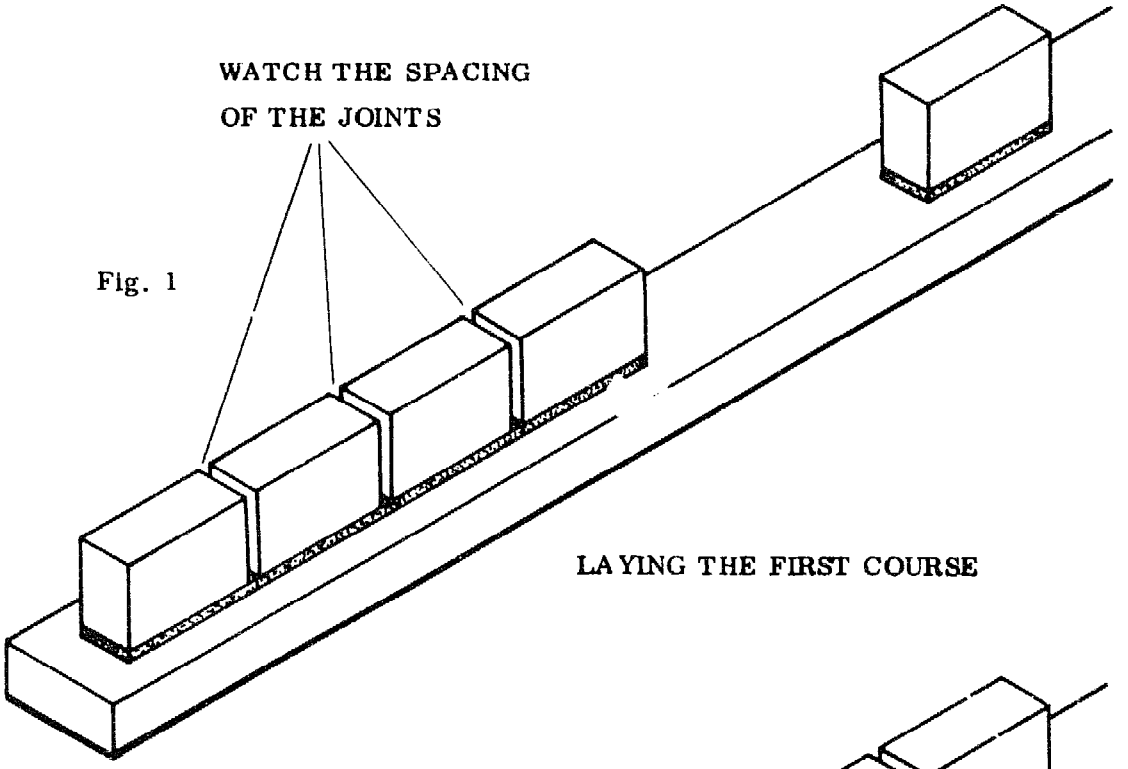

Fig. 1

LAYING THE FIRST COURSE

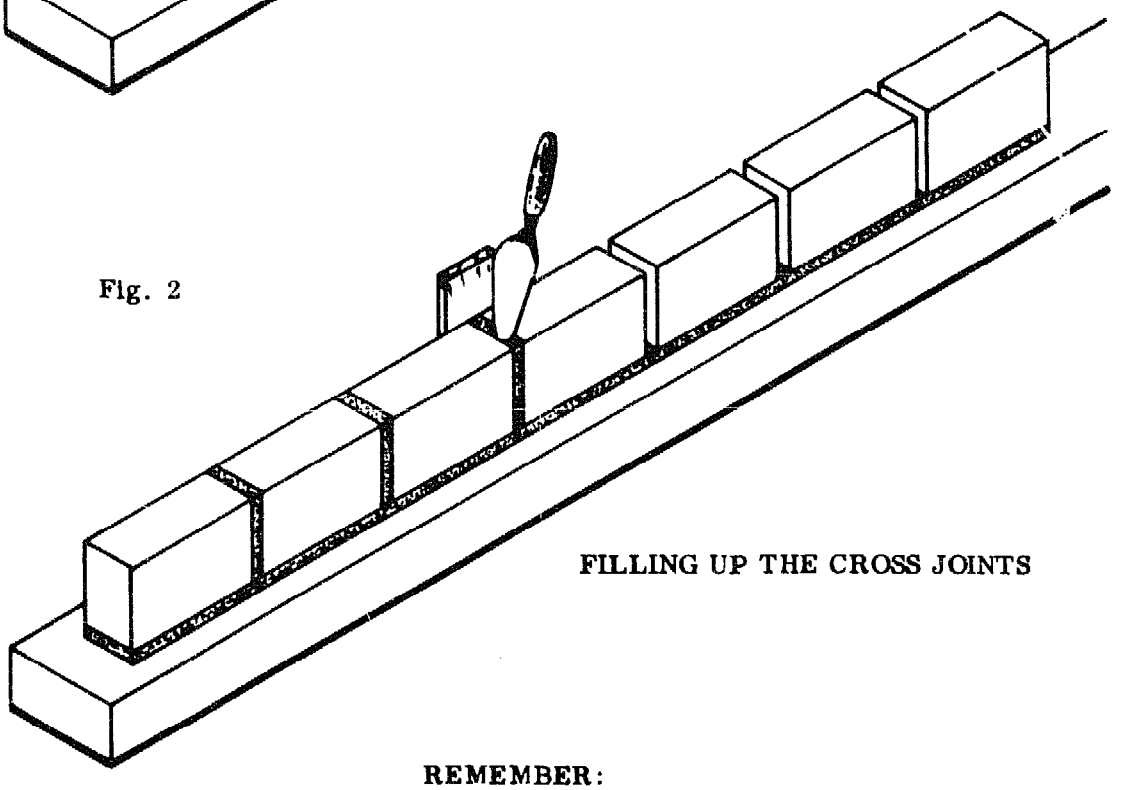

Fig. 2

FILLING UP THE CROSS JOINTS

REMEMBER:
RETURN SURPLUS MORTAR TO THE
HEADPAN !!

NPVC	
17	BASIC.

THE FIRST WALL.

THE FIRST COURSE

Because the first two blocks are in line and at the same height, we can complete the course without using the spirit level, only using the straight edge. Starting from either block (but still working on only one side of the wall) more blocks are inserted between the first two (Fig. 1).

Their height is adjusted by placing the straight edge on top and pressing the blocks down until the top surfaces of all the blocks touch the straight edge equally, along their whole length.

Line out the course (make it perfectly straight) by holding the straight edge against the stretcher faces and moving the blocks until they touch it along their full length.

During these operations take care to maintain the proper distances between the blocks. The next step is to fill the remaining open gaps between the blocks with mortar, thus forming the cross joints. This job is done by closing the back of the gap with the aid of a small wood float while carefully pushing the mortar down into the joint with the trowel (Fig. 2).

All cross joints must be completely filled up with mortar so that no holes are left, which would reduce the strength of the course and the whole wall.

All the excess mortar which has dropped down or was squeezed out of the bed must now be collected and returned to the headpan to be mixed with the rest of the mortar.

NOTES:

Fig. 1

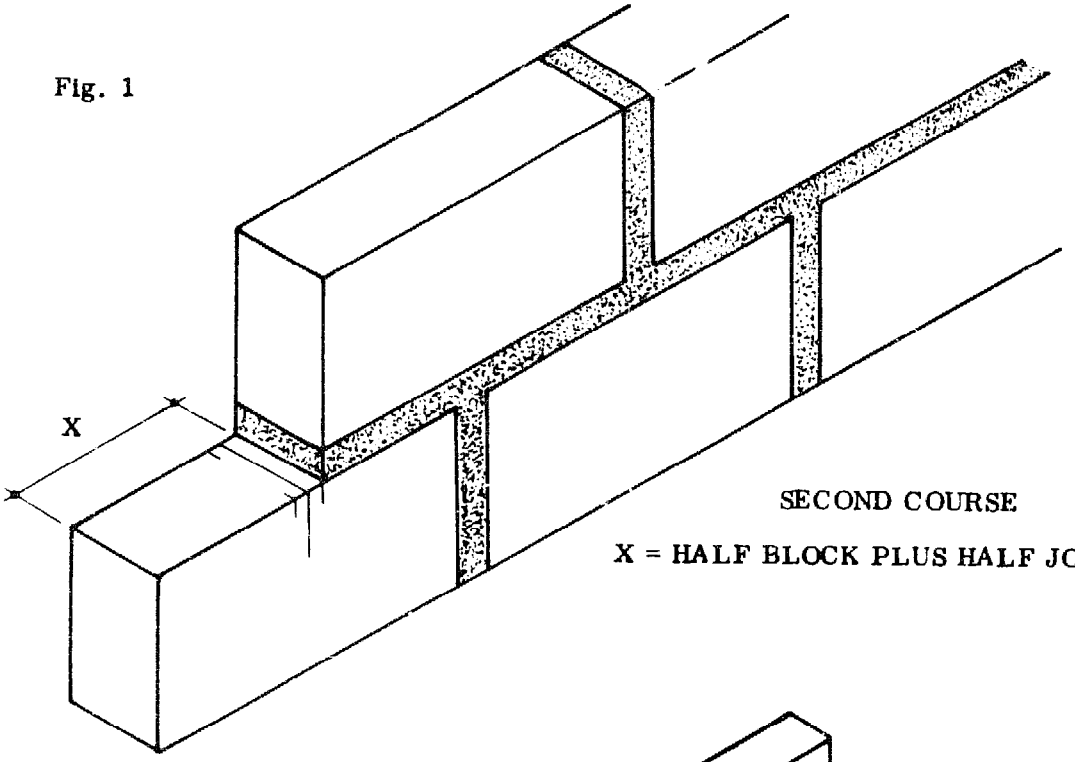

SECOND COURSE

X = HALF BLOCK PLUS HALF JOINT

Fig. 2

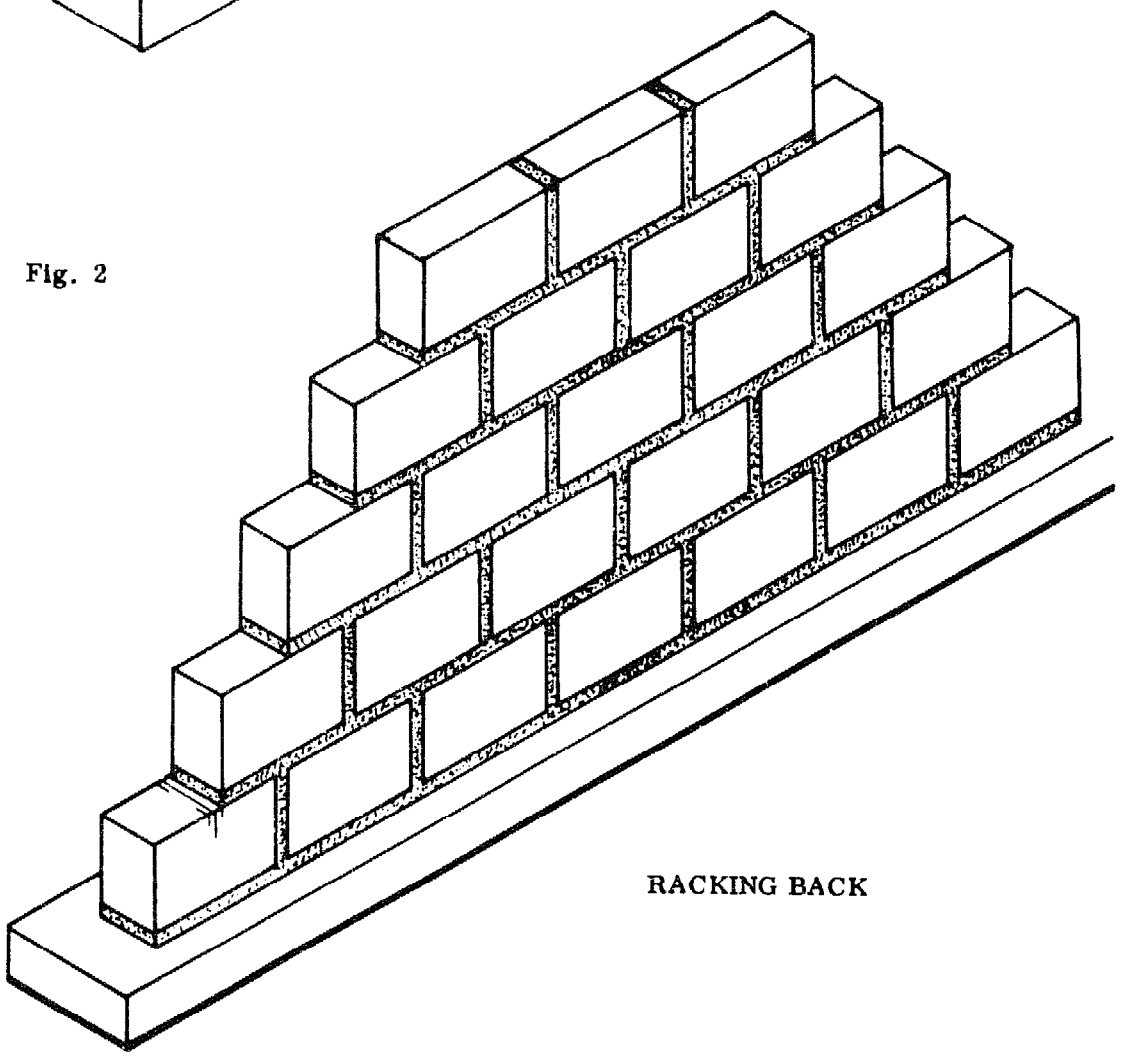

RACKING BACK

N P V C	
19	BASIC.

THE FIRST WALL.

THE SECOND COURSE

Lay the first block of the second course with its centre exactly above the first cross joint so that it overlaps both blocks below equally.

No matter what sort of wall-ending is desired, the first block of the second course is always a full block laid above the first cross joint between two stretchers. This is known as the 1 - 2 - 1 rule. By doing this you maintain the half-block bond throughout the wall (Fig. 1)

After you check the height of this block, you must plumb its face. Hold the spirit level vertically along the face of the lower block with one hand, while with the other hand you move the upper block until its face is also in full contact with the spirit level, and the bubble is in the centre of the tube.

Follow the same operation with the second block, laying it above the last cross joint in the lower course. Insert the remaining blocks between them according to the method used for the first course.

The construction of any subsequent course is merely a repetition of the above operations and will result in a wall with racking back at both ends (Fig. 2).

- NOTE: If the Rural Builder has a choice between racking back and toothing, racking back should be the preferred method. This is because the joints used in toothing are difficult to fill properly when completing the wall, which often results in a weak grip all along the joints.

NOTES:

Fig. 1

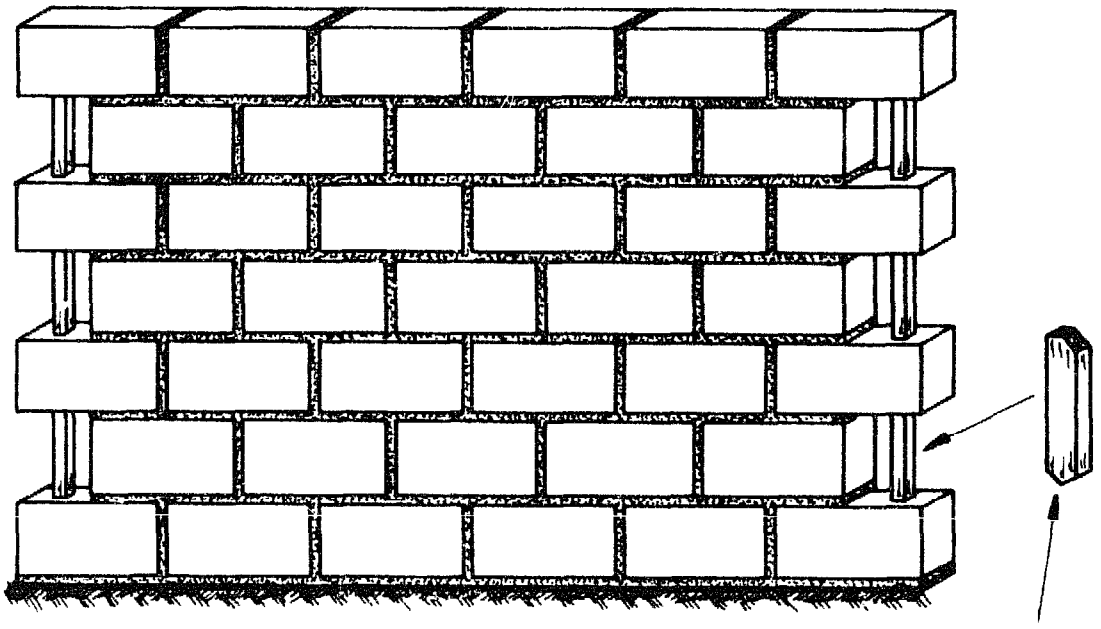

TOOTHED END

Fig. 2

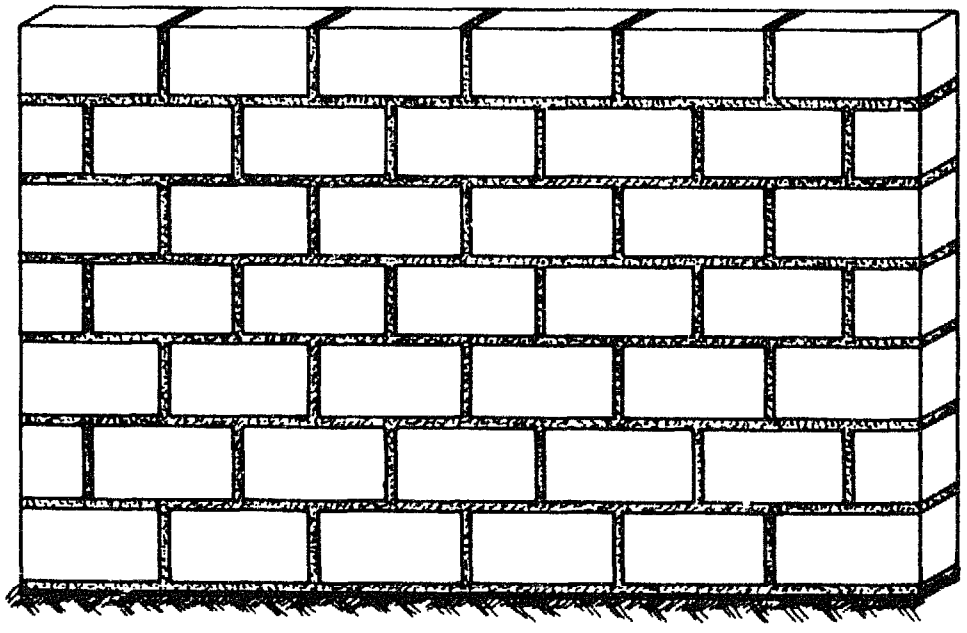

STOPPED END

N P V C	
21	BASIC.

THE FIRST WALL.

TOOTHED END

The construction of a wall with a toothed end starts with the same operations used for a wall with a racking back. After you lay the first block of the third course, the next block you lay forms the toothed end. As this block projects past the one below by more than half its own length, it should normally tip over on its projecting end. To prevent this, a temporary support must be provided until the block is overlapped by the first block of the fourth course and the mortar has set hard. This temporary support is preferably a short piece of board cut to the height of the block plus two bed joints. The upper and lower ends of the supporting board may be chamfered slightly to keep it from wedging between the blocks when it is removed (Fig. 1).

This block must be exactly above the first block of the first course. To ensure this, hold the spirit level against both header faces and make any necessary corrections. It is not necessary to level the top face if the stretcher and header faces have been plumbed.

The construction of further courses is again only a repetition of these operations.

STOPPED END

The construction of a wall with a stopped end is very similar to that with a toothed end. The sequence of operations is exactly the same except that instead of the supporting board, half a block is added at the end of the second course before the third course is laid (Fig. 2).

This means that there are no gaps left as in the toothed end, so it is called a stopped end.

NOTES:

Fig. 1

MARKING THE BLOCK

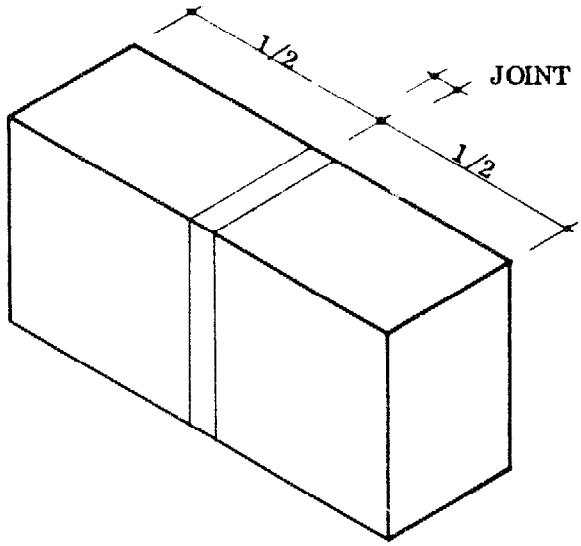

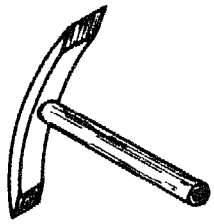

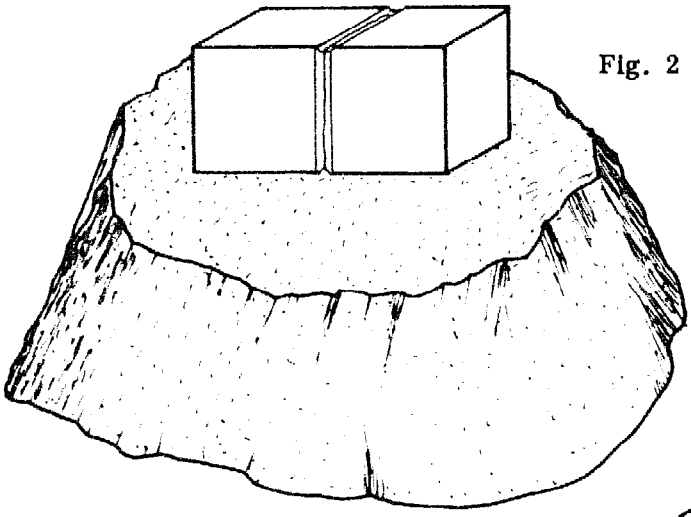

Fig. 2

CUTTING THE BLOCK
INTO HALF BLOCKS

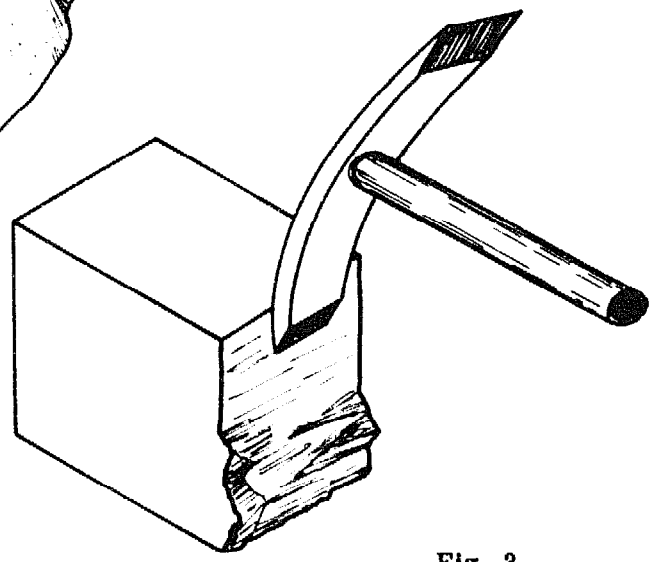

Fig. 3

TRIMMING OF HEADER FACE

N P V C		THE FIRST WALL.
23	BASIC.	

MARKING AND CUTTING BLOCKS

It is usually not possible to construct walls using only full blocks. In most cases 1/4, 1/2, and 3/4 blocks or intermediate sizes are also required. The previous description of the stopped end, for example, has shown the need for 1/2 blocks.

This does not mean that 1/2 blocks are obtained by simply cutting a full block into two identical halves. This is because the cross joint and its thickness must be considered.

Therefore, the 1/4, 1/2, and 3/4 blocks are actually that part of a full block minus half the thickness of the cross joint (Fig. 1).

Before cutting a block, mark the required size around all the faces. To prevent mistakes and to speed up the work, use a block gauge (see Rural Building Reference Book, Tools, page 12). Position the appropriate setting of the gauge against the block, then mark off the measurements on the block face using a pencil or a nail.

Set the marked block on a small heap of sand and then cut it with the block scutch by repeatedly and carefully knocking along the mark, making a groove in the surface. Direct the blows close to each other all around the four faces and continue until the block breaks apart along the groove (Fig. 2).

Trim the resultant rough header faces, if necessary, with the edge of your trowel blade (for landcrete blocks). When cutting sandcrete blocks, you should use the block scutch for trimming (Fig. 3).

- NOTE: Avoid cutting blocks on hard ground: they can easily break into irregular pieces and be wasted.

  Never cut blocks on a scaffold for the same reason, also because they might fall and injure someone below.

  It is always better to prepare in advance the number of blocks that you think will be needed that day.

  Do not use blocks which are cracked; these must be replaced by good blocks or the wall will be weakened.

NOTES:

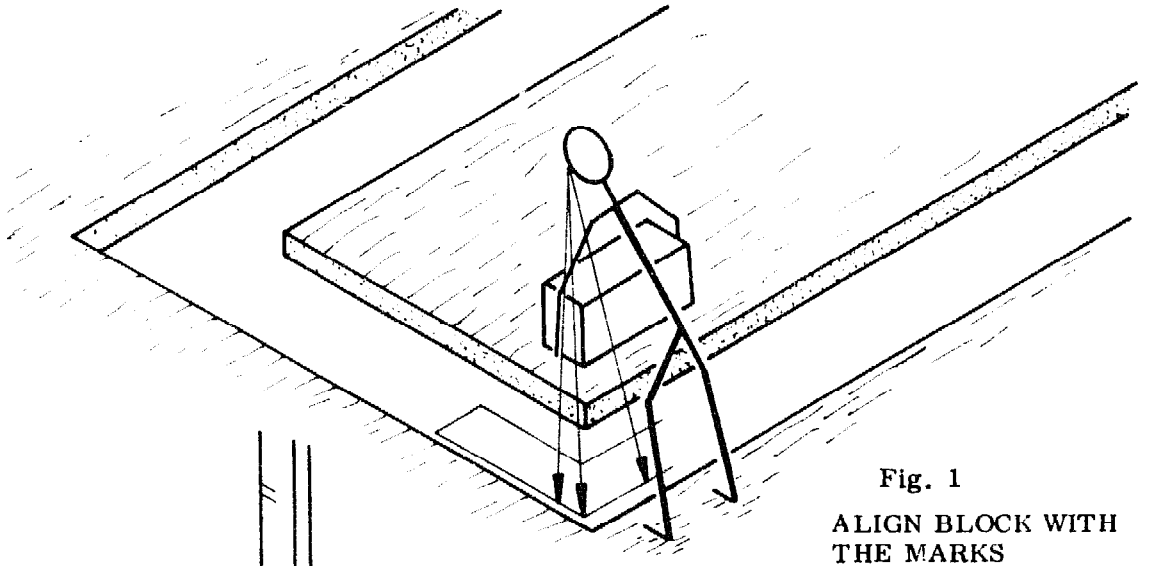

Fig. 1

ALIGN BLOCK WITH THE MARKS

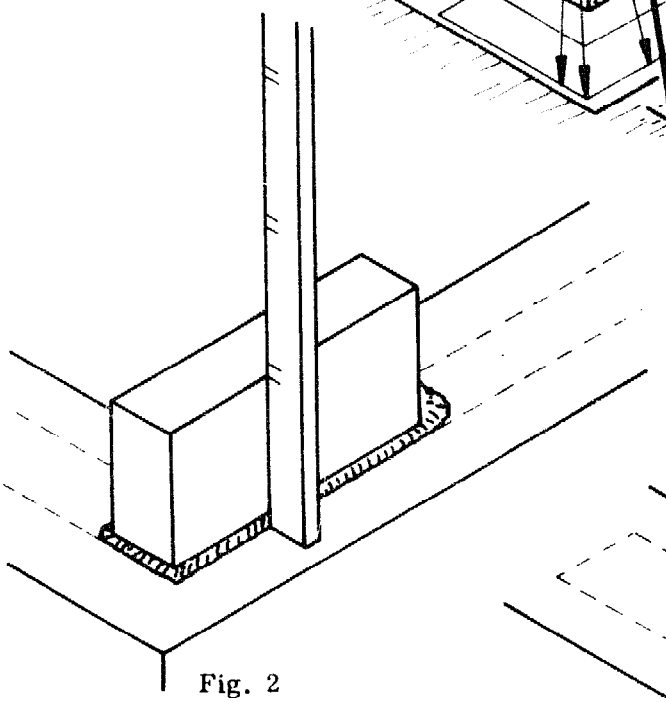

Fig. 2

CHECK CORRECT HEIGHT

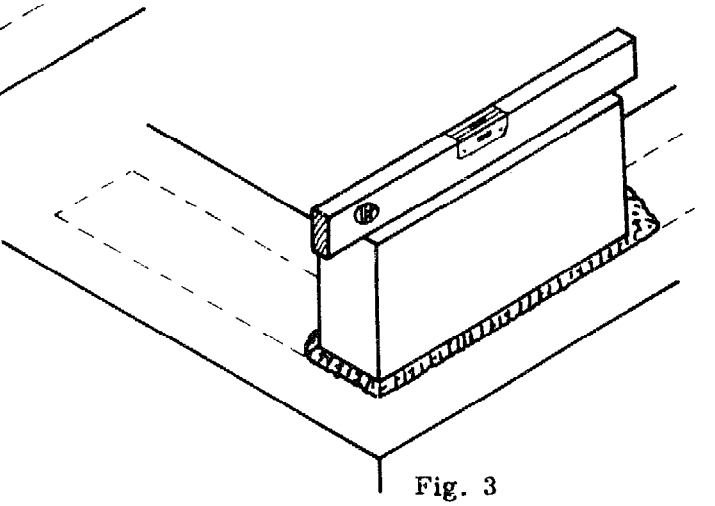

Fig. 3

LEVEL THE BLOCK

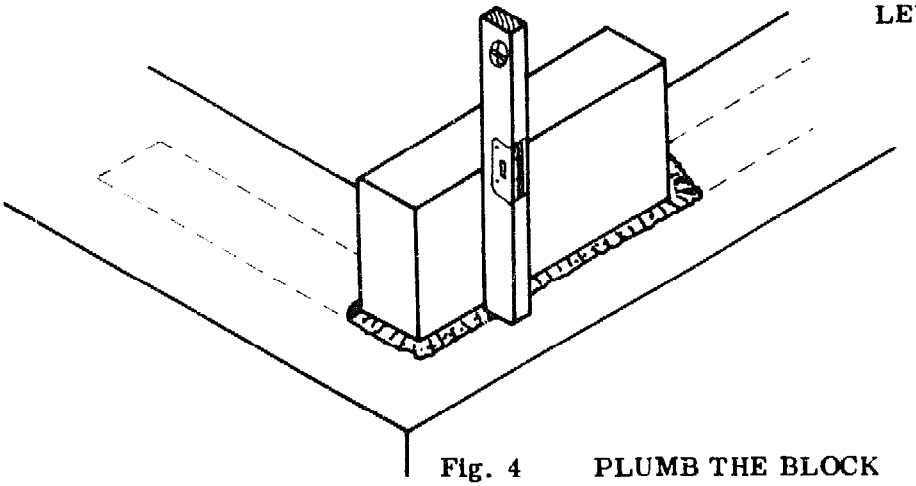

Fig. 4 PLUMB THE BLOCK

N P V C	QUOINS.
25 BASIC.	

QUOINS

When external walls are constructed the corners or quoins are built first, to a height of several courses. Usually it is best to build six courses as this will reach to about 1,5 m high, the so-called scaffold height; and in most cases this will be half of the total height of the wall. The walling between the courses is completed later, course by course. The accuracy of the whole wall is determined by the corners, so great care must be taken to build them properly.

At the beginning of training, the positions of the quoins are determined by marking them out on the floor using the mason square.

A quoin is constructed in the following manner:

Blocks are sometimes not correctly shaped, so the first block or angle block must be chosen carefully so that all its faces are square to each other.

As you lay the angle block, stand close to the foundation with your head vertically over the block. You should be able to see that both outer faces of the block are aligned with the mark below (Fig. 1). After this the block has to be accurately levelled and plumbed.

Use the straight edge with gauge marks to ensure that the block is laid at the correct height. Hold the straight edge vertically against the block; the top edge of the block should correspond to the gauge mark (Fig. 2).

Now you have to make certain that the header face and the stretcher face are truly vertical. To do this hold the spirit level against one face about 5 cm from the corner, keeping it in this position while with your other hand you move the block until the bubble in the tube is centered. This operation must be repeated with the other face of the block (Figs. 3 & 4).

NOTES:

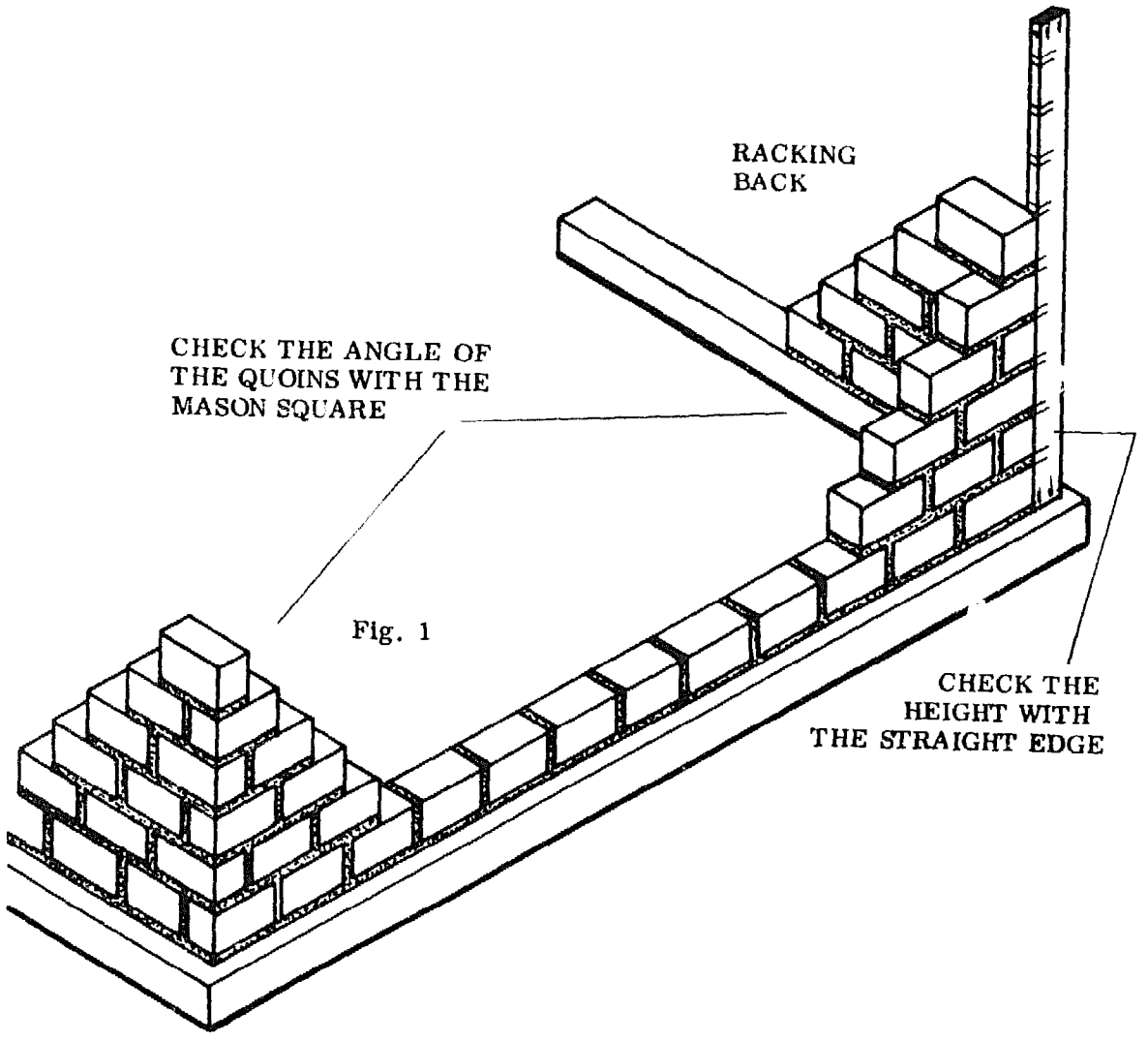

Fig. 1

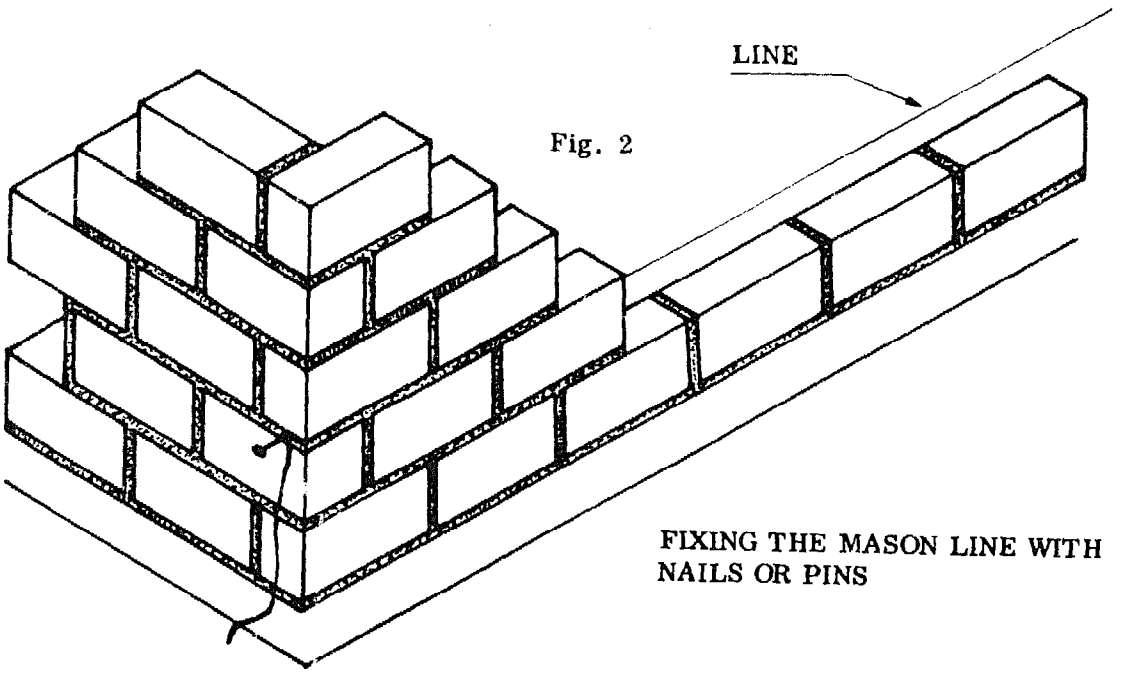

Fig. 2

NPVC	
27	BASIC.

QUOINS.

Now lay several blocks in each direction according to the method described before. On the quoin stretcher side three more blocks should be laid; followed by four on the header side of the quoin. This will be a sufficient base for building up a height of six courses with either a toothed end or racking back (Fig. 1).

Use the mason square to make sure that the quoin has an angle of 90 degrees. Hold it against the quoin so that both of the blades fully touch the faces of the blocks. Repeat this operation after turning the square around, so that the direction of the blades is reversed.

SECOND COURSE

Following the 1-2-1 rule, the first block of the second course will not be the angle block; but the one covering the cross joint between the quoin stretcher and the adjoining stretcher. If the angle block were laid first it could get pushed out of position when the other blocks are laid. The correct method fixes the angle block in position by the cross joint between it and the first block. A further reason for this procedure is that the cross joint between the quoin headers and the adjoining stretchers has a different thickness than the other cross joints. This problem will be explained later when we come to bonding problems.

To complete the second course use the same method as described for the construction of the first course.

- NOTE: The arrangement in any course is repeated in the courses two above or two below it. Therefore only two alternating block arrangements are used.

WALLING BETWEEN QUOINS

When both corners of a wall have been built up to a height of six courses, it is necessary to fill in the blockwork between them. This is done with the aid of the mason line and either nails, pins, or line bobbins.

FIXING THE MASON LINE

If nails or pins are used, insert one of them in the bed joint at one corner so that the line will be level with the upper edge of the course (see Rural Building Reference Book, Tools, page 6). Fix the mason line to the nail or pin without using a knot, as shown in Fig. 2. This is so that later it can be easily removed.

Stretch the line taut to prevent any sagging, and push the second nail or pin into the corresponding bed joint in the opposite quoin. The line should now be level with the top of the course to be built; and about 2 mm or the thickness of a trowel

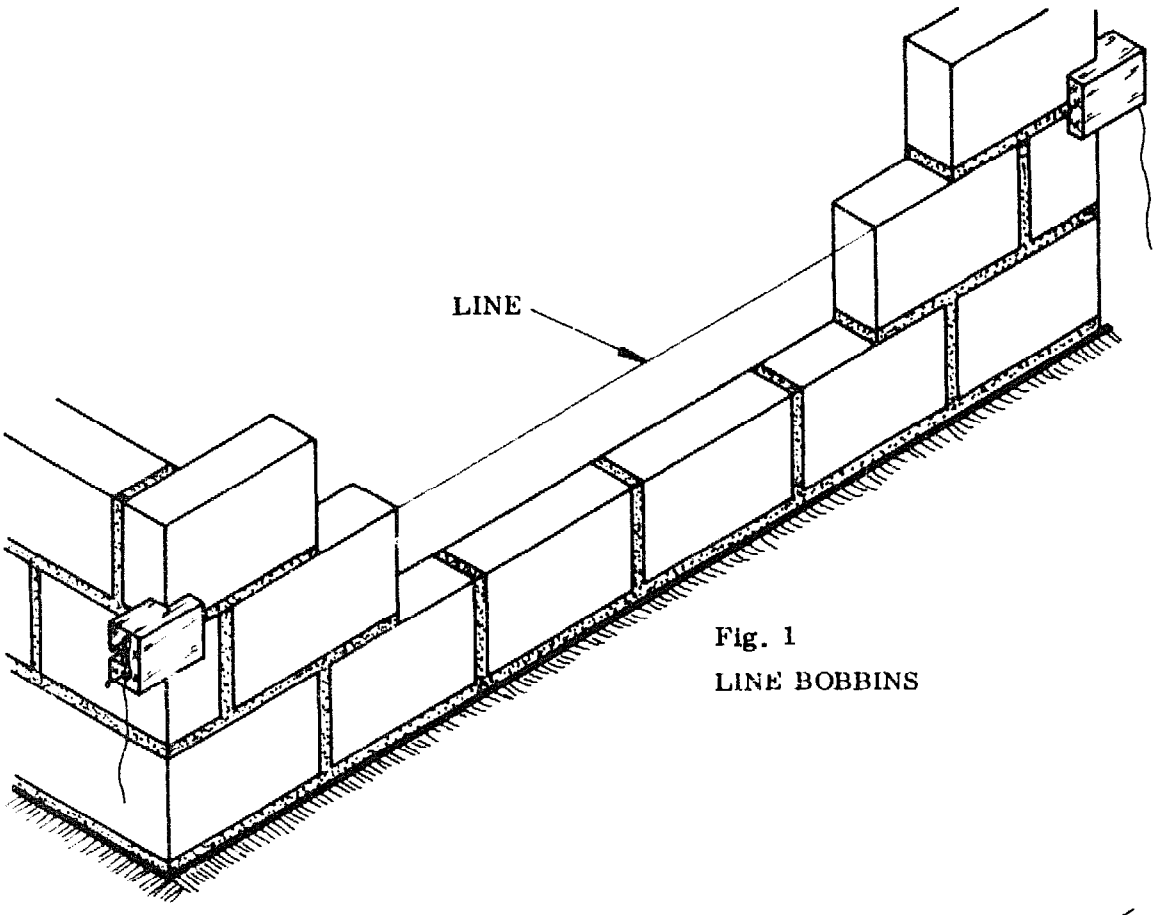

Fig. 1
LINE BOBBINS

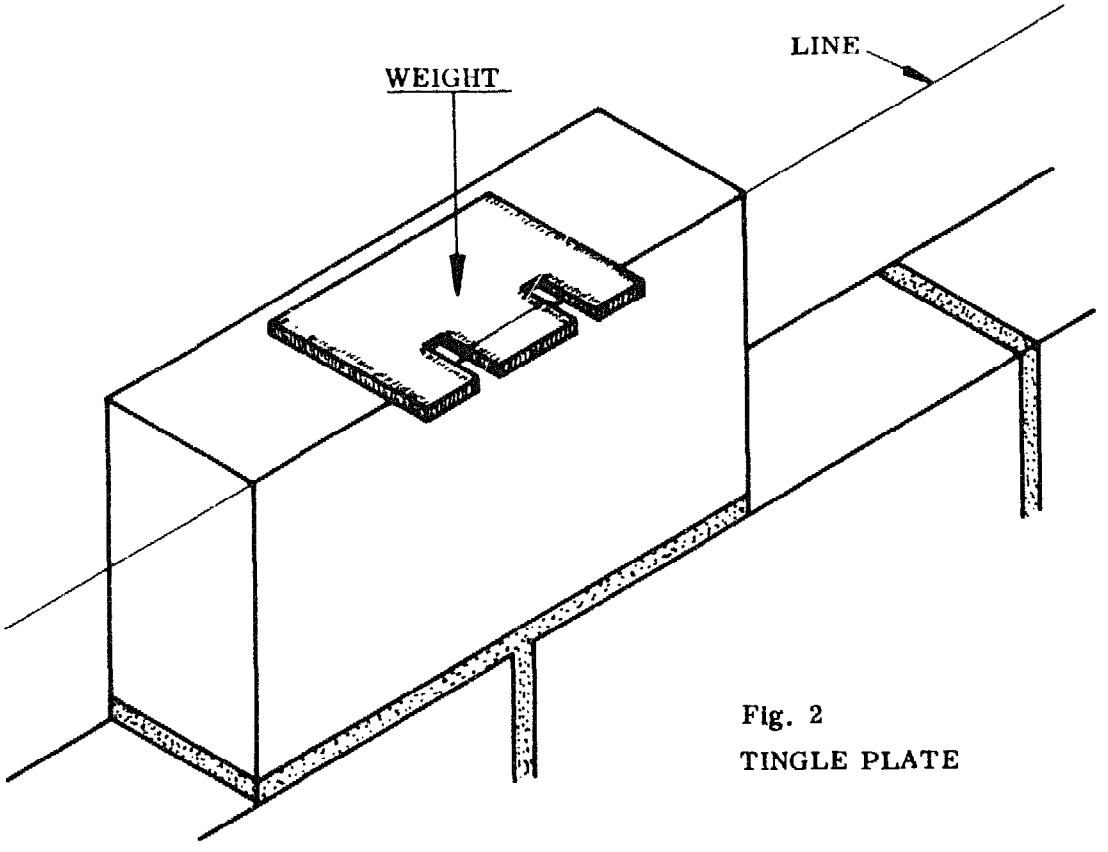

Fig. 2
TINGLE PLATE

N P V C		QUOINS.
29	BASIC.	

blade away from the blockwork. Put a wedge of paper between the wall and the line to keep the distance of 2 mm. The line should be horizontal.

If you use line bobbins instead of pins, take one with the line fastened around the screws and engaged in the saw cut; and position it with the notch against the corner of the quoin so that the line is level with the top edge of the course to be built. At the opposite quoin insert the line in the saw-cut of the second bobbin and set it at the correct height against the corner. Stretch the line taut and secure it by winding around the screws (Fig. 1).

The tight mason line holds the bobbins against the corners, keeping them in position. Once the line has been fixed in this manner no further adjustment is needed, unless the line starts to sag and needs tightening.

After one course is completed, simply slide the bobbins up the corners to the level of the next course.

USE OF THE TINGLE PLATE

If the line is stretched over a longer distance, it will tend to sag and will no longer provide a straight guide. In the case of a long wall where the distance between the bobbins exceeds 6 m, it becomes necessary to use one or more tingle plates (Fig. 2). This is done to keep the line from sagging. The tingle plate must be set on a so-called tingle block. Lay this block plumb, in position and at the correct height in the course to be built. This block keeps the tingle plate at the required height to support the mason line. Place the plate flat on the block, and weight it down with a half-block. The taut line is passed under the outer nibs and over the centre nib (Fig. 2).

COMPLETING THE COURSE

Now lay the blocks to complete the course. Take care that the outer top face edge of each block is level with the line.

At the same time be sure to keep the lower stretcher face edge in line with the edge of the course below. Avoid the tendency to lay the blocks too close to the line; the 2 mm distance must be maintained and checked from time to time by sliding the trowel blade between the line and block.

If the blocks are laid correctly, plumbing and levelling are not necessary. It is advisable however to check the face of the wall for a possible overhang, using the straight edge.

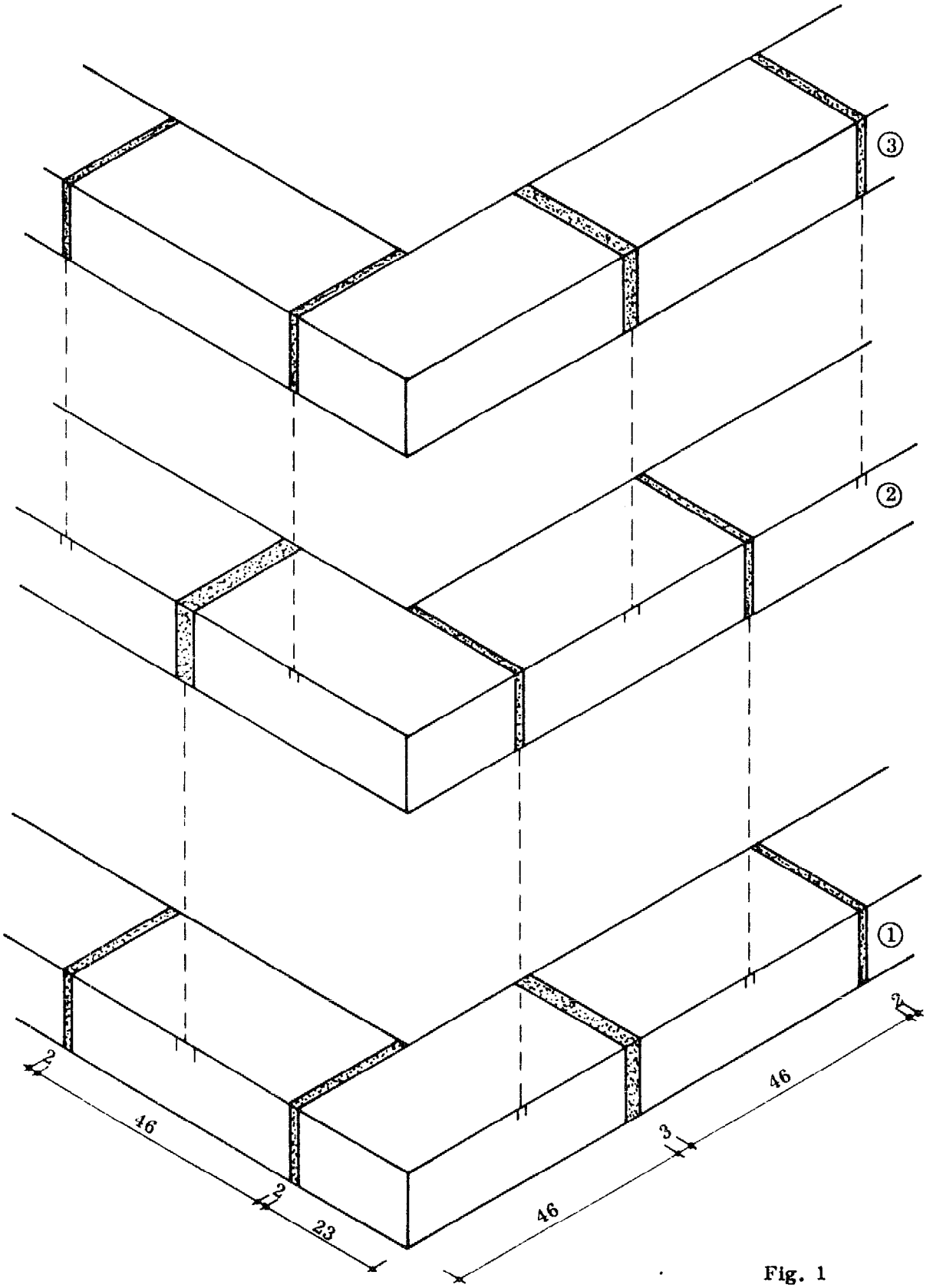

Fig. 1

N P V C	
31	BASIC.

BONDING PROBLEMS & CORNER BONDS.

After you have filled the cross joints, carefully rake out all the joints of the freshly laid courses to provide an additional grip for the plaster.

BONDING PROBLEMS

Problems arise when we use different types of blocks in the same wall. Usually in Rural Building we use sandcrete blocks for the lower courses of a wall to avoid problems with dampness, and landcrete blocks for the higher courses. Unfortunately the dimensions of sandcrete blocks and landcrete blocks do not match up well to each other. This means that it is not as easy to maintain a half-block bond as it is in a wall made up of only one kind of block.

For example, a sandcrete block has dimensions of 46 x 23 x 15 cm. A sandcrete half-block has the dimensions 22 x 23 x 15 cm. Even when the sandcrete blocks are cut in half they still will not match up exactly to the landcrete blocks (see the table below).

	Full block	Half block
Sandcrete	46 x 23 x 15	22 x 23 x 15
Landcrete	29 x 22 x 14	13,5 x 22 x 14

The dimensions of the 1/4 and 1/3 blocks also do not correspond, so in order to maintain the half-block bond between the sandcrete and landcrete courses we would have to make quite an adjustment.

Practically this means that although it would be better, we cannot maintain exactly a half-block bond between the sandcrete and landcrete. They must be considered as separate parts of the wall, properly bonded in themselves but not necessarily showing a half-block bond between them.

CORNER BONDS

CORNER BOND FOR FOOTINGS

The materials used for footings are sandcrete blocks which must be laid flatwise, giving a wall thickness of 23 cm. Since this measurement exceeds the length of a half-block by 1 cm, the first cross joints following the quoin stretchers must be 3 cm wide instead of the normal 2 cm. All the other joints are still 2 cm thick. By doing this the half-block bond is maintained (Fig. 1).

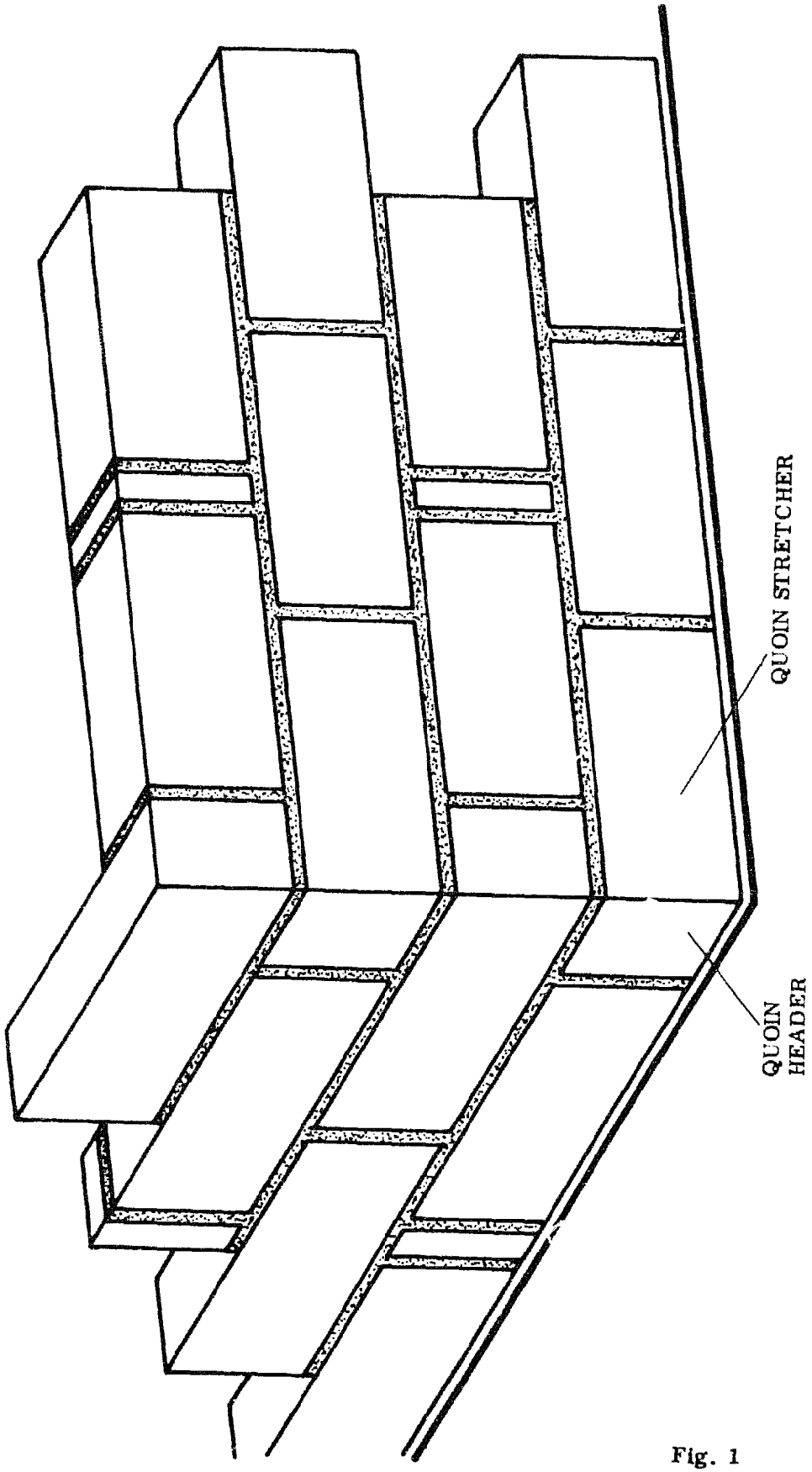

Fig. 1

N P V C	
33	BASIC.

CORNER BONDS.

There are of course two other ways to maintain the half-block bond:

- All the cross joints directly following the quoin header could be reduced to a thickness of only 1 cm. The effect would be the same but these joints would be difficult to fill properly, which could result in a weak quoin.
- All stretchers following the quoin headers could be cut to a length of 45 cm. This takes time and may damage the blocks.

In general, it is best not to use these last two methods.

CORNER BOND FOR A RISING SANDCRETE WALL

So-called wet rooms such as kitchens, showers and toilets must be built with sandcrete blocks. This is to avoid any damage to the walls caused by moisture.

If landcrete blocks are exposed to moisture for a long time the blocks will start to expand. This pushes the plaster off the walls and makes them weaker and weaker until finally they collapse under their own weight.

Rising walls in Rural Building are generally built by laying the blocks edgewise. When sandcrete blocks are used the wall has a thickness of 15 cm.

In order to avoid making too many cross joints within the quoin area, each quoin header as well as each quoin stretcher is followed by a full block.

To maintain the required half-block bond, a 7 cm lack of overlap has to be made up. This is done by inserting a 5 cm block between the first two stretchers that follow the quoin headers (5 cm plus 2 cm joint equals 7 cm). Almost every building project does thin blocks for copings or rain gutters etc., and these specially made blocks can be simply cut in half and used to fill the gaps (Fig. 1).

NOTES:

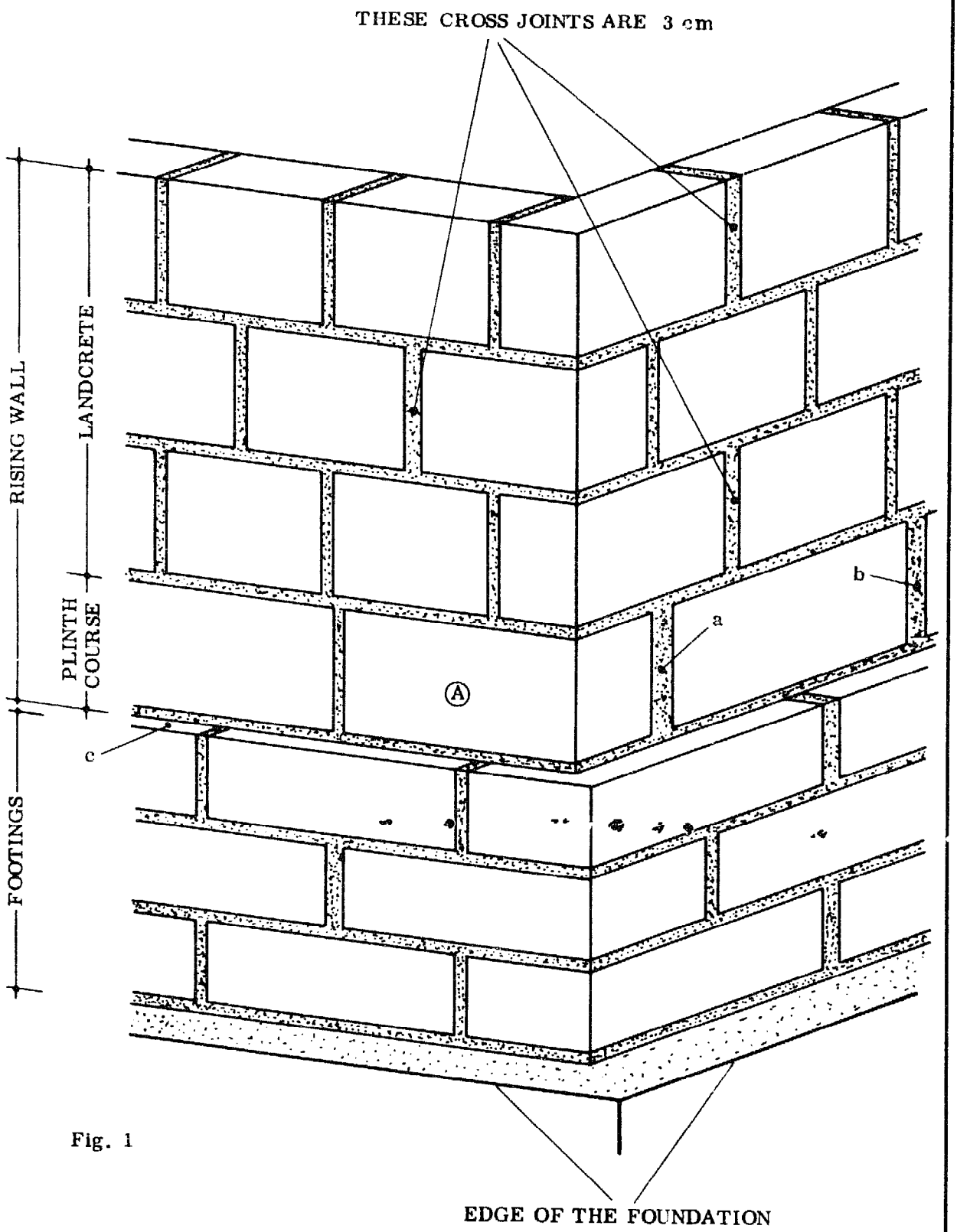

Fig. 1

N P V C	
35	BASIC.

CORNER BONDS.

CORNER BOND FOR RISING LANDCRETE WALL

As far as bonding is concerned, the footings, the plinth course and the rising landcrete wall are all regarded separately. They are properly bonded in themselves but don't necessarily show a half-block bond, especially between the plinth course and the landcrete wall.

As Fig. 1 illustrates, a half-block bond between footings and plinth course (both sandcrete) is possible despite the 4 cm setting back (c) and should be maintained.

- PLINTH COURSE: Since the rising wall is erected exactly in the middle of the footings, the plinth course has to be set back 4 cm from both faces: 23 cm (thickness of footings) minus 15 cm (thickness of plinth course) divided by 2 equals 4 cm (at both sides).

  The angle block (A) has to be shortened by 3 cm because of the setting back, thus we automatically make the correct half-block bond on the quoin stretcher side. The first two cross joints (a & b) following the quoin header must be widened to 4 cm each to overcome a lack of 4 cm in overlap. By doing this we distribute the lack of 4 cm over two joints equally.

- RISING LANDCRETE WALL: As already stated, the rising landcrete wall is regarded separately from the plinth course. This is because the dimensions of the landcrete and sandcrete blocks prevent the construction of a half-block bond between them.

  However, one important rule must be observed: No matter what part of the construction or what material it consists of, each quoin header must be overlapped by a quoin stretcher; each quoin stretcher is automatically followed by a quoin header (Fig. 1).

  To maintain the half block bond within the landcrete wall, all the cross joints directly following the quoin stretchers must be widened to 3 cm. All other joints remain the same.

NOTES:

CORNER BONDS.	N P V C	
	BASIC.	36

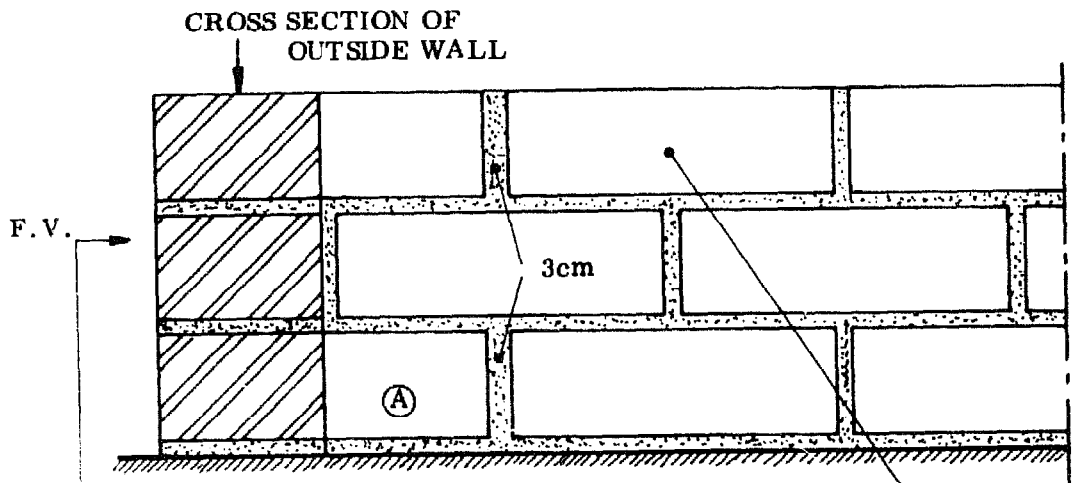

Fig. 1 COMBINED SECTION OF OUTSIDE WALL AND VIEW OF INSIDE WALL

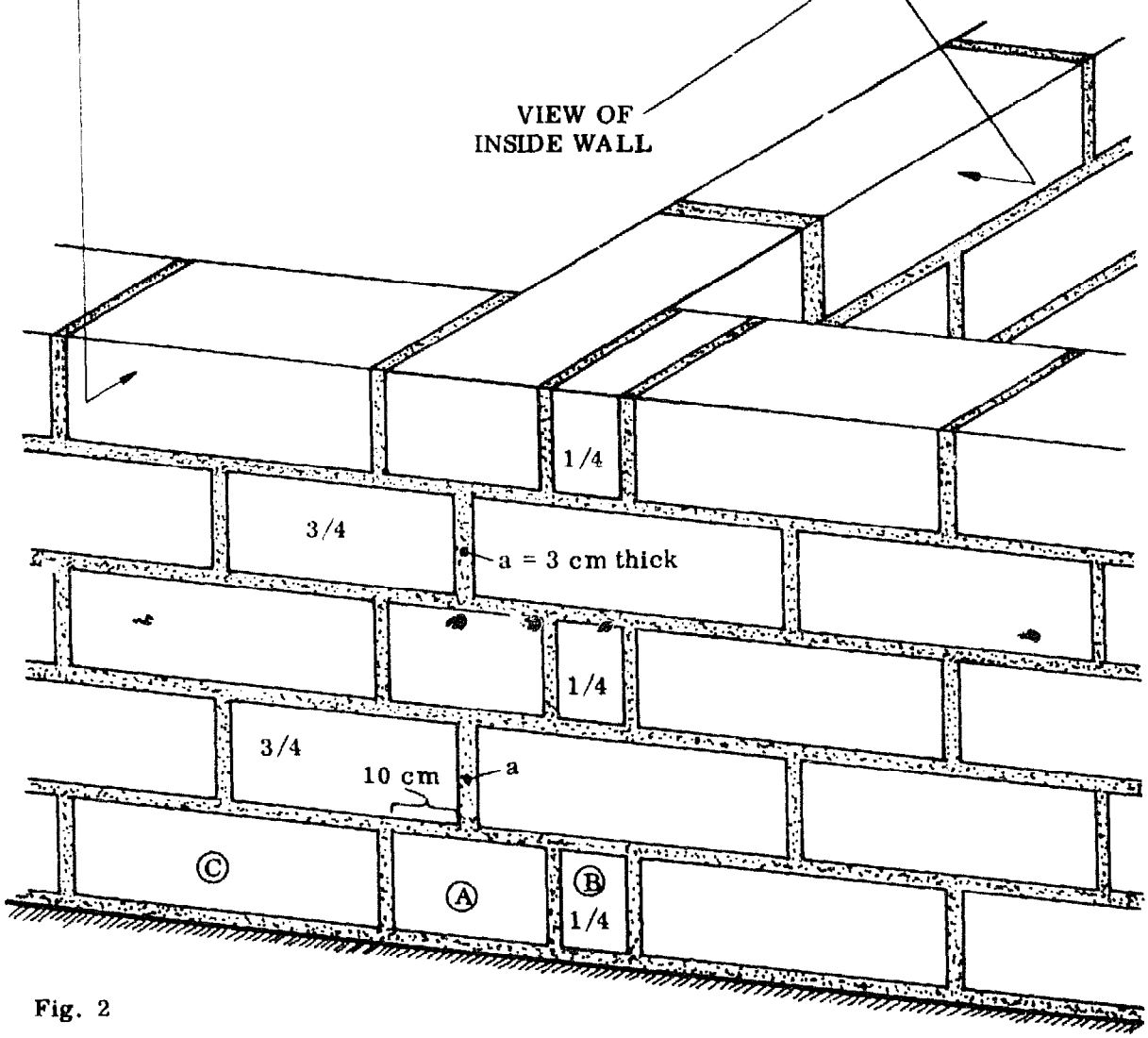

Fig. 2

N P V C	
37	BASIC.

T-JUNCTION BONDS.

T-JUNCTION BONDS

The term T-junction is given to connections between walls which form a T shape, although it is not essential that the angles be right angles. This situation occurs most often where outside walls are met by inside walls.

T-JUNCTION BOND FOR FOOTINGS

Like quoins, the T-junctions are built first or at the same time as the quoins, and the walling between them is completed later.

The first block to be laid is the first block (A) of the inside wall: it will be seen as a header in the face of the outside wall (Figs. 1 & 2). This followed by a 1/4 block (B) at one side of it in the direction of the outside wall, and by a full block (C) on the other side (Fig. 2). This is followed by laying full blocks in all three directions.

The second course, and all the alternate courses, go through in the direction of the outside wall, that is, they do not share a block with the inside wall. Thus the inside wall is bonded to the outside wall only at alternating courses: at the 1st, 3rd, 5th etc. courses (Figs. 1 & 2).

The second course starts with a 3/4 block overlapping the header below by 10 cm but from the side opposite from the 1/4 block below. This is followed by full blocks in all three directions (Figs. 1 & 2).

The cross joints between the headers of the inside wall (a) are 3 cm thick and must be exactly in line with the centre of the headers (Fig. 1). The cross joints directly following the blocks which are bonded to the outside wall are also 3 cm thick (Fig. 2). All the other joints are 2 cm thick.

- NOTE: All courses with odd numbers (1st, 3rd, 5th etc.) share one block with the inside wall; these blocks are seen as headers in the face of the outside wall, each one next to a 1/4 block.

  All courses with an even number (2nd, 4th, 6th, etc.) go through in the direction of the outside wall and contain a 3/4 block at the opposite side of the 1/4 block below and above.

NOTES:

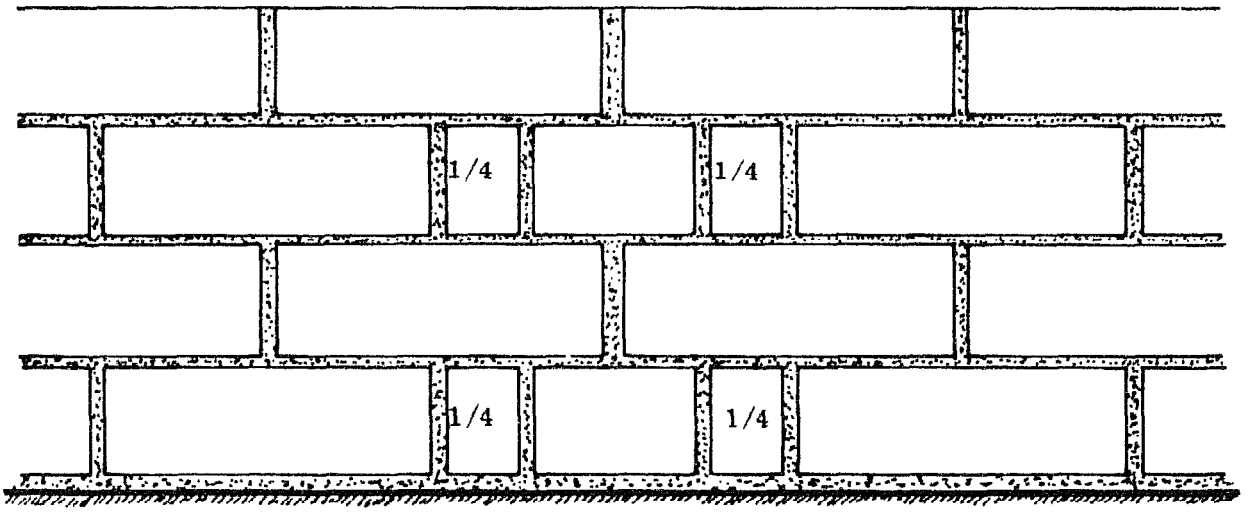

Fig. 1 2nd CONSTRUCTION

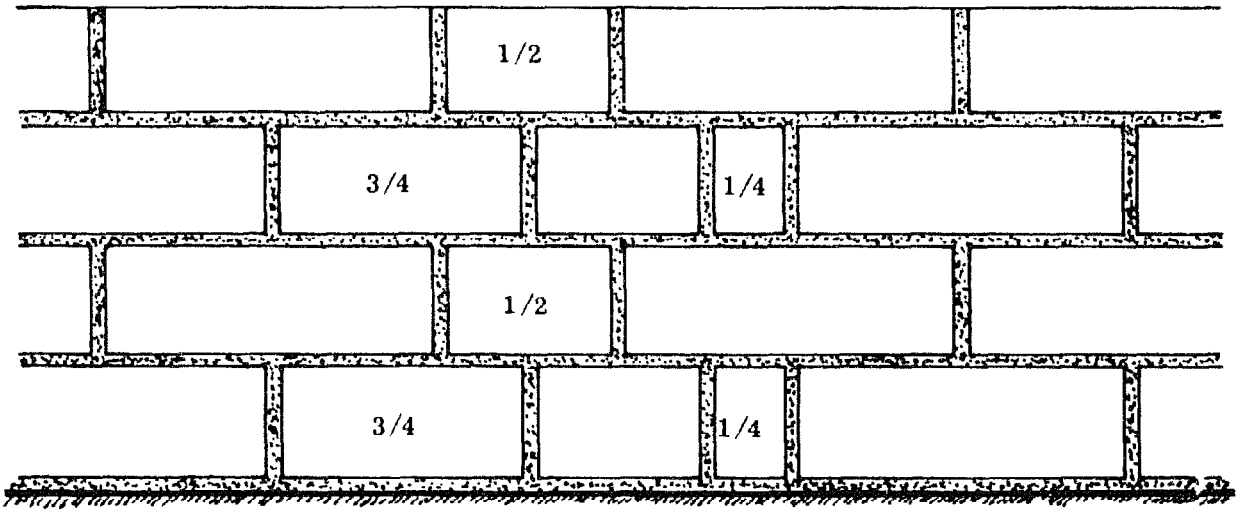

Fig. 2 3rd CONSTRUCTION

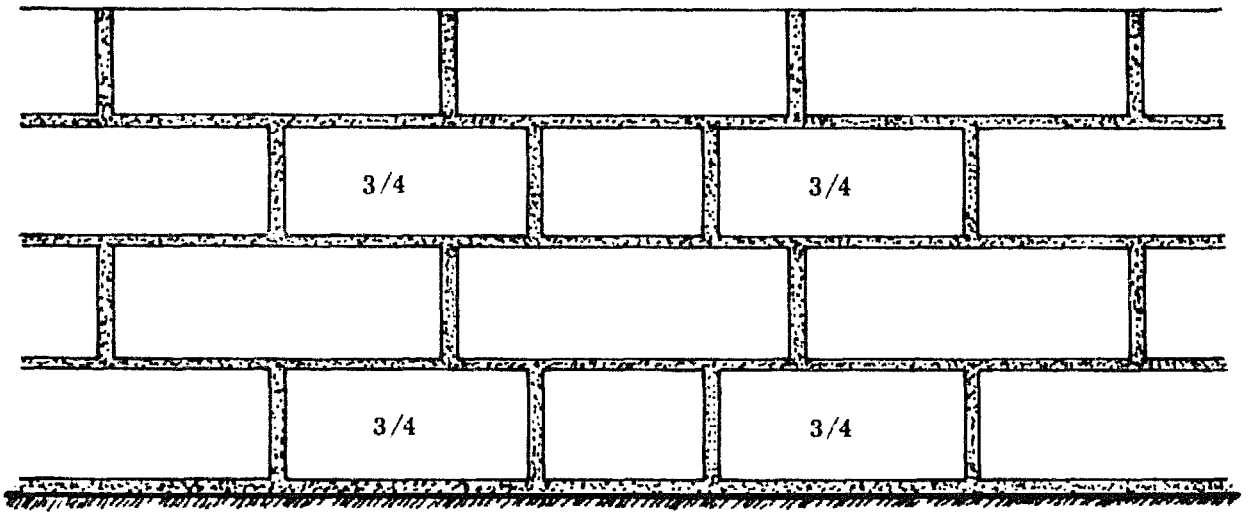

Fig. 3 4th CONSTRUCTION

N P V C	
39	BASIC.

T-JUNCTION BONDS.

The illustrations on the opposite page show three other possible constructions for T-junctions in footings, all of which maintain the half-block bond (Figs. 1, 2, & 3).

Which method is used depends on factors such as the distance between the junction and the next quoin, or the next junction.

One way to find out the best choice is to lay out the first course of blocks without mortar, and try different arrangements. In this way the builder can decide what will be the best final arrangement.

If two or more constructions are possible the Rural Builder should chose the most efficient method. This is the method that wastes the least time and materials.

Specifically, the more blocks that have to be cut the more time will be needed; and if for example only 3/4 blocks are needed, the remaining 1/4 blocks are wasted unless there is a need for them somewhere else.

By comparing the four possible constructions (Figs. 1 & 2 on page 37, and Figs. 1, 2 & 3 at left) we see that the first three can be carried out without any waste of blocks while in the last case (Fig. 3) all the 1/4 blocks are left-over.

As far as efficient work is concerned, we see that for the first method (page 37) only one cut needs to be made for two courses as both parts of the block are used. The alternatives shown in Figs. 1, 2 and 3 need two cuts for two courses.

By considering carefully the advantages and disadvantages of the four, we see that the first construction is the best, the 2nd and 3rd constructions are less good and the 4th construction is the worst. Therefore the first type should be used whenever possible.

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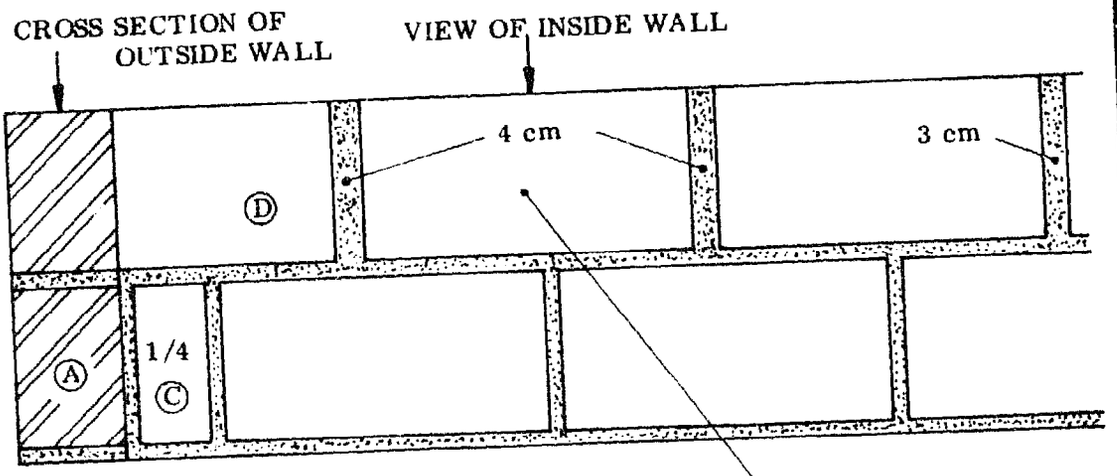

Fig. 1

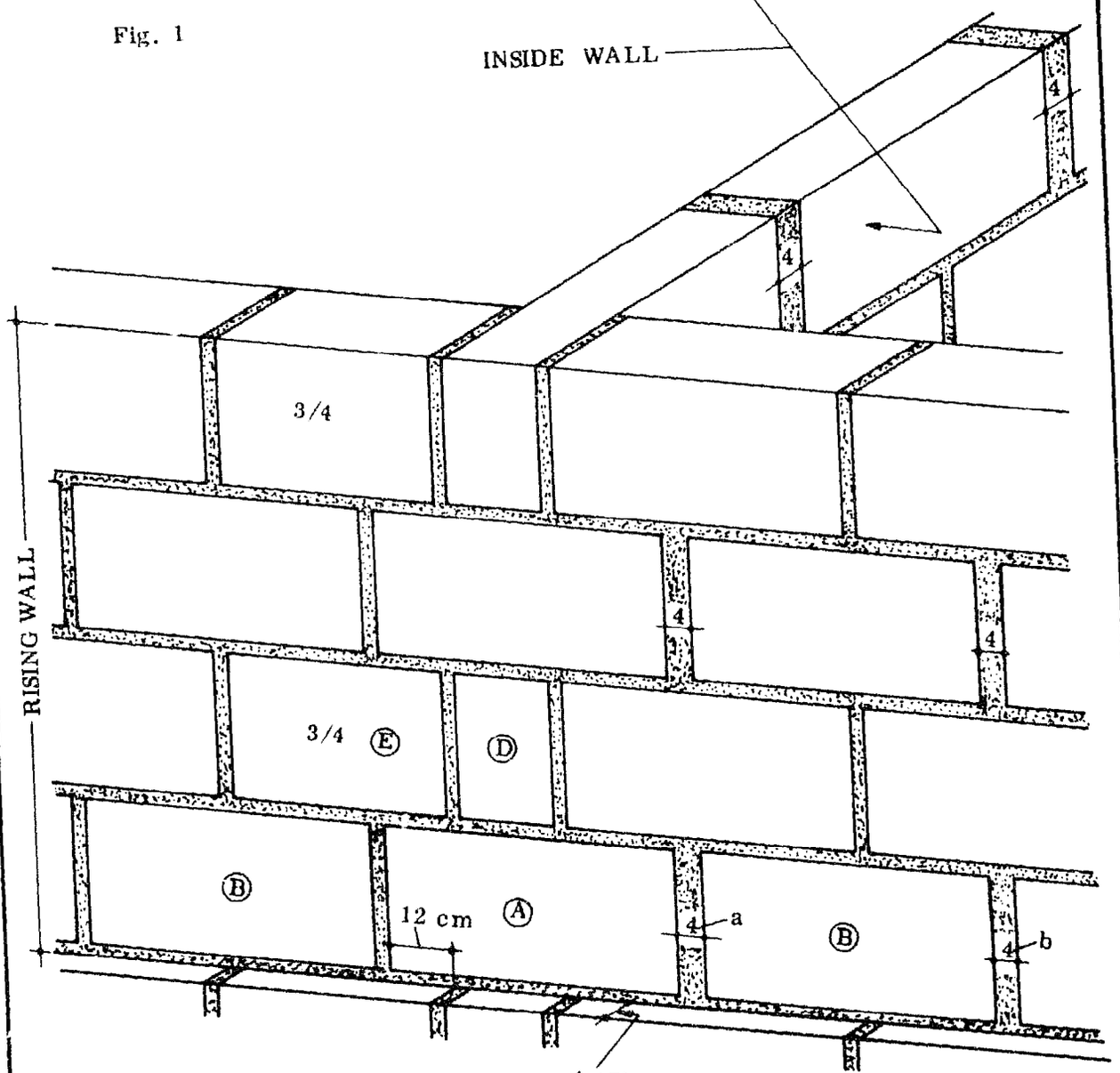

Fig. 2

N P V C	T-JUNCTION BONDS.
41 BASIC.	

T - JUNCTION BOND FOR RISING SANDCRETE WALLS

Since the footings are normally 3 courses high, the third course of the footings contains the block which bonds the inside wall. Thus the first course of the rising sandcrete wall must go through in the direction of the outside wall to cover the header of the footings (see previous pages).

The first block of the rising wall is placed so that it extends past the header below by 12 cm on one side (Fig. 2, block A). Don't forget to set this block back from the face of the footings by 4 cm. This block is followed by full blocks on either side (Fig. 2, blocks B). The inside wall starts with a 1/4 block (Fig. 1, block C), this too is followed by full blocks.

The second course of the T-junction begins with the full block of the inside wall that is bonded into the outside wall (Figs. 1 & 2, block D). This is followed by a 3/4 block (Fig. 2, block E) on the same side of the header where the stretcher (block A) below projects by 12 cm. Continue with full blocks in all three directions.

The odd-numbered courses of the outside wall contain widened cross joints to catch up with the half-block bond. The first two cross joints opposite the 12 cm projection (Fig. 2, a & b) are 4 cm thick, followed by one more joint which is 3 cm thick (not shown). In this way the half-block bond is maintained.

The same must be done with the first three cross joints following the bonded block of the inside wall (Fig. 1).

NOTES:

Fig. 1

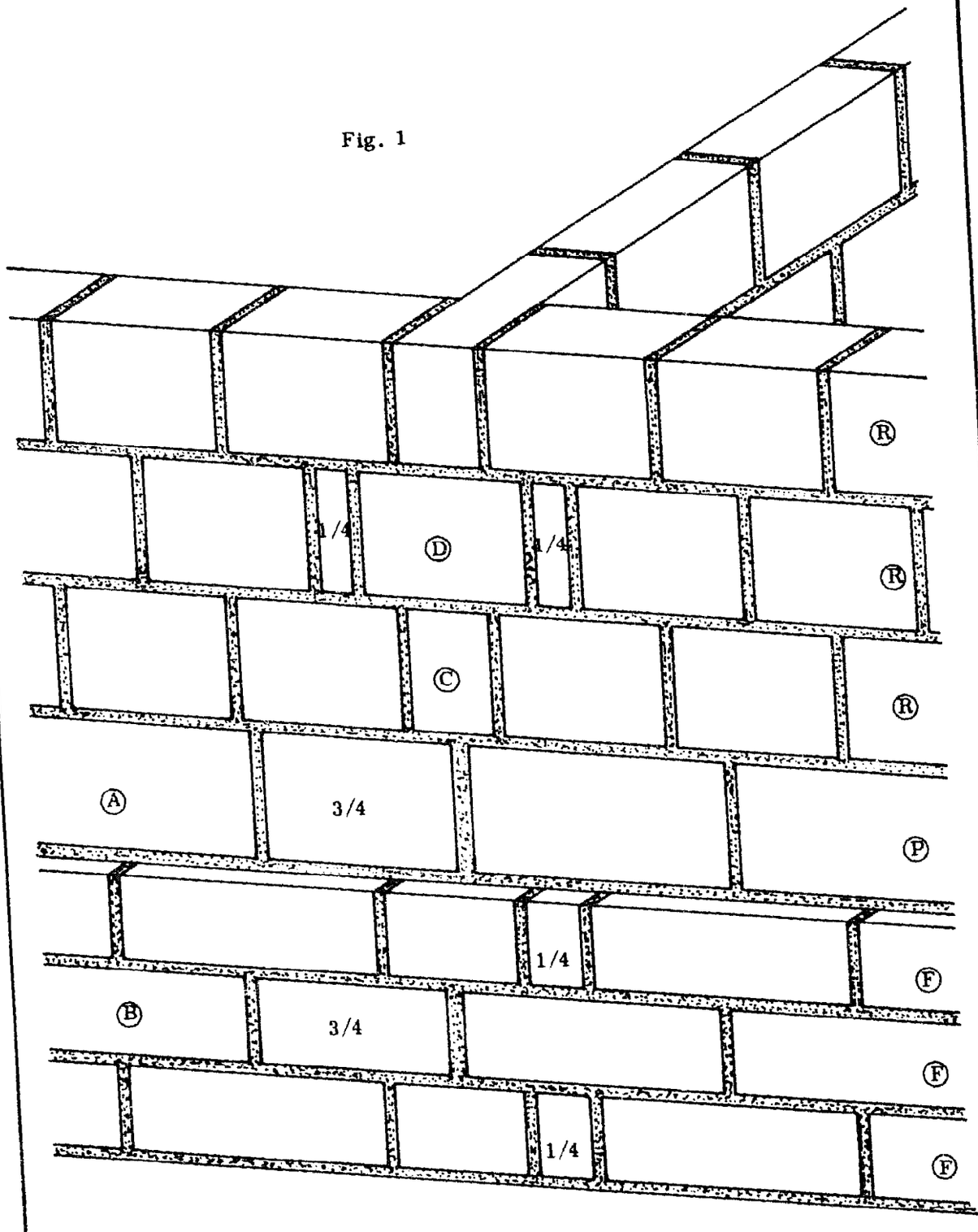

Ⓡ = RISING WALL
Ⓟ = PLINTH COURSE
Ⓕ = FOOTINGS

N P V C	T-JUNCTION BONDS.
43 BASIC.	

T-JUNCTION BOND FOR RISING LANDCRETE WALLS

- PLINTH COURSE: Except that the blocks are laid edgewise rather than flat, the plinth course is simply a repetition of the footing course two courses below (Fig. 1, blocks A & B).

  The only difference is that the first two cross joints in the inside wall are widened to 4 cm each, in order to maintain the half-block bond in relation to the footings.

  Do not forget to set the plinth course back from the face of the footings by 4 cm.

- RISING LANDCRETE WALL: Since the landcrete wall is 1 cm thinner than the plinth course, it is essential to continue the "good" face of the plinth by setting the landcrete blocks flush with the outside face of the plinth. The Rural Builder should choose one face of the inside wall to be the "good" face; where the surface of the plinth course is flush to that of the rising wall. This is the face from which the plumbing and levelling are done; the Rural Builder should alway work from this face. On outside walls the "good" face is normally the outside face.

  The first block of the landcrete wall is the one which is shared by the inside and outside walls and covers two cross joints (Fig. 1, block C). It is followed in all three directions by full blocks.

  The second course of the rising landcrete wall begins with a full block centred exactly over the header below, with 1/4 blocks on either side (block D). All of the other courses in the rising wall are repetitions of these two courses.

NOTES:

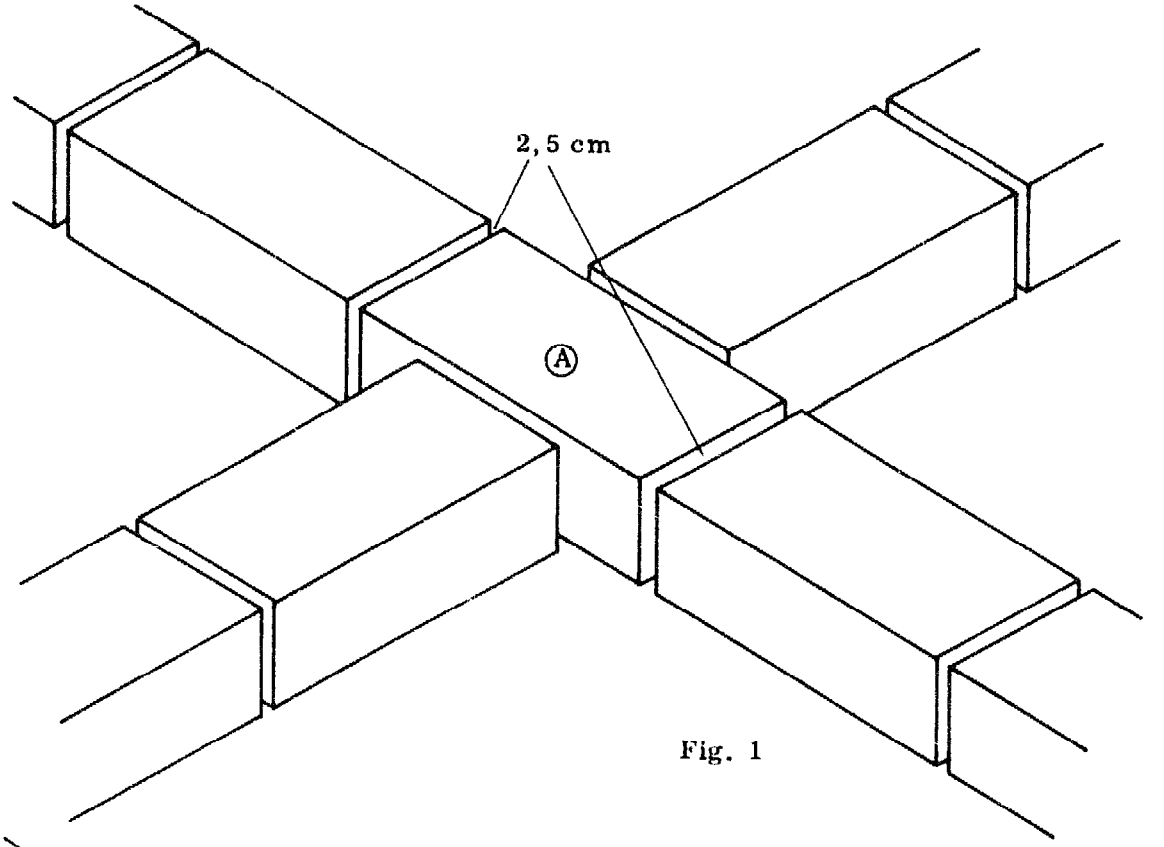

Fig. 1

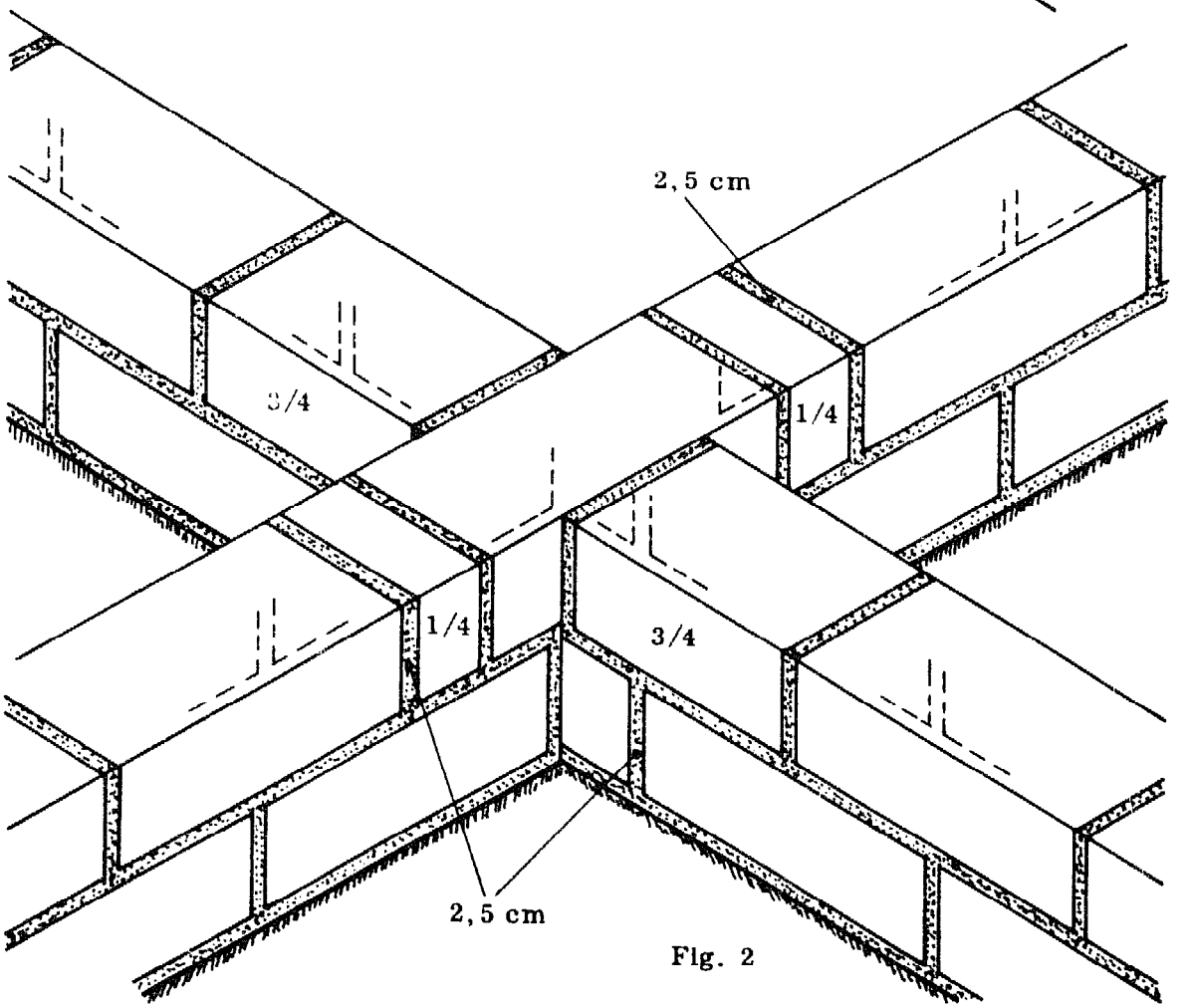

Fig. 2

NPVC	
45	BASIC.

CROSS JUNCTION BONDS.

CROSS JUNCTION BONDS

A cross junction, also called an intersection, consists of two continuous walls which intersect, or cross each other.

The following are only a few examples out of many methods for bonding at a cross junction. In actual practice the dimensions of the building will not always permit the use of these particular bonds. In such cases some adjustments must be made.

The essential requirements for a cross junction always remain the same:

- avoid making continuous cross joints; and
- try to use a minimum number of cut blocks.

CROSS JUNCTION BOND FOR FOOTINGS

The first course consists entirely of full blocks (Fig. 1). The through-going block (A) projects equally from both sides of the crossing wall. This block has cross joints of 2,5 cm on each end, but all the other joints are still 2 cm thick (Fig. 1).

The second course starts with a full block centred over the through-going block below. This block is followed by 1/4 blocks on either end. The 1/4 blocks each have one cross joint which is 2,5 cm thick. All other joints are still 2 cm thick.

The second course of the crossing wall continues with 3/4 blocks on both sides. This is followed by full blocks in all four directions.

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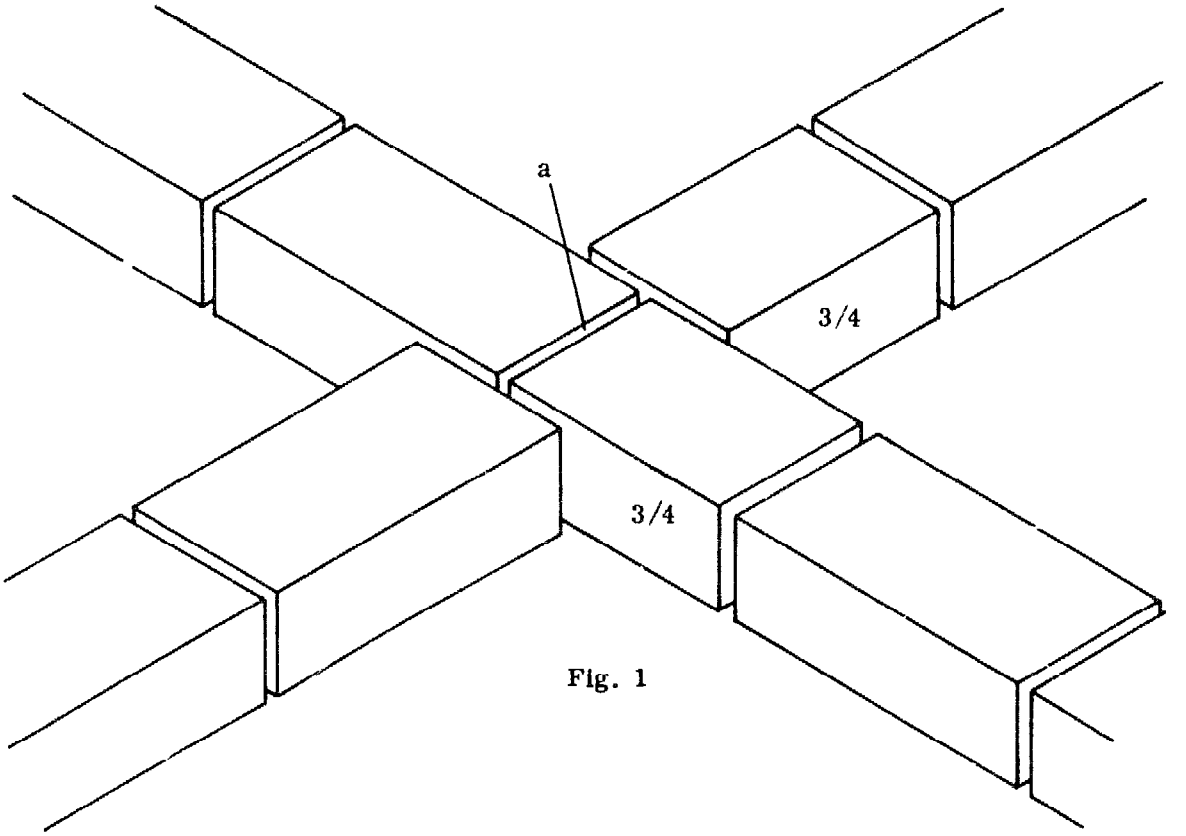

Fig. 1

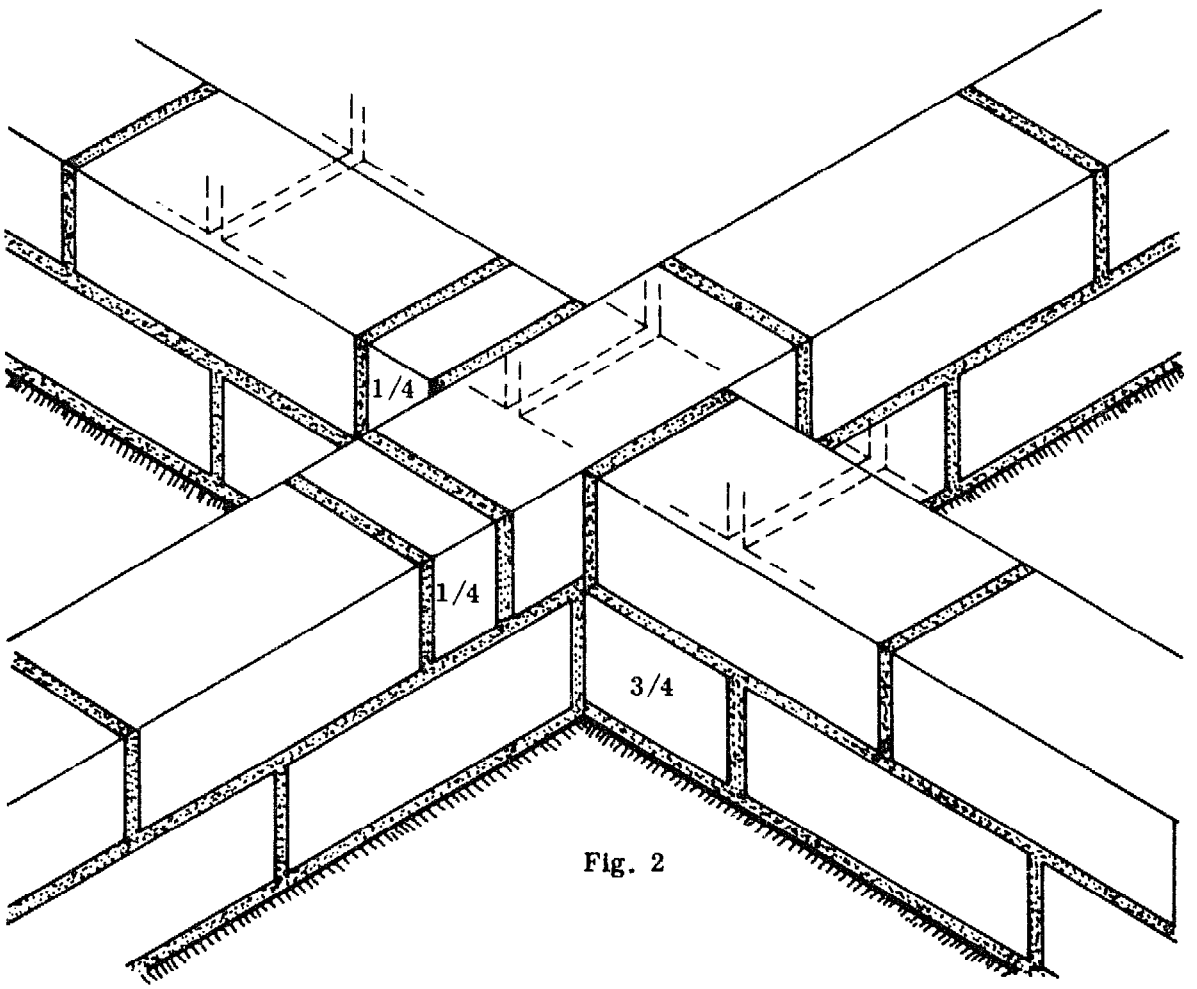

Fig. 2

N P V C	
47	BASIC.

CROSS JUNCTION BONDS.

The second possible construction is where the crossing walls enclose a cross joint (Fig. 1, a). In this case two 3/4 blocks are used in the first course while the remaining 1/4 blocks are kept aside for the second course (Fig. 1).

The two 3/4 blocks of the first course are arranged so that they are at right angles to each other. One of the 3/4 blocks always starts from the middle of the crossing wall while the other is placed on either the right or left side of it. This is followed in all four directions by full blocks (Fig. 1).

The second course begins with a full block crossing the through–going wall below and overlapping equally at both sides. This block covers three cross joints at once instead of two as in the last method. The first block is followed by the 1/4 blocks placed on opposite sides from the 3/4 blocks below. The second course is continued with full blocks in all four directions (Fig. 2).

Each 1/4 block must have one cross joint of 2,5 cm; all other joints remain the same, 2 cm thick.

Try to figure out more possible ways to do a cross junction bond, and discuss the results with your fellow trainees, your instructors, and your foreman on the building site.

NOTES:

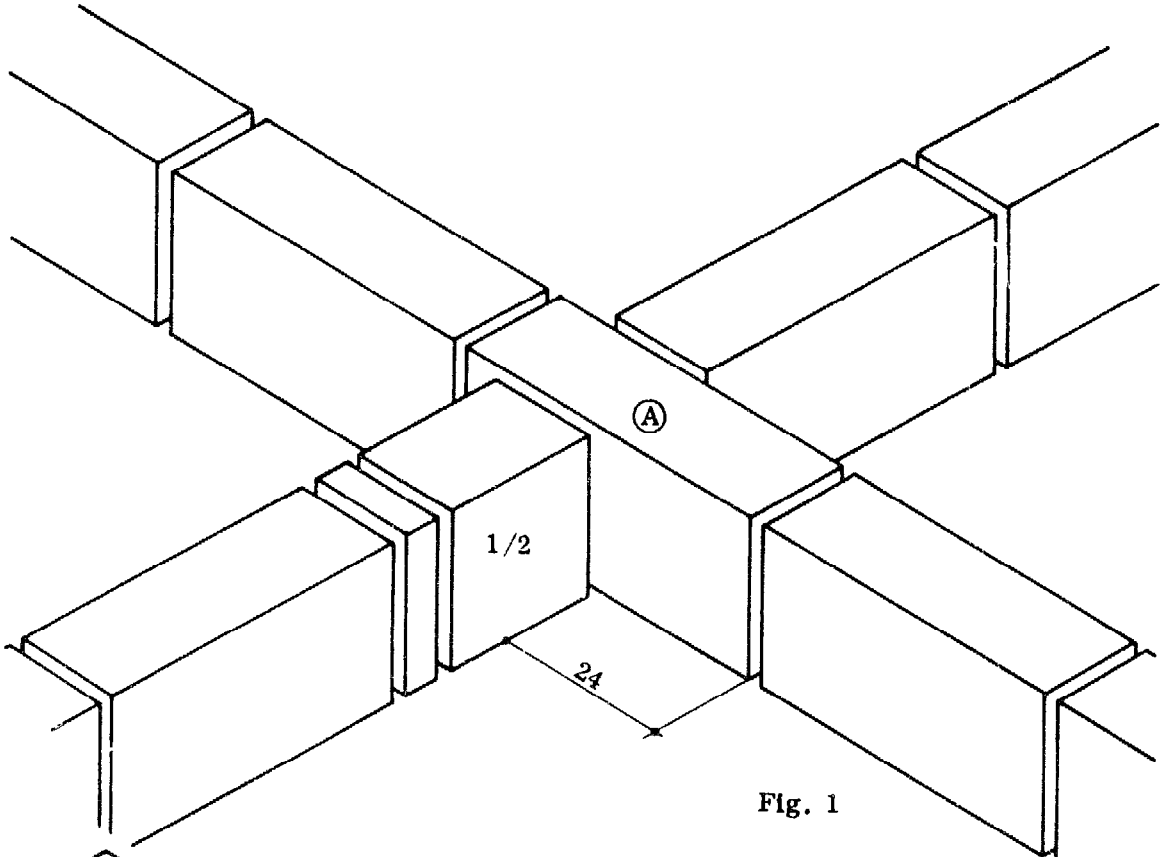

Fig. 1

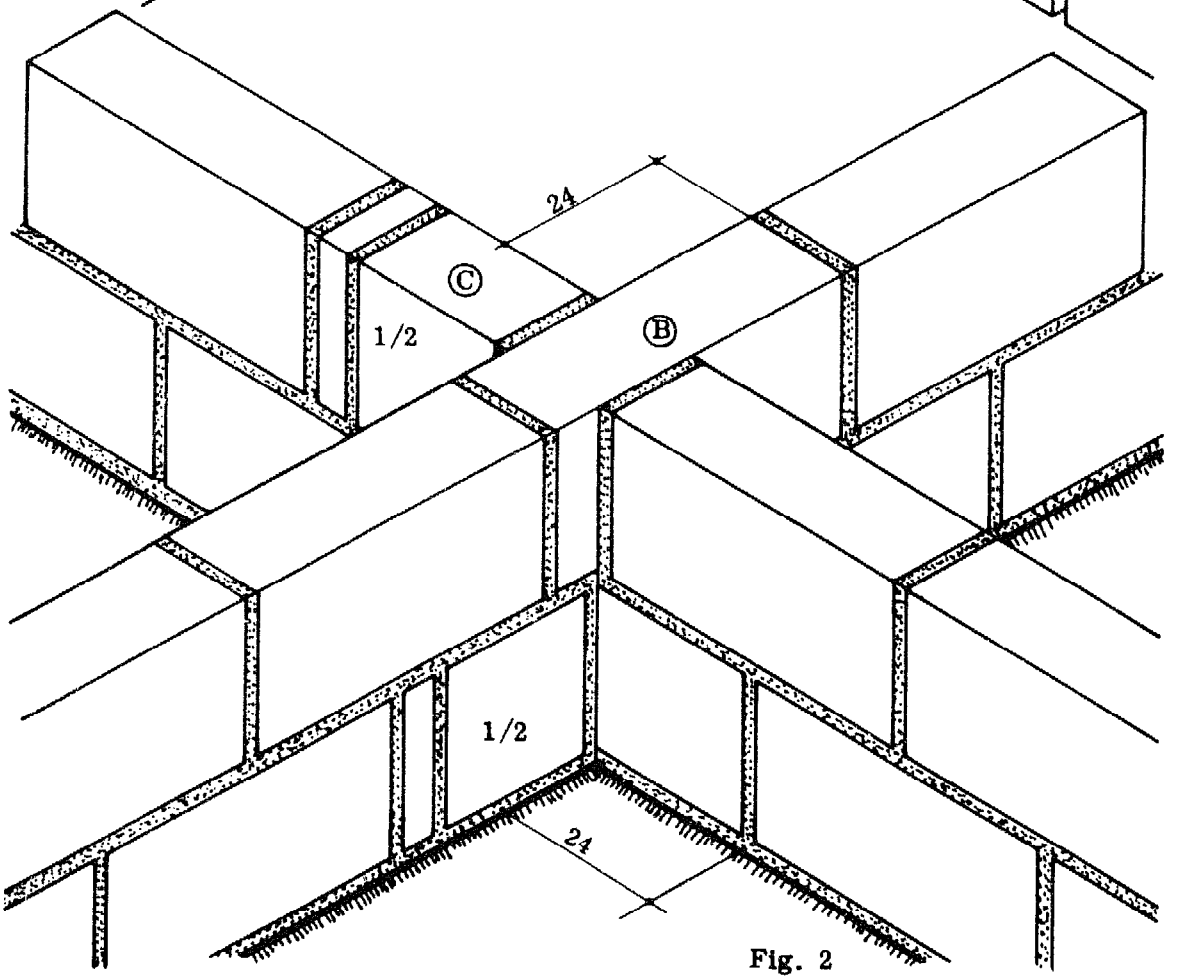

Fig. 2

N P V C	
49	BASIC.

CROSS JUNCTION BONDS.

CROSS JUNCTION BOND FOR RISING SANDCRETE WALLS

The smaller wall thickness in relation to the block length makes it necessary that all cross junction bonds for rising sandcrete walls contain a block that is 5 cm thick (compare with corner bonds for rising sandcrete walls, page 34).

The opposite illustrations show the most economical method for constructing a cross junction. Apart from the one 1/2 block and one 5 cm block, both the first and second courses contain only full blocks.

Fig. 1 shows the first course. The through wall consists of only full blocks, while the crossed wall starts on one side with a 1/2 block combined with a 5 cm block. This is continued in all four directions with full blocks. The through-going block (A) must extend past the crossed wall by 24 cm, which is the length of a 1/2 block plus the joint.

In the second course, the wall which was crossed in the course below now goes through. The through block (B) again extends past the crossed wall by 24 cm, but on the side opposite from the 1/2 block in the course below. Block B is followed on its left-hand side by a 1/2 block (C) combined with a 5 cm block. This is continued in all four directions with full blocks (Fig. 2).

In the first course the crossing block and the 1/2 block form a corner. This is also true in the second course but the corner is diagonally opposite from the one in the first course below.

- REMEMBER: All through courses in either wall consist of full blocks only. All crossed courses in either wall contain one 1/2 block combined with a 5 cm block.

NOTES:

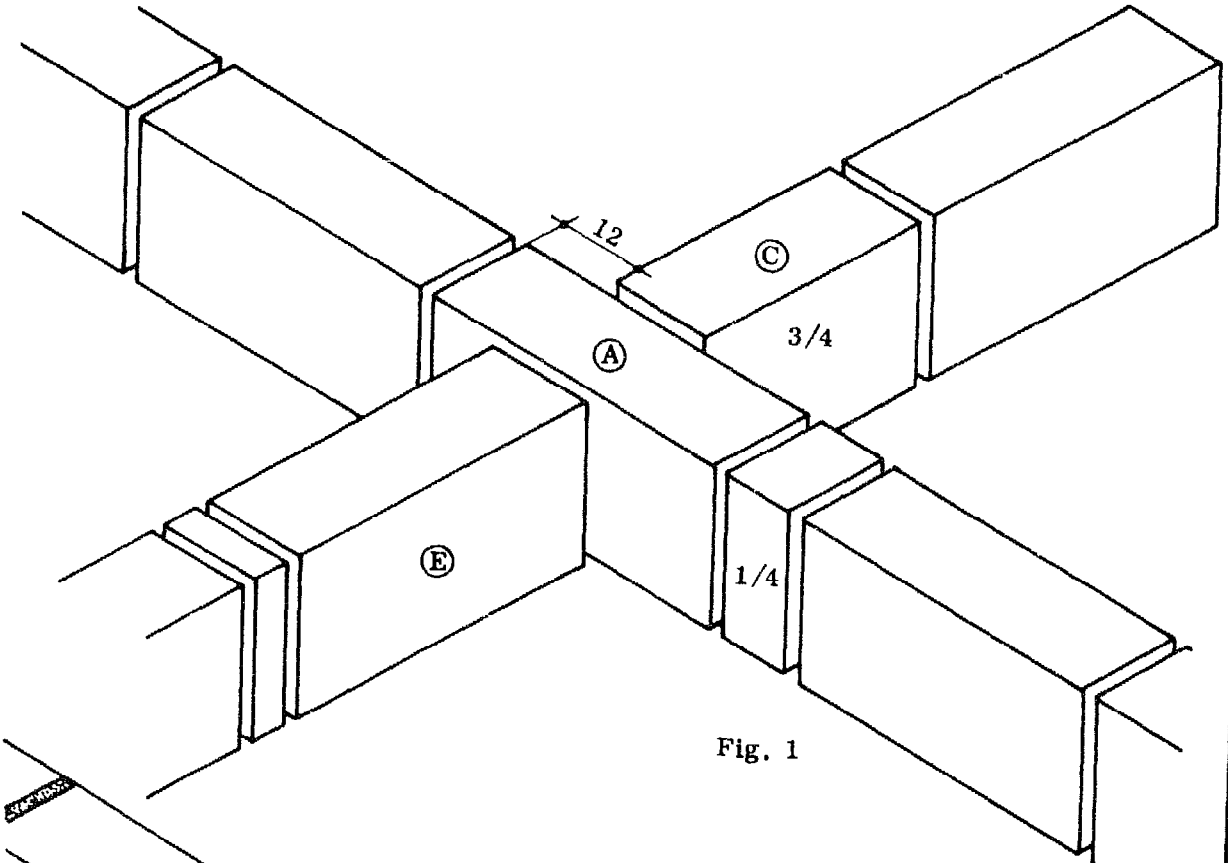

Fig. 1

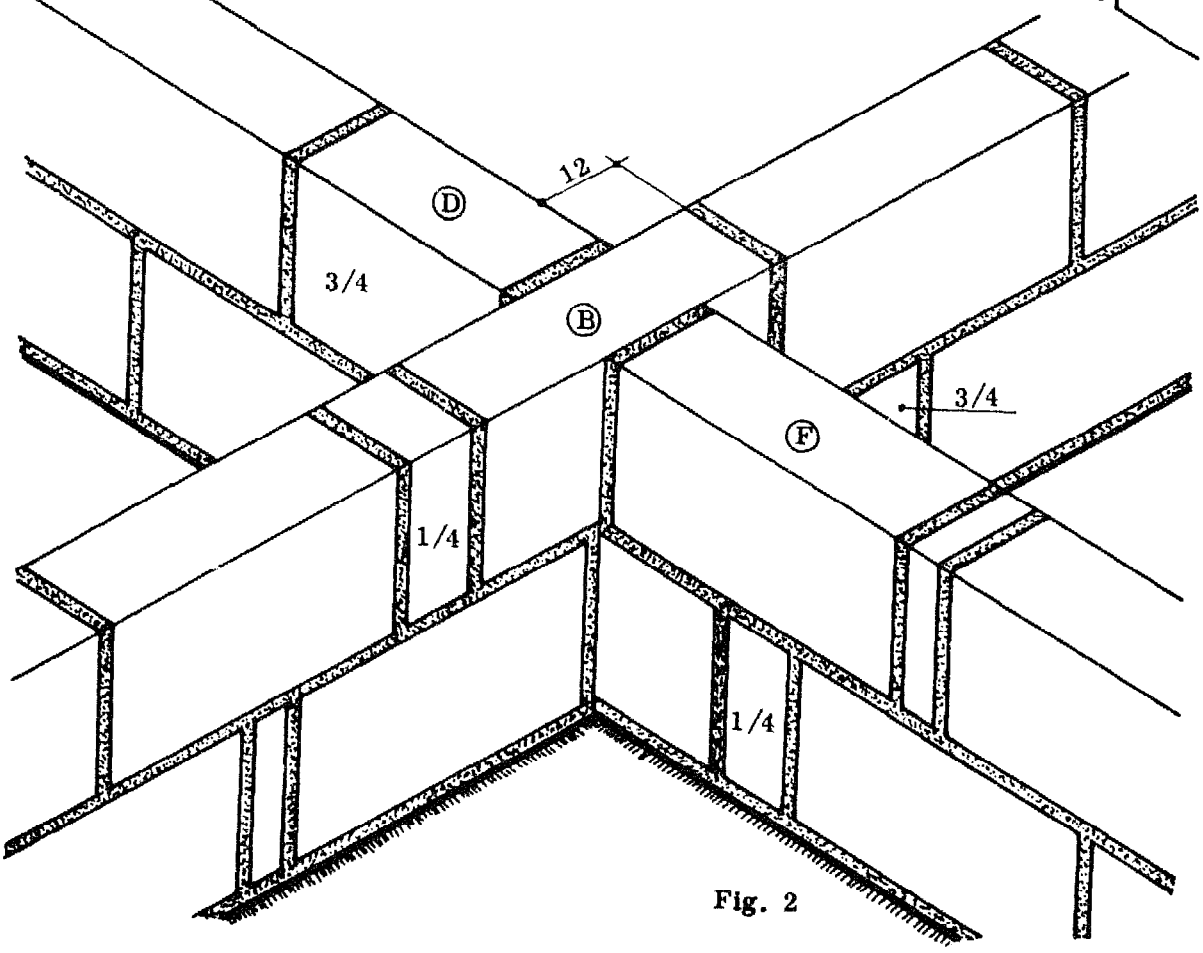

Fig. 2

NPVC	
51	BASIC.

CROSS JUNCTION BONDS.

The second method of making a cross junction in a sandcrete wall is different from the first method because 3/4 and 1/4 blocks are used instead of 1/2 blocks.

Because of this the rules for this bonding method are also different:

- All through blocks (Figs. 1 & 2, blocks A & B) project from the crossed wall by 12 cm at one end (12 cm is 1/4 block plus the joint). These blocks are followed by 1/4 blocks at the other end (Figs. 1 & 2).
- All crossed walls contain a 3/4 block (Figs. 1 & 2, blocks C & D) set directly against the through-going block. This 3/4 block is on the opposite side from the 1/4 blocks in the course below (Fig. 1). The crossed wall continues with a full block (Figs. 1 & 2, blocks E & F) and a 5 cm block, on the other side from the 3/4 block.
- NOTE: The above method involves a lot of block-cutting, which makes it less efficient than the other method.

Try to figure out more possibilities and discuss them with your fellow trainees, your instructors and your foreman on the building site.

NOTES:

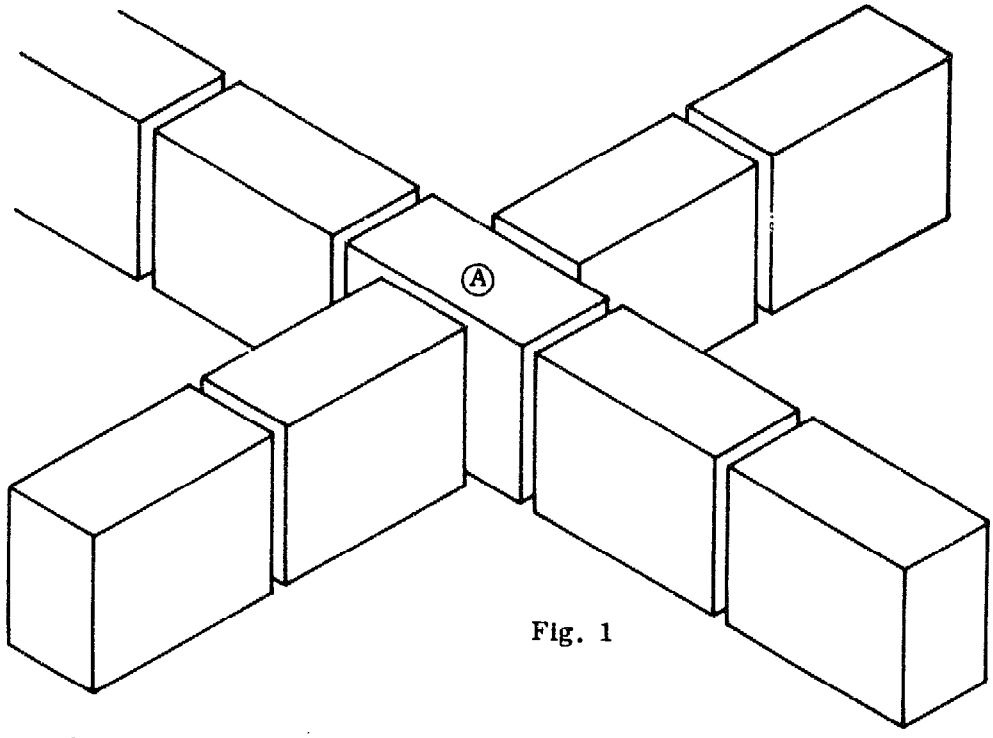

Fig. 1

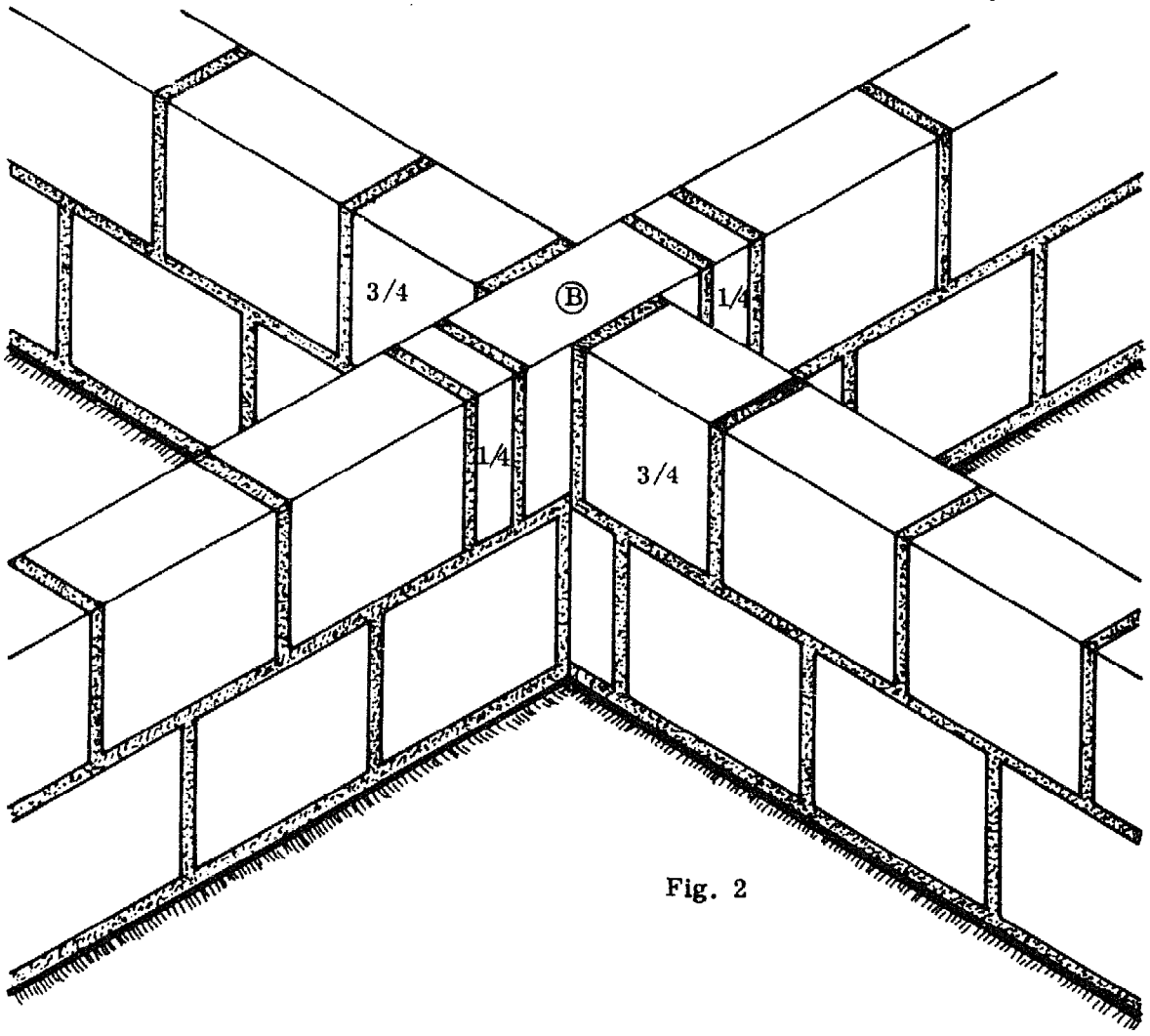

Fig. 2

N P V C	
53	BASIC.

CROSS JUNCTION BONDS.

CROSS JUNCTION BOND FOR RISING LANDCRETE WALLS

The arrangement of blocks to construct a cross junction with landcrete blocks is almost the same as for the footings (see previous pages).

Fig. 1 shows the bond for all courses with an odd number (1st, 3rd, 5th, etc.). These consist of full blocks only. The through block (A) is set exactly in the middle of the crossed wall.

The arrangement for courses with an even number (2nd, 4th, 6th, etc.) is shown in Fig. 2. These courses also start with a full block (B) set exactly across the middle of the through-going block below. This block is followed by 1/4 blocks on its ends and 3/4 blocks on its stretcher sides. This is continued in all four directions with full blocks.

NOTES:

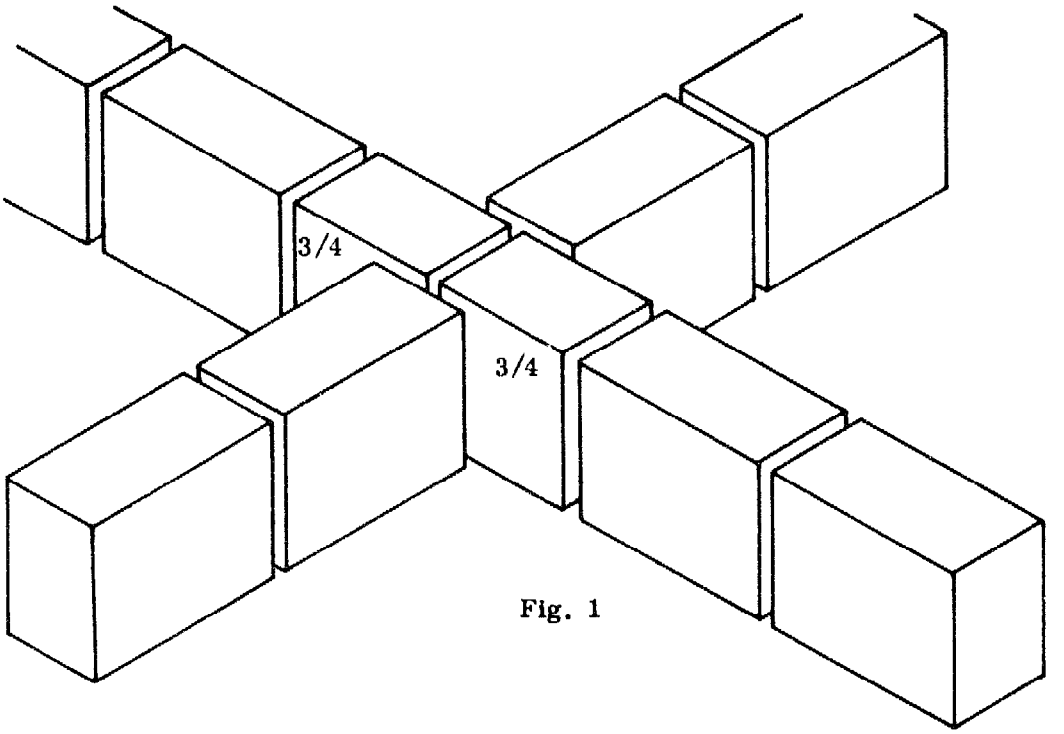

Fig. 1

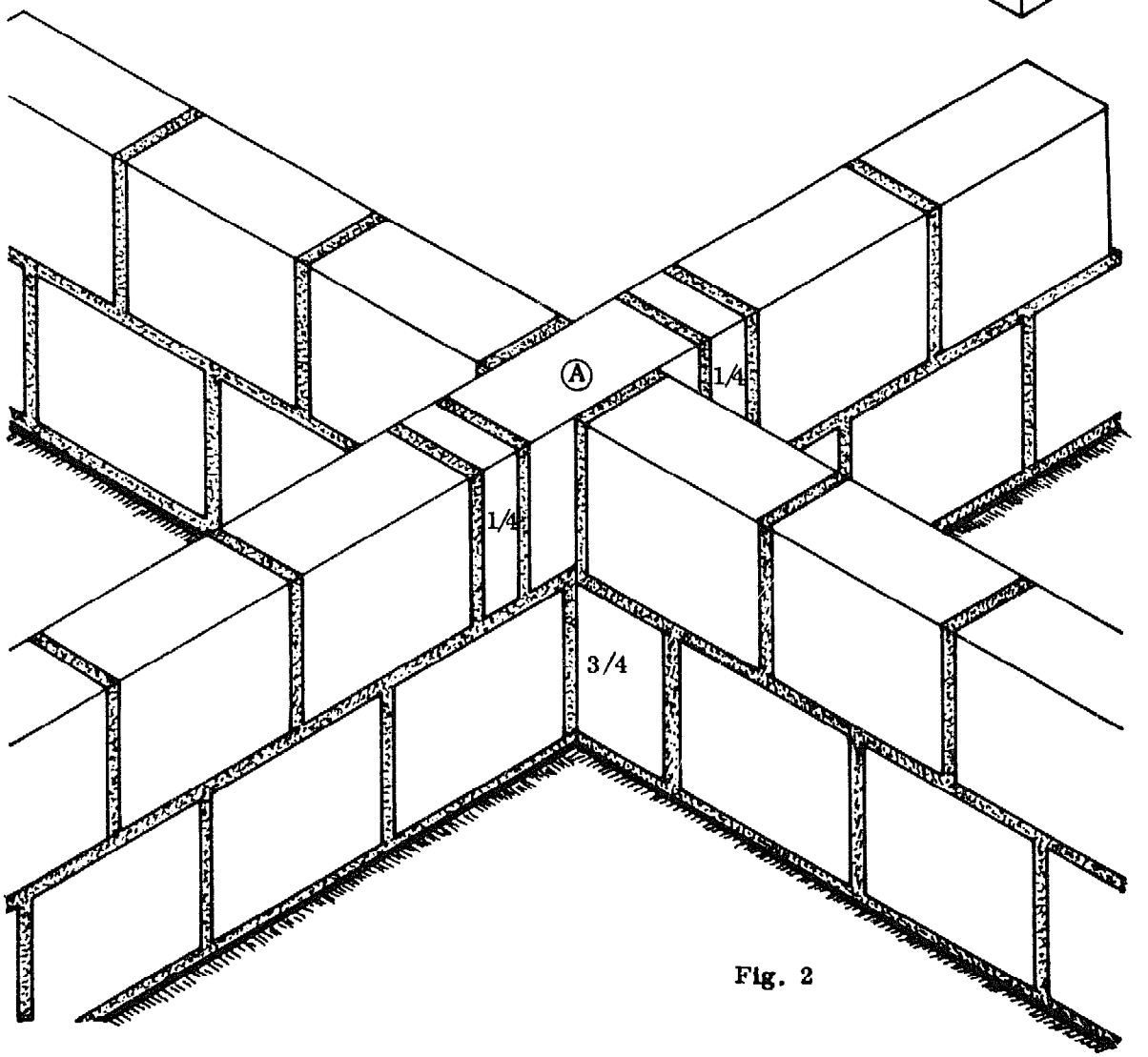

Fig. 2

NPVC	
55	BASIC.

CROSS JUNCTION BONDS.

Another method of bonding uses the cut blocks in alternate courses, unlike the last method which used all cut blocks in the same course. There is no waste in either method.

The first crossing (Fig. 1) is formed by two 3/4 blocks which project equally from the crossed wall, meaning that the joint between them is exactly in the centre of the crossed wall. The course is continued in all four directions with full blocks.

The second course begins with a through-going block (Fig. 2, block A) set exactly in the middle of the crossed wall. In this way, three cross joints are covered by the block, instead of two as in the last method (Fig. 2).

The through-going block is followed by 1/4 blocks on its ends but then the course continues in all directions with full blocks.

Try to develop more possibilities but do not forget the requirements mentioned on page 46.

NOTES:

Fig. 1

Ⓐ = FOUNDATION
Ⓑ = FOOTING
Ⓒ = PLINTH COURSE (SANDCRETE)
Ⓓ = RISING WALL (LANDCRETE)

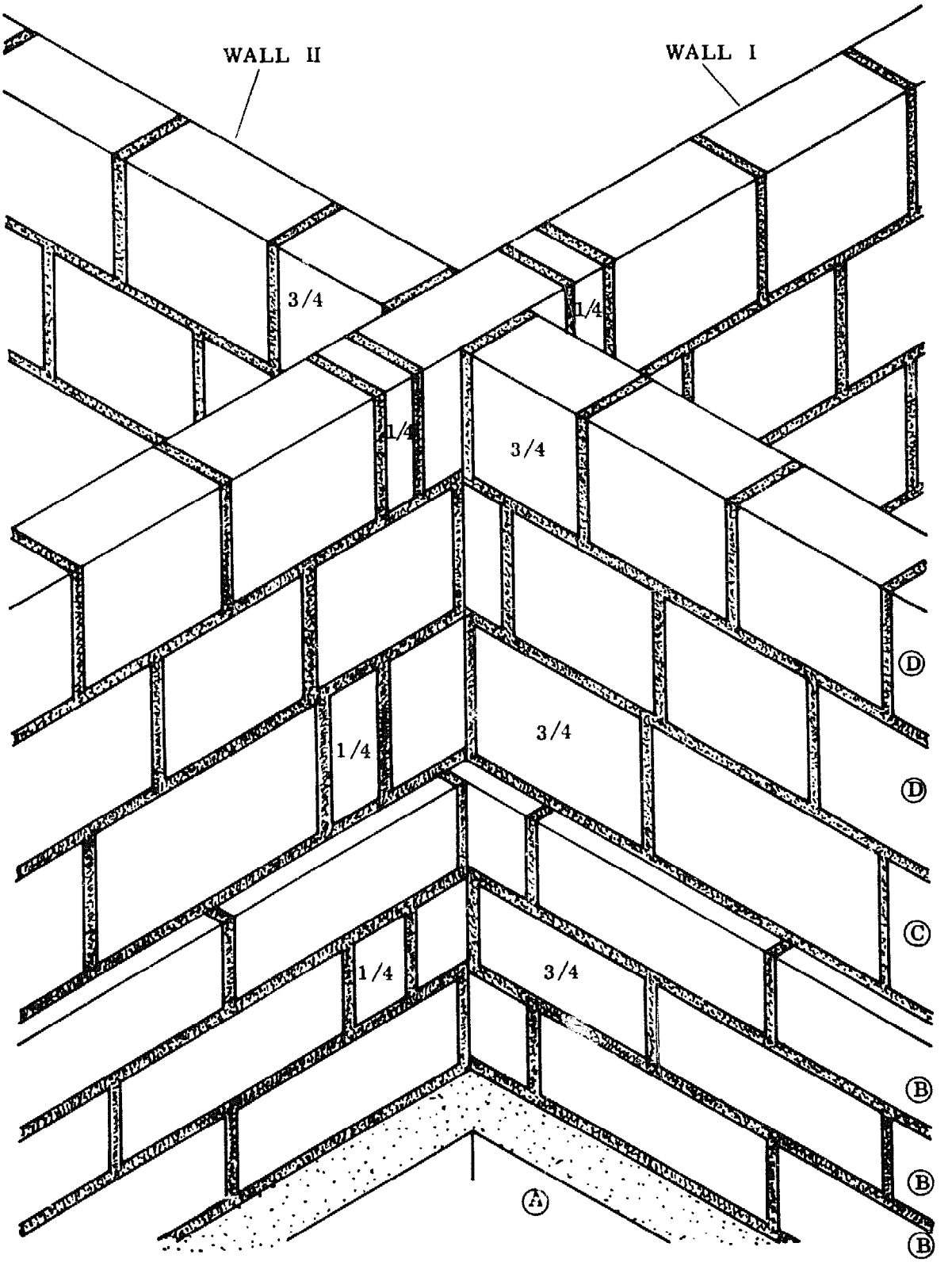

NPVC	
57	BASIC.

CROSS JUNCTION BONDS.

FOOTINGS - PLINTH COURSE - RISING LANDCRETE WALL

The illustration opposite shows what a cross junction will look like during the construction (Fig. 1).

Again, it is possible to maintain the half-block bond between the footings and the plinth course in wall I, as described on the previous pages. The bonding of the plinth course is a repetition of the bonding of the second footing course.

However, it can be seen that the half-block bond between the footings and the plinth course is not perfectly maintained in wall II. This is because of the 4 cm setting back on both sides as well as the reduced wall thickness.

The bond of the rising landcrete walls is the same as described on the previous pages. Only two courses are shown because the rest of the courses are repetitions of these two.

If you compare the bond of the rising landcrete wall with the plinth course, you will see that the half-block bond is not maintained between them. The only way it could be maintained is by cutting more blocks and changing the thicknesses of some of the joints. This would weaken the entire wall as well as wasting materials, so the Rural Builder should consider this bonding all right as it is shown here.

- REMEMBER: The rising landcrete wall is 1 cm thinner than the plinth course. Do not forget to maintain the "good" faces of the walls by laying the landcrete blocks flush with the plumbed faces of the plinth courses below.

NOTES:

Fig. 1

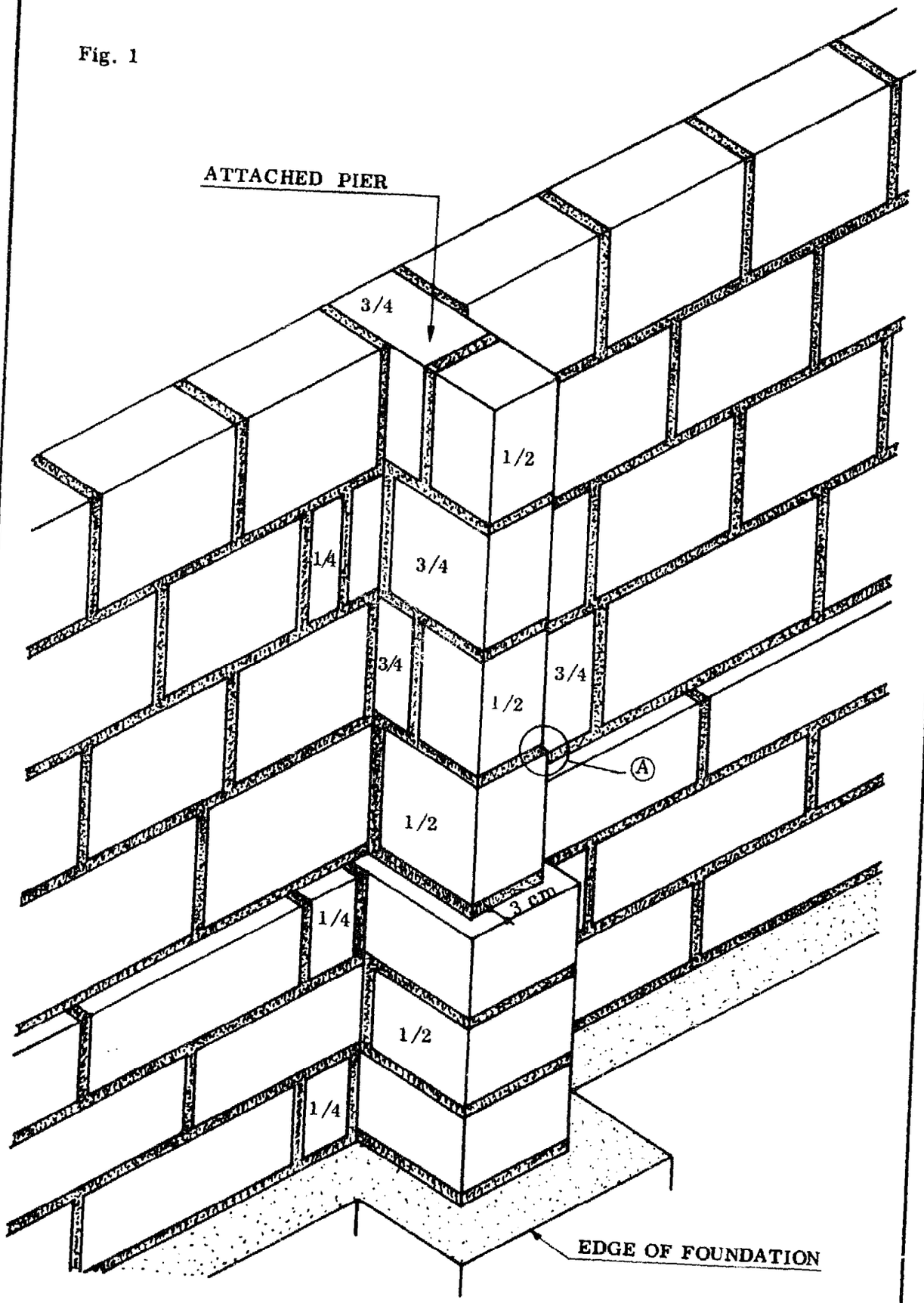

NPVC	
59	BASIC.

PIERS.

PIERS

ATTACHED PIERS

Attached piers; also called engaged piers, wall piers, blind piers or pilasters, are piers partly sunk into a wall and properly bonded into it.

Normally the visible part of a pier projects only slightly from the wall, but in Rural Building the projection may be as much as the thickness of the wall or even more.

Formerly, attached piers were most often used as decorative elements. The Rural Builder, however, uses attached piers chiefly to strengthen walls. At the same time he saves valuable materials such as cement, reinforcement bars and timber for formwork that would be needed for a reinforced concrete pillar.

The construction of an attached pier is very similiar to that of a T-junction. The only difference is that the wall which joins the front wall is very short, and with a stopped end, thus forming an attached pier (Fig. 1).

The illustration shows that the bonds used to construct this pier are the same as those introduced in the chapter on T-junction bonds. Compare it with the text and illustrations from pages 38 to 44.

- NOTE: The plinth course is set back everywhere from the footings by 4 cm, except on the back side of the attached pier where it is set back only 3 cm (Fig. 1).

  Do not forget to build the landcrete blocks flush with the plumbed (good) face of the plinth course. This means that on the other face of the wall there will be a 1 cm set-back caused by the 1 cm difference in size between the sandcrete blocks in the plinth course and the landcrete blocks in the rising wall (Fig. 1, point A).

NOTES:

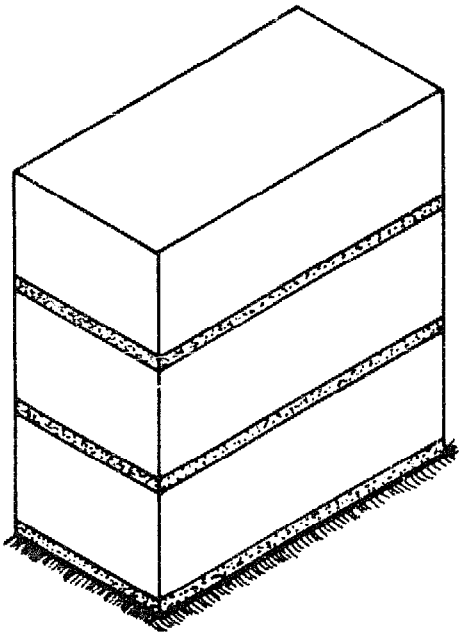

Fig. 1
SANDCRETE PIER

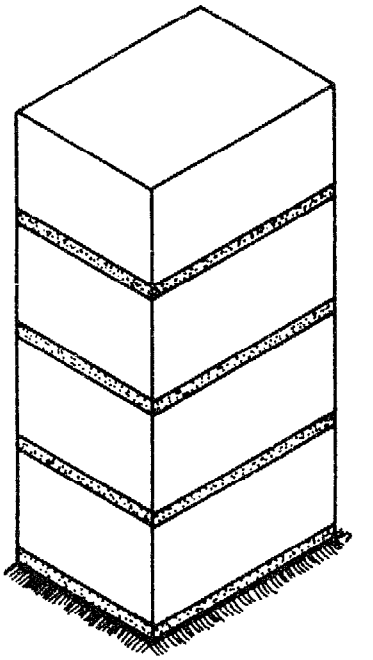

Fig. 2
LANDCRETE PIER

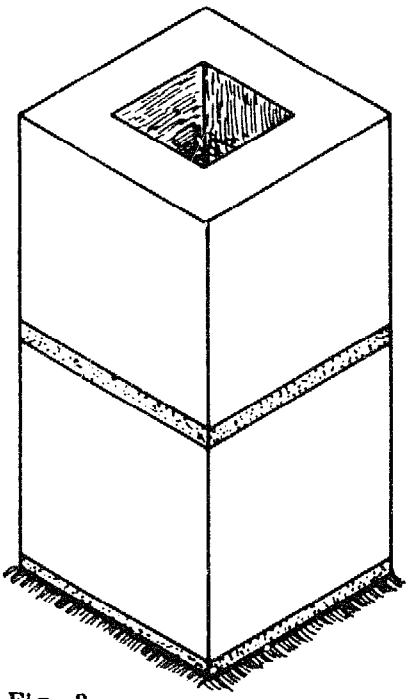

Fig. 3
PIER BUILT WITH OPEN BLOCKS

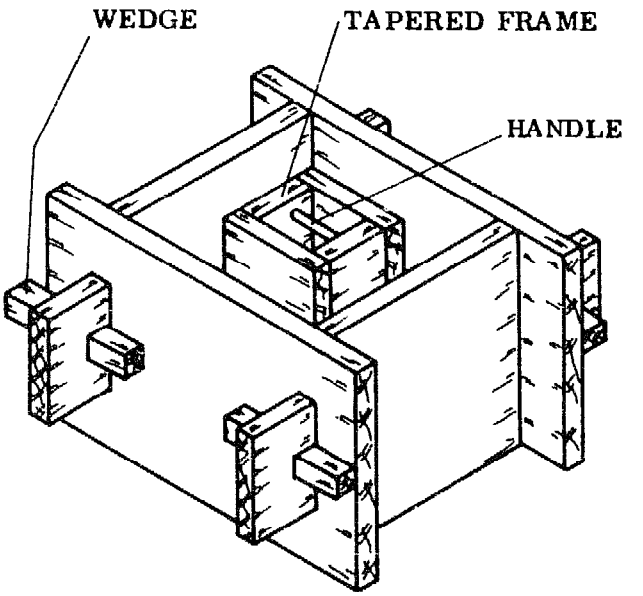

Fig. 4
WOODEN MOULD

N P V C		PIERS.
61	BASIC.	

SIMPLE PIERS

A pier is a pillar-shape of brickwork, blockwork or stone which usually has a square or rectangular section, and supports a load. In Rural Building its mass also helps to anchor the roof structure.

The easiest way to construct a pier is by simply laying full blocks flatwise one above another (Figs. 1 & 2). This will be sufficient in situations where the pier does not have to carry a very heavy load.

The disadvantage of this construction is that any roof anchorage must be fixed to the sides of the pier.

The best way to anchor a member of the structure to a pier is through the centre of the pier.

So-called perforated blocks can be made by using a specially made wooden mould (Fig. 3). In contrast to the common type of perforated block which has many smaller holes, this type has only one large hole through its centre. It is also called an open block.

Open blocks are made by casting mortar between two frames (Fig. 4). The bigger frame is made similarly to the wooden mould described in the Reference Book, Tools section, page 29. The smaller frame is tapered and has a handle to make it easier to remove from the block.

After the pier is built, the anchoring bar is inserted in the hole and the remaining space is filled up with mortar or concrete.

NOTES:

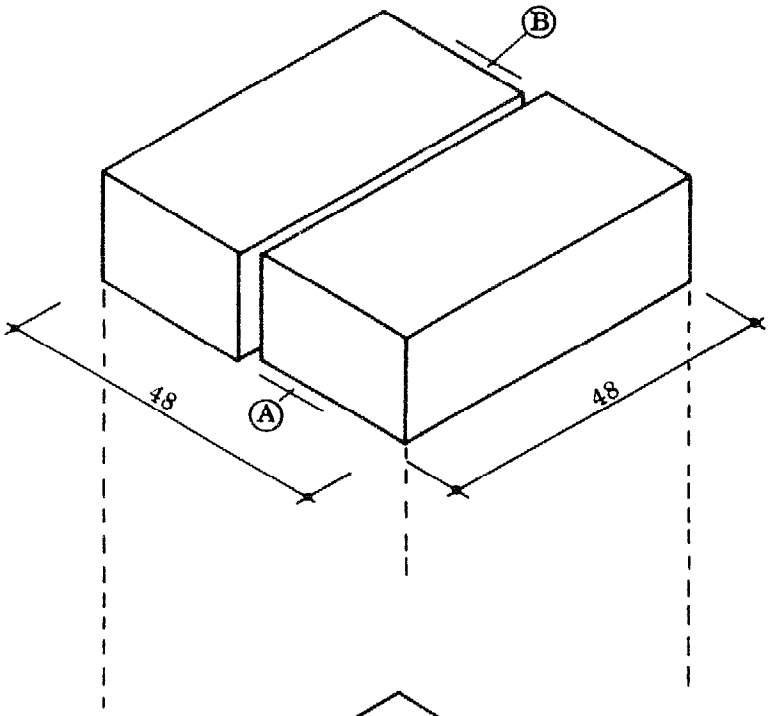

Fig. 1

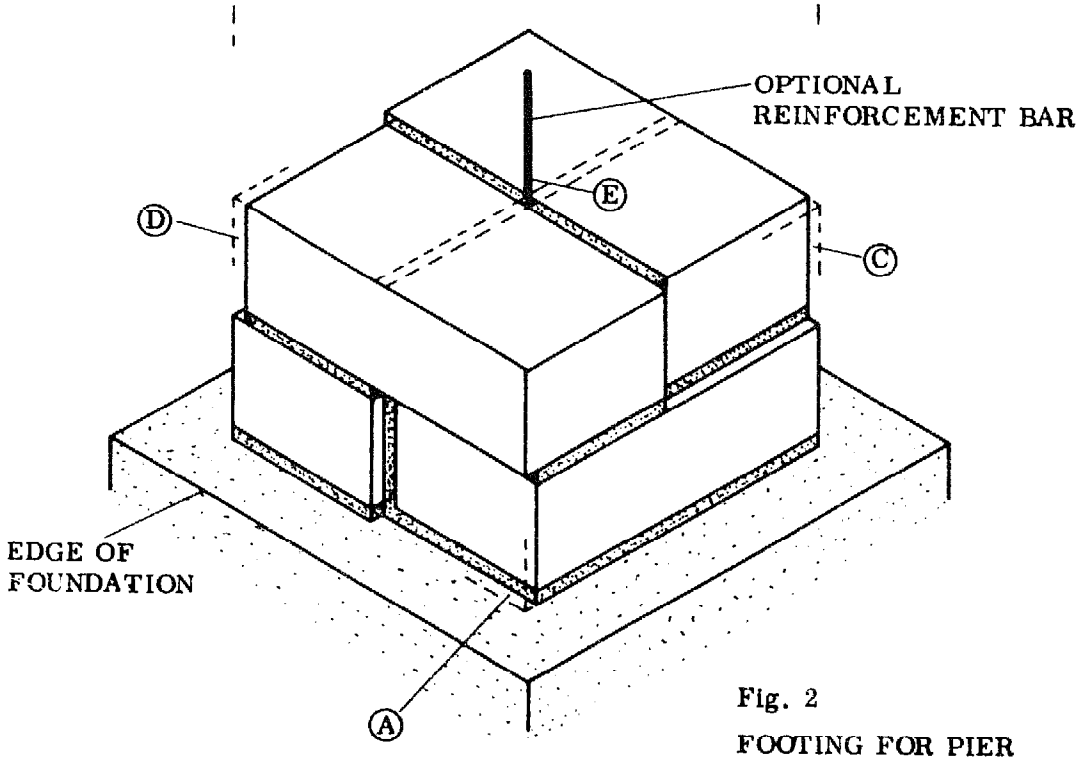

Fig. 2

FOOTING FOR PIER

N P V C		PIERS.
63	BASIC.	

FOOTINGS FOR PIERS

There are situations where piers are needed which not only have to carry heavy loads but also have to be very heavy in themselves. This is to anchor the roof against the suction of strong winds.

In order to save valuable building materials such as cement, reinforcement bars and timber, as well as to reduce the construction time, blockwork piers are often built.

There are several possible bonding arrangements. The bonds introduced in this chapter represent only a few types, but they will meet the requirements of the Rural Builder.

The type of bond which is used depends largely on which materials are available and on the size of pier which is desired.

The opposite illustrations show a bond for footings with sandcrete blocks laid flatwise. Refer to page 67 for another footing method. Both bonds can also be used to build up an entire pier, in case a heavy duty pier is desired.

All the courses in the illustration on the left consist of a pair of blocks which are set 2 cm out of line with each other at the header sides. You can see this 2 cm difference at points A, B, C, D in Figs. 1 and 2.

This is done to maintain a square shape of 48 cm by 48 cm, since the width of the two blocks plus a joint is 48 cm, while the length of each block is only 46 cm. Since the courses cross each other, a reinforcement bar for anchorage could be built-in between the cross joints (Fig. 2, E).

NOTES:

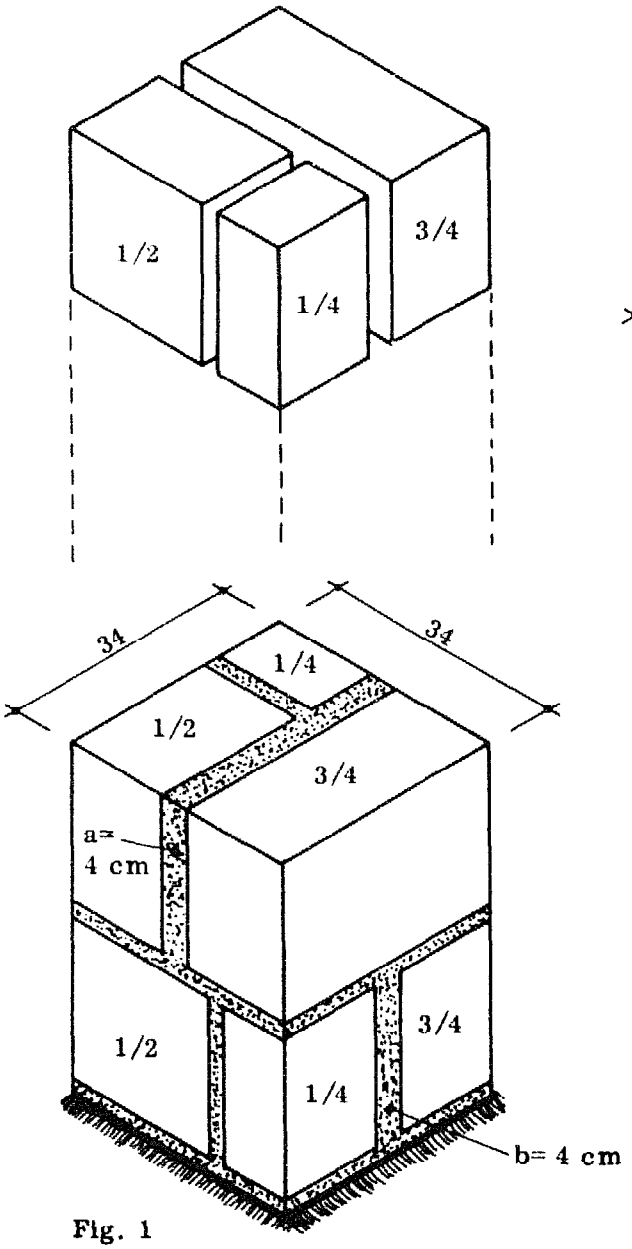

Fig. 1

SANDCRETE PIER EDGEWISE

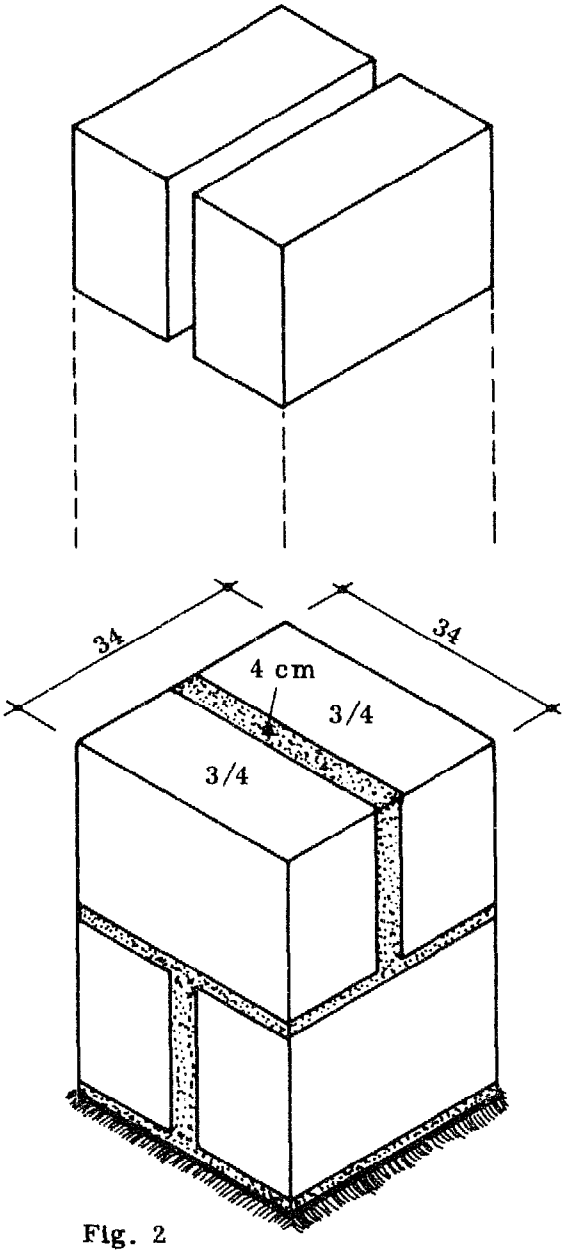

Fig. 2

SANDCRETE PIER EDGEWISE

N P V C		PIERS.
65	BASIC.	

BONDS FOR SANDCRETE PIERS

The following two bonds are also square-shaped but have shorter dimensions than the footing bonds: 34 cm by 34 cm.

Fig. 1 shows the best bond for a pier with the above measurements. This is because each course uses a total of $1\frac{1}{2}$ blocks, which means that there is no waste.

The through-going cross joints in each course must be widened (Fig. 1, a & b) to 4 cm in order to obtain a width of 34 cm across the two blocks; 34 cm is the length of the 3/4 blocks.

The 3/4 block in each course is set over the 1/4 block below, and across the 4 cm joint, making an alternating arrangement as shown (Fig. 1).

Fig. 2 shows another bond for a sandcrete pier. The pier is built entirely of 3/4 blocks. The cross joints all go through and all have a 4 cm thickness.

It is obvious that this type of pier should be built only if there are a lot of 3/4 blocks left-over from another construction, because otherwise all the 1/4 blocks are left-over and wasted.

NOTES:

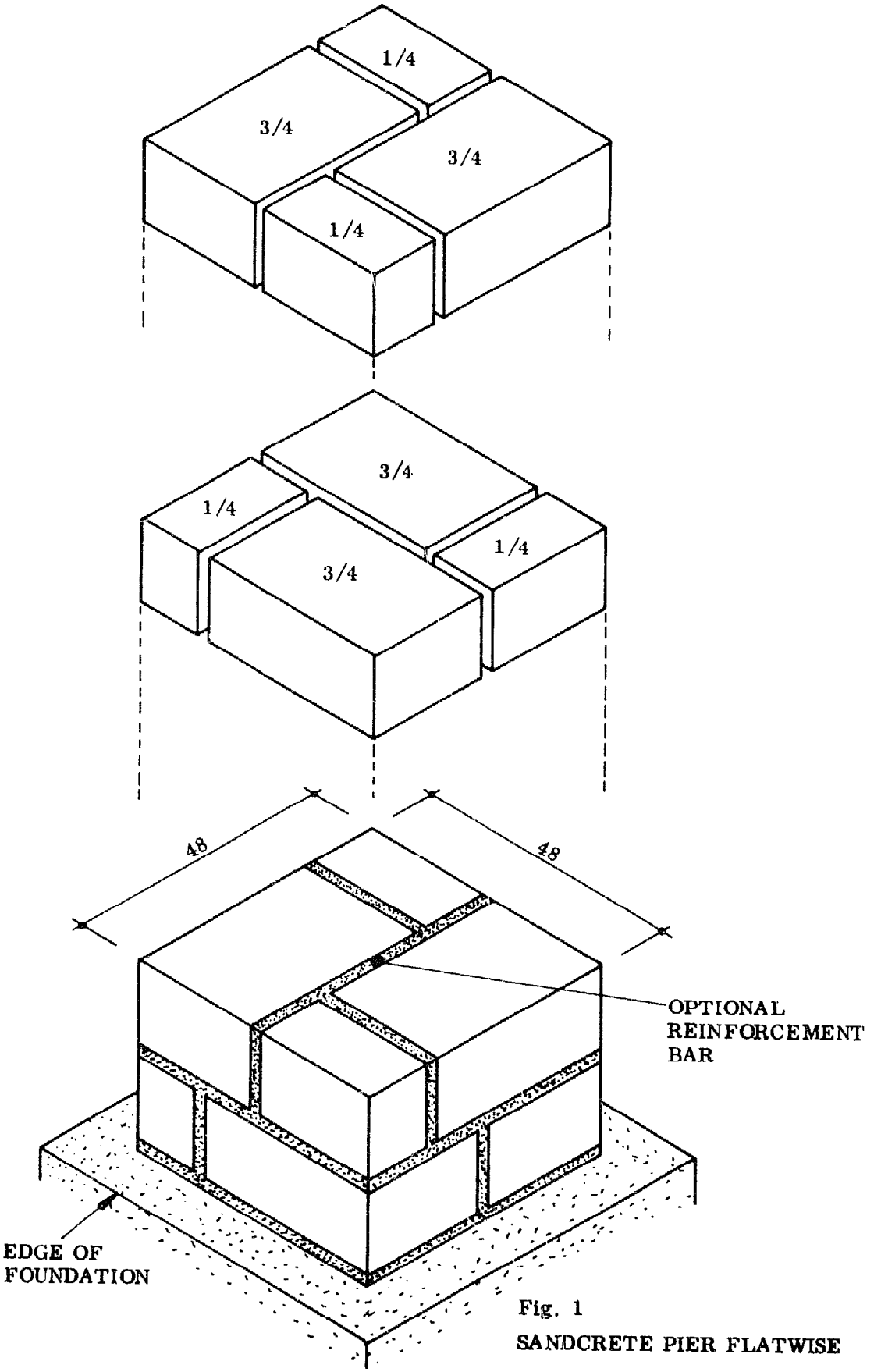

Fig. 1

SANDCRETE PIER FLATWISE

N P V C		
67	BASIC.	PIERS.

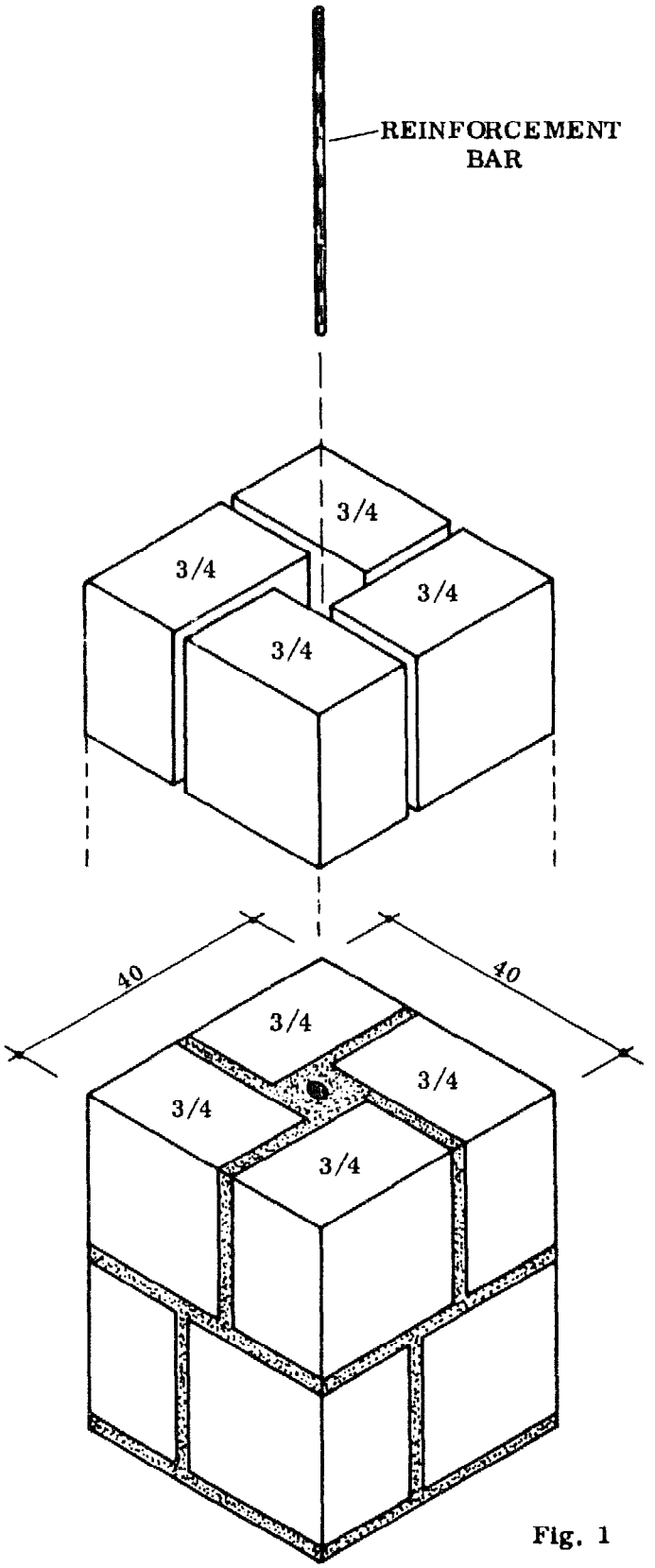

Fig. 1
LANDCRETE PIER EDGEWISE

PIERS.	N P V C	
	BASIC.	68

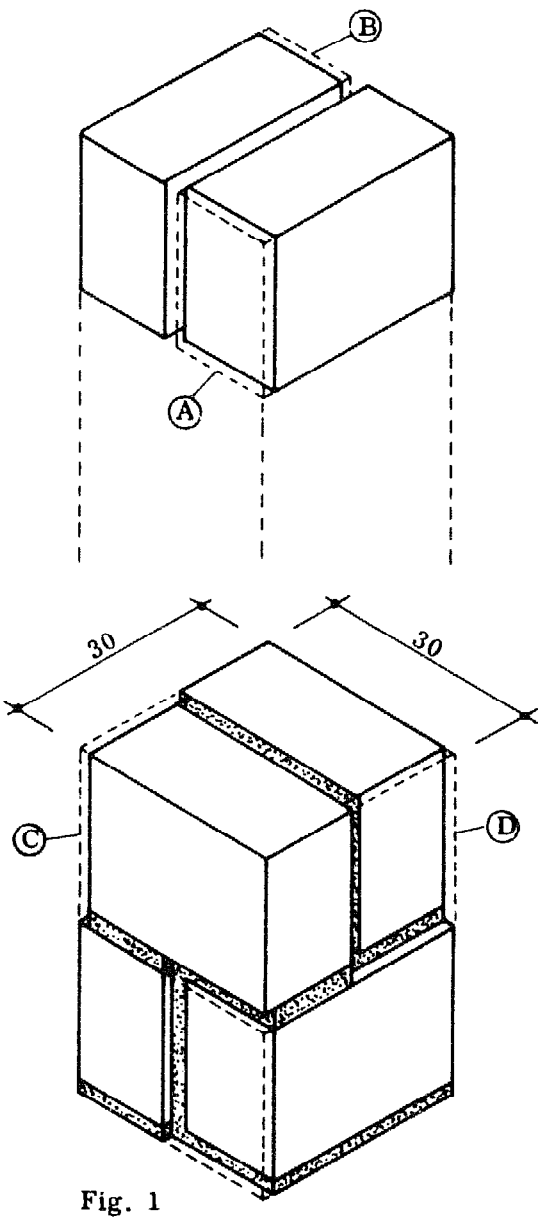

Fig. 1

LANDCRETE PIER EDGEWISE

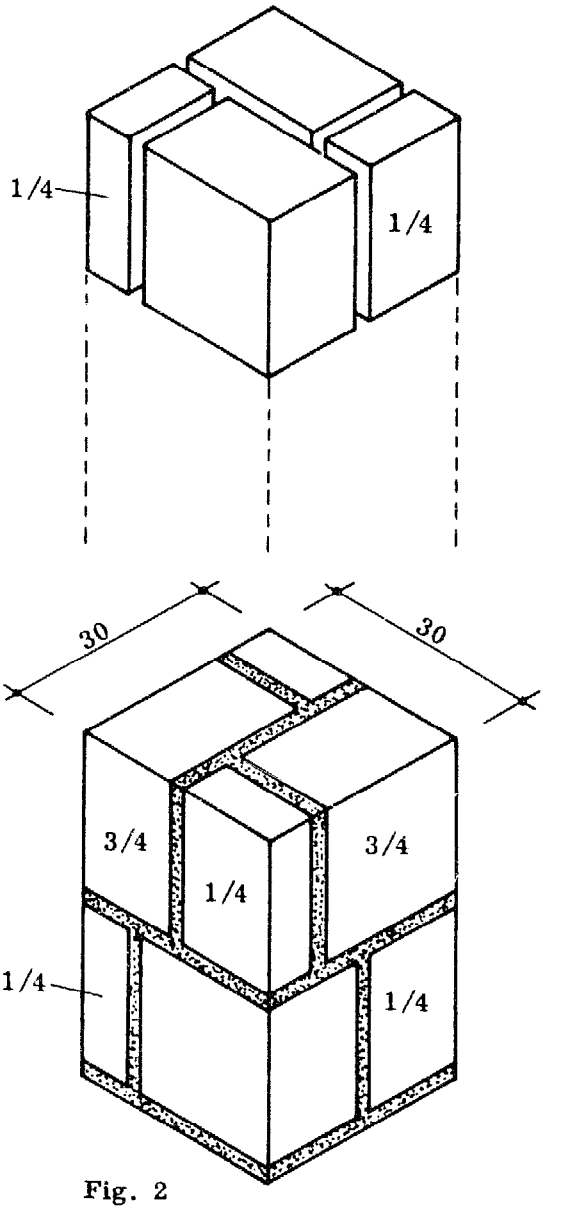

Fig. 2

LANDCRETE PIER EDGEWISE

N P V C		
69	BASIC.	PIERS.

BONDS FOR LANDCRETE PIERS

The examples of bonds for landcrete piers shown on pages 68 and 69 are similar to some of the bonds already explained. Fig. 1 shows a bond which is basically the same as the footing bond on page 63, except the blocks are laid edgewise.

Each course consists of two full blocks laid edgewise and across the course below. In order to maintain a square shape of 30 cm by 30 cm, the blocks are set 1 cm out of line with each other at their header sides (see points A, B, C, & D).

The bonding method seen in Fig. 2 requires cutting two blocks per course and results in a rather weak bond. The Rural Builder should avoid making this type of pier except when he needs to use up some part-blocks left over from another construction.

Fig. 1 on page 68 shows another bonding method for landcrete piers with the blocks laid edgewise. This method has the advantage that an iron rod can be set into the centre of the blocks, either to reinforce the pier or to act as an anchor, or both.

- NOTE: Landcrete piers should not carry heavy loads such as a truss or a concrete beam, because they are too weak. They may be used to support and anchor overhanging rafters of a roof above a verandah.

  If a landcrete pier has to carry heavy loads, its dimensions should be increased to a minimum of 55 cm by 55 cm.

NOTES:

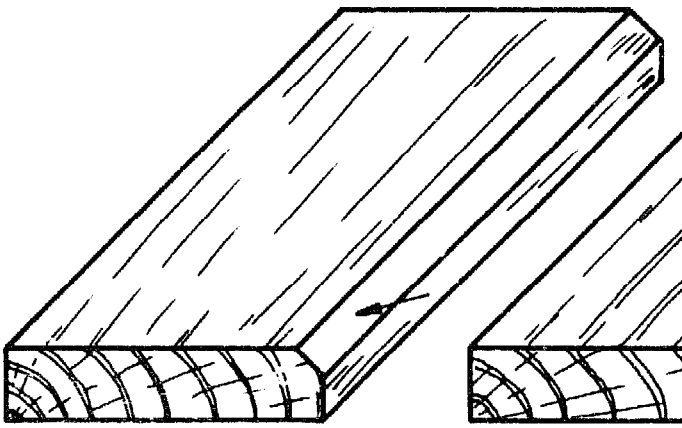

Fig. 1

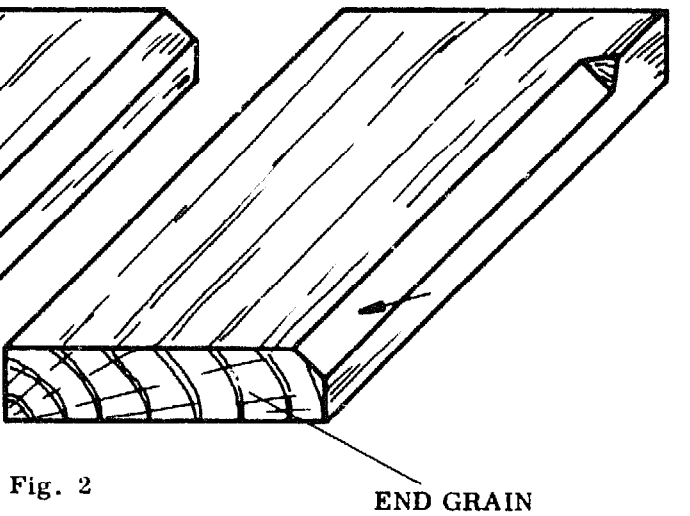

Fig. 2

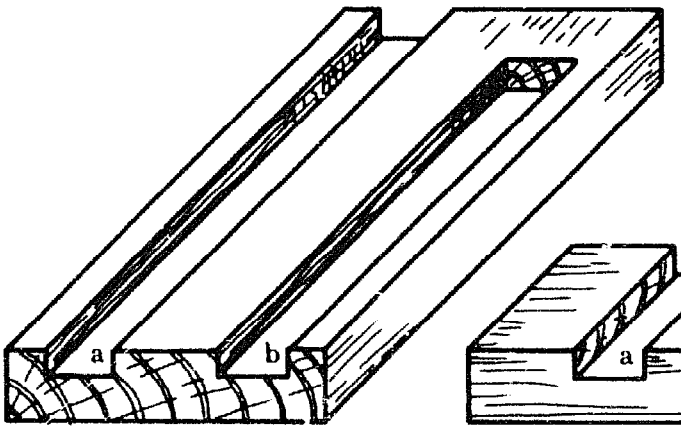

Fig. 3

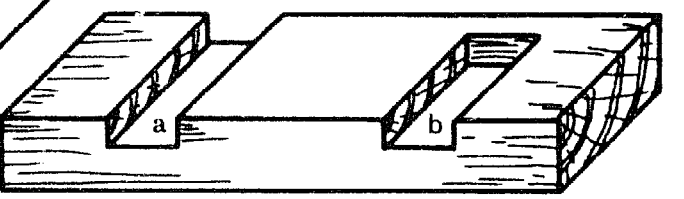

Fig. 4

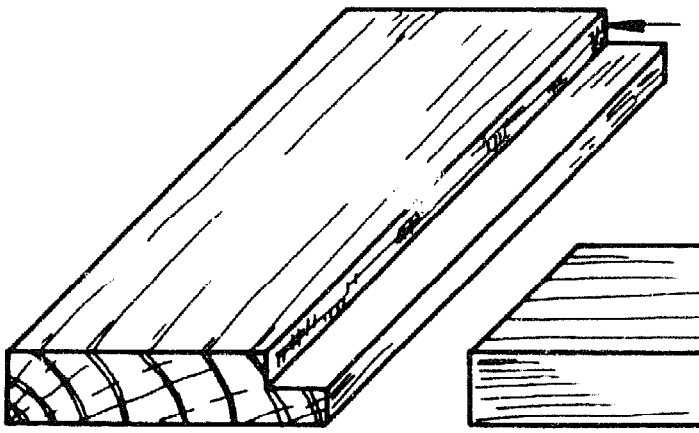

Fig. 5

Fig. 6

TECHNICAL TERMS

- GRAIN: This refers to the direction of the wood fibres. Length is measured along the direction of the grain. Width is measured across the grain at right angles to the length. When wood is cut across the grain, END GRAIN is exposed.
- WITH THE GRAIN: This term is used in connection with planing. If the fibres are cut cleanly and smoothed down by the cutting iron, the wood is said to be planed with the grain; like stroking a dog's coat so the hair lies down smoothly.
- AGAINST THE GRAIN: This means that the plane goes in the opposite direction, lifting and breaking the wood fibres and leaving a rough surface; as if a dog's coat were brushed the wrong way and roughened.
- STRAIGHT GRAIN: The wood fibres lie straight and parallel to the length of the piece of wood. Such wood planes smoothly and easily.
- CROSS GRAIN: The wood fibres do not lie parallel to the length of the piece. This makes the wood hard to work.
- BEVEL: This is made by planing off the sharp edge to form a new surface which is not at right angles to the side of the piece of wood. A CHAMFER is a special bevel, cut at 45 degrees. A "through" chamfer or bevel runs the whole length of the edge (Fig. 1). A "stopped" chamfer or bevel is stopped at one or both ends (Fig. 2).
- GROOVE: This is a recess cut along the grain. A "through" groove runs the whole length of the piece (Fig. 3, a); while a "stopped" groove is stopped at one or both ends (Fig. 3, b).
- TRENCH: This is a recess cut along the grain. A trench can also be either through (Fig. 4, a) or stopped (Fig. 4, b).
- REBATE: This is a recess cut along the edge or across the end of a board as in Figs. 5 & 6.
- TRUE: In woodworking this indicates that a surface is flat and perfectly level.
- SQUARE: Square angles are exact 90 degree angles. "Square" is used to describe pieces in which all the corners and edges have 90 degree angles.
- SHOULDER: The vertical portion of a trench or rebate (arrows, Figs. 5 & 6).

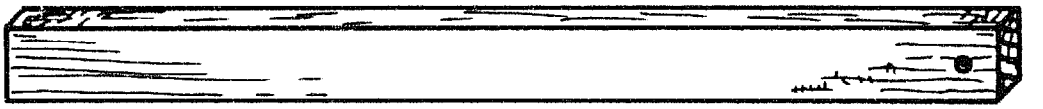

Fig. 1

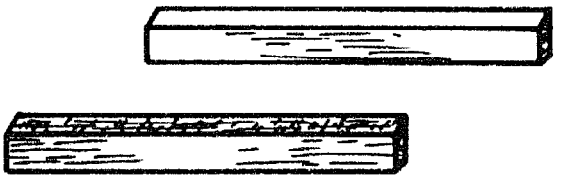

Fig. 2

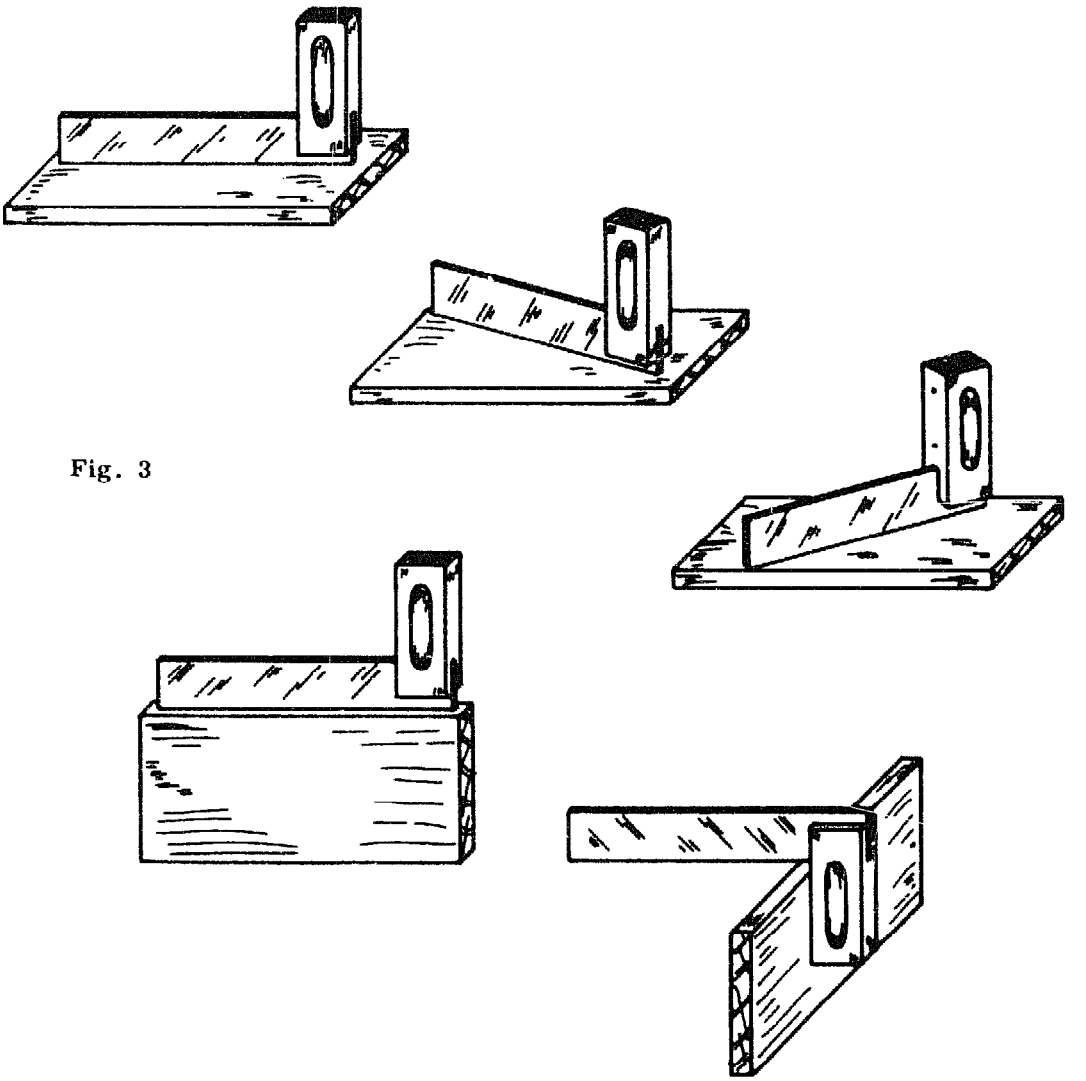

Fig. 3

N P V C	TESTING BOARDS.
73 BASIC.	

TESTING BOARDS

When you prepare a board for use in some project, you must make certain tests on it to make sure that it is flat and true in all directions and that the angles and corners are all square. These tests are made during the actual preparation of the timber, but we describe them here separately because they are generally useful techniques which you will need again and again in your work.

Before you continue reading, look in your Rural Building Reference Book, Tools section, page 36, and read about the try square, which is one of the tools you will need for testing boards. You will also need winding strips (Fig. 2) and a straight edge (Fig. 1), which is usually a piece of wood with one long edge that you are sure is perfectly flat and straight.

Also look in the Reference Book, Materials section, page 132 and find out what is meant by the words: twisting; cupping; and bowing.

WINDING STRIPS

These are used as an aid to help you to see if a board twists or "winds". They are two strips of wood about 35 cm long, 2,5 cm wide and 1,5 cm thick. The top edge has a bevel and all the edges must be perfectly straight. One of the two strips may be made darker so that sighting along them is easier (Fig. 2).

HOW TO TEST SMALL WORK PIECES

Test with the try square or the edge of a jack plane in different positions for flatness. Also test the squareness of the edges with a try square at a few different spots (Fig. 3).

NOTES:

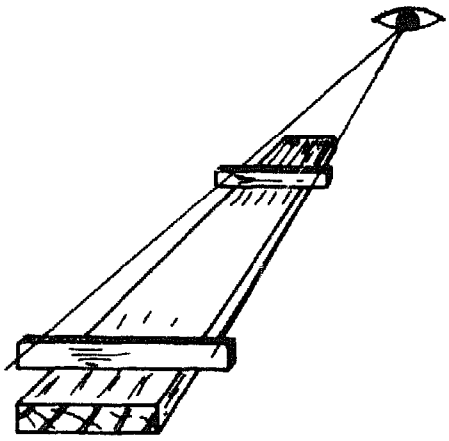

Fig. 1

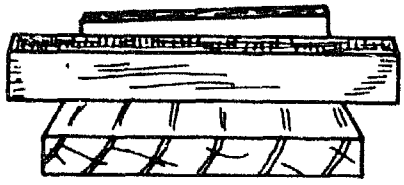

Fig. 1a

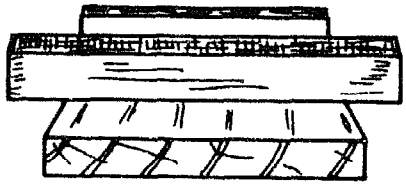

Fig. 1b

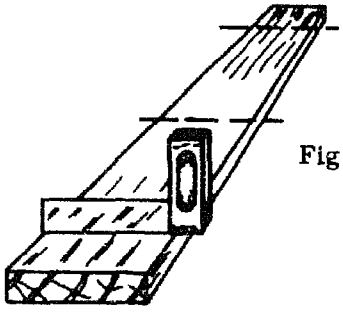

Fig. 2

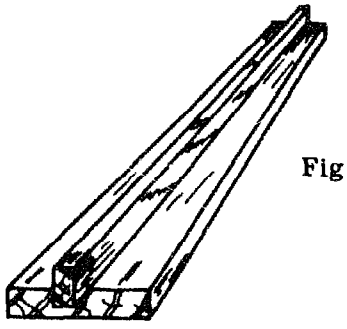

Fig. 3

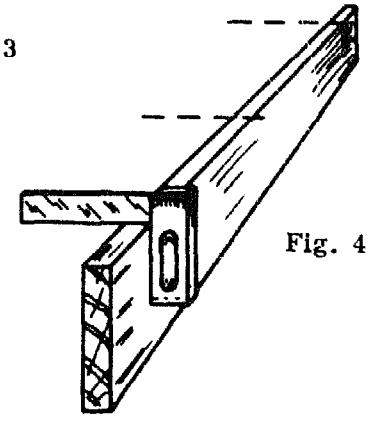

Fig. 4

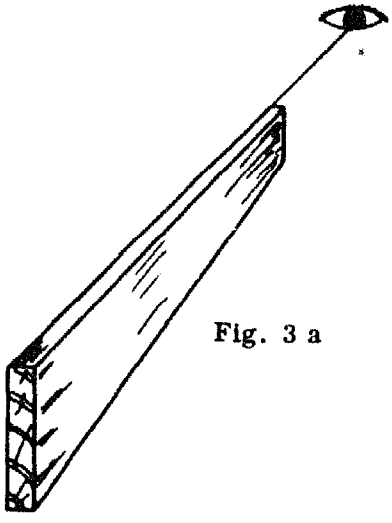

Fig. 3 a

N P V C		TESTING BOARDS.
75	BASIC.	

HOW TO TEST LONG WORK PIECES

Test for winding (twisting) using the winding strips; one at each end of the board, across the grain. Go to the end of the board and look along the board, with your eye just at the same level as the strips (Fig. 1). When the top edges of the strips do not appear parallel (Fig. 1a), the board is not flat. Check with the winding strips at different spots, making sure that the strips are parallel (Fig. 1b).

Test for cupping by putting a try square across the grain at different spots along the board. If you check this against the light, you will see all of the uneven places (Fig. 2).

To check for bowing you can do the same test, using a straight edge along the grain (Fig. 3).

For long boards you can sight along the boards with one eye closed, to see the places which are uneven (Fig. 3a).

Using a try square, check whether the angle between the face side and the edge is exactly 90 degrees. Make this test at several places (Fig. 4).

When all these tests have been performed with satisfactory results, the board will be straight and true in all directions and it is ready to be used in a project.

NOTES:

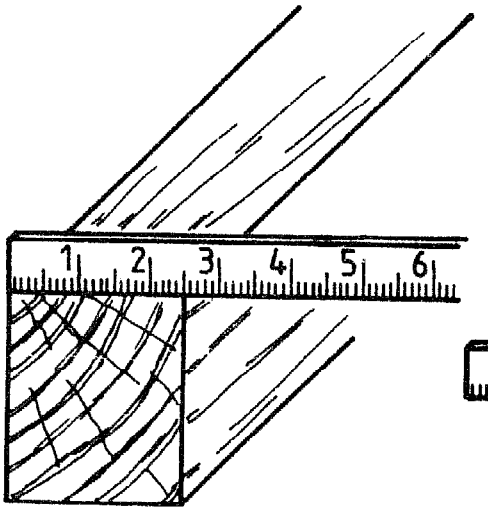

Fig. 1

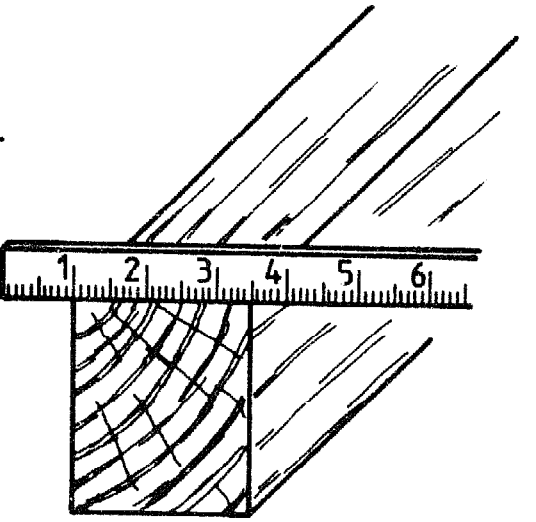

Fig. 2

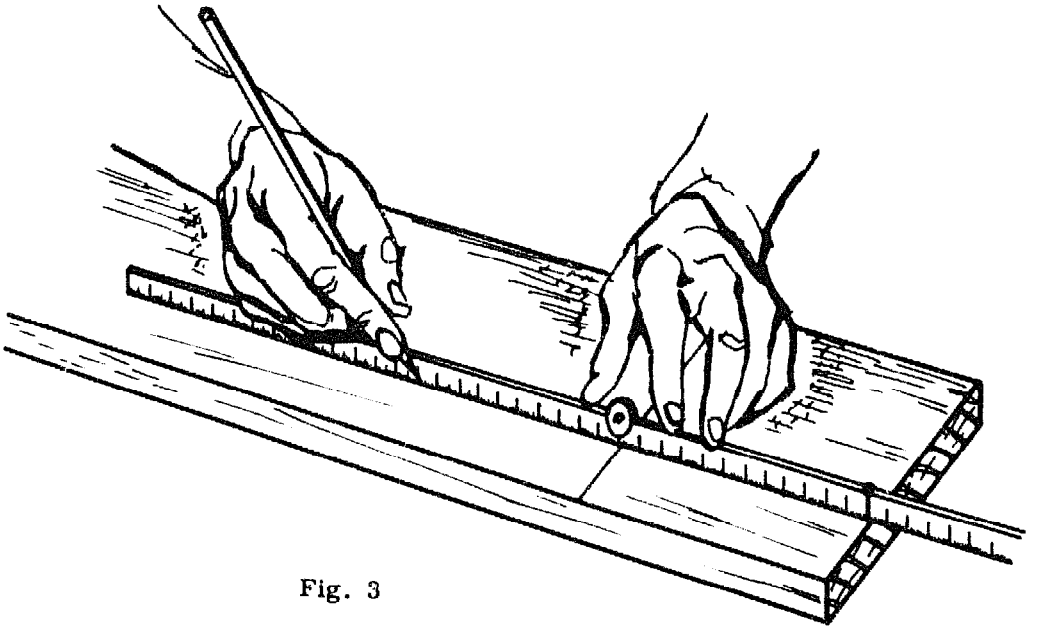

Fig. 3

N P V C	
77	BASIC.

MEASURING AND MARKING OUT TIMBER.

MEASURING AND MARKING OUT TIMBER

Accurate measuring and marking out are the first requirements for success in the building trade. Common measuring and marking tools are the folding rule and zig-zag rule (Reference Book, page 11).

MEASURING WITH A RULE

To measure between two points, place the rule on one point and read the mark nearest to the other point (Fig. 1).

When the end of the rule has become worn and inexact, you can still get an exact measurement. Place the 1 cm mark of the ruler at the first point and read at the second point. The true measurement is that reading minus 1 cm. For example, the measurement in Fig. 2 is: 3,5 cm minus 1 cm equals 2,5 cm.

MARKING OUT WITH A RULE

To mark out measurements with a rule, place the end of the rule (or the 1 cm mark) carefully at the start of the measurement and then make a fine mark with a pencil exactly even with the marking on the rule at the correct distance.

For very accurate marking and measuring, lay the rule on its edge so that the marks on the rule touch the work (Fig. 3).

To mark out several measurements on a line, it is best to mark all of the measurements without raising the rule or moving it. If the rule is moved and each measurement is made separately, there is a much greater possibility of error.

NOTES:

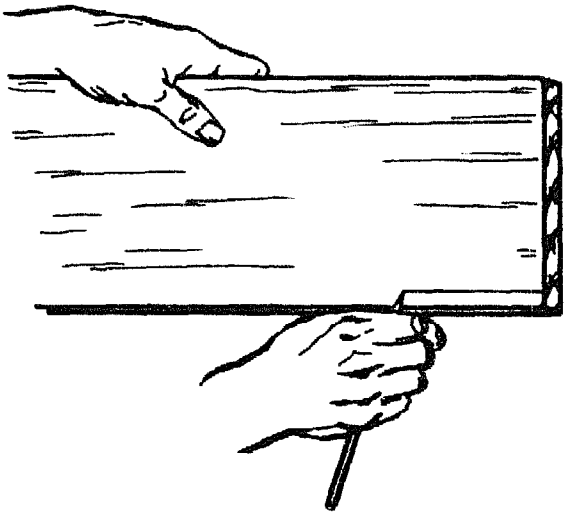

Fig. 1

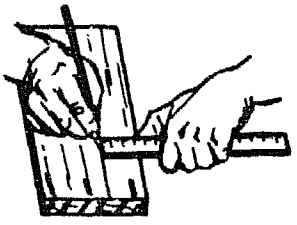

Fig. 2

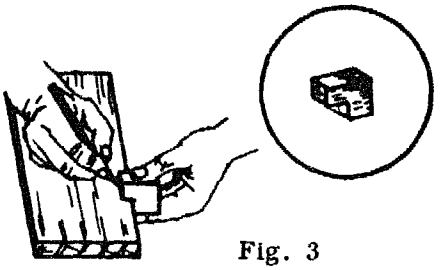

Fig. 3

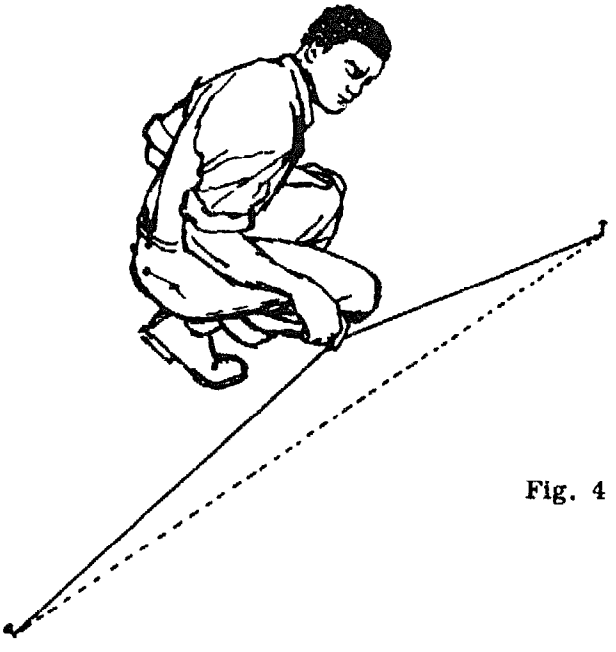

Fig. 4

N P V C		MEASURING AND MARKING OUT TIMBER.
79	BASIC.	

MARKING WITH A PENCIL

When a marking gauge (Reference Book, Tools, page 39) is not available, straight lines can be gauged along timber by one of the following methods.

- Grasp the pencil lightly in your closed fist with the point protruding the desired distance. For example, to make a line 1 cm from the edge of the timber, the point of the pencil should stick out exactly 1 cm from your fist. Now pull the pencil along the board keeping your thumbnail pressed firmly to the edge of the board (Fig. 1).
- To gauge lines further from the edge of the board, use a rule and a pencil. Grasp the rule in one hand with your thumbnail at the desired marking. Then draw the rule along while keeping your thumbnail against the edge of the board. With your other hand hold a pencil at the end of the rule to make the line (Fig. 2).

With these methods you should be careful not to get splinters in your fingers.

- Another method of drawing lines parallel to an edge is with a small pencil gauge. This is simply a small, rebated wooden block which is pressed against the edge of the timber and used to guide the pencil, as shown in Fig. 3. The pencil gauge is often used to mark out the position of chamfers.
- A straight edge can also be used in marking out longer lines.

MARKING WITH A CHALK LINE

A quick and simple way of marking out a straight line on any surface is with a chalk line. This is simply a piece of string that has been rubbed with chalk until it is coated in chalk dust (charcoal may also be used for this purpose).

To use the chalk line, stretch the line between two points which are the ends of the line you want to mark. Hold it in place by tying the ends to nails, or have a helper hold it for you.

Lift the line up in the middle and allow it to snap back (Fig. 4), making a straight chalk line on the surface.

NOTES:

TIMBER CONSTRUCTIONS

The last few lessons were about the very basic things you will need to know before you can actually make any construction of wood. Therefore we started with some technical terms which are important because you will see them again and again in the lessons and will use them in practical work.

The next sections include all the information you will need to prepare for a project: how to get the wood pieces to the right size and shape; how to mark the timber; and how to plan a project using a cutting list. Included here is a section on nailing and one on driving screws. Before you study those sections, look up nails and screws in the Reference Book, Products, pages 207 to 211, so that you are familiar with the parts of nails and screws and how they look.

Each section starts with a list of tools. Refer to the Reference Book, Tools section, and learn about each of these tools before you study the rest of the section.

NOTES:

PREPARATION OF TIMBER

In order to carry out the construction of any practical exercise or project, it is essential to have the wood pieces for the project prepared so that they have the correct size, true and flat surfaces, and square corners and angles.

There is of course a correct procedure to be followed for this preparation. It is important to carry out the following steps in their correct order on every piece of timber, whether large or small.

An easy way to remember the steps in their correct order is to keep the following word in mind: F E W T E L.

Face	Edge	Width	Thickness	End	Length
F	E	W	T	E	L

The tools which are required for this preparation are the bench, jack plane, straight edge, winding strips, pencil, try square, marking gauge, charcoal line, back saw, ruler and crosscut saw. Look these up in the Reference Book and make sure that you understand what they are and how they are used.

NOTES:

F

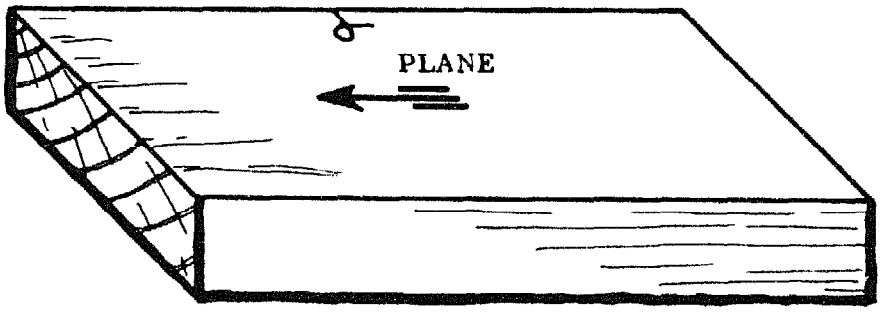

E

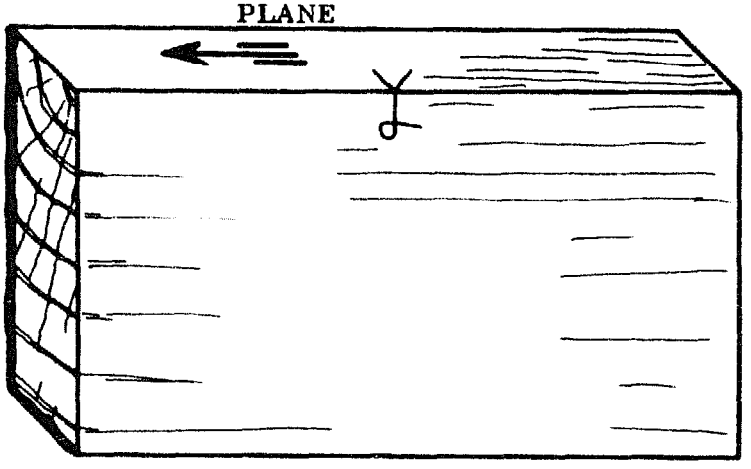

W

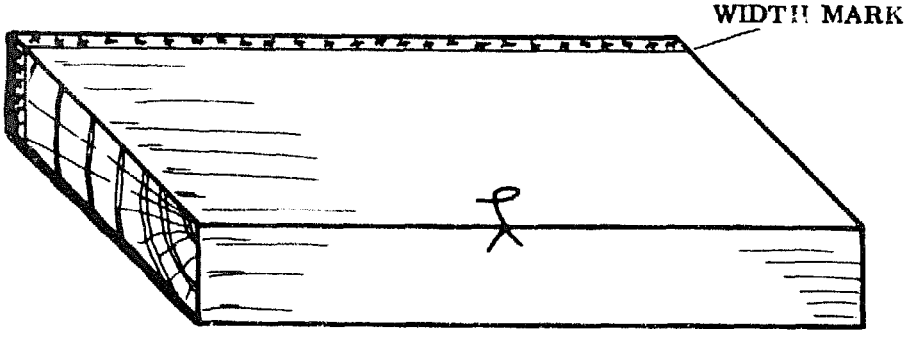

N P V C		PREPARATION OF TIMBER.
83	BASIC.	

SEQUENCE OF OPERATIONS FOR PREPARING TIMBER

Step 1. Plane the face side (F)

- Put your work on the bench with the better side up. If the board is not flat, put the hollow side down to keep it from rocking or moving around. In the case of very long or thin boards or twisted or deformed boards, put thin wedges of wood underneath where needed, to keep the work steady and keep it from bending in the middle during planing.
- Plane this side perfectly true.
- Test for flatness with the straight edge, winding strips and try square.
- Mark this side as the face side; the face mark should point to the edge which will be the face edge. The face edge will be the best edge of the board.

Step 2. Plane the face edge (E)

- Fasten your board to the side of the bench, with the face mark up. The planed side must be towards you and not against the bench, unless this would mean you would have to plane against the grain. In that case, you should turn the board so the other edge is up, keeping the face side towards you because the try square has to be set against the face side.
- Plane the face edge perfectly straight and square to the face side.
- Test for straightness with the straight edge and for squareness with the try square.
- Mark it with a face edge mark pointing to the face side.

Step 3. Plane the width (W)

- With a marking gauge, mark the width of the board. Press the gauge against the face edge and mark on the face side.
- Plane down to the middle of the gauge line and be careful to get a square, straight edge when you reach the mark.
- Test for flatness with a straight edge and try square.

NOTES:

- During planing mind the direction of the thread of the wood.

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NOTES:

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T

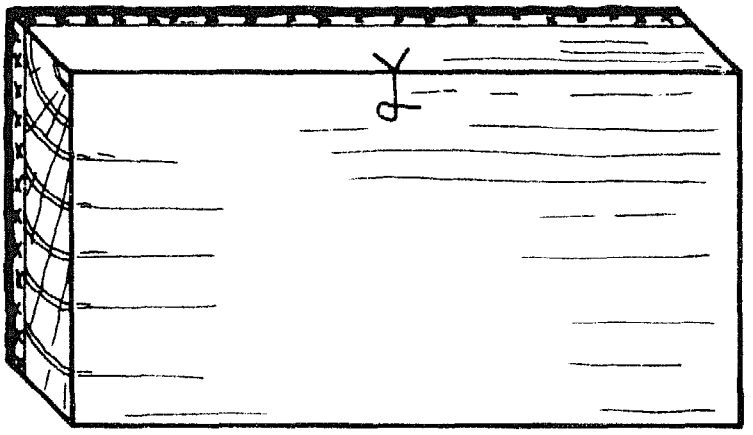

E

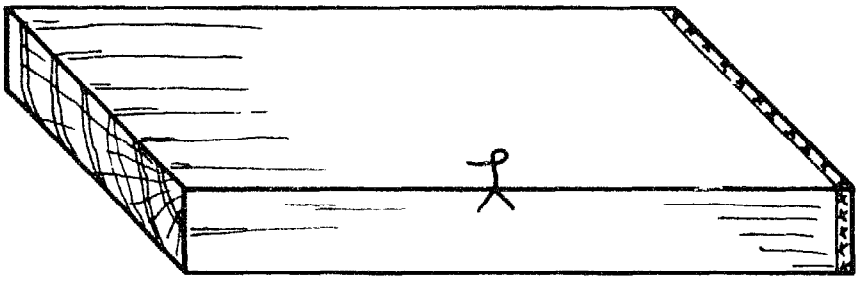

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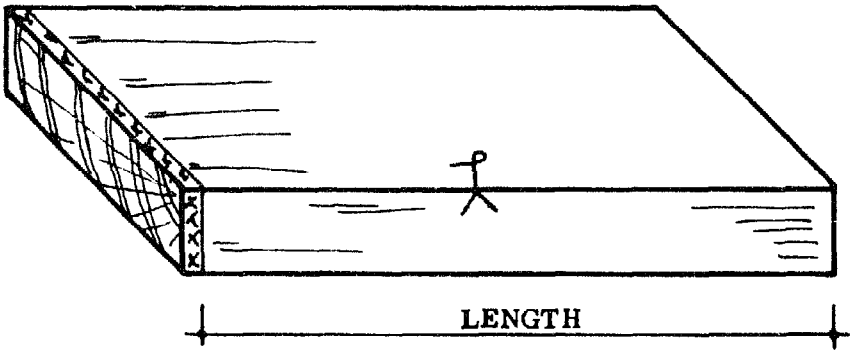

N P V C	
85	BASIC.

PREPARATION OF TIMBER.

Step 4. Plane the thickness (T)

- Use a marking gauge to mark the thickness of your board. Press the gauge against the planed side and mark both edges.
- Plane down to the middle of the gauge lines.
- Test for flatness as you get near the two marked lines. Be sure to check for flatness across the board at several points. Check for winding with the winding strips.

Generally timber is not prepared to the exact length. Waste is left on each end to protect the corners from damage. If it is necessary to prepare it to the exact length, the procedure is as follows:

Step 5. Cut one end (E)

- With a try square, square the best end; with as little waste as possible.
- Cut that end perfectly square to the face side and face edge. Saw on the waste side of the line.
- Test for squareness in all directions.
- Mark the end with a cross, so that you know which is the prepared and tested end.

Step 6. Cut the length (L)

- Measure the required length from the prepared end and square with the try square.
- Cut that end perfectly square in all directions.
- Test it with a try square.

NOTES:

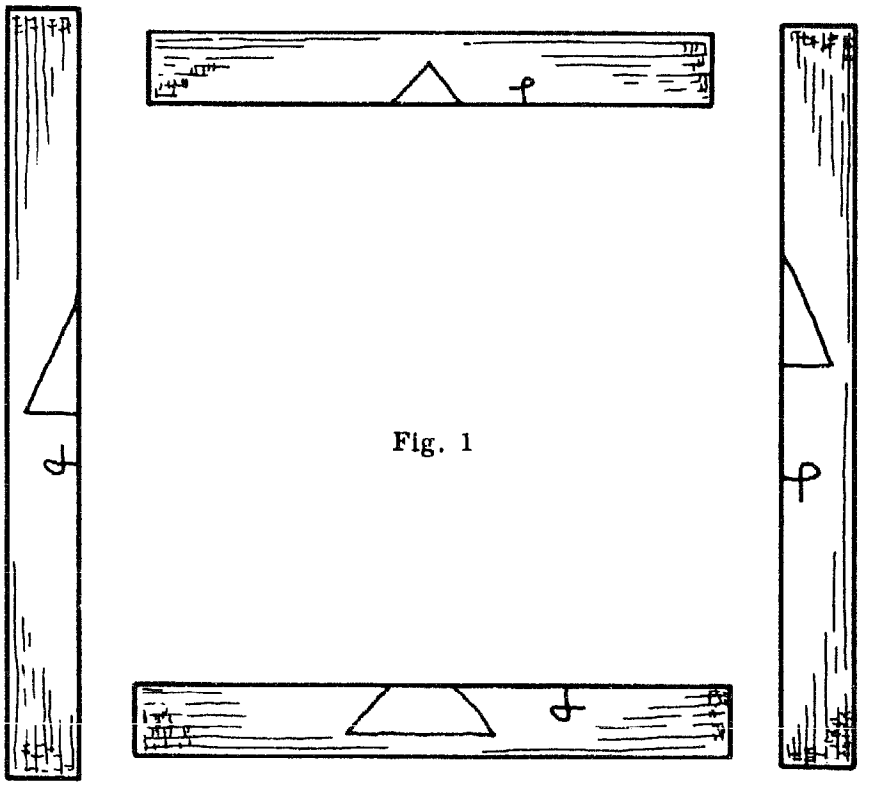

Fig. 1

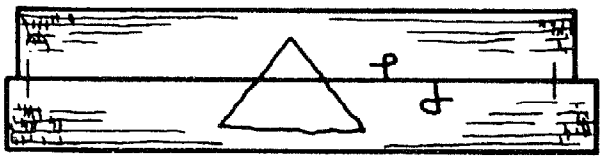

Fig. 2

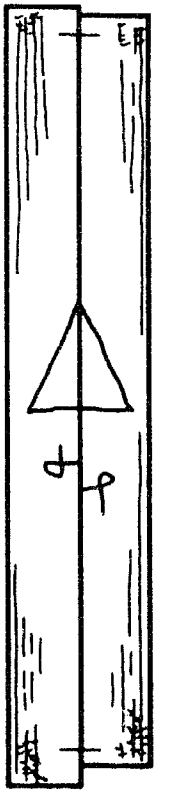

Fig. 3

N P V C	
87	BASIC.

PREPARATION OF TIMBER.

TIMBER MARKS

The purpose of face marks, as they are shown under preparation of timber, is to show clearly the prepared and tested sides and the edges which are square.

During all further marking, squaring and gauging we should try to work from these sides and edges.

MARKING OF FRAMES

Making frames is an important part of Rural Building. We have to mark the members of a frame in a standard way so that we do not confuse their positions.

- Select and prepare the timber according to the sequence given in the section on preparation of timber. Lay out the various members as they will be when they are finally assembled into a frame (Fig. 1).
- Take care that all surfaces which will be visible in the finished product are of good timber and without defects. Usually these will be the face sides and face edges. Always try to keep the face sides on one side, and the face edges all on the inside or all on the outside.
- Now put the inside edges of the horizontal members together, mark the length of the members and put the triangular mark as shown in Fig. 2. The triangle always should point up.
- Now do the same thing for the vertical members. Put the inside edges together, mark the lengths and put the triangular sign, again pointing upwards (Fig. 3).
- All further marking should be done using these sides as a reference.

NOTES:

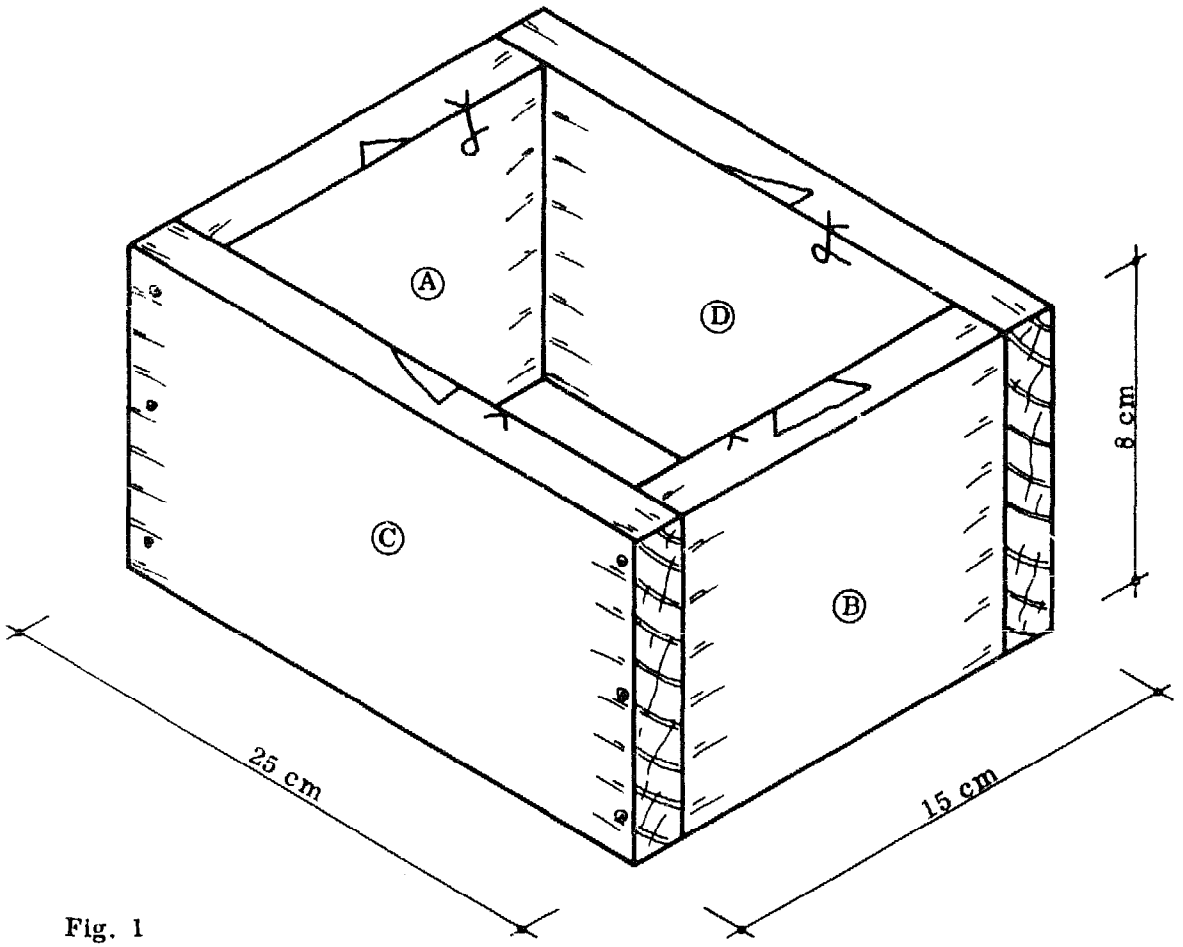

Fig. 1

NOTES:

N P V C		PREPARATION OF TIMBER.
89	BASIC.	

CUTTING LIST

After you design and make the drawing for a piece of work, you need to make a cutting list showing the length, width and thickness of all the parts. These will be the finished sizes. So that each part will be straight, true and smooth, we must begin with slightly bigger pieces to have an allowance for planing the sawn timber true.

The planing allowance for a board is:
3 mm extra in thickness
6 mm extra in width
12 mm extra in length

For square pieces the allowance is:
3 mm extra on each side
12 mm extra in length

An example is shown below of a cutting list for a simple box (Fig. 1). The list shows the parts of the box, the kind of wood, the number required of each part and the finished size of the part. In the last column we find the size of the timber that will be required when the planing allowance has been added.

Usually it is best to plan a project according to the sizes of timber you have available, subtracting the planing allowances first in order to prevent waste.

Cutting list:

			finished size (cm)			timber size (cm)		
part	wood	no.	L	W	T	L	W	T
A	Odum	1	10,6	8	2,2	11,8	8,6	2,5
B	Odum	1	10,6	8	2,2	11,8	8,6	2,5
C	Odum	1	25	8	2,2	26,2	8,6	2,5
D	Odum	1	25	8	2,2	26,2	8,6	2,5

When you are choosing timber for a piece, choose the best, straight boards for the long pieces. The crooked or defective boards can be used for the shorter pieces.

NOTES:

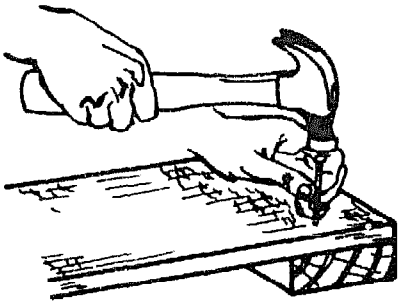

Fig. 1

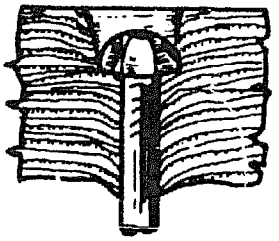

Fig. 2

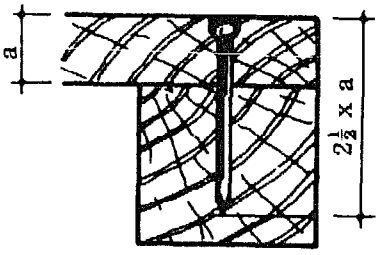

Fig. 3

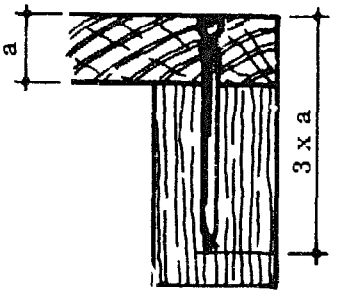

Fig. 4

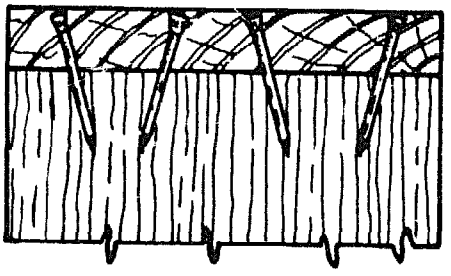

Fig. 5

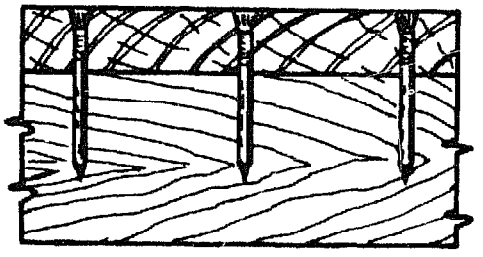

Fig. 6

N P V C	
91	BASIC.

FASTENING WITH NAILS.

FASTENING WITH NAILS

Before you read this section, look up Nails in the Reference Book, Products section, page 207.

DRIVING NAILS

To start a nail, hold it steady between your thumb and fingers with one hand and strike one or two light blows with the hammer (Fig. 1).

After the nail is well started, drive it in with firm blows. Hold the handle of the hammer near the end and strike the nailhead straight.

When you drive a nail all the way in, be careful on the last blows not to hit the wood and leave a hammer mark on it.

HOLDING POWER

The holding power of the nail depends on the pressure of the wood fibres against the shank of the nail and also on the size of the nailhead (Fig. 2).

Hard dry wood holds better than soft or wet wood. End grain doesn't hold nails very well. If the nail is driven across the fibres, the nail's length should be $2\frac{1}{2}$ times the thickness of the top piece (Fig. 3). If it is driven into end grain, the length should be 3 times the thickness of the top piece (Fig. 4).

The holding power of nails in end grain can be improved by dovetail nailing, which means the nails are inserted at slight angles (Fig. 5) instead of straight in (Fig. 6) which is the usual way.

If possible the nails should be inserted at right angles to the force that will be applied to the piece; so that any force tends to shear off the nail rather than pull it out.

The correct placing of the nails is important with respect to the strength of the finished piece.

NOTES:

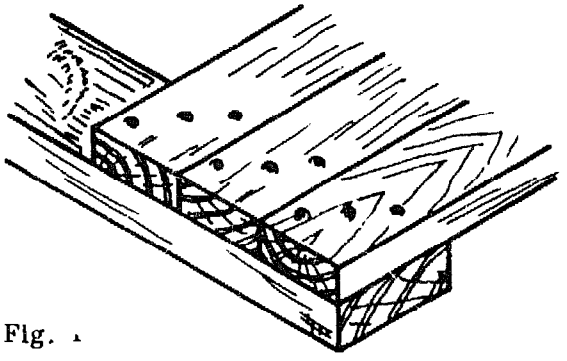

Fig. 1

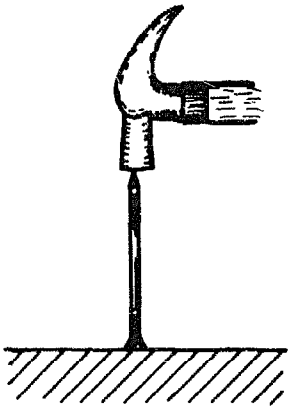

Fig. 2

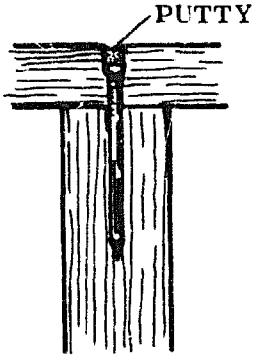

Fig. 3

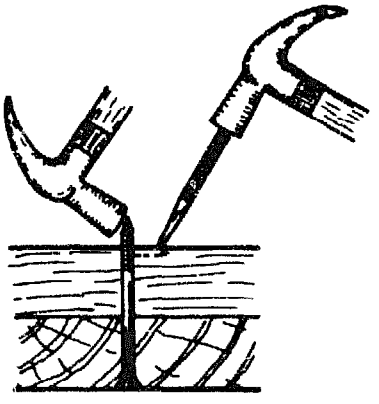

Fig. 4

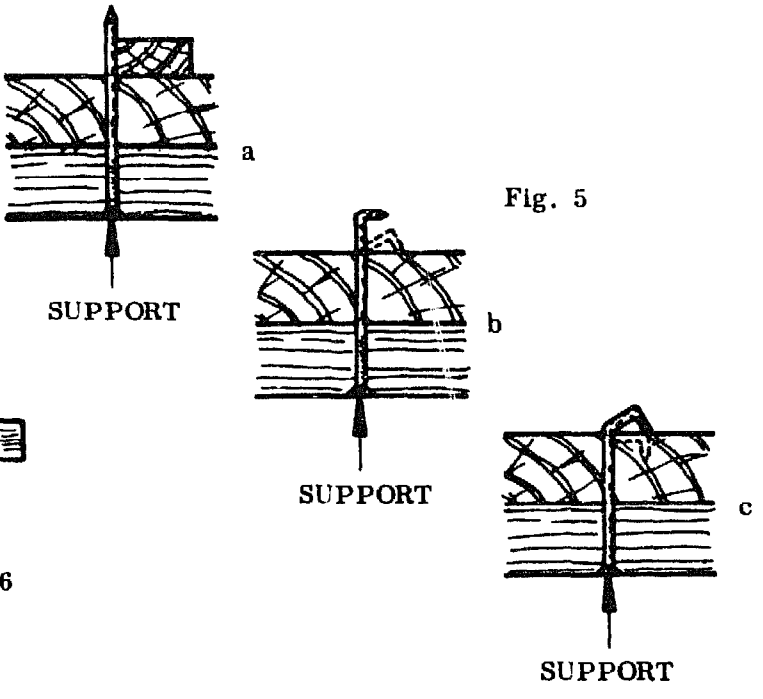

Fig. 5

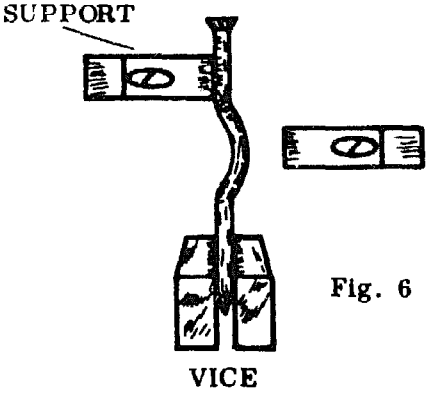

Fig. 6

N P V C	
93	BASIC.

FASTENING WITH NAILS.

HOW TO PREVENT SPLITTING DURING NAILING

Nails can be staggered (inserted out of line) to prevent splitting along the fibres of the wood (Fig. 1).

Blunting the nail with one or two hammer blows on the tip also helps to prevent the nail from splitting the wood (Fig. 2).

If large nails are to be fixed, drill holes first to keep them from splitting the timber. The holes should be slightly smaller in diameter than the nails.

FINISHING OFF

Lost head nails are punched (knocked below the surface of the wood) with a nail punch or a large blunt nail. The remaining hole can be filled with putty (Fig. 3).

When the sharp points of nails come all the way through the timber and out on the other side, they are clenched; that is the tips are bent over and flattened against the wood, out of the way. There are two ways of doing this:

- Knock the tip flat and punch it into the wood with a nail punch (Fig. 4).
- Bend the point at a right angle first, and then knock it back into the wood (Fig. 5; a, b, & c). This is done where the nail projects more than 1 cm.

The head of the nail should be supported during clenching to keep it from being pushed out again.

Bent nails can be straightened if you tighten one end in a vice and support the other end with a hammer while knocking out the bent part with another hammer (Fig. 6).

NOTES:

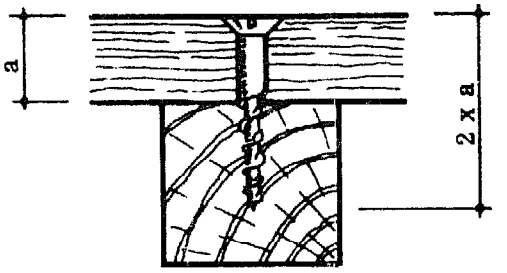

Fig. 1

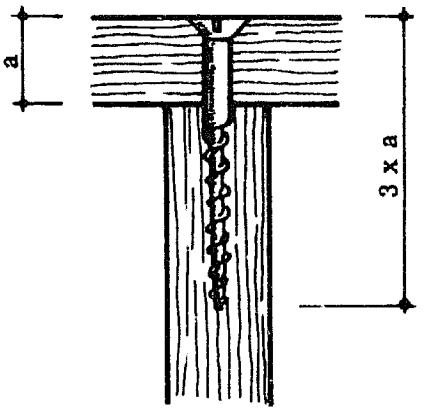

Fig. 2

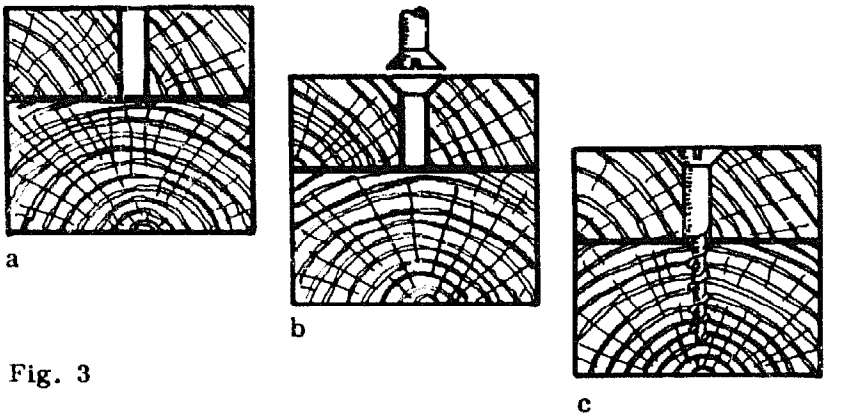

Fig. 3

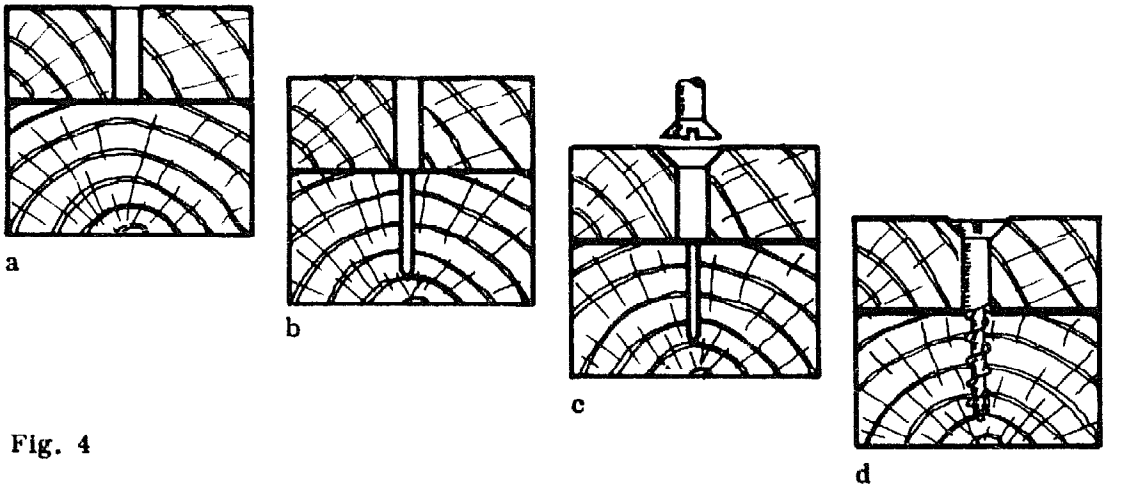

Fig. 4

N P V C	
95	BASIC.

FASTENING WITH SCREWS.

FASTENING WITH SCREWS

Before you read this section, look up screws in the Reference Book, page 209; screwdrivers on page 77; and maintenance of screwdrivers on page 103.

HOLDING POWER

The holding power of a screw depends on how the thread embeds in the fibres, the length of the screw and the strength of the head which holds the top piece.

When a screw is driven across the grain, the screw's length should be about twice the thickness of the top piece (Fig. 1).

Screws driven into the end grain should be longer, about 3 times the thickness of the top piece (Fig. 2).

DRIVING SCREWS IN SOFT WOOD

- Bore a hole in the top piece with the same diameter as the shank of the screw (Fig. 3a). The bottom piece may be punched with a large nail or awl (Reference Book, page 73).
- Countersink if necessary (Fig. 3b).
- Drive the screw (Fig. 3c).

DRIVING SCREWS IN HARD WOOD

- Bore a hole in the top piece with the same diameter as the shank of the screw (Fig. 4a).
- Bore a hole in the bottom piece with the same diameter as the core of the screw (Fig. 4b).
- Countersink if necessary and drive the screw (Figs. 4c & 4d).

Use a screwdriver with the correct tip only. If the screw turns too hard, the hole may be too small or not deep enough. Remove the screw and find out what the problem is so it can be corrected, otherwise the screw may break or split the board.

- Turn the screw down until the head is just seated. Overturning weakens the holding power and may break the screw.
- To make driving easier and to protect against rust, a bit of soap or oil may be put on the tip of the screw.

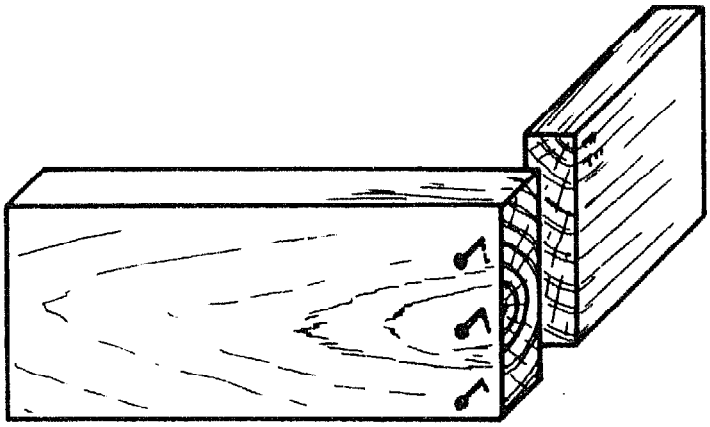

Fig. 1

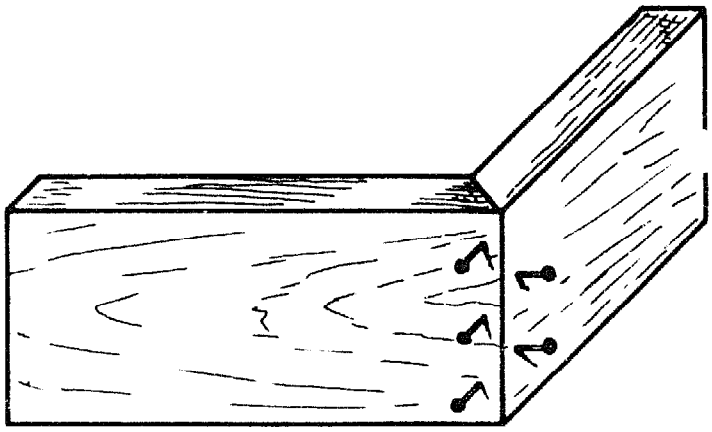

Fig. 2

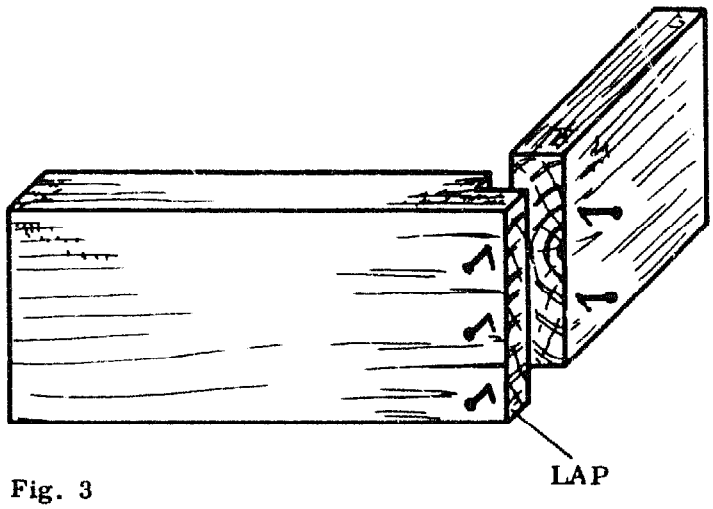

Fig. 3

N P V C		ANGLE JOINTS.
97	BASIC.	

ANGLE JOINTS

Angle joints are joints where the sides of the pieces (the wide surfaces) meet at right angles to each other. Angle joints are used for box-like constructions such as small boxes, tool boxes etc. For an example of a box using angle joints, see the illustration for the Cutting List lesson, on page 89. In this chapter we will consider the most common types of angle joints and their construction.

NAILED BUTT JOINT

The simplest angle joint is the nailed butt joint. The end of one piece of wood is cut square, then butted against the face of the other piece. It is held in place with nails, or both nails and glue (Fig. 1).

PLAIN MITRED JOINT

The ends of the pieces are mitred (cut at 45 degrees) across the thickness. The mitred ends are butted together and held in place with glue and nails (Fig. 2). This is a weak type of joint although it is stronger than the butt joint because it is nailed from two sides. Its advantage is that the end grain is not exposed to damage from water or insects, and it has a neater appearance.

REBATED BUTT JOINT

The end of one piece fits into a rebate at the end of the other piece. This joint is strong because two surfaces are available for nailing, and because the shoulder of the rebate supports and helps to hold the other piece (Fig. 3).

The lap is the section of wood which is left projecting after the rebate is cut (Fig. 3). The lap is usually one-half of the thickness of the board. This lap will be important later when we are figuring out the length of our pieces for making a box.

The rebated butt joint is simple to construct. In the following sequence of operations we will describe how to make a simple box with this joint while also practising some techniques discussed earlier, like making a cutting list and preparing timber to size.

The tools required here will be the same ones we used for the preparation of timber; with the additions of a firmer chisel, a smoothing plane, and a backsaw. Make sure you know what these tools are and how to use them before you go on.

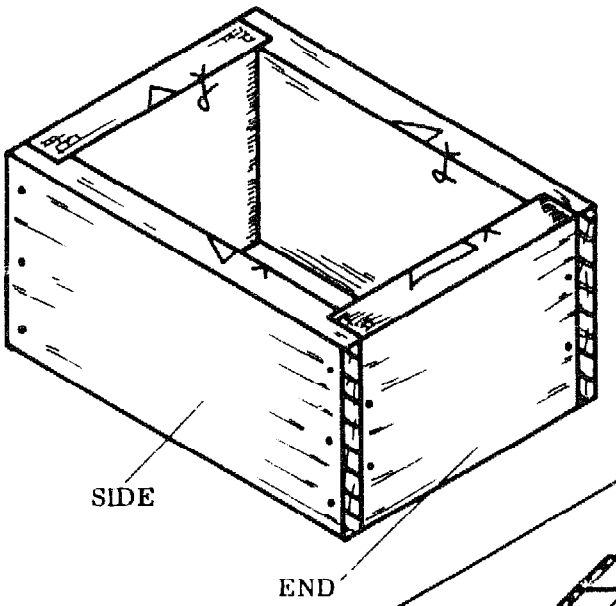

Fig. 1

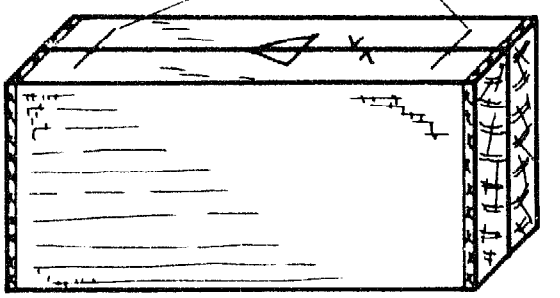

Fig. 2

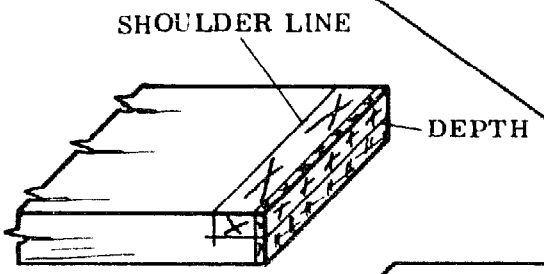

Fig. 3

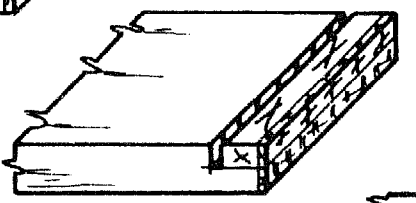

Fig. 4

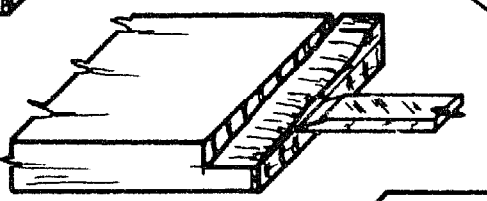

Fig. 5

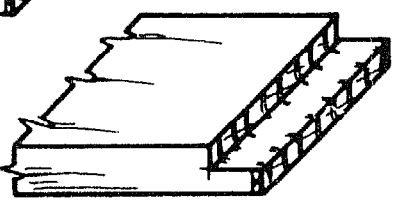

Fig. 6

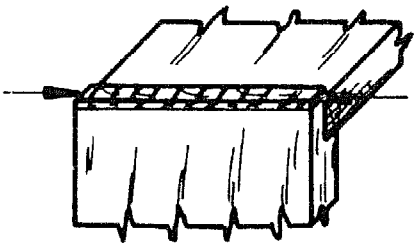

Fig. 7

N P V C		ANGLE JOINTS.
99	BASIC.	

SEQUENCE OF OPERATIONS FOR CONSTRUCTING A BOX WITH THIS JOINT

Step 1. Preparation of timber

- Make a cutting list. The end pieces can be cut to the required length, that is the outside width of the box minus the width of the two laps. Allow 3 mm extra at each end of the side pieces, for planing off after assembly (Fig. 2).
- Prepare the pieces (see Preparation of Timber section, pages 84 to 86).

Step 2. Marking out

- Mark the sides and ends as shown in Fig. 1, on the face edges (Marking of frames, page 88). All further marking will be done from the sides with these marks.
- Place the two sides together and mark the position of the rebates, squaring with the try square (Fig. 2).
- Mark the shoulder lines of the rebate on the inside face of the piece, using the try square (Fig. 3).
- Mark the depth of the rebate on the end grain and the edge, using a marking gauge (Fig. 3). Show the waste with crosses.

Step 3. Cutting the rebate

- Saw the shoulders down to the gauge line. Cut on the waste side of the line. If the piece is very wide, nail or clamp a guide over the line to guide the saw. Use a backsaw (Fig. 4).
- Remove the waste carefully to the gauge line with a firmer chisel (Fig. 5). Find out the direction of the grain by chiselling out small pieces first, so that you don't accidentally chisel too deep.

Step 4. Assembling

- Clean up the inside faces with a smoothing plane (Fig. 6).
- Assemble the box with glue and nails.
- Measure the diagonals to check for squareness.
- Clean up the face and bottom edges with a smoothing plane.
- Plane off the waste from the sides with the smoothing plane. Prevent splintering by working inwards from the ends (Fig. 7).

NOTES:

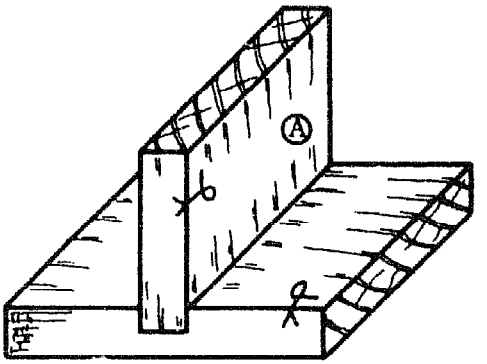

Fig. 1

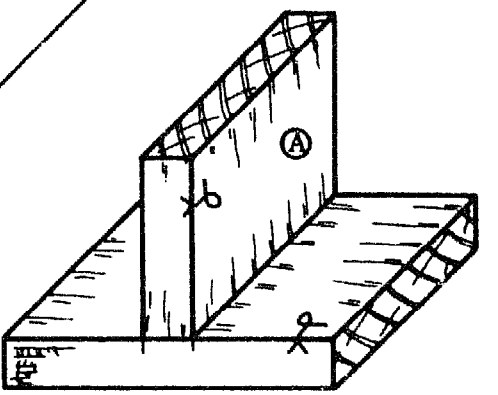

Fig. 2

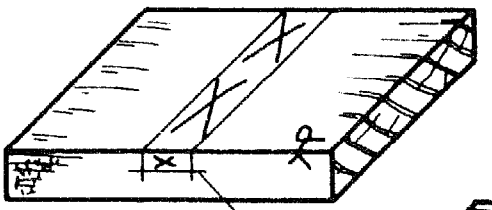

Fig. 3 DEPTH

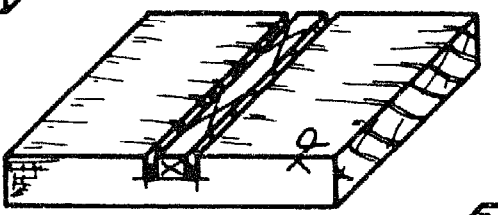

Fig. 4

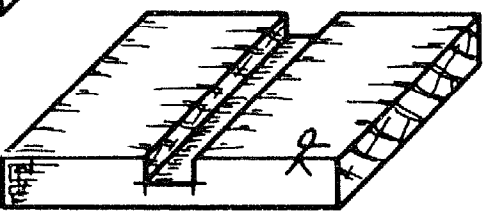

Fig. 5

NOTES:

N P V C		ANGLE JOINTS.
101	BASIC.	

HOUSED JOINT

These joints are another type of angle joint, also used in box-like constructions.

Housing consists of sinking the end of one piece into a trench which is cut into the face of another piece (Fig. 1).

The tools required for making this type of joint are the same ones used to make the rebated butt joint.

SEQUENCE OF OPERATIONS FOR CONSTRUCTING THE JOINT

Step 1. Preparation of the timber

- Make a cutting list.
- Prepare the timber (see Preparation of Timber section).

Step 2. Marking out

- Mark one edge of the trench with a try square and the other edge by using piece A as a guide (Fig. 2). (Smooth piece A before using it to mark the trench).
- Gauge the depth of the trench at each edge (Fig. 3).
- Show the waste with small crosses (Fig. 3).

Step 3. Cutting the trench

- Saw the sides of the trench (on the waste side of the lines) down to the gauge lines (Fig. 4).
- Chisel out the waste from the trench (Fig. 5).

Step 5. Assembling

- Assemble the two parts with nails and glue.
- Clean up the edges with a smoothing plane.

NOTES:

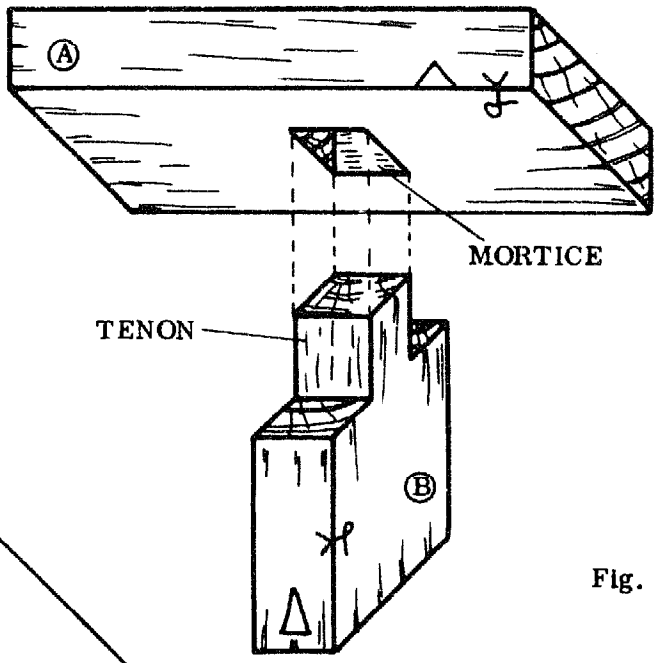

Fig. 1

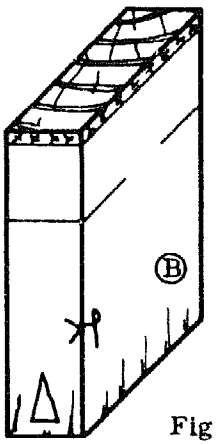

Fig. 2

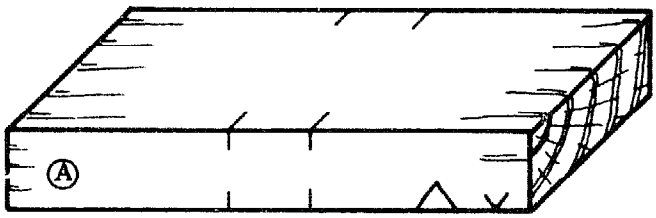

Fig. 3

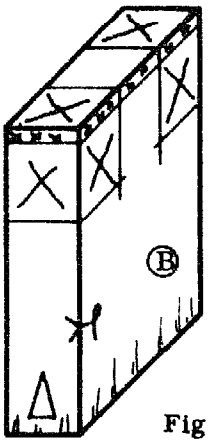

Fig. 4

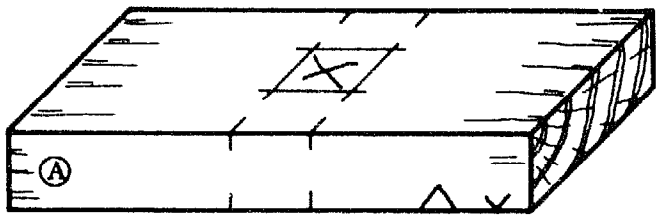

Fig. 5

N P V C	
103	BASIC.

ANGLE JOINTS.

COMMON MORTICE AND TENON JOINT FOR BOX-LIKE CONSTRUCTIONS

This is one of the commonest and strongest joints. The two parts are (Fig. 1): the tenon (B) which is a projection on the end of one part and the mortice (A), the hole in the other part into which the tenon fits. The tenon is usually 1/3rd of the width of the board.

The tools we need are ones we have discussed before, plus a mortice chisel, a brace and drilling bits.

SEQUENCE OF OPERATIONS FOR CONSTRUCTING THE JOINT

Step 1. Preparation of timber

- Make a cutting list.
- Prepare the timber to the required sizes. (In the following steps, the piece with the mortice is "piece A" and the one with the tenon is "piece B".)

Step 2. Marking out

- Mark out the length of the tenon on piece B. Allow 3 mm waste in the length and make square lines all around with a try square and pencil (Fig. 2).
- Take piece A and mark out the position of the mortice on the face edge and make square lines on the edges on both sides with the try square (Fig. 3).
- Set the marking gauge to the width of the tenon and mark the lines around piece B at the width. Mark the waste with small crosses (Fig. 4).
- Use the same setting to mark both faces of piece A and use a try square and (already smoothed) piece B to mark the remaining two lines for the width of the mortice (Fig. 5). Mark the waste with a small cross.

If the marking gauge has two pins, set each at its correct measurement and mark both lines at once. If not, mark with the first setting on all the members, then change the setting and mark the other measurement on all the members.

- Always mark from the face edge. Check the marking by setting piece B against the marks on piece A to see if they fit. Piece B must be smoothed first.

NOTES:

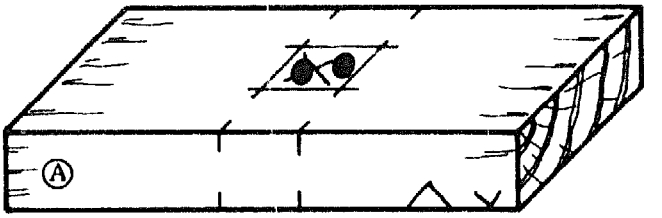

Fig. 6

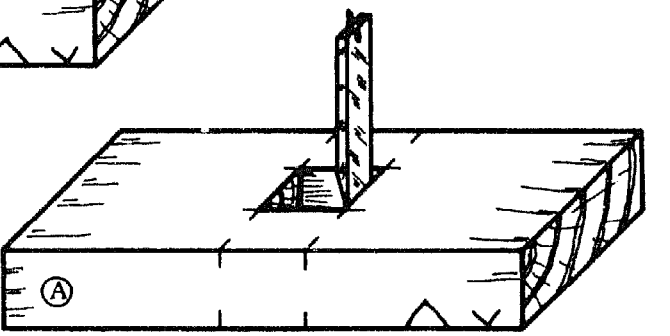

Fig. 7

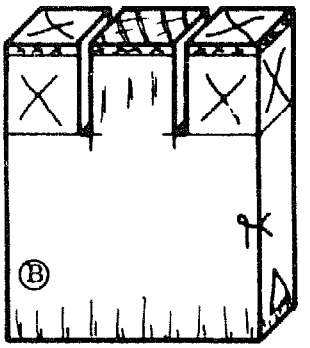

Fig. 8

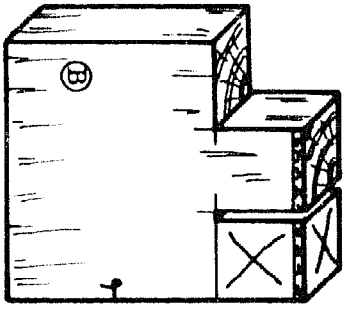

Fig. 9

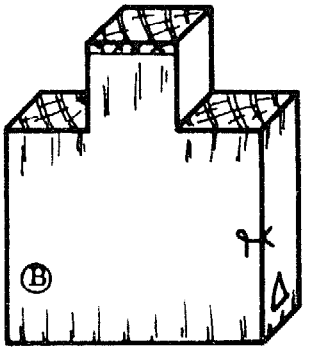

Fig. 10

Fig. 11

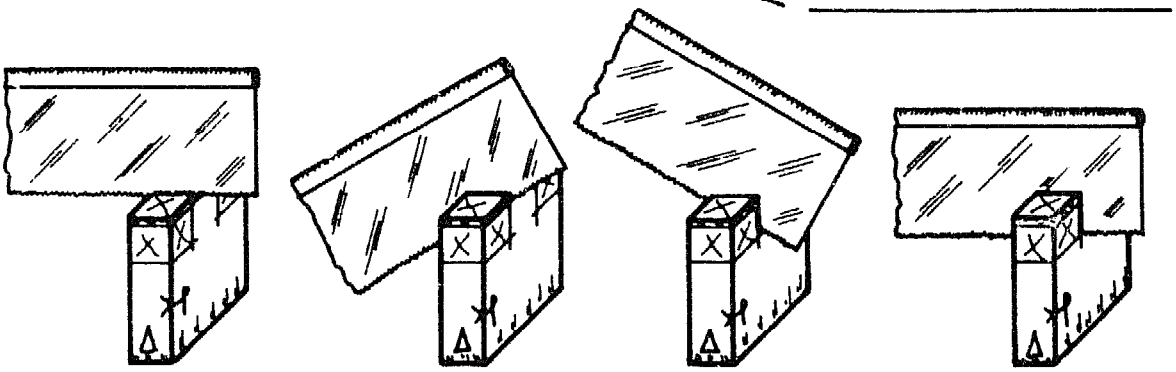

a b c d

N P V C		ANGLE JOINTS.
105	BASIC.	

Step 3. Cutting the mortice

- Bore out most of the waste, using a brace and bit (Fig. 6). Clamp a piece of wood to the underside to prevent splintering and damage to the bench.
- Chop out the remaining waste with a mortice chisel, chiselling halfway through from both sides. Leave about 2 mm extra waste on all sides to prevent damage to the sides. Keep the cutting edge of the chisel across the grain.
- Carefully chop out the rest of the mortice up to the lines (Fig. 7). Keep the bevel of the chisel towards the inside of the mortice. Do not use the mallet.

Step 4. Cutting the tenon

- Rip the sides of the tenon, sawing on the waste side of the line (Fig. 8). Cut in stages as shown in Fig. 11, a, b, c, & d).
- Carefully saw the shoulders, making sure to hold the saw straight. Keep on the waste side of the line (Figs. 9 & 10).

Step 5. Assembling the joint

- Check the fit of the members. The tenon should fit tightly into the mortice without splitting the morticed piece. There should be no gap between the shoulders of the tenon and the morticed member. Don't force the members together. If they don't fit, find the problem and correct it.
- Clean up the inside of the joint where it can't be reached after assembly with a smoothing plane. (Remember that the tenon should be smoothed before using it to mark out.)
- Assemble the joint.
- Plane off the waste end of the tenon, clean up all sides and edges with the smoothing plane.

NOTES:

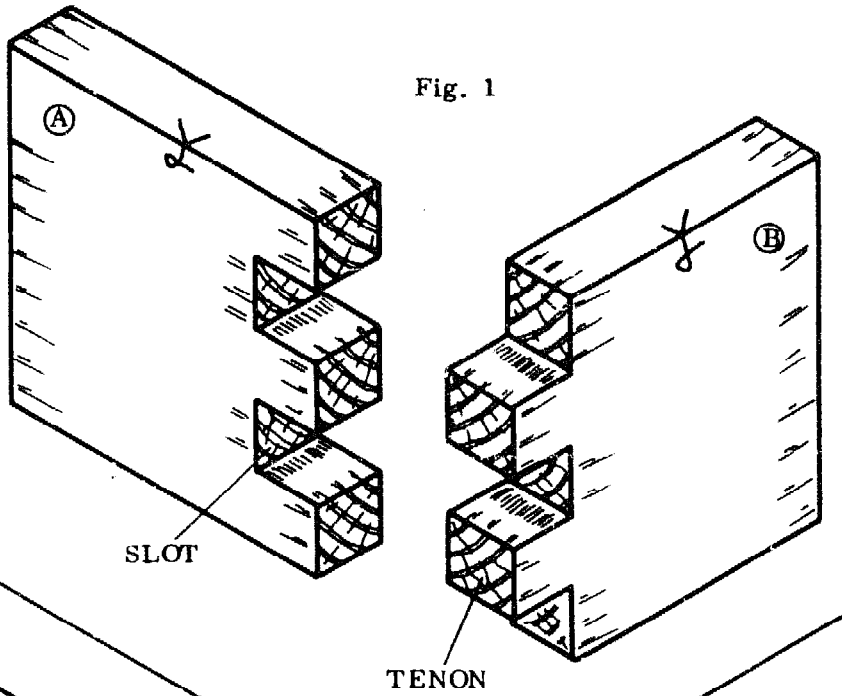

Fig. 1

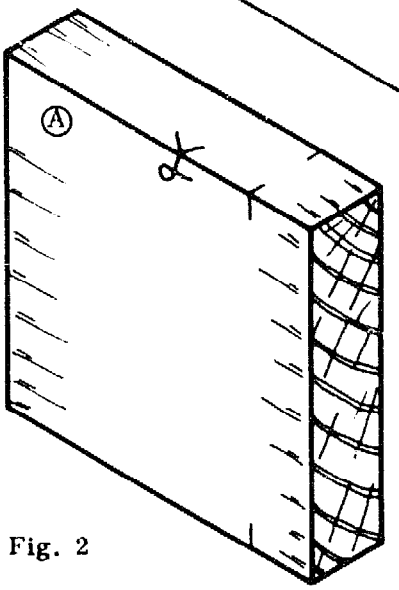

Fig. 2

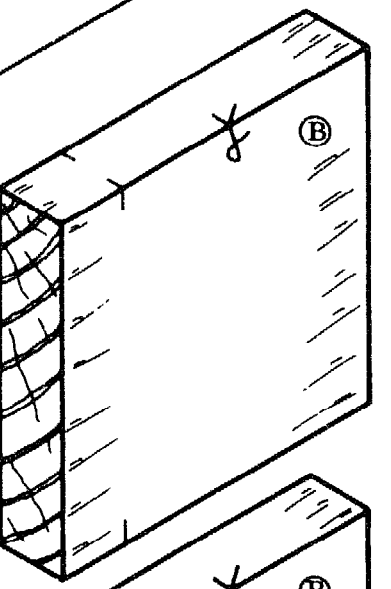

Fig. 3

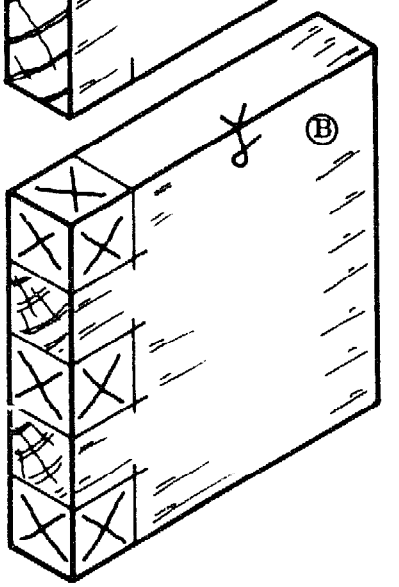

Fig. 4

N P V C		ANGLE JOINTS.
107	BASIC.	

CORNERLOCKED JOINT

The cornerlocked joint is similar to the mortice and tenon joint. It is an angle joint with a series of tenons on one member which correspond to slots on the other member (Fig. 1). The resulting joint is strong because it can be nailed from two sides, and the interlocking tenons and slots also help hold the pieces together.

The tools required to make this joint are the same ones used for the mortice and tenon joint.

SEQUENCE OF OPERATIONS FOR CONSTRUCTING THE JOINT

Step 1. Preparation of the timber

- Make a cutting list.
- Prepare the timber to the required sizes. (In the following steps, the member with the slots is piece "A" and the one which has the tenons is piece "B".)
- If the members are to be used for a box where the external appearance is important, the face sides should be outside.
- In most cases the face edges are kept upwards.

Step 2. Marking out

- Mark out the position of the tenons and slots by gauging or squaring lines at the corners on the ends of the pieces: on piece A the depth should be equal to the thickness of piece B (Fig. 2); while on piece B the depth should be equal to the thickness of piece A (Fig. 3). Allow 2 mm waste for cleaning up after assembly.
- Mark out the shape of the tenons on piece B. Keep all tenons the same size (Fig. 4).
- Immediately mark the waste between the tenons with crosses (Fig. 4).

NOTES:

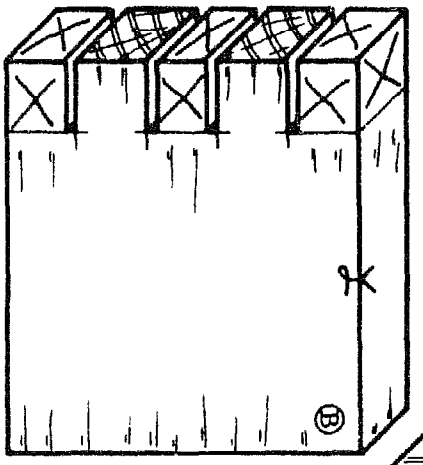

Fig. 5

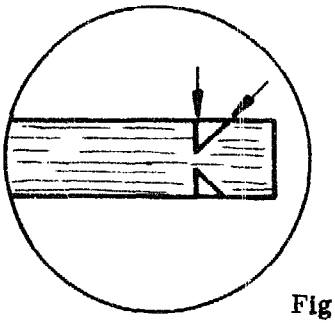

Fig. 7

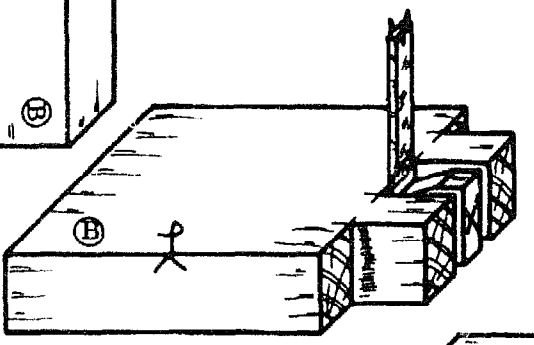

Fig. 6

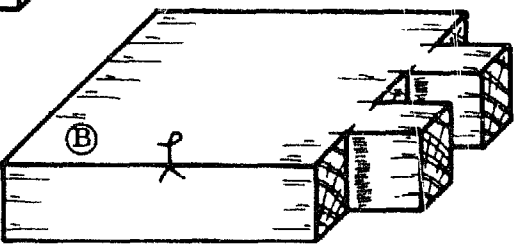

Fig. 8

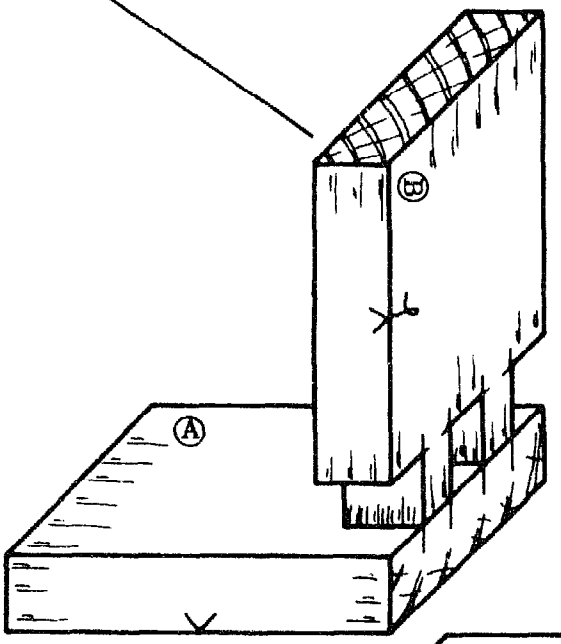

Fig. 9

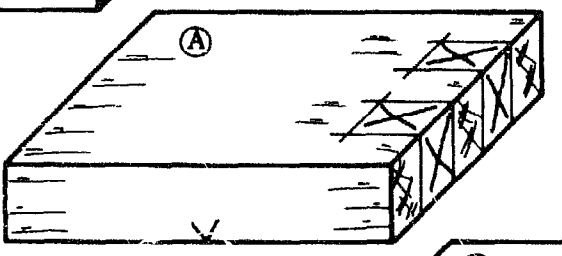

Fig. 10

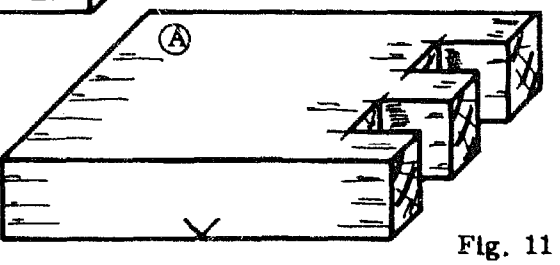

Fig. 11

N P V C	
109	BASIC.

ANGLE JOINTS.

Step 3. Cutting the tenons

- Rip the sides of the tenons down to the gauge line (Fig. 5). Saw on the waste side of the line.
- Chop out the waste by chiselling alternately vertically and then at an angle, making "V" cuts halfway through from each side (Figs. 6, 7, & 8).

Step 4. Cutting the slots

- Place piece B (with the tenons) over the end of piece A, with the face side towards the outside as indicated in Fig. 9.
- Mark the shape of the tenons onto piece A with a pencil (Fig. 9).
- Square the sides of the slots down both sides (Fig. 10).
- Mark the waste with small crosses (Fig. 10).
- Rip the sides of the slots, sawing on the waste side of the line.
- Chop out the waste from the slots, chiselling from both sides as explained in the previous step (Fig. 11).

Step 5. Assembling the joint

- Clean up the inside faces of the joint.
- Assemble the joint with glue and nails.
- When the glue is dry, clean up the waste of the tenons and slots with a smoothing plane. Make sure the nails are punched well below the surface to prevent damage to the sole of the plane.
- Clean up the outside faces and edges with a smoothing plane.

NOTES:

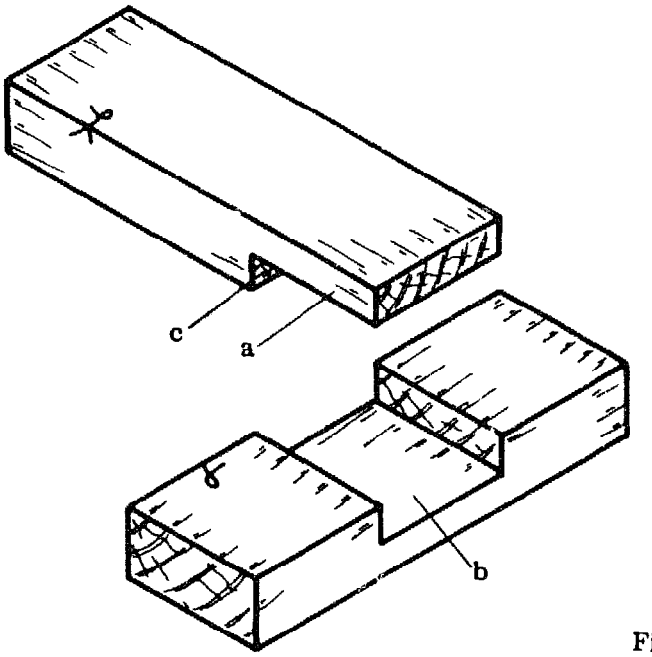

Fig. 1

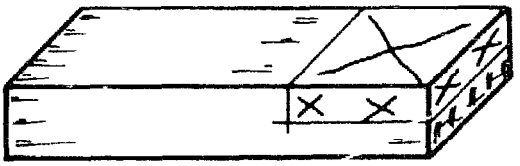

Fig. 2

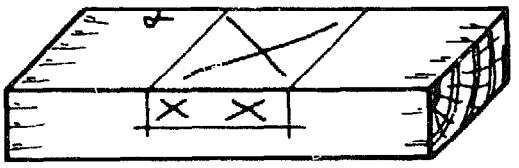

Fig. 3

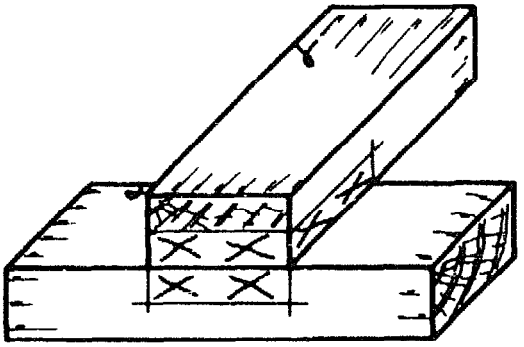

Fig. 4

N P V C	
111	BASIC.

FRAMING JOINTS.

FRAMING JOINTS

Framing joints are those used in frame-like constructions. The members are usually constructed with their edges at right angles to each other; in contrast to the angle joints used in box-like constructions, where it is the sides which form the right angle (previous pages).

HALVED JOINTS

Halved joints are one type of framing joint. The name is applied to joints where the pieces of timber which meet or cross each other are halved; that is, at the place where they cross, each piece is 1/2 the thickness of the rest of the piece. The result is that in the assembled joint, the surfaces of both pieces are flush.

Halved joints are used for constructing simple frames.

In Rural Building, we deal with four different kinds of halved joints. Here we will cover the description and construction of the "tee-halved joint", since the construction of the other joints follows much the same procedures.

The tee-halved joint consists of a pin (a) on the end of one piece which fits into a socket (b) in the other piece (Fig. 1).

The pin is half the thickness of the timber, and the depth of the socket equals the thickness of the pin. The shoulder of the pin (c) fits against the face edge of the socket (Fig. 1).

The tools required to make this joint are the same ones we used to make the mortice and tenon joint in the last chapter.

SEQUENCE OF OPERATIONS FOR CONSTRUCTING THE JOINT

Step 1. Preparation of timber

- Make a cutting list.
- Prepare the pieces to the required size.

Step 2. Marking out

- Mark the length of the pin by placing the socket piece on top of it and marking at the width. A small amount of waste can be left on the end of the pin, to be planed off after the joint is assembled.
- Make lines square at the shoulder of the pin, drawing them across the side and halfway down the edges, with a try square and pencil (Fig. 2). Mark the waste.

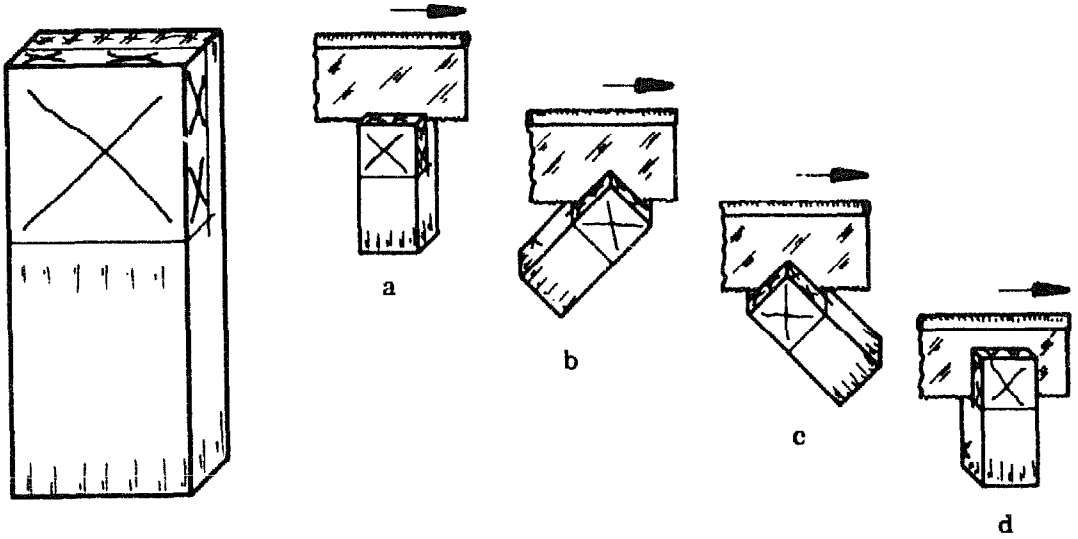

Fig. 5

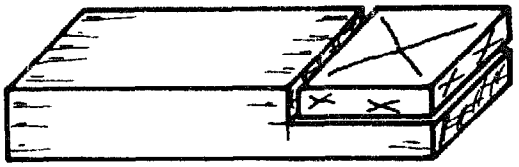

Fig. 6

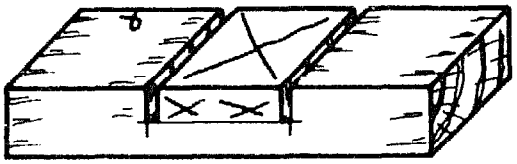

Fig. 7

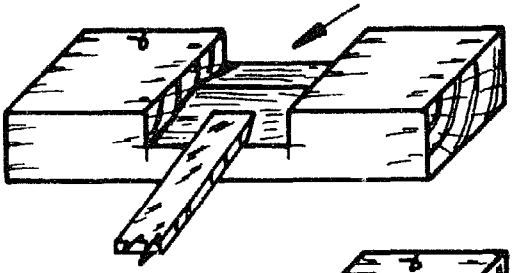

Fig. 8

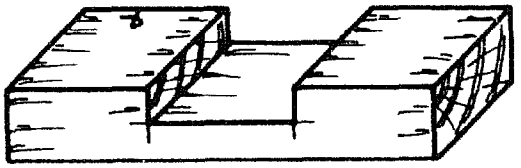

Fig. 9

N P V C		FRAMING JOINTS.
113	BASIC.	

- Mark the position of the socket, using the piece with the pin as a guide. Smooth the pin before using it to mark the socket.
- Square the lines across the side and halfway down the edges with a try square. Mark the waste (Fig. 3, previous page).
- Gauge the thickness of the pin around its edges and mark the waste (Fig. 2, previous page).
- With the same setting, gauge the depth of the socket on both edges and mark the waste (Fig. 3, previous page).
- Both pin and socket should be gauged from the face side.
- Place the pin over the position of the socket and check the fitting (Fig. 4, previous page).

Step 3. Cutting the pin

- Rip the thickness of the pin. Cut in stages as shown in Fig. 5, a through d. Take care to keep on the waste side of the line.
- Saw the shoulder of the pin, keeping on the waste side of the line (Fig. 6).

Step 4. Cutting the socket

- Saw down to the gauge lines of the socket, keeping on the waste side of the lines (Fig. 7).
- Chisel out the waste, chiselling halfway through from both edges (Figs. 8 & 9).
- Test the flatness of the socket with the blade of the try square.

Step 5. Assembling the joint

- Clean up the inside edges with a smoothing plane.
- Assemble the joint with glue and nails.
- When the joint is dry, plane off the waste of the pin.
- Clean up all sides and edges with the smoothing plane.

NOTES:

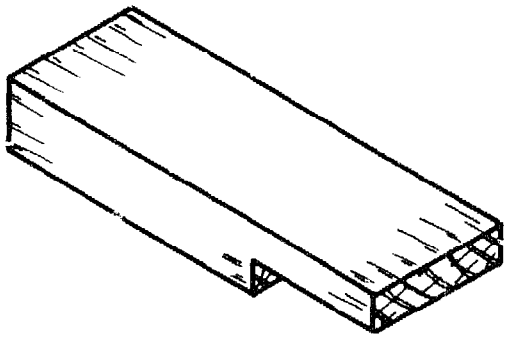

Fig. 1

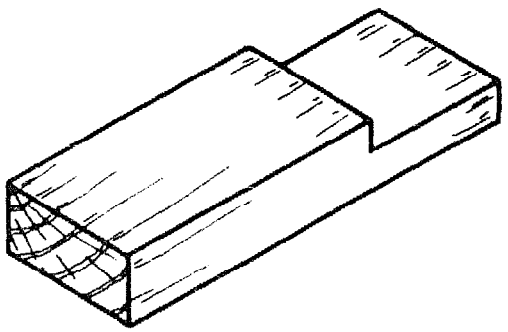

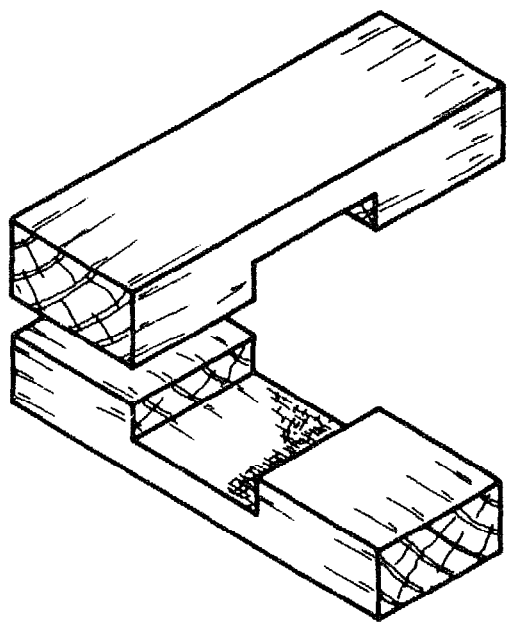

Fig. 2

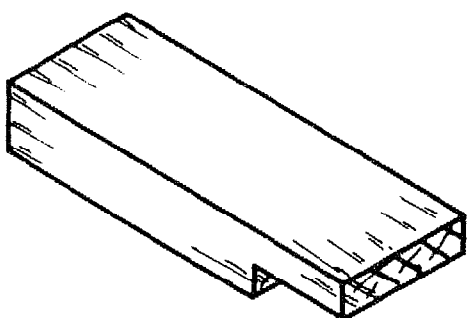

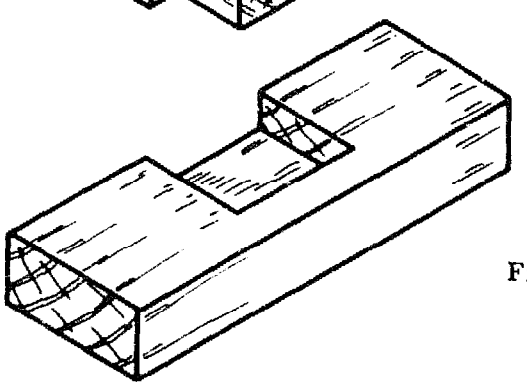

Fig. 3

N P V C	
115	BASIC.

FRAMING JOINTS.

CORNER-HALVED JOINT

Another halved joint is the corner-halved joint (Fig. 1). It is used where the pieces meet at their ends to form a corner.

The sequence of operations to construct this joint is similar to the one for the tee-halved joint, except that instead of a pin and a socket, two pins have to be marked and cut.

CROSS-HALVED JOINT

The third halved joint we deal with is the cross -halved joint (Fig. 2). It is used where two members cross each other.

The sequence of operations to construct this joint is similar to the tee-halved joint, but instead of a pin and a socket, two sockets have to be marked and cut.

STOPPED TEE-HALVED JOINT

In this joint the socket is stopped away from the edge and the pin is cut short, so that in the assembled joint the end grain of the piece is not seen (Fig. 3).

Otherwise, the same sequence is followed as for the tee-halved joint.

NOTES:

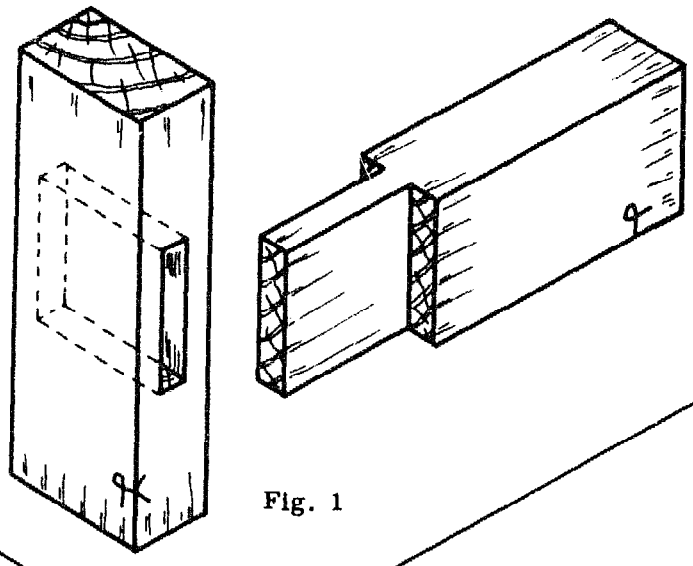

Fig. 1

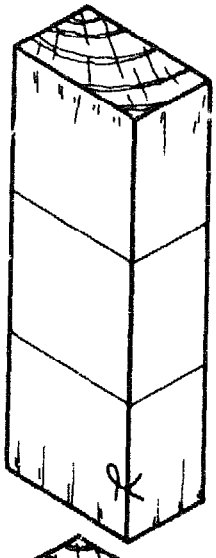

Fig. 2

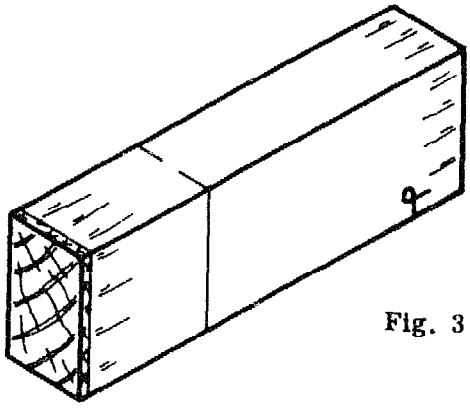

Fig. 3

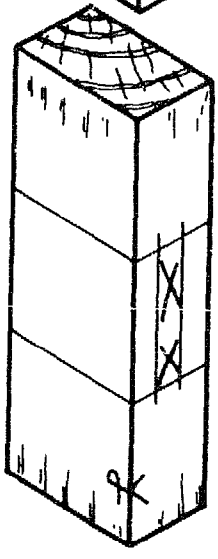

Fig. 4

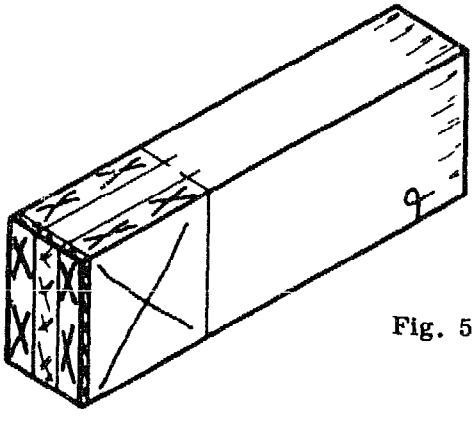

Fig. 5

N P V C	
117	BASIC.

FRAMING JOINTS.

COMMON MORTICE AND TENON JOINT FOR FRAME-LIKE CONSTRUCTIONS

One of the most common and strongest forms of framing joint is the mortice and tenon joint (Fig. 1).

The sequence of operations to construct a mortice and tenon joint for frame-like constructions is almost the same as for box-like constructions. Of the four types of mortice and tenon joints mentioned in this chapter, we will only go into detail about the construction of one of them, the common mortice and tenon. No new tools will be needed.

SEQUENCE OF OPERATIONS FOR CONSTRUCTING THE JOINT

Step 1. Preparation of timber

- Make a cutting list.
- Prepare the timber.

Step 2. Marking out

- Mark out the position of the mortice and square the lines across the face side and edges, using a try square and pencil (Fig. 2).
- Mark out the length of the tenon on the other member. Allow 3 mm waste on the end.
- Square lines all around (Fig. 3).
- Set a marking gauge to the size of the tenon (one-third of the width of the piece) and mark around the end of the tenon (Fig. 5). Mark the waste.
- Use the same setting to mark both edges of the mortice and mark the waste (Fig. 4).
- Do all marking from the face side.
- Check the marking, using the pieces as a guide by placing them over the marks (compare this sequence to the mortice and tenon for box-like constructions, page 104).

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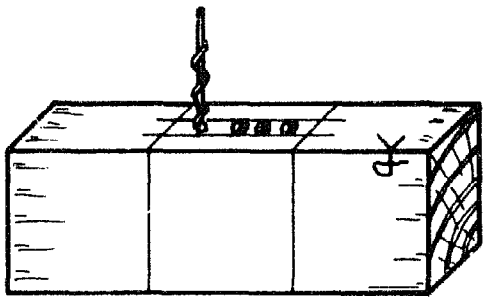

Fig. 6

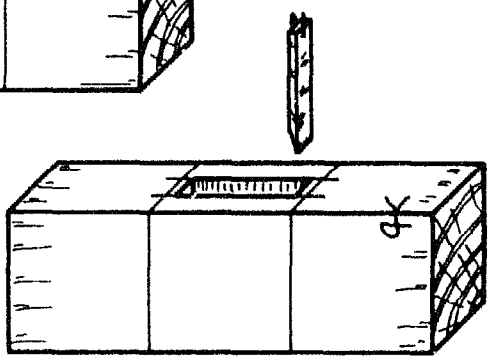

Fig. 7

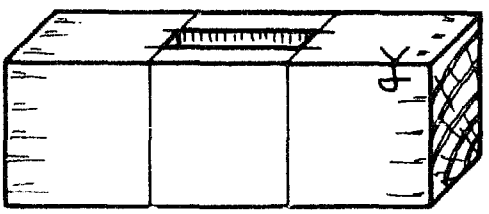

Fig. 8

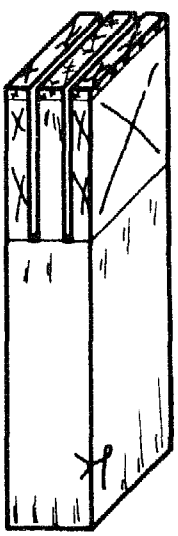

Fig. 9

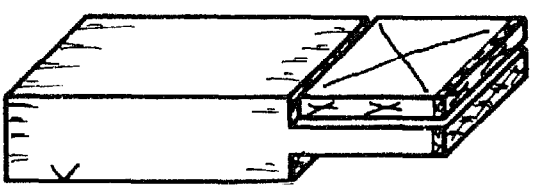

Fig. 10

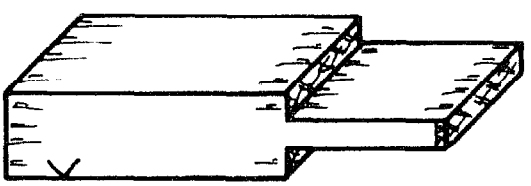

Fig. 11

N P V C	
119	BASIC.

FRAMING JOINTS.

Step 3. Cutting the mortice

- Most of the waste may be bored out (Fig. 6). Bore halfway through from both edges. Make sure you keep the brace at a 90 degree angle to the edge.
- Chop out the remaining waste, chiselling halfway through from both edges. Leave about 2 mm extra to prevent damage to the sides of the mortice during chiselling (Fig. 7).
- When most of the waste is out, chisel out the remainder to the line (Fig. 8).
- Keep the cutting edge of the chisel across the grain.

Step 4. Cutting the tenon

- Rip the sides of the tenon, sawing on the waste side of the lines (Fig. 9).
- Saw in steps (see tee-halved joint).
- Carefully saw the shoulders, keeping the saw vertical and on the waste side of the line (Fig. 10 & 11).

Step 5. Assembling the joint

- Check whether the members fit together (see Assembly section for the mortice and tenon joint for box-like constructions).
- Clean up inside the joint where it cannot be reached after assembly.
- Assemble the joint with glue.
- When it is dry, plane off the waste of the tenon.
- Clean up the edges and sides with a smoothing plane.

Note the importance of marking the waste as you mark out the pieces. This cannot be over-emphasized. Most construction mistakes are made by cutting on the wrong side of the line, due to improper marking.

NOTES:

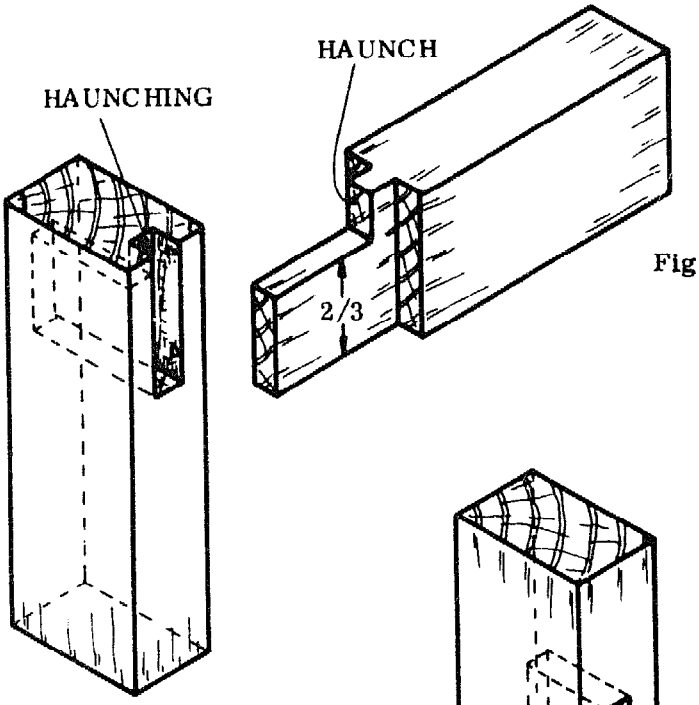

Fig. 1

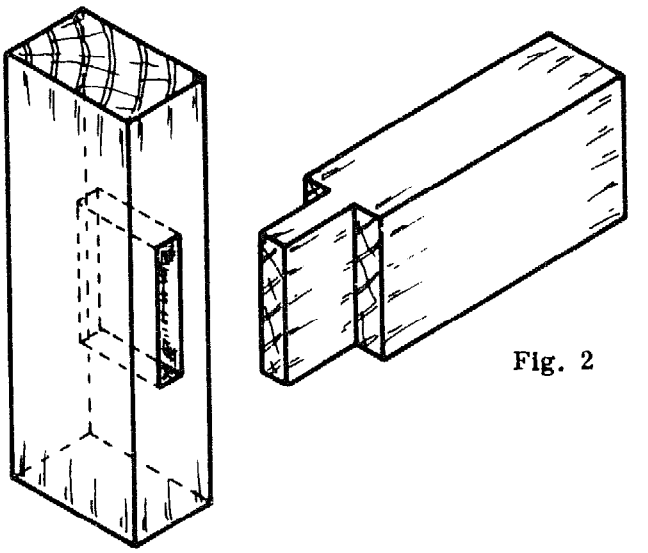

Fig. 2

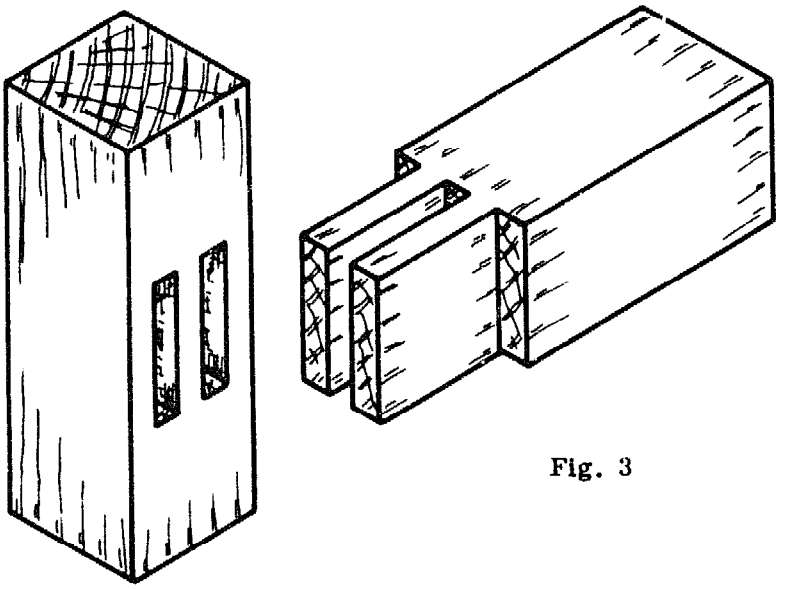

Fig. 3

N P V C		FRAMING JOINTS.
121	BASIC.	

HAUNCHED MORTICE AND TENON JOINT

Another type of mortice and tenon for frame-like constructions is the haunched mortice and tenon (Fig. 1). This joint is used where one member meets another at a corner.

The width of the tenon is reduced to 2/3rd of the width of the board and the mortice size is reduced to suit (Fig. 1).

A haunch is left on the tenon to prevent it from twisting in the mortice. The length of the haunch is equal to the thickness of the tenon and it fits into a recess above the mortice, called the haunching.

Otherwise, the sequence of operations for construction of this kind of joint is the same as for the common mortice and tenon joint.

When you make the cutting list for this type of joint, the allowance in length for the member with the mortice should be 25 mm instead of 12 mm to help prevent splitting of the haunching (see Cutting List, page 90).

STUB TENON JOINT

Where the end grain of the tenon and the opening of the mortice must be hidden, the stub tenon joint is chosen (Fig. 2). In this joint the tenon does not pass through the morticed member, but is stopped inside. The sequence of operations for constructing this joint is the same as for the common mortice and tenon joint. Stub tenons are also used for box-like constructions.

At times a combination of the haunched and stub tenons is required. This is called a haunched stub mortice and tenon joint.

TWIN TENON JOINT

Where the members to be joined are very thick, twin tenons are used (Fig. 3). Each tenon is then not 1/3rd, but 1/5th of the thickness of the members.

The sequence of operations is almost the same as for the common mortice and tenon joint, with the only difference being that two mortices and tenons have to be marked and cut instead of only one.

This joint can be used for both frame-like and box-like constructions.

NOTES:

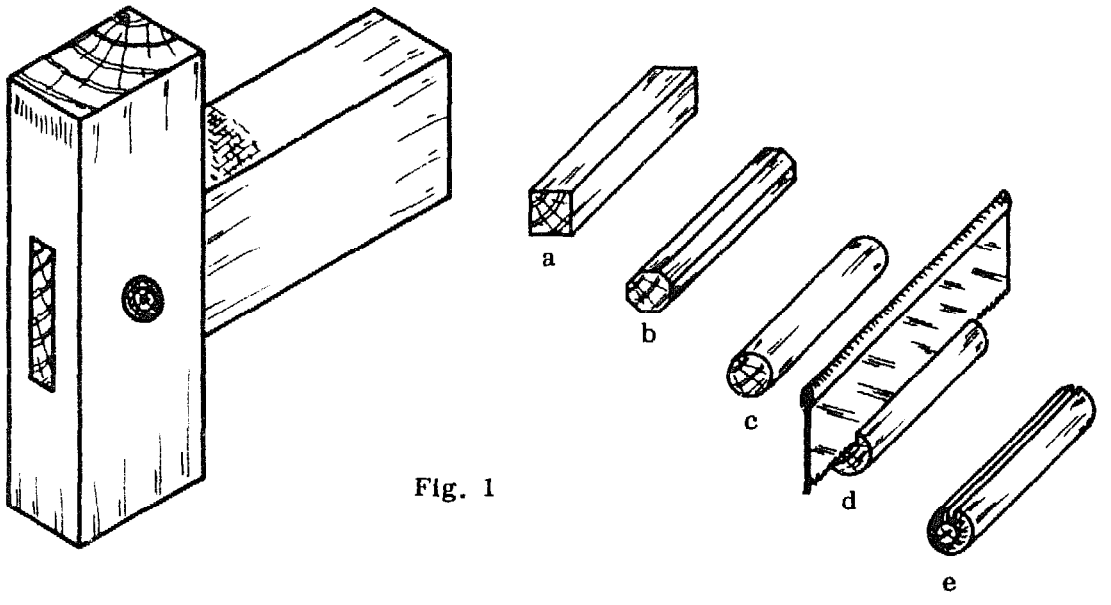

Fig. 1

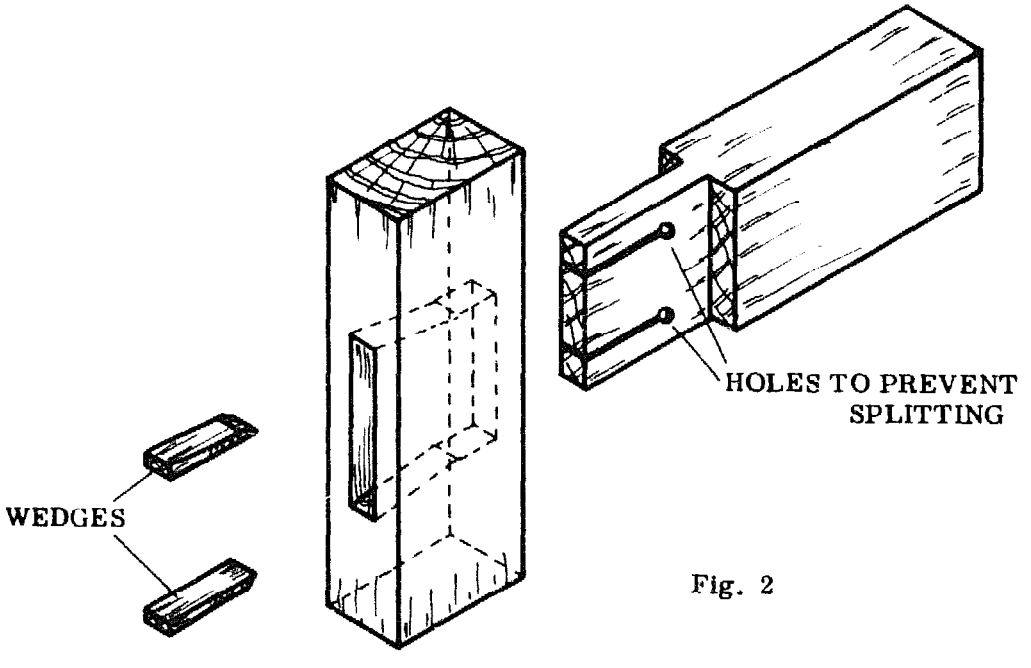

Fig. 2

NOTES:

N P V C	
123	BASIC.

FRAMING JOINTS.

SECURING THE JOINTS

Instead of nails to secure mortice and tenon joints, either pegs or wedges can be used.

One or two holes are drilled through the assembled joint and wooden dowels, or pegs, as they are called in this case, are inserted with glue to securely fix the joint (Fig. 1).

- To make the dowels, plane off the corners of a square piece of hard wood, until the piece is round. When the dowel is cut to length, chamfer the ends and cut a groove along the length to permit air and excess glue to escape (Fig. 1, a - e).

Follow the steps below to secure a joint by means of wedges.

- Cut the mortice with an allowance of 2 mm in width, tapering from the outside edge to about 2/3rd of its depth (Fig. 2).
- Make cuts in the tenon to receive the wedges.
- To prevent splitting of the tenon, drill small holes at the end of each cut.
- Cut the wedges from small pieces of waste wood; they should have the same length as the tenon.

Haunched mortice and tenon joints in frame-like constructions should not be wedged, because of the danger of breaking off the small haunch at the corner of the joint.

Both wedges and pegs can be used for securing mortice and tenon joints in box-like constructions.

NOTES:

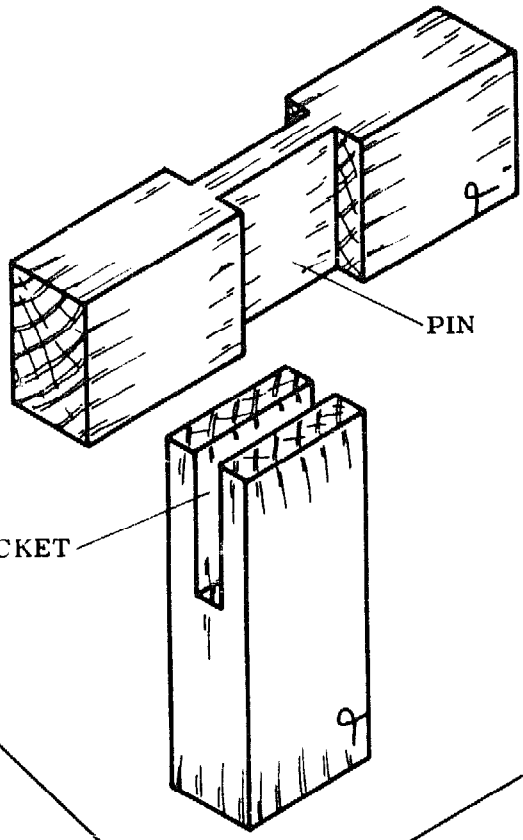

Fig. 1

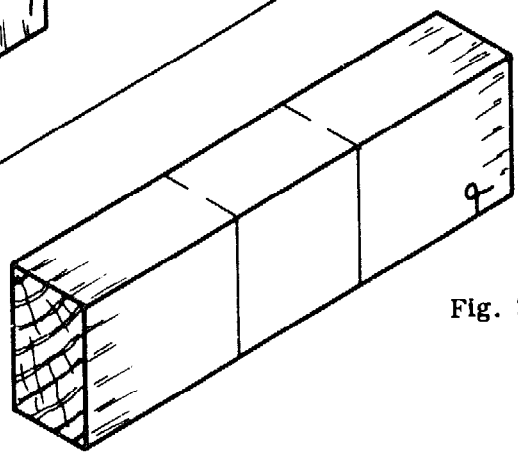

Fig. 2

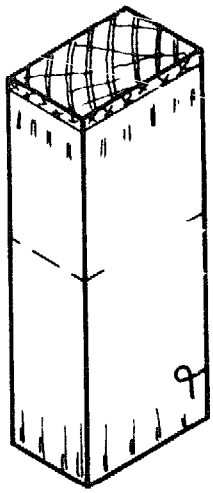

Fig. 3

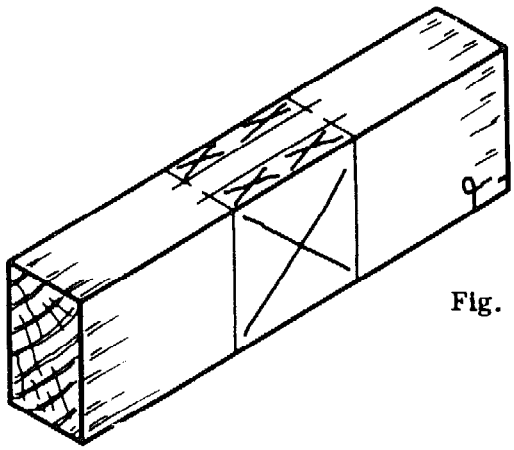

Fig. 4

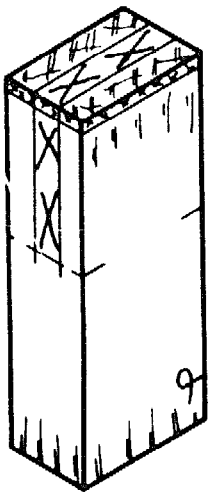

Fig. 5

N P V C	
125	BASIC.

FRAMING JOINTS.

BRIDLE JOINT

Bridle joints are similar to mortice and tenon joints. They consist of a pin and a socket (Fig. 1). The thickness of the pin is 1/3rd of the thickness of the member. The two types of bridle joint are the tee bridle (Fig. 1) and the corner bridle. Here we will only go into detail about the tee bridle, since the construction of the corner bridle joint follows much the same procedure.

SEQUENCE OF OPERATIONS FOR CONSTRUCTING THE JOINT

Step 1. Preparation of the timber

- Make a cutting list.
- Prepare the timber.

Step 2. Marking out

- Mark the position of the pin on one member, making the distance between the shoulders equal to the width of the other piece. Square the lines all around the piece with a try square and pencil (Fig. 2).
- Mark the length of the socket (plus 2 mm waste) on the end of the other member, making the length equal to the width of the pin. Square the lines across the face side and on both edges (Fig. 3). Remember to smooth the pieces before using them to mark.
- Set a marking gauge to 1/3rd of the thickness of the member and gauge along both edges of the pin. Use the gauge from the face side only. Mark the waste with small crosses (Fig. 4).
- With the same setting on the gauge, mark around the end of the socket. Mark the waste (Fig. 5).
- Mark the other side of the socket in the same manner, from the face side, with the gauge set at 2/3rds of the thickness of the piece. If you have a gauge with 2 pins, mark both lines at once.
- Check the fitting.

NOTES:

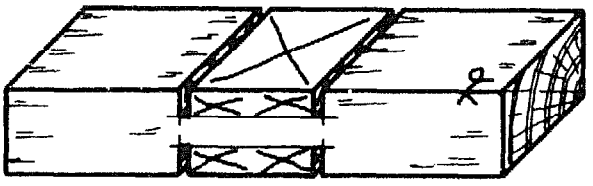

Fig. 6

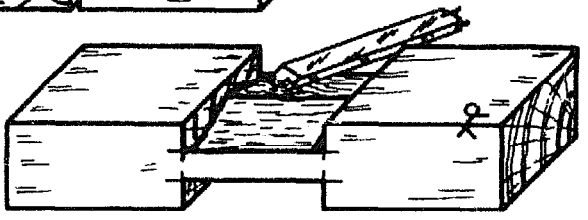

Fig. 7

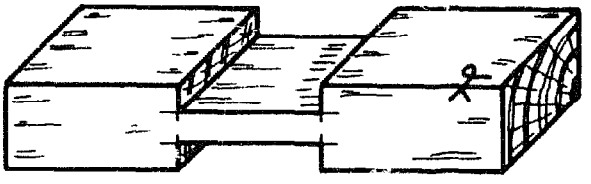

Fig. 8

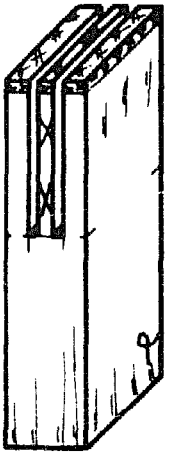

Fig. 9

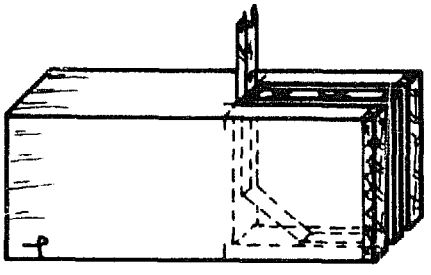

Fig. 10

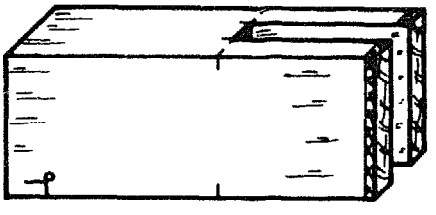

Fig. 11

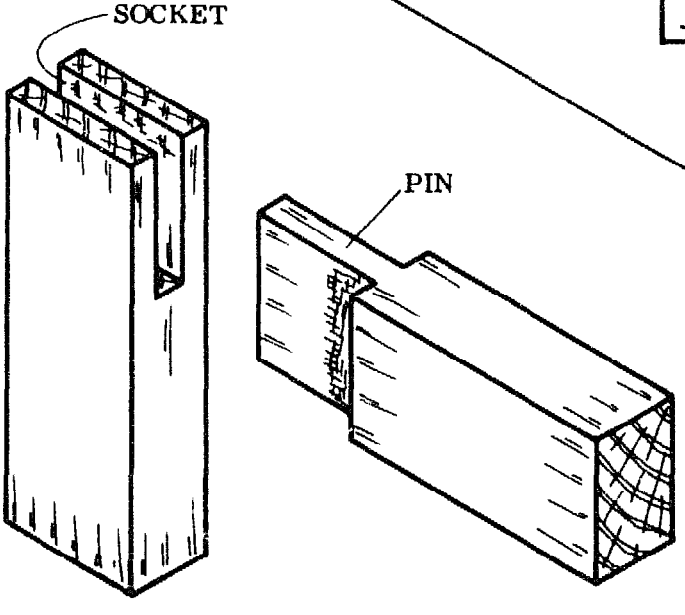

Fig. 12

N P V C		FRAMING JOINTS.
127	BASIC.	

Step 3. Cutting the pin

- Carefully saw the shoulders down to the gauge line, sawing on the waste side of the line (Fig. 6).
- Chisel away the waste, chiselling halfway through from both edges (Fig. 7).

Step 4. Cutting the socket

- Rip the sides of the socket down to the required depth, sawing on the waste side of the lines (Fig. 9). Saw in steps (see Tee-halved joint, Cutting the pin, page 114).
- Chop out the waste with a mortice chisel, chiselling halfway through from both edges (Figs. 10 & 11).

Step 5. Assembling the joint

- Clean up the inside edges which cannot be reached after the joint is assembled.
- Assemble the joint with glue and nails.
- When the glue is dry, plane off the waste of the socket.
- Clean up the sides and edges with a smoothing plane.

CORNER BRIDLE JOINT

The corner bridle joint is used where members meet to form the corner of a frame. Like the tee bridle, it consists of a pin and a socket (Fig. 12).

The pin is constructed like the tenon in the sequence of operations for the mortice and tenon joint for frame-like constructions, pages 118 to 120.

The socket is constructed in the same way as the socket for the tee bridle joint, above.

NOTES:

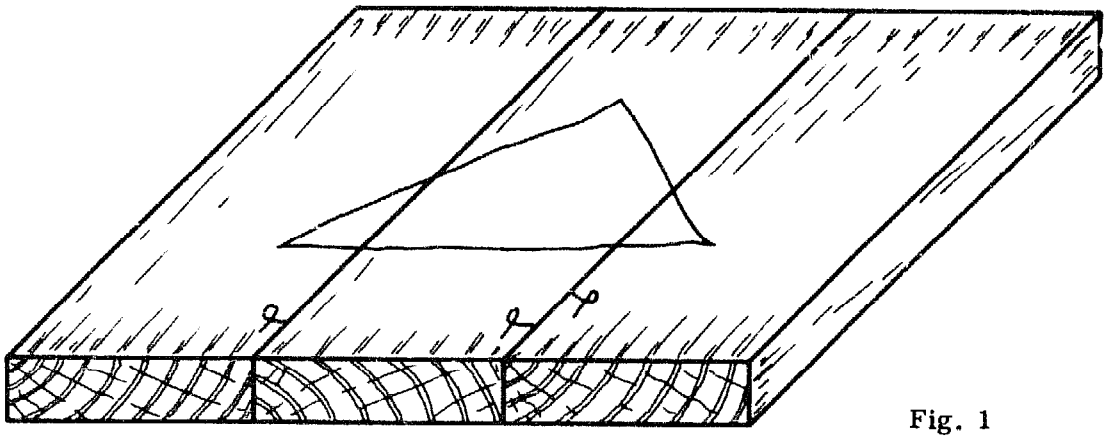

Fig. 1

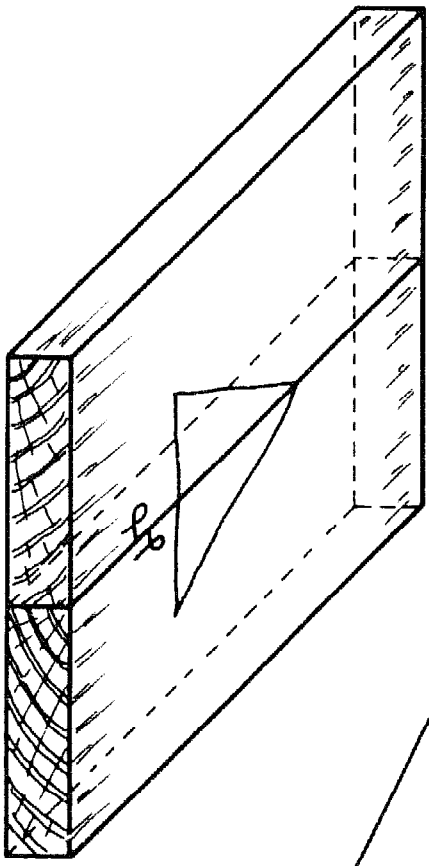

Fig. 2

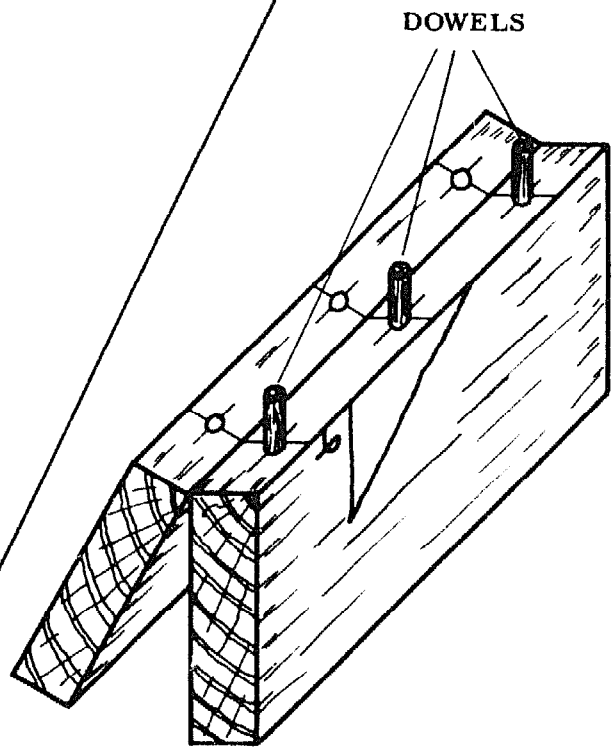

Fig. 3

N P V C	
129	BASIC.

WIDENING JOINTS.

WIDENING JOINTS

Widening joints are joints used to make a single, wide board by joining two or more narrow boards along their length, edge to edge (Fig. 1).

The boards that will be joined must first be marked. Lay the boards out in the desired position and mark them with a triangular mark over all the boards (Fig. 1). The triangle should point upwards. This mark will help us to keep in mind the position of each board during the steps that follow.

PLAIN GLUED BUTT JOINT

This is the simplest widening joint (Fig. 2). The edges of the boards are planed perfectly straight and square, and then butted together. The joint is glued and clamped tightly to force out the surplus glue. For narrow pieces this is done with G-clamps. For wider pieces, wooden or metal sash clamps are used.

DOWELLED WIDENING JOINT

This joint is similar to the plain glued butt joint, but strength is added by means of cylindrical wooden pins, called dowels. Dowels are made as explained in the section on securing joints. The dowels are then glued into holes in the edge of each board (Fig. 3). The diameter of the dowels should be about one-third of the thickness of the pieces that are being joined.

The holes should be about as deep as the boards are thick, and they should be slightly countersunk (see Fastening with Screws, page 96).

Mark out the position of the dowels by putting the boards on top of each other, sides together and marking both edges at the same time. The centre can be marked with a marking gauge, marking from the face side.

Metal or wooden sash clamps are used to press the boards together during glueing.

NOTES:

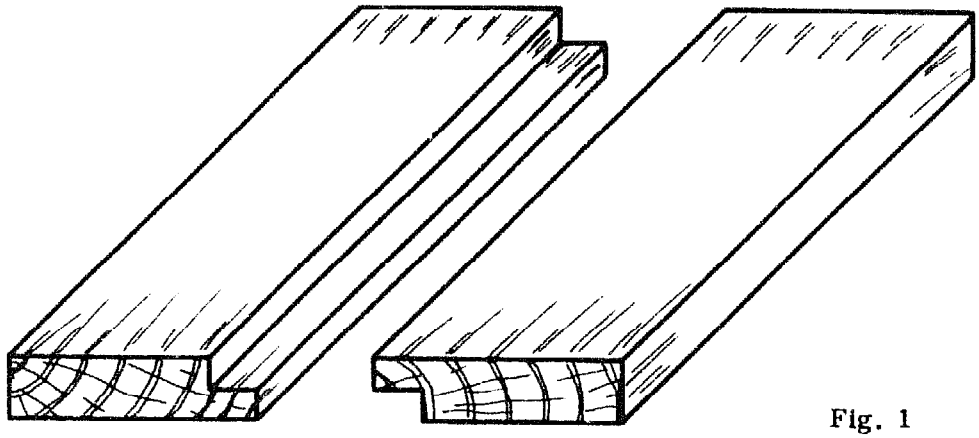

Fig. 1

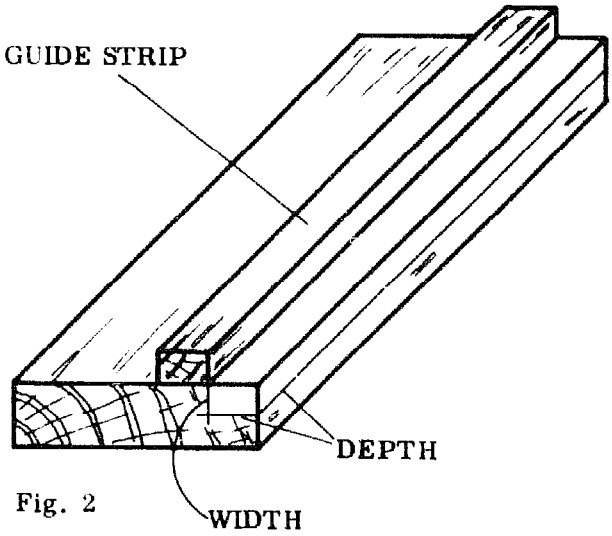

Fig. 2

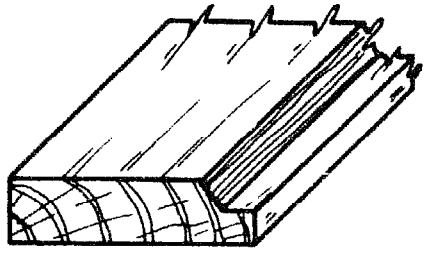

Fig. 3

NOTES:

N P V C		WIDENING JOINTS.
131	BASIC.	

REBATED JOINT

In this widening joint, the edges of the boards are rebated to match each other (Fig. 1). The rebating is done with either an ordinary rebate plane or an adjustable one. This joint is stronger than the plain glued butt joint.

HOW TO PLANE A REBATE WITH AN ORDINARY REBATE PLANE

Step 1.

- Mark the depth and width of the rebate with a marking gauge (Fig. 2).

Step 2.

- Fix a wooden guide strip along the line that marks the width of the rebate (Fig. 2). The guide strip must be perfectly square and it should lie flat.

Step 3.

- Plane until you reach the line marking the depth of the rebate. Take care that the side of the plane is always against the guide strip, so that the width of the rebate is the same along the whole length.
- If you notice that you are planing against the grain, stop just before you reach the required depth and plane from the other direction. This will ensure that the surface of the rebate is smooth.

An important point in planing rebates is setting the plane correctly. The side of the cutting iron that faces the rebate must be set so it is exactly flush with or only slightly coming out at the side of the plane. If it projects too far it will damage the guide strip, and if it is set in from the side it will not plane true (Fig. 3).

When you set the cutting iron, do not knock on it with a steel hammer. This will damage the iron. Rather, loosen the wedge slightly and knock it with a mallet or a piece of wood.

When the rebate plane is not set well, it will tend to slip off the rebate and will not produce a good surface.

NOTES:

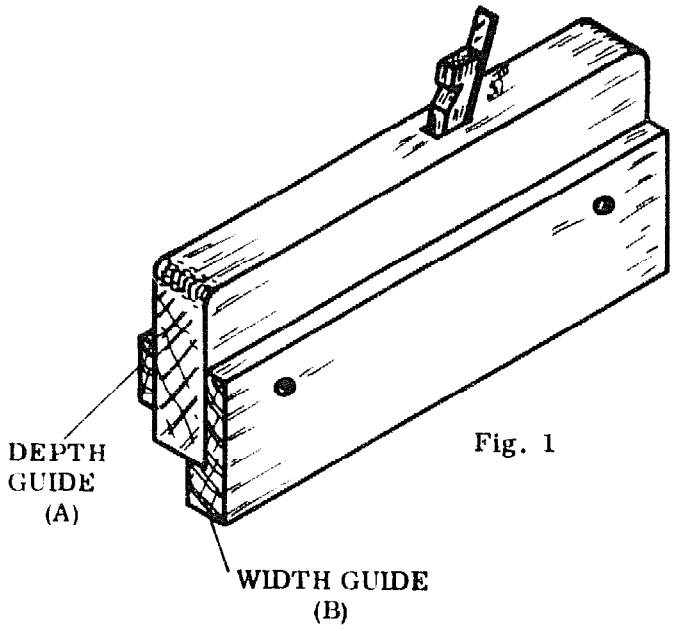

Fig. 1

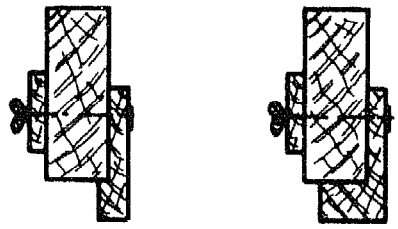

Fig. 2

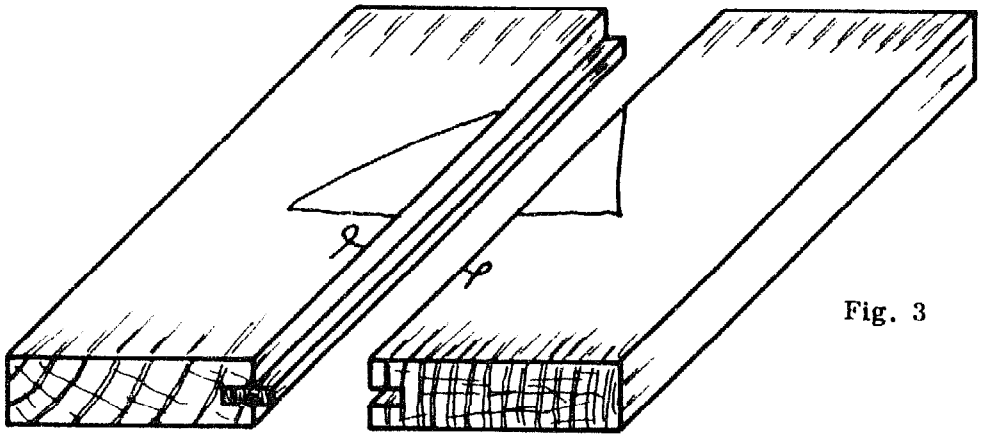

Fig. 3

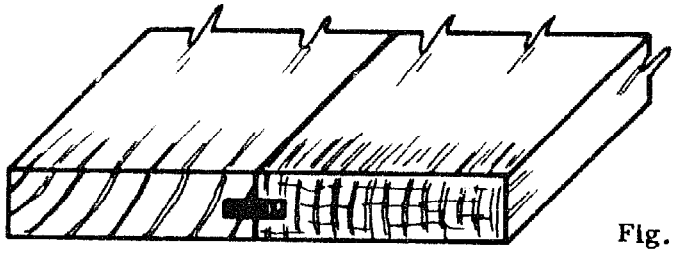

Fig. 4

N P V C		WIDENING JOINTS.
133	BASIC.	

HOW TO PLANE A REBATE WITH AN ADJUSTABLE REBATE PLANE

To make work simpler, we can fix guides onto the rebate plane itself. Thus, fixing guide strips on the boards is unnecessary (Fig. 1).

One wooden piece is fixed on the sole of the plane (B) at the standard width for rebates and another piece is fixed on the side of the plane (A) and can be moved up or down to adjust the depth of the rebate. The width can also be adjusted, by using a wider or narrower wood guide (Fig. 2).

The guides should not be nailed to the plane, since that would damage it. They should be fixed by bolts and nuts, so that they can be easily removed.

Plane until the depth guide just touches the work. Take care that the width guide is always firmly pressed to the side of the timber. If you notice that you are planing against the grain, stop just before you reach the required depth and finish planing with the guide strips removed, which enables you to plane in the other direction. This gives a good surface to the rebate.

See the section on the ordinary rebate plane for tips on how to set the cutting iron.

LOOSE TONGUED JOINT

This joint is used where a joint stronger than the plain glued or rebated joint is needed. The boards to be joined must be at least 2 cm thick (Fig. 3).

The joining edges are grooved and a tongue is glued into the grooves. The depth of the groove is about 2/3rd of the thickness of the board. The width of the groove is equal to the thickness of the tongue. The groove should be slightly deeper than the projection of the tongue, to allow for expansion (Fig. 4).

Plywood makes a very strong tongue and it is frequently used for this purpose.

If solid wood is used as a tongue, care must be taken that it is always cut across the grain. A tongue cut with the grain will make a weak joint.

NOTES:

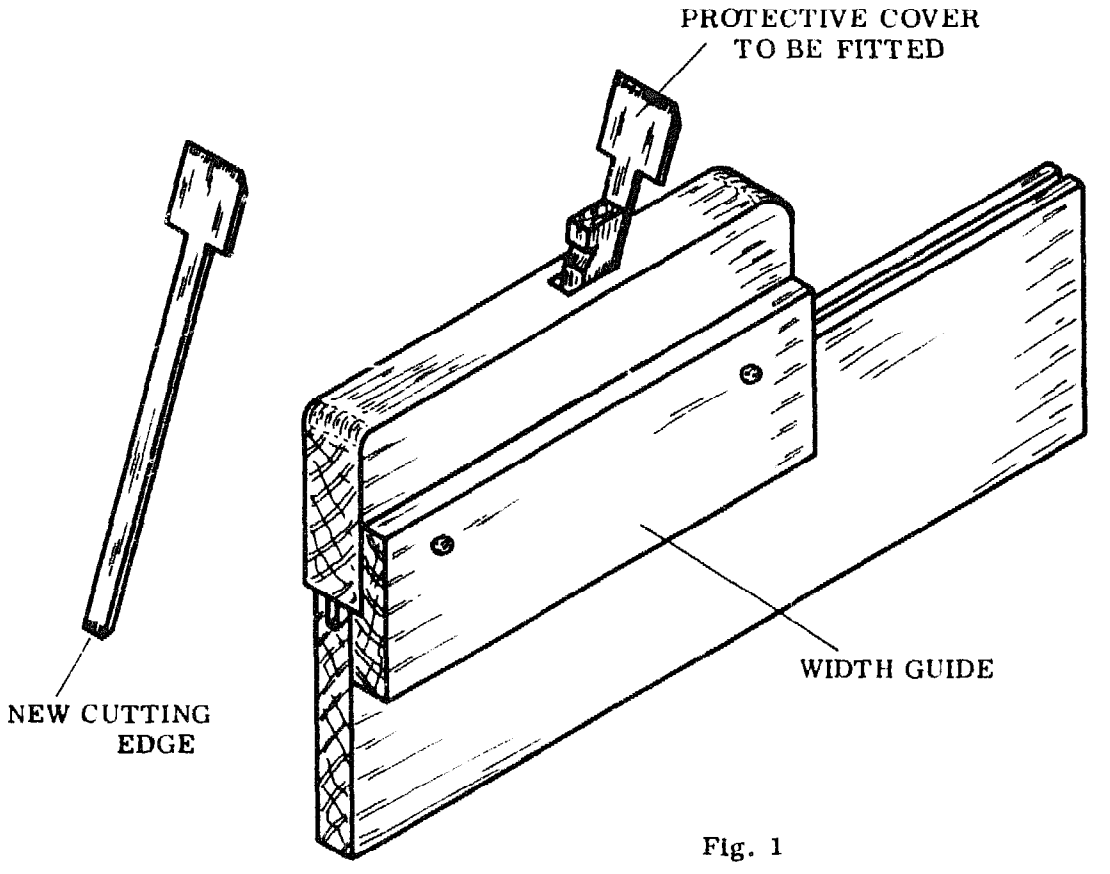

Fig. 1

NOTES:

N P V C		WIDENING JOINTS.
135	BASIC.	

HOW TO PLANE A GROOVE FOR A LOOSE TONGUED JOINT

Usually special planes called plough planes are used to plane grooves for this kind of joint. If a plough plane is not available, we can adapt our rebate plane for this purpose and make an improvised plough plane (Fig. 1).

To do this, grind and sharpen the narrow end of the rebate plane cutting iron to make a cutting edge. Grind the sides of the iron to the size of the most commonly used tongue, which is 6 mm plywood. The sides should be slightly bevelled to ensure free movement in the groove.

When the iron is fitted into the plane it is adjusted so that the cutting edge projects out of the sole by exactly the required depth of the groove.

A guide, similar to the one used for the adjustable rebate plane, is now fitted to the side of the plane. This guide keeps the cutting iron at the right distance from the face side of the boards. It should be adjusted according to the most common thickness of the boards, in this case it is about 22 mm for a planed board. For a tongue size of 6 mm then, the distance between the edge of the guide and the edge of the cutting iron will be 8 mm.

When planing press the guide firmly against the side of the wood and hold the plane exactly at a right angle to the edge of the board.

The most difficult part will be to start the groove, since the cutting iron will tend to slip off the edge and it requires some experience to keep it steady. Go slowly at first.

Work from the face side at all times.

To prevent injuries cover the cutting edge where it sticks out of the top of the plane.

NOTES:

Fig. 1

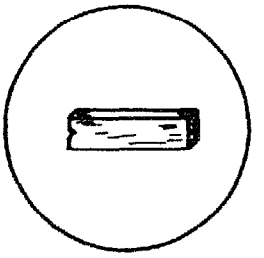

Fig. 1a

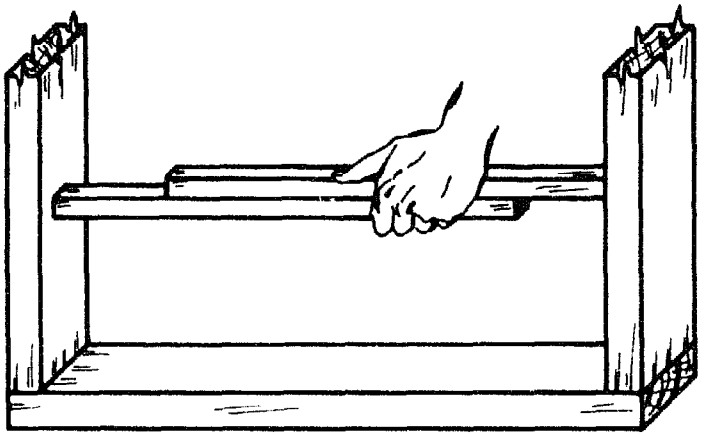

Fig. 2

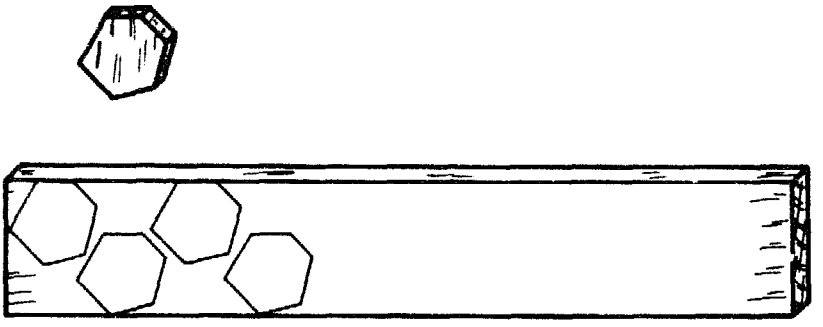

Fig. 3

N P V C	
137	BASIC.

MISCELLANEOUS CARPENTRY TECHNIQUES.

MISCELLANEOUS CARPENTRY TECHNIQUES

MARKING A BOARD TO FIT AN IRREGULAR SURFACE

To mark the edge of a board which you want to fit against an irregular surface such as an unplastered wall, hold the board firmly and level to the wall and mark it with a compass or a similar device as shown in Fig. 1.

As one leg of the compass moves along the wall, the other leg will mark on the board an exact copy of the irregularities of the wall surface. The legs of the compass have to be set apart by a distance a little greater than the width of the biggest gap between the wall and the board.

If no compass is available, a small wooden block can be used instead (Fig. 1a). The pencil is held in the notch at one end and the other end is moved along the surface of the wall.

MEASURING THE WIDTH OF OPENINGS

A convenient way to measure the width of openings such as doors and windows is to use two sticks as shown in the illustration (Fig. 2) to just span the opening. Then transfer the measurement to a single board by marking and measure it with a rule.

MARKING OUT IRREGULAR DESIGNS WITH TEMPLATES

When you want to mark out several pieces with the same irregular shape, you can save time and ensure more accurate work by marking from a template (Fig. 3). Templates are thin pieces of cardboard or plywood onto which the required pattern is drawn and then cut out.

The template is used by placing it on the material to be marked and holding it firmly in place while drawing around it.

NOTES:

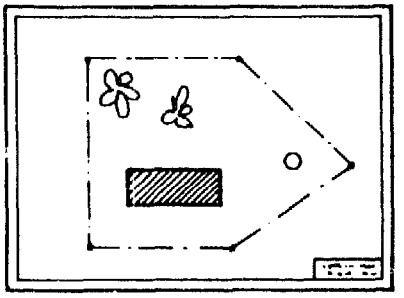

Fig. 1

LOCATION PLAN

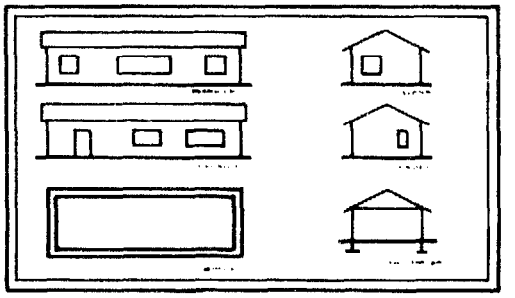

Fig. 2

BUILDING PLAN

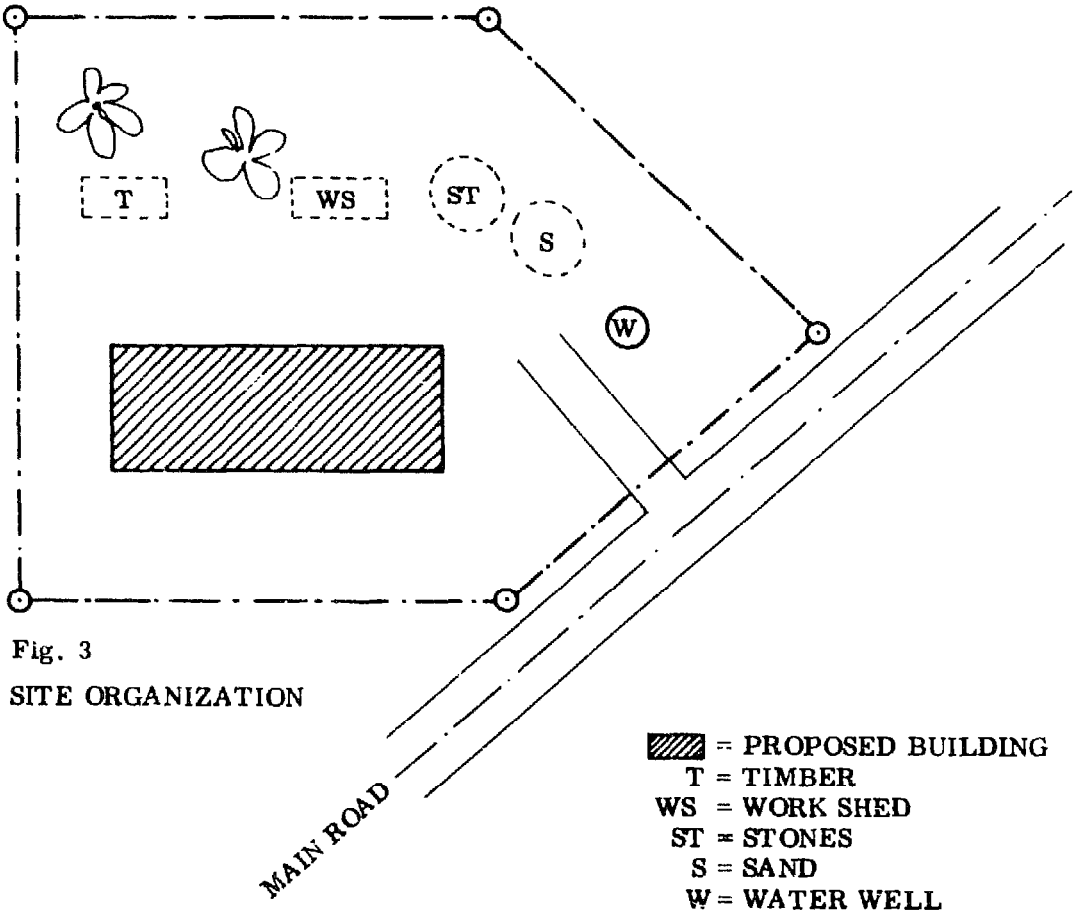

Fig. 3

SITE ORGANIZATION

= PROPOSED BUILDING
T = TIMBER
WS = WORK SHED
ST = STONES
S = SAND
W = WATER WELL

N P V C	PART 3: PREPARATION FOR ON-THE-JOB TRAINING. BUILDING PRELIMINARIES.
139 JOB.	

PART 3: PREPARATION FOR ON-THE-JOB TRAINING

BUILDING PRELIMINARIES

Before anyone can actually start to erect a building, a number of preliminary steps must be completed. The very first step is the preparation of the plan.

PLAN

The plan, also called the drawing, is a layout of a building drawn on paper. It contains all the information necessary to erect the house (see Drawing Book, page 55). The data and measurements given in the plan are essential for the builder to be able to construct the building so that it satisfies the customer's demands (Figs. 1 & 2).

PLOT AND SITE CLEARING

A plot is an area of land containing one or more sites. It is determined and limited by boundaries (Fig. 1).

The site is that area of land within the plot which is actually used for construction.

With the location plan in hand, the builder can prepare both plot and site for the construction of the building. The location plan tells him exactly where the trees and bushes have to be removed so that they don't interfere with the work. This preparation includes making a drive, cutting the grass, and levelling the surface of the ground.

The builder must pay special attention to the roots of trees which are on the site or very close to it. These must be completely removed. If some roots, such as those of the neem tree, remain in the ground, they can grow again and damage the structure.

SITE ORGANIZATION

When the land clearing is completed, the building materials can be brought in to the building site.

Temporary work-sheds and stores may be erected in suitable places (Fig. 3).

The builder must ensure that there is an adequate supply of clean water. Without water no building can be constructed.

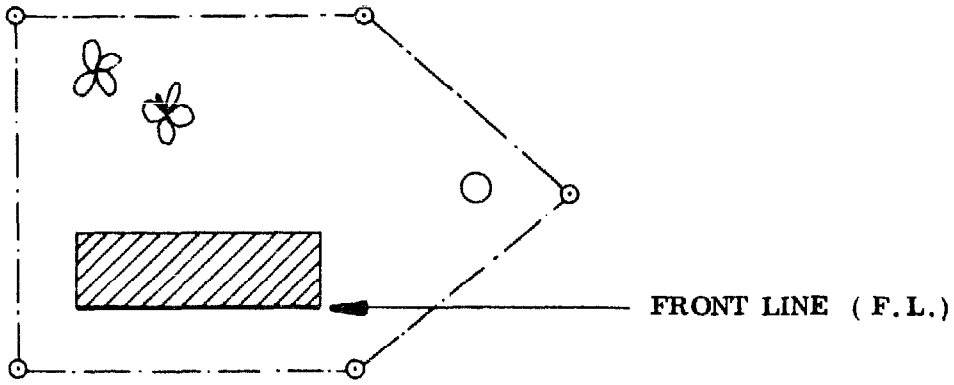

Fig. 1
LOCATION PLAN

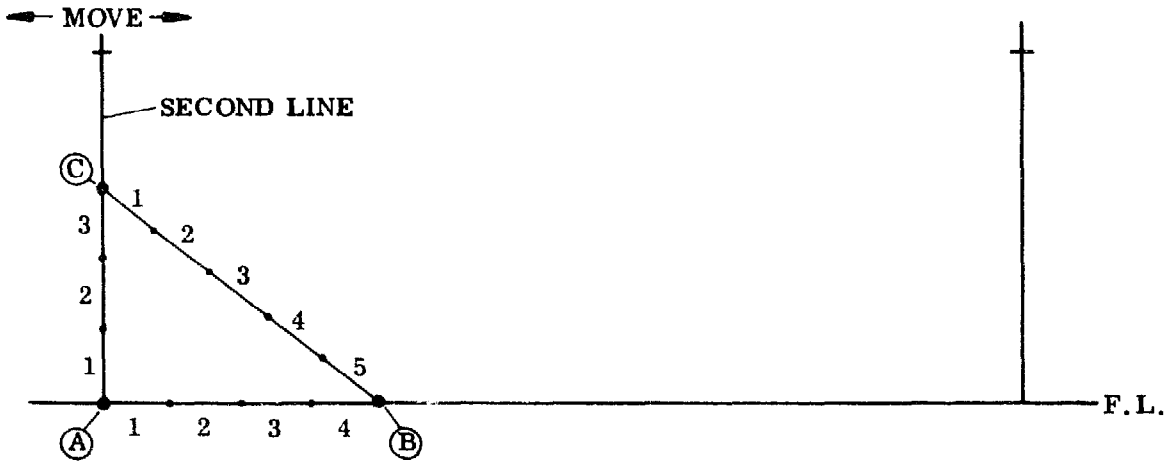

Fig. 2 3-4-5 METHOD

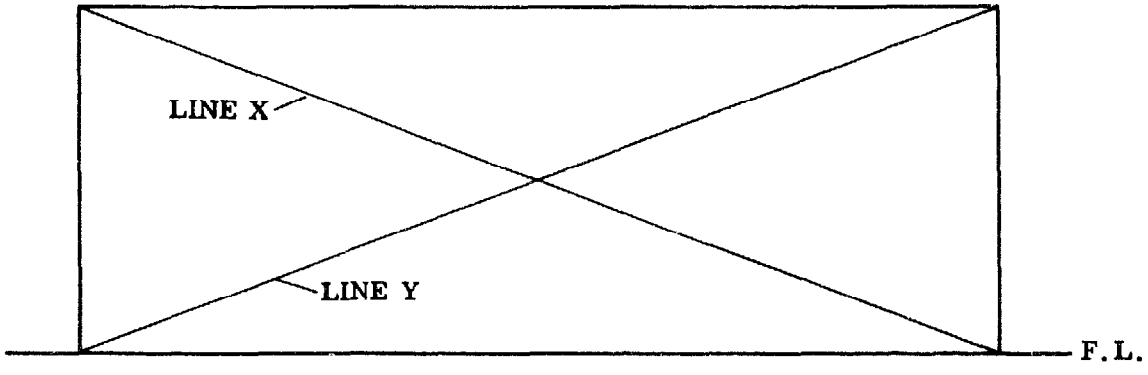

Fig. 3 LINES X AND Y ARE EQUAL IN LENGTH

N P V C		SETTING OUT.
141	JOB.	

SETTING OUT

At the beginning of any construction activity the work must be carefully set out. This is also known as pegging out or lining out.

Setting out means to put pegs in the ground to mark out an excavation; or to mark on the floors to locate walls.

3 - 4 - 5 METHOD

The first line to be set out is the front line of the carcass (Fig. 1). A "carcass" is the building when it is structurally complete but otherwise unfinished. In this case we mean that the front line marks the position of the outside face of the (future) unplastered wall. The lines of all the other walls are measured from this front line. If the building is rectangular, right angles are set off from the front line by using the 3-4-5 method.

The second line to be set out is the line of one of the side walls of the carcass. This line intersects the front line at the corner of the future building. To make sure that this corner is a right angle, we use the 3-4-5 method.

- Measure a distance of 4 m along the front line starting from point A, and mark this on the line (point B) (Fig. 2).
- Measure a distance of 3 m along the second line, starting from the corner (point A) and mark this distance (point C).
- Now take a line which is marked with a distance of 5 m, and stretch it taut from point B towards the line with point C. Keeping the end points of both lines steady (points A & B) and the lines taut; move the free ends of the side line and the 5 m line until the 5 m mark and the mark at point C meet each other. This is best done with two men, one at the end of each line.
- The corner angle must now be a right angle.
- Measure the required length of the side line and insert a peg at the end. Set out the opposite side line in the same way.

If the setting out has been done accurately, the length of the back line between the two pegs should be equal to that of the front line. Make a further check by measuring the diagonals, which must be equal (Fig. 3).

NOTES:

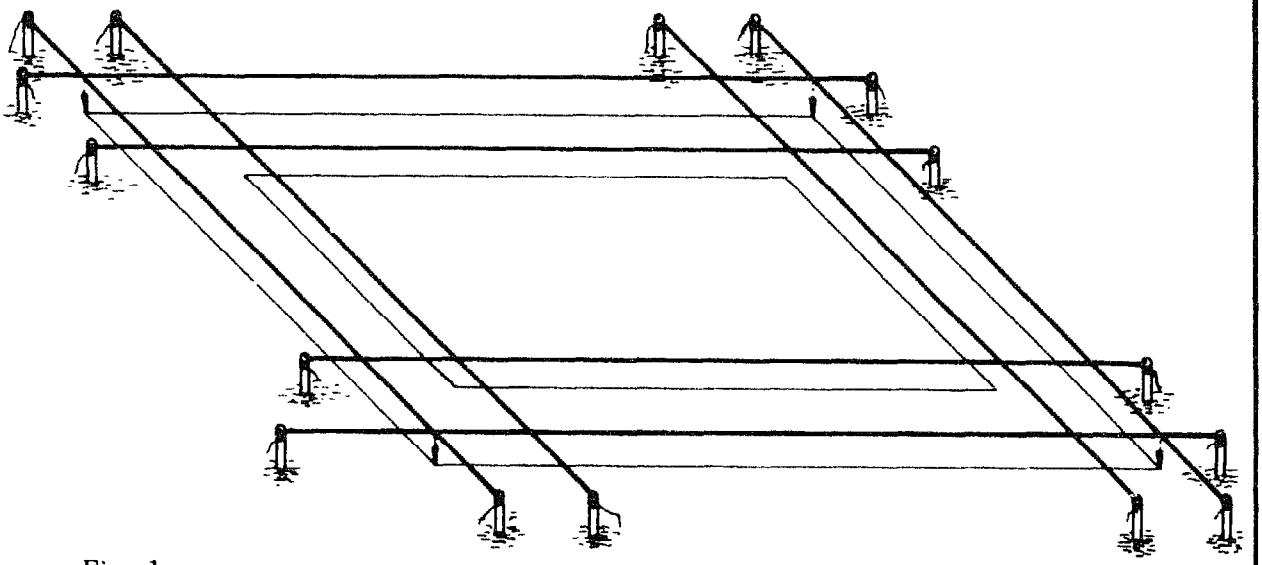

Fig. 1

SETTING OUT THE LINES & MARKING THE GROUND

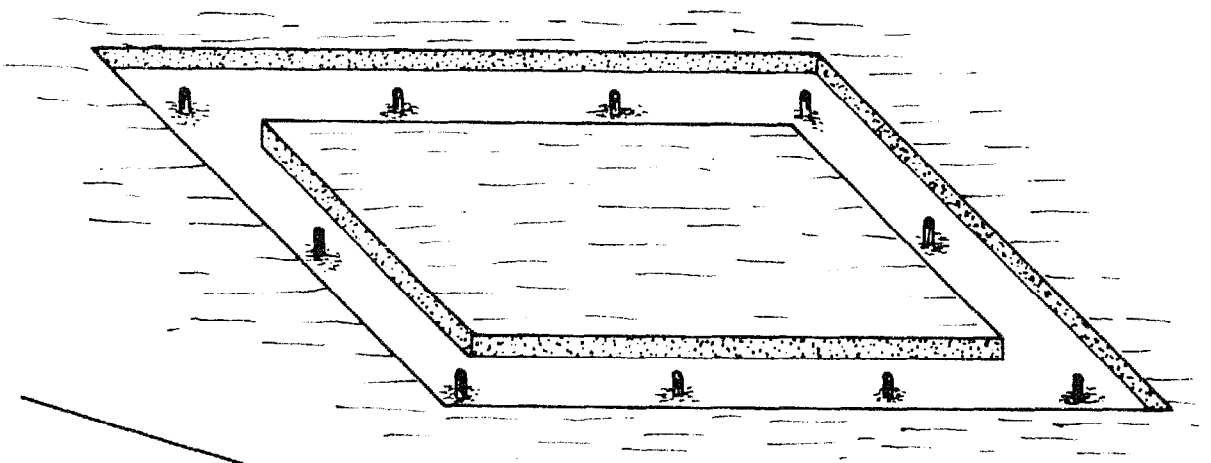

Fig. 2

PEGGING OFF THE FOUNDATION DEPTH

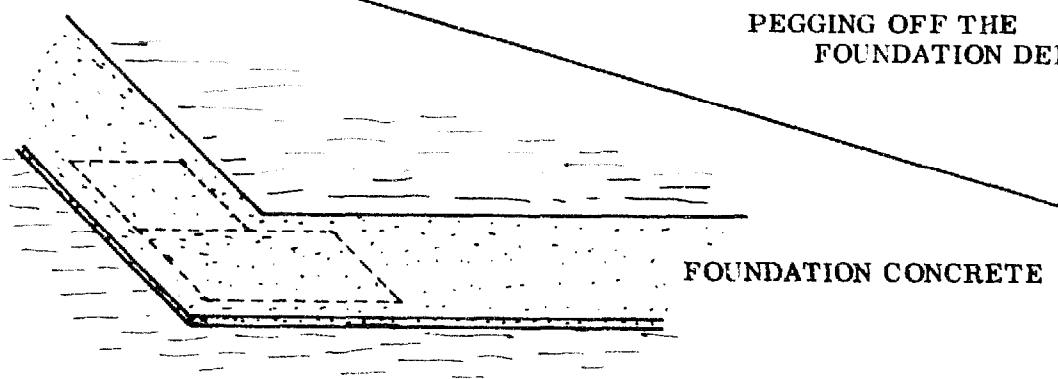

Fig. 3 SETTING OUT THE FOOTINGS (ENLARGED DETAIL)

N P V C		SETTING OUT.
143	JOB.	

LINING OUT

Once the positions of the corners and the distances between them are determined, the positions of the foundations, footings and walls as well as their thickness must be marked. A simple example of setting out and marking a foundation is shown in Fig. 1. The more complicated and permanent methods will be treated later.

These marks will be needed until the plinth course is completed, so they must be relatively durable, so that they remain accurate for a longer period and are not destroyed by rain or other influences.

DIRECT MARKING

Small buildings or small extensions of houses may be marked directly on the flat ground, provided that the excavation work can proceed immediately and can be quickly completed, so that the marking need not be repeated (Fig. 1).

In this procedure, the setting out must be done in stages.

- Mark the position and width of the foundation directly on the ground, and dig the trenches immediately.
- The next step is to level the bottom of the trenches and to peg off the foundation depth (Fig. 2).
- After the foundation concrete is cast and set hard, set out the footings directly on the surface of the foundation (Fig. 3) and build them to the required height.
- When the footings and hardcore filling are complete, set out the plinth course on the footings.
- NOTE: The information given in this section and in most of the following sections is not intended to be a detailed explanation. It is simply meant to give you, the trainee, an idea of the operations you can expect to encounter in your on-the-job training. Lining out, marking, etc. will be covered in detail in the Construction Book.

NOTES:

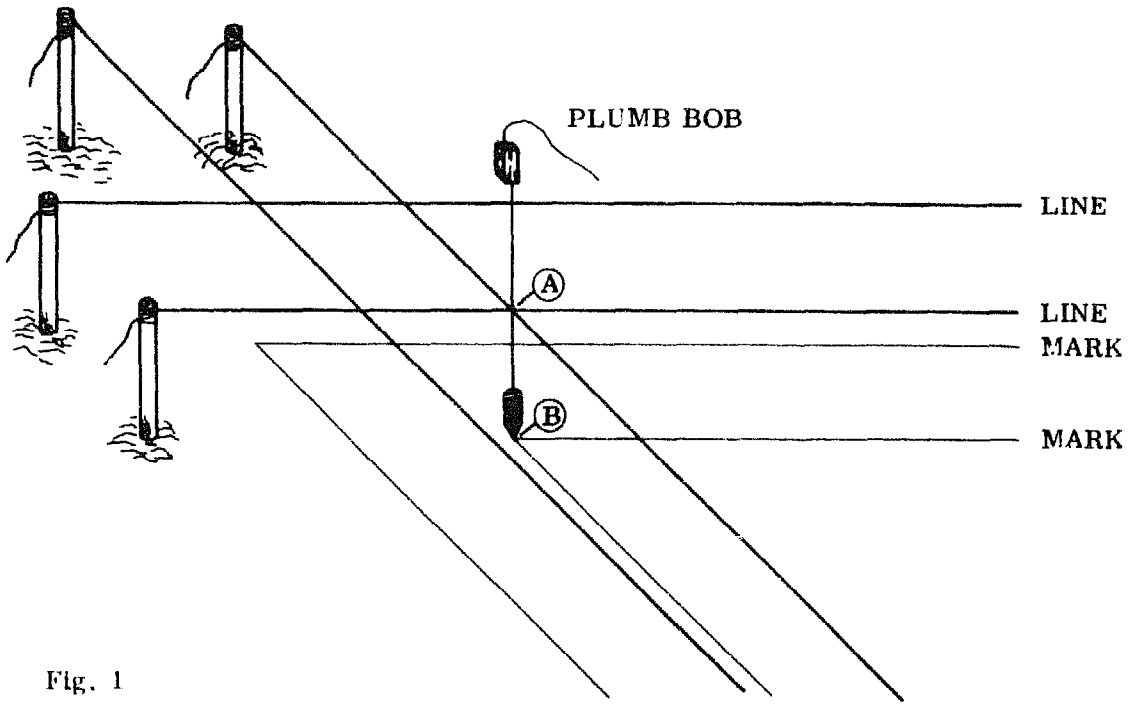

Fig. 1

USING THE PLUMB BOB

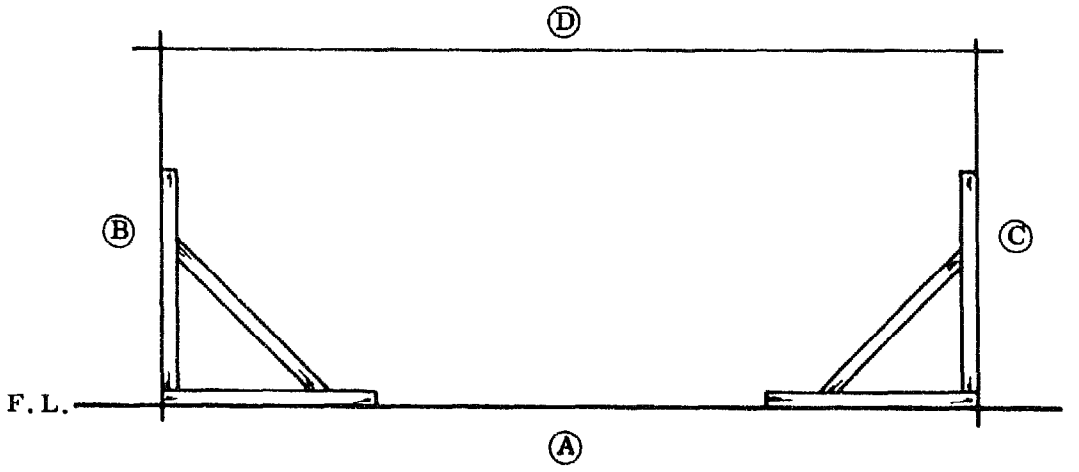

Fig. 2

USING THE LARGE SQUARE

PROCEDURE:

1 - FIX THE FRONT LINE; LINE A.
2 - MARK POINTS 1 AND 2.
3 - SET OUT LINE B SQUARE TO LINE A.
4 - SET OUT LINE C SQUARE TO LINE A.
5 - LINE D SHOULD BE THE SAME LENGTH AS LINE A.

N P V C		SETTING OUT.
145	JOB.	

USING THE PLUMB BOB TO MARK THE FOUNDATIONS

Hold the plumb bob with one hand by the suspending line so that the tip of the cylinder is just off the ground. Move it slowly until the suspending line just touches the intersection of the lines stretched between the pegs (see A & B, Fig. 1). When the swinging movement of the plumb bob has stopped, mark the point directly below the tip of the cylinder by inserting a peg.

The peg is directly in line with the intersection of the lines above.

This procedure is repeated at all inside corners and outside corners, so that the edges of the foundation trenches can be marked on the ground.

USING THE LARGE SQUARE

The large square, described in the Reference Book, Tools, page 12, may be used to set out and mark off the positions of inside walls. This is less time-consuming than using the 3-4-5 method.

Place the large square on the ground with one side along an already determined line, and mark off the corner on the other side (Fig. 2).

Not only the whole building, but also each room in the building must be checked for squareness by comparing the diagonals, which have to be equal.

USING THE MASON SQUARE

Although it is less accurate than the large square because of its smaller size, the mason square can be used to mark off the corners of short set-backs such as niches designed to receive built-in wardrobes, etc. Follow the same procedure as with the large square (Fig. 2).

- NOTE: A niche, also called a blocked doorway, is a small recess in a wall, usually not extending to the ceiling. A set-back or return is the part which goes back, away from the front or direct line of the structure.

NOTES:

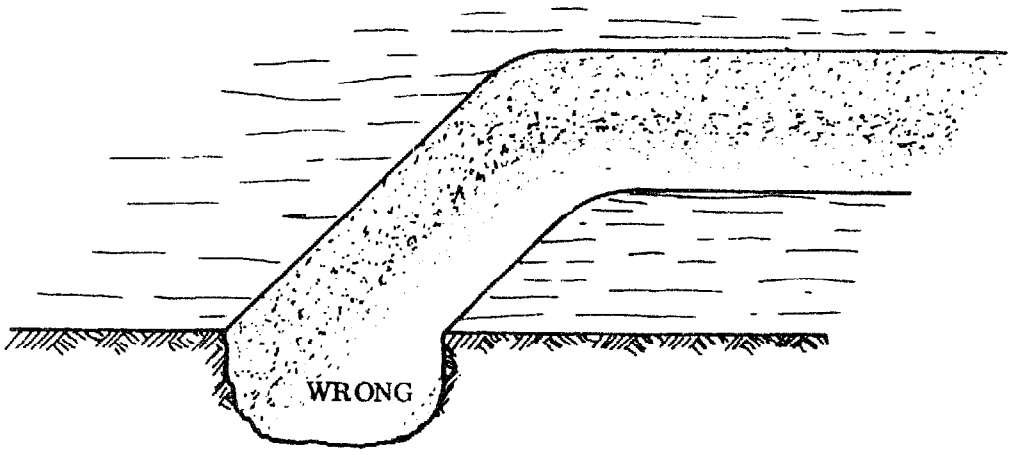

Fig. 1

CORNERS ARE NOT SHARP

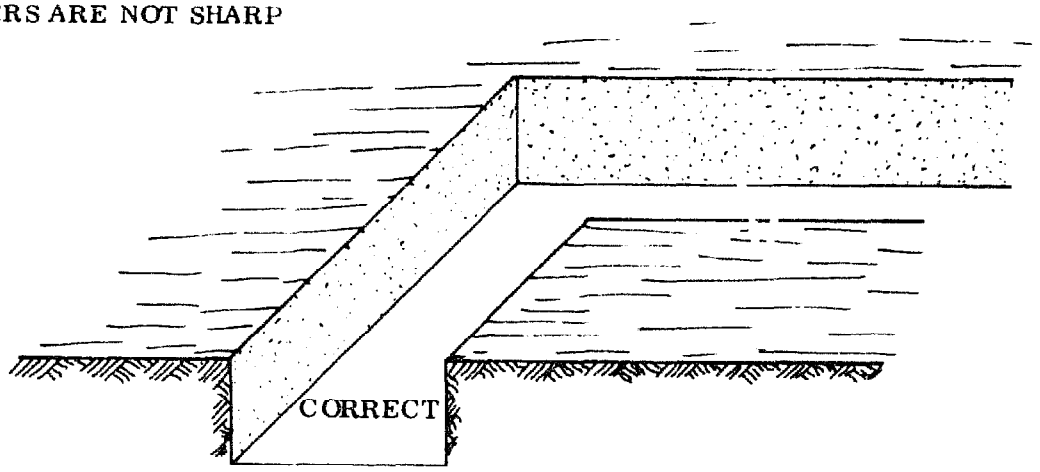

Fig. 2

CORNERS ARE SHARP

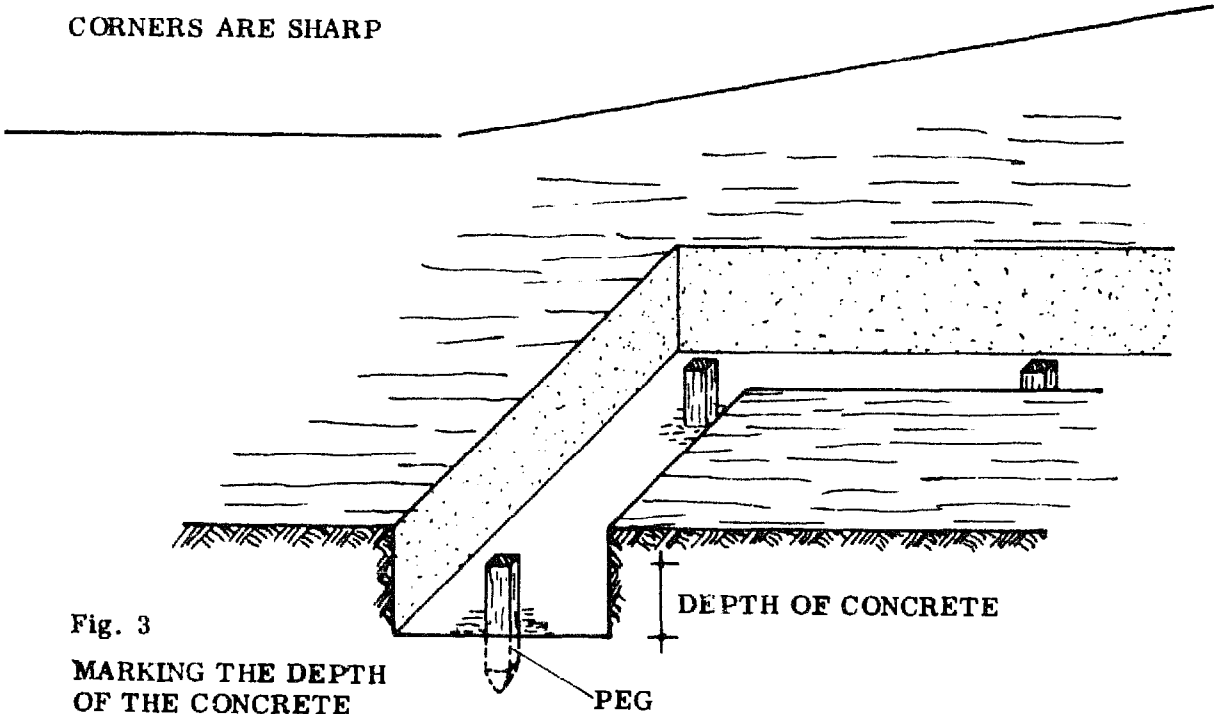

Fig. 3

MARKING THE DEPTH OF THE CONCRETE

N P V C	
147	JOB.

FOUNDATIONS.

FOUNDATIONS

A foundation is the strong base of a building. It is the lowest part of the structure, the part which is in direct contact with the ground.

The purpose of the foundation is to receive the loads from the structure above and to spread them over a larger area of supporting soil or rock.

EXCAVATING THE FOUNDATION TRENCHES

Once the setting out is completed and the position of the foundation is marked on the ground, the next step is to dig the trenches for the foundation concrete.

Remove the loose, soft topsoil to uncover the firm subsoil, preferably rocky soil. Dig the trenches to the required depth.

The soil which is taken out should be piled within or near to the area of the future building, so it can be used later for the hardcore filling. Take care to make the sides of the trenches vertical, and the bottom level. The corners should be sharp, not rounded (Figs. 1 & 2).

MARKING THE DEPTH OF THE CONCRETE AND LEVELLING THE TRENCH

When the trenches have been dug, the next step is to mark the depth of the foundation concrete. This is done by driving pegs in the bottom of the trench. The pegs are levelled across their tops, and their height above the trench bottom should be equal to the planned depth of the concrete bed (Fig. 3).

If the exposed heights of the levelled pegs are not equal, that means the bottom of the trench is not level. The uneven spots have to be levelled by taking out some soil, until all the pegs project equally.

- NOTE: Never level the bottom of a trench by adding loose soil, as this might lead to uneven settlement which causes cracks in the structure. Trenches are always levelled by removing soil. If this means that the trench is deeper than planned, then either the foundation concrete has to be deeper or the height of the footings must be increased.

NOTES:

FOUNDATION CONCRETE

When the trenches are dug and the thickness of the concrete has been marked, the next step is to mix the foundation concrete. The proportions for the mix can be from 1: 10 to 1: 15 (Reference Book, pages 166 to 170; and Tables of Figures, page 234).

CASTING - COMPACTING - LEVELLING

If the work is done during the dry season, the sides and bottom of the trenches must be watered down before the ready-mixed concrete is cast. This keeps the soil from absorbing too much moisture from the concrete before it has set. The concrete is carefully poured into the trenches and compacted by tamping.

Rammers are used to compact the concrete (Reference Book, page 18). The heavy rammer is repeatedly lifted and dropped, compacting (packing together) the comparatively stiff concrete.

A strike-board (Reference Book, page 25) is used to level the concrete to the height of the pegs. A straight edge can also be used instead of the strike board.

If wooden trench pegs were used, remove them now and fill in the holes.

If iron pegs were used, they can be left in the concrete unless they are needed for another job.

CURING

Cover the top of the freshly cast foundation with empty cement bags or straw. This keeps it from drying out in the sun and air, and keeps the surface clean.

Once the concrete starts to harden, the top of the foundation should be kept wet.

NOTES:

FOOTINGS

The term footing is given to the courses of brickwork, stone or blockwork at the foot of a wall. The footing courses start immediately above the foundation and are laid flatwise. The rising wall is erected in the middle of the footing courses, so the footings, which are wider than the rising wall, project equally on both sides of the rising wall.

PURPOSE OF FOOTINGS

Two main functions must be fulfilled by the footings:

- They are the connecting link between walls and the foundation and act as an intermediate foundation for the walls, spreading the loads over a wider area of the concrete below.
- They raise the floor level high enough above ground level to keep water out during the wet season.

HEIGHT OF FOOTINGS

In Rural Building, the top of the foundations is usually at ground level, although they can be either above or below ground level depending on the subsoil.

When three footing courses are laid on top of the foundations, the soffit of the future floors will be 51 cm above ground level. This will meet the requirements of most situations.

If the building is in a valley, or in a place where the rain-water cannot run off quickly, the height of the footing courses must be increased.

NOTES:

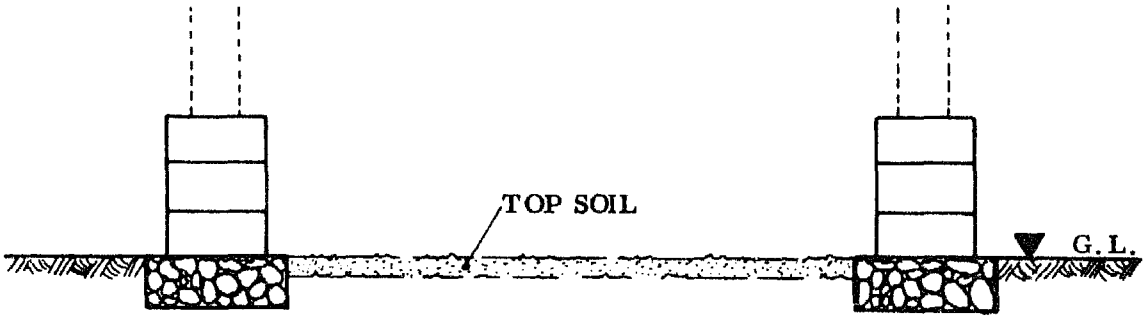

Fig. 1

FOOTING COMPLETED

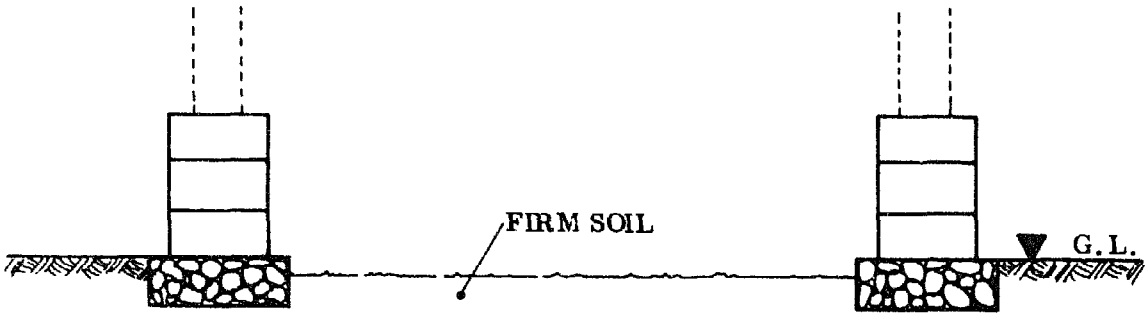

Fig. 2

TOP SOIL REMOVED

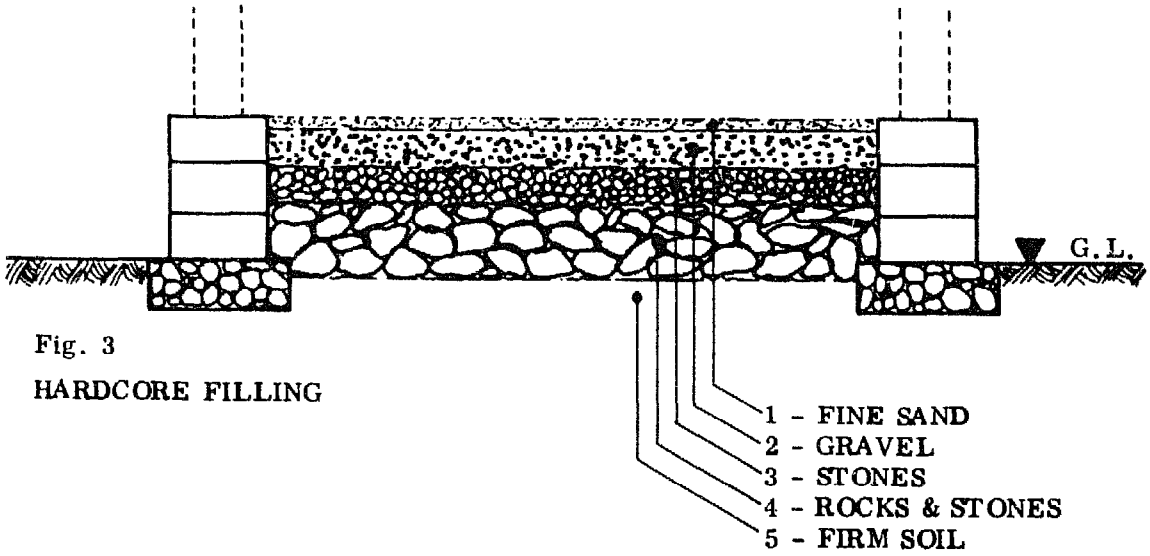

Fig. 3

HARDCORE FILLING

N P V C	
151	JOB.

HARDCORE FILLING.

HARDCORE FILLING

Hardcore filling is the compacted sub-base of floors; it consists of stones, broken sandcrete blocks or coarse gravel. It fills up the space between the subsoil and the soffit of the concrete floor.

FUNCTION OF THE HARDCORE FILLING

The hardcore filling has to carry most of the mass of the concrete floor, except for a small portion supported by the projecting inside edges of the footings. The filling must be well compacted to be firm enough to withstand the weight of the floors.

In addition, the hardcore filling must be built up in such a way that it prevents moisture from rising through it to penetrate the concrete floor.

METHODS OF FILLING AND COMPACTION

The topsoil is removed first (Figs. 1 & 2), then the hardcore filling is added in layers no more than 15 cm deep. Each layer is compacted very well before the next is added.

The bottom layer consists of small rocks, stones or broken sandcrete blocks. The second layer consists of smaller stones. Coarse gravel is used for all the remaining layers, up to about 6 cm below the tops of the footings. The last 6 cm or so is filled with fine sand, which seals off the surface so that no cement is wasted during the floor construction.

As can be seen in Fig. 3, the structure of the hardcore filling becomes denser and finer with each layer, starting from the bottom to the top. This is the correct way to protect the floor from the penetration of moisture.

All layers are compacted with rammers. The coarse gravel can be watered down to ensure proper compaction and to ease the work. If there is a tractor available, it may be used to move the fillings and to speed up the heavy work.

NOTES:

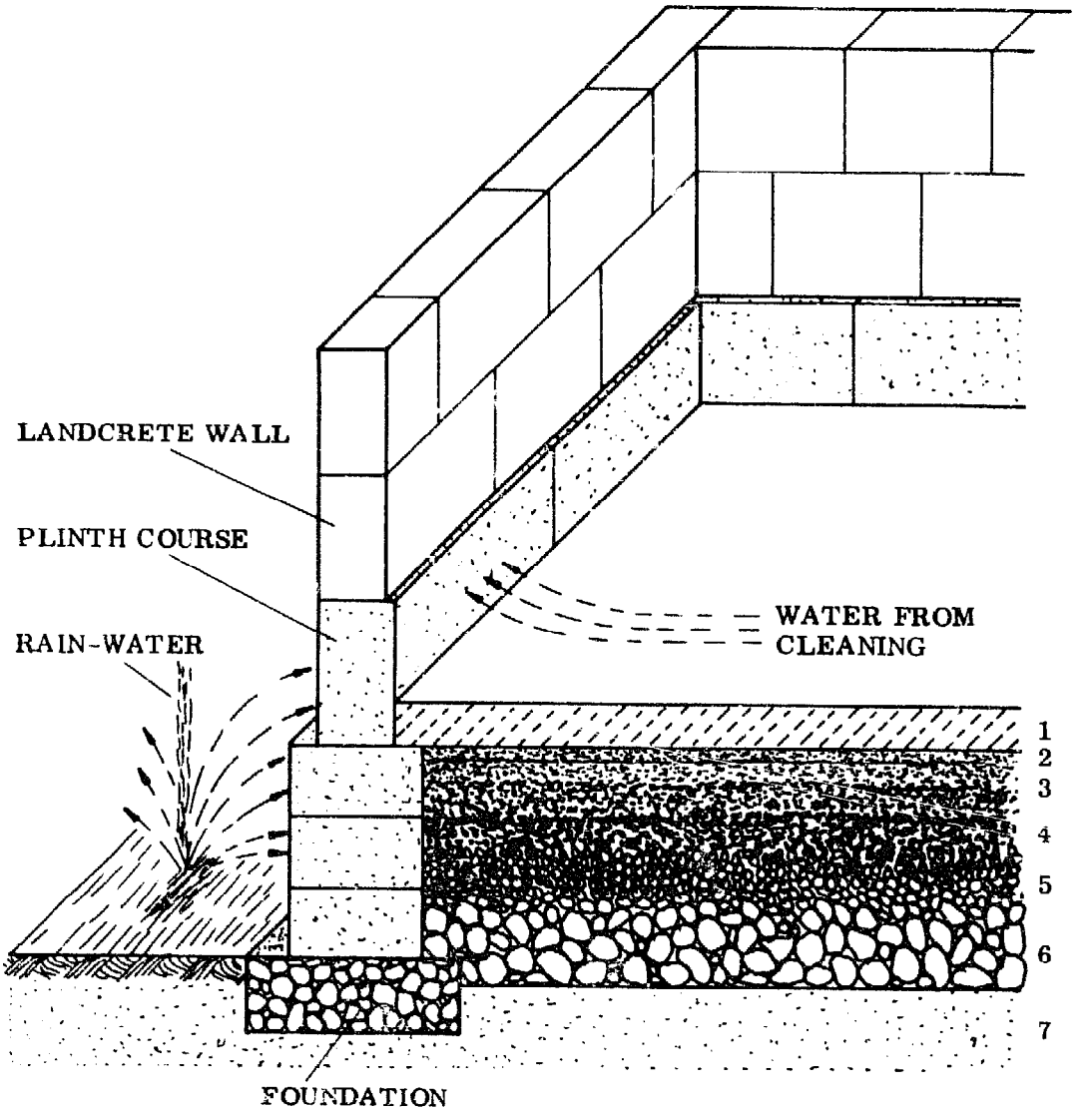

Fig. 1

1 - CONCRETE FLOOR
2 - FINE SAND
3 - FINE GRAVEL
4 - COARSE GRAVEL
5 - SMALL STONES
6 - ROCKS & STONES
7 - FIRM SOIL

N P V C	
153	JOB.

PLINTH COURSE.

PLINTH COURSE

The plinth is a slightly thicker course at the base of a wall or a column; often made of a more durable material than the rest of the wall or column.

In Rural Building, the plinth commonly consists of only one sandcrete course. The plinth course forms the first course of the rising wall immediately above the footings, and it is 1 cm wider than the landcrete blocks (Fig. 1). This 1 cm difference is evident from the inside face of the wall, but it is covered when the wall is plastered.

FUNCTION OF THE PLINTH COURSE

The plinth course raises the landcrete blocks above the finished floor level so that they cannot be penetrated by moisture (from outside by rain, from inside by water used for cleaning, etc.).

Although the landcrete blocks can withstand a skin-deep penetration of water for a short time, they must be protected against the long-lasting influences of the rainy season.

The most affected part of a building is always at the foot of the walls. Rain-water coming from the roof splashes up against the wall and creates a dirty strip about 60 cm in height, which is seen all along the footings. This area is more exposed to penetration by water than the rest of the wall, but the landcrete blocks are raised by the plinth course well above the endangered zone.

The illustration on the opposite page shows the possible paths which the water can take when penetrating the structure.

NOTES:

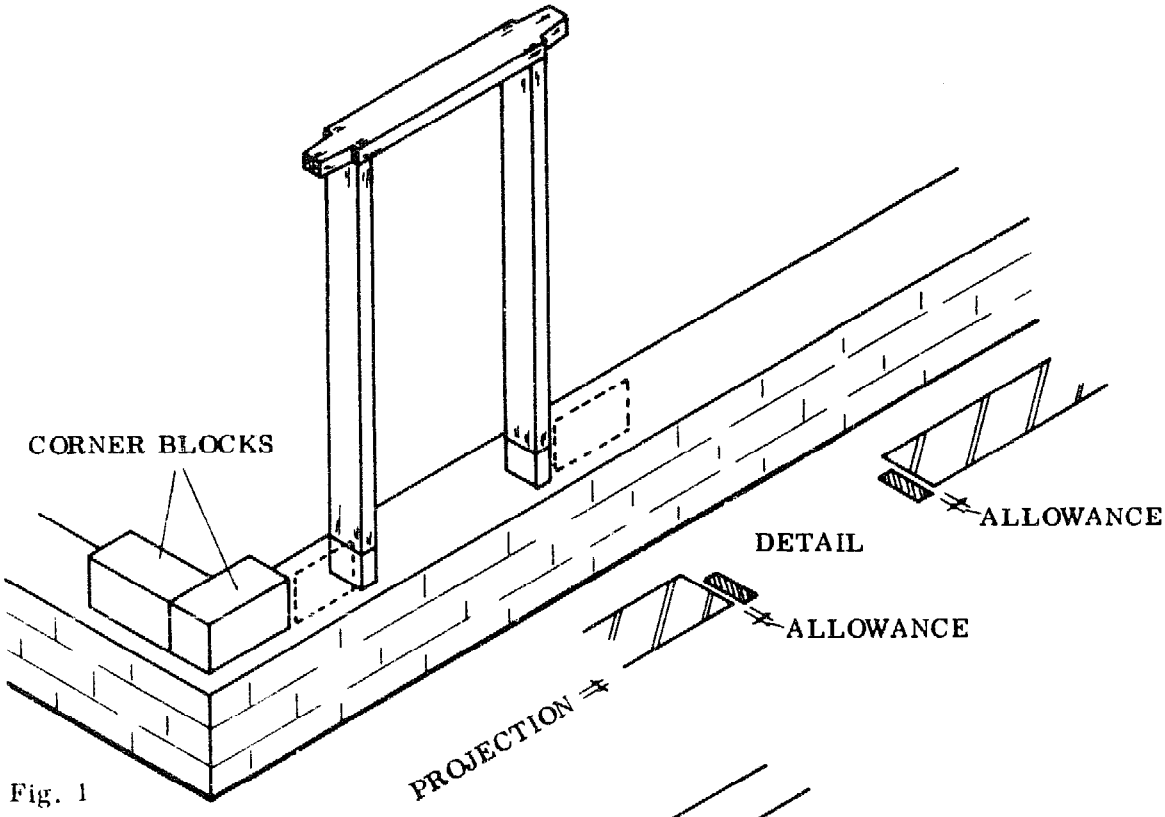

Fig. 1

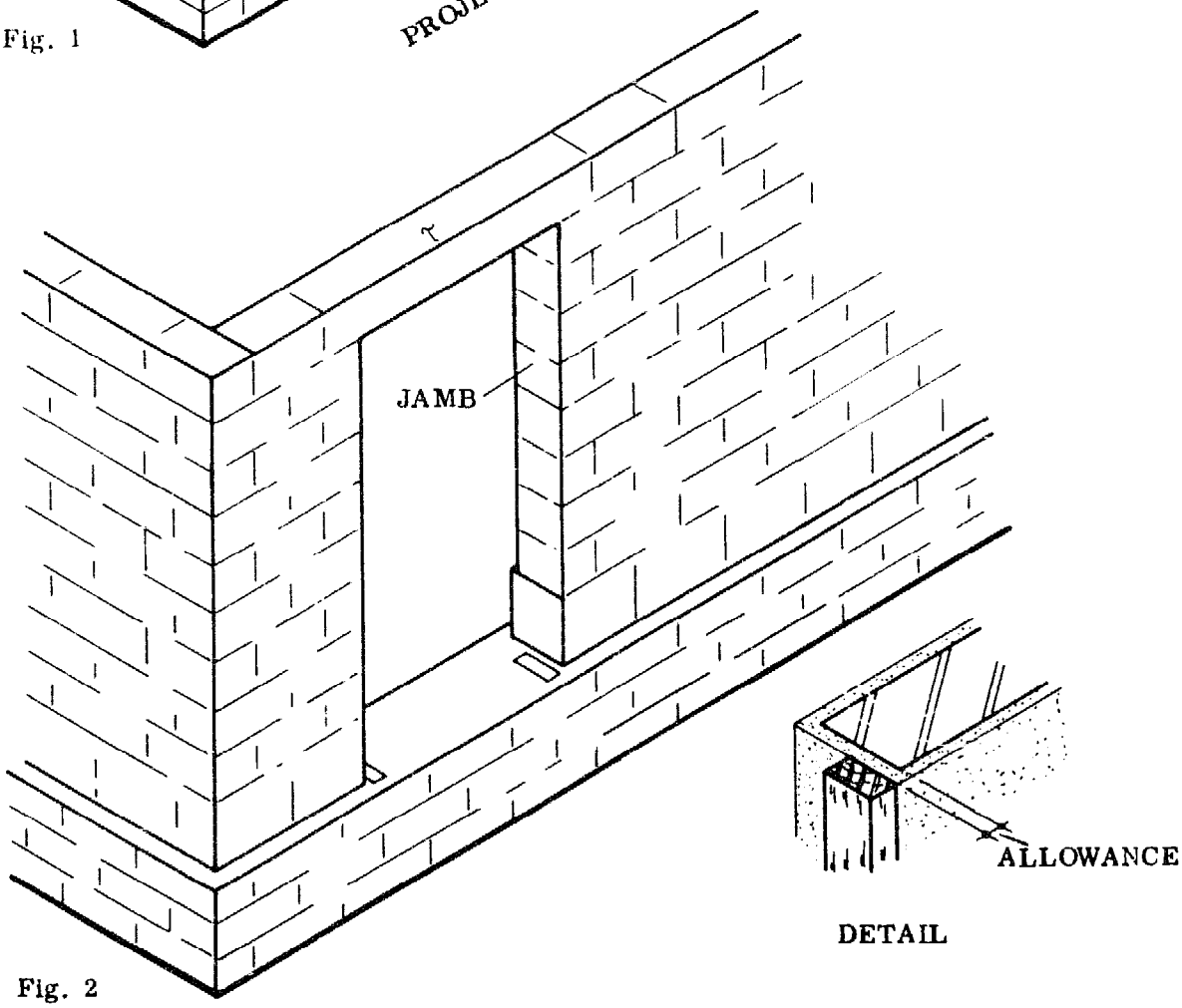

Fig. 2

N P V C		OPENINGS.
155	JOB.	

OPENINGS

An opening is a space in a wall left open for a door or a window. The first openings to be made in walls are the door openings.

DOOR OPENINGS

Before the plinth course is built, the door openings are marked in their correct positions on the footings.

In Rural Building, the door frames are usually made and set into place on the footings before the plinth course is built against the frames (Fig. 1).

If for some reason the door frames are to be installed later, the jambs of the openings (Fig. 2) are built up as described in the chapter on stopped ends, page 22.

A jamb is the portion of wall, or wall face, at the side of an opening. The jambs are built a little wider than the outside measurement of the frame (Fig. 2) so that the frame can fit into the wall opening.

Walling then continues until the window cill level is reached. This is the height where the window openings are set.

WINDOW OPENINGS

The window frames are set and braced before the walling between them is completed. If the frames are to be set later, the window openings must also be built a little wider than the frames, so that the frames can be fitted in later.

In case the opening is to be filled with a decorative grille (Reference Book, page 193) or ventilation blocks (Reference Book, page 195), it is advisable to complete course by course including the special blocks.

This is done because it is easier than putting the decorative blocks into an opening later, and it provides the openwork screen blocks with more stability within the wall during construction.

NOTES:

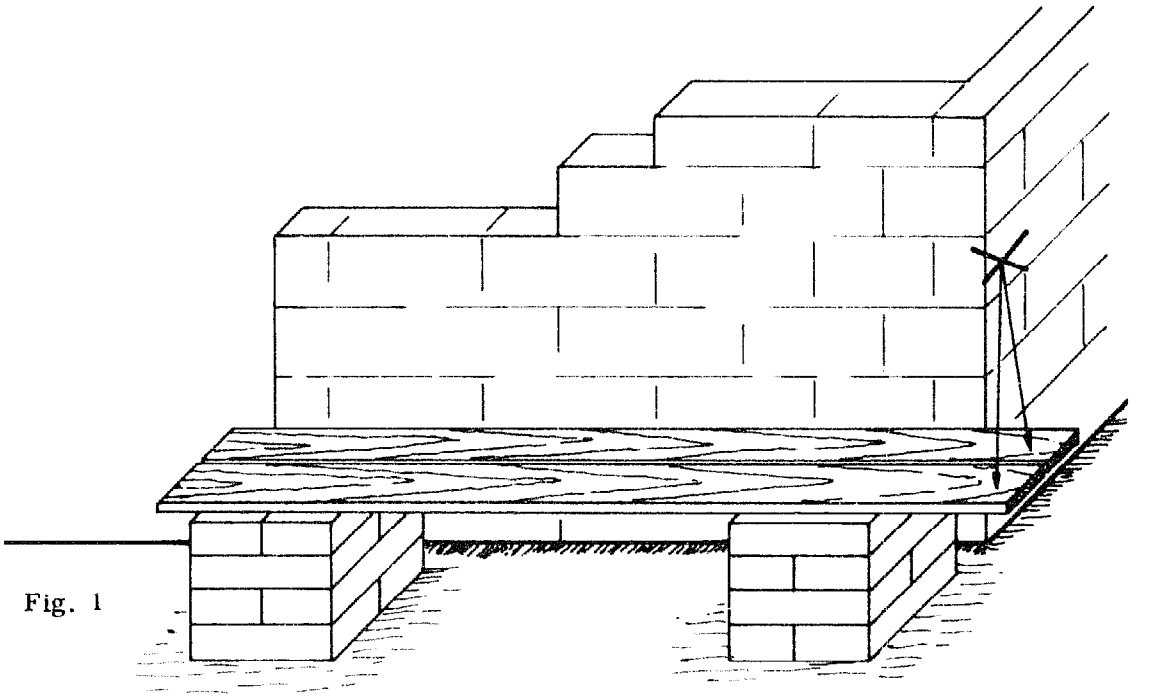

Fig. 1

CORRECT

- THE TOP SET OF BLOCKS IS SET CROSSWISE TO THE BOARDS

WRONG

- BOARDS PROJECT TOO FAR
- TOP BLOCKS ARE LAID LENGTHWISE TO THE BOARDS AND ARE LESS STABLE

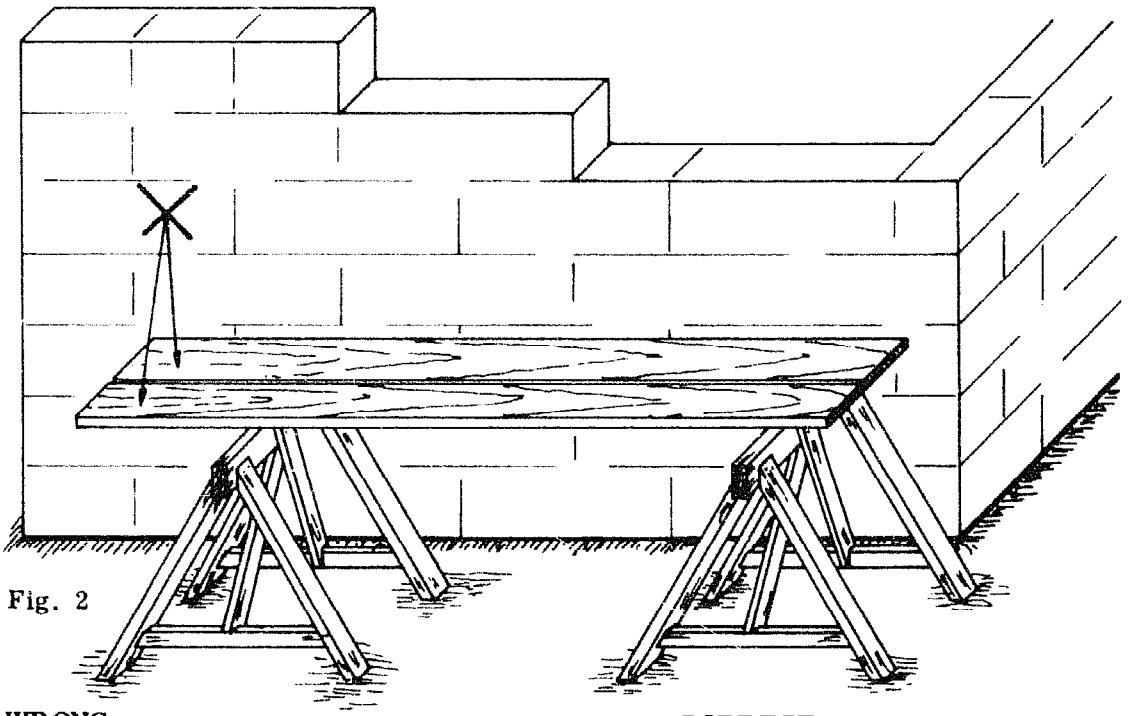

Fig. 2

WRONG

- BOARDS PROJECT TOO FAR

CORRECT

N P V C	
157	JOB.

SCAFFOLDING.

SCAFFOLDING

A scaffold is a temporary structure which supports workers and materials during building and other work. It can be made of steel, aluminium, timber or bamboo.

According to their functions, there are three main types of scaffolds:

- Working scaffolds
- Protecting scaffolds
- Supporting scaffolds

Each type may be erected separately and serve only one purpose. Some situations however, require a combination of two or even all three types.

WORKING SCAFFOLDS

As the name indicates, the working scaffold is used for working from. It holds the worker at a height which enables him to comfortably complete walls etc. when the construction has proceeded to a level that makes it difficult to work from the ground. The following is a description of two simple scaffolds used to complete walling between door and window frames. Protecting scaffolds, supporting scaffolds and a number of more complicated scaffolds and their construction will be treated in the Construction Books.

- BLOCK SCAFFOLD: This is the lowest and simplest working scaffold. It is used to raise the worker a bit higher to make it easier to build the wall up to the actual scaffold height of 1,5 m. Set the sandcrete blocks on solid, level ground and lay one or two boards across them (Fig. 1).
- TRESTLE SCAFFOLD: This is a low-level scaffold, consisting of wooden trestles covered by two or three boards (Fig. 2). A trestle is a horizontal beam of wood with two legs on each end. Two or more of them are used to support the boards. Set them on firm, level ground, no further than 1,5 m apart. The height of the trestles can be from 75 to 100 cm. Small quantities of blocks and mortar can be kept on the platform. This scaffold enables the worker to continue walling up to lintel height, and to erect the formwork of the lintels.

NOTES:

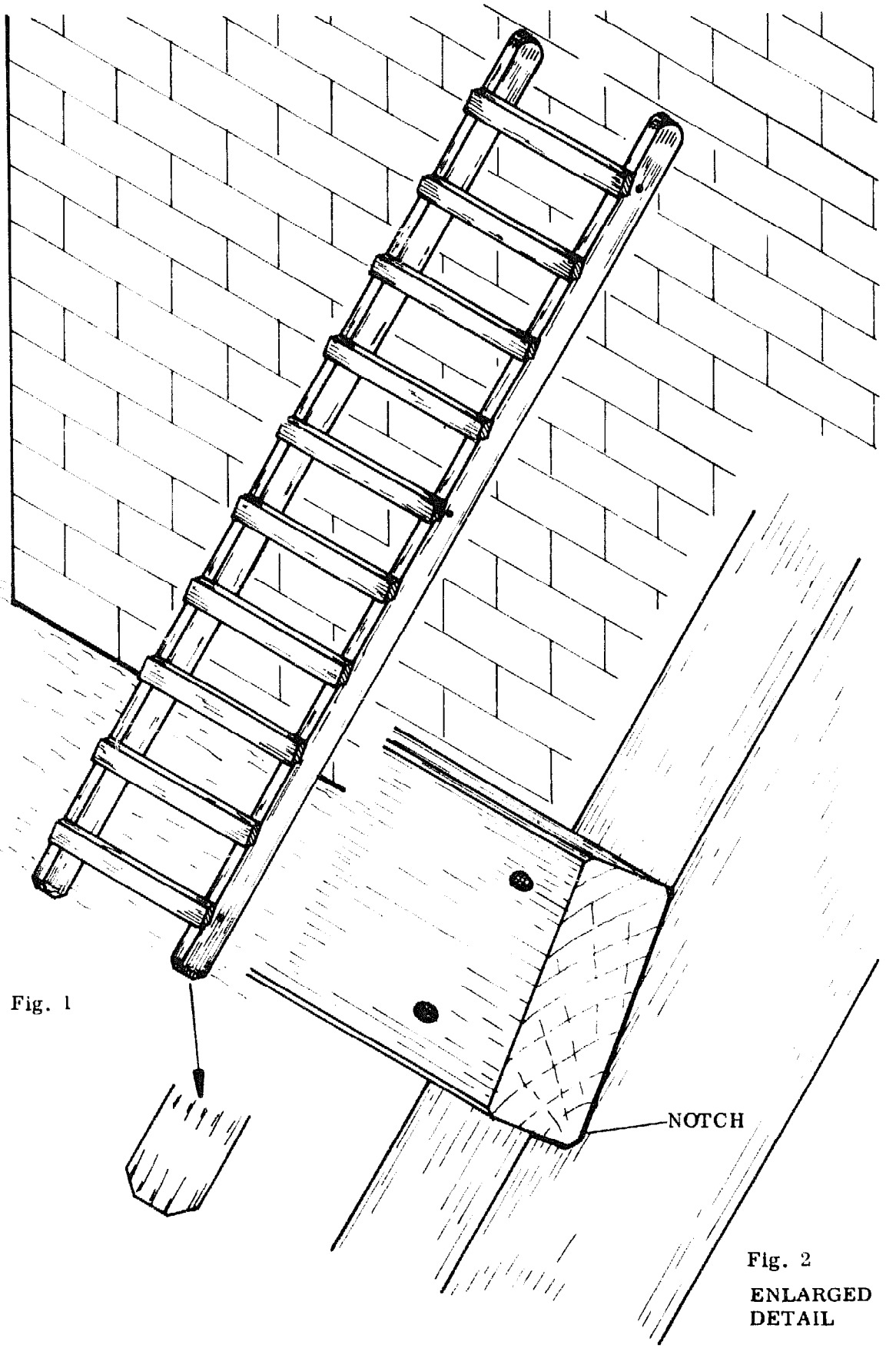

Fig. 1

Fig. 2
ENLARGED DETAIL

N P V C	
159	JOB.

SCAFFOLDING.

LADDERS

A ladder consists of two lengths of wood, metal or rope, called rails; which are connected at a certain distance from each other by rungs (Fig. 1).

Ladders are used to climb and descend scaffolds, walls, etc. during the construction of a building, and to do light maintenance work from later. Since such a piece of equipment is needed not only during the construction but also later in and around the house, it should be made from sound timber in a proper way so it can be used as a permanent ladder.

- CONSTRUCTING THE LADDER: Both the rails and rungs are made out of Odum. The dimensions of the two rails are 5 x 7,5 x 325 cm, while the ten rungs are 2,5 x 5 x 75 cm. The wood should be straight grained and planed to the above sizes.

  Round the top ends of the rails where they touch the wall and cut off the foot ends as shown in Fig. 1, with a 45 degree bevel from each side. To prevent splinters and help the hands to move safely up and down the rails, round off all the edges. Incidentally, when climbing or descending ladders, keep your hands off the rungs. Grip the rear edge of the rails.

  The over-all width of 75 cm gives an inside width of 65 cm which is wide enough to hold two scaffold boards on the rung. Later we will discuss making a ladder scaffold, in the Construction Book.

  The distance of 30 cm between the rungs must not be exceeded, as a wider spacing would make it difficult to climb the ladder.

  The rungs are inserted in notches cut in the rails, and fastened by using 75 cm nails as shown in Fig. 2.

  Sometimes ladders are reinforced by fastening iron rods, threaded at both ends, through both rails behind the first, centre, and last rungs. The rods are held in place by nuts on the threaded ends.

- NOTE: A good ladder should be treated with oil or another preservative. Dried-out wood is the greatest threat to the safeness of the ladder. Always keep ladders in the shade when they are not in use.

NOTES:

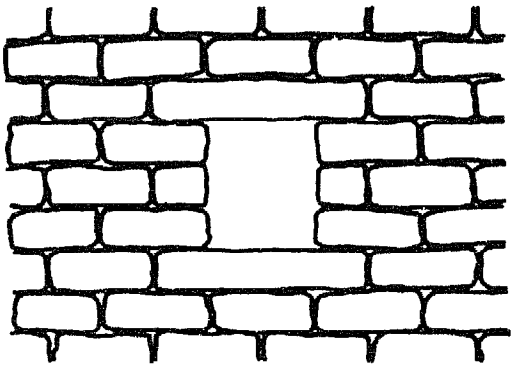

Fig. 1

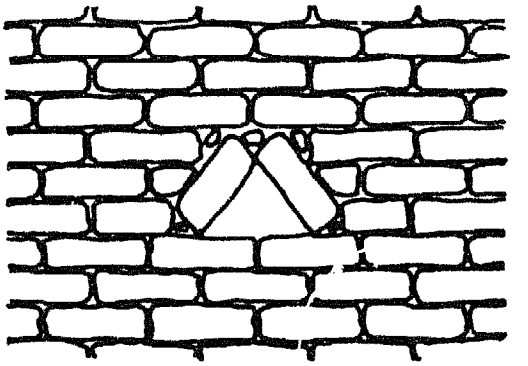

Fig. 2

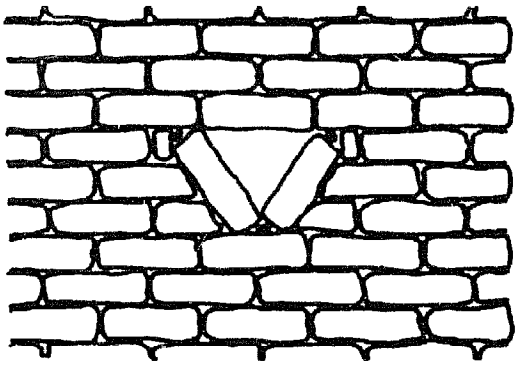

Fig. 3

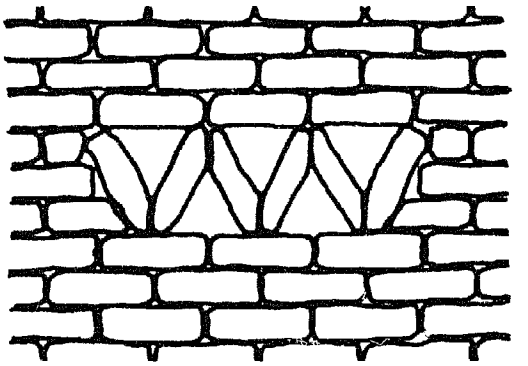

Fig. 4

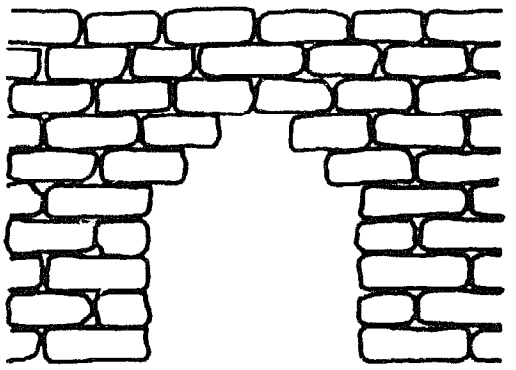

Fig. 5

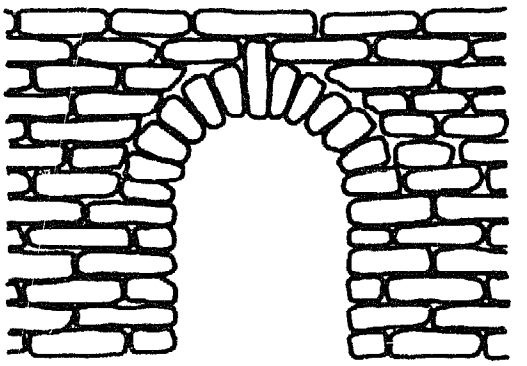

Fig. 6

N P V C	
161	JOB.

BRIDGING OPENINGS.

BRIDGING OPENINGS

To bridge something means to connect the two sides or parts. This can be done in building with a structure of wood, stone, block work, steel or concrete. The essential thing is that the door and window openings must be safely bridged so that the walls above or other members of the structure cannot collapse and damage the house or the people inside.

METHODS OF BRIDGING

There are various ways of bridging an opening. Which one of these is used depends on the distance to be bridged, the shape of the opening and the materials available.

One method which was common in former times was to make the openings so small that a single stone could be laid across them (Fig. 1). Openings which are low enough can also be bridged by inserting supporting blocks arranged like a "V" (Figs. 2, 3, & 4). This method is still common in the dry areas of Africa.

The wider an opening becomes, the more difficult it is to bridge. Builders from many parts of the world eventually learned that if the blockwork remains closed above an opening, both sides of the wall will support each other, maintaining stability. This knowledge was often applied not only to bridge openings but also to construct roofs. The technique was to let each course overlap the one below until the blockwork met at the top and the two sides bonded into each other (Fig. 5).

From this simple method, arches were the next development. They are much stronger and have a more attractive appearance (Fig. 6).

Lintels were introduced in order to produce a square opening into which a frame could be fitted.

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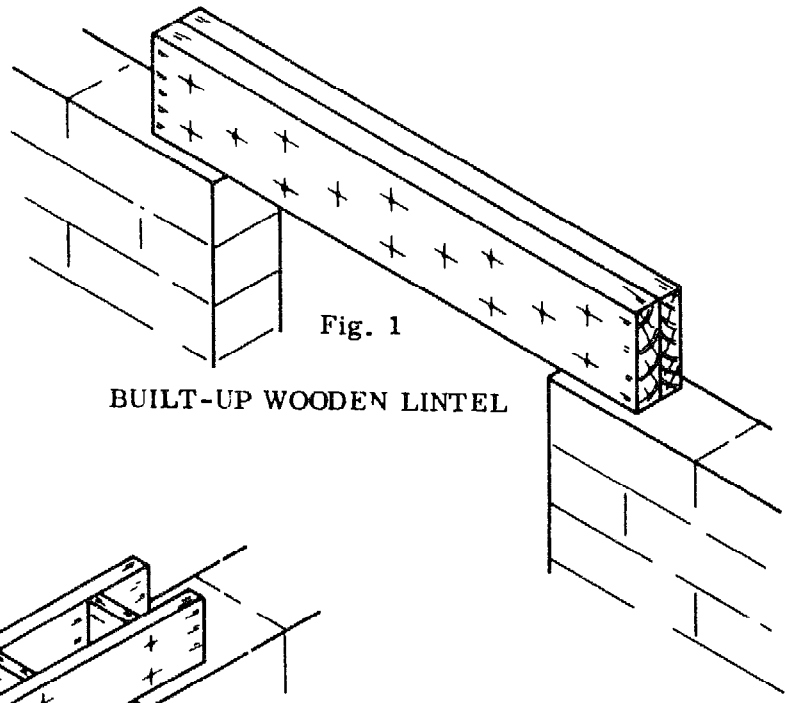

Fig. 1

BUILT-UP WOODEN LINTEL

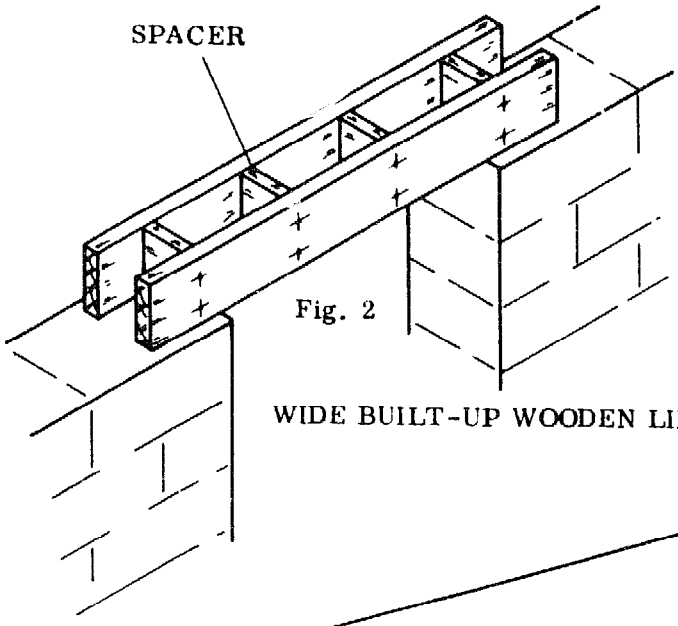

Fig. 2

WIDE BUILT-UP WOODEN LINTEL

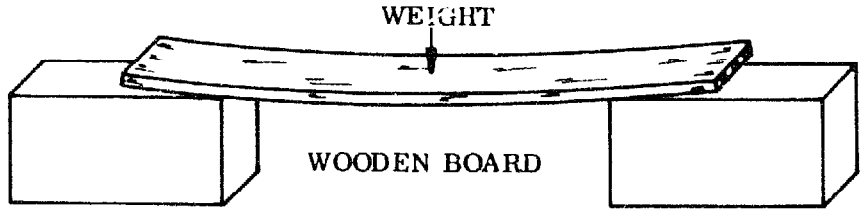

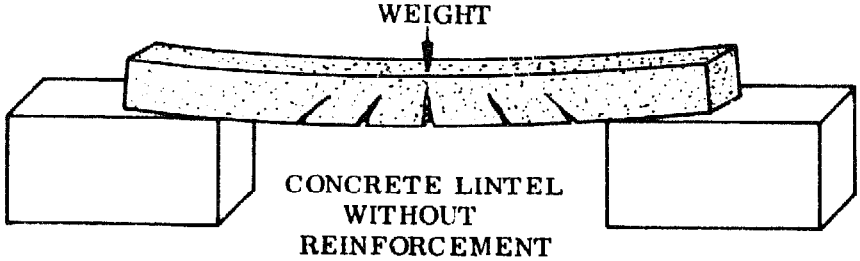

Fig. 3

N P V C		LINTELS.
163	JOB.	

LINTELS

BUILT-UP WOODEN LINTEL

A lintel, whatever material it is made from, is a horizontal member of the structure which bridges an opening (Fig. 1).

Its function is to distribute the weight of the blockwork above and any other loads to the supporting walls. With a lintel the opening of the door or window can be lower than with an arch, and it is also easier to fit a frame into the opening.

For short-span openings such as doors and smaller windows which have no additional loads above, the wooden built-up lintel can be employed.

This lintel consists of two or more hardwood boards which are nailed, bolted or screwed together (Fig. 1). In order to save materials when a wider lintel is required, the boards are sometimes connected with spacers between them (Fig. 2).

For long-span openings and in situations where additional loads are present, arches or reinforced lintels are used.

REINFORCED CONCRETE LINTEL

Like the human body which is strengthened by bones, reinforced concrete is made stronger by the steel bars or metal netting embedded in it.

It is known that concrete alone can withstand enormous pressures, but if it is exposed to tensile stresses it will break (Reference Book, pages 168 & 169). Fig. 3 shows that a long board supported only on its ends will bend if weight is set on it. Similarly, a pure concrete lintel will try to bend under a heavy weight, but because the concrete is not flexible this will result in cracks forming across the soffit face, or even in collapse (Fig. 3).

To prevent this, reinforcement bars are embedded in the concrete if the lintel is expected to receive tensile stresses. The combination of concrete and steel does the job where one of them alone would not work: the concrete resists all pressure while the embedded steel resists all stresses.

The reinforcement for a lintel consists of several members with different diameters, shapes and functions. The members are often assembled beforehand in the form of so-called cages (see Fig. 1, next page).

NOTES:

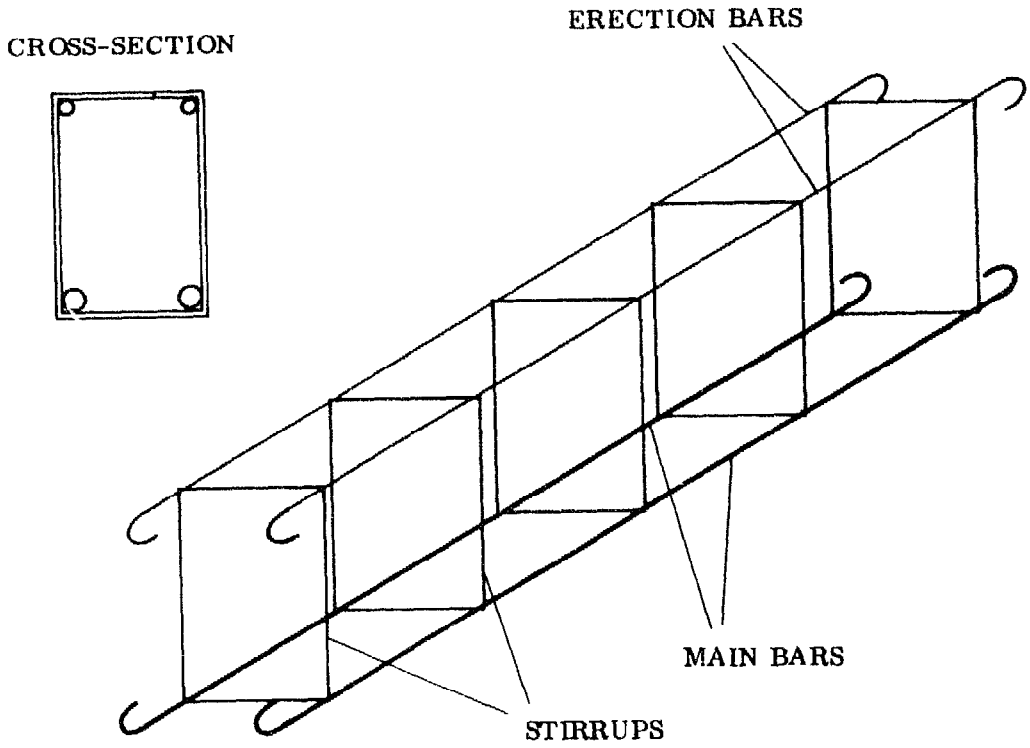

Fig. 1
REINFORCEMENT CAGE

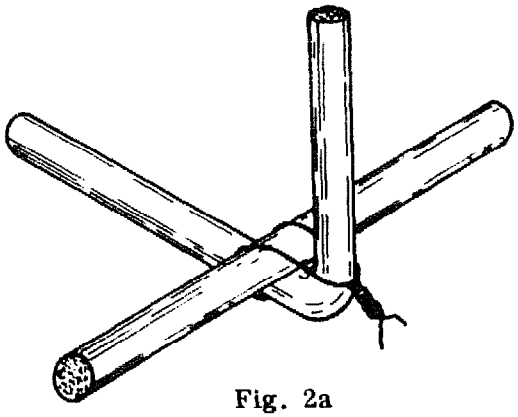

Fig. 2a

STIRRUP TO MAIN BAR

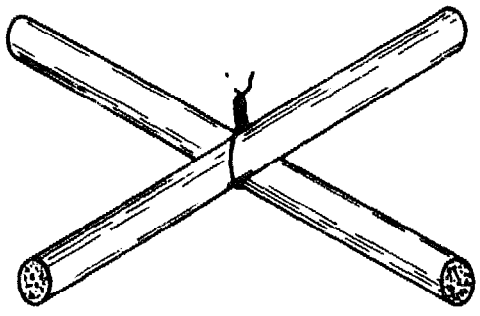

Fig. 2b

BINDING OF CROSSING BARS

N P V C	LINTELS.
165 JOB.	

- REINFORCEMENT CAGE: A typical reinforcement cage is shown in Fig. 1. The lower bars are the main bars. They are normally 12 mm in diameter because they do the actual strengthening of the lintel. The upper bars are thinner and are called erection bars. Since their main function is to hold the cage together, their diameter is only 6 mm. The square-shaped pieces are called the stirrups. They hold the main bars and the erection bars in position. All the different members are bound together with binding wire.

- CUTTING: All reinforcement bars have to be carefully measured and marked off before they are cut. A well equipped building site will have two different sized bolt cutters available. One is to cut the bars ranging from 4 to 10 mm in diameter and one is for bars up to 19 mm. If bolt cutters are not available, a hacksaw or a chisel may be used instead (Reference Book, page 19).

- BENDING: The bars are bent with the aid of the bending plate which is fixed on the work bench; and the bending bars (Reference Book, page 23). Each diameter of bar has to be bent with a specific size of bending bar.

  The bending is done according to a certain radius (this refers to the sharpness of the bend) in order to prevent overstraining and cracking of the bar (this will be explained in more detail later). The stirrups for the cages may be bent around a peg that has the same diameter as the main bars.

- BINDING: The members must be bound together in order to ensure that the bars remain in the correct positions while the concrete is being poured. Binding wire is bound around pieces at the connections (Figs. 2a & 2b). The wire should be stretched taut and then twisted tight with the pincers.

- NOTE: Examine the bars before you use them to make sure that they are free from paint, grease, loose scale or mud. Slight rusting will do no harm, but any loose rust should be removed.

For additional information on concrete and reinforcement steel, see the Reference Book, Materials and Products sections.

NOTES:

SIDE BOARD

CLEAT

SHUTTERING

SPACER

BLOCK

SOFFIT BOARD

BRACE

HEAD TREE

FISH PLATE

BRACE

STANDARD OR STRUT

Fig. 1

BRACE

WEDGES

SOLE PLATE

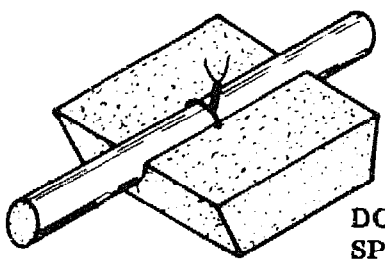

Fig. 3
DOVETAILED SPACER

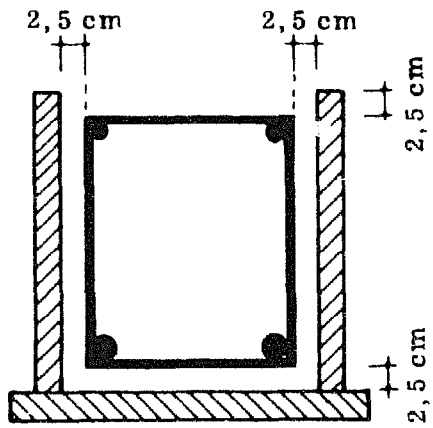

Fig. 2 CLEAR COVER

N P V C	LINTELS.
167 JOB.	

FORMWORK FOR A REINFORCED CONCRETE LINTEL

The form is simply a temporary box into which the freshly mixed concrete is cast and kept until it has hardened. The inside shape of the box will be the outside shape of the concrete member.

All parts and members of a formwork used for casting reinforced concrete lintels are shown in Fig. 1 on the opposite page. The parts are nailed together in such a way that they can easily be taken apart after the concrete has hardened.

Formwork is made of wood or metal and consists of two structural parts: the shuttering and the strutting.

- SHUTTERING: The shuttering is the actual shaping part of the formwork which is in direct contact with the concrete. Usually Wawa boards are used for shuttering because they are soft and light-weight, thus easy to work with.
- STRUTTING: The strutting is the supporting and bracing part of the formwork. It keeps the shuttering in position and supports both the shuttering and the concrete inside it until the concrete has set hard. Odum boards are usually used for the strutting because they are harder and stronger than the Wawa.
- CONCRETE COVER: Concrete cover, also called clear cover, is the thickness of concrete between the surface of the concrete and the nearest reinforcement bar enclosed in the concrete (Fig. 2).

  When the formwork is ready, the reinforcement cage is set into it. Spacers are attached to the bottom side of the stirrups (Fig. 3). These ensure that the reinforcement bars are correctly positioned within the concrete. The spacers are made beforehand out of cement mortar to the dimensions specified for the concrete cover thickness. A short piece of binding wire should be pressed into the fresh mortar of the spacer, so that it can be fixed properly on the rod.

  There must also be spacers on the sides of the cage, to hold the stirrups away from the side boards of the shuttering.
- NOTE: When casting concrete, take care that the cage remains in position and that the concrete is well compacted around the reinforcement bars.

NOTES:

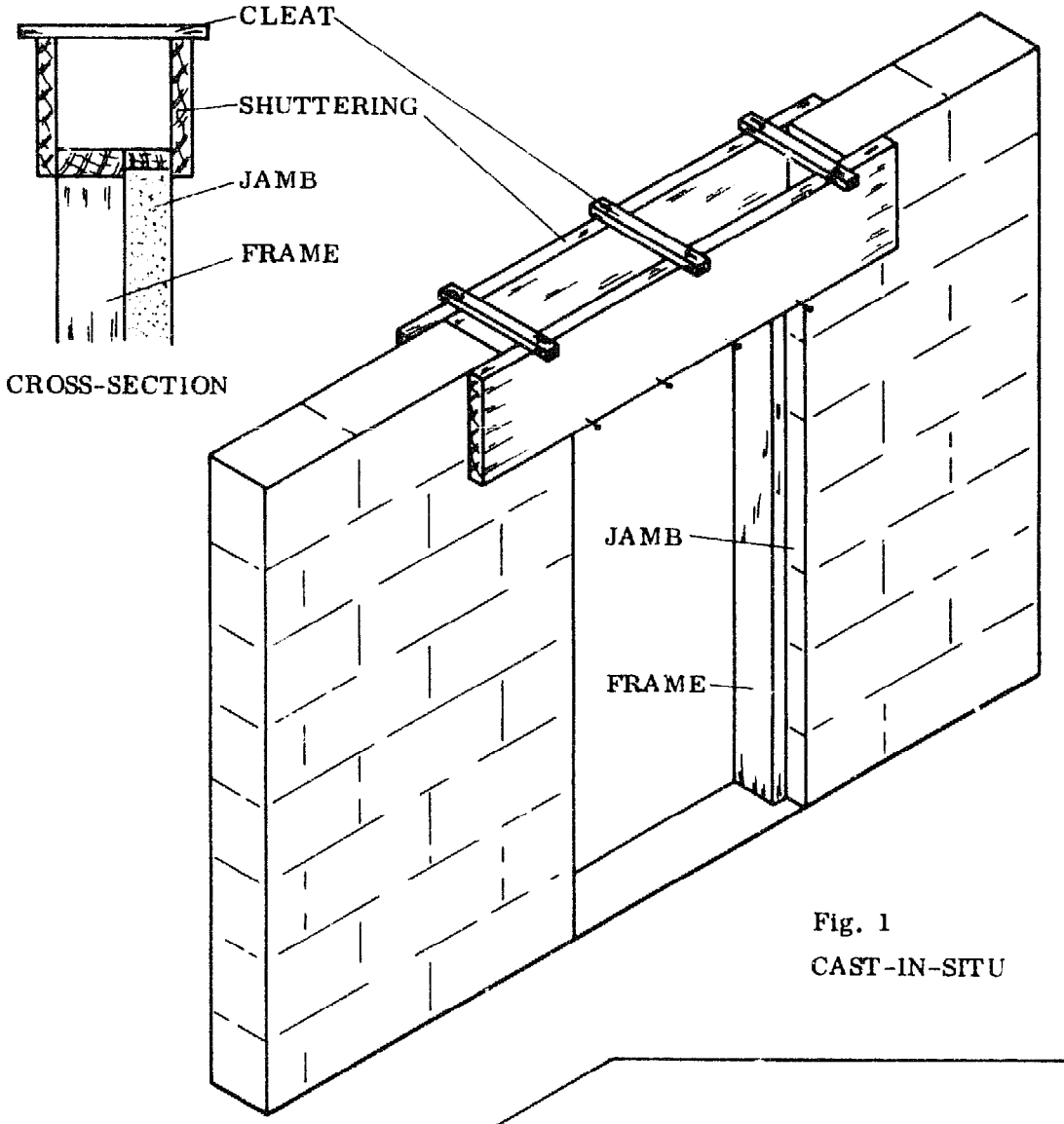

Fig. 1
CAST-IN-SITU

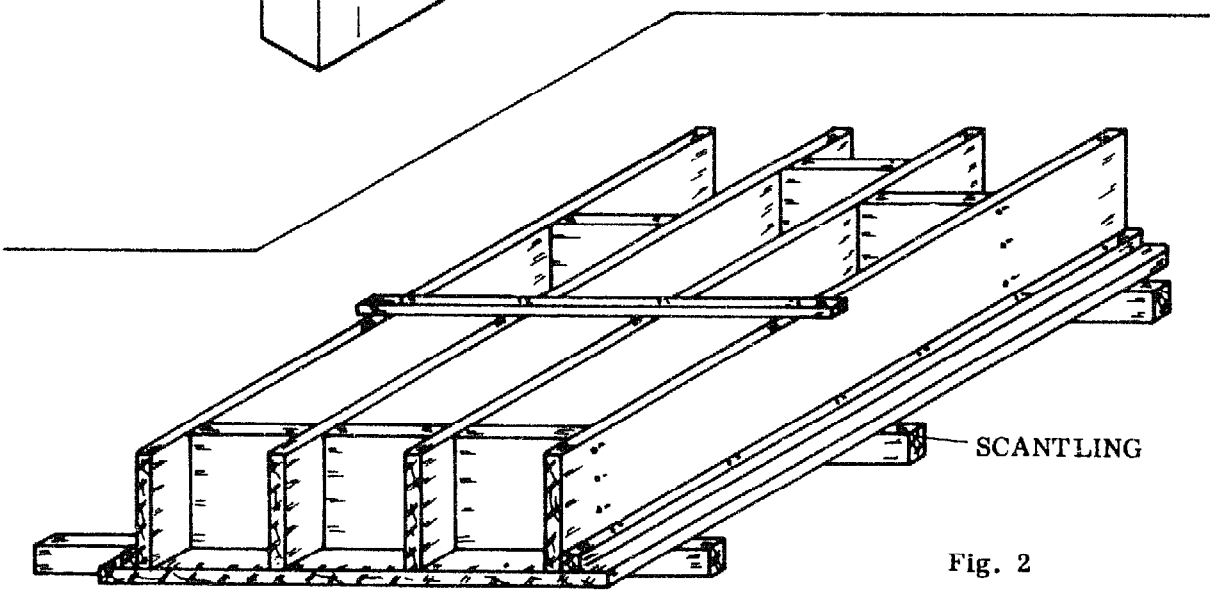

Fig. 2
PRECAST

FORM FOR SEVERAL LINTELS OF DIFFERENT LENGTHS

N P V C	
169	JOB.

LINTELS.

CASTING REINFORCED CONCRETE LINTELS

Concrete lintels are made in two ways. They are either cast-in-situ or they are precast.

- CAST-IN-SITU: This method is the most common one in Rural Building. The lintel is cast in situation; in the place where it is needed (Fig. 1). The advantage of this method is that no soffit board is needed for the form, because the head of the door frame acts as the bottom of the form, provided that the frame has been installed already. A further advantage is that any roof anchorage, if needed here, can easily be inserted into the reinforcement cage at the correct position.

- PRECAST: A precast concrete lintel is a lintel which is made in advance. The formwork is on the ground and the concrete is cast there. When the construction reaches lintel height, the concrete lintel has set hard and can be set into position. The advantage of this method is that it saves time, since the wall above can be completed immediately after the lintel has been laid (Reference Book, page 137).

  If several lintels have to be made, a form like the one shown in Fig. 2 can be used.

- NOTE: Precast concrete lintels must be marked on their top face with the letter "T" to ensure that they are placed in the correct position and not upside-down.

- PREPARATION OF THE FORMWORK: No matter which of the above methods is used, the formwork has to be prepared before the concrete is cast. This involves cleaning dirt and dust from the surfaces which will be in contact with the concrete, and watering or oiling them.

  The formwork must be completely sealed so that no gaps remain for the cement paste to escape. This would result in voids and weak concrete.

- COMPACTION: The concrete is filled into the formwork in layers, and compacted by tamping with an iron rod or the trowel. Tapping lightly on the formwork with a hammer also helps to consolidate the concrete.

- CURING: When the concrete is starting to get hard, the lintel must be kept wet and covered. This process is called curing and must be continued until the concrete is completely set and the formwork can be removed.

NOTES:

- STRIPPING: Stripping refers to the removal of the formwork; this has to be done carefully to avoid causing shocks or vibrations.

  After the formwork is removed, clean all the parts of it and remove the nails. Stack the different parts neatly to keep them from getting bent or warped.

- STRIPPING TIME: This is the period between the casting of the concrete and the time the formwork can be stripped off. During this time the formwork containing the fresh concrete must not be disturbed, so that the concrete can set hard without any cracks forming in it.

  Depending on the size, shape and position of the concrete member, the stripping time varies from 4 to 28 days.

NOTES:

ROOFS

ANCHOR BEAM

When the walling above the lintels is completed, the top of the wall may be covered with a strip of reinforced concrete, all around the outside walls of the house. This is the anchor beam, where the roof construction is anchored. It is also known as the ring beam or concrete belt.

WALL PLATE

For smaller spans, the Rural Builder can install a wooden wall plate instead of an anchor beam. Both of these are explained further in the section on roofs in the Construction Book.

TERMS

On this page and the next page, most of the parts and members of the roof construction are mentioned. The details of roof construction are dealt with in the Construction Book.

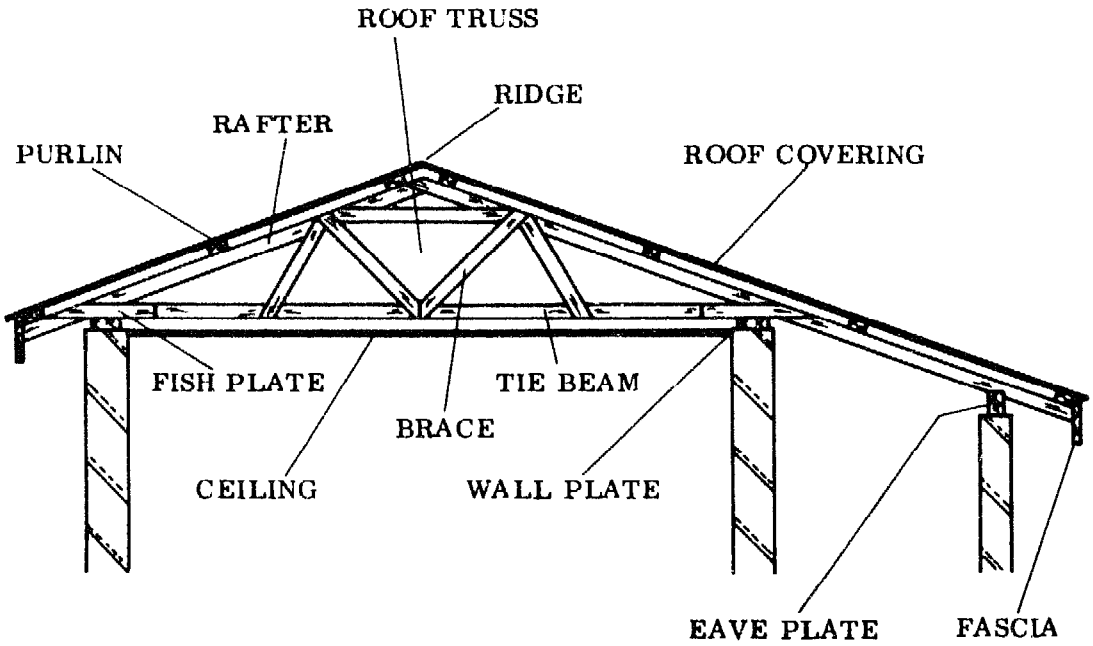

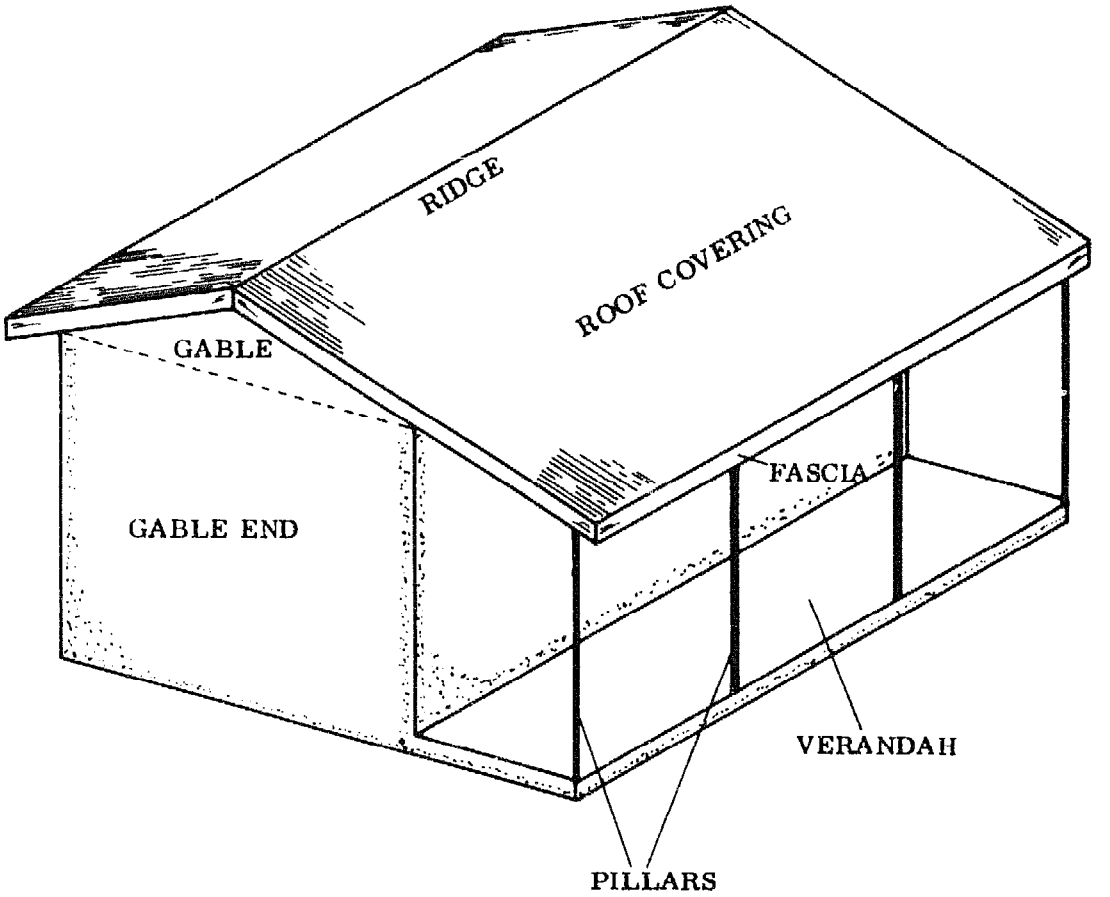

NOTES:

N P V C	
173	JOB.

ROOFS.

PLASTER - RENDER

Plaster and render are mortars with different mix proportions; they are applied to walls to protect the blocks from weather etc.

Internal surfaces are plastered; the mortar used is called plaster.

External surfaces are rendered; the mortar is called render.

FUNCTIONS OF PLASTER AND RENDER

Since most of the wall consists of landcrete blocks, it has to be rendered to make it weatherproof, and to protect the blocks against rain which otherwise quickly damages them. The ideal rendering will prevent water from penetrating, will be free from cracks and will stick tightly to the wall. At the same time, the appearance of the building is improved.

The function of plaster is to give the inside walls a smooth, plain finish so that the rooms both look nice and are easily cleaned. No gaps or holes should remain for insects, spiders, etc. to find shelter in. Wet areas such as bathrooms, showers, kitchens and toilets, are plastered to protect the landcrete blocks from moisture penetration. In addition, the plaster serves as a protection against fire in buildings which are made out of a wood skeleton covered with mud (a common construction in southern Ghana).

APPLICATION

The application of the plaster can be done with one coat or two coats. Generally one coat work is done, but two coats may sometimes be required, for example when the wall is very uneven and a thick plaster coat is needed to cover the irregularities.

Sometimes a spatterdash coat is applied to the wall before the plaster, to give a good grip to the plaster. This is discussed on page 176; see also the Reference Book, page 29.

NOTES:

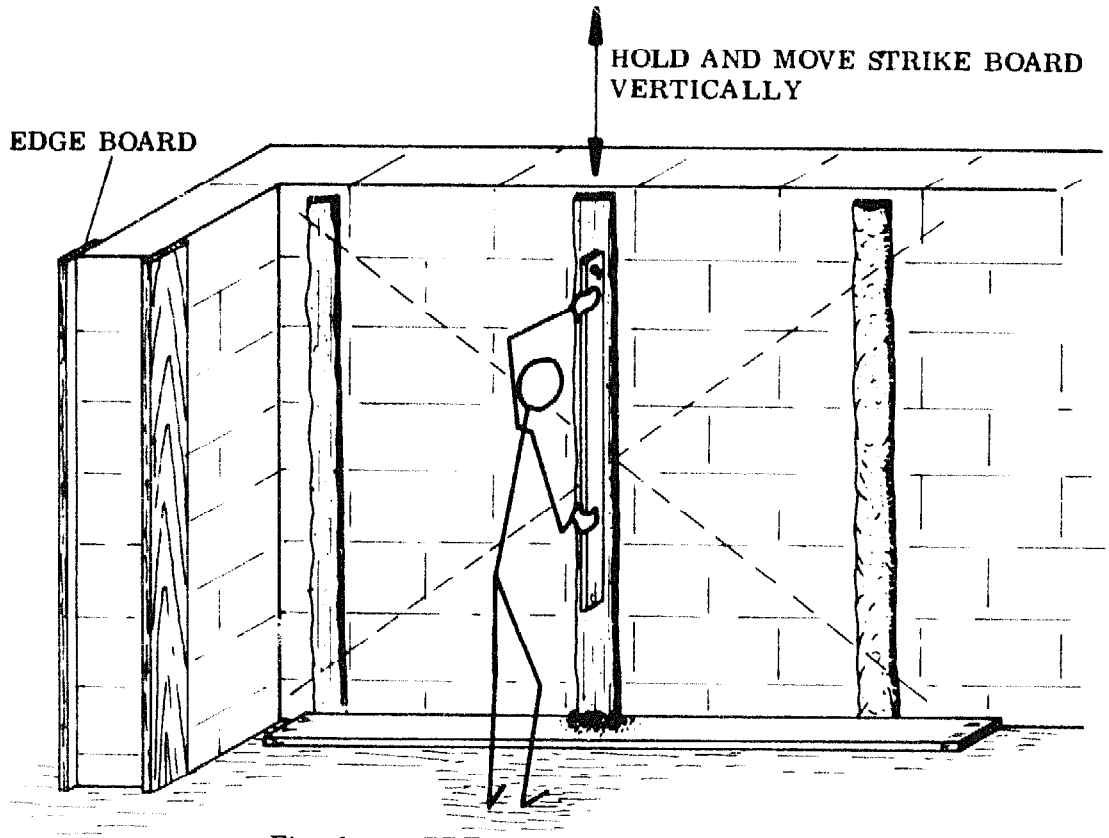

Fig. 1 PREPARATION OF SCREEDS

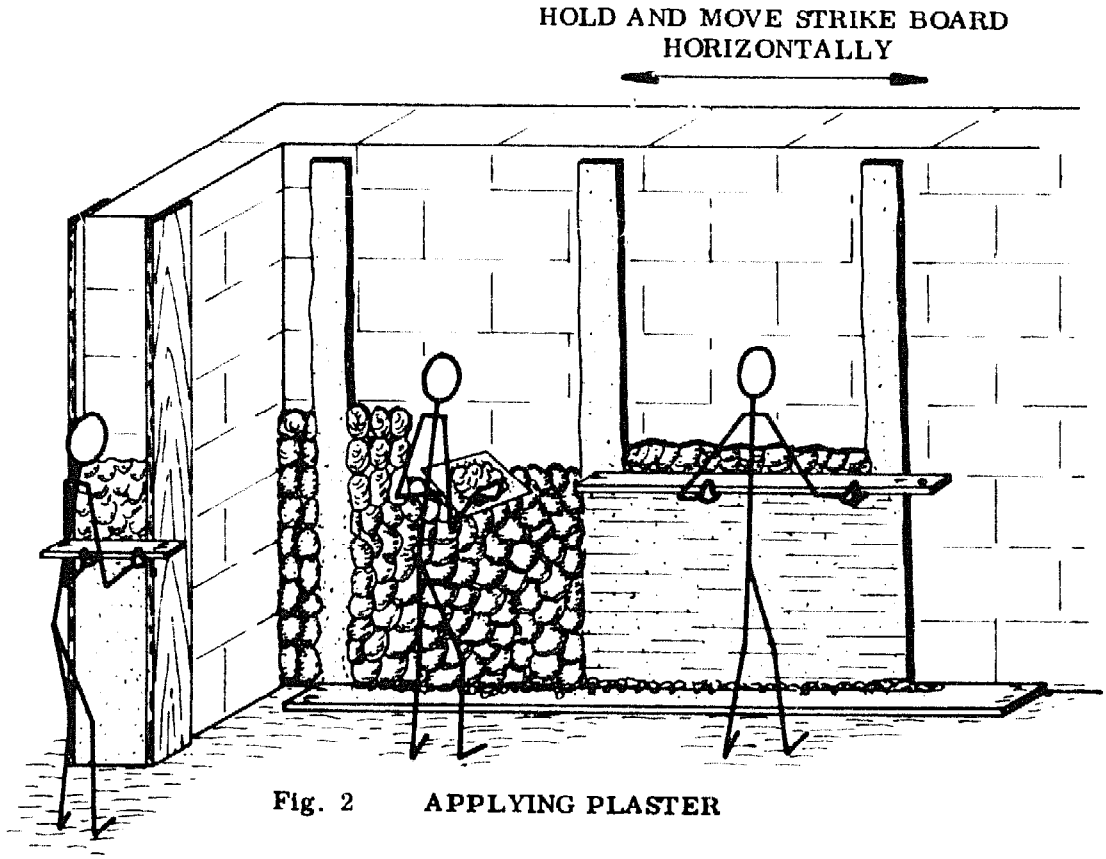

Fig. 2 APPLYING PLASTER

N P V C		PLASTER - RENDER.
175	JOB.	

PLASTERING OR RENDERING

Before the plaster or render is applied, the wall should be thoroughly checked to make sure that it is plumb and its surface flat. Holes and hollow parts should be filled in, and single projecting blocks must be chiselled off. The latter problem can often occur on the inside of walls due to irregularly made blocks.

The face of the wall should be free from loose dirt and dust, and it must be well dampened to reduce the absorption of moisture from the mortar.

On outside corners, so-called edge boards are fixed so that they project past the edge by a distance equal to the thickness of the coat to be applied (Fig. 1).

On inside walls and between edge boards, screeds are prepared according to the required thickness; they are situated as wide apart as the strike board (Reference Book, page 25) can readily bridge.

A screed is a strip of plaster or render which is carefully applied to the correct thickness to act as a guide for the strike board. In making the screeds, hold the strike board vertically and give it an up and down motion as you move it across, smoothing the screed (Fig. 1). The screeds will be flush with the finished surface and must be carefully plumbed and lined out (Fig. 1).

A board can be laid close along the bottom of the wall so that any mortar which is dropped can be picked up again, to avoid wasting material.

When the screeds are ready, the plaster can be applied as shown in Fig. 2. For this step the strike board is held horizontally and moved from side to side as it is pushed up the wall, smoothing the plaster.

THE AGGREGATES

Regardless of where the sand for the plaster or render comes from, it must be clean and suitably graded (Reference Book, page 159, and pages 147 to 151).

Sand for rendering should be sharp and well graded, from fine to very coarse. The mortar may be difficult to apply, but nevertheless this is the best way to get a rendering that will not crack and let water in.

Sand for plastering should be well graded, from fine to fairly coarse; and for a finishing coat from fine to medium. Well graded sand reduces the drying shrinkage and cuts down the danger of cracking and crazing. Crazing means the formation of hairline cracks on the surface of concrete, plaster or render; usually it is caused by too much water in the mix, or by a too rich mix.

MIX PROPORTIONS

In Rural Building, most of the mortars used for plaster and render are cement mortars, because lime is not always available.

The mix proportion for plaster ranges from 1:8 to 1:12, depending on the condition and grading of the sand. Both coats should have the same strength as far as possible if two coats are applied.

The mix proportion for render can vary from 1:6 to 1:10. It is generally agreed that the sides of the house which are exposed to rain should have a better mix. However, the mix proportion should never be better than 1:6, and should be adapted if possible to the strength of the background (Reference Book, pages 158 to 165).

ADDITIONAL PROTECTIVE MEASURES

When the plaster or render has set hard and has dried, it is advisable to paint the whole surface with emulsion paint (Reference Book, page 201).

If lime is available (Reference Book, page 152 and page 200) the walls are first white-washed to fill up the tiny holes in the surface. After this the emulsion paint is applied in two coats. The paint prevents water from penetrating into the plaster or render; reflects light and thus keeps the walls cooler, and gives the house an attractive appearance.

When emulsion paint has dried, it will not dissolve in water, so it can easily be cleaned with water and a soft brush.

- REMEMBER: Sand for plaster and render should be clean, properly graded and as coarse as is appropriate for the particular application.

  Joints should be carefully raked out while the mortar is still fresh, so that the plaster or render can grip well. Another method is to apply a spatterdash to the wall to give a good grip to the plaster or render.

  No coat should be richer than the coat underneath it. If you have to make two of different strengths, then the undercoat should be stronger than the finishing coat. Try to avoid making two coats of plaster or render, because it is difficult to get a good connection between the two coats. The spatterdash is not a coat, it is a background for the plaster or render.

NOTES:

SPATTERDASH

Spatterdash can be used to produce an attractive appearance, or it can be applied before plastering in order to make a good surface for the plaster or render.

Spatterdash is a wet, rich mix of cement and sand, called a slurry. This sand and cement is mixed to a proportion of 1:1,5 or 1:3. This slurry is thrown hard, or spattered, against the smooth block or concrete surface, and then allowed to harden (Fig. 1).

When you work with this hand operated machine (Reference Book, page 29), do not overload the machine with material. It is better to use small quantities at frequent intervals. All of the slurry must be used within 1 hour of the time it is mixed.

Do not set the flicker bar adjuster beyond the second notch when the machine is new. Only when the bar wears out should it be set to a lower notch (Fig. 2).

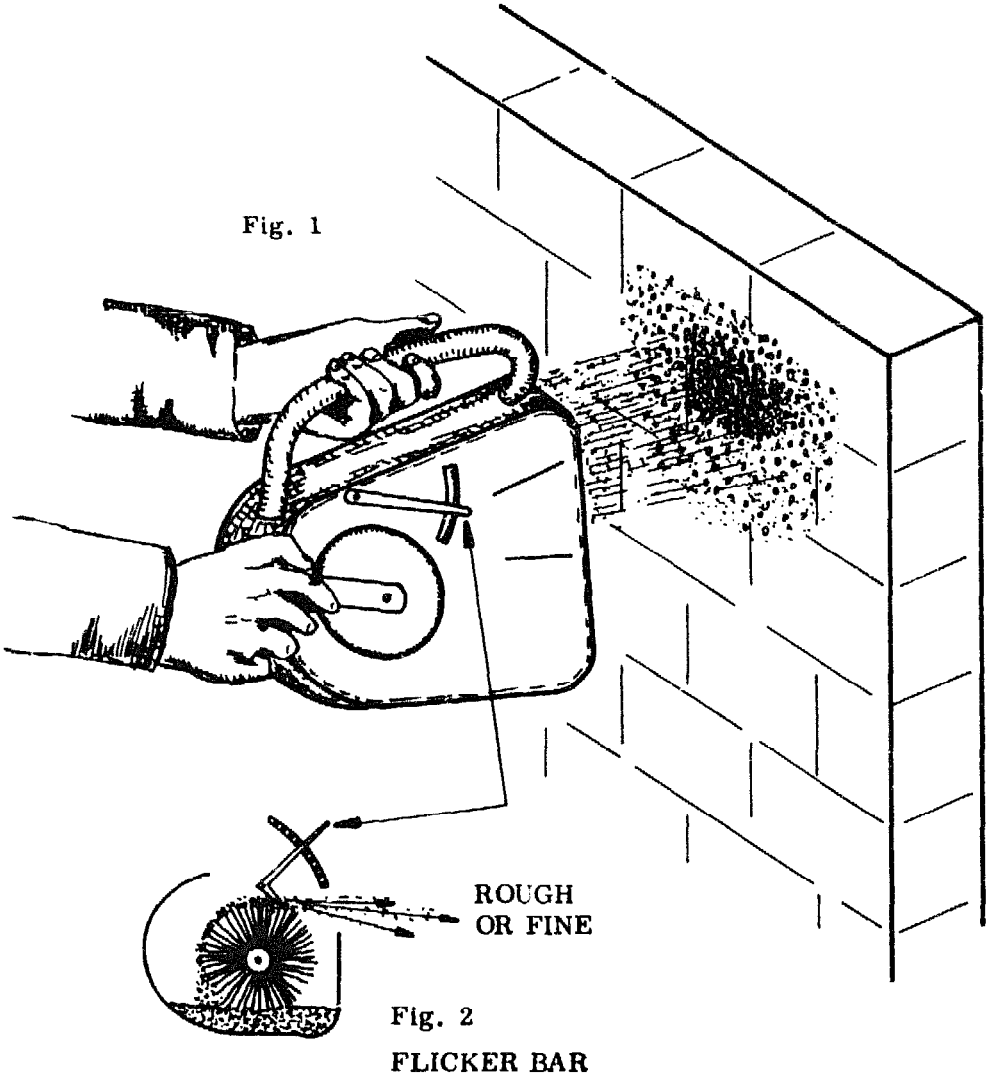

Fig. 1

Fig. 2
FLICKER BAR

FLOOR CONSTRUCTION

The dry climate in the north of Ghana makes it advisable to construct the floor after the roof covering has been completed. This makes it easier to cure the concrete, and to make sure that the floor sets hard without cracking due to excessive drying. There are various methods to construct floors. In Rural Building the main ones are: one-course work, and two-course work.

ONE - COURSE WORK

This means that the final surface finish is completed before the base layer has set hard. The result is a monolithic floor construction; which means that the floor throughout can be considered as one solid mass (Fig. 1). The advantage of this method is the short construction time, using a minimum of materials, and no separation between the top layer (screed layer) and the base layer.

TWO - COURSE WORK

This means that the base layer and the finish layer are constructed separately. After the base layer has set hard, a floor screed is applied. This is a fine-grained mortar layer, about 2 cm thick, laid to finish the floor surface (Fig. 2).

The advantage of this method is that any faults in the base layer, such as cracks, can be covered. However, it takes longer to construct and requires more cement. Another disadvantage is that it can be difficult to get a good connection between the base layer and the floor screed. The base layer should be carefully treated with cement and water to form a good connection between the floor screed and the base layer.

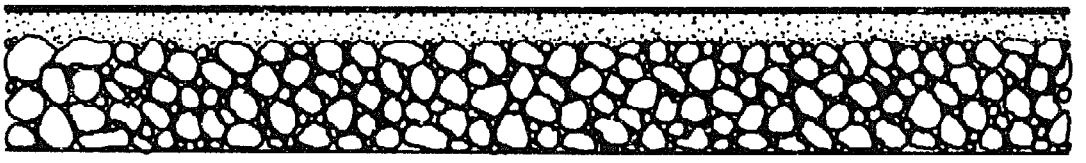

Fig. 1 ONE - COURSE WORK

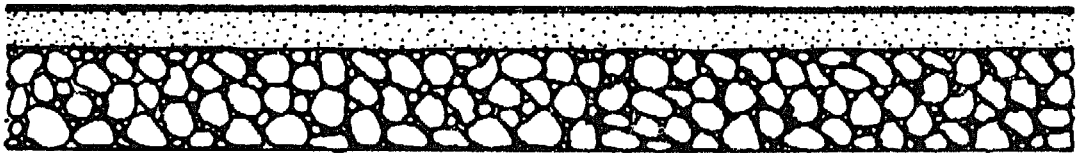

Fig. 2 TWO - COURSE WORK

CASTING METHODS

If a floor area is larger than approximately 10 square meters, the area should be divided into bays for concreting. A bay is one of several uniform divisions of a concrete floor which are cast at any one time.

The bays are separated by edge boards, which are laid and levelled to the required floor thickness. The edge boards act as a guide for the strikeboard to level off the concrete surface, therefore they must be laid and levelled with great care.

On the drawing below you can see the positions of the edge boards when the floor is divided into six bays. The boards should be arranged as shown so that the corners of the concrete bays will match each other when the floor is complete.

The division of the floor into bays helps to prevent the development of cracks due to shrinkage during the hardening process. The smaller the area, the less the shrinkage, and the fewer cracks will appear. Square-shaped bays are the best because all the sides will shrink by the same amount.

Bays also make the construction process easier. The bays are small enough to be cast, levelled and finished within a manageable time. The work can be interrupted to allow the already completed bays to harden. Then the edge boards are removed and the empty bays are cast, using the completed ones as a guide. Once you start casting a bay, it must be completed. Never interrupt a concreting process, as this can result in a faulty bond and the joint will always be visible. For the sequence of operations for casting a floor see Figs. 1 to 8 on the following two pages.

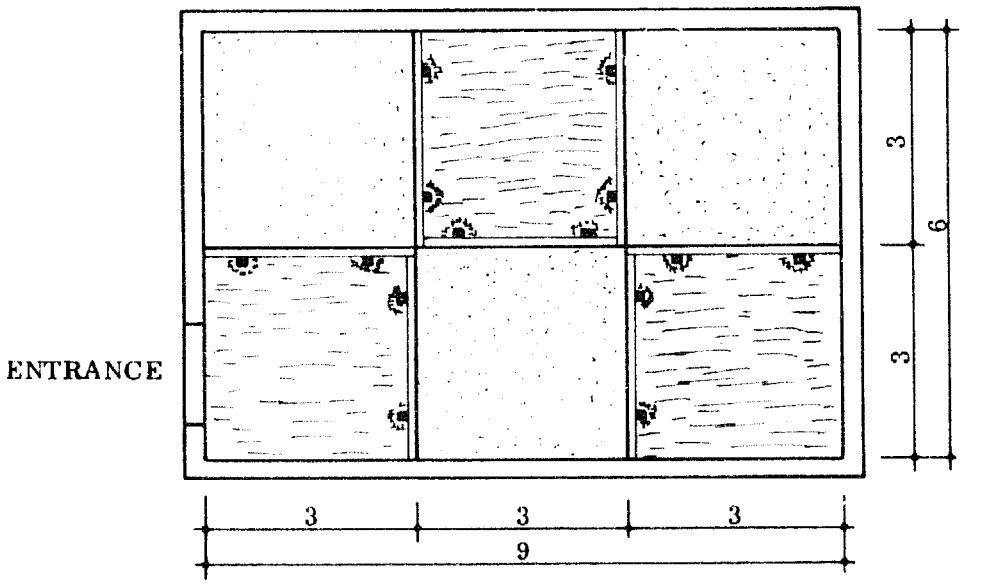

DIVISION INTO BAYS

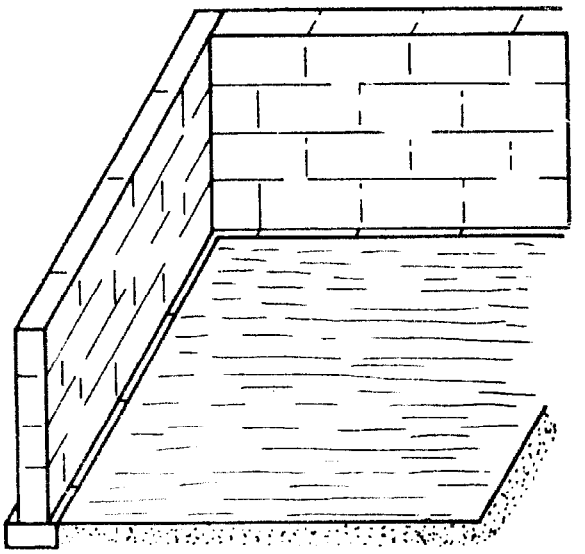

Fig. 1

- CLEAN THE AREA
- CLEAN THE EDGES OF THE FOOTINGS
- LEVEL THE AREA WITH A SHOVEL

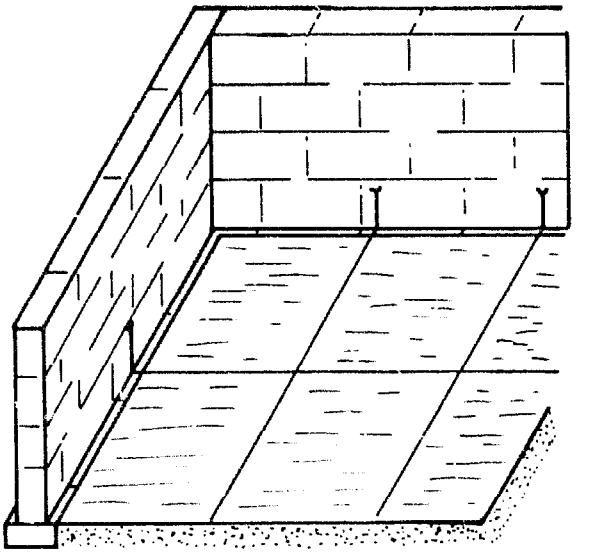

Fig. 2

- MARK THE BAYS ON THE WALLS
- SET OUT THE POSITIONS OF THE EDGE BOARDS ON THE GROUND

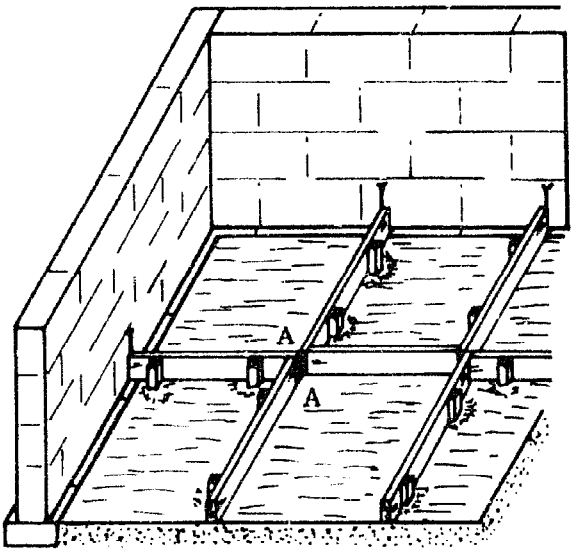

Fig. 3

- FIX THE EDGE BOARDS WITH PEGS
- LEVEL THE TOPS OF THE EDGE BOARDS
- THE CORNERS SHOULD MATCH (A to A)

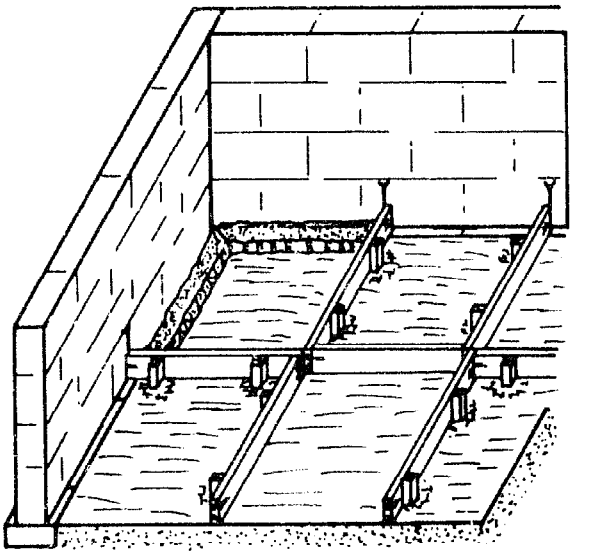

Fig. 4

- POUR GUIDE STRIPS TO THE HEIGHT OF THE BASELAYER
- LEVEL THE GUIDE STRIPS

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FLOOR CONSTRUCTION.

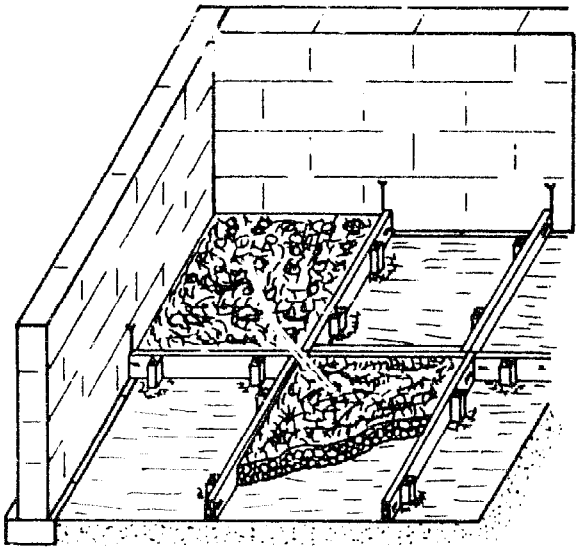

Fig. 5

- POUR THE BASE LAYER AND TAMP IT DOWN WITH THE RAMMER TO THE REQUIRED LEVEL

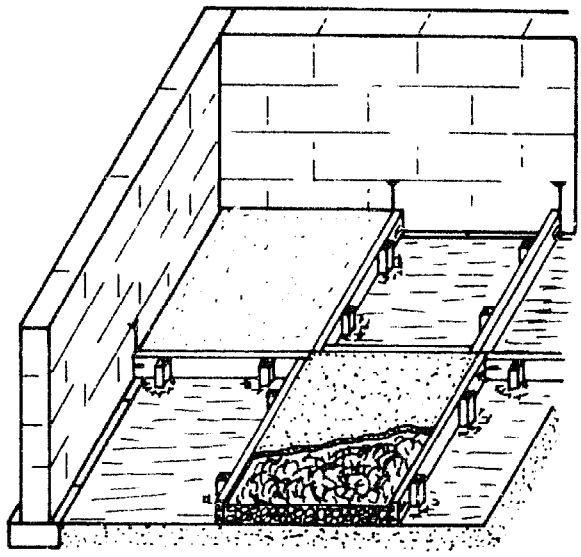

Fig. 6

- LAY THE FLOOR SCREED LAYER (FAIRLY DRY MIX) AND TAMP IT DOWN WITH THE WOOD FLOAT UNTIL MOISTURE COMES THROUGH

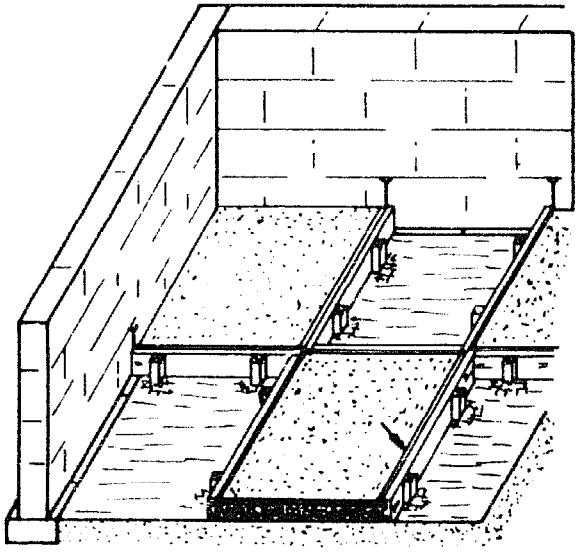

Fig. 7

- FINISH OFF THE TOP WITH THE TROWEL OR STEEL FLOAT
- MAKE A BEVEL ALONG THE EDGES FOR THE SHRINKAGE JOINTS (ARROW)

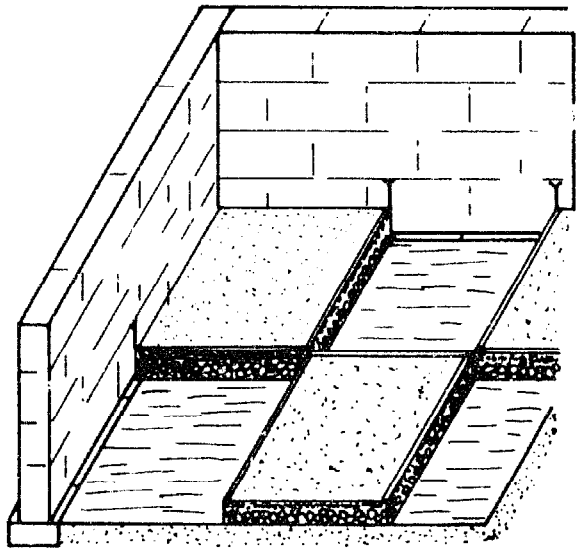

Fig. 8

- TAKE AWAY THE EDGE BOARDS AND PUT SAND ON TOP OF THE FLOOR
- WATER THE FLOOR REGULARLY

FLOOR CONSTRUCTION.

N P V C	
JOB.	182

SHRINKAGE GAPS

When one set of bays has hardened, the edge boards are carefully removed and the remaining bays can be cast. Shrinkage gaps are made between the adjoining bays. This is done by placing plastic or paper between the bays when the second set of bays is cast, so that the bays are kept separate from each other.

The shrinkage gaps allow the concrete bays to shrink a bit as they harden without cracking. This type of gap is used where the floor is not exposed to the sun or to great temperature changes; usually only for inside floors. Shrinkage gaps can be made in either one-course work or two-course work. A "V" is made along the top edges of the gap to improve the appearance of the floor (Fig. 1).

EXPANSION GAPS

Where the floor is exposed to the sun, as in a verandah floor or any concreted area outside the house itself, expansion gaps have to be made. In this case the edge boards are not removed until all the bays have been cast and hardened. The boards are then removed and the gap between the bays is filled with wet sand, and the floor screed is applied over the top (Fig. 2). Expansion gaps can only be made in two-course work.

The expansion gap allows the floor to expand and contract with the temperature changes without forming cracks. Expansion occurs when the floor is heated by the sun during the day, and shrinkage occurs at night when it cools down. Floors exposed to the sun should be divided into bays of no more than 5 square metres, and expansion gaps should be made in them. The floor screed must also be provided with a shrinkage gap; this should be located directly above the expansion gap in the base layer (Fig. 2).

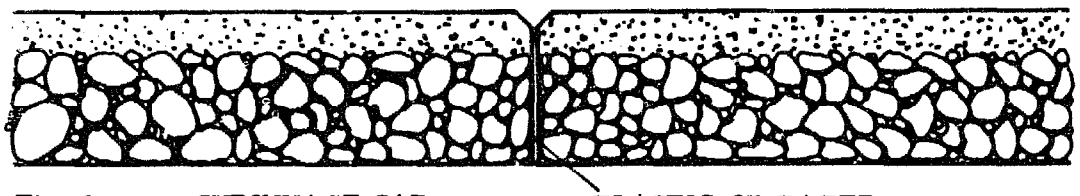

Fig. 1 SHRINKAGE GAP

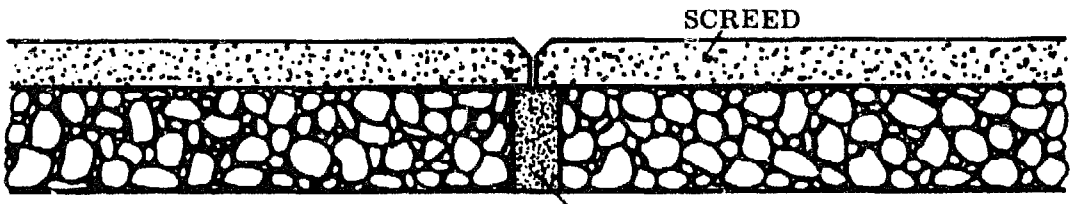

Fig. 2 EXPANSION GAP

A WORD FOR THE TRAINEE BEFORE ON-THE-JOB TRAINING

With the basic knowledge you have gained in this part of the course, you should now be prepared to go to a building site for on-the-job training.

Remember that so far you have covered only the first part of the course. You will still need to acquire much more knowledge and many more skills before you can be called a Rural Builder.

While you are working at the building site, remember that this time is also supposed to be a learning experience. If you want to learn, you have to ask questions about how and why certain things are done. If you can't get your questions answered at the time, write them down and bring them to your instructors for explanation. It is a good idea to keep a notebook; writing down in it the methods you applied at the building site, the time that a certain operation required, the materials used and how much was needed, and any ideas you have about how it could have been done differently.

You should occasionally review the information in this book, especially as it comes up on the job. Don't be afraid to use the book and to write notes in it; the notes which you make at this time can be very helpful to you later on, when you have finished the course and are working as a builder.

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Rural Building Volume 3: Construction

By: J. van Winden

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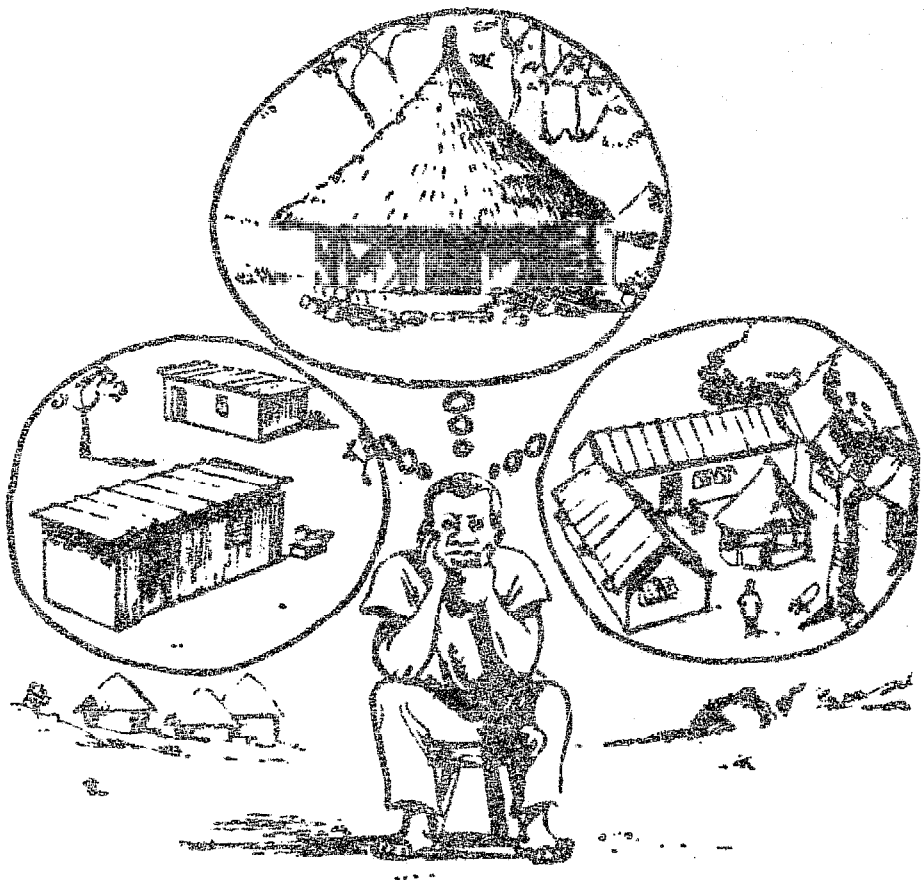

CONSTRUCTION

RURAL BUILDING

VOLUME 3

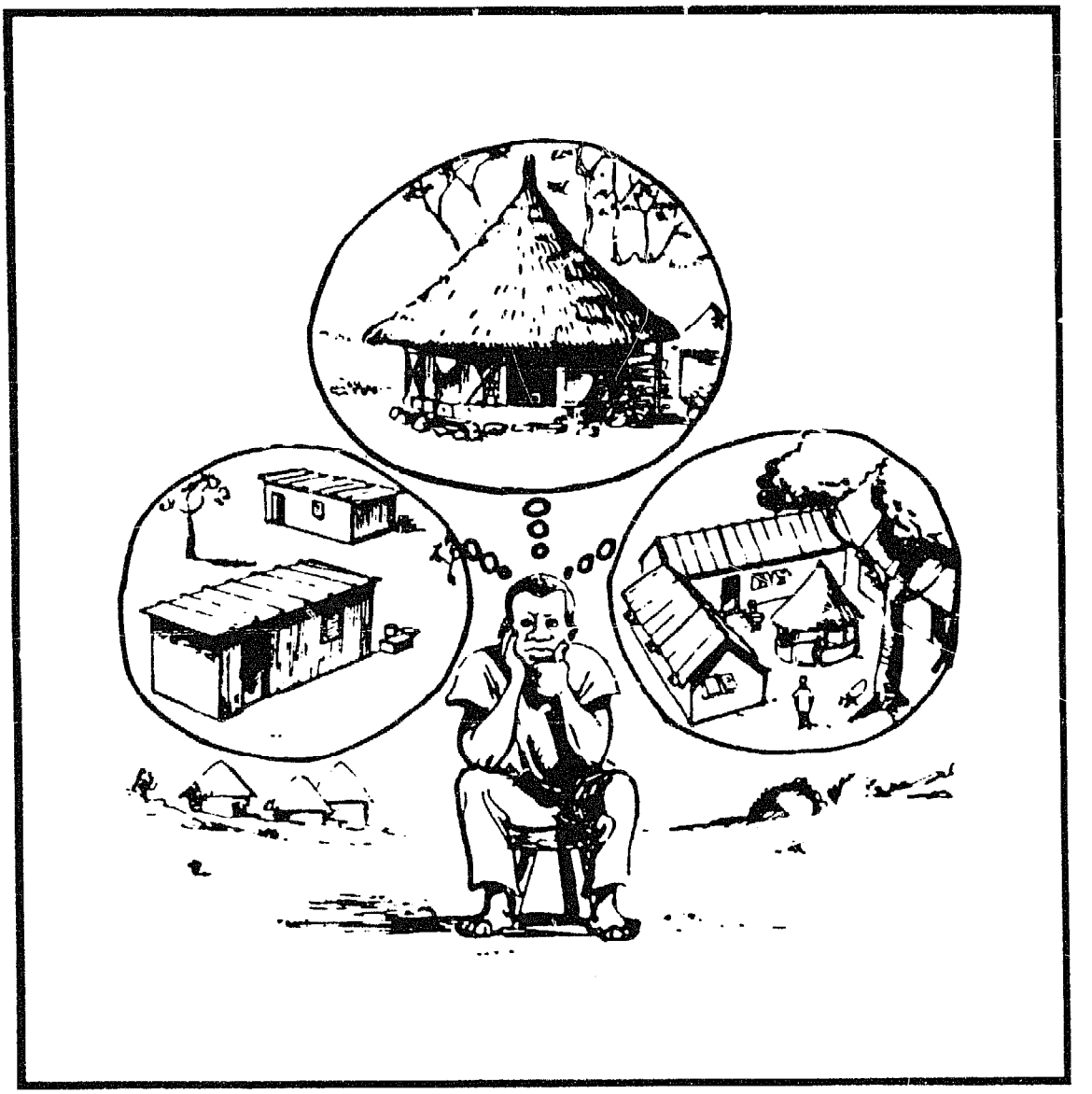

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PREFACE

In response to the many requests by people involved in technical vocational training and in general development work, we have decided to publish a second edition of the Rural Building Course.

The main aim of this set of books is still to provide technical training information in understandable language and with illustrations suited to the understanding of those involved.

Except for a few corrections, the text and illustrations are the same as in the first edition. The binding of the technical drawing book was revised and the size of the books reduced for economy reasons.

We are grateful to the Stichting Brothers F.I.C., Stichting CEBEMO and Mensen In Nood for their assistance in the re-printing of these coursebooks.

It is our sincere wish that the contents of these bocks may be of assistance to stimulate the use of appropriate techniques in Rural Building and General Development.

Bro. John van Winden F.I.C.

INTRODUCTION TO A RURAL BUILDING COURSE

Vocational training in Rural Building started in the Nandom Practical Vocational Centre in 1970. Since then this training has developed into an official four year course with a programme emphasis on realistic vocational training.

At the end of 1972 the Rural Building Course was officially recognised by the National Vocational Training Institute. This institute guides and controls all the vocational training in Ghana, supervises the development of crafts, and sets the examinations that are taken at the end of the training periods.

The Rural Building programme combines carpentry and masonry, especially the techniques required for constructing housing and building sanitary and washing facilities, and storage facilities. The course is adapted to suit conditions in the rural areas and will be useful to those interested in rural development, and to farmers and agricultural workers.

While following this course, the instructor should try to foster in the trainee a sense of pride in his traditional way of building and design which is influenced by customs, climate and belief. The trainee should also be aware of the requirements of modern society, the links between the old and new techniques, between traditional and modern designs -- and how best to strike a happy medium between the two with regard to considerations like health protection, storage space, sewage and the water supply. The trainee should be encouraged to judge situations in the light of his own knowledge gained from the course, and to find his own solutions to problems; that is why this course does not provide fixed solutions but rather gives basic technical information. The instructor can adapt the course to the particular situation with which he and the trainee are faced.

This course is the result of many years of work and experimentation with different techniques. The text has been frequently revised to serve all those interested in Rural Development, and it is hoped that this course will be used in many vocational centres and communities. It is also the sincere wish of the founders of this course that the trainees should feel at the completion of their training that they are able to contribute personally to the development of the rural areas, which is of such vital importance to any other general development.

We are grateful to the Brothers F.I.C., the National Vocational Training Institute and the German Volunteer Service for their assistance and support during the preparation of this course.

Bro. John v. Winden (F.I.C.)
Wolfram Pforte (G.V.S.)
Fritz Hohnerlein (G.V.S.)

LAY-OUT OF THE RURAL BUILDING COURSE

The Rural Building Course is a block-release-system course, which means that the trainee will be trained in turn at the vocational centre and at the building site. The period of training at the centre is called "off-the-job" training, and the period on the building site is called "on-the-job" training. Each will last for two years, so that the whole course will take four years and will end with the final test for the National Craftsmanship Certificate.

BLOCK RELEASE SYSTEM

YEAR	TERM 1	TERM 2	TERM 3
1	X	X	X
2	O	O	O
3	O	X	O
4	X	O	X

X = OFF-THE-JOB TRAINING
O = ON-THE-JOB TRAINING

The total "off-the-job" training period is approximately 76 weeks, each week 35 hours. During this training about 80% of the time is spent on practical training in the workshop. The remaining 20% of the time is devoted to theoretical instruction.

The total "on-the-job" training period is approximately 95 weeks, each week 40 hours. During this period the trainee does full-time practical work related to his course work. In addition some "homework" is assigned by the centre and checked by the instructors.

A set of books has been prepared as an aid to the theoretical training:

A - Rural Building, Basic Knowledge (Form 1)
B - Rural Building, Construction (Forms 2, 3, 4)
C - Rural Building, Drawing Book (Forms 1, 2, 3, 4)
D - Rural Building, Reference Book

All these books are related to each other and should be used together. The whole set covers the syllabus for Rural Building and will be used in the preparation for the Grade II, Grade I, and the National Craftsmanship Certificate in Rural Building.

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BOOK INTRODUCTION

Rural Building Construction is your main construction book. It is built up in the same logical way that a house is built up: starting with the preliminaries of setting out and ending with the roof construction, hanging the doors, and the finishing.

Because of the structure of the training course, it might sometimes be necessary for the instructors to rearrange this sequence and treat certain working methods either earlier or later in the course (for example, plastering is done late in the construction of a building, but it might have to be treated quite early in the actual Centre training). In any case the instruction should follow the current Rural Building syllabus, and the instructor should pick out the chapters which need to be covered according to the syllabus.

There is room for the instructor to add his own ideas, knowledge and experiences concerning the local ways of building, and to adapt the lessons to the local circumstances. The trainee should be able to adapt the knowledge he has gained to the requirements of the rural areas.

In order to work with this text book, you should be familiar with drawing techniques so that you can understand the sketches and drawings. Don't be afraid to make notes and sketches in the book: the notes made here can be helpful to you again and again in your future building career.

- The tools and materials mentioned in this book are described and explained in the Rural Building Reference Book. Some figures essential for the Rural Builder are given in the Tables of Figures at the end of the Drawing Book.
- All measurements, figures and constructions given and explained in this book are made in accordance with the standard sizes of timber, steel, etc. which are commonly used in Ghana.

The appendix gives some basic designs and construction information for water filters, wells, sanitation systems, and a silo for improved grain storage.

BUILDING PRELIMINARIES

SITE SELECTION

When choosing the location of the planned building, the responsible builder will strongly advise his client to avoid building on valuable farm land, if possible.

Most Rural Builders come from farming communities; they are building for farmers, and they also do farming themselves. Thus they are very conscious of the land and know that good land should never be wasted by building on it.

Moreover, the Rural Builder is aware that there are a number of advantages in building on higher, stony areas not suitable for farming.

Some of the advantages are:

- The higher the building is situated, the healthier and more comfortable it will be to live in, because of the better ventilation and the reduced danger from dampness rising from the ground.
- Building materials such as stones and laterite are often available on the spot, and do not need to be brought from far away.
- The soil in higher areas is more likely to be the desired type to form a firm base for the house. This makes the construction of the foundations easier, and reduces the amount of building materials required, keeping the costs lower.

Some disadvantages are:

- Excavations will require more effort.
- Be aware of sliding soil in case of a slope.

NOTES:

- Foundations should be on soil of rock of the same nature to avoid differences of settlement.

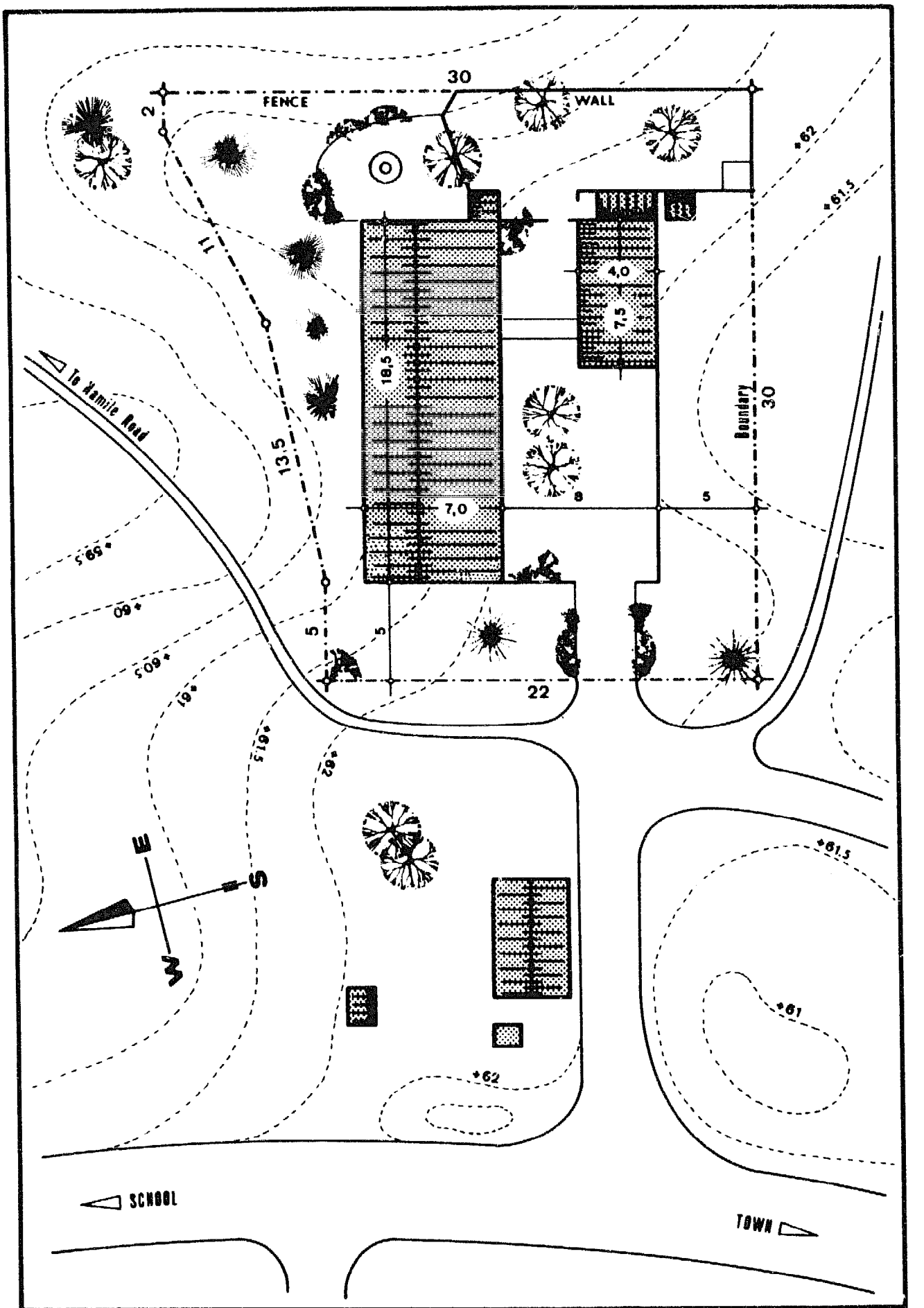

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BUILDING PRELIMINARIES.

LOCATION PLAN

When building a house or any other structure one must have certain information available, in order to arrive at the best and most economical result.

The most basic information is the location, size and nature of the plot. This is contained in the location plan, which shows the plot and the immediate surroundings in scale. The scale can be from 1:200 up to 1:1000, depending on the size of the project.

The plan outlines the shape of the plot and the dimensions of its boundaries, as well as the location of the future building. It should also show the nature of the area, because it is very important to know whether the site is sloping or if the ground is uneven.

Roads, drive ways and the positions of the bigger trees are also marked on the location plan (Fig. 1).

In Rural Building, location plans are often not available, so in order to get the necessary information, both the client and the builder have to examine the plot thoroughly. Important matters such as the best position for the future building are discussed and decided on the spot.

When the site has been examined thoroughly and all the measurements and particulars have been obtained, the drawings for the house can be prepared.

- NOTE: Before the building can be started, all the required drawings have to be ready, and at the disposal of the foreman. Before you can prepare any drawings, you need to have all the particulars of the site.

NOTES:

WORKING DRAWINGS

The working drawings are the drawings which the builder uses before the construction starts and during the construction; to plan for materials requirements, to plan the work; and finally to carry out the construction according to the directions contained in the drawings.

The drawings include "plans", "cross sections", "elevations", and "detail drawings". They are all prepared in scales which are suitable to the particular drawing. The first three types of drawing have a scale of between 1:50 and 1:20.

- PLANS: A plan is a view that shows a certain layer or horizontal section of a building as if it were looked at from above (see Drawing Book, page 55). The plans usually include the "floor plan", which shows the walls, positions of the doors and windows, etc. (Drawing Book, page 54); the "foundation plan" gives the dimensions of the foundations and footings; and the "roof plan" which shows the shape of the roof and its dimensions. The floor plan and the foundation plan are often combined into one drawing.
- CROSS SECTIONS: A cross section is a drawing which shows the inside of the structure, as if the building were cut into two (see the Drawing Book, pages 61 and 62). The exact position where the cross section is taken has to be shown on the plan.
- ELEVATIONS: These are the views of the building as it would look from the outside (see pages 59 and 60 in the Drawing Book).
- DETAIL DRAWINGS: These show members or portions of the structure in a larger scale than the other drawings; such as 1:10, 1:5, 1:2,5, etc. Detail drawings are made when:
  - There is not enough space in the other drawings to clearly indicate all the required measurements.
  - The member of the structure is too small to be properly shown in the other drawings.
  - The member has a complicated shape and more views or cross sections are needed to explain it (see Drawing Book, page 84).
  - Important construction hints have to be pointed out.
  - The member is built up from several different materials.

The working drawings have to show the various materials used in the structure (see Drawing Book, pages 49 to 50). This enables the builder to make a list of

the materials that will be required and the amount of each material (see the Reference Book, Tables of Figures, pages 234 to 240.

When this is done the builder can estimate the cost of the building and order the materials he will need. Ordering materials has to be done in advance so that the materials are there when they are needed.

PLOT AND SITE CLEARING

Once the planning work has been completed, the plot and site both have to be prepared for the setting out. The location plan shows exactly from which areas the trees, bushes, grass and stones must be removed. The ground is levelled. The part of the plot which is cleared will be the actual site that the future building will occupy, including a space of about 5 m all around the building.

One very important measure is to remove all the tree roots from the site area. If the roots remain, they will sometimes grow again and might damage the structure. This is particularly true with the roots of the neem tree.

Clearing does not mean that all the trees on the whole plot are removed. Beyond the 5 m clear space, as many trees as possible should be allowed to remain, because they will provide shade for the people using the building or living there.

SITE ORGANIZATION

The first step in organizing the site is deciding where to make the driveway.

Next, choose the area where the building materials will be stored and arrange the storage facilities. Certain materials like sand and stones may have to be located, excavated, and transported to the site. This can be done as soon as the storage areas are located.

The building materials should not be stored too far away from the working place, nor should they be too close.

Space has to be provided for making blocks, and for mixing concrete and mortar. This also should not be too close to the future building.

The same applies to any temporary work sheds or storage sheds that are erected.

NOTES:

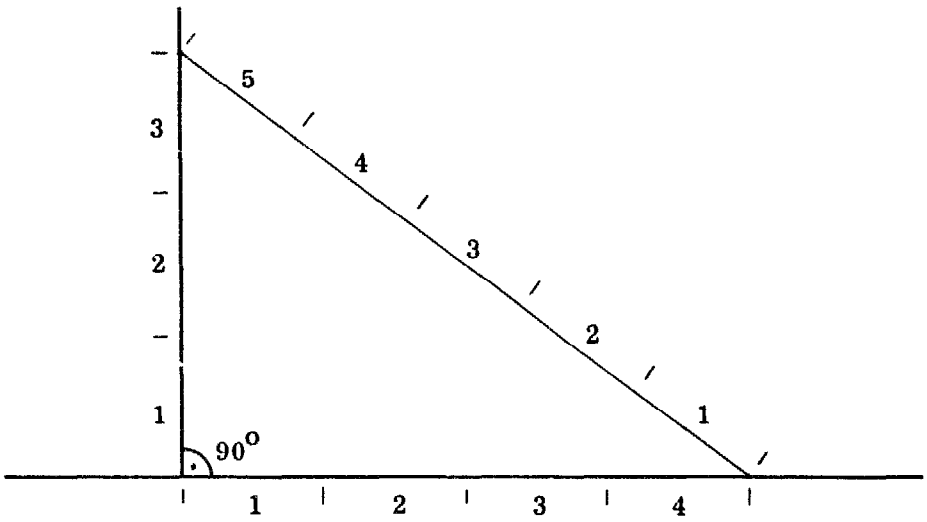

Fig. 1 3 - 4 - 5 METHOD

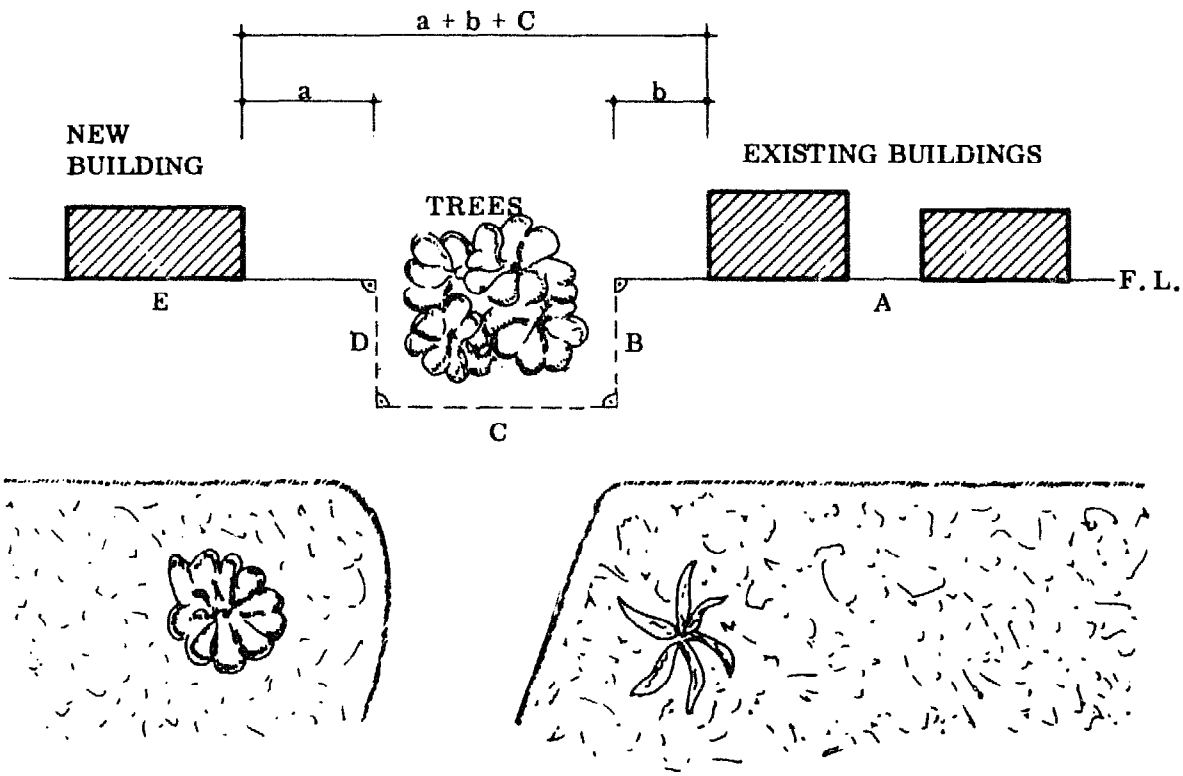

Fig. 2

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BUILDING PRELIMINARIES & SETTING OUT.

WATER SUPPLY

Any kind of building would be impossible without water. Therefore one of the main tasks of the builder is to provide a guaranteed supply of clean water.

Usually piped water is not available, so it is advisable to build a simple water tank, or else dig a well if this is possible (see the Appendix, pages 277 to 281).

The water tank should be located so that after construction is completed it can be used to store rain water collected from the roof. The best site will be close to either gable end of the house so that the rainwater from the gutters can be fed into the tank directly.

Investigate the possibilities for digging a well, as this would eliminate the need to transport water and thus cut down on unnecessary effort and cost.

SETTING OUT

Once the plot and site clearing is completed, the setting out can be done: first mark the frontline of the building and from there mark all the other lines using the 3-4-5 method described in the Basic Knowledge book, page 142.

However, not all sites are conveniently flat and level, and the Rural Builder will frequently face more difficult situations. While the construction of a right angle remains the same, the measurement of distances and the determination of directions might sometimes be difficult.

There is also the case where there are trees or other buildings which should remain, but which are in the way when we are making a particular measurement.

INTERFERING OBJECTS

Provided that you have mastered the 3-4-5 method, it is relatively easy to by-pass interfering trees or buildings in setting out: it only requires a bit more time to construct the additional angles (Fig. 1).

Fig. 2 illustrates an example: the frontline of the existing buildings must be maintained in the new building, but it is difficult to set out directly because there are trees which are in the way. Rather than cut the trees down, we can by-pass them.

From the frontline of the existing buildings (line A), set out line B, using the 3-4-5 method, perpendicular to line A. Then construct lines C and D using the same method, followed by line E which is the front line of the new building. Check that line C plus the distance "a" and "b" all add up to the total planned distance between the new building and the existing buildings (Fig. 2).

Fig. 1

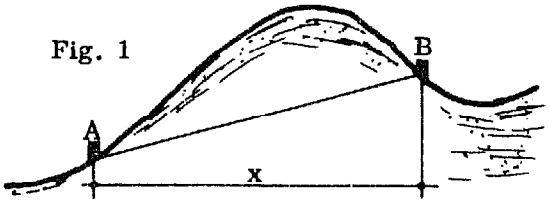

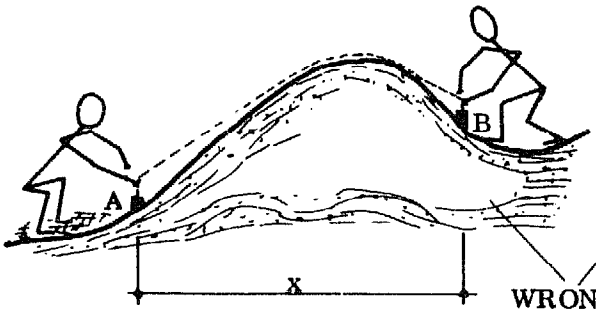

Fig. 2

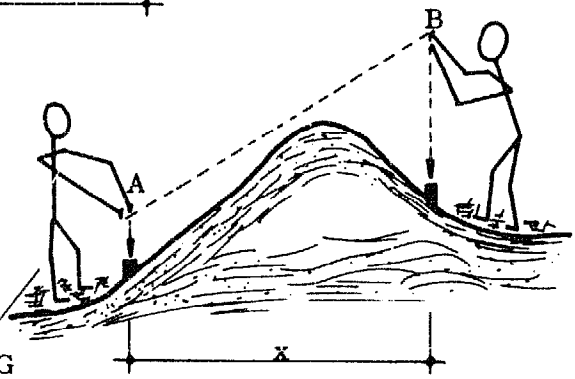

WRONG

Fig. 3

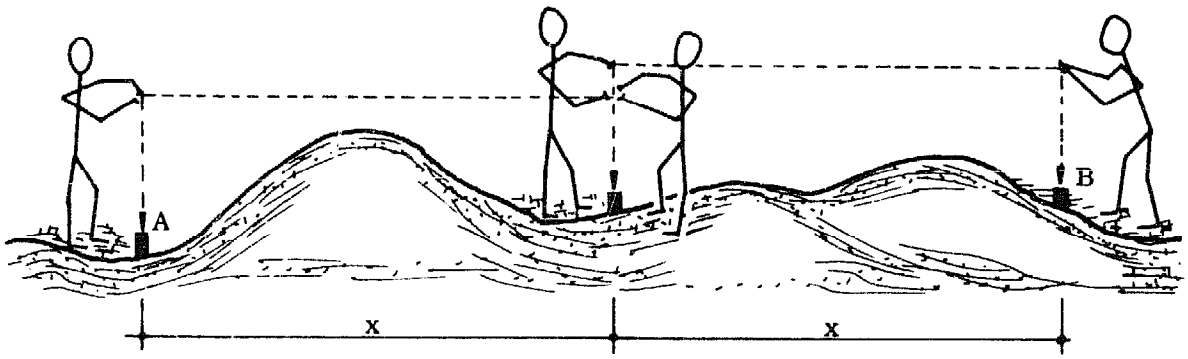

Fig. 4

CORRECT

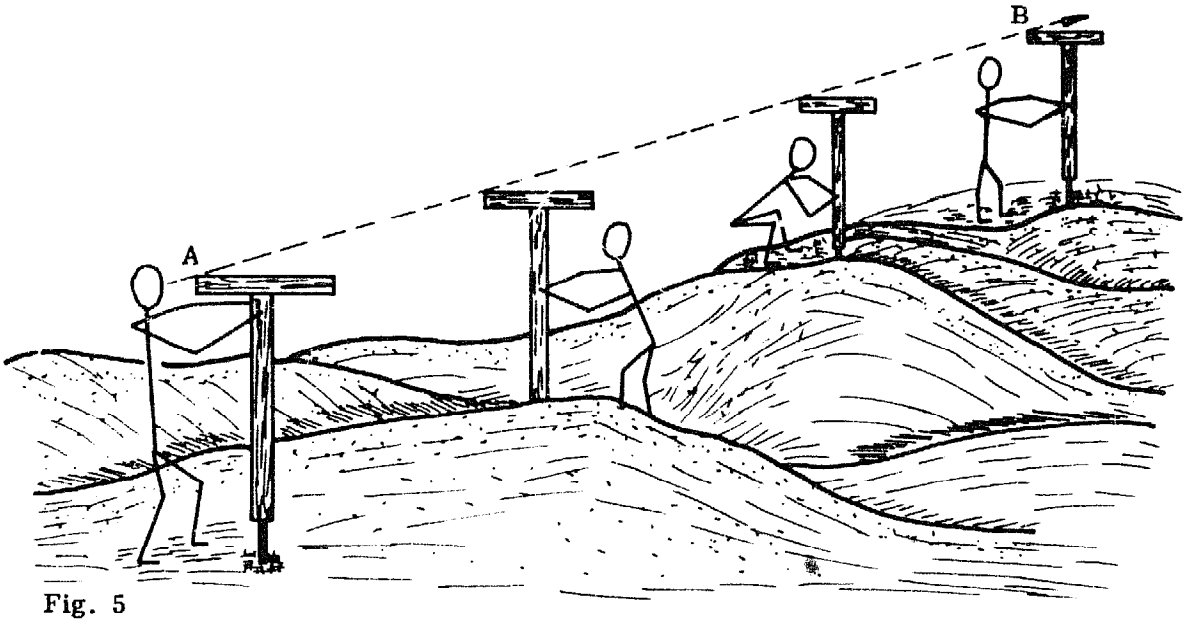

Fig. 5

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SETTING OUT.

UNEVEN GROUND

Setting out on uneven ground, and particularly measuring distances, requires you to apply some simple geometry.

When we measure distances in setting out, we are actually looking for the horizontal distance between two points (Fig. 1, x). We don't measure the distance along a slope, because the house we want to build will not slope; it will have level floors and walls.

Since the ground is not flat, and the points are at different heights (point A is lower than point B), the horizontal distance between them has to be measured indirectly.

Fig. 2 shows two men trying to measure the distance between pegs A and B along uneven ground. Their result cannot be correct because the line they are holding is neither straight nor is it horizontal (measure "x" and compare it to the length of their line).

The men in Fig. 3 also fail to get the correct measurement. Their line is stretched taut and is therefore straight, but it is still not horizontal (measure "x" and compare it to the length of their line).

In order to find the true horizontal length "x", the line or tape measure has to be held horizontally and stretched taut so it is straight. Both ends of the line are kept vertically above the pegs A and B by means of plumb bobs (Fig. 4). This method as shown is a good rough method for short distances.

If a larger distance has to be measured, the work is carried out in intermediate steps of suitable lengths (Fig. 4).

For very large distances, the use of boning rods (Reference Book, page 25) can help to make sure that the different steps are in line and the total length measured is straight (Fig. 5). With the boning rods and a water level (Reference Book, page 25) you can also make sure that the whole distance is horizontal.

Use the water level to level between two boning rods; then any points in between can also be levelled by simply sighting along the boning rods (Fig. 5).

NOTES:

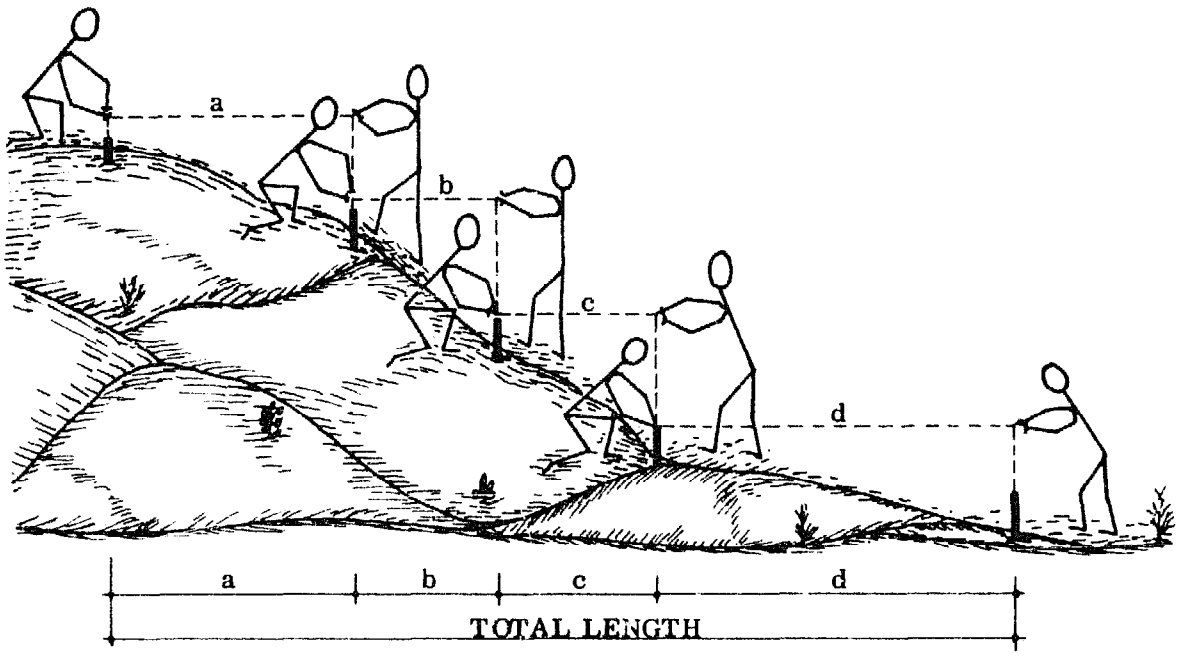

Fig. 1 MEASURING A DISTANCE ON A SLOPING SITE

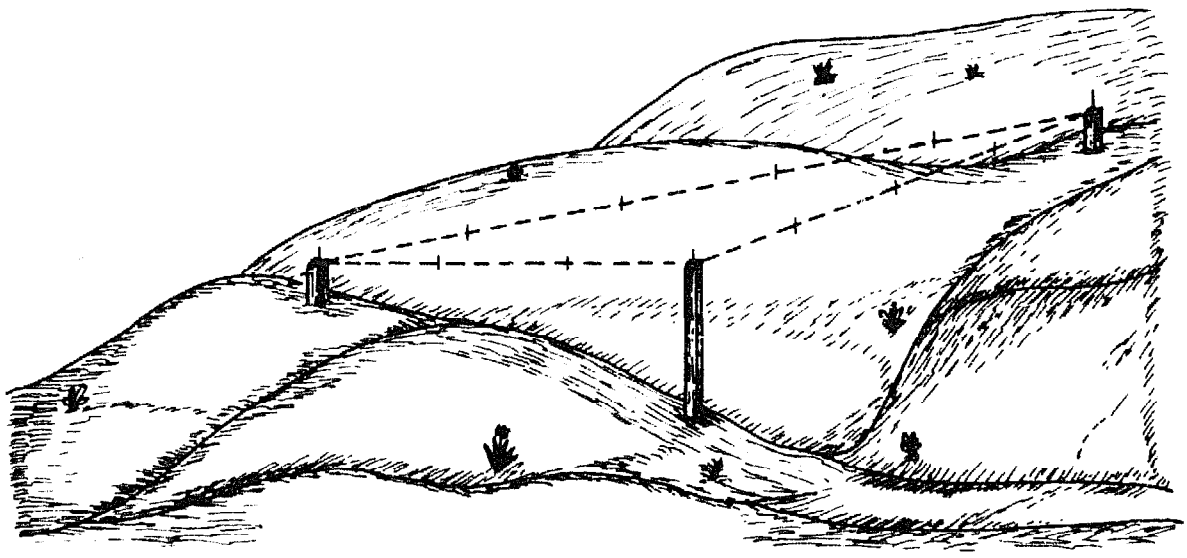

Fig. 2 3 - 4 - 5 METHOD ON A SLOPING SITE

SLOPING SITES

Setting out and measuring distances on sloping sites is simply the same procedure as explained in the section on uneven ground.

The work is carried out in steps (Fig. 1), with the line always held horizontally when measurements are taken.

The length of each section depends on how steep the slope is. The steeper the slope, the shorter the section, while slightly sloping areas allow longer sections (Fig. 1).

The construction of a right angle according to the 3-4-5 method is the same on a slope, as long as all the lines involved are straight. To see that this is true, take your try square and turn it around in your hands. You will observe that whatever the position of the try square, the angle is always the same, because the sides of the try square remain straight.

Even on a site which slopes in two or more directions (Fig. 2) it is possible to construct a right angle as long as the lines are straight and do not touch the ground. The pegs may have to be different lengths, in order to keep the lines off the ground.

Keep in mind that on sloping sites all lines stretched between the pins do not represent the horizontal length (unless they are also levelled) but only the future positions and directions of the walls, etc. (Fig. 2, see also Figs. 1 to 4 on the previous page).

The Rural Builder knows that the decision to build on a sloping site can have expensive consequences. There are some advantages such as easier sewage disposal, but the disadvantages are usually greater (Drawing Book, page 103).

NOTES:

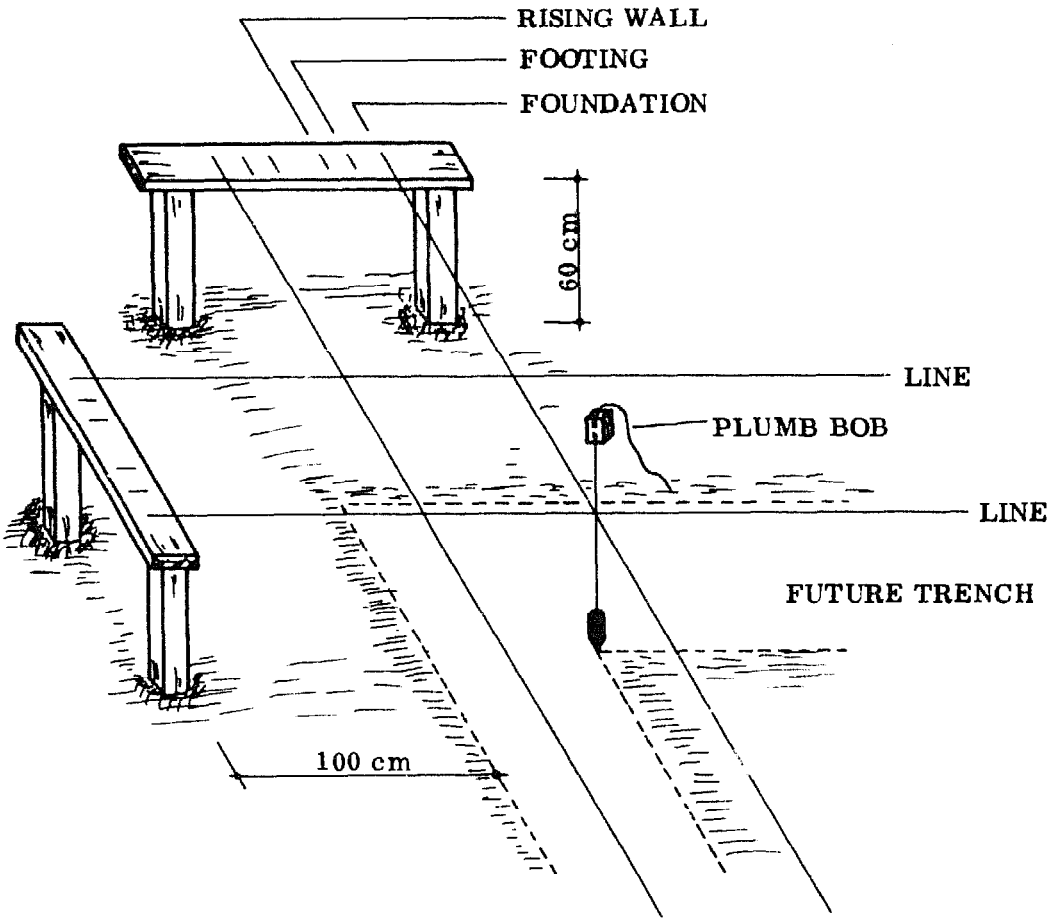

Fig. 1 MARKING THE POSITION OF THE FOUNDATION ON THE GROUND

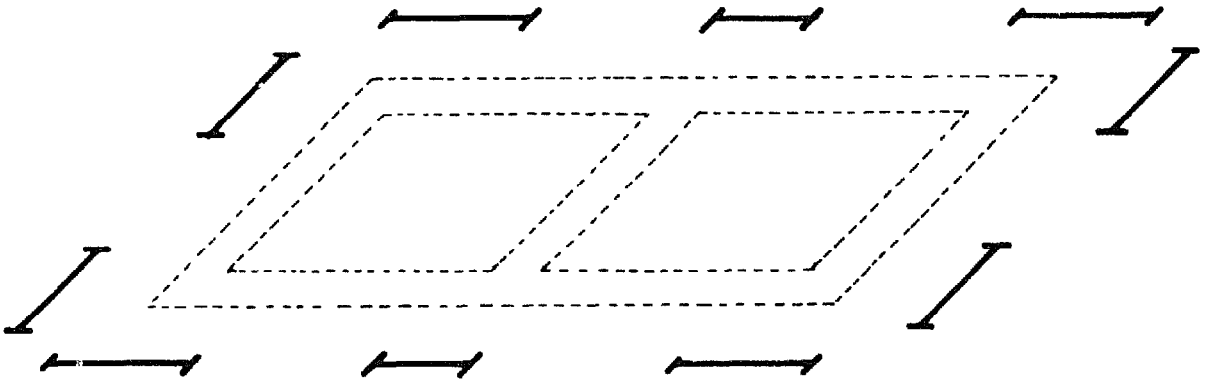

Fig. 3 POSITIONS OF THE PROFILE BOARDS

PROFILES

When the positions of the corners of the building are known, and the distances between them, then we can mark the positions and widths of the foundations as well as of the footings and plinth course.

This marking should be carried out in a relatively permanent way, so that it is accurate for a longer period. We do this by using profiles. A profile is a simple, temporary structure which maintains the correct locations of the various marks.

The profile consists of a board nailed flatwise on top of two pegs which are set in the ground, at a height of about 60 cm (Fig. 1). This height is necessary to lift the line well above the footings, so that later the plinth course can be marked from the profile.

If the soil is too hard to drive the wooden pegs into, then specially made iron pegs designed to receive a profile board can be used (Fig. 2). If these are not available, plain iron rods can be used, although they are less accurate since the lines are fixed directly onto the rods.

At the corners of the building, two boards are used, to mark in two directions (Fig. 3). To mark off the dividing walls, one board is used at each end of the future wall (Fig. 3).

The profiles are erected at a distance of about 1 m from the outside edge of the foundation (Fig. 1). Permanent divisions are marked on the boards to indicate the width of the foundations and the thicknesses of the footings and rising walls. The marks may be either saw-cuts or short nails, so that lines can easily be fixed to them as they are needed.

The positions of the foundations are then marked on the ground by plumbing down from the lines stretched between the profiles (Fig. 1).

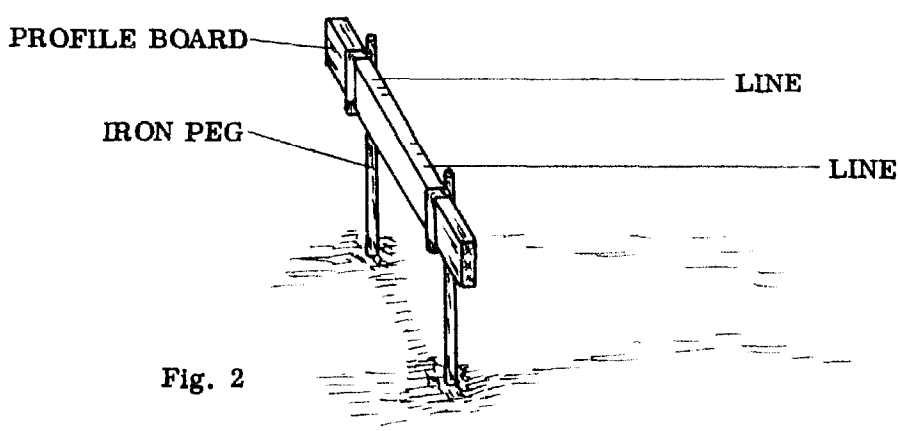

Fig. 2

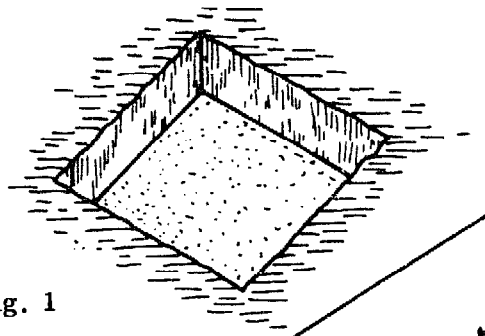

Fig. 1

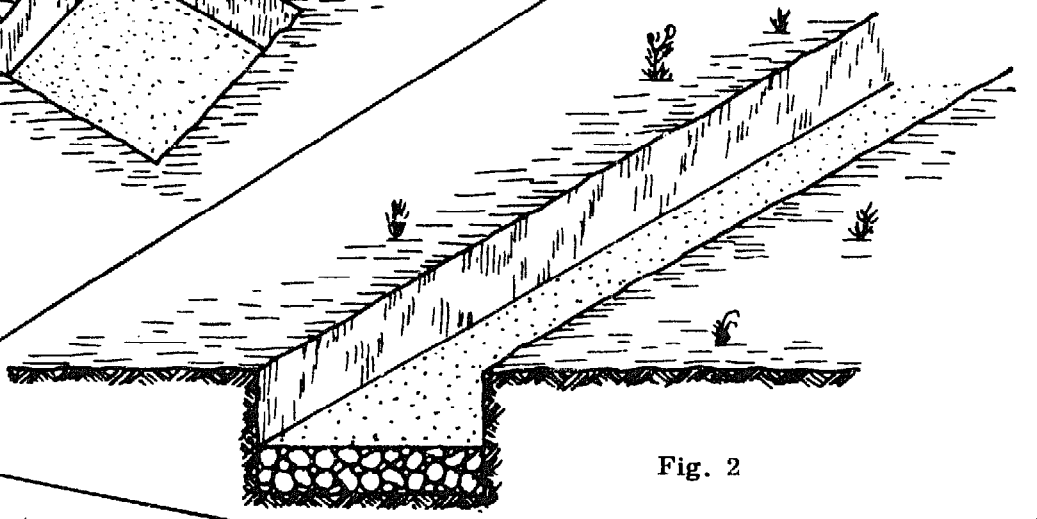

Fig. 2

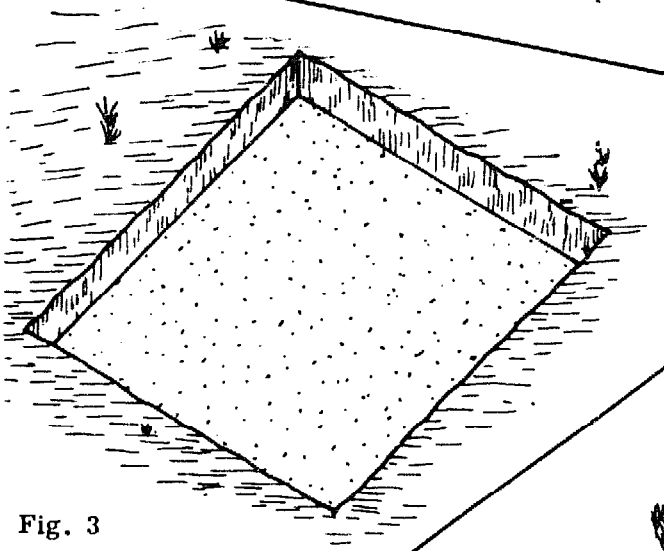

Fig. 3

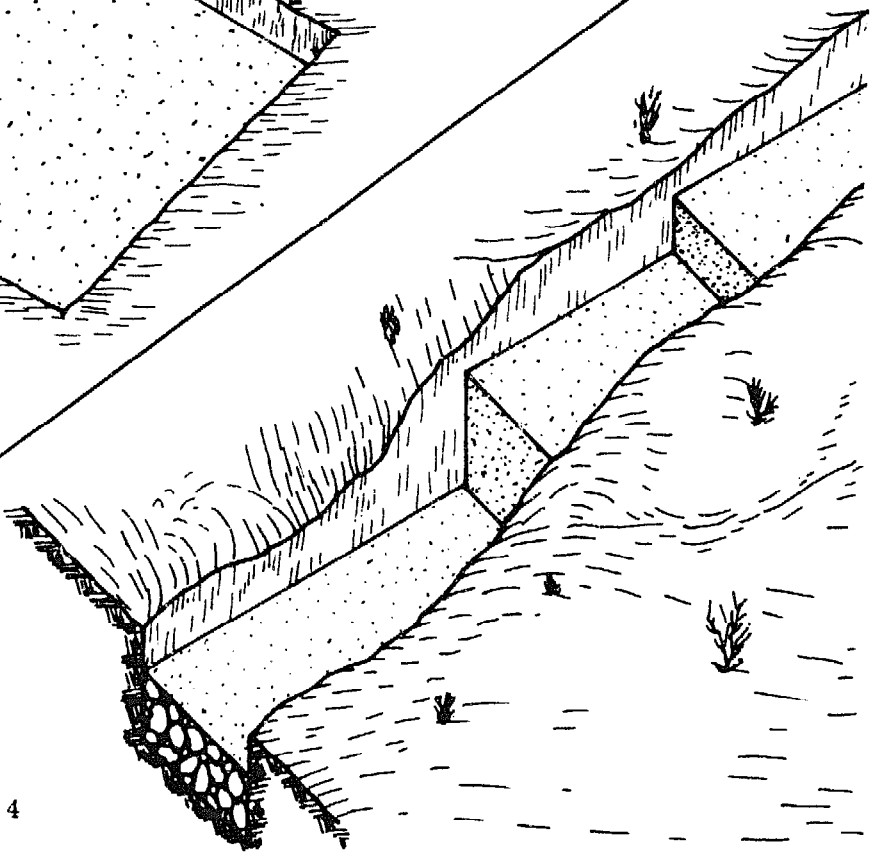

Fig. 4

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FOUNDATIONS.

FOUNDATIONS

The stability of all buildings depends largely on the load-bearing capacity of the ground under them. As far as Rural Building is concerned, all hard soils are suitable for building. Soft soils, and those soils which become very soft and turn into mud when wet, are not suitable.

If a building is erected on the wrong kind of soil or if the foundations were constructed incorrectly, the building might settle unevenly, tilt or slide, or even collapse.

This can be avoided by selecting the right site for the building and by adapting the foundation construction to the soil conditions and the nature of the building.

TYPES OF FOUNDATIONS

The most common forms for foundations in Rural Building are:

- SINGLE FOUNDATION: This is for columns, pillars and poles, if they are detached from the building (Fig. 1).
- STRIP FOUNDATION: This is the most widely used foundation for walls (Fig. 2).
- SLAB FOUNDATION: This is used for water tanks and septic tanks (Fig. 3).
- STEPPED FOUNDATION: On sloping sites the so-called stepped foundation must be used, which is in fact just a special form of the strip foundation (Fig. 4).

NOTES:

- Disturbed soil has to be excavated or compacted to avoid settlements.
- When black cotton soils are found one has to be very careful because this is swelling clay, when wttened it is able to damage a building.

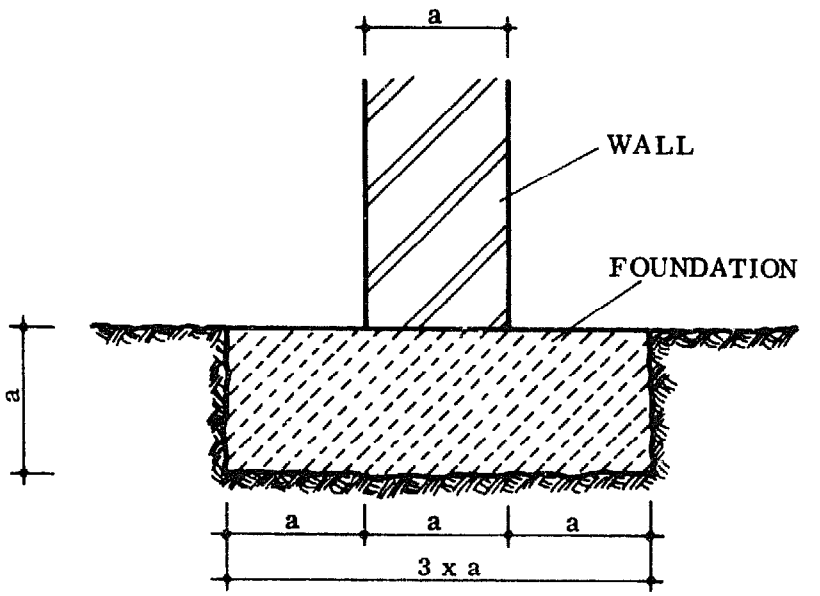

Fig. 1

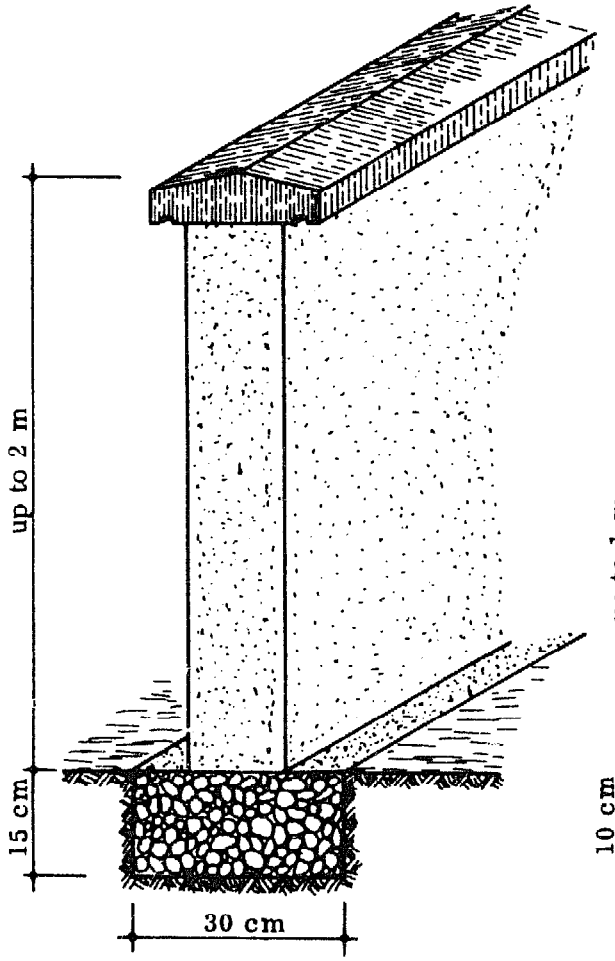

Fig. 2

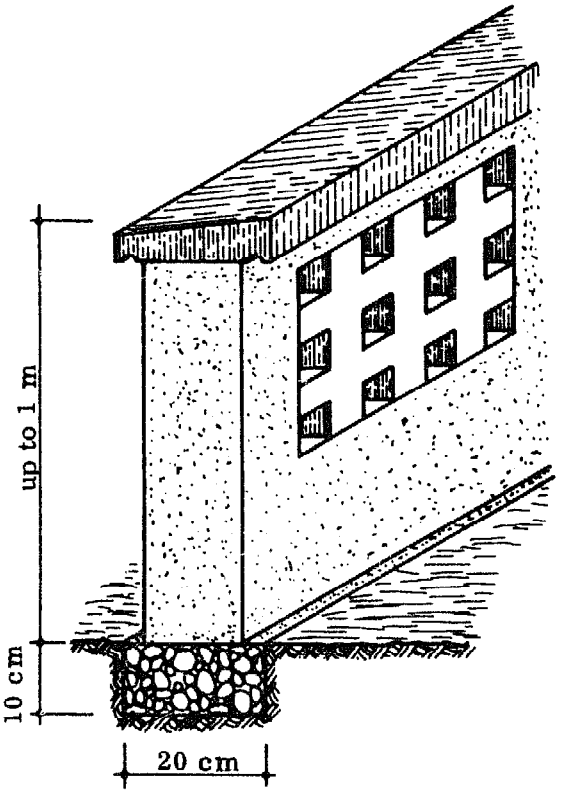

Fig. 3

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FOUNDATIONS.

FUNCTIONS OF THE FOUNDATION

A foundation has to be constructed in a way that it can fulfill the demands that the building structure places on it. These are:

- To provide a solid, level base for the building
- To receive loads from the structure above
- To distribute the loads onto the ground over a larger area
- Thus, to prevent uneven settling of the building.

The above demands are met through the correct choice of dimensions, materials, and constructions for the foundation.

DIMENSIONS FOR STRIP FOUNDATIONS

Many years of building experience in northern Ghana have proven that the dimensions for concrete foundations shown in Fig. 1 are sufficient, provided that the structure consists of only a ground floor and it is built upon firm soil.

A simple rule is: the depth of the foundation should be no less than the thickness of the rising wall; while its width should be no less than 3 times the thickness of the rising wall (Fig. 1).

Lower walls (not exceeding 2 m in height) which do not carry loads can be built on smaller foundations; these should be at least 30 cm wide and 15 cm deep (Fig. 2).

Foundations which carry very low walls (less than 1 m high) such as decorative openwork screen walls enclosing verandahs, may be reduced to no less than 20 cm wide and 10 cm deep (Fig. 3).

NON-CONCRETE FOUNDATIONS

Although most foundations in Rural Building are made of concrete, there are situations where the choice of another material would be practical and economical. Some of the common alternatives to concrete foundations are:

- Rubble and boulder foundations
- Ashlar masonry foundations
- Laterite rock foundations
- Artificial stone (brick and sandcrete block) foundations.

In certain areas of the world, the first two types of masonry were formerly widely

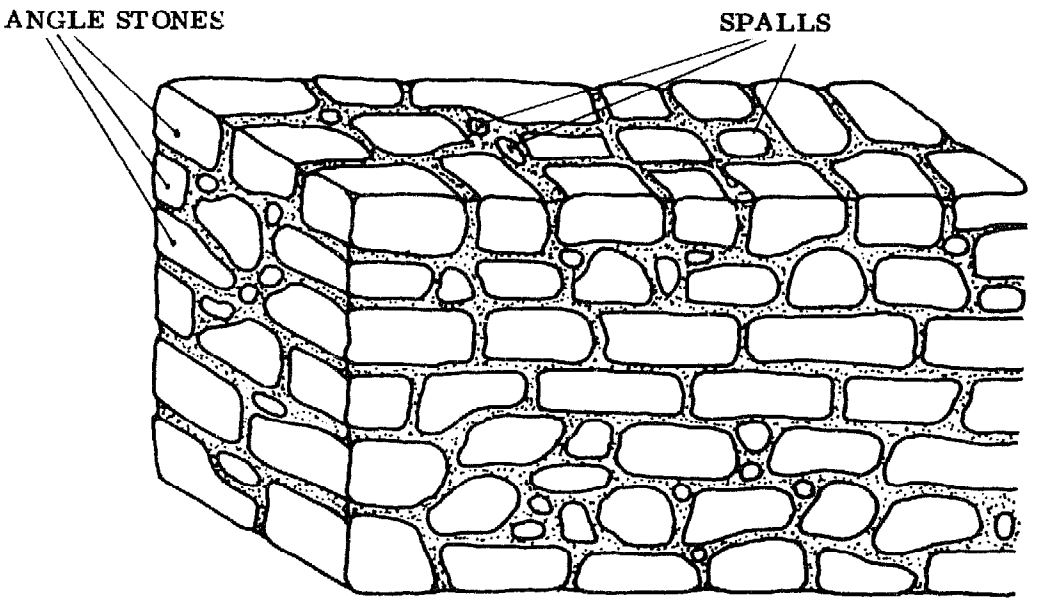

Fig. 1

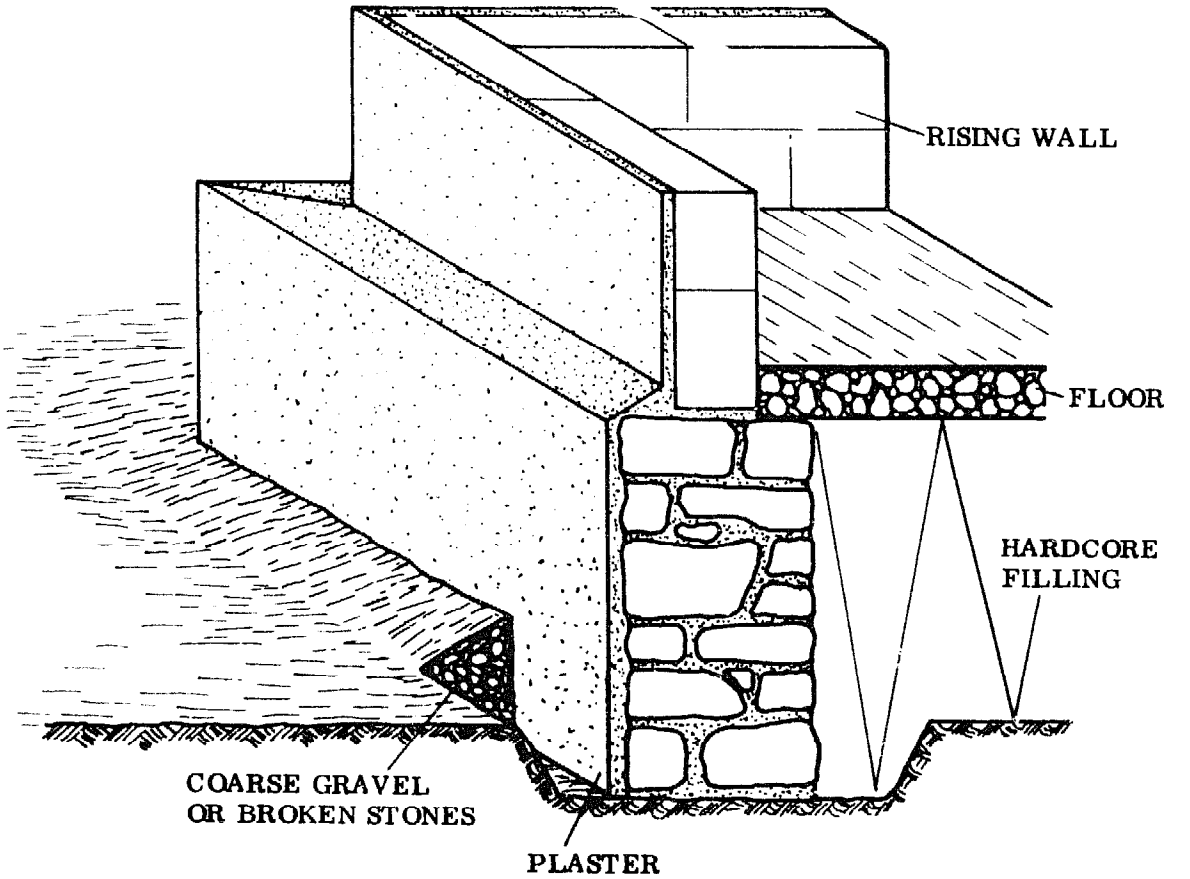

Fig. 2

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NON-CONCRETE FOUNDATIONS.

used: not only foundations but also footings, plinths and even rising walls were made out of stones. Due to the increased use of cement worldwide, and the improved concrete technology, stone masonry became uneconomical to build with because it takes more time and labour. Eventually the use of some of these types of masonry disappeared.

However, cement can be very expensive and it makes sense to return to the use of local materials when possible.

RUBBLE AND BOULDER FOUNDATIONS

This kind of foundation is preferred on stony sites where rubble, rocks and boulders are found in large quantities, and where the soil is firm enough to permit its use.

This foundation saves building materials such as cement and timber for formwork, but it takes more time to construct and requires some skill.

As shown in Fig. 1, as far as possible very large stones are used, and the spaces that remain between them must be filled up with spalls. Spalls are smaller stones used to fill up the voids left in boulder masonry, in order to save cement mortar.

The stones are used in their raw state, but the boulders forming the quoin should be shaped a bit more regularly to form a secure corner bond. The first course is laid in mortar, not directly onto the bare ground. It is usually impossible to construct regular courses because of the irregular shapes of the stones.

If the foundation is made of a porous rock like laterite rock, it is advisable to plaster both the inside and outside faces to prevent dampness from penetrating. Otherwise only the outside face is plastered.

The excavation for the trench is made a little wider than the foundation (Fig. 2) so that the plaster can be applied right down to the bed of the first course. Coarse gravel or broken stones can be used later to refill the space when the plastering is finished. This prevents the erosion of soil along the foundations, especially under the eaves of an overhanging roof.

NOTES:

- Rubble and boulder foundations can also be made with a trapezium shape.

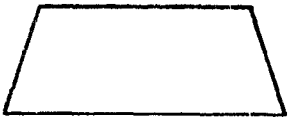

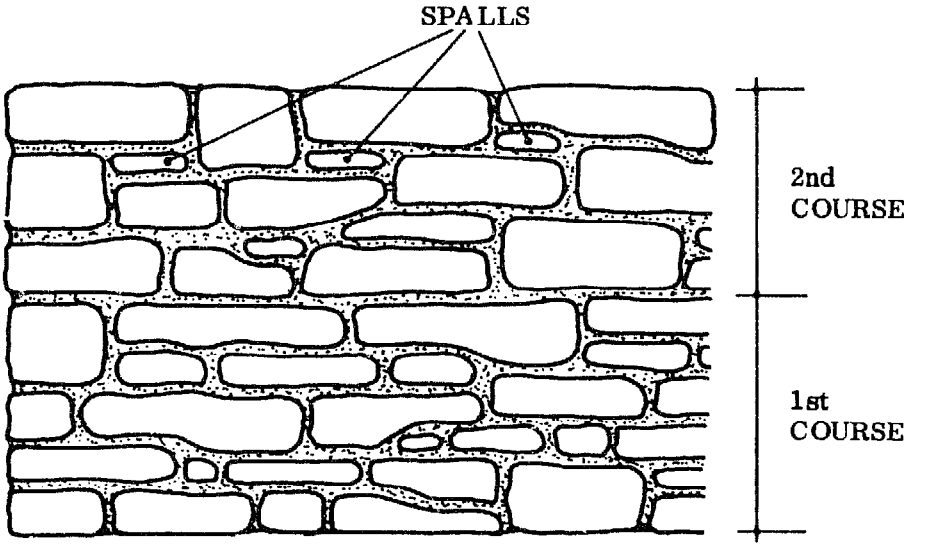

Fig. 1 ROUGH STONE MASONRY

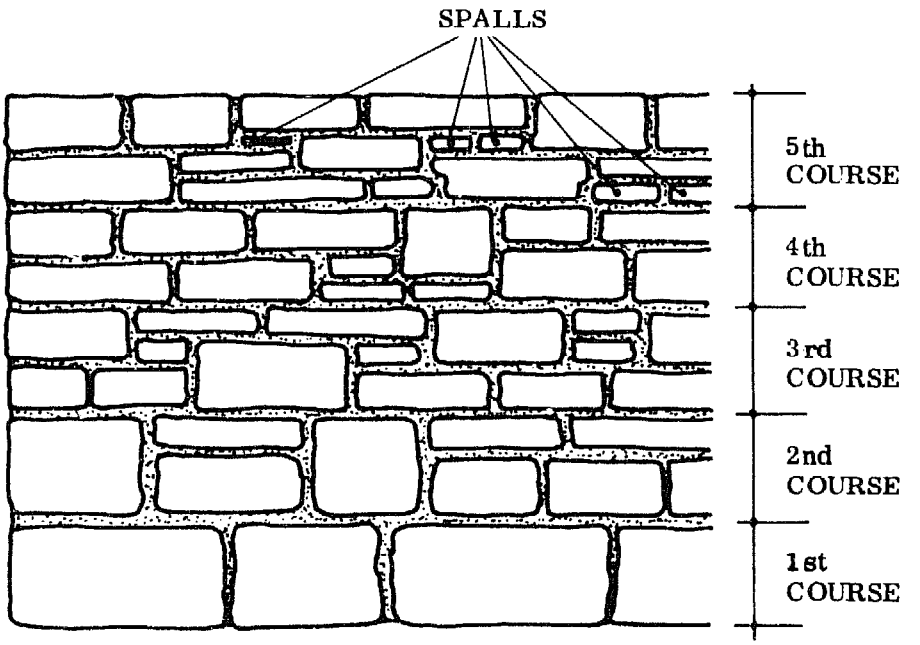

Fig. 2 HAMMER-DRESSED ASHLAR MASONRY

ASHLAR MASONRY FOUNDATIONS

In this type of masonry, the stones are "dressed" before they are used in the structure. To dress stone means to cut and shape it, and it is done to make the stones fit together better. There are four different types of ashlar masonry, depending on how much dressing is done and how the stones are put together. These are:

- Rough stone masonry
- Hammer-dressed ashlar masonry
- Broken range masonry
- Range masonry.

These are listed according to the increasing amounts of stone dressing and stone arrangement required for each method.

- ROUGH STONE MASONRY: This sort of masonry consists of natural stones which are shaped only slightly along their bed faces, or not shaped at all. As in boulder masonry, regular courses are not seen because of the irregularly shaped stones (Fig. 1).
- HAMMER-DRESSED ASHLAR MASONRY: As the name implies, the stones used for this type of masonry are roughly shaped with a hammer, so that the stretcher and header faces are approximately square to each other.

  The stones are laid in regular courses but the thickness of the stones may vary within one course (Fig. 2).

NOTES:

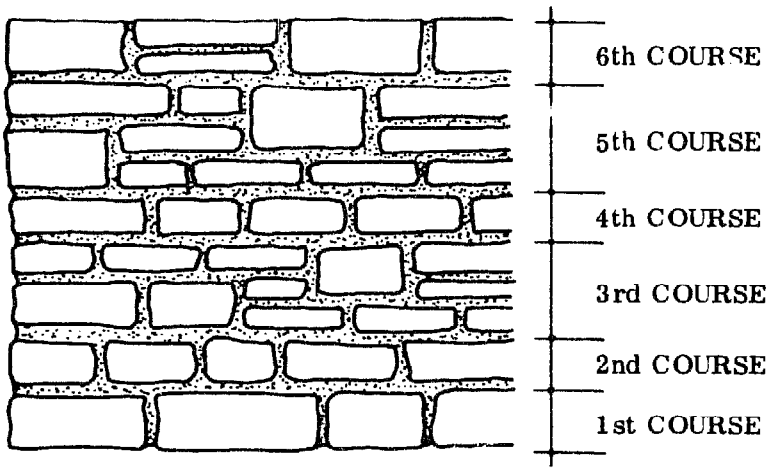

Fig. 1 BROKEN RANGE MASONRY

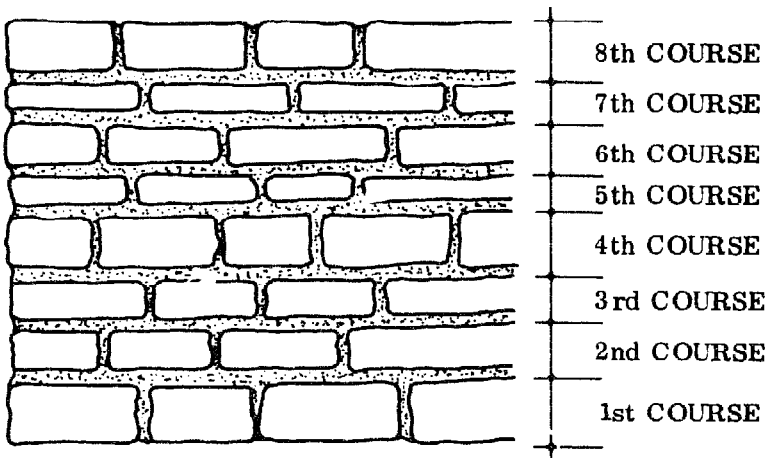

Fig. 2 RANGE MASONRY

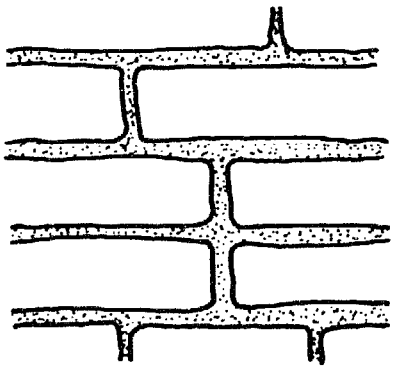

Fig. 3 WRONG!

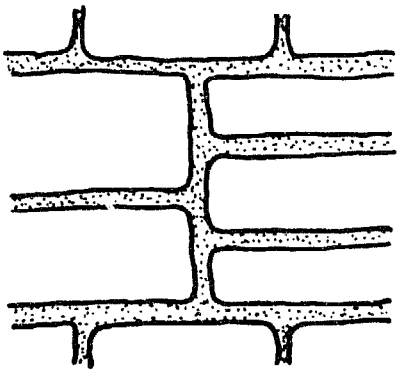

Fig. 4 WRONG!

- BROKEN RANGE MASONRY: The stones of this masonry are accurately shaped with the club hammer and cold chisel (Reference Book, page 15) so that all the faces are square to each other. The bond should not contain joints more than 3 cm thick. The height of the stones may vary within a course, and the height of the courses may also vary, with the result that the courses are continuous for only short distances (Fig. 1).
- RANGE MASONRY: The accurately squared stones are laid in courses, and each course is uniformly thick throughout its length. However, the courses are not all necessarily all the same thickness (Fig. 2).

BONDING PRINCIPLES

The following rules are observed for all four ashlar masonry techniques, regardless of how much dressing is done on the stones.

- Observe the structure of the rock, and if possible lay the stone in the way it has "grown". For example, if the stone appears to have horizontal layers, it should be laid so that the layers are flat.
- Never lay stones edgewise.
- The stones should overlap each other as far as possible; avoid making any continuous cross joints between two courses (Fig. 3).
- Also avoid making a group of continuous cross joints in one course (Fig. 4), as this creates an unpleasant appearance and an impression of a separation. A better arrangement is shown in Fig. 1.
- Fill up the bigger voids between stones with spalls, to save mortar.
- If ashlar masonry is used as a foundation, the first course is always laid in mortar, not directly on the ground.
- In case the foundation is combined with the footings and the plinth course, all ashlar masonry must be coursed and levelled at a height not exceeding 1,5 m, and preferably every 50 cm.

NOTES:

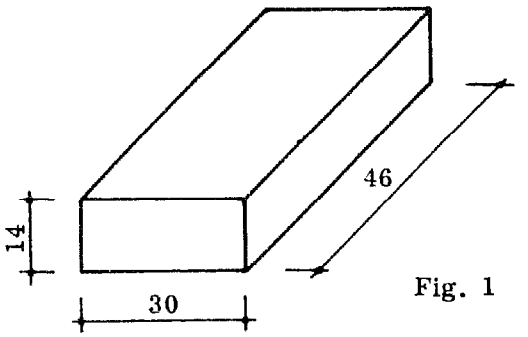

Fig. 1

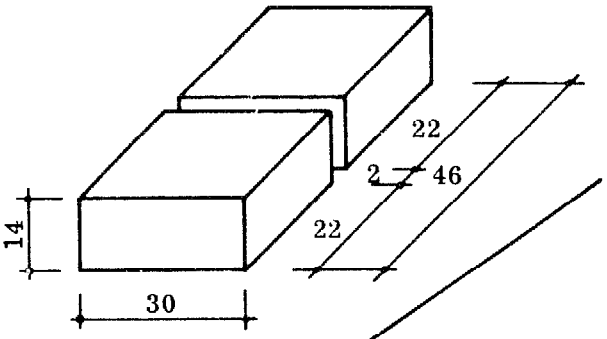

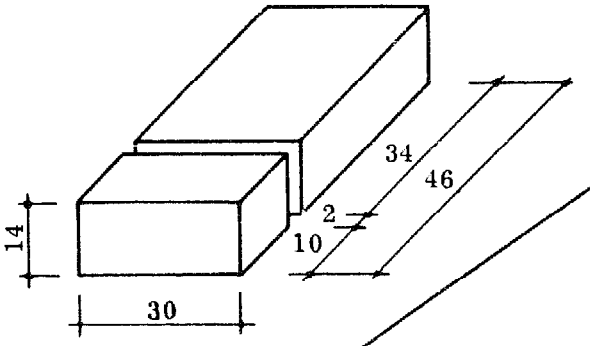

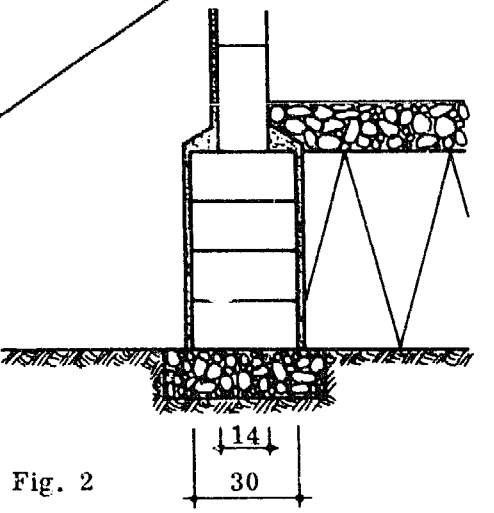

Fig. 2

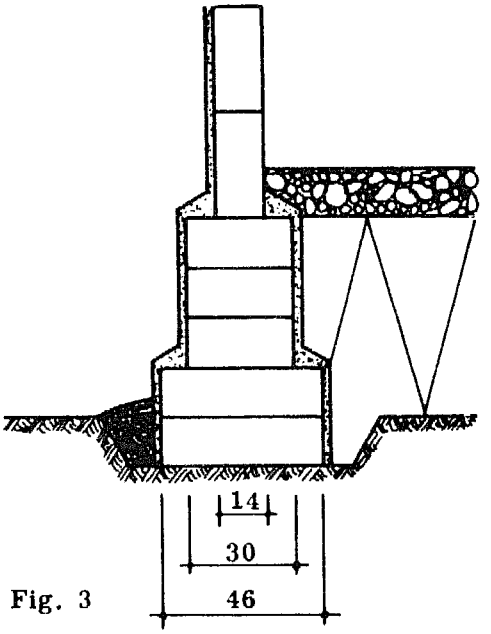

Fig. 3

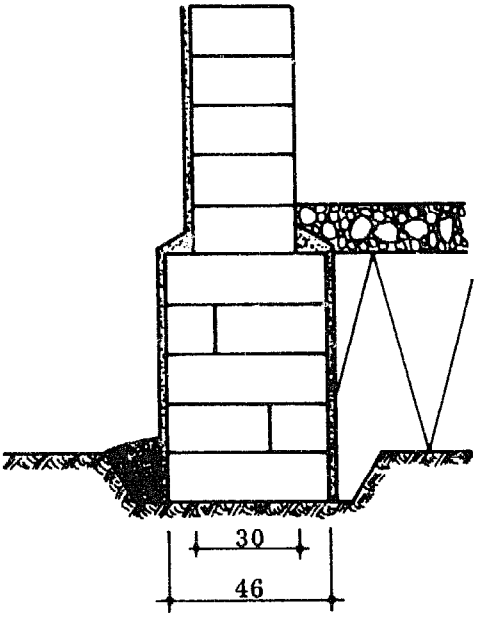

Fig. 4

N P V C	NON-CONCRETE FOUNDATIONS.
24 CON.	

LATERITE ROCK FOUNDATIONS

Many areas of northern Ghana offer the opportunity to work with a highly suitable building material; namely laterite rock.

In structure and colour it appears similar to laterite soil, and although it is rather porous and comparatively soft when freshly dug from the earth, it gradually becomes hard and rock-like when it is exposed to the air.

Laterite stone has been used for many sorts of masonry because it is readily available, easily shaped, and strong.

Its only disadvantage compared with concrete is that it takes time to excavate the stone and shape it into blocks.

However, taking all the factors into consideration, there are some cases where laterite rock represents the most economical choice for building material.

Although the stone can be given any convenient shape, the dimensions of blocks made from laterite stone should preferably be 14 x 30 x 46 cm, which allows proper bonding with all sorts of masonry. Accordingly, the dimensions of half-blocks are 14 x 30 x 22 cm; for 3/4 blocks, 14 x 30 x 34 cm; and for 1/4 blocks, 14 x 30 x 10 cm (Fig. 1).

When blocks of laterite stone are used for footings, they are laid in stretcher bond, flatwise, which results in a footing which is 30 cm thick instead of 23 cm when sandcrete blocks are used (Fig. 2).

Foundations can be built out of laterite stone blocks; the blocks are laid in header bond, with a minimum of two flatwise courses (Fig. 3). Foundation and footings can be combined as shown in Fig. 4, which allows the erection of stronger outside walls.

Since the laterite stone is porous, the foundations should be plastered on both the inside and outside faces.

NOTES:

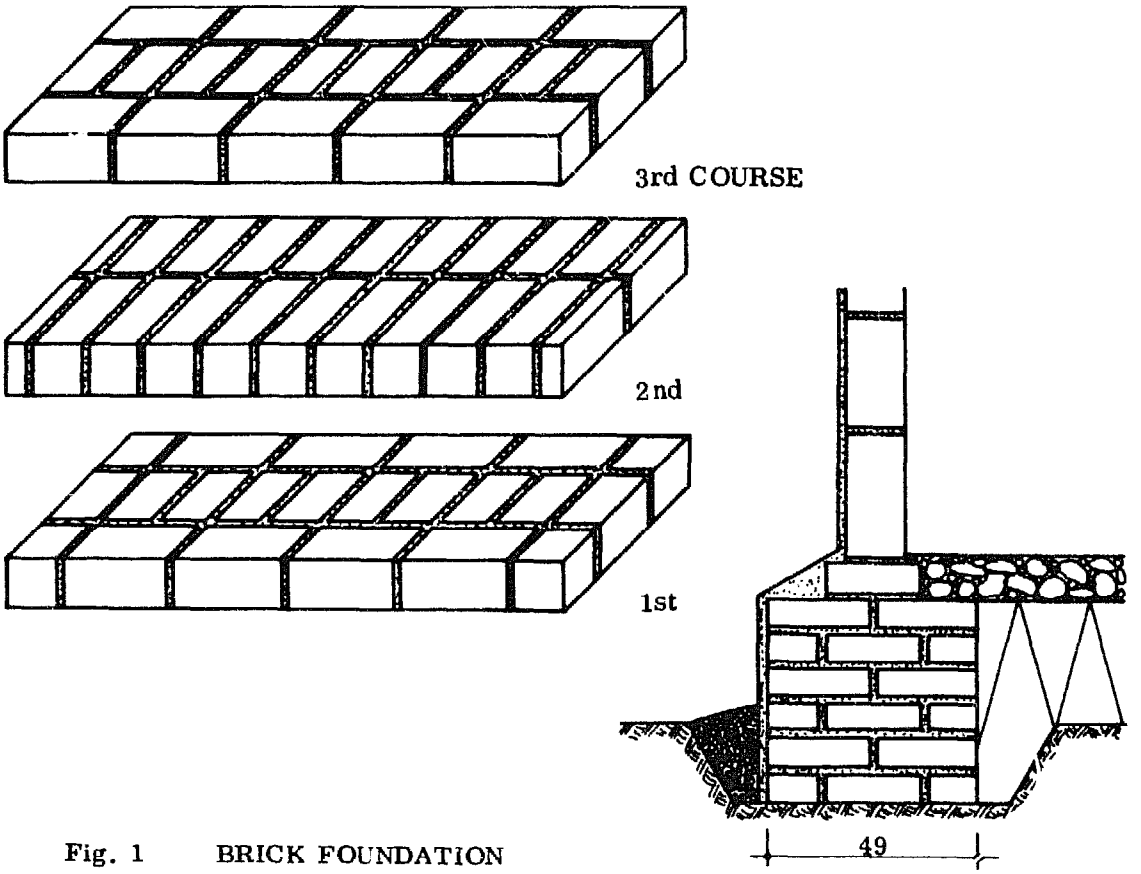

Fig. 1 BRICK FOUNDATION

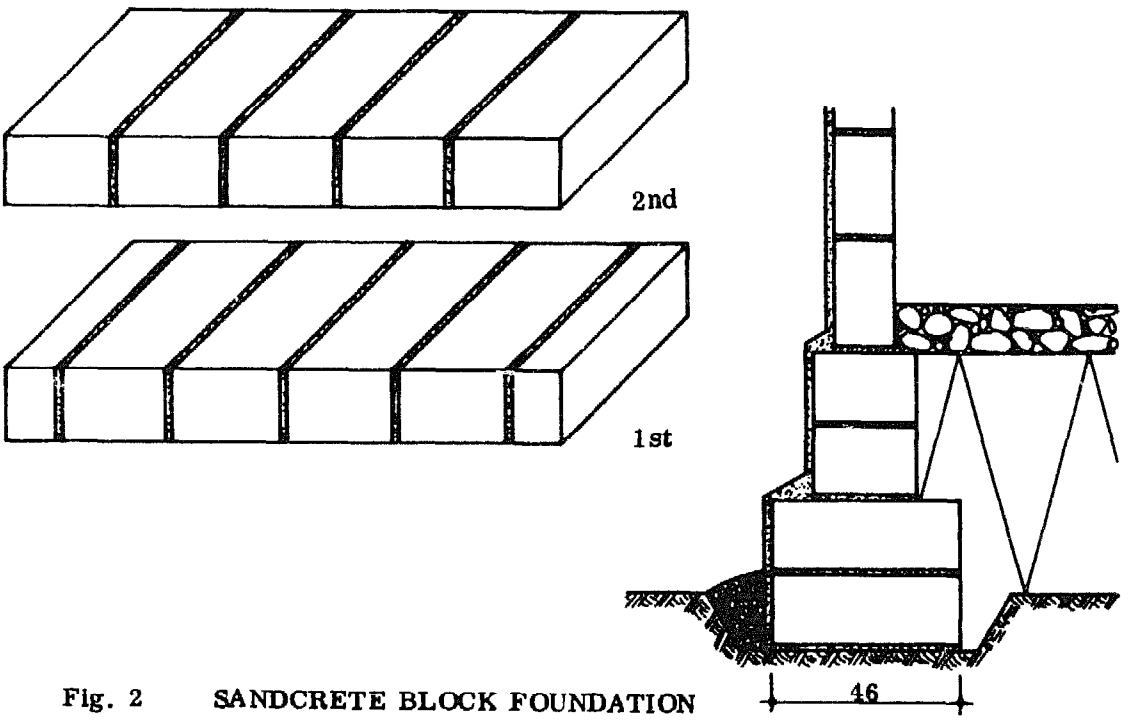

Fig. 2 SANDCRETE BLOCK FOUNDATION

N P V C	
26	CON.

NON-CONCRETE FOUNDATIONS.

ARTIFICIAL STONE FOUNDATIONS

As far as Rural Building is concerned, there are only two artificial stone products of importance for foundations: bricks and sandcrete blocks.

Both products are seldom used for foundations in northern Ghana. We don't use bricks because, while the clay is available to make them, it would take too much firewood or other fuel to fire the bricks. Concrete or laterite stone blocks are usually more economical to use than sandcrete blocks.

- BRICK FOUNDATIONS: Brick is one of the oldest known artificial stones; it is made from clay which is shaped, dried, then fired in a kiln. The usual dimensions of a brick are 7,1 x 11,5 x 24 cm, a size which results in a masonry containing many joints, but which allows the construction of most complicated bonds.

  Foundations made out of bricks must be at least 5 courses high and carefully laid in cross bond or English bond (Fig. 1). Note the different arrangements of the alternating courses.

- SANDCRETE BLOCK FOUNDATIONS: In an area where there is a lot of sand available but no broken stones, gravel or laterite rock, etc., one may be forced to use sandcrete blocks to build the foundations. The mix proportion for these blocks should be no less than 1:8, and the blocks themselves should be laid in header bond, as seen in Fig. 2.

NOTES:

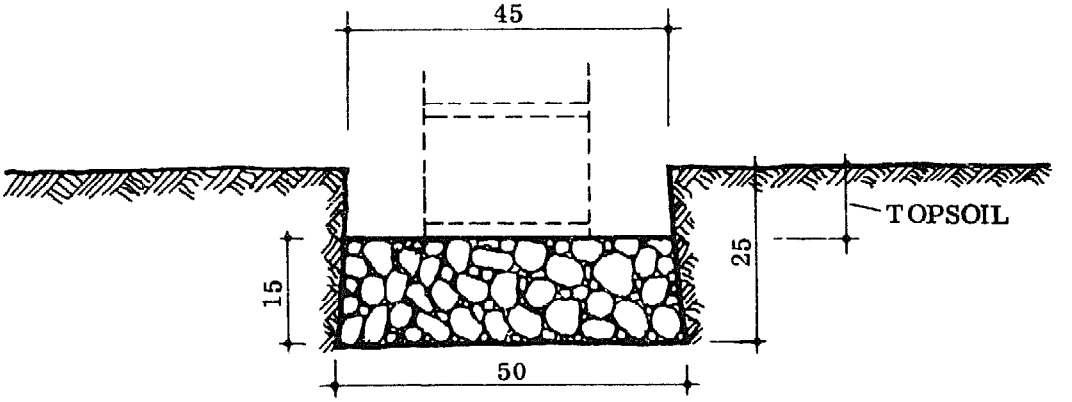

Fig. 1

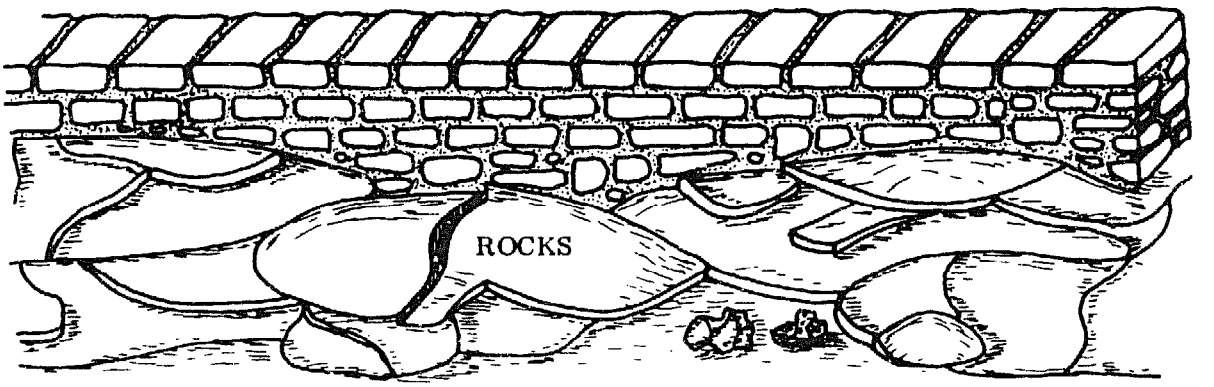

Fig. 2

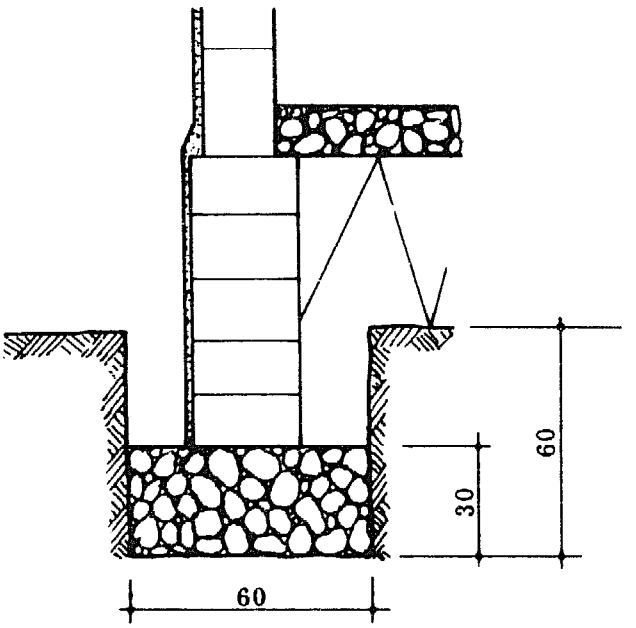

Fig. 3

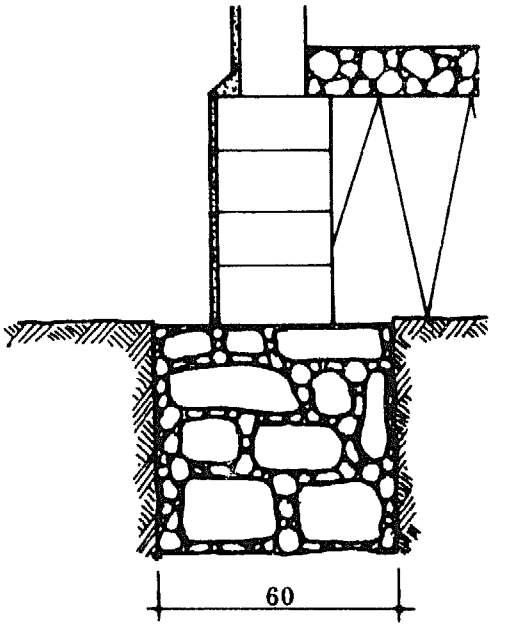

Fig. 4

N P V C	
28	CON.

CONCRETE FOUNDATIONS.

CONCRETE FOUNDATIONS

EXCAVATING THE FOUNDATION TRENCHES

After the setting out is complete, including marking the positions and widths of the foundations on the ground, the lines are removed from the profiles or pins and the excavation work is started.

All the topsoil and as much as possible of the soft soil and light soil is removed, and brought to a place where it can either be used immediately or kept for a future dry season garden.

In most cases soils of a firm consistency and good load bearing capacity are found at depths ranging from 15 to 25 cm, which is deep enough for the construction of foundations for a rural dwelling place (Fig. 1).

There are of course exceptional cases where the rock is close to the surface, or even at the surface, which makes the work easier; or the opposite situation of very deep soft soil, which is a problem.

In areas where there is light or heavy rock close to the surface, the thickness of the foundation can be reduced, but to no less than 5 cm thick. The surface of the rocks should be roughened if necessary to provide a good grip, and cleaned before the concrete is cast. These areas are usually rich in stones, so one should check out the possibility of making boulder foundations. The boulder foundations can also be carried out as a stepped foundation if necessary, following the contours of the rocky surface (Fig. 2).

Very deep soft soil is a problem, and it requires special measures. In general, all excavations should be continued until a layer of good firm soil is found. When a depth of 60 cm is reached and the soil is still too soft, the excavation work is stopped.

Instead of digging deeper, widen the trench to at least 60 cm. This increases the total area on which the structure rests, with the result that the pressure on the soil underneath is distributed over a wider area.

Fig. 3 shows that the thickness of the widened foundations must be increased to 30 cm, because of how the foundation material distributes the pressure of the wall above.

In order to save concrete, put bigger stones, rubble or boulders into the foundation; it should preferably be flush to the ground surface (Fig. 4).

SECTION THROUGH THE LENGTH

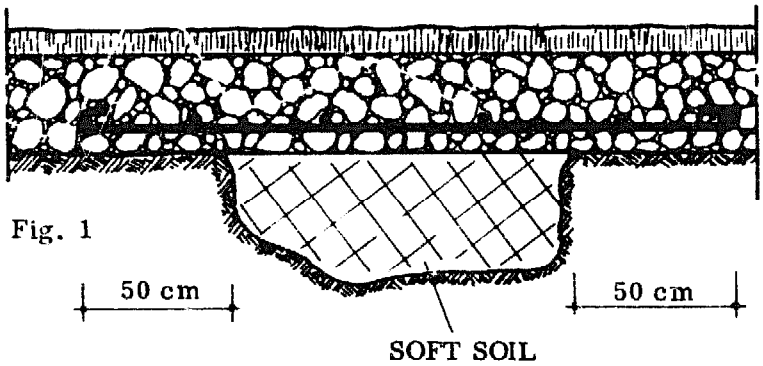

Fig. 1

CROSS SECTION

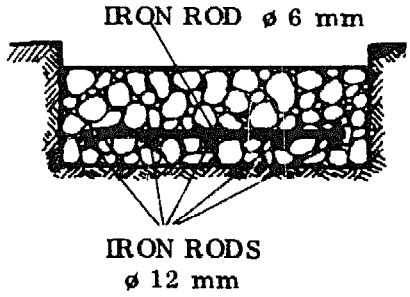

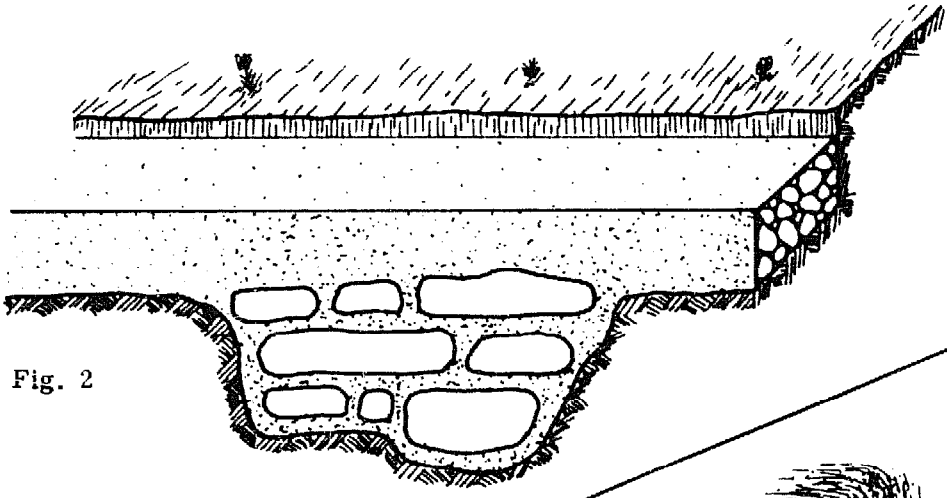

Fig. 2

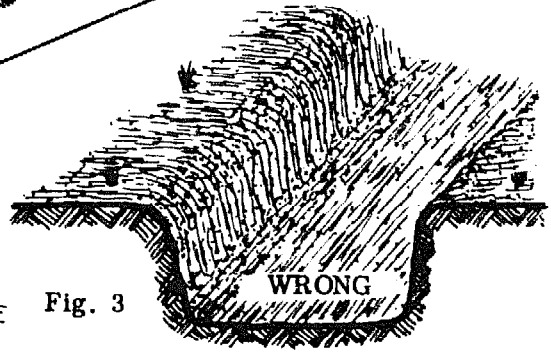

Fig. 3

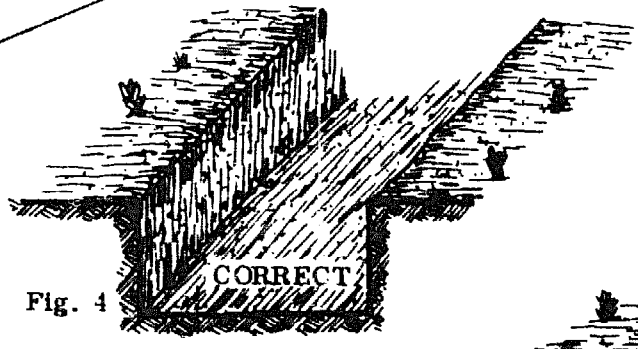

Fig. 4

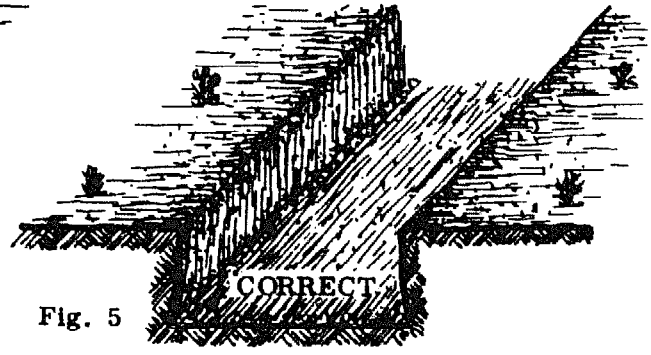

Fig. 5

NPVC	
30	CON.

CONCRETE FOUNDATIONS.

- SOFT POCKETS: During the excavation work it sometimes happens that the character of the soil changes unexpectedly: spots or pockets of soft soil are found in the firm soil. These may be natural deposits or man-made holes that have gradually filled in. The load bearing capacity of the soil is reduced in these places.

  If the area is relatively small and runs across the trench, it is advisable to reinforce the concrete foundation covering the pocket with a network of crossed iron rods (Fig. 1). The rods should be long enough to bridge the soft part and project past it on both ends to anchor securely in the foundation which is supported by firm soil.

  In case the area is too wide to be reinforced in this way, the soft soil is removed and the hole is refilled with compacted layers of boulders, stones, and sharp sand; or with concrete, thus improving the load bearing capacity (Fig. 2).

  When the foundation has to cross a very wide section of soft soil, that section of the foundation has to be made wider and deeper than the rest (see the previous page).

- SHAPE OF THE TRENCHES: Although it is generally accepted that the ideally shaped foundation trench has walls that are at right angles to the levelled bottom of the trench (Fig. 4), it is often observed that unskilled or even skilled workers tend to dig trenches which are incorrectly shaped. Special attention should be given to this problem during excavations in harder soils, because the more difficult the digging, the more likely it is that incorrectly made trenches will result (Fig. 3).

  Experience has shown that it is best to ask the workers to make the trenches a bit wider at the bottom, to ensure that the minimal width of the foundation is maintained everywhere (Fig. 5).

NOTES:

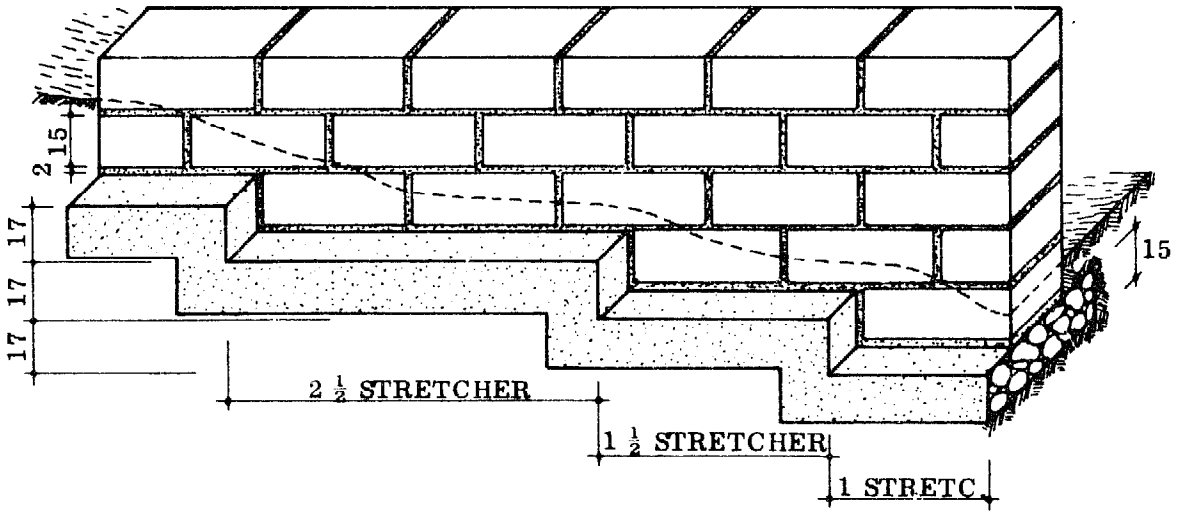

Fig. 1 STEPPED FOUNDATION WITH SANDCRETE FOOTING

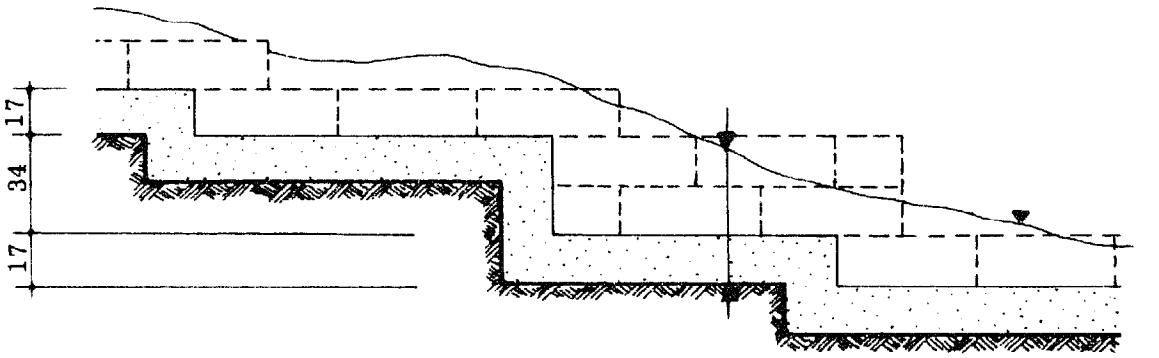

Fig. 2 STEPPED FOUNDATION WITH 2 COURSES ON ONE STEP

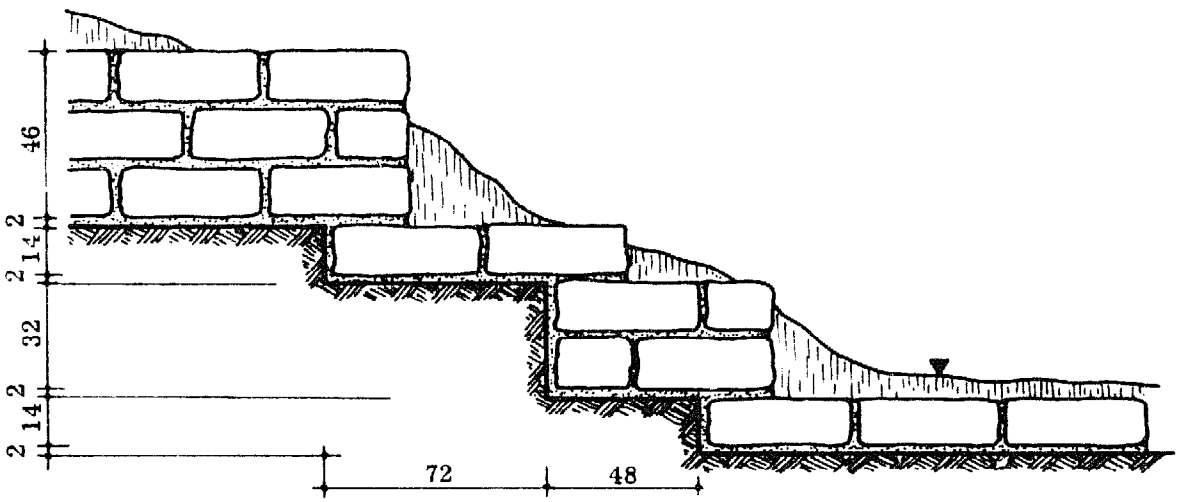

Fig. 3 STEPPED FOUNDATION WITH LATERITE STONE

N P V C	
32	CON.

CONCRETE FOUNDATIONS.

MEASUREMENTS OF STEPPED FOUNDATIONS

The number, length and height of the steps in the foundation depend on the shape and steepness of the ground contours. To make it easier to construct the footings later and to save materials, the skilled builder will adapt the length and height of the steps to fit with the type of blocks that will be used for the footings.

Fig. 1 shows a common stepped foundation made of concrete, and footings built of sandcrete blocks. It can be seen that the concrete thickness is 15 cm throughout, while the steps are different lengths.

- HEIGHTS OF THE STEPS: The height of each concrete step is always the thickness of a sandcrete block, plus the thickness of the mortar bed; making 15 cm plus 2 cm equals 17 cm.

  In case the steps have to be steeper, the height of the step is always a full multiple of 17 cm: 34, 51 cm, etc. so that 2 or 3 courses of sandcrete blocks can fit on the step (Fig. 2).

- LENGTHS OF THE STEPS: All masonry is supposed to be built in half-block bond. Accordingly, the minimum length of a step is half a block plus the joint: 22 cm plus 2 cm equals 24 cm; or for longer steps, a full multiple of this: 48 cm, 72 cm, 96 cm and so on.

If the foundation is to be constructed with laterite stone blocks (Fig. 3), the height of one step is reduced to 16 cm, that is 14 cm for the block plus 2 cm for the joint. The lengths of the steps are the same as for sandcrete blocks.

The actual construction of a stepped foundation and its footings must always be started from the lowest step, to prevent bonding mistakes.

NOTES:

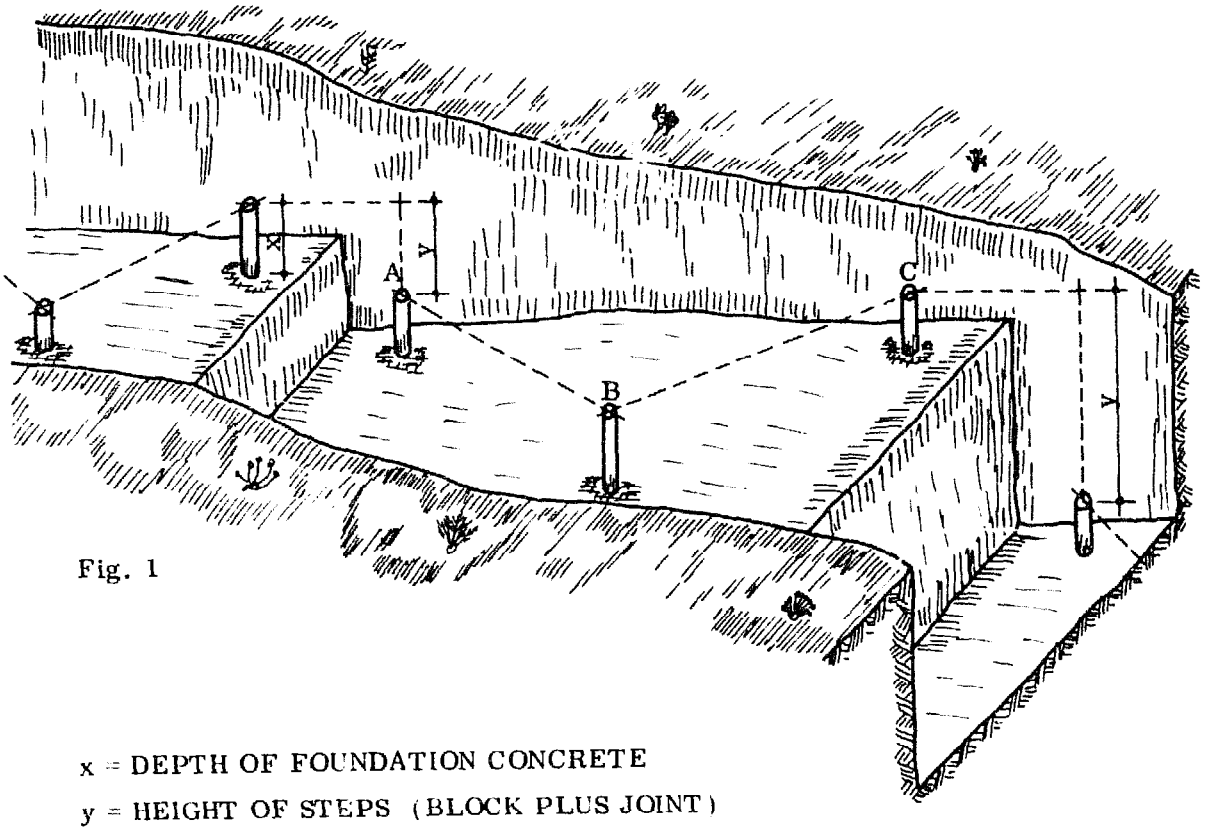

Fig. 1

x = DEPTH OF FOUNDATION CONCRETE

y = HEIGHT OF STEPS (BLOCK PLUS JOINT)

NOTES:

N P V C		CONCRETE FOUNDATIONS.
34	CON.	

LEVELLING THE TRENCHES AND MARKING THE FOUNDATION DEPTH

The bottoms of all foundation trenches must be perfectly level, not only in the length but also across the width. Otherwise the building may settle unevenly, which can cause cracks in the structure or even a complete collapse.

This is why a foundation on a sloping site must be constructed in steps (Fig. 1) instead of taking a course parallel to the slope of the ground.

An improperly constructed foundation can result in a building that is a danger to the people living in it, and also a possible loss of valuable property.

When the trench has been excavated and roughly levelled, the next step is to determine the depth of the foundation concrete and at the same time, to level the bottom of the trench more exactly.

This is done by inserting iron or wooden pegs in the trench so that they project from the bottom by a distance equal to the depth of the foundation (Fig. 1). The distance between the pegs should be no further than the straight edge can bridge, so that it is possible to level between them using the straight edge and spirit level. Trenches can be levelled more accurately over longer distances by using the water level.

The triangular pattern of the pegs is necessary to obtain a level surface: if the distances A-B and B-C are level, then A-C must also be level (Fig. 1).

When the tops of the pegs are level, we can measure how far each peg sticks out from the bottom of the trench, and thus check whether the trench bottom is also level. High areas are skimmed off with a shovel, while hollows are filled with concrete. Never refill hollow areas with excavated soil, as this might lead to uneven settling of the foundation.

NOTES:

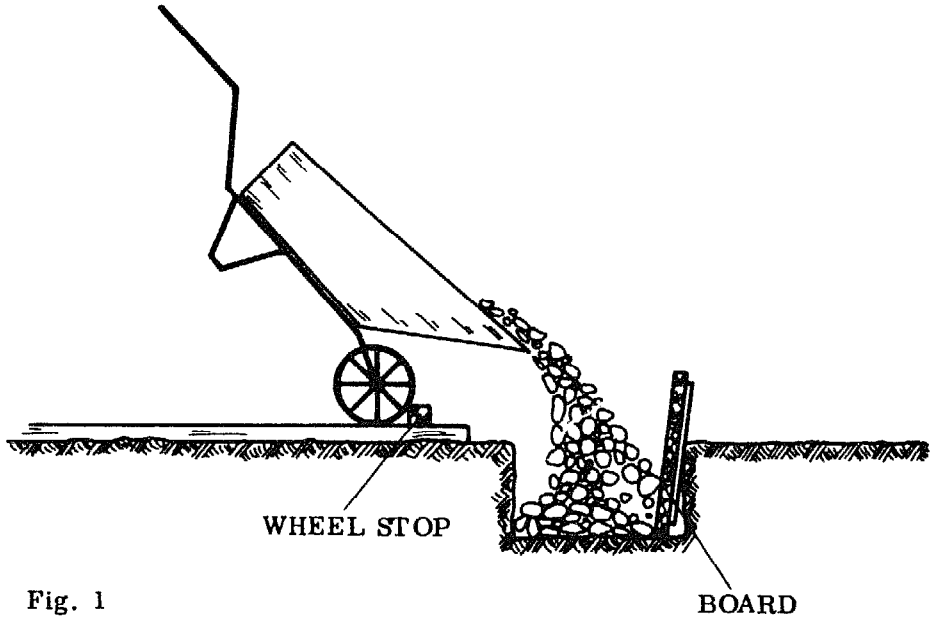

Fig. 1

NOTES:

N P V C	
36	CON.

CONCRETE FOUNDATIONS.

MIX PROPORTIONS

The correct mix proportions for foundation concrete should generally be determined through the calculations of an engineer. Since this is usually not possible in Rural Building, the Rural Builder can decide the mix proportion with the help of the Tables of Figures, Reference Book, page 234. The data given there and the following hints are approximate values and are intended as a guide. The general range for the mix is from 1:10 to 1:15.

- For small projects like single dwellings, stores, etc., a mix proportion of 1:15 is sufficient because the total weight on the foundation is not so great.
- Bigger buildings like two-storeyed houses, halls or churches require a better mix proportion of 1:12.
- Elevated water storage tanks, bell-towers and other large heavy structures should be based on foundations mixed in a proportion of 1:10.

PREPARATIONS BEFORE CASTING

If the ground is dry, the foundation trenches have to be wetted down before the concrete is cast. This helps to reduce the absorption of moisture from the concrete by the soil. Take care that the sides of the trenches are also thoroughly wetted.

After the foundation concrete is mixed (Reference Book, pages 161 to 163), it has to be transported to the trenches, either in buckets, headpans or wheelbarrows. All transportation of the concrete has to be done without too much delay or vibration, as this could lead to the aggregates becoming separated. If wheelbarrows are used, the paths should be covered with boards to reduce vibration and to make it easier to push the wheelbarrows.

It is a good idea to provide a wheel stop (Fig. 1) beside the trench. This helps to ensure that the concrete is emptied right in the middle of the trench and does not take along dust and dirt from the sides of the trench. A board can be used to protect the opposite side of the trench (Fig. 1). This is not necessary when the concrete is picked up with a shovel from the wheelbarrow.

The containers in which concrete is transported should be kept wet, so that no concrete sticks to the container when it is poured.

NOTES:

- If a plastic foil is available a better result can be obtained, especially laterite soils can loose there stability, there can be a liquifaction when wettened.

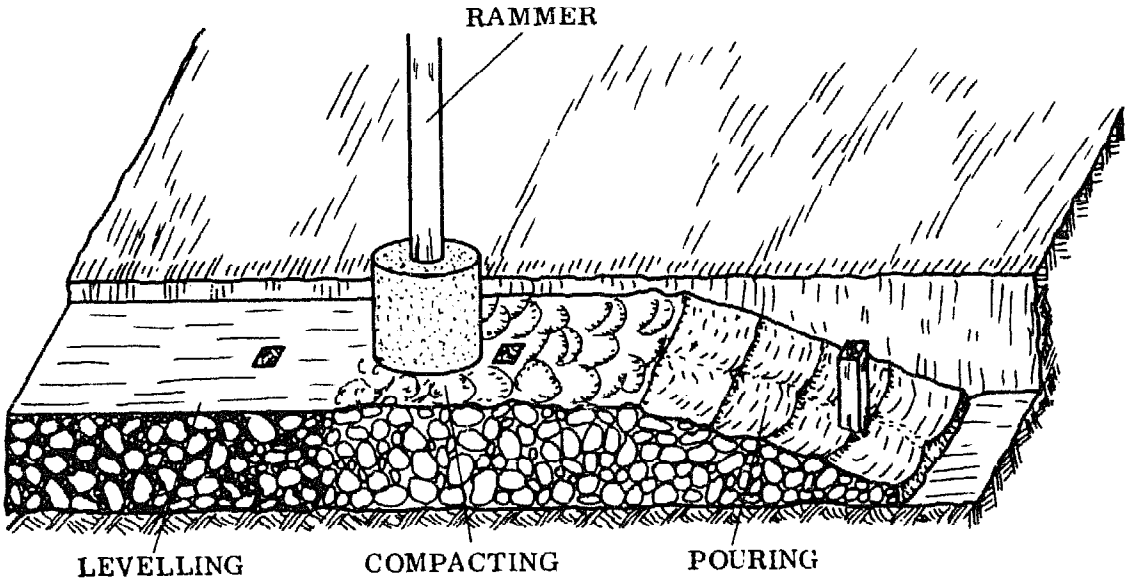

Fig. 1

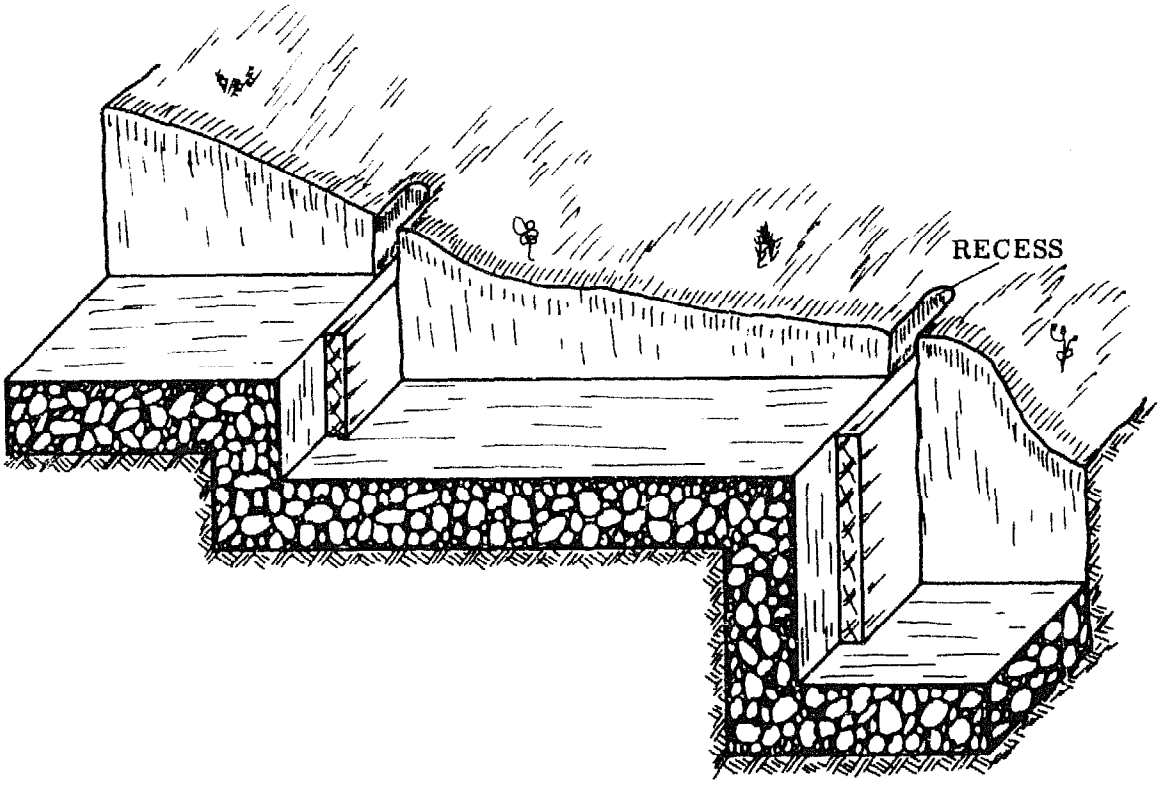

Fig. 2 CASTING A STEPPED FOUNDATION

N P V C		CONCRETE FOUNDATIONS.
38	CON.	

CASTING

The concrete must be cast systematically so that the compacting and levelling follow immediately after it is poured in the trench. The headpan loads or wheelbarrow loads are deposited in an orderly way, not just dumped anywhere in the trench (Fig. 1).

Do not cast foundation concrete in sections with spaces in between, as this can lead to disturbances of the hardening process when the gap is filled up later. Always start from the far end of the trench and work your way closer to the mixing area. Two groups of workers can cast foundations on different sides of the building at the same time.

- COMPACTION: The concrete must be well compacted so that no air voids remain. Since foundation concrete has a rather stiff consistency, to compact it requires the use of heavy rammers (Reference Book, page 19).

  The concrete is applied in layers no more than 15 cm deep, and each layer is compacted with the rammers. Pay special attention to compacting the corners and the outside edges. Stiff concrete should be compacted until its surface becomes wet.

  Do not be tempted to compact the concrete just roughly, or to add water to ease the work. The production of a good foundation is a hard job, but only hard work will result in a good quality foundation.

- STEPPED FOUNDATION: In casting the vertical parts of a stepped foundation, pieces of board are used as shown in Fig. 2. These are fitted into recesses cut in the side of the trench. The width of the board is the same as the height of the step (Fig. 2).

NOTES:

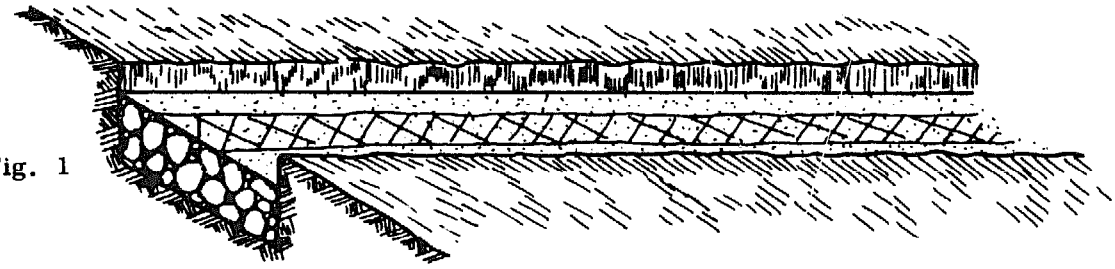

Fig. 1

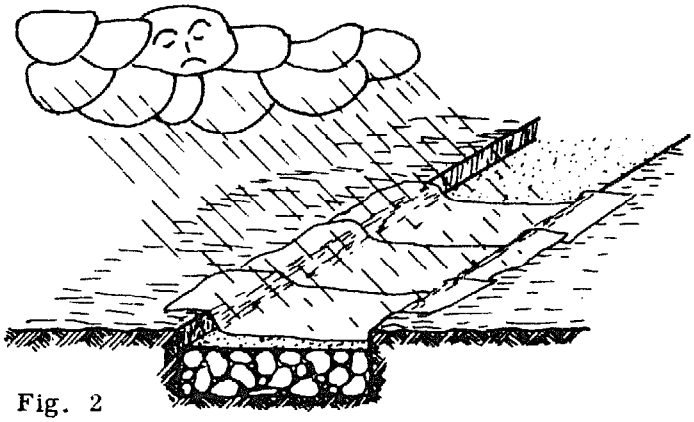

Fig. 2

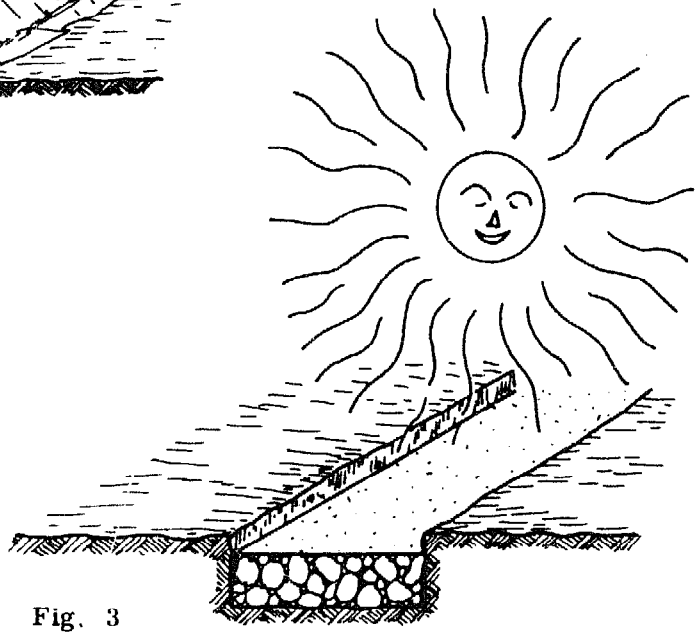

Fig. 3

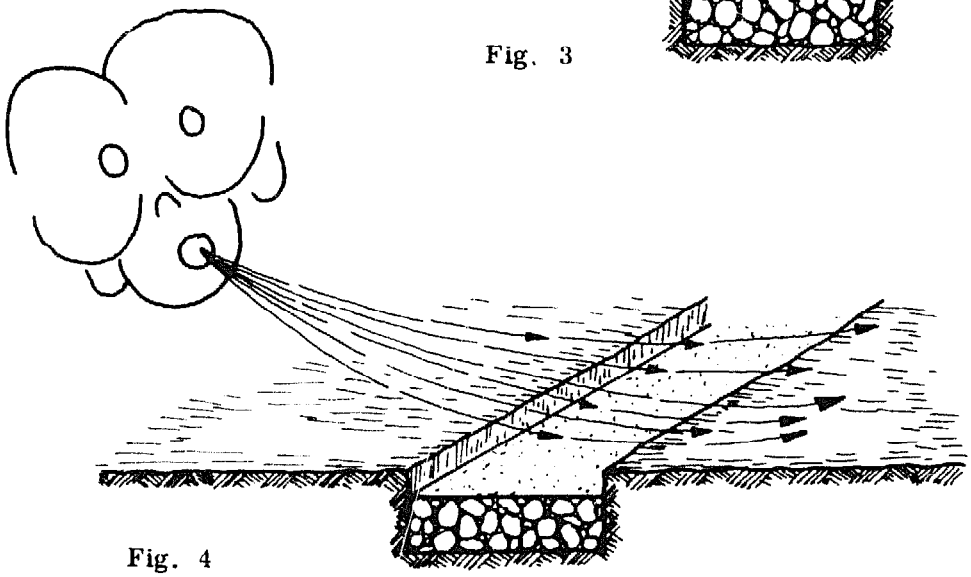

Fig. 4

N P V C	
40	CON.

CONCRETE FOUNDATIONS.

LEVELLING THE FOUNDATIONS

As soon as the foundation is compacted, the top has to be levelled flush with the top of the pegs. For this purpose a strike board is used.

If the compaction has been carried out correctly, the levelling should be fairly easy as there is not much concrete left to strike off.

All wooden pegs have to be removed and the holes filled with concrete, while the iron pins may remain if these were used.

As soon as the hardening process starts, as can be seen by the dull and dry looking surface, the area where the footing course will be set must be slightly roughened with the blade of a trowel, to provide a good grip for the mortar (Fig. 1).

CURING

If the concrete is disturbed during the hardening process, serious defects may be produced.

Freshly cast concrete must therefore be covered with empty cement bags, straw, mats, boards or moist sand to protect it against:

- The rain, which can wash out the cement paste, leaving the non-bound aggregate behind (Fig. 2).
- The sun, which can "burn" the surface of the concrete, so that although the concrete looks cured, under the surface it has not set hard enough (Fig. 3).
- The wind, which can dry up the surface, resulting in cracks due to excessive dryness and shrinkage: especially during the harmattan season (Fig. 4).
- The dirt, which may get on the surface and interfere with the grip of the footings.

Any vibration near the hardening concrete could cause cracks and destroy the internal structure of the concrete. Don't continue with any excavation work, etc. near the just-completed foundation.

Once the surface has set sufficiently hard, the concrete must be wet down and kept wet for three days.

NOTES:

BUILDING WITHOUT FOOTING

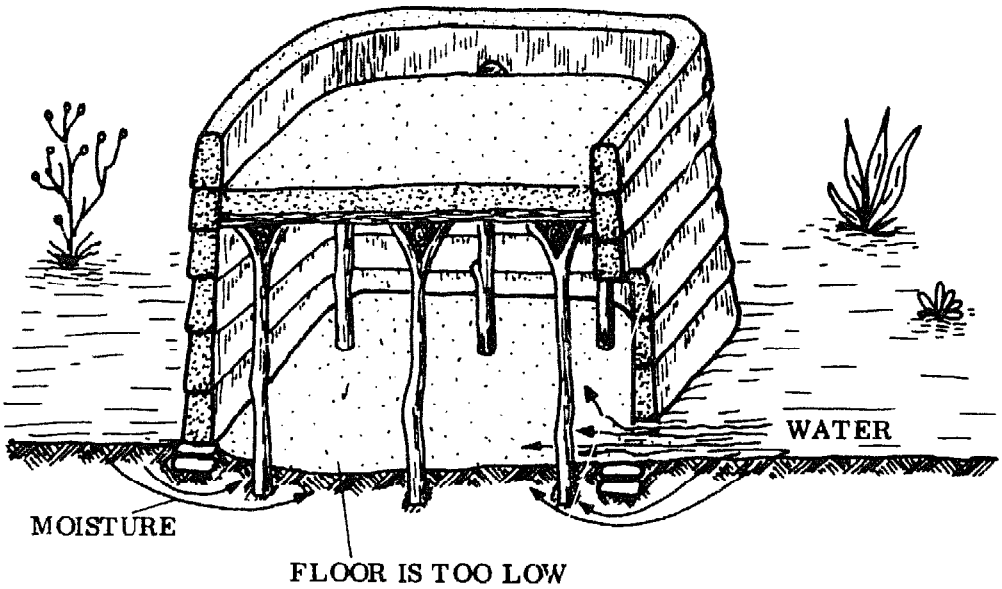

Fig. 1

BUILDING WITH FOOTING

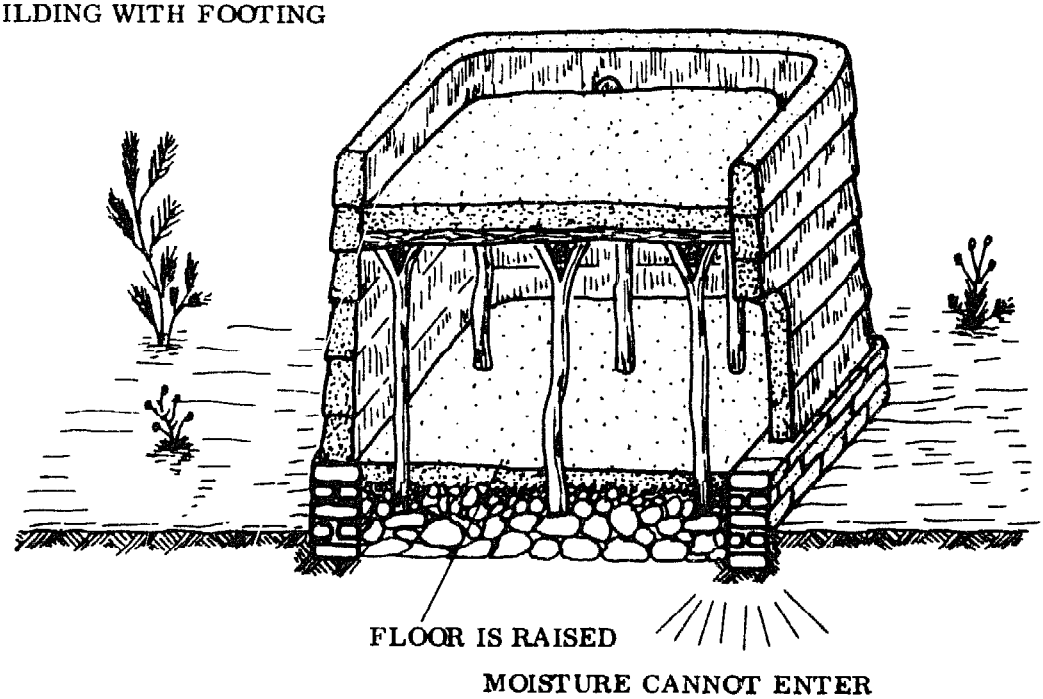

Fig. 2

N P V C		FOOTINGS.
42	CON.	

FOOTINGS

The projecting courses at the foot of a wall, between the rising wall and the foundation, are called the footings. If there is no wider concrete foundation, the combination foundation/footing is called a footing (see Foundations, page 25).

FUNCTIONS OF THE FOOTINGS

Since the footings form the link between the rising wall and the foundation, the demands on them are similar to those set on the foundations. These are:

- To provide a solid, level base for the walls
- To receive loads from the structure above
- To distribute the loads onto the foundation (or the ground).

In addition, the footings have to:

- Raise the floor high enough above ground level to prevent moisture from rising through to the floor, and to keep the landcrete blocks of the rising wall dry.

As far as Rural Building is concerned the last function is the most important one.

MATERIALS AND MEASUREMENTS

The most common material used for footings is sandcrete blocks, laid flatwise in a half-block bond. The courses are 23 cm thick and 17 cm in height, and they are laid in the centre of the foundation strip.

In order to effectively prevent moisture penetration, three courses should be laid above ground level, thus raising the soffit of the floor to a height of 51 cm above ground level. This is the minimum for all bedrooms and living areas.

Only in cases where the building is not to be used as a dwelling place for people, for example a store or a shelter for animals, may the footings be built to a lower level.

The use of boulder or laterite rock masonry is preferred as this can save considerable amounts of cement. The dimensions of such footings will be the same as those of sandcrete footings, when the laterite rock blocks are cut to the same dimensions as sandcrete blocks.

- COMPARE: Fig. 1 shows a building with no footing. The floor is at ground level and water can easily enter. The building in Fig. 2 rests on a footing and the floor is raised above ground level, so it will be drier and thus healthier to live in, and also less likely to collapse since the mud walls are kept drier.

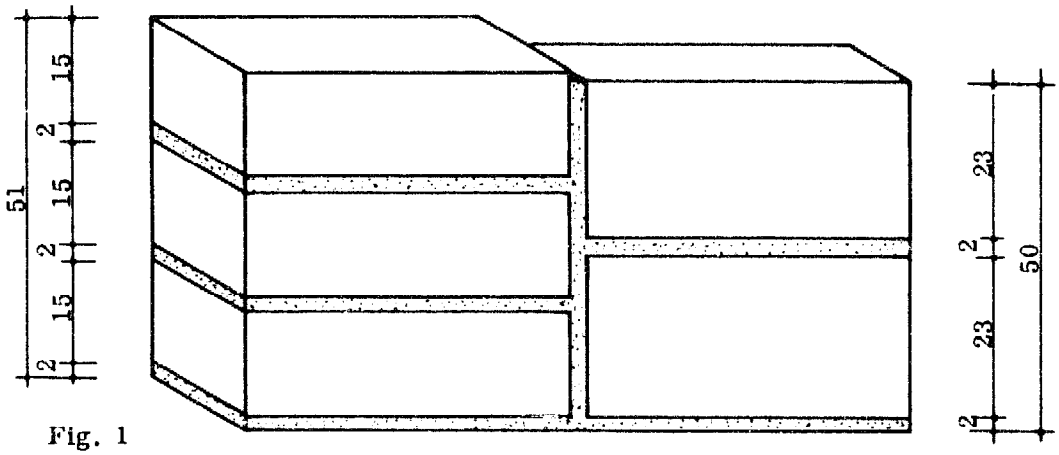

Fig. 1

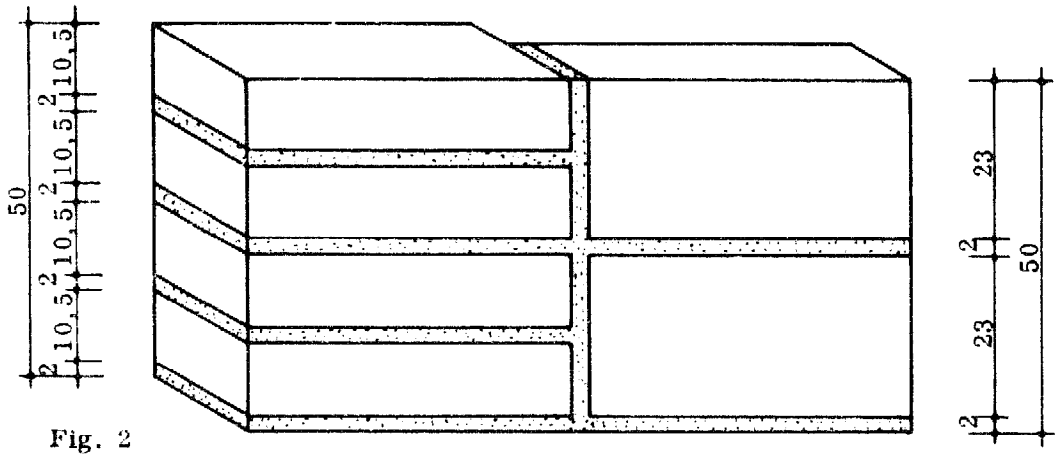

Fig. 2

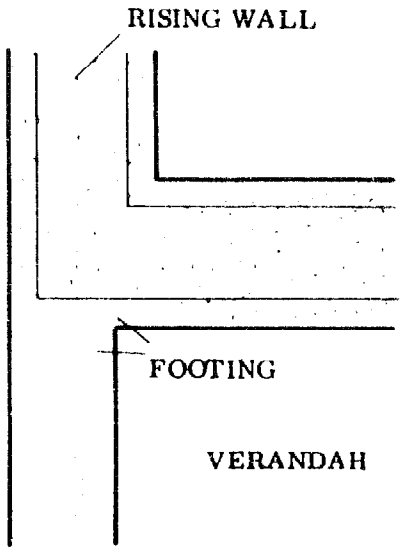

Fig. 3

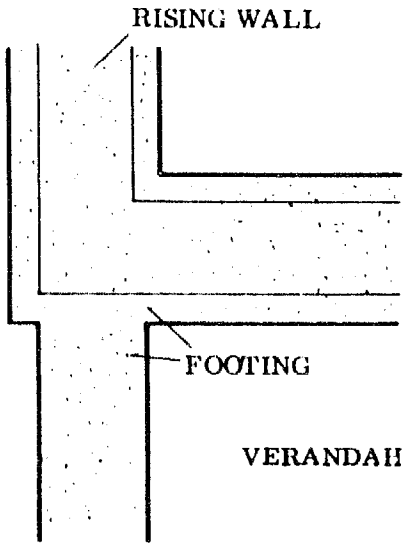

Fig. 4

N P V C		SPECIAL BONDS.
44	CON.	

SPECIAL BONDS

Special bonding problems occur at quoins, T-junctions and cross junctions where walls of different thicknesses meet. These situations are frequently found in connection with the footings. They may also occur in other masonry.

An example where footings with different thicknesses meet is in the construction of a verandah. This is because the footing courses under verandahs are laid edgewise instead of flatwise, in order to save material. This is possible because there are no great loads on the verandah footings.

The bonding problem arises from the fact that the dimensions of common sandcrete blocks make it difficult to form a bond between the edgewise courses and those laid flatwise. Fig. 1 shows that two courses laid edgewise do not exactly correspond with three courses laid flatwise: there is a 1 cm difference in height.

Footing blocks can be specially made to dimensions that will show a better correspondence, so that bonding is easier and less block-cutting is needed to make the bonds. Fig. 2 shows four flatwise courses of specially made blocks, 10,5 cm thick, which correspond perfectly with two courses laid edgewise. Thus bonding is made easier.

The verandah footing may be kept in line with the outside face of the wall footing (Fig. 3), or in line with the rising wall (Fig. 4) which results in a recessed footing (see Drawing Book, pages 65, 66, and 90).

Each type of block can be used with either a recessed footing or a flush footing. Therefore there are four possible situations:

- Common sandcrete blocks in a flush footing
- Common sandcrete blocks in a recessed footing
- Specially made sandcrete blocks (10,5 cm thick) in a flush footing
- Specially made sandcrete blocks in a recessed footing.

NOTES:

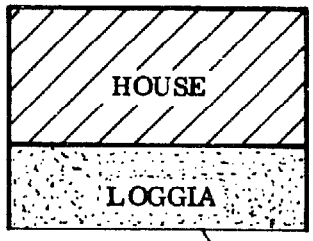

Fig. 1

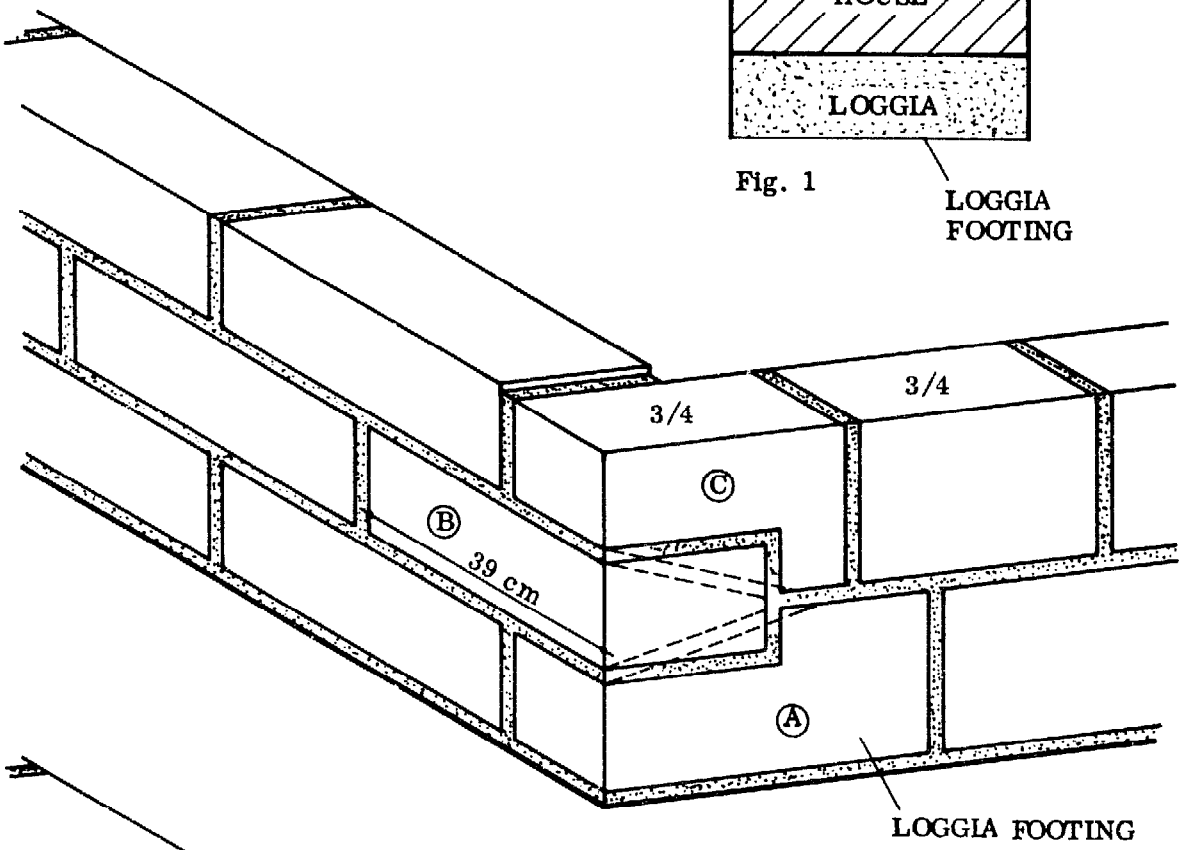

Fig. 2

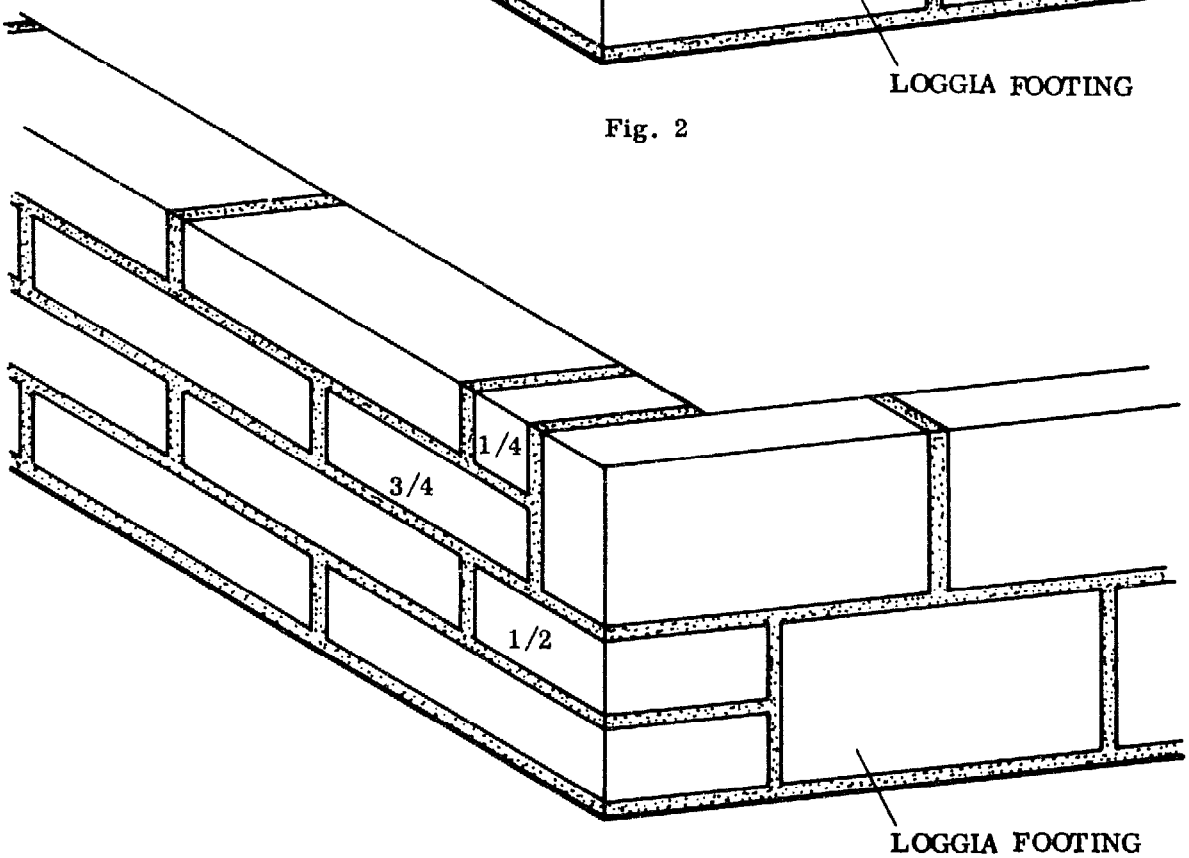

Fig. 3

N P V C		SPECIAL BONDS.
46	CON.	

DIFFERENT WALL THICKNESSES AT A QUOIN

This situation occurs when a verandah is closed at one end with a wall, or where a "loggia" is made. A loggia is a room which has one side open to the courtyard, garden, etc. (Fig. 1). The footings which carry walls have to be regular flatwise footings, while the footing on the open side can be constructed with the blocks edgewise, since it does not carry any wall.

- COMMON BLOCKS, FLUSH TO OUTSIDE: Fig. 2 shows that both quoin stretchers of the edgewise courses (blocks A and C) have to be cut to an odd shape to fit together with the flatwise quoin header of the second course (block B). In order to maintain the half-block bond, block B has to be cut to a length of 39 cm.
- SPECIALLY MADE BLOCKS, FLUSH TO OUTSIDE: If specially made blocks are used, it is not necessary to cut them to odd shapes, and the bond is easy to make as well as more economical (Fig. 3).

A corner bond in which the edgewise courses are set back (recessed) in order to be in line with the outside of the rising wall does not make sense and it is therefore not shown here. It is best to apply one of the arrangements above, or to make the whole structure stronger by laying all the corner blocks flatwise (Fig. 4, below).

- NOTE: It is best to avoid making these bonds with common blocks: use specially made blocks instead if possible, because it is extremely difficult to cut the odd shaped blocks (Fig. 2, blocks A and C) to the ideal shape without breaking them. If specially made blocks are not available, the common blocks can be given a wedge shape where they intersect, as indicated in Fig. 2 by the broken lines. This shape is easier to cut without breaking the blocks.

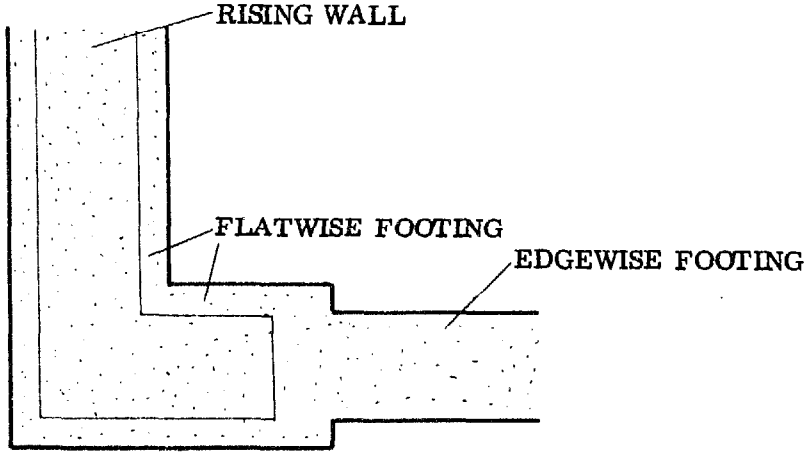

Fig. 4

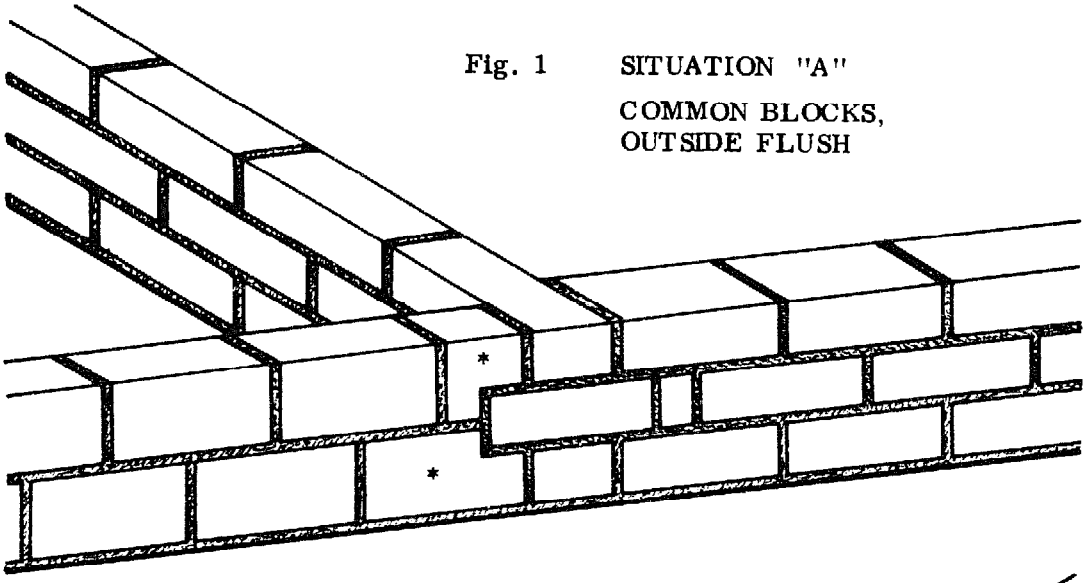

Fig. 1 SITUATION "A"

COMMON BLOCKS,
OUTSIDE FLUSH

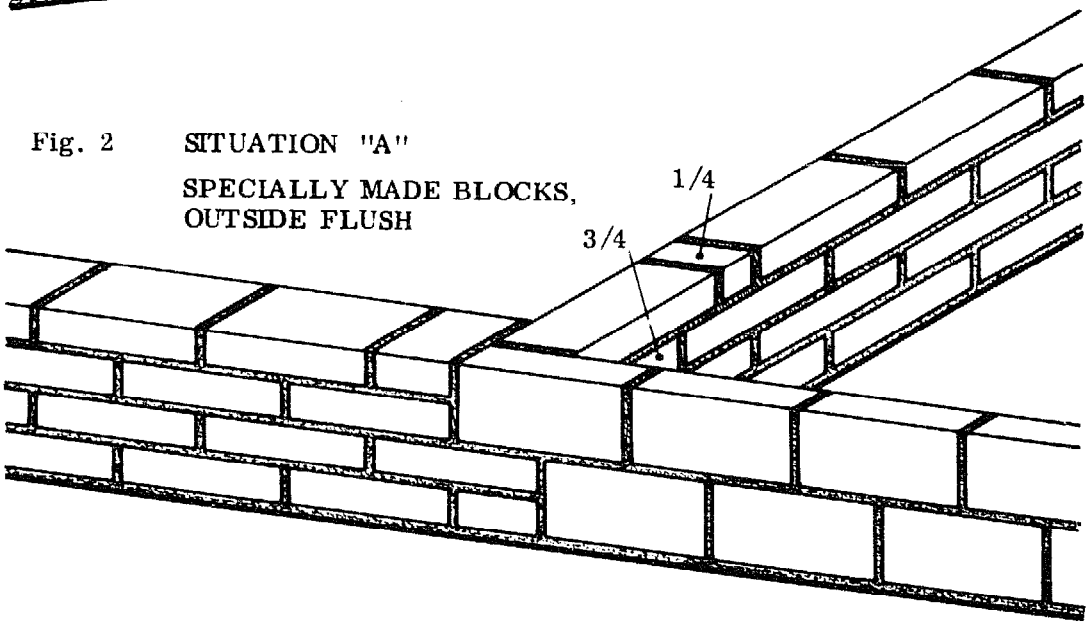

Fig. 2 SITUATION "A"

SPECIALLY MADE BLOCKS,
OUTSIDE FLUSH

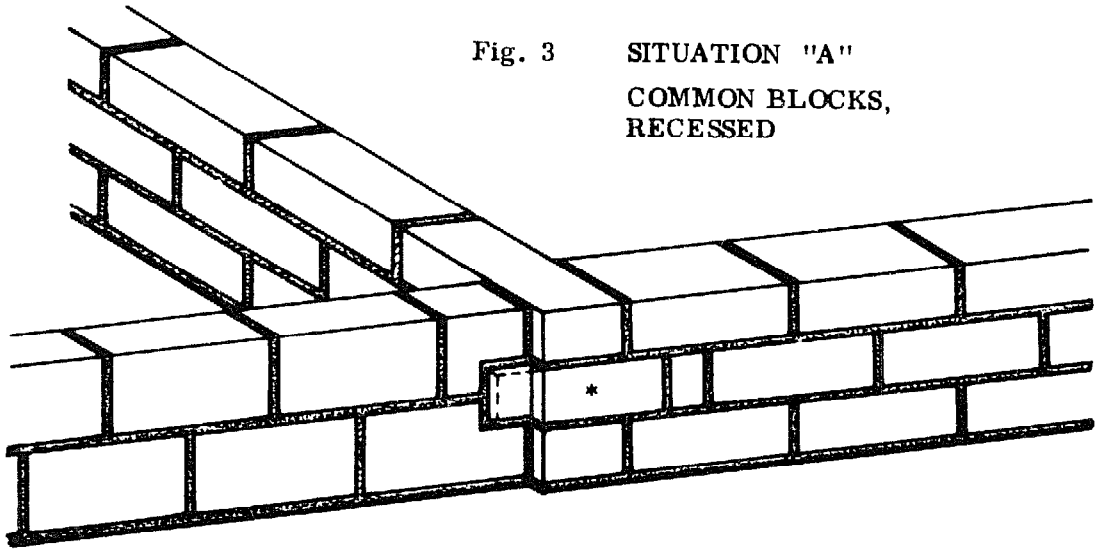

Fig. 3 SITUATION "A"

COMMON BLOCKS,
RECESSED

N P V C		SPECIAL BONDS.
48	CON.	

DIFFERENT WALL THICKNESSES AT A T-JUNCTION

In Rural Building we are mostly concerned with those T-junctions in which a course of edgewise blocks meets either a corner ("A" below) or a wall ("B" below) of flatwise blocks.

Situation "A" occurs for example when a verandah is built flush with the corner of the house; while situation "B" will occur if the verandah meets the wall of the house away from the corner.

There are also possible situations where a flatwise course meets a corner or wall of edgewise blocks, but these situations are not common in Rural Building.

Here we discuss four methods which can be used in situation "A", depending on the type of blocks available and on whether the edgewise course will be recessed or flush to the outside of the flatwise courses. Two methods are given to deal with situation "B".

- SITUATION "A", COMMON BLOCKS, OUTSIDE FLUSH: As with the corner bond using common blocks (previous page), this bonding problem can only be solved by shaping the first blocks of both courses of the thin wall so that the second course of the thick wall can be bonded (Fig. 1). This requires precise and careful cutting.
- SITUATION "A", SPECIALLY MADE BLOCKS, OUTSIDE FLUSH: Bonding becomes simpler and more economical when these blocks are used. Fig. 2 shows that there is no material wasted since the 1/4 block which is left from cutting the 3/4 block will be used in the fourth flatwise course.
- SITUATION "A", COMMON BLOCKS, RECESSED: This bond is almost the same as the first method above, except that the stretcher of the second flatwise course projects on both sides in the direction of the thin wall (Fig. 3, broken lines). After the mortar has set hard, the projecting corners are chiselled off.

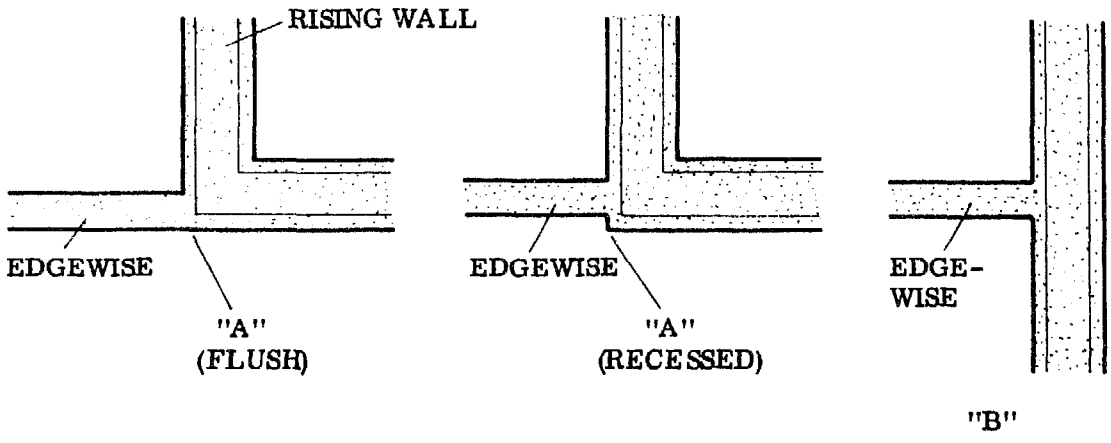

SPECIAL BONDS.

N P V C	
CON.	49

Fig. 1 SITUATION "B"
COMMON BLOCKS

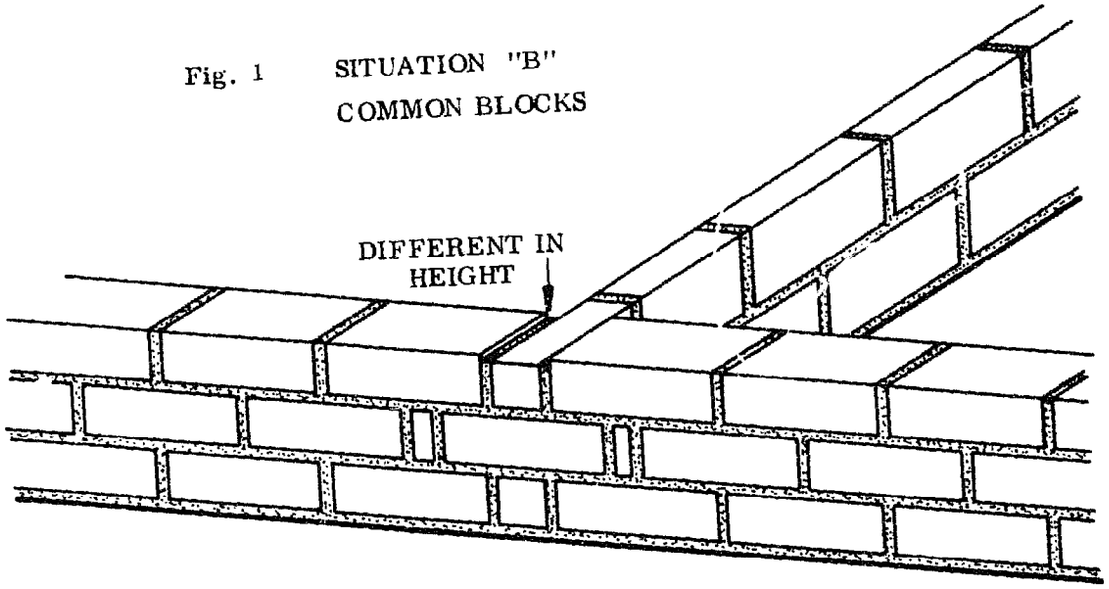

Fig. 2 SITUATION "B"
SPECIALLY MADE BLOCKS

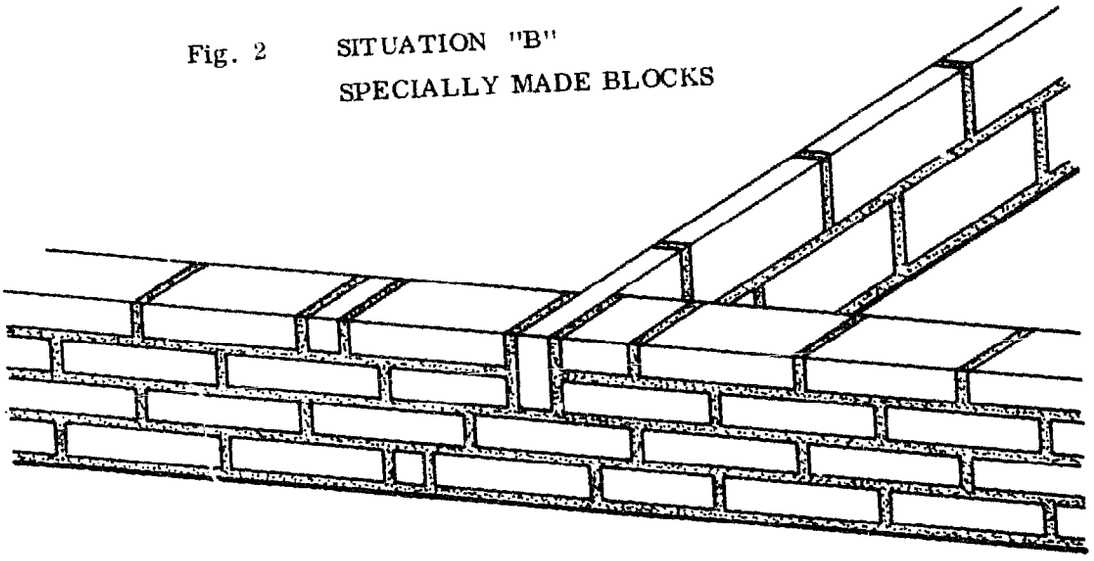

N P V C	
50	CON.

SPECIAL BONDS.

- SITUATION "A", SPECIALLY MADE BLOCKS, RECESSED: In this case we can use the same bond as in the second method (Fig. 2, last page). The 3/4 block and the full block above it have to be shortened by 4 cm. This will reduce the inside overlap of the junction, but that cannot be helped.

- SITUATION "B", COMMON BLOCKS: Again, here it does not make sense to talk about making a recessed thin wall: as at a quoin, the edgewise course will always be flush with the outside face of the flatwise footing course.

  Fig. 1 shows that here again we find the same problem which always arises when common blocks are used in a bond between different wall thicknesses. The first blocks of the two edgewise courses have to be cut to odd shapes.

- SITUATION "B", SPECIALLY MADE BLOCKS: When this bonding method (Fig. 2) is compared with the last method, it is clear that once again the specially made blocks are the best choice.

NOTES:

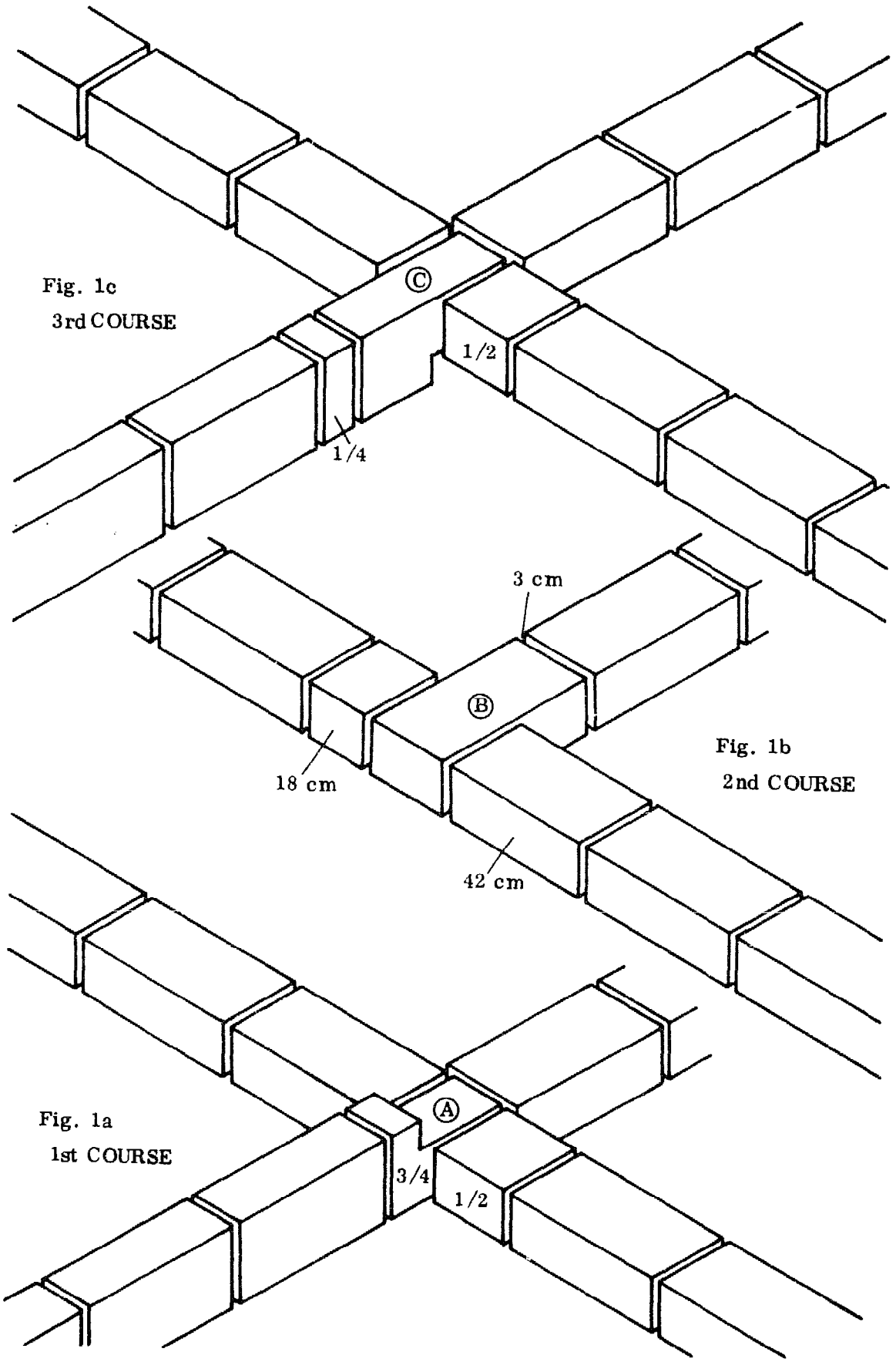

N P V C	
52	CON.

SPECIAL BONDS.

DIFFERENT WALL THICKNESSES AT A CROSS JUNCTION

There are four possible situations for a cross junction with different wall thicknesses. The one which is described here is the most common in Rural Building. This situation occurs when the end of a verandah joins the wall of the house and is in line with an inside wall (Fig. 2, below). This means that the footing blocks are laid flatwise in three directions, and edgewise in one direction.

- COMMON BLOCKS: The first course of the thin wall is bonded into the thick one by a 3/4 block (block A) which must be shaped in such a way that the second course of the thick wall can overlap it (block B). Block A is followed on one of its stretcher sides by a 1/2 block, while all other directions are continued with full blocks (Fig. 1a shows the first courses).

  In order to maintain the half-block bond, the second course of the thick wall must contain a block which is 18 cm long, and another 42 cm long; the latter overlaps the 1/2 block below. Don't forget that the first cross joint following the stretcher overlapping the thin wall is 3 cm wide, or else the first two cross joints are made 2,5 cm wide (Fig. 1b).

  The third course of the thick walls is a repetition of the first one. The second course of the thin wall starts with a full block (block C) which is the same shape as the 3/4 block below it, so that it can be bonded into the thick wall. It is followed by the 1/4 block which was left over from the first course. Note that the thin wall remains 1 cm lower than the other walls, unless the mortar beds in the thin wall are both made 2,5 cm thick (Fig. 1c).

  A disadvantage of this bond is that the overlap across the thin wall is rather short. This problem is not fully solved by using the specially made blocks.

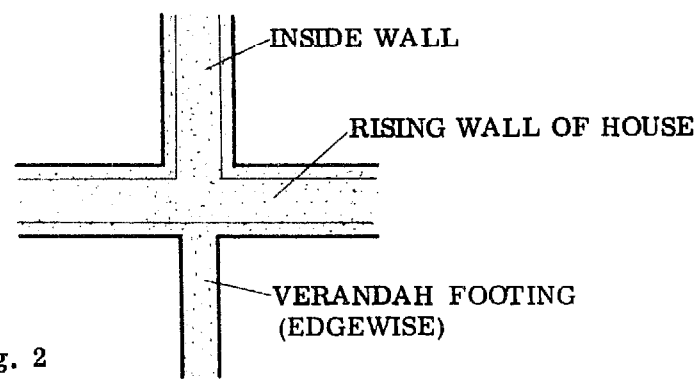

Fig. 2

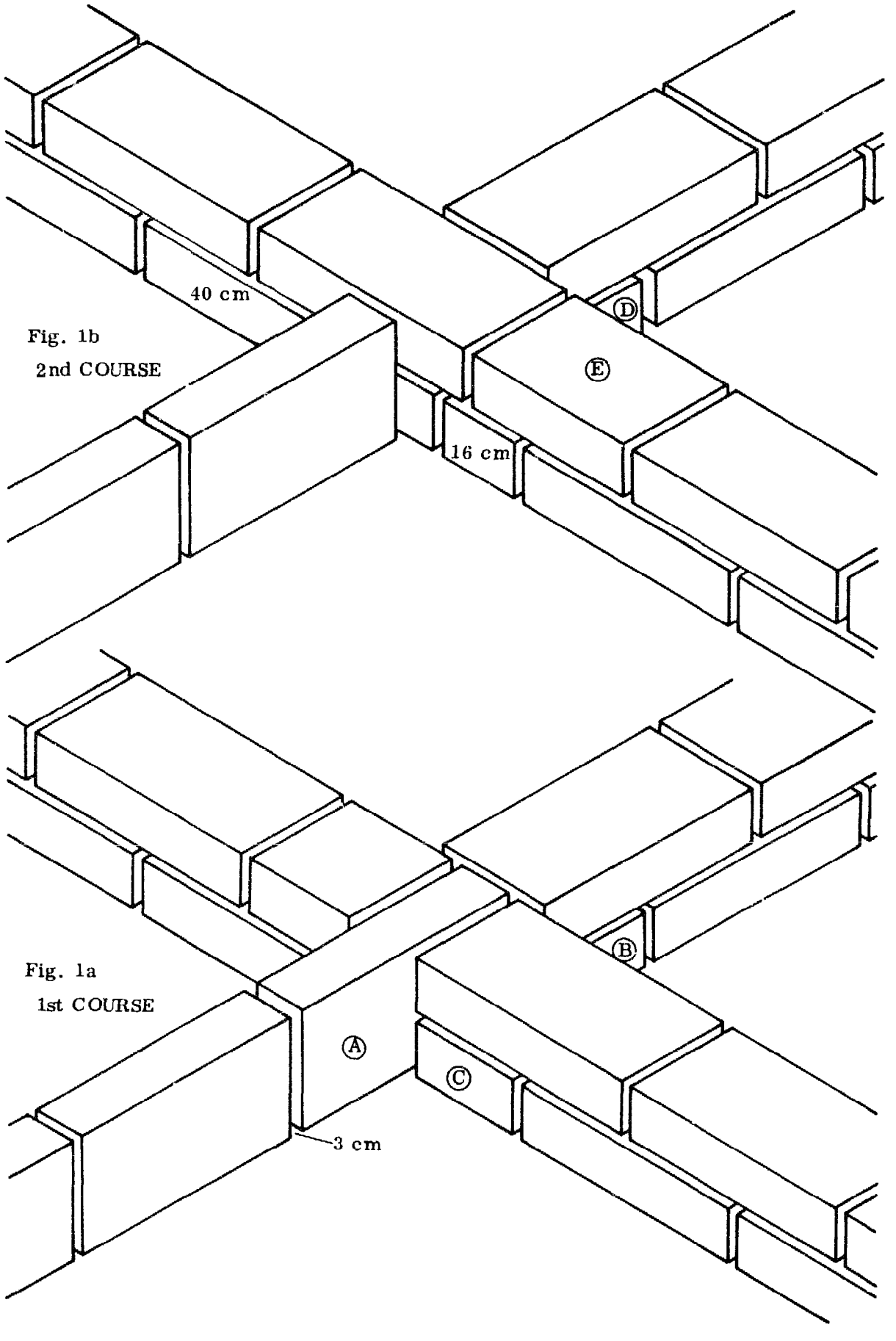

Fig. 1b
2nd COURSE

Fig. 1a
1st COURSE

N P V C		SPECIAL BONDS.
54	CON.	

- SPECIALLY MADE BLOCKS: The first course of the thin wall is bonded into the first two courses of the thick one by using a full block (block A). The first cross joint following this block is made 3 cm wide, or else the first two cross joints are made 2,5 cm wide. The first course of the thick walls continues with a 1/2 block (block B) in the direction of the thin wall, and with a 1/2 block (block C) either to the right or left side of the cross. The second course of the thick walls starts with full blocks where there are half-blocks below, and with a half-block which is above the full block of the first course (Fig. 1a).

  The third course of the thick walls starts with a full block (block D) covering three cross joints. A block of 16 cm in length is placed beside this, above the full block; and a block of 40 cm length is placed on the other side, above the 1/2 block. The second edgewise course and the fourth flatwise course consist of full blocks, with the exception of a 3/4 block (block E) overlapping the 16 cm block below by 10 cm (Fig. 1b).

  This cross junction bond, even with the use of the specially made blocks, still does not provide a very good overlap.

NOTES:

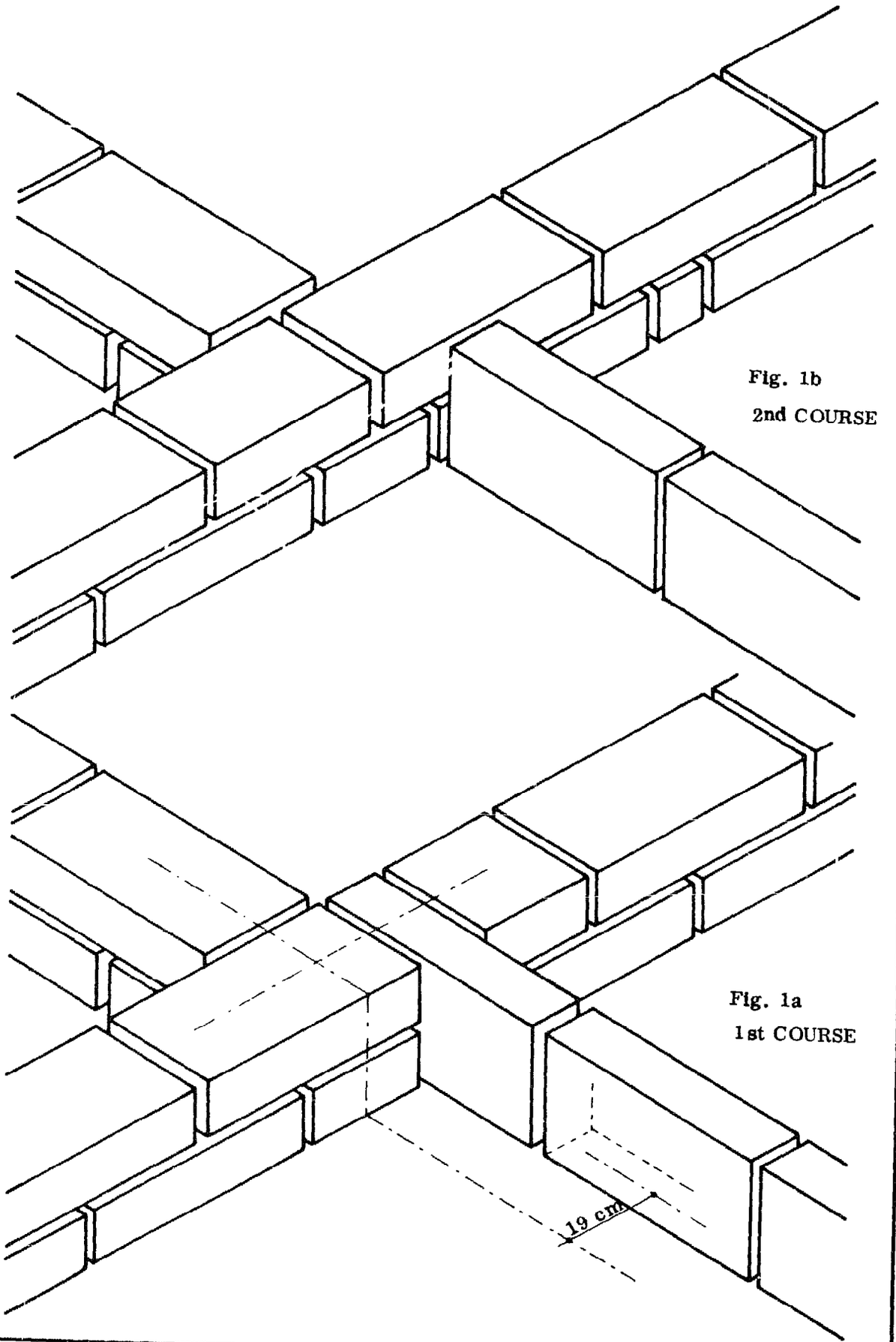

Fig. 1b
2nd COURSE

Fig. 1a
1st COURSE

NPVC	
56	CON.

SPECIAL BONDS.

- STAGGERED BOND WITH SPECIALLY MADE BLOCKS: A simple but good masonry bond can be achieved by staggering the bond. This means that the thin wall is shifted to either side of the crossing thick wall. The distance between the two centre lines of the walls will be about 19 cm (Fig. 1a).

  The first course of the thin wall is bonded into the thick one by using a full block. The two courses on the left side of this almost form a quoin, while the courses on the other side are completed in the normal way. Apart from the 1/2 block in the second course, only full blocks are needed (Fig. 1a).

  The third and fourth courses of the thick wall are bonded as if in a T-junction, except that the 1/4 block of the third course is placed further away from the junction, to avoid having too many cross joints in the junction area (Fig. 1b).

- NOTE: By planning ahead and doing a little extra work in setting out, you can avoid complicated and costly constructions.

  For footings where there will be junctions between flatwise and edgewise blocks, it is always better to use specially made blocks which are 10,5 cm thick. These allow proper bonding, are more economical, and avoid the necessity for constructing junctions between two edgewise courses and three flatwise courses.

  Cross junctions between different wall thicknesses should be avoided because the bonding is difficult and the overlap is poor. A staggered bond is preferred in those cases where a simple T-junction cannot be made instead of the cross junction.

NOTES:

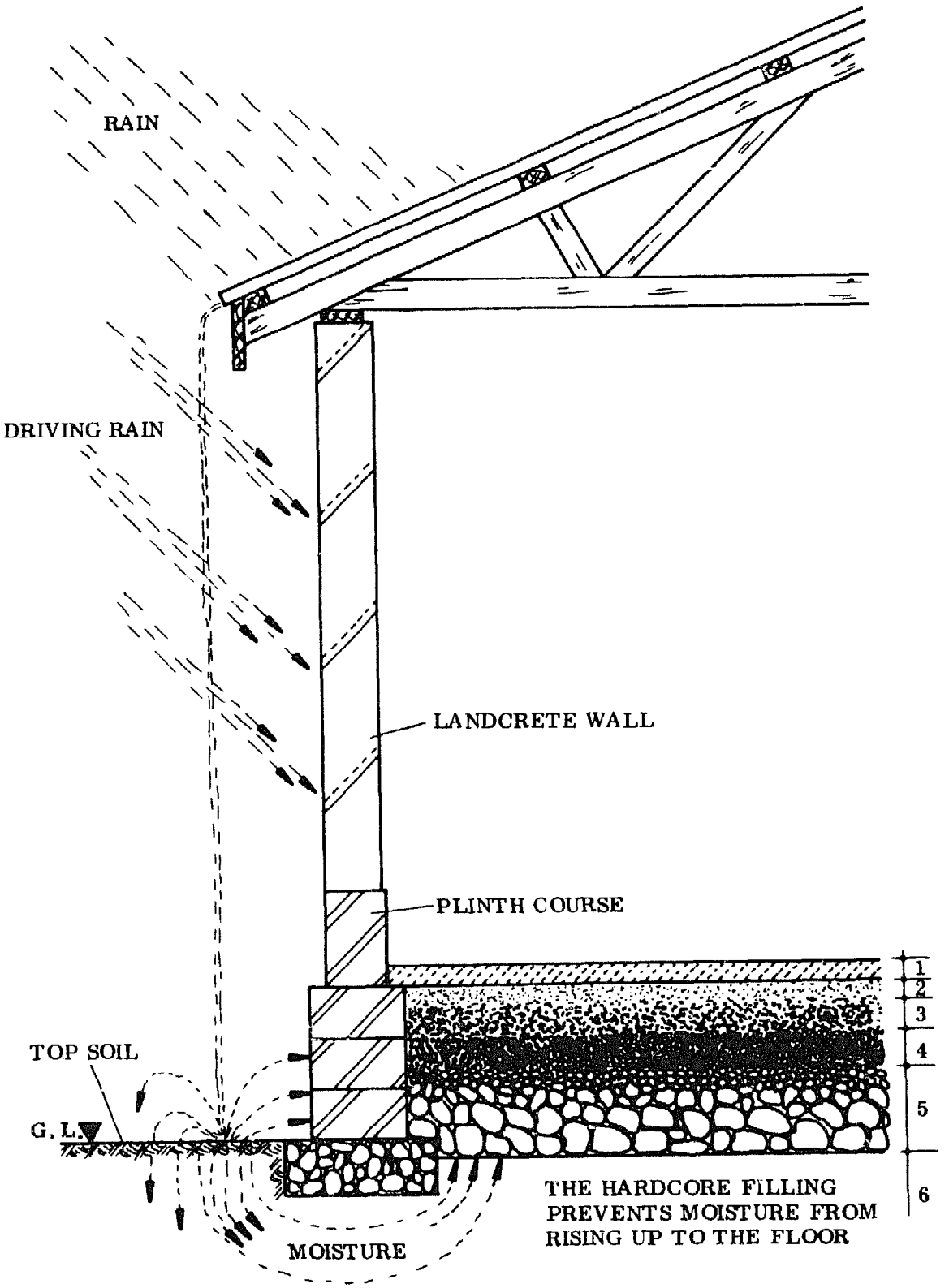

1 = CONCRETE FLOOR
2 = FINE SAND
3 = FINE GRAVEL
4 = COARSE GRAVEL
5 = ROCKS & STONES
6 = FIRM SOIL

N P V C	
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HARDCORE FILLING.

HARDCORE FILLING

FUNCTIONS OF THE HARDCORE FILLING

The two main functions of the hardcore filling are:

- To support the concrete floors, including all loads imposed on the floors
- To raise the floors high enough above ground level to prevent dampness from penetrating.

The hardcore has to be made from hard, solid materials which are arranged in such a way that moisture is not able to rise through them to the floor.

MATERIALS AND ARRANGEMENT

All topsoil is removed before the hardcore is applied. Then the filling is applied in layers no more than 15 cm thick. Each layer is compacted thoroughly before the next one is added. The hardcore filling occupies the space between the subsoil and the tops of the footings (Fig. 1).

The first layer consists of rocks, stones and broken sandcrete blocks. These are no smaller than fist-size and no bigger than 15 cm in diameter. The stones for this layer are preferably set into place by hand, according to their shape, in order to fit them together.

For the second layer we use broken stones which are about half the size of a fist. The following layers are formed of smaller stones, coarse gravel, or gravelly laterite soil; up to about 6 cm below the tops of the footings.

The last 6 cm to the top of the footings should be filled with sand or laterite soil to seal the surface of the hardcore, in order to keep the cement paste from the floor from leaking downwards.

- BACK-FILLING: If the foundation consists of stone masonry, the extra space left inside the foundation trenches has to be filled in before the hardcore is done. If the space is more than about 30 cm wide, it is best to use hardcore to fill it. If less, rammed soil will be sufficient.

  The outside of the trench excavation has to be refilled with gravel, to prevent erosion around the foundations (Foundations, page 19).

Never be tempted to fill up the site with soil underneath the hardcore, even on a sloping site: even if the soil is compacted it will still settle and cause the floor above to settle and crack. The hardcore should rest directly upon the subsoil.

COMPACTION OF THE HARDCORE

All the layers are normally compacted by hand with heavy rammers. This exhausting work can be made easier by using heavy iron or concrete rollers, or by driving a tractor several times over the hardcore to compact it.

Wet down the gravel and sand layers as they are filled in. This not only reduces the dust in the air but also makes compaction easier and ensures a dense layer.

Sometimes the building schedule allows construction to halt during the rainy season. If so, then it is a good idea to plan ahead in order to complete the hardcore filling before the rains come. This is done so the hardcore can be left open during the rainy weather to become very well compacted by the rain. However, it is still necessary to compact the layers of hardcore as they are added. The hardcore can be inspected from time to time during the rainy season, and any sunken areas can be filled up as they develop.

- NOTE: It is sometimes observed that a builder uses soil excavated from the foundation trenches to make the hardcore. This is convenient, but it is a bad procedure. The laterite soil acts as a sponge to draw moisture up from the subsoil into the building. The hardcore is made with a rock base because the rocks do not draw moisture upwards, so the building stays drier.

  Gravelly laterite soils can be used for the layers just below the final layer, and fine laterite soil may be used for the final layer which seals the hardcore filling.

PLINTH COURSE

The plinth course forms the first course of the rising wall, immediately above the footings. Its sole function is to raise the landcrete blocks or sun-dried laterite blocks of the following courses high enough to protect them from moisture penetration.

The materials used for the plinth course should therefore be moisture resistant to some extent, such as natural stone or sandcrete blocks (Fig. 1, last page). It is known from experience that one plinth course is sufficient in northern Ghana, but there are situations where it is better to use a more durable material up to window cill level, especially in the rain-forest areas of Ghana.

In northern Ghana the rising landcrete walls are erected flush with the outside of the plinth course. In the south, however, it is advisable to lay the landcrete blocks flush to the inside of the plinth, so that thicker render can be applied on the outside to protect against moisture penetration.

POSITIONS OF DOOR AND WINDOW FRAMES

Before the plinth course is laid, the positions of the doors are marked on the footings.

If the door frames have been already made and painted they may now be set into place according to the marks. If the frames are not yet available, the plinth course and the rising walls can be erected anyway. In this case one must remember that the measurements given in the drawing are the outside measurements of the frame. Therefore the opening left in the wall must be about 1 cm wider on all sides, so that later on the frame can fit in (see Fig. 1).

The way the door and window frames are positioned in the surrounding masonry depends on the type of door or window, which way it opens, and whether mosquito-proofing and/or burglar-proofing will be installed.

Fig. 2 shows the most common position in which the frame is set flush to the outside of the render. The frame may be flush to both the inside and outside surfaces (Fig. 3), although the cill may project past the render on the outside face. Keep in mind the thickness of the plaster or render when you set the frame in the unplastered wall. The frame edge should be in line with the future plaster surface.

Vibrations from opening and closing the door or window, as well as the shrinking and swelling of the frame, will cause cracks to appear in the plaster and even cause pieces of plaster to come off. To prevent this and to cover the unavoidable cracks, a V-joint is made wherever plaster or render is flush to the frame. This may be covered with a wooden strip (Fig. 4). It is incorrect to apply plaster or render directly against the frame (Fig. 5, arrow).

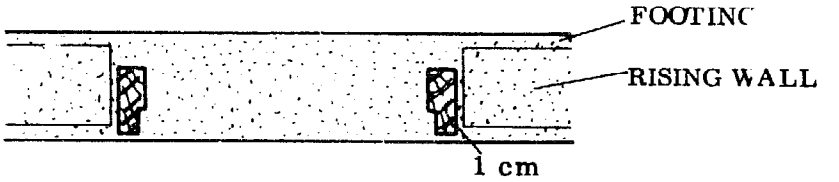

Fig. 1

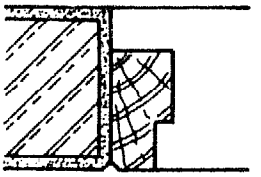

Fig. 2

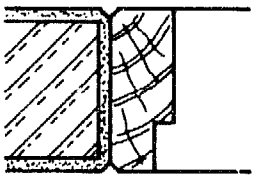

Fig. 3

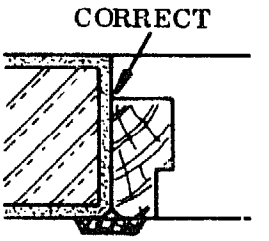

Fig. 4

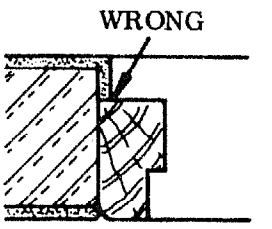

Fig. 5

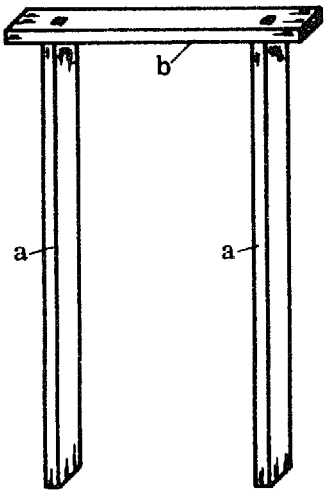

Fig. 1

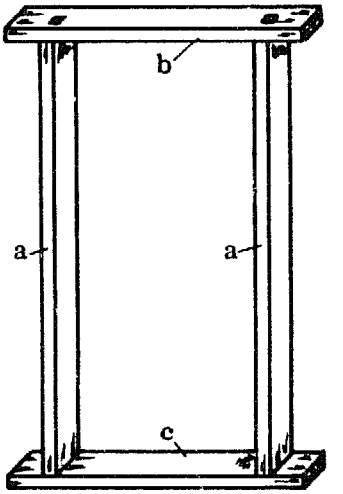

Fig. 2

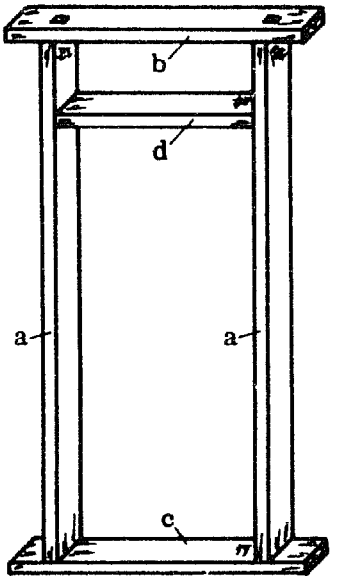

Fig. 3

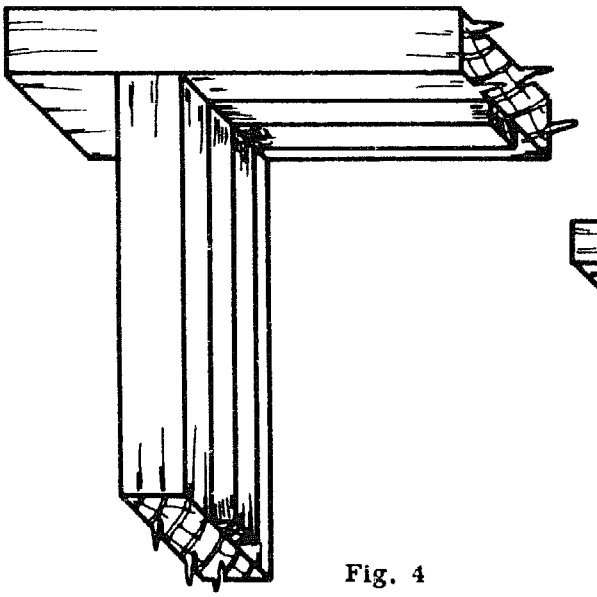

Fig. 4

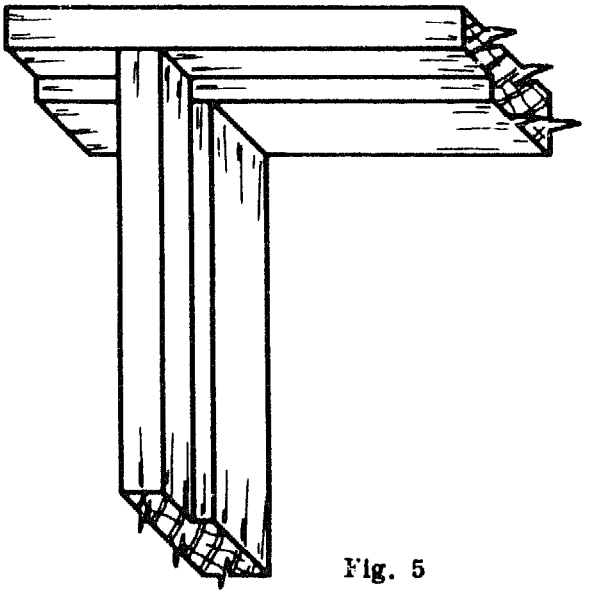

Fig. 5

N P V C	
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DOOR FRAMES.

DOOR FRAMES

TYPES OF DOOR FRAMES

The door frame provides a secure attachment for the door. Depending on the type of door, its function, and its location, different types of door frames can be constructed. The most common door frame consists of three members (Fig. 1):

- Two vertical members called posts (a)
- One horizontal member called a head (b).

When it is necessary for the door to fit tightly in the frame, it consists of four members (Fig. 2):

- Two posts (a)
- One head (b)
- One member on the floor, called the threshold (c).

When additional light or ventilation is needed for a room, a fanlight is added to the frame structure by adding one more member between the posts, called a transom (Fig. 3, d).

Note that since the threshold is in direct contact with the floor, or even partly embedded in the floor, it is in special danger from attack by termites or fungus (Reference Book, pages 141 to 144).

- BEAD OR REBATE TYPE DOOR FRAMES: Each of the above door frames can be made either with beads (Fig. 4) or a rebated construction (Fig. 5).

  Beads are preferred over a rebate for two reasons: the construction is easier, and it is possible to adjust the beads after the door is hung. Beads are always fixed into place after the frame is installed and the door is hung.

  Rebates, however, do have a better appearance than beads, and no extra wood is required to make a rebated frame.

NOTES:

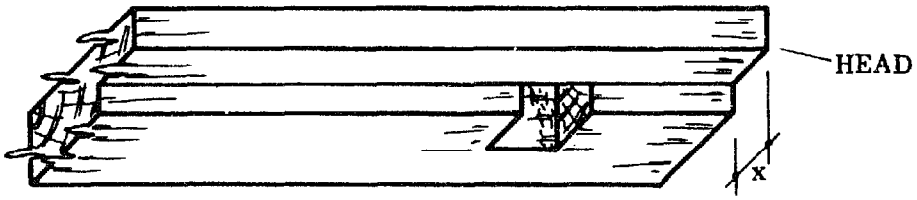

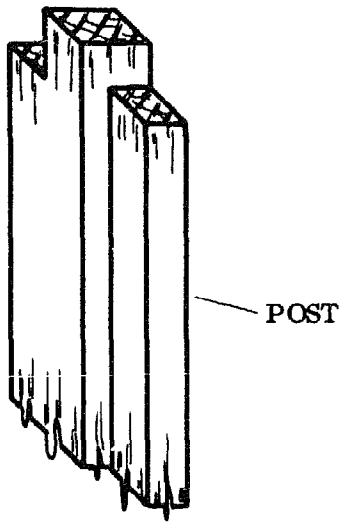

Fig. 1
WIDTH OF REBATE (x)
1/3 OR LESS

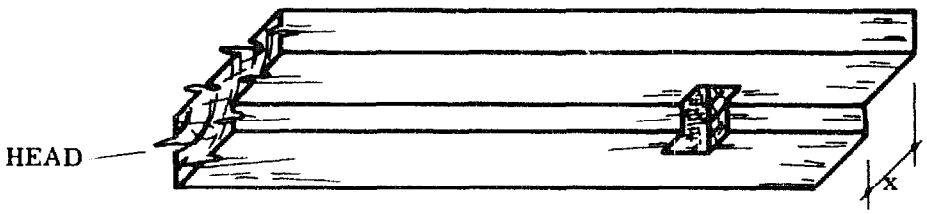

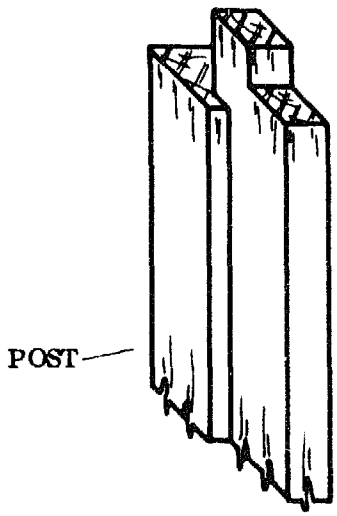

Fig. 2
WIDTH OF REBATE (x)
MORE THAN 1/3

N P V C		DOOR FRAMES.
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JOINTS FOR DOOR FRAMES

- JOINTS FOR DOOR FRAMES WITH BEADS: The joints for a door frame made with beads can be common mortice and tenon joints for box-like constructions. They may be either pegged, wedged or nailed (Basic Knowledge, pages 104 to 106, and 124; also Drawing Book page 43 and pages 67 to 71).

  If a transom is required, it should be installed using a stub tenon joint to prevent water from penetrating the mortice (Basic Knowledge, page 122).

  If a threshold is installed, a common mortice and tenon joint is used for it, but wedges should not be used since they might fall out. Pegs cannot be used either, because the threshold is too thin. This joint should be nailed.

- JOINTS FOR DOOR FRAMES WITH REBATES: If the door frame is made with a rebate, take care that the shoulders of the tenons are set out and cut correctly. One shoulder of the tenon is cut longer to fit the rebate (Drawing Book, pages 67 & 68).

  The thickness of the tenon is affected by the size of the rebate. If the rebate is 1/3rd or less of the width of the member, the tenon will not be reduced in size (Fig. 1). If the rebate is wider than 1/3rd of the member, the thickness of the tenon (and accordingly the mortice width) is reduced by the depth of the rebate (Fig. 2).

  Besides these considerations, the construction of these joints will be the same as for any common mortice and tenon joints for box-like constructions.

NOTES:

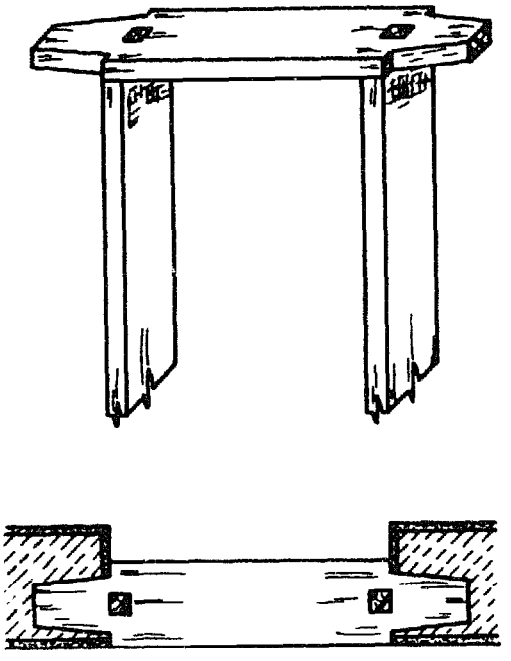

Fig. 1

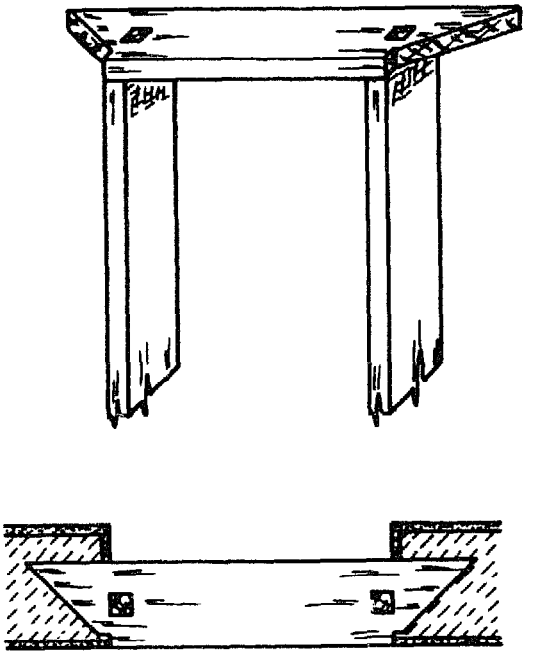

Fig. 2

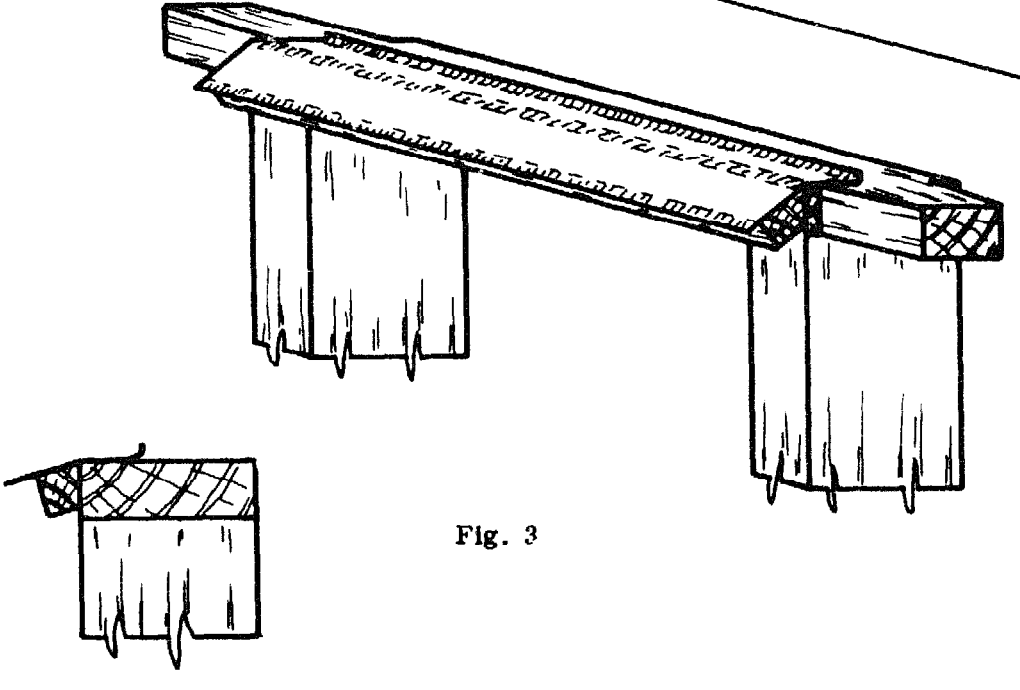

Fig. 3

N P V C		DOOR FRAMES.
66	CON.	

HEADS OF DOOR FRAMES

- HORNS: In order to provide an additional attachment to the wall, the ends of the head and the threshold can project beyond the posts into the wall. This is especially necessary in mud walls.

  These projecting parts can be shaped like horns (Fig. 1), or else the front corners can be cut off at an angle (Fig. 2). These shapes give a good appearance to the frame head when the frame is built into the wall.

- WEATHER STRIPS: If a door frame is to be installed in an outside wall, you need to take some extra precautions to prevent water from entering between the lintel and the frame head, and between the door itself and the door frame.

  Weather strips (Fig. 3) can be fixed on the door head to keep water out. We will learn more about weather strips later in the book, in the section on window frame heads.

- STEEL CRAMPS: These are pieces of mild steel rod which are fixed into the door posts (Fig. 1, next page). They are fixed about 60 cm apart; near the head, middle and foot of the frame.

  The function of these cramps is to secure the frame rigidly to the blockwork. They are set in the posts in positions which correspond with the bedjoints of the blocks, so that they can be built into the bedjoints.

  To fix the cramps in the door frame, drill holes in the posts. The holes should have a diameter a little smaller than the rods, and should not go all the way through the post. Bend one end of the rod to form a head (Fig. 2, next page) and knock the head into the post. Bend the other end to a right angle so it fits into the cross joint between the blocks (Fig. 2, next page).

NOTES:

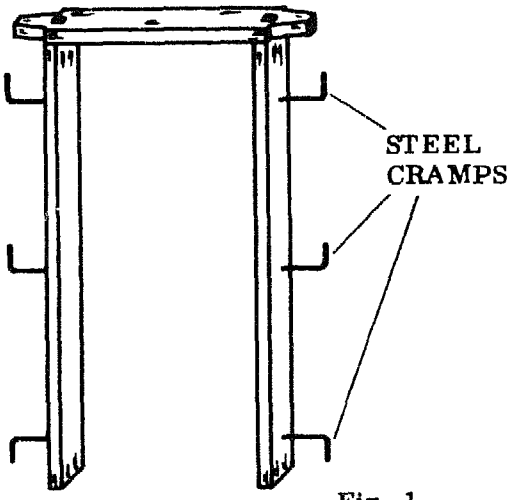

Fig. 1

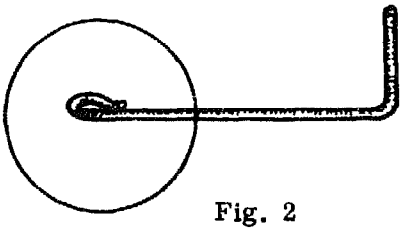

Fig. 2

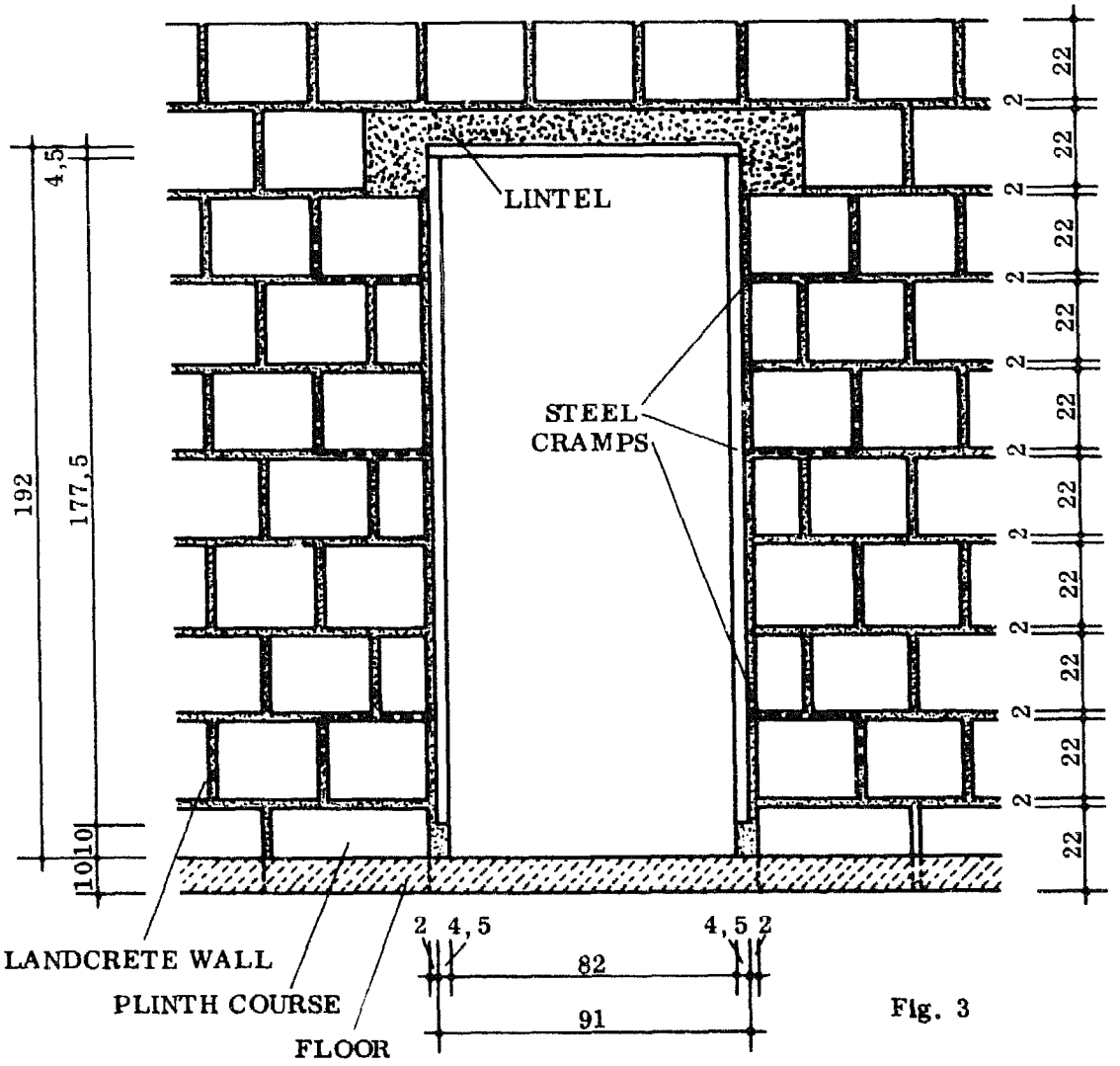

Fig. 3

N P V C	
68	CON.

DOOR FRAMES.

MEASUREMENTS FOR DOOR FRAMES

- MEASUREMENTS OF THE TIMBERS: Usually door frames are made of timbers which are about 10 cm wide and about 5 cm thick. If the posts are held in the wall by steel cramps, it is possible to reduce the size of the timbers to 7,5 by 5 cm. The cramps provide a good grip to the wall so the frame doesn't have a lot of stress on it. This means that the timbers can be made smaller and thus less costly. The cramps are made by cutting iron reinforcement rods.

  The frame itself is always measured from inside face to inside face. Unless it is stated otherwise on the estimate, measurements given for door frames are always inside measurements.

- MEASUREMENTS OF THE FRAME WITH RESPECT TO THE MASONRY: To make the work easy, to avoid extra block-cutting, and to reduce waste, the outside measurements of the frames should correspond to the building unit measurement of the blocks used to construct the wall. For example:

  - The building unit measurement for landcrete blocks is 31 cm wide by 24 cm high.

    The outside height of the door frame will be 8 x 24 = 192 cm.

    The ouside width of the door frame will be 3 x 31, minus 2 cm for one cross joint = 91 cm (Fig. 3).

    The steel cramps are also placed according to the building unit measurement of the blocks, so that they will fit into the bedjoints of the wall (Fig. 3).

NOTES:

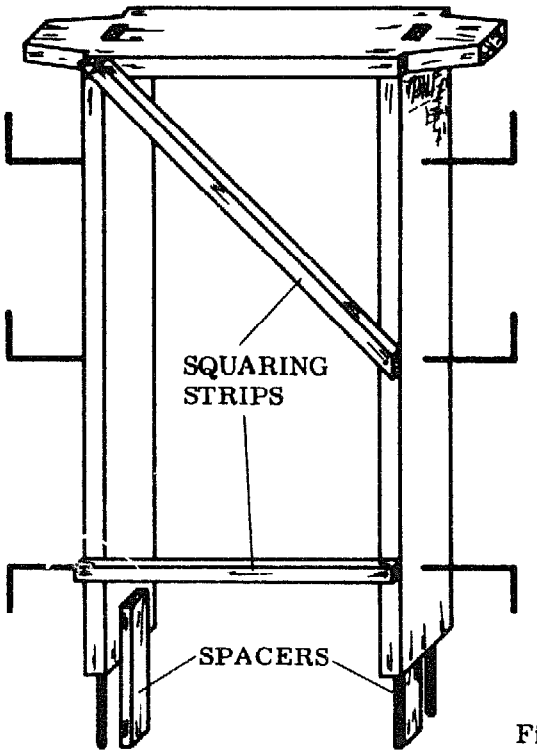

Fig. 1

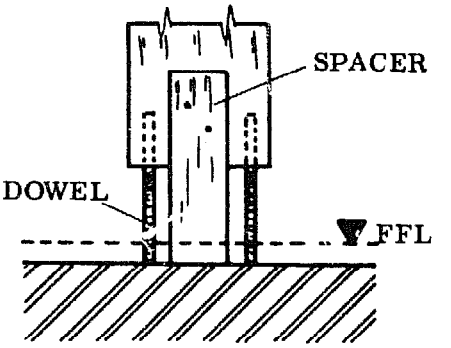

Fig. 2

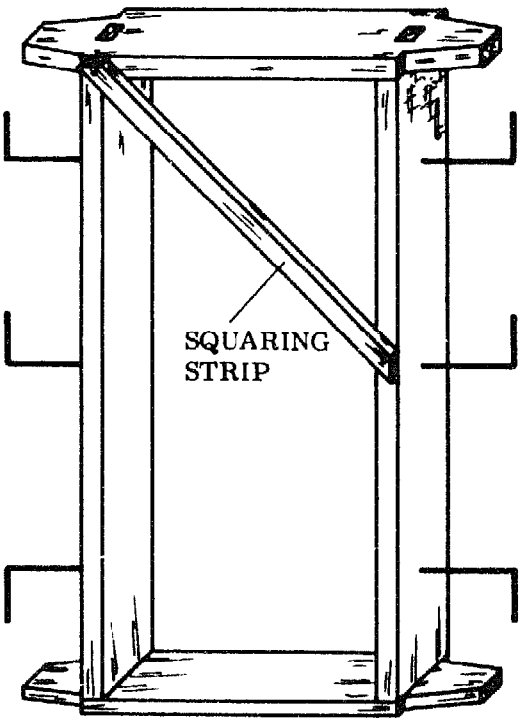

Fig. 3

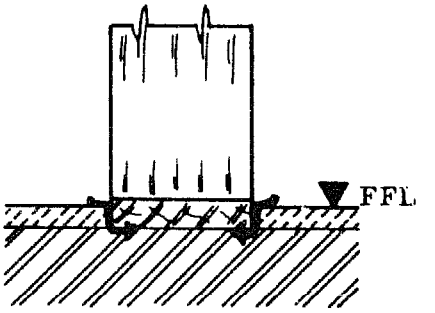

Fig. 4a WRONG - WATER CAN PENETRATE BETWEEN THRESHOLD AND FINISHED FLOOR

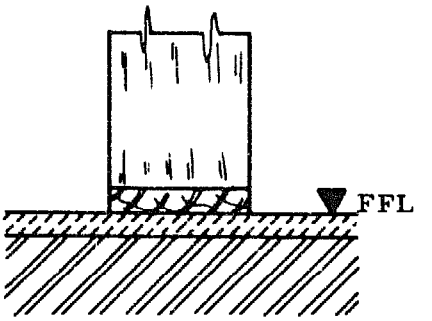

Fig. 4b BETTER - THRESHOLD ON TOP OF FINISHED FLOOR

NPVC	
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DOOR FRAMES.

CONCRETE SHOE

In order to give a firm base to a door frame with no threshold, concrete "shoes" can be fitted on the posts.

To make the shoes, drive steel dowels into the bottom end of each post before setting the frame in the wall (Fig. 1). The projecting ends of the dowels are enclosed later by the finished floor and the shoe (Fig. 2).

Spacers are used to keep the frame at the correct height during the building operations (Fig. 1). The steel dowels are short pieces cut from reinforcement rods.

- ADVANTAGES AND DISADVANTAGES OF THE THRESHOLD (Fig. 3):

advantages:

- The door closes tightly into the framework.
- If the threshold is thick enough, it can be made with a rebate.

disadvantages:

- The threshold is easily attacked by wood diseases or termites.
- More materials are needed.
- More joints have to be made, therefore construction is more difficult.
- Water can penetrate between the threshold and the finished floor (Figs. 4a & 4b).

- ADVANTAGES AND DISADVANTAGES OF THE CONCRETE SHOE

advantages:

- The wood is not in direct contact with the floor, so there is less danger of attack by termites, etc.
- Less materials are needed.
- The shoe secures the doorframe to the floor.

disadvantages:

- The door might not close as tightly as with a threshold.
- If the frame is not well braced during the building operations, there may be a danger of distorting it while fixing it in place.

- SEQUENCE OF OPERATIONS FOR MAKING A REBATED DOOR FRAME WITH A CONCRETE SHOE: (see Drawing Book, page 67)

a. Study the drawing.

b. Prepare a cutting list.

c. Select the wood.

d. Plane the wood to the required sizes (as indicated on the cutting list).

e. Make the face marks.

f. Mark out the joints (take special care in marking out the shoulders of the

tenons on the posts) and mark the length of the posts.

g. Mortice the head and rip the tenons at the posts.

h. Plane the rebate.

i. Cut the shoulders of the tenons.

j. Drill the holes for the steel dowels.

k. Clean up the inside edges.

l. Paint all the members with a primer, especially the joints.

m. Fix the steel dowels and the wooden spacers.

n. Drill the holes and set anchors at the correct places (steel cramps).

o. Assemble the frame with squaring strips.

p. Cut the horns to the required shape and paint them.

Take care when marking the lengths of the posts. They should be the length of the door; plus the upper joint, and minus the height of the concrete shoe.

- ASSEMBLING THE DOOR FRAME: To keep the door frame rigid and square during the various building operations, it needs to be braced. This bracing is done with squaring strips (Fig. 1, last page). These strips are about 2 x 5 cm, and they are cut into the rebate or nailed to the face of the frame. They hold the frame square and keep the correct distance between the posts.

The proper steps for assembling a door frame are as follows:

a. Knock the frame together.

b. Place the frame, rebate side up, on the workbench.

c. Clamp the posts to the head (use sash clamps or the wedges on the bench).

d. Nail a squaring strip to hold the posts at the correct distance apart.

e. Test for squareness from corner to corner (diagonally).

f. With the clamp still in position, fasten the joints.

g. Cut and nail the other squaring strip diagonally from the head to the post (Fig. 1, last page). This holds the frame square.

h. Cut the posts to the required length.

i. Drill the holes for the steel dowels and fix them. They should be long enough to anchor into the concrete floor.

j. Nail wooden spacers into the inside of the rebate. These keep the frame at

the correct height during the building operations (Figs. 1 & 2, page 70).

k. Finish off the frame. The priming coat of paint should be applied to the external woodwork before it is fixed in place.

When timber with a small section, for example 5 x 7 cm or 5 x 10 cm, is used for the posts, an extra squaring strip should be fixed horizontally in the middle of the frame. This prevents the pressure of the blockwork from distorting the frame.

INSTALLING DOOR FRAMES

Frames which are improperly built-in can cause problems later, when the plastering is done or the doors are hung. Therefore we must give special attention to setting the frames properly.

A door frame should be fixed in such a way that the door can open flat to the wall. Otherwise, the door will form a lever to the frame, and the hinges will be forced out when the door swings wide open suddenly.

Door frames can be fixed in position either during the masonry construction or after the walling has been completed.

- SETTING FRAMES DURING MASONRY CONSTRUCTION: The first frames to be set are those of the outside walls. When the masonry work has been built to floor level, the door frame is placed in position according to plan and at the correct height, and held there by means of wedges (Fig. 1, a, next page).

  To hold the frame in position during the following building operations, we use struts. These are braced against blocks on the ground and lean up to the head of the frame, where they are secured with two nails (Fig. 1, b, and Fig. 2, next page).

  The masonry line is used to align the frame with the face of the wall. The line is fixed at the two corners of the wall and two small wooden blocks are used to hold the line out from the wall by the same amount as the thickness of the future render layer; so that the line shows the position of the face of the render on the finished building (Fig. 1, c, next page).

  The line should be free (not touching any frame or block) from corner to corner of the building. It should be separated from the frame faces by about a trowel's thickness (Fig. 3, next page).

  Because the posts are long, the plumb bob is the best tool for making sure that the frames are straight and upright. Hold the bob at the inside top of the frame,

DOOR FRAMES.

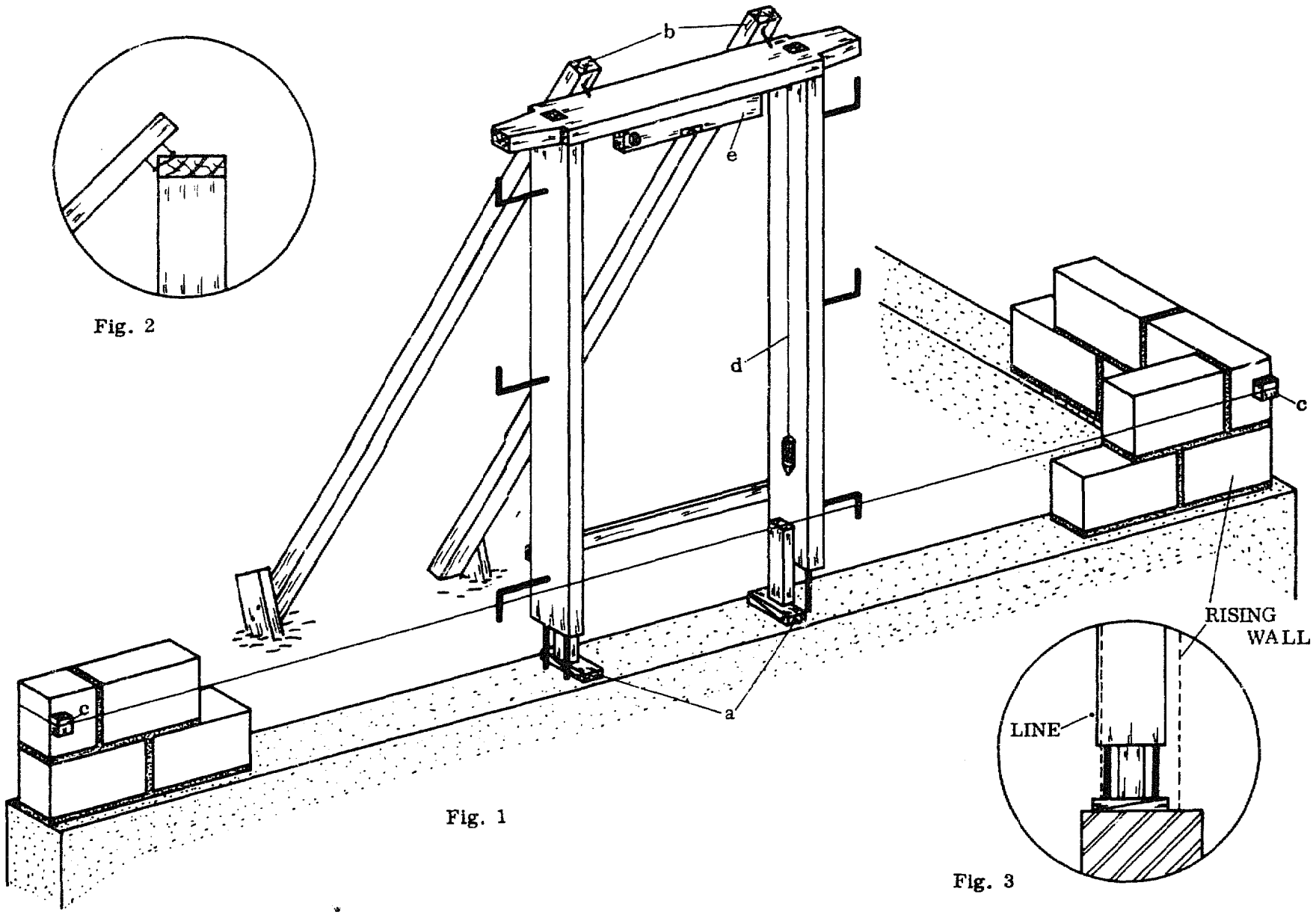

Fig. 2

Fig. 1

Fig. 3

so it has room to swing freely (Fig. 1, d). Check both posts (Reference Book, page 5)

To adjust the frame, the wedges are knocked a bit in or out, thus raising or lowering one post at a time until the frame is straight.

The face of the frame can be plumbed at the same time. To do this, step to one side of the frame and sight the edges of the post and plumb line. A helper should stand by the struts and either "give" or "pull" them until the frame is straight. Take care that the space between the face of the frame and the mason line remains correct (Fig. 3).

As a final check, the soffit (underside) of the head can be levelled with a spirit level (Fig. 1, e).

- REMEMBER: Be sure that the face of the frame is in line with the mason line, not flush with the face of the blocks. When the building is finished, the render surface and the face of the frame should be flush.

  Make sure that the frame remains at the correct height, so that the steel cramps can fit into the bedjoints and the frame does not get twisted.

  After several courses of blocks have been laid, the frame should be rechecked to make sure that it has not become distorted by the blocklaying. Blocks should be laid on both sides of the frame at the same time, so that it does not get pushed out of plumb.

  The struts and braces are taken off only when the blockwork has reached the head of the frame.

  If more than one frame is erected, walk around the building and look from a distance to compare the frames with each other and make sure that they are all in the correct alignment.

- SETTING FRAMES AFTER THE WALLING HAS BEEN COMPLETED: In this method, the installation of the frames is postponed until the roof construction is complete, in order to reduce the risk of damage to the woodwork from the rain and sun.

  Hardwood or plastic plugs (Reference Book, page 215) are driven into the bedjoints to serve as anchors for the frame. The frame is then put into position and nailed or screwed to the plugs.

NOTES:

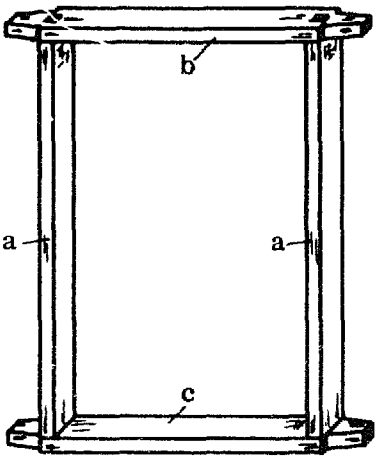

Fig. 1

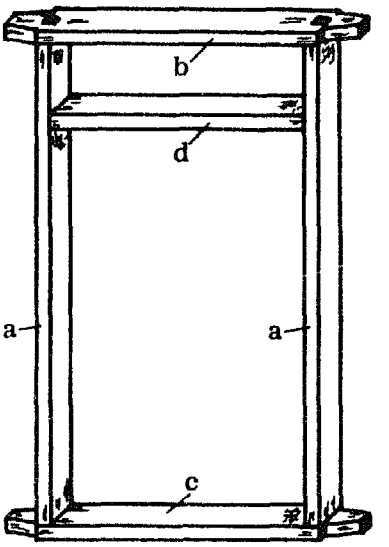

Fig. 2

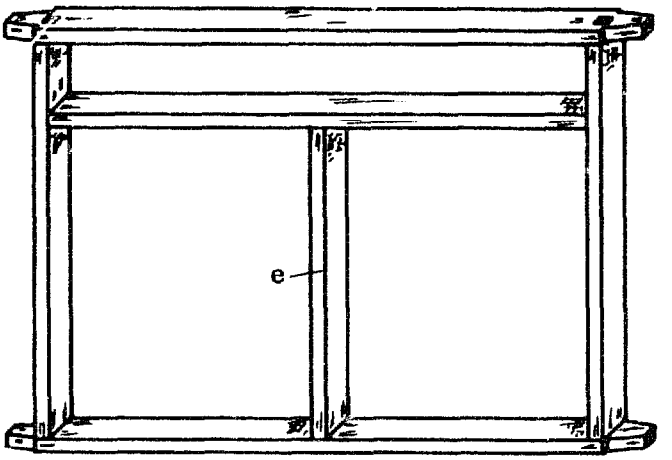

Fig. 3

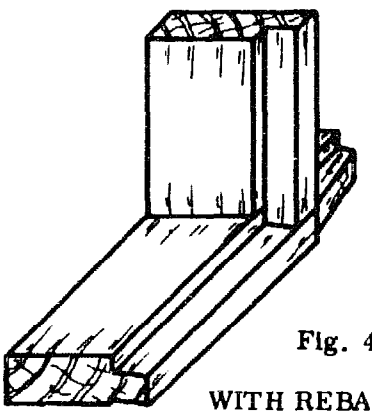

Fig. 4

WITH REBATE

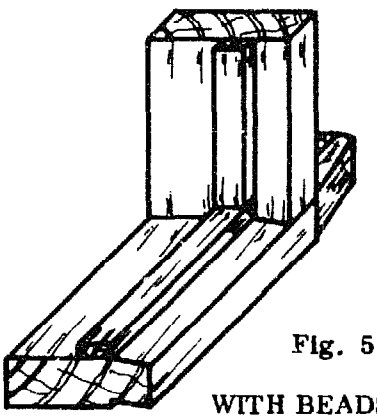

Fig. 5

WITH BEADS

N P V C		WINDOW FRAMES.
76	CON.	

WINDOW FRAMES

TYPES OF WINDOW FRAMES

The function of a window frame is to admit light and air into the building. The most common frame used in Ghana is the solid window type, consisting of an outer frame into which a casement or louvres are fitted.

The most common window frame consists of four parts (Fig. 1):

- Two posts (a)
- One head (b)
- One cill (c)

When additional light and ventilation are needed, a fanlight can be added. The extra piece is called a transom (Fig. 2, d).

If wider windows are required, a mullion (Fig. 3, e) can be added.

Any of these frames can be made with a rebate or with beads, or with a combination of the two (Figs. 4 & 5).

For a list of the advantages and disadvantages of beads or rebates, see the section on door frames. If beads are used, they are fixed after the casement is installed, so they can be adjusted (see Drawing Book, pages 42 & 72).

MEASUREMENTS OF WINDOW FRAMES

Before you start constructing a window frame, you have to decide:

- whether the window will have shutters, louvres or any other kind of closing;
- if there will be any burglar proofing, and if so what kind;
- if any mosquito proofing is required;
- and where the window will be installed (does it have to be opened frequently, for example).

All these factors can influence the kind and sizes of timber we use, and the size of the frame itself.

- REMEMBER: Window frame measurements which are given with no further explanation are always inside measurements.

NOTES:

- MEASUREMENTS OF TIMBER SIZES FOR WINDOW FRAMES: A very common size of timber used for window frames is 7,5 to 10 cm wide, by about 5 cm thick. This size of timber is readily available and relatively inexpensive. If large frames are required, the timber size should be about 15 cm by 5 cm.

- MEASUREMENTS WITH RESPECT TO THE CASEMENTS: The height and width of the window frame are partly determined by the kind of casements which will be used. If ready-made casements are used, the frame has to be the right size to fit them. If the casements are to be made, consider the timber sizes which are available and choose the size of the casements according to the size of the boards, to avoid waste.

- MEASUREMENTS WITH RESPECT TO LOUVRES: If glass louvres will be installed, their size will determine the height and width of the frame. Find out the size of the louvre first, then start making the frame, not the other way around. Mistakes here can be very expensive!

  Also make sure that there is room enough to open and close the louvres and that the mosquito proofing, if present, does not interfere with them.

  Louvre windows will be discussed thoroughly in one of the next lessons.

  The type of burglar proofing which is chosen will also affect the construction of the window frame, and we will consider this in one of the later lessons.

STEEL CRAMPS

If steel cramps are used to hold the frames, they should be positioned to fit into the horizontal joints (bedjoints) of the walls (see Measurements of Door Frames section, page 69).

JOINTS FOR WINDOW FRAMES

When you are marking out the joints, first decide whether the frame is to have a rebate or beads.

In general, the joints for window frames are the same as those for door frames (see the section on Joints for Door Frames, page 65).

NOTES:

- SEQUENCE OF OPERATIONS FOR MAKING A WINDOW FRAME WITH TRANSOM AND MULLION: The joint for the transom-mullion connection should be a stub tenon, to prevent water from entering the mortice at the top.
Take care when marking out and cutting the shoulder of the tenon where it meets the slope of the cill, so that they fit together exactly (Drawing Book, pages 46, 47, 70, 71 and 72).

a. Study the drawing.

b. Prepare the cutting list.

c. Select the timber.

d. Cut the timber to size.

e. Plane the timber to size and make the face marks.

f. Mark out the joints. Take special care in marking out the shoulders of the joints. The head, transom, and cill must be marked out together, as the two posts and the mullion must also be marked out together.

g. Mortice the head and cill, and make stopped mortices in posts and transom.

h. Rip the tenons for the transom, posts and mullion.

i. Rip the horns on the head and cill.

j. Prepare the rebate and throating if required.

k. Cut the shoulders of the tenons.

l. Smooth and clean up the inside edges.

m. Paint the frame with a primer coat, especially at the joints.

- ASSEMBLING THE WINDOW FRAME:

a. Place the frame on the workbench, with the rebated side up.

b. Fix the transom to the posts.

c. Fix the mullion to the transom.

d. Clamp the head and the cill to the posts and mullion.

e. Test for squareness at the four corners, and check the diagonals.

f. Cut and nail the squaring strips.

g. With the clamps still in position, fasten the joints.

h. Finish off the frame.

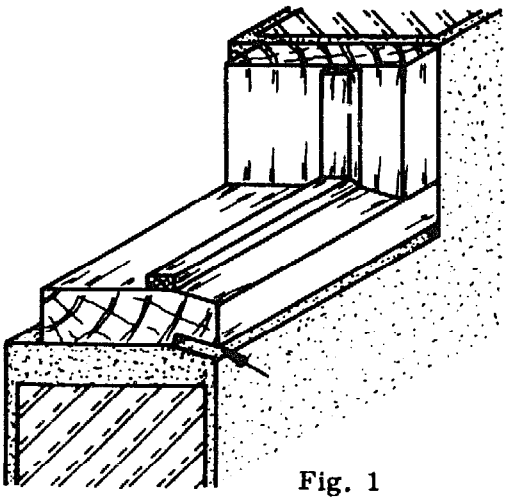

Fig. 1

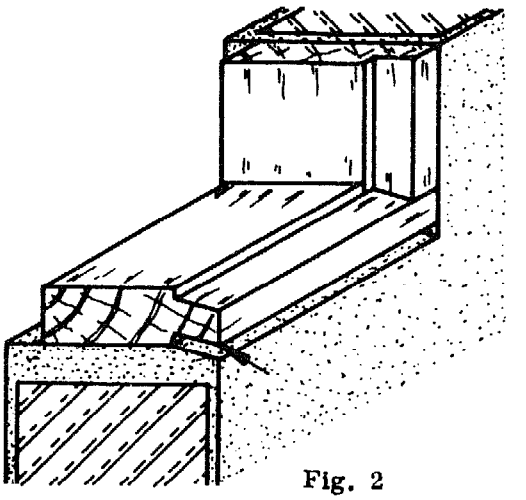

Fig. 2

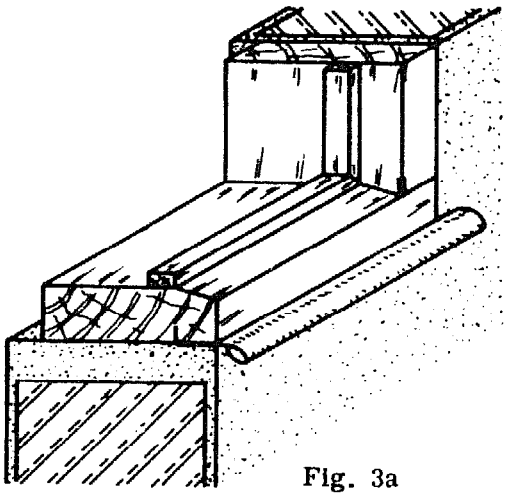

Fig. 3a

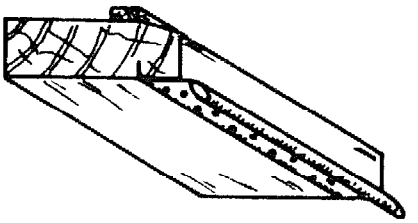

Fig. 3b

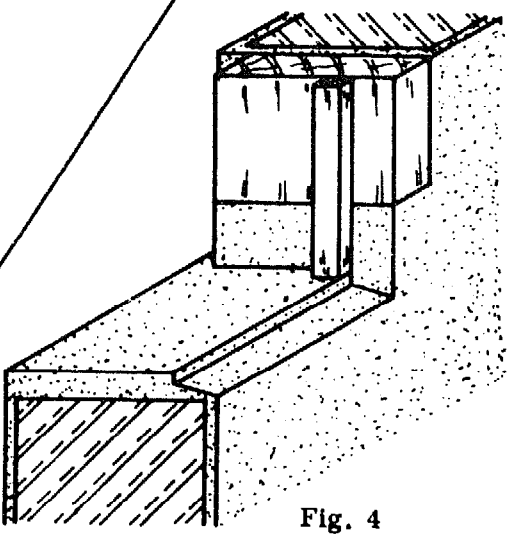

Fig. 4

N P V C	
80	CON.

WINDOW FRAMES.

CILLS OF WINDOW FRAMES

The cill should have a slope on the outside, to keep rain out of the building. This slope can be constructed by chamfering the cill (Fig. 1) or by a combination of chamfering and rebating (Fig. 2).

It is important to prevent rainwater from entering the space between the cill and the wall, where it could cause the cill to rot. A throating at the soffit of the cill (Figs. 1 & 2, arrows) allows water to drip down instead of running back under the cill. The angle of the throating should be parallel to the slope of the cill.

Another way to keep water out is to fix a metal strip, called a drip, under the cill (Figs. 3a & 3b). The drip is fixed in a sawcut in the underside of the cill, so that the water which drips onto the metal will not run inwards. The slope of the metal comes to just inside the face line of the cill (Fig. 3b).

The metal strip should extend past the ends of the cill. If it does not, the water which runs down the posts of the frame will damage the render around this part at the corners of the frame.

It is also possible to combine the two solutions, by fixing a metal strip onto the throating.

Every cill should have some kind of protection to keep water from entering between the cill and wall. All cills must come out at least as far as the finish line of the render.

As an alternative to the wooden cill, the window can be constructed with a plaster cill. The posts are fitted with steel dowels and a concrete shoe. The construction is similar to that of a door frame with a concrete shoe (Fig. 4, also see Concrete Shoe, page 71).

NOTES:

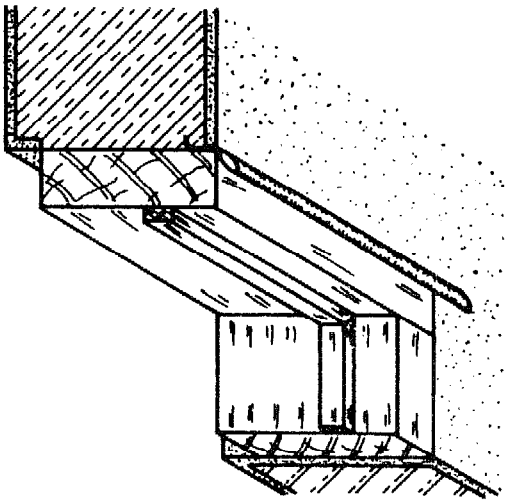

Fig. 1

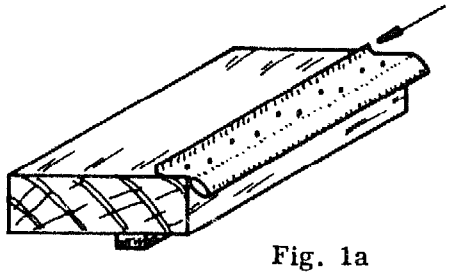

Fig. 1a

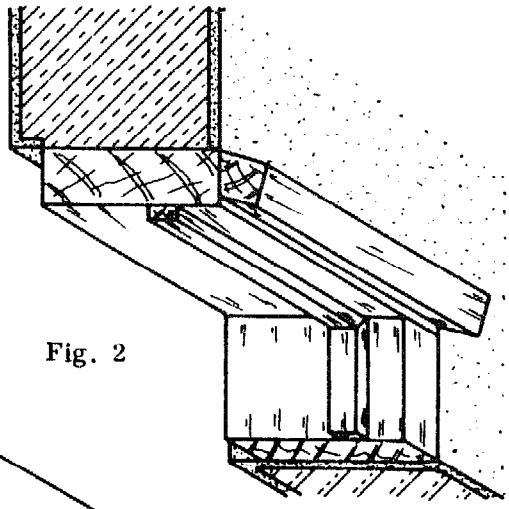

Fig. 2

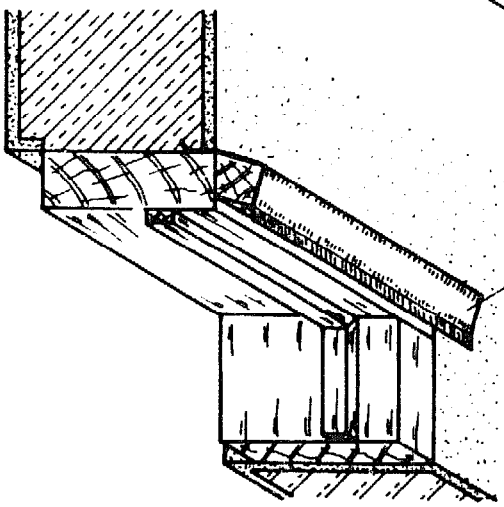

Fig. 3

N P V C	
82	CON.

WINDOW FRAMES.

HEADS OF WINDOW FRAMES

Some protection must also be added at the head of a window frame to prevent any water from entering the space between the head and the lintel and causing damage to the wood. The simplest method is to fix a metal strip similar to the one on the cill. The part of the strip which is plastered over should be bent slightly upwards to prevent water from entering (Fig. 1a, arrow).

Note that the line of nails is staggered so that the drip (or weather strip) is firmly secured to the head (Fig. 1a). Otherwise, movement of the strip during heavy rains or storms would probably loosen the render.

These metal drips may be put on when the frame is set up, or left until just before the rendering is done.

An alternative method would be to fix wooden battens, shaped as shown in Fig. 2, on the face of the window head. This method gives a more satisfactory appearance to the window frame.

A combination of both these methods is also possible (Fig. 3).

The importance of fixing weather strips on both the cill and the head of the frame cannot be over-emphasized. They are easily overlooked during the construction of the building and one might be tempted to do a quick job and leave them out. But in the long run the strips will save money by preventing water damages to the wood and expensive repairs.

The same kind of protection can be applied to the heads of door frames.

The heads and cills of window frames can be provided with horns to give an additional secure fixing to the wall (see Heads of Door Frames).

NOTES:

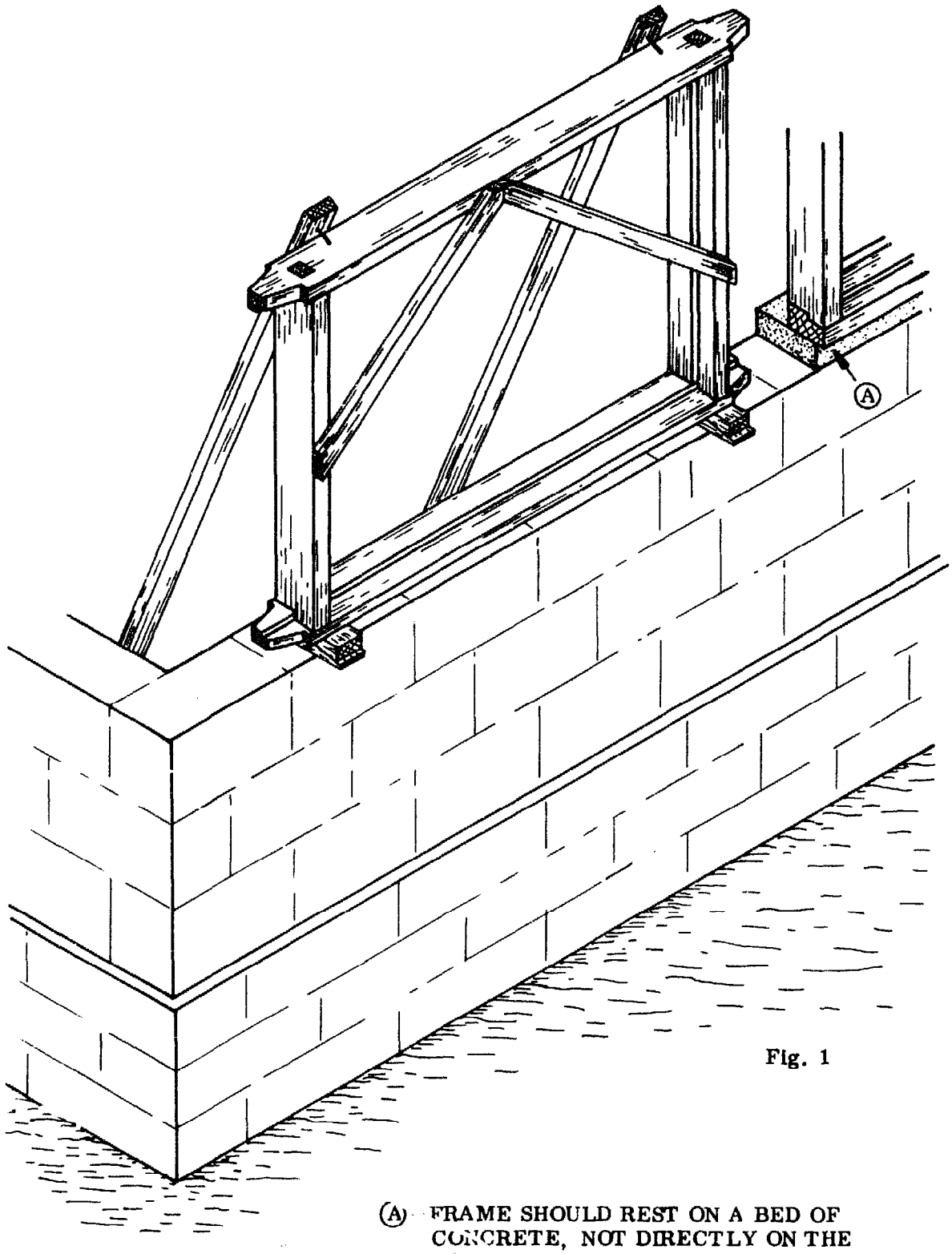

Fig. 1

(A) FRAME SHOULD REST ON A BED OF CONCRETE, NOT DIRECTLY ON THE LANDCRETE.

N P V C		WINDOW FRAMES.
84	CON.	

INSTALLING WINDOW FRAMES

Installing window frames is similar to installing door frames (see Door Frames section). A window frame should be fixed in such a way that the casement can open flat to the wall, otherwise the casement will form a lever with the edge of the wall. This can cause the hinges to be forced out when the window is blown open by the wind.

Window frames can be installed either during the construction of the walls, or after the walling has been completed.

- INSTALLING THE FRAMES DURING THE WALL CONSTRUCTION: When the blockwork has reached window cill level, the frames can be set and aligned in the same way as a door frame. The chief difference is that in the window frame the horizontal members are usually longer than the vertical members, and for that reason more attention is given to levelling the head and cill of a window frame than to levelling the head of the door frame (Fig. 1).

  If more than one frame is installed, check them by comparing from a distance to see if they are aligned, as with door frames.

- INSTALLING THE FRAMES AFTER WALLING HAS BEEN COMPLETED: This second method is not so commonly used, but it also has its advantages. In order to keep the frames clean, square and dry, they are kept in a store until the building is roofed. Openings are left in the blockwork to receive the frames, horns, and steel cramps. The frame is set into this opening and the steel cramps and horns are secured with mortar.

  Sometimes hard wood or plastic plugs are used to secure the frame in the wall.

  - NOTE: The window frame does not rest directly on the landcrete wall; this would provide a path for moisture to get into the landcrete and weaken or damage it. The window frame is set upon a bed of concrete or cement mortar (Fig. 1, A).

NOTES:

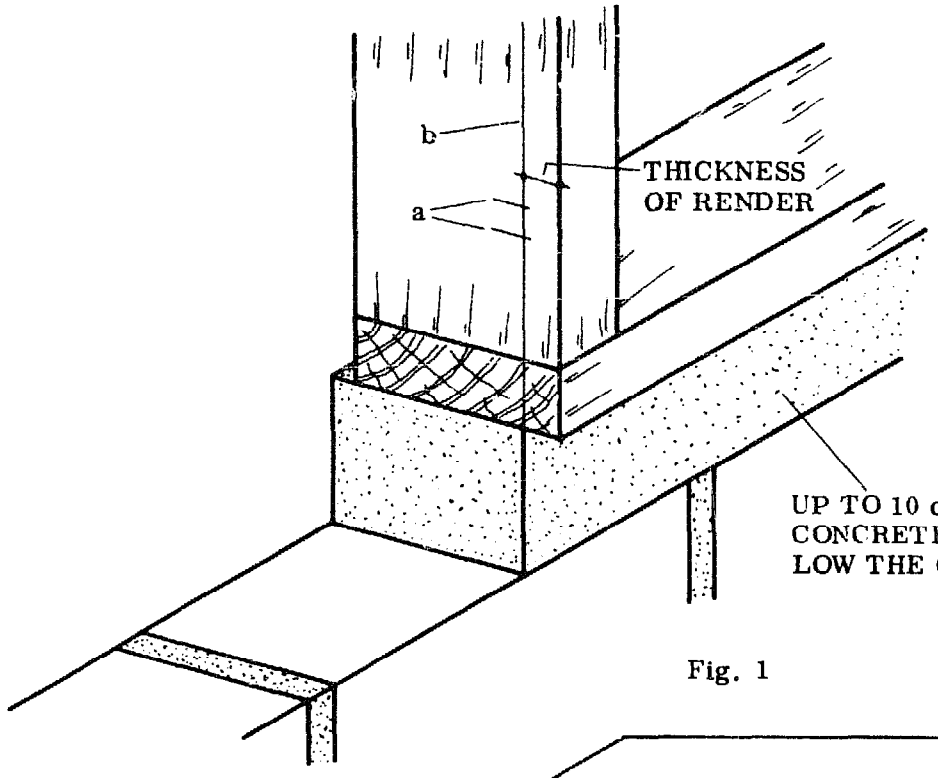

Fig. 1

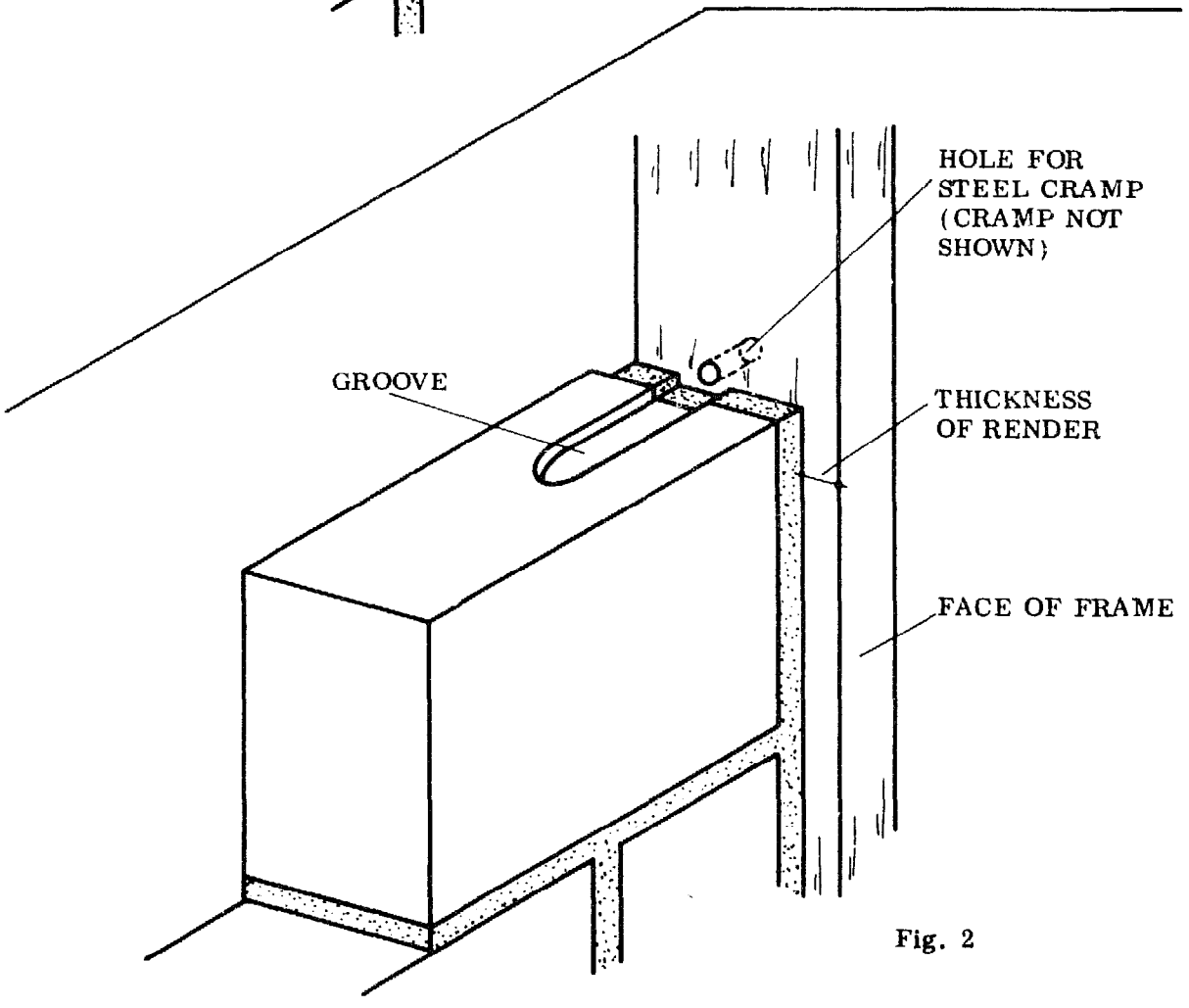

Fig. 2

N P V C		WALLING UP BETWEEN FRAMES.
86	CON.	

WALLING UP BETWEEN FRAMES

First mark the positions of the blocks on the outsides of the frames. Mark both the height of the blocks (Fig. 1, a) and the face line of the blockwork (Fig. 1, b). The face line of the blockwork will be inside the face line of the frames, because the faces of the frames must be flush with the finish line of the render.

- NOTE: The window frame does not rest directly on the landcrete blocks. This is because moisture could enter between the cill and the landcrete and get into the blocks, where it would cause them to swell and fall apart. To protect the landcrete blocks, the cill must rest upon a bed of concrete which can be up to 10 cm thick. By adjusting the height of this concrete bed, the anchorage irons and the heads of the frames can be brought into alignment with the bed joints of the blocks.

The first blocks laid are those which touch the frames. The courses in between are completed and aligned with the aid of either a straight edge, spirit level, or mason line, depending on the distance between the frames.

Pay special attention to the anchorage irons of the frames. Make sure that they are not just embedded in the bed joint; instead make grooves in the bed faces of both blocks, which can be filled with mortar to anchor the iron and to protect it from rust (Fig. 2).

MOSQUITO PROOFING

It is often necessary to install mosquito wire on doors and windows. The wire screen is normally attached with wooden beads directly onto the window frame. For louvred windows it is fixed on the outside. For casement windows which open outwards, the wire screen has to be attached on the inside or onto a separate framework which is hinged onto the inside of the frame.

A separate framework for the mosquito wire is commonly constructed on doors. Make this framework like a panelled door (this door and its construction are described in one of the following sections, under Doors). Use one or two braces in the framework to keep the door rigid. Often a spring is attached to the wire door to keep it in the closed position.

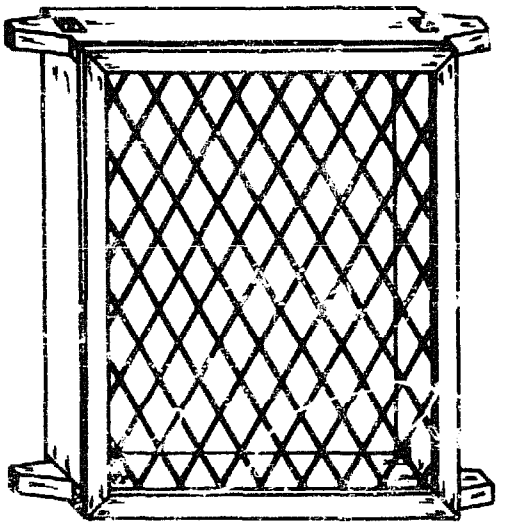

Fig. 1

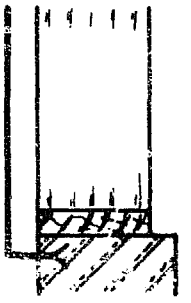

Fig. 2a

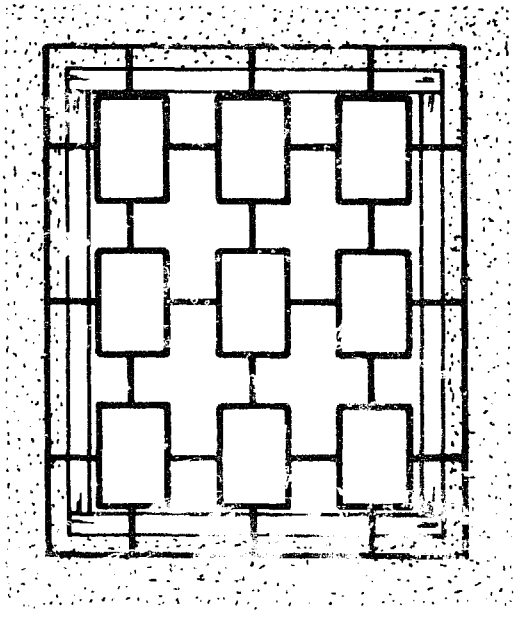

Fig. 2

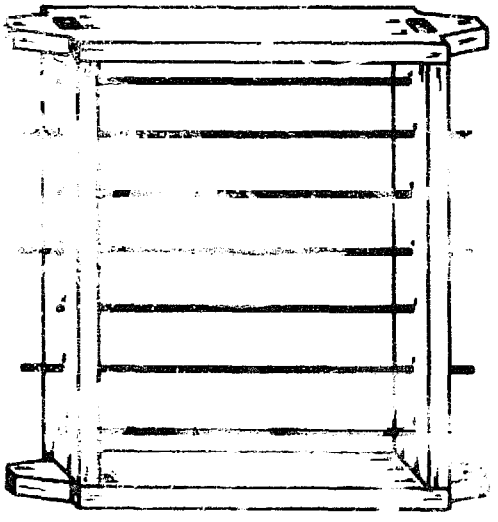

Fig. 3

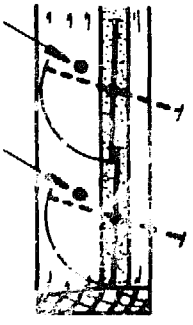

Fig. 3a

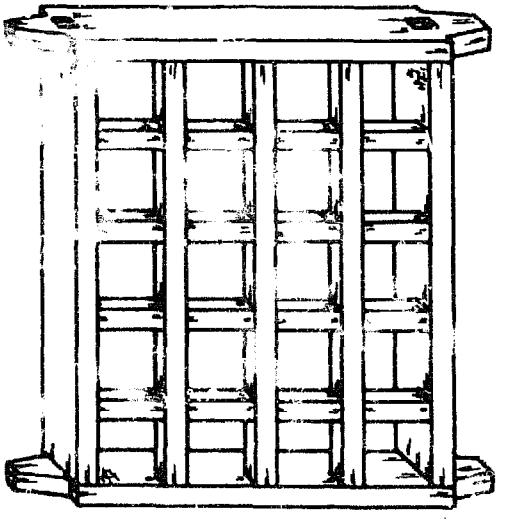

Fig. 4

N P V C	
88	CON.

BURGLAR PROOFING.

BURGLAR PROOFING

It is practically impossible to keep burglars out of a house when the occupants are away, but it is at least possible to make the house burglar proof to the extent that burglars cannot enter without making considerable noise and so alerting people in the area.

TYPES OF BURGLAR PROOFING FOR WINDOWS

- One of the most common methods is to fix mesh wire or expanded metal directly onto the frame, in a way that it cannot be torn off without making considerable noise or using a special cutting tool. Use strong beads to attach the wire to the frame and plenty of screws or nails (Fig. 1).
- Sometimes burglar proofing is made from welded iron rods in different patterns and fixed directly into the wall around the window. It should be anchored well and deeply enough so that it cannot be pulled out (Figs. 2 & 2a).
- Another way to make a window safer is to fix iron bars horizontally into the frame. This must be done during the assembly of the frame. If some of the bars stick out at the sides of the frame, they can also be used as an additional anchor for the frame in the wall (Fig. 3). If the span between the posts of the window is large, the horizontal bars may need to be reinforced by having vertical bars welded onto them, so that they cannot be bent up or down to allow the burglar to enter.
  The bars can also be applied to windows fitted with louvres. In that case, the iron bars are placed between the louvre glasses (Fig. 3a). They must be placed in such a way that they will not obstruct the louvres when they are opened.
- A relatively inexpensive and reliable burglar proofing is the wooden type. During assembly of the frame, this burglar proofing is installed into mortices made in the head, cill and posts of the frame. The separate pieces are fitted together with halving joints in a crosswise pattern (Fig. 4).

If outward-opening casements are installed in a frame, install the burglar proofing on the inside face of the frame. Leave a small opening in the burglar proofing for the hand to pass through in order to open and close the window.

For louvred windows the burglar proofing is always installed on the outside.

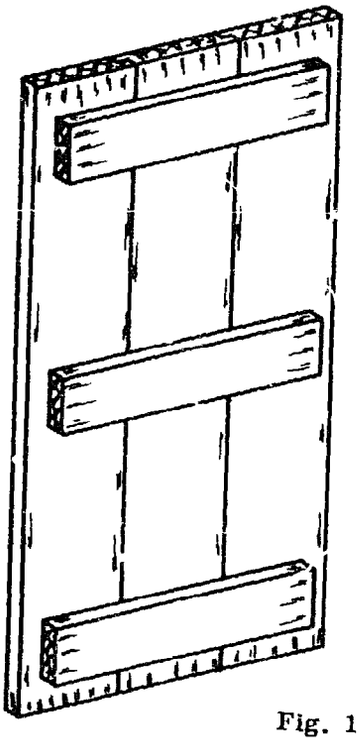

Fig. 1

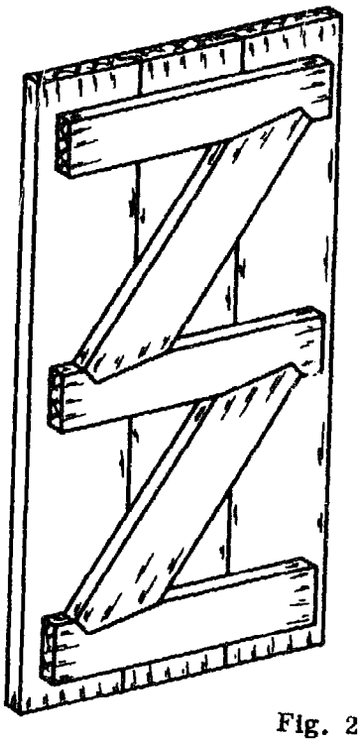

Fig. 2

Fig. 3

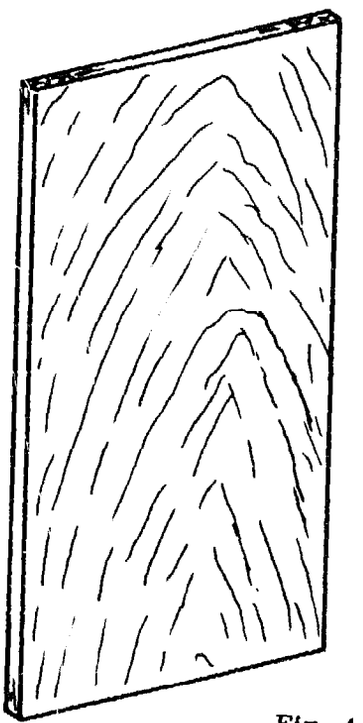

Fig. 4

N P V C	
90	CON.

DOORS.

DOORS

The door is an essential part of the building structure. It must have the right proportions: not so large that it weakens the wall of the building, and not too small either. People, goods, and equipment, according to the uses of the building, have to be able to pass through the door easily.

TYPES OF DOORS

In Rural Building, doors are classified as follows:

- Ledged and battened doors (Fig. 1)
- Ledged, braced and battened doors (Fig. 2)
- Panelled doors (Fig. 3)
- Flush doors (Fig. 4)

For an outside door which is exposed to rain and sun, it is best to choose a weather resistant door like a battened or panelled door. If the door is protected inside the building then a flush door made of plywood will be satisfactory.

SIZES OF DOORS

The size of the door depends on:

- Where it will be used (entrance doors will naturally be slightly larger than other doors, and bathroom doors will be a bit smaller)
- The materials which are available (plan the door according to the sizes of wood and plywood which are available).

A common door size is 198 cm by 76 cm. This is wide enough to allow most sizes of furniture to pass through. Nearly all modern furniture has one dimension which is 76 cm or less: a standard table, for example, is 76 cm high.

Living room and bedroom doors are sometimes larger for reasons of ventilation.

POSITION OF THE DOOR

Outside doors should always open to the outside. This makes them more weatherproof and easier to open in case of an emergency such as a fire, when you want to get out quickly.

Try to position the door so that you cannot look directly into the room from the outside.

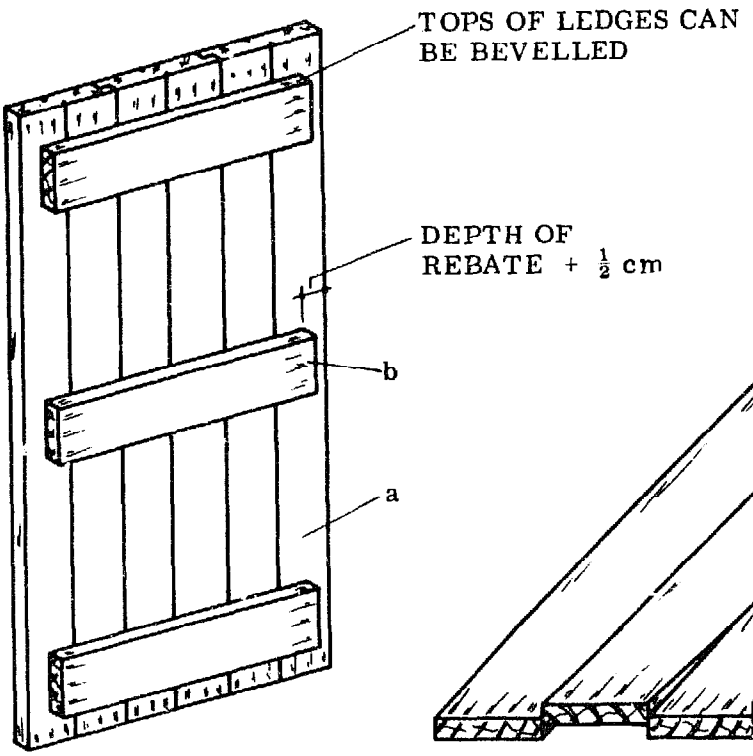

Fig. 1

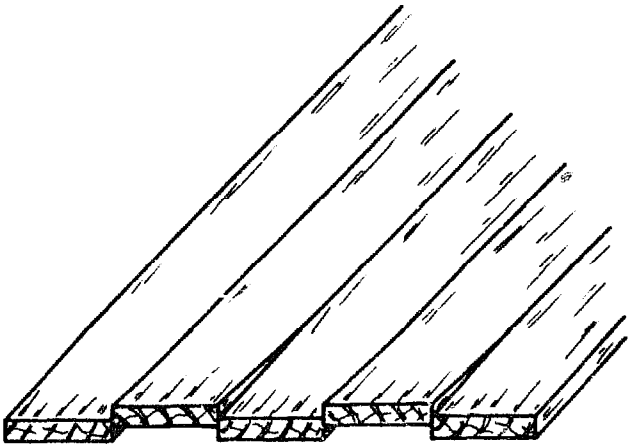

Fig. 2

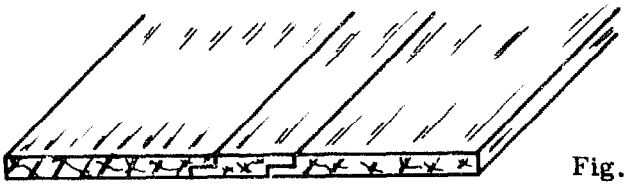

Fig. 3 2 ½ BOARDS

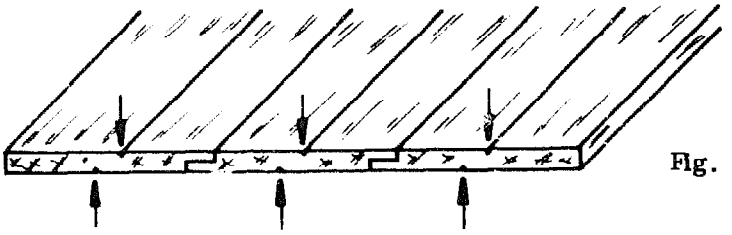

Fig. 4 3 BOARDS

CORRECT - GROOVES ARE NOT ABOVE EACH OTHER

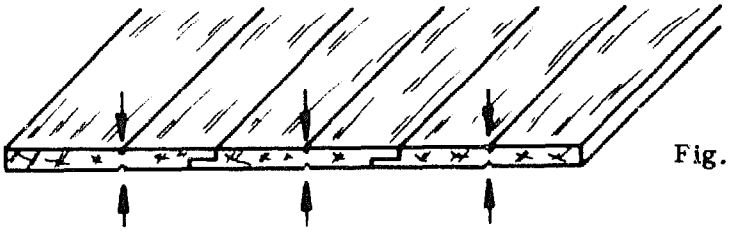

Fig. 5

WRONG - GROOVES ARE ABOVE EACH OTHER

N P V C	
92	CON.

DOORS.

FINISHING TREATMENT OF THE DOOR

All doors should be painted or varnished, or preserved in some way. A good paint job preserves the door from decay and reduces shrinkage and swelling, thereby lengthening the life of the piece (Reference Book, pages 200 & 201).

Paint is especially important for flush doors. They should be well painted and the edges of the door should be soaked in paint.

LEDGED AND BATTENED DOORS

These doors consist of vertical boards called battens (Fig. 1, a) which are nailed or screwed to the horizontal members, called ledges (b). Often the battens are about 15 to 18 cm wide and 2 to 3 cm thick. Doors made with narrow battens like these have a better appearance.

Because of the climate in the northern part of Ghana, here it is better to use boards which are up to 30 cm wide. These wider boards are less likely to twist and warp at the ends (Fig. 2). The boards should be well seasoned so that they won't crack at the ends.

The width of this door is usually the width of $2\frac{1}{2}$ or 3 boards (Figs. 3 & 4).

Grooves can be made in the wide battens, to produce a pleasing appearance as if the door were made with narrow battens (Fig. 4). The grooves should not be made from both sides of the door at the same spot, above each other, because this will make the door weak (Fig. 5).

The ledges should be as long as possible to prevent cupping of the battens, and to provide a solid attachment. The length of the ledges will be the width of the door minus the depth of the two rebates or beads in the door frame, and minus a $\frac{1}{2}$ cm allowance on each side (Fig. 1). The ledges are usually 2 to 3 cm thick. When this construction is used for an external door, the tops of the ledges should be bevelled (Fig. 1).

The ledged and battened door is the simplest type of door. It is often used for narrow openings. It is relatively cheap to construct, but unfortunately it tends to sag because of its weight.

NOTES:

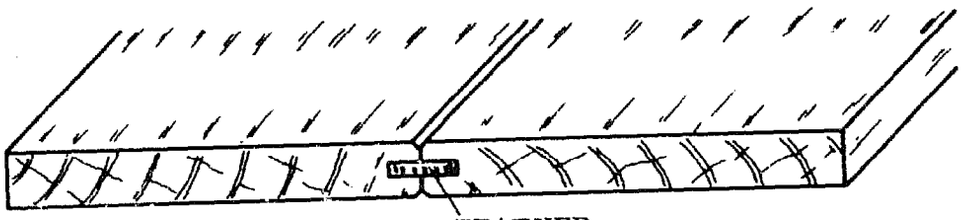

Fig. 1

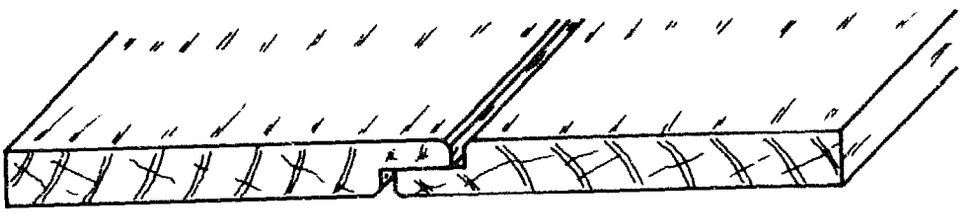

Fig. 2

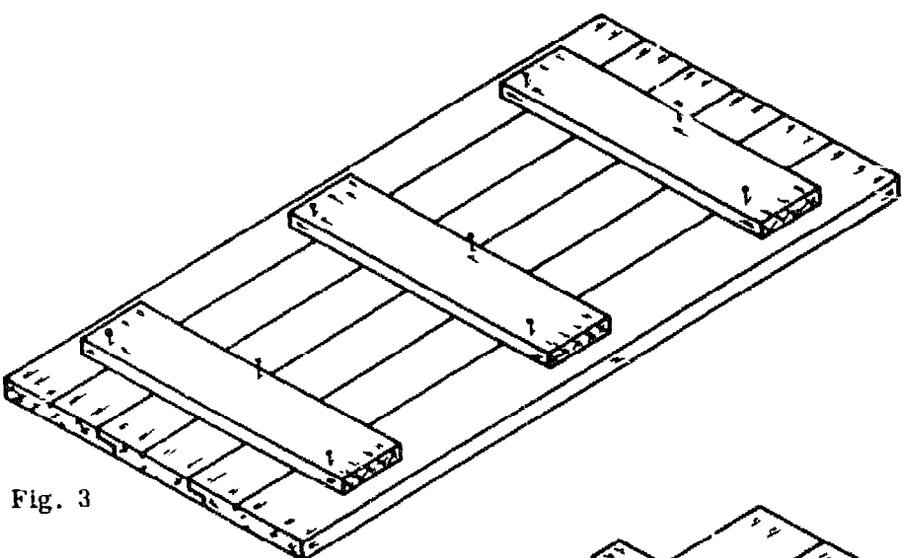

Fig. 3

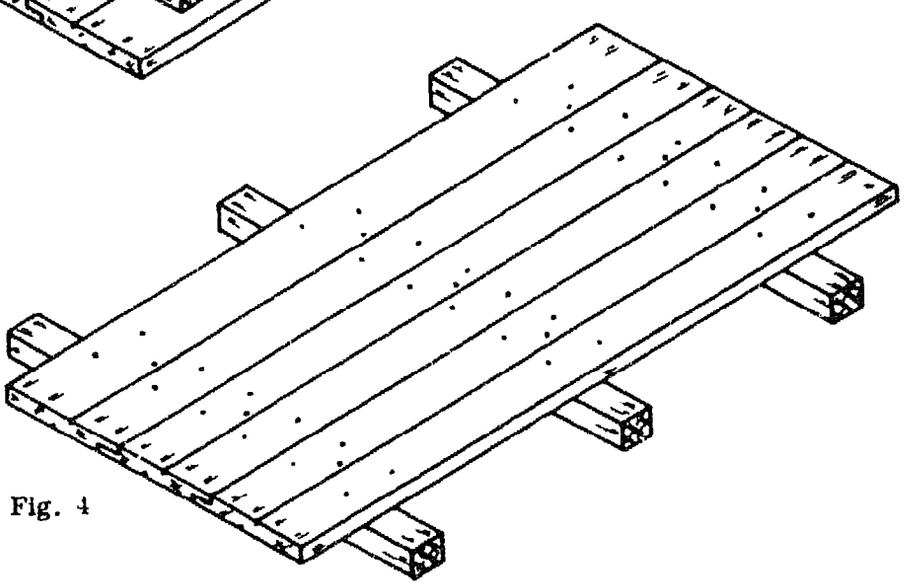

Fig. 4

N P V C		DOORS.
94	CON.	

- JOINTS FOR LEDGED AND BATTENED DOORS: We use special types of joints to connect the battens of this door. These joints are known as matchboarding joints.

A matchboarded door will have a good appearance even when the boards have shrunken and the joints are opening. Matchboarding joints are not glued like ordinary widening joints (Basic Knowledge, pages 130 to 136). They are left loose so that shrinkage can take place, and the battens are held together by the ledges.

In Rural Building we use two different matchboarding joints: the loose tongued joint (Fig. 1), and the rebated joint (Fig. 2).

The loose tongued joint has a tongue made of plywood. It is glued into only one side of the groove so that shrinkage can take place (Basic Knowledge, page 134).

There are several possible ways to make the rebated joints used in battened doors (Fig. 2).

When you assemble this joint, put a strip of wood in between the battens with the same thickness as the gap you want. This keeps the gap between the battens open as the door is assembled.

Any batten-type door made during the rainy season should be assembled with the matchboarding joints closed. If the door is assembled during the dry season, then the joints should be kept open (Fig. 2, also see Reference Book, pages 129 to 130). There should be enough allowance between the battens to allow them to swell up to 5% of the width of the board (for a 30 cm board size the gap will be up to $1\frac{1}{2}$ cm). If this is not done the door will start to warp when it swells in the rainy season.

- SEQUENCE OF OPERATIONS FOR MAKING A (NAILED) LEDGED AND BATTENED DOOR:

a. Study the drawing.

b. Prepare the cutting list.

c. Select the wood.

d. Cut the timber to the right size, leaving a 1 cm allowance in the length of the battens for finishing off.

e. Plane the timbers to size. Mark the boards (Basic Knowledge, page 88).

f. Plane the matchboarding joints.

g. Paint or varnish the edges of the battens.

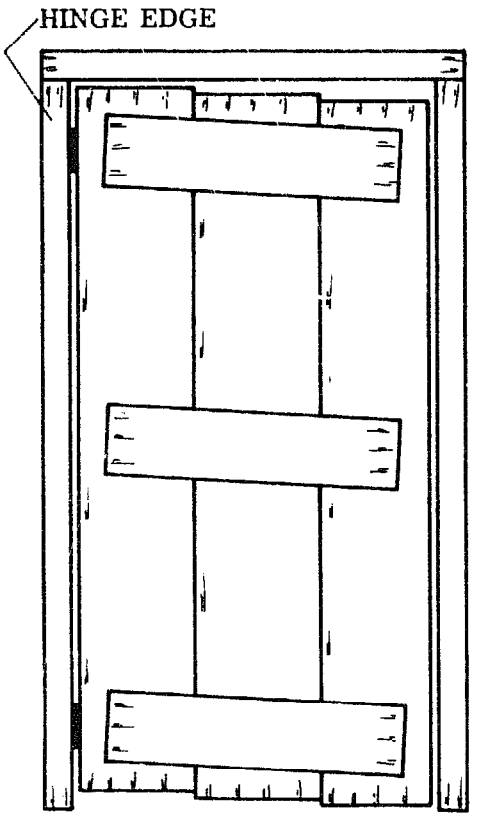

Fig. 1 NO BRACES
DOOR MAY SAG

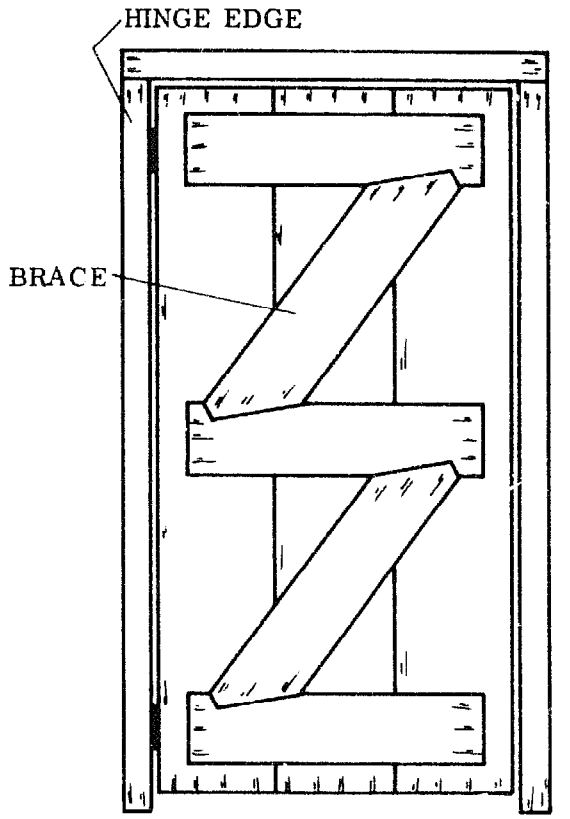

Fig. 2 BRACES PREVENT SAGGING

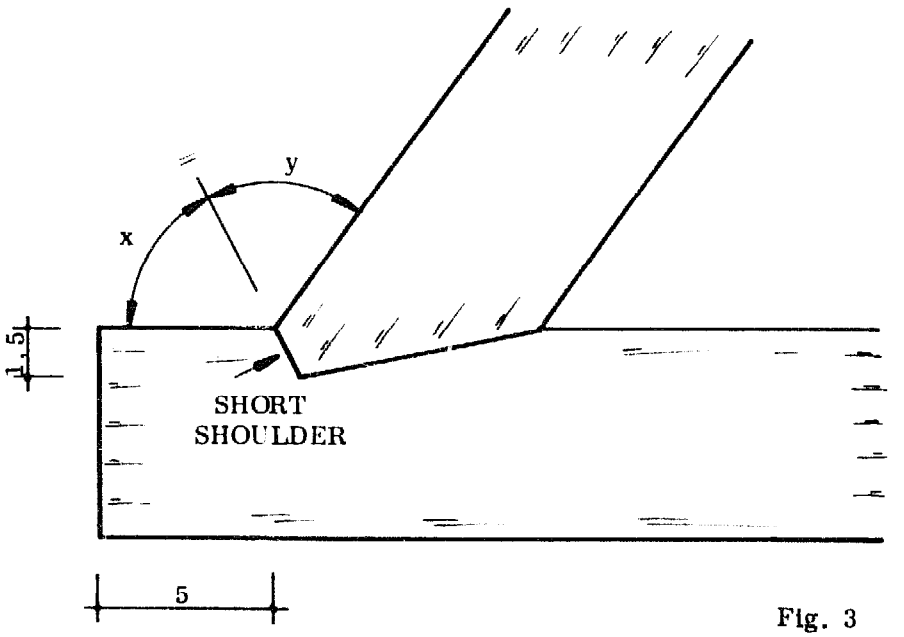

Fig. 3

N P V C	
96	CON.

DOORS.

h. Fit the battens together. Use a wooden or metal sash clamp to hold them.

i. Mark the positions of the ledges.

j. If the door is to be an external one, bevel the tops of the ledges.

k. Paint or varnish the inside faces of the ledges and battens.

l. Nail the ledges lightly to the battens (Fig. 3, previous page).

m. Turn the door over put three pieces of wood under the ledges for support during nailing (Fig. 4, previous page).

n. Drive the nails through the battens and ledges and punch the heads under the surface of the wood.

o. Turn the door over and clench the nails. Remove the nails used in step "l" to nail the ledges lightly to the battens.

p. Cut off and level the battens at the top and bottom.

- REMEMBER: To avoid splitting the wood, always blunt the nails and drive them in a staggered pattern (Fig. 4, previous page). Clench all the nails to prevent them from being pulled out if the wood warps or swells. For clenching, the nails have to be long enough to go through the wood and out the other side by about 5 mm (Basic Knowledge, pages 92 to 94).

LEDGED, BRACED AND BATTENED DOORS

This is a ledged and battened door to which braces have been added to prevent sagging (Figs. 1 & 2). These braces must slope upwards from the hinge edge of the door, and they are housed with a skew notch into the ledges (Drawing Book, page 73).

The skew notch helps to distribute the force from the weight of the door, so that the ledges have an even pressure on them. To achieve an equal distribution of the force, the angle of the short shoulder of the skew notch has to bisect (divide in two) the angle between the ledge and the brace (see Fig. 3, angle "x" = angle "y").

The skew notch should start from a point 5 cm from the end of the ledge, to prevent shearing off. The depth of the skew notch will be 1,5 cm (Fig. 3).

This type of door construction may be used for large openings because of its greater strength.

The sequence of operations to make this door is the same as for the ledged and battened door. The braces are fitted to the door after the ledges are nailed lightly to the battens (step "l" in the construction).

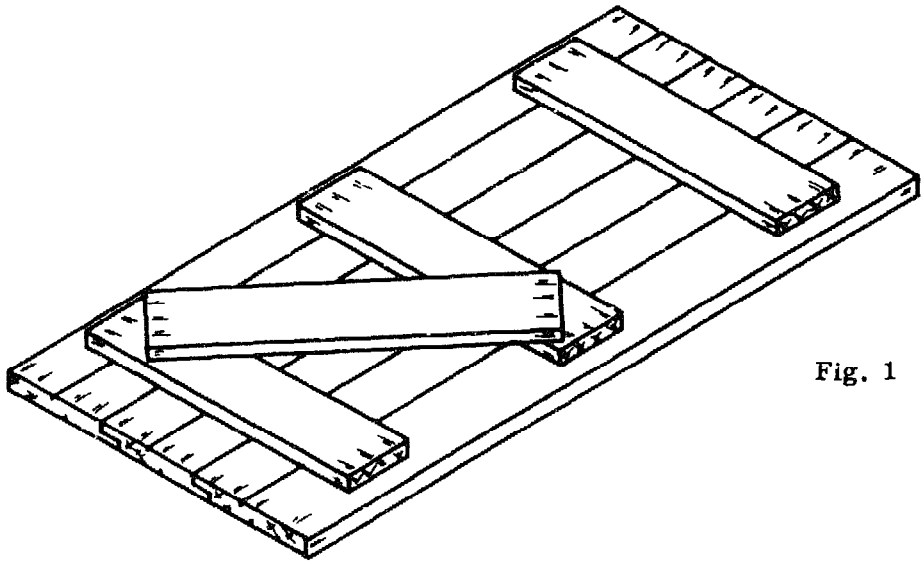

Fig. 1 (m)

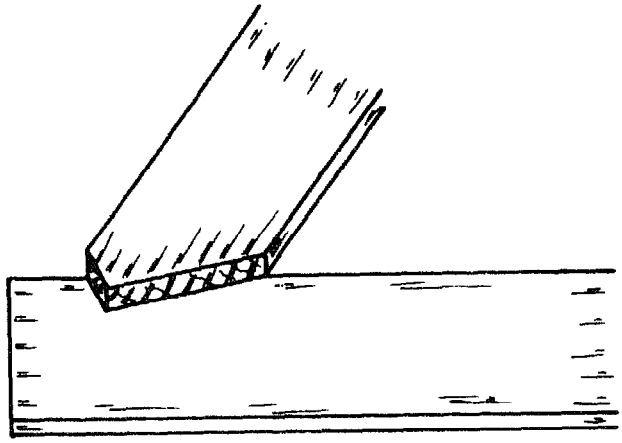

Fig. 2 (p)

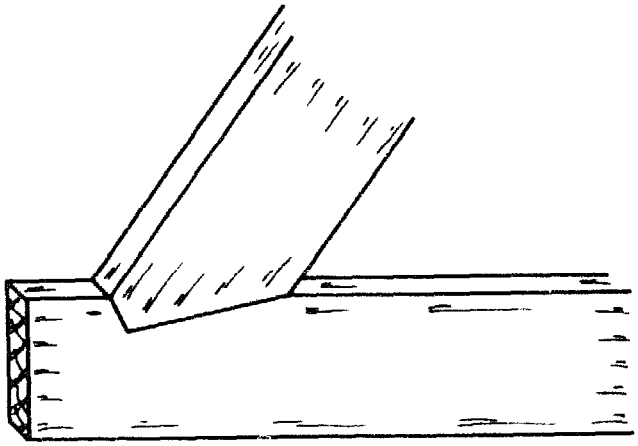

Fig. 3 (q)

N P V C		DOORS.
98	CON.	

- SEQUENCE OF OPERATIONS FOR MAKING A (NAILED) LEDGED, BRACED AND BATTENED DOOR: Proceed in the same manner as for the ledged and battened door, until you reach step "l". Continue as follows:

m. Place the braces on top of the ledges (Fig. 1).

n. Mark out the skew notches on each end of the braces.

o. Cut the braces according to the marks.

p. Place each brace in position and mark out the positions on the ledges (Fig. 2).

q. Chisel the notches in the ledges (Fig. 3).

r. Paint the skew notches.

s. Nail the braces lightly to the battens.

t. Turn the door over and place three pieces of wood under the ledges for support during nailing.

u. Drive nails through the battens, ledges and braces, and punch the nail heads under the surface.

v. Turn the door over and clench the nails. Remove the nails which were used to hold the braces and ledges lightly to the battens in step "s".

w. Cut off and level the battens at the top and bottom.

NOTES:

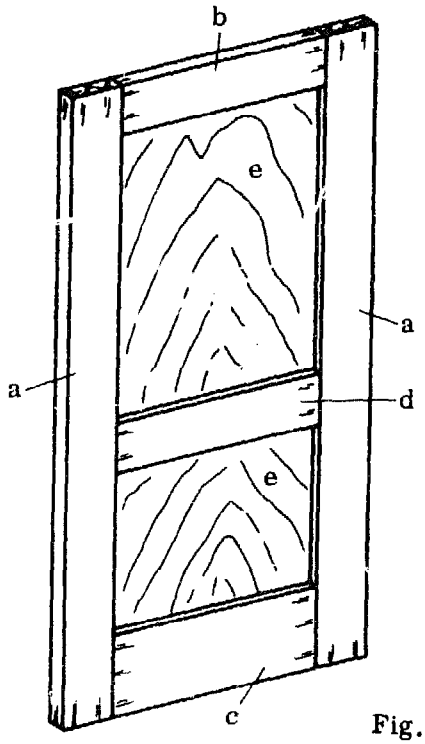

Fig. 1

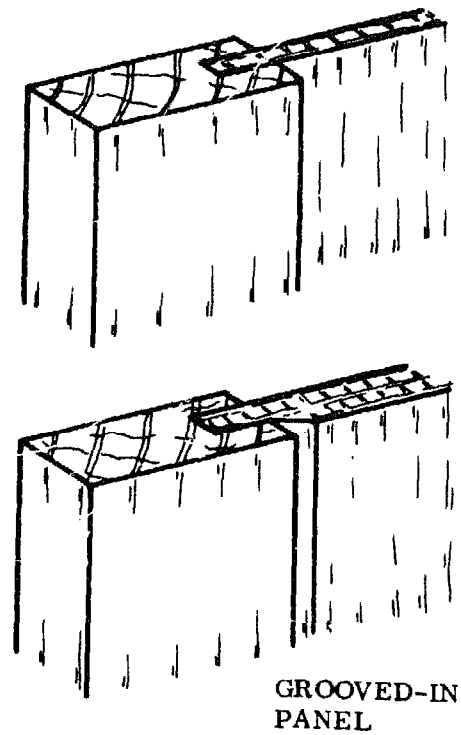

Fig. 2

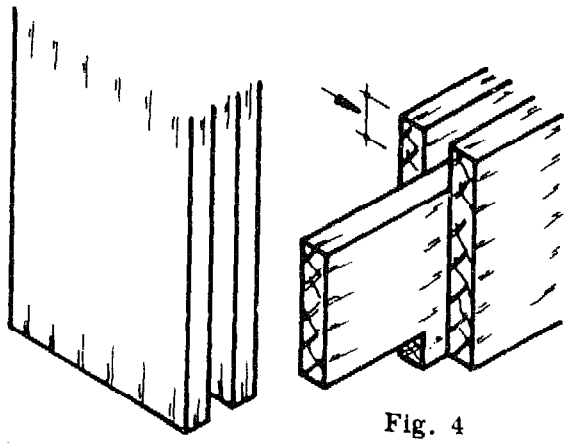

Fig. 4

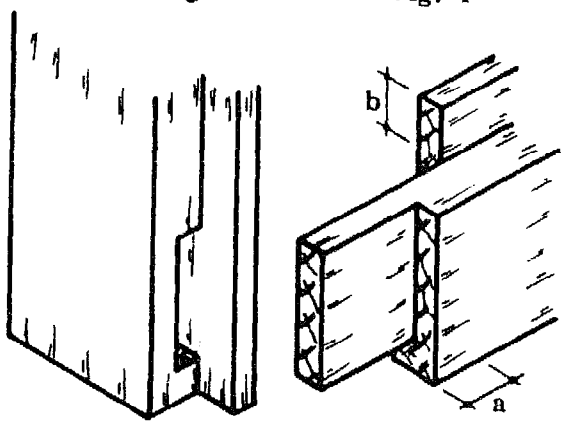

Fig. 5

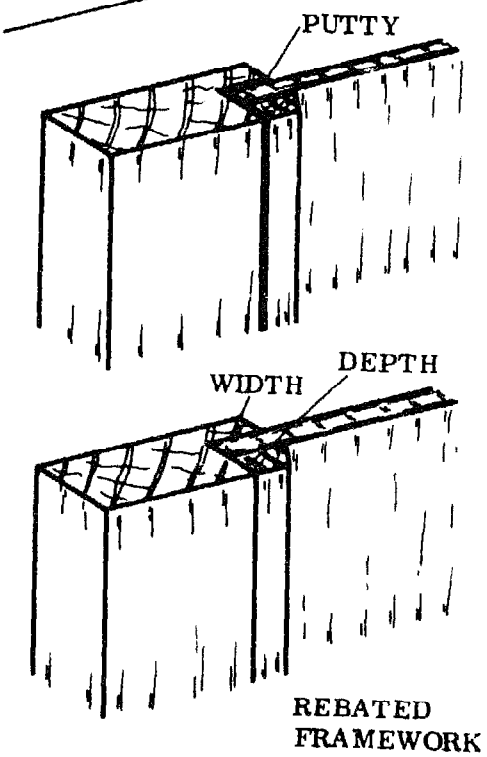

Fig. 3

N P V C	
100	CON.

DOORS.

PANELLED DOORS

These doors (Fig. 1) consist of a frame made up of stiles (a), a top rail (b), a bottom rail (c) and sometimes an intermediate rail (d). Into this framework a plywood panel (e) is fitted. This panel may fit into a groove or a rebate (Drawing Book, pages 75 to 78).

- GROOVED-IN PANEL: This construction can be used only on doors which will be protected from the rain. If water enters the groove, it will not be able to dry out and can cause the plywood to rot (Fig. 2).

  If the door will be painted or varnished, the edges of the plywood panel and the inside of the grooves should be treated before the door is assembled.

  The depth of the grooves is usually 1/3rd of the thickness of the members. The grooves are made as explained in the Basic Knowledge book, page 136.

  The joints for this kind of door will be a haunched stub tenon for the top and bottom rails (Fig. 4), and a stub tenon for the intermediate rail (Basic Knowledge, pages 118 to 122). Note that the width of the tenon has to be reduced by the depth of the groove (Fig. 4, arrow) and the mortice is reduced accordingly.

- REBATED FRAMEWORK: When the panel will be fixed after the frame is assembled, a rebated framework is used. A rebate is made in the frame and the panel is secured with beads (Fig. 3).

  Unlike the grooved-in panel door, this door can be used in places where it is exposed to rain. In that case, the plywood is set in putty so that water cannot penetrate inside, and the tops of the intermediate and bottom rails should be bevelled. The beads are also set in a thin layer of putty, then secured with nails.

  If the door will be painted or varnished, the joints, edges of the plywood, rebates and beads all have to be painted before assembly.

  The width of the rebate is usually 1/3rd of the thickness of the frame member, and the depth is usually 2/3rds of the thickness of the member (Fig. 3).

  The joints for this kind of door will be haunched stub tenons for the top and bottom rails and stub tenons for the intermediate rail. Note that one shoulder of the tenon has to be longer to fill the rebate (Fig. 5, a). The widths of the tenon and mortice have to be reduced by the size of the rebate (Fig. 5, b; also Drawing Book, page 78, and Basic Knowledge, pages 118 to 120).

NOTES:

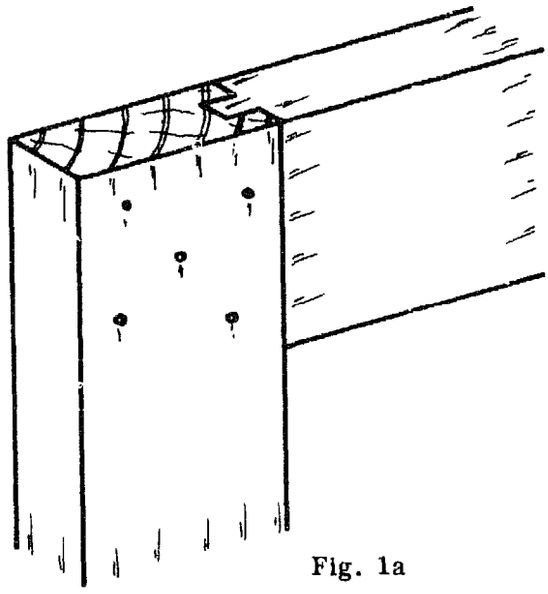

Fig. 1a

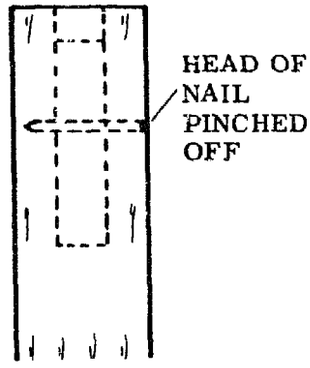

Fig. 1b

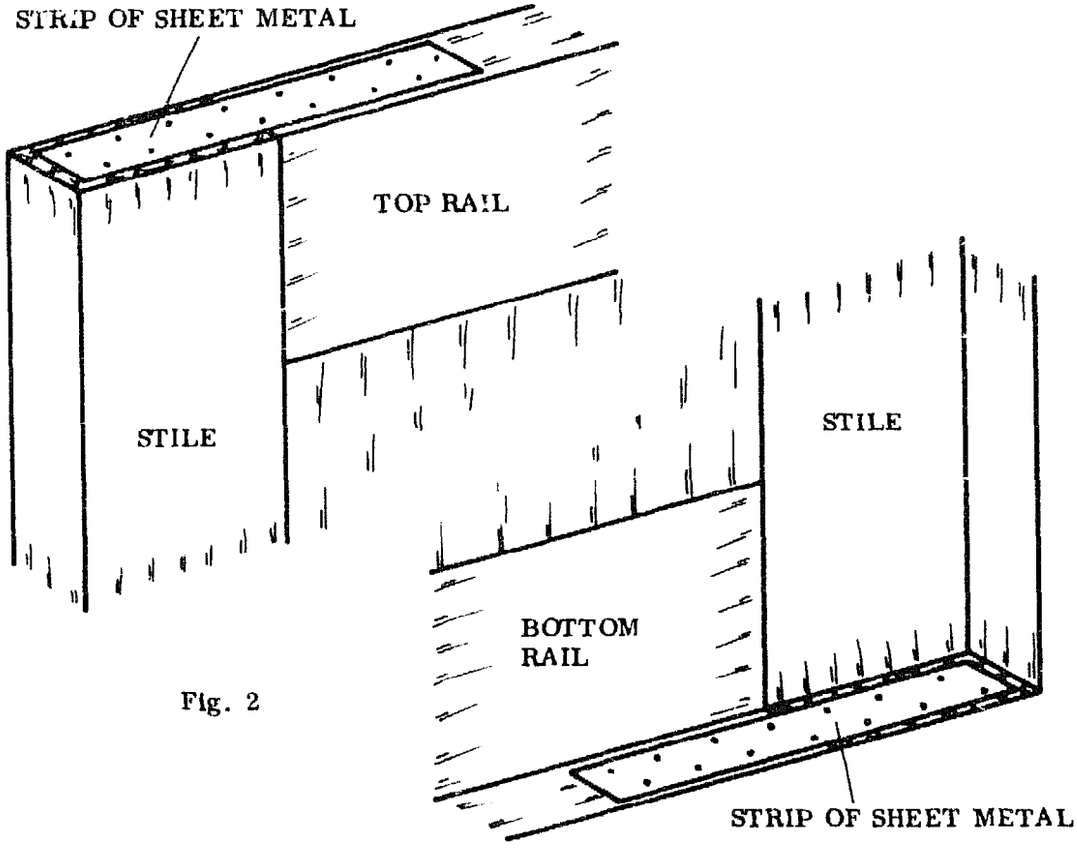

Fig. 2

N P V C		DOORS.
102	CON.	

- TIMBER MEASUREMENTS FOR PANELLED DOORS:

Stiles and top rail	-	3 to 4 cm thick, 10 cm wide
Intermediate rail	-	3 to 4 cm thick, 10 cm wide
Bottom rail	-	3 to 4 cm thick, 15 to 20 cm wide

- HOW TO PREVENT A PANELLED DOOR FROM SAGGING: Very often panelled doors will sag after a certain length of time. This is due to the joints drying out and loosening, and to the weight of the door.

The key to the door's ability to resist sagging is the plywood panel. For this reason the panel must be properly secured and fit tightly into the frame.

The tenons must also be well secured. If we can prevent the joints from opening we prevent the door from sagging. A good method of securing the joints is to nail through the joint and pinch off the heads of the nails. They should only be long enough so that they can be punched under the surface but do not come through the other side of the frame (Fig. 1b).

Note the staggered positions of the nails in Fig. 1a on the left. This prevents the nails from splitting the wood.

On the hinge stile of the door, the joints tend to pull apart at the lower edge. To prevent this, fix strips of sheet metal at the top hinge corner and at the lower corner opposite from the hinge stile. Use small nails to fix the metal (Fig. 2).

NOTES:

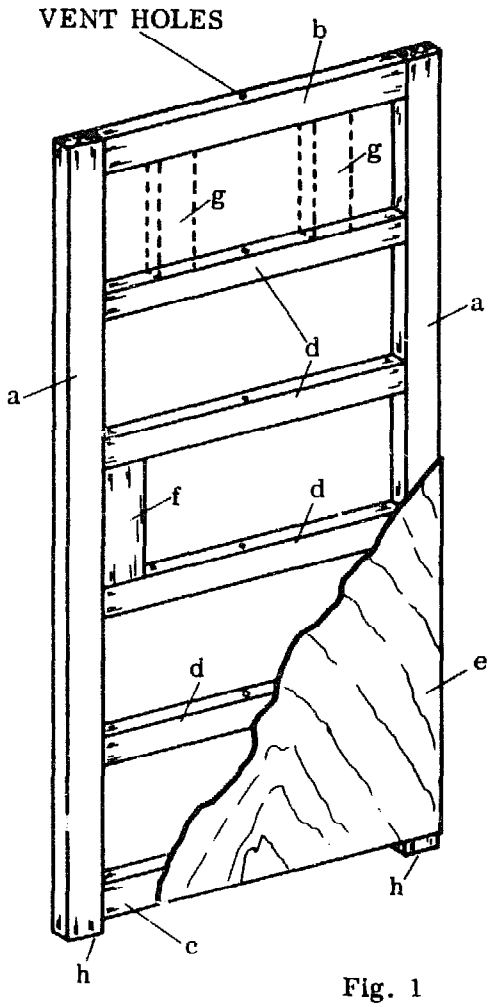

Fig. 1

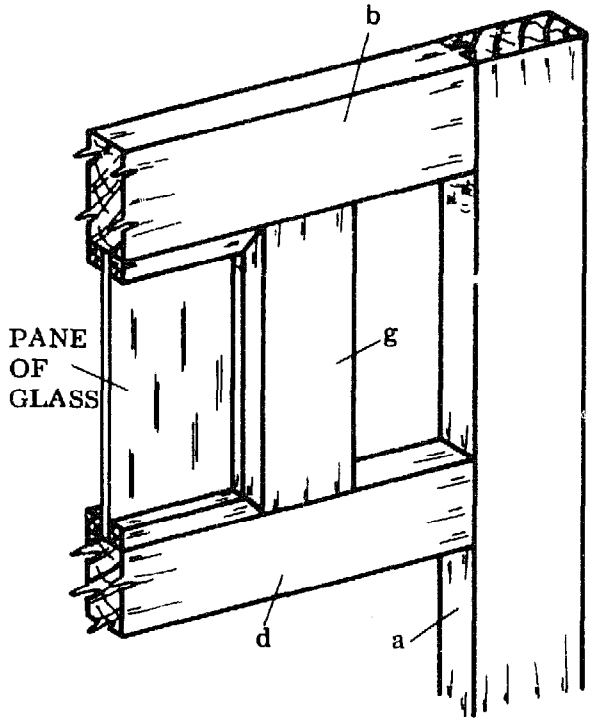

Fig. 2

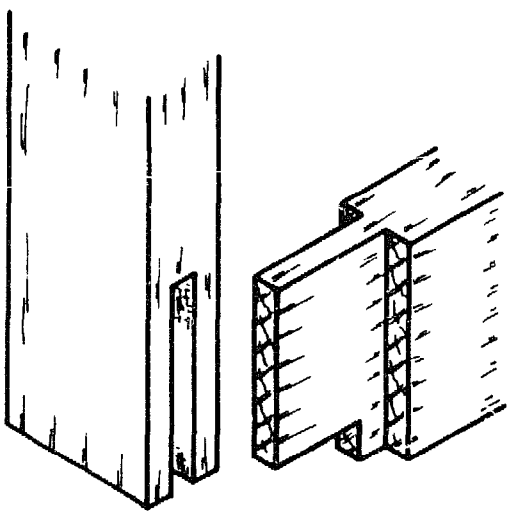

Fig. 3

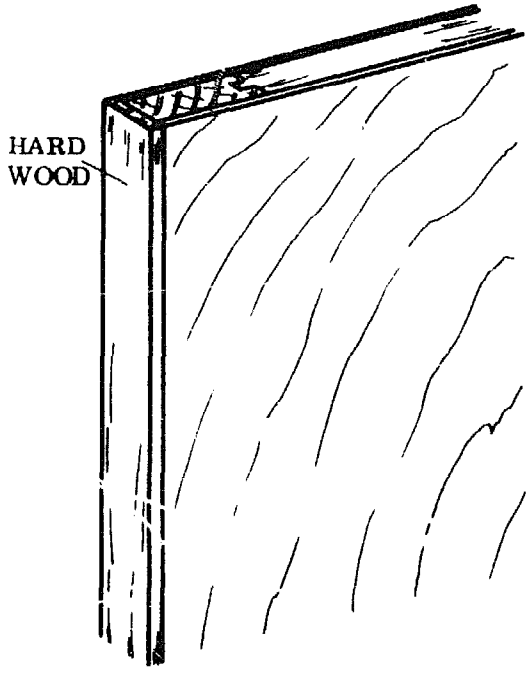

Fig. 4

N P V C		DOORS.
104	CON.	

FLUSH DOORS

The flush door with a framed core (Fig. 1) is a type of door that we frequently make in Rural Building. This door consists of a frame which has stiles (a), top and bottom rails (b & c), and narrow intermediate rails (d). It is covered on each side by a sheet of plywood (e). Sometimes flush doors for the outside of the building are covered on one or both sides by sheets of thin metal, usually aluminium or galvanized iron. Plywood-covered flush doors cannot be used where they will be exposed to rain and sun.

Well seasoned Wawa is used for the frame. If the stiles are not wide enough to provide room for the mortice lock (Reference Book, page 223), then a lock block (f) is added. This block should be long enough so that does not restrict the lock position to only one spot. The location of the lock block should be indicated on the outside edge of the frame so it can be found later after the plywood or metal sheets are fixed.

When two additional members are placed between the rails (g), a pane of glass can be set in them to provide additional light for the room (Figs. 1 & 2).

To prevent damage to the top and bottom rails when the door is stored and moved around, the stiles can be left projecting past the rails (h), thus forming a rest for the door.

Ventholes can be drilled through each of the rails to ensure good air circulation within the frame. Take care that the ventholes in the top and bottom rails are not blocked by paint.

The joints for the flush door can be haunched stub tenons for the top and bottom rails (Fig. 3) and stub tenons for the intermediate rails.

- LIPPING: A strip of hard wood (Fig. 4) can be fixed to the striking stile to prevent damage to the plywood edges. Lipping is always done after the plywood has been fixed. A thoroughly painted lipping can be added to the top of the door if necessary to keep water out. The lipping joint should be a mitre joint.

NOTES:

- SEQUENCE OF OPERATIONS FOR MAKING A FLUSH DOOR: (also see Drawing Book, page 74)

a. Study the drawing.

b. Prepare a cutting list.

c. Select the wood.

d. Cut the wood to the right size. The plywood should be cut slightly larger than the door, so it can be planed to size later.

e. Plane the wood to size, and make the face marks.

f. Mark out the joints.

g. Prepare the joints.

h. Drill the ventholes.

i. Glue and clamp the frame together.

j. Fix the lock block. Indicate the position of the block on the outside edge of the door.

k. Plane the frame so the surfaces are flush.

l. Glue the plywood on both sides of the door and secure it with wire nails to the rails and stiles. If more than one door is being made, the doors can be set on top of one another and weighted down until the glue hardens.

m. Fix the lipping and finish off the door.

- TIMBER MEASUREMENTS FOR FLUSH DOORS:

Top and bottom rails	-	3 to 4 cm thick, 7 cm wide
Stiles	-	3 to 4 cm thick, 7 cm wide
Intermediate rails	-	3 to 4 cm thick, 5 cm wide
Plywood	-	6 mm thick
Distance between rails	-	30 cm

NOTES:

LARGE DOORS

Sometimes a large door is needed for a store or a similiar building.

Large doors can be constructed like panelled doors. In addition to this framework, braces are used. The braces slope up from the bottom of the hinge side to the top of the opposite side.

The frame can be covered with plywood on the inside, and with either sheet metal (Fig. 1) or horizontally fixed overlapping boards (Fig. 2) on the outside. If corrugated sheet metal is used, the top edge has to be covered to prevent water from entering between the sheet metal and the door frame (Fig. 1, arrow).

The frame used for this kind of door should be heavier than the one used for an ordinary panelled door. The timber for the frame should be no less than 5 cm thick.

Each large door should have 3 band-and-hook hinges. If T-hinges are used, the strap has to be long enough to overlap a part of the rails. If the hinges are fixed to the stile only, the door will tend to sag.

In the Reference Book, page 229, there is a description of a simple locking device which can be made for this type of door.

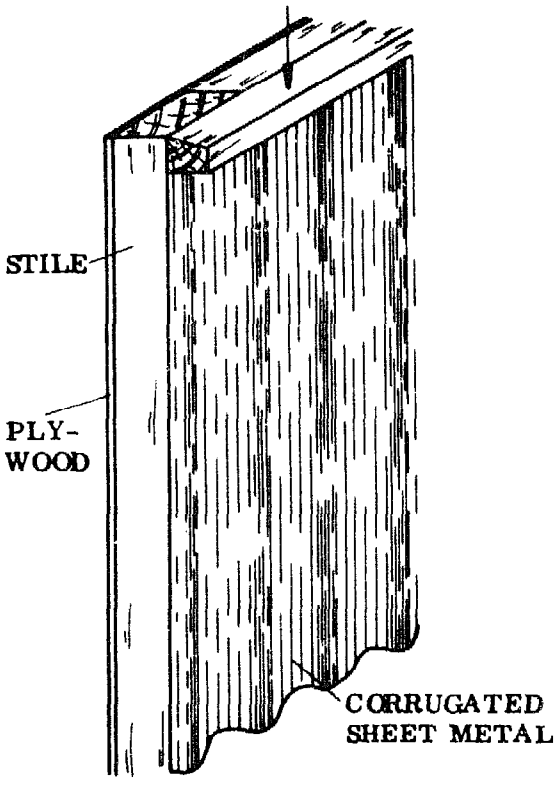

Fig. 1

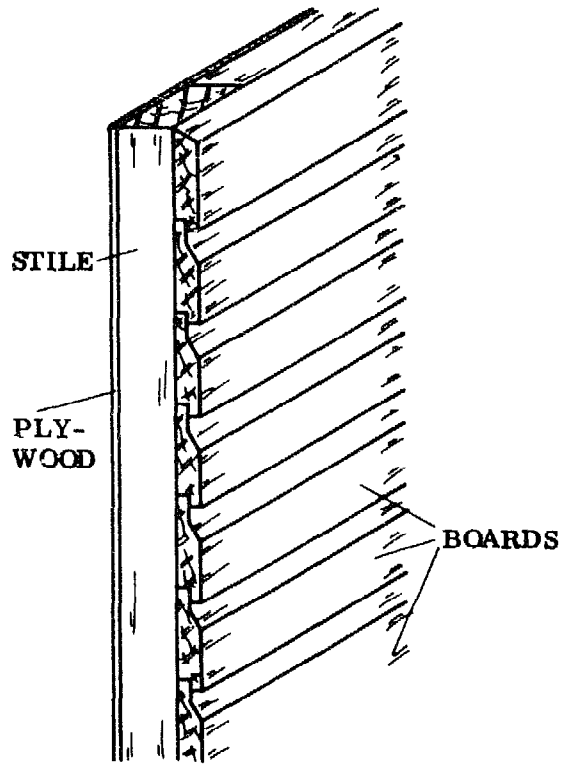

Fig. 2

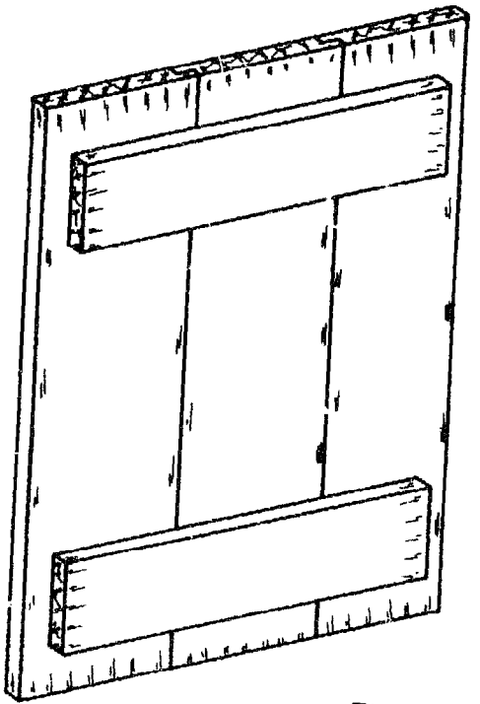

Fig. 1

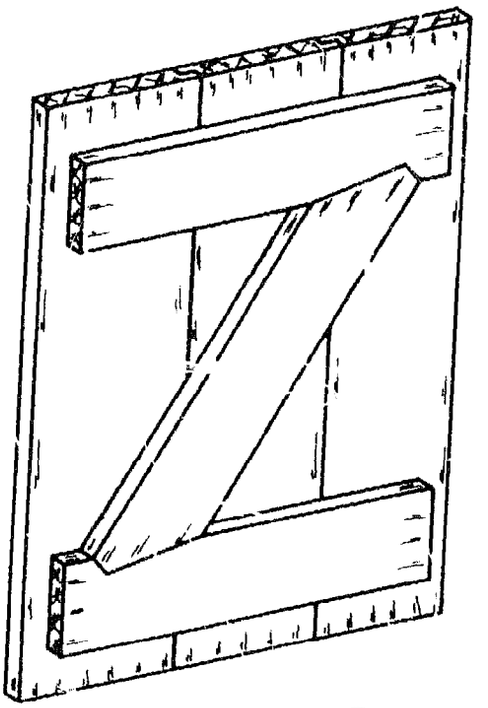

Fig. 2

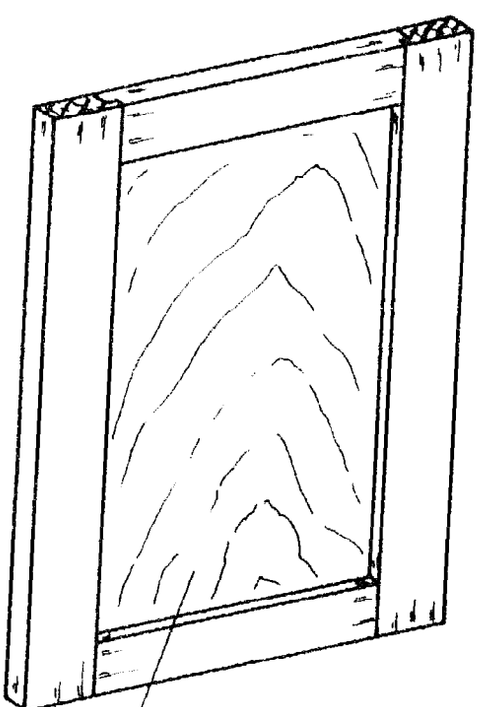

Fig. 3

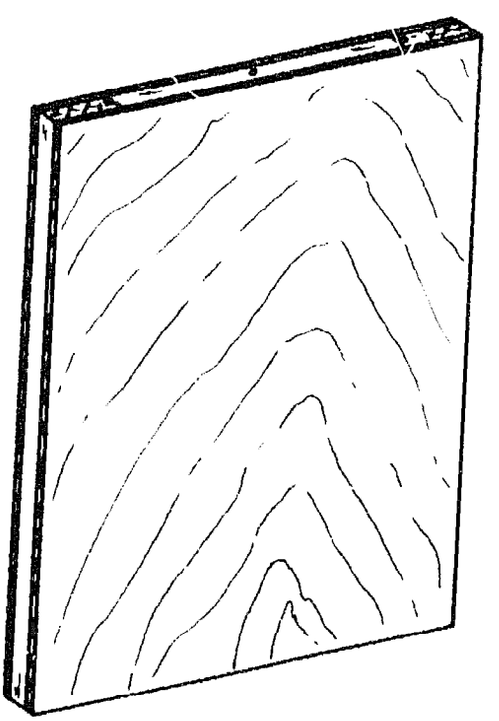

Fig. 4

N P V C	
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WINDOWS.

WINDOWS

The function of a window is to let light and air into the building. When closed, the window should be draught-proof, weather-proof and burglar-proof. The size of the window should be appropriate for the room.

In Rural Building, windows consist of a window frame into which louvres or casements are fitted.

Casements are hinged to open to the outside. This makes them easier to waterproof than if they opened to the inside. The hinges should be fixed so that the casement opens flat to the wall. The frame of the window is set flush to the outside surface of the wall (see Installing Window Frames section, page 85).

Sometimes the hinges are fixed at the head of the window frame. This allows the casement to open upwards, thus providing shade for the opening and the wall. Refer to the Drawing Book, page 50, for ways to show the positions of hinges in the drawing.

TYPES OF CASEMENTS

In Rural Building, we deal with 5 different kinds of casements:

- Ledged and battened casements (Fig. 1)
- Ledged, braced and battened casements (Fig. 2)
- Panelled casements (Fig. 3)
- Glazed casements (Fig. 3)
- Flush casements (Fig. 4)

It is necessary to leave at least 3 mm of play on all sides between the casement and frame (more if the casement is made during the dry season) so that the casement can open freely. This allows for expansion and shrinkage in the frame and casement.

BATTENED CASEMENTS

Both types of battened casements are constructed in the same way as the corresponding type of door.

Matchboarding is also done in the same manner as for a door. Depending on the size of the casement, usually only two ledges are needed (Drawing Book, page 73).

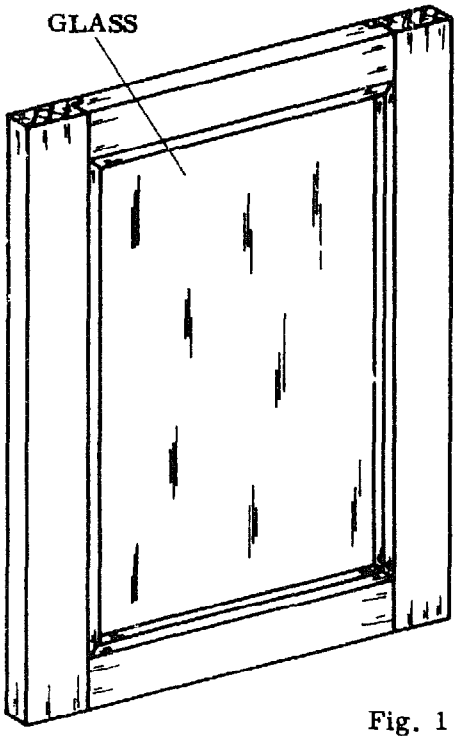

Fig. 1

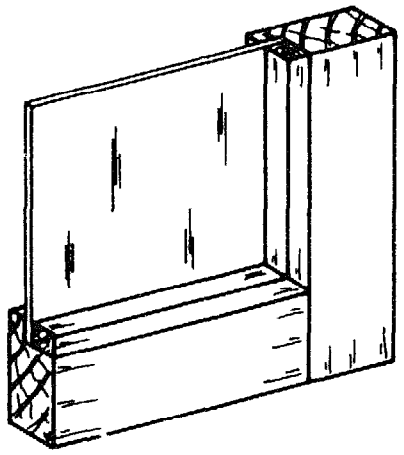

Fig. 1a
BEADS

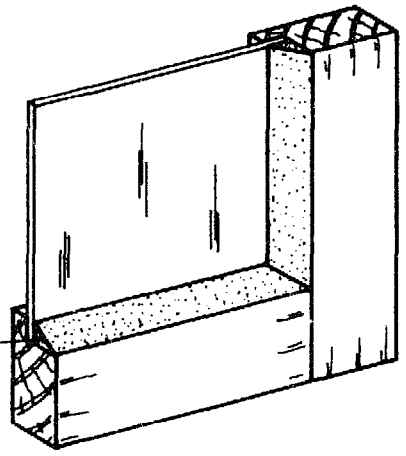

Fig. 1b

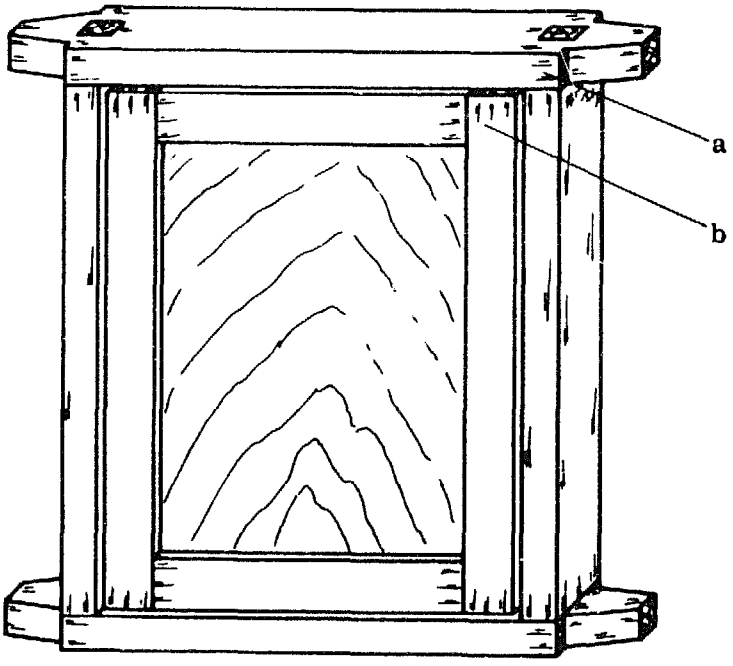

Fig. 2

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WINDOWS.

PANELLED CASEMENTS

These can be made with grooved-in or rebated frameworks, in the same way as panelled doors (see Doors, page 101).

Usually the panels are made from plywood. Be sure to cut the bottom rail of the casement according to the slope of the cill.

The measurements of the members can be 5 to 7 cm wide and 3 to 4 cm thick.

The overall size of a panelled casement equals the inside measurement of the window frame, minus the allowance of at least 3 mm all around (Drawing Book, page 75).

GLAZED CASEMENTS

These are made with a rebated framework. The construction is the same as for a panelled door or casement (see Panelled Doors, page 101). Instead of a plywood panel, a pane of glass is installed in the framework (Fig. 1).

Select the wood for this casement very carefully. It should be well seasoned and straight grained, so that the frame will not twist and cause the glass to break.

The joints are usually haunched stub tenons. Paint the joints and rebates before assembling the frame. The glass pane is always fitted after the frame has been assembled. The rebated framework is used because it permits the replacement of broken glass.

There are different ways of securing the glass in the rebated framework:

- By using beads, where the casement does not have to be waterproof (Fig. 1a)
- By using putty, to make a waterproof seal (Fig. 1b)
- By a combination of a thin layer of putty and beads.

The glass should always be cut 2 mm shorter in the length and the width, to make it easier to fit in the frame.

The sections of the frame members will be: 5 to 7 cm wide and 3 to 4 cm thick.

FLUSH CASEMENTS

These are constructed in the same way as flush doors. Flush casements can be covered on one or two sides with plywood or sheet metal (aluminium or galvanized iron).

Flush casements should only be used where they will be protected from the rain and sun, for instance on a verandah.

Plywood should be glued and nailed to both sides of the casement, not one side only, to keep the casement rigid, straight and strong. For outside work, use waterproof glue.

- TIMBER MEASUREMENTS:

Top and bottom rails	-	3 to 4 cm thick, 5 to 6 cm wide
Stiles	-	3 to 4 cm thick, 5 to 6 cm wide
Intermediate rails	-	3 to 4 cm thick, 4 to 5 cm wide
Plywood	-	6 mm thick

The lower part of the bottom rail must be planed to fit the slope of the cill. The distance between the rails is approximately 30 cm (Drawing Book, page 74).

JOINTS

Note that in the construction of window frames and casements, different methods of framing are used.

For window frames, the horizontal members (heads and cills) have mortices, and the vertical members (posts and mullions) have tenons (Fig. 2, a; previous page).

For the casements, the vertical members (stiles) have mortices and the horizontal members (rails) have tenons (Fig. 2, b; previous page).

The same system applies for door frames and doors.

NOTES:

LOUVRE WINDOWS

- SEQUENCE OF OPERATIONS FOR INSTALLING LOUVRE WINDOWS: (see Reference Book, page 217)

a. If there will be mosquito wire on the window, you will have to be careful to set the louvre channels so that the louvres will be able to open without touching the wire.

b. Mark the position of the channel on the wooden frame, at the side where the operative channel (the one with the handle) will be fixed.

c. Grease the moving parts on the inside of the channel (use grease, not oil).

d. Fix the operative channel with one screw near the top.

e. Plumb this side. Secure the channel firmly with screws (the screw size will be 3 x 30, round head screws).

f. Install the non-operative channel, parallel to the first channel.

g. Secure this side loosely near the top, leaving the bottom free so it can be adjusted later.

h. Put in the louvre glasses, starting from the top and working down. Close the clip ends to secure the glasses in place.

i. When all the glasses are installed, close the louvres.

j. Move the bottom of the non-operative channel until the louvres fit tightly together and are parallel.

k. Now secure this side firmly with screws.

l. Check the installation (screws, clip ends, etc.) and operate the handle several times to make sure that the louvres move freely.

m. Fix the waterbar (either a wooden bead or a ready-made aluminium bar) at the head (outside the glass) and the cill (inside the glass), so that it is just touching the glass when the louvres are locked.

NOTES:

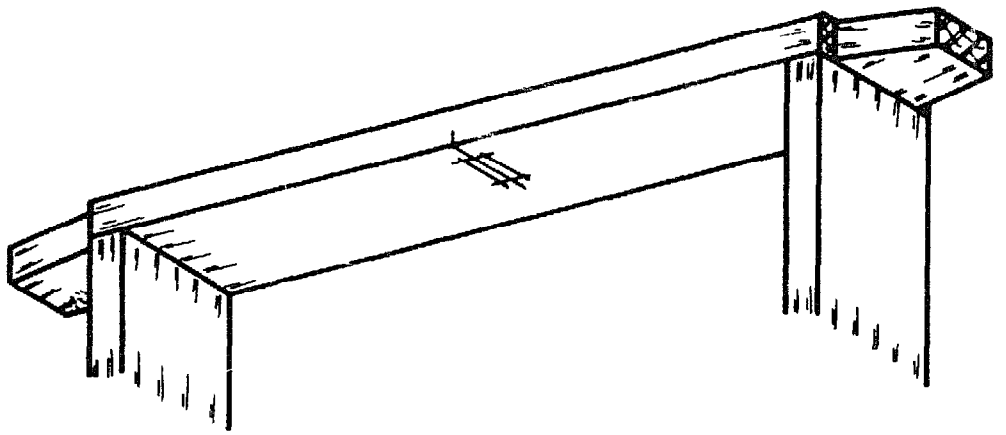

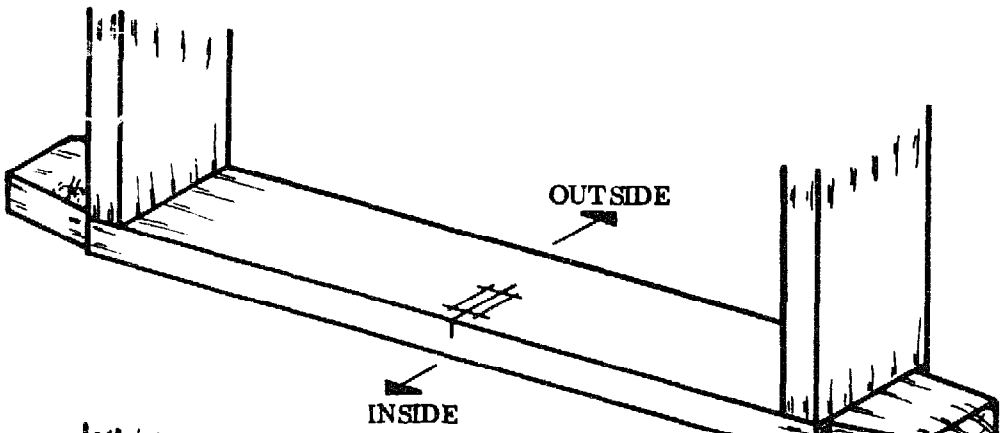

Fig. 1

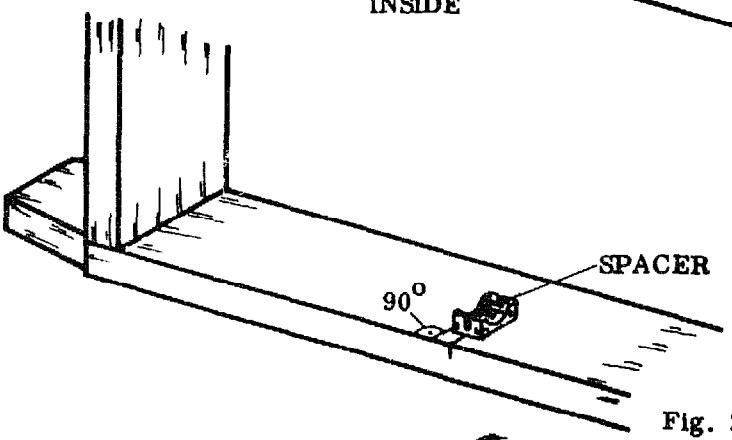

Fig. 2

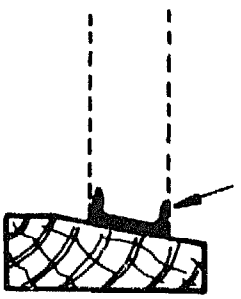

Fig. 3

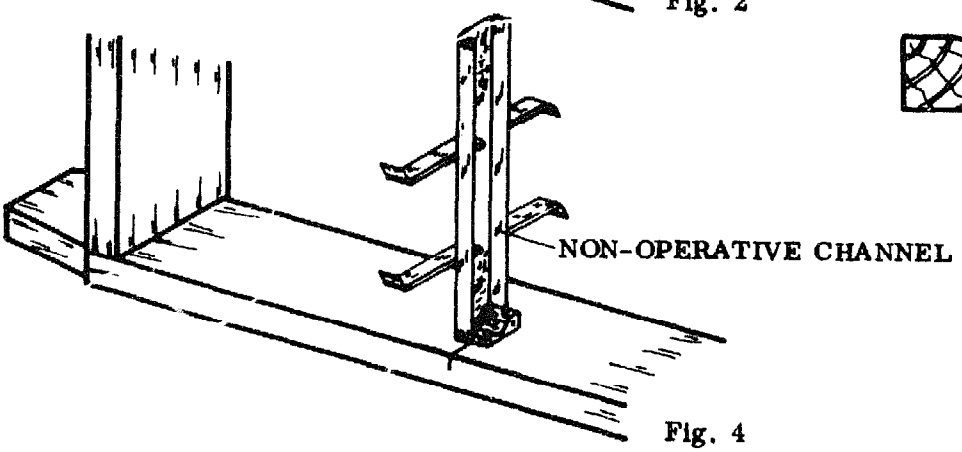

Fig. 4

N P V C		WINDOWS.
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- SEQUENCE OF OPERATIONS FOR INSTALLING A SELF-MULLIONING LOUVRE WINDOW: If two or more louvres are to be set across the window frame, the metal channels can be fixed together with screws, to form a metal mullion. The metal mullion is installed before the other channels.

a. Mark the centres of the head and cill. The width of the window frame has to correspond to twice the length of a louvre glass, plus 3,8 cm for each set of channels, making 7,6 cm for both sets.

b. Mark out the position of the metal mullion on the head and cill. Keep in mind the position of the mosquito wire (Fig. 1).

c. Fix the bottom spacer on the cill (Fig. 2) at right angles to the face of the frame. The frame must be painted before the spacers are fitted.

d. If the cill is sloping, bend the lugs of the spacer so that they are upright. The bottom end of the louvre channel should be cut to fit the slope of the cill, so that it fits tightly (Fig. 3).

e. To position the top spacer, place a louvre channel against the bottom spacer and plumb it with a spirit level. When it is straight, fix the top spacer exactly above the bottom spacer.

f. Take the non-operative channel and fit spacers into it at the places indicated by holes; these serve to stiffen the mullion.

g. Attach the non-operative channel to the spacers at the head and cill of the frame (Fig. 4).

h. Attach the operative channel to the non-operative channel with the special bolts and nuts.

i. Check the installation and operate the handle several times.

j. Install the other louvre channels to the window frame as in the previous page on installing louvre windows.

k. Make sure that all the channels are the same distance from the inside face of the window.

NOTES:

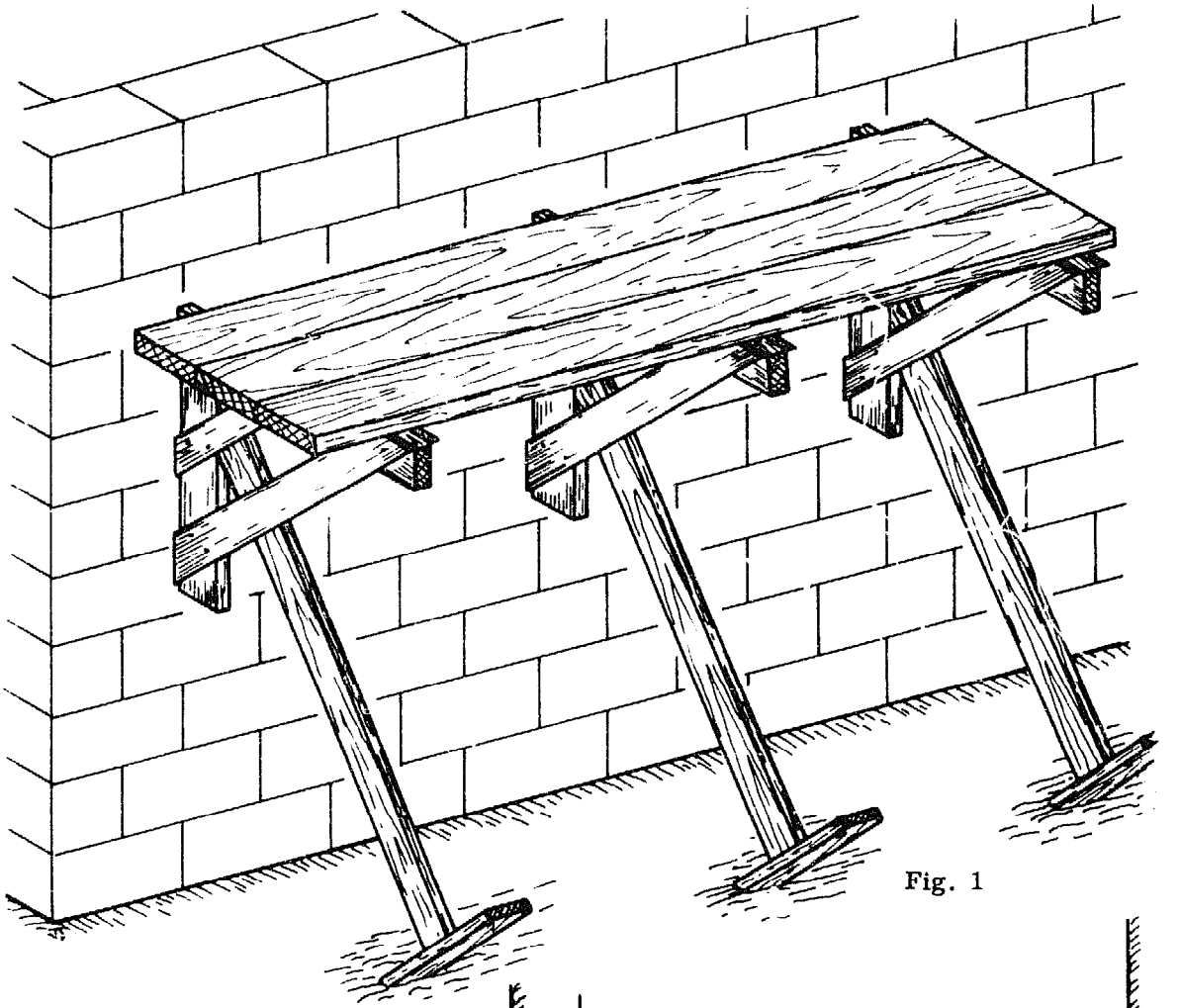

Fig. 1

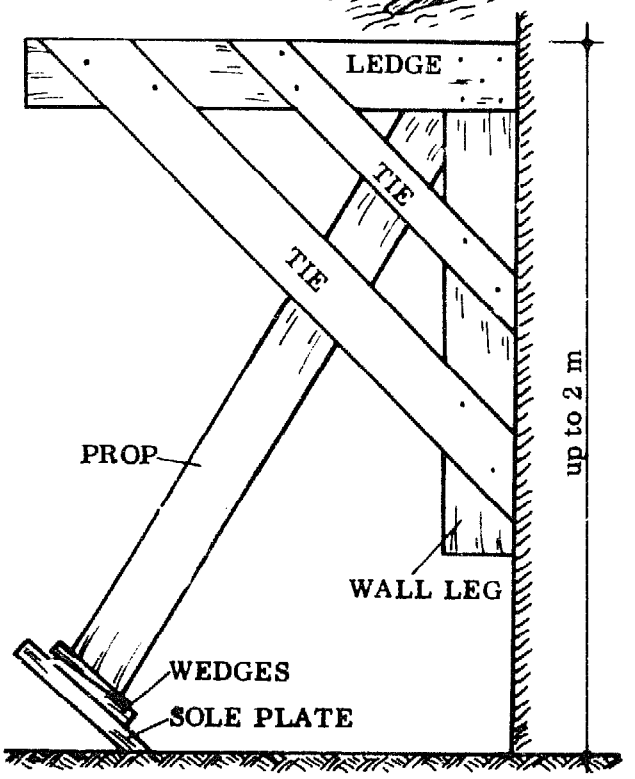

Fig. 2

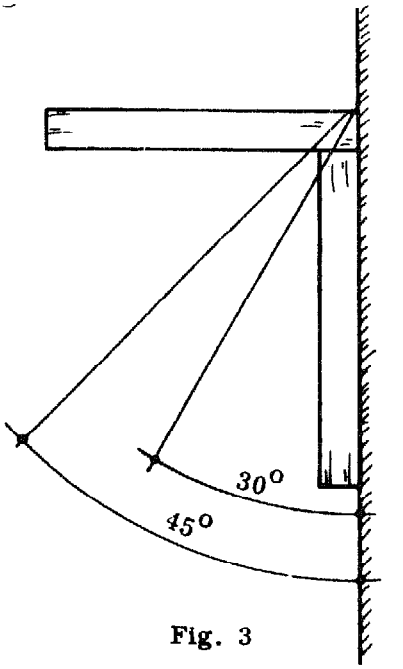

Fig. 3

N P V C	
116	CON.

WORKING SCAFFOLDS.

WORKING SCAFFOLDS

These are scaffolds which the workers stand upon to reach the higher parts of the construction. The tools and a supply of materials are also on the platform with the worker.

JACK SCAFFOLD

Although it can be no more than 2 m high, the jack scaffold is a satisfactory working scaffold for most jobs in Rural Building (Fig. 1). The block and trestle scaffolds which may be used for low level work are described in Basic Knowledge, page 158.

The jack scaffold is a dependent scaffold, which means it is propped against the wall for support instead of standing independently like other scaffolds. The feet of the props have to be properly set in place so that they will not move and settle when the scaffold is in use. Never try to put any support under the wall leg of the jack, as this would actually make the scaffold unstable.

Each jack scaffold consists of three jacks, three props and three (approximately 4,5 m long) planks. If the scaffold is to be only 2 m long or less, two jacks are enough.

- CONSTRUCTING THE SCAFFOLD PIECES: The jacks consist of a wall leg and a ledge which is nailed edgewise to the top of the wall leg. Both boards must be at least 5 cm thick by 10 cm wide, and about 100 cm long. The right angle is braced with two ties on each side, in a way similiar to the construction of a large square (Fig. 2, also see Reference Book, page 13).

  The shorter tie should be set so that it does not cover the corner of the jack, where the prop meets the angle. An opening is left, through which the position of the prop can be checked. The prop has to fit securely into the corner of the jack, without any "play" in the connection. The ties should be at least 2,5 cm thick, and the prop will be 5 by 10 cm by whatever length is required (remember that this scaffold should not be more than 2 m in height).

- ERECTING THE SCAFFOLD: Hold the jack with its wall leg against the wall, and fit the prop into the corner of the jack. Set the foot of the prop securely in the ground. The other jacks are set up in the same way. Check that all three are at the same height and the distance between them is not more than 2 m. The angle between the prop and the wall should be no less than 30 degrees and no more than 45 degrees (Fig. 3). In soft soil, sole plates must be set under the feet of the props.

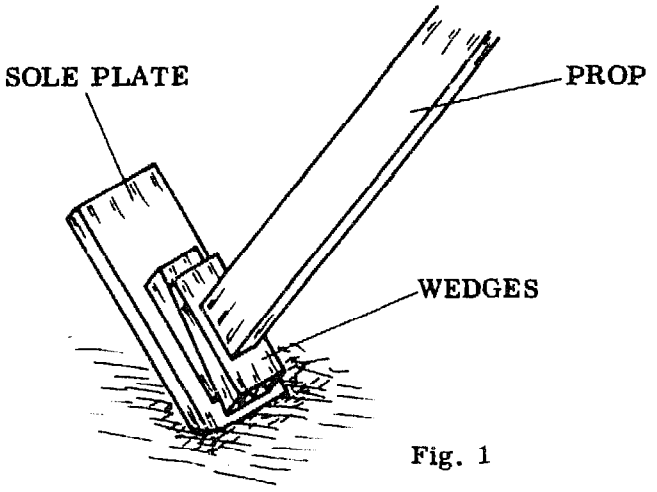

Fig. 1

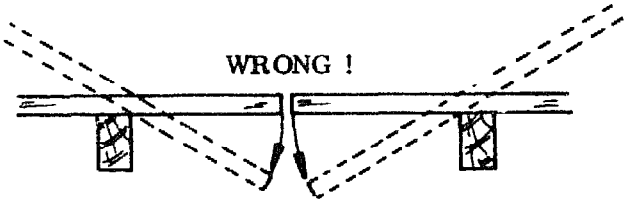

Fig. 2

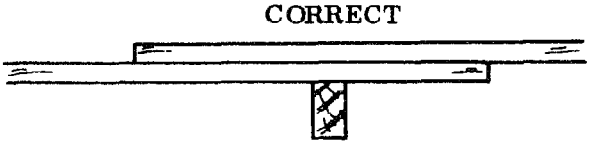

Fig. 3

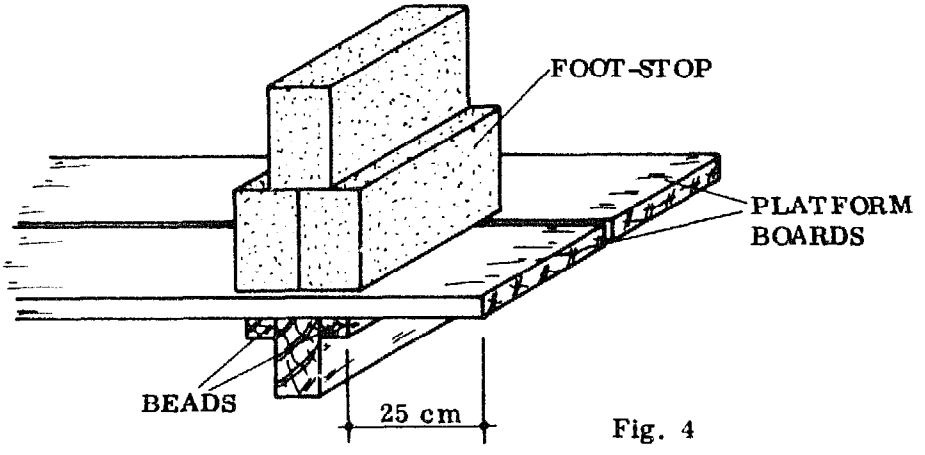

Fig. 4

N P V C		WORKING SCAFFOLDS.
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- SAFETY PRECAUTIONS:

  - Check that all the members of the scaffold are sound and without cracks.
  - Check whether the upper ends of the props fit well and without play into the corners of the jacks
  - Make sure that the feet of the props will not slip. In soft soil, they should be supported by sole plates set in the ground, at right angles to the props (Fig. 1).
  - Pay attention when you lay the platform boards, so you don't create a scaffold trap. This is a place which looks safe but is not (Figs. 2 & 3 . The free ends of the platform must not project by more than 25 cm past the ledge, and they should be blocked off by a foot-stop (Fig. 4).
  - Wedges are used between the foot of the prop and the sole plate. By adjusting these, the prop can be tightened against the angle.
  - Beads can be attached to the bottom of the platform boards to prevent them from shifting along the ledges (Fig. 4), or the platform boards can be nailed directly to the ledges.

- NOTE: Always pay attention to the safety of the scaffold. A carelessly erected scaffold is a danger to the lives of workers and passers-by.

NOTES:

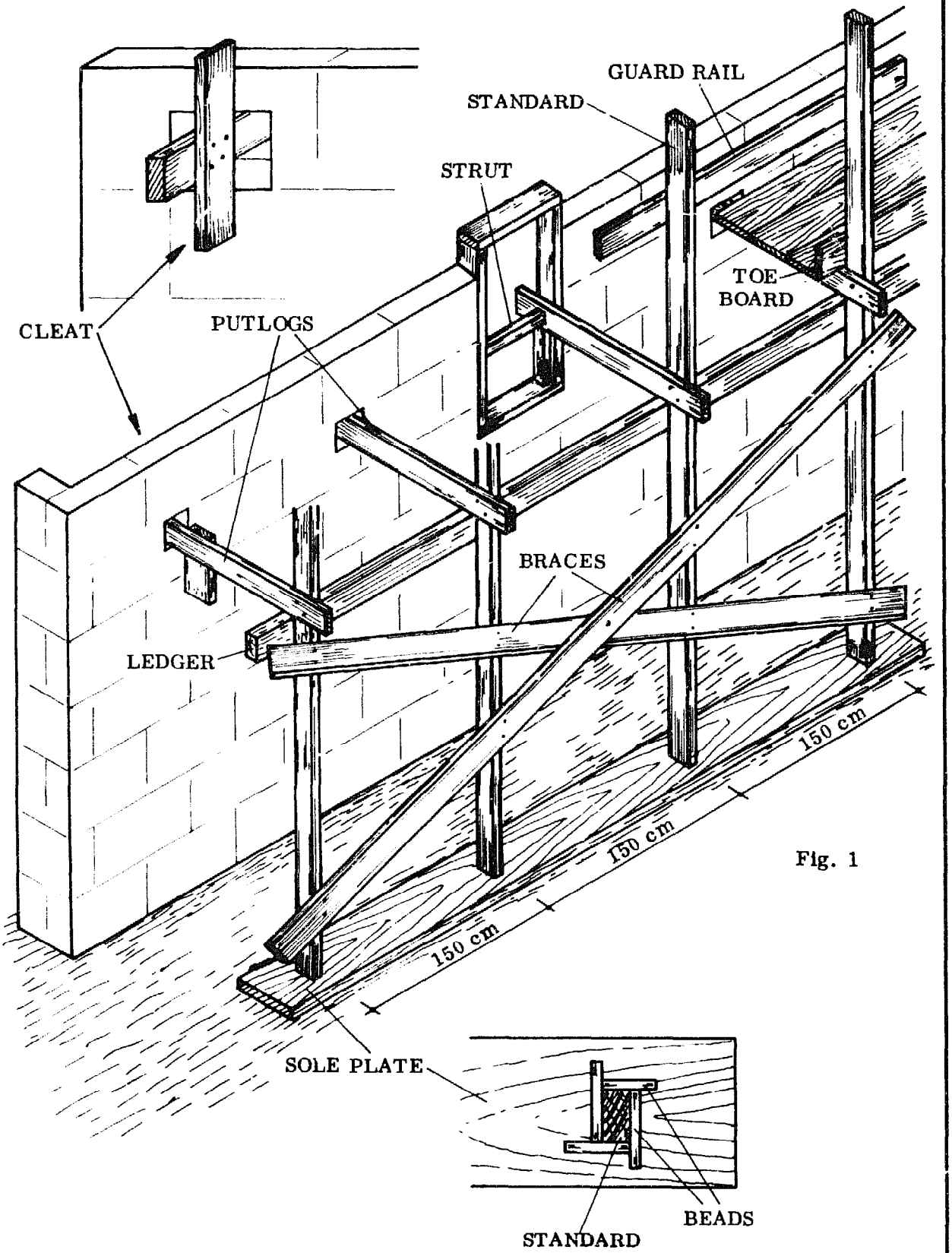

Fig. 1

Fig. 2

N P V C	
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WORKING SCAFFOLDS.

BLOCKLAYERS SCAFFOLD

Like the jack scaffold, this scaffold is dependent on the wall for support. The construction is fixed with "putlogs" into the wall, and secured on both sides of the wall with cleats which are nailed to the putlog (Fig. 1).

Erect the standards on top of the soleplate (Fig. 2) and nail the ledger at the required height. Each putlog will have one end in a wall opening which was left during the blocklaying; and the other end is supported by the ledger and nailed to the standard. Secure the putlogs into the wall with two cleats, one on either side of the wall. Make sure that the cleat on the outside of the wall does not project above the putlog, where it will interfere with the platform boards.

Once all the putlogs have been secured, nail braces across all the standards to make the whole construction rigid.

Check the construction, then lay the platform boards. Fix the toe board, and nail the guard rail at a height of 90 cm above the platform.

If a putlog is secured inside of a window frame, add an additional strut inside the frame (Fig. 1).

The advantage of this type of scaffold is that it requires less wood to make the frame. The holes left in the wall are easily filled with small blocks before the plastering is done.

- MEMBERS OF THE SCAFFOLD: (see Fig. 1)

- Sole plate
- Standards
- Putlogs
- Cleats
- Ledger
- Braces
- Platform boards
- Toe board
- Guard rail
- Struts (if needed)
- Pieces to secure the standards to the sole plate (Beads)

NOTES:

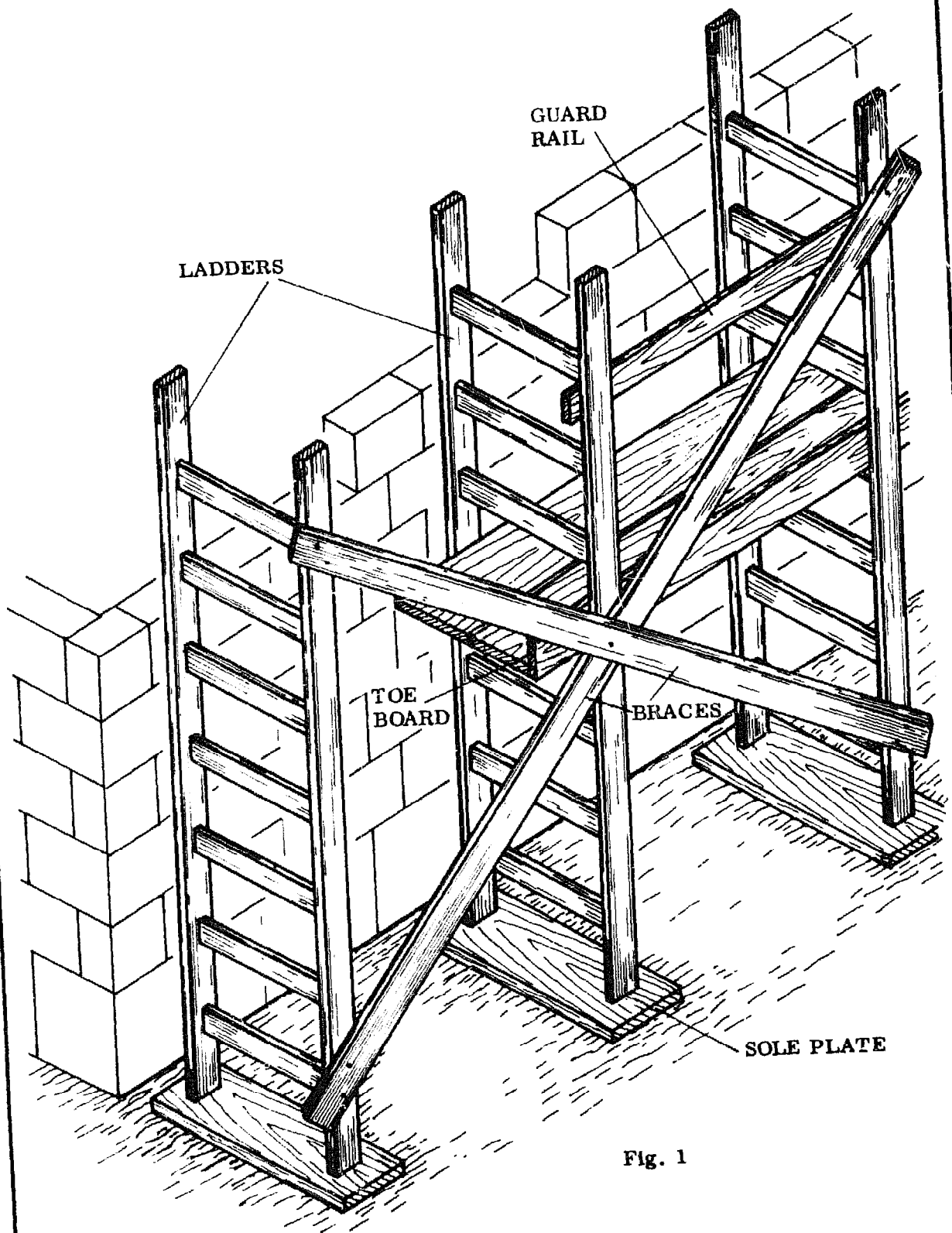

Fig. 1

N P V C		WORKING SCAFFOLDS.
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LADDER SCAFFOLD

This is an independent working scaffold, that is, it is not supported on the building but stands free. A ladder scaffold can be used where the height of the building is no more than 3,5 m.

Three or four ladders are usually used. Erect the ladders on top of the sole plates so that they do not sink into the ground under use. Keep the ladders plumb and straight, and nail two braces diagonally across the side.

If necessary use some wedges under the ladders to keep the structure steady.

Lay the platform boards and fix the toe board and the guard rail. The guard rail is fixed 90 cm above the platform.

Before any workers use the newly erected scaffold, make sure that all the parts are well secured and fixed according to the safest manner. Be aware that the scaffold has to carry not only the workmen but also a load of building materials.

NOTES:

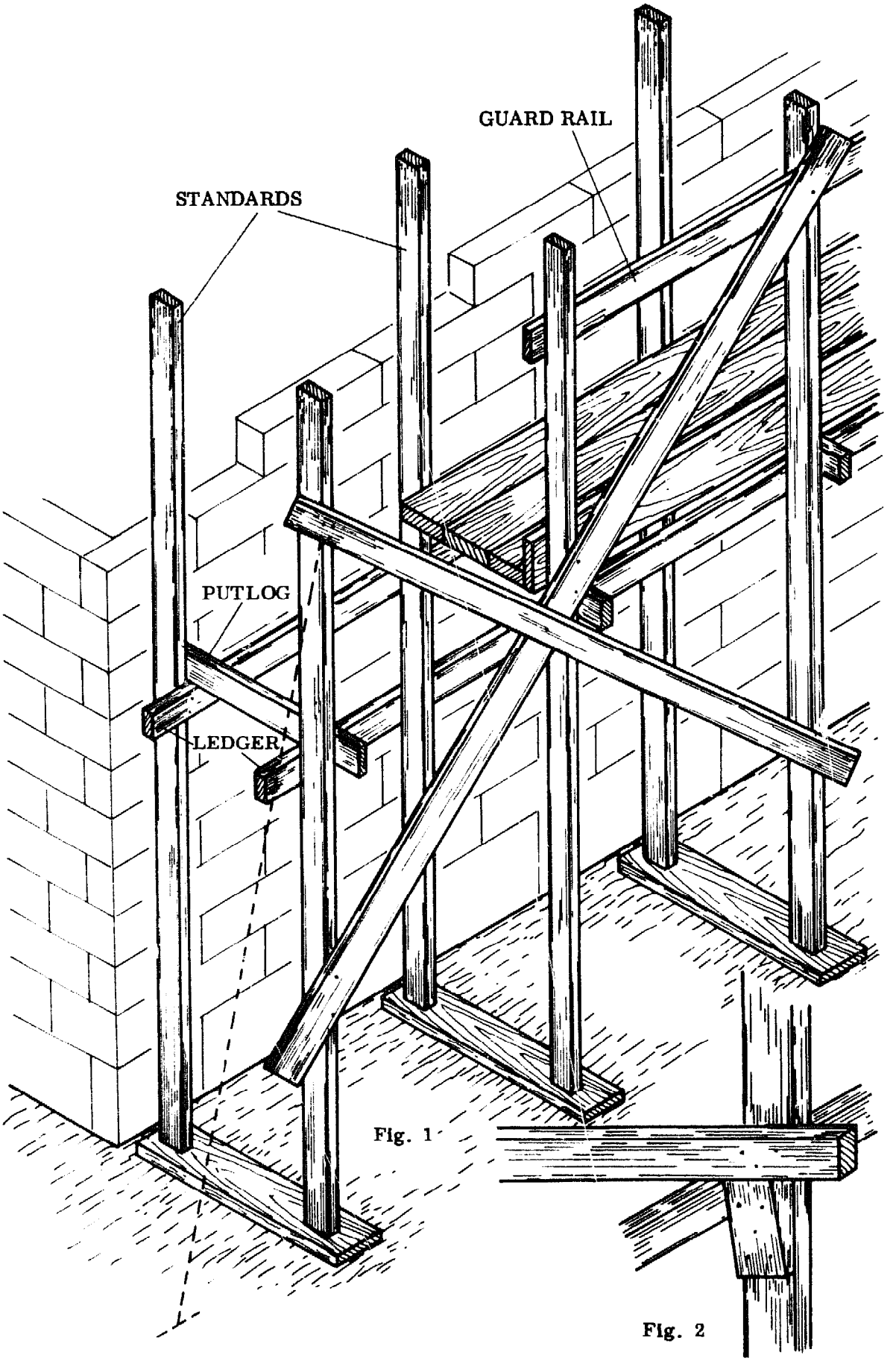

N P V C	
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WORKING SCAFFOLDS.

INDEPENDENT SCAFFOLD

This is similar to a ladder scaffold with the difference that no ladders are used. Timbers are used instead; these should be 5 x 10 cm by approximately 4,5 m long.

Sort out the timber, keeping the straight pieces for standards and the bent pieces for shorter members like putlogs.

Mark the height of the working platform on the standards, and nail the putlogs to the standards. Erect the standards on top of the sole plates, and nail the necessary braces to the outside of the structure.

Nail two additional boards (ledgers) under the putlogs. These give support to the putlogs.

Lay the platform boards and secure them with nails or battens. Fix the toe board. Nail the guard rail 90 cm above the platform.

If necessary, place some wedges under the standards to make sure that the whole structure is steady. Extra braces can be added to the outside of the structure; secure them to the ground with pegs (Fig. 1, broken lines).

Fig. 2 shows an alternative way to support the putlogs, with a wedge-shaped piece of wood nailed to the standard underneath the putlog.

SUPPORTING SCAFFOLD

As the term indicates, a supporting scaffold is used to support members of the structure until the mortar or concrete has hardened or cured; or until the parts are assembled, when the member will be able to support itself and the scaffold can be taken away.

The supporting scaffold is seldom used in Rural Building because in most cases a lighter and simpler strutting will serve for the purpose of supporting the usual reinforced concrete members as they are cast-in-situ. See page 167 of the Basic Knowledge book for an illustration of a typical strutting for a reinforced concrete lintel.

The heavier supporting scaffold is used only in cases where the member to be supported is very large and heavy. The supporting scaffold arrangement is shown in the illustration on the next page.

Fig. 1 SIDE VIEW

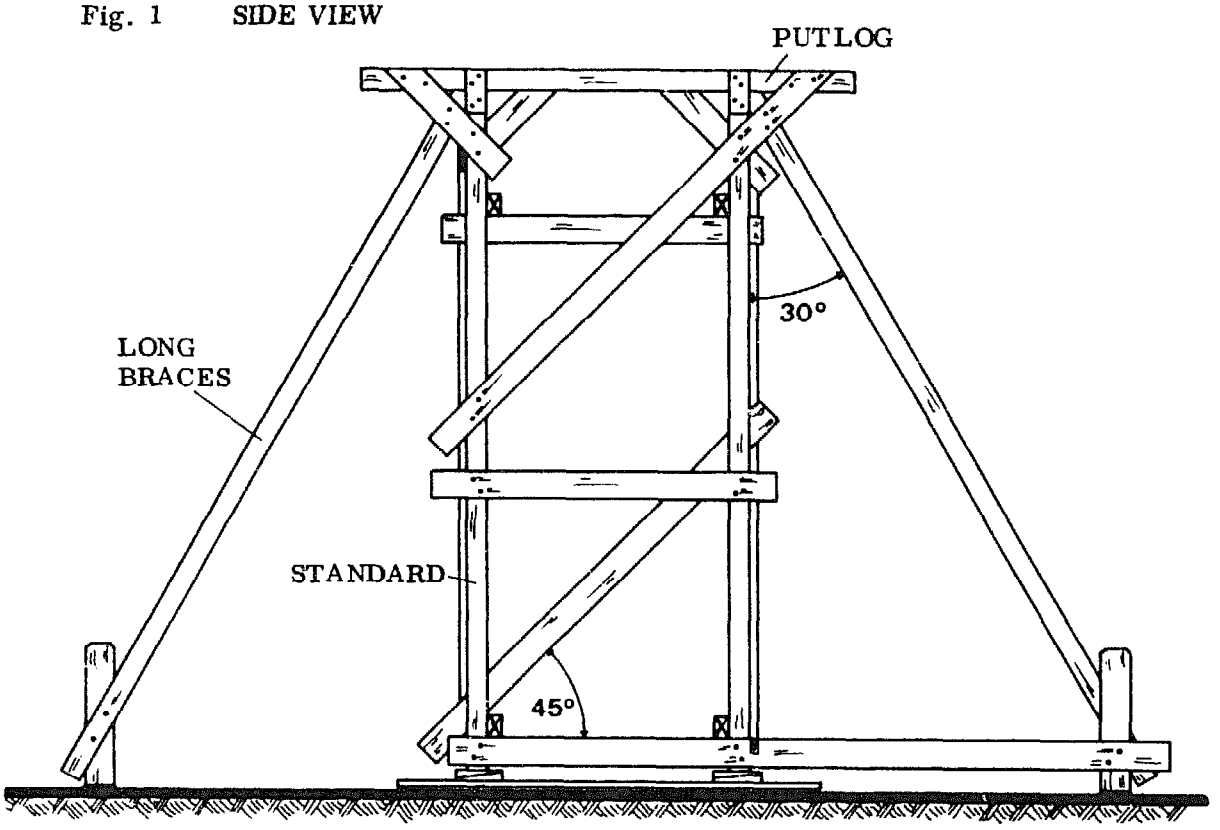

Fig. 2 FRONT VIEW

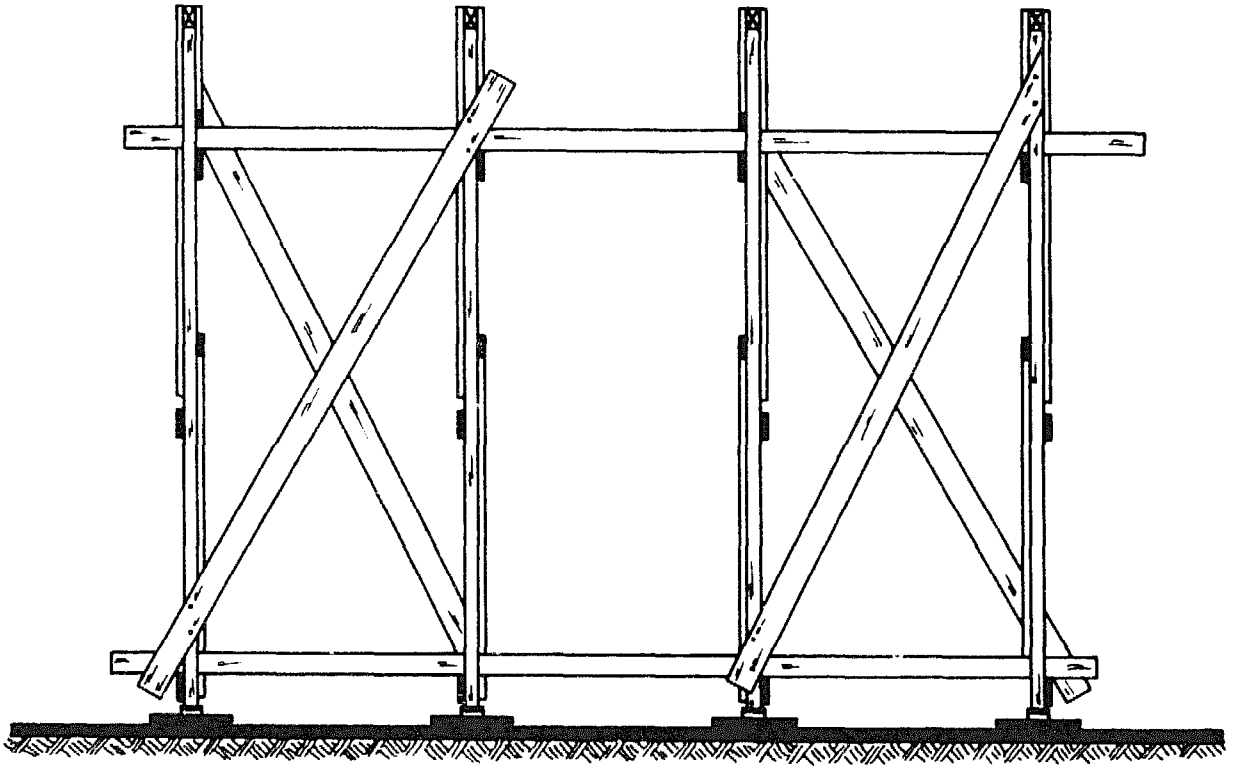

N P V C	
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SUPPORTING SCAFFOLD.

When you construct a supporting scaffold, pay particular attention to the stability of the structure, since it usually has to support very large and heavy members. The distance between the standards (also called struts) must be no more than 1 m (Figs. 1 & 2). All the shorter braces, which reinforce the connections between the putlogs and the standards and between the standards themselves, are fixed at 45 degree angles. The long braces, which go from the top of the structure down to pegs in the ground, are fixed at an angle of no less than 30 degrees. These help to keep the scaffold from tilting or overturning.

PROTECTIVE SCAFFOLDING

On most Rural Building construction sites, protective scaffolding is not necessary. This is because the structures are relatively low in height. However, when a higher structure such as a water tower is constructed, protective scaffolding becomes necessary to protect the people underneath from falling objects. On jobs where walls are being broken down, or where large and heavy objects are handled, it is advisable to erect a protective scaffold of some sort.

A second platform is made below the working platform, and a side projection is fixed at an angle to this (Fig. 3).

The projecting piece is attached to the standards by wooden braces.

Any tools or materials which fall from the working platform will hit the projecting piece and roll onto the second platform, instead of falling to the ground.

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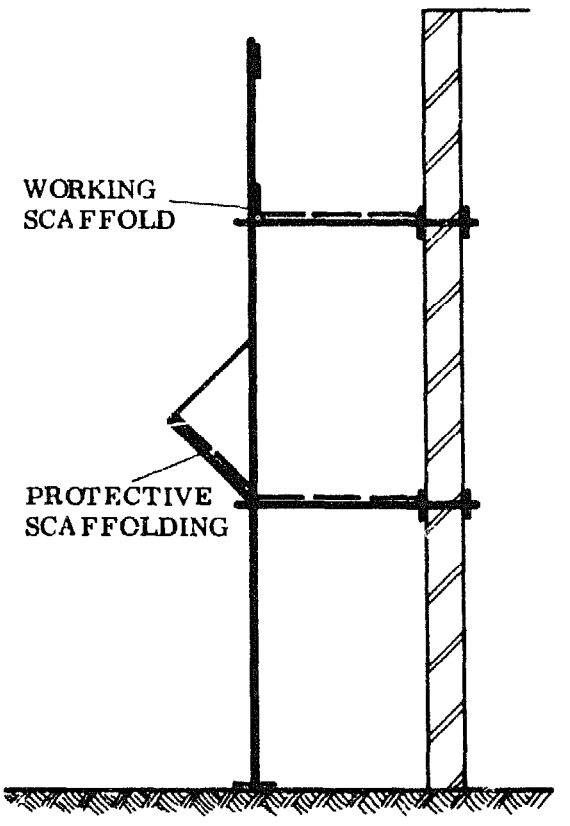

Fig. 3

ARCHES

Openings in walls such as doors and windows have to be closed at the top in such a way that the structure above them is supported. Before the use of reinforced concrete became common, smaller openings were bridged with wooden lintels, solid stone lintels and arches (see Basic Knowledge book, pages 162 to 164).

Wider openings were generally spanned by arches, or by a series of arches carried on piers or columns: the so-called arcade. In this book we discuss only one type of arch, the "segmental arch" where the arch is formed like a segment of a circle. Many other forms are possible with arches, but they are not important for Rural Building.

Before we continue with this chapter, it is essential to understand the technical terms that are used in connection with arches. The terms below are indicated in Fig. 1.

TECHNICAL TERMS

- ABUTMENT: The word "abut" means to meet at one end or to border on something. An abutment (Fig. 1, a) is that portion of solid masonry that carries the weight of the structure of an arch. In Rural Building, the minimum width of an abutment at the end of a wall should be 3/4 of the span of the arch. This means that the distance from the arch to the end of the wall should be at least 3/4 of the span of the arch.

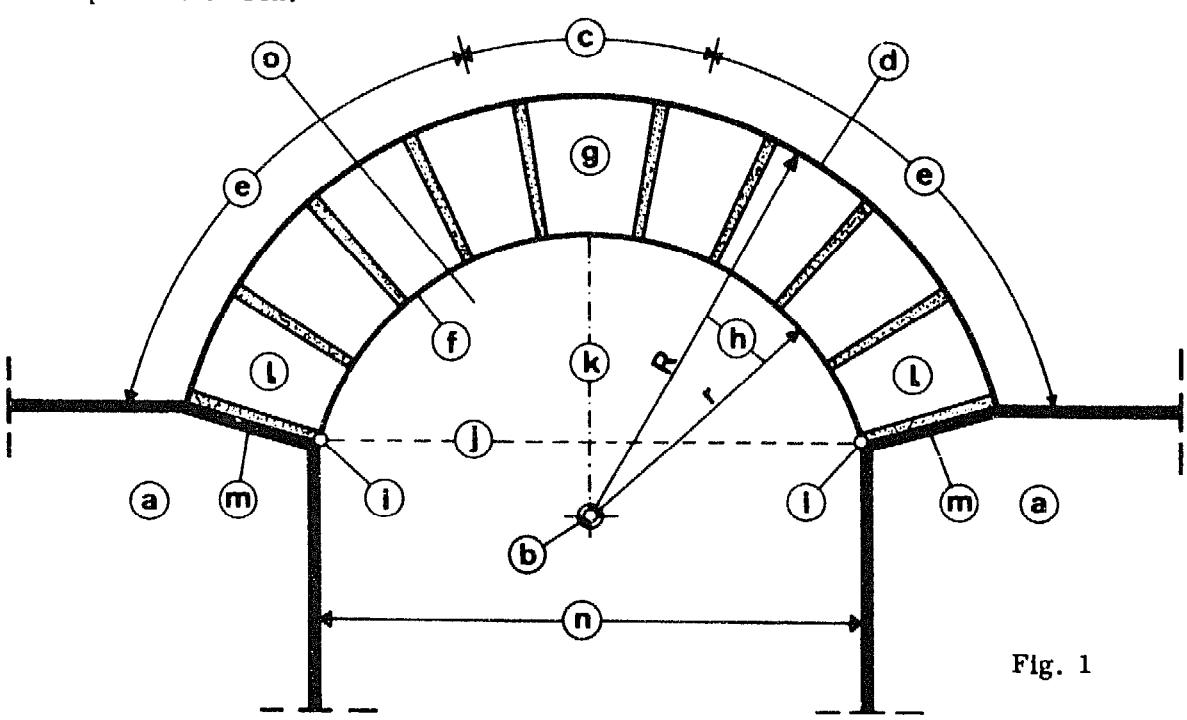

Fig. 1

- CENTRE: This is the midpoint of the circle which describes the curve of the arch (b).
- CROWN: This is the portion of the arch which forms the top of the curve (c).
- EXTRADOS: The outer curved line of an arch, or the upper surface of the archstones (d).
- HAUNCH: The flanks of an arch, the sides of the curve (e).
- INTRADOS: The under surface or soffit of an arch (f).
- KEYSTONE: The central wedge-shaped archstone at the crown of an arch (g), which is the last stone to be put in place.
- RADIUS: The straight line (h) from the centre of an arch to any point on its intrados (the shorter radius, r); or to any point on its extrados (the longer radius, R).
- SPRINGING LINE: The line across the arch which would connect the springing points (j).
- RISE: The height of an arch measured perpendicularly from the springing line to the highest point of the intrados (k).
- SPRINGER: The first stone laid in an arch on either side (l).
- SKEWBACK: That portion of the abutment which directly supports the springers (m). It is so called because the surface slopes towards the opening.
- SPAN: The horizontal distance between the springing points (n); the length of the springing line.
- CAMBER: This is the space between the springing line and the intrados (o).
- ARCHSTONES: These are any of the stones or blocks which form the arch itself.

NOTES:

Fig. 1

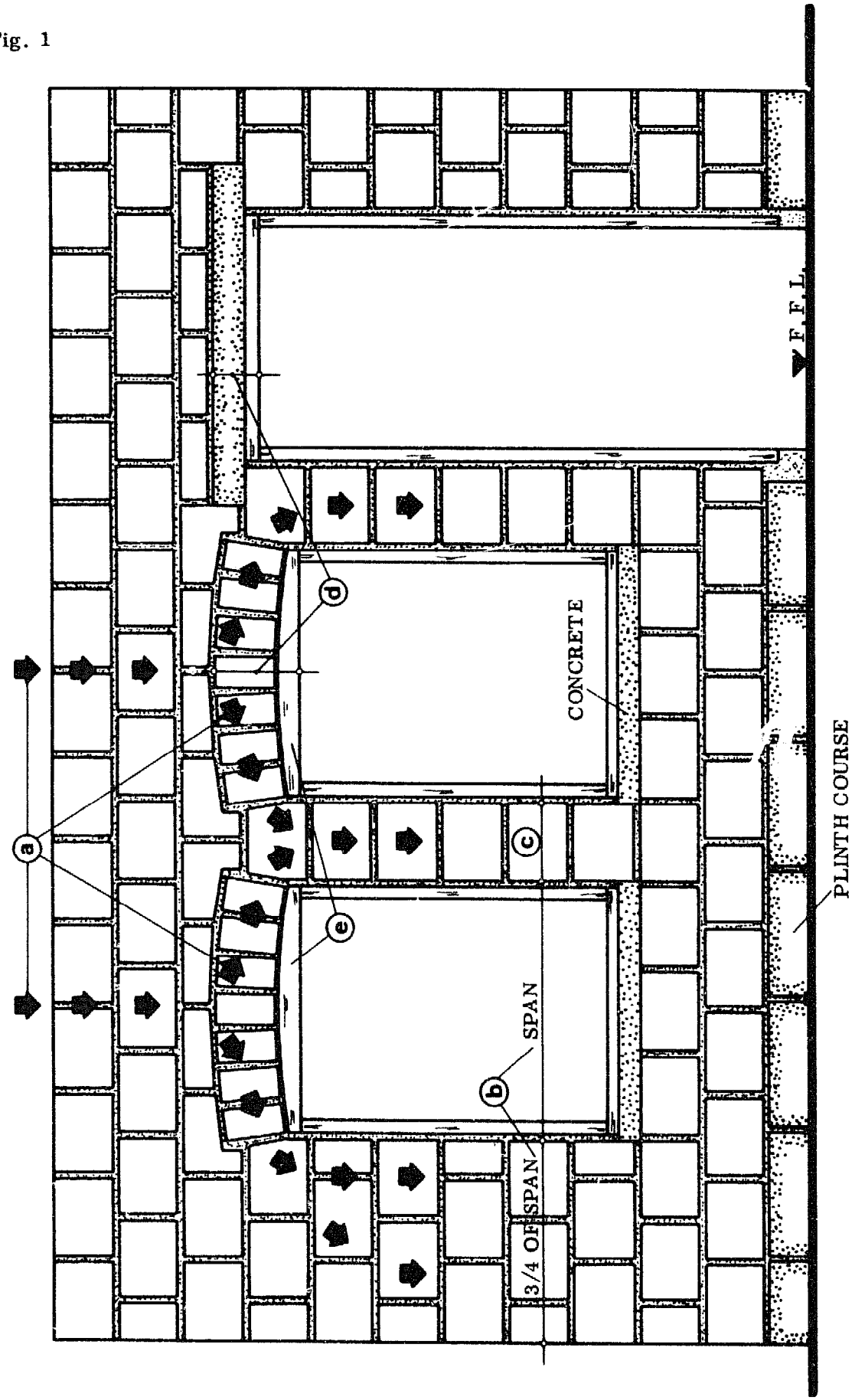

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ARCHES.

STABILITY OF ARCHES

All arches, regardless of their shape or dimensions, function as wedges. An arch distributes the load imposed on it to the abutments on both sides; these have to be strong enough to withstand the pressures (Fig. 1, a). This is the reason why the abutment which is at the corner or end of a wall must be at least as wide as 3/4 of the span of the arch (Fig. 1, b). Between two arches, thinner supports such as columns or piers can be used (Fig. 1, c).

It is always better to build two or three courses of blocks above an arch because this weight will improve its stability. The preferred material for constructing an arch is sandcrete blocks, because they can be cast to any shape required and can withstand high pressures. Of course landcrete or mud blocks can also be used, but these must be well protected against moisture penetration.

- DISADVANTAGES OF ARCHES:
  - All arches, especially those which have unusual shapes, require more space than a lintel (Fig. 1, d).
  - Frames must be shaped on their top according to the curve of the intrados (Fig. 1, e); or if a square frame is to be fitted, the remaining space above it must be closed with plywood etc.
  - A temporary wooden support, the centring or turning piece, is needed during the construction; this piece has to be exactly the correct shape.
  - Masonry arches cannot be prefabricated.
  - Specially made archstones are often required.
- ADVANTAGES:
  - Arches are more economical because scarce and expensive building materials like reinforcement iron are not needed.
  - Locally available building materials such as mud blocks can be used to build arches.
  - In contrast to cast-in-situ lintels, the walling above an arch can continue immediately after it is completed, because the arch does not have to set.
  - Traditional building styles can be maintained and developed in a simple and cheap way.
  - Arches, if well constructed, give the building a more attractive appearance and demonstrate the skill of the builder.

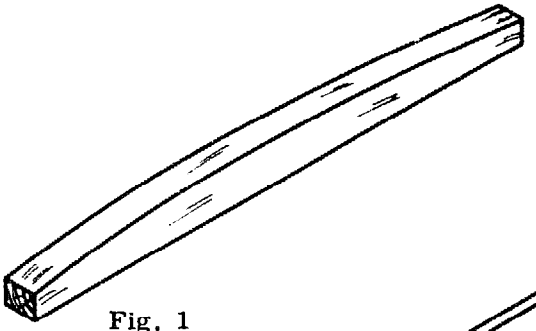

Fig. 1

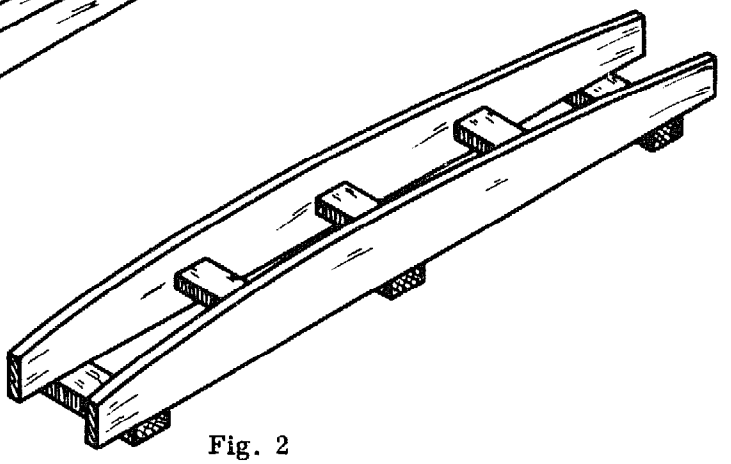

Fig. 2

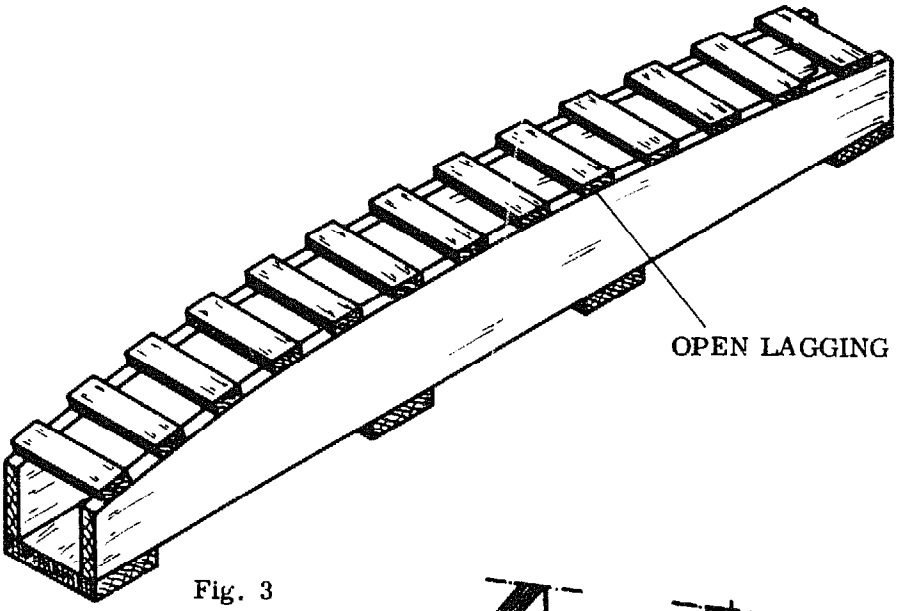

Fig. 3

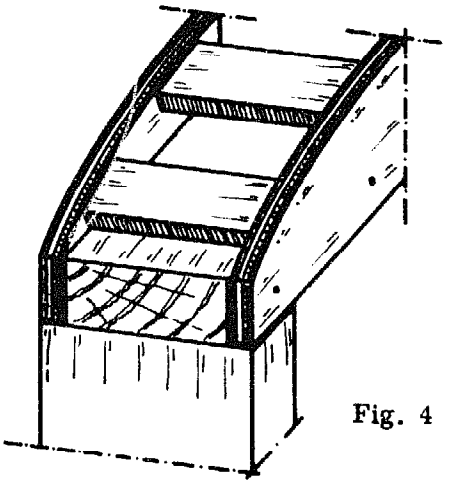

Fig. 4

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ARCHES.

THE SEGMENTAL ARCH

The segmental arch is the most important one in Rural Building. This is mainly because:

- The construction depth measured from the springing line to the crown is comparatively small; with the result that the building costs are low.
- The construction is not too difficult and specially made tapered blocks are not necessarily required.
- The time spent on the construction of this kind of arch can be shorter than the time spent for constructing a reinforced concrete lintel.

TYPES OF CENTRING

"Centring" is the term generally applied for the curved wooden piece which temporarily supports arches or domes during their construction. It is comparable to the strutting (not the shuttering) for concrete members.

The actual shaping part of the centring is called the "turning piece". There are three main types of centring:

- A solid wooden board, about 5 cm by 7,5 cm, placed edgewise. Its upper surface is carefully and evenly shaped according to the curve of the intrados (Fig. 1). Its use is restricted to short-span openings; not exceeding about 100 cm wide. The disadvantage of this type is that the archstones rest on only a small area, which might lead to the blocks tilting during the laying.
- Two wooden planks or sheets of plywood are connected by spacers, so that the archstones are supported on their outer edges (Fig. 2). Both turning pieces must be precisely cut and planed to the same shape, and must match with the curve of the intrados.
- Arches spanning wider openings and those which have a rise of more than about 1/10th of the span need to be supported by a stronger centring, with either open or closed lagging (Fig. 3).

The three types of centring may be combined with the frame or may form part of the frame; the head. In this case no strutting is needed, and the centring piece simultaneously acts as a permanent seal of the space between the springing line and the intrados (Fig. 4). The lagging must then be fixed in between the turning pieces so it is flush with the upper curved edge and is not seen (Fig. 4).

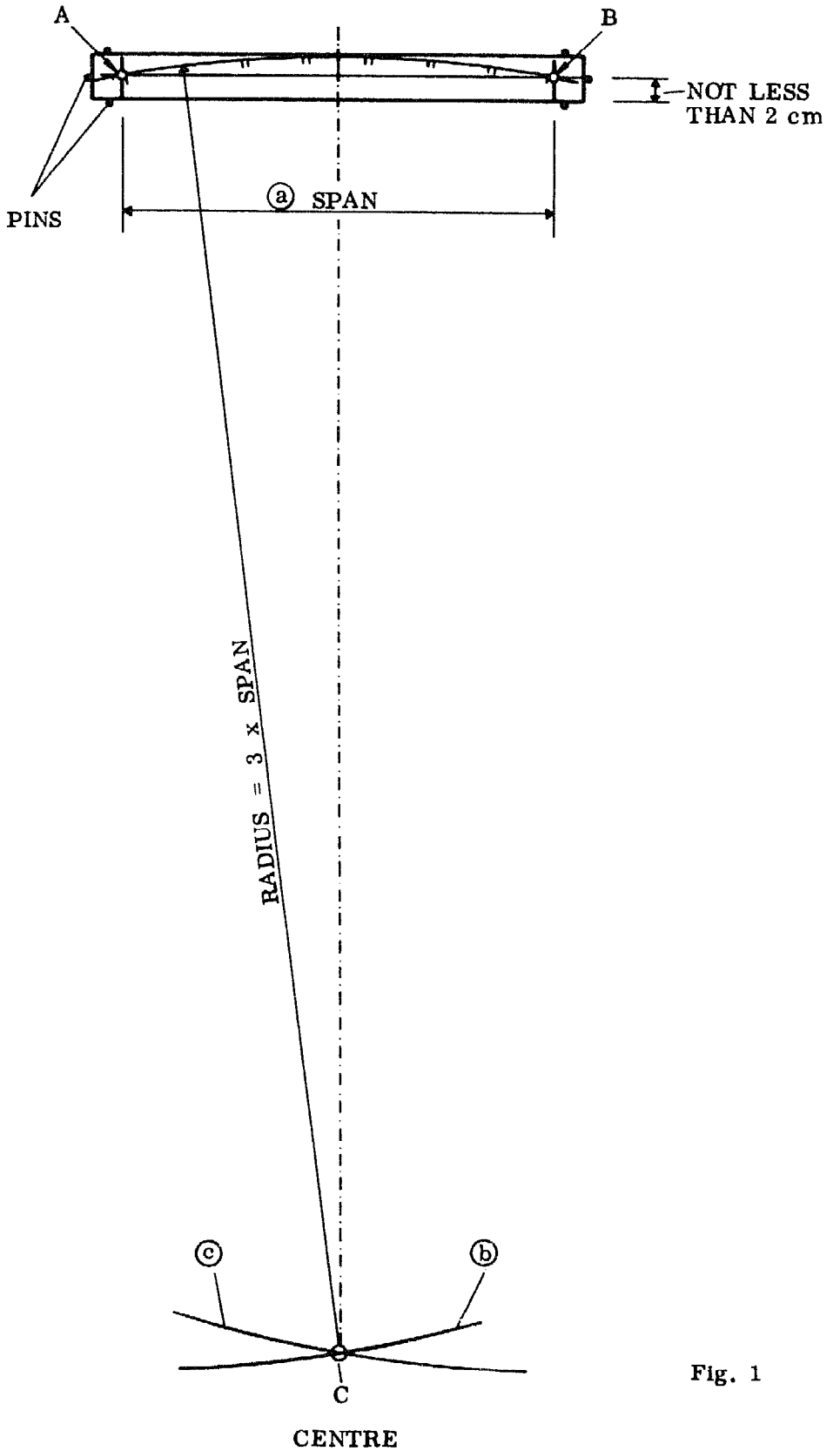

Fig. 1

N P V C		ARCHES.
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SETTING OUT THE TURNING PIECE

To set out the turning piece means to mark the curve of the intrados on a suitable piece of board or plywood, so that after it is cut and planed it can serve as a temporary support and guide for the arch construction. The positions of the archstones are also marked on the turning piece so that no mistakes can be made during laying.

As far as Rural Building is concerned, the radius of the circle which describes the curve of the intrados will always be three times the span of the opening. For example: if the span of the opening is 80 cm (the clear width), the radius must be 3 x 80 cm = 240 cm; if the span is 180 cm, the radius is 540 cm, etc.

The curve obtained from this rule will result in an arch which is flat enough so that not much space is wasted, but also curved enough to ensure stability.

- SEQUENCE OF OPERATIONS:

  - You need a large, flat and level space for the setting out.
  - Mark the span of the opening on a suitable board (Fig. 1, a).
  - Determine the springing points (at least 2 cm from the edge of the board) and drive in short nails to mark these points. Leave the nails projecting, and make sure that they are both the same distance from the edge of the board (Fig. 1, A & B).
  - Place the board on the ground and secure it with nails or pegs as shown, so that it cannot shift to any side.
  - Fix your mason line on nail A, and measure off from there three times the span of the opening along the line. Use this length to describe a short section of a circle on the ground (Fig. 1, b).
  - Repeat this procedure with the line fixed on nail B (Fig. 1, c). Both circle sections will intersect at point C, which is the centre of the arch. Secure the centre point with a nail or peg.
  - Fasten the mason line on peg C and tie a pencil at the distance of three times the span of the opening.
  - Keep the line taut and describe a circle section, while marking the section on the board. This curved line should intersect with the springing points, A and B, and the curve resembles the curve of the intrados.
  - To check the accuracy of the setting out, measure the rise of the arch perpendicularly from the springing line to the highest point of the curve. This distance must be 4,2% of the span (0,042 x span (in cm) equals the rise (in cm).

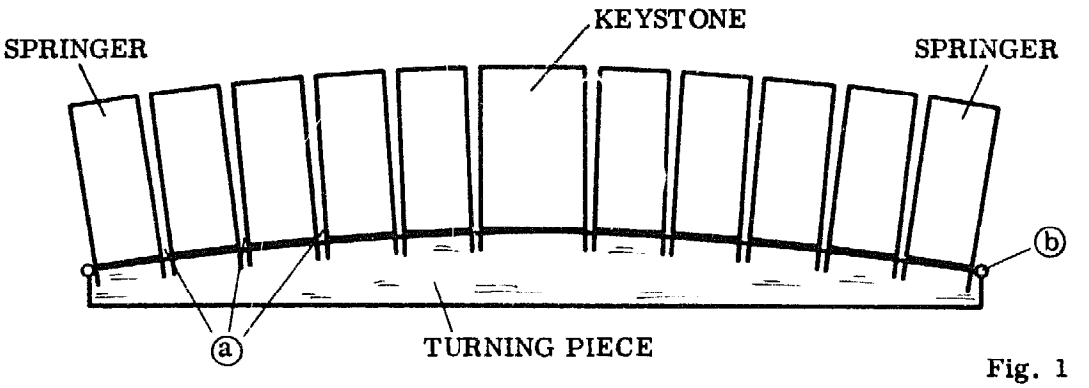

Fig. 1

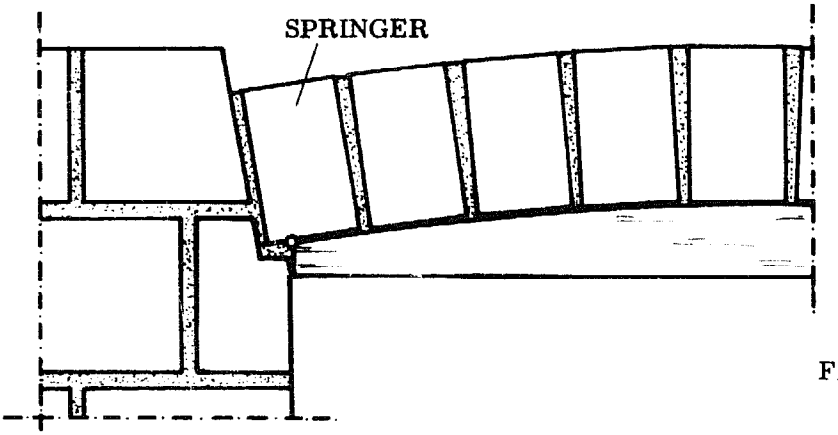

Fig. 2

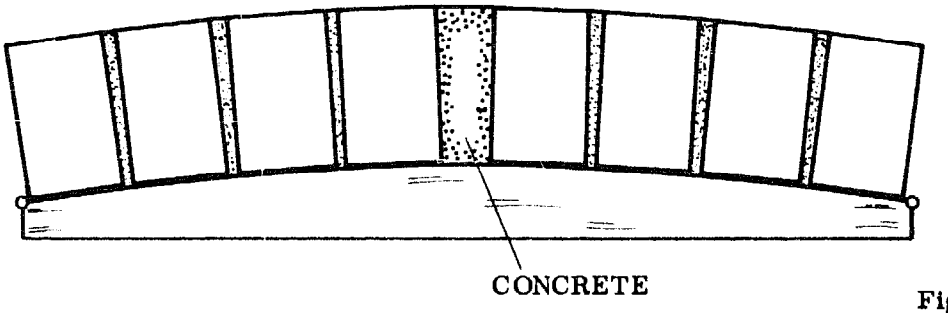

Fig. 3

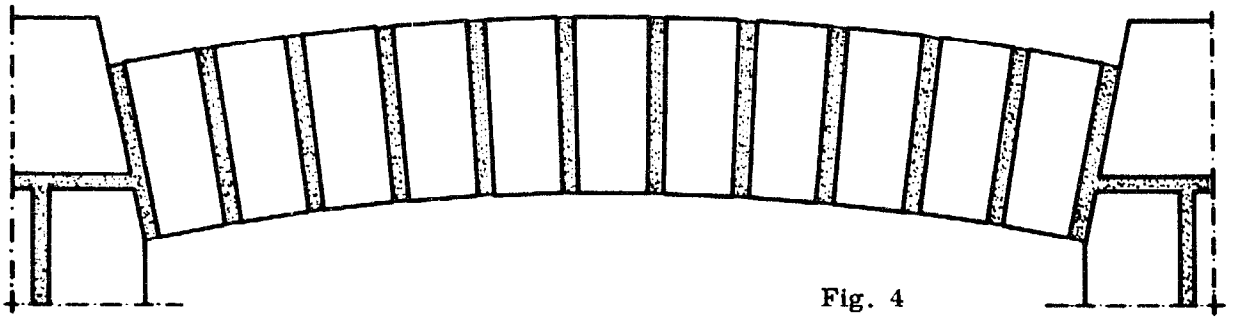

Fig. 4

N P V C		ARCHES.
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POSITIONS OF THE ARCHSTONES

Regardless of which type of arch is constructed and what kind of archstones are used, the total number of blocks or bricks must add up to an odd number: the keystone in the middle is flanked by an even number of archstones (Fig. 1).

Therefore the position of the keystone is usually marked first, followed by the archstones to the left and right. Cross joints are 1 cm wide at the intrados (Fig. 1, a), and wider at the extrados, because common blocks are used which results in wedge-shaped joints.

The marking continues until the springing points are either just reached or a little overlapped (Fig. 1, b). If it happens that there is a distance of more than 1 cm between the lower outside corner of the springers and the springing points, then one more block must be added to each side (Fig. 2). These two blocks will then become the springers, although they overlap by far the springing points.

There are two ways to avoid this:

- One can reverse the marking by starting from the springing points and marking by turns from the left and right up towards the crown. The remaining opening is then filled with either a specially made keystone, or with concrete (Fig. 3). This is preferred if the springers would overlap the springing points by too much.
- The most perfect solution would be to use specially made archstones which are wedge-shaped and fit exactly in the arch (Fig. 4). This requires some detailed and accurate planning, and more time and materials.

NOTES:

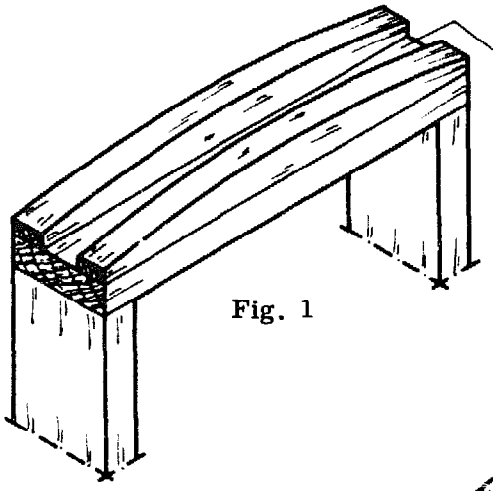

Fig. 1

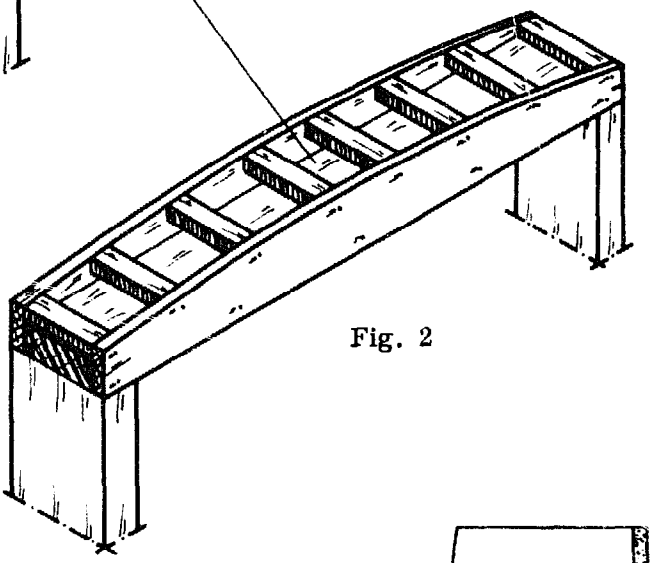

Fig. 2

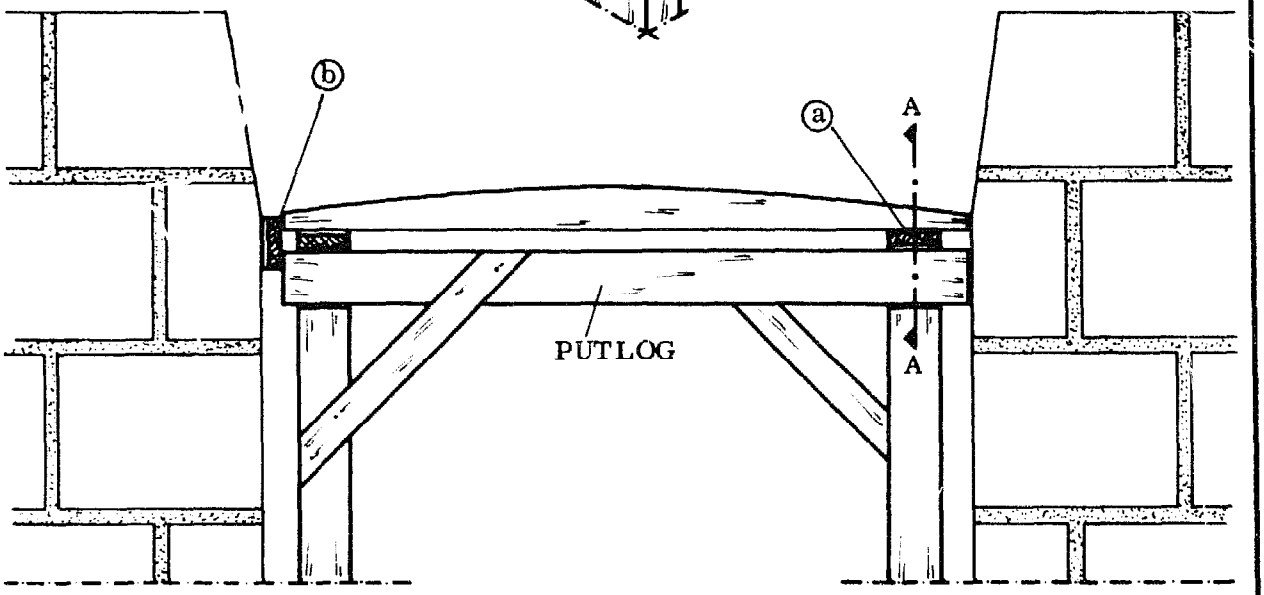

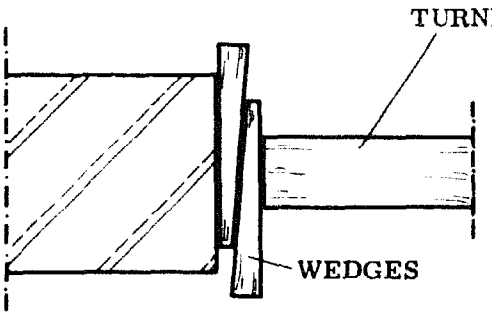

DETAIL TO ⓑ
(TOP VIEW)

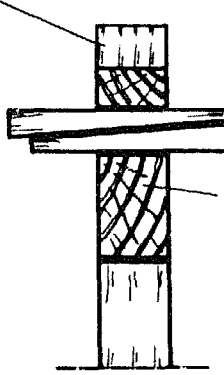

DETAIL TO ⓐ
(SECTION A-A)

Fig. 3

N P V C	
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ARCHES.

SETTING UP THE CENTRING

The board on which we marked the curve of the intrados and the positions of the archstones is now prepared for assembly and erection.

The first step is to cut off both ends of the board squarely at the marks which indicate the span. These cuts must pass through the springing points. Then the intrados is roughly shaped with the saw and then exactly planed to the mark, to make a smooth and evenly curved edge.

If the centring will be a part of the frame, it is now fitted to the frame head as in Figs. 1 and 2, and set into its place together with the frame. In this case it is best to make two identical turning pieces to seal the camber on both sides of the wall. They are fixed outside and inside flush with the frame. The hollow part in between the pieces is filled with a mixture of sand and ash; both to keep insects out and -- if there is no lagging -- to give more support to the archstones which otherwise would have to rest on the turning pieces only.

Note that the marks of the springing points are cut off when the turning piece is combined with the frame. This is because it is cut flush with the outside of the frame. This means that the thickness of the joint between the frame and the wall has to be taken into account when marking the slope of the skewback.

If the centring piece is to be removed after the arch is finished, it must be set in a way so that it can easily be taken out. This is done by placing it on wedges as in Fig. 3, (a). It might be necessary to cut the turning pieces slightly shorter on one end so that the centring fits easily into the opening. In that case the end which has not been cut rests against the wall while the gap on the other side is closed tight with wedges to prevent shifting (Fig. 3, b).

Try to avoid making the springing points in line with a bed joint. The sideways force from the arch can possibly cause cracks along the bed joint. The best solution will be to distribute the pressure over two courses (Fig. 3).

When you set the centring piece in position, do not forget to level the soffit, which must be exactly horizontal and parallel to the springing line.

NOTES:

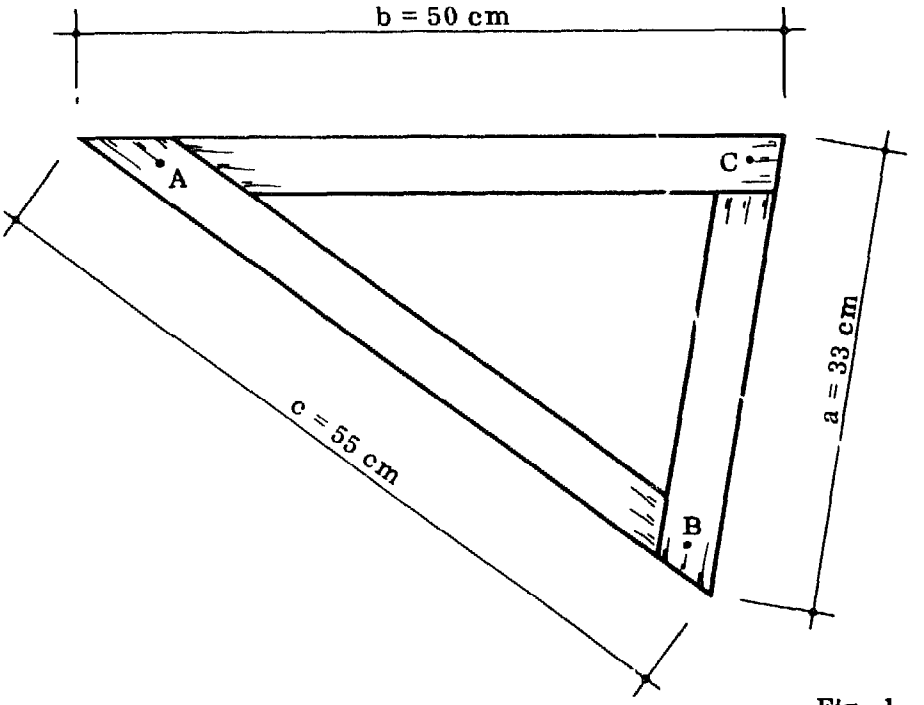

Fig. 1

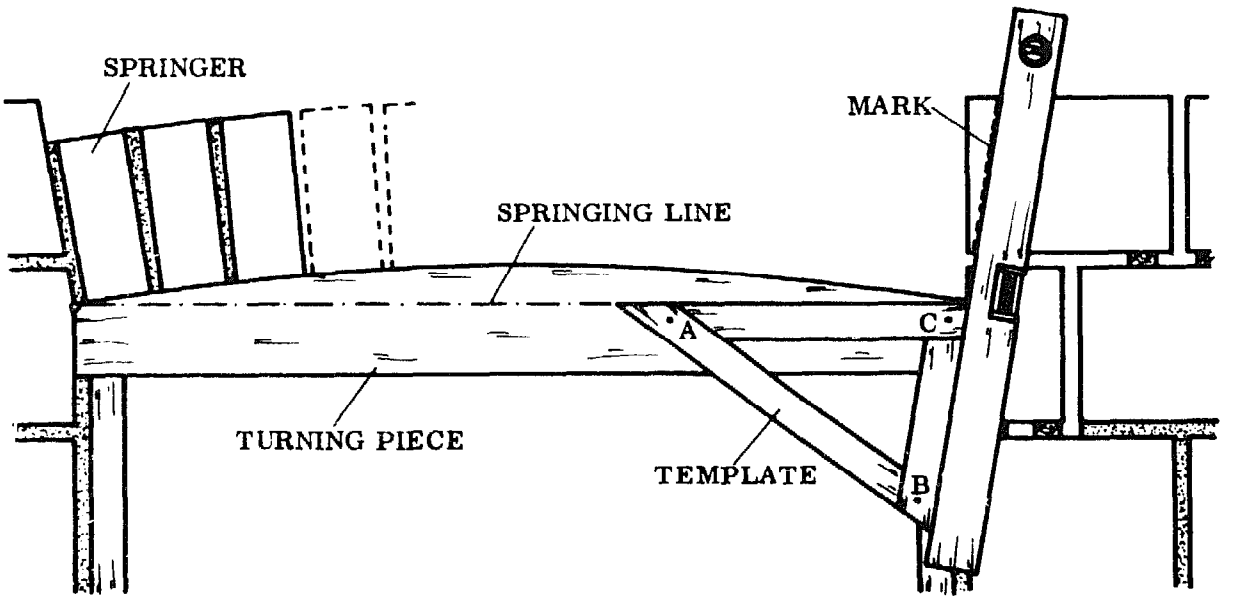

Fig. 2

N P V C		ARCHES.
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SKEWBACK TEMPLATE

Before you can start laying the archstones, the abutments with their skewbacks must be prepared so that the springers can be laid at the correct angle. To be sure that the angle of the skewback is correct, the Rural Builder can use the template described below (Fig. 1).

This skewback template can only be used for a segmental arch where the radius of the arch is 3 times the span of the opening. Provided the rule of "r = 3 x span" is observed strictly, the same template can be used for any segmental arch, regardless of the length of the span. In other words the width of the opening and the size of the arch make no difference in the angle of the skewback for arches made according to this rule; the angle will always be the same.

- MAKING THE TEMPLATE: The template is made from wooden battens. It is simply a triangle with the outside dimensions as follows: side "a" = 33 cm, side "b" = 50 cm, and side "c" = 55 cm (Fig. 1). The angle at C is the angle we need to mark the skewback.

  Use three battens that are a few centimetres longer than the measurements required. This allowance can be cut off when the template is assembled. Plane one edge of each until it is exactly straight and mark the length on this edge. Nail the battens together as in Fig. 1; or make accurate halving joints and join the pieces together with wing nuts instead of nails, so that they can be taken apart and put back together when they are needed in the future. The corners should be marked on both sides with the letters A, B and C, so that the ends are not accidentally mixed up when it is reassembled.

- USE OF THE TEMPLATE: The outside edge measuring 50 cm (side b) is held along the springing line, while the tip of the corner C is at the springing point (Fig. 2). The direction of the shortest side (side a) extended upwards with a straight edge gives the slope of the skewback. To mark the skewback on the other side, the template is simply turned around and the procedure is repeated.

  - Note that corner B must always point downwards during the marking.

NOTES:

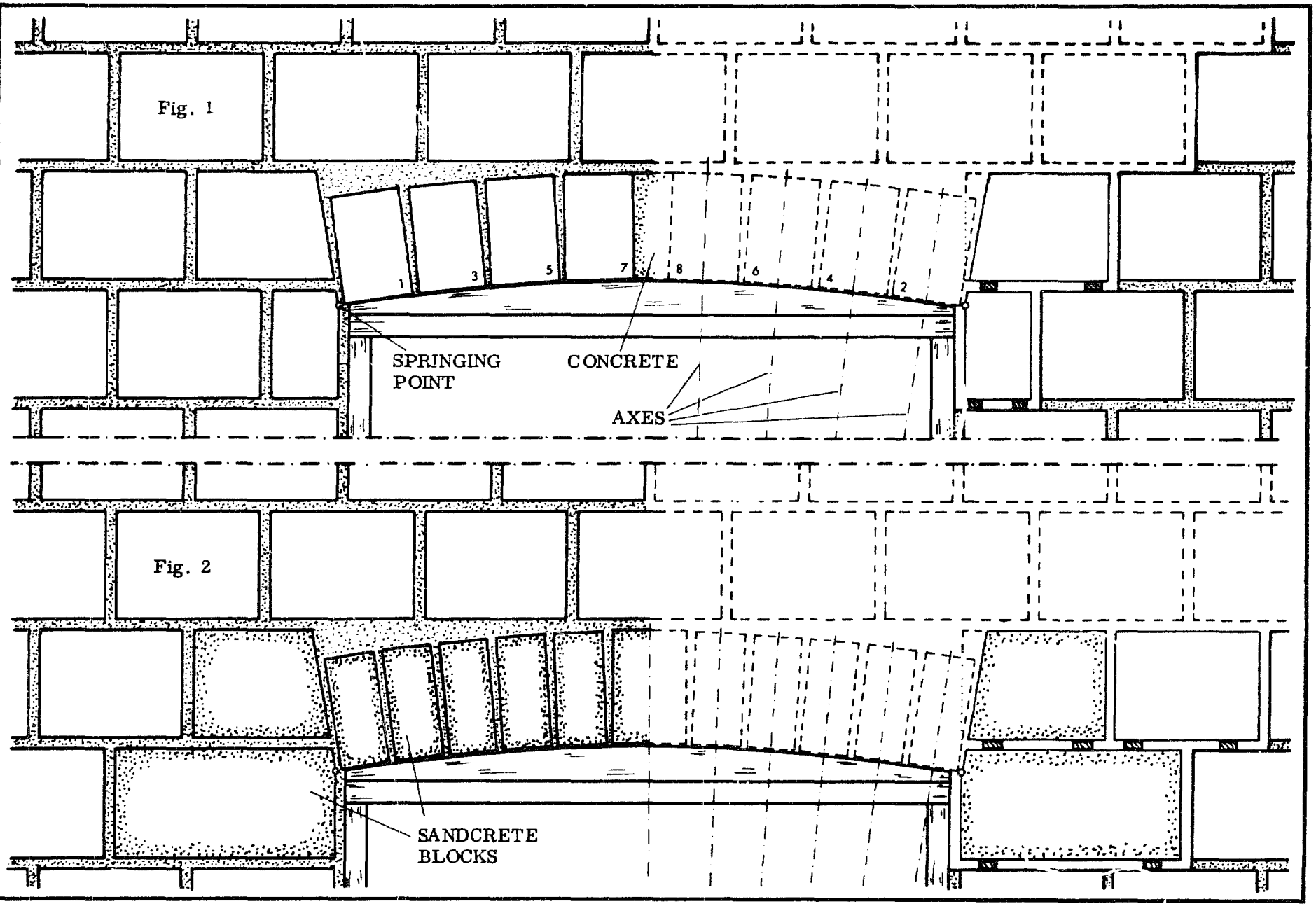
Fig. 1
1
3
5
7
8
6
4
2
SPRINGING POINT
CONCRETE
AXES
Fig. 2
SANDCRETE BLOCKS

ARCHES.

LAYING THE ARCHBLOCKS

The four blocks which have the skewbacks are marked and cut before they are laid in mortar. They are set temporarily in place on wooden battens which have the same thickness as the bed joint (Figs. 1 & 2, right sides). Mark the slope of the skewback with the template, and remove the blocks to cut them to shape. Then they can be laid in mortar and the arch can be continued.

Fig. 1 shows a segmental arch built with landcrete blocks. For this purpose, 1/2 blocks have to be cut, or preferably made specially in the Tek block press. This is easily done by putting a 1 cm thick board (for the 1 cm joint) edgewise in the middle of the mould box. The arch is built up by laying the blocks by turns on alternate sides, as indicated in Fig. 1 by the numbers.

The axis of each block should point towards the centre of the arch, with the result that ideally only the middle part of each block should rest on the turning piece, and the lower corners of the blocks do not contact the turning piece; there should be small wedge-shaped gaps. This is because the block faces are straight but the top edge of the turning piece is rounded.

The wedge-shaped joints between the archblocks need special attention. They must be properly filled with a rather wet mortar. If there is a gap left in the centre of the arch it is closed with concrete, which functions as a keystone (Fig. 1).

Segmental arches over a span exceeding approximately 120 cm should be constructed with sandcrete blocks. The skewback blocks which abut the springers should also be sandcrete, so as to better distribute the pressure (Fig. 2).

To meet this requirement specially made blocks are needed. The skewback blocks must be 1 cm smaller in height than normal sandcrete blocks, so that they fit in with the landcrete courses. This is achieved by inserting a 1 cm thick piece of wood into the sandcrete block machine.

The archstones consist of 1/4 blocks which can also be made in the machine by inserting three 2 cm thick boards at a distance of 10 cm apart. The keystone is formed with a normal block of 15 cm thickness, cut to match the thickness of the wall.

If the centring is not combined with the frame, it is slightly lowered on completion of the arch, and removed after four days.

- NOTE: Try to set the centring so that the crown of the arch will be level with the top of the upper abutment course (Figs. 1 & 2) and not somewhere in the middle. The distance between the springing line and crown can be calculated as follows: 0,042 x span, plus height of archblocks.

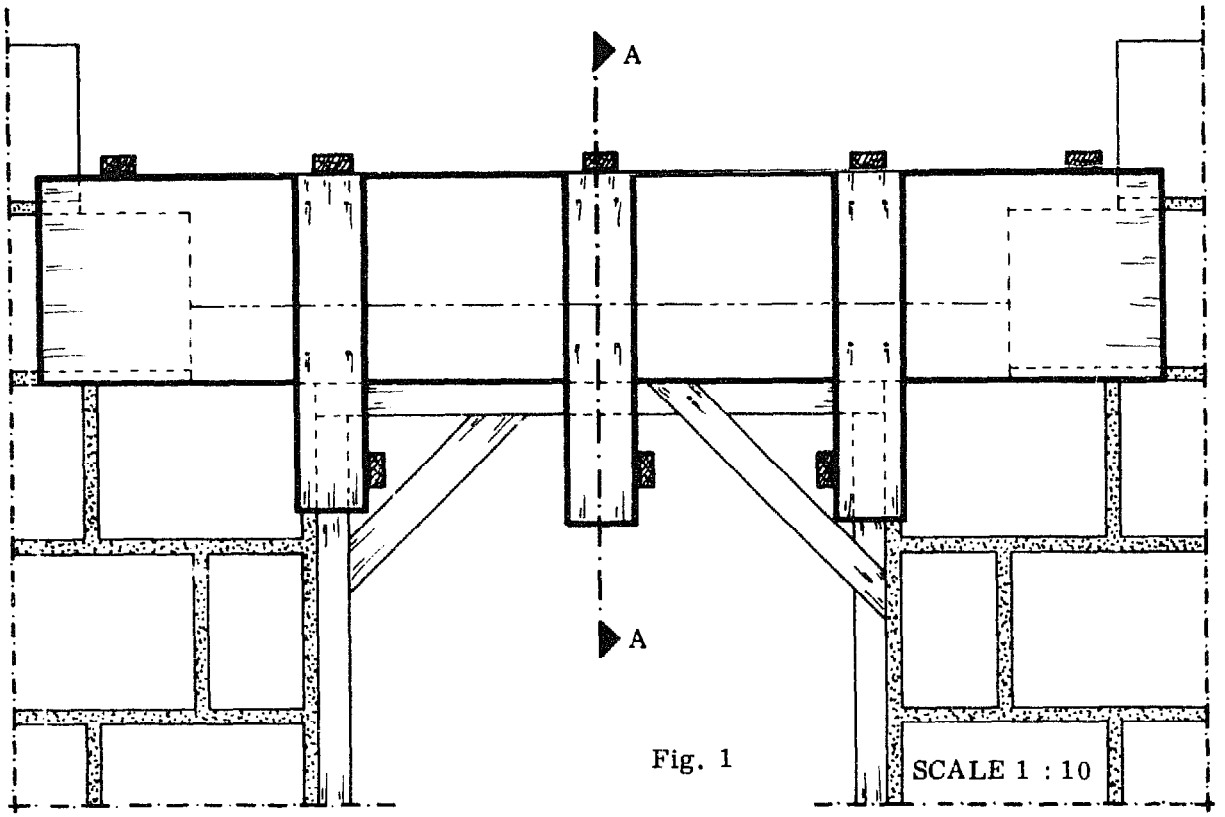

Fig. 1

SCALE 1 : 10

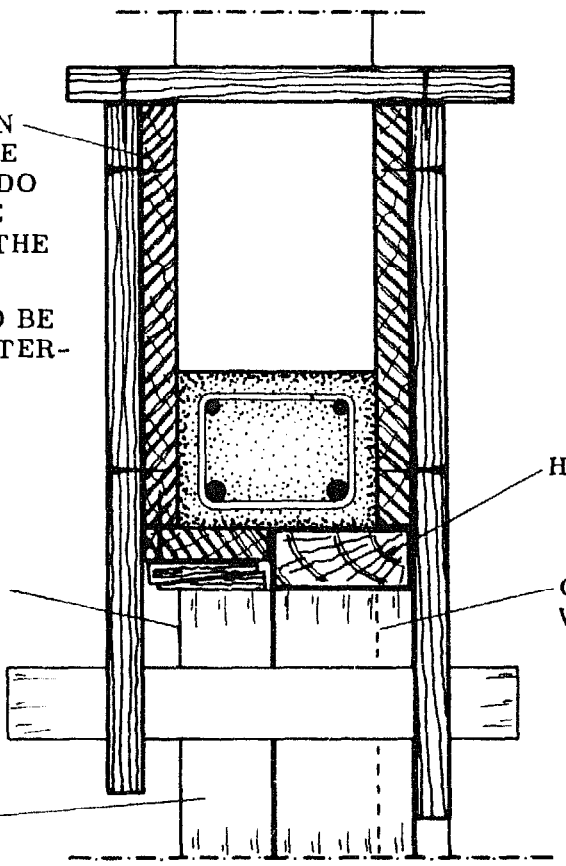

Fig. 2

CROSS SECTION A-A
SCALE 1 : 5

N P V C	
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REINFORCED CONCRETE LINTELS.

REINFORCED CONCRETE LINTELS

FORMWORK

The formwork for cast-in-situ lintels consists of two main parts: the shuttering and the strutting. Precast lintels need only shuttering because they are cast on the ground.

- CONSTRUCTION: The construction of the formwork is shown in Fig. 1, page 167 of the Basic Knowledge book. This illustrates a situation where the frame will be set later or where there is an opening without a frame.

  Since in most cases the frames are set already, the formwork does not require special strutting (Fig. 1). The head of the frame then acts as part of the soffit of the shuttering. The side boards must be fixed so that the vertical sides of the concrete lintel will be flush to the surface of the blockwork (Fig. 2).

- PREPARATION: If the lintel will not be plastered over later, the inside of the shuttering boards which are in contact with the concrete should be planed until they are smooth. This makes the stripping easier and also gives the concrete surface a nicer appearance. The inside of the shuttering may be treated with a special formwork lubricant, if this is available. Old engine oil can serve the same purpose; it should be applied lightly.

  In case the lintel will be plastered later, it is better to leave the contact faces of the shuttering rough-sawn. Instead of oiling, wet the shuttering boards thoroughly with water, so that they don't absorb too much moisture from the freshly cast concrete.

  Before casting the concrete make sure that the inside of the shuttering is clean; all joints, slits and gaps closed; and that the clear cover (the thickness of the concrete covering the reinforcement iron) is the correct thickness everywhere.

NOTES:

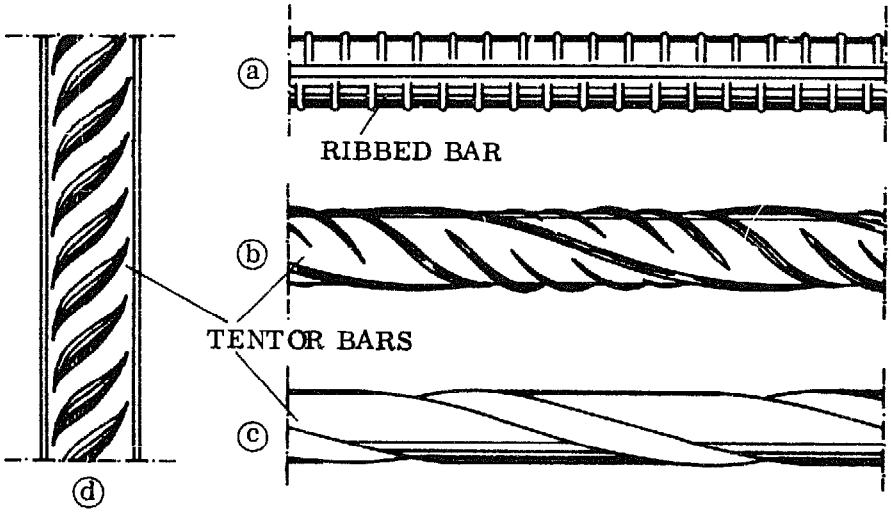

Fig. 1

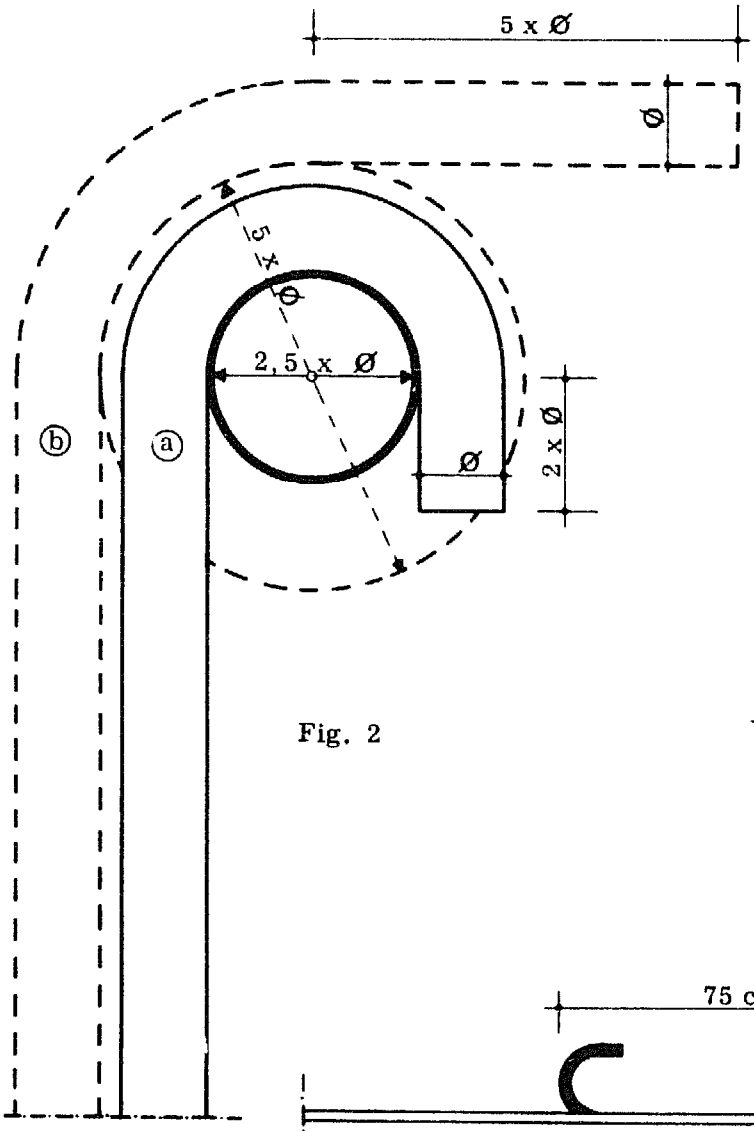

Fig. 2

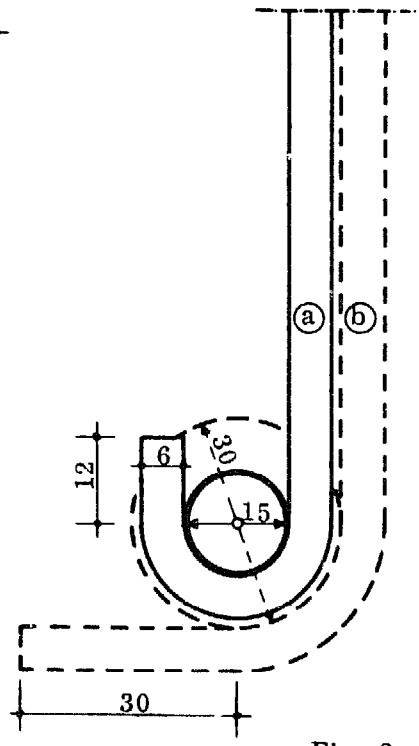

Fig. 3

Fig. 4

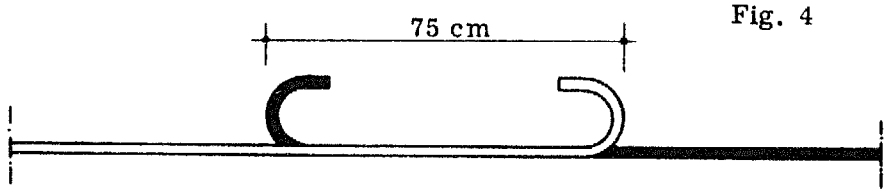

N P V C	
146	CON.

REINFORCED CONCRETE LINTELS.

REINFORCEMENT

The reinforcement for a lintel consists of a combination of different iron rods assembled to form a so-called "reinforcement cage" (see Basic Knowledge book, page 166).

In Rural Building the most commonly used reinforcement iron is round and has a smooth surface. It is available in rods with diameters ranging from 6 mm to 28 mm; but the most common sizes the Rural Builder uses are 6 mm (1/4") rods and 12 mm (1/2") rods.

If ribbed bars or tentor bars are available, these are preferred because the concrete grips better to a rough surface. Figs. 1a, b, c, and d show how the surfaces of some reinforcement bars look. Also see page 171 of the Reference Book.

- BENDING REINFORCEMENT BARS: According to how they will be used, sometimes iron rods must be bent or shaped to a hook form at the ends so that they can be well anchored. This must be done according to the following rules:
  - All circular bars with smooth surfaces must have U-shaped end hooks (see Figs. 2a & 3a). For ribbed bars and tentor bars L-shaped hooks are sufficient (Figs. 2b & 3b).
  - The minimum length for the straight end part of the hooks is: 2 times the rod diameter for circular bars; and 5 times the rod diameter for ribbed bars and tentor bars (Figs. 2 & 3).
  - The smallest permissible bending diameter can be calculated according to the figures in the table below.

DIAMETER OF ROD	CIRCULAR BARS	RIBBED BARS & TENTOR BARS
6 mm up to 20 mm	2,5 x rod diameter	5 x rod diameter
22 mm up to 28 mm	5 x rod diameter	7 x rod diameter
more than 28 mm	----------	10 x rod diameter

The smallest permissible bending diameter for the 6 mm circular bar in Fig. 3a will be 15 mm; or 2,5 x 6 mm. For the 6 mm ribbed bar in Fig. 3b, the bending diameter will be at least 30 mm, or 5 x 6 mm.

- NOTE: As a rule, main bars should never be extended. If this is necessary, the shortest overlap for bars under tension is 75 cm, and the ends of the bars must have U-shaped hooks (Fig. 4).

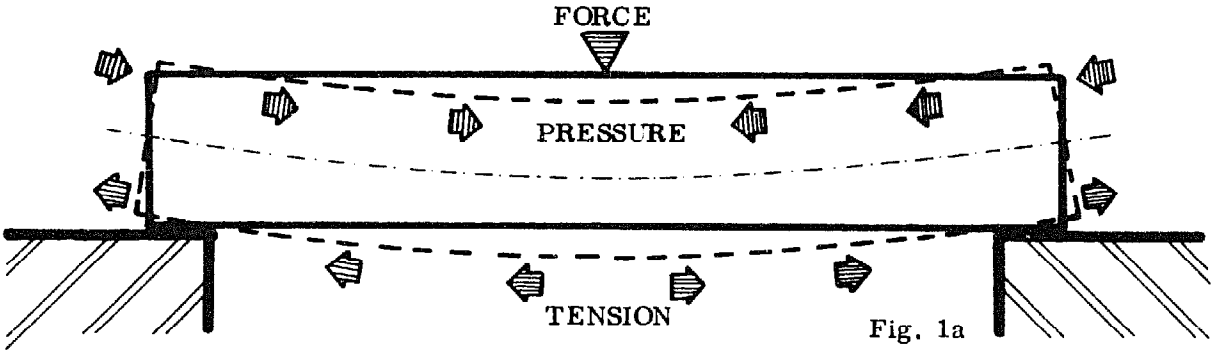

Fig. 1a

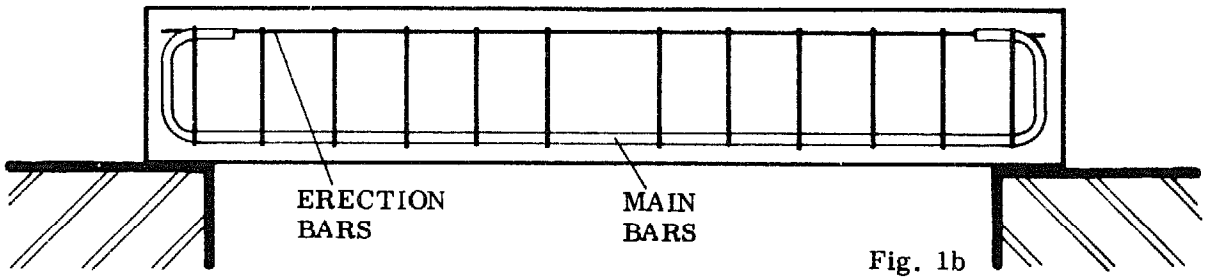

Fig. 1b

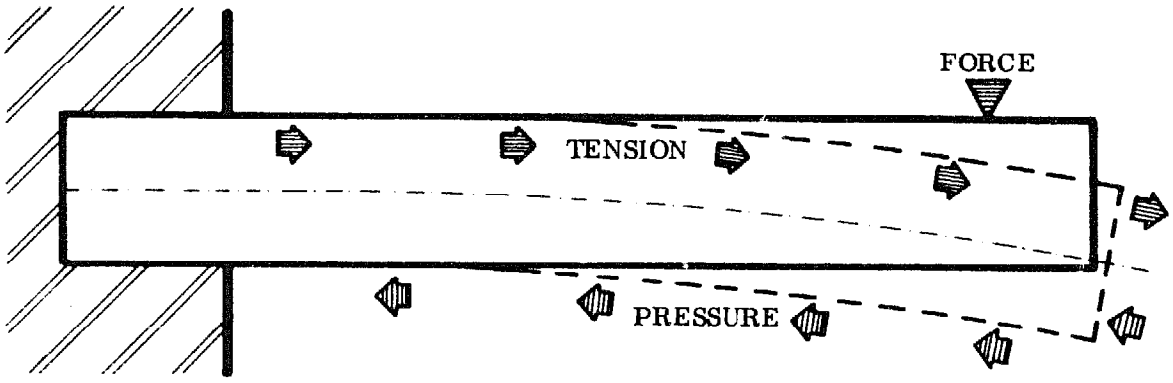

Fig. 2a

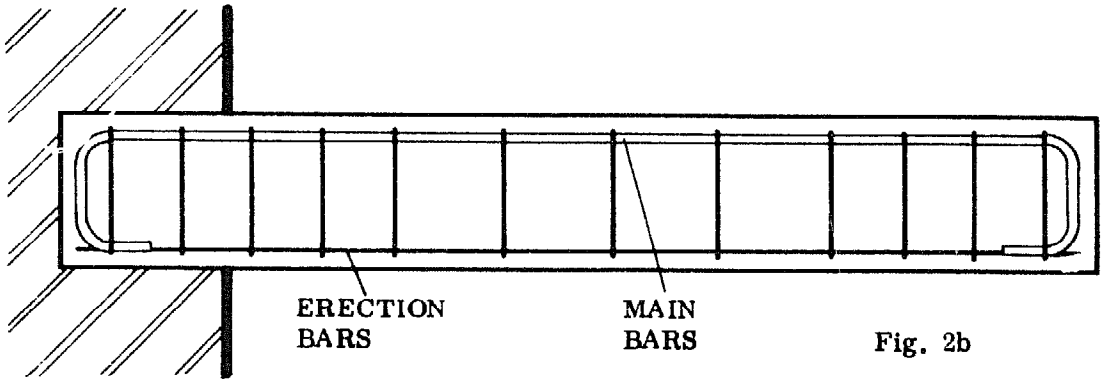

Fig. 2b

N P V C	
148	CON.

REINFORCED CONCRETE LINTELS.

REINFORCEMENT SYSTEMS

The construction of large reinforced concrete members usually requires complicated calculations to determine the diameters, number, shape and arrangement of the rods. This job should be left to a qualified design engineer.

However small and simple members of the structure such as lintels, columns, short span beams, etc. can be constructed by the Rural Builder according to the sketches, particulars and hints given here.

To place the reinforcement rods correctly, it is essential to understand and be able to predict in which part of the concrete member tensile stress (tension) is likely to occur. This is where the member has to be reinforced by the main bars. Fig. 1a shows the bold outline of a lintel; the dotted line shows how it would tend to bend under pressure. The arrows show how the whole upper part is under pressure, while the lower surface is under tension.

Fig. 1b illustrates how the lintel can be reinforced against this tension. Note that the main bars are on the bottom, in the zone which is under tension; and that the ends of the main bars are anchored on top, within the zone that is under pressure.

Fig. 2 shows another situation, where a beam is supported from one side only. This is called a cantilever beam. The unsupported end will tend to bend as shown. Here the main bars are on top to counteract the tension in the top surface (Fig. 2b).

NOTES:

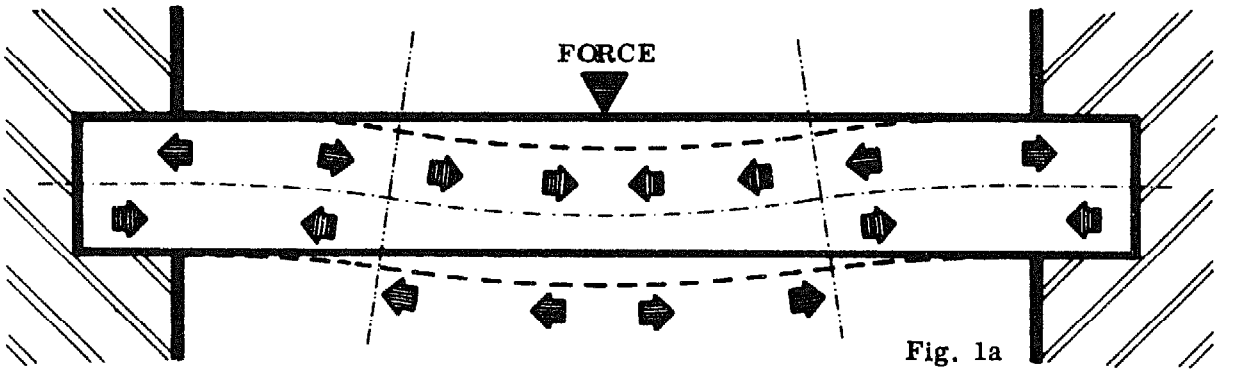

Fig. 1a

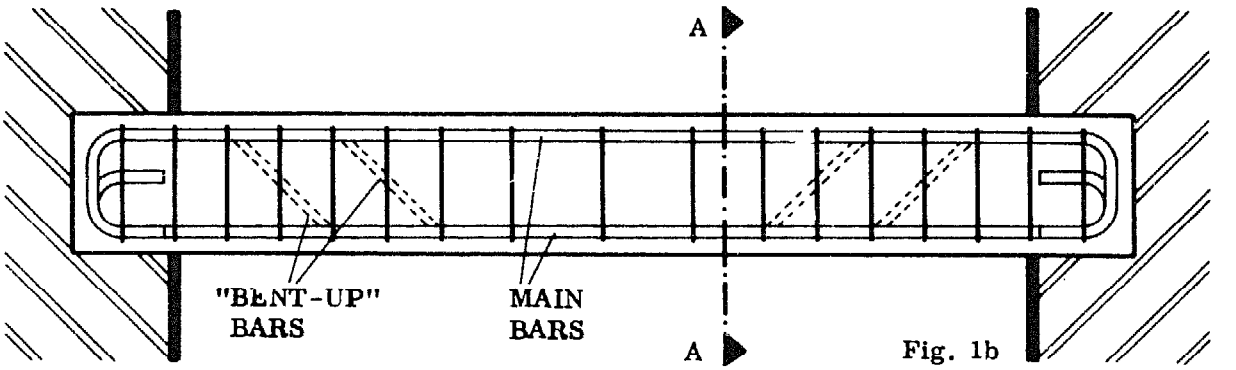

Fig. 1b

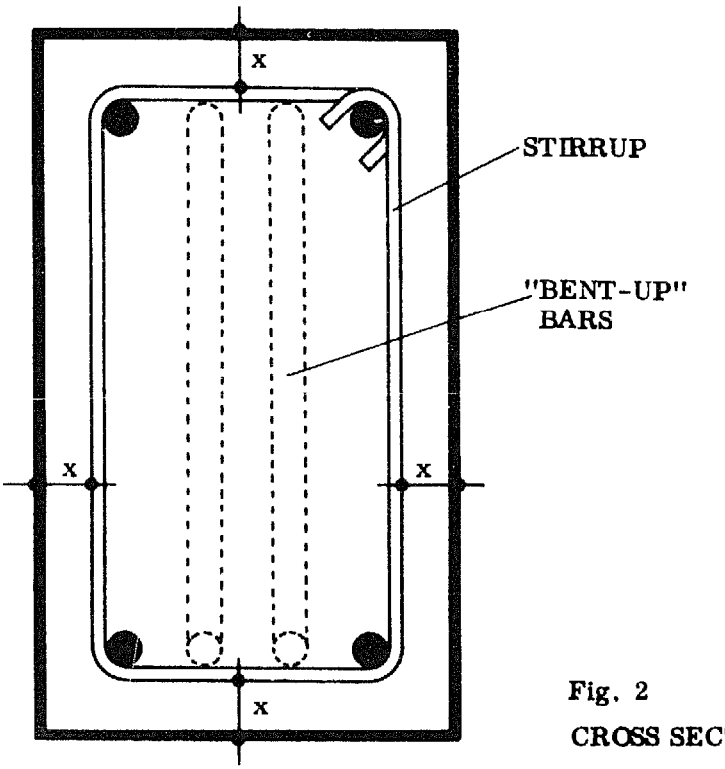

x = CLEAR COVER

Fig. 2

CROSS SECTION A-A

N P V C	
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REINFORCED CONCRETE LINTELS.

The longer reinforced beam or lintel shown here in Figs. 1a and 1b is reinforced with main bars on the top and bottom.

The cross section in Fig. 2 shows how the clear cover is measured from the outside of the stirrups to the outside face of the concrete. In other words, the clear cover or concrete cover is the distance between the concrete surface and the nearest reinforcement bar, regardless of the function of the bar.

The distance between the stirrups is never more than 20 cm. For safety, the Rural Builder is advised to put the stirrups no more than 15 cm apart. The stirrups closer to the supporting walls (50 cm away and closer) should be no more than 10 cm apart (see the illustrations here and on the next page).

So-called "bent up" bars are sometimes used as part of the reinforcement system (Figs. 1 & 2) but these are not used in Rural Building because of the difficult calculations required to place them correctly; also they are not necessary for the small structural members which are required in Rural Building.

NOTES:

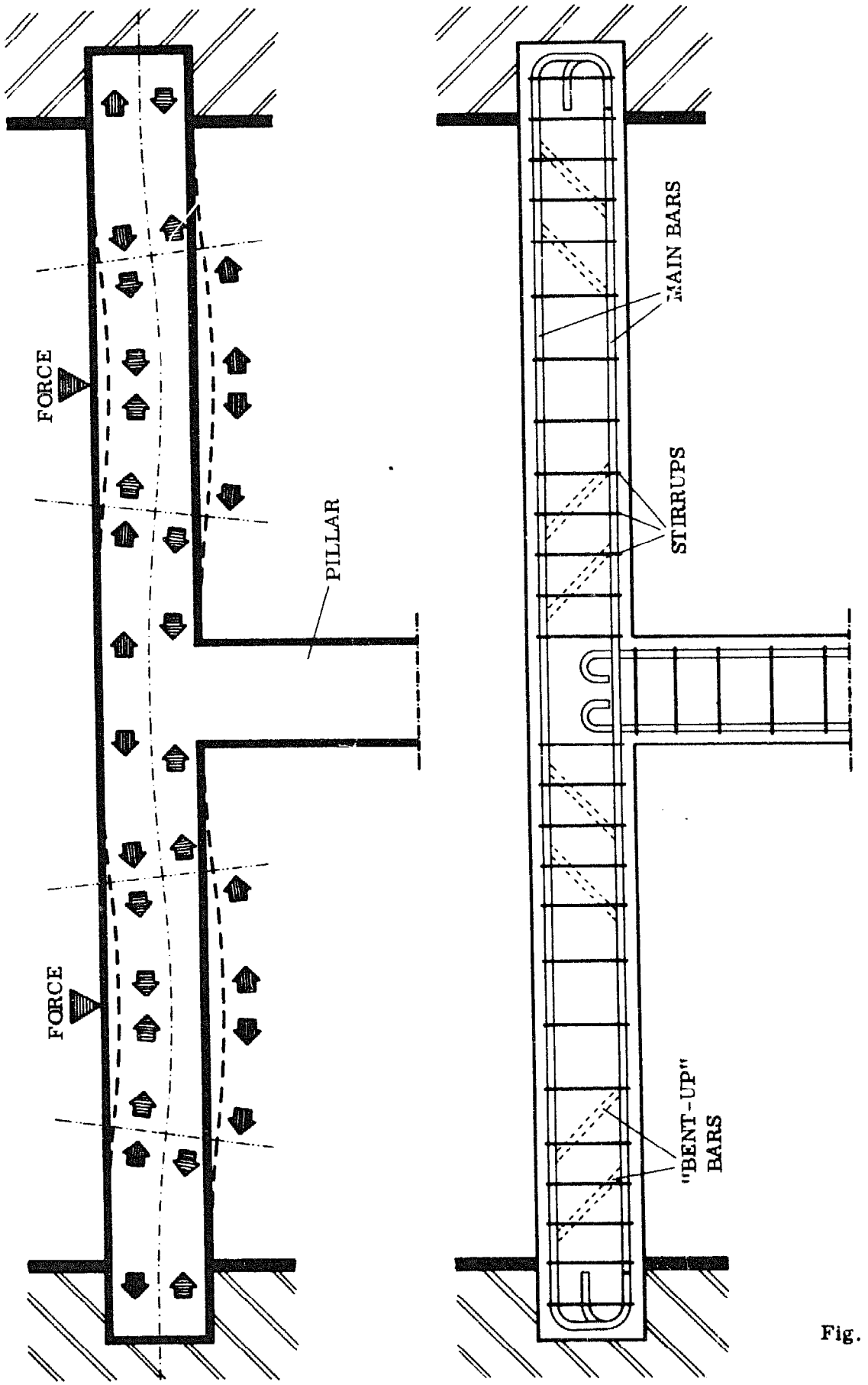

Fig. 1

N P V C	
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REINFORCED CONCRETE LINTELS.

On the left is a drawing of a reinforcement system for a continuous beam; this might occur for example in an eave beam supported by a reinforced pillar (Fig. 1).

CORROSION IN REINFORCED CONCRETE

It may seem strange, but the weakest part of a reinforced concrete structure is the hard iron, because it is easily broken down if it is not protected well. The structure remains stable only as long as the iron is protected against corrosion.

The main problem with reinforced concrete is the development of very small cracks in the concrete, which means that the iron is exposed to air and becomes rusty. On the concrete surface below the cracks, reddish brown rust stains appear. Once these are visible it is usually too late to save the member.

Unless immediate protective measures are taken, the rust develops more and pressure builds up between the iron and concrete, causing the concrete cover to break open; this speeds up the rusting process and eventually the reinforcement bars become too weak to carry loads or to withstand other forces. The system then collapses.

- PREVENTION OF CORROSION: Here we must include a strong warning against over-reliance on concrete strength. Not only laymen, but also many construction experts believe "the more cement, the harder and the better the concrete", and they tend to improve the mix proportions by using greater amounts of cement. This is wrong, because very hard concrete is not only expensive but it is also not necessarily the best protection against rust. Therefore, the Rural Builder is advised to follow the correct mix proportions.

  If possible use high quality steel for the reinforcement as this does not rust as easily as common circular bars.

  The surface of the concrete should be protected against the weather by the application of a waterproof cement paint (see Reference Book, page 201). However, such a paint coat is wasted if rust stains are already present. The paint does not seal the cracks and only makes the stains disappear for a short time, if at all.

- NOTE: Never apply paint on concrete surfaces that have not set hard yet. Possible shrinkage of the concrete during the hardening process would cause tiny cracks in the paint coat, making the paint useless as protection against the penetration of water and air.

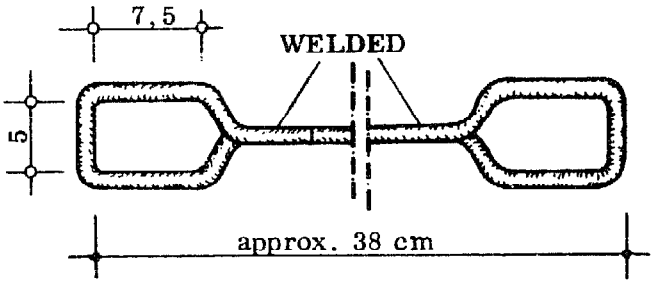

Fig. 1

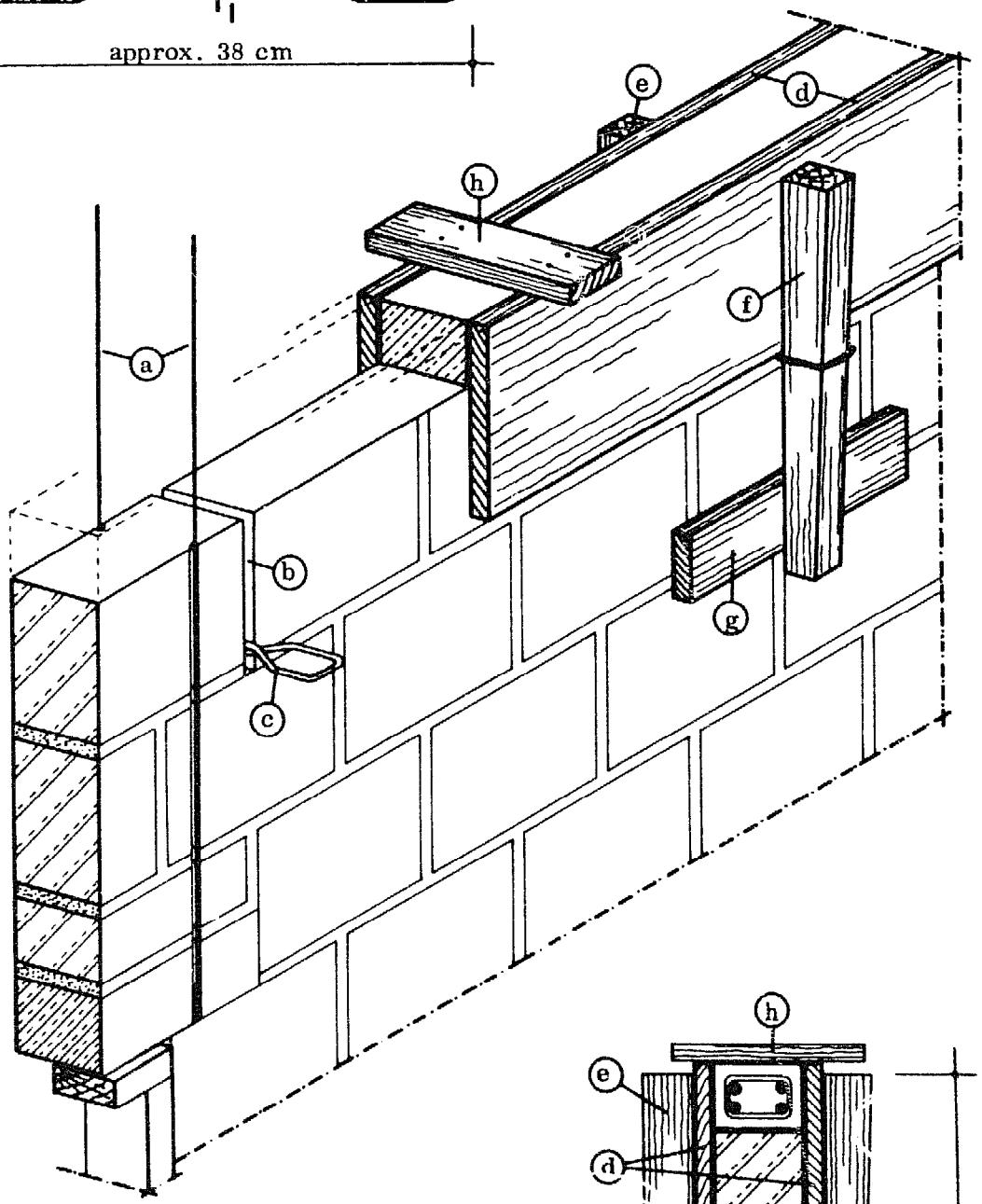

Fig. 2

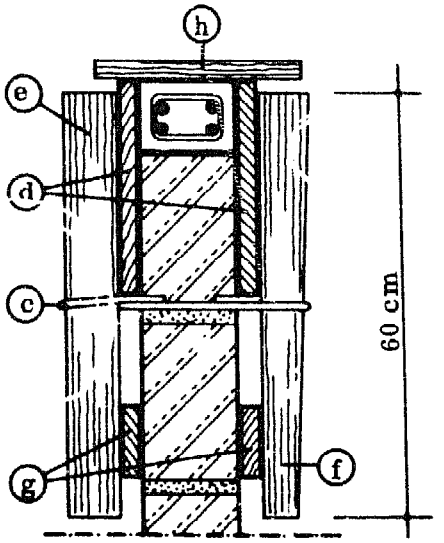

Fig. 3

N P V C		WALLING ABOVE FRAMES & FORMWORK SYSTEM FOR RING BEAM.
154	CON.	

WALLING ABOVE FRAMES

The last part of the walls above the frames should consist of at least three courses of blocks, so that the roof construction can be well anchored. Experience has shown that anchoring the trusses in the ring beam alone is not sufficient for them to withstand strong wind forces. Therefore, the anchorage irons are placed in the first bed joint just above the frames (see Anchorage, page 197).

If the exact positions of the trusses are not known yet, the irons can be set later, in the finished wall. This is done by passing the iron through a hole chiselled in the bed joint (Fig. 2 a). It is generally better and easier though to plan ahead and place the irons during the wall construction. The irons are set in grooves so that they will be flush to the wall surface and will be covered and protected later by the plaster or render.

FORMWORK SYSTEM FOR RING BEAM

If a reinforced concrete ring beam will be made, every third cross joint in the last course is left open (Fig. 2, b) so that formwork clasps can be inserted.

These special clasps have been developed and manufactured at N P V C in order to save strutting materials and to ease the construction of the formwork for a ring beam. Formerly long standards and braces in great number were needed to construct the formwork. With the clasp however, only a few short boards are necessary for the bracing. The formwork clasps are easy to handle and have passed all tests at N P V C. They are made from a piece of iron rod bent as shown in Fig. 1. and welded to hold the loop ends closed.

Fig. 2 shows the formwork system, and Fig. 3 shows the cross section. When the clasp is inserted in the open cross joint (Fig. 2, c) the remaining open space must be closed with paper (empty cement bags) to make it possible to remove the clasp later. The side boards (d) rest on the clasps and are pressed against the wall by straight boards (e) on one side, and wedge-shaped boards (f) on the other side. Short pieces of board below the side boards (g) act as distance pieces to keep the shuttering boards plumb. Cleats or spreaders (h) may also be used to maintain the correct width of the beam. There are no nails used, except for fixing the cleats, which reduces the damage to the boards.

The Rural Builder is advised to supply himself with at least four clasps and to carry them along with his set of tools.

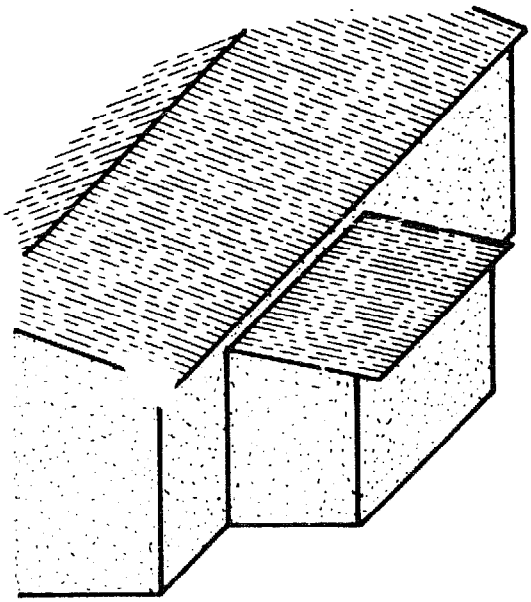

Fig. 1

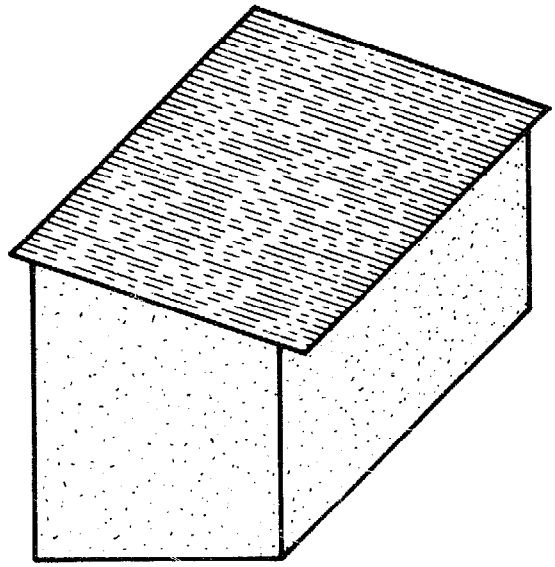

Fig. 2

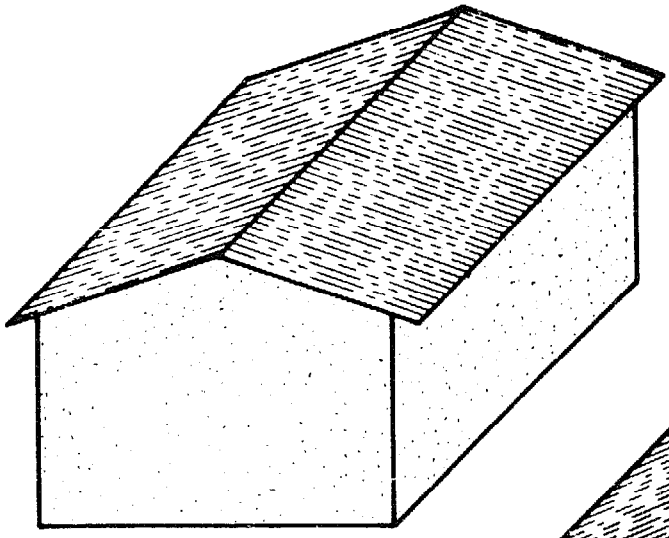

Fig. 3

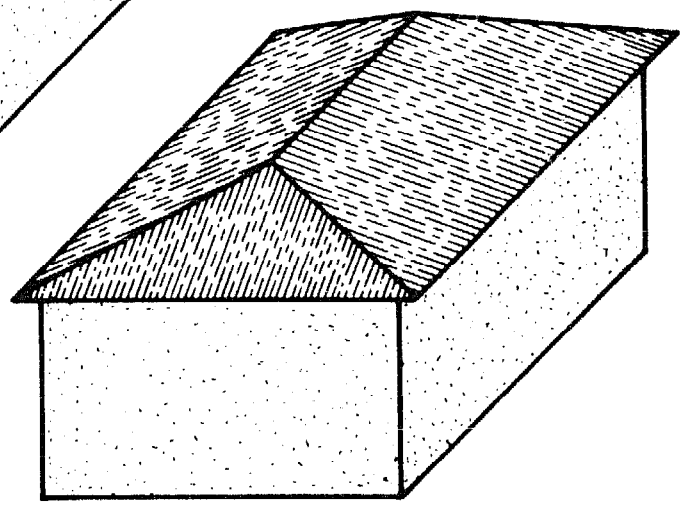

Fig. 4

N P V C	
156	CON.

ROOFS IN GENERAL.

ROOFS IN GENERAL

The roof is a very important part of the building structure. It performs several essential functions:

- It gives shelter to people.
- It provides shade.
- It isolates the building from cold and heat.
- It keeps out dust and dirt.
- It protects the interior of the building.
- It sheds rainwater.

ROOF TYPES

There are many different types of roofs. In Rural Building we deal only with the following four types:

- The lean-to roof (Fig. 1)
- The pent roof (Fig. 2)
- The gable roof (Fig. 3)
- The hipped roof (Fig. 4).

These roofs will be described in detail in the following sections of the book. In the next few sections we will describe some factors which are important in the construction of all roofs. These must be understood well before we can go on to describe the construction details of the particular roof types.

NOTES:

SIZE OF THE ROOF

The cost of roofing sheets will be a significant part of the cost of the whole building. Therefore it is the size of the roofing sheets which will determine the size, and especially the width, of the whole building.

For this reason, we make an outline design of the roof before we determine the other measurements of the building. We cannot design the building first and later fit a roof on it. The outline design tells us the width that our building should have so that we can fit a roof on it without unnecessary and wasteful cutting and trimming of the sheets (Reference Book, pages 239 & 240).

To make the outline design of the roof, we need to know:

- the pitch of the roof
- the effective length of the sheets
- the distance the roof will project past the outside walls of the building.

ROOF PITCH

The angle of the slope of the roof is called the pitch. Most roof types have a standard pitch. If corrugated sheet materials (Reference Book, pages 230 and 231) are used, the pitch angle should be between 15 and 20 degrees (Fig. 1).

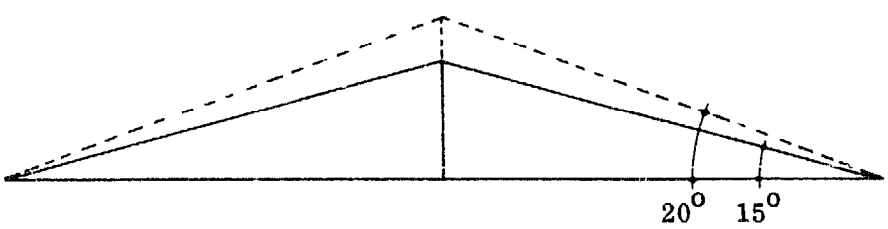

Fig. 1

NOTES:

EFFECTIVE LENGTH OF THE SHEETS

The effective length of roofing sheets is the length of the sheet (x) minus the overlap (y) between the sheets (Fig. 2).

The minimum overlap in the length for corrugated sheeting materials is 15 cm. The most common length for roofing sheets in Ghana is 244 cm.

In order to use the sheet materials as economically as possible, we use either 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, or 3 (and so on) sheets to cover the distance from the highest point of the roof to the lower edge. Thus the effective length will be:

- for 1 sheet - 244 cm
- for $1\frac{1}{2}$ sheets - 244 cm + 122 cm - 15 cm = 351 cm
- for 2 sheets - 244 cm + 244 cm - 15 cm = 473 cm
- for 3 sheets - (244 cm x 3) - (15 cm x 2) = 702 cm

and so on.

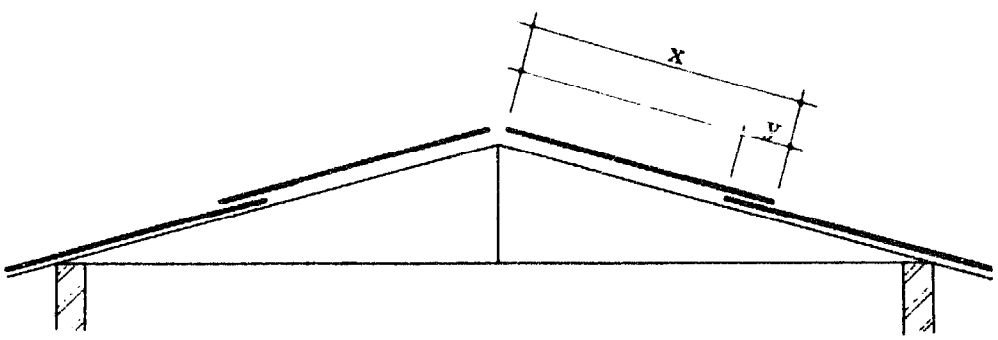

Fig. 2

NOTES:

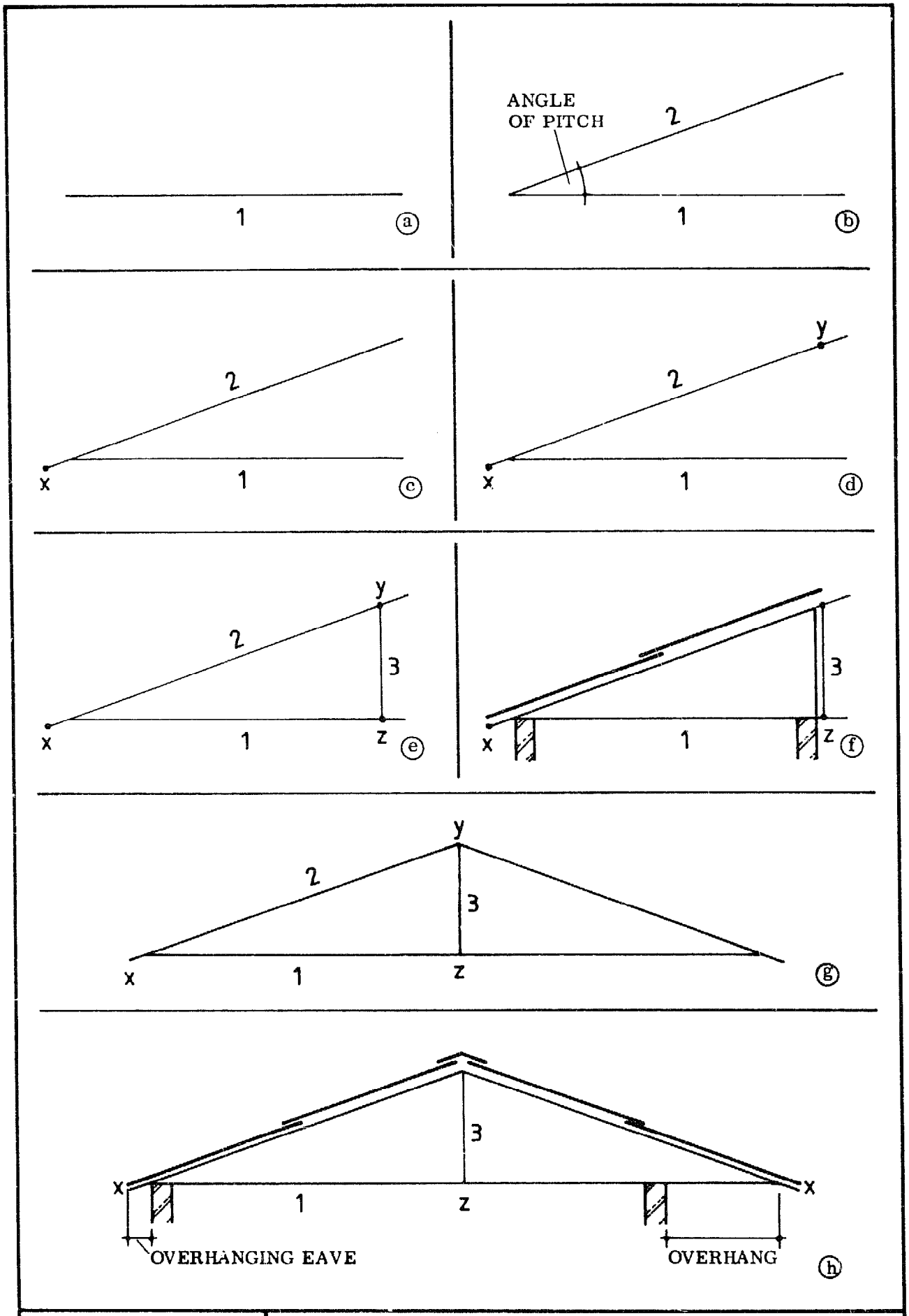

N P V C	
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ROOFS IN GENERAL.

OUTLINE DESIGN

The outline design should be made in as large a scale as possible, since it is used to find some measurements for the future building design.

a. Draw a horizontal line (line 1).

b. Draw line 2. The angle between line 1 and line 2 should be the angle of the pitch of the roof.

c. Extend line 2 to show the projection of the roof beyond the wall of the building. Mark point x at the end of line 2.

d. Measure the effective length of the sheets from point x, remembering to subtract the overlap. Mark point y on line 2.

e. Make a line perpendicular to line 1 and passing through point y. This is line 3. Mark point z on line 1.

f. If a lean-to or pent roof is planned, the length of line 1 up to point z gives the width of the building. Now indicate the supporting walls and the sheets with the overlap. In a lean-to roof, remember that the end of the sheet at the top is enclosed in the wall; and for the pent roof, the sheets project past the wall on the top side.

g. If a gable roof is planned, draw the other half of the roof in the same manner. The extended line 1 will give the width of the building.

h. Indicate the supporting walls, sheets and the overlap.

- TERMS: The point where the sloping lines meet, point y, is called the "ridge".

Line 3 is the "rise" of the roof.

If the horizontal line (line 1) projects beyond the supporting walls, the projecting part is called an "overhang".

If the sloping part projects beyond the wall, the projecting part is called an "overhanging eave".

The lowest part of a sloping roof is called the "eave" (point x).

NOTES:

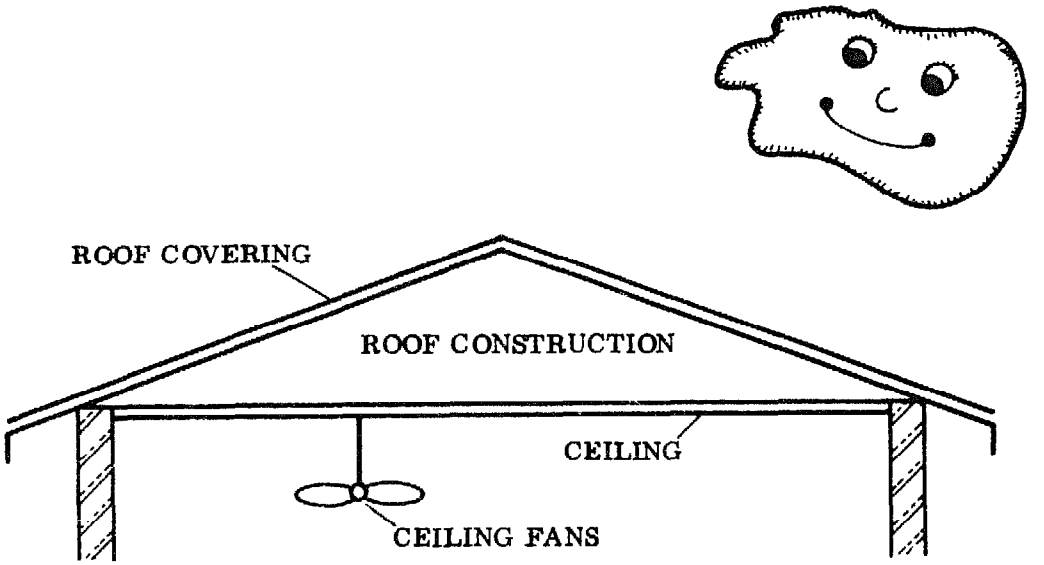

= dead load

Fig. 1

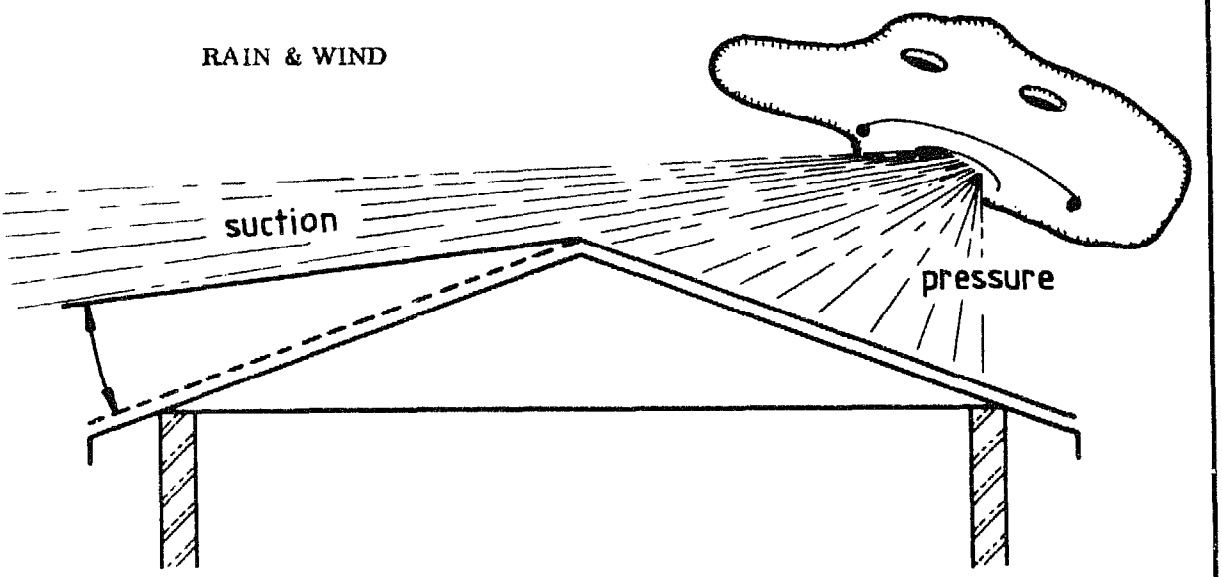

= external load

Fig. 2

N P V C		ROOFS IN GENERAL.
162	CON.	

LOADS

In order to build a good strong roof, it is necessary to take into account certain forces that will affect it. We call these forces "loads".

Some of the loads come from the weight of the roof itself and the ceiling. These are called "dead loads". They consist of: (see Fig. 1)

- the weight of the roof covering
- the weight of the roof construction
- the weight of the ceiling
- the weight of anything attached to the ceiling such as ceiling fans or light fixtures.

Other loads are caused by external (outside) forces such as rain or wind. These are called "external loads". External loads are: (see Fig. 2)

- windloads
- rainloads

All loads, external and dead loads, must be taken into account in the planning and construction of a roof.

The most dangerous load in Ghana is the windload. Strong winds or storms can cause a lot of damage to a roof if it is not well made and securely fixed to the building.

One particular danger is the suction on one side of the roof caused by the wind, which creates pressure on one side and suction on the other side of the roof (Fig. 2). This suction on roofs can be demonstrated by an experiment. Fold a sheet of paper in half and blow over the top edge. The other half of the paper will be lifted up by suction.

- SHAPE OF THE ROOF WITH RESPECT TO WINDLOAD: Roof constructions can be severely damaged by storms. Apart from the precaution of anchoring the roof well, which will be discussed later, there are some ways to shape a roof so that it is less vulnerable to the force of the wind:
  - Consider carefully the pitch of the roof. Roofs with a pitch of less than 10 degrees are much more prone to high suction forces.
  - 15 to 20 degrees is a better roof pitch, because it causes less suction.
  - Consider making a hip roof instead of a gable roof. This will decrease the suction even more.
  - See the Drawing Book, pages 105 and 106, for more suggestions.

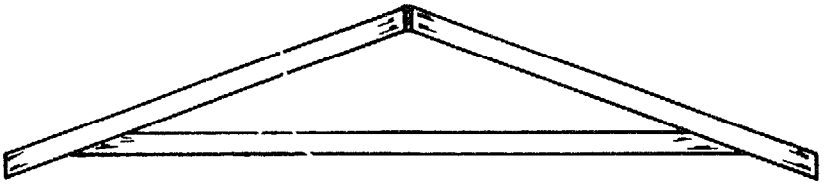

Fig. 1

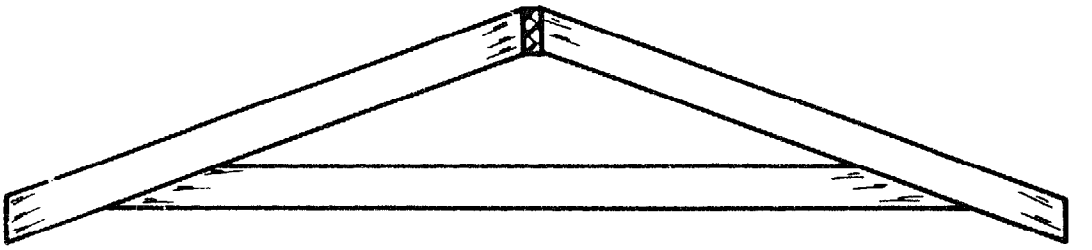

FOR INCREASED SPAN LARGER TIMBERS ARE USED

COMPARE

TRADITIONAL ROOF CONSTRUCTION

MODERN LIGHT-WEIGHT STRUCTURES

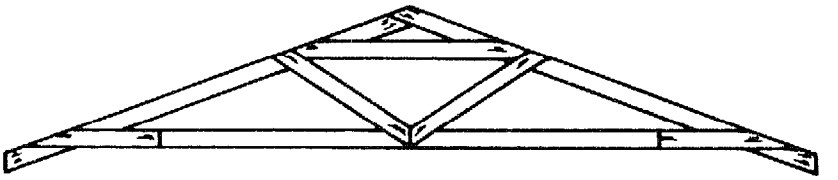

Fig. 2

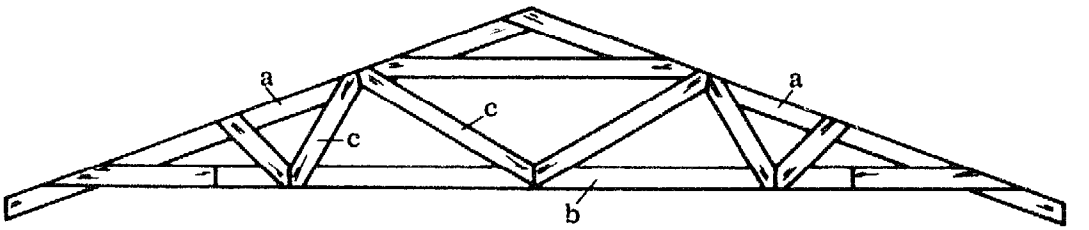

FOR INCREASED SPAN MORE BRACES ARE USED

N P V C		LIGHT-WEIGHT STRUCTURES.
164	CON.	

LIGHT-WEIGHT STRUCTURES

As the span (width) of the building increases, the strength of the roof construction must also be increased. Formerly this was done by using thicker and wider timbers (Fig. 1).

This method resulted in very heavy and expensive roof constructions. Large timbers are normally much more expensive than smaller timbers (compare the cost of 5 x 7,5 cm Odum and 5 x 15 cm Odum).

This kind of roof construction is now uneconomical, as well as difficult because of the complicated joints needed for large timbers.

In modern light-weight structures, the strength of the roof is increased for larger spans by building up brace structures in the shape of triangles (Fig. 2), instead of using larger timbers. This construction uses small timbers, which are cheaper and lighter in weight; therefore we get a light-weight structure.

Light-weight structures are less costly, and result in a smaller dead load on the roof. Another advantage is that we can use simple joints instead of complicated roofing joints.

Since the construction is built up from small members, it is sometimes called a "built-up structure". This is the only type of roof construction we will learn in Rural Building.

- TERMS: The sloping members are called "rafters" (Fig. 2, a).

  The horizontal member is called the "tie beam" (b).

  The members strengthening the construction are called "braces" (c).

NOTES:

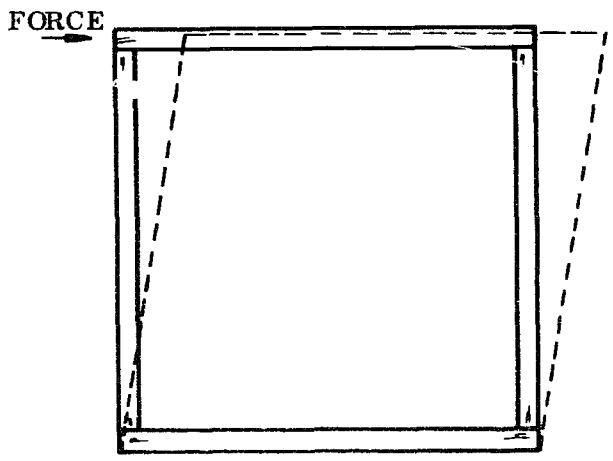

Fig. 1

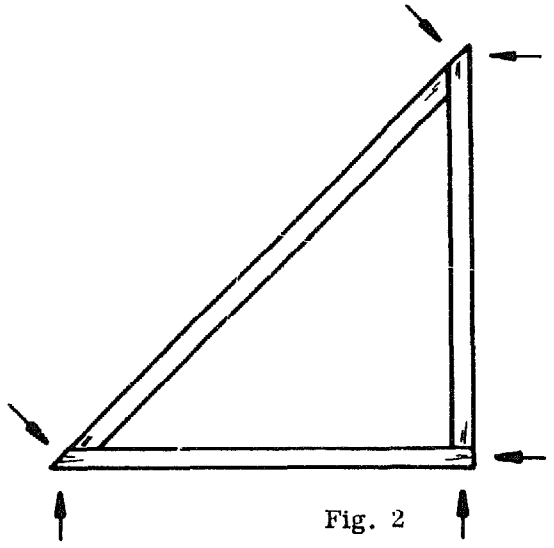

Fig. 2

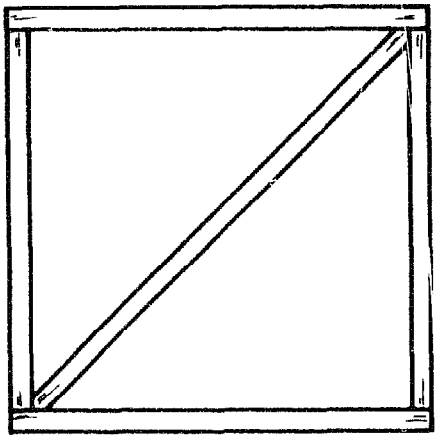

Fig. 3

Fig. 4 PERFECT STRUCTURES

Fig. 5 IMPERFECT STRUCTURES

N P V C		LIGHT-WEIGHT STRUCTURES.
166	CON.	

BASIC SHAPE OF THE ROOF CONSTRUCTION

It is essential that the roof construction remains rigid. To ensure this, we need to find a shape for it which cannot be distorted.

- NOTE: The only construction shape that cannot be distorted is a triangle.

The strength and efficiency of the triangular construction can be proven by experiment:

For example, a square shaped construction (Fig. 1) can easily be distorted. The only resistance to the distortion is in the corner joints. This construction is called a "non-perfect" or imperfect structure.

A triangle shaped structure cannot be distorted (Fig. 2). When force is applied to any part of it, the frame remains rigid. This construction is called a "perfect" structure.

As soon as a diagonal brace is introduced to a square shaped frame (Fig. 3), it becomes rigid. The brace changes the square shape into two triangles, making it a perfect structure.

If the brace were to be installed vertically or horizontally instead of across the diagonal, the structure could still be distorted because it would still be non-triangular, and thus an imperfect structure.

There are many examples of triangular constructions in our surroundings. Look at a bicycle frame, scaffold braces or braces for a door frame, for example.

In Fig. 4 are shown some perfect structures.

In Fig. 5 are shown some imperfect structures.

In roof construction, it is essential to make only perfect structures.

TECHNICAL TERMS

- TIE BEAM: This is the horizontal member of the roof structure which ties together the feet of the rafters (Fig. 1, next page).
- RAFTERS: These are the sloping members which give support to the purlins (Fig. 1, next page).
- BRACES: These are the members which strengthen the construction.
- ROOF TRUSS: This is the structure made up of the rafters, tie beam and braces, which forms the main load carrying unit in some kinds of roofs.

- PURLINS: These members lie across the rafters and support the roofing sheets.
- RIDGE: This is the highest point of a roof construction.
- RISE OF THE TRUSS: This is the vertical height of the truss (Fig. 1, a), measured between the highest point of the truss and the soffit of the tie beam.
- SPAN OF THE TRUSS: This is the clear horizontal distance between the internal faces of the rafters (b) at the point where they meet the soffit of the tie beam.
- SPAN OF THE BUILDING: The building span is the clear horizontal distance between the inside faces of the walls which support the roof (c).
- OVERHANG: When the tie beam projects beyond the supporting wall, the projecting part is called the overhang (d). The overhang is measured square to the wall.
- OVERHANGING EAVE: When the rafters project beyond the supporting wall, the projecting part is called an overhanging eave (e). The width of the overhanging eave is measured square to the wall.
- EAVE: This is the lowest part of the overhang or overhanging eave (point x).

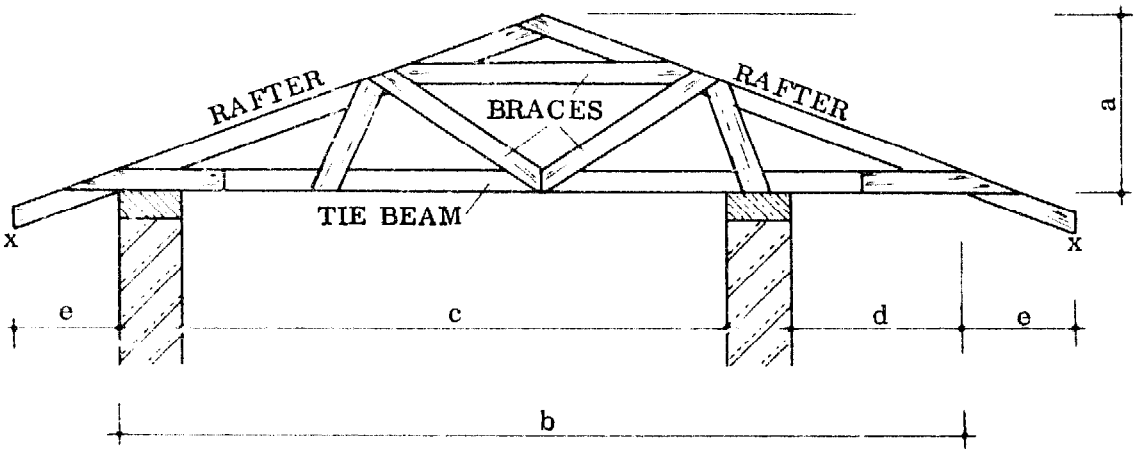

Fig. 1

NOTES:

N P V C		LIGHT-WEIGHT STRUCTURES.
168	CON.	

LENGTHENING JOINTS FOR LIGHT-WEIGHT STRUCTURES

Always select the timbers before starting work on the roof construction. Keep the long straight pieces for the rafters, tie beams, and purlins; and the short pieces for braces.

Sometimes pieces of the right length may not be available. Then it may be necessary to join the members in order to make them longer.

All joints used for lengthening the members of the roof construction will be fish joints with one or two fish plates. These will be discussed in detail in the next section.

Keep in mind that each lengthening joint in the roof construction will weaken the roof. Therefore, try to select the timbers so that you don't need to use many lengthening joints.

WHERE TO PLACE A LENGTHENING JOINT

It is often difficult to judge where to place a lengthening joint. In general, one can say that it should be as close as possible to a support such as a wall or pillar, but we must also keep in mind that the joint is weak, so it cannot be in a place where it is under strain.

For example: A 6 m long tie beam is needed. The only long piece of wood you have is 5,70 m long. If you join that to a 30 cm piece to make 6 m, then the joint will indeed be near a load-carrying wall -- but in relation to the entire structure the joint will be in the wrong place, because most of the weight of the truss is concentrated in that area, where we now have a weak joint.

In this case, a better solution is to join two shorter pieces to get the required length.

Lengthening joints should also not be placed where the braces meet the member.

NOTES:

ONE NAILED FISH PLATE

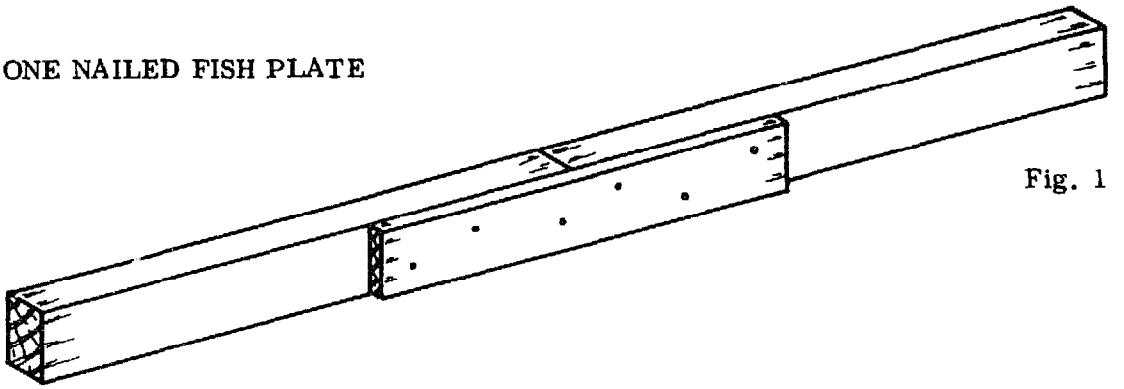

Fig. 1

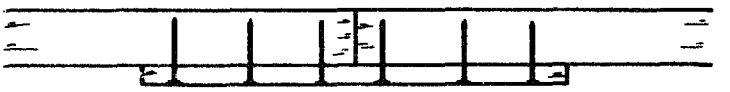

Fig. 2

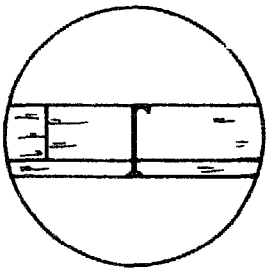

Fig. 4

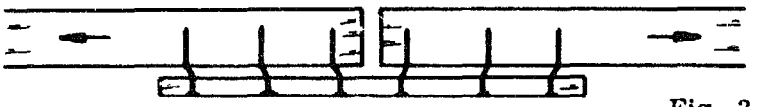

Fig. 3

TWO NAILED FISH PLATES

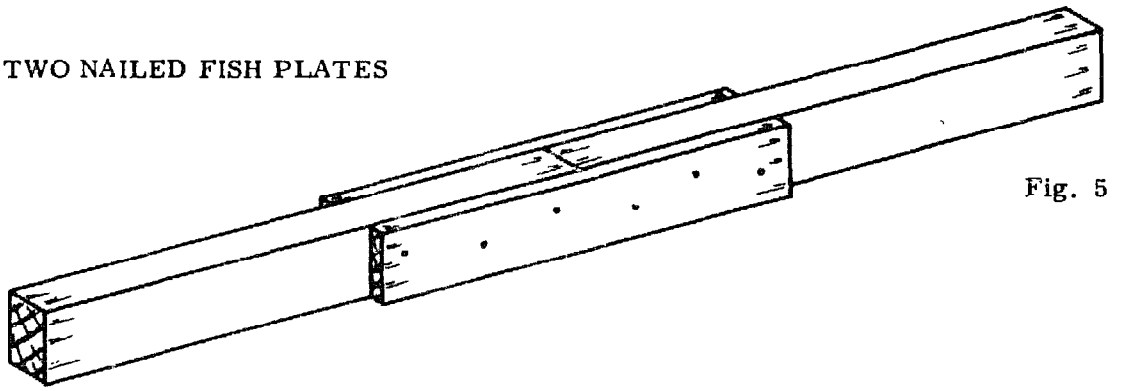

Fig. 5

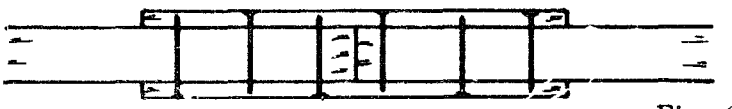

Fig. 6

Fig. 7

N P V C	LENGTHENING JOINTS FOR LIGHT-WEIGHT STRUCTURES.
170 CON.	

FISH JOINTS

We have said that a fish joint will be sufficiently strong for most parts of the roof construction. However, when we assemble a fish joint, we have to follow certain guidelines to end up with a strong joint.

A fish joint will usually be assembled with nails. The strength of the nailed fish joint depends first on the number of nails used; and second on whether one or two fish plates are used. The length of the fish plates should be at least 5 times the width of the joined members.

- SHEAR STRESS IN A JOINT WITH ONE FISH PLATE: If one nailed fish plate (Fig. 1) is used, the nails tend to shear off (break) at the joint line between the members and the fish plate because of the force exerted as the members try to move apart (Fig. 3). The joint is said to be in single shear (Fig. 2).

  In order to prevent the members from moving apart and shearing the nails, it is necessary to clinch the nails, so that they are anchored firmly (Fig. 4).

- SHEAR STRESS IN A JOINT WITH TWO FISH PLATES: When two nailed fish plates are used (Fig. 5) to join the members together, the nails tend to shear at two points. The joint is said to be in double shear (Fig. 6).

  In this joint there is less tendency for the members to pull apart, since there are two fish plates (Fig. 7). The nails must go through both fish plates.

- NOTE: The strength of a joint in double shear (with two fish plates) is approximately twice that of a similiar joint in single shear (with one fish plate).

- NAILING THE FISH JOINT: We have seen that the strength of a nailed fish joint depends on the number of nails used in it and on the number of fish plates. It is important that the nails are fixed correctly, or the joint will be weakened.

  - The nails should be evenly distributed over the entire fish plate.
  - Nails should always be staggered.
  - Nails should always be blunted.
  - If thick nails are used, they have a tendency to split the wood. Often staggering and blunting cannot prevent this splitting. In this case it is necessary to drill holes for the nails. The holes should have a slightly smaller diameter than the nails.

  There are certain rules for spacing the nails on the fish plate. These are:

  - In the direction of the grain, the distance between the nails should be 10 times the thickness of the nail (Fig. 1, next page).

- The distance to the margin of the fish plate should be: in the direction of the grain, 10 times the thickness of the nail; and across the grain it should be 5 times the thickness of the nail (Fig. 1).
- See the Reference Book, page 207, and Basic Knowledge, pages 92 to 94, for more details about nails and nailing.

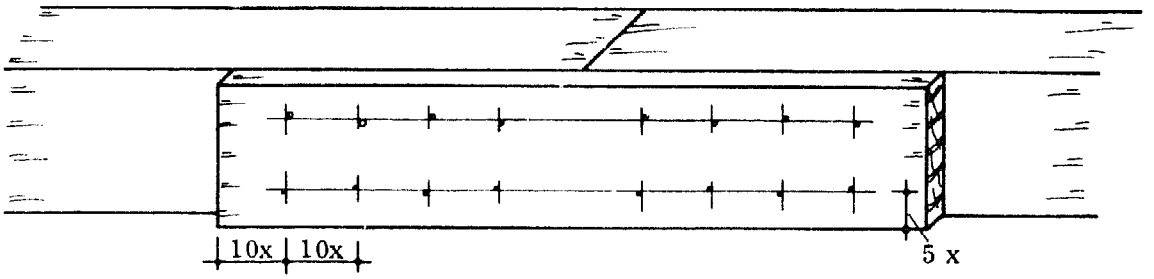

Fig. 1

OTHER LENGTHENING JOINTS

Other joints besides the butt joint with fish plates are sometimes used to lengthen the members of a roof construction. These joints require more work to make and they are not necessarily better than the ordinary fish joint. They are used only if extra strength is required.

These joints are:

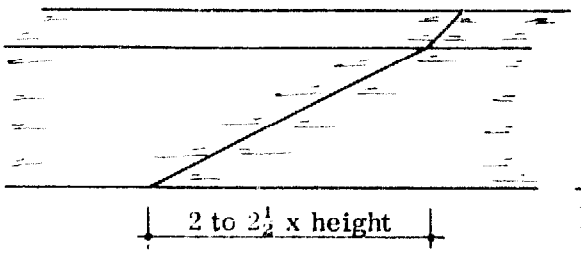

1. COMMON SCARF

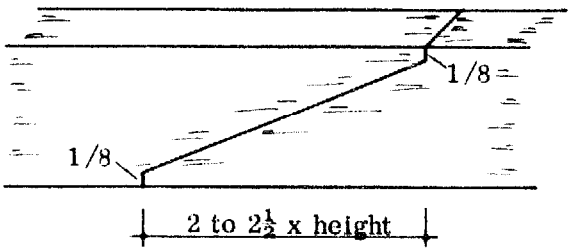

2. STOPPED SCARF

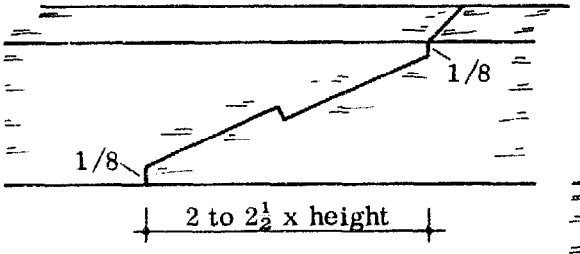

3. STOPPED HOOK SCARF

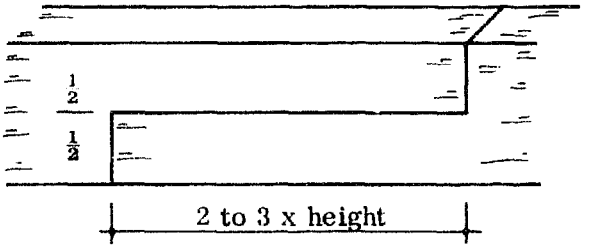

4. HALVING JOINT (if fish plates are used it is a "splice")

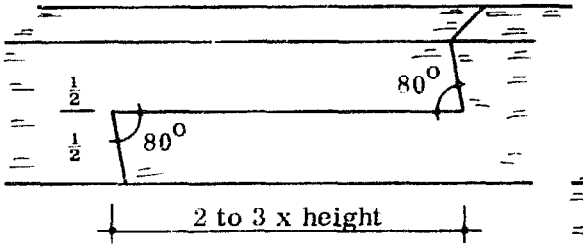

5. HALVING JOINT

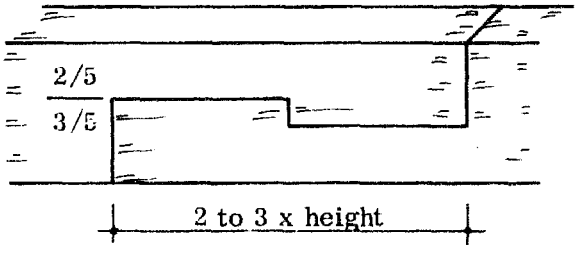

6. HOOK HALVING JOINT

Joints 1 - 6 are normally used for joining rafters, tie beams or purlins in the length. They can be used with one or two fish plates.

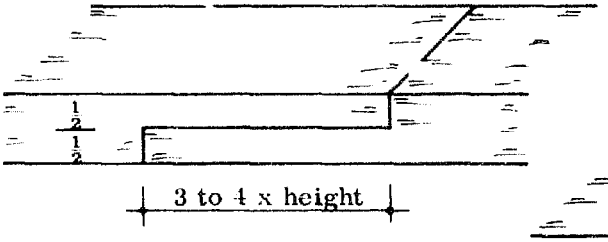

7. HALVING JOINT

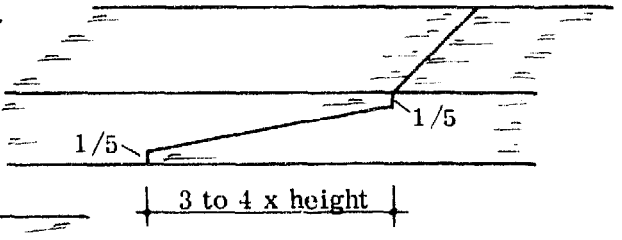

9. STOPPED SCARF

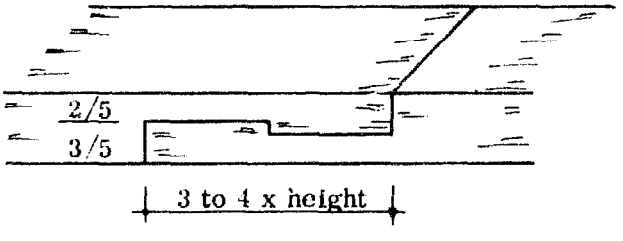

8. HOOK HALVING JOINT

Joints 7 - 9 are used mostly for joining wall plates in the length. The corner joint for a wall plate can also be a halving joint.

LENGTHENING JOINTS FOR LIGHT-WEIGHT STRUCTURES.	N P V C	
	CON.	173

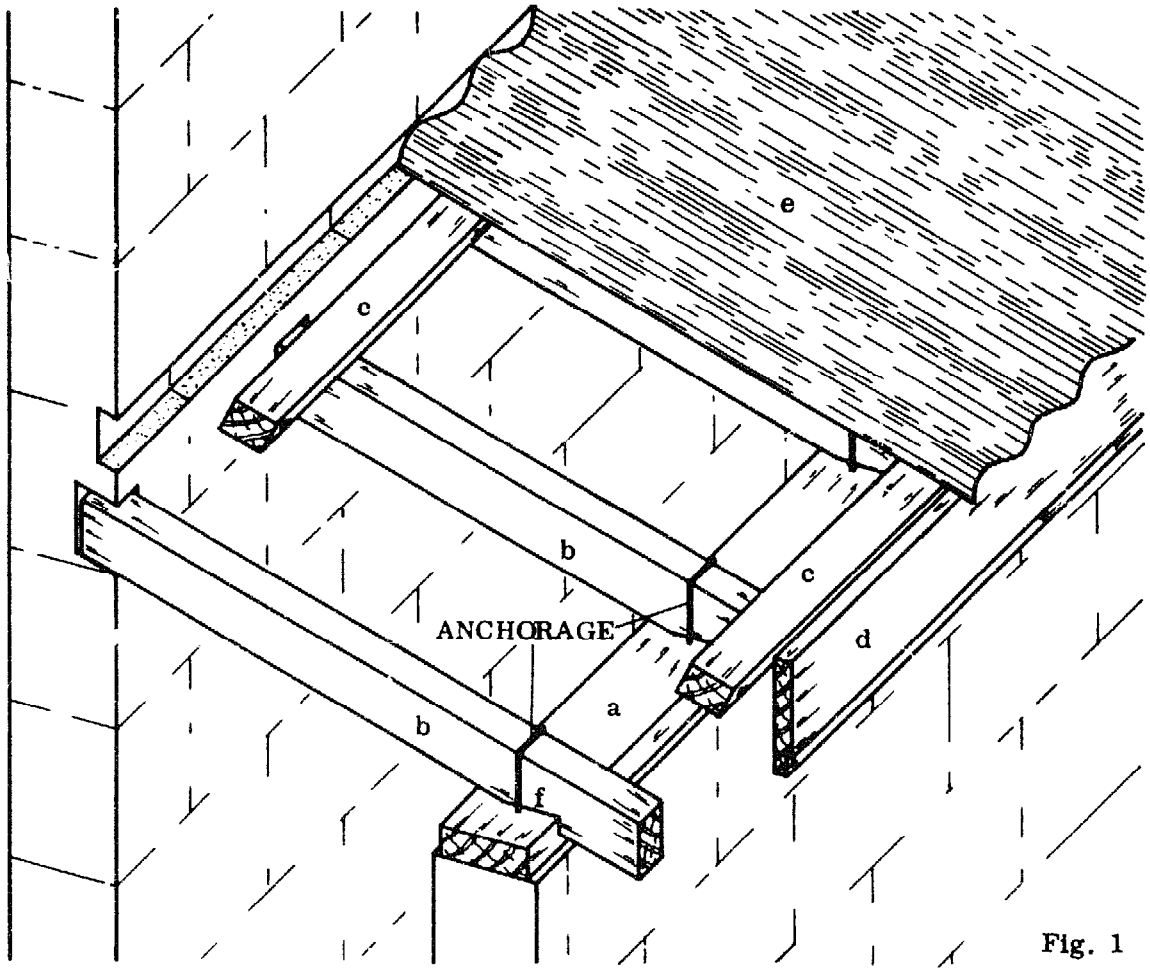

Fig. 1

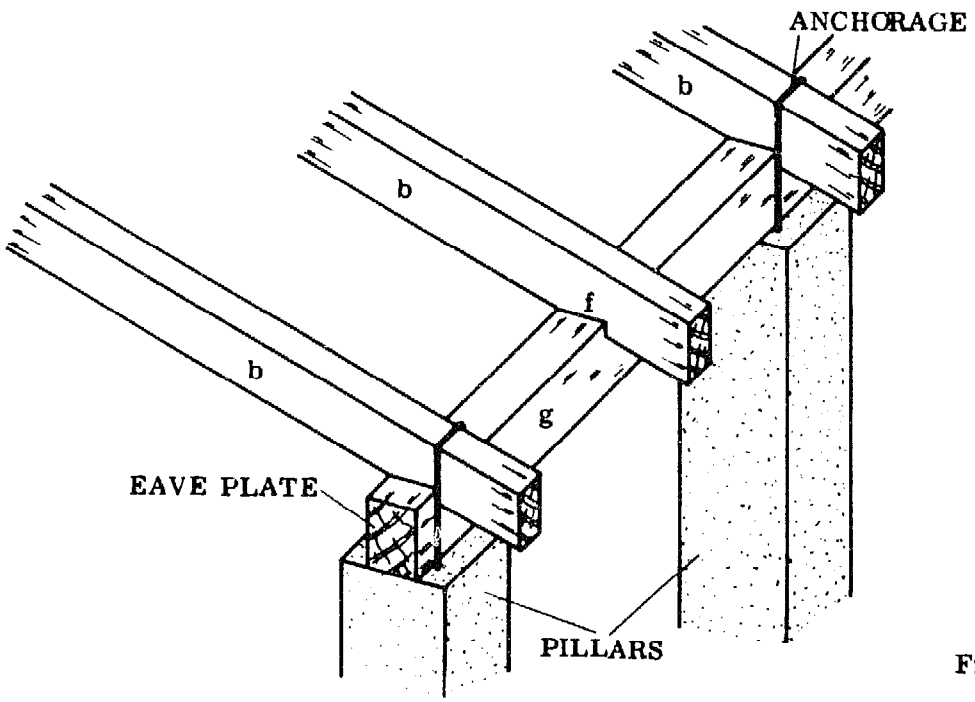

Fig. 2

N P V C	
174	CON.

CONSTRUCTION DETAILS.

CONSTRUCTION DETAILS

LEAN-TO ROOF

A lean-to roof is a sloping roof attached to the wall of another building. It is "leaning" against the building. It is usually used for a small store or similiar building which is attached to an existing building. The main members are: (Fig. 1)

- the wall plate (a) 5 x 10 to 15 cm
- the rafters (b) 5 x 7,5 to 10 cm
- the purlins (c) 5 x 7,5 cm
- the fascia board (d) 2,5 x 20 to 30 cm
- the sheet material (e)

The above measurements can be used as a guide in selecting timbers for this kind of roof.

Below are some rules for the construction.

- A good method for fixing rafters onto the main wall is to chisel holes in the wall into which the rafters can be fitted. The holes should be deep enough to ensure a safe rest for the rafters (Fig. 1).
- The lower part of the rafter should rest on a wall plate (a) or a concrete belt. The rafter and wall plate should be firmly anchored through at least 3 courses of blocks.
- The rafters should each be fitted with a "bird's mouth" near the end (f). The depth of the bird's mouth should be 1/5th of the width of the rafter. This is so that the rafters rest securely on the horizontal support.
- The purlins (c) should be well secured to the rafters.
- To prevent water from entering between the wall and the sheeting material, the part of the sheet which attaches to the main wall should fit into a recess in this wall, so that the ends of the sheets can be plastered over later (Fig. 1).
- In an open fronted structure, the roof is supported by pillars on the open side, instead of by a wall. The plate which rests on the pillars and supports the rafters is called the "eave plate" (Fig. 2, g). The size of the eave plate should be about 5 x 7,5 to 10 cm.

NOTES:

LEAN-TO ROOF, continued

- Remember that in an open construction the pillars must not only support the dead load of the roof construction, but also must be strongly anchored in the ground so they cannot be pulled out by a strong wind catching the roof from underneath.
- Note that in an open-fronted construction side walls are to be avoided. If they are required, there must be openings in them to permit wind to escape. A building with an open front should never face in the direction of the prevailing wind (the direction from which the wind usually comes).

PENT ROOF

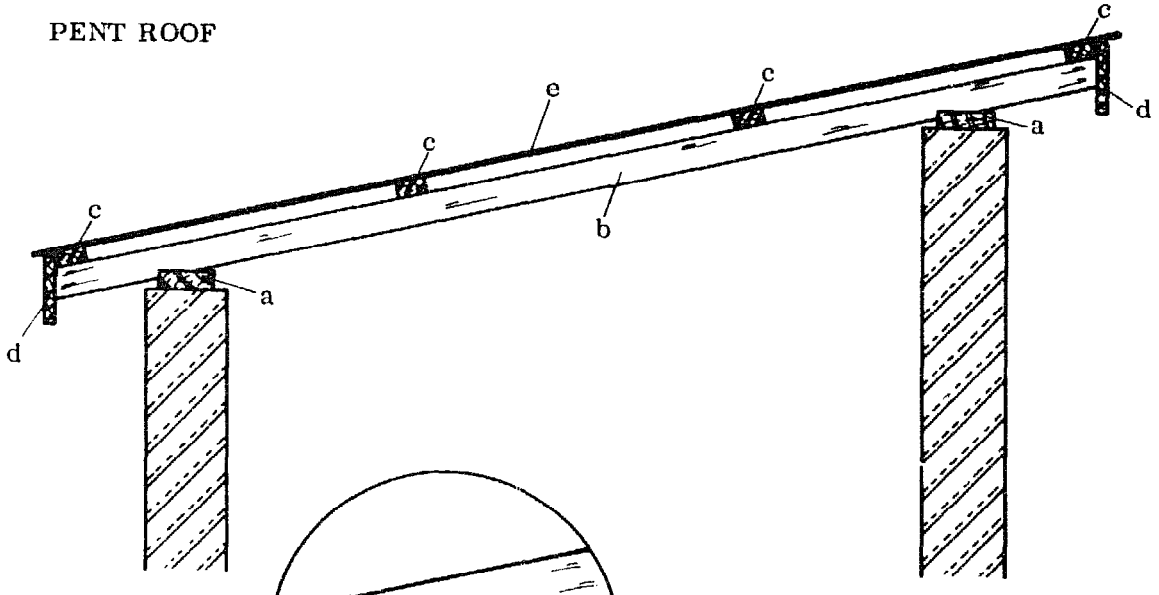

Fig. 1

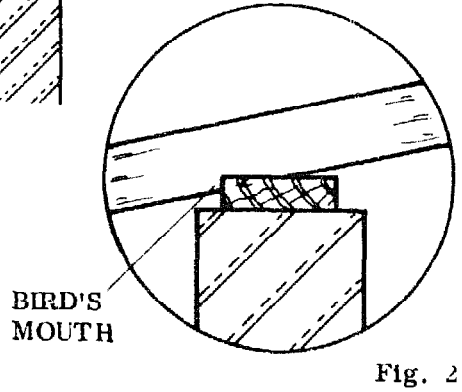

Fig. 2

PENT ROOFS

A pent roof is a roof which slopes to one side. It differs from a lean-to roof in that it is not attached to the wall of another building, but is supported by its own walls.

In Rural Building, we deal with two types of pent roof: the ordinary pent roof and the enclosed or parapetted pent roof.

- ORDINARY PENT ROOF: In this roof, the rafters and purlins project beyond the outside walls and a fascia board is fixed all around the building. The pitch of this roof will usually be about 15 degrees. The main members are: (Fig. 1)

  - the wall plate (a) 5 x 10 to 15 cm
  - the rafters (b) 5 x 15 cm
  - the purlins (c) 5 x 7,5 cm
  - the fascia (d) 2,5 x 20 to 30 cm
  - the sheet materials (e)

The above timber measurements can be used as a guide in selecting the timbers for an ordinary pent roof; that is, a pent roof with a span of less than 3,5 m. The distance between rafters should be 1 to 2 m, and the distance between the purlins depends on the size of the sheet material.

There are certain rules for constructing this type of roof:

- The rafters should always be fitted with a bird's mouth so that they rest securely on the wall plate (Fig. 2).
- Wall plates, rafters, and purlins should be well anchored (see the section on anchorage which comes later in this book).

The pent roof is often used because it is cheaper to construct than other roofs, since only rafters and purlins are used, and no tie beam, braces, etc. are needed.

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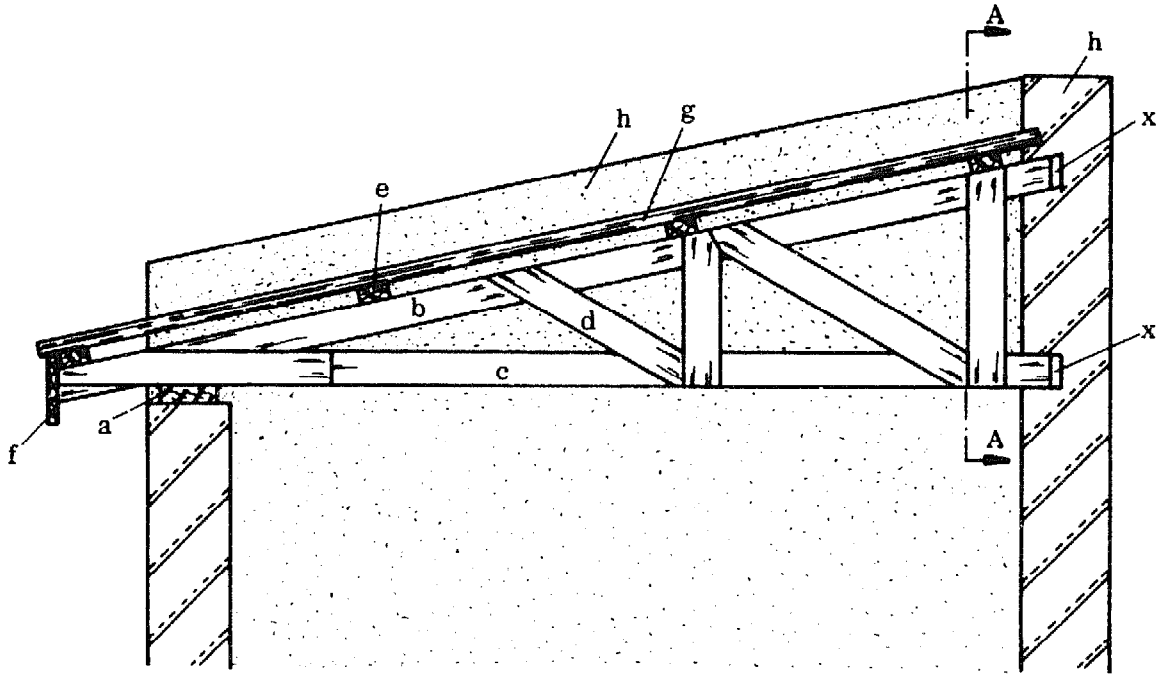

Fig. 1

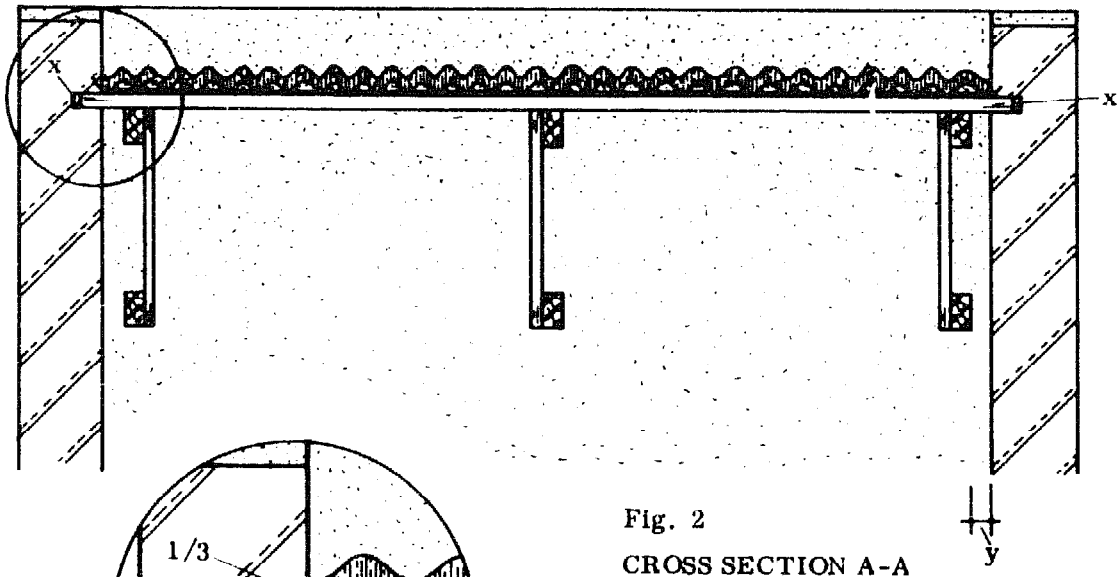

Fig. 2

CROSS SECTION A-A

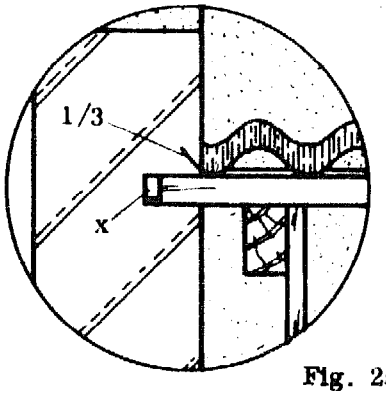

Fig. 2a

ENLARGED DETAIL

N P V C	
178	CON.

CONSTRUCTION DETAILS.

- ENCLOSED OR PARAPETTED PENT ROOF: In this roof, the higher wall and the two sloping walls enclose and protect three sides of the roof. The parts of the walls which project above roof level are called parapets. Parapets help to reduce suction on the roof and to keep the sheets in place. The pitch of this roof will be about 15 degrees (Fig. 1). The parts of the roof are:

  - the wall plate
    or concrete belt (a)
  - the rafters (b) 5 x 7,5 cm
  - the tie beam (c) 5 x 7,5 cm
  - the braces (d) 2,5 x 7,5 cm
  - the purlins (e) 5 x 7,5 cm
  - the fascia (f) 2,5 x 20 to 30 cm
  - the sheet material (g)
  - the parapet (h)

The measurements above can be used as a guide for constructing this kind of roof. The distance between the rafters should be 1 to 2 m, and the distance between the purlins will depend on the size of the sheet material.

Keep in mind the following construction pointers:

- A built-up structure is used for this roof (a half truss). We will learn about how to make the truss in a later lesson.
- Before the half truss is erected, all the walls should be built to the level of the tie beam. The truss is then erected and the walling continued.
- There should be an expansion gap at the end of each rafter and tie beam (Fig. 1, x) where they fit into the wall; and at the ends of the purlins (Fig. 2, x). The gap prevents the wall from being cracked when the wooden member expands.
- The sheet material should be fixed so that about 1/3rd of a corrugation on each side of the roof is enclosed in the wall (Fig. 2). To keep water out, this edge should be pointing upwards (Fig. 2a).
- Leave about 10 cm space between the last truss and the wall so that there is enough space for plastering (Fig. 2, y).

NOTES:

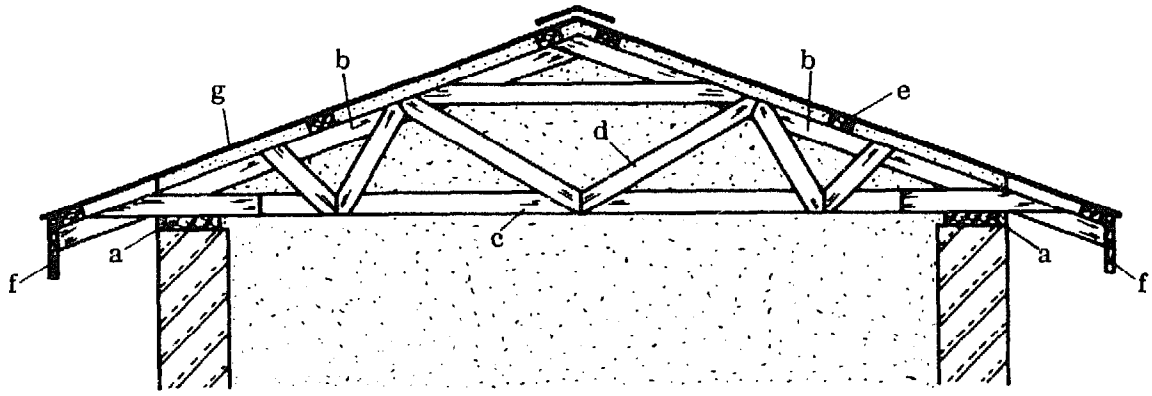

Fig. 1

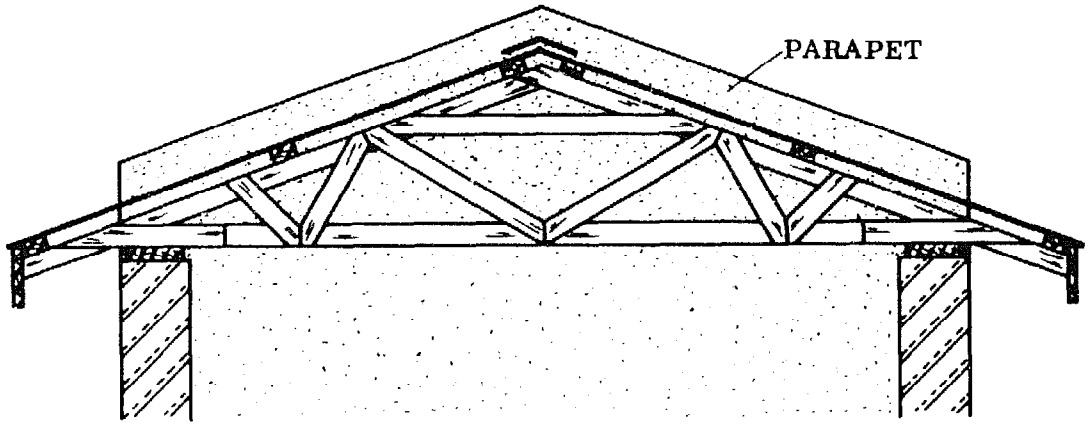

Fig. 2

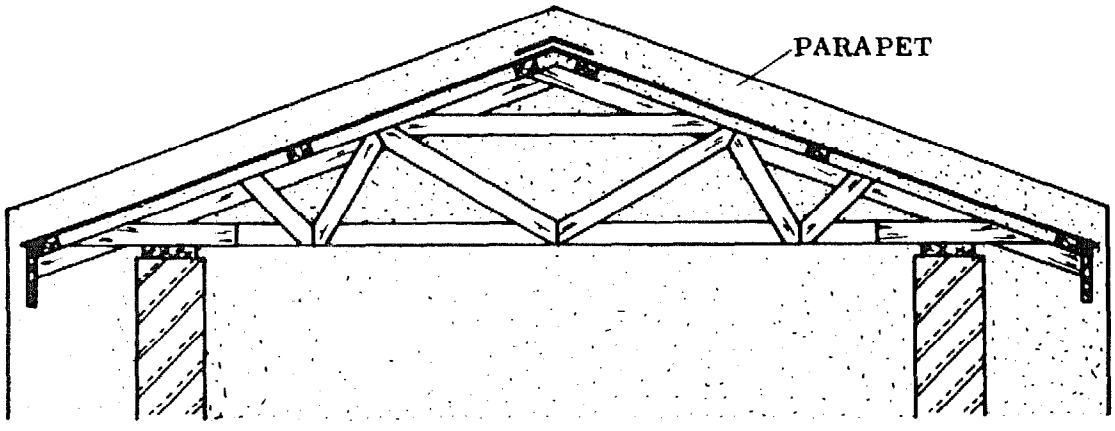

Fig. 3

N P V C	
180	CON.

CONSTRUCTION DETAILS.

GABLE ROOF

This is a roof which slopes down on the two sides of the ridge and has a gable on one or two end walls. The gable is the triangular shaped part of the end wall where it comes up to the sloping edges of the roof.

The advantage of the gable roof over the pent roof is that it can be constructed to permit cross ventilation. It can be used for large or small spans.

In Rural Building, the kind of gable roof we make is constructed with built-up trusses. The main parts and members of the gable roof are (Fig. 1):

- the wall plate or concrete belt (a)
- the rafters (b) 5 x 7,5 cm
- the tie beam (c) 5 x 7,5 cm
- the braces (d) 2,5 x 7,5 cm
- the purlins (e) 5 x 7,5 cm
- the fascia (f) 2,5 x 20 to 30 cm
- the sheet materials (g)

The above measurements should be used as a guide when you make this type of roof. The distance between the trusses will be about 200 cm. The last truss should be close to the wall, except if parapets are used. In that case leave about 10 cm space for mortaring.

The gable ends can be constructed so that the purlins project beyond the gable and the fascia boards are nailed onto them. The end sheets should be nailed so that the last corrugation folds down over the top of the fascia.

Another way of constructing the gable is to put a parapet on top of the gable in the same way as for a parapetted pent roof. Again, the sheets should be enclosed in the parapet wall by about 1/3rd of a corrugation, with the edge pointed up.

The parapet can be on top of the gable wall only (Fig. 2), or the wall can project with the parapet beyond the ends of the sheets (Fig. 3).

NOTES:

DESIGNING BUILT-UP TRUSSES

Built-up trusses are used in gable roofs to support the purlins and the roof covering.

In constructing these trusses, we must remember the principle of "perfect structures" (see Light-Weight Structures), otherwise the roof construction may get distorted.

The following points will show why roof trusses are built up in the way they are.

1. Figure 1 shows that a roof construction of only rafters tends to spread the walls. This is because the roof doesn't have a triangular shape, so it is not a perfect structure. This construction could cause damage to the walls, the roof, and the whole building.

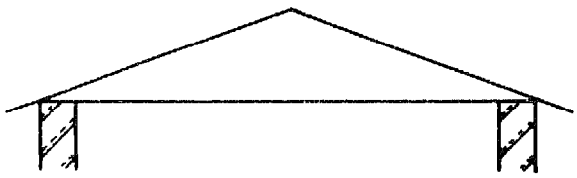

2. As we see in Fig. 2, as soon as a tie beam is introduced we get a triangular shaped, perfect roof structure.

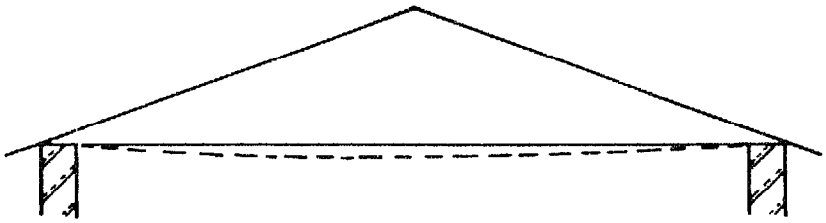

3. As the span of the roof increases the tie beam tends to sag.

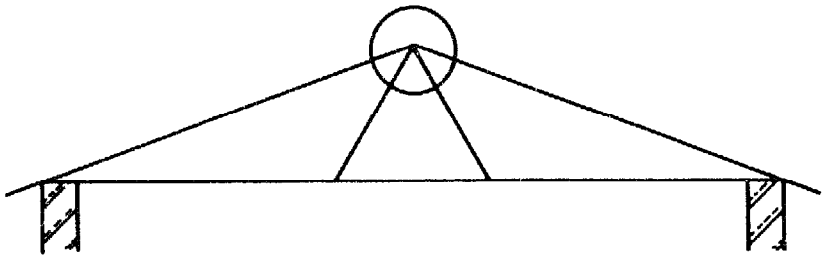

4. To prevent the sagging of the tie beam, braces are introduced. Because there are 4 members (2 rafters and 2 braces) that meet at the ridge, there is a danger of over-nailing the joint, which would weaken the truss. Therefore we need to find another way of fixing the braces while keeping a perfect structure.

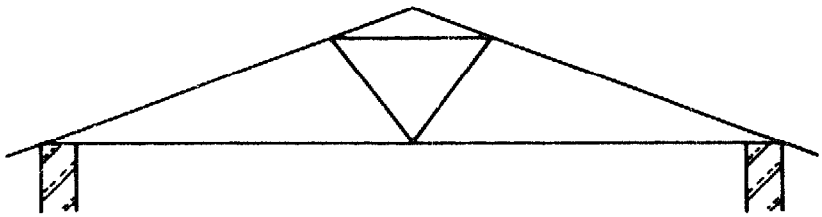

5. This is a possible solution to prevent overnailing.

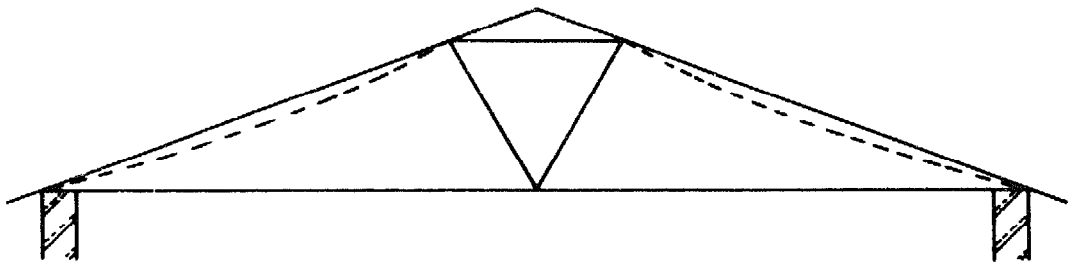

6. As the span increases still further the rafters will also be longer and they will tend to bend.

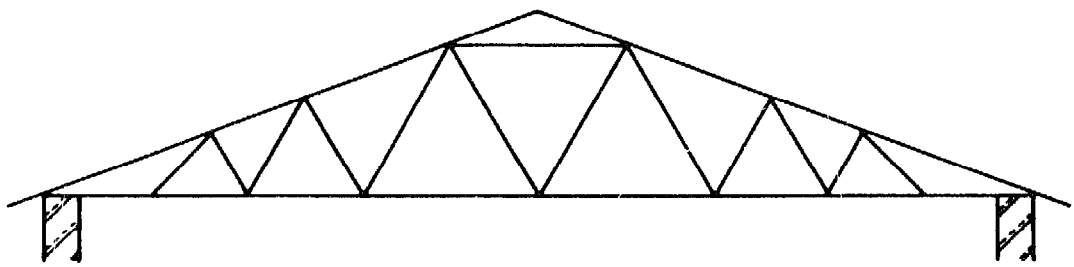

7. To prevent the rafters from bending, more braces are introduced.

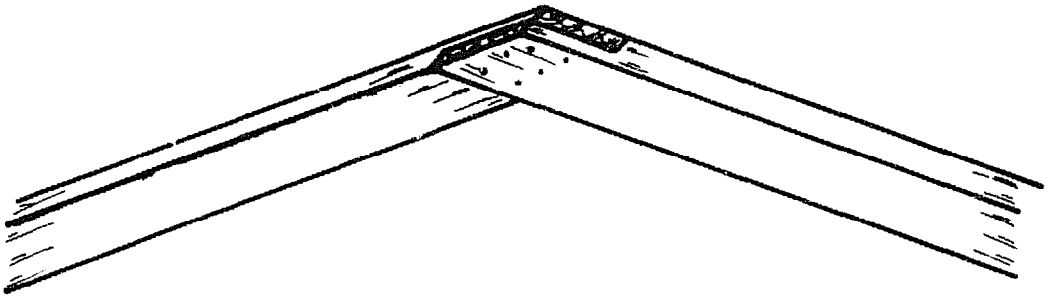

Fig. 1

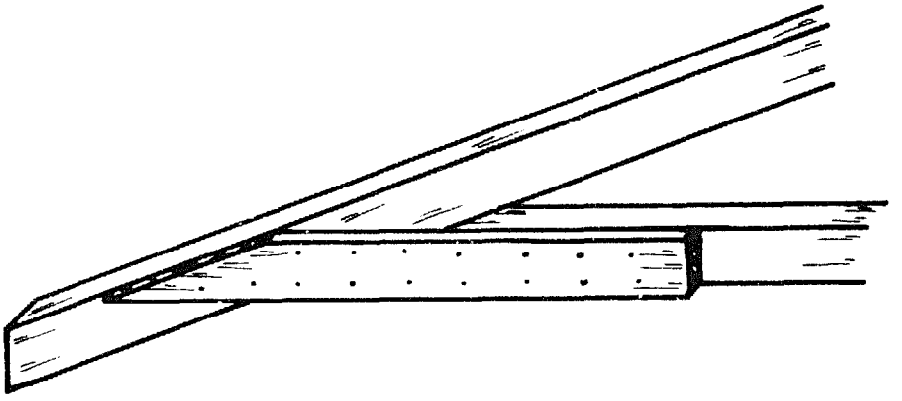

Fig. 2

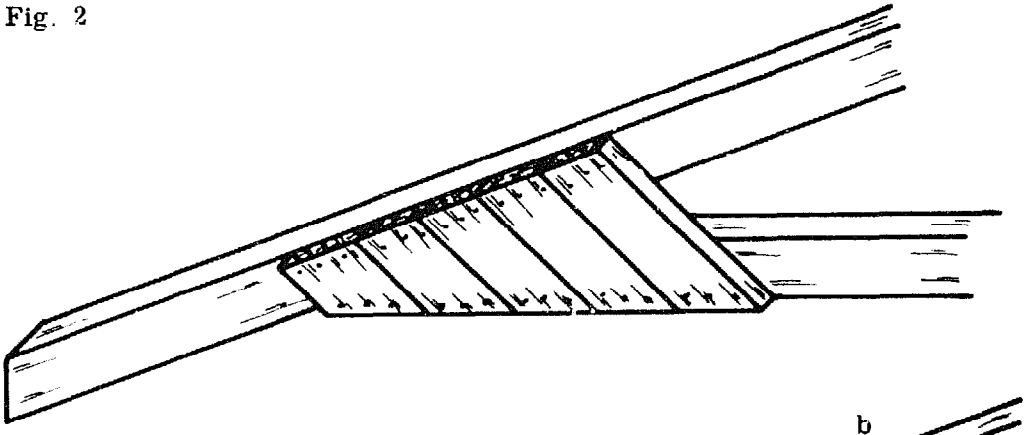

Fig. 3

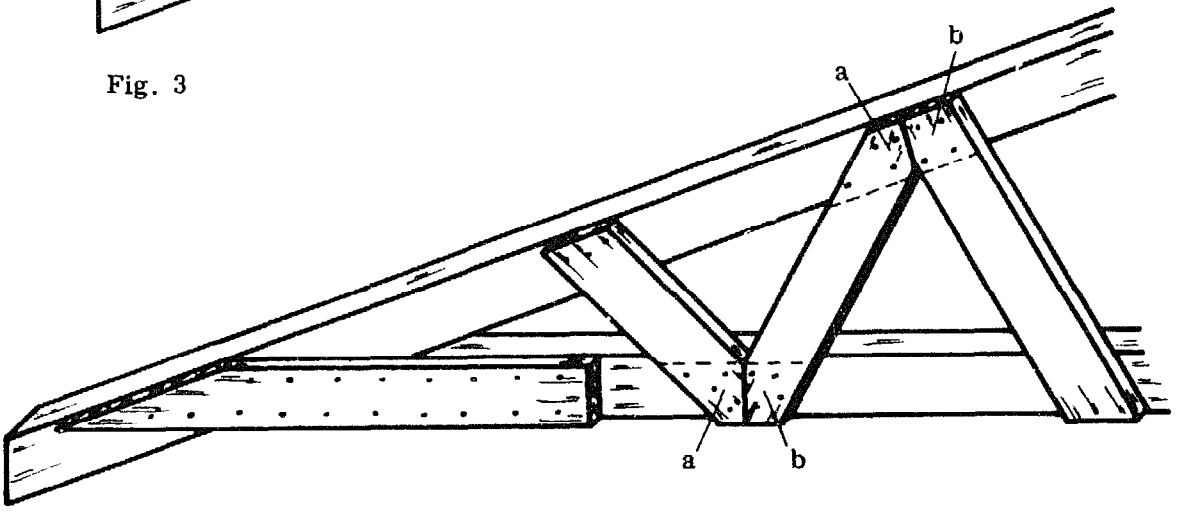

Fig. 4

N P V C		CONSTRUCTION DETAILS.
184	CON.	

JOINTS FOR THE TRUSS

At the ridge, two rafters must be joined together. This is done with a halving joint (Fig. 1).

The halving joint is assembled with a few long nails. They should be long enough that they can be clenched on the opposite side. Take care not to overnail the joint.

The rafter - tie beam joint can be a fish joint with two nailed fish plates (Fig. 2). After the fish plates are fixed, they must be cut so that they don't project past the edge of the rafter.

If large trusses are made, short braces can be used to strengthen the joint instead of fish plates (Fig. 3).

The braces are added according to the required pattern of the truss. At the place where the two braces meet, they should be cut so that the areas where they are nailed to the truss (areas a and b) are as large as possible and of equal size on both braces (Fig. 4).

This is done by placing them on top of each other, marking and cutting during the assembly of the truss.

All of these reinforcements can be added on either one or both sides of the truss, depending on the strength that is needed for the construction.

NOTES:

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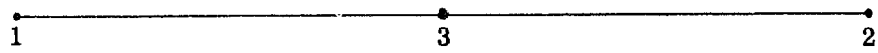

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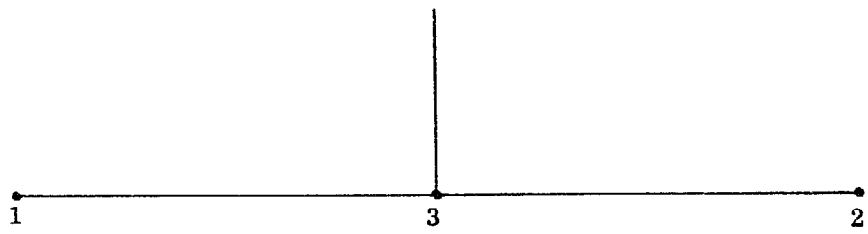

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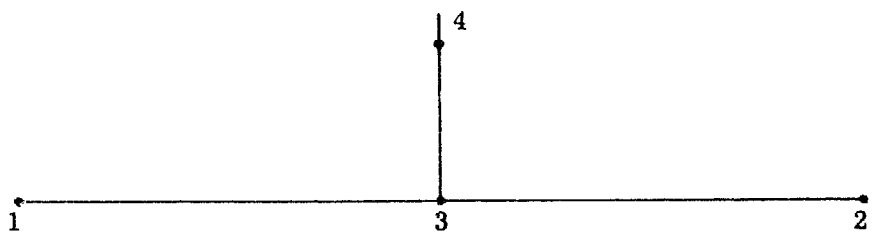

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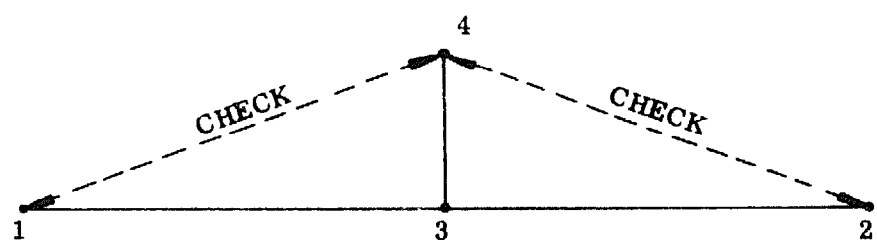

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N P V C		CONSTRUCTION DETAILS.
186	CON.	

MARKING OUT BUILT-UP TRUSSES

Before you start to mark out the trusses, measure the span of the building at several points and find out the span of the truss. Make sure that the truss is long enough to cross even the widest span of the building.

Do not forget the difference between the span of the building and the span of the truss. You must take into account any verandahs or overhangs in the span of the truss. The outline design will help you to find out the different spans for the building and the truss.

The marking out is done in a cleared, flat area of the building site. After the area is cleared, the shape of the trusses is laid out with iron pins knocked in the ground and with the mason line.

- SEQUENCE OF OPERATIONS:

a. Place pegs 1 and 2 at a distance equal to the span of the truss, and stretch a line between them.

b. Divide the distance from point 1 to point 2 in half, and mark point 3.

c. From point 3, erect a line perpendicular to line 1-2 (use a large square or the 3-4-5 method).

d. Place peg 4 along the line from point 3, at the distance of the required rise of the truss.

e. Check that the distances 1 - 4 and 2 - 4 are equal.

f. Check that the roofing sheets will fit as planned, including a sufficient overlap. Check this by measuring from peg 1 to peg 4, then add the overhang and the projection of the fascia board.

NOTES:

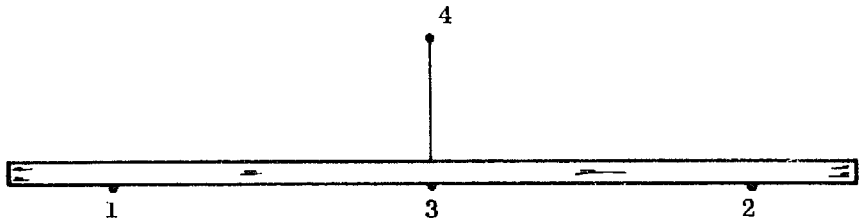

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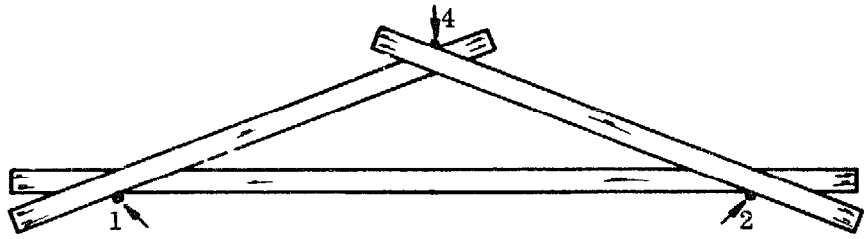

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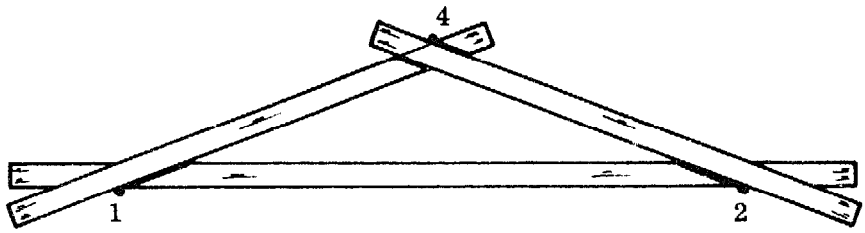

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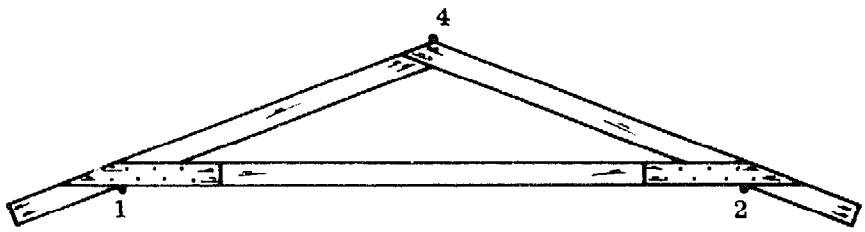

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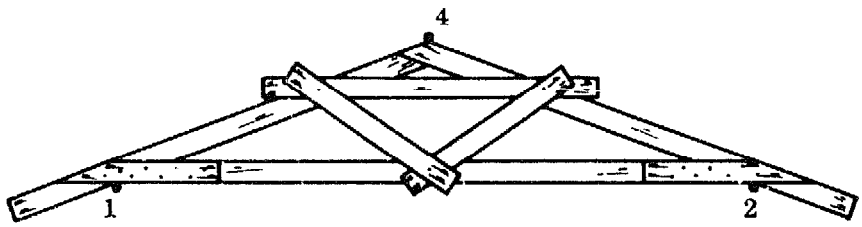

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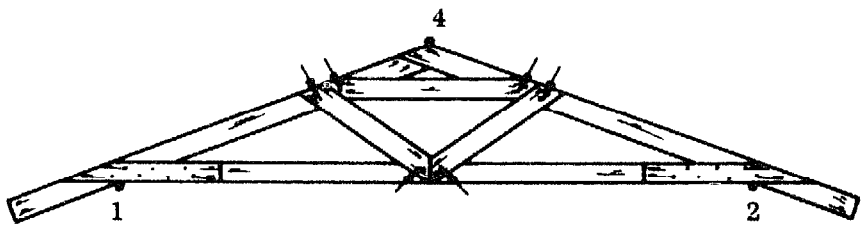

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N P V C	
188	CON.

CONSTRUCTION DETAILS.

ASSEMBLY OF BUILT-UP TRUSSES

Before you assemble the truss select the timbers, measure them against the setting out, and if necessary joint pieces to get members with the required lengths (see Lengthening Joints, pages 169 to 173).

- SEQUENCE OF OPERATIONS:

a. Lay the tie beam along the line from peg 1 to peg 2.

b. Place the two rafters between pegs 1 and 4; and between pegs 2 and 4. Note the positions of pegs 1, 2 and 4 with respect to the boards. This is very important. Rafters should be slightly longer than needed. This allowance is cut off after the trusses are erected.

c. Mark the halving joint on the rafters at the ridge and cut it.

d. Mark the cutting lines on the tie beam and cut the ends.

e. Assemble the ridge joint with a few nails; and the rafter to tie beam joint with fish plates.

f. Mark the positions of the braces according to the plan, on the rafters and tie beam.

g. Lay the braces one over another on top of the tie beam and rafters. Use a single nail to fix them temporarily.

h. Cut the braces to the correct shape, keeping in mind that the size of the area where each is nailed to the truss must be the same for all of them (arrows).

i. Fix the braces with nails.

j. After the braces are fixed, if necessary a second fish plate can be fixed on the other side of the rafter-tie beam joint. Turn the truss over and fix this plate. Sometimes it is also necessary to fix braces on both sides.

k. Mark the positions of the purlins on the rafters. This will make work easier later on.

l. The other trusses can be assembled on top of the finished first truss.

- NOTE: Always use dovetail nailing, throughout the truss.

NOTES:

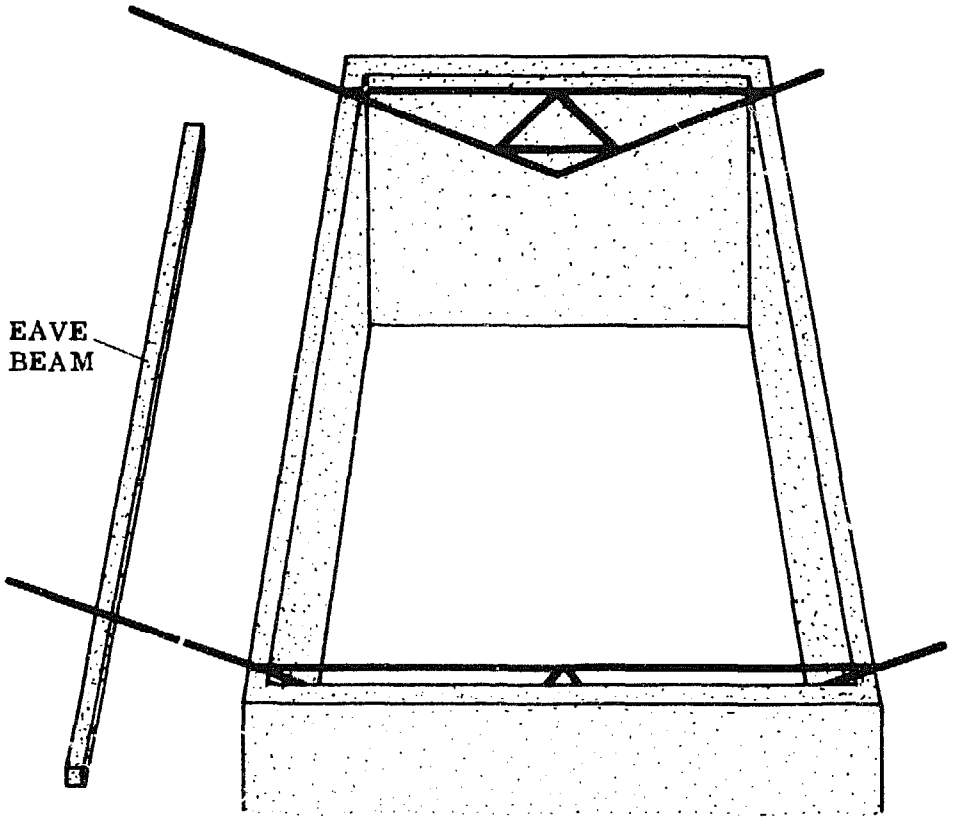

Fig. 1

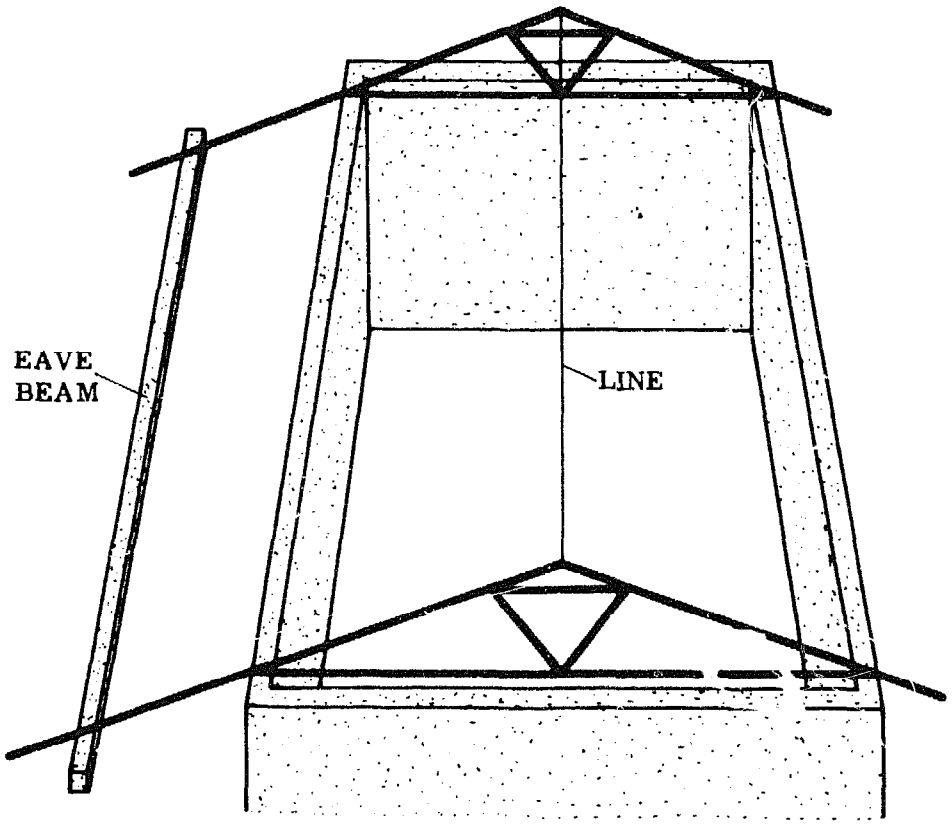

Fig. 2

N P V C	
190	CON.

CONSTRUCTION DETAILS.

ERECTING A ROOF STRUCTURE FOR A GABLE ROOF

As soon as the trusses are finished, the roof can be erected. If wood preservatives are used they should be applied before the truss is erected. Creosote is often used as a preservative for trusses. If the roof will not be erected immediately, keep the trusses dry and in a shady place.

- SEQUENCE OF OPERATIONS:

a. Hang a truss upside-down across the span of the building, at each gable end (Fig. 1).

b. Turn the trusses over and plumb them (Fig. 2).

c. Secure the trusses at the bottom with anchor rods and brace them temporarily from the rafter to the wall plate.

d. Fix a line from one ridge to the other (Fig. 2).

e. Hang the other trusses, one after the other, upside-down between the walls. Turn each one over and plumb it according to the line before hanging the next one. Brace them temporarily.

f. Nail the purlins according to the measurements of the roof covering (the sheets) and secure them (a section on Anchorage is included later in this book). If the rafters overhang to cover a verandah, make sure that the eave plate is also well secured.

g. Fix a line at the bottom end of the rafters, on the gable ends of the roof, at the level of the required overhang. Cut off the ends of the rafters according to the line.

h. Cut off the purlins to the correct length.

i. Build up the gables.

j. Nail the fascia boards on the purlins and rafter ends.

Once the roof structure is erected, cover it as soon as possible to keep out the sun and rain; otherwise the wood may start to twist and the joints will loosen. If the trusses rest on a concrete belt, put roofing felt between the concrete belt and the tie beam to help prevent dampness.

NOTES:

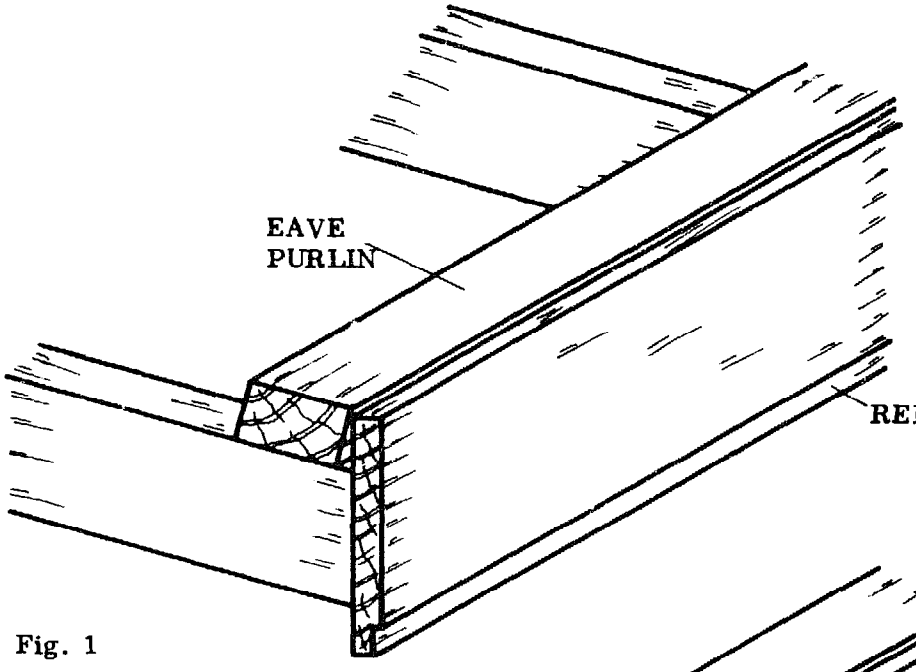

Fig. 1

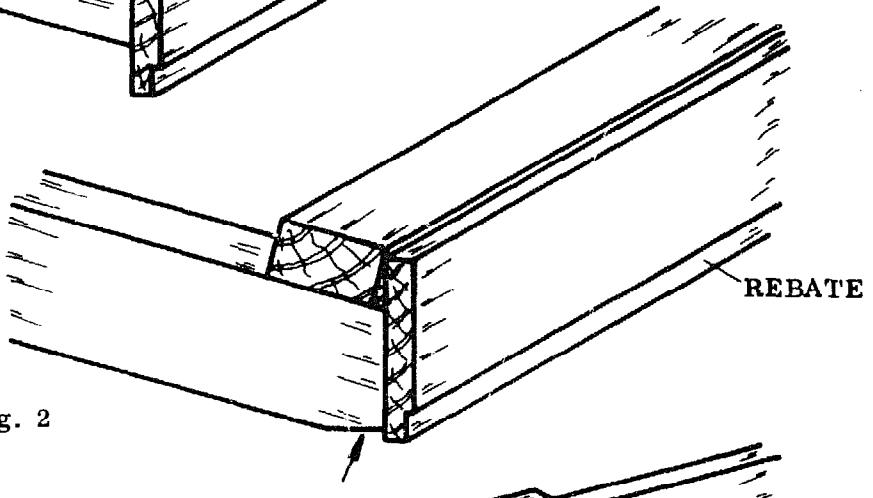

Fig. 2

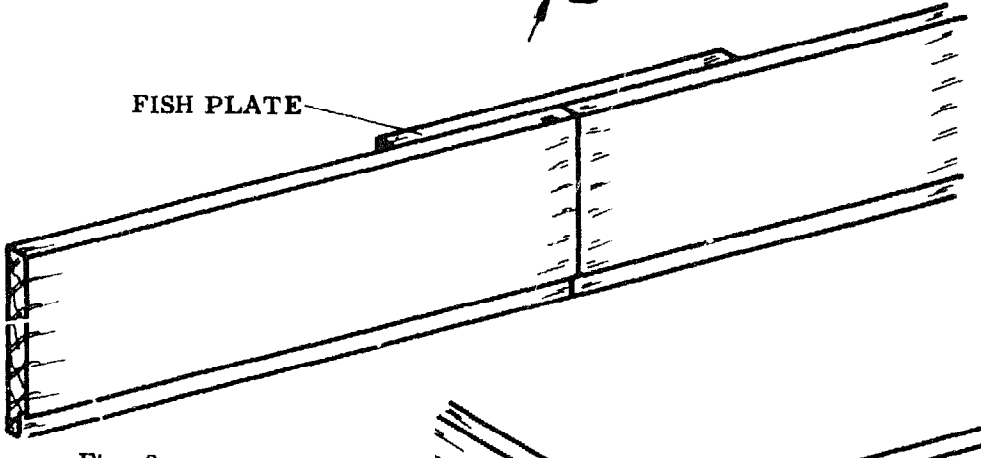

Fig. 3

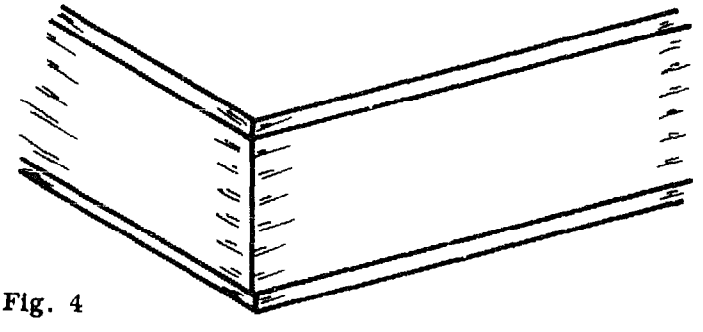

Fig. 4

N P V C		CONSTRUCTION DETAILS.
192	CON.	

PURLINS

The function of the purlins is to support the roofing sheets and to stiffen the whole roof structure. They are supported by the trusses and sometimes the gable ends. The lengthening joints for purlins can be fish joints.

The size of the purlins should be 5 by 7,5 cm.

The lowest purlin of the construction is called the eave purlin (Fig. 1). The highest one is called the ridge purlin.

To make a wider area for nailing the sheets, lay the purlins flat on the rafters. If larger distances must be bridged, lay the purlins on edge. This reduces the nailing area, but it prevents the purlins from sagging.

The distance between the purlins depends on the size and type of sheets which are used for the roof covering. If thick sheets with the normal 244 cm length are used, then one purlin at each end of the sheet plus one in the middle will be sufficient. For very thin sheets one extra purlin should be added for each sheet.

If the building will require more than 2 sheets to cover the length of the rafter, be careful that the purlins are set at the correct distance apart.

It makes work much easier if you mark the positions of the purlins on the rafters as you assemble the trusses.

FASCIA BOARDS

Fascia boards are often added to the roof construction. They are wide boards which are fixed on the rafter ends and the purlin ends at the gables of the roof construction.

Fascia boards are about 20 to 30 cm wide and 2,5 cm thick. A small rebate can be made into the lower edge of the board to give it a better appearance (Fig. 1).

If the rafter projects below the fascia it can be cut off as shown in Fig. 2.

The eave purlin should be at the correct height so that it does not interfere with the fascia. The fascia boards are fixed before the sheets are laid.

A butt joint is sufficiently strong to use for lengthening the fascia boards, if a fish plate is nailed behind it for strength (Fig. 3). The corner joints should all be mitre joints so that the end grain of the boards is not exposed (Fig. 4).

Before the boards are fixed they should be painted, since it will be difficult to reach some parts later, especially the top edge. Pay special attention to the places where they are joined together. The end grain should be soaked with paint to prevent water from entering there.

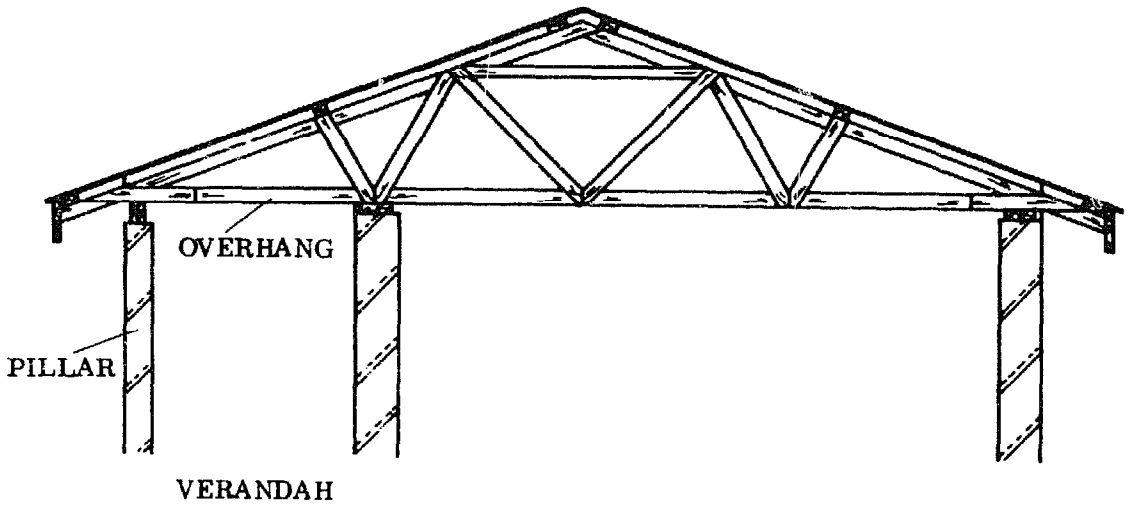

Fig. 1
EXTENDING THE TIE BEAMS

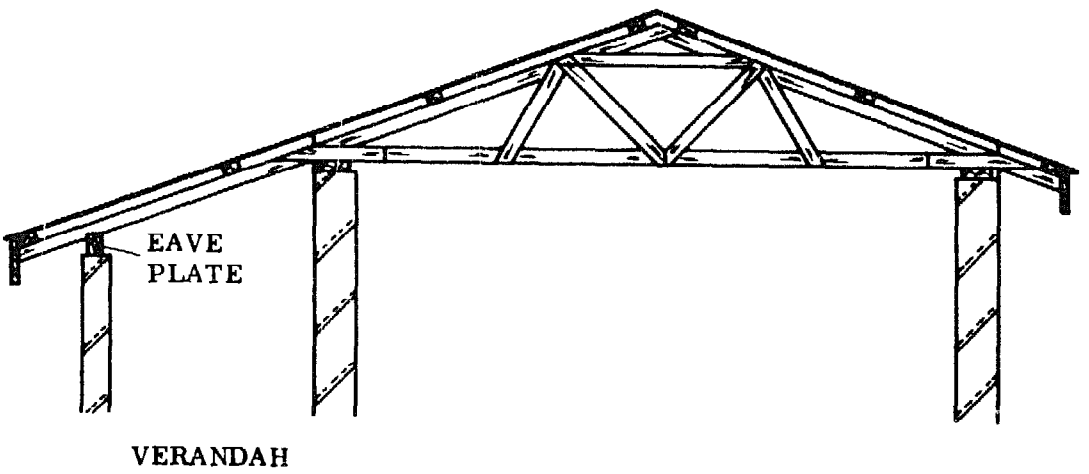

Fig. 2
EXTENDING THE RAFTERS

N P V C		CONSTRUCTION DETAILS.
194	CON.	

VERANDAHS

When a building with a gable or pent roof has a verandah, there are two possible methods for constructing a roof to cover it:

- By extending the tie beams to cover the verandah (Fig. 1)
- By extending the rafters to cover the verandah (Fig. 2).
- REMEMBER: Open verandahs should not face the direction of the strongest winds.
- EXTENDING THE TIE BEAMS: The part of the tie beam that covers the verandah is called the overhang (Fig. 1). For a small overhang, supporting pillars are not necessary, but it should be braced very well. If the overhang is wide, then pillars are needed to support it (Fig. 1).

  If the building has a gable roof, an ordinary truss construction can be used, with the span of the truss including the width of the verandah.

  Since the parapetted pent roof has a half truss construction with a tie beam, this construction may also be used with it.
- EXTENDING THE RAFTERS: The overhanging rafters cover the verandah. Note that the building must be high enough so that the lower edge of the verandah is not inconveniently low (Fig. 2). This construction can be used with either an ordinary pent roof or a parapetted pent roof as well as with a gable roof.

  The feet of the rafters are supported by an eave plate or a concrete eave beam which rests on pillars. The joint between the rafters and the eave plate should be a bird's mouth to ensure proper support for the rafters. The depth of the bird's mouth should be about 1/5th of the width of the rafter.

  The eave plate is normally set edgewise on the pillars. In most cases 5 x 10 Odum is large enough for the eave plate. Take care that it is well anchored on the pillars.

  There are certain lengthening joints which are often used for joining eave plates. These are described in the chapter on "Lengthening Joints".

  The pillars themselves have to be well anchored in the ground, since they not only have to carry the weight of the structure but also have to hold the roof down in heavy storms (see Lean-to Roofs).

At times the builder may choose to construct the verandah roof using a combination of projecting rafters and projecting tie beams.

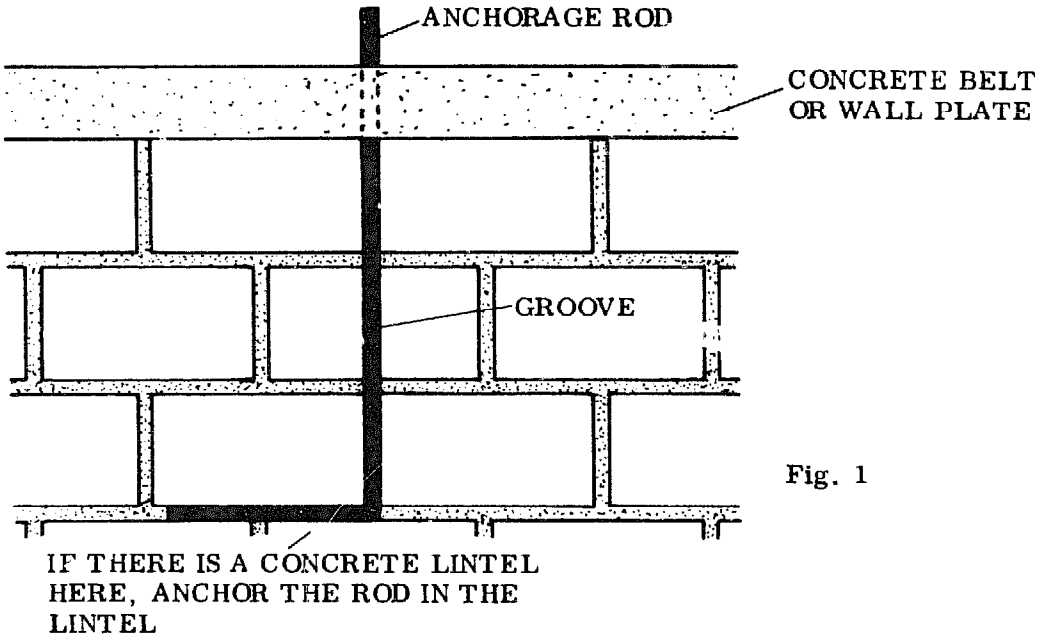

Fig. 1

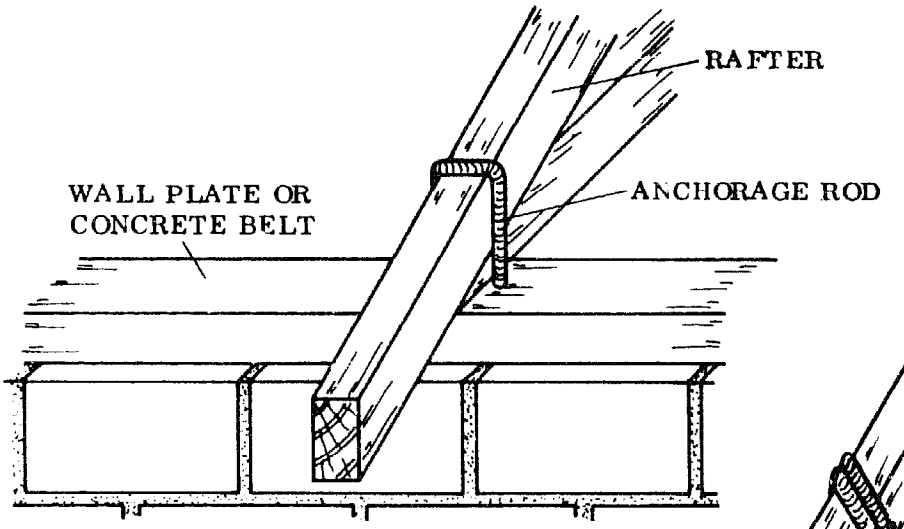

Fig. 2

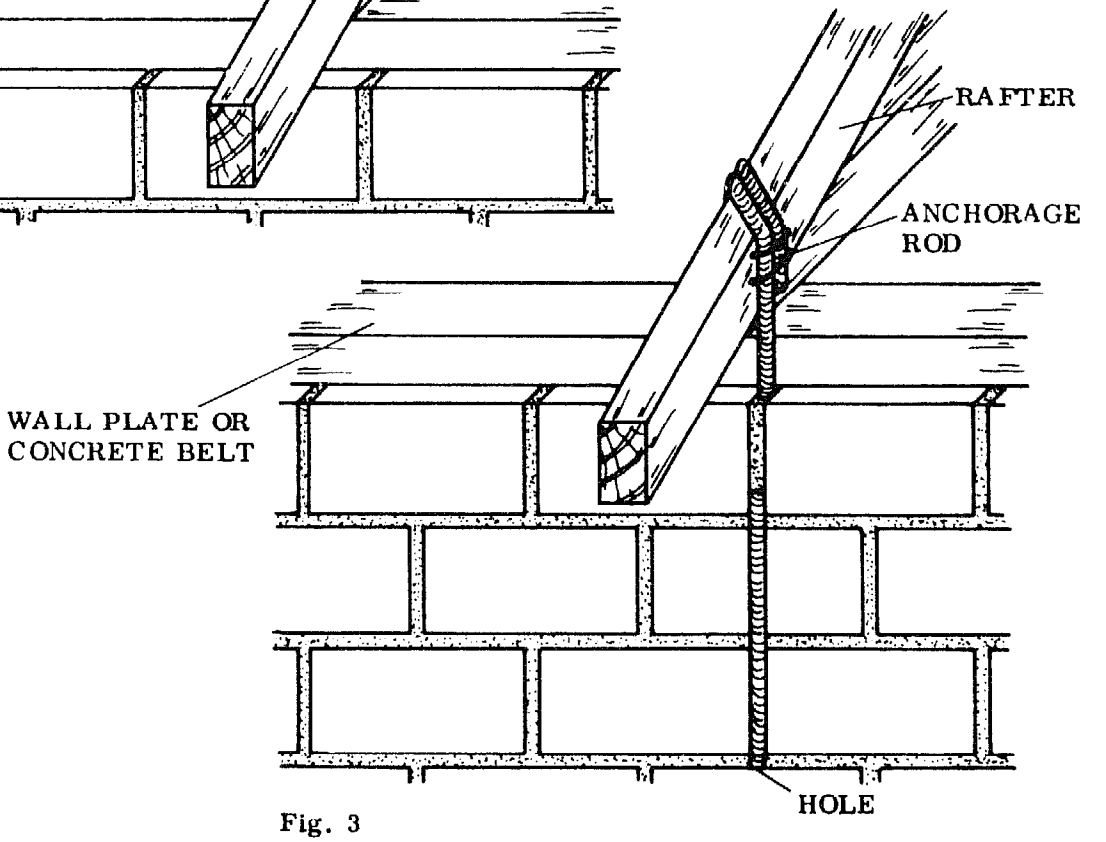

Fig. 3

N P V C	
196	CON.

CONSTRUCTION DETAILS.

ANCHORAGE

Whatever the form of the roof construction, it must be tied securely to its supporting walls or pillars. If this is neglected, the roof can easily be damaged or even torn off in strong winds.

The following are some points which are important in anchoring a roof.

- ANCHORAGE RODS: The roof is secured to the walls by these iron rods. They can be fixed in the wall during the wall construction if the positions of the trusses have been decided, or else they can be fixed in the finished wall.

  - In the first method, the rod is inserted in the bed joint as the third course below the top of the wall is laid. The rod is bent at a right angle so it can fit into the cross joint (Fig. 1); and it is positioned just inside the face of the wall.

    When the next course is laid, the block above is chiselled out to make a shallow groove (approximately 1 cm deep) for the rod (Fig. 1).

    The rod fits into the next cross joint and is bent gradually inwards toward the top centre of the wall, coming out where it can pass later through the wallplate or concrete belt (Figs. 1 & 2).

    When the truss is erected, the rod is bent around the rafter and tie beam both, and secured with nails (Fig. 2).

  - With the second method, the rod is inserted through a hole chiselled in the bed joint of the third course from the top, after the wall is complete. The ends of the rod are bent up and over the tie beam and rafter, overlap each other, and are secured on both sides with nails (Fig. 3).

  The second method is chiefly used when the roof of an existing building has to be secured. If you are constructing a whole new building, it is best to plan ahead a bit and use the first method, which is both easier and stronger.

- ANCHOR BEAM: Once the wall is completed, the top of the wall may be covered with a strip of reinforced concrete all around the outside walls of the building. This is the anchor beam, also known as the ring beam or concrete belt. The roof anchorage passes through this belt. The anchor beam performs three functions:

  - It keeps the outside walls of the house together, thus strengthening them.
  - It provides a firm base for the trusses and distributes their weight over the softer landcrete blocks below.
  - It anchors the trusses and adds weight to help keep the roof construction from being lifted up in heavy winds.

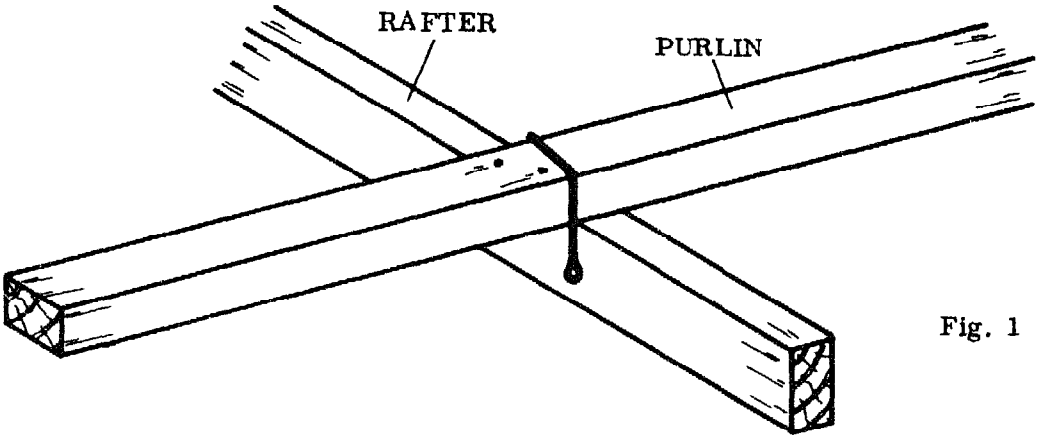

Fig. 1

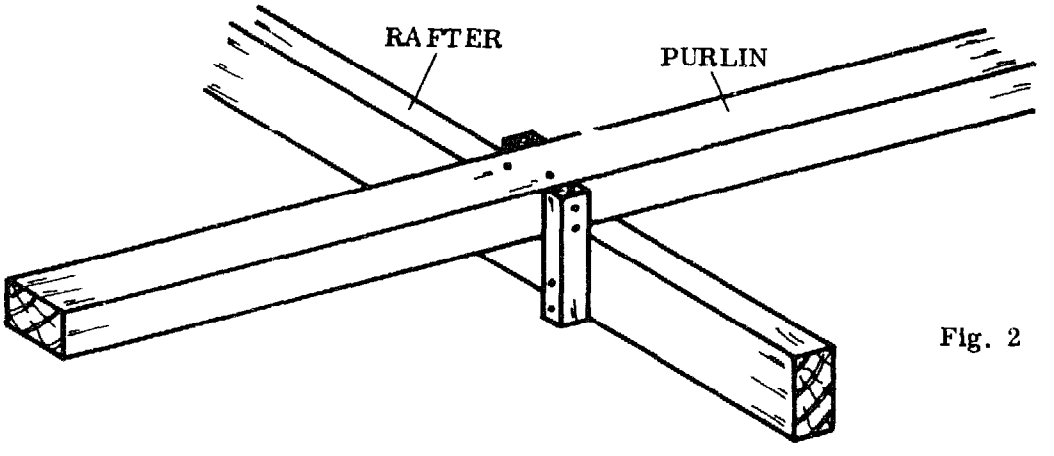

Fig. 2

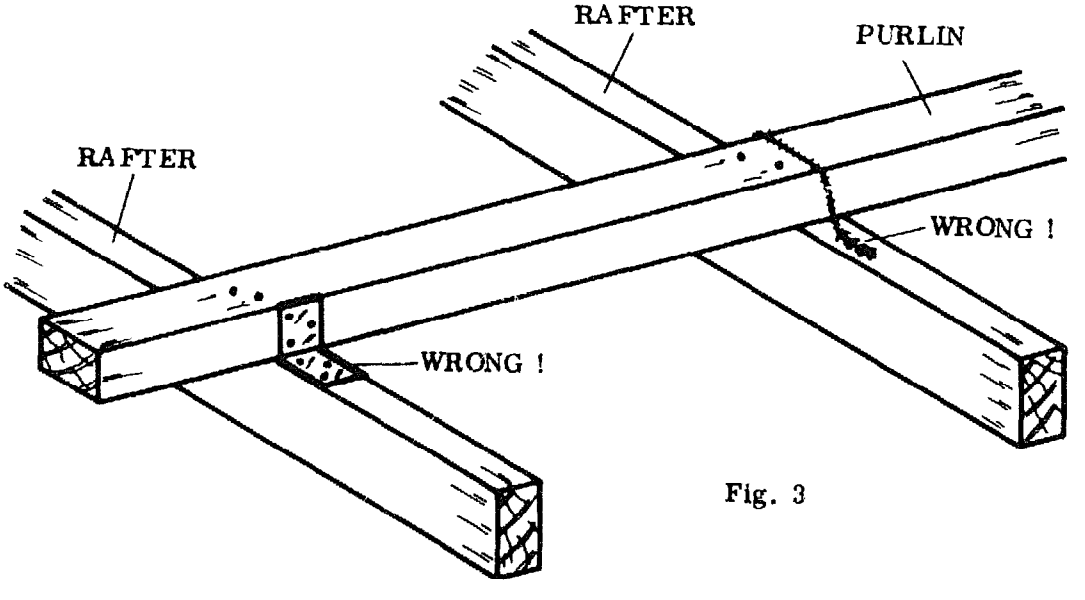

Fig. 3

N P V C	
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CONSTRUCTION DETAILS.

- WALL PLATE: For smaller spans the Rural Builder can install a wooden wall plate instead of an anchor beam. The roof anchorage passes through the wall plate and through at least three courses of blocks.

  There are several joints that may be used to connect pieces lengthwise to make the wall plate (see Lengthening Joints, page 173). The wall plate should be about 5 cm thick by 15 cm wide.

- TRUSSES: The trusses should be evenly spaced across the roof, with one at each gable end and the rest about 2 m apart from each other. Every truss should be anchored to both the walls that it rests upon. The anchorage rod is bent around both the tie beam and the rafter, and secured with nails (Fig. 2, previous page).

- PURLINS: Tie all the purlins to every rafter, preferably with iron rods. These are shaped as shown in Fig. 1, by hammering the rod flat on both ends and drilling holes in the ends, then bending the rod to a U-shape.

  If these fixings can't be made, it is possible to make wooden fixings (Fig. 2). Two wooden pieces are used, one on either side of the purlin.

  Barbed wire can also be used as an alternative to the iron rods. Wrap it firmly around and nail it securely.

  Whatever fixing you use, take care to fix the nails so they are not pulled out by the force of the wind on the roof. Fig. 3 shows two badly nailed fixings.

NOTES:

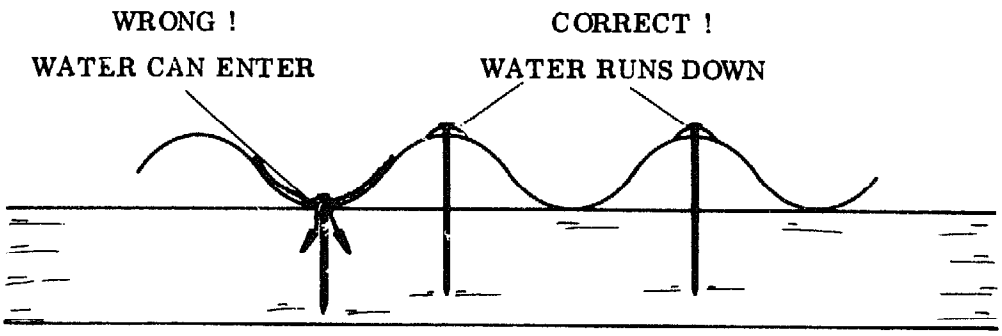

Fig. 1

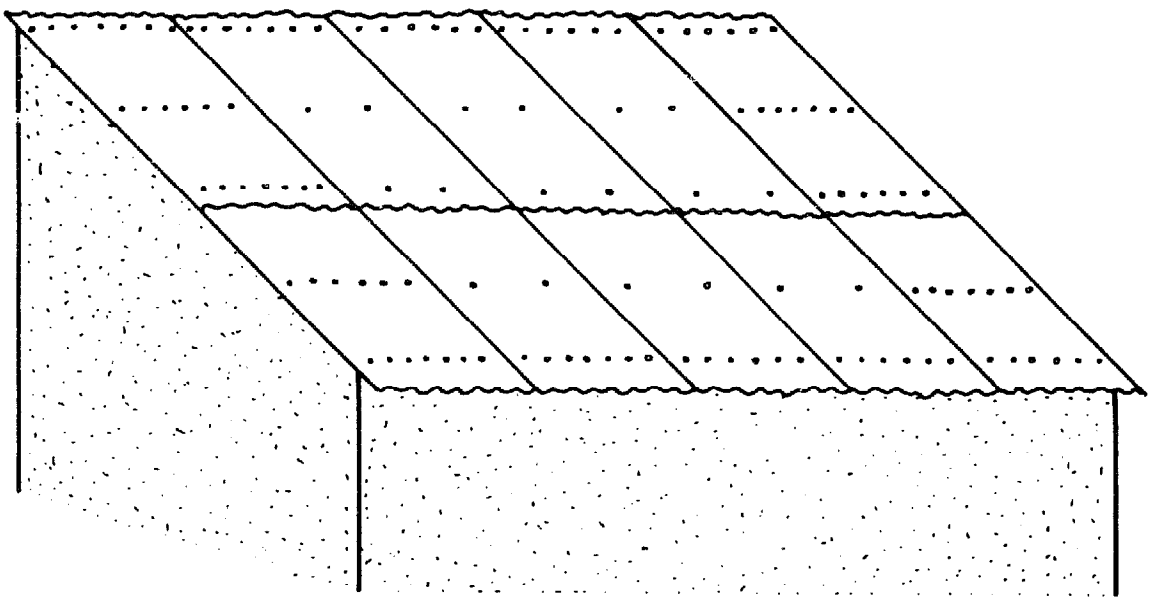

Fig. 2

NOTES:

N P V C		ROOF COVERING.
200	CON.	

ROOF COVERING

See the Reference Book, pages 207, 230 and 231 for descriptions of the sheet materials and roofing accessories; also see pages 239 and 240, Tables of Figures.

ALIGNMENT OF THE SHEETS

If possible, always start laying the sheets from one end of the roof so that the free ends of the sheets face away from the direction of the wind. This reduces the danger of the sheets being blown away as they are being installed.

Start laying from one end of the building to the other. As each new sheet is laid, lift the edge of the previous one so that it overlaps the new sheet by 2 corrugations. Each sheet is thus held in position by the one previously fixed, so they are more easily aligned in the correct position.

Exact sidelaps (2 corrugations) and endlaps (15 cm) are essential to make the roof waterproof.

- NAILING: When you nail corrugated roofing sheets to purlins, always nail through the top of the corrugation. This is so that rain will tend to run away from the nail (Fig. 1).

  Each nail should be driven in until the roofing felt just touches the sheet. If it is driven further, the nail will flatten the corrugation and distort the sheet. This can cause the roof to leak.

  The sheets should be nailed to all the purlins. Nail every second corrugation in the sheets along the eave purlin and along the ridge purlin; and also on the end sheets at the gables. Over the rest of the roof, nail at every third corrugation over the purlins (Fig. 2).

- HOW TO LAY THE SHEETS: Before the sheets can be laid, the gables must be built up to the correct height. Make sure that all the nail heads of the wooden construction are punched well below the surface.

  Fix a line on the eave to indicate the desired projection of the sheets. Note that the sheets should project about 2 cm over the fascia board in order to provide a drip overhang.

  It helps to station a helper at eave level to observe if the general line of the sheets is straight and that they project uniformly. Another helper can check that the sheets are straight along the corrugations from the eave to the ridge.

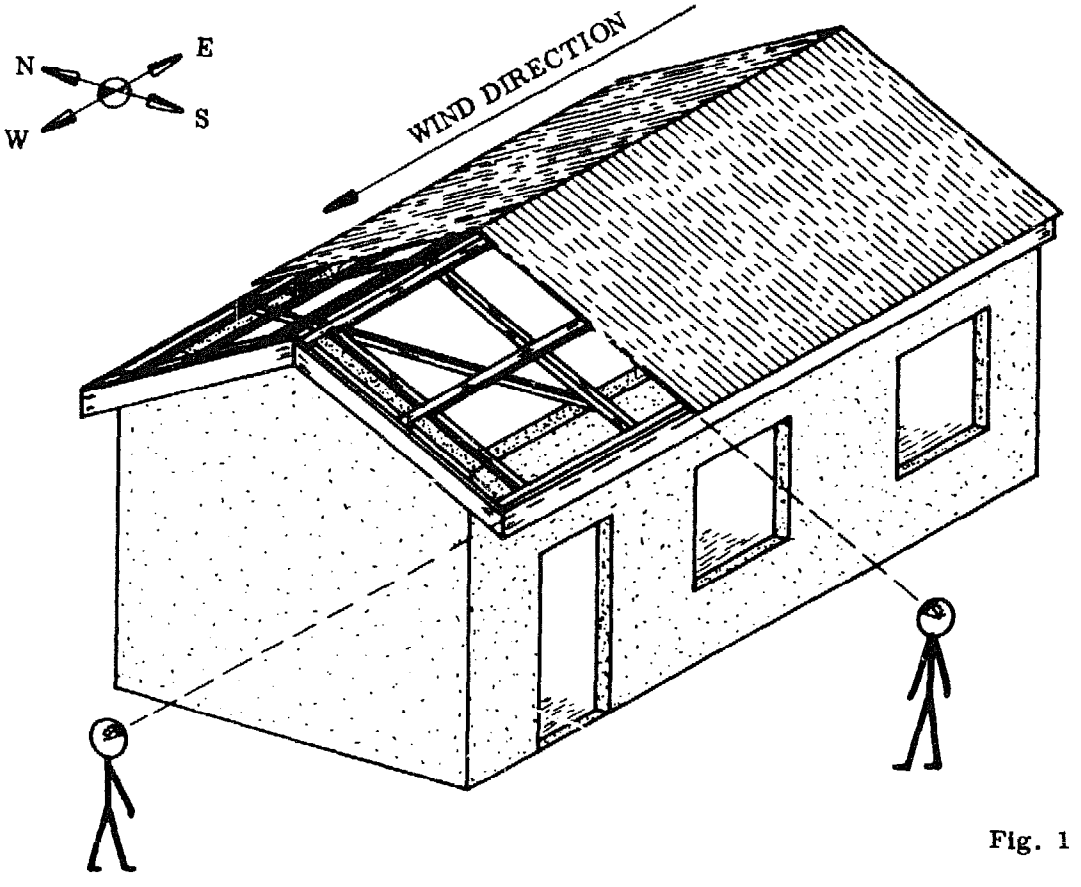

Fig. 1

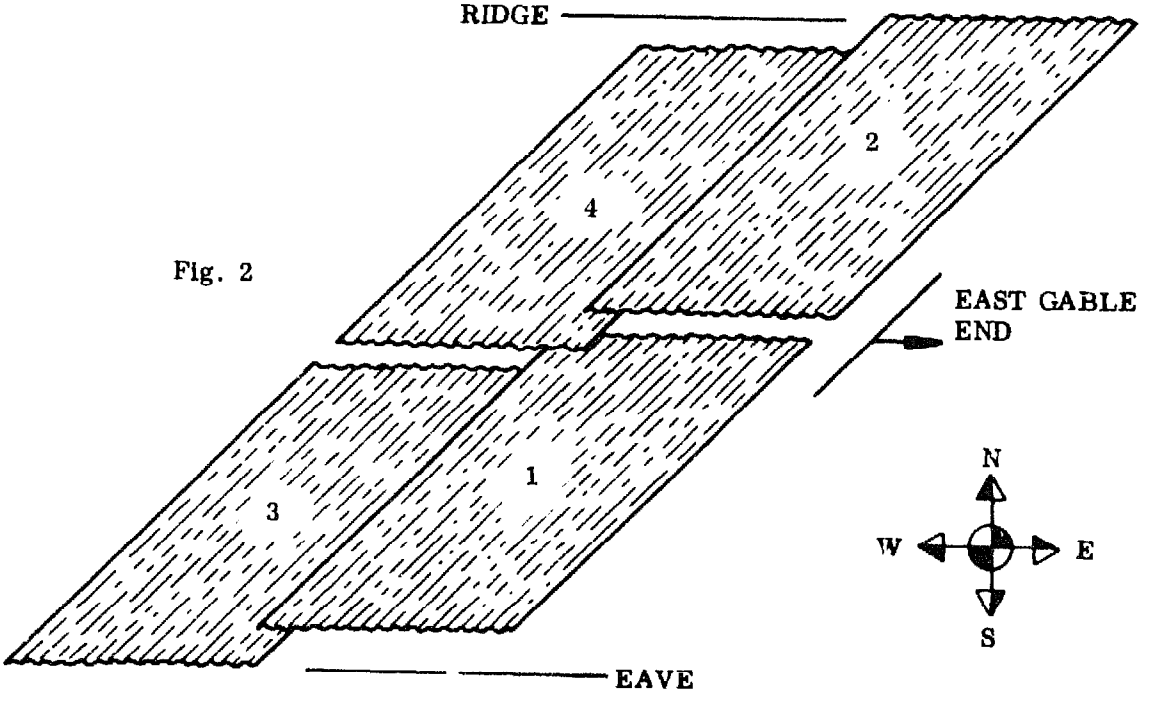

Fig. 2

N P V C	
202	CON.

ROOF COVERING.

The helpers can also check from both sides of the roof to see if the corrugations match at the ridge line (Fig. 1).

For nailing the sheets it is best to have one man at each purlin.

- SEQUENCE OF OPERATIONS: In order to join the overlaps correctly, follow this sequence, starting from the end of the roof which is in the direction where the strongest winds are coming from (here it is the east) (Fig. 1).

a. Place sheets 1 and 2 loosely along the gable end, with sheet 2 overlapping sheet 1 by 15 cm in the length (Fig. 2).

b. Align them with the help of the two observers on the ground.

c. Secure the sheets with one nail in the middle. One man should do the securing, or the sheets might shift because of the shocks of the hammer blows.

d. Have the observers check that the sheets are still straight in both directions.

e. Nail the sheets home with all of the required nails except the nails at the edges where the next sheet will be fixed under.

f. Place sheet 3, lifting up the edge of sheet 1 until it overlaps sheet 3 by two corrugations (Fig. 2).

g. Place sheet 4, lifting sheet 2 until it overlaps sheet 4 by two corrugations. Sheet 4 should overlap sheet 3 in the length by 15 cm (Fig. 2).

h. Align sheets 3 and 4 with the help of the two observers on the ground.

i. Secure the sheets with one nail each at the centre.

j. Recheck the straightness in two directions.

k. Nail the sheets home with all the required nails except the ones at the edge where the next sheet fits.

l. Continue with this sequence until the whole roof is covered.

m. Proceed to build the parapets if they are required.

If no parapets are made, the last corrugation at the gable ends can be lapped over the fascia board, turned down and nailed onto the face of the fascia. Place the nails at intervals of about 10 cm.

- NOTE: In northern Ghana, the strongest winds are from the east, so you should start laying the sheets from the east end of the building. In areas where the wind comes from another direction lay the sheets accordingly.

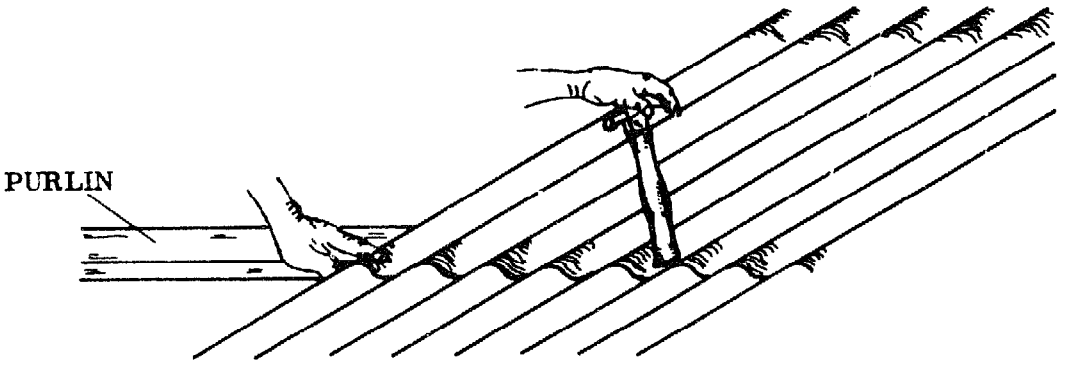

Fig. 1

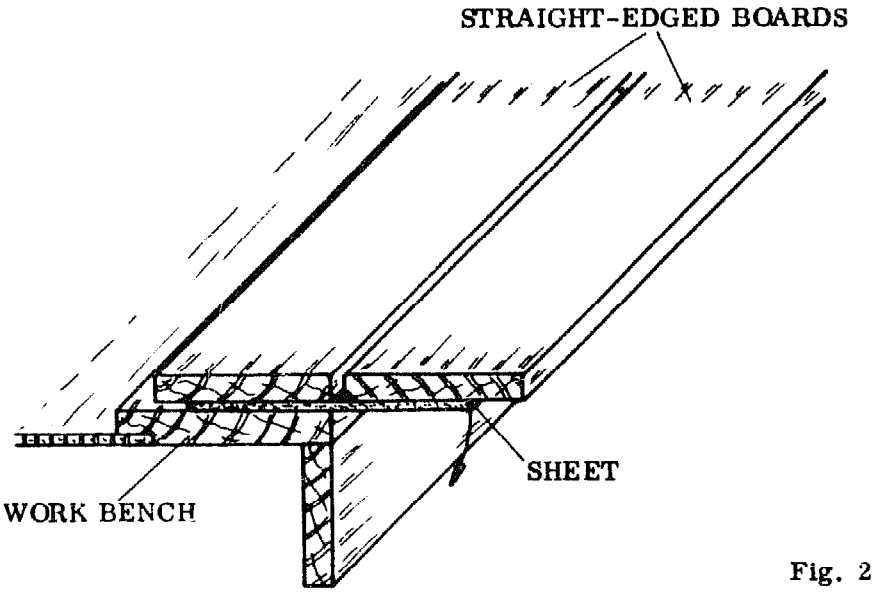

Fig. 2

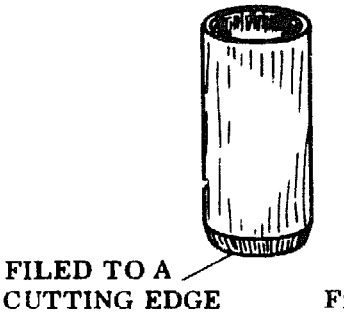

Fig. 3

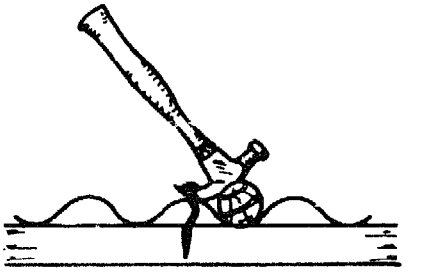

Fig. 4

N P V C		ROOF COVERING.
204	CON.	

SIDELAPS

Since corrugations often get distorted or flattened, it can sometimes be difficult to get an exact and watertight sidelap between the sheets.

To straighten the sheet and get a good sidelap, fix all the required nails in the middle corrugation after first securing the sheet with one nail and checking the straightness. Then press the sheet to the correct position and nail the rest of the sheet (Fig. 1).

Do not try to get a sheet in the correct position by nailing the corners where the 4 sheets meet. This will distort the sheet even more.

RIDGE CAPS

If no ready-made ridge caps are available, they can be made on the site with aluminium or galvanized iron sheets. With the help of two straight-edged boards, the sheets are bent to the required angle on the work bench (Fig. 2).

It is better to make the ridge cap so that the bend goes across the corrugations, rather than along them. This ensures a tighter fit, but the corrugations on both sides of the roof have to match exactly (see Reference Book, pages 231 & 239).

HELPFUL HINTS FOR ROOF COVERING

- Put all nails into the washers with the roofing felt before you start laying sheets, to prevent delays.
- The roofing felt can be cut with an iron pipe that has been filed to a cutting edge at one end (Fig. 3).
- Use soap to make driving nails easier in hard wood.
- There should be people on the ground ready to hand up the sheets.
- Before you put a sheet in place, make a mark on the previous sheet to show where the purlin is for nailing.
- Always use a line at the eave, with supports if necessary to keep it straight.
- Have a long, slim and pointed punch ready. It can be made locally from an iron rod. This punch is used to pierce holes through in places where the nail must pass through 4 sheets. Without piercing the hole for the nail first, there is a danger of flattening the corrugation and distorting the overlap while nailing it.
- If a nail begins to bend and should be pulled out, use a round piece of timber or metal as shown in Fig. 4.

- Be careful in handling the sheets. They have sharp edges which can cut you deeply.
- If a corrugation has been badly damaged through pulling out a nail, try to restore the area around the nail hole to as near as possible the original shape. A round piece of metal can be put under the corrugation to help in this.
- If the sheets have to be cut, do not leave the cut-off pieces lying around. They can still be used for other work.
- Do not leave sheets lying where people might step on them and flatten the corrugations.
- Be sure, especially in seasons where there is a danger of storms, that no sheets are left loosely nailed to the roof, or left on the ground without being weighted down or otherwise secured. A sheet blown around by the wind can easily kill someone.

NOTES:

HEAT PENETRATION - INSULATION

One of the main goals of building in the tropics is to reduce heat penetration into the building. There are a number of building constructions which help to make the building cooler.

- Build in an east-west orientation, so the sun hits directly on only the end walls of the building.
- Construct a verandah to shade the wall.
- Construct overhanging eaves or overhangs to shade the walls.
- Use an open roof construction (no ceilings) on the verandahs, overhangs and overhanging eaves; to permit cross ventilation between the roof and ceilings in the rooms.
- Make ceilings in the rooms so that the sun cannot heat the room directly through the roofing sheets and so that there is cross ventilation between the sheets and the ceiling.
- When possible, use a combination of any or all of the above constructions.

LIGHTENING

To prevent lightening from striking a building, you can install a lightening conductor. This is a pointed copper rod, which is fixed above the highest point of the roof and connected to a copper rod driven into the ground. Long buildings need more than one lightening rod. Follow the manufacturer's instructions to install the conductor.

NOTES:

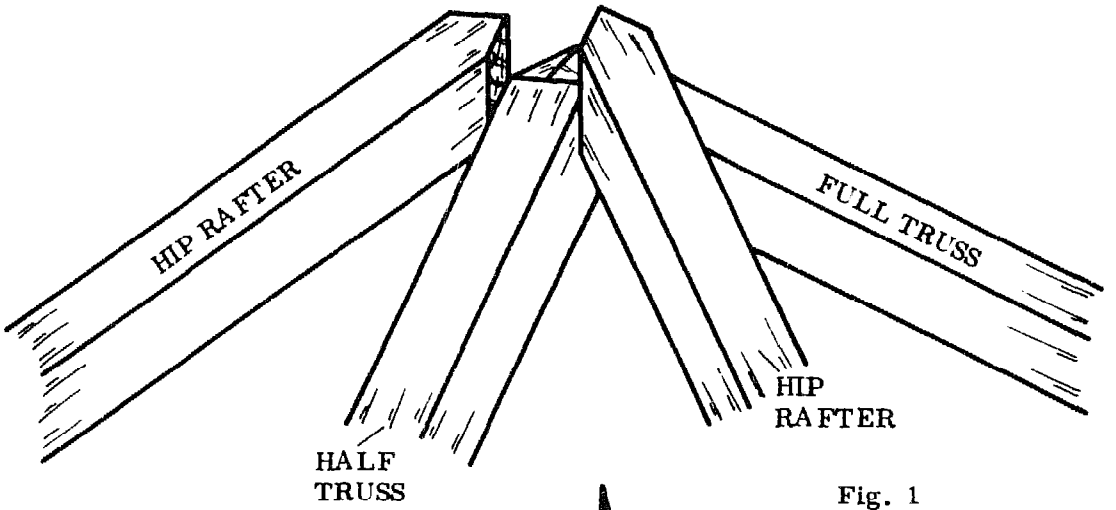

Fig. 1

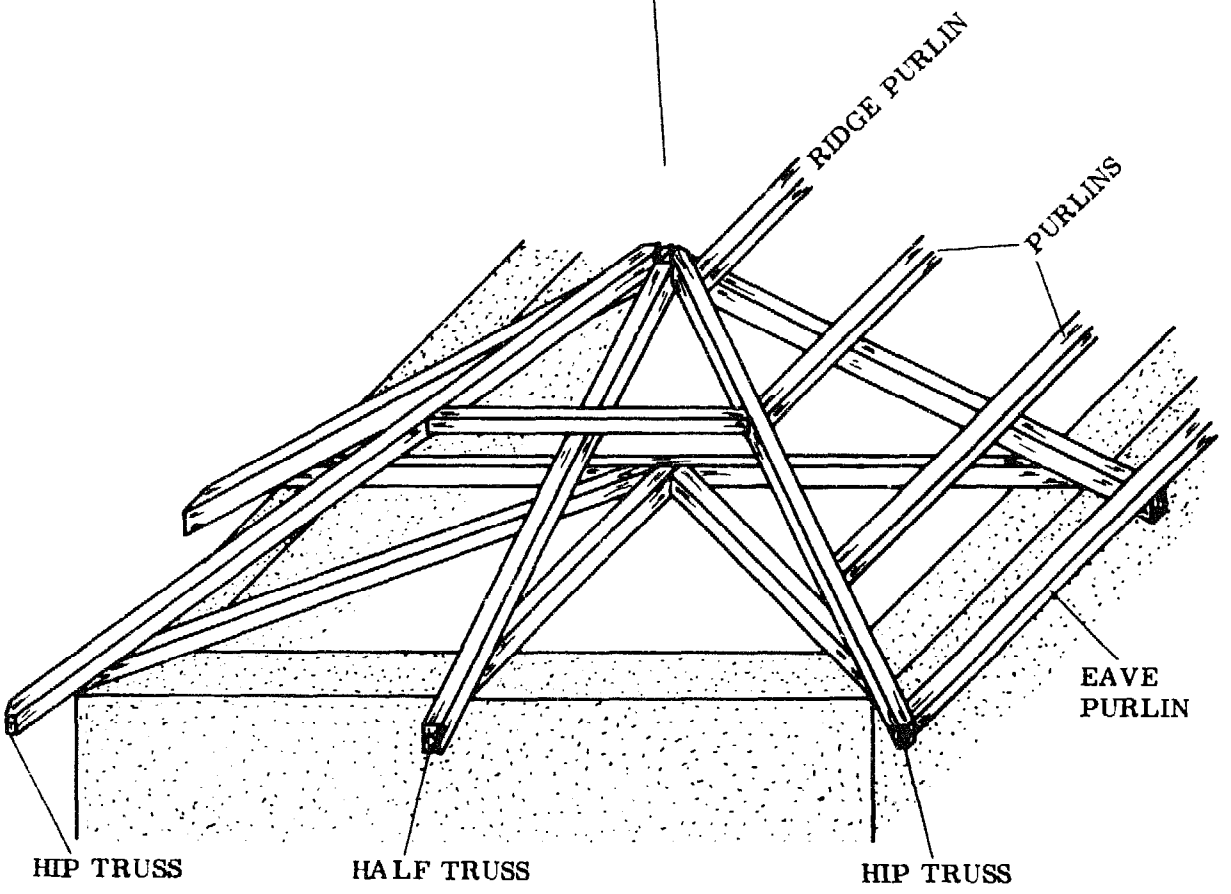

Fig. 2

- NOTE: TO MAKE THE ABOVE DRAWING SIMPLER, BRACES ARE NOT SHOWN.

N P V C		HIP ROOFS.
208	CON.	

HIP ROOFS

A hip roof is often chosen as an alternative to a gable roof. It has a nicer appearance, and it is less vulnerable to suction from heavy winds. However it takes more work to construct it, and requires more timber than a gable roof. Also there is a certain amount of waste involved in cutting the sheets at the corners. The hip roof is more apt to leak unless it is constructed exactly right.

The main part of the construction is the same as for the gable roof. In addition, a half truss and two hip trusses are needed for each hip (Fig. 2).

The two hip trusses run diagonally from the ridge of the last full truss to the corners of the building. The hip rafter has to sit higher than the other rafters, so that the purlins butt into it at the side instead of lying on top of it. This is so that the sheets will be able to fit smoothly around the hip (Fig. 1).

The half truss is set out in the same way as the full truss, with only half the span. If the tie beams of the other trusses will project beyond the walls, the half truss tie beam has to project by the same amount (Fig. 3).

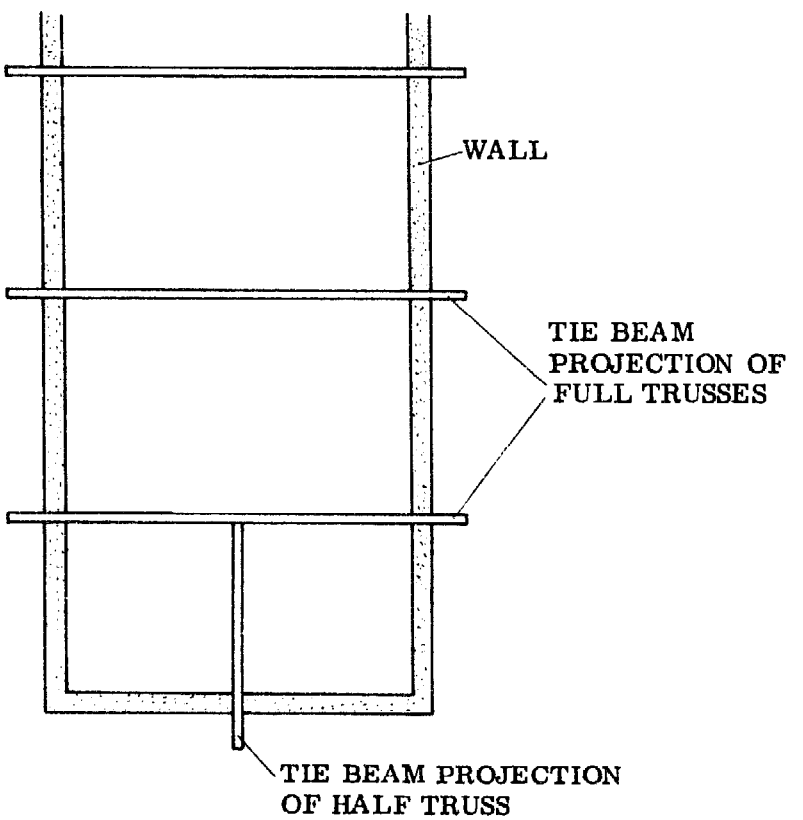

Fig. 3

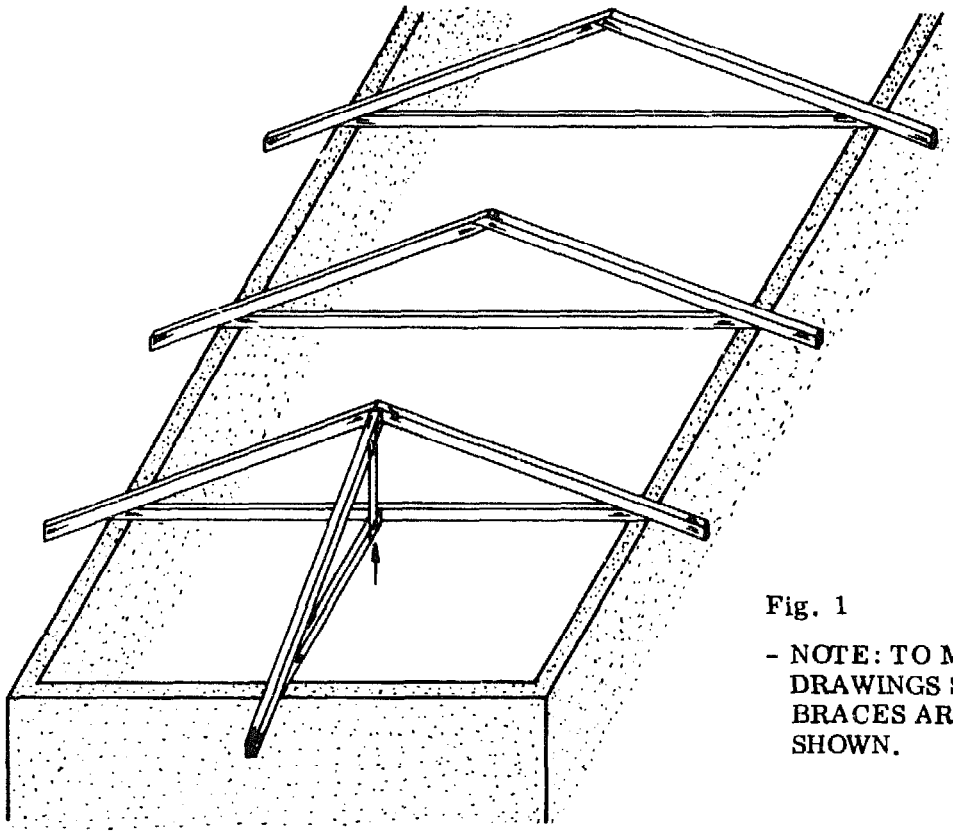

Fig. 1

- NOTE: TO MAKE THE DRAWINGS SIMPLER, BRACES ARE NOT SHOWN.

Fig. 3

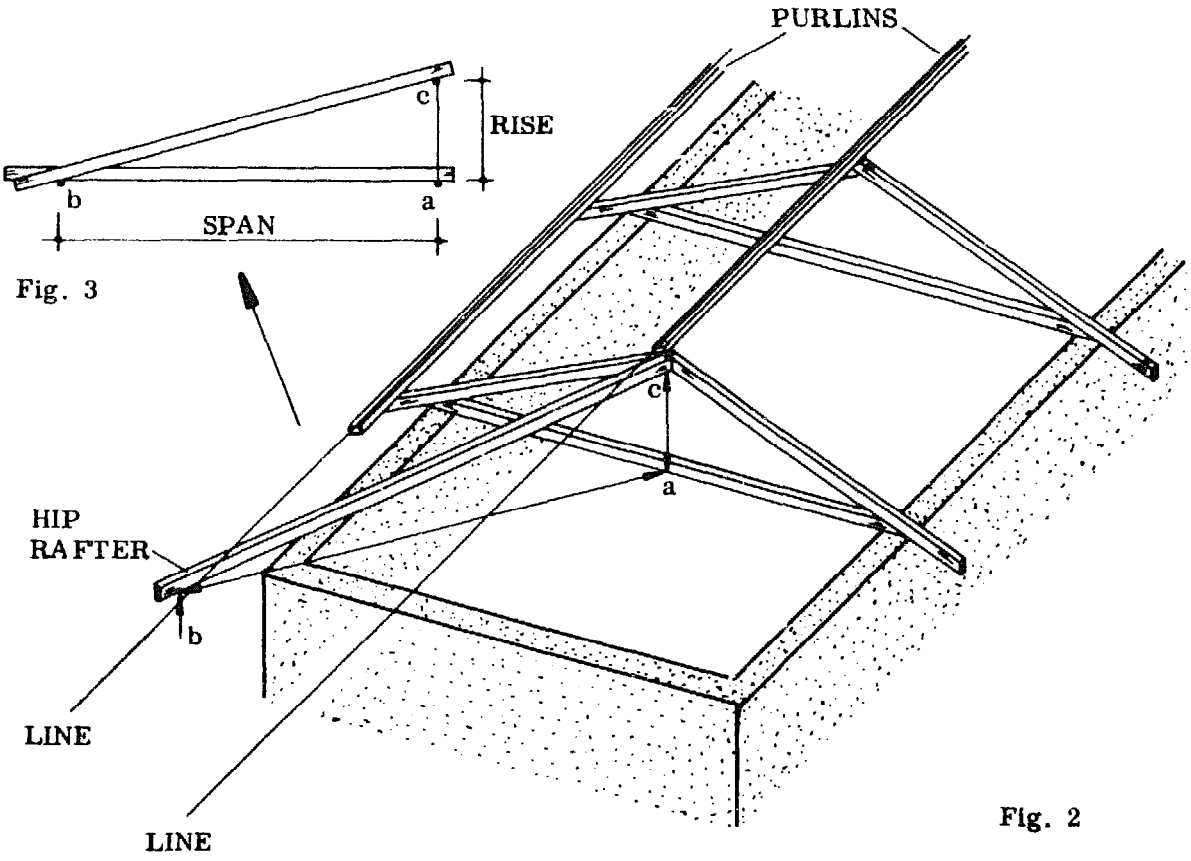

Fig. 2

N P V C		HIP ROOFS.
210	CON.	

SETTING OUT AND CONSTRUCTING THE HALF TRUSS

Before the half truss is fixed, all the other trusses have to be in place.

To assemble the half truss, use the same setting out which was made for the full trusses. Simply construct half of a full truss. The last brace near the ridge should be set back about 10 cm from the end, to leave space for fixing the trusses together (Fig. 1, arrow).

When the half truss is ready, fix it temporarily into place against the full truss. Remember that if the other tie beams project past the walls, the half truss tie beam must also project, by the same distance.

POSITION AND MEASUREMENTS OF THE HIP TRUSS

Follow the sequence below to find the measurements for the hip truss, as well as its correct position.

a. Lay two purlins flatwise near the eave and ridge, across the last 3 full trusses of the roof. Make sure that they are aligned parallel to the wall, and nail them temporarily (Fig. 2).

b. Fix a line along the top surface of each purlin. The lines should extend past the ends of the purlins to the end wall of the building, where they can be held taut by a temporarily fixed pole. The lines must be taut and parallel to the side wall. Each line should touch the whole length of the top surface of the purlin (Fig. 2)

c. Have two men put the hip rafter in position, holding it so that one end is at the ridge and the other end is above the corner of the building. The top surface of the hip rafter should just touch both lines. Thus, the top of the hip rafter is on the same level as the top of the purlins.

d. Now another man can measure the length of the hip truss tie beam, which will be the horizontal distance from the centre of the full truss tie beam (Fig. 2, point a) to the soffit of the hip rafter outside the wall (point b). This distance is the span of the tie beam for the hip truss (see Fig. 3).

e. To obtain the rise of the hip truss, measure the distance from the soffit of the full truss tie beam to the soffit of the hip truss rafter (Figs. 2 & 3, point a to point c).

Now that you have the measurements for the hip truss, you can go ahead to construct it. Measure the other hip truss for the opposite side of the roof in the same manner.

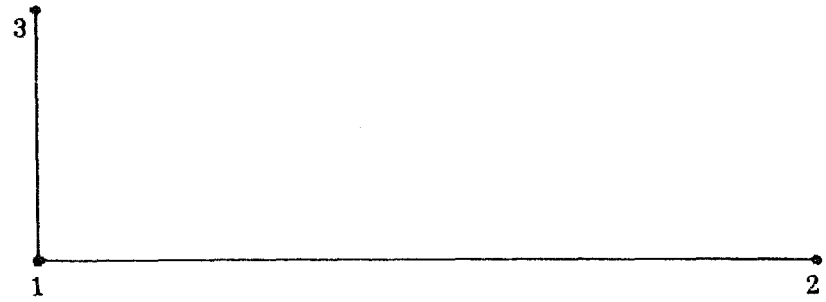

Fig. 1

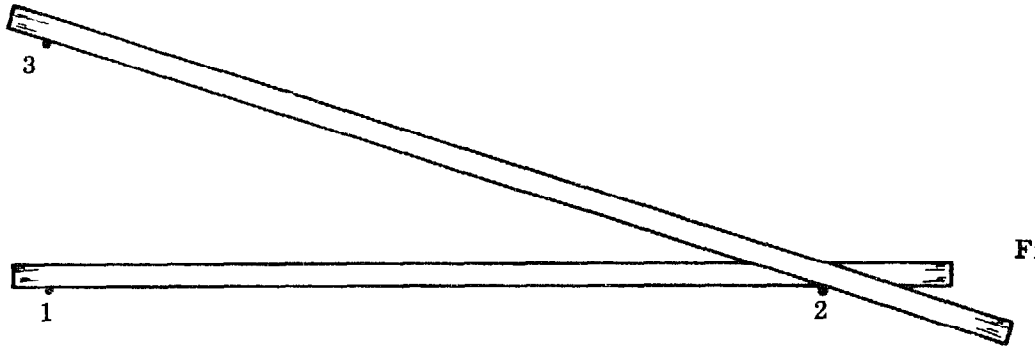

Fig. 2

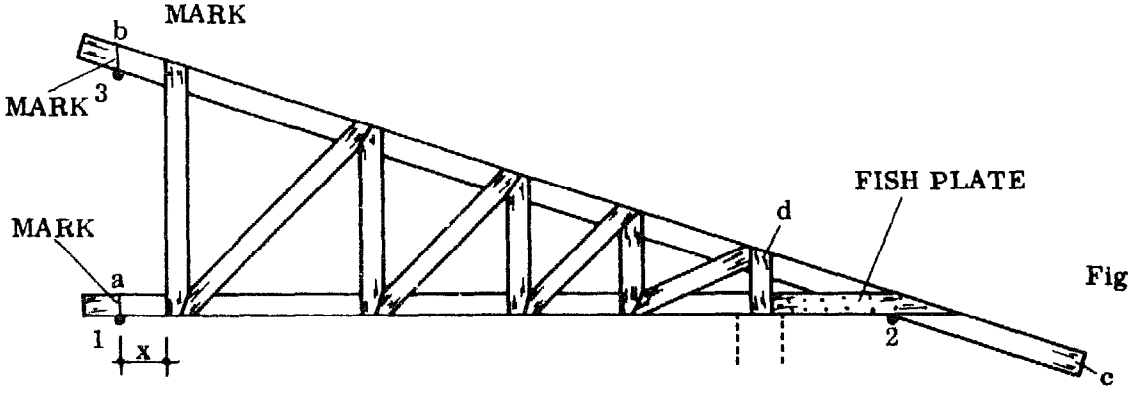

Fig. 3

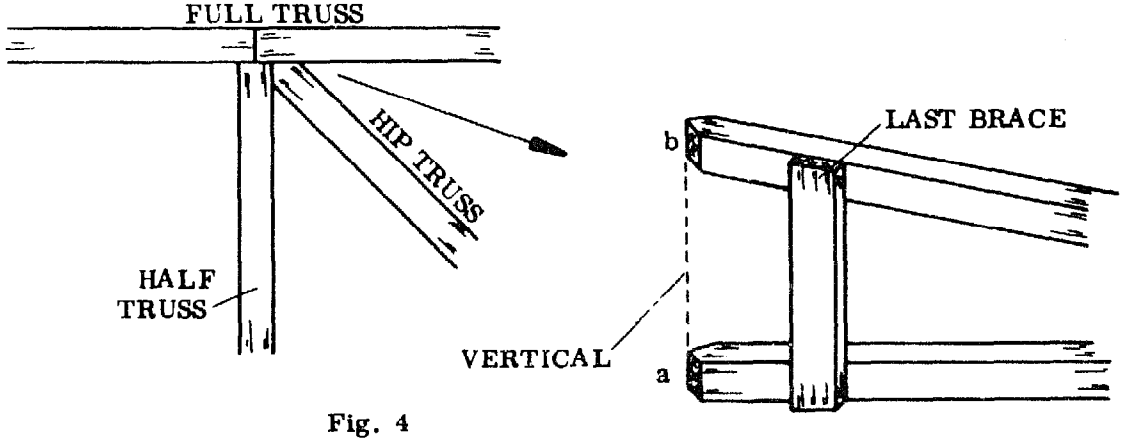

Fig. 4

N P V C	
212	CON.

HIP ROOFS.

CONSTRUCTING THE HIP TRUSS

Look at the hip roof design in the Drawing Book, page 108.

- SETTING OUT:

a. Drive pegs 1 and 2 in the ground at a distance equal to the span of the hip truss (the span is measured as described on the previous page). Fix a line between the pegs (Fig. 1).

b. Fix a line perpendicular to line 1-2, starting from peg 1 (Fig. 1).

c. Drive peg 3 at a distance equal to the rise of the hip truss (Fig. 1).

- ASSEMBLING THE HIP TRUSS:

d. Lay the hip tie beam against pegs 1 and 2 (Fig. 2)

e. Lay the hip rafter against pegs 2 and 3 (Fig. 2). Make sure that the tie beam and rafter are correctly positioned with respect to the pegs.

f. Cut the rafter-to-tie beam joint. Mark the inside end of the tie beam (a) and the inside end of the rafter (b). Make sure that the rafter has a long projection on the eave end (Fig. 3). This projection is trimmed only just before the fascia board is fixed (c).

g. Nail the braces and the fish plates. The last vertical brace on the ridge end is set back (Fig. 3, x) so that there is space to fit the trusses together later. Nail a short vertical brace (Fig. 3, d) where the tie beam meets the supporting wall.

h. Cut the ends of the rafter and tie beam (ends a and b) at a 45 degree angle, as shown in Fig. 4.

i. Assemble the second hip truss on top of the first one.

NOTES:

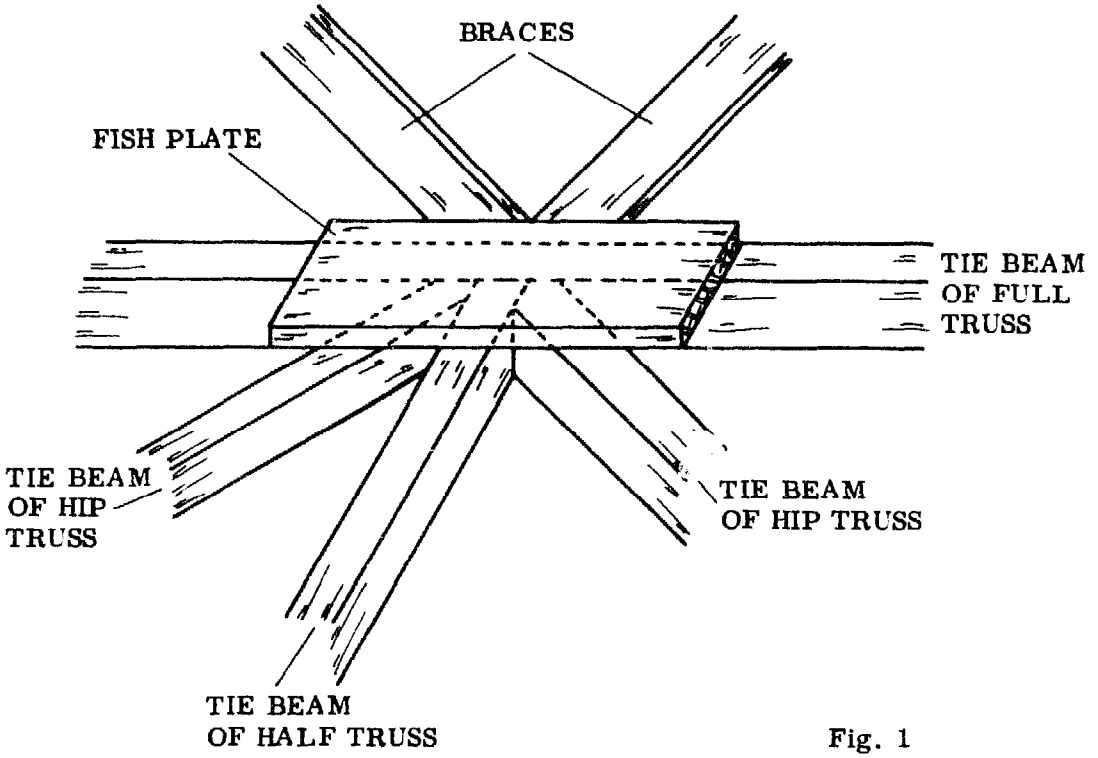

Fig. 1

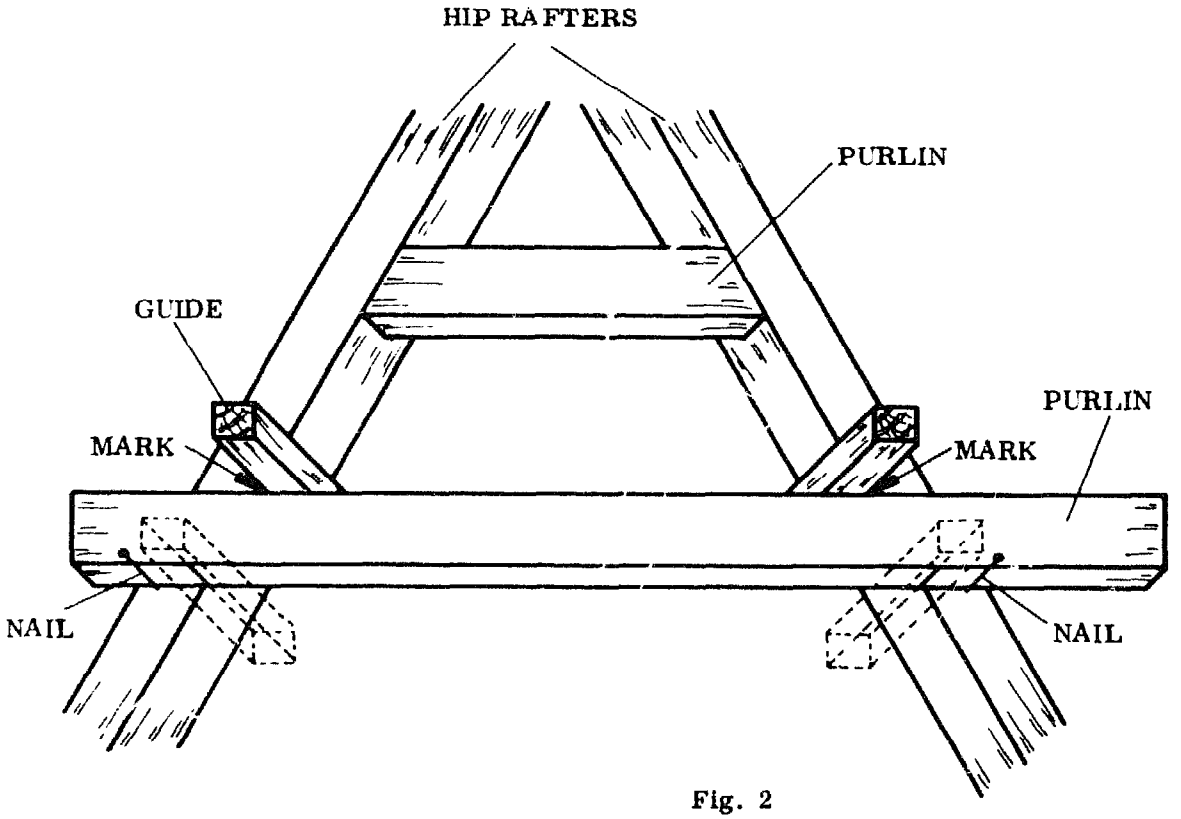

Fig. 2

N P V C		HIP ROOFS.
214	CON.	

ERECTING THE HIP OF THE ROOF

When the half truss and hip trusses are ready, the hip structure of the roof can be erected. The connection between the tie beams of the half truss, hip trusses, and full truss can be made as shown in Fig. 1. The rafter connection is made as shown in Fig. 1 on page 208.

- FIXING THE PURLINS: The purlins which butt against the hip rafter must be cut at exactly the correct angle so that they will fit snugly against the rafter.
  - Mark the positions of the purlins on top of the hip rafters, and insert a nail at the mark to support the purlin during marking (Fig. 2).
  - Place the purlin against the nails and mark the cutting lines. Use a short piece of wood as a guide (Fig. 2). Make the marks on both sides of the purlin at once, then mark both sides at the other end.
  - Cut the butt joints and fix the purlin.

  Fix the rest of the purlins in the same manner. The layout for the purlins on a roof with a single sheet length on each side is shown below (Fig. 3).

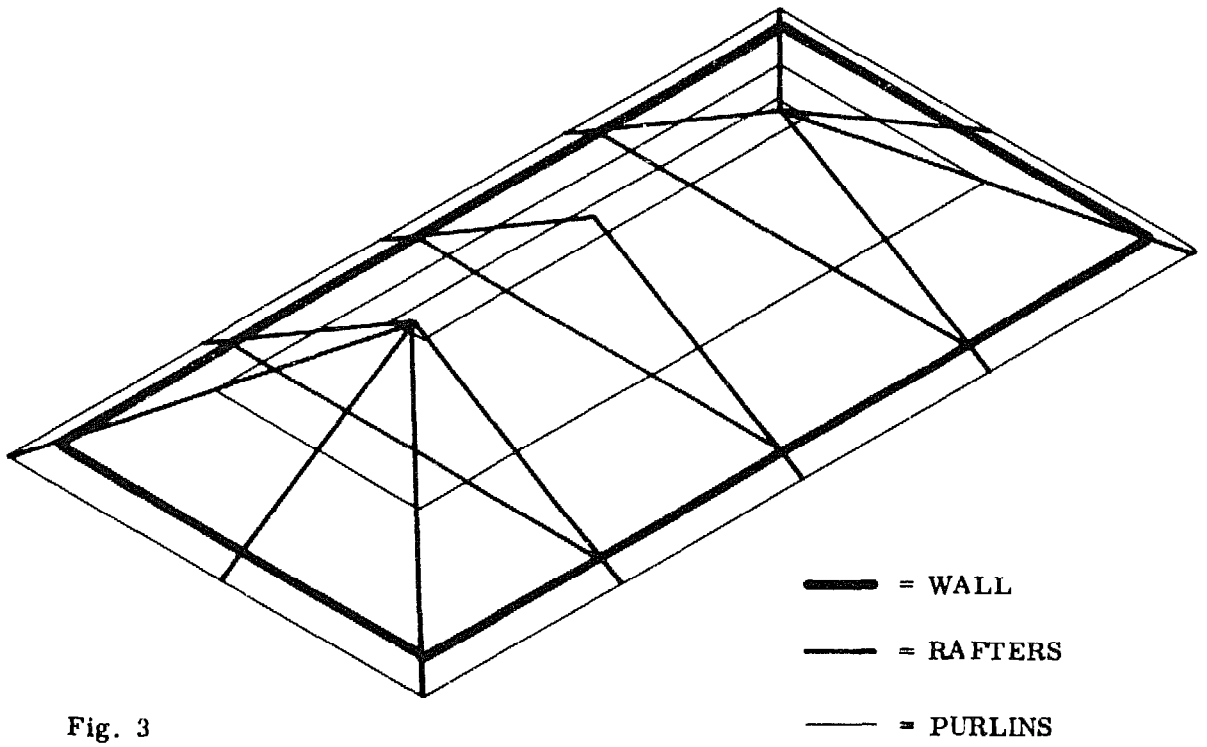

Fig. 3

- NOTE: TO MAKE THE DRAWING SIMPLER, BRACES ARE NOT SHOWN.

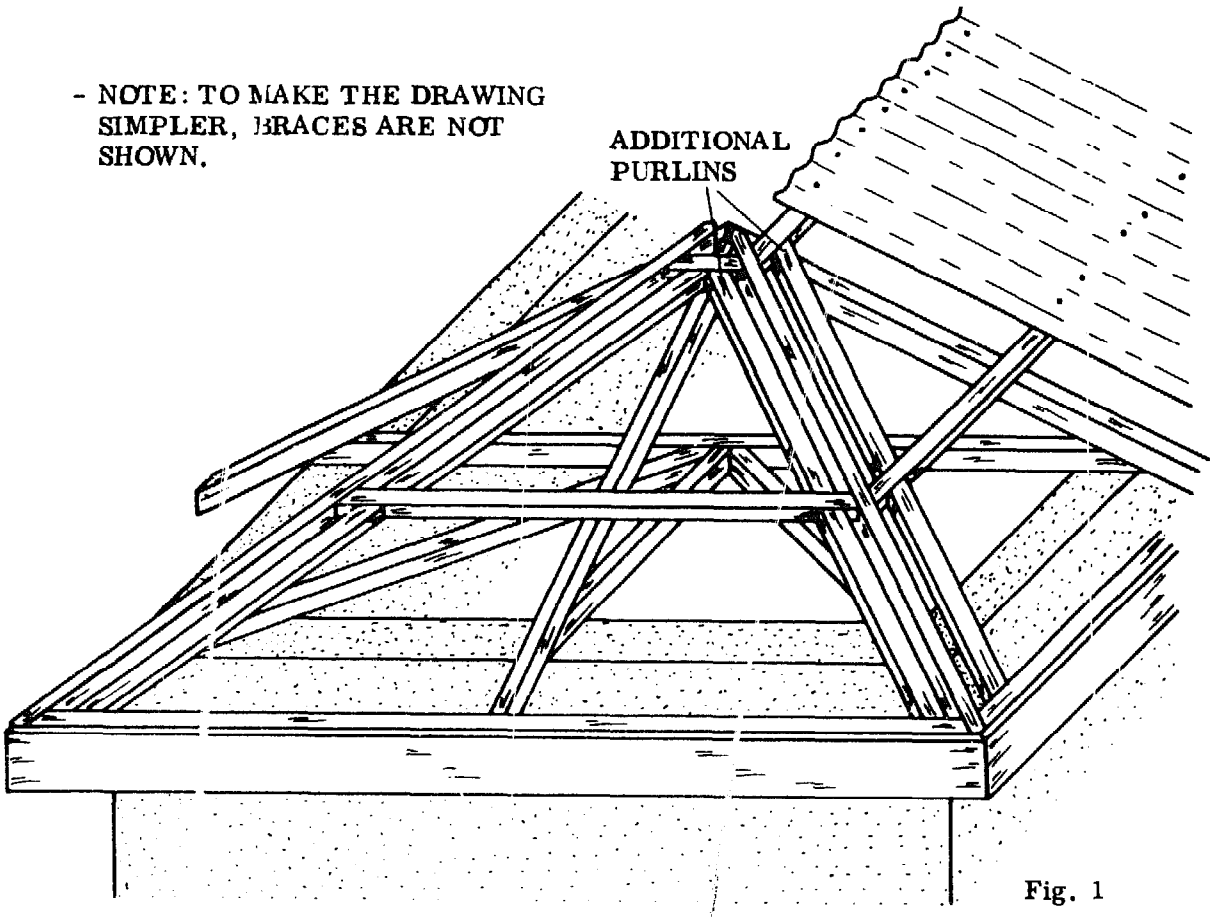

Fig. 1

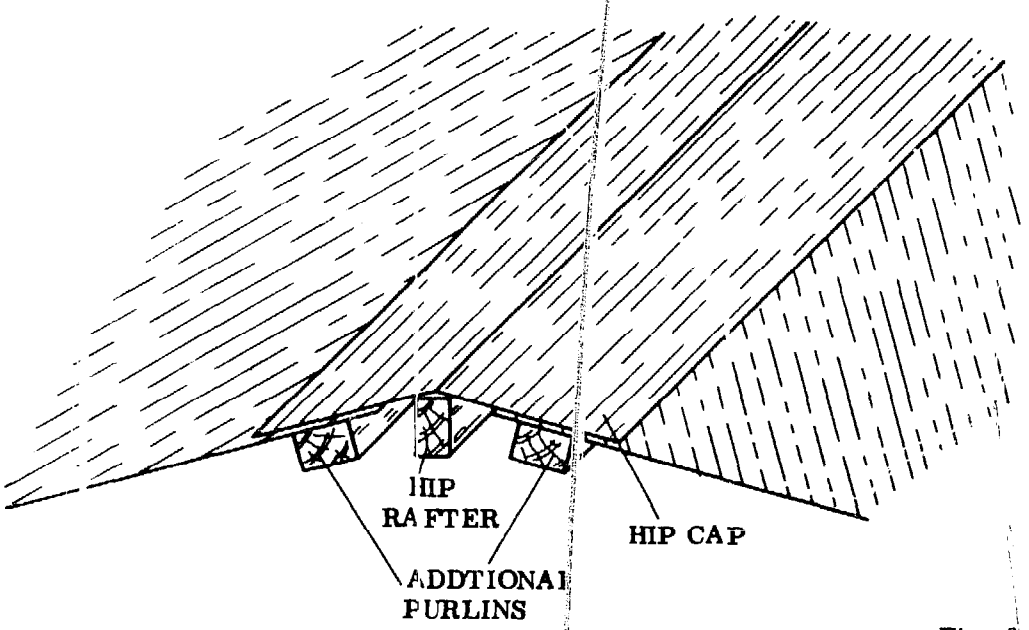

Fig. 2

N P V C		HIP ROOFS.
216	CON.	

COVERING A HIP ROOF

Nail two purlins parallel to the hip rafters, as shown in Figs. 1 and 2. The extra purlins provide more area for nailing the hip ridge cap.

Lay the first sheet at the hip rafter in position and mark with a straight edge where it should be cut. Cut the sheet and nail it in position before you mark and cut the next sheet. Continue in this way until the hip is covered.

A hip cap, similar to the ridge cap, must be used to cover the hip line, where the sheets meet. If no ready-made caps are available, one can be made as explained on page 205.

NOTES:

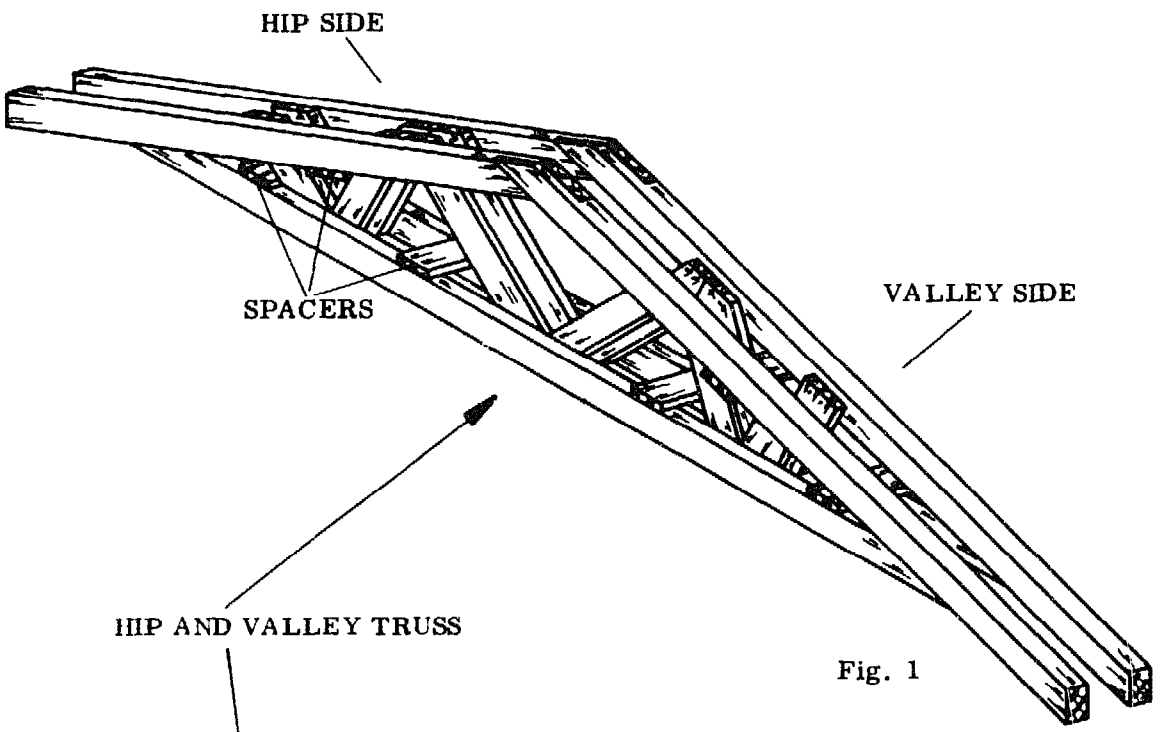

Fig. 1

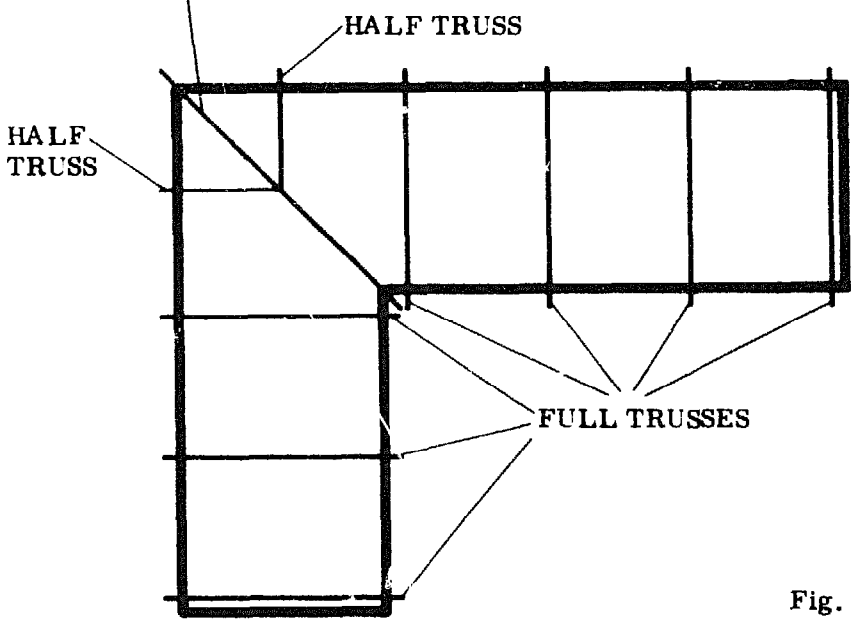

Fig. 2

N P V C	
218	CON.

HIP AND VALLEY ROOF.

HIP AND VALLEY ROOF

When a roof is constructed for an L- or U-shaped building, a hip and valley roof is normally used.

The main problem of this construction is to make a truss which provides sufficient nailing area for the valley and also for the hip. This is solved by assembling two trusses, with spacers in between to connect them (Fig. 1). The spacers provide the required distance between the trusses. This distance is important, because the valley should be wide and deep enough so that rain can run down it easily and so it does not get blocked by leaves (Fig. 1).

As in the hip roof, the hip rafters and the valley rafters must be set higher so that the purlins meet them at the sides, and don't lie on top as they do with the other trusses.

If a large span must be covered with a hip and valley truss, it may be necessary to add some half trusses onto the hip and valley truss to provide enough support for the purlins (Fig. 2).

NOTES:

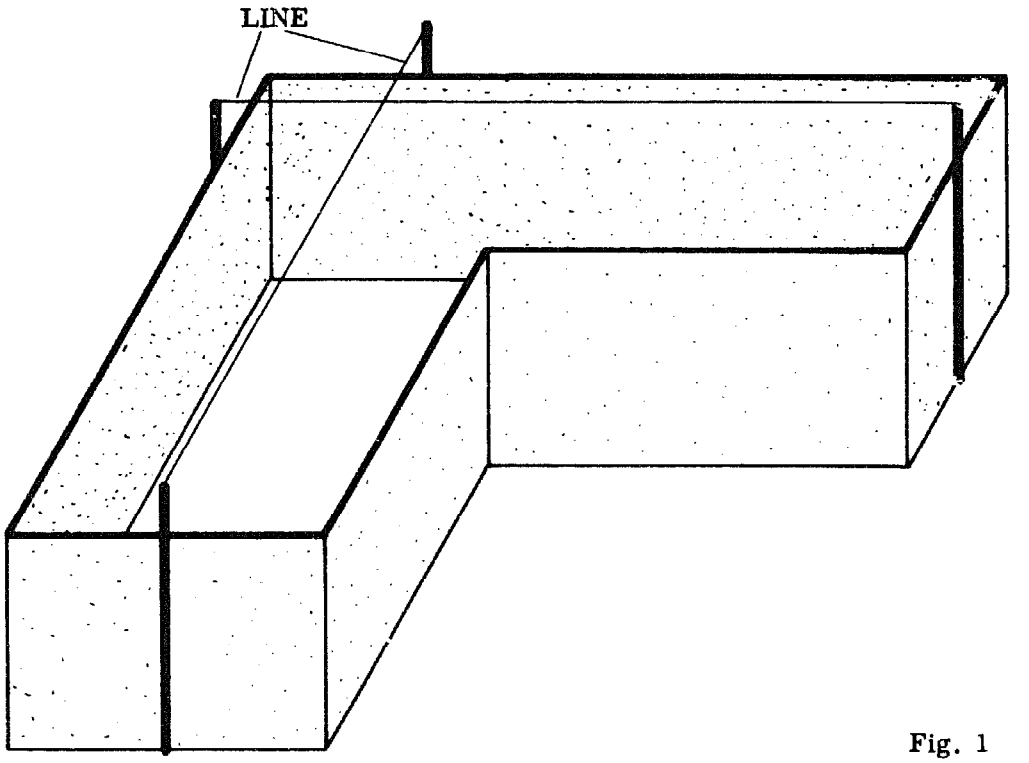

Fig. 1

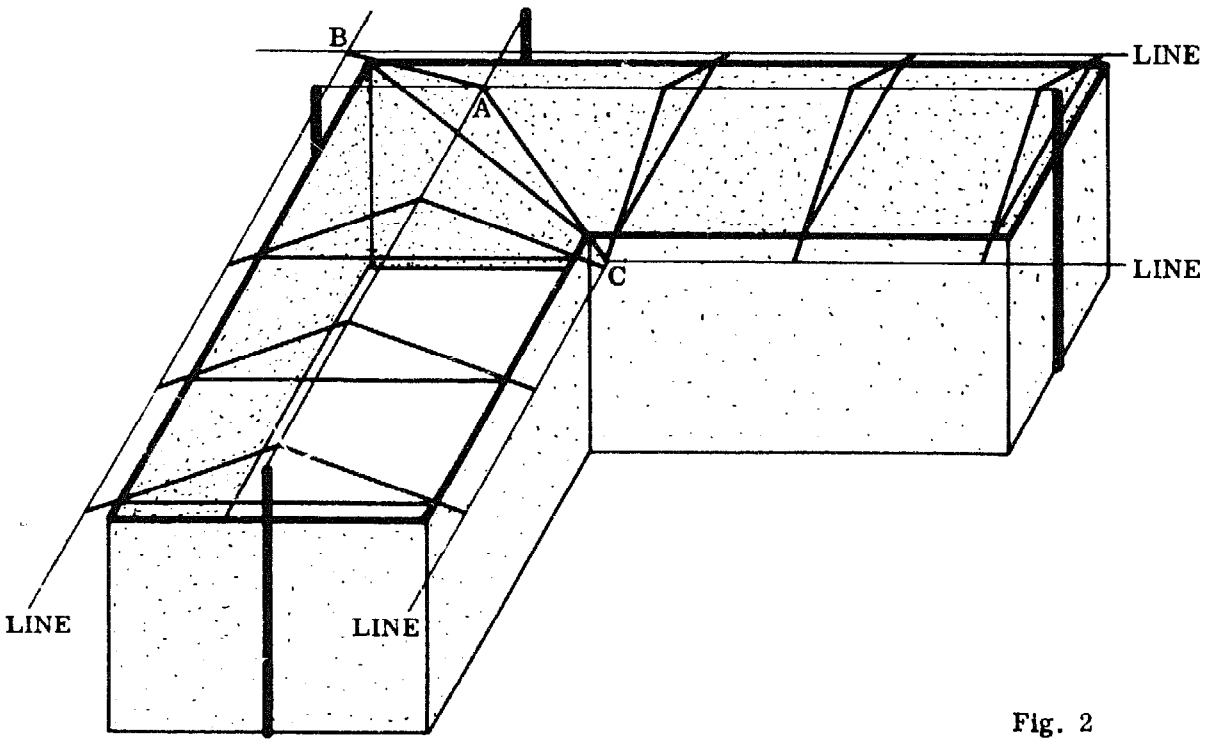

Fig. 2

N P V C	
220	CON.

HIP AND VALLEY ROOF.

POSITION AND MEASUREMENTS OF THE HIP AND VALLEY ROOF

- Start by erecting poles in the positions shown in Fig. 1, and fix lines at the ridge.
- Erect the ordinary trusses according to the lines in their correct places (Fig. 2). Refer to the section on erecting a gable roof, page 191.
- Lay purlins temporarily on top of the rafters, as was done with the hip roof (page 211).
- Fix lines parallel to the walls along the tops of these purlins, at eave height on both sides of the roof (Fig. 2).
- Set the ridge lines higher, by the amount of the purlin thickness (Fig. 2).
- Now you will have three points where the lines cross. These are: point A at the ridge; point B at eave height, and point C on the other side at eave height (Fig. 2). These points mark the outer surfaces of the hip and valley truss.
- Next construct a lightweight, temporary model truss. Hold it in position on top of the roof (Fig. 3). Adjust it until points A, B, and C touch the outer surface of the truss.
- Now the model truss will have the correct dimensions and can be used as a model for constructing the two trusses of the hip and valley truss.

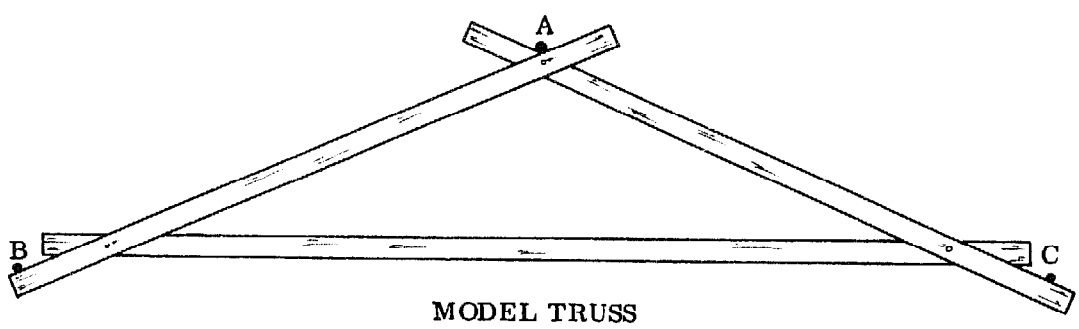

MODEL TRUSS

Fig. 3

NOTES:

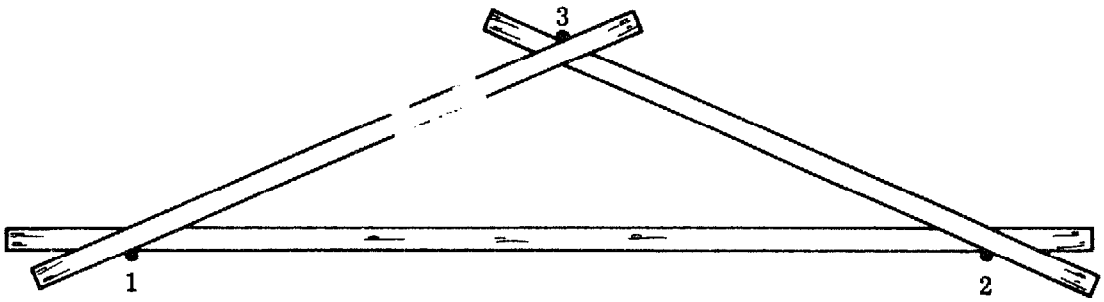

Fig. 1

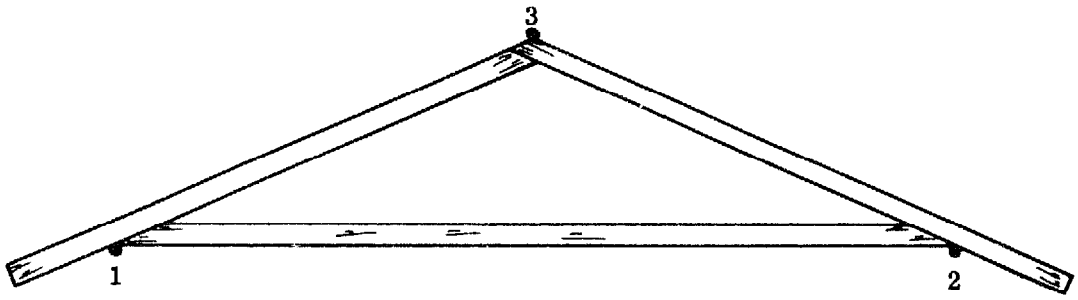

Fig. 2

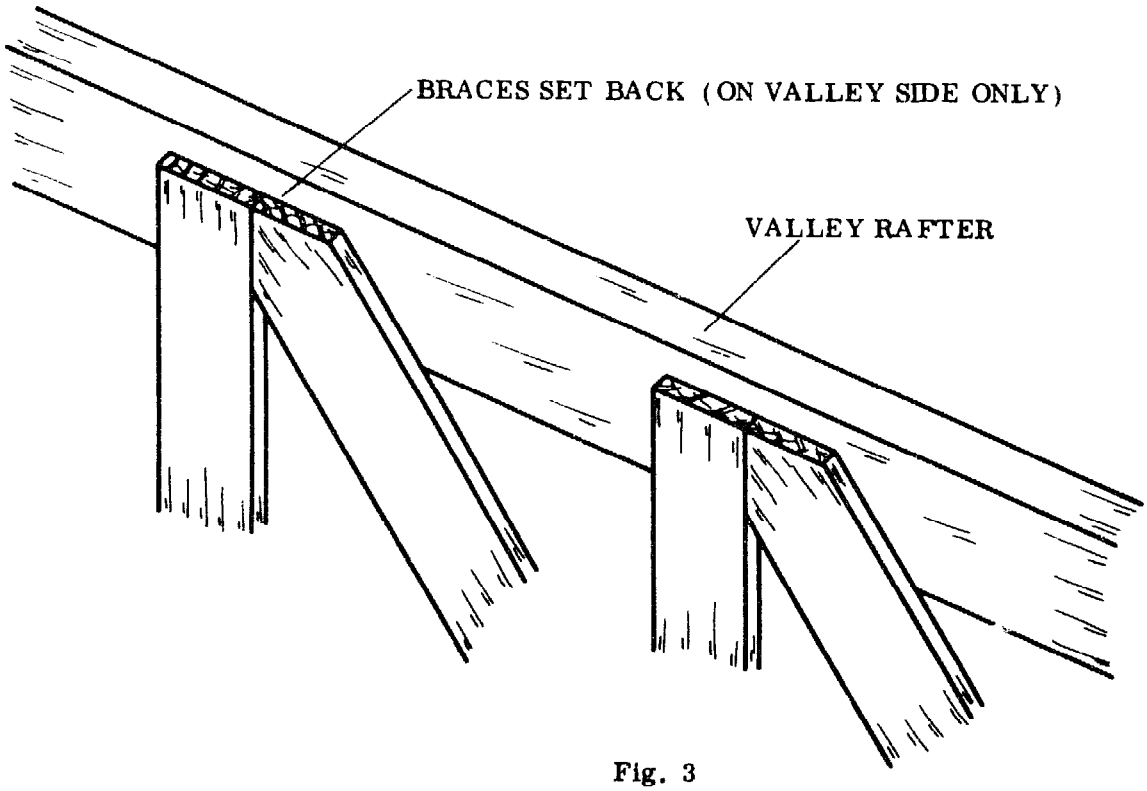

Fig. 3

N P V C		HIP AND VALLEY ROOF.
222	CON.	

CONSTRUCTION OF A HIP AND VALLEY TRUSS

Take the model truss down and set it on the ground in a cleared and level spot.

- Place an iron peg at each side of the model where the rafters meet the tie beam (Fig. 1, pegs 1 and 2) and one peg at the ridge (peg 3). Remove the model truss.
- Now lay the actual tie beam on the ground against the pegs.
- Lay the two rafters on the ground in the correct positions. Be sure that the members are in the correct positions with respect to the pegs, as in Fig. 1.
- Cut the rafter-to-tie beam joint, and the ridge joint (Fig. 2).
- Nail the braces. Take care that the braces are set back from the top of the rafters on the valley side, so there is room to construct the valley later (Fig. 3).
- Assemble the second truss on top of the first one. Be careful to nail the braces so that later when the two trusses are combined, the braces will all be on the inside (Fig. 4).
- When both trusses are ready, they can be set in place on top of the wall. Then the spacers can be nailed to keep the trusses at the correct distance apart. Remember that the distance between the trusses should be wide enough (approximately 15 cm) to provide a wide valley.

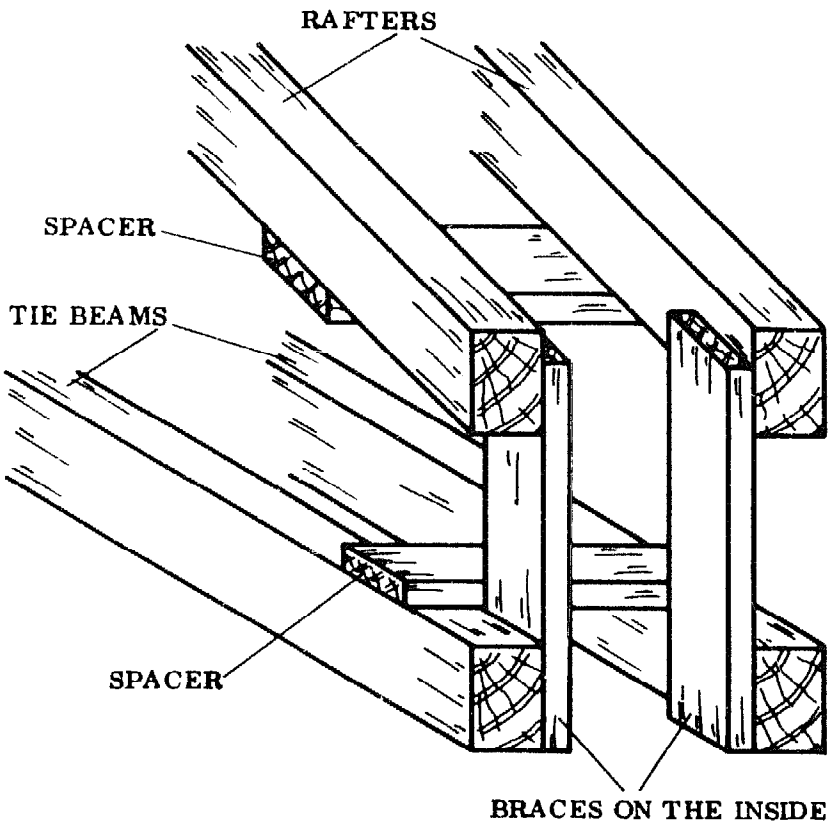

Fig. 4

HIP AND VALLEY ROOF.	N P V C	
	CON.	223

COVERING A HIP AND VALLEY ROOF

First fix the fascia boards and the purlins. Fix a line at eave level and cut the rafters according to this line. Then nail the eave purlin and the fascia boards.

At the place where the fascia boards meet at the valley, cuts have to be made in the fascia boards according to the shape of the gutter (Fig. 1).

Now fix the gutter in the valley. Lay a strip of sheeting metal lengthwise in the valley in the form of the required gutter. Fix it there temporarily with nails. The final fixing will be done as the other sheets are laid, since they have to be laid on top of the gutter. The overlap for the gutter sheets should be about 30 cm in the length.

Now lay the first sheet into position at the valley, mark and cut it. Nail this sheet and place the next sheet in position. Continue in this way until the hip and valley are covered.

Install the hip cap as explained for the hip roof.

The ridge cap on the main ridge is always covered last, since it has to overlap all the rest.

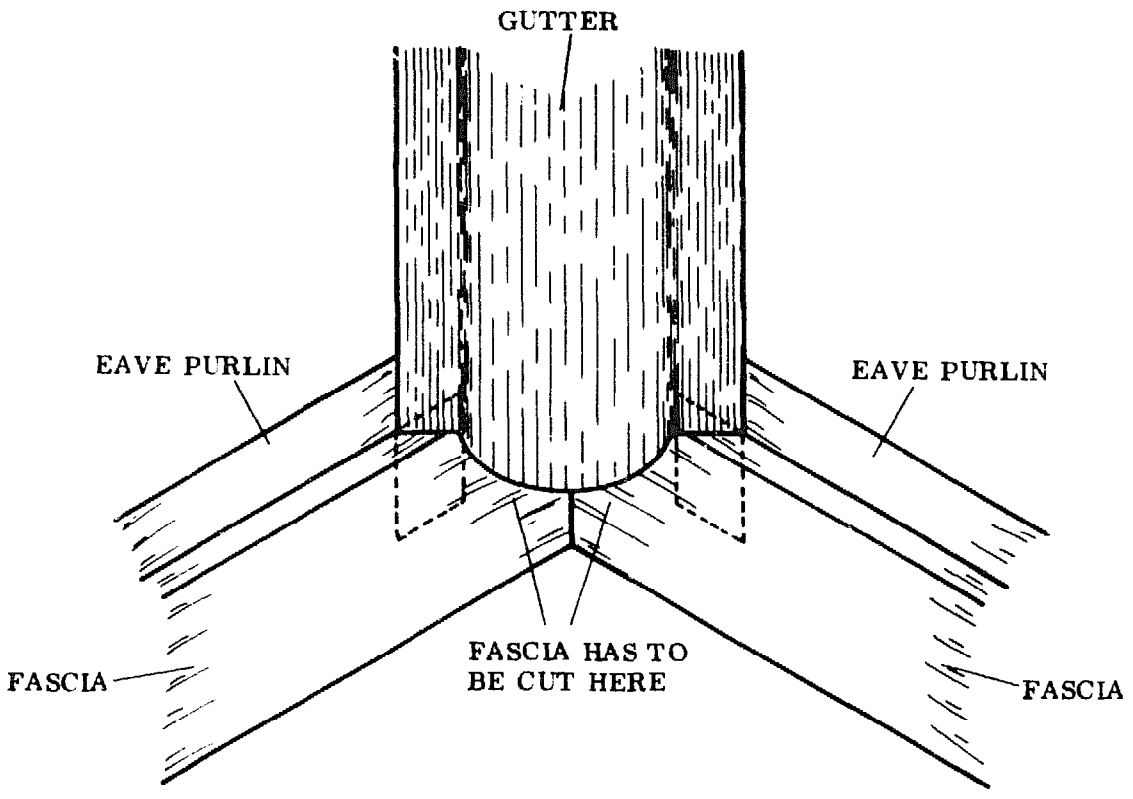

Fig. 1

N P V C		HIP AND VALLEY ROOF.
224	CON.	

PLASTER AND RENDER

Plaster or render is a mortar coating over the blockwork. We call the coating on the inside walls "plaster" and the coating on the outside walls "render". The main difference between the two is that render is generally richer in cement than plaster, because it has to be weather resistant. In the following pages we will refer to the application of either plaster or render as "plastering".

The function of the plaster inside is to make the walls smooth so that they are easier to clean, free of insect hiding places, and have a better appearance. Also, if the house is constructed out of wood or bamboo closed up with mud or clay, the plaster acts as a protection against fire.

The render on the outside surface of the walls is essential to protect them from the influence of the weather, especially if landcrete blocks or mud blocks are used. When these blocks are exposed to moisture for long periods, they gradually become soft, expand, and finally crumble away. The render must therefore be water resistant.

- All external walls should be covered with render. The sides of the building that face the heaviest weather (in north-western Ghana, this comes from the north-east) should be covered with a somewhat richer mix (Fig. 1, a, next page).
- All so-called wet rooms such as bathrooms, toilets, kitchens, and washing areas should be plastered and painted. (Fig. 1, next page: K = kitchen; S = shower; and W = washing area.)

COMPOSITION OF PLASTER OR RENDER

In Rural Building, plaster or render consists of cement, sand, and water. Lime can be added to the mix, but this is not always available.

Sharp and relatively coarse sands are preferred for render, although they produce a mortar which is not easy to work with. The size of the grains should be no greater than 5 mm; the sand should be well graded (Reference Book, pages 148 and 149); and it should not contain more than 20% very fine particles (powdered sand).

The sand for plaster should be well graded, but less coarse than sand for render (see Reference Book, page 159).

- MIX PROPORTIONS: The mix proportion for plaster need not be better than 1 : 8, and may be as low as 1 : 12. The exception to this is the plaster for an

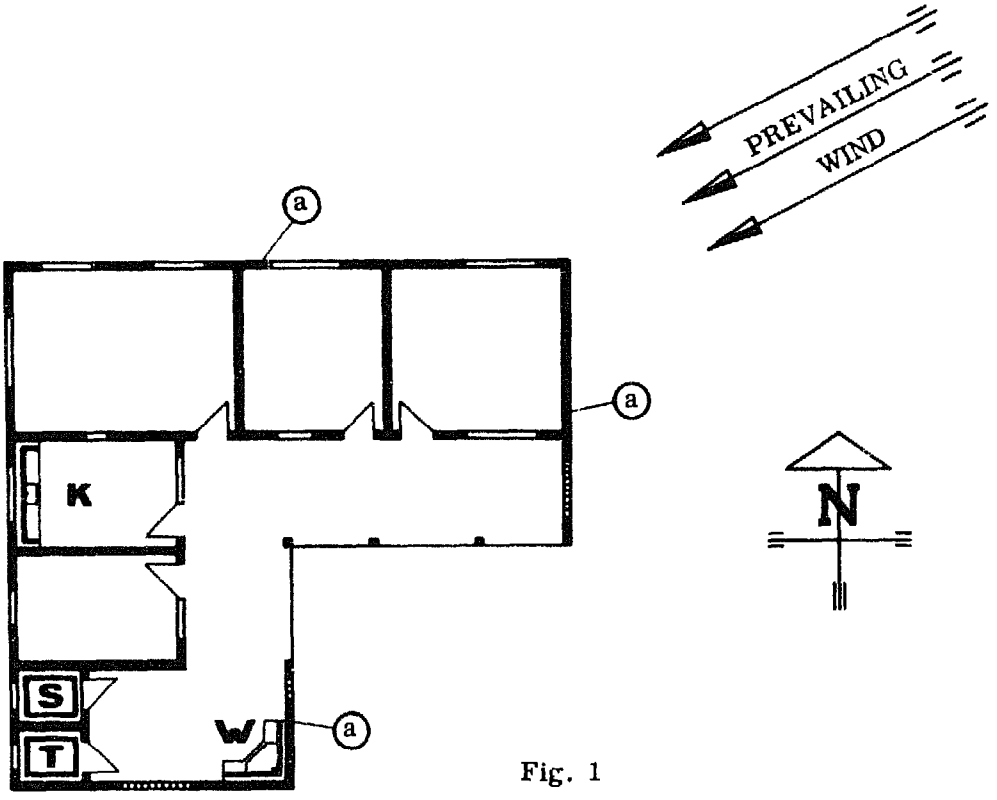

Fig. 1

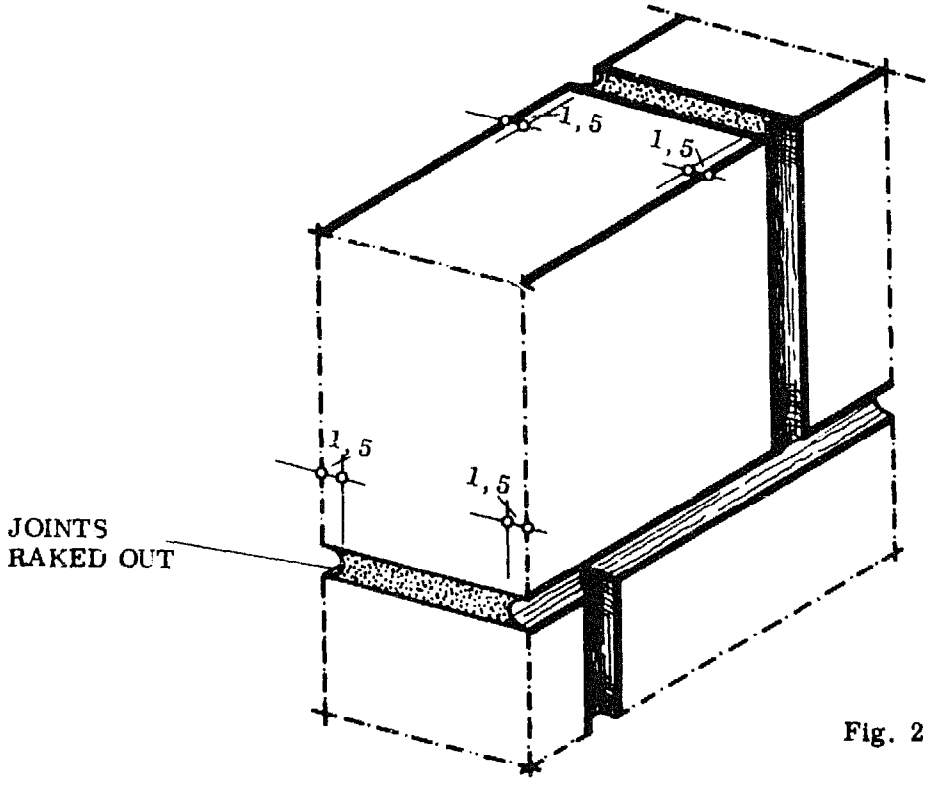

Fig. 2

N P V C	
226	CON.

PLASTER AND RENDER.

area which is often wet, such as a bathroom or washing area. These should be plastered with a mix of about 1 : 6.

The mix proportion for render should never be better than 1 : 6; this is for the north and east sides of the building (or whatever direction the heaviest rain comes from). The other sides of the building can be covered with a mix which is at least 1 : 10 (see the Reference Book, Tables of Figures, page 234).

Exceptions are made for special structures which need waterproof plastering, such as water storage tanks, septic tanks, inspection chambers, manholes, etc. The mix proportion of the plaster used on these may vary from 1 : 3 up to 1 : 1, because the permanently moist surfaces keep cracks from developing.

- REMEMBER: The richer the mix, the more likely it is to develop cracks. Save materials and money by following the rules for correct mix proportions.

PREPARING THE WALL FOR PLASTERING

During the blockwork as the wall is built-up, the first measure is taken to prepare the wall for plastering: the joints are raked out to a depth of approximately 1,5 cm (Fig. 2). This is done immediately after each course is completed. Raking out the joints gives the plaster or render a better grip to the wall.

Before any plaster or render is applied, the wall must be brushed to remove the dust and dirt which would weaken the grip of the mortar. The masonry must then be thoroughly watered, especially during the dry season. This reduces the absorption of water from the freshly applied mortar, so that the mortar hardens well.

- NOTE: Some experiments at NPVC have shown that the landcrete surface can be improved by leaving the walls exposed to one or two short rains before plastering. The rain washes out the finer particles, leaving a rough surface which bonds to the plaster or render better. This method is risky however, because it is impossible to tell in advance how long the rain will last and how heavy it will be.

APPLICATION TECHNIQUES

- SPATTERDASH: In order to give a good grip on smooth surfaces such as sandcrete, or to reduce the amount of moisture absorbed from the freshly applied mortar, spatterdash may be applied before plastering. This is done with the spatterdash apparatus (see Basic Knowledge, page 178), using a very wet and rich mix (1 : 3, up to 1 : 1). The spatterdash layer is never more than 5 mm thick.

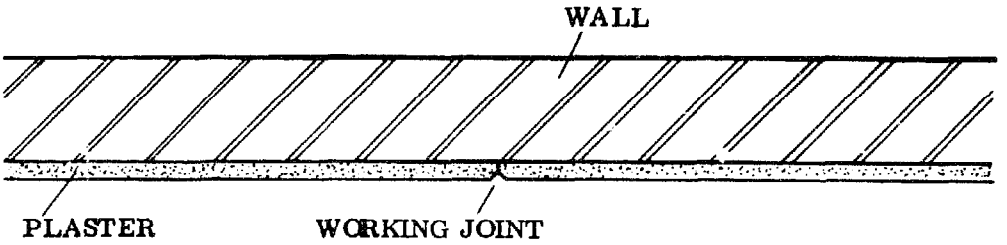

Fig. 1

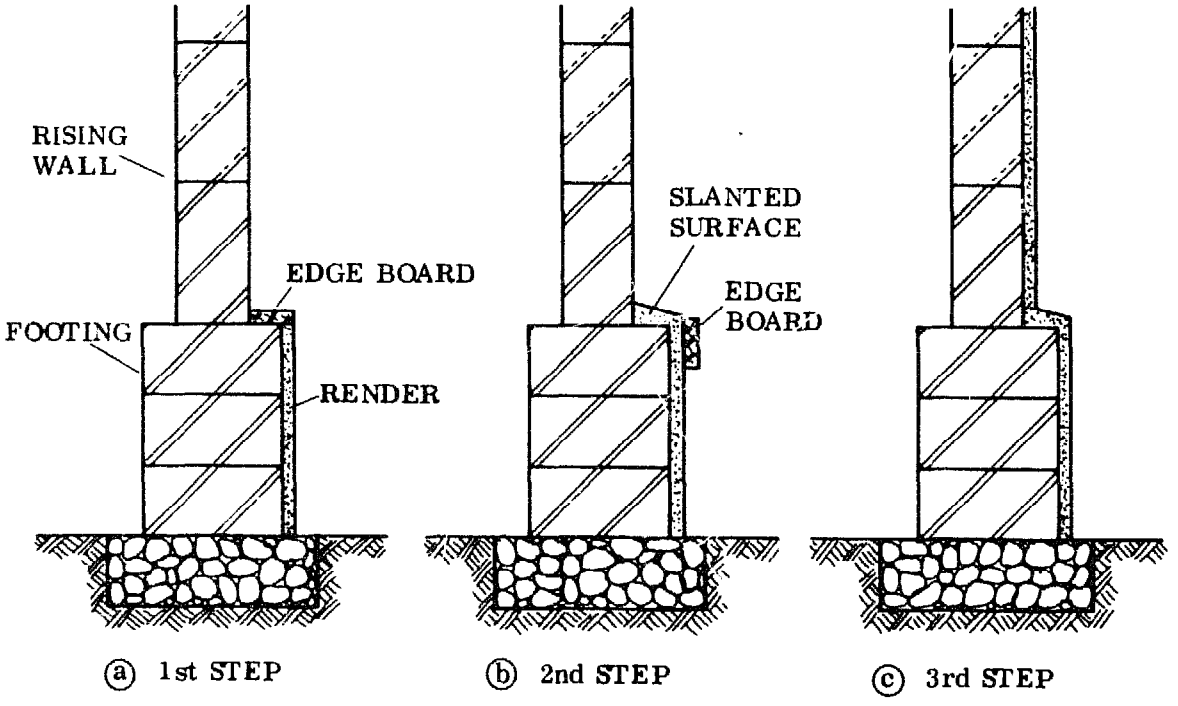

Fig. 2

N P V C	
228	CON.

PLASTER AND RENDER.

The plaster or render is generally applied in a single layer on top of the spatter-dash, or else directly on the blockwork surface. This layer will be 15 to 20 mm thick.

Sometimes a second coat or finish coat is applied on top of the first layer. This must be done before the first layer has hardened. The second coat is usually made where the plaster has to be very thick, for example where the wall is very uneven so that a thick coat of plaster has to be applied to get a smooth surface. The second coat should be about the same mix as the first coat, and about 5 mm thick.

Don't start plastering on a wall which is in direct sunlight. This would cause the render to dry out too quickly, resulting in a "burnt" render which is useless.

Instead, start plastering in the early morning on the west side of the building, going clockwise around the building to the north, east, and south sides so that the freshly plastered areas are always in the shade.

Areas which are too large to be completely plastered in one day are divided into smaller areas by introducing working joints (Fig. 1). The joints should always be vertical, so that water will flow away as quickly as possible from the joint.

In Rural Building, the inside of the building is generally plastered after the roofing is completed.

- PLASTERING THE FOOTINGS: Here we must add a note about the footings. These have to be plastered before the rising wall. This is done as shown on the left (Fig. 2; a, b, & c).

  An edge board is laid on the ledge of the top of the footings, and the vertical surface below is plastered according to the procedure explained on the following pages.

  Next the ledge is plastered. The render must form a slanted surface so that water runs away from the wall. It is important that this slanted surface is made before the rising wall is plastered, because otherwise the joint between the two would allow water to enter (Fig. 2; b & c).

NOTES:

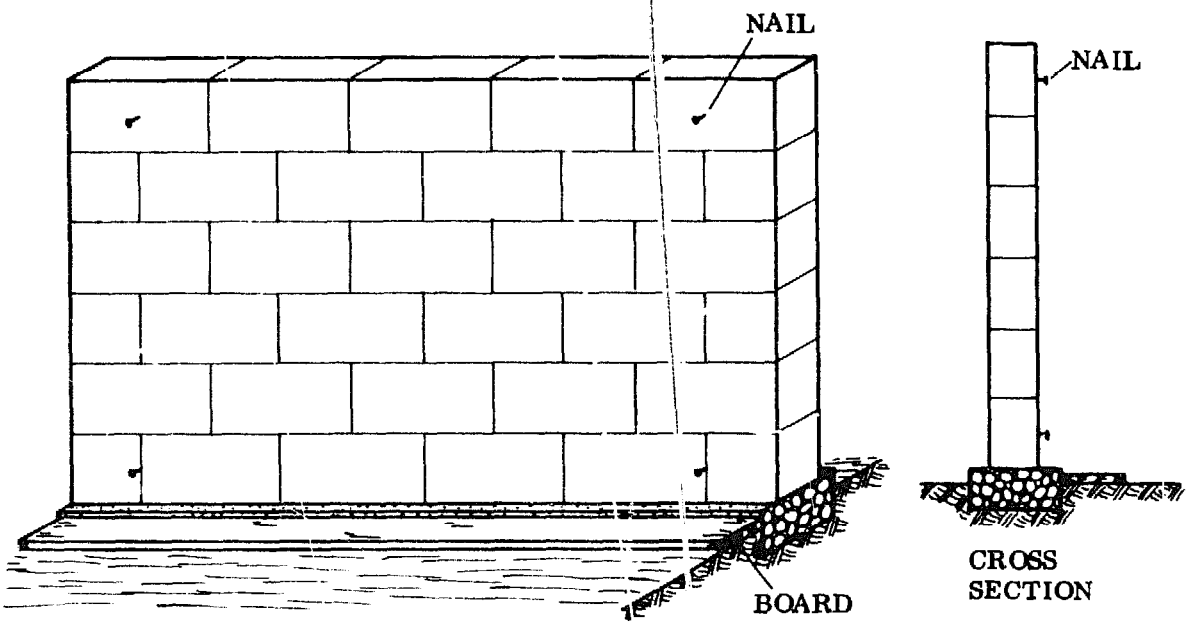

SEQUENCE OF OPERATIONS FOR PLASTERING A STRAIGHT WALL

a. Study the wall which is to be plastered; notice the holes and projecting parts.

b. Clean the wall with a hard brush and chisel off any projecting blocks.

c. Soak the wall thoroughly with water; try to wash off the loose particles. Clean the wall very well, especially the area near the footings and the footings themselves.

- NOTE: In the drawings here the footings have been left out, to make the drawing simpler. The plastering of the footing - rising wall connection is made as explained on the previous page.

d. Place boards against the foot of the wall to catch the mortar which is dropped.

e. Prepare some mortar which is of the same strength as the wall, and use it to fill up the larger holes in the wall.

f. Make a scaffolding to work from, if this is needed.

g. Insert four nails, one at each corner of the wall.

NOTES:

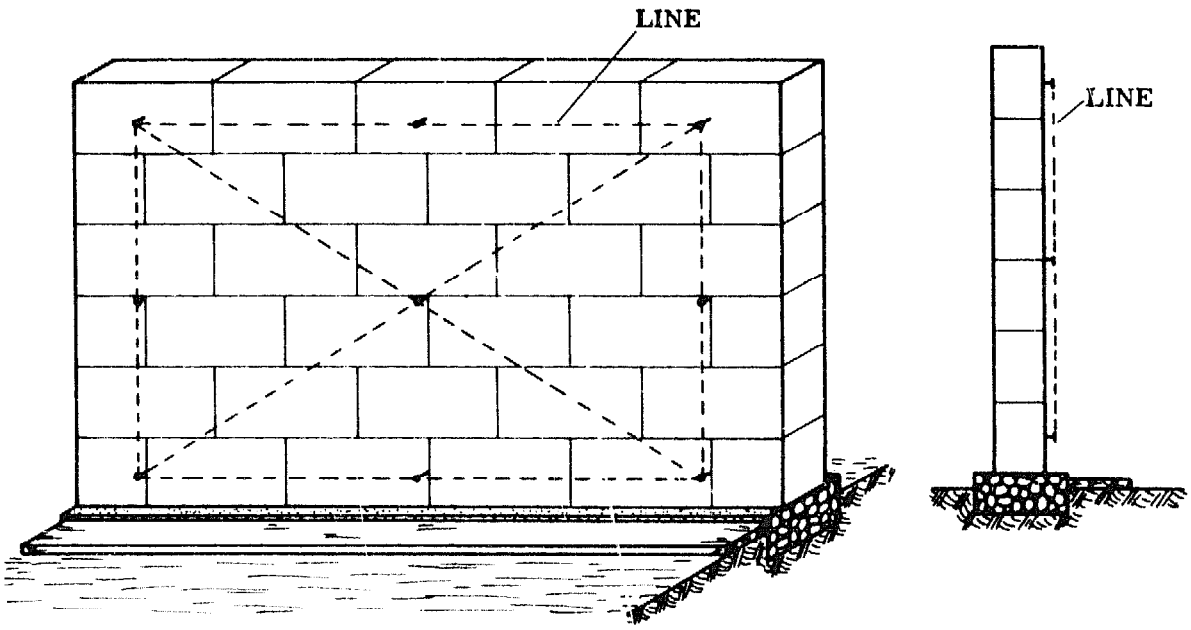

h. Fix lines around all four corners and across the diagonals.

i. The surface contained by the nail heads and the lines should be flat and plumb. Check this using the plumb bob and straight edge. Make corrections by knocking the nails in until they are all in the same plane; this will be the surface of the future plaster layer.

j. When the four corners have been adjusted, insert more nails along the mason lines, as shown above. The heads of the nails should be at the same height as the lines. The distance between the nails should be no more than the strike board can bridge.

NOTES:

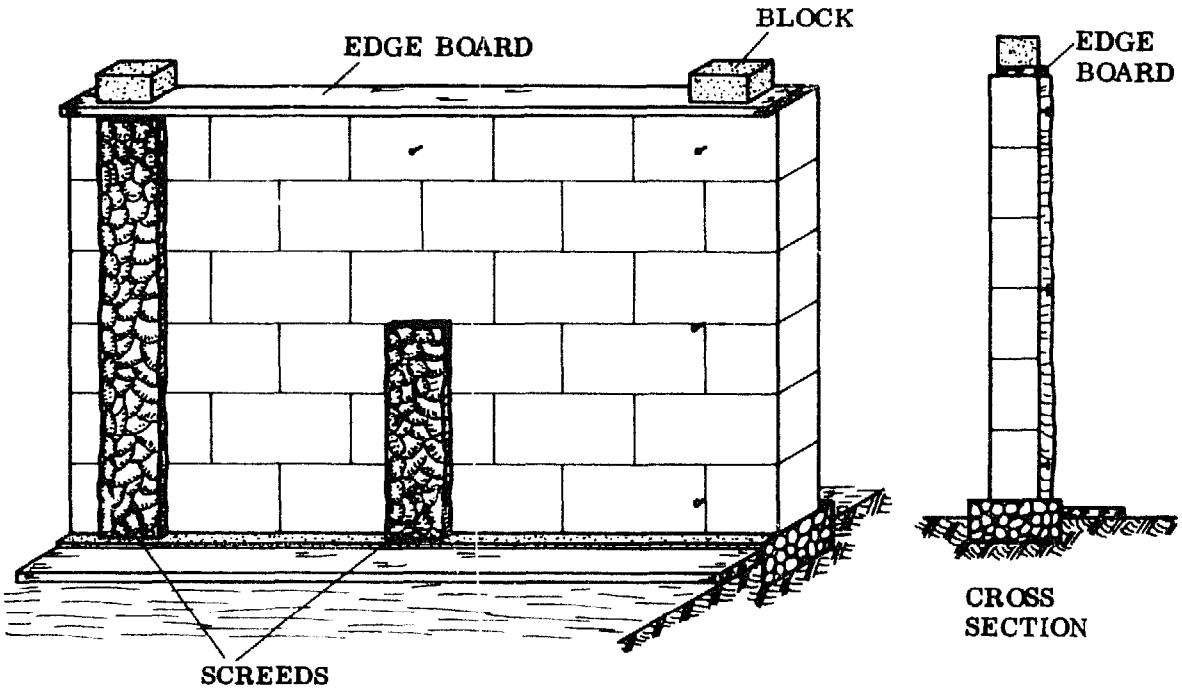

k. Fix the edge boards. The edge board at the top of the wall can be held in place with blocks on top of it. The edge boards should project by the same amount as the nails -- the thickness of the future plaster layer.

l. Now the plastering can start. Make sure that you have enough time to finish the whole area you want to plaster at once, otherwise wait until the next day.

m. Mix the mortar according to the required proportions. Take care that there are no stones in the plaster. Make up a dry mixture first and add water to this as it is needed. Do not mix too much at once, and keep the mortar covered with paper bags or other covering to keep out the sun and wind.

n. Sprinkle the wall with water again.

o. Build up screeds (guiding strips) by throwing mortar against the wall in vertical strips. The mortar should cover the nail heads completely.

NOTES:

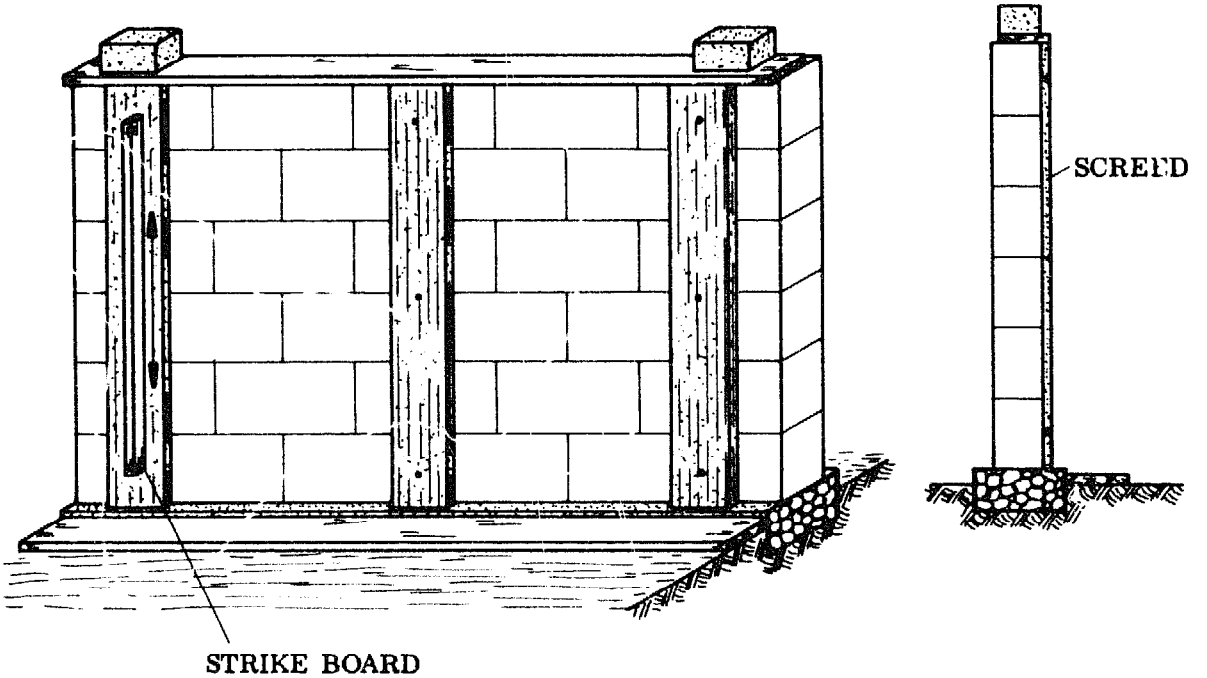

p. Use the strike board to smooth off the screed flush with the heads of the nails. Return any mortar which drops down to the headpan. Give the strike board an up and down movement as you move it across the screed, to obtain a good surface.

q. Let the screeds set for a while, until they are hard enough so that no mortar will be taken off by the strike board during the next steps.

NOTES:

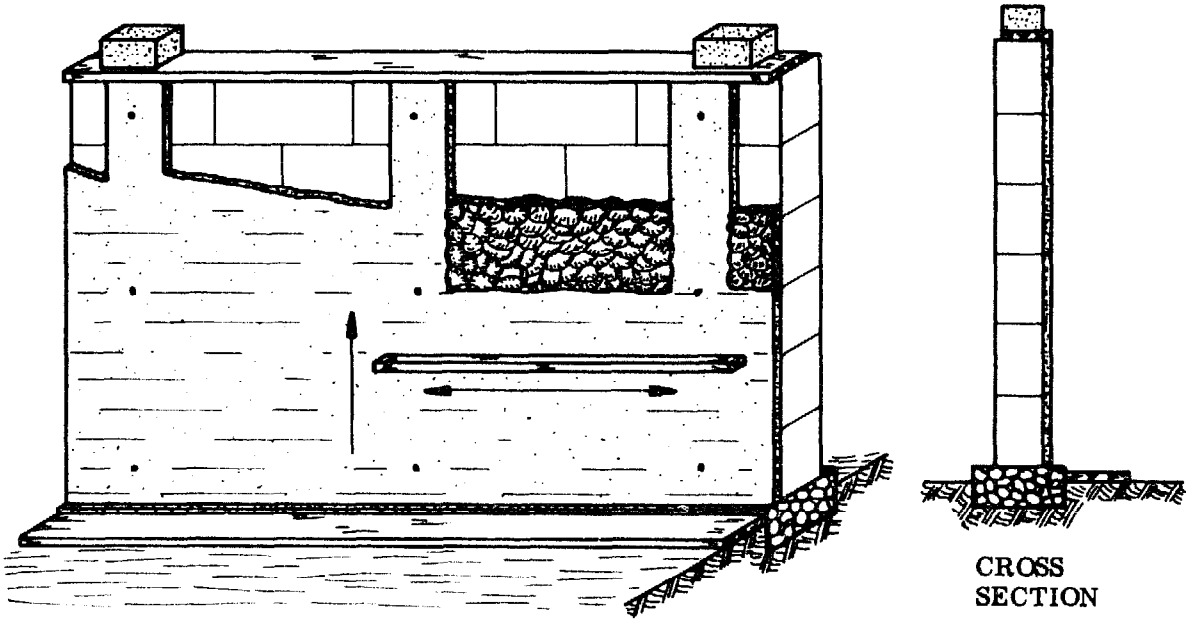

r. When the screeds are hard enough, sprinkle the wall with water again.

s. Fill in between the screeds with mortar. Throw the mortar against the wall, so that it grips well to the wall. The mortar should be a bit thicker than the screeds.

t. Press the strike board to the screed and move it up the wall, holding it horizontally. The board should remove the excess mortar so that the surface of the mortar is flush with the screeds. Make sure that the strike board does not remove any of the mortar from the screeds. Return all surplus mortar to the headpan.

   It is not necessary to fill up the whole section between the screeds before you start to smooth the plaster. Fill in the plaster as high as you can comfortably reach, then smooth this and fill in the rest with the help of a scaffold so you can reach the top of the wall. Smooth up to the top of the wall. However, you should never leave a section halfway finished, because it will not join properly when you continue the next day.

u. When the whole wall has been levelled off the nails should be removed and the last finishing work can be done.

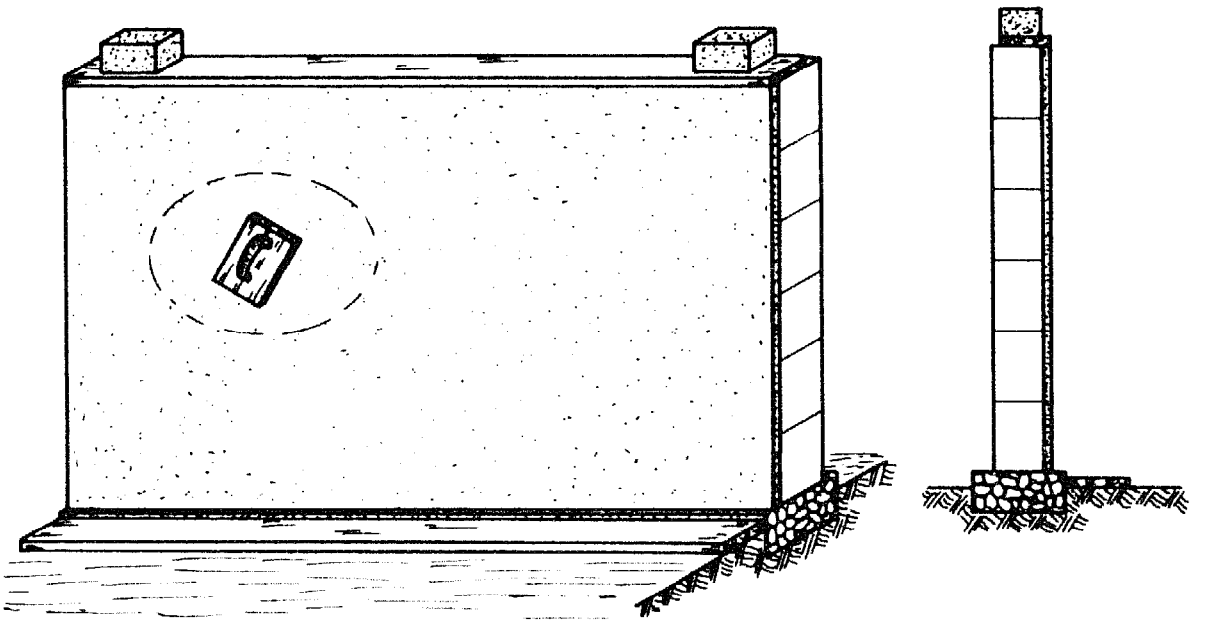

- FINISHING: If the wall should be finished with a textured surface, a wood float can do the job. Turn the float around systematically to obtain a regular texture.

  If a wall should be smooth-surfaced, use a steel float and take care that the sharp edges do not remove mortar from the plastered surface.

  Dip the wood float in water regularly, but don't over-wet the mortar because it could come down or "sag".

  Take care that the plaster or render comes to the footings (here, to the foundations) and cut it off properly. The edges around openings and outside corners should be rounded or chamfered.

  Before stopping work, make sure that the work is finished off properly and is clean. Someone should return in the evening and sprinkle water on the freshly made plaster or render. Water the plaster or render regularly in the next few days so that it cures properly.

  The edge boards can be removed the next day.

- CURING: Watering the plaster or render is very important, especially during the dry season when the harmattan is blowing. Don't wait until the whole work is finished before you put water on the parts which were done first; the fresh plaster can dry out in a few hours.

  If you started on the west side of the building in the morning, be sure to water those sections in the afternoon when the sun is shining on them.

POSITIONS OF EDGE BOARDS FOR PLASTERING CORNERS

Below are illustrations of the correct method for plastering around corners. In Fig. 1a, the first step is shown; in Fig. 1b the second step. The arrows indicate the areas which are plastered in each step. The boards project by the thickness of the plaster.

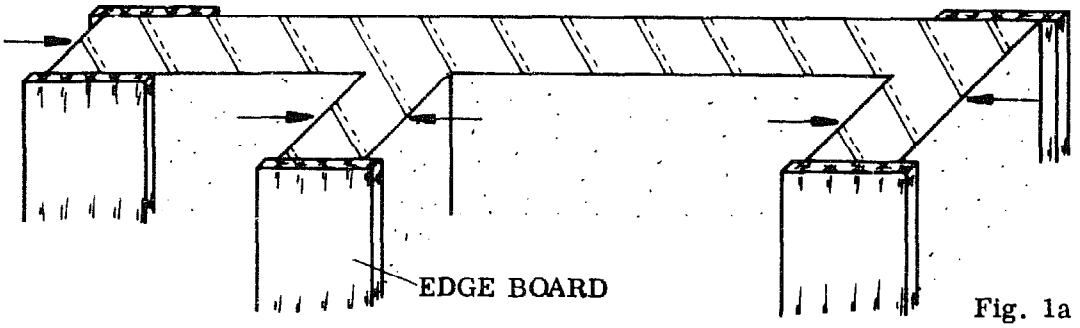

Fig. 1a

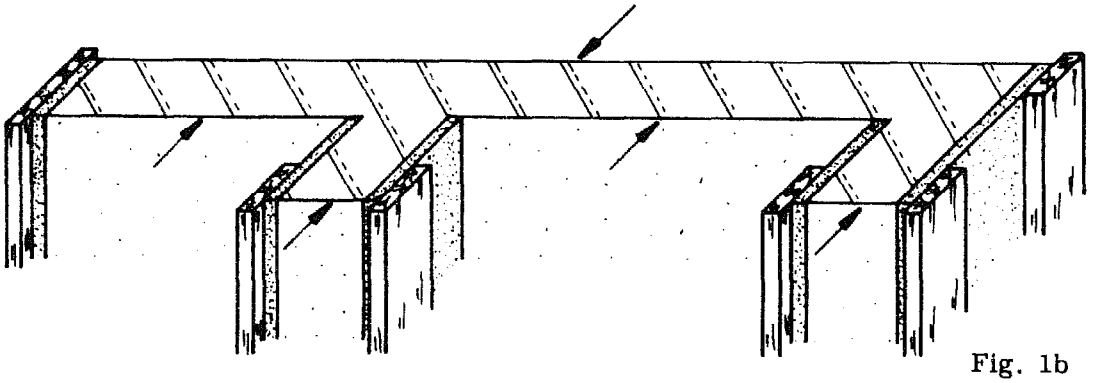

Fig. 1b

POSITIONS OF EDGE BOARDS FOR PLASTERING AROUND FRAMES

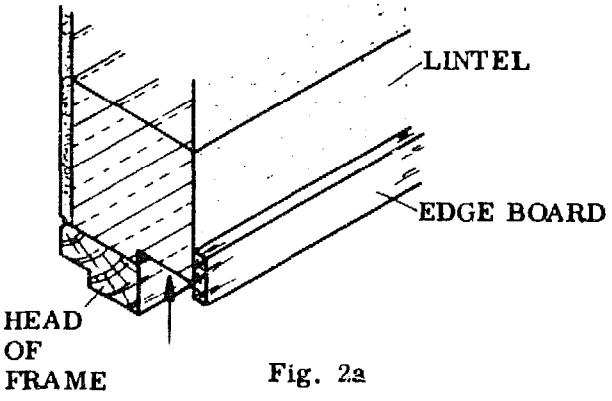

Fig. 2a
1st STEP

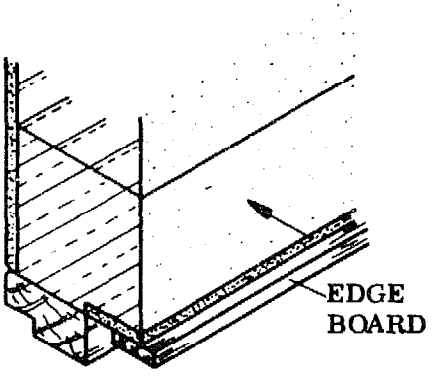

Fig. 2b
2nd STEP

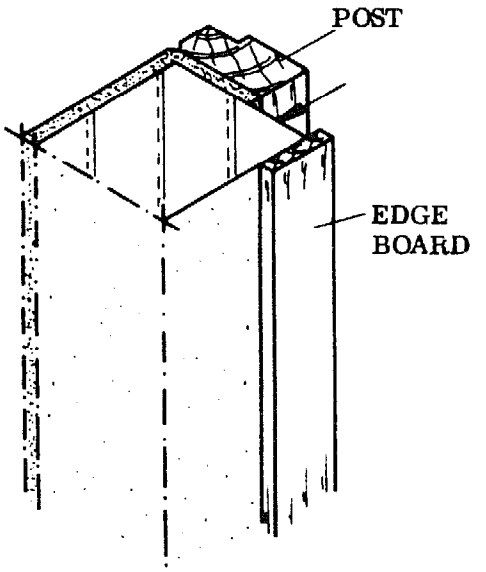

Fig. 3a
1st STEP

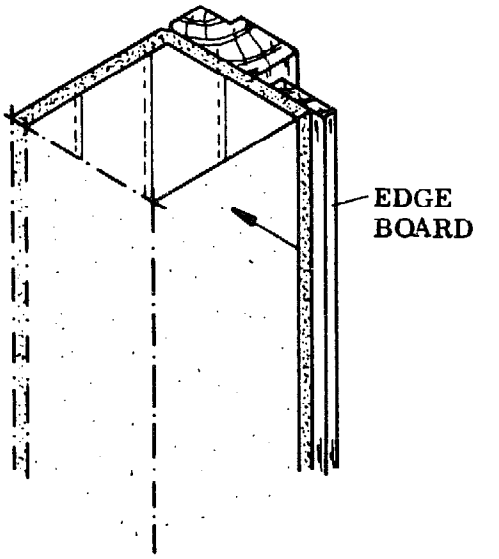

Fig. 3b
2nd STEP

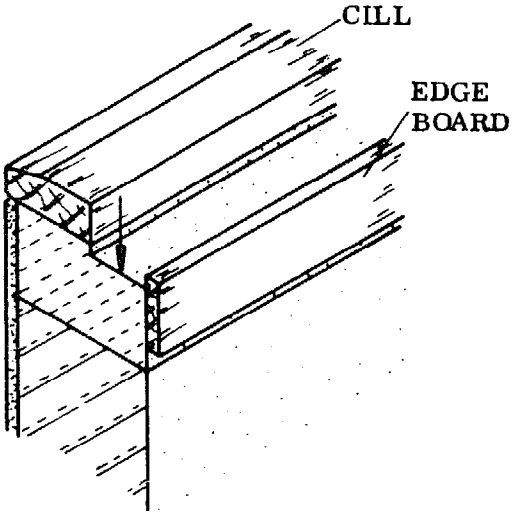

Fig. 4a
1st STEP

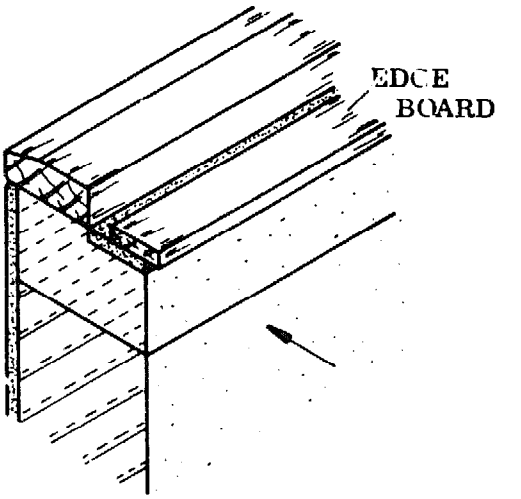

Fig. 4b
2nd STEP

PLASTER AND RENDER.	N P V C	
	CON.	237

POSITION OF EDGE BOARDS FOR PLASTERING THE TOPS OF GABLES

Figs. 1a and 1b show the positions for the edge boards.

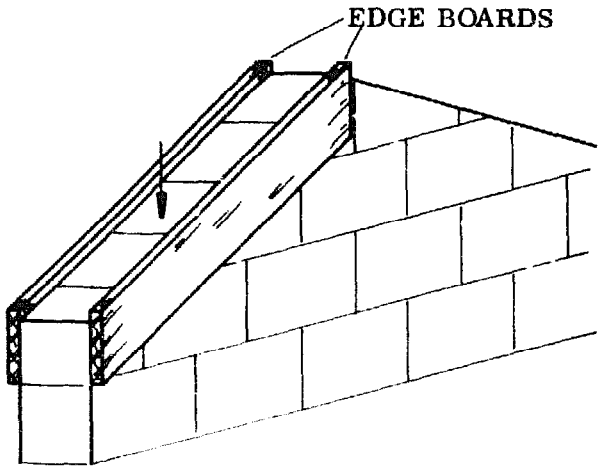

Fig. 1a
1st STEP

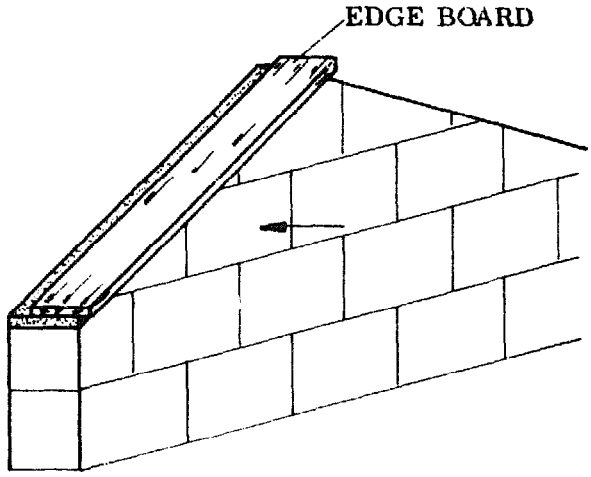

Fig. 1b
2nd STEP

NOTES:

N P V C		PLASTER AND RENDER.
238	CON.	

POSITIONS OF EDGE BOARDS FOR PLASTERING THE TOP OF A PARAPETTED PENT ROOF

Figs. 2, 3, and 4 show the positions of the edge boards for plastering.

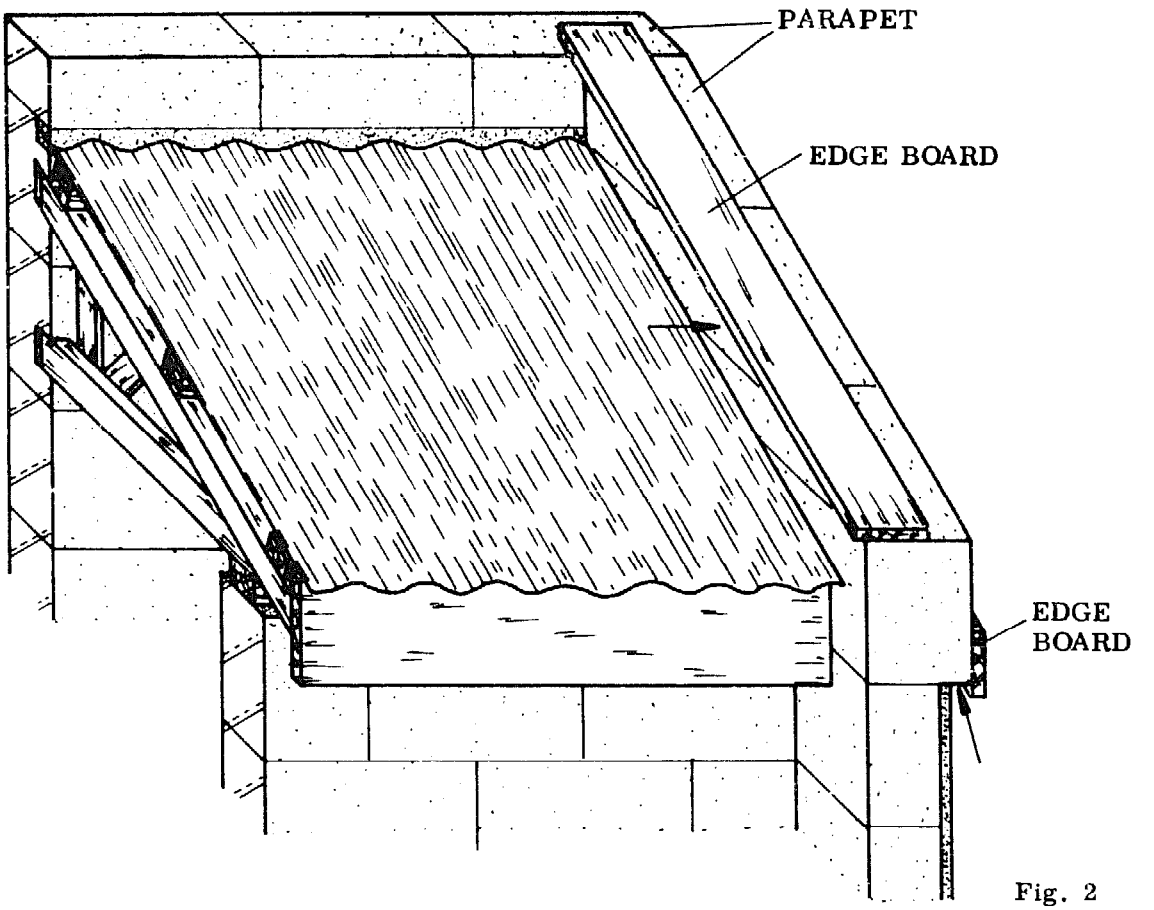

Fig. 2
1st STEP

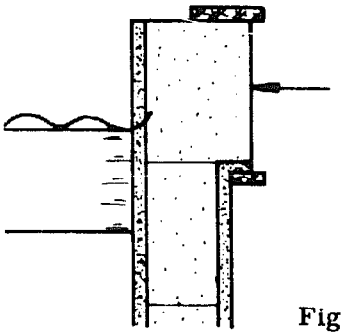

Fig. 3
2nd STEP

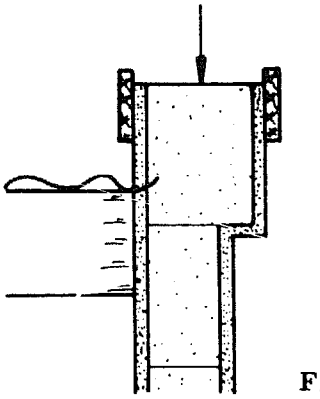

Fig. 4
3rd STEP

POSITIONS OF THE EDGE BOARDS FOR PLASTERING OPENINGS

Plaster the inside surfaces of the opening first (Fig. 1), then the rest of the wall can be plastered as usual (Fig. 2).

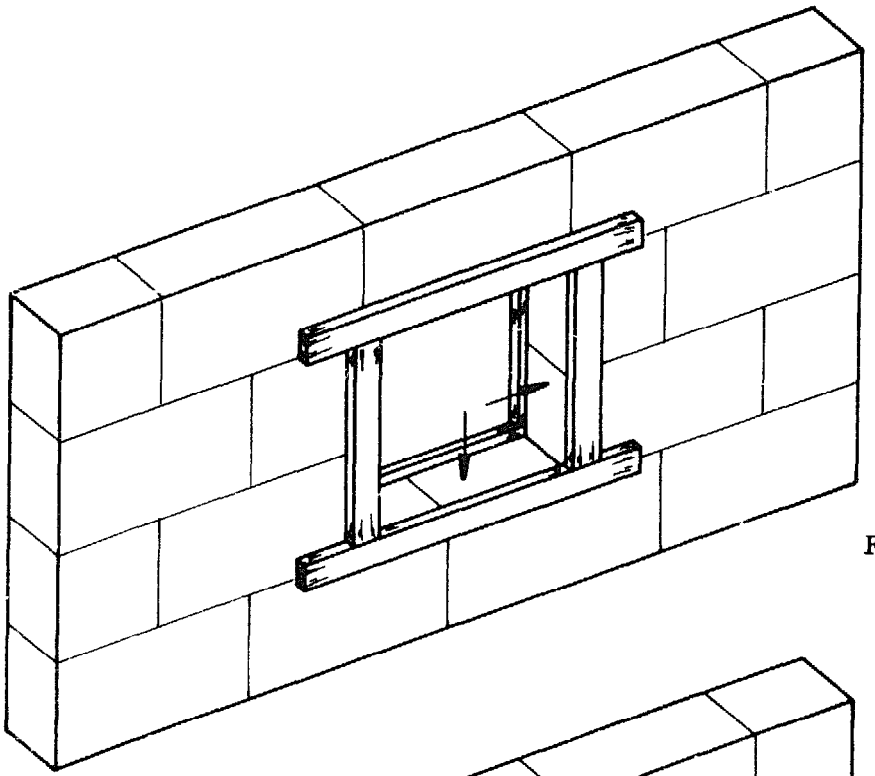

Fig. 1

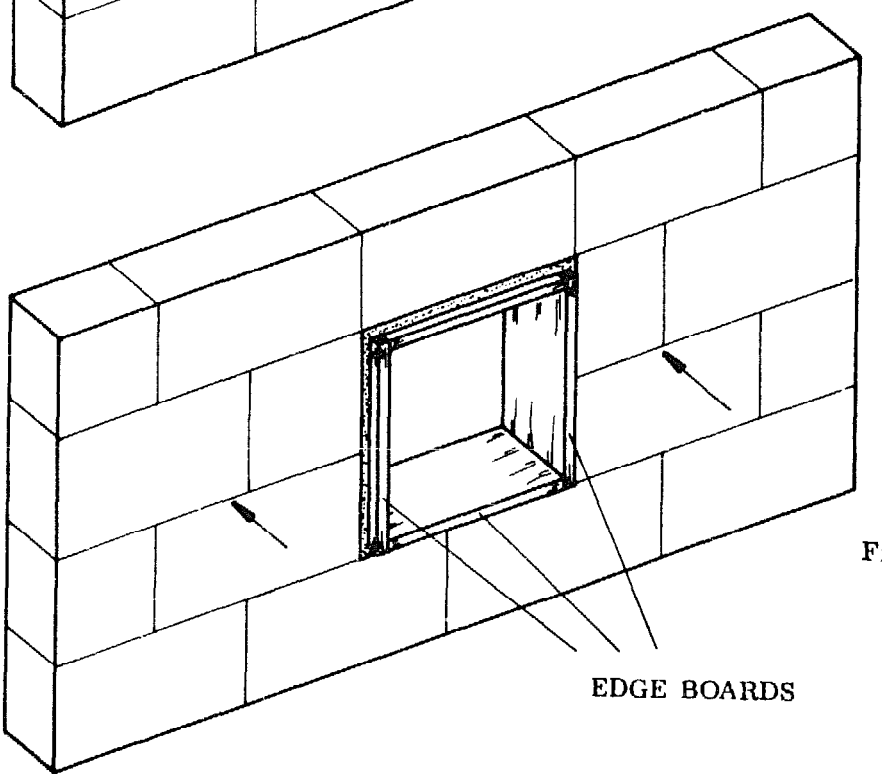

Fig. 2

N P V C	
240	CON.

PLASTER AND RENDER.

FLOOR CONSTRUCTION

It is best to construct the floor after the roof covering has been completed. This makes it easier to cure the floor without problems caused by the concrete drying out too quickly and cracking.

Floors are constructed on top of the hardcore filling. There are two methods for floor construction used in Rural Building: one-course work and two-course work. One-course work means that the floor is made in a single layer; while in two-course work the floor is constructed in two layers, the base layer and the floor screed or finishing layer. For an explanation of the two methods and their respective advantages and disadvantages, see the Basic Knowledge book, page 179.

Any floor which is larger than 10 square metres should be divided into "bays" before it is cast (Basic Knowledge, page 180). The bays should be as nearly square-shaped as possible, so that the shrinkage on each side of the bay will be the same. The bays are separated from each other by edge boards during the casting. The smaller the bays, the fewer cracks will appear. In floors which are in the sun, the bays should be no more than 5 square metres in area, and expansion gaps should be made between them.

Expansion gaps and shrinkage gaps are explained in the Basic Knowledge book, page 183. Shrinkage gaps are made between the bays in either one-course or two-course work, to keep the floor from cracking as it hardens and shrinks a bit. Expansion gaps are larger gaps made in the base layer of two-course work when the floor is exposed to the sun or to large temperature changes, which can cause cracks when the floor expands with the heat and contracts as it cools.

The procedure for casting a floor is explained on the following pages.

NOTES:

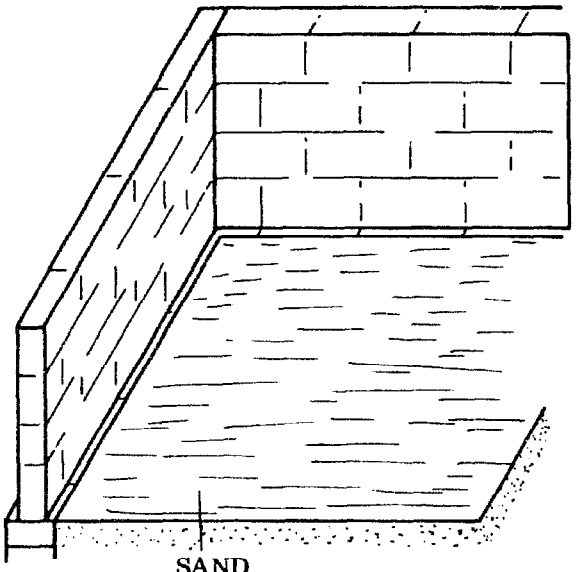

Fig. 1

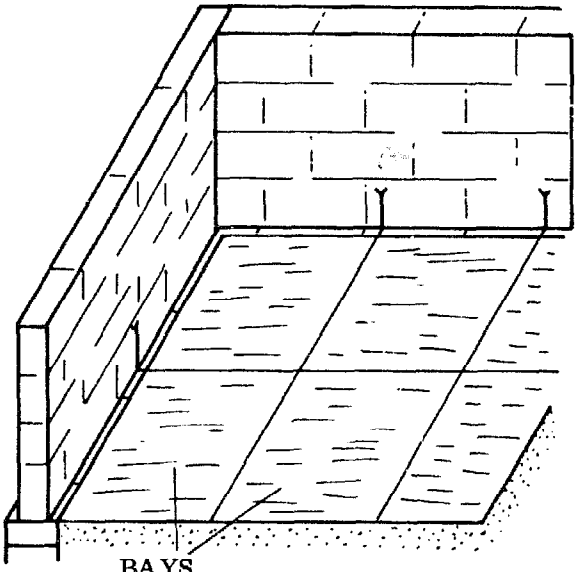

Fig. 2

SEQUENCE OF OPERATIONS FOR ONE-COURSE WORK

The hardcore filling is usually made well beforehand, to allow it to settle properly. It is constructed as explained on pages 59 and 60 in this book. The last 6 cm up to the top of the footings is filled with sand. The hardcore forms a firm support for the floor (Fig. 3).

a. Clean the whole area and level the sand surface (Fig. 1).

b. Divide the area of the room into bays and mark the bays on the walls (Fig. 2).

c. Mark the positions of the edge boards on the sand between the marks on the walls (Fig. 2). Lines may also be fixed between the wall marks at the height of the finished floor level (Fig. 3).

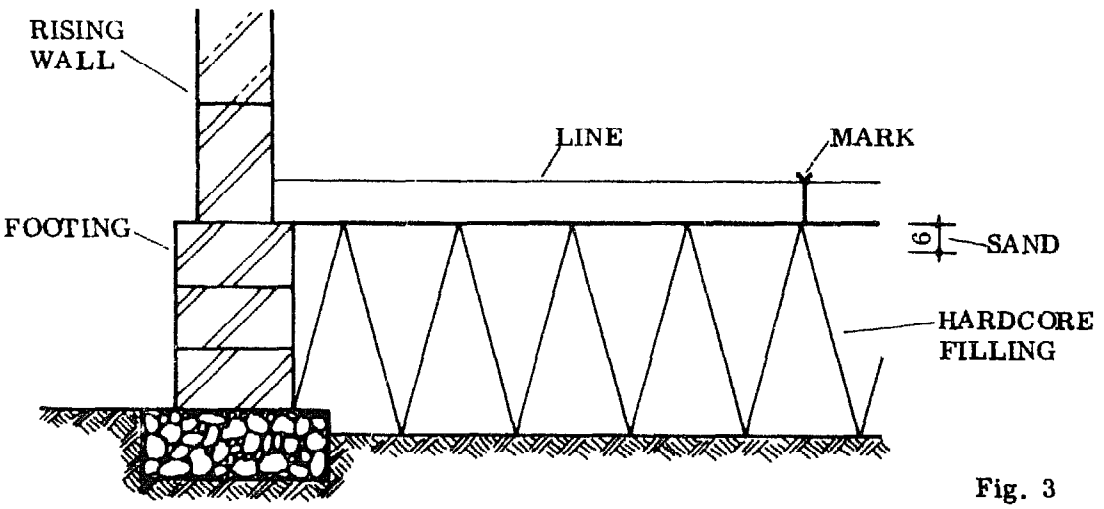

Fig. 3

N P V C	
242	CON.

FLOOR CONSTRUCTION.

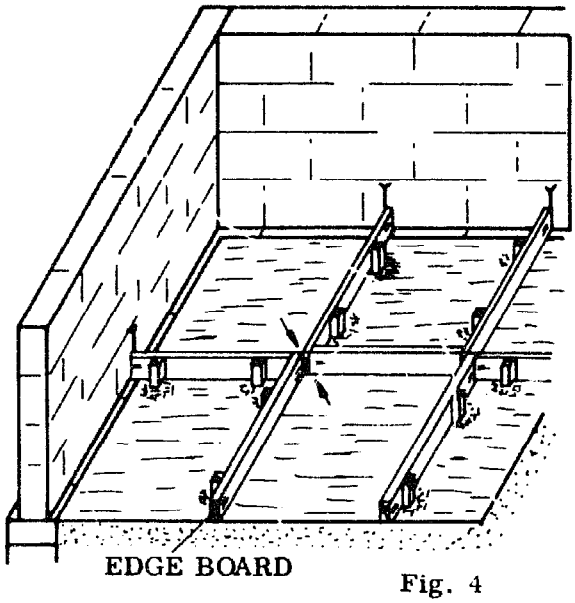

Fig. 4

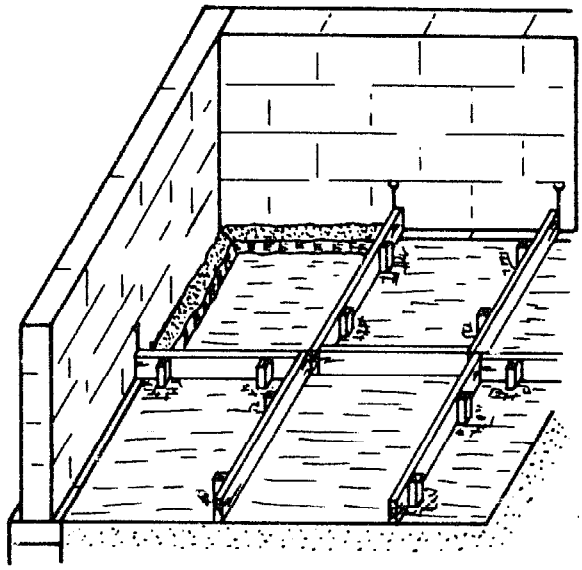

Fig. 5

d. Cut the edgeboards to the proper length. Note the arrangement of the boards shown above in Fig. 4 and in Fig. 6 below, and cut the boards so that they fit in this pattern.

e. Nail the pegs to the sides of the edge boards.

f. Place the edge boards as shown in Fig. 4, along the marks. The corners of the boards should meet as shown in Fig. 6 below.

g. Knock lightly on the pegs until the edge boards are level (check with the spirit level) and at the correct height (the tops of the boards should be level with the finished floor surface).

h. Pour the guide strips to the height of the base layer (approximately 8 cm) (Fig. 5). Level the tops of the guide strips (Fig. 7).

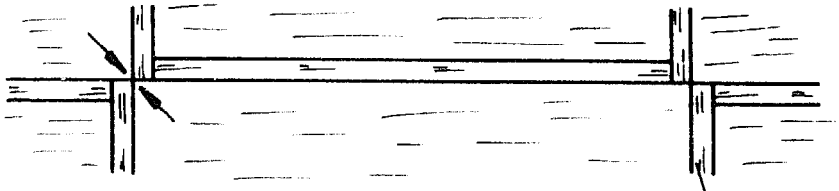

Fig. 6

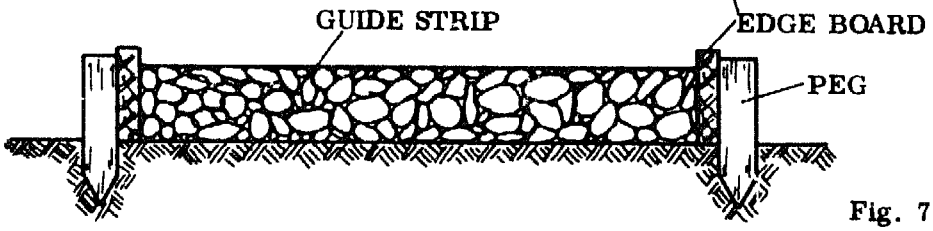

Fig. 7

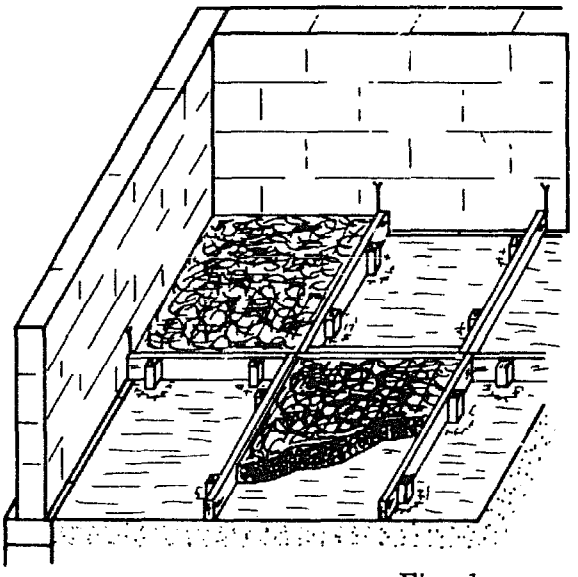

Fig. 1

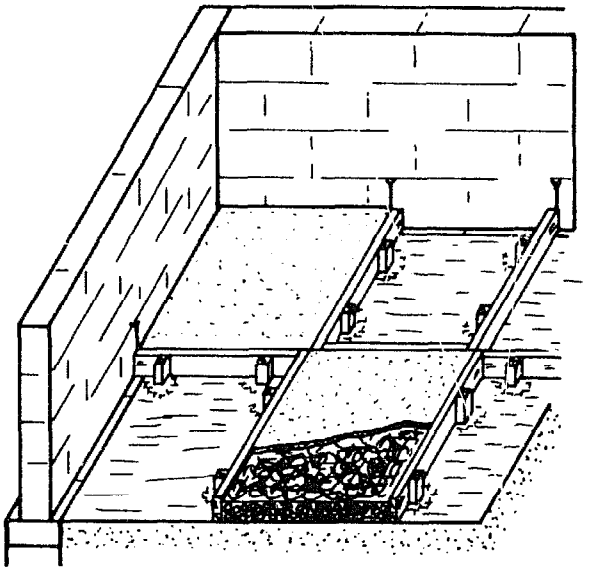

Fig. 2

i. Pour the concrete for the base layer of one bay, making sure that it is well distributed near the walls and corners especially. Mix proportions can be found in the Tables of Figures, Reference Book, page 234 (Fig. 1).

j. Compact the concrete with a rammer, especially the corners and edges.

k. Use the notched strike board (Fig. 3) to level the surface by gently tamping until the layer is screed-thickness below the top of the edge boards.

l. Prepare the mortar for the screed layer. This should be moist but not wet.

m. Pour this mortar on top of the concrete. The screed is about 2 cm thick.

n. Tamp the screed down with a strike board until a level surface is obtained (Fig. 2).

o. Use the wood float to tamp the screed until the moisture from the concrete comes through. At the same time smooth the surface with the float. During this operation dip the float regularly in water and sprinkle water on top of the screed if necessary to make the work easier.

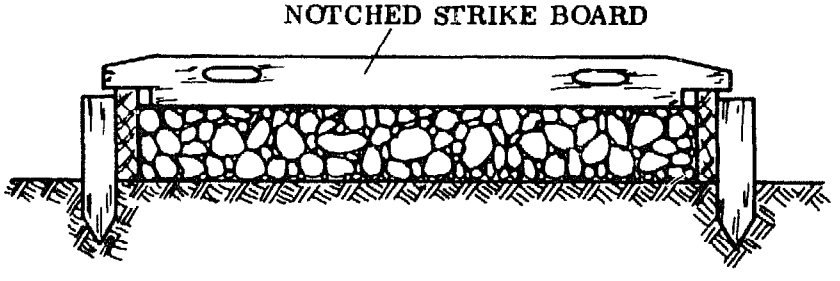

Fig. 3

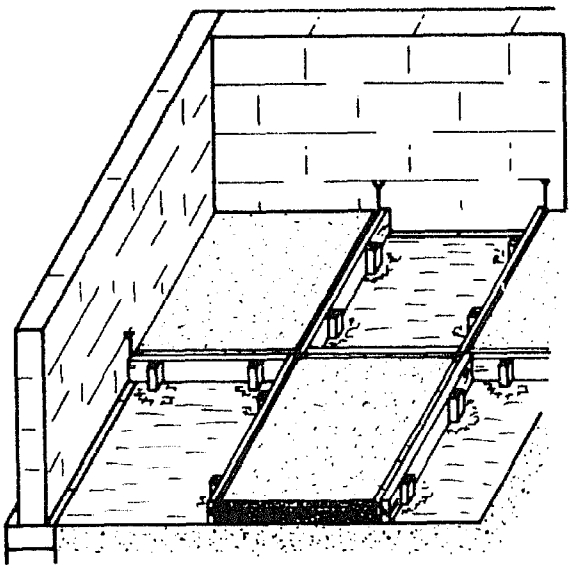

Fig. 4

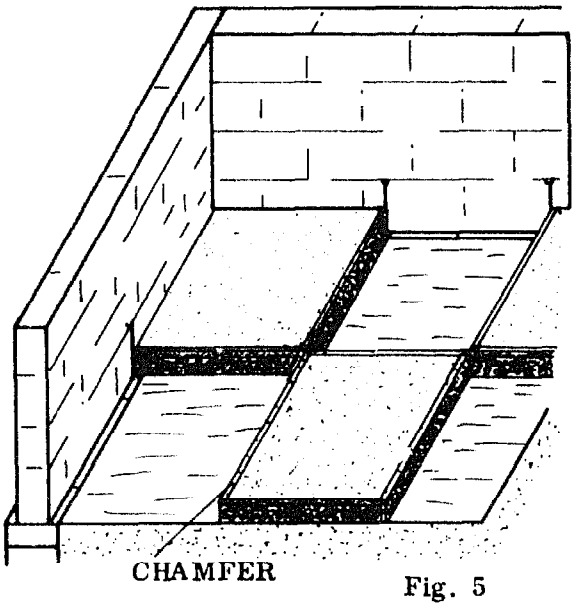

Fig. 5

p. If a smoother surface is desired, finish off with a steel float. Make a chamfer along each edge next to the edge board to form half of the "V" groove above the shrinkage gap (Figs. 4 & 6).

q. If blisters or bubbles appear when the concrete starts to harden, pop them and close the holes.

r. Let the floor harden for some hours, then sprinkle water over it. Keep the floor wet at all times.

s. The next day, put some clear sand on top of the floor and wet it thoroughly. Keep the sand wet until the hardening process is over in several days time.

t. Remove the edge boards and cast the remaining bays in the same way. Make sure that the bays are separate by putting pieces of plastic or paper between them before pouring the concrete in the other bays (Fig. 5). The tops of the finished bays act as guides for the strike boards, but be careful not to damage them (Fig. 7).

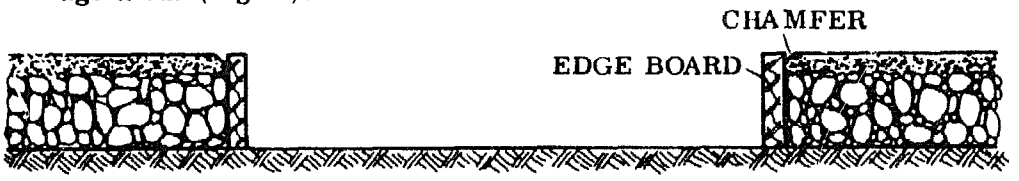

Fig. 6

Fig. 7

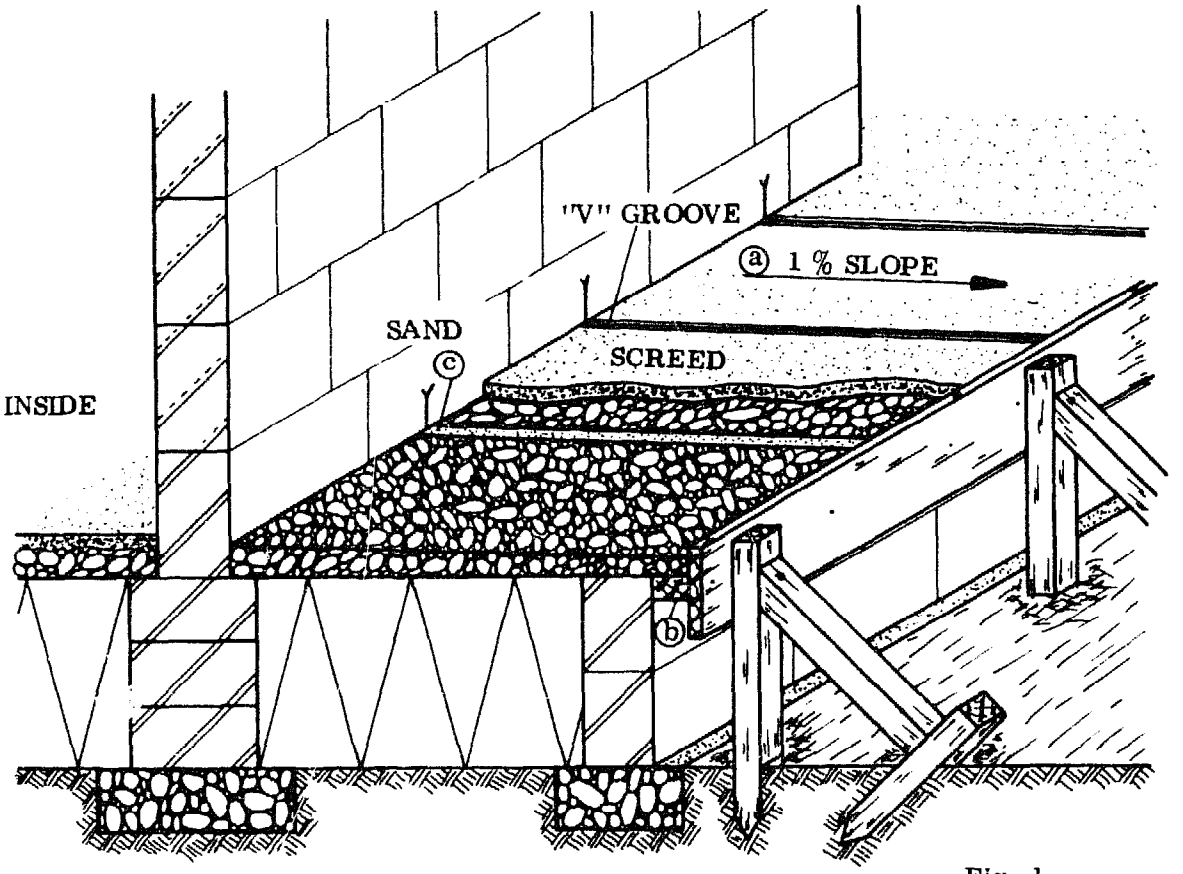

Fig. 1

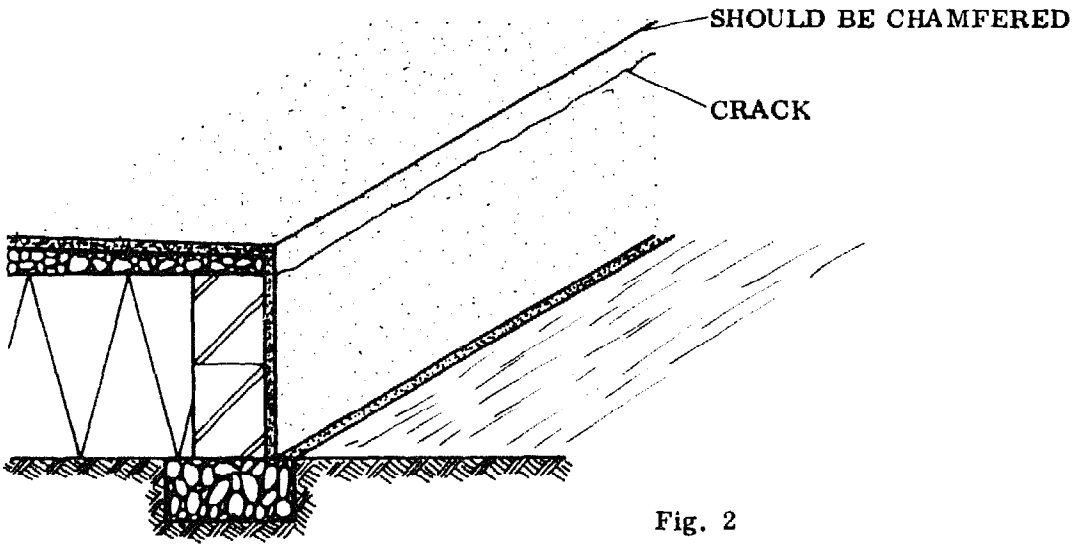

Fig. 2

N P V C		FLOOR CONSTRUCTION.
246	CON.	

VERANDAH FLOORS

The construction of a verandah floor is different from that of an inside floor in three particular ways.

- Usually the verandah floor is built with a small slope towards the outside so that rain water can run off quickly (Fig. 1, a).
- The verandah floor can have a projecting outside edge (Fig. 1, b).
- Because the floor is exposed to the sun, expansion gaps have to be made in it. This means that the floor must be made with the two-course method. (Fig. 1, c, and Basic Knowledge book, page 183).
- SLOPING FLOOR: Verandah floors may have a slope which is about 1%; no more than 2%, because this could cause problems in walking and working on it. The greater slope increases the danger of slipping when the surface is wet.

  A slope of 1% means that the floor slopes 1 cm lower in every metre; in this case the slope is across the width of the floor.

  The construction of the slope is done by simply setting the edge boards between the bays at the required slope.
- PROJECTING OUTSIDE EDGE: If the outside edge of a verandah floor is kept flush with the render of the footing (Fig. 2), then cracks would soon appear along the edge. This is prevented by constructing the floor so it projects past the footing by no more than 7,5 cm. The shorter the projection the better, because the floor is not reinforced.

NOTES:

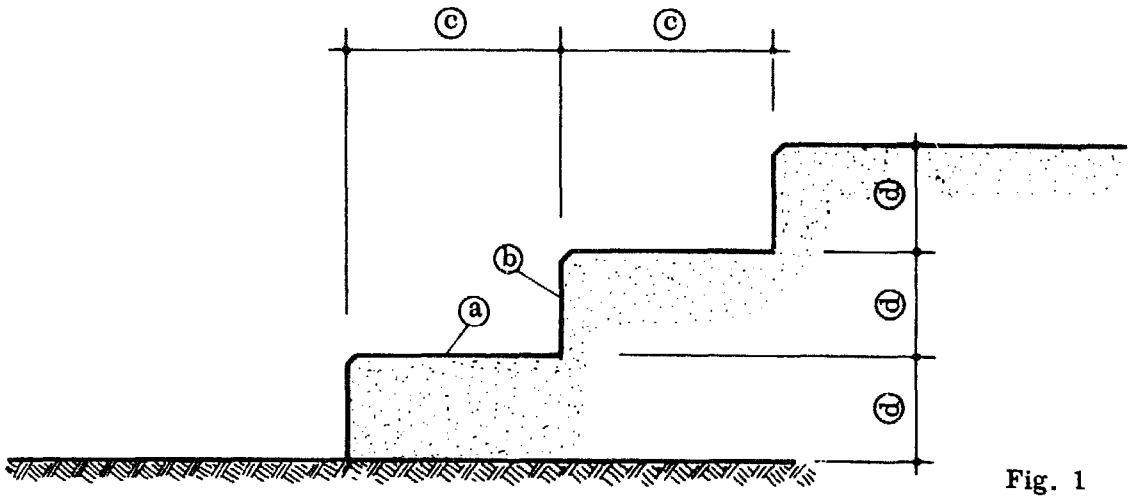

Fig. 1

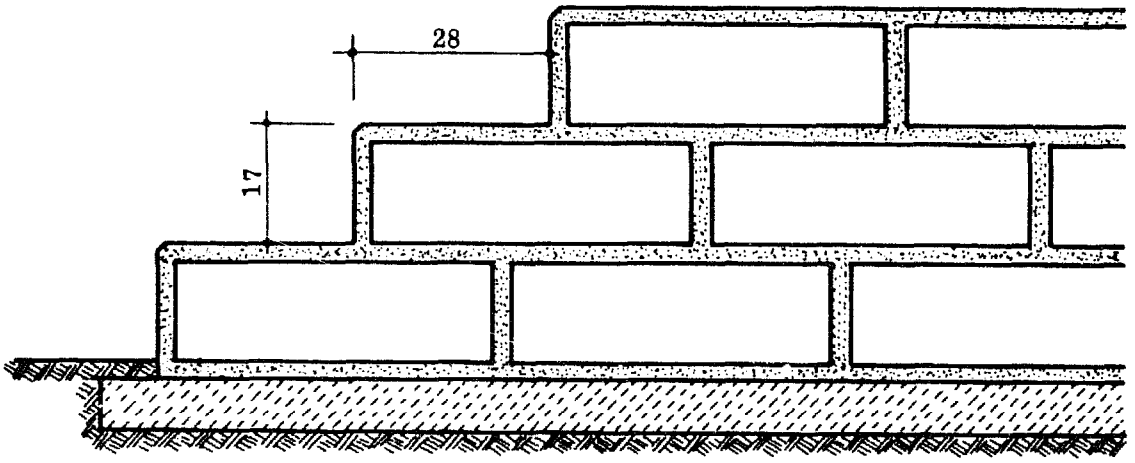

Fig. 2

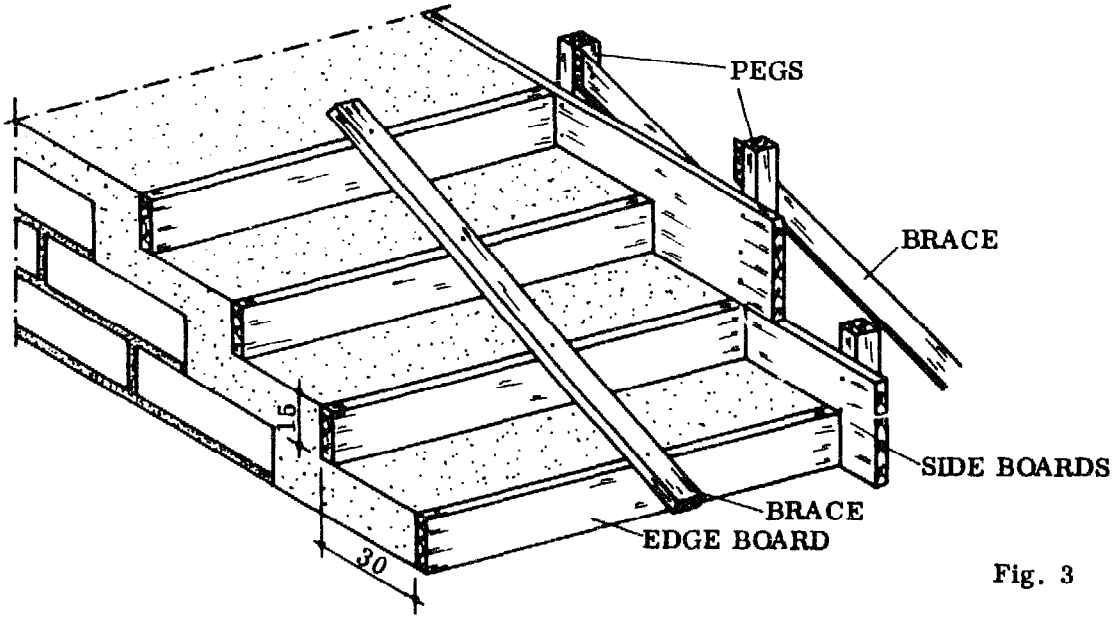

Fig. 3

N P V C	
248	CON.

STAIRS.

STAIRS

A stair means a series of at least three steps, also called a flight of stairs. A stair can form the link between two storeys of a building. In Rural Building we are only concerned with one storey buildings, so the stairs are usually only needed up to the level of the floor of the building, which is normally not much higher than 60 cm above ground level.

- TECHNICAL TERMS: Fig. 1 shows the parts of a staircase.
  - TREAD: The tread is the horizontal part of the step (a).
  - RISER: This is the vertical part of a step (b).
  - GOING: This refers to the width of the tread (c). The "going" of a flight of steps is the sum of the "goings" of all the steps of the flight.
  - RISE: This is the vertical distance between two treads, equal to the height of the riser (d).

REQUIREMENTS

The short flights of stairs we make in Rural Building are usually built with sandcrete blocks or are cast out of concrete. Regardless of the materials and the method of construction, the steps must be all the same height and the same width. A staircase with steps of different sizes is likely to cause accidents.

The rise of the steps is usually 15 cm (approximately) and the width of the tread, the "going", is usually about 30 cm for each step.

The steps in Fig. 2 are built with sandcrete blocks, so the rise of 17 cm is convenient because it fits in with the block size. The width of the tread can be about 28 cm, or slightly more than the half-block size.

Steps cast out of concrete can have any convenient rise, but normally the rise is about 15 cm high, and the width of the tread will be approximately 30 cm. The formwork for casting the steps is shown in Fig. 3.

Plan ahead. If the steps with a 15 cm rise do not reach the right level (measure the height before you start to make the steps) either change the height of the rise (to 14, 16, or 17 cm, etc); dig out some soil before to lower the height of the whole stair; or add a foundation slab to raise the whole construction by a few centimetres to the required height.

- REMEMBER: Never make steps of different sizes in the same stair.

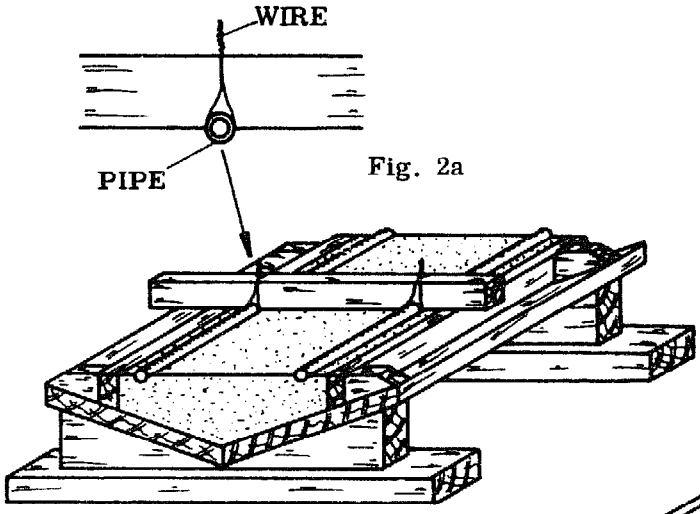

Fig. 2a

Fig. 2

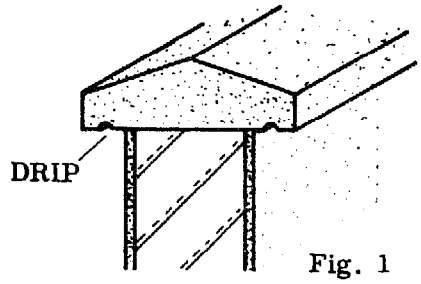

Fig. 1

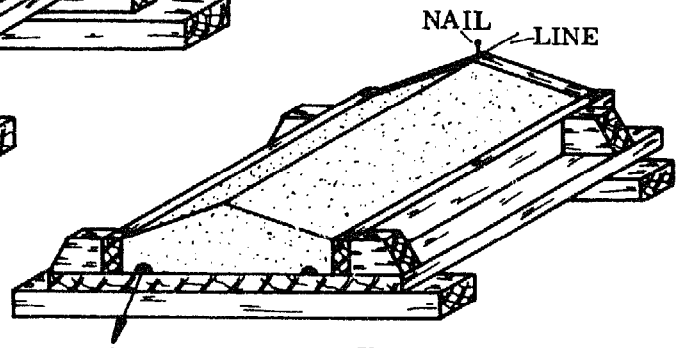

Fig. 3

Fig. 3a

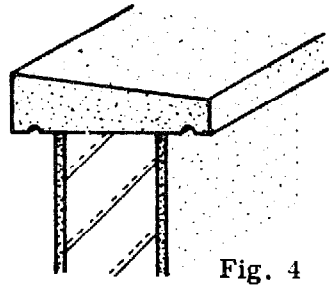

Fig. 4

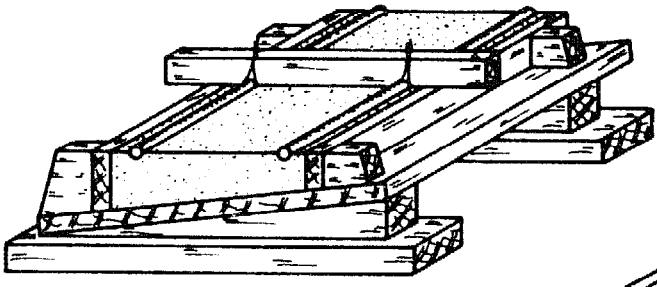

Fig. 5

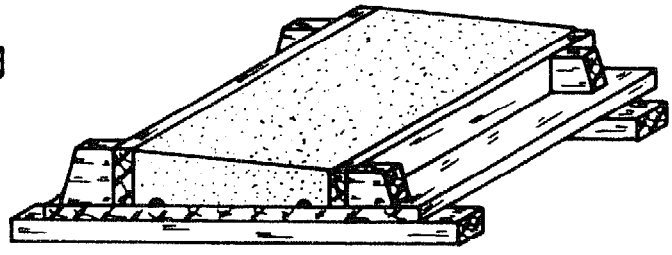

Fig. 6

N P V C		FORMWORK.
250	CON.	

FORMWORK

FORMWORK FOR COPINGS

A free-standing wall which is not part of the building (not under the roof) needs to be protected against rain, which otherwise might penetrate at the top of the wall and damage it. This is done by adding a "coping" at the top of the wall.

- SADDLE-BACK COPING: This is placed on top of the wall as shown in Fig. 1. The formwork for the coping is shown in Fig. 2. The drip or throating is made by setting two pipes or smooth iron rods in the wet concrete. The correct position can be assured by using wooden spacers tied to the pipe (Figs. 2 & 2a).

  A second way of making the coping is shown in Fig. 3. A line is fixed at the height of the ridge and the surfaces are shaped with the steel float. The drip is made by fixing half-round beads onto the soffit board of the formwork (Figs. 3 & 3a).

- SPLAYED COPING: The splayed coping in Fig. 4 can also be made in two ways, in a fashion similar to the saddle-back coping above (Figs. 5 & 6).

FORMWORK FOR PILLARS

The formwork for a concrete pillar is shown in Fig. 7 below.

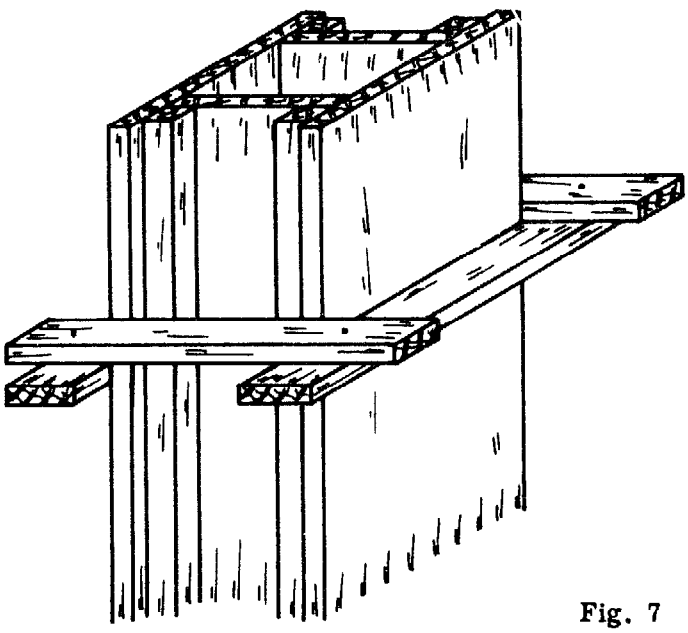

Fig. 7

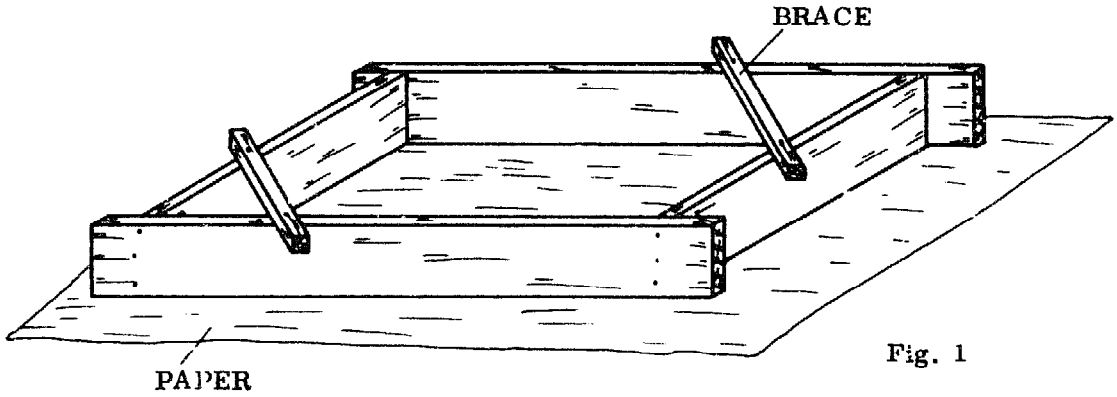

Fig. 1

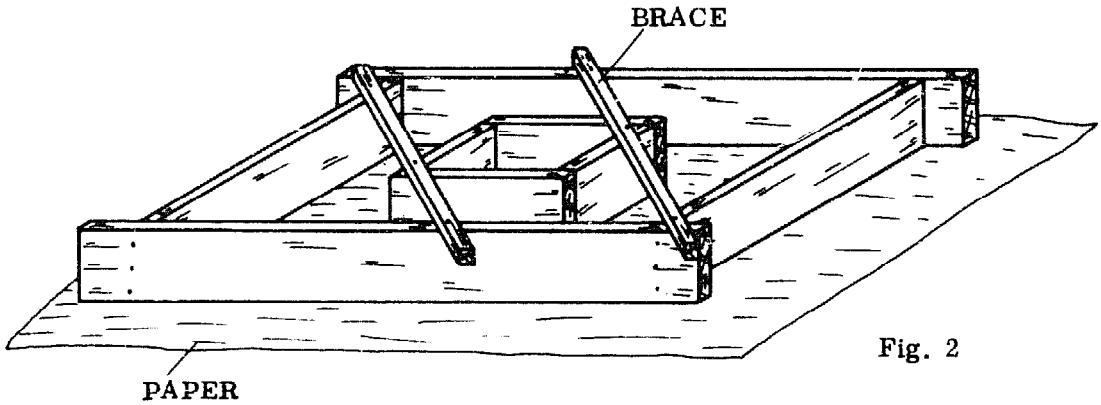

Fig. 2

NOTES:

N P V C		FORMWORK.
252	CON.	

FORMWORK FOR SLABS

Fig. 1 shows an example of formwork for a slab. Paper should be set underneath before the concrete is cast.

Fig. 2 shows an example of the formwork for a slab with an opening in it.

GENERAL HINTS FOR FORMWORK

- Use good, straight-grained wood.
- Make a sketch of the formwork before you start to make it.
- Design the formwork so it can be easily removed from the piece after curing.
- Use enough supports and braces to make the formwork rigid and strong.
- Be aware that the wood swells when it is in contact with the wet concrete.
- If the concrete will not be plastered later, plane the formwork members smooth where they are in contact with the concrete.
- Do not overnail the structure, and fix the nails so that they can be taken out easily.
- Oil the form lightly where it is in contact with the concrete.
- For precast members, put the form on the ground in a level spot, and put paper underneath it (old cement bags).
- Remove the formwork only when the concrete has hardened sufficiently (the time depends on the member which is cast).
- Be careful not to damage the edges and corners of the concrete piece when you remove the formwork.
- Clean off the formwork with a steel brush and take out all nails when you finish.

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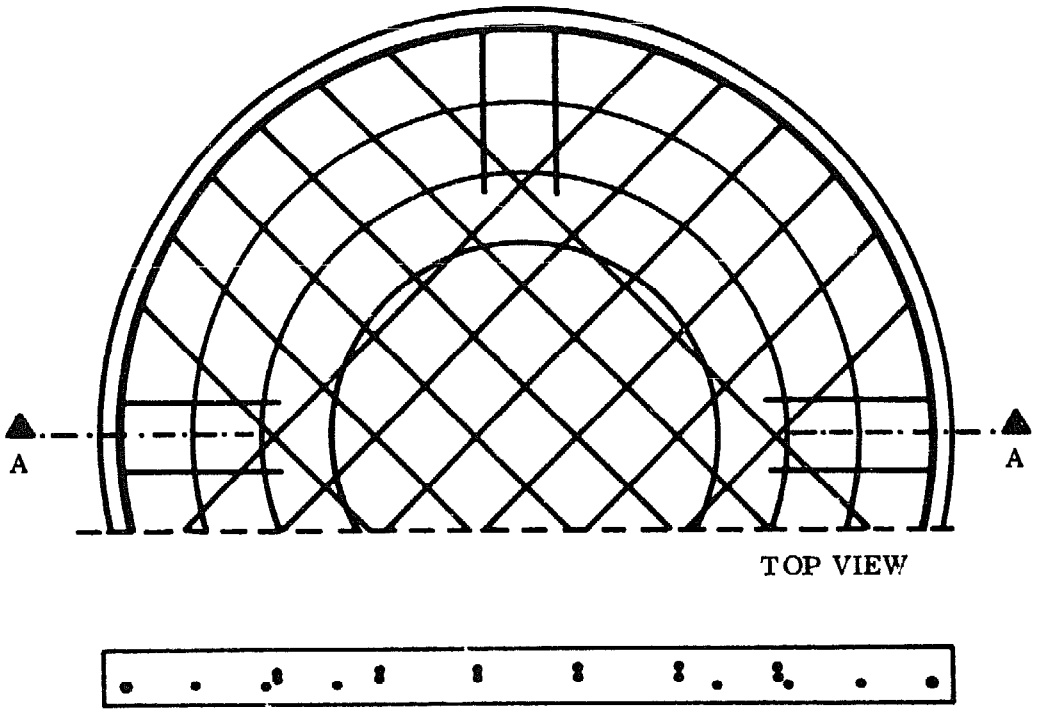

Fig. 1

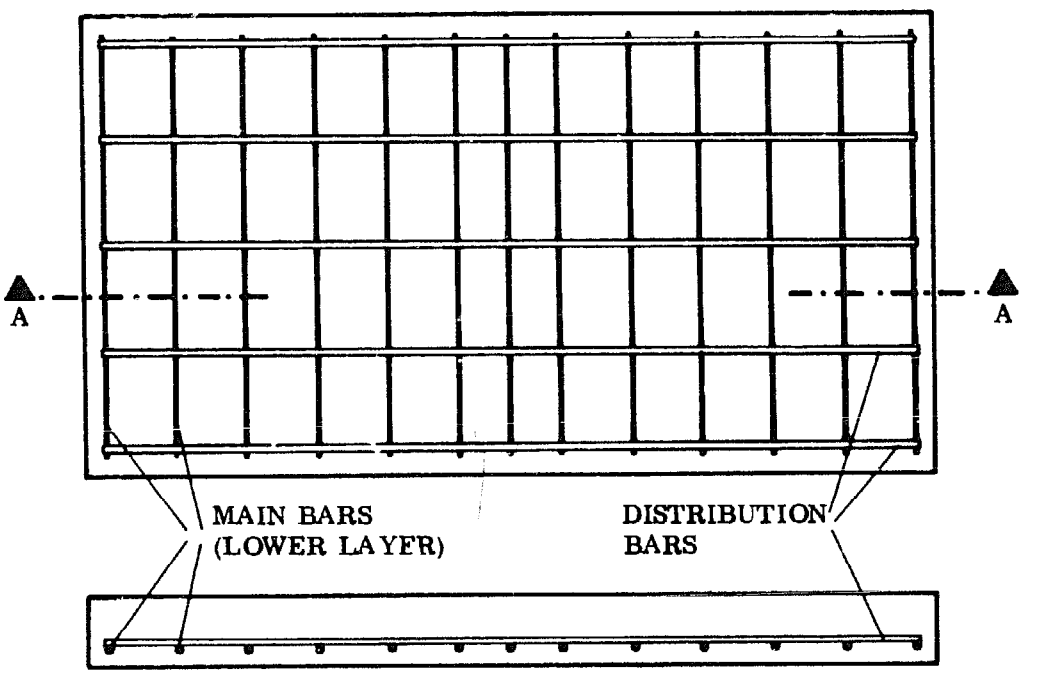

Fig. 2

N P V C	
254	CON.

REINFORCED CONCRETE SLABS.

REINFORCED CONCRETE SLABS

In the northern part of Ghana a typical traditional house has a flat roof made of mud plastered over sticks, and supported by tree trunks. The flat roof is very appropriate for the area, but sometimes these traditional constructions have problems like leaking or even collapse during heavy rains.

In Rural Building we do not deal with the construction of flat roofs, even though these would be more appropriate to the local customs. The reason is because the materials to construct a safe, strong flat roof are expensive, and the construction of a reinforced concrete roof is very difficult and complicated.

Therefore, in this course we only treat the construction of relatively small reinforced concrete slabs such as manhole covers, latrine slabs, septic tanks, etc.

CONSTRUCTION

Reinforcement mats are a simple way of reinforcing slabs (Reference Book, page 173) but they are sometimes hard to obtain and they are expensive. The Rural Builder usually has to rely on single reinforcement bars to reinforce slabs.

Fig. 1 shows a typical arrangement for a circular slab, and Fig. 2 shows that for a rectangular slab.

The distance between the 12 mm main bars is never more than 10 cm. The thickness of the slab can vary between 7,5 cm for smaller slabs like manhole covers, and up to 15 cm for covers of septic tanks, or slabs on which people may walk.

- NOTE: This book is not meant to train engineers; it merely gives basic information. If you need to construct a larger reinforced concrete member, you are advised to seek help from a building expert.

NOTES:

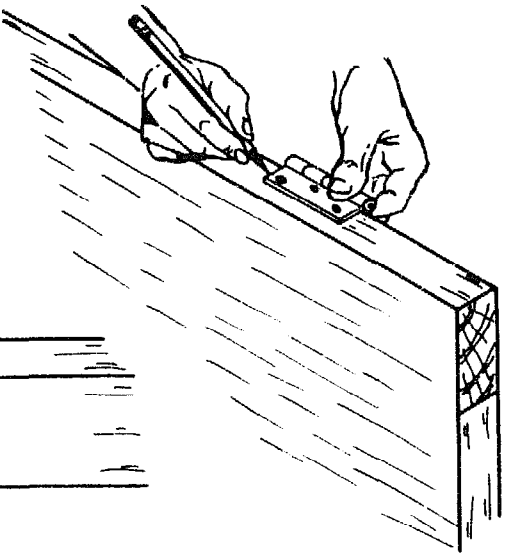

Fig. 1

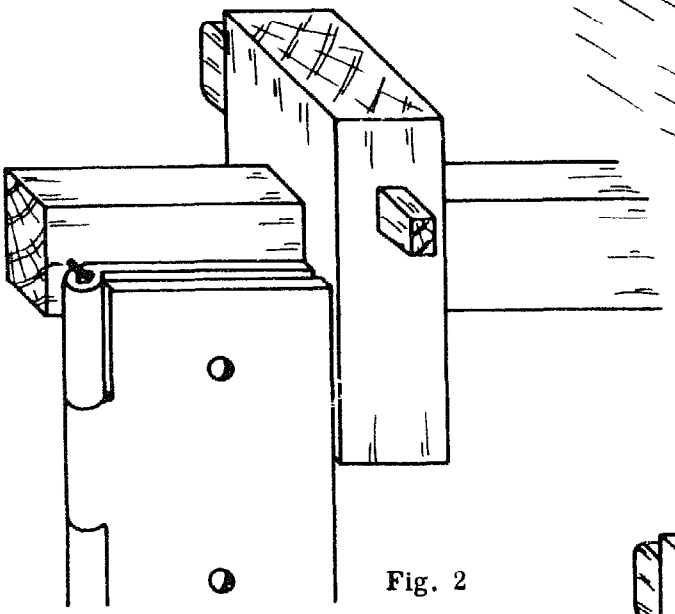

Fig. 2

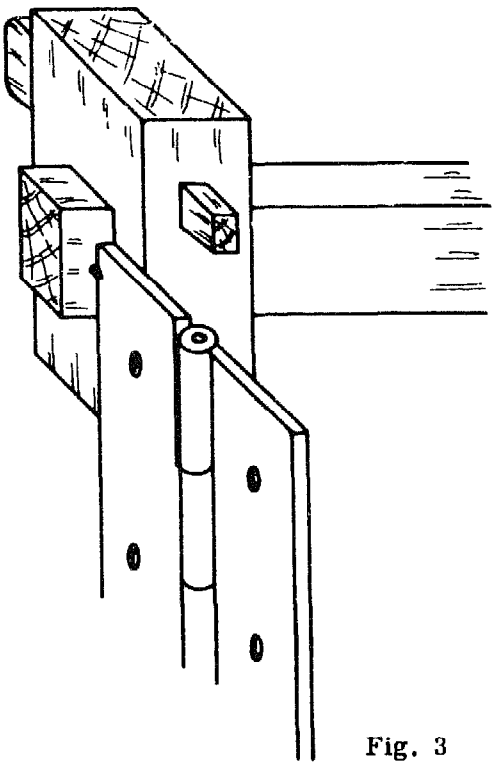

Fig. 3

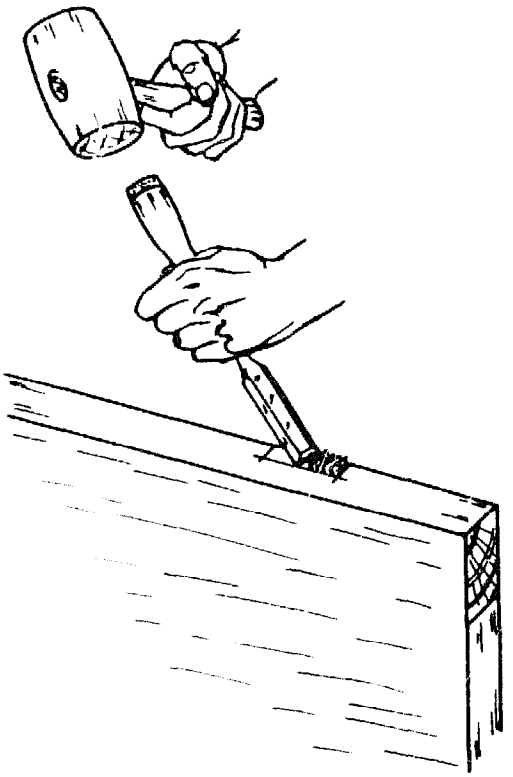

Fig. 4

N P V C		HANGING DOORS AND WINDOWS.
256	CON.	

HANGING DOORS AND WINDOWS

The first step in hanging a door is to make sure that the posts of the door frame are plumb. If the posts are not plumb the door will not hang properly. A door should remain in position, either open or closed, without the aid of a stop. It should not swing open or closed by its own weight. The same applies for window casements.

If the door posts are not plumb, the only solution is to fix the hinges in positions such that the door itself hangs plumb.

HANGING A DOOR WITH BUTT HINGES

Before you read the following section, look up butt hinges in the Reference Book, pages 219 to 221.

- SEQUENCE OF OPERATIONS:

a. Set the door into the door frame.

b. Check whether there is a sufficient clearance all around the door (at least 3 mm, more in the dry season).

c. Mark the positions of the hinges, then take the door down and mark the length of the hinges on the door (Fig. 1).

d. Set the marking gauge from the middle of the pin of the hinge to the edge of the hinge leaf, and mark the distance on the edge of the door (Fig. 2).

e. Set the marking gauge to the thickness of one hinge leaf, and mark this on the face of the door (Fig. 3).

f. Chisel the recesses for the hinges in the door, and fix each hinge with one screw (Fig. 4).

g. Place the door in the door frame so that there is equal clearance around all the edges. A few thin pieces of wood between the door and frame will help to keep it in place.

h. Mark the positions of the hinges on the post. Remove the door.

i. Mark the depth and width of the hinge recess on the post, using the marking gauge.

j. Chop the recesses in the post.

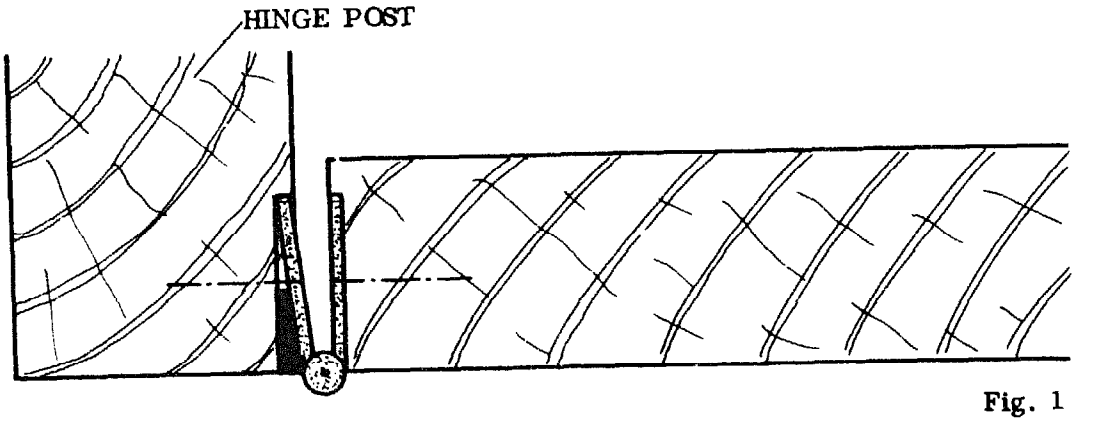

Fig. 1

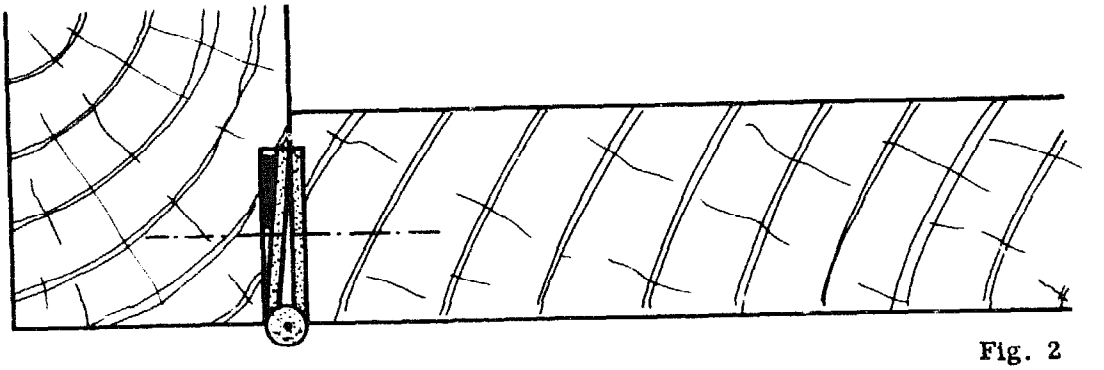

Fig. 2

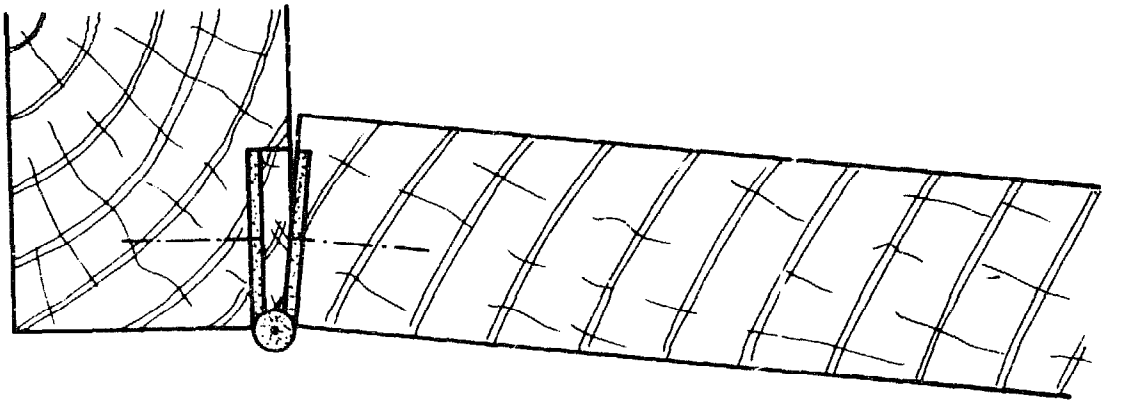

Fig. 3

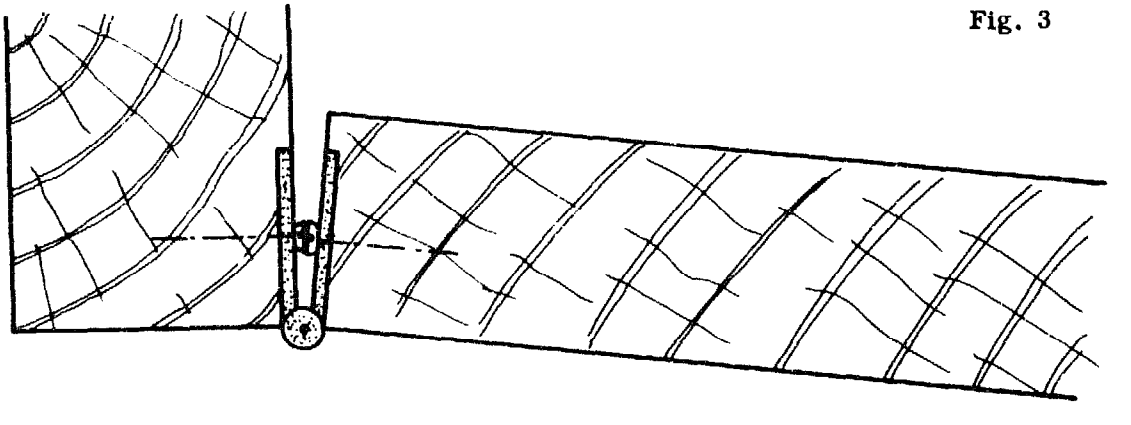

Fig. 4

N P V C		HANGING DOORS AND WINDOWS.
258	CON.	

k. Place the door in position and fix it to the door post with one screw in each leaf of the hinges. Close and open the door several times to see if it works smoothly. Notice in particular whether the door closes completely and does not scrape either post. It should stay closed by itself.

The same sequence as above also applies for casements.

- ADJUSTMENTS OF THE HINGES: Below are some tips for getting a door or casement to close properly.

  - If one hinge recess is deeper than the other, loosen the screws and pack the deeper recess with thin strips of wood, until the depths of the recesses are the same.

  - When a door binds (catches or rubs) on the hinge post, insert thin pieces of wood at the face edge of the hinges (near the pin) until the problem is relieved (Fig. 1). A strip about 1 cm wide and as long as the hinge will do.

  - When a door binds on the locking post, insert the wood strip at the back of the hinge, to force the door away from the lock post (Fig. 2).

  - If the wood strips are not enough to relieve the problem, you will have to remove the door and plane something off, alter the hinge recesses or even move them a bit up or down.

  - One possible reason that a door won't close well is that it is hinge bound. This means that the leaves of the hinges are set too deep. To remedy this, you must remove the hinge and place a thin piece of wood between the leaf and the post (Fig. 3).

  - When the hinge is screw bound, the heads of the screws obstruct the door so that it can't close properly. This is often the case when the screws are too thick for the hinges, or the heads are too large. The only remedy is to fix the correct screws (Fig. 4).

NOTES:

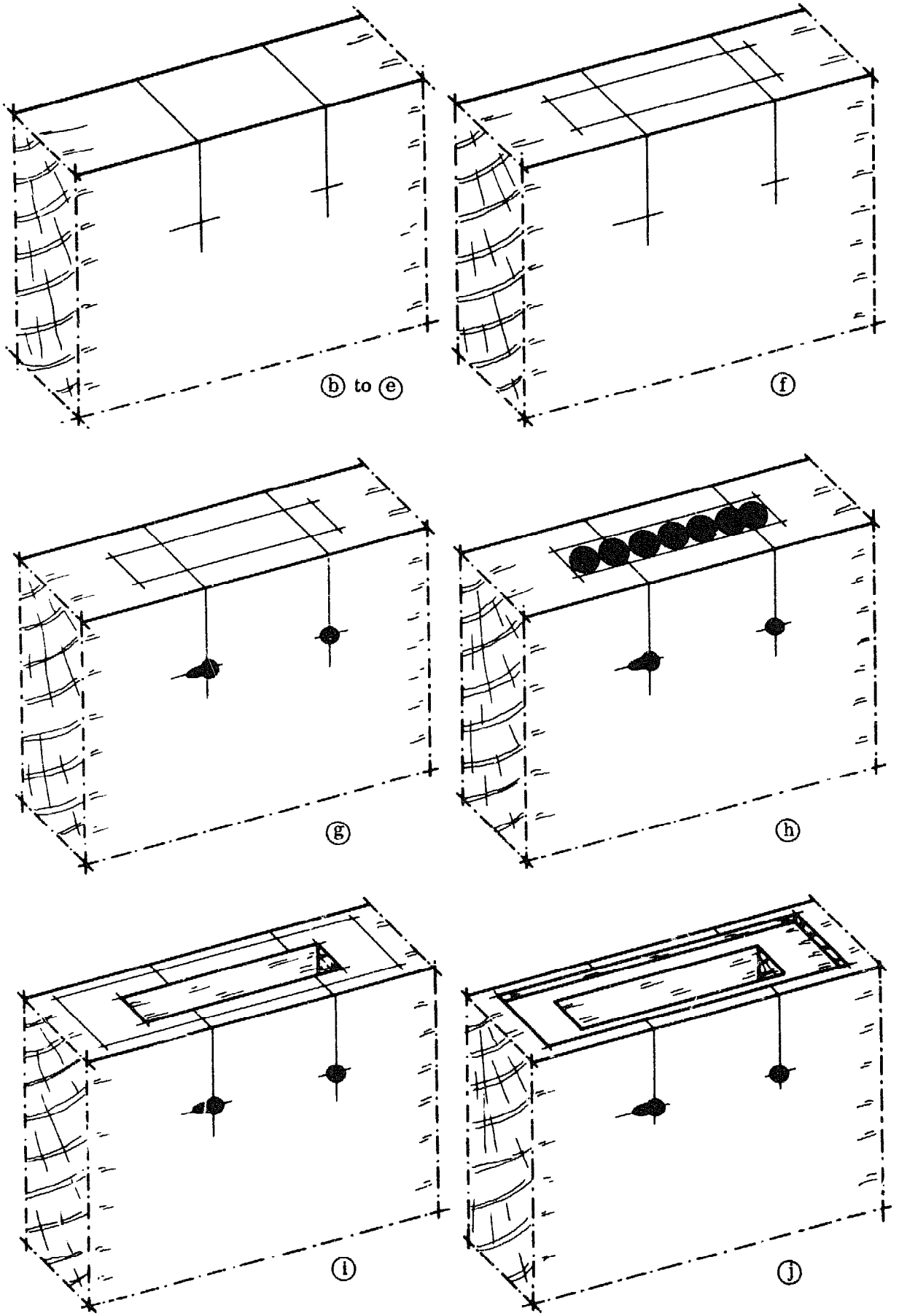

N P V C	
260	CON

LOCKS AND FITTINGS.

LOCKS AND FITTINGS

MORTICE LOCK

Before you read this section look up mortice locks in the Reference Book, pages 221 to 223. Pay attention to the names of the parts of the lock.

- SEQUENCE OF OPERATIONS FOR INSTALLING A MORTICE LOCK:

a. Place the door on edge against the side of the work bench, with one face against the bench and with the shutting stile upwards.

b. Mark the distance from the bottom edge of the door to the centre of the "bush" (the bush is the hole where the handle fits through, normally it is 105 cm from the bottom edge of the door).

c. Square the positions of the key hole and the bush on the face and edge of the door.

d. Set a marking gauge with the distance from the outside edge of the lock face plate to the centre of the key hole. Add 2 mm allowance for planing off later.

e. Mark this gauge setting on the door.

f. Mark the position of the lock stock onto the shutting edge of the door.

g. Clamp a piece of waste wood under the door to prevent splintering. Drill the bush hole and the keyhole. Complete the slot for the key hole with a chisel.

h. Chop the recess for the stock with a mortice chisel. Much of the waste can be bored away with a drill. Take care that the stock fits tightly against the sides of the mortice.

i. Drop the lock in the mortice and mark the position of the face plate on the door edge. Remove the lock.

j. Chop the recess for the face plate with a mortice chisel.

k. Drop the lock in again and insert the key and the handle with the fixed spindle. Check that there is nothing blocking the key and handle.

l. Attach the lock with screws.

m. Hold one leaf plate in position on the outside of the door. Insert the key and the handle with the spindle.

n. Attach the leaf plate to the door with screws.

o. Fix the leaf plate on the other side of the door in the same manner.

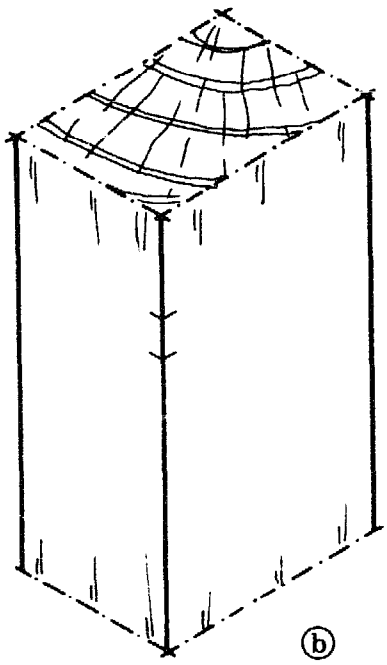

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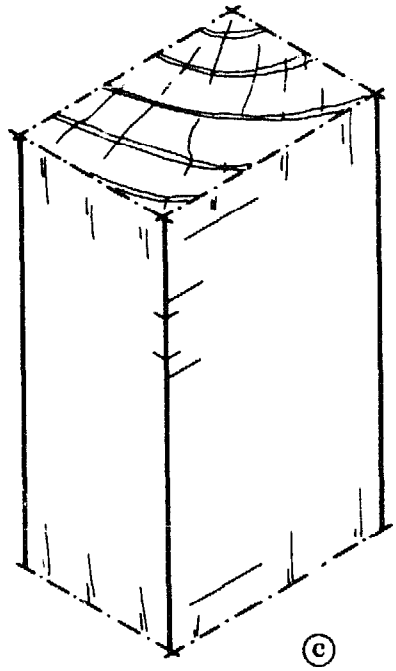

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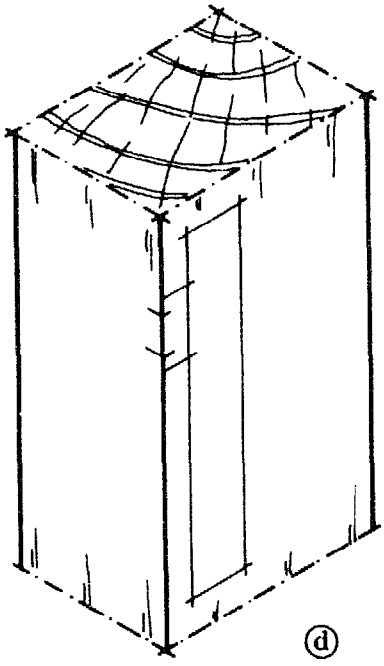

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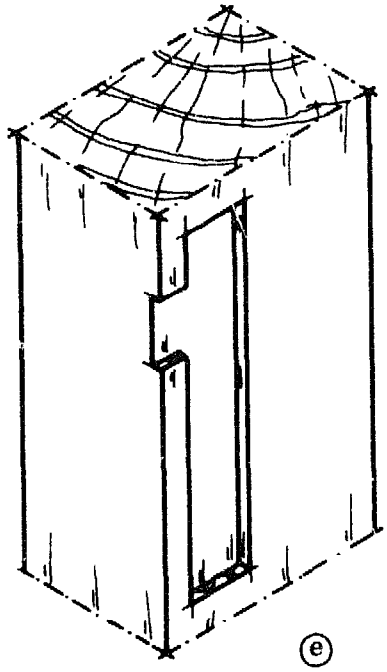

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N P V C	
262	CON.

LOCKS AND FITTINGS.

p. Secure the loose handle onto the spindle, with the pin.

The installation of a mortice lock with a cylinder is similar to the above procedure; but instead of a key hole, a hole is drilled for the locking cylinder.

- SEQUENCE OF OPERATIONS FOR INSTALLING THE STRIKING PLATE:

a. Set the door with the mortice lock into the door frame.

b. Mark the position of the latch bolt onto the door frame.

c. Hold the striking plate to the post in the correct position and mark the position on the post.

d. Set the gauge and use it to mark the vertical lines.

e. Cut the recess for the striking plate.

f. Fasten the striking plate to the post with screws.

g. Chop the recesses for the latch bolt and the lock bolt while the striking plate is in position.

h. Cut off the projecting lug of the striking plate (arrow).

i. Close the door and check whether the latch bolt and the lock bolt can move freely and fit into their recesses.

In the case of a door frame with beads, the beads can be fixed after the door is properly hung and the locks installed.

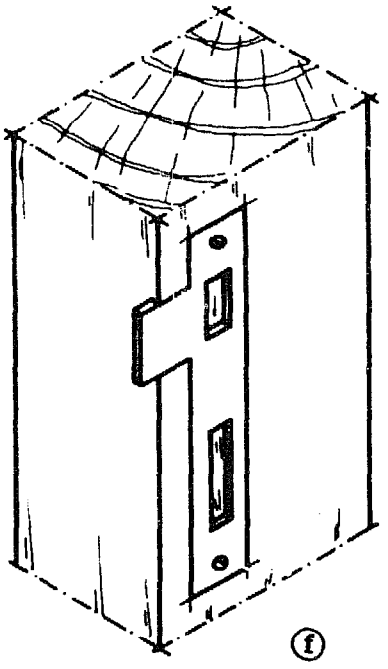

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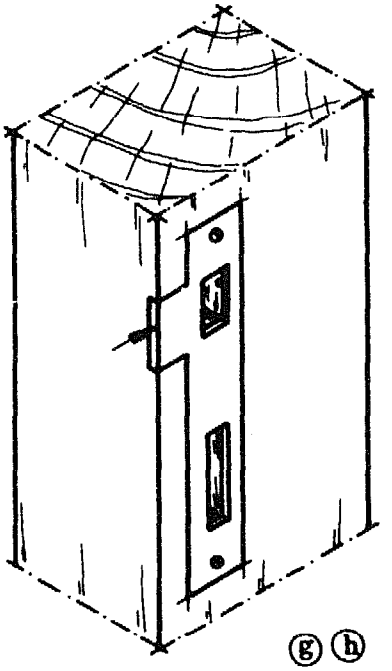

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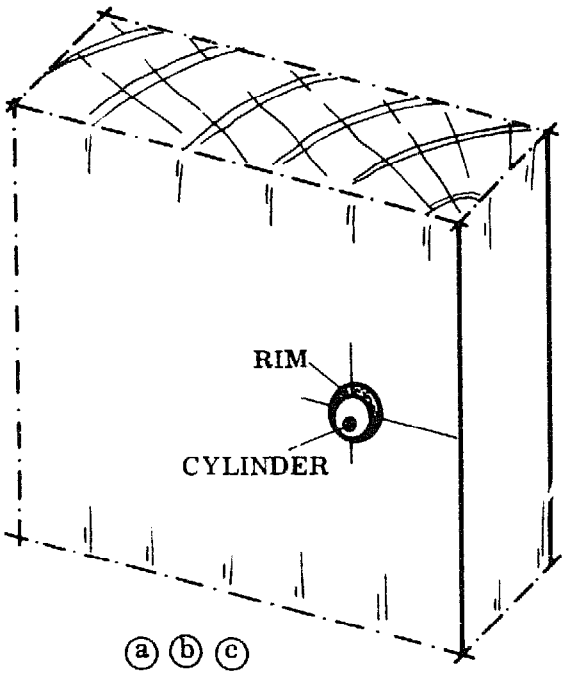

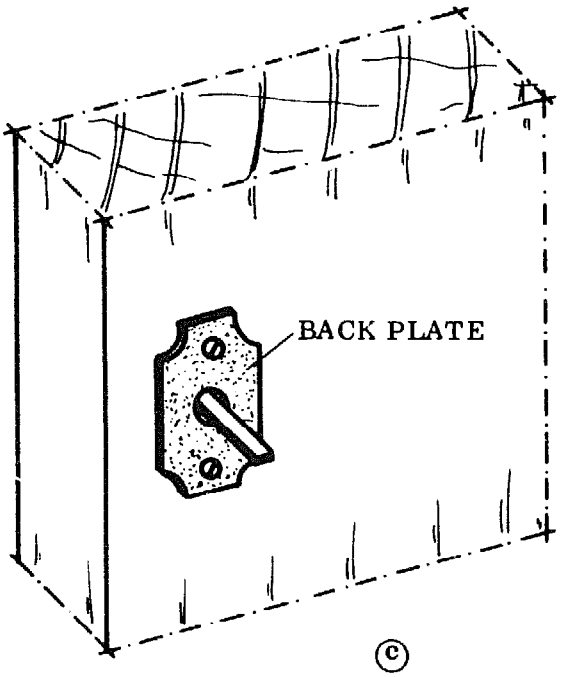

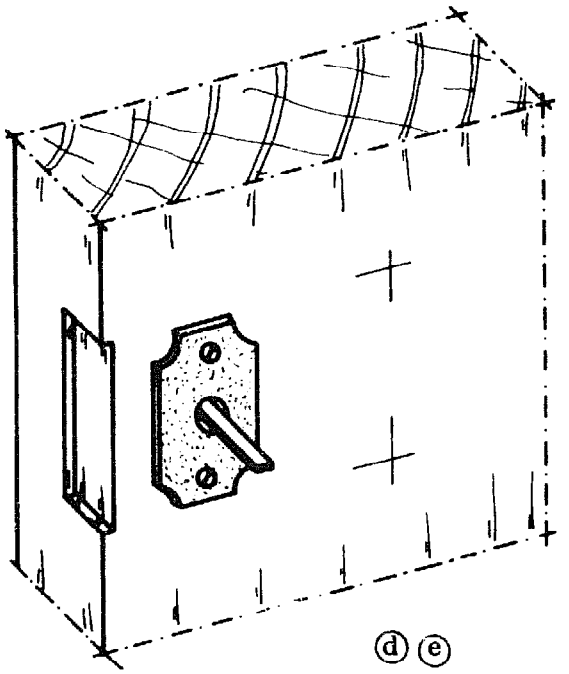

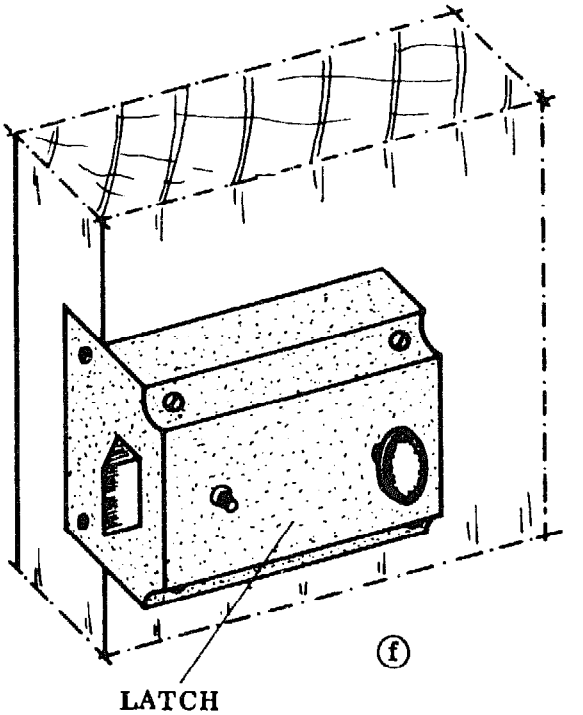

N P V C	
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LOCKS AND FITTINGS.

RIM LOCK

Look in the Reference Book, page 225, for information about this type of lock and its parts before you read on.

- SEQUENCE OF OPERATIONS FOR INSTALLING A CYLINDER RIM NIGHT LATCH:

a. Mark out the position of the cylinder on the door (normally 105 cm from the bottom of the door).

b. Drill a hole with the diameter of the shell.

c. Insert the cylinder with the rim into the hole, and attach the back plate to the opposite side of the door with screws.

d. Mark the position of the latch and its face plate.

e. Chop the recess for the face plate.

f. Attach the latch to the door with screws. Also use two screws on the face plate to attach the lock securely.

g. Turn the knob and check that the latch operates smoothly.

h. Mark the staple on the post and chop the recess for the staple face plate.

i. Attach the face plate to the post with screws.

j. Check that the bolt of the latch fits in the staple.

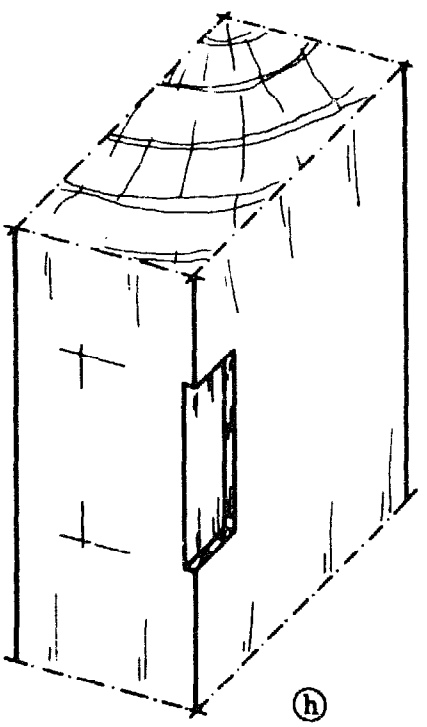

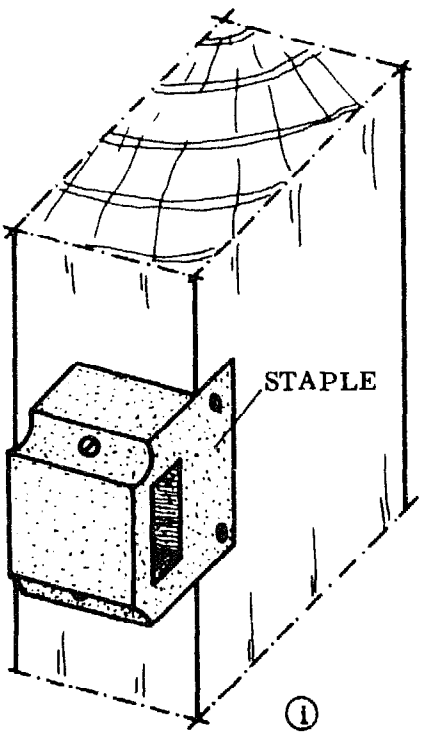

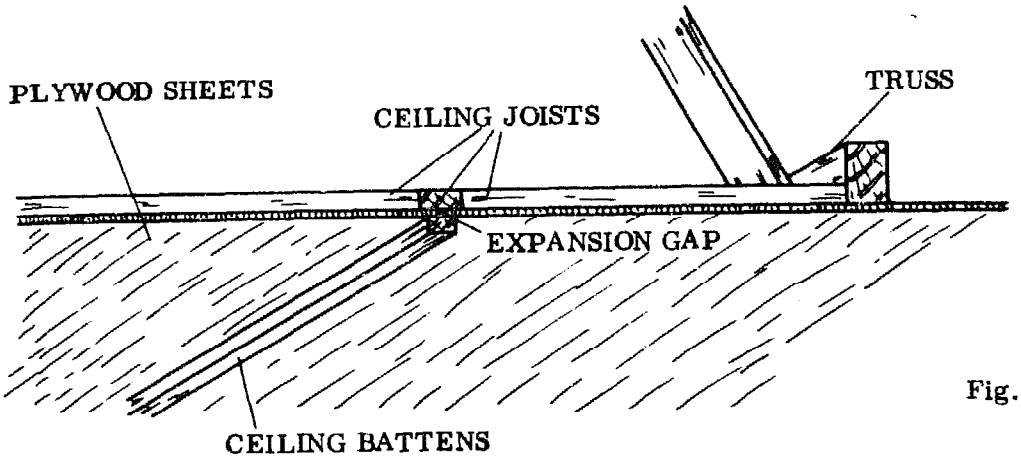

Fig. 1

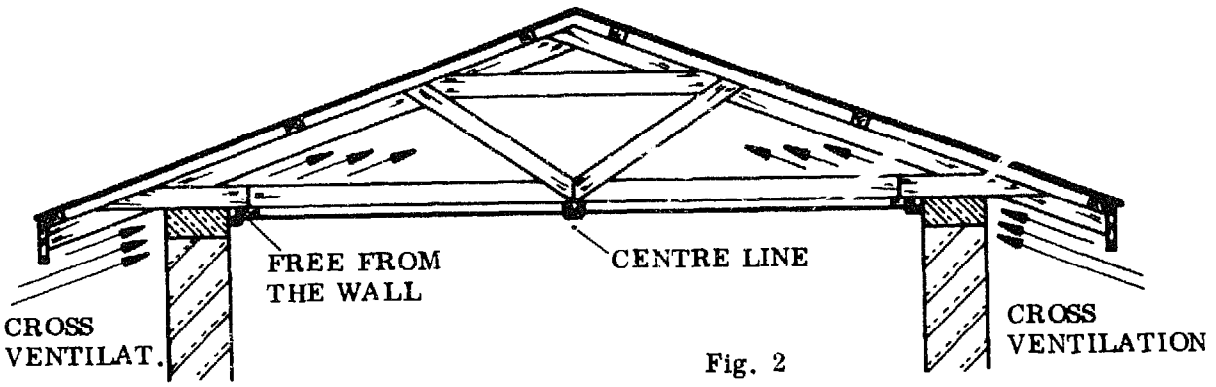

Fig. 2

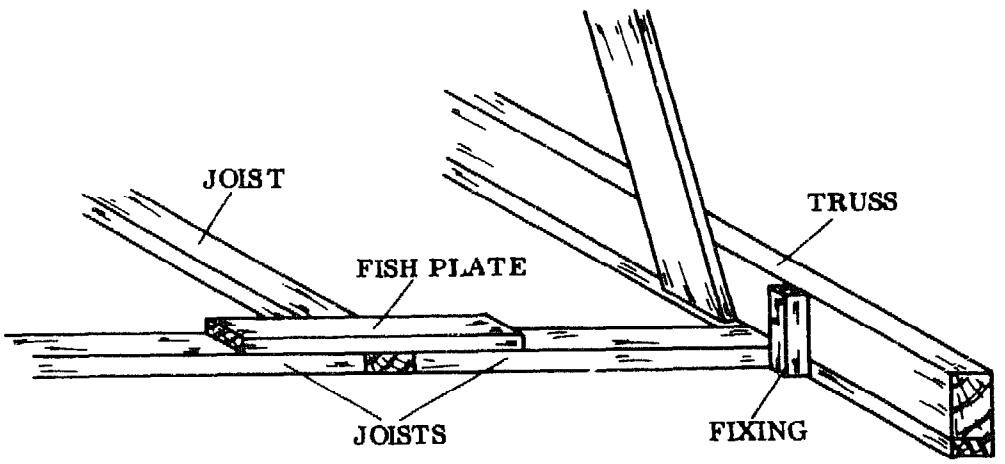

Fig. 3

N P V C		CEILINGS.
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CEILINGS

The best method of keeping the building cool is to separate the rooms from the roof by a ceiling. The ceiling also keeps out dust and dirt, gives the room a nicer appearance, and makes it quieter.

In Rural Building, we deal only with plywood ceilings. These consist of sheets of thin plywood nailed to ceiling joists (the wooden beams which carry the ceiling). The edges where the plywood sheets join are covered by the ceiling battens (Fig. 1).

- NOTE: Cross ventilation is extremely important. Every ceiling should be constructed so that there is cross ventilation between it and the roof. If this is not done, bats and other animals will make their homes above the ceiling; and also any dampness will soon cause the ceiling sheets to rot.

  Cross ventilation keeps heat from building up between the roof and the ceiling, and thus the rooms are cooler (Fig. 2).

CONSTRUCTION, PARTS AND SIZES OF PLYWOOD CEILINGS

It is easiest to construct a ceiling under a roof with built-up trusses. If the soffits (undersides) of the trusses are level, the ceiling joists can be nailed between the tie beams. If the tie beams are not level, use battens nailed to the tie beams to build up until the surfaces are level (Fig. 3).

If you want to fix a ceiling in a building with an ordinary pent roof (without trusses), a separate construction must be attached to the roof construction or to the wall, to provide support for the ceiling joists. Be sure to provide plenty of cross ventilation by some means (ventilation blocks could be used).

The distance between the ceiling joists should be no less than 122 cm. The joists can be left rough, because they are out of sight behind the plywood sheets.

When possible, design the rooms with the plywood sheet size in mind, just as the roof plan is made according to the size of the sheet material. Plan the size of the verandah and the positions of the inner walls so that the rooms are a convenient size and the plywood sheets fit without unnecessary waste.

NOTES:

- INSTALLING THE PLYWOOD CEILING SHEETS: Always start by fixing a line to show the exact centre of the room (Fig. 2, previous page). Start fitting sheets from this line. In case the sheets will not fit exactly in the room without being cut, start by putting one whole sheet in the centre of the ceiling, then divide the remaining space into equal areas.

  There should be expansion gaps between the sheets to allow for changes in size with the changes of humidity. These gaps are covered by the ceiling battens. The battens are about 1 by 2,5 cm in size. Paint the ceiling and the battens before fixing the battens.

PAINTING

Paint preserves building materials from rot, rust, and general decay. Timber especially needs some finishing treatment, whether it is used inside or outside the building. Paint helps keep the wood from swelling or warping.

Protective finishes such as oil paints or varnish (Reference Book, pages 200 to 201) cover the wood with a protective "skin". In order to be effective this skin must be undamaged, and so we have to repair and maintain these finishes periodically.

Which type of finish is used depends on whether the wood will be used outside or inside the building and on the particular function of the wood piece.

The selection of the colours for the inside and outside of the building is important because it affects the temperature of the building. Light colours keep the building cooler.

PREPARATION OF SURFACES FOR PAINTING

Surfaces to be painted should be dry and clean; free from mud, dust, dirt, grease, rust, and old scaly paint.

All the boring, cutting, and shaping should be finished before the paint is applied.

Timbers should be well seasoned to prevent cracking. Paint with cracks in it is worse than no protection at all; water can enter the wood through the cracks, but it cannot evaporate off through the skin of paint so it causes the wood to rot.

If cracks appear in painted wood, sandpaper the wood before you apply new paint, to prevent the cracks from coming back. When you cut painted wood, don't forget to repaint the ends.

HOW TO PAINT

Paint when the weather is good for drying, and when there is little or no wind or dust in the air. Paint should not be applied in wet weather or when the wood is damp. In new buildings first make sure that they are not damp. New masonry must be thoroughly dry before paint is applied to it. Drying, especially of floors, can take up to 6 months.

Mix the paint thoroughly before you apply it.

Painting is done with a brush. Dip the brush into the paint up to about 1/3rd of the length of its bristles, and remove the excess paint. Never dip the whole brush into the paint because the excess paint will drip out and be wasted.

Use long sweeping strokes and brush the paint well to form an even coating. Start at the top of a surface at one edge, and work across and down. Try to finish each day's work at a corner of the building or at a window. If you stop in the middle of a wall the mark will show where you resume painting the next day.

All new work, either of wood or masonry, requires three coats of paint. Surfaces which have been painted before need only two coats.

Before you apply a new coat, the previous coat has to be thoroughly dry. With most paints, the first two coats may be diluted with thinner to allow a better distribution and penetration. Only the final coat must be undiluted.

If wood is unprotected from the rain and sun, it will be necessary to repeat the application of finish from time to time. Take care that the end grain absorbs as much paint as possible.

Never allow a brush to rest upright on its bristles. If you stop work for a few minutes, remove the excess paint from the brush by wiping it on the edge of the tin, then lay it flat across the top of the tin or on a smooth clean surface.

If work is stopped for a longer time (overnight or for a few days), put the brush in a tin of kerosene. Here is an illustration of a good way to keep the paintbrushes; note that the bristles are covered with kerosene but they do not rest on the bottom of the tin. Simply drill a hole in the brush for the stick to pass through.

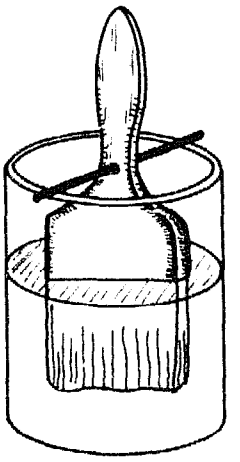

HOW TO APPLY TIMBER PRESERVATIVES

There are two practical methods for applying timber preservatives:

- By painting (as described in the previous two pages)
- By soaking or dipping.

Different types of timber preservatives are required for different situations. The different kinds are described in the Reference Book, page 145.

- SOAKING OR DIPPING: Soaking or dipping is a much more efficient method than painting for applying any kind of timber preservative, because the chemical can penetrate deeper into the wood. This method can also be used for protective finishes such as oil paint.

  Use a bucket or other suitable container to soak the wood for several hours or days. This method is only practical for smaller pieces like the ends of fence posts or frame pieces.

In cases where you are repeating the application of a preservative, use a preservative from the same group as the first application. Remember that the waterborne preservatives cannot penetrate over oil preservatives, but it is possible to apply an oil preservative over a waterborne one.

Only waterborne preservatives should be used if the wood will be painted later.

Take care that the end grain and splits absorb as much preservative as possible.

- NOTE: Be careful; most finishes are poisonous and can be fatal to human beings. Paints and paint thinners are often flammable.

NOTES:

APPENDIX

The following pages contain information and designs for constructions which do not necessarily fit under the topic of Rural Building, but which are nevertheless important for the Rural Builder to know about, at least in general. One of the purposes of this course is to prepare the Rural Builder to become a part of the development process in the rural areas, and this includes not only the construction of safe, healthy and comfortable buildings, but also the provision of safe water supplies, sanitation methods, and even the storage of the agricultural produce which is indispensable to rural life.

The following simple designs can be adapted and should be useful to almost any rural community.

NOTES:

NOTES:

WATER PURIFICATION

A water source is important in planning any building. The source can be a well, deep bore hole, spring, stream, or rain water collected from a roof and stored in a tank. The importance of water needs no explanation: it is worth spending both time and money to make sure that pure water is available at all times.

Many diseases come from drinking impure water. The danger of disease can be reduced by taking such precautions as boiling and/or filtering drinking water. Water obtained from a clean source such as a properly dug well or a borehole should carry no disease in it.

There is much that the Rural Builder can do to help the people in his community to have clean water to drink.

SMALL WATER FILTER

One way to improve the quality of water is to use a water filter. A simple design for a filter which can be made by anyone is shown below. It is used for small amounts of water. The filter consists of a locally made pot which hangs from wires or ropes.

The pot is partly filled with layers of fine sand, gravel and stones. The water sinks down through this and drains off through holes in the bottom of the pot. The diameter of the holes should be small enough so that the stones can't pass through.

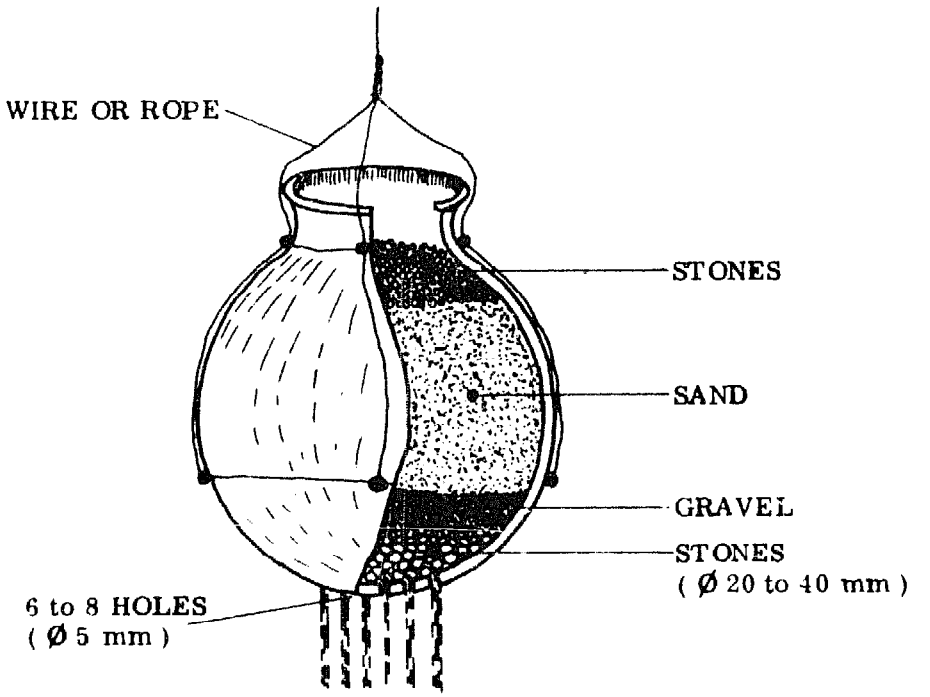

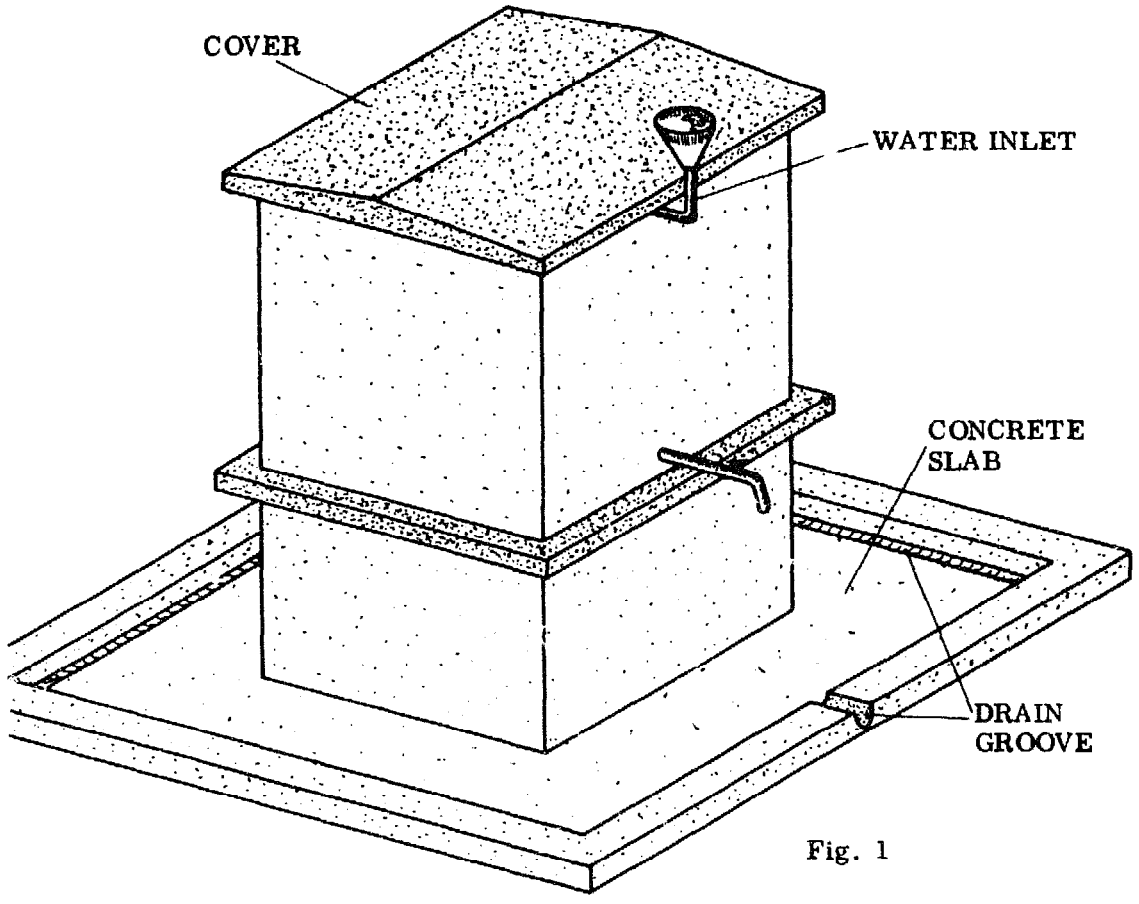

Fig. 1

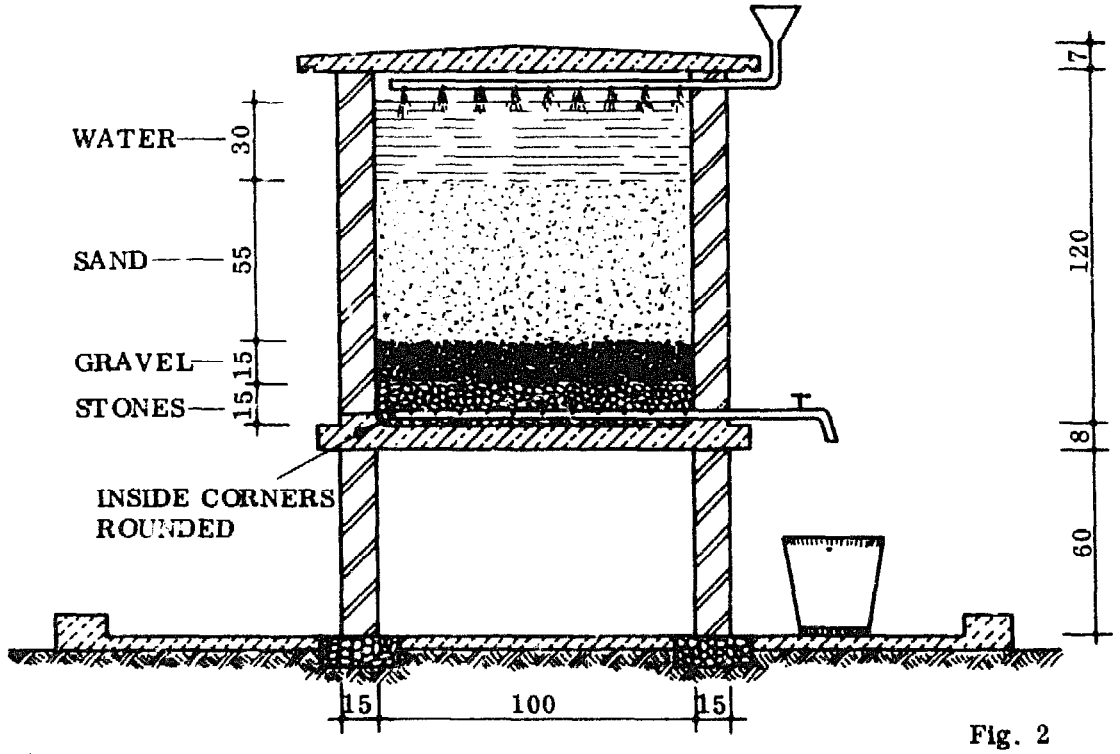

Fig. 2

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LARGE WATER FILTER

A built-up water filter (Fig. 1) can be used to purify larger amounts of water. Its size depends on the amount of purified water that is needed.

The cover can be removed to allow the user to clean the filter materials and the entire inside of the tank. If the cover is very heavy it can be made in two halves.

The water inlet also acts as a ventilation opening. The top of the funnel should be covered with copper or aluminium mosquito wire to keep insects out of the tank. The distribution pipe inside (Fig. 2) has many fine holes to make sure that the water is spread evenly over the sand. If necessary install more distribution pipes so that the whole top surface of the sand can be soaked with water; thus using all of the filter materials inside the tank rather than overloading a small area.

The space of 30 cm at the top for water storage may be increased if necessary. The depths of the different layers of filter materials should be no less than indicated. If the layers are made deeper still the water will be filtered more thoroughly, but generally the indicated depths are sufficient (also see Drawing Book, page 120).

At the bottom of the tank a piece of pipe with holes in it allows the filtered water to drain off. There should be plenty of holes, and the diameter of the holes should be small enough to prevent the fine gravel from entering the drain pipe. At the end of the pipe a valve can be used to stop or start the flow of water. It drains into a container which is placed under the pipe.

The floor of the tank should be constructed with a rim all around (Fig. 2), which carries the walls and projects at the base of the walls, so that there is no crack between the walls and the floor. The whole inside should be plastered smooth to make it easy to clean.

The filter should be built off the ground so that the water can drain easily into buckets. It is advisable to concrete the area surrounding the filter and to provide a drain for spilled water (Fig. 1).

When the filter needs cleaning the water flow will become very slow. To clean the filter it is only necessary to take off the top 2 cm of sand and replace it with clean sand. Depending on how clean the water is at the start, the filter may need cleaning only after several weeks or even months.

NOTES:

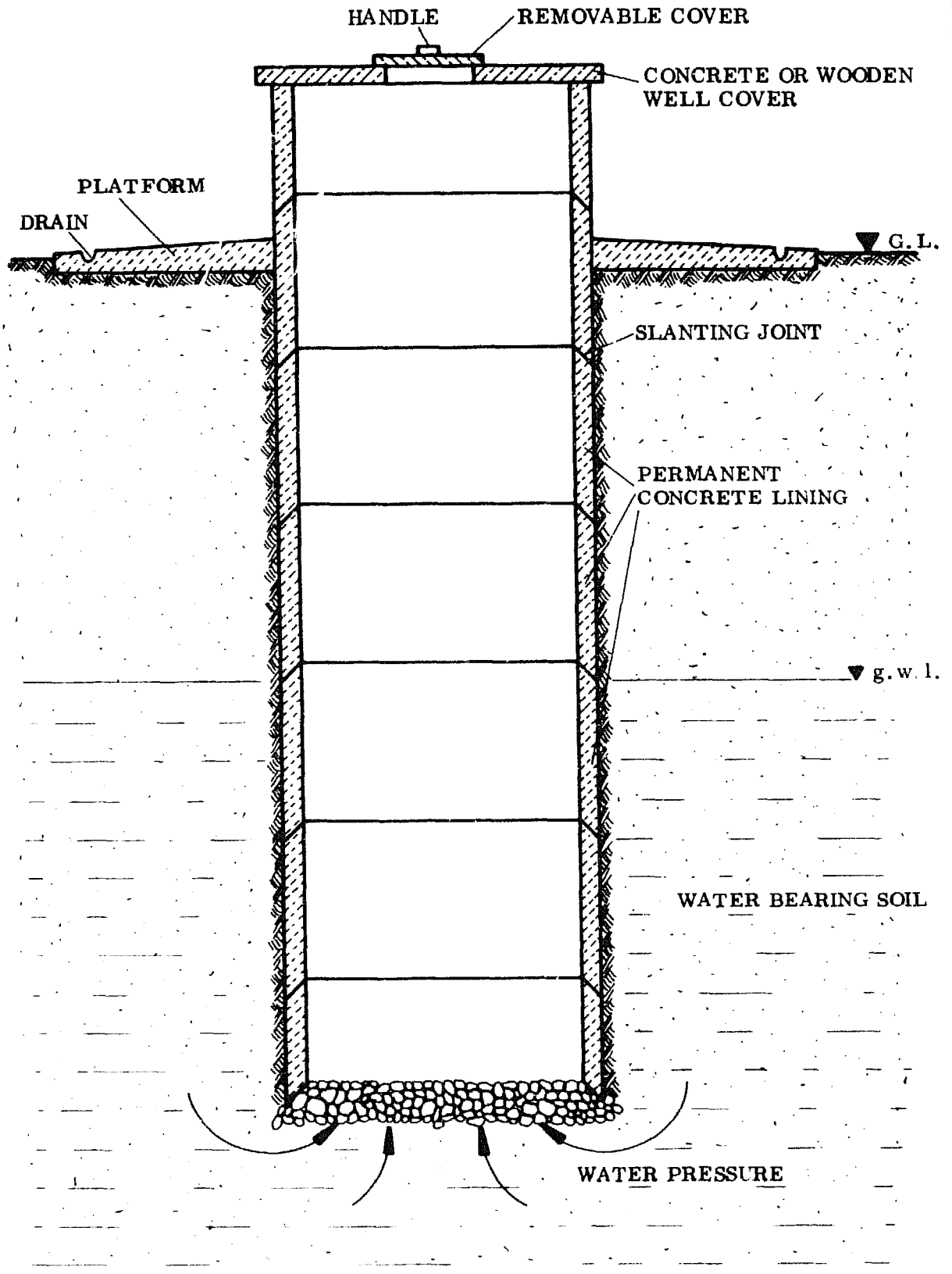

Fig. 1

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HAND-DUG WELLS.

HAND-DUG WELLS

The hand-dug well is the most common kind of well. Unfortunately, most wells are dug according to very basic "hole-in-the-ground" methods, and they can become health hazards as they are easily infected by parasites and bacterial diseases. With modern methods and materials, hand-dug wells can safely be made up to 60 m deep and will give a permanent source of good water.

Untrained workers, if they are properly supervised, can safely dig a deep well with simple light equipment. The basic method is outlined here. This information is intended to help you to dig more safely, and also to make a well that will not become contaminated by surface water. However, there are other problems concerning well digging that are not covered here, and you are advised to seek the help of an experienced well digger when you make a well by this method.

LINING WELLS

Masonry or brickwork are widely used in many countries to line the walls of wells. These can be very satisfactory in the right conditions. In bad ground however, unequal pressures can make the lining bulge or collapse. Building with these materials is slow, and a thicker wall is required than with concrete linings. There is also the danger of the blocks moving during the construction in loose sandy soil or shale, before the mortar has set firmly between them.

This danger is prevented with concrete linings because the form is left in place to support the lining until the concrete has set hard.

Lining (Fig. 1) prevents the hole from collapsing; keeps out contaminated surface water; and supports the pump platform if there is a pump.

It is usually best to build the lining as the well is dug, since this avoids the need for temporary supports and also reduces the danger of cave-ins during digging.

There are two methods for doing the lining:

- As the hole is dug, the sections of lining are built into their permanent positions. This is the method explained on the following pages.
- Precast sections of lining are added at the top and the whole lining moves down as the hole is dug and earth is removed from under it.

NOTES:

- The concrete rings in the lower part can also be of poor concrete with honeycombing to allow water into the well.

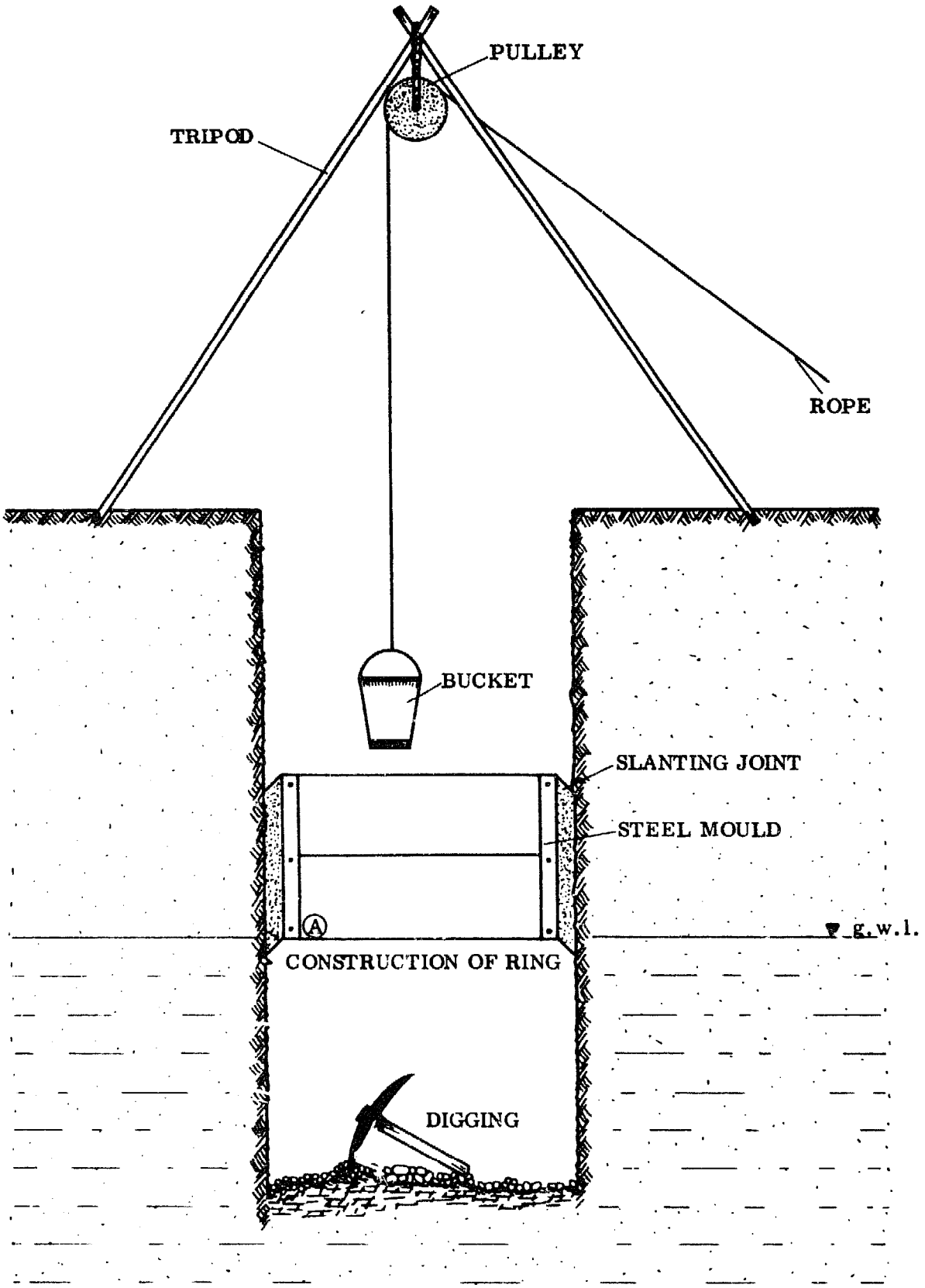

Fig. 1

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HAND-DUG WELLS.

TOOLS AND MATERIALS NEEDED

- Shovels
- Pick-axes
- Buckets
- Ropes and pulley
- Steel forms and bolts
- Wooden or steel tripod
- Cement
- Reinforcement bars
- Sand
- Gravel
- Oil

CONSTRUCTION

Experience has shown that when one man is digging, he will be able to dig most efficiently if the well is about 100 cm in diameter. However if two men are digging together, a 150 cm diameter is best, and the two can dig more than twice as fast as one man. Thus two men in the larger hole is usually best, also for safety reasons.

- NOTE: Do not construct a well near a latrine, septic tank, or other source of contamination. The well should be as far away from these as possible; at least 30 m, and it should never be downhill from a source of contamination.

- SEQUENCE OF OPERATIONS:

a. Erect a wooden or steel tripod to support a pulley and bucket for bringing out soil from the hole.

b. Dig down until you reach ground water level (g.w.l.).

c. Make the first concrete ring section just above the g.w.l. (Fig. 1, A)

d. While the first section cures, proceed with digging the hole for the second section. The rings should be made with slanting edges as shown in Fig. 1, so that the joints between the rings slant downwards.

e. Continue constructing ring sections until the well is deep enough.

f. The other rings above ring A can be constructed during the digging.

g. When the concrete lining is completed, the walls of the whole well should be waterproof, so that surface water can't enter the well. A concrete platform with a groove for drainage should be constructed, and a wall around the edge to k[illegible] people and animals from falling in. Either blocks or reinforced concrete can be used for the wall (Fig. 1, previous page).

h. The well is closed off with a wooden or concrete cover, with a small opening for buckets to go through (Fig. 1, previous page).

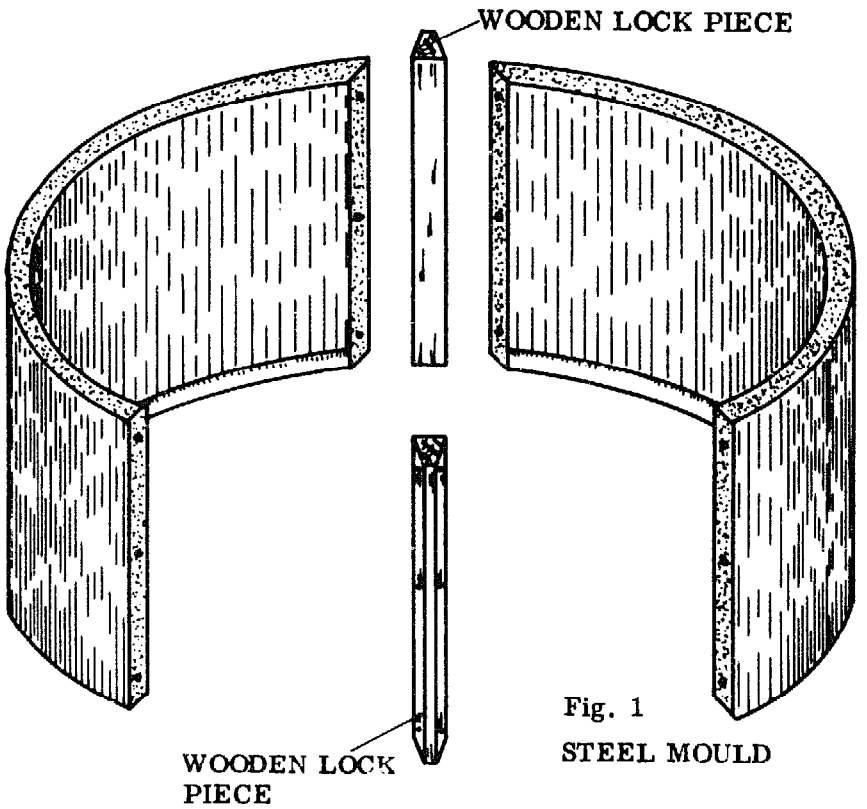

Fig. 1
STEEL MOULD

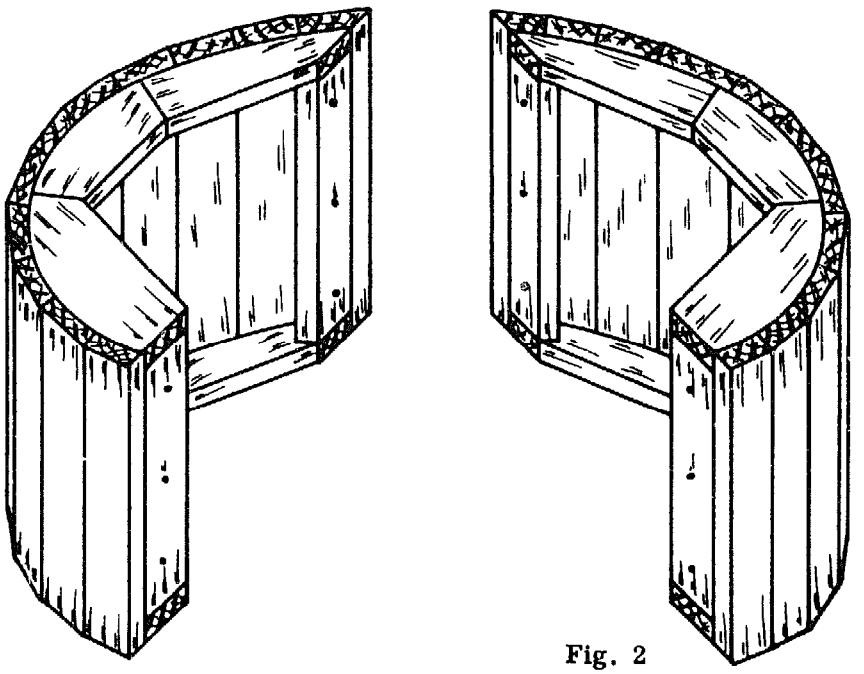

Fig. 2
WOODEN MOULD

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HAND-DUG WELLS.

i. If possible, disinfect the entire well by adding a chlorine solution to it. Use about 1 heaping tablespoon of bleaching powder to 2 buckets of water and mix. Make up three buckets of the solution to wash the walls of the well thoroughly, and pour the remainder into the well. Make up another three buckets and put that into the well too. Leave it overnight before using the water.

- NOTE: Since there is a lot of water in the soil, don't use too much water in mixing the concrete for the lining. Be careful that there are no voids (empty pockets) in the concrete lining. These give surface water and soil a path to enter the well.

- MOULDS: A steel mould (Fig. 1) or a wooden mould (Fig. 2) is used to support the sections of concrete lining during construction and curing. After the ring has hardened sufficiently, the wooden lock pieces are removed and the mould is taken out and used for the next ring (Fig. 3).

When you assemble the mould, be sure that the wooden mould or wooden lock pieces are first soaked in water so that the wood does not expand when it contacts the wet concrete. If the pieces expand they will crack the concrete ring, and it will be very difficult to get the mould out again.

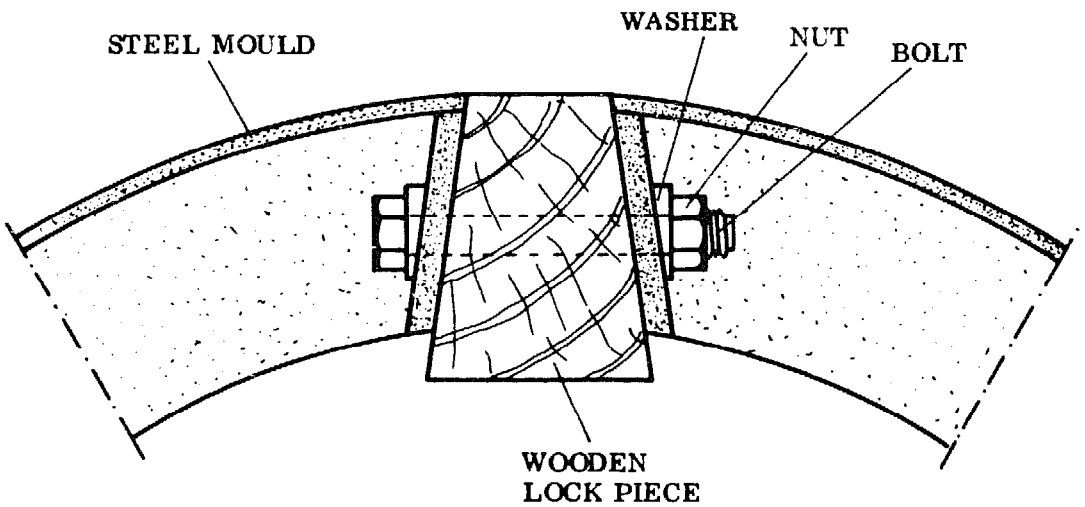

Fig. 3

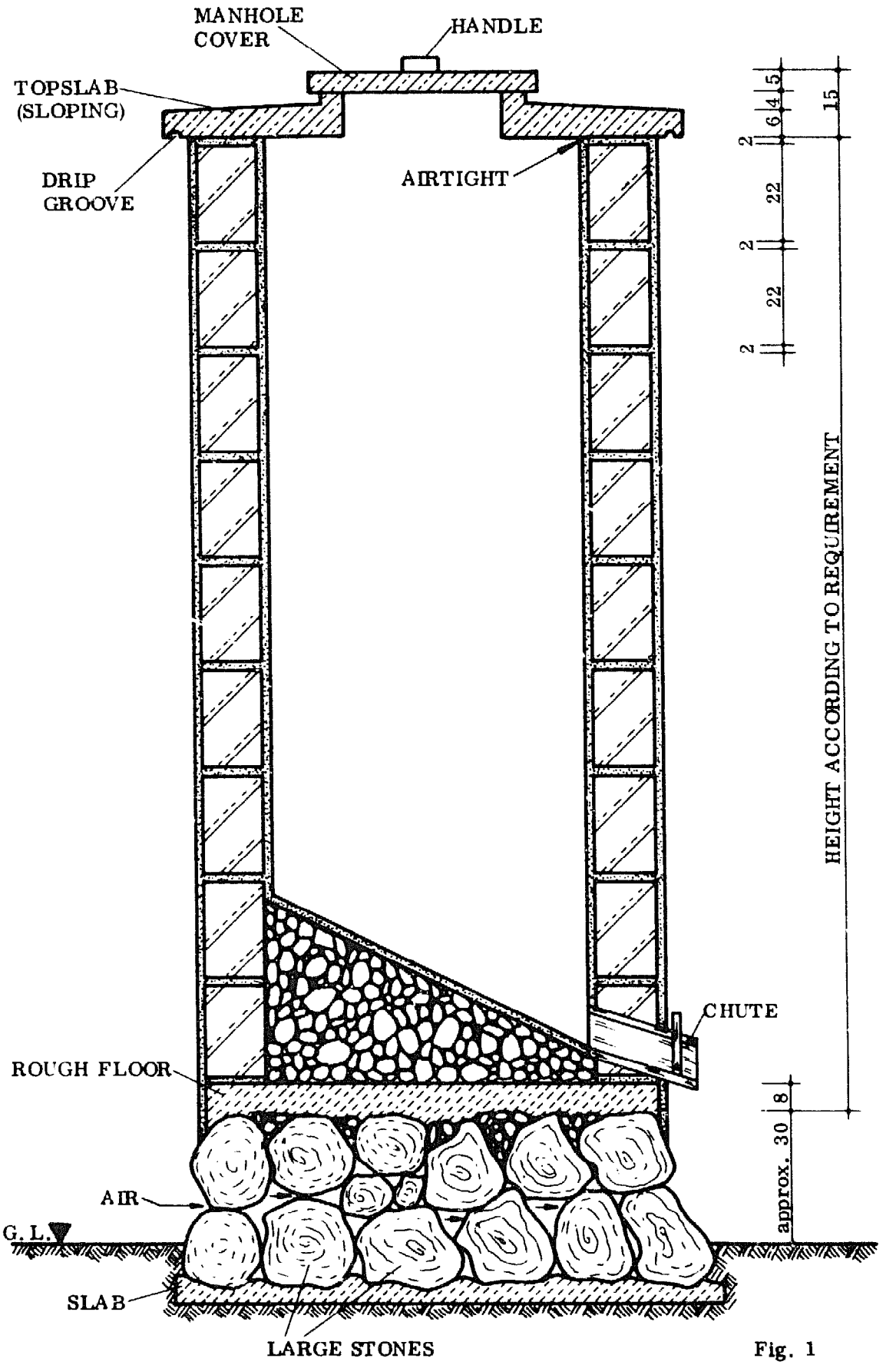

Fig. 1

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GRAIN STORAGE SILO.

GRAIN STORAGE SILO

Often traditional storage methods result in the loss of valuable grain, because insects or mice etc. get into the grain. To help farmers with this problem the Garu Agricultural Station in the Upper Region has developed a new type of grain silo. This silo requires a few bags of cement plus stones or gravel to construct. It can hold between 9 and 16 bags of grain.

Compared to some types of traditional storage, the silo gives better protection to the grain against mice and insects. When the silo is closed so that no air gets in, CO_2 gas develops from the grain and stops the insects from developing.

CONSTRUCTION OF A SILO

Sun-dried laterite blocks are used for the walls of the silo. The blocks are made in the same way as any other mudblock.

Cast the topslab before starting to construct the rest of the silo, so that it will be cured and ready to use when you need it. Construct a frame for casting the slab, with an inner frame for the manhole (Fig. 1, next page). Reinforce the slab with some rods. For measurements, refer to the Drawing Book, page 118. Note that the top of the slab slopes to the outside. Also note that the edge of the slab is fitted with a groove underneath so that rainwater drips down instead of running back under the slab (Fig. 1, left).

Also make a frame for the manhole cover and cast this piece. Use a piece of iron rod set in the concrete for a handle (Fig. 1).

Place wet paper under the frames before you begin to pour the concrete. The concrete has to remain in the frame for three days. Water it twice daily so that it hardens well without cracking. After the concrete hardens (cures) remove the frames carefully so that they can be used again.

- FOUNDATION AND FOOTING: Dig out the top soil and make a concrete slab if needed (if the soil is soft). The slab will be 125 cm in diameter and about 6 cm thick. The footing is made of large stones set on the slab or on the ground. The stones should be placed in such a way that air can circulate freely between them and they should be built to a height of 30 cm above ground level. On top of and in between the large stones, small stones are used to fill in the gaps to form a surface for the floor to rest upon (Fig. 1).

- FLOOR: The floor is poured directly onto the footing. This floor is a working surface only and the top should be left rough so as to give a good grip to the slanting floor (Fig. 1, previous page).

- FIRST COURSE: Place the chute in position. The chute is a kind of open-ended box made from wood, with a sliding closure that can be locked (Fig. 1, previous page). Now proceed to lay the first blocks. The section after this one describes the procedure for laying blocks in a round structure.

- SLANTING FLOOR: Build up four courses, then pack the slanting floor on top of the rough floor. The mixture for this slanting floor should not be too rich, so it doesn't crack. After the mixture is poured into the silo, pack it down well and plaster the top of the slanting floor smoothly. To do this apply some cement powder and add some water, then smooth with a steel float.

- WALLING: Build the walls up straight, using a plumb bob on all sides and for each course. The height of the silo depends on the required storage area. When the desired height is reached, plaster the inside of the silo. The inside plaster should be very smooth and without holes or cracks, so that the silo is airtight.

- TOPSLAB: Provide a mortar bed for the topslab on top of the wall. Then place the slab into position. The slab will be heavy, so several people will be needed for this operation. One man should be inside the silo to direct the operation.

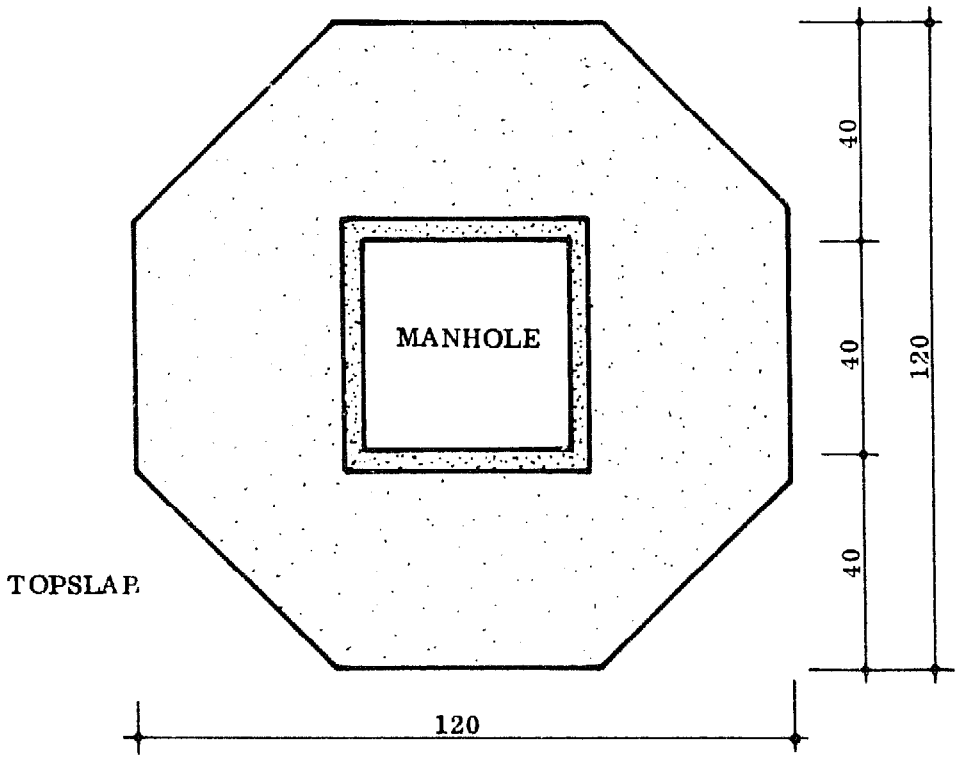

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GRAIN STORAGE SILO.

- PLASTERING OUTSIDE: When the slab is set in position you can do the plastering on the outside of the silo. This has to make the silo waterproof, so the finish should be smooth and without cracks.

USING THE SILO

Dry the grain very well before you put it in the silo. Moist grain will rot, the silo will crack, and all the food will be lost. Distribute the grain well and fill the silo to the top.

Put the cover on the manhole and seal the edges with mud or cow dung. Also seal the chute so that nothing can enter the silo.

Keep the footings and the area around the silo clean.

Check the silo often for cracks, especially when it is full. Replaster any cracks immediately. The wooden chute should always close tightly and the plaster around it should not be cracked.

Paint the silo white or whitewash it. This makes it cooler inside and gives it a nice appearance.

When the silo is emptied, take care to empty it completely. Left-over grain attracts insects and rodents.

Before the silo is filled up again next year, it should be clean and insect free. Light a small bundle of grass on fire inside the silo. The smoke and heat will kill any insects or insect eggs. Sweep out the ashes and dust, and clean the entire silo thoroughly.

CIRCULAR MASONRY WORK

A section on circular work is included here because in Rural Building circular work applies mostly to structures like silos or protective walls around wells.

Here we describe a sequence which might be used to construct a silo. It may be adapted for other structures as well.

Regular blocks are used. Wedge-shaped blocks can be specially made for the job, but the shape of the wedge has to be calculated exactly according to the size of the circle.

NOTES:

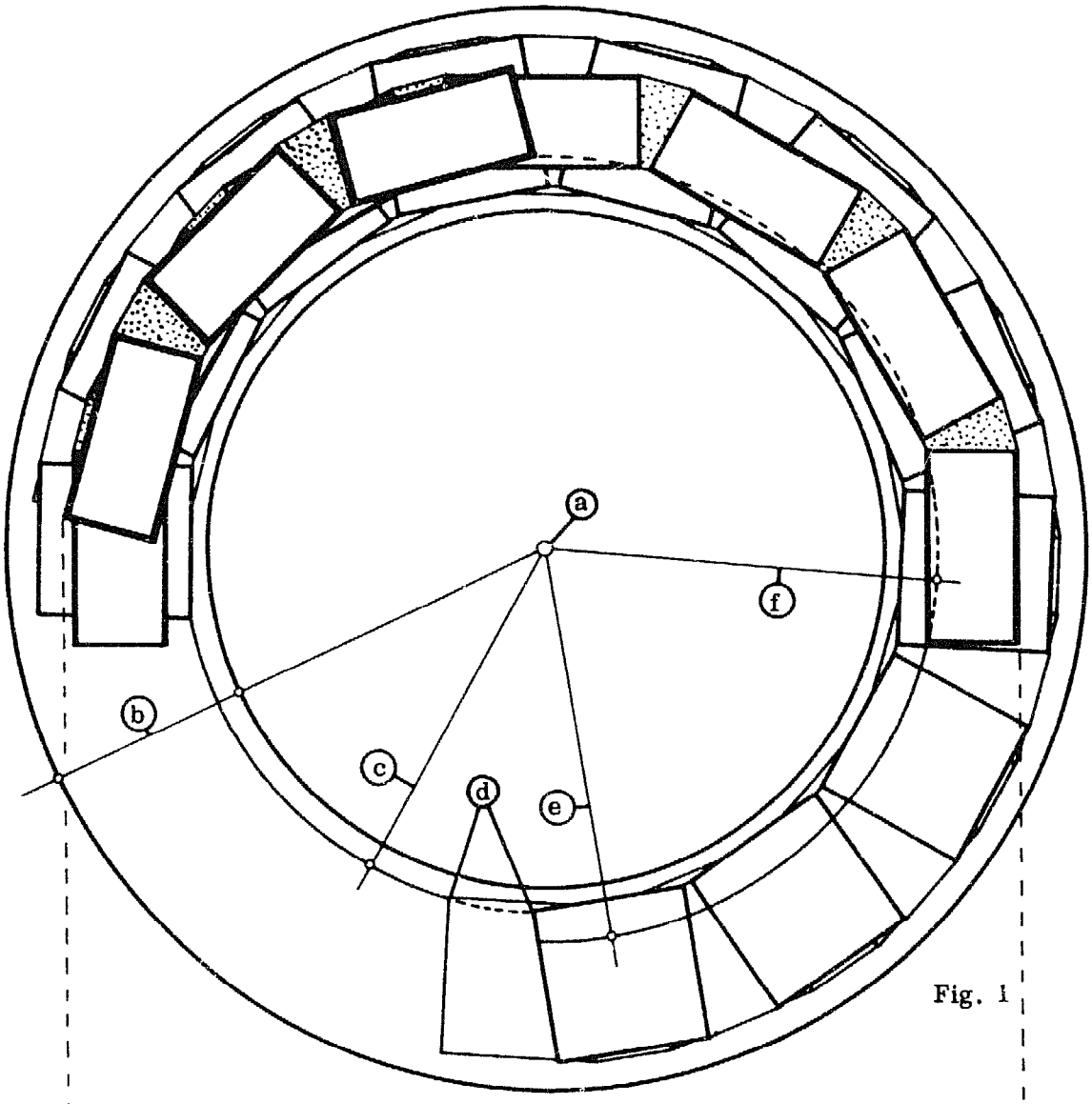

Fig. 1

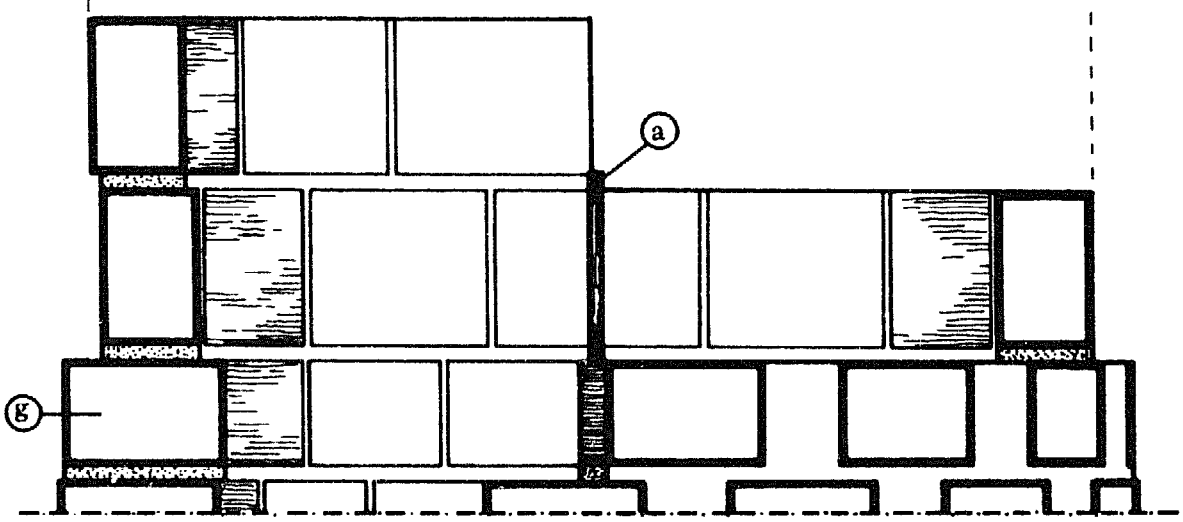

Fig. 2

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GRAIN STORAGE SILO.

SEQUENCE OF OPERATIONS

a. Determine the centre of the circle. Drive an iron rod into the ground at this point (Figs. 1 & 2, a). The rod should be a little higher than the top of the first course of the future rising wall.

b. The inner and outer curves of the foundation are marked on the ground by fixing a mason line to the rod and describing circles with this at the desired radii (Fig. 1, b).

c. The foundation is completed, then the inner curve of the footings is marked on the top of the foundation using the same method (Fig. 1, c).

d. The footing blocks are laid so that the inside corners of each block touch the marked circle (d). The next course is marked on top of the first course and laid in the same manner.

NOTE: In this construction the footings are made with blocks, unlike the silo described in the preceeding pages, where the footings where made of large stones. If a silo is to be built on top of the footings, the cross joints between the blocks are not filled in; this permits cross ventilation. The space up to the top of the footings is filled in with large stones and the floor is made on top of these, as in the silo described before. Remember to set the chute in place on top of the footings before you continue with the rising wall construction. Only two footing courses are necessary to reach the required height of 30 cm for the silo floor.

e. When the footings are completed, the rising wall is laid out on top of the footings with the line and peg as before (Fig. 1, e). The blocks are positioned with the corners touching the circle as before.

f. The second course of the rising wall is laid out on top of the first course (Fig. 1, f), and the blocks are laid as before.

g. The following courses are laid with the aid of the plumb bob. All cross joints are 1 cm thick along the inner curve. Each course of the rising wall is plumbed according to the course two courses below it (3rd to 1st, 4th to 2nd, 5th to 3rd, etc.).

Fig. 2 shows a side view of Fig. 1, but only the last footing course is shown (g).

NOTES:

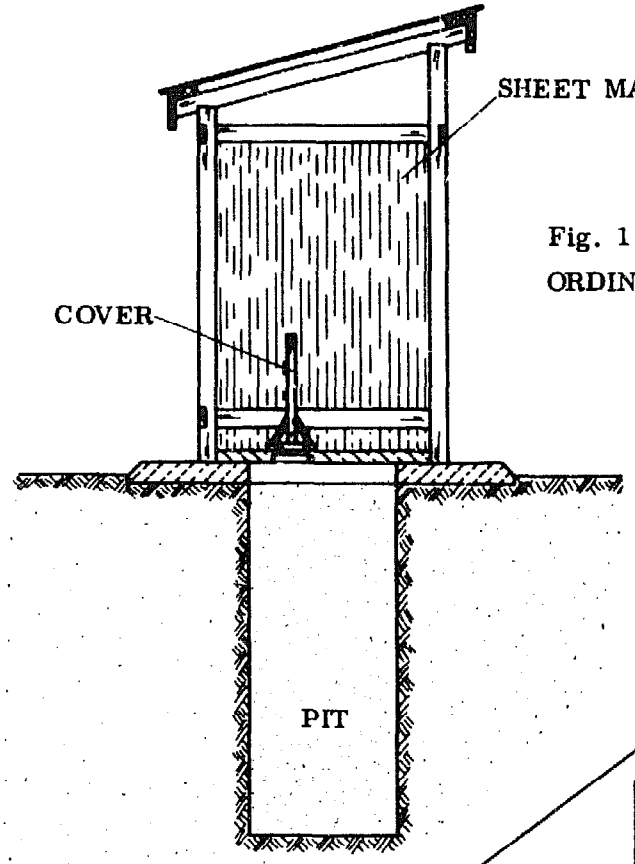

Fig. 1
ORDINARY PIT LATRINE

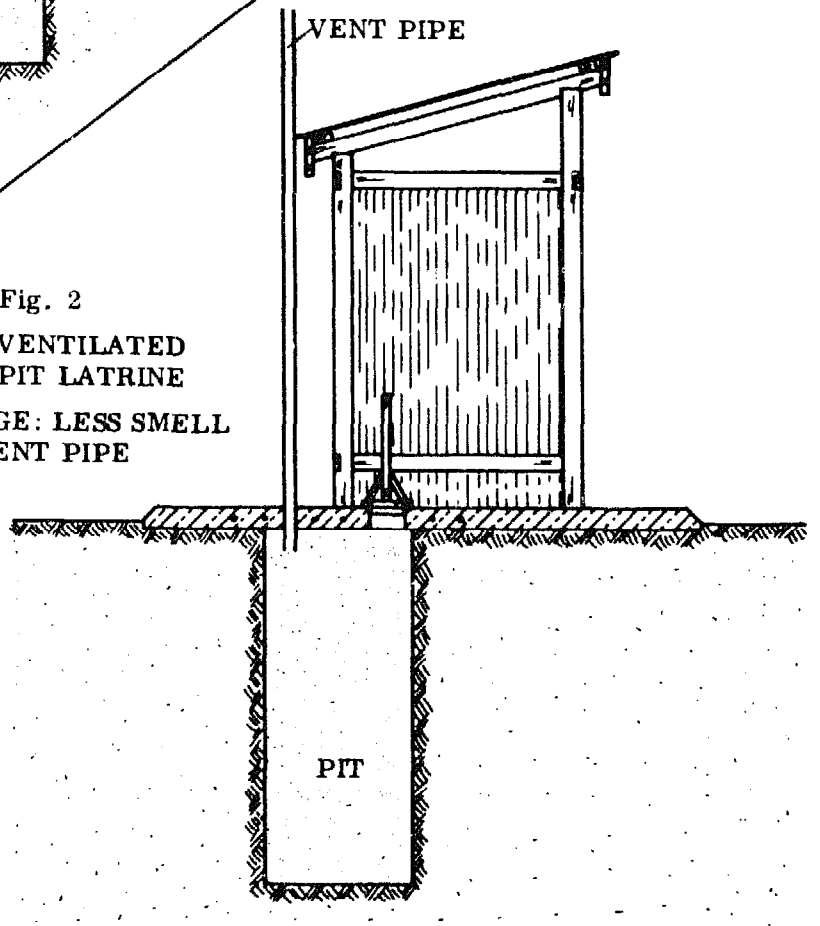

Fig. 2
VENTILATED
PIT LATRINE

ADVANTAGE: LESS SMELL
DUE TO VENT PIPE

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PIT LATRINE.

PIT LATRINE

Latrines, and especially pit latrines, are the most common and simple sanitation systems. A pit latrine is practical for rural areas because it is the cheapest possible system and the easiest to build.

One major problem with pit latrines is the limited capacity: only a certain number of people can use the latrine, or else it becomes full too quickly and another pit must be dug. Another problem is that the latrine, if it is improperly made or made in the wrong place, can contaminate nearby wells or surface water. Also, if the ground water level is near the surface it may not be possible to dig a deep pit.

CAPACITY

The volume of the pit may be planned by using the rough figure of at least 0,06 cubic meters per person per year. Thus a pit which is 1 m square and 3 m deep may serve a family of five for about 6 years, before it becomes two-thirds full and a new pit has to be dug.

Pit latrines of the type shown on the opposite page (Figs. 1 & 2) should not be used by large numbers of people unless there is space available to dig several pits. If many people use the same pit it will quickly become full, and the ground around it can become contaminated.

It is a good idea to dig two pits at once, so that when one is 2/3rds full it can be closed, filled to the top with soil, and left there for 6 months to a year; by which time the harmful, disease-causing organisms in it will have been destroyed. The sludge can be taken out and mixed with compost, making a very valuable (and non-imported) fertilizer for gardens or farms.

- NOTE: Human wastes which have not been composted for at least 6 months should never be used as a fertilizer for food crops, because disease can be spread that way.

LOCATION

The pit latrine should be located at least 6 m away from any house, and at least 30 m away from any water source: well, bore hole or stream. The latrine should never be located uphill from a water source -- this is extremely important.

NOTES:

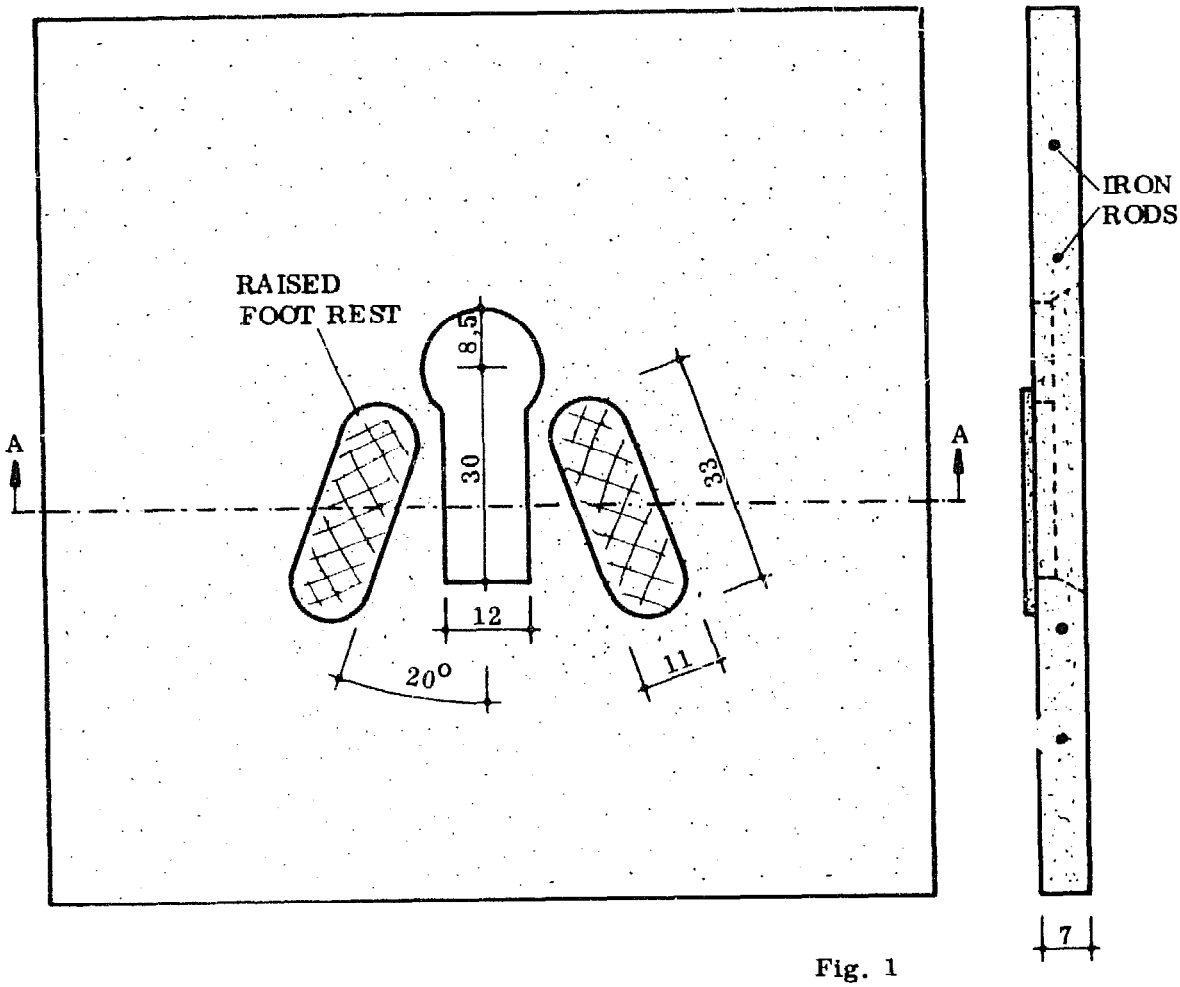

Fig. 1

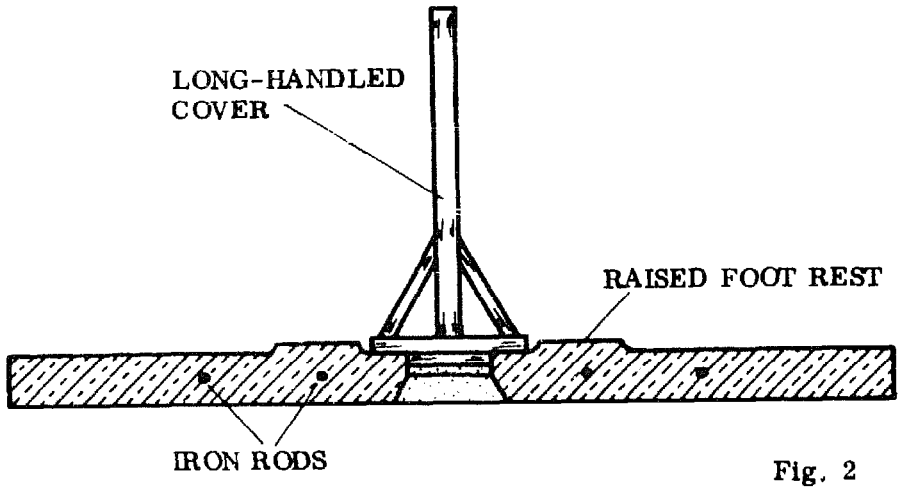

Fig. 2
CROSS SECTION A-A

N P V C		PIT LATRINE.
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DESIGN AND CONSTRUCTION OF THE SQUATTING SLAB

The squatting slab should be designed with easy cleaning in mind. It is made out of concrete reinforced by iron rods as shown in Fig. 1. The rods should be about 8 mm in diameter.

The slab may be square, round, or rectangular in shape. A common size is 100 by 100 cm. The whole slab will weigh about 140 kg. The advantage of a round slab is that it can easily be rolled around the site and into place. The slab should be about 7 cm thick. The raised foot rests make the slab easier to clean. The shape of the hole and foot rests may vary; a typical arrangement is shown here. The hole should be at least 36 cm long to prevent soiling of the slab, and less than 18 cm wide so that small children can't fall through.

The distance from the back of the hole to the back wall of the latrine should be at least 15 cm, so that it is not necessary to lean against the wall when squatting.

Make a cover for the latrine hole out of wood, with a long handle (Fig. 2).

NOTES:

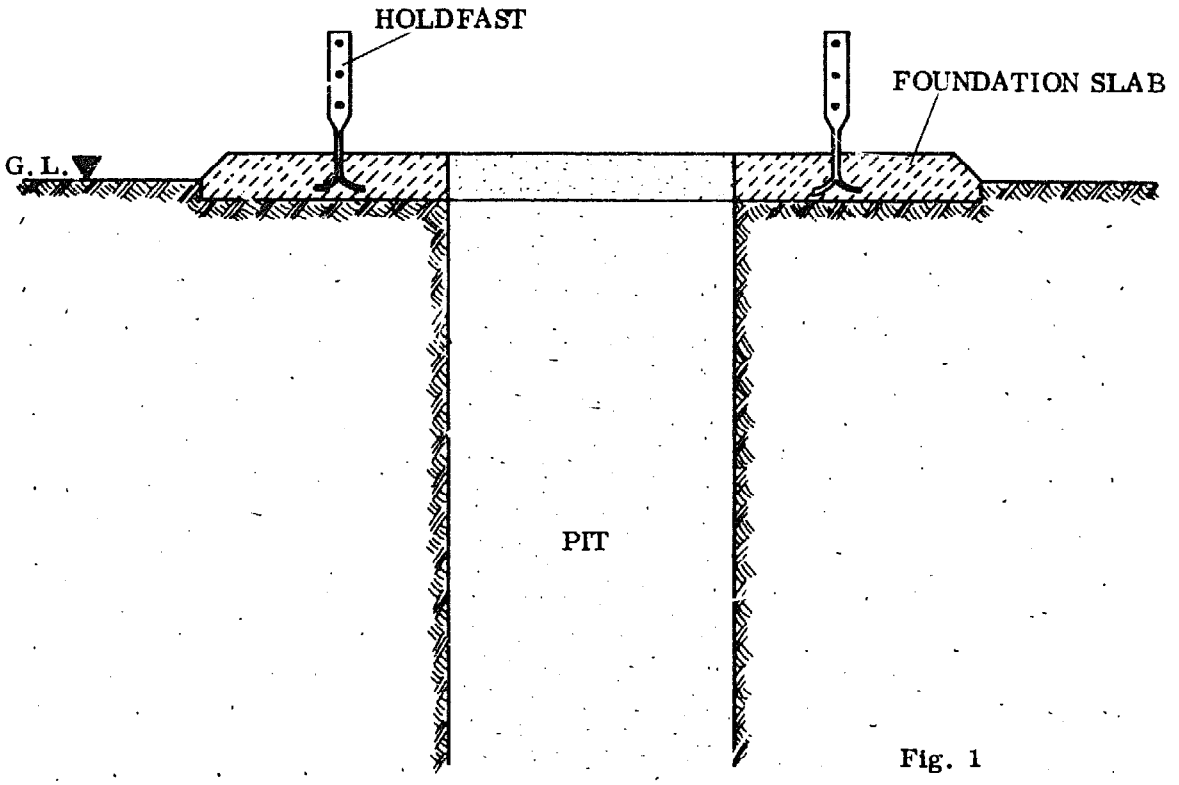

Fig. 1

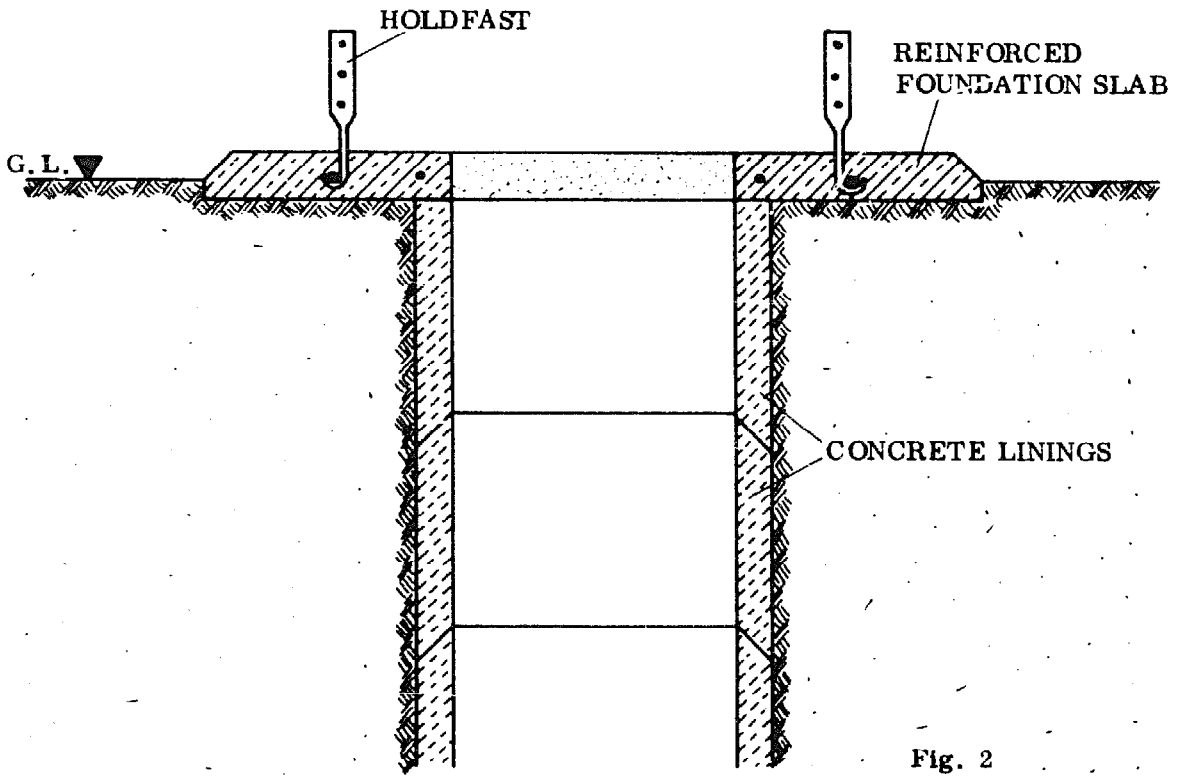

Fig. 2

N P V C	
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PIT LATRINE.

CONSTRUCTION

The first step is to precast the squatting slab, as described on the previous page.

Make the hole for the latrine large enough so that it won't become full too quickly. The soil should be firm enough so that the weight of the latrine structure won't cause the hole to collapse. If the soil is firm enough, the foundation slab can be poured around the edge of the hole (first remove the top soil) (Fig. 1). If the soil is a bit soft, reinforce the foundation slab.

If the soil is very soft, it will not be able to bear the weight of the construction. Then it will be necessary to construct a lining for the hole to be sure that it will not collapse. The lining can be made with blocks; or in a round hole with concrete rings, as described under the section on wells, page 279. The foundation slab then rests on top of the lining and cannot sink down into the soft soil (Fig. 2).

When you construct the foundation slab, fix some steel rods or holdfasts in the concrete, as shown in Figs. 1 & 2. These can be used later to anchor the wooden structure of the toilet.

When the foundation slab is cured, place the precast squatting slab on top of the foundation and secure it in place with a weak mortar (Fig. 3).

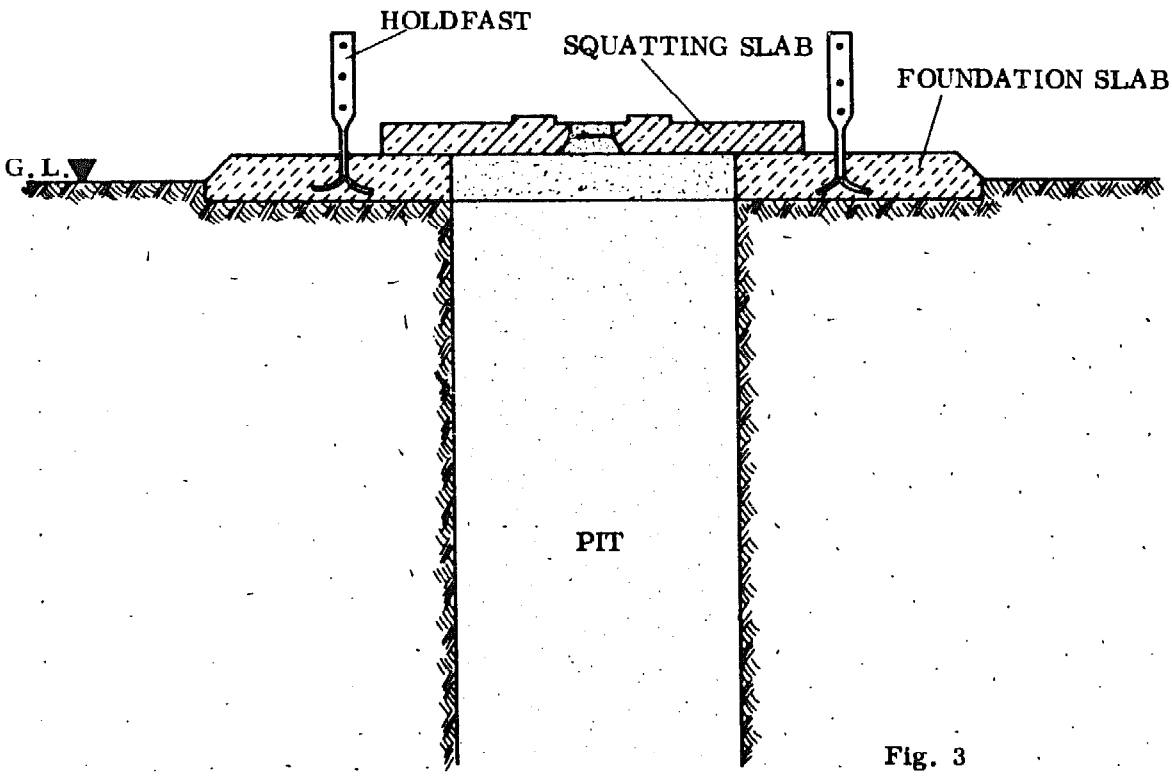

Fig. 3

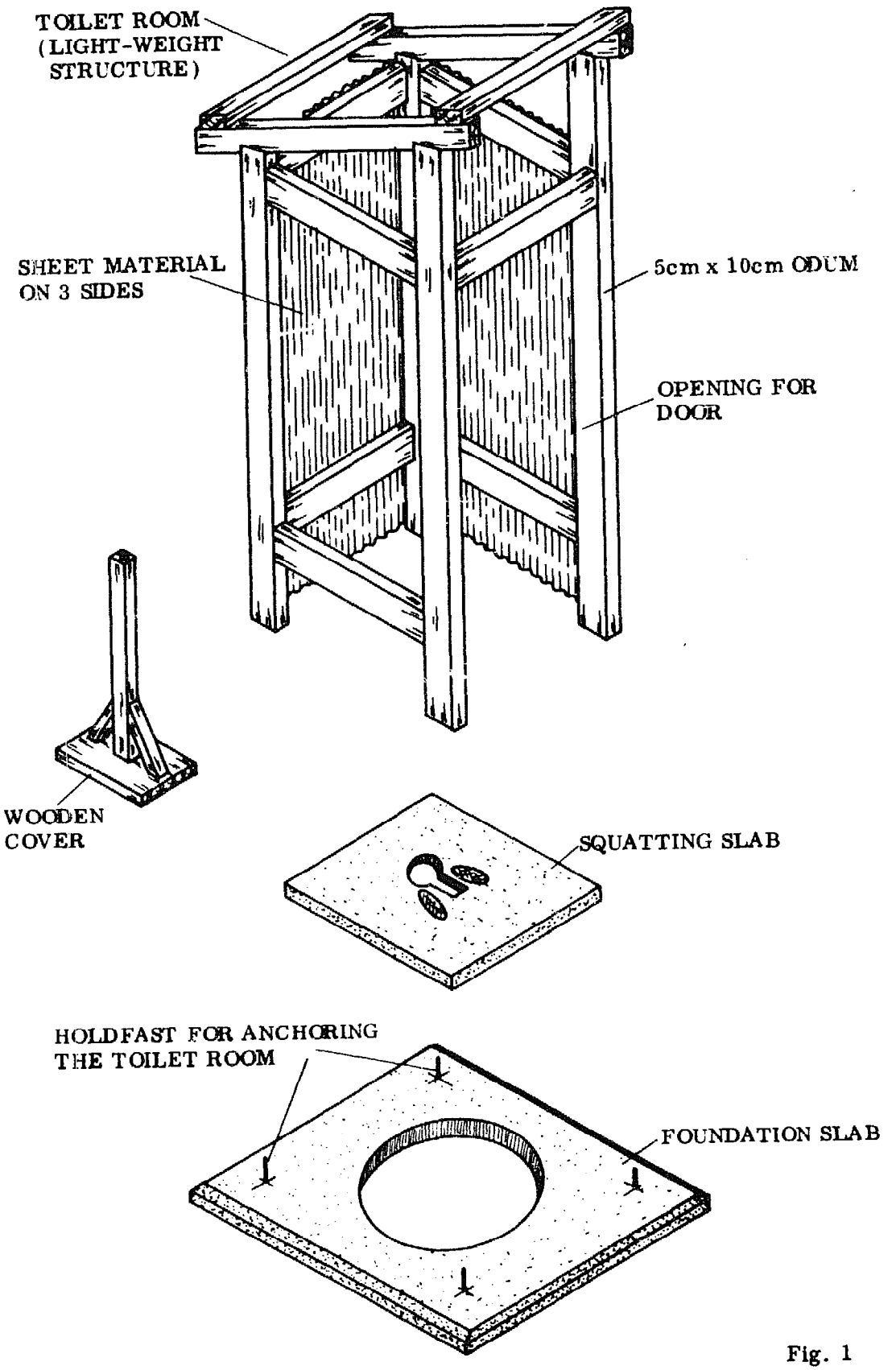

Fig. 1

N P V C		PIT LATRINE.
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TOILET ROOM

The toilet room can be built from mud or landcrete blocks, and plastered with mud. However, be sure that the foundation can support the walls because they are heavy, and in soft soil they may sink down and collapse the hole. Also, when the hole is full and a new one has to be dug, the walls have to be built completely new.

Because of the above problems with block walls, it is advisable to construct a light-weight structure out of timber and metal sheets. The light-weight structure can be removed when the pit is full and installed again over a new pit. The squatting slab can also be re-used (Fig. 1).

The structure must be anchored well to the foundation slab so that it is not blown away in strong winds.

TOILET PARTITIONS

If a community latrine with several compartments is needed, use the system drawn on page 124 of the Drawing Book.

First do the setting out. Then dig the round pits and make foundation slabs around the pits. Construct arches or lay a reinforced concrete beam across the center of each pit.

There are four squatting slabs over each pit. Lay each one carefully so that one edge rests on the concrete beam and two other sides rest on the foundation slab. Use some weak mortar between the slab and the supports, to ensure that the slabs are flat and stable.

The partitions between the toilets should be light-weight structures of timber and metal sheets or waterproof plywood. The outside walls can be constructed from landcrete blocks or mud.

Many of the materials from the above structure can be re-used after the holes become 2/3rds full and new pits are dug. The light-weight partitions, the squatting slabs and the reinforced beams can all be taken out and used in the new construction.

NOTES:

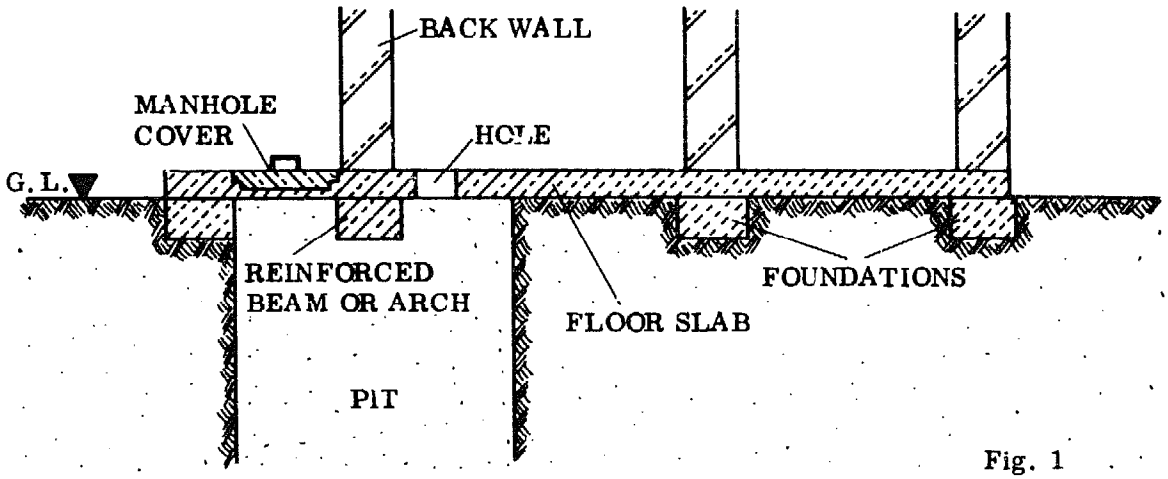

Fig. 1

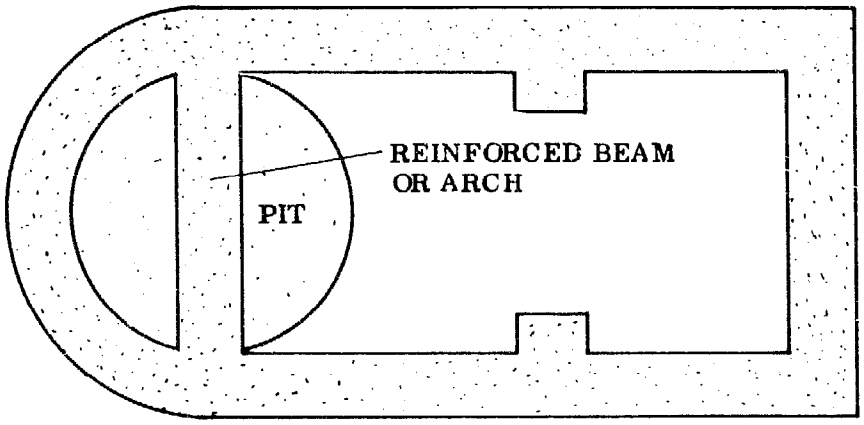

Fig. 2 FOUNDATIONS

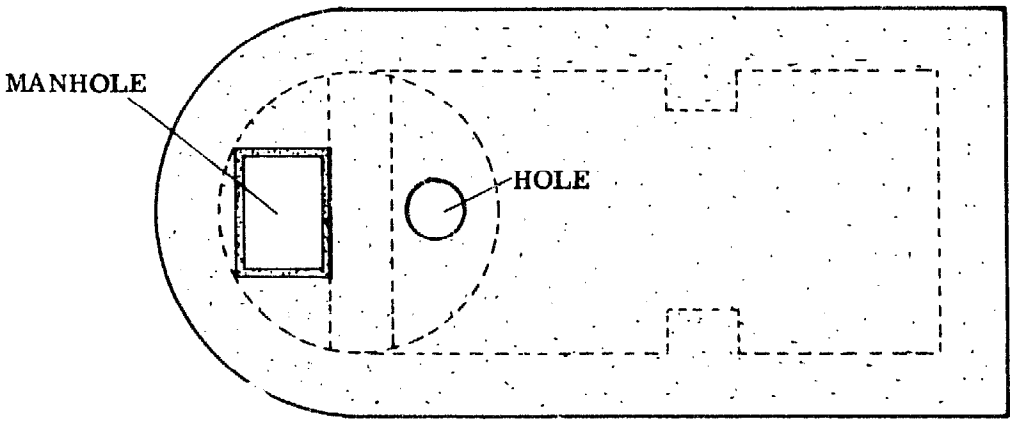

Fig. 3 FLOOR SLAB

N P V C		PIT LATRINE.
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PERMANENT LATRINE

If the latrine is constructed so that the pit can be cleaned out when it becomes two-thirds full, then it is no longer necessary to dig a new pit every few years. In the design explained here, the pit contents are removed through a manhole from the outside of the toilet room.

Make a reinforced concrete beam or an arch across the pit (Figs. 1 & 2) to support the back wall of the toilet, the floor, and the concrete manhole cover (see also the Drawing Book, pages 121 and 124).

Cast the foundations around the pit and under the future walls of the toilet (Figs. 1 & 2). On top of the foundations cast the floor slab with the openings for the manhole and toilet. The toilet can be made with the same squatting slab design as the other latrines, or a seat may be constructed above the hole (Fig. 3).

The rising walls are constructed directly on top of the floor slab (Fig. 4). They may be built out of mud, sandcrete or landcrete blocks, since the structure will be permanent. Make sure that the toilet room is well ventilated and the roof is securely anchored to the building. The wall in front of the entrance can be built up to about 180 cm high (Fig. 4).

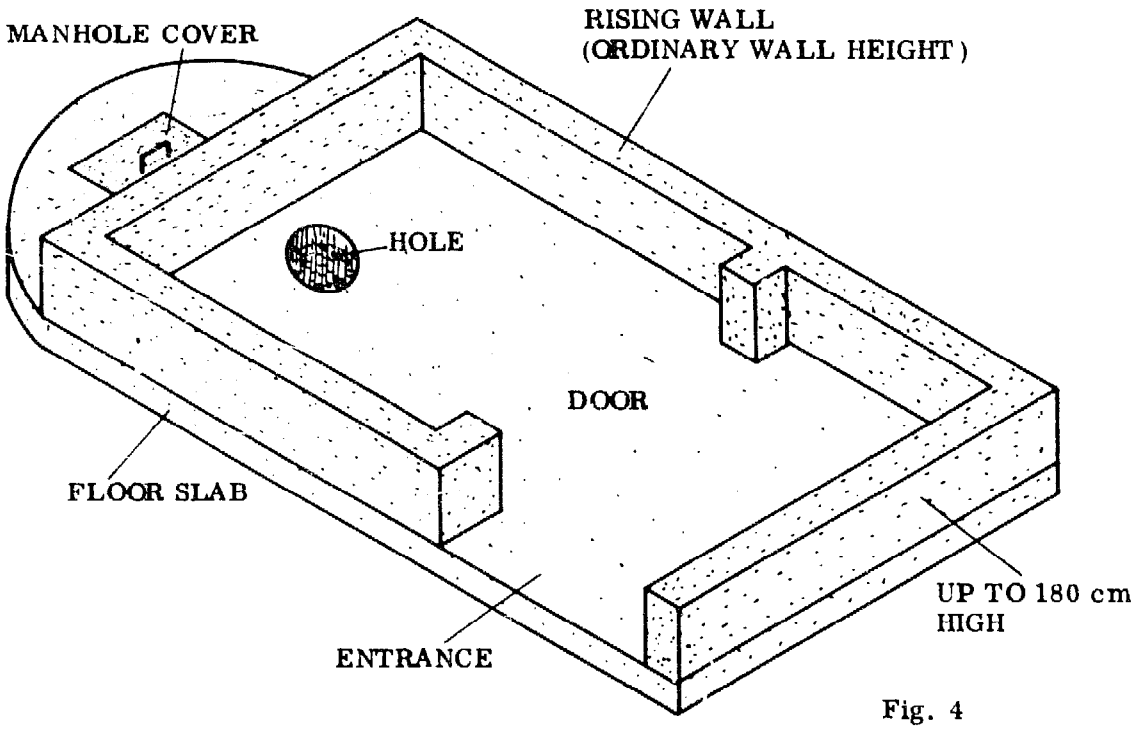

Fig. 4

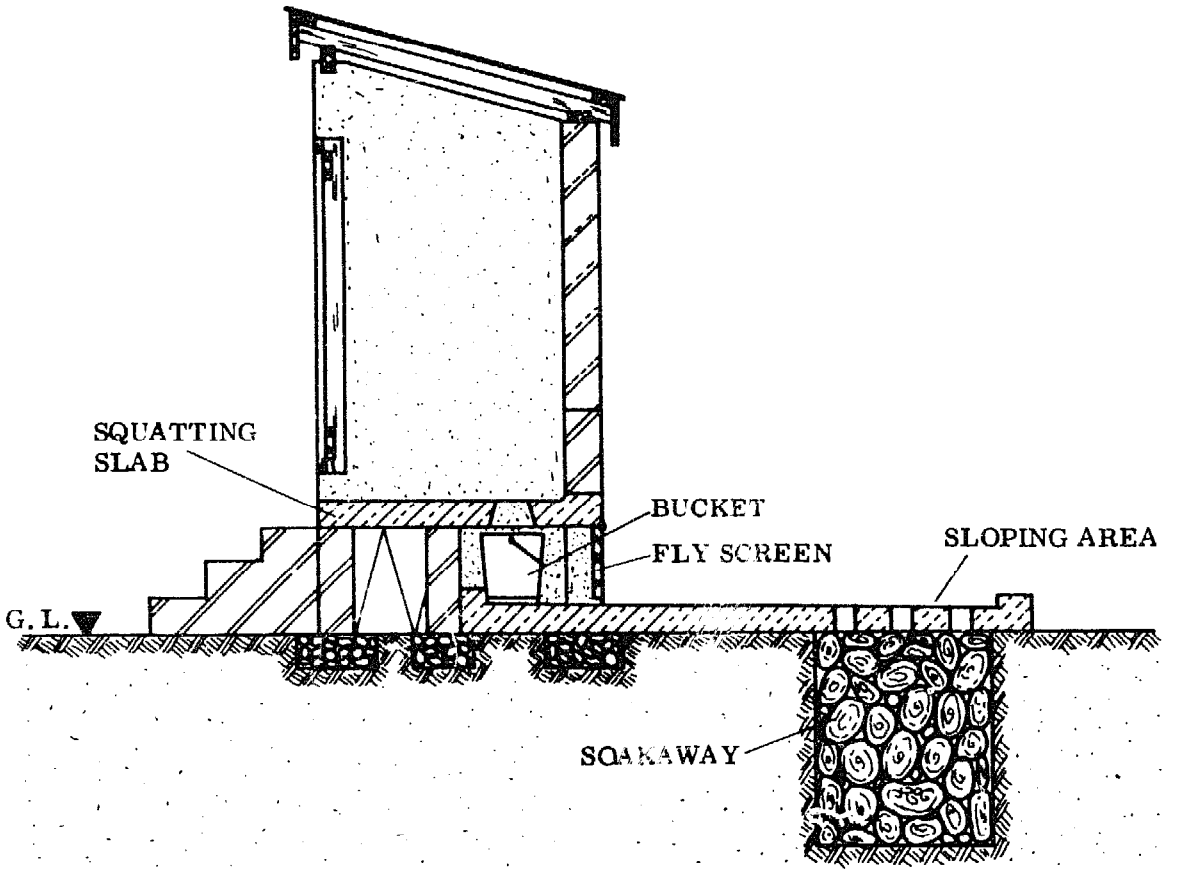

Fig. 1

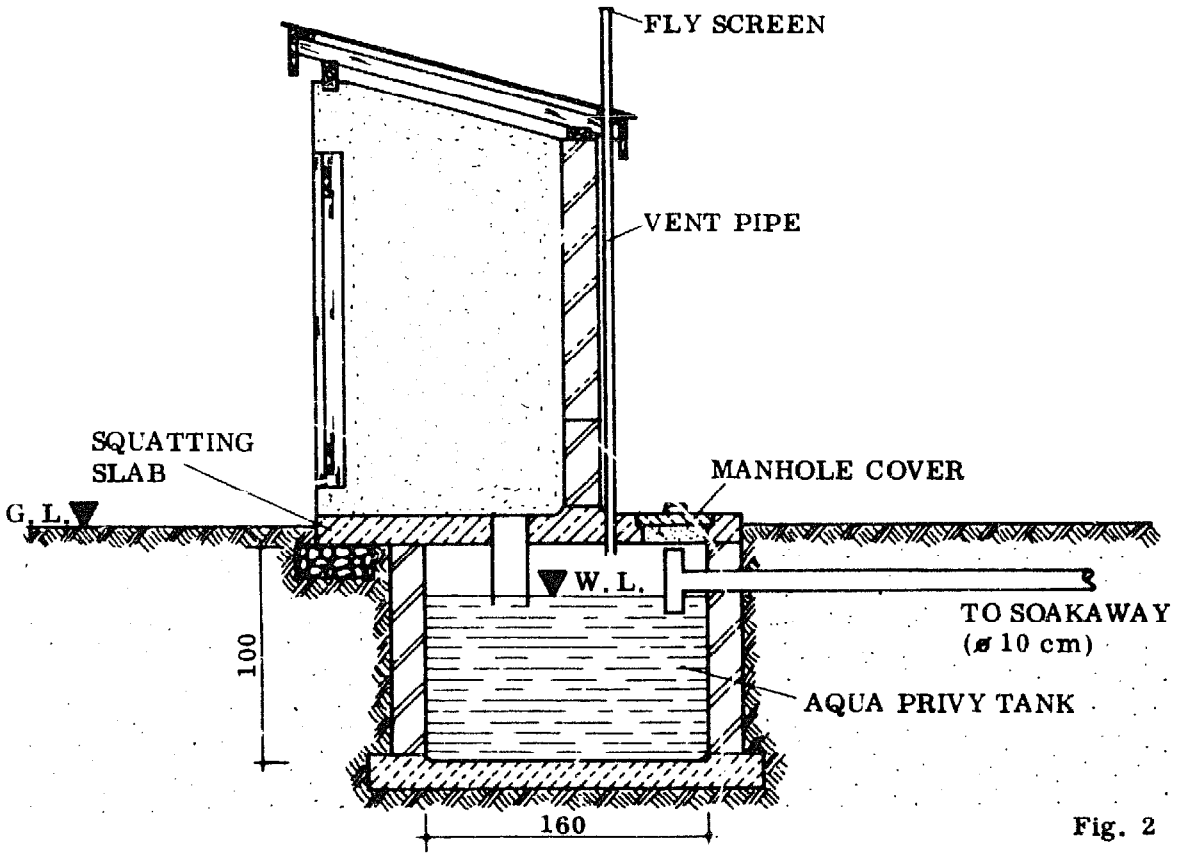

Fig. 2

N P V C	
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BUCKET LATRINE & AQUA PRIVY SYSTEMS.

BUCKET LATRINE

One of the oldest and generally least cleanly systems for waste removal is the bucket latrine. As in the cross section in Fig. 1, the squatting slab is set over a collection chamber with a bucket. The chamber should be closed off with a removable fly screen. The bucket should fit into a niche on the floor, so it is always returned to position directly under the hole in the slab when it is replaced after cleaning.

The area behind the latrine should be paved, and a drain and a soakaway should be made to get rid of the water used for cleaning the toilet and collection chamber.

The bucket latrine system is only possible where there is an organized system for regular collection and disposal of the bucket contents. This is usually not possible in rural areas.

AQUA PRIVY SYSTEMS

An aqua privy is basically a septic tank directly under a latrine. Its advantages are that it has fewer problems with smells, flies, and disease spreading than a regular latrine. However, at least two buckets of water must be poured into the privy every day for it to operate properly, and this can be a problem where there is no water source nearby.

An aqua privy for the use of one family may hav pit which is about 1 cubic meter in volume (about 0,15 cubic meters per person) The manhole should be large enough so that the sludge can be removed from the pit from time to time; whenever the tank is one-third full. If the tank is not emptied in time the drain pipe will become blocked and the system will fail.

Add some reinforcement to the squatting slab over the tank to support the back wall of the toilet. Make sure that the inside of the tank is waterproof, because if it leaks the water level cannot be maintained and smells can pass through the chute. If necessary paint the inside walls of the tank with waterproof paint. Make sure that there is a good ventilation system, with a fly screen over the end of the pipe which ventilates the tank (Fig. 2).

It is very important to maintain the water level within the tank. If possible, washing facilities can be made nearby and connected with the tank, so that the water from the sink or shower room goes into the tank and maintains the water level.

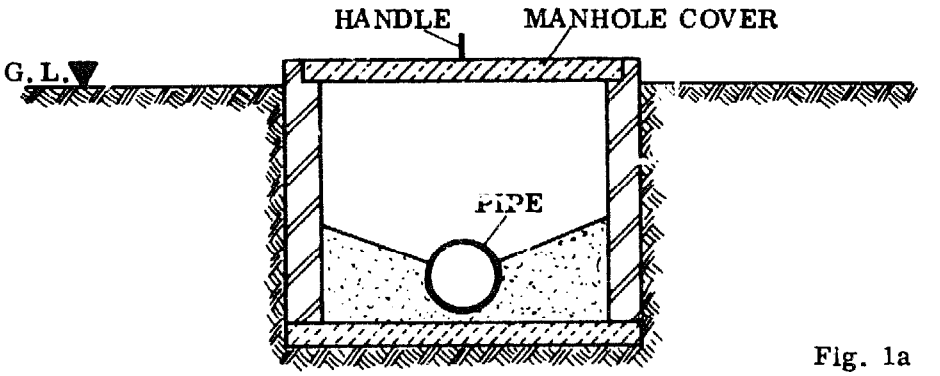

Fig. 1a

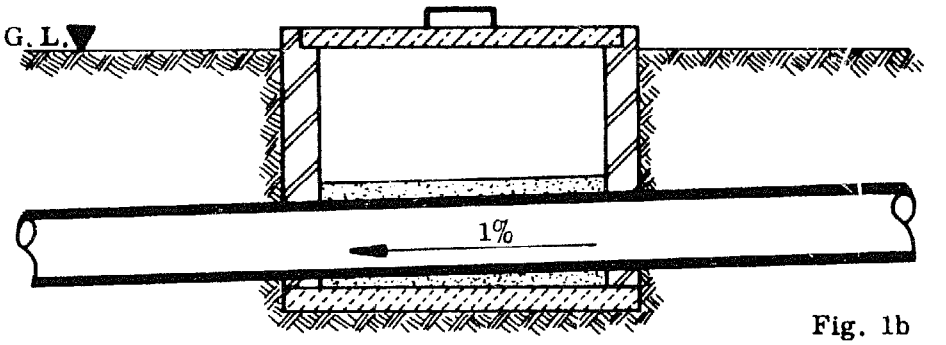

Fig. 1b

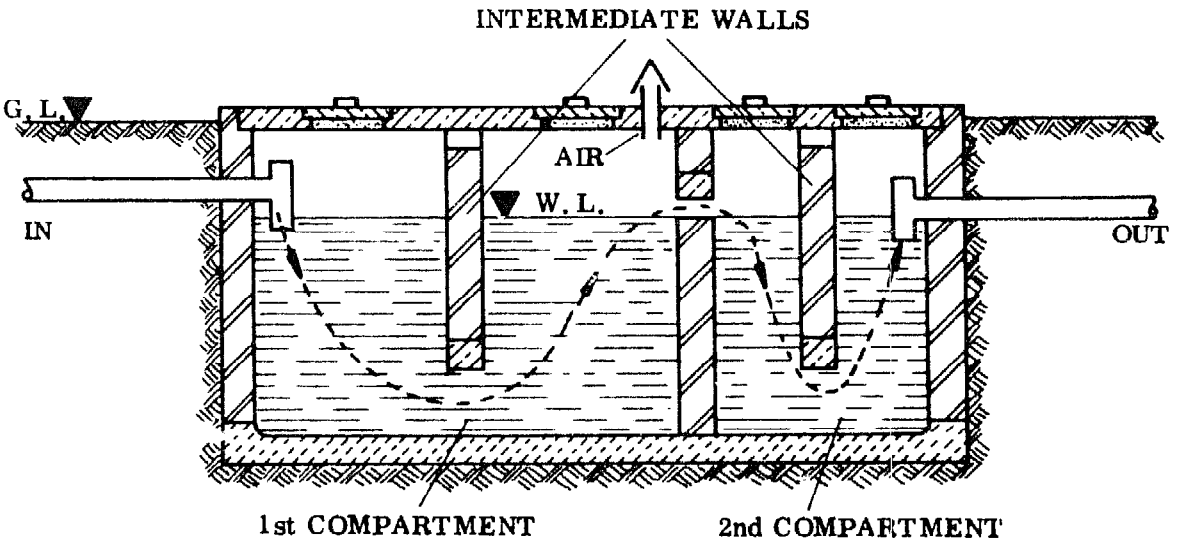

Fig. 2

N P V C	
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SOAKAWAYS & MANHOLES & SEPTIC TANKS.

SOAKAWAYS

A soakaway is basically a hole in the ground filled with stones, through which water can seep away into the surrounding soil instead of forming a pool on the surface of the ground where mosquitos can breed.

Dig a hole and fill it with large stones at the bottom and smaller ones at the top. Drain pipes from bathing areas, etc. can lead into the pit; they should end up in the centre. Cover the soakaway with soil, but make sure that the soil does not enter between the stones and block the drainage pipe. The soakaway can be covered with a layer of concrete to keep the top soil out (Fig. 1, previous page).

Soakaways should be at least 30 m away from wells or streams, and never uphill from a water source.

MANHOLES

Sometimes manholes are needed where long pipes have to be inspected at intervals. Manholes give easy access to the pipe junctions. A typical manhole layout is shown in the Drawing Book, page 125. This manhole can also serve as a kind of junction hole, from which more than one pipe can cross. The slope should be the same for pipes entering and leaving the manhole (Figs. 1a & 1b).

SEPTIC TANKS

Septic tanks are designed in such a way that the water takes at least 24 hours to pass through the system. During that time the heavier solids will settle to the bottom, forming the sludge. In the tank the solids are gradually broken down and become much reduced in volume.

Septic tanks should have two compartments (Fig. 2). The first compartment is twice the size of the second compartment. Intermediate walls are sometimes made in order to reduce the speed of the water flow, and to make the distance that the water has to travel longer (Drawing Book, page 126).

The sludge has to be removed from the tank every few years, whenever it becomes 1/3 full. This sludge will not be safe to use as fertilizer until it has been composted for several months. The water flowing out from the tank will also be contaminated with bacteria and disease organisms.

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By: J. van Winden

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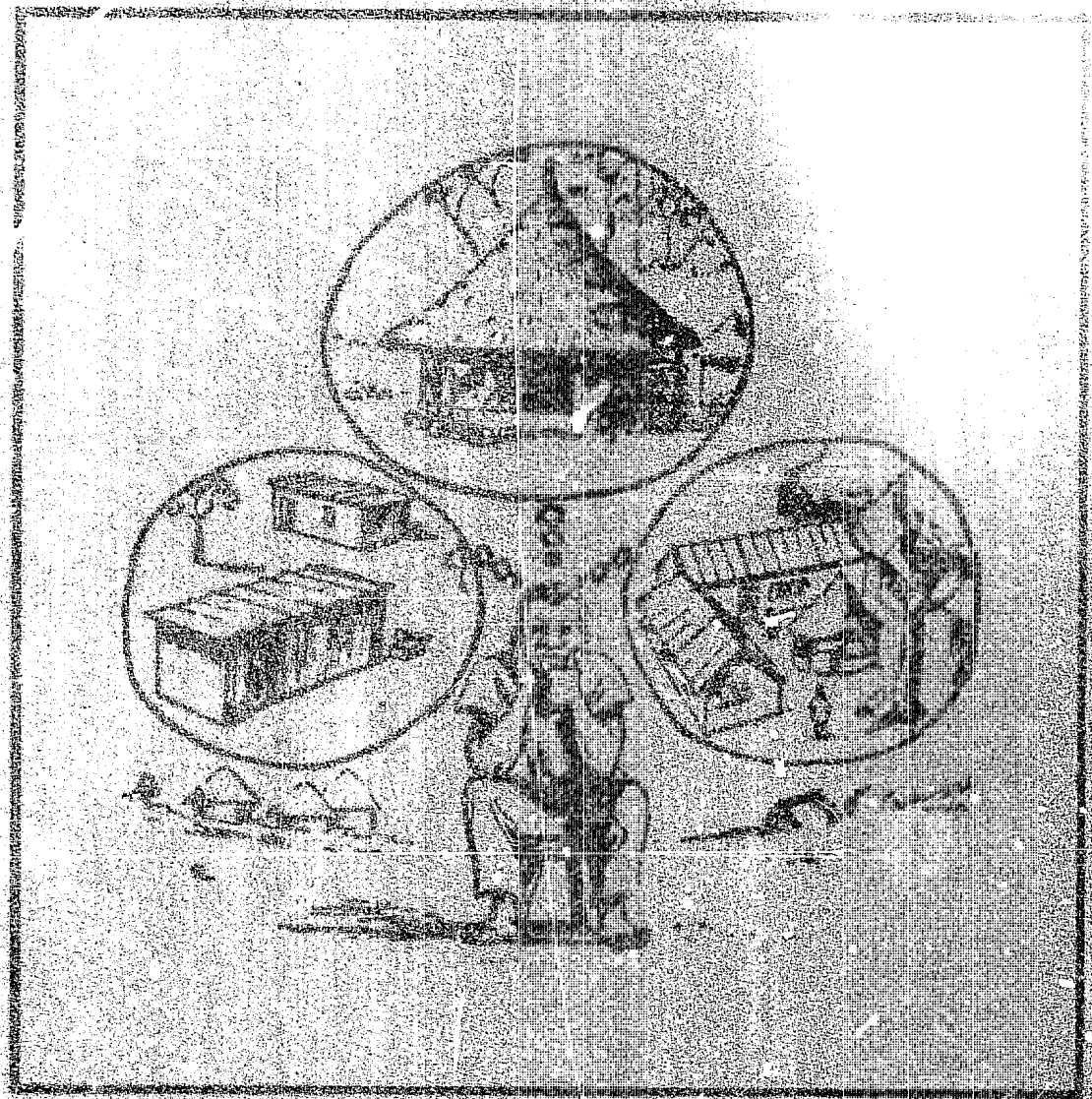

DRAWING BOOK

RURAL BUILDING

VOLUME 4

DRAWING BOOK

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PREFACE

In response to the many requests by people involved in technical vocational training and in general development work, we have decided to publish a second edition of the Rural Building Course.

The main aim of this set of books is still to provide technical training information in understandable language and with illustrations suited to the understanding of those involved.

Except for a few corrections, the text and illustrations are the same as in the first edition. The binding of the technical drawing book was revised and the size of the books reduced for economy reasons.

We are grateful to the Stichting Brothers F.I.C., CEBEMO and Mensen In Nood for their assistance in the re-printing of these coursebooks.

It is our sincere wish that the contents of these books may be of assistance to stimulate the use of appropriate techniques in Rural Building and General Development.

Bro. John van Winden F.I.C.

INTRODUCTION TO A RURAL BUILDING COURSE

Vocational training in Rural Building started in the Nandom Practical Vocational Centre in 1970. Since then this training has developed into an official four year course with a programme emphasis on realistic vocational training.

At the end of 1972 the Rural Building Course was officially recognised by the National Vocational Training Institute. The institute guides and controls all the vocational training in Ghana, supervises the development of crafts, and sets the examinations that are taken at the end of the training periods.

The Rural Building programme combines carpentry and masonry, especially the techniques required for constructing housing and building sanitary and washing facilities, and storage facilities. The course is adapted to suit conditions in the rural areas and will be useful to those interested in rural development, and to farmers and agricultural workers.

While following this course, the instructor should try to foster in the trainee a sense of pride in his traditional way of building and design which is influenced by customs, climate and belief. The trainee should be aware of the requirements of modern society, and the links between old and new techniques, between modern and traditional designs -- and how best to strike a happy medium between the two with regard to considerations like health protection, storage space, sewage, and the water supply. The trainee should be encouraged to judge situations in the light of his own knowledge gained from the course, and to find his own solutions to problems; that is why this course does not provide fixed solutions but rather gives basic technical information. The instructor can adapt the course to the particular situation with which he and the trainee are faced.

This course is the result of many years of work and experimentation with different techniques. The text has been frequently revised to serve all those interested in Rural Development, and it is hoped that this course will be used in many vocational centres and communities. It is also the sincere wish of the founders of this course that the trainees should feel at the completion of their training that they are able to contribute personally to the development of the rural areas, which is of such vital importance to any other general development.

We are grateful to the Brothers F.I.C., the National Vocational Training Institute, and the German Volunteer Service for their support and assistance during the preparation of this course.

Bro. John v. Winden (F.I.C.)

LAY-OUT OF THE RURAL BUILDING COURSE

The Rural Building Course is a block-release-system course, which means that the trainee will be trained in turn at the vocational centre and at the building site. The period of training at the centre is called "off-the-job training", and the period on the building site is called "on-the-job training". Each will last for two years, so that the whole course will take four years and will end with the final test for the National Craftsmanship Certificate.

BLOCK RELEASE SYSTEM

YEAR	TERM 1	TERM 2	TERM 3
1	X	X	X
2	O	O	O
3	O	X	O
4	X	O	X

X = OFF-THE-JOB TRAINING
O = ON-THE-JOB TRAINING

The total "off-the-job" training period lasts approximately 76 weeks, each week 35 hours. During this training about 80% of the time is spent on practical training in the workshop. The remaining 20% of the time is devoted to theoretical instruction.

The total "on-the-job" training period lasts approximately 95 weeks, each week 40 hours. During this period the trainee does full-time practical work related to his course work. In addition some "homework" is assigned by the centre and checked by the instructors.

A set of books has been prepared as an aid to the theoretical training:
- Rural Building, Basic Knowledge (Form 1)
- Rural Building, Construction (Forms 2, 3, 4)
- Rural Building, Drawing Book (Forms 1, 2, 3, 4)
- Rural Building, Reference Book

All these books are related to each other and should be used together. The whole set covers the syllabus for Rural Building and will be used in the preparation for the Grade II, Grade I, and the National Craftsmanship Certificate in Rural Building.

SYLLABUS FOR RURAL BUILDING DRAWING

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Drawing equipment (pages 1-2)
Lines and lettering (pages 3-5)
Orthographic drawing (pages 6- 9)
Oblique drawing (pages (pages 10-13)
Oblique drawing to orthographic drawing and orthographic to oblique (pages (pages 14-21)
Scale drawing (pages 22-23)
Inside and outside dimensions (pages 24-25)
Designing from sketches (pages 26-31)
Oblique and orthographic drawings of a box-like object (pages 32-33)
Cross sections (pages 34-35)
Sketching (pages 36-39)
Window frames (pages 40-42)
Door frames (page 43)
Frames and joints (pages 44-47)

FORM II

General building information (page 48)
Building drawing key (pages 49-50)
How buildings are drawn (pages 51-54)
Floor plans (pages 55-58)
Elevations (pages 59-60)
Sections and cross sections (pages 61-62)
Plans - elevations - cross sections (page 63)
Foundation plans (pages 64-66)
Door frames (pages 67-71)
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Building with pentroof (pages 81-82)
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Parapetted pentroof (page 84)
Parapetted gable roof (pages 85-86)
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Building design (pages 97-98)
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Basic outline of different buildings and roofs (pages 107-116)
Circular work (page 117)
Grain silo (page 118)
Water well (page 119)
Water filter (page 120)
Pit latrine and aqua privy (page 121)
Pit latrine and squatting slab (page 122)
Bucket latrine (page 123)
Community pit latrine (page 124)
Manhole (page 125)
Septic tank (page 126)

BOOK INTRODUCTION

The drawing book is divided into four sections, corresponding to the four forms in the Rural Building curriculum.

The lessons are planned to last approximately 90 minutes, during which the instructor should spend some time going over mistakes made in the drawings from previous lessons. Then the instructor can give the introduction to the new lesson, following this by a discussion of the how and why of the lesson. At the end of the session, the instructor should furnish the trainees with the technical data for the new drawing they are assigned for that week. Assignments should be handed in a few days before the next lesson so the instructor has time to correct them and make himself acquainted with the general difficulties which appear as a result.

Tests should be given at intervals. The drawings should then be made within the time specified in the book. The instructor can write the necessary technical data on the blackboard.

In the first part of the book much emphasis is put on the techniques for oblique and orthographic drawings. This kind of drawing has to be mastered early for the trainee to be able to understand drawings made on the blackboard during lessons. Sketching is important because during practicals many explanations are made with the aid of sketches. Plenty of time should be allowed for these exercises, and it is only at the end of the first year that the trainee should attempt drawings of simple frames. The instructor can add other drawings or sketches as needed to help the trainees to understand.

The last three parts of the book are oriented towards the course content for Rural Building. In these parts the trainee will find the lay-out of a whole building from the foundations to the roof construction, with the plans, elevations and cross sections; and building design is discussed as well. Here too, the instructor should feel free to change the sequence of the lessons if necessary to fit them together with the practicals in the workshop. During the lessons the instructor is advised to visit building sites with the trainees so that they can compare the drawings with the actual structures.

Ability to read drawings is also very important and ample time should be spent to help the trainees master this. It is helpful at times to have the trainees exchange drawings and correct each other's work.

DRAWING EQUIPMENT

DRAWING BOARD

A drawing board should be made from well seasoned wood or good quality plywood. One edge of the board -- usually the left edge -- should be very straight so it can be used with the T-square.

T-SQUARE

T-squares are rulers with a cross piece or stock fixed on one end to form the letter "T". The stock is either glued or attached to the blade by screws. Like drawing boards, T-squares should be made from materials which do not warp easily.

SET SQUARES

Set squares are triangular shaped tools which are used with the T-square. Two angles are available; 45 degrees and 60 degrees.

RULERS

Rulers used for drawing have 30 centimetre (cm) scales, subdivided into 300 millimetres (mm).

PENCILS

Pencils used for drawing are usually 2H, 3H, or 4H. The higher the number, the harder the lead. Sharpen pencils with a pocket knife. Cut the wood at a low angle to expose about 7 mm of lead, then sharpen the lead by carefully rubbing it on a piece of sandpaper.

Pencil lines must be fine, light and clear. It is a good habit to rotate the pencil as you draw a line, to keep a sharp point on the lead. When drawing lines follow the instructions on page 3.

DRAWING PINS

Drawing pins are used to fix paper to the board. The pins should have short fine points so that they don't make large holes in the drawing board. The pins should have large flat heads so that they can be removed easily. Because drawing pins can damage the T-square, various types of adhesive (sticky) tapes are often used instead of pins.

THE COMPASS

The compass is a precision instrument used to draw circles. One of the legs has a pointed end; this point must be thin and sharp so that it makes only a small hole in the paper. Especially when drawing small circles, make sure that the pencil point is the same length as the steel pin.

ERASERS

An eraser should be soft and of good quality so it does not damage the paper. The eraser should be used very little, and only with great care. If the corners of the eraser are rounded, it is a good idea to cut one end sharp again if you need to erase very exactly.

DRAWING PAPER

Drawing paper is special paper and it is cut to standard sizes.

ALWAYS "DRAG" THE PENCIL ----------- NEVER "PUSH" IT

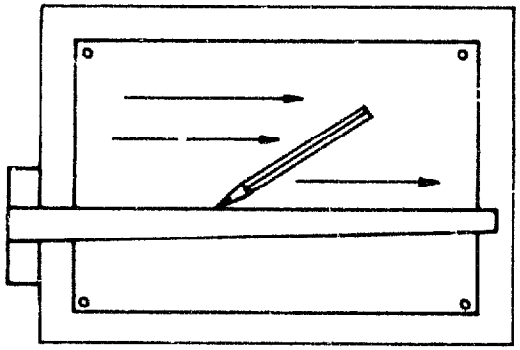

HORIZONTAL LINES

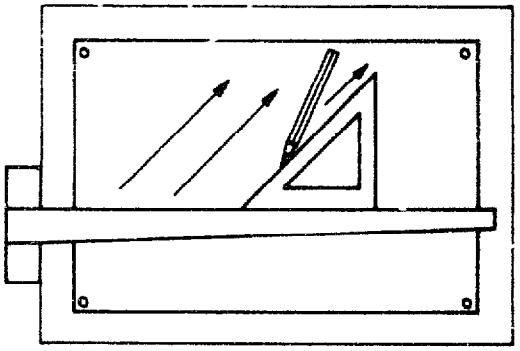

SLANTING LINES

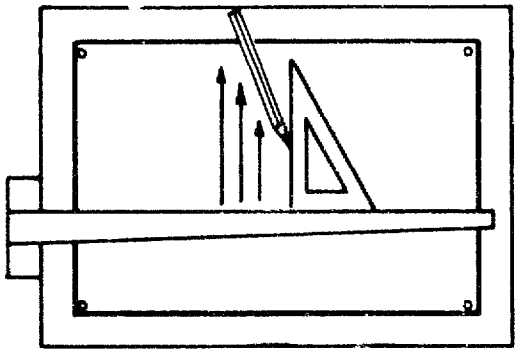

VERTICAL LINES

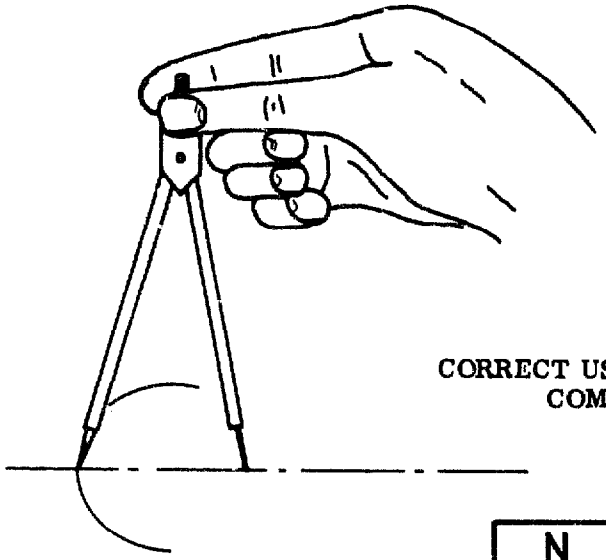

CORRECT USE OF THE COMPASS

N . P . V . C .	
	3.

LETTERING

Any writing which is done on a drawing is always in the form of lettering and never in ordinary writing. Make sure that all the lettering on a drawing is the same height, with the exception of the title, which may be in larger capitals.

GUIDELINES

Guidelines are made to show the height and proper alignment of the letters on a drawing. They should be ruled very faintly with a sharp pencil so that they can be erased easily. For pencil lettering use an H or HB pencil.

TYPES OF LINES

Various types of lines are used on drawings; these are shown in the examples on the right.

A- FAINT LINES: These should stand out very fine and clear.

B- VISIBLE OUTLINES: These are bold continous lines and they should stand out clearly.

C- HIDDEN OUTLINES: These are chains of short, sharp lines.

D- SECTION LINES: These show the plane on which an object is cut for the section view.

E- DIMENSION LINES: These lines always have a number on them, giving the length of a part of the object.

F- CENTRE LINES: These show the centre line of an object and are usually used in sketching.

G- RADIUS AND DIAMETER LINES: In drawing circles, two lines are particularly important; these are the radius and diameter of the circle.

WHICH KIND OF LINES DO YOU SEE IN DRAWINGS 1, 2, AND 3?

ABCDEFGHIJKLMNOPQRSTUVWXYZ

123456789

ABCDEFGHIJKLMNOPQRSTUVWXYZ

A

B

C

D

E 24,5

F

G

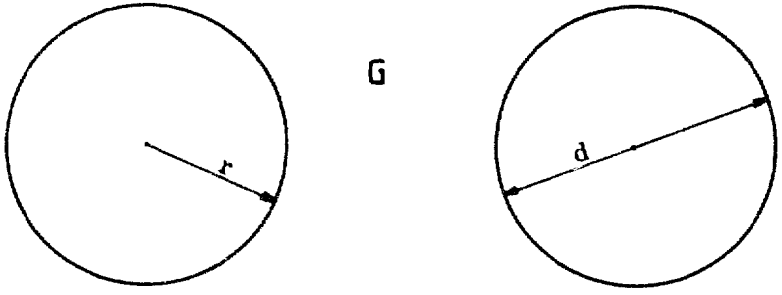

r = RADIUS

d= DIAMETER

1

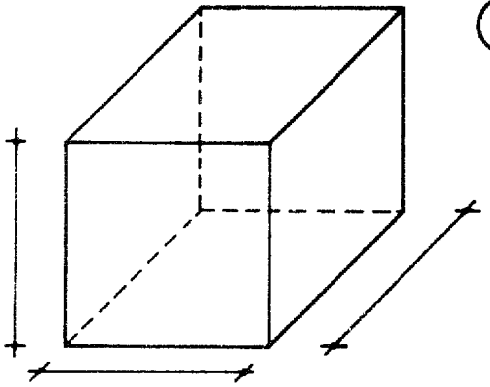

2

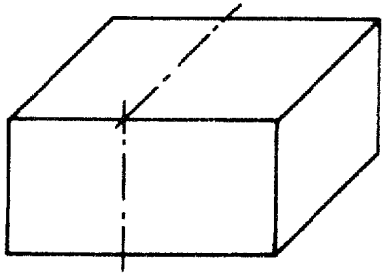

3

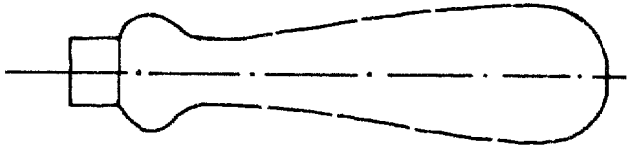

N . P . V . C .	
	5.

ORTHOGRAPHIC DRAWING

An orthographic drawing shows an object by means of a number of different views. Each view shows one side of the object as it is seen if looked at straight on. The diagram here shows a rectangular solid (A) along with an orthographic drawing of it (B).

- If a certain view will be the same as another view, you need draw only one of the views (compare the left side view and right side view from A).
- If certain measurements on one view are the same as measurements on another view, you should not label these measurements on both views. It is better to arrange the views so it is clear that the measurements are the same. The drawings on the right show how this is done (E & D).

In making an orthographic drawing, it is necessary to first choose the "front view". Any side can be choosen as the front view (even the top!) although it is usual to choose the most important side of the object.

- THE IMPORTANT POINTS TO REMEMBER IN MAKING AN ORTHOGRAPHIC DRAWING ARE:
  - Space the views an even distance apart.
  - Make accurate measurements.
  - Make clear lines. Make sure that the outlines are darker than the dimension lines.
  - The scale, in cm or mm, should be mentioned in the title block of the drawing (see page 9).
  - The lettering must be uniform and clear.
- STUDY: Look at solid A and orthographic drawing B. You need only three views for the drawing. Why is this?
  Look at solid C and orthographic drawing D. Why do you need more views in orthographic drawing D?
- DRAW: Make an orthographic drawing of solid C with side X as the front view.

(A)

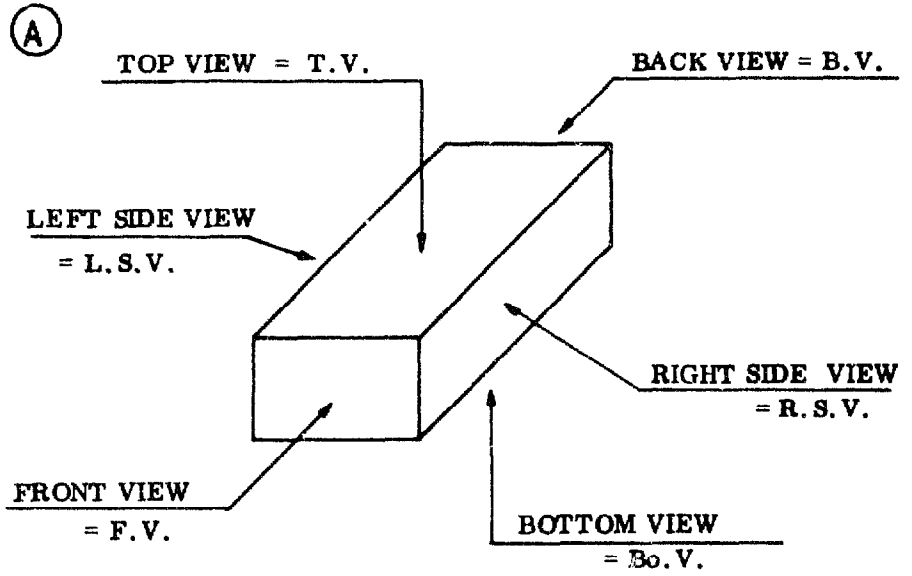

(B)

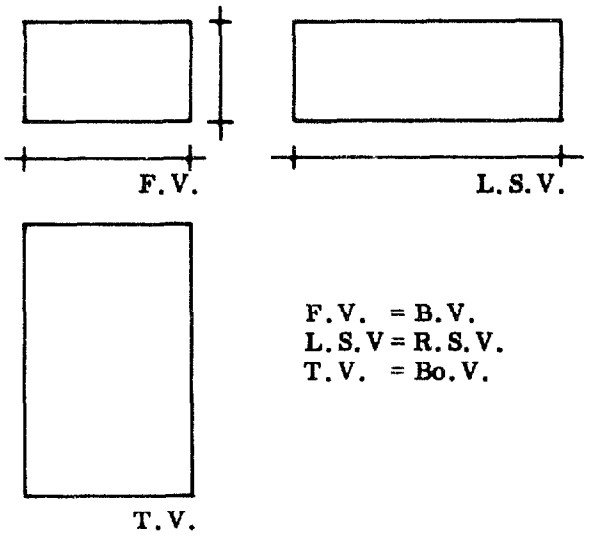

F.V. = B.V.
L.S.V = R.S.V.
T.V. = Bo.V.

ORTHOGRAPHIC DRAWING

(C)

OBLIQUE DRAWING

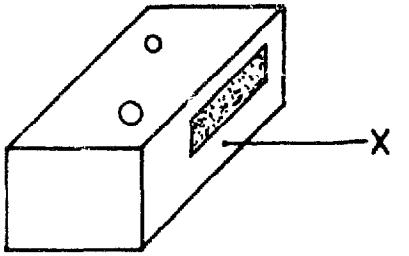

(D)

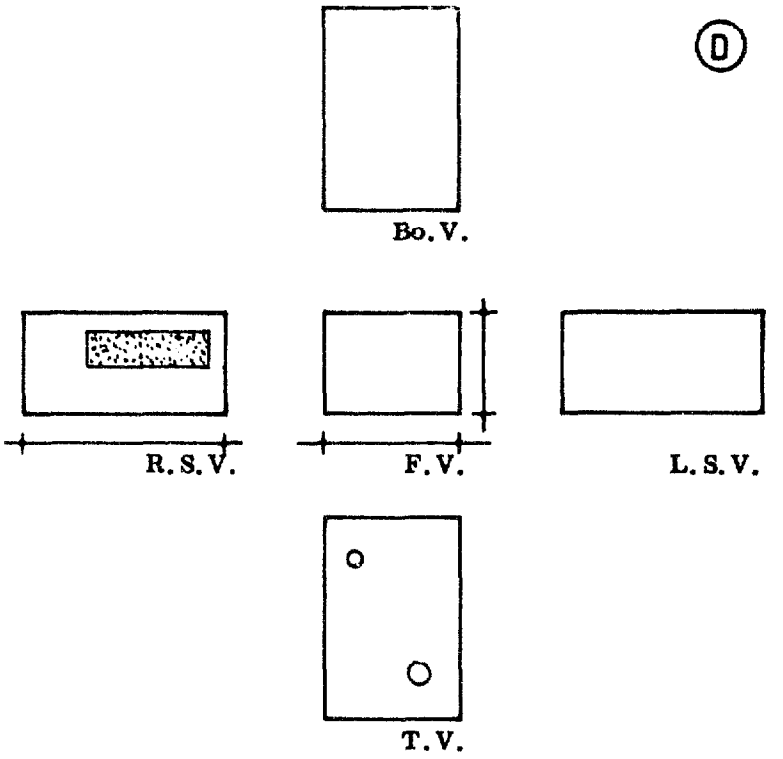

ORTHOGRAPHIC DRAWING

N . P . V . C .	
30 MIN.	7.

SETTING OUT THE DRAWING

When you set out the different views of an object on the paper, make sure that they are evenly spaced. Never squash them all on one side. Leave enough space for the necessary titles, sub-titles, and descriptions.

The name of each view should be written on the lower right side of the view. Abbreviations of the view names can be used:

F.V.	= front view	B.V.	= back view
T.V.	= top view	Bo.V.	= bottom view
L.S.V.	= left side view	R.S.V.	= right side view

MARGIN LINE

A margin line should be drawn around the paper, 1 cm from the edge.

DIMENSIONS

No drawing is complete unless the dimensions or lengths of all the sides are given. The illustration on the right shows how dimensions are given on a drawing. Make sure that no dimensions are left out or repeated.

TITLE BLOCK

When the drawing is complete, the last thing that has to be done is to make a title block in the bottom right corner of the paper. The title block gives the title of the drawing, the scale used, the date on which it was drawn, and who drew it. The standard size of the title block is given in the drawing on the right.

- DRAWING: Make an orthographic drawing of solid A.

CORRECT SPACING OF THE VIEWS

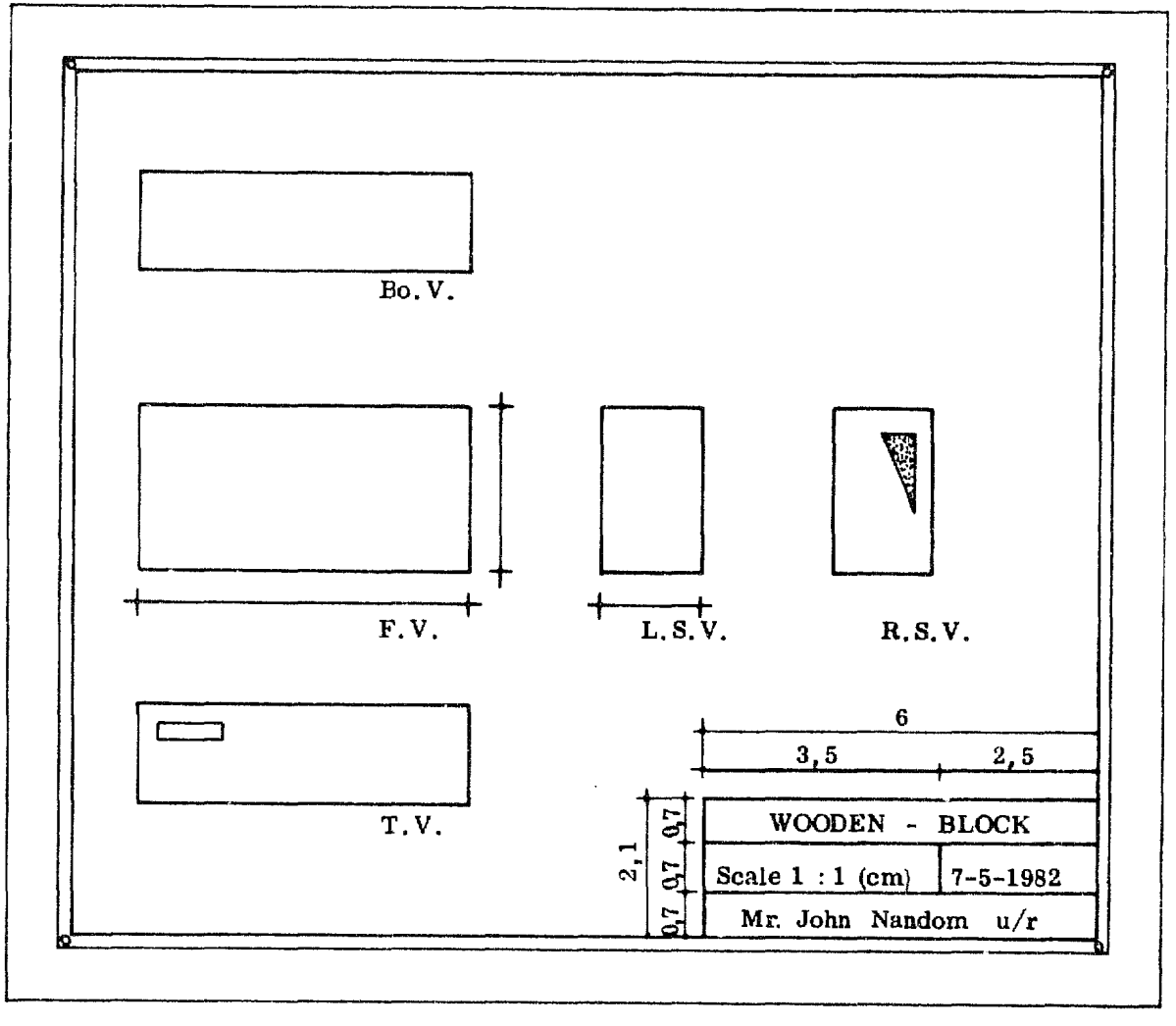

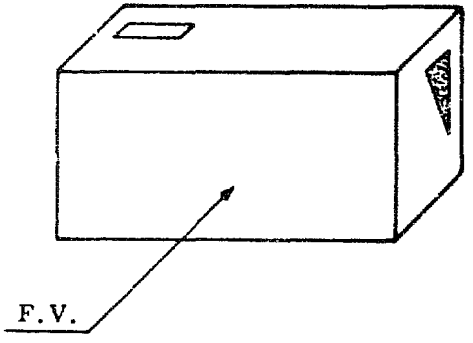

OBLIQUE EXAMPLE

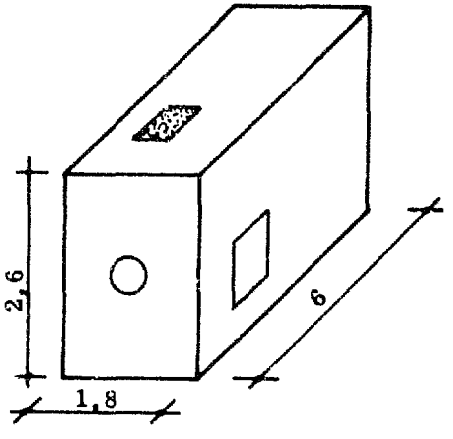

(A)

○ = FRONT VIEW

MAKE AN ORTHOGRAPHIC DRAWING OF THIS SOLID.

N . P . V . C .	
40 MIN.	9.

OBLIQUE DRAWING

An oblique drawing is a pictorial representation of an object. The difference between oblique and orthographic drawings is that in oblique drawings the object appears as a single drawing and looks like it does in real life. It is important that you be able to understand both types of drawing and be able to turn one type of drawing into the other.

In oblique drawing one face of the object is drawn in its true shape. This face is always the front view. The rest of the drawing is then built up using three "axes" or directions. One axis is always horizontal (A); another axis is always vertical (B); but the third axis (C) can be at any other angle. It is usual, however, to have the third axis at 45 degrees. These are shown in the illustration on the right.

Oblique drawing can be done step by step.

1 - Choose the front view. Draw it faintly on your paper.
2 - Draw the oblique lines at 45 degrees. Make sure that they are all the same length.
3 - Connect the oblique lines together using vertical lines or horizontal lines as needed.
4 - Erase all unnecessary lines.
5 - Mark all dimensions.
6 - Redraw the outline of the object with an HB pencil to make it darker.

CURVED OBJECTS

An object with a curved surface can easily be shown in an oblique drawing. To do this, draw the shape of the curve in the front view, so that the curve appears in its true shape. Finish off by drawing the oblique lines etc. as usual (see below).

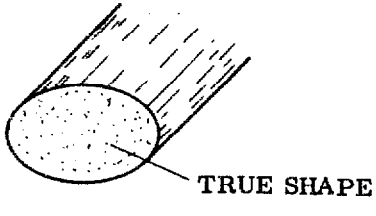

1 FRONT VIEW

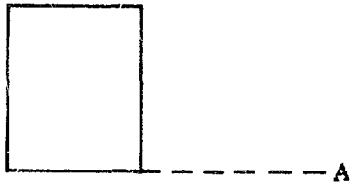

2 OBLIQUE LINES

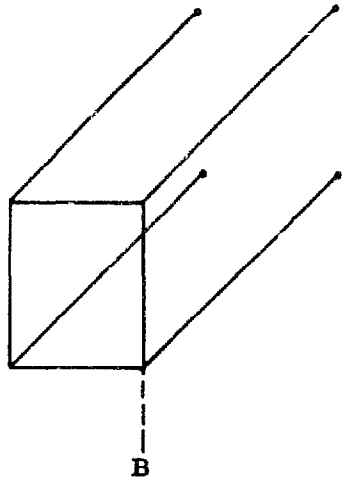

3 CONNECT LINES

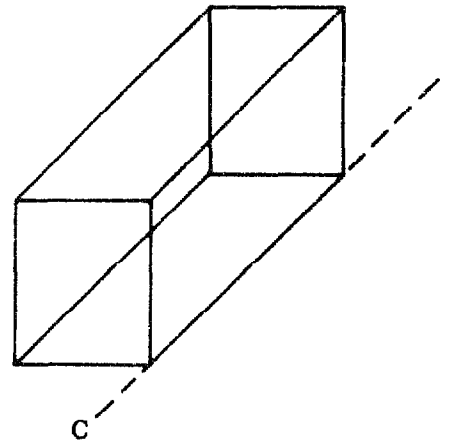

4 ERASE UNNECESSARY LINES

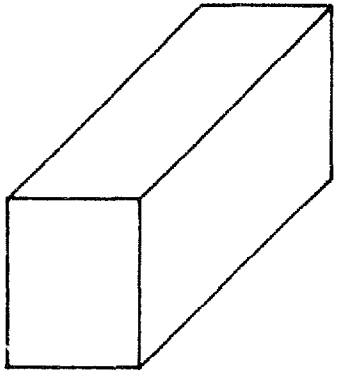

5 MARK DIMENSIONS

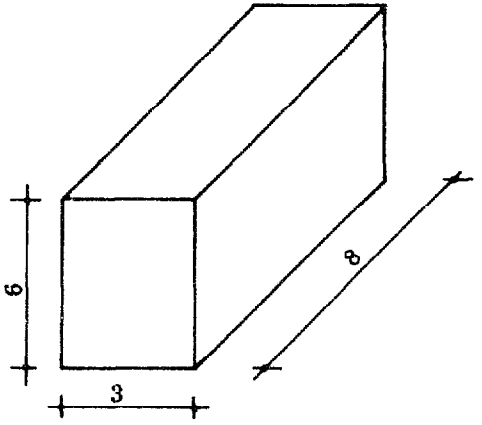

6 REDRAW OUTLINES

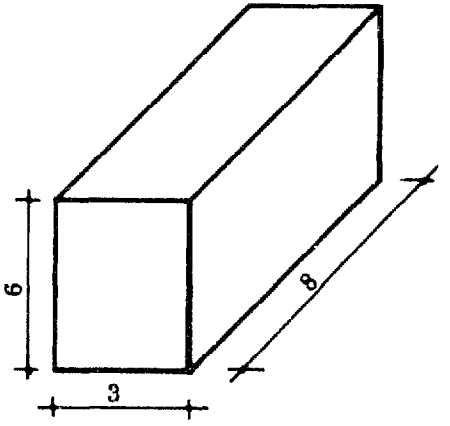

N . P . V . C .

11.

TECHNIQUES IN OBLIQUE DRAWING

There are some techniques and conventions that you need to know to make good oblique drawings. The most important of these is choosing the best view of the object. The best view is the one that gives you the most information about the object. A good rule to follow is: the best view is the one that is the hardest to draw.

On the next page you can see four different drawings of the same object. They all have the same front view but they are all projected in different directions. You should see that they all give different amounts of information about the object (A).

- Which view gives you the most information?
- Which view is the hardest to draw?

  The answer is "B", for both questions.

- CONVENTIONS: All types of drawing have their own conventions. At first the conventions may seem unnecessary, but you will soon find that they all help you to understand a drawing better. One of the most important conventions in oblique drawing is the marking of dimensions. The drawing here (B) shows how this should be done. Remember that the dimensions are given simply as numbers on the drawing itself, and that the unit (cm, mm, etc.) is given in the title block.

  For example: if the length of a block is 6 cm, the dimension in the drawing is given as "6"; and the unit "cm" is recorded in the title block.

- DRAW: Draw or sketch several solids, as in the following pages. Judge which side should be the front view. Decide upon the position in which the solid will be drawn.

(A) FOUR DIFFERENT POSITIONS IN OBLIQUE

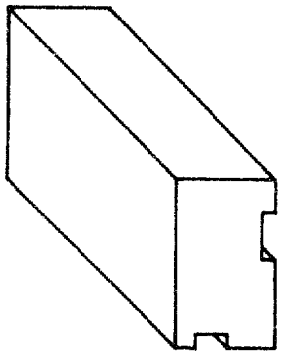

T.V./F.V./L.S.V.

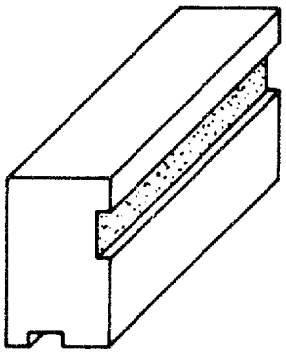

T.V./F.V./R.S.V.

F.V./L.S.V./Bo.V.

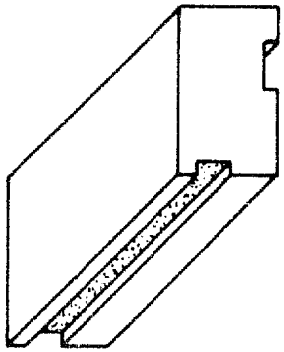

F.V./R.S.V./Bo.V.

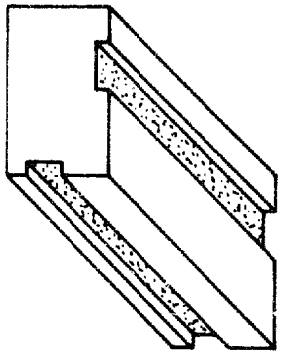

WHICH POSITION IS THE BEST ?

MARK DIMENSIONS LIKE THIS !

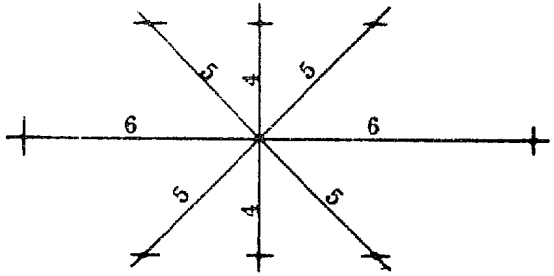

(B)

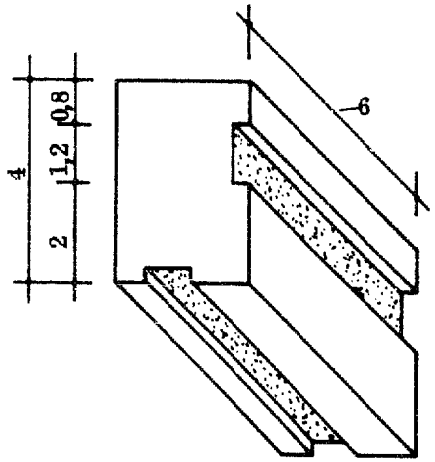

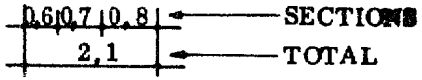

F.V./Bo.V./R.S.V.

N.P.V.C.

OBLIQUE —— TO —— ORTHOGRAPHIC

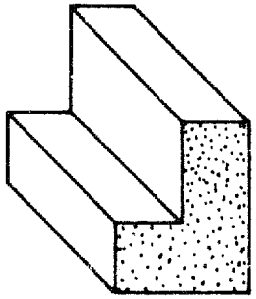

THIS IS WHAT YOU SEE!

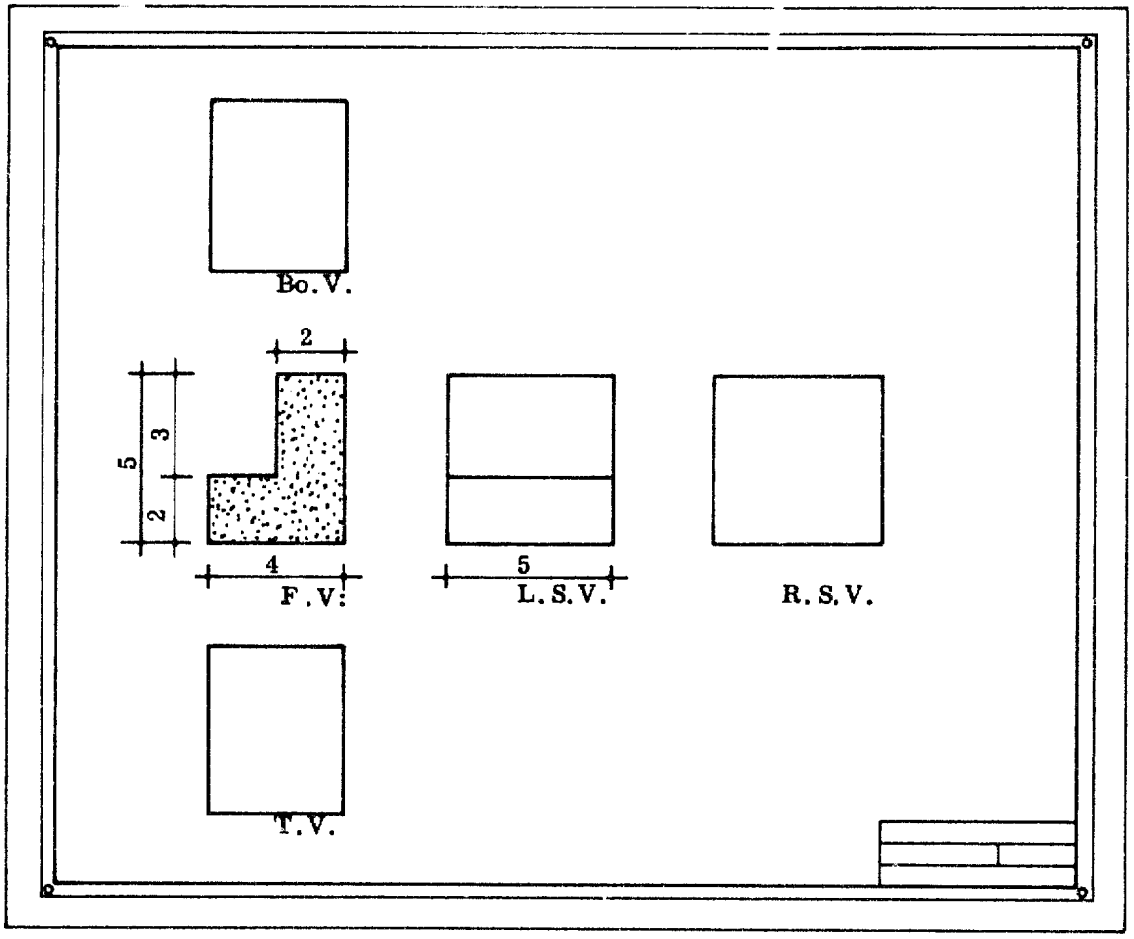

FINISH UP WITH THIS!

N.P.V.C.	
14.	40 MIN.

ORTHOGRAPHIC — TO — OBLIQUE

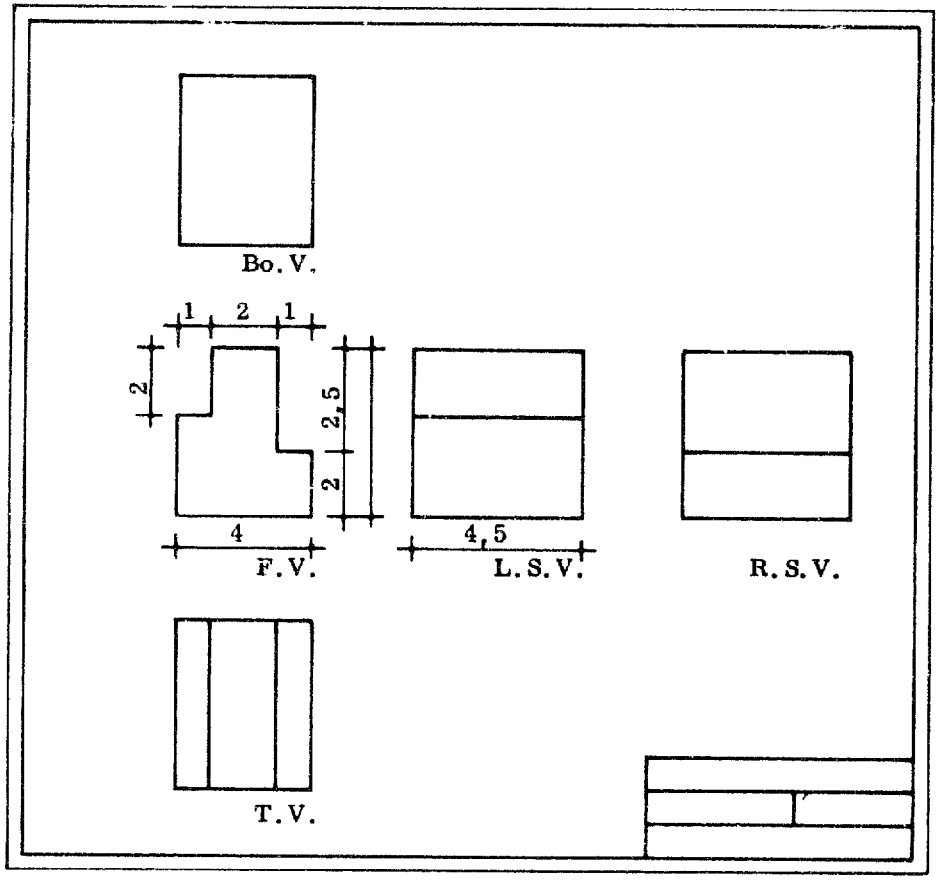

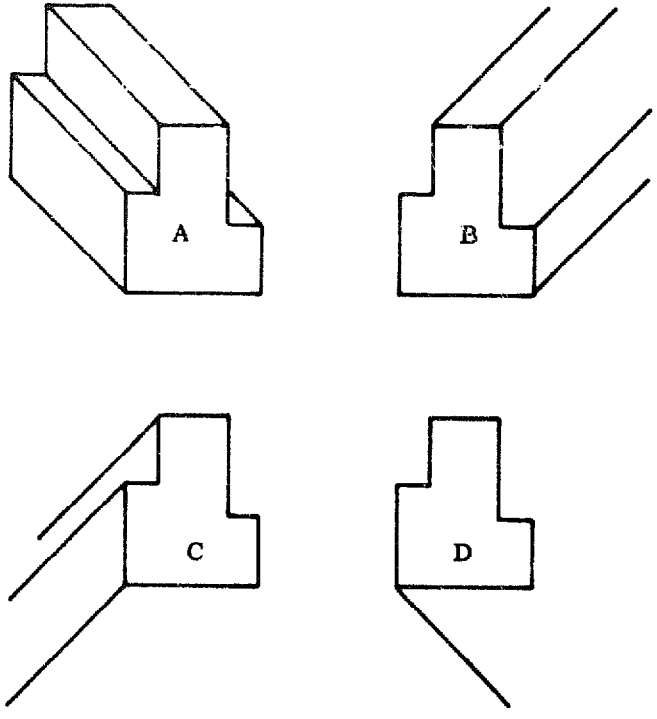

FINISH OFF DIAGRAMS B, C and D

THIS IS AN ORTHOGRAPHIC DRAWING — THIS IS WHAT YOU SEE!

N. P. V. C.	
60 MIN.	15.

EXERCISE: OBLIQUE TO ORTHOGRAPHIC

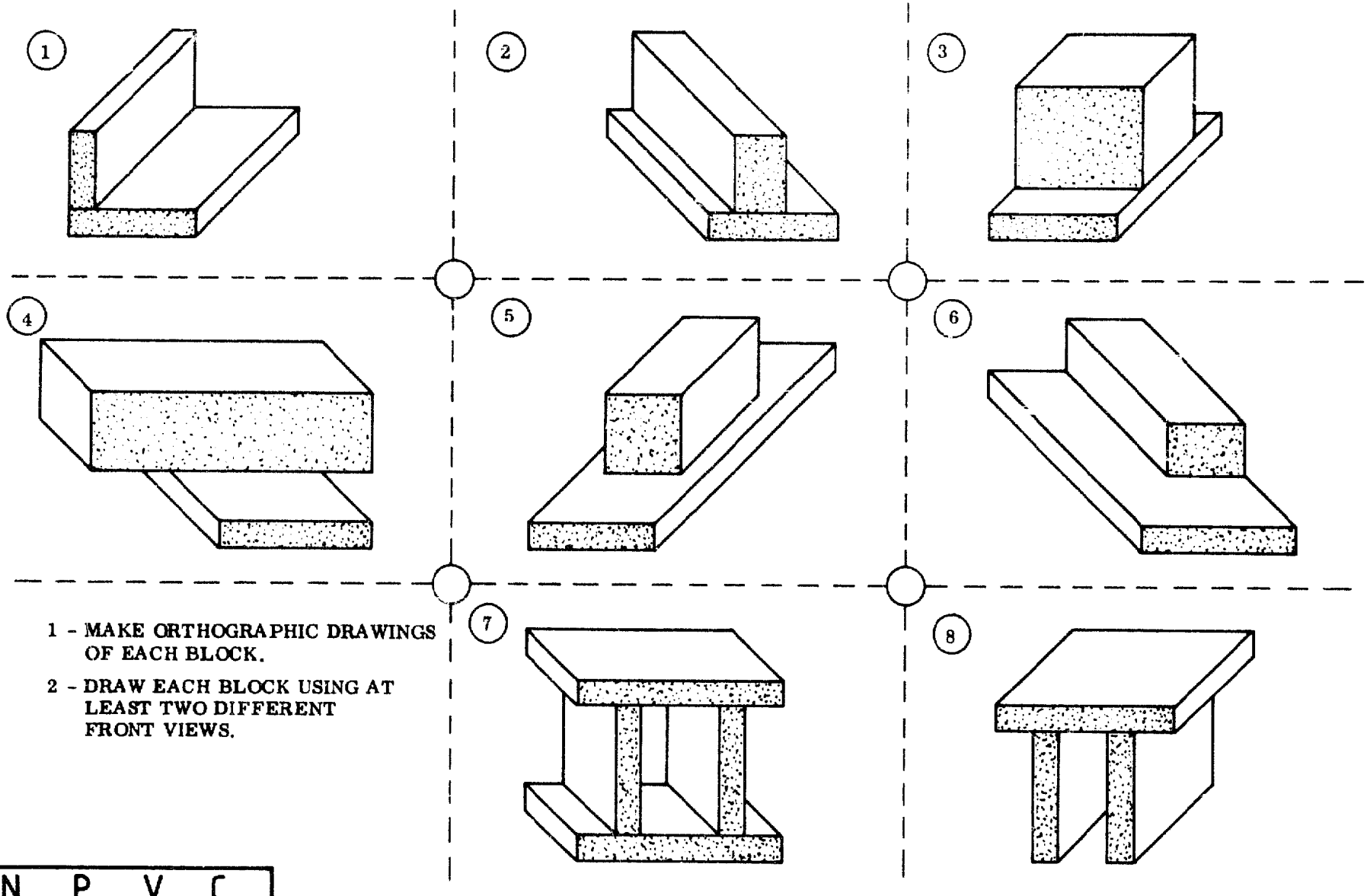

1 - MAKE ORTHOGRAPHIC DRAWINGS OF EACH BLOCK.

2 - DRAW EACH BLOCK USING AT LEAST TWO DIFFERENT FRONT VIEWS.

N . P . V . C .	
16.	50 MIN.

EXERCISE: ORTHOGRAPHIC TO OBLIQUE

1

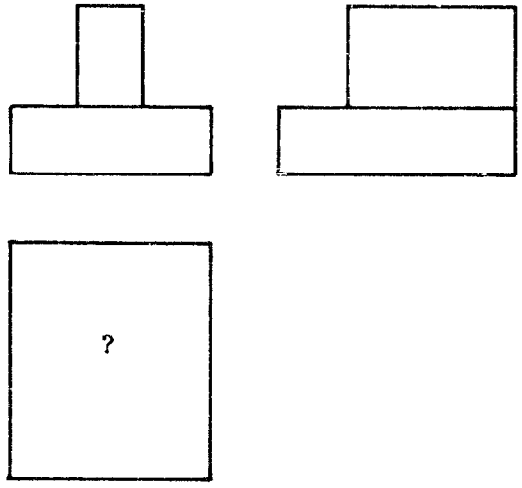

2

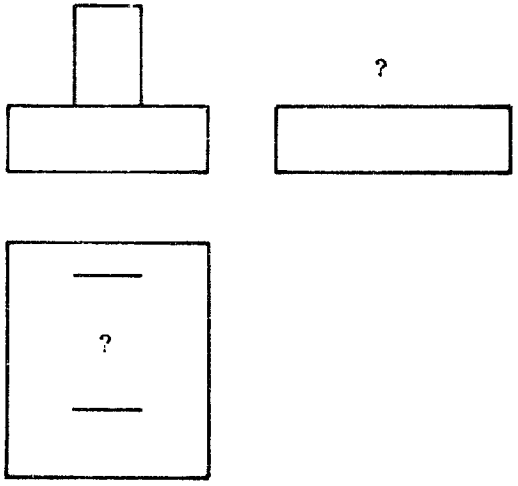

3

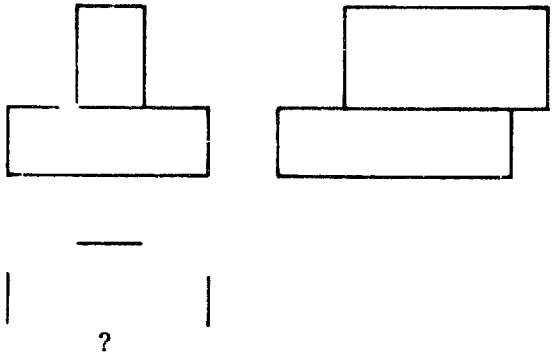

- COMPLETE ALL VIEWS.
- NAME ALL VIEWS.
- FILL IN ALL DIMENSIONS.
- MAKE OBLIQUE DRAWINGS FROM THESE ORTHOGRAPHIC DRAWINGS. SCALE 1 : 2 (cm)

N . P . V . C .	
30 MIN.	17.

EXERCISE: OBLIQUE TO ORTHOGRAPHIC

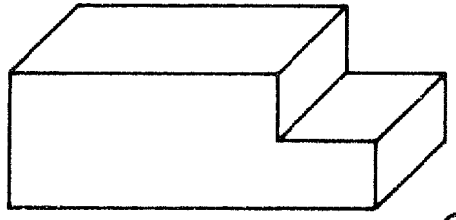

1

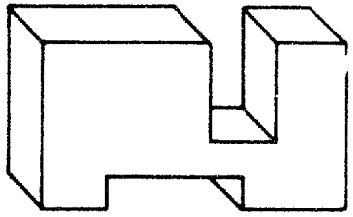

2

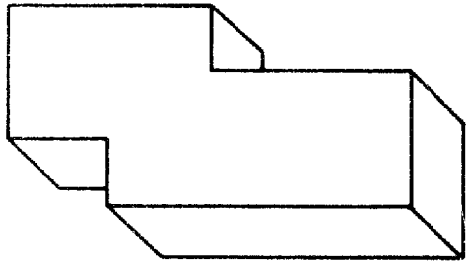

3

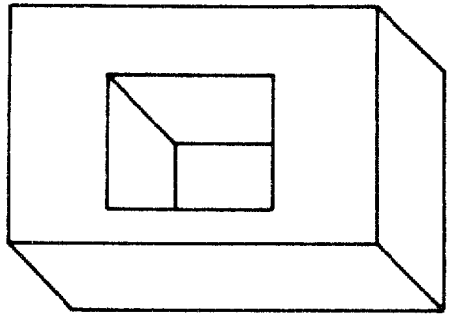

4

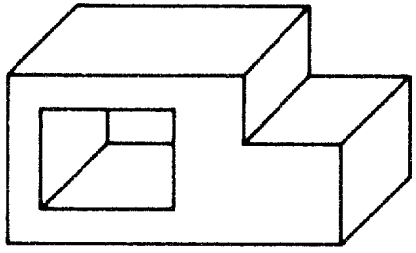

5

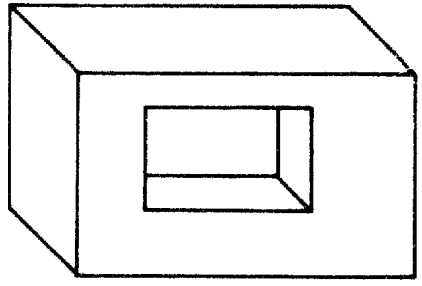

6

- MAKE AN ORTHOGRAPHIC DRAWING OF EACH BLOCK.
- MARK ALL DIMENSIONS OF THESE 8 BLOCKS.
- DRAWINGS SCALE 1 : 5 (cm)

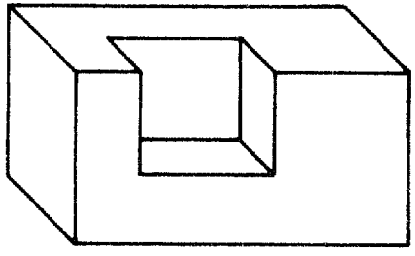

7

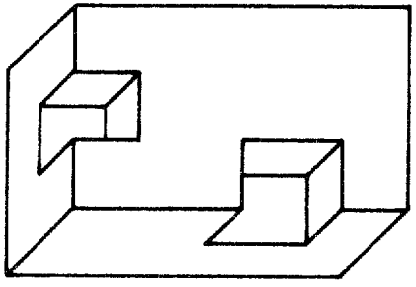

8

N . P . V . C .	
18.	40 MIN.

EXERCISE: ORTHOGRAPHIC TO OBLIQUE

1

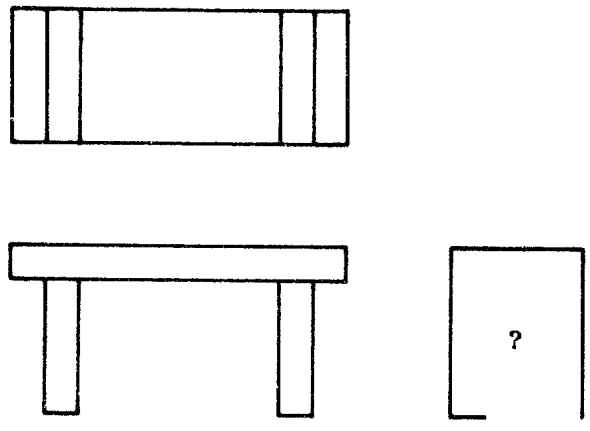

F.V.

Do you need L.S.V and R.S.V ?

2

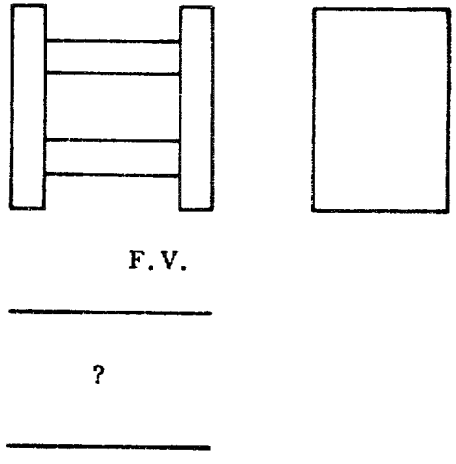

Do you need R.S.V. and L.S.V. ?

3

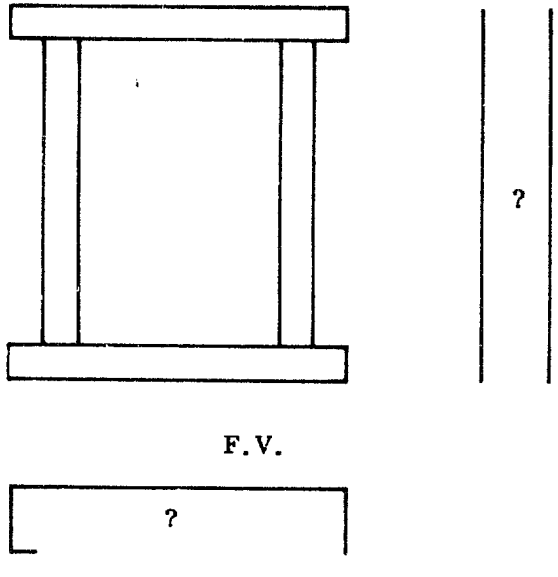

4

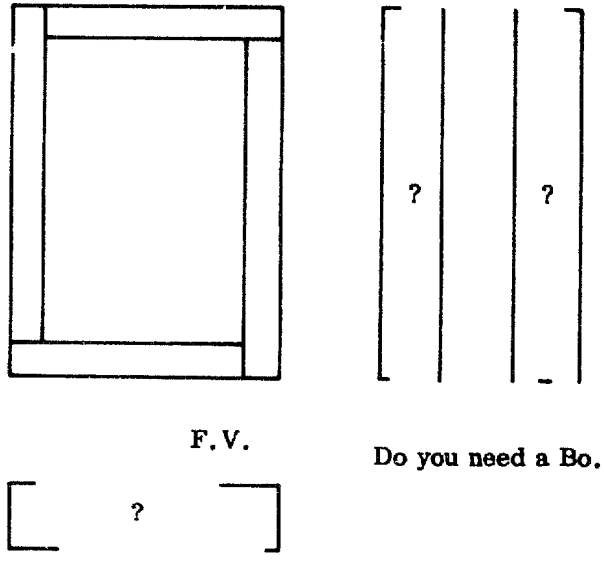

Do you need a Bo.V. ?

- COMPLETE ALL VIEWS.
- NAME ALL VIEWS.
- MARK ALL DIMENSIONS.
- MAKE OBLIQUE DRAWINGS. SCALE 1 : 2 (cm)
- PRACTICE DIFFERENT POSITIONS.
- TAKE DIFFERENT DIMENSIONS AND DIFFERENT SCALES.

N.P.V.C.	
40 MIN.	19.

EXERCISE: OBLIQUE TO ORTHOGRAPHIC

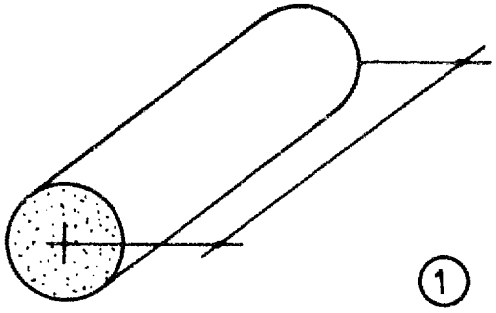

1

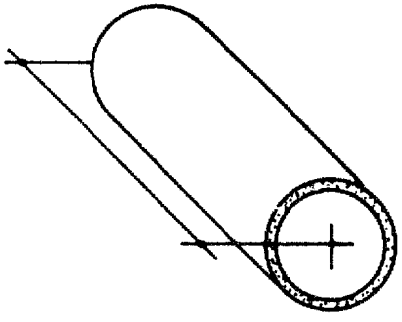

2

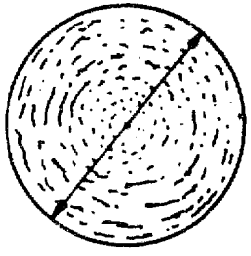

3

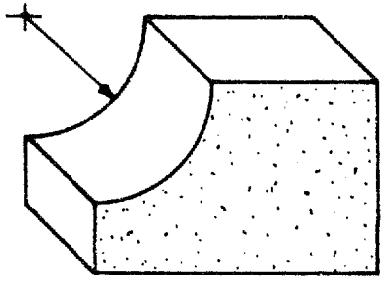

4

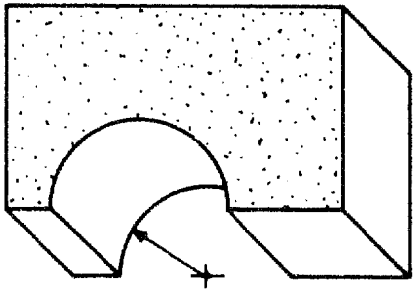

5

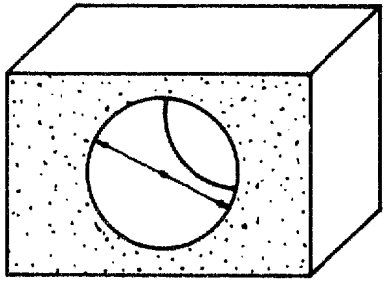

6

- MARK IN ALL DIMENSIONS.
- MAKE AN ORTHOGRAPHIC DRAWING OF EACH BLOCK. SCALE 2:1 (cm)

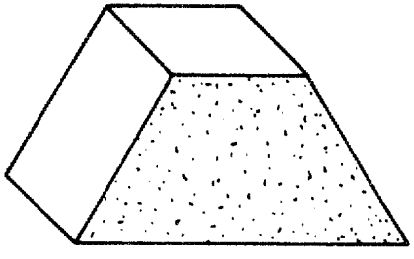

7

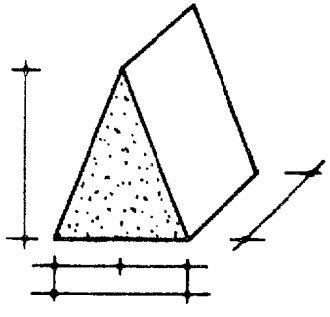

8

N . P . V . C .	
20.	60 MIN.

EXERCISE: ORTHOGRAPHIC TO OBLIQUE

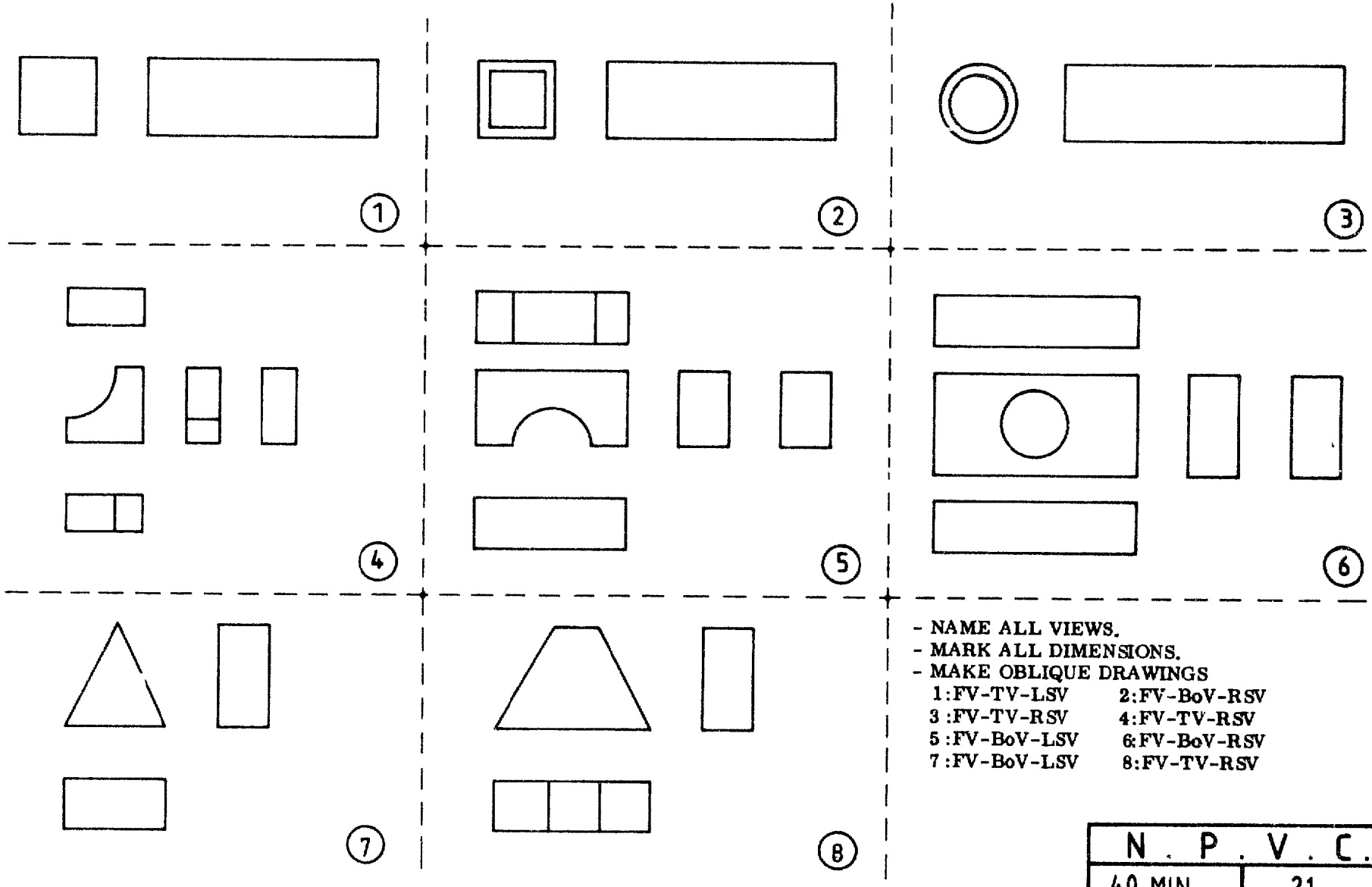

- NAME ALL VIEWS.
- MARK ALL DIMENSIONS.
- MAKE OBLIQUE DRAWINGS

1:FV-TV-LSV	2:FV-BoV-RSV
3:FV-TV-RSV	4:FV-TV-RSV
5:FV-BoV-LSV	6:FV-BoV-RSV
7:FV-BoV-LSV	8:FV-TV-RSV

N. P. V. C.	
40 MIN.	21.

SCALE DRAWING

Before you start to make any kind of workpiece, it is necessary to make a drawing showing how it should be made. This drawing is usually called the "layout". When making a layout it is important to use the correct scale. The scale tells you how much bigger or smaller the actual object is, compared to the drawing.

- Large objects have to be drawn smaller than they actually are: in this case you have to use a REDUCED SCALE.
- Very small objects have to be drawn larger than they actually are so that all the details can be seen. In this case you have to use an ENLARGED SCALE.
- If the object is neither very large nor very small, it may be drawn as it actually is. In this case you use FULL SCALE.

SCALES

The scale affects the size of every side of the object in the drawing. Make sure that you draw all lengths, widths, and to the correct scale.

- EXAMPLES OF SCALE: A scale of 1 : 5 (mm) tells you that 1 mm on the drawing represents 5 mm in real life. In other words, the drawing shows the object as 1/5th of its real size, with all dimensions in millimetres.

  A scale of 2 : 1 (cm) tells you that 2 cm on the drawing represents 1 cm in real life. In other words, the drawing shows the object as twice its actual size, and all the dimensions are in centimetres.

  What do the scales 1 : 10 (m) and 5 : 1 (cm) tell you?

- COMMON SCALES: Some commonly used scales are 1 : 2; 1 : 5; 1 : 10; 1 : 20; and 1 : 50.

SCALE DRAWING

NOTICE, THE NUMBERS REMAIN THE SAME.

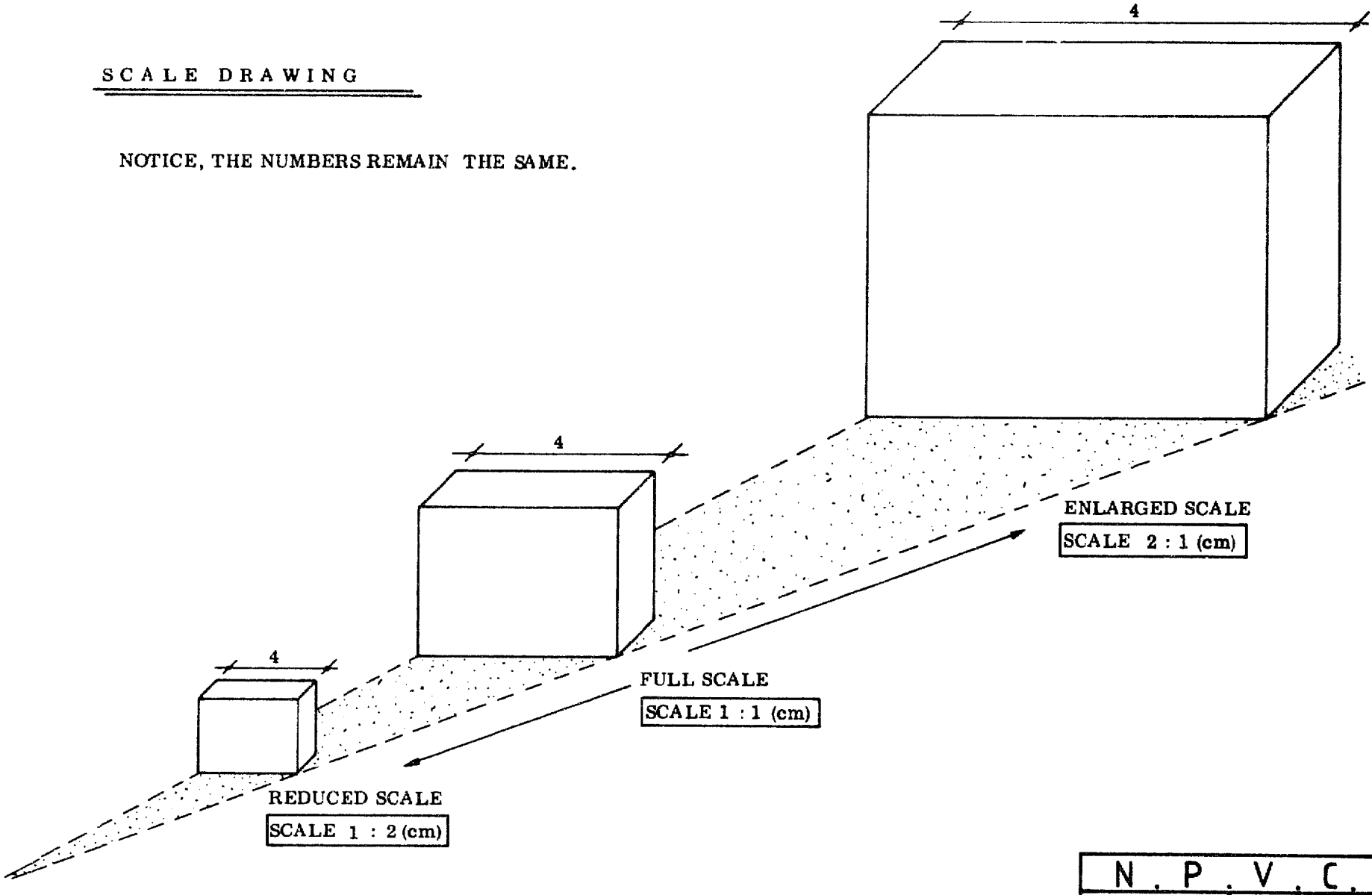

INSIDE AND OUTSIDE DIMENSIONS

If you measure the inside of a box, you will find the measurements are smaller than the outside measurements. This is because of the thicknesses of the sides of the box. Look at the drawing on the next page (A) and note that the outside length of the box is equal to the inside length plus TWICE the thickness of the walls. The same applies to houses: the outside dimensions of a room will always be larger than the inside dimensions.

- EXAMPLE: A box has inside dimensions of 30 x 55 cm and is made of boards which are 3 cm thick. What are the outside dimensions of this box? (see A).

FRAMES

Many articles such as windows and doors can be bought as ready made pieces. These have certain sizes. Both doors and windows usually need a frame around them, and this has to be taken into account when the plans are made for the house.

Figs. B and C on the next page show some ready made articles. Below each you see the same article with a frame around it. In both cases the frame is 6 cm thick.

Fig. B shows a single article such as a casement. The frame goes all the way around the casement, which means that the window opening in the wall must be 12 cm longer and 12 cm higher than the casement itself, so that there is room for the frame.

Fig. C shows a pair of casements. In this case the frame goes all the way around the casements and also between them. This means that the window opening in the wall must be 18 cm longer and 12 cm higher than the casement itself.

EXERCISE: IN AND OUTSIDE DIMENSIONS

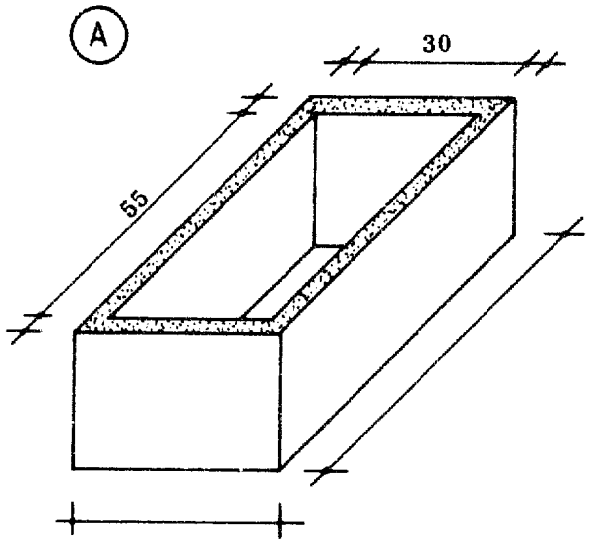

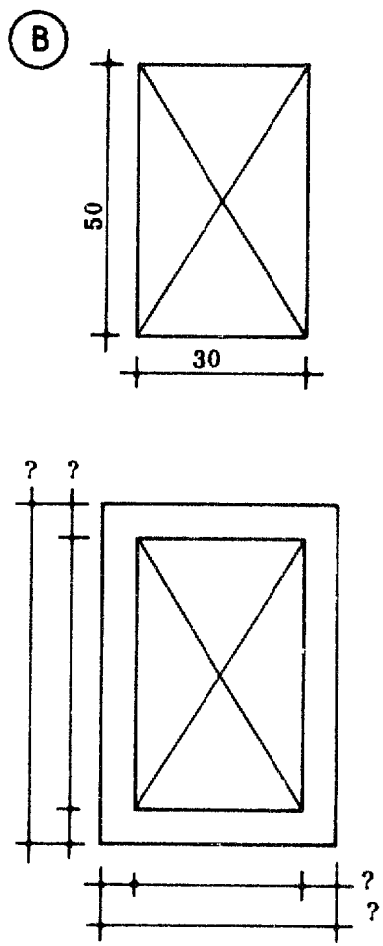

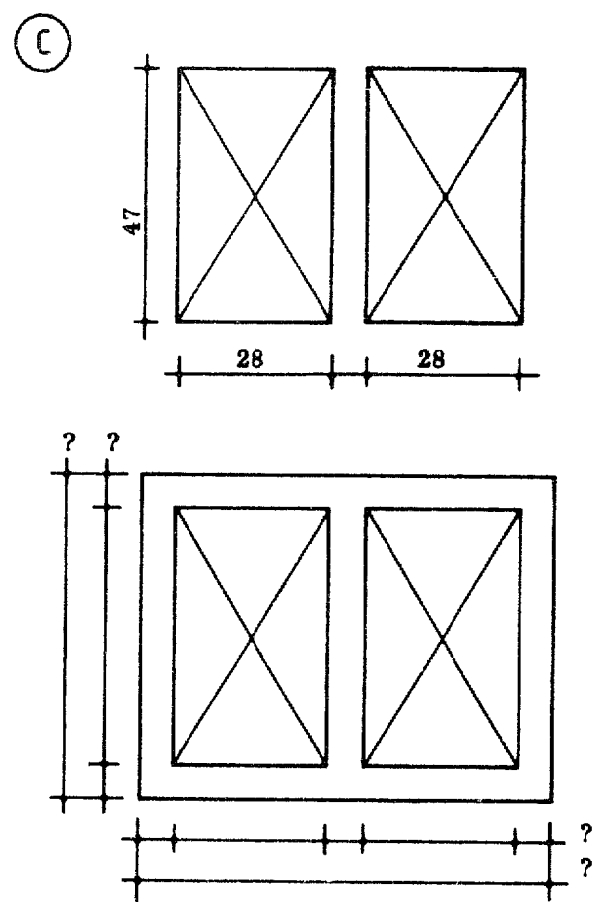

A - THE BOX HAS WALLS THAT ARE 3 cm THICK.
MARK IN THE OUTSIDE DIMENSIONS.

B - MARK IN ALL DIMENSIONS.

C - MARK IN ALL DIMENSIONS.

N. P. V. C.

DESIGNING FROM SKETCHES

You will often have people coming to you with a rough sketch of something they want you to make, for example a set of casements. In order to make the frame around the casements and to know the size of the opening which has to be made in the wall, there are two important things to notice about most rough sketches:

- The dimensions are the outside dimensions of the casements.
- The thickness of the frame has been left out.

Someone may come to you with a rough sketch of a complicated box with many partitions. In order to be able to construct the box, you have to notice two important things about the sketch:

- The dimensions are the inside dimensions of the partitions.
- The thickness of the partitions and the sides of the box has been left out.

As a craftsman you have to turn these types of sketches into good plans. The plans you draw should have inside and outside dimensions, as well as the thicknesses of the members of the frame or partitions.

- BUILD UP YOUR PLAN IN THE FOLLOWING WAY:

  - Draw two planning lines, one vertical and one horizontal (lines A and B).
  - On line A, start at the left and mark the thickness of the frame member; then the width of the casement. Next mark the thickness of the central frame member and then the width of the right casement. Finally mark the thickness of the right frame member.
  - Starting from the bottom, do the same thing on line B. Your marks should indicate in order: frame; casement; frame; casement; frame; casement; frame.
  - Transfer lines A and B onto your drawing paper so that they form a right angle (page 28).
  - You should now be able to finish the drawing as shown on page 29.

In the original sketch here, it looks as though the large space at the top of the sketch was 259 cm long. On your final drawing you will see that it is 269 cm long. Can you see why?

ORIGINAL SKETCH OF CASEMENT ARRANGEMENT

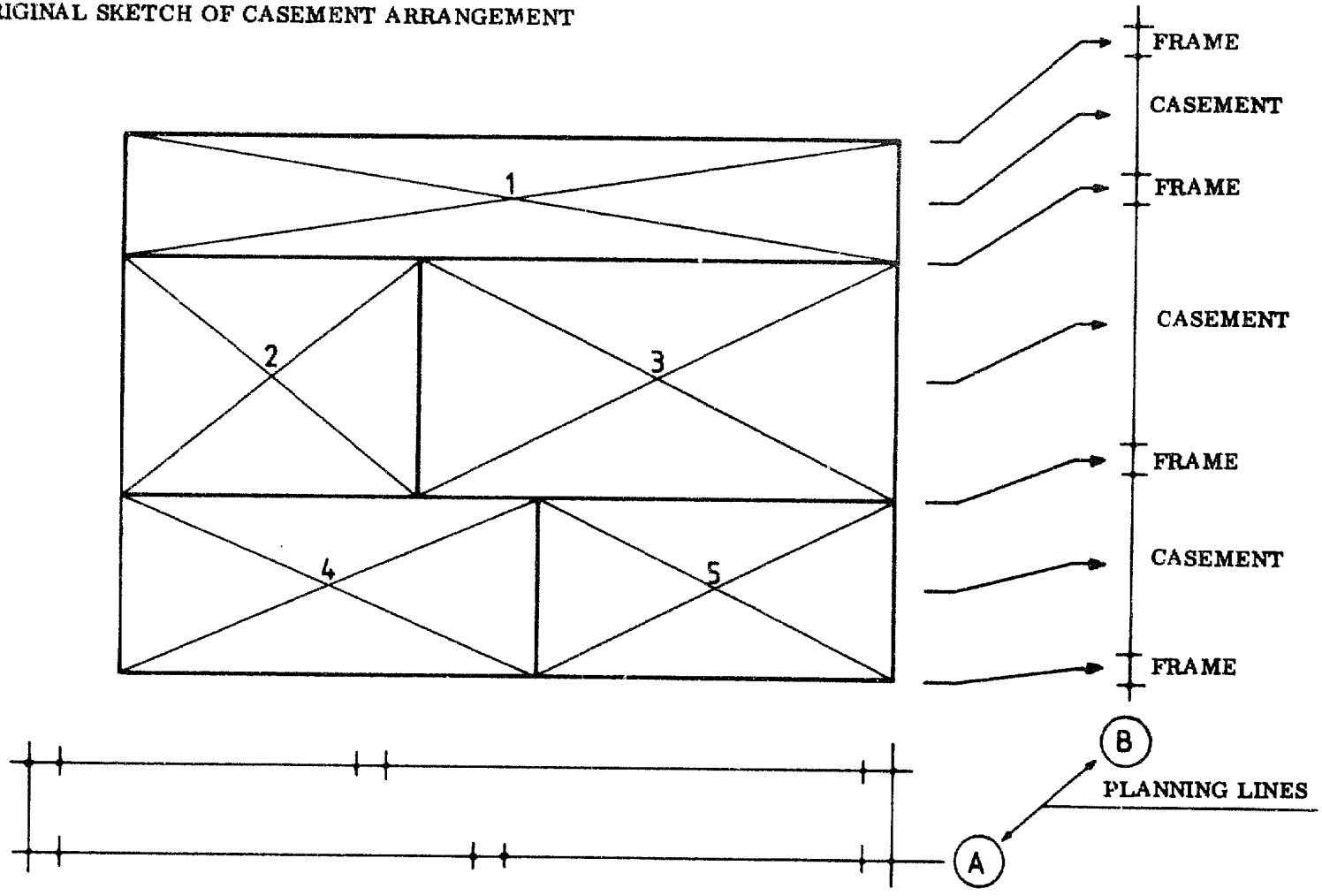

- SKETCH IS DRAWN IN A SCALE OF 1 : 20 (cm).
- FRAME MEMBERS ARE 10 cm THICK.

- MARK IN ALL DIMENSIONS!

N . P . V . C .

PLANNING LINES FOR CASEMENT ARRANGEMENT

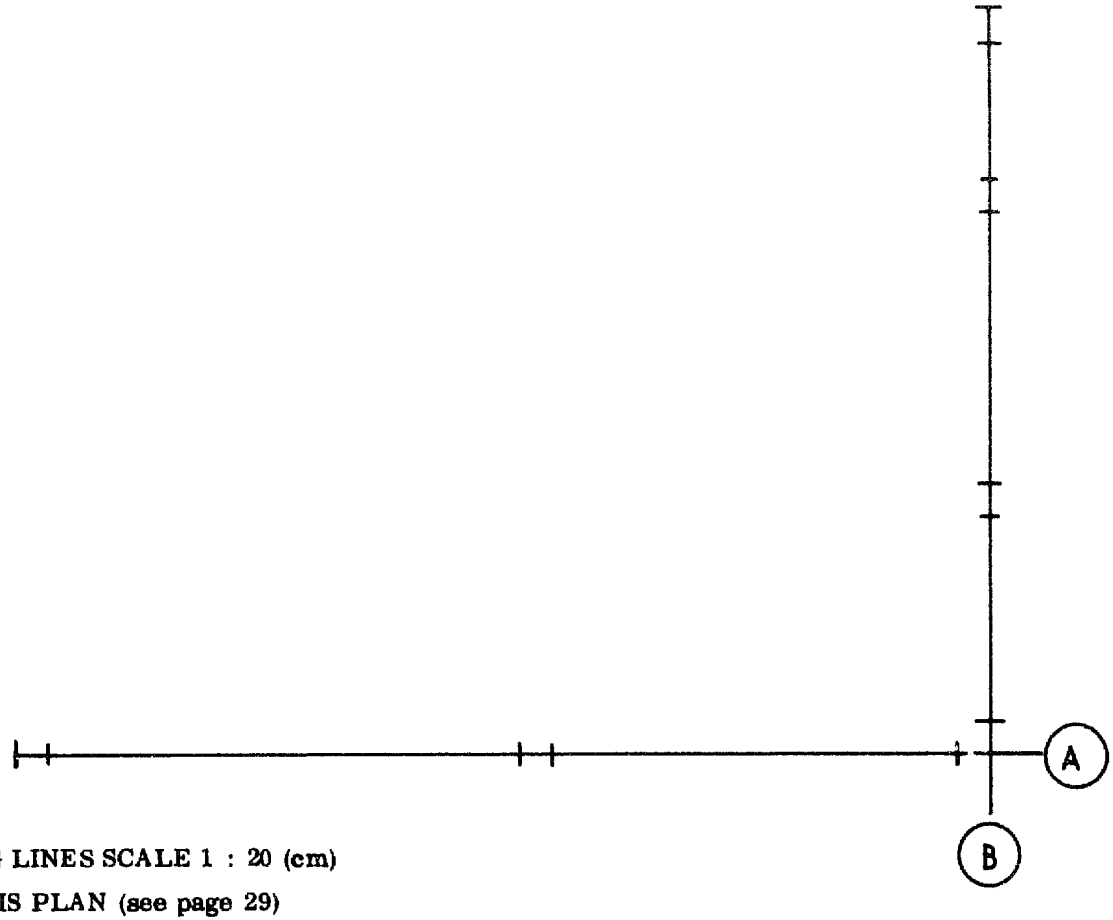

- PLANNING LINES SCALE 1 : 20 (cm)
- FINISH THIS PLAN (see page 29)

FINISHED PLAN OF CASEMENT ARRANGEMENT

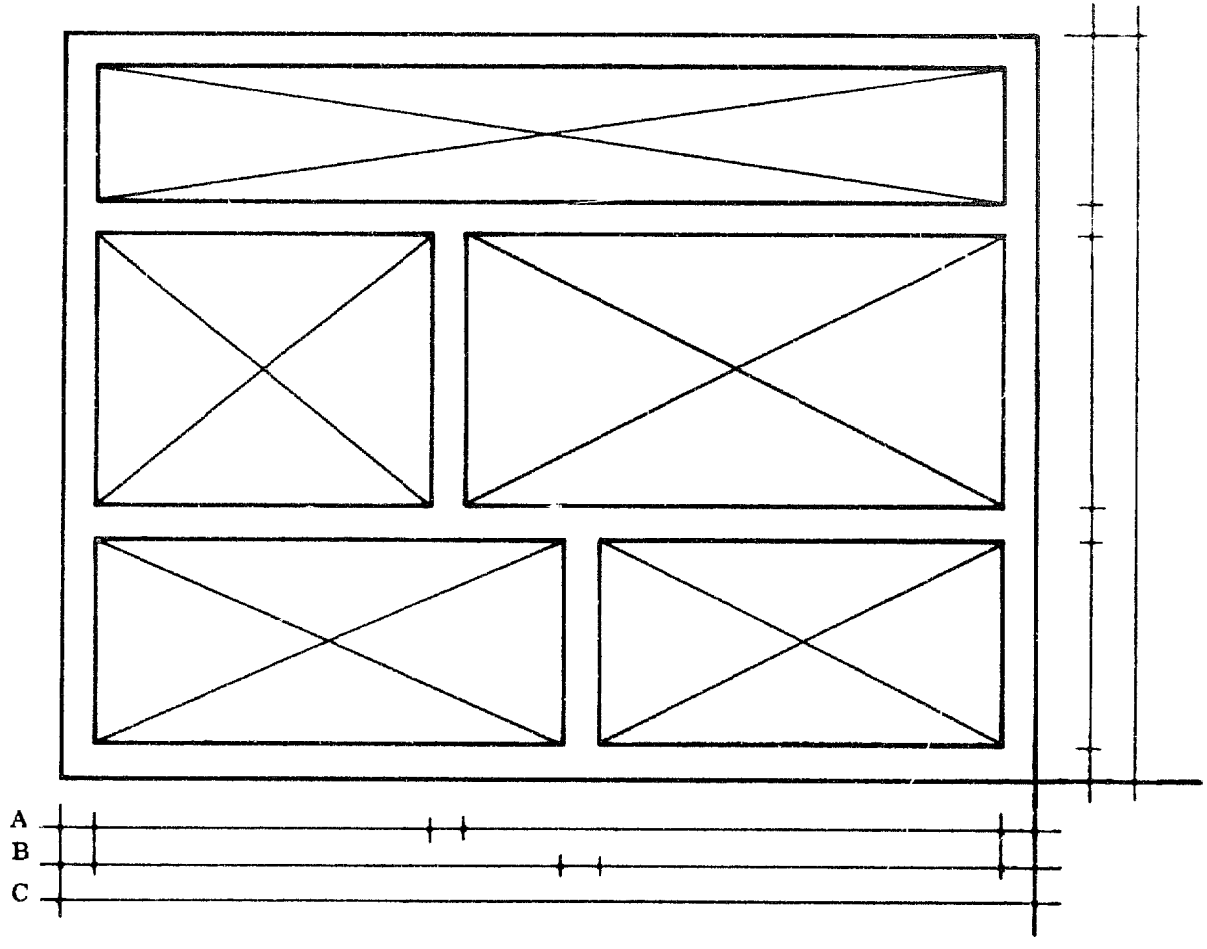

- DRAWING SCALE 1 : 20 (cm)
- MARK IN ALL DIMENSIONS.

N . P . V . C .	
	29.

DESIGN

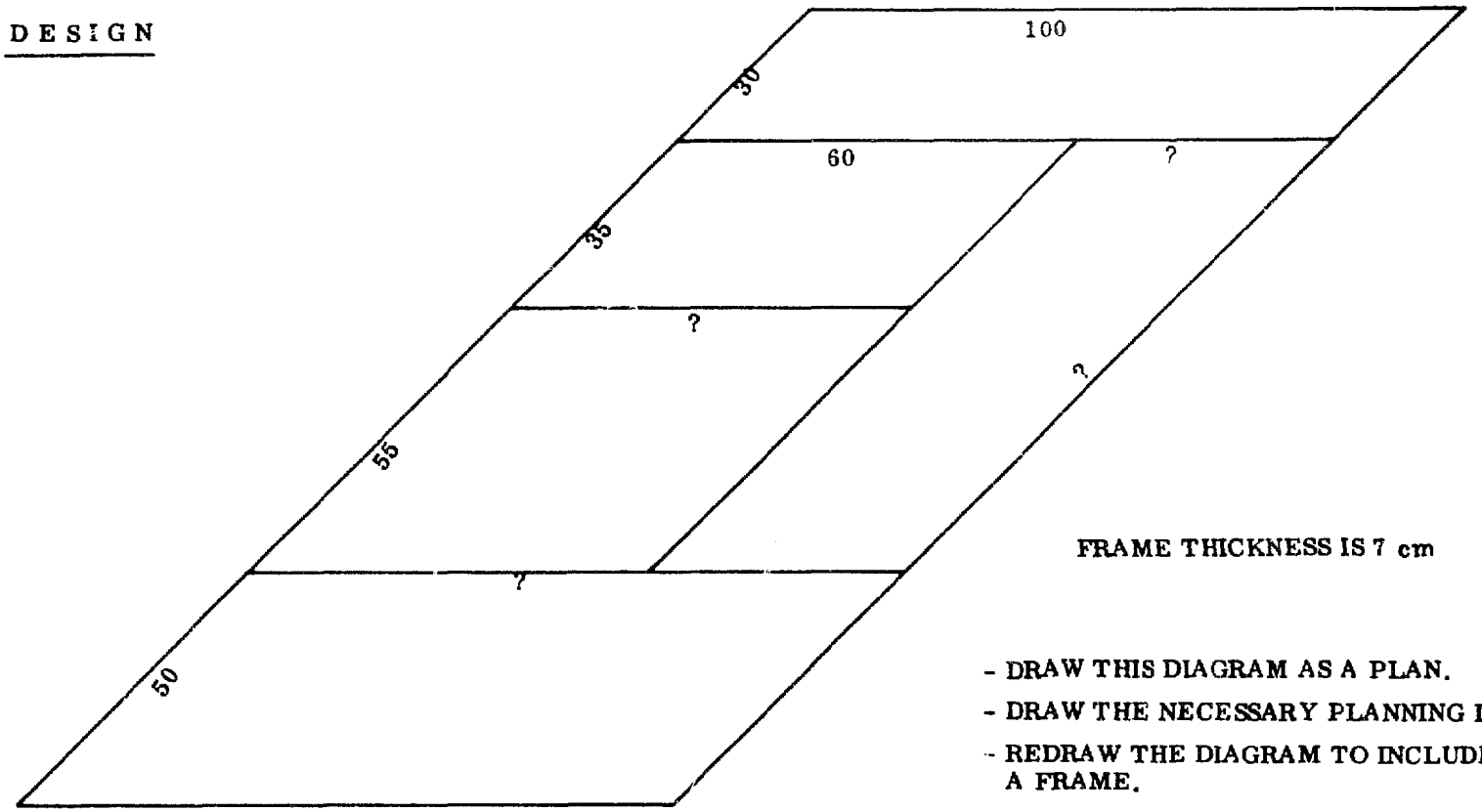

FRAME THICKNESS IS 7 cm

- DRAW THIS DIAGRAM AS A PLAN.
- DRAW THE NECESSARY PLANNING LINES.
- REDRAW THE DIAGRAM TO INCLUDE A FRAME.

N . P . V . C .	
30.	30 MIN.

DESIGN

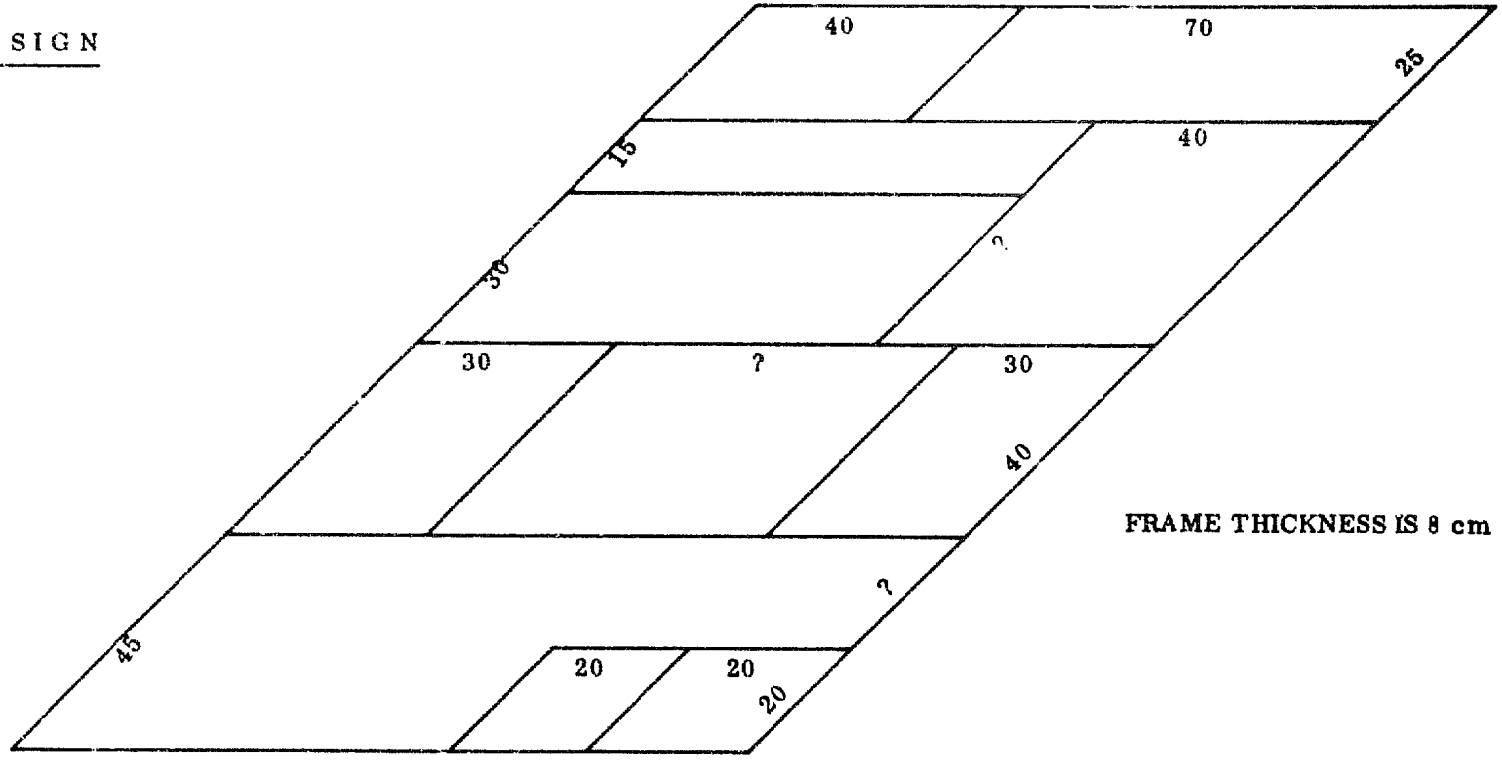

FRAME THICKNESS IS 8 cm

- DRAW THIS DIAGRAM AS A PLAN.
- DRAW THE NECESSARY PLANNING LINES.
- REDRAW THE DIAGRAM TO INCLUDE A FRAME.

N . P . V . C .	
35 MIN.	31.

OBLIQUE DRAWING OF A BOX-LIKE OBJECT

1

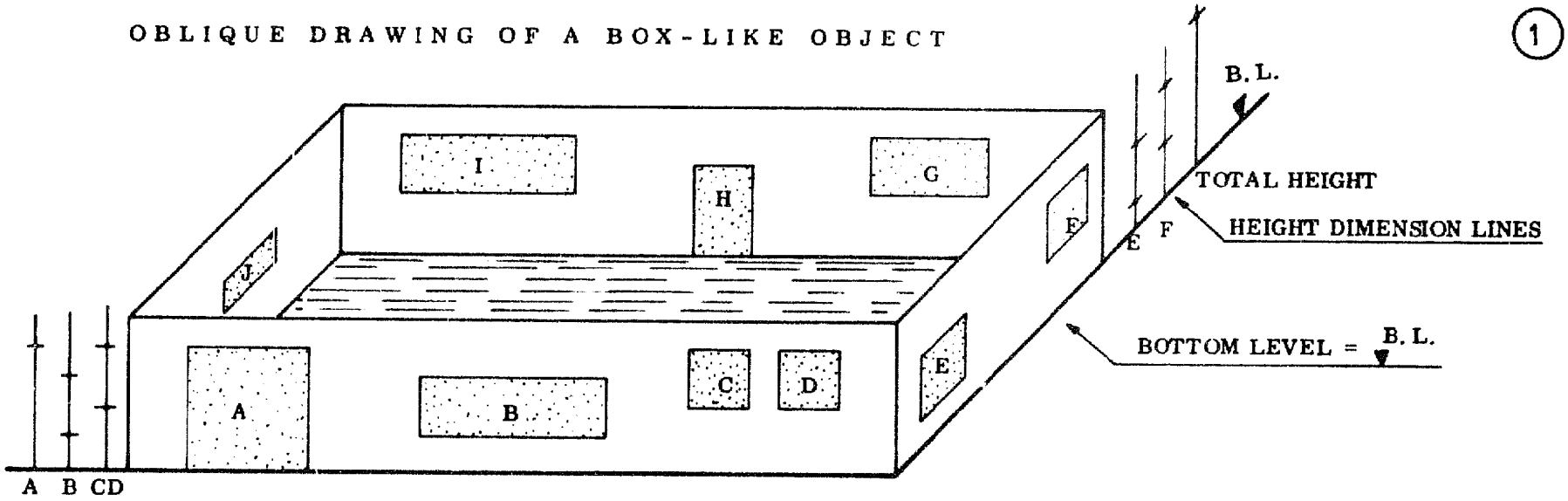

TECHNICAL DATA

2

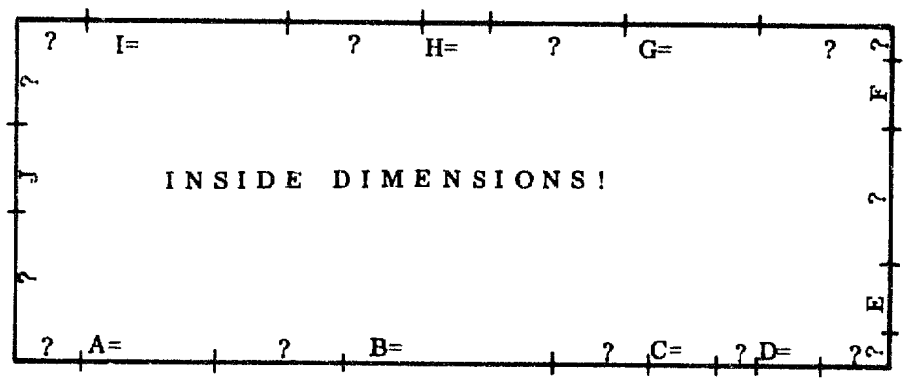

SKETCH PLAN

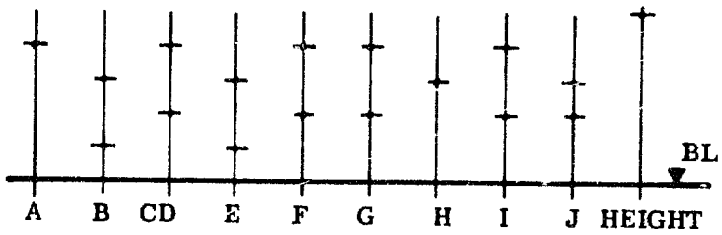

SKETCH = SCALE 1 : 10 (cm)

- FILL IN ALL DIMENSIONS.

- FULL DRAWING ON PAGE 33.

ORTHOGRAPHIC DRAWING

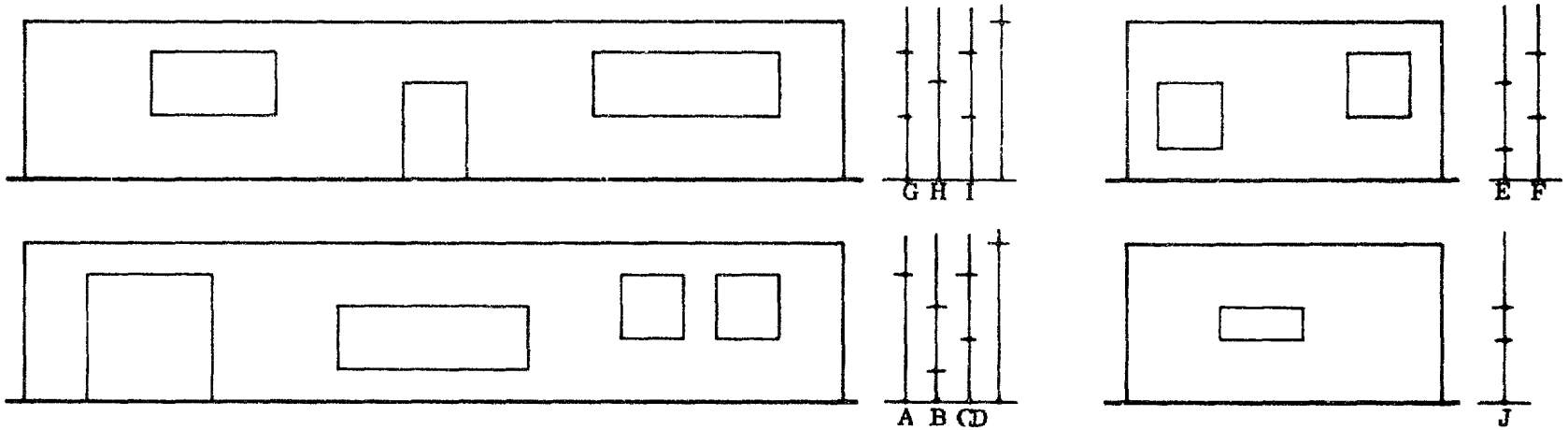

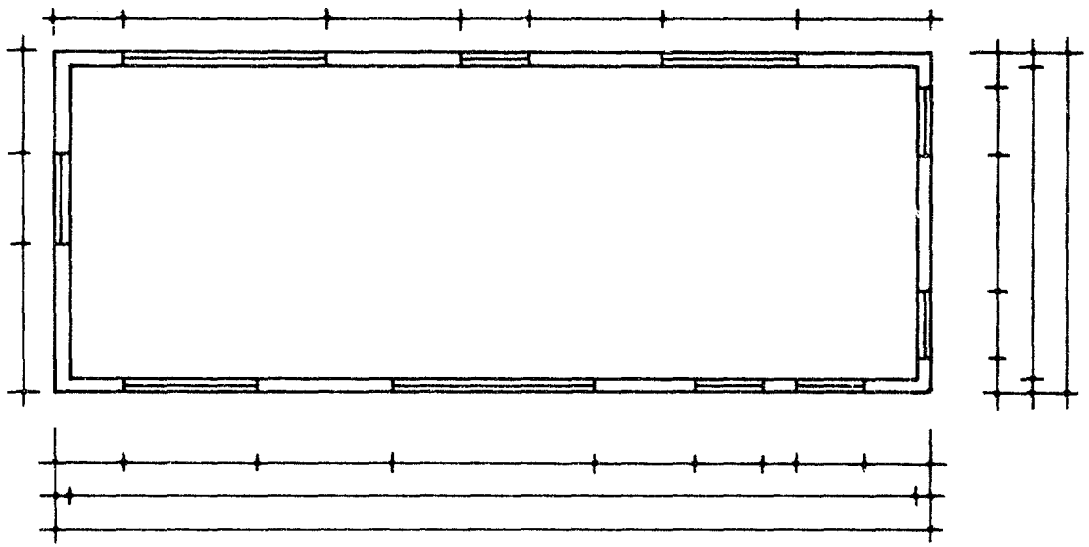

ORTHOGRAPHIC DRAWING
SCALE 1 : 10 (cm)

- FILL IN ALL VIEW NAMES.
- MARK IN ALL DIMENSIONS.
- MARK THE CORRECT LETTERS IN THE BLOCKS.
- MAKE OTHER DESIGNS.

N . P . V . C.	
2 HOURS	33.

CROSS SECTIONS

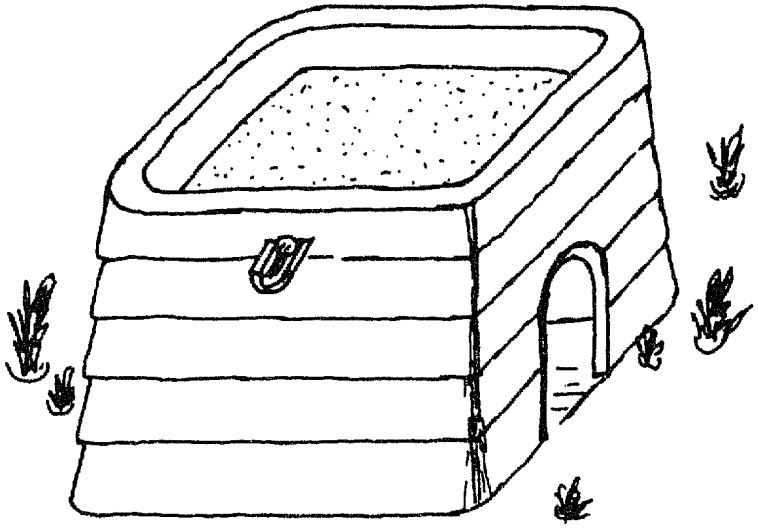

SIDE VIEW OF A HOUSE

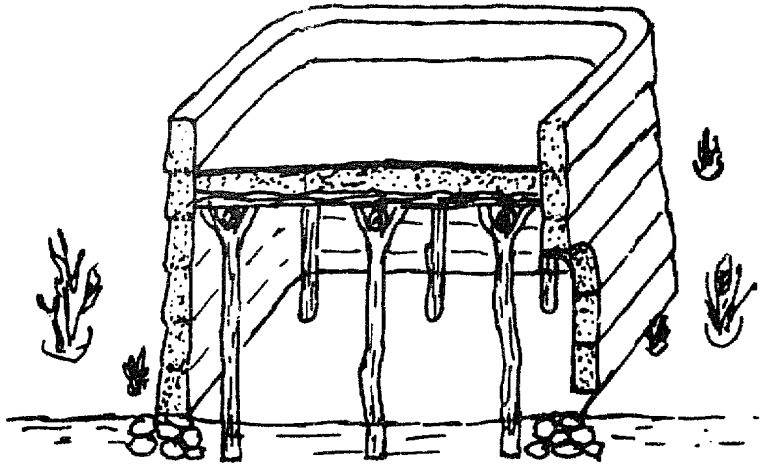

THE CROSS SECTION SHOWS THE INTERIOR OF THE WHOLE HOUSE

MANGO

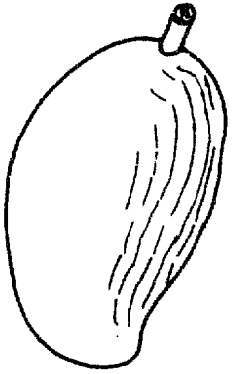

VIEW

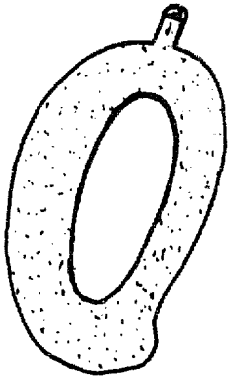

IN THE CROSS SECTION YOU CAN SEE THE FLESH AND THE STONE

COCONUT

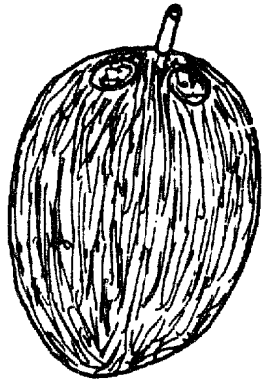

VIEW

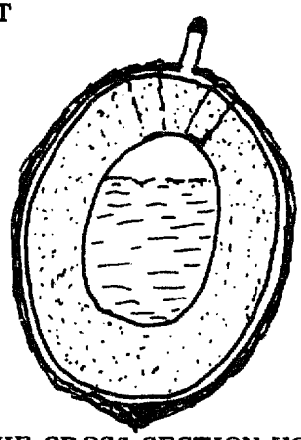

IN THE CROSS SECTION YOU CAN SEE THE SHELL, THE FLESH AND THE JUICE

HORIZONTAL SECTIONS AND CROSS SECTIONS

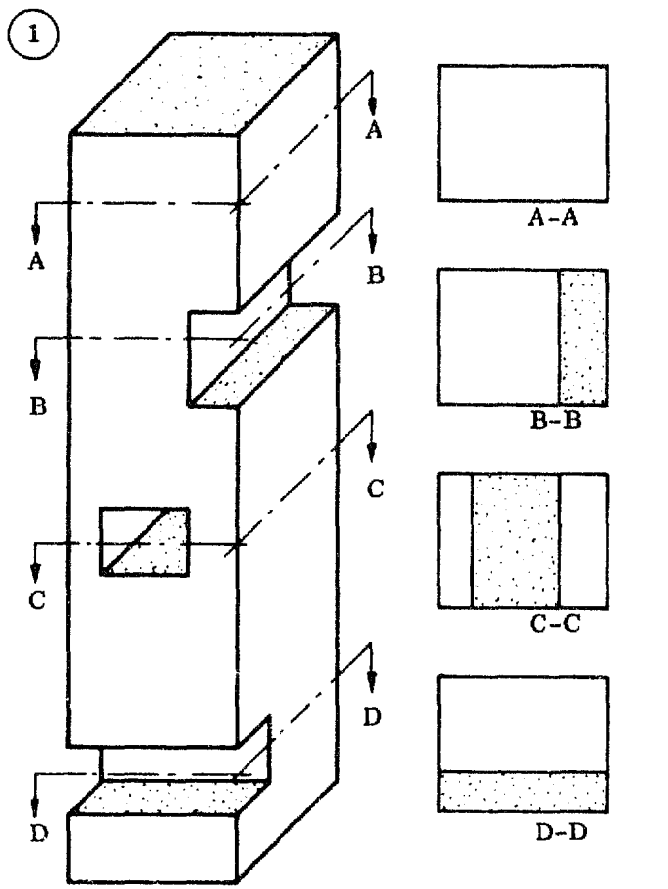

HORIZONTAL SECTIONS

- AT SECTION C-C YOU CAN SEE THAT THE HOLE GOES THROUGH THE BLOCK.
- THE ARROW SHOULD POINT IN THE DIRECTION YOU WANT TO SHOW.

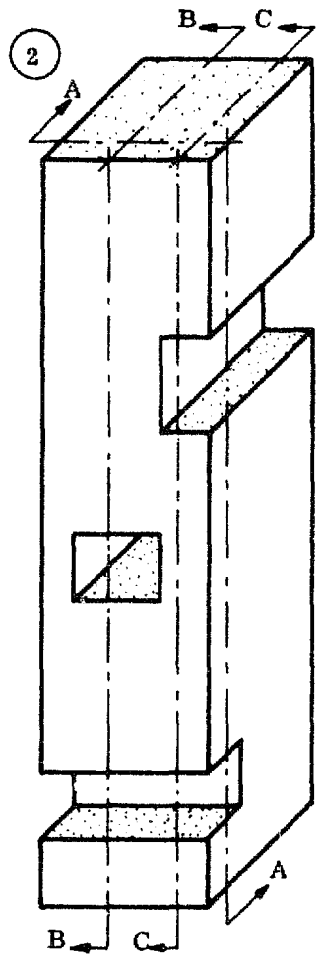

COMPLETE THESE CROSS SECTIONS

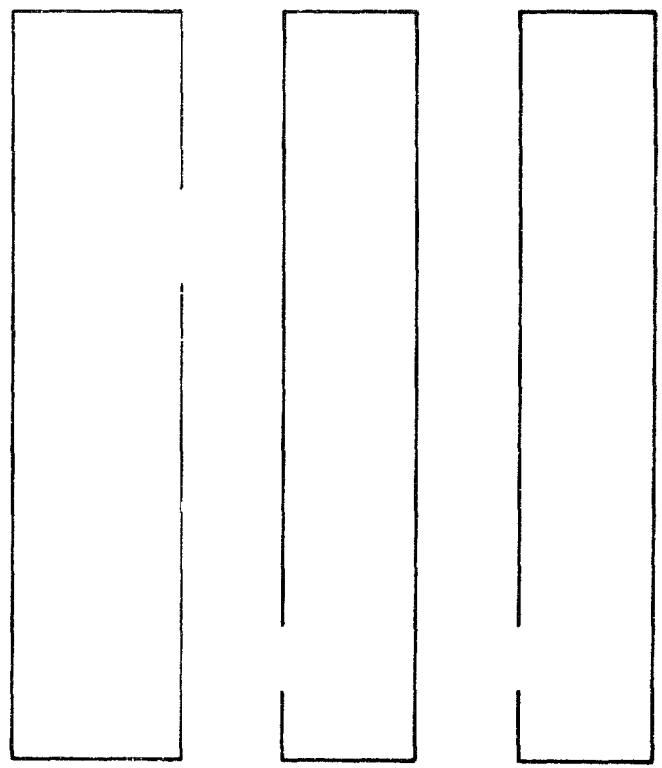

AS A RULE TAKE THE SECTIONS AT THOSE POINTS WHICH WILL SHOW THE GREATEST AMOUNT OF DETAIL.

SKETCHING

You will often find that you will have to make a rough drawing in which accurate dimensions are not really necessary. In this case it is usually best to make a sketch. To sketch means to make a drawing without using drawing instruments like rulers, etc. You will find that this type of drawing is much quicker than technical drawing with the drawing instruments. However, sketching is probably harder than technical drawing, especially at first. It requires a steady hand, a sense for proportions, and an appreciation of detail.

Sketching is the art of putting ideas into pictures and is especially useful for understanding technical drawings and making rough plans.

The only equipment you need for sketching is an H pencil, an eraser, and some paper. Use plain paper for sketching.

- TECHNIQUE: Practice makes perfect. Practice drawing straight lines and curves. After a while you will find that your straight lines look almost as if they were drawn with a ruler! On the next page you can see the best way to draw horizontal, vertical, and inclined lines, and the best way to draw a circle.
- REMEMBER:
  - Take your time while sketching, be careful.
  - Don't try to draw long lines with one motion.
  - Rest only the side of your hand on the paper.
  - Don't turn the paper while you are sketching. You should be able to draw all your lines with the paper in the same position.

EXERCISE: FREE HAND SKETCHING

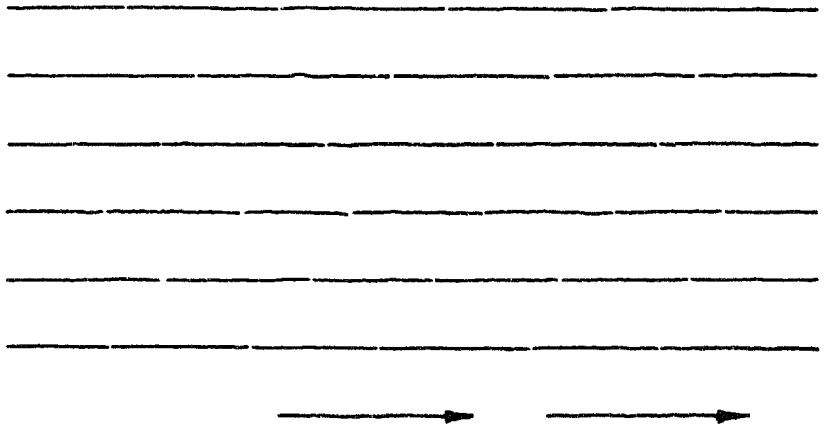

HORIZONTAL LINES

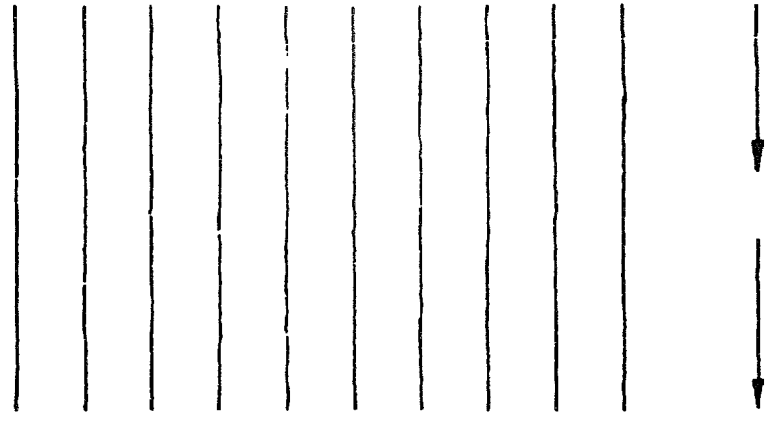

VERTICAL LINES

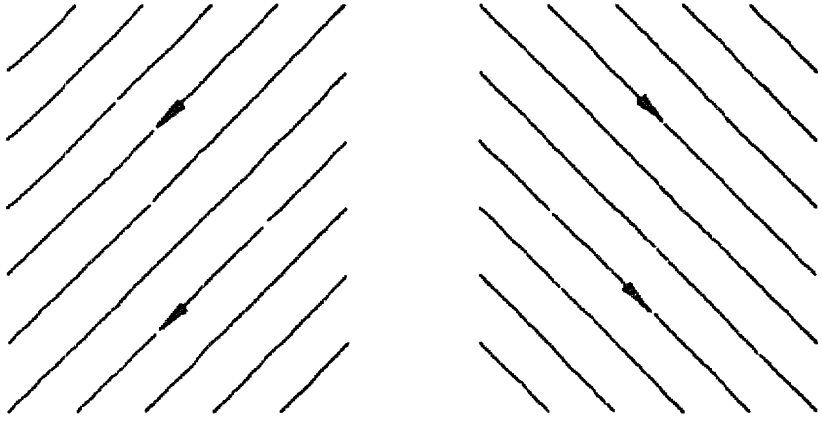

INCLINED LINES

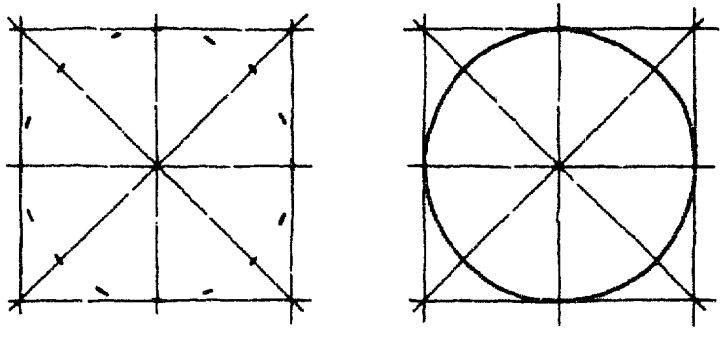

CIRCLES

NOTICE: THE DIFFERENT DIRECTIONS IN WHICH THE LINES ARE DRAWN.
LINES ARE NOT ONE LONG LINE.

EXERCISE: FREE HAND SKETCHING

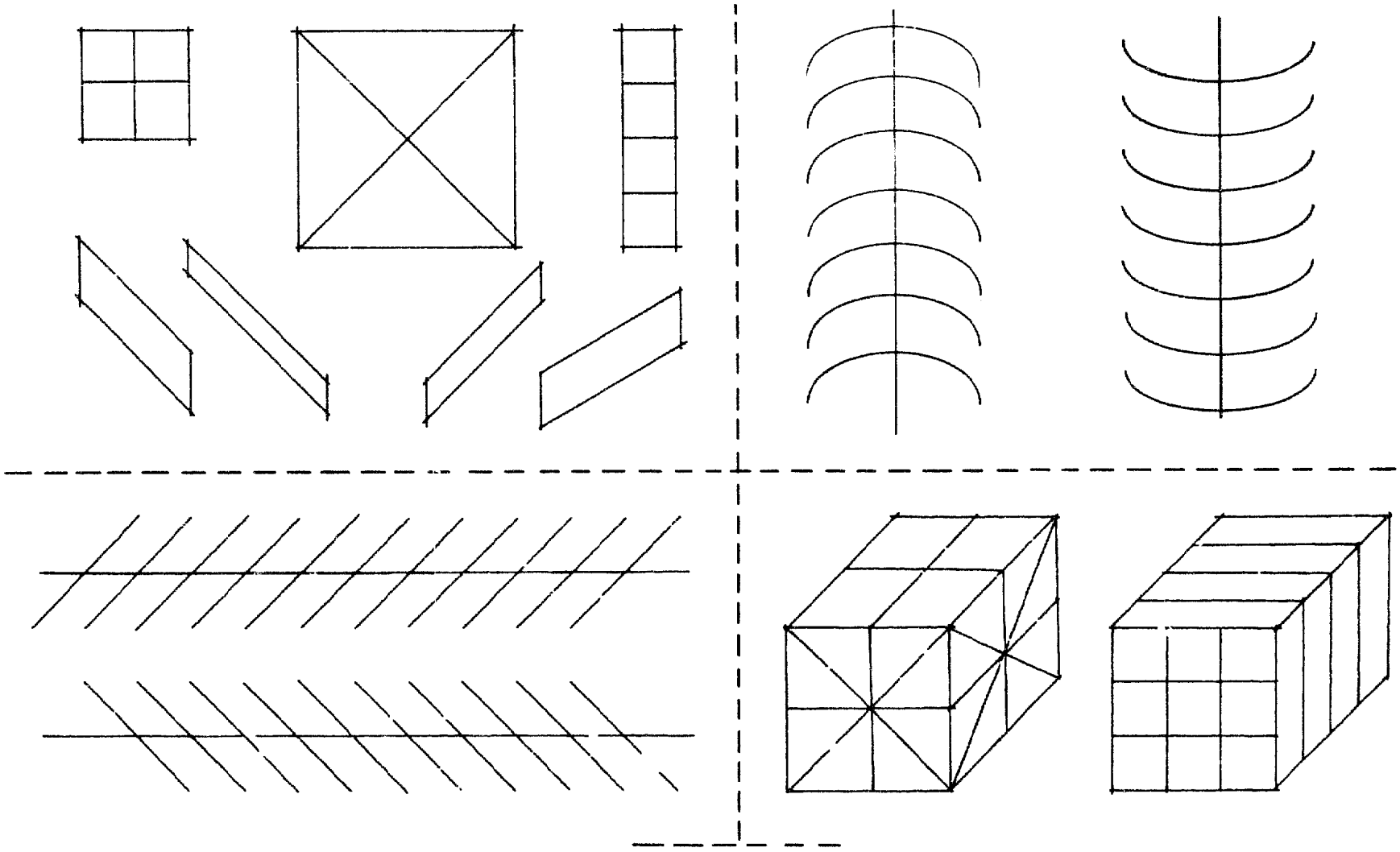

REPEAT THESE EXERCISES, USING DIFFERENT ANGLES.
DRAW ARROWS TO SHOW THE DIRECTION IN WHICH YOU SKETCH ALL OF THESE LINES.

EXERCISE: FREE HAND SKETCHING

A

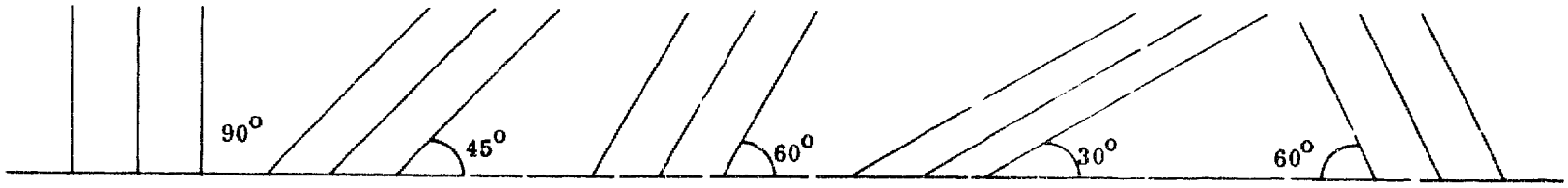

B

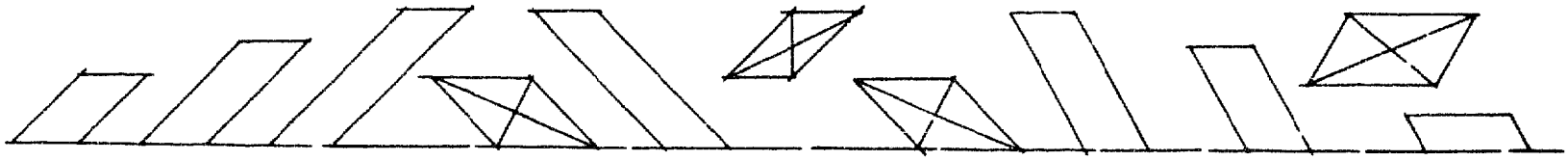

C

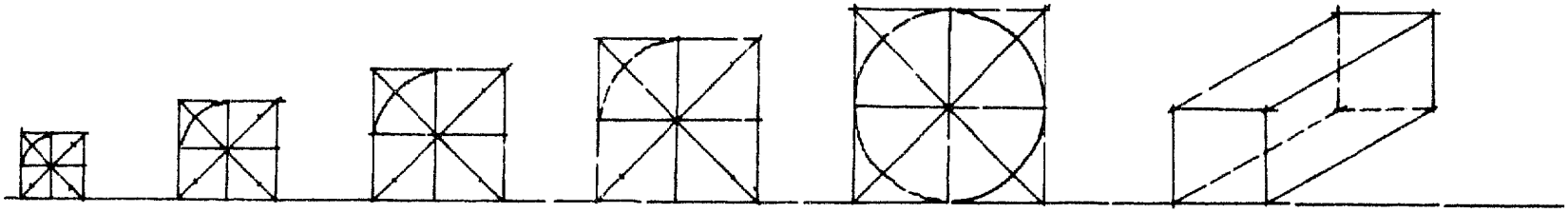

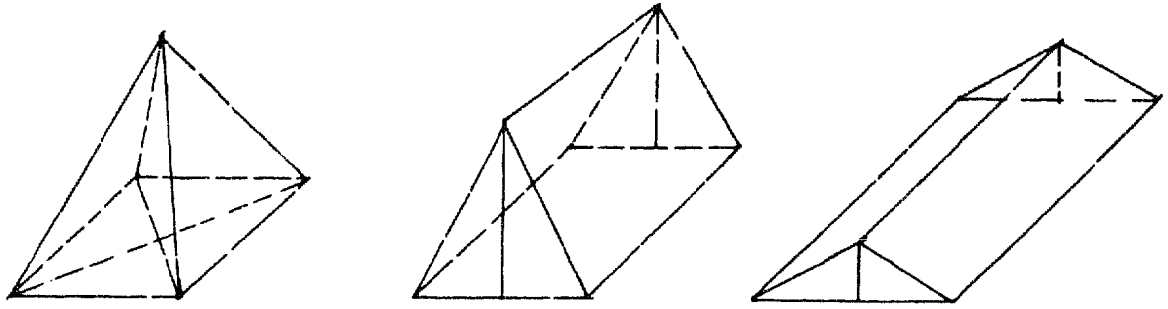

REPEAT THESE EXERCISES
USING DIFFERENT ANGLES.

WINDOW FRAME (BASIC LAYOUT)

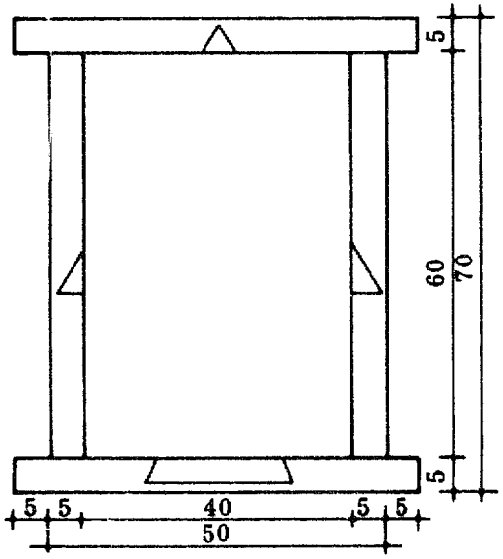

SIDE VIEW

FRONT VIEW

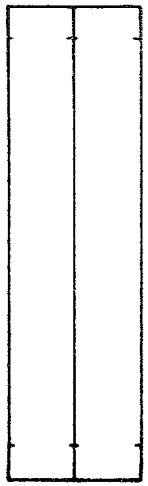

INSIDE VIEW

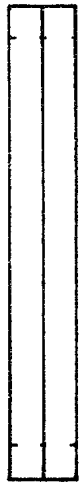

BACK VIEW

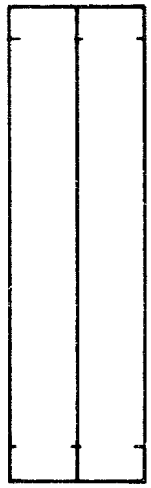

OUTSIDE VIEW

MARKING OUT THE JOINTS

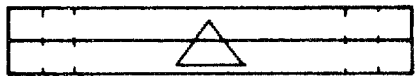

FRONT VIEW

BACK VIEW

INSIDE VIEW

OUTSIDE VIEW

SIGN FOR MORTICE----------⊠

SIGN FOR END GRAIN---------▨

FACE MARK ----------△

INSIDE AND OUTSIDE DIMENSIONS OF FRAME ARE VERY IMPORTANT (In cm).

MAKE SURE THAT THE LINES ON ALL VIEWS MATCH UP WITH THE FRONT VIEW. CHECK THIS WITH THE AID OF A RULER.

MARK IN ALL MORTICES AND TENONS.

N . P . V . C .

40.

WINDOW FRAME (MARKED OUT FOR JOINTS)

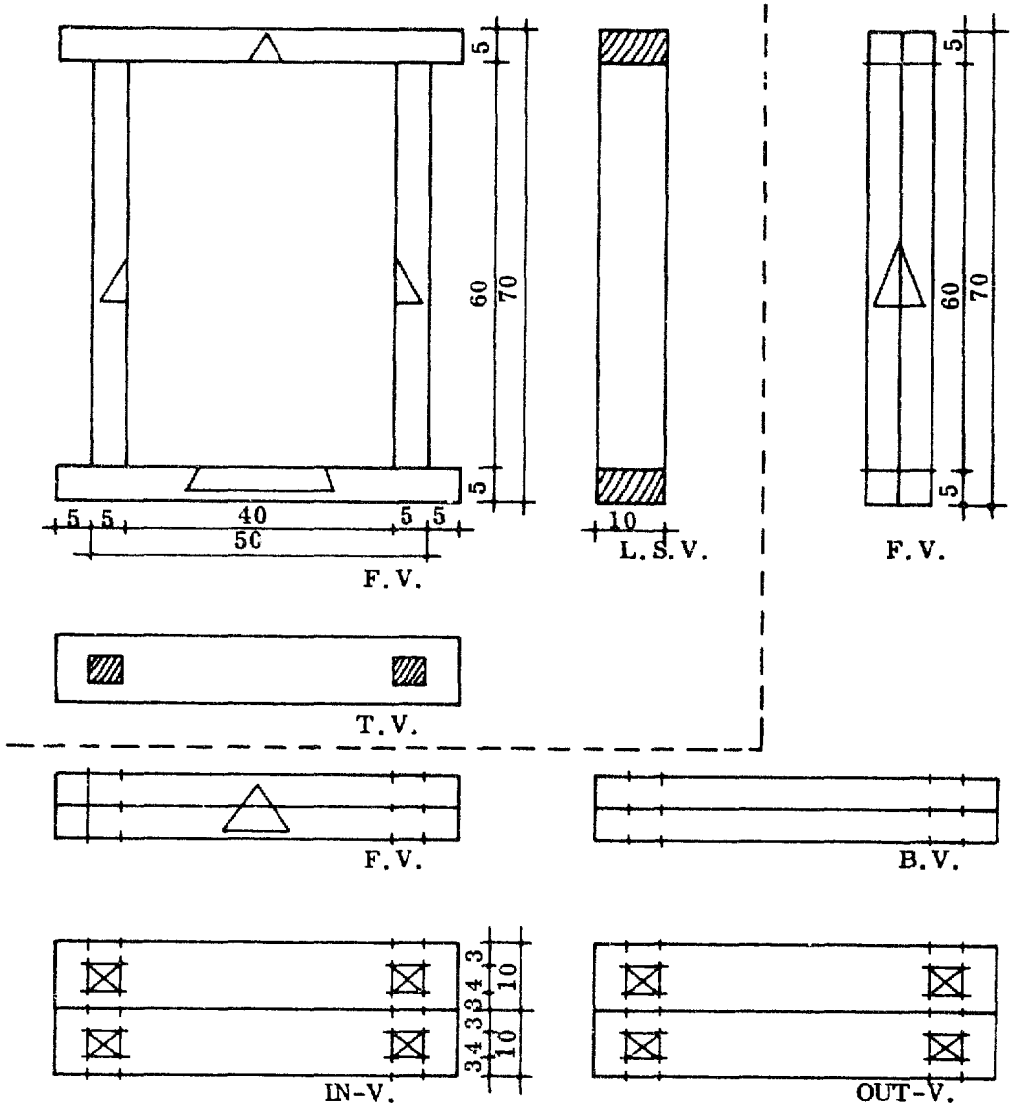

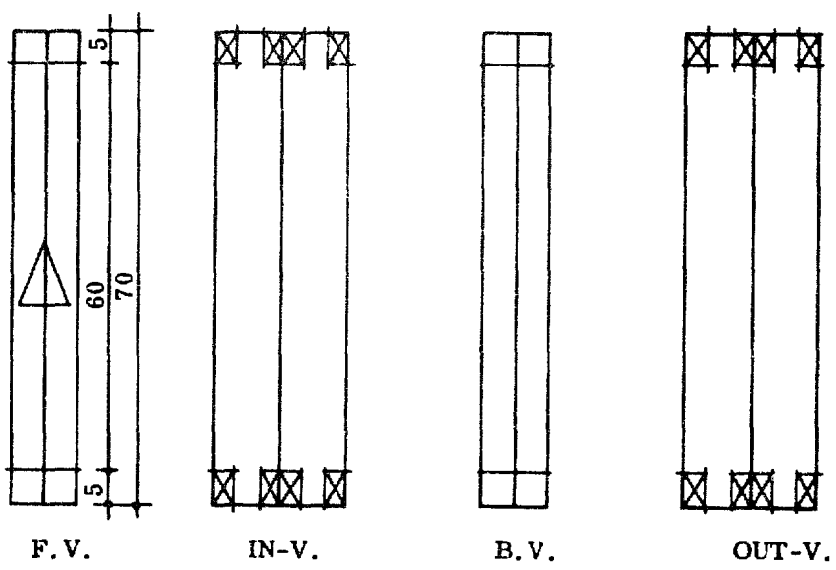

MARKING OUT THE JOINTS

MAKE AN ORTHOGRAPHIC DRAWING FROM A WINDOW FRAME WITH DIFFERENT MEASUREMENTS.

DRAW ALL THE MEMBERS AND MARK THE JOINTS OUT ON THE DRAWING.

N . P . V . C .	
2 1/2 HOURS	41.

WINDOW FRAME SCALE 1 : 10 (cm)

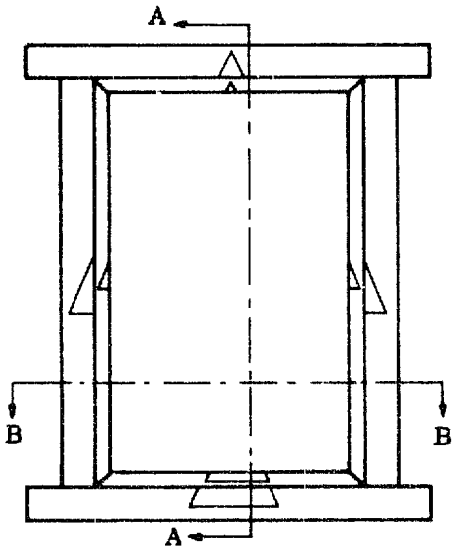

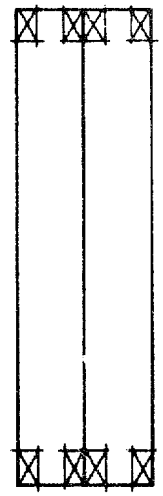

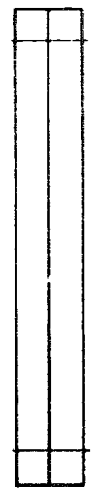

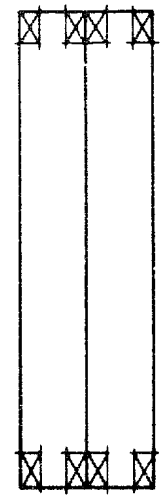

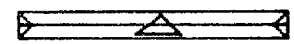

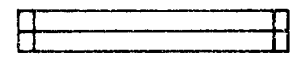

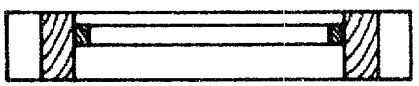

- NAME ALL VIEWS.
- DRAW ALL DIMENSION LINES.
- MARK ALL DIMENSIONS.
- MARK THE POSITIONS OF THE BEADS.

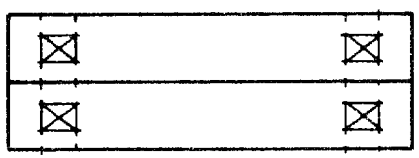

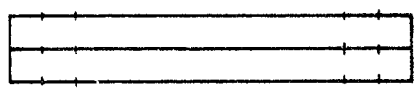

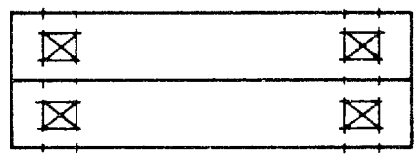

DETAIL

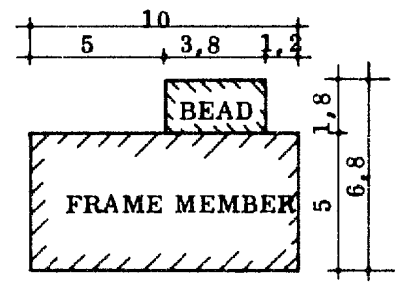

MAKE A DRAWING OF A WINDOW FRAME WITH DIFFERENT DIMENSIONS.

N . P . V . C.	
42.	2 ½ HOURS

DOOR FRAME FOR A SMALL DOOR SCALE 1 : 10 (cm)

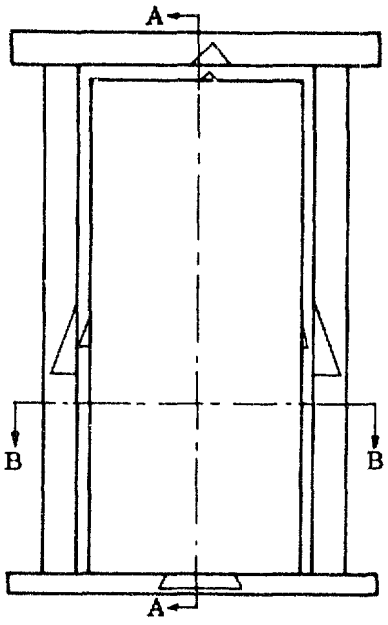

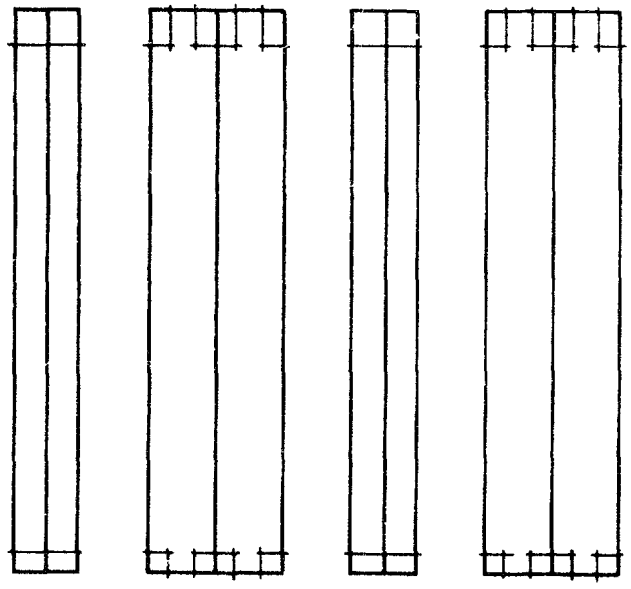

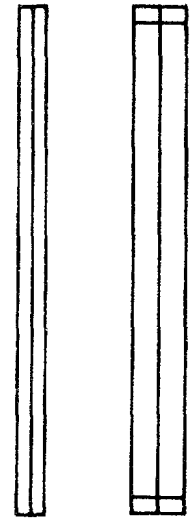

- NAME ALL VIEWS.
- DRAW ALL DIMENSION LINES.
- MARK ALL DIMENSIONS.
- MARK THE POSITIONS OF THE BEADS.
- MARK THE JOINTS.

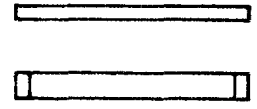

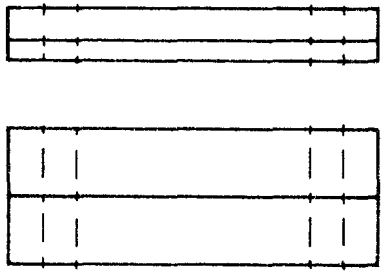

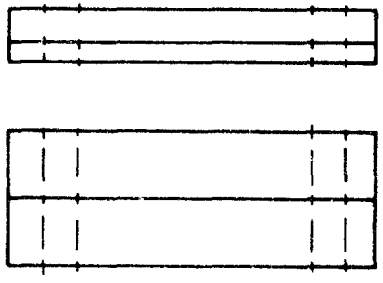

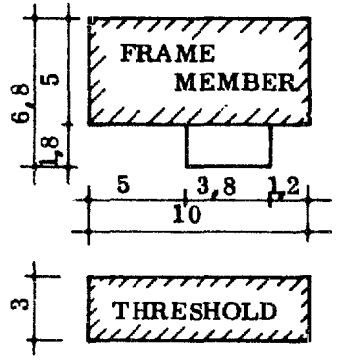

MAKE A DRAWING OF A DOOR FRAME WITH DIFFERENT DIMENSIONS.

N . P . V . C.	
2½ HOURS	43.

WOODEN FRAME SCALE 1 : 10 (cm)

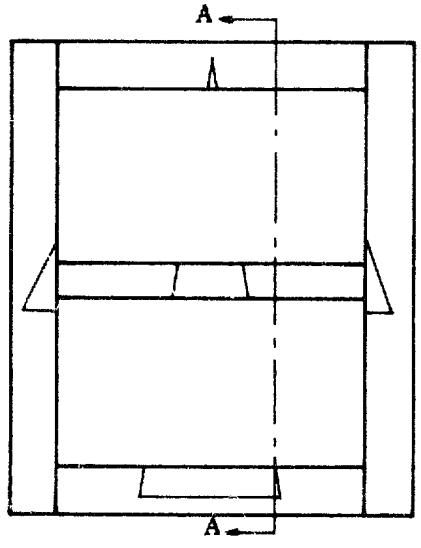

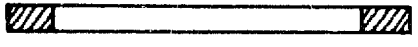

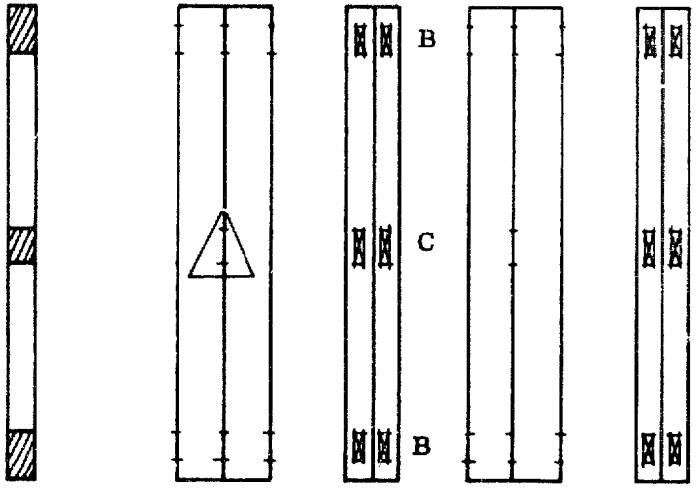

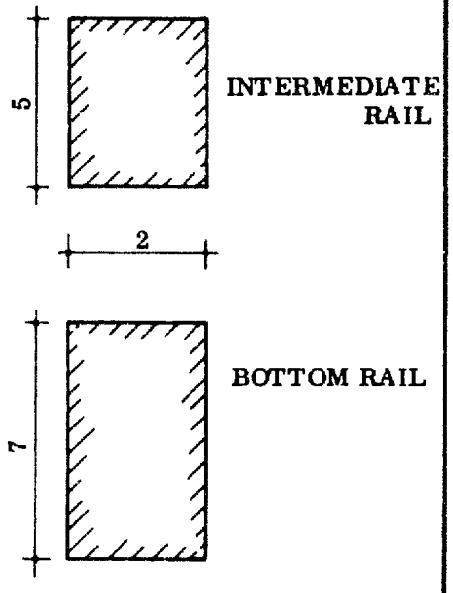

DETAILS

COMPLETE THIS DRAWING

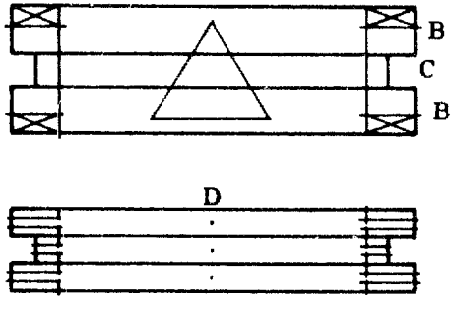

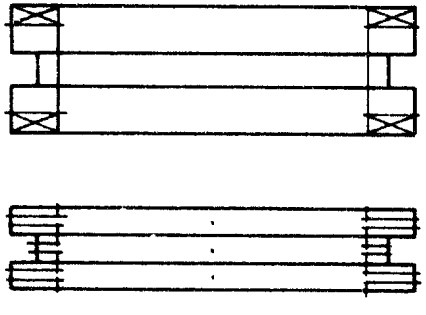

NOTICE:

- THE FACE MARK OVER THREE MEMBERS
- THE INTERMEDIATE RAIL
- WIDTH OF THE MORTICE AND TENON
- THROUGH MORTICE AND TENON
- STOPPED MORTICE AND TENON
- VENTILATION HOLES AT D

MAKE A DRAWING OF A FRAME

- SCALE 1 : 10 (cm)
- USE DIFFERENT DIMENSIONS
- CORNER JOINTS: HAUNCHED MORTICE AND TENON
- OTHER JOINTS: STOPPED MORTICE AND TENON

N . P . V . C .	
44.	2½ HOURS

MORTICE AND TENON JOINT

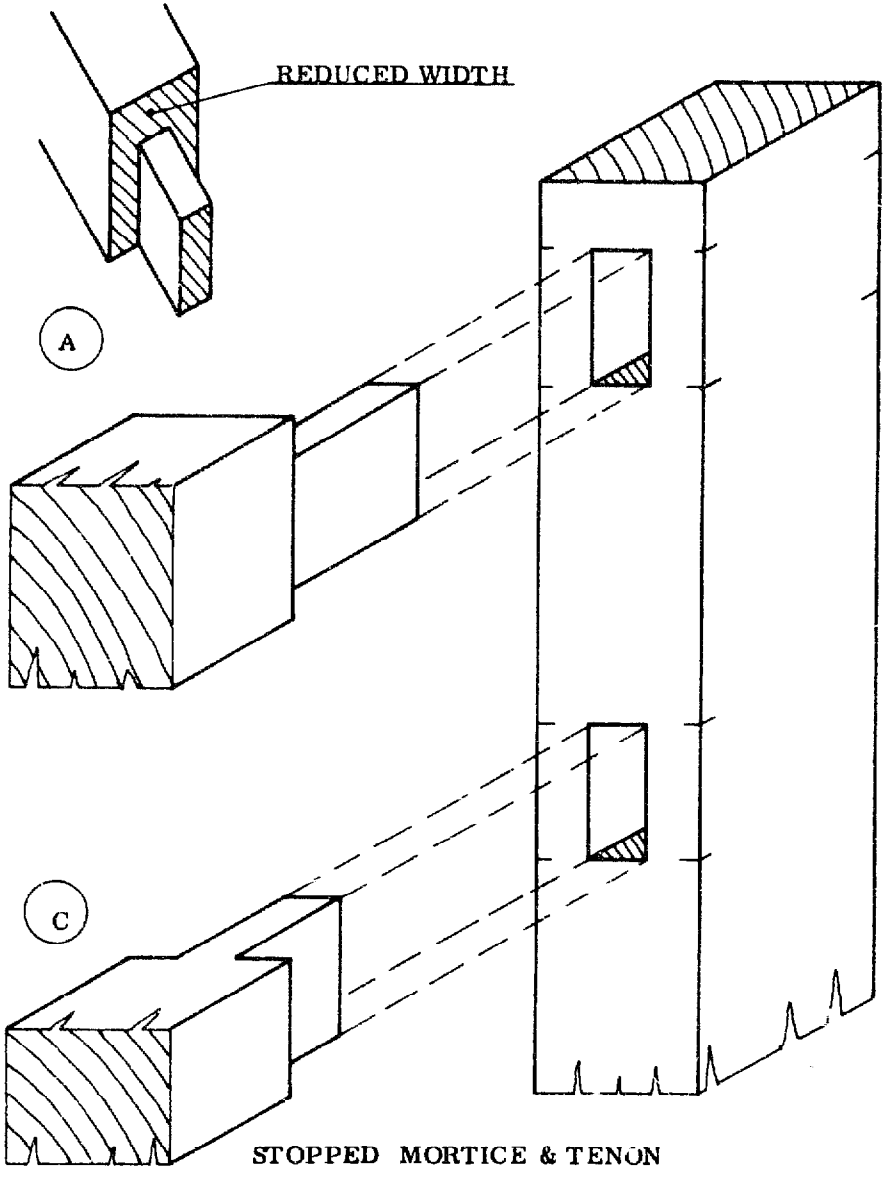

STOPPED MORTICE & TENON

HAUNCHED MORTICE AND TENON JOINT

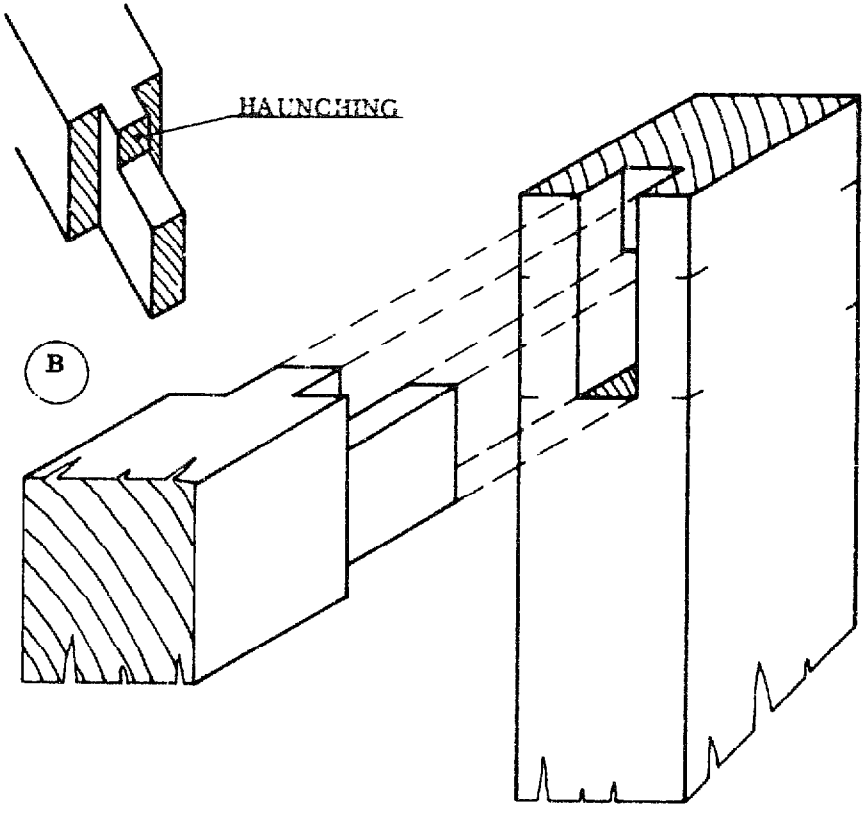

- MAKE AN OBLIQUE DRAWING OF:

A STOPPED HAUNCHED MORTICE AND TENON JOINT.
USE DIFFERENT POSITIONS.

N . P . V . C .	
	45.

WOODEN FRAME WITH SLANTING CILL

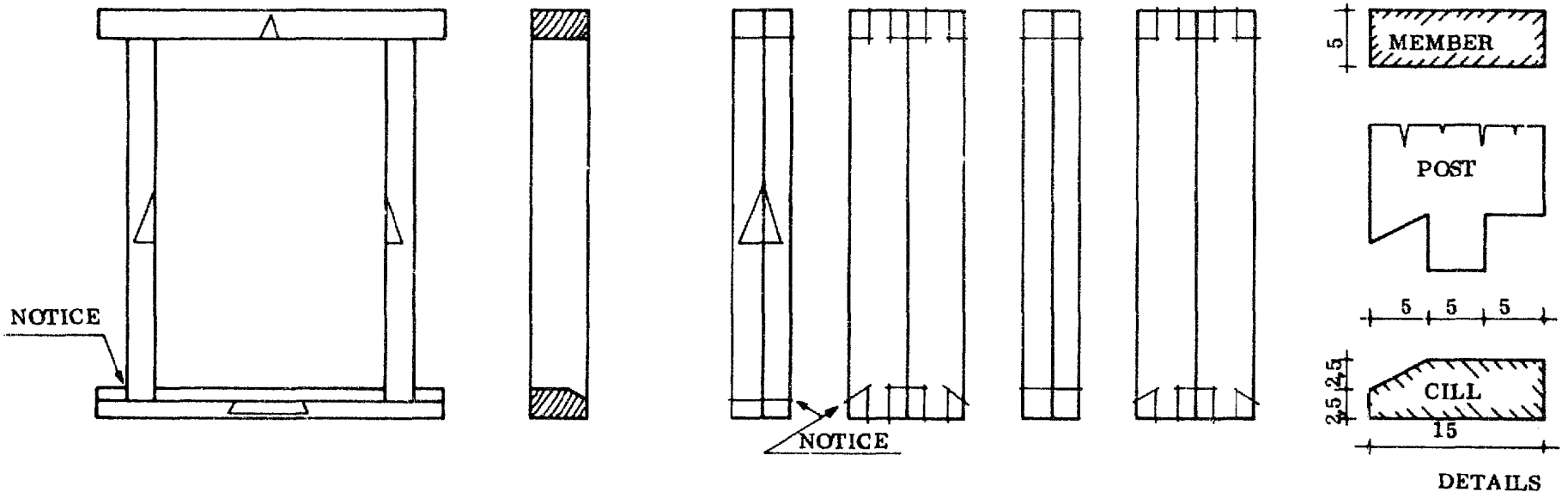

COMPLETE THIS DRAWING

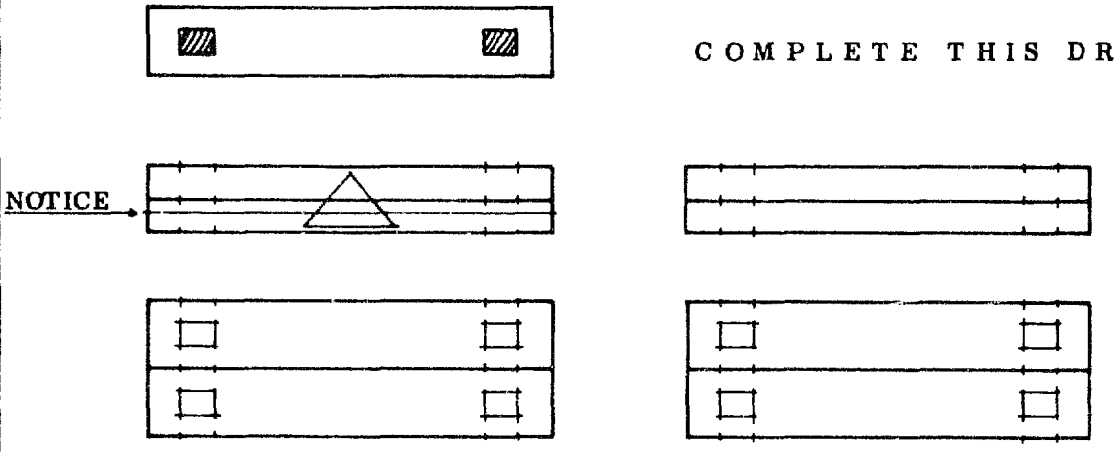

NOTICE

CILL & POST CONSTRUCTION
MARKING OUT OF JOINTS
MARKING OF CILL

MAKE A NEW DRAWING WITH DIFFERENT DIMENSIONS AND CILL SHAPE.

N . P . V . C .	
46.	2½ HOURS

OBLIQUE DRAWING OF "CILL-POST" CONSTRUCTION

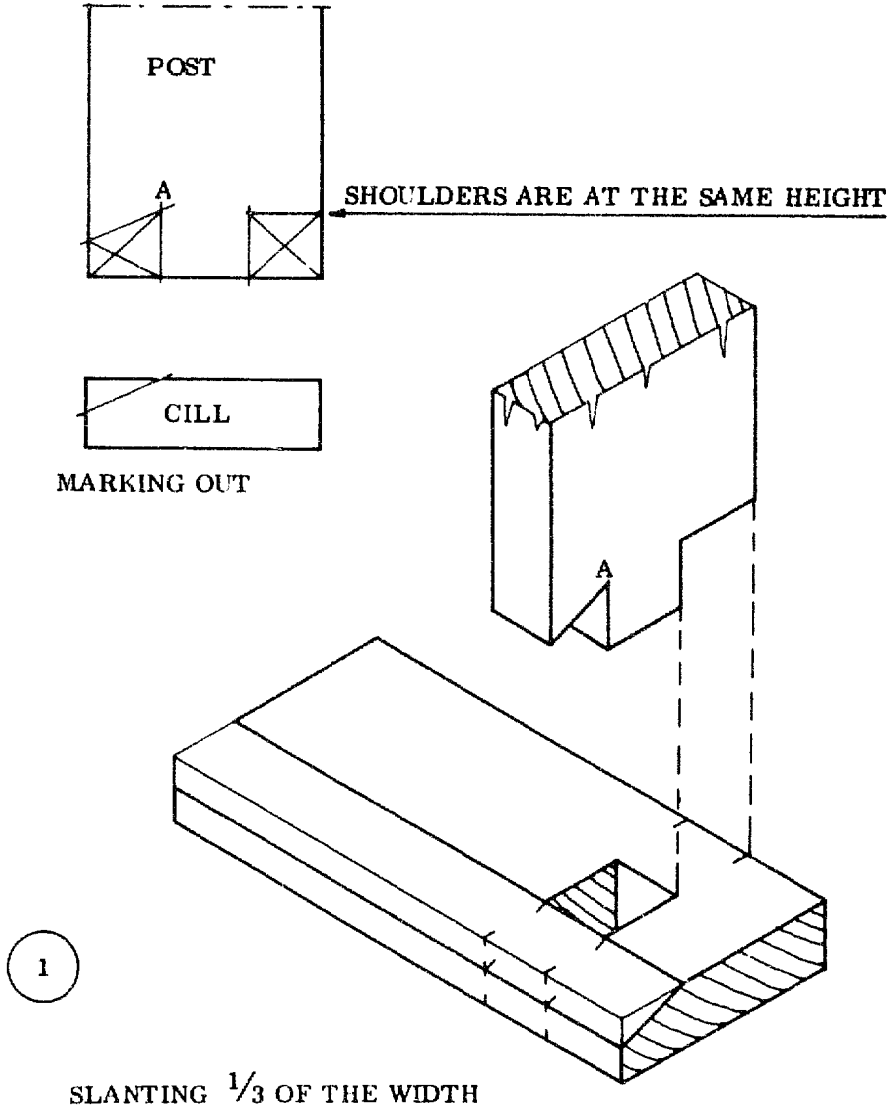

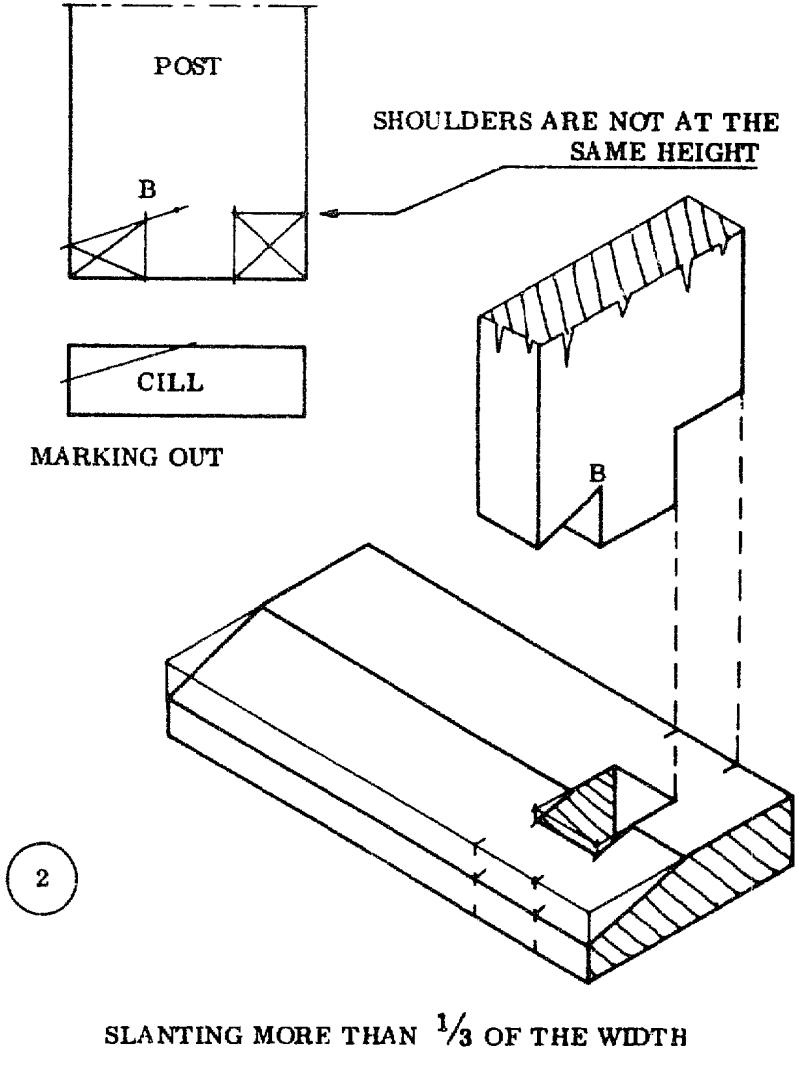

N. P. V. C.

47.

REMEMBER

NOW THIS BOOK IS REALLY YOURS!
FOR YOU IT OPENS MANY DOORS
TO KNOWLEDGE. ON ITS PAGES WRITE
NOTES TO HELP YOU UNDERSTAND, MAKE LIGHT
SKETCHES AND DRAWINGS ALL YOUR OWN.

THOUGHTS OF YOURS, LIKE SEED ARE SOWN
FRUITS COME LATER UNDER SUN AND RAIN
IN THE FORM OF BUILDINGS WITH DOORS, ROOF AND WINDOW-PANE.

KEEP YOUR WORK BOLD, CLEAR AND CLEAN
THIS BOOK WILL BE YOUR PRIDE, AND GUIDE TO ALL
YOU'VE LEARNT AND SEEN.

FORM 2: GENERAL BUILDING INFORMATION

The important rules for a Rural Builder to remember in general are:

- PLAN CAREFULLY EVERYTHING THAT YOU MAKE OR BUILD.
- DRAW ALL IDEAS OUT ON PAPER FOR THE BENEFIT OF THOSE WHO WILL HAVE A PART IN THE PROJECT BEFORE, DURING AND AFTER CONSTRUCTION.
- ALWAYS TAKE INTO ACCOUNT MATERIALS WHICH ARE LOCALLY AVAILABLE, AND WHEN POSSIBLE USE THESE RATHER THAN EXPENSIVE IMPORTED MATERIALS.
- TAKE INTO ACCOUNT THE SIZES OF READY-MADE MATERIALS WHEN YOU ARE PLANNING THE BUILDING.
- BE AWARE OF THE REQUIREMENTS OF THE ENVIRONMENT AND THE LOCAL CUSTOMS.

Drawings should be precise and clear and should take account of the sizes of all the ready-made materials, so as to avoid unnecessary waste. It is therefore important to be informed about all the materials which are available for Rural Building, and their sizes. These can be found in the Reference Book, Materials and Products sections.

Remember that a building is an investment and the construction should be long-lasting. Proper construction, using good materials, will avoid unnecessary expense, inefficiency, and dissatisfaction.

As a rule, mistakes in design or construction are costly, obvious, and permanent.

BUILDING KEY

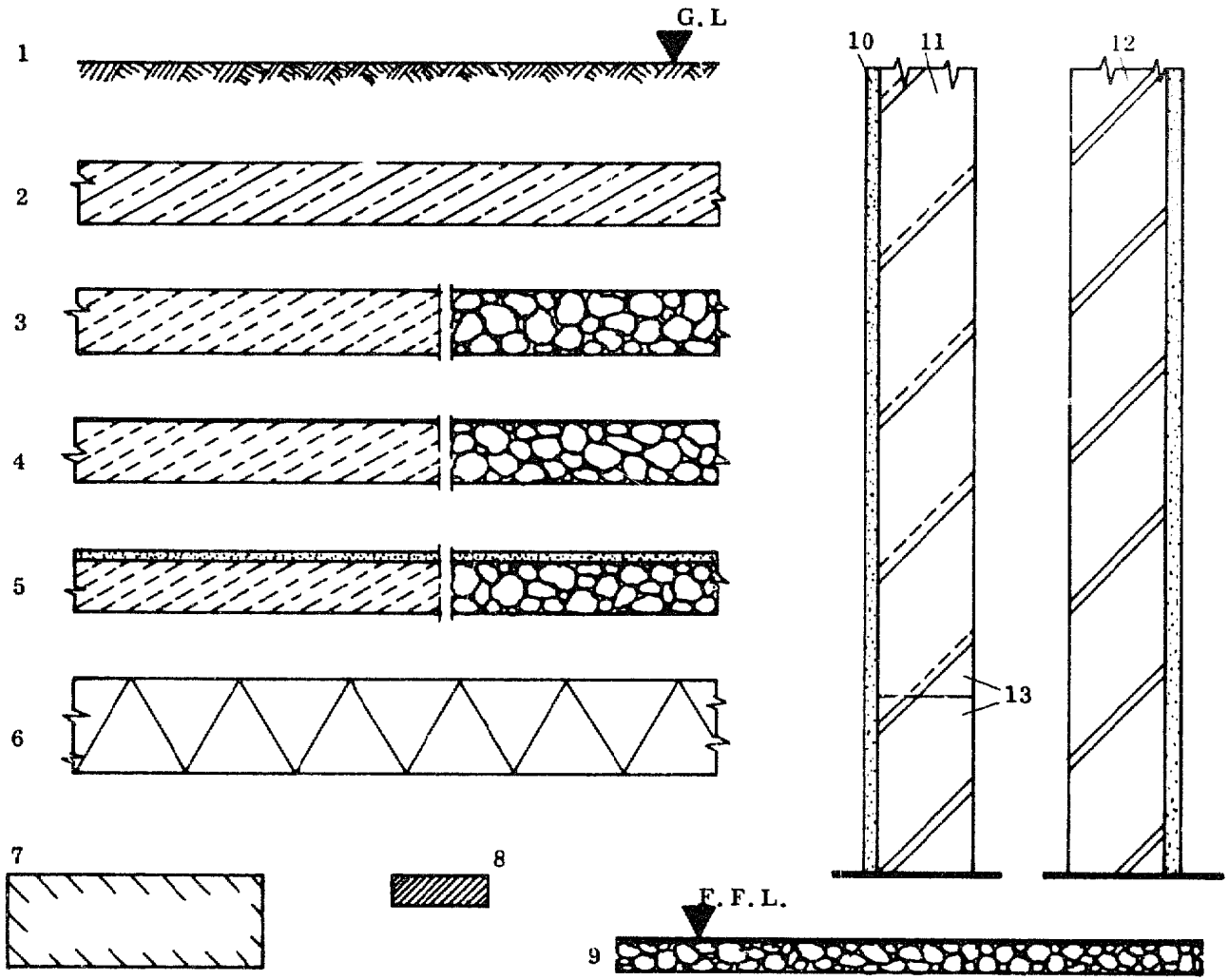

BUILDING KEY

1 = GROUND LEVEL

2 = REINFORCED CONCRETE

3 = CONCRETE

4 = ONE COURSE WORK

5 = TWO COURSE WORK

6 = HARD CORE FILLING

7 = WOOD (large)

8 = WOOD (small)

9 = FINISHED FLOOR LEVEL

10 = PLASTER

11 = LANDCRETE WALL

12 = SANDCRETE WALL

13 = SANDCRETE TO LAND-CRETE

N. P. V. C.

49.

BUILDING KEY

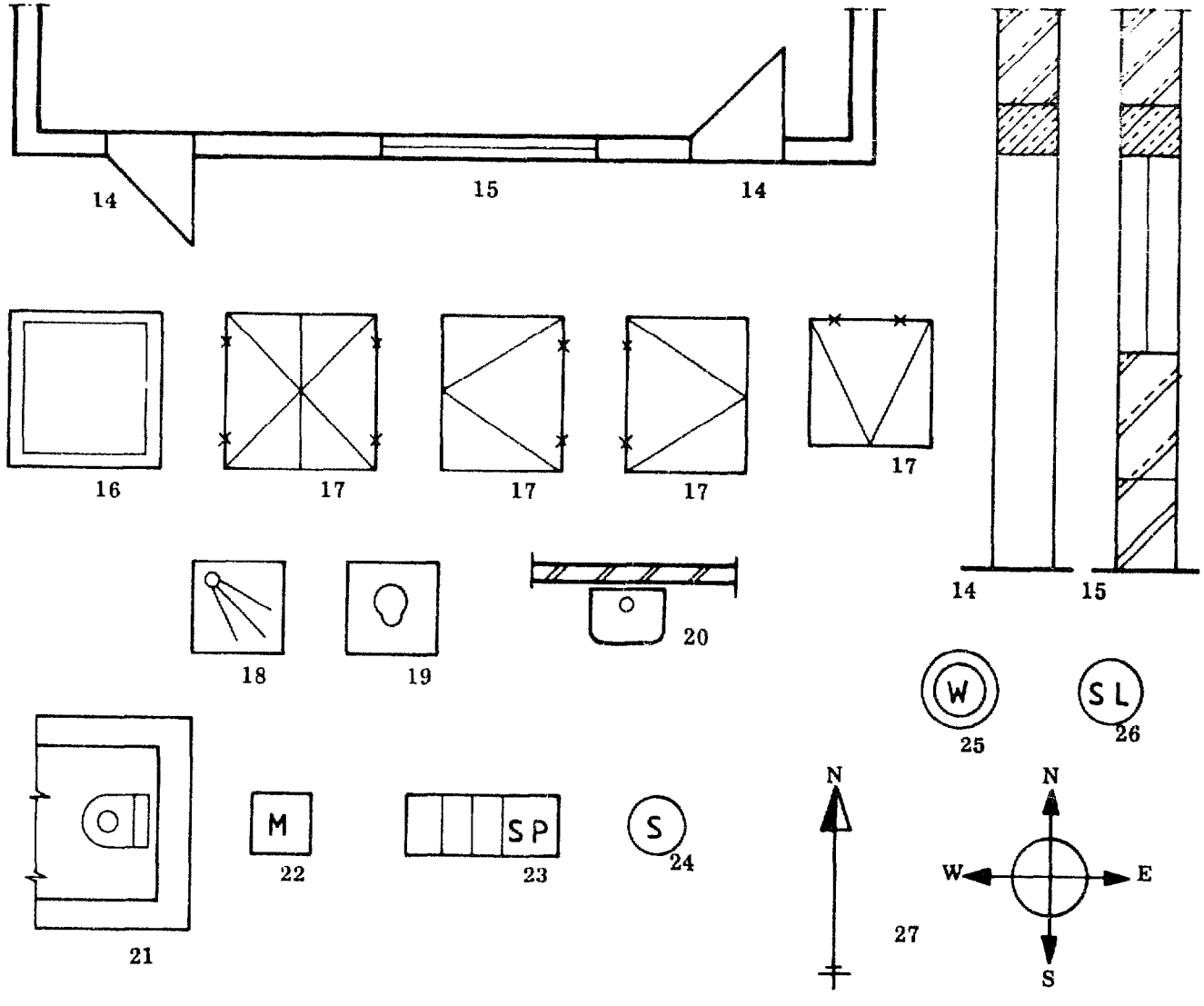

14 - DOORS(without threshold)

15 - WINDOW (plan)

16 - WINDOW (front view)

17 - HINGE POSITIONS

18 - SHOWER

19 - PIT LATRINE

20 - SINK

21 - FLUSH TOILET

22 - MANHOLE (sewage)

23 - SEPTIC TANK

24 - SOAKAWAY (waste water)

25 - WELL

26 - SILO

27 - DIRECTIONS

N. P. V. C.

50.

HOW BUILDINGS ARE DRAWN

SCALE

When you draw a plan of a building on paper you will find that you have to use a scale, to make the plan small enough to fit on the paper. Scales were explained earlier, but here are some examples to help you remember how to use them.

- EXAMPLES: A scale of 1:50 (cm) tells you that 1 cm on the drawing represents 50 cm in real life. In other words all the dimensions on the drawing are 1/50th of their real size and all the dimensions are in centimetres.

  A scale of 1: 500 (cm) tells you that all the dimensions on the drawing are 1/500th of their real size and that all the dimensions are in centimetres.

  Both of these scales make the drawing smaller than the actual building size. These types of scales are called "reduced scales".

  The man you see on the next page is making a scale drawing of an electricity pole. The pole is 800 cm high and the man is using a scale of 1 : 100 (cm) which means that his drawing will be 8 cm high. The 8 cm on the drawing represents 800 cm in real life.

  If the crossbar on the pole is 150 cm long, how long will the man draw it on his paper?

All building drawings are made in reduced scale. Here are some examples of drawings used in building, and the scales commonly used with them:

- LOCATION PLAN 1 : 500
- DESIGN DRAWING 1 : 100
- FINAL DRAWING 1 : 50
- DETAIL DRAWING 1 : 20; 1 : 10, or 1 : 5

Always remember to include the UNITS of the scale you have used; these are usually "cm" or "mm".

IF THIS POLE IS 8 METER HIGH

AND

IS DRAWN

8 CENTIMETER HIGH

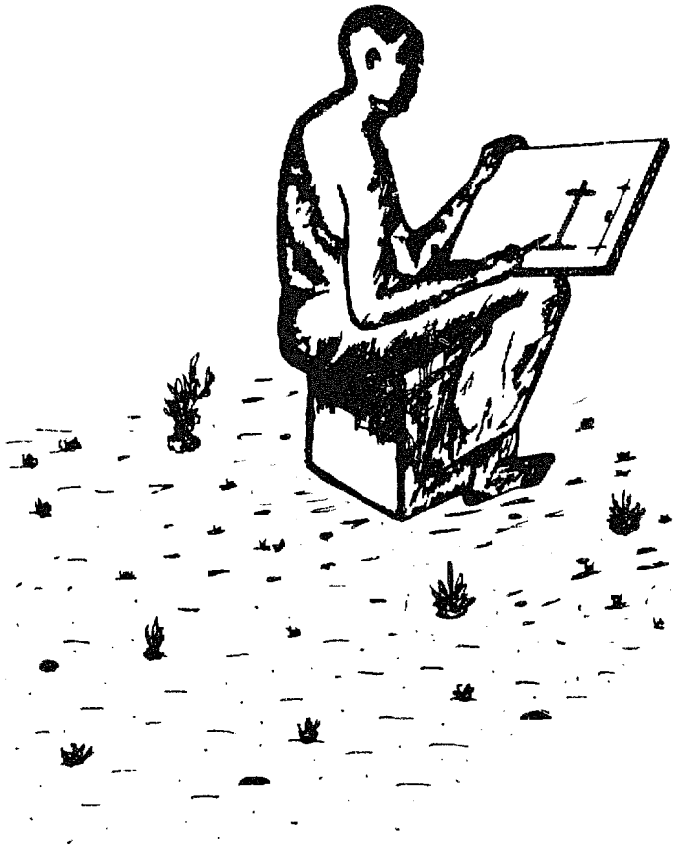

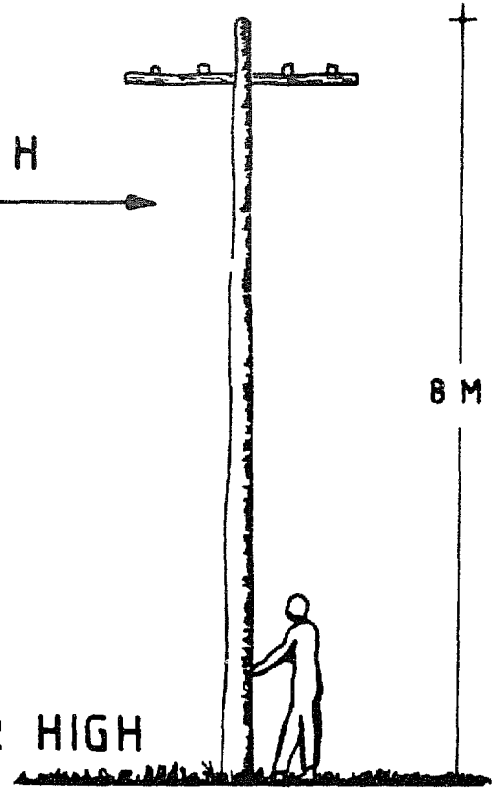

THEN THE POLE IS DRAWN

SCALE 1:100 [cm]

N. P. V. C.	
	52.

WORKING DRAWINGS

Three different types of drawings are needed to show the builder exactly how the building should look, on the inside and the outside. These include the elevations and sections, as well as the plans. Here we describe the different types of plans which have to be made: the foundation plan, floor plan, and roof plan.

- FOUNDATION PLAN: A foundation plan, along with its sections, shows the builder how deep the foundations should be laid and gives all the dimensions for the foundation and the footings. Sometimes the corners of the rising walls are indicated on the footings.
- FLOOR PLAN: This plan should show the builder the size of the building and the verandahs, the thickness of the walls, and where to place the doors and windows. It also shows which way the doors are meant to open.
- ROOF PLAN: Roof plans are made to show the builder what shape the roof should be and how it is to be built. The roof plan should contain such information as the angle of the roof, the shape, and the materials to be used.

The drawing here illustrates the types of plans and what it is they show to the builder.

Elevations and cross sections are of course essential parts of the working drawings. These are examined in detail after some further examples of plans in the next pages.

PLANS

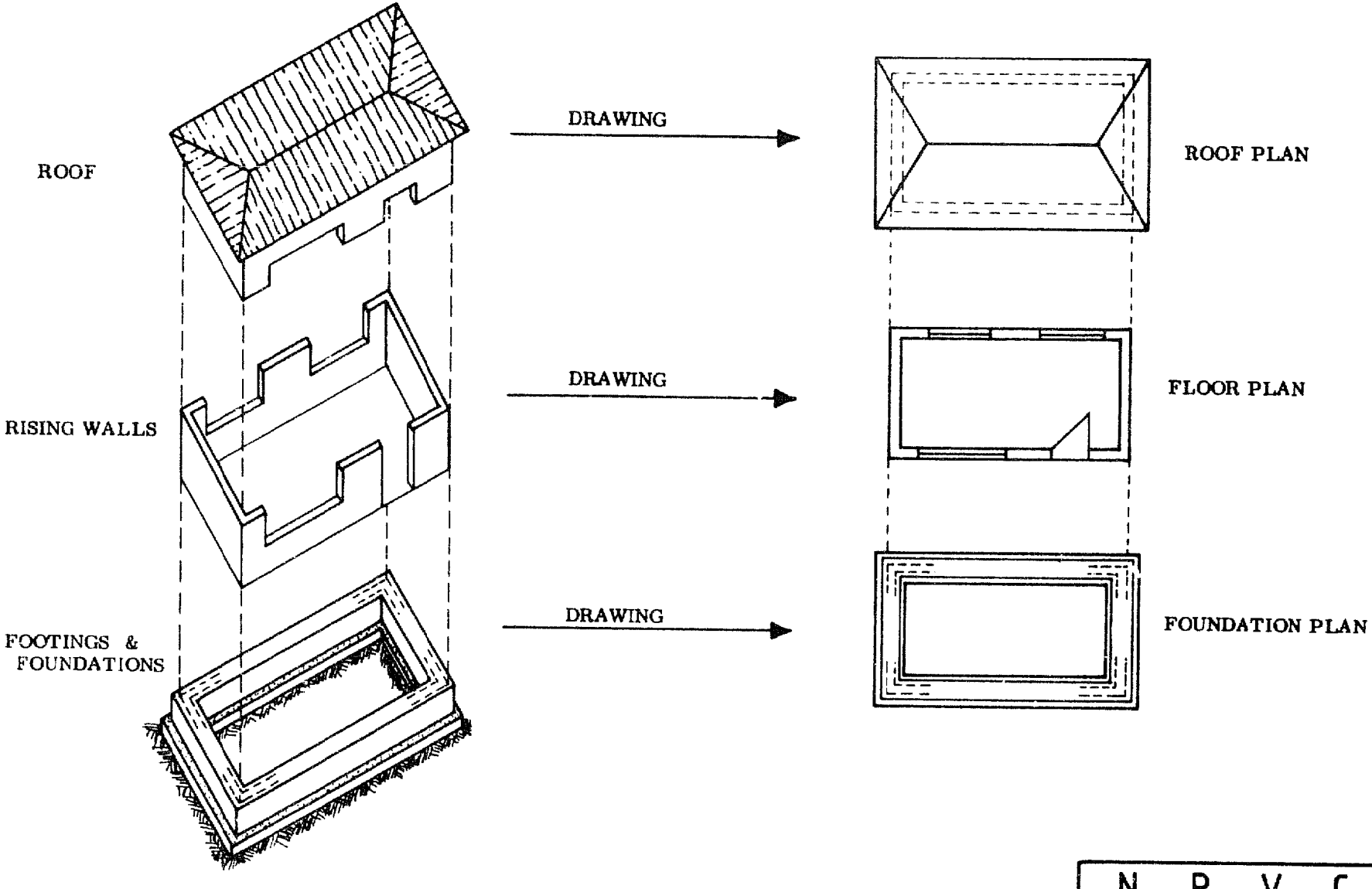
ROOF
RISING WALLS
FOOTINGS & FOUNDATIONS
DRAWING
DRAWING
DRAWING
ROOF PLAN
FLOOR PLAN
FOUNDATION PLAN

FLOOR PLANS

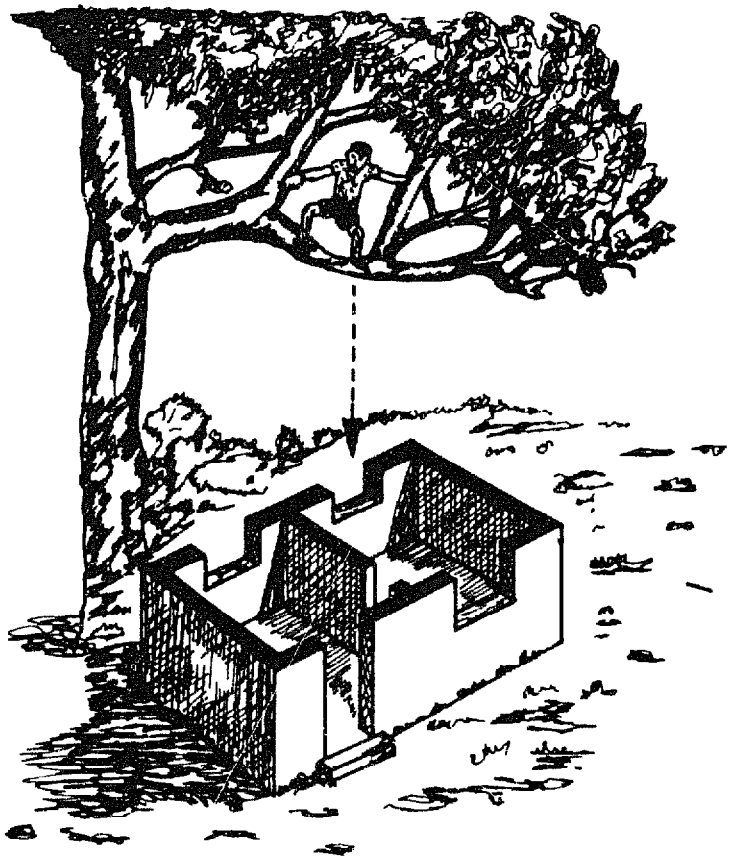

B

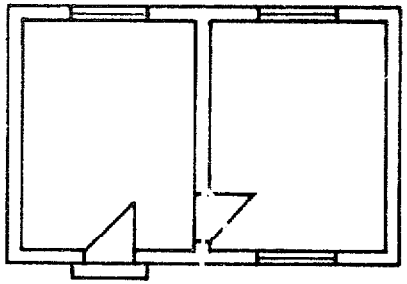

FLOOR PLAN

A

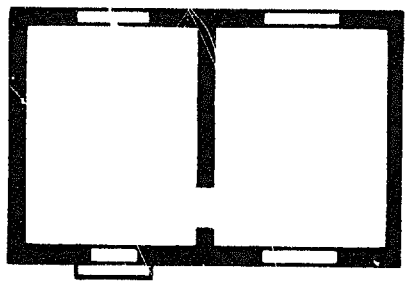

SKETCH PLAN

IF YOU WERE UP IN A TREE AND LOOKED STRAIGHT DOWN
AT THIS HALF-BUILT HOUSE IT WOULD LOOK LIKE "A".
YOU SHOULD DRAW IT LIKE "B".

FLOOR PLAN

DIMENSION LINE A = OPENINGS
,, ,, B = WALLS
,, ,, C = TOTAL LENGTH

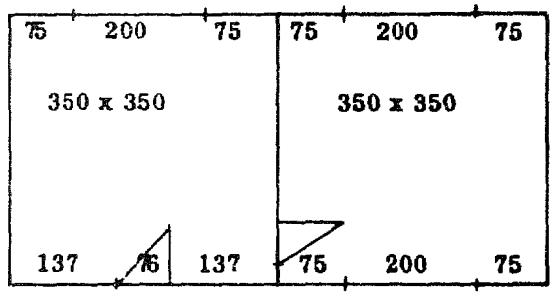

DIMENSIONS IN CM

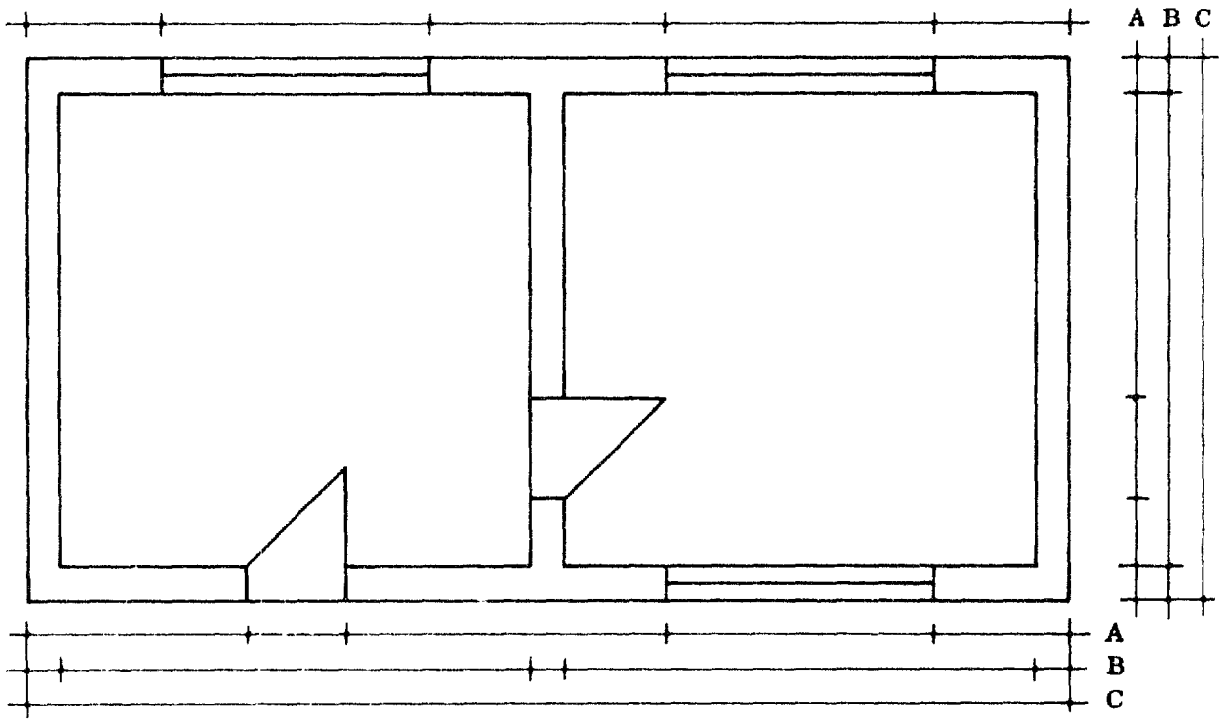

TECHNICAL DATA
WALL THICKNESS = 15cm
WIDTH OF FOOTINGS = 30cm
WIDTH OF FOUNDATION = 45cm

EXERCISE

MARK IN ALL DIMENSIONS.

N . P . V . C .

56.

FLOOR PLAN

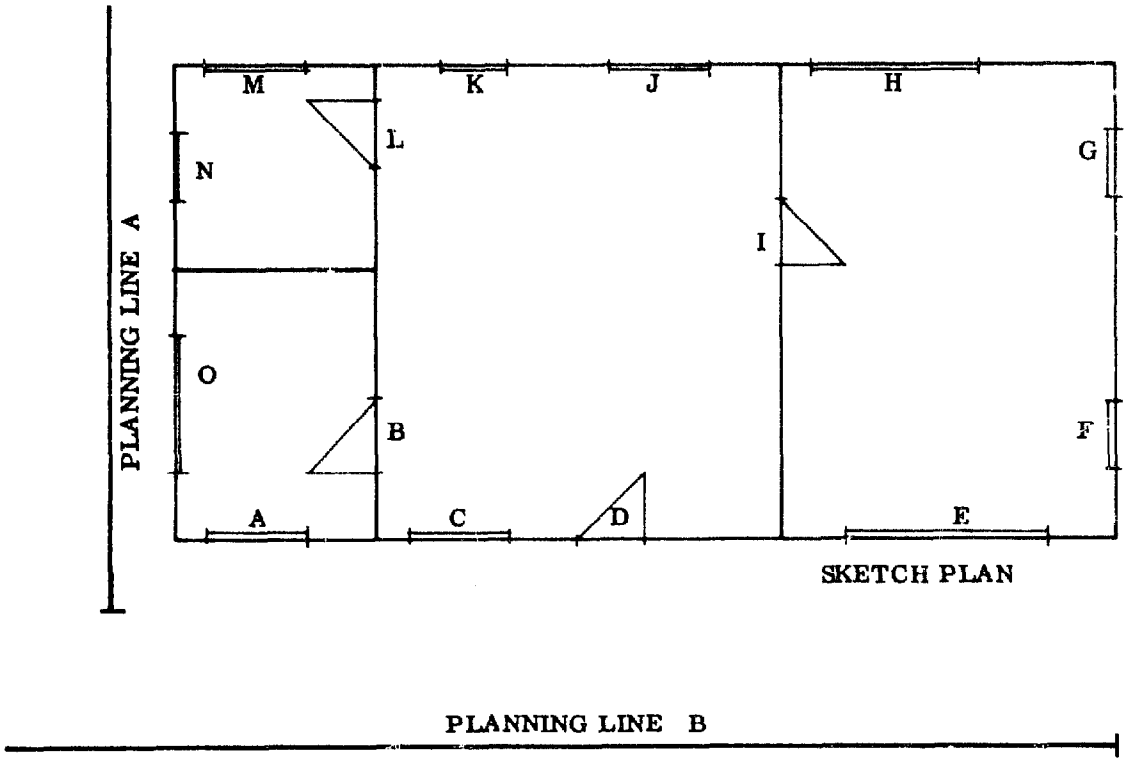

SKETCH PLAN

WINDOW AND DOOR HEIGHTS

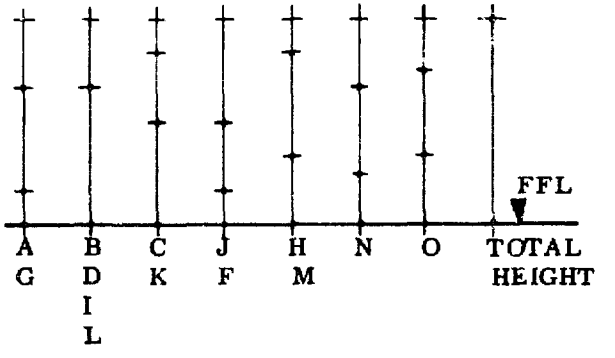

EXERCISE
- MARK IN ALL DIMENSIONS ON PLAN.
- MARK IN ALL DIMENSIONS FOR DOOR AND WINDOW HEIGHTS.
- MARK IN PLANNING LINES A & B.
- FIND THE TOTAL LENGTH AND WIDTH (SCALE = 1 : 100 cm).

MEASUREMENTS OF AREAS ARE ALWAYS INSIDE MEASUREMENTS!

SKETCHES FOR FLOOR PLANS

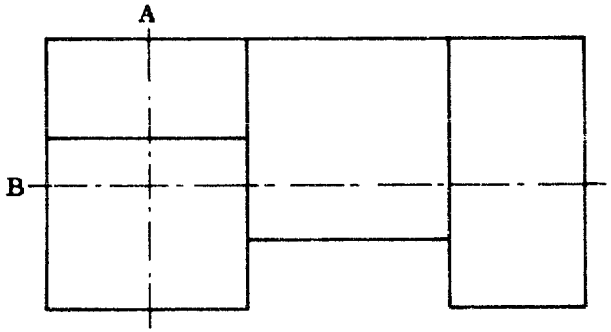

SKETCH 1

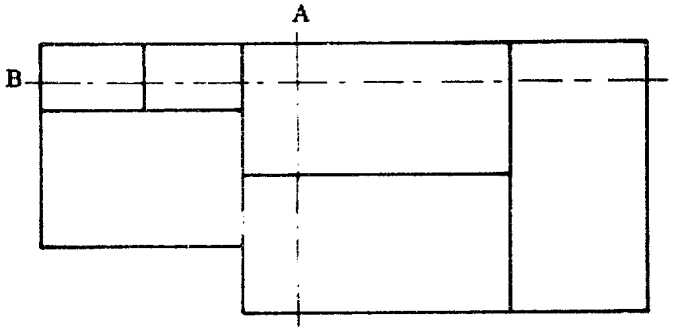

SKETCH 2

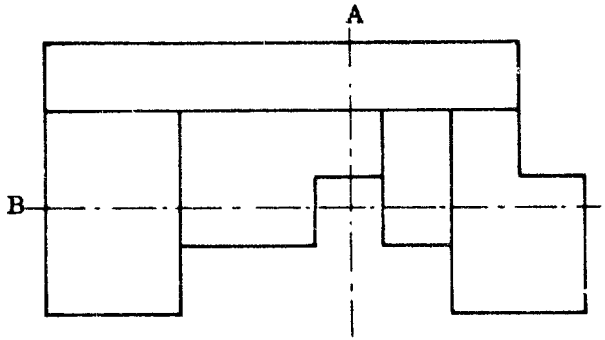

SKETCH 3

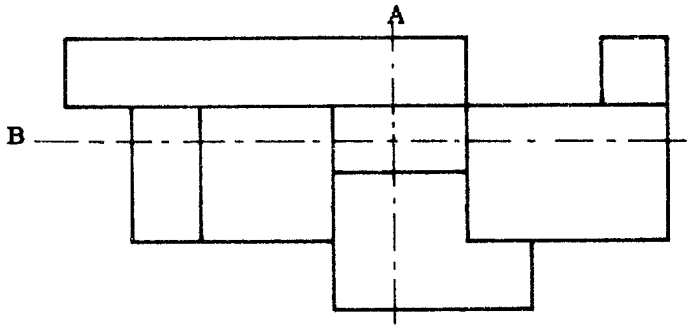

SKETCH 4

EXERCISE

- DRAW THESE FOUR BUILDING PLANS: SCALE 1 : 50 (cm) INCLUDE DOORS AND WINDOWS IN THE POSITIONS OF YOUR OWN CHOICE.

TECHNICAL DATA

THE RISING WALLS ARE 15 CM THICK AND 200 CM HIGH.

NOTE: PLANNING LINES (LINES A & B) ARE POSITIONED WHERE THEY WILL SHOW THE MOST DETAIL.

N . P . V . C .	
1 ½ HOURS	58.

ELEVATIONS

A special type of drawing is used to show what a building will look like from the outside. These drawings are called "elevations" and they show what you would see if you looked straight on at the side of the house. Of course a house has more than one side, and so there are always a number of elevations. There are as many elevations as there are sides of the house. Houses usually have four sides and so there are usually four elevations.

It is not always necessary to draw all the possible elevations of a building, especially if some of the sides look very similar to each other.

The drawing here shows the front elevation of a small house. You should notice that the sides of the house are not drawn. This is because if you stand directly in front of the house you cannot see the sides. The front elevation shows the sizes and positions of the doors and windows as well as the height and length of the house itself.

The building shown on the next page faces south. The front elevation is therefore called the "south elevation". The other three elevations are the east elevation, the north elevation, and the west elevation.

In general only main features are shown on the elevations. Small details of the doors, windows, etc. are given in the detail drawings.

ELEVATIONS

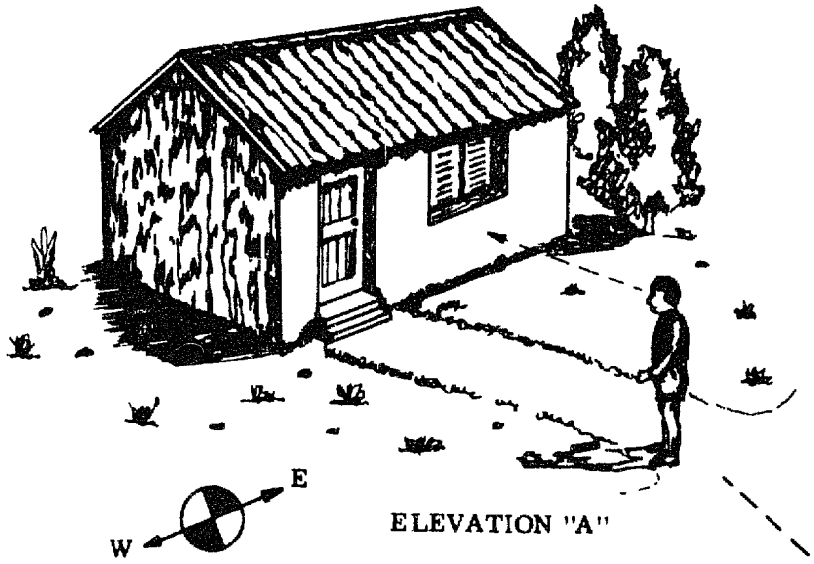

ELEVATION "A"

IF YOU LOOKED STRAIGHT AT ONE SIDE OF A BUILDING IT WOULD LOOK LIKE "A".

<u>YOU SHOULD DRAW IT LIKE "B".</u>

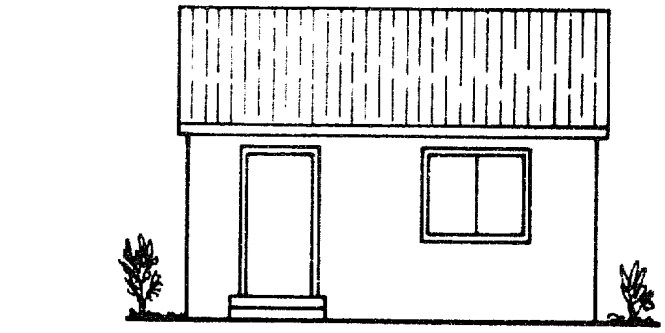

FRONT ELEVATION "B"

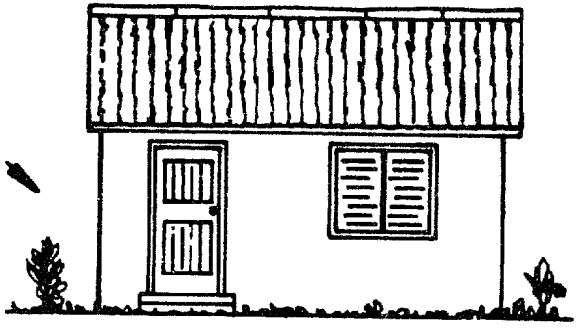

FRONT ELEVATION "A"

SECTIONS

Suppose you were able to cut right through a building and then take away one part. What you would see would look something like the diagram on the next page (1). If you now look at the building straight on, you will see a "cross section" of the building (2). The cross section shows the insides of the roof and the room as well as the footings and foundations.

Sections are useful because they give a lot of information about the building which is not found in the elevations and the plans. For example, on a section you can see the height of a room inside the building, the thickness of the ceiling, and the floor and roof construction. You can also see the thickness and width of the foundation, which is not given in the plans and elevations.

- CHOOSING SECTIONS: You will usually find it necessary to take at least two sections through the building. You can take any section through any part of the building, but of course the best sections are the ones which are the hardest to draw! When you take a section through a building, you have to mark on the plan exactly where you have "cut" and the direction from which you look at the section.

  On the right page you can see the conventional way of doing this. The place where the building is cut is marked by a broken line which has arrows at its ends to show which way the section faces. All sections should be marked on the plan, and you should label each end of the line with a letter. On the plan here, the section has the letter "A" at each end. When this cross section is drawn, it is labelled as "cross section A-A". The next section would be "cross section B-B" etc.

CROSS SECTIONS

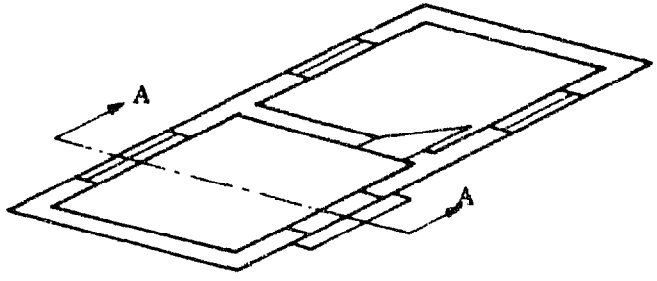

3

SKETCH PLAN

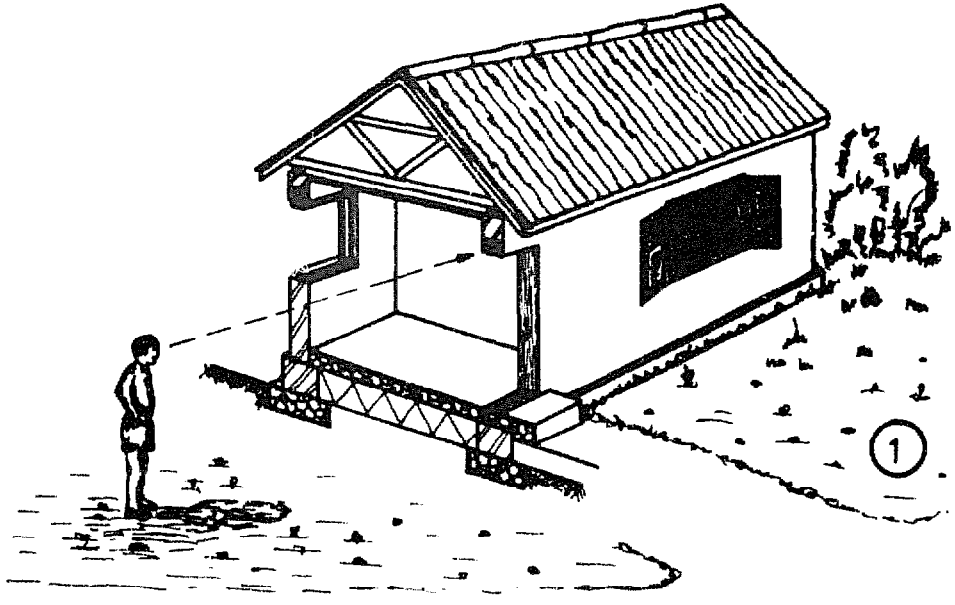

1

SECTION THROUGH BUILDING

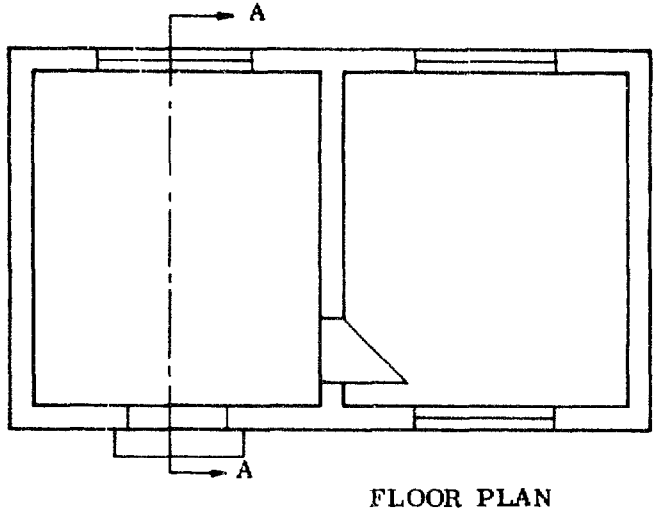

3

FLOOR PLAN

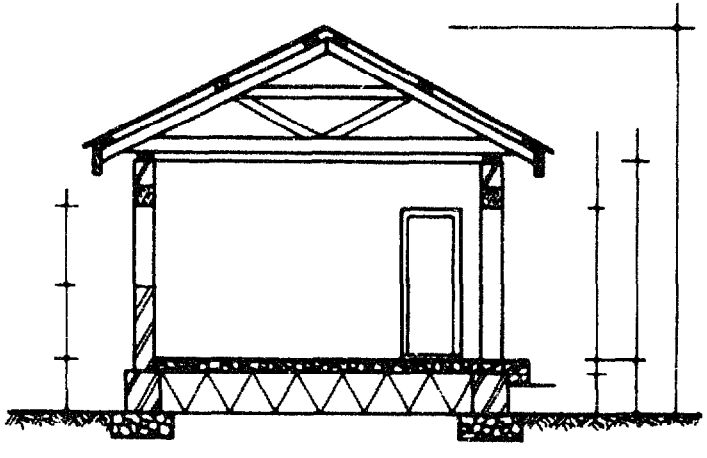

2

CROSS SECTION A-A

N . P . V . C .	
	62.

PLANS - ELEVATIONS - CROSS SECTIONS

IMPORTANT

- INDICATE ALL DIMENSIONS AT LEAST ONCE.
- MAKE CROSS SECTIONS OF THE MOST DIFFICULT PARTS OF THE BUILDING.
- ALL ELEVATIONS SHOULD BE IN LINE WITH EACH OTHER.
- IF THERE IS NOT ENOUGH SPACE MARK DIMENSIONS LIKE AT "D"

NOTICE

- THE FLOOR GOES THROUGH AT "A".
- THE FLOOR IS STOPPED AT "B".
- FLOOR THICKNESS AT "C"

EXERCISE

MAKE A SIMILIAR DRAWING WITH DIFFERENT DIMENSIONS AND DIFFERENT DESIGN.

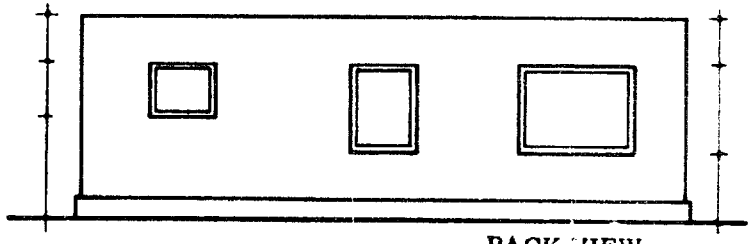

BACK VIEW

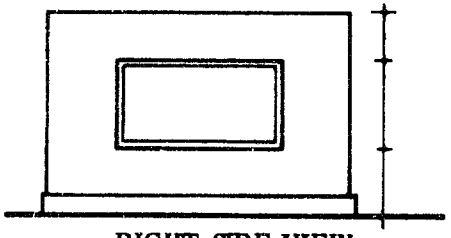

RIGHT SIDE VIEW

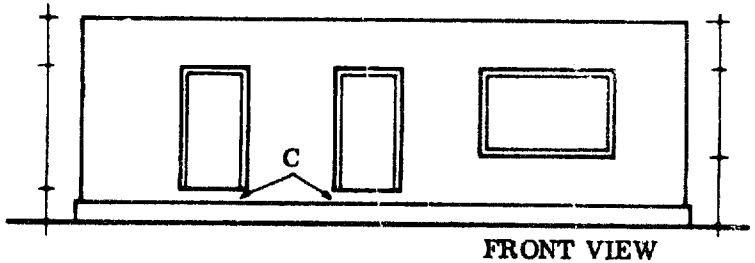

FRONT VIEW

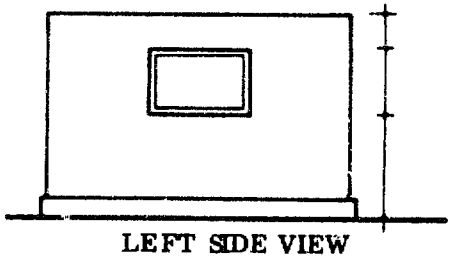

LEFT SIDE VIEW

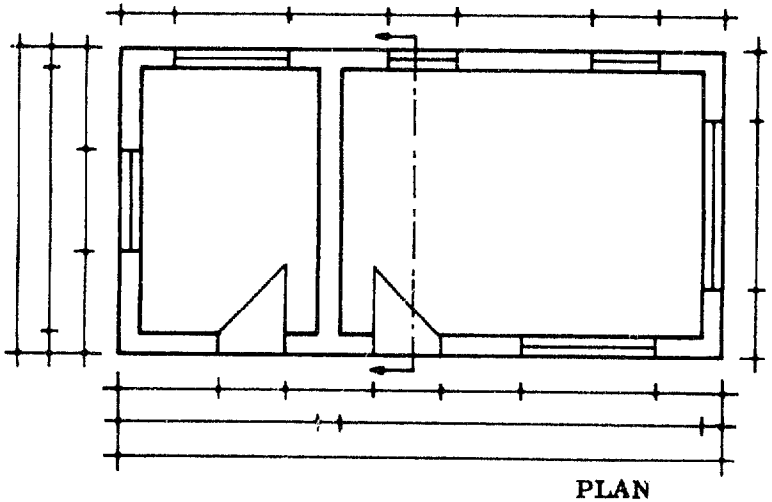

PLAN

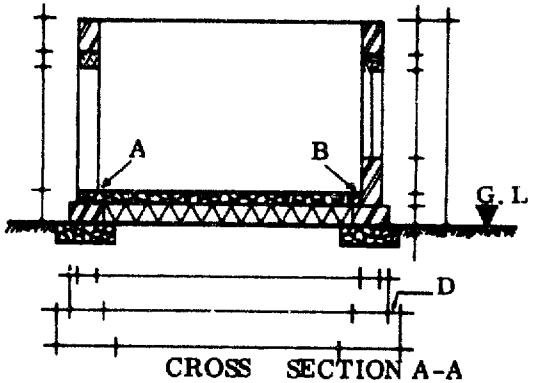

CROSS SECTION A-A

N . P . V . C .	
63.	4 HOURS

FOUNDATION PLAN

MAKE THE PLANNING LINES FIRST!

A = TOTAL WIDTH
B = FOUNDATION WIDTH
C = FOOTING WIDTH
D = RISING WALLS

E = FOUNDATION THICKNESS
F = FOOTING HEIGHT
G = TOTAL HEIGHT

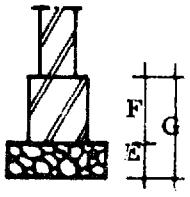

CROSS SECTION K-K

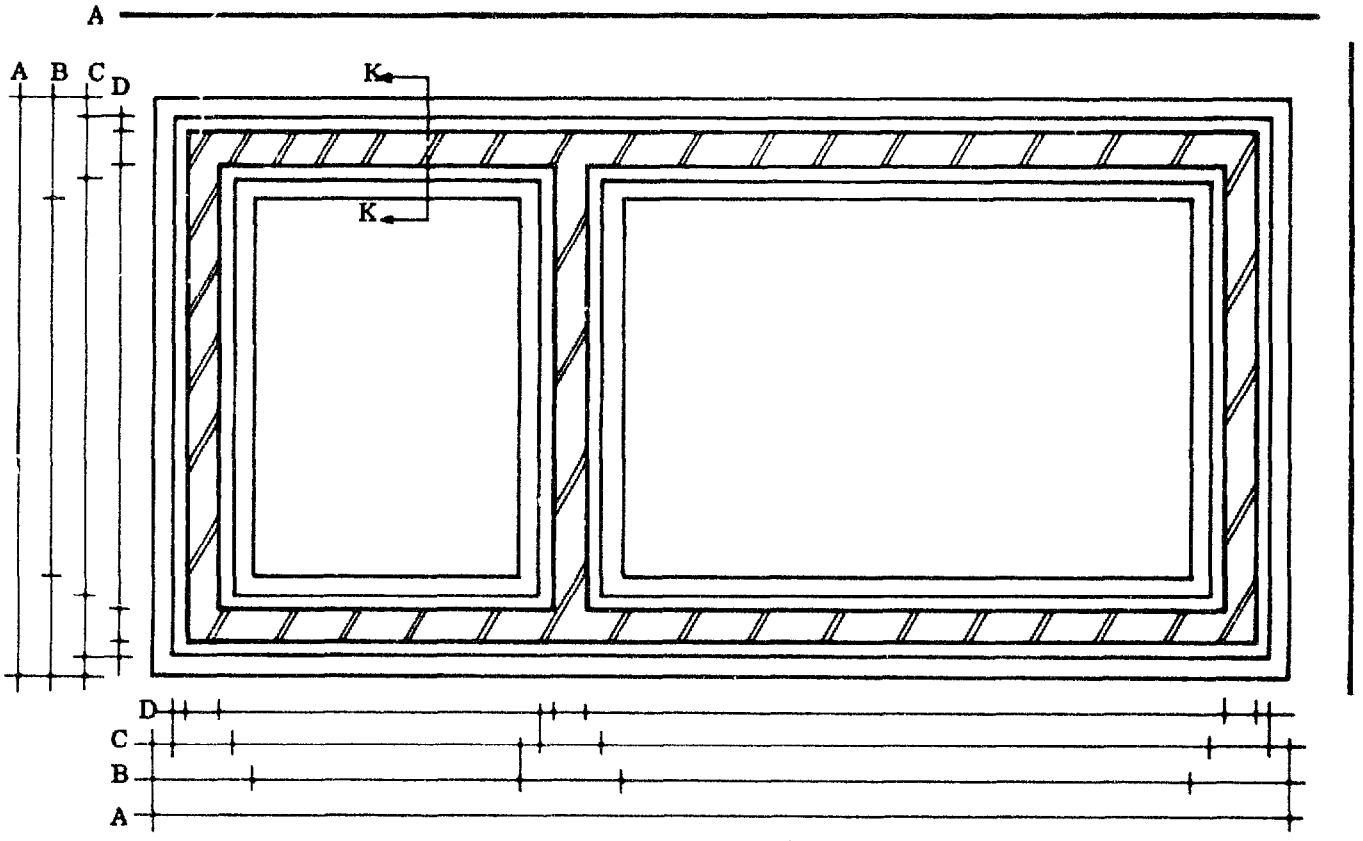

FOUNDATION PLAN

<u>EXERCISE</u> DRAW FOUNDATION PLANS FOR THE FOUR FLOOR PLANS ON PAGE 58.
USE A SCALE OF 1: 20 (cm).

N. P. V. C.	
1 HOUR	64.

BUILDING WITH VERANDAH

PLANS - ELEVATIONS - CROSS SECTION

TECHNICAL DATA

FOOTING FOR THE VERANDAH IS SMALLER.

FOUNDATION FOR THE VERANDAH IS SMALLER.

VERANDAH FLOOR IS AT THE SAME LEVEL AS THE INSIDE FLOOR (X).

VERANDAH FLOOR IS PROJECTING ON THE PLAN (D).

NOTICE THE DIFFERENCE IN THE VERANDAH FLOOR AND THE FOOTINGS HEIGHT (K).

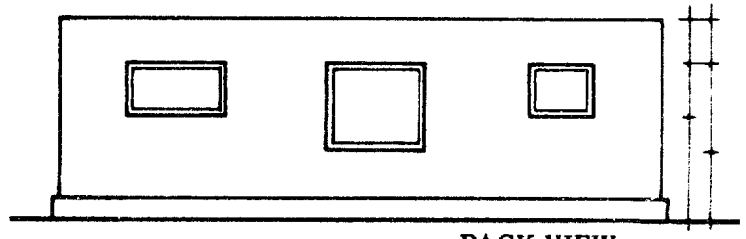

BACK VIEW

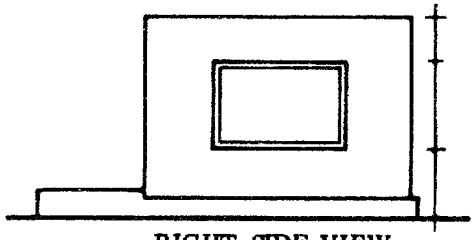

RIGHT SIDE VIEW

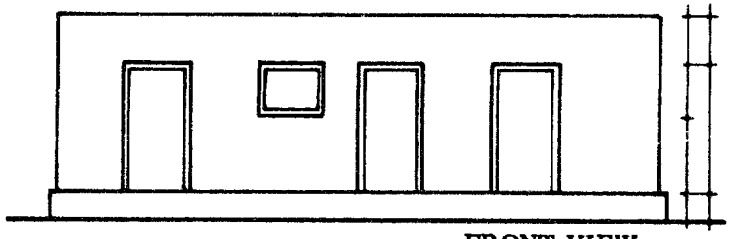

FRONT VIEW

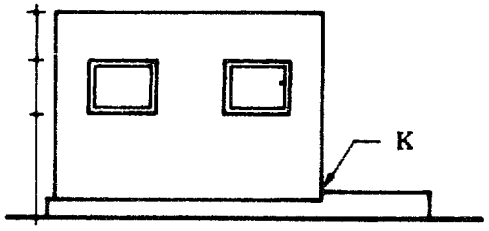

LEFT SIDE VIEW

EXERCISE

MAKE A DRAWING OF A BUILDING WITH VERANDAH.

USE SCALE 1 : 50 (cm)

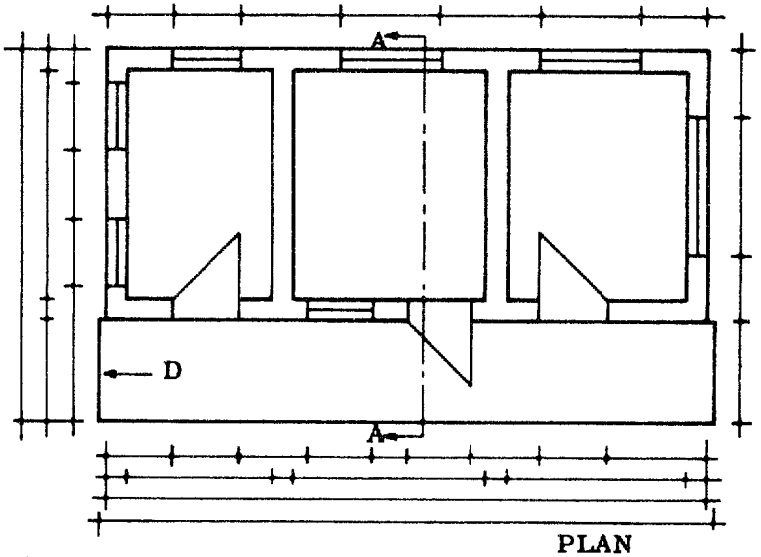

PLAN

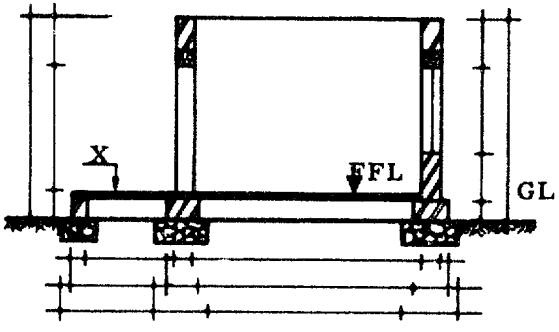

CROSS SECTION A - A

N . P . V . C .	
65.	4 HOURS

FOUNDATION PLAN FOR BUILDING WITH VERANDAH

NOTICE

K - K & N - N ARE CROSS SECTIONS.

DIMENSION LINES:
A = TOTAL LENGTH
B = FOUNDATIONS
C = FOOTINGS
D = WALLS

EXERCISE

MAKE FOUNDATION PLANS FOR THE PLANS ON PAGE 65.

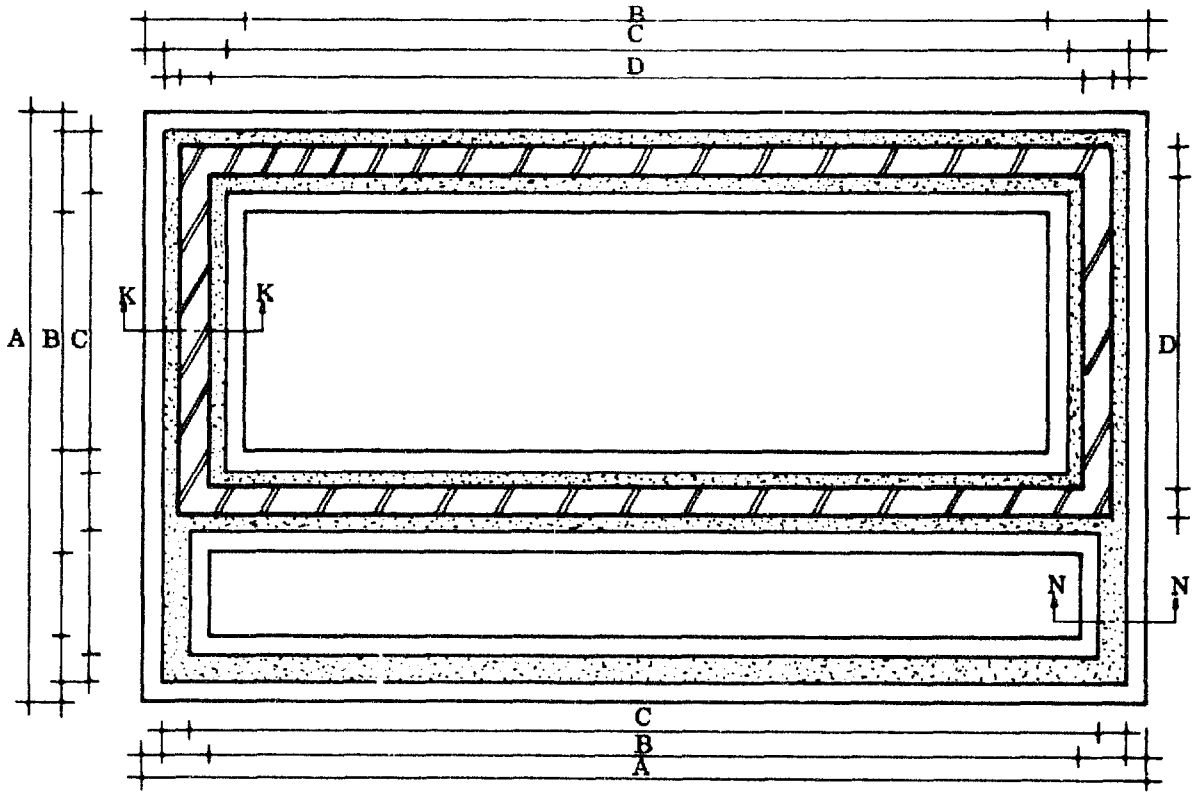

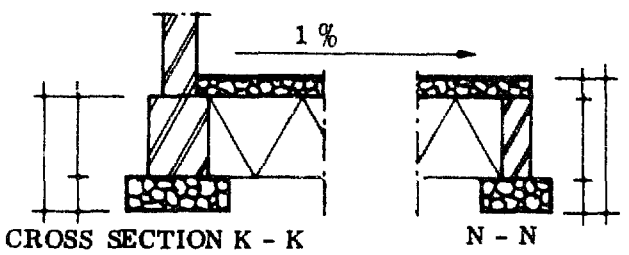

SURFACE OF FOOTING --

N . P . V . C .	
1½ HOURS	66.

FRAME WITH REBATE

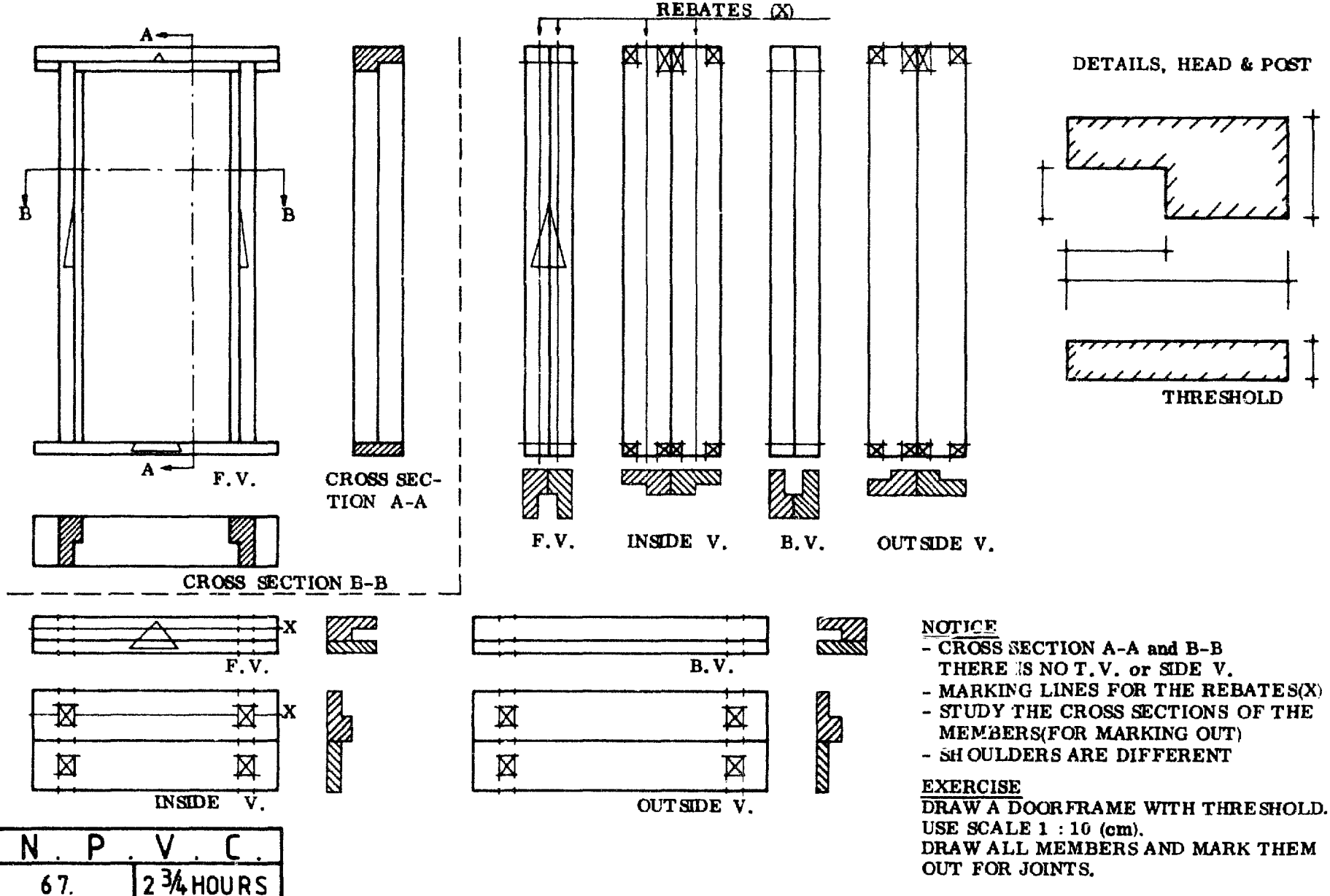

NOTICE

- CROSS SECTION A-A and B-B THERE IS NO T.V. or SIDE V.
- MARKING LINES FOR THE REBATES(X)
- STUDY THE CROSS SECTIONS OF THE MEMBERS(FOR MARKING OUT)
- SHOULDERS ARE DIFFERENT

EXERCISE

DRAW A DOORFRAME WITH THRESHOLD.
USE SCALE 1 : 10 (cm).
DRAW ALL MEMBERS AND MARK THEM OUT FOR JOINTS.

N. P. V. C.	
67.	2 3/4 HOURS

WHEN TO REDUCE MORTICE AND TENON (use teaching aids)

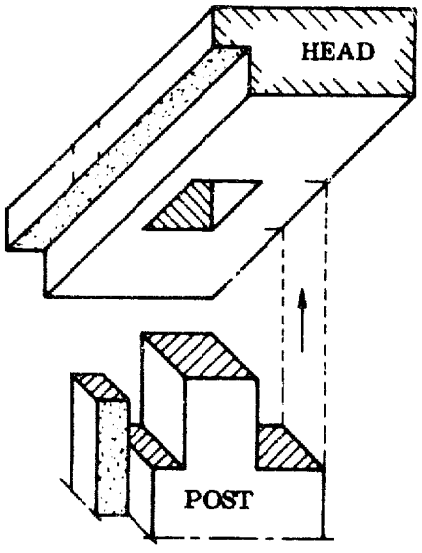

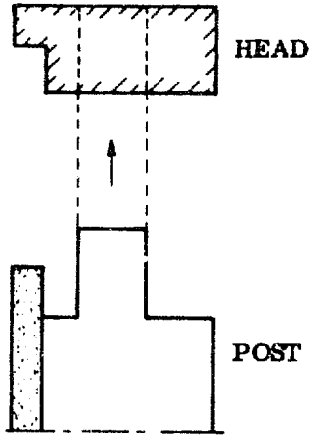

REBATE DOES NOT DISTURB THE TENON.

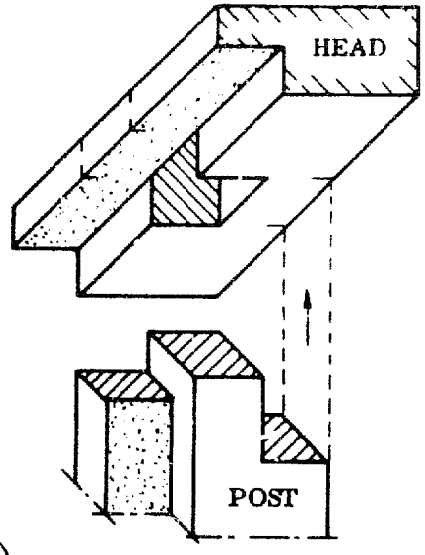

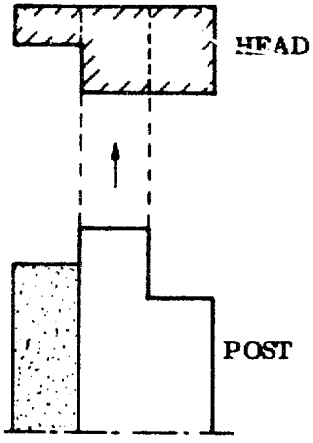

REBATE DOES NOT DISTURB THE TENON.

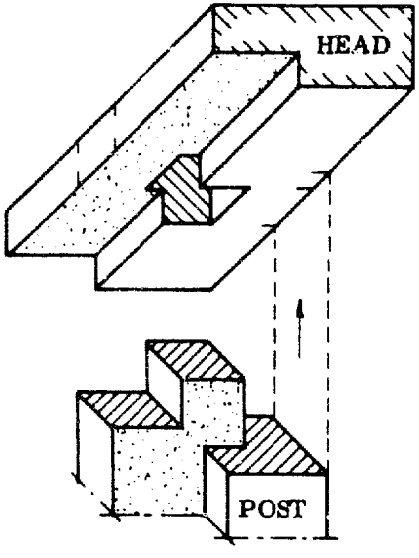

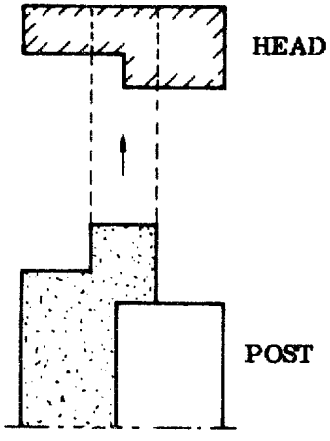

REBATE DOES DISTURB THE TENON.

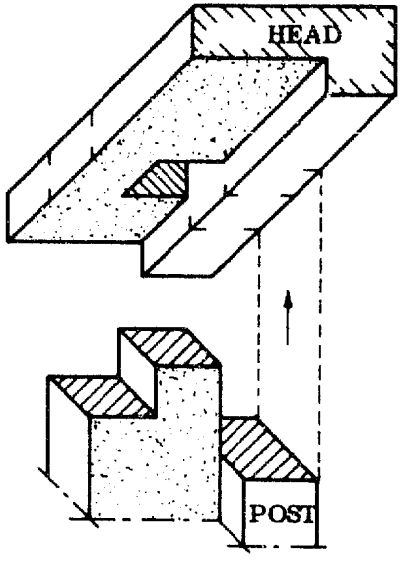

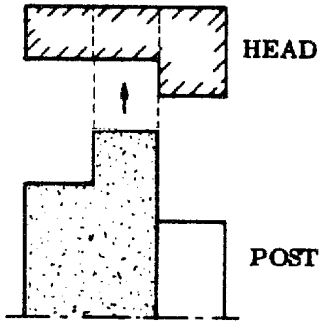

REBATE DOES DISTURB THE TENON.

N . P . V . C .

FRAME WITH CONCRETE SHOE

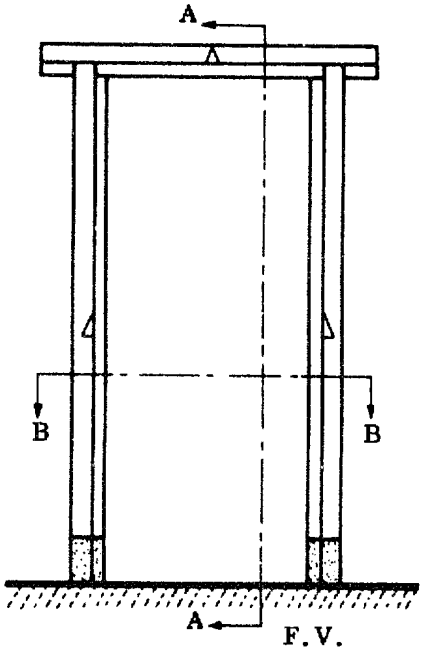

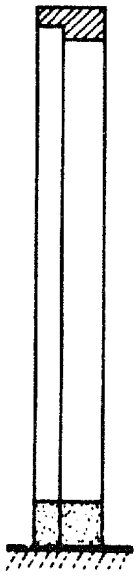

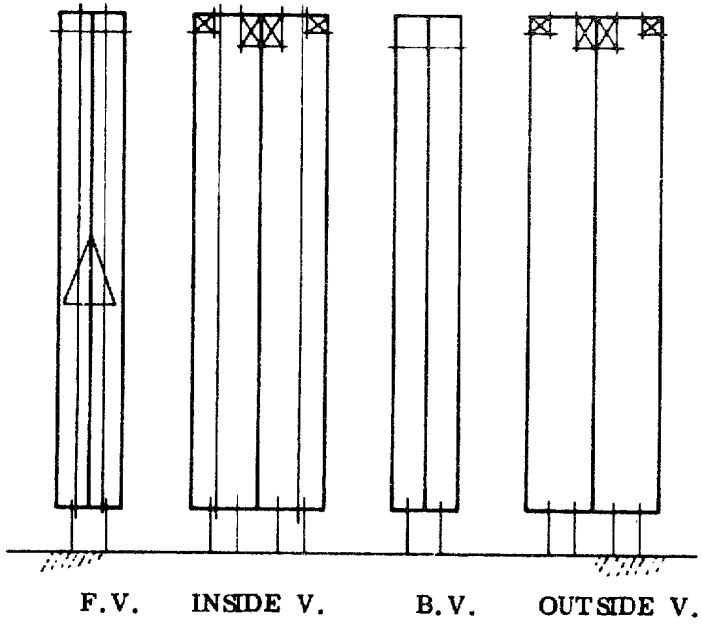

DETAIL:
DOWEL CONSTRUCTION

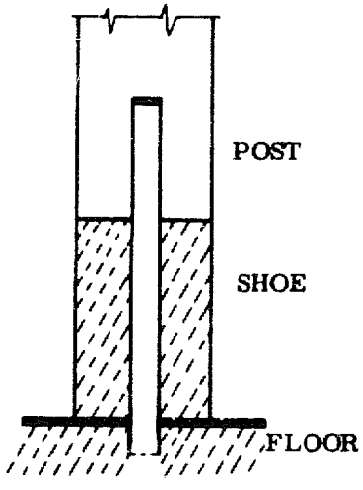

CROSS SECTION B-B

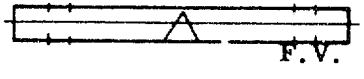

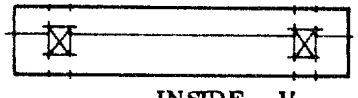

INSIDE V.

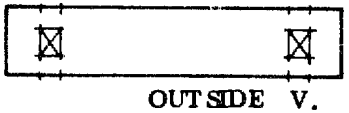

OUTSIDE V.

NOTICE
- HEIGHT OF FRAME WITH CONCRETE SHOE
- PLACING OF THE STEEL DOWELS
- CROSS SECTION B-B

EXERCISE
- MARK IN ALL DIMENSIONS.
- MAKE A DRAWING OF A DOOR FRAME WITH CONCRETE SHOE.
  USE SCALE 1 : 20 (cm).

N. P. V. C.	
69.	2 ½ HOURS

FRAME WITH TRANSOM AND THRESHOLD

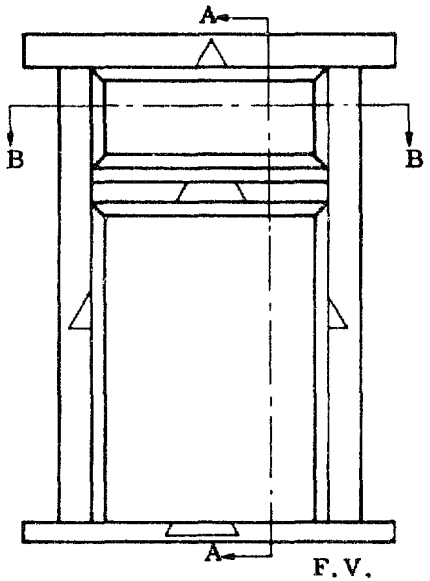

F.V.

CROSS SECTION A-A

F.V.

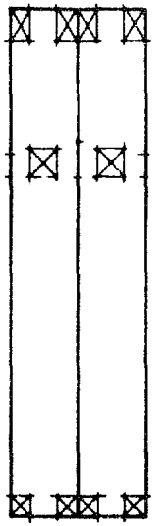

INSIDE V.

B.V.

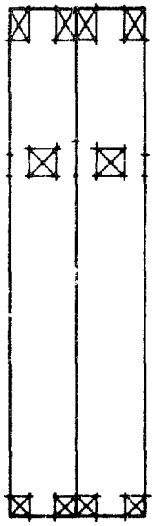

OUTSIDE V.

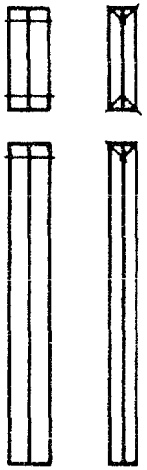

BEADS

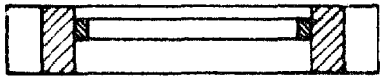

CROSS SECTION B-B

F.V.

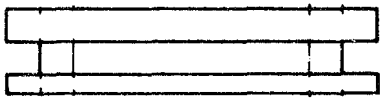

B.V.

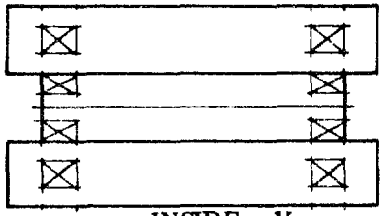

INSIDE V.

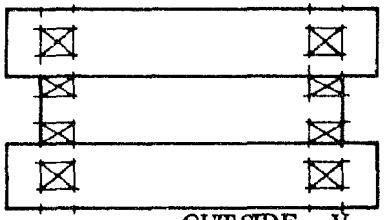

OUTSIDE V.

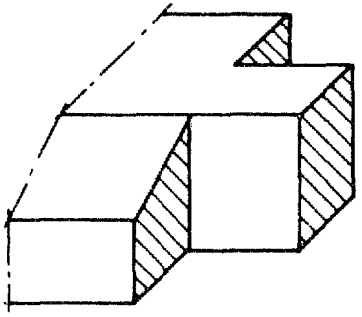

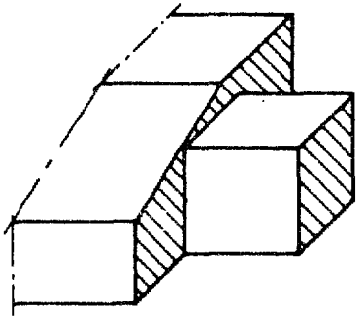

NOTICE THE DIFFERENT TENONS !

N . P . V . C .	
3 HOURS	70.

WHEN TO REDUCE MORTICE AND TENON

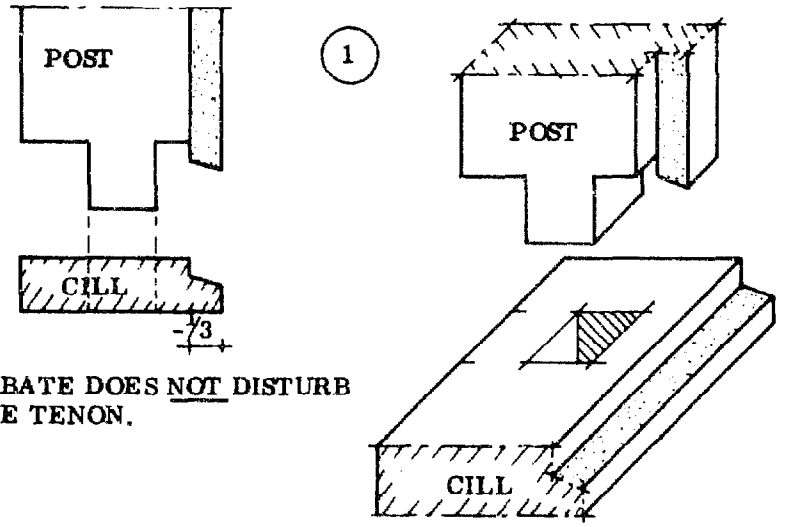

REBATE DOES NOT DISTURB THE TENON.

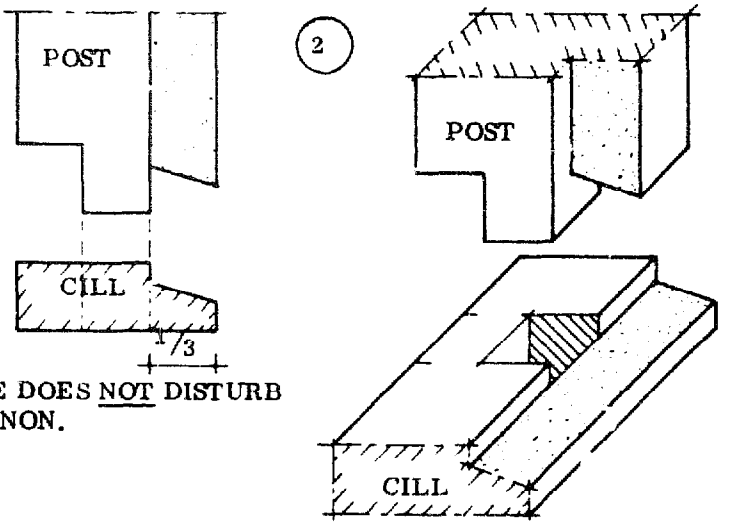

REBATE DOES NOT DISTURB THE TENON.

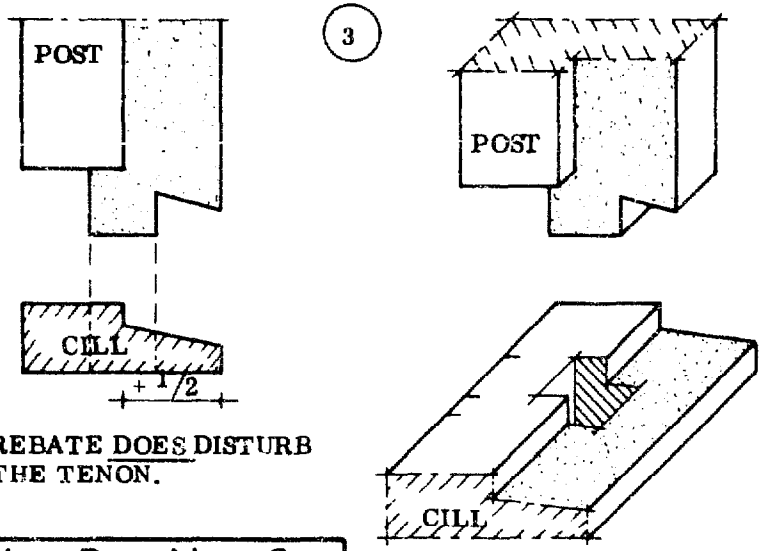

REBATE DOES DISTURB THE TENON.

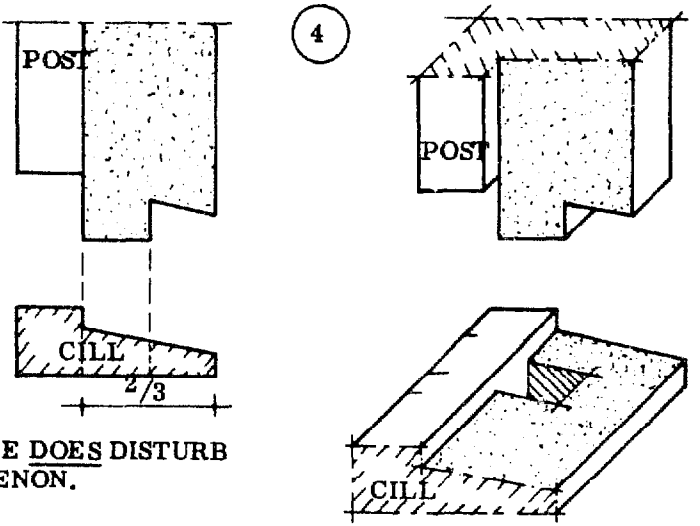

REBATE DOES DISTURB THE TENON.

N . P . V . C .	
71.	

WINDOW FRAME WITH REBATE

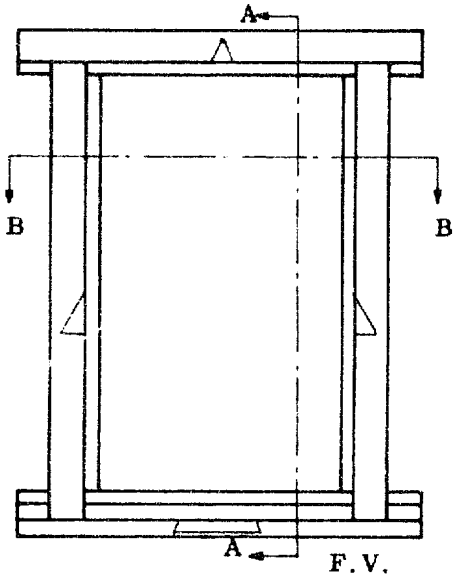

F.V.

CROSS SEC. A-A

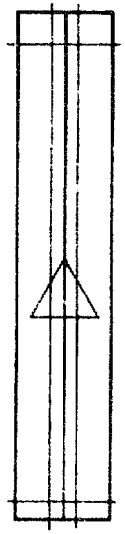

F.V.

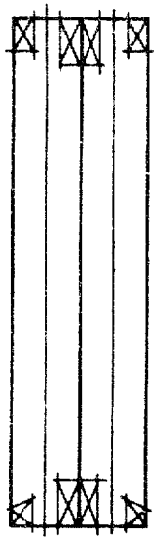

INSIDE V.

B.V.

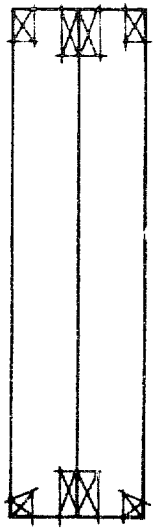

OUTSIDE V.

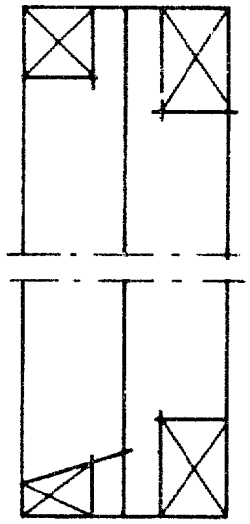

DETAIL

CROSS SEC. B-B.

F.V.

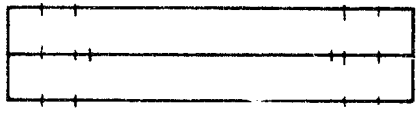

B.V.

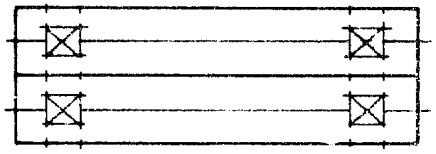

INSIDE V.

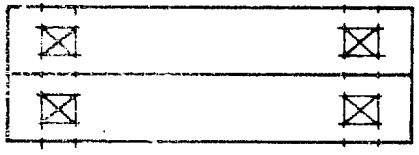

OUTSIDE V.

NOTICE

- FOR HEAD AND POST CONSTRUCTION SEE 68.
- FOR CILL-POST CONSTRUCTION SEE PAGE 71.

EXERCISE

- DRAW ALL DIMENSION LINES AND MARK THEM.
- MAKE A DRAWING OF A WINDOW FRAME WITH TRANSOM AND REBATE.

N . P . V . C .	
2 1/2 HOURS	72.

LEDGED, BRACED AND BATTENED CASEMENT

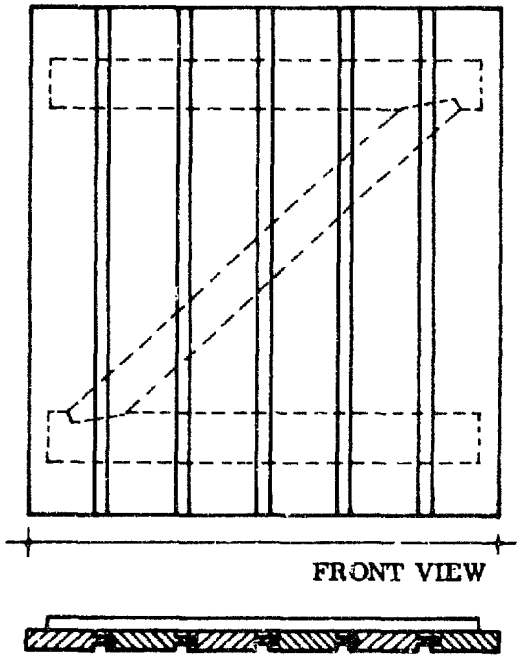

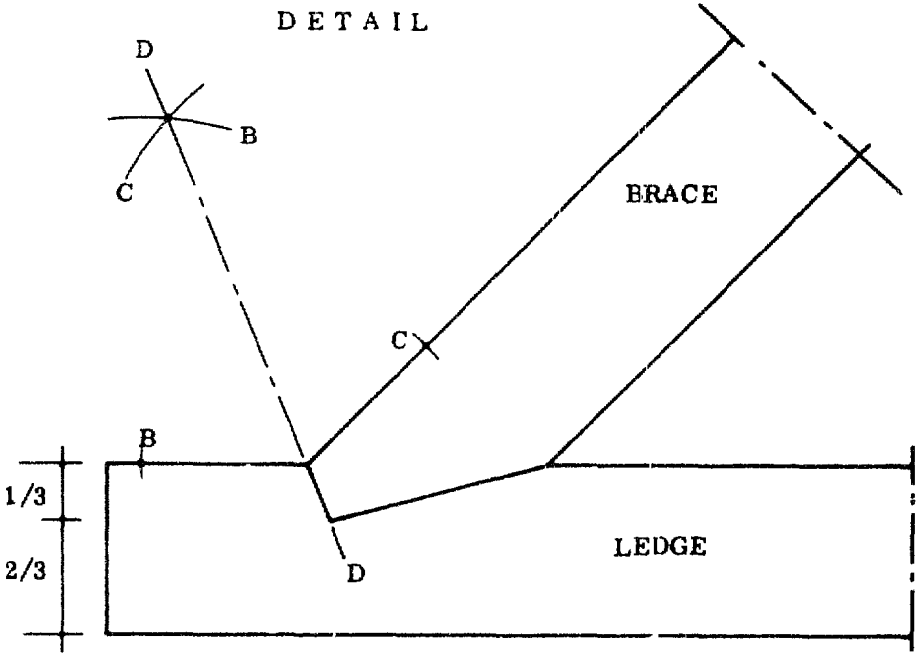

WIDTH HERE IS DETERMINED BY DOOR FRAME REBATE SIZE

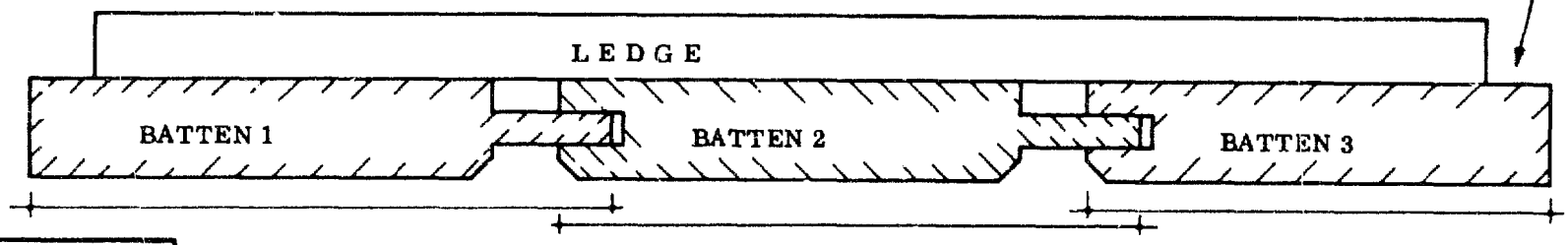

N . P . V . C .	
73.	2 HOURS

FLUSH CASEMENT

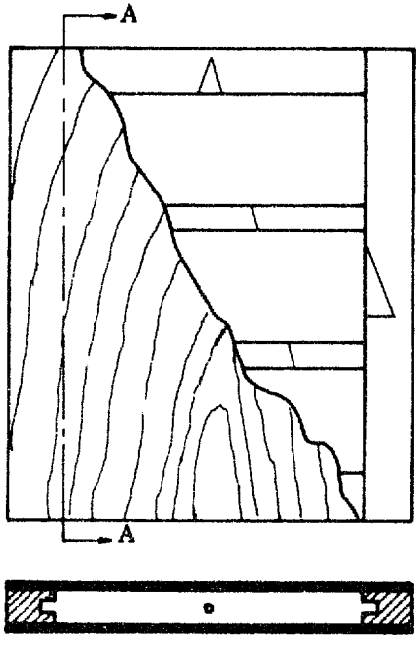

CROSS SEC.
A-A

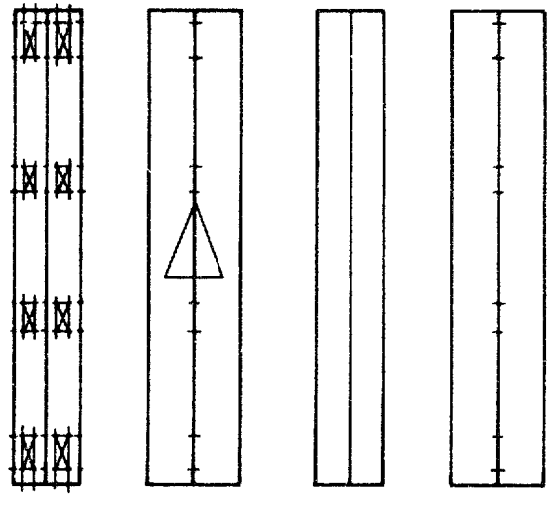

DETAIL

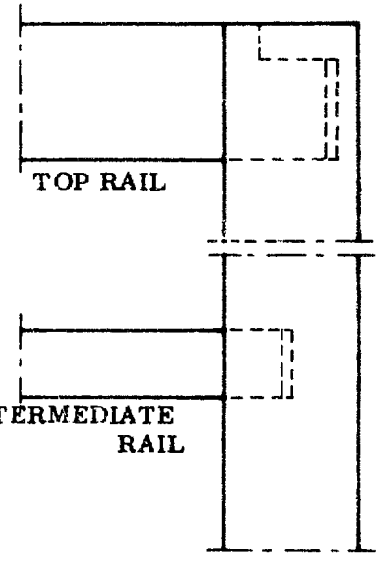

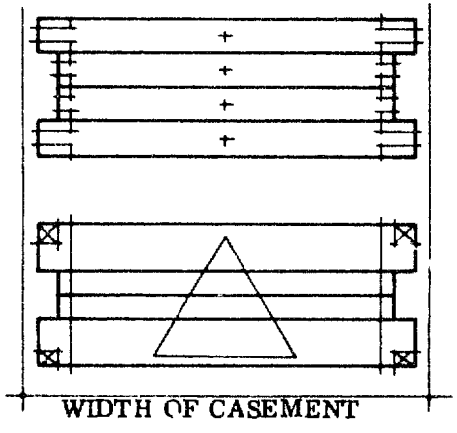

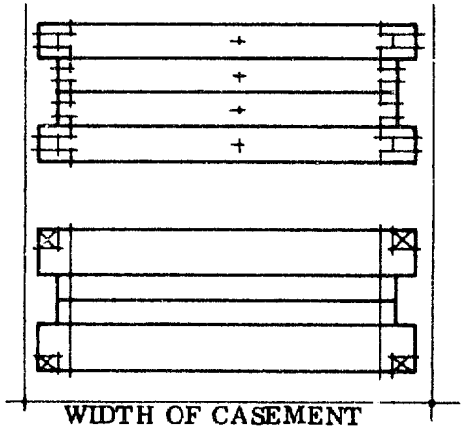

NOTICE

- HAUNCHED TENON ON TOP AND BOTTOM RAILS
- SHORT TENON ON INTERMEDIATE RAILS
- HOLES FOR VENTILATION
- FOR DOORS: ADD LOCK BLOCK

EXERCISE

- DRAW ALL DIMENSION LINES.
- MARK IN ALL DIMENSIONS.
- MAKE A DRAWING OF A FLUSH DOOR.

N . P . V . C .	
2 3/4 HOURS	74.

PANELLED CASEMENT

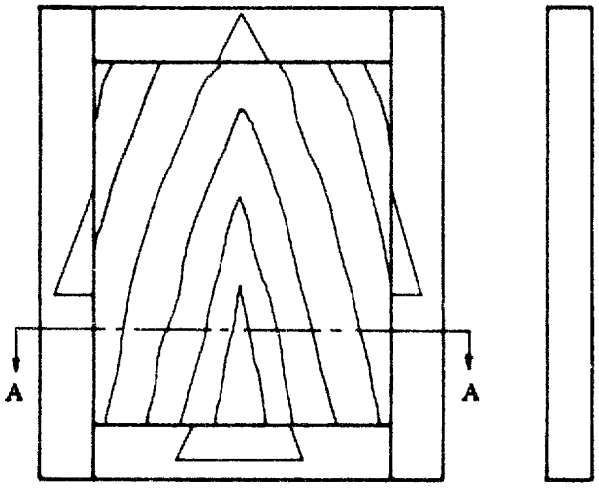

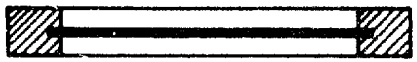

CROSS SECTION A-A

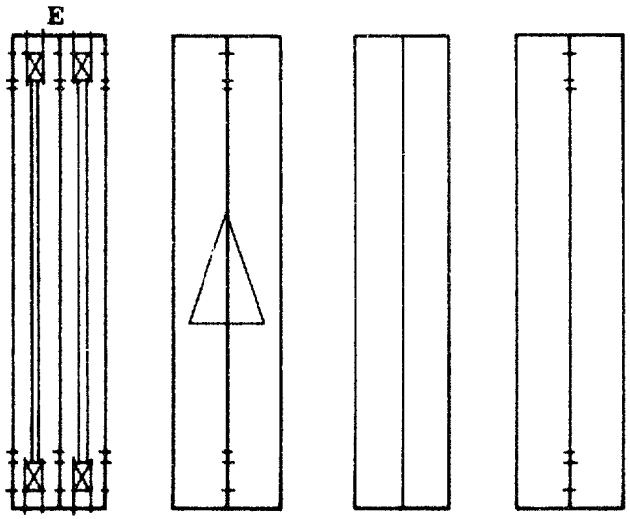

DETAIL

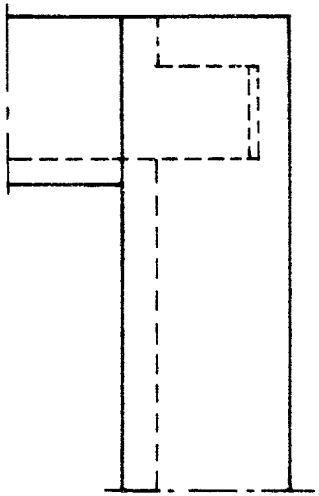

FRONT VIEW
(RIGHT TOP CORNER)

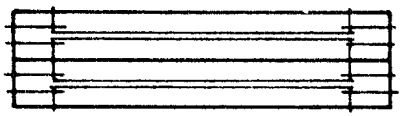

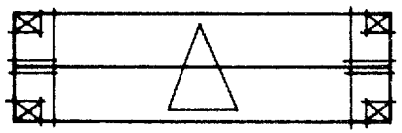

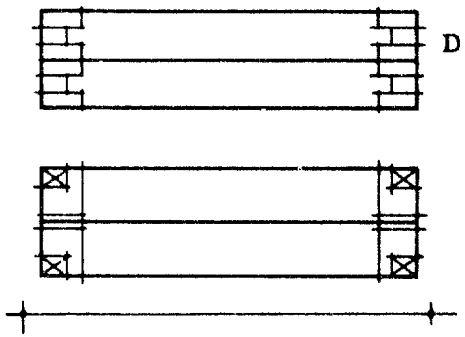

NOTICE

- COMPARE TO PAGE 76.
- THEN COMPARE "B" "C"
  "D" "E"

EXERCISE

- DRAW ALL DIMENSION LINES.
- MARK IN ALL DIMENSIONS.
- NAME ALL THE VIEWS.
- MAKE A DRAWING OF A PANELLED DOOR.

REMEMBER THAT THE TOP AND BOTTOM RAILS ARE SHORTER BECAUSE OF THE STOPPED MORTICE AND TENON !

N . P . V . C .	
75.	2 1/2 HOURS

GROOVED STILE AND TOPRAIL MARKING OUT

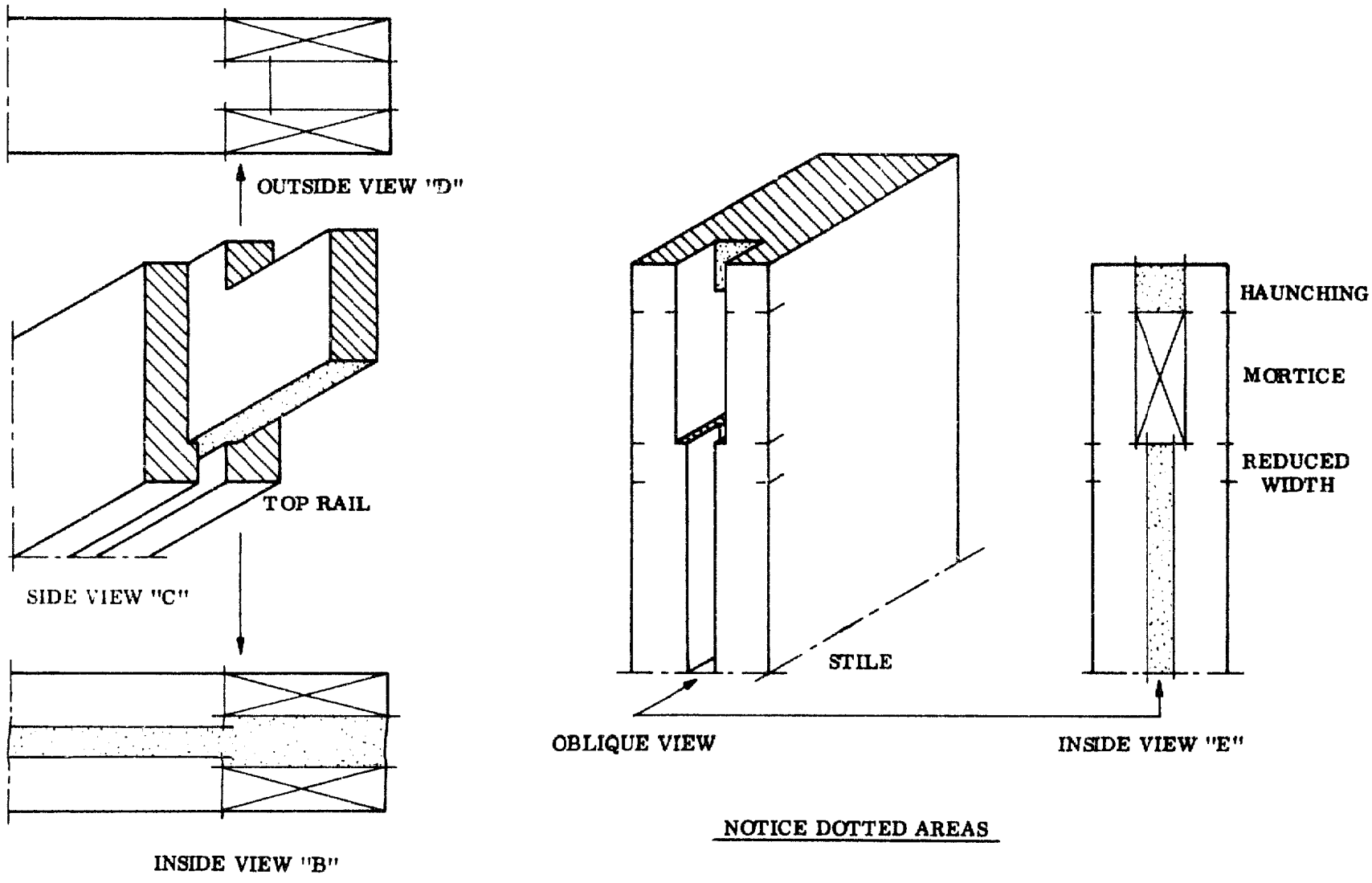

NOTICE DOTTED AREAS

REBATED CASEMENT

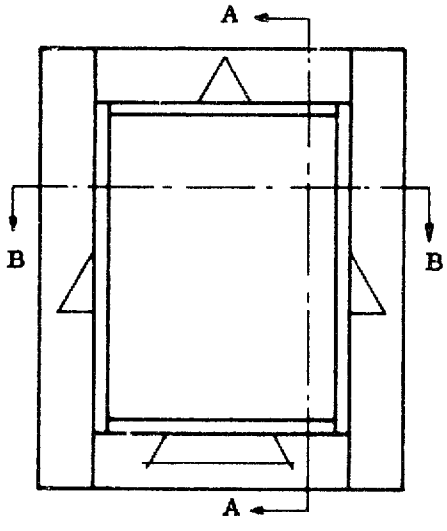

A - A

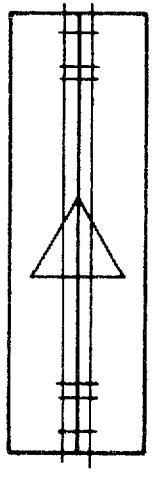

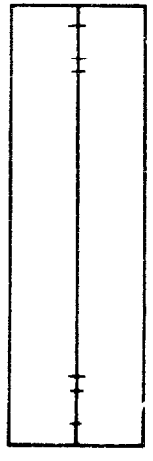

CORNER DETAIL

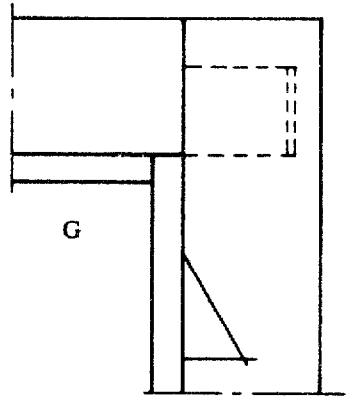

FRONT VIEW

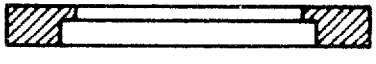

B - B

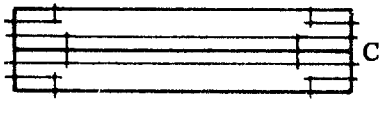

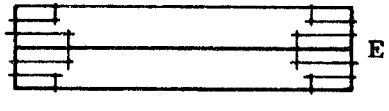

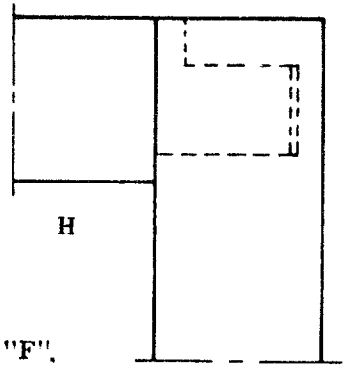

BACK VIEW

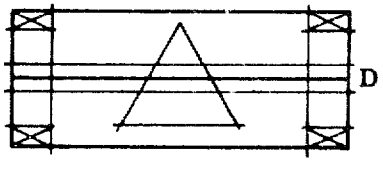

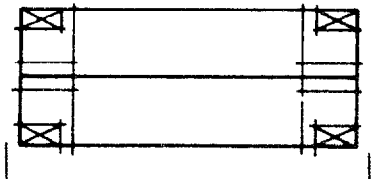

ACTUAL WIDTH OF CASEMENT

NOTICE
- COMPARE WITH PAGE 78.
- THEN COMPARE "C" "D" "E" "F".

- NOTICE SHOULDERS AT "G" "H".

EXERCISE
- NAME ALL VIEWS.
- DRAW ALL DIMENSION LINES.
- MARK IN ALL DIMENSIONS.
- MAKE A DRAWING OF A REBATED DOOR.

N . P . V . C .	
77.	2¾ HOURS

REBATED STILE AND TOPRAIL CONSTRUCTION

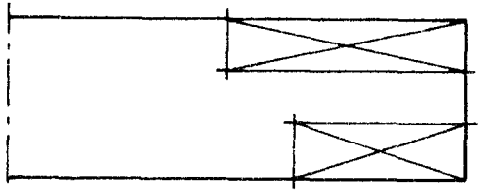

MARKING OUTSIDE VIEW "E"

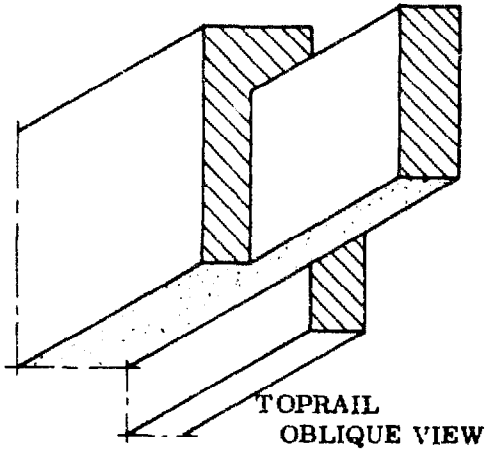

SIDE VIEW "D"

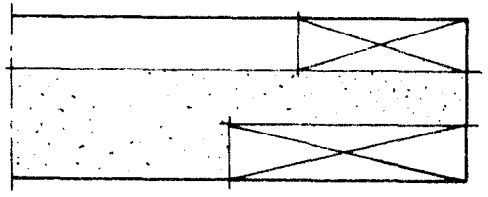

INSIDE VIEW "C"

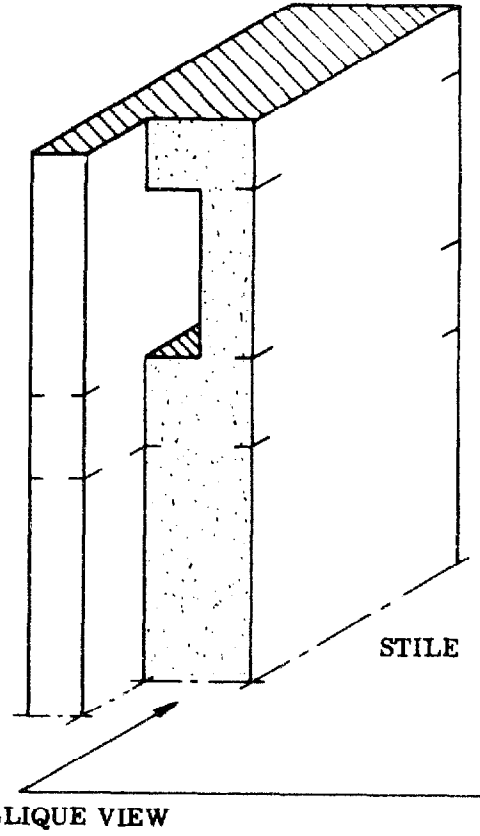

MARKING
INSIDE VIEW "F"

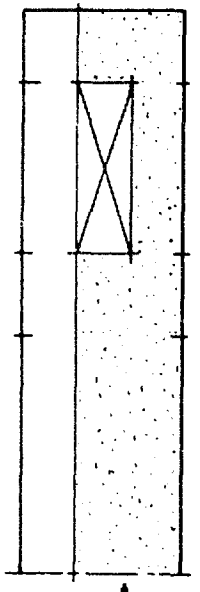

NOTICE DOTTED AREAS

N . P . V . C .	
	78.

WORKING DRAWINGS

TO BE ABLE TO MAKE A WORKING DRAWING FOR A BUILDING YOU NEED A SKETCHPLAN WITH THE NECESSARY DETAILS SUCH AS INSIDE DIMENSIONS OF THE ROOMS, THE POSITIONS OF THE WINDOWS AND DOORS, ETC.

ON THE NEXT PAGE YOU WILL FIND A LAY-OUT OF HOW TO WRITE DOWN ALL THE TECHNICAL DATA REGARDING MATERIALS AND SOME DIMENSIONS.

SKETCH PLAN

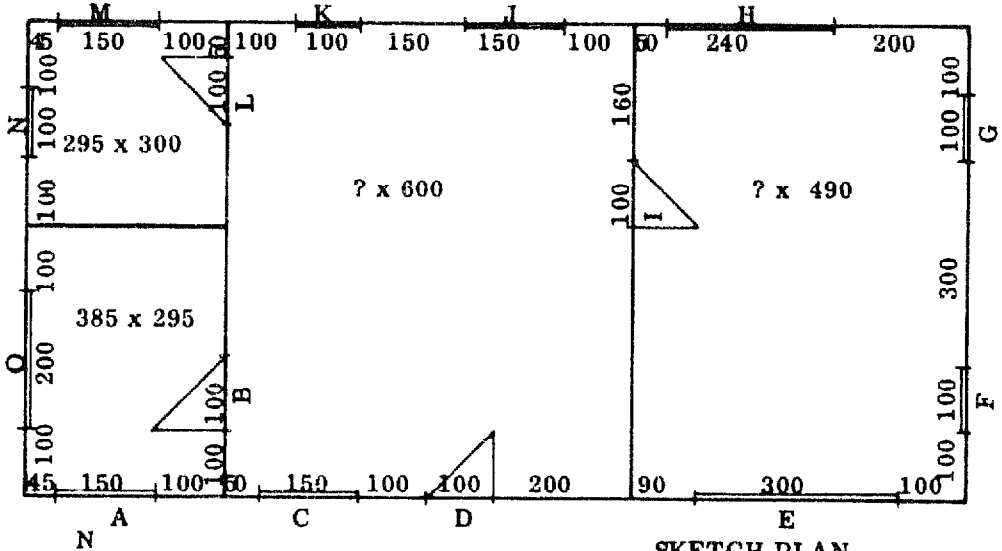

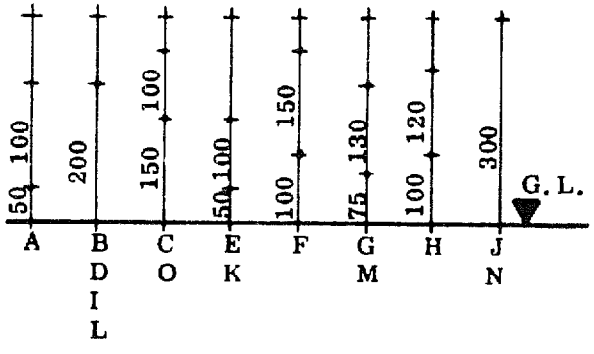

WALL THICKNESS = 15 cm

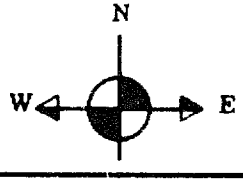

N . P . V . C .	
79.	FORM III

TECHNICAL DATA

ROOF CONSTRUCTION, MAIN BUILDING

KIND OF ROOF			ODUM WOOD
RISE OF ROOF		cm	
RISE OF TRUSS		cm	
KIND OF COVERING	x	cm	ALUMINIUM
SPAN OF TRUSS		cm	
ROOF OVERHANG, LONG SIDES		cm	
ROOF PROJECTION AT GABLE		cm	
CEILING THICKNESS		cm	PLYWOOD
FASCIA BOARDS	x	cm	WAWA
RAFTERS	x	cm	ODUM WOOD
PURLINS	x	cm	,, ,,
TIE BEAM	x	cm	,, ,,
BRACES	x	cm	,, ,,
WALL PLATE	x	cm	,, ,,

VERANDAH, ROOF CONSTRUCTION

			ODUM WOOD
KIND OF ROOF			ODUM WOOD
RISE OF ROOF		cm	
SPAN OF TRUSS		cm	
OVERHANG ON LONG SIDES		cm	
PROJECTION AT GABLE ENDS		cm	
CEILING THICKNESS		cm	PLYWOOD
FASCIA BOARDS	x	cm	WAWA
RAFTERS	x	cm	ODUM WOOD
PURLINS	x	cm	,, ,,
TIE BEAM	x	cm	,, ,,
BRACES	x	cm	,, ,,

MAIN BUILDING

FOUNDATION	x	cm	CONCRETE
FOOTING HEIGHT ABOVE G.L.		cm	
FOOTING WIDTH		cm	SANDCRETE
WALL THICKNESS		cm	LANDCRETE
PLASTER THICKNESS(inside)		cm	CEMENT PLASTER
PLASTER THICKNESS(outside)		cm	,, ,,
FLOOR THICKNESS		cm	ONE COURSE WORK

VERANDAH MAIN BUILDING

COLUMNS	x	cm	REINFORCFD CONCRETE
EAVE BEAM	x	cm	REINFORCED CONCRETE
EAVE PLATE	x	cm	ODUM WOOD
FLOOR SLOPE		%	PER METER
FOOTING HEIGHT ABOVE G.L.		cm	
FOOTING WIDTH		cm	SANDCRETE
FOUNDATION	x	cm	CONCRETE
FLOOR THICKNESS		cm	ONE COURSE WORK

DIRECTION OF BUILDING EAST / WEST NORTH - SOUTH

SPECIAL REQUIREMENTS

N. P. V. C.	
	80.

N. P. V. C.

81.

5 HOURS

EXERCISE: MAKE AN ORTHOGRAPHIC DRAWING WITH CROSS SECTION OF A BUILDING WITH PENTROOF. USE SCALE 1 : 100 (cm).

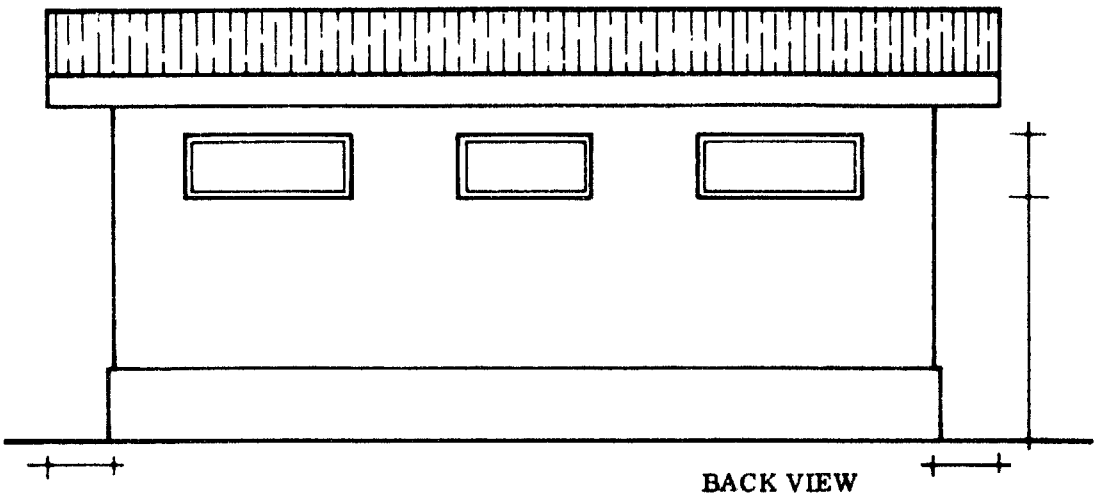

BACK VIEW

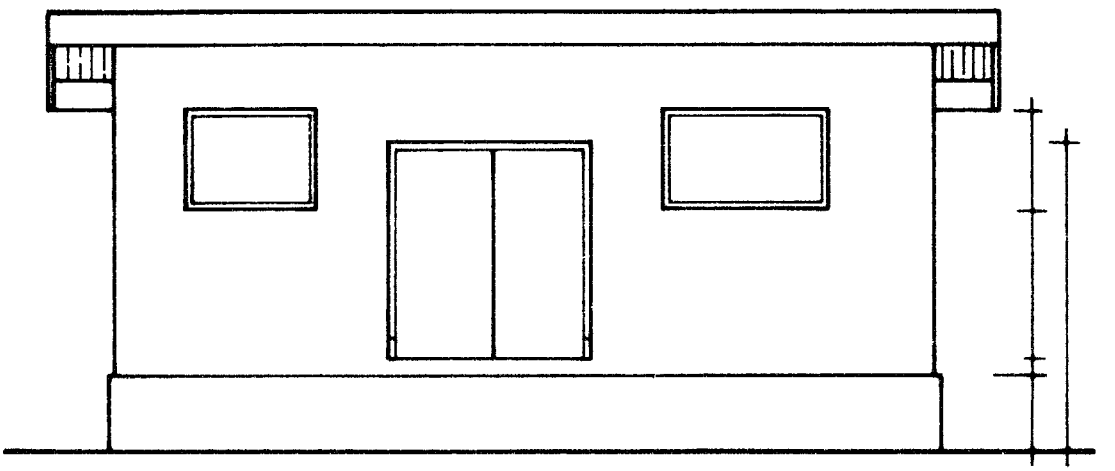

FRONT VIEW

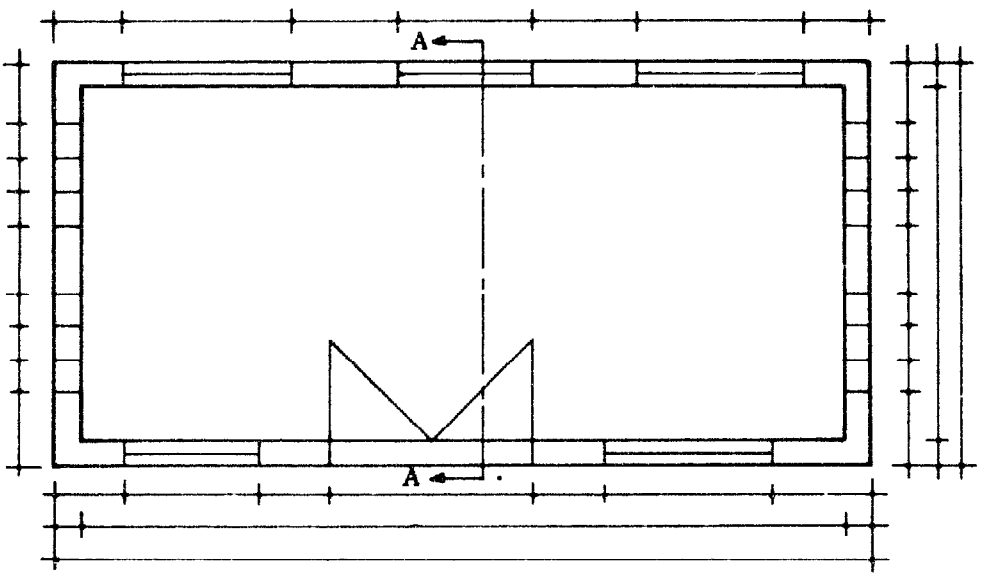

PLAN

TEAR OUT THIS PAGE AND GLUE IT TO PAGE 81

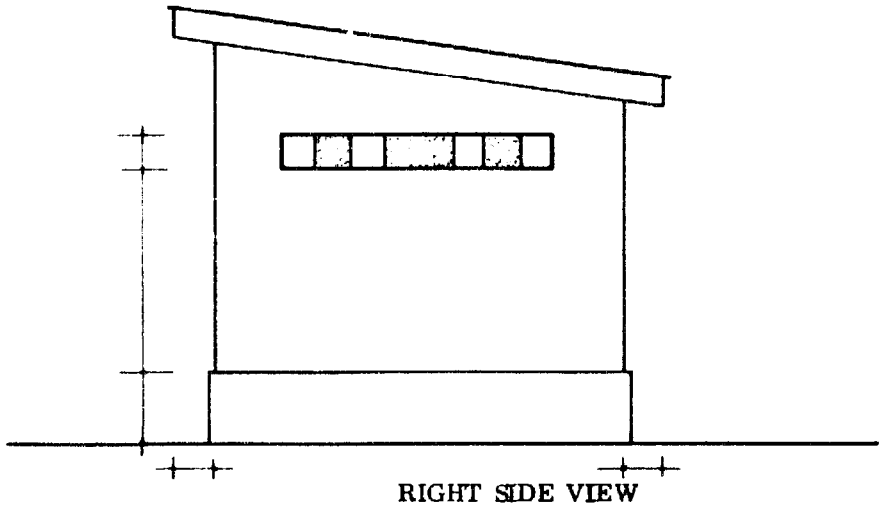

RIGHT SIDE VIEW

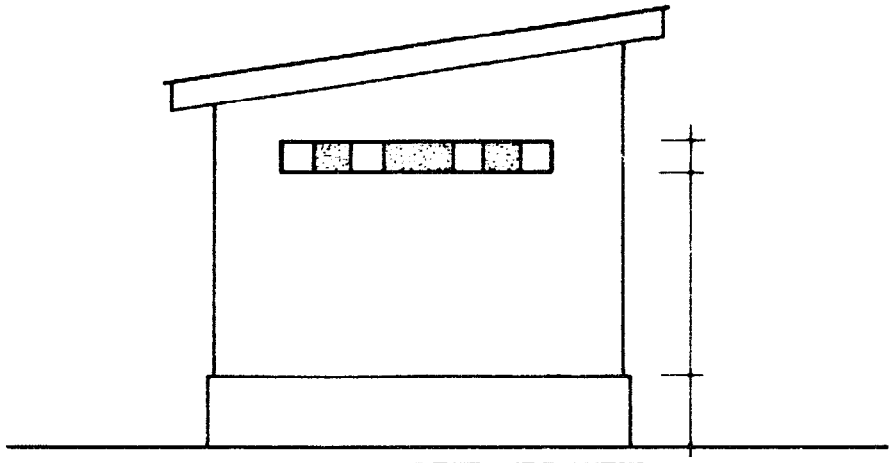

LEFT SIDE VIEW

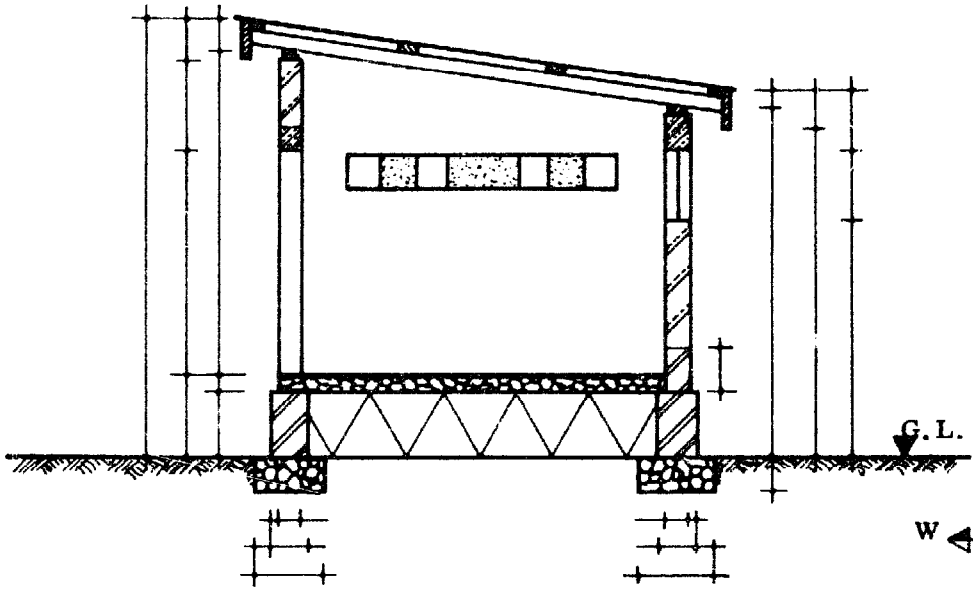

CROSS SECTION A - A

N.P.V.C.
82.

BUILDING WITH PENTROOF

PENT ROOF PLAN

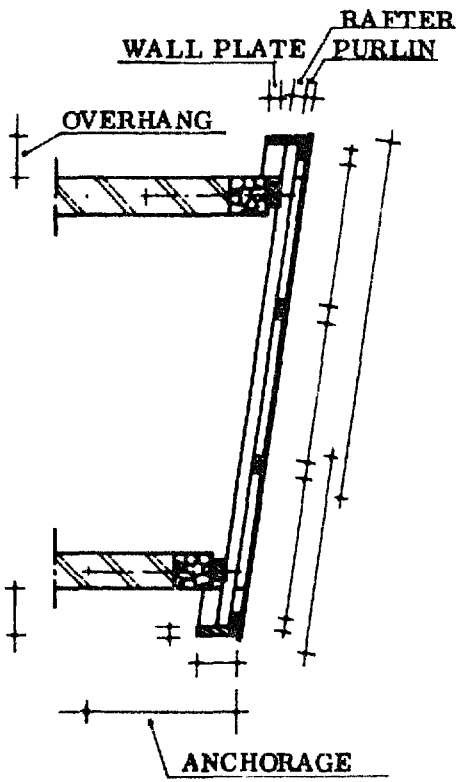

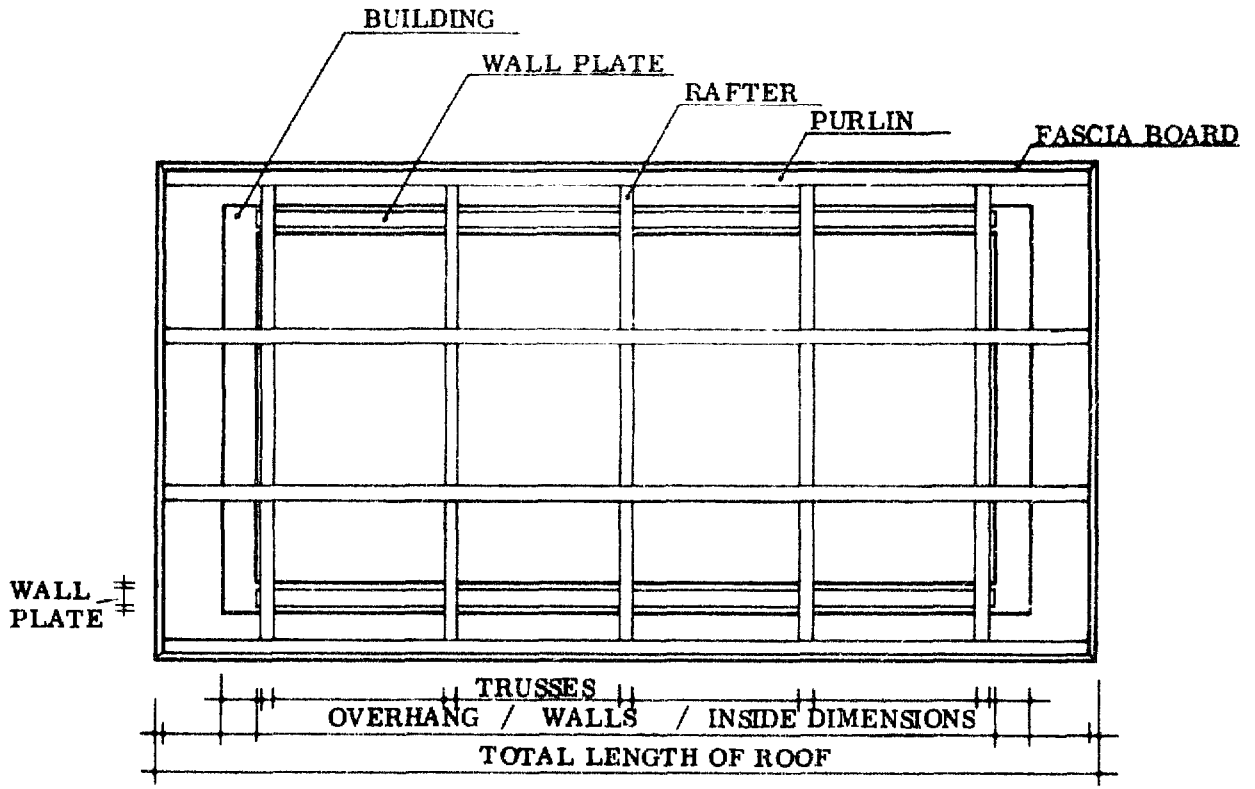

REMEMBER:
- LENGTH OF THE ROOF IS MEASURED ON THE PLAN.
- WIDTH OF THE ROOF IS MEASURED ON THE CROSS SECTION.
- THE OVERHANG OF THE ROOF IS MEASURED SQUARE TO THE WALL.
- FIRST DRAW THE CROSS SECTION, THEN THE PLAN.

EXERCISE : MAKE A ROOF PLAN FOR A STORE WITH A PENT ROOF.
USE A SCALE OF 1 : 50 (cm).

N . P . V . C .	
83.	2½ HOURS

PARAPETTED PENT ROOF

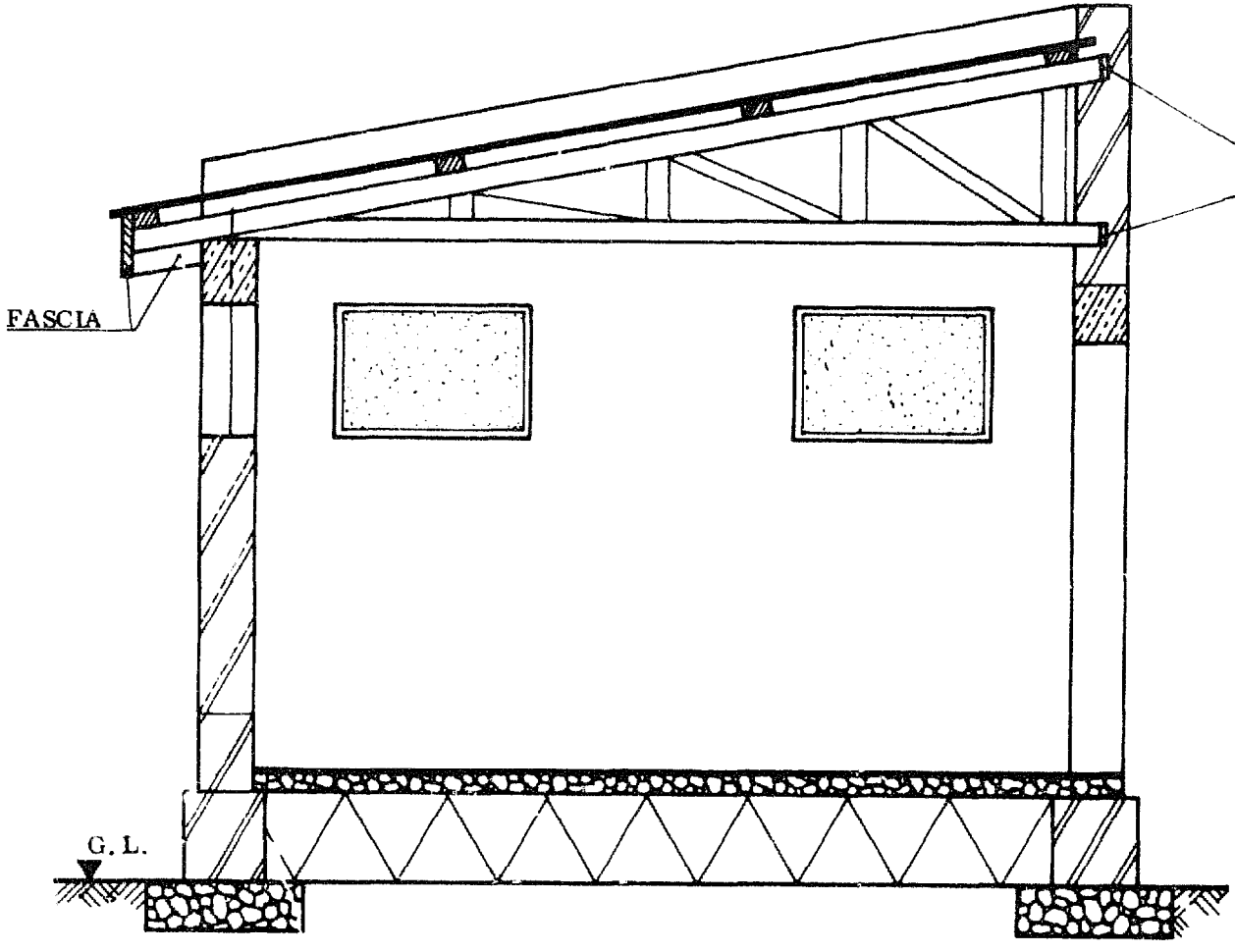

CROSS SECTION K - K

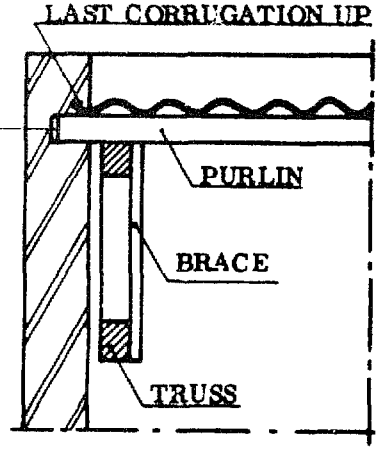

DETAIL

NOTICE
- EXPANSION GAPS AT "A"
- FASCIA OVERHANG
- PARAPET PROJECTION
- CONCRETE BELT INSTEAD OF A WOODEN WALL PLATE
- FOR BACK VIEW SEE PAGE 86

EXERCISE
MAKE AN ORTHOGRAPHIC DRAWING WITH CROSS SECTION OF A STORE WITH A PARAPETTED ROOF.

STUDY CAREFULLY THE BACK VIEW OF THE BUILDING ON PAGE 86.

N. P. V. C.	
4 HOURS	84.

PARAPETTED GABLE ROOF

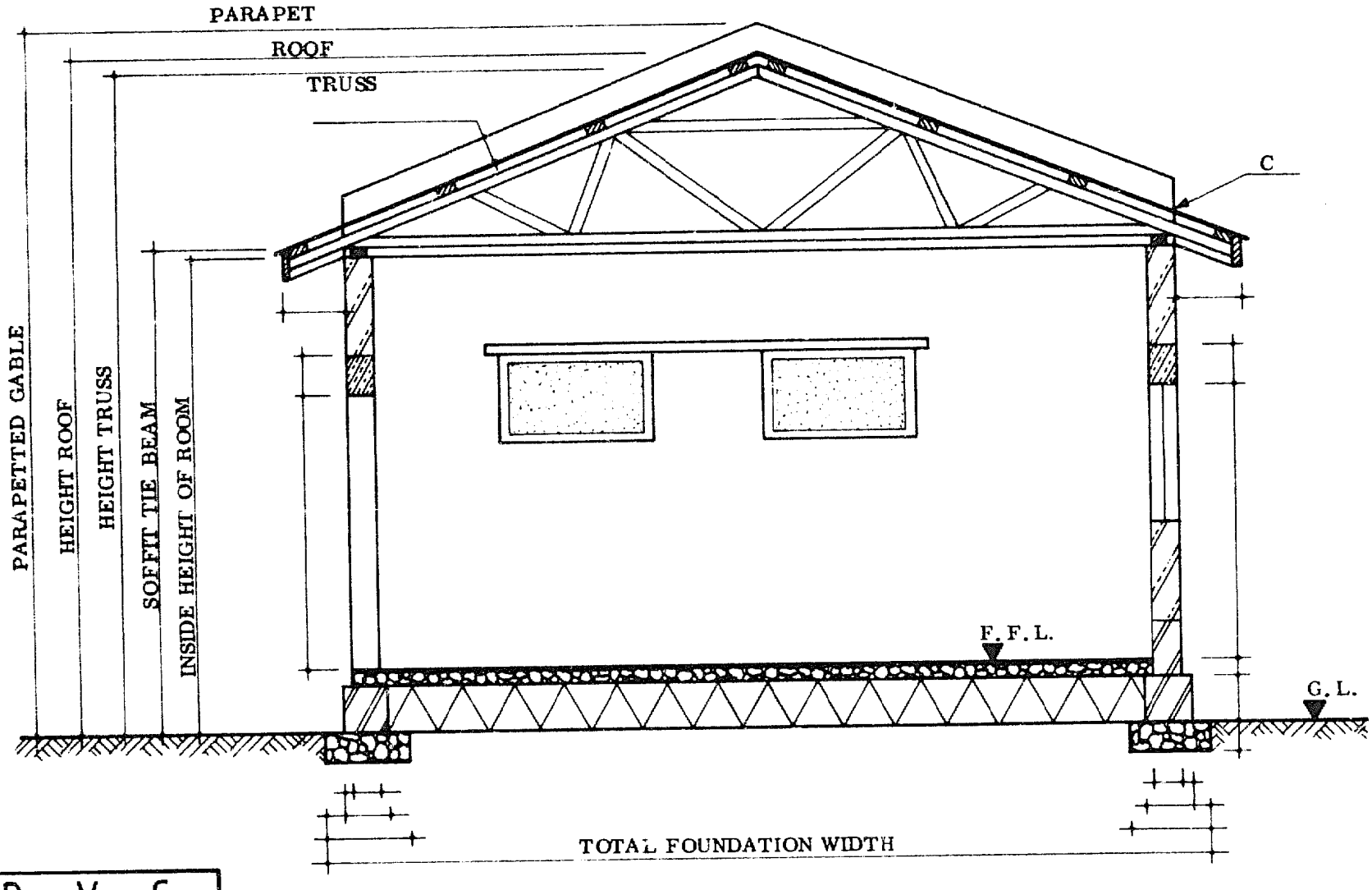

N. P. V. C.	
85.	

BACK VIEW OF A BUILDING WITH GABLE ROOF

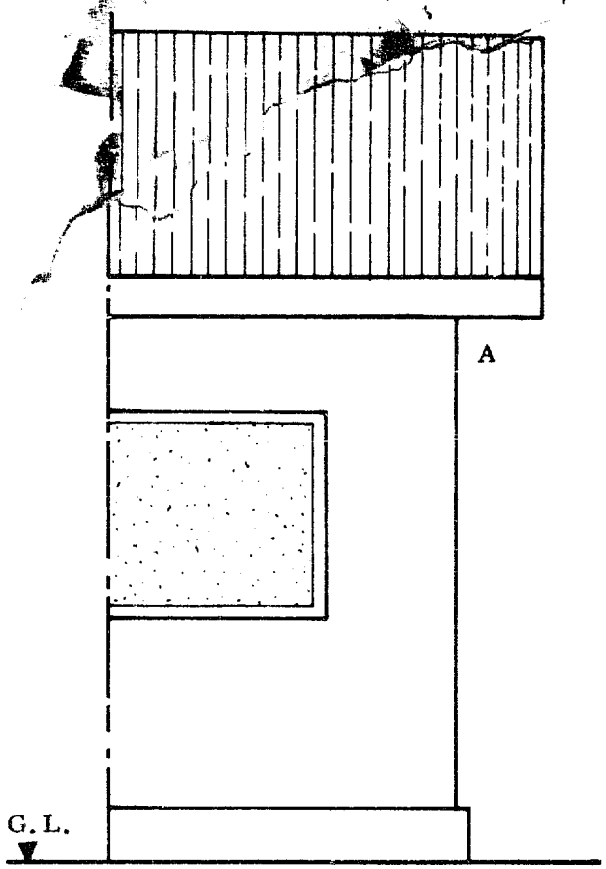

BACK VIEW

GABLE PROJECTION

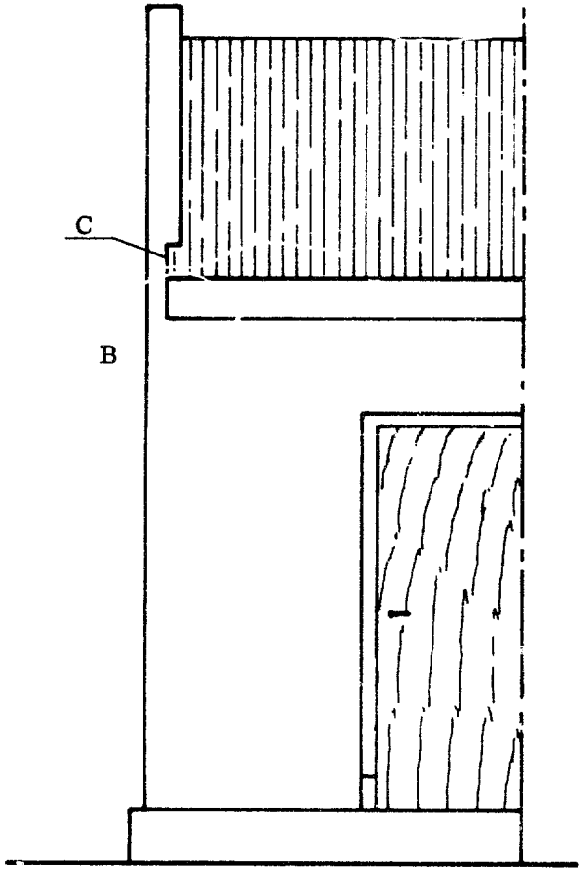

BACK VIEW

PARAPETTED GABLE

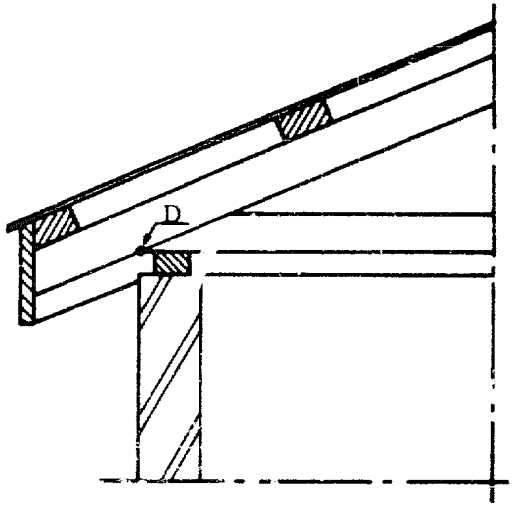

ENLARGED DETAIL

NOTICE
- PROJECTION AT GABLE A
- PARAPETTED GABLE AT B
- THE SHEETS ARE SET INTO THE WALL AT C.
- THE SPAN OF THE TRUSS IS MEASURED FROM POINT D.

N. P. V. C.

86.

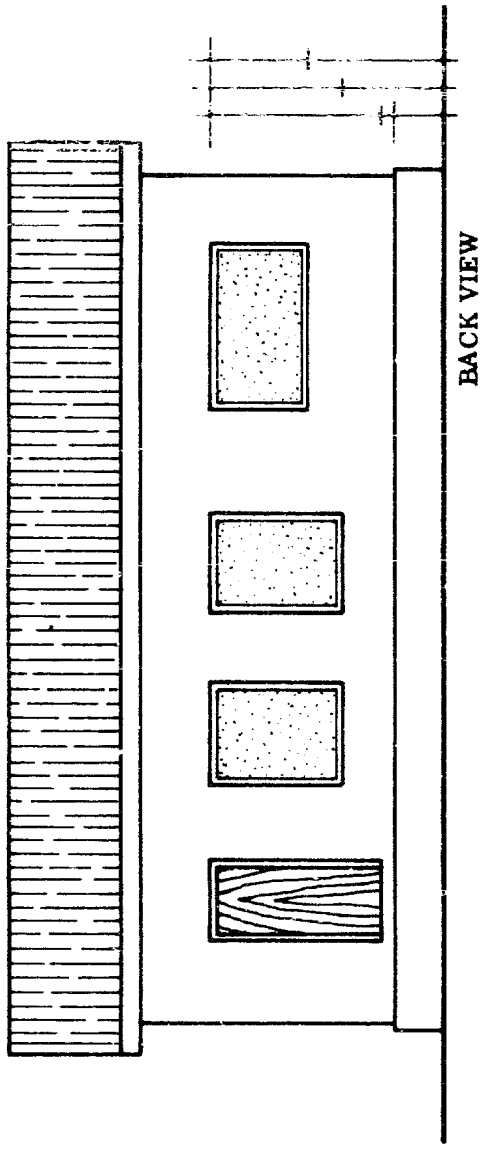

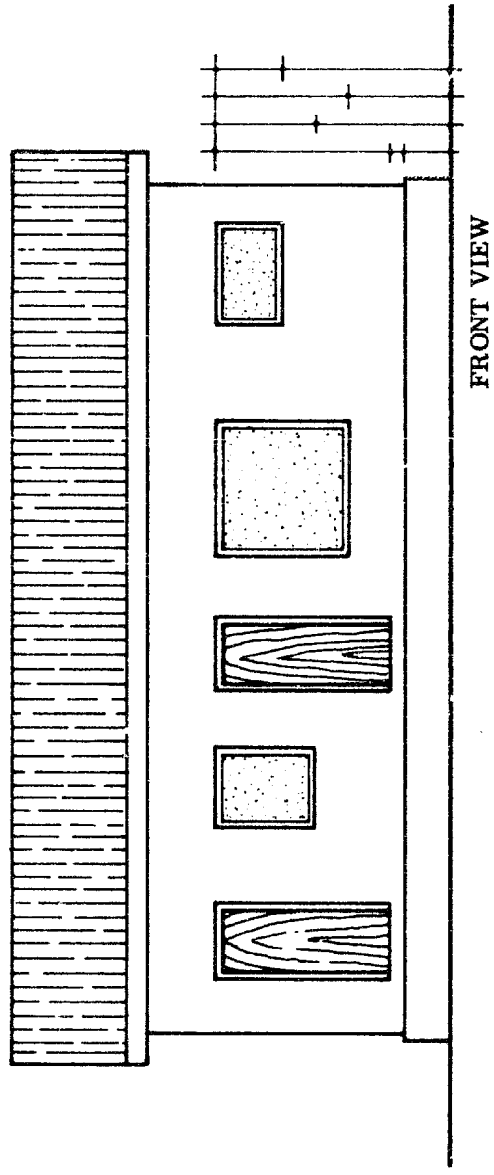

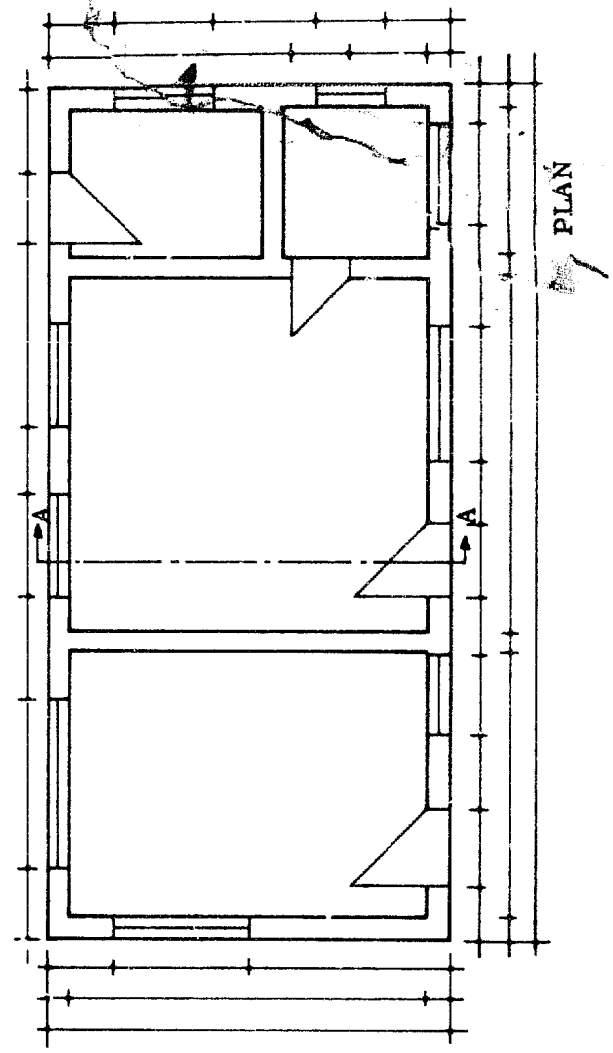

N . P . V . C .	
87.	4 1/2 HOURS

EXERCISE: MAKE AN ORTHOGRAPHIC DRAWING WITH CROSS SECTION OF A BUILDING WITH A GABLE ROOF; USE SCALE 1 : 100 (cm).

TEAR THIS PAGE OUT AND GLUE IT TO PAGE 87

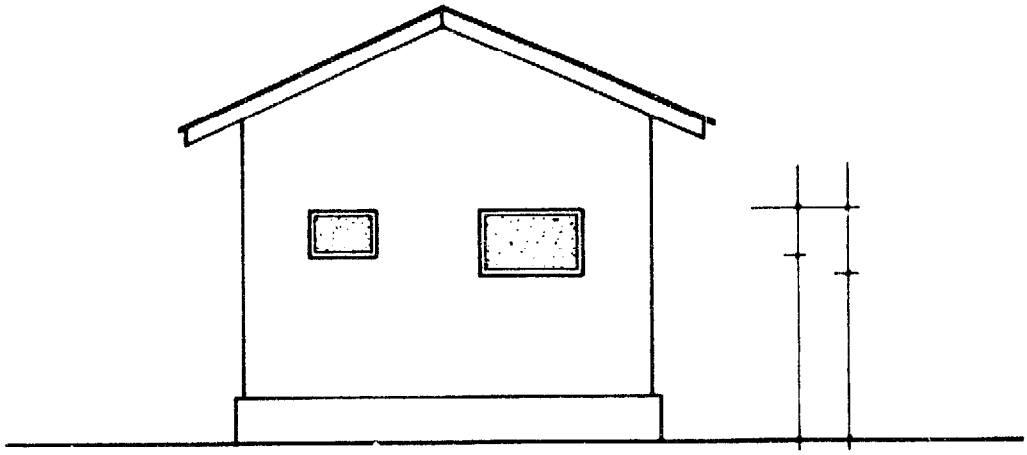

RIGHT SIDE VIEW

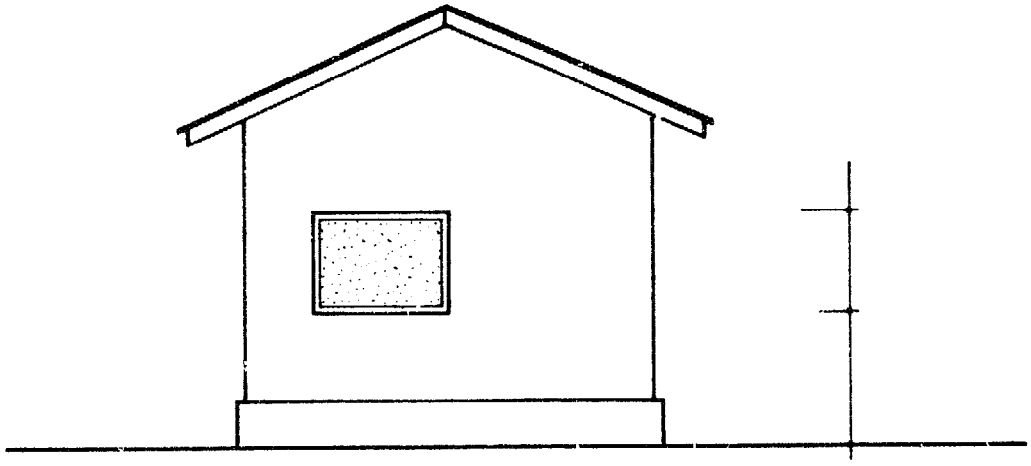

LEFT SIDE VIEW

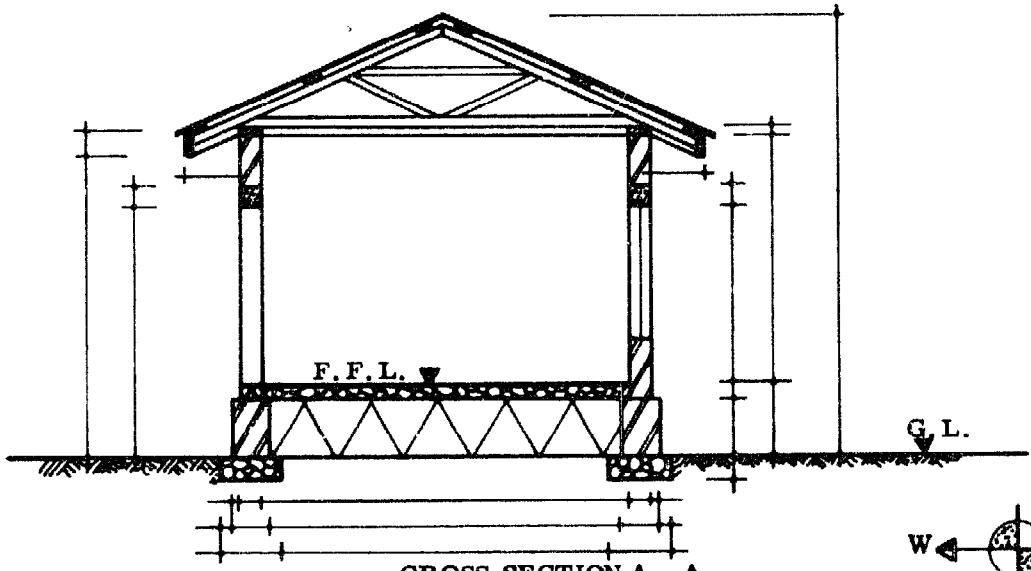

CROSS SECTION A - A

N.P.V.C.

88

GABLE ROOF AND PARAPETTED GABLE ROOF

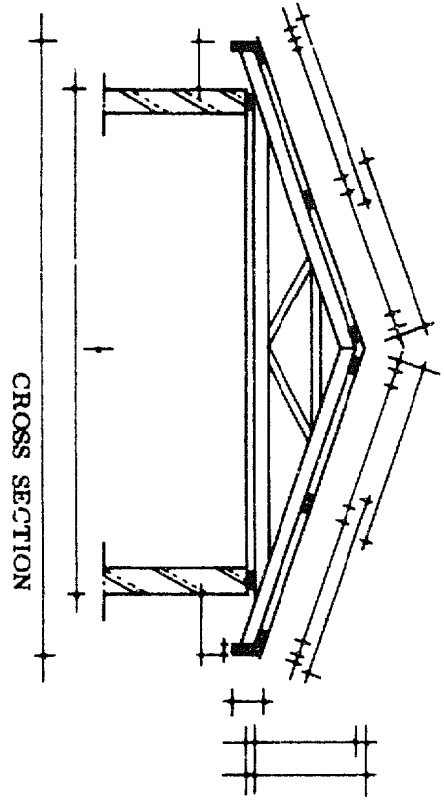

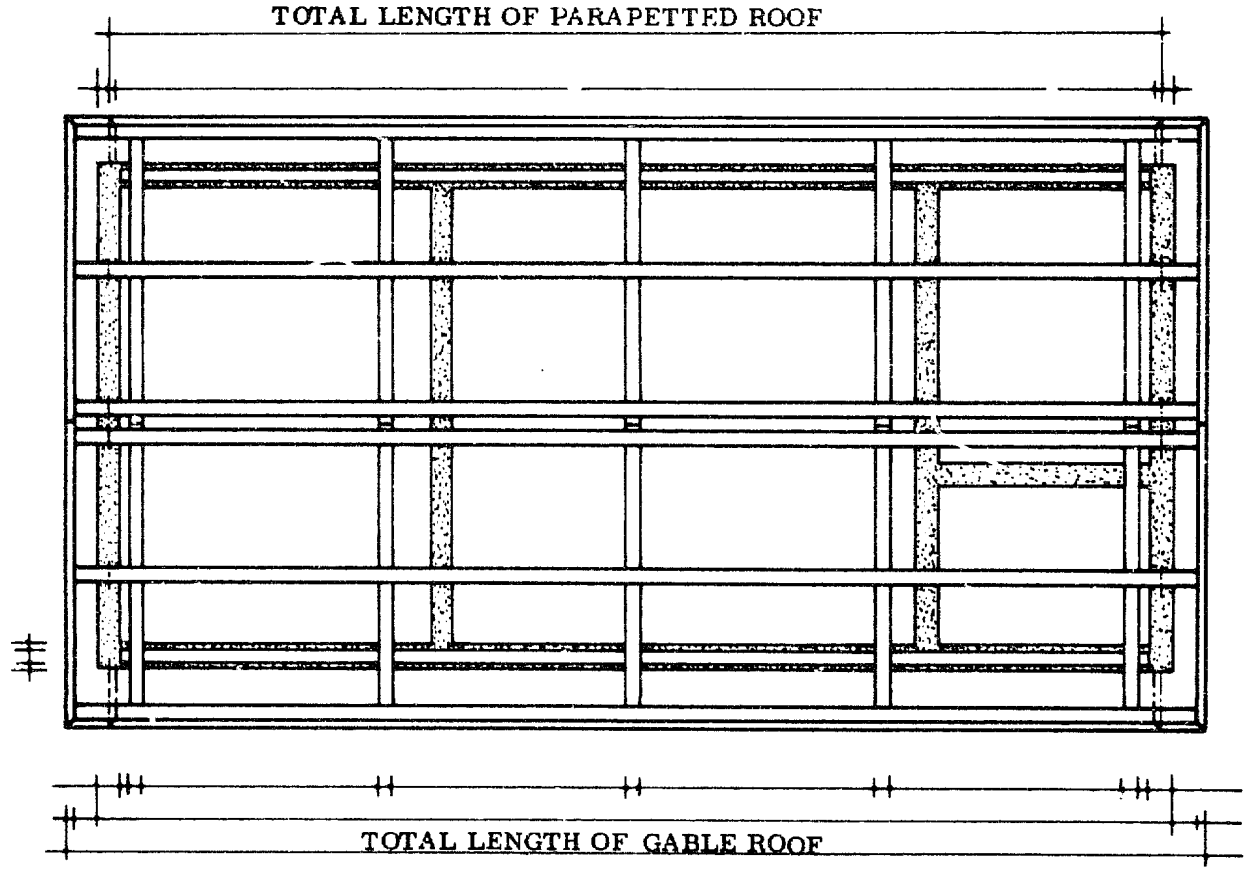

EXERCISE: NAME ALL DIMENSION LINES.
MAKE A DRAWING OF THE ABOVE ROOF DESIGNS.

N . P . V . C .	
89.	3½ HOURS

PLAN FOR HOUSE WITH VERANDAH

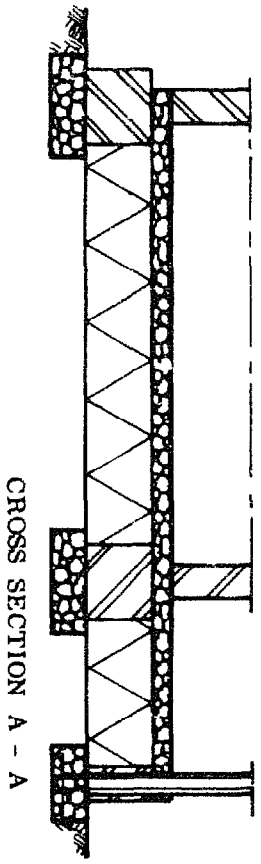

CROSS SECTION A - A

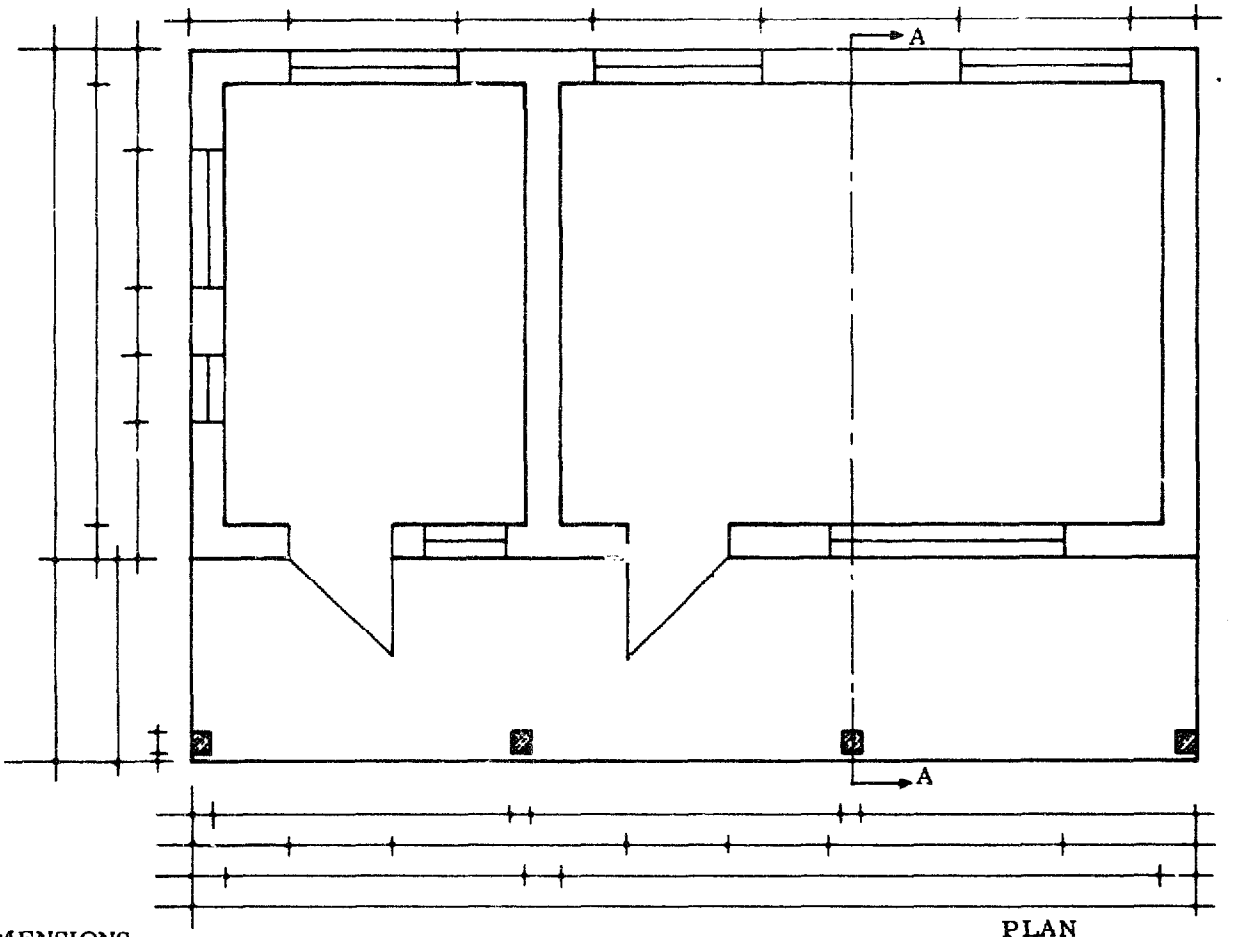

PLAN

EXERCISE: MARK IN ALL DIMENSIONS.
MAKE AN ORTHOGRAPHIC DRAWING OF A BUILDING WITH A VERANDAH;
DRAW PLAN, VIEWS AND CROSS SECTION.
USE SCALE 1 : 100 (cm). BEFORE DRAWING SEE ALSO PAGE 91 and 92.

N. P. V. C.	
1½ HOURS	90.

BUILDING WITH VERANDAH

GABLE ROOF DESIGN

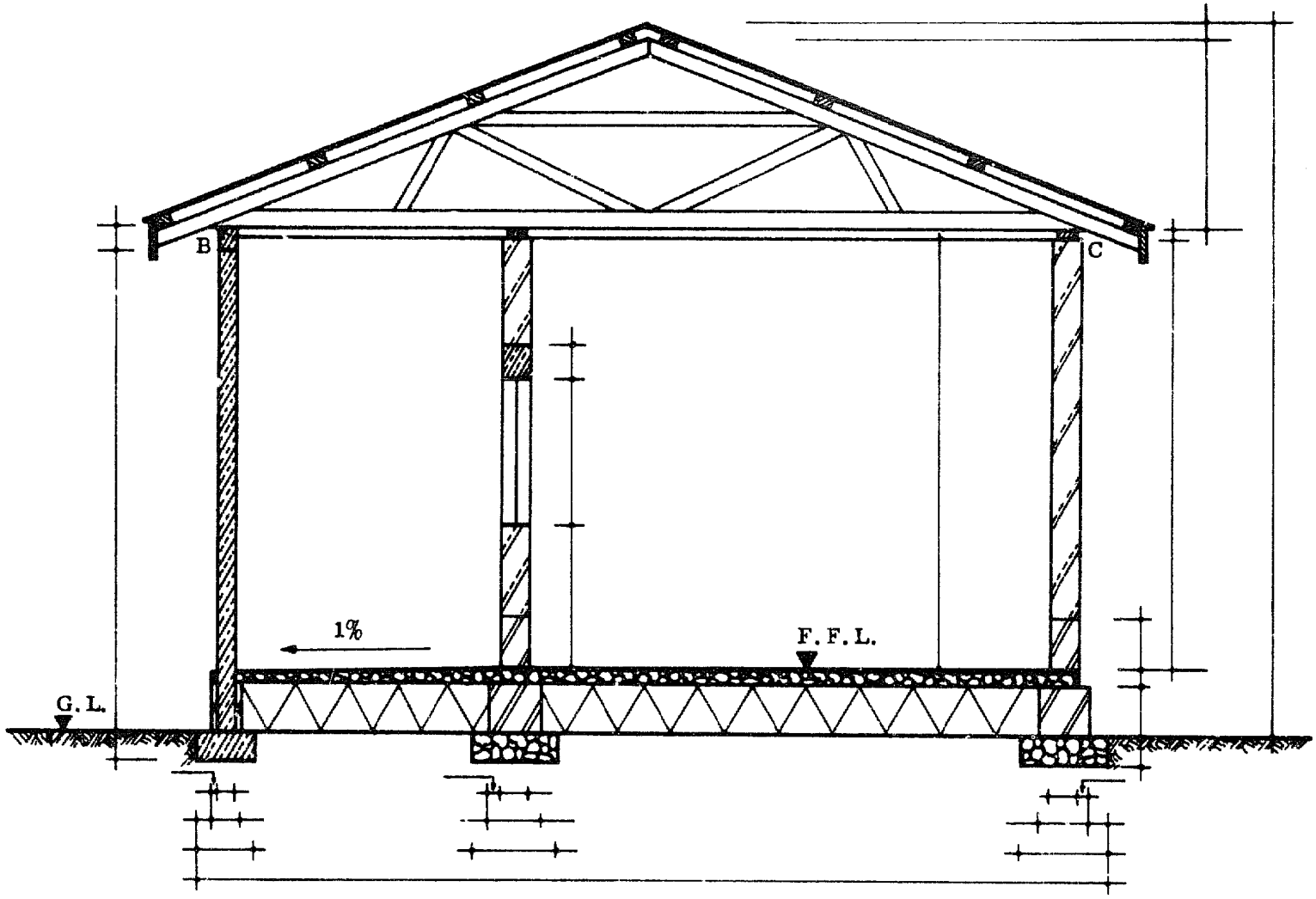

NOTICE: SPAN OF TRUSS GOES FROM OUTSIDE FOOTING TO OUTSIDE WALL (B & C).
SEE ALSO PAGE 90.
COMPARE THIS CROSS SECTION WITH PAGE 92.

BUILDING WITH VERANDAH

GABLE ROOF AND OVERHANG DESIGN

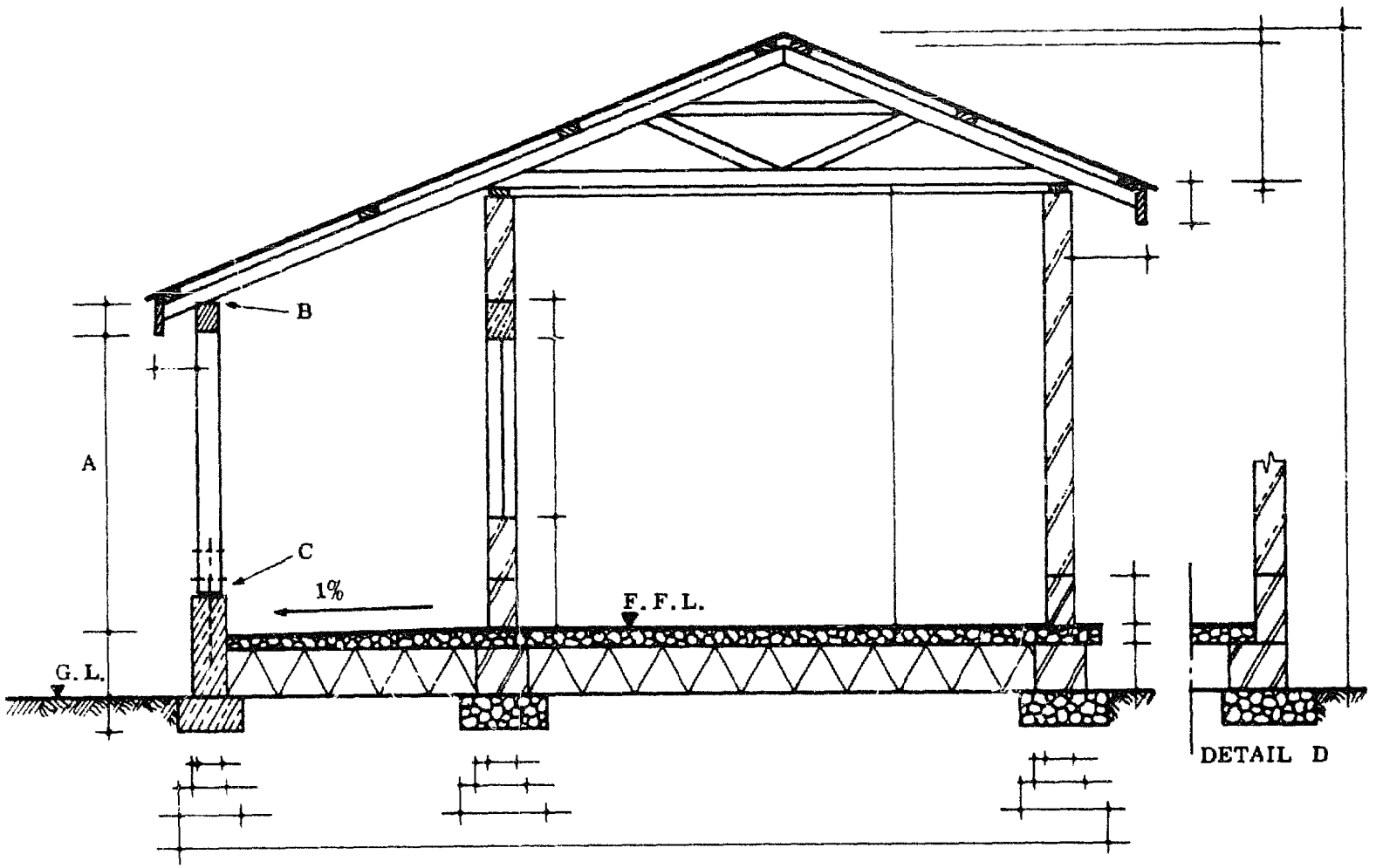

A = HEIGHT IS VERY IMPORTANT

B = NOTICE THE BIRD'S MOUTH

C = WOODEN POST CONSTRUCTION

D = ALTERNATIVE FLOOR CONSTRUCTION

N.P.V.C.

FOUNDATION PLAN

BUILDING WITH VERANDAH

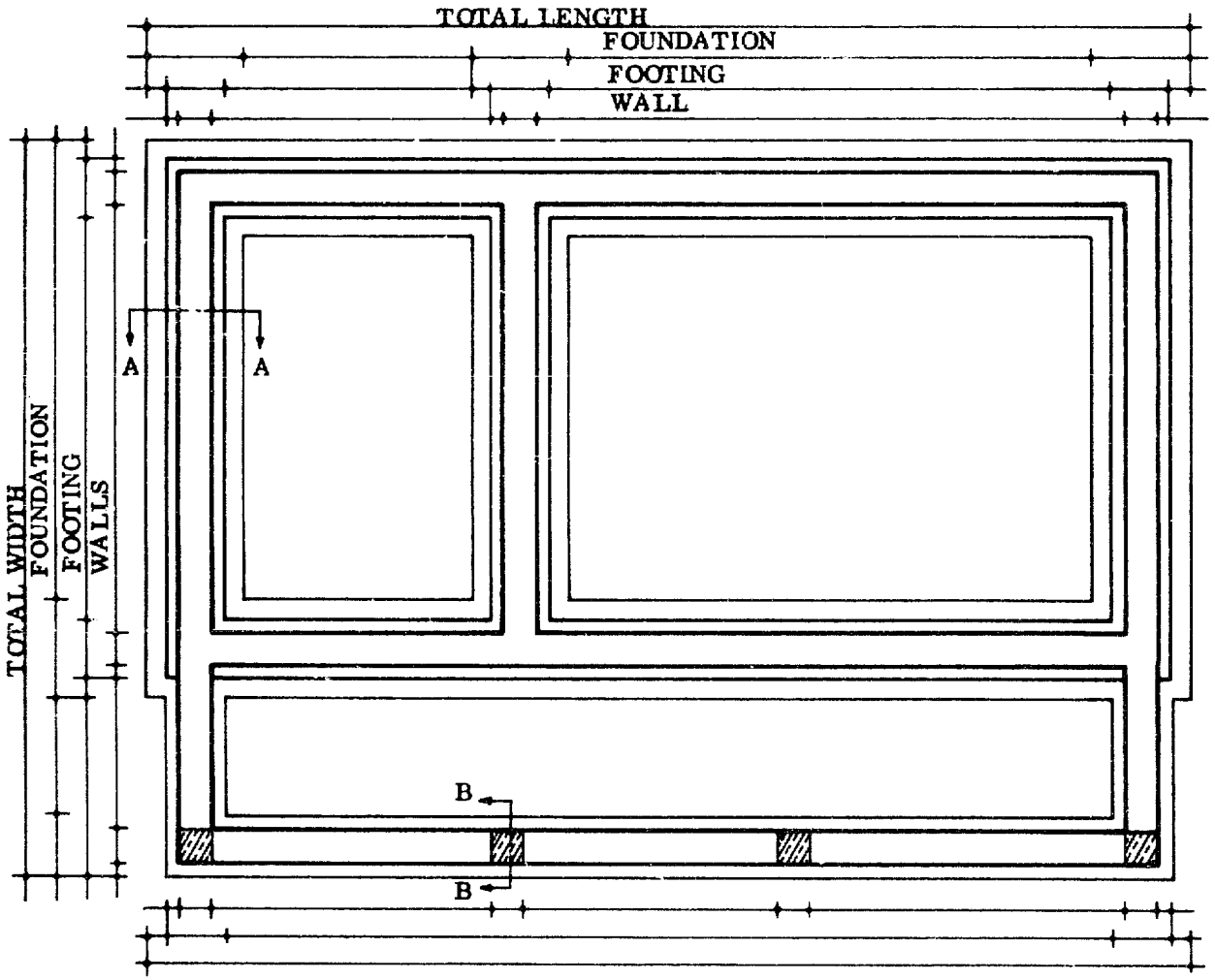

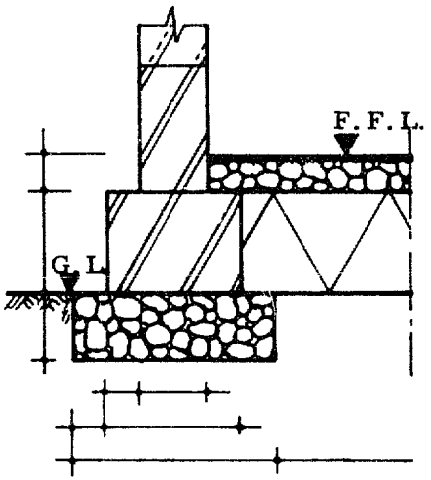

CROSS SECTION A - A

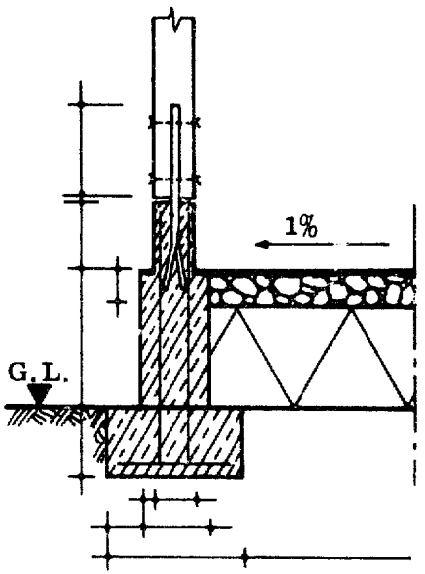

CROSS SECTION B - B

N. P. V. C.	
93.	2 HOURS

SEE ALSO PAGE 92.

GABLE ROOF WITH OVERHANG

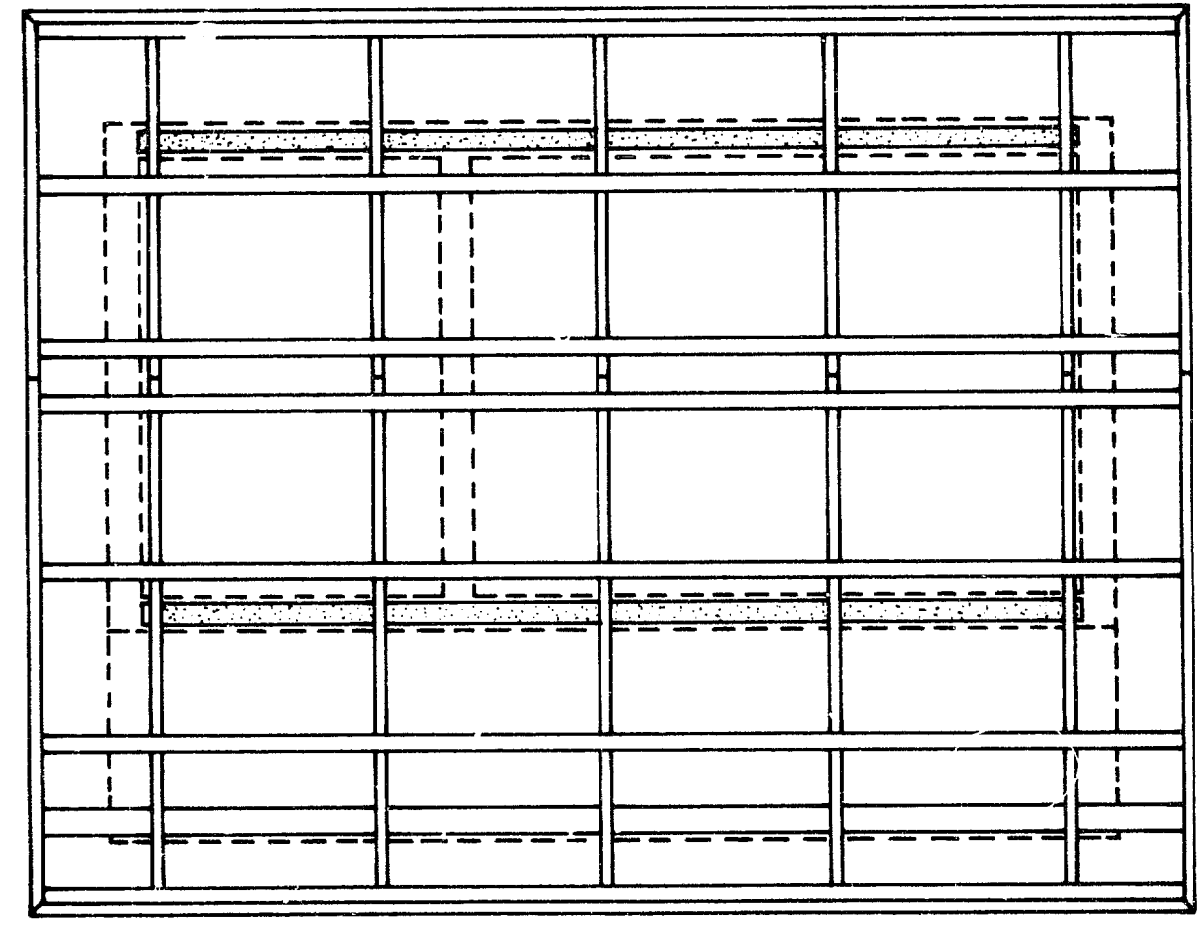

LENGTH OF BUILDING WITH PROJECTION
TRUSSES AND FASCIA BOARDS
TOTAL LENGTH.

WALL PLATE = DOTTED AREAS.
SEE ALSO PAGE 92.

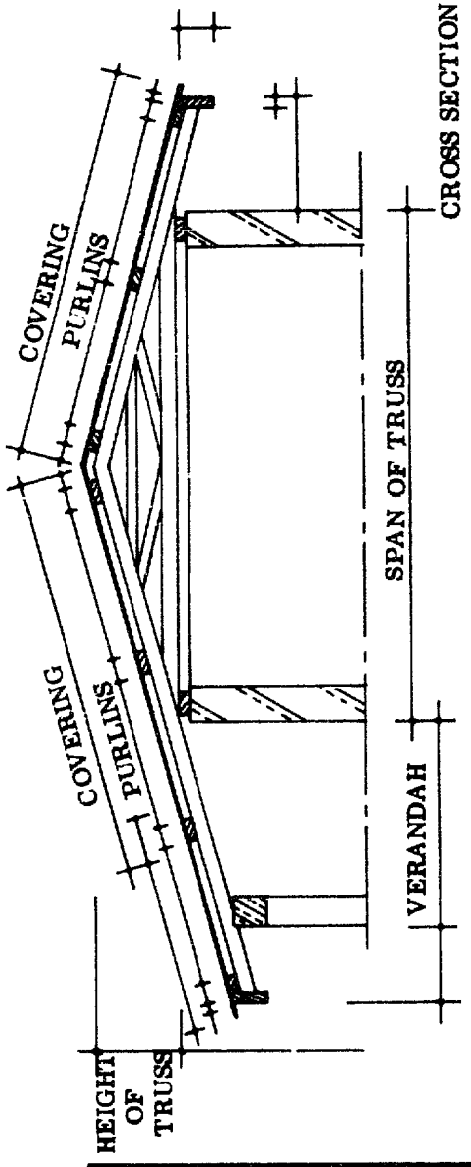

CROSS SECTION

N . P . V . C .	
3½ HOURS	94.

NOTES.

THE PEOPLE

AND THE WAY IN WHICH THEY LIVE

SLEEPING

EATING

WORKING

SPARE TIME

COOKING

WASHING

AND

CUSTOMS

TRADITION

RELIGION

ARE INFORMATION FOR

THE RURAL BUILDER

N. P. V. C.	
FORM IV	96.

BUILDING DESIGN

You have some general technical information about building. Now you can try to make your own designs, with the aid of the basic outlines on the next pages. Keep in mind all that you know about building, and follow a policy of design:

GENERAL POLICY

Plan for the future in your design. Perhaps it may not be possible to build the entire building at once; it may be completed section by section as funds become available. The building can be planned as a whole, properly constructed piece, and then built up over the years. It is better to design what is actually needed than to design something which is not adequate and have to change it, or even abandon it when it cannot be changed into the desired structure.

Remember that a building is a lasting structure. Try to think ahead and lay out the site and the building with the future requirements in mind. Also keep in mind the points listed on page 96. Think about how people do these daily things and design around their needs.

NOTES:

DESIGN POLICY

- EFFICIENCY: This is so that the whole structure will function as it is meant to do. There should be sufficient room for all the activities and for furniture and whatever equipment is needed. Provide ventilation, privacy, protection against insects, and pay attention to water and sewage problems.
- DURABILITY: The building should withstand the stresses of its own weight, and the outside forces such as wind. It should be as protected as possible against attack from weather, dampness, insects, and the normal wear and tear of use. Keep in mind the climate and its influences, and choose your materials with some thought to their durability.
- ECONOMY: Design and erect buildings economically. Plan ahead and have the materials ready to go through with whatever section has been planned. Knowledge about materials, their quality and durability prevents much waste.
- FINISH: Finish the whole as attractively as possible. Finishes not only improve appearance, but they are usually preservatives as well. Appropriate colours make the building pleasant as well as cooler.

NOTES:

LOCATION PLAN

The illustration on the right page shows a piece of land as it looks from the ground, and how it would look if you were above it in an aeroplane looking down. The view you would see from the plane resembles the plan.

A plan tells you all the things which are on the site such as buildings, trees, roads, streams, bridges; and where all of these are located. The plan also shows the orientation of all these features with respect to directions: north, south, east and west; and how the surface of the ground slopes.

It is impossible to properly plan a building without a great deal of knowledge about the land on which it is to be built. The plan is essential to help the builder to design a building which will fit into the surroundings in the most economical and convenient way.

If a building is planned without taking into account the basic information contained in the location plan, it may turn out to be the wrong shape to fit the site. It may be more costly to build because it is not placed correctly along the "contours" of the land. It may be uncomfortable to live in if it is facing into the hot afternoon sun. It may be hard to reach if there is not a good entrance way from the road.

The following pages contain some information about the factors which need to be considered about the site when you are planning a building. These include the measurements of the site and plot, the building regulations and restrictions, the direction of the breeze and of storms, the slope of the site, the direction of the sun's rays at different times of day: all of these need to be considered when planning so that the building will be comfortable to live in and economical to build.

YOU WOULD SEE ONLY THE ROOFS OF THE BUILDINGS AND THE TOPS OF THE TREES, SO THE VIEW YOU WOULD SEE IS LIKE THIS:

IF YOU LOOK DOWN FROM AN AEROPLANE:

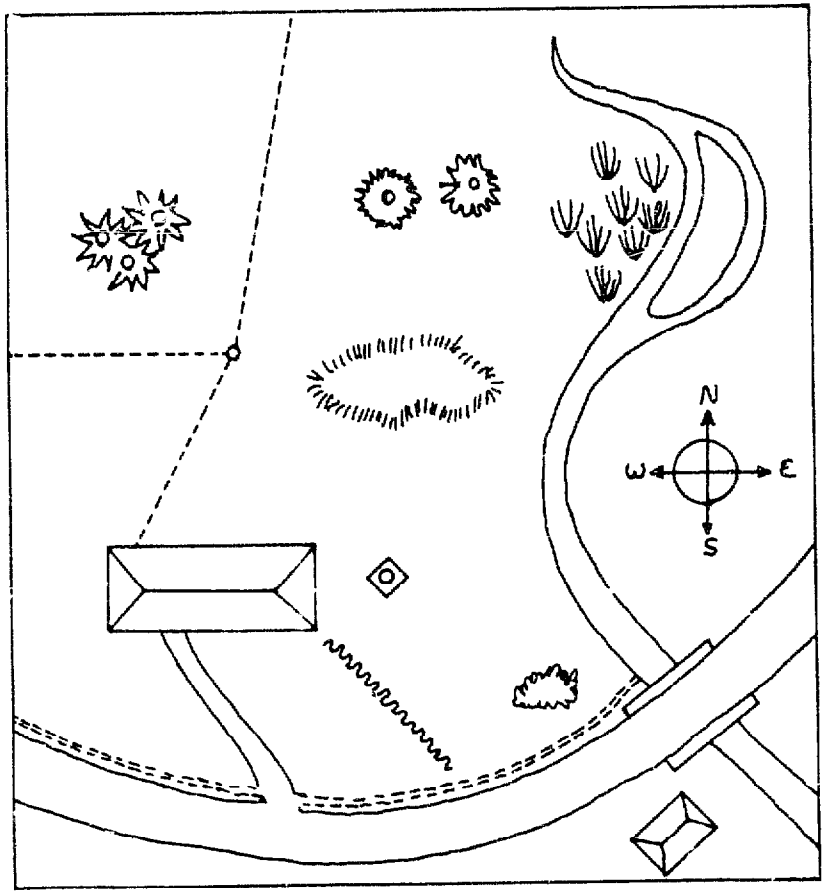

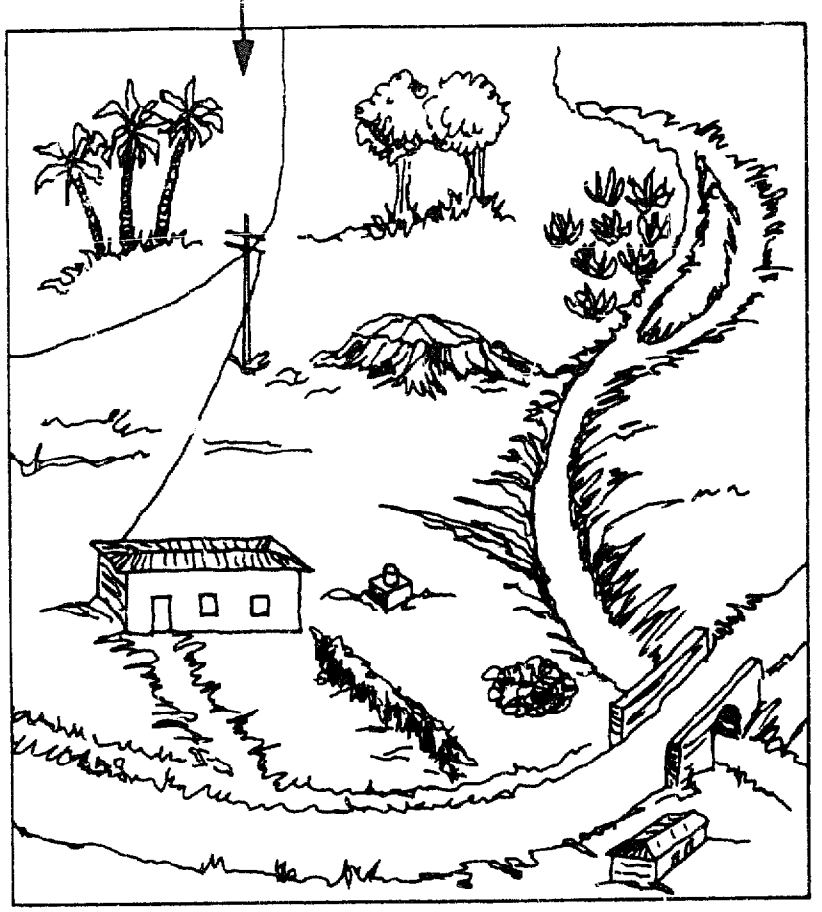

THIS VIEW IS A PLAN OF THE LAND AND MAY BE CALLED A MAP OR SURVEY PLAN.

PICTORIAL VIEW

BOUNDARY LINE

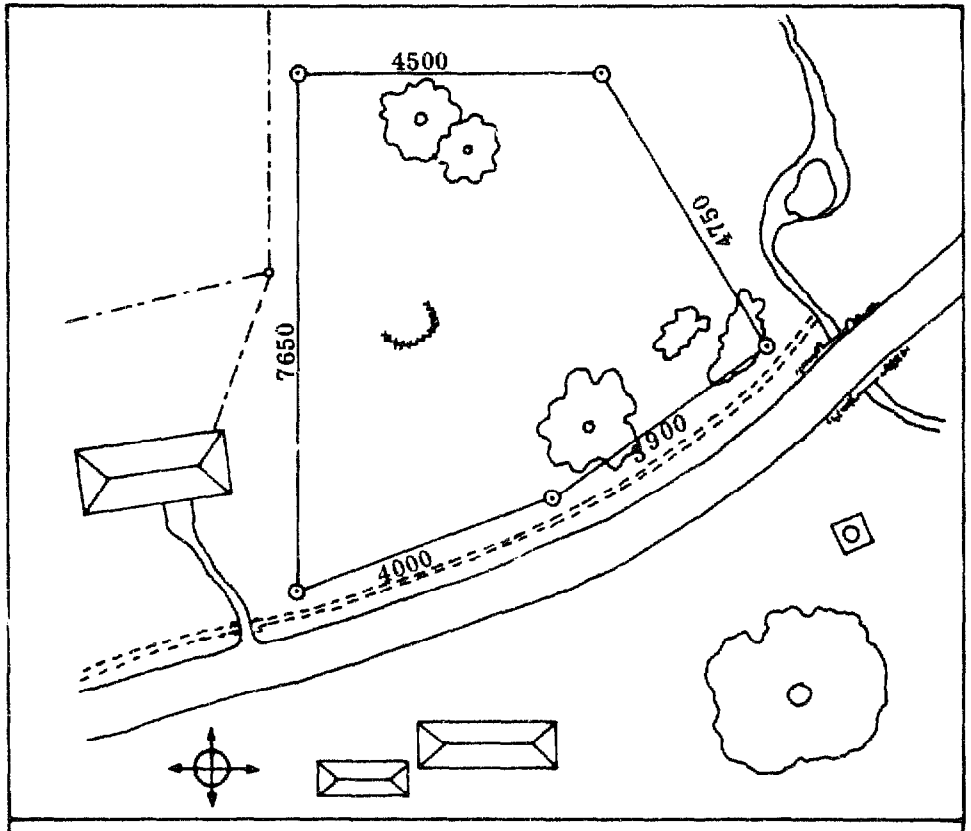

SCALE : 1 : 1000 (cm) PLAN No 145 - B

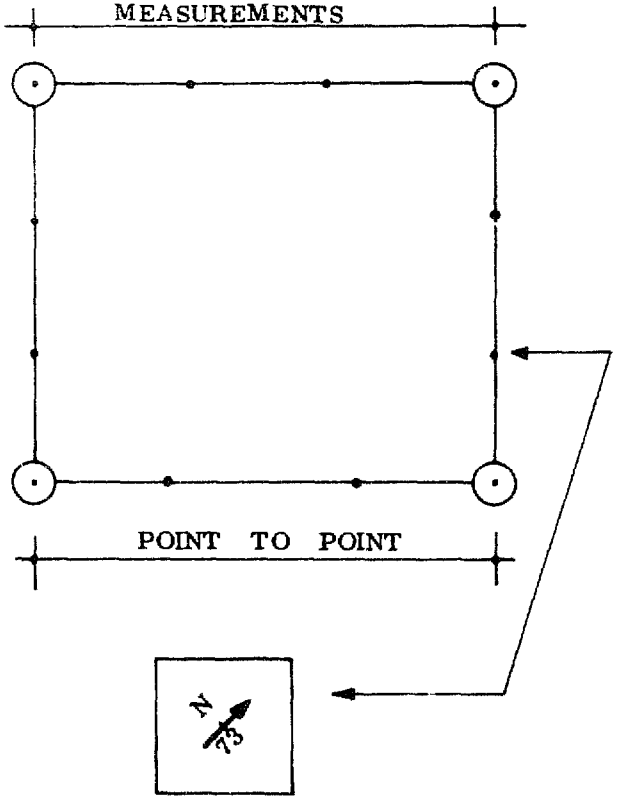

"BOUNDARY STONE". THE ARROW IS FACING THE NORTH. THE NEXT STONE IS 73 METRES AWAY.

SITE PLANS HAVE THE LENGTHS WRITTEN ALONG THE BOUNDARIES SO THAT THE EXACT LOCATION OF THE PLOT IS KNOWN.

N . P . V . C .	
101.	

BUILDING LINE

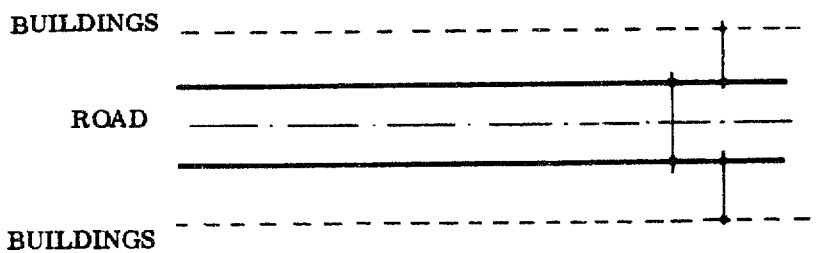

IN PLANNED TOWNS NO BUILDING IS ALLOWED TO REACH TO THE EDGE OF THE ROAD: A BUILDING HAS TO BE A CERTAIN DISTANCE AWAY FROM THE ROAD TO ALLOW FOR FUTURE ROAD WIDENING AND SO THAT THERE IS ENOUGH SPACE BETWEEN BUILDINGS.

SITE COVERAGE

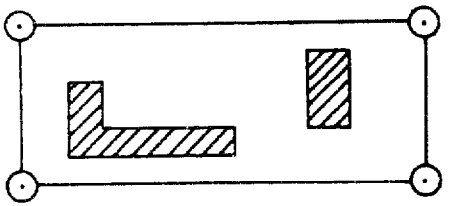

IN SOME TOWNS THERE ARE RULES ABOUT HOW MUCH LAND CAN BE BUILT OVER: FOR SO MANY SQUARE METRES OF LAND, THE BUILDINGS CAN TAKE UP ONLY A CERTAIN AMOUNT OF THE SPACE. IN ADDITION, THE BUILDINGS USUALLY HAVE TO BE A CERTAIN DISTANCE AWAY FROM THE PLOT BOUNDARIES. THIS IS TO MAKE SURE THAT THE BUILDINGS WILL HAVE PLENTY OF LIGHT AND AIR SO THEY ARE HEALTHY TO LIVE IN.

BREEZE

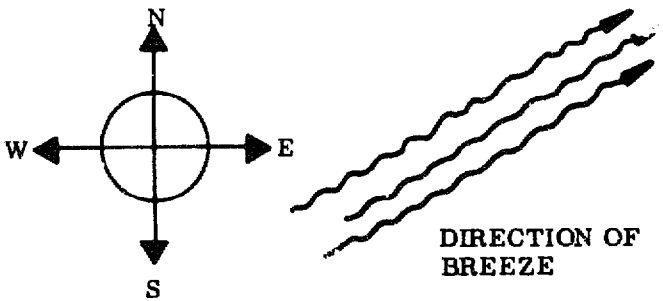

IN HOT WET CLIMATES, IT IS IMPORTANT TO HAVE A BREEZE BLOWING THROUGH THE BUILDING SO THAT THE PEOPLE INSIDE ARE COOLER.

THE DIRECTION OF THE PREVAILING BREEZE (THE USUAL DIRECTION THE BREEZE COMES FROM) IS MARKED ON THE PLANS.

STORMS

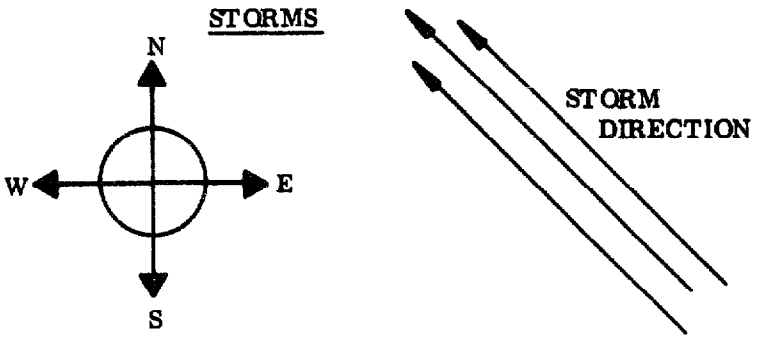

IN AREAS WHICH GET BAD STORMS, THE RURAL BUILDER WILL PLAN THE BUILDING SO THAT THE OPENINGS WHICH FACE THE STORM ARE PROTECTED.

BUILDING ALONG THE CONTOURS

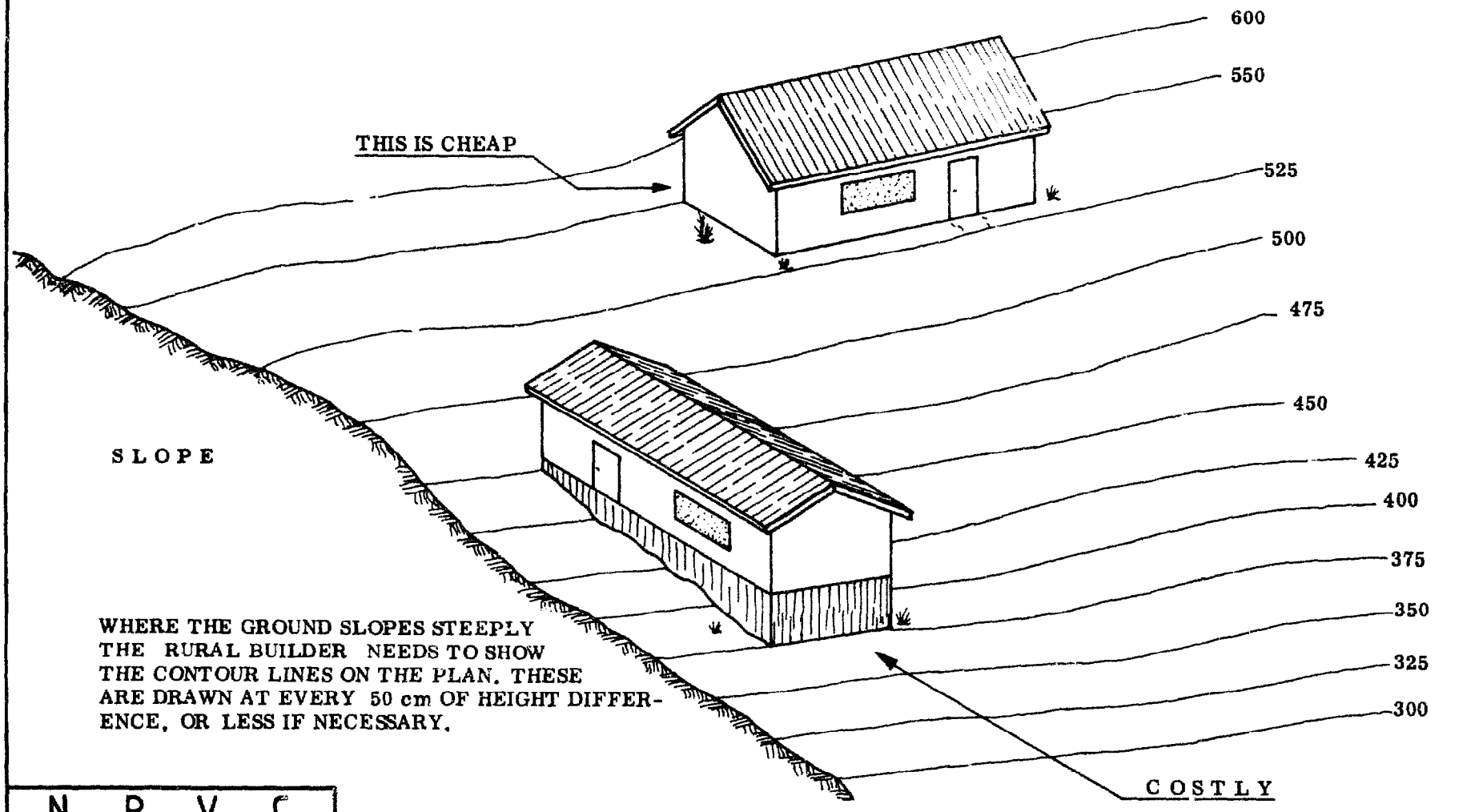

WHERE THE GROUND SLOPES STEEPLY THE RURAL BUILDER NEEDS TO SHOW THE CONTOUR LINES ON THE PLAN. THESE ARE DRAWN AT EVERY 50 cm OF HEIGHT DIFFERENCE, OR LESS IF NECESSARY.

N.P.V.C.

103.

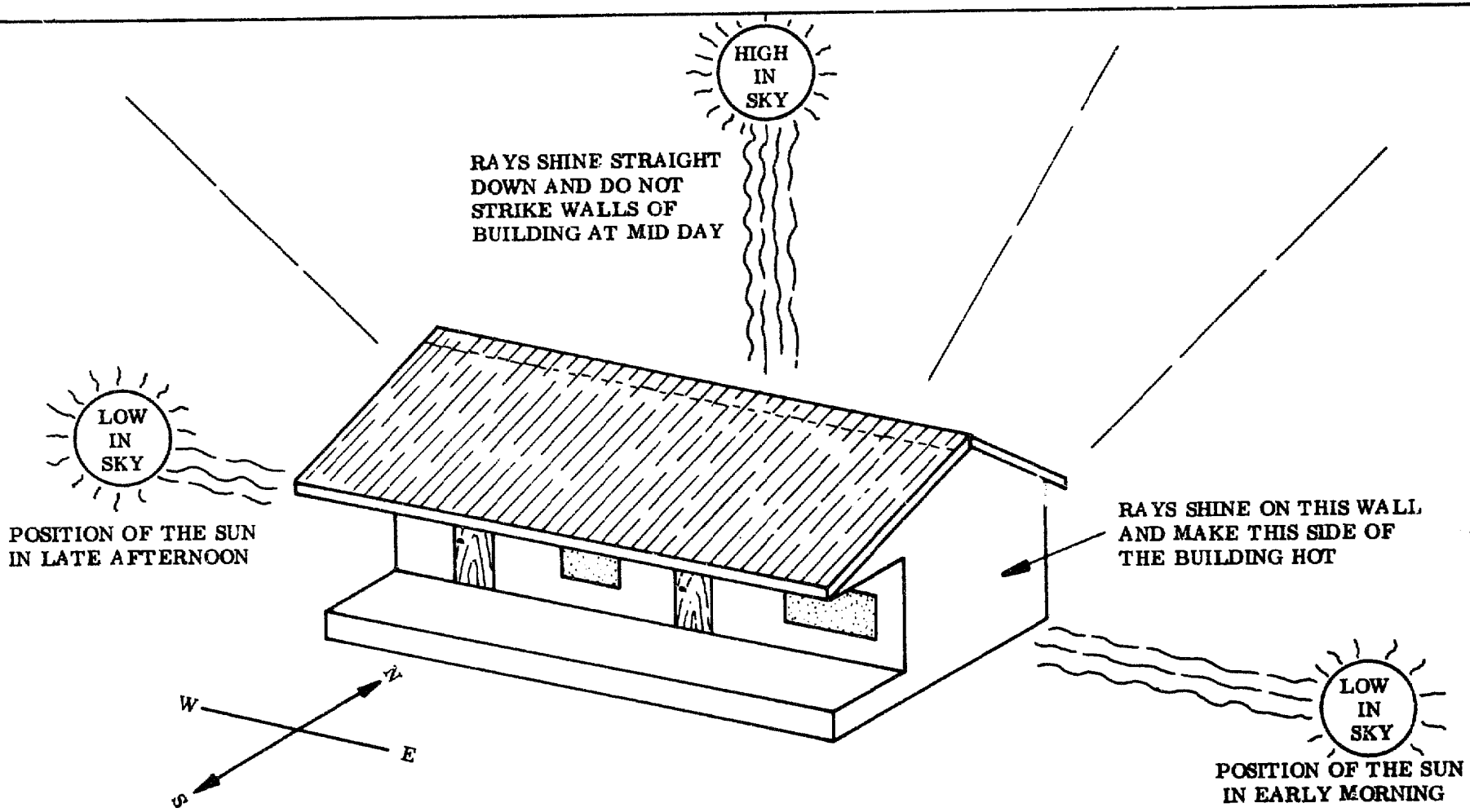

BUILDINGS WHICH HAVE THE LONG SIDES FACING NORTH AN' SOUTH AND HAVE A VERANDAH ARE COOLEST AND MOST COMFORTABLE IN HOT COUNTRIES BECAUSE THE SUN SHINES ON THE SHORT SIDES ONLY.

N. P. V. C.

DESIGNING BUILDINGS TO WITHSTAND STRONG WINDS

Many buildings are not strong enough to resist the forces of very strong winds. They may be destroyed and the people inside can be injured or even killed. The guidelines here aim to help the Rural Builder to design and construct buildings so that such occurrences are reduced in the future. The point of these guidelines is to reduce the force of the wind against the building, and to make the building more resistant to wind forces. The following points are illustrated on the right.

A - Take advantage of natural windbreaks such as trees or hedges when deciding on the site for the building. Such a location can reduce the force of the wind.

B Sites on hills and near hilltops can have much higher windspeeds.

C - Valleys can funnel winds and create higher windspeeds.

D - The pitch of the roof is very important. This should be between 15 and 20 degrees.

E - A hip roof resists wind forces better than a gable roof.

F - Avoid making large overhangs, even if they are supported by columns. Locate verandahs away from the direction of the strongest winds.

G - A parapet around the roof helps to reduce the wind force along the roof edges.

H - Avoid making large openings such as doors or windows near the roof line or near the corners of walls. These tend to weaken the structure if they are located where the loads are greatest.

I - Make sure that every part of the building is secured: the roof parts to each other, the roof itself to the walls, the walls to the other walls, the walls to the floors, the floor to the foundations. The foundations should rest on firm soil if possible.

- REMEMBER: Whatever the form of roof construction, the parts of the roof must be securely tied together. Anchor the whole structure to the building. Ignoring this precaution means that the roof will almost certainly be damaged in any strong wind.

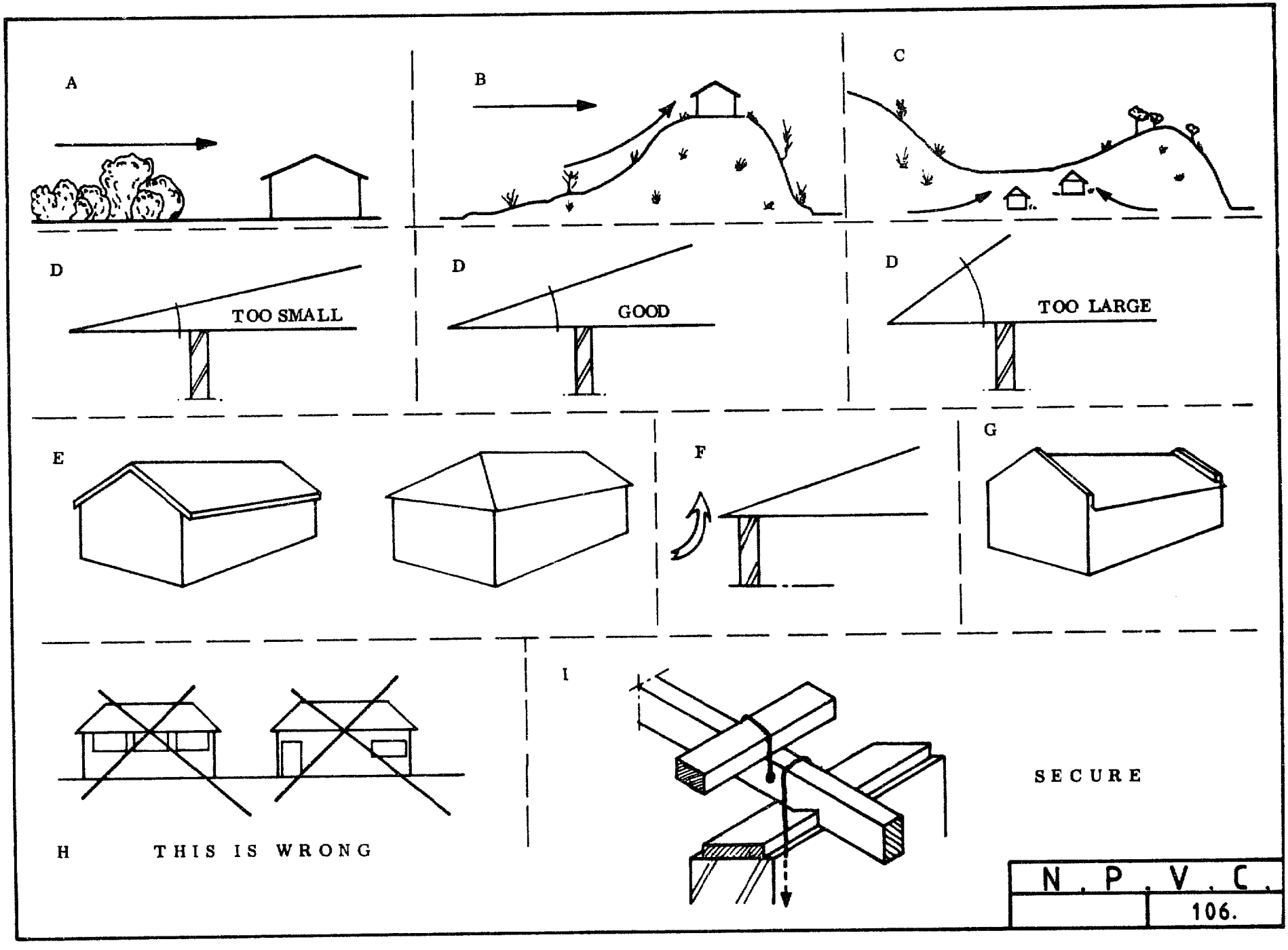
A
B
C
D
TOO SMALL
D
GOOD
D
TOO LARGE
E
F
G
H
THIS IS WRONG
I
SECURE
N . P . V . C .
106.

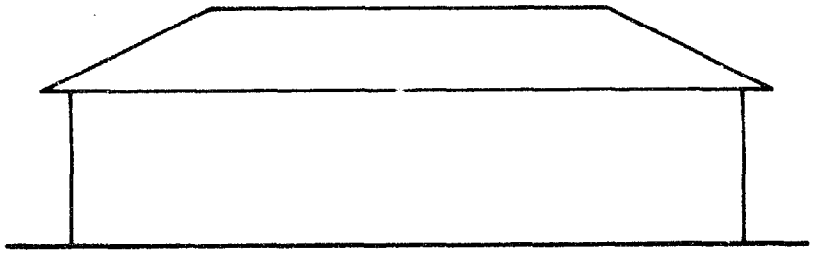

NORTH ELEVATION

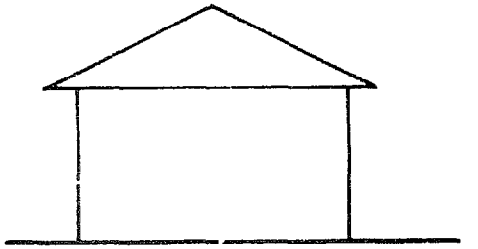

EAST ELEVATION

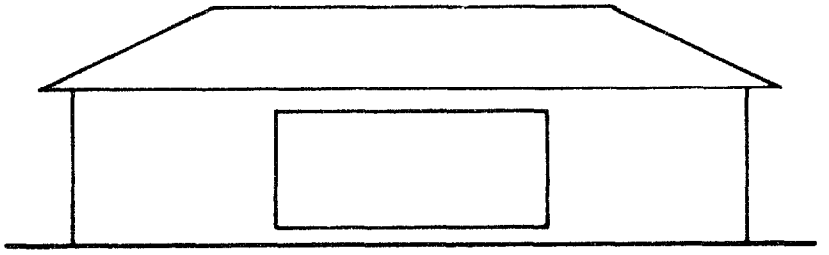

SOUTH ELEVATION

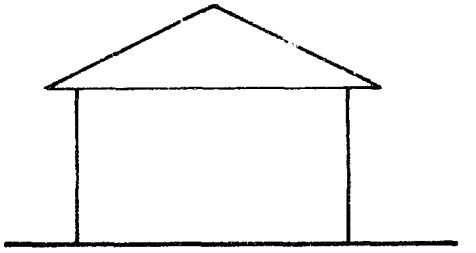

WEST ELEVATION

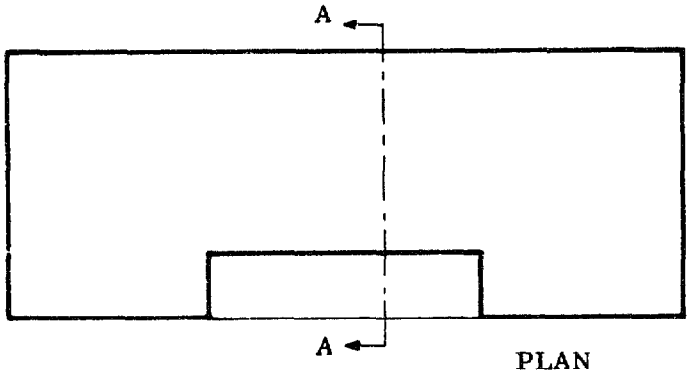

PLAN

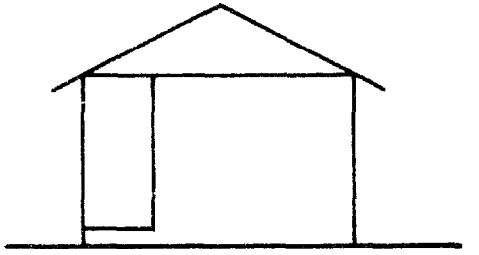

CROSS SECTION A - A

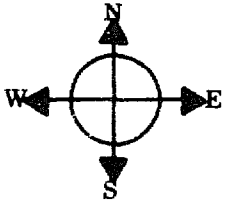

BASIC OUTLINE OF BUILDING UNIT WITH ENCLOSED VERANDAH

N . P . V . C .	
107.	

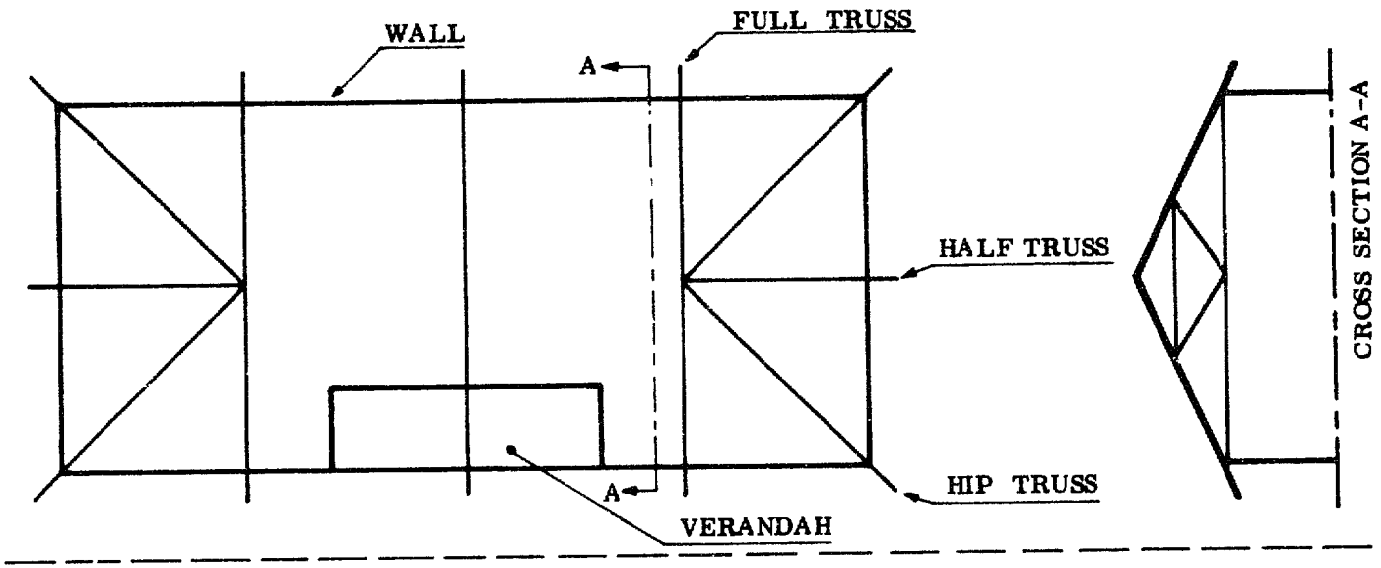

1st STAGE

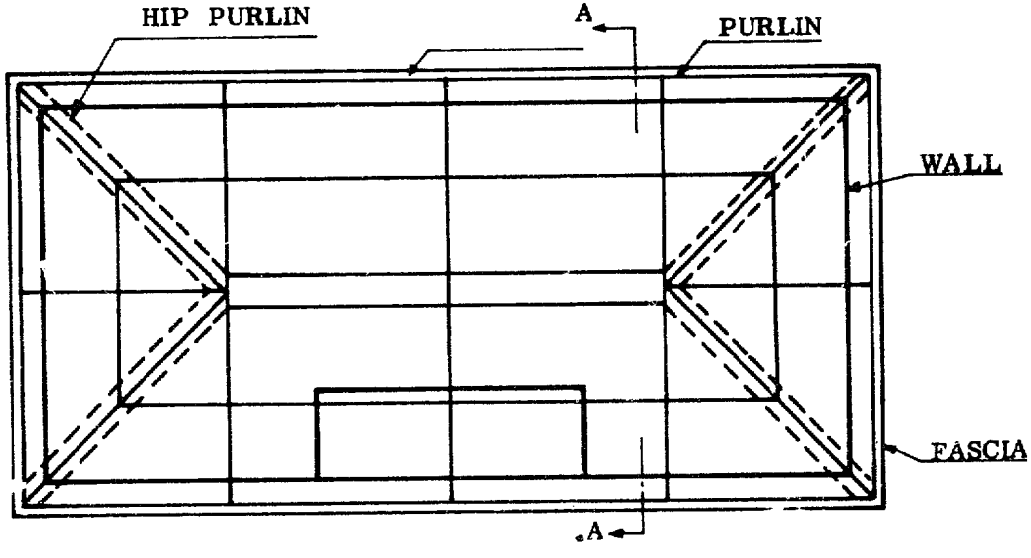

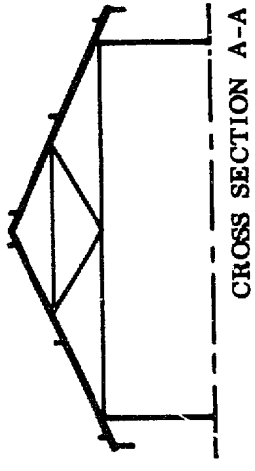

2nd STAGE

BASIC OUTLINE FOR HIP ROOF CONSTRUCTION

N . P . V . C .	
	108

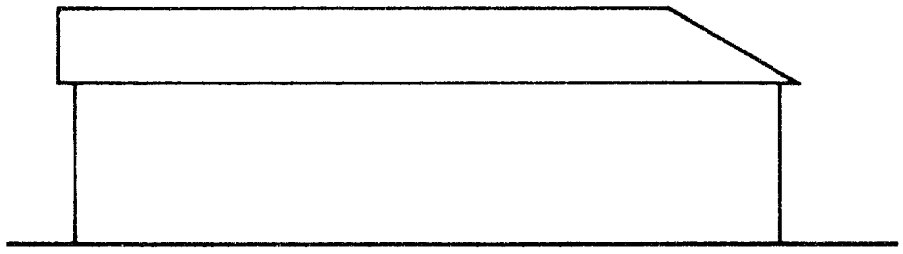

NORTH ELEVATION

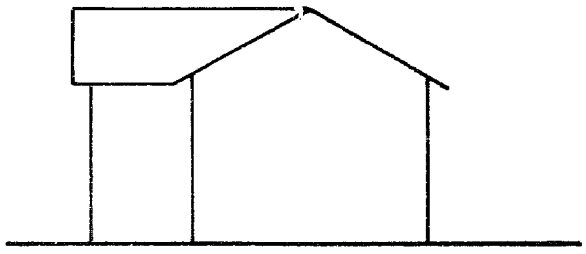

EAST ELEVATION

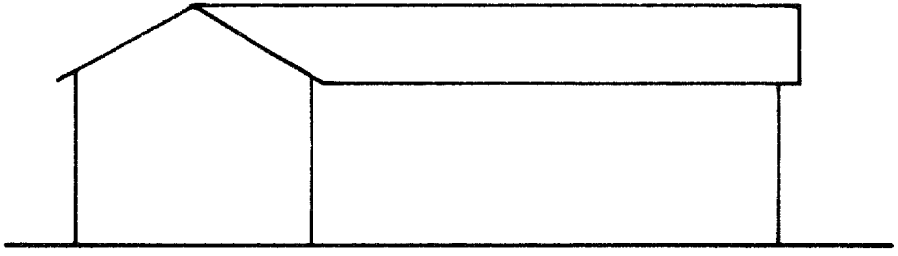

SOUTH ELEVATION

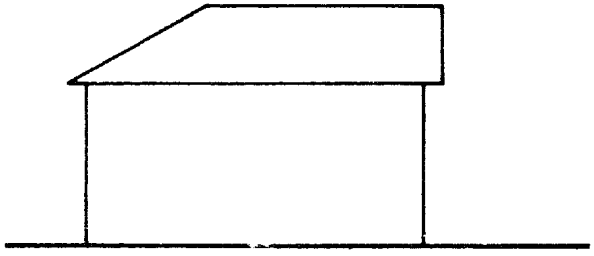

WEST ELEVATION

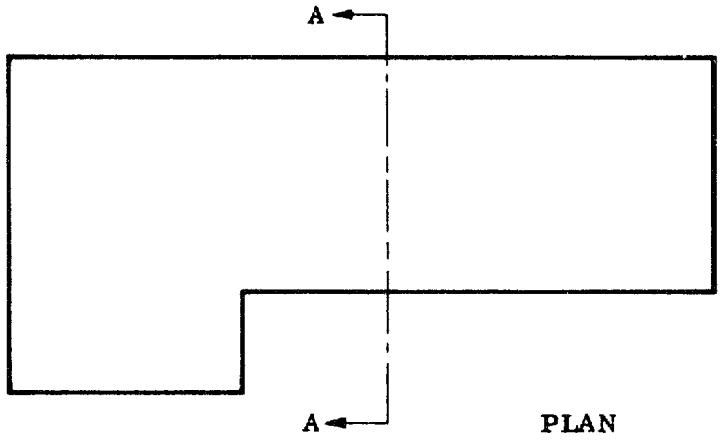

PLAN

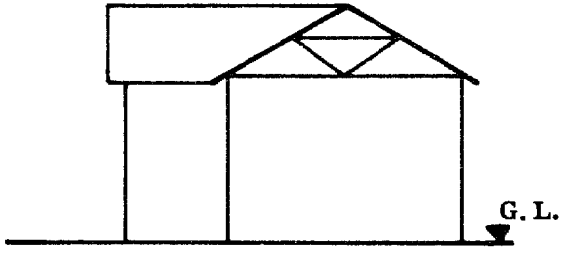

CROSS SECTION A-A

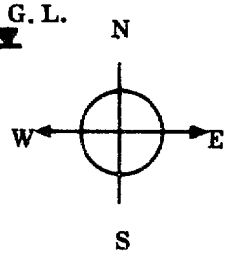

BASIC OUTLINE "L" SHAPED BUILDING UNIT

N . P . V . C .	
109.	

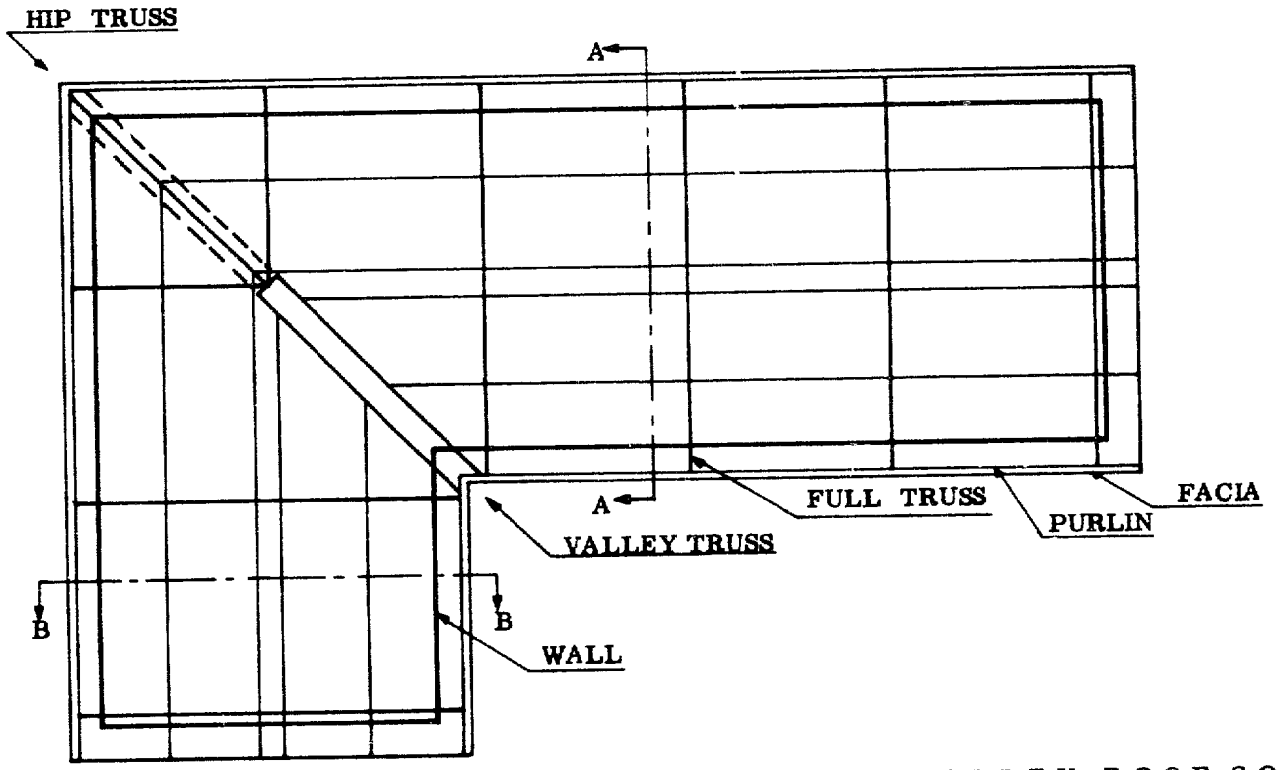

PLAN

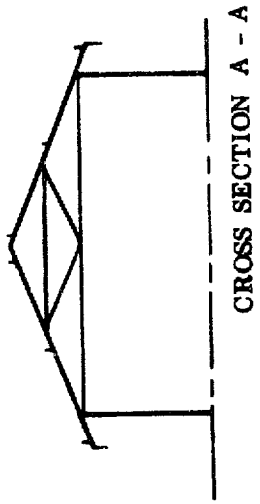

HIP & VALLEY ROOF CONSTRUCTION

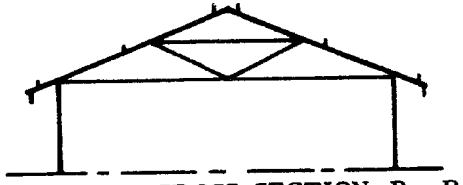

CROSS SECTION B - B

BASIC OUTLINE " L " SHAPED ROOF CONSTRUCTION

N . P . V . C .	
	110.

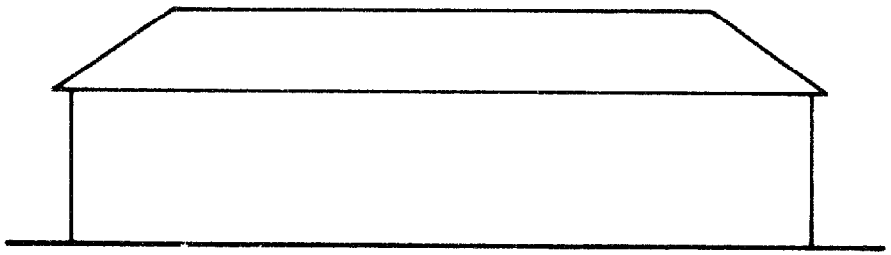

NORTH ELEVATION

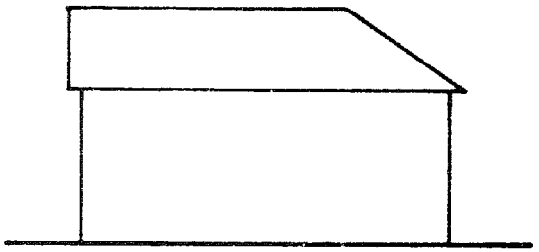

EAST ELEVATION

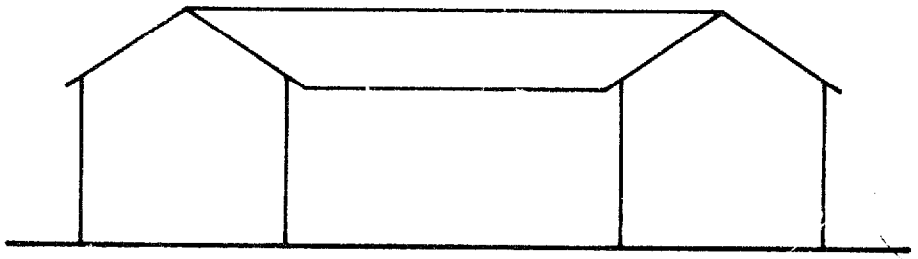

SOUTH ELEVATION

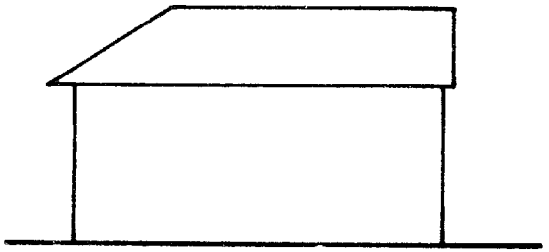

WEST ELEVATION

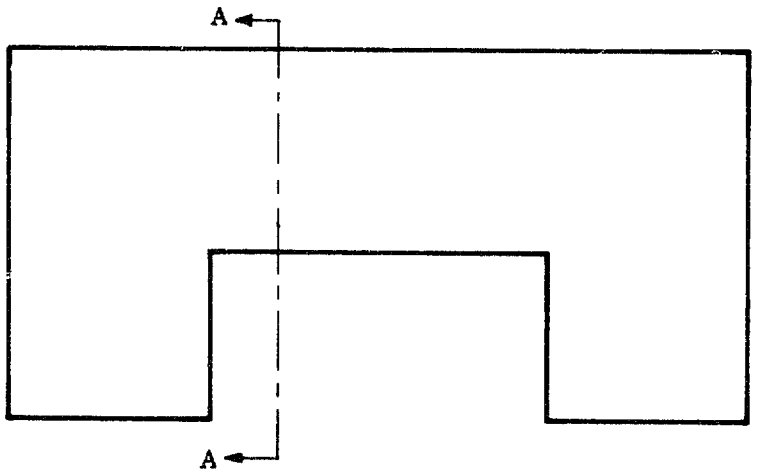

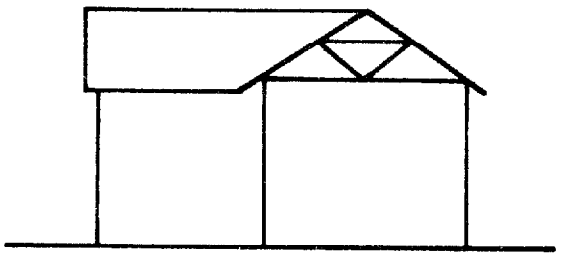

CROSS SECTION A-A

BASIC OUTLINE "U" SHAPED BUILDING UNIT

N.P.V.C.	
111.	

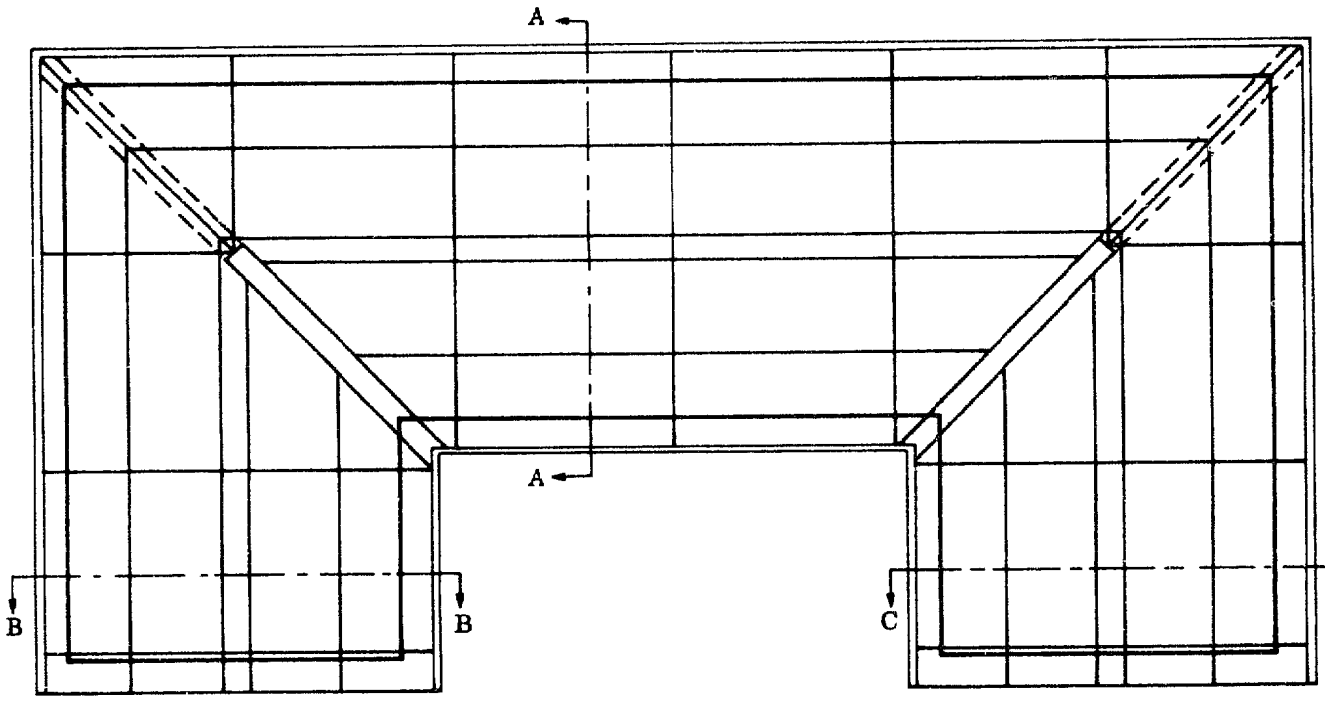

PLAN

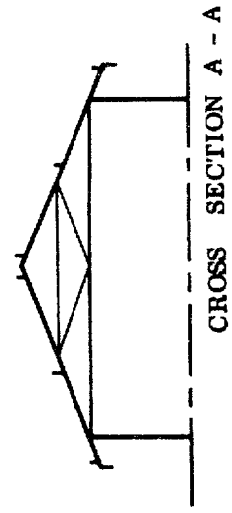

CROSS SECTION A - A

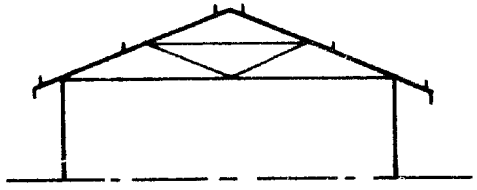

CROSS-SECTION B - B

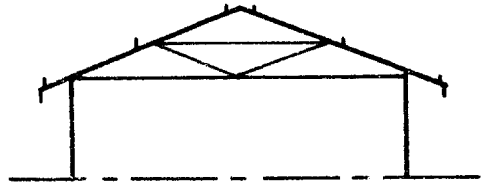

CROSS SECTION C - C

BASIC OUTLINE "U" SHAPED ROOF CONSTRUCTION

N. P. V. C.	
	112.

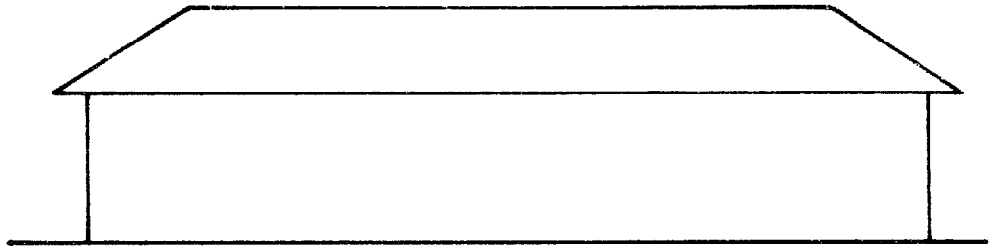

NORTH ELEVATION

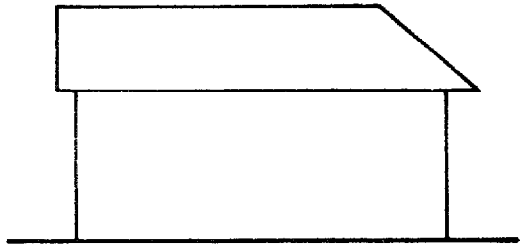

EAST ELEVATION

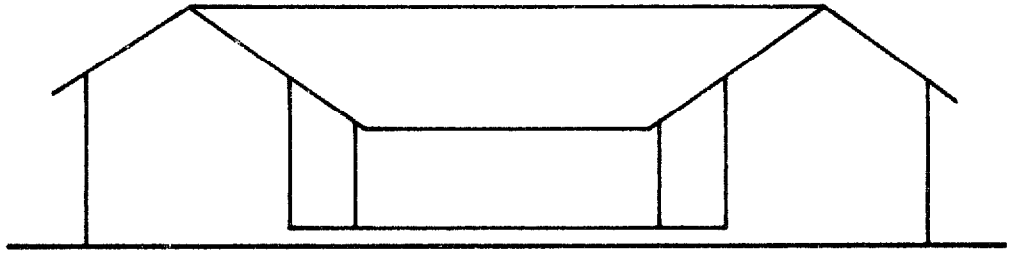

SOUTH ELEVATION

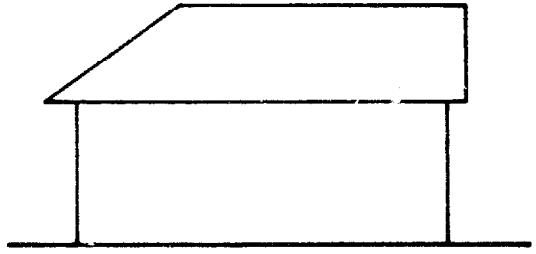

WEST ELEVATION

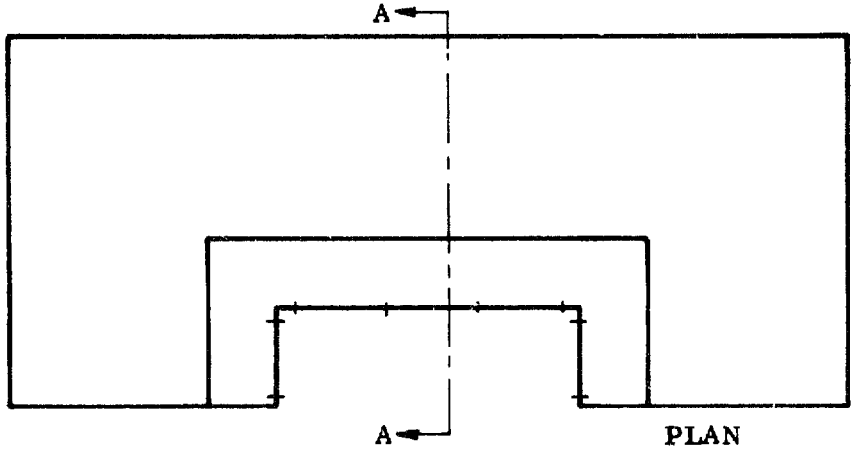

PLAN

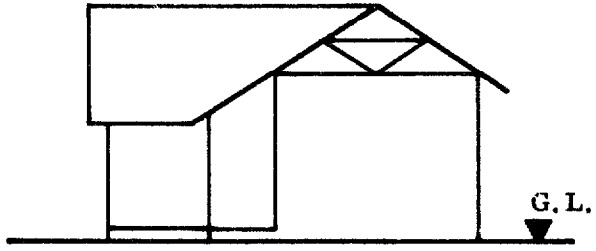

CROSS SECTION A - A

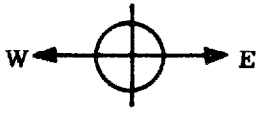

N . P . V . C .	
113.	

BASIC OUTLINE "U" SHAPED BUILDING UNIT
WITH RAFTER EXTENDING OVER VERANDAH

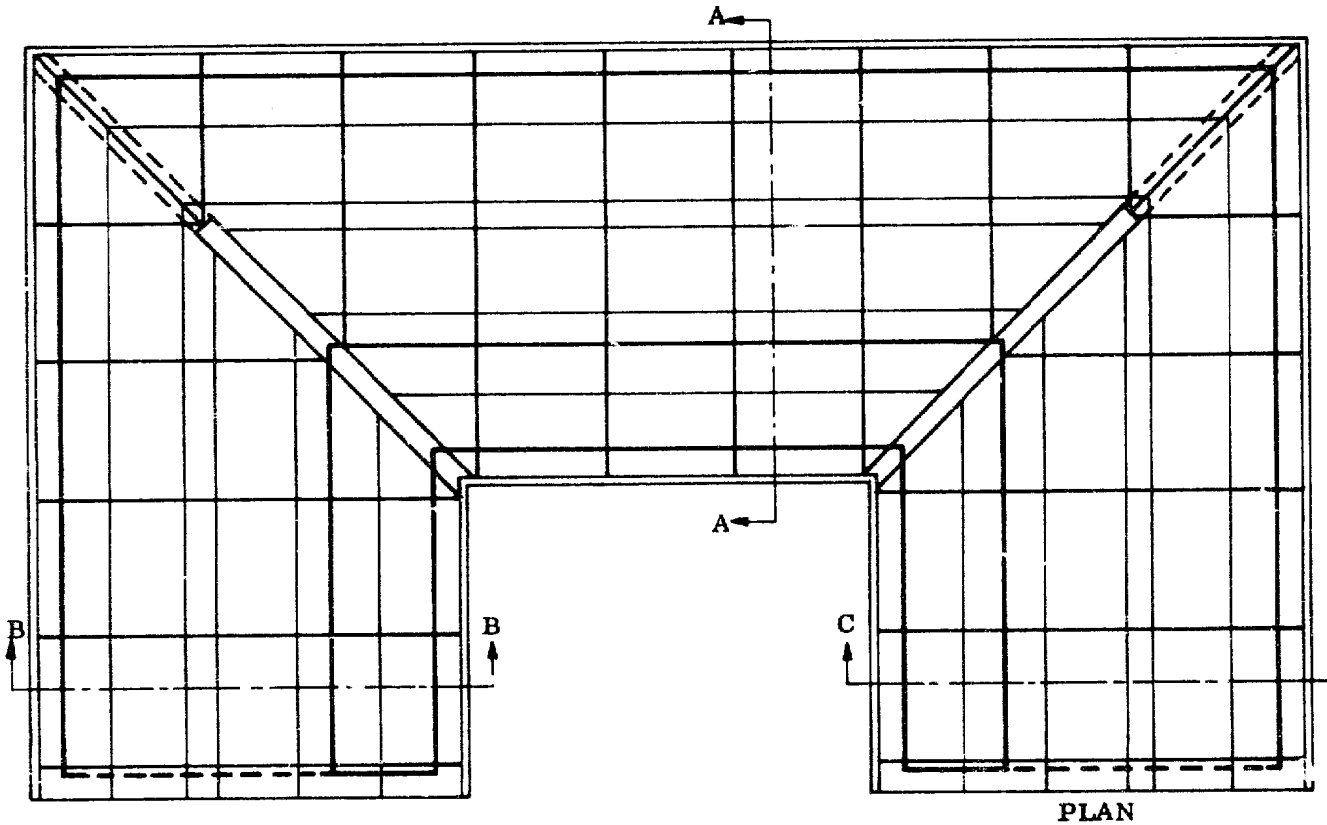

PLAN

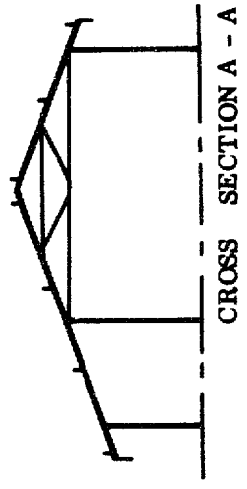

CROSS SECTION A - A

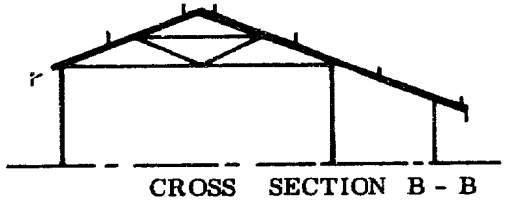

CROSS SECTION B - B

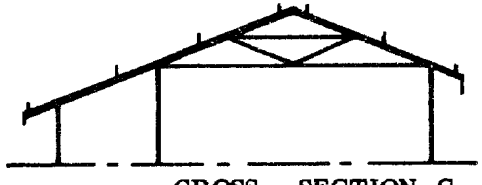

CROSS SECTION C - C

BASIC OUTLINE "U" SHAPED ROOF WITH RAFTER EXTENDING OVER VERANDAH

N. P. V. C.	
	114.

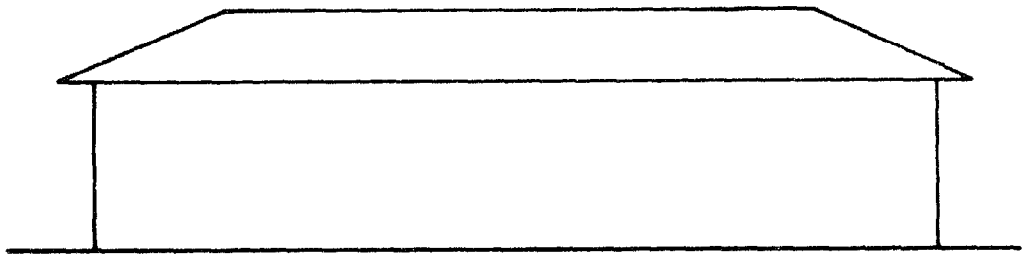

NORTH ELEVATION

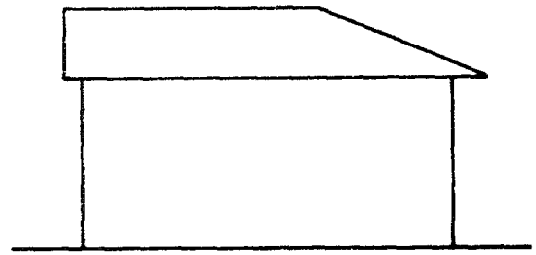

EAST ELEVATION

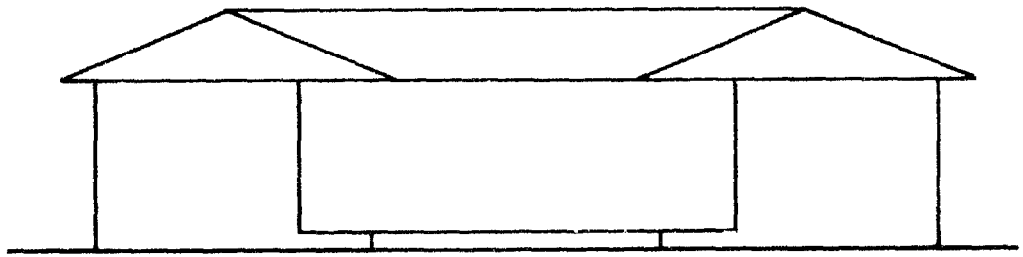

SOUTH ELEVATION

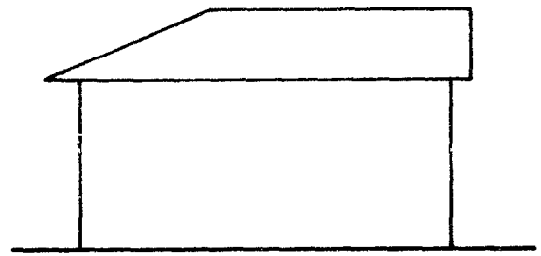

WEST ELEVATION

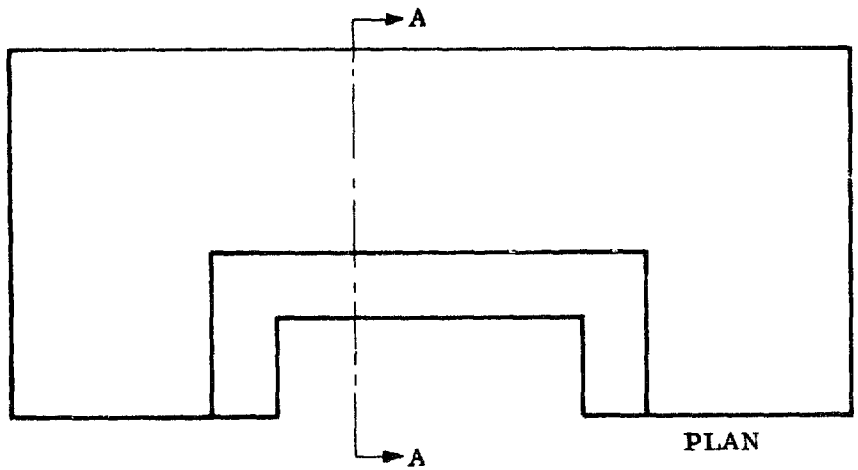

PLAN

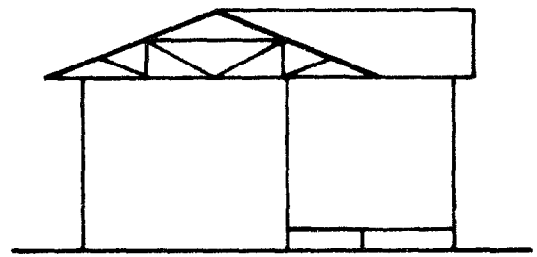

CROSS SECTION A - A

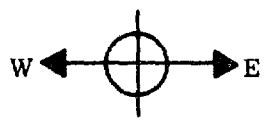

N . P . V . C .	
115.	

BASIC OUTLINE "U" SHAPED BUILDING UNIT
WITH TIE BEAM EXTENDING OVER VERANDAH

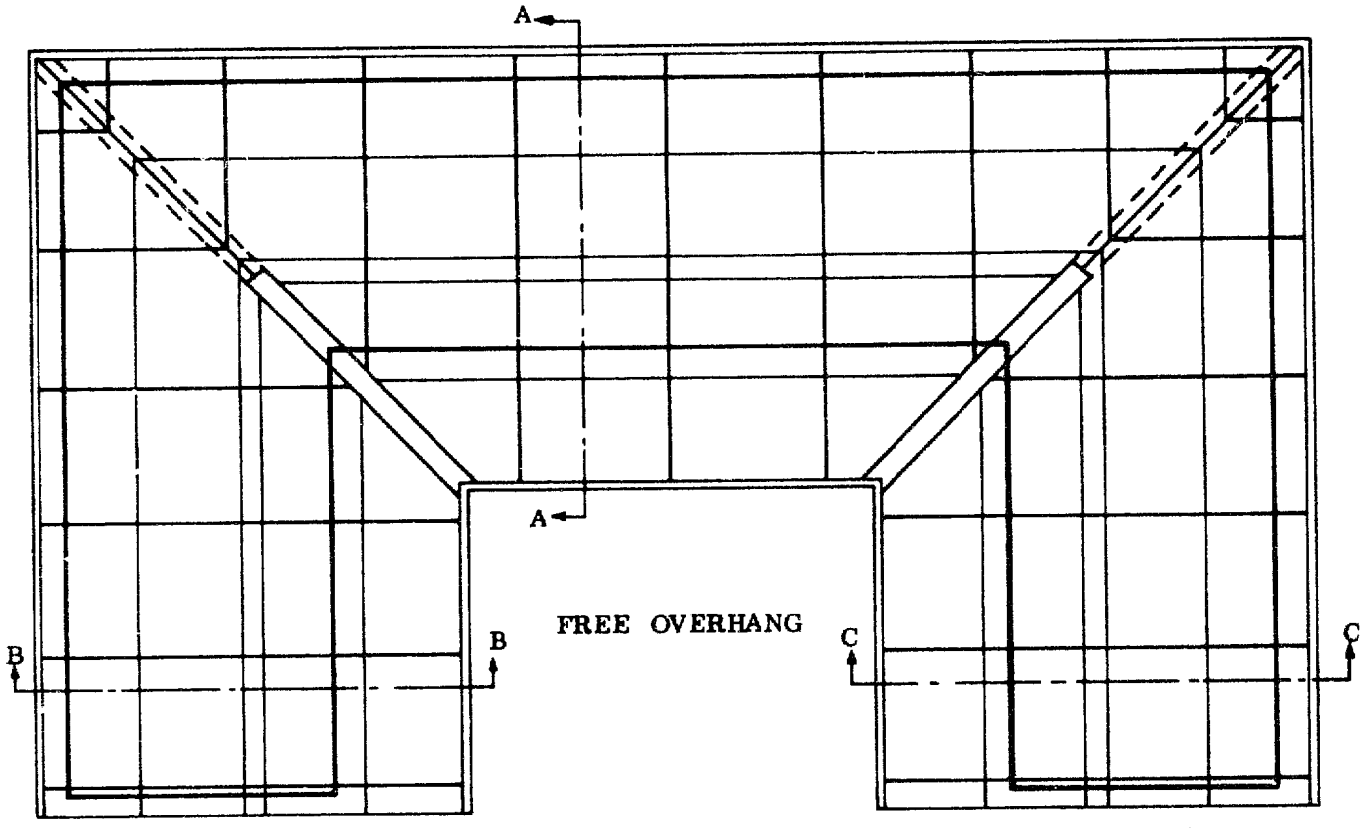

PLAN

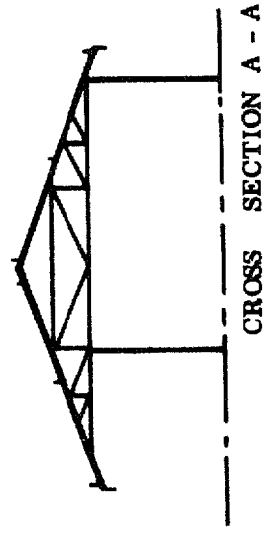

FREE OVERHANG
NEEDS
EXTRA BRACES

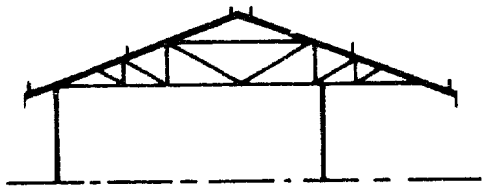

CROSS SECTION A - A

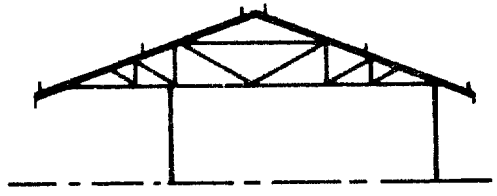

CROSS SECTION B - B

BASIC OUTLINE "U" SHAPED ROOF WITH TIE BEAM
EXTENDING OVER VERANDAH

N . P . V . C .	
	116.

d = LENGTH OF BLOCK

COURSE 2 - 4 ETC.

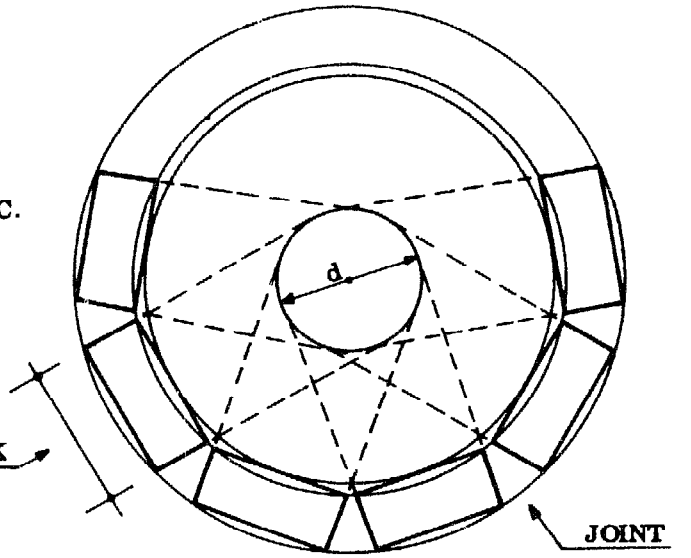

TOP VIEW

COURSE 1 - 3 ETC.

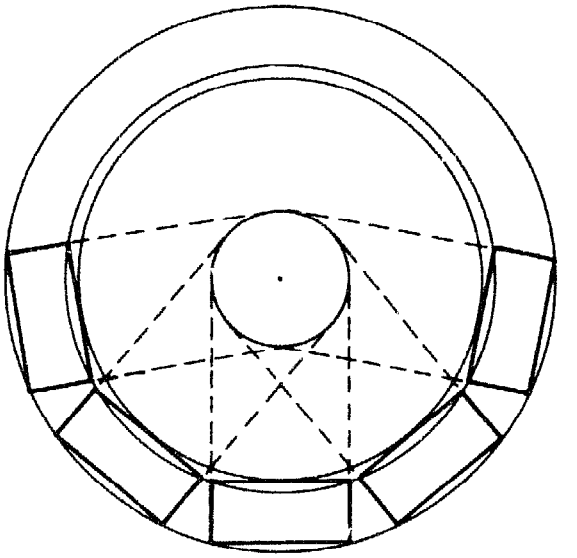

TOP VIEW

CIRCULAR WORK

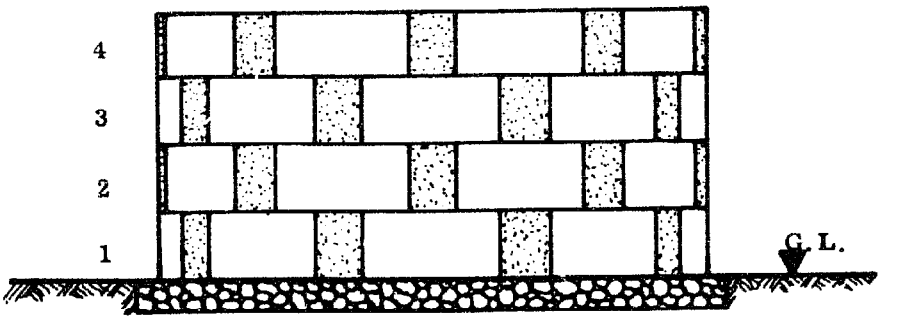

SIDE VIEW

N. P. V. C.

117.

GRAIN SILO

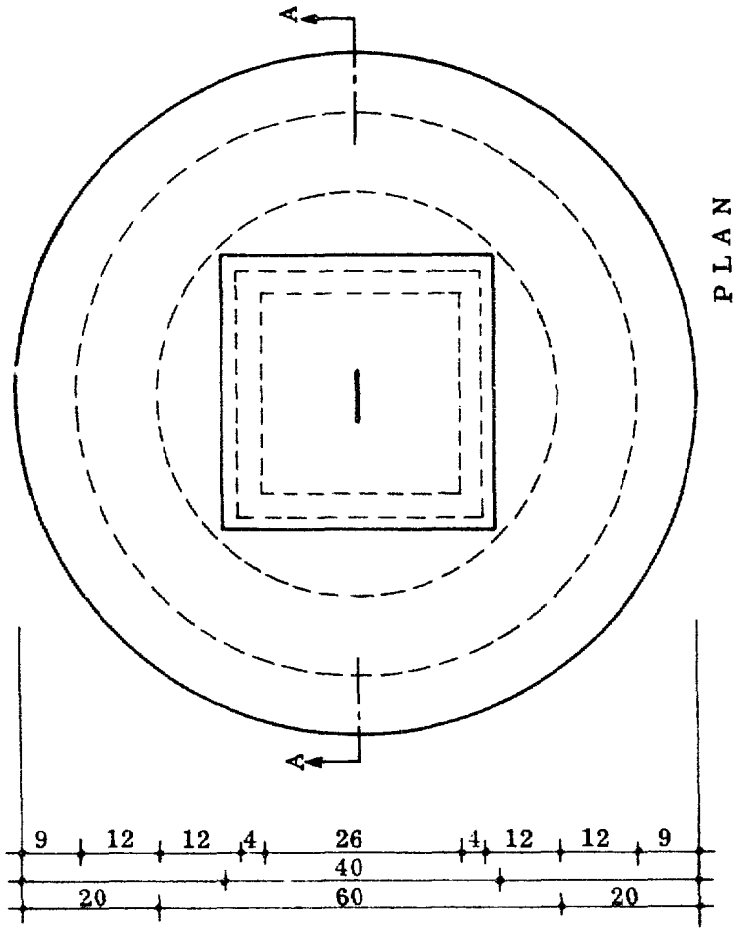

PLAN

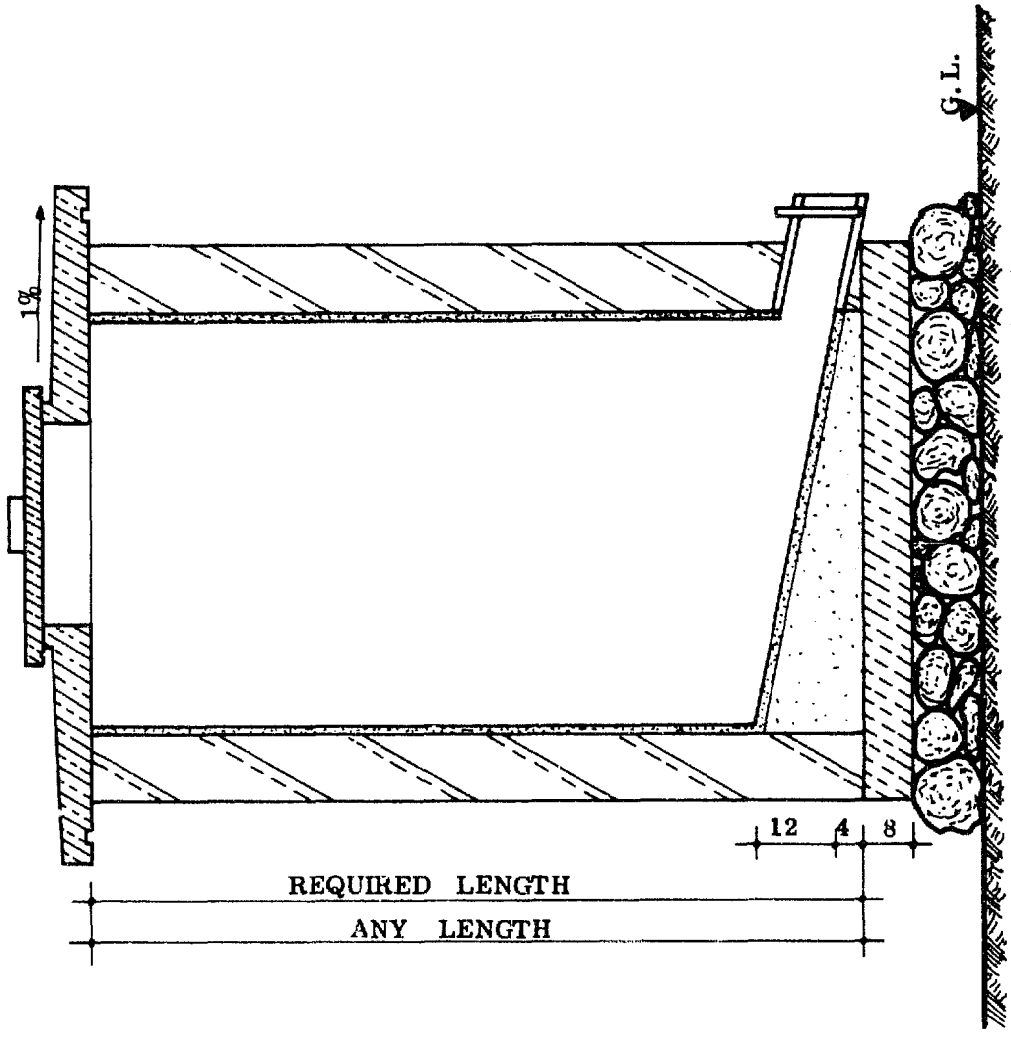

CROSS SECTION A - A

N. P. V. C.	
	118.

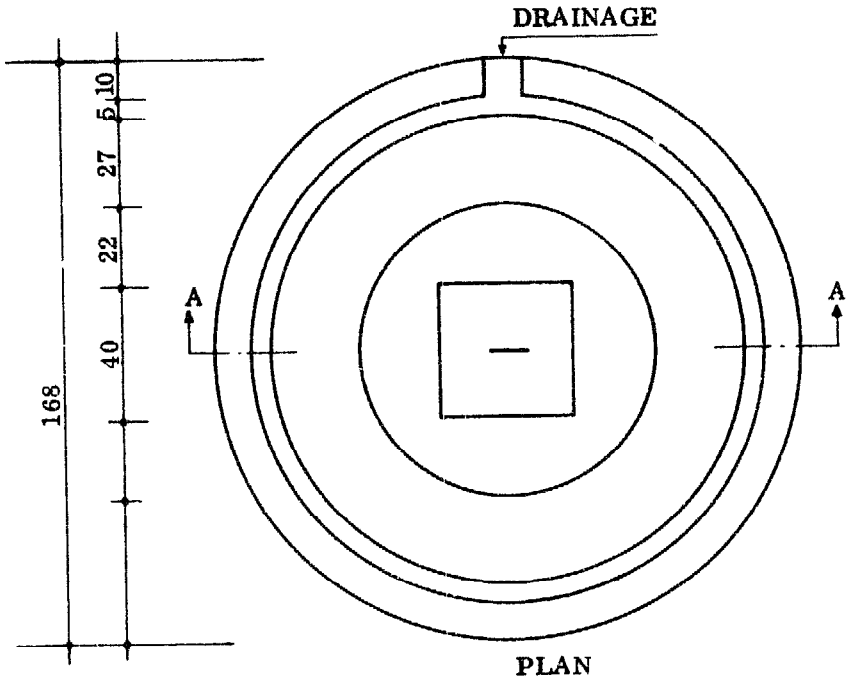

PLAN

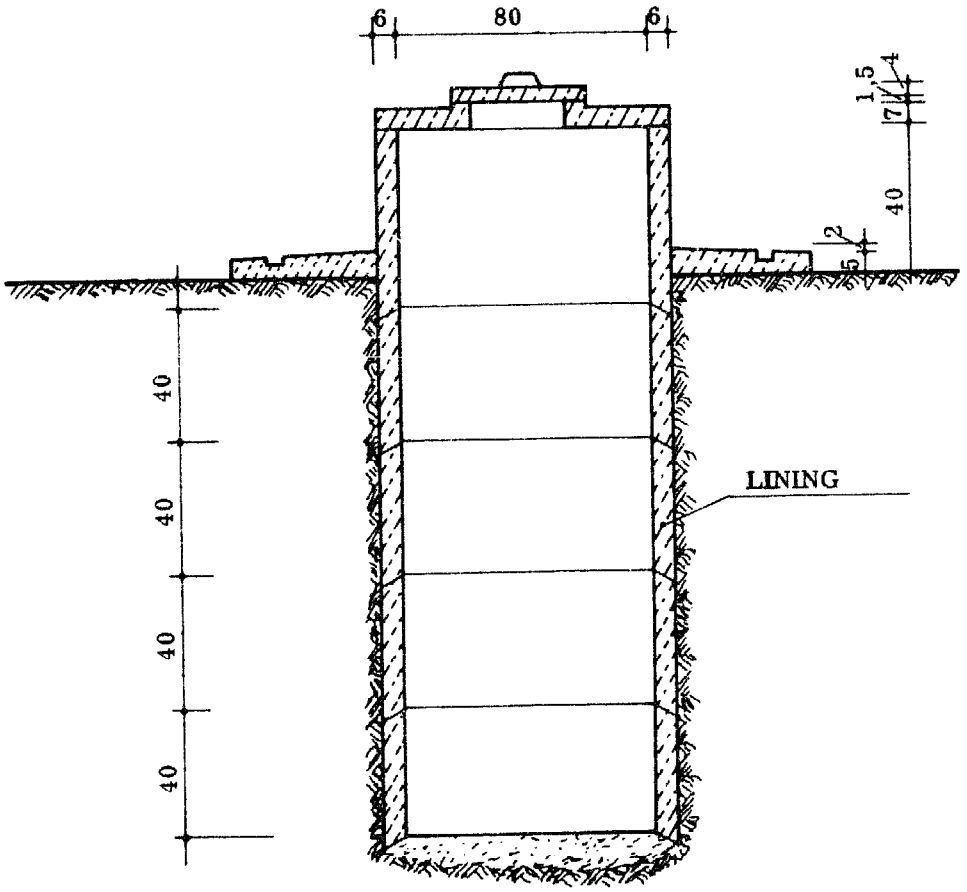

CROSS SECTION A - A

WATER WELL

N.P.V.C.

119.

WATER FILTER

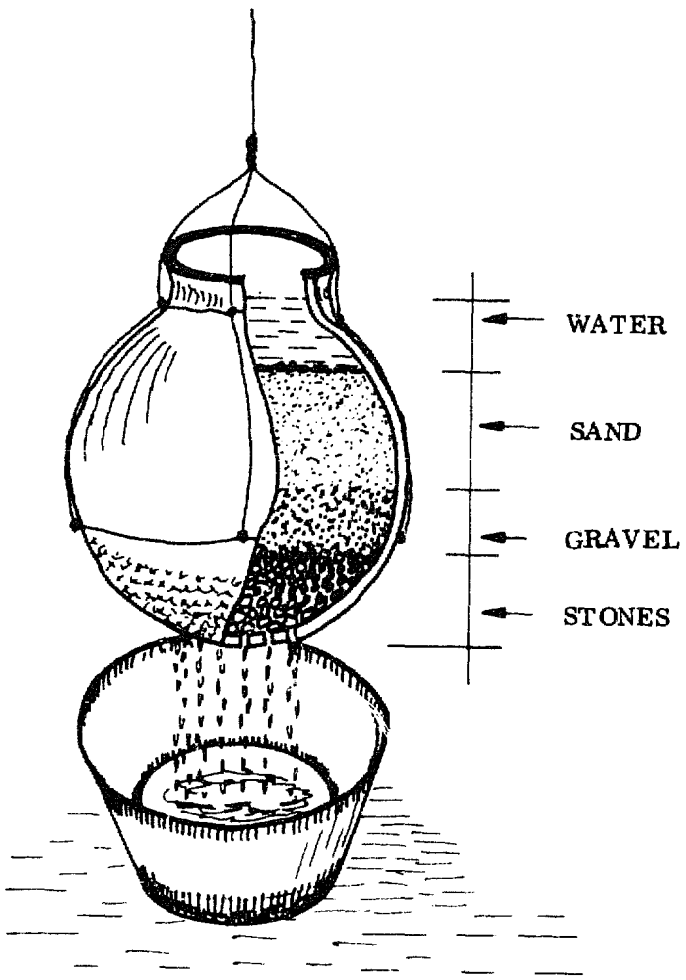

LOCAL POT

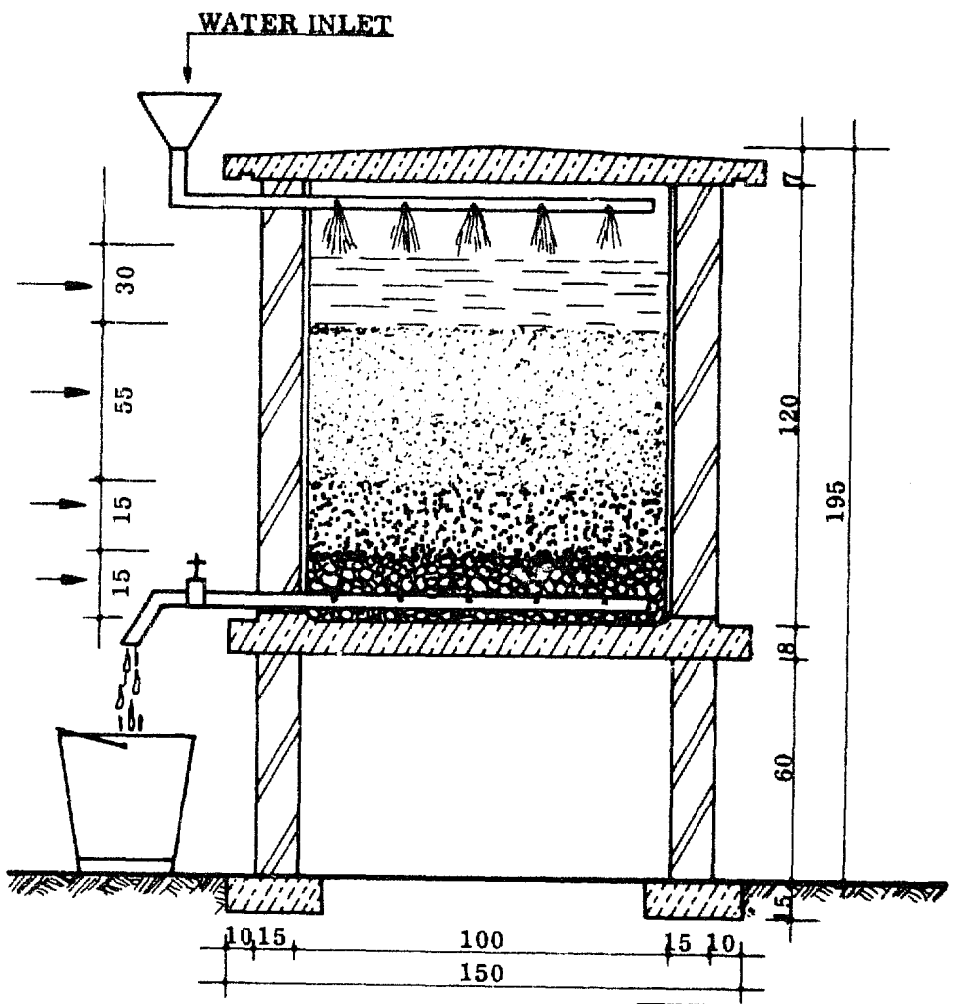

CROSS SECTION

N. P. V. C.	
	120.

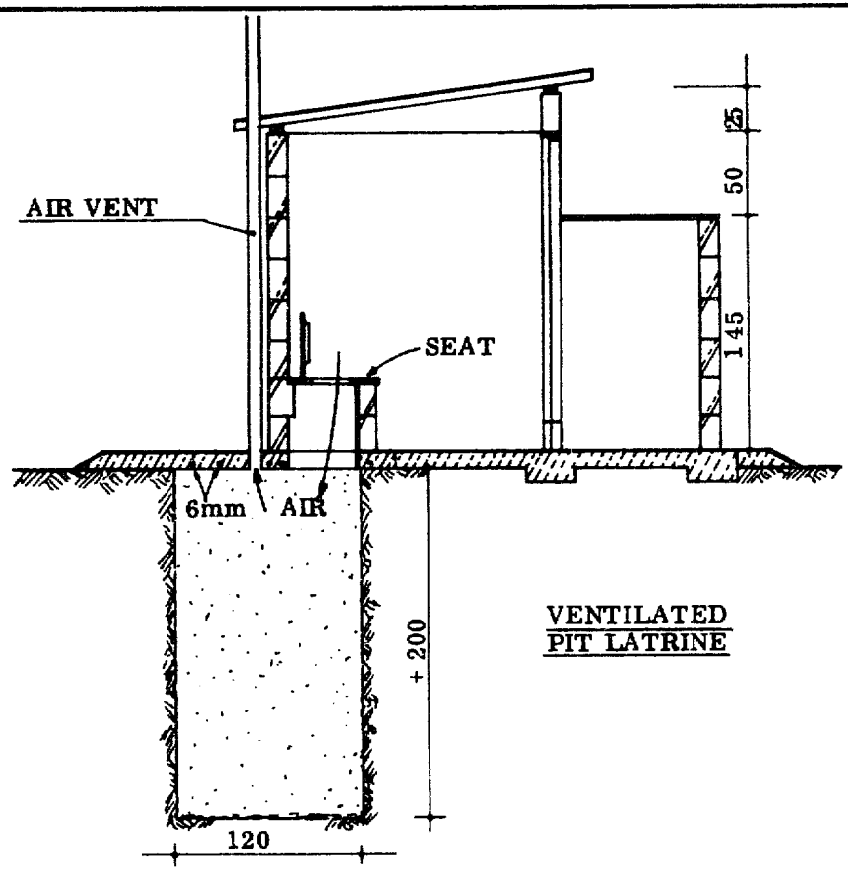

VENTILATED PIT LATRINE

CROSS SECTION A - A

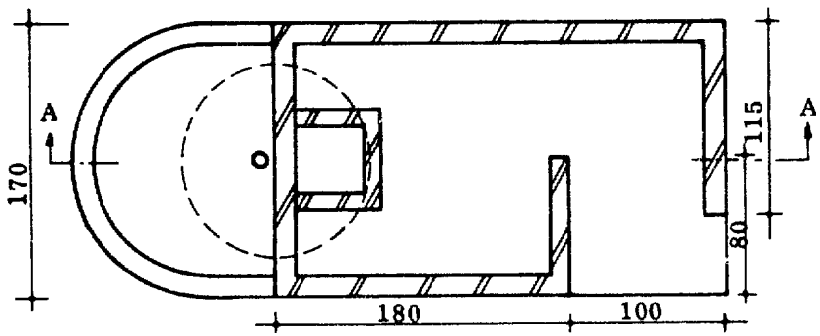

PLAN

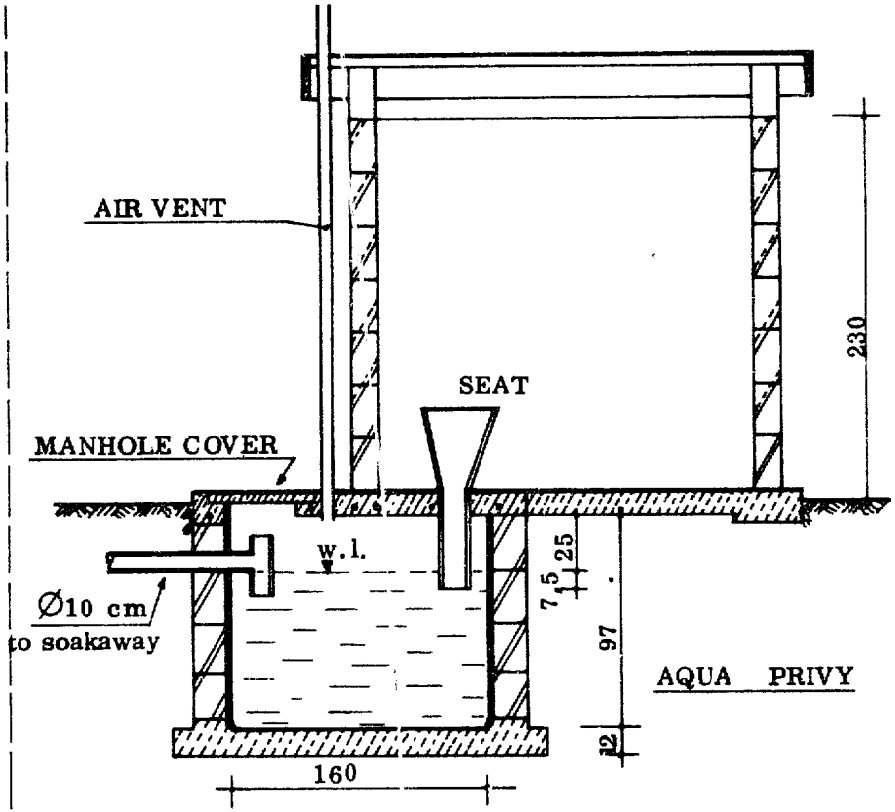

AQUA PRIVY

CROSS SECTION A - A

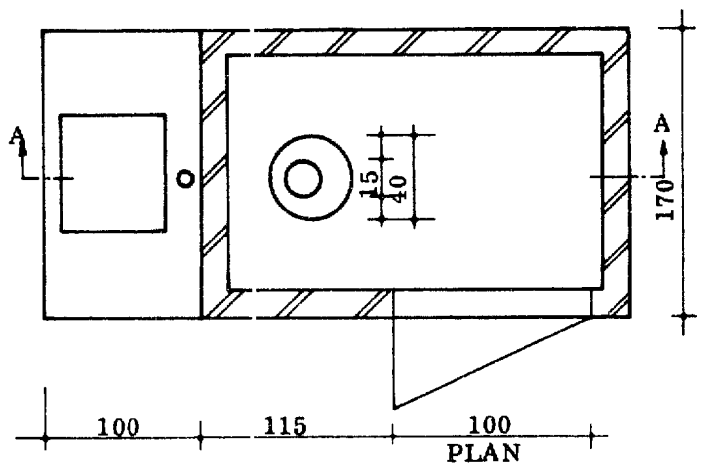

PLAN

N . P . V . C .	
121.	

PIT LATRINE

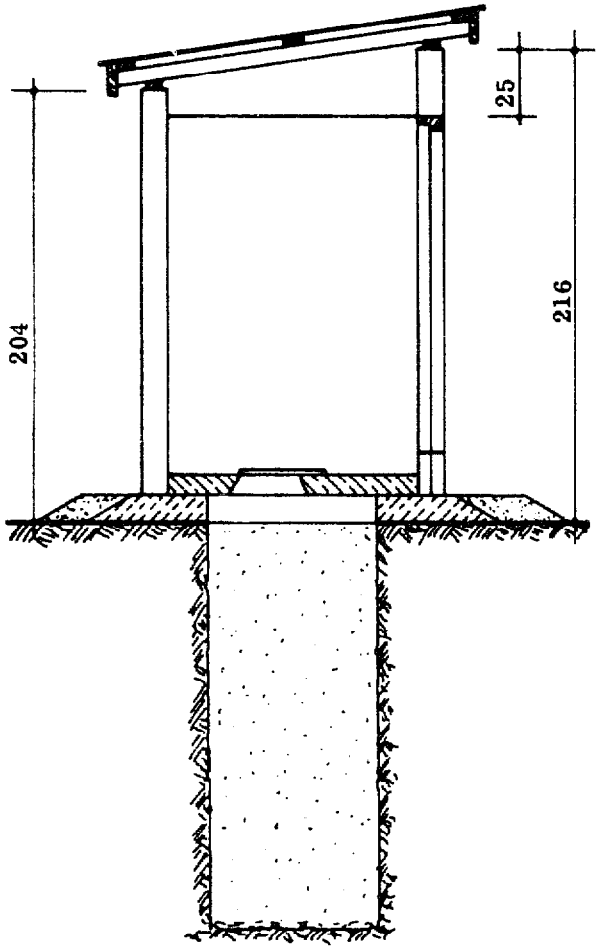

REMOVABLE LIGHT-WEIGHT CONSTRUCTION AND SLAB CAN BE REUSED.

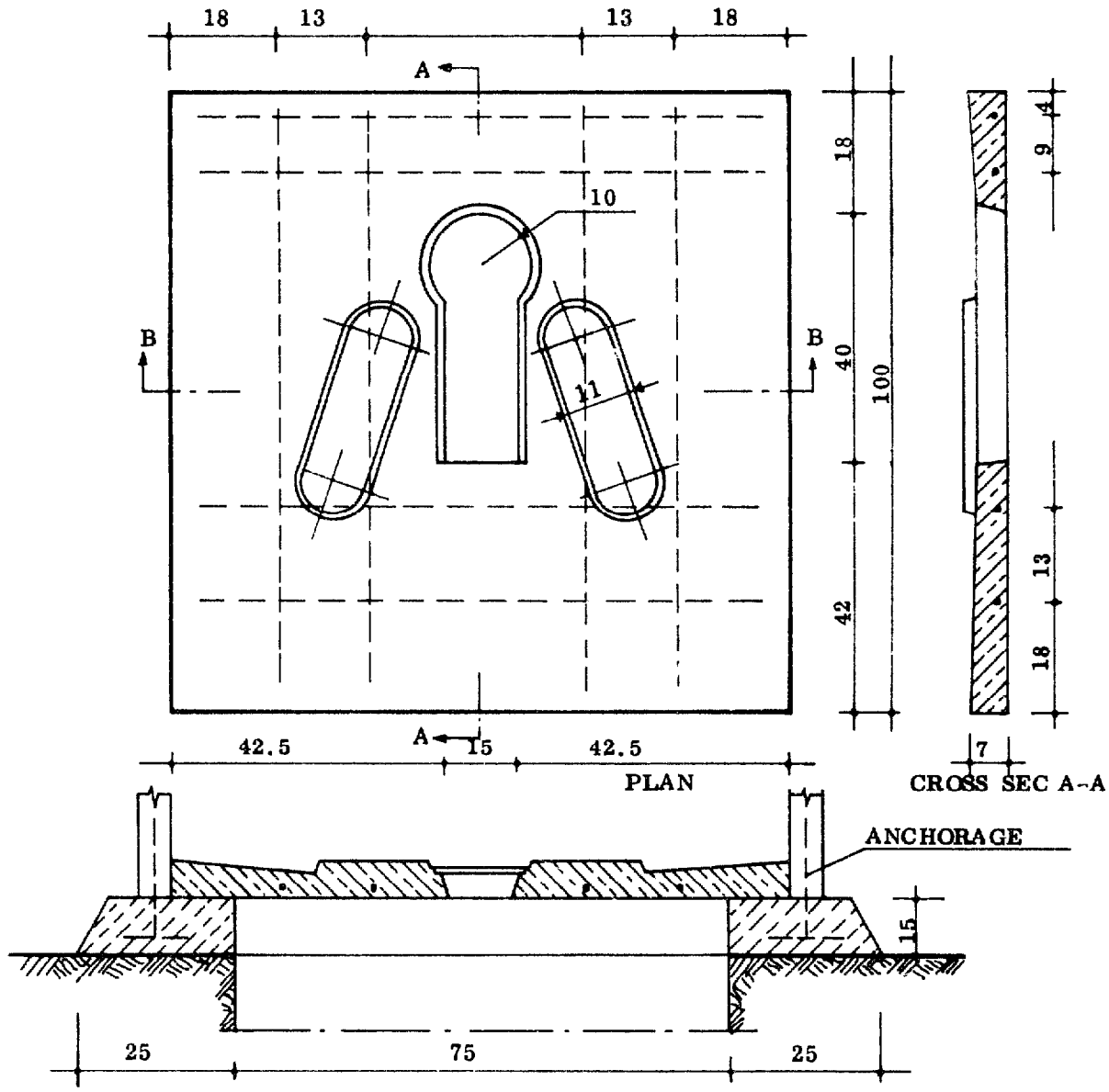

SQUATTING SLAB

N. P. V. C.	
	122.

BUCKET LATRINE

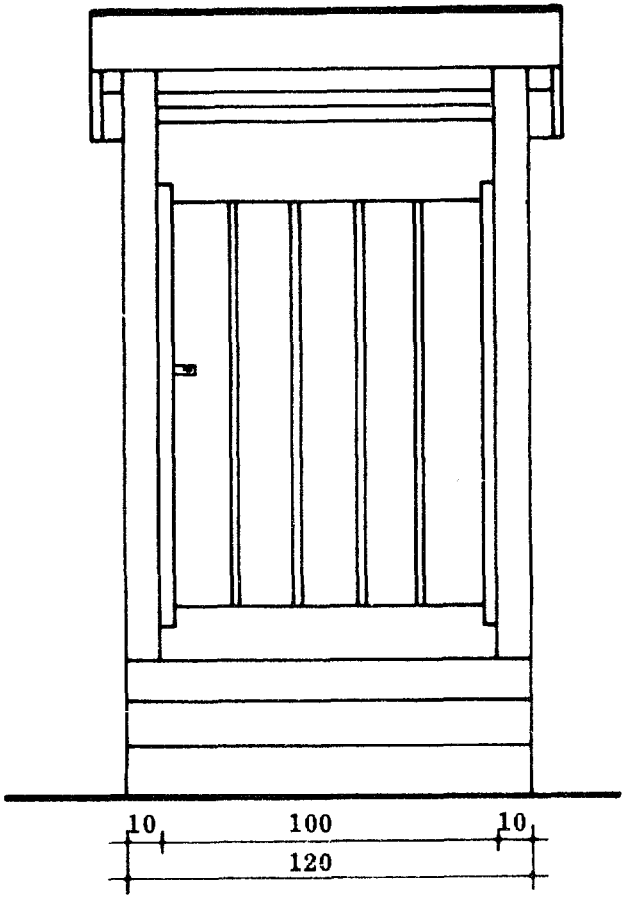

FRONT ELEVATION

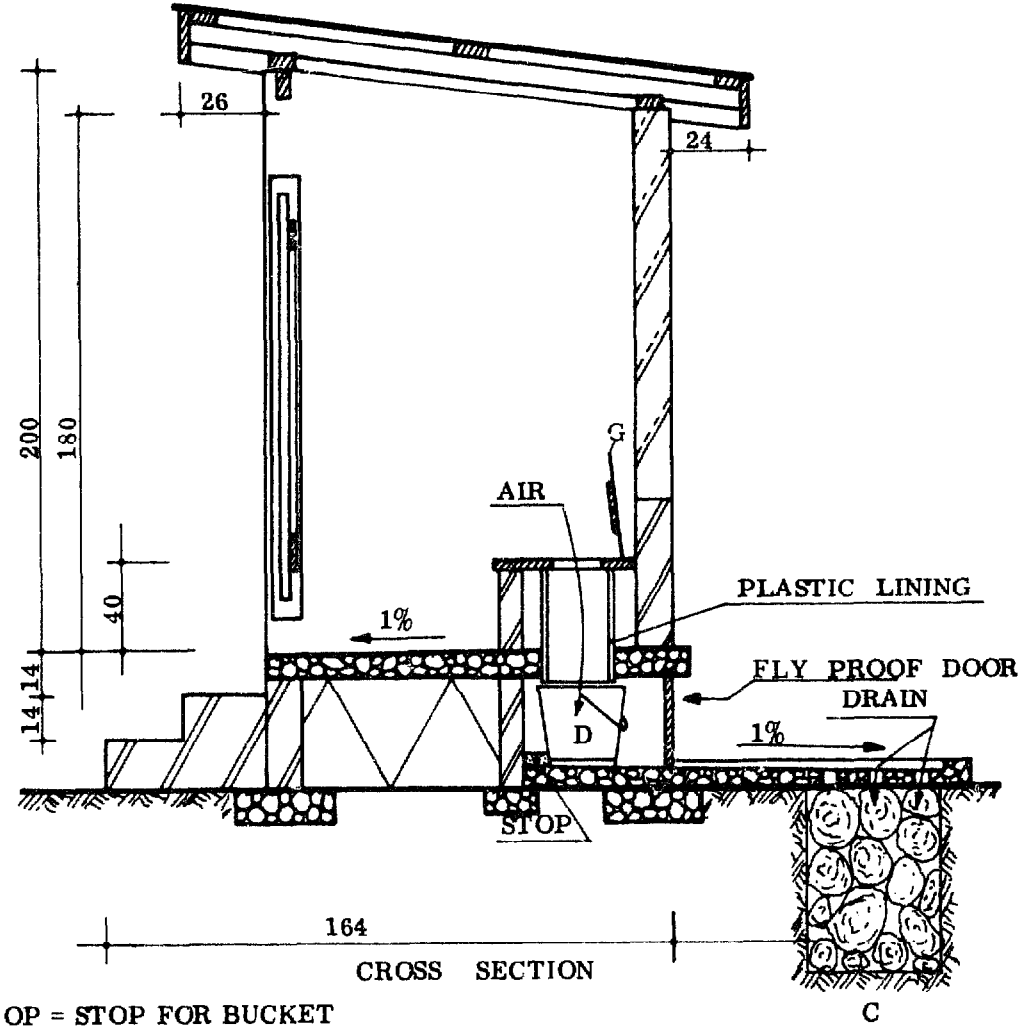

CROSS SECTION

STOP = STOP FOR BUCKET
C = SOAKAGE PIT
D = BUCKET
G = COVER

N . P . V . C .	
123.	

PIT LATRINE

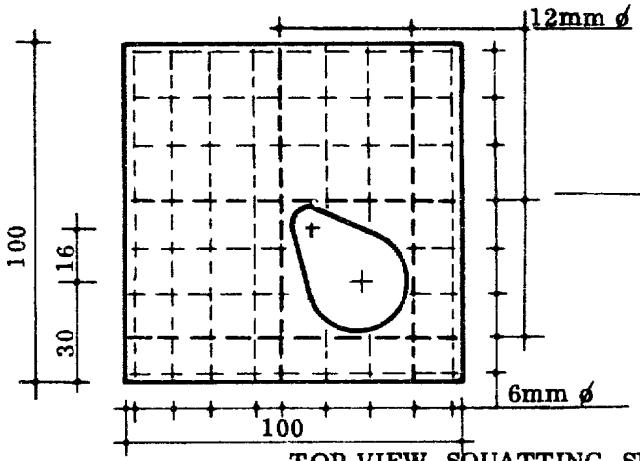

TOP VIEW SQUATTING SLAB

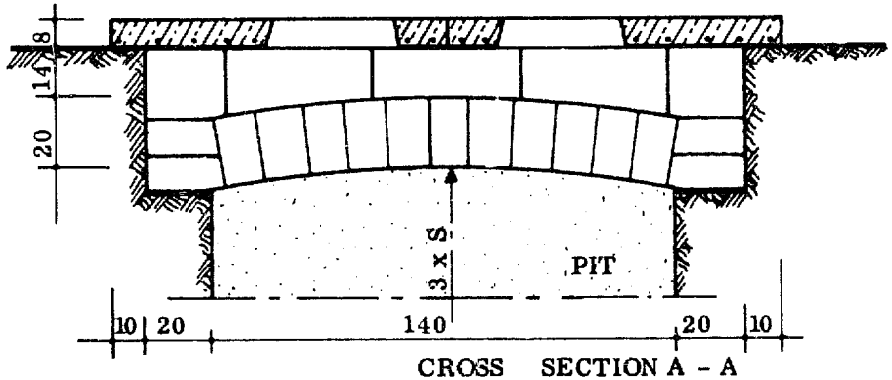

CROSS SECTION A - A

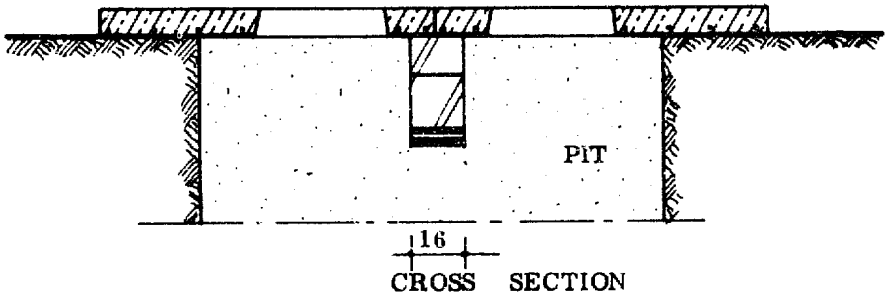

CROSS SECTION

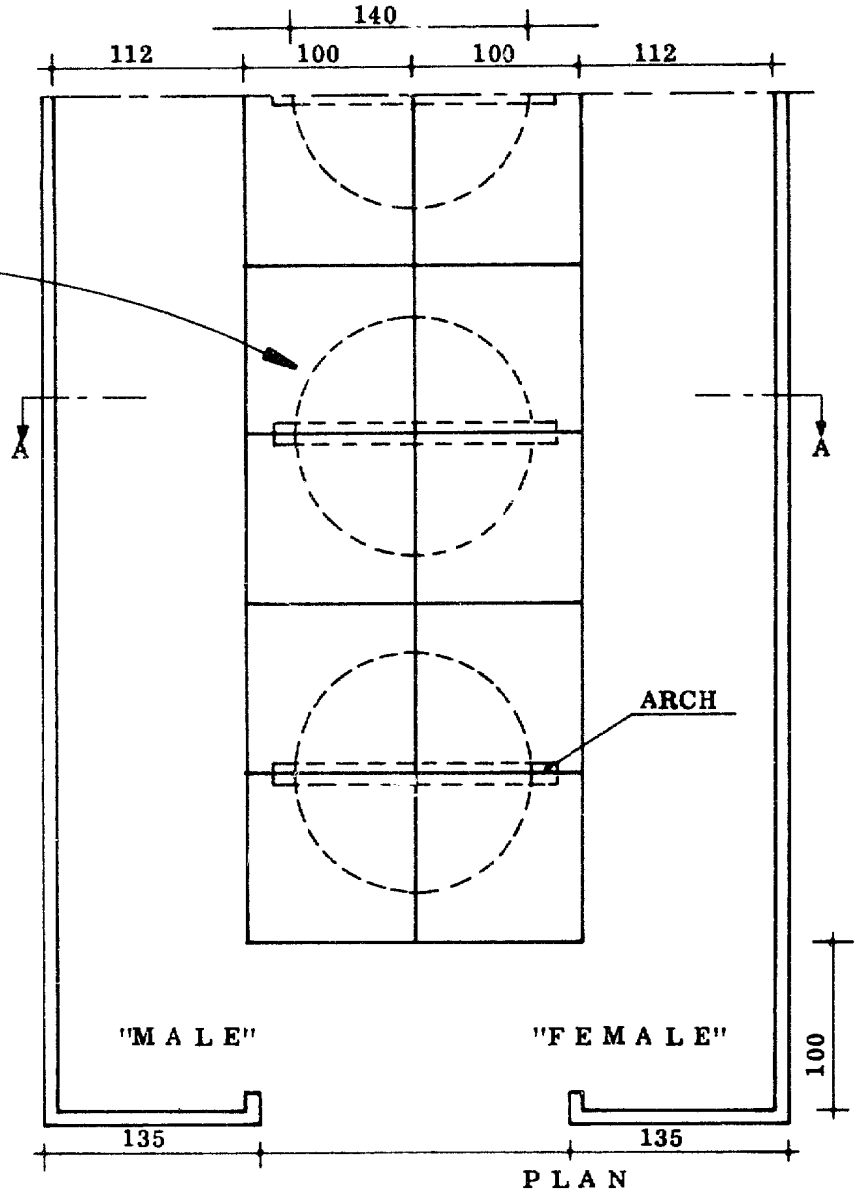

PLAN

TOILET PARTITIONS ARE LIGHT-WEIGHT STRUCTURES.

N. P. V. C.

124.

MANHOLE

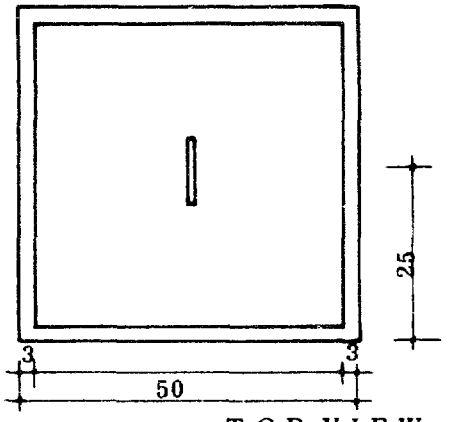

TOP VIEW

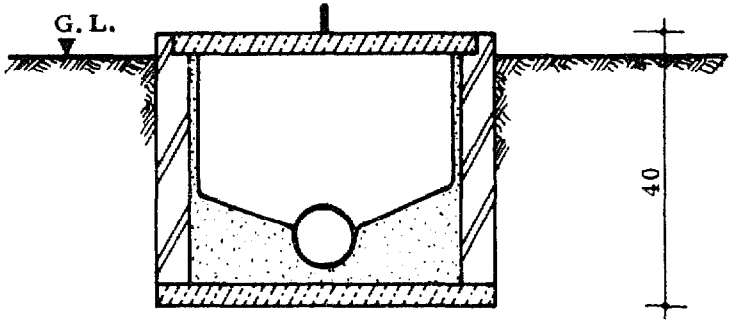

CROSS SECTION B - B

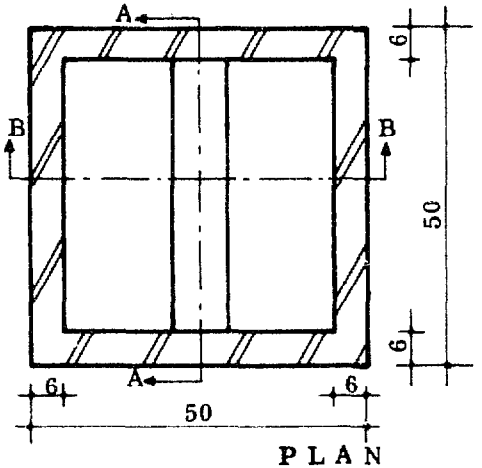

PLAN

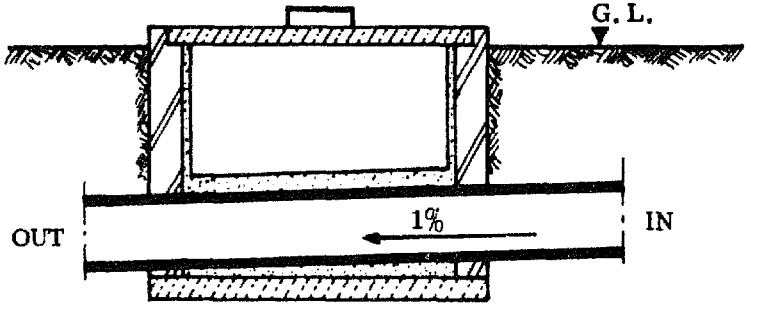

CROSS SECTION A - A

INSIDE DIMENSIONS DEPEND UPON TOTAL FLOW.

N . P . V . C.	
125.	

SEPTIC TANK

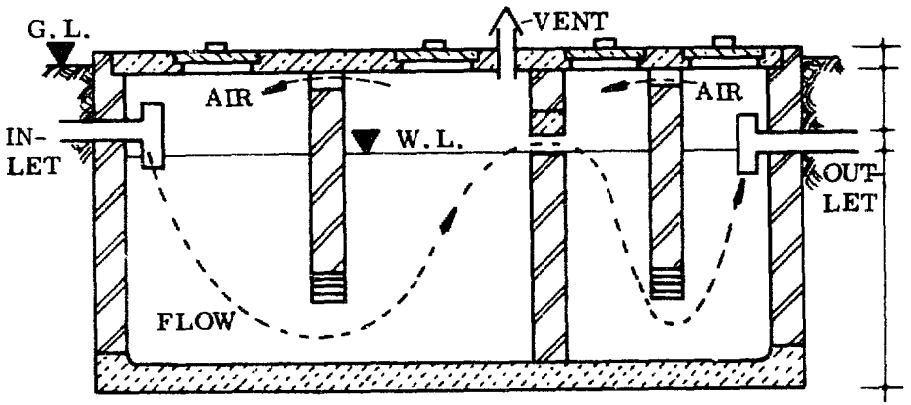

CROSS SECTION A - A

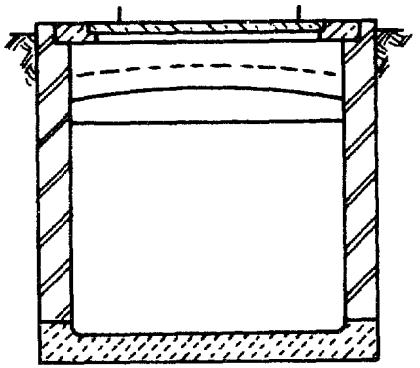

CROSS SECTION B - B

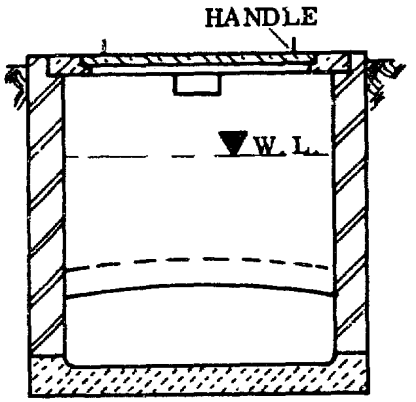

CROSS SECTION C - C

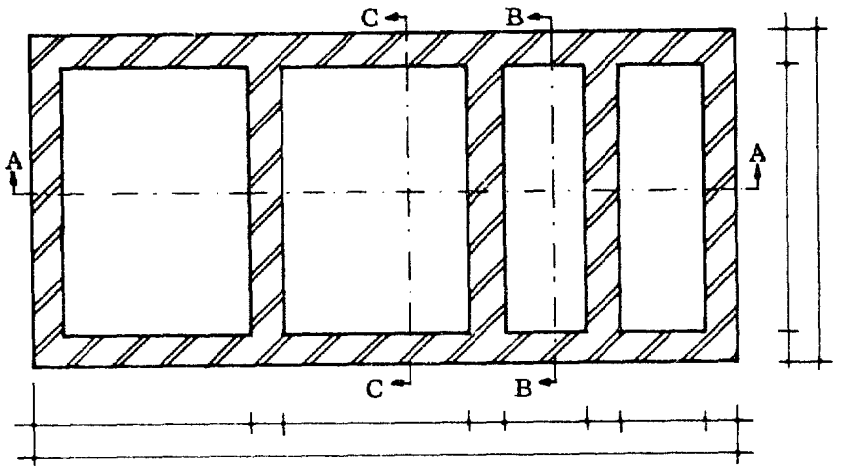

PLAN

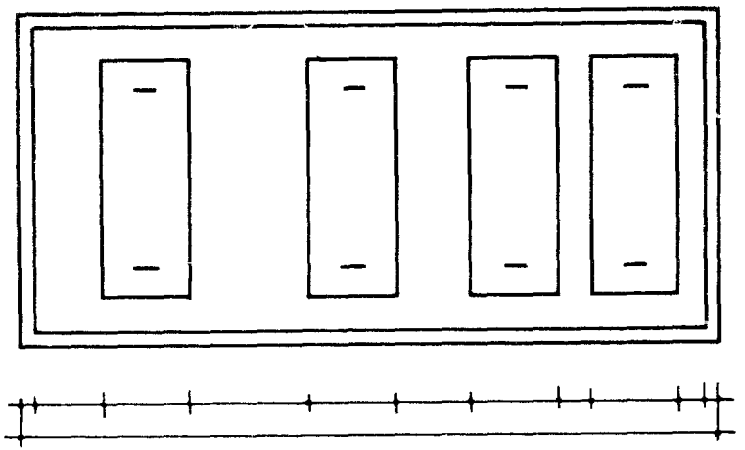

TOP VIEW

DIMENSIONS DEPEND ON THE TOTAL SEWAGE INPUT

N . P . V . C .	
	126.

Rural Coastal Sewerage Concept in Papua New Guinea

Boas Sengi, bsengi@adra.org.pg
Adventist Development and Relief Agency of Papua New Guinea
http://www.adra.org.pg

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Introduction

About 1/3 of the communities which is about 1.5 million of population in Papua New Guinea are located on the coastal periphery of the mainland and the islands of PNG. In most cases, there are no proper sanitation facilities for the disposal of human feaces identified in those regions. A sample of 25% of such communities identified by ADRA in its program strategic locations of Morobe Province defecates in the nearby bushes, rivers or sea-side due to inappropriate and or lack of latrine facilities and also poor hygiene practices. The pit latrines are not suitable because of high water table and sand-soil strata that permit diffusion of ground water and erosion of pit walls, which affect the durability of the pit latrine system and its contentment.

Consideration for the design of coastal rural sewerage system in Morobe Province

The type of sanitation facility to be modified and implemented for the coastal rural communities in Morobe Province should embark on environmental impacts, hence, that the latrine or sewerage system be geographically suitable and quantifiable to the rural population settling along sea-side and also on high water table areas who are experiencing high water log and other weathering situations all year around. A pre-intervention analysis of two appropriate and simple rural sewerage system will be look at to improve this situation in the coastal rural population of Morobe Province.

a) Improved Version – Asian Water Closet

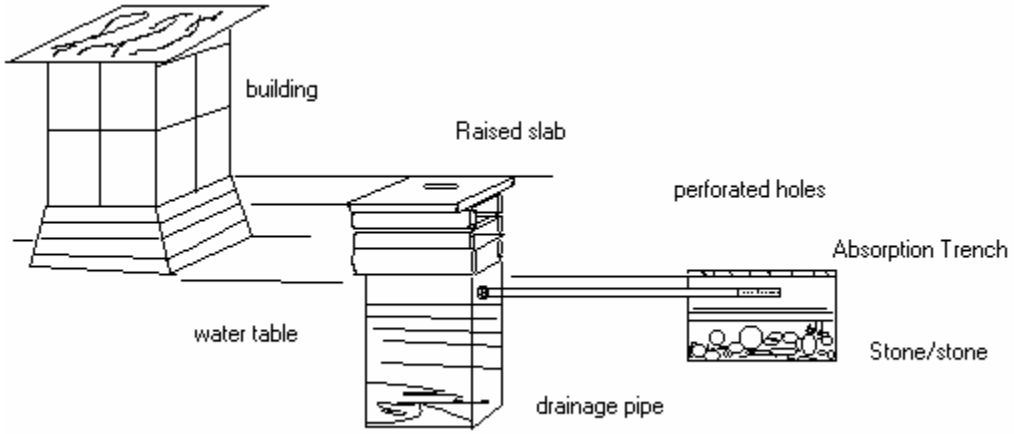

Figure 1: A design of the IV-Asian Water Closet

Figure 2
Pre-intervention Matrix for IV-Asian Water Closet

Features	Specification	Reliability	Risk Factors
Building Structure -Timber for the walls and raised platform can be collected from the bush free of charge - Roof, walls and raised platform can also be constructed using the local bush materials	Roof materials can be of sago leaves or kunai grass Walling and framing can be made from bamboo or local bush timbers	All households can afford one A four wall cabin, which gives the patron privacy and shelter	Local bush materials can be easily burned by bush fire Moderately reliable to strong winds and thunder storms
Slab Can be constructed at a cost of a cement bag and a quarter of a reinforcement mesh wire The raised basement for the slab can be an empty 44 gallon drum or other similar hard fix materials and should be placed at 0.3m around the pit hole	Slab dimension can be 1.2m x 1.2m x 0.06m Reinforcement G5 weld mesh of 1.1m x1.1m has a strong interior bonding capacity to cement and sand mix Tongue and grove timbers or hard facia - board timbers can make a strong wooden slab	An household can afford to meet the cost of a cement bag 4 x Households can share the cost of a G5 mesh wire for a piece each Concrete slab are proven to be more permanent and can be reused afterwards	Moderately reliable to strong winds and thunder storms
Pit Empty 44 gallon drums can be inserted as a wall lining for the pit and as chambers for the water table	3 x empty 44 gallon drums can be cut with 5 openings tied to the tip of each other and have an enclosed end raised 50m – 80m above ground level	Communities who cannot afford to find empty 44 gallon drums can either use local bush timbers, bamboos or such reinforcement to make a wall lining to the pit	Heavy rain and flood can soak down the soil wall Earthquake can also destroy the soil strata
	Pit dimension should be 0.3m square less than the slab size	Water in the pit helps the decomposition of feacal matters and other organic substances	
Absorption Trench	Trench dimension may be 1.5m x 1.5m x 1.5m	Increase in water table will be drained to the absorption trench. The absorption trench may have a sealed off lid from tin sheet or other hard local materials	
		Excessive wastewater in the absorption trench is filtered into the soil through the sand/pebbles and stones.	
Drainage Pipe The inlet should have a strainer and the outlet with a perforated holes on the sides with an UPVC End Cap	UPVC DWV 100mm x 6.5m Fly Strainer with a screw clamp Perforated Holes with UPVC 100mm DWV End Cap	Hard and permanent and can be used again	

b) Improved Version – Water Seal Latrine

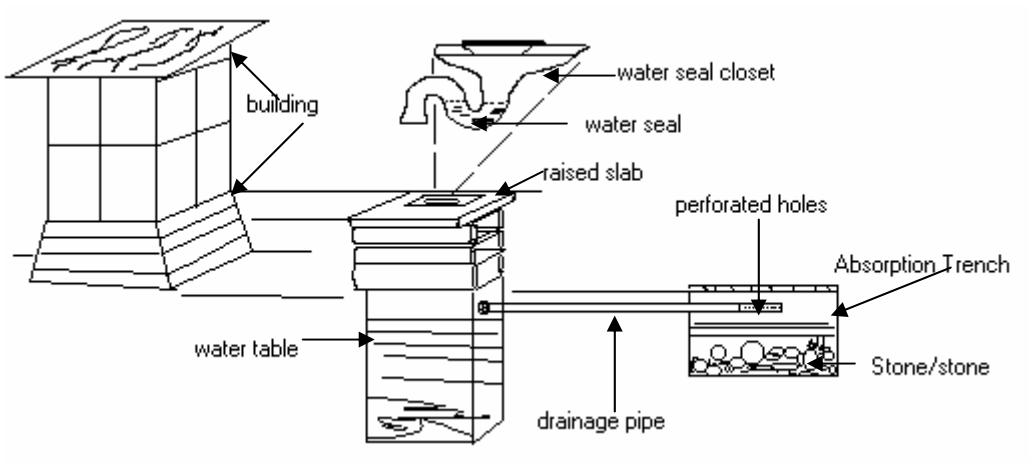

Figure 3: A design of the IV- Water Seal Latrine

Figure 4: Pre-intervention Matrix for IV-Water Seal Latrine			
Features	**Specification**	**Reliability**	**Risk Factors**
Building Structure -Timber for the walls and raised platform can be collected from the bush free of charge - Roof, walls and raised platform can also be constructed using the local bush materials	Roof materials can be of sago leaves or kunai grass Walling and framing can be made from bamboo or local bush timbers	All households can afford one A four wall cabin, which gives the patron privacy and shelter	Local bush materials can be easily burned by bush fire Moderately reliable to strong winds and thunder storms
Slab Can be constructed at a cost of a cement bag and a quarter of a reinforcement mesh wire The raised basement for the slab can be an empty 44 gallon drum or other similar hard fix materials and should be placed at 0.3m around the pit hole	Slab dimension can be 1.2m x 1.2m x 0.06m Reinforcement G5 weld mesh of 1.1m x1.1m has a strong interior bonding capacity to cement and sand mix Tongue and grove timbers or hard facia - board timbers can make a strong wooden slab	An household can afford to meet the cost of a cement bag 4 x Households can share the cost of a G5 mesh wire for a piece each Concrete slab are proven to be more permanent and can be reused afterwards	Moderately reliable to strong winds and thunder storms
Pit Empty 44 gallon drums can be inserted as a wall lining for the pit and as chambers for the water table	3 x empty 44 gallon drums can be cut with 5 openings tied to the tip of each other and have an enclosed end raised 50m – 80m above ground level	Communities who cannot afford to find empty 44 gallon drums can either use local bush timbers, bamboos or such reinforcement to make a wall lining to the pit	Heavy rain and flood can soak down the soil wall Earthquake can also destroy the soil strata
	Pit dimension should be 0.3m square less than the slab size	Water in the pit helps the decomposition of feacal matters and other organic substances	
Absorption Trench	Trench dimension may be	Increase in water table will	

Figure 4: Pre-intervention Matrix for IV-Water Seal Latrine			
Features	**Specification**	**Reliability**	**Risk Factors**
	1.5m x 1.5m x 1.5m	be drained to the absorption trench. The absorption trench may have a sealed off lid from tin sheet or other hard local materials	
Drainage Pipe The inlet should have a strainer and the outlet with a perforated holes on the sides with an UPVC End Cap	UPVC DWV 100mm x 6.5m Fly Strainer with a screw clamp Perforated Holes with UPVC 100mm DWV End Cap	Hard and permanent and can be used again	
Water Seal Closet	Can be fabricated from concrete using appropriate clay and waste paper mold portraying the shape of the water seal closet Needs chicken wire reinforcement in the concrete layer. A quarter of a cement bag and 0.3m square chicken wire is enough to do one Enough supply of water is needed to keep the system in operation. Water can be collected from water Taps, springs, creeks or seawater to pour flush the human faeces in the closet.	Very simple technology and can be afforded by many Easily Maintained	

Community Structure and Social Issues

Households clustering together in a village community shift the focus of an individual sewerage system to a communal system where similar principles tabled in Fig 2 and Fig 4 of both VI-Asian Water Closet and VI-Water Seal Latrine applies respectively. As such women and children must be given the privilege to decide on the relevancy and suitability of each system before making it become part of the community. Cultural and traditional values should also be considered on a sanitary merit to avoid culture - clash in the societies.

Population and beneficiary

The people who should be benefiting from this approach are the rural population settling along the coastal periphery of the PNG mainland and its islands (See Annex 1). Local authorities, planners and NGOs and funding agencies who are interested to carry out or fund water and sanitation programs in rural coastal communities can consider this approach in their program.

ADRA PNG rural coastal sewerage management intervention

Communities who have excess to sufficient water for domestication will be benefiting a lot because the system needs water to operate, hence, for communities who live near the sea, rivers or any water points. ADRA PNG is currently working closely with the 50 000 rural population in Morobe Province by providing safe drinking water and sanitation facilities and will be implementing this concept in its second phase of program which begins in 2006. Post intervention of this concept will also apply to the successfully completed 88 water projects in Morobe Province.

ANNEX. 1

The Map of PNG showing potential coastal areas around the land mass and island areas needing funding to implement the rural coastal sewerage program concept.

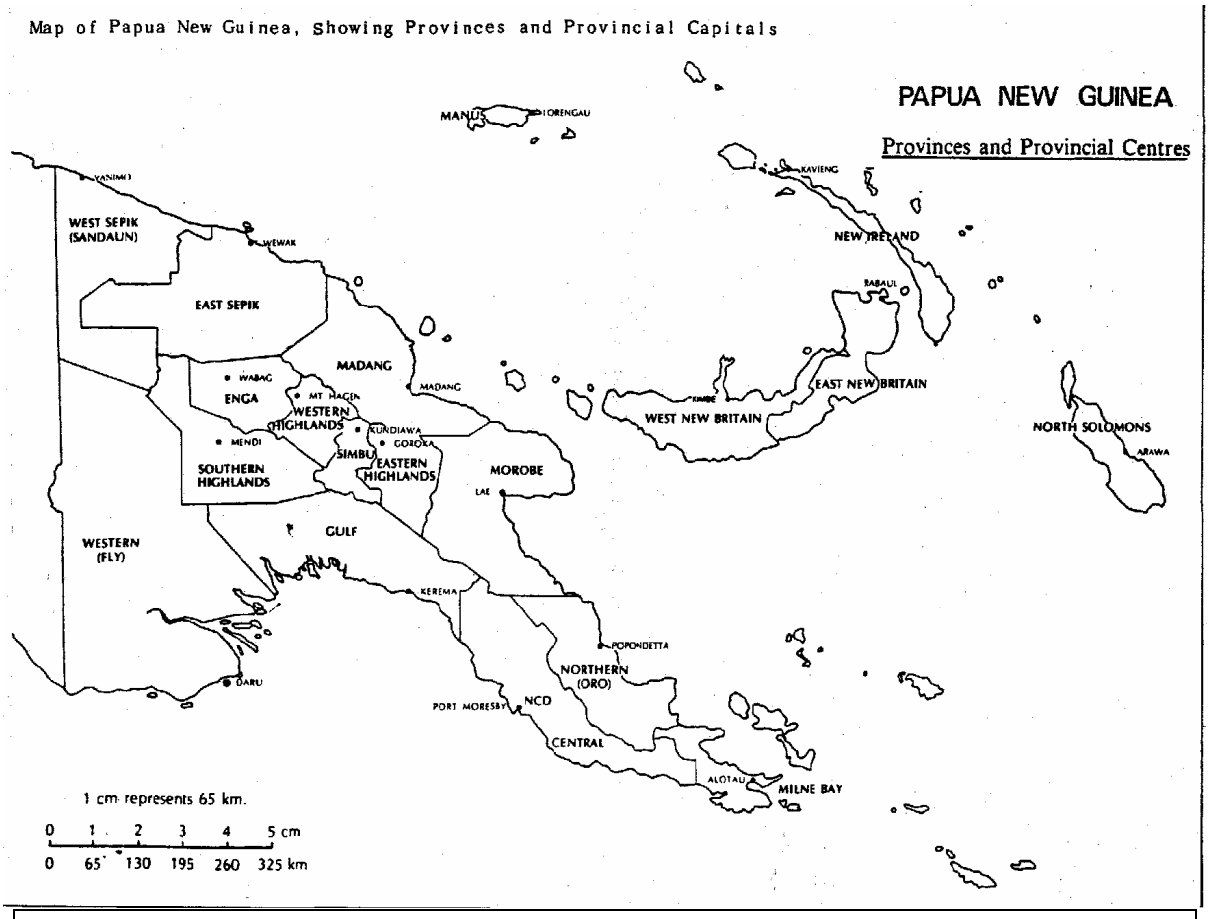

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Liklik Buk: A Rural Development Handbook/Catalogue for Papua New Guinea

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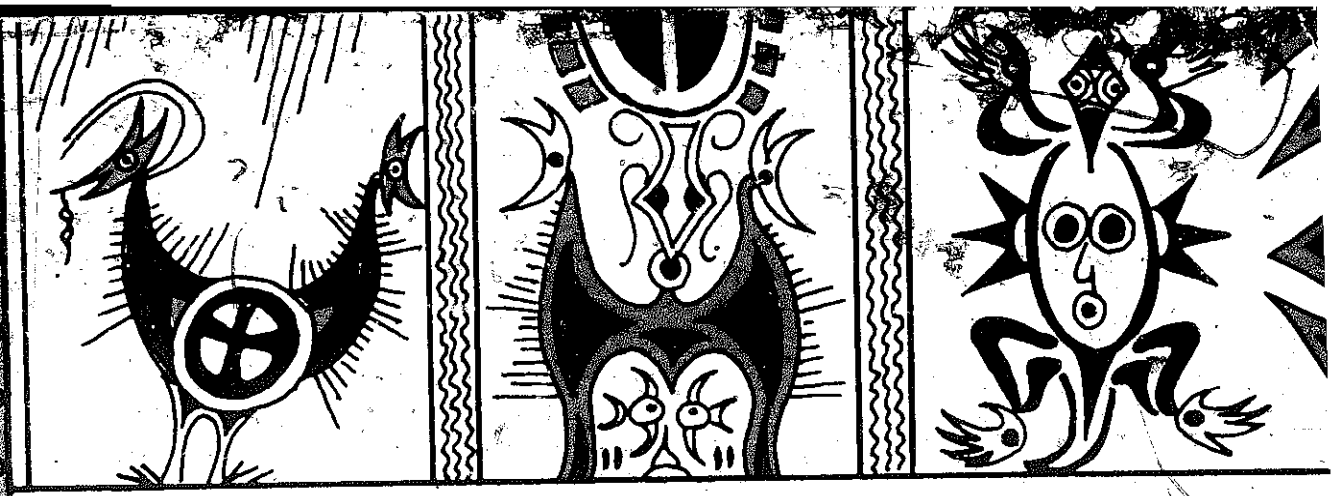

LIKLIK BUK

A Rural Development Handbook Catalogue For Papua New Guinea

English Edition 1977

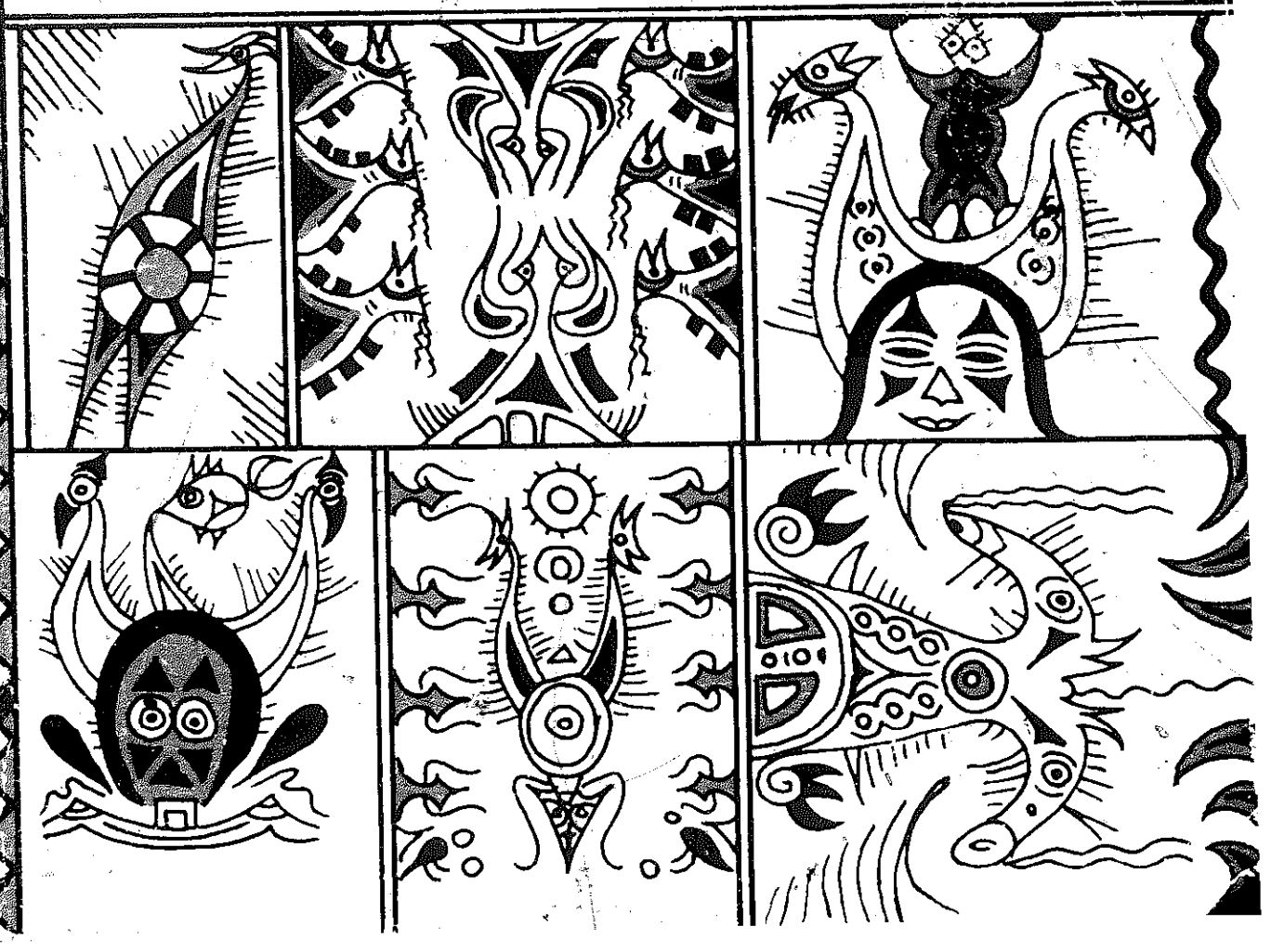

CAUTION S7

Supply of this technology except on consideration of social and cultural factors is inappropriate.

LIKLIK BUK

A Rural Development Handbook Catalogue For Papua New Guinea

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Business Development Officers/Priests
Adult Education Officers / Politicians
Rural Development Officers / Pastors
Trainers / Student Volunteers / Leaders
Good deed Doers / Nutrition Workers
Vocational Training Centres / Leaders
Volunteers / Bisnismen / Missionaries
Community Leaders / Welfare Workers
Health Workers / High School Leavers
Communicators / Animators / Trainers

Liklik Buk gives community level leaders and trainers in Papua New Guinea better access to rural development information sources, with the goal of village self-help action. Short, rich articles on crops, animals, processes, designs, health, animating rural development; lists of books, pamphlets and organizations; plus comments and editorials from a broad range of contributors. Information given on particular topics is not complete, but it is basic, technically sound, and helps the reader define an interest and find further information.

If you take away from the midst
of you the yoke,
the pointing of the finger, and
speaking wickedness,
If you pour yourself out for the
hungry
and satisfy the desire of the
afflicted,
Then shall your light rise in the
darkness
and your gloom be as the
noonday.

And the Lord will guide you
continually,
and satisfy your desire with good
things,
and make your bones strong;
and you shall be like a watered
garden,
like a spring of water,
whose waters fail not.

Isaiah 58:9b-11

THE MELANESIAN COUNCIL OF CHURCHES:

The Anglican Church
The Evangelical Lutheran Church
The Roman Catholic Church
The Salvation Army
The Wabag Lutheran Church
The Western Highlands Baptist Church
The United Church

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FORWORD

Appropriate technology, intermediate technology, self-help technology are becoming common terms in Papua New Guinea. Even though we do have considerable advanced technology, there is a growing appreciation for technology which our people in the villages can initiate, maintain, and control - technology which uses locally available resources, and which fits better with our way of doing things.

Papua New Guinea has a rich and varied treasure of basic technology as an integral part of her culture. So appropriate technology is not new - only the name is new. The challenge is to encourage our people to continually rediscover themselves and their capability to create and innovate.

Liklik Buk is an invaluable tool for those who work at this task. We commend it for widespread use, and congratulate all who participated in producing it.

M. T. Somare
Prime Minister

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HOW LIKLIK BUK HAPPENED

In April 1975 about one hundred church-related grass roots level rural development workers met in a seminar in Lae to share their experience. We heard again and again, "But where do I find out about this?" or "Where do I find out about that?" Discussing ways to help the workers get the information they need became a very important part of that seminar. There was strong agreement that a printed handbook catalogue of information should be developed to support the activities of village workers all over Papua New Guinea.

The objective was a readily available and reasonably up-to-date reference that would give workers access to the information that they need.

We have been delighted at the response to this effort shown by a broad range of contributors. We have found many new friends and allies of village development among church, government, academic and business groups, and have been pleased at the continuing response from the rural development workers themselves.

The 1976 edition of 5,000 copies sold out in less than two months. This time we have twice as many pages, three times as many contributors, and 12,000 have been printed. A modest office has been set up as a three-year special project to handle production of Liklik Buk and to respond to information requests. A pidgin version of the Buk is in progress, and portions of the Buk are being translated and reprinted by Lotu Pasifika Productions for use in the South Pacific.

THE PURPOSE OF LIKLIK BUK

Finding and evaluating answers to specific questions is a difficult, sometimes hopeless task for a person (even a competent person) who has no library, no telephone, few everyday professional associates, and very irregular mail service.

At the same time, many of those persons in PNG who have the greatest wealth of technical information and experience in rural development have been "promoted" out of rural life into desk-bound administrative jobs.

Liklik Buk is a way to give easier access to information sources and to stimulate more dissemination of the expertise available. It is patterned somewhat after the approach used by The Whole Earth Catalogue in the United States, though the finished book is of course quite different.

A key part of this concept is that the materials are to be updated more or less continuously through the written responses of the readers. It is a big job, of course, but basically, Liklik Buk is designed to be self-supporting, self-revising, self-updating (just as Rural Development ought to be).

LIKLIK BUK IS NOT FINISHED

We have only "scratched the surface." As you will see, there are many areas of information which must be improved, and many good things happening in Papua New Guinea which have been left out. With your help the next issue will be better.

The Buk is printed on newsprint because we don't think you'll need to keep it for more than a year or so. When the next Buk comes out it will contain the good things from this one, plus the new things you have sent us. When you get your new one, throw this one away! (but don't use it for smoking!)

HOW YOU CAN HELP US

1. If you know how to do something that isn't already in Liklik Buk, and you think that someone else might like to try it, write to us and tell us about it. Tell us as much as you can, so that we can tell others in the next Buk.

2. If you see something in the Buk that you can tell us something more about, tell us so that we can add it to the next Buk. We will write your name next to that information.

3. If you see something that is wrong in the Buk, write and tell us about it so that we can change it in the next Buk.

So - the next Buk will be much better!

To encourage you to write something for the next Buk, we will give you a free copy if you send us something that is printed in it.

cont'd

HOW TO USE LIKLIK BUK

For Heaven's sake DON'T READ THIS BUK! It is a book for browsing a little bit at a time. Hide it in the bottom of your "in" basket as encouragement to empty it. Put it in the box where you hide your bank passbook - (You'll be a rich man if you read the Buk each time you plan to withdraw money). Keep it next to your Bible for reading when the Bible doesn't have the solution for your particular problem. But please don't be like the didiman we know who left his unopened copy at home while he spent three months researching the following problems for council projects: an easily built fish smoking unit for village use, a source of supply for coffee pulpers, and a recipe for rat bait - which were all in the LIKLIK BUK!

Look at the m[illegible] index in the front of the Buk if you are tryi[illegible]o solve a particular problem. You will see that the materials are divided into:

- CROPS
- LIVESTOCK
- PROCESSES
- DESIGNS
- ANIMATING VILLAGE DEVELOPMENT
- HEALTH
- GENERAL REFERENCES

Some basic information for your question will be found (we hope) in one of the major sections. But since many problems have several parts to a solution, extra information will be found in other sections, too. The page numbers in the margins give you the place to find this information.

There are some topics that we still don't have contributions for. We have put these headings in, to encourage you to fill the blank in the next edition (and receive a free copy of that edition if your contribution is accepted).

If you find that the information in the Liklik Buk is not enough for what you want to do, write to the person who contributed the article OR get the books or pamphlets that are mentioned OR write OR visit the people and places that have had experience with the matter. Or do all three! If all these fail, write to the Editors, Liklik Buk, Box 1920, Lae, and we'll try to help.

Be sure to slip through the pages from time to time. It will put new ideas into your head, and someday you may find a use for them.

It takes time and money to do many of the things in the Liklik Buk, but more importantly, knowledge and ability. Liklik Buk will give you an idea of how much time and money you will need, and some hints on where to find a little knowledge. But the Buk can not give you the ability. This you will get only from trying and practicing.

VILLAGE SELF-HELP ACTION IS OUR GOAL

We will not pretend that Liklik Buk is for the direct use of village people - though it is meant to be for their benefit. It is primarily a support for those who have dedicated themselves to working with village people: didimen, teachers, business development officers, pastors, university students, overseas volunteers, or village leaders. May it give inspiration, new ideas, helpful information, and may it lead to action!

We hope that even those with limited ability in English can make some sense out of the names, addresses, and suggestions.

PNG may well have more available technical expertise than any country of its size anywhere in the world. When we read of the publications available, the research and study going on, the different organizations ready to give information and assistance, we must come to the conclusion that in PNG availability of technology is not the problem. Its effective application is a problem, though. On balance, PNG seems to be strong on research, study, discussion, publicity, and weak on dissemination of information, coordination, field action, critical evaluation. We tend to be strong on tools and machines, technical innovations, and weak on the all-important question of how to "animate" the process of total human development.

We dedicate Liklik Buk to PNG village self-help ACTION.

Peter R. Hale

B. David Williams, Jr.

MEMBERS OF THE LIKLIK BUK COMMITTEE:

Pedi Anis
Central Planning Office
Haru Bekker
Yangpela Didiman
Ulrich Bergmann
Evangelical Lutheran Church
Jean Kekedo
Village Development Office
Seri Pitoi
Village Representation
Department of Primary Industry
(1977 Edition: Alan Abala, Lynn Harris, Ian Reardon)
Unitech Community Development Committee
(1977 Edition: Helen Bates)
WANTOK Publications
(1977 Edition: Kevin Walcot)

CROPS

Primary Energy Crops

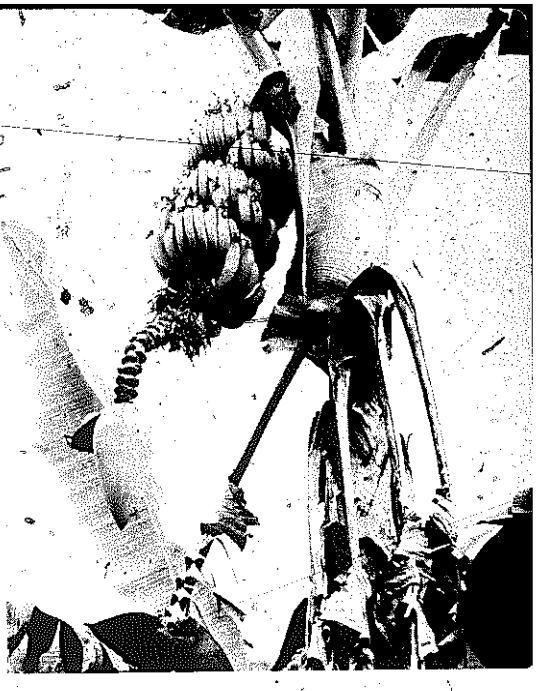

Bunch of triploid bananas

BANANAS BANANAS

Botanical name: Musa sp.
Height: 3 - 6m.
Age to first production: 8-12 months
Normal life span: Diploids: 2 yrs.
Triploids: several years

Insect pests and control: Scab moth (Nacoleia octasema) only in NG Islands, not NG mainland and Papua. A very serious pest, makes a scab on the fruit. Some control with DDT dust and spray, but not very effective. Banana Weevil Borer (Cosmopolites sordidus). Control by getting rid of old corms and butts on top of the ground, or use Solgar Banana Fruit Fly (Strumeta musae). Place polythene bags around bunch. Bags also protect from fruit bats. Nematodes may also be a problem in the roots.

Diseases and control: Sigatoka Leaf Spot (Cercospora musae). This attacks the leaves and reduces the yield a lot. Use resistant varieties (ABB group) or plant only a few of the susceptible ones in one area.

Indication of maturity: The fruit become full and somewhat rounded, leaves begin to dry out.

Planting information: Spacing depends on variety but for large varieties plant at about 2.5m on the square. Dig a deep hole. Use the suckers with the narrow leaves.

(p 91) (p 115) (p 116)

Useful products at village level: Fresh fruit (certain varieties) and cooked fruit. Thinly sliced cooking bananas fried in oil or fat make popular snacks, and are especially good for children on low-fat diets. The large, coarse varieties are, when cooked, a good source of energy foods for pigs. Thinly sliced bananas may be dried and stored.

Further reading: D.P. Heenan (1976). (p 244) (p 245) Methods for Commercial Banana Growing. Harvest 3 (2): 42-47. Preliminary Observations on the Growth and Production of Bananas in the Northern District of Papua New Guinea. PNG Agric. J. 24 (4): 145-155 (1973). Bunch Covers for Bananas in the Northern District. PNG Agric. J. 24 (4): 156-161 (1973). Bourke, R.M. (1976). Know Your Bananas. Harvest 3 (2): 48-54. Lambert, M. (1970) Banana Production in the South Pacific. SPC Handbook No 5. Feakin, S.D. (1966). Pest Control in Bananas, Pans Manual No 1 or LAES Information Bulletin No 6 Know Your Bananas. English and Pidgin.

Industrial use: Banana starch or flour.

Sources of supply of planting materials: local.

Remarks: Research work is done at DPI, Kerevat, ENB. Bananas are found everywhere in PNG and are the staple food in very dry areas such as the Markham Valley, and Cape Vogel, the Papuan coast, also in areas where land is short like the Gazelle Peninsula. There are very many varieties in PNG. Diploids are the traditional low yielding ones. Triploids are the higher yielding introduced varieties. There are groups of bananas that are drought resistant and very tough. See article by Bourke. (Know Your Bananas)

Initial contributor: R.M. Bourke, LAES, Kerevat, ENBP.

Bunch of diploid bananas

CASSAVA TAPIOK

Description: A longlived shrub, with enlarged tuberous roots. The leaves are large and palmate with 5 to 9 or more lobes.

Botanical name: Manihot esculenta
Height: 3 - 4 metres
Age to first production: 9 - 12 months
Normal life span: 15 - 24 months, but tubers will tend to become woody.

Pests and control: Rats, bandicoots and pigs are a minor problem. Baits and traps are set up to control rats and bandicoots; build fences to keep pigs out. No known evidence of major insect pest infestation in PNG as yet.

Diseases and control: No evidence or presence of major cassava diseases occurrence as yet in PNG. Occasional occurrence of Leaf Spot (Cercospora spp.) on plant leaves, a minor problem. Use of resistant varieties as a control measure.

Indication of maturity: When the leaves begin to yellow and fall, dig up a few tubers and try.

Planting information: The best results are usually obtained using sticks with at least 3 buds 20 to 30cm long, 2.5 to 4cm thick, selected from lower or midsection wood of plants at least 10 months old. Planting distances of 80-140cm. Closer spacing leads to lodging of plants. Cassava stems planted close together in line with bamboo strips interwoven make a reasonably good fence. (Though pigs might try to root under it.)

Useful products at village level: The tubers are good for human consumption and for stock feed. The leaves make good green feed for chickens. The tubers may be sliced thinly and dried for storage. Flour may be made. (p 91) (p 94)

Industrial uses: Starch Source. Flour from Cassava used in bread-making, useful as a partial substitute for wheat flour; chips pellets, flour from dried crushed leaves for livestock feed. Stalks used in manufacture of particle boards.

Sources of supply of planting materials: local. A number of varieties are available at LAES, Kerevat, ENBP.

Further reference: Kay, D.E.(1973). Root Crops, TPI Crop and Product Digest No 2. Free from TPI, 56/62 Gray's Inn Road, London WCIX 8LU, England.

Phillips, T.R., Cassava Utilization and Potential Markets, IDRC-020e, Ottawa, Canada.
Purseglove, J.W.T. Tropical Crops: Dicotyledons Longmans.

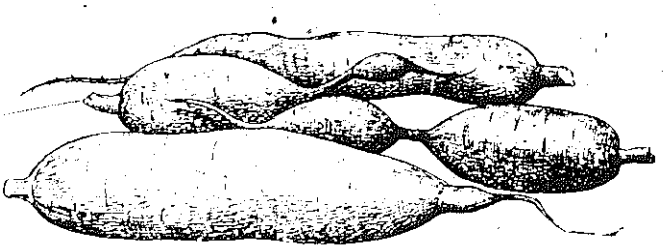

Remarks: Very little has been done about this crop in PNG. It yields 30t/ha or more. Good famine reserve crop, since certain varieties can be left in the ground for long periods without the food value being reduced. Will not grow well in cold Highland areas and can be killed by frost. Certain bitter varieties contain cyanogenetic glucosides which may lead to poisoning if they are eaten raw. To make them safe the roots should be cut into pieces and steeped in water for a day before cooking - this water is poisonous and should be carefully thrown away. Tubers contain Hydrocyanic acid which can be harmful to humans if eaten in large quantity. Could lead to Goitre in humans. Some Cassava varieties are sweet and others bitter. Bitter ones are due to presence of Hydrocyanic acid and can be destroyed by normal cooking or boiling and roasting. A suitable crop to grow in areas where environmental conditions of low and uneven rainfall and poor soil are not suitable for growing crops like potato or taro.

Initial contributor: A. Opu, LAES, Kerevat, ENBP.

CORN (MAIZE) KON

Botanical name: Zea mays
Height: about 1.5 - 3 metres
Age to first production: about 9 weeks (fresh)
Normal life span: 15 weeks.

Insect pests and control: Stem borer (Ostrinia furnicalis). The grubs eat into the stem. It can be controlled with lindane granules, but the

attack would have to be very bad to justify this. Another insect: Heliothis amigera gets into the cob. Weekly sprayings with 0.1% Carbaryl solution suggested.

Diseases and control: Leaf rusts (Puccinia spp.) Use resistant varieties from Kerevat or Bubia (DPI). Leaf blight, downy mildew, and blister smut.

Indication of maturity: For selling fresh to Europeans: Tassle on the cob goes brown. For Papua New Guineans: A few weeks after this. For stockfeed or seed: Wait until the plant is dead.

Planting information: Use improved seed from DPI spacing 90cm x 20cm. Plant 1 or 2 seeds per hole only. Get seed for planting from many cobs, not just a few cobs. This is important.

Useful products at village level: Fresh food for people, or dry grain for stockfeed. The dried corn may be used in limited amounts in baking when mixed with wheat flour. (p 93) (p 106) (p 176) (p 115)

Industrial uses: Cooking oil from germ of seed; flour from the seed for some kinds of bread.

Sources of supply of planting materials and cost: LAES, Kerevat, ENB; Regional Office, DPI Box 348, Lae; Regional Office, DPI Box 6639, Boroko; DPI, Aiyura via Kainantu, EHP: high yielding seed available free in small amounts.

Related tools or equipment: Hand-operated corn huller @ K80, from Agquip, Box 1121, Rabaul, or Plantation Supply and Services, Box 92, Goroka.

Further references: Free publications: Superior Corn Varieties Now Available (Nupela Pikinini Kon Bilong Planim) LAES. Information Bulletin 3, DPI Bubia Information Bulletins 5, 11, 22; Corn DPI Port Moresby. Rural Development Series Handbook 8. (price 50t)

Remarks: Corn is becoming an important crop in the Markham Valley and is found everywhere in subsistence gardens. Local varieties produce about 1-2tonnes/ha. Improved ones produce about 5-6tonne/ha. Corn is probably a more suitable stockfeed for PNG generally than sorghum. It is good to have some corn in your garden because it grows quickly if there is drought or frost that kills the garden. Corn must have good drainage, is not resistant to flooding.

Initial contributor: R.M. Bourke, LAES, Kerevat, ENB.

POTATO (IRISH OR ENGLISH POTATO)

Description: A soft-stemmed plant sometimes regarded as a perennial, because of its ability to reproduce vegetatively by means of tubers left in the ground from one season to the next, although normally cultivated as an annual. There are a great many different varieties. The highest yields are found in areas with a moderate climate, but they may also be grown in the tropics in the cool highlands areas.

Botanical name: Solanum tuberosum L.

Mature Height: 30 - 60cm

Age at maturity: early varieties 3 - 3 1/2 months; medium varieties at 4 - 5 months, and late ones up to 7 months. Normal 3 to 4 months in the tropics.

Indication of maturity: when the skins have set.

Temperature: a rainfall of 50 - 75cm evenly distributed throughout the growing period is considered essential. Not below 500 m.

Soil: Potatoes can be grown on all soil types, except heavy waterlogged clays, but for optimum yields, a deep well-drained loam or sandy loam relatively free from stones and with a pH of 5.5 to 6.0 is needed.

Altitude: Late-maturing varieties from temperate regions can usually be grown successfully in the tropics at altitudes of approx. 390 to 2,100m. Some of the indigenous So. American varieties can be grown at altitudes higher than 2,100m.

Planting: Tubers, either whole or cut, are planted. Whole tubers are preferred, as they save labour and are less liable to develop rots in the soil. The planting material should weigh at least 40 - 55g. Good healthy planting material is essential. Potato tubers enter into a period of rest after harvesting and under normal conditions will not sprout until this period has ended (usually about 8 weeks.) Before planting the field should be ploughed to a depth of 25 - 30cm at least twice and harrowed so as to produce a fine deep tilth. Plant seed potatoes in ridges, 5-15cm deep, every 20-30cm, with 75-120cm between the ridges. The very best spacing depends upon the variety used and local conditions.

Pests and diseases: Potatoes are subject to a large number of pests and diseases, and prompt identification and control is essential if

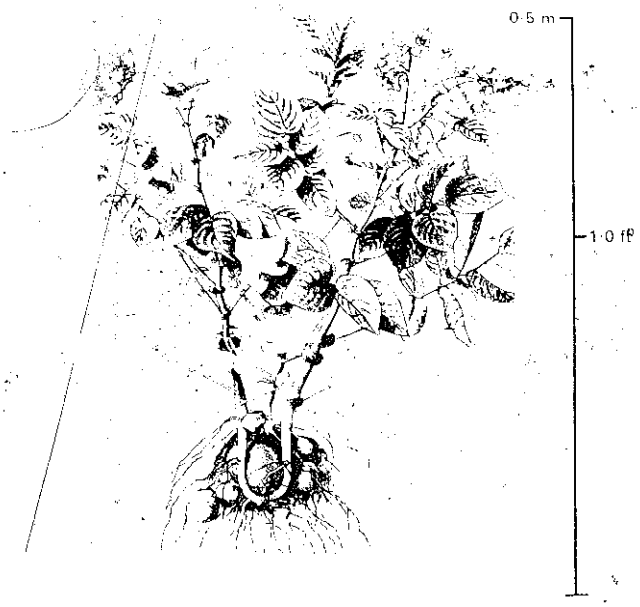

planting is to be economic. Aphids, potato tuber moth, root eating ants, flea beetles, fungal diseases, blights, bacterial diseases, and virus diseases can all cause serious losses. Seek expert advice on control methods.

Uses: Eaten boiled, roasted, baked or fried. Processed into a variety of products such as canned whole potatoes, frozen french fries or chips, dehydrated flakes, powder or granules, potato salad.

Secondary uses: Stockfeed, starch, flour, alcohol.

By-products: Potato pulp for livestock, potato peels for livestock, potato sprouts for vegetable, citric acid.

PNG Experience: SAMU LTD., a new potato growers' cooperative related to WASD LTD., probably has the most solid experience in the country. Address: Samu Ltd., Wapenamanda, Enga Province.

References: Root Crops, D.E. Kay, Tropical Products Institute.

RICE RAIS

Description: A short-lived grass able to grow in flooded conditions.

Botanical Name: Oryza sativa
Height: 90cm to 110cm
Crop life: 4 to 5 months depending on variety
Harvest at maturity, when 9/10 of the rice is yellow.

Insect pests and control: (p 164)

1. Pink Stemborer: use Diazinon spray
2. Brown planthopper: Diazinon or Orthene
3. Chinch bugs: Lindane seed treatment
4. Mole crickets: Diazinon
5. Rice bugs (Leptocoryza): Actellic or light traps.
6. Whorl maggots, leaffolders, army worms, nymphalids, green vegetable bugs do not generally present a problem. If they do Orthene, Diazinon, or Malathion will control.

Diseases and control: No virus diseases have been noted in PNG; Bacterial leaf blight in some areas, minor; Helminthosporium brown spot, and Cercospora leaf spot are caused by fungii. Occasionally Helminthosporium will cause seeds to turn brown and not develop, no control. Zinc deficiency in some soils causes leaf tip to appear burned, but this should not be confused with a burned tip that shows after the plant has recovered from drought. Phosphorous deficiency causes uneven maturity of rice.

Indication of maturity is when 80% of the grains are yellow, firm and clear, but 20% of the grain are firm but still green. In almost all cases this will occur thirty days after the flowers appear.

Planting of dry rice (Rainfed, not flooded fields): Two methods of planting are recommended:

1. With a pointed stick make a planting hole 3-4cm deep and drop 5-10 seeds in each hole, cover hole. Holes should be about 25cm from each other in a line.

2. Plant seed in a continuous line. Lines should be about 23cm apart, and the seed planted 2-3cm deep.

In both cases, after three to four weeks transplant any missing places where the rice didn't grow, by taking seedlings from places where there are many.

50-150kg of Nitrogen per hectare will improve yields in all parts of PNG.

Planting paddy rice (flooded fields): Those interested should contact: Manager, Gabmazung Rice Farm, Box 80, Lae. It is not difficult, but involves a different technology best learned through a field experience.

Useful products at village level: (p 93) Rice to eat, using mortar and pestle or simple concrete mill. Rice hulls make very good litter for chickens; Rice hulls can be placed between two walls to make very good insulation for cold storage; Rice hulls mixed with clay soils will improve soil by being a mulch (very slow to decompose); Rice bran and polish is a good feed for pigs and chickens; ash from burning rice hulls makes excellent scouring powder for the kitchen.

Industrial uses: The polish is used in baby foods and health foods; hulls are mixed in feeds, fertilizers to prevent caking; hulls are mixed in concrete to make lightweight bricks; ground hulls are used for making polishing abrasives; oil is expelled from the bran to make rice oil; hulls are burned to make ash for cement, and as a dust to help sweep up spilled oil; broken grains are made into flour to mix with wheat flour.

Rice seed is available from DPI in all provinces, or direct from the Agriculture Experiment Station at Bubia, Lae, for special varieties.

No special tools are required to grow rice, but there are many tools that help to make it easier: seeders, drum threshers: Tutt Bryant, Badili; rice knives, winnowers: OIC, DPI, Bainyik, ESP -

(p 165) (p 166)

-cont'd

Further references (also see bibliography):

Tietze, R., Planim Rais, Buk 7, Yangpela Didiman bilong Niugini, 20t, Kristen Pres, Madang;

Rice Production Manual (P 250)
Field Problems of Tropical Rice, by K.E. Mueller, IRRI, PO Box 1300 MCC, Makati D-708, Philippines.

Information Bulletin 16, Rice, anon, DPI Bubia, 1975; Farming note 6, Rice, DPI Konedobu, 30toea.

PNG Experience: Rice is grown in the Markham, East Sepik, West Sepik and New Ireland Provinces, and the Mekeo. Agriculture Officers in these areas are familar with rice. Interesting experiences with dry rice: contact Manager, Puas Vocational Centre, PMB, Kavieng, NIP.

Remarks: Rice should only be grown where temperatures are above 21°C and where there is a minimum rainfall of 250mm per month. Some areas have shorter rainfall seasons than others and the proper variety is one which will flower before the end of the rainy season. Dry weather at flowering will cause the seeds to be empty. Sometimes, by chance, rice is grown when there is a drier period. Usually this will make the rice take longer to mature and the rice will be shorter in height than normal. Many things that happen to rice are thought to be burn caused by the sun, but unless you see the leaves rolling up in a tube during the sunny period it is something else like insects or disease.

Brown rice and white rice come from the same plant and can be made from the same seed. The seed is the part that is planted and is harvested. It has a yellow skin and this is called the hull. Rice with the hull on is called "paddy" or "padi". When the hull is removed in a hulling machine, brown rice comes up. This is the most nutritious rice. White rice is made from brown rice by scraping the brown part off in a machine called a "whitener". The brown part is called "bran", and is very good pig food and chicken food.

When rice is harvested it should be dried so it will be milled well and will keep well in storage. You know that rice is dry enough for storage if you can bite a seed with your front teeth and hear a snap when it breaks. Do not mill rice until it has stored for three weeks after drying, or you will have many broken grains.

Initial contributor: J.T.Hale, Box 215, Wewak, ESP

MAMI (No Article)

SAGO SAKSAK

Sago is seldom cultivated, but usually grows wild. It provides the staple food of many marsh-dwelling Papua New Guineans.

Botanical name: Metroxylon rumphii (thorned stem)
Metroxylon aagu (smooth stem)

Height: 10 - 15 metres
Age to first production: 12-15 years
Normal life span: 12-15 years

Insects pests and control: Palm Weevil (Rhynchophorus sp.) The grubs enter injuries on the stem or crown of the palm. Chemicals for control are very dangerous in inexperienced hands. Control of breeding sites, often by eating the grub, is common biological control.

Indication of maturity: Highest level of starch is accumulated when flower begins to appear at about 12-15 years. Palm dies shortly after.

Planting information: Suckers growing from the base of older trees are planted in fresh water swamps at 5m x 5m. Under most conditions replanting of an existing swamp is not necessary, but it is necessary to cut out extra suckers when trees grow too close together. Smooth stem varieties yield better than thorned stem ones.

Useful products village level: Starch is used for food as a pure starch or mixed with shredded coconut or pieces of meat or fish. Leaves are used as a thatch for roofs when folded over sticks and sewn with bush twine. (P 95) (P 184)

The mid-rib of the leaf (pangal) is split and used as a wall cladding. When split very fine it is woven by hand or a simple loom into blinds for wall coverings. Loom plans are available from the Forests Products Research Centre.

Industrial products: Sago is a source of commercial starch.

Source of planting material: local.

Location and result of PNG experience: Sago is a traditional crop of coastal and lowland people. Yields range from 100 to 350kg per tree depending on variety and soil, and requires the effort of a family for 3-4 days to process the starch.

Remarks: Although sago is low in protein and vitamins it is a widely used starch form in coastal lowland and islands PNG. The low protein level is compensated by the custom in most areas of mixing coconut, vegetables and pieces of meat before eating.

Sago ferments and spoils very quickly.

Initial contributor: E. Cox, Bagi Agr. Centre, Box 65, Angoram, ESP.

SORGHUM

(p 244)

Botanical name: Sorghum bicolor
Height: 100-130cm dwarf varieties
Crop life: 100-135 days

This is a drought-resistant crop which is often grown in regions where other cereals do not thrive. The grain-type sorghum is an excellent animal feed. It is not only more drought-resistant, but more flood-resistant than maize.

Many productive hybrid varieties are available from Australian seed companies. A popular open-pollinated variety is "Alpha", available from DPI Experiment Station, Bubia, Lae.

Sorghum may be threshed when mature and dry, or the whole heads may be cut and given to chickens or pigs anytime after the hard dough stage. Sorghum is usually about 9% protein, a little under maize.

Recommended population per hectare is 180,000 or plant in rows 36cm apart, about 15cm between plants. It is better to overplant a little and then thin out later. Most varieties take around 100 days to mature.

Remarks: After harvest many Sorghum varieties will grow a second and third crop from the base if there is enough water. Yields will be much less than first crop.

SUGAR CANE

Botanical name: Saccharum officinarium
Height: 2 - 3 metres
Age to first production: 12 to 14 months, may take 18 months to 2 years.
Normal life span: After the first cutting the plants throw up successive stems called "ratoons", which take about the same period to mature as the original crop. The yield declines slowly with each ratoon, and after two or three ratoon crops have been harvested replanting is usually done.

Indication of maturity: In commercial production harvesting operations are carefully timed so as to get maximum sugar content, and sampling laboratories are used for testing. In the village the stems are taken when they appear woody.

Planting information: The planting material is usually stem cuttings (setts) which have 2 or 3 nodes each, planted around 1 metre apart in 1.5m rows. Weeding is important. Since sugar cane is a heavily soil-depleting crop, fertilization is important if it is grown continuously. It is understood that in order to build up a large concentration of sugar in the stems, a natural period of stress is required, usually a dry period. Timing of planting should be done with this in mind.

Harvesting information: Sugar cane should be squeezed within 48 hours after cutting, as the sugar content drops rapidly after that time.

Useful products at village level: People chew on the fresh, mature cane; fresh juice for drinking; dark brown sugar (gur or jaggery, or muscovado) which can be used for jams, candies, cooking, coffee or tea. The crushed stems can, after drying in the sun, be used for fuel. (p 96)

(p 97)
(p 178)

Industrial products: White refined sugar, molasses, residue (press cake) for cattle feed, bagasse (crushed stems) is used for building materials (fibreboards) and for fuel.

Sources of supply of planting materials: local; Many varieties available at DPI Experiment Station at Bubia, Lae.

PNG Experience: Agronomist-in-Charge, DPI Experiment Station, Bubia, Lae.

Remarks: In chewing sugar cane, always start from the top end. If one starts from the bottom end, he is known as "one who does not know much about growing sugarcane."

SWEET POTATO KAUKAU

Description: A soft stemmed perennial vine cultivated as a annual.
Botanical name: Ipomoea batatas
Height: Vine, lays on the ground.
Age to first production: 2 months
Normal life span: 4 - 5 months, lowlands. 5-6 months and up to 8 months at high altitudes.

Insect pests and control: Sweet potato weevil (Cylas formicarius) can be very severe, especially in dry weather. Control is by crop rotation, but this is not always effective. Dipping of planting material may be needed. See Harvest article for further information.

Sweet Potato Hawkmoth (Herse convolvuli) eat the leaves. Spraying with carbaryl may be justified if damage is very severe. (See Harvest) Leaf miner (Bedellia somulentella) (See Harvest)

Diseases and control: Little leaf occurs on the Gazelle Peninsula and in the Central Province and New Ireland Province. Do not take planting material from these areas to other areas.

A scab disease caused by the fungus (Elcinoe batatas) occurs. Most varieties are resistant.

Indication of maturity: In some varieties the leaves turn yellow.

Planting information: Plant at about 50,000 cuttings from the youngest part of the vines per hectare. Planting density is not too important. At very close spacings it gives about the same total weight, but the tubers are larger and fewer. Use cuttings 30-40cm long. Mounds give better yields than ridges, which in turn are very much better than planting on the flat or heavy (clay) soils. Mounding or ridging is not so important on light (sandy) soils. There are hundreds, perhaps thousands, of varieties in PNG, with big differences in taste and yield. You must choose the variety that suits you best. (p 93) (p 94) (p 115) (p 116)

Useful products at village level: Tubers: human and stock feed. Leaves: a green vegetable.

Industrial products: Starch source. Flour made from sweet potatoes can partially replace wheat flour in bread making.

Sources of planting materials: local.

Further references: Kimber, A.J. (1972), Sweet Potato in Subsistence Agriculture. Papua New Guinea Agriculture Journal 23, (3 and 4): 90-95. (p 244)
Kimber, A.J. (1971). Cultivation Practices with Sweet Potato. Harvest 1 (1): 31-33.
Kimber, A.J. (1972). Widespread Damage by Insect Pests in Highlands Sweet Potato Gardens. Harvest 2 (4): 117 - 121

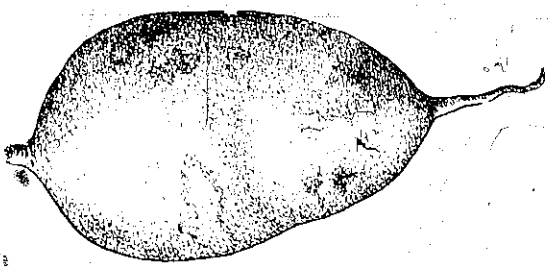

Kay, D.E. (1973) Root crops. TPI Crop and Product Digest No 2. Available free from Publications Section, TPI, 56/62 Gray's Inn Road, London WC1X 8LU, England.

PNG Experience: Sweet potato is the most important crop in PNG. It is grown almost everywhere, and is especially important in the highlands. It yields about 14 tonnes of edible tubers per ha. in the highlands and 18-20 tonnes per ha. in the lowlands. A lot of research has been done on the crop at DPI, Aiyura via Kainantu, EHP and at LAES, Kerevat, ENB.

Remarks: Sweet potato is very responsive to fertilisers, and if used properly their use can give very good returns. N and K are the main nutrients needed.

Initial contributor: R.M. Bourke, LAES, Kerevat, ENB

TARO TARO TRU

Description: A long lived, cormous plant with large heart-shaped leaves.
Botanical name: Colocasia esculenta
Height: 50cm - 200cm, usually 100cm.
Age to first production: 7 months.
Normal life span: 7-10 months.

Insect pest and control: Taro beetle (Papuana spp) Often a serious pest. Can be controlled with lindane granules. For 6% granules apply 1.5gm of chemical in each planting hole before planting. Sweet potato hawk-moth: Damage would have to be very severe before spraying is worthwile. Use a 0.1% solution of carbaryl (Septene 80; Resistox; Sevin) if spraying is necessary.

Diseases and control: Virus diseases can be very destructive. Use resistant varieties. Leaf blight can be bad in wet weather. Use resistant varieties. Separate new plantings from old ones. Avoid pure stands of taro. (See paper by Putter).

Indication of maturity: The leaves become smaller.

Planting information: Large setts give a quicker ground cover, produce bigger plants, and give a higher yield. There are thousands of varieties in PNG which differ in yield, disease resistance and taste. You must choose the variety that is best for you.

Useful products at village level: Corms - food for people, leaves are a good vegetable; Cormels (suckers) are good food for pigs or for people.

Sources of supply of planting materials: local.

Further reading: Massal, Emile and Barrau, Jacques (1955). Pacific Subsistence Crops, Taros, SPC Quarterly Bulletin 5 (2): 17-21. (p 246)
Plucknett, D.L., de la Pena, R.S. and Obero, F. (1970) Taro (Colocasia esculenta). Field Crop Abstracts 23 (4): 413-426. (A review paper).
Putter, C.A.J. (1975). Disease Resistance in Plants and its Role in Crop Protection Strategy and Tactics in Papua New Guinea. Proc. PNG Crop Conference, Lae. April-May 1975.

PNG Experience: Taro is a most important staple in the lowlands. It yields about 7 tonnes per ha. usually, but up to 17 tonnes per ha. Research is being conducted on the agronomy and pests and diseases at LAES, Kerevat and Vudal ENB. For other information: The Agronomist-in-Charge, LAES, Kerevat ENB.

Remarks: Taro production is declining in PNG but it remains a most important crop and has great spiritual significance for many villagers.

Initial contributor: R.M. Bourke, LAES, Kerevat, ENB.

CHINESE TARO TARO KONG KONG

(Known as "Tinaupa" in Gazelle, "Karavela" in SDA Mission).

Description: A long-lived cormous plant with large course heart-shaped leaves. It looks similar to taro tru (Colocasia esculenta) but the veins are more prominent, the leaves larger and the V of the leaf extends as far as the petiole. The suckers (cormels) are usually

eaten rather than the mother sucker (corm).

Botanical name: Xanthosoma saggittifolium
Height: 2 metres
Age to first production: 9 - 12 months
Normal life span: A perennial

Insect pests and control: Taro beetle (Papuanna spp.) attacks the corm and cormlets. 6% lindane granules applied at 1.5g of chemical per plant in the planting hole gives some control.

Diseases and control: A virus (?) disease attacks the crop and makes it short. The trunk becomes very large compared with the leaves.

Indication of maturity: The edges of the older leaves turn yellow and die.

Planting information: Use large setts. Space at about 1.5m square.

Useful products at village level: Corms as pig feed. Cormlets as food for people.

Sources of planting material: local.
Further references: Kay, D.E. (1973). Root Crops, TPI Crop and Product Digest No 2. Available free from Publications Section, Tropical Products Institute, 56/62 Gray's Inn Road, London, WC1X 8LU, England.

Remarks: Chinese taro is a new crop to PNG. It is now important on the Gazelle Peninsula and in the Finschhafen area, but can be found throughout PNG.

Further information from the Agronomist-in-Charge, LAES, Keravat, ENB. Chinese taro is increasing in importance. It is tolerant of shade and is often grown under bananas or coconuts. It yields about 20 tonnes of edible cormlets/ha.

Initial contributor: R.M. Bourke, LAES, Kerevat, ENB.

GIANT TARO PARAGUM

Description: Leaves are long, arrow shaped and have rounded lobes. The stem (corm) forms a trunk and is the part of the plant eaten.

Botanical name; Alocasia macrorrhiza
Height: 2 metres
Age to first production: 1 year (?)
Normal life span: Several years

Planting information: The mother plant or sucker is used.

Sources of planting materials: local.

Further references: Kay, D.E., Root Crops; TPI Crop and Product Digest No 2. Available free (for official bodies) from Publications Section, TPI 56/62 Gray's Inn Road, London WC1X 8LU, England.

Paragum taro in a garden in Southern New Ireland

Remarks: Tastes similar to taro tru (colocasia esculenta). It is locally important in a few areas, but a fairly minor crop generally. Paragum is useful because it can be left in the ground for many years, so it is a useful emergency food. There are many wild varieties as well as edible ones. Some of these may cause irritation of the mouth, but apparently are not harmful.

Initial contributor: R.M. Bourke, LAES, Kerevat, ENB.

SWAMP TARO

Description: A giant herbaceous perennial. Leaves are arrow-shaped with long lobes.

Botanical name: Cyrtosperma chamissonis
Height: 2 metres or more
Age to first production: 2 years
Normal life span: Up to 9 years before harvesting

Insect pests and control: Little problem. Rats have been a problem in the Mortlock Islands.

Planting information: Grown from suckers or setts from harvested plants. Planted in pits in the Mortlock Islands.

Useful products: The corms are used as food, mainly for animals, but some people eat them.

Swamp taro, Vudal

The leaves and flowers can be used as a vegetable.

Sources of supply of planting materials: local.

Further References: Kay, D.E. (1973). Root Crops. TPI Crop and Product Digest No 2; Boag, A.D. and Curtis, R.E. (1969), Agriculture and Population in the Mortlock Islands, PNG Agricultural Journal 12 (1): 20-27.

Remarks: Found in swampy areas around the coast. It is the main food on coral atolls such as the Mortlock Islands off Bougainville. It will grow on swampy, salty soils that are useless for most other crops. Yields about 10 tonne/ha.

Initial contributor: R M Bourke
LAES, Kerevat ENB

WILD TARO ELEPHANT YAM

Description: A herbaceous plant bearing a single three part leaf, each part of which is divided into a number of segments.

Botanical name: Amorphophallus campanulatus
Height: 1 to 2.5 metres
Age to first production: 1 year
Normal life span: 4 - 6 years

Indication of maturity: The leaves begin to wither and die.

Planting information: It is grown from small corms, or pieces of 3-4 year old corms. There is a resting period of 2-3 months for planting material.

Wild taro plants grow in grassland in Bogia area

Uses at village level: The corms are used as food, and the young petioles may be eaten as a vegetable.

Sources of planting materials: local.

Further references: Kay, D.E. (1973). Root Crops. TPI Crop and Product Digest No 2. (Available free from Publications Section, TPI, 56/62 Gray's Inn Road, London WC1X 8LU, England.)

This taro is sometimes seen growing wild and is sometimes cultivated. It is common in grassland areas such as Markham Valley, Bogia area, and Central Province. Because the crop takes about 4 years to mature it is not particularly important, but it can act as a useful food reserve.

Initial contributor: R.M. Bourke, LAES,
Kerevat, ENB.

YAM

Description: Includes over 600 species of tuberous plants, usually with short fibrous roots and long vines that grow up poles.

Botanical name: Dioscorea spp.
D.alata: greater yam
D.esculenta: lesser yam
D.bulbitera: aerial yam
Height: A vine, long or short, depending upon variety.
Age to first production: 8 - 11 months
Indication of maturity: Harvest when the leafy material is completely dead.

Insect pests and control: Yam beetles, mealy bugs. Control with 6% lindane granules, 1.5g of chemical in each planting hole. Do not apply unless damage is severe.

Diseases and control: Leaf spot, certain virus diseases. Plant on new ground.

Planting information: Plant just before the rainy season with small whole tubers, the little bulbs, or pieces of big tubers that have been kept

for some months. Plant in rich well-drained soil, if possible, where the new gardens are made. Spacing varies from 1-2 metres. Keep free of weeds for at least three months. A 3 - 4 m post is planted next to each yam for the vine to grow on.

Harvesting and storing: It is sometimes wise to leave the tubers in the ground until they are needed, as they keep quite well there. Most varieties may be successfully stored for many months if they have adequate ventilation and protection from flooding, rats, and insect attacks.

Uses at village level: Tubers for human food can be boiled, baked or fried. Sometimes dried and (p 100) made into flour. It is good to use the peelings and waste for feeding livestock.

Sources of planting material: local.

Further reference: Root Crops, D.E. Kay, Tropical Products Institute.

Remarks: It is said that some varieties contain toxic substances and must be cooked well. Check local customs.

Legumes

COWPEAS

Cowpeas can be a useful source of protein at the village level in many areas. The following information is for grain cowpeas.

Botanical name: Vigna unguiculata (L.)
Height: About 2m, highly variable, some varieties are tall climbers
Age to first production: about 70 days
Normal life span: 4 months
Indication of maturity: 90% of pods are golden brown

Insect pests and control: black bean aphids, spray with Malathion; pod borers, spray Orthene.

Planting information: Plant at high density (50cm x 10cm apart) for maximum grain yield. Many varieties give no response to fertiliser. Avoid both very high rainfall times and very high soil fertility. Both promote leaf growth at the expense of pods and turn the crop into a green manure and fodder crop rather than a grain crop.

Sources of supply of planting materials and further information: small quantities from Agr. Faculty, UPNG, Waigani, or ILB, Box 1920, Lae.

Remarks: The pods can be threshed after harvesting and drying by putting them in copra bags and bashing the bag against the ground. See recipes for grain legumes. (p 108)

Initial contributor: W. Erskine, UPNG, Waigani

Gathering mung beans in the garden.

MUNG BEAN

The mung bean is easily cooked, has about 24% protein, is popular at village level in Indonesia, the Philippines and India. It is generally easier to grow in the tropics than soybeans. It is high in the vitamin thiamine (B_1)

Botanical name: Phaseolus aureus
Height: 40 - 60cm
Age to first production: approx 65 days
Normal life span: approx 80 days

Insect pests and control: Mung beans are commonly attacked by a broad range of insects from the time after germination up to near harvest, but the most destructive infestations occur during flowering to pod-formation stage. Spraying with Orthene might be advisable at that time. Other foliar sprays will work. Otherwise, a moderate level of insect damage is acceptable to avoid spraying costs.

Diseases: an occasional rust, but usually not worth treating. Dithane will control.

Planting information: Avoid the wettest times. Mung beans make an excellent secondary crop. Row spacing 50cm. Sow 40-50 seeds per linear metre. Cover with fine moist soil about 2-3cm deep. No inoculant is necessary. 5-7 days after planting, thin to 30-40 plants per lineal metre. Retain the most vigorous plants. Weed as early as possible. Cultivation is necessary only for weed control. Harvest when the pods are mature (dark brown).

Uses at village level: Good food! See recipes for grain legumes. Makes excellent bean sprouts.

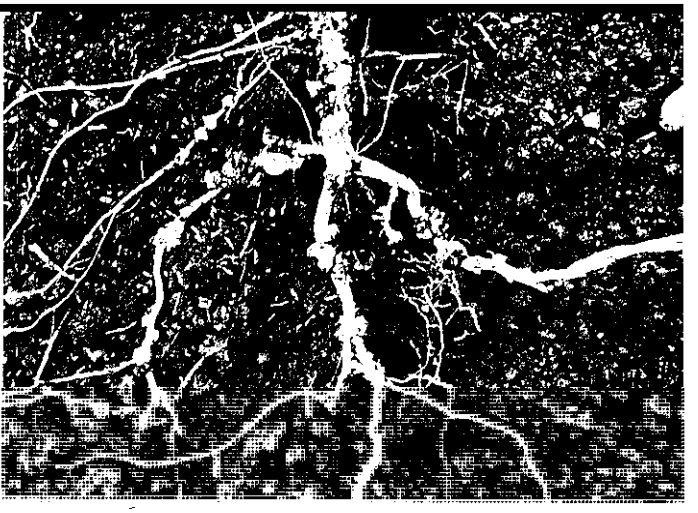

Bumps on these roots are nodules. The nodules contain bacteria that convert nitrogen from the air to nitrogen that can be used by the bean.

Sources of planting materials: Liklik Buk, Box 1920, Lae; OIC, DPI Exp. Station, Bubia, Lae. Try to get Variety NG 7272, which is newly introduced from the Philippines.

PNG Experience: Some mung beans have been grown in the Markham Valley on a commercial basis, for stock feed, with mediocre results. I suspect that a mediocre variety was used. This bean is labour intensive and is much more suitable at village level, for human food. My own garden produced a computed yield of 950kg/ha of dried beans during the wet season, and yields should be better during the drier time. Apparently mung beans have not yet been promoted as a village-level crop in PNG. They should be better at lower elevations, but are worth a try at any location below 1,500m.

Remarks: The beans are most easily prepared for eating by boiling for 30 to 60 minutes, depending upon hardness. Soaking overnight greatly shortens cooking time. After cooking separately, mung bean goes well with other vegetables. A small amount of vegetable or animal fat (try coconut cream!) improves palatability, and other seasonings should be added according to taste. Some like it with curry. See recipes. (P 108)

Mung beans in the pod being threshed.

PEANUTS (GROUNDNUTS) GALIP PINAT

If we consider the energy yield per unit area of land, peanuts probably offer the greatest potential of all the legumes. They are a familar village crop in most areas of PNG, but are definitely under-used.

Botanical name: Arachis hypogaea
Height: 40 - 60cm
Age at harvest: 100-140 days, depending upon variety and location

Major pests and diseases and control: In many places peanuts are quite free from pests and diseases, but rust and certain soilborne fungi can cause problems. The DPI Station at Bubia recommends the use of fungicide seed dressing (for example, captan and PCNB). In the village situation crop rotations may be sufficient to control these.

Indication of maturity: yellowing and wilting of the leaves.

Planting information: plant in light soil, if possible, or on ridges. Spacing may be variable, but 60-80cm rows are typical, with about 10cm between plants. White Spanish peanut variety (grown widely in the Markham Valley) is recommended. Inoculation is not necessary.

Used at village level: Eat boiled, roasted, fried, as peanut butter, chopped. See recipes. (p 178) (p 251) (p 110) (p 111)

Commercial uses: oil for cooking, margarine, soap-making, printing ink. Residual oil-cake is used for stock feed.

Sources of planting material: easily found in most localities.

Further references: Peanuts, DPI Exp. Station, Bubia, Lae. (p 244)

Remarks: Peanuts can easily be dried and stored by hanging them in the shell, and usually still on the stalks, over the kitchen fire. Peanuts are much more digestible when cooked, though many in PNG eat them raw. Only mature peanuts which have been freshly harvested and/or free from moulds should be used for cooking, as a toxic substance called aflatoxin can be generated on mouldy peanuts.

SNAKE BEAN YARDLONG BEAN

Description: A soft-stemmed climbing vine grown for pods and leaves.
Botanical name: Vigna unguiculata var. sesquipedalis
Height: to 3 metres
Age to first production: 60 days
Normal life span: 120 days

Insect pests and control: Common pests are aphids and pod borers. A spray with malathion or Orthene will control most species.

Indication of maturity: Village tastes for snake beans require that the bean become quite fat, but Westerners prefer harvesting when still thin. Vitamin content is highest at the more immature stage. Should be cooked only for a short time, or may be eaten raw.

Planting information: Plant in ridges or hills 60 to 90cm apart and 20-25cm in the row. Place stakes at each seedling for climbing.

Initial contributor: E. Cox, Box 65, Angoram ESP.

SOYBEAN (SOYA)

Under favourable conditions, soybeans are the plant with the highest potential protein yield per unit area of land, and are also very high in fat. The

LAES Station at Kerevat reports yields as high as 2,500kg per ha.

Botanical name: Glycine max
Height: 60-100cm
Age to production: about 12 weeks

Insect pests and control: Some green vegetable bugs, small pink root scale; control with Orthene. Rusts, control with fungicide (Dithane M45).

Indication of maturity: Pods turn brown.

Planting information: Typical spacing is 60cm rows, 10cm apart in the row. Soybeans grow better in temperate or sub-tropical climates than in the tropics, so in PNG do better at higher altitudes than at sea level. In many situations you will need to inoculate the seeds to initiate the growth of nodules on the roots (see government inoculum service below). (p 15)

(p 107)

Uses at village level: Good food! Soak, cook, and make into various soups, and stews (see recipes for grain legumes); Soybean high protein flour for soy milk and baking; beansprouts. (p 110)

Commercial uses: Oil for cooking, margarine, soaps, plastics, high protein flour, soysauce, bean curds (tofu); soybean oil meal (residue from oil extraction) is high-protein stock feed concentrate.

Sources of planting materials: Small quantities from DPI. Bubia, LAES Kerevat; CLTC, Banz c/- Box 382, Mt. Hagen, WHP. Order large quantities from the seed companies. Order inoculant (state amount of seed to be treated) from Rhizobium Supply Service, DPI, Box 2417, Konedobu.

Remarks: Success in soybean growing in PNG is quite mixed. Some are highly successful, and others quite unsuccessful. Be sure you can do it yourself before promoting these. It is definitely worth a try, whatever your situation, because of the high potential yields and high food value.

Unfortunately, soybeans are not widely acceptable as a food without special methods of preparation. Most varieties have a somewhat bitter taste and a hard, indigestible cellulose seedcoat. Soak the seeds overnight, throw away soak water, and remove the seedcoats by hand, before cooking. Another problem with soybeans is the presence of an inhibitor called "trypsin" in the raw beans. This inhibitor probably interferes with the intestinal digestion of protein. Boiling the beans for an hour or pressure-cooking for 10 minutes destroys the trypsin. This is important to know if you are planning to grind or mill the dried beans for a more direct use.

Initial contributor: B. Heyward
Baiyer River, WHP

WINGED BEAN

The winged bean, popularly known as "arsebean", or "bin", has been causing a great deal of interest in recent years because: it is a traditional crop in the PNG highlands; it is high in protein (as high as 37% in the dried grains); and it produces tubers, which are also popular and relatively high in protein (up to 11% of the wet wt., as compared with yam and potato, which are about 2%).

Almost all parts of the plant are eaten: flowers, leaves, green beans, seeds and tubers. In the highlands, however, the tubers are preferred. Winged beans are grown for both home consumption and cash. It is rarely used for animal feed.

Botanical name: Psophocarpus tetragonolobus
Height: A long vine which grows on stakes
Age to first production: Flowers, leaves, green pods, 3 months; Tubers after 5-6 months.
Normal life span: 6 months

Climate: Winged bean can be grown in almost any part of PNG. However, it is generally not grown at altitudes above 1,800m. In both the highlands and lowlands drier weather is better (less disease).

Varieties: Many varieties of winged bean are found in PNG. There are basically two types: roots and pods. A collection of different varieties is maintained at UPNG, and particular types of varieties can be obtained on request.

Ground preparation and planting: Winged bean can be grown in almost any type of soil, as long as it is well-drained. In the highlands, beds or mounds are used. Seeds are planted 2-3cm deep at 20cm distance in rectangular or triangular patterns. Planting on ridges can also be done, although this method is not very common. Ridges are made 50cm apart and about 40-50cm high. Seeds are planted at a distance of 10cm on these ridges. Sometimes winged beans are also grown mixed with other crops such as Maize or Soybeans. Planting is done generally at the onset of the dry season, but - if pests and diseases can be controlled - winged beans should grow equally well in the wet season. An abundant moisture supply is necessary if winged beans are being grown to obtain roots.

Nodulation: Winged bean roots form abundant pea-sized nodules which fix atmospheric Nitrogen. This makes the soil more fertile for the crops that follow. In most soils the nodules grow freely. However, if this does not happen, the inoculation is necessary.

Fertilizer: No fertilizer is needed in recently cleared areas. In poor soils NPK, each at the rate of 25kg per hectare is recommended.

Weeding and staking: In the first six weeks after planting, weeds should be removed to encourage healthy growth. Weeding is usually not necessary after that, especially during the dry season. When the crop is 6-8 weeks old, stakes (such as pit pit or other cane) should be provided, one stake per 2-3 plants. The stakes should be 2-3m high for a grain crop; 1-1.5m high for a tuber crop. If staking

materials are scarce, improvise with vines or string between stakes. It is often grown along garden fences.

Pruning: Pruning is not necessary if the crop is grown for green pods. However, if roots are wanted, the young shoots, flowers and pods are periodically removed.

Diseases: These diseases are of major importance:-

1. Leaf spot - which is destructive in wet season. It can be controlled with regular spraying with Benlate (50 ml / 100 litres twice a week)
2. False rust - is also of importance under wet conditions. This disease is difficult to control.
3. Root-Knot Nematodes - is one of the most widely distributed diseases. Its attack reduces yield, and it also reduces the quality of the tubers. The only control method is prevention, or growing winged bean on new ground or soil that is free of the Nematode problem.

Pests: Insect pests that attack under dry conditions are not usually serious. However, a number of pests, including Aphis, Pod borers, and leaf miners can cause considerable damage under lowland conditions. Spray.

Harvesting: The harvesting of flowers, leaves and green pods for eating may start from 3 months after planting. Roots are harvested after 5-6 months. In the highlands the general maturity time is higher than in the lowlands.

Yields: The seed yield varies from 800 - 1000kg per hectare. The yield of Green pods and other vegetative parts may vary considerably. Tuber yield varies between 5,000 - 10,000kg per hectare.

Marketing: At present local markets are the only places to sell winged bean. Flowers, leaves and young pods are sold in small bunches at 10t each. Cooked green beans sell for 10-15t per kg. Cooked tubers sell at 25-30t per kg. Cooked beans and tubers may be stored for 2-3 days.

Useful references: The Winged Bean - A High Protein Crop for the Tropics by National Academy of Science, Washington, DC, USA. 1975.

"Cultivation of the Winged Bean in the Papua New Guinea Highlands" by T.N. Khan, J.C. Bohn and R.A. Stephenson, World Crops, 1976.

"Papua New Guinea: A Centre of Genetic Diversity in Winged Bean", by T.N. Khan, Euphytica, 1976.

"Psophocarpus tetragonolobus, a Crop with a Future?" by G.B. Masefield. Field Crop Abstract 24(4): 157-160, 1973.

"Investigations of Winged Bean in Ghana" by F. Pospisil, S.K. Karikari and E. Boamah-Mensah, World Crops 23(5): 260-264, 1971.

"Traditional Legumes of the Papua New Guinea Highlands" by Jocelyn M. Powell. Science in New Guinea 2. 48-63, 1974.

"Diseases of the Winged Bean in Papua New Guinea", by T.V. Price Aust. Plant Pathology Society Newsletter Vol 5(2).

Technical information and planting materials: Winged Bean Research Group, Faculty of Agriculture, UPNG, University.

Initial contributor: T. Khan, UPNG, University.

COVER CROPS (No Article)

RHIZOBIUM SUPPLY SERVICE

Most legumes need bacteria called Rhizobium to use nitrogen from the air for growing. There are many different types of Rhizobium and these are called strains. Different species of legumes need different Rhizobium strains. For most legumes, the right strain is already in the soil, but some need a Rhizobium strain that is not in the soil. Centro, soybean and leucaena are some of the legumes that need inoculating with the correct Rhizobium if they are being grown in an area for the first time, and improved strains are also available for other legumes.

You can obtain the correct Rhizobium for your crop by writing to the Rhizobium Supply Service, DPI, Box 2417, Konedobu. There is no charge for this, but you will be asked to examine the roots of the inoculated legume for nodules and to send a form back to Konedobu. Instructions on how to use the Rhizobium are given when it is sent to you.

Reading: Shaw, D.E. and others (1972). "The Rhizobium Supply Service in Papua New Guinea." Papua New Guinea Agricultural Journal 23 (1 and 2) 12-26.

Oil Plants

COCONUT

Botanical name: Cocos nucifera
Height: Tall variety - up to 26m
Dwarf variety - up to 14m
Commencement of bearing: Tall variety, 4.5 to 10 years; dwarf variety 4 to 6 years, depending on management.
Life span: 80 to 100 years
Potential yield depending on good nutrition, 2½ tonne copra/ha, but varies with varieties.

Pests	Control
Rhinoceros beetle (Scapanes australis) (Oryctes rhinoceros)	Young palms: Lindane granules placed in frond axils and regular hand picking. Mature palms: no simple effective control
Palm weevil (Rhinchophorus bilineatus)	Prevent wounds which act as entry sites for the weevil.
Treehoppers (Segestidea sp.) (Segestes sp.) (Sexava sp.)	No simple control applicable to small holders. Banding of palms with 'Osticon' may be partially effective.
Coconut leafminer (Promecotheca papuana)	Natural biological control may occur.
Coconut flower bug (Axiagastus cambelli)	Biological control in some areas. Trunk injections with systemic insecticides possible.
Seedling leafminer (Brontispa longissima)	Application to young fronds of Lindane and Gammexane type sprays.
Amblypelta bug (Amblypelta sp)	Biological control using 'kurakum' ants.
Coconut spathe moth (Tirathaba rufivena)	Usually not necessary
Rats	Poison baits, trapping, protective barriers.

Diseases	Control
Chlorosis, wilt and other deficiency diseases.	Application of the deficient nutrient as fertilizer.
Seedling leaf spot (Drechslera incurvata)	Regular application of "Outer" fungicide. Potassium fertilizers used to increase the palm resistance.
Lightning strike	No effective control
Finschafen disease	Control of the vector insect.
White thread blight (Corticium penicillatum)	In areas subject to this leaf disease palms should be planted on a 9m triangle rather than at closer spacing.

Planting information: In planting coconuts for profit the following should be heeded: select good nuts from good palms; some varieties in PNG are better than others and seed of these can be obtained for planting. Proper nursery construction and adequate maintenance - polybag nurseries have many advantages over field nurseries; transplant into the field during moist soil conditions and at a suitable depth in a planting hole; select only the best seedlings from the nursery; correct spacing (an 8.2m triangular spacing is good for most areas); good and regular maintenance; regular pest control.

Uses at village level: (p 92) (p 118) (p 173) Coconut meat from mature nuts is dried for copra production, is grated for milk used in cooking, is grated for oil extraction, is used fresh for pig and chicken feed. Immature nuts are used for food and drink. Fronds, leaves are used for thatching, basket work and fuel. Timber is used for house construction, fences, bridges, but rots quickly.

Industrial uses: Copra is used for oil production. The oil is used in soaps, detergents, margarine and confectionaries. The residues are used as stock feed. The meat is often processed as dessicated coconut for confectionaries. The husk can be made into coir (for ropes, brushes, mats, okum, and other uses).

Sources of planting material: Usually available locally. Seed of the better varieties, such as KarKar, are available through DPI, Madang. Usual price (not including shipping) is 5t per nut. DPI intends to produce high yielding hybrid seed near Madang. This will not be available for several years.

Materials: Polybags for nursery, from ICI, Lae. Insecticides from ICI New Guinea Pty. Ltd., Box 1105, Lae; Elvee Trading Pty. Ltd., Box 151, Rabaul; Nufarm Rural Products, Raynolds St., Mareeba, Qld., 4880, Australia. ('Duter' - K4/k)

References: Various articles in PNG Agricultural Journal Vol. 17 (2) April, 1965. Also,

Management: Vol. 21 (3 & 4) 93-101 (1970)
22 (2) 77-86 (1971)
22 (3) 167-173 (1971)
23 (3 & 4) 73-79 (1972)

Pests and Diseases: Vol. 22 (1) 1-5 (1970)
23 (1 & 2) 27-40 (1972)
24 (3) 79-86 (1973)

Annual Reports of DASF up to 1969, and Agronomy Research Report, Section 11 - Coconut, 1969-1972. All of these are published by DPI, Konedobu.

cont'd

General references: The Coconut Palm - a Monograph by Menon and Pandalai, Indian Central Coconut Committee, 1958; Coconuts by R. Child, Longmans; Coconut Growing by C.J. Piggatt, Oxford U.P.; Pacific Islands Planters Handbook, Imperial Chemical Industries (New Guinea) Pty. Ltd. Insect Pests of Coconuts in the Pacific Region by J.H. Stapley, reprint from Outlook on Agr. Vol 7 No 5 1973, pp 211-217. (P 244) (P 245)

PNG experience is found in most PNG coastal areas. H. Gallasch, LAES, Kerevat; J. Sumbak, Bubia Experiment Station, via Lae; C. Perry, Entomologist LAES, Kerevat; The Entomologist, DPI, Konedobu; The Chief Pathologist, DPI, Konedobu.

Miscellaneous: Pests and diseases are usually recognized but soil deficiencies may be greatly lowering yields without being recognized. Deficiencies in sulphur and potassium and to a lesser degree nitrogen are very widespread in PNG. An indication of the presence or not of a nutrient deficiency can be gained from chemical analyses of leaf and coconut water, samples submitted to the Chief Chemist, DPI, Konedobu or to the Chief Chemist, Analysis Laboratory PNG University of Technology, Box 793, Lae. Charges can be advised by the University.

Initial contributor: H.E. Gallasch, LAES, Kerevat, ENB.

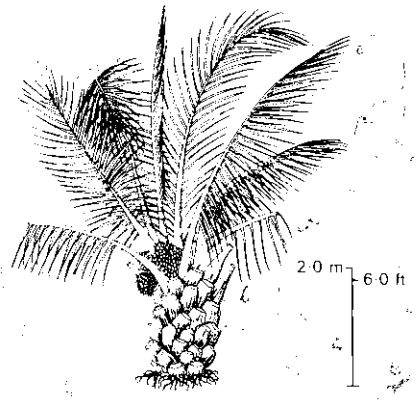

OIL PALM

Botanical name: Elaeis guineensis Jacq.
Height: Up to 20metres depending on age and growing conditions.

First production: At 2½ years, but usually the flowers are removed until 3 years, so the bearing commences about 3½ years.

Life span: Palms may continue bearing 50 years or more. However, these palms would be very tall and difficult to harvest. 25 years may be the economic life of a palm in PNG.

Potential production: In the region of 25-30 tonnes fresh fruit bunches per hectare from fertilized palms.

Pests	Control
Rhinoceros beetles (Oryctes rhinoceros) (Scapanes australis)	Plantation hygiene. Insecticide (lindane granules) in leaf axils. Hand collecting of beetles.
Bagworms (Plutorectis sp.) (Clania sp.)	Usually biological control is sufficient.
Rats	Warfarin baits applied when damage significant.

Diseases	Control
Leaf strek, spotting and chlorosis (Physiological origin)	Determine the nutrient deficiency and apply appropriate fertilizer.
Bud rot (cause unknown)	Recovery may occur naturally. No control known.
Gradual decline (cause unknown)	No control known.
Leaf blight (Curvularia sp.)	Spraying of seedlings with Captan or Thiram fungicides.

Planting information: Use only specially bred seed; seedlings are raised in a centrally administered nursery, in poly bags; seedlings are ready for planting out at about 9-12 months of age; usually seedlings are planted on a 9.8 or 8.8m triangle; seedlings are given an initial fertilization and a cover crop maintained between the young palms; castration of flowers is carried out until the palm

is considered large enough for bearing - usually at about 3 years; hand pollination of female flowers is necessary in the early years to ensure good fruit set and production. Once commercial production has begun, harvesting must be done regularly to be sure of good quality fruit. Given suitable economic conditions, fertilizers are regularly applied to the bearing palms. (P 95) (P 187)

Uses at village level: No processing is done at present at village level, although the extraction of oil is widely done in parts of Africa, and could be adapted to conditions here. Oil is good for cooking, for lamps, and the fruit or the residue from extracting oil may be fed to pigs.

Industrial uses: The fruit is crushed and palm oil is extracted from the fleshy skin at the factory. The nut is broken and palm kernel oil extracted from the kernel. The residues of bunches and fruits are burned and ash used as fertilizer. The heat generated may be used for firing boilers. Residues may also be used for road surfacing. The palm oil is an edible oil used in shortening and margarine manufacture and in soap making. The palm kernel oil is used in margarine, cooking oils, cosmetics, confectionary (uses similar to those of coconut oil).

Planting materials: Improved planting material may be supplied at a nominal cost by the central estates. For non commercial purposes seed is obtainable from many DPI Extension Centres.

Materials and equipment may be obtained through commercial or co-operative enterprises in the areas of oil palm projects or from DPI, Kimbe, WNB.

References: The Papua New Guinea Agricultural Journal, Vol 18 No 4 (1976), Vol 22 No 4 (1971); The Oil Palm, by C.W.S. Hartley, Pub by Longmans, Green and Co., London, (1967); The Oil Palm in Malaya, Pub by Ministry of Agr. and Co-operatives, Kuala Lumpur, Malaysia (1968); Oil Palm Developments in Malaysia and Their Control, by B.J. Wood, The Incorporated Society of Planters, Kuala Lumpur (1968); Diseases and Disorders of the Oil Palm in Malaysia, by P.D. Turner and R.A. Bull, The Incorporated Society of Planters, Kaula Lumpur (1967)

PNG Experience: H. Gallasch, Agronomist, LAES, Kerevat, ENB; OIC, Dami Oil Palm Exp. Station, via Kimbe; The Entomologist, LAES, Kerevat, ENB; The Chief Pathologist, DPI, Konedobu.

Remarks: In PNG oil palm is only grown commercially adjacent to or in conjunction with large estates which provide joint processing facilities. The only producing area at present is centered on Mosa Plantation and factory at Kimbe, WNB. A second area will centre on the oil palm project commencing at Bialla, while a third project is planned for the Popondetta region of the Northern Province.

Due to the high yields obtained in PNG it is advisable to fertilize the palms regularly. Chemical analysis of foliar samples can indicate which fertilizers should be applied.

Initial contributor: H.E. Gallasch, LAES, Kerevat, ENB

THE APPROPRIATE TECHNOLOGY GAME

EVERY TIME AN INTERNATIONAL FLIGHT LANDS IN PORT MORESBY, WE GET AT LEAST ONE MORE APPROPRIATE TECHNOLOGY EXPERT. PNG HAS MORE APPROPRIATE TECHNOLOGY EXPERTS PER CAPITA THAN ANY OTHER COUNTRY IN THE DEVELOPING WORLD, MOST OF THEM FOREIGNERS.

THE TROUBLE WITH APPROPRIATE TECHNOLOGY EXPERTS IS THAT MOST ARE EXPERTS AT LITTLE EXCEPT CONVINCING THEMSELVES THAT THEY HAVE SOMETHING TO TEACH. PERHAPS LIKLIK BUK IS NO EXCEPTION!

IT IS VERY PLEASANT TO SIT AROUND THE YARD OF A HIGH COVENANT HOUSE SIPPING BEER AND DRAWING PLANS FOR DEHYDRATED KAUKAU FACTORIES. IT IS EVEN SATISFYING LIVING IN A BUSH HOUSE AND BUILDING AN EVAPORATIVE COOLER FROM POLES AND MOSQUITO NETS.

THE TROUBLE IS THAT MUCH OF THE "APPROPRIATE" TECHNOLOGY IS WHAT SOMEBODY THINKS IS APPROPRIATE FOR SOMEONE ELSE.

WE HAVE EVEN HEARD IT SAID THAT "APPROPRIATE TECHNOLOGY" IS SIMPLY A CONSPIRACY TO FORCE DEVELOPING COUNTRIES TO ACCEPT TECHNOLOGIES OF LOW PRODUCTIVITY.

OR COULD APPROPRIATE TECHNOLOGY BE AN "EGO TRIP" FOR EXPATRIATES WHO CAN'T MAKE IT IN THEIR OWN COUNTRY?

THESE QUESTIONS MAY BE UNFAIR, BUT UNTIL MORE OF WHAT IS CALLED APPROPRIATE TECHNOLOGY IS INVENTED, MADE, AND ADOPTED BY PAPUA NEW GUINEANS, THE APPROPRIATE TECHNOLOGY "EXPERT" SHOULD EXAMINE HIS MOTIVES VERY CRITICALLY.

Vegetables

TRADITIONAL VEGETABLES

(p 229)

There are two food groups that form the basis for meals in PNG. One group consist of energy foods such as sweet potato, taro, yams, bananas or sago. The other group is the vegetables. The vegetables are very important in the village diet. For many people they provide much of the protein, vitamins and minerals that people eat. Very little has been written about them and most of the information is in the heads of experienced gardeners. There is a danger that some of the vegetables will be lost as they are replaced by introduced ones.

It would be a great pity if the traditional vegetables are replaced by introduced ones, as many of the traditional species are superior in food value to introduced ones. (A good indication of food value is the colour of the vegetable: dark green ones are usually richer than lighter coloured ones). Also pest and disease problems are generally less serious on the traditional species. And finally PNG's vegetables, some of which are only eaten here, are part of the country's cultural heritage.

Some introduced vegetables will find a place in the gardens, of course. Their spread should be encouraged if they are easy to grow and are nutritious. Successful introductions include kangkong (Ipomoea aquatica or aquatic sweet potato) and pumpkins which are grown for both tips and fruit. More recent introductions such as basella (Basella rubra) and Russian comfrey (Symphytum spp) may also become common.

Notes on some of the traditional vegetables are given below. There are very many more species than these eaten and you would find it an interesting project to gather information on traditional vegetables in your area.

Aibika - one of the world's most nutritious leafy vegetables.

AIBIKA (Abelmoschus manihot). This well known crop is a shrub 1 to 1.5m high. It is grown in many areas. It is propagated from stem cuttings. There are a great number of varieties which show big differences in leaf shape, colour and production. The young leaves are picked and are cooked in coconut cream or water in a saucepan or banana leaves. They can also be fried. It is a very rich food and has a high protein content. Harvesting can commence 2-3 months after planting and production continues for 1-2 years.

Insect damage is fairly common. The most common pest is a beetle (Nisotra spp) which makes "shot holes" on the leaves. A moth (Sylepta corogata), army worms (Spodoptera spp), and a stem borer also damage it. The stem borer can reduce production greatly. It is sometimes attacked by nematodes on the roots.

Amaranthus or pigweed: a weed in the temperate zone but a useful green vegetable in the tropics.

AMARANTHUS (Amaranthus, spp) Amaranthus is a traditional crop usually grown on cultivated lands. It is usually started by scattering the seeds on moist soil. It prefers wet weather, should be planted at the beginning of rainy season. It doesn't require drainage.

The first harvest is when thinning. You pull the whole plant and then discard the roots and keep the leaves. The second harvest is the main harvest when the plant is about 6-8cm high, and the tops are plucked. The third harvest would be the time when the side branches are plucked. After that the shrub gets old and dries up.

There is some insect damage by grubs chewing the leaves of the young plant. However, there is no disease damage.

It is cooked and eaten immediately after it has been harvested. If stored in a shady place it can last a day or two, but no more than that.

AUPA (no article)

FERNS. Shoots and young leaves of various ferns are commonly gathered and eaten.

KAGUA. (Ficus spp). Kagua is a Tolai name given to a tree that produces a thick edible leaf. The surface of the leaf is coarse, like sandpaper. Kalakala is the Tolai name of a similar tree which also produces an edible leaf.

KARAKAP (Solanum nigrum). This self-sown green is very commonly found in gardens. It is a small herb that grows to about 40cm in height. The black fruits are also edible. It can be propagated from seed.

OENANTHE (Oenanthe javanica) is a traditional highlands vegetable domesticated from bush varieties which are abundant in the area. The wild varieties are eaten in times of hunger and by hungry children, but they are not so tasty as are the cultivated varieties. Varieties range in colour from yellowish green to purplish green. Once they grow in an area they are hard to get rid of. Because of their vigorous growth, they are sometimes planted in coffee gardens to keep the weeds down.

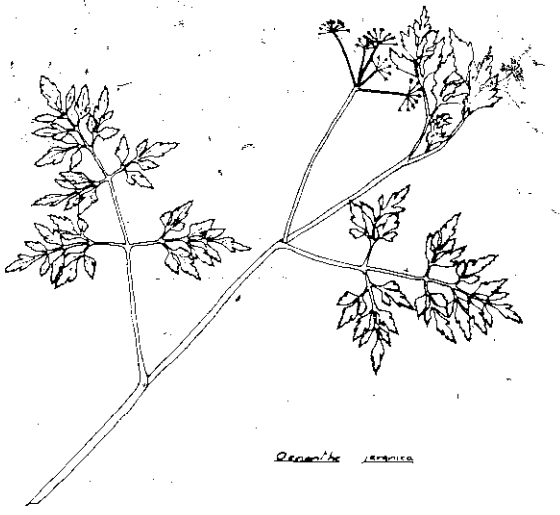

The plant is grown by cuttings with both midstems and tops used. Planting is done with a digging stick and usually 5-6 cuttings are planted in one hole. It grows in both wet and dry soils.

This vegetable cannot be stored, as it loses its flavour and becomes bitter. Large quantities are eaten both raw or cooked. Cooking is usually done in pits or in small wooden drums together with Rungia klossii and Setaria palmaefolia. These days it is boiled, but doesn't taste as good as when roasted.

Besides being a food, the hollow stems are used by children to make small trumpet-like noises.

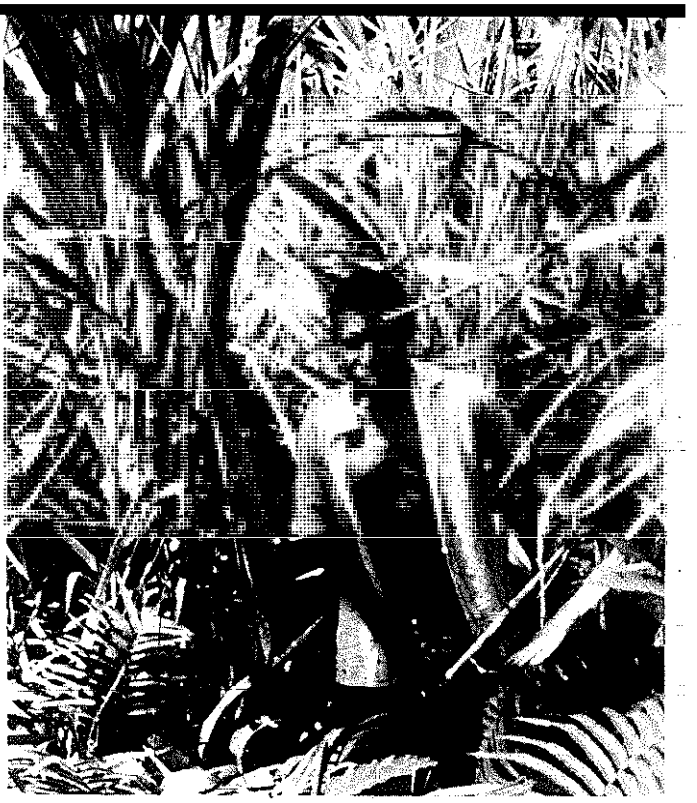

Tall pitpit, Morobe Province.

PITPIT (Sacclarum edule) is a cane of unknown origin with an edible inflorescence. There are no wild forms known and if gardens are neglected the pitpit soon seems to die out. Traditionally pitpit has no special value as does sweet potato or yams, but is simply an interplanted extra.

Pitpit is planted mainly into virgin soils on dry ground. It has no specific climatic requirements and can be planted at any time of the year. It is grown from cuttings 30-50cm long. Each cutting contains three to four nodes, and is taken from the mature part of the plant. The cuttings are planted at random in the garden by making holes at a slant with a digging stick and then planting 3-4 cuttings in one hole. The planting material is planted so that 15-20cm of the cuttings are underground. If too many plants result, some are removed at weeding

There are a number of varieties, some of them more popular than others.

The crop takes 7-9 months to come into bearing, depending on the variety. The unopened flower on top is the portion of the plant eaten. Generally it is considered to be ripe when most of the leaves on the stalk are brownish coloured and the leave sheaths lose their hair. Harvesting is done by cutting the stem a few nodes away from the base of the inflorescence. The tender stem just below the inflorescence is also eaten. If the inflorescence is not harvested when mature it gets attacked by a fungal disease which starts at the top end. After several harvests, or in 3 to 4 years the edible portions become smaller in size and are usually abandoned.

It can be eaten raw, but is usually cooked over the open flames. The inflorescence and leaf sheath

coverings are put on the fire for a few minutes. When cooked the outer leaf sheath is removed leaving the hot, inner tender leaves and inflorescence for consumption.

This tall pitpit (Saccharum edule) is significantly more nutritious than the short (Setaria palmaefolia).

PITPIT ("MOI") (Setaria palmaefolia) is thought to be one of the original crops of the people in the Mt. Hagen area. It seems to have been domesticated and improved through selection and continuous growing. Wild forms grow in the bush and along river banks. These wild forms are often used in times of famine and by hunting parties.

It is a hardy plant and can be grown in dry or damp soils. In very wet soils, drainage is required. It can be planted at any time of the year, but is usually planted before the rains with a digging stick, two cuttings per hole. Shoots are taken from older plants, which are usually left to dry for a day or so, they then tend to root quicker. There are a number of varieties grown.

The crop takes 4-5 months to mature and then the big shoots are harvested. Harvesting consists of breaking the shoot off 2-3 nodes below the first unopened leaf sheat. Shoots may be harvested from a single plant for about two years prior to plants being left. Setaria is an important famine food as the plant survives in fallow gardens for many years.

Setaria is a much favoured food by the women and children. It can be eaten raw, but it is usually cooked, as too much raw Setaria can cause stomach aches. To eat raw, the hard outer parts are removed, and the soft inner shoot is eaten, usually with "Kenkaba" (Rungia klossii). Traditionally, Setaria was cooked either in the ashes or in "mumus" with other greens.

RORIPPA ("Kund") (Rorippa spp) Rorippa is a traditional highland vegetable of unknown origin. No wild forms of it are known. It is planted mainly by the women in mixed gardens when the rains start. It grows well in wet soils but can also be planted in drier garden sites, and is grown by seeds broadcast over the garden site when the soil is wet.

"Kund" is thinned at an early stage so that other plants can grow better. The plants that are removed are eaten. The tops are cooked while the roots are cut off and discarded. For eating only the younger plant portions are used. "Kund" can be roasted with meat or by itself.

RUNGIA ("Kenkaba") (Rungia klossii) is considered to be a very old traditional highlands plant. Wild forms still grow in the bush and are consumed by hunting parties or in times of famine.

It is a small herb which is eaten raw or cooked. It is grown in mixed gardens together with short pitpit (Setaria palmaefolia). It has no special climatic requirements and so can be planted at any time of the year.

It is grown by cuttings. A hole is made with a digging stick and then a number of cuttings are put in the hole. The growing plant is seldom attacked by pests or diseases. The plant is considered to be mature when it is about 30cm high, and this may take 3-4 months. Two or three leaves are all that are picked. If plucked too far down the stem it becomes quite hard.

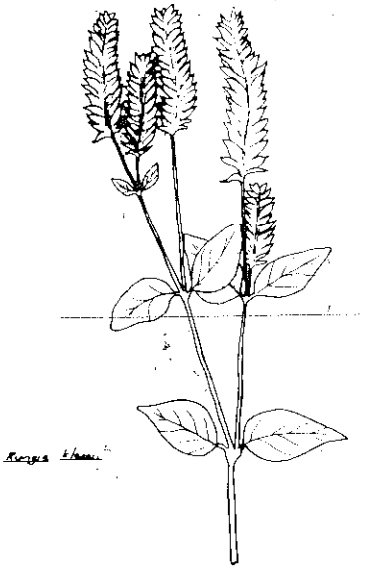

Rungia klossii

TARO LEAVES.

Taro is most important for its edible corm but the leaves are often an important vegetable as well. The young leaves or petioles are used. Taro leaf blight (caused by Phytopthora colocasiae) and insect larvae that eat the leaves can make the leaf unsuitable as a vegetable.

TULIP (Gnetum gnemon)

The name of this tree comes from the English words "two leaf" and it should not be confused with the West African Tulip (Spathodia campanulata) which is an introduced tree common in secondary regrowth

in some areas. Tulip is a long lived tree. The young leaves are eaten as are the seeds, which have a nice nutty flavour. It is especially common in the Sepik area.

Valungur - a common shrub in the Gazelle used for flavoured greens. Much wider use of local vegetables is possible.

VALANGUR (Polyscias grandifolia) is a shrub that normally grows 1 to 1½m. In the Gazelle and New Ireland it is grown as a fence near houses The leaves have a pleasant odour, and the young leaves are picked for a vegetable and flavouring in stews.

Planting material all of the above: Find local sources.

Readind: Barrau, J. 1958). Subsistence Agriculture in Melanesia. B.P. Bishop Museum Bulletin 219. (US$9 from the Museum Bookshop).
Martin, F.W. & Ruberte, R.M. (1975). Edible Leaves of the Tropics. Antillian College Press, Mayaquez, Puerto Rico.

Initial contributor: R.M. Bourke, LAES, Kerevat, with notes from Nicholas Kuman and Cecelia Poniq, UPNG Agriculture Students.

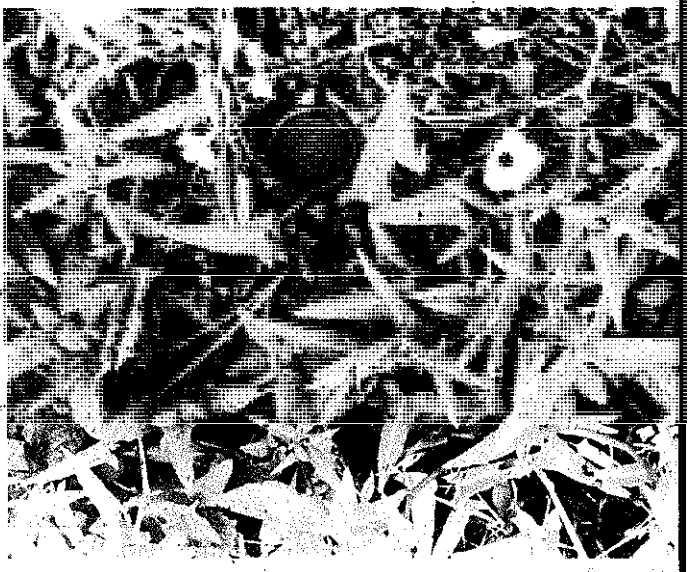

Kangkong - also called aquatic sweet potato

INTRODUCED VEGETABLES

CEYLON SPINACH BASELLA

Description: A dark green soft stemmed vine with juicy leaves. Good as a cooked green.
Botanical name: Basella rubra
Height: Vine up to 10 metres long
Age to first production: 4-6 weeks
Normal life span: 4-6 months
No insect pests observed.

Planting information: This is a useful green vegetable that will grow almost anywhere, including slightly swampy ground. It can be grown from cuttings or from seed. Plant cuttings 20-25cm long or seeds on a square 20x20cm. Seeds may take 3 weeks to germinate. During the rainy season vines should be trellised to prevent disease and increase output. Begin picking when the vines have covered

the trellis. Early picking stunts later growth. Harvest one leaf in three.

Uses at village level: As a cooked green. A few drops of muli juice can improve flavour. Soak seeds and boil them in a small amount of water to make ink.

Sources of planting material: Seeds only, Manggai High School, PMB, Kavieng.

Further references: Vegetable Production in South-east Asia by J.E. Knott and Jose R. Deanon, University of the Philippines 1967 p. 273-276.

PNG experience: Manggai High School, PMB Kavieng.

Remarks: The useful life of the planting can be increased by picking flowers as they develop. Also production can be increased by harvesting the entire last 15-30cm of the vine. This will promote branching. Ceylon Spinach is resistant to snails. Leaf growth responds well to nitrogen fertilizer, especially urea and compost.

Initial contributors: W. Kitchen, W. Gabara, Manggai High School, PMB, Kavieng,NIP.

PEOPLE are not the problem.
PEOPLE are what it's all about.
PEOPLE are the answer.

COMFREY

Botanical name: Symphytum asperrimum
S. pereginum

Though there are many types of Comfrey, the one most commonly eaten by people is Russian Comfrey (S. pereginum). The dried leaves can be ground and used as a course flour in bread, biscuits etc.

It is a high-yielding perennial of the Boraga family, and the greens make a good cooked vegetable.

According to the Energy Primer, Portola Institute, 1974, p112 Comfrey has one of the highest protein contents (21% of dry matter) of any plant known. It is also one of the few plants that concentrates Vitamin B-12. Its flowers are an important source of nectar and its leaves can be used to help wounds to heal. (Crush the leaves and apply to the wound or make a strong tea and soak wound in tea. Especially good for tropical ulcers.)
The name "Symphytum" means "to grow together", a reference to these healing qualities.

The DPI Experiment Stations at Kerevat and Aiyura are familar with Russian Comfrey. St. Pauls's Lutheran High School, in Wapenamanda, EP, grows it, and it grows like a weed around Mt. Hagen.

Reference: Comfrey - An Ancient Medicinal Remedy, Henry Doubleday Research Assn., 20 Convent Lane, Bocking, Braintree, Essex, UK. 36p.

Initial contributor: H. Bekker.

OKRA

Okra is an extremely easily grown tropical and sub-tropical vegetable, sometimes called "Lady's Finger"

or "Gumbo". Nutritionally, it is not very special, but it compares favourably with other green vegetables. It grows best at the lower elevations, but has a wide adaptibility to a variety of soil and climate conditions.

Botanical name: Hibiscus esculentus
Height: 80cm - 150cm
Age to first production: 60 - 70 days
Normal life span: Will bear edible fruits for 2 to 3 months, especially if pruned from time to time.

Insect pests and control: Usually it is not economic to spray, but if infestations are serious, Orthene is effective. This is not a cash crop.

Indication of maturity: Harvest when the fruits are about the size of a "lady's thumb", well before they start to become fibrous and woody. Regular harvest of the fruits when they are young and tender prolongs the fruit-bearing.

Planting information: Plant seed in a well-tilled soil about 1 to 1½cm deep, in rows 80-90cm apart, with about 30cm between each plant in the row. Planting rates can be thicker, with thinning done later. Regular weeding is necessary. Periodic plantings of smaller plots will give a steady supply of fruits.

Use at village level: A useful green vegetable. Some people like okra because it is slightly "slimy" when boiled, and others dislike it for the same reason. It is often used in tropical cooking to thicken soups and stews. Frying small slices of okra or the use of a small quantity of vinegar or muli juice will take away the slimy characteristic. Fried okra tastes surprisingly like oysters.

Sources of planting materials: Liklik Buk, Box 1920, Lae; Vudal Agr. College, ENB; Manggai H.S., PMB, Kavieng, NIP; Agricultural College, UPNG, Waigani; Yates Seeds.

Remarks: Food value per 100g raw foodstuff, edible portion: 32 calories; 1.8g protein; .2g fat; 7.4g total carbohydrates; 82mg calcium; .7mg iron; 740 I.U. pro-vitamin A; 440mcg carotene; .08mg thiamine; .07mg riboflavin; 1.1mg niacin; and 30mg ascorbic acid. (Food tables, WHO, Western Pacific).

PLANTING DISTANCES FOR VARIOUS VEGETABLES

TRANSPLANTING SEEDLINGS

Lettuce	25-30cm apart in rows. Rows 30-50cm apart.
Cabbage	"
Cauliflower	"
Chinese Cabbage	"
Tomatoes	45cm apart in rows. Rows 60cm apart.
Egg plant	"

DIRECT PLANTING OF SEEDS

Carrots	In 1-2cm deep drills 30cm apart, water well on planting. Weakest seedlings removed until a space of 5cm between seedlings obtained. May also be planted by broadcast method.
Radish	"
Silver Beet	"
Parsley	As above, but requires plenty of watering until seedlings emerge.
Capsicums	50-60cm apart in rows. Rows 40-45cm apart.
Oak Dwarf French Beans	24cm apart in rows. Rows 40cm apart. Seed planted 2cm deep and watered.
Cucumbers	In mounds 90cm apart, 4 seeds/mound, planted 2cm deep and watered.

Initial contributor: C. Benjamin, DPI, Box 351, Kimbe, WNB.

VEGETABLE NURSERY NERSERI

Description: A nursery is a small house where delicate young seedlings are grown to protect them from too much sun and rain. Vegetables like lettuce, cabbage, cauliflower, tomato, chinese cabbage, and eggplant are very weak when they are young. In a few weeks the seedlings are strong enough for transplanting on their own in the garden.

Materials: 4 corner posts 1.5 - 2.0 metres (bush material) 5 poles for frame of the roof (bush mat) bush twine, leaves or kunai for the roof.

Order of work:

Mark the corner posts so that the nursery runs from north to south.

Construct nursery, but be sure the roof is high enough so that early morning and late afternoon sun gets to plants.

Place good topsoil with much organic matter under the nursery, and make the surface smooth with no lumps of soil, so that small seeds will germinate easily.

Sources of supply of materials: All are available locally.

Further references: C. Kemp, 1976, Proceedings of the 1975 Papua New Guinea Food Crops Conference, "Trial Work with Introduced Vegetables in West New Britain". p. 238-259.

PNG experience: K. Brewer, AIC, Dami Oil Palm Research Station, Dami, via Kimbe WNB; Kimbe

Community School; Mai Community School, via Kimbe; Buvussi Community School, via Kimbe; Sarakolok Community School, via Kimbe.

Remarks: Plant posts solidly in ground so the building will not fall on the seedlings. Make sure that the long sides face east-west so that the seedlings get the gentle morning and afternoon sun, but are protected from the hot noon-day sun. The high side of the nursery should be to the east, so that the ground will warm up quickly in the morning. Water plants in nursery twice a day, early morning and late afternoon. Pull out weak seedlings as they appear so only strong healthy plants will be transplanted.

Initial contributor: C. Benjamin, DPI, Box 351, Kimbe, WNB.

AGRICULTURE IS THE BASIS OF INDEPENDENT DEVELOPMENT

VEGETABLE NURSERY

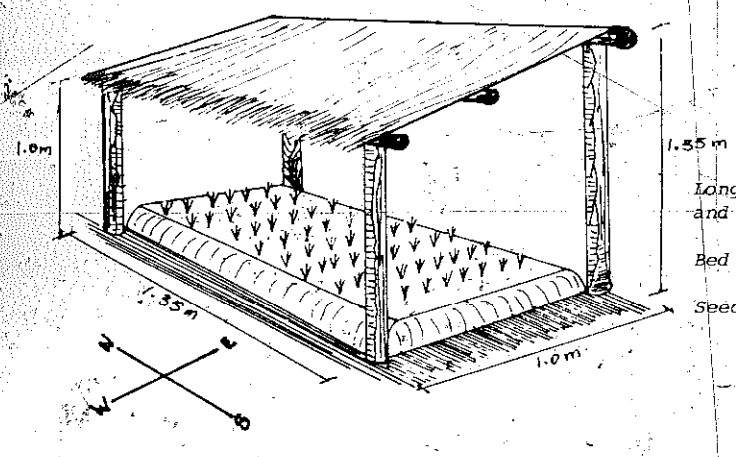

Long sides face east and west to catch the morning and evening sun.

Bed is made of mounded topsoil rich in organic matter.

Seeds are sown either in drills or broadcast.

VEGETABLE BED

Beds are constructed by mounding organic matter.

Soil in beds is turned well and all clods broken up to give a fine tilth.

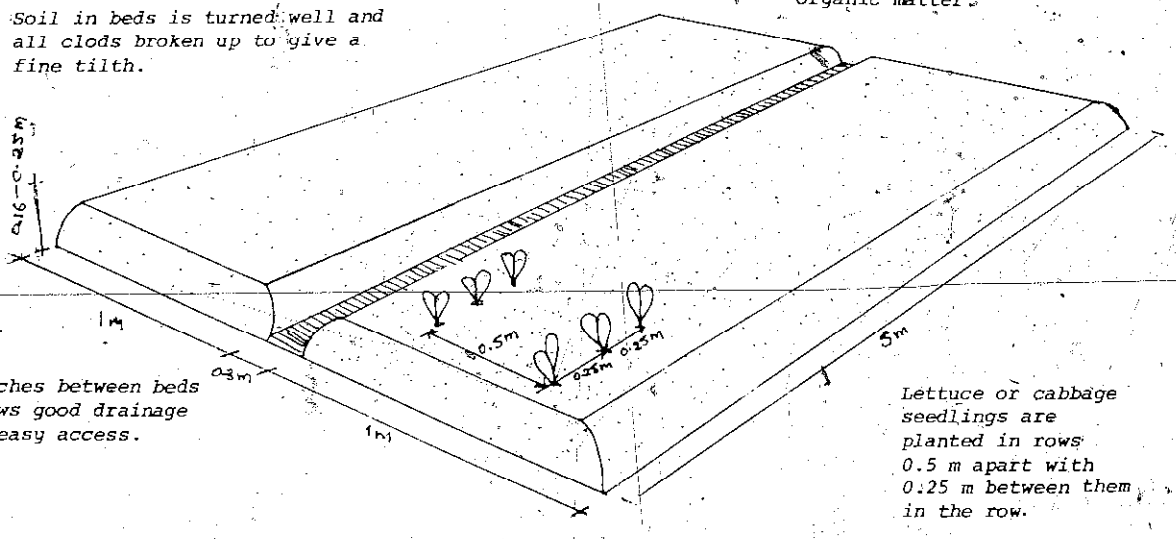

Trenches between beds allows good drainage and easy access.

Lettuce or cabbage seedlings are planted in rows 0.5 m apart with 0.25 m between them in the row.

PLANTING GUIDE

	How planted*	Amount to sow per 30m row	Distance between rows (cm)	Space betw. plants in rows (cm)	Time to maturity (weeks)
Beans, climbing	direct	50-70g	100-130	15-25	
Beans, dwarf	direct	60-80g	60-100	5-10	
Beetroot	direct	50g	45-60	6-10	9-12
Broccoli	transpl	50 plants	50-90	30-60	10-16
Brussels sprouts	transpl	50 plants	50-90	45-60	18-25
Cabbage	transpl	50-80 plants	60-90	35-70	8-16
Capsicum	transpl	50-70 plants	45-60	30-60	12-16
Carrots	direct	25g	40-50	5-10	10-15
Cauliflower	transpl	40-50 plants	50-60	50-60	12-26
Celery	transpl	200 plants	40-90	15-20	20-24
Cucumber	direct	25g	120-180	30	9-12
Egg plant	transpl	50-70 plants	60-120	60-90	14-18
Kohlrabi	direct	50g	45-60	20-30	10-12
Leek	direct	50g	30-75	5-15	20-24
Lettuce	transpl	25g	45-60	20-30	9-12
Zucchini	direct	50g	90-120	70-100	5-7
Water melon	direct	50g	180-240	60-75	12-14
Onion	direct or transpl	50g	30-50	5-12	18-30
Parsley	direct	25g	30-60	10-30	10-12
Parsnip	direct	50g	45-75	7-12	18-25
Pumpkin	direct	50g	220-330	90-140	14-22
Radish	direct	50g	30-40	1.5- 3	4-5
Silver beet	direct	50g	30-45	20-30	8-12
Spinach	direct	50g	30-65	8-20	7-10
Sweet corn	direct	250g	100-120	20-35	10-12
Squash	direct	50g	100-200	70-100	8-14
Tomato	transpl	40-50 plants	90-160	50-90	14-18

* "Direct" means that the seed is planted straight into the garden. "Transplant" means the seed is first planted in a seedbox or seedbed, then transplanted to the garden.

Adapted from Introduced Vegetables, DPI Handbook #9.

VEGETABLE SEED SUPPLY

The regular supply of good quality vegetable seed has always been a most unsatisfactory matter in P.N.G. The type of seed and the range of seed presented to the largely uninformed public has been confusing and the ordering of seed has quite often been completely haphazard with little expertise on requirements involved. Generally, Australian or New Zealand temperate vegetable varieties prove to be satisfactory in the Highlands areas but many of these varieties are not suited to the high temperatures and high humidity of the coast. By personal contact with the firms involved, DPI has made an effort to rationalise the supply of vegetable seed.

The Takii Seed Company of Japan has an impressive range of vegetable varieties that are well suited to tropical conditons. A great deal of seed has been obtained from that company as well as Farmer's Seed in Taiwan for experimentation over the past year. Most of the Yates seed evaluated in 1974 was from Yates New Zealand. The Yates companies in Australia and New Zealand are completely separate and although many of their vegetable varieties are similar some varieties listed are available from one company only. Both Rumsley's Seeds and New World seeds have almost identical variety lists to Yates Australia, but again with a few differences.

In Port Moresby, vegetable seed can be obtained from the following sources:

1. Steamships Trading Co. Ltd.
   Hardware and Paint Division
   Ela Beach
   Manager - Mr. Ron Hancock. Steamships is agents for Yates New Zealand "Longlife" seed. They have quantities of small packet and bulk seed in stock and will arrange large orders of bulk seed.
2. Tutt Bryant Pacific Ltd.
   Hubert Murray Highway
   Badili
   Manager - Agricultural Division,

cont'd

Mr. Bevan Holden. Tutt Bryant markets vegetable seed from Yates New Zealand Yates Australia, New World, Rumsley's and from Takii Seed Company of Japan. They will also be supplying seed from Farmer's Seed, Taiwan very shortly.

3. Makana Vocational Training Centre
P.O. Box 5664
Boroko
Manager - Mr. Cliff Curant. Makana Supplies Yates New Zealand seed and has provided a good mail order service for seed.

4. Burns Philp (N.G.) Ltd.
Builders Hardware
Boroko
Agents for Yates Australia seed.

5. Exmark Stock and Produce
P.O. Box 6060
Boroko
Manager - Mrs. S. Mudge. Exmark will supply Yates Australia seed in bulk quantities.

6. Mr. Ron Burness
Agencies Pacific Pty. Ltd.
P.O. Box 5044
Boroko
will supply seed from Takii Seed of Japan and Farmers Seed of Taiwan in commercial quantities.

7. Carpenters Hardware
Boroko
P.O. Box 3043
Port Moresby

Supplies Yates Australia seed.

Readers should note that importation of seeds from overseas is restricted under P.N.G. Plant Quarantine regulations, which aim to protect vegetable growers against the introduction of new diseases. Vegetable seed from Australia and New Zealand is admitted freely, but a permit is required for import of seed from other countries. Certain types, where the danger of disease introduction is greater, are more closely restricted. These include tomato, lettuce, beans and peas. Where local agents are listed as supplying Japanese or Taiwanese seed, the agent has imported this seed under permit.

Many of the firms listed above also carry good stocks of other requisites such as fertilisers, fungicides, insecticides, spraying equipment and nursery supplies.

(Excerpts from Information Bulletin No. 1, DPI Plant Introduction Station, Laloki)

TRANSPLANTING

Plants which are grown as seedlings in a nursery must be transplanted to the final bed. This is usually done when the seedling is three weeks old. It is very hard on the seedling when it is pulled up by the roots, because many small bits of the root are broken, no matter how carefully you uproot it. There are steps for transplanting so that the young seedling will recover well from the damage of being up-rooted.

Follow these steps for all kinds of plants that are planted by transplanting, such as lettuce, cabbage, paw paw, onion, and small trees. The nursery makes it easy to look after many young plants at one time.

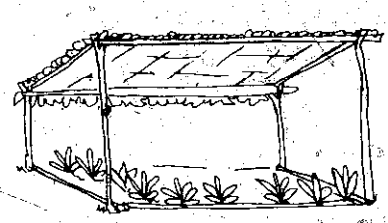

1. Seedlings are ready to transplant when three weeks old. The best time is in the late afternoon.

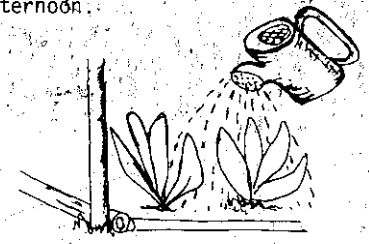

2. Water seedling before uprooting.

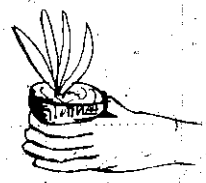

3. Remove seedling with damp soil around the roots.

4. Make holes in garden where each plant will grow.

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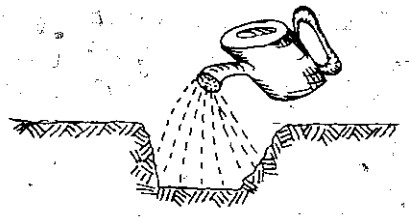

5. Water each hole well before transplanting.

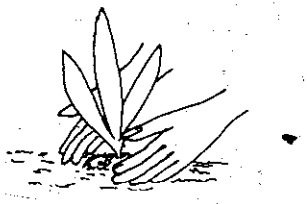

6. Place seedling in hole and pack the soil.

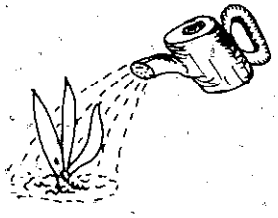

7. Water the planted seedling well.

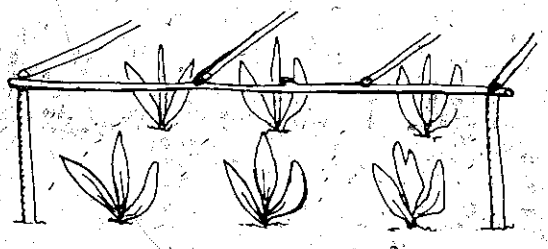

8. Build a shade frame over the garden, until seedlings are growing well.

If you have a large garden and it is hard to make shade houses for all of it, any large leaf is good. Kapiak leaves are best because they harden when dry.

SPECIAL REQUIREMENTS FOR TOMATOES

The soil must be well-cultivated.

The plant must be watered twice a day.

The top of the soil should be covered with dead grass or weeds to keep the soil cool and to stop water from evaporating. This is called mulching.

PLANTING TOMATO SEEDLINGS

RIGHT

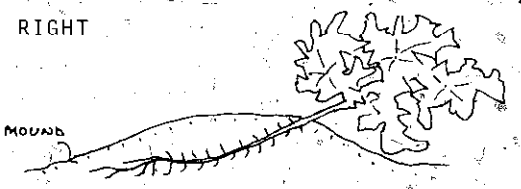

1/3 of tomato seedling is planted above the ground.
2/3 of tomato seedling is planted below the ground.

More stem planted under the ground causes more roots to grow. These roots give more food and a greater support to the plant.

WRONG

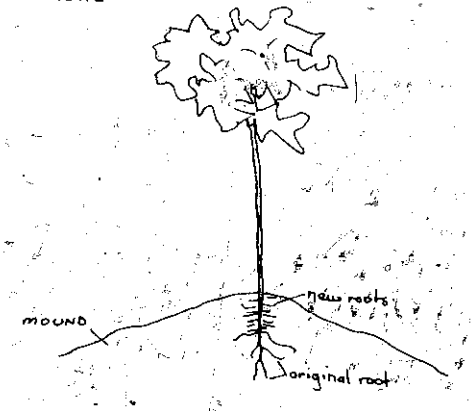

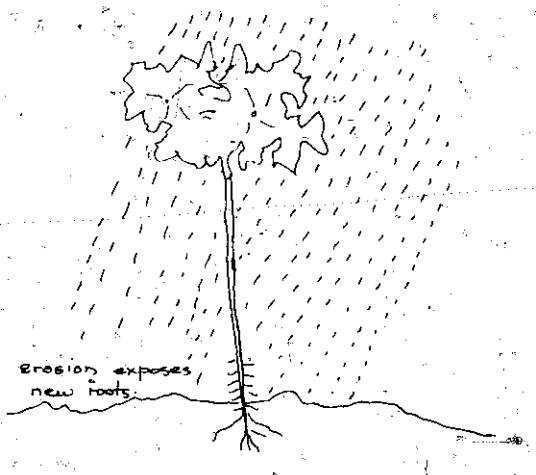

If the tomato is planted like this any heavy rainfall will wash the mound away, exposing the new roots.

C. Benjamin, DPI, Box 351
Kimbe, WNBP

GENERAL REFERENCES

Commercial Vegetable Growing, H.D. Tindall, Oxford University Press, London, 1968 Pounds1.50 (pb).

Despite the title this book is for smallscale gardening in the tropics, written primarily for Africa, The Caribbean and Asia, it is still useful for PNG. The first quarter of the book deals with general considerations of good gardening practices to permit continuous cropping on tropical soils. It also has some very useful advice on marketing and simple business considerations for the market gardener.

The remainder of the book is an excellent series of short descriptions of the wide variety of vegetables most of which are grown in PNG, together with brief suggestions for planting practices and other considerations.

Level simple.

Vegetable Growing in Southeast Asia, by James E. Knott and Jose R. Deanon, Jr., University of the Philippines Press, 1967.

This is a very detailed book on the growing of a wide range of common vegetables in humid tropics. Each of the crops is discussed with reference to history, important uses, varieties, soil and climatic requirements, harvesting, handling and control of insects and diseases. This book has broad application to extension and management for fresh food production in this country. A bonus is the most complete list of the wild vegetables and fruits used in many parts of Asia as food, most of which are recognizable in PNG diets.

Level intermediate/advanced.

EDIBLE LEAVES OF THE TROPICS, by Franklin W. Martin and Ruth M. Ruberte, Mayaguez Institute of Tropical Agriculture, Mayaguez, Puerto Rico, 1975, Agricultural Research Service, Southern Region, US Department of Agriculture, Printed by the Antillian College Press, Mayaguez, Puerto Rico.

Seems to be reasonably comprehensive. Includes tables for nutritional and chemical composition for a wide range of plants having edible leaves. Illustrated with 56 black and white plates.

Initial contributor: R. Stephensen, Faculty of Agriculture, UPNG, Port Moresby.

INTRODUCED VEGETABLES, DPI Handbook #9, edited by C.A. Fowler, 33pp. Is supposed to be distributed through your DPI Office.

A useful summary of basic information for those who want to grow vegetables to sell. Includes raising of seedlings, planting and packing, insects and diseases, organizing production and marketing. Special advice for particular crops, planting guide.

HIGHLANDS FOOD CROPS NEWSLETTER,
Box 339,
Mt. Hagan, WHP.

Short timely bulletins from KUK RESEARCH STATION, monthly; includes a variety of recommendations, advice on problems, planting and management practices, all on vegetables.

A. Jacob and H. Von Uexkull, Fertiliser Use, Nutrition and Manuring of Tropical Crops, Translated by C.T. Whittles, Verlogsgesellachaft fur Ackerbau, Hanover.

Discussion of the principles of nutrition followed by a review of fertilizer recommendations for the most important crops. Tables of composition of fertilizers, manures, and crops.

Initial Contributor: Ken Willson
PNG Univ. of Tech.
Box 793, Lae

Oxford Book of Food Plants, by S.G. Harrison, Masefield and Wallis, Oxford U. Press, London, 1969, Pounds 3.50.

A beautifully illustrated (colour) book of the major food crops of the world, including oil crops, mushrooms, seaweeds, spices, root crops, and fruits. Temperate zone crops are included, but exotic foods not. Detailed illustrations. An excellent teaching aid for agriculture or botany in upper primary or high school.

No. 2 Root Crops, by Mrs. D.E. Kay, Tropical Products Institute, 1973, 56/62 Gray's Inn Rd., London WCIX 8LU, England.
I pound 50 plus postage

250 pages of very helpful information on tropical root crops. Highly recommended.

Soils of The Humid Tropics, by The Committee on Tropical Soils, Agricultural Board, National Research Council, National Academy of Sciences, Washington D.C., 1972, 217 pp.

Technical papers on all aspects of tropical soils by leaders in the respective fields. This is a response to the recognition that the transfer of technology from temperate to tropical regions is greatly hampered by the great differences between the soils of the two. An effort is made to distinguish the specific problems of tropical soils from the commonly held generalizations. An important book for teachers of agricultural science.

level/advanced

Technical Manual for Fertilizers, Fungicides, Weed Killers, Insecticides, Veterinary Products, Home Products, - free from Amalgamated Chemicals (NSW) Northam Ave., Bankstown, N.S.W. 2200.

A wide range of products is listed with their uses, rates, available sizes. Very useful for those directly involved in agricultural production.

J.W. Purseglove, Tropical Crops, Dicotyledons, Vol I and II; J.W. Purseglove, Tropical Crops, Monocotyledons, Vol. I and II; both published by Longmans.

These four volumes (the first two are now available in one book, paperback) include annual and perennial crops, and describe cultural practices in many parts of the world.

This is a most valuable reference work for all of the most important crops.

SUPPLY OF PLANTING MATERIAL

IT IS OFTEN HARD FOR PEOPLE TO GET NEW KINDS OF SEED. THERE ARE WAYS, IF YOU CAN BE PATIENT AND PERSISTENT, BUT THERE ARE GOOD REASONS WHY YOU MAY HAVE A SLOW RESPONSE.

REQUESTS FOR SEED AND PLANTING MATERIAL ARE IRREGULAR, AND IT IS VERY EXPENSIVE TO STORE THEM WITHOUT LOSS. AGRICULTURE PEOPLE ARE DISCOURAGED, TOO, THAT REQUESTS FOR FREE SEED IN LARGE QUANTITIES HAVE BECOME ANNUAL EVENTS FROM FARMERS AND SCHOOLS THAT MAKE LITTLE OR NO EFFORT TO MAINTAIN THEIR OWN SEED SUPPLIES.

LAES KEREVAT IS A GOOD EXAMPLE OF A SINCERE ATTEMPT TO STORE AND SUPPLY SMALL QUANTITIES OF SEED FOR MULTIPLICATION. THEY ARE QUICK TO RESPOND, BUT IT IS UNFAIR TO EXPECT THEM OR ANY OTHER DPI STATION TO SUPPLY LARGE QUANTITIES ON A RECURRING BASIS.

PNG HAS AN EXCEPTIONALLY GOOD STOCK OF PLANTING MATERIALS TESTED AND ADAPTED TO PNG CONDITIONS. ONLY IN RARE CIRCUMSTANCES IS IT NECESSARY TO GO OVERSEAS FOR NEW VARIETIES, AND THEN IT IS ESSENTIAL TO PROTECT THE COUNTRY BY HAVING THEM GROWN OUT IN QUARANTINE.

BUT THE PUBLIC NEEDS BETTER ACCESS TO NEW OR IMPROVED PLANTING MATERIAL. THIS WOULD BE A MOST USEFUL BUT SOMEWHAT EXPENSIVE AND DIFFICULT SERVICE FOR SOMEONE TO RENDER ON A NATIONAL BASIS.

HIGH SCHOOLS, VOCATIONAL CENTRES, COLLEGES AND THE UNIVERSITY, PLUS THE MANY INFORMAL AGRICULTURAL PROGRAMMES OF THE CHURCHES AND OTHER ORGANIZATIONS COULD PLAY A VERY HELPFUL LOCAL ROLE IN RURAL DEVELOPMENT BY MAINTAINING SMALL SEED GARDENS AND SHARING SEEDS PARTICULARLY FOR NUTRITIOUS CROPS.

Companion Plants (And How to Use Them) by Helen Philbrick and Richard B. Gregg. 1.50 Watkins, London, 93 pp, Mostly about temperate crops, but might be useful in a library. Some samples:-

"Corn does well with beans and peas, which help the soil by putting back nitrogen which the corn uses up. Beans benefit from the slight shade given by the corn plants." "Other plants which appreciate the sheltering shade of corn are melons, squash, pumpkins, and cucumbers."

"Garlic, onions and shallots inhibit the growth of peas and beans. European peasants used to put pieces of garlic into their grain for protection against weevils"

"The guava tree (Psidium guajava) protects nearby citrus trees."

"Spearmint is a plant antagonist against ants, aphis, black flea beetles, cabbage butterfly caterpillar; Garlic against aphis, weevils;"

"Potatoes and sunflower stunt each other."

"Root excretions from potatoes somewhat inhibit growth of tomatoes".

"Peas and radishes are mutually helpful."

"Soybeans will loosen heavy soil and make it pliable.

"Toads (Bufo) are very useful in the garden, eating many insects and other pests which attack our plants. They exude a slime distasteful to enemies but not poisonous to man. Their skins contain adrenalin and have been used medicinally. Toads do not cause warts."

"Tobacco, like the tomato, likes to grow in the same place year after year, and like tomato prefers compost made of its own leaves and stalks" (readers may like to react to that one!)

Level Simple

ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTRE
Box 42,
Shanhua, Tainan 741
Taiwan, R.O.C.

Coordinated effort by highly qualified plant scientists and economists to improve the quality and quantity of vegetable production in the tropics. Emphasize Soybean, Mungbean, Tomato, Chinese Cabbage, Sweet Potato and White Potato. Research, training, technical advisory service, seed samples.

Fruits and Nuts

AVOCADO BATA

Description: An evergreen tree which grows in flushes.
Botanical name: Persea gratissima or Persea americana
Height: 15 - 20 metres
Age to first production: 5 - 6 years (seedlings)
Normal life span: 50 years
Insect pests and control: None of importance

Diseases and control: Root rot (Phytophthora cinnamomi) Don't plant orchard in poorly drained soil.

Indications of maturity: Stem breaks easily from the fruit. Poke a little stick into the skin and if it goes in easily, it is ripe. Also, when cut in half, the seed should draw easily from the flesh. Allow to ripen 1-3 days until soft to touch.

Planting information: Easily grown from seed but quality varies. Should be grown vegetatively. Seeds planted in plastic bags should not be covered with more than 1cm soil. Seedlings can be budded after 2-4 months. In PNG current recommendations are to produce seedlings and transplant at 6-9 months to orchard, planting 7-15m apart depending on the vigour of the variety. Plant in well-drained soil. A pueraria cover crop under the trees is good. Cultivation should not be done as the tree roots are surface feeders. Weeds can be controlled by very shallow cultivation, cover crops, or herbicides.

Useful products at village level: Edible fruit (very high food value), especially good for infant diets, a nutritious, marketable fruit.

Industrial use: Oil is extracted for edible oil and as a cosmetic base.

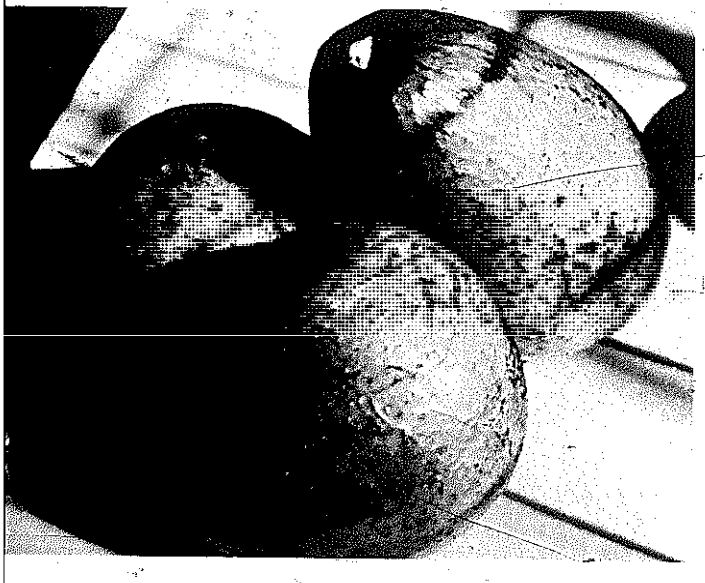

Sources of supply of planting materials and cost: LAES, Kerevat, small amounts free. Large amounts 2t per seed plus freight costs.

Further references: LAES Information Bulletin No 5, free; Dicotyledons, by Purseglove, Longmans, K8.50

PNG experience: Yield trials, LAES, Kerevat.

Remarks: Fruits rich in Vitamin B, A, & E, highly digestible oil. Highest energy value of any fruit - 1% sugar, 4% protein, 30% oil, 65% water.

Initial contributor: D.W. Loh, LAES, Kerevat, ENBP.

BREADFRUIT KAPIAK

Botanical name: Artocarpus altilis
Height: 20 metres
Age to first production: 3-6 years
Normal life span: 50 years
Rarely attacked by serious diseases or pests.

Indication of maturity: Fruits start to yellow slightly and can easily be picked.

Planting information: Breadfruit can be planted by seed or by root cuttings. In the nursery root suckers can also be used. Seedless varieties from Polynesia must be planted by cuttings which are 2cm in diameter and 20cm long, laid in a shaded nursery bed either flat or at a slight angle. The seeded varieties commonly found in PNG can be grown from fresh seeds or cuttings. Seeded varieties are also known as bread nuts. (p 91) (p 114)

Uses on the village level: Although it is a staple food of many Polynesian societies it is not so important in Melanesia. It is usually cooked as a vegetable, baked, roasted, fried or in soups. Coconut cream or grated coconut are often added. Polynesians generally cook the breadfruit after peeling, but Melanesians usually peel after baking.

The seeds may be eaten after boiling or roasting. Rope fibre can be made from the bark, and the white sap is used to seal canoes. The sap can also be spread on sticks and can be used as a bird trap since it remains tacky for several days. Leaves are suitable livestock food, and the wood is good for furniture and making canoes.

Breadfruit can also be preserved for up to a year. There are no formal trials in PNG, but it is grown widely in tropical lowlands.

Sources of supply: Villages and markets in lowlands for seeded varieties, and varieties with few seeds. There is no identifiable seedless stock in PNG.

Further references: Dicotyledons by Purseglove, Longmans, K8.50

Remarks: Although there is no known seedless stock in PNG, it is anticipated that seedless varieties will be introduced in the near future. Most work on breadfruit is in Fiji.

Initial contributor: D.W. Loh, LAES, Kerevat, ENBP.

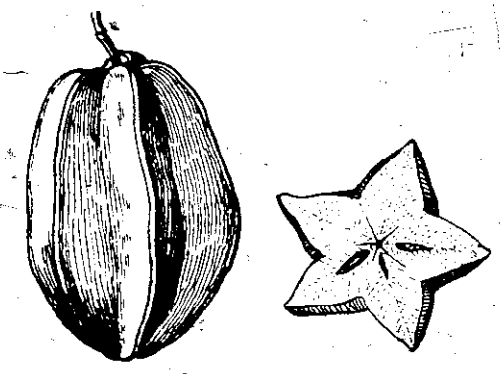

CARAMBOLA FIVE CORNER

Description: An attractive small tree flowering with clusters of pink flowers.
Botanical name: Averrhoa carambola
Height: 5 - 12 metres
Age to first production: 2 years
Normal life span: 20 years

Insect pests and control: Fruit fly - Malathion 1% spray.

Indications of maturity: Yellowing of fruit.

Planting information: Seed planted in seedbed is planted out when 15-20cm high. Planted 10-15m apart in field.

Useful products at village level: Edible and marketable fruit. Fruit drink - grate fruit, add sugar and water to taste. The juice removes stains from linen and can be used for cleaning and toning brassware.

Sources of supply of planting materials and cost: LAES, Kerevat, no charge, freight costs only.

Further references: LAES Information Bulletin No 5, free; Dicotyledons by Purseglove, Longmans K8.50

Remarks: "Hawaiian Sweet" is the most popular variety.

Initial contributor: D.W. Loh, LAES, Kerevat, ENBP,

CITRUS FRUIT MULI

Botanical name: Citrus spp.
The commercially important fruits of this genus may be classified as follows:

Sweet orange	Citrus sinensis
Sour orange	C. aurantium
Pummelo, shaddock	C. grandis
Mandarin, tangerine	C. reticulata
Lemon	C. limon
Lime	C. aurantifolia
Citron	C. medica
Grapefruit	C. paradisi
Calamondin	C. mitis

Height, age to first production, and normal life span are all highly variable, depending upon species, manner of propagation, and pruning. With some exceptions, most citrus trees have an economic life of about 40 years.

Pests and diseases: A wide range of insects and mites attack some or all species of citrus. The most serious are scales, mites, aphids, thrips, several species of fruit flies, moth borer, trunk and bark borers, ants and termites. Among diseases, viruses such as psorosis, tristeza, and xyloporosis, bacterial diseases such as canker, and fungal diseases such as Phytophthora root rot, various foot rots, sour orange scab, and melanose, as well as burrowing and citrus nematodes, may be serious. Control of most insects and mites, sour orange scab, and mealanose may be controlled with standard insecticides and fungicides. For fruit fly control, use Malathion plus poison bait. Certain virus diseases like psorosis or xyloporosis can be avoided by use of healthy budwood. The only feasible control for citrus canker is to plant resistant varieties. Root rot can be kept in check even with susceptible varieties by planting the trees high, providing for good air circulation around the base of the trunk, and treating of lesions with copper paste as they are found. Trees suffering from root rot should be destroyed.

Cultural information: Citrus can be grown on almost any type of soil, provided it is well drained.

To prepare site, clean out underbrush, trees and large roots or rocks that might hinder growth. If possible grow a cover crop for a year before planting.

Most varieties can be grown from seed, but take much longer to bear, and will not grow true to type. If possible, bud on locally adapted stocks. Seeds for root stocks should be sown fresh, lightly covered in well-prepared beds with sterilized soil. Germination is 2-4 weeks. Collect as needed - use mature, well-rounded wood with plump buds. Bud on root stocks 5-8mm in diameter.

(P 39)

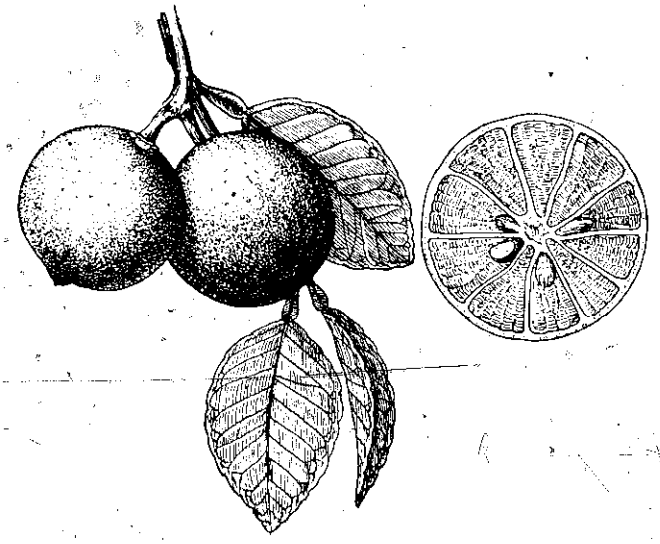

Set out young year-old trees in field just before rainy season begins, or provide for watering. Spacing will vary from 4.5m for limes up to 12.0m for pummelos. Better results will come if trees are not crowded. Holes should be big enough that roots will not be crowded. Fill holes with good soil. Initial care consists of watering, applying fertilizer after about 6 weeks (50-100g per tree), periodic removal of unwanted sprouts, and selection of 4-6 good branches with wide crotches. Newly set trees should be mulched heavily, with a cover crop between the trees.

Citrus trees seldom need pruning except to form a good branch framework and to remove diseased, dead, or tangled branches. Excessive pruning merely reduces yields.

Lemons, limes and calamondins flower and bear fruit more or less continuously, though they may have a main bloom. Citrus fruits do not contain starch, so they must be fully mature before they are picked. Some varieties do not lose their green colour when they are mature; others must be fully coloured. Periodic sampling and tasting will give an indication of when fruit are ready.

Uses: Citrus fruits are eaten fresh, and are processed into numerous products, including juice, juice blends, sections, salads. Fruit contain 20 to 60mg Vitamin C per 100g and also have amounts of provitamin A. Fruits unfit for human consumption are well-liked by cattle and other animals. (p 112)

Sources of supply of planting materials: Various varieties are found throughout PNG. You might have to grow your own seedlings. Consult your Provincial Rural Development Officer for sources of budwood. The DPI experiment stations and the agricultural schools often have some varieties available in small quantities.

References: Reither, Batchelor, and Webber (Eds.), The Citrus Industry, Vol 1 History, World Distribution, botany and Varieties; Vol 11 Anatomy, Physiology, Genetics, and Reproduction; Univ. of California.

Remarks: Many Citrus give added flavour to green vegetables, okra and fish. A "cheese" can be made with milk and muli. (p 101)

(Excerpts from "Tropical and Subtropical Fruit Crops," James Soule, Univ. of Florida, USA.)

LLB

GRANADILLA

Botanical name: Passiflora quadrangularis L.
Height: 10 - 15 metres
Age to first production:
Description: A strong, long-lived climber with fleshy tuberous roots and square stem.

Pests: Rats, bats and birds. May be protected by covering the fruit.

Indication of maturity: Fruits are 10-15cm x 20-30cm and change from dark green to yellow-green.

Planting information: May be planted from seed or cuttings at 3 metre spacings and trained to overhead trellises made of posts and wire or bamboo so that the fruit hang down.

Useful products at the village level: Fresh fruit. The ripe fruit, peeled, then cut in little pieces, mixed with the seeds, a little milk and a little sugar, makes a very refreshing snack. The seed is crunchy, the flesh around the seed is tart, and the pulp is smooth and gives body -- a nice combination. The ripe fruit can be steamed with sugar and cloves to make imitation "apple" pie. The green unripe fruit can be boiled or baked and eaten as a vegetable like pumpkin or marrow.

Industrial uses: Flavour for ice cream, soft drink or jams, but not usually grown commercially.

No PNG trials, but widely grown in wet lowlands. Does not do well at higher altitudes.

Initial contributor: D.H. Loh, LAES, Kerevat, ENBP.

GUAVA

Description: A shallow-rooted shrub or small tree producing suckers from roots near the base of trunk. Smooth greenish to reddish brown bark.

Botanical name: Psidium guajava
Height: 3 - 10 metres
Age to first production: 1 to 2 years
Normal life span: 30 years

Insect and disease: none of importance

Indication of maturity: Fruit turns from green to light green or yellow and becomes soft.

Planting information: Sown in plastic bags 1 to 1.5cm deep and transplanted to field at 15-20cm in height. Planted out at 6-8 metres apart.

Useful products at village level: Edible and

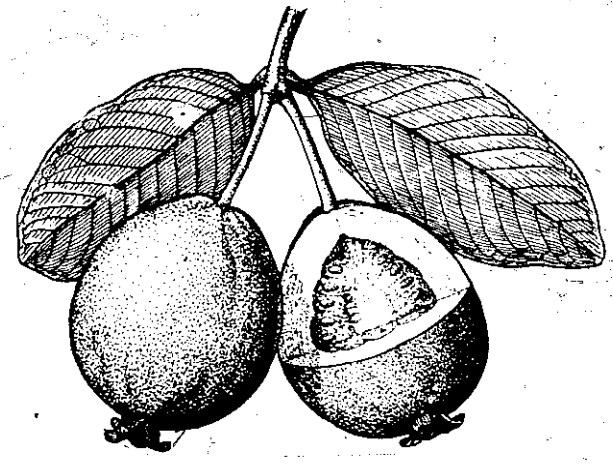

marketable fruit. High in pectin, makes good jellies or jams. Mature wood of guava tree makes good handles for tools, as it is very hard and resilient. The ripe fruit is a valuable source of vitamin C with 2 to 5 times that of an orange (300mg or more Vit C per 100g). It is also high in Vit A, iron, calcium, and phosphorus. Dehydrated guava jelly powder is a rich source of Vit C and was used to fortify rations of Allied troops during WW2.

The leaves are sometimes used medicinally for diarrhoea, and for dyeing and canning.

Sources of supply of planting materials and cost: LAES Kerevat; Rabaul market, many other local markets. Most varieties can be grown from seed, but take much longer to bear, and will not grow true to type. If possible, bud or graft on locally adapted stocks, or propagate by cuttings. Seeds for root stocks are best obtained from select trees. Seeds remain viable for about one year, and germination takes place in 2-3 weeks.

Remarks: Relished in the village as an immature fruit especially by children. Guava may be declared a noxious weed in certain areas. The problem is that the seeds remain viable so long and the birds scatter them about. This would mean that it would be a legal offence to grow them on your property.

Further references: LAES Information Bulletin No 5. Free. Dicotyledons, by Purseglove, Longmans K8.50

PNG experience: Widely found throughout PNG.

Initial contributor: D.W. Loh, LAES, Kerevat, ENBP.

JAK FRUIT

Description: An evergreen tree with white resinous latex in all parts, similar to bread fruit.
Botanical name: Artocarpus integrifolia
Height: 20 metres
Age to first production: 3 - 8 years
Normal life span: 50 years
Insects and diseases: Not seriously encountered.
Indication of maturity: Strong odour from fruit when ripe. Fruit becomes soft.

Planting information: Seed must be fresh. Preferably planted in final location or in large plastic bags. Few seedlings survive transplanting due to extremely delicate taproot.

Useful products at village level: Edible and marketable fruit. Seeds may be boiled and eaten like large nuts. The yellow heartwood is a valuable timber (especially valued for making guitars in the Philippines).

Sources of supply of planting materials and cost: LAES, Kerevat, free, freight charges only; DPI, Kavieng.

Further references: LAES Information Bulletin No 5 free; Dicotyledons, by Purseglove, Longmans K8.50.

PNG experience: Orchard trials LAES, Kerevat.

Remarks: Important food with the poorer people of the eastern tropics. The capsule around the seed is eaten raw, not the outside pulp. Fruits can weigh up to 30kg each. Related to Breadfruit.

Initial contributor: D.W. Loh, LAES, Kerevat, ENBP.

MACADEMIA NUT

Description: A large tree with nuts which are round, hard and have thick shells.

Botanical name: Macadamia integrifolia
Height: 10 metres plus
Age to first production: 7 years
Normal life span:
Bears fruit in Kudjip, WHP and Kainantu, EHP.

Nuts are very nutritious. Oil content is 73% at maturity and the kernels are a good source of calcium, phosphorus, iron and vitamin B_1.
The kernel contains 9% each of protein and carbohydrate.

Seeds are planted 2.5cm deep in sand in full sun and germinate in 1-4 months. Germination is often very difficult. After 18 months, the seedlings are ready to graft with side or veneer grafts. They also may be cleft-grafted or whip-grafted. Cuttings from mature branches with the leaves intact may be rooted in sand with high humidity. Wood for grafting should be ring barked well in advance of the time of use. The entire graft is covered with grafting tape to avoid drying. Transplanting needs to be done carefully and preferably in the cool season.

Difficulty in propagating, slowness in coming into bearing and the limited areas in which it produces well are factors in preventing any rapid expansion of production. In PNG best success above 1500 m.

Source of planting material: L. Schulz, SIL., Ukarumpa, via Lae.

Information taken from: Handbook of Tropical and Subtropical Horticulture, Dept of State, Agency for International Development, Washington, DC. Free.

Initial contributor: H. Bekker.

GIANT MALAY APPLE LAULAU

Description: A tall erect evergreen tree flowering profusely with scarlet blooms.
Botanical name: Eugenia megacarpa
Height: 20 - 25 metres
Age to first production: 6 - 8 years
Normal life span: 40 years
Insects and Diseases: None of importance
Indication of maturity: Pink to red colouring on fruit.

Planting information: Seeds planted in plastic bags in shaded nursery and transplanted to the field at 10-15cm height. Usual field spacing 5-10 metres.

Useful products at village level: Large edible and marketable fruit.

Sources of supply of planting materials and cost: LAES, Kerevat, free, freight charges only.

Further references: LAES Information Bulletin No 5 free; Dicotyledons, by Purseglove, Longmans, K8.50.

PNG experience: LAES, Kerevat.

Remarks: Larger than the common village Laulau. A very tall, erect tree.

Initial contributor: D.W. Loh, LAES, Kerevat, ENBP.

MANGO

Description: An erect branched evergreen tree living for 100 years or more, with a dense dome-shaped canopy.
Botanical name: Mangifera indica
Height: 10 - 40 metres
Age to first production: 6 years
Normal life span: 40 years (commercial life)
Insects and diseases: none of importance
Indication of maturity: slight yellow to pink colour of fruits.

Planting information: Raised in special seedbeds to restrict development of tap roots - 20cm deep with iron or concrete floor. Seeds must be fresh, not dried. Plant in seedbed 15cm apart with light shade 1m above. Plant out after second leaf flush has matured. Planted 10-12m apart.

Useful products at village level: Edible and marketable fruit; jams and preserves; makes excellent dried fruit when dried in sun in halves.

Sources of supply of planting materials and cost: Villages in Gazelle Peninsula, 10-20t each.

Further references: LAES Information Bulletin No 5, free. Dicotyledons, by Purseglove, Longmans.

Remarks: Has a caustic sap. Related to Cashew nuts. Try to avoid the poorer turpentine-flavoured fruits and the fibrous varieties. The large elongated varieties are the best. Fruiting is usually more successful where there is a distinct dry season. Smudging (with heavy smoke), and more recently, chemical sprays, are used commercially to induce fruiting. Preserve good stock by budding.

Initial contributor: D.W. Loh, LAES, Kerevat, ENBP.

MANGOSTEEN

Description: A slow growing, smooth leaved, evergreen tree with yellow latex in all its parts.

Botanical name: Garcinia mangostana
Height: 15 metres
Age to first production: 10 to 15 years
Normal life span: 50 years

Insect pests and control: Fruit fly-miner, control usually uneconomic. Malathion 1%.

Diseases: None of note.

Indication of maturity: Red to purple colouring on fruit.

Planting information: Seeds planted in large bags containing good rich soil - germinate 6 to 8 weeks. Planted out in field at 18 to 24 months, at 7-10m spacing.

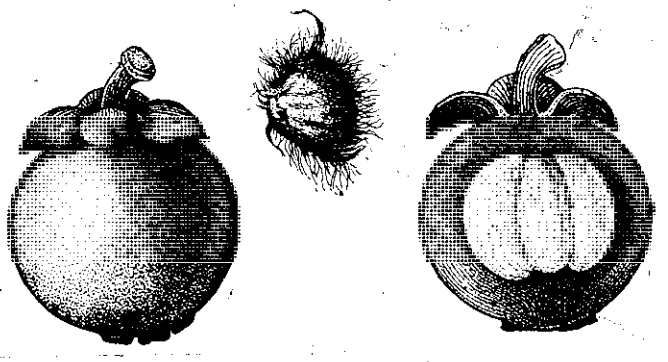

Useful products at village level: Quality edible and marketable fruit.

Sources of supply of planting materials and cost: LAES, Kerevat, small amounts available at no charge.

Further references: LAES Information Bulletin No 5, free; Dicotyledons, by Purseglove, Longmans, K8.50.

PNG experience: Kerevat. No formal trials.

Remarks: Often acclaimed as the most delicious of all tropical fruits.

Initial contributor: D.W. Loh, LAES, Kerevat, ENBP.

PASSIONFRUIT (p 244)

Description: A vigorous woody, long-lived climber up to 15m long, with tendrils. The purple fruit variety has egg shaped fruits 4-5cm in diameter and is adapted to altitudes of about 1500m. The yellow fruit variety has fruit 5-6cm in diameter and is more acid. It is adapted to the tropical lowlands.

The flowers of the purple variety open at dawn and close at noon, while those of the yellow variety open at noon and close at dusk.

Pollination is mainly by carpenter bees (Xylocopa spp) but occasionally by honey bees and wasps. If the flowers are pollinated by hand the fruit are larger. Most varieties are self incompatible, that is, they will not bear fruit unless there are enough vines for cross pollination.

Flowers will not pollinate during periods of rainfall.

Botanical name: Passiflora edulis f. edulis-Purple
Passiflora edulis f. flavicarpa-Yellow
Age to first production:
Diseases and insect pests: None of importance.
Indication of maturity: F. edulis - green to deep purple
F. flavicarpa - green to bright yellow

Planting information: Plant seeds from ripe fruit without removing the pulp. They take 2-4 weeks to germinate. Seeds planted into plastic bags can be planted into the field after 3-4 months or when they are 25cm tall.

Good varieties can be maintained vegetatively by cuttings of 2-3 internodes taken from reasonably mature wood of pencil thickness.

Plant seedlings 3-7cm apart and provide trellises of posts and wire. Most soils are satisfactory except heavy, poorly drained soils.

Useful products at village level: Good quality edible and marketable fruit.

Sources of supply of planting materials: Yellow variety seed is available in small quantities at no cost from LAES, Kerevat. Purple varieties from Goroka market.

PNG experience: No formal trials on yellow varieties but widely grown in lowlands on plantations and villages. Purple varieties are widespread in Eastern Highlands Province. During 1960's DASF and Cottees established a processing plant for fruit juice. Further information on purple varieties from J.J. Nitsche, DPI, Goroka.

Remarks: A delicious tropical fruit, easily grown and with a very high content of Vitamin C. May be eaten directly from the shell or used as a fruit salad. The yellow pulp around the seed may be used for jams and jellies.

The name "passionflower" was given by early missionaries in South America who believed that the flower represented the crucifixion.

Initial contributor: D.W. Loh, LAES, Kerevat, ENBP.

PAWPAW

Botanical name: Carica papaya
Height: 5 - 7 metres
Age to first production: 6 - 10 months
Normal life span: 4 - 5 years

Insect pests: Nematodes may stunt growth, so plant only in new ground or in places where there have not been gardens for several years.

Indication of maturity: Pick when the fruit begins to turn yellow on the underside. Let ripen naturally.

Planting information: 2.5m x 2.5m for plantation. Seed direct or transplant seedlings grown in nursery. Pawpaw trees do not like wet feet. They must be on well-drained soil. They do like wood ashes, so you might mix in a few when you prepare the places for the tree.

Village level uses: Fresh edible fruit: (p 112) fresh fruit juice; meat tenderizer (wrap meat in pawpaw leaf, or rub with pawpaw fruit and poke holes in meat with a fork); relief from insect bites (place pawpaw rind on insect bites); clearing of dead tissue in tropical ulcers (place pawpaw rind on

wound, change frequently).

Industrial uses: Meat tenderizer, green fruit is tapped for white latex from which is made papain. It is an important ingredient in many medical preparations, as it is an enzyme.

Sources of supply: local.

Further references: A Handbook of Tropical Agriculture, G.B. Masefield, Oxford Univ. Press.

Remarks: Pawpaw trees may be (1) male, (2) female or (3) both male and female. The best pawpaw are the red pawpaw sometimes called "pawpaw melon" in pidgin. The reason that the seeds of red pawpaw don't always grow into red pawpaw trees is that the mother flower might have been fertilized by pollen from another kind of pawpaw.

PINEAPPLE ANANAS

Botanical name: Ananas comosus
Height about 1 metre
Age to first production: Up to 3 years if no hormone applied. Usually 1-2 years, depending upon what planting materials are used.

Normal life span: Perennial, but yields decline with time if not replanted.

Insect pests and control: Mealy bug is sometimes a serious problem. Dip planting material in Malathion solution.

Diseases and control: Pineapple wilt disease (a fungal disease) can be serious. Treated by the preplanting dip used for mealy bug. Nematodes can be a problem.

Indication of maturity: Fruit turns yellow or orange.

Planting information: Aerial suckers (suckers that grow from the stem above the ground) are the best planting material as they produce a fruit quickly and give better yields than other planting materials. Ground suckers (from under the ground), slips (on the fruit stalk below the fruit) and tops are also satisfactory planting material. Strip the lower leaves off the suckers and allow them to dry for a week before planting. Spacing: Double rows 1.8m apart, 30cm between plants within rows if cultivated mechanically.

Useful products at village level: Fresh fruit, or fresh fruit juice for people. Makes excellent jams, especially when mixed with pawpaw, with sugar being processed at the village level. (P 112) (P 114)

Sources of supply of planting materials and cost: local rough variety has many more suckers than the smooth variety.

Related supplies: Phyomone to cause early and controlled flowering is available from Elvee Trading Co., Box 151, Rabaul; N.G. Pastoral Supplies, Box 83, Lae. Cost is about K1.90 for 227ml bottle.

Pineapple plant. Note slips at base of fruit and suckers at base of plant. Plant these, and not the top of the fruit.

Further references: R.M. Bourke, Pineapples, DPI Rural Development Series, 50t; J.L. Collins, Pineapple, Leonard Hill, London; R.M. Bourke, Making Pineapples Fruit/Mekim Painap i Karim Prut, LAES, (1976) Information Bulletin No.9; M.N. Hunter and Sickey,B.,Pineapple Production in the Markham Valley. Harvest 2(1). (P 244)

PNG experience: Pineapples are widespread in village gardens and are a good source of vitamins

Applying flowering hormone to a pineapple plant

in the village diet. The rough leaf variety yields only about 8 t/ha. Research has been done on them at LAES, Kerevat; DPI, Bubia, near Lae; and DPI near Madang; at the University of Technology, Lae (Dr. Ken Willson).

Remarks: There is a chemical called Phyomone that makes the plants carry fruit quickly and all year round. It is very cheap. You place 4 drops in a fish tin of water and put the solution onto the plant. A fish tin will do 7 plants. 5 months after you put the chemical on, the plant carries a fruit. Phyomone does not work well on smooth leaved varieties. Use a calcium carbide solution for these varieties instead. More information from LAES, Kerevat, ENBP. Pineapples grow well in shade and yields are almost as good as in full sunlight, but there is much less weeding and nitrogen deficiency does not occur. They do well under coconuts, bananas, pawpaw, buai, pigeon pea, etc.

Initial contributor: R.M. Bourke, LAES, Kerevat, ENBP.

RAMBUTAN

An evergreen, bushy tree with male and female flowers on separate trees.

Botanical name: Nephelium vappaceum
Height: 20 metres
Age to first production: 5 - 6 years
Normal life span: 50 years
Insect pests and control: Minor fruit fly attacks.
Diseases and control: None noted.
Indications of maturity: Fruit changes from green to red or yellow; birds feed on ripe fruit.

Planting information: Planted into field when 15cm high. Initial growth fast, subsequent growth very slow.

Useful products at village level: Edible and marketable fruit.

Sources of supply of planting materials and cost: LAES, Kerevat, free, freight charges only.

Further references: LAES Information Bulletin NO 5, free; Dicotyledons, by Purseglove, Longmans, K8.50

PNG experience: Kerevat orchard, LAES, Kerevat.

Remarks: A sweet slip stone variety is available. Good flavour varieties should be propagated from marcotts (cuttings).

Initial contributor: D.W. Loh, LAES, Kerevat, ENBP.

MARCOTTING LAYERING

These are ways of getting new plants by making roots grow on old plants.

"Marcotting" is when the branch is left on the tree and soil is put around the branch. Roots are produced where the soil is. "Layering" is putting the branch into the soil. These methods are easy and usually work. The plants will be exactly the same as the parent plant. The marcotted tree produces fruit up to two years earlier than a seedling.

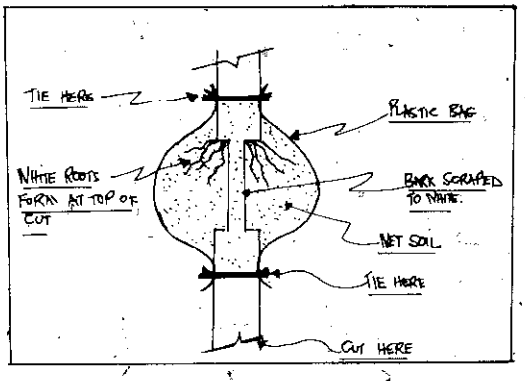

HOW TO MARCOTT

1. Select the tree you want. The tree must be healthy, well grown, and the best of its kind (citrus are most suitable).
2. Choose a tree that is already producing fruit.
3. Select a fruiting branch that is as thick as your finger.
4. With a sharp knife cut away the bark in a ring around the stem. Remove bark only, do not cut too deep as this will cut the sap and the plant will die.
5. Scrape away all green fibres so bark will not grow again.
6. Place plastic bag, tying below the cut (scraped bark). Add very wet soil and tie the top so that the soil will not dry out.
7. After 2 to 4 months roots will appear (seen white through the plastic) and the branch is removed and planted.
8. Choose a time when trees are growing fast.

Contributed by: R. Fisher, Navota Farm, Santo, New Hebrides.

A LESSON IN BUDDING

It is often very advantageous to bud a tree. It will ensure that you get the same kind of fruit as that of the tree from which the bud is taken; and often the new tree bears fruit much earlier than one which is not budded. Trees commonly budded are: Citrus, Mango, Rambutan, Durian, Avocado, and Rubber. There are many others. Budding is easier than grafting.

SOME GENERAL NOTES:

Preparing the root stocks:

1. Plant seeds from a vigorous kind of tree of the same species as your bud. When the seedling is pencil size or slightly larger is a good time for budding.
2. Give this root stock some nitrogen fertilizer either chemical or organic - about 30 days before budding. A new flash of growth indicates readiness for budding.
3. The root stock should have ample moisture before and after budding.
4. Clean the stem of the root stock with a dry rag.
5. Keep the root stocks in the sun. The buds will sprout faster, and the leaves of the root stock will shade the bud during the 3 week waiting period.

Preparing the bud wood:

1. The guidelines are very similar to those for the root stocks, with regards to size of branch fertilizer, moisture, and cleanliness.
2. The selected bud eye must be dormant (alive, but not sprouting). It should come from a recent flash of growth that is becoming mature - the green colour turning to brown.
3. Do not bud in the rain, as it will be very difficult to keep the work clean. Cleanliness is very important.

Your Tool: Use a small razor-sharp knife with a nice point, as shown. If your knife is too big or dull you might mutilate the bud eye.

1.

2.

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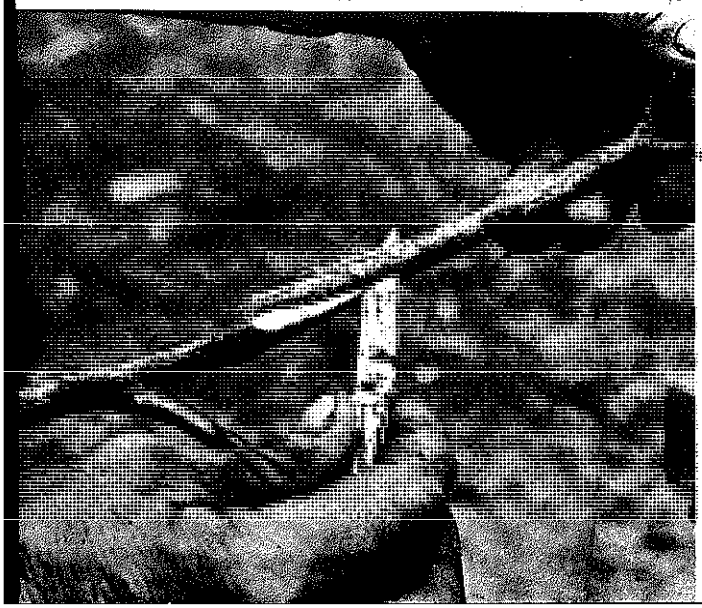

See photo captions on next page.

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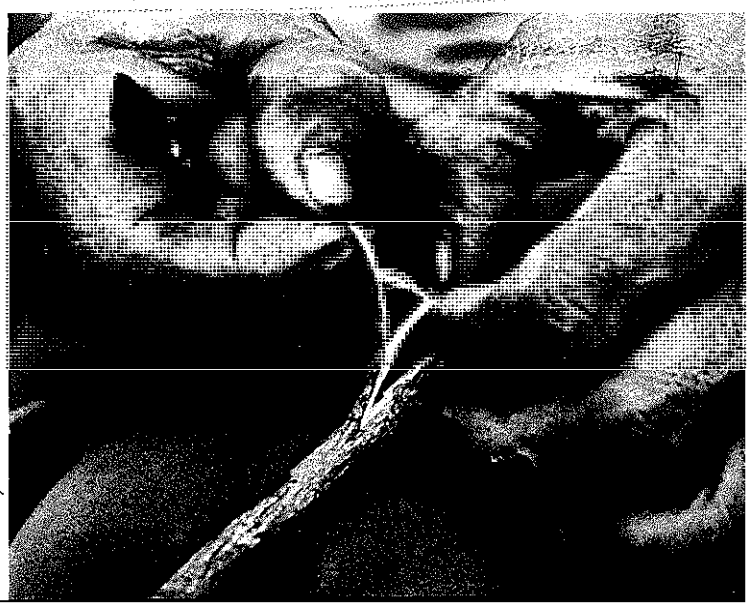

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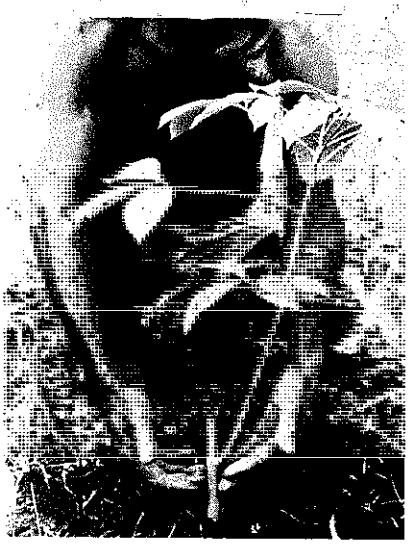

11.

Photo Captions:

1. Cut two lines up and down on a clean place of the root stock, about 3cm long; a little farther apart than the bud is wide, and as deep as the bark.

2. Cut across at the bottom and then lift that whole portion, starting from the bottom.

3. Cut off about 2cm of the bark.

4. Cut two lines on the bud wood, one on either side of the selected bud eye, also about 3cm long; with the bud in the centre. Lift the bud along with the bark and some wood by cutting under the bud with the knife.

5. Pull the wood away from the bud, using care that the clean part on the back of the bud is not touched.

6. Insert the bud under the 1cm flap of the root stock.

7. Trim the bud to the exact length of the open space on the root stock.

8. Wrap plastic tape around the bud. Make your own tapes out of clean and dry plastic bags, preferably clear. Start down and wrap upwards (so that water will run off).

9. Twist the end of the tape and tie with a simple slip knot on the last turn. Leave the plastic tape on for three weeks. If it is clear plastic you can see the bud eye taking life from the root stock. Sometimes the bud dies. After three weeks open the tape. Wait one more week with the bud exposed. Cut the root stock clear off about 4cm above the new bud, using a sharp pruning tool.

10. The bud will sprout. In some cases the other natural buds of the root stock will also sprout. Cut these off. This shows a mango bud several months after it sprouted.

11. This is a budded rubber seedling after about six months. Note that the old trunk above the bud is already quite small compared to the lower trunk. Later it will dry up and drop off, and the whole trunk will become straight.

Cut off a small branch of a tree and practice this until you feel confident. Then try the real thing.

Initial contributor: Camilo Toledo, Box 80, Lae.

Tree Crops

BAMBOO MAMBU

Botanical name: The most common genera are:-

Phyllostachys
Arundinaria
Bambusa
Dendrocalamus

There are about 500 species.

People eat it (the tender shoots) while sitting in a chair made of it, live in houses made of it, bake things in it, cook things with it as a fuel, carry water in it (as a vessel or as a pipe), and sleep in a bed made from it.

The farmer keeps his animals in cages or pens made from it, castrates his pigs with a sterile blade made from it, makes the yoke for his beast of burden from it, and ties the beast with a rope made from it.

The fisherman patrols his bamboo fish traps on a raft made of it, or a canoe outfitted with it.

Their wives carry food from the market in a bamboo basket, sift, sieve, stir their cooking with it. They comb their hair with it, and afterwards put in an ornament made from it.

Their naughty little boys shoot a bamboo/kerosene cannon to make a big noise at New Year's.

A unique and outstanding example of the use of bamboo is the great bamboo pipe organ, found in Las Pinas, Rizal, Philippines.

The Japanese are famous for their countless objects of utility and beauty made of bamboo.

PLANT SOME!

Unfortunately, some of the most useful varieties of bamboo are not widely found in PNG. It is easy to propagate, and in almost any region some planting materials may be found. Quite a number of types are found in the Botanical Gardens, Lae.

The following are common practices for propagating bamboo in the Philippines: Take 4 nodes from a stem about a year old (this means not mature, but already a bit woody). Plant near a creek or a stream, or in a place that will usually have plenty of moisture. Put into the ground at a 45 degree angle, with 2 nodes under the ground and 2 nodes above the ground. You might plant several sticks in one hill. But put the hills somewhat far apart, say 10m or more.

Following is an excerpt from a book BAMBOO, by Robert Austin, Dana Levy, Koichiro Ueda, 1970, 215 pp, US$15.00, postpaid, from John Weatherhill, Inc., 720 Fifth Ave., N.Y., NY 10019, USA:-

"Bamboo is one of the most extraordinary plants

that exists. It flowers perhaps once in a hundred years, and then it dies. It grows faster than anything in the world. In fact, it is sometimes possible to see it growing, just as one can see the hands of a large clock moving: there are recorded instances of bamboo's growing four feet in a single day. In a grove in spring the vitality of the surrounding green pillars is almost palpable. While the stem is growing above ground, the root stops: when the stem has finished, then comes the turn of the other. Bamboo also possesses the characteristic of making its complete growth in about two months only. Thereafter it remains the same size as long as it lives.

"But bamboo is interesting for much more than this: it is the most universally useful plant known to man. For over half the human race, life would be completely different without it. The Fast and all its peoples can hardly be discussed without bamboo being taken into account. Accepted as a mere fact of life or prized for aesthetic reasons, it touches daily existence at a thousand points which vary as widely as its employment in literary metaphor and its use in the walls of houses. It serves the most mundane purposes, and the most refined: Dwellings are constructed from bamboo; it is widely used for eating and drinking utensils and for countless other household implements. Ubiquitous, it provides food, raw materials, shelter, even medicine for the greater part of the world's population. The interlocked roots of a bamboo grove restrain the river in flood and during earthquakes support the insubstantial dwellings of country villages.

"Regarded as a material to work, bamboo shows itself "grateful" - to use the artisan's term. It is flexible, yet tough, light but very strong. It can be split with ease, in one direction only, never in the other; it may be pliant or rigid as

the occasion demands; it can be compressed enough to keep its place in holes; after heating, it can be bent to take and retain a new shape. It is straight and possessed of great tensile strength.

"Praise God for bamboo!"

KAPOK

Description: A lowland tree which can make living fence-posts, and at the same time produce firewood, charcoal, and material for pillows. Not a crop to plant in groves.

Botanical name: Ceiba pentandra
Height: Up to 30 metres
Age to first production: 3-5 years
Normal life span: 20-30 years
Disease and Insect pests: None of importance

Indication of maturity: Pods should be harvested before they open. The dry pod is ready for harvest when a light tap with a stick or shaking the branch makes the pod fall.

Planting information: It is easiest to plant cuttings. Seeds or seedlings can also be planted. A 6m distance is suitable, but you can plant Kapok fence posts closer if you will cut off the sprouts from time to time for firewood.

Source of supply of planting materials: local.

Remarks: A mature tree will produce 3-5kg of kapok a year, which is a lot of pillows. To separate the floss from the seed, allow the pods to dry in the sun for 2-3 days. Break open the pod and place seeds and floss in a large deep box to 1/3rd full. Take a very straight pole 3-5cm thick and 1.5m long.

The stick should be very smooth but the tip at the bottom can have very short branch studs. Place the stick tip down into the box of kapok and spin rapidly between your hands. The spinning motion causes the kapok to fluff up to the top of the box and the seeds to settle to the bottom.

Initial contributor: E. Cox, Bagi Agr. Centre, Box 65, Angoram, ESP.

RUBBER RUBA GUMI

The PNG Government has indicated its intention to promote wider planting of natural rubber (NR) on a small holder basis, and will be asking for UN/FAO expertise. Rubber is an excellent crop for small-holders because it is labour intensive and could provide many jobs. It can utilize hilly land unsuitable for other types of cash cropping. Hopefully, those planting rubber will keep a realistic perspective (since you can not eat rubber!) Plant only after your food requirements are assured, and retain your best land for food production.

Botanical name: Hevea brasiliensis
Height: 10 - 15 metres
Age to first production: 4½ years to 7 years, depending upon climate and management.

Normal economic life: 30-40 years, depending upon prices, labour costs, and other factors.

Insect pests: minimal.

Diseases: The most difficult are the fungus diseases of the fast-growing soft tissues of the forks of branches; of the tapping panel; and of the roots. These are all readily controllable with various standard fungicides. Other diseases exist, but are not a major problem.

Indication of maturity: Trees approximately 50cm in girth (circumference). Usually tapping is not begun until about 60% of the trees are of this size or larger.

Planting information: NR can only be grown economically within 15 degrees of the equator, generally, and lower than 450 metres above sea level, due to temperature considerations. (Rate of growth is all-important). NR can not withstand regular strong winds or typhoons. It is not economical where there are prolonged dry seasons. 2000mm of rain annually, well-distributed, would be an absolute minimum. 3000mm would be optimum, and somewhat more than that should not be a problem, if modern techniques (plastic bags) for gathering latex in the case of frequent morning rains, and modern fungicides. NR requires an acidic, well-drained soil. Never plant on poorly drained low-lying areas.

The most commonly found pamphlets available in PNG are the DPI (5) booklets "Grow Good Rubber". These do not show the most modern and effective techniques for NR propagation. Be sure to seek expert advice if you want to plant. NR root stocks are propagated from seeds in a nursery, preferably

in plastic bags. When they are about the size of a pencil they are budded with a high-yielding variety (this is a modern technique called "green-budding".) After the young bud sprouts, the tree is placed in the field 3m apart in 9m-rows. (p 39)

Management up to tapping is relatively simple, consisting mainly of removing weeds immediately around the trees ("ring-weeding") for about 3 years; establishing a leguminous cover crop (such as Pueraria phaesolides), and protecting against grass fires. Animals should not be allowed within the plantation, as they might damage the trees.

Inter-cropping can be practiced for 2 or 3 years, but it is not highly economical in the long run, as the time to reach tappable size might be extended.

Uniformity of tree size is very important, as trees greatly retarded will be shaded out once the canopy forms.

Some rough economic guidelines: 400 to 600 trees per hectare (or 167 per acre minimum); conservative production estimate, 5kg of dry rubber per tree per year; approximate value (usually higher) of dry rubber per kg is K0.50. Based on these figures, one ha. will produce dry rubber each year worth about K750.00. Greater production is quite possible with good management.

Useful products at village level: This is mainly a cash crop. NR requires processing. It is easily marketable as ribbed smoked sheets, or if you are near a large rubber mill, as coagulum or "cup lump" (coagulated in the collection cup.)

Sources of planting material: RRIM variety 600 is recommended. Popondetta Agr. Training Institute, Popondetta, NP. has a ployclonal seed garden with the following varieties: RRIM 623, 605, 600, 501, and PB551; a budwood garden for RRIM 600 has been started at the Lutheran Rice farm c/- Box 80, Lae; for additional sources write the Chief Agronomist, DPI, Konedobu.

Further references: For information on propagation, including budding, write Rev. Camilo Toledo, Gabmazung Rice Project, Box 80, Lae. Camilo is an expert rubber budder, and has had much experience with all phases of rubber-growing. The most competent organization for answering specific technical questions is the Rubber Research Institute of Malaya, Box 150, Kuala Lumpur, Malaysia. Good publications are also available from RRIM. (p 244)

PNG experience: You can see rubber growing in Northern Province around Popondetta; Milne Bay; at Sogeri (though these trees are not very good, and the conditions hardly economical); New Ireland at various places. Your provincial DPI office can tell you the nearest place to see it growing.

Remarks:- The labour of rubber production is generally of a pleasant nature, mainly in the morning, and practically all in the cool shade of the trees. Long term market prospects are very good, as world and PNG consumption are expected to rise steadily,

Tapping a tree about 10 years old. Note scars where tapping was improperly done.

and its main competitor, synthetic rubber, is increasingly more expensive to produce due to the rising cost of petroleum. A number of simple small industries can be based on NR, such as manufacturing rubber shoes, rubber products for the home.

ROLLERS FOR MAKING RIBBED SMOKED SHEETS OF RUBBER

These are important for farmers with small areas who want to process their own rubber for maximum control over their marketing. Most of the world's natural rubber is marketed in "ribbed smoked sheet" form (RSS).

Kian Lee SMR Factory (PTE) Ltd.,
527-528 Fifth Floor,
Plaza Singapura,
Orchard Rd.,
Singapore 9.

Their Model "T" No 5 is especially good, as it is for either hand or motor operation. Ruggedly built, it comes with a fly-wheel/crank, which may be removed and replaced with a pulley.

Other sources:

Klang Motors,
244, Jalan Meru
Klang, Selangor State, N. Malaysia

Kwang Cheong Engineering,
312 Jalan Sungei Besi,
Kuala Lumpur, Malaysia

Wong Chian and Son,
9D, Jalan Dua, off Sungei Besi Rd.,
Kuala Lumpur, Selangor, Malaysia.

TREES GROWN FOR TIMBER, POSTS AND FIREWOOD

CASUARINA (Casuarina spp) is a fast growing tree which has an important place in highlands agricultural systems because of its ability to fix nitrogen, pull nutrients up from deep in the soil, and to complete with Kunai grass. It is an important shade tree and source of firewood.

When planted around a garden within the last year of gardening it can get ahead of the Kunai and slow its growth, and can be strong enough to withstand the damage of the pigs when they enter the area.

The demand for fuel and the fact that many highlands areas have gone to Kunai make it very advisable to plant more Casuarina.

HOOP PINE (Araucaria cunninghamii) is an indigenous Araucaria of great economic value. The species gives high class lumber and plywood, and due to the long fibre length gives a superior paper.

Hoop is located in a wide range of conditions. In PNG it ranges from near sea level (Southern Morobe Coast) to approximately 2,400m. It is common in the central cordilla and is also found on the islands of the east of Papua. It is fire sensitive and remnants of many stands reduced by shifting cultivation and burning off show its once wider occupation of forest areas. Extensive hoop pine area remains in the Bulolo/Wau Valley where the pine forest is being harvested and will be replaced by hoop and klinkii plantations.

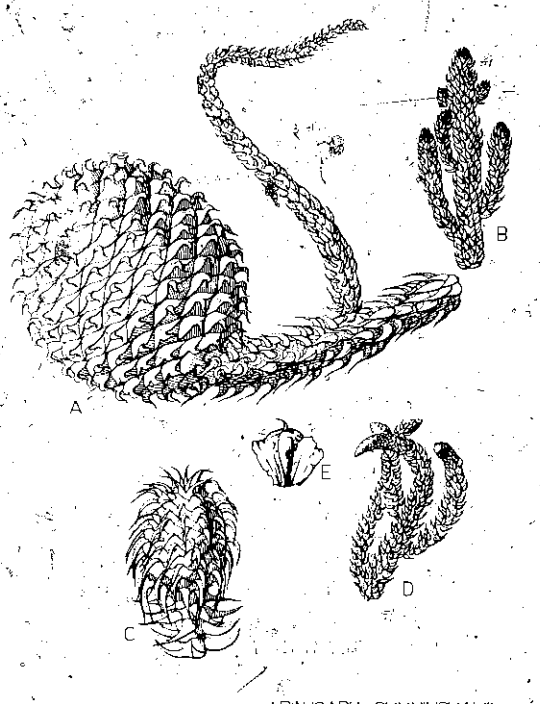

ARAUCARIA CUNNINGHAMII

The species has proved easy to handle in the nursery and plantation establishment.

Timber strength: Group 6: the timber is readily converted and is easy to work with both machine and hand tools.

Timber durability: Class 4.

Timber uses: for plywood, flooring, moulding, lining and poles.

At village level the wood can be used for fence and house posts and more commonly as firewood and shade.

Booklets are available at Forest Stations. For further reference contact closest Forest Station. (p 50)

KAMARERE (Eucalyptus deglupta Blume) is a large tree reaching 72 m high and 2.5m in diameter. Gross volumes to 60 cubic metres volume per tree have been measured, and very high volumes per hectare have been recorded.

Seedlings of Kamarere demand full overhead light for development, and stands are restricted to natural clearings (river, pumice or gravel beds, landslides, volcanic blast areas) or the garden areas which are established in the traditional shifting cultivation procedures of the lowlands. In these areas it forms pure stands but is soon provided with an understory of more tolerant species. Later the Kamarere will be eliminated from the site as it is unable to regenerate under these conditions. Then the typical lowland rain forest will remain.

The naturally occurring stands are within the 250-500cm of rainfall per year range, with perhaps

See drawing, page 47

the mean near 300cm, and without a prolonged seasonal drought. A temperature range between 25° and 30°C and a relative humidity 78% to 90% is common in the lowland stands. The highland climates may range 12-26°C for temperatures and 60% to 80% for relative humidity.

Kamarere occurs on a variety of soils. It requires a good supply of available minerals and though often associated with creek and river beds it will not stand water-logged conditions. The optimum condition will appear to be a deep, rich, well drained soil with a non-seasonal rainfall of approximately 300cm per year.

The species is not frost tolerant.

Timber Strength: Group 4.

Durability: Class 3.

Timber uses: It is readily milled and works well with both machine and hand tools. It is suitable for heavy construction, flooring, furniture and boat building.

Use in village level: Posts, poles and fire wood. More detailed publications are available at Forest Station. (P 50)

KLINKII PINE (Araucaria hunsteinii) is an indigenous Araucaria of great economic value to PNG - not only because of the large virgin stands but also in its adaptability to plantation techniques. The species gives high lumber and plywood, and due to the long fibre length gives a superior quality paper. The tree form is generally excellent and superior to that of A. Cunninghamii with which it is associated in its PNG distribution.

Klinkii is located 600-1500m above sea level in a belt stretching from the Milne Bay hills to the slopes of the Didana Range (140° east, 32km inland from Collingwood Bay) scattered on the Owen Stanley slopes through to Bulolo/Wau and to the Jimi River Valley (145°E) and in the ranges behind Finschhafen.

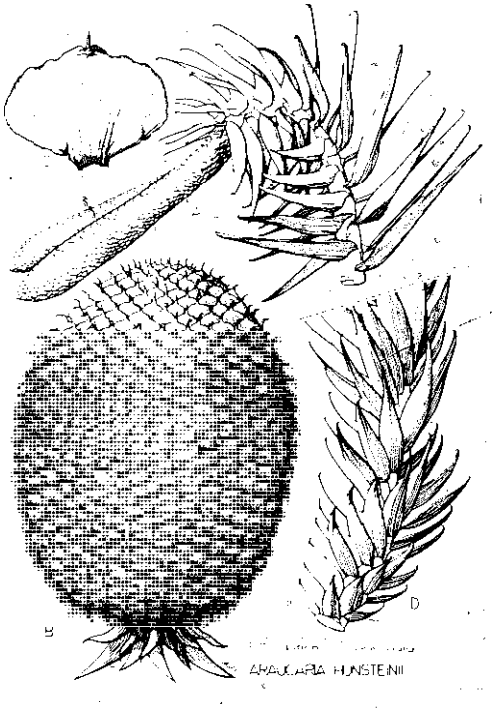

Both species of Araucaria tend to grow together, but with one species or the other predominating. In the Jimi Valley, while Klinkii is widespread, Hoop Pine is rare, if present at all. However, Hoop Pine has a much wider range extending from south of New South Wales/Queensland border, to Irian Djaya.

Klinkii is one of the large trees of the world, and heights to 87m have been recorded. Trees of 3.6m girth are common and it is thought these are between 300 and 400 years old.

There were initial difficulties in establishing Klinkii in plantations due to nursery and early field problems.

Timber strength: Group 6.

Durability: Class 4.

Timber uses: Timber is easy to work with both machine and hand tools. It dresses well to a smooth finish used widely for all interior work including panelling and moulding. May be used for fence posts, poles and as firewood. For further reference contact nearest Forest Station. Publications are available. (P 50)

GIANT LEUCAENA

An extremely fast-growing leguminous tree useful for forage, shade, erosion control, firewood, living fence posts, poles, timber, charcoal, and pulpwood. It is different than the well-known Leucaena glauca.

Botanical name: Leucaena leucocephala

High performance varieties are being promoted in the Philippines, and seeds will soon be available in PNG. The major uses:

Forage: Produces up to twice the amount of high protein highly digestable forage as ordinary Leucaena. Amounts of 77.8 met. tonnes per hectare per year with an average of 4.6 cuttings (back to 10cm) have been reported. Converted dry weight yield was about 20 metric tonnes per hectare. In these tests it was grown in rows 50cm apart.

Fertilizer: Research at the University of Hawaii indicates that as a green manure crop the fertilizer equivalent of a year's harvested hectare of Leucaena leucocephala is estimated to have exceeded 550kg N, 225kg P_2O, and 550kg K_2O.

Wood production: Even ordinary Leucaena is considered to be a moderately high volume wood producing species. It is claimed that the Giant Leucaena will exceed the ordinary Leucaena by 100-200%. Variety K-8 (Hawaiian Giant) has reached heights of over 15 metres in 6 years. Firewood yield is very high as well. The wood also makes excellent quality charcoal.

Pests, diseases, problems: Few known enemies except animals which browse and humans who cut it down or eradicate it. The main problem seems to be weevils that attack the seeds which are not as waxy and hard as those of the ordinary Leucaena.

Planting information: Plant seeds in seedbeds or plastic bags, or for forage directly in the field. To improve germination it is recommended that the seeds be scarified (seed coat weakened). The easiest way is to heat water to boiling, let it cool just slightly, then put the seeds in an equal volume of that water to soak for 12 hours. For maximum nitrogen fixation a suitable rhizobium should be used (DPI Rhizobium Service, Box 2417, Konedobu.) In seedbeds plant seeds no more than 4cm apart in rows 25cm apart. Transplant to permanent location at 2-4 months. If seedlings are transplanted bare-root, prune top stem back to a point where the bark has turned brown. Seed trees may be planted at a spacing of 2 x 5m. For hillside planting (erosion control and intercropping) drill in paired contour rows 40cm apart and 2-5cm apart in the row. The paired rows should be about 2m apart, centre to centre. For timber production plant at 10 x 2m with a later thinning of less vigorous trees to a spacing of 10 x 4m or 10 x 6m. For firewood plant 1 x 2m with a later thinning to desired density. Can also be planted from cuttings.

Sources of supply of planting material: Variety K-67 El Salvador is already present in PNG, but not

yet in large quantities. Small quantities of seed are known to be in the hands of Division of Botany, Lae; Wesley High School, Salamo MBP; and Liklik Buk, Box 1920, Lae. Varieties K-8 and K-28 are presently being cleared through DPI Plant Quarantine in Port Moresby. Note that the most common variety in PNG is "Peruvian", which is not as good as the above.

References: "Bayani - Leucaena leucocephala, A Source of Fertilizer, Feed, and Energy for the Philippines", by Michael Benge 1976, 21pp. available from Agricultural Development Section, USAID., Magsaysay Centre, Roxas Blvd., Manila, Philippines.

(p 15)

PINE TREE (Pinus spp) is an important fast-growing timber product tree. It provides good pulpwood and wood for construction, furniture, posts and poles, and firewood.

Pinus grows well in both fertile and infertile soils, in grasslands, in both highland and lowland areas. The tropical species which can germinate well here in PNG are P. caribaea, P. merkussi, P. patual, and P. strobus.

Viable seeds are usually produced by Pinus within 8 years, but larger amounts are not available until later.

Pinus seedlings need well-prepared seed beds, so advice from an experienced forest officer is important.

See "Silviculture of Pinus in PNG" Forestry Bulletin No 5, available from Forest Offices.

TEAK (Tectona grandis) has been widely planted throughout the tropics and was introduced to New Guinea at the beginning of this century.

It is a large deciduous tree with a long clear cylindrical stem. It is sometimes fluted (has grooves) and is often buttressed at the base, (well-braced by highly developed roots).

It grows from sea level up to 1220m but does not thrive at higher altitudes. An average rainfall of 125-250cm per year with a marked dry season of 3-5 months and a temperature range of 5°C to 44°C appears to be optimum. The species is not frost tolerant except at the northern limit of its range.

Teak requires a deep well drained soil of moderate fertility. Sub soil clay pans or massive laterites or deep sands are not good. Teak will not stand water-logging.

Many of the lowland areas of PNG are excellent for the growth of teak, particularly on the Papuan side of the island where a marked dry season occurs.

The wood is hard and can be used for fence and house posts, or can be used for firewood.

(p 50)

It can be planted with seeds or by cutting, and may grow very fast.

For further details references contact closest Forest Station.

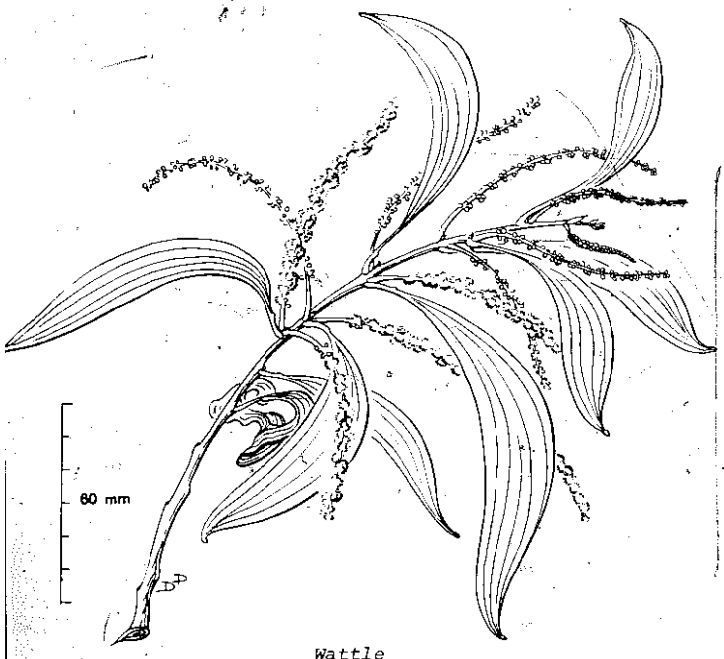

Wattle

Acacia auriculiformis A.Cunn.

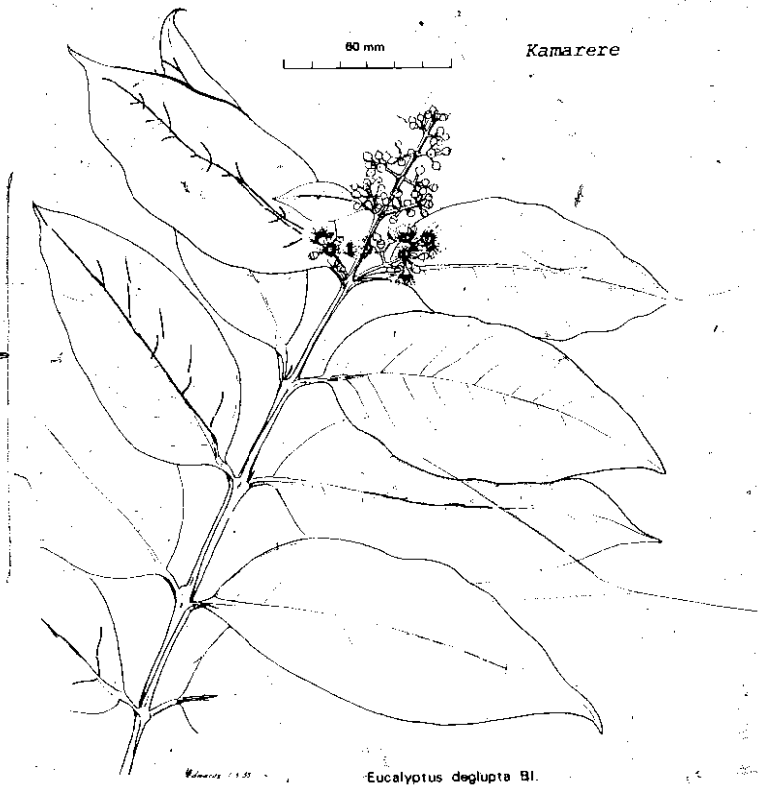

Kamarere

Eucalyptus deglupta Bl.

Gum

Eucalyptus tereticornis

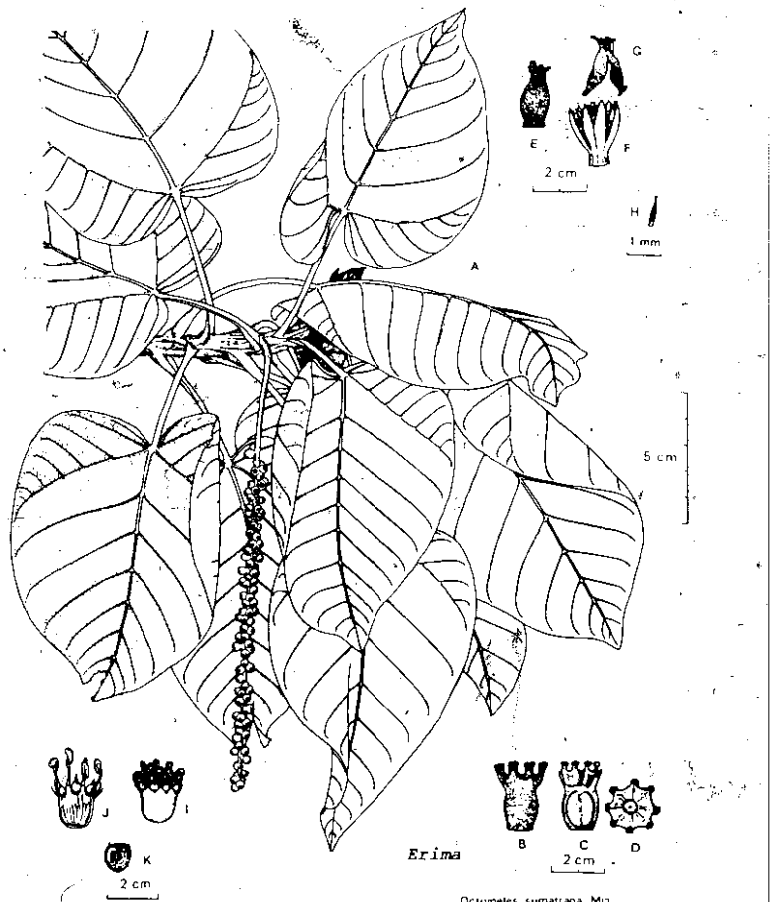

Erima

Octomeles sumatrana Miq

COMMON NAME	BOTANICAL NAME	WHERE IT GROWS	WHAT WOOD IS LIKE	CHARACTERISTICS OF TREE	PLANTING MATLS SOURCE	PAPERS AVAILABLE
Kamarere	Eucalyptus deglupta	Highlands and Coastal zones	S 4, D 3, red-brown, straight, used for posts, firewood, shade, heavy construction.	Very fast growing, heavy branches, smooth bark, grows 72m tall and 2.5m in diameter.	Forest Station	Yes
Gum Trees	Eucalyptus	Highlands and Coastal zones	S 3-4, D 2-3, red-brown, used for posts, firewood, general construction.	Very fast growing, double stem may occur, grows 18m tall and 0.6m in diameter.	Forest Station	Yes
Teak	Tectona grandis	Lowlands, Morobe, Central, N.P.	S 4, D 1, yellow to golden brown, used for posts, firewood.	Fast growing, heavy branches, bad form, grows 58m tall and 7.6m in diameter.	Forest Station	Yes
Wattle	Acacia spp	Highland and Coastal zones	S 4, D 2-3, hard & heavy, used in boat building, heavy construction, furniture.	Fast growing, light branches, straight spurred trunk, grows 40m tall and 80cm in diameter.	Forest Station	Yes
Hoop	Araucaria hunsteinii	Bulolo/Wau Highlands	S 6, D 4, straw colour, uniform texture, used for sawn timber, plywood, veneer.	Fast growing, straight form, dark brown bark, grows 66m tall and 2m in diameter.	Forest Station	Yes
Klinkii	Araucaria cunninghamii	Bulolo/Wau Highlands	S 6, D 4, straw colour, light. Used for plywood, veneer, sawn timber.	Fast growing, reddish brown rough bark, needle-like leaves, straight form, grows 93m tall 2m diameter.	Forest Station	Yes
Pine Trees	Pinus spp	Highlands and Lowlands	Light, straight grain. Used for posts, firewood.	Very fast growing, straight, needle-like leaves, grows 25m tall, and 0.5m in diameter.	Forest Station	Yes
Casuarina	Casuarina spp	Highlands and Lowlands	S 2, D 2-3, hard, heavy. Used for posts, firewood, general construction.	Average growing, needle-like leaves, bad form, grows 40m tall and 1m in diameter.	Forest Station	Yes
Erima	Octomeles	Central, N.P. New Britain	S 7, D 4, light brown to grey-yellow. Used for Canoes, firewood, sawn timber.	Fast growing, buttressed, flat crown, straight trunk, grows 60m tall, 2m in diameter.	Natural stand & Nursery	No
Anisoptera	Anisoptera polyandra	Morobe	S 5, D 3, pale yellow or yellow brown. Used for general construction.	Average growing, buttressed and straight, grows 50m tall and 1.2m in diameter.	Natural stand	No
Vitex	Vitex cofassus	New Britain	S 3, D 2, yellow to grey-brown. Used for boat and house construction.	Average growing, buttressed, heavy branches, 36m tall 0.5m in diameter.	Natural stand	No
Terminalia	Terminalia spp	General, not Highlands	S 6, D 3, pale yellow to yellow. Used for flooring, posts, firewood, poles.	Very fast growing, very straight, no taper, grows 50m tall and 2m in diameter.	Forest station	Yes
Rosewood	Pterocarpus indicus	General, not Highlands	S 4, D 1, white to pale yellow. Used for boat building, posts, general constr.	Average growing, fairly straight, leaning heavy branches, grows 35m tall and 1m in diameter.	Natural stand	No
Taun	Pometia spp	General	S 4, D 3, pink to pinkish brown. Used for domestic flooring, furniture.	Average growing buttressed, straight, grows 45, tall and 1.2m in diameter.	Natural stand	No
Pencil Cedar	Palaquium	General, not Highlands	S 6, D 4, hard, heavy, pale pink to brown. Used for light const. flooring, furniture.	Average growing, buttressed, straight, grows 40m tall and 1.2m in diameter.	Natural stand	No
Hopea	Hopea spp	General, not Highlands	S 3-4, D 2, pale straw yellow brown. Used for heavy construction, wharf and bridge.	Fast growing, straight, heavy branches, grows 40m tall and 1m in diameter.	Natural stand	No
Kwila	Intsia bijuga	Sepik, Madang, most Coastal Reg.	S 2, D 1, heavy, brown to dark brown. Used heavy constr. posts & carvings.	Average growing, crooked, weakly buttressed, broad crown, grows 38m tall and 1.2m diameter.	Natural stand	No
Brown Albizia	Albizia procera	General	S 6, D 4, light, yellow to brown. Used for furniture, canoes, form work.	Very fast growing, straight, heavy branches, grows 20m tall and 50cm in diameter.	Natural stand	Yes
Mango	Mangifera	General, not Highlands	S 5, D 4, rays narrow, straw to pale brown. Used for light construction, flooring.	Fast growing, broad crown, straight, grows 36m tall and 1.5m in diameter.	Natural stand	No
Canarium	Canarium	Sepik, Morobe, C.P., N.B.P.	S 4, D 4, pale brown to pink brown, smooth. Used for light const. flooring, boxes.	Average growing, buttressed and fluted, grows 50m tall and 1m in diameter.	Natural stand	No

S = Strength; D = Durability.

AVERAGE STRENGTH OF WOODS

Strength Group	Density in lbs/ cu.ft. at 12% MC	Modulus of rupture in pounds per cubic inch	Modulus of Elasticity in millions of pounds per cubic inch	Maximum crushing strength in lbs per cubic inch	Maximum shear strength in lbs per cubic inch
1.	56.0	23,000	2.72	11,800	2,720
2.	47.5	19,500	2.36	10,300	2,430
3.	40.0	16,500	2.06	9,000	2,180
4.	33.5	13,600	1.80	7,750	1,900
5.	28.0	11,500	1.55	6,700	1,700
6.	23.5	9,750	1.32	5,800	1,500
7.	20.0	8,250	1.15	5,000	1,320

AVERAGE DURABILITY OF WOODS

Class 1, Very durable, suitable for long term use in contact with the ground.

Class 2. Durable, suitable for use in the ground and for unprotected exterior use.

Class 3. Moderately durable, suitable for protected exterior work and for interior use.

Class 4. Non-durable, not suitable for exterior use unless treated.

GENERAL PLANTING PROCEDURES FOR FOREST TREES:

1. If possible, plant when the soil is moist.
2. Remove tube.
3. Plant firmly up straight.
4. Avoid stones and logs.
5. Approximately 3m x 3m distance.

SOME COMMON PEST AND DISEASE PROBLEMS WITH TREES GROWN FOR TIMBER.

Insects: Termites, Hyblace Puera, various seed larvae, white grubs, moths, hemiptera beetles, and white ants. Vanapa attack Hoop Pine that have already been damaged. No cure. Haylurdrectonus: prune affected parts.

Control: Chemical control is not generally recommended. Vanapa (prune and completely remove the infected parts) and white ants (destroy nests) are of most concern.

Diseases: Damping Off (a root fungus at seedling stage), prevent by heat sterilizing soil; Chlorosis a nutrient deficiency corrected with the corresponding plant food (usually NPK is given).

Others: Snails, rodents (rats & other small animals with strong teeth), weeds and fire.

FOREST NURSERIES

Starting an artificial grove of trees, as well as regenerating a previous forest, usually depends on the production of good seedlings. These can be better grown in nurseries.

The object of the nursery is to produce good seedlings at low cost.

Temporary nurseries are those used for only a few years. They supply small numbers of plants for a particular area. They are usually built close to planting area, usually in previously forested areas where soil fertility is high. Advantages are:- low cost since they require no permanent installations; because they are close to the planting site they produce plants that are better adapted; and transport costs are low.

Some disadvantages are:- low production; harder to supervise; higher per plant cost; and it is restricted to kinds of trees that do not require many special nursery aids.

Temporary nurseries should be located on flat ground, near water source, where suitable soil exists.

Village groups will seldom need a permanent nursery, but if one is needed you may get detailed information from your closest Forest Station. Publications and booklets are available at Forest Stations.

Prepared by Office of Forests, Lae.

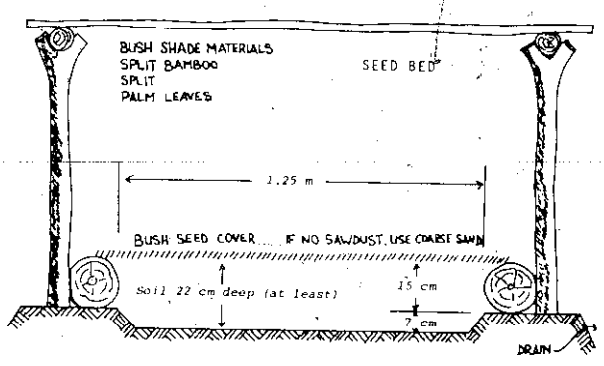

LIVING FENCE POSTS

There are sometimes big advantages in using living fence posts, if you have the materials for planting them. Leucaena or Kapok are good species, and there are others. They don't rot, they produce firewood, give shade, and in the case of legumes are good for the soil. Living Kapok fenceposts give materials for pillows and mattresses.

Plant fresh cuttings 5cm to 20cm in diameter depending upon your needs in the same way that you would put a fence post. They will sprout and grow. If possible let them get established before putting the fence wire. If some die, replace them. If you live where the rain is uncertain, you might start the posts to sprout by putting them in a .5 m

deep hole, filling the hole with soil, and keeping the soil moist. This hole should be near a source of water.

Some possible disadvantages: This might not be good for the sun side of a garden where you want plenty of sunshine. The posts will tend to grow around your fence wire, and you can't re-use it. If you don't want them to grow into large trees you must cut them back regularly.

FORESTS DEPARTMENT - REGIONAL OPERATING STATIONS

CENTRAL PROVINCE

Port Moresby - Regional Forest Office,
Box 1754, Boroko
Phone 257138
Forest Station, Brown River, Phone VHF 240117

NORTHERN PROVINCE

Popondetta Department of Forests,
Phone 297016

MOROBE PROVINCE

Lae - Regional Forest Office, Box 638, Lae.
Phone 422022
Forest Station, Bulolo, Box 87.
Phone 445202
Wau, Box 42 Phone 446370.

WESTERN HIGHLANDS PROVINCE

Regional Forest Office, Box 267, MT. Hagen
Phone 521333
Forest Station, Kagamuga, Phone 551353

SOUTHERN HIGHLANDS PROVINCE

Box 29, Mendi. Phone 591172

MADANG PROVINCE

Box 2116, Yomba. Phone 822127
Box 43, Wewak. Phone 871004
Forest Station, Vanimo. Phone 871004

EASTERN HIGHLANDS PROVINCE

Forest Officer. Phone 721737
Forest Station, Lapeigu. Phone 721072
Box 338, Goroka.
Kainantu. Phone 771163

NEW GUINEA ISLANDS

Box 172, Kavieng. Phone 941548.
Rabaul - Regional Forest Office, Box 406,
Rabaul. Phone 922188
Forest Station, Kerevat. Phone 926215

THAT LAST IDEA WAS SIMPLE, WASN'T IT?
WE BET YOU HAVE AN IDEA THAT'S AS GOOD.

WE'RE SO CERTAIN THAT YOUR IDEA IS GOOD ENOUGH FOR THE NEXT EDITION OF THE LIKLIK BUK THAT WE'LL BET YOU A FREE COPY OF THE BUK THAT YOUR IDEA WILL GET IN.
SEE NOTES FOR CONTRIBUTORS - PAGE 268.

Beverages

COCOA KAKAO

Description:

Botanical name: Theobroma cacao
Height: 5-8 metres
Age to first production: 2-3 years
Normal life span: 25 years
Insect pests and control:

1. Cacao Weevil (Pantorhytes) - introduce "crazy ants".
2. Cacao Web Worm (Pansepta) - in young trees brush off the rubbish and paint the mouth of the channel underneath with o.3% dimethoate. In old trees, control is probably uneconomical. Ensure a good cocoa canopy and enough overhead shade.
3. Pod-suckers ("capsids") - spray twice, 2-3 weeks apart, with 150-200g of lindane active ingredient per hectare.
4. Termites ("White ants") - open the channels in the tree and pour in a small quantity of 0.2% chlordane. Prune so that there are no dead stubs.
5. Longicorns (bark borers) - avoid too much shade and keep grass cut. Treat channels with 0.5% active ingredient Lebaycid (ICI) or Vapona (Shell).
6. Caterpillars - usually controlled after a short time by their parasites and predators. 0.2% carbaryl is effective.

Diseases and control:

1. Black Pod - harvest ripe pods frequently. Hook off black pods at separate harvests. Fungicidal sprays are sometimes economic.
2. Dieback (vascular-streak dieback) - use resistant planting material. Check young plantings at least monthly and prune out any infections found. (Not found in New Ireland or Bougainville).
3. Canker - cut off the affected bark to allow the canker to dry out.
4. Root rot - remove all of the root system of an infected tree. Carefully cart away and destroy by burning.
5. Pink disease - prune off and burn infected branches.
6. White threadblight - prune off and burn infected branches.

Indication of maturity: Pod changes colour (green to yellow, red to orange).

Planting information: First establish overhead shade (Leucaena, coconuts, Gliricidia). Cocoa seed or cuttings may be planted straight into the field, seed on a 3 metre triangle and cuttings on a 3.5 metre square. However, seed is best planted into a nursery first. Use polythene bags 35cm x 18cm, plant one seed per bag, and plant out the best plants at age 4 months during favourable weather. Discard the slow-growing plants. Weed the young plants regularly by hand (not by knife or spade) to remove competitive grass and weeds.

Useful products at village level: Fresh beans are pleasant to suck. Industrial level: Fermented dried beans are processed into chocolate for eating or cocoa powder for drinking purposes.

Sources of supply of planting materials and cost: Pods and cuttings are available, free of charge at present, from the Lejo Station in the N.P. and Kerevat. Cuttings cannot be shipped to New Ireland or Bougainville.

Sources of supply of related tools or equipment and cost: Suppliers - Burns Philp & Co.; Steamships Trad. Co.; Elvee Trad. Co.; Theo Thomas & Co.

Materials and cost: Lindane 16% K10.20, 4 litres; dimethoate 30% K37.00, 4 litres; copper oxychloride 50% K94.00, 25kg; 2, 4, 5-T 80% (for shade thinning) K22.20, 4 litres; urea fertilizer K175.00 tonne; cocoa hooks K2.50 each; bush knives K1.70 each; planting bags K7.00 for 1000; spades K3.00 each; knapsack sprayers K94.00 each.

Further references: PNG Agricultural Journal Vol. 13 (1) 41-42, 13 (4) 127-147, 14 (1) 1-15, 15(3/4) 79-90, 16 (1) 1-19.
Harvest Vol 1 (4) 129-138.
Annual Reports of DPI (formerly DASF) up to 1969.

General: Cocoa, by G.A.R. Wood, published by the Longman Group, London; Cacao Manual, by T. Hardy, Inter-American Institute of Agricultural Sciences, Turvialba, Costa Rica; Tropical Crops, Dicotyledons 2, by J.W. Purseglove, pp 571-598 Longmans.

Location and result of PNG experience with this crop: Cocoa has been grown for about 75 years in the lowlands of PNG and 80,000 hectares are currently grown in 13 provinces. For the majority of growers the crop has been a profitable one, while others have experienced serious pest and disease problems. Control methods are now available for

these pests and diseases. Contact - J.B. O'Donohue, LAES, Kerevat.

Remarks: Careful management of the young cocoa is repaid by higher production and fewer problems in later years. The development and maintenance of a complete cocoa canopy should be a primary aim.

Initial contributor: J.B. O'Donohue, LAES. Kerevat, ENBP.

ROBUSTA COFFEE KOPI

Botanical name: Coffea canephora

Height: 8m or more or may adopt a bush habit. Constant pruning is necessary to restrict the height to about 2.5m for easy picking of the fruit.

Age to first production: 20-24 months after field planting of the seedlings. Bearing is usually seasonal.

Indication of maturity: Berry turns pink or red.

Potential yield: Dependent on the following factors: Density of planting, pruning system, level of shade, level of management, variety or clone planted. Up to 5000kg coffee cherry per ha. per year or up to 1000kg parchment per ha.

Life span: Dependent on pruning system and management factors. Useful life up to 25-30 years.

PESTS	CONTROL
Coffee Stem Borer (Zeuzera coffee)	Low incidence of damage usually makes control unnecessary
Longicorn Beetles (various species)	
Armyworm Caterpillars (Tiracola sp) (Ectropis sp)	High or low volume insecticide spraying or shade management.

DISEASES	CONTROL
Pink Disease (Corticium salmonicolor)	Pruning and burning of infected branches.
Root Rot (various fungi)	Tree isolated by trenching The tree and roots removed and burnt.
Brown Thread Blight (Pellicularia koleroga)	Correct shade management and removal of infected branches.
White Thread Blight (Corticium marasmius spp)	Correct shade management and removal of infected branches.
Chlorosis and dieback (Physiological disorder)	Caused by insufficient shade or lack of nutrients and moisture.

Planting information: Seeds are germinated in a small nursery bed and good seedlings selected for planting in polythene bags. Suitable shade, such as Leucaena trees, are established through the area to be planted. At about the 6 leaf-pair stage the seedlings are transplanted to the field. The spacing depends on the pruning system used, but will usually be a 2m triangle or a 1.5 x 2.5m hedge. Good management is necessary for the seedlings to come into bearing quickly. As the trees mature the level of shade can gradually be reduced.

Fertilizing Coffee: Chemical fertilizers may help your coffee to earn more. Some points to consider: The major nutrients are not all needed in the same amounts, and in order to get the best yields they should be available in the right quantity and balance at the right time; each farm, with its own particular soil and other conditions should have its own individual fertilizer programme.

In order to get the full benefit from chemical fertilizers, the trees should be protected from weeds, pests, and diseases, drainage should be adequate, and pruning done properly.

Village level harvesting and processing: When ripe the berries are picked (harvesting), berries are passed through a hand machine to remove the skin (pulping). The slimy seeds are placed in a wooden or concrete trough and just covered with water (fermentation). After several days the seeds are washed and placed in the sun (drying). The dry seeds (parchment coffee) are bagged and sold to buyers. (p 174) (p 262)

Industrial usage: Coffee berries are converted to parchment coffee using machine-operated pulpers and hot air driers in conjunction with sun drying. The coffee parchment is hulled to remove the parchment skin. The green coffee bean remaining is bagged for export. Green coffee may be roasted, ground, and used for making coffee beverage, or may be converted to instant coffee powder.

Planting material: Clonal seed of robusta coffee is available, on request, from LAES, Kerevat.

Related materials or equipment: Polythene planting bags: ICI(NG) Pty. Ltd., Box 1105, Lae or their agents throughout PNG. Pulping machinery, etc: Plantation Supply and Services Co. Pty. Ltd., Box 92, Goroka., Tru-Cast Foundry Pty. Ltd., Box 160, Lae. Major trading companies in coffee areas. (p 262)

References: Articles applicable to Robusta coffee are to be found in the following numbers of the PNG Agricultural Journal: Vol 12 No 1, 9-12 (1959); Vol 19 No 3, 115-124 (1967); Vol 15, No 1&2, 1-6 (1962). Modern Coffee Production, by A.E. Haarer, Leonard Hill Books Ltd, London, 1962. An information letter "Coffee - and its Nutritional Requirements in the Highlands of New Guinea", is available from Plantation Supply and Service Co. Pty. Ltd., Box 92, Goroka, EHP.

PNG experience: H. Gallasch, LAES, Kerevat; Chief Pathologist, DPI, Konedobu, Chief Agronomist, DPI, Konedobu.

Coffee seeds live for only a few weeks and should be planted as soon as they are received. Coffee is a fairly hardy crop and can survive under poor management although it only yields well given good management and conditions. Robusta coffee will grow in almost all lowland regions of PNG, that is, below 800m above sea level. At higher altitudes (up to 1800m) Arabica coffee is grown.

Information on Arabica coffee is available from The Agronomist-in-charge, HAES, Aiyura, EHP, or Chief Agronomist, DPI, Konedobu.

Remarks: Shortage of certain elements in the soil may reduce yield even if management is good. It is possible to learn which elements are needed by testing leaf samples. Information on selecting samples and getting them analysed by the Chief Chemist, DPI, Box 2417, Konedobu.

Initial contributor: H.E. Gallasch,
LAES, Kerevat, ENBP.

TEA TI

Description: A small tree growing to 6-7 metres unless pruned regularly.
Botanical name: Camellia sinensis L.
Height: 1½ - 2 metres
Age to first production: 2½-3 years, depending on management.
Normal life span: 40-50 years
No pests and diseases of importance.

Planting information: Tea is grown from selected cuttings at 60cm x 60cm in fertile loam soils with a high organic matter and tending toward acid (pH 4.0 - 6.5). Soil must be well drained. Nitrogen and Sulphur (ammonium sulfate fertilizer) are important. Tea grows well from the coast to over 2700 metres. At higher altitudes production is low and growth slow, while on the coast quality of tea is reduced. Yield 1-6 tonnes/ha/year.

MARKETS FOR COMMERCIAL PLOTS OF TEA: These exist only in WHP. Small holders on Wurup, Nogoba, Avi, Kindeng, Kondepina and some small tenure conversion schemes near Banz sell green leaf to DPI officers on the roadside for spot cash. DPI transports green leaf to tea factories (W.R. Carpenters Estates, ANG Developments, Pioneer Concrete Industries and Mt. Hagen Teagrowers). These large Tea Plantations were established on drained peat swamps in the Wahgi Valley. The smallholder Tea was developed on similar drained swamp country close to these "Nucleus" Estates. Tea smallholders also raise vegetables and livestock. Limited development of Tea growing could be expected in the SHP in the future. For the small holder Tea requires regular attention as good tea can only be made from fresh tips, that is, two leaves and a bud. One person working steadily for 8 hours should pick 45kg of leaf which can be sold for approximately 7t/kg.

Useful products at village level: Cash crops, home-made tea.

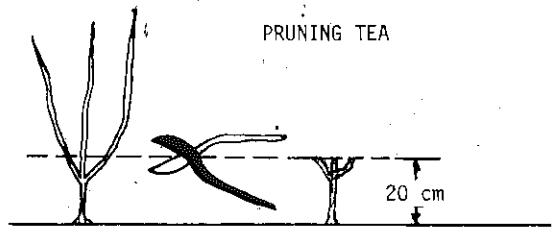

FIRST YEAR

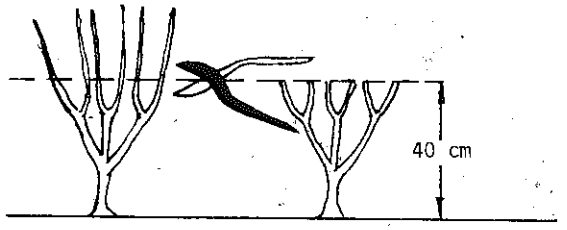

SECOND YEAR

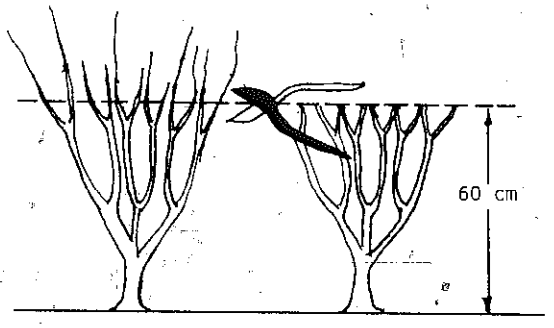

THIRD YEAR

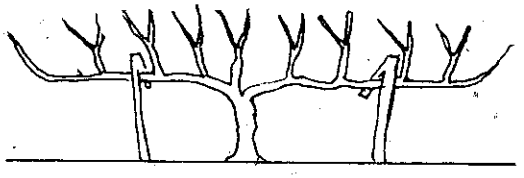

ANOTHER WAY: Hold the main branches down with pegs. They should be level on both sides, or else the new shoots will not grow nicely. Prune year by year as shown above.

Further references: "Tea" Eden, 2nd edition Tropical Agriculture Series, Longmans. "Tea Manufacture" Harler, Oxford Tropical Handbooks. Kuk Tea Research Centre, J.G. Morgan, Harvest Vol 2, No 4, 1972.

Contributed by: D.W. Kidd, Box 312, Mt. Hagen WHP.

Spices

BIRDSEYE CHILLIES (No article) (p 244)

CARDAMOM

Description: A tall herbaceous perennial, with branched underground rhizomes, from which arise several erect leafy shoots and erect panicles.

Botanical name: Elettaria cardamomum
Height: 2 - 5 metres tall.
Age to first production: Three years after field planting.
Normal life span: 1 - 15 years

Insect pests and control: Myrids (a pod sucker), controlled by spraying or dusting the young foliage of individual plants with lindane. Rats. control can be done with rat poisons or traps. Wasps lay eggs in pods, letting weevils in.

Diseases and control: Soil-borne fungal rot diseases observed in nurseries. It can be controlled by drenching or dusting.

Indications of maturity: When they are just changing from yellow to green.

Planting information: Cardamoms are propagated either vegetatively by division of rhizomes or by seed. Land is lined using 1.5m to 3m triangle spacing and holes 60 x 60cm and 45cm deep are dug.

Useful products at village level: Dried cardamom fruits are marketed, or used with betel nut.

Industrial uses: They are used for flavouring curries, cakes, bread and other kinds of food and drink.

Sources of supply of planting materials and cost: LAES, Kerevat, ENBP. Free, freight charge only.

Further references: Tropical Crops: Monocotyledons, Purseglove K8.50: Cardamom Handbook, Rural Dev. Handbook No 3, A.W. Grant, free, DPI, Box 2417, Konedobu.

PNG experience: LAES, Kerevat.

Initial contributor: F. Aia, LAES, Kerevat, ENBP.

GINGER KAWAWAR

Description: Slender long-lived herb, with branched rhizomes born horizontally near surface of soil, bearing leafy shoots close together.

Botanical name: Zingiber officinale
Height: 30 - 100cm
Age to first production: 8 - 9 months
Normal life span: 8 - 9 months

Insect pests and control: Larvae of a dipterous insect (unidentified) bore through the leafy shoots. Natural enemies often give some degree of control.

Diseases and control: Some diseases are leaf spot and dieback. The most common rhizome diseases are soft rots caused by Pythium spp. Planting material should be carefully selected and drenched in fungicide such as ceresan and hot water treatment before planting.

Indication of maturity: The shoots have turned brown and begin to fall over, usually in the driest part of the year.

Planting information: Carefully select planting material. Cut rhizomes into small pieces each weighing 30-40 gram pieces, plant in a small hole 5-10cm deep and cover with loose soil. Spacing within ridges is 15-30 x 30-45cm. Spread sawdust evenly on the surface of the ridges to the depth of 5-10cm.

Useful products at village level: (p 92) As a vegetable with meals. Wash and sell in market.

Industrial uses: The dried rhizomes, which may be scraped or peeled before drying, are the spice. In western countries it is used for cooking in ginger bread, biscuits, cakes, puddings, soups and pickles. It is often used in curry powder, and is very important in Chinese cooking. It is used in making ginger beer, ginger cola and ginger wine.

Sources of supply of planting materials and cost: LAES, Kerevat, free. Freight charge only.

Further references: Tropical Crops: Monocotyledons Purseglove: K8.50.

PNG experience with this crop: Yield trials, (p 244) LAES, Kerevat, ENBP.

Initial contributor: F. Aia, LAES, Kerevat, ENBP.

NUTMEG

Description: A spreading evergreen tree with male and female flowers on separate trees. 5-13 metres high, sometimes attaining 20m. Root system superficial. The fruits yield two spices: Mace and Nutmeg.

Botanical name: Myristica fragrans
Height: Up to 20 metres high
Age to first production: 5 - 8 years
Normal life span: 30 -40 years

Diseases and control: Observation at Kerevat show that nutmeg trees are relatively free from major pests and diseases.

Indications of maturity: When the outside skin splits open to expose the seed.

Planting information: Plants are normally raised from seeds. Seeds should be put into soil immediately after harvest as they die very quickly. Plant out under established shade after they are 15-30cm tall; planted at distance of 8m x 4m or 9m x 4.5m.

Useful products at village level: Nutmeg (the nut) and Mace (the red skin) are both dried and marketed. Fresh mace in soups is a good spice. (p 94)

Industrial uses: Nutmeg fruits are used for flavouring milk dishes, cakes, drinks and other foods, while mace is preferred in meat dishes, pickles and sauces.

Sources of supply of planting materials and cost: LAES, Kerevat, free. Freight charge only.

Further references: Tropical Crops: Dicotyledons 2, Purseglove, K5.94.

PNG experience: LAES, Kerevat, ENBP.

Initial contributor: F. Aia, LAES, Kerevat, ENBP.

Ripe Nutmeg fruit.

PEPPER

Description: A long-lived, smooth-stemmed woody climber to 10 m in height, but under cultivation the mature vine has a bushy appearance 2-4m high and 1.5m in diameter.

Botanical name: Piper nigrum
Height: 10 metres
Age to first production: 18 months after planting
Normal life span: Temporary gardens, 3-4 years; semi-permanent 10-12 years; permanent 30-50 years.

Insect pests and control: A small pepper bug eats the underside of leaves causing small yellow/brown spots. Control with 0.1% Lindane spray.

Diseases and control: Black leaf disease: chemical control involves regular spraying with 0.5% copper oxychloride or Captan; Pink Disease: chemical control involves spraying with o.5% copper oxychloride and prune 15cm below the point of infection and destroy prunings; Thread Blight: this can be controlled with 0.5% copper oxychloride sprayed at regular intervals until there is no sign of the disease spreading.

Indication of maturity: White pepper: To make white pepper harvest spikes with 50-90% of berries red in colour; Black Pepper: To make black pepper harvest when one or two red berries are noticed on the spike. (photo p 57)

Planting information: Primary vines raised in nursery. These are then planted out on the field after 6 months under shade supports at the spacing of 3m x 3m.

Useful products at village level: (p 95) Pepper marketed in two forms: Black and White.

Industrial uses: Pepper fruit is dried and used as a spice to flavour meat dishes and in making pickles, sauces, ketchups, sausages and other meat products.

Sources of supply of planting materials and cost: LAES, Kerevat, free. Freight charge only.

Further references: Tropical Crops: Dicotyledons 2 by Purseglove; Aburu, Kana, Pepa, Free from LAES, Kerevat, ENBP (in Pidgin). (p 244)

cont'd

PNG experience with this crop: LAES, Kerevat.

Remarks: White pepper is not as pungent as black pepper.

Initial contributor: F. Aia, LAES, Kerevat, ENBP.

ROSELLA

Description: A short lived perennial shrub cultivated as an ornament and for its red flowers and leaves.
Botanical name: Hibiscus sabdariffa
Height: 1-2 metres
Age to first production: 4 months or more. Begins flowering in February.
Normal life span: 18 months to 2 years
Insect pests: Leaf chewing insects.
Diseases: Nematodes attack roots.

Indication of maturity: The flowers close and become deep red. Harvest before flowers become woody. Snap stem at base of flower.

Planting information: Plant seeds 60cm apart in 90cm wide rows. If planted for a single hedge, closer planting is alright.

Useful products at village level: Leaves may be eaten as a kumu. The flower can be used to make lolly water, jelly or jam: (p 113) (p 114)

Industrial products: Calyces (the fleshy red part) are high in pectin, which is used in making jams, jellies and custards. Potential exists for an industry when demand for commercial pectin exists in the tropics, and when apples cannot be grown. Bast fibres of stem can be used for making paper, but only 30% recovery is possible.

Sources of planting material: Yates seeds at seed stores, and locally in many places.

Further references: Knott J.E. and J.R. Deanon (1967) Vegetable Production in South East Asia p. 268-9.

Remarks: The flower is a very attractive decorative plant, and is a useful replacement for lolly water and jams in village and in town.

TUMERIC

Description: A perennial herb to 1 metre tall with a sheet stem and tufted leaves.

Botanical name: Curcuma longa
Height: 1-2 metres
Age to first production: 10 - 11 months before harvesting.
Normal life span: 10 - 11 months

Insect pests and control: The larvae of lepidoptera (unidentified) bore the shoots but damage is little. Grasshoppers feed on the leaves.

Diseases and control: Large water-soaked spots of the leaves caused by the fungus Phyllosticeta spp. Spray the plants with 0.5% copper oxychloride when early symptoms are seen.

Indication of maturity: Lower leaves turn yellow; or shoots dry and fall over.

Planting information: The land should be thoroughly prepared. Best planted in September/October (Kerevat). Is often planted on ridges, usually about 30-45cm apart and with 15-30cm between plants. Recommended spacing is 30 x 15cm. The crop is propagated by setts (finger or rhizomes) with one or two buds, planted 5-7cm deep. Approximately 1,700kg of setts are required to one hectare.

Useful products at village level: (p 99) May be used as a spice in food. Note: after harvest the primary rhizomes are separated from the side rhizomes, washed and dried. They may be boiled in water and dried in the sun for 7-8 days.

Industrial use: Used mainly to make curry powder. The yellow colour of tumeric is what gives curry its colour.

Sources of supply of planting materials and cost: LAES, Kerevat, free. Freight charge only.

Further references: Tropical Crops: Monocotyledons, Purseglove, K8.50.

Yield trials have been conducted at LAES. For information contact Agronomist-in-charge, LAES, Kerevat, ENBP.

Notes: Indian tumeric has the following approximate composition: Water 13.1%; protein 6.3%; fat 5.1%; carbohydrates 69.4%; ash 3.5%; fibre 2.6%. On distillation it yields 1.3 to 5.5% volatile, aromatic orange red and slightly fluorescent oil.

Initial contributor: F. Aia, LAES, Kerevat, ENBP.

VANILLA

Description: A long-lived fleshy herbaceous vine climbing by means of aerial roots up trees or other supports to a height of 1 - 15m. In cultivation it is trained to a height which will allow easy hand pollination and harvesting.

Botanical name: Vanilla fragrans or Vanilla planifolia
Height: 10 - 15 metres
Age to first production: 3 years
Normal life span: 15 - 20 years

Insect pests and control: The larvae of two insects of the order lepidoptera damage the flowers and young capsules by feeding on them. They are kept in check by predators and parasites.

cont'd

Diseases and control: Collar rot: to reduce chance of this infection loop the vines a few centimetres above the ground.

Indications of maturity: When the dark green colour of the pod begins to yellow or is yellow in colour.

Planting information: Commercial vanilla is always propagated by stem cuttings. These should be taken from healthy vigorous plants, and may be cut from any part of the vine. The length of cutting is usually determined by the amount of planting material available. Cuttings 90-100cm in length are usually preferable. With short cuttings at least 2 nodes should be left above ground. The portion above ground should be tied to the support until the aerial roots have obtained a firm grasp. Spacing used: 2.75m between rows and 1.37m. within rows.

Useful products at village level: The beans or capsules are dried and cured. After curing they are packed and marketed. (P 100)

Industrial uses: Vanilla is used in the manufacture of ice cream, chocolate, sweets, perfumes.

Source of supply of planting materials and cost: LAES, Kerevat, free. Freight charge only.

Further references: Tropical Crops: Monocotyledons by Purseglove, K8.50.

Location and result of PNG experience with this crop: Vanilla trials, LAES, Kerevat; Suma Pltn., Box 6, Kavieng, NIP; Dalum Plantation, Poliamba Estates, Box 6, Kavieng, NIP.

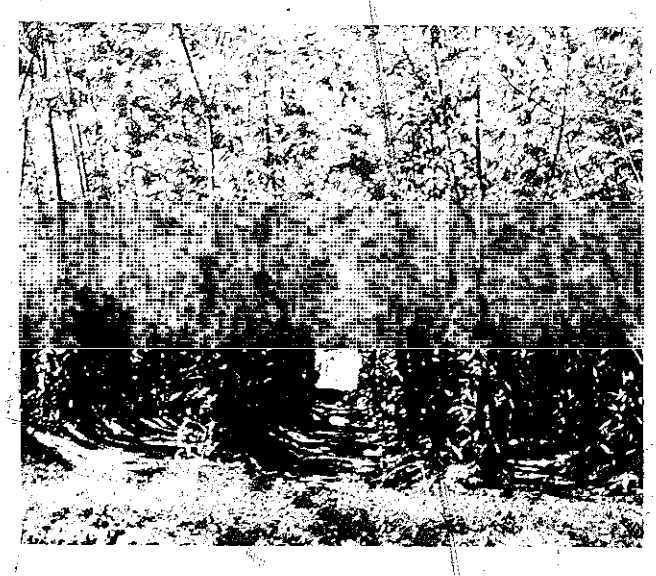

Vanilla trained on Leucaena glauca at LAES, Kerevat. Pepper may be trained on Leucaena glauca in the same manner.

Initial contributor: F. Aia, LAES, Kerevat, ENBP.

Soil Management

FOOD CROP FARMING SYSTEMS

The farming system that a farmer uses is made up of the different crops he grows, how the crops are grown together or follow each other, the type and length of fallow and the use of animals and tools and irrigation. It is everything the farmer does in his farming work. A good example of a PNG farming system is the long forest fallow or shifting cultivation system. This is based on a short garden period followed by a long forest fallow.

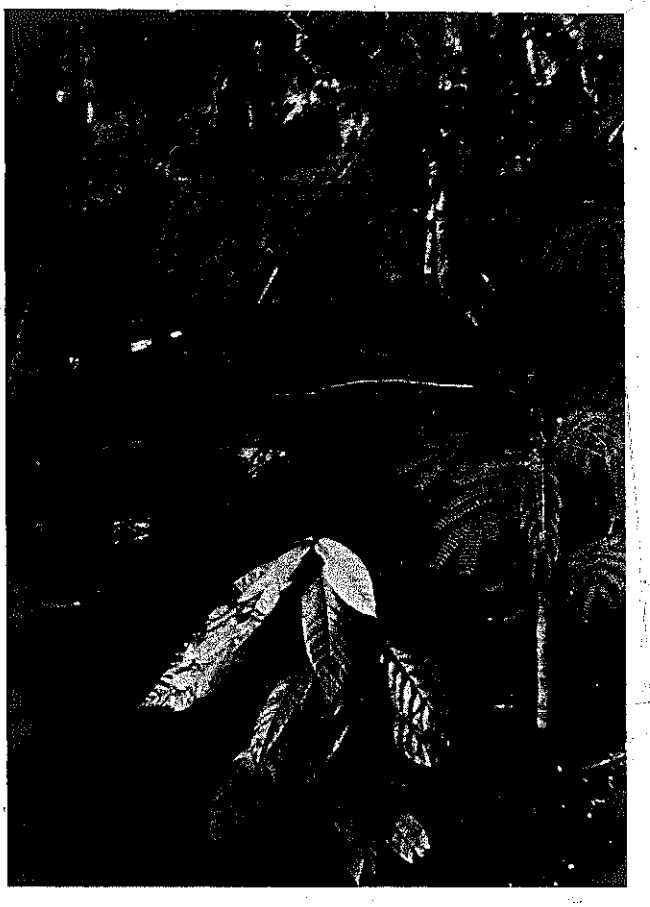

New systems are evolving. A Tolai farmer plants cocoa and Leucaena under diploid bananas and Chinese Taro.

There are very many farming systems in PNG and generally they are used because they are the most suitable for the environment. However, in some places changing conditions require new systems, for example, where land is short or where mechanization becomes possible. The new systems are being found both by the farmers themselves and with the assistance of agriculturalists. But it is important to keep in mind that traditional practices, such as mixed cropping of different species and varieties, are often more productive than introduced ones.

cont'd

Some ideas on farming systems for institutions in the lowlands and systems for farmers short of land are given below.

FARMING SYSTEMS FOR INSTITUTIONS

Given the present prices for foods, institutions should seek self-sufficiency first in fruits and vegetables (protective foods), and coconuts (high energy food). If land and time permit, grow staples, and finally protein crops.

There are a large number of suitable vegetable crops, but the emphasis should be on traditional ones like aibika, tulip, pumpkin tips or karakap rather than temperate climate crops like tomato, cabbage and cucumbers, which are less productive and often of lower food value.

Institutions should place greater emphasis on fruit and nut crops, especially trees, both traditional species (like galip, talis, aila and taun) and introduced species (such as guava, avocado, citrus and pineapples).

Sweet potato is the main staple food grown by institutions, but cassava and banana give more food for the work and could be used more. Other energy crops that could be used are swamp taro in swampy areas and sugar cane for garden snacks.

Peanuts, cowpea and soybean are probably the most suitable protein species, but mung bean should be considered as well.

Land should be allotted for the following uses:

1. Main gardens devoted to staples, vegetables, grain legumes and fallows.

2. Blocks of perennial crops such as coconuts, bananas, fruit and nut trees.

3. Additional vegetable gardens.

4. Near buildings plant fruit trees and other perennials.

5. Wet areas for water tolerant crops such as kangkong and swamp taro.

6. Trail climbing species on fences.

For the main gardens choose a series of crop and fallow rotations. It is suggested that a relatively intensive system using fertilizers and a planted pigeon pea fallow is suitable for institutions prepared to use inorganic fertilizers. For those that do not wish to use chemical fertilizers, a combination of a short pigeon pea fallow and a long forest fallow is suggested.

FARMING SYSTEMS FOR FARMERS IN THE LOWLANDS WHO ARE SHORT OF LAND.

The traditional long forest fallow farming system is a very efficient system, but alternatives are needed where population pressure is high. There is no "magic" alternative, however, such as using a legume fallow instead of a forest fallow. All of the modifications or alternatives to the long forest fallow are already used by some people in PNG. Some of the possible modifications and alternatives are:

1. Shorter fallow period. Yield per crop and the food return for labour input is decreased, but total food production over a long term period is increased.

2. Use of higher yielding varieties of existing crops.

3. Change of staples from lower yielding traditional crops to higher yielding ones, eg. from taro and diploid bananas to sweet potato and triploid bananas.

4. Greater use of long lived crops such as triploid bananas.

5. Interculture of feed crops with plantation crops. Coconuts offer the greatest possibility, but other plantation crops such as cocoa, rubber and coffee can share space with food crops when they are young.

As well, there are non-agricultural alternatives such as migration and cash employment.

Further reading: Fuller discussions on these subjects are contained in the following two papers which may be obtained from the author:

Bourke, R.M. (1976). Food Crop Farming Systems for Institutions in the Lowlands. Paper presented to Tenth Waigani Seminar, Lae, May 1976.

Bourke, R.M. (1976). Some Alternatives to the Long Fallow System in the Lowlands. Unpub. paper.

Initial contributor: R.M. Bourke, LAES, Kerevat, ENBP.

SOIL EROSION CONTROL

CONTOUR MOUNDING - An effective Erosion Control in the Enga Province.

Erosion of rocks and soils by water is a normal happening. It is responsible for the leveling of our mountains, the breakdown of rocks, the development of valleys.

But uncontrolled water can take away our precious topsoil, carry away the food of our plants, and even cause big parts of a hill to break away.

In some countries of the world water has been so controlled and soils so managed, that even with over 300 years of continuous farming, they are reported to be better than ever.

We should all recognize the seriousness of the problem of soil erosion in PNG and take positive steps to control it. Unfortunately, many communities fail to realize this problem until it is too late.

The contour mound outlined here is a scheme developed over a period of four years through St. Paul's Lutheran High School at Pausa, Wapenamanda, E.P. Students from a wide area of Enga provided the village contacts for actual tests of the scheme.

cont'd

On a slope of 20% or less, a continuous mound 2.1m in width with a minimum height of 40cm will effectively control soil erosion.

For a 20-40% slope the width of the mound must be increased to 2.5m with the depth of the mound increased proportionately.

Slopes over 40% have not been tried.

CONSTRUCTING A CONTOUR MOUND - END VIEW

Start at the top and work down.
Use green, not dry, compost.
This tends to suit deep rooting crops best.

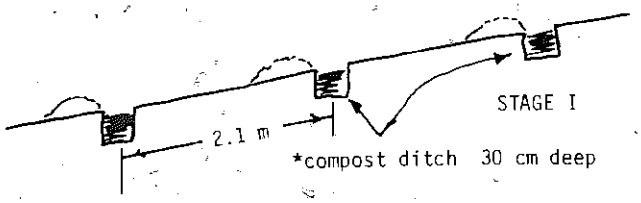

permanent ditches

*compost means green fresh kaukau vines, grass, etc.

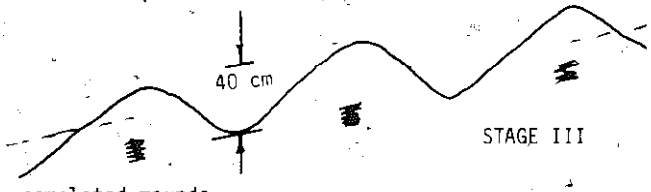

completed mounds

Contributed by M.L. Herman, St. Paul's High School, Pausa, Wapenamanda, EP.

Soils of the Humid Tropics, Committee on Tropical Soils, Agricultural Board, NRC, National Academy of Sciences, Washington, D.C. 1972, 217 pp.

Technical papers on all aspects of tropical soils. Specifically written to emphasize the difference between tropical and temperate soils, so that tec technology transfers can be made more appropriate. A particular effort is made to distinguish between the specific problems of tropical soils and commonly held generalizations. An important book for teachers of agriculture sciences.

Advanced.

SOIL AND FERTILIZERS

(p 244)

All plants take from the soil water and some essential foods (nutrients).

The important foods are minerals. They can be divided into two classes.

Plants need a large amount of the first class, which are known as Major nutrients. These are:-

NAME		SYMBOLS
Nitrogen		N
Phosphate	(Phosphorus)	P, P_2O_5
Potash	(Potassium)	K, K_2O
Lime	(Calcium)	Ca, CaO
Magnesia	(Magnesium)	Mg, MgO
Sulphur		S

Very small amounts of the second class are required. These are known as Minor nutrients or micronutrients. There is a very large number of these; the most important are:-

Zinc	Zn
Copper	Cu
Boron	B
Manganese	Mn
Iron	Fe

Each species of plant requires different amounts of each nutrient. The amount of one nutrient required, compared with the amounts of other nutrients, must be such that it suits the particular crop being grown.

If a plant has too much of one or more nutrients, or not enough of one or more nutrients, the plant will not grow properly. The crop will be small. When there is not enough of one or more nutrients, we say there is a deficiency.

Too much or not enough of one or more nutrients may make the plants look sick. The leaves may change colour or lose their colour and scorch. Leaves may be very small, twisted, or fall off. Sometimes the inside of the plants rots. Some of these symptoms can be confused with the effects of diseases and insect pests. If you see such signs, consult a Didiman.

Chemical analysis of the soil, or of leaves from plants, can often tell us whether there is too much or too little of various nutrients. DPI may be able to do this analysis. The University of Technology at Lae will do it, but they charge prices which may be beyond a small farmer. If you believe that it would be helpful to have analysis done, consult DPI, or Mr. A. Gerard, Analysis Laboratory, at the University of Technology, Lae, or Dr. K.C. Willson of the Agriculture Faculty of the University of Papua New Guinea at Lae.

The more fertile soils will have plenty of nutrients available and bad effects from deficiencies may occur. Organic material in soil usually has large

amounts of nutrients available. Natural topsoil is usually more fertile than subsoil. It is therefore important to retain topsoil and to add organic material such as mulch, compost, animal manure and so on to soil to maintain fertility and avoid problems from deficiencies.

Very often the soil cannot provide enough nutrients and there is not enough organic material available to provide the nutrients required. When this happens nutrients must be provided by buying and applying fertilisers, which are chemicals containing the nutrients.

Those who sell fertilisers must be able to tell you the amount of each nutrient in the fertiliser. For example:-

Single superphosphate contains 20% P_2O_5 and 11.9%S

Triple superphosphate contains 43% P_2O_5 but no S

Buy the right fertiliser to give the nutrients you need. Calculate the amount of fertiliser to give the amount of nutrient. For example, you will need over twice as much single superphosphate as you will need triple superphosphate to give the same amount of the phosphate nutrient, P_2O_5. However, if you buy single superphosphate you also get sulphur. This nutrient is often required in PNG.

Some fertilisers contain only one nutrient. Others contain two or more. The latter is convenient when more than one nutrient is required. Sometimes you can buy individual fertilisers to provide the nutrients you need, and mix them together on the farm so that you have only the one mixture to apply. Before doing this, make sure that the fertilisers can be mixed safely and without harming each other. DPI or the main suppliers will be able to advise you.

Recommendations for the fertiliser applications to particular crops are given in the sections on each crop. Start by using the recommended applications. However, soils vary, and you may find by experience that the application rates need altering to suit local conditions. If you think that some alteration of application rates is needed, consult DPI. Analysis of soil or leaf samples may be helpful.

Soil fertility can be improved and thus the amounts of nutrients available in the soil can be increased, by growing a different crop. This crop may only be natural regrowth after a garden is abandoned. This traditional method of shifting cultivation is quite effective, provided the area is left undisturbed for a sufficiently long period of time. Six to ten years is desirable. If gardens are reused after a shorter period, the soil fertility will not be fully restored, and the crop yields will be low unless fertiliser is used.

The period for restoration of soil fertility can be reduced if a special crop is planted. Legumes, for example Pueraria phaseolides or one of the beans, are very good for this purpose as they take nitrogen from the air and put it into the soil. Tall but shallow-rooted grasses, for example Guatemala Grass, can be used but for the best results the grass must be fertilised. Another alternative is to plant a pasture and graze animals for two or three years. At the end of the period of the special crop, all the plants must be ploughed into the soil. An important example of this is sugarcane; when this is grown on a plantation scale, two crops of cane must be followed by growing a legume for six to nine months. Similarl-, if pyrethrum is grown by itself, it must be followed by another crop after two to three years; pasture for cattle makes a very good system.

Books for further reading: Tropical Agriculture, pub by Angus and Robertson, written by A. Jacob & H.von Vexkull, Chapters 3, 4 & 5, a good elementary discussion with simple diagrams.

Fertiliser use. Nutrition and Manuring of Tropical Crops. Verlagsgesellschaft fur Ackerhau, Hamburg.

Initial contributor: Dr. K.C. Willson, PNG University of Technology, Box 793, Lae.

SOIL AND LEAF ANALYSIS

The Chemical Analysis Laboratory at the PNG University of Technology, (Box 793, Lae) can provide the following analyses:

Classical analysis of ores and metallurgical products.
Soil and leaf analysis.
Bacteriological examination of waters.

However the service is not free and commercial rates are charged. For example, analysis of one soil sample for major elements costs K26.00. Write to them for charges before you send a smaple.

Initial contributor: R.M. Bourke, LAES, Kerevat, ENBP.

HOW TO MAKE COMPOST page 158

THE IDEA OF "USING" THE LAND IN THE WESTERN SENSE, THE THOUGHT OF WEARING IT OUT, NEVER OCCURRED TO THE TRADITIONAL MELANESIAN COMMUNITY, WHICH WAS "ALIVE IN THE LAND."

COMPOSITION OF FERTILISER MATERIALS (1)

MATERIAL	NITROGEN %	PHOSPHORUS AS AVAILABLE P_2O_5 %	POTASSIUM AS SOLUBLE K_2O %	CALCIUM %	MAGNESIUM %	SULFUR %	CHLORINE %	COPPER %	MANGANESE %	ZINC %	BORON %	APPROX. CALCIUM CARBONATE EQUIVALENT (2) LBS/TON
Ammonia anhydrous	82											-2,960
Ammonia, aqua	16-25											-720 to -1,080
Ammonium nitrate	33.5									.01		-1,200
Ammonium nitrate-limestone mixtures	20.5			7.3	4.4	.4	.4					0
Ammonium phosphate (mono)	11	48	.2	1.1	.3	2.2	.1	.02	.03	.03	.02	-1,300
Ammonium phosphate (am. phosphate-sulfate)	13-16	20-39	.2	.3	.1	15.4	.1	.02	.2	.02	.03	-1,520 to -2,260
Ammonium phosphate	(di) 16-21	48-53										-2,240
Ammonium sulfate	20.5-21.0			.3		23.7	.5	.03		.01		-2,200
Ammonium sulfate-nitrate	26.0					15.1						-1,700
Ammoniated superphosphate	3-6	18-20		17.2		12					.02	- 140
Basic slag, Open-hearth	(3)	8-12		29	3.4	.3			2.2			+1,000
Bone meal	2-4.5	(4) 22-28	.2	22-25	.4	.1	.2			.02		+500
Borax											11.6	+1,260
Calcium cyanamide	21			38.5	.06	.3	.2	.02	.04			+1,245
Calcium nitrate	15			19.4	1.5	.02	.2					+320
Castor pomace	5.2	1.8	1.1	.4	.3	.04	.3		.04	.05	.01	-100
Copper oxide								75				-
Copper sulfate						12.8		24.9		.55		
Fish scrap	6-10	7	.8	6.0	.2	.2	.4					-100
Gypsum (land plaster)			.5	22.5	.4	16.8	.3					
Magnesium oxide				1.1	56.1	.2	.5					+4,600
Manganese sulfate				6.6	1.9	14.5		.05	25.1	.08	.3	

MATERIAL	NITROGEN %	PHOSPHORUS AS AVAILABLE P_2O_5 %	POTASSIUM AS SOLUBLE K_2O %	CALCIUM %	MAGNESIUM %	SULFUR %	CHLORINE %	COPPER %	MANGANESE %	ZINC %	BORON %	APPROX. CALCIUM CARBONATE EQUIVALENT LBS/TON
Nitric phosphates	14-22	10-22	.1-16	8-10	.1	.2-3.6	0.1-12.0	.02	.2	.02	.03	-300 to -580
Nitrogen solutions	21-49											
Phosphoric acid (liquid)		52-54										-1,000 to -1,400
Potassium chloride (muriate of potash)			60-62		.1	.1	47.0				.03	0
Potassium-magnesium sulfate			22		11.2	22.7	1.5					0
Potassium nitrate	14		44-46	.4	.2	.3	1.1				.09	+520
Potassium sulfate			50-53	.5	.7	17.6	2.1					0
Rock phosphate		(5)		33.2	.2	.3	.1		.03			+200
Sewage sludge, Activated	5-6	2.9	.6	1.3	.7	.5	.6	.07	.07	.1		
Sewage sludge, Digested	2	1.4	.8	2.1	.5	.1	.2	.3	.3	.4		
Sodium nitrate	16		.2	.1	.05	.07	.4	.07			.01	+585
Superphosphate, Normal		18-20	.2	20.4	.2	11.9	.3			.01		0
Superphosphate, Concentrated		42-50	.4	13.6	.3	1.4		.01	.01		.01	0
Tankage, Animal	6-9	6-15	.4	8-11	.2	.5	.8			.02		+240
Tankage, Process	7-9	1	.1	.8	.01	.9	.8				.03	-320
Urea	42-46			0-1.5	.7	.02	.2			.02		-1,500
~~Urea-formaldehyde~~	~~36-40~~											
Zinc oxide										77.2		
Zinc sulfate					.06	13.6		.02		27.8		

1.) Most of the percentages larger than one of N, P_2O_5 and K_2O are the usual guarantees. Where more than one grade is commonly sold, the range is indicated by two numbers separated by a dash. The rest of the percentages are averages compiled by A.L. Mehring, USDA chemist, from many published analyses.
2.) Ind. Eng. Chem., Anal Ed. 5, 229-34 and other sources. A minus sign indicates the number of pounds of calcium carbonate needed to neutralize acid formed when one ton of the material is applied to the soil. A plus sign indicates basic materials, and a zero physiologically neutral materials.
3.) By the 2-% citric acid method.
4.) Total P_2O_5. All of the phosphorus in natural organics is considered available.
5.) 30 - 36% total P_2O_5, which is relatively unavailable in many soils.

FROM: "OUR LAND AND ITS CARE", NATIONAL PLANT FOOD INSTITUTE, U.S.A.

Soil Tillage

SMALL MACHINES

ROTARY HOES

Many people in PNG today are using a small machine to help them in their gardens to grow more food. One kind of machine is the rotary hoe.

The rotary hoe is usually made so that the man walks behind it and steers it. The engine turns many hoes and also makes the machine go forward. The driver only has to steer it.

In PNG you can buy three kinds of small rotary hoes: The first kind is the Troy-bilt, available from Kamscoin, Kavieng, New Ireland. The price is about K800. Another kind is the Howard 350 rotary hoe. It costs about K1,000. Both machines use the same brand of engine and do the same kind of work. These have big wheels with tires like tractors and the wheels pull the machine. Behind the machine are the turning hoes which dig the ground. The hoes can be set to dig deep or shallow, for ploughing or for weeding. With attachments you can make ridges for planting other kinds of crops. These machines are strong enough to dig new ground.

The third kind of machine is the Masport Rota-hoe. This machine is the cheapest, and it costs only K425 from South Pacific Machinery in Boroko. It can also use many attachments for special work in the garden. It is different from the other two rotary hoes because the hoes are in the front of the machine and the wheels are not powered. The turning hoes dig the ground and pull the machine at the same time. This machine is not strong enough to dig new ground. It is very good for weeding and digging old ground.

These machines are very useful for a man who wants to make business growing food to sell, but who does not have enough money to buy a big tractor. These can easily be put into a utility and driven to another place to do work, and they can also be put on canoes.

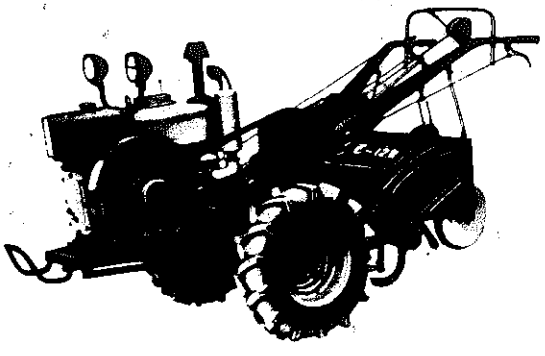

Dongfeng 12 h.p. two-wheel tractor

See page 263

CeCoCo Agricultural Equipment

See page 263

A rotary hoe - "masin baira"

AGRICULTURAL POISONS:

THE INCREASING SOPHISTICATION OF BOTH RURAL AND URBAN PEOPLE IN PNG HAS LED TO AN INCREASED USE OF HOUSEHOLD AND GARDEN INSECTICIDES AS WELL AS POISONS FOR OTHER PEST CONTROL.

MANY OF THE PRODUCTS THAT ARE SOLD WITHOUT RESTRICTIONS ARE EXCEEDINGLY DANGEROUS, INCORPORATING CHEMICALS SUCH AS CHLORDANE, PARATHION, DIELDRIN, AND AZODRIN. ASIDE FROM THE CARE TAKEN BY THE SELLER IN INSTRUCTING THE BUYER IN THE PROPER USE OF CHEMICALS, THERE IS NO REAL CONTROL OF THE SALE OF THESE CHEMICALS.

WE ARE LUCKY THAT THERE ARE VERY FEW RECORDED DEATHS FROM THE MISUSE OF AGRICULTURAL CHEMICALS IN PNG, BUT THE GREATER USE BY MORE PEOPLE TODAY REQUIRES GREATER CARE IN THE DISTRIBUTION OF THESE CHEMICALS.

MOST COUNTRIES HAVE CONTROLS ON THE SALE AND USE OF DANGEROUS CHEMICALS, BUT TODAY IN PNG ONE TRADING COMPANY STILL SELLS 20 LITRE DRUMS OF 75% CHLORDANE CONCENTRATE.

ISN'T IT TIME FOR LEGISLATION RESTRICTING THE CATEGORIES OF PESTICIDES AVAILABLE TO THE PUBLIC WITHOUT PERMIT IN THE SAME MANNER THAT PRESCRIPTIONS ARE REQUIRED FOR MEDICINES? WHAT ABOUT A PESTICIDE REGISTRATION LAW?

Pest Control

CONTROLLING INSECT PESTS WITH CHEMICALS

The two fundamental laws of ecology are, we are told:

"1. Everything affects everything else. 2. There is no such thing as a free lunch."

Using Agricultural Chemicals is no exception. We might increase production, but so often there are long-term hidden costs in using them.

The Companies making and selling Agricultural Chemicals are more sensitive than ever before to the dangers of their products, and due to political realities are doing careful and expensive research just to ensure their own survival. So there are good products available.

But the best approach to chemicals is under-use them. Direct them towards very specific problems, and only when the problem cannot be solved by other economic means.

We would like to be able to give more systematic, helpful information about the common chemical insecticides available in PNG, but it is not easy. As you will notice, even the names of the pests are not uniformly presented, so you'll have to feel your own way.

Any one insect pest may be controlled by several insecticides. Your choice will depend upon a number of factors. These are probably the most important:

1. Cost - you will want the most economical, other factors being equal. But the most effective and safest ones are often the most expensive.
2. Availability - you may not always be able to get just what you want.
3. Local experience - local advisers can often recommend something that works.
4. Time of application - some Chemicals must be avoided at certain times in the crops life.
5. Safety - some chemicals are dangerous. Don't use them if the recommended safety precautions cannot be carried out.

Ed. note: LD_{50} is a way of measuring the danger of poisons. Each number here is a measure of how much poison is needed to kill male rats. The smaller numbers are more poisonous than large numbers. "a.i." means "active ingredient."

SOME OF THE PRODUCTS AVAILABLE IN PNG:

KLORFON (ICI) - Controls a wide range of insects, is quick-acting, and easy to use. Recommended for Army Worm, Barley Grub, and Webworm in pasture and field crops; Cabbage White Butterfly, Cabbage Moth, Cabbage Looper, and Green Vegetable Bug; flys in households, public buildings, stock and poultry buildings; Pantophrytes Weevil Borers in Cacao.

a.i: trichlorphon LD_{50}:630

ACTELLIC (ICI) - A new relatively safe organo-phosphate general purpose insecticide which can be used on practically every agricultural crop. Controls the following:-

Acarina - Red spider and other mites.
Homoptera - Aphids, White Fly, Scale Insects, Mealy Bugs, Jassids.
Heteroptera - Plant bugs.
Coleoptera - Beetles and Weevils.
Lepidoptera - Caterpillars, Moths, Borers.
Thysanoptera - Thrips.
Diptera - Flies, Cereal Flies & Midges.
Orthoptera - Locusts & Grasshoppers.

a.i: pirimiphos methyl LD_{50}:2050

ORTHENE (ICI) - An organo-phosphate insecticide of moderate persistence with residual activity for 5-10 days at suggested use rates. Reasonably safe. Has been shown effective against some insects which are tolerant to other organic phosphates. Controls:-

Homoptera - Potato Leafhopper, Potato Aphid, Pea Aphid, Cabbage Aphid, Green Bug, Greenhouse White Fly.

cont'd

Hemiptera - Lygus Bug, Southern Green Stink Bug, Brown Stink Bug, Harliquin Bug.
Coleoptera - Spotted Cucumber Beetle, Bean Leaf Beetle, Bean Beetle, Potato Flea Beetle.
Lepidoptera - Cabbage Looper, Soybean Looper, Diamond Back Moth, European Corn Borer, various Army Worms, various Cut Worms, Velvet Bean Caterpillar, Potato Tuber Worm, Coddling Moth, Corn Earworm.
Thysanoptera - Citrus Thrips.

a.i: acephate LD_{50}:1494

GAMMAPHEX (ICI) - An emulsifiable concentrate of BHC based on Lindane. Toxicity about the same as DDT. Highly inflamable. Suitable for control of Aphids, Thrips and most leaf-eating pests of vegetables.

a.i: gamma benzene hexachloride LD_{50}:88

SOLGAR (ICI) - An emulsifiable concentrate, for soil pests. Recommended for the long term control of Banana Borers and vegetable soil pests.

a.i: pirimiphos ethyl LD_{50}:>1500

GAMMEXANE 7 MISCIBLE OIL (ICI) - An emulsifiable concentrate of BHC based on Lindane. Recommended for:- Rhinoceros Beetle and Black Palm Weevils in Coconuts, Curl Grubs & Wire Worms in Cacao, Shot-hole and Ambrosia Beetles in rubber, Leaf-eating Beetles in Oil Palms, soil pests in vegetables crops, house-flies and mosquitos, Pin-hole Borers in timber and Termites.

a.i: gamma benzene hexachloride LD_{50}:88

DIELDREX 30 (SHELL) - An economical but rather toxic chemical for a wide range of insects including Amblypelta, Ants, Banana Weevil, Borers, Banana Rust Thrips, Beetles, Centipedes, Cockroaches, Coconut Leaf Hopper, Coffee Ring Borer, Crickets, Cut Worm, Ear Wigs, Grass-hoppers, Leaf Hopper, Locust, Longicorn Beetles, Palm Weevil, Ryparid Beetle, Sandflies, Sexava, Spiders, Sweet Potato Weevil, Taro Beetle, Termites, Thrips, Timber Borers, Tip Wilt Bug, Tortise Shell Beetle, Weevils, White Ants, Wire Worms, White Curl Grubs.

a.i: dieldrin LD_{50}:46

MALATHION 50 - A well-known standard insecticide available from many companies recommended for Aphids, Cabbage Moths, Cabbage White Butterfly, Citrus Scale, Climbing Cutworm, Corn Ear Worm, Diamond Backed Cabbage Moth, Fleas, Green Shield Bug, Leaf Hopper (not all types), Lice, Mealy Bugs, Mites, Mosquito Pumpkin Beetle, Scale insects, stored grain pests, Ticks.

a.i: malathion LD_{50}:2800

D.D.T. (25% MISCIBLE OIL) - An emulsifiable concentrate is widely used, but is already banned in some countries because tends to accumulate in toxic amounts. It kills a wide range of insects, it is cheap, but we hope that you can find something else.

a.i: D.D.T. LD_{50}:114

RATS OR CATS?

ONE OF THE REASONS THAT MANY PEOPLE FIND RATS TO BE A PROBLEM AROUND THE HOUSE IN THE VILLAGE IS THAT THERE ARE NOT AS MANY CATS AS THERE USED TO BE BEFORE THE MALARIA CONTROL BRANCH OF THE PUBLIC HEALTH BEGAN SPRAYING WITH DDT TO KILL MOSQUITOES.

THE PUBLIC HEALTH DEPARTMENT ADVISES THAT CATS SHOULD BE SAFE IF THEY ARE KEPT OUT OF A HOUSE FOR THREE DAYS AFTER SPRAYING, BUT HAVE YOU EVER TRIED TO TIE UP A CAT FOR THREE DAYS?

EACH HOUSE RECEIVES MORE THAN 300 GRAMS OF ACTUAL DDT DURING EACH SPRAYING, BUT IT TAKES LESS THAN 3 GRAMS OF DDT TO KILL A 2KG CAT. CATS GET DDT BY LICKING THEIR FUR AFTER RUBBING AGAINST THE WALLS OF A SPRAYED HOUSE AND BY EATING COCKROACHES AND GECKOS THAT HAVE PICKED UP DDT ON THEIR FEET WHILE WALKING AROUND A HOUSE.

THE PUBLIC HEALTH DEPARTMENT DOESN'T CONSIDER THAT THE LOSS OF CATS IS TOO HIGH A PRICE TO PAY FOR MALARIA CONTROL AND THEY DO NOT THINK THAT RATS ARE A PUBLIC HEALTH PROBLEM.

DDT SPRAYING IS CONSIDERED THE CHEAPEST FORM OF CONTROL AVAILABLE FOR MOSQUITOES THAT CARRY MALARIA, AND NO ONE SERIOUSLY QUESTIONS THAT IT WORKS. IF YOU WORRY MORE ABOUT YOUR CAT THAN YOU DO ABOUT GETTING MALARIA YOU HAVE THE RIGHT TO TELL THE MALARIA CONTROL SPRAYERS NOT TO SPRAY.

ONE OTHER THING ON CATS. A LOT OF PEOPLE USE CHLORDANE DUST TO KILL COCKROACHES IN THE HOUSE. ASIDE FROM BEING A DANGEROUS CHEMICAL TO MAN, CHLORDANE WILL ALSO KILL CATS EVEN FASTER THAN DDT.

IF YOUR CAT IS VERY LISTLESS AND SHAKES A LOT ASK YOURSELF IF YOU HAVE USED CHLORDANE OR DDT IN THE HOUSE RECENTLY.

ALWAYS REMEMBER TO READ INSTRUCTIONS BEFORE USING.

SAFETY SUGGESTIONS: Store sprays and dusts in labeled containers; keep pesticides out of reach of children, pets, and irresponsible people; keep storage areas locked; avoid smoking while spraying or dusting; avoid inhaling sprays or dusts, and wear protective clothing and masks when exposed to them; avoid spilling materials on your skin, and if you do, wash immediately; wash your hands thoroughly after spraying or dusting before eating or smoking; cover food and water containers when

spraying around livestock areas; dispose of empty chemical containers so they will not be a danger; wash contaminated clothes before re-use, if the label tells you to; check equipment before spraying or dusting; clean equipment after each use; avoid spraying in high wind; don't allow your spray to drift to neighbouring crops; be sure that you're using the right chemical for the job you want to do.

IMPORTANT NOTES ON USING CHEMICALS

WARNING: Many chemicals are dangerous. They are transported in concentrated form and then diluted with a large amount of water before spraying. In the concentrated form they are quite strong enough to kill a man. In the diluted form they can kill insects and can certainly make people sick although the diluted form would not normally kill a person.

1. DANGER TO THE SPRAYMAN

When using sprays there are some very important rules to follow:

a) Use only the sprays that are recommended.
b) Read the label carefully, and follow the instructions.
c) Don't get the chemical on your skin.
d) Change spray clothes as soon as possible after spraying, and wash them.
e) After spraying, wash yourself with soap & water.
f) Do not smoke or eat while spraying.
g) Keep the spray away from water or food that people or animals will be eating.
h) Store all chemicals in a safe place away from food and children.
i) When a chemical container is empty it should be destroyed, not washed out or re-used.
j) Do not expose yourself needlessly to the spray liquid.
k) Wash the spray machine completely when spraying is finished.

2. DANGER TO THE CONSUMER

There is another danger. If the insecticide is sprayed onto a vegetable just before the vegetable is picked and sold, then the person who eats the vegetable will eat the insecticide too. He will probably get sick, and he might even die. So growers must not spray their vegetables for insects just before they pick them to sell them. The label of the insecticide bottle will tell him when he should not spray his vegetables. If he sees "WITHHOLDING PERIOD - 14 DAYS" (sometimes "HARVEST DELAY - 14 DAYS") that means that he should not spray the vegetable 14 days (or less) before he picks them. It is not easy to tell in advance exactly when the vegetables will be ready for picking. That is something that people learn by experience.

Method of Spraying

Read the instructions on the insecticide container, and follow them carefully. If you don't understand them, ask someone to help you, otherwise you may kill your vegetables, or even kill yourself. The insecticide will need to be diluted with water before spraying.

The usual machine for spraying is a 12-14 l knapsack sprayer which is carried on the sprayman's back. He holds the hose in one hand while he pumps with the other hand.

A detergent (such as Teepol made by Shell Company, or Lissapol made by I.C.I.) helps to spread the spray liquid over the leaves. Add 30ml of detergent to a 12-14 l knapsack sprayer.

Shake the liquid in the knapsack sprayer just before you start to spray. Some of the chemicals will sink to the bottom and will not be sprayed out unless you shake well.

When filling up the knapsack sprayer, always put the water in first, then add the detergent and the insecticide. Shake well and start using immediately If there is any delay after you have made up the spray mixture, shake it again before you start spraying.

Each plant should be sprayed to "run-off" point - that is until the liquid starts dripping from the tips of the leaves. The spray must be directed to completely cover the underside of leaves and the inner parts of the plant as well.

Suggested by: J. Greve, from DPI Rural Development Handbook No. 9.

A low cost bucket pump sprayer

SPRAYERS FOR AGRICULTURAL CHEMICALS

When using a sprayer for applying insecticide, be sure to read the instruction book, and don't lose the book that gives you the numbers for ordering spare parts.

Use of the sprayer: The operation of the sprayer is different for the different kinds of sprayers, but the sprayers all work much the same way: the pump builds up pressure and forces the liquid through the small hole at the tip. This causes the liquid to become a spray. Be careful not to lose the part with the hole or the sprayer will not work. If the water is dirty the hole might be

plugged. Then you will have to remove the part with the hole and take out the rubbish.

When you fill the sprayer you will be putting a small amount of chemical in with a large amount of water. How much chemical depends on the chemical, and you should read the instructions for the chemical. Usually this is on the tin. These instructions are for putting the right amount of the chemical on the leaf. (Unfortunately, these instructions are not always clear for the beginner).

When you spray you should hold the sprayer long enough for the liquid to begin to make drops that will run off the leaf. This is called the "run-off point". When this point is reached, the right amount of chemical is on the plant to be able to do the job that you want it to do.

There are many kinds of sprayers available in New Guinea. Some use motors to pump the spray, and they cost about K250. Another type is the knapsack sprayer. We know of three brands sold in PNG.

Rega: Lead coated brass, holds 15 litres, cost: K90 to K100, available from many agricultural supply firms.

Solo: Plastic, 16 litres, cost K55., distributed by Plantation Supply and Service Co., high pressure.

CP3: Plastic, 18 litres (3.3/4 gallons) cost K60., distributed by Mt. Hagen Technical Services Co., medium pressure. By all accounts this is the most durable sprayer available in PNG and represents good value for money.

Smaller sprayers are also available for the home gardener at a cost of K16 to K25. Check on spare parts before you buy.

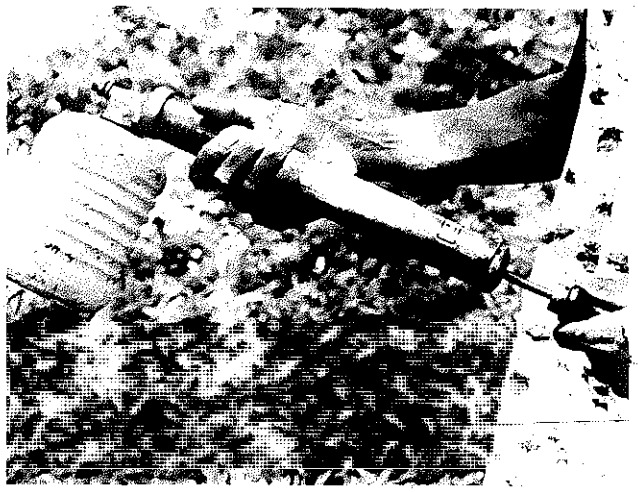

A low cost hand sprayer

HOME-MADE INSECT REPELLANT

A home made repellant for keeping insects away from leafy vegetables can be made from small red chilli peppers (lambo) and soapy water. The insects are not killed, they just stay away from the leaves that are sprayed.

Take a large amount of small red chillies and grind them. Add enough water to cover the chillies and a little soap powder or liquid soap. Mix this well. The soap is important because it helps the chillie water stick to the leaves.

The liquid can be sprayed directly or you can sprinkle it by pouring it through a tin that has had several small holes punched in the bottom.

This is good for all kinds of cabbage and for other green leaf vegetables.

Initial contributor: Sr. K. Murphy, Pangia Voc. Centre, Pangia, SHP.

INSECT IDENTIFICATION

A dead insect will fall to pieces quickly, so it is necessary to send any specimens of insects, eggs, larvae or pupae in preservative. The preservative usually used is methylated spirits.

The insect to be identified should be placed in a small bottle or tube, then methylated spirits is poured in to fill the bottle completely. The bottle should be securely sealed, placed in a plastic bag, and then packed in a box which is much larger than the bottle. The space in the box should be filled with cotton wool or crushed up newspaper so that the bottle is not broken in transit.

Address parcel to: Senior Entomologist,
Dept. of Primary Industry,
Box 2417,
Konedobu.

Write (or type) three copies of an information sheet. Put one copy in the parcel with the specimen, and send another copy separately to the Senior Entomologist. Keep the third copy in your files.
The information sheet should contain the following details:

Name of vegetable on which insect was found.
Place where insects were found - name of village and name of nearest town, and name of owner of land where insects were found.
Details of damage done by insect.
State whether all plants are affected or only a few.
Date specimens sent.
Name and address of person sending specimens (and designation if DPI staff).

DISEASE IDENTIFICATION

If you want to find out the name of a disease on a crop, you can send specimens to the Chief Plant Pathologist, DPI, Box 2417, Konedobu. Leaves or parts of the plant with the disease should be sent so as to arrive in Moresby on a week day, preferably early in the week.

For identification, the plant pathologist needs to know which plant the disease is on; the symptoms on the plant; how bad it is; where the specimen was collected; who collected it; and on what date.

It is not always easy to identify the disease, especially by the time the plant gets to Moresby. However, you will always receive a quick reply to your letter, even if the pathologist is not able to identify the disease.

NEMATODES

Nematodes, sometimes called eel worms, are a common pest in many parts of PNG. Most nematodes attack the roots, and because they are so small and are underground people do not notice them.

Usually the sign of nematodes is that the leaves die. Many people think that leaves die because the sun is too strong, and they do not want to dig up the plant to check it because they know that uprooting will kill most plants. If there are nematodes you will see that parts of the roots have swollen up.

The nematode is too small to see. The swelling is due to a family of nematodes feeding and causing the roots to grow too fast in the place they are feeding. The swelling chokes the roots, and water and food does not reach the leaves.

Other insects also attack roots, and you should not be afraid to pull up sick plants to check the roots for insects if they are very sick.

RATS

(p 245)

Rats are a common pest in towns and rural areas. The biggest problem is in the house and storehouse, where they eat food, and at night nibble on peoples feet. They have sometimes seriously injured small children. Occasionally they are serious pests in plantations and gardens but only rarely are they of economic importance. They are most likely to be a problem on small islands with well developed plantations, because the development deprives them of bush, and kills off many of the natural predators like snakes, birds and lizards.

The rat traps are the cheapest and most effective means of controlling rats in houses and storehouses, but they are a labour intensive method. For best results change the bait every day, change the location of the trap once a week, and change the type of bait every two or three weeks. Good baits are small bits of fresh coconut, pumpkin or watermelon seeds, or hard cheese, but they must be fresh. Trade stores and Trading companies sell traps for 25-40t each.

Biological control of rats is the simplest means and for long term control is the best. Generally the natural predators such as snakes, birds and lizards, are hunted by people for food and from fear and this gives the advantage to the rat in the garden, the plantation and the bush.

Cats are an excellent natural control near houses and warehouses. A difficulty with cats is that they die quickly in villages where DDT is sprayed to control the mosquitoes that give malaria. Because cats like to rub themselves on walls, and eat geckos and cockroaches in the house, they are poisoned by the DDT. A very small amount of DDT less than 3g for a 2kg cat - is likely to kill a cat. The shaking and drunken behaviour of a cat before it dies is a sign of DDT poisoning. Although you can tell the Malaria Control not to spray your house, you run a much higher risk of malaria. It means you must choose between cats and malaria.

Man is another biological control. There is nothing wrong with eating rats from rural areas, and roast rat is a little like chicken. But the idea is not to everyone's taste.

Rats do not like clean places. Burying rubbish, covering food, cleaning weeds, and building ratproof warehouses on stilts will make rats leave. You can also poison rats. Many people like this idea, because they think it will kill all the rats. Poisons for rats work by causing the rat to bleed to death in the stomach and since the rat cannot throwup, it must drown in its blood.

The oldest poison of this kind is called Warfarin. It comes as a powder that is mixed with bait. When the bait is eaten over a period of several days, the rat dies. One trouble with warfarin is that it will also kill dogs and pigs who eat a lot of it, so you must hide the bait where only the rat will find it. A very simple rat bait is made from putting 10g of Warfarin with 5kg of rice or wheat meal. Mix this very well and put small portions inside a piece of bamboo, where only the rat can get it. Every few days you will have to add some more bait as the rat eats a little bit.

If you need a longer lasting bait you can make 50kg from:

20kg paraffin wax
25kg wheatmeal
5kg sugar
4 tins fish
70g Warfarin
120g Busan fungicide

(p 172) The process:

1. Melt the wax in a large pot.
2. Mix the warfarin with a little wheatmeal and then mix it altogether with the rest of the wheatmeal, the sugar, and the Busan fungicide.
3. Add the fish to the wheatmeal and sugar and mix well.

cont'd

A bamboo rat bait station to protect bait from weather and domestic animals.

4. Take the melted paraffin from the fire, and add all the other ingredients to the wax. Stir well.
5. Pour the mixture onto corrugated iron and let cool in the shade.
6. When the mixture is hard, break it into small pieces. This is the bait that you put in places where rats will find it. It is better to hide the bait from other animals and from the rain. Bamboo or old tins are good.

Source of ingredients: Warfarin can be bought from Elvee Trading, Box 151, Rabaul. K20.00 plus freight for a 454g tin. Paraffin wax can be purchased from the same source (approximately K14.00 per 25kg box). Total cost of materials @ 50t per kg.

Paraffin wax rat bait has one problem. The heat of the cooking can reduce the effectiveness of the warfarin, also the paraffin reduces the effectiveness of the warfarin.

Warfarin also has the problem that pigs and dogs can die from eating it. You can buy other kinds of rat poison as well. Ratak is a ready made poison that kills rats but does not kill pigs. It does not spoil or get eaten by insects. It is available from ICI, Box 1105, Lae, or stores that sell plantation supplies. It comes in 500g packets or 40kg drums and costs about K2.00 per kg.

Remarks: Rats are very intelligent animals. They quickly learn to avoid traps and some poisons. They only eat things that they think taste good. Rats will always be with us, but they can be controlled. Rat control is not a responsibility of government; it is the responsibility of each man or community who is affected, because it is the man and the community that make the conditions that the rats like.

SNAILS DEM DEM

The African Giant Snail

Scientific name: Achatina fulica

This pest is also useful for pig food (cooked), chicken food (cooked and dried), duck food (cracked and raw), and human food (cooked & spiced).

Originally introduced to the New Guinea Islands during the war by the occupying Japanese army, the snail has spread to almost all parts of PNG. Many areas are not yet affected, but with the extension of roads it is inevitable that in time all coastal areas will be invaded.

Most introductions of the snail are by accident, such as when a person brings cuttings from one area to another and the small snails are on the cuttings. A resting snail may hide from the sun on a muddy part of a car during the day and then drop off in another area the next night. Cold kills the snail, so the highlands will not be affected. Once introduced into an area the snail is virtually impossible to get rid of, but there are several ways that it can be controlled and even exploited.

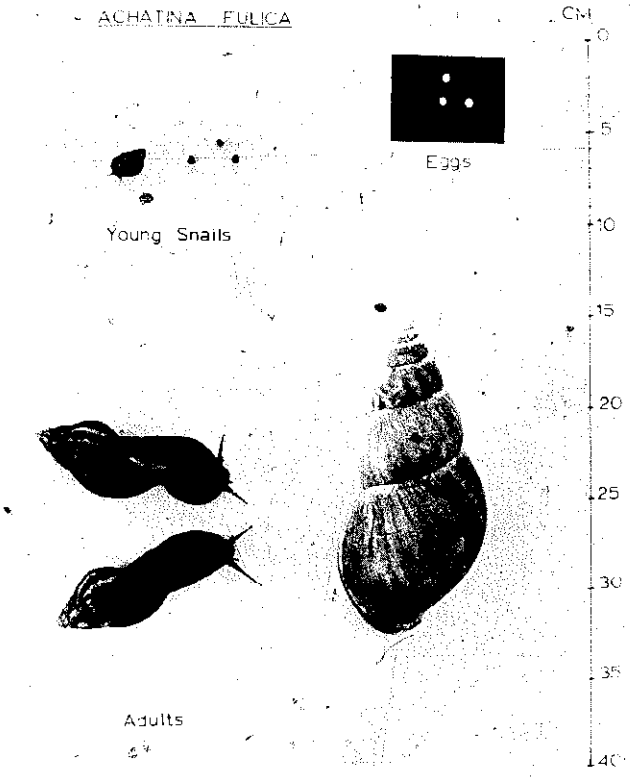

1. The cannibal snail, Euglandia rosea attacks only the African snail. The South Pacific Commission has financed the introduction of this biological control in the New Hebrides and in New Caledonia, and it has been introduced into some parts of PNG. It does not seem to be effectively established here.

2. Another predator snail, Gonaxis quadrilateralis, eats the eggs of the Giant African Snail. It eats only the eggs of this snail. The fleshy body of this snail is orange yellow. If you introduce this predator to your area you must put two or three of them with each pile of Giant Snail eggs that you find in the ground. This should be done during the wet season when the Giant Snail lays its eggs. Gonaxis introductions are not always successful.

3. Baiting: The use of methaldehyde bait is a cheap and successful means of local control of the snail. You can buy small quantities in garden supply and trading company stores all made up or you can make your own.

The best recipe for making your own bait is 1kg of sawdust, 1½kg cement and 10 g of methaldehyde mixed together with enough water to make a mortar (plaster that hardens). Form the mortar in to balls or blocks 2-4cm in diameter and let dry in the shade. The bait is placed every 2-4 metres around the garden or it can be easily crumbled and spread evenly around the garden. See the piles of dead snails the next morning near the bait.

4. Collect live snails and feed to animals. It is an excellent protein equivalent to many grades of fish meal. For ducks, break the shell and feed raw. For chickens, break the shell, cook the snail, and sun-dry before feeding. For pigs, cook the snails (since pigs can get disease from the parasites of the snail).

The pigs will soon learn to crack the shells with their teeth. Recipes for humans can be found in some cookbooks (Joy of Cooking), but the basis for all recipes is to place the snails in covered buckets without food for 5 to 10 days before cooking. Each day the shells should be washed in clean water.

(p 121)

Further references: Giant African Snail, A Problem in Economic Malacology, A.R. Mead, Univ. of Chicago Press, 256pp. 1961.
The African Giant Snail, Achatina fulica in the Pacific Islands, M. Lambert, South Pacific Bulletin, 4th Quarter 1974, Vol 24 No 4, pp35-40; "The Giant Snail", G.S. Dun, PNG Agricultural Journal, Vol 18, No 4, March 1967.

Note: Methaldehyde is available from the Planter's Association, Box 14, Rabaul. Cost about K3.50 per kg in 35kg drums.

Additional note: Biological predators have probably been introduced to your province already. If you want to try them in your village, check with the didiman before you write to Kerevat for help. Kerevat can collect snails from its own area and ship them, but it's easier to get them from places closer to you.

Remarks: Once the Giant African Snail is introduced to an area, there is no hope of getting rid of it. All the methods of control recommended here only keep the populations low enough so the damage is not too serious. Of all the methods, the one that gives the best control is to collect all available snails every day in the area close to your gardens and eat them.

Initial contributor: P.G. Hicks, LAES, Kerevat, ENBP.

PEST CONTROL - for technical assistance - the addresses of the DPI insect experts (entomologists) are:-

1. The Entomologist,
   Plant Industry Station Bubia,
   DPI.,
   Lae.
2. Entomologist,
   DPI.,
   Popondetta NP.
3. Entomologist,
   Lowlands Experiment Station,
   DPI.,
   Kerevat, ENBP.
4. The Chief Entomologist,
   DPI.,
   Box 2417,
   Konedobu, CP.
5. Entomologist,
   Kuk Research Station,
   Box 339,
   Mt. Hagen, WHP.
6. Entomologist,
   Highlands Agr. Experiment Station,
   P.O. Kainantu, EHP.

G. Frohlich and W. Rodewald, Pests and Diseases of Tropical Crops and Their Control

Covers most pests and diseases of all important crops, detailed description and colour photographs of the most important pathogens and affected plants.

HANDLE WITH CARE

This book is loaded with technology, which, when applied without sensitivity, can do more harm than good.

NEEDED: A PNG GRAIN POLICY.

IN 1972-73 PNG IMPORTED 22,930 TONNES OF WHEAT PRODUCTS WORTH 2.29 MILLION KINA, 61,656 TONNES OF RICE PRODUCTS WORTH 7.81 MILLION KINA, AND 6481 TONNES OF OTHER CEREAL PRODUCTS WORTH 2.68 MILLION KINA. ALTOGETHER MORE THAN 91067 TONNES OF CEREAL PRODUCTS COSTING NEARLY 13 MILLION KINA WAS IMPORTED. DURING THE SAME PERIOD PNG PRODUCED 909 TONNES OF RICE. THIS IS A CONSUMPTION OF MORE THAN 37KG OF CEREAL PRODUCTS FOR EACH MAN, WOMAN AND CHILD OF THE ESTIMATED 2.5 MILLION PEOPLE IN THE COUNTRY. IT ALSO REPRESENTS TEN PERCENT OF THE CARBOHYDRATE INTAKE OF THE COUNTRY.

NATURALLY, THE PEOPLE EATING MOST OF THE CEREAL PRODUCTS ARE URBAN PEOPLE OR PERSONS LIVING IN URBAN-TYPE ENVIRONMENTS SUCH AS INSTITUTIONS AND BOARDING SHCOOLS. EACH YEAR MORE PEOPLE ARE EATING MORE CEREAL PRODUCTS AND PAYING MORE FOR THEM: BREAD, RICE, TWISTIES, BISCUITS, AND BEER.

DESPITE HOPES THAT ROOT CROPS CAN ULTIMATELY FILL A GREATER PROPORTION OF THE FOOD REQUIREMENTS OF THESE PEOPLE, THE COUNTRY GREATLY DEPENDS ON IMPORTED CEREAL GRAINS. THE PRICES PAID AND THE AVAILABILITY OF THE CEREALS DEPEND ON WEATHER, WAR, POLITICS AND THE PRICE OF FUEL AND FERTILIZER IN THE PRODUCING COUNTRIES. PNG IS POWERLESS TO CONTROL ITS DESTINY IN THESE MATTERS.

THE STEADY INCREASE IN THE PROPORTION OF PAPUA NEW GUINEANS LIVING IN TOWNS AND CITIES WILL CAUSE A CORRESPONDING INCREASE IN DEPENDENCY UPON EASILY STORED, EASILY TRANSPORTED FOOD. IT IS IMPORTANT ALSO TO ASK WHETHER PEOPLE ARE MOVING TO CITIES IN ORDER TO BECOME DEPENDENT ON THESE STORED FOODS OR WHETHER THEY ARE DEPENDENT ON STORED FOODS BECAUSE THEY HAVE MOVED TO THE CITY. URBAN POPULATIONS IN PNG ARE INCREASING AT 8.5% PER YEAR AS COMPARED WITH THE POPULATION AS A WHOLE, WHICH IS GROWING ABOUT 3% PER YEAR. IF THIS CONTINUES, ONE FOURTH OF THE POPULATION WILL LIVE IN TOWNS AND CITIES BY 1986.

SINCE 1972-73 THE PRICE OF MOST CEREAL PRODUCTS HAS NEARLY DOUBLED. FOR URBAN FAMILIES AND INSTITUTIONS WITH A VERY HIGH PROPORTIONAL CONSUMPTION OF CEREAL PRODUCTS EVEN SMALL RISES IN THE PRICES CAUSE SEVERE HARDSHIP.

ISN'T IT TIME THAT WE THOUGHT ABOUT WHERE THIS DEPENDENCY ON IMPORTED GRAINS IS TAKING US? GRAINS SUCH AS MAIZE, RICE, MILLET, SORGHUM, AND OATS CAN ALL BE GROWN HERE AND MIGHT ALL PLAY A PART IN AN INTERGRATED APPROACH TO THIS PROBLEM. ISN'T IT TIME THAT WE DEVELOPED A NATIONAL CEREAL GRAIN POLICY TO LIMIT OUR DEPENDENCE?

FOOD STORAGE

Farm products often have to be held for a while on their way from the producer to the consumer. Storage losses can be very great, so it is important to keep them in the best possible condition.

Insect damage is one of the main causes of loss. Reduce or prevent it by:

1. Drying the food or commodity properly;
2. Using suitable chemical insecticides strictly in the recommended manner;
3. Keeping the store house clean and dry;
4. Keeping the food or commodity in neat stacks away from the parts of the building;
5. Selling or disposing first of those goods that were first taken in;
6. Keeping old bags away from the stored goods;
7. Inspecting regularly and taking immediate action when problems arise.

Further notes on preparing and maintaining the store house:

1. The building should be waterproof and well drained.
2. The structure and floor should be swept clean.
3. Pallets on which the goods are stacked should be at least 15cm high.
4. After cleaning and every 2 months thereafter the building should be sprayed with 2.5% Malathion plus 1% Lindane. (This is made by putting 680ml of Malathion 50% together with 850ml of Lindane 16% in 14litres of water). Do not allow the spray to contact the stored products. Cover the stored products with a waterproof cloth or sheet when spraying. Apply 5 litres of this spray mixture per 9 sq metres of surface.
5. No machines, crates, or other objects should touch the building on the outside, and vegetation should be kept cut back to ground level for at least 3 m or 10ft all around.
6. The food or commodity should be stacked neatly on pallets, with a metre between each stack, never against the walls, and no closer than 1m to the roof trusses.
7. Sweep the storehouse daily; re-bag or get rid of any spilled goods; repair broken bags in the stacks as soon as they are noticed.

The Entomology Section, DPI, Konedobu can give further advice on materials and methods for controlling insects. BE CAREFUL! Some insecticides can make food unfit for people.

Initial contributor: J. Greve, DPI, Konedobu.

INFORMATION BULLETINS ON CROPS

(P 244)

DPI,
AGRICULTURE RESEARCH CENTRE BUBIA,
BOX 348,
LAE.

Information Bulletins available free:

1. Soybeans (Glycine max)
2. Observations on Sunflower, Sesame, Safflower
3. Responses of Coconuts to Potash Fertilizer in Coastal Papua
4. Peanuts in the Markham Valley
5. Maize in the Markham Valley
6. Grain Sorghum in the Markham Valley
7. Soybean
8. Control of Digitaria and Devil's Fig
9. Economics of Fertilizer Use in Coconuts
10. Sugar Cane
11. Maize in the Markham Valley
12. Soyabean
13. Grain Sorghum in the Markham Valley
14. Peanuts in the Markham Valley
15. The Locust Outbreak in the Markham and Ramu Valleys 1973 - 75.
16. Rice
17. Stored Products
18. Important Pasture Weeds particularly in the Markham/Ramu Valleys
19. Hybrid Coconuts
20. Grain Sorghum in the Morobe and C.P.
21. Peanuts in the Markham Valley
22. Maize
23. Soyabean

Lowlands Agricultural Experiment Station,
Kerevat, ENB.

The following Information Bulletins are available free from the Agronomist-in-Charge, LAES, Kerevat.

Available in both English and Pidgin.

No 1 Tok save long wok long Didiman long Kerevat. (The Lowlands Agr. Experiment Station)

No 2 Marasin bilong kilim dai ol Demdem. (Baits for Giant African Snails).

No 3 Nupela Pikinini kon bilong planim. (Superior Corn Varieties now Available)

No 4 Han Kakao. (Cacao Cuttings)

No 5 Rot bilong kisim ol kain pulpul na pikinini prut na kaikai belong planim I kam long didiman long Kerevat. (Planting material available from LAES)

No 6 Save long ol banana bilong yumi. (Know Your Bananas)

No 7 Nupela pasin bilong kirapim kokonas - planim long bek plastik. (Coconuts, Polybag Nursery)

No 8 Wokim bilak pepa tasol. (Make Black Pepper, Not White)

No 9 Mekim painap I karim prut. (Making Pineapples Fruit)

No 10 Tok save long ol kainkain marasin. (Pesticide Labels)

No 11 Kilim dai dilakpela binatang I save bakarapim ol kokonas. (Control of the Indigenous Rhinoscerous Beatle in Coconuts).

HIGHLANDS AGRICULTURAL EXPERIMENT STATION,
AIYURA, VIA KAINANTU, EHP.

Bulletins available:

1. "Tok Save Long Arabika Kopi", van Horch, Kimber, and Teke, 18pp. 1975.
2. "Tok Save Long Stroberi", by W. Teke, 10pp. 1976.
3. "Prospects for Grain Sorghum, Maize and Soybean in the Highlands", A.J. Kimber 5pp.
4. "The Development and Utilization of Root Crops in PNG" by A.J. Kimber, 8pp.

OTHER BULLETINS ON CROPS ARE LISTED IN THE "GENERAL REFERENCES" SECTION UNDER THE VARIOUS ORGANISATIONS PRODUCING LITERATURE.

(P 244) (P 246)

SOME BOOKS ON CROPS

East African Crops, by J.D. Acland, Longmans 252 pp. K2.40 at the University Book Shop, Port Moresby.

A Manual of plantation and field crops with good illustrations, simple English, and details for management. Suitable for High School Teachers and advanced Didimen.

Guide for Field Crops in the Tropics and the Sub-Tropics .USAID. Free.

This well illustrated but abbreviated guide to growing cereals, beans, oil plants and root crops should be considered an introduction only and recommendations should be tested for PNG conditions. It is free from the Office of Agriculture, Technical Assistance Bureau, USAID, Washington, DC 20523, USA.

Root Crops, Digest No 2, by Tropical Products Institute, 56/62 Gray's Inn Road, London WCIX 8LU.

A well-organized manual on production and utilization of nearly fifty root crops. Gives clear instructions for processing many crops so that the starch can be stored. Good for libraries. Of limited use for fieldworkers.

Underexploited Tropical Plants with Promising Economic Value, National Academy of Sciences, Washington DC, 1975, 188pp, free on request.

Of marginal value for community-level workers, as it simply outlines areas where further research is needed. It tends to speak in relation to commercial scale production. Though suggested by some readers, we cannot recommend it for village oriented people.

LOCALLY GROWN PLANTING MATERIALS MUST BE THE FOUNDATION FOR VILLAGE GARDENING.

THE LOCAL WORKER SHOULD NOT EXPECT THAT A REGULAR SUPPLY OF SEEDS CAN BE PROVIDED TO THE VILLAGES FROM OUTSIDE. EVEN LARGE GOVERNMENT OR COOPERATIVE-SPONSORED PROGRAMMES FOR FRESH VEGETABLES HAVE PROBLEMS SUPPLYING PLANTING MATERIALS.

EVERY VILLAGE WILL HAVE AN INVENTORY OF ECONOMIC PLANTS WHICH CAN BE READILY IDENTIFIED BY SOMEONE WHO WILL ASK ABOUT IT. MY EXPERIENCE INDICATES THAT THIS INVENTORY MAY INVOLVE FROM 50 TO 100 ITEMS IN THE TYPICAL PNG VILLAGE. IN MOROBE PROVINCE WHERE I LIVE IT IS PROBABLY AROUND 75.

THIS INVENTORY IS NOT FIXED, BUT IT IS SLOW TO CHANGE. IT INVOLVES CONTINUOUS PLANT PROPAGATION. FOR A PLANT TO BECOME NUTRITIONALLY SIGNIFICANT AT THIS TIME AT THE VILLAGE LEVEL, IT SHOULD REALLY BECOME A PART OF THIS BASIC LOCAL INVENTORY. THIS WOULD EXCLUDE IMPORTED HYBRID SEEDS, AND PLANTS WHICH ARE VERY DIFFICULT TO PROPAGATE TRUE TO TYPE. IT WILL EXCLUDE PLANTS WITH SEEDS OF LIMITED VIABILITY.

NEW "FINDS" THAT ARE REASONABLY EASY TO PROPAGATE AND THAT ARE OF CLEAR VALUE WILL BE GROWN AND SAVED. NEW PLANT OPTIONS SHOULD BE PRESENTED CLEARLY, WITH DEMONSTRATIONS NOT ONLY AS TO HOW THEY ARE GROWN, BUT ALSO HOW THEY ARE EASILY AND ADVANTAGEOUSLY USED.

PLANT IDENTIFICATION

The Division of Botany, Office of Forestry, Department of Primary Industry, (Box 314, Lae) has a plant identification service. If you want to find out the name of a certain plant, you can send part of that plant to Lae and the Division of Botany will write back with scientific and common name. The reply is usually quite quick. They can identify food crops, weeds, pastures, poisonous and wild plants or whatever you send.

For grasses and small plants, send leaves, stems and flowers. For shrubs and trees, send a twig with leaves and flowers or fruit on it. All specimens must be dried between newspapers before sending them.
You must tell them; Who collected it; the exact place of collection; when it was collected; the sort of plant it is; and what you want to know about the plant. Do not ask for all the information they have on a plant, but just what you need to know, such as, is this a good pasture plant? Is it poisonous?

They will also tell you where you can find out more about the plant if such things have been published.

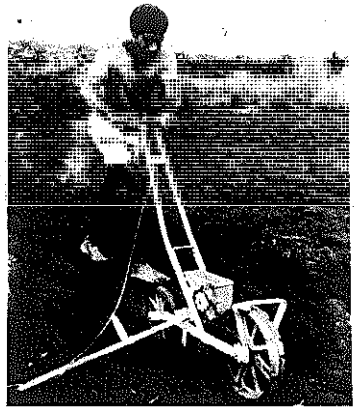

Esmay low cost seeder for planting. Available from Tutt Bryant Port Moresby for K40.

HAND SEEDERS

Planting large areas of ground by hand is very expensive if you have to hire labour. If you don't have tractor-driven planters to hire, here are two kinds of hand seeders that can plant very large areas of ground. They are useful for rice, sorghum, corn, peanuts and beans, as well as vegetable crops.

The first is called the Planet Jr. type. It is a rugged design that has been used for more than a hundred years. As the tool is pushed, like a wheel barrow, the seed falls through a hole in the bottom of the box. The hole can be made bigger or smaller depending on the kind of seed. As the big wheel turns it causes a door to open and close so that the seed is spaced at the right distance. In the ground one part of the tool opens a furrow, the seed falls into the furrow, and then another part covers the seed. The back wheel packs the ground for good germination. It will work even on rough, trashy soil.

The Esmay seeder is a lightweight aluminium and plastic tool, and does the same work as the Planet, Jr. It isn't quite so rugged, but it is easier to use. The drive wheel turns a plate that picks up the seed from the hopper and drops it into the soil. For different sized seeds use a different plate - six come with the machine. There are no metal parts to rust and the seed is not damaged by the opening and closing door.

Tutt Bryant sells both kinds. The Planet Jr. costs about K150 and the Esmay about K40.

MORE NUTRITION FROM OUR FARMING

How may we maximize the nutritional returns from our efforts in agricultural improvement? Some activities clearly have a far bigger nutritional payoff than others, and some are largely irrelevant to immediate village nutritional needs.

In dealing with the problem of insufficient food intake, with children especially in mind, we might recognize the following aspects of the problem: (1) Many villages are simply not producing enough food. They may or may not recognize this, as (2) the traditional low fat staples are extremely bulky foods. Persons, children, especially, may feel full without really getting enough food; and (3) cultural factors may be a significant contributing cause in the problem, as, for example, in many groups the men eat first, the women and children last, with the smaller children often having the very last choice.

In spite of their bulk, traditional staples such as kaukau, taro, bananas and yams still have the greatest potential for supplying carbohydrates at the village level on a regular basis. Even a proportionately small improvement in the production and/or utilisation of these would result in the availability of thousands of tons more food across the country. Conversely, activities which might distract attention from production of staples for family use could have serious negative effect. Some persons now claim that producing fresh foods or non-foods such as coffee or tea for cash may in some areas actually decrease the size of the nutrition package available to the family. It is not easy in PNG to demonstrate that access to cash brings better nutrition. A multi-level long-term educational effort should obviously be coupled with technical and economic promotion.

Hopefully, we will see some gradual shift in local customs in favour of the better nutrition of children. Education efforts among women should be given highest priority.

Vitamins are generally not deficient in PNG diets at the village level, so strong emphasis on green leafy vegetables does not need to be made, especially for introduced varieties. A broad range of native leaves and fruits rich in various vitamins can be found in most villages.

Due to cultural factors and the usual manner in which they are utilized, growing more pigs or cattle at the village level might have little effect on the regular diet of the average villager. This doesn't mean that we would discourage the promotion of pigs or cattle, but that these should be put into their proper perspective. The nutritional payoff of these will vary greatly from place to place, depending upon local customs, availability of government inspectors, access to abattoirs, access to markets.

Growing more chickens or ducks for either eggs or meat might bring positive direct nutritional results. Though they produce fewer eggs, native hens are a better risk if the farmer insists on "self-support". Introducing an improved-breed rooster may have beneficial effect on egg production. The regular practice of scattering a few seeds (such as sorghum, sunflower, maize) near the house in the early morning or late afternoon will help their diet and remind them where "home" is. Farmers who are obviously more progressive and who have access to baby chicks and good feeds might be encouraged to start a small poultry unit on a business-like basis with the birds confined.

In coastal and swamp areas where fish and other seafoods are plentiful, insufficient protein may only be an occasional or seasonal problem. Simple preservation techniques like salting and smoking might have significant effect in making these foods more widely available, both geographically and seasonally. Though this is not "agricultural", it is related to agricultural strategy.

Legumes in the form of dried beans offer one of the greatest opportunity areas in PNG nutrition, and more attention is now being paid to them. They especially lend themselves to recipes for infants and children. Based on experience in other countries in the Western Pacific, on World Health Organization papers, and on my own experience elsewhere under similar agro/economic conditions, we might best focus on three: peanuts (Arachis hypogaea), soybeans (Glycine max); and mung beans (Phaseolus aureus). Every rural worker should try these and evaluate them locally. Some workers would put winged beans and cowpeas ahead of the mung bean for PNG, but it is really an open question. (p 229)

In addition to the "big three" mentioned, depending upon local conditions, the following might be very useful in PNG: winged beans (Psophocarpus tetragonolobus) cowpeas (Vigna unquiculata spp.), kidney beans (Phaseolus vulfaris), lima beans (Phaseolus lunatus), peas (Pisum sativum), and field beans (Dolichos lablab). All of these can fit very nicely into crop rotations, and can have beneficial side effects for the other crops.

A STEP AT A TIME

If the farm and the farmer do not develop together then there will be trouble. We can compare the development of a farm with a man climbing stairs. If the man takes one step at a time he will climb the stairs safely. If he tries to run up the stairs or to jump two or three stairs he is likely to trip and fall over. It is like this with farmers. The problem is that extension advice often encourages farmers to jump a number of stairs. We often tell farmers about starting intensive piggeries with expensive housing before they are able to understand the basic simple improvements, especially better feeding. Field experience shows that farmers who adopt higher practices before they experience and master the bottom steps usually fail and waste a lot of money.

For example, here are some stages in the development of a pig project:-

1. Traditional - Sweet potato supplement, night housing.
2. Semi-intensive - Protein supplement, pig-proof fencing, legume grazing crops, rotational grazing, rotational cropping, controlled breeding, culling, "Nilverm" for parasites, boar paddock, Anthrax vaccination.
3. Intensive - Intensive housing, permanent water, protein concentrate, planned food crops for pigs, pen hygiene, balanced diet, waste disposal, culling of breeding stock.
4. Intensive (commercial)- Breeding records, grade boar, two litters per year, financial records, purchased feed, feed mixing machinery, feed storage, permanent material housing, piped water, marketing arrangements, separation of stock classes, weighing equipment.
5. Advanced- Modern scientific farming. Detailed performance records. Artificial insemination, employed geneticist, large scale, air conditioned buildings etc.

Some of the practices that can be introduced to improve pig husbandry are more important than others. We call these KEY Practices. Some key practices are:

a. Protein Concentrate Supplement: an adequate protein intake is very important for improving pig husbandry. It is no use going on to introduce more complex practices if the protein content of the diet is not high enough.

b. Pen Hygiene: as you get more and more pigs living closely together disease becomes a problem. Permanent water supply, concrete pens, and regular additions of litter to keep litter systems are required. These key practices are difficult to introduce: Farmers are often interested in introducing things which will give them status, such as an impressive pig house;

It is difficult to demonstrate that these key practices are in fact necessary (for example, the farmers may really believe that sweet potato is the best feed;) and

Extension officers might not see the importance of these key practices themselves. When they demonstrate "better" pig husbandry they usually think of a "model piggery." This model is usually an intensive piggery with expensive housing. When the farmer looks at the demonstration the most obvious thing he can see is the housing, not the feeding. The demonstration is not really showing the key practices to the farmer.

c. Records: Many of the practices which can be introduced to improve breeding and nutrition are dependent on having records of what is happening on the farm. These include performance records (such as breeding records, weight gains) and financial records.

(From "Pig Handbook", D.A.S.F. Rural Development Series Handbook No. 5.)

LIVESTOCK

Poultry

CHICKENS KAKARUK

Scientific name: Gallus domesticus
Nature of products: Eggs, meat
Size or age at maturity: Broilers for meat are usually killed at 9-10 weeks at about 1600g. These are improved breeds. Layers usually start giving eggs at 24-26 weeks of age (improved breeds).

Normal productive life: Layers usually give economic production for about 12 months after they begin laying, or up to 18 months of age. (improved breeds).

Breeds available: Rhode Island Red, Australorp, Sussex, White leg horn.
Chickens most readily available at present are a "Hyline" meat bird and "Hyline" layer from Ilimo Farm Products, Pty. Ltd., Box 1885, Boroko. The Australorp, a relatively hardy, all purpose breed, are available from the Poultry Research Centre, Lae.

Feeding: Commercially, day-old chickens require a 20-21% protein feed. (up to 6 weeks). Then from 6 weeks to 24 weeks 15% protein ("grower" feed). The laying hen requires a well-balanced feed containing about 16% protein. (P 167)

In the village, the birds usually find much of their own food, and production is usually much lower. Feeding a little sorghum or corn, or better still some dried legumes or sunflower seeds, will help to increase their productivity.

Breeding, hatching, handling of young: roosters are not necessary for hens to lay eggs. But roosters must run with the hens if you want the eggs to hatch into baby chicks. If you want a commercial poultry project you should probably buy your chicks direct from a hatchery. For village poultry keeping, allow the hen to sit on her own eggs, and provide a secure place for her. Eggs require 21 days of incubation to hatch.

Baby chicks need a uniform mild temperature until they are 6 weeks old. In nature their mother's body heat provides warmth. When chickens are raised "artificially" an electric bulb or kerosene lamp is good. In this case provide an enclosure to conserve the heat and a guard around the lamp to prevent burning of the young birds.

Housing: In a semi-commercial system only about .25 sq.m per bird are needed, and may be made of bush materials. (For 10-12 hens and a rooster, for example, a house 1.5m x 1.5 or 2.0m will do). Have a nest for every 3 birds, some roosting space, a feed trough, and a water trough. (P 168)

For commercial broiler production housing allow .1 sq.m per bird. Allow 56cm of feeding space per 10 birds and 28cm watering space per 10 birds.

At village level "colony" type housing is of interest. A small bush materials house is provided, such as a small "A" frame house with bamboo slats on the ends. The birds are kept inside all morning, when they lay some eggs; are released at noon so that they are able to hunt for food; and are fed some grain or seeds in the house at late afternoon, then locked up for the night. (P 168)

"Deep litter" is a popular management of the poultry house in PNG: The house must be kept dry; must not be over-crowded; and the litter (any dry materials such as coffee hulls, rice hulls, sawdust, chopped dry grass) must be turned about once a week. Advantages: it is cooler in hot weather, warmer in cool weather; birds like to scratch in it; droppings combine with the litter for less smell, less flies; deep litter is valuable fertilizer.

Most common diseases: Coccidiosis - prevent by using medicated feed or water; Leucosis - prevent and cure with feed medicated with aureomycin; Vitamin and mineral deficiencies; Fowl Pox - vaccinate, as there is no cure.

Sources of supply for breeding stock: Australorp from Poultry Research Centre, Box 348, Lae. Order these through your Provincial Livestock Officer with DPI in your province.

Ilimo Farms supply only hybrid birds which are excellent for production, but which should not be used for breeding. If you are near an agricultural school you might obtain improved breed chickens in small quantities. In the Western Highlands try the Lutheran Agricultural School and CLTC both in Banz.

References: Pigs and Poultry in the South Pacific, Watt and Michelle, may be purchased at leading PNG Bookstores.

cont'd

Poultry Handbook. DPI Rural Development Series Handbook No 4, 1974, 73 pp. order from Coordinator, Rural Development Series, Publications Section, DPI . Box 2417 Konedobu (prepared for DPI Field Officers).

Poultry and Pigs compiled by Dale Busse, 1975, Balob Teachers' College, Box 80, Lae. Prepared for training teachers, may be made available upon special arrangement. Write direct.

Important terms:	Layer:	an adult female bird
	Rooster:	an adult male bird
	Pullett:	an immature hen, 6-24 weeks of age
	Chicken:	bird up to 6 weeks age
	Nest:	a box where a hen lays her eggs
	Brooder:	a source of heat for young chickens
	Broiler:	a kind of bird especially bred and grown for meat production
	Roost or perch:	a piece of wood where the bird sleeps.

DUCKS PATO

Scientific name: Mallard: Anas platyrhynchus
Muscovy: Cairina moschata
Product: Meat, eggs, feathers, down
Size: Males 4 - 5.5kg; females 2 - 4.5kg
Age to breeding: Ducks 6.5 months
Muscovies: 7.5 months
Normal life span: 3 years
Breeds available: for meat - Muscovy, Pekin, Aylsebury, Rouen. for eggs - Indian Runner, Khaki Campbell

Description: Ducks are web-footed birds that like to live near water. They can move quickly in water, but their legs make it difficult for them to move on land. They have large heads, slender necks and broad bills with tiny saw-like teeth on the edges, that helps them to pull weeds and grass. They have an oil gland above the tail to waterproof the feathers. Domestic ducks have lost the ability to fly. They are often easier to look after than fowl but they still require good feed and management.

Muscovies are not true ducks, but are probably a cross between a swan and a duck. They are better parents than true ducks and are slightly hardier.

Most ducks in villages are Muscovies. They are easily recognized by the enlarged hairless skin on the face of older birds.

Feeding: Ducks do well eating grasses like paspalum, panicum, setaria or sogeri with legumes, and eat insects, snails, frogs and fish. Some flocks of Muscovies have learned to break the shell of demdems on their own. Ducks do well on chicken feed but should also have greens or kaukau. While ducks will grow well without added feed, regular feeding each evening will keep them near the house, and chicken feed will help them to lay many eggs. Ducks are messy feeders and it is necessary to take special care in a duck house.

Breeding: Muscovy eggs take 35 days to hatch. True duck eggs take only 28 days to hatch. Muscovies will breed with true ducks but only a few of the eggs will hatch. Ducks from those eggs can not have offspring. One male (the drake) for each 5 females is enough. Muscovies are very good setters, and will hatch the eggs of other birds that are forgetful. A duck will raise more young if the newly hatched ducklings are raised artificially like baby chickens.

Housing: A simple house like those for chickens is enough, but special care is necessary to see that they cannot spill the water on the litter. Ducks lay their eggs in the morning and should be kept in the house until about 9am. Young ducklings should be kept in the house until they are four weeks old and large enough to avoid being eaten by crows and eagles. Although ducks like water for swimming, they do not need it. They should have water troughs deep enough to put their heads under water since they need to wash their eyes regularly.

Diseases: Ducks are more resistant to coccidiosis than chickens, which is one reason that they are hardier. They can get food poisoning, so special care is needed to keep food and water containers clean.

Sources of supply for breeding stock: Many missions and schools keep ducks. Both ducks and Muscovies can be got from Vudal and PATI, as well as from Ilimo Farms, Box 1885, Boroko; Bible College, Evangelical Brotherhood Church, Box 324, Lae; DPI Poultry Research Centre, Box 348, Lae, but order through your own provincial livestock officer.

Remarks: When catching ducks or Muscovies hold them by the wings, not by the legs. Muscovies are ready for eating at 14-16 weeks when they should weight about 4kg. Well managed ducks (not Muscovies) can produce more eggs a year than chickens, but good management is difficult. Muscovies seldom give more than 60-90 eggs depending on their age.

Initial contributor: D. Busse, Balob, Box 80, Lae.
Updated by: R. Weber, PATI, Box 131, Popondetta, NP.

GEESE

Scientific name: Anser anser (except Chinese goose)
Product: Meat, feathers, down
Size: 6-8kg
Age to breeding: 1 year
Normal life span: 20-30 years

Description: Geese are larger than ducks, have longer necks, make a loud honking noise and are good "watch dogs". They have heavy down feathers under the big feathers which can be plucked for soft pillows and mattresses. Like ducks they have oil glands near their tail for oiling the feathers. They are cautious, not "silly". They are very intelligent. They are able to protect themselves very well, with their wings and bill used as weapons. They have lost their ability to fly long distances.

Breeds: Although there are many breeds of domestic goose, the best for the tropics is the Chinese goose since they breed easily in the tropics and lay eggs all year round. Other domestic geese need a cold period before breeding.

Male and female Chinese Geese with their babies (goslings).

Uses: Geese are usually raised for meat. The offspring of a pair of geese will provide 45-70 kilograms of fatty meat a year. The down feathers may be plucked from both the live geese (carefully!) and dead geese to be used for pillows and blankets. Since they eat mostly grass, some farmers use them for weeding crops, if the crop is not attractive to the geese.

Habits: Geese need free access to grass and other edible leaves. They will also eat insects, small water animals, vegetables and grain. The grass eating habit makes them a good lawnmower. They eat little bits all day. Geese like water but do not need it for breeding. The female lays 3-6 eggs at a time, and will raise as many as 6 families a year. One male (called a gander) is needed for every 2 or 3 females. Usually geese mate for life.

Housing: Is not required for geese in small numbers.

Sources of supply for breeding stock: Some mission stations and high schools have geese, and they can be purchased for breeding purposes from HATI, PATI, and Vudal and the DPI Poultry Research Centre Box 348 Lae.

References: Ducks and Geese in the Tropics by A.G. Wanen, The Complete Poultry Book, by W. Powell - Owen, Cassell, London.

Initial contributor: D. Busse, Balob, Box 80, Lae.
Updated by: R. Weber, PATI, Box 131, Popondetta, NP.

GUINEA FOWL

Scientific name: Numida meleagris
Products: Meat and eggs
Size: 1 - 1½kg
Age to breeding: 12 months
Normal life span: 6-8 years
Breeds available: Peal Guinea

Description: Guinea fowl are from Africa, and are wilder than most domestic fowls. They have dark grey feathers with small white spots and a bare head and neck. The small head has a bony ridge called a casque on top. The short tail usually points down. The eggs are smaller than chicken eggs and are pointed at one end. They will lay 40-60 eggs a season, but as many as 100 under good management. They like to hide their eggs in a corner with bushes. The chicks are brown with red beaks and legs. White guinea fowls are [illegible] from hatching. Males are difficult [illegible] females but normally has a cry sound- [illegible] chee", the female sounds like [illegible] buckwheat". The male often walks on [illegible]

Habits: Guinea fowl are often hard to manage. They like to fight with themselves and with other birds, and they are very brave, and will attack animals that are dangerous to them. They like to follow a leader and will play, fight or run as a group. Guinea fowl can fly, although even in the wild they do not fly far. They like to roost on high branches and are hard to catch during the day. Chicks are able to get to high perches at 8 weeks.

Management: Adults are very strong and do not get sick often. Chicken feed or kaukau in addition to foraging will help them to grow faster or lay more eggs. They should be fenced or they may go wild. The best way to keep them in a fence is to clip the feathers of one wing so that they can't fly over a fence. Chicks should stay inside a house until they are 3-4 weeks to protect them from hawks and wet weather.

Sources of supply of breeding stock: DPI Poultry Research Centre, Box 348, Lae, and PATI, Box 131, Popondetta. (only small flocks are available at this time).

Initial contributor: D. Busse, Balob, Box 80, Lae.

PIGEONS

Scientific name: Columbia livia
Age to first breeding: 5-6 months
Age to maturity: 5-6 weeks
Expected life span: 12 years and up
Weight at maturity: 700g
Breeds available: King Pigeon (meat)

Description: The pigeon is raised both in temperate and tropical zones as a meat bird, because it likes to stay close to its home and therefore requires no fencing. Specially trained pigeons are used by military and postal services for delivering messages, - and regularly fly over distances of more than 1500km back to their home.

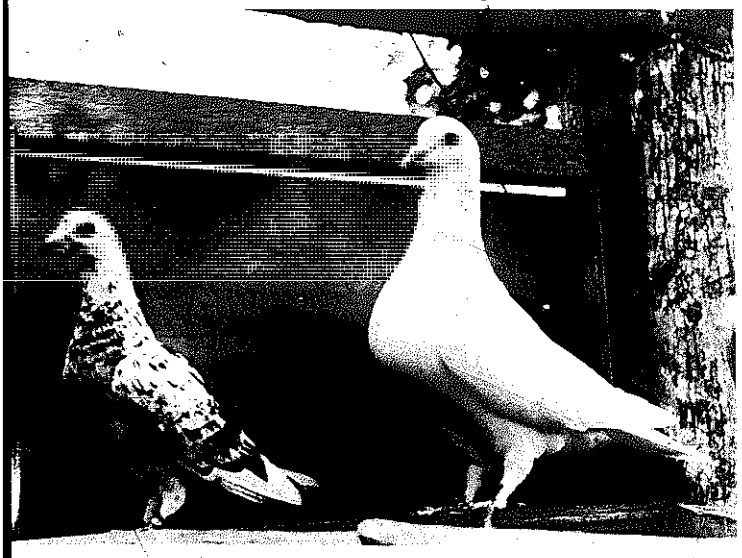

Female homing pigeon (left) and male King Pigeon. Note the great size and high forehead of the male.

BREEDING:

Housing: Any waterproof house that is cool and easy to clean is suitable. Nesting shelves should be placed in dark corners about 20cm by 20cm with short walls on three sides to keep eggs falling off.

To keep the cats, dogs and snakes out of the pigeons it is better if the house is on legs.

Feeding: Like all poultry, pigeons in houses require a balanced diet. Poultry feed is suitable.

Diseases: There are few diseases of pigeons in PNG. Worms, lice and coccidiosis (diarrhoea) can be expected, and the treatment for chickens is suitable for pigeons.

Sources of Breeding Stock: PATI and private breeders in Lae, Rabaul and Port Moresby.

PNG Experience: Snr. Livestock Lecturer, PATI, Box 131, Popondetta, but very little has been done so far.

References: Keep Your Pigeons Flying by L.F. Whitney, Faber, London; Pigeon Racing, F.W.S. Hall, Arco Mayflower, London; Pigeon B. Thornton, EP Group of companies, London.

Remarks: Indigenous wild pigeons of the Ducula species are a popular meat bird. On Tench Island, New Ireland Province, wild pigeons are fed on coconut and other scraps in the village area, and the pigeons quickly lose their fear of man. In time they become too fat to fly and shortly afterwards they are invited to a singsing.

Pigeon raising has not yet become widespread in PNG, but it is popular in many developing countries as a meat source because it requires very little effort.

A Goura pigeon on the New Guinea mainland is protected under PNG law. This means that only Papua New Guineans may hunt them, and they can hunt only with traditional weapons and only for traditional purposes (not for selling).

Initial contributor: R. Weber, PATI, Box 131, Popondetta, NP.

TURKEYS

Scientific name: Meleagris gallopavo (for domestic turkeys descended from North American wild turkeys)

Products: Meat, feathers, eggs.
Size: Hen to 7kg; Tom to 12kg, 1.2m long
Age to first production: 8 months - laying
6 months - meat
Normal productive life: 4 years
Breeds available: Bronze Wing and White

Feeding: Poultry ration is too low in protein for young turkeys (poults) and too low in vitamin A, D, B_2, Calcium and Phosphorpus as well. For raising in houses special feeds or feed supplements are required.

Breeding: One gobbler needed for each 10 hens. The hen will lay 22-28 eggs before nesting. Incubation is 26-28 days. Keep gobbler away from eggs as he will try to break them.

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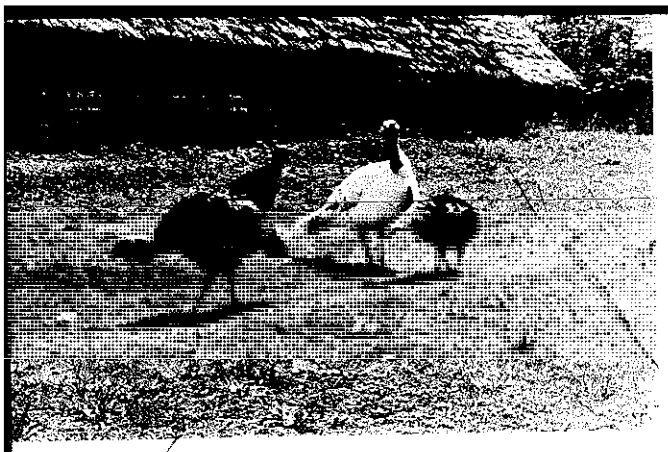

White and Brownwing turkeys

Housing: The difficulty of providing a balanced food for turkeys in PNG means birds should be allowed to run about to supplement any feeding. Dry housing is necessary to protect turkey from wet weather.

Diseases: Turkeys catch cold very easily, and are generally more susceptible to disease than chickens.

Sources of breeding stock: PATI, Box 131, Popondetta; and scattered flocks in the highlands and NP.

PNG Experience: PATI, various missions, schools.

Further reference:

Remarks: Turkeys are not considered intelligent birds, and will get excited very easily. Turkey eggs are larger than duck eggs, and a hen will lay year round in the tropics and produce up to 80 eggs per year.

Initial contributor: D. Busse, Balob, Box 80, Lae, MP. Updated by R. Weber, PATI, Box 131, Popondetta, NP.

Animals

PIGS PIK

Scientific Name: Sus scrofa (The European Hog, from which domestic hogs are largely descended). The PNG native pig is probably a descendent of Sus Vittatus.

Nature of Products: Meat; leather for shoes, hand bags, gloves, and other leather goods, hair for brushes; glue, soap; medicines.

Size when mature: A native pig will usually reach about 50kg under village conditions, 75kg under intensive feeding; an improved breed pig will weigh at least twice that in 9 months. An improved breed female may be mated at about 9 months or at least 120kg weight. 55 to 70kg is a typical weight range for a town meat market.

Normal productive life: Meat animals should be sold or slaughtered when the feed consumed no longer produces at least an equivalent gain in value of the animal. Breeding animals may be used for 4 to 5 years, after which time they should be replaced.

Breeds available: Bush native pigs, Berkshire, Tamworth, Large White, Landrace, Crossbreds.

Feeding: Feeding is the most important factor in pig production. Quality and quantity of protein is the major challenge confronting the farmer.

Weight range	Class	Protein required
3-30 k	sucker	22%
30-60	weaner	18%
60-140	porker	16%
140-180	baconer	14%

(p 168) (p 68)

Sows that are pregnant or giving milk to their piglets need as much protein as baby pigs. Access to green feeds and soil will help to ensure that the pigs will get minerals and vitamins. Plenty of fresh clean water is necessary.

Breeding: Use the best animals for breeding. Breeding animals must not get too fat. Mate gilts at 9 months or older, 120kg in weight or more. The heat period(oestrous) lasts 3-4 days. Breed on 2nd day. The cycle is 21 days. One boar can service 15-20 sows. The period of gestation is 114 days (3 months, 3 weeks, 3 days). A sow will come into heat about a week after her litter has been weaned. 7 or 8 piglets raised successfully to weaning is considered a good sized litter. Do not use a boar before 9 months of age. Two litters a year is considered normal.

Farrowing: Keep sow separated from other animals. Piglets occasionally require assistance in clearing membranes away from face, otherwise sows usually have little difficulty and should be left alone. Provide young piglets with solid food after 3-4 weeks, and if sow is not a good milk-producer, after one week.

Housing: A pen 9 square metres in size is adequate for: a sow and her litter; or up to ten porker pigs; or 2-3 sows. A boar's pen should be at least 5sq m. if the sow is brought to him. There is much flexibility in how the housing is designed. The best floors are concrete with plastic vapor barrier below, or deep litter. *(p 169)*

Most common diseases: Parasites (prevent through cleanliness and by using pig "wormers"); Pneumonia (provide warm, sheltered housing, protect against parasites); Anthrax (prevent by vaccination, cure with antibiotics).

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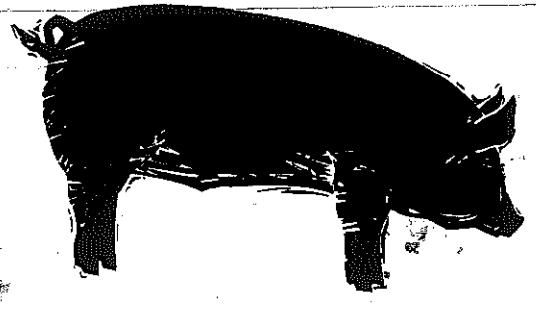

Sources of supply of breeding stock: Consult your nearest DPI Office.

Further references: Books - Pigs and Poultry in the South Pacific, Watt and Michelle, available in leading PNG bookstores.

Pig Handbook DPI Rural Development Series, Handbook No. 5, 100 pp. 1975, order from Publications Section, DPI, Box 2417, Konedobu.

For specific technical questions, write: Mr. Ian Watt, DPI. Pig Breeding and Research Centre, Goroka, EHP.

Terms:

Baconer: a pig suitable for curing ham or bacon
Balanced ration: a good ration which contains all that the pig needs
Barrow: a castrated male pig
Boar: a male pig
Creep area: an area of the house only for piglets, with small entrances so that only piglets may enter
Farrow: to give birth to piglets
Gilt: a female pig before she is ever mated
Oestrus or heat: the time when a female is ready to be mated
Piglet: a pig still sucking milk
Porker: a pig suitable for fresh meat
Sow: a female pig
Wean: to separate piglets from the sow
Weaner: a weaned pig

Related housing and equipment (p. 168 - 170)

Remarks: If you use snails for protein supplement, be sure to cook before feeding to pigs.

A herd of Brahma beef cattle

BEEF CATTLE BULAMAKAU

Scientific name: Bos taurus, Bos indicus
Products: Fresh meat, dried/salted meat, leather
Size: Males 550-800kg at maturity: females 325-500kg at maturity.

Age to breeding: Males, two years, 350kg; Females, 1½ - 2 years, 225kg. Do not use for breeding at low weights or the animals will not bear as many calves.

Normal productive life of cattle is ten years.

Breeds available: Brahma, Droughtmaster, Javanese, and Brahman crosses with Angus, Hereford, etc.

Feeding: Graze animals on kunai at a rate of one beast to two hectares, on kangaroo grass at the rate of one beast to 4 hectares. Improved pastures with better grasses and legumes can be stocked at 1 beast per hectare. For feeding animals kept in a pen you will need 50 to 75 kilograms of grass and 50 litres of water a day. Salt blocks or mineralized salt blocks should be provided.

Breeding: A cow is able to conceive (oestrus cycle) every 18 to 21 days, and it takes 280-290 days until birth (gestation). Brahman cattle take longer. Birth takes 3 hours from the beginning of hard labour, and one hour from the appearance of the feet of the calf. If the calf is not born in this time help will be needed. Treat the navel of the calf with screw worm smear daily until well-healed. One bull is needed for every 20 to 30 cows.

Housing is not needed for cattle but there must be shade.

Diseases and pests: (1) Screw worm enters cuts and sores. Apply smear daily to all cuts until healed. Check cattle every few days for new cuts. All parts of PNG. (2) Liver flukes: Use 'Zanil' drench (ICI) every eight weeks in the highlands where flukes are found. (3) Round worms: use 'Nilverm' (ICI) drench every eight weeks in the highlands.

Buying and moving cattle: To get cattle you should either contact the Provincial Livestock Officer at DPI or purchase from other cattle raisers. You must have a permit from the Provincial Livestock Officer to move cattle. Bulls cost about K400, cows about K120-K150, and heifers about K90-K150. The higher prices would be for pregnant animals.

Further references: Keeping Cattle in PNG, DPI, 5 vol. Free, English & Pidgin, 16-20 pages each booklet; Beef and Dairy Cattle in the Tropics

Training: Farmer Training Schools at Erap, Urimo, and Baiyer River. For information contact Provincial Livestock Officer.

PNG experience: Cattle raising has been successful in nearly all districts in PNG. Cattle have been

raised in the country since the end of the nineteenth century.

The New Guinea Graziers Association is the society for people who raise cattle, Box 1671, Lae.

Remarks: Do not breed cattle too early or they will not do so well. Be sure to get a stock movement permit from the Provincial Livestock Officer when you want to move cattle. He will inspect the cattle for diseases or flies so you know the cattle are healthy. You cannot butcher meat except for rations or your own personal food unless the animal is killed in an abbatoir and is inspected for healthy meat.

Initial contributor: J. Holmes, DPI Erap, Box 348, Lae.

DAIRY CATTLE

Scientific name: Bos taurus
Products: Fresh milk, cheese, yogurt (primary) and meat and leather (secondary)
Size: as for beef cattle
Normal productive life: 6-8 years
Breeds available: Freasian, Seride, Sahiwal (all scarce)

Feeding: Dairy cow feeding is the most complex of all animals. Native grasses are not good enough. Very good improved pastures and supplementary feeding are needed. For a specific situation, consult OIC, Beef Cattle Research Centre, Erap, Box 348, Lae.

Breeding: As for beef

Housing: Shade is very important for dairy cattle in the tropics. Also a milking shed is required for commercial business of selling milk and must meet Dept. of Health specifications.

Diseases and pests: As for beef

Breeding stock is very limited: Wanaru Dairy and Malahang Dairy, in Lae; CLTC, Banz; and Tanubada Dairy in Port Moresby. Also Lutheran Agricultural School, Banz, and Lutheran Dairy, Wabag.

PNG experience: above dairies

Remarks: Throughout the tropical world dairy cattle raising is the most difficult form of animal technology. It is not a good business for beginners, particularly because of the very high cost of building safe milking sheds.

Initial contributor: J. Holmes, DPI Erap, Box 348, Lae.

Cattle Production in the Tropics, by W.J.A. Payne Vol I (Breeds and Breeding), Longmans, Great Britain, 1970, 336 p.

WATER BUFFALO

Scientific name: Bubalus bubalis
Products: Meat, leather, milk and work
Mature size: Males: 500-700kg
Females: 350-500kg

Productive life: It is not uncommon for buffaloes to produce and rear a calf at 20 years of age. However, in a breeding herd cows would normally be culled no later than 12-15 years of age. Meat animals should be slaughtered no later than 3-4 years.

Breeds: There are two main breeds of domestic water buffalo. They are the riverine breeds such as the Murrah used for milk production, and the swamp breeds used mainly for meat and work. Only the swamp breed is present in PNG and it may be either white or grey in colour.

Feeding: Water buffaloes are ruminants (animals with 4 parts to their stomach) with the ability to convert grasses into meat. They are most suited to wet swampy areas and generally outperform cattle in these environments. They should be provided with ample water, forage and mineral supplements. The area of land required for one water buffalo will vary according to the type of pasture, rainfall and class of animal.

Breeding: The average age at first calving is about 3 years. Buffalo bulls can be used for service from 2 years onwards. The proportion of bulls to females should be about 1 to 20. Oestrus occurs every 21 days and the duration is 1½ days. The gestation period for the swamp breed is 310-320 days, but varies slightly depending upon the age of the cow and the sex of the calf. Buffalo do not usually have difficulty giving birth to their calves. Water buffalo will not cross breed with cattle. Selection of buffaloes should be based on productive characteristics such as liveweight gain and reproductive performance.

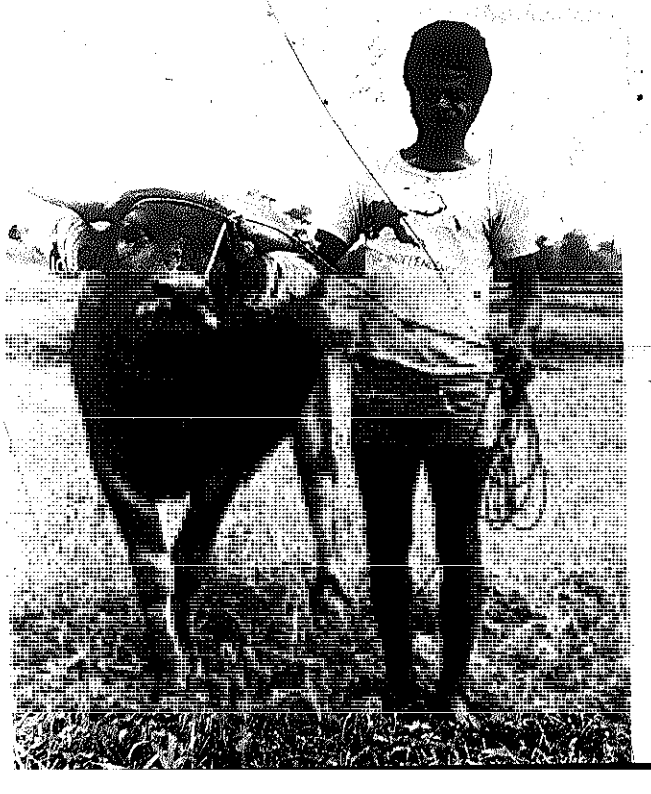

Housing: A wallow and/or shade are required, otherwise the buffalo would suffer extreme discomfort during the day.

Diseases and Pests: Buffaloes are not as susceptible to external parasites as cattle. However, calves are susceptible to screw sorm strike and wounds should be treated with a suitable smear. Internal parasites:

(i) Neoascaris vitulorum, a roundworm, can be a problem in young calves - Drench with Piperazine at a rate of 200mg per kilogram body weight, shortly after birth and again one month later;

(ii) Strongyloides spp. - Drench with "Nilverm";

(iii) Liver fluke - Zanil.

Source of breeding stock: Sepik - DPI, Urimo; Madang - Catholic Mission, Alexischafen; Morobe & highlands - DPI, Erap; Islands - Selapui Plantation via Kavieng and Catholic Mission, Rabaul; Papua - DPI, Launakalana

Because of the limited number of buffaloes, stock may not be available from the sources listed. Prices are in line for comparable cattle types, except where buffaloes have been trained for work. A movement permit must be obtained from a stock inspector prior to movement.

Remarks: Buffaloes were introduced into PNG around the turn of the century, and have been utilized for both meat and work. DPI commenced evaluation of the buffaloes in 1971 on the Sepik Plains. In this area they are far superior to cattle. Limited observation suggests that they will perform very well in wetter areas.

The present population of buffaloes is about 1350 (July'76) and supplies will be limited for the forseeable future.

Initial contributor: J. Stutter, DPI, Erap, Box 348, Lae.

The Husbandry and Health of the Domestic Buffalo, F.A.O., Rome 1974, 993 pp., US$8.00 Very thorough. A compilation of papers on all aspects of the domestic buffalo.

NOTES ON TRAINING AND CARING FOR WATER BUFFALO

Camilo Toledo, a Filipino rice technician and water buffalo-trainer for the Lutheran Gabmazung Rice Farm at Lae, gives a few basic pointers for training:

1. One of the first lessons the animal learns is to untangle itself from its own rope. This usually takes only a week or so. Tie the rope around the horns or neck at first, through the nose later.

2. It is helpful to have someone handling the animal every day, sometimes gently patting and stroking the various parts of its body. Preferably it is the same person, who becomes a "friend".

3. It is tempting to get the animal to do work very early by having a man lead from the front. Do not do it, as the animal must learn to work with the man behind. Be patient and do it right.

4. For directional training (go right, or go left), the man who trains should always be on the left and at the rear. The usual signal is a steady pull on the rope to go left, and a gentle jerking to go right.

5. After some directional training the animal also learns to carry a man on its back.

6. Usually you hitch the animal first to a sled, then to a harrow, then a plough, and finally a cart. The sled is the easiest. Gradually the animal will get used to pulling, and its skin will get tougher under the yoke.

7. Incentives are very important: let untrained or difficult animals train around or move toward other familar buffalo, especially during directional training; train the animals when they are "partially" hungry, then after their work give them a bath, some salt, and good grass.

8. The animal will always try to be rebellious at first, but the man has the control, and the animal must learn to accept it.

9. Water buffalo need shade when it is very hot, as well as plenty of water for drinking and bathing.

NOTES ON PIERCING A BUFFALO'S NOSE

The ideal age to pierce the nose of a water buffalo is one year. A nylon rope through a hole in the nose is better than a brass ring, not only because it is cheaper, but also because the animal feels the direction of the pull more clearly. With a brass ring the feeling is distributed to all sides of the nose and the animal may be confused.

Prepare a nylon rope about 8 mm thick and 1m long. Also prepare a sharp bamboo stick about 30cm long. The wood should be mature, the tip very sharp, and the other end broad enough to hold very firmly. The stick should taper from the point to a thickness greater than that of a rope.

Tie the animal securely between two rails, locked in both front and rear, with head held firmly against a vertical pole. (See photo)

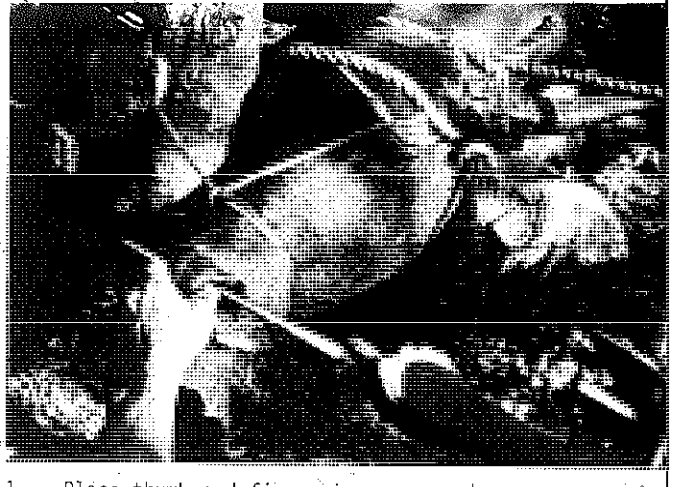

1. Place thumb and finger in nose as shown. Locate the thinnest place in the cartilege.

It is very easy to find. Put the bamboo point through, quickly working it in until the hole is big enough for the rope. Leave the stick in place for 1-2 minutes.

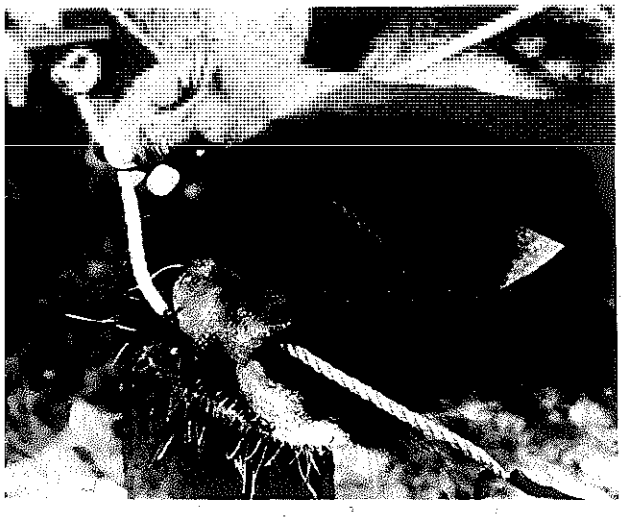

2. Insert the rope. Tie as shown.

3. Attach the loose end of the nose rope to the rope around the horns for at least one week, allowing the nose wound to heal. After a week you can tie the nose rope to a longer rope, for handling.

AGRICULTURE IS THE BASIS OF INDEPENDENT DEVELOPMENT

GOATS, MEME

Scientific name: Bovidae capra
Nature of products: Fresh meat, high quality leather possibly milk (though not very common in the tropics)

Size when fully grown: Native tropical goats are around 25-30 kg.

Normal productive life: Goats live to an age of 7 to 10 years, generally.

Breeds available: Pure-bred goats of the European milking breeds are usually not recommended in the tropics, as they have a rather high mortality from disease. The ordinary native tropical goat is recommended for PNG.

Feeding: Goats are "notoriously" able to feed themselves, being voracious foragers. Masefield gives the following figures for feeding a 25-30kg native tropical goat, per day: starch equivalent, 0.4kg; protein equivalent, 0.02kg; dry matter capacity 1.1kg. Being a ruminant, the goat does well on ordinary grasses, and will survive even when the food supply is small. Clean water supply is important.

Breeding: The gestation period of a goat averages 155 days. The first heat or oestrus after birth of young is 1 to 3 months, with recurrences every 18-21 days, and a duration of 1-3 days. The lactation period is indefinite, and depends largely on the treatment given. Multiple births are less common in native tropical goats than in the improved breeds.

Housing: Simple shelter is sufficient, though tieing or fencing is important if you wish to protect your gardens and/or for practicing selective breeding. Some arrangement for supplementary feeding of pregnant and suckling females is advantageous.

Diseases and pests: Native tropical goats are quite resistant to disease. The usual sanitation practices for handling farm animals should be ample protection against disease.

Sources of supply for breeding stock: Goats are not easy to buy at this time, but it is possible if you are presistent and want only small quantities. For more information you might try one or more of the following: Mr. A. Quartermain, PNG Univ. of Technology, Box 793, Lae (Unitech has around 20 goats): Sub-provincial Rural Development Officer, DPI Finschhafen (several herds are found in Finsch area): The Principal, PATI, Popondetta, NP (PATI has around 10 goats); The Director, Seventh Day Adventist College, Kabiufa, EHP (They are supposed to have a small herd); Talidig Vocational Centre, Box 2070, Yomba, Madang (K45 per breeding pair),

Further references: See items on goats in book review: "Lukautim Meme", Yangpela Didiman, 13pp, Pidgin, Box 39, Banz, WHP. Farming notes "Goats", DPI Publication; Introd. to Tropical Agriculture, 1971, section on goats.

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cont'd

Remarks: Large numbers of goats can cause serious deforestation if not systematically managed.

Goats in the tropics should have:
(1) Some rocky ground or rough concrete to wear down and keep their hoof nails healthy, should be drenched with Nilverm regularly to prevent loss of condition from internal parasites.

(2) Be closely controlled by wire chain or small boys.

(3) Be castrated and or dehorned where appropriate to prevent deaths through mating rivalries.

References: Goat Production in The Tropics, by Devendra and Burns, Commonwealth Agriculture Bureau, England, 1970. Argues for increased use of goats in the tropics, where 2/3 of the world's goats live. Many of the current criticisms are shown to be exaggerated. Tropical breeds are studied.

Observations on The Goat, by M H French, FAO Agricultural Studies No. 80, Rome, 1970. Includes origins and history of the goat. Weighs advantages and disadvantages of the goat in subsistence economy. More than 400 reference in the bibliography make this book a first step for further study.

SHEEP SIP SIP

Scientific name: Ovus aries
Products: Fresh meat, dried meat, wool
Productive life: Not yet known under PNG conditions.

Feeding: Short and fine grasses such as Kikuyu and Kangaroo grasses in the highlands and Kangaroo, and Buffel in coastal areas.

Age at Maturity: Males 18 months, females 12-18 mos.

Gestation: 150 days, oestrus cycle 17 days, multiple births common but not usual.

Housing: Dog-proof housing is important, and they must be penned at night where wild dogs roam. Men, dogs, and pigs attack sheep.

Disease: Liver fluke controlled with Zanil Nilverm, or Thiobenzole; Screw worm controlled by inspection and use of smear.

Preangan sheep from Erap at Bugandi H.S.

Supply: None will be released by DPI until 1978 when numbers have been increased. Earlier trials in the mid-50's failed for reasons not understood. No releases are planned until we know more about them.

No PNG references known.

PNG experience: Dr. T. Leche, DPI N.Z. sheep project, Box 766 Goroka (wool and feed); Lloyd Hurrell, Wau; Graeme Murray, Valley View Farm, Lae.

Remarks: There are less than 2000 sheep in PNG. 800 of these are three breeds recently imported from New Zealand. There are others on some DPI stations, mission stations, and farms. Sheep are not yet recommended until proper management in PNG is understood. Some very good farmers have succeeded, but others equally good have failed.

Initial contributor: J. Holmes, DPI, Box 348, Lae.

REPRODUCTION OF FARM ANIMALS

A. Gestation Periods, in days

Animal	Shortest Period	Average	Longest Period
Horse	305	340	400
Cow	210	283	353
Donkey	365	374	385
Buffalo	290	310	330
Sheep	140	147	160
Goat	148	155	165
Pig	109	112	130
Rabbit	25	32	35

B. Incubation Periods

Bird	Average time to hatch
Chicken	21
Duck	28
Guinea-fowl	28
Turkey	28
Goose	30
Pigeon	20

C. Periods of Oestrum (Heat periods)

Animal	Duration of heat	First Heat after birth	Recurrences
Horse	3-9 days	7-11 days	2-4 weeks
Cow	1-2 days	1-2 months +	16-24 days
Buffalo	1-3 days	2-3 months +	3-4 weeks
Sheep	1 day	2-6 months	2-3 weeks
Goat	1-3 days	1-3 months	18-21 days
Pig	3-4 days	5-6 days fr. weaning	15-30 days

FROM: Handbook of Tropical Agriculture by Masefield

PASTURE

A pasture is an area of ground on which one or more crops is grown as food for animals. Pasture must be managed in such a way that there is always sufficient food for the animals. The food must supply all the requirements of the animals for different types of nutrients. If the pasture does not do this, either the animals will not grow well or food will have to be bought, which is expensive.

Pasture for cattle and sheep requires the highest standard of management because these animals will eat only a limited number of crops. Pigs, goats, chickens and ducks will eat a much wider range of plants.

PASTURE PLANTS

The basis of all pasture for sheep and cattle is grass. A species of legume is often added to the grass so that the grass and the legume grow together. The legume brings two benefits. First it will take nitrogen from the air and put it into the soil; this nitrogen will help to make the grass grow better. Second the legume will contain more of the important foods called proteins; the presence of these proteins will make the animals grow faster.

A good pasture grass must produce a high yield of leaf which is attractive to the animals and is nutritious. Finally, the grass must be able to regrow quickly after the animals have eaten it. The most palatable and nutritious growth of most grasses is the young regrowth which follows cutting, grazing or burning.

There are several species of legume which are used in pasture. There is little difference between these as food for animals; a legume must be chosen which grows well in the situation of each particular farm.

Pastures can be classified into three types:-

1. Unimproved pastures grow only the local grass.
2. Semi-improved pastures grow a legume in addition to the local grass.
3. Improved pastures grow selected grass species which yields higher than a local grass and also grow a legume.

Your nearest Agricultural Office should be able to suggest plant species suitable for your area and where you can get them.

PASTURE MANAGEMENT

The most important part of management of pasture is the 'stocking rate', that is the number of animals feeding on the pasture. This is generally written as number of beasts per hectare (one beast equals one mature cow). If the stocking rate is too high, the animals will eat the grass more quickly than it will grow. This will eventually kill the grass plants so that the food available will become less and less. Weeds will grow where the grass plants die; some of these are harmful to cattle.

RULES FOR PASTURE MANAGEMENT

1. Animals should start grazing when the pasture produces the rush of green growth ('blaze of growth') which will follow grazing, cutting or burning. There will be a delay of several weeks between grazing and the 'blaze of growth'.

2. Each plant in the paddock should be cut by a grazing animal once only. The animals should be moved to another paddock before they need to return to a grazed area for a second time.

3. Animals with the highest nutritional needs (milking cows, cows in calf) should be put into the paddock first. Animals with lower requirements (dry cows, beef animals) can be put into the paddock after the others have had the best of the grass. The first group should be removed before all the foliage is eaten - rule 2 still applies.

PASTURE IMPROVEMENT

The better the pasture the more beasts that can be stocked. Growing a legume with local grasses will improve a pasture. Legumes are usually grown from seed. The seed can be sown among the grass. Legume seeds must be inoculated; the inoculum can be obtained free from DPI, Konedobu. In many cases the seed needs scarifying also. This can be done conveniently by boiling some water in a suitable container, taking the fire away, dropping the seed into the water and allowing it to remain while the water cools down. Alternatively put the seed into a cement mixer and run the mixer for ten minutes.

For the best pasture, the area should be ploughed to remove all existing plants. However, the ground need not be worked to a fine tilth. The new grass should be sown as soon as possible. Some grasses are grown from seed, others by planting vegetative pieces. A legume should be sown at the same time or shortly afterwards.

PASTURE MAINTENANCE.

Other methods can also be used to keep a pasture in good condition.

Cutting after the animals are removed from a paddock removes uneaten growth which has grown old or is of poor quality. New regrowth will come over all of the pasture.

Rolling will break or damage weeds. Where the grass spreads vegetatively, rolling will force additional pieces of stem into the ground where they will root and thicken the grass cover. Vegetatively spread weeds like blue rattail will also be spread.

Chemicals can be used to kill weeds.

Fertilisers can improve growth. Nitrogen fertiliser can be beneficial when the pasture consists only of grass. When a legume is present, nitrogen fertiliser is of little value. Phosphate fertiliser will benefit a legume. Potash fertiliser may be

necessary in some places. Fertiliser use should be discussed with an advisory officer beforehand.

Contributed by: K.C. Willson, Unitech, Box 793, Lae.

A Guide to Better Pastures for the Tropics and Sub-Tropics, Wright Stephenson and Co, Ltd., 330 St. Kilda Road, Melbourne 3004, Australia.

This was distributed free, may be out of print now, but is very very good, and worth trying to find.

An Introduction to Tropical Grasslands Husbandry, by R.J. McIlroy, Oxford U. Press, London, 1964.

This book is already a classic field reference, is found in most DPI offices throughout PNG. Tropical pasture management and improvement are the focus of the book. Grasses and legumes suitable for the tropics are identified and discussed by each species. Level: simple

"More and more often I have the horrible thought that all our spending, instead of building up the community, is destroying the community by teaching it to sit on its backside and put out its hand."

Julius Chan
Post Courier 27/8/75

SELF RELIANCE MAY BE THE FAVOURITE TERM IN PNG THESE DAYS. BUT SO MANY OF US STILL CALL FOR HELP BEFORE WE HAVE MADE GOOD USE OF THE RESOURCES ALREADY AT HAND.

SELF RELIANCE MAY BE THE ABILITY TO DO THINGS WITHOUT HELP, BUT EVEN MORE THAN THAT, IT'S A WAY OF THINKING, A WILL TO SOLVE ONE'S OWN PROBLEMS.

THERES NOTHING WRONG IN ASKING FOR HELP WHEN YOU REALLY NEED IT. THE PROBLEM IS THAT SOME KINDS OF HELP LOCK US INTO PERMANENT ONGOING DEPENDENCY UPON HELP.

SOME OF THE ACTIVITIES FOR IMPORT REPLACEMENT FOR EXAMPLE, MAY OR MAY NOT MAKE US MORE SELF RELIANT. THEY MIGHT MAKE US SELF-SUFFICIENT BUT NOT SELF-RELIANT. THERE'S A DIFFERENCE.

SELF RELIANCE IS THE DEGREE TO WHICH YOU ARE ABLE TO CONTROL YOUR OWN DESTINY. NOBODY IS TOTALLY SELF-RELIANT. WE CAN LIVE WITH INTER-DEPENDENCE. BUT NO NORMAL PERSON OR COMMUNITY WANTS TO BE CONTROLLED BY OR DEPENDENT UPON OUTSIDE FORCES.

IF YOU WANT HELP, BE SURE THAT YOU UNDERSTAND JUST WHAT KIND OF HELP YOU NEED AND CAN CONTROL. THAT'S STILL BEING SELF-RELIANT.

THIS BUK IN YOUR POSSESSION IS NOW ONE OF YOUR RESOURCES, JUST AS YOUR MONEY IN THE BANK, YOUR SKILLS AND KNOWLEDGE, YOUR GROUND AND GROWING GARDENS, YOUR COUNCIL AND YOUR GOVERNMENT. HOW YOU USE ALL OF THESE TO GET WHAT YOU NEED OR WANT IS YOUR MARK OF SELF-RELIANCE.

DOMESTIC RABBIT

Editor's note: Rabbits are illegal in PNG. This article has been included because it contributes accurate, helpful information to this continuing debate. We urge our readers to respect the present law, and at the same time we advocate improving restrictive government policies.

Scientific name: Oryctolagus cuniculous
Description: Domestic rabbits provide meat and the skins can be made into useful pelts. At full growth a Domestic rabbit weighs 4-5kg, giving 2-4kg of meat, depending on the breed. Domestic rabbits may be bred at age 5-6 months and will breed well up to 3 years, occasionally to 6 years. Breeds that do well in the tropics are "New Zealand Whites' and "Californian Whites."

Feeding: It is a common misconseption that Domestic rabbits can survive on a diet of leaves only. Caged rabbits need grain as well.

Breeding: At maturity (5-6 months), Domestic rabbits may be bred. They take 31-32 days for gestation, and may be rebred six weeks after the litter is born. 6 to 8 babies are usually born. Up to four litters a year are possible with good feed.

Housing: This can range from a minimal packing crate that has a few holes for ventilation and a place for food and water to more sophisticated houses especially designed for rabbits. A water-tight roof is necessary.

cont'd

Common pests or diseases: Domestic rabbits get a number of sores and mites that result from dirty or wet cages, and also ringworm. Coccidiosis and diarrhoea are sometimes a problem. Nearly all diseases of Domestic rabbits can be prevented with clean dry housing. And if you don't have secure housing, dogs or cats will get them.

Sources of breeding stock: There are no known supplies of breeding stock in PNG at this time.

Further references: Rabbit raising for Fun and Profit, Farm Bulletin 19, Dept. Development Communications, College of Agriculture, College, Laguna, Philippines, 1967, P1.50; Domestic Rabbit Production George S. Templeton, Interstate Printers, Danville, Illinois 61832, USA. US$6.75; American Rabbit Breeders Assoc. 4323 Murray Ave., Pittsburg, Pa. 15217, USA. US$0.25

It is believed that there has been no experience with rabbits in PNG. But domestic rabbit production is a feature of tropical countries such as Philippines, Indonesia, Mauritius, Nigeria, Vietnam, and Jamaica.

The following is reproduced in whole without comment from The South Pacific Bulletin Vol 24, No 4. pp 19-20, "Rabbits for Meat", by W.P. Bewg, Animal Production Officer, South Pacific Commission:

"Meat is becoming more expensive and demand is increasing. At the same time, attempts are being made to reduce levels of imports to save dollars. Under these circumstances, there is a move in some countries to try and produce more beef, and to become self-supporting, however, many people are not in a position to keep cattle. Almost anyone can keep rabbits. The purpose of this article is to give a general idea of what is involved in domestic rabbit-keeping for anyone who is interested.

"One way in which the Government of Nigeria in West Africa is trying to increase protein consumption in peoples' diets is by encouraging a rabbit industry. Farmers can obtain rabbits from 18 Government breeding centres which produce thousands of rabbits each year.

"Another country, Mauritius, off the coast of Africa, has a similar programme.

"West Germany produces twenty thousand tons a year of domestic rabbit meat. This is equivalent to about half the total recorded meat consumption of the 19 countries in the SPC area.

"Tame rabbits are more efficient converters of food into meat than the usual farm animals like pigs, poultry and cattle. They need less food to produce the same amount of meat as the other animals mentioned.

"Tame rabbits, as they are sometimes called, are quite different from the wild rabbits which are such a pest in Australia and New Zealand. They are much less able to look after themselves outside a cage and their life is not likely to be very long should they escape. They are often white in colour, which makes them easy to see, not very fast runners, and unlike their wild cousins they live on top of the ground instead of in the protection of underground holes.

"Researchers in Australia found that domestic rabbits reared in cages and then released did not reproduce and succumbed to injury, disease and predation.

"The basis of rabbit-keeping is to have one or more females (does), each in a separate cage, and to fatten and eat their offspring. These are usually killed while still young, and are sometimes referred to as "Fryers" because they are suitable for cooking by frying. They are normally ready for killing at eight weeks of age.

"A doe produces her litter 28-30 days after mating, but the young do not come out of the nest until they are about three weeks old. Where the animals are well managed, it is quite possible to mate the doe four times each year and produce four lots of rabbits for killing. All being well, she can produce between 30 and 40 young annually. These will weigh about 40kg alive, representing about 20kg of meat. Slightly more than half (55%) of the animal is carcass meat.

"Old packing cases make good rabbit cages. About ½sq m of floor space is sufficient for one rabbit, but since the doe and her young will be together about 1sq m is recommended for each doe.

"One of the advantages of rabbits is that they eat grass. The better the food, the better they will produce, but green grass, green leaves or legumes and vegetable kitchen scraps will do quite well. Commercially concentrated foods rather like chicken mash or pellets can be fed, of course, this adds to the expense.

"Five minutes spent cutting some green material is often the main work of the day for the domestic rabbit keeper.

"Strong and sometimes emotional views are held by some people on the advisability of keeping domestic rabbits. This is connected with the experience with wild rabbits, particularly in New Zealand and Australia. However tame rabbits are not quite the same animal, and if they escape, they are not so well equipped to survive.

"It is also worth noting that even in Australia, rabbits have not spread into the subtropical and tropical parts of the country and, of course, most Pacific Islands lie in this climatic area.

"For the average householder, rabbits offer an opportunity to produce meat for home consumption without the need to buy expensive feed."

GUINEA PIGS (No Article) (do you know what a baby one of these is called ? a new guinea pig! Bah!)

Fish Culture

TILAPIA MAKAO

Scientific name: Tilapia mossambica

This article will not tell you how to grow tilapia, but it may help you to decide whether or not you should try.

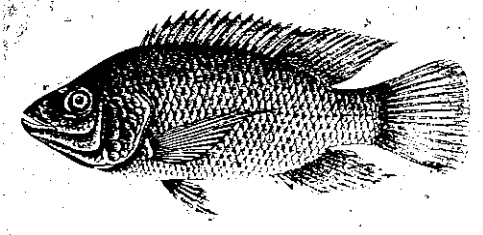

Tilapia was first introduced to the Sepik in 1959. Since then it has spread to all parts of the river and has now become the protein staple for the river people, and a vital part of their economy.

The estimated possible total production is 30,000 tonnes per annum. (Inland Fisheries Research Unit, Angoram) 22,000 tonnes would be utilized for commercial exploitation developed by villages at Angoram, Amboin, Chambri lakes and Ambunti. Production is steadily increasing and has reached 4,000kg per month for marketing.

Work involved in producing salted fish is as follows:

1. Catching: Most of the fish are caught in gill nets set overnight and picked up about 5 o'clock in the morning.
2. Cleaning: Fish are beheaded, de-scaled and cut down the back, leaving the belly skin intact. Guts are removed and the fish is washed carefully.
3. Salting: Fish are laid flat in a plastic bucket between layers of salt, and left for a period of two days.
4. Drying: After removal from the brine, the fish are dried on limbun beds in the sun for 3 or 4 days. Hot air dryers can be used.
5. Packing: Fishermen take the fish to Angoram where it is repacked into 20kg lots for shipment or airfreight.

Initial capital investment required by the people to commence salting operations is K3.00 for purchase of 25kg of salt. It is ideal for low income villagers to start. The price paid to the fishermen is 25t per kilo for their catch.

Fisheries Officers concentrating on a continual supply of this product have now overcome the two major problems of marketing of the fish: transportation and storage. Salted tilapia has proved to keep for a period of months without refrigeration. Tilapia is now economically transported by boat and highway trucks throughout the country.

Fresh Food Markets handle most of the wholesaling, while government institutions can also get Tilapia through their government stores account.

Tilapia has become a popular part of the diet in many PNG villages. The salt is a very valuable component when the tilapia is steamed or mumu'd with kaukau or rice. The tilapia exhibits a 30 to 40% increase in weight when soaked. There is no wastage of tilapia if it is ground or hammered into a fine meal, which can be used as a paste or cake.

Nutritionally tilapia compares favourably with tinned mackerel, but has a lower amount of energy per gram of fish. Tilapia is actually less expensive for the consumer than mackerel for protein. However, mackerel still provides an extra measure of energy in the form or oil. Nutritionists say either type of fish is worthwhile to include in the village diet. Roughly, three tilapia are equal nutritionally to one tin of mackerel.

Trade stores will be interested to know that there is just as much profit per bag of tilapia as per case of imported tinned fish. Wholesale purchase of 48 cans @ 26t per tin and retailing at 30t, leaves K1.92 margin per case. A 10kg bag of tilapia holds approximately 100 fish, wholesaling at 60t per kilo and retails at 10t per fish (k1.00/kg). This leaves between 2.5 to 4t mark-up per fish or K2.50 to K4.00 for storage, handling and profit.

Tilapia is a PNG product, and its promotion will help decrease food imports. It is however, illegal to introduce tilapia to waters where it is not presently established.

For more information approach your business development officer. See book, p 88

Initial contributor: C.T. Kelley, Box 179, Mt. Hagen, WHP.

The Fishes of New Guinea, by Ian Munroe, DPI, Port Moresby, 1967.

This is the definitive book identifying the fishes of the New Guinea waters, if you need such a book. Many colour plates and drawings. Names are the common English names and the scientific names, but no local names are included. Level: advanced.

CARP (No article)
OYSTER (No article)
SHRIMP (No article)

Insects

HONEY BEES

Scientific name: Apis mellifera
Products: Bulk honey or comb honey

Age to first production: A colony will begin production within 6-12 months.

Normal productive life: Under proper management a colony will produce indefinitely. Honey may be extracted every few months for a total of 50kg per colony per year.

Breeds available: Italian strain

Feeding: It should never be necessary to feed colonies in tropics as bees feed from flowers.

Breeding: It is important to have a high quality queen for domestic colonies or for upgrading wild colonies. Under good management a good queen will maintain a strong colony with plenty of foragers.

Housing: Specially constructed wooden hives are required. Plans available from DPI, Box 766, Goroka. Woodware is available from Kubinja High School, Goroka. Other equipment (smokers veils, foundations etc.) from PNG Beekeeping Supplies, Box 319, Goroka.

There are no recorded diseases of bees in PNG. The wax moth, a pest of hives is no problem under good management.

Sources of supply of breeding stock: Wild colonies or hobbyists in PNG. Stock will be available from DPI in late 1977 when research phase is completed. Wild colonies can be upgraded with DPI supplied queens.

Further references: The Australian Beekeeper Magazine, Box 20, Maitland, NSW 2320. A$7.20 per year. Lists articles, suppliers, references. Bee Keeping in the Philippines, Morse & Laigo, 56pp 1968 ₱4.10. Dept. of Development Communication, UPCA College, Laguna, 3720, Philippines.

Location and result of PNG experience: J. Swincer, DPI, Box 766, Goroka. Research still underway but looks promising. Best recorded 12 month production 90kg, average 50kg.

Remarks: The initial costs of a hive are about K30 and the smoker and veil cost K18. Other equipment as desired for protection.

Throughout this article good management is stressed, because it is so important for successful beekeeping. A potential bee keeper should arrange to visit a colony and work with it before investing. Some people have a natural aptitude for bee keeping, and if you are not one of these, bee keeping is probably not for you. Bees need continued proper management to produce well, and if you feel it is too hard you will not have success. If you naturally like looking after bees, your first reward will be pleasure, and the honey will be a bonus.

There are many difficulties with bee keeping. The most discouraging is that even with the best of care, a colony may swarm - that is it will decide to move to another place - and you will have lost the colony.

Initial contributor: J.C. Swincer, DPI,
Box 766, Goroka EHP.

Photos from ONWARD magazine

INSECT REARING (No Article)
INSECT MARKETING (No Article)

SILKWORM REARING

The silk industry in PNG is presently centered at a breeding/experimental station at Kagamuga. A number of village mulberry plantations have been established at various locations in the Southern Highlands, but production has been very low.

Proper temperature and cleanliness are critical for successful silk breeding. A number of mulberry strains have proven suitable for the highlands,

and bombyx worms are the best for these conditions.

Fungus diseases have been a problem, but these can be controlled through strict hygiene. Spore-borne viral diseases are also dangerous and effective preventative methods are being worked on.

Rearing of cocoons has proven successful at Kagamuga, with a high quality silk being produced. Processing is still in the experimental stage.

Growth in this field will only take place if production stabilizes at a high enough level to warrant the necessary capital investment, and if detailed studies prove silk rearing to be an attractive economic activity. Silk cannot be recommended as a viable village activity, at this stage.

Initial contributor: C.T. Kelley, Box 179, Mt. Hagen, WHP.

Wildlife

CROCODILES

Scientific name: Crocodylus spp.

There has been considerable talk in the past year about rearing crocodiles for their skins in village pens. Here are some excerpts from the DPI Bulletin "Raising Crocodiles in Village Pens", by D.F. Puffett:

Some typical prices (subject to change); Fresh water 45 x 10cm belly width, 20-50t; 90 x 20cm, K4.00; belly width 25cm, up to K14.00; belly width 30cm up to K21.00.

A strong pen is essential, either wire or strong poles imbedded in the ground. The height above ground should be at least the length of the longest crocodile you intend to keep.

A pond is needed inside the pen, if possible, lined with wood, as crocodiles can dig into the side of a pond.

Crocodiles 45cm long are good for starting, as they are easy to handle.

It is better not to mix large and small crocodiles as the big ones might eat the small ones. But fresh water crocodiles and salt water crocodiles can be mixed.

The skin of salt water crocodiles is more valuable than that of fresh water crocodiles, because the scales are smaller. But most skins sold in PNG are from fresh water crocodiles.

Crocodiles eat meat from animals, birds and fish. They will live without regular feeding, but do not grow as quickly.

Crocodile meat may be fed back to crocodiles.

People can also eat crocodile meat.

It is normal for some of the crocodiles in the pens to die. But if the skins are recovered quickly, they are marketable.

The easiest way to keep the water in the pond clean is to channel water in from a stream to flush it out.

Shade is necessary.

Another helpful publication: "Crocodile Industry Training Manual" by John Lever, March 1975. Free.

For more complete information, write:
Wild Life Branch
Dept. of Natural Resources
Box 2585
Konedobu.

WILDLIFE

The Wildlife Branch of the Department of Natural Resources has the best record in PNG for sharing information regarding its work. A large number of practical pamphlets on wildlife raising and protection are available. Some of the most interesting are:

69/5 A Guide to Dangerous Snakes in PNG.
71/3 The Preservation of the Garu Wildfowl Egg Grounds
71/6 A National Project for the Conservation of Birds of Paradise in PNG
72/2 Raising Crocodiles in Village Pens
75/2 Wildlife Laws in PNG
75/8 A Deer and Wallaby Farm in PNG
75/9 Wildplant Utilization in PNG
75/19 Proposed Organization of Crocodile Farms in Western Province
75/27 Endangered Animals of PNG
76/4 Collection Export, Research and Filming Involving Wildlife in PNG

There are also two Crocodile Farming Manuals:

Book 1 Low Cost Pen
Book 2 Caring for Crocodiles

There is also a manual on raising Cassowaries

You'll get a complete list of the pamphlets by asking for 75/17 List of Wildlife Leaflets from Wildlife Branch, Box 2585, Konedobu.

CASSOWARY (No Article)
BUTTERFLIES (No Article)

Crop Processing and Utilisation

DRIED BANANAS

In Uganda green bananas (probably plantain varieties) are split and sun dried. The dried bananas are then crushed in a mortar and pestle. The product, a type of flour, is used for porridge or similar recipes.

J. Greve

PRESERVATION OF BREADFRUIT

In the New Hebrides breadfruits are dried and stored for later use.

You will need: Breadfruit
- firewood or coconut shells
- stone
- a portable bed 60cm high made of split bamboo
- Pandanas leaves
- clean salt water

A large pit is dug 30cm deep and a table big enough to cover it is made from bamboo. The pit is filled with stones and a large fire is built on the stones. The breadfruit are put in the fire to cook just long enough to loose their green colour.

Then the breadfruit are cooked they are removed from the fire to cool. When cool the skin is peeled and the breadfruit is cut in half. The part in the middle of the breadfruit is taken out until the wall of the breadfruit is 5cm thick. The breadfruit is washed carefully in fresh seawater, and then placed on the bamboo bed like an upside-down cup

over the hot stones

All the unburnt wood is removed from the fire, and the bed of breadfruit is placed over the hot stones. Each day for four days the breadfruit is dried over hot stones after a big fire has been made to heat the stones.

After four days the breadfruit is dry enough to finish drying in the sun, but first the breadfruits are turned the other side up. After three more days the breadfruit is harder than a dry biscuit.

in the sun

For storage the breadfruit is wrapped in pandanas leaves which have had the thornes removed. They are wrapped tight enough to be sealed from air. In a smoky kitchen or a cool dry place the preserved breadfruit will keep for several years.

Initial contributor: Q.G. Tapisuwe, Vudal, PO Kerevat, ENBP.

CASSAVA (TAPIOCA) STARCH

Starch Production:

(a) The mature roots are first washed to remove dirt and loose soil.

(b) In small-scale operations the roots are then peeled by hand to remove the skin and cortex; on a factory scale only the outer skin is removed, since when processing large quantities of roots it becomes economic to recover the starch from the cortex although it only contains about 50% of that in the core of the root.

(c) The roots are next sliced and put through a rasping or grating machine to produce a slurry or pulp.

(d) The slurry is then sieved to separate the fibrous tissue from the starch milk. Considerable quantities of clean water are used at this stage in order to ensure efficient separation of the starch granules from the slurry.

(e) The starch milk is collected and left in settling tanks for at least six hours, when the starch sinks to the bottom and the liquid is drained away.

(f) The surface layer of the starch mass is usually a yellowish-green colour and contains impurities and is therefore scraped off, leaving a creamy white mass below, which is stirred vigorously with water and then left to settle. This washing and settling process is repeated once or twice more until the starch is judged to be sufficiently pure.

(g) The starch cake is dried, either by spreading it out in trays in the sun or in factories in hot air driers.

(h) Finally, the hard lumps of starch are crushed into a powder and sieved.

It should be pointed out that because the cells of cassava roots are relatively tough, the grinding process must be efficient in order to liberate all the starch granules and to obtain an extraction rate of approximately 20-25% commercially.

USE OF FRESH COCONUTS

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Use of coconut cream and coconut milk is basic. It is added to taro, yams, kaukau, pumpkin, green leaves, cooking bananas, sago, and pit pit. It is also excellent with fish, meat, and fowl.

Coconut cream: Grate the coconut. Add ½ cup of the coconut water or other hot water. Allow this to stand a few minutes. Squeeze with the hands and then put the grated coconut in a piece of cheesecloth or a strainer, and wring or press out the coconut cream.

Coconut milk: Use about 1 cup of water to every 2 cups of scraped coconut. Follow the same procedure as above with the same coconut you have already squeezed the cream from. Or you can skip the first process and do this directly. If the milk stands in the fridge, the cream will come to the top and harden, and it can easily be removed for using in special ways.

Drying: Put the grated or shredded coconut in a shallow pan and dry in the sun, or place in the oven, but stir frequently to keep it from turning brown, in the case of an oven. The sun method may take several days, but takes little effort. The oven is faster, but constant attention is required. Store in tightly covered containers.

Freezing: The grated coconut (not squeezed) can be frozen in plastic bags or containers for use when needed.

Chips for use with dips: As above, the coconut is dried in the oven. However, instead of shedding, it is cut into fine strips.

Baking: This coconut can be used in place of dessicated coconut, even without drying it, if you reduce the amount of liquid in the recipe. This is because there is so much milk in the fleshly grated coconut. For using on top of meringues or cakes, just toss together lightly the freshly grated coconut meat and a bit of sugar. Sprinkle it on the top of the meringue before baking - the sugared coconut turns a nice brown and becomes slightly crispy.

Initial contributor: Lae YWCA, Box 1463, Lae.

OIL FROM COCONUT

This is a traditional method for extracting oil from coconuts. The usual use of such oil has been for oiling the hair and body, especially for feasts. In Tonga you can see plenty of such coconut oil in small bottles being sold in the markets for this purpose.

Coconut oil is also good for cooking, and for making soap. In the Philippines many people in the rural areas used it for fuel during World War II to run their small diesel engines for rice and corn mills when no other fuel was available.

Ingredients needed: mature fresh coconuts

Equipment needed: Large cooking pan
Coconut scraper
Optional - oil press
or optional - cloth bag for squeezing grated coconut.

The Process:

1. Grate the mature fresh coconuts as you would for most cooking purposes.
2. Squeeze out the cream, either with your hands, or with a cotton sack, or better still, with a small press.
3. Rinse out the grated coconut with the water, and squeeze that, too.
4. Cook the combined cream and the rinsed (coconut milk) gently over a fire. The oil will gradually rise to the surface and become somewhat clear. (A small amount of salt, about 3-4% will speed the settling of the solids.
5. Separate oil from water by pouring off the oil.

Note: This oil will not keep for a long time, and it can make people very sick if they eat it when it is too old.

The residue from squeezing the grated coconut is useful for cooking purposes or for animal feed.

PROCESSING GINGER

Utensils: Plastic basins, knives, ladle, plastic film bags, colander (a perforated utensil for draining food).

Raw materials: Ginger, sodium benzoate (or benzoic acid)

The Process: A. For sliced Ginger:

1. Wash fresh whole ginger
2. Peel by scraping off the skin with a knife
3. Slice 25mm thick
4. Dip in 4% sodium benzoate (or benozic acid) solution (2 to 3 tbsp. per litre of water) for 5-10 minutes. Sodium benzoate may be purchased from ICI or from drug companies. Drain off liquid. Spread on wire trays lined with nylon mesh or woven bamboo.
6. Dry in a forced draft drier or any suitable drier at 63-66°C to 5-7% final moisture content or until slices are crisp and feel dry to the fingers. If possible, dry under the sun.
7. Pack in insect-proof containers.

B. For whole Ginger:

1. Wash whole fresh ginger
2. Peel by scraping off the skin with a knife
3. Soak in 4% sodium benzoate solution (one week or longer) in a covered container
4. Spread on wire or bamboo trays
5. Dry in a forced draft drier or any suitable drier at 66-67°C to a final moisture of 9-11% or until the ginger feels dry to the fingers. If possible, dry under the sun.
6. Pack in insect-proof containers.

Initial contributor: A. Hepworth, Box 793, Lae.

GRAIN PROCESSING

RICE PROCESSING

Rice hulls are not tasty, so there are a number of ways to remove them. The cheapest method is to use a mortar and pestle. Cut or burn a dish-shaped hollow in a tree stump and pound a kilogram of paddy with a long post 10 - 15cm in diameter. You will break many grains, and you must later blow away the husks, but all can be done with bush materials.

A more advanced method is a hand operated mill that is like a coffee huller. (below) Properly adjusted it will produce brown or white rice with mostly whole grains. Cost is about K100, but it will last many years. With a large pulley it can be motorized. Order through Plantation Supply and Services.

A larger mill using the same principal is installed at Gabmazung near Lae. Mills of this design produce a lot of bran, polish and brokens, so you should have pigs or chickens nearby to eat the waste. For a larger mill initial cost and maintainance are low.

Most rice mills in PNG use rubber rollers. From the smallest village mill to the big mill at Bainyik rubber rollers are used to separate the hulls from the paddy rice. With rubber rollers there is very little damage to the grain.

Rubber roller mills are more expensive to buy and to maintain because the rollers wear out in 5-20 tonnes of rice, but they are easier to run.

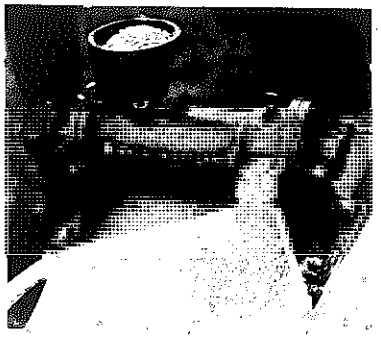

The Gordon rice mill. This mill operates on the same principal as a coffee huller, and is developed from the Engleburg huller. It will easily meet the needs of two or three families.

A rubber roller rice huller. The two "wheels" roll toward each other at the top, but one wheel turns a third faster than the other. There is a small space between the two rollers so that the husk is wiped off but the grain is not broken. (below)

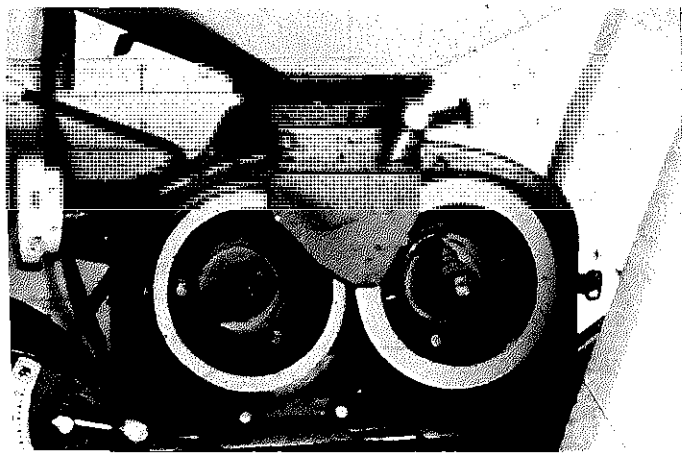

CORN PROCESSING - GRINDING

Many people in PNG eat fresh corn after boiling it or roasting it, but corn can also be kept for a long time until you are ready to eat it if you dry it properly.

Dry corn must usually be processed before eating. It is best to grind it, unless you make it into hominy, but there is no recipe for hominy yet in the Liklik Buk.

Grind the corn, either by breaking it fine in a mortar and pestle, or by using a grinder. You can use a metal grain mill *(p 106)* or a concrete one.

Do not grind more grain than you can eat in 2 or 3 days. The embryo of the grain will be broken during the grinding, and the oil in the embryo will turn rancid quickly in storage.

To get a fine meal from corn you may have to pass it through the grinder several times. Save time by screening the meal through a piece of flywire, and only regrind what does not pass the screen.

You cannot make ordinary bread from corn meal because it is low in gluten protein. There are good recipes to use for cakes and porridge from corn.

DRYING KAUKAU (Sweet potato)

Equipment needed: Plastic film sheets, knives or cutting machine for slicing.
Ingredients required: only kaukau

The Process: Cutting:

a) Select only sound, strong tubers, both large and small
b) Wash. Do not remove skins.
c) Cut with a sharp knife into slices no more than .5cm in thickness (or use slicing device).
d) Put out on clean plastic
e) Use the rubbish kaukau and cut pieces as pig food immediately.

Drying: (1 to 3 days under average conditions)

a) Plastic should lay up and down a slope, so that water has no opportunity to lay in pockets either on or under the plastic.
b) Keep the grass under the plastic cut short. Long wet grass slows down drying considerably.
c) Lay the cut kaukau out in a thin layer. No double layers!
d) When opening plastic in the morning -
   1. Do it early and every day.
   2. Spread the kaukau out so that it covers the whole plastic.
   3. Anchor the edge of the plastic with enough stones to prevent the wind from blowing the plastic shut.
   4. Watch for tends developing, such as leaky plastic, water pockets, etc. and correct them immediately.

e) Black plastic is superior to other colours. It absorbs heat rather than reflecting and therefore dries the kaukau faster.

f) When closing plastic before a rain or in the evening:
   1. Cover properly so that no rain will enter during the night.
   2. Use older, broken plastic as a double layer on top of other plastic to give extra protection.
   3. Use your newest plastic during the rainy days, and the older, cracked plastic during the dry times.
   4. Use stones to help hold down edges.
   5. Roll the bundle half turn, so that the open edge is down.
   6. When the kaukau is dry, get it off quickly and into clean bags.

Storage: Dry kaukau is not hard to store.

1. When dried enough, the kaukau slice will snap, and not bend.
2. Put into a dry house, not on a dirt floor.
3. Weevils do not bother dry kaukau.

Sources of supply of materials: Plastic film found in most builders supply stores.

PNG experience: Dried kaukau has been successfully stored with the above method in the Wapenamanda area for up to one year with no noticeable deterioration.

Initial contributor: M.L. Herman, St. Paul's H.S., Wapenamanda, EP.

KAUKAU FLOUR

Production:

1. Use fresh kaukau. Wash and clean it well. It is not necessary to peel it.
2. Slice this kaukau thinly across the grain into slices about 2-3mm thick.
3. Spread the sliced kaukau out in the sun to dry, if possible on something which will allow air to circulate around it. Dry for 2-3 days, or until slices are quite brittle. Take it in at night and during rainy or damp weather.
4. Grind it.

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Uses:

1. As long as the flour is kept dry it can be stored for quite a long time.
2. It is possible to mumu it using just the kaukau flour, and also to mix it with other ingredients such as peanuts.
3. It can be mixed into a batter and fried in a pan.
4. It has been mixed with wheat flour and used for bread-making.
5. It can be used in soups and stews.
6. Hard or softer biscuits may be made from it. You may like to try some other ways!

Note: Taro and tapiok flour may also be produced by this method. The tapiok must be peeled.

Initial contributors: J.P. Powell, J.S. Tomkins.

FURTHER NOTES ON PROCESSING KAUKAU

1. Remember - processing kaukau can be considerable work. In many situations it will not be worth the trouble. It will be quite difficult during rainy or damp weather without special drying facilities.
2. Dried kaukau is not easy to grind into flour - it tends to be tough.
3. Kaukau flour does not have the desirable properties of wheat flour. It can be substituted for wheat flour up to only about 20% in baking. It is very low in protein. Its taste is not particularly "special".
4. Shredded kaukau dries very nicely and is an attractive form, if dipped momentarily in boiling water (blanching) immediately after shredding. This is a good form for human consumption, and it stores well. All things considered, it probably costs about as much to make as rice costs to buy. If you have the kaukau and the time, it may be worth doing.
5. When re-constituted with water, dried kaukau is less bulky than fresh kaukau, which is good.
6. Dried kaukau may be effectively pulverized and mixed with other materials for animal consumption in an ordinary hammer mill.

NUTMEG AND MACE PROCESSING

Drying can be done on trays in the sun if the sun shines all day for three or four days.

Drying of nutmeg and mace is a very simple operation. After harvest the mace is separated from the seed. The seed or nutmeg is spread evenly on wooden trays and allowed to dry slowly indoors until the seed rattles in the shell. The shell is removed by a tap on the end with a wooden mallet. The nuts are graded according to size and packed for export. Sometimes the nuts are exported in the shells.

The mace is flattened out and spread flatwise on wooden trays and dried in the sun until the colour changes from bright red to yellow. This takes up to six months.

Initial contributor: F.Aia, LAES, Kerevat, ENB.

OIL FROM OIL PALM

Not many people realize that the oil may be extracted from oil palm nuts very easily at the village level. This is widely practiced in West Africa. Doug Franklin, former principal of PATI, has impressively demonstrated the following process.

Village level uses for palm oil: High quality cooking oil, oil for making soap, oil for lamps. Palm oil is rich in Vitamin A.

Ingredients needed: Oil palm nuts.

Equipment needed: Large [illegible] for boiling nuts
Simple oil press
Fine mesh sieve or screen
Containers

The Process:

1. Harvest mature nuts in bunches. A sort of chisel with long handle might be helpful in cutting the main stem of the bunch.
2. Break nuts off the cluster and wash them.
3. Boil the nuts for 30 minutes.
4. Squeeze them in a simple screw-type press. A juice will come out that is mostly water, but also containing considerable oil. Some small bits of pulp will also be present.
5. The oil will rise to the top. Pour it off, separating it from the water.
6. Filter the oil by pouring it through a sieve. The small bits of pulp will be removed. If you want to use the oil immediately, no further treatment is required.
7. If you want to store the oil for weeks or months, heat it briefly to sterilize it. (We do not know the time and temperature, but presume that this is not critical. Make it quite hot but do not allow it to burn).

Palm kernels can be fed to pigs, which quickly learn to crack the shell. Too many palm kernels causes a very yellow fat, and the high fibre slows growth. S.P. Hale says they are a good snack for people.

NOTES: There are quite a number of oil palm trees found around PNG, but many of them were planted simply for ornamental purposes. Extracting oil from these may or may not be worthwhile. The high-yielding hybrid varieties are very worthwhile through this process. Remember that you can not plant a seed from a hybrid tree and get the same kind of tree. Get good seeds from a reliable source.

It is common in West Africa also to extract palm oil by cooking the nuts in a drum, and as oil rises to the surface of the water, to skim it off. We understand that this method is less efficient than using an oil press.

Below: Removing the inner pith of the sago.

PEPPER PROCESSING

Drying can be done on trays in the sun if the sun shines all day for three or four days.

We only recommend black pepper to be processed. To make black pepper harvest when one or two red berries are noticed on the spike. Fruits may be given the following treatment:

a) Dry direct in the sun for 4-6 days.
b) Scald in hot water then sun dry for 3-5 days. To scald the fruits heat the water to 82°C then place the pepper in a wire basket and immerse the contents in the hot water for two minutes. The fruit is properly scalded when the colour changes from green to greyish or when a thin silver skin splits.

When properly dried, the dry berries still attached to the spikes or stalks are either rubbed between the hands or heaped and beaten with a wooden stick until the berries separate from the stalks. The stalks are separated by screening and winnowing. Further screening using a 4.8mm wire mesh removes dust and small foreign objects and immature berries. After screening the berries are floated in water to remove imperfect or immature berries and other foreign objects which float to the top and are washed off. The berries are redried in the sun for 38-48 hours, then packed in either burlap bags or small 2 kilogram plastic bags and stored in a cool airy room.

Drying may also be done in hot air driers when unfavourable weather prevails.

Initial contributor: F.Aia, LAES, Kerevat, ENB.

SAGO PROCESSING

When mature the sago palm is cut down and then cut into 1-2 metre lengths. After the bark is removed the inner pith is scraped out using an adze-like tool with hollowed tips. The pith is beaten and washed in a water trough made from the midrib of an old sago leaf. The fibre is separated from the starch by filters made from sago leaves. The starch and water suspension is allowed to flow to another trough when the starch settles to the bottom and the water flows into the river.

The sago is wrapped in leaves, allowed to drain for a day, and while still in leaves is placed in a very hot fire for one minute. This parcel is rewrapped in leaves for storage or marketing.

For eating the sago meal can be cooked by pouring boiling water over the crushed meal and stirring quickly until it makes a starchy paste. The meal can be fried, with or without grease, and with or without added coconut, meat pieces or fish. It can be baked in leaves and used for snacks or hard rations. It is also used as the starch filler in mumus.

Since sago has only 0.5% protein, a straight diet of sago will result in malnutrition. It is part-

icularly serious if spoiled children eat nothing but sago without supplement. The great value of the sago is that it produces large quantities of storable energy food with relatively little effort. For a balanced diet vegetables and protein must be added.

Sago is not popular in all areas where it is eaten. Where alternative foods are available, sago is considered to be food for taim hangri.

Initial contributor: E. Cox, Baqi Agr. Centre, Box 65, Angoram ESP.

PRODUCTION OF FULL BROWN SUGAR

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There are basically three stages in this process: the extraction of juice from sugar cane, the purification of this juice, and then its crystallization into a full brown sugar.

Extraction from cane:

The juice can be extracted from the cane by means of some roller-type crushing mechanism. We have used old hand-operated clothes wringers to crush the sliced cane. With these the cane must be put through a number of times to extract almost all the juice. If you do not have a strong set of rollers, try
(a) splitting the cane in half, or
(b) pounding it first with a hammer. Sugar crushers are becoming more and more common in PNG, especially home-made ones (see designs).

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Editors note: Don't waste your time trying to use a clothes wringer to squeeze sugar cane. The springs aren't strong enough, and if they were the rollers might break.

Purification of juice:

Strain the freshly crushed juice into a container using a piece of cloth. Then heat the juice to boiling point and continue boiling while carrying out the following steps.

1. Remove scum from the surface using a wire gauze strainer.
2. Obtain a few aibika leaves and stems, or okra, crush with water, and mix a small quantity of the sticky water obtained into the boiling juice. This causes dissolved impurities to form a thick surface scum which can be removed as before. (If the aibika water is quite concentrated, use about 10mls for 2-3kg of juice).
3. Next, the natural acidity of the juice must be neutralized. This can be done by placing some pieces of limestone (either previously heated or not) or some clean wood ash contained in a cloth bag into the boiling juice for quite some time. Remove these before the syrup becomes too concentrated. Or, if you have lime available for chewing betelnut, use about one tablespoon for each 6 litres of juice - just stir it into the juice. Also remove any more dark scum and the waxy material which sticks to the sides of the pot.

cont'd

Crushing sugar cane at Bugandi High School, Lae.

Boiling the sugar juice

Stirring during the final stages, when the sugar is cooling and turning into crystals

Concentration of clear juice into full brown sugar:

As the boiling process is continued, frothing of the syrup will take place. Because of this the container must be fairly deep.

Once the syrup has become quite thick, and it moves easily in the pot, and the bubbles are large and burst noisily, there are two possible methods of continuing the process:

1. Soon after this if there are signs of sugar crystallizing on the sides of the container, this must be stirred in but the heating may be continued. Then crystallization starts to occur in the main mass. This should be poured out and stirred as it cools to break it up.

2. If a short time has elapsed at the above stage without signs of crystallization, it would be wiser to pour it out into another container and stir considerably as it cools. Crystallization should then take place as this cooling and stirring process is continued. This is done because some sugars, generally those with a higher molasses content, do not reach an obvious point of crystallization while being heated, but if taken too far, tend to be darker and have a richer flavour than the ones first mentioned.

The variation between varieties of sugar can only be discovered by actual experience. At present we have produced sugar in the manner described from about 12 cane varieties in the Kagua and Hagen areas which have generally been of very good quality.

Initial contributors: J.P. Powell, J.S. Tomkins.

SOME USES FOR VILLAGE SUGAR

We doubt that production of dark brown sugar at the village level will be a good money earner. But it is fun, especially if done on a social basis, and the concentrated sweets are very good for children who are on a bulky low-fat diet. This type of activity also helps people to realize what nice things they can "create" with materials right at hand. Here are some suggestions:

Uses for raw sugar juice: Filter through a clean cloth, add water and muli (citrus) juice for a refreshing drink. Other juices and pulps from ripe fruit may be added. Much better for you than Coca Cola!

In the final stages of boiling: You can cook kaukau and banana "chips" (thin slices) in it. They will not be crisp, but sweet and "mealy". Or fry the slices in oil first, until crispy, then dip briefly in syrup. Or make small balls of flavoured biscuit dough and cook in the boiling syrup.

Use the dark brown sugar: For fruit jams (see recipes or for coconut candy: 2 cups fresh grated coconut (P 112)
1 cup dark brown sugar

Cook gently for about 20 minutes, stirring constantly. Spread on waxed paper or banana leaves. If you want it to stick together more, for candy bars, add ¼cup of wheat flour before cooking. A little vanilla flavour is nice.

MAKING SUGAR COMMERCIALLY AT THE VILLAGE LEVEL

In India, the dark brown sugar made at the village level is called "Gur" or "Jaggery". Gur making is a traditional cottage industry of India and is one of the major agro-industries of the country. Ordinarily the gur-makers are those who cultivate sugar cane and are self-employed. These notes will help you to understand how it is done.

The process of manufacture is divided into the following stages: 1) crushing, 2) boiling (clarification and concentration), and 3) moulding.

1. Crushing

The extraction efficiency of juice from cane varies with different crushers, ranging from 60 to 65%. Both bullock driven crushers and power driven crushers are available.

The quality of cane is one of the principal factors responsible for the quality of gur. Hence it should be ensured that dried, damaged, diseased, fallen, over-ripe or unripe, over-manured, water-logged, stale, unclean, or improperly cut (many roots and long tops) are not used for quality gur. In case these have to be used, they should be used separately and not mixed with the good cane. For these the process of clarification is more critical.

Accurate weighing of the cane is necessary, as the various checks and calculations are based on the weight of the cane crushed.

Deterioration of the cane starts soon after it is harvested, so it should be crushed as soon as possible.

The fresh juice should go into concrete or steel tanks for measurement and to be readied for the boiling pans.

2. Boiling

a) Clarification of the Juice.

Different types of juice boiling furnaces have been designed according to individual requirements and to suit local conditions. A single pan furnace using 1.25m diameter standard pans is able to boil 75kg of juice per hour, and suits a cane grower working with the bullock driven crusher. To handle the juice obtained from power driven crushers, a furnace having two or more pans is necessary. The pans usually have bottoms ½cm thick or more. The fire is usually in a pan that can be moved from under the sugar juice pan when the syrup reaches the desired stage.

The clarificants in use are either vegetable or chemical. The vegetable clarificants commonly found in PNG would be aibika, okra, castor seed, or peanuts. Ordinarily chemical clarificants are not advisable.

To prepare the vegetable clarificants, the green stems and the roots of the plants are first crushed and then steeped in water. After some time the crushed material is rubbed vigorously in water till a thick mucilagenous liquid is produced in sufficient quantity. The crushed material is again steep-

ed in water and rubbed as above to yield more mucilage. The process is repeated again and again in order to obtain maximum extract which is used in clarification. About 2kg of the plant is sufficient to clarify 45 l of juice.

Peanut kernels or castor seeds are crushed in a mortar or grinder, with water. The resultant milky liquid is then strained through fine cloth and collected in a vessel. The process is repeated while the seeds continue to yield milky fluid, which is used for clarification. Extract of about 1½kg of peanuts or 3kg of castor seed would be enough to clarify 45 l of juice.

Chemical clarificants are helpful when the juice obtained from abnormal quality of cane has to be processed. The commonly used chemical clarificants are lime water, sodium carbonate, sodium bicarbonate, super phosphate, sodium hydrosulphite. The juice of abnormal cane always contains a higher percentage of reducing sugar and the acidity is also high. While the chemicals do improve the clarification, yielding gur of lighter colour, their use involves risk. The acidic chemicals cause inversions of sugar into invert sugar and the alkaline ones make the colour of gur. Moreover, the effect of chemical clarificants is not lasting and the product is not fit for long storage. Therefore the use of chemicals should be made sparingly. When necessary the chemical clarificants are applied after the clarification with vegetable extracts is completed.

Sodium hydrosulphite is a bleaching agent. It is used by some producers because it makes the colour of gur whiter. But this effect is only temporary, as the original colour returns after a few days. An overdose of the chemical also imparts a bad taste to the product.

The clarification of juice plays an important part in the production of a quality product. The main object of clarification is to remove the maximum of impurities and colouring matter at the earliest stage. The cane juice is a liquid which varies in colour from grey to dark green according to the colour of the cane itself. It contains all of the soluble constituents of cane, such as sucrose, reducing sugars, salt, organic, acids, and carries in suspension gums, fine fibres, wax, clay, colouring matter, and albumin.

The juice as received from the crusher is filtered into the first pan on the furnace through a coarse cloth or wire gauze strainer to remove trash and fibre particles. When the quantity of juice is sufficient, it is heated slowly to boiling. In the course of this process the scum appears on the surface of the juice and accumulates to the sides of the pan. At this time a hissing sound is heard from the heated juice in the pan. This should gradually become less and less as the temperature rises. Before the sound stops, the specified quantity of the extract of vegetable clarificants is added to the juice. This is the stage when the temperature of the juice is supposed to have risen to boiling point, and the cracking of the scum layer on the top is well advanced.

The vegetable clarificants have no chemical reaction on the juice. The extract contains vegetable albumins, which coagulate on heating, entangle the suspended and colloidal impurities and bring them up to the surface, where they are skimmed off by means of a perforated ladle.

During the skimming process, care should be taken to see that the juice does not boil vigorously. Otherwise the layer of scum would be disturbed and get mixed up with the juice, causing difficulty in the removal of impurities. In order to reduce vigorous boiling while skimming, cold water is occasionally sprinkled on the juice. The boiling subsides briefly, and the clarification is also helped to a certain extent.

The scums are dark green in the beginning. But towards the completion of clarification these are like white froth. If the scums appear to be still dirty, a further dose of clarificant is given till the froth rising to the surface is perfectly white.

Sometimes it may be found that even repeated additions of vegetable mucilage does not remove the impurities completely, which is indicated by the persistence of the dirty scums. In such cases, a dose of diluted milk (one part milk with 4 parts of water) is very helpful. The milk may be replaced by the milky fluid from crushed peanuts, which is used in the same manner.

The scums removed during clarification contain some juice, which can be filtered out and collected in a container. This juice should be fed back into the pan, as it is liable to deteriorate.

b) Concentration of the juice

In single pan furnaces the clarification and concentration to final stage is carried out in the same pan, while in furnaces having two or more pans the clarified juice is forwarded to consecutive pans in stages. When the clarification of the juice is completed the boiling is accelerated and the concentration of juice into a thick syrup is taken on to "striking point" (the gur stage). There is a lot of frothing in this last stage. To prevent overflowing, an aqueous extract of castor seeds is sprinkled over the surface and the froth subsides immediately. The concentrated juice reaches the striking point at a temperature of 115-117°C. Experienced workmen judge the time for stopping the boiling by the shape and size of the bubbles formed on the surface of the concentrated syrup and from the sound produced from the bursting of the bubbles. Constant stirring is done at this stage so that the heating may be uniform and charring does not take place.

At this stage if a drop of thick syrup is taken out with the help of a wooden rod and dipped in cold water, a hard ball is formed. Or, the hot liquid is taken out with the help of a wooden rod and allowed to trickle down from one end to form a thread which immediately breaks on cooling. Or, if the syrup is stirred, it appears as if it is leaving the bottom of the pan and is not sticky.

3. Moulding

As soon as the juice is concentrated to this stage the pan is removed from the fire and the boiled mass is poured into a shallow cooling pan. The cooling pan for solidifying gur may be of clay, wood, or iron. The mass transferred to the cooling pan is allowed to cool for some time and then stirred and mixed up thoroughly with the help of wooden spoons, and then allowed to cool until it begins to solidify.

It may then be placed in moulds of desired shapes and sizes and kept aside for a few hours for hardening. When ready the blocks are taken out of the moulds, packed in clean containers and stored for disposal.

Initial contributor: A. Hepworth, Box 793, Lae.

(Note: this is a heavily edited version of a paper from India, probably from the Planning and Action Research Institute, Lucknow, India.)

TAPIOCA SAGO MADE FROM CASSAVA STARCH

Tapioca/sago consists of pieces of partly gelatinized cassava starch and can be prepared in the form of flakes, seeds and pearls. In the preparation of tapioca flakes, the moist starch, (see page 91) is rubbed through a sieve of about 20 mesh/in. to give a coarse ground moist flour and partially gelatinized by cooking for about 2 minutes in iron pans previously smeared with oil. The flakes of tapioca are then dried at about 112°F (50°C) to a moisture content of approximately 12%. In the preparation of tapioca seeds or pearls, the sieved damp starch is made into globules by shaking in cloth bags or by the use of mechanically operated granulators. The globules are then graded according to size and gelatinized by roasting them for about 15 minutes on hot pans smeared with coconut oil. They are finally dried in a hot-air drier at 104°-112°F (40-50°C) for about 1.2 - 2 hours; the yield of tapioca from fresh tubers is usually about 25%.

from Root Crops, TPI.

PROCESSING TEA

Although the machinery and processing at a tea factory looks complicated, the steps are simple and easy to duplicate.

Process:

1. Pick only 2 leaves and a bud from the tea bushes
2. Allow the leaves to wither and become soft and limp. This takes about 24 hours if the leaf is spread out thinly (1kg of green leaf covering 2.7 sq metres of stretched jute or lap lap). Tea should lose nearly half its original weight during this period.
3. Rub the withered leaves firmly between the palms of the hand. This is necessary to bruise the cells of the leaves and to spread the juices over the entire leaf surface.
4. Cover a bulk of the leaves. A "fermentation" now occurs. (Do not let the leaf mass overheat). Maximum allowable temperatures 27-33°C. During this time the leaf turns dark and a tea aroma develops. This should take less than 4 hours. Over-fermented teas are less soluble and therefore weaker when brewed.
5. To kill the fermentation: The fermented mass should be (a) Dried in an oven, preferably with the oven door partly open to prevent "stewing", using temperatures of 54-66°C.
   (b) Spread very thinly on a sheet of clean flat iron and dry in the sun until brittle dry.
6. Tea will pick up moisture from the air and go mouldy, therefore store it in a airtight container.
7. 1kg of Green Leaf should make 200g of tea. Altogether in 1976 PNG had approximately 3800 ha of tea planted and produced 6000 tonnes of made tea. Production per hectare is still rising.

Experience in PNG: DPI carries out clonal selection, testing, and multiplication at Kuk Tea Research Station near Mt. Hagen, WHP.

Contributed by: D.W. Kidd, Box 312, Mt. Hagen, WHP

THE PREPARATION OF TUMERIC

Tumeric is one of the chief ingredients of curry powders, giving a yellow colour as well as a spicy flavour to the curry. It consists of the dried, boiled rhizomes of Curcuma longa L., a plant cultivated extensively in India, Sri Lanka, and Indonesia. It is usually propagated by means of setts or small portions of the rhizome. Its cultural requirements are similar to those of ginger, to which it is closely related. The rhizomes are harvested during dry weather, after the leaves and stems have withered. The whole clumps are lifted carefully, adherent earth removed, and the fibrous roots cut off. The rhizomes are then broken up, the secondary lateral rhizomes being known as "fingers" (on account of their shape), and the main stem producing rhizomes, which are shorter and thicker, as "bulbs". These bulbs may be cured separately, either whole or cut in halves or quarters. These are known as "splits".

Curing consists of 1) boiling the rhizomes in water, 2) drying in the sun, and 3) "polishing".

The rhizomes are placed in a large iron pan or earthenware pot, and sufficient water is added to cover them to a depth of 5 to 8 cm, and the rhizomes boiled over a slow fire until they are soft; this may require from two to four hours. They are tested for completion of cooking in the same way as potatoes, with a thin pointed stick. When they are sufficiently cooked, the stick will penetrate easily. Overcooking and undercooking should both be avoided, as this yields an inferior

product.

The rhizomes are then removed from the boiler, spread out in a thin layer in the sun and dried. They should be turned over from time to time, and at night they should be heaped and covered over. Drying requires up to 10 days.

When thoroughly dry, the rhizomes are "peeled" or "polished". This was formerly done by rubbing with the hands or feet, but it is now done either by shaking the rhizomes, mixed with stones, in a long narrow gunny bag, or in a bamboo basket, or by rotating them in a polishing drum.

A polishing drum may be made from wooden cask or barrel, closed at both ends. It is provided with a small door 15-20cm in the side, and is perforated all round with holes about ½cm in diameter and 10-15cm apart. The barrel is fitted with a central axle, in the form of an iron rod long enough to project horizontally on two wooden posts. It is turned by means of a handle fixed to one end of the axle.

After tumeric is polished, it is ready for export. For use it is either ground, or pounded, or grated.

Initial contributor: A. Hepworth, Box 793, Lae.

VANILLA PROCESSING

Vanilla is a flavouring material and comes from the Capsules (pods) of the vanilla plant, which is an orchid.

1. The pods are harvested when slightly yellow. These are placed indoors for 10 days to wilt (become brown).
2. After wilting the pods are exposed to the sun for three hours each day for 10-20 days till oily in appearance.
3. Exposure to sun is reduced to one hour after 10-20 days until the pods reach correct moisture (30%).
4. The dried pods are sorted, graded into different lengths then tied into 200 g bundles.
5. The bundles are placed in air tight containers and conditioned for 3-4 months.
6. After conditioning, the bundles are packed in cartons for export.

Initial contributor: F. Aia, LAES, Kerevat, ENBP.

YAM PROCESSING

(a) Yam dough - the yams are peeled and any inedible parts removed, then are then cut into small pieces and boiled in water until soft. After this they are pounded in a mortar until a glutinous dough is formed, which is usually sufficiently firm to be cut into slices.

(b) Yam flour - traditionally the tubers are sliced to a thickness of approximately 1cm, peeled and dried in the sun. After drying, the hard pieces of yam are ground or milled to give a coarse flour. Recently the following improved method has been developed for use in W. Africa. After washing thoroughly under running water, the tubers are cut into slices approximately 5cm thick and cooked for 20-25 minutes or until soft, after which they are peeled and mashed into a pulp, which is spread out to a depth of about 2cm and dried for 6-8 hours at a temperature of 122-158°F (50-70°C), until the moisture content is 10% or less. The dried product is next finely ground and passed through a sieve before being packed into polyethylene sacks.

from Root Crops, TPI.

> Our objective is not to be "well-liked", but to support people in their process of growth, whether they like it at the moment or not. In the short run many persons would rather be dependent than alive and growing. So we can't just do whatever people say they want us to do. In the long run, persons appreciate the ones who help them to grow, not the ones upon whom they have become dependent.

THAT LAST IDEA SOUNDED EASY, DIDN'T IT? YOU THINK THAT YOU COULD WRITE SOMETHING LIKE THAT, TOO, DON'T YOU?

WE'LL BET YOU A COPY OF THE NEXT EDITION OF THE LIKLIK BUK THAT YOU CAN WRITE AN ARTICLE THAT WILL BE ACCEPTED.

LOOK ON PAGE 268 FOR INSTRUCTIONS ON HOW TO SUBMIT A CONTRIBUTION.

Livestock Processing and Utilisation

PASTEURIZATION OF MILK AND CREAM

Pasteurization is a mild, carefully controlled heating process which effectively halts many dreaded milk-borne diseases.

Raw milk or cream may be pasteurized at home in one of the three following ways. The first two require the use of a dairy thermometer and all demand a quick cooling of the processing water or pan so that the milk does not take on a "cooked" taste.

1. This is the preferred method: Arrange empty, sterile, glass, heatproof jars on a rack, in a deep kettle. Allow 2.5cm - 5cm of headroom when you pour the raw milk or cream into the jars. Fill the kettle with water until it comes above the fill line of the milk in the jars. Put the thermometer in one of the jars. Heat the water, and when the thermometer registers 72°C hold the heat at that temperature for 15-30 minutes. Cool the water rapidly to about 10°C. Refrigerate, covered, at once.

2. This method is more apt to leave a cooked taste, as the heat is harder to control then in 1. Heat milk or cream slowly over direct heat to 60°C and keep it there for 30 minutes. Plunge the pan at once into ice water and reduce the heat to about 10°C. Refrigerate, covered, at once, in sterile jars.

3. This method should be used only in emergencies, as the milk flavor is definitely altered. Place the milk to a 2.5cm depth in a wide pan and bring it quickly to a rolling boil, stirring constantly. As soon as the boiling reaches its full peak, reduce the heat by plunging the pan into ice water. When the bottom of the pan is cool enough to touch, refrigerate the milk at once in covered sterile jars.

(From the Joy of Cooking, by Rombauer & Beckker) (P 122)

BUTTER AND BUTTERMILK

Butter: Let cream sit in a litre jar until slightly sour (or use a buttermilk starter). Leave ½ air space. When sour, shake jar. Release the gas from time to time by loosening the lid. When the fat has separated from the liquid, the butter is made. Gather the fat globules with a fork into a bowl and rinse well, pressing the butter to get all the buttermilk out (if left in, it sours). Salt if desired.

Buttermilk: Use in baking instead of whole milk. Substitute 1 tsp. baking soda for 3 tsp baking powder when using buttermilk, and no lemon.

Buttermilk pancakes:

2 cups whole wheat flour	1 egg
½ tsp salt	1 tsp baking soda
2tbs fat	2 cups buttermilk

Mix well and drop from a spoon into small cakes into a hot, greased skillet. Turn when bubbles appear on one side. Brown on other side.

H. Bekker.

Ghee

1. Boil the butter gently until the milk fat is clarified and all water evaporated.
2. Filter.
3. Pack in bottles or tins. Stock in a cool place.

CHEESE

Because milk in the tropics spoils rapidly, many people are interested in making cheese to preserve the food value of milk. There are nearly as many recipes as there are people who make it. Here are a few that have been tried in PNG.

Definitions:-

Curd: the nearly solid portion of soured milk

Whey: the liquid part of soured milk. It can be substituted for milk in all baking.

Rennet: an enzyme derived from the largest stomach (omasum) of unweaned ruminant animals (goats, cattle, sheep, buffaloes)

Rennet is available in tablets in the supermarket as Junket Tablets or you can make your own. When a 2-4 week old calf or goat is killed the largest of the four stomachs, the omasum, is saved to extract the enzyme rennin. The omasum can be identified also by the pleats inside and the usual presence of curds.

Fill a litre jar with brine. Make brine by dissolving as much salt as possible in warm water, and then add a little more for the omasum to absorb. When the brine has cooled add the clean omasum and then store in a cool place. The omasum from a young goat will provide rennet for up to 60kg of cheese.

Fresh milk to make cheese should first be strained through a sterile cloth, then pasteurized by heat quickly to a boil, then allowing to cool. Full fat milk powder when dissolved according to the manufacturer's instructions can be used directly.

ONE SIMPLE METHOD OF MAKING CREAM CHEESE

Warm the milk to body temperature and add 1 teaspoon of lemon juice per litre of milk. Pour the milk into a clean container, cover with a clean cloth and allow it to ripen in a warm place for one day. (At this stage the milk should smell sour but should be thrown away if it smells putrid).

After the milk has ripened, warm again to blood

temperature and add rennet (junket tablets from Supermarkets) in half the quantity that is used for making junket. Stir and leave to coagulate for 8-12 hours (overnight).

Sterilize some muslin, cheesecloth or thin laplap by boiling in water. Stir the coagulated milk, scoop it into the cloth and hang the cloth by the corners to drain out the whey. Let the curds drain for 2 days stirring the curds twice a day to help the whey drain out.

Remove the new cheese from the muslin and mix with salt to taste. This is a type of cream cheese that will keep for a few weeks in the refrigerator. Interesting ways of eating this cheese are to mix it with finely chopped herbs, onions or fruits such as pineapple and then to spread on bread.

To make a cheese which keeps longer, more of the moisture should be removed. Turn the salted cream cheese into a mould with a sterile cloth and press for about 3 days with a weighted board, turning the cheese daily. A cake tin with a removable bottom may be used as a mould. This is a type of white cheese. The addition of 1 teaspoon of commercial yoghurt per litre to the milk before ripening will give cheese another flavour.

Initial contributor: A. Hepworth, Box 793, Lae.

MULI CHEESE

Materials and equipment needed:

4.5 litres (1 quart) milk
2 tablespoons vinegar or juice of two large lemons
One cloth

Optional: 2 tablespoons butter
½ teaspoon salt

Process:

Boil the milk (even powdered milk can be used)
Remove from the heat and immediately add the vinegar or muli juice.
Stir this mixture until well mixed and then let the solid portion coagulate out from the whey (liquid portion).
Pour everything into a cloth; tie the cloth up and squeeze the cloth until most of the liquid is extracted. This liquid can be fed to animals.
Three days later you have cheese which can be eaten as it is or can be further processed.
To further process the cheese, cook the cheese with the butter and salt; cool the mixture and press into the desired shape. The cheese can be refrigerated or tied in banana leaves. Flavour improves with age, but never entirely loses muli taste.

Initial contributor: J.T. Hale, Box 215, Wewak, ESP.

COTTAGE CHEESE: Put 8 litres of milk into an enamel pan. Slowly heat until it is lukewarm. Remove it from the heat. Add 2-3 teaspoons of rennet solution. Stir once or twice. Let sit in a warm place until set. Test by inserting a finger and lifting it. If the whey floats in the space made by the finger and the space is clear, it is ready.

Stir with hands until the curds are small and evenly broken.

Put a cheese cloth on a bucket and use clothespins to hold the cloth in place. Strain the whey off the curds. After all the whey has dripped through, salt the curds and hang the cheesecloth with a looped string with a container underneath to catch the last drops. Use when dry.

CHEESE CURD: Same as for cottage cheese, but do not break the curds. Pour into cloth and drain. Allow to stand for 12-24 hours. Cut the solid cheese into small squares or use in slices.

FRENCH GOAT CHEESE: To 8 litres of still warm goat's milk, add 2-3 teaspoons of rennet solution. Let stand in warm room for 12-30 hours. When whey is yellow liquid and the curd is floating in a chunk, it is ready. Pour off whey and spoon curds into moulds. (Tuna or lard cans with both ends cut off). Let drain approximately 12 hours and turn and drain another 6-12 hours. Salt sides as cheese is turned. Can be eaten fresh or old as desired. Pack in oil to keep. Cheese is soft, mild and tasty.

RICOTTA CHEESE WITH WHEY: Bring whey to near boil. Skim off curds, salt and hang for a day.

NORWEGIAN WHEY CHEESE (best with goat whey): Boil whey down (takes a day) stirring occasionally. When thick and brown, stir more often. Add some cream, lower heat and let thicken. Pour into buttered dish. Use as spread on biscuits.

CULTURES FOR MAKING CHEESE

Rennet and Cultures from:

Australian Rennet Manufacturing Co. Ltd.,
23 Fuller Street,
Walkerville, S.A.

Phone Adelaide M.L. 2491
Cables: "RENNETCO WALKERVILLE"

Prices work out at about .1¢ per gallon of milk for cottage cheese. Other cultures are from $2.00 to $3.00 for starter. Of course once you get your own starter you can continue propagating it if you are careful.

PRESERVING MEAT AND FISH: We have received a great many contributions for the Liklik Buk on how to preserve meat and fish. In general they fall into two ways: salting and smoking. There are so many different variations that we cannot give them all.

Traditional preservation allowed excess meat and fish to be stored only a few weeks at the most, and generally required constant attention during the storage period. Today the traditional methods remain popular in the face of tinned meat and fish largely because of the special taste, but not because they facilitate trade or long term storage.

TRADITIONAL SMOKING: The meat or cleaned fish is cut into convenient sizes and placed on a rack about 60cm over a fire. Various techniques are used to direct the smoke to the meat. Most "smoking" processes are basically dry cooking and a medium amount of preservation by the smoke occurs. The meat will sometimes keep for up to a month, but only if it is kept in the smoke of a fire.

TRADITIONAL SALTING: Some traditional salting methods for meat and fish will keep indefinitely, and their basic techniques are similar to long term preservation methods. The short term preservation by salting is to drain the meat or fish of all blood remove all scales from the fish and proceed to rub salt on all surfaces until it is fully absorbed into the flesh and any more that is added remains on the surface. Meat should be cut to slices 2-3cm thick. Meat salted in this fashion is left on a rack in the sun during the day, and in a bag of salt at night until it is required for use. As with all salted meat or fish a long soak in fresh water is needed before eating.

Thanks to P. Amamagi & B. Awagem of Vudal: and T. Nohoro, I. Kaipo. G. Bevan, W. Ruki, A. Sumunda, K. Sumunda and J. Down of PATI.

DRIED SALTED MEAT (SIMPLE PROCESS) "JERKY"

You can use any cut of meat to make "Jerky". Cut the meat with the grain into strips 2.5cm wide and 1cm thick. Make them any length you can. Prepare a brine of 7 litres of water to 1kg of salt (the brine should be salty enough to float an egg in its shell). Soak the strips for 2 days in the brine. Remove and wipe dry. Hang the strips of meat in the sun to dry; they may be pinned to the clothesline with spring clips. When they are dry they may be smoked or simply stored as is in an airy place well protected with netting.

(From The Last Whole Earth Catalogue)

JERKY or BILTONG (as it is called in South Africa):

I make it by cutting the meat into strips as described above, but I do not prepare a brine - I simply salt the meat liberally and leave in a container overnight - drain off the liquor - resalt with a mixture of salt and curry powder and hang up to dry as described. It is important to keep the flies off the meat until the outside of the meat is no longer wet - otherwise blow flies will lay their eggs in it and make it rot. Cover with fly wire or mosquito net.

Contributed by: J. Greve, DPI., Konedobu.

BRINE CURING: As well as salting, meat and fish can be preserved in brine, which is made from salt, sugar, potassium nitrate (saltpetre), and water.

You will need:
4kg salt,
1kg sugar
60gm saltpetre (from a chemist)
22 litres of clean fresh water
a large plastic container

1. Mix the ingredients in the water to make the brine. You can do this directly in the plastic container, but be sure that everything is dissolved.

2. Cut the meat into convenient sizes, after the blood is all drained from the meat. Long thin pieces cure more quickly than thick pieces. You should weigh all the meat at this time, so you will know how long to keep the meat in the brine. The meat should remain in the brine for 6-8 days for each kilogram of meat, or longer if the pieces are thick.

3. Place the meat in the container of brine, as much as you have, but don't let any meat stick above the brine. Use a stone to stop the meat from floating.

4. Put the container in a cool place. If it is not cool, you may see a green slime beginning to grow on the top of the brine. If this happens you will have to throw out the brine and make new brine or the meat will spoil.

5. Once a week take the meat out of the brine and then repack it in the container. You can use the same brine, if it is not slimey. The repacking ensures even curing of the meat.

6. The meat should stay in the brine 6-8 days for each kilogram of meat. That is, for 1 kg it should stay 6-8 days, but for 4kg it will need 24-30 days, and for 10kg it will need 60-80 days.

7. After curing take the meat out and let it drain before you smoke it. Of course at any time you like you can take the meat out if you are going to eat it.

Contributed by: R. Bassett, HATI, Box 312, Mt. Hagen.

DRY SALT PRESERVATION OF MEAT AND FISH:

You will need:

1kg salt for each kg meat or fish
a large container - a plastic rubbish bin, a clay pot or a good wood box.

1. The meat should be hung for one day to allow all blood to drain from it. All bones should be removed because the salt will not enter the marrow of the bone and the marrow will spoil. Cut the meat into strips no wider than 30cm and no thicker than 10cm, but as long as you like. Make sure there is no fat on the meat.

cont'd

2. Rub plenty of salt into all sides of each piece of meat.

3. Then put the meat into a container that has first had about 5cm of salt placed in the bottom. Make the first layer and be sure no piece is touching its neighbour. Cover the first layer of meat completely with salt, then put another layer of meat, continue until the meat is finished, and put a final layer of salt on top. Put a cover on top and a heavy stone on the cover to act as a press.

4. After 2-3 weeks the meat can be removed for smoking, but it can be left in the salt without spoiling for as long as you like.

Remarks: When the meat is finished, you can use the salt for the next batch of meat.

If the meat is not well drained you will see blood in the salt after some time. This will not keep well, and the meat should be repacked.

Initial contributor: R. Basset, HATI, Box 312, Mt. Hagen.

SMOKING MEAT: You cannot store smoked meat very long unless you have salted it or cured it in brine first. Smoking serves a number of purposes.

1. It improves the flavour of the meat.
2. It will dry the meat if the smoke is warm.
3. It protects the meat while it is in the smoke by keeping the flies away that carry the bacteria that start spoilage.
4. The smoke that stays in the meat will help the meat keep longer.

The idea of smoking meat is to dry the meat only slightly, but not to cook it while the smoke is getting into it. This improves the flavour. Here is a simple smoking house built from a drum, but you can use a tightly built box as well.

Cover the trench with roofing iron or plants or bush timber and leaves and cover it all with soil to keep the smoke in. Hang the meat with wire from rods or sticks poked through the sides of the drum or box. You don't want to lay the meat on wire mesh or it will not smoke evenly.

Build a fire in the fire pit and when it is burning well cover the pit so the smoke will have to go out past the meat. If you are smoking brine cured meat you must have a cold smoke or the meat will begin to cook. A cold smoke is from a very slow burning fire, and one of the best ways is to burn dry hardwood sawdust.

Initial contributor: R. Basset, HATI, Box 312, Mt. Hagen.

FISH: CURING AT HOME: The best way to keep fish is to keep them alive, but that's not always possible. If you have no ice or refrigeration then smoking or salting are practical ways to preserve fish at village level. These are simple methods which do not require much equipment. It should be understood, though, that these methods do not preserve fish for a very long time, like tinned fish.

There are several methods which are called "curing". Dry salting, salting with water/salt solution, hot smoking, and cold smoking. Do not try to air-dry fish when you have rainy or damp weather. (P 121)

It is important to know the basic principles and rules, so send for this helpful pamphlet before you try: "Home Curing Fish",
A Guide for Extension and Village Workers,
Department of Primary Industry,
Kanudi Fisheries Station,
Box 2417,
Konedobu.

Another booklet is available which tells about cutting various types of fish, with many good photographs:
"An Illustrated Guide to Fish Preparation",
Rogers, Cole, and Smith 73pp.
Tropical Products Institute,
56/62 Gray's Inn Road,
London WCIX 8LV, England. Price: Pounds1.40 including postage.

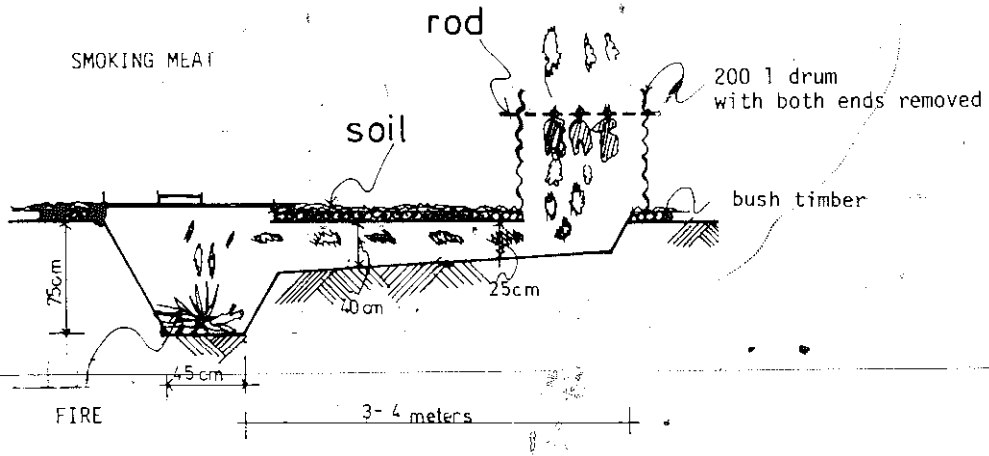

Some new Fisheries Research and Development items which technically oriented readers may want to follow (Through Tropical Products Institute, 56-62 Gray's Inn Road, London WCIX 8LU, England):

(a) Storage in Ice:

It has been discovered that tropical fish stay fresh longer in ice than temperate or cold water fish, probably because spoilage bacteria and the fishes' own enzymes are adapted to the high temperatures of the tropics. This could mean that simpler and less expensive small scale fishing enterprises may be possible than it was earlier thought.

(b) Smoking Kilns:

Overheating of fish during smoking can cause significent losses of certain amino acids (protein). Design of smoking kilns is being studied carefully.

(c) Fish Silage:

Sometimes the daily catch of fish is so much more than usual that fish goes to waste. But usually the amounts are too small to justify making fish meal. Minced or chopped fish is acidified to pH 3.0 and allowed to hydrolyse to form fish silage. A carbohydrate filter is then added to absorb moisture. Afterwards the product is sun-dried and powdered for use as an animal feed. Feeding trials indicate that it may be used as an ingredient, but not as a complete feed.

(d) Shark/Salt Cake:

Low-value fish may be stored for a long time in the form of a simple fish/salt cake. Initial taste trials are encouraging and further research is being done.

Suggested by: J. Gluckman, DPI Fisheries
Box 2417, Konedobu.

Processing and Utilization of Animal By-products, by I. Mann. FAO Agricultural Development Paper, No. 175. 2nd printing 1967,246pp, US$3.00.

One of the best FAO Technical Papers around. It has excellent diagrams and pictures that show how to build the tools for processing animal by-products. Very appropriate technology, particularly where slaughtering is a small scale operation.

Gives processes for meat meal, blood meal, bone meal, hide preservation, glue manufacture and the utilization of horns, hooves, glands, casings, and compost, as well as the generation of methane gas from any remaining waste. Designs are low cost; more sophisticated designs are briefly described.

An excellent manual for designs appropriate to village economies. It is clear, simple, and complete. It is probable that PNG Public Health regulations would forbid many of the designs.

Niugini Table Birds Pty. Ltd.,
Box 1152, Lae. Telephone No 422229.

Pricelist available only.
Buys: Produce Poultry Products

Niugini Table Birds Pty. Ltd., is primarily a poultry abattoir and processor. Through extensions and management officers they are affiliated with breeder farms and broiler growers. The company owns its own abattoir producing fresh broilers. They are supported in production by over 120 independent local farmers who produce all of their unprocessed birds.

Agents for Niugini Table Birds, Pty. Ltd., Ross Michael, Managing Director, Michael PNG Pty Ltd.

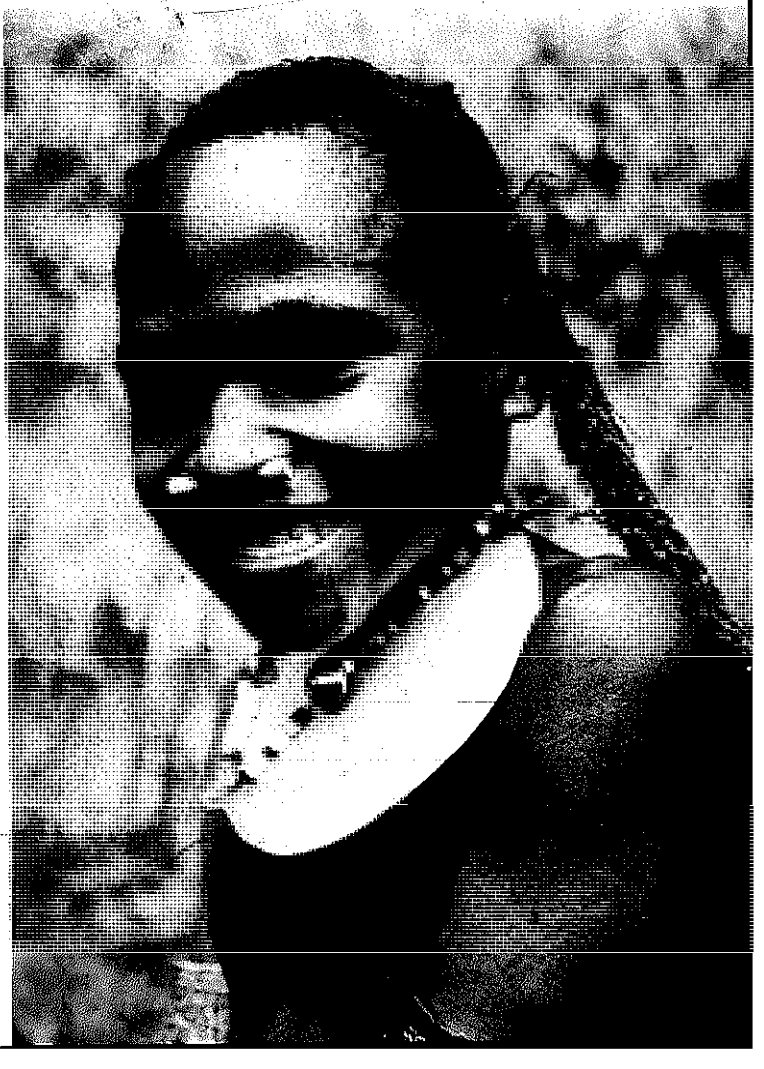

Food Preparation

DRIED LEGUMES

SOYBEANS, PEANUTS, COWPEAS, MUNG BEANS, WINGED BEANS, AND OTHER SMALL DRIED BEANS MAY ALL BE USED WITH THE FOLLOWING RECIPES.

SAMPLE RECIPES FOR DRIED LEGUMES

Selected from The Health Aspects of Food and Nutrition, World Health Organization, Western Pacific Regional Office, Manila, 1969.

These recipes are intended only as guides and samples. They should be adjusted, revised, and flavoured according to local tastes and available foods.

Some useful equivalents for these recipes:

1 tsp. = 5 grams water; 1 tbsp = 15 grams water or 10 grams dried beans

3 level tsps make 1 level tbsp
8 level tbsp make ½ breakfast cup (approx 120 cc)
1 cup = 240 cc.
2 cups make 1 pint (approx 500 cc)
2 pints make approx 1 liter (1000 cc)
8 pints or 4 liters make 1 gallon
4 cups make approx 1 liter
1 liter of water weighs 1 kg = 2.2 pounds

1 large breakfast cup holds about 200 cc water, (as drunk)
1 large breakfast cup brimful holds 250 cc water
1 large breakfast cup brimful holds 170 gr dried beans

INFANT FEEDING RECIPES
(for infants 4 - 12 months) (p 93) (p 176)

Notes on preparation of infant foods in general:

a. Grinding- Fine pounding or grinding or mashing and sieving is often necessary. For home use, a mortar and pestle may be used. (p 107). For quantity preparation of dried beans and cereals, a grinder made of stone (traditional style) or iron (commercial) is convenient.
b. Mashing and sieving- For older infants (7 - 12 months) many foods can be thoroughly mashed with a fork. For younger infants (4-6 months) they should be mashed and then sieved or strained.
c. Pulping- For soft-cooked vegetables, cheap lightweight vegetable mills or grinders are available and very effective.

The left-hand column gives the quantity for one serving (Home use). The right hand column gives the quantity for ten servings (feeding stations).

1. DRIED BEANS-RICE PORRIDGE

	For one	For ten
Dried beans	2 tbsp.	1½ cups
Rice	2 tbsp.	1½ cups
Water	1 cup	8 cups
*Milk powder (*if available)	1 tbsp	2/3 cup
Brown sugar	1 tbsp	2/3 cup

a. Prepare dried bean flour and rice flour from well-dried beans and rice by pounding or grinding. If thorough drying in sunlight is not possible, heating gently over a low fire helps to yield a fine flour.
(Flour of dried beans or rice may keep for one month in an airtight container, if the grains are first slowly toasted for fifteen minutes until golden brown, then ground or pounded and quickly stored in the air-tight container.)

A flour which is more readily soluble in water can be made by boiling the beans for 30 minutes, then drying thoroughly and finally pounding or grinding.
b. Blend dried bean flour and rice flour in small amount of cold water.
c. Boil remaining water and add mixture, stirring constantly to prevent scorching.
d. Add sugar and milk, or fish flour* (*if available).
e. Cook for fifteen minutes more to a soft custard consistency, adding more water if necessary.

This simple type of hand driven grain mill is very useful in preparing ground legume recipes.

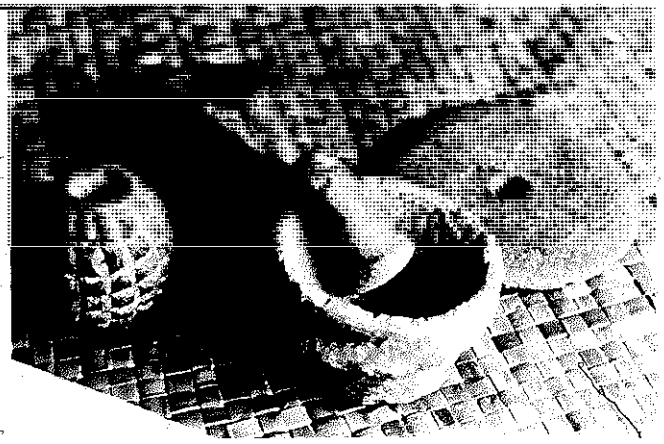

The traditional mortar and pestle may be used for crushing grain legumes.

f. Serve warm to infants four months of age and over** (The stool may be more bulky and softer than usual but this is not harmful).

**Although this mixture is in general recommended to begin only after 4 months, in circumstances where no breast milk or artificial milk is available, it is known that it can be tolerated by infants even in the first months of life, if begun initially in small quantities.

2. MIXED VEGETABLE/DRIED BEANS PUREE

	For one	For ten
Sweet potato (yellow), mashed	2 tbsp	1½ cups
Dark leafy greens	¼ cup	2½ cups
Dried beans (any type)	2 tbsp	1½ cups
Water	1½ cups	12 cups
Salt	½ tsp	1 tbsp
Milk powder* (or any milk available), or fish flour		

a. Boil dried beans until soft (½ - 1 hour); mash.
b. Boil sweet potato until soft (10-20 minutes); remove skin and mash.
c. Boil the dark leafy greens with a little water and salt for 5 minutes. Mash.
d. Mix all these ingredients and pass through a sieve (for infants 4 - 6 months.)
e. Add the milk (dissolved in one-half cup water) and cook for another 5 minutes, stirring constantly.
f. Serve warm to infants four months and over.

* if available

3. SOYBEAN SOUP

Soybeans	2 tbsp	1½ cups
Salt	¼ tsp	1 tbsp
Water	1 cup	8 cups
Any dark leafy greens	½ cup	2½ cups

a. Put soybeans in excess water. Remove the imperfect beans (which float). Soak overnight or about twelve hours. Drain. (The water used for soaking may have a slight bitter and beany taste, therefore change the water before cooking.)
b. Boil in clean water until tender (1-2 hours).
c. Boil the dark leafy greens in a small amount of water for three minutes.
d. Pass cooked soybeans and leaves through a grinder (either stone or metal).
e. Cook for five minutes more.
f. Serve warm to infants six months and above.

4. SOYBEAN PUREE WITH COCONUT MILK

Soybeans	2 tbsp	1½ cups
Coconut milk	¼ cup	2½ cups
Salt	¼ tsp	1 tbsp

a. Prepare soybeans as in recipe 3 steps a and b.
b. Pound or pass soybeans through a grinder. Boil again for five minutes.
c. Add coconut milk to soybeans (coconut milk is the diluted coconut cream, or the product obtained by repeated washing of the residue after first expressing the cream).
d. Cook for five minutes. Add salt.
e. Serve warm to infants six months and above.

5. GROUND PEANUT BALL

Peanuts, shelled	¼ cup	2½ cups

a. Slowly bake or toast selected mature well dried peanuts (without moulds) until golden brown (at least half hour). Do not allow to burn.
b. Remove the skin (optional)
c. Pound or grind finely, using pestle and mortar or corn grinder. Wash hands and form ground peanut into balls.
d. Feed one whole ball daily to infants over six months, or toddlers, along with any other food. (Divide into 2 or 3 portions, if not all consumed at once.)

Note: Ground peanuts should be stored in clean, tightly covered containers, when preparation is not consumed in one serving. Commercial peanut butter is not recommended for infants because the ingredients (coconut oil, etc.) and the quality can not be controlled.

Working for the people.

Working for thank you.

These are two different things, and there is often goal conflict between them.

6. PEANUT/BANANA MASH**

Peanuts shelled	¼ cup	2½ cups
Bananas, ripe*	1 piece	10 pieces

(a) Prepare ground peanuts as in Recipe 5.
(b) Peel the bananas and mash smoothly with fork.
(c) Blend with the finely ground peanuts.
(d) Serve to infants five months and above in divided portions if necessary. (for infants below five months, add a little boiled water to make a creamy consistency).

* Preferably a variety with yellow core (containing Vitamin A) if available.

** Although this mixture is in general recommended to begin only after 4 months, in circumstances where no breast milk or artificial milk is available, it is known that it can be tolerated by infants even in the first months of life, if begun initially in small quantities.

SINCE RECIPES INVOLVE A DELICATE BALANCE BETWEEN INGREDIENTS, WE KEEP THE OLD IMPERIAL SYSTEM FOR OUR RECIPES UNTIL TESTED METRIC RECIPES ARE AVAILABLE. IF YOU MAKE A GOOD CONVERSION, LET US KNOW FOR THE NEXT EDITION.

RECIPES FOR SCHOOL CHILDREN (AND PRESCHOOL)
ALSO SUITABLE FOR ADULTS
(Quantities to serve 100 or 10 persons)

1. DRIED BEANS WITH LEAFY VEGETABLE
(1 cup portions)

	For 100	For 10
Dried beans	20 cups	2 cups
Rice (or substitute sweet potato)	20 cups	2 cups
Dark leafy greens (cleaned)	30 cups	3 cups
Water (or rice washing)	5 gallons	10 cups
Dried fish (10 cm long or other seafood or meat)*	100 pcs	10 pcs
Ginger or other seasonings		season to taste
Powdered milk* dissolved in a little water		2 kilo packet

a. Clean and wash the dried beans and rice.
b. Heat the water, add washed dried beans and cook until nearly soft.
c. Add rice (or sweet potatoes), seasonings, and meat. Cook 20 minutes longer (or longer in the case of sweet potatoes).
d. Add dark leafy greens and milk* Cook five minutes more.

*If Available.

2. DRIED BEAN SOUP (1 cup portions)

Dried beans	20 cups	2 cups
Rice (or substitute sweet potato)	20 cups	2 cups
Mixed vegetables (diced) such as yellow sweet potato, squash, okra, scratched corn, onions.	10 cups	1 cup
Dark leafy greens	20 cups	2 cups
Water	5 gallons	10 cups
Oil or fat	600 gr.	5 tbsp

a. Wash the dried beans, cover with cold water and bring to a boil
b. When tender, add the oil, salt, rice, and diced vegetables.
c. Continue cooking until the mixture becomes pulpy.
d. Add the leaves three minutes before removing from fire. If desired, pass through sieve or grinder to obtain creamy consistency.

3. DRIED BEAN STEW (1 cup portions)

Dried beans	20 cups	2 cups
Water	4 gallons	8 cups
Banana (cooking Variety)	50 pcs appr. (5 kg each)	5 pcs
Sweet potato yellow	50 pcs	5 pcs
Rolled wheat or wheat flour*	10 cups	1 cup
Salt	1 cup	3 tbsp
Meat	1 kg.	1 cup (150 gr)

a. Toast the dried beans lightly and grind finely.
b. Put this and the meat into water and bring it to boil.
c. Add the diced banana and yellow sweet potato, rolled wheat and salt. Boil for 15-20 minutes.

*If Available

4. DRIED BEANS AND EGG SOUP (1 cup portions)

Ingredients as for Recipe 2

Eggs	20 pcs	2 pcs

a. Prepare the dried bean soup as in Recipe 2
b. Beat the raw eggs. Add into the soup by pouring down a 30 cm chopstick held nearly vertically and passed in spiral fashion over the mixture so that the egg is thinly distributed throughout the whole.
c. Mix and simmer for one minute.

5. SOYBEAN SOUP (3/4 cup portions)

Soybeans dried	20 cups	2 cups
Water	5 gallons	12 cups
Oil	600 cc	5 tbsp
Tomato (chopped)	10 cups(1 kg.)	1 cup
Salt	½ cup	2 tbsp
Yellow sweet potato or squash, diced, or carrots*	10 cups	1 cup
Any leafy greens	20 cups	2 cups
Garlic or other seasonings	20 cloves or to taste	2 cloves
Flour*	1 cup	3 tbsp
Onion (chopped)	20 pcs	2 pcs
Milk powder* dissolved in water; or fish flour or small dried fish or shrimps	10 cups	1 cup

a. Soak soybeans in water overnight
b. Wash and cook 1 - 2 hours
c. Dissolve milk in warm water. Set aside
d. Saute the garlic, onions and vegetables. Add the soybeans, salt and flour
e. Make thick or thin soup according to one's taste. Add the milk or fish and leafy greens five minutes before removing from fire.
f. Serve hot.

6. SOYBEAN STEW (with milk) 3/4 cup portions)

Soybeans	20 cups	1 cup
Meat, or fish, or snails	1 kg	1 cup
Salt	½ cup	2 tbsp
Water	4 gallons	10 cups
Milk powder*	10 cups	1 cup
dissolved in water	5 gallons	10 cups

a. Boil the soaked soybeans for 1-2 hours, then add meat or fish and boil until tender.
b. Season with salt.
c. Add the leafy vegetables five minutes before removing from fire.
d. Serve hot with 1 cup of milk* for each person

7. FRIED SOYBEANS (with milk*) (3/4 cup portions)

Soybeans	20 cups	2 cups
Water	5 gallons	10 cups
Oil (Cooking)	900 cc	½ cup
Salt	½ cup	2 tbsp
Milk powder* dissolved in Water (warm)	10 cups	1 cup
	5 gallons	10 cups

a. Soak soybeans overnight, and boil 1-2 hours. Drain water
b. Add salt.
c. Fry in vegetable oil until soybeans are light yellow and crispy.
d. Eat fried soybeans with milk*.

*if available.

8. SAVORY SOYBEANS (with milk*) (3/4 cup portions)

Soybeans	10 cups	1 cup
Onions, minced	2 cups	¼ cup
Tomato sauce*	10 cups	1 cup
Sweet pepper (red)	10 pcs	1 pc
Cooking oil	600 cc	5 tbsp.
Water	5 gallons	10 cups
Salt	½ cup	2 tbsp
Milk powder* dissolved in water	10 cups	1 cup
	5 gallons	10 cups

a. Soak soybeans overnight, add salt and boil 1 - 2 hours.
b. Heat the oil and add the onion and pepper. Cook for five minutes.
c. Add the boiled soybeans and tomato sauce. Allow to simmer over the low fire until thoroughly heated. Serve warm or hot.

9. SOYBEANS WITH COCONUT (3/4 cup portions)

Soybeans, dried	20 cups	2 cups
Coconut, grated	20 cups 5 coconuts	2 cups
Salt	½ cup	2 tbsp
Sugar (white)	5 cups (3/4 kg.)	½ cup
Water	5 gallons	10 cups
Milk powder* dissolved in	10 cups	1 cup
Water	5 gallons	10 cups

a. Soak beans overnight. Drain and cook in boiling water until tender.
b. Add the salt. When done remove from fire, drain and set aside to cool.
c. Place in a platter. Make a ring around the soybeans with grated coconut.
d. Serve with one cup milk*

*If available.

10. SPROUTED BEAN STEW (with milk*) (1 cup portions)

Soybeans or mung beans, dried	20 cups	2 cups
Shrimps*, or fish* or meat*	5 cups	½ cup
Fat (Oil)	600 cc	5 tbsp
Water	5 gallons	10 cups
Onions, diced	10 pcs	1 pc
Garlic, minced (or other seasonings)	10 pcs	1 pc
Powdered milk* dissolved in	10 cups	1 cup
Water	5 gallons	10 cups

a. Soak the beans overnight. Drain off water and place in a container with holes. (p 110) Cover the soybeans with a cloth to keep warm.
b. Sprinkle water on the beans twice a day until they have a sprout of 2 - 3 cms. long (2 or 3 days.).
c. Saute garlic, onions, shrimps or meat in oil. Add five gallons/10 cups water. When water boils add the bean sprouts and cook until tender.
d. Serve with milk* (1 cup)

NOTE: Bean sprouts could also be cooked for soup.

NOTES FOR USE OF GREEN SOYBEANS

1. Pick soybean pods before they are mature (just turning yellow). Clean them.
2. Mumu; or steam in pot, adding salt.
3. Eat straight out of shell.
   This is a method of eating soybeans that the Japanese use. Special varieties are grown for this, but almost any other varieties will do, except the black soybeans. It is a good way because it is similar to peanuts, and because the protein content is not much different from dry beans. Also, it is an easier way - none of the mess of drying, shelling, etc.

Initial contributor: H. Bekker

CRISP SOYBEANS: Put cooked soybeans into the sun to dry. When dry, roast them in an oven until crisp and slightly browned. Keep in sealed container. Excellent snack.

SOYBEAN CASSEROLE: Soak the soybeans. When swollen grind in a mill. Mix the ground beans with garlic, onions, tomatoes, salt and pepper. Bake in slow oven until done.

Initial contributor: H. Bekker

BEAN SPROUTS

Especially good where fresh food is not readily available. Seeds of Soybean, Mung bean, Cowpea, Wing bean, Sunflower seed, and Corn seeds can be sprouted, but the traditional Asian bean sprout is from Mung beans.

Put mature seeds into a container with water. Let sit one or two days in the water, changing the water at least three times a day. After beans have started to sprout, drain the water and let sit in a dark place (to keep the sprouts blanched and from getting bitter). Rinse frequently, but do not let the sprouts sit in any water (tends to rot them). Sprout until the roots are thick.

Another way to do them is to put the sprouts, after they have been soaked, between two hessian sacks (or terry cloth towels) on a screen and to pour water over them, keeping them moist and dark.

To cook: Fry in quick fry Chinese dishes (with thinly sliced capsicum, green beans, carrots, onions, peas, or any other suitable vegetable). Or fry with onions and oil, then add cooked egg noodles, salt and pepper.

Initial contributor: H. Bekker

PEANUTS, USES

BOILED PEANUTS IN SHELL (with milk, if available) (½ cup portions)

Peanuts in shell (dried)	7½ kg	3/4 kg.
Salt	1 cup	2 tbsp
Water	10 gallons	1 gallon
Milk powder* dissolved in	10 cups	1 cup
Water	5 gallons	10 cups

a) Boil washed peanuts in water (plus salt) for about an hour, adding more water as necessary.

b) Remove from fire and drain off the water. Serve warm with 1 cup of milk per person*

*If available.

FRIED PEANUTS (¼ cup portion)

Peanuts, shelled[1]	3.3 kg	2 cups
Cooking oil[2]	1 gallon	1½ cups
Garlic*	10 cloves	1 clove
Salt	1 cup	2 tbsp

a) Soak the shelled peanuts overnight. Remove the skins and dry the peanuts under the sun for an hour.
b) Heat the cooking oil, add the garlic and peanuts.
c) Stir constantly to prevent scoring. Add salt.
d) Remove from the fire when the peanuts are golden brown.

1. One kg of peanuts in shell yields 670 grams of shelled peanuts (5 cups)
2. Most of this can be recovered and used again.

* If available

PEANUT SOUP (1 cup portions)

Peanuts shelled	3.3 kg	2 cups
Dried shrimps*	10 cups (1 kg)	1 cup
Sweet pepper, sliced	10 pcs	1 pc
Onions	10 pcs	1 pc
Salt	1 cup	2 tbsp
Water	3 gallons	5 cups
Dark Leafy greens	20 cups	2 cups

(a) Boil the peanuts until soft (20-26 minutes).
(b) Add washed shrimps and prepared vegetables. Simmer for five minutes.
(c) Serve warm.

Note: If fine consistency is desired, pass all ingredients through grinder and simmer again.

*if available

ROASTED IN SHELL PEANUTS

The peanuts are cleaned, dried in the sun and then roasted. Roasting may be carried out on a sheet of iron over a fire, in a hand roaster (see design) or on a large scale in an electrically driven rotating cylindrical screen using LP gas or oil burners as a heat source.

Roasting takes between 45 minutes to 1 hour and temperatures at 150°C to 200°C are commonly used.

Roasting is complete when the kernels have a golden-brown colour. The peanuts are then taken out of the roaster and cooled.

To retain the texture and taste of fresh roasted peanuts the peanuts are stored in airtight containers.

Initial contributor: A. Hepworth, Box 793, Lae.

SALTED ROASTED PEANUTS

Shelled peanuts are fried in oil at 138-143°C for approximately 10 minutes, cooled, sprinkled with salt and stored in airtight containers or sealed into cellophane bags. The thin skin is sometimes removed before frying.

Alternatively the peanuts may be dry roasted, as for roasted inshell peanuts, mixed with 1.5 to 2.0% oil and salted.

PEANUT BUTTER

Peanuts are shelled, dry roasted and cooled. The thin skins are removed and the peanuts are then finely ground usually in two stages. During grinding 2% salt, up to 5½% vegetable oil and sometimes 1-2% sugar are fed into the grinder with the peanuts. The peanut butter is then packaged in airtight containers.

Initial contributor: A. Hepworth, Box 793, Lae.

PEANUT BUTTER

Smooth and delicious as commercial peanut butters may be, they are often made without the germ of the nut. This valuable portion - as in grains - contains minerals, vitamins and proteins and is literally fed to the birds. The commercial objection to the germ is twofold: 1. that the flavour of the butter is made somewhat bitter, 2. that, as grains, the heat of processing and the heat in storage may cause the finished product to grow rancid. If you are smart make your own full-bodied peanut butter in an electric blender (substitute small hand-operated mill).

Use: Fresh roasted or salted peanuts. Remove skins from peanuts. It is wise to start with a bland oil: Safflower or vegetable oil. Allow 1½ - 3 tbsp to 1 cup peanuts. If nuts are unsalted, add salt to taste. (about 2 teasp salt per cup).

From: Joy of Cooking, by Rombauer and Becker

CURRIED PEANUTS

1. Melt a tablespoon of oil or fat in a pan.
2. Add a teaspoon of curry powder and a chopped chilli to the oil.
3. Cook the raw peanuts slowly in the pan.

PEANUT CAKES

You will need:
- 2 cups of cooked sweet potato
- 1 cup grated coconut
- 2 teaspoons salt
- 1 beaten egg, or 2 tbsp of flour (to bind the mixture)
- 2 cups of ground roasted peanuts

1. Mix all of the ingredients thoroughly, add a little water, milk, or coconut cream if necessary to moisten the mixture.
2. Make into flat cakes.
3. Fry in fat or bake in an oven.

This mixture makes about 20 small cakes.

PEANUT BUTTER CANDY

You will need:
- 2 cups sugar
- ½ cup milk
- 2 tablespoons peanut butter

1. Put in a pot and mix well together; boil for 5 minutes.
2. Remove from the fire and beat steadily till cool.
3. Pour into soup plate or cake tin. When set cut into squares.

PEANUT BARS

You will need:
- 2 cups flour
- 1 cup coarsely chopped peanuts
- 1 tsp. baking powder
- ½ cup milk
- 1 egg
- ½ cup sugar
- 2 tbsp butter
- a pinch of salt

1. Sift flour, salt, and baking powder into a bowl; rub in the butter, nuts, and sugar.
2. Mix to a rather stiff dough with the egg and milk.
3. Turn on to a floured board and roll out almost an inch thick.
4. Cut into bars of convenient size and fry in a pan with fat until golden brown.

From: "12 Things to Do with Peanuts", South Pacific Commission Literature Bureau

ALSO TRY GRINDING SHELLED, ROASTED PEANUTS TO COARSE PASTE AND COOKING WITH VEGETABLES.

JAMS AND MARMALADES

We give these considerable space because there are so many fine fruits available during certain seasons, and because these might help to get more calories into the diets of children.

How will you eat jams if you don't have bread? The heavy sea biscuits (strongpela bisket) are found in trade stores throughout the country, and you can also eat jams with kaukau and taro. Jams are commonly eaten as a sauce with rice in some parts of Southeast Asia.

GENERAL INSTRUCTIONS FOR MAKING JAMS

Peel the ripe fruit and mash until it is reduced to very fine pieces or pulp; add from 50-100% of its weight of sugar and cook until thick. Transfer to sterilized jars while boiling hot and seal tightly.

CITRUS FRUIT JAM MAKING

Ingredients: Citrus fruit, sugar
Utensils required: Cooking pan, coarse sieve, kitchen knife.

Summary: Citrus jams or marmalade is prepared by cooking the fruit material to a pulp, then adding sugar and boiling again until the setting point is reached. At this stage the jam is packed in jars. (Setting point is when it becomes thick).

Ingredients

1. For Marmalade (yields about 5kg.)
   1½k oranges, juice of 2 lemons
   3 litres water
   2½kg sugar
2. For three fruit (yields about 5kg)
   2 grapefruit
   4 lemons } total weight about 1½-2kg
   2 oranges
   2½ litres water
   2½k sugar
3. For Tangerine
   Tangerines
   1 grape fruit } total weight about 1-1½kg
   1 lemon
   juice of 2 lemons
   2 litres water
   1kg sugar

The Process:

1. Clean the fruit
2. Dip in boiling water for 1-2 minutes
3. Peel as for eating
4. Cut the peel into fine shreds. Put the shredded peel and lemon juice and half of the water in a pan, and boil until the peel is tender.
5. Cut up the rest of the fruit and simmer in a closed pan for 1½hours.
6. Rub the pulp through a sieve.
7. Add the strained pulp to the peel.
8. Add the sugar - stir until dissolved.
9. Boil rapidly until the setting point is reached (about 15 minutes).
10. Allow to cool slightly, then pour into hot sterilized jars and put on the lids.

Note: Jars and lids are sterilized by boiling in water for 10 minutes.

If recipe 3 is followed the following modifications should be made to the method:

step 4: Cut the peel of the grapefruit and lemon, and boil together with the fruit and water for two hours.

step 5: The tangerine peel should be cut into shreds and tied in a cotton bag. Put the bag in with the boiling fruit but remove after 30 minutes.

Initial contributor: J.H. Hepworth, Box 793, Lae.

CUMQUAT MARMALADE

Materials or equipment needed: Knife, two bowls, cumquat fruit, sugar, cooking pot, glass bottles with lids.

One cup of sugar is required for each cup of reduced cooked cumquat pulp.

Description of the process: Slice cumquats thinly and remove seeds. Put seeds into bowl, cover with water and leave overnight. Put sliced cumquats into another bowl, cover with water and leave overnight. Next morning put cumquat slices and water into saucepan, add strained water from cumquat seeds. Bring to boil, then simmer until fruit is soft and liquid is reduced to half.

Measure and allow one cup sugar for each cup comquat mixture. Bring cumquat mixture to boil. Add sugar and stir until dissolved. Simmer for 2-3 hours on low heat until it jells. Pour into sterilized jars (boil jars in water for 20 minutes).

This process has been used in Kavieng, New Ireland with excellent results.

Initial contributor: J. Hale, Box 122, Kavieng NIP.

MANGO JAM

Utensils required: Blender or coarse sieve or masher, kitchen knife, mixing bowls measuring cup, wooden spoon.

Ingredients required: Ripe mangoes, sugar, citric acid (food grade).

Packaging materials: Sterilized glass jars with caps that can be sealed.

The process:

1. Wash mangoes to remove surface dirt.
2. Slice and scoop out flesh. Pass through blender or coarse sieve or mash.
3. Mix the pulp with an equivalent amount of sugar.

cont'd

4. Heat over low fire with constant stirring. When almost thick, add 0.3% citric acid based on the weight of the pulp used.
5. Continue heating until temperature is 105°C (211°F) or until the mixture can be spooned out.
6. Fill into sterilized jars and seal.
7. Air cool, label and store.

Initial contributor: A. Hepworth, Box 793, Lae.

PAWPAW -PINEAPPLE JAM

Utensils: Kitchen knife, chopping board, measuring cup, aluminium saucepan, wooden spoon, jars.

Raw materials: pawpaw, pineapple, sugar.

The process:

1. Select fully ripe, sound pawpaw. Remove seeds and scoop out pulp with a spoon. Mash with a fork.
2. Peel pineapple, remove eyes and chop till fine.
3. Mix equal parts of mashed pawpaw and chopped pineapple.
4. Add 1½ cups sugar to every 2 cups fruit mixture.
5. Boil briskly in an aluminium pan until thick. Stir constantly to avoid scorching.
6. Pour immediately in hot sterile jars and seal tightly.
7. Cool and store.

Initial contributor: A. Hepworth, Box 793, Lae.

ROSELLA JELLY

Ingredients: Rosellas, sugar, water.

Utensils: 2 cooking pots, white cloth, any measuring container, bottles with caps.

Process: Wash the rosellas that you have picked including seeds, tips and calyces, and place in pot. *
2. Add enough water to cover everything.
3. Boil over the fire for one hour.
4. Pour the juice into another pot through the cloth to remove all the bits.
5. Measure the number of cups of juice.
6. Add this many cups of sugar to the juice.
7. Boil juice and sugar gently, stirring frequently for 20 minutes.
8. Pour into bottles and seal. This will be jelly when it is cool.

Initial contributor: M. Cockburn, 125 Prince Albert Parade, Newport, NSW. 2106

ROSELLA JAM

Ingredients: Rosellas, sugar, water, muli rinds (if desired).

Utensils: 2 cooking pots, scales, measuring cup, white cloth, and storage jars.

Process: Separate calyces (the red part) from seeds and tails.
2. Weigh out 1kg of calyces*
3. Put in one pot and add 625ml. water (1.1 pint)
4. In another pot put 670g of seeds and tails and add 625ml. water. Boil this rapidly for exactly five minutes.
5. Strain the seeds and tails from step 4, through the cloth and put this liquid into the pan with water and calyces.
6. Boil the combined liquids for about 20 minutes until colour of liquid is a deep red. Add chopped up skin of lemon muli to taste at this time if desired.
7. Remove saucepan from fire and measure the amount into the other pot. Add this many cups of sugar.
8. Boil combined sugar and fruit and juice as quickly as possible for 10 to 15 minutes. After 10 minutes spoon out a little onto a plate to see if it jellies. Keep cooking until sample jellies.
9. When jellied, remove from fire, pour into bottles and seal. Serve when cool.

Initial contributor: M. Cockburn, 125 Prince Alfred Parade, Newport, NSW. 2106

*The calyces are the thick outside flower petals.

FRUITJUICE PROCESSING

Equipment required: Sharp knife, juice extractor, sieve, large pan, bottles or jars with screw top lids, thermometer, scales, measuring jug.

Raw materials required: Citrus fruit, sugar, sodium benzoate (or benzoic acid)- available from ICI or New Guinea Wholesale Drugs, or other drug companies.

Summary: Fruit juices are prepared by extracting the juice from the fruit, filtering, adding sugar and preservative, pasteurising, and bottling.

The Process:-

1. Sterilise bottles and lids by boiling in water for 10 minutes.
2. Clean the fruit in cold water.
3. Remove any over-ripe fruit and cut out any damaged or rotten parts.
4. Cut the fruit in halves.
5. Extract the juice and filter the juice through a sieve.
6. For every 1 litre of juice add ½ kg of sugar.
7. Pasteurise the juice by raising the temperature to 85 degrees C and holding at that temperature for 10 minutes.
8. Allow to cool slightly and then stir in sodium benzoate (or benzoic acid) 0.6 gr. per litre of juice. (This chemical will make the juice keep well for a long time.)
9. Fill while still hot into the sterilised bottles and close immediately with the lid.
10. Dilute juice to taste with cold water for drinking.

cont'd

CROWN SEALS FOR BOTTLING FRUIT JUICES

Mr. K. Beutel
Plaza Health Foods
K - Mart Plaza
Cannon Hill, Brisbane, 4170
Queensland
Australia

Note: crown tops and simple hand-operated crowners are sometimes available at reasonable prices at Burns Philp stores.

PINEAPPLE CORDIAL

(using the trimmings from a fresh pineapple)

Ingredients: 1 pineapple
½ cup sugar (more or less to taste)
1 pint water

Equipment: 1 saucepan
1 screw top bottle
stove or fire

Method:
Cut off green top of pineapple and bottom stalk and throw these away.
Wash pineapple skin well.
Peel and core pineapple.
Cut up the core.
Put the peel and core pieces in the saucepan.
Add sugar and water.
(The actual eatable part of the pineapple is not used in the cordial)
Boil for 5 minutes.
If you keep boiling for too long (over 10 mins) the cordial will go bitter.
Cool liquid.
Drain and bottle.
To serve: dilute with water to taste.

S. Tracy

ROSELLA DRINK

Materials and equipment needed: Cooking pot; mature rosella plants.

To make 14 cups of rosella drink: remove red sepals (these look like flower petals and enclose the large seed case) and put into a large saucepan with 8 cups water and 1½ cups sugar. Boil for 45 minutes or until such time as the red sepals turn white and the water becomes a deep red colour.

Remove sepals and let rosella water cool until you can easily pour it into clean containers. Mix one part water to one part rosella or dilute the rosella water according to taste.

Source of supply for rosella: Yates Seed Co.

PNG Experience: Puas, New Hanover.

Initial contributor: J. Hale, Box 215, Wewak, ESP.

BREAD, BISCUITS AND CAKES

USES OF GRAIN

BREADFRUIT BISCUITS

Here is a way that my people preserve a seasonal fruit using a simple technique:

Materials needed:

4-5 fruits from a favoured variety, preferably the seedless one
2 new baskets made of coconut leaves
firewood
a wire net above the fireplace
knife

Method:

Build fire. Place the fruits on the fire and turn them from time to time as they cook.

When they are cooked peel them with a knife. Remove the inside core, and let the fruit cool.

Cut into thin slices and place them evenly in the baskets. Put the baskets above the fireplace on a wired net.

When the slices are dry and hard they are finished, and will keep for months.

Contributed by: M. Kemp, Vudal, Kerevat, ENBP.

BUCKWHEAT

Buckwheat flour: Grind buckwheat into flour, and use in bread, about 1 part buckwheat flour to 3 parts wheat flour.

Buckwheat Pancakes:

2 cups buckwheat flour	1 egg
1 tsp salt	2 tbsp fat
1 tsp baking soda	2 cups milk
juice of 1 lemon	

Mix batter well. Spoon into a hot, greased skillet, making patties. When bubbles appear on one side, turn and cook the other side.

Groats: Crack the buckwheat. Cook the same way as rice: Use plenty of water, bring to a boil; when boiling, turn down heat a little. When all the water is evaporated and bubbles stop (and groats are almost cooked), turn down heat and do not open cover. After 15 minutes, remove from heat and let sit for another 15 minutes without lifting the cover. Take a flat paddle and remove (can be made from large diameter bamboo).

H. Bekker

CORN (p 93)

Cornmeal: Husk the corn, leaving the inner husks attached. Dry with the husks on for a day, then braid the husks and hang to dry. When dry, remove the kernels from the ears and grind in a flour mill. Use the flour in bread with wheat or as follows:

Cornbread:

Mix 2 cups cornmeal	1 tsp baking soda
1 cup wheat flour	juice of 1 lemon
1 egg	2tbs butter, oil or lard
1 tsp salt	milk to mix (stiff dough)

Bake in a low greased pan in a moderate oven until bread draws from the sides and a knife comes out clean. If all cornmeal is used, use 3 cups cornmeal and 3 eggs.

Hush Puppies:

2 cups cornmeal	1 tsp baking soda
1 cup wheat flour	juice of 1 lemon
1 tsp salt	dash of pepper
1 small onion, chopped fine	milk to mix (stiff dough)

Make into little balls and fry in shallow, hot fat, turning to brown evenly.

Scones: (cooked on top of stove or flat grill)

1 cup cornmeal	1 tsp salt
1 cup wheat flour	2 tbsp fat
1 tsp baking soda	milk to mix (staff dough)
juice of 1 lemon	

Mix and form into small disks 2cm thick. Fry in dry skillet with a cover on it, over low heat. When one side is cooked, turn over. Variations: Use all whole wheat flour and/or add honey, sugar, fruit for a sweet cake.

Porridge: Let 1 cup cornmeal sit in 4 cups water to reconstitute. Add salt. Bring mixture to a boil and let simmer at least 15 minutes. Cook until thick and meal soft.

Variations: 1. Add ground peanuts to mixture.
2. Add ground soybeans to mixture.
3. Use milk instead of water.

Chapatis: Use half cornmeal and half wheatmeat, adding salt and water to make a dough. If desired, add some fat. Make little balls and roll out into flat disks, as thin as possible. (Wine bottles make good rollers). Fry in a dry skillet or on a flat grill. Also can be fried in some fat. Fry until one side is puffed up and turn to cook on other side. Soft without fat; crisp with fat. Also can be made with all whole wheat flour.

Masa: (cornmeal for making Mexican tortillas)

1 kg corn kernels
60gm lime
3 litres water

Wash the corn, add the lime and water and put on to boil. Let boil until the kernel skins loosen. Remove from flame and let cool. Rub handfulls of kernels between the palms until all skins are loosened and removed. Wash the skinned kernels thoroughly in cold water. Grind very fine and make tortillas by rolling out or by patting between the hands to a very flat disk. Cook dry or with fat in a skillet or on a grill.

Enchiladas: Take an uncooked tortilla or chapati and fill with chopped cooked pork, tomatoes and onions. Line in a pan and pour over it a sauce of tomatoes, capsicum, onions, garlic, chiles, salt and pepper. Bake until cooked, or steam in a heavy, covered skillet.

Tamales: Take fresh sweet corn. Remove husks carefully. Remove the kernels with a grater (can be made by punching holes in bottom of a fish can) or grind in a food mill. Add rendered pork fat to ground corn and some salt.

Make a filling: Brown some chiles in pork fat, add finely chopped pork, tomatoes, salt and pepper Simmer until thick.

Put a thin layer of corn mixture on each husk. Put some filling in and cover with more corn mixture. Put another husk around it so that the mixture is completely wrapped. Tie together with husks. Place in steamer or a mumu. Tamales are done when the corn draws away from the husk (about 1 hour).

May be made plain with just fat added to corn with salt and/or sugar. The chiles may be too hot for children. Make plain ones for young children - an easy way for them to eat corn.

Initial contributor: H. Bekker.

THE FOLLOWING RECIPES WERE SENT BY C. KELLEY, BUSINESS DEVELOPMENT OFFICE, MT. HAGEN

KAUKAU BISCUITS

8oz sweet potato flour	2 tsp baking powder
1½ox margarine	milk to mix

Method: Rub margarine into the flour and baking powder. Mix to a stiff dough with the milk. Roll out on a floured board to 2-3cm thick. Cut into rounds with a scone cutter. Bake at 400°F for 15-20 minutes.

BANANA CAKES

1 banana	6 tbsps milk
½ cup sweet potato flour	

Method: Mash the banana. Stir banana, milk and flour together to make a stiff dough. Form into a slab cake on greased foil or banana leaf. Bake at 350°F for 30 minutes.

KAUKAU CAKE

2 cups sweet potato flour
¼ cup margarine
1 cup sugar
1 egg
2-3 cups milk
2 tsp baking powder
pinch salt

Method: Beat sugar and margarine together. Beat in egg. Sift flour, baking powder and salt together. Add flour mixture and milk alternately, a little at a time to beat in egg mixture. Stir gently. Place in cake tin and bake in hot oven 30 minutes.

FRIED SCONES

1 cup wheatmeal flour
1 cup sweet potato flour
1 tsp salt
water to mix

Method: Mix all ingredients together to form a stiff dough. Form into large flat scones. Deep fry in boiling fat until golden brown.
Note: Pieces of chopped meat, fish or peanuts can be added to the mixture before frying.

PEANUT CAKES (makes about 20 small cakes)

2 cups cooked sweet potato
2 tsp salt
1 beaten egg
2 cups peanut flour

Method: Mix all ingredients thoroughtly. Add some water or milk if mixture is too stiff. Form into small flat cakes. Fry in fat or bake in hot oven for 10-15 minutes.

PLAIN SCONES

2 cups plain flour
1 tsp salt
2 tbsp fat
4 tsp baking powder
3/4 cup milk

Method: Sift flour, baking powder and salt into a bowl. Rub in fat. Add enough milk to make a soft dough. Turn out onto floured board and knead slightly. Roll out to about 1cm thick. Cut into even pieces with knife or small tin or scone cutter. Place on greased flat tin. Bake hot oven (400°F) for 10-15 minutes.

Variations for Scones

Add 2 tbsp milk powder to flour and mix with water instead.
Add 2 tbsp sugar to make sweet scones.
Add 3/4 cup mashed pawpaw & 2 tbsp sugar. Use less milk.
Add 2 mashed bananas and 2 tbsp sugar.
Add ½ cup peanut flour.
Add 1 cup mashed cooked pumpkin.
Add 1 cup cooked corn (scrape from cob).
Add 1 cup fish or 1 cup chopped meat.
Add 1 cup grated cheese (use tinned cheese - cheaper)
Add 1 egg and use less milk to mix.

SAVORY FLOUR CAKE

1 cup wheatmeal
½ tin fish
salt, water
oil or dripping

Method: Mix wheatmeal and salt. Mash the fish and mix into the wheatmeal. Add water and mix to stiff dough. Make into flat cake. Fry in hot fat or wrap in softened leaf and bake in oven.

SWEET FLOUR CAKES

1 cup wheat meal
2 mashed bananas
2 tbsp sugar
water or milk
oil

Method: Mash bananas and mix into the wheatmeal and sugar. Add water or milk and mix to a stiff dough. Make into flat cakes and cook as for savory flour cakes.

WHEATMEAL BREAD (1 x 4lb loaf or 2 x 2lb loaves)

8 cups (4lb) wheatmeal
8½ tbsp (4½oz) margarine
4 tsp (2½oz) dried yeast
1 pint liquid (½ water and ½ milk)

Method: Sift wheatmeal into bowl. Warm liquid slightly. Dissolve yeast in half the liquid. Mak- a hole in the wheatmeal and pour in yeast liquid. Sprinkle with a little wheatmeal. Cover with a cloth and leave in warm place until yeast starts to bubble. Add rest of liquid, margarine and salt. Knead until smooth and not sticky. Put dough back in basin, cover with a cloth and leave in a warm place until double size (proving). Knead again. Place in floured baking tin and cover with cloth. Prove in warm place until double size. Bake in hot oven (400°F) for 25 minutes.

BREAD

3 cups plain flour
1 tbsp dried yeast
1-2 oz margarine
1 tsp sugar
1 cup water
1 tsp salt

Method: Sift flour and salt into bowl. Half fill cup with warm water, add sugar and yeast. Rub margarine into flour. Fill the cup with the yeast i.e. to the top, with cold water. Pour yeast mixture into centre of flour. Mix into a dough. Turn onto a board and knead for 5-10 minutes. Shape into bread and put in greased tins. Cover with plastic bag or damp cloth and leave to rise until dough has doubled in size. Remove bag or cloth. Bake in hot oven (400°F) for 30-45 minutes. When cooked bread should be golden brown and sound hollow when bottom knocked with knuckles. Turn out of tin and cool on wire rack.

Variations:

Use 2½ cups plain flour and ½ cup peanut flour.
Add 1 tin chopped meat to the dough.
Sift 3 heaped tbsp milk powder with the flour.

YEAST (Root vegetable or potato yeast)

3 tbsp flour 1½ tbsp sugar 1 cup water	Clean peelings from - potato, yam, taro, or tapioca.

Method: Mix all together. Put in a bottle. Cork it and tie on firmly. Leave overnight. Next day empty the bottle but do not wash it. Make a new mixture (as above), put in bottle and leave overnight. Next day empty the bottle but do not wash it. Make a third mixture and put in bottle. Leave until ready to use - it bubbles when ready. Do not wash the bottle - next time you will only need to make 1 mixture. Make up mixture 12 hours before you need it.

LEMON YEAST

Same as potato yeast but use 8 drops of lemon juice instead of peelings.

USE OF THESE YEASTS

In any recipe requiring yeast use 1 cup of lemon or potato yeast instead of dried yeast. Use less water to mix the dough.

THE PRECEDING RECIPES WERE SENT BY C. KELLEY, BUSINESS DEVELOPMENT OFFICE, MT. HAGEN

BASIC BREAD RECIPE

Ingredients: 1 kg. of wheat flour
10 gr. salt
15 gr. sugar (1 tbsp)
30 gr. oil (2 tbsp)
15 gr. dried yeast (1 tbsp)
650 c.c. water at 37 degrees C.

Baking temperature: 220 degrees C.

Baking time: 25 - 35 minutes

Loaf size: 500 gr.

Method: Dissolve yeast in some water. Leave for 10 minutes. Mix yeast solution, water, sugar, salt. Sift in the flour, Knead well.

Leave for rising until double size. Form loaves. Allow to rise again (prove). Bake.

Initial contributor: A. Hepworth, Box 793, Lae.

BREADMAKING

The following recipe was found to be a successful one at the Balimo Vocational Training Centre:

Ingredients:	Utensils:
4 tsp yeast 3 tbsp sugar 24 cups flour 8 tsp salt	8 bread tins 2 large aluminium basins 2 bowls for yeast flat working surface round bottle for rolling

The Process:

1. Put 4 teaspoons of yeast in 8 cups of warm water, add 2 large tablespoons of flour, 3 tablespoons of sugar. Stir and leave for one hour.
2. Put 14 cups of flour in a dish, add the yeast ferment liquid, and mix. Leave in a warm place for one hour.
3. Mix 1½ cups of warm water and 3 cups of flour into the risen dough.
4. Put 7 cups of flour on a table and sprinkle on 8 teaspoons of salt.
5. Place the dough in the middle of the flour on the table and knead until all the dry flour has gone into the wet dough.
6. Roll the dough flat with a bottle and cut into 8 equal parts and shape these into loaves.
7. Put the rolls into tins and place in a warm place for one hour, then without bumping the tins place them into the hot oven (temp. 380-400) F and cook for about one hour.

By using 16 bread tins, 4 large aluminium basins, 4 bowls for yeast ferment liquid, and having a large warm cupboard on top of the oven it is possible to cook 32 loaves of bread in one day.

A note on difficulties: No problem has been experienced at Balimo with either mould or rope in the bread. ROPE, which is caused by an organism similar to yeast, causes the bread to become putrid in about 24 hours. A repulsive odour is present. This organism is very difficult to kill. Boiling water will not destroy it. Vinegar can be used to wash all items used in the bakery to destroy rope. Vinegar should then be used in every loaf of bread until all traces of rope disappear. 1½ pints of vinegar to 100 lbs. of bread is recommended.

Reference: Bread and Breadmaking, A.J. Edwards, Mauri Bros. and Thompson, 812 Bourke St., Waterloo, Sydney, Australia.

Suggested by: C. Hemmes, Box 214B, Konedobu

WHITE BREAD

½ pint milk or milk-water or water
1 level tbsp sugar
1 lb plain flour
1 dessertspoon salt
1 tbsp margarine
1 level tbsp yeast

1. Scald milk, add sugar. Cool to lukewarm. Add yeast, cover, and leave for a few minutes until yeast starts to work.
2. Sift flour and salt
3. Rub in margarine
4. Make a well in the centre of the flour and add yeast mixture.
5. Mix to a soft dough.
6. Knead on a floured board until smooth (10 mins)
7. Cover with a cloth and stand in warm place for 10 minutes.
8. Shape into loaves or rolls.
9. Place on greased trays. Cover with cloth and leave in warm place until dough has doubled in bulk.
10. Bake loaves in hot oven 400° for 15 minutes and 350° for 20 minutes. Rolls for 425° for 15 minutes.

Initial contributor: R. Beasley, Wesley High School, Salamo. MBP.

BREADS:

Yeast muffins: Add 1 tablespoon yeast to 1½cups lukewarm water (or whey). Let dissolve. Add about 3 cups wholewheat flour and 1 tsp salt. Let rise. Punch down and form into flat disks. Let rise. When risen, fry or dry grill on both sides until done.

Scones: 2 cups wholewheat flour
1 tsp baking soda
1 tsp salt
2 tbsp fat
1 cup buttermilk

Mix well. Form into small disks 2cm thick. Fry in dry skillet with a cover, over low heat.

H. Bekker.

The Tassajara Bread Book, by Edward Espe Brown, 1970, 146 pp., US $2.95 postpaid.

Available from: Shambala Publications, Inc.
1409 5th St.
Berkeley, California 94710 U.S.A.

"Here's a breadmaking guide that stands on profound respect for simple, wholesome ingredients and a 'ripening, maturing, baking, blossoming' process, that turns a glob of dough into a fragrant food fit for any man's meal. Good bread is always magically more than the sum of its ingredients. There are recipes for breads yeasted and unyeasted, fruit-filled loaves, sourdough, pancakes, pastries, muffins, and various favourite snacks from the Tassajara Kitchen. This Zen cook knows the true nature of bread."

- Hal Hershey, from The Whole Earth Catalogue

COCONUT

Coconut Candy: See recipe, p 97, "Uses for sugar."

Coconut chips: Remove the meat from the dry coconut, keeping the pieces as large as possible. Slice thinly & salt. Spread on flat sheet and place in oven on low heat, or fry on top of stove in heavy skillet. Roast until crisp and slightly browned. Keep in sealed container to retain crispness.

Coconut pudding: 3 cups grated coconut
½ cup cornstarch (tapioca flour)
½ cup sugar
¼ tsp salt

Add boiling water to grated coconut until the coconut is just covered. Let sit for 15 minutes then strain. Measure coconut milk into the pan. Add sugar, cornstarch and salt. Stir until the cornstarch is dissolved. Cook on slow heat, stirring constantly until it boils. Let boil a few minutes on low heat. Pour into a shallow pan and let cool. Cut into pieces and serve.

Breakfast cereal: Take the grated coconut from the pudding, sprinkle with salt and toast until browned. Add toasted rolled oats, fresh fruit, lemon juice, milk, honey, chopped peanuts.

Initial contributor: H. Bekker

COCONUT ICECREAM

Ingredients: 2 pints thick coconut cream from two or three coconuts
juice of 1 coconut
chopped vanilla pod (remove seed) or vanilla essence
2 cups sugar
2 heaped tablespoons cornflour

Equipment: saucepan
stirring spoons
small bowl
stove or fire
storage container
freezer

Method:
Boil coconut cream, vanilla pod and sugar for 10 minutes.
In small bowl stir cornflour and coconut juice into a smooth paste.
Add paste to coconut cream.
Boil till thick, stirring all the time.
Cool to room temperature, stirring occassionally.
Freeze for about 12 hours before serving.
Stir once an hour for the first three hours.

Contributed by: S. Tracy.

MANGO CHUTNEY

Utensils: Kitchen knife, paring knife, cutting board, measuring cup, saucepan, wooden spoon.

Ingredients:

4 cups diced green mango	1 small box raisins
½ piece large ginger root	2 cups vinegar
1 clove garlic	3 cups brown sugar
8 pieces small onions	4 tbsp coarse salt
2 pieces hot pepper	

The process:

1. Salt the sliced green mango and allow it to stand overnight.
2. Drain the salted mangoes.
3. Boil vinegar, sugar and spices. Simmer for 5 minutes.
4. Add sliced mangoes and cook until thick.
5. Pack in sterilized jars. Seal.
6. Air-cool. Label and store.

Initial contributor: A. Hepworth, Box 793, Lae.

MANGO PICKLES

Utensils: Stainless steel knife, pickling jars, bowls.

Ingredients: Fresh immature green mangoes
10% brine (approx, 1½ tbsp coarse salt for every cup water; boil & cool)

Packaging materials: Sterilized glass jars with tops that will seal.

The process:

1. Wash mangoes to remove surface dirt.
2. Peel mangoes, remove seeds, and slice into longitudinal pieces of ½cm thick. (if desired, the fruits may be used unpeeled.)
3. Place in pickling jars and immerse in 10% brine solution.
4. Let stand for at least a week until the mixture has a pleasant fermented odour. Stir mixture daily.
5. Boil the brine and remove scum if there is any formed.
6. Rinse mango slices with boiling hot water and pack in jars.
7. Fill jars with boiled brine, cap, seal and cool immediately.

Initial contributor: A. Hepworth, Box 793, Lae.

PICKLED EGGS

Utensils: Saucepan, utility bowl, cheese cloth, utility plate, glass jars.

Raw materials: chicken eggs or quail eggs
vinegar
sweet pepper (red)
1½ tsps. whole mixed spices (black pepper, bay leaf, cinnamon, cloves)
salt, garlic, sugar.

The process:

1. Have eggs at room temperature to prevent cracking during cooking.

2. Start in cold or boiling water. For a cold start, completely cover eggs in saucepan with cold water. Heat until water boils. Remove from heat. Cover pan. Let stand 2-3 minutes off the heat. For a boiling water start, bring water to boil in a saucepan. With a spoon carefully lower eggs into the water to prevent cracking the shell. Reduce heat. Keep water simmering until eggs are cooked, about 18-20 minutes for chicken eggs, 5-10minutes for quail eggs. To keep yolks centered, turn eggs several times during the cooking.

3. Immediately cool eggs under cold water.

4. Remove shells and pack carefully in a jar.

5. Mix vinegar, sugar (1:1), salt, red pepper cut into slices, and garlic. Immerse mixed spices tied in a spice bag. Simmer for about 10 minutes.

6. Pour hot pickling into the jars to cover the eggs completely.

7. Let stand for at least 2 weeks before serving.

8. Keep in a cool place.

Initial contributor: A. Hepworth, Box 793, Lae.

SALTED EGGS

Utensils: Kettle, glass jars, measuring cups.

Raw materials: chicken eggs with shell
course salt
plastic bag
muslin cloth

The process:

1. Wash eggs very clean
2. Prepare brine solution by boiling enough water to cover the eggs. Add salt by the handful and stir to dissolve it. Continue adding salt until the last addition will no longer dissolve. Saturation point is reached by adding about 2 cups salt to 1 cup water. Allow brine to cool.

3. Carefully pack eggs in wide-mouthed glass jar or ceramic container.

4. Pour cold brine solution over eggs. Weigh down with plate or cup to keep eggs from floating or use a sealed plastic bag filled with the brine solution.

5. Cover mouth of container with 2 or 3 layers of muslin cloth or any suitable cover.

6. Keep in a cool, dry place.

7. After 12 days, boil an egg and taste. If not salty enough for your taste, keep remaining eggs in the solution for one week longer.

Initial contributor: A. Hepworth, Box 793, Lae.

SAUSAGES

Sausages are made from minced meat. It is sometimes mixed with a filler and seasonings, and is filled into prepared animal intestines or casings. (It may or may not be cured) Fresh sausages do not keep any longer than fresh meat, but sausages which are cured and then dried or smoked have good keeping qualities.

Preparing casing: The intestines are removed from the animal and the fat is separated. The intestines are stripped by squeezing to remove any remaining contents and then placed in a bucket of warm, clean water. After soaking, the outer and inner linings of the intestines are stripped off. Beef intestines are then turned inside out and stripped of lining material. The prepared casings are then packed in salt until needed. Only casings free from parasites and holes should be used, and the type of intestine used determines the shape of the sausage.

Sausage fillings: Minced meat is mixed with fillings such as bread crumbs or cooked mashed sweet potatoes, salt and seasonings until the mixture binds together. The mix is then forced into the prepared casings through a nozzle or funnel and links formed at intervals by twisting. For cured sausages ¼ level teaspoon of sodium nitrate is added for each 1kg of meat. After mixing thoroughly the mix is spread out approximately 2 - 2.5cm deep on trays, covered with a clean cloth and stored in a cool place for 24 hours before filling into casings. The sausages are then hung to cure in a cool place for 2-3 days and then dried or smoked slowly.

Sausages are an easy way of preserving meat and can be made from cheap, but still good, pieces of meat and a filling to your own taste.

Initial contributor: A. Hepworth, Box 793, Lae.

Selling Tilapia in a Highlands trade store

Tilapia cooking demonstration, Western Highlands

HOW TO USE SALTED OR SMOKED FISH (p 103) 104)

TALAPIA SALTED FISH: Office of Business Development is trying to promote the sale of salted fish, especially in the highlands, through the Fresh Foods Depots. It is available at 60t per Kilogram, which is relatively cheap, and the salt component is desirable when the fish is cooked with Kaukau or rice.

Apparently there is a problem of acceptance, due to the preference for tinned fish. Business Development says, however, that pending price increases on imported fish will make salted fish more attractive. It is being pushed for institutions, fast food outlets and trade stores.

Cured fish needs to be "freshened" before it is used. Soak the fish in cold water overnight or as long as 48 hours. Change the water several times. Freshening may also be done by breaking the fish into large flakes, putting it in cold water and heating it very slowly, but not boiling it, for 30 minutes to 1 hour. This is called simmering. Fish that are very salty and very dry may need to be soaked in cold water and then simmered.

Be sure to cook all cured fish before eating it. Cured fish can be cooked and served in many different ways. Some general suggestions are given here but, most people have their own favourite way of cooking, seasoning and serving cured fish.

FISH SOUPS AND STEWS: You can make a good-tasting soup or stew by cooking dried cured fish in liquid with many different kinds of vegetables. Use water the fish was simmered in when you freshened it. Some of the vegetables most commonly used for soups and stews are yams, rice, tomatoes, and potatoes. You can also use okra, peppers, spinach, or other green leaves, groundnuts, and pimento. Season soup and stews to suit your own family's tastes.

BROILED CURED FISH: Wash and freshen the fish. Drain, dry, and sprinkle it with cooking fat or oil. Place the fish on a metal rack, flesh side up. Place the rack 10 or more cm depending on heat, above hot coals. Cook the fish for 3-4 minutes, then turn it over and cook it about 4 minutes more. How long it will take to cook

all the way through depends upon the size of the fish. Thick pieces take longer.

BAKED CURED FISH: Freshen the fish, then wash and dry it. Place it, flesh side up, in a greased pan. Sprinkle it with cooking fat or oil. Cover it with milk or a combination of milk and the water you simmered the fish in when you freshened it. You may add cut up vegetables and seasonings if you want to. Place the pan in a Mumu oven and bake the fish for 20 minutes to 1 hour, depending on the thickness of the fish. Add more liquid as the liquid in the pan evaporates. Take the fish out of the pan and place it on a serving dish. Melt some butter in the liquid that is left and pour it over the fish. Serve the fish while it is hot.

PLAIN COOKED FISH: Wash and soak the fish in cold water overnight or longer. Change the water occasionally. Put the fish in a deep pan or skillet. Cover it with cold water and heat it very slowly until it is almost boiling. Do not let it boil. Boiled fish tends to fall apart. Simmer the fish until it is tender. This may take an hour or more. Skim off the scum. Lift the fish onto a hot platter. Put oil or melted butter and pepper over the fish and serve. You can also use this cooked fish in many other ways. Be sure to take the bones out before using the fish.

CREAMED FISH: You can make creamed fish by adding flaked, cooked fish to a sauce. Make the sauce by cooking fat, flour, and liquid such as the water the fish was cooked in, milk or plain water together. Add some flaked boiled fish and seasonings, mix well, and heat. Serve the creamed fish with bread, potatoes or rice.

FISH CAKES: You can make fish cakes with Kaukau or Yams. Peel the yams or kaukau. Cut them into small pieces and cook them until they are tender. Drain the yam or kaukau and mash it. Add flaked boiled fish, a lightly beaten egg, and seasonings. Shape the mixture into cakes and roll them in meal or flour. Brown them lightly in a little hot fat or fry them in deep fat until they are golden brown. Drain the fish cakes and serve them hot.

SCALLOPED FISH: You can mix flaked fish with cooked rice, and then add some milk and well-beaten egg. Pour the mixture in a pan and bake it in an oven. This makes a very tasty food called scalloped fish. You can add seasonings to please yourself and your family.

SEASON TO YOUR TASTE: However you cook cured fish, the kind and amount of seasoning you use will depend on the way you and your family like your food to taste. Vegetables and cooking fats and oils add flavour to fish. People in most countries also add other seasonings. Some seasonings that go well with dried cured fish are hot pepper, dried ground pepper, curry, paprika, locust bean. Be careful if you add salt. You may not have soaked out all the salt used in curing the fish. If you add more salt when you cook it, it may be too salty.

Sent by C. Kelley, Box 179, Mt. Hagen

Kukbuk Bilong Hilans, by H. Bekker, pamphlet in Pidgin, 25t from Yangpela Didiman, Box 39, Banz, WHP

International Food Information Service
Farnham House
Farnham Royal, Slough, U.K.

Provides information in all fields of food science and technology; monthly abstracts on topics ranging from basic food science, food economics, hygiene, toxicology and packaging for specific food groups; annotated bibliographies on a wide range of subjects.

The Joy of Cooking, by Rombauer and Becker, 1931-1967, 849 pp, US$6.95. Available from Bobbs Merrill Co., Inc., 4300 W. 62nd St., Indianapolis, Ind 46206, USA.

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Building and Road Construction

BRICK MAKING

Permanent buildings with low maintenance are often built of bricks or blocks. Many parts of PNG are earthquake areas, and steel or wire reinforcement is necessary for brick load bearing walls.

A brick is smaller than a block. When building with bricks or blocks a 10mm layer of mortar is used between each row.

Bricks or blocks can be made of the following materials:-

1. Stabilized earth:-
   - (a) Soil and cement or
   - (b) Soil and lime or
   - (c) Soil and cement and lime
2. Coronous bricks:-
   - (a) Coronous and sand and cement
   - (b) Coronous and cement

(You have to crush or screen coronous before using)

3. Sand Cement Bricks - river or beach sand and cement.
4. Sand Gravel Cement Bricks.

In 1969 Public Works developed a rugged brick machine that was supposed to be available through the government stores. If it ever was available it isn't any more. But there is a Technical Bulletin No 6 from the Local Government Engineers that gives details, and Local Government Engineers will advise on where to purchase such machines. (Box 1108, Boroko).

Bricks can also be manufactured from clay, and burned to make them long lasting. The Building Research Station of PWD has done some work on clay brick making and there are two Technical Research Bulletins: No 7, Selection of Materials for Burnt Clay Brick Manufacture; No 12, Capacity Brick Kiln.

Making clay bricks in China with simple wood forms. These will be dried and then burned.

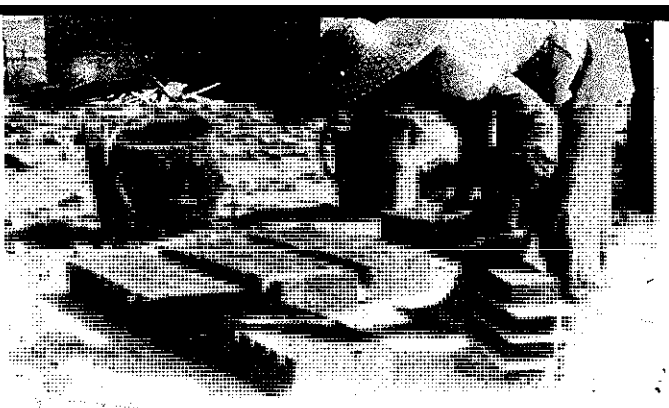

Setting clay bricks out to dry

PWD doesn't want to give general recommendations in the Liklik Buk, because a lot depends on the different kinds of soil or coronous that you have. They have a Soils Laboratory (Box 1108, Boroko) that will test soil samples (they need 2-4kg of each soil being considered), but the Technical Bulletins give you a simple field test for your own trials.

M. Simpson, Local Govt. Engineer, Box 1108, Boroko.

ADOBE BLOCKS

Description: Building blocks made from garden soil and reinforced by chopped straw or grass.

Materials: Garden soil, fresh water, chopped grass stalks.

Tools: Several spades or shovels, a block mould, (see diagram) a ramming implement, bush knife.

Description of work: Select soil for block making that does not have a lot of sand (or coronous) or large amounts of clay. Garden soil free from obvious vegetable matter and stones is best.

It is best to make the block close to the place where they will be used for building, to save transport costs. If good soil is available in the same place, this is better.

It is desirable to dig a large amount of soil, and clean the rubbish the day before blocks are going to be made.

Kunai grass chopped to 10cm lengths is added to the soil with water and the mass turned until it is evenly mixed. Other types of grass, especially runner grasses are suitable.

The damp soil is covered with banana leaves or copra sacks and allowed to mature over night. The soil should never be allowed to become muddy. An even dampness is needed. You will have to learn by experience.

before making blocks the soil should be turned again and checked for proper dampness.

Block Making: Soil is shovelled into the mould and rammed firmly down and into the corners. Keep topping up until the upper surface is level with the edge of the mould. When you lift the handles on the

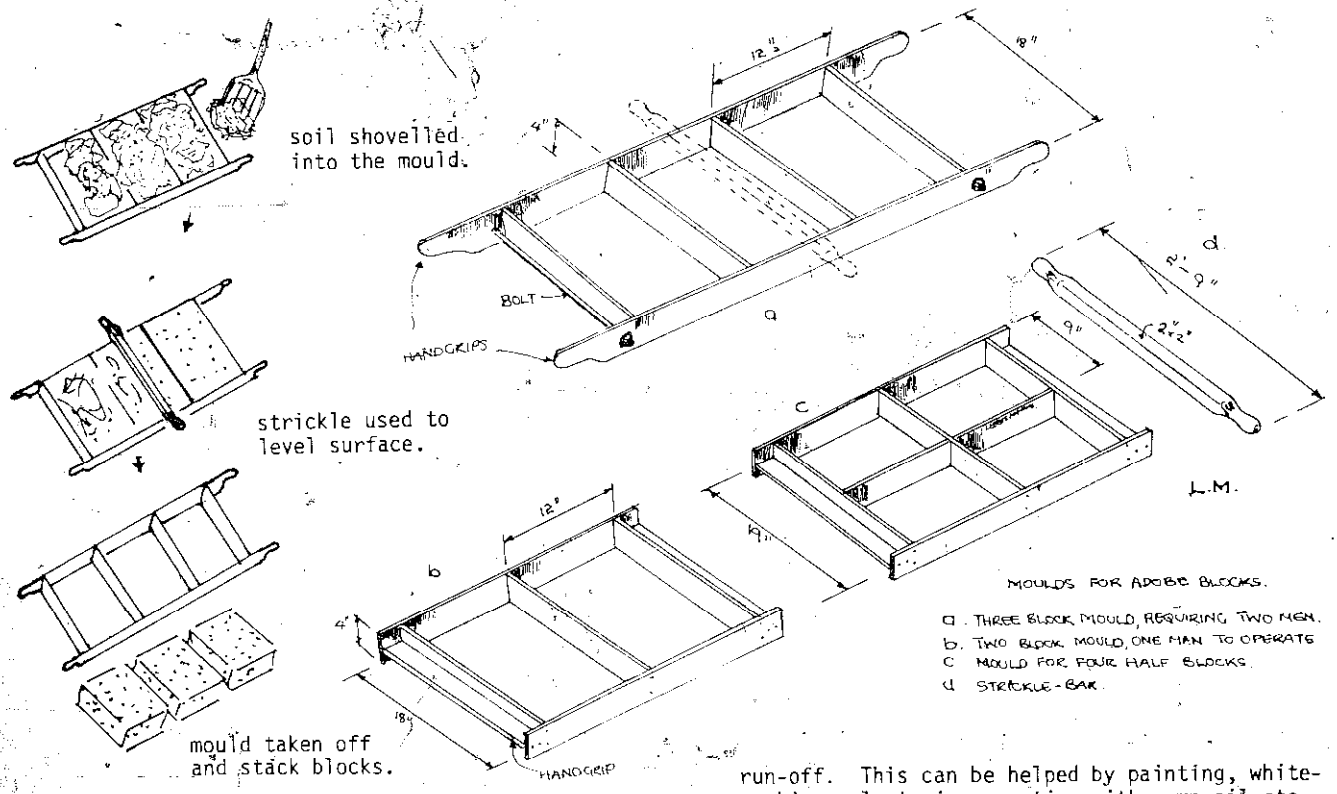

mould the block should stay in position, as the mould comes away. Greasing the inside of the mould with sump oil is helpful in getting release. Some block makers like to construct a mould that is slightly bigger at the bottom than at the top. This also helps to break the suction more quickly, and release the mould.

The completed block(s) can be lifted carefully and stacked. Never stack in direct sun because sun tends to dry the blocks unevenly. Stack with space between blocks to allow air flow, and in a shady place. Protect from rain.

Reference: "Build Your House of Earth" G.F. Middleton, Compendium, Centreway 259 Collins St., Melbourne 3000. Aust. (Paperback)

Experience in PNG etc: There is very little experience with adobe in PNG. There is a lot of tropical experience with adobe in Africa and South America, where it is very good. An experimental adobe building at Madina High School NIP was successful.

Remarks: Adobe blocks uses a resource in plentiful supply. It is very cheap because the only expense is for labour and basic tools.

Adobe buildings have thick dense walls which are very cool in hot areas and keep heat in where built in cooler climates.

Adobe does not allow termites, and if correctly made is as permanent as cement bricks are. It is very important that the outer surface of a wall is protected from rain, and splashing from roof run-off. This can be helped by painting, white-washing, plastering, coating with sump oil etc. Adobe walls will support the heaviest types of roofing structures.

Excellent blocks of uniform density can be made with a CINVA-RAM brick machine.

Adobe block walls combined with shingle roofing, gives a high quality, permanent building.

Initial contributor: L. Wilson, Kerevat National High School, Rabaul.

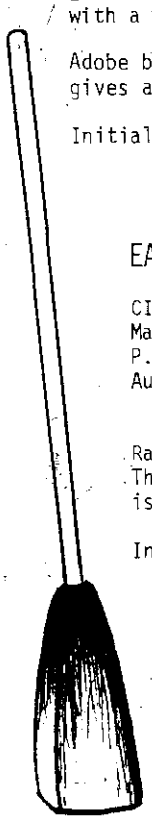

RAMMER

EARTH BUILDING BLOCKS

CINVA-RAM
Marac Exports Ltd.
P.O. 366
Auckland, New Zealand

This firm markets the well-known Cinva-Ram brick-making machine, cost around K125.00. They give excellent service, and a catalogue is available.

Initial contributor: Jack Ruth
S.I.L.
Ukarumpa via Lae

Stamford Bros.
18 Woodfield Boulevarde
Caringbah 2229
Australia

Simple aluminium moulds for ordinary and decorative bricks, flower pots, paving stones.

Chicago Co. Pty. Ltd.
3 Short St.,
Chatswood, N.S.W. 2067, Australia

"Specialised equipment, technical advice, and marketing assistance for the concrete and allied industries." Block-making machines and structural moulds.

CONCRETE MAKING IN PNG

(p 129) (p 183)

Concrete is a basic, universal building material that will last a long time when properly made. With the rising cost of cement it is a especially important to make it the proper way, so that it will last a long time.

Strong concrete requires a few simple tools to make it well.

A. Materials and facilities required:

Shovel or spade
Bucket to carry water (size to hold 4-5 litres)
Measuring box (300mm x 300mm x 300mm) or about 0.03 cu metres
Wire mesh (copra or cocoa wire)
Mixing surface - a concrete floor, plywood, metal or other hard surface.
Cement: This is the manufactured material that comes in 40kg bags. It holds approximately 0.03 cu. m.
Fine aggregate: Normally sand is the fine aggregate Dry sand runs easily in the hand. Sand from rivers or the beach can be used but it must be clean or the concrete will be weakened.
Course aggregate: This is known as gravel. The individual particles are from 5mm to 20mm. You can use river stones, crushed rock, coronos or similar materials.
Water: Clean water without mud or leaves should be used. Dirty water will give weaker concrete.

B. For each 0.2cu m of concrete you will need 0.03 cu m cement - (1 measuring box)
0.06cu m fine aggregate (sand) - two measuring boxes
0.12cu m course aggregate (gravel) - four measuring boxes
3.0 litres water. Be sure to use clean water, clean enough for drinking.

C. Method.

1. Choose a hard surface that is flat near where you will put the concrete.
2. Make the box for measuring the materials from wood and be sure it has handles to make it easier to carry.
3. Screen all the gravel that you will be using on the wire mesh by throwing the gravel on the mesh. The big pieces will not pass through the screen. Use only the gravel that passes through the mesh.
4. Measure out the materials for the first batch of concrete this way:
Put one box of cement on the mixing surface.
Add two boxes of sand to the cement.
Add four boxes gravel to cement and sand.
This will give a mix of 1:2:4.
5. Mix this material together with the shovel or spade by turning it again and again until it is all mixed and the texture and colour is even.
6. Form the mixed materials into a mound and make a hollow in the centre. Pour 1 litre of water into the hollow.
7. Mix the dry material with the wet by taking dry material from the edges and turning it into the water in the centre. Don't let the water run away. Mix well.
8. When all is mixed make a new mound, add one more litre of water, and mix as before.
9. Reform the mound again, add the last litre of water, and mix until it is even in texture and colour.
10. The concrete is ready to use. DO NOT ADD EXTRA WATER if the concrete is damp enough to be formed. Extra water will make the concrete weaker.
11. After the concrete is put in its place and has become firm in an hour or two, begin to keep it wet for the next three days to get strong concrete. This step is as important as all the other steps. Either pour water so that the surface never drys out, or cover the surface with old copra sacks or banana leaves, to hold the water in place. This will make the concrete as strong as possible and will prevent it from cracking while it sets.

D. Sources of supply: Cement is available from many trade stores and from all major trading companies. Gravel, sand, and water are where you find them.

Remarks: If fresh water is not available you can use seawater, but the cement will not be so strong with the salt in it.

Contributed by: L. Sukap, Technical Officer, Local Government Advisory Service, Dept. of Transport, Box 1108, Boroko.

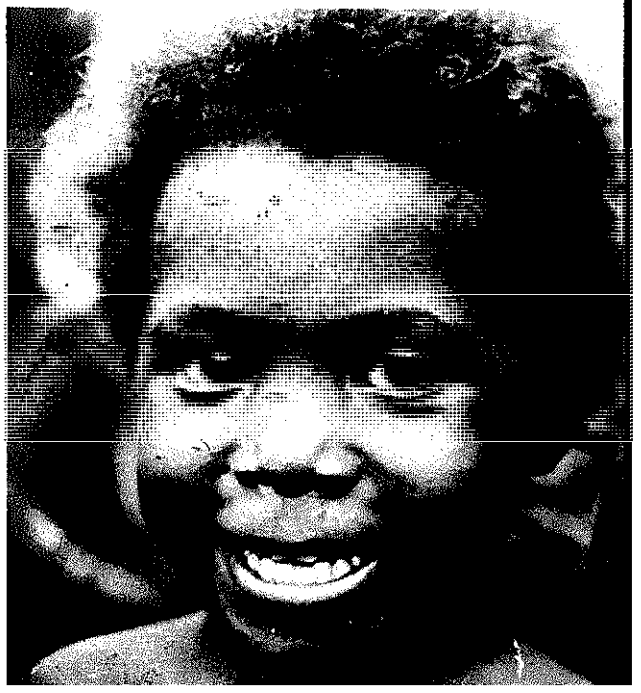

Friendship is the cement that holds the world together.

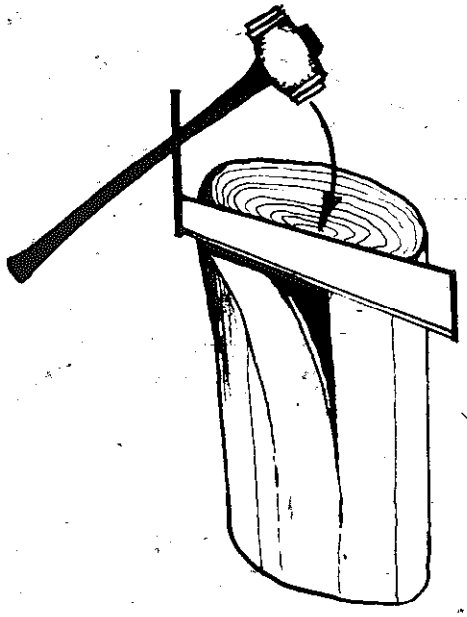

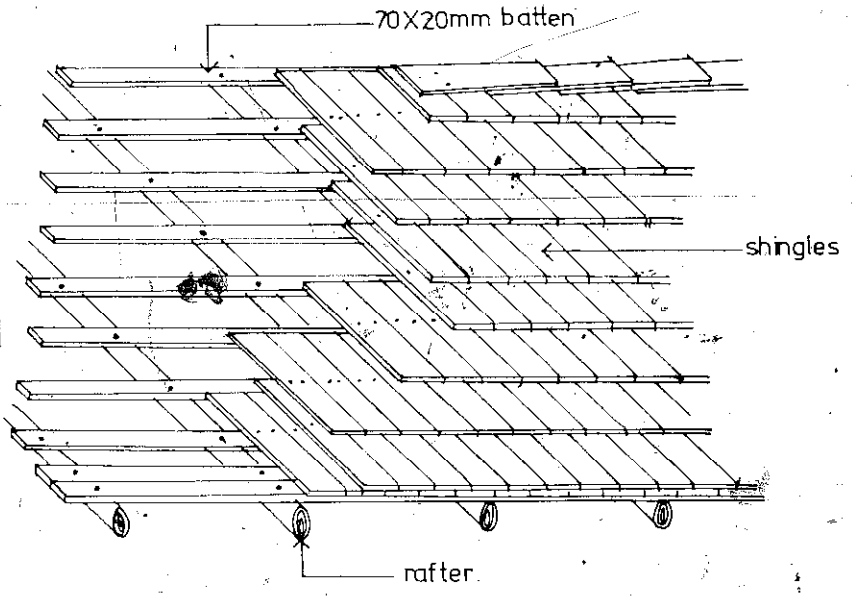

SHINGLE ROOF CONSTRUCTION

— SHINGLE KNIFE —

13 MM. STEEL PLATE, BEVELLED ONE EDGE. 25 MM. ROD WELDED TO ONE END, TO SERVE AS HANDLE.

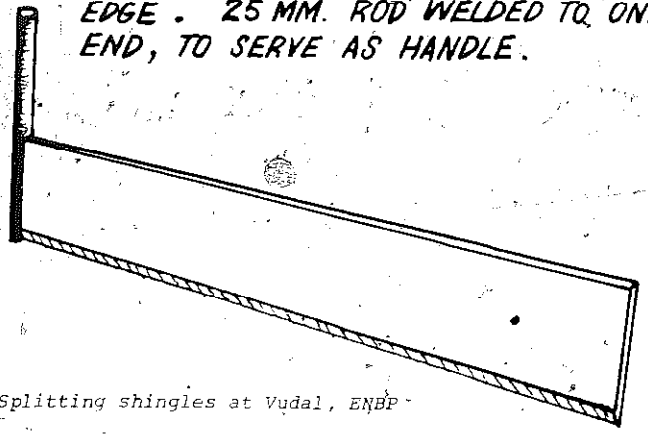

Splitting shingles at Vudal, ENBP

ROOFING SHINGLES

Description: Thin boards or tiles, hand-made from wood, used to cover a roof. They are an alternative to kunai grass, sago leaf, corrugated iron etc.

Materials and Tools: A log (or more, depending on size of building) of a clean splitting, straight-grained timber such as Taun.
A shingle knife, a heavy wooden mallet, a tomahawk.
Use a cross-cut or chain saw to cut log into even cross-sections.

Order of Work: The two basic tools, a shingle knife and mallet, must first be made (see diagram).

A sound log of Taun (or other suitable straight grain timber) should be cut into 70cm cross-sections using a chainsaw. Each section is stripped of bark and the sapwood, with an axe.

A cross section is placed on end and the knife placed about 2cm in from the edge in an upright position. While it is held in this position, the top edge is struck a heavy blow with the mallet. A shingle of wood should separate from the block, perhaps needing another blow to continue the split to the bottom. The knife is then placed in a similar position adjacent to the area split and another shingle struck off. The process is continued around the circumference of the block, the block getting smaller as shingles are struck off it. The core is thrown away.

Rough shingles can be trimmed with a tomahawk, to ensure a uniform thickness of a little under 2cm. Width of the shingles will vary, but this is acceptable and does not affect their use in roofing.

Laying a Roof: The principal is like kunai and sago leaf roofs. Light timber battens are fixed at regular intervals across the rafters, instead of bamboo or cane. The shingles are laid from the bottom, moving towards the ridge. Each shingle is fixed to the batten by a single nail and should touch the shingle next to it, if possible..

When overlapping starts on the second row (and above rows) keep in mind that at least half of the row below should be covered by the over lap. This ensures a watertight roof. Care is taken to cover the spaces between shingles in the lower row, when laid.

Sources of Supply: Timber from a logging company or cut on site if available. Taun is a common timber in many parts of PNG. The shingle knife must be made by a competent welding shop. The mallet can be easily made in a village situation.

References: The Shingle Roofing Manual is available from the Forest Products Research Centre, Box 1358, Boroko. "Earth Garden" (Box 378, Epping NSW) No 10, September 1974 carries an article on shingle making and laying.

Results of use in PNG: Taun shingles have been extensively used in the Northern Province by the Anglican Mission. They are both durable and economical. There are other buildings which have employed them with similar success in Madang and New Ireland.

Remarks: Shingles have big advantages over traditional roofing materials because they are more permanent. Experience in PNG does not permit an accurate estimate of their life span, but a well laid roof should last 10 years or more with normal maintenance.

Shingles do not provide a place for rats and insects as may be found in grass roofs.

A shingle roof, after an initial bleaching period, is very good for catching rainwater.

Shingle roofing is most attractive throughout its life span.

Shingle roofing combined with adobe brick walls is a good building combination for PNG conditions using local materials.

Treating wood shingles with preservative will make them last longer, but this is not good if you drink water from your roof.

Initial contributor: L. Wilson, Kerevat National High School, Rabaul.

> THE ESSENCE OF KNOWLEDGE IS,
> HAVING IT,
> TO APPLY IT.
>
> Chinese proverb

MAKE YOUR BUILDINGS LAST LONGER (p 182)

There are many ways to make a building last longer. Wood preservative will help a lot and it is also important to make the building last longer by good building practice. One of the most important parts of this is to keep the wood in the finished building as dry as possible. Some of the ways of doing this are:-

USE WIDE EAVES (ROOF OVER HANGS): The wider the roof overhangs the more it will protect the walls from getting wet. It will also keep the sun off the walls so that the house will be cooler. An overhang should never be less than 60cm (2ft) and is much better if it is 1 metre (3ft) or 1.3 metres (4ft).

PROTECT PROJECTING ENDS: Water gets into the end of a piece of wood much more easily than the side, so ends of bearers, joints, rafters or other pieces of wood that are exposed to the rain and sun should be protected. You can do this by using a fascia of large board nailed onto all of the ends, or you can simply project the roofing iron out over the ends of the rafters, or bring the wall siding down over joints. You can also make little caps of galvanised iron and nail them over the end of the pieces of wood. A final method is to paint the ends with paint or tar.

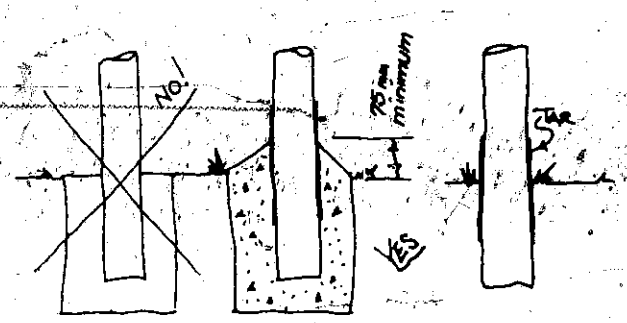

PROTECT POLE ENDS IN THE GROUND: When you put a pole into wet ground it also becomes wet. Chemical treatment will help the wood resist rotting, but if you can keep the wood dry, it is even better. The best way to do this is to paint the end that is going into the ground with tar or bitumen. Use the same stuff that is used on the road. Just melt some and paint it on. You should do this to all poles going into the ground.

KEEP WALL LINING OR SIDING CLEAR OF THE GROUND: Because lining is usually made of thin material like bamboo, pit pit or thin weather boards, it rots more quickly than large pieces of wood. Keep it away from the ground so that when it does get wet it can dry off easily. If you are building a house on a concrete slab or with an earth floor, it is a good idea to build a wall of bricks or stone around the edge up to a height of 60cm (2ft). You can also lay a large log that has been treated by "sap replacement" on the ground. Then start the bamboo, pit pit or weather board above this. This way the siding will not get as wet and can dry off better.

cont'd

CAP FENCE POSTS AND OUTSIDE POLES: The top end of a pole that is exposed to the rain usually will let water into the wood. This is because there are small splits or cracks running in from the end. It is a good idea to sharpen it to a point at the top. If you want to protect it even better, you can paint the end with tar, or nail a galvanised iron cap over it.

CHOOSING THE RIGHT WOOD: PNG has many different kinds of trees with different kinds of wood. Some will last a long time and some will not. If you are using wood that lasts a long time, then don't bother treating it. If you don't have any long-lasting wood, then you should. Some treatment method information may be obtained from the closest Forest Station. Some methods will treat all kinds of wood, others will only treat some kinds. It is important to choose the right wood.

SPACE FLOORING: One of the main causes of rot is water. If a floor is going to get wet often, leave a small space between the boards to let the water run out. A space 5mm (¼") wide will do very well. You should do this on all verandahs. It is also a good idea in shower rooms. If you want to wash the floor in the rest of your house often, then you can do this everywhere in the house. When you put spaces between the boards, do not use tongue and groove flooring.

REFERENCE: Manual of Rural Wood Preservation by PNG Forest Products Research Centre, Hohola.

Prepared by Office of Forests, Lae.

EARTH MOVING WITH WATER

Hap Skinner, Bernie Crozier, and Ray Hocking of SIL have successfully used running water to move tonnes of earth in building airstrips. The same way can be used in some places to build roads, terrace gardens, level village sites and sports fields.

An excellent booklet "Principle of Hydraulic Mining" has been written about it, available from Office of Village Development, Box 6937, Boroko. Or write to these men, c/- SIL, Box 5359, Boroko.

PRINCIPLES OF DRAINAGE

All land drainage problems are different. They differ because of:

(a) Different soil types
(b) Different drainage requirements for crops
(c) Topographic changes
(d) Size

However in spite of these differences there are four basic principles which should be applied to all drainage work. These are:-

1. DIVERTING WATER FROM OUTSIDE THE AREA TO BE DRAINED.

It is unusual to find an area completely isolated from outside drainage water. This outside drainage water must be disposed of before you can lower the watertable of the land you are trying to drain.

The control of this "outside" water can be done in two ways:

(a) by diverting it before it gets onto your block.
(b) by providing a big enough drain to carry it through your block without having it get on the area.

2. SELECTING A SAFE AND RELIABLE OUTLET

The outlet must provide reliable drainage even through the wettest parts of the year. If you are draining into a creek or watercourse you must be sure that if the water in the creek rises it will not "back up" along the drain lines.

As well as being reliable at all times of the year the drainage outlet must also be safe from erosion. This means making sure that the outlet is not too steep or does not drop into an unprotected gully. Using a naturally grassed depression overcomes this problem.

3. ADAPTING DRAINAGE SCHEME TO FIT SOIL, SLOPE AND CROP CONDITIONS:

The drainage system must be adapted to suit changes in soil and slope conditions.

On deep porous soils, drains can be spaced further apart than on shallow clay soils. On steep slopes it is desirable to have drainage across the slope. Different crops have different drainage needs. Highlands tree crops such as Tea or Coffee need at least 75cm (2'6") of well drained soil. Shallow rooting crops such as vegetables or pastures can get by with a much higher watertable.

4. MAKING PROVISION FOR ACCESS:

You must think about road access for cultivating implements such as tractors and ploughs when designing a drainage scheme. Usually with a bit of planning, it is possible to run roads and drains together - giving a maximum return for your drain digging work and providing best use of land.

The "top end" of drains should also be left open to provide access for cultivating equipment.

Further reading: "Comments on Drainage in the Highlands of Papua New Guinea" by A. McGrigor. This can be obtained from Publication Section, Dept. of Primary Industry, Konedobu.

Initial contributor: A. McGrigor, HATI, Box 312, Mt. Hagen, WHP.

SURVEYING AND MAP MAKING

Surveying is a useful skill for people involved in the development of Rural Areas. It can be used to:-

(a) Measure distances;
(b) Mark land boundaries;
(c) Calculate the area of a piece of ground; and
(d) It is a useful tool for Farm Planning - to define and calculate areas of different soils, land use, vegetation and to record features such as creek, fence lines etc.

SURVEYING

The basic equipment required for simple land surveying is:-

(a) Prismatic Compass - for measuring direction or bearing.
(b) 100 metre steel band - for measuring distance.
(c) Field Book, Pencils and Eraser - for recording bearing and distances taken during the survey.
(d) Bamboo poles or straight sticks - for marking lines.

Surveying equipment is available from the following sources:-

Brian Bell & Co., Box 1228, Boroko. or Theodist, Box 3437, Port Moresby.

Prismatic Compasses range from K47.00 to K87.00 depending on the make or model.

100 metre chains in canvas covered spools are K50 - K60.

MAP MAKING

Surveying usually involves producing a map or plan of the surveyed area. To do this you will need:-

(a) A rule marked in centimetres
(b) Metric Graph paper
(c) A circular protractor
(d) Pencils and erasers

These can be obtained from most Stationery stores.

For further information and advice on surveying and mapping contact the Dept. of Lands, who have offices in all major centres. The Prime Minister's Dept. at your District Headquarters usually has an officer who is experienced in surveying.

You can also write to the Highlands Agricultural College, Box 312, Mt. Hagen for a copy of their Surveying and Mapping notes.

Note: Department of Lands sometimes accepts people for on-the-job training in surveying on a voluntary basis.

Initial contributor: A. McGrigor, HATI, Box 312, Mt. Hagen, WHP.

THE LOCAL GOVERNMENT ADVISORY SERVICE is part of the Department of Transport, Works and Supply. Engineers and architects in this service, work only with rural design and engineering problems, on projects such as schools, aid posts, roads, bridges, markets, etc. There is also a mechanical section to advise on cost, purchase and maintenance of machinery and vehicles.

Normally the service is only available to councils and Area Authorities on their projects, but if your council supports your project and approves it, you can get assistance for a mission, school, or total self-help project in the village.

(P 255)

Further information: The Secretary,
Department of Transport Works and Supply,
Local Government Advisory Service,
Box 1108,
Boroko.

BULLETINS AVAILABLE FROM THE ABOVE

No 5 Selection of materials for Stabilized Brick Manufacture.

No 9 Construction of a Brick Hot Air Copra Drier. (This is a permanent but costly design)

No 11 Moving of Burnt Clay

No 13 Shaft Lime Kiln

BULLETINS ON WOOD

No 10 Manufacture of Charcoal by Retorts.

No 14 Low Cost Housing Prefabricated Panel System both from Local Government Advisory Service Box 1108, Boroko.

Self-Help and Rural Development Roads Construction Manual. From Local Government Engineer, Box 1108 Boroko. You don't need a bulldozer to build a road, though it can help. This book is a little technical, but it is the best for its size available anywhere. Free.

Suggested by: M. Simpson, Local Government Architect, Box 1108, Boroko.

FOREST PRODUCTS RESEARCH CENTRE

Forest Products Research Centre
P.O. Box 1358
Boroko.

The Research Centre has a number of very helpful publications. Perhaps the most useful for rural development workers is the "Manual of Rural Wood Preservation". Here are the main items:

1. "Manual of Rural Wood Preservation", 2nd edition, June, 1975, 25 pages. Tells about wood-destroying insects and fungi, building practices, treatment methods for rural areas. Includes poles, bamboo shingles, weather-boards. Simple and practical. A very important publication.

cont'd

2. "Preservative Treatment of Tropical Building Timbers by a Dip Diffusion Process", by Tamblyn, Colwell, and Vickers, 8 pp., 1972. A test report. Rather technical. Might be helpful for builders and teachers of building construction.

3. "Pole Buildings in Papua New Guinea", a review of the work of Peter Lattey of the Forest Products Research Centre. Aug. 1974, 41 pages. Peter Lattey was a C.U.S.O. volunteer in P.N.G. This interesting booklet containing many photos and drawings reviews some of his creative work. Lots of ideas for those with ambitious ideas about using local materials.

4. "The Introduction of Wood Preservation into P.N.G. and its effect on the Rural Economy," by C.R. Levy. Feb. 1975, 16 pp. Because of unstable soils and frequent earthquakes, pole construction is an ideal building technique for P.N.G. It is only truly effective, however, when the poles and other woody materials are adequately protected against insects and decay. Wood preservation can significantly reduce the non-productive work involved in maintaining private and community buildings.

5. "The Jalousie", an All Wood Louvre Windo, by Sequerra and Levy, March, 1975. 4 pp. A popular Philippine design is explained.

Department of Architecture
University of Queensland
St. Lucia Australia

Designs for low-cost housing for the tropics with special emphasis on designs using indigenous technology.

Ministry of Technology
Forest Products Research Laboratory
Prince's Risborough
Aylesbury, Bucks, U.K.

Various publications on Forest products research. Write for list and prices.

New Zealand Portland Cement Association
11th Fl. Securities House
126 The Terrace
P.O. Box 2792, Wellington, N.Z.

Technical Bulletins, articles on the use of cement including a home and farm series. Write for lists and prices.

Village Industry/Arts and Crafts

/BOTTLE CUTTING

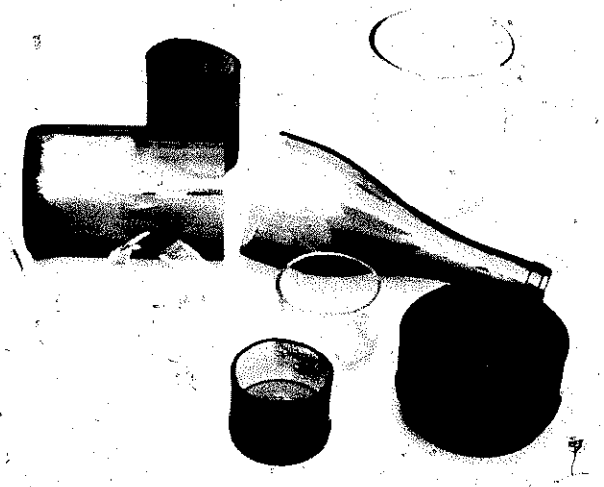

According to one informed source there are 14.37 zillion empty bottles lying around PNG. Most of them belong to the Moresby Bottling Company as each of the bottles tells you. They spend a lot of money on legal fees to stop people from using the bottles a second time and on advertising the fact, but they don't spend much time picking up the bottles that are lying all over the countryside. (Question: If the bottles belong to them, why aren't they responsible for picking up the bottles and paying the medical costs of people who step on their broken bottles?)

For some time now there has been a popular cult overseas of people who cut bottles to make glasses and candle holders. You can buy fancy kits for K10 - K15, so we haven't included the way in Liklik Buk before. Here is one way that works using only materials found next to an empty bottle.

Equipment needed: Metal file or freshly broken quartz pebble; candle or kerosene burner, or string wick alcohol burner; newspaper; empty round bottles any size.

Method:

1. Cut a short deep scratch on the bottle at the level you want to cut it with the edge of a metal file or quartz.

2. Tear four strips of newspaper 3cm wide and as long as a double page of the Post Courier, and soak in water. You will need more strips for larger bottles or bottles with thicker walls.

3. Carefully wrap two wet strips around the bottle on each side of the scratch so that the strips on one side of the scratch are almost one cm from the strips on the other side. The scratch should be exactly in

the middle. It is very important that the strips are wrapped so that the edge closest the scratch is straight, if you want to have a straight cut in the glass.

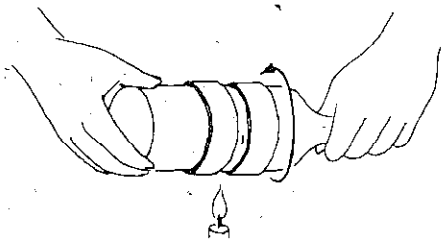

4. Slowly rotate the bottle a few times over the flame so that the glass between the two strips is just heated by the tip of the flame. If too much carbon on the bottle makes it difficult to crack, metholated spirits or alcohol flame may be necessary. Then turn the bottle a short distance each way with the scratch over the flame until you hear a slight cracking sound. Turn the bottle more and more each way as the crack grows longer. When the two cracks nearly meet, gently pull the two halves of the bottle apart until they separate. This whole step should take one to three minutes only.

5. Rub the cut edge with sandpaper, emery cloth or a smooth stone to remove the sharp edge.

Remarks: With a little practice it is very easy to make an even cut. If the bottle does not crack before the newspaper dried, it means the bottle wall is:- (1) too thick and you need more newspaper, or
(2) you have placed the strips too close to the scratch mark, or
(3) you have not made the scratch deep enough to begin.

If you find that the cut is not even, it means that
(1) you did not give enough heating when you rotated the bottle in the beginning, or
(2) the strips of newspaper were too far apart.

Initial contributor: A. Inversin,
Box 4981, Unitech, Lae

BASKET WEAVING

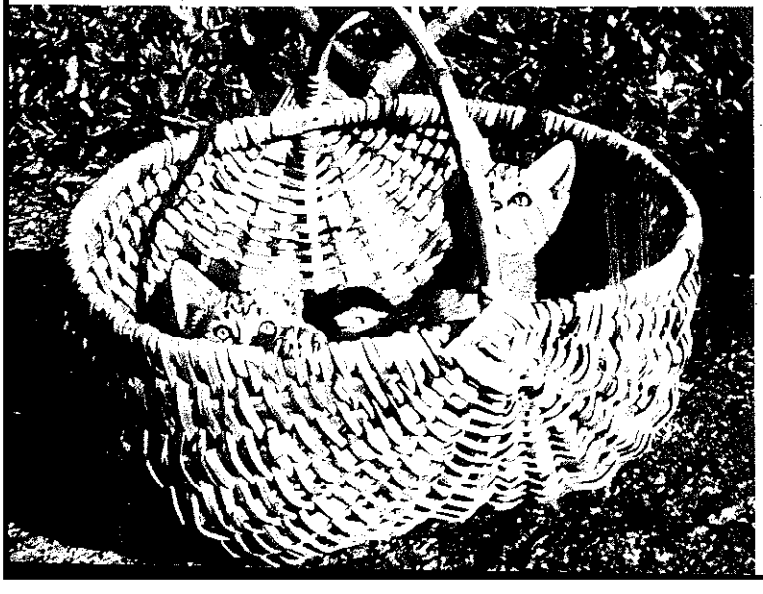

This traditional German design is one of the easiest to do, and the baskets are very practical. Use strips of cane or bamboo.

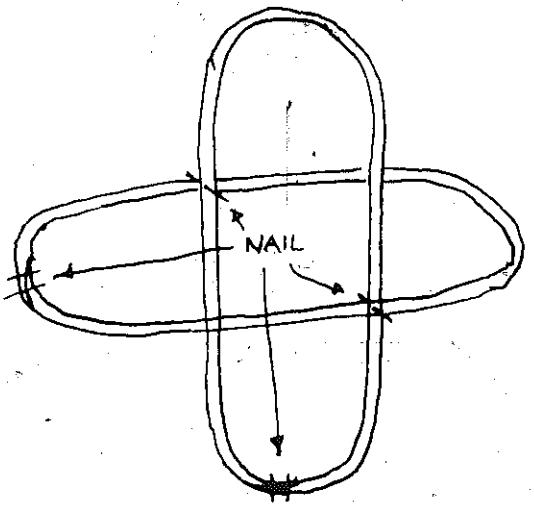

Make two circles, preferably with round cane. Fasten with small nails or wire.

To make bamboo or cane strips: Cut 5 or 6 wide strips around outside wall, then cut into narrower strips and clean them. You want the durable hard outer layers. Dispose of soft inner layers. Use mature but fresh materials.

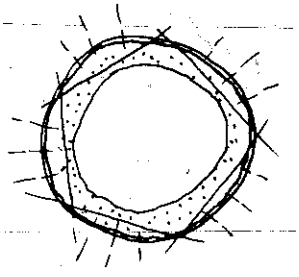

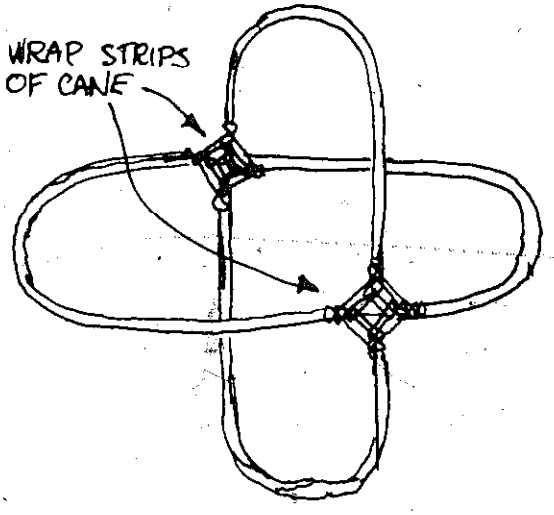

Wrap strips of cane where they cross. See photo.

cont'd

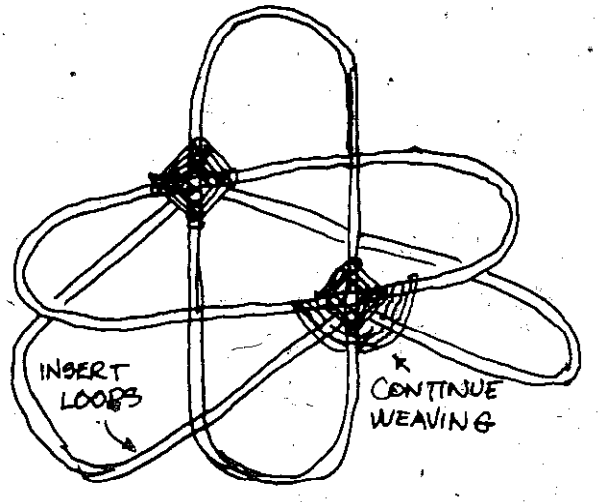

Insert the two loops which form the bottom outside corners of basket. Make a nice point on the ends of the loops for easy insertion. Continue weaving a little bit.

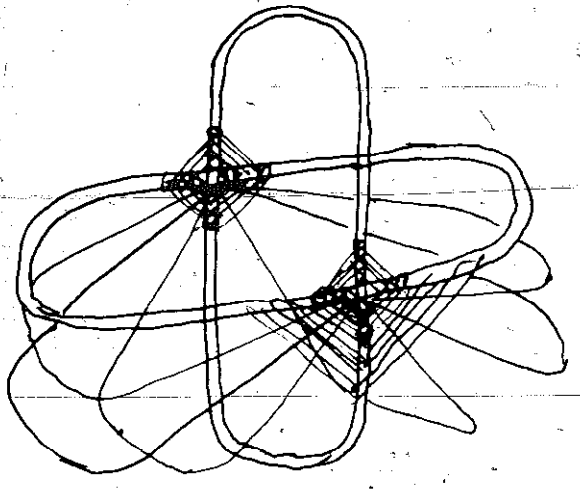

Now insert more loops, as many as you need. You will have at least 5 loops on each side in addition to the two basic circles. You can add more loops later if you need to. When the weaving becomes too wide or uneven in one place, turn around before reaching that place, to make it even.

With a little practice you will teach yourself how to make it look nice. There are several variations on this design. See photo of poultry nests on page 167.

Suggested by G. Bergmann, Boana, M.P.

THAT LAST IDEA SOUNDED EASY, DIDN'T IT? YOU THINK THAT YOU COULD WRITE SOMETHING LIKE THAT, TOO, DON'T YOU?

WE'LL BET YOU A COPY OF THE NEXT EDITION OF LIKLIK BUK THAT YOU CAN WRITE AN ARTICLE THAT WILL BE ACCEPTED.

LOOK ON PAGE 268 FOR INSTRUCTIONS ON HOW TO SUBMIT A CONTRIBUTION.

MORE BASKET WEAVING

The Base - Cut 10 stakes about 40cm long. Split 5 of them in the middle and slip the other 5 through to form a cross.

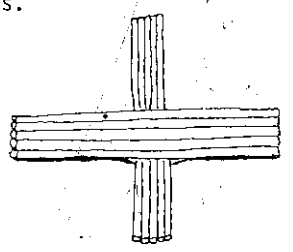

Weave the base with a weaving cane doubled. This is called pairing. First weave around the 5 stakes as a group, going around twice. Then divide 2 - 1 - 2 going around twice again.

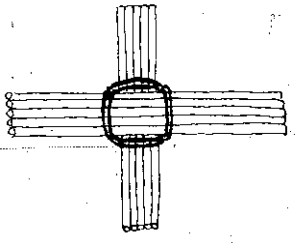

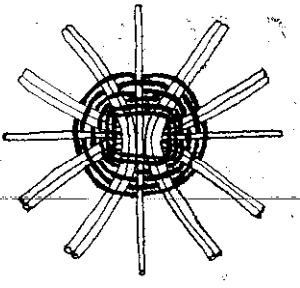

Then separate the stakes and weave individually keeping them the same distance apart.

As you weave bend the ends of the stakes down a bit so the center of the base will be raised up a bit. This will permit the basket to sit more steady and not be wobbly.

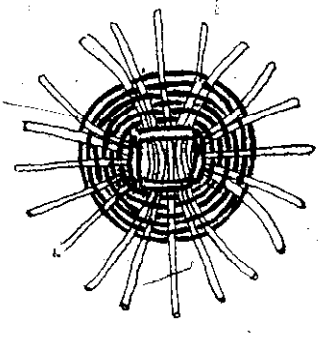

Keep weaving until the base is the size you want. Make sure as you weave the cane is pulled very tight against the round before it. It helps to hammer it with a length of cane after each round.

The Sides - Cut 39 stakes for the sides of the basket. The length of the stakes should be about 30cm longer than you want the height of the sides. This will allow for the part that is pushed into the bottom and the part that is used for finishing the sides off.

cont'd

Sharpen the side stakes on one end so they are pointed like a pencil. Insert the stakes one on each side of the base stakes. One stake will only have one since there needs to be an odd number of stakes for the sides. After sticking the side stakes in the bottom so they all extend the same amount, squeeze them all tight at the end of the base where they will be bent up.

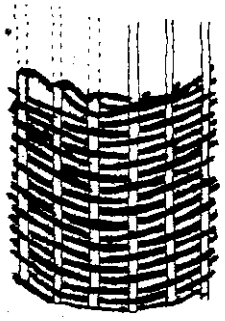

When the side stakes are bent up, it's easier to use four weaving canes. Start each weaving cane one stake to the right of the one before it going in the direction of right. After going around once with the four weaving canes, cut off three and continue with one the rest of the time. This is called randing.

Finishing off - When about 15cm of the stakes remain, stop weaving and soak the stakes, squeeze and start turning down to make the border. One stake is bent inside the stake to the right of it, outside the next one and inside the third one and finishes there. The next one is bent over the first one and inside the stake to the right of it and outside the second one and inside the third stake and finishes there.

Initial Contributor: Dale Busse, Box 80, Lae

BLACKSMITHING

(p245)

The Making of Tools, 93 pp, 1973, and The Modern Blacksmith, 96 pp, 1974, Both by Weygers, published by Van Nostrand Reinhold Co., N.Y., Toronto, London, Melbourne, Price: Canadian $4.95 each.

Both books are profusely illustrated by the author and deal with the basic techniques of old fashioned blacksmithing. Detailed description of the manufacture of tools, such as hammers, chisels, tongs, shears, augers, wrenches (spanners), shovels, etc. It even deals with the making of an anvil from a piece of railroad rail.

For raw material, Weygers does not use store-bought stock. Instead he recommends the use of waste iron such as drilling rod, car springs, axles, bumpers, power hacksaw blades, old files, etc. These are two books well worth investing in-especially if one is in an isolated area where gas welding equipment is either not available or expensive. Intermediate level.

J. Bekker

BLACKSMITH TRAINING: The office of Business Development has brought an IVS volunteer from Sri Lanka to help set up some small pilot blacksmith shops. If you want someone to be trained at the 2 to 3 month blacksmithing course in Rabaul, write: Nick Grato, Business Development Office, Box 385, Rabaul.

CHARCOAL MANUFACTURE

(p 128)

In Africa and Asia wood charcoal is a widely used cooking fuel. It has five important advantages. 1. It is a concentrated energy source, with 3-4 times the heat value of green wood and twice the heat value of dry wood. Thus it is more practical for high temperature work like blacksmithing. 2. It is easier to transport long distances. 3. It does not make smoke when it burns. 4. It preserves wood that would otherwise rot before burning, and can be stored indefinitely in all kinds of weather because it will not rot. 5. It adds no taste to food which is cooked over it, and there are no residues in smoke to damage the cooking pots.

Although charcoal can be used in confined spaces, since there is no smoke, you must have ventilation to prevent the buildup of poisonous carbon monoxide gas.

Charcoal is made by heating wood in a limited supply of air. When the wood temperature is heated to about 300°C, there is a heat generating reaction that comes from the tars in the wood breaking down. This heat causes the water, acids, tars and oils - which are about 70% of the weight of the wood - to be driven off as gasses. The unburned carbon and ash which remains is called charcoal.

Commercial plants made of brick and steel are used to produce large quantities. Often the gasses in these plants are recovered and made into useful products like acetic acid, methanol, acetone and various tars.

Small quantities of charcoal can be manufactured very easily in a 200 litre (44 gal) drum. One drum will produce about 20kg of charcoal a day. Two men with a minimum of training can handle 6-8 drums at a time. Charcoal can be made from any debarked wood, green or dry, hardwood or softwood, timber off-cuts or branches. Coconut shells can be used and will produce a very fine grade of charcoal. Pieces should not be more than 15cm in diameter nor more than 85cm long so they will fit in the drum.

To prepare the drum first cut out the bottom. Cut two small holes about 15cm x 15cm each in the top in addition to the two bung holes that come with the drum. (photo)

Place the drum over two logs or pipes so that a little air can enter the bottom through the holes when the fire is started. Stack the wood vertically upright and pack it as tightly as possible. Leave an empty space in the centre of the drum to

fill with twigs and leaves when the fire is started.

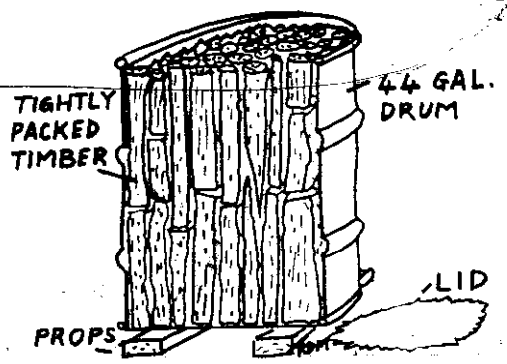

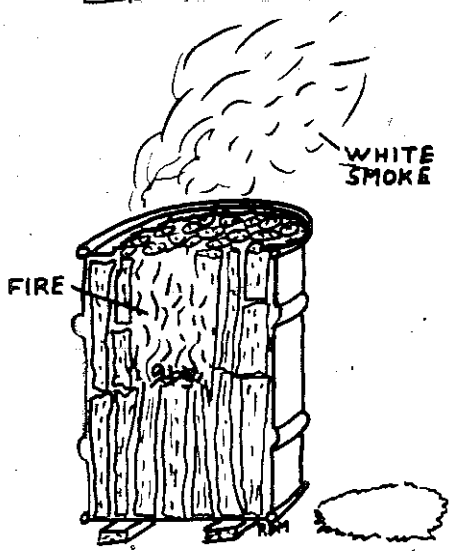

It is important to control the fire so that the wood will not burn but will become charcoal instead. The air supply must be adjusted so that only white smoke comes out. If black smoke or no smoke is visible, the air supply is incorrect.

There are four steps to control the air:

1. Use the cutout from the bottom of the drum to close the opening enough to keep a steady flow of thick white smoke.
2. When the use of the cutout is not enough, rock the drum to reposition the logs or shells inside. (The drum will be hot, so use tools or heavy gloves to protect your hands.) Usually the drum should be rocked every 15-30 minutes during the burn.
3. After the drum is heating well, about 30-60 minutes after the start, remove the drum from the logs or pipes. This will cut the flow of air through the bottom. The timing for lowering the drum is when neither steps 1 or 2 are enough to keep the thick white smoke coming out.
4. After 90 minutes, begin adding short pieces of wood to the drum. You should refill the drum 2-3 times during the run, so that at the end of the run you will have a full drum of charcoal. The extra wood also cuts down the amount of air available as the charcoal settles. If steps 1, 2, and 3 are not enough to keep a steady white smoke coming out, you know it is time to add more wood.

After about 5½ hours of white smoke you should have a drum filled with red hot charcoal. Now you must seal the large opening at the top of the drum to put out the fire and let the charcoal cool. This is the most difficult part, and has the greatest risk of injury to the beginner.

Fit the cover back in the opening. One person should hold this in place with a long pole, so that when the drum is tipped over, the charcoal will not fall out. Carefully tip the drum, using poles or pipes and heavy gloves to prevent burns. Tip the drum to its side, and then completely over.

When the drum is vertical again, seal the base with mud around the edges, and plug the four holes at the top. Left overnight, the drum will cool enough to empty it the next day.

Ed. note: The obvious danger to operators from potential burns if they are not careful concerns us. In other countries, the run is closed down simply by sealing the base and covering the open top with a piece of flat iron that is weighted. With this method it is necessary to have a straight edge to the drum opening so that there will be a good air-tight seal.

With a little practice it is possible to make charcoal free from ash and unconverted wood. Of course any pieces of unconverted wood can be used in later batches. Charcoal is different from charred wood because it is totally black throughout and can be broken up by hand.

Use the charcoal for household cooking, blacksmithing, or other times when you need high heat in a confined space. It is an economical fuel when the only alternative is firewood which must be carried a long distance.

Initial contributor: N. Grato, Box 385, Rabaul.

DYEING WOOL WITH MORDANTS

Mordant: A substance which makes dyes permanent. Different dyes and different materials may require different mordants for a desired effect. Different mordants are used at different times in the dyeing process. Follow instructions for each mordant.

General directions: Quantities here are for 0.5kg of wool and 20 litres of water.

1. Use clean wool.
2. Wet wool in warm water before dyeing or using mordant.
3. Add ¼teaspoon acetic acid to 4 litres of water to all dye baths. This helps swell fibres and makes them absorb dye more readily, colourfast.
4. Boil wool and dye subjects together, moving them frequently to prevent uneven dyeing. Boil gently until required shade obtained. Add salt, boil longer.
5. Lichens that are dry should be soaked 24 hours in water before dyeing. Bark or dried berries, put in muslin bag and soak overnight.
6. Iron and copper pots affect the colour (darkens it); tinned or stainless steel pots are better (neutral).

Mordants used before dyeing:

Alum: 90g alum
30g cream of tartar

1. Dissolve alum and cream of tartar in boiling water.
2. Put wool in mixture and raise temperature slowly. Keep just to boil for 1 hour. Keep cover on.

cont'd

NATURAL DYE PLANTS FOR WOOL

PLANT	PART USED	MORDANT	COLOUR
Bamboo	Leaves	Alum	Pale green
Bracken fern	New brown fronds	Alum	Golden fawn
Bracken fern	Roots		Red to black
Carrots	Leaves	Alum	Yellow
Chrysanthemums	Flowers	Alum	Shades of green
Dahlia	All shades/flowers	Alum	Red/orange shades
Elderberry	Ripe Berries	Alum	Lilac blue
Elderberry (Sambucus)	Ripe Berries	Chrome	Violet purple
Elderberry (Nigra)	Leaves		Yellow
Eucalyptus (varies with species)	Leaves	Alum	Yellow-green
"	"	Tin	Yellow
"	"	Copper	Light brown
"	"	Iron	Brown
"	"	Iron & copper	Dark grey
"	"	Tin & Iron	Green
Hibiscus (red)	Flowers	Tin	Brown
"	"	Iron	Lavender-grey
"	"	Chrome & Alum	Yellow
"	Flowers/caly/stalk	Tin	Olive green
Horsetail	Stalks	Alum	Warm grey
(Equisetum)	Green tips	Alum	Greenish-yellow
Indian Mulberry	Bark		Red
(Morinda citrifolia)	Roots		Yellow
Marigold	Flowers	Alum	Deep yellow-green
"	"	Aluminum & Soda	Old gold
New Zealand Spinach	Leaves	Alum & Soda	Primrose yellow
Onion (round)	Skins	Alum	Yellow to brown
Passion Fruit	Skins	Chrome & Iron	Brown
Spagnum moss		Alum	Lemon yellow
"		Chrome	Yellow
Sweet potato	Leaves	Iron	Yellowish blue
			Brown
Tamarilles tree tomato	Red fruit	Cream of tartar/tin	Mauve blue
Tankets	Roots		Brown
Tobacco & Comfrey	Leaves & stems	Ammonium sulphate, Ferrous sulphate	Grey
Tumeric	Root	Alum	Bright yellow, gold

3. Then either (a) let wool cool, squeeze, store in damp condition for 2-3 days (wrap in towel)

   or (b) allow to steep in liquor overnight, squeeze and start dyeing colour.

Potassium Di-chromate (chrome): Chrome 15g

1. Dissolve chrome in cold water.
2. Immerse damp wool, cover container, heat to boiling point, agitate, simmer for 1 hour.
3. Cool and allow wool to stay in mordant overnight. Can be used immediately, but better to leave several days in damp towel in cool, dark place.
4. Rinse out mordant well, then put in dye bath.

Mordants used during dyeing:

15g Ferrous Sulphate (Sulphate of iron)
30g cream of tartar

1. Dissolve iron and cream of tartar in hot water and stir very thoroughly when adding to the dye bath (tends to dye unevenly).
2. Enter wool and keep gently moving for 15-20 minutes, stirring all the time.
3. Rinse thoroughly - mordant weakens fibres. (Keep separate vessel for iron - difficult to clean).

Potassium Bitartrate (cream of tartar):

20g stannous chloride (tin crystals)
80g cream of tartar

1. Boil dye subject until good dye extracted. Lift from dye bath.
2. Add cream of tartar and tin and simmer a few minutes, then leave to cool.
3. Wet wool and add to cooled dye bath.
4. Boil gently until shade desired obtained.

No Mordants needed: Lichens.

Parmelia lichens: found lying flat on trees or rocks. Shaded fawn, grey or black and white. Often have spores. Colours obtained - tans to rich brown.

Usnea: Old Man's Beard - stringy greenish yellow, hangs from trees. Colours obtained - yellow to fawn, rust and brown.

Xanthoria parientina: bright orange lichen on walls or rock. Colour obtained - yellow.

NATURAL DYES FOR SILKS

Silk in skeins must be handled carefully to prevent its matting; dip the skeins in and out of the dye instead of stirring them. In both mordanting and dyeing, the bath should not be over 70°C. Otherwise proceed as wool. Bracken fern use shoots, Iron mordant, grey colour.

Boil 500g of fern shoots 30 minutes and strain liquid into warm dye bath. Enter washed, wet silk and steep one hour. Remove silk; cool dye bath and add 30g ferrous sulphate and 60g cream of tartar. Mix well; return silk to bath, heat gradually to 70°C and steep half an hour longer. Dry silk before rinsing.

Dyemaking with Australian Flora, The Handweavers and Spinner's Guild of Victoria, 31-33 Victoria St., Melbourne, 1974 A$4.50
Dyes from Plants of Australia and New Zealand, Joyce Lloyd, AH & AW Reed, 182 Wakefield St., Wellington, or 51 Whiting St., Artarmon, NSW. 1971 A$3.95
"Cloth Dyes from Natural Sources", K. Robinson in Appropriate Technology Vol 2, No 4 (Feb 1976)
An excellent reference if you are serious about making your own dyes.

Dye Plants and Dyeing by E.J. Schety, editor, Pub. by Brooklyn Botanical Garden, 1000 Washington Ave., Brooklyn, N.Y. 11225, USA. US$1.50 plus postage. Gives description and recipes of different natural dyes from around the world with instructions for a beginner. Illustrated. A very handy intermediate level book for those interested in dyeing.

Nature Plant Dyeing by Palmy Weigle, editor, Pub. by Brooklyn Botanical Garden, 1000 Washington Ave., Brooklyn, N.Y. 11225 USA. US$1.50 plus postage.

More on natural dyeing with different mordants, instruction on preparation of wool, a supplement to Dye Plants and Dyeing. Advanced level, useful for those teaching dyeing.

H. Bekker

The Use of Vegetable Dyes by V. Thurston, Dryad Press, Bristol, England.

Though listing mostly British plants this pamphlet is very good for more details on tricks of dyeing and the use of mordants.

SMALL ENGINE TROUBLE SHOOTING

A. PROBLEM: ENGINE DOES NOT START:

Possible causes:

1. Fuel tank empty, fuel tap not turned on.
   Check fuel level - check fuel tap.

2. Fuel flow obstructed.
   Remove fuel line at carburettor to check flow. If restricted, check fuel line; breather hole in cap; filter in tap.

3. Spark plug failed or dirty.
   Remove spark plug, clean and reset to .025 - .028 (about the thickness of wood of a matchbox cover). Reconnect high tension lead and lay spark plug on engine. Operate starter mechanism. If no spark between the electrodes, replace the spark plug with a new one of the same type.

4. Ignition points faulty.
   Clean, reset gap to about 0.38 mm (.015")

5. Faulty condenser or coil.
   Replace condenser (can cause badly pitted points). Have mechanic check coil.

6. High tension lead fault or suppressor cap failure.
   Remove suppressor from the end of the spark plug lead, and hold end of wire about ½cm from the engine while operating the starter. A spark should jump the gap; if not inspect the lead for any cracks. If damaged, replace the lead, or suppressor cap.

7. Incorrect mixture of oil/benzine.
   If in doubt as to the fuel mixture, drain and replace. (2 stroke only)

8. Blocked air filter.
   Clean foam type filters in benzine, dry, add oil, squeeze dry, replace. Replace paper-type with a new one.

9. Carburettor faulty.
   Clean carburettor, jets, and needle valves.

10. Worn or broken piston rings, crankcase seals leaking, or cylinder head gasket failure.
    Switch off fuel. Remove spark plug lead. Turn engine by hand in the normal direction of rotation. Each complete turn should have two distinct compression periods - one strong and one weak. If compression weak, overhaul engine (2 stroke only).

    Switch off fuel. Remove spark plug lead. Turn engine by hand in the normal direction of rotation. Each complete turn should have one distinct compression period. If compression is weak, overhaul the engine (4 stroke only).

B. PROBLEM: ENGINE STARTS BUT RUNS POORLY OR LACKS POWER.

Possible causes:

1. Spark plug dirty or not set at correct gap.
   Remove-clean-reset gap at .64-.71 mm (.025-.028")

2. Ignition points binding, or set at wrong gap.
   Check that they move freely. Check gap. Check that there is no oil on point's surfaces.

3. Coil or condenser breaking down.
   Replace condenser. Have coil checked.

4. Ignition timing slipped.
   Check that the flywheel key has not broken on the crankshaft.

5. Incorrect mixture of oil/benzine.
   Drain and replace with correct mixture (2 stroke only).

6. Small quantity of water in fuel.
   See B-5 also drain carburettor.

7. Intermittant fuel obstruction.
   Check fuel flow at carburettor, clean needle valves, check breather hole in fuel cap.

8. Carburettor faulty.
   Dismantle - clean jets, float chamber and needle valves.

9. Air filter dirty.
   See A-8.

10. Excessive carbon build up.
    If the muffler is heavily coated with oily deposits, decarbonise the engine.

11. Burned valves, seats, or sticking valves.
    Remove cylinder head, and turn the engine. If valves remain open, or if valve seats are pitted or burnt, overhaul the engine (4 stroke only)

12. Loss of compression.
    Check as in A-10

C. PROBLEM: ENGINE STOPS DURING USE:

Possible causes:

1. Out of fuel
   Refill the tank.

2. Spark plug failure or dirty spark plug
   Check as in A-3

3. Contact points gap incorrect or jammed.
   Check gap - reset if necessary.

4. Condenser, coil or suppressor cap failure.
   Replace condenser, have coil checked, replace suppressor cap.

5. Restricted fuel supply
   Check as in B-7

6. Governor linkage broken or badly adjusted.
   If broken replace. Get mechanic to adjust (4 stroke only).

7. Vapour lock in fuel.
   If engine and thus carburettor are very hot, allow to cool.

8. Dirt in carburettor.
   Dismantle, clean all jets, needle valves, and float chamber.

9. Excessive carbon build up.
   Check as in B-10

10. No oil in crankcase.
    Check oil level, refill as necessary. If engine is noisy when restarted, overhaul.

11. Mechanical failure.
    Check as in A-10 Also, if the engine will not turn, allow it to cool, and then check the compression. If it still will not turn, or if the compression is weak, overhaul the engine. Check as in A-10 Read the above note also.

Contributed by: R.G. Haeusler, Kurum Plantation, Karkar, via Madang.

HOME-MADE DEGREASER

For cleaning up engines or machinery before working on them: Mix 1 part liquid detergent to 6 parts diesel fuel or kerosene. Brush on, loosen dirt, then rinse off with water

The Shell Book of How Cars Work, by Gordon Walmsley, John Baker Publishers Ltd., 4 Soho Square, London WIV 6AD, 1966. Pounds 1.80.

This is a very nice little book full of drawings and diagrams to explain the mysteries of the internal combustion engine and the running gear of an automobile. The ability to visualize the actual engine is required, but the explanations are clear, straightforward and brief. The book is available from the Technical Education Library, Dept. of Education, Konedobu, and is very suitable for class work in motor mechanics courses. An added bonus - it explains how various fuels and lubricants are extracted from petroleum.

Level simple/intermediate J.T. Hale
Box 215, Wewak, ESP.

Automotive Operation and Maintenance, VITA, 1973

A specialised handbook giving hundreds of pieces of appropriate information for more effectively operating a car or truck in places with bad roads, a weak servicing infrastructure, and a difficult climate.

It deals with problems seldom encountered in an industrialised country and which a driver usually learns about through great costs and bitter experience.

Cost: US$6.50. Available from VITA, 3706 Rhode Island Ave, Mt. Rainier, MD 20822 USA.

FISHING

MAKING A NET

Only a few tools are needed in net making and mending: a needle, a small knife for cutting twine, and a mesh gauge which measures the size of the mesh (see Fig. 1). The process of making a simple cast net involves almost all the fundamental skills which you will need to know.

FIGURE 1

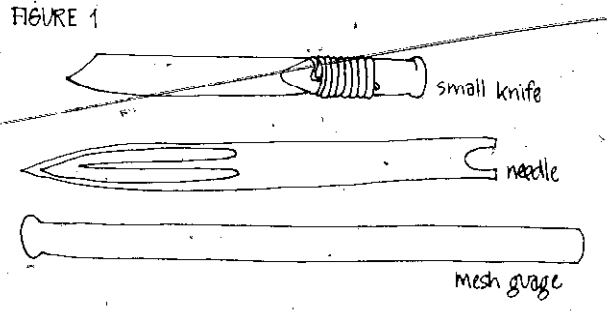

Figure 2

The Cast Net

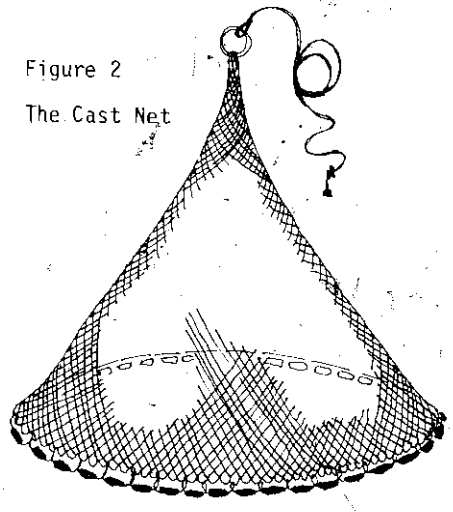

FIGURE 3

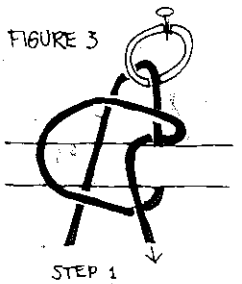

STEP 1

FIGURE 4

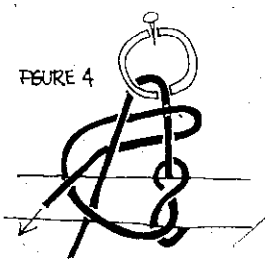

STEP 2

First, make the foundation mesh. Make a loop of rope or twine hooked on a nail. Pass the needle through the loop. Hold the mesh gauge in the left hand and with the left thumb press the end of the standing part of the twine against the mesh gauge, spacing the gauge about the width of the needle away from the rope. Slip the needle behind the first bar or strand, cut through the loop (Fig. 3), and pull the twine down. Make another loop to the left and over the gauge. Pass the needle behind the two bars and cut through the loop (Fig. 4). Pull the twine down and tighten the knot as in (Fig. 5). Pass the twine below the gauge and up through the loop of rope and repeat the first operation shown in (Figs. 5 - 6) until you have made about 30 or 40 meshes.

FIGURE 5

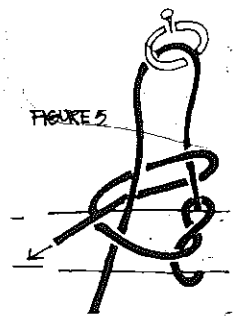

PULL TIGHT

FIGURE 6

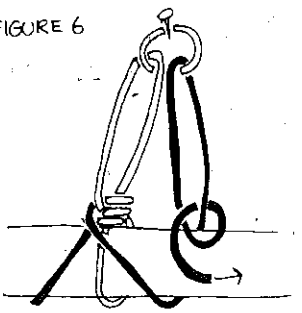

COMPLETING ROW 1

Second, join the last mesh with the first mesh. Start the second row of mesh. Slip the needle through the first mesh pulling the twine over the mesh guage until the loop of the mesh reaches the top edge of the gauge (Fig. 7). With the left thumb clamped over the mesh, form a loop to the left and up through the thumb. Pass the needle behind the mesh and through the loop forming a knot (Fig. 8). Repeat until the second row of meshes is made.

FIGURE 7

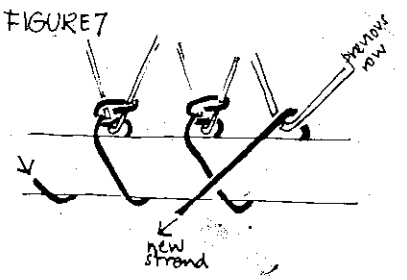

FIGURE 8

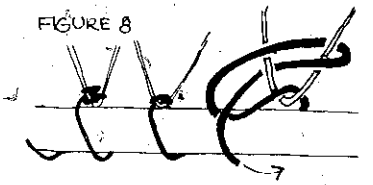

After the third row of mesh, begin increasing the number of meshes. This should be done every other knot. Variations may be done by increasing the meshes with every knot depending on the type of net being made. (Fig. 9).

Make three rows of meshes and start again to increase the number of meshes by making extra loops just in line with the first. Increasing the loops should be done after completing every three rows of meshes until you have made the desired length of net. The last row of mesh may be doubled to make it stronger

FIGURE 9a

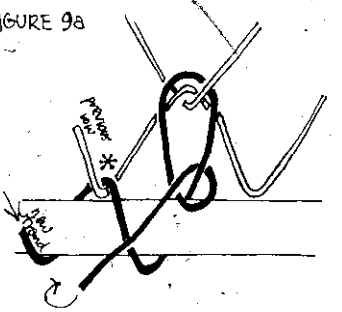

STEP 1 for adding extra loops to the mesh

* NOTE ON FIGS 9a–c: Step described in fig. 8 omitted for clarity.

FIGURE 9b

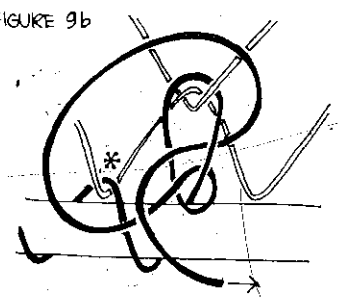

FIGURE 9c

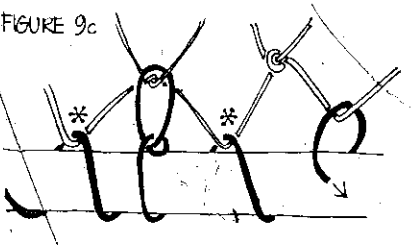

FIGURE 10

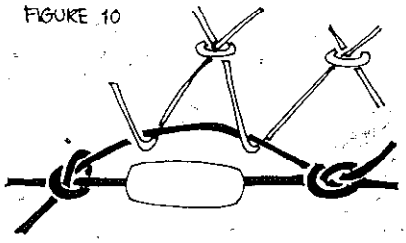

Attach the lead sinkers. They should be tied together with a piece of twine and a rope where the lead pieces are hooked. Fig. 10 illustrates how lead sinkers are tied together.

To make the netting more durable, count about 30 meshes from the lead sinkers upwards. At the thirtieth mesh reinforce the meshes by doubling the thread or twine. This should be done for every twenty-five meshes.

Initial contributor: V. Estillore
Magarida Voc. Ctr
Amazon Bay, C.P.

BASIC KNOTS FOR FISH NETS

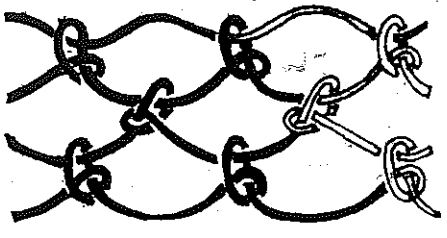

The "Lake Dwelling" knot: first found in European lakes, now also Pacific and Congo. Will not slip if coarse fibre is used, and the mesh remains constant.

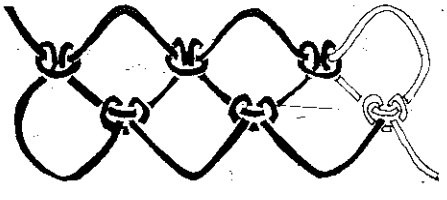

The "Peruvian" knot: will slip unless hand-twisted. Irregular fibres are used.

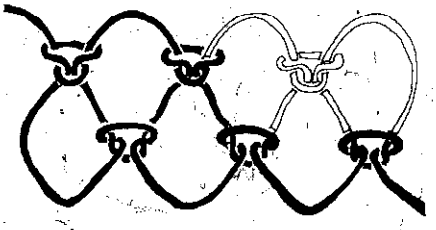

The "Reef" knot: An improvement on the Peruvian, slips only if synthetic fibres are used. Common in Asia.

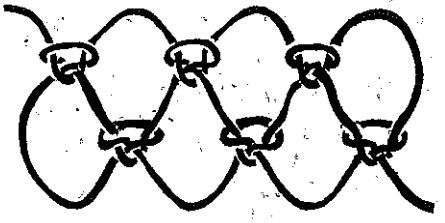

The basic "Weaver" knot: Complicated. Nowadays found worldwide. Suitable for natural and synthetic fibres, and for machine weaving.

References:

Fish Catching Methods of The World, A. von Brandt, 1972; and How to Make and Mend Nets, by J. Garner, 1962, a useful instruction manual; both published by Fishing News (Books) Ltd, 110 Fleet St., London EC4, UK

Initial contributor: J. Lowson
Box 793, Lae

DERRIS FOR CATCHING FISH

Throughout PNG people use one of the derris root legumes to stun fish. Although poisonous even to humans in large amounts, in small amounts it is widely used as a safe insecticide called roetenone. In very small quantities it stuns fish so that they float to the top of the water. If not harvested quickly they will recover when fresh water mixes with the treated water.

In the Western Province during the dry season, people watch for schools of fish swimming in from the sea up small rivers. It is the custom then to fence the mouth of the river by driving stakes in the mouth of rivers that are no deeper than a man's chest. Then they weave or tie finely split bamboo to the stakes to act as a fence so the fish cannot go back to the sea.

Derris roots are then crushed between stones or any other suitable way and the liquid collected. When the fish come close to the fence the liquid is poured in the water. The unconscious fish are collected when they rise to the top. Any fish not collected will recover in time and survive as fresh water comes down the river.

cont'd

Derris juice can also be used in salt water pools on the reef where water movement is not rapid.

There is very little danger to people using this method and the effect of the poison does not last long. It is safe to eat fish caught this way.

Initial contributor: J. Wapi, Vudal, PO Kerevat, ENBP.

LEAD FISHING SINKERS FROM OLD BATTERIES

Melt the lead plates in a steel container over a fire. Pour the HOT molten lead into moulds. Moulds are sometimes available from sports stores. Or you can use small pieces of bamboo, or even paw paw stem for moulds. For the centre hole use a piece of round grass or something similar. Or make moulds right in the ground. The product will be crude, but they are easy to make.

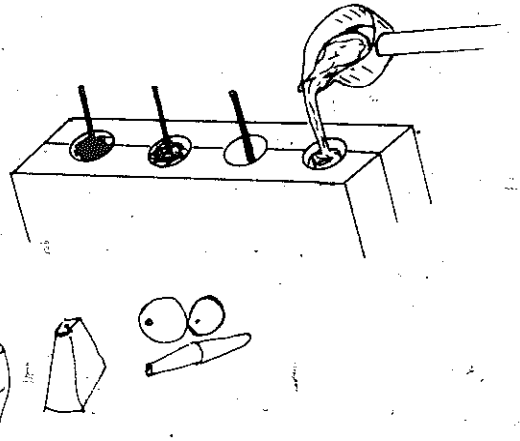

LEATHER TANNING

With the PNG cattle population rapidly increasing, and with more and more animals being killed at local levels, we would expect considerable interest to develop in the production of leather.

Facilities required: Three tanning tanks 240 x 100cm deep with gradations of 250 litres marked every 6.5cm from the bottom: One drying rack as large as the biggest skin; two 200 litre drums.

Materials needed for 100kg of dry skins:

50kg lime or kambang	from	Trading companies
2kg sodium sulfide	"	Shell Chemical
2kg borracic acid	"	Chemists
200kg mangrove bark, oak, casuarina, or wattle	"	local trees
10 litres vinegar	"	Trading companies
40 litres coconut oil	"	Coconut Products Ltd Rabaul or pressed at home.
Fleshing knife	"	Stockman's supply, firms or make your own
Hose for siphon	"	junk heap
10 Copra sacks	"	local sources

The process:

1. Put 100kg chopped mangrove bark, five litres vinegar, and 1000 litres of clean water in Tank No 3. Stir daily for a week.

2. After one week put 500 litres of liquid from Tank No 3 in Tank No 2 using siphon and add 500 litres of clean water to it. Put 250 litres of liquid from Tank No 2 into Tank No 1 using siphon, and add 750 litres of clean water to it. Then refill Tank No 3 to the 1000 litre mark.

Note: to keep tanning liquid strong after each 100kg of hides is tanned add 40kg of mangrove bark to Tank No 3 and fill to the 1000 litres mark with clean water. Continue after each tanning until Tank No 3 is full of bark, then throw out the bark (but keep the liquid), continue adding 40kg of bark after each tanning.

3. Each time you add 40kg of bark to Tank No 3 take 250 litres of liquid from Tank No 3 and add to Tank No 2. Then take 250 litres from Tank No 3 and add to Tank No 1. Refill all tanks to the 1000 litre mark. When the tanks are ready you can begin tanning.

Note: if you have to wait more than 12 hours after skinning an animal before you begin tanning, you should salt it by first scraping all the meat and fat carefully from the skin. Rub salt in the skin, roll up skin for one day, then dry it. When you are ready to tan, wash the salt out by soaking in clean water for half a day until hide is soft. When hide is soft again or if the hide is fresh, go to step 4.

4. Paint the inside of the skin with a solution of 50 parts kambang or lime, 50 parts water and 5 parts sodium sulfide. Then fold the skin in half with the insides together and leave for 12 hours. Scrape the hair off with a long curved knife. When hair is off, wash out the lime by soaking the skin for two hours in a drum with 250g of boracic acid in 50 litres of water. Then wash and drain.

4a. If you want to keep hair on the skin do not use lime but you must wash the skins very well overnight in a strong mixture of detergent, bleach and water or else the grease in the skin will make the leather rot.

Now you can begin tanning.

5a. Put skin in Tank No 1 for 3 days, but turn the skin every day.

b. On the 4th day put the skin in Tank No 2 for four days but turn every day.

c. On the 8th day put the skin in Tank No 3 for 4 days but turn every day.

d On the 12th day take the skin from Tank No 3 and hang on a rack to drain. The rack should be level so that the hides lie flat. Cover with copra sacks so the hides won't dry out. Leave for 3 days.

e. After 3 days of draining wash the skins in clean water and take off any bits that stick to the hide. Then drain for 3 more days, but keep covered with copra sacks so they won't dry out.

f. Rub copra oil or neatsfoot oil into the skin then pile in a stack for a day. Do this again the next day and one more time the 3rd day.

g. Now hang the skins in the shade where there is lots of wind and no sun so that the hides can dry slowly.

6. Softening: This is done by wirebrushing the inside of skin and then sanding well with a coarse sandpaper. It can then be pummelled and worked to make pliable. The leather is ready for using then. Furs can be done in the same manner but take only a few days to tan if small i.e. cuscus.

Further references: File 10-310, 18 November 1974, Business Development Office, Box 385, Rabaul.

Equipment for the Tanning of Hides and Skins, by L.R. Ray & E. Backman, 1951, 18pp. US$0.25. FAO Agriculture Development Paper #13.

Home Tanning and Leather Making Guide

Best information on tanning we've seen. If you're eating deer or calf or dog or whatever and throwing the skin away, you don't need this book. Meathead.

—SB

Home Tanning and Leather Making Guide
A. B. Farnham
1950; 176 pp.

$1.50 postpaid

from:
Harding's Books
2878 East Main Street
Columbus, Ohio 43209
or WHOLE EARTH CATALOG

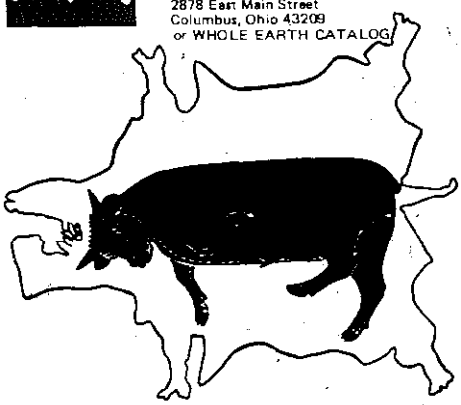

PROPER RIPPING OPEN CUTS FOR A CORRECT PATTERN
The dotted lines show the path of the knife, and the solid lines show the appearance of the hide when spread out.

TWO HANDLED SCUDDING KNIFE
Used like Slicker, curved to fit beam. Brass, copper or slate edge, to avoid rust.

I.D. Clarke and J.S. Rogers. Home Tanning of Leather and Small Fur Skins. U.S.D.A. Farmers Bulletin No. 1334, Superintendant of Documents, U.S. Government Printing Office, Washington, DC 2D402, USA. 15¢.

In 25 pages this booklet gives the most complete introduction to tanning for use in village industries . Many alternative methods are described including a salt/battery acid method for making belting leather.

PNG Experience: This has apparently been tried in ENB., but no report of results has been received, also at Kelabovia, SHP. (Photo opposite)

Remarks: Note that while the process for one hide takes nearly three weeks, the amount of time each day is very little. Those working in cooler climates will find it easier than those in very warm areas.

For a trial, use smaller scale - in the proportions outlined above. A copper laundry kettle or a 200 litre drum is good.

Neatsfoot oil can be made by putting fresh hooves and shin bones of beast in a sugar bag and boiling well. The oil will float. Skim and bottle when cool.

Updated by: B. Telford, CMML, Kelabovia, via Wewak, ESP.

RAWHIDE

Making Rawhide from cattle leather is simpler than tanning, and the product is really quite good. Some of the Vudal students made rawhide successfully last year, and the product was so popular that we couldn't get any ourselves to try making handcraft articles.

Basically the process is just removing the moisture from the skin and replacing it with a non-mineral oil or fat, over a period of about three weeks. The students used a mixture of neatsfoot oil and beef tallow, heated in tins.

It is best to do this when the humidity is not high, as the skin must dry, and cannot be put in the sun. A slow steady drying process is what you want.

The thoroughly cleaned skin is placed in some sort of frame, and regularly, preferably every day or two, more oil is worked into it. This doesn't take much time. When it is well-dried it may be taken out of the frame. During the three weeks time the colour changes from reddish brown to brownish white.

The skin will still have the hair on it, which is nice for some purposes. The hair can be shaved off

with a sharp tool if desired. We have heard that the hair can be removed by placing the skin in the ground for a while, but we don't know how.

The rawhide is only slightly stiff when finished, unlike certain types of tanned leather. It may be loosened by pulling it back and forth over a smooth round pole or pipe.

Rawhide makes good boot laces, belts, handbags, woven straps for a bed frame, and even water-tight containers.

Contributed by: J. Tyler, Vudal, Kerevat ENBP.

Let us know of your experiences and ideas about rawhide.

Leather Making Tools

Available from C.S. Osborne and Co.
125 Jersey St.
Harrison, New Jersey 07029
U.S.A.

Catalogue available.

METAL CASTING (No Article)

LIME-KAMBANG

In all coastal areas of PNG people make lime from coral for adding to the mixture of betel nut. High quality edible lime is made from live coral which is collected from the reef and allowed to dry for 2-3 months before it is cooked.

The traditional way to cook the lime is to dig a deep hole much larger than is needed for the coral collected. Firewood is placed in the hole to fill it, the coral is placed on top of the firewood and then more firewood is placed on top of the coral until as much firewood is on top of the coral as is in the hole. It is important to choose firewood that will burn very hot and leave little ash. In many places leucaena (landro) is used.

The fire is set and allowed to burn fiercely until all the wood is burned. The lime remaining in the whole is covered as soon as possible with the leaves of the ADUI plant (Kuanua), and on top of the Adui leaves a mat of coconut leaves covers everything. Earth is then put back in the hole to cover the leaves, and the lime is left until the next day.

The following day the earth and protecting leaves are removed and the lime is carefully taken out of the hole so that it does not get dirty. Immediately it is sieved on a piece of fly wire over leaves or a basket to collect only the fine lime powder. The rest is thrown away.

Remarks: Commercial quality of lime for building and agricultural purposes can be made from limestone. To test a sample pour a little dilute hydrochloric acid over the sample and look for bubbling in the liquid. If it bubbles it is worth doing further tests. Limestone can be burned in a hot fire. To learn more about making lime, get Technical Bulletin No 13 from Local Government Engineers, Box 1108, Boroko.

Note: Limestone and coronous are not the same, but limestone is often found near areas where coronous is.

Initial contributor: Serry Loamin, Vudal,
PO Kerevat, ENBP.

POTTERY

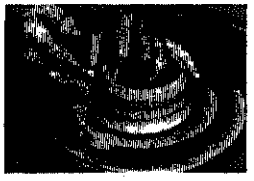

(p 214)

To make clay pots to modern standards is a very technical business requiring specially blended clays, wheels for throwing pots and sophisticated ovens. Yet for many thousands of years pots have served men in PNG and they were made only with the materials at hand. The drying was very simple.

You need clay, and the choice of clay is important. Generally the good clays are grey in colour, but some red clays are suitable. It is important that the clays don't crack when dry, and you should test the clay be drying a small piece.

The clay should be made wet evenly through the pile and any rubbish or hard pieces should be taken out. It should be soft enough to work easily, but not so soft that it will not hold its shape. Add enough water a little at a time and work it with your hands so it is all the same consistency.

There are many ways for making pots. One is to form the pot a bit at a time from handfuls of clay. The clay is wet on the surface so it is slippery and will not stick to your hand. As the pot takes shape it is tapped smooth and finished with a light-weight, smooth paddle.

t'd

cont'd

Another way is to wet the clay a little on the surface and roll it into ribbons or "snakes" about 2cm in diameter. These are coiled around and around the desired pot. The ends and edges are then worked by hand to join each other.

Whenever you are working with clay have enough water close by so that you can keep your hands wet, then they will not stick to the clay.

The pot must be dried slowly so that it dries evenly through the whole thickness. This is usually done by placing the pot in the shade and letting it dry for at least a week. The pots can also be placed on a shelf or in a basket over a very small fire so that the pot dries slowly. When it is hard the pot is fired, or baked to give it strength. The pot is placed on a fire of hardwood or coconut shells and then the pot is covered with more and more wood. The pot should be baked until the colour changes to a red brown. If it is another colour it will not be a good pot.

References:
Discovering Pottery, by H. Memmott, Paul Hamlyn Pty Ltd, Dee Why West, NSW 2099, 1972, 136 pp, K1.95 in many PNG bookshops. A good introduction to pottery making, with lots of clear pictures. Don't start until you have read a book like this. If you have already started, buy something else.

Ceramics, by G. C: Nelson, Holt Reinhart and Winston. This is the something else. A comprehensive studio guide, with more than 150 step-by-step photos and examples, by one of America's outstanding contemporary potters.

Initial contributor: Damien Naiyaleva, Jack Wokipim, Salome Masina, Vudal, PO Kerevat, ENBP.

FRANGIPANI PERFUME

Long ago in the olden days the Namatanai people in New Ireland Province used to make a scented oil from frangipani flowers.

They used coconuts, frangipani flowers collected from beneath the tree, and betel nut leaf.

They broke up the flowers and placed the small pieces into a container made from the base of a betel palm leaf. The base was cut from the rest of the leaf and each end tied tight to give a curve like a toy boat.

The coconuts were scraped and the liquid was squeezed directly on top of the pieces of the flower.

Each morning for a week the container was put in the sun to dry, but in the afternoon it was put in a cool place so it would not dry too quickly. By the end of the week the oil would be shiney on the surface and have a sweet smell.

Men would use this oil to rub in their hair or on their skin to make themselves attractive. The oil would keep for 4-6 weeks. Some people still do it once in a while, but I must admit that it's no longer as exciting - maybe because we're now civilized.

Initial contributor: E.A. Wesley, Vudal, PO Kerevat, ENBP.

SAWMILLING

You can use a pitsaw, but just try to buy one in PNG! Very difficult.

MINI -MILL Lumber-making Chain Saw Attachment.

Granberg Industries, Inc., Richmond, Ca 94804 USA.

Here is something I've been looking for for years, and now I've found it! I have one, and it really works. An attachment to be used with your own Chain Saw.

Available from: Morgan Equip. Pty. Ltd.,
Box 1729, Lae
Box 252, Arawa
Box 5423, Boroko
Box 1234, Rabaul

This is how the MINI-MILL works:

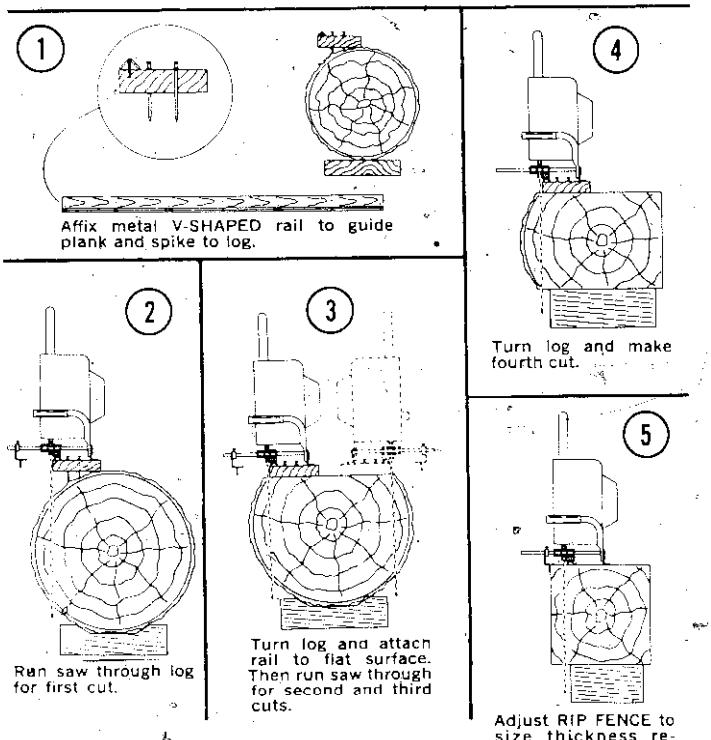

This little compact attachment combined with a chain saw converts the two tools into a single precision lumber-making mill. With this MINI-MILL anyone can make smooth ready-to-use dimensioned lumber from logs; no special talents are necessary. Lumber can be milled in any desired thickness. From these boards one-by-sixes, two-by-fours, or any size can be made. A handy lumber-making tool for anyone who enjoys building and repairing all sorts of things made of wood. Comes complete with 12-feet of metal V-shaped guide rail in three 4-foot lengths.

Contributed by: U. Bergman, Wantoat, via Lae

Mobile Mfg. Co.
681D N.E. Cornfoot Drive
Portland, Oregon 97218
U.S.A.

"Mobile Dimension Saw", three models priced between US$3,000 and US$4,500, with capacities of 1500 to 3500 board feet per hour. Simple, rugged, choice of engines. One man can operate. Runs on track, with large vertical blade and small horizontal blade. Comes as a complete sawmill ready to operate, with blades, engine and track, plus trailer, trailer hitch, tooth grinder, tooth wrench, lag bolts, lag bolt ratchet wrench, was wrench, and jack. Equipped with spark arrestors. Beginners are supposed to be able to learn operation easily. Cuts any size lumber from ¼" X 1 3/4" to 4¼" X 12¼".

International Enterprises of America, Inc.
4000 N.E. Columbia Bvd.
Box 20066
Portland, Oregon 97220
U.S.A.

"Mighty Mite" transportable sawmill, two models, each with choice of gasoline, diesel, or electric power. Horizontal main saw, vertical edger saws. Runs on track. Cuts any size lumber from 1" X 2" to 8" X 12".

Portable Electric Sawmills Pty. Ltd.,
68 High Street,
Box 199, Wodonga, Vic. 3690. Aust.

Two sizes available. A Lister aircooled generating unit powers electric saws mounted on a portable frame to cut high quality timber right where the logs are.

BLACK MARKING INK FOR LOGGERS

Ingredients required: Old torch batteries and old motor oil.

How it is done: Take the carbonstick of the old battery, pulverise, and mix with oil.

This is being done in Morobe Province.

Initial contributor: U. Bergmann
Wantoat, via Lae

SILK SCREEN PRINTING

(p 195)

Preparing Screen: Stretch silk or tetoron over frame of desired size and attach with either drawing pins or stapler.

Preparing Design: Method 1 - PAPER STENCIL: Simple - allows many designs with one screen, but is not permanent. Suitable for use at village level.

1. Cut out design on cartridge paper. Paper which has been painted with linseed oil or shellac would be more lasting, but is not necessary.
2. Attach to screen with small pieces of masking tape. If design is to be printed with a squeegee (see below) edges will have to be masked.

Method 2 - PROFILM OR LACQUER PAPER: Permanent, but allows only one design per screen.

1. Use blue lacquer paper. Cut out design, being careful not to cut backing paper.
2. Place lacquer paper on top of newspaper, and silked frame on top of lacquer paper.
3. Fuse paper to silk, exerting pressure all around frame to ensure good contact between silk and lacquer.
   (a) Blue stencil paper (oiled). Fuse to silk by using a rag dipped in DUCO THINNER. Rub thinner over a small area, rub this area quickly with a dry rag. Repeat until all lacquer paper is attached.
   (b) Brown iron-on paper: fuse to silk by ironing with iron at a low temperature.
   Note: not recommended, as it does not last long, and as silk must be used (Nylon stretches when ironed). Silk is expensive.
4. Remove backing paper gently.
5. Use masking tape to cover all of the back of the screen not masked by the stencil paper. Apply tape all around the edge of the inside of the frame.
6. The frame can be shellacked or varnished if liked. Mix shellac flakes with methylated spirits. The liquid should not be too thick. Spread over the design: quickly remove any from the open areas by rubbing it with dry rags till silk is clean. If shellac is not removed immediately from open areas, screen will remain clogged, and will be ruined.

Sources of Dyes

PERMASET: R. Collie & Co. Pty. Ltd.,
GPO Box 829L
Brisbane 4001 Qld.

THERMOFIX: Edman Wilson,
18-20 Whiting Street,
Artarman, NSW. 2064. Aust.

Printing of Material

Method I- SPONGE: Edges do not need to be masked. A smaller amount of dye is required, and as many colours as you like can be used. Takes more time,

so screen must be washed more often (so that ink won't set on screen).

1. If not using a permanent screen, place paper stencil on back of screen. Stick, using small strips of masking paper.
2. Applying pressure to screen, take a dry piece of sponge, dip in dye and rub over the areas not covered by the stencil.
3. You may use as many colours as you like. Use a dry sponge for each colour.
4. Remove paper stencil (if paper stencil method is used) and wash screen immediately.
5. Iron the design to set the colours.

Method II- SQUEEGEE: This requires edges of screen to be masked, as a pool of dye is needed. This method is much faster, and gives a professional finish. It uses more dye. If more than one colour is desired, more than one stencil has to be cut. Different colours may be placed along the end of the screen, in sequence, to obtain a multihued effect.

1. Pour a little dye into one end of the screen.
2. Applying pressure to the screen, pull squeegee across the screen and back again.
3. Lift screen and place in the next position.
4. Repeat until the printing has been completed.
5. If using a paper stencil, remove it immediately and place it on a newspaper.
6. Wash the screen immediately, using a bucket of water and a cloth. If dye is allowed to dry, it will clog screen and cannot be removed later.
7. Iron design to set colours.
8. Note: If overprinting, place newspaper over each print, or dye from the first print will get on the underside of the frame and smudge the next print.

Setting the Print

Heat is required to set Permaset or Thermofix. Permaset requires 5-6 minutes at 350°F; Thermofix requires 1½ minutes. If no iron is available, place work in the sun for an hour, if possible on the top of a tank.

It is possible to design a setting cupboard in which materials reach this heat, and this greatly increases production levels. This is necessary only when a large volume of work is to be done.

Useful Hints

Only print on flat fabrics. Most synthetics do not print satisfactorily. Resin-coated materials do not print.

Fabrics must be printed on a padded, calico covered table to absorb excess dye.

Always have sufficient dye in your screen when printing all-over designs.

Use at least two pulls of the squeegee. The first pull prints, the second pull levels off the colour concentration and gives an even finish.

Firmly close all tins and jars when not in use. Always stir thoroughly with rotary beater or stick before use.

Popular Silk-Screened Items (p 195)

- Afro shirts, adult and child
- Caftans
- Shifts, with printed yoke and pockets
- Placemats and serviettes
- Tablecloths
- T-Shirts
- Wall-Hangings
- Dress Length material (3½ yds)
- Shirt Length material (2 yds)
- Tea towels
- Ties
- Bags
- Laplaps

Contributed by: Lae Vocational Training Centre for Girls

SOAP (p 248)

Equipment needed: 2 large bowls, buckets, or pails, made of iron, enamelled steel, clay or plastic. DO NOT USE ALUMINIUM.

A mould for making soap - a wooden form or a plastic container will do, but must be water tight. If the mould is not flexible, line it with cloth or paper to make it possible to remove the soap. Split bamboo halfs or plastic loliwater cups are good too.

Ingredients required for 4kg of soap:
13 cups vegetable oil or animal fat
2 2/3 cups of caustic soda crystals
5 cups of rainwater

The process:

1. Add all the caustic soda to the rainwater (NEVER ADD WATER TO CAUSTIC SODA CRYSTALS, as it may splatter and burn). This is now called lye water. It will begin to get very warm. Stir it with a wooden stick until all the crystals are dissolved, then let the liquid cool until the temperature of the outside of the pot is the same as your hand. DO NOT PUT YOUR FINGER IN THE LYE WATER. It can burn your skin. The temperature must be right or the soap will not be good. If you have a thermometer, the temperature should be 37°C.

2. Place all the oil in another pail, and slowly, in a steady thin stream add the lye water. While pouring the lye water, slowly stir the mixture all the time. Stir steadily and in one direction for up to one hour. You will begin to see small milky white particles beginning to follow the path of the stirring stick. If this does not happen within one hour, stop and wait fifteen minutes, then stir again for five minutes. Do this until you see the track.

3. When you have tracks, carefully pour the mixture into the mould, and leave for two days in a dry place where it will not be disturbed. If it is shaken or moved the soap will not set.

4. After two days remove the mould and cut it

into bars using a thin wire stretched tight between your hands. Pile the bars so that the air will circulate on all sides for two to four weeks. When the soap is cured at the end of this time, it will be better than soap purchased in the store.

You ~~will never have "spoiled" soap, if you use the~~ right materials. If it doesn't work out the first time, you can rework it. Sometimes the soap will not be good if:
(a) the oil is rancid or salty; or
(b) the lye water is too hot or too cold; or
(c) you stir it too fast or not long enough.

If you think that the soap is not strong enough, cut it into small pieces and put it into a container with five pints of water. Melt the soap on a low heat and stir occasionally. When it is all melted, raise the heat until the mixture boils. Keep on boiling until the mixture becomes syrupy and drops in sheets from a spoon. Pour it into a mould and let stand for two days. Then take it out of the mould and cut it into bars as before.

Sources of materials: Any cheap vegetable oil or ~~fat will do. In large quantities~~ coconut oil can be purchased from CPL in Rabaul, but they mean tonnes not barrels. Palm oil sludge can be purchased from the factory in Kimbe, and at other Palm oil projects. Grease and fat from cattle or pigs can be used.

If you have no other source you can make your own (p 192) oil from coconuts or oil palm in the village. Caustic Soda is sold at Trading Companies and other stores in one pound tins for about K1.00 per pound. It is also called sodium hydroxide.

Further references: "How to make soap using Coconut Oil", Division of Technical Education, Department of Education, Konedobu.

PNG experience: Process was developed at Puas Vocational Centre where it was done frequently, and at other schools.

Remarks: Coconut oil makes softer soap than other oils, because it is low in stearic acid. It tends to be a little greasy, but it is a very good soap. It is the only soap that will make lather in sea-water.

Potassium hydroxide can also be used to make soap from all oils and fats except coconut oil. It is cheaper than sodium hydroxide. DO NOT TOUCH any of the liquid remaining in the mould after the soap hardens, as it can cause serious burns. Sr. Veronica of CM Lavongai, Kavieng, reports that girls in a training school used the liquid in the pot left over after pouring the mould as a shampoo. Their hair fell out. (It grew back.)

Important: If you ever get lye water on your skin, you must remove it carefully and quickly. If it is not removed it will burn your skin. Vinegar or muli juice can be used to neutralize the lye, and you should have some near when you are making soap.

Initial contributor: P.R. Hale, Box 215, Wewak, ESP

INKLE LOOM

Description: A simple framework made from sawn timber, bamboo, tree forks or round poles with which braids, belts and straps can be woven. Size can be varied from a table model, to one which stands on the ground.

Materials for Manufacture: Use materials that are most easily available. Bamboo, sawn timber and dowling, round timber from de-barked tree branches. Fasten joints with rope lashings (see photograph). If using sawn timber, use screws and glue or dowels and glue. Bolts make the most solid assembly if sawn timber is used. Quantities depend on size of loom required.

How to use the loom: Select materials according to type of braid, and purpose for which it is to be used. Woolen yarn, synthetic yarn, cotton, linen, banana fibre (Natural colour or dyed), pandanus root fibre, sisal, abaca. Warp strings should be strong as tension is considerable. Warps should be chosen for colour as the warp shows most in the finished braid. (Warps are the lengthwise threads.)

1. Cut about 20 fine heddle loops in a strong thread, each sufficient to reach from X to Y on your loom. All are exactly the same size.

2. Take a warp string, beginning at Peg A, pass it round C, D, E & F then back to A. Continue on with the second ~~round~~, over Peg B then ~~through~~ a Heddle Loop and over C, D, E, F & again back to A. This method is repeated with each alternate string passing through a Heddle Loop. Change colour by putting a different coloured string at A when wanted. When the warp strings are wide enough, the loom is ready for weaving.

3. Weaving is done between Y and C. A thread is passed in Zig Zag fashion across the warp, first pressing down the A to B threads, then A to C threads. A ruler or thin piece of bamboo is used to "beat down" the weft threads after each row.

After a few centimetres have been woven, remove the Peg D to release tension, and move the whole strip downwards. This places the part being woven in a comfortable position again. Replace Peg D and continue weaving.

Sources of Supply for Materials: Large stores such as Burns Philp and Steamships sell woolen and synthetic yarn in various colours. These can be used with natural fibres used in the village. Sisal, abaca, pandanus, banana, even young coconut leaf and pandanus leaf can be used.

String can be made the same as it is made for string bags and dyed or used in natural colours.

Remarks: There are many uses of Inkle braids such as headbands, belts, decorative bands on clothing, straps for bags and baskets. They are very strong, and can be made easily up to 15cm wide. They may be joined by the edge to make mats, clothing or decorative panels.

cont'd

The Inkle Loom

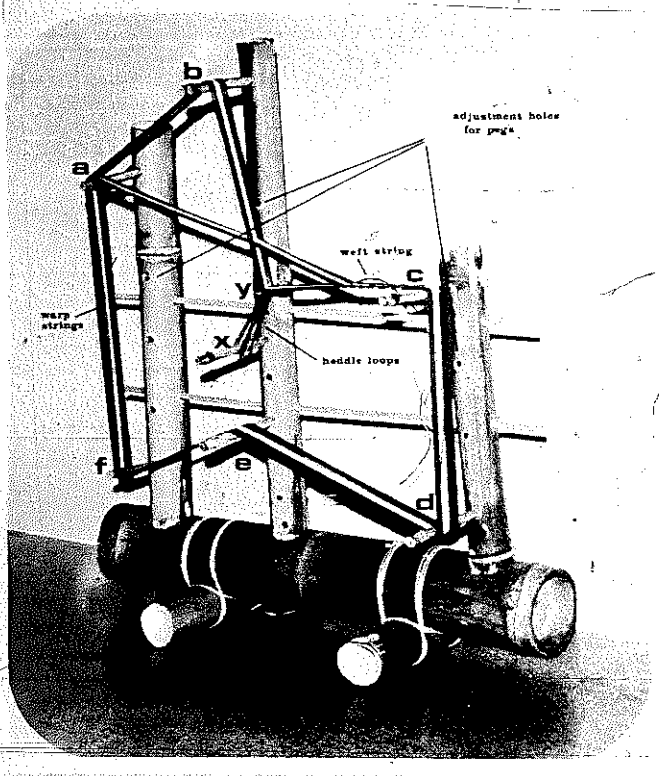

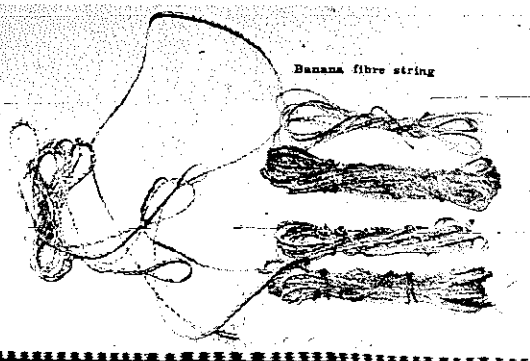

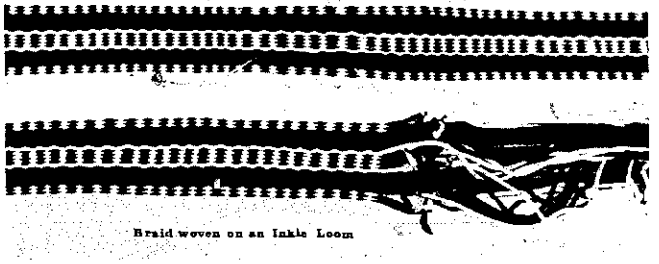

Braid woven on an Inkle Loom

The Inkle Loom is one of the simplest forms of loom, but makes a very pretty braid. It does not need any purchased parts.

Further references: "Golden Hands" Encyclopedia of Crafts. Part 60, at most newsagents 90t.
"Band Weaving", Tacker, Studio Vista.
"Weaving", Znamierowski. Pan Craft Books.

Initial contributor: M. Tyler, Kerevat National High School, Rabaul.

WELDING WITH ELECTRIC ARC

Arc welding is a process of joining metals by means of the heat created in an electric arc. The many jobs that arc welding does are all around us. It is said that there is not ~~a single industry or business~~ which does not depend in some way upon arc welding. It is also said that an arc welder is one of the few tools in existence which can pay for itself in only one job!

Arc welding has great potential for stimulating employment, and particularly self-employment. As hydro-electric power becomes more widely available in P.N.G., especially in the town, arc welding will be quite feasible and practical for persons who want to make a small business.

There are many schools and vocational training centres in P.N.G. that teach arc welding. You might be able to find a friend who can teach you.

Arc welding lessons for school and farmshop: James F. Lincoln Welding Foundation, obtained from Lincoln Electrical Co., Aust. Pty. Ltd., 36 Bryant St., Padstow NSW 2211, Australia.

The companies selling arc welding equipment are usually willing to provide basic information. Try C.I.G. New Guinea Pty. Ltd., P.O. Box 93, Lae.

WOODCARVING

WOODCARVING TOOLS

1. Ashley Iles, Ltd.
   Fenside
   East Kirkby
   Spilsby, Lines.
   England

2. Woodcraft Supply Corp.
   313 Montvale Ave.
   Woburn, Mass. 01801 U.S.A.

3. Craftsman Wood Service Co.
   2127 Mary St.
   Chicago, Ill. 60608 U.S.A.

4. Carl Heidtmann
   563 Remscheid - Hasten
   Unterholterfelder Str. 46
   West Germany

HOW TO SHARPEN TOOLS (No Article)

REFERENCES

HANOCRAFTS: The Office of Business Development has a Handcrafts section in its Small Industries Division. This section performs three main functions:

1. Advisory: aid to would-be entrepreneurs in the retailing or exporting of handcrafts. It also advises on what handcrafts are available in PNG and encourages the introduction of new handcrafts for particular areas.
2. Marketing: promotion of PNG handcrafts overseas, selling of handcrafts, assisting local handcraft dealers in marketing and assisting producers to get their products to market.
3. Production: assisting local producers in what to produce, what finish to give (quality control) how to pack and freight for local and overseas markets. It includes technical advice to producers on equipment and maintenance.

We have Headquarters staff as well as field staff but it is a very small section at present and all Provinces cannot be given full service.

HANDCRAFTS RESEARCH AND TRAINING: We have trained many people now engaged in Weaving and Pottery as a business and we are researching the possibilities of people working in handcrafts associated with the orchid/plant growing industry such as wire baskets, wooden slat baskets, rope pot hangers (macrame work). Other handcrafts being investigated are stone and shell jewellery making (at Rabaul), traditional and introduced wood carving, bamboo ornaments and utensils (now being done with students at Kerema), and leatherwork.

Much work has been done in encouraging production of quality carvings based on traditional designs and colours and in establishing markets. We have also helped local artifact firms in the technicalities of packing and shipping overseas.

CONTACTS: We have the names and addresses for equipment, raw materials, retailing and overseas markets. For further information contact:

Handcrafts Office,
Office of Business Development,
Post Office,
WARD STRIP.
WAIGANI, PNG

Council for Small Industries in Rural Areas
Box 717
35 Camp Rd.
Wimbledon Common, London S.W. 19, England

British government-sponsored. Publishes a large selection of both technical and general booklets and leaflets, such as "The Blacksmith's Craft", "Fabricating Simple Structures", "The Thatcher's Craft", "Design for Mobile Shelter", "Motorising of Hand Screwing Machine." Write for lists and prices.

ARTS AND CRAFTS OF HAWAII

by Te Rangi Hiroa, Bishop Museum Press, 1964, Honolulu, Hawaii, US$16 plus 50¢ shipping.

There are 14 volumes: I - Food; II - Houses; III - Plaiting; IV - Twined Baskets; V - Clothing; VI - Canoes; VII Fishing; VIII Games and Recreation; IX Musical Instruments; X - War and Weapons; XI - Religion; XII - Ornaments and Personal Adornment; XIII Death and Burial; XIV Index. These describe in detail: designs, construction, materials used, uses, etc. A useful resource set; many items applicable in PNG. May be ordered separately. Not all volumes are the same price.

Intermediate level H. Bekker

MISCELLANEOUS

CARE AND OPERATION OF HURRICANE AND PRESSURE LAMP

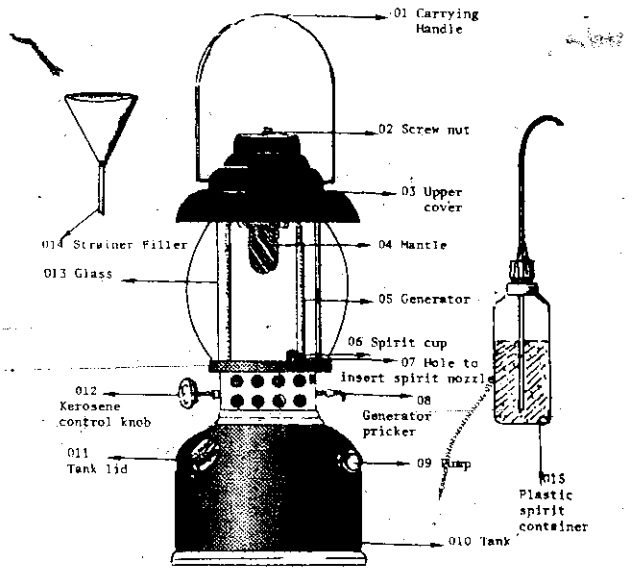

In all my experience with pressure lamps, I have found people quite happy to operate a primus stove, but when it comes to a pressure lamp many people are scared. But there is no need to be afraid of them if you follow the given instruction for operating them. Pressure lamps are not dangerous if handled and cared for properly.

A pressure lamp is a good friend and gives a good bright light and will last a long time if cared for properly.

1. Always use the best kerosene, which has been strained.
2. Always preheat the generator with spirit and not kerosene.

cont'd

3. Always see that the glass is kept clean.
4. If you wash the glass, make sure it is thoroughly dry before you light the lamp. If not, the glass will break.
5. Always handle the lamp gently. Handling the lamp roughly can break the mantle or the needle in the generator, or the glass.
6. Remember all these parts are expensive to buy and sometimes they are not available.

DIRECTIONS FOR USE:

1. Fill tank three quarters full with clean kerosene and replace cover tightly.
2. Fill the spirit cup with spirit nearly full. Light with a match.
3. While the spirit is heating the generator, check that the kerosene control knob is closed.
4. Just before the spirit is burnt out, turn the generator pricker a few times and open the pump by turning it anti-clockwise. Give a few full pumps and then close it turning it clockwise and open the kerosene control knob a little.

   (Note:- on some models the pump is always open) When the spirit has completely burned out and the lamp is burning properly, fully open the kerosene control knob and give the pump a few more full pumps as before. Now you should have a nice bright light. You may need to pump the lamp from time to time.
5. While the lamp is burning and not being carried, turn handle to the side so it does not get hot. This will prevent a burnt hand if you wish to carry the lamp.
6. To turn the flame out, firmly close the kerosene control knob and the flame will die. Open the tank lid slightly and gently release the air pressure in the tank. If you leave air in the tank it might leak fuel.

GENERAL NOTES.

1. To replace a broken mantle, remove the carrying handle, then the screw nut on top, then lift off the upper cover and the glass. (Some models may be slightly different.) Remove the broken mantle and tie on the new mantle. Now replace the glass and upper cover. A new mantle is covered with a protective covering, which has to be burnt off with a lighted match. Take care as once this protective covering has been burnt off the mantle can easily be broken.

2. If the flame shoots up very high when you turn on the kerosene control knob, turn it off quickly and let the flame go out. Usually this happens when the generator has not been preheated enough.

3. There are different makes of pressure lamps. The most commonly used in PNG are the Coleman 300, Coleman 500, the Tilley and the new Chinese 'Light' brand pressure lamps. All four lamps operate on the same principle but with a few variations.

4. The Tilley lamp's mantle is fitted around the generator and is preheated with a special clamp that is soaked in spirit and clamped on to the generator below the glass. The clamp is lit with a lighted match and when the generator is heated sufficiently the lamp is lit in the usual way and the spirit clamp removed.

5. The 'Light' brand Chinese pressure lamp has a special knob for releasing the air. This knob must be closed before pumping the lamp and opened when the kerosene is turned off.

6. Each brand of lamp has its own brand of mantle and generator.

A Note for teachers:- When using these notes for instruction - have a pressure lamp, the three kinds mentioned if possible, for practical demonstration.

CARE AND OPERATION OF PRIMUS STOVE

A primus stove can be very useful where there is no electricity or gas for heating or cooking purposes, where firewood is scarce, or when the electricity and gas fail. But like all things it must be cared for well.

1. It likes to be kept clean
2. It needs clean kerosene
3. It must be preheated with spirit, and not kerosene

If you carry out these instructions your primus stove will perform well. If not, it will give you plenty of headaches and black saucepans.

WORKING PRINCIPLE: In the primus stove the kerosene turns into a gas while circulating through the burner. The burner is heated with spirit first, and the kerosene passes through the brass nipple, mixes with air, and develops an intensely hot, blue flame. If the primus stove is not kept clean it will not produce a nice clean blue flame.

DIRECTIONS FOR USE:

1. Fill tank not more than three quarters full with clean Kerosene. Use a strainer. Open the air release screw.

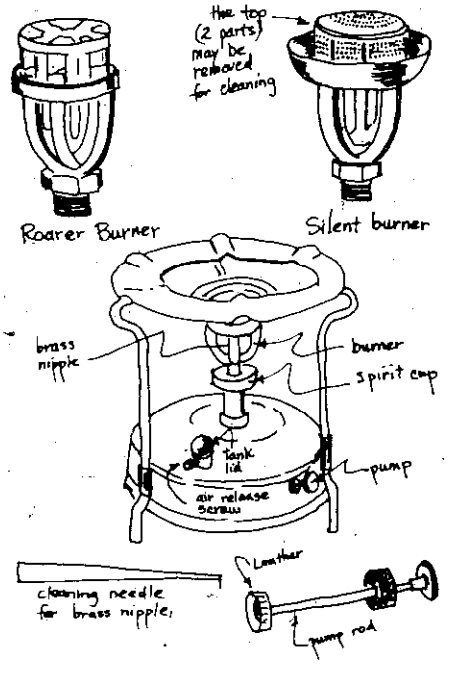

2. Fill the spirit cup with spirit and light the spirit. Care should be taken that the flame is out of the wind.

3. When the spirit in the cup has almost burned out, firmly tighten the air release screw. Give pump several full pumps and the stove will start burning. If, however, the spirit should burn out before the stove starts burning, apply a lighted match to the top of the burner to set it alight. As soon as the burner is well heated, the flame may be increased by further pumping.

4. To reduce the flame, open the air release screw slightly, and tighten it immediately when the flame is sufficiently reduced.

5. To turn the flame out, open the air release screw. Always leave the air release screw open when the stove is not in use.

GENERAL INSTRUCTIONS:

1. If the flame does not increase after pumping, or if the flame is not even or not blue, clean the hole in the brass nipple by inserting the cleaning needle.

2. Clean the nipple while the stove is burning and always have a lighted match at hand to light it at the top of the burner, should the flame go out. Always keep the brass nipple very clean to obtain the best results.

3. If after long use, the stove does not burn properly in spite of cleaning the nipple with the needle, the burner is probably clogged and a new burner will be needed.

4. If, while pumping, the flame shoots up and turns yellowish white, open the air release screw at once. This usually happens when the burner has not been preheated enough - either not enough spirit has been put into the spirit cup, or the wind causes the flame not to burn properly, or the flame from the spirit goes out before pumping the stove. If this occurs repeat (2) & (3) listed under Directions for Use.

Empty the tank occasionally and rinse with kerosene, to remove any foreign matter that may have accumulated in the tank and which is likely to block up the burner and the nipple hole.

If the pump does not work properly unscrew the pump and pull out the pump rod. Put some grease on the dry pump leather and flatten the leather out a little. When replacing the pump rod, fit the leather of the pump carefully. The leather should face downwards into the barrel of the pump.

Contributed by: B. Dolling, Braun Health Centre, Butaweng, Finschhafen, via Lae.

CARE AND OPERATION OF KEROSENE REFRIGERATOR - FREEZERS.

These general principles apply to all blue flame and white flame refrigerators or deep freezers.

For the refrigerator to work efficiently, it needs care and routine maintenance.

SOME PROBLEMS AND HOW TO DEAL WITH THEM

Refrigerator defrosting unintentionally: Sometimes you may find the refrigerator or freezer defrosting itself when you don't want it to.

First check the flame - has it gone out? If the flame is out, see if the kerosene tank has run dry. If you fill twice a week, this should not happen, unless the tank is leaking.

If the refrigerator is placed in a strong draught, the wind can blow out the flame. Find a corner out of the wind. Also if there is too much carbon in the flue or on the wick, the flame will go out.

Remedy: Remove the tank, check the wick, clean it and the flue of all carbon; replace and adjust the flame. It is easier to replace the tank when it is only half full, and then top it up when it is in position. FILL THE TANK BEFORE LEAVING IT.

Flame may be too low: If this is the case, adjust the flame so that it is as high as possible without smoking or making a noise.

Smoking: If black smoke is coming from the chimney, it could be that the flame is too high, or there is carbon on the wick. Whenever a freezer smokes you must clean the burner, wick, flue, etc. If it still smokes after cleaning everything and adjusting the flame, it could be that the burner is not fitting exactly into the bottom of the chimney, or that dirt has got into the kerosene tank. If this is so, clean out the tank by washing in kerosene only. Pour a small amount of clean kerosene in and tip it out into a separate container. Do this until the kerosene comes out clean. Don't throw away the dirty kerosene as it can be filtered and used again.

Other Points: It is a good rule to open a freezer or refrigerator as seldom as possible. Frequent opening will prevent them from getting cold. The wick may have burned down and be in need of replacement. Read the instructions on the box of the new wick carefully, and do exactly what they say. Different kinds of wicks fit differently. Be sure that you have the right type and size wick for your burner.

Blue flame burners can be difficult if not treated carefully: If your freezer is defrosting the rules above apply in the same way. The flame must be blue all around and burning evenly. If it is white it is either too high or has carbon on it or carbon in the flue; also the burner may not be fitting exactly into the bottom of the chimney. Carefully adjust the tank to a better position. The wick may have to be turned up and down a few times before the flame is right. There should be only blue flame and not white (or yellow) flame. If the flame is higher on one side than the other, then trim the wick even.

Contributed by: M. Bradbrook, Anglican Church, Dogura, MBP.

Energy

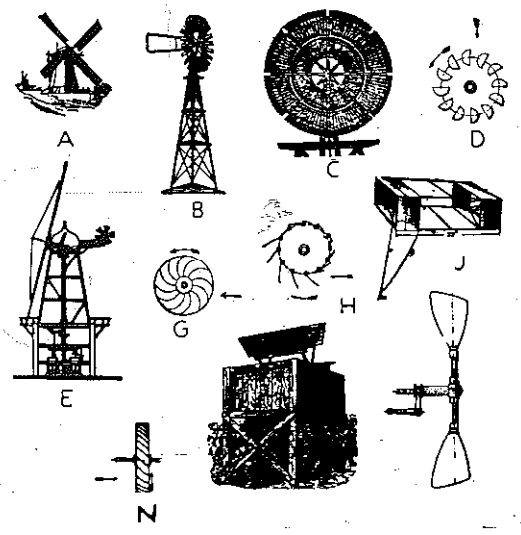

WATER

HYDROELECTRICITY

If you are considering building a small hydroelectric unit, these two publications will be very helpful:

1. "Micro-hydro: Civil Engineering Aspects", by D.S. Mansell, G.P. Atkins, S.N. Kiek, 11 pp, available free from Civil Engineering, Box 793, Lae.

2. "Low Cost Development of Small Water-Power Sites", by H.W. Ham, 43 pp., available from VITA, 3706 Rhode Island Ave., Mt. Rainier, Md. 20822, U.S.A., US.$3.60 airmail postpaid, US$2.00 surface mail postpaid.

MANUFACTURED TURBINES AND REGULATORS FOR HYDROELECTRIC PLANTS

1. James Leffel and Co.
   Springfield Ohio 45501
   U.S.A.

2. Ossberger Turbinenfabrik
   Weissenburg
   Bavaria, Germany

3. Officine Buehler
   Taverne, Canton Ticino
   Switzerland

WATER WHEEL

The use of water power has wide potential in many mountain communities. The initial difficulty is to build the wheel to convert the energy of the falling water to work that is useful to man.

The overshot water wheel is most efficient, but it requires damming a river so that the water will be able to flow on top of the water wheel.

More than a year ago an overshot water wheel was installed at Zafilib village, near Finschhafen, to drive a No 2½ Bentall coffee pulper. The total cost of all materials was K100.

Materials required:
2 x 2m length of 100 x 100mm hard wood post
1 x 1.25m length of 1" pipe
30 metres of 75 x 25mm dressed hardwood
4 sheets 900 x 1800mm (3' x 6') flat iron
1 sheet 900 x 1800mm (3' x 6') ¼" marine ply
glue, nails, screws, paint and solder or rivets
2 Vee pulleys of about 250mm diameter
1 Vee belt to suit pulleys
2 flanges to attach shaft to wheel.

Dimensions in the drawing are given in Imperial measurements because the ratios in the original design are simple numbers.

There are 24 buckets in the design, all made of flat iron. This will make a well balanced wheel by having three buckets per section.

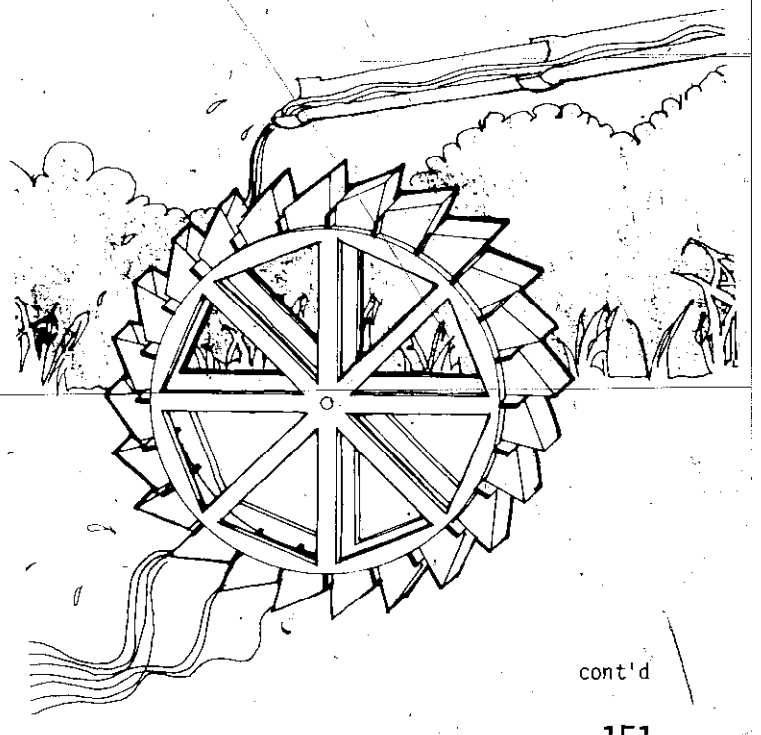

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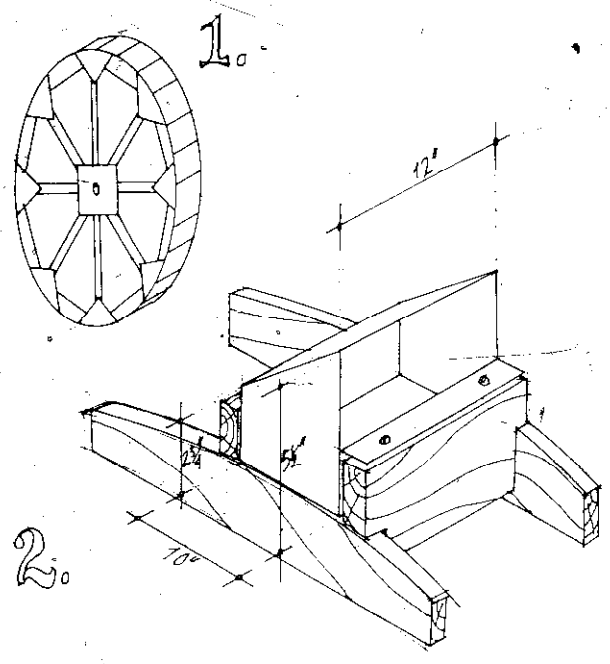

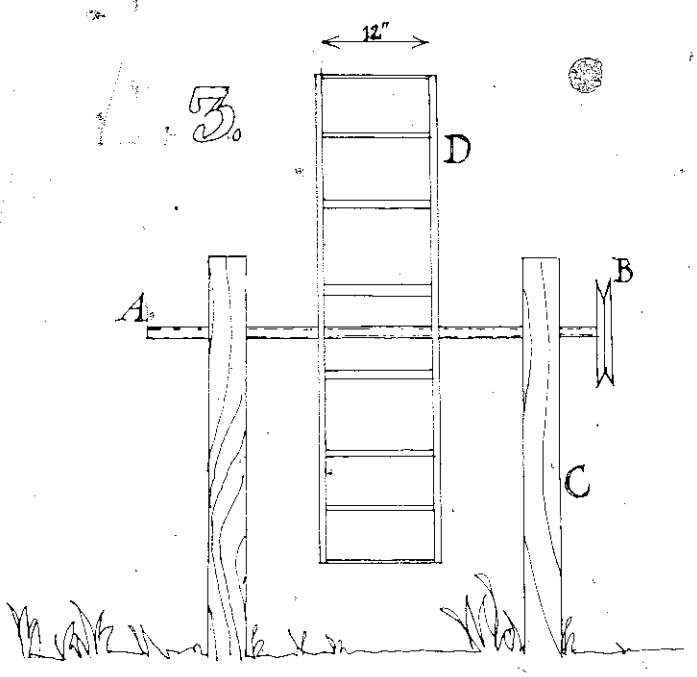

Figure 1: shows glued plywood cleats fixing together wheel frames of 3" x 1" dressed hardwood used throughout.

Figure 2: shows bucket construction of soldered flat iron screwed or nailed to frame.

Figure 3: A. 1" galvanized water pipe
B. 250 mm vee pulley
C. 100 x 100 mm kwila hardwood posts
D. Water wheel on its mounting

NOT TO SCALE

An alternative design is to make the buckets out of dressed 150 x 25mm (6" x 1") hardwood, using the same dimensions of height but slightly narrower buckets. On a five foot wheel 27 wooden buckets are required.

The design is built to operate at 40rpm on a flow of water of 250 litres (50gal) per minute. If the wheel is made very much smaller, it will not be big enough to do very much work; if it is bigger, these materials will not be strong enough.

The life expectancy of the wheel in constant use is about 3 years without maintenance if well built and painted.

After boring the hole in the hardwood posts for the shaft, place the end of the posts with the hole in a bucket of warm engine oil for several days, so the shaft will turn easily.

Editors note: There are many details missing here. The critical point of this design is the way in which the wheel and the pulley are attached to the shaft. Welding is an easy solution if available, but it may not be available to most of our readers. If you use a bolt through the shaft, don't use one larger than 6 mm (½"), as it will weaken the shaft.

Initial contributor: I.M. Bean, DPI Rural Development Centre, Pindiu, MP.

Overshot water wheel (above) and generator (below) at the Swiss Mission near Minj, WHP. Power is transmitted through a counter shaft in order to increase the rpms.

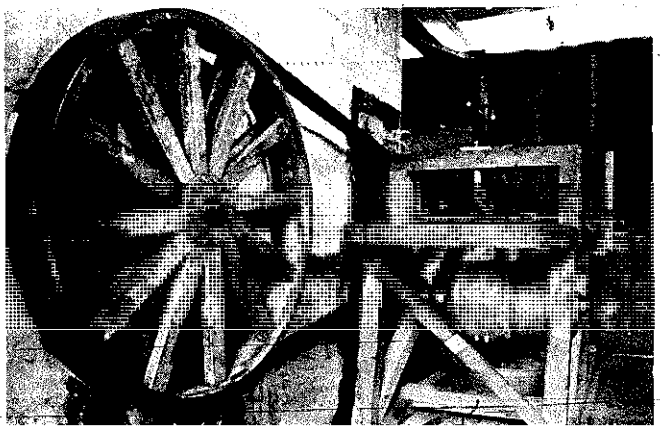

WIND

WINCO
DYNATECH. ,INC.
P.O. Box 3263
Sioux City, Iowa 51102

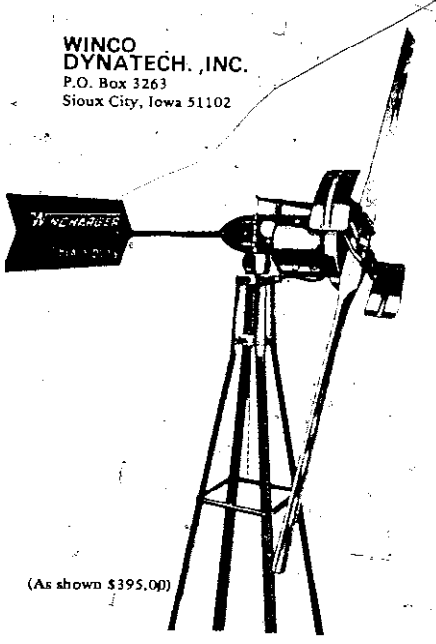

(As shown $395.00)

WIND GENERATORS

F.W. Davey and Co. Pty. Ltd.,
Box 120 Oakleigh, Victoria 3166
Australia

(Quirk's Windlite). They need detailed information on your wind situation and your power needs before they can quote prices.

COMMERCIAL WINDMILLS AND PUMPS

1. Southern Cross Dealers throughout Papua New Guinea.
   Representative: Ken Parker
   P.O. Box 498
   Port Moresby

WATER PUMPING WINDMILLS

DEMPSTER INDUSTRIES INC.

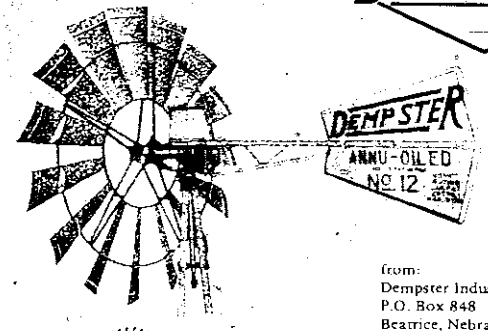

from:
Dempster Industries Inc.
P.O. Box 848
Beatrice, Nebraska 68310

HELLER–ALLER COMPANY:
BAKER WINDMILLS

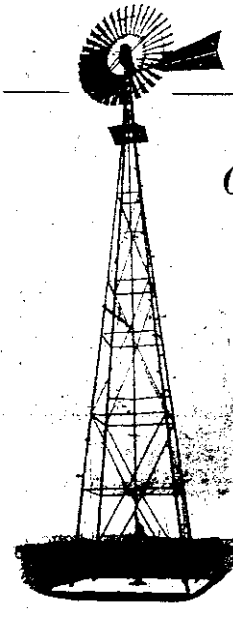

The Original **BAKER**
RUN-IN-OIL
WINDMILL

from:
The Heller-Aller Co.
Corner Perry & Oakwood
Napoleon, Ohio 43545

Distributor:
O'Brock Windmill Sales
Rt. 1- 12th Street
North Benton, Ohio 44449

AERMOTOR WATER SYSTEMS

AERMOTOR PUMPING CAPACITY

Diameter of Cylinder (inches)	15 MPH Capacity per Hour, Gallons		Total Elevation, in Feet — SIZE OF AERMOTOR					
	6 Ft	8-16 Ft	6 Ft	8 Ft	10 Ft	12 Ft	14 Ft	16 Ft
1¾	105	150	130	185	280	420	600	1,000
1⅞	125	180	120	175	260	390	560	920
2	130	190	95	140	215	320	460	750
2¼	180	260	77	112	170	250	360	590
2½	225	325	65	94	140	210	300	490
2¾	265	385	56	80	120	180	260	425
3	320	470	47	68	100	155	220	360
3¼		550			88	130	185	305
3½	440	640	35	50	76	115	160	265
3¾		730			65	98	143	230
4	570	830	27	39	58	86	125	200
4¼		940			51	76	110	180
4½	725	1,050	21	30	46	68	98	160
4¾		1,170				61	88	140
5	900	1,300	17	25	37	55	80	130
5¾		1,700				40	60	100
6		1,875		17	25	38	55	85
7		2,550			19	28	41	65
8		3,300			14	22	31	50

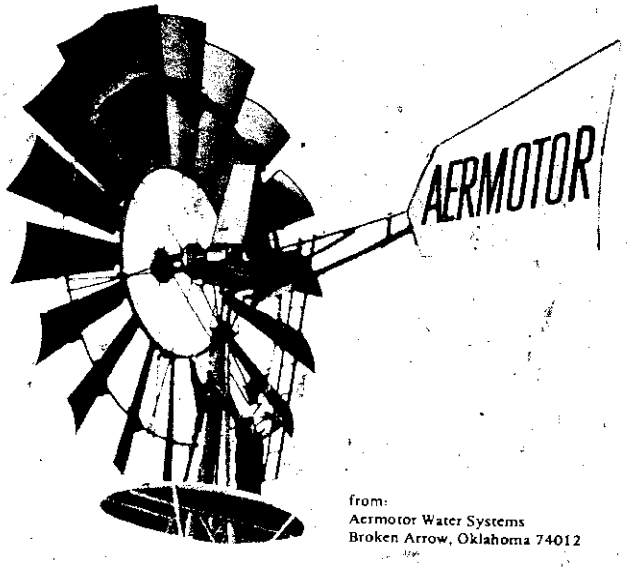

from:
Aermotor Water Systems
Broken Arrow, Oklahoma 74012

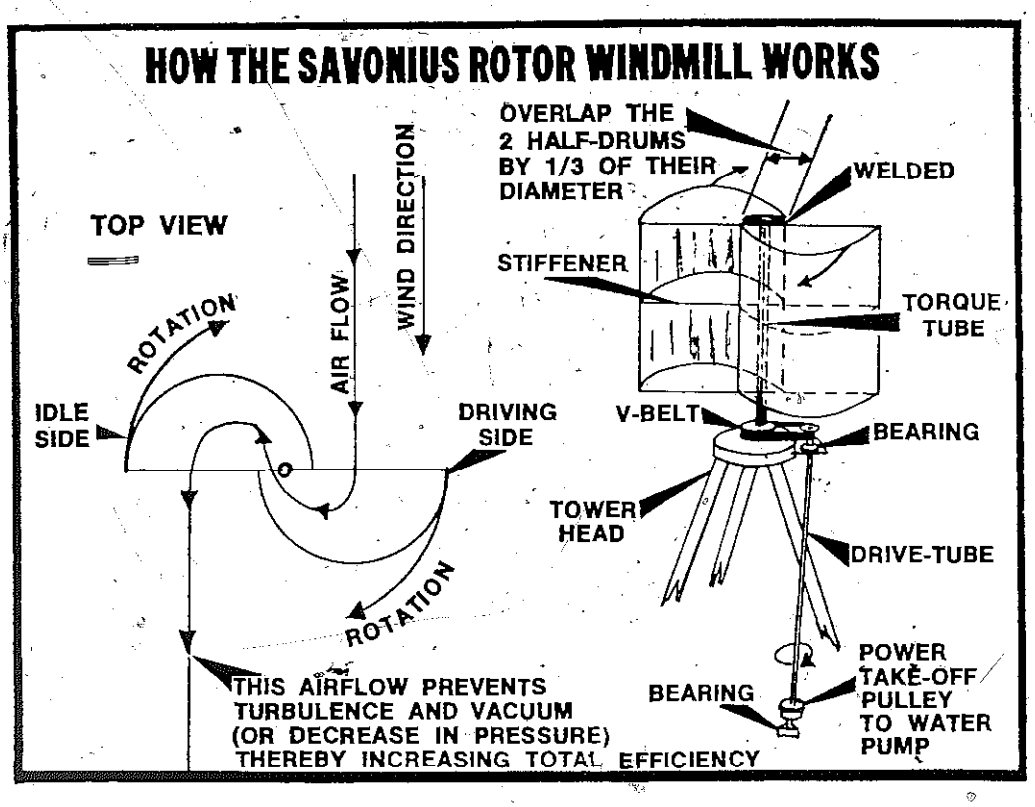

It will be easy to predict how Papua New Guinea will develop once we know why coastal people eat tinned fish.

WINDMILLS, "HOW-TO" INFORMATION

"How to Construct a Cheap Wind Machine for Pumping Water", by A. Bodek, 12 pp., Feb. 1965 U.S. $0.75, from Brace Research Institute, McGill Univ., Montreal, P.Q., Canada.

"Low Cost Windmill for Developing Nations" (1970) US$2.00 surface mail postpaid, or US$3.60 airmail postpaid to P.N.G. from VITA, 3706 Rhode Island Ave., Mt. Rainier Md., 20822 U.S.A.

WINDMILL PUMP

A reliable, simple windmill/pump mounted on a pole with 4 wire stays, built of basic materials like wood, canvas, and leather. The wind turns canvas sails, which are self-governing, being held by bands made of rubber. Detailed construction and installation plans are available in an 80 page booklet for Swiss Francs16 from World Council of Churches CCPD Technical Unit, 150 route de ferney, Box 66, 1211 Geneva 20, Switzerland.

See article, The Cretan Sail Windmill, Appropriate Technology, Vol 2 No. 3 p.4

(p248)

IS THE CHEAPEST, MOST RELIABLE WINDMILL YOU KNOW LISTED HERE ? IF NOT, THE REASON IS PROBABLY THAT YOU HAVEN'T TOLD US ABOUT IT. SO DO IT NOW. TODAY. BOX 1920, LAE.

(p 268)

SOME DAY, AFTER WE HAVE MASTERED THE WINDS, THE WAVES, THE TIDES, AND GRAVITY, WE WILL HARNESS FOR GOD THE ENERGIES OF LOVE: AND THEN FOR THE SECOND TIME IN THE HISTORY OF THE WORLD MAN WILL HAVE DISCOVERED FIRE!

Teilhard de Chardin

SOLAR ENERGY

In many parts of PNG solar energy is used to heat water for homes. Solar water heaters are cheap to install, and easy to construct - if you need hot water. Many people think that hot water is a waste of time and an unnecessary luxury, but in some cases it is very important. Hospitals and restaurants need hot water for cleaning, and most hospitals have water heaters that use a great deal of fuel or electricity. Properly designed solar water heaters are long-lasting and can store hot water during the night. Some will even make hot water on cloudy days.

The heat energy from the sun which is called "infra red" light, and which is different from the light energy from the sun that lets us see, can heat water which is inside a closed container. Infra red energy is the same as that used in special globes in hospitals for treating sore muscles. Infra red is the same energy that makes a cement floor so hot in the sun, or makes the roofing iron so hot. A simple water heater for small amounts of water can be made by filling a plastic bag with water, tieing off the open end, and leaving it in the sun for a few hours. Solar water heater designs are readily available.

Another use of solar energy is to make electricity. This is very expensive way, even though the sun is free because the collector is very expensive to make. But it is definitely economic for some uses. One example is out-station radios that work on batteries. If you have to charge the battery and have no other use for the electricity, a small engine-powered charger is very expensive. If the benzine runs out or the motor breaks the battery will run down. With a solar collector the sun is always charging the battery, and even on cloudy days the charger works at half power. A four watt by 12 volt sun charger will keep a full charge on the battery of a typical out-station transmitter that is used for two "skeds" a day. Such a unit will cost about K16D including installation - far cheaper than the smallest generator. Such sunchargers are available from AGQUIP, Box 1121, Rabaul.

To make electricity from sunshine, special materials such as selenium and silicon are used to catch the energy. When they are hit by energy from the sun, a small electric current is started. This current can be stored in a battery until it is needed.

The selenium material is able to see visible light, the same as that light which lets us see. The silicon material works on heat energy. This means that battery chargers made from selenium will work well on cloudy days too, because the heat energy of the sun is able to pass through clouds better than the energy that makes it possible for us to see.

The major use of solar battery chargers used to be providing electricity for satellites. Now the cost of these chargers is low enough that they can be used more widely. A village radio transmitter on Tench Island in NIP. is powered by this charger and it never wears out.

Brace Research Institute,
Macdonald College of McGill University,
Ste. Anne de Bellevue,
Quebec, H9X 3M1,
Canada.

List of available publications from the Institute.

L. 1 How to Make a Solar Still (plastic covered), by A. Whillier and G.T. Ward, 9 pp., January 1965. Revised February 1973, Price X$1.25

L. 2 How to Make a Solar Steam Cooker, by A Whillier, 6 pp. January 1965. Revised October 1972. Price C$1.25

L. 4 How to Build a Solar Water Heater, by D.A. Sinson and T. Hoad, 10 pp., February 1965. Revised February 1973. Price C$1.25

L. 5 How to Construct a Cheap Wind Machine for Pumping Water, by A. Bodek, 12pp., February 1965. Revised February, 1973. Price C$1.25

L. 6 How to Make a Solar Cabinet Dryer for Agricultural Produce, by T.A. Lawand, 9 pp., March 1973. Price C$1.25

T.10 Performance Test of a Savonius Rotor, by M.H. Simonds and A. Bodek, 20pp., January 1964 Price C$2.00

T.17 Instructions for Constructing a Simple 8sq. ft. Solar Still for Domestic use and Gas Stations, by T.A. Lawand, 6 pp., Revised September 1967. Price C$1.25

T.58 Plans for a Glass and Concrete Solar Still, by T.A. Lawand and R. Alward, 9 pp., December 1968. Revised October, 1972. Price C$4.50

T.85 Production Drawing for Solar Dryer by O. Goldstein, June 1973, Price C$2.50

T.99 Survey of Solar Agricultural Dryers, by Brace Research Institute, 144 pages plus photos, January 1976. Price C$7.00

Please send a postal money order or if you send a cheque please add C$0.25 for handling charges.

If you order just one leaflet, please add an additional C$0.25. Please mail to the attention of The Publication Department.

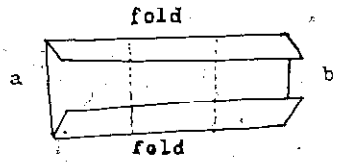

SAVE AN ENVELOPE

Many letters which are written only on one side can be mailed without an envelope.

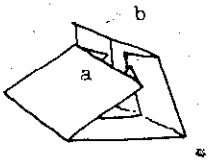

Fold as shown. Tuck "a" into "b". Put a stamp to seal it.

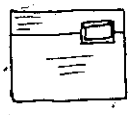

H. Bekker

IAND AND PEDAL POWER (No Article)

3IOGAS DIGESTORS

hus far in PNG these have generated a lot more eat than light! Popularised by George Chan, who as a lecturer in Environmental Health at the Univ. f P.N.G., the "Digester" is a system for producing igh quality organic fertilizer plus methane gas rom organic wastes in an air-tight container. nimal projects, algae ponds, ducks, and vegetable ardens form a balanced integrated production unit, ccording to the concept.

ithout a doubt these have potential for high-density opulation areas among highly motivated groups, robably more for the organic fertiliser than for he gas. Attempts should continue to make these uccceed. One might wonder, though, if the emphasis hich has been given is realistic at this stage - ime will tell.

t present practically all of the digester units in NG are found at a school of one sort or another. his is exactly where they belong, as this is probably where we presently find the management capability equired, and the money and interest for experimentation - surely in PNG situation these must still be considered quite experimental. Practically all of those in PNG with which I am acquainted were "donated" and were initiated by expatriates. When Papua New Guineans show a readiness to start building them with their own money, then perhaps we can get excited.

This is definitely not meant to criticise the Digester as a concept, but a plea for us to stay in touch with PNG realities, and to build Digesters right when we do them. If you want to build one, here are some suggestions:

a). Visit an existing unit - there are already a number of them around - talk to those who built and manage them;

b) Try a small system on a pilot basis - perhaps using an old oil drum. Build the "real" unit when you are confident that you have mastered the technology;

c) Design the digester to a scale compatible with your available waste and water resources - if you're counting on enough methane to cook with or to run some lights, you'll need a lot of waste and water, continuously;

d) Seek competent technical help;

e) If you have difficulty producing methane, and the rest of the system is working, be patient- the benefits from the organic fertiliser (both the liquids and the solids) should be the primary concern;

f) If you succeed - let us know about it so that we can tell others. We're eager for a success story!

The following are available from Intermediate Technology Publications, Ltd., 9 King Street, Covent Garden, London WC2E 8HN, U.K: (P 247) (P 258)

Methane Digesters - For Fuel, Gas and Fertiliser, by John Fry and Richard Merrill. Includes designs for a small and an intermediate scale system. 47pp. 1973 US$3.90 surface mail, US$4.95 airmail.

Methane: Fuel for the Future, by Bell Boulter, Dunlop and Keiller. Surveys current use and future possibilities. Prism Press, Dorchester. 86pp. 1975; $2.90 net; US$3.45 surface, US$4.85 airmail.

Methane Production by Anaerobic Fermentation, proceedings of a recent ITDG seminar. 12 papers, discussion, references. Illustrated. 1975, price not known.

Practical Building of Methane Power Plants, by John Fry, pioneer of the first displacement digester. Pub. by Know, Andover, 97pp. 1974; US$9.20 net; US$10.15 surface, US$12.80 airmail.

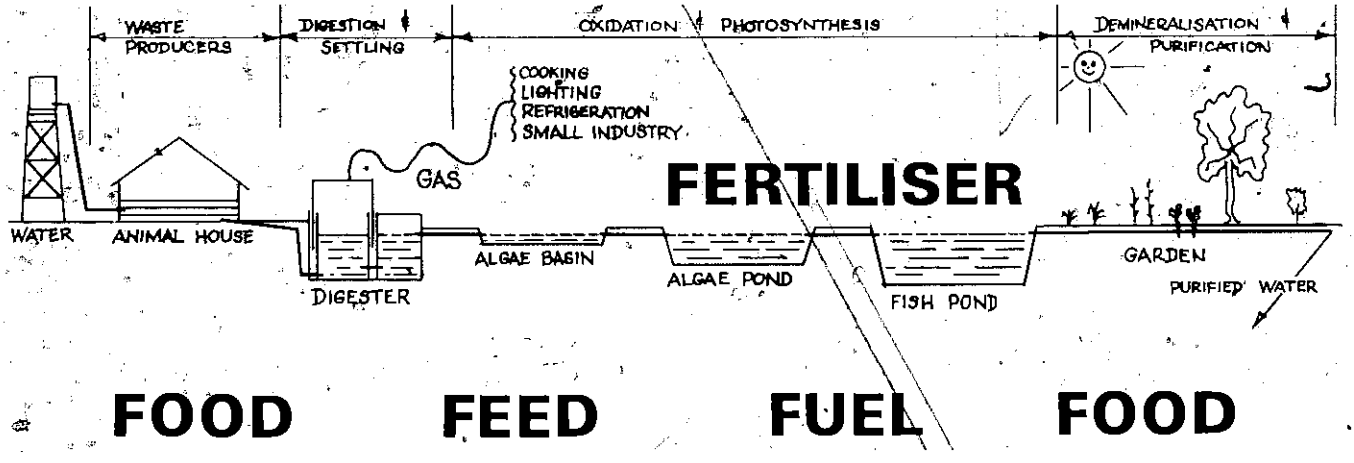

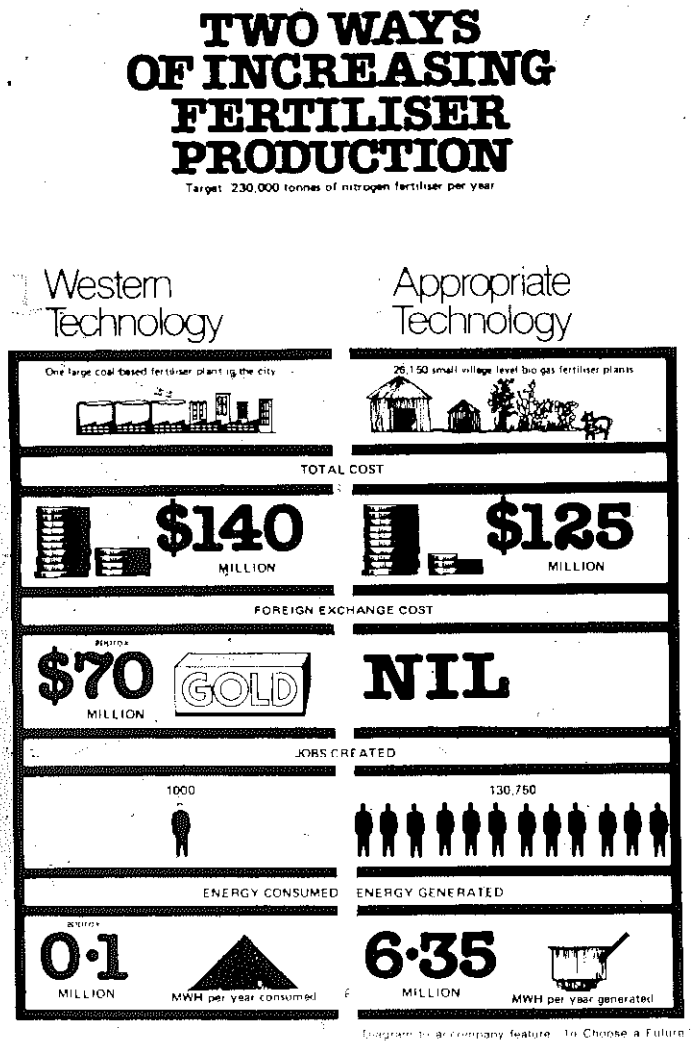

Diagram to accompany feature 'To Choose a Future'

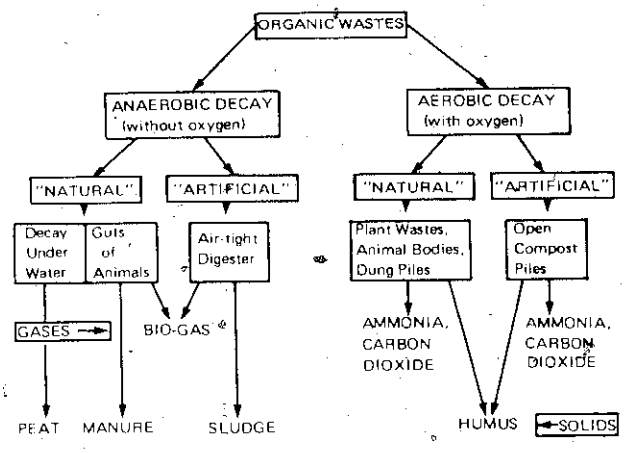

END PRODUCTS OF ORGANIC DECAY

Pioneer at Makana Vocational Training Centre, Port Moresby under construction (top), and 1975

VILLAGE AGRICULTURE

FROM TRADITIONAL SYSTEMS TO NEW SYSTEMS

——————— TRANSITION ———→

Bush gardens
shifting agriculture
balanced
stable
integrated
self-sustaining
limited

More cash oriented
More outside inputs
Settled?
Integrated?

ORDER OR CHAOS?

Forced by:
cultural change
population/land pressures
markets
gov't and other programmes

Are the people in your village aware of this process?
Are they critically aware of it?
Do they talk about it?

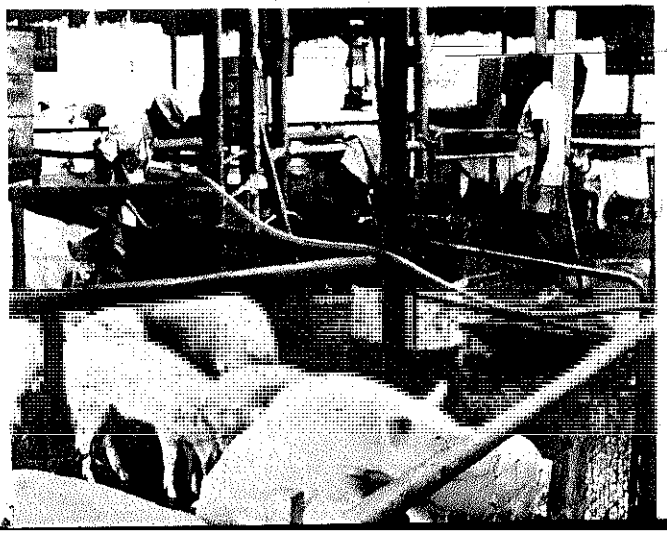

COMPOST

Plant and animal wastes give us a practical way of adding nitrogen and other important elements to our gardens. When organic matter is well-rotted and becomes a part of the soil, it helps the soil to hold the mineral plant foods in a readily available form for the plants. Organic matter also helps the soil to hold water. When it is wet, organic matter swells up like a sponge, gently holding the water and making it less likely to evaporate.

On the other hand, coarse, woody organic matter may temporarily make less nitrogen available to plants, as nitrogen is taken up rapidly by the bacteria that are breaking down these materials. Such materials are best left in a compost heap until they are well-rotted. Dried leaves are somewhat slow to break down and sawdust very slow. Succulent green materials break down fast.

Many different kinds of plant and animal materials may be used to produce compost: leaves, grass, weeds, garden refuse, kitchen wastes, animal manure, and fish scraps are all suitable.

While composting may be too hard to practise for general use, it is often very practical for gardens where there are plenty of composting materials available and where a high level of fertility is especially important.

Ordinarily it is good to supply nitrogen to the compost heap in addition to the wastes to help the micro-organisms break down the wastes. Animal manure will help. Other forms of nitrogen like ammonium sulfate may be used, but they leave an acid residue which should be neutralized by adding a small amount of lime.

The compost heap should be a convenient size for the amount of materials you have on hand, usually a meter wide, at least a meter long, and around a meter high. The top should be left flat or with a slight depression in the centre to catch and hold rain. (The compost should be kept moist). If you get a lot of rain, though, you might even want to cover your compost a bit.

The pile of waste will heat and rot. If it is kept moist, and depending upon how much coarse material and nitrogen is added, it will rot enough in 3 or 4 months for you to use. If you add no nitrogen you might want to leave it for as long as 6-8 months.

If the compost is ready, but you don't need it yet, put it under shelter so that the nutrients will not be lost when it rains. On vegetable seedbeds compost should be applied at the rate of one to two kg per square metre and thoroughly mixed with the soil.

FIREWOOD AND OTHER FUELS (No Article)

GENERAL REFERENCES

Energy Primer, Portola Institute, 1974. 200pp US$6.50 postpaid. Make payment and order to:
Whole Earth Truck Store,
558 Santa Cruz Ave.,
Menloe Park, CA 94025 USA.

It is the best available single resource on energy: solar, water, wind, and biofuels. Absolutely loaded with further references. "A comprehensive fairly technical book about renewable forms of energy. The biofuels section covers biomass energy (energy that is released from plant materials when they are eaten, burned, or converted into fuels), agriculture, alcohol, methane, and wood. The focus is on small-scale systems for individuals, small groups, or community. More than ¼ of the book is devoted to reviews of books and hardware sources. Hundreds of illustrations and a dozen original articles are used to describe the working of solar water heaters, space heaters and dryers, waterwheels, windmills, wind generators, wood-burning heaters, alcohol stills and methane digesters. The final section of the book focuses on the need for energy conservation and some of the problems and potentials of integrated energy systems."

Level: intermediate/advanced.

Alternate Sources of Energy,
Rt 2 Box 90,
Milaca Mn 56353 USA.

A newsletter emphasizing alternate technologies of energy for agriculture, architecture, transportation, and communication. US $5.00 for 6 issues. Also publishes "Coming Around", an introductory sourcelist on Appropriate Technology, 11 duplicated pages, US $1.00.

Conservation Tools and Technology Limited,
143 Maple Road, Surbiton, Surry KT6 4BH. U.K.

This firm sells books, equipment and plans for people needing to use their own resources to provide energy. This includes windpower, solar heating, water turbines for electricity, hydraulic ram water pumps, and methane gas production. (They don't sell solar powered electrical products) A catalogue is available for Pounds 1.00. The firm also has a CTT Association with membership Pounds 5.00 per year. Members receive a quarterly newsletter, and a 5-10% discount on purchases.

They don't sound cheap, and UK is a long way for shipping, but their books, materials and equipment are of first rate quality. The advantage is that almost everything is under one roof.

Suggested by: B.A. McLennan, 56 Fitjohns Ct No 8,
Hampstead, London NW3 U.K.

SPECTRUM, Alternative Sources of Energy Rt 2, Box 90A, Milaca MN 56353 USA. US$2.00

Catalogue of tools (mostly US) and processes for small scale use of solar, wind, water, and other forms of energy.

Water Resource Development and Use

SPRINGS, WELLS AND FILTERS

(p 245)

Fig. 33. PROPERLY PROTECTED SPRING (I)

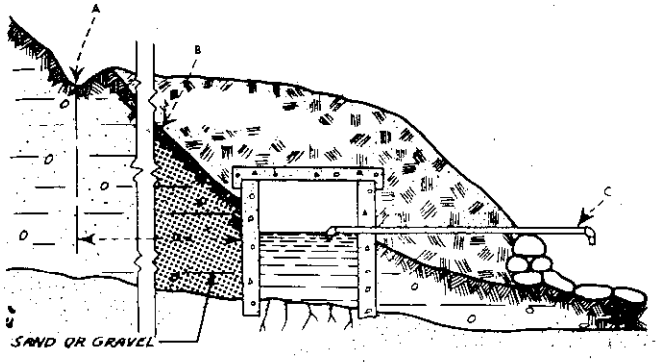

A Protective drainage ditch to keep drainage water a safe distance from spring
B Original slope and ground line
C Screened outlet pipe : can discharge freely or be piped to village or residence

Springs can offer an economical and safe source of water. A thorough search should be made for signs of ground-water outcropping. Springs that can be piped to the user by gravity offer an excellent solution. Rainfall variation may influence the yield, so dry-weather flow should be checked.

Fig. 34. PROPERLY PROTECTED SPRING (II)

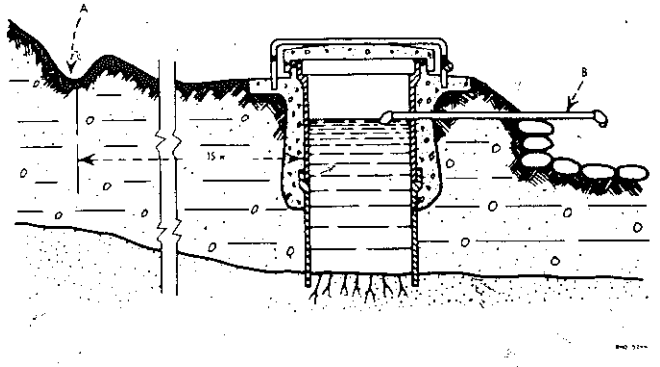

A = Protective drainage ditch to keep drainage water a safe distance from spring
B = Screened outlet pipe : to discharge freely or be piped to village or residence

RURAL WATER SUPPLY AND SANITATION IN LESS DEVELOPED COUNTRIES - A SELECTED ANNOTATED BIBLOGRAPHY, by White and C. Seviour, 82pp. Price C$1.00 from IDRC, Box 8500, Ottawa, Canada KIG 3H9.

The broad view given here will help planners, administrators, engineers and community leaders to locate literature describing experiences and problems similar to the ones they face.

SAND FILTER

There are many areas in PNG where only muddy river water and cloudy brackish water are available if there is no rain for more than two weeks.

Sand filtration does not make all polluted water safe for drinking, but if properly built and kept will remove most of the undissolved impurities, and the water will be much easier to boil or treat.

It is important to note that the filter must be cleaned periodically, and the water must be boiled or treated with Chlorine to be truely safe. If not operated correctly, the sand filter can actually add bacteria to the water.

But the advantages of the filter are that it removes the larger worm eggs, cysts, and things hardest to kill with Chlorine; you can use smaller doses of Chlorine - better taste: the water looks cleaner; re-contamination is less likely, because you have reduced the amount of organic matter.

This unit gives about 1 litre of water per minute. It is important to use clean, fine sand, but not too fine. It should be able to pass through ordinary fly wire, and it is best to wash it.

NOTES: Do not allow the sand to dry out, or the microorganisms that form on the surface layer will die. Do not let the water flow too fast, or they

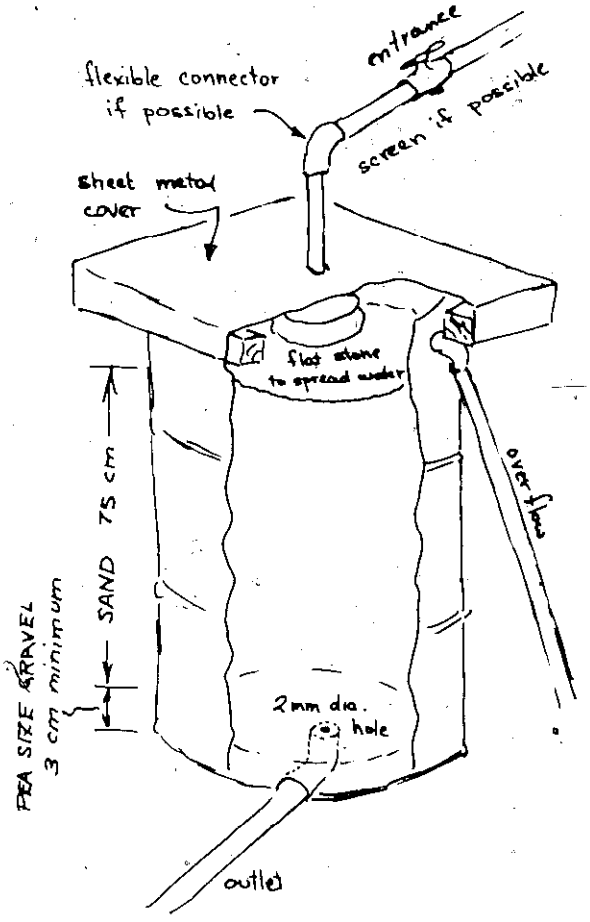

will be washed away. Fix the water intake so that there is always a small overflow. Screen the intake and provide a settling basin to help keep pipes from becoming plugged.

Keep light from the sand surface but allow air to circulate. This will prevent the growth of green plant matter on the surface but help the growth of miccroorganisms that aid the filtering action.

When the flow becomes too slow, clean the filter by scraping off and discarding the top centimetre of sand and lightly raking or scratching the surface. After several cleanings, scrape the old sand down to a clean level and add clean sand. Cleaning should not be more often than every several weeks or even months.

Material from: WHO Monograph #42, Water Supply for Rural Areas and Small Communities, E.G. Wagner and J.N. Lanoix (1959).

Suggested by: A.A. Gerard, Box 793, Lae.

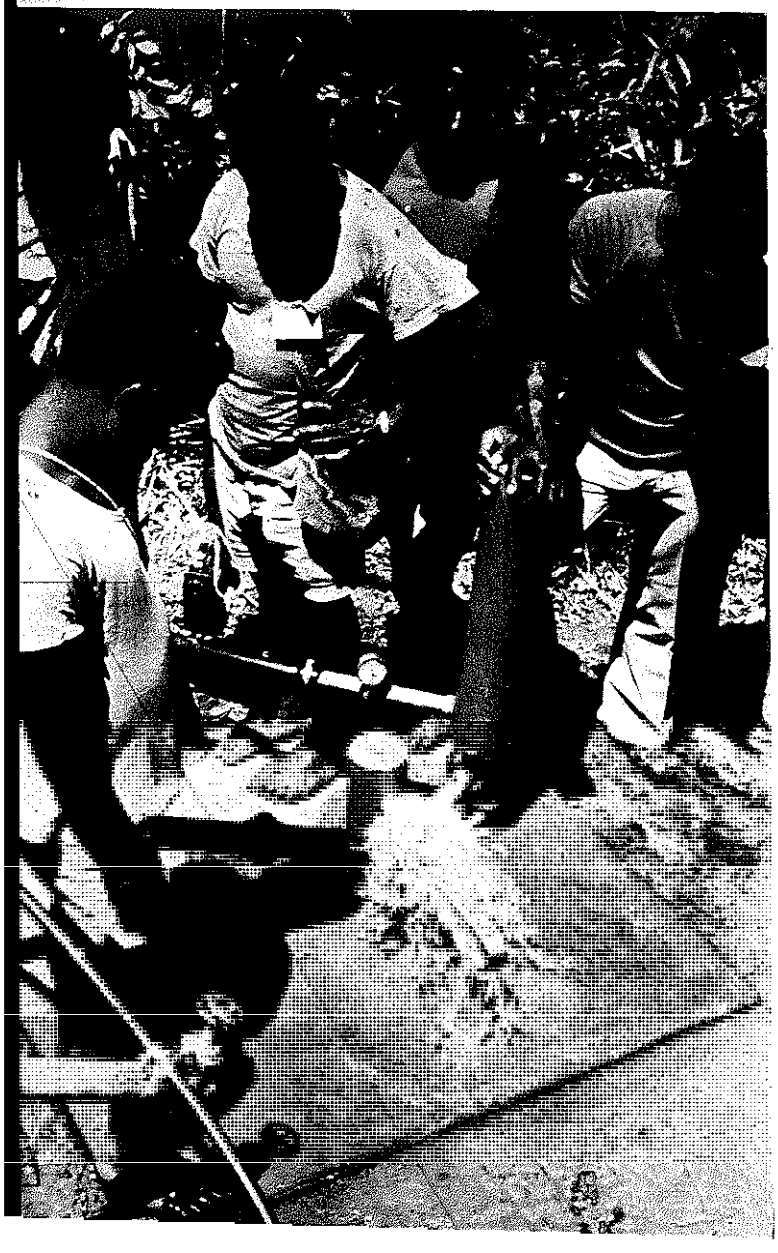

PUMPS

(p 248)
(p 250)

HYDRAULIC RAM (See photo, lower left)

The hydraulic ram is a simple device which uses the power from falling water to force a small portion of the water to a height greater than the source.

It is without a doubt the cheapest method of raising water, and there is no other device which needs so little attention after installation. It has no engine, and functions with only two working parts. The only maintenance required is to clear rubbish away from the strainer on the intake and to replace the valve rubbers when they wear.

But it must be suited to its job. If your conditions are not right, or if the pump is wrongly designed, it will be little better than nothing.

Between 7 and 14 times as much water is required to

cont'd

Performance Graph for a 50mm Hydraulic Ram Pump Employing a 7.7m Drive Head

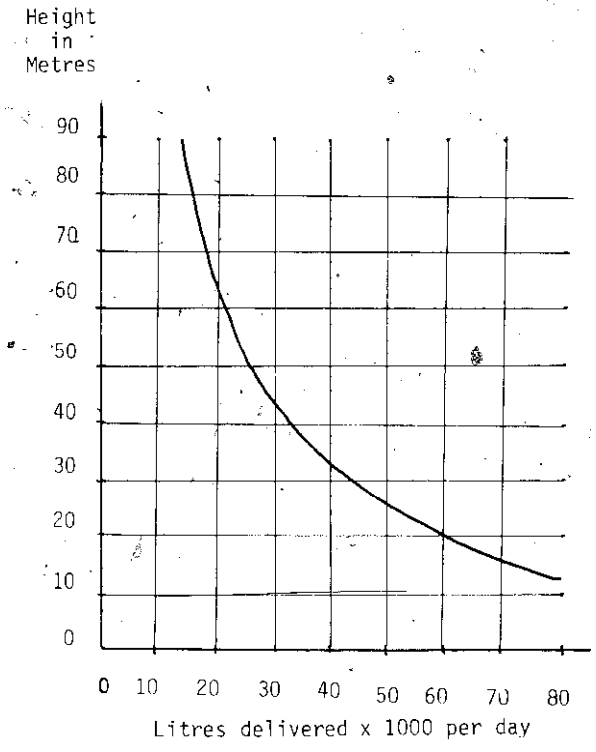

Recommended (Galvanized Iron) Drive Pipe: 50mm diameter, 18.5m length. Recommended (Plastic) Delivery Pipe: 25mm diameter. Minimum water supply required, 90 litres per minute. Ratio of waste water to delivered water = 6.56/1 @ 77m Delivery Head. Kinetic Energy conversion efficiency = 15.24% (Atmospheric vent). Optimum pump operational speed = 60 strokes per minute.

Supplied by Fred Keating, Goroka

work the pump than will be raised. A small amount of water with plenty of fall will pump as much water as a greater amount with only a little fall.

The drivepipe should be metal, unless it is encased in concrete. It should be as straight as possible without elbows, and normally the same pipe size as the intake end of the ram. It should be watertight and rigidly anchored, with a strainer at the top to keep out rubbish. For 50mm rams one length of pipe is suitable (about 6.1m); for 100mm rams, two lengths.

Always locate the ram as near the source of supply and the delivery point as is possible while maintaining the lowest elevation. This will ensure the minimum expense for the pipe. Digging a deeper ram pit and digging out for drive and wasteline might improve the installation at a saving.

Further Information in PNG: Write Fred Keating, Goroka Technical College, Box 556, Goroka. Fred has helped form 6 school leavers to start an enterprise to make hydraulic rams for sale. His design is an improvement over the VITA hydraulic ram, which he says has "low efficiency, too many screw threads, and unworkable dimensions". The model they are making with 50mm drive pipe connector has the following specifications:

a) All-welded steel pump body assembly.
b) Easily removed base plate for access to clack valve assembly.
c) Delivers up to 11,000 litres daily at 36.5 metres, but variable according to drive and delivery head.
d) Can be operated in battery formation or with larger models for higher performace up to heights of 150 metres.
e) Supplied with drive pipe filter and instructions for installation and operation.

You may also write to Mr. D. Burton, PNG University of Technology, Box 793, Lae. He has had experience with these.

Further information, Overseas sources:

1. Hydraulic Ram for Village Use (1970), US$1.00 plus .80 airmail postage to PNG. Complete plans, c/- VITA, 3706 Rhode Island Ave., Mt. Rainier, Md. 20822 (A very clear condensation of this material is found in Appropriate Technology, Vol 1, No 4, Winter 1974-75).

2. If you want to go "first class", buy one from RIFE RAMS, Box 367, Millburn, N.J. 07041, USA. Ask for descriptive material and prices. A 2 inch (drive pipe size) model costs about US$400, including crating.

3. "CECOCO" motorless Hydro-hi-lift pump, 6 different models (1½ inch, 2", 3", 4", 6" & 12" drive pipes). For description and prices write to CECOCO, Box 8, Ibaraki City, Osaka, Japan.

4. China Agricultural Machinery Co. Ltd., 11 Tung Hsing St., Taipei 105, Taiwan, R.O.C. (probably the cheapest available outside PNG).

WATER PUMP

A hand operated water pump for deep wells built of readily available materials was built by LUKIS RAMASO, a 5th year Mechanical Engineering student at Unitech in Lae.

Imported pumps can be bought at relatively low cost, but rising prices may make it increasingly advantageous to make them in PNG.

Lukis used 50mm (2") steel pipe with a 35cm section at the bottom honed (made smooth) on the inside for the pump cylinder. The rod to move the piston was 7mm (½") round bar.

A standard foot valve was used. The photos show the manner of assembling the piston with leather cups and the top arrangement of the pump.

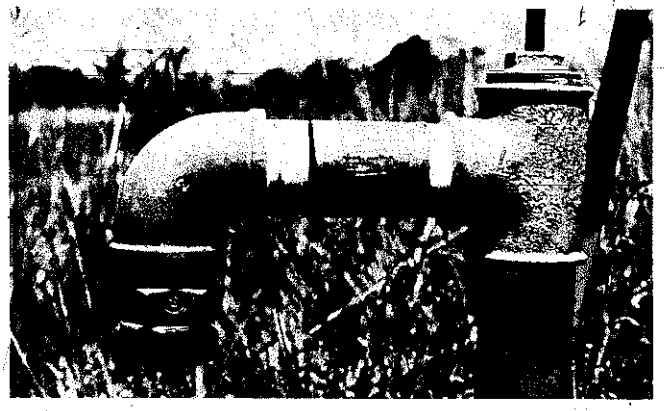

Most of the parts are from ordinary pipe fittings.

This shows what the parts down inside the pump look like.

cont'd

FOOT-OPERATED PUMP for a submerged deep-well cylinder.

"With this simple design, a person can pump 3 times as much water with his legs as he could with his arms." For details write:

Technical Services CCPD
World Council of Churches,
150, route de Ferney, Box 66,
1221 Geneva 20, Switzerland.

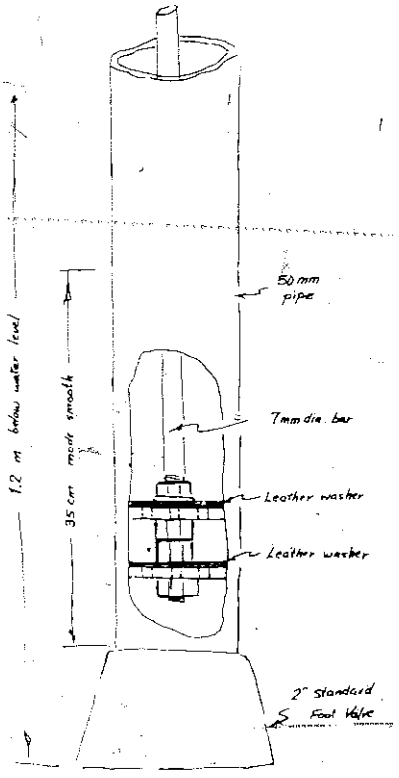

FOOT OF PUMP, CUTAWAY VIEW

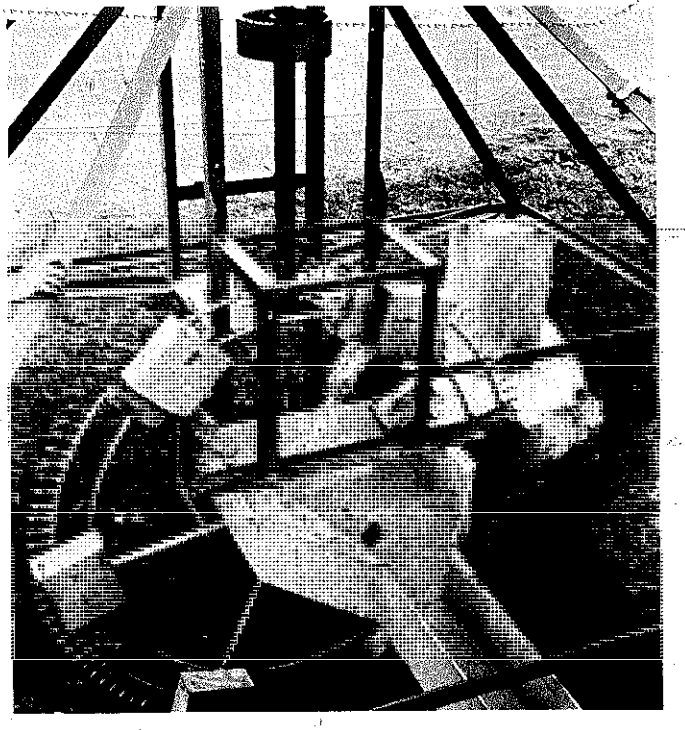

A MALAY INDONESIAN WATER LIFTER

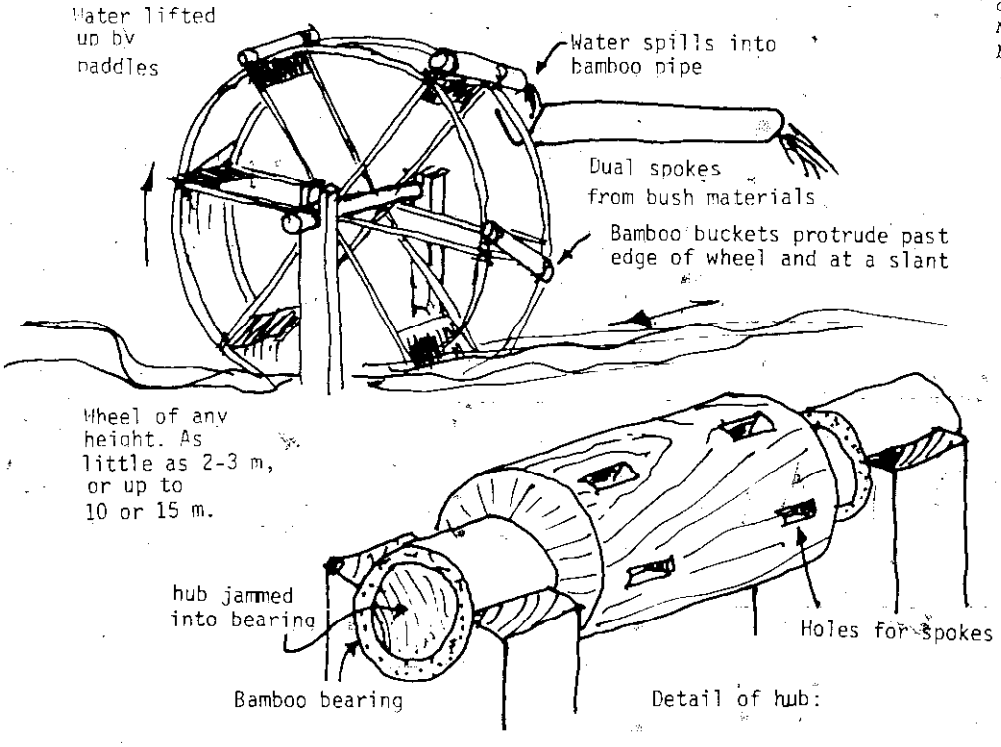

Above: Wheel for lifting water one metre, driven by a small Savonius windmill. Note "peg gears" welded from round bar.

TRANSPORTING WATER

This bamboo tube carries water for over two kilometres to village Kandumin, Wantoat, Morobe Province.

TWO MAN SHOVEL

This widely used tool serves to prepare alternating ridges and furrows, to form bounds for irrigated crops, and for other shovel work. It consists of a large, slightly concave, flat sided blade with two rings on the inside. The rings hold the ends of a rope. In use, one man pushes and directs the shovel with the long handle, while a second man facing the first, pulls on the rope. When the proper rhythm is maintained, work is generally faster than two men using two shovels. It is widely used in Arabia, the U.S.S.R., central and northern Iraq, Iran, Afghanistan, Turkestan, China, and Korea.

Reference: H.J. Hopfen, Farm Implements for Arid and Tropical Regions, FAO, Agricultural Development Paper No 67, Rome, 1960.

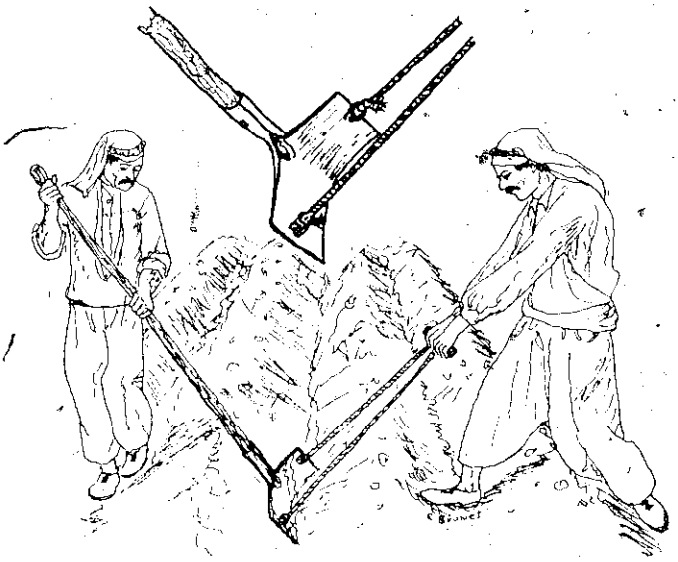

Suggested by: J. Greve, DPI., Box 2417, Konedobu.

Crop Production

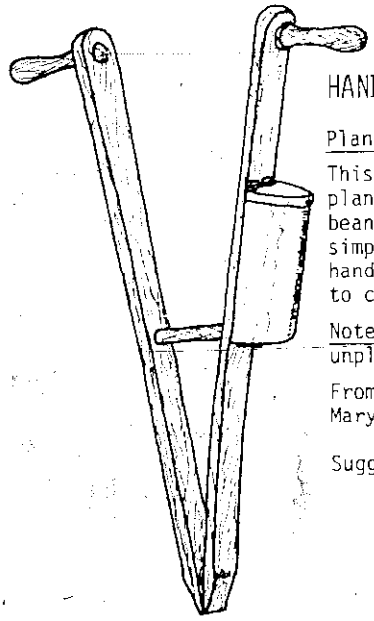

HAND PLANTER

Planter, hand-operated jab type

This hand-operated tool is a simple automatic planter which can be used to plant corn, peas, beans and seeds of similar size. To operate, simply jab the point into the soil and push the handles together. The seed plant is adjustable to control the number of seeds planted.

Note: This corn planter cannot be used in unplowed soil.

From: VITA., 3706 Rhode Island Ave. Mt. Rainier, Maryland 20822, USA.

Suggested by: J. Greve, DPI., Box 2417, Konedobu.

This useful digging tool was ok made from a piece of pipe. After heating, split along the weld line with a point or wedge. Insert wood handle and sharpen.

A. Inversin, Box 4981, Unitech, Lae.

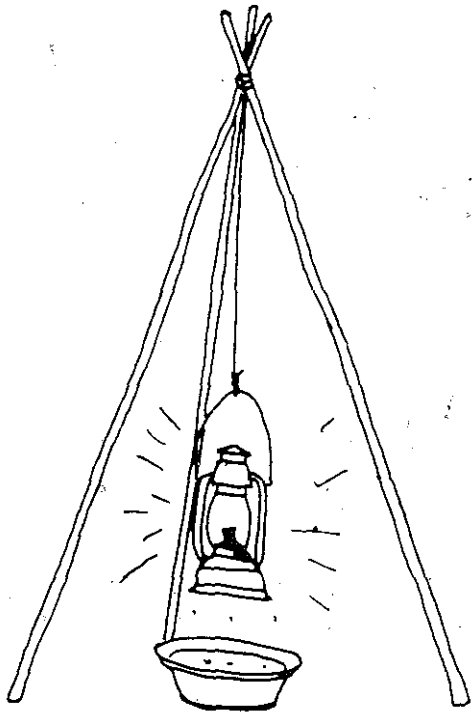

INSECT TRAP

This catches insects that like to fly at night to a light. You catch many insects that feed in the daytime and are fooled to think it is daytime. It is good for many rice pests.

Materials needed: 1 kero lamp (about K2.00) 3 bush sticks, a little twine, and 1 basin. These may be bought at most trade stores, or perhaps you already have them.

Tie the three sticks at one end to make a tripod and hang the lamp, and fill the basin with water. Let the lamp burn during the night. Insects fly against the lamp and fall in the water. A little kerosene in the water will insure that they will die quickly and not get away, and the glow of the kerosene attracts the insects.

Use a lamp big enough to burn the whole night. Don't let anyone steal your lamp!

HAND WEEDER

This simple and highly effective weeding tool can help to eliminate a lot of stoop labour and kneeling.

It can be made from a 46 cm(18") section of certain sariff materials or other metal. It is important to select stock that can be bent sharply without heat and without breaking. Discarded heavy duty banding material and 1¼" wide galvanized hoop iron will work.

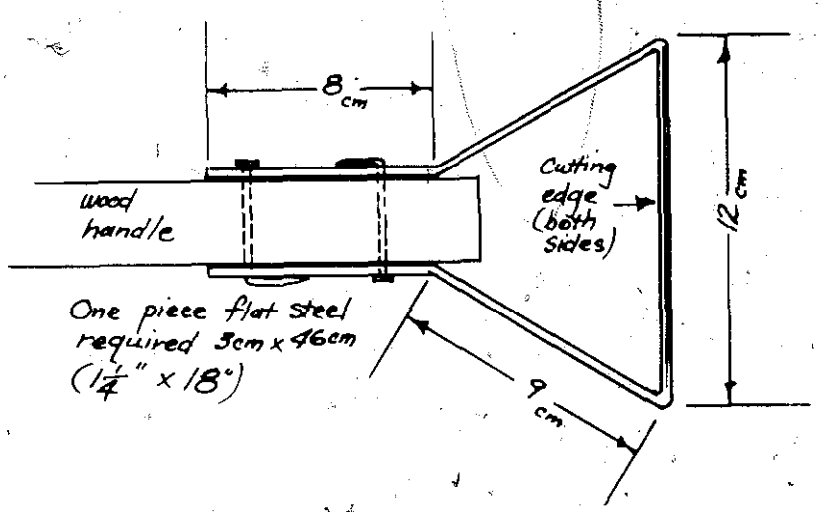

Mild steel works, since the triangular shape gives the weeder rigidity.

Bend and punch holes as shown.

After bending the tool and punching the holes, a strong wood handle about 3 cm in diameter is attached with flat head 2" nails, bent over.

Finally, both sides of the cutting edge are sharpened.

The tool is operated with either a pushing or a pulling stroke, or a push-pull stroke. A light pressure is applied to hold it to the ground. It is especially suitable for dry rice, vegetables, corn, peanuts, and pineapples. It is most effective when used on young weeds which can be cut without chopping.

B. Pulpulis, Box 49, Kavieng, NIP.

DUST APPLICATOR

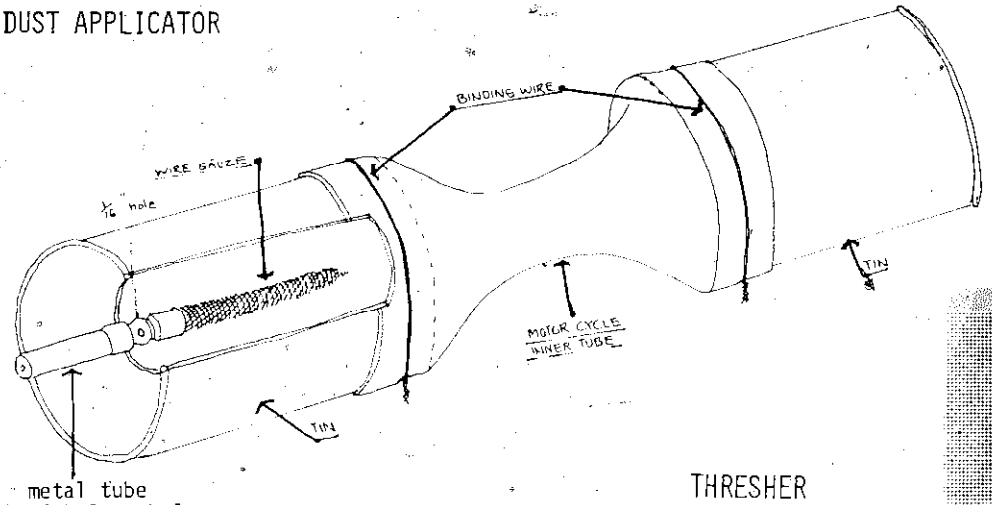

Description: A homemade tool for applying agricultural dusts to control fungus and insects.

Materials:
2 empty small milo tins
15-20cm length of motorcycle inner tube
5cm piece of copper brake fluid tubing
tie wire
scrap fly wire (wire gauze)
solder or Araldite

Order of work:
1. Cut out the bottom of one of the milo tins.
2. Drill or punch hole in bottom of remaining tin.
3. Drill small (1/16") holes in one half of the copper tube, as in picture.
4. Attach with wire a flywire (wire Gauze) filter to the end of the tube with the holes. A short piece of wire gauze rolled and wired to the copper tube and twisted tight at the end is sufficient.
5. Solder or Araldite the tube into the hole at the bottom of the tin.
6. Wire one end of the length of motor cycle inner tube around the mouth of the tin, and the other end around the cut out portion of the other tin. Do not lose the tin lid.
7. Place dust to be used inside the tin and close lid tightly. Operate by short push-pull strokes of the tins.

Further references PANS, Vol 21 No 4, Dec 1975. p.-418 - 19.

PNG Experience: Not yet used in PNG except for a working model at Tigak Agriculture Station, NIP. The design is by P.C.Mercer, Box 215, Lilongwe, Malawi, and is used for control of peanut fungus.

Remarks: The use of dusts for fungus and insect control, has limited use during rainy seasons, since rain washes the dust off. However locally formulated dusts for agriculture are very cheap, and are generally much safer for unskilled workers to use. Examples of available insect dusts: Gamma B.H.C. and D.D.T. powder; fungicides: Bordeaux mixture, and copper oxychloride.

THRESHER

A simple frame for threshing rice.

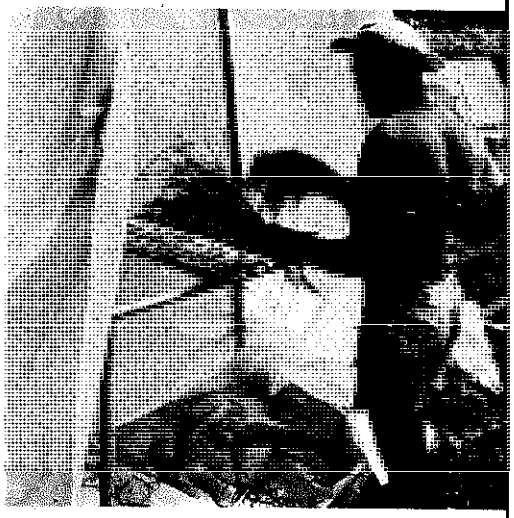

The plans for this foot operated thresher for rice and other small grains may be ordered from Village Development Office, Box 6937, Boroko.

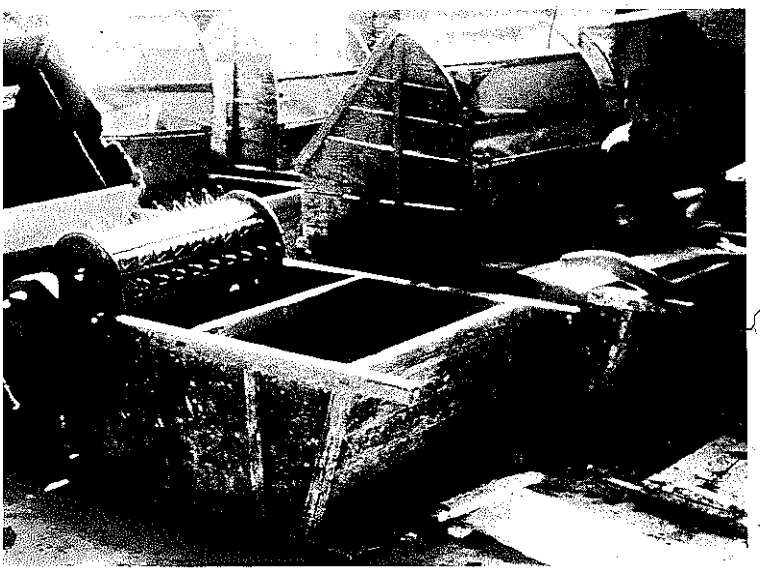

These pedal driven rice threshers are found by the thousands in South China. Interesting features are the barge-shaped box to catch the grain, and the removable hood. These are kept near the rice harvesters to minimize carrying.

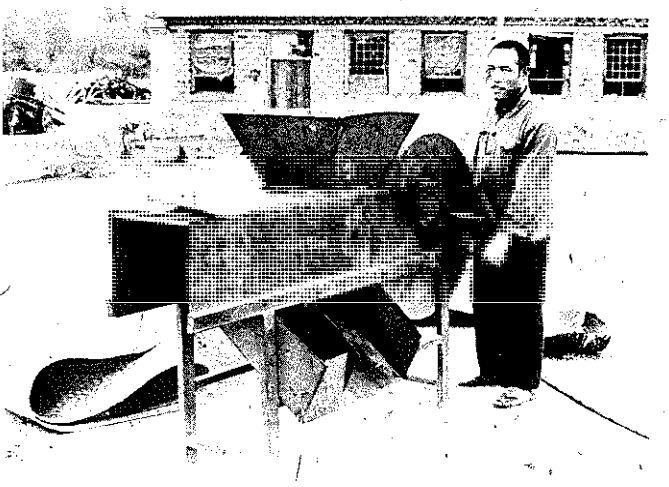

Chinese winnowing machine made of steel. The shape of these is not critical provided you have adjustable partitions inside.

Tradition Central Luzon Philippines model winnowing machine, plans available from International Rice Research Institute, Box 933, Manila, Philippines.

(p 248)

Drying rice in trays. These may be made using old pieces of iron for the bottoms, and may be stacked one upon the other in the case of rain, or at night. Puas Vocational Training Ctr., PMB Kaviong.

Livestock Production

POULTRY

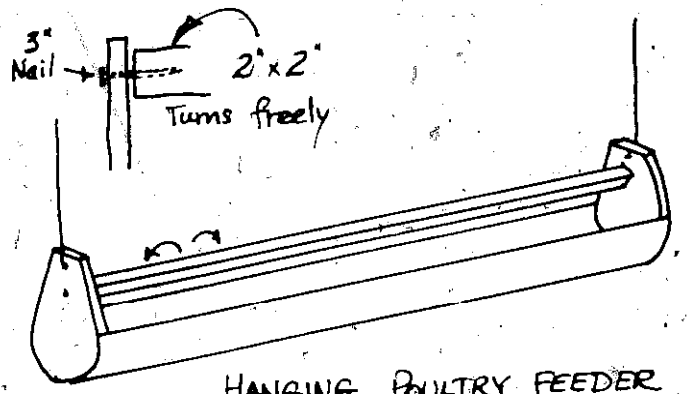

HANGING POULTRY FEEDER prevents chickens from standing in feed.

Suggested by Tony Watts Box 126, Popondetta

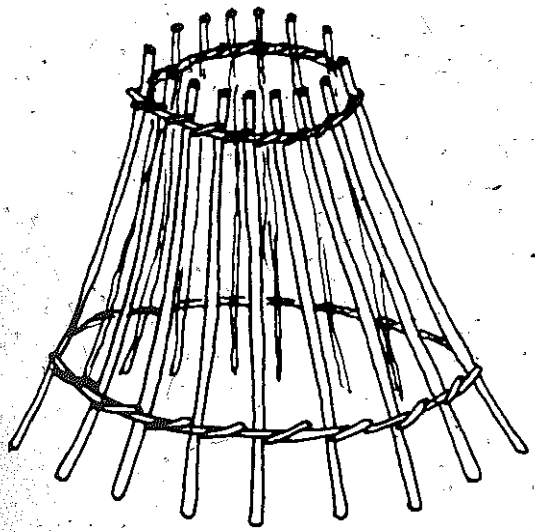

Pitpit or Bamboo

from Ulrich Bergman Wantoat, via Lae

POULTRY FEEDER

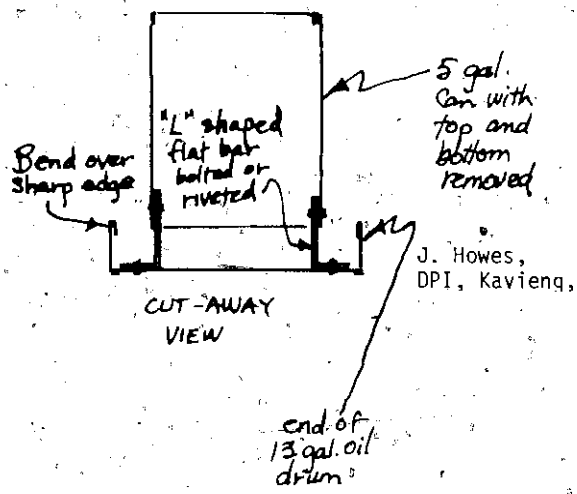

J. Howes, DPI, Kavieng, NIP

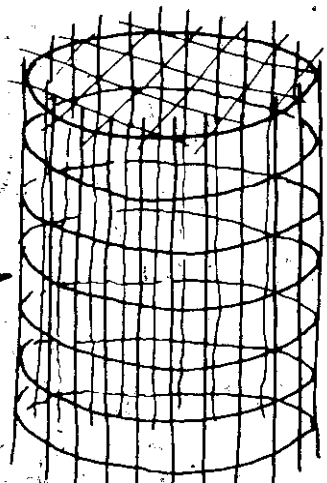

Arc Mesh 2"x3"

Tie in circle with wire

CREEP FEEDERS FOR BABY CHICKS

KEEP THE BIG CHICKENS OUT

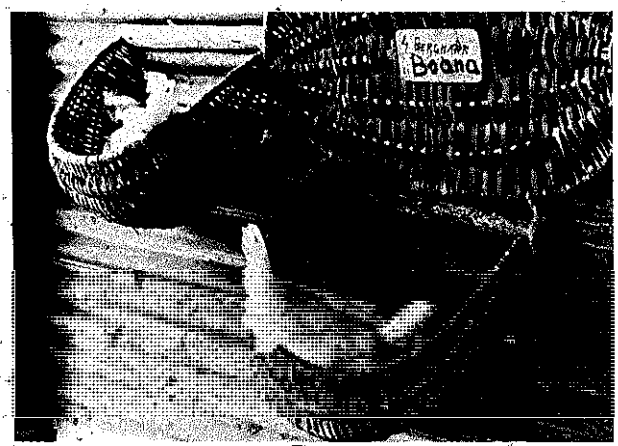

"basket" nests. See basket weaving, (p 130)

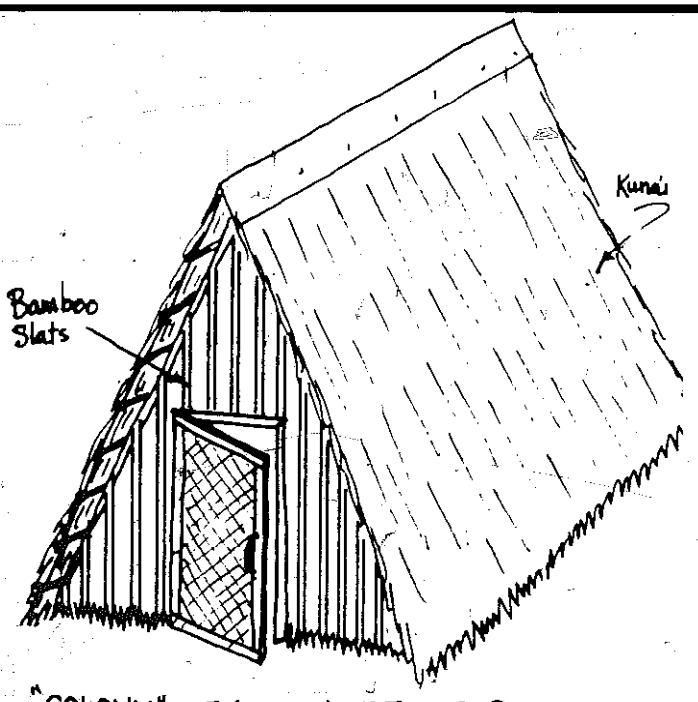

"COLONY" TYPE HOUSE FOR POULTRY
Made of bush materials

PIGS

CONCRETE PIG TROUGH

Description: A heavy feed or water trough that holds 35 litres. It is very stable, and cannot be turned by the pig, but with the handle, can be moved and cleaned by the person.

Materials list:
4 x 10 litre buckets sand
2 x 10 " " gravel
1 x 10 " " cement @ K1.00
1 piece chicken wire 45 x 42cm
2 pieces chicken wire cut into a half circle 40cm on base and 22cm radius.
2 pieces ½" reinforcing iron 60cm long @ 50t
timber to form
13 gal drum split lengthwise
waste oil (sump oil)

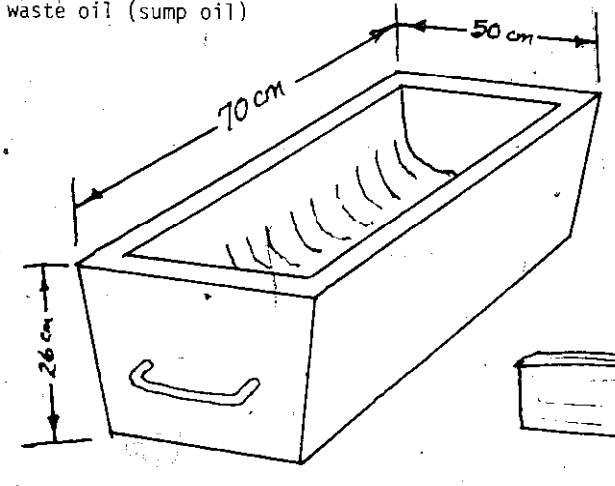

Order of work:
1. Construct the framework for the form following drawing. There is a floor to the frame which is not nailed to the sides. Leave heads of nails protruding slightly so form can be removed easily and used again.

2. Fit split drum inside wooden battens on floor, but do not nail in place.

3. Coat outer surface of drum with oil to prevent concrete sticking.

4. Place upper form over floor. (P 124)

5. Mix concrete, and add a little extra water so it will pour well.

6. Install reinforcing wire and a handle if desired. Leave a slot in the end form so that it will slip off.

7. Pour concrete into form, allow to set 24 hours before removing the form. The trough may be used in 7 days. Cure it in the shade.

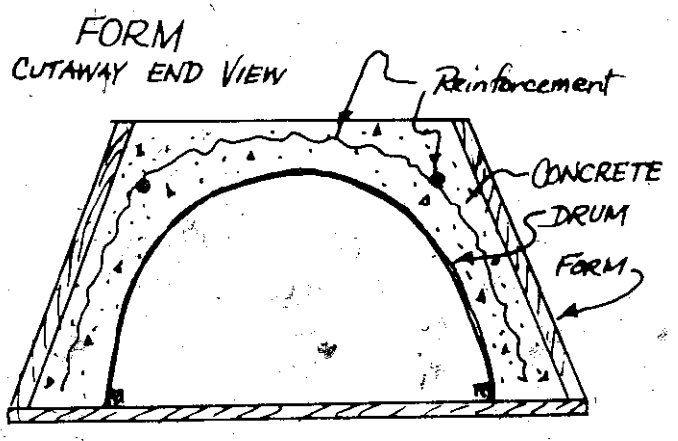

PNG. Experience: Manggai High School, PMB Kavieng, since March 1976.

Remarks: One form is sufficient to make one trough a day. Leave the heads of nails loose so the form can be dismantled easily and avoid damage. To clean trough the person can easily tip the trough with the handle.

Initial contributor: Manggai High School, Kavieng.

FEED TRAY FOR PIGS

This feeding tray for pigs, made of wood and flat iron or a piece of 13 gal. drum has no corners for food to stick in, is

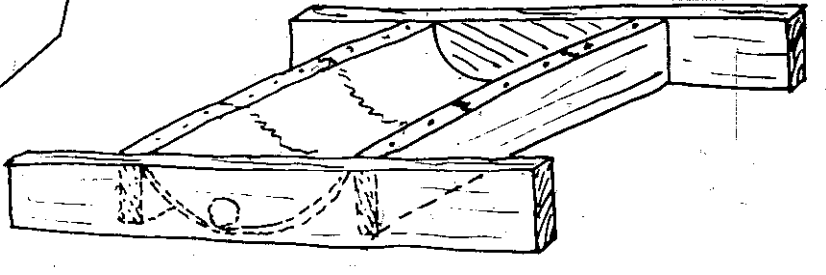

durable, and it fits under the side wall of the pighouse so that you can pour in the food from outside. It has been tried at Dosambago Skul Bilong Kirapim Ples, Wantoat, Morobe Province. In 6 months of use it has been very satisfactory. You can make different sizes for different ages of pigs. Long timbers on sides give weight and stability.

Initial contributor: U. Bergmann
Wantoat via Lae

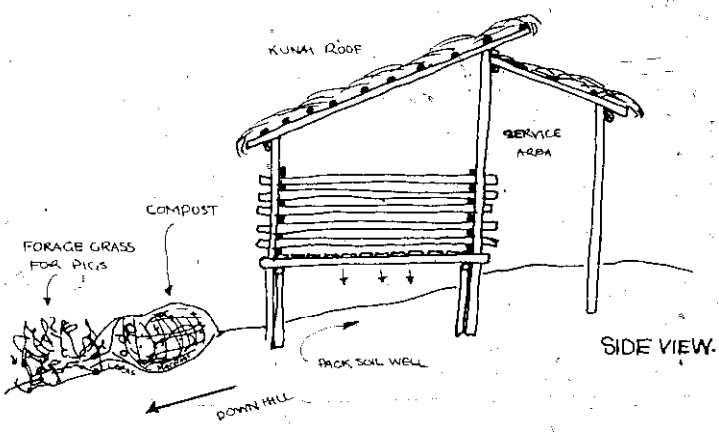

PIG HOUSING

TAKE NOTE!

A DPI experiment in Goroka by Malynicz showed that FEED could be 4 times as important as breed and 39 times as important as housing.

Breed was 8 times more important than housing.

Are you sure you need better housing?

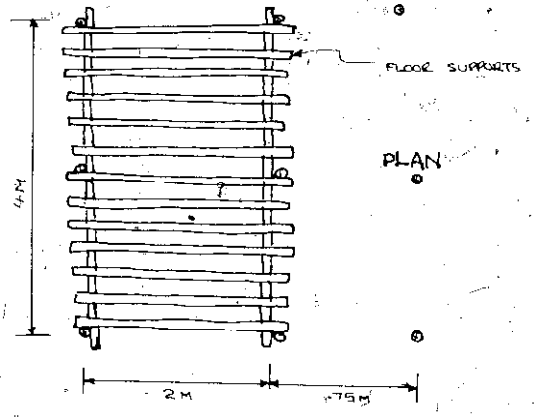

PIG HOUSE MADE OF BUSH MATERIALS GOOD FOR FATTENING TWO PIGS. 2 m x 4 m

Note:
1. A little sunshine in the morning;
2. A little green grass each day, in addition to the other food;
3. Plenty of clean drinking water;
4. Good drainage: Splash floor daily to wash manure through cracks in the floor; and
5. Durable posts and floor, ordinary materials for roof.

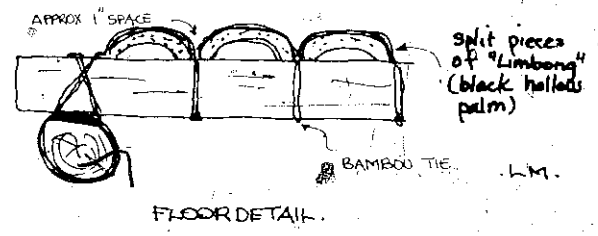

This timber pighouse keeps pigs off the ground and out of the gardens. Make provision for getting pigs in and out easily. Feeding tray fits in under side of wall and food can be poured in from outside. A disadvantage - sunlight has difficulty getting in if not properly oriented or designed.

PNG experience: Dosambago Skul Bilong Kirapim Ples, Wantoat, and many Wantoat villages. Original information provided by David Williams, here presented with minor alterations by Ulrich Bergman, Wantoat, via Lae.

Pig house built of bush materials, Martyrs' High School, NP

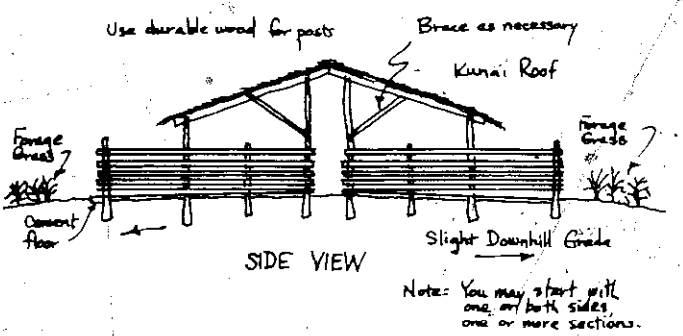

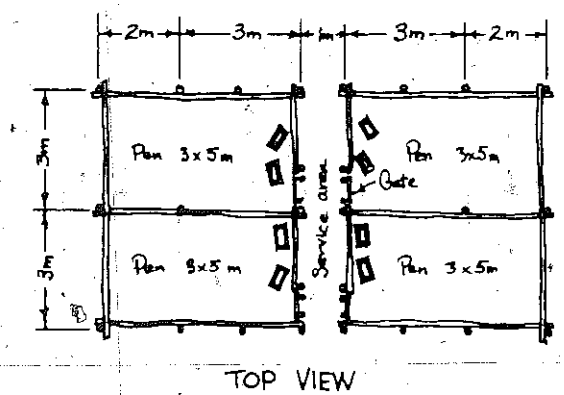

PIG HOUSE

This type of pighouse (initial construction, one side) has been successful at the Dosambago Skul Bilong Kirapim Ples, Wantoat, Morobe Province. It is built in a place where the manure can drain off into an area which produces plenty of forage grass for the pigs.

NOTES:

1. Except for cement floor, it is all made of bush materials. (If the soil is well-packed, even a very thin cement floor will suffice.)
2. It can be expanded as much as you like simply by adding similar sections.
3. It's very easy to move pigs from one section to another (especially good for mating purposes).
4. One section is large enough for a sow and her piglets, or for 2 or 3 fattening pigs, or for one fully grown boar.
5. The caretaker can usually put the feed and water without going inside.
6. It is easy to clean. Just wash the manure out the back.
7. At the back, the manure will support a beautiful forage grass garden which can be used to feed the pigs. The green feeds help them to stay healthy and to have a good appetite.
8. If you start with "clean" pigs and never move them from this unit, worms should not become a serious problem.
9. If you want to use rainwater from the roof, put gutters and catch the water in a tank.
10. If you need a "guard", a sleeping place can be built up high in the center.

Recommended by U. Bergmann, Wantoat via. Lae. Original design D. Williams, Box 80, Lae.

Cross-section of an insulated concrete floor

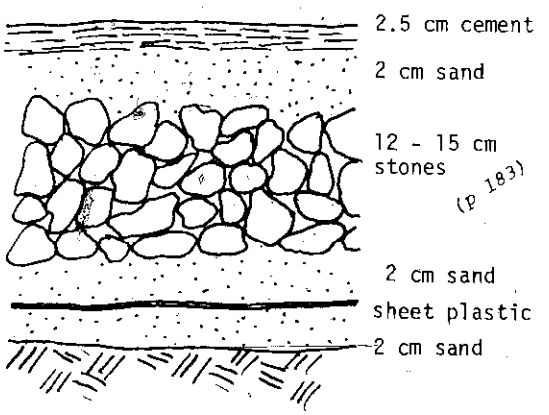

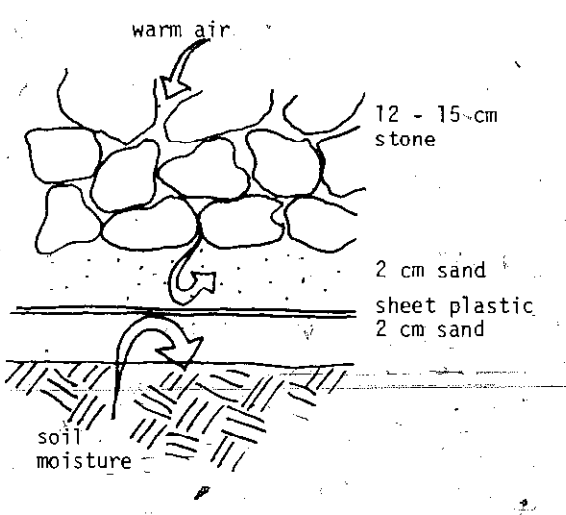

The effect of sheet plastic in the insulated floor.

from Pigs and Poultry in the South Pacific

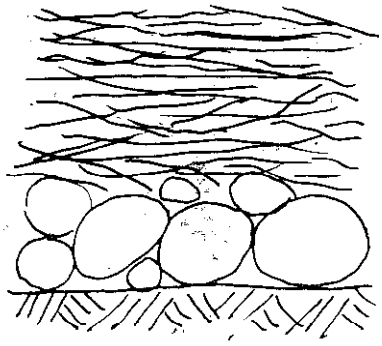

Cross-section of a deep litter floor

from Pigs and Poultry in the South Pacific

PORTABLE CONFINEMENT FOR PIGS AND OTHER SMALL ANIMALS

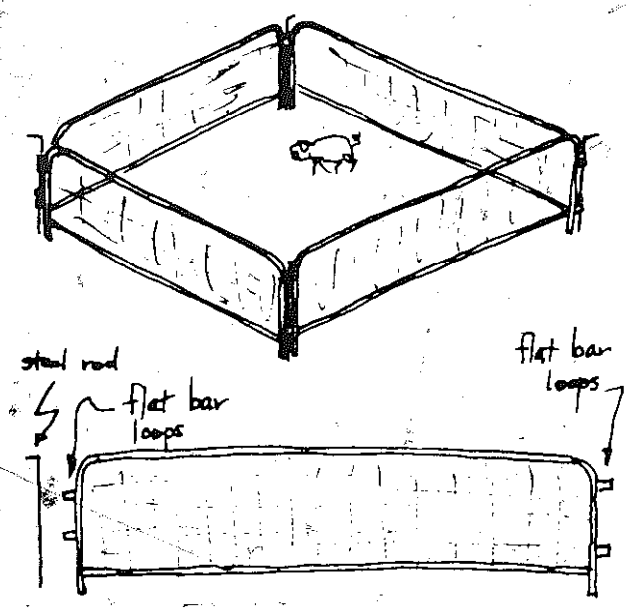

Panels made of pipes and hog wire. Use 3 or more.

Or make similar panels out of hardwood and hog wire.

Or try arc mesh circles.

Pigs under control in a garden can provide tillage plus fertilizer.

Hunting and Fishing

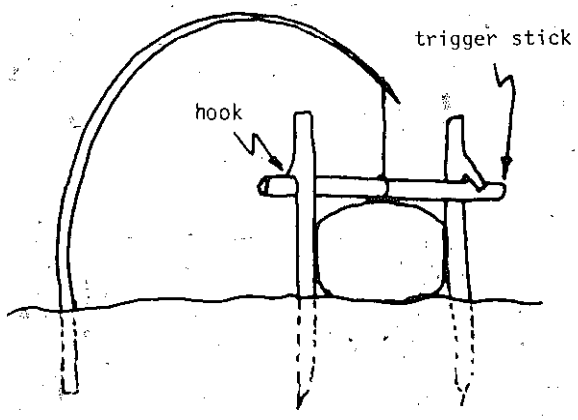

NOOSE TRAP FOR WILD PIGS

Pigs are often trapped in many parts of PNG using a noose trap. While there are many variations in details this is a common one.

A very strong stick that will bend without breaking is planted in the ground and a noose of rope or cane is hung over the trail used by a pig. Brush and barriers are placed around the trail to keep the pig going along the trail. Often a young tree growing next to a pig trail is used, by just cutting branches. To set the noose, the cane or rope is tied just above the noose to a branch. The noose is pulled tight until it reaches the ground. Two sticks with parts of a branch like hooks are driven into the ground. The hooks face in opposite directions and the stick attached to the noose is caught under the branch parts so that a small movement lets the noose loose.

When the pig rubs its back walking under the trigger stick the trap is sprung and the pig is caught by the noose.

Check the trap daily or more often in case a pig is caught so that dogs or another person will not steal a pig that is caught in your trap.

There are many other ways of making such traps, and some use very sensitive and complicated triggers made of bamboo balanced in a certain way, but this is the easiest trap for a beginner.

Initial contributor: B. Levi, Vudal, PO Kerevat, ENB

Yes, you have a role in DEVELOPMENT, leader, but is your role DEVELOPMENTAL?

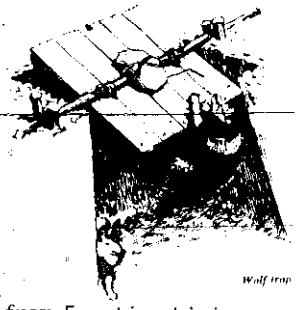

from Frontier Living

RAT AND BIRD TRAP

This rat and bird trap made from bamboo is very effective. It is tied together with bits of inner tube and string, and an inner tube spring activates it and holds the "catch".

The bottom part of the vertical piece can be tied to a fence post, or the pointed left end of the horizontal part can be stuck into a banana stalk. Or the trap can be mounted inside a house.

The stick on top of the "catch" (a small plastic bottle is shown here), held down by the strong rubber band, is the trap. The small stick under the "catch" is the trigger. The bait is tied to the trigger. When the "catch" pushes down the trigger, it lets go of the trap release stick, and the trap snaps down.

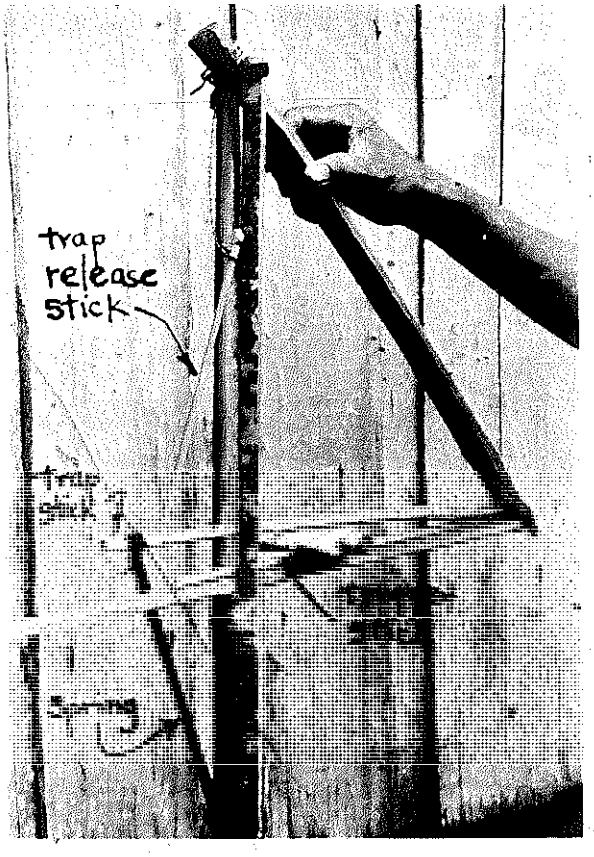

This shows the trap in a loaded condition, ready to go off. The trap release stick is held precariously by the trigger stick at point X.

from Orestus Martin, MARA, c/ UCCP Church, Butuan City, Philippines

RIVER FISH TRAP (NOT FOR SALT WATER)

Use: 3 circles made of heavy wire, or even old wheel rims from a bicycle.
Chicken wire netting.
8 gauge fencing wire.
Copper or soft iron tie wire.

cont'd

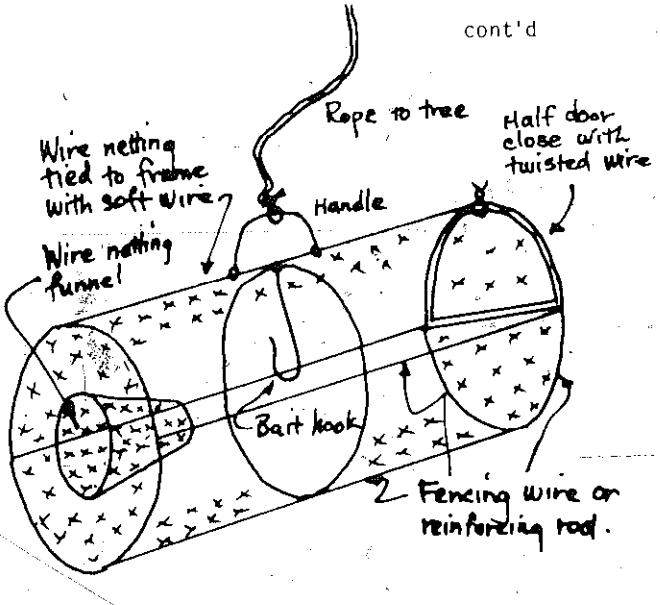

Although the people of P.N.G. make many varieties of fish trap, the above trap is strong and will last many years in fresh water.

Bait the hook with meat, old bones, or a bag of kaukau, etc. Leave the trap near the river bank well below the surface of the water. Tie the rope to a tree. Check the trap for fish every three or four days.

Initial contributor: M.J. O'Riley
Dep't of Education, Madang

BAMBOO FISH TRAP

A simple bamboo fish trap using the white ants found at the base of trees as a bait is used in the West Sepik.

Very large bamboo is cut into one metre lengths. All but the node at one end is removed, and in that node a small hole is bored with a piece of pointed steel that has been made very hot.

Masses of the white ants are broken into pieces just small enough to fit inside the bamboo. The trap with bait is placed in slow moving streams where fish feed during the night. Place the length of the bamboo crosswise to the flow of the stream so that the ants will not be washed away, and anchor the bamboo with a rock.

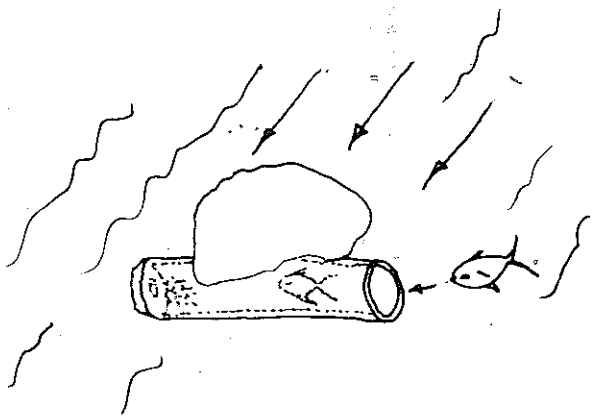

During the night the feeding fish enter the bamboo to get the ants, and remain there during the next day since the bamboo is a good hiding place.

On the morning after when you check your trap be sure to quickly place your hand over the open end of the bamboo, then pour out the fish, prawns or crabs into a bucket on dry ground. Be sure to put fresh ants each time you check the trap.

Initial contributor: R. Seki, Vudal, PO,
Kerevat, ENBP.

Crop Processing Food Preparation and Preservation

COCONUT SCRAPER

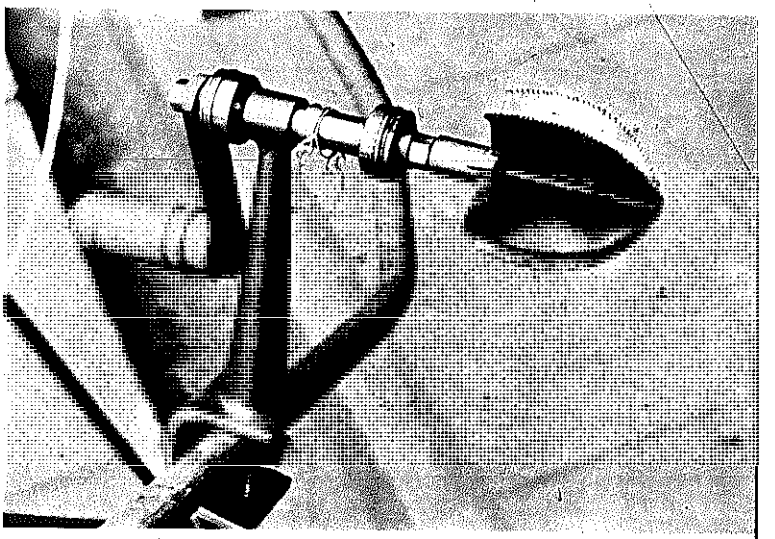

"Lucky Meri Super Scraper" coconut scraper, using front axle and bearing of bicycle wheel from New Britain Engineering, P.O. Box 163 Rabaul. Price K7.50 plus shipping.

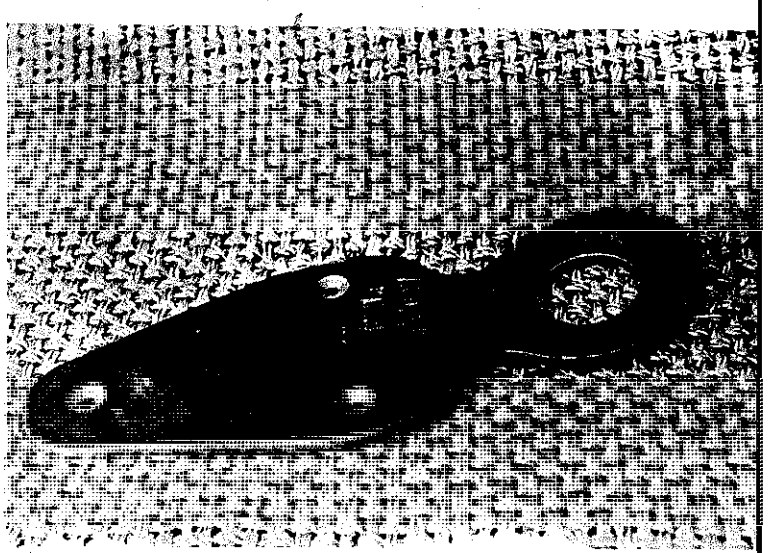

Coconut scraper made at St. Joseph's Vocational Training Centre, Lae

The level and basis upon which persons can turn outwards to seek solidarity with other human beings reflects or even defines the measure of their security and their maturity.

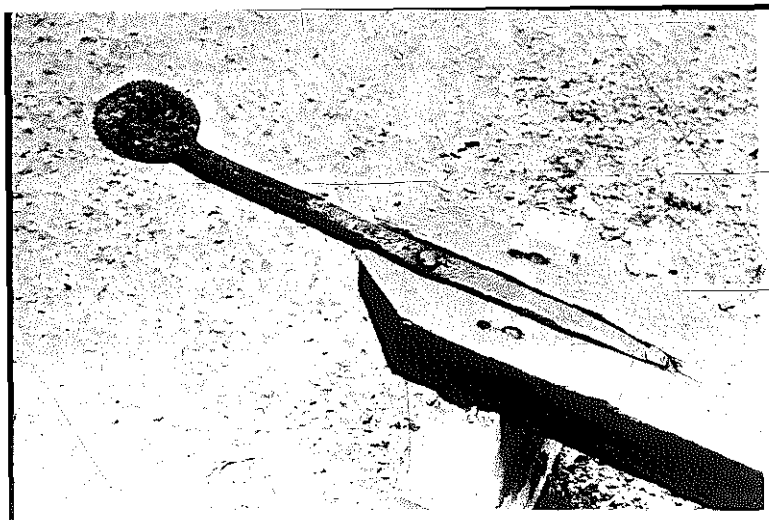

Very common type of coconut scraper found in the philippines. Made from 12 mm (½") round bar.

COCONUT SCRAPER

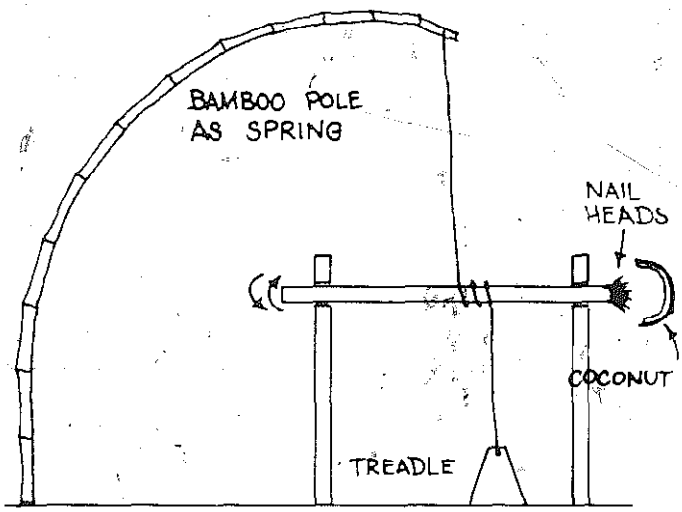

This is a simple treadle-operated scraper for extracting coconut, common in some parts of Indonesia, unknown in others. This appeared in Appropriate Technology, August 1975, where it was reported that the scraper was used successfully by BUTSI, the Indonesian Board for Volunteer Service, through a newly created village Technology unit. For more information on BUTSI write: Dr. W.P. Napitupulu, BUTSI Secretary, Tromol Pos 3290, Jakarta, Indonesia.

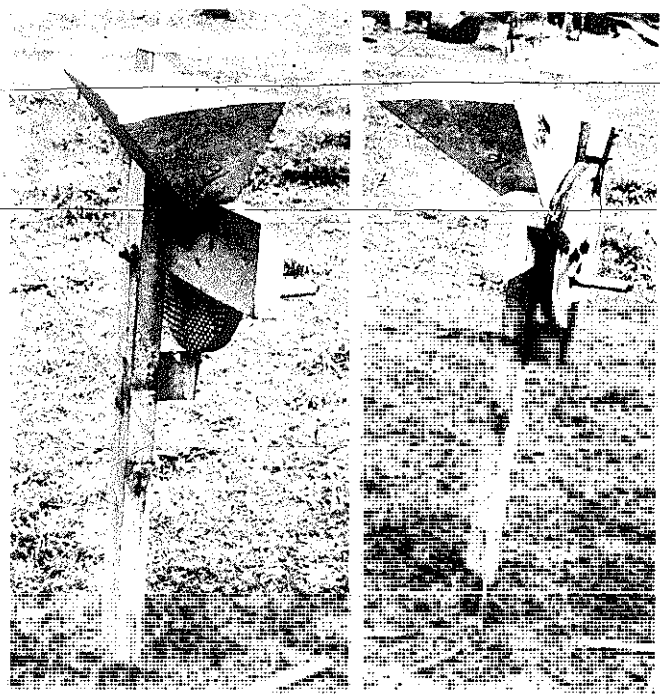

Home made coffee pulper made of wood, tin, and a few odds and ends. More information from Village Development Office, Box 6937, Doroko.

COFFEE PULPER

MR BISNISMAN/ MR VOCATIONAL CENTRE MANAGER! DO YOU MAKE OR SELL SOMETHING THAT WOULD HELP THE READER OF THIS BUK? WRITE AND TELL US WHAT IT IS AND WE'LL PUT IT IN THE NEXT EDITION. IF YOU LIKE, A CONTRIBUTION TO HELP KEEP THE COSTS OF THE BUK DOWN WILL WIN YOU AN HONOURED POSITION IN THE ACKNOWLEDGEMENTS SECTION AT THE END OF THE BUK. EVEN IF YOU DON'T LIKE, WE'LL STILL INCLUDE YOUR PRODUCT OR SERVICE, IF IT WILL HELP THE READER.

COFFEE ROASTER

Coffee roaster made at Kundiawa Vocational Training Centre.

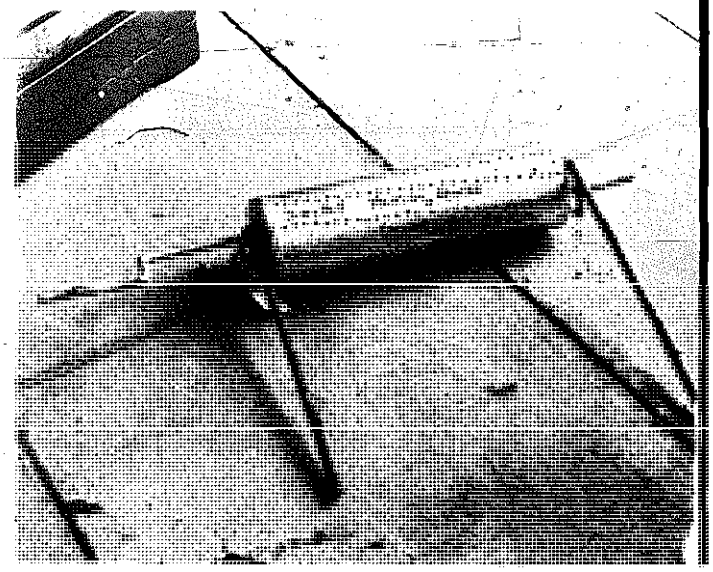

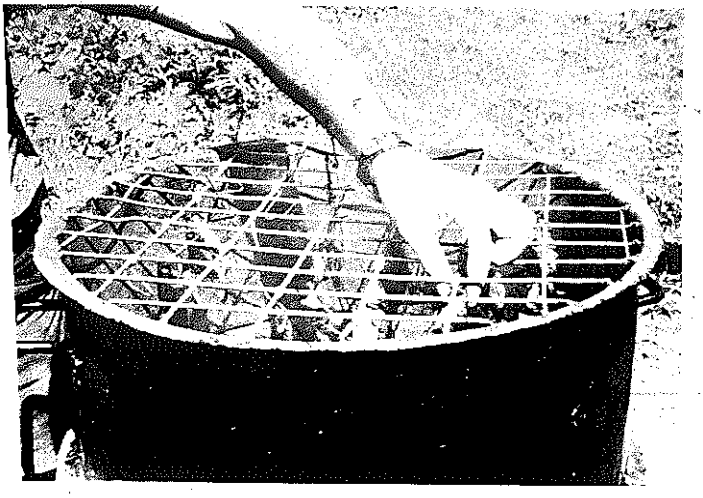

FISH SMOKER

(p 250)

Smoking fish, Bugandi High School, Lae. This unit was designed by Howard Hepworth, Dept. of Business Development, Box 568, Lae. Note burner at bottom. Top sections were each made of 1/3 of an oil drum, each having a security wire grid for hanging the fish tail down, and they may be stacked up to ten units high. A cover or wet copra sack is placed on top. As the units on the bottom are sufficiently smoked they are removed, and the next unit is brought closer to the burner. A slow smoky fire is desired. Depending upon the size of the fish and the heat of the fire, smoking takes anywhere from 8 to 12 hours. Big fish should be split and the fillets slashed.

Be careful with this design. The heat from the fire can cook the fish, and can seal the surface so that the smoke does not enter the fish. Keep a cool, c o o l fire going.

At the treaty of Lancaster, in Pennsylvania, anno 1744, between the Government of Virginia and the Six nations, the commissioners from Virginia acquainted the Indians by a speech, that there was in Williamsburg a college with a fund for educating Indian youth; and that if the chiefs of the Six nations would send down half a dozen of their sons to that college, the government would take care that they be well provided for and instructed in the learning of the white people.

The Indians' spokesman replied:

"We know that you highly esteem the kind of learning taught in those colleges, and that the maintainance of our young men, while with you, would be very expensive to you. We are convinced, therefore, that you mean to do us good by your proposal and we thank you heartily.

"But you, who are wise, must know that different nations have different conceptions of things; and you will not therefore take it amiss, if our ideas of this kind of education happen not to be the same with yours. We have had some experience of it; several of our young people were formerly brought up at the colleges of the northern provinces; they were instructed in all your sciences; but, when they came back to us, they were bad runners, ignorant of every means of living in the woods, unable to bear either cold or hunger, knew neither how to build a cabin, take a deer, nor kill an enemy, spoke our language imperfectly, were therefore neither fit for hunters, warriors, nor counsellors; they were totally good for nothing.

"We are however not the less obligated by your kind offer, though we decline accepting it; and to show our grateful sense of it, if the gentlemen of Virginia will send us a dozen of their sons, we will take care of their education, instruct them in all we know, and make men of them."

Initial contributor: B. Franklin, Philadelphia, PA USA.

(p 104)

GRAIN GRINDER OR MILL

This small concrete grain grinder works like the millstones used in many parts of the world over the centuries. It is especially good for cracking corn and grain legumes. You can make fine corn meal with it if you run the corn through several times and then screen it through fly wire. This type of mill will remove the hulls from rice kernels, but this particular size, which is good for cracking corn, is a bit heavy and breaks the rice grains excessively. Of course, such a rice mill does not separate the hulls from the grains, which has to be done in another operation (winnowing and screening).

(p 166)

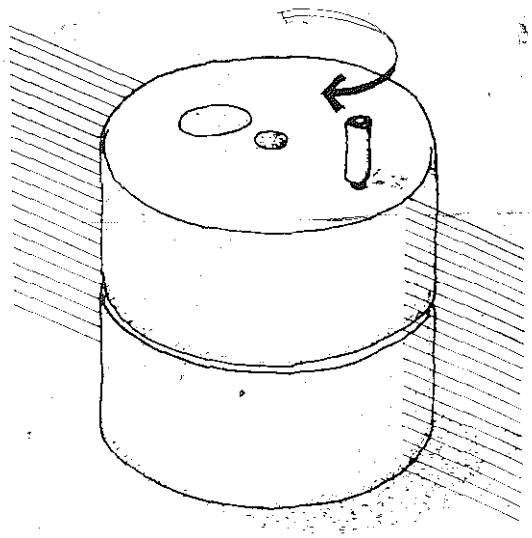

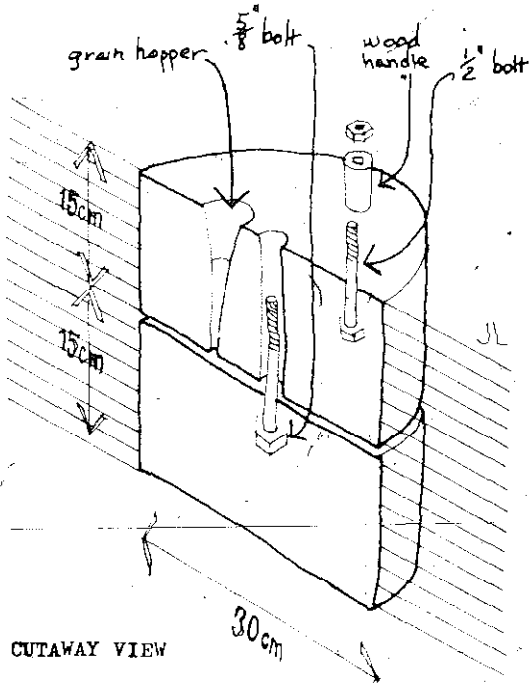

CUTAWAY VIEW

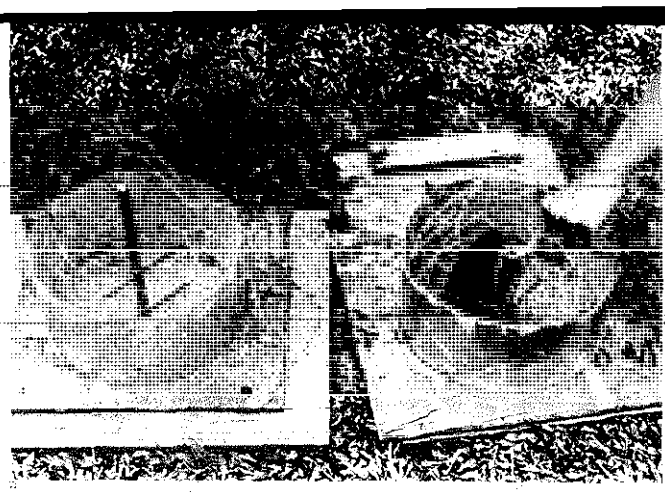

The forms can be made from scrap pieces of iron, or from pieces of 20 litre round tins. Any old bolt will do for the pin. The piece of pipe for the bearing (top) is not really necessary, if you don't have it. Poultry wire reinforcing is advisable, but not absolutely necessary. The hole for the grain (top piece) should be like the drawing or like the wood grinder shown. ⟶

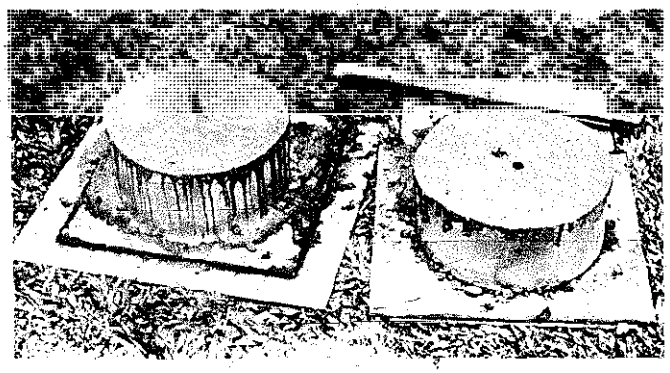

The freshly poured concrete.

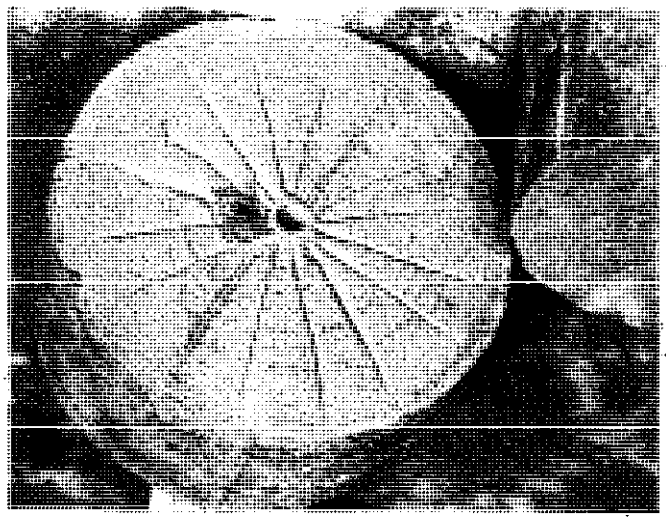

Marks like this are made in both faces with the corner of a small board. On the second day you can fit them together and turn the top enough to seat them nicely. The concrete will be well cured in 3 to 4 weeks.

cont'd

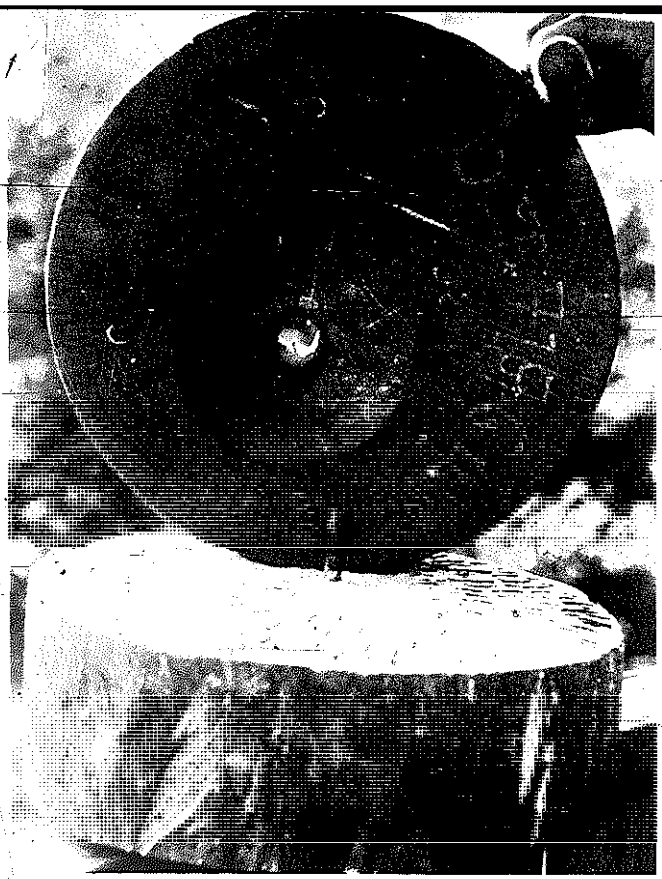

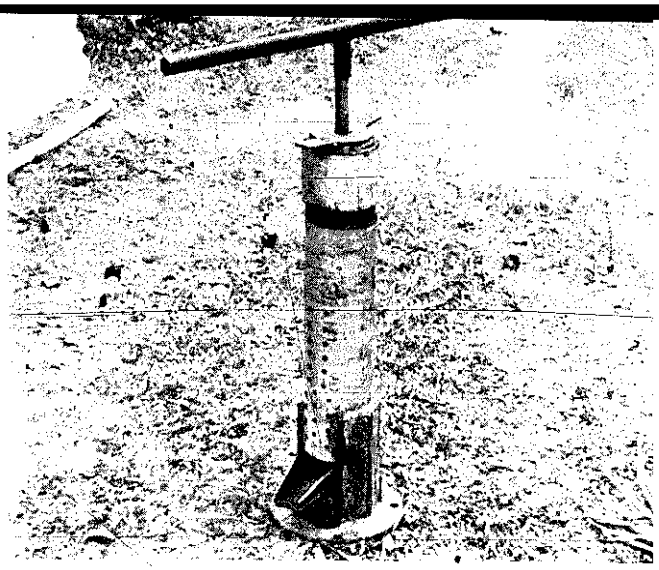

The press shown at lower left looks like this when it is assembled.

Here is a similar grinder, but made with hardwood and with small pieces of cast iron (from an old Chinese frying pan) driven into both faces.

When using such a grinder, put it in a shallow box or on a mat or piece of plastic to catch the grain.

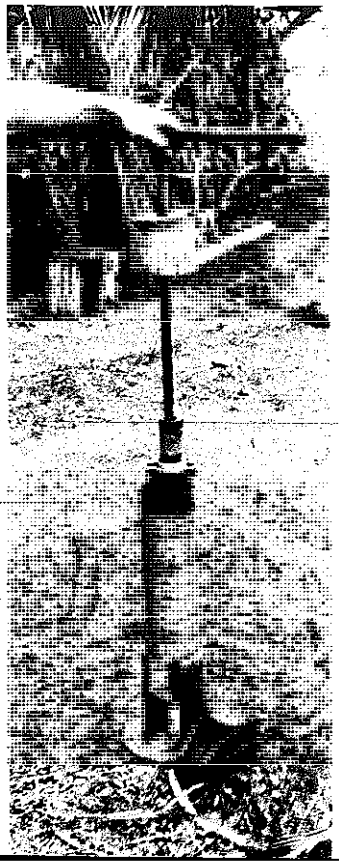

Oil press similar to one at right, but with differences in some details. The bottom can easily be removed for loading and unloading.

OIL PRESS

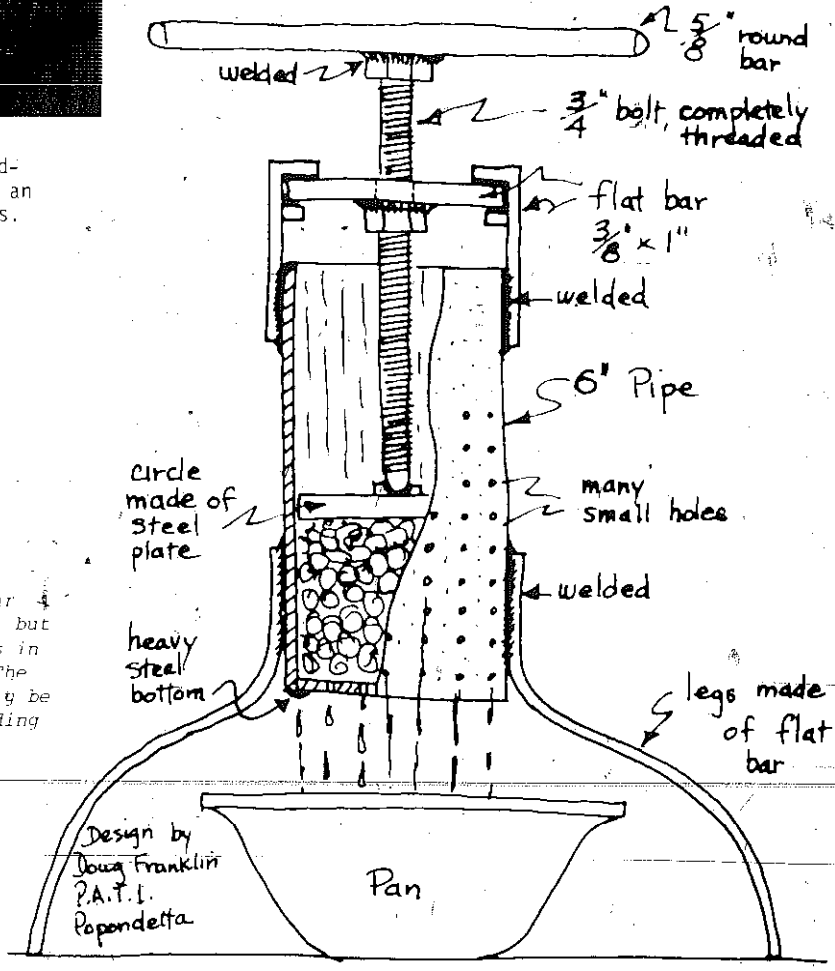

SIMPLE OIL PRESS
(cutaway view)

AGRICULTURE IS THE BASIS OF INDEPENDENT DEVELOPMENT

PEANUT SHELLER

(P 250)

This type of peanut sheller has proved itself in many countries and can be quite efficient as long as the right size screen is used. The degree of efficiency will depend very much on both the moisture content of the peanuts and the type of nut being shelled. These machines are easy to operate, provided that only about 5 cm of nuts are placed in the sheller at any one time. To have an ideal set-up one would put a number of machines using different sizes of screen. The nuts are first placed in the machine with the largest size screen. Any nuts not shelled would then be passed through the second size, and so on. Winnowing has to be carried out as a separate operation.

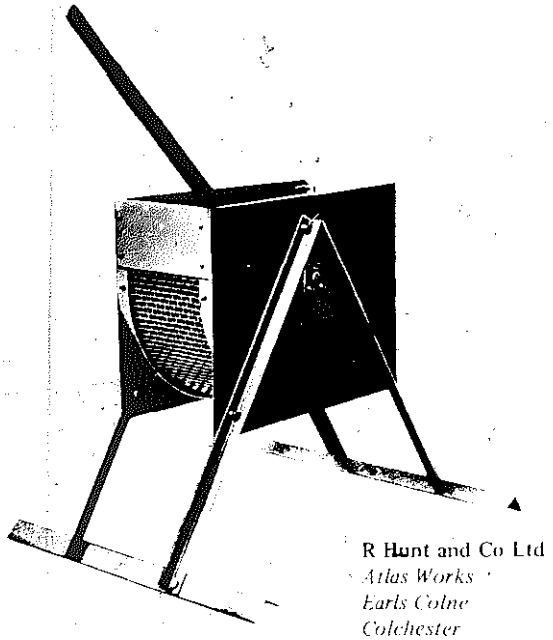

R Hunt and Co Ltd
Atlas Works
Earls Colne
Colchester
Essex
England

Make your own, or buy from:

PEANUT ROASTER

This is constructed from a wire mesh cylinder supported on a frame, as shown in the diagram, or from a round 20 litre tin with the lid securely fastened and holes punched in it. In the cylinder or tin, provision is made for loading and unloading by a trap door or sliding door. The roaster is mounted so that it can be slowly rotated over a fire or heat source. (See notes on roasting peanuts)

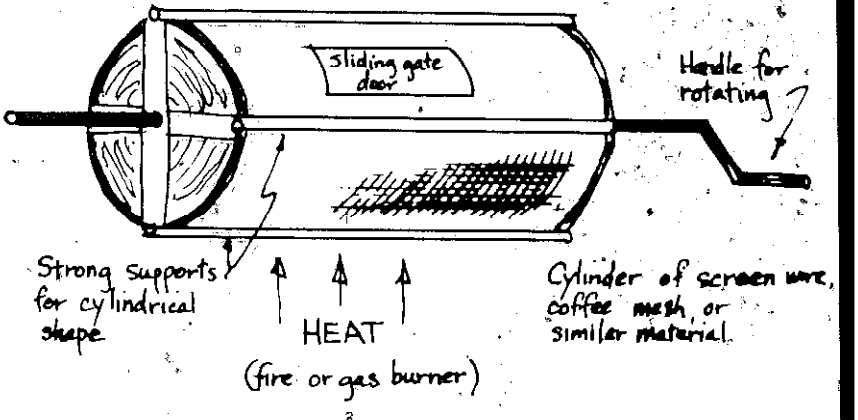

SUGAR CRUSHERS

IF YOU THINK YOU CAN CRUSH SUGAR CANE EFFECTIVELY WITH AN OLD CLOTHES MANGLE OR WRINGER, YOU'RE WRONG. SAVE YOURSELF THE BOTHER.

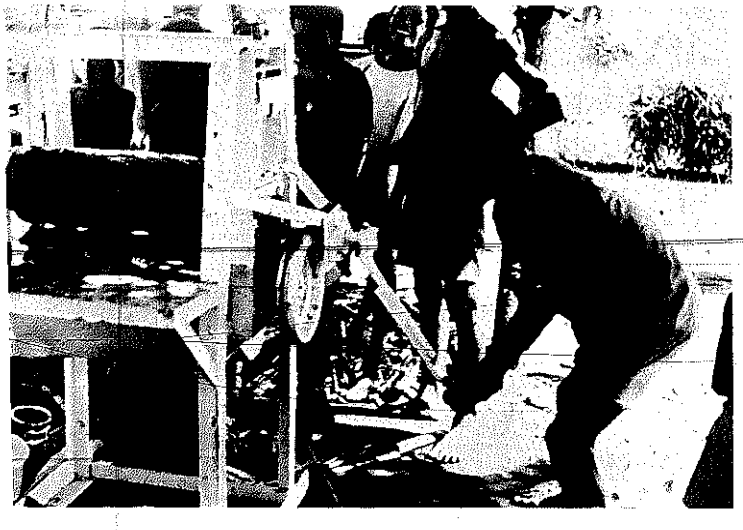

This powerful sugar cane crusher (left) was built at PATI, Popondetta from available junk with welding equipment. A man can easily drive the crusher with 5 canes loaded at a time.

Rollers are pre-set and spring-loaded, so that no further adjustment is made. The rollers are 21 cm (8") x 60 cm (24"), mounted on 38 mm (1½") steel shafting, with ball bearings. A Toyota 3R flywheel gear and a 12 tooth pinion gear drive the unit. The crank handle radius is 30 cm (12").

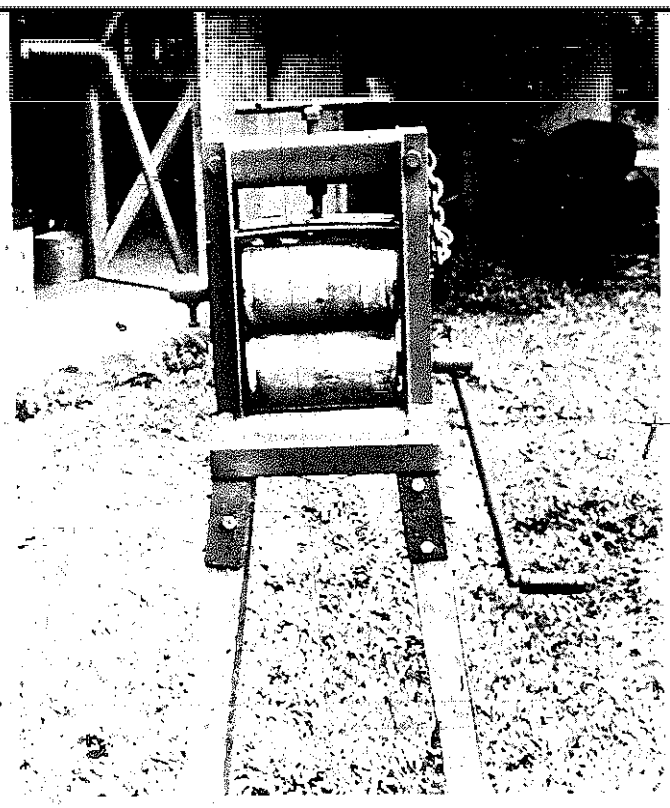

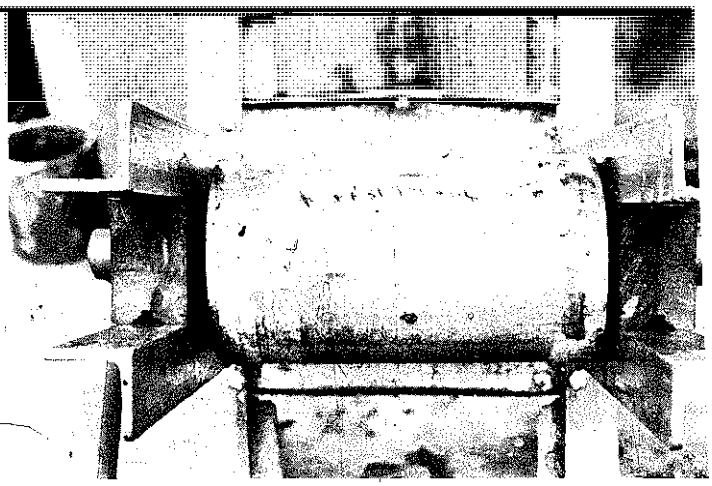

Rollers are pieces of 4" galvanised pipe, 8" long. Shafts are 1" mild steel. Bearings are hardwood, and the top pair slide up and down depending upon the thickness of the cane. The angle iron is 1½" X 1½" X 3/16". The pan to catch juice slants downward and to the centre of one side. The chain is simply to keep the spring from getting lost.

SUGAR CRUSHER

This is a simple 2-man sugar crusher without gears. It can easily be fabricated if you have access to a welder and cutting torch.

Sugar cane is passed 3 or 4 times, with adjustment screw on the top tighter each time.

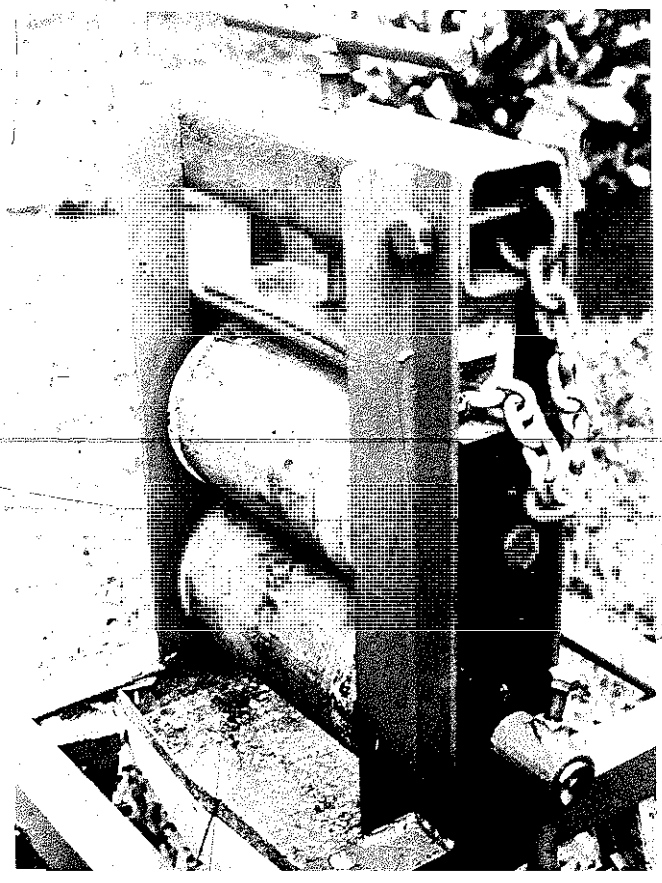

DRUM STOVE

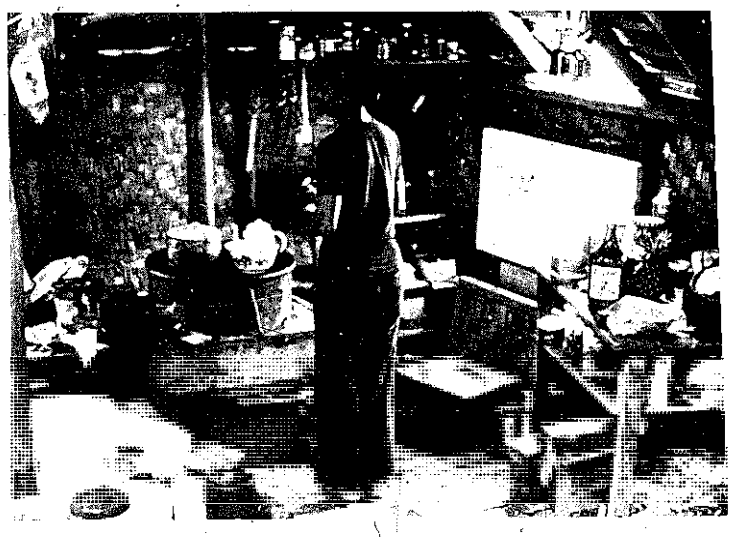

Note movable door to control burning.

H. Bekker

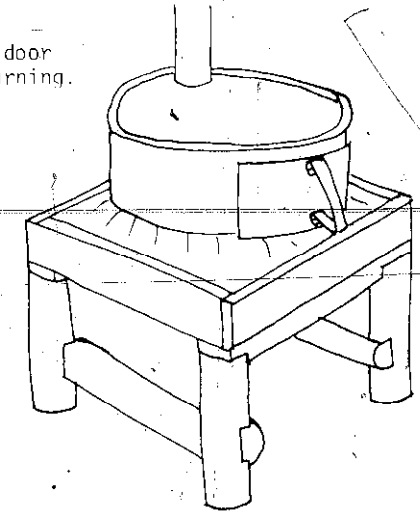

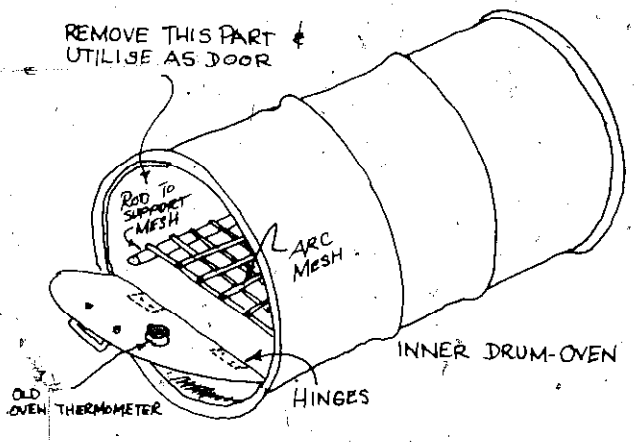

STOVE

Smokeless cooker shown at Vudal Appropriate Technology Workshop, October, 1976. It is made of clay, and has a bamboo chimney. The clay should be allowed to dry out slowly and evenly, if possible, to avoid cracks. A metal chimney would be safer.

A similar plan is found in VITA Village Technology Handbook, p. 335. (p 250)

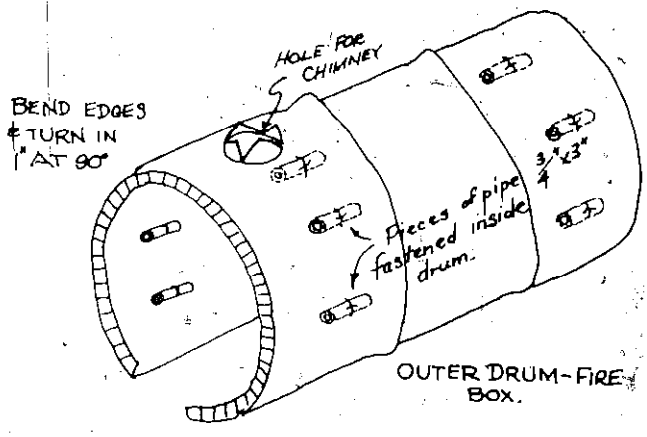

BREAD OVEN

FROM BALIMO VOCATIONAL CENTRE

Materials List:

- 1 good quality 200 litre drum (no holes)
- 1 old 200 litre drum
- 2 pieces flat iron (for door and tray of oven)
- scrap pieces corrugated iron for fire box
- 10 pieces 3/4" water pipe 3" long.
- short pieces fencing wire to tie them
- 2 1" hinges for oven door.
- 2 pieces 4" diameter chimney pipe.
- 1 piece of fibro cement, for front of oven door.
- 1 thermometer from old stove (optional).

How to Make the Oven:

1. Take the good drum and cut the top for the door.
2. Rivet two rails inside this drum, for the tray to slide on.
3. Take the old drum and cut all of the top and bottom out of it. Cut it from top to bottom. Mark every 1" around the top and bottom. Use your hacksaw and cut in 1" at every mark. Now bend all these edges in at right angles. Make small holes in this drum to put wire through, to hold the 10 pieces of 3/4" pipe. These small pieces are to hold this outside drum from touching the inside drum. Cut a hole to fit the chimney into.

See Bread Recipes p114-118.

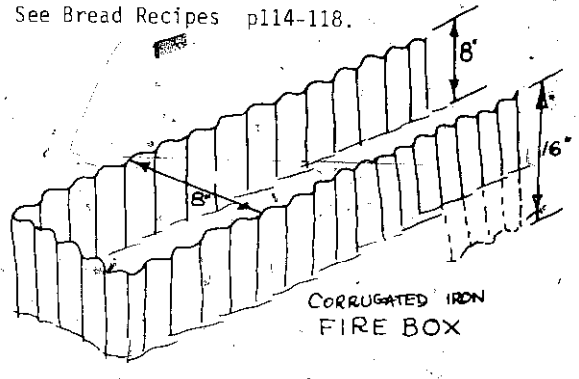

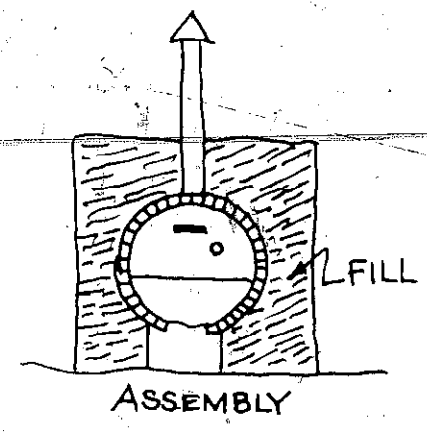

4. Make the oven door from a sheet of flat iron. If you have some fibro, bolt it on the outside of this door. Put a thermometer from an old stove in the door. Make a handle for the door.
5. Push the good drum inside the old drum.
6. Now make the fire-box. It will need to be about 8" high, and about 5 feet long. One end will be closed. The top and one end must be left open until you set the oven on it. After you put the oven on the fire-box, then cover the remaining openings of the fire-box with pieces of corrugated iron.
7. Put the chimney into the hole cut in the old drum, and hold it straight up with some timber. Cut the bottom of the chimney and bend out some tags, before you put it in the hole. These tags will stop the chimney from going inside too far.
8. Build a box around the oven. Fill the box with dirt. Now you will only see the oven door at the front of the box, a hole for making the fire at the back, and a chimney coming out the top.

Submitted by Case Hemmes, Box 2148, Konedobu.

A similar design, but covered with rocks and cement.

MEAT COOLER

Where there are cold running streams, people can use them for refrigerating meat for extended periods of time. The method is time consuming for small amounts of meat, but is suitable for storing large amounts.

Choose a small stream that runs continuously, but is capable of being dammed or temporarily diverted. In the centre of the stream bed below the dam, dig a hole about 0.6m deep. The hole is lined on the sides and bottom with 10cm of clay to seal it. Then line the clay with several layers of banana leaves (or a sheet of plastic). Wrap the cut meat in banana leaves or plastic bags and lay this in the hole in a single layer. Then cover the packaged meat with banana leaves or plastic, and a 10cm layer of clay before putting back the gravel from the river bed. Place a few large rocks on top of the "refrigerator" so the water will not wash it away, and then let the stream run again. It is only necessary to dam the stream again for a short time to get the meat back again.

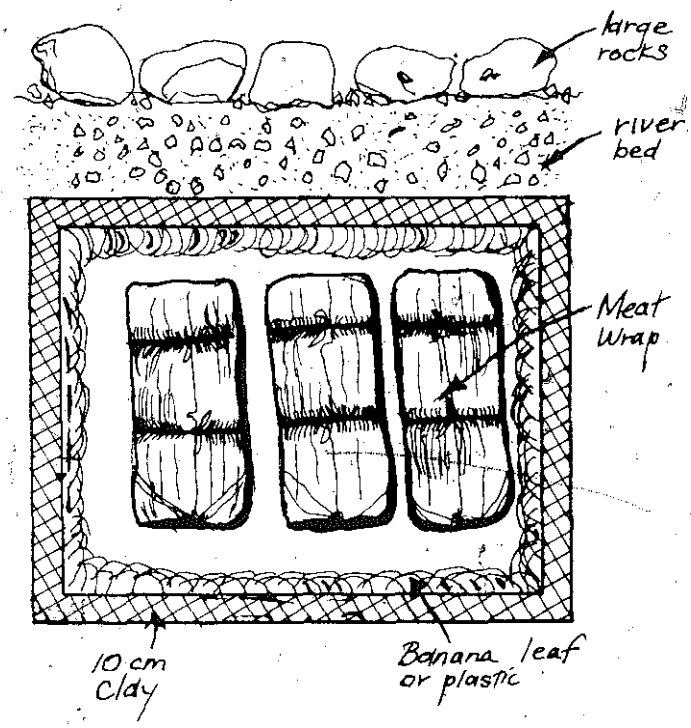

This method is used by people near Waghu, WHP.

Initial contributor: M.W. Mare, Vudal, P.O. Kerevat.

KNOWLEDGE IS OF TWO KINDS. WE KNOW A SUBJECT OURSELVES, OR WE KNOW WHERE WE CAN FIND INFORMATION UPON IT.

Samuel Johnson

Building and Road Construction

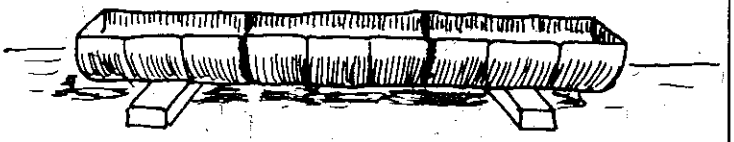

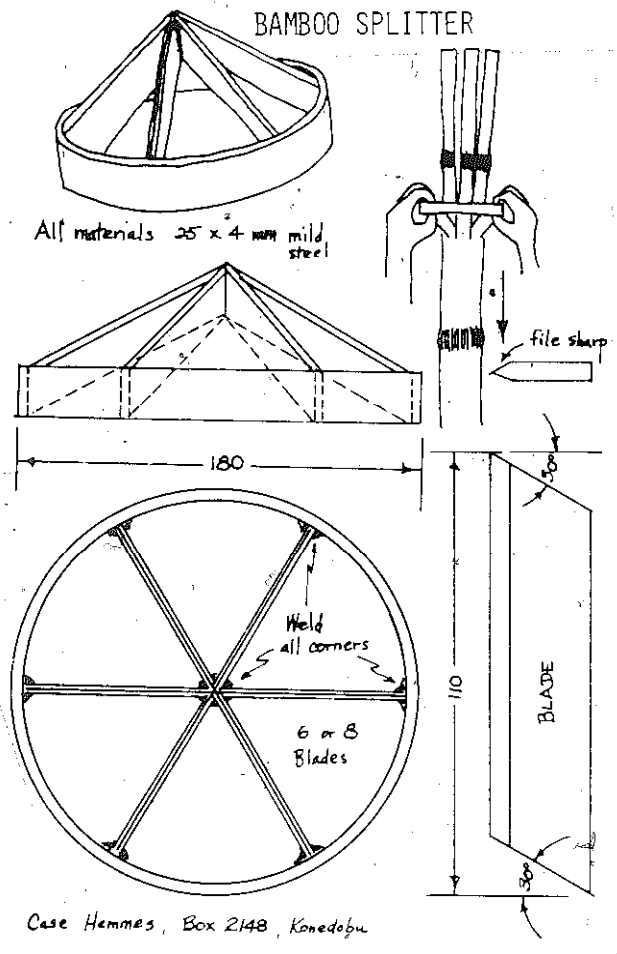

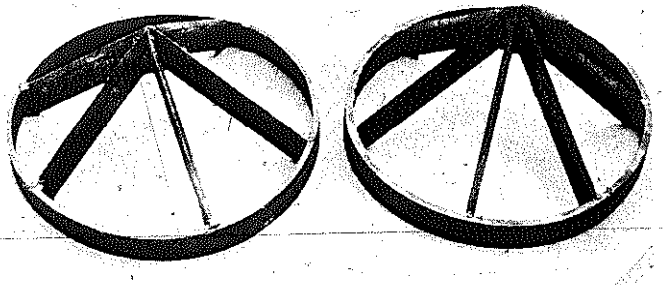

DON'T YOU THINK YOU COULD SHARE YOUR KNOWLEDGE WITH SOMEONE ELSE? SHARE IT IN THE LIKLIK BUK, THIRD EDITION. DO IT BEFORE 15 AUGUST 1977. DO IT NOW, BEFORE YOU FORGET YOU KNOW IT, MAIL IT TO BOX 1920, LAE.

WOOD PRESERVATION

This long tank made of 3 half drums welded together makes a good container for treating your wood building materials.

POLE BUILDING CONSTRUCTION

(P 126)

No one building material is the ultimate answer for building problems in P.N.G. Each material has its advantages and disadvantages.

If sawn timber is available at reasonable prices, it has many advantages over poles.

However, in many places poles are readily available, and sawn timber is not. In such a case it should be seen that functional, durable, attractive buildings can be made using poles.

Even though pole construction is the ages-old technique throughout P.N.G., strong prejudices have developed in favour of "European" designs and imported materials, and against the use of bush materials. We need to point out continuously that locally available materials have major advantages, and that proven, scientifically determined ways exist for using them.

See "Manual of Rural Wood Preservation", and "Pole Buildings in P.N.G.", both from Forest Products Research Centre, P.O. Box 1358, Boroko. (P 50)

BUILDING MATERIALS AND DESIGNS

The Local Government Architect, Box 1108, Boroko will send you the Technical Information Handbook that they wrote. In many ways it is like the Liklik Buk, except that it is free. Each Council should request one, and it is available to others who write. It is a collection of plans for housing and engineering projects for rural areas. Each page gives the description of a plan that you can order from the office that drew it. Lots of pictures, material lists and references to other publications. A good example of interdepartmental cooperation, especially with the Forestry. English.

FERRO-CEMENT

Ferro-cement as a building material is not new. It was invented before conventional reinforced concrete, and is a descendant of the family of construction materials which includes straw and mud bricks, wattle and daub, bamboo and clay.

It has its widest application in thin walled shell structures such as boats, barges, roofs, grain bins. It consists of sand and cement mortar densely reinforced by fine wire mesh, and is a high performance, high strength material.

One of its main attractions is its forgiving nature- it can be made up by unskilled workers, and survives poor workmanship. It is uniquely suited to the tropics, where rust, decay and insect damage are serious problems.

An excellent 90 page booklet, "Ferro-cement: Applications in Developing Countries" may be obtained free of charge from:

Board on Science and Technology for
International Development
Office of the Foreign Secretary,
National Academy of Sciences
1201 Constitution Avenue
Washington D.C. 20418 U.S.A.

RUBBISH GLASS IN CONCRETE

Empty non-returnable bottles are excellent building materials. Glass is very strong material and can be used for floors and walls, to save on the expense of cement.

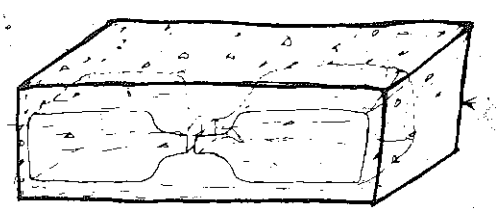

1. In building solid concrete blocks, two empty bottles in the centre of the block will save 15% in materials.

(p 124)

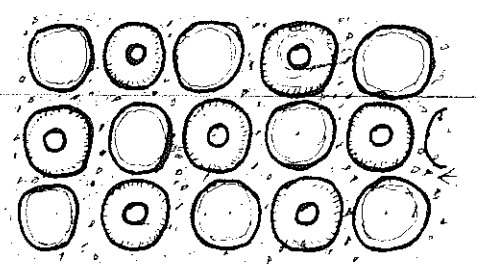

2. A permanent wall can be made of bottles using mortar between each bottle.

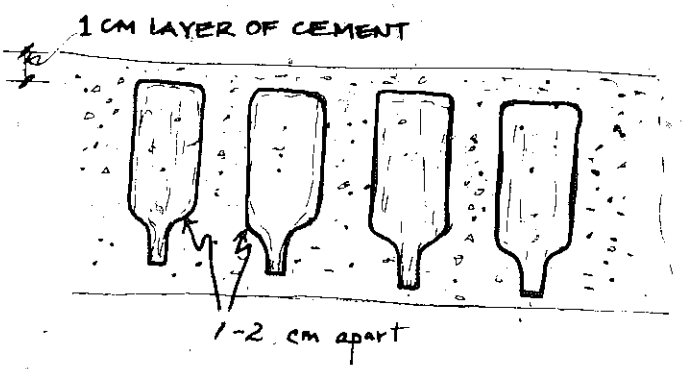

3. In pouring a concrete floor, you can place bottles neck down with a 1-2 cm space between each bottle and 1cm layer of cement on the top.

Suggested by I.M. Bean, DPI., Pindiu, MP.

USE OF OLD TYRES AS ROOFING

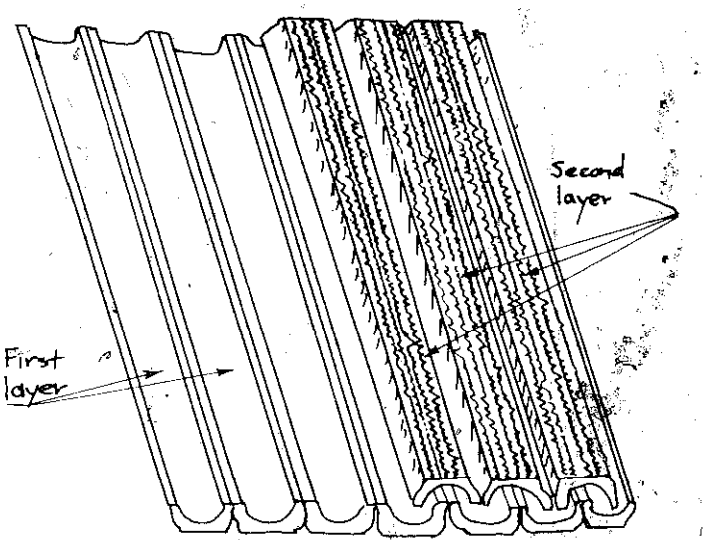

Reference: Australasian Post, May 1976
Suggested by C. Hemmes, Box 2148, Konedobu

Shelter, edited by LLoyd Kahn, Random House, 1973 176pp. US$6.00 from Random House Inc., Wesminster, Maryland 21157, USA.

A beautiful, fun book with hundreds of pictures and much text about simple homes, natural materials, and human resourcefulness. The book is concerned about discovery, hardwork, the joys of self-sufficiency, and freedom. It is about Shelter, which is more than a roof overhead.

5. Check the slopes and levels on formation along ditch to make sure that water can run

6. Lay the topsoil on the ditch slopes to encourage grass to grow again.

NOW MAINTAIN IT - keep drains clear - fill in holes - maintain slopes.

Suggested by C. Hemmes, Box 2148, Konedobu

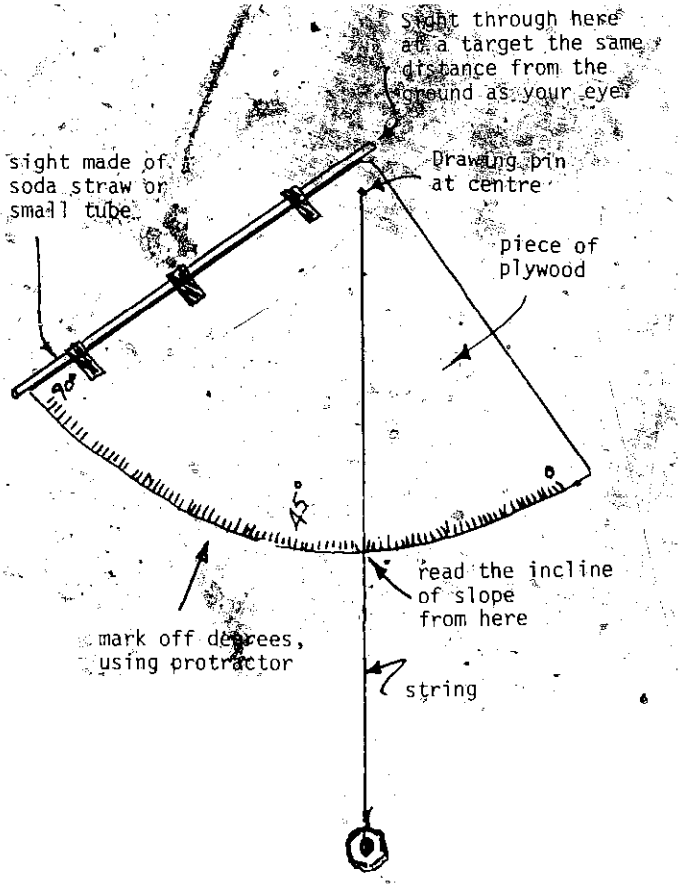

INCLINOMETER

A simple inclinometer can be most useful in making approximate measurements in difficult situations when more precise instruments are not available.

Determine: slopes of hills for classifying land
road grades
heights of trees
widths of rivers
falls for water systems
contours for terracing or planting

To find the approximate elevation of a place above a pump site when you have no surveying instrument:

1. Measure the distance along the slope.
2. Measure the incline or slope of the hill using the home-made inclinometer.

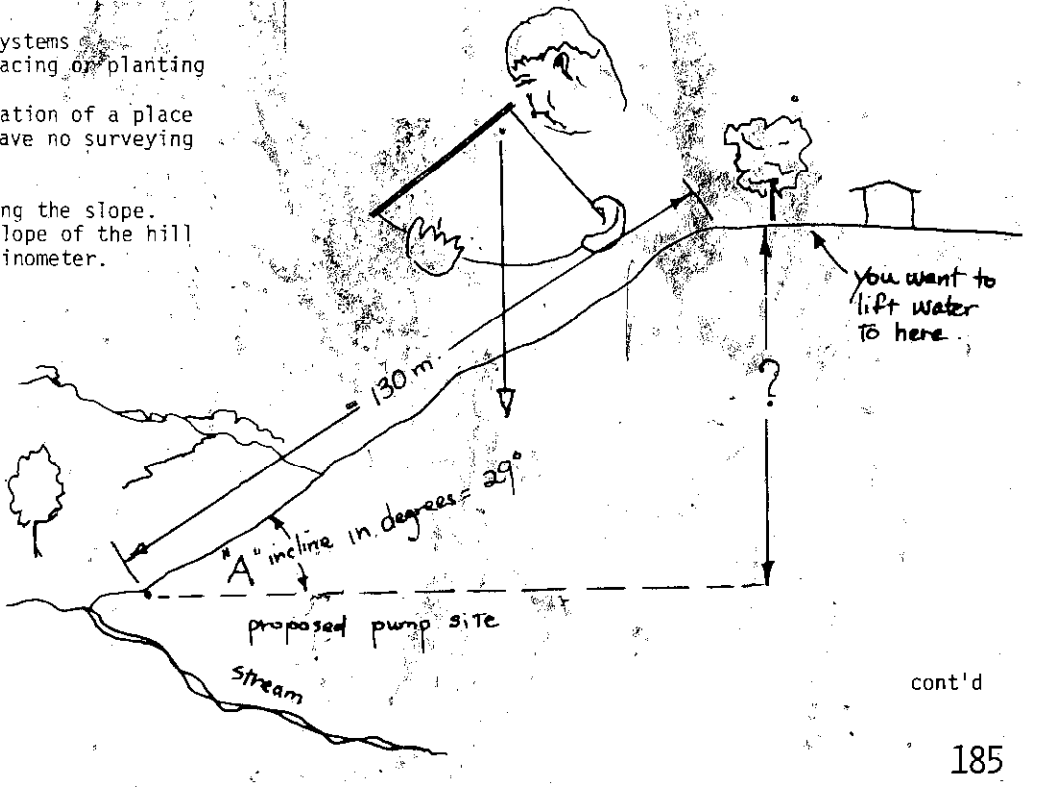

cont'd

3. Compute the height, using a table "Natural Values of Trigonometric Functions". From trigonometry we have the following formula:

$$\text{The Sin of any angle "A"} = \frac{\text{opposite (perpendicular)}}{\text{hypotenuse (distance)}}$$

$$\text{Sin } 29^{o} = \frac{?}{130 \text{ m}}$$

In the table at the back of a math book we find that the Sin of 29° = .4848.

$$.4848 = \frac{?}{130 \text{ m}}$$

$$\text{or } ? = .4848 \times 130$$

$$= 63.02 \text{ m}$$

4. If the hill is irregular, do it in two or more stages.

Suggested by F. Keating, Goroka.

NOTE: degrees slope and percent slope are not the same. 10 percent slope means 10 metres rise in 100 metres. If you don't know Trigonometry, plot your case on a piece of paper with a ruler and protractor.
Or, a rough guide:
Angle in degrees = % slope X.6

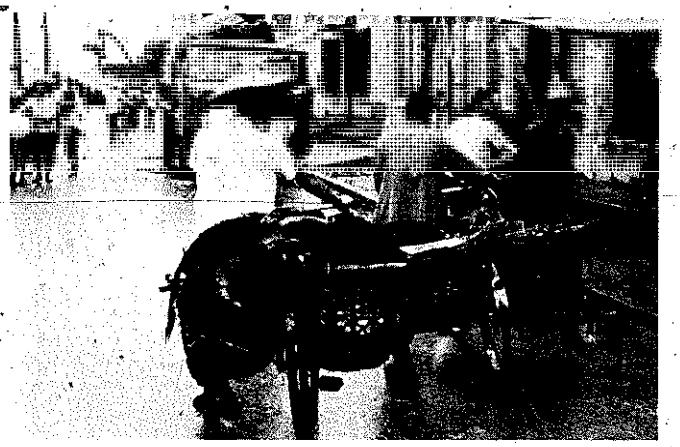

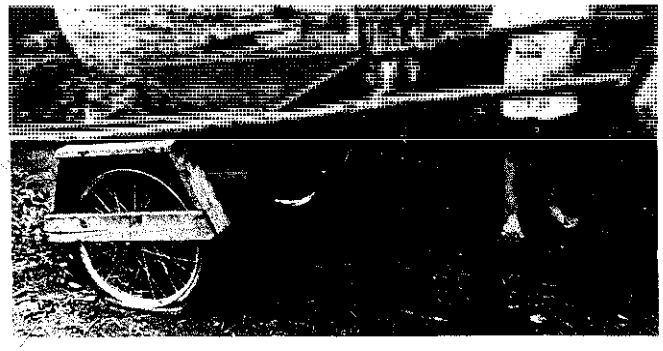

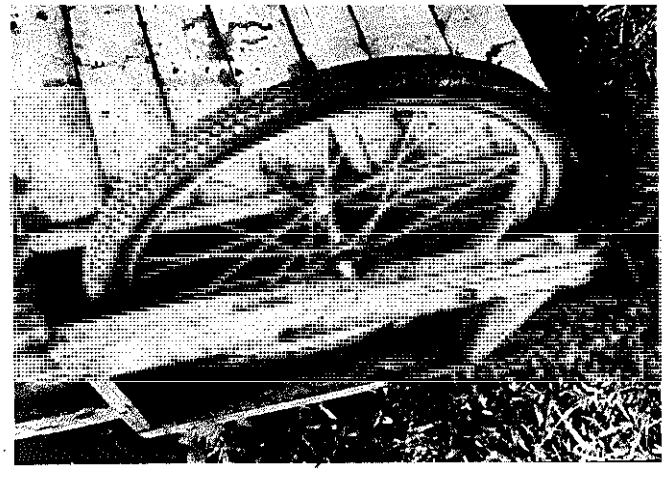

TRANSPORT

BICYCLES

"TECHNOLOGY OF BICYCLES" S.S. Wilson, SCIENTIFIC AMERICAN, March 1973 - A good discussion on the mechanics and efficiencies of bicycles.

BICYCLE TRANSPORTATION, N. Dougherty and W. Lawrence, Environmental Protection Agency, 1974 (US Govt Printing Office. Washington DC 20402 USA. US$0.94)

Bicycles and Bicyle parts supplier:

Mr. Y.S. Pai
Cycle Division
Ace Cycle Itl. Inc.
P.O. Box 117
Taipei, Taiwan

Messers. Feliz Corporation
P.O. Box 68 - 382
Taipei
Taiwan

A MOTORIZED CANOE

We have had several requests for information on how to put a small gasoline engine in a canoe. This is basically how small fishermen in the Philippines do it - a simple, economical, time-tested and refined design. There are probably good PNG ways to make such a canoe, using techniques already found here.

This canoe is used for fishing, for transporting people, and for light hauling. It is more manoeuvrable than an outboard motor, is relatively fast, and it handles well in heavy seas. The engine can easily be removed for other uses or for safe keeping.

A key part of the design is how the shaft goes through the dugout bottom. The 16mm (5/8") shaft

(cont'd on p 189)

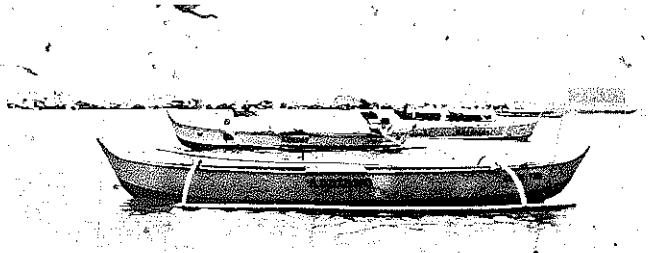

1. The engine is mounted roughly in the centre.

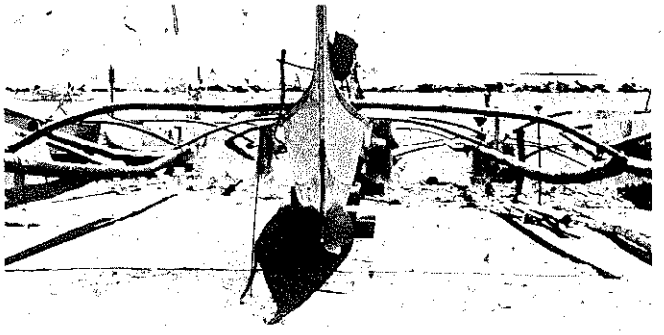

2. The distance between the outriggers is about 3/4 the length of the canoe. 2 or 3 arms may be used. The bamboo is bent permanently over a fire.

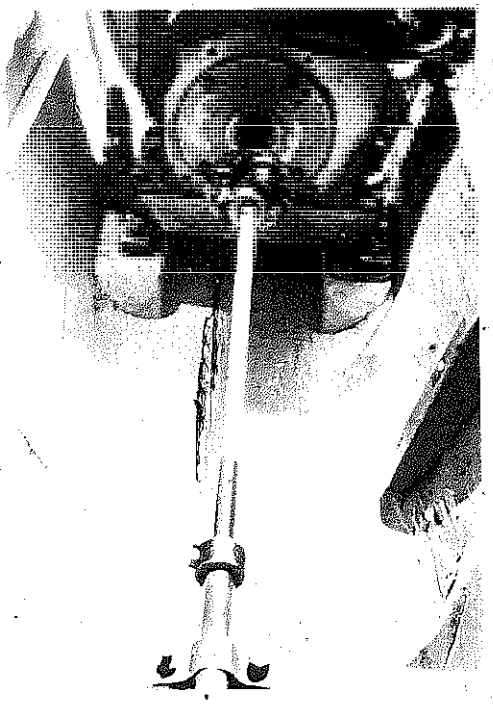

3. The shaft is connected to the engine with a flexible joint.* The Engine shaft is aligned with the propeller shaft. Note at bottom of photo where shaft enters tube. The round collar with set screw is not really needed, except to keep the shaft from sliding downwards when the engine is removed.

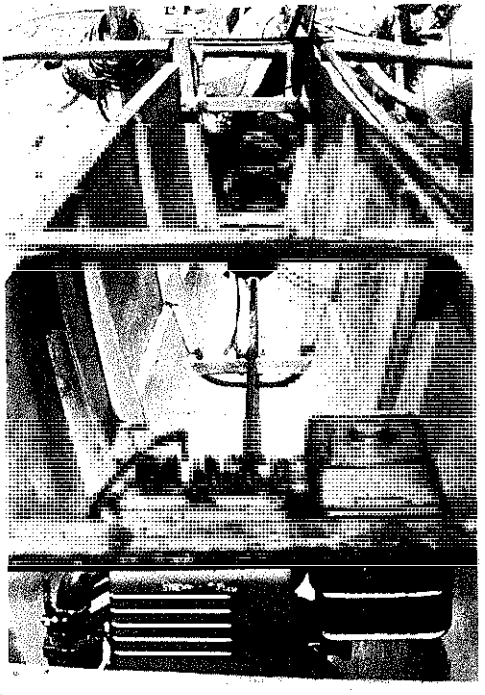

4. Looking aft from engine. Note how the marine plywood sides are attached to the dugout hull.

5. Outside view from the rear of the canoe.

*See flexible joint in figure 7, made with pieces of pipe, flat bar, tyre sidewall, and small bolts.

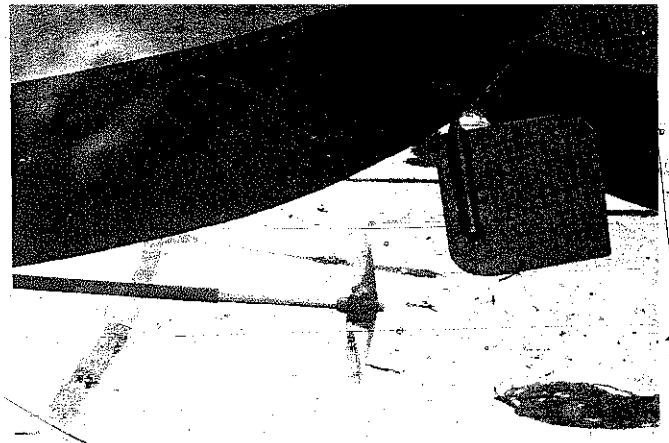

6. Side view of propeller and rudder. The rudder can be made of brass, but many simply weld them out of steel and keep them painted. The rudder shaft also goes through a tube.

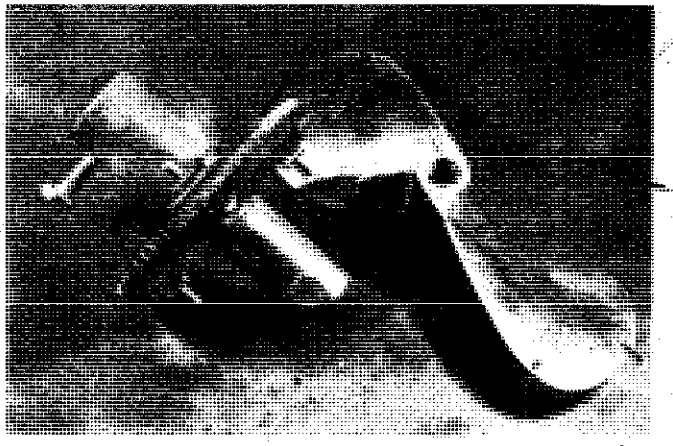

7. These parts you will not find in PNG hardware stores. If you are really clever, you can make both of these, but you may want to buy your first set ...

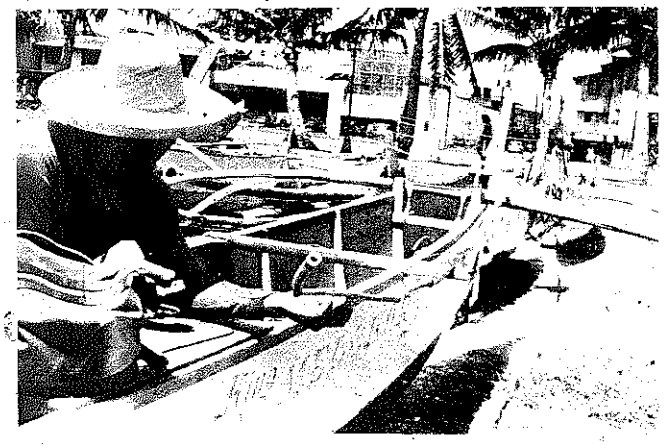

8. The rudder is controlled with a bamboo stick.

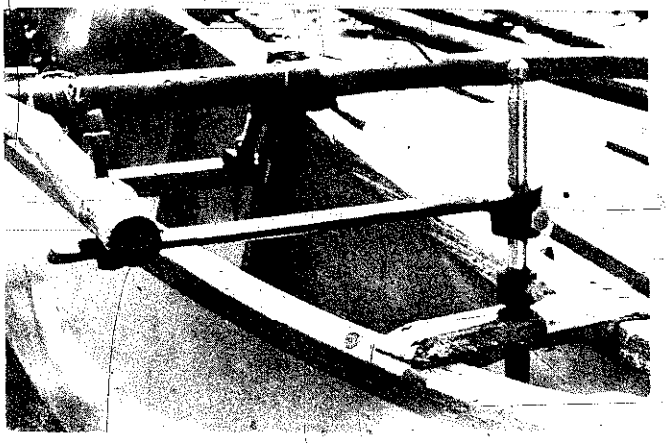

9. This rudder assembly is very fancy. A much simpler one will do.

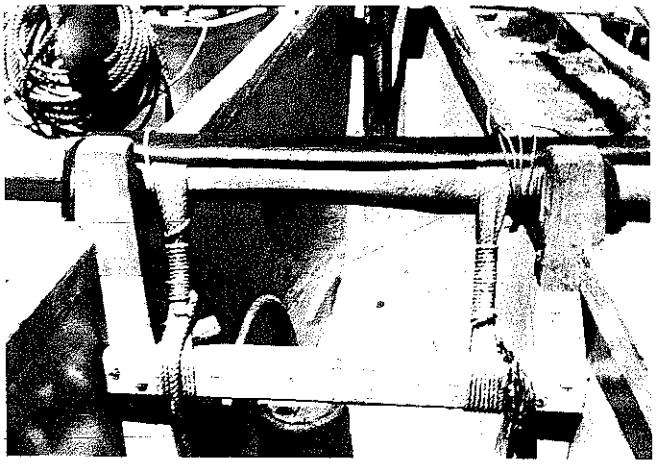

10. The outrigger arms are attached with nylon ropes. Often a narrow platform is attached on top of the outrigger arms at either side of hull. In such a case three arms are used.

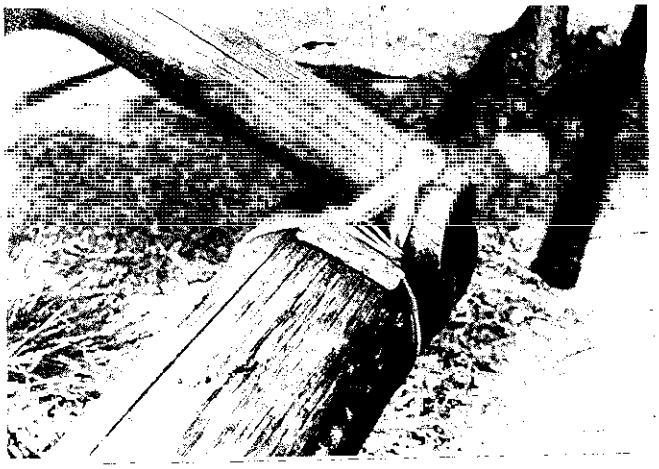

11. The bamboo runners are attached to the arms with heavy nylon fishing line. Note brass nail in top of bamboo arm and piece of old slipper between two bamboos. A thick-walled durable kind of bamboo is used.

cont'd

(which must be stainless steel or brass) goes through a 19 mm (3/4") galvanized steel water pipe (or brass pipe) which is sealed into the wood. The long tube is packed with heavy grease, and serves as both bearing and water seal. Even if the water rises in the tube it seldom leaks into the hull because the tube comes up close to the engine, higher than the water line when the boat is unloaded. The hull should be curved enough so that the propeller won't hit bottom.

Typical specifications:

Length of hull:	7 metres
Size of engine:	8-12 hp.
Size of shaft:	16 mm (5/8")
Size of propeller:	8" (20cm)

Where do you get the parts?

Make your own from locally available hardware. Two parts you will not find, and these are available one per customer from LIKLIK BUK, the propeller for K4.00, and the flexible joint for K3.00. Or order from Seaside Trading, 117 Union Civica St., Galas, Quezon City, Philippines.

Plywood work boats being built by the Technical Department, United Church, Salamo, MBP.

PROPELLING FERRIE

To change the direction move the tow cable to the other end of the horse:

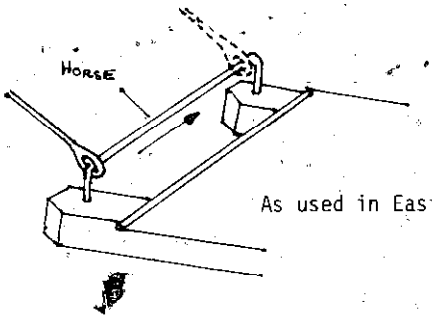

As used in East New Britain

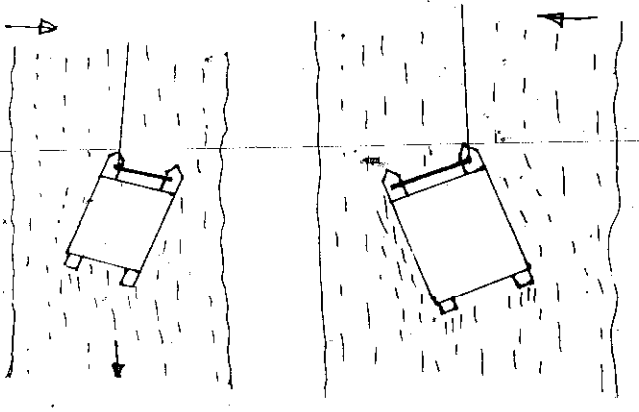

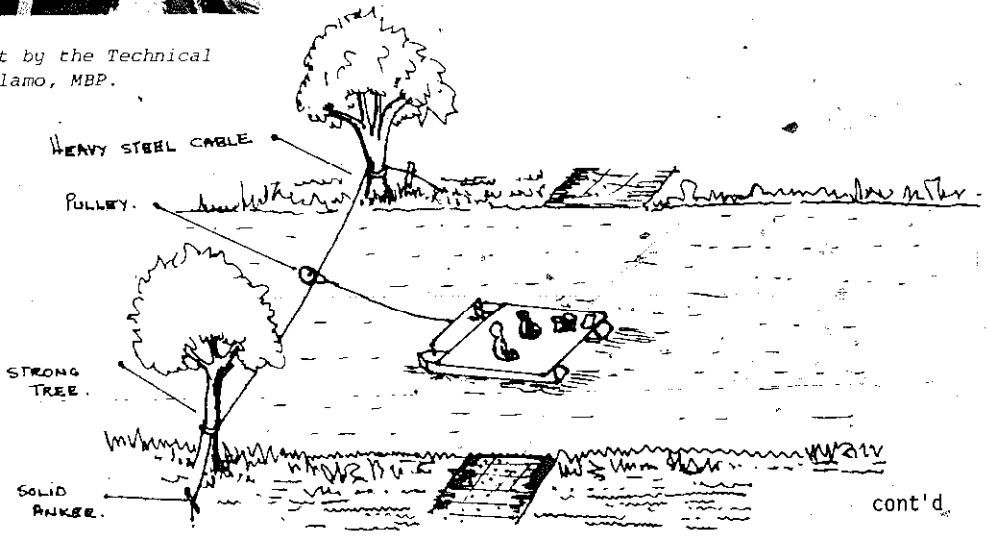

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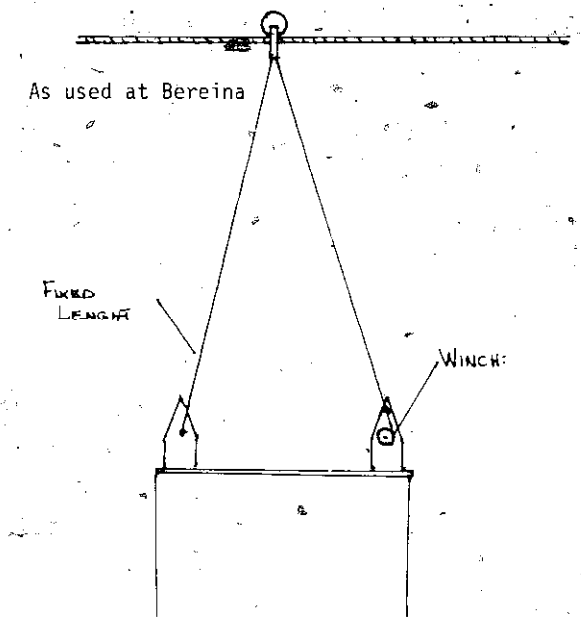

An alternative design: Use two tow cables, one with a fixed length, and one with a winch. To change direction or speed of travel, shorten or lengthen the second tow cable by using the winch.

Suggested by C. Hemmes, Box 2148, Konedobu

OUTBOARD MOTORS p 262

Village Industry Arts and Crafts

CLOTHING

We included a few items on clothing in the 1976 edition with the advice that more patterns and ideas could be obtained from the Lae YWCA. They have had so many letters that they are not able to cope with them!

So we have expanded this section - don't write to the Lae YWCA.

We have drawn on two major sources: "Sewing Children's Clothes", a kit from FAO United Nations; and patterns of the Lae Vocational Centre for Girls.

The FAO item "Sewing Children's Clothes" is a very popular kit which includes cards giving instructions for clothes and other useful items, life-size plastic patterns, and a basic sewing course guide. It has been especially designed by a Home Economics expert for women with no experience in cutting or sewing. Though it was developed in Africa, it is quite suitable for PNG. Each kit costs US$5.00. You may order by sending the equivalent amount in Kina (approx. K3.85) to the United Nations Information Centre, Box 472, Port Moresby, and they will get it for you.

SAMPLE SEWING LESSONS FOR UNSKILLED ADULTS

1. THE MATERIAL

Threads of the material run in two directions:

a) The WARP or LENGTH. The threads forming the warp are the first to be set up on the loom and are all parallel.
b) The WEFT or WIDTH. This is woven from a continuous thread running to and fro across the warp, under and over the warp threads. It makes a firm edge on either side, called the selvage.

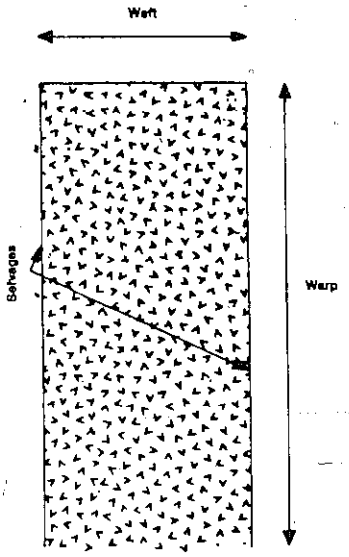

Fabrics come in different widths. Most of them are 80, 90, 100, 130 or 140cm wide (37, 36, 39 or 55").

The warp and the weft run at right angles.

cont'd

They are the two STRAIGHT ways of the fabric. If you hold up a piece of material, gripping it between the thumb and forefinger of each hand, and pull it lightly, you find that:
- in the direction of the WARP the fabric will not stretch;
- in the direction of the WEFT it will stretch slightly;
- in the other direction, ON THE BIAS, it will stretch quite readily.

2. PATTERNS AND CUTTING

Where a seamless part of a garment is to be cut out (eg the front of the child's dress), the edge of the pattern is placed along the fold of the material.

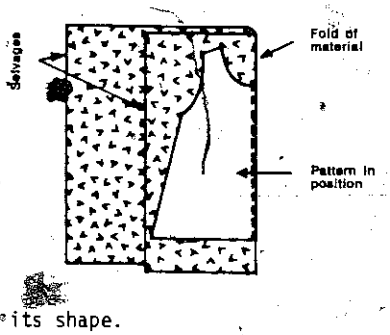

The material must be folded absolutely straight and preferably lengthwise to ensure that the garment does not lose its shape.

The edge of the pattern to be placed along the fold is marked with a dotted line.

Cutting should be done on a large table, so that the material can be spread out flat. Pin the pattern to the folded material, making sure that the material stays flat. Cut along the very edge of the pattern. Seams and hems are included in each pattern piece.

Avoid wasting material in cutting: leave no waste spaces between the pattern pieces and, before you start, arrange the pieces on the material to make sure you make the most of it. This is particularly important if you are using the pattern to cut a batch of garments out of one piece of material.

3. NEEDLE AND THREAD.

A working length of thread should not be longer than about 50cm (18"). Learners often tend to make the working length too long.
The first stitch is secured by a knot. The knot should be small, placed on the very end of the thread and tucked into the seam so that it does not show. The last stitch is fastened by making two small stitches one over the other.
Stitching is always done on the wrong side of the material.

4. TACKING.

Tacking is done in large running stitches to hold the work together temporarily until the permanent stitching is completed.

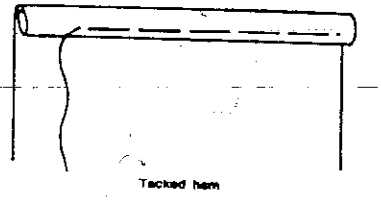

Tacking stitches should be 3mm long. at intervals of about 1 - 1.5cm. This will hold the seam firmly together.

5. HEMMING.

The first, narrow turn-in is marked with the finger-nail. Then the second turn-in is tacked and stitched. Hemming should be done with small, oblique stitches, which should hardly show on the right side of the material.

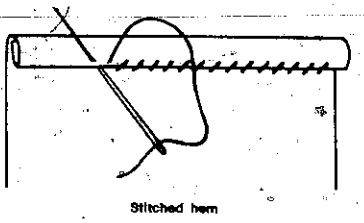

6. RUNNING STITCH.

The stitches and the spaces between them are of equal length.

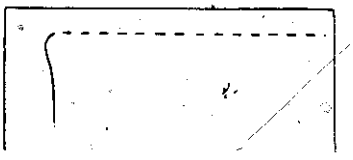

7. BACK STITCH.

This is similar to running stitch, except that at each stitch the needle is put back in the last hole of the previous stitch and brought out twice the distance beyond.

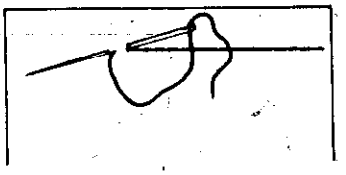

The stitches are end to end, forming a continuous line.
Back stitching is used instead of running stitch where a strong seam is required and also as ornamental stitching on the right side of a garment.

8. OVERCASTING.

This is used to hold the raw edges of any material that may fray.

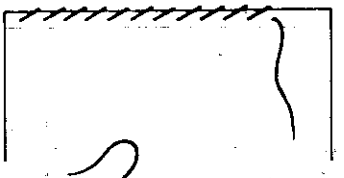

9. WHIP STITCH.

This is used to join two selvages or two turned-in edges. Use small stitches, holding the two pieces of material edge to edge

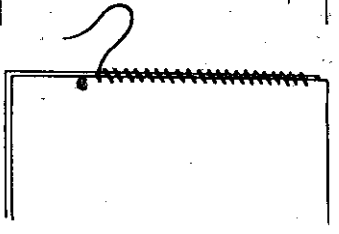

10. OVERCAST FLAT SEAM

This is the easiest seam for joining two pieces. The pieces are held edge to edge and joined with running stitch. Each of the raw edges is then overcast, and the edges are opened out and flattened down with the finger-nail. Alternatively, the raw edges may be overcast together.

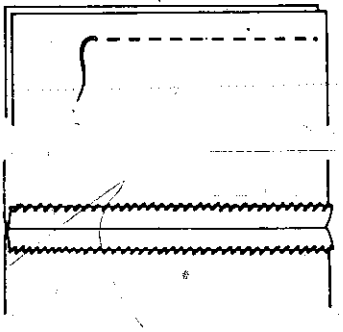

11. FELL SEAM

A fell seam is worked in two stages:

a) Use running stitch to join the two pieces of material, which should be so placed that the edge of the piece underneath shows by 0.5 cm.

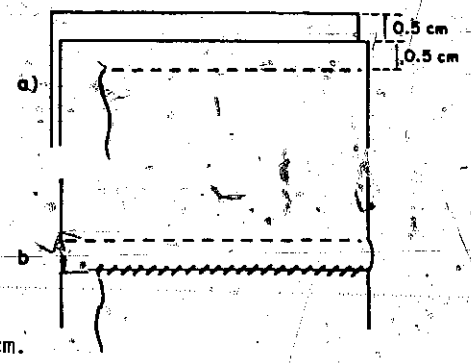

b) Smooth down the seam. Then turn in the wider edge and stitch it down like a hem over the other.

12. STEM STITCH

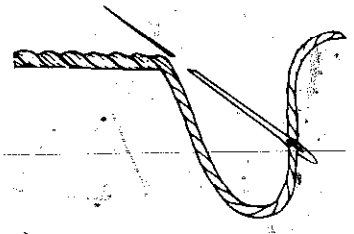

13. HERRINGBONE STITCH.

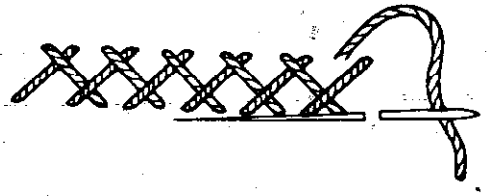

14. SCALLOP STITCH.

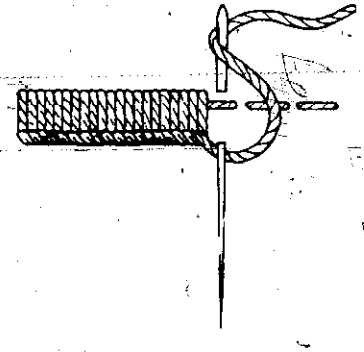

15. BUTTON LOOPS

a) On the edge of the hem, make a few long stitches, loose enough to form a loop as wide as the button.

b) Cover the loop with closely placed scallop stitches (or better still, buttonhole stitch).

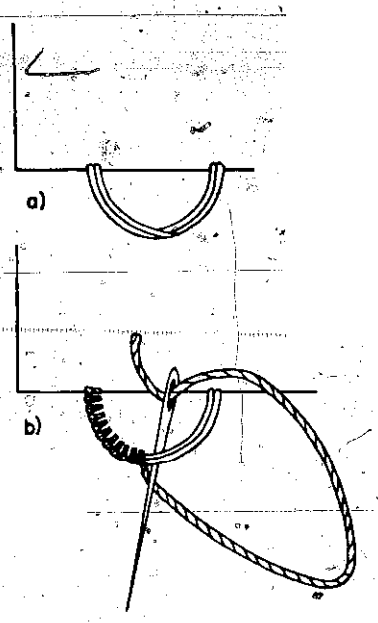

16. BUTTONHOLES

a) Working carefully on the straight, cut a slit as long as the button is wide.

b) Work the edges of the slit with buttonhole stitch.

c) Secure the ends of the buttonhole by worked bars.

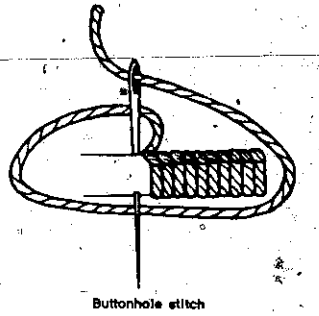

Buttonhole stitch

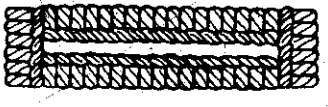

Finished buttonhole

17. SEWING ON A BUTTON.

a) Secure the thread with a knot and make one stitch where the button is to be.

b) Pass the thread 4 or 5 times through each hole in the button, taking care not to pull it too tight, so that there are 2mm or so (a fraction of an inch) between the button and the material.

c) Wind the thread several times round the threads holding the button, and secure with two stitches on the wrong side.

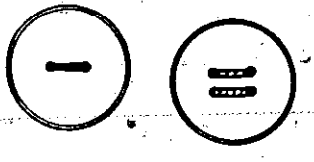

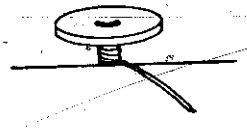

18. POCKETS.

a) Cut out the pocket as shown.

b) Along the top edge, make a 1cm hem. Use either of these two methods:
- hem stitch, on wrong side,
- back stitch, on right side.

c) Tack a 1cm turn-in all the way round.

d) Tack the pocket onto the garment where required, ensuring that it is straight.

e) Stitch on with a row of back stitch 2mm from the edge. Strengthen the corners of the pocket by working a triangle at the top of each side seam.

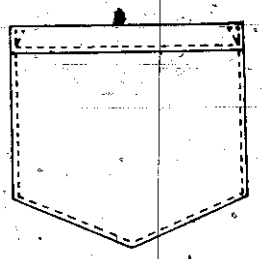

Patch pocket

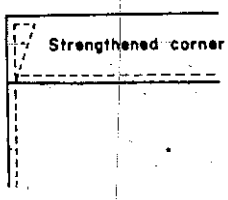

MENDING

Mending sometimes requires special skills such as darning and patching, but most mending needs only those skills which are used in sewing. This is so for mending hems and seams, sewing on buttons and turning worn collars.

The lesson in mending will consist in showing learners how to neatly repair their own clothes and other items they may bring from home.

It may, however, include a piece of practice work in darning to help learners master a skill which is frequently used.

As whip stitch or fell seam patching is difficult for beginners, this kind of mending will be adequately dealt with by showing learners how to set on a hem-stitched patch where required.

DARNING.

Darning is done with so-called "darning cotton" or, failing this, with thread. Either should match the garment in colour and thickness. A darn is made up of parallel rows of running stitches. The stitches in each row correspond to the spaces between the stitches in the previous row. No knot is used at the beginning, and the last stitch is not secured with extra stitches. At the beginning of each row the thread should form a tiny loop so that the darn is not pulled tight.

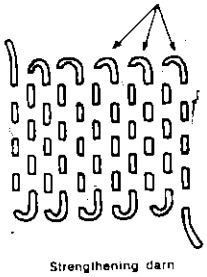

Strengthening darn

STRENGTHENING DARN.

This is a darn made on a part of the garment which has worn thin without wearing through.

DARNING A SPLIT.

Darning stitches are made on the straight, at right angles to the split. A single stitch should never cross both edges of the split. Broken threads on the raw edges of the split are laid along the edges and held down while the work proceeds. The darn begins and ends with a strengthening darn over a centimetre or so at either end of the split. It should cover 1cm on either side of the split.

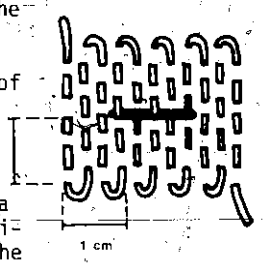

DARNING AN L-SHAPED TEAR.

Each portion of the L is darned in the same way as a split, and the two darns overlap at the angle.

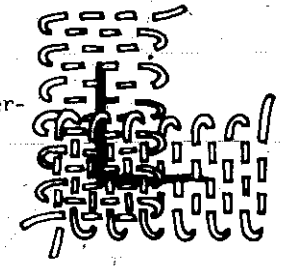

DARNING A HOLE.

The first part of the darn is done so that the hole is covered by parallel threads. The second part is worked at right angles to the first, the needle being passed alternately over and under each of the parallel threads, so that a kind of weave results.

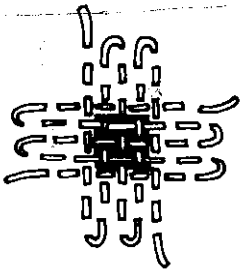

NOTE: To mend a split whose edges are clean or a tear in a little-worn garment, work a simplified darn, passing the needle alternately over and under each of the edges, with a single row of stitches along each edge of the tear.

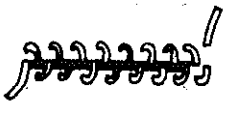

HOW TO PUT A NECK FACING IN A GARMENT

1. Put slightly oversize material in position, the two right sides together. Mark the desired neck opening. If you are putting a slit for the front or for a zipper, allow at least 1 cm between the two lines. Now sew on your mark.

2. Cut out the circle, 1.5 cm inside from stitching. Also cut down centre of slit.

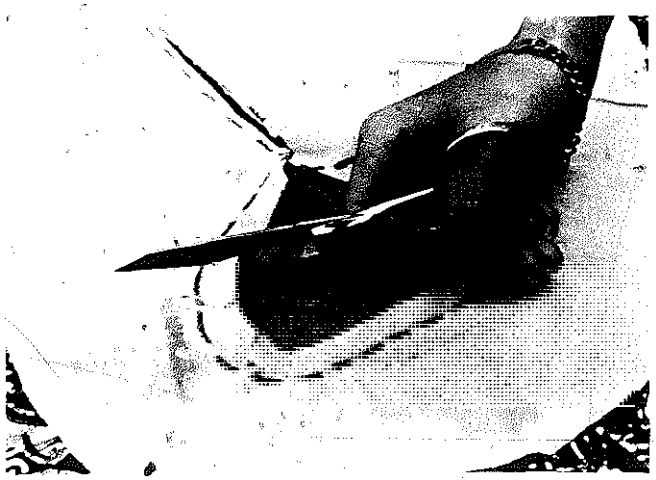

3. Snip around curved areas. Don't get too close to stitching. Trim corners where slit meets circle.

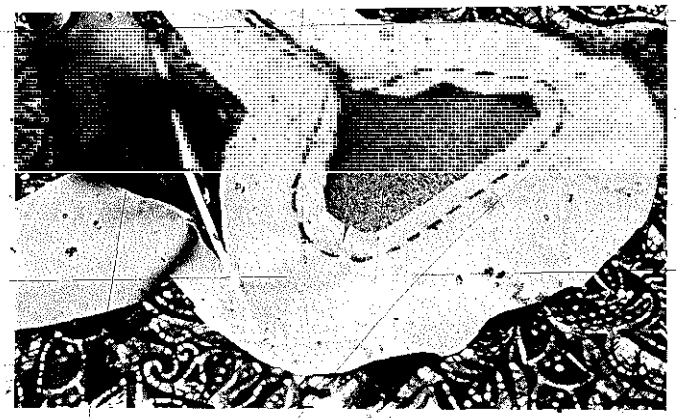

4. Trim excess facing material.

5. Turn facing under, exposing the right side. If you like, hem-stitch the edge of the facing inside.

Suggested by L. Williams, Box 80, Lae

PATTERNS

Girls at the Lae Vocational Training Centre model some of the attractive clothing that they printed and sewed.

From the left: No. 5 is wearing a square neck mini blouse (see pattern p 201); No. 3, a caftan (p 200); No. 4 has a butterfly dress (p 198); and No. 7 has a circle top blouse (p 200). All of the girls are wearing garments printed by silk screen process (p. 144).

PATTERNS FROM THE LAE VOCATIONAL TRAINING CENTRE FOR GIRLS

With special thanks to Colleen Keena

EASY SHIFT (DRESS) PATTERN FOR GIRLS

To Make The Pattern:

1 - 2 The same length. This is the measure
1 - 5 of the third (or middle) finger
1 - 6 of the person you are making the dress for.

2 - 3 This is the measure of the handspan plus the third finger of the person you are making the dress for.

3 - 4 The measure of the handspan
4 - 7 The length of the third finger
1 - 8 The measure of the person from the shoulder to the length required
8 - 9 The measure of a handspan plus the length of a small finger
9 - 10 Half the length of a small finger (about one inch).

Join marks 10 and 5. This is the bottom of the dress.

cont'd

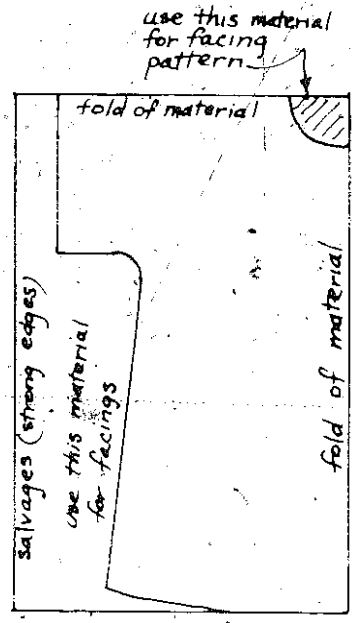

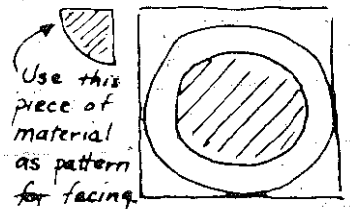

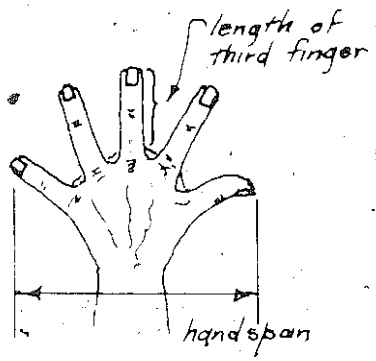

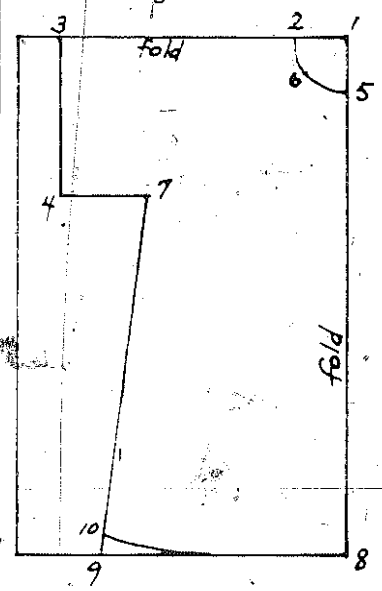

To Sew Dress:

1. Running stitch - edges of dress (4 - 7 - 10) using small stitches, turning under a little bit of material (¼")
2. Slip hem sleeves (4-3-4).
3. Running stitch outside edge of facing, turning material under as you sew.
4. Place facing on dress with right side of facing. Back stitch around neck using very small stitches. Slip hem facing down onto wrong side of dress.
5. Join sides of dresses (4-7). Back stitch - place a piece of material (4" X 1") around curve of side seam. Sew. Clip (short cuts with scissors) curves of side seams.
6. Hem bottom of dress.

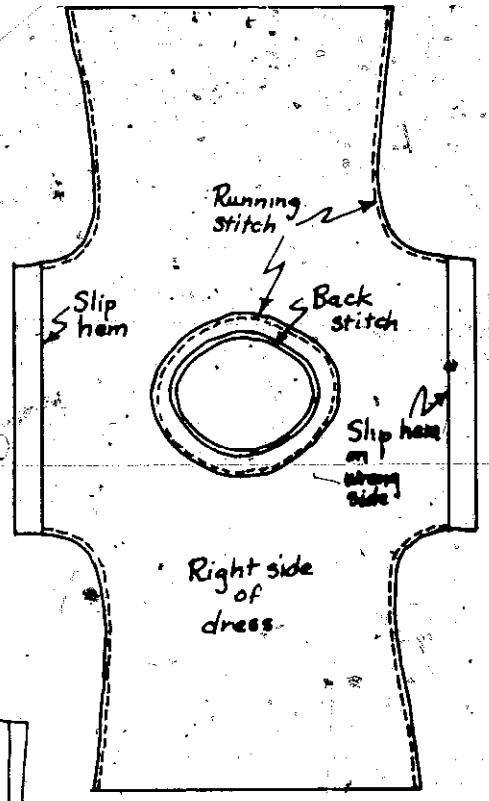

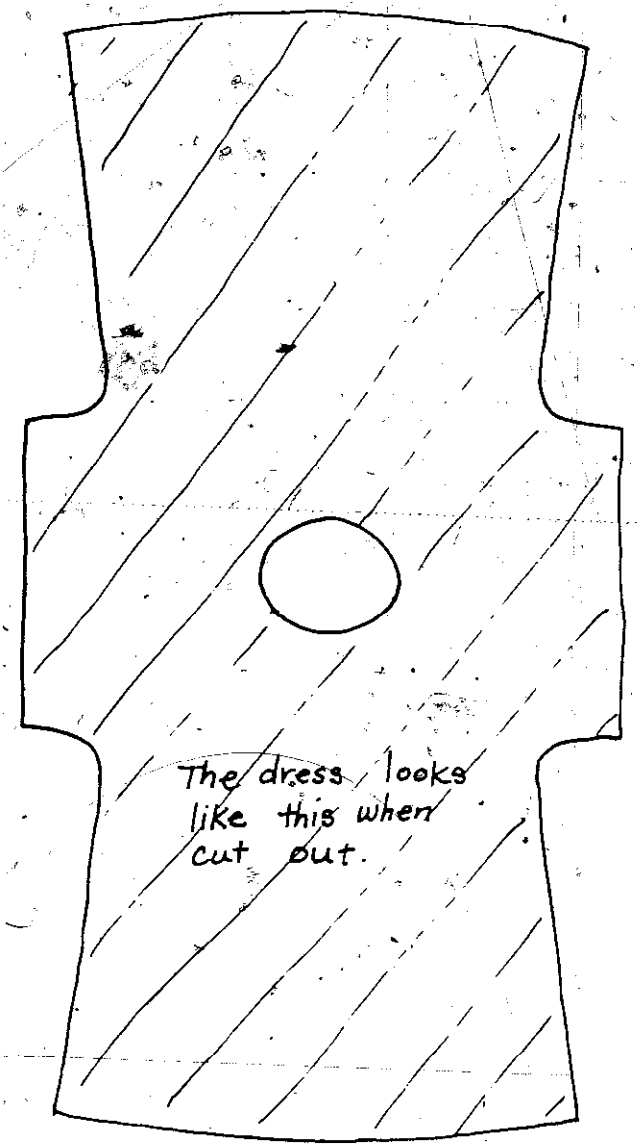

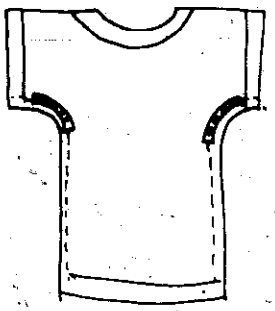

BUTTERFLY DRESS

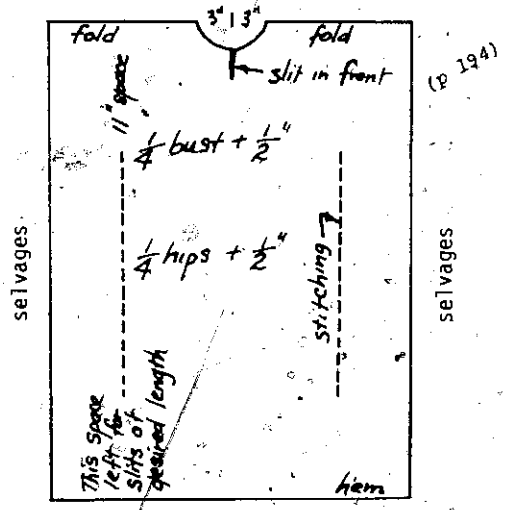

ALL DIMENSIONS IN THIS SECTION ARE IN INCHES

EASY SHIFT

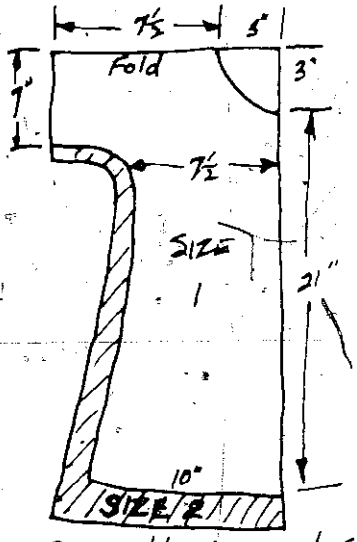

SIZE 2 - add ½" to side seam
1" to hem

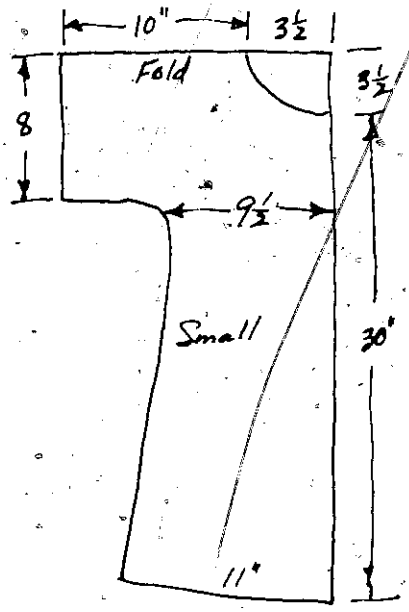

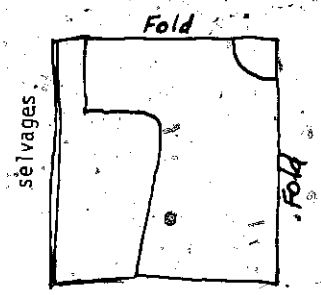

TO PLACE PATTERN ON MATERIAL

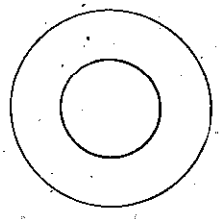

(p 194)

FACING

Complete circle 2½" wide

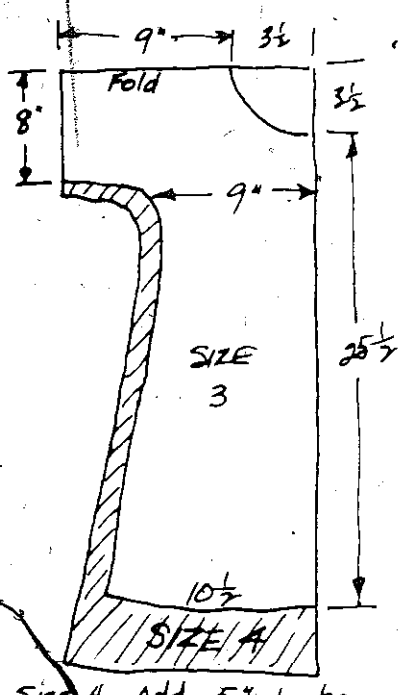

Size 4 Add 5" to hem
1" to side seam

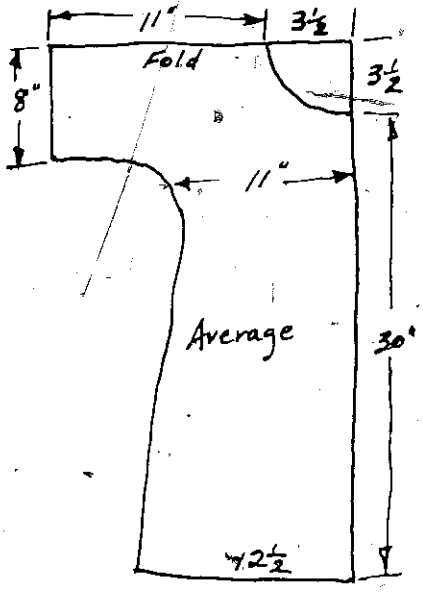

Sewing:
1. Neaten edges of side seams and facings.

2. Sew hems of sleeves.

3. Sew facing on shirt, then turn facing inside. Then on the outside sew a line of stitching ¼" from edge, around the neck.

Alas! Most patterns we have were originally in Imperial measurements. We'd like to change, but we're afraid to make convenient conversions until the metric measurements are tested. Please send us your tested measurements for these (and any other) designs.

ALL DIMENSIONS IN THIS SECTION ARE IN INCHES

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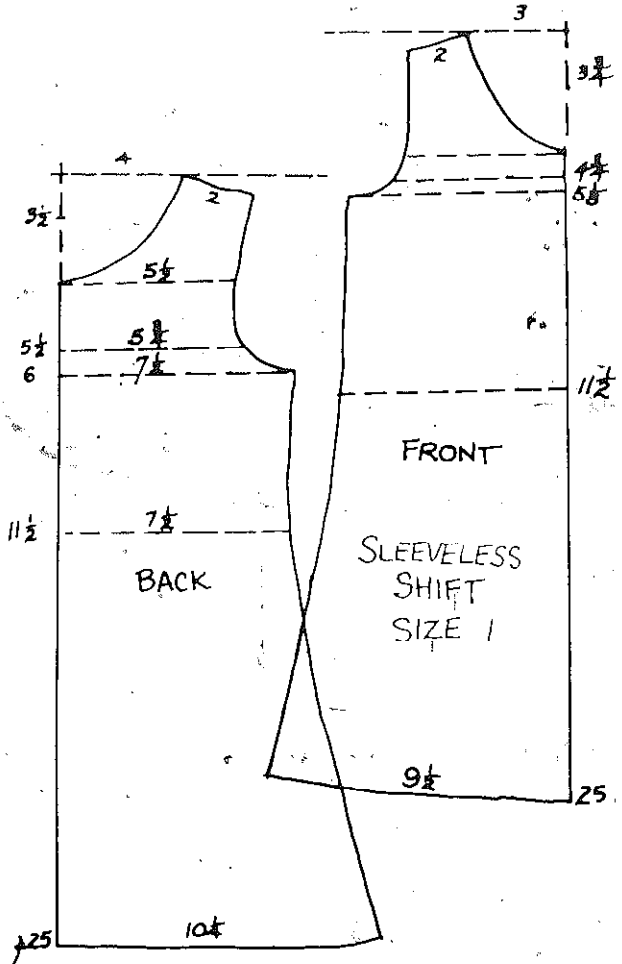

all measurements in this column are from top corner in all shift patterns.

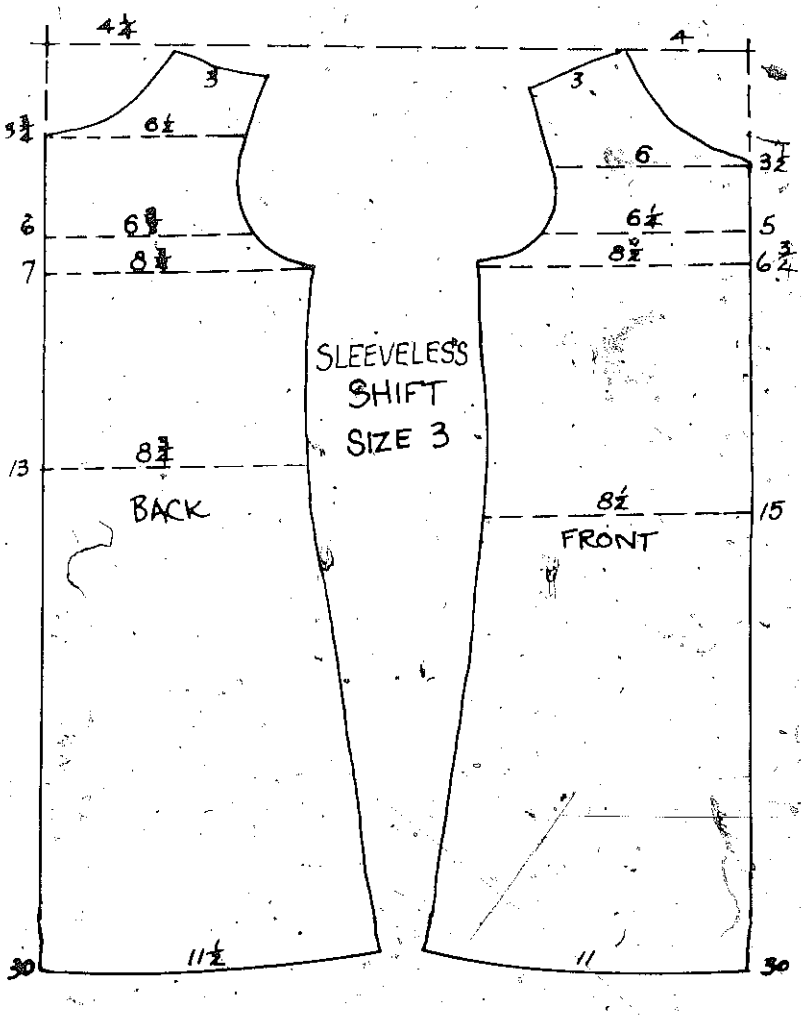

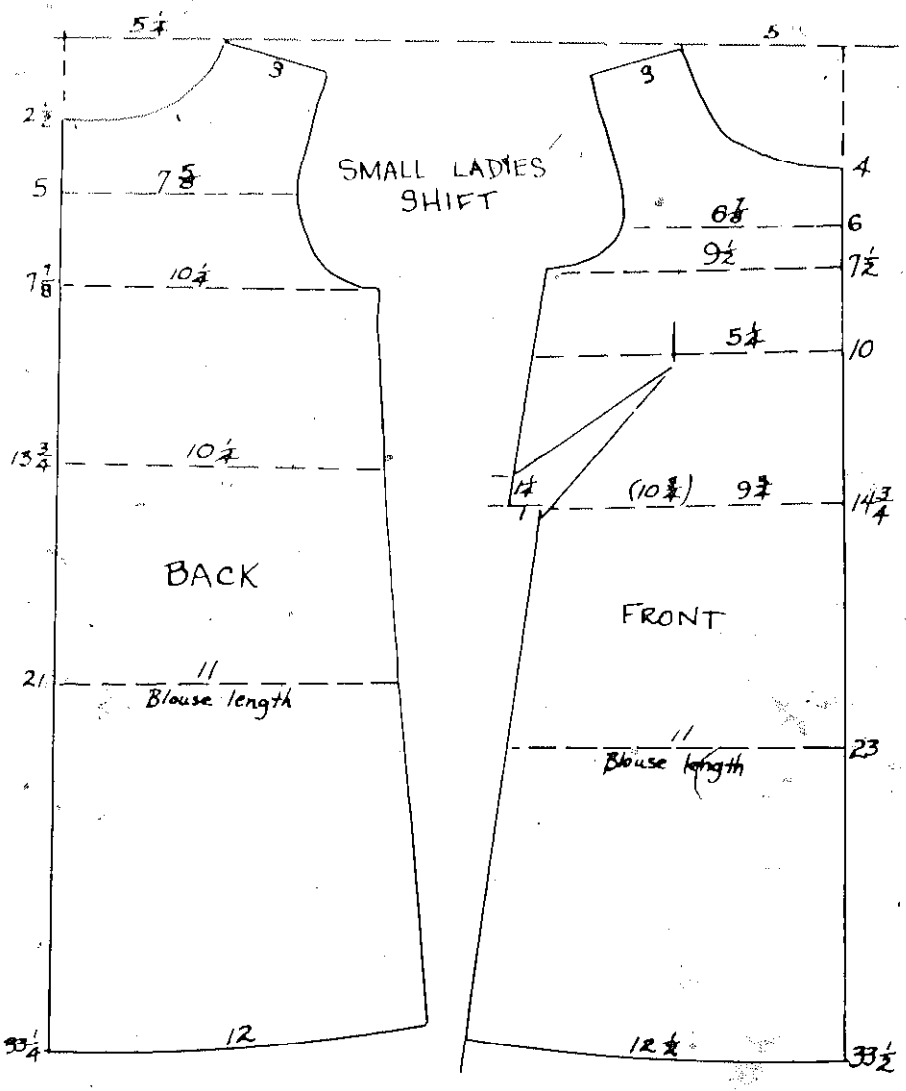

EASY PANTS

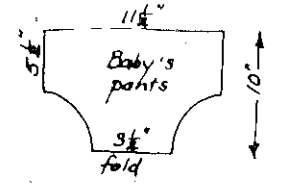

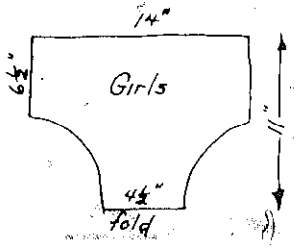

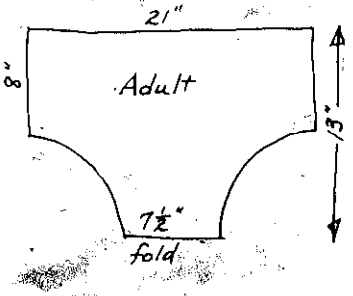

SEWING

1. Hem legs first by hand or machine, turning a small hem (½").

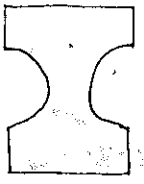

2. Join side seams together. Overcast edge.

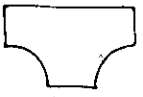

3. Turn hem at top wide enough for elastic.

ALL DIMENSIONS IN THIS SECTION ARE IN INCHES.

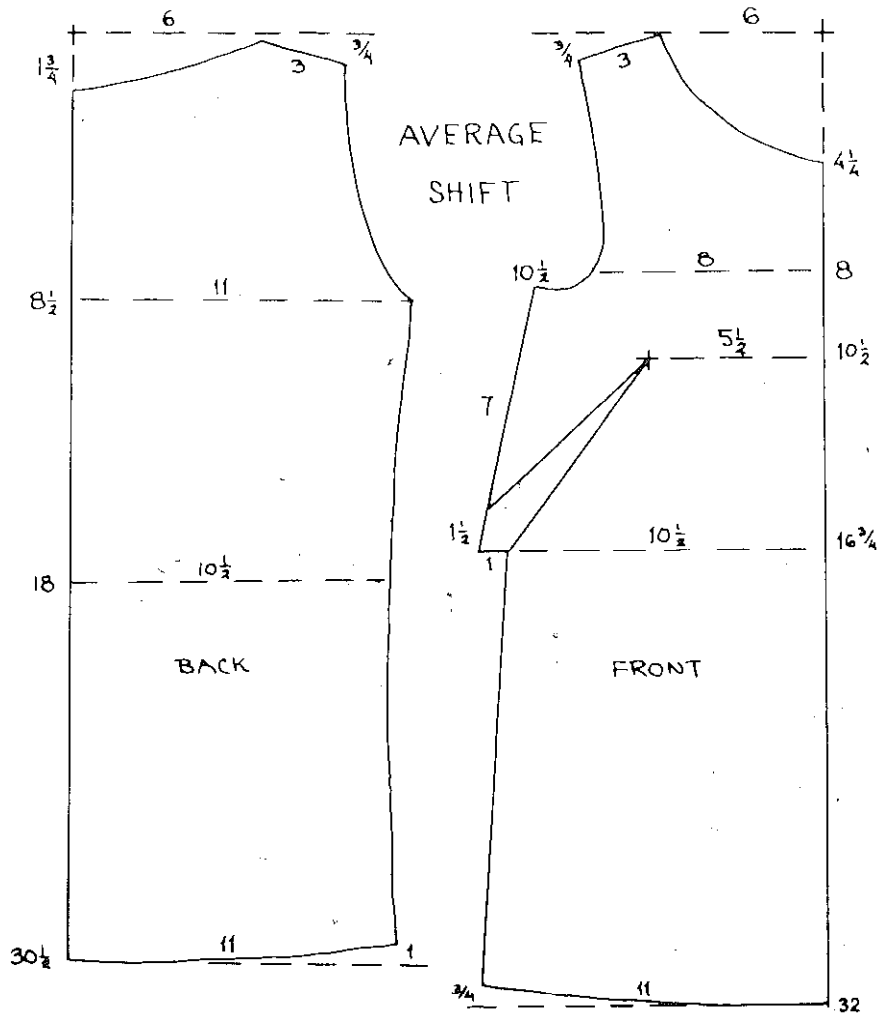

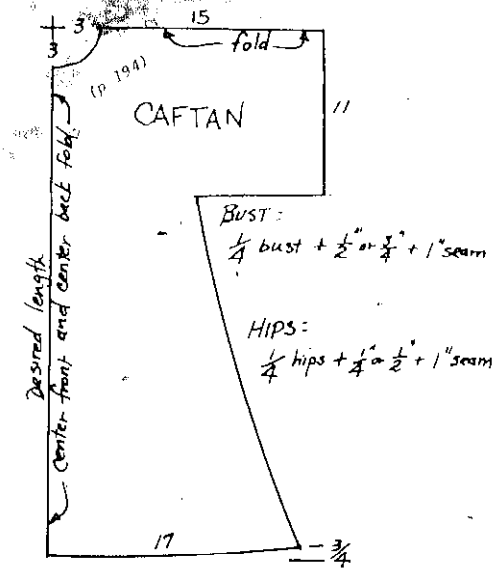

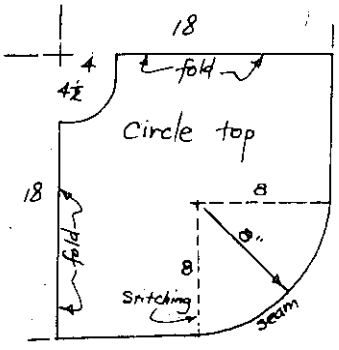

ALL DIMENSIONS IN THIS SECTION
ARE IN INCHES.

MERI BLOUSE

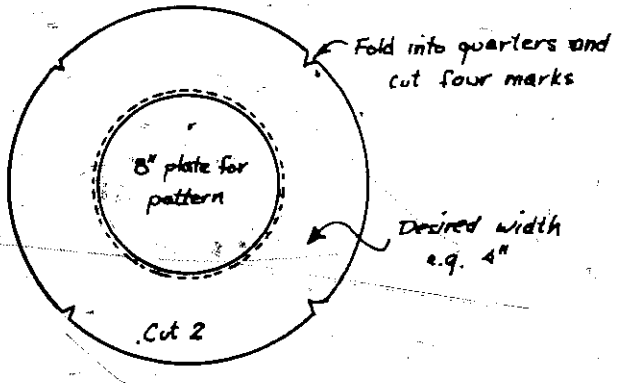

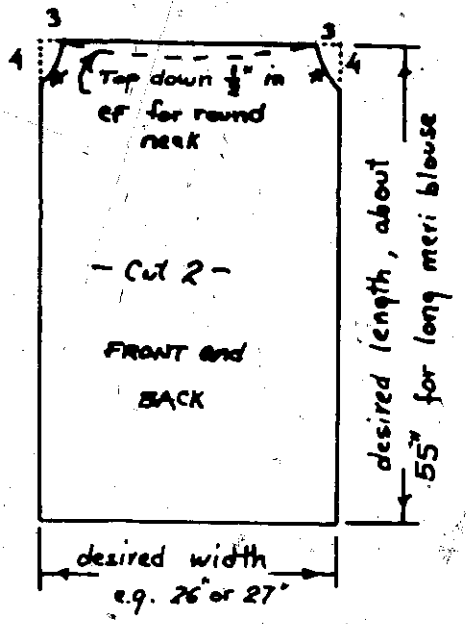

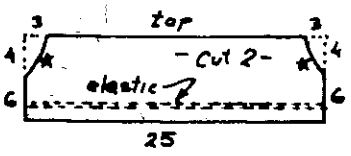

SLEEVE with elastic

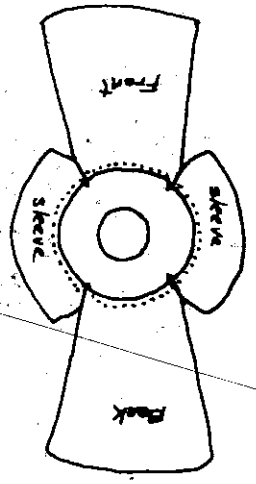

ROUND NECK

1. Sew neck pieces together, right sides together. Clip and turn.

2. Gather top of front, back, and 2 sleeves.

3. Sew armholes (marked *) together. Attach to neck, matching marks cut in round neck with armhole seams.

4. Sew elastic hem or armbands. If you want a sleeve with armband rather than an elastic, make the sleeve 7" wide (not 10") and make sleeve band 11½" x 5" or to fit.

5. Join side seams

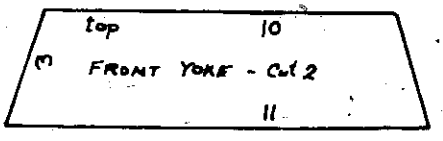

SQUARE NECK

Instead of round neck make front and back yokes and shoulder straps.

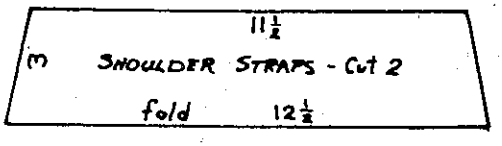

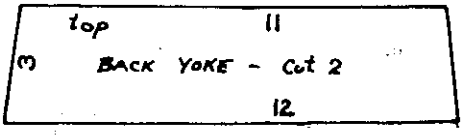

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SHIRTS FOR BOYS

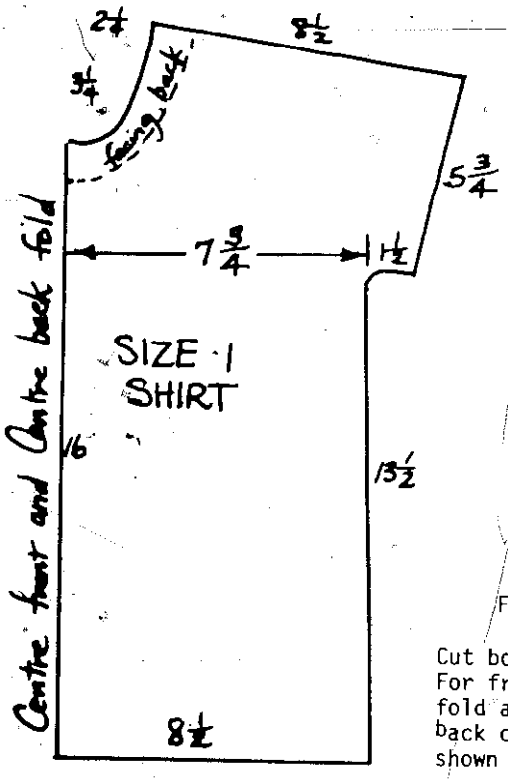

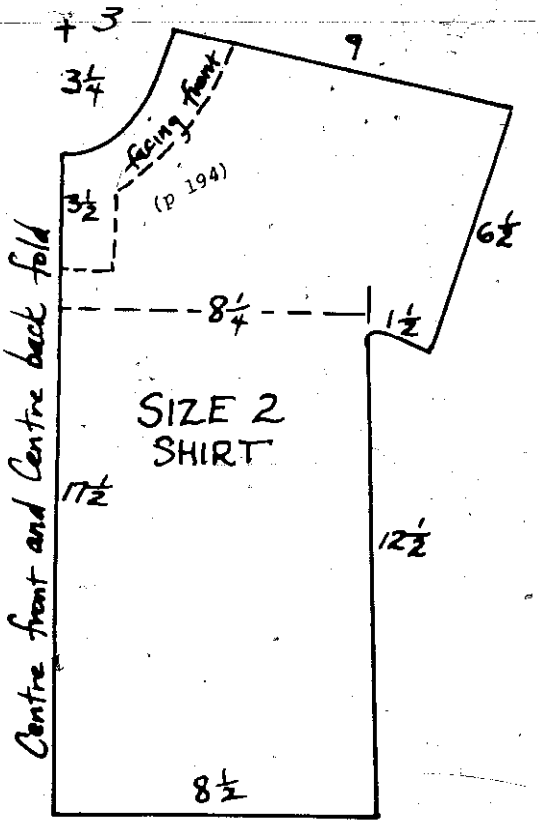

FOR ALL SHIRTS:

Cut both front and back on fold. For front cut facing, also on fold as shown on size 2. For back cut facing on fold as shown on size 1.

ALL DIMENSIONS IN THIS SECTION ARE IN INCHES

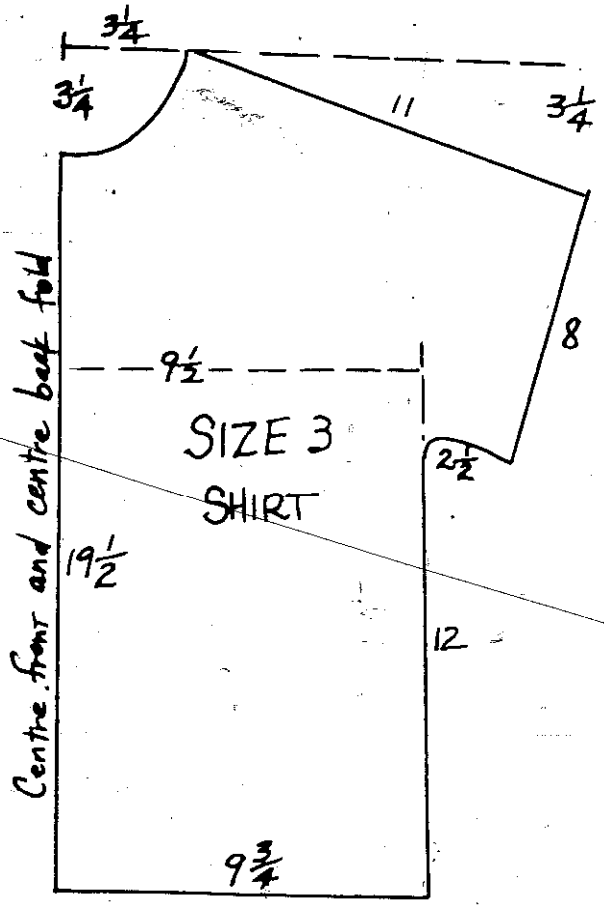

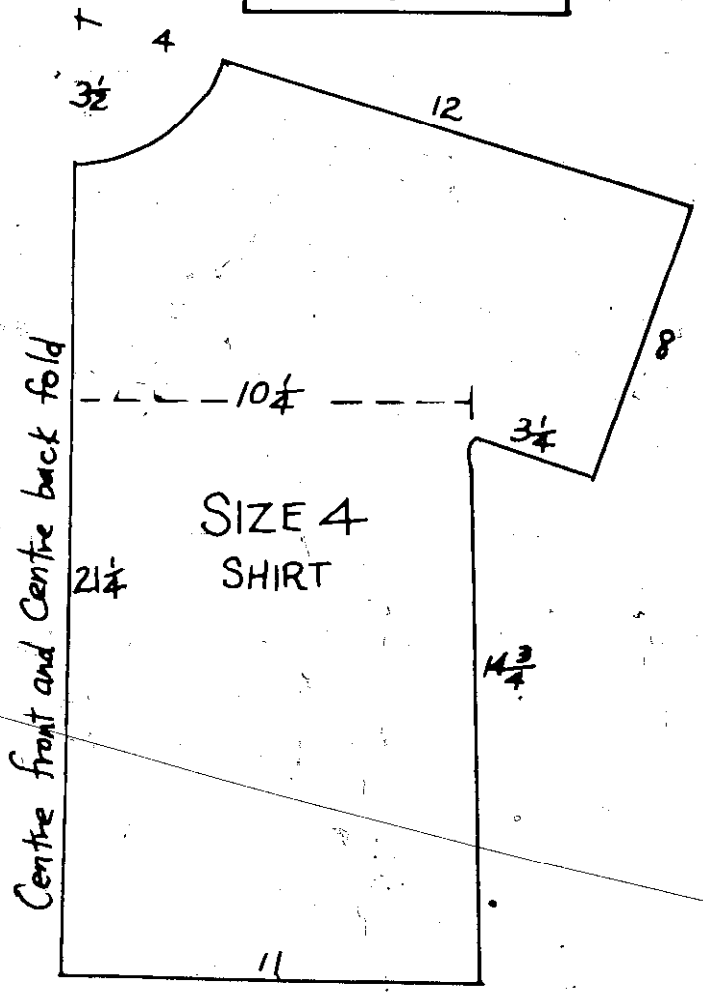

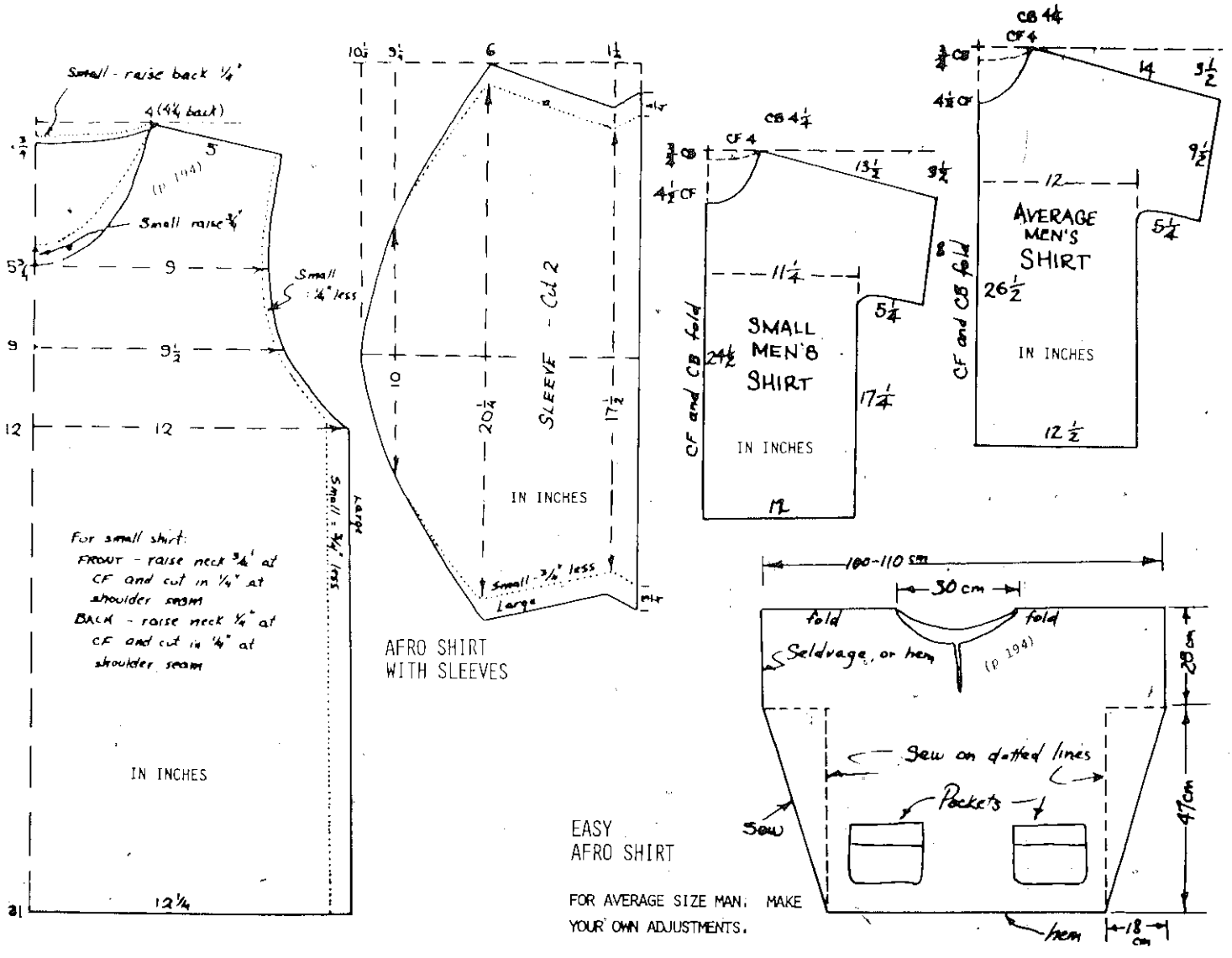

EASY
AFRO SHIRT

FOR AVERAGE SIZE MAN. MAKE YOUR OWN ADJUSTMENTS.

THE FOLLOWING SERIES OF PATTERNS IS FROM "SEWING CHILDREN'S CLOTHES", A POPULAR KIT PREPARED BY FAO, UNITED NATIONS.

(p 190)

SLEEVELESS TOP FOR A CHILD

6 - 12 months

The top will be made from a thin material, plain, checked or striped. It may be made to match the pants.

Materials: Sewing materials. Fabric 25 x 70 cm wide. Four tops can be made from 75 cm in a width of 90 or 100 cm. 2 fasteners.

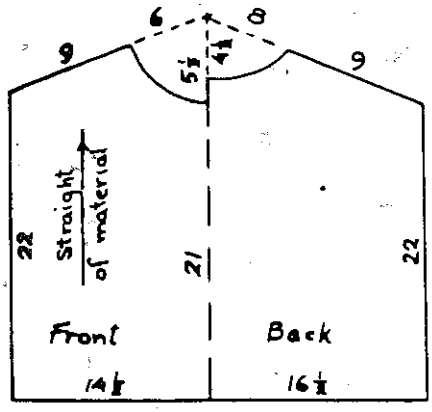

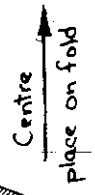

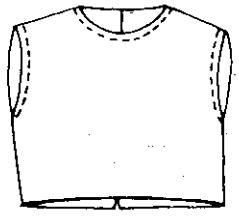

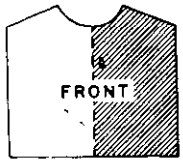

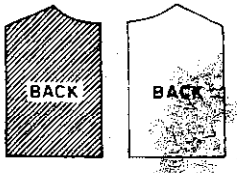

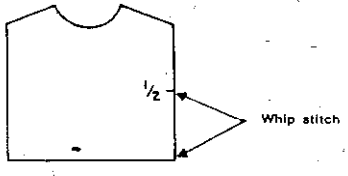

Cutting: The front is cut in one piece. The back is in two halves and has a 1 cm overlap. The bottom edge and sides are cut on the straight.

Sewing:

1. Hem sides and bottom edge of front and back pieces. Width of hem: 0.6 cm.
2. Work narrow hems round the neckline, front and back.
3. Work a 1 cm hem down the centre edge of each half of the back.
4. Fell seam the shoulders.
5. Whip stitch the sides together to half way up their length.
6. Decorate the neckline with a row of herring-bone stitch about 0.6 cm from the edge.
7. Sew the two fasteners to the hems of the back pieces, one in the top corner and the other 8 cm lower down. Buttons and buttonholes may be used instead of fasteners.

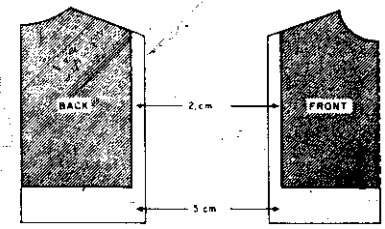

NOTE

To adjust the pattern to fit a 2 - 3 year-old child, add 2.5 cm to the side of each pattern piece, and about 5 cm at the bottom.

SIMPLE DRESS FOR A LITTLE GIRL

1 - 2 years

This dress requires very little material and is easy to make. Use a bright-coloured cotton fabric.

Fabric: 35 x 70 cm

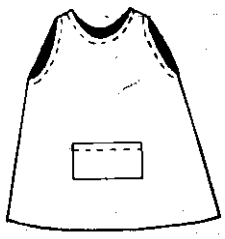

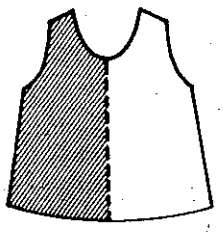

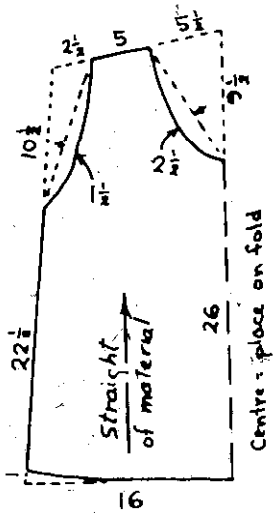

Cutting: The dress is made of two identical pieces, front and back, joined by side and shoulder seams. The dress has a slightly rounded hem.

cont'd

ALL DIMENSIONS IN THIS SECTION ARE IN CENTIMETRES

Sewing:

1. Fell seam the shoulders.
2. Fell seam the sides.
3. Work facings for the neck and armholes or work narrow hems.
4. Make a 2 cm bottom hem.

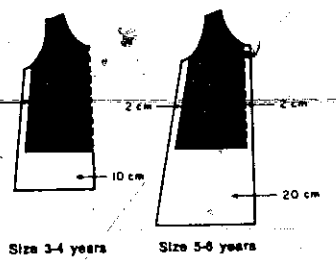

Notes:

A sleeveless shirt to fit a 1 to 2 year-old boy will be obtained from this pattern, shortened by 10 cm.

A rectangular piece 12 x 8 cm may be added to front to form a pocket. The pocket as well as the neck and armholes may be decorated with embroidery.

GATHERED DRESS FOR A LITTLE GIRL

1 - 4 years

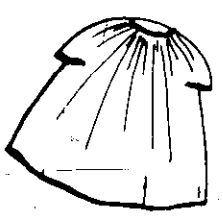

This is an attractive little dress, which can be worn for several years if a wide hem is allowed at the bottom. Use a thin cotton fabric. The dress is extremely easy to cut and to sew, although edging the armholes may be slightly difficult for beginners.

Fabric:
a.) To fit age 1 - 2 years: 40 x 70 cm.
b.) To fit age 3 - 4 years: 55 x 80 or 90 cm.

Elastic: 25 cm

Cutting: The dress consists simply of a rectangular piece of material with a seam down the back and an elastic to gather it round the neck. Two curved slits make up the armholes.

Cut the rectangle to the size required, leaving the selvages intact. Mark out with a pencil first the half and then each quarter of the total length of the top edge.

Ten cm below each quarter-mark, pencil the arm slits on the fabric. Cut neat slits along the pencilled lines.

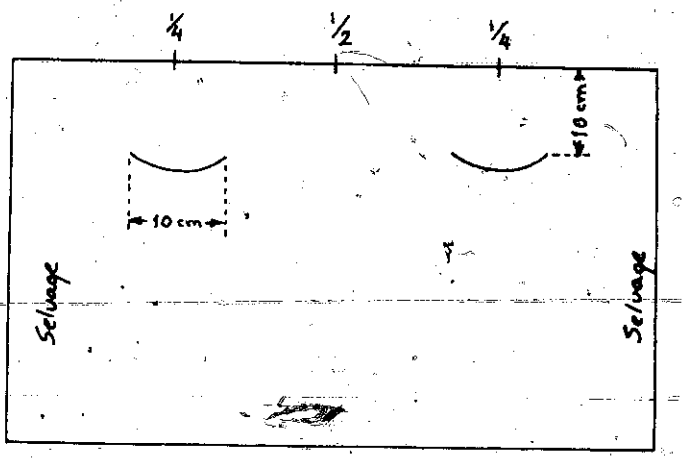

Sewing:

1. Tack a single turn-in not more than 3 mm wide all round the arm slits.
2. Cover the turn-in all round with buttonhole stitch, using embroidering cotton.

Armhole embroidered in buttonhole stitch

3. Flat-seam together the two short sides of the rectangle (the selvages).
4. Make a 2 cm hem at the bottom.
5. Hem the top, allowing 1 cm clear inside the hem for the elastic to pass through.
6. Pass the elastic through this hem with a safety pin. Overlap the ends of the elastic and join them by overcasting.

Notes:

1. This pattern may be used to make a child's top opening at the back (size to fit age 1 - 2 years). The top requires 30 cm of fabric 70 cm wide, and 80 cm of tape. The tape (or ribbon) is used instead of elastic to gather the neck and is tied at the back.
2. The dress or top can have a front pocket (rectangular piece 14 x 8 cm). The pocket may be embroidered to match the edging round the arm slits.

ALL DIMENSIONS IN THIS SECTION ARE IN CENTIMETRES

AFRICAN TUNIC FOR A LITTLE GIRL

2 - 4 years

The tunic is made from bright-coloured cotton fabric.

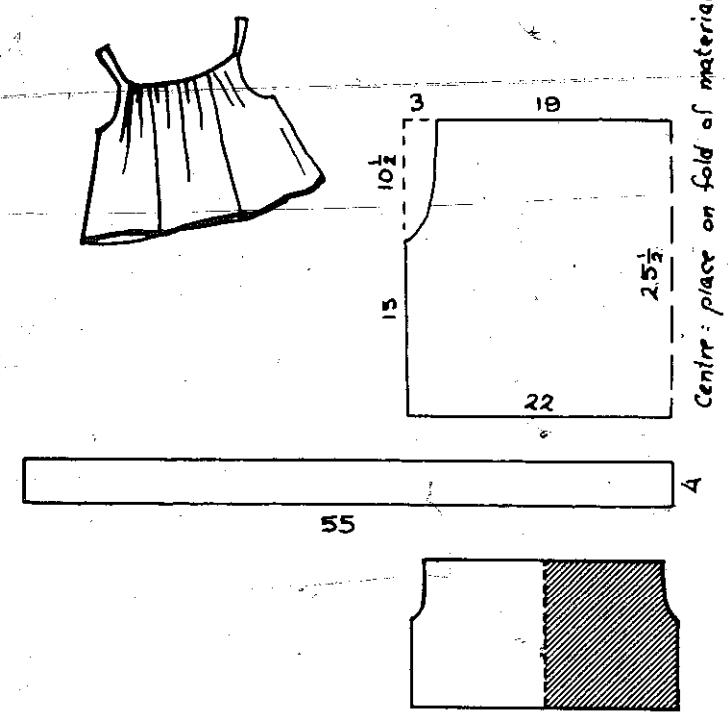

Fabric: 30 x 90 cm

Cutting: Back and front are the same. Both are gathered at the top by means of a strap passed through the hem. The strap is made from a strip of material 55 x 4 cm.

Sewing:

1. Work narrow hems round armholes.
2. Work 2 cm hems at top of front and back.
3. Join sides with fell seams.
4. Make a 1 cm hem at bottom.
5. To make a strap, tack a 1 cm turn-in along the edges and whip stitch together.
6. Pass strap through both hems at top and sew the two ends together.

Notes:

1. To adjust the pattern to size 5 - 7 years, add 5 cm at the bottom and make the strap 65 cm long.

2. A little dress may be obtained from the same pattern. Simply add 10 to 20 cm at the bottom, according to age.

ALL DIMENSIONS IN THIS SECTION ARE IN CENTIMETRES

TUNIC (SINGLET) FOR A LITTLE GIRL

5 - 7 years

Fabric: 40 x 80 cm wide.

Cutting: Back and front are identical.

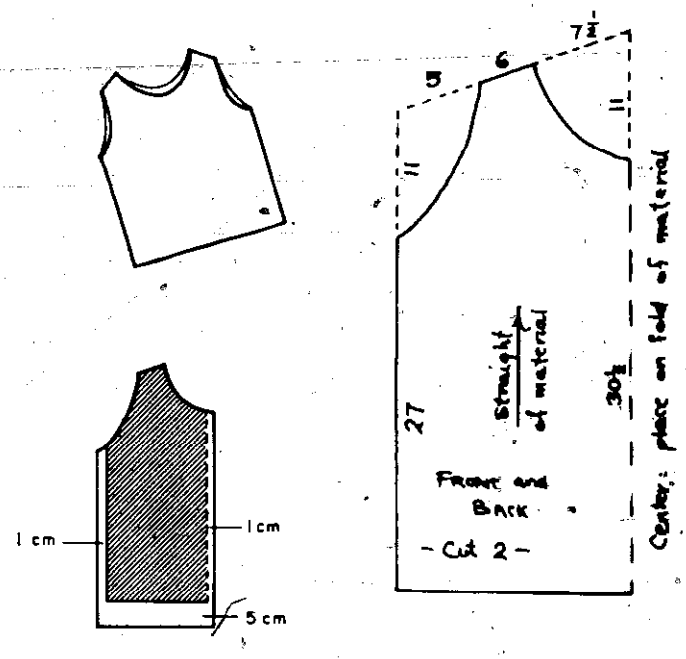

Sewing:

1. Fell seam shoulders.
2. Fell seam sides.
3. Work narrow hems round neck and armholes.
4. Make a 2 cm bottom hem.

Note: To adjust the pattern to size 8 - 10 years, add 1 cm to the side and to the centre edge of the front piece and 5 cm at the bottom.

SHORTS FOR A CHILD

6 - 10 years

Use a plain, tough, nonsoiling cotton fabric. The shorts have an elastic waistband and are slightly gathered. They are easily run up and make a practical garment, just right for little boys at school.

Fabric: 30 x 100 cm
Elastic: 40 cm

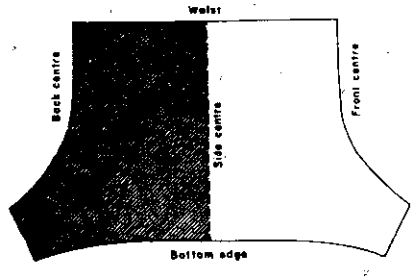

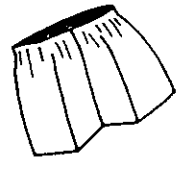

cont'd

Cutting: Front and back are the same. Cut out twice, with the material folded double. There are no seams down the sides. The garment has only centre seams, front and back.

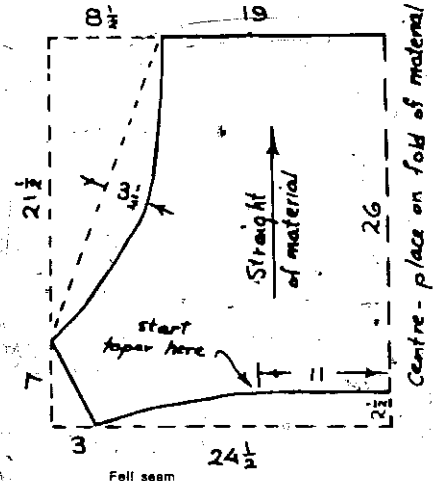

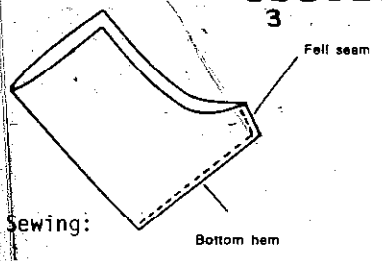

Sewing:

1. Fell seam each leg to form leg openings.
2. Make a hem 0.4 cm wide round each leg opening.
3. Join the two halves of the garment with a fell seam, making sure that the two inside leg seams fit together accurately.
4. Make a hem a little wider than 1 cm round the waist, and pass the elastic through it with a safety pin. Overlap the ends of the elastic and join by overcasting.

Note: The shorts may be provided with a pocket. Place a square piece of material 12 x 12 cm on the back of the right-hand half of the garment.

SLEEVELESS BLOUSE FOR A CHILD

6 - 10 years

The garment is cut out in one piece and requires 90 cm wide fabric. The collar and pocket are cut out separately.

Fabric: 55 x 90 cm

Cutting: Fold the material selvage on selvage. Apply the pattern so that the centre line of the back (dotted line) lies exactly on fold of material.

Mark the centre line of the front on the fabric with a pencil.

Cut out so that the selvages at the edge of the facing are left intact. (The facing is the inside turn-in of the garment.) If the fabric is

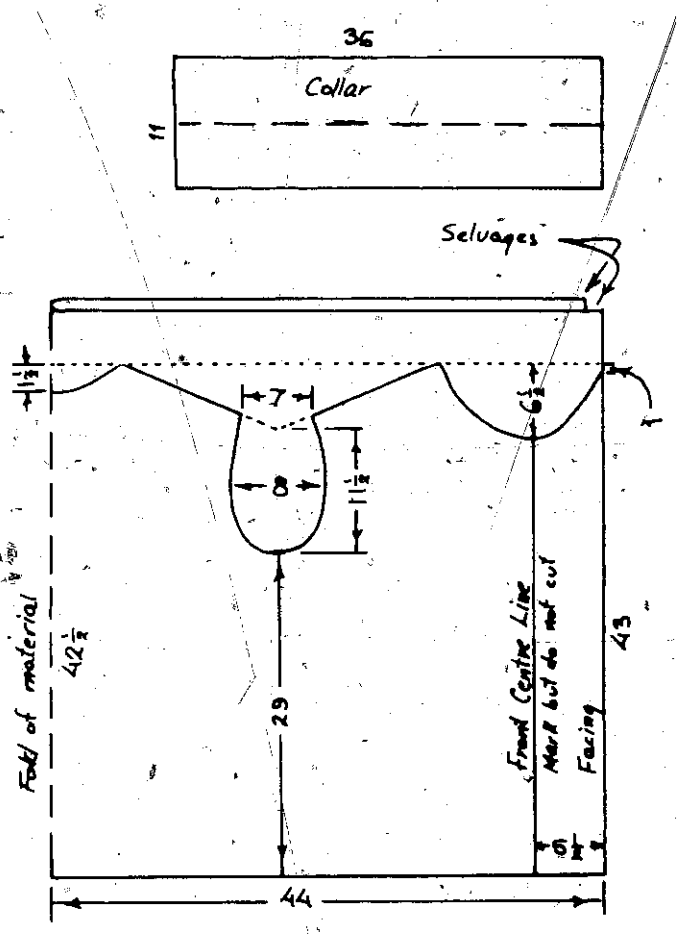

exactly 90 cm wide, the edge of the facing will coincide with the selvages. If the width of the material is slightly more or less than this figure, the facing will be made that much wider or narrower, but do not change the front centre line or cut away the selvages.

The collar is made from a rectangular piece of material, measuring 36 x 11 cm which will be folded in half lengthwise.

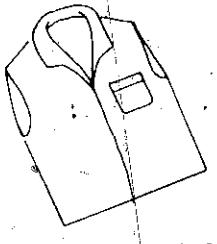

Sewing:

1. Make a narrow hem around armholes.
2. Fell seam shoulders.
3. Make a 1 cm hem at bottom.
4. Turn in facings as pencil-marked, tack them down and whip stitch at bottom.
5. Fold collar piece lengthwise and seam the ends 1 cm from edge. Turn inside out. Smooth down seams.
6. Fit collar. To do this, first pin the ends and centre of the collar to front corners and centre of opening, on the inside. Then tack inside portion of collar to neckline from the inside and back

stitch, 0.5 cm from the edge. Finally, working from the outside, hem stitch the outer portion of the collar over this seam.

7. Whip stitch the front of the garment up to 13 cm from the collar.

Note: A pocket made from a square piece of material 12 x 12 cm may be added on the left side of the front. The pocket may be embroidered with a design or with the child's initials.

AFRICAN TUNIC FOR A TEENAGER

Bust 80 - 90 cm

Fabric: 50 cm x 100 cm wide

Mark material as shown, or make pattern first, if desired.

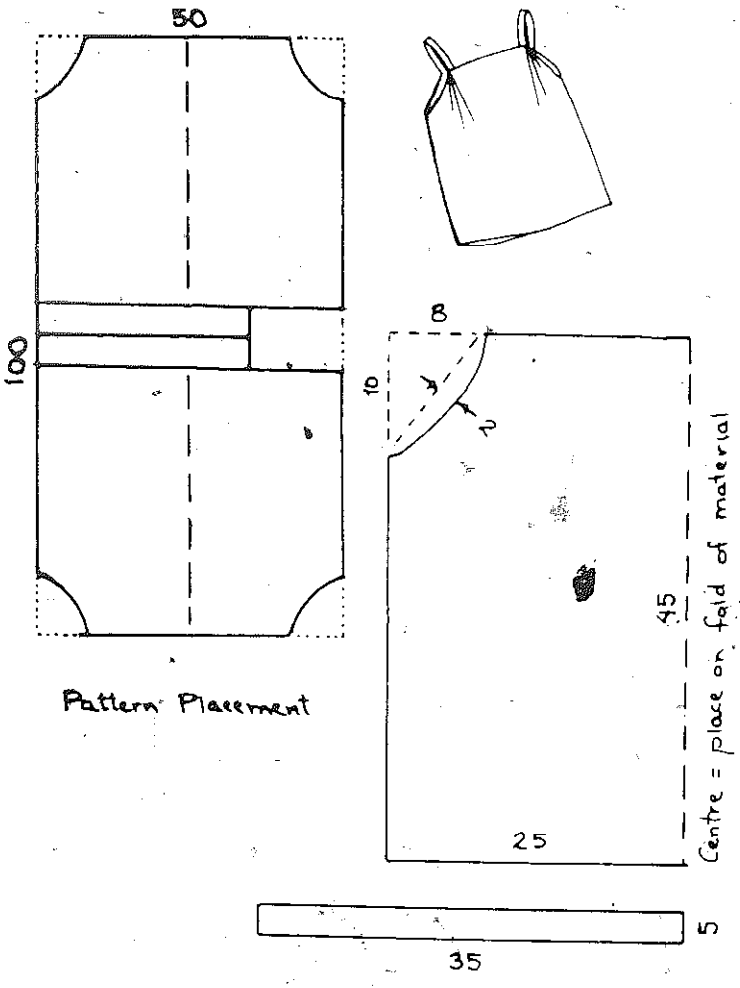

Sewing:

1. Make a narrow hem around each armhole.
2. Make a fold 2 cm wide at each top angle of the front and back piece, and secure the fold with a few stitches. See that on the outside the fold is laid toward the armhole.
3. Work 1 cm hems along the top of the front and back.
4. Fell seam the sides together.

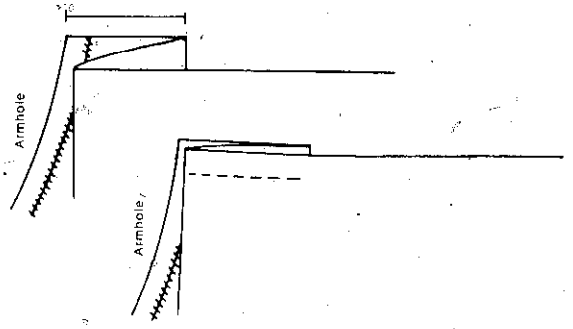

5. Make a 1 cm hem at the bottom.
6. Make the straps by tacking a turn-in, just over 0.8 cm wide, along the edges and then whip stitch the edges together.

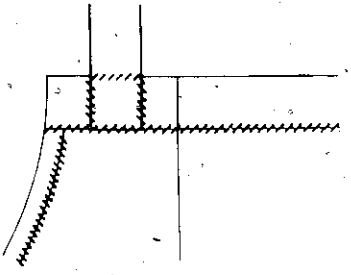

Position of strap on the inside

7. To attach the straps, fasten their ends to the centre of each fold on the inside, and hem stitch down.

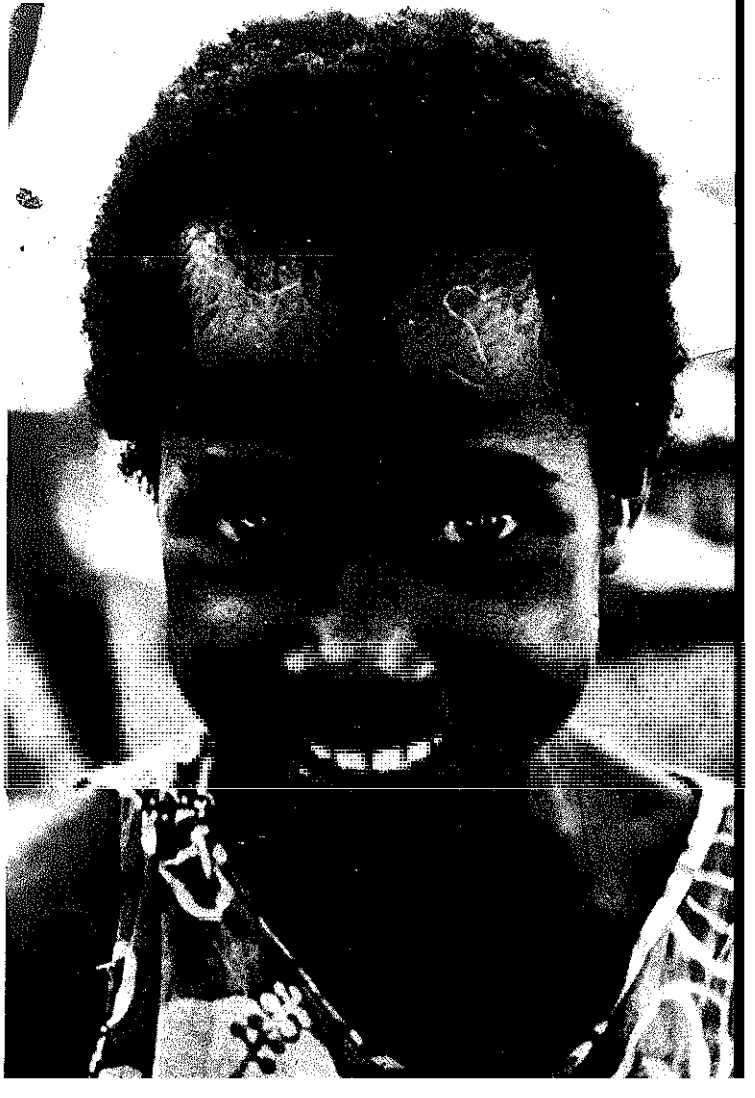

WRAP AROUND SKIRT

1.

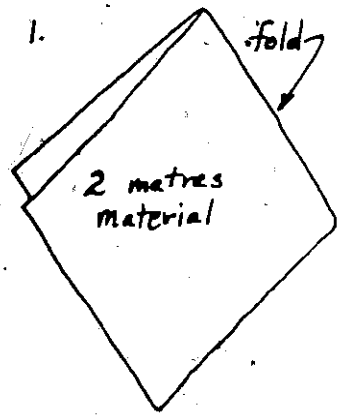

2.

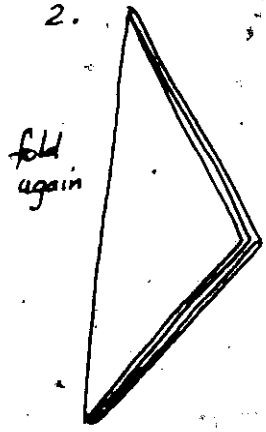

3.

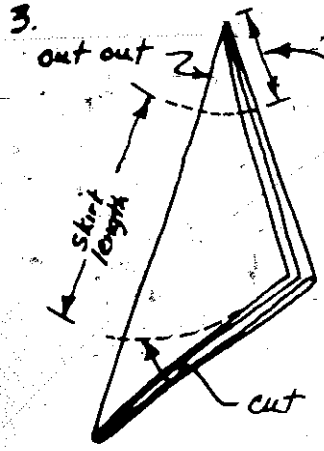

about $\frac{1}{3}$ of your waist measurement plus 5 cm.

Try a pattern for the waist with paper first.

4.

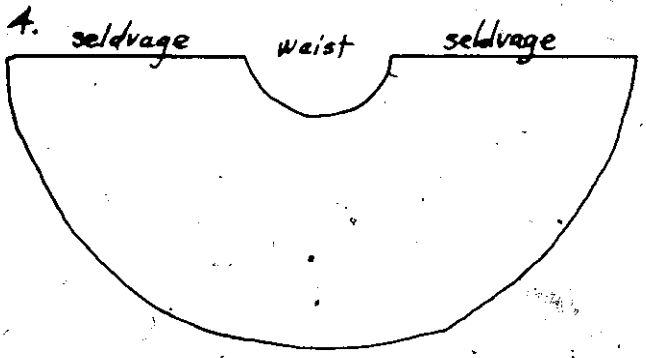

5.

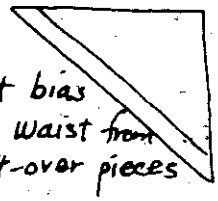

cut bias for waist from left-over pieces

6.

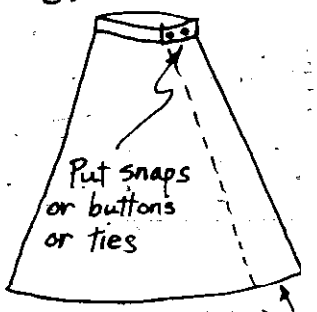

With a yard of material you can get a skirt about 60 cm long.

H. Bekker

WOVEN COLD SHIRT

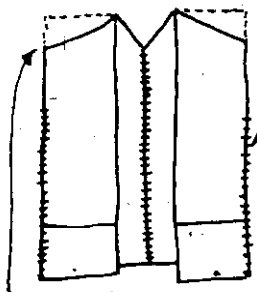

2 PIECES 23 CM WIDE

Sew on inside with matching yarn

turn up for pockets

Sew dart inside for shoulders

OR

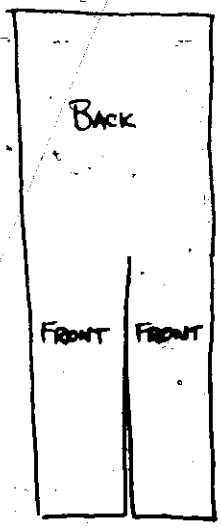

One long piece with 2 shuttles for front

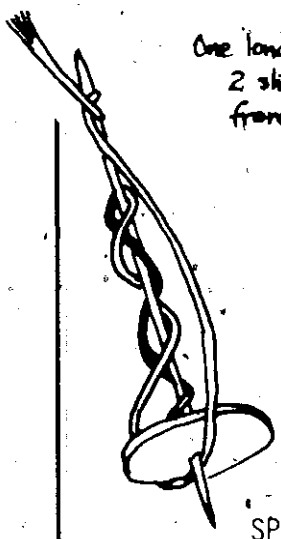

Turn up for pockets

SPINDLE

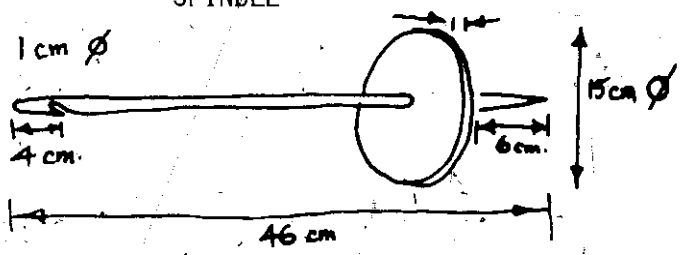

Crochet hook made from hard wood or bamboo

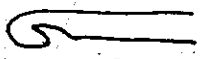

Used for

Cold Shirts*
Ponchos
Blankets
Caps

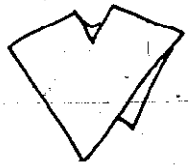

*Same as long piece woven. Crochet sides; add sleeves if desired. Spin wool or silk on spindle loosely, crochet, or knit, make needles from bamboo.

H. Bekker

EASY DECORATIONS

(p. 146)

Easily done embroidery on rik-rak braid can brighten plain clothes.

Pin rik-rak braid on material.

Tack rik-rak in place.

Sew anchoring stitch in embroidery cotton.

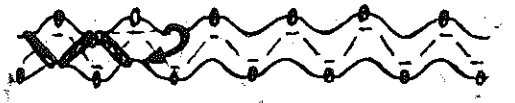

Sew holding stitch in embroidery cotton across rik-rak.

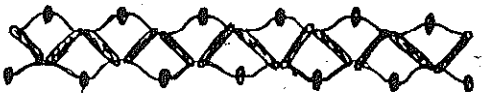

Remove tacking stitch.

Use 3 strands at a time out of 6 strand embroidery cotton.

Also try multiple rows at different spacings, or add a pattern of simple stitches between or around the rows of rik-rak.

Initial contributor: S. Holzknecht
Box 5854, Boroko

HOW TO CROCHET

*See footnote

1. To begin: Hold wool or string between thumb and index finger of the left hand, with the thread extended between the other fingers. Hold the hook by the flange between the thumb and index finger of the right hand. Use the second finger of the right hand to control the stitches on the stem of the hook. Take the hook under and over the extended thread, forming a loop over the hook as shown in diagram (a). Take the hook under and over the thread again as shown in (b). Draw the wound thread through the initial loop to form the first stitch on the hook as shown in diagram (c). Pull the end of the wool to draw up the slip knot below the stitch. Hold this knot (or the base, as work proceeds) between the thumb and index finger of the left hand.

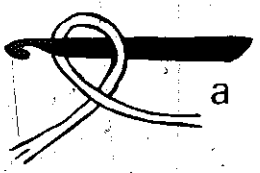

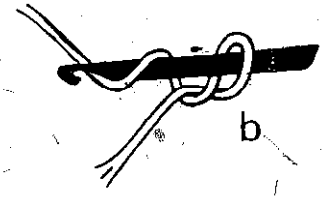

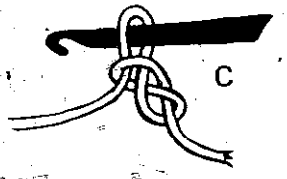

2. Chain: This forms the basis of all crochet stitches and it should be practised until it is worked to perfection. Each stitch should slip easily over the hook and must be even throughout. With the first loop on the hook, take the hook under and over the extended thread as shown in diagram (a). Draw the wound thread through the loop on the hook, forming a chain stitch as shown in diagram (b). Continue working chain stitches as required. See diagram (c).

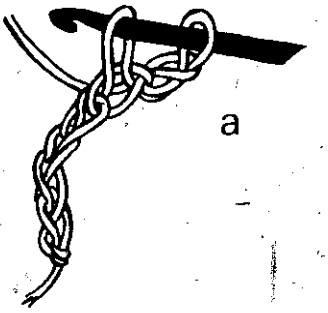

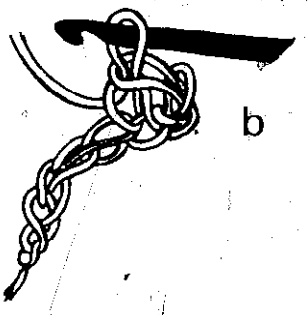

3. Double Crochet: Work through both loops of stitch unless otherwise stated in the pattern. Miss 1 ch., *draw loop through next ch. as shown in diagram (a). Draw loop through the 2 loops on hook, completing 1 double crochet stitch (1 d.c.) as in diagram (b). Repeat from *, working 1 d.c. in each successive ch. to end. To turn, work 1 ch.

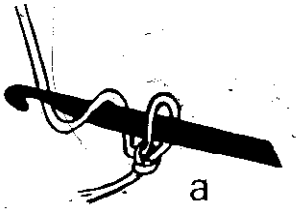

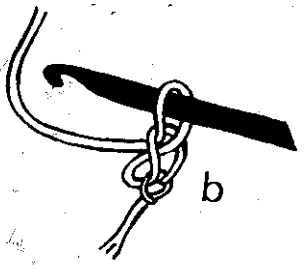

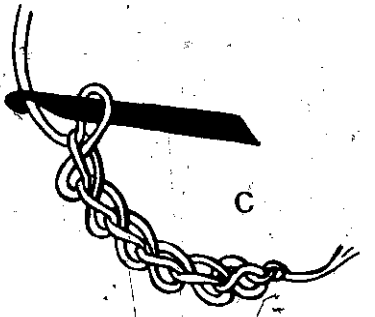

4. Half Treble: Miss 2 ch, * wool over hook, insert hook through next ch. as shown in diagram (a). Draw loop through 3 loops on hook as shown in diagram (b). Wool over hook and draw through 3 loops, completing half treble stitch as shown in (c). Repeat from * for number of stitches required. To turn, work 2 ch.

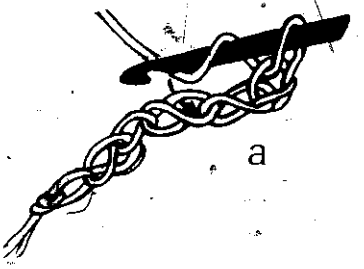

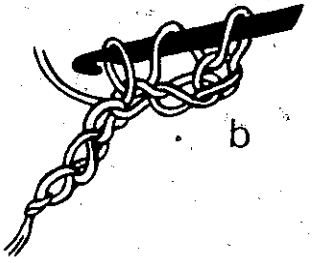

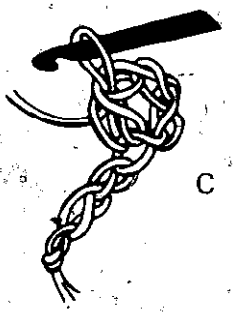

means "repeat until the next"

cont'd

5. Treble: Miss 3 ch., *wool over hook, draw loop through next ch. -3 loops on hook as shown in diagram (a). Wool over hook and draw through 2 loops as shown in (b), wool over hook and draw through remaining 2 loops, completing one treble stitch as shown in (c). To turn, work 3 ch.

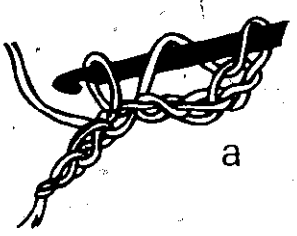

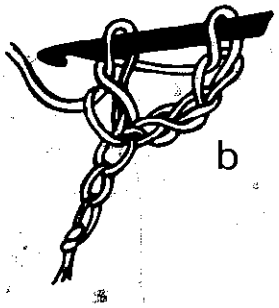

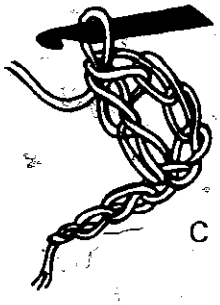

6. Double Treble: Miss 4 ch., *(wool over hook) twice, draw loop through next ch., 4 loops on hook as shown in (a). (Wool over hook and draw through 2 loops) 3 times, completing 1 double treble stitch as shown in (b). To turn, work 4 ch.

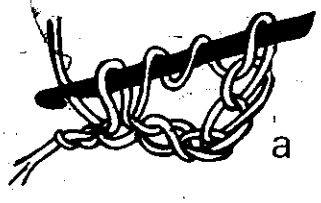

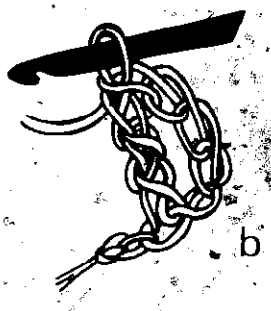

Contributed by Sr. Godelief, Box 3, Lae

FURNITURE

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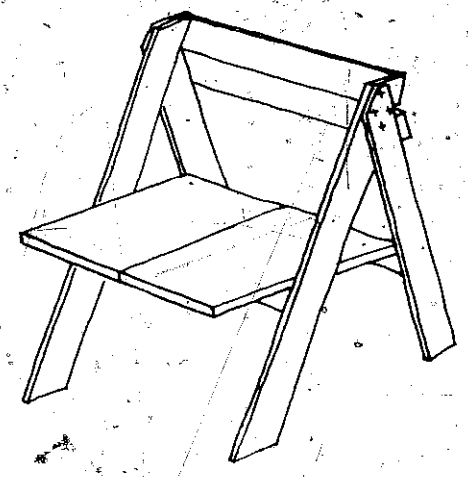

STUDENTS CHAIR TYPE - C

age group 9 - 12

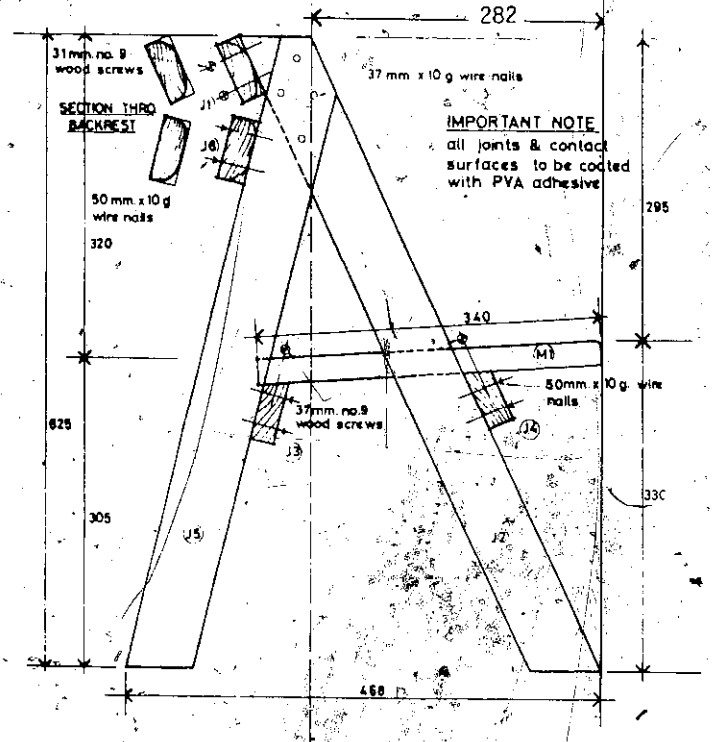

STUDENT DESK

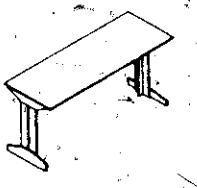

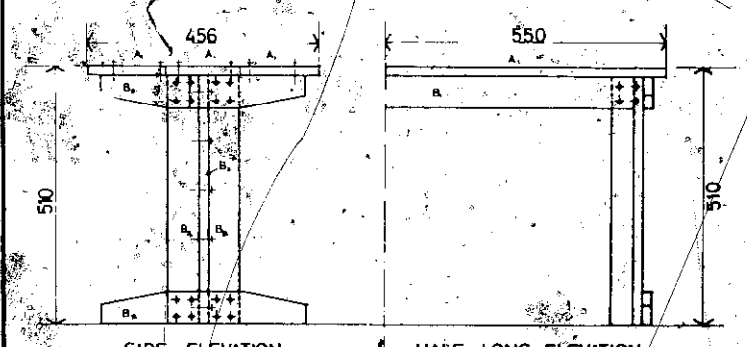

Legs for a portable bench are made of pieces of pipe. Let legs angle outward and they become stronger with a load.

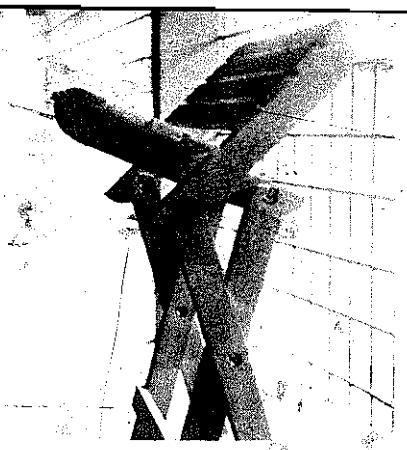

Stool made at Baitabag Vocational Centre, Madang, folds into a compact flat package. Joints are held with split rivets (made from nails) and washers.

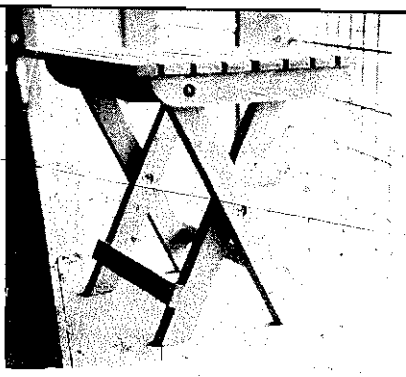

*split rivets made from large nail (cut with hacksaw).

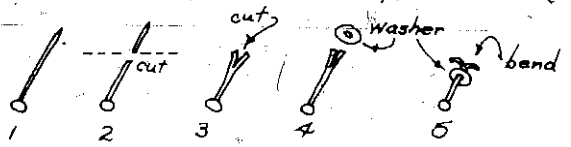

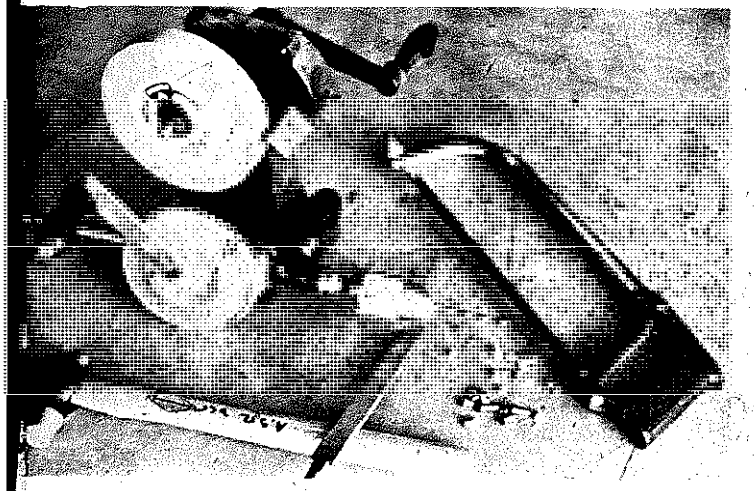

With just these tools and rivets you can do a surprising amount of metalwork in the village without electricity or a forge. The crank grinder (made in China) is available from Steamships Hardware, Lae, for K13. w/o stone.

GRINDING WHEEL

A home-made grinding wheel at SIL, Ukarumpa, EHP. The stone is made from sharp-cornered sand with just enough cement to bind it together. It has a square hole.

The shaft is made from a square board carefully fit into the hole. It is rounded where it turns in its "U" shaped bearing. A piece of galvanized iron holds it in.

The piece of tyre has water in it.

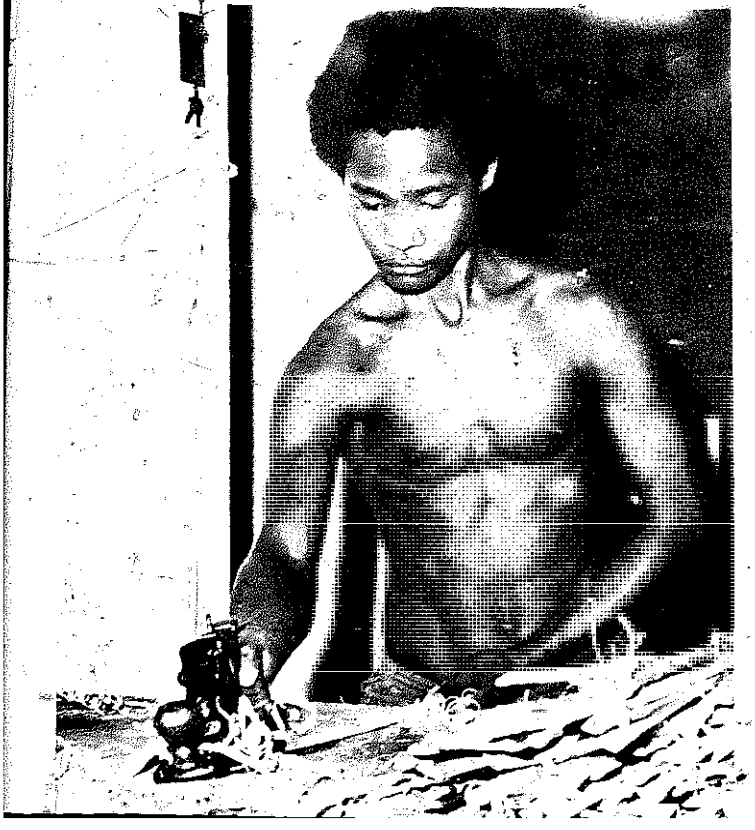

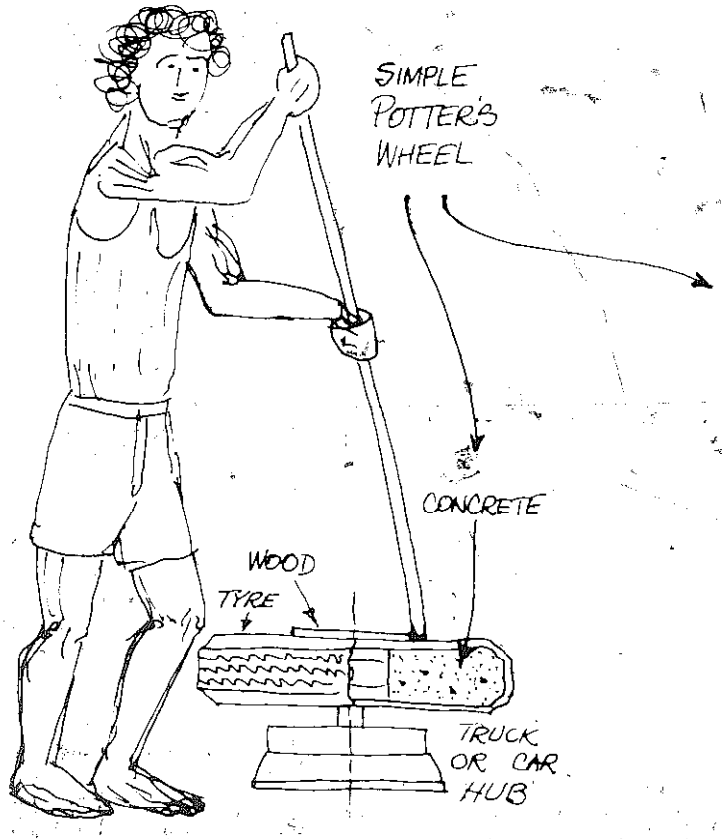

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POTTER'S WHEEL. Make it spin fast by turning it with a pointed stick in a small hole in the concrete. The wheel is heavy enough that with practice you can throw a pot with each spin.

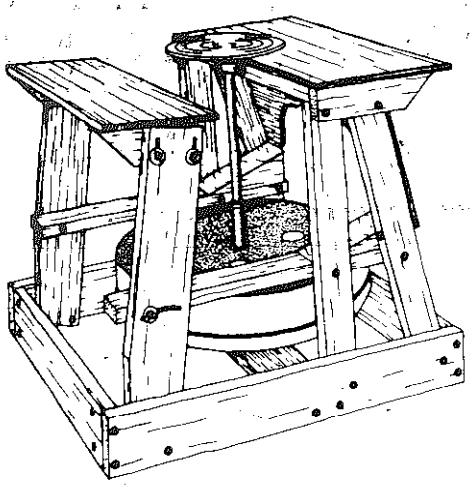

Another design: A simple kickwheel

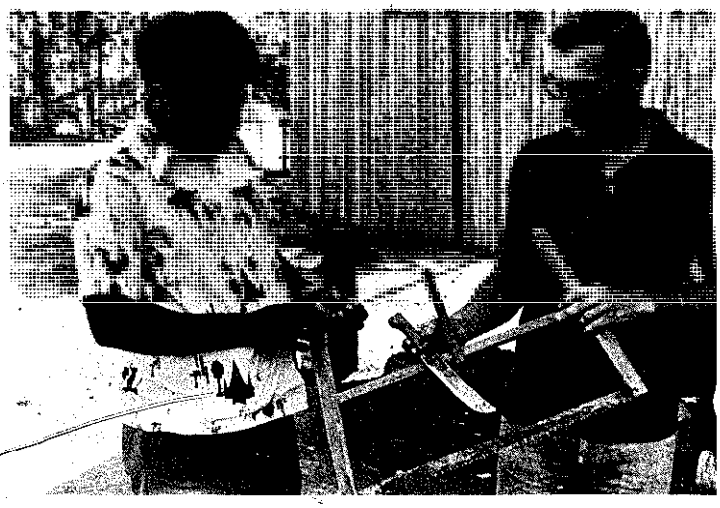

Father Kingsley Gegeyo, Executive Officer of the Melanesian Council of Churches, and Bud Larson of SIL examine a knife and saw frame made by villagers in Sui Village, Northern Province.

Trays for many uses

OLD TYRES

1. Boat bumpers at piers - or on boats.

2. Tread for wooden or steel wheels - cut tread of tyre into bands of desired width, nail to wood, or "sew" with wire to the steel wheel.

3. Harness for work animals - cut side walls (in a spiral) into strips, rivet (or sew with wire) according to your own harness design.

4. Shock absorber for towing vehicles with rope, or on front bumper when pushing vehicles.

5. Cushion for portable generator - lay appropriate size tyre on ground, set generator frame on top - very smooth!

6. Feed troughs - cut in half around tread.

7. Temporary engine mounts - cut pieces of tread to size - this can keep your vehicle going until you get the right part.

8. Hinges for heavy gates or doors. Two or more rectangular pieces of side wall nailed well to post and to gate or door.

9. Playground equipment - swings of various types, crawl-through obstacles.

10. Flower pots:
    a) cut tyre in half around tread.
    b) cut off inner bead; bend in a circle, with the tread part up and outside to try for size.
    c) cut off at desired point.
    d) sew ends together with wire.
    e) sew rubber circle into bottom with wire.

11. Sandals - these are difficult, but with practice some attractive soles can be made with treads and straps made of leather or inner tube. (be careful - they mark floors!)

12. Stop soil erosion on steep hillsides - join the tyre circles with wire or cable, flat on the ground. Plant bushes or shrubs in the centre of the tyres. The soil will be held and the plants will grow.

13. Smoke screen - burning tyres will keep birds from raiding the crops you're growing. (but also kills trees and shrubs in the vicinity.)

14. The wire left from burnt tyres is sometimes useful, although it rusts very fast.

15. Make your roof! *(p 183)*

16. Now you add some - write us a letter!

How can we cut old tyres? The hardest part is getting the first cut through the tyre. Use a pointed knife or a pointed chisel and hammer. It helps to have two persons - one to held the tyre. Once you get started, a sharp bush knife will do the job, with the person holding the tyre spreading the rubber so that the knife will not "stick". Pouring a small trickle of water as you cut will make it easier. For a big tyre, pound the back side of the bush knife with a hammer, "steering" the knife as you go. But start with a small tyre, and when you know how, move to larger ones.

How can we put holes in old tyres? We can drill them with a steel bit, or burn through with a red hot iron rod. Make 2 or 3 pointed rods with handles. Heat over red hot coals. Use in rotation.

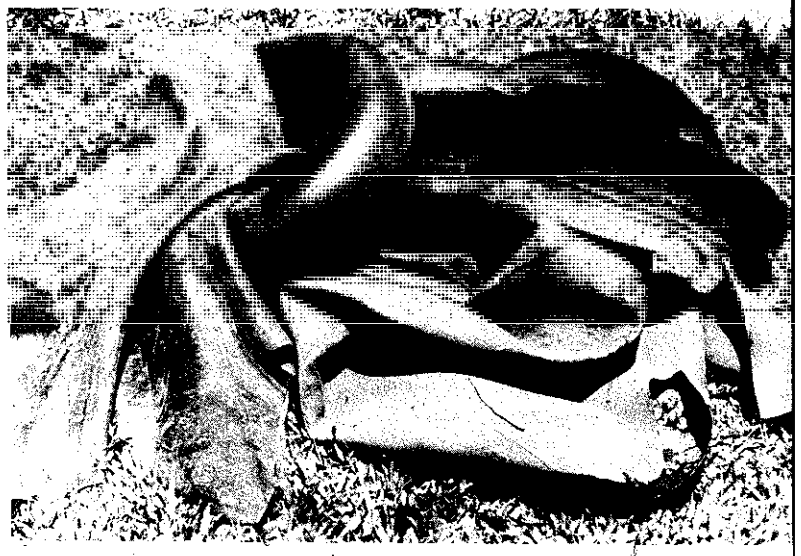

OLD INNER TUBES

1. Cut into strips and tie your things on the back of a bicycle or motorcycle.

2. Bind up a broken car or truck leaf spring as an emergency repair.

3. When glueing, clamp two pieces of wood together with strips of inner tube.

4. A door spring or other kind of stretch spring.

5. Nail a rubber flap to a door, just above the padlock, to protect it from rain.

6. Wrap thin strips around a bundle of coconut leaf mid-ribs to make an out-door broom.

7. Tie bamboo scaffolding with strong rubber strips to paint a building.

8. Assemble a small building or shelter of local materials by tieing with rubber strips.

cont'd

9. Wrap inner tube strips around leaky pipes as a temporary repair. It might last for years!

10. Inner tube squares will make hinges for animal cages or small cabinets. Fasten with tacks.

11. Sling shots - mustn't forget those!

12. Faucet washers or other types of rubber gaskets.

13. "Flap" valves for air billows for a forge.

14. Diaphragm for small water pumps.

15. A model bio-gas digester was made from an inner tube and shown at a recent workshop in Port Moresby.

16. Whole inner tubes can be used to float things in water. Many inner tubes used together in a frame can be used to float heavy things.

17. A round canvas cover tied to an inflated inner tube can turn it into a trampoline, or inverted, into a play boat or a life raft.

18. Weave straps on a bed frame for a comfortable bed.

19. Insecticide duster. (p 165)

20. Bookstrap - cut a complete circle like a big rubber band.

21. Elastic for a fish spear gun.

How do we cut old inner tubes? Heavy duty scissors are the best tool, but a sharp knife will do, if only a rough cut is needed.

When wrapping something with rubber strips, the top layers of rubber usually exert enough pressure to hold the starting end secure. The finishing end can usually be tucked under a tight earlier wrap.

BEDDING FROM INNER TUBE STRIPS

Construct a rectangular bed frame with wood poles or boards, support it on wooden legs.

Cut inner tubes into lengths approx 6-7cm wide.

Half the strips must be a bit wider than the bed, the other half must be a bit longer than the bed.

Weave the strips. It need not be tightly woven - you can allow gaps.

Nail the ends to the frame.

FLOWER POT FROM TYRE

Cut tyre in half across tread using knife and hacksaw.

Put a hole at both ends of each half, and one at the bottom for drainage.

Tie rope through the holes of each half and hang.

Contributed by: S. Tracy, Box 1539, Lae.

TOOL FOR CUTTING OIL DRUMS

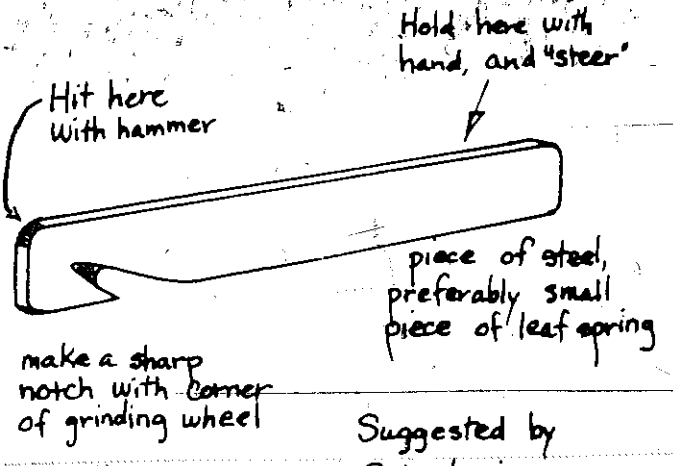

Suggested by
Bob Jamieson
Box 571
Goroka

OLD 200 LITRE DRUMS

1. Drains under roads.
2. Fill with cement and stones to stop erosion near wharves.
3. Hot air pipes for copra driers.
4. 101 different kinds of ovens and stoves.
5. Forms for concrete bridge and pier pilings.

ANIMATING VILLAGE DEVELOPMENT

"Animate" - "To breathe life into; enliven; inspirit; inspire; actuate" ...

"Animate" is a good word because its meaning speaks of life. It carries with it the suggestion that somebody is doing something to someone else. But what? In this case, it is action that makes others alive, obviously not in the flesh and blood sense but in the bodily sense of being more wholly alive. It is action that helps others to move forward, to decide and to create. That movement, decision and creation is not for personal advance but for the people as a community. The "people" may be any group whose life we share - a village, a town community, a trade union, a club.

The difficult thing about animation is that it is an action different in nature from actions which we usually make for communication or education. The key to animation is to live in dialogue. But the fact is that most work with people is a process of telling, teaching, or at best, extending to them some special knowledge.

Real dialogue (or deep mutual speaking and listening) turns this approach inside out. Because it is not just telling ... it is listening. It is not just teaching ... it is learning with. It is not extending knowledge ... it is discovering the richness of knowledge already present in the life of the people - knowledge which they themselves may have come to believe does not exist.

Dialogue means discussing the life we share - the world in our midst - so that together we can discover the things we want to change. (Dialogue is not the action of an I, nor is it the action of a small powerful group.) The animator can think of himself or herself as entering a different world - the world as it is experienced by the people he/she is working with. It is a loving act, which does not say "no" to the known world of the animator but says a clear "yes" to the life and experience of the people.

As the animator listens and shares in the life of the community, he/she will become aware of the discontents, the worries, the deep and nagging questions of the people, such questions can be profound because they have to do with a people's sense of human dignity. These questions can also be so difficult to take hold of that even the people themselves may not know what is concerning them. These questions have to do with the relationships of men and women to their natural environment, their relationships with their ancestors, their relationships with each other and their relationships with the land and the produce of the land. These are the matters of basic human dignity. In scientific language we call them social, economic and political affairs.

As the animator begins to see and understand, then his/her role becomes more concrete because now the animator can help the people to see. This can be done by re-presenting to the people the life situations which they are having difficulty seeing. Their condition is like being inside a box and therefore not being able to see the box. A re-presentation can help the people to get out of the box to see it.

Paulo Freire, who explored this process of animation with peasants of northeastern Brazil, used slides and drawings to objectify or show in a real form the life of the people. In this way their life

> "The development issue is not the amount of money and expertise we can hand out but the prophetic fire and depth we can communicate to ask new questions and summon people to take their destiny in their own hands together as co-workers with God."
>
> Phillip Potter

became for them an object - something concrete which they could talk about, criticize and act upon. The idea of re-presenting is a reverse approach from that of presenting, which is the common method of teaching and communicating. In the act of re-presenting the animator tries to make simple, clear and concrete for the people what they already know. It is a process of "making alive" because it reverses the process of presenting. Over the years, "presenting" has convinced the people that they do not know.

But what kind of picture will accomplish this re-presentation? The picture must express the basic question which the animator has perceived. Freire uses the example of labourers constructing beautiful buildings of Brasilia, their capital city. He explains that the workers were building beautiful houses, "but they did not have houses". A picture of men with bricks, trowels and mortar working on a building helped the people to clarify the nature of their true situation, one of enslavement. A picture might be of wharf workers or road labourers or market women or provincial officers. A picture of a man in grass clothing standing in an outrigger canoe holding to the rope of an administration vessel has proved effective in helping people to see themselves, and to voice their sense of injustice about economic and political arrangements.

A development worker reported hearing a man declare "These politicians are trying to sell us like a basket of kumala". The words reveal an awareness of the inhumanity present in the political structures of which that man is a part. As long as he was sunk in these structures unable to control them, he was unaware. He could not see the box. Once he sees, and once he knows he sees, then he is motivated to begin to shape structures that restore to him his human rights and dignity.

Sometimes these questions about the meaning of life or the injustices that oppress us are called "themes". The themes in the life of people are the dilemmas which, in a sense, give the people energy. The themes stir them, motivate them, get them going. To the extent that the theme can be clarified by the people, they are capable of choosing an action to overcome the obstacle and improve their own quality of life.

Or the re-presentation may not be a picture. In PNG today there are many artists of the contemporary struggle. Poets and playwrights are expressing the dilemmas, the sorrows, the confusions in the life of today's people, all of whom are caught in some way in the whirlpool of change. Any of these expressions of the deeper reality of life - where we play out the drama of winning our human dignity and our cultural identity - can be used to re-present to the people their own specific themes.

> We must find ways to stimulate our people to ask themselves basic questions about where they are going, what forces are taking control over their lives:
>
> "What is happening to our young people?" / "What is happening to our ground?" / "What is happening to our customs & values?" / "What is happening to our money?"

In this use of pictures, poetry, plays and even some radio programmes and newspaper quotations as re-presentation, a totally different understanding of media emerges. The media are no longer aids to the communicator but become instead the medium or means through which people dialogue about their world. The picture or drama or poem stands in the midst of people - re-presenting to them their own life, which is the true medium for their dialogue. In this way men and women can begin to fashion and refashion their world; they can create and recreate their culture in their own time.

The need to live in dialogue never ceases in this process. The animator does not tell the people their themes. He/she represents them in such a way that the people can discover and speak clearly about them. The role that follows may be in planning a strategy and finding the necessary resources, but this stage too is one of saying "yes" to the strengths and knowledge that the people already posses.

(For pictures, search the files of a government information office. Collect the pictures in magazines or newspapers. Borrow pictures of people engaged in their everyday life from the social studies files of the education department. Calendars may also yield thematic representations. Photographers can make their own slides and prints.)

Some examples of the way this approach has worked in communities may help to encourage leaders who deeply trust the people and who seek to stimulate and organize them. But some warnings are needed.

Animation is a long process. People are not empowered to act overnight. A few sessions using techniques of animation will not prove to be magical solutions. Ideas used by other people in other settings cannot be transferred to another community. Every community has its own life, its own themes, which give the people a unique destiny. Some communities may share common themes, or a nation may have its themes, but it is important for the animator to realize that he or she will need to invent the media that will help a particular community to see its own life. Also through the animation process, some people may begin to change their behavior, but for most people to live differently is a very risky struggle, demanding patience and understanding.

The following examples use Biblical quotations together with pictures to open up the life situation. These are often a good starting point because most Papua New Guineans respect the Bible. However, other written materials which express the basic ideas of justice, truth and human dignity - national constitution, human rights declarations, Eight Point Plan - or written statements by trusted leaders - can serve as well, providing they have a place in the life of the people.

cont'd

JAMES CHAPTER 2

My brothers! In your life as believers in our Lord Jesus Christ, the Lord of glory, you must never treat people in different ways because of their outward appearance.

Suppose a rich man wearing a gold ring and fine cloths comes in to your meeting, and a poor man in ragged cloths also comes in.

If you show more respect to the well-dressed man and say to him, "Have this best seat here," but say to the poor man, "Stand, or sit down here on the floor by my seat," then you are guilty of creating distinctions among yourselves and making judgments based on evil motives.

Here is a picture that was used to help people face the discomfort they felt in relationship to traders.

These questions guided the discussion:

What is happening in this picture?
What are the thoughts of the man?
How do you think he feels?

Share stories about ships coming to your village or your island. Think about these things:
Why did the ships come?
Why do they come today?
Ships bring much to the islands. What do they take away?
Is the man richer or poorer because of the ship?
What will happen to him?

Through this discussion a group found that their romantic ideas about ships, part of the stories of the past, do not fit the real life situation.

This picture helped a group of mothers to rediscover their role as teachers of their children. Most parents and other relatives today have given away responsibility to formal schools and no longer have confidence in their knowledge, skills or ability to teach.

The picture shows a boy who used the materials of nature to change his environment. His bow and arrow is a fundamental tool, created by him or the people who teach him. He represents to a community the reality that they are creators of culture. In today's society, where people feel that culture is pouring in upon them, requiring their adaptation, they can begin to rediscover their creativity and traditional self-reliance. The animator read the Biblical passage from Genesis (1:27-28) and used these questions to keep the discussion moving:

What does it mean to "subdue the earth?"
How has this boy subdued the earth?
In what ways are we master over "the fish .. the birds .. and every living thing?

Who taught this boy to make a bow and arrow?
Who taught him where to look for fish?
What are some other things he has learned from the people of his village?

Man's religious understanding of himself can affect his power to create or to believe that he is capable of changing the conditions in which he lives. This picture has helped a community to think about their confusion around the idea, "what is man?"

cont'd

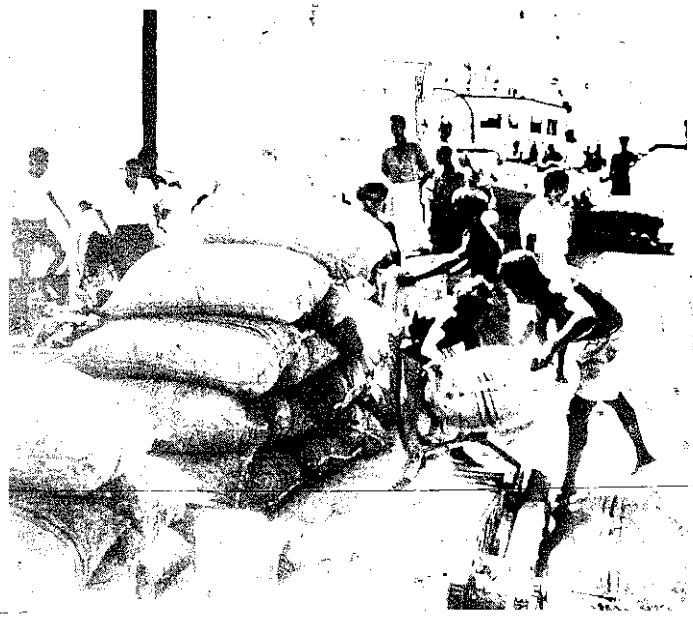

What are we saying about ourselves and who we are as human beings?

What are your thoughts as you look at this picture? Share them with others. Does this man remind you of someone you know? Tell a story about him? Read Psalm 8:3-9. Through Biblical revelations we come to see man as he truly is. How would you describe this man? You may choose words such as the following or think of others:

slave	ruler	creator	free man	liberator
master	servant	imitator	prisoner	sinner
powerful	small	intelligent	alone	
weak	mighty	ignorant	together with others	

cont'd

This picture helped a group that was troubled by the fact that their work was no longer related to their community life. The animator asked, "Who are these people working for?" and then later read some statements about socialism from the writings of Julius Nyerere, the president of Tanzania in East Africa. The people were able to distinguish between work which they do (1) for money, (2) for self-advancement, (3) for community, (4) for businessmen who live outside the community. They were able to see how patterns of work often conflict with their basic beliefs about the purpose of work.

A good source of pictures is the CAVA Calendar - The National Catholic Calendar, available in many bookshops or from CAVA Studio, Box 133, Goroka.

Contributed by: R. Coop, Box 90, Rabaul.

CHANGE rarely takes place when people are "comfortable" or think that they are comfortable. A tension must develop before persons or groups can have meaningful change. These tensions are often expressed as a felt need, and are finally articulated in one way or another.

Community development workers who merely help people to become "comfortable", who simply do things for people - identifying and analyzing their problems for them, and "doling out" answers, are part of the problem, not part of the long-term answer.

INFORMATION ON SOUTH PACIFIC ISSUES

POVAI

People's Action Front, Suva, Fiji. F$3.00

POVAI aims to provide information and views on the various struggles of people in the Pacific to determine their own lives. Contains material not usually found in the regular news media. Six issues per year.

SURELY YOU CAN HELP US IMPROVE LIKLIK BUK! SHARE YOUR EXPERIENCES IN THE IMPORTANT WORK OF BRINGING ABOUT MORE SOCIAL AND POLITICAL AWARENESS. SEND AN ARTICLE TO LIKLIK BUK, BOX 1920, LAE.

Modern and Traditional

THE CONFLICT BETWEEN TRADITIONAL MELANESIAN AND MODERN WESTERN VALUES AND GOALS IN DEVELOPMENT

SOME TYPICAL TRADITIONAL MELANESIAN CHARACTERISTICS OR GOALS	SOME TYPICAL WESTERN SOCIAL CHARACTERISTICS OR GOALS
The traditional Melanesian societies sought to preserve a state of stability, balance, harmony. Above all, the leaders struggled to keep their group intact as a society, to survive as a people. This usually meant guarding against change. The strong communal bonds were emphasized. Individualism was considered threatening, and was frowned upon.	Most modern western societies prefer an open society with capacity to change. Individualism in encouraged. There is great mobility, with persons free to find "community" on their own terms. Privacy is valued. Bonds of kinship are often very weak. Security is often based on a job or on the nuclear family.
Children were educated informally and practically right in the village to take clearly defined roles which reinforced the bonds of kinship and interdependence.	Children are educated formally in classrooms, often rather theoretically, often away from the immediate community, with a great diversity of roles, opportunities for specializations.
Leaders, or "big men" emerged through a complex informal process, usually an unspoken process, to defend the group, organise the people, settle disputes, and manifest personally the wealth, dignity, and strength of the group.	Politics are highly developed, formal. Leaders are elected through a clearly defined process, with leadership centered more on intellectual rather than physical qualities. The leaders don't carry the great range of functions, as in Melanesian societies. A great deal of "delegating" takes place.
Relationships with outside persons and groups were entered into very cautiously over a long period of time.	Relationships with other persons and groups tend to be entered into easily, but are less personal, more superficial, more easily broken.
Objective concepts of right or wrong did not really thrive. Behaviour was promoted which supported kinship obligations and customs more than any particular moral code. Enforcement was carried out through social pressures. Conflict within the group was minimized, but conflict with outsiders was quite common. Identifying with a side of "right" was not nearly so important as identifying with wantoks. Handling of conflict within the group was more concerned with reconciliation than with punishment.	Most western societies tend to be rather moralistic (at least most of them have rather highly developed laws and moral codes, even if they're not closely followed in practice!) Enforcement is quite formal with more emphasis on punishment than on reconciliation.
The ground was not only a place on which to live and produce. It was the seat of cultural ties, the focal point for human relationships, cultural values, language, ambitions. A specific geographical place where a person has his physical and spiritual roots was the place of one's ancestors, the location of the familar myths handed down from one generation to the next. It could not be owned by any one individual, and "sale" or lease of land meant something far different and less absolute than in the western sense of the word.	Land is primarily a place on which to live, a place from which you can do business, or a resource for production. It is seen for its usefulness, not for its sentimental value or religious significance. Individuals can often own land and do almost anything they want with it - divide it, sell it to anyone, destroy its usefulness if they please. It's interesting that in very densely populated countries such as The Netherlands, Israel, Japan, however, we see land laws coming back to tribal-type controls.

The primary economic goals were subsistence and prestige. Through communal enterprise food was grown and collected. There was much sharing, little storing. Capital was accumulated in the form of food (usually pigs) or money (such as shell money) which could buy food, and in a highly ritualistic fashion was directed in most complicated ways to achieve situations which might return maximum prestige. Prestige was often visibly measured in terms of pigs and women.	Economic goals of most western societies, as in Melanesian societies, might be seen in terms of subsistence and prestige. However, they are usually more simple and direct: earning money to improve physical comfort, convenience, security, prestige. Wealth is defined differently. The house, the clothing, the car, the electrical appliances are all visible signs or criteria of success or failure. Pursuit of success is carried out in highly individualistic manner. Sharing is limited usually to nuclear family, there is much saving, much accumulation of wealth by individuals. Capital is often accumulated for the purpose of enhancing earning capacity.
Exchange was not mainly for the purpose of obtaining consumer goods - it served to maintain balance, to bring about sharing, to play out "one-upmanship".	Exchange is very practical, not ceremonial, usually based on cash, and is seldom subject to group control.
The economy as a system was not dynamic, but was rather static or changeless.	The economic system is highly dynamic, very subject to change and fluctuation.
Division of labor was mainly between men and women. There was otherwise very little specialization or division.	A high degree of specialization is found.
Religious and secular goals were highly integrated. Religious knowledge gave power for economic and other forms of success. Religion was a community matter, not just an individual matter. Sharing, rather then obedience to a religious code, was stressed. Fulfillment was seen in terms of this worldly life, not in another unseen life.	In most western societies there is a clear separation of the sacred and the secular. Religious knowledge is irrelevant to economic success. Religion is a private, individual matter, often, with even the family avoiding interference with individual religious preferences. Religion often aims at fulfilment in some other life, rather than this one.

Prepared from various papers of the Melanesian Institute

SOME GUIDELINES FOR DEVELOPMENT PROJECTS

These guidelines indicate the kinds of activities which the Melanesian Council of Churches would like to encourage:

1. Community-oriented activities which
   a) Serve human needs in the context of the whole community;
   b) Have incentives and vested interest for success resting with the community served, and not with outside leadership;
   c) Foster group cooperation and community spirit.

2. Indigenous-led activities which
   a) Represent indigenous initiative, use indigenous leadership, and which "release" the energies of the people.
   b) Emphasize indigenous participation in decision making, and tend to build indigenous responsibility and initiative.

3. Activities which produce self-reliance rather than dependency (especially in relation to things like leadership, running expense, expertise, supplies of essential materials).

4. Activities which aim for long-range, basic effect, rather than short-term amelioration.

5. Activities which
   a) Promote reconciliation and understanding between persons, clans, groups, and larger communities.
   b) Enhance cooperation, coordination, and utilisation of existing resources.

6. Creative activities which lead the way in trying or demonstrating potentially useful techniques.

7. Activities which help to make the churches' resources of manpower, expertise, and organizational network available to the larger community.

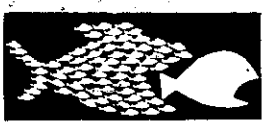

COOPERATIVES AND DEVELOPMENT

The key to successful cooperatives is EDUCATION IN BASIC HUMAN DEVELOPMENT. The process of creating awareness is the most vital need in Melanesia today: awareness for and participation in what is happening. Then secondly, and only secondly can come the training in economic development.

The second aim of development education should be to devise economic models based on our culture, social needs, and environmental patterns. We consider many of the imported economic models to be irrelevant or harmful.

Of all the imported economic models, the community and communal aspect of the cooperative model is the nearest to Melanesian life traditions. However, in many cases cooperatives have been wrongly led to develop as big companies, dependent upon foreign expertise, and overly concerned with profit-making.

(Edited portions of a report from the Tubiana, North Solomons, Seminar on Cooperatives, June 1976.) For further information write:
Church and Society Programme
Pacific Conference of Churches
Box 5768
Boroko, PNG

WOMEN IN RURAL DEVELOPMENT

"INTERNATIONAL WOMEN'S YEAR WILL BE A SNARE AND A DELUSION UNLESS IT INCLUDES MOBILIZATION OF APPROPRIATE TECHNOLOGY TO HELP THE OVERBURDENED PEASANT WOMAN EASE THE BURDENS OF HER TASKS, BECOME MORE SELF-RELIANT, AND ACHIEVE GREATER DIGNITY AND EQUITABLE STATUS. OVER THE YEARS, VERY LITTLE ATTENTION HAS BEEN GIVEN TO HELPING HER FIND THE SKILLS AND TOOLS SHE NEEDS TO BECOME A BETTER FOOD PRODUCER AND PREPARER, WITH BETTER CONSERVATION OF HER ENERGY, AND BETTER NUTRITION FOR HER FAMILY. THE LONG NEGLECT OF HER NEEDS AND CLAIMS IS, TO MY MIND, THE MOST OUTRAGEOUS SIN OF BOTH NATIONAL AND INTERNATIONAL STRATEGIES FOR DEVELOPMENT AND FOR THE EXTENSION OF BASIC HUMAN RIGHTS. THE TIME IS OVERDUE TO OVERCOME THIS NEGLECT."

From a World Council of Churches staff report.

A FEMALE BODY COUNT IS NOT A GOOD MEASURE OF THE MEANINGFULNESS OF WOMEN'S INVOLVEMENT OR THE HELPFULNESS OF A PROGRAMME. WOMEN SHOULD PARTICIPATE IN EVERY ASPECT OF AN INSTITUTION PROVIDING SERVICES TO WOMEN AND CHILDREN NOT ONLY AS RECIPIENTS OF SERVICES BUT IN DESIGNING PROGRAMMES, CARRYING THEM OUT, SERVING ON GOVERNING BOARDS AND IN EXECUTIVE LEADERSHIP.

"RURAL WOMEN HAVE BORNE ON THEIR BACKS THE ECONOMIES OF WHOLE NATIONS, THE WELL-BEING OF MILLIONS. THEY HAVE DONE THE WORK, WITHOUT WHICH THEIR FAMILIES, THEIR COMMUNITIES, THE WORLD, WOULD FALTER AND COLLAPSE INTO CHAOS. THEY ARE AS STRONG AS THE LAND, AND AS THEY FREE THEMSELVES, THEY BECOME STILL STRONGER, AND ALL THE WORLD WITH THEM."

From the filmstrip "As Strong As The Land"

ARE YOU CONSIDERING A PROJECT FOR WOMEN?

1. To what extent are the women who are the project's beneficiaries involved in its initiation, formulation, direction and evaluation?

2. How does the project empower women to affect their own situation, enabling them to be self-reliant and self-determining? What opportunities does it offer for retraining or upgrading skills which enhance opportunities for self-reliance?

3. How does the project help develop economic, political and family life patterns and models that are liberating?

4. To what extent does the project include women from the poorest or most dependent sectors of their society?

5. In what ways does the project increase political consciousness about social and political status, enabling women to speak out about their concerns to government, church, farmers' or labour organizations, and other institutions that affect their lives?

6. How does the project strengthen supportive links among women, and help to reduce the sense of isolation so often experienced by rural women?

7. How does the project integrate rural communities into processes of national and regional development?

8. How does the project encourage development of national and local institutions, enabling them to identify problems, plan solutions, organize work and carry out operations all on an integrated/comprehensive basis? Could it serve as a model for other projects?

cont'd

9. What provision does the project have for monitoring its affect on girls and women at every age level?

10. How does the project contribute toward a more positive self-image for women, especially in perceptions of themselves as important members of the rural labour force?

From: Women in Rural Development
The Women's Division
Board of Global Ministries
United Methodist Church.

RURAL DEVELOPMENT TRAINING FOR WOMEN

South Pacific Commission,
Community Education Training Centre,
Box 5082,
Raiwaga PO.
Suva, Fiji.

Gives a 10 month course in home economics for leaders and trainers, mainly for women. Programme includes practical skills in meal planning, use of foods, home gardens, health, first aid in the home, sewing/clothing, use of family resources, handcrafts, techniques and methods of teaching.

Communication

VISUAL AIDS

THIS DOES NOT SIMPLY MEAN MOVIES AND EXPENSIVE OVERHEAD PROJECTORS! You can make many of your own visual aids.

Visual (sight) aids help teachers and leaders to create and maintain interest, increase retention, develop greater understanding, provide variety, simplify complicated ~~ideas~~, create realistic impressions, motivate, and can help us to reduce the number of words we use.

Some examples:

MODELS: are three-dimensional. They can reduce large objects, enlarge small objects, provide interior views, accent important features, and may be assembled or taken apart. They can emphasize fundamentals and remove non-essentials. You can make your own models.

PHOTOGRAPHS AND SLIDES: can be very real. They can reduce large subjects, enlarge small subjects, can take us to other times and places. They can stop action, can be easily kept up to date. They can spotlight a problem or issue. We can easily collect pictures from magazines, newspapers, pamphlets. Slides can be made at a relatively low cost, if we already have a camera, and the pictures can easily be arranged and re-arranged. Slide projectors are much cheaper than movie projectors.

CHALKBOARDS: are perhaps the most widely available visual aid, familiar to us all. But few teachers have really developed their techniques for using a chalkboard. Here are some ideas:

a) Start with a clean board
b) Use large pieces of chalk, if possible, and soft chalk, if possible.
c) Use coloured chalk as well as white.
d) Print wherever possible.
e) Use straight lines. Keep material neat, orderly, and uncrowded.
f) Use templates or patterns if you have to repeat a basic form many times.
g) Use a good eraser.
h) Use a stick for pointing.
i) Put materials on the board step by step as you present your idea.
j) Plan ahead what you will put on the chalkboard and when you will put it.

Other notes: Try to use a glare-free board. A green-coloured board is restful to the eyes. Don't wash the board with water very often - it will fill the surfaces. If you want to make semi-permanent marks, moisten the board before writing.

FLANNEL BOARDS OR FELTBOARDS can be attractive, colourful, inexpensive, versatile, and make rapid presentation of your ideas very easy.

As you know, flannel is a soft, fuzzy cloth. A flannelboard may be just as big as the cloth you can buy. You stick things on it - letters and words, pictures and shapes. You can stick the following things to flannel: flannel, styrofoam, blotter paper, sponges, sandpaper, yarn, suede paper, "flocked" paper.

You can make nice charts and graphs on a flannelboard using yarn. Black flannel makes a striking background. Flannel may be attached to a piece of plywood with a light coating of glue.

CHARTS are a sort of stylized picture. Some types: time lines, streams (showing relationships between parts and the whole), trees (showing relations of whole to parts), flow charts (showing routing or process), issues (pro and con), timetables, organisational structures.

Charts may be simple, pin up, flip charts, hinged, hidden, plastic or acetate overlay, in the form of a thermometer or a clock.

POSTERS can teach a process, remind viewers of something, motivate people, advertise events or campaigns. They can be made in any local situation.

Attract attention by using colour, contrast, motion, shape, textures, size, mystery, titles, repetition, unusual elements, white space. Produce outstanding posters through competitions.

Letters should be large and simple. 1 cm letters can be read about 5 m away; 2 cm letters can be read about 10 m away; 5 cm letters can be read about 20 m away.

OVERHEAD PROJECTORS are expensive, but if available can be very useful. You can stand in front of the group and see your listeners' faces. You can write or draw beforehand, or "on the spot".

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MOVIES are very popular, and have advantages, especially with large groups. But often we overlook the disadvantages. They are expensive. Because they are expensive there are only a limited number of view points on a given subject; especially if produced by a business firm or a government information agency there may be biases.

Because movies are also entertainment they cannot be stopped for questions. When the film is over the question has lost its urgency or is forgotten.

Because movies are passive learning experiences knowledge, ideas, and viewpoints are often learned without realizing it, and so too the biases and distortions.

Some suggestions if you want to use movies. Preview your film. Make sure that the film is directly related to your objective.- and if it isn't, be ready to stop the film or make comments. Prepare the group, prepare the room, prepare the machine so it is ready to go. When the film is finished, go back to the subject quickly, relate the film to the subject, and correct any errors in the film immediately. Discuss the film.

ALWAYS ASK - ARE MY VISUAL AIDS WORTH THE TIME, EXPENSE AND EFFORT INVOLVED?

(p 249)
(p 243)

VISUAL AIDS FOR COMMUNITY EDUCATION

Most people who work with rural communities are interested in finding more effective ways of communicating information or of starting a discussion. Sometimes just sitting down and listening and talking to people is the best way. There may be other times when you are not able to be with them, or you may feel that talking with them is not the most interesting way of communicating, or of helping them to understand and remember something important. You may want to try a more dramatic way to encourage people to gather to think about a problem.

Students at the University of PNG have been experimenting with different forms of communication for rural communities, working with the University's Educational Research Unit. Here are some examples of what can be done. All (except film) are cheap and not too difficult.

Short Plays: Act out stories that are entertaining and educational, through clubs, youth groups, school groups.

Slide-tape sets: Combining cassette tape and colour slides, are particularly useful.

Cassette tapes: An entertaining play or a cassette tape may convey much information and can be used many times. It can even be used on the radio.

Movie films: If you have the money and expertise for making them, they are almost always enjoyed and can help to start discussions.

Literacy sheets: Simple one-page pidgin literacy sheets with line drawings can enable people to read things related to their own village projects.

Demonstrations: Instead of talking about a good diet and new ways of cooking food, the better way is to have people actually watch and cook and taste.

For more information on any of these forms of communication, write the Educational Research Unit, UPNG, Box 4820, University.

Initial contributor: G. Kemelfield, ERU, Box 4820, University.

VISUALLY SPEAKING THIS SECTION VIOLATES NEARLY EVERY PRINCIPAL OF EFFECTIVE VISUAL COMMUNICATION, DOESN'T IT? HELP US BETTER COMMUNICATE VISUALLY THE USES OF VISUAL AIDS NEXT YEAR. CONTRIBUTIONS TO LIKLIK BUK, BOX 1920, LAE, BY 15 AUGUST, 1977! DO IT NOW, OR SOONER.

Preparing Instructional Objectives, by R. Mager, Fearon Publishers, Inc, Palo Alto, California, 1962, US$1.75.

A very helpful, unconventional presentation with discussion of techniques for getting feedback from trainees. The moral of the book: "If you're not sure where you're going, you're liable to end up someplace else - and not even know it!" Intermed. level.

RURAL YOUTH ORGANIZATIONS

BOUGAINVILLE FAMAS KLAP
c/- St. Patrick's Agricultural School,
Mabiri, Box 106, Kieta, Bougainville.

Bougainville Famas Klap is an entirely indigenous self-help association of farmers, founded in 1971, and fully directed by Bougainvilleans. Emphases are to foster dignity of rural life, fellowship and unity, self-help, and greater security for members. Provides a forum for discussion. There is an annual fee of K10.00, and a distinctive badge.

An annual meeting is held, always in conjunction with a field day or agricultural show. There are also monthly area meetings and field days on members' farms.

Agricultural text books have been produced in Pidgin. A bimonthly farm newspaper "Bougainville Fama" is issued.

Members also help with agricultural projects at primary and secondary schools, help members teaching agriculture on home or village farms, assist with agricultural correspondence courses.

There is a very close association with the St. Patrick's Agricultural School, due to the fact that the organizers were graduates, and due to the outstanding work of Brother Patrick there.

YANGPELA DIDIMAN,
Rural Youth Movement,
Box 30,
Banz. WHP.

Yangpela Didiman is a rural self-help and self-reliance movement which is sponsored by the Lutheran Economic Service, the development branch of the Evangelical Lutheran Church. Its aim is to assist group self-help action at the village level.

Village clubs, school clubs, and other interested bodies may ask for teaching aids, literature, and information. Groups of clubs organize meetings and courses which are conducted by Yangpela Didiman staff.

A monthly newsletter is issued in Pidgin.

A new group is accepted into the movement only if the leaders provide a programme which is accepted by the members of the group. Membership fee is not compulsory, but most clubs charge 50t per year, which is used for sporting equipment, musical instruments, kerosene lamps, or other selected local needs.

Typical local projects: food production projects, cash projects, community projects (such as building a community centre, literacy classes, sports, community gardens for experiment or seed production, road and bridge-building), exhibitions, competitions, field days, demonstrations. For most of these activities there are booklets, pamphlets, and other materials available at the headquarters.

The Yangpela Didiman organisation seems to be going through a period of difficulty. Maybe they've expanded their funding and staff too fast and too much.

CHURCH AND DEVELOPMENT

In order to give validity and consistency to its development message the Church must be prepared to bring about changes in its own life. It should strive to become in a local sense the self-actualized, self-propelled, self-propagating people of God.

As much as possible the Church should recognize and work with the local leadership which has emerged naturally, and should avoid imposing its own leadership. Special encouragement might be given to those, especially young persons, showing leadership potential. By example the Church should seek to promote Servanthood as the appropriate leadership style.

The Church should avoid overlapping or competing with government or other agencies, and should strive to consult and coordinate as widely as possible.

The Church should make its resources of manpower, expertise, organisational network, and wherever possible, finance, freely and unselfishly available for overall development effort.

(Edited excerpts from a statement of The Melanesian Council of Churches)

CHURCH AND PEOPLES' MOVEMENTS

One seminar has said: "Development is not an idea. It is people participating in planning their own future."

Romans 8:22 expresses the fact that the creation or the world surrounding us is not at rest. It is "groaning", or in constant struggle. Human beings are in the centre of this groaning or struggle. Man is at the centre of his environment, which he is called to "subdue", or take care of.

Human development is social, and total human development embraces everything that affects the life and growth in a society: political, economic, social, cultural, religious. These parts of the total are inter-related and cannot be separated.

We ask ourselves: "How are we involved together in serving and supporting the process of total human development in PNG?" The various groups to which we belong are an expression of our "togetherness in fellowship". This togetherness or solidarity is an important part of the concept of total human development.

At the same time this poses challenges to our perspectives and vision. In the North Solomons, The Gazelle Penninsula, Papua, The Highlands, regional united action has thrown people from various groups, various Churches, together. In many cases the Churches have identified with these peoples' movements, in some cases not. Sometimes these movements have created sharp divisions within the Churches.

If the Churches are really concerned about people, then peoples' movements must concern the Churches. Church leaders cannot simply sit back and watch as the people insist on participating, insist on having the kind of development that they really want.

It is interesting, and perhaps inevitable in these peoples' movements that there are new forms of unity cutting across old denominational divisions, old tribal divisions, and at the same time, new divisions created. We must be prepared to accept this if these movements are truly of the people.

Peoples' movements are at the very grass roots of development and whether or not we agree with them in every detail, they convey the aspirations of the people for total human development.

Contributed by: D. Avi, United Church, Waigani.

BUSINESS GROUP INCORPORATION ACT OF 1974

This law says that if three or more people from the same clan or tribe wish to set up a business they may register the business as a Business Group, and except for dealings with people outside the group they may run the business according to their

traditional laws and customs.

There are good reasons for registering a business, and a Business Development Officer can explain these to you. It will make it easier to deal with a bank, for example.

Before this law was made, registering businesses was not always suitable for village businesses. This new law was designed especially for PNG conditions.

A successful village group chairman in the highlands says, "Because we are registered, it is much easier to talk to banks, and some kinds of grants are available only to registered groups ... A business group is easier to run than a company ... It has given our clan a sense of pride ... The Development Bank recognizes our labour in building up capital, because we are registered."

Some important points in this law:-

1. Only Papua New Guineans may form Business Groups or receive any of the profits of a Business Group.

2. There must be at least three members of a Business Group and all members must be bound by the traditional laws of their customary group.

3. Any disputes between the Business Group and a member of the Group, or between members of the Group, are settled by the Dispute Settlement Authority who has been named by the members of the Group. He will judge the dispute according to the traditional laws followed by the Group.

4. Written records of the Group's activities do not usually have to be kept, although the Registrar may direct that certain records are kept.

5. Receipts for contributions must be issued.

6. A statement of assets and liabilities must be prepared once a year and presented to the Registrar of Business Groups.

7. The liability of members is limited.

8. The liability of committee members is unlimited for actions incurred while they are committee members.

9. It is possible for a co-operative society, a company, an association or a savings and loan society to convert to Business Group status.

10. When an application for Registration as a Business Group is lodged, a fee of K10.00 must be paid. If the application is refused the fee is not refunded.

If you wish to form a Business Group you should contact a Business Development Officer in plenty of time because the application process can be very slow in some provinces.

Initial contributor: BDO, Mt. Hagen.

SKUL BILONG STUAKIPA, Box 330, Wewak, provides practical training for a minimum of one year in all aspects of retail store management. Because of limited facilities, the Skul is open only to people from the Sepik.

TELEPHONES

The telephone service in PNG is one of the best in any developing country. It is useful for the ordinary citizen as well as the businessman and the government.

If you want a telephone in your house or business you should write or visit:

The Manager
Customer Service
Postal and Telecommunications Service
Port Moresby, or Lae, or Rabaul, or Mt. Hagen.

He will want to know:

1. The name of your village or town.
2. If your place is near a road.
3. If your place is on a hill,valley or flat land.
4. If there are tall trees all around.
5. If you have electric power.
6. How many telephones you need.
7. If there are other villages close by that want phones.
8. If you want a public telephone as a business.

He will help you to decide the best service for your area. There are many kinds of service. Some are:-

1. An ordinary telephone, connected by wire on posts or underground.
2. A manual VHF radio, good for a distance of up to 40 kilometres to the nearest base station, if there are no big hills between the radio and the base station.
3. An automatic VHF, so that you can dial the numbers yourself without waiting for the operator.
4. A coin operated public telephone.
5. An outstation (SSB) radio. Although not as good as VHF it will operate anywhere in PNG. You can only get one if there is not another service within 10 kilometres.

You will need power for radio equipment, but if you don't have electricity you will need a battery charger using a petrol engine, water, wind, or

sunshine.

Outstation radios require a licence which you get by applying to: The Manager,
Radio Branch,
Department of Public Utilities,
Port Moresby.

The cost of an outstation radio is K2000-3000 for all the equipment, and you still have to pay for each call or telegram.

Outstation radios are a public service and you must send messages for anyone who asks, although he must pay the cost. Anyone who feels an outstation radio is not doing its job properly can complain to the Manager, Radio Branch.

Telephone or outstation service requires planning. For new locations it may take 2 years to install a telephone or radio service. Post and Telecommunications owns the equipment and charges rent each month. First it must find the money to buy the equipment and install it, but you can speed things by loaning P & T the money and helping to dig trenches or install posts. You will need to plan ahead.

Because the equipment is expensive there must be someone to take responsibility for the radio or telephones.

POSTAL SERVICES

Many places that have a lot of mail still do not have Post Offices. An agency post office can be a good business and a help to the community.

Write to the Assistant Secretary
Postal Services
Postal and Telecommunications Dept.,
Port Moresby,
and ask about what you must do to start an agency.

Contributed by Posts and Telegraphs, Public Relations Office.

AGRICULTURE IS THE BASIS OF INDEPENDENT DEVELOPMENT

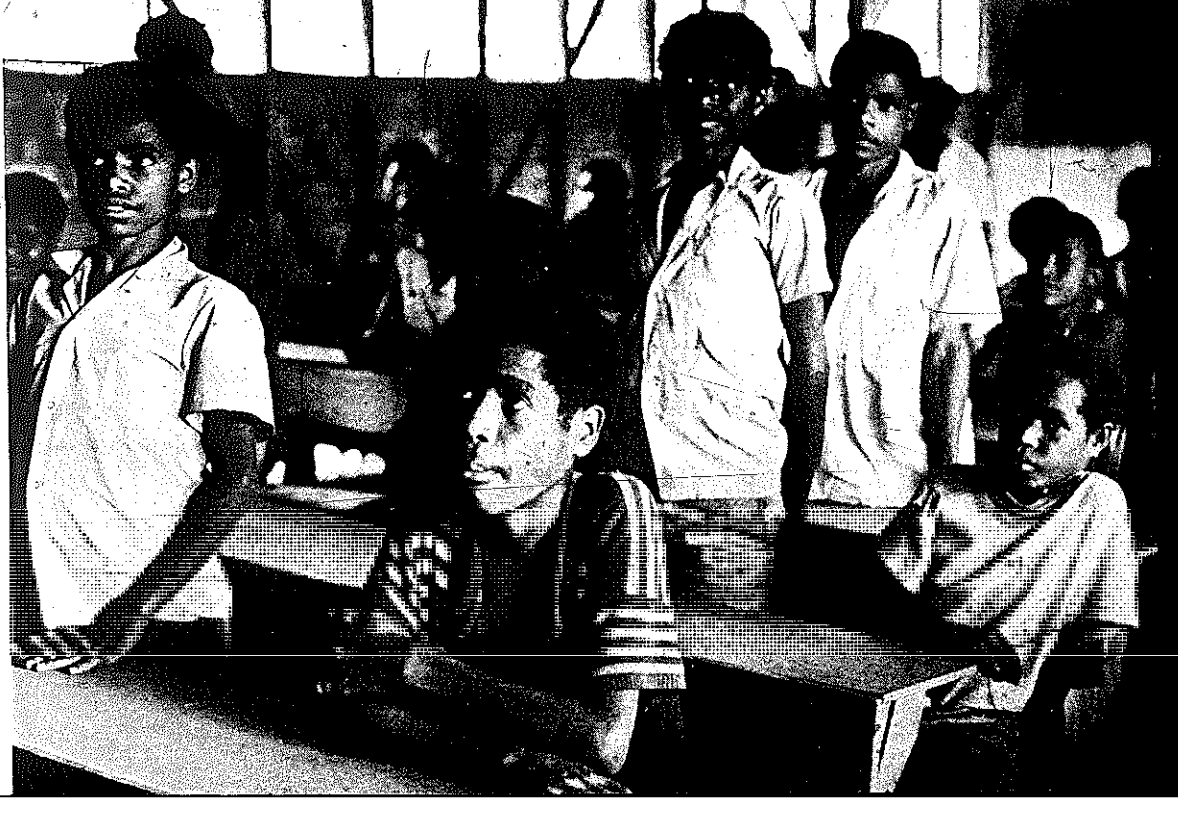

READ READ READ READ READ READ

LITERACY

READ, The Adult Literacy Magazine, Quarterly, published and printed by Summer Institute for Linguistics, Ukarumpa, via Lae. 25t per issue

Write S.I.L. for literacy info.

HEALTH

Nutrition

Nutrition is the study of food and how the body uses the food which is eaten. Good nutrition means that the body is getting enough of the right kinds of food so it can grow, work and stay healthy. Malnutrition, or bad nutrition, means that the body is not getting enough of the right kinds of food. People who are malnourished do not grow as well as they should, they do not have enough energy to work as hard as they might, and they are sick more often than people who are eating properly.

All people of all ages need to be concerned about the food they eat. We must choose food that will give us energy to work and that will protect our bodies from disease. Children need plenty of good food so that they will grow properly. Pregnant women and women who are breast feeding need extra food for the fetus to grow properly and so the mother can produce plenty of good milk without getting weak and malnourished herself.

In order to be well-nourished, a person must eat a variety of foods. The most common way to stress the importance of eating a variety of foods is to talk about the three food groups.

GROWTH FOODS are protein foods such as fish, meat, eggs, milk, beans, and peanuts. These foods supply more amounts of protein per unit of measure than foods such as leafy greens and sweet potatoes, although these foods provide some protein, too. Protein is essential for growth and body repair, so we should eat foods high in protein each day. It is especially important for children to eat protein foods, such as peanuts and tinned fish. Breast milk is the most important source of protein for babies.

PROTECTIVE FOODS provide us with the vitamins and minerals that our bodies need to function properly. Vitamin A is found in dark green and orange coloured foods.. Children who are not given these foods may go blind. Iron, calcium and iodine are important minerals in our foods. Iron is important as part of the hemoglobin in the blood. Calcium is necessary for formation of strong bones and teeth. Lack of iodine can cause goitre. All the salt sold in stores is iodized, and should be used to prepare the family's food.

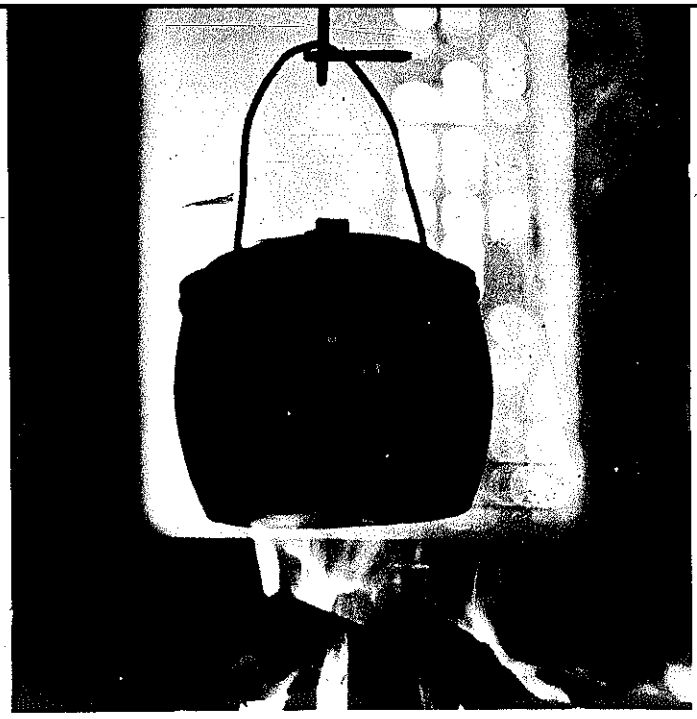

Traditional varieties of vegetables are better sources of vitamins and minerals than the newly introduced ones. In Tables 1-4 the vitamin A, vitamin C, calcium and iron content of three traditional foods are compared with three "European" vegetables. The amaranthus, aibika, taro leaf and pumpkin tips are better sources of these nutrients than are cabbage, cucumbers and lettuce.

Dark green leaves have much more iron, calcium and vitamin A in them than light green leaves do. Most of the local greens also contain more protein than imported varieties. Plants such as aibika, pumpkin tips and amaranthus, which are already being grown and eaten in most areas, should not be replaced by the less nutritious imported plants.

cont'd

Tables 1 - 4: Comparison of vitamins and minerals in traditional and introduced green vegetables.

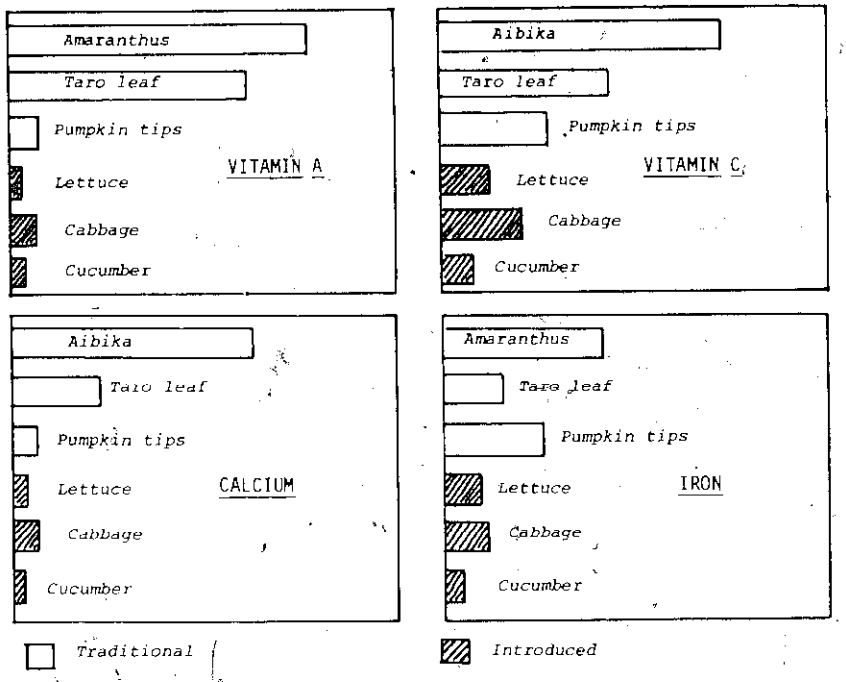

Staple foods, such as sweet potatoes, sago, taro, bananas, English potatoes and rice, are ENERGY FOODS, which is the third group. While these foods may provide some protein and vitamins, they are mostly valued for the calories they supply so we have enough energy to work. Fats are more concentrated sources of energy than the staple foods. Peanuts, pandanus and other nuts, coconut cream, drippings, butter and margarine are good sources of fat. Fat should be included in cooking, if possible, to add extra calories for extra energy. Most Papua New Guinean diets are low in fat.

Energy foods, ~~such as sweet potatoes, taro~~ and sago should always be eaten with protective and protein foods. Mixed foods provide better nutrition and are stronger foods. We should eat a staple food, plus other food, such as peanuts and greens with sweet potatoes, to make a good mixed food.

Good nutrition means eating enough of the right kinds of food. Children have small stomachs and it is impossible for them to eat enough in two meals a day to get enough food to grow properly. This is especially true when their main food is a bulky, high volume food, such as sweet potatoes. Children must eat 3 or 4 times a day. This means school children must have a noon-time meal so they will be more alert and able to learn better. Concentrated, low-volume foods, such as peanuts, tinned fish, beans, nuts, fats and meat should be fed to children as well as adults. These foods supply lots of energy as well as protein for growth.

Simply knowing about good nutrition is not enough. People must practice good nutrition, too. In nutrition, as in every other aspect of our lives, our actions demonstrate our real beliefs. We can show our belief in good nutrition by planting a variety of foods in our gardens, by eating a mixed diet, and by choosing nutritious snacks, such as peanuts and fruit juices instead of cheese pops and lolly water. This is a very important part of nutrition education.

Initial contributor: M. Cast, Nutritionist, Provincial Health Office, Box 458, Lae, (with excerts from an article by J. Eng, Area Nutritionist for the highlands).

BOOKS

(p 242)
(p 243)
(p 249)

Nutrition for Papua New Guinea. Nutrition Section, Department of Health, Konedobu, 1975 182pp. Based in part on "Nutrition for Developing Countries" by King, King, Mosley, Burgess, it is a must for field workers in PNG who are involved in Community Education activities. Cost K1.60 from UPNG Bookshop, Box 4820, University.

Papua New Guinea Cook Book. Louise Shelly, Wirui Press, 1977, 105pp. Written by a former CUSO worker the book gives descriptions of local foods and traditional and modern recipes for PNG, as well as a collection of international recipes using local foods. This would be a good book for foreigners living in PNG who want to use more local foods in their cooking and also good for Papua New Guineans who want to try foreign recipes or recipes from

another region of the country. For sale in local bookshops.

The following posters may be ordered from: Health Education Section, Department of Health, Box 2084, Konedobu.

Pictures of Food suitable for use on a flannelgraph:

Food Series (2) Blood #51
Food Series (2) Body Building #52
Food Series (2) Protection #53
Food Series (2) Work #54

Kaikai bilong Man #124

Good Food Makes us Strong and Healthy #6 (shows the 3 food groups)

School Lunches #112
Child Care #66
Child Care - Good Food No 1 #62
Child Care - Attend Clinic No 3 #64
Good Food for Baby #59

The following teaching and visual aids can be ordered from: Nutrition Section, Department of Health Box 2084, Konedobu.

Booklets:
Good Food for Your Baby
Gutpela Kaikai bilong Bebi belong Yu
Food for School
Kaikai bilong Skul
Recipes for Papua New Guinea

Posters:
Good Food - Healthy Baby
Peanuts are Good for all the Family
Breast Feeding is Best
Food for a Baby at 6 months.

Journal: Nutrition & Development
Published periodically by the Nutrition Section, Department of Health. It contains articles pertaining to nutrition teaching and research of interest to teachers, health workers and other field workers.

Flipchart: A Happy Baby is a Healthy Baby.
A series of pictures, each accompanied by a short script in English, Pidgin and Motu, tells the story of 2 mothers and their new babies. It emphasizes supplementary feeding.

BABY AND CHILD CARE

Breastfeeding

All mothers should breastfeed their children until they are two years old. Breast milk is the best food for a baby because it is natural. It contains all the nutrients needed for the baby. There are other reasons why it is so good for the baby.

1. Breast milk is always ready whenever the baby is hungry.
2. It is safe because it is made and kept inside the breast.
3. The harmful bacteria which can get into drinking water and dirty feeding bottles never get into a mother's breast milk.
4. Breast milk has antibodies which help the baby to fight disease.
5. Breast milk never goes sour or bad, even when a mother is pregnant.
6. It is always the right temperature for the baby.
7. It does not cost anything and it does not give the mother extra work.
8. Breast-feeding makes mother and child happy.

Breast-feeding is the natural way to feed a baby. Any other way of feeding is called artificial feeding.

Bottle feeding - The Baby Killer ? *(p 243)*

"Third World babies are dying because their mothers bottle feed them with western style infant milk. Many that do not die are drawn into a vicious cycle of malnutrition and disease that will leave them physically and intellectually stunted for life."

"The frightening fact is that this suffering is avoidable. The remedy is available to all but the small minority of mothers who cannot breast feed, because mothers' milk is accepted by all to be the best food for a baby under six months old."

"Although even the baby food industry agrees that this is correct, more and more Third World mothers are turning to artificial foods during the first few months of their babies' lives. In the squalor and poverty of the new cities of Africa, Asia, and Latin America this decision is often fatal."

Why is bottle feeding dangerous for the PNG child? The risk of death or severe malnutrition is greatly increased in the child who is bottle fed.

1. PNG homes do not generally have functioning refrigerators for storing prepared milk. It quickly becomes contaminated and causes disease in the child.
2. Milk bottles and teats are difficult to sterilize. They quickly become contaminated unless boiled or soaked in sterilizing solution.
3. Milk products are expensive. They are often over-diluted to make them last longer. The child then starves.

What can be done? PNG women are extremely good with breast feeding their children, despite the fact that they themselves often suffer from malnutrition. They should all be encouraged to continue. For the more sophisticated there is the temptation to follow "European" patterns. They should be told of the risks and without exception encouraged to breastfeed their children.

In certain cases of illness in the mother, artificial feeding may be necessary. This will usually be commenced in a hospital using a cup and a spoon for the first 2 months of life and after that the baby is continued on a mainly solid diet.

Diarrhoea is a very serious disease in children. Always take the sick child to an aid post or health centre. When a child gets diarrhoea the mother must;

1. Give him water from a clean cup or with a cup and spoon. A child with diarrhoea should drink four or more cups of water every day.
2. The mother must also put a little salt and sugar in the water.
3. Do not stop feeding a child with diarrhoea. Feed him three times everyday and snacks 2-3 times everyday. Food gives the child strength.
4. Bananas are very good for children with diarrhoea.

Remember that diarrhoea is a very serious disease in young children and will happen many times when a child is malnourished. Not feeding a child that has diarrhoea makes the child very weak so he has little strength to fight the diarrhoea or any other infection.

Contributed by: M. Cast, adapted from Information written by C.M. Binns and Holst, Wapenamanda, EP. Quotes from "War on Want" publication.

WHAT MAKES CHILDREN GROW?

THE COMPLEXITY OF THE PNG NUTRITION PROBLEM IS REALIZED WHEN YOU ASK PEOPLE, "WHAT MAKES CHILDREN GROW?" (OR WHAT PREVENTS THEM FROM GROWING?) THE IMPORTANCE OF SUFFICIENT FOOD OF THE RIGHT KIND IS OFTEN NOT FULLY REALIZED.

SOME EXAMPLES OF THE DIFFICULTY: MANY CHILDREN ARE TOLD THAT IF THEY MISBEHAVE, THEY WON'T GROW. IN SOME GROUPS GIRLS ARE TOLD NOT TO PLAY WITH BOYS, OR THEY WON'T GROW. SOME THINK THAT TO EAT THE EGGS OF WILD BIRDS WHEN YOU ARE A CHILD WILL RETARD YOUR GROWTH. MORE THAN ONE GROUP, WE'RE TOLD, BELIEVE THAT PUTTING A CHILD'S BABY TEETH, AS THEY COME OUT, INTO A YOUNG GROWING BANANA STALK, WILL HELP THE CHILD TO GROW. AT LEAST ONE GROUP BELIEVES THAT FRIGHTENING A BABY WHILE HE OR SHE SLEEPS CAUSES HIM TO STRETCH, AND MAKES HIM GROW FASTER.

SO IMPROVING NUTRITION AT THE VILLAGE LEVEL IS NOT SIMPLY AN AGRICULTURAL OR MEDICAL QUESTION, BUT A COMPLEX MIX OF FACTORS. WE CANNOT HOPE TO MAKE MUCH PROGRESS IF WE TAKE A PURELY AGRICULTURAL OR MEDICAL APPROACH. AN INTEGRATED APPROACH WITHIN THE SPECIFIC CULTURAL FRAMEWORK IS THE ONLY ANSWER. WORKERS FROM THE VARIOUS DEPARTMENTS AND ORGANISATIONS MUST WORK OUT A VIABLE PATTERN OF COOPERATION AT THE LOCAL LEVEL.

SUPPLEMENTARY FEEDING

1. SUPPLEMENTARY FEEDING STARTING AT 4 MONTHS:

Breast milk is the best food for a young baby. However, it is important that the mother start feeding her child solid foods when it is 4 months old (before the baby gets its first tooth). Supplementary feeding this early in life is important because when the baby is 6 months old, milk alone will not keep the fast growing child well fed. Mother's milk is still the most important food for the baby.

A baby 4 mos. old can begin eating soft ripe fruits such as banana or pawpaw. Kaukau and pumpkin that has been well cooked is also very good for a small baby. Make it soft with breast milk and feed the baby with a spoon or with your fingers. Make sure you always wash your hands before feeding the baby.

As the baby gets a little older try giving new foods such as greens, tinned fish, beans, peas, peanut butter. Always make the foods soft and mash them into very small pieces. The baby will not like these new foods at first. Give him a little bit every day. When he is 6 mos. old he will enjoy eating.

When the baby is one year old it will want to start eating by itself. Give the baby its own plate and spoon. He will want to play with his food. It is important that the mother helps him put the food in his mouth.

2. WEANING A YOUNG CHILD: A child needs its mother's milk until it is old enough to get all the nourishment it needs from food; therefore it is important for a family to space its children.

End breast feeding slowly. Taking a child away from the breast suddenly may upset it so much that it will not eat. It is also painful for the mother because her breasts will swell up with milk.

When the child is weaned the mother must watch closely to see that the child is eating enough food. All young children must eat three meals every day and have snacks between meals too.

A young child's stomach is very small so it must eat many times every day to grow strong and healthy. Many children become malnourished when they have been weaned because the mother spends more time with the new baby. The older child may feel that it is no longer loved and stop eating. A child that has been weaned slowly and still gets attention from his mother will not do this.

3. DIARRHOEA IN THE HOME: When a child has diarrhoea often it may be caused by two things: lack of cleanliness, or malnutrition. A malnourished child gets sick much easier and more often than a healthy child.

Keeping our bodies and our clothes clean and being careful when we are handling food will do much to stop diarrhoea.

TABLE A.1.4
SOURCES OF ENERGY
(Rich in carbohydrates or fats)
Composition per 100g of raw foodstuff, edible portion (E.P.)

	E.P. as % of A.P.	MOISTURE	CALORIES (per 100 g)	PROTEIN: g per 100 g	PROTEIN: % cals. fr. prot.	PROTEIN: Protein score *	PROTEIN: NPU *	PROTEIN: NDp Cal. % *	FAT (g per 100 g)	CARBOHYDRATE: Total (g/100 g) (incl. fibre)	CARBOHYDRATE: Fibre (g/100 g)	CALCIUM (mg per 100 g)	IRON (mg per 100 g)	PRO-VITAMIN A I.U. per 100 g	β-CAROTENE (mcg per 100 g)	THIAMINE (mg per 100 g)	RIBOFLAVIN (mg per 100 g)	NIACIN (mg per 100 g)	ASCORBIC ACID (mg per 100 g)	Source	REMARKS
1. RICE—"brown" (under-milled or home pounded) (Oryza sativa)	100	13	359	7.1	6.7	76, 57	70.2	5.0, 4.0	1.1	78.0	0.7	14	1.0	(0)	(0)	0.16	0.04	4.5	(0)	a	70-74% extraction
—"white" (highly-milled)	100	13	360	6.7	7.1	77, 56	57.2	5.2, 4.2	0.7	78.9	0.4	10	0.9	(0)	(0)	0.08	0.03	1.6	(0)	a	70% extraction
2. MAIZE (grain or whole meal)	100	12	356	9.5	9.6	55, 41	62.7 51.1 54.5	5.0, 4.0	4.3	72.9	2.1	7	2.3	450*	270	0.45	0.11	2.0	(0)	a	97-100% extraction
(Zea mays) (fresh)	38	73.9	92	3.4	9.0	—	73.7	—	1.2	20.7	1.0	5	0.6	350**	210**	0.15	0.09	1.7	14	a	
3. SORGHUM (Sorghum vulgare)	100	11	343	10.1	11.9	42, 31	—	4.7, 3.8	3.3	73.8	1.7	39	4.2	200	120	0.41	0.15	4.0	(0)	a	80-100% extraction
4. MILLET (Ragi eleusine)	100	11	332	6.5	7.9	59, 45	—	5.0, 4.0	1.7	78.0	2.6	350	4.0	(100)	60	0.35	0.05	1.5	(0)	a	80-100% extraction
5. WHEAT (grain or whole meal) (Triticum vulgare)	100	12	333	10.5	11.3	68, 43	40.3	7.0, 4.7	1.9	73.9	2.1	36	4.0	(0)	(0)	0.41	(0.10)	(4.6)	(0)	a	94-100% extraction
(white flour)	100	12	365	8.6	9.5	50, 30	—	4.6, 3.0	1.1	77.9	0.2	16	1.0	(0)	(0)	0.13	0.04	1.1	(0)	a	80% extraction
6. BREAD, loaf, brown (50/50)	100	37	245	7.2	11.2	—	—	—	1.8	51.3	0.4	20	1.7	0	0	0.19	0.05	1.9	0	h	half white, half brown flour
— loaf, white	100	37	254	6.7	10.7	—	37	—	1.3	52.5	—	14	1.0	0	0	0.10	0.03	0.9	0	k	
— roll (pan de sal)	100	24.6	325	10.1	12.6	—	—	—	4.5	59.8	—	24	3.0	—	—	0.22	0.15	3.0	—	g	
7. BISCUITS (wheat meal) (50/50)	100	2.7	420	7.3	6.6	—	—	—	10.5	77.0	—	45	2.7	0	0	0.16	0.12	1.5	0	h	half white, half brown flour
— plain, sweet	100	6.2	452	4.8	4.3	—	—	—	17.7	69.1	—	45	1.2	0	0	0.05	0.02	0.5	0	k	
— crackers	100	2.7	477	7.5	6.4	—	—	—	19.4	69.0	—	36	2.8	—	—	0.16	0.10	3.6	—	g	
8. BARLEY (whole except hulls and grosts) (Hordeum vulgare)	100	12	332	11.0	11.9	78, 54	64.6	8.1, 5.9	1.8	73.4	3.4	33	3.6	(0)	(0)	0.46	0.12	5.5	(0)	a	60-70% extraction
9. OATMEAL (rolled oats) (Avena sativa)	100	10	385	13.0	12.1	79, 57	65.7	8.2, 6.2	7.5	67.8	1.9	56	3.8	(0)	(0)	0.63	0.14	0.9	(0)	a	40-55% extraction
10. SWEET POTATO (Ipomoea batatas)	87	70	117	1.3	3.0	64, 38	—	2.0, 1.2	0.4	27.3	0.8	34	1.0	500**	300**	0.10	0.05	0.6	23	a	
		68.0	120	0.8	1.8	—	—	—	0.1	29.1	0.6	30c	0.6	60	36	0.07	0.05c	0.24	65	b	white
		68.0	127	0.6	1.3	—	—	—	0.1	30.8	0.8	30	0.6	1670	1000	0.07	0.05c	0.7	65	b	yellow
	85	70	119	2.8	6.4	—	—	—	0.3	27	1.0	25	1.0	0-4000	0-2400	0.1	0.04	0.7	30	e	
11. TARO (Colocasia spp.)	82	72.5	104	1.9	5.0	69, 53	—	3.8, 2.7	0.2	24.2	0.9	22	1.1	ø	ø	0.15	0.03	0.9	5	a	
(C. esculenta)		53.5	165	1.4	2.3	—	—	—	0.5	39.0	3.0	22	—	5	3	0.27	0.04	0.20	5	b	
12. YAM (Dioscorea spp.)	86	72.4	105	2.4	6.3	75, 50	—	4.5, 3.0	0.2	24.1	0.9	22	0.8	4	2	0.09	0.03	0.5	10	a	
(D. alata, white)		54.5	161	1.4	3.6	—	—	—	0.1	38.7	0.5	23c	0.5	0	0	0.14	—	0.19	0-8	b	
	85	73	106	2.0	5.2	—	—	—	0.2	24.5	0.5	10	1.2	20	12	0.1	0.03	0.4	10	e	
13. POTATO, Irish (Solanum tuberosum)	85	78	82	2.0	6.7	53, 34	59.6	4.8, 2.3	0.1	18.9	0.4	8	0.7	ø	ø	0.10	0.03	1.4	10	a	
14. CASSAVA (Manihot utilissima) fresh	75	62.5	146	1.2	2.2	—	—	—	0.3	34.7	1.3	33	0.7	ø	ø	0.06	0.03	0.6	36	a	
Meal and flour	100	14		1.5	2.8	84, 41	—	2.2, 1.3	0.6	81.5	—	12	1.0	ø	ø	(0)	(0)	(1.0)	0	a	
15. STARCHES (Cornstarch, tapioca, arrowroot, sago)	100	12	362	0.5	0.55	—	—	—	0.3	86.9	0.2	0	0	0	0	0	0	0	0	a	
16. PLANTAINS (Musa paradisiaca)	66	68.2	113	1.2	3.6	—	—	—	0.5	29.2	0.4	7	0.8	320**	190	0.06	0.04	0.6	16	a	
17. BANANA (Musa sapientum)	71	73.5	94	1.3	4.6	71, 44								200**	120	0.04	0.05	0.7	11	a	

	E.P. as % of A.P.	MOISTURE	CALORIES (per 100 g)	PROTEIN: g per 100 g	PROTEIN: % cals. fr. prot.	PROTEIN: Protein score *	PROTEIN: NPU *	PROTEIN: NDp Cal. % *	FAT (g per 100 g)	CARBOHYDRATE: Total (g/100 g) (incl. fibre)	CARBOHYDRATE: Fibre (g/100 g)	CALCIUM (mg per 100 g)	IRON (mg per 100 g)	PRO-VITAMIN A I.U. per 100 g	β-CAROTENE (mcg per 100 g)	THIAMINE (mg per 100 g)	RIBOFLAVIN (mg per 100 g)	NIACIN (mg per 100 g)	ASCORBIC ACID (mg per 100 g)	Source	REMARKS
18. SUGARCANE JUICE (Saccharum robustum)	100	81	71	0.3	1.7	—	—	—	ø	18	ø	6	2.0	ø	ø	0.02	0.1	0	0	e	
19. SUGAR, refined	100	—	387	—	—	—	—	—	—	—	—	ø	ø	0	0	0	0	0	0	a	
20. SUGAR, crude (from cane, palm, coconut)	100	7	351	1.0	1.1	—	—	—	—	90	—	78	5.0	ø	ø	ø	ø	ø	0	a	
21. MOLASSES	100	24	232	—	—	—	—	—	—	(60)	—	273	6.7	0	0	0.06	0.11	2.8	0	a	
22. COCONUT meat, fresh, mature (Cocos nucifera)	46	48	351	4.2	4.1	82, 55	55.0	3.5, 2.4	34.0	12.8	3.3	9	1.7	0	0	0.06	0.03	0.6	2	a	AP means in shell; EP means shell removed
			414	4.0					40.0	15.0		14	2.2			0.04	0.01	0.6	38	i	
— meat, fresh, immature	34	70	180	4.0	7.7	—	—	—	15	10	3	8	1.3	10	6	0.05	0.03	0.7	4	a	
			106	(1.4)					9	6	(0.7e)	6	0.8			004-.025	.02	.3-.5	5.3	m	
— milk (from mature nut)	100	58.5	311	2.5	2.8	—	—	—	34	5	0	15	1.0	0e	0e	0.02g	0.01g	0.3g	0	f	
			346	4.3					34.8	6		11	2.3			0.03	0.008	0.9	2.8	m	
— water (mature nut)	100	94.3	22	0.3	4.7	—	—	—	0.4	5.0	0	20	0	—	—	0	0	0	—	f	
— water (immature nut)	100	94.8	17	0.2	4.1	—	—	—	0.4	3.6	—	30	—	—	—	0	—	—	—	i	
			11	0.2					ø	2.6			0.7			0.002	0.08	0.1-0.2	1.4	m	
23. BREADFRUIT (Artocarpus altilis)		80	106	0.9	2.8	—	—	—	1.5	25.2	1.2	35	0.5	19	11	0.08	0.06	0.8	72	b	
	77	70.8	102	1.7	5.6	—	—	—	0.3	26.2	1.2	33	1.2	40	24	0.11	0.03	0.9	29	d	
24. JAKFRUIT (Artocarpus heterophyllus)	28	72.0	98	1.3	4.5	—	—	—	0.3	25.4	1.0	22	—	—	11	0.03	—	0.4	8	d	
seeds	-	52	129	5.1	13.3	—	—	—	0.5	30	4.0	60	—	—	—	—	—	—	—	c	
25. VEGETABLE OILS	100	0	884	0	—				100	0	ø	0	0	0	0	0	0	0	0	a	
26. MARGARINE	100	15.5	720	0.6	—	—	—	—	81	0.4	—	(15)	ø	0	0	0	0	0	0	a	
27. BUTTER	100	15.5	716	0.6	—	—	—	—	81	0.4	—	15	ø	**	**	ø	ø	ø	0	a	
28. PORK FAT	100	0	816	3	—	—	—	—	89	0	0	0	0	0	0	0	0	0	0	a	
29. ALCOHOL & OTHER BEVERAGES																					
a. Beer, brown ale, bottled (30% alcohol)	100	97	35	0.3	—	—	—	—	ø	3	0	8	0.1	0*	0	ø	0.05	1.0	0	e	
b. Palm wine (½-1 day fermentation) (0.5% alcohol)	100	99.5	17	0.2	—	—	—	—	0	3	—	—	0.32	—	—	0.02	0.01	0.38	145	e	
c. Spirits, 70% proof (31.5% alcohol) (mean of brandy, gin, rum, whisky)	100	68.5	222	ø	—	—	—	—	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	k	
d. Coffee, extracted from 100 g ground coffee by boiling 5 minutes	100	92	48	6.8	49.1	—	—	—	ø	6	0	30	1.0	ø	ø	ø	0.01	270	0	e	
e. Tea, extracted from 100 g leaves with hot water (5-10 minutes)	100	90	24	10.0	100	—	—	—	—	—	0	30	ø	0	0	0	0.9	6.0	0	e	

ø means "trace"

— means "no data available," not necessarily "0"

** Total Vitamin A activity: (Summer) 4000 I.U. (1200 mcg retinol) per 100 g. This includes the provitamin A (β-carotene) activity.
(Winter) 2400 I.U. (720 mcg retinol) per 100 g.

TABLE A.1.5 SOME ANIMAL SOURCES OF PROTEIN Composition per 100g of raw foodstuff, edible portion (E.P.)

	E.P. as % of A.P.	MOISTURE	CALORIES (per 100 g)	PROTEIN: g per 100 g	PROTEIN: % cals. fr. prot.	PROTEIN: Protein score *	PROTEIN: NPU *	PROTEIN: NDp Cal. % *	FAT (g per 100 g)	CARBOHYDRATE: Total (g/100 g) (incl. fibre)	CARBOHYDRATE: Fibre (g/100 g)	CALCIUM (mg per 100 g)	IRON (mg per 100 g)	VITAMIN A I.U. per 100 g	β CAROTENE (mcg per 100 g)	THIAMINE (mg per 100 g)	RIBOFLAVIN (mg per 100 g)	NIACIN (mg per 100 g)	ASCORBIC ACID (mg per 100 g)		REMARKS
30. HUMAN MILK (Mature, i.e. after 30 days of lactation)		—	60	1.2	8.0	(100)	—	8.0	3.8	7.0	0	33	0.15	177 ***	53 ***	.01-.02	.02-.04	0.17	4.3		Ref. 32,136
31. COW's MILK fresh, whole (3.5% fat)	100	87.3	65	3.5	22.9	66, 60	81.6	9.8, 9.2	3.5	5.0	0	119	0.1	140	42	0.04	0.18	0.1	1	a	
Evaporated whole	100	73.7	138	7.0	21.7	—	—	—	7.9	9.9	0	240	0.2	320	100	0.05	0.35	0.2	1	a	
Sweetened condensed	100	27	320	8.1	10.8	—	—	—	8.4	54.8	0	293	0.2	330	100	0.05	0.43	0.2	1	a	
Powdered whole	100	4	506	26	21.9	69, 64	—	6.8, 6.4	30	34	0	897	0.7	1,080	320	0.24	1.31	0.7	4	a	
Powdered (skimmed)	100	4	360	36	42.7	—	—	—	1	51	0	1,235	0.9	40	12	0.35	1.80	1.0	6	a	
32. GOAT's MILK	100	86.4	73	3.8	22.2	—	—	—	4.5	4.5	0	141	0.1	160	48	0.05	0.11	0.3	1	a	
33. CARABAO MILK (Water buffalo)	100	80	121	5.8	20.5	—	—	—	9	4.4	0	(120)	(0.2)	(90)	(27)	(0.05)	(0.10)	0.1	1	a	
34. PORK—medium fat	100	52	364	12.0	13.2	81, 69	—	9.0, 7.8	35.0	0	—	6	6.5	0	0	0.58	0.14	3.1	0	h	
35. BEEF—lean	100	69	183	17.5	38.2	80, 69	66.9	9.5, 8.5	12.5	0	—	10	2.6	0	0	0.08	0.16	4.2	0	h	
36. BEEF—corned, canned	100	60	224	18.6	33.2	—	—	—	16.5	0	—	20	4.3	0	0	0.02	0.24	3.4	0	h	
37. LIVER—beef	100	69.7	136	19.7	57.9	—	65.0	—	3.2	6.0	0	7	6.6	43,900	13,170	0.26	3.33	13.7	31	d	
pork	100	72.3	134	19.7	58.6	—	—	—	4.8	1.7	0	10	18.0	14,200	4,260	0.40	2.98	16.7	23	d	
38. POULTRY	61	66	200	20.2	40.4	79, 64	70.7	8.8, 7.3	12.6	0	—	12	1.5	400	120	0.10	0.16	8.1	(0)	a	
39. EGG, fresh hen	89	74	163	12.4	33.2	100	93.5	13.5	11.7	0.9	—	50	2.5	1,000	300	0.10	0.30	0.1	0	a	refuse—shell
fresh duck	87	71	189	13.0	29.4	—	—	—	14.5	0.5	0	57	2.8	1,200	360	0.15	0.30	0.1	0	a	refuse—shell
40. FISH, fresh, fatty (sea)	50	68.6	176	20	45.4	80, 70	79.5	74.5	10	0	—	38	1.2	(100)	(30)	0.08	0.21	2.7	g	a	
fresh, other (sea)	45	77.2	104	19	76.1			****	2.5	0	—	28	0.8	g	g	0.06	0.08	2.2	g	a	
fresh, (tilapia)	39	77.3	107	17.5	65.4	—	—	—	4.1	0	—	77	0.1	100	30	0.03	0.10	4.2	0	g	
fresh, (anchovies)	75	78	82	17.9	87.3	72, 67		4.5 ****	1.1	0	—	469	0.7	—	—	0.01	0.08	3.7	0	g	
41. FISH, preserved:																					
canned in oil	100	51	314	22	28.0	—	—	—	24	1	0	44	1.3	(100)	(30)	0.06	0.20	2.6	0	a	
canned, not in oil (fatty)	100	65	188	20	42.5	—	—	—	11	1	0	40	1.2	(100)	(30)	0.03	0.20	4.0	0	a	
canned, not in oil (other)	100	75	108	21	77.8	—	—	—	2	0	0	32	0.8	g	g	0.03	0.06	1.9	0	a	
medium-cured (fatty)	69	41	261	40	61.3	75, 66		74.5 ****	10	0	0	80	2.4	(100)	(33)	0.10	0.36	4.4	0	a	dried, salted or smoked
medium-cured (other)																					
anchovies, dried and powdered	55	37	223	46	82.5				3	0	0	69	1.8	g	g	0.09	0.18	4.6	0	a	
	100	5.2	351	82.0	93.4	—	—	—	2.6	0		2,296	31.3	320	100	0.05	0.16	9.4	0	g	
42. TURTLE	30	80	82	16.0	78.0	—	—	—	1.0	2	—	100	1.0	—		0.2	0.5	3.0	—	e	
43. MOLLUSCS (oysters, mussels, clams, etc.)	25	83	71	10.0	56.3	81, 71	—	7.4.5 ****	2.0	3	—	150	10.0	200	60	0.05	0.15	1.0	g	e	
44. CRUSTACEANS (lobster, crab)	37	77	94	18.0	76.6	78, 66	—	7.4.5 ****	1.5	2	—	100	5.0	g	g	0.05	0.10	2.5	g	e	
45. SHRIMP (large, fresh)	63	75.6	96	19.6	81.7	—	—	—	0.8	2.5	—	146	1.1	250	75	0.07	0.04	3.6	—	g	
46. SHRIMP (small, fresh) (acetes indicus)	100	79.1	78	16.6	85.1	—	—	—	1.3	0	—	699	3.0	—	—	0.07	0.15	2.4	—	g	
47. SHRIMP (small, dried)	100	21.6	286	52.4	73.5	—	—	—	3.6	10.2	—	2,306	21.4	115	34	0.06	0.19	5.5	—	g	
48. FERMENTED SHRIMP PASTE	100	63.3	69	14.9	86.4	—	—	—	1.0	0.2	—	469	5.4	—	—	0.01	0.10	1.6	—	g	
49. FERMENTED FISH PASTE (Anchovies)	100	49.0	129	26.7	82.8	—	—	—	2.5	0	—	280	8.3	—	—	0	0.27	5.0	—	g	
50. SNAIL (river, pond)	100	78	83	12.0	57.8	—	—	—	2.0	4		1,500	8.3	—	g	0.05	1.3	—	—	e	
51. SEA SLUG (Beche de mer)	100	76	92	22.0	95.6	—	—	—	g	1		120	1.4	—	—	g	—	—	—	e	
52. CATERPILLAR	100	80	81	12.0	59.3	—	—	—	3.0	1.5	2.0	61	6.3	—	—	0.08	0.43	2.4	—	e	
53. TERMITE	100	75	148	10.0	27.0	—	—	—	12.0	0	1.2	12	1.0	—	—	—	—	—	—	e	
54. LOCUST	100	75	134	20.0	59.7	—	—	—	6.0	0	4.0	30	1.0	—	—	—	0.5	2.2	—	e	
55. SAGO GRUB	100	70.5	181	6.1	13.5	—	—	—	13.1	9	—	461	4.3	—	—	0.08	0.43	2.4	—	i	

g means "trace" — means "no data available", not necessarily "0"

** These figures represent total vitamin A activity (including provitamin A portion). The percentage of this total vitamin A activity which is actually derived from β-carotene is estimated (WHO 232A, Appendix 6) as follows: milk, poultry, eggs — 30%; fish — 10%

***Breastmilk contains on average, in addition, 27 mcg carotenoids per 100 g [136], of which about 6 mcg is β-carotene, so that total provitamin A activity is about $\left(\frac{6}{0.6} + \frac{21}{1.2}\right) = 28$ I.U.

****These values are artificially low. The percentage of calories derived from protein is so high that, when fish alone is eaten, much of the protein is used for energy production. The percentage of calories derived from protein indicates better the real protein value.

TABLE A.1.6 SOME VEGETABLE SOURCES OF PROTEIN Composition per 100g of raw foodstuff, edible portion (E.P.)

	E.P. as % of A.P.	MOISTURE	CALORIES (per 100 g)	PROTEIN: g per 100 g	PROTEIN: % cals. fr. prot.	PROTEIN: Protein score *	PROTEIN: NPU *	PROTEIN: NDp Cal. % *	FAT (g per 100 g)	CARBOHYDRATE: Total (g/100 g) (incl. fibre)	CARBOHYDRATE: Fibre (g/100 g)	CALCIUM (mg per 100 g)	IRON (mg per 100 g)	PROVITAMIN A I.U. per 100 g	β-CAROTENE (mcg per 100 g)	THIAMINE (mg per 100 g)	RIBOFLAVIN (mg per 100 g)	NIACIN (mg per 100 g)	ASCORBIC ACID (mg per 100 g)		REMARKS
56. SOYBEANS (Glycine max) whole	100	8	335	38.5	46.0	62, 47	61.4	5.0, 4.9	18	31.3	4.8	208	6.5	140	84	03	0.30	2.1	0	a	Yield from 1 kg soybeans:
full-fat flour (seedcoat removed)	100	8	357	39	37.9	—	—	—	21	27.4	2.4	197	6.2	160	96	0.77	0.28	2.0	(0)	a	0.95 kg
low-fat flour, grits, etc.	100	8	261	46	61.2	—	—	—	5	35.2	2.3	247	7.6	110	66	0.73	0.30	2.0	(0)	a	0.84 kg
curd (tofu)	100	87.4	58	6.3	37.7	—	—	—	3.1	2.5	0.1	46	1.1	20	12	0.05	0.04	0.4	(0)	a	3.5 kg
fermented (natto)	100	61	153	17	38.6	—	—	—	9	11	3	100	3.7	(40)	(24)	0.09	(0.20)	(1.0)	(0)	a	2.0 kg
fermented (tsiang)	100	65	153	17	38.6	—	—	—	10	6	3	100	3.7	40	24	(0.09)	(0.20)	(1.0)	(0)	a	2.0 kg
sprouts	100	86.3	46	6.2	46.8	—	—	—	1.4	5.3	0.8	48	1.0	180	108	0.23	0.20	0.8	13	d	
57. PEANUTS (Groundnuts) (Arachis hypogaea)	71	5.2	546	25.6	16.3	69, 43	42.7	8.8, 6.0	43.3	23.4	3.3	52	1.9	30	18	0.84	0.12	16.0	g	a	
58. GREEN GRAM (MUNG BEANS) with coat	100	12	336	22.0	22.7	32, 22	48.5	5.5, 4.3	1.0	61.7	4.7	100	8.0	40	24	0.45	0.2	2.0	g	e	
(Phaseolus aureus) sprouts	100	92	31	2.5	19.7	—	35.6	—	g	5.5	0.5	10	0.6	g	g	0.2	0.2	0.5	30	e	
59. KIDNEY BEANS (Phaseolus vulgaris) dried	100	12.2	336	23.1	23.9	47, 34	43.7	7.5, 5.8	1.7	59.4	3.5	163	6.9	(0)	(0)	0.57	0.22	2.5	2	d	
mature, moist, fresh	91	89.1	35	2.4	25.8	—	—	—	0.2	7.6	1.5									a	
60. LIMA BEANS (Phaseolus lunatus) dried	100	12	338	20.0	20.5	50, 41	51.5	7.4, 6.4	1.5	63	5.0	90	6.0	g	g	0.5	0.14	1.5	g	e	
61. HYACINTH BEANS (Field Beans) dried (Dolichos lablab) (Lablab niger)	100	11.8	338	22.2	22.8	37, 27	59.9	6.2, 4.8	1.5	61.0	6.8	88	3.5	—	—	0.62	0.20	2.3	—	d	
62. WINGED BEANS, dried (Psophocarpus tetragonolobus)	100	14	399	33.0	28.7	—	—	—	16.0	37	5.0	—	—	—	—	0.08	—	—	g	e	
63. BROAD BEANS, dried (Vicia faba)	100	12.2	338	25.4	26.1	41, 28	47.8	6.9, 5.1	1.7	57.8	7.8	95	6.5	130	78	0.60	0.26	2.5	5	d	
64. PEAS (whole) dried (Pisum sativum)	100	11.6	339	23.8	24.4	50, 37	47.9	7.9, 6.2	1.4	60.2	5.4	57	4.7	140	84	0.77	0.28	3.1	2	d	
65. CHICK PEAS, dried (Cicer arietinum)	100	10.6	359	20.8	20.1	53, 40	52	7.7, 6.3	4.7	60.9	5.3	162	8.4	90	54	0.49	0.18	1.6	g	d	
66. COW PEAS (whole) dried (Vigna sinensis)	100	10.6	342	22.9	23.2	57, 41	45.1	8.7, 6.6	1.4	61.6	4.2	77	6.5	30	18	0.92	0.16	2.2	2	d	
67. PIGEON PEAS (husked) dried (Cajanus cajan)	100	13.1	333	21.9	22.8	39, 27	—	6.4, 4.8	1.6	59.9	1.5	92	4.5	140	84	0.47	0.18	2.0	5	d	
68. RICE BEANS, dried (Phaseolus calcarata)	100	10.1	352	18.4	18.1	—	—	—	3.1	64.5	7.3	397	4.0	55	33	0.54	0.17	2.2	—	g	
69. SUNFLOWER, PUMPKIN, WATERMELON (Dried seeds, seedcoat removed)	53	5	535	27.4	17.7	93, 61 63, 42	58.3 —	12.0, 8.2 8.5, 6.2	43.0	19.7	2.7	48	9.3	70	42	0.23	0.18	2.7	g	a	Sunflower Melon
70. SESAME SEEDS (Sesamum indicum)	100	6	574	18.1	10.9	63, 42	53.4	6.3, 4.4	51.3	20.0	3.7	1,200	9.0	g	g	0.80	0.22	4.5	0	a	
71. CASHEW NUT (Anacardium occidentale)	100	5	560	17.0	10.5	—	57.8	—	45.0	30.3	1.3	50	5.0	g	g	0.6	0.2	2.1	0	e	
72. PILI NUT (Canarium spp.)	16	8.9	644	14.2	7.6	—	—	—	68.5	5.5	3.2	119	2.6	45	27	0.95	0.12	0.4	g	g	
73. KAUWI NUT (Macaranga spp.)		8.8	601	18.9	10.9	—	—	—	60.4	7.4	2.2	474	—	—	—	—	0.08	—	—	j	
74. PANDANUS NUTS		9.0	683	11.9	6.0	—	—	—	66.0	22.0	6.1	419	—	—	—	—	0.36	—	—	i	

g means "trace"
— means "no data available", not necessarily "0"

TABLE A.1.7
SOME OTHER VEGETABLES
Composition per 100g of raw foodstuff, edible portion (E.P.)

	E.P. as % of A.P.	MOISTURE	CALORIES (per 100 g)	PROTEIN g per 100 g	PROTEIN % cals. fr. prot.	PROTEIN Protein score *	PROTEIN NPU *	PROTEIN NDp Cal. % *	FAT (g per 100 g)	CARBOHYDRATE Total (g/100 g) (incl. fibre)	CARBOHYDRATE Fibre (g/100 g)	CALCIUM (mg per 100 g)	IRON (mg per 100 g)	PRO-VITAMIN A I.U. per 100 g)	β-CAROTENE (mcg per 100 g)	THIAMINE (mg per 100 g)	RIBOFLAVIN (mg per 100 g)	NIACIN (mg per 100 g)	ASCORBIC ACID (mg per 100 g)	Source	REMARKS
A. LEAVES																					
75. LEAVES, (a) dark green	80	85	41	5.0	29.8	57, 53 **	—	8.8, 8.2	0.7	6.5	1.5	250	4.0	3 000	1 800	0.1	0.3	1.5	100	e	
(b) medium	80	91	25	2.0	19.5		—	—	0.3	4.8	0.8	80	2.5	1 000	600	0.08	0.02	0.5	50	e	
(c) light green	80	03	23	1.5	15.9	—	—	—	0.2	4.8	0.8	40	0.5	30	18	0.05	0.05	0.3	40	e	
76. ABELMOSCHUS MANIHOT (Aibika, New Guinea)		82.7	47	5.7	29.6	—	—	—	0.3	8.6	1.8	580	—	—	—	—	—	—	—	i	
77. AMARANTHUS spp.	71	86.9	36	3.5	23.7	88, 62	—	13.0, 9.5	0.5	6.5	1.3	267	3.9	6 090	3 600	0.08	0.16	1.4	80	d	
78. CABBAGE, common (Brassica oleracea capitata)	69	91.8	25	1.6	15.6	65, 39	35.2	8.1, 5.3	0.1	5.7	1.0	50	0.4	100	60	0.06	0.05	0.3	50	a	
79. CABBAGE, Chinese (Brassica sinensis)	79	95	14	1.4	24.4	—	—	—	0.1	2.6	0 6	100	2.0	3 500	2 100	0.06	0.03	0.4	25	a	dark green
80. CASSAVA leaves (Manihot dulcis)		82.0	55	7.2	31.9	59, 51	—	8.8, 7.7	1.9	6.1	2.4	175	2.0	2 000	1 200	0.33	1.07	1.7	275	b	
81. HORSERADISH-TREE leaves (Moringa oleifera; Malunggay, Philippines)	61	77.4	75	5.9	19.2	—	—	—	1.8	12.8	1.8	353	3.5	12 450	8 470	0.20	0.73	3.7	232	g	
82. KALE (Brassica oleracea acephala)	63	85.9	42	3.9	22.7	60, 23 ***	54.3	9.1 4.4	0.6	7.8	1.3	230	2.3	7 600	4 560	0.11	0.25	1.6	120	a	
83. MUSTARD greens (Brassica juncea)	83	92.2	23	2.2	23.3	—	—	—	0.3	4.1	0.8	188	3.0	5 670	3 400	0.09	0.25	0.7	100	a	
84. SAUROPUS ANDROGYNUS (Sayur manis, Malaysia)																					
85. SPINACH (Spinacia oleracea)	81	92.1	22	2.2	24.4	71, 68	—	10.7, 10.3	0.3	3.9	0.7	81	3.0	9 420	5 650	0.11	0.20	0.7	59	a	
86. SPINACH, Philippine (Talinum triangulare)	67	92.5	22	1.7	18.8	—	—	—	0.4	4.2	0.7	79	5.5	5 255	3 150	0.11	0.17	0.5	58	g	
87. SWAMP CABBAGE/SPINACH (Ipomoea aquatica) (Kangkong)	60	89.7	30	3.9	31.7	73, 44	—	10.5, 6.9	0.6	4.4	1.0	71	3.2	4 825	3 000	0.09	0.24	1.3	49	g	
88. SWEET POTATO leaves (Ipomoea batatas)		85	47	3.5	18.2	—	—	—	0.5	9.5	1.5	70	8.0	6 000	3 600	0.10	0.20	0.9	25	c	
89. TARO leaves (Colocasia spp.)		85	57	5.0	24.4	—	—	—	2.5	6.6	2.3	—	—	—	—	—	—	—	—	b	
B ROOTS, Bulbs, etc.:																					
90. CARROT (Daucus carota)	92	88.6	40	1.1	6.7	79, 40		5.1, 2.8	0.2	9.1	1.0	34	0.8	2 000 (-10 000)	1 200 (-6 000)	0.06	0.04	0.7	6	a	
91. CHAYOTE (Sechium edule)	85	91.5	29	0.6	5.0				0.1	7.4	0.6	12	0.5	20	12	0.02	0.04	0.5	19	d	
92. LEEKS and green onions (Allium porrum, odorum, cepa)	47	87.8	43	1.8	10.2				0.2	9.4	1.2	80	1.0	50	30	0.06	0.04	0.5	18	a	
93. ONIONS, mature (Allium cepa)	93	88.8	40	1.4	8.5				0.2	9.0	0.8	32	0.5	50	30	0.03	0.04	0.2	9	a	
94. RADISH	56	93.7	20	1.1	13.4				0.1	4.2	0.7	37	1.0	30	18	0.03	0.02	0.3	24	a	

0 means "trace"
— means "no data available"; not necessarily "0"

** Pumpkin leaves
*** Turnip (Brassica rapa) leaves

TABLE A.1.7 (continued)
SOME OTHER VEGETABLES
Composition per 100g of raw foodstuff, edible portion (E.P.)

	E.P. as % of A.P.	MOISTURE	CALORIES (per 100 g)	PROTEIN g per 100 g	PROTEIN % cals. fr. prot.	PROTEIN Protein score *	PROTEIN NPU *	PROTEIN NDp Cal. % *	FAT (g per 100 g)	CARBOHYDRATE Total (g/100 g) (incl. fibre)	CARBOHYDRATE Fibre (g/100 g)	CALCIUM (mg per 100 g)	IRON (mg per 100 g)	PRO-VITAMIN A I.U. per 100 g)	β-CAROTENE (mcg per 100 g)	THIAMINE (mg per 100 g)	RIBOFLAVIN (mg per 100 g)	NIACIN (mg per 100 g)	ASCORBIC ACID (mg per 100 g)	Source	REMARKS
C. VEGETABLE FRUITS:																					
95. BEANS snap, fresh, young, in pod (Phaseolus vulgaris)	91	89.1	35	2.4	16.7	56, 39		7.4, 5.5	0.2	7.6	1.5	57	.8	400	240	0.08	0.12	0.5	17	a	
96. CUCUMBER (Cucumis sativus)	75	95.6	13	0.8	15.0				0.1	3.0	0.6	10	0.3**	0**	0**	0.03	0.04	0.2	8	a	
97. EGGPLANT (Solanum melongena)	82	92.7	24	1.2	12.2				0.2	5.4	0.9	15	.4	30	18	0.04	0.05	0.6	5	a	
98. MARROW (White) or immature pumpkin (Cucurbita spp.)	83	95	15	0.8	13.0				0.1	3.5	0.6	18	.6	100	60	0.06	0.04	0.5	20	a	
99. MELON, bitter (Momordica charantia)	82	93.4	22	0.9	10.0				0.4	4.6	0.9	32	0.9	335	200	0.06	0.03	0.03	55	g	
100. OKRA (Hibiscus esculentus)	88	89.8	32	1.8	13.7	85, 56		9.5, 4.6	0.2	7.4	1.0	82	0.7	740	440	0.08	0.07	1.1	30	d	
101. PEPPER, sweet, large, green (Capsicum annuum)	82	92.8	24	1.2	12.2				0.2	5.3	1.4	6	0.8	290	170	0.04	0.05	0.9	103	a	
102. PEPPER, chili, small, red (Capsicum frutescens)	87	72.2	62	4.8	18.9				2.2	9.0	1.4	65	2.3	7 010	1 200	0.31	0.25	1.8	69	g	
103. PUMPKIN (YELLOW SQUASH) (Cucurbita spp.) (mature)	68	89.9	33	1.3	9.6				0.3	7.7	1.2	18	0.6	400 (-4 000)	240 (-2 400)	0.06	0.03	0.4	11	a	
104. TOMATO (Lycopersicum esculentum)	80	93.8	20	1.1	18.5	66, 21		8.4, 4.1	0.3	4.2	0.6	11	0.6	700	420	0.04	0.04	0.5	24	a	
105. TREE TOMATO (Cyphomandra betacea)	73	85.9	48	1.5	10.5				0.3	11.3	2.2	13	0.8	—	—	0.04	0.04	1.0	17	d	
D: STALKS & STEMS:																					
106. BAMBOO SHOOT (Bambusa spp.)	29	91.0	27	2.6	23.5				0.3	5.2	0.7	13	0.5	20	12	0.15	0.07	0.6	4	d	
107. SETARIA PALMAEFOLIA, hearts (Pitpit, New Guinea highlands)		92.4	27	0.5	4.5				0.2	6.8	1.1	21	—	—	—	—	—	—	—	j	
108. TARO, stalk (Colocasia esculenta)		93	21	0.5	5.8				0	5.5	1.6	218	—	—	—	—	—	—	214	j	
E. FLOWERS:																					
109. BANANA heart	54	88.9	36	1.6	10.8				0.4	8.0	1.1	56	1.1	440	260	0.02	0.02	0.5	13	g	
110. PUMPKIN flowers	59	89.8	29	2.0	16.8				0.5	5.6	0.7	74	3.1	910	550	0.05	0.11	0.9	24	g	
111. SACCHARUM EDULE (efflorescence) (Pitpit, New Guinea lowlands)		89	37	4.1	27.0				0	7.6	0.7	10	—	—	—	—	—	—	—	i	
F. MISCELLANEOUS:																					
112. MUSHROOM (Agaricus spp.)	91	91.1	23	2.4	25.5	42, 18	72.4	7.0, 4.2	0.3	4.0	0.9	9	1.0	0	0	0.10	0.44	4.9	5	d	
113. "FUNGUS"		85	51	2.4	11.5				3.5	4.3	0.3	—	—	—	—	—	—	—	—	b	
114. SEAWEEDS:																					
(a) Agar (Gelidium spp.)	100	17.8	2	(0)					0.2	(0)	—	—	—	—	—	—	—	—	—	d	
(b) Kelp (Laminaria spp.)	100	23.6	9	(0)					1.1	(0)	—	—	—	—	—	—	—	—	—	d	
(c) Laver (Porphyra laciniata)	100	16.9	5	(0)					0.6	(0)	—	—	—	—	—	—	—	—	—	d	

0 means "trace"
— means "no data available"; not necessarily "0"
** pared cucumbers

SOME FRUITS TABLE A.1.8

Composition per 100g of raw foodstuff, edible portion (E.P.)

	E.P. as % of A.P.	MOISTURE	CALORIES (per 100 g)	PROTEIN g per 100 g	PROTEIN % cals. fr. prot.	PROTEIN Protein score	PROTEIN NPU	PROTEIN NDp Cal. %	FAT (g per 100 g)	CARBOHYDRATE Total (g/100 g) (incl. fibre)	CARBOHYDRATE Fibre (g/100 g)	CALCIUM (mg per 100 g)	IRON (mg per 100 g)	PRO-VITAMIN A (I.U. per 100 g)	β CAROTENE (mcg per 100 g)	THIAMINE (mg per 100 g)	RIBOFLAVIN (mg per 100 g)	NIACIN (mg per 100 g)	ASCORBIC ACID (mg per 100 g)		REMARKS
115. APPLE (Malus sylvestris)	84	84.0	58	0.3	1.7	65, 38		1.0, 0.5	0.4	15.0	0.9	6	.3	90	54	0.04	0.03	0.2	5	a	
116. APPLE "Malay" or "rose" (Eugenia malaccensis)	77	85	51	0.6	3.3				ø	13.7	0.7	10	.5	ø	ø	0.03	0.03	0.3	15	e	
117. APPLE "Star" (Chrysophyllum caimito)	87	80	80	1.0	4.2				2.0	16.5	1.5	15	0.5	10	6	0.03	0.02	1.0	8	e	
118. AVOCADO—low fat	67	82.9	98	1.4	4.8				8.3	6.5	1.5	10	.6	180	110	0.06	0.12	1.5	10	a	
(Persia)—high fat	70	67.1	225	1.8	2.7				23.4	6.3	1.7	15	.9	340	200	0.10	0.44	1.5	10	a	
119. CITRUS: Orange (C. sinensis)	72	87.1	45	0.9	6.7	57, 28		4.0, 1.9	0.2	11.3	0.8	34	.4	170	100	0.08	0.03	0.2	50	a	(Sweet)
— Mandarin (C. reticulata)	71	87.3	44	0.8	6.1				0.3	10.9	1.0	(33)	(0.4)	(420)	250	0.07	(0.03)	(0.2)	31	d	
— Lemon (C. limonia)	62	88.7	41	0.8	6.6				0.5	9.5	0.9	40	.6	0	0	0.04	ø	0.1	50	a	
— Lime, small (C. microcarpa)	38	89.8	40	0.4	3.6				1.0	8.3	ø	18	0.8	0	0	0.02	0.01	0.2	45	g	
— Pomelo (C. grandis osbeckii)	56	83.4	59	0.5	2.8				0.3	15.3	0.6	30	0.7	ø	ø	0.03	0.01	0.1	42	g	
120. DURIAN (Durio zibethinus)	24	62.9	144	2.5	5.8				3.1	30.4	1.7	9	0.9	30	18	0.24	0.20	0.7	24	d	
121. FIG (Ficus carica)	97	81.7	65	1.2	6.0	80, 44		4.8, 2.8	0.4	16.1	1.4	54	.6	80	48	0.06	0.05	0.5	2	a	
122. GUAVA (Psidium spp.)	78	80.6	69	1.0	4.9				0.4	17.3	6.2	18	.9	180	110	0.03	0.04	1.2	160	a	
123. MANGGO (a) ripe	62	81.7	65	0.7	3.6				0.2	17.0	0.8	11	.4	1 900	1 140	0.05	0.06	0.6	48	a	
(Mangifera indica) (b) green	72	85.1	53	0.5	3.2				0.2	13.8	0.4	16	0.3	135	80	0.08	0.04	0.2	73	g	
124. MANGOSTEEN (Garcinia mangostana)	29	83.0	63	0.6	3.2				0.6	15.6	5.1	8	0.8	—	—	0.03	—	—	2	d	
125. MELON, musk (Cantaloupe) (Cucumis melo)	56	92.6	26	0.7	9.0				0.2	6.0	0.5	20	.4	1 200	720	0.05	0.03	0.6	30	a	
126. MELON-water (Citrullus vulgaris)	53	92.9	25	0.5	6.3				0.2	6.1	0.2	6	.3	170	100	0.04	0.04	0.2	6	a	
127. PAPAYA (a) ripe	66	88.6	39	0.6	5.2				0.1	10.1	0.9	24	0.4	1 000	600	0.03	0.04	0.4	64	a	
(Carica papaya) (b) green	64	93.2	23	1.0	14.6				0.1	5.2	0.8	59	0.3	0	0	0.03	0.02	0.2	22	g	
128. PASSIONFRUIT (Granadilla) (Passiflora spp.)	33	80.0	70	0.6	2.9				(0)	18.9	(0)	11	1.1	10	6	ø	0.10	1.3	16	a	
129. PERSIMMON, Japanese (Diospyros kaki)	80	79.6	73	0.8	3.7	80, 60		3.0, 2.2	0.3	18.7	1.2	7	0.4	1 900	1 140	0.05	0.05	0	9	a	
130. PINEAPPLE (Ananas sativus)	64	86.7	47	0.5	3.9				0.2	12.2	0.5	18	0.5	90	54	0.08	0.03	0.2	40	a	
131. PLUMS (Prunus spp.)	94	82.0	64	0.8	4.2				0.2	16.5	0.5	17	0.5	350	210	0.06	0.04	0.5	5	a	
132. POMEGRANATE (Punica granatum)	48	81.3	66	0.6	3.0				0.3	17.2	0.3	3	0.4	0	0	0.02	0.02	0.2	8	a	
133. SOURSOP (Annona muricata)	66	80.2	71	0.8	3.8				0.4	18.0	1.0	20	0.5	20	12	0.06	0.06	1.0	19	a	
134. TAMARIND	48	31.4	239	2.8	3.9				0.6	62.5	5.1	74	0.6	30	18	0.34	0.14	1.2	2	a	
135. TIESA (Lucuma nervosa)	73	57.2	154	2.5	5.4				0.6	39.1	7.5	40	1.1	2 060	1 240	0.02	0.03	2.5	43	g	

ø means "trace" — means "no data available"; not necessarily "0"

Family Planning

Family planning is concerned with improving the life situation of families, through:

a) Spacing of childbirth;

b) Helping couples to limit their family to the size they really want and can support;

c) Helping couples who find it difficult to have children; and

d) Providing information and counselling on matters related to parenthood.

Human beings have the capability of producing many children during their lifetime. This capability must be used carefully, responsibly. It is the parent's responsibility to make sure that every child they cause to be born is wanted, loved, and can be properly cared for.

Papua New Guineans are quite used to the idea of preventing births, as they have traditionally used various means of preventing births and causing abortions. However, few of these traditional methods are reliable, and some are dangerous.

The most reliable and safe methods have been developed only in the last 20 years. More and more people are now realising that family planning is vitally important for the well-being of families, and the nation as a whole.

There is sincere disagreement over the use of some of the methods of family planning, but general agreement about the need for married couples themselves to take the responsibility for their own family planning decision-making.

It is important that every rural development worker be able to tell families where they can get family planning information, if they want it. The basic source of medical information is the Dept. of Public Health, through its hospitals, health workers, clinics, and aid posts.

It is also important that the rural development worker understand and be able to explain the process of human reproduction.

How a Baby is Made

At the time of sexual intercourse the husband's semen, which contains millions of sperm, or seed, is left in the upper part of the woman's vagina. These sperm swim through the cervix, through the uterus, and into the tubes to "look for" the egg.

At ovulation time, usually about every 28 days, a ripe egg bursts out of the woman's ovary, and is "sucked up" into the end of the pipe. It will live for only one day if it is not fertilized with a

The Main Parts of The Female Reproductive System

1. The Uterus - the house or basket for the baby. It is the place where the baby lives and grows for 9 months before it is born.
2. The Ovaries - these are two "egg baskets". There are thousands of eggs inside each basket. But only one egg (or two for twins) gets ripe at one time each month.
3. Fallopian Tubes - these are the passage ways for the egg and the sperm. The end of each tube is open and has "fingers" which catch the ripe egg when it bursts out of the egg basket. The other end opens into the uterus.
4. Cervix - this is the bottom part of the uterus where the mucus is made. This mucus looks like the white of a raw egg, and it is a clear, slippery, stretchy water. This mucus comes through the vagina each month at the same time that the egg begins to get ripe. It tells the woman: "This is the time you can become pregnant."

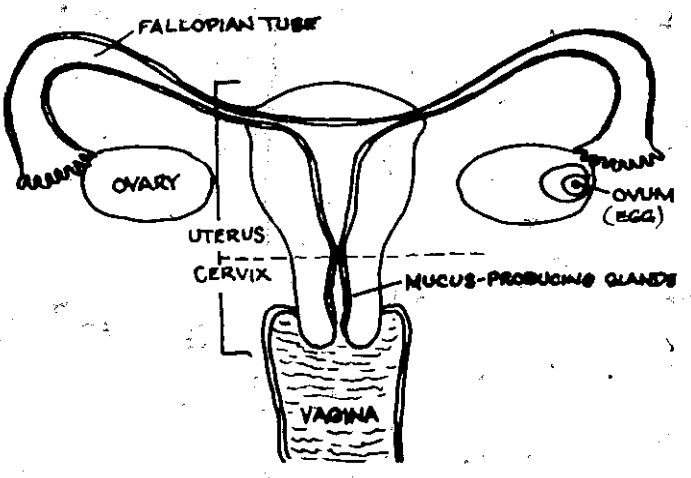

FEMALE REPRODUCTIVE ORGANS (INSIDE)

sperm. If it is fertilized, only one male sperm will go inside the ripe egg, and at that time the baby begins to grow. That moment is called "conception".

This new life grows into a "ball" of cells which moves slowly inside the tube to the uterus. At 2 weeks this new life is about 1 centimetre in size, and it will settle in the uterus, which has formed a thick soft lining, making a good bed for a new baby. (This is the substance which is released with each monthly period, if there is no baby to begin.)

As the little baby grows, it gets its food at first from the mother's uterus, and then later through her blood, through the placenta, which is attached to the baby's belly.

After nine months the baby is born. The mother will not have her menstrual period during this time.

The Menstrual Cycle

The menstrual cycle begins when a girl is about 12 to 14 years old, and can continue every month until she is 45 to 50 years old.

For the purposes of family planning the thing we are interested to know is the exact time of ovulation. This is when it is not safe to have intercourse (if we want to avoid having a baby) if we are using no other methods to prevent conception.

METHODS OF FAMILY PLANNING

There are several methods of Family Planning.

One method may be best for one family, another method better for another family. Each family should carefully choose one they feel is best for them. They may want to talk to a Health worker. When a man and woman use family planning, they can have sexual intercourse as usual, but a baby does not start to grow as long as they are properly using the method.

THE OVULATION METHOD

The "Ovulation Method" of family planning helps us to determine rather closely when ovulation takes place. Understanding it will enable us to use any other method more effectively, and to select another method more wisely.

Below is a picture of a typical menstrual cycle. However, each woman is different, and she should make her own chart. Furthermore, her chart might be different from one month to the next.

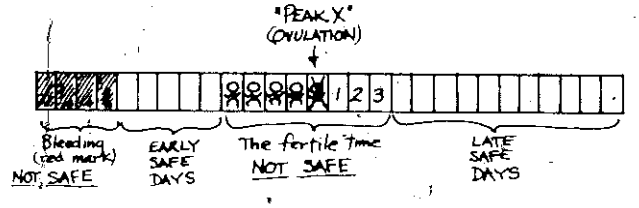

Here are the rules for following the Ovulation Method of family planning to avoid pregnancy.

1. Begin to chart at once: every night before you go to bed put only one mark on your chart for that day:
   a) Bleeding - put a red mark
   b) Dry for the whole day - put a pencil mark
   c) Wet, slippery, mucus - draw a baby
2. Abstain from intercourse for one cycle so you will know the mucus days.

3. In the next cycle avoid intercourse during the days of the period. These days are NOT SAFE: in short cycles ovulation can happen during the period.

4. If there are dry days after the period, these are safe days to have intercourse.

5. As soon as mucus comes, avoid intercourse. Fertile mucus days are NOT SAFE.

6. Mark the last day of clear slippery stretchy mucus with an X. This is the most fertile time, the "PEAK X".

7. Avoid intercourse for the next 3 dry days after the Peak X. These days are NOT SAFE.

8. The dry days from the 4th day after the PEAK until the next period are SAFE DAYS.

9. If intercourse takes place on an early safe day and the first time you have intercourse after the PEAK X, mark the day with a line. Then your teacher will be able to see if you make a mistake.

10. When a new period begins, start a new line.

11. If someone is teaching you this method, try to see them at least once each month until you learn the method well.

These points are emphasized:

Watch for mucus as the period is finishing; if mucus is seen avoid 3 dry days after it stops.

In short cycles there may be no early safe days.

In long cycles there may be many early safe days.

Fertile mucus feels slippery. It is clear, smooth, and stretchy, like the white of a raw egg.

Infertile mucus is cloudy, sticky, not stretchy, not slippery.

Until you know the difference between fertile and infertile mucus, avoid analysing the mucus the day after intercourse when using the early safe days. It may be wet from the man's semen. Just put a baby mark for that day.

If your next period does not come 2 weeks after the PEAK X watch for mucus and avoid all mucus days and 3 dry days after.

Each cycle, each month might be different.

Do not copy from the previous cycle.

Following this method to avoid pregnancy while breastfeeding:

1. Begin to chart soon after the baby is born. Every night before you go to bed put a mark on your chart for that day.

   a) Bleeding - put a red mark
   b) Dry for the whole day - put a pencil mark
   c) Wet, slippery, mucus - draw a baby

2. Avoid intercourse on all fertile mucus days (clear, smooth, slippery, stretchy mucus) and for 3 more days after it stops. You can become pregnant on these days.

3. All other dry days and infertile mucus days (thick, sticky, non-stretchy mucus) are safe. There may be many months of only dry days. These days are "safe". You cannot become pregnant.

4. Avoid any days of bleeding or spotting of blood and 3 days after. This may be ovulation.

5. When it is close to your having your period again, after 3, 6, 12 months or more, you may have many days of mucus. Be careful at this time.

6. When your period (bleeding) starts again, the first few months (cycles) can be very irregular. Therefore, be careful to avoid all mucus days and 3 days after.

Note: While the baby is taking only breast milk you will be dry nearly every day. When you start to give food to the baby you will notice mucus days. This means the egg inside your body is trying to get ripe (ovulate) and you can get pregnant again. This is how some women get pregnant without having a period between babies.

For more information about the Ovulation Method, write to: The Health Secretary, the Catholic Church, Box 1306, Boroko.

THE PLASTIC LOOP (for women) is one of the most common methods used in PNG. It is a small piece of plastic which is placed inside the women's uterus.

The best time to have a loop put inside is six weeks or more after the baby is born. If menstrual periods have started again, the best time is when the bleeding is finishing, or during the next few days.

The loop is straightened out inside a thin tube, and then inserted. A Sister or Doctor can put it into the uterus in a few minutes. The woman may not feel it, or may just have slight discomfort.

While the loop is inside, she can have sexual intercourse and she is unlikely to become pregnant. The man does not feel the loop when they have sexual intercourse because it is right inside the uterus.

A few women may have some questions first, such as heavier menstrual periods, but usually after a month or two the body gets used to the loop and the woman does not know it is there. She can do hard work or carry heavy loads. The loop does not make any difference. Many women have loops in for many years without any problems.

In a few women the loop comes out by itself. If so she should go back to the clinic as soon as possible, and another can be put in.

If a man and woman want to have another baby, the Sister can easily remove the loop by pulling on the threads. Then another baby can start to grow. After the birth of the next baby, another plastic loop can be put inside.

This is an easy method because the man and woman do not have to do anything else to prevent pregnancy while the loop is in place.

THE PILL - is another very common method. While a woman takes one pill every day she will not become pregnant. Her body does not make an egg each month while she is taking the pills, so a baby cannot start to grow.

A health worker can teach women how to take the pills, and can check them first. There are just a few women who should not take pills due to medical conditions.

The Health Department gives 3 kinds of pills. The woman must go to the clinic for these, and should be told and understand clearly about how to use the kind she gets. Microlut (Blue Packet) is for women who are breastfeeding a baby less than 12 months old; Neogynon ED Fe (red and yellow packet) is for women who can read with babies over 12 months old; Eugynon ED Fe (Red spot packet) is easier for women who do not read to understand and who have babies over 12 months old.

THE INJECTION (for women) is called Depoprovera.

If a woman uses this method, she has an injection in her arm every 12 weeks until she wants to have another baby. Her body does not make an egg while she is having injections.

Most women who have these injections lose very little blood each month. Some have no menstrual periods at all while they are having the injections. This does not mean a baby has started. It means the medicine is working.

In some women there are days of blood spotting in the middle of the month. If this is a trouble or if it is heavy she should go back to the clinic for treatment.

When the woman wants to have another baby she can stop having injections. Then she can get pregnant again, but it may take several months or even a year or two because the medicine is still affecting the body. So the Health Department only gives this method to women with two children or more.

It is also expensive and not as available as other methods. It is only used when other methods are not suitable.

THE CONDOM (for men) is a bag of thin rubber which is used by a man when he has sexual intercourse. He puts the bag over his penis before it touches the woman. There is a little space left at the end of the bag to catch his fluid and seeds. They cannot get out to the woman's egg and start a baby.

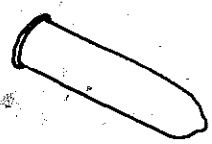

After sexual intercourse the man has to be careful not to spill any of the fluid inside the woman. If he puts his finger on the rubber ring, it will not come off inside the woman.
The man takes off the condom and puts it in the rubbish tin or in a hole in the ground. Condoms are usually only used once.

This is a safe and easy method with no medical side effects, so the man does not have to go to a health worker. It is a useful method for people in rural areas who are not close to a health worker.

Condoms can be bought at Chemist shops or trade stores. The man should keep several so that a condom is used every time he has sexual intercourse.

OPERATIONS (for men and women). If a man and woman are sure that they have enough children, and do not want any more babies later, either the man or the woman can have a little operation.

A doctor performs the operation after the husband and wife both sign a paper to say that they want to have the operation and understand its effects.

If the woman has the operation (called a tubal ligation), the doctor ties her tubes on each side so that the egg and the sperm cannot join. If the man has the operation (called a vasectomy), small tubes are tied just under the skin so that the man's fluid has no sperm in it.

The easiest time to do the woman's operation is straight after the birth of a baby. She can discuss it with the sister at the Antenatal Clinic.

Many men and women like the little operation, because there are no side effects afterwards, and they do not have to do anything more to prevent pregnancy. It is the most reliable way to prevent pregnancy, so it is a good method for a man or woman with a large family, or if the wife has a condition which would make it dangerous to have another baby.

After the little operation, a man or woman feels just as strong as before, and sometimes women even feel stronger.

WHERE TO GET THESE METHODS

Loops, injections - at health centers and hospitals.
Pills, condom samples - at aid posts, health centers and hospitals.
Condoms - sold at Chemist shops and trade stores.
Ovulation method - taught by specially trained teachers.
Tubal ligation, Vasectomy, investigation of infertility - by doctors at hospitals and some health centers.

All health workers can give information and refer people to where the methods are available.

For general information and training materials write: The Family Planning Section,
Department of Health,
PO Box 2084,
Konedobu.

Thanks to Dr. N. Muirden, Dept. of Health, for her help in updating this item.

Pregnancy, Childbirth and the Newborn, a Manual for Rural Midwives, Leo Eloesser, Edith Galt, Isabel Hemingway. 1959. 150 pp. $2 (Am.) from Ninos Heroes

139, Mexico 7, D.F., Mexico. Teacher's Guide, 43 pp. 50 cents. 25 cents postage and handling.

The manual was based on the ideas of the Canadian surgeon, Bethune, and was first printed in China in 1950. Since then, it has been used in Mexico and South America. As the title says, it is "a manual for rural midwives", and deals with normal births in rural areas. The illustrations are helpful in understanding the development of the mother and foetus and the position of the baby to be born. Suggestions for improving the diet include eating whole grains, growing a bigger garden, getting some extra hens for protein, etc. A very practical and sensible teaching guide.

Level: intermediate.

Reviewed by: H. Bekker.

Healing

BUSH MEDICINES

We have found very little material on "bush medicines". However, the following letter from Dr. Des A. Scholz, Yagaum Lutheran Health Centre, Box 107, Madang, gives some insights:

"There are a number of bush medicines in use, but most of these are concerned with pain relief, e.g. rheumatic aches, headaches, abdominal pains. Most of the things used for relief are in the nature of counterirritants, like 'salat', which is related to the stinging nettle. They are about as effective as most of our liniments and rubs, and in general do no harm.

"The second category of medications are those with a known beneficial effect, e.g. Pawpaw. If this is applied to sores and tropical ulcers, it does quite effectively dissolve the old and necrotic tissue in the ulcers, and will result in a clean wound. Its beneficial effect is related to an enzyme in the pawpaw, which will help dissolve dead tissue. It seems likely that some of the bark and sap of certain trees does help to stop diarrhoea, and this could be of use.

"The third category of medications are those with a powerful effect e.g. 'Koniak', which is the same, or similar to Kava, and I think has a cocaine-like effect. This is given in some areas for relief of a chronic, severe pain in old people, and is very effective. It would also be addictive. In this category are the poisons found in certain roots, used to poison fish. This is, or has been, used, in at least one place to treat hookworm, and apparently is effective.

"The fourth category are those remedies which would be similar to some of our traditional remedies, and equally useless, e.g. putting spit or urine in infected eyes, etc.

"The fifth category are the magical remedies, in which the active agent is seen to be the ritual, which in most cases is accompanied by some application of leaves, chewing ginger, etc. This latter is reserved for the 'saveman' only, while all of the former tend to be more the property of the whole tribe."

MEDICINAL PLANTS

ALOE VERA

Different species of Aloe have been used in Africa and Asia for various purposes, but Aloe vera is best known to me as a burn plant. When our 2 year old son had a second degree burn (blistered skin), we applied the sap from Aloe vera and his crying ceased. We kept the dressing clean, he was never again bothered by the pain and there is no scar.

Because it is useful and convenient to use, we would like to see it propagated and distributed throughout PNG, especially to villages distant from hospitals. At home in Hawaii as a child, we always had a Aloe in the yard, and the local Plant & Transport there had a Aloe next to their welding torches.

The Aloe vera is in the family Liliaceae, of African origin. The leaves are 30-60cm long, erect, thick, light green with white markings, and very juicy. The spines do not prick. The sap is thick, yellow and bitter, with a penetrating odour.

Burkill, in A Dictionary of the Economic Products of the Malay Peninsula, 1966 describes the preparation of the drug: "The plant is very succulent and mucilaginous, the greater part of the leaf-tissue containing none of the medically active substance; but deep in along the courses of the fibro-vascular bundles are strands of large cells full of a yellow juice, which is the aloetic juice and source of the drug. To get it, the leaves are cut off and placed so that the juice may bleed into a collecting vessel. The rest of the leaf scarcely bleeds, and being inactive, is not wanted to do so. It remains only to concentrate the extract, either by the sun's heat, or artificially. If concentrated by evaporation quickly and completely, followed by sudden cooling, the extract becomes vitreous in fracture; if not cooled suddenly, it becomes opaque.

This preparation is Bitter Aloes or Jadam."

From Burkill and other sources, we found that in Malaysia, the sap is put on wounds, daubed on the fever, and used on swellings and skin diseases; that the sap of the heated leaves may be squeezed out, mixed with sugar and taken for asthma, and that a similar preparation is used in Java for coughs; that in Malaya, the mucilagenous flesh and sap are used to poultice burns: in India, it is used internally for various complaints of the intestinal tract and for poulticing burns; in the West Indies, it is made into a watery extract and applied to the head to destroy lice. It is used as a laxative, and in larger dosages, used to stimulate menstrual flow. Known as Bitter Aloes, it is sold as a tonic. Also commercially it is an ingredient for sun tan lotion and burn ointment.

The Aloe likes sun and suffers from too much water; it does not need rich soil. It is propagated like a pineapple.

Editor's note: Aloe is also well known in the Philippines for its medicinal qualities. Many there believe that regular application of the slimy juice will help to cure baldness in many cases.

Aloe vera is available through the Division of Botany, Office of Forests, Box 314, Lae, MP.

Initial contributor: H. Bekker.

DENTAL HEALTH

The most common health problem in our country is dental disease! When the teachers of the Port Moresby Dental College looked at the teeth of the people in a typical Highlands village they found many people with:

Holes in their teeth (cavities),
Infected gums that were red, sore and swollen,
Loose teeth caused by infected gums and bone,
Many missing teeth.

Strong healthy bodies include good teeth. Good teeth are:

Clean (no dirt, pipia, stain, debris, or food on them); Have no holes (cavities); and Have a firm pink skin (gum) around them.

There are two steps to good strong teeth:

1. Keep the teeth clean.
2. Do not eat too much sugar.

Let us look at each of these. All of us have seen a post (stump) in the ground that has been eaten by ants until it is soft and rotten. Something like this happens to teeth. If we leave dirt on teeth, the bacteria (which are like very very small ants) in the mouth eat it and give off an acid which makes a hole in the tooth. This same dirt near the skin of the tooth (gum) causes the skin to be sore (inflamed) and the bone becomes sore and the tooth becomes loose. To prevent both holes in teeth and loose teeth, clean the teeth every day. How? With a tooth brush or with a brush you make. Make your brush by taking a small piece of bamboo as long as your little finger and half as thick. Chew one end of the bamboo to make a brush that looks like this:

Now use this brush and brush around the tooth, both on the lip side and tongue side next to the skin. Do a very careful job and brush between each tooth as far as you can. When you first start brushing your skin (gums) may bleed a bit but keep up the brushing every day and the skin (gums) will soon become strong.

A good brush can also be made from the husk of the beetle nut. Take a small piece of the husk and remove the green outer layer. Chew the wide end and you will now have a good brush that looks like this:

The curve of this brush makes it good for reaching and cleaning the tongue side of the teeth.

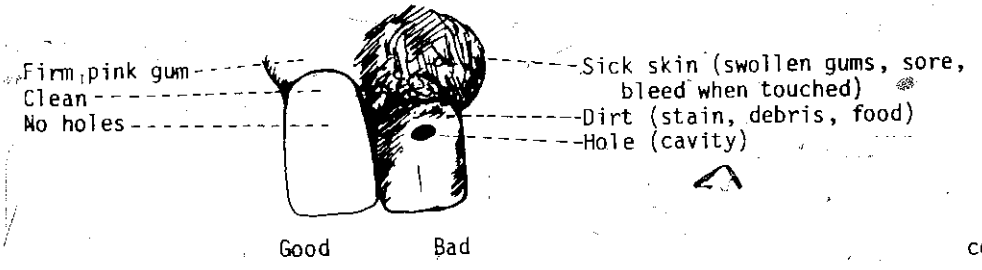

cont'd

You should also eat good strong food for strong teeth. Read these two lists carefully:

GOOD FOODS FOR TEETH

Milk	Peanuts	Cucumber
Sweet Potatoes	(Kau kau)	Fruits
Beans	Nuts	Pineapples
Peas	Cabbage	Papaya
Maize (corn)	Carrots	Fats
Bananas	Pumpkin	Seeds
Meat	Tomatoes	Coconut
Fish	Spinach	

POOR FOODS FOR TEETH

Lolly water
Sweet biscuits
Cheese pops
Candy
Gum

References

Barefoot Doctor's Manual, U.S. Dept of Health, Education & Welfare, Public Health Service Publication No 75-695 (NIH) $9.75 from: U.S. Government Printing Office, Washington, DC 20402 USA.

Field Workers Medical Manual, by Summer Institute of Linguistics Staff, Summer Institute of Linguistics, Inc., Huntington Beach, California 92648, USA, 1973.

This book is intended for persons with little medical training to help them develop a pattern of thinking about illness and its treatment. The manual was developed for use of workers in isolated areas where professional medical help is not readily accessible. The material of the volume is organized under both symptoms of the common diseases and under their medical categories and the descriptions, treatments and preventive measures are given in clear, laymen's language. This book is excellent source material for all areas of PNG, especially those that are isolated. Price K10.00. Order from SIL., Ukarumpa, via Lae, PNG.

Level: intermediate.

Reviewed by: Dr. J. Patto, Nazarene Hospital, Box 70, Banz.

Medical Care in Developing Countries, by M. King, Oxford U. Press, 1966. Available from University Book Shop, Port Moresby. May come out in paperback. This is the basic reference and textbook for the provision of appropriate health care in the developing world. Intermediate level.

Women and Child Care in China, Ruth Sidel, 1972, $1.25 from: Penguin Books, Inc. 7110 Ambassador Road, Baltimore, MD 21207 USA.

Teaching Aids at Low Cost (TALC)
30 Guilford Street,
London WCIN IEH, England.

TALC is a teaching activity of the Institute of Child Health, University of London, to provide teaching aids at or below cost price for health workers, particularly in developing countries.

Books and Pamphlets Available.

Health Care in China.

An introductory study of what China has achieved in revolutionizing health care in 25 years. We believe that all health workers in developing countries should know something about how this has been achieved, and study whether similar changes can be brought about in their own community. Price 60p.

Medicine in China

5 articles by Dr. E.M. Adey & Dr. A.J. Smith, published in the British Medical Journal and reprinted specially for TALC. This gives further information on health care in China. Price 40p.

BOOKS FOR AUXILIARIES

Nutrition in Developing Countries, by King, Morley and Burgess.

One of the few books for health workers written in simple English, with practical exercises which school children and others can undertake in the community. Price Pounds 2.20

Paediatric Out-Patient Manual, by Pauline Dean, Paediatrician.

An excellent little book, locally produced from St. Luke's Hospital, Anua, Nigeria. It is very well suited for medical assistants and nurses in out-patients. Price 25p.

Sympton-Treatment Manual, from Shanta Bhawan Hospital, Nepal.

A simple statement of the care of common conditions. Price 35p.

Care of the Newborn Baby in Tanzania, by Hamza and Segall.

A well-written booklet suitable for use in many countries other than Tanzania.

Simple Dental Care for Rural Hospitals, by D.J. Halestrap.

Gives the basic knowledge required by a medical worker who has to take responsibility for dental conditions. Price 40p.

Nutrition Rehabilitation Village, by Joan Koppert

Describes nutrition rehabilitation in an urban setting. Price 2Dp.

Health Care of Children Under Five.

Outcome of a conference on child care in India. Price 35p.

Visual Communication Handbook, by D.J. Saunders

Written for the person who wishes to become more effective in communication at village level. Price Pounds 1.00

Memorandum on Tuberculosis in Developing Countries, by Oxfam.

Describes methods of tackling tuberculosis with limited resources.

Memorandum on Leprosy Control, by Oxfam, Lepra and the Leprosy Mission.

Available in English, French, German and Spanish, this sets out the basis of management. Price 15p.

Paediatric Priorities in the Developing World, by D. Morley.

A book of 450 pages which sets out possible alternative priorities to those suggested by traditional western paediatrics.

The 'Baby Killer' by M. Muller, produced by War On Want (2nd edition)

Highlights the problems produced by unrestricted advertising of bottle-feeding in the developing countries. Price 40p.

The Care of Babies and Young Children in the Tropics, by D. Morley.

A leaflet written for European mothers taking their children to hot climates for the first time. Price 15p.

OTHER MATERIAL AVAILABLE FOR THE COST OF PACKING AND POSTAGE ONLY.

Measuring Malnutrition - The Shakir Strip

School children evaluating under-fives clinics. A method that can be tried where three-quarters of the children in the village have home-based weight charts.

Reading list, and a list of sources of teaching material in maternal and child health for developing countries.

Patterns of Mortality in Childhood, by Puffer.

This is a summary of the PAHO study of infant mortality in the Americas.

COLOURED SLIDES W/Casette Tapes for Teaching: List available upon request.
Charge for administration, packing, and post, 30p.
For orders over Pounds 3.00 add 10% for postage.
If paying by cheque or money order in currency other than sterling, add 50p. Cheques should be made out to "TALC".

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For further information, write Mr. P.M. Hayden, above address.

WE ALL WANT LESS TALK AND MORE ACTION. BUT UNCOORDINATED, POORLY PLANNED ACTION CAN GET PRETTY MESSY. THE FUTURE IS IN THE HANDS OF THE PEOPLE WHO ARE WILLING TO SIT THROUGH MEETINGS, MORE MEETINGS, MORE MEETINGS. THE RIGHT MEETINGS, OF COURSE: MEETINGS WHICH LEAD TO ACTION.

GENERAL REFERENCES

Literature, South Pacific

DEPARTMENT OF PRIMARY INDUSTRY, PNG

DPI Publications,
Box 2417,
Konedobu.

(p 71)

Publications available August, 1976:

PNG Agricultural Journal, K1.00 per issue. Research Bulletin, K2.00 per volume. Harvest, 50t per issue.

Farming Notes:

1 Looking after the soil
2 Sorghum
3 Corn (Maize)
4 Goats
5 Passionfruit
6 Rice
7 Peanuts
8 Pineapples
9 Sweet potato
10 Vegetables
11 Rubber
12 Bananas
13 Coconuts
14 Pyrethrum
15 Wildlife
16 Pepper

All approximately 30t.

Rural Development Series Handbooks:

1	Basic Extension Skills	K2.00
2	Rural Broadcaster's Handbook	K1.50
3	Cardamom Handbook	"
4	Poultry Handbook	"
5	Pig Handbook	"
6	Chillies	50t
7	Pepper	"
8	Corn	"
9	Introduced Vegetables	75t

Keeping Cattle in PNG - 20t per book

1 Introduction
2 Choosing land for a cattle farm, finding money for a cattle farm
3 Fence, yards and crush
4 Looking after cattle
5 Pastures for cattle
6 Sickness in cattle

Raise good pigs - 20t per book

1 Housing - coastal
2 Housing - highlands
3 Feeding and management
4 Breeds
5 Marketing

Some new publications will be coming soon:

Extension Bulletins:

History of Agriculture in PNG
Study in Subsistence Agriculture

Farming Notes:

Cardamom
Chillies
Winged Beans
Fruits and Nuts
Coffee
Food Crops
Rice

Send your order without payment. You will receive a bill with the publications with instructions as to how to pay.

NOTE: If you are a farmer or a politician you are entitled to one free copy of each of the ones you need. You may get these through your Agricultural Officer, or through the Provincial Rural Development Office.

DEPARTMENT OF BUSINESS DEVELOPMENT

Department of Business Development
Post Office, Wards Strip

Has a number of booklets for people to help their businesses. They are beginners books, but everyone has to start somewhere. Some booklets have a small charge. You can get these booklets from your nearest Business Development Office, or if they are out, from the Publications Officer, above address.

1. Trade Stores in Papua New Guinea is three separate books. The first is called Starting a Store, the second, Managing a Store, and the third is Bookkeeping for Small Trade Stores. They are free. They are in English.

2. Making a Profit from your Truck is also three books, called How to Start your Truck Business, How to Manage your Truck, and Truck Accounting. Books two and three together cost 50t, but the first one is free. They are in English and also in Pidgin.

3. Lukautim Autbot Mota Bilong Yu, is a Pidgin book on care and operation of outboards. It won't tell you about Seagull outboards, but it's a good reminder of proper care of your new outboard.

4. A Guide to Setting up an Urban Trade Store was written by The PNG Chinese Association of Port Moresby, and is very good for help with the kinds of goods to stock. It's free.

5. Basic Commercial Forms shows a number of common forms a new business man may be sent, and describes their purpose and what he must do if he gets them or needs to use them. Free.

6. Business Group Incorporation Act - 1974. In English, Pidgin and Motu. Tells the requirements for registering under this new act to legalize traditional forms of organization to do modern business. Free. (p 277)

7. Business Terms Dictionary in Simple English and also in Pidgin. Clears up a lot of the difficult words in doing modern business. Free.

EDUCATIONAL RESEARCH UNIT

Box 4820, University P.O.,
Port Moresby.

ERU Research Reports Related to Rural Development

G. Kemelfield & P. Palmer, Education and Village Life
S.G. Weeks, How Tertiary Students Use Their Vacations
S.G. Weeks, National Service and Community Involvement as Seen by Tertiary Students in Papua New Guinea

ERU Occasional Papers

S.G. Weeks, Ed. Education and Independence, 1975: A Resource Book on Documents and Issues in Education

ERU Working Papers

S.G. Weeks, Nuigini Hailans I Go Ahet (A Tok Pisin Literacy Game)

The price of each research report is 70 toea for up to fifty pages.
Please make your cheque payable to the University Bookshop (PNG).

ERU Reports:

G. Kemelfield, A Community-Based Education System: A Proposal.
S.G. Weeks, Community School in Africa: Is There a Lesson for PNG?

50 toea each from University Bookshop (PNG).

VILLAGE DEVELOPMENT OFFICE has the following books:

The Village Blacksmith: by Ray Dubert (pidgin text) a simple booklet detailing the construction of a village forge, blacksmith shop and working metals. (p 132)

Foot Operated Thresher: by K. Hemmes and D. Williams (English text). How to construct a simple thresher for stripping the grain from crops such as wheat, rice and barley. (p 163)

Gravity Feed Waters System: by Neil Anderson (Pidgin text) How to construct, level and install a simple reticulated village water system with gravity feed.

The Principles of Hydraulic Mining: by B. Crozier, H. Skinner & R. Hocking (English text). A process for excavating, transporting and filling ground without the use of heavy equipment, providing there is an ample supply of water above the excavating site. (p 127)

Publications may be obtained from:

The Director,
Village Development Office,
PO Box 6937,
BOROKO.

(p 256)

GOVERNMENT PUBLICATIONS

THE DEPARTMENTS OF PRIMARY INDUSTRY, BUSINESS DEVELOPMENT, PUBLIC HEALTH, EDUCATION, AND PUBLIC WORKS REGULARLY PUBLISH HANDBOOKS, MANUALS, PLANS, AND REFERENCES USEFUL FOR RURAL DEVELOPMENT. BUT ONLY RARELY CAN ONE GET A COPY OF THESE AT THE PROVINCIAL LEVEL OFFICE.

IT IS UNDERSTANDABLE THAT WE DON'T FIND A PUBLICATIONS OFFICER FOR EVERY DEPARTMENT FOR EVERY PROVINCE. PNG CAN'T AFFORD IT.

BUT THERE IS IN EACH PROVINCE AN INFORMATION OFFICER IN THE DEPT OF PROVINCIAL AFFAIRS. THERE IS MUCH TALK ABOUT INTER-DEPARTMENTAL COOPERATION AND COORDINATION - HERE IS A REAL TEST FOR IT! WHY NOT LET THE PROVINCIAL INFORMATION OFFICER MAINTAIN AN UP-TO-DATE SUPPLY OF PUBLICATIONS FOR ALL DEPARTMENTS FOR DISTRIBUTION AND SALE TO THE PUBLIC?

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Banz, WHP

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SPC PUBLICATIONS

SOUTH PACIFIC COMMISSION, Noumea, New Caledonia

Handbooks/ 1968.

1. Rat Control in the South Pacific, by F.P. Rowe 1968.
2. Cocoa Production in the South Pacific, by K. Newton, 1968.
3. Improving Land Tenure, by R.G. Crocombe, 1968. Rev. ed. 1973.
5. Banana Production in the South Pacific, by M. Lambert, 1970.
6. Coconut Production in the South Pacific, by M. Lambert, 1970.

3. Vegetable Production in the South Pacific, by M. Lambert. 1971.
9. Handbook of Practical Bacteriology, by J. Saugrain, 1973.
10. Weed Control in the South Pacific, by M. Lambert, 1973.
12. Handbook of Hospital and Health Service Administration, by D. Horne, V. Williams, 1975.

Information Circulars

34 Taro/Taro, by M. Lambert. August 1971.
52 Fruit Cultivation, by M. Lambert. June 1973.
55 Special Project-Vegetable Production in the South Pacific, by M. Lambert, January 1974.
56 Comments on Experiments Recently Undertaken in some Pacific Islands on Certain Varieties of Vegetables, by M. Lambert, March 1974.
58 Some Aspects of Pasture Research and Development, by P. Bewg. April 1974.
59 Something New in Sewage, by C. Richard, Sept 1974.
60 Solar Energy, by C. Richard. November 1974.
65 The Marketing of Fresh Vegetables, by J. Ishida. May 1975.
66 Special project on Vegetable Production, by M. Lambert. June 1975.
68 Evaluation of Broiler Meat Chicken Performance, by D. Armstrong, September 1975.

Information Documents.

8 Processing of Banana Products, by D.E. Kay 1967
24 A Manual of Introductory Soil Science and Simple Soil Analysis Methods. S.G. Reynolds. 1971.
33 Rat Control Without Rat Destruction, by E.J. Wilson 1974.

Notes: Prices are shown only for those publications of which the free distribution is very limited. Charges may also be made for Handbooks, Technical Papers and for postage costs. When making requests, please say whether sea or airmail postage is required but do not send payment in advance.
Requests may be made to:

The Secretary-General,
South Pacific Commission,
Box D5, Noumea. New Caledonia.
or
The Director, S.P.C. Publications Bureau,
Box 306, Haymarket NSW 2000. Aust.

RESOURCE BOOKS

The P.N.G. Telephone Directory
Available at P.N.G. local post offices at 50t each.

The "pink pages" contain a host of helpful addresses and ideas for those trying to find goods and services. Even if you don't have a telephone you'll find these well worth the investment.

Papua New Guinea Handbook, 7th edition, 1974, Ed. by J. Tudor, Pacific Publications, Sydney A$5.50 plus A$1.50 for mailing. The most complete handbook on PNG suitable for the desk. Many references are out of date, but the Handbook is still very useful for its maps and data on areas and their resources. Particularly helpful for newcomers. Level: simple.

The Pacific Way: An Emerging Identity, by Ron Crocombe, 56pp. Lotu Pasifica Productions, Box 208 Suva, Fiji Price F$1.20 postpaid.

Assessments, criticisims, hope for the future by a well known and highly respected Pacific Studies Authority. Nine full pages of photos. Liberal discounts for bulk orders.

Level: intermediate

PUBLISHERS

Christian Publisher's & Booksellers Association, Box 111, Wabag, EP.

The South West Pacific Book List, gives basic information about a selection of publications and cassette tapes produced in this area. Most items are religious in nature, but Community Development, Literacy work, Social Issues, are also categories included. Lists of publishers and suppliers to bookshops, bookshops, and publications by title and category.

WANTOK PUBLICATIONS, INC

Main office: Box 1982, Boroko.

Other offices: Box 396, Wewak
Box 749, Madang
c/- Box 90, Rabaul
c/- Box 1920, Lae.

Publishers of WANTOK, a weekly newspaper in Melanesian Pidgin with particular emphasis on rural development issues. Subscription K5.00 per year.

Distributors of LIKLIK BUK (in PNG and overseas), THE NEW INTERNATIONALIST (third world development issues) K14.00 per year (by arrangement with Community Aid Abroad, Fitzroy, Victoria, Aust.)
WIRUI PRESS CALENDARS (Port Moresby area only)

BOOKSELLERS

See section on Book Suppliers p 253.

Literature, Overseas

PUBLICATIONS AVAILABLE FROM

INTERMEDIATE TECHNOLOGY PUBLICATIONS
9 King St.
London WC2E 8HN, England

Unless otherwise stated, all books and leaflets are Intermediate Technology publications. PRICES ARE SURFACE AND AIRMAIL OVERSEAS, in Pound Sterling and US $.

GENERAL:

Appropriate Technology A quarterly journal (annual subscription). A forum for the exchange of ideas amongst those directly involved in development work; includes technical articles, book reviews, readers' contributions. 3.00 ($7.00); 4.50 ($10.50).

Aid and Self-Help by Elizabeth O'Kelly. Distills a good part of the new wisdom in the field of developing aid. Published by Charles Knight and Co., London. 140 pp. 1973. 4.50 ($10.35), 5.75 ($13.25).

Disaster Technology: An Annotated Bibliography by Diana Manning. Aimed at supplying relief agencies with information on the published and unpublished literature available concerning technical aspects of disaster relief and prevention, with special emphasis on developing countries. Published by the London Technical Group. 331 pp. 1974 6.25 ($14.40), 9.75 ($22.45)

Small is Beautiful: A Study of Economics as if People Mattered Dr. E.F. Schumacher, Founder-Chairman of Intermediate Technology, shows how fragmentation of specialised competence, particularly that of economists, scientists and technologists, has led to confusion of the means and ends of modern life; he stresses the need for a return to wisdom in planning for the future. Published by Blond and Briggs, London, 288 pp. 1973, Paperback 1.10 ($2.55) 2.05 ($4.70) Hardback 3.95 ($9.10), 5.20 ($12.00).

Also by Dr. E.F. Schumacher - three booklets; The Age of Plenty - A Christian View Published by The Saint Andrew Press, Edinburgh, 23 pp. 1974, .45 ($1.05), .70 ($1.60); People's Power published by National Council of Social Service, 16 pp. 1975, .30 ($.70), .50 ($1.15); Thinking About Land ; Published by Catholic Housing Aid Society, 10 pp. 1973, .20 ($.45), .40 ($.95).

AGRICULTURE

Complete Technical Drawings for eight farm implements designed for local construction. 1973. (print size varies up to 30" X 30")

18. Manual broadcast sower (UK) 3.85 ($8.85), 4.80 ($11.05)
19. Welding jigs, three designs (UK) 1.65 ($3.80), 1.95 ($4.50)
20. Treadle-operated peanut thresher (Malaya), 2.85 ($6.55), 3.60 ($8.30).
21. "Wananchi" ox-cart (Tanzania) .70 ($1.60), 1.05 ($2.40)..
22. Donkey cart (Tanzania) 1.20 ($2.75) 1.80 ($4.15).
23. Polyrow peristaltic-pump sprayer (UK) 1.70 ($3.90), 2.15 ($4.95)
24. Hand-pushed sod seeder (UK) 1.20 ($2.75), 1.65 ($3.80)
34. "SATEC" multi-crop seeder (France) 2.85 ($6.55) 3.60 ($8.30).

Dimensional Drawings/Photoprints with text; Agriculture Green Leaflets. 1973, .35 ($.80); .50 ($1.15) for each leaflet.

1. "Wananchi" ox-cart (Tanzania)
2. Cart for one draught animal (Tanzania)
3. Ox-cart using old car wheels (Malawi)
4. "Kabanyolo" toolbar (Uganda)
5. Chitedze ridgemaster toolbar (Malawi)
6. Prototype multi-purpose ox-drawn tool (Nigeria)
7. Five-tine sweep cultivator (India) and high clearance peg-tooth harrow.
8. Triangular spike-tooth harrow (India)
9. Flexible peg-tooth harrow (Iran) and rigid frame Japanese harrow
10. Two clod crushers (Malawi)
11. Ox-drawn tie-ridger/weeder implement (Nigeria)
12. IDC weeding attachment for Emcot plough
13. Adjustable width "V" drag ditcher/bund former (USA)
14. Sled-type corrugated irrigation furrow former (USA)
15. Single-row and 3-row rice seeders (Zambia), (photoprints).
16. Rotary weeder for row-planted rice (Zambia) (photoprints).
17. Multi-action paddy field puddling tool (Zambia) (photoprints)
27. Cassava Grinder (Nigeria)
28. Rotary corn thresher (Nigeria)
29. IDC-BORU groundnut lifter for Emcot plough; IT groundnut lifter (Nigeria).
30. IT granule applicator (Nigeria)
31. IT expandable cultivator (Nigeria)
32. Hand-operated seed dressing drum (Malawi)
33. IT high-clearance rotary hoe (Nigeria)

Technical Report with Constructional Drawings on a Hand-operated Winnower produced by the IT Working Group at Technische Hogeschool, Eindhoven, Holland, 1974. 1.90 ($2.05), 1.55 ($3.55).

HEALTH

Health Manpower and the Medical Auxiliary Three articles twelve case studies, and an annotated bibliography of 134 references. 65 pp. 1971. 1.70 ($3.90), 2.20 ($5.10)

Intermediate Techniques booklet of sketches of specialised hospital furniture and equipment for the physically handicapped, for local construction. 23 pp. 1973.

Paediatric Priorities in the Developing World by Dr. David Morley. A valuable addition to the medical literature on child care in developing countries. Published by Butterworths 470 pp. 1973 1.65 ($3.80), 2.60 ($6.45)

The Training of Auxiliaries in Health Care An annotated bibliography listing a wide variety of material used in training auxiliaries at different levels; includes text-books, course descriptions and visual aids. 100 pp, 1975, 1.85 ($4.25), 2.80 ($6.45)

Simple Designs for Hospital Equipment. The following leaflets are available in booklet form, 1973, for each booklet .35 ($.80), .60 ($1.40):

1. Invalid carriage with chain drive and brake
2. Hospital bedside table and locker
3. Hospital ward screen
4. Dressing and instrument trolley
5. Hospital wheelchair
6. Bush Wheelchair
7. Bush ambulance
8. Hospital blood transfusion drip stand
9. Folding bed (wire spring)
10. Paraplegic turning frame
11. Hospital folding bed (metal plate spring)
12. Hospital patient's trolley

RURAL WORKSHOP

How to Make a Metal-Bending Machine Technical specifications with plans and drawings for a hand-operated metal-bending machine, with photographs. 1973, 1.20 ($2.80), 1.70 ($3.90)

Oil Drum Forges Full technical specifications for making a simple forge from an oil drum with (a) foot-operated bellows pump or (b) hand-operated fan. Revised edition. 1975 .95 ($2.20), 1.75 ($4.00).

WATER

A Bibliography of Low-Cost Water Technologies. Third edition (1974) of G.H. Bateman's 1971 appraisal of the information assembled by the ITDG Research Project on low-cost, low-skill water technologies. 39 pages, includes sources and references on water supply storage, transport, lifting and use. 1.20 ($2.75), 1.75 ($4.00).

A Manual on the Automatic Hydraulic Ram Pump. contains details of how to make and maintain a small hydraulic ram on a suitable site. The second part takes a more technical look at the ram performances and design considerations and contains a useful annotated bibliography. 37 pp. 1975. 1.20 ($2.75), 1.70 ($3.90).

OTHER ITEMS AVAILABLE ON "BUILDING", "CHEMISTRY", CO-OPERATIVE ACCOUNTING", "ENERGY" (See Digesters), "INDUSTRIAL", "REPORTS ON RECENT INTERMEDIATE TECHNOLOGY PROJECTS."

STICHTING TOOL

MauritsKade 61a, Amsterdam, Netherlands.

A non-profit foundation representing cooperating groups mostly from university science departments or technical colleges. "Seeks to form a bridge between the scientific knowledge in developed countries and the practical problems in developing countries." Technical advice, documentation, some publications.

Publications list - February 1976.

Blackboardtips, an illustrated guide for the effective use of the school blackboard. 12pp US$1.00

Grain Silo, construction manual for a silo made of clay bricks, with a concreted upperplate.6pp US$1.00

Lectures on Socially Appropriate Technology. Reviews of 12 aspects of technology, such as building, small workshops, farming tools, energy, and their relation to third world development. 235pp. US$6.00

The Salawepump, construction manual for a hand-operated piston pump. 6pp US$1.25 (P 161)

Soap Preparation, How to prepare soap at home 6pp US$1.00

Windmill bibliography (2 vols) (P 154)
part 1: Alphabetical index
part 2: Keyword index, with abstracts US$10.00

Winnower,Construction manual for a handoperated winnower. 35pp US$2.00 (P 166)

INDUSTRIAL TECHNOLOGY

Industrial Technology: a guide to sources of information in Britain available to developing countries. 1971, 29pp.

The Guide has entries on 57 different organisations in the industrial technology field and gives details of the work they do and the information they can provide, together with their full address, telephone number and telegram or telex code.

To enable the Guide to be given widespread free circulation, its size has been restricted and its entries have been kept concise.

COMMODITY/PROCESS REPORT TITLES: Many are available. Here are samples. Write for complete list.

The Small-scale Manufacture of Soluble Coffee. Price 60p. 1973. G82
An Illustrated Guide to Fish Preparation. Price Pounds 1.40. 1975. G83
The Market for Tuna. Price Pounds 1.15. 1973. G80
The Improvement of Hand-operated Groundnut Decorticating Machines. Price 25p. 1971 G68
The Use of Protein-rich Foods for the Relief of Malnutrition in Developing Countries: An Analysis of Experience. Price 90p. 1972. G73
The Market for Natural Rubber with particular reference to the competitive status of Synthetic Rubber. Price 65p. 1970. G47

TROPICAL PRODUCTS INSTITUTE

56/62 Gray's Inn Rd.
London WCIX 8LU England

Complete lists and a newsletter are available. Some samples:

CONFERENCE PROCEEDINGS : Proceedings of the Conference on Animal Feeds of Tropical and Subtropical Origin.

Tropical Products Institute Conference held in London 1-5 April 1974, 347pp. Price including postage, Pounds4.45 in UK and surface mail; Pounds7.50 airmail.

Proceedings of the Conference on Tropical and Subtropical Fruits.

Tropical Products Institute Conference held in London15-19 September 1969, 307pp. Price including postage Pounds2.10 in UK surface mail; Pounds4.12 airmail.

CROP AND PRODUCT DIGESTS

No 1 Oils and Oilseeds, 1971, x + 170 + xxii pp. Price including postage Pounds0.95 in UK surface mail; Pounds1.55 airmail.

No 2 Root Crops, 1973, 245 + xxxv pp. Price, including postage, Pounds1.75 in UK; Pounds1.85 surface mail, Pounds3.05 airmail.

No 3 Grain Legumes to be released soon, price not available (We look forward to this one with great interest)

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UNITED NATIONS PUBLICATIONS

There are so many UN publications available that we couldn't possibly list them, and have merely placed selected references under various topics. If you want a particular UN publication the UN Information Centre can get it for you at a great savings of time and money, but you have to know exactly what you want.

UN Information Centre,
Box 472, Port Moresby.

Focus, An ink-duplicated monthly newsletter on international social, political, and economic issues. Good for high school and college libraries. Free.

FAO periodicals: Order through above UN Information Centre.

Ceres, FAO Review on Development; Issued bimonthly in separate English, French and Spanish editions. Annual subscription rate US$8.00. Reports on the multiple aspects of agriculture and socio-economic progress in developing countries, and deals with aspects of trade, technology, foreign aid, international finance legislation, education and training, the protection of the world from pollution, world affairs and food production.

cont'd

Food and Nutrition, A review devoted to world developments in food policy and nutrition - issued quarterly in separate English, French and Spanish editions. Annual subscription rate US $8.00.

World Animal Review , A quarterly journal devoted to world development in animal production-animal health and animal products - issued in separate English, French and Spanish editions. Annual Subscription rate - US$5.00. Includes reports on new methods, techniques, equipment, machines, news, notes, book reviews. Profusely illustrated.

Plant Protection Bulletin, issued bi-monthly in separate English, French and Spanish editions. Annual subscription rate - US$5.00. Promotes mutual understanding between countries concerning current situation and control of plant pests and diseases, and plant protection organizations and activities of individual countries. Makes available much information not generally contained in other publications.

AGRINDEX, Monthly bibliography of the latest agricultural literature. Issued in English, giving also titles in original language when available. Annual subscription rate - US60.00. Comprehensive current awareness service in all fields of agriculture.

Films and Filmstrips available from UN Information Centre. (p 224)

One week loan for borrowers in Port Moresby and one month for those in rural areas. The Centre pays forwarding costs and borrower pays for return. Two to three films may be borrowed at a time. A report form must be filled each time. Films must be shown free of charge to the public.

U.S. GOVERNMENT PUBLICATIONS

United States Government Publications
Superintendent of Documents
US Government Printing Office
Washington D.C. 20402 USA

While most of the materials produced by this office are for American consumption, some are helpful for PNG. Various lists of publications are issued for different categories of information. Since they handle approximately 25,000 different publications, no single catalogue could list all of these. There are no free items, although the lists are free. Remittances from countries outside the U.S. should be by bankers draft, payable to the Supt. of Documents. Here are a few of the lists:

No. 21 Fish and Wildlife
38 Animal Industry
42 Irrigation, Drainage, and Water Power.
44 Plants
46 Soils and Fertilizers
68 Farm Management

The monthly catalogue, which costs US$4.50 for a year's subscription, is a comprehensive current listing, and might be useful for the larger libraries.

UNIVERSITY OF THE PHILIPPINES

Department of Development Communication
College of Agriculture,
College, Laguna, 3720, Philippines.

LEAFLETS: (PARTIAL LIST)

3 Methods of Seeding and Planting Garden Crops, C.L. Madrazo. Price ₱0.25
8 Disease Control Guide for Vegetable Growers, F.C. Quebral & R.G. Davide Price ₱0.25

CIRCULARS:

6 A Guide to Broiler Production, E.C. Coligado Price ₱0.60
10 Get the Best Effects From Herbicides, M.R. Vega Price ₱0.30
11 Home Preservation of Mangoes and Papayas, Onate et. al. Price ₱1.65
12 How to Make Compost, B.C. Felizardo, S.M. Tilo & E.C. Elefano ₱1.05
15 Management of Soybean Production, I.C. Cagampang, R.M. Lantican & S.N. Tilo ₱0.50

FARM BULLETINS:

1 New Ways With Rice (cookbook), A.M. del Mundo & N.R. Bustrillos Price ₱1.50
5 Landscape Your Garden, E. de la Cruz Price ₱1.25
6 Egg Farming for Beginners, A.C. Campos & M.M. Labadan Price ₱1.75
7 Increase Profit Through Culling and Selection, M.M. Labadan Price ₱1.65
8 How to Propagate Fruit Plants, R.V. Valmayor & R.E. Coronel Price ₱1.25
14 Care of Baby Pigs from Birth to Eight Weeks, R.B. Puyaoan, M.G. Supnet & J.A. Eusebio ₱1.00
15 Crop Production Goals for Vocational Agriculture A.O. Gagni & G.F. Saguiguit Price ₱1.25
16 Successful Brooding of Chicks, M.M. Labadan & A.S. Adejar Price ₱1.15
17 Corn in Meals and Snacks (cookbook), L.U. Onate, A.M. del Mundo & S.M. Novero Price ₱1.25
19 Rabbit Raising for Fun and Profit, L.L. Clamohoy Price ₱1.50
20 Better Meals with Root Crops, A.M. Del Mundo & L.U. Onate Price ₱1.15
22 Goat Raising in Your Backyard, L.L. Clamohoy Price ₱3.60
23 Preserving Fruits (cookbook), L.U. Onate ₱1.80
24 Cassava - A Guide to Its Culture, C.D. Molinyawe Price ₱1.50
27 Beekeeping in the Philippines, R.A. Morse & F.M. Laigo Price ₱4.10
28 Black Pepper, I.S. Anunciado Price ₱1.50
29 How to Grow Grain Sorghum, A.A. Gomez & A.C. Mercado, Jr. Price ₱1.25
30 How to Grow and Store Ginger, T. Cadiz Price ₱0.75

32 Peanut Production, I.C. Cagampang & R.M. Lantican Price ₱3.70
33 How to Make a Farm Plan for Rice Farming, E.P. Abarientos Price ₱0.60
34 Growing Mungo (Mung Bean), I.C. Cagampang & R.M. Lantican Price ₱1.20
36 36 Ways of Cooking Soybeans, L.I. Onate, A.R. Aguinaldo & J.A. Eusebio ₱2.50
39 Easy Recipes for Sorghum, L.U. Onate & N. Lantican Price ₱1.50

TECHNICAL BULLETINS:

6 Swine Raising for Beginners, J.A. Eusebio Price ₱2.15
7 Rambutan, R.V. Valmayor, H.L. Valmayor & L.G. Gonzales Price ₱4.30
22 Beef Cattle Selection and Culling, M.G. Supnet, L.L. Clamohoy & J.C. Madamba ₱1.80
24 A Handbook of Citrus Diseases in the Philippines Ma. Salome E. del Rasario Price ₱2.50
25 Insect Pests of Vegetables, N.M. Esguerra & B.P. Gabriel Price ₱9.00
27 Beef Cattle Health and Sanitation Manual, O.C Martin & F.P. Vergara Price ₱4.50
28 Harvesting Handling and Storage of Leading Philippine Fruits, D.B. Mendoza Jr., Er.B. Pantastico & J.C. Hapitan Jr. Price ₱2.50
29 Handling and Storing Perishable Foods for Home Use, Er. B. Pantastico Price ₱1.85
30 The Principles and Practice of Plant Disease Control, O.E. Schultz & F.C. Quebral Price ₱4.80
35 Common Rice Diseases and Their Control, D. Lapiz & O.S. Opina Price ₱3.60

MANUALS AND SYLLABI

Rice Production Manual 1970- Revised Edition, Price ₱16.00 postage fee ₱1.70
Vegetable Training Manual ₱10.00 postage ₱1.20
Rural Broadcasting (Syllabus on Radio) P.B. Bueno, P.M. dela Paz & F. Librero Price ₱8.00 postage fee ₱1.20
Irrigation and Drainage Principles and Practices A.O. Gagni, W.P. David, V.A. Sahagun & M.R. de Vera Price ₱7.50 postage fee ₱1.20
Principles of Soil Science (Laboratory Manual) Price ₱7.50 postage ₱1.20
Swine Production and Management (Laboratory Manual) Price ₱7.50 postage fee ₱1.20
Corn Production in the Philippines Price ₱6.00 and postage fee ₱1.20
Coconut Production in the Philippines, Price ₱3.90 postage ₱0.90
Poultry Production in the Philippines, Price ₱5.60 postage ₱0.90
Rice Production in the Philippines, Price ₱5.50 postage ₱1.20

Please address all letters and cheques to the;

Department of Development Communication,
College of Agriculture,
U.P. at Los Banos,
College, Laguna 3720, Philippines.

Postage listed is Philippine domestic postage; for surface mail to PNG send twice the amount for the domestic postage. Be sure to send a bank cheque in Philippine Pesos. (K1.00 = approximately ₱8.90) Allow 4 months for seamail delivery.

VITA (Volunteers in Technical Assistance)
3706 Rhode Island Ave.
Mt. Rainier, Md, 20822 USA (p 259)

(Note: The VITA Field Representative, Box 4981, Unitech, Lae, has a limited supply of VITA publications.)

LIST OF PUBLICATIONS:

Village Technology Handbook, revised edition, 1975, 387 pages, US $9.00 postpaid (add US $7.20 for airmail)

A popular "Old Standard" which has been around since 1963. 37 well-prepared articles on a variety of topics. 143 pages on water resource development and use. About 30 pages on toilets. Good article on earthmoving for irrigation and road-building. Excellent article on soap-making. But it cannot be considered comprehensive, most references cited are rather old and are not available for readers in developing countries to buy, and it is much too expensive. Invest your money in VITA's shorter papers. Level: Simple

2E Automotive Operation & Maintenance (1975) 202 pages. A manual for drivers using pioneer roads and for novice mechanics in areas without extensive service facilities. Price US$6.50

Agriculture and Food Processing

5E Smoking Fish in a Cardboard Smokehouse (1966) Price US$0.50
6E How to Salt Fish (1966) Price US$0.50
9E Solar Cooker Construction Manual (1967) US$2.00
12E Fresh Produce Handling & Distribution (1965) Price US$0.50
15E Groundnut Huller (1970) Price US$0.50
24E How to Perform an Agricultural Experiment (1971) Price US$1.50

Construction

7E Making Building Blocks with the Cinva-Ram Block Press (1966) Price US$1.50
10E Small Scale Manufacture of Burned Building Brick (1968) Price US$1.00
25E Waterproofing Soil Construction (1973) US$1.00

Health

22E Health Records System (1971) Price US$1.50
23E Bandages Impregnated with Plaster of Paris (1971) Price US$1.50

Power and Water Resources

8E Low Cost Development of Small Water Power Sites (1967) Price US$2.00
18E Hydraulic Ram for Village Use (1970) US$1.00
20E Low Cost Windmill for Developing Nations (1970) US$2.00
27E Design Manual for Water Wheels (1975) US$4.00
28E Handpumps for Village Wells (1975) US$1.50

Other Helpful Manuals

3E Bat Control (1963) Price US$0.50

13E Chalk Stick Making (1969) US$1.50

14E Playground Manual (1969) US$2.00

30E Simple Furniture Design (1975) US$0.50

Price includes cost of surface mail. For airmail, add 80% to the total price of the order.

Sourcebooks

SOURCEBOOKS

Appropriate Technology Sourcebook, 2nd edition. US$2.00 from The Appropriate Technol. Project, Box 4543, Stanford, California 94305, USA.

This is a 304 page booklet of reviews of a wide range of books and pamphlets about appropriate technology. Like the Liklik Buk it does not tell you how to do something. It tells you where to go to find out how. There are general books and how-to pamphlets published by a number of groups throughout the world from Nigeria to the Philippines and from South Africa to Canada.

There are many books or pamphlets on different free energy sources, as well as on housing, public health, agriculture tools, agriculture product processing, and even books on how to make tools to make other tools.

Where there are reviews of technical plans the reviews are based on the construction of the item and lists the materials required, the cost of the materials, and the tools needed to build. Of particular interest to PNG are plans for pedal powered peanut threshers, a hand powered peanut huller from automobile wheels, and an excellent book on the construction of methane digesters. The Sourcebook says that the Energy Primer, which is also reviewed elsewhere in the Liklik Buk, is the most valuable book they have reviewed. (p 158)

Next to the Liklik Buk, the Sourcebook is probably the most useful list of references available.

Level: intermediate.

Books

A HANDBOOK ON APPROPRIATE TECHNOLOGY, Brace Research Institute and Canadian Hunger Foundation, from CHF, 75 Sparks Street, Ottawa, Ontario, Canada KIP 5A5. 280 pp. Formerly loose-leaf, now paperback. Papers on Appropriate Technology, its philosophy, techniques. Case studies are shown with pictures and diagrams. Contains a glossary, a catalogue of tools and implements, biblography, and lists of groups around the world involved in Appropriate Technoloy. Price C$6,00 not including postage. Airmail and handling C$7,85. We don't know the Surfacemail rate.

The Cumberland General Store Wish and Want Book (Being a Comprehensive Selection of Down to Earth Tools for Living the Good Life), Price US$3.00 incl. surface post.

Available from The Cumberland General Store, Rt. 3, Box 479, Crossville, Tennessee 38555.

It is, as it indicates, comprehensive. Virtually all of the tools are hand powered: canners, forges, windmills, pumps, plows, traps, grinding mills, pruning tools, washing machines, and animal pulled farm equipment.

These things are expensive in this catalogue, but all of the tools can be made in PNG, just as they used to be made in small factories in American rural areas. Every item is illustrated, and usually clearly enough that you could make your own from the drawing. These are the tools that made early America "self-reliant."

Radical Technology, Godfrey Boyle and Peter Harper, Ed., 1976 $5.95 from:
Pantheon Books
201 E. 50th St.
New York, NY 10022

An impressive collection of essays, reports, access to information and counterculture philosophy. Interesting essays on tree farming, textile making, biological chemicals, metal working and paper making. An introduction to appropriate Technology from a counterculture perspective. By the editors of Undercurrents.

WHOLE EARTH CATALOGUE (US$6.00)
WHOLE EARTH EPILOGUE (US$4.00)
CO-EVOLUTION QUARTERLY (US$8/yr)

Box 428, Sausalito, California 94965 USA.

Continual update by the "original" access catalogue (inspiration for Liklik Buk).
Various "appropriate" tools, books, philosophy, and comments, mixed with gossip.

BOOKS FOR STIMULATION AND REFERENCE

Appropriate Technology - Problems and Promises. ed. by N. Jequier, Development Centre, OECD, Paris, 1976, 344p. From OECD Publications, 2, Rue Andre-Pascal, 75775 Paris, Cedex 16, France.

An interesting treatment of the philosophical and policy issues of Appropriate Technology, with 19 papers from practitioners in the field. Helpful for those sorting out priorities and formulating policies.

Level: Intermediate/advanced.

African Food Production Systems, Cases and Theory, by P. McLaughlin, Johns Hopkins Press, Baltimore, USA US$12.50.

A collection of seven studies by anthropologists which emphasize seven African societies' responses to innovations in food production technology. The editor's introduction is a cry for greater under-

standing and investigation into the constraints on food productivity instead of just talking about it. It is also an outline of the areas where greater research is needed if the tide of reduced productivity is to be turned.

This series is particularly interesting in that it shows how many African societies reflect PNG. The introduction that lists the constraints on productivity, with social aspects listed in great detail, make the book valuable for anyone concerned with planning or implementing development projects on any level. Level:intermediate.

Agricultural Development: An International Perspective, by Yujiro Hayami and V.W. Ruttan, Johns Hopkins Press, Baltimore, USA, 1971, US $12.00.

A study of the potential for technology transfer and growth in agriculture. It emphasizes studies of U.S. in comparison to Japan and her former colonies of Korea and Taiwan. Comprises a significant amount of general data on farm productivity and production in these and other countries. Considerable economic theory and formulae. Basically a university text in agricultural development and of interest to planners and policy makers. Level: advanced.

Experiences With Agricultural Development in Tropical Africa, (2 vols), by J.C. de Wilde et al, Johns Hopkins Press, Baltimore, USA, 1967, US$17.50

Published for World Bank, this two volume study focuses on development schemes financed by the Bank in six African countries. The volume dealing with the case studies is descriptive of the economic aspects of the projects, but some insight is shown as to social, political, and cultural factors that have effected the schemes. The other volume attempts to draw general conclusions about changes in the societies, land tenure, technology, agricultural education, credit and marketing and cooperative structures as a result of the impact of the projects.

Although a bit heavy and filled with data the volume of synthesis is very useful background for people who think that their own development problems are unique - they aren't. A failing of the books is the perfection of their 20/20 hindsight, and the few solutions to the problems they identify. Level:intermediate/advanced.

A Handbook of Tropical Agriculture, by G.B. Masefield, Oxford Univ. Press, 1970, 196 pp.

As the name indicates it is a handbook of brief statements on tropical soils and environment, crops of all major types, livestock, pests and diseases. Not for the specialist, but helpful in a school library. Level:simple.

Rural Reconstruction and Development, a Manual for Field Workers, by Yen, Feliciano, et al, International Institute of Rural Reconstruction, Silang, Cavite, Philippines, 1967, 456 pp, Order direct, approx US$4.00.

This is a manual for the fieldworkers of the Rural Reconstruction movements, with basic guides in areas of livelihood, education, health, and village self-government. Written primarily for Philippine conditions, it has useful materials for those working with rural youth movements and people's organizations at village level in PNG. Level:simple/intermediate.

We Don't Know How, by William and Elizabeth Paddock, Iowa State Univ. Press, Ames, US$4.50.

Long experience with some keen disillusionment of the development process qualify the authors for this controversial book. They have investigated projects supported by charitable and government organizations in several South American countries which the organizations had identified as being very successful. The Paddocks had hoped to learn what makes a successful project. The problem they found was that there were none among the various health, educational, agricultural, and economic projects. Just why the projects were not successful is the meat of the book. Since many of the projects have similarities in means of financing and focus with many projects in PNG, the warnings are useful. Level:intermediate.

China: Science Walks on Two Legs, Science for the People, Avon Books, 1974, $1.75 from:
Hearst Corporation
959 Eighth Ave.
New York, NY 10019 USA.

First Steps in Village Mechanization by George A. McPherson, Tanzania Publishing House, Box 2138, Dar es Salaam, 1975. No price given.

This is a how-to-do-it book for peasant farmers in Tanzania, and so many of the needs are different from PNG. Village carpentry suggestions are primitive by PNG standards, and agriculture equipment for animal power is not yet relevant, but there is a very good section on village forges and tools that can be made from scrap. One agriculture tool which might be useful in the Markham Valley, is a corn sheller made from wood and staples. There are many useful suggestions on the use of old rubber tyres, including knife and chisel handles, animal harnesses, and solid rubber tyred wooden wheels. All drawings are clear and photographs of the finished product are shown.

The instructions are a little sophisticated for village technicians, but would be very useful in vocational centres and more sophisticated workshops.

Level: simple.

Modern Agriculture for Tropical Schools, Oxford University Press, Kuala Lumpur, 1970. Price Singapore $5.50.

This is the best school book for High School agriculture, for students learning in English as a second language. It is a rare book because it assumes that the High School students are capable of thinking. It actually teaches something about agriculture beyond the how-to level.

Available from: Marican and Marican Booksellers G57 Katong Shopping Centre, Singapore 15, Republic of Singapore.

Level: simple/intermediate.

THE SAMAKA GUIDE TO HOMESITE FARMING

"Samaka" is an abbreviation which means approximately "A united effort of a group to have more plentiful food for their families". And this is what it's all about.

A good book, a useful book, but somewhat uneven in its treatment of subjects. No school should be without one and group leaders, missionaries and private individuals engaged in mixed farming would find it extremely useful. It is a particularly useful idea book for people changing from subsistence bush gardens to home lot gardens.

If you're looking for quickly obtained yet useful advice, then this book will help you. If you are looking for commercial advice, or a lot of detail about a subject, then you will need to find a more specialized book.

About 30 subjects are covered: the sections on Goats; Vegetables; and Chickens, being particularly useful

The book was written in 1954 and suffers from this to a degree. A revision has been made, but it could have been better. There are bad examples of mixing Metric and Imperial measurements.

Some of the measurements, and many of the names, will be unfamiliar to people in PNG; but most of these become clear after reading on for a few pages.

Available from UPNG Bookshop.

Level: simple

Reviewed by: F. Robinson, Konedobu.

We're as unhappy as you with the quality of this section. Too few contributors have shared with us useful books on Development and Technology. Let us know the best references and books by sending us a review for the third edition. *(see p 268/269)*

Book Suppliers

PNG

Christian Book Store
Box 78, Mt. Hagen WHP

The Book Depot
Box 90, Rabaul ENBP

Menduli Book Depot
Box 35, Mendi SHP

Christian Book Centre
Box 122, Madang MP

Christian Bookstore
Box 91, Goroka EHP

Christian Book Shop
Box 169, Wewak ESP

Attic Book Shop
Box 802, Lae

Christian Book Centre
Box 718, Lae

Madang Bookshop, Pty. Ltd
Box 484, Madang

New Guinea Book Depot
Box 5495, Boroko

Goroka Book Shop
Box 621, Goroka

University Bookstore
Box 4820, University

OVERSEAS

Blackwells
Broad Street
Oxford OX 1 3BQ England

A major bookseller that specializes in mail order and special order. Catalogues of books are available by subject matter to regular purchasers without charges. Very good service, prices are net plus postage and insurance. Expect 4 to 5 months delivery wait. Books published in Britain are cheapest this way.

Compendium, Pty. Ltd.
Books for Self Sufficiency
Centreway
259 Collins St., Melbourne, Australia 3000

This is a bookstore that specializes in ecology-oriented, self-sufficiency and handicraft books, generally of the "how to" nature. Despite high cost of catalogue and the supplements, it is the best available in the South Pacific. Remember, though, that the store caters primarily to Australian needs. Catalogue and three supplements A$2.70/year.

Periodicals

Countryside and Small Stock Journal
Countryside Publications Ltd, Route 1 Box 239
Waterloo, Wisconsin 55594, USA, Jerome Belanger, Editor. One year US6.20, 2 yrs US10.40, 3 yrs 15.60.

A monthly magazine for the homesteader who is relearning self-reliance. Much of what is written is not for PNG, but there are many ideas that are suitable. The magazine is reader-oriented, and this means that many of the readers share their own bits of traditional knowledge. Many of the designs assume that the reader can scavenge in an American dump for pieces, but only the Lae dump seems to be in the same category of conspicuous consumption. There is great emphasis on energy conservation, non-mechanical farming and organic gardening. An editorial bias in favour of small farms, goats, and rabbits.

Development Forum, by Centre for Economic and Social Information, United Nations, Palais des Nations, CH1211, Geneva 10 Switzerland. Monthly, Free, but specify language desired (English, French Spanish, German, Italian.

This is airmailed monthly on newsprint. The reporting is journalistic and deals with current issues and controversies on the development scene. Discusses films, pamphlets, display materials that are available through the various U.N. agencies. DF is designed not to offend. Level:simple/intermediate.

Development News Digest,
Box 1562,
Canberra, ACT 2601.

A$6.50 per year for a news digest concerned with third world issues. Published by the Educational unit of the Australian Council for Overseas Aid. Directed at voluntary aid agencies, members of parliament, the media, education institutions, and community groups, it aims to encourage a critical and questioning approach to activities in the Third World.

Earth Garden
P.O. Box 111
Balmain, N.S.W. 2041
Australia

Comes out approx 4 times a year, A$1.00 per issue. Presents a range of so-called "natural" life styles. It is intended as a key to sources, practical ideas, alternatives, self-sufficiency.

Grass Roots "The Craft and Lifestyle Magazine"
Box 900
Shepparton 3630
Australia

Subscription A$4.40 for 4 issues, back copies $1.20. "Produced for those who wish to regain control over their lifestyle by exploring the alternatives to modern mass consumption." Many articles on simple agriculture and intermediate level technology.

Ideas and Action Bulletin
C/- Freedom From Hunger Campaign/Action for Development, Via delle Terme di Caracalla, 00100 Rome, Italy.

Issued approximately every six weeks, free. Lots of "preaching", lots of "jargon", from an organization which means well, but which is largely a "paper" committee. Not for those working at village level. Will provide some stimulation for those working at regional and national level.

Mother's Bookshelf,
Box 70, Hendersonville, NC 28739, USA.

The books listed can tell you how to produce energy from the wind and sun, build a low-cost comfortable home, garden organically, make money at home (legally), raise food in a cupboard, find underground water, use natural pest controls, raise rabbits and chickens, make soap, can and dry home-grown fruit and vegetables, sell handicrafts, keep bees, build walls fences and gates, store a year's supply of food ... and do a thousand and one other useful things.

Reviewed by: J. Dash, Gerehu.

The New Internationalist,
Wantok Publications,
Box 1982,
Boroko.

K14.00 Airmail per year. Reports on the issues of world poverty; focuses attention on unjust relationship between rich and poor worlds; debates and campaigns for radical change for meeting basic human needs; and seeks to mobilize people, ideas, and action for world development. Sponsored by Christian Aid, OXFAM, and Third World First. Articles and opinions do not necessarily represent the views of the sponsoring organisations. Editorial Offices: 62a High Street, Wallingford, Oxon. OX10 OEE. U.K.

The New Technologist,
c/- Voluntary Committee on Overseas Aid and Dev't,
International Development Centre,
25 Wilton Road,
London SW1V 1JS U.K.

Free. Published by the Academics Against Poverty programme, with the purpose of encouraging workers in science and technology in institutions of higher learning to adapt their teaching and research to the expressed needs of communities. Basic articles, bibliography, further contacts.

Power Farming Magazine
29 Alberta St.
Box 3408
Sydney 2001

Subscription A$10.00 for P.N.G. Generally advanced level agricultural technology, but with occasional articles on intermediate technology.

RAIN/Environment Education Centre,
Portland State University, Portland, OR 97221 USA.

Publishes RAIN, an environment/intermediate technology oriented periodical with various ideas, book reviews, briefs on who is doing what and where. Subscription US$5.00

Rural Life
C/ Institute of Rural Life
27 Northumberland Rd.
New Barnet, Herts, U.K.

Three pounds annually. A quarterly review of the Institute, which promotes lectures, conferences, and courses of study on Rural Life and home and overseas. It is in contact with more than 200 societies throughout the world; over 100 registered correspondents in some thirty countries.

Small Industry Development Network,
Quarterly Newsletter,
Engineering Experiment Station,
Georgia Institute of Technology,
Atlanta, Georgia 30332, USA.

Subscriptions free. News, Comments, Contacts, Book and other publications lists, oriented towards appropriate technology. When writing give your name, title, organization, address.

World Farming
1014 Wyandotte St.
Kansas City, Missouri, 64105 U.S.A.

Free subscriptions for "agriculturists" living outside of continental United States, US$5.00/yr for others. Lots of advertising, some good articles.

Succour and Comfort

It is claimed that PNG receives from all sources more foreign aid per capita than any other developing nation. It is true that the per capita aid is greater than the per capita Gross National Product of the eighteen least developed nations. We urge readers to keep this in mind before seeking development funds from outside resources.

PNG DEVELOPMENT BANK

How is the Development Bank different from other Banks?

1. You cannot open a passbook, a cheque account, or deposit and withdraw as you do with other banks.
2. The Development Bank gets most of its money from the Government and from organizations like World Bank and Asian Development Bank. This money is then loaned to Papua New Guineans to establish businesses to help develop the country.
3. Interest rates are usually lower than those charged by other banks. (Interest is what you pay the bank for its service in giving the loan).
4. The Development Bank does not ask that the borrower give as much "Deposit" (The borrower's contribution to the project) as other banks.
5. The Development Bank often lends money for longer periods than other banks.
6. The Development Bank does not always require as much "security" (something of value given by the borrower to support the loan) as other banks.

The Story of the Papua New Guinea Development Bank is available from their branches and offices. The booklet tells a person who wants to borrow from the bank how he should go about getting a loan, and how the bank works once the loan is approved. It doesn't tell about the delays that are involved in getting a loan, due to the paper work that is necessary, but most people know about that already.

The PNG Development Bank tends to make regular changes in its policy, so it is a bit difficult to keep up. For up-to-date information, write:

Publicity Office
PNG Development Bank
Box 6310
Boroko

ENGINEERING, ARCHITECTURAL AND MECHANICAL ADVISORY SERVICE

Within the Department of Transport, Works and Supply there is a branch called the Local Government Advisory Service. Its function is to provide technical and professional advice to all Local Government Councils and Area Authorities within Papua New Guinea.

The Engineering section mainly assists with design

for roads, bridges, wharves, causeways and village water supplies. The Architectural section undertakes design of such things as offices, meeting halls, markets, aid posts, theatres, class rooms, houses, museums and guest houses. The Mechanical section offers advice on the costs, purchase and maintenance of machinery and vehicles.

It is possible for village groups and associations to make use of this advisory service provided their Local Government Council or Area Authority supports their enquiry with a letter approving the proposed project.

For further information write to: (P 128)

The Secretary,
Department of Transport, Works & Supply,
Local Government Advisory Service,
PO Box 1108,
Boroko.

VILLAGE DEVELOPMENT OFFICE

Box 6937, Boroko. Phone No 25-9999. (P 245)

This office in the Department of the Prime Minister has advised us that they have four basic functions:

1. There is a fellowship scheme that pays ½ the salary of a public servant or K50 per month for a private individual who wants to use his skills to help his village, for a period of 6-12 months, if his leave is approved. Details of the project must be made with application.

2. The office conducts appropriate technology workshops to assist villages with technical ideas for improving village life. (Ukarumpa & Vudal last year).

3. The office, together with the South Pacific Appropriate Technology Foundation, helps people get in touch with the proper department for assistance with projects. The office also makes sure that you have enough information about your project to be able to get action from the department that is to help you. If you feel that some department is not helping you enough write or visit the Village Development Office to get their assistance.

4. The office also publishes information sheets and technical books on new ideas for village level technology.

For more information on any of this work write to the above address.

SELF-HELP

RURAL IMPROVEMENT PROGRAMME is a source of money for Area Authorities and Councils to supplement funds raised through taxes and fees for carrying out projects in rural areas.

Villages and groups can ask for assistance on their projects by making a proposal through their councillor for money if they have made a self-help contribution. If the council approves the application it is forwarded to the Area Authority for evaluation. You should have your application made by November if you want to be considered for money for the next financial year. You will have a much better chance of getting approval if you check out your application with officers of any departments concerned before you submit the application. They will often be able to help with technical details to make your application stronger.

One problem with RIP grants is that approval is politically motivated in some areas.

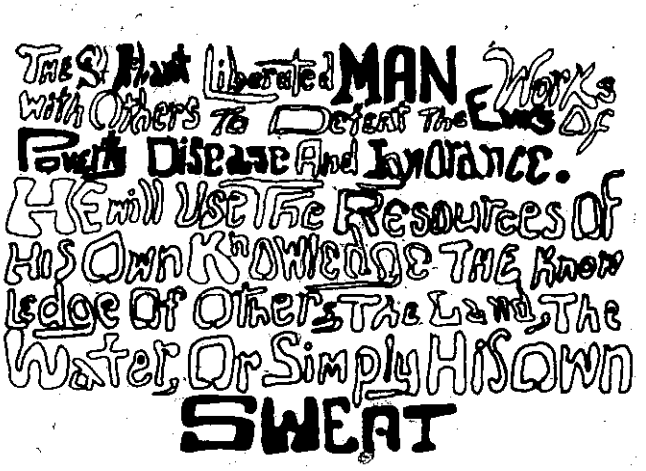

Graffiti on a Wesley High School wall.

VILLAGE ECONOMIC DEVELOPMENT FUND

The Village Economic Development Fund is a way of getting money for business projects. In each Province a Committee outside the Area Authority administers the fund on the advice of the PNG Development Bank and the Department of Business Development. A project can get a grant of up to 40% of the total needed for the project, but it must raise the rest of the money from its own resources or from bank loans.

For more details see the Development Bank or the Business Development Office near you.

Here again politics play a part in some decisions. One Area Authority passed a resolution that the name be changed to the "Ministers Development Fund" as a protest against what they felt was political favouritism in approving a grant. (Post Courier, 5 Oct, 1976). But don't despair. Good projects are approved too, but sometimes the bureaucratic delays are frustrating.

Wau Ecology Institute
P.O. Box 77
Wau

The Wau Ecology Institute is an organization dedicated to the study of the plants, animals, and ecology of Papua New Guinea, and to conservation and education in relation to these. A small but competent staff plus visiting students and consultants study a variety of specific interests. This is a good example of solid accomplishment on a very limited budget. If you ever go to Wau, you'll find this a most interesting and worthwhile place to visit. If you have questions about P.N.G. ecology, these people may be able to help you.

Community Development Committee
University of Technology
Box 793, Lae

Your technical questions requiring expertise will be referred to appropriate persons. Civil, agricultural, mechanical, and electrical engineering, plus chemical and food technology are especially active areas at Unitech.

> *If you give a man a fish, you feed him for a day. If you teach him to fish, you feed him for a lifetime.*
>
> *-ancient proverb.*

OTHERS

Action Library
1717 H. Street, N.W. Rm T 345,
Washington D.C.20525 U.S.A.

Specialised technical information on agriculture, housing and teaching, bibliographical data, and advice on where to find information.

Agricultural Missions, Inc.
475 Riverside Drive
New York, N.Y. 10027 USA

"Agricultural Missions, Inc. serves churches (Protestant and Catholic) in their work among rural people in the Third World. It provides technical information and assistance to rural development projects; orients and trains personnel and missionaries for rural programmes and development, provides leadership and support for seminars and short courses; helps create, strengthen and prepare leadership for overseas church-related rural development organizations; builds and strengthens rural programme-planning capabilities of churches in the Third World; supplements and cooperates with the efforts of government and other agencies to achieve a world without hunger."

Anti-Poverty Ltd.
c/Mr. Paul Sherlock
Oxford College of Further Education
Oxford, England

Projects in intermediate technology research are being carried out, including development of a mechanical tablet-counting machine for rural dispensaries; simple pumps which can be made from spare pieces of drain-pipe; a small machine for knitting chicken-wire; a low-cost lathe; a small aluminium crucible made from an oil drum; various applications of solar energy. Detailed drawings available.

Brace Research Institute
Agricultural Engineering Building
MacDonald College
McGill University
Montreal, P.Q., Canada

(p 155)
(p 251)

Plans, publications on intermediate technology. Especially active in seeking practical uses for solar energy.

Canadian Hunger Foundation,
75 Sparks St.,
Ottawa, Ontario KIP 5A5
Canada

Handbook, publications and referral service on appropriate technology.

Christian Relief and Development Association,
Appropriate Technology Unit,
Box 5674,
Addis Ababa
Ethiopia.

Assists community improvement projects by providing information. Publications or reports are available on wind power for pumps, well drilling, getting rid of porcupines, bamboo pipes, termites, soap-making, handbook for agronomy crops, handbook for soil and water conservation, manual on rural leather tanning, hand dug wells, handcraft production in Ethiopia. A small fee plus postage is charged. We do not have a price list.

Gandhian Institute of Studies
A.T. Development Unit,
P.O. Box 116, Rajghat,
Varanasi 221001, Uttar Pradesh, India.

Recently published a Directory of Appropriate Technology which includes information on appropriate technologies being successfully practiced in India.

Small Industries Development Organization
Box 2476, Dar es Salaam, Tanzania.

Has done a lot in beekeeping, crafts, methane gas from cow dung, lime-burning, and others.

The Institute of Development Studies UK
University of Sussex
Brighton BN1 9RE, UK

Mainly oriented to teachers and planners. Offers courses and maintains a publications service for various development related topics and issues. Current lists and prices available upon request.

Intermediate Technology Development Group Ltd
Parnell House
25 Wilton Rd
London SW1V 1JS, UK (p 247)

Its main aims are: to compile inventories of existing technologies which can be used within the concept of low-cost, labour-intensive production; to identify gaps in the range of existing technologies; to research into and develop by invention or modification new or more appropriate processes; to test and demonstrate in the field the results of its investigations; and to publish and make known the results of its work as widely as possible so as to facilitate the transfer and use of appropriate technology.

Missions Liaison Group
91 Darebin St.
Heidelberg 3084 Australia, Phone 45 5325

"Under the auspices of the Methodist Departments of Home and Overseas Missions, endeavors to provide assistance to the needs of mission areas in developing countries and at the local level by purchasing goods, materials and equipment; endeavoring to match the needs of some with the availability of surplus or obsolete goods of others; obtaining specialized advice and guidance; by organising work parties both large and small to assist in meeting needs. Assistance is not restricted to any particular country, denomination, or religion."

National Institute of Agricultural Engineering
Restpark
Silso, Bedfordshire, England

Plans for small devices and technical information.

Overseas Development Council
1717 Massachusetts Ave. N.W.
Suite 501
Washington D.C. 20036 USA

"An independent non-profit organization seeking to ensure wise decisions affecting the process of development of the poorer nations. Functions: to provide a national centre serving as a clearing house, coordinator and catalyst with respect to the manifold activities related to overseas development; to conduct studies of its own on current and emerging problems; to serve as a forum for those directly concerned with development."

Seminars, conferences, information distribution. Generally the Council publishes 14 - 16 titles a year in its Monograph, Development Paper, Occasional Paper, and Communique series. Write direct for current lists and prices.

Society for International Development
1346 Connecticut Avenue, N.W.
Washington, D.C. 20036 USA

Promotes discussion of development issues; publishes International Development Review (quarterly) and Survey of International Development (10 issues yearly); reference service on development information, directing individual inquiries on any development matter to appropriate sources. Annual membership dues for those in developing countries at local salary levels is US$6.00, and ~~which entitles~~ members to the two publications.

READERS: WE WOULD APPRECIATE KNOWING YOUR EXPERIENCES IN OBTAINING THE SERVICES OF SOME OF THESE GROUPS, ESPECIALLY THOSE WITH THE "POSH" ADDRESSES. ARE THEY DOING WHAT THEY CLAIM?

Technical Assistance Information Clearing House,
200 Park Avenue South
New York, N.Y. 10023, USA

"Serves as a centre of information on the socio-economic development programs abroad of U.S. Voluntary agencies, missions, and foundations and other non-profit organisations-" Free newsletter (irregular) includes new publications and conference announcements.

Seatec International (Southeast Asia Technology)
Consulting Engineers Design, Research & Planning,
131 Townsend Street, San Francisco,
California 94107 USA.

An engineering consulting firm specializing in the fields of environmental and water resources engineering and applications of intermediate technology in the developing countries of South East Asia. Has carried out work for United Nations, US Agency for International Development, and international lending agencies. Contacts throughout Asia.

International Rice Research Institute,
Box 933,
Manila, Philippines.

IRRI Engineering Department has developed a number of simple and economical designs for Agriculture, mainly rice, and is willing to make these available free along with expert technical assistance to manufacturing firms (both small and large) willing to produce them. Some examples: foot-operated irrigation pump, various types of grain threshers, grain cleaners, grain driers, power tillers, lug wheels for tractors which go into rice paddies.

NEW ZEALAND AID PROGRAMME includes a special High Commissioners Fund administered from the High Commissioner's Office in Boroko. It is a form of direct assistance to the village, for projects with a significant portion of self-help that are unable to get further assistance through existing channels. A well documented submission will get a very rapid response, often resulting in the assistance arriving in six weeks. Only non-business projects are eligible, and the maximum assistance is K1,000. Further information from High Commissioner's Fund New Zealand High Commission, Box 1144, Boroko.

VITA - Volunteers in Technical Assistance
3706 Rhode Island Avenue
Mt. Rainier, MD 20822 USA
or
P.O. Box 4981, Unitech, Lae.

(p 250)

Through correspondence with individuals and organizations in developing countries, VITA Volunteers provide personalized assistance in areas such as ...

- agriculture and animal husbandry
- food processing and preservation
- small scale rural industries
- equipment design
- housing and construction
- crafts production
- medicine and health
- alternative energy sources
- water and sanitation

VITA provides its services free of charge to development organizations, small businessmen, extension agents, missionaries, and others who are engaged in serious development-related activities but who cannot afford the cost of conventional consultants.

When you need help in solving a problem or implementing a project, VITA provides ...

- by-mail technical assistance by volunteer consultants
- over two dozen low-cost manuals on village-level technology
- cooperative projects with local development organizations
- short-term consulting on-site by a volunteer consultant when requestors can provide travel and other expenses.

cont'd

HOW TO MAKE A REQUEST:

1. Define the problem, giving all pertinent details, such as measurements, amount of rainfall, symptoms of disease, kind of soil, vegetation, etc.

2. Comment on the development of the project, idea or study and mention all previous attempts to solve the problem.

3. Indicate local resources, both funding and raw materials, naming those previously contacted or used.

4. Spell out any difficulties that could affect the solution - location, short growing season, lack of fuel, local customs.

5. If a group project, identify the organization and its purpose.

6. Allow 6-8 weeks for a response from VITA.

Allen Inversin has recently arrived in Lae where in addition to working at the Appropriate Technology Unit of the University of Technology, he is the VITA Field Representative for PNG. His concern will be to improve the quality of VITA services for requestors in the country. Any requests to VITA may be sent through him and he will try to ensure that you get the assistance you require. In pursuing his work, he will do some traveling to meet as many requestors as possible. If you have any questions on how VITA can help you with a specific technical problem, feel free to get in touch with him: Box 4981, Unitech, Lae.

Also let him know if you would like to receive the free VITA quarterly newsletter which gives you both an idea of some of the work VITA is doing in appropriate technology and some useful addresses.

Voluntary Service Overseas,
Field Office, Box 5685, Boroko, PNG.

An independent charitable organisation concerned with the recruitment of professionally qualified volunteers in Britain and their placement in appropriate development projects in the developing countries. VSO has been involved in supplying volunteers for work in PNG since 1961. Volunteers' work for both Government and Non-Government organizations and projects, and are particularly interested in supporting projects in rural development through such bodies as Local Government Councils, or Non-Government organizations such as Local Co-operative Societies etc. VSO is able to recruit volunteers to work in agriculture, education, engineering, medicine, social work, and other development activities but always try to ensure that there is a training element incorporated into the volunteer's job so that in due course the need for a volunteer is removed as national personnel take over. Projects are normally asked to provide a volunteer with accommodation and living allowance but costs such as travel from the UK to PNG are borne by VSO.

World Council of Churches
Technical Services Unit
Commission on The Churches' Participation in Dev't
150, route de Ferney P.O. Box 66
1211 Geneva 20
Switzerland

Responds to requests for documentation on various technological problems. Write for lists of publications and prices.

SELF-HELP

World Neighbors
5116 N. Portland Ave.
Oklahoma City, Okla 73112
U.S.A.

A non-profit agency engaged in village-level self-help development projects in 26 countries. Has printed information and filmstrips.

Suppliers

PNG

THE FOLLOWING FIRMS RESPONDED TO OUR INVITATION TO LIST GOODS AND SERVICES OF INTEREST TO PNG VILLAGE PEOPLE:

Agquip New Guinea,
Box 1121, Rabaul. Phone: 921470

Distributors for Holder Tractors and Spraying Equipment; Bosch Power Tools; Stahlwille Handtools, Agricultural Chemicals and Machinery.

Agquip is one of the few firms in PNG which can find you a spare part for almost anything. They have a telex and use it to get quick service. This service costs a bit, but it gets results.

Angco Pty. Ltd.,
Box 175,
Rabaul.

Telephone 921413/921233

Branches at Goroka, Lae, Kavieng, Kieta, Mt.Hagen.

Buys: Coffee, Cocoa, Tea.

Angco Pty. Ltd., are the premier purchasers of PNG cocoa, coffee and tea, handling in the vicinity of 60% of both the PNG coffee and cocoa crops respectively.

BOOK BINDING

Bookbinding is an art. Make your copy of LIKLIK BUK a permanent reference. The chairman of the Port Moresby Sheltered Workshop, c/ Port Moresby General Hospital, says that many of the physically disabled people there can bind books. Write for details.

Coffee Marketing Board
Goroka

Sells small coffee roasters to village people at a subsidized price of K2.00. Made by the students at Goroka Technical College.

Elvee Trading Pty. Ltd.,
Box 151, Rabaul. Phone 922175
T/graph code ELVEE RABAUL

A free price list is available.

Sells: Supplies, special orders, agricultural equipment, agricultural supplies, hardware, marine equipment.

"Elvee Trading Pty. Ltd., has been in business for the past 15 years and specialises in importing and reselling the most suitable and economical range of agricultural chemicals, poultry and pig feed, veterinary chemicals, seed, sprayers, pruning equipment, domestic and industrial pest control, Epiglass marine protection and boat building products and Wormald fire extinguishers".

Exmark Stock and Produce (PNG),
Box 6060, Boroko. Phone 253560
T/graph code "EXMARK" Boroko.

Sells: Supplies, special orders, agricultural equipment, agricultural supplies.

Advisory services on stockfeed, mineral & vitamin supplements.

"Exmark is located in Hohola, Port Moresby, and retails all forms of stockfeed, mineral/vitamin supplements and protein concentrates for domestic animals. In addition we specialize in saddlery, horse care products, and some veterinary lines. Enquiries regarding retail, wholesale prices, product availability and supplies to outstations are welcome."

Harry Heath and Company,
Box 1028, Boroko. Phone 255216/256505.

Buys: Scrap and salvage.
Sells: Bicycles, services, special orders, marine hardware, marine equipment, custom manufacturing.

Advisory services, diving and salvage work, underwater repairs, marine engineering, aqualung/skin diving sales and service, boat chandlery, bicycle sales and service, scrap metal dealers, sales and service Kawasaki generators.

Agents for: Gardner Marine, Industrial and Automotive Engines, Epiglass Marine and Industrial Paints, Gamlen Marine and Industrial Chemicals.

C. Logan Machinery - Gleason Cranes - Australia,
203 Grant Street, South Melbourne 3205.

Phone 692331 / 693666. Telex 34474
T/graph code "LOGMAC"

Buys: Used machinery
Sells: Services, marine equipment, food processing equipment, metal products.

"Supplies of new and used machinery in the mining field construction and heavy industry. Specializing in cranes (all types), generating sets, petrol/diesel/turbine, contractors' plant, mining equipment, road making equipment."

Lohberger Engineering Pty. Ltd.,
Box 810, Port Moresby. Phone 243185 / 243063
T/graph code HONTOM

Branches: Port Moresby only.

Sells: Supplies, services, special orders, agricultural equipment, agricultural supplies, some hardware, custom manufacturing, metal products.
Advisory services: Water supply and electric power supply.

"We can advise and supply equipment on all types of water supply systems. We can advise and supply equipment for all your electric power supply needs".

Morobe Newsagencies Pty. Ltd.,
Box 960, Lae. Phone No 421830

Sells: Supplies wholesale, retail magazines, books and newspapers, comics, parker pens, greeting cards, postcards, paperbacks, toys of all sorts.

New Guinea Book Depot,
Okari Street, Box 5495, Boroko. Phone 254611.

Price List available upon request.

Sells: Books, stationary, special orders.
Other services: Mail orders to Government Departments, schools, and private persons.

New Guinea Pastoral Supplies Pty Ltd
Stock and Station Agents
Box 83, Lae, Phone 42 2635
42 3919
Cables "PASTSUP" Lae

Agricultural and veterinary chemicals, veterinary instruments, fencing materials, saddlery, feeds and seeds, cattle equipment, agricultural machinery, catalogue available.

New Guinea Wholesale Drug Co. Pty. Ltd.,
Box 349, Lae. Phone No. 424133

Free catalogue available. Branches: Madang.

Sells: Supplies, special orders, agricultural supplies.

"We manufacture & wholesale veterinary medicine for pigs, horses and cattle. Also syringes, scalpels, special screwworm medicine. We also manufacture and wholesale medicines for humans."

Plantation Supply & Service Co. Pty. Ltd.,
Box 92, Goroka.

Phone 721069, Telex 72566. Free catalogue available. Branches at Lae and Mt. Hagen.

Buys: Birdseye chillies, peppercorns, cardamoms and vanilla, (vast quantities needed). Also crocodile skins, basketware, pottery, wood manufactures, trochus shells and any other exportable products.

Sells: supplies, services, special orders, agricultural equipment, agricultural supplies, hardware, marine equipment, food processing equipment.

Advisory services in the use of agrochemicals, application of village level food or crop processing equipment.

PSS's new slogan is 'Serving Rural Industry', and its product lines cover every possible need in the rural sector - plantation or village level. From fertiliser to fencing or seeds to soil cultivation equipment PSS can supply the product and back-up service. Full details are available from PSS Lae, Goroka, or Mt. Hagen.

Ross Engineering,
Box 10, Rabaul. Phone 922009 T/graph code ROSSENG

A free information sheet is available. Branch at Rabaul only.

Sells: Marine Equipment and Custom Manufacturing

Advisory Services: "Lister" agents and general marine and Engineering supplies.

Sohi Gilsenan Pty. Ltd.,
Box 25, Mendi. Phone 591030.

Branches at Mt. Hagen.

Sells: Supplies, services, special orders, hardware, Custom Manufacturing, Metal products.

"We retail Builders and General Hardware in Mendi. Also gift lines, mens, womens and childrens clothing and footwear, stationery etc. We do building, new and renovations etc, plumbing and miscellaneous small jobs.

In Mt. Hagen we have a Sheet Metal Factory and manufacture all Sheet Metal products including custom made duct work etc."

South Pacific Machinery Pty. Ltd.,
Box 6115, Boroko.

Phone 253184 Telex NE22222 T/graph code PACMAX

A free newsletter will be available shortly.
Branches: Lae, Agents at Rabaul & Mt. Hagen.

Sells: Supplies, agricultural equipment, agricultural supplies, marine equipment, food processing equipment, custom manufacturing, metal products.

Advisory services: General application of farm

machinery and irrigation technique in PNG.

Imports and manufactures a wide range of farm implements, engineering woodworking and marine supplies.

Stockmans Pty. Ltd.,
Box 684, Lae. Phone 423936/422880
T/graph code STOCKMANS LAE

A free catalogue is available. Branches: Mt. Hagen.

Types of services offered: Auctioneering, Insurance, livestock buyers, meat wholesalers, meat retailers, rural merchandise, and General Stock & Station Agents.

Buys: Cattle, pigs, eggs, dressed chickens, sheep, horses, goats, vegetables as required.

Sells: Full range rural equipment including ploughs, tractors, chemicals, stockfeed, butchers supplies, abattoir equipment, veterinary equipment and livestock requirements. Auctioneering services, Insurance agents services, special orders, hardware, and food processing equipment

---

Tru-Cast Foundry Pty. Ltd.,
Box 160,
Lae.

Make cast iron wood-burning stoves and coffee-pulpers which are sold through Steamships, Burns Philp, and New Guinea Co. Hardware departments. Also make iron and non-iron castings to order.

Buy scrap cast iron

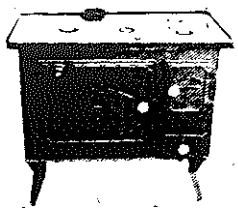

No. 3 K100.

Copper Stand 1.2 Gal
K30. without copper

No. 1 K53.

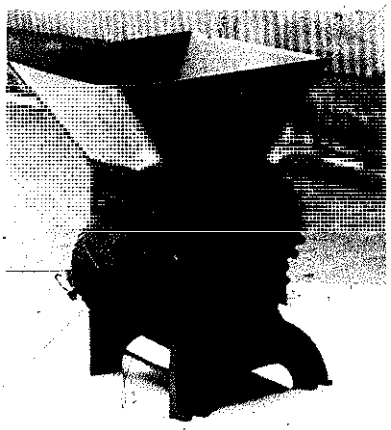

Coffee Pulper K124

OUTBOARD MOTORS

The survey by the Committee on Standardization of Selected Imports showed that at any given time nearly half the outboard motors in PNG are not working. Why?

1. Operator abuse.
2. Spare parts hard to find.
3. There are few service facilities and they are expensive.

This means a big loss to the nation and to the people who use outboards. But there is one make of outboard called SEAGULL. It has such a good reputation that in the Solomon Islands the Pidgin word for Outboard is Sigul. It is extremely reliable.

WHAT IS WRONG WITH SEAGULLS.

They are noisy and have an ugly appearance. They are slow. They use a special sparkplug. They use a special fuel mixture (10:1). They have no reverse gear. The biggest model is only 4.5 HP. The maximum speed is 8 km per hour.

WHAT IS RIGHT WITH SEAGULLS.

They are very rugged and have a better chance of surviving operator abuse. They will run forever if cared for. They start easily and use very little fuel. There are few parts to break, and they are easy to replace.

cont'd

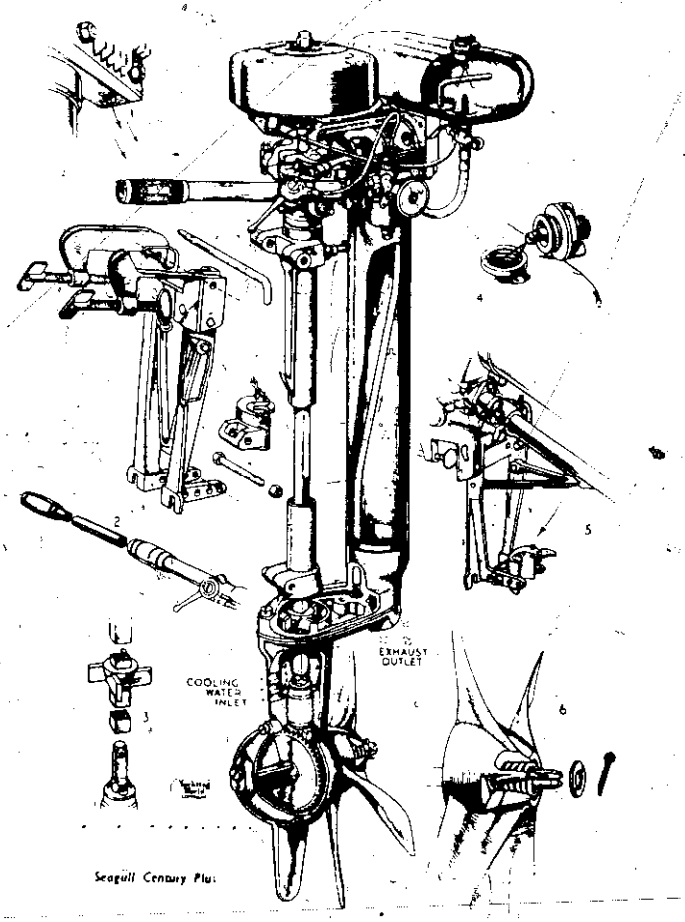

SEAGULL outboards are cheap. The most expensive model is only a little over K300.00. They will push a heavy load as fast as a small one.

The manufacturers call the SEAGULL'The Best Outboard for the World'. The same design has been used for more than thirty-five years.

Therefore - Advantages of SEAGULL are:
1. Require no skill or mechanical ability to run.
2. There is no running in period.
3. Require minimum maintenance.

The SEAGULL is sold in PNG by:-

Auto Outboard Engineering, Box 349, Madang.
Bougainville Marine, Box 277, Arawa.
Diver Services, Box 1049, Rabaul.
Marua Traders, Box 22, Kerema.
Musa Agencies Pty. Ltd., Box 143, Popondetta.
Needham & Co., Box 67, Lae.
Needham & Co., Box 63, Madang.
New Ireland Tyre Supply, Box 157, Kavieng.
Oil Company Services Pty. Ltd., Box 582, Wewak.
Ross Engineering, Box 10, Rabaul.
United Church Technical Department, Salamo, MBP.

Initial contributor: R.A. Lachall, Box 103, Kavieng.

OVERSEAS

Australian Telephone Directories

Australian Capital City alphabetical and business ("Pink Pages") telephone directories give addresses and brief indications of almost every business in Australia. They are published annually, and until 1973, promptly. More recently the system has become a little unwieldy, and some directories are a year late. Strong suggestions have been made to change the directories system for the larger cities.

A most important aspect: the 1965 to 1973 directories were only 30¢ (30t) each. These are available at post offices in Australia, and may be available in some P.N.G. post offices. For postage considerations, the largest directories weigh about 1 kg.

CeCoCo (Chuo Boeki Goshi Kaisha)
Box 8, Ibaraki City
Osaka, Japan

Distributors of a broad range of simple tools and machines for farming, village-level and small industrial processing, and manufacturing. A 158 page catalogue is available for US$10. airmail postpaid. Somewhat high prices but excellent service.

China Agricultural Machinery Co. Ltd.
11 Tung Hsing St.
Taipei 105, Taiwan, ROC

Tillers, various kinds of simple agricultural machinery and tools. Wide range of hand tools. Information on request.

China National Machinery Import and Export Corporation.
C/- China Resources Company,
Bank of China Building,
Hong Kong.

Head Office: Erh Li Kou, Hsi Chiao, Peking, China.

An interesting range of basic tools and equipment at low prices, but must be ordered in large quantities. Information available on request. Some sample items:

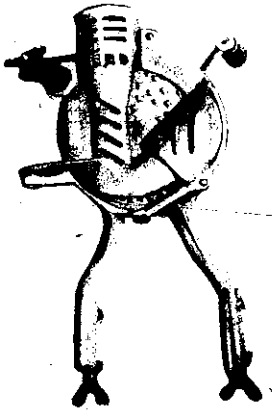

Hand-driven Maize Sheller, Model 5TYR-0.1

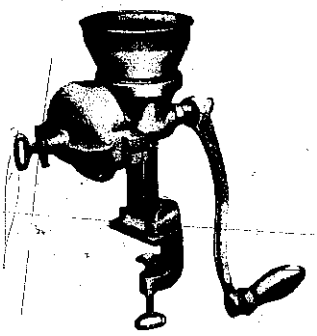

Hand Operated Grinder, No. 201

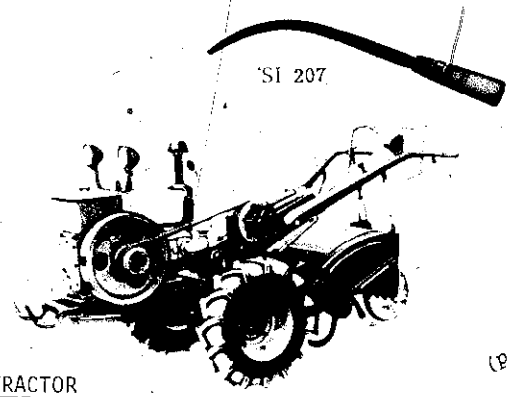

(P 62)

DONGFENG TRACTOR

The Chinese standard 'workhorse' is the 12 HP Model Dong Feng. It is used throughout China in many different applications - rotary tiller, water pump, bench-sawing, transport and ploughing.

There are many 'Rotary hoes' available in PNG, and several of them have features which this machine does not have. None are built so solidly, however, and none are so simply constructed and easily serviced. From the financial point of view, none are as cheap for the power offered.

It costs K1,380 at any of the main ports and comes complete with spare PTO, two sets of tines, and a

cont'd

complete - (I mean complete!) range of tools and the sort of spare parts that one really needs. Its nearest rival in this horsepower range is nearly K1,000 more, and needs more skilled adjustments more often.

My machine came from: Kimbe Bay Shipping Agencies
Box 27,
Kimbe, WNBP.

With some of the equipment you can ride while you guide the tractor. At other times you must walk. It is harder work than operating a four-wheel tractor, but a lot easier than working by hand.

This Dong Feng has a trailer on the back and powers a wood saw at the front (in Sha Shi Yu Commune, China).

Some persons are buying Dong Feng Tractors with the help of Development Bank loans, but it is up to the buyer to arrange this. Not all persons or groups will be qualified.

Some of these tractors are being stocked in Lae, but most are held at Kimbe. Delivery is quick, usually only a week or two.

Service is still limited, but this should not be a great problem, as most mechanics will understand how to work on them.

Suggested by: F. Robinson, DPI, Box 2417, Konedobu.
Konedobu.

Cossul and Co. Private, Ltd.
123/367 Industrial Area
Kanpur India
Cable:"Implements"
Kanpur

Manufacturers of hand and animal powered tools for agriculture. Some products may be suitable for PNG. Reasonable prices but long wait. We know of one firm that has been waiting nearly a year for equipment to be delivered - and the payment was sent with the order!

Glascraft Marine (Qld) Pty. Ltd.,
499 Adelaide Street, Brisbane. Phone 221 4022.

Two catalogues available, price 50¢ + postage
Branches at Brisbane, Adelaide, S.A.

Sells: Supplies, special orders, hardware (stainless steel nuts, bolts, screws, wood screws, washers), marine equipment, metal products (sail & power boat fittings) and most marine requirements.

Agents for: Arrow sailboats, Mirror sailboats, Mariner Craft, Hook N.Z. Sails, "Blue Streak" Battens, Canoe Distributors, Champion Spars, Fico Marine, Ronstan Marine, Riley Marine, "Sapphire", Aquameter Instruments, VDO Instruments, Jabsco Pumps, Tawco Conversions, Rolco Conversions, Weatherall Lifejackets, Kopsens - Sydney, Inglis Smith Melb., Epicraft Paints, Dynel Cloth & Tapes, Selleys.

ISEKI Agricultural Machinery Mfg. Co. Ltd.
1 - 3 Nihonbashi 2 - chome, Chuo-ku
Tokyo 103, Japan

Tractors 12 - 28 hp., Power Tillers 2-11 h.p., Combine Harvester, Reaper Binder, Rice Polisher, Rice Huller, Thresher, Rice Transplanter, Grain Drier, Grass and Bush cutter, others. Write direct for info.

Kirloskar Brothers Ltd.,
Export Division,
Udyog Bhavan, Tilak Rd., Poona 411002, India.

Cable: KIRLOSKAR POONA. Telex No 014-247 KB, PN.

Manufactures pumps and accessories mainly, but also some agricultural machines, including sugar crushers, hand-operated peanut shellers.

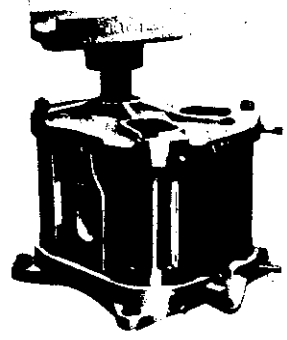

KUMAR animal-driven sugar crusher. Three vertical rollers, crushes 130 - 150 kgs cane per hour.

Ransomes, Nacton Works,
Ipswich, England. IP3 9QG. UK.

A wide range of well-designed agricultural equipment much of it rather specialized or sophisticated, but some items suitable for village use.

Seaside Trading
117 Union Civica
Galas, Quezon City, Philippines

This firm is willing to make purchases and arrange shipping to PNG on a commission basis. They have access to Philippine made small tools and equipment such as bush knives, rice harveting knives, water buffalo implements, rice mills, threshers, seeders.

HOW TO ORDER BY MAIL

Ordering by mail is often the easiest way to get things. Often the companies outside Port Moresby don't have many requests for certain kinds of things and they don't keep them in stock. If you wait for them to order for you it may take a very long time, and will probably cost you more money, too. Your business is losing money if you can't get the things you need for you to be earning money. Ordering by mail is often the best way to get going again. It certainly might save you a long expensive trip.

There are two kinds of mail orders:

(a) The first is when you order by catalogue. Popular catalogues for ordering clothing in PNG are Australian catalogues such as Wynn's and David Jones. Many times though people also want to order from advertisements they see in magazines.

If there is an order blank or a form for sending your order, USE IT! The company has a system to handle the orders it receives. If you use another paper, it can be lost.

Read the order form carefully and give all of the information that they ask for.

They want to know you name. Give them your usual name for receiving mail.

They want to know your address. Give them your full address for receiving mail. Don't forget on an overseas order to include 'Papua New Guinea' as part of your address.

For each item that you want to order from a catalogue there will be a code number. Usually this is on the line right next to the price. For each item you order you must write the order number. Also you should write the name of the article you want to buy. There is a space in the order blank.

Next there is a space for how many you want to buy. Write the number even if it is only 1.

If you have a choice of colour or size, be sure to write the proper size or colour you want. Let them know your second choice, too. If the company is out of the one colour that you want, then they can send you another one that you will like almost as much. Write the price in the space provided and the weight of the thing you are buying.

All of these things are important, because people who work in these companies processing your order are not very smart. They only go by what you write in the proper spaces and they won't guess what you want.

The hardest part is to add all the weights of the items you want to buy and then figure how much extra money for postage you must send. Sea mail from Australia takes 6-8 weeks, and sometimes more if there is an industrial action somewhere (these are very common in Australia, you know). Air mail is quickest, but is much more expensive. You must choose how much you are willing to spend for having the item quickly.

Send your money with the order. It is best to send a bank draft, a cheque, or a money order. Don't forget that now that PNG is independent, other countries will prefer a bank draft in their own currency from one of the banks in PNG.

Send this with the order. There are no dinaus or credits in mail order business unless you make arrangements first.

If your arithmetic isn't as good as it used to be, ask a friend who can do arithmetic well to check your numbers. It is very hard to wait a long time for a thing you have ordered and then have a letter come to say that they won't send it unless you send ten cents more!

(b) The other kind of ordering is for things that you don't know the price of, like spare parts, books, materials for building, etc.

Unless you have an account with a company, ALWAYS write to them first to ask the cost of the item and for them to tell you the cost of postage or freight to have it sent to you.

Give them complete information about what you want to buy. For example, if you are buying a book, give the name of the book, the author, the company that published the book and the year it was published. This way you will get the right book.

If you are ordering spare parts ALWAYS give the serial number and the name of the machine you are getting the parts for. Then get the part number and the name of the part. For example, if you want a head gasket for your utility, write the name of the utility, for example "Toyota Stout 2000." AND BE SURE TO GIVE THE SERIAL NUMBER. Even though the name of the machine may be the same the company may have made some changes. If you give the serial number, the parts man in the company can give you the right part for your machine by checking the serial number.

When you know the price, send your order with the money required. Be sure to send the money safely: use a cheque, a money order, or registered mail to send cash. If the letter is lost or stolen, then you won't lose your money.

HOW TO PLACE AN OVERSEAS ORDER

Many of the books and plans listed in the Liklik Buk are not easily available in PNG, except as reference books in libraries or homes. It is often difficult to get a copy for yourself. The Liklik Buk Information Centre can duplicate copies in its own files for the cost of the duplicating.

For books, you can place an order with one of the book stores in PNG, but they will not handle orders for small pamphlets because of the high clerical costs.

It is often very hard to order from foreign countries and sometimes very expensive. It seems that the present system in PNG is designed to prevent the little man from making a small international purchase.

Now that PNG is independent and has its own money you cannot send PNG money or cheques overseas. You cannot buy a money order for overseas the way it was once possible.

The only approved way is to buy a bank draft in a foreign currency from a Bank in a major centre, but not at an agency or a branch. The cost of these drafts is prohibitive for a small order. The charge for each draft is K1.00 plus 6 toea duty stamp. For a small book or a pamphlet, this can be many times the cost of the book itself.

It is illegal to use another way under the current exchange controls. Only authorized Banks can change foreign currency. But sometimes a friend who has a cheque account in his own country will write a small foreign currency cheque to pay for the order and you can make him a gift of the equivalent in Kina & Toea. United States Dollar cheques are the most useful since they are widely accepted in many countries.

There really ought to be another way for making small foreign currency transactions to get books and magazines and pamphlets. International money orders can be bought in other countries but not in PNG. For small amounts there should be a simpler and cheaper way, so that this kind of information can reach as many people as possible.

PNG MAPS

The only source for maps of all types in PNG is the National Mapping Bureau. All maps which are on file are available to the public at a charge. Aerial photographs of many areas are also available.

If you wish copies of maps of particular areas, write to; Superintendant of Mapping,
National Mapping Bureau,
Box 5665,
Boroko Telephone 271463.

In your request for maps tell the place of major

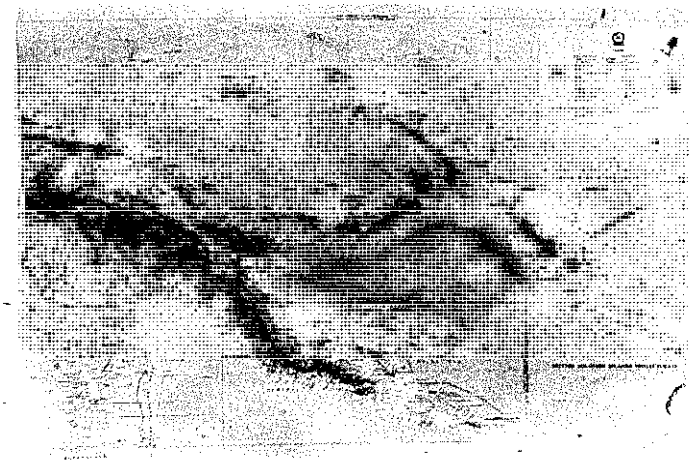

interest, how much surrounding area is important to you, and the scale of the map that you want.

Scales available are generally 1:25,000, 1:50,000, and 1:100,000. The most detailed maps are the 1:25,000.

These maps cost 50t a copy, but it may take two or three maps to cover the area that interests you. The Superintendant will tell you how many maps you will require.

Maps of townships are available in 1:10,000 at a cost of 80t, and aerial photographs at a scale of 1:30,000 are also available at a cost of K1.50 per photo.

Unfortunately there is no catalogue or register of maps available, but there is one in preparation.

Initial contributor: J. Van Af, Box 5665, Boroko.

PNG Bureau of Statistics, PO.Wards Strip, Port Moresby.

A Catalogue is available listing publications containing statistics on PNG: Serials; Irregular publications; and Monographs. A helpful index is included with a broad range of subject headings. A charge is made for publications.

METRIC CONVERSION

Papua New Guinea uses the International System of Units, and this is the only legal system of measure in the country. Many people still are used to the Imperial System and find it hard to change.

Centimetres (cm) are not listed as a unit of measure in the International System of Units. You are supposed to use millimetres (mm). A piece of wood is no longer a 3 x 1 but is now a 75 x 25. In agriculture, lengths commonly used would be in very big numbers if we used millimetres. So, we often use centimetres (for example, 90cm instead of 900mm);

MAKING THE CHANGE EASY

Learn to "think metric". If you continue to work by using conversion factors you will need a pencil and pad as a permanent companion. Better to banish the concept of imperial measurements and substitute metric concepts. The following will help:

10 millimetres	**(equal to 1 centimetre)**
10 centimetres	**about four inches**
1 metre	**a long pace (a little more than a yard)**
1 kilometre	**1000 metres (a little more than half a mile)**
10 square metres	**about 12 square yards**
1 hectare	**= 10 000 square metres (about two-and-a-half acres)**
50 grams	**a little less than two ounces**
500 grams	**a little more than one pound**
1 tonne	**= 1000 kilograms (a little less than one ton)**
500 millilitres	**a little less than one pint**
1 litre	**about one-and-three-quarter pints**
200 litres	**the volume of a 44-gallon drum.**

MEASUREMENTS (USING THE BODY) AND OTHER COMMON REFERENCES.

Often when you want to measure something you find that you have left your ruler behind. One ruler that you can't lose is yourself. Different parts of your body can be conveniently used as a ruler. These measurements may be a little different for different people. Here are some typical measurements for one person. You can check your own. If you don't need to be exact these will give you a close measurement.

3-4 cm	The distance from the tip of your thumb to first knuckle.
8 cm	The distance across your hand at the widest part of four fingers.
10 cm	The distance across a flat hand including the thumb.
20-22cm	The distance from your thumb tip to the tip of your little finger when stretched as far apart as possible.
25 cm	The length of a bare foot, heel to big toe.
45 cm	The distance from elbow to tip of longest finger. Often you can estimate this as half a metre (50cm)
1 metre	The distance of a long pace. This distance is slightly longer than a step when walking comfortably. Measure out metre lengths for about 20 metres with chalk on concrete. Practice walking so that your toe always hits the metre mark. Soon your body will learn the feel of a metre step. This is particularly useful if you need to measure the side of a garden, or the length of a fence.

Properly used these measurements will give you within 10% of the actual distance. This is close enough for most agricultural requirements.

1 fish tin holds about ½kg (500 g) of fertilizer, salt, sugar.
1 bottle cap holds 3 cc when level.
The wood of a matchbox cover is approx. .50mm (Suitable to check the gap for spark plugs or contact points in an emergency. (A hacksaw blade is approx. 0.030", or 0.76 mm.)

We declare our first goal to be for every person to be dynamically involved in the process of freeing himself or herself from every form of domination or oppression so that each man or woman will have the opportunity to develop as a whole person in relationship with others.

We accordingly call for:

1. Everyone to be involved in our endeavours to achieve integral human development of the whole person for every person and to seek fulfilment through his or her contribution to the common good; and
2. education to be based on mutual respect and dialogue, and to promote awareness of our human potential and motivation to achieve our National Goals through self-reliant effort; and
3. all forms of beneficial creativity, including sciences and cultures, to be actively encouraged; and
4. improvement in the level of nutrition and the standard of public health to enable our people to attain self fulfilment; and
5. the family unit to be recognized as the fundamental basis of our society, and for every step to be taken to promote the moral, cultural, economic and social standing of the Melanesian family; and
6. development to take place primarily through the use of Papua New Guinean forms of social and political organization.

from the Preamble of the P.N.G. Constitution

ORDER FORM

WANTOK PUBLICATIONS
BOX 1982
BOROKO

The LIKLIK BUK is just what I need. I can't get it at my nearest bookstore. Please send me ____ copies.

NAME _____

ADDRESS _____

CITY/TOWN _____

STATE/PROV. _____

COUNTRY _____ POSTCODE _____

POSTPAID PRICES FOR 1977 LIKLIK BUK

Papua New Guinea

Orders of 1 - 15 copies	K3.00 each
16 - 119 copies	2.50 each
120 or more copies	2.20 each

Overseas single copy price

	Surface mail	Airmail
Asia and Oceania	K4.00	K6.00
Rest of the world	5.50	9.00

Please make payment by bank draft in PNG Kina.

Overseas Bulk Orders

Special rates. Write for more information.

ORDER FORM

WANTOK PUBLICATIONS
BOX 1982
BOROKO

The LIKLIK BUK is just what I need. I can't get it at my nearest bookstore. Please send me ____ copies.

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NAME _____

ADDRESS _____

CITY/TOWN _____

STATE/PROV. _____

COUNTRY _____ POSTCODE _____

NOTES FOR CONTRIBUTORS

We invite readers to send us articles for the next edition of LIKLIK BUK. If your article is accepted or makes a substantial change in an existing article you will receive a free copy of the edition in which your contribution first appears. However, if you submit more than one article you will receive only a single copy.

We don't try to tell everything about everything, although for very short or very important subjects we will be somewhat complete. It is the purpose of the LIKLIK BUK to tell enough about something to help a person decide if it is suitable for him. For further information he should seek out the references and contacts listed in the article.

We want articles about things that have been tried in PNG, and we do accept articles about things that have been tried, but don't work. Failure is useful information too, to warn the person who comes behind. If you make a contribution we expect that you have tried it, or at least have participated in a trial. Don't think that we want only "new" technology; traditional methods that are not generally known in PNG are also wanted.

Untried items that are simply pulled out of someone's fertile imagination or from some foreign publication will be excluded.

BE BRIEF. Use an outline given below. The outlines will help you to remember the important points to help the person who reads your article. Sometimes subjects can't be expressed in just the outline. We know that. Add what you feel is important. But try to include the minimum. We find that nearly every article in LIKLIK BUK will fit one of these outlines.

We also welcome essays or editorials on matters of nationwide importance about the use of technology and resources. The social and cultural as well as technical aspects of technology must not be forgotten. Again, please try to be brief.

Here are some outlines. When you have completed your contribution send it to the Editor, LIKLIK BUK, Box 1920, Lae. PNG.

OPS - Use this outline for trees, getables, (traditional & introced) and cash crops.

me: English/Pidgin/Motu
Description:
1 Botanical name
2 Height
3 Age to first production
4 Normal life span
5 Major pests and control
6 Major diseases and control
7 Indication of maturity
8 Altitude limits in PNG
Planting Information & spacing
Useful Products
1 Village level
2 Industrial level
Sources of supply of planting material & costs
Sources of supply of related tools or equipment & cost
Further references (include publisher, price, place to order)
Locations and results of PNG experience (include names & addresses of contacts)
Remarks: any extra information that you think will help the reader, or that doesn't fit this outline
Your name and address

IVESTOCK - Use this outline for nimals, birds or insects.

lame: English/Pidgin/Motu
. Description
1 Scientific name
2 Weight at full growth
3 Age at first production
4 Normal life span
5 Major pests and control
6 Major diseases & control
7 Breeds available in PNG
8 Altitude limits in PNG
. Feeding
. Housing, if required
. Breeding, birth & handling of young (include mating cycle & period of gestation)
. Useful products
1 Village level
2 Industrial level
F. Sources of supply of breeding stock and cost.
G. Sources of supply of related tools and equipment and cost
H. Further references (include publisher, price and place to order)
I. Locations and results of PNG experience (include name and addresses of contacts)
J. Remarks: any extra information that you think will help the reader, or that doesn't fit this outline
K. Your name and address

PROCESS - Use this outline for how-to-do things such as recipes, crop processing, or product utilization. Can also be used for techniques.

Name: English/Pidgin/Motu
A. List materials or facilities required
B. List ingredients required and amount of each
C. Description of process (Give quantitative measurements such as times, temperatures, frequencies etc).
D. Sources of supply of materials and ingredients and cost
E. Further references (include publisher, price and place to order)
F. Locations and results of PNG experience (include names and addresses of contacts)
G. Remarks: any extra information that you think will help the reader or that doesn't fit this outline
H. Your name and address

DESIGN - Use this outline for tools equipment, patterns and plans.

Name: English/Pidgin/Motu
A. Brief description of item and its purpose
B. Material list, including quantities, & approximate total cost
C. Simple design drawing and/or photo
D. Description of order of work
E. Sources of supply of materials
F. Further references (include publisher, price and place to order) Source of detailed plans if available
G. Locations & results of PNG experience (include names and addresses of contacts)
H. Remarks: any extra information that you think will help the reader, or that doesn't fit this outline
I. Your name and address

SUPPLIERS - Use this outline for information about organizations and companies to get things.

A. Name of Company/Organization
B. Address
C. Telephone
D. Cable address
E. List of materials, services or supplies
F. Is a catalogue available? Price?
G. Quality of service
H. Your name and address

BOOKS - Use this outline for books, pamphlets, or magazines you recommend.

A. Title
B. Author
C. Publisher
D. City
E. Price
F. Is it available in PNG? Where?
G. Statement of subject of publication
H. Evaluation: Good? Bad? Relevant?
I. Level: Simple, intermediate, or advanced
J. Your name and address

Please send us a copy of any photographs that you have to illustrate your contribution. We would like to keep the photo for the permanent files of the LIKLIK BUK CENTRE.

Below is an example of an ideal article for a contribution. As an illustration, we use a fictitious tree crop.

WOMPOM KARUK (Pidgin) PLAT (Motu)

The Wompom Fruit (Hysopia saggitarus L.) is a viney shrub that grows to 90 metres. It is grown in village gardens and as a shade tree for dodad trees.

Planting Guide: 20 metres by 20 metres, grown from seedlings and planted out at 6 months.

Useful products: The fruit can be eaten raw, or can be cooked to prepare a nutritious meat substitute "Wompom Steak". The skin of the Wompon can be processed into belting leather. Leaves contain resins suitable for water-resistant glues. The wood of the trunk is very hard and can be used to manufacture wood products requiring flexibility, such as bows, whips for caning children, and wireless antennas. Industrial uses: petrol additives (from the bark) printing ink (leaf), grinding polish (fruit pits) and all forms of shrink-proofing of haplon cloth (sawdust extraction).

Botany: The tree begins to produce 8 months to 40 years after planting and will live for 2 to 98 years. Fruit harvests are about 8 kg to 7 tonnes per tree. Ripe fruit is indicated by 5/6 of the fruit turning bright black and separating from the stem with a gentle tug. The tree will rattoon when cut. Minimum temperature for growth is 78°C.

Diseases: Wompom is susceptible to polio and malaria but can only be controlled by severe pruning of infected parts.

Pests: Whales and gold bugs are pests recorded in the literature. Whales should be carefully picked off the tree and the gold bug, which eats leaves, is usually controlled by lighting a large bon fire under the tree to burn the bugs. People in the coast of Chungu Province know how to work magic to get rid of the bug.

Sources of supply: Seeds are available from Toot Bryan and Seashipps, packed in special tropical packs. Clonal cuttings are available from the Coastal Agricultural Experiment Station in Goroka.

Further information: Grow Good Wompom (pidgin and motu) DOSF free; Botany and Agronomy of the Wompom, Hutchins, Old Delhi University Press, US$125.00

Remarks: Mr. Dingaan Molekila at Dingle PTS in Lip Province says he has used the small branches to reinforce cement for a 110 foot clear span prestressed concrete bridge. Fr. Henry Sharp at Able Seminary says that when he first came to New Guinea in 1928 an old German Priest told him that he saw people using the leaf buds on sores to cure tropical ulcers, and Henry Tulili of Kaugere says he was able to make a replacement kingpin for his 1927 Holden when spares were unobtainable.

Initial contributor: Simon Peter Rock, Kavieng.

EDITOR'S NOTE: We're not sure how this got in here. Please use your own careful judgment about some of the strange information included in Liklik Buk.

The irresponsible use of new technologies is an ever present danger in any society.

Treat technology and societies with the respect that they deserve.

Tanget and kawawar are traditional warnings of prohibition. The use of kawawar warns of magical or extremely powerful forces behind the warning.

THANK YOU!

To our families, not only for patient acceptance of several months of chaos and confusion, but also for helpful criticism, articles, photos, advice.

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The Editors

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METRIC UNITS FOR EVERYDAY USE

Quantity	Metric unit and symbol	Conversion Factors (Approximate): Imperial to Metric Units	Conversion Factors (Approximate): Metric to Imperial Units
Length	millimetre (mm)	1 in = 25·4 mm	1 mm = 0·0394 in
	centimetre (cm, 10 mm)	1 in = 2·54 cm	1 cm = 0·394 in
		1 ft = 30·5 cm	
	metre (m, 100 cm)	1 yd = 0·914 m	1 m = 3·28 ft
	kilometre (km, 1000 m)	1 mile = 1·61 km	1 km = 0·62 mile
Mass (commonly called "weight")	gram (g)	1 oz = 28·3 g	1 g = 0·0353 oz
	kilogram (kg, 1000 g)	1 lb = 454 g	1 kg = 2·2 lb
		1 stone = 6·35 kg	1 kg = 0·157 stone
	tonne (t, 1000 kg)	1 ton = 1·02 t	1 t = 0·98 ton
Area	square centimetre (cm^2)	1 in^2 = 6·45 cm^2	1 cm^2 = 0·155 in^2
	square metre (m^2, 10 000 cm^2)	1 ft^2 = 929 cm^2	1 m^2 = 10·8 ft^2
		1 yd^2 = 0·836 m^2	1 m^2 = 1·2 yd^2
		1 perch = 25·3 m^2	1 ha = 9·88 roods
	hectare (ha, 10 000 m^2)	1 acre = 0·405 ha	1 ha = 2·47 acres
	square kilometre (km^2, 1 000 000 m^2, 100 ha)	1 $mile^2$ = 2·59 km^2	1 km^2 = 0·386 $mile^2$ = 247 acres
Volume	cubic centimetre (cm^3)	1 in^3 = 16·4 cm^3	1 cm^3 = 0·061 in^3
	cubic metre (m^3, 1 000 000 cm^3)	1 ft^3 = 28 300 cm^3	1 m^3 = 35·3 ft^3
		1 yd^3 = 0·765 m^3	1 m^3 = 1·31 yd^3
		1 bushel = 0·0364 m^3	1 m^3 = 27·5 bushels
Volume (liquids and gases)	millilitre (ml)	1 fl oz = 28·4 ml	1 ml = 0·0352 fl oz
	litre (1, 1000 ml)	1 pint = 568 ml	1 litre = 1·76 pints
	kilolitre (kl, 1000 l, 1 m^3)	1 gal = 4·55 litres	1 kl = 220 gal
Time interval	second (s)		
	minute (min, 60 s)		
	hour (h, 60 min)		
Speed	kilometre per hour (km/h)	1 mph = 1·61 km/h	1 km/h = 0·621 mph
Pressure	kilopascal (kPa)	1 psi = 6·89 kPa	1 kPa = 0·145 psi
Pressure (for meteorology)	millibar (mb, 0·1 kPa)	inch of mercury = 33·9 mb	1000 mb = 29·5 inches of mercury
Energy	kilojoule (kJ)	1 Btu = 1·06 kJ	1 kJ = 0·948 Btu
		1 kilocalorie* = 4·19 kJ	1 kJ = 0·239 kilocalorie*
	megajoule (MJ, 1000 kJ)	1 therm = 106 MJ	1 MJ = 0·009 48 therm
	kilowatt hour (kWh, 3·6 MJ)	1 therm = 29·3 kWh	1 kWh = 0·034 therm
		1 "gas unit" (1 kWh) = 3·6 MJ	1 MJ = 0·278 kWh = 0·278 "gas unit"
Power	kilowatt (kW)	1 hp = 0·746 kW	1 kW = 1·34 hp
Temperature	degree Celsius (°C)	$°C = \frac{5}{9}(°F-32)$	$°F = \frac{9 \times °C}{5} + 32$

* kilocalorie, commonly called "Calorie" is a non-SI metric unit

See Article "Metric Conversion" *(p 266)*
and "Measurements" *(p 267)*

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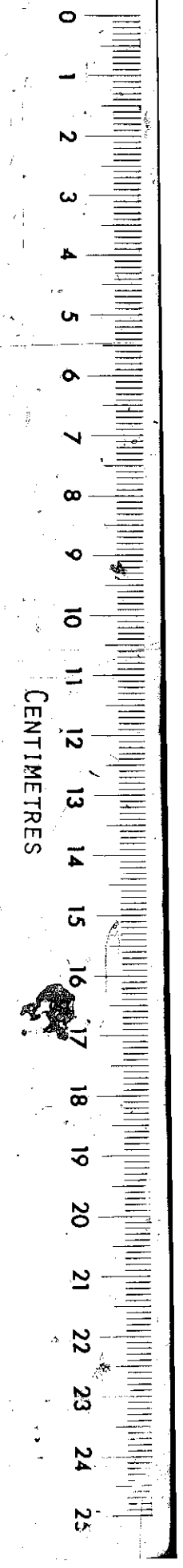

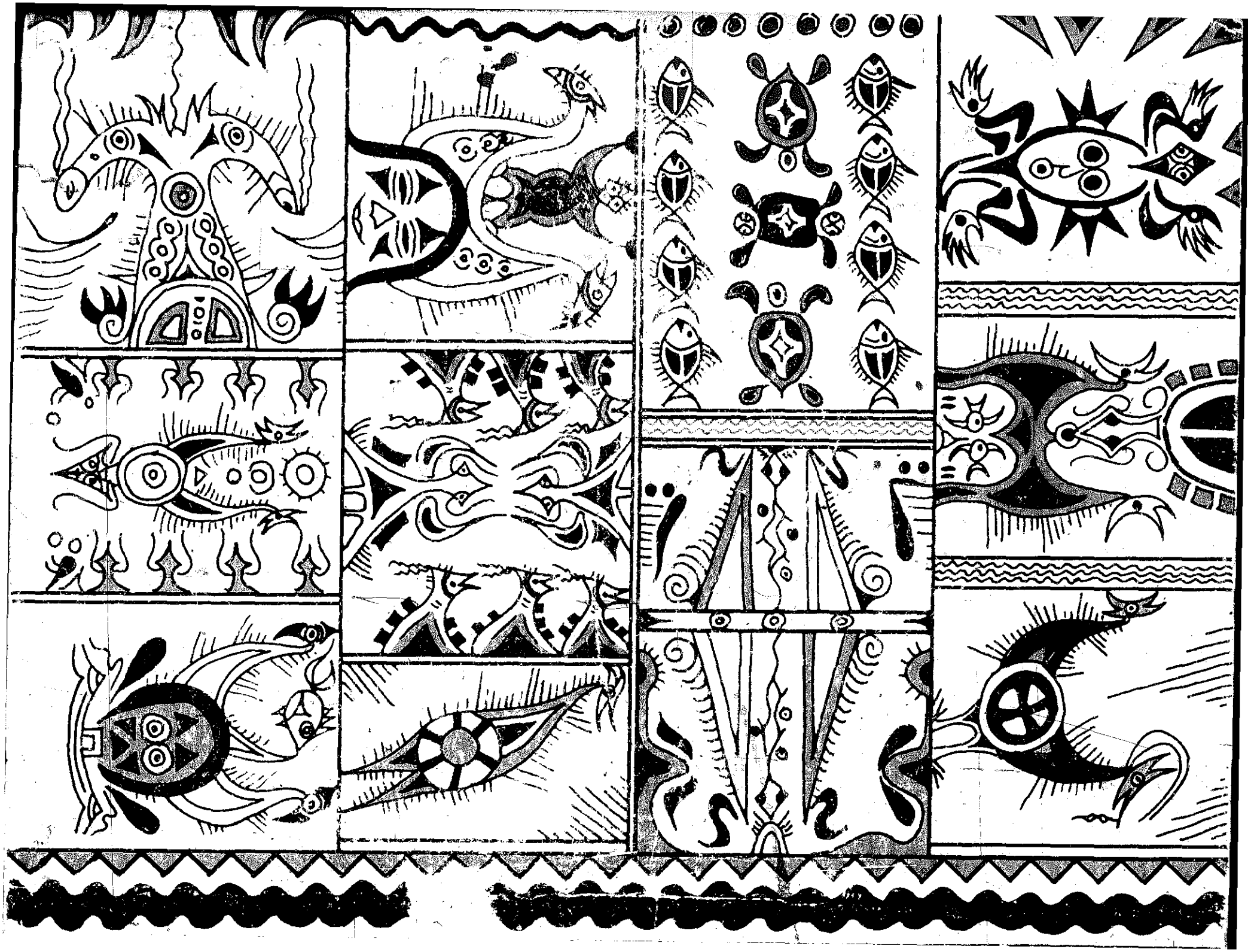

rural energy in developing countries

CHAPTER 10

José Goldemberg (Brazil)

LEAD AUTHORS: Amulya K.N. Reddy (India), Kirk R. Smith (United States), and Robert H. Williams (United States)

ABSTRACT Supplying modern energy services to the 2 billion people who still cook with traditional solid fuels and lack access to electricity is probably one of the most pressing problems facing humanity today. The amount of energy needed to satisfy the basic needs of rural populations around the world is relatively small, and appropriate technologies are available. However, widening access to modern energy services is limited by the extreme poverty found particularly in the least developed countries.

Living standards in rural areas can be significantly improved by promoting a shift from direct combustion of biomass fuels (dung, crop residues, and fuelwood) or coal in inefficient and polluting stoves to clean, efficient liquid or gaseous fuels and electricity. Although consumers tend to shift to these modern, higher-quality energy carriers as their incomes rise and the carriers become more affordable, the process is slow. Yet a shift to such carriers can reduce the damage to human health and the drudgery associated with continued reliance on inefficient, polluting solid fuels.

This chapter describes experience with and prospects for improving the technologies used to cook with biomass in several countries, as well as the development of clean, non-toxic cooking fuels. Progress in rural electrification—using both centralised, grid-based approaches and small-scale, decentralised technologies—is also described.

Technological developments alone, however, will not improve access or promote greater equity. New institutional measures are also needed, including financing to cover the initial capital costs of devices and equipment. Energy initiatives will be most successful when integrated with other policies that promote development. And because local populations will ultimately use, maintain, and pay for energy services, they should be involved in making decisions about energy systems. ■

Accelerating the introduction of modern energy is a key strategy for promoting sustainable development in rural areas.

The lack of adequate energy services in rural areas of developing countries has social dimensions (chapter 2) as well as serious environmental and health effects (chapter 3). Many of these problems are exacerbated by the almost exclusive reliance of rural populations in most areas on traditional fuels coupled with simple technologies characterised by low energy efficiency and harmful emissions. This chapter thus focuses on technological opportunities, as well as other strategies, for delivering adequate, affordable, cleaner energy supplies to rural areas.

The second half of the 20th century witnessed a strong urbanisation trend and the emergence of megacities (those containing more than 10 million people) in most developing countries. Between 1970 and 1990 the share of people living in cities grew from 28 to 50 percent. But while the rural population relatively decreased during this period, the absolute number of people living in rural areas increased to 3 billion. Despite this, rural development often remains low on government agendas because of increasing demands of growing, politically and economically dominant urban populations. Thus the explosive growth of cities makes it difficult for policy-makers to give rural development the attention it deserves.

The dispersed character of rural populations and their low commercial energy consumption result in poor capacity utilisation efficiency for transmission and distribution systems and other energy infrastructure. Extending an electric grid to a few households in a rural setting can result in energy costs of up to $0.70 per kilowatt-hour, seven times the cost of providing electricity in an urban area (World Bank, 1996). Thus conventional approaches to extending energy infrastructure are economically inefficient, for both public and private providers—which is another reason the energy problems of rural populations are given low priority by governments.

Because the poor people in rural areas lack access to electricity and modern fuels, they rely primarily on human and animal power for mechanical tasks, such as agricultural activities and transport, and on the direct combustion of biomass (wood, crop residues, dung) for activities that require heat or lighting. Human energy is expended for household work (gathering and preparing biomass for fuel, fetching water, washing clothes), agriculture, and small industry. Biomass fuels are typically used for cooking (which dominates inanimate energy consumption in most warm regions), space heating, heating water for bathing, and meeting some industrial heating needs. Kerosene is used predominantly for lighting, and to a small extent in rural industry. Although much of the world's rural population has no access to electricity generation, many have small battery-operated devices such as radios and flashlights.

Rungs on the energy ladder

Large amounts of human energy are spent gathering fuelwood in many parts of the world, and the burden tends to fall more heavily on women and children.[1] Although there are exceptions, history has generally shown that when alternatives are available and affordable, consumers opt for more modern energy carriers. As incomes rise and opportunities for using better technologies become available, consumer preferences shift to more efficient, convenient, cleaner energy systems as they become more affordable. That is, consumers move up the energy ladder (chapter 3). This involves a shift to modern energy carriers or to more convenient and energy-efficient conversion devices.

For cooking and other heating purposes, the lowest rungs on the energy ladder involve use of dung or crop residues, with fuelwood, charcoal, kerosene, and liquefied petroleum gas (LPG) or natural gas representing successively higher rungs. For lighting, the lowest rung is represented by fire, followed in turn by liquid-fuelled (such as kerosene) lamps, gas lanterns, and electric bulbs. To do mechanical work, consumers shift from human and animal energy to diesel fuel and electricity as soon as they become available, because they are almost always more cost-effective. Often a synergy between modern energy carriers and more efficient end-use devices occurs.

One of the aims of this chapter is to explore the technological, economic, social, and institutional prospects for more rapidly introducing modern energy carriers into rural areas—which would allow households to move quickly to the top of the energy ladder, ideally skipping (leapfrogging) some of its rungs. Accelerating the introduction of modern energy, then, is a key strategy for promoting sustainable development in rural areas of developing countries. Principally, it involves providing:

- Clean liquid or gaseous fuels for cooking, and electricity for lighting and other basic household amenities.
- Liquid fuels and electricity to mechanise agriculture.
- Electricity sufficiently low in cost to attract industrial activity to rural areas (thereby providing well-paying jobs and helping to stem migration to urban settlements).

It is desirable to skip rungs and advance to the highest rungs on the energy ladder wherever feasible.[2] But because the 2 billion rural poor live in many different circumstances, a complete range of approaches need to be explored, and those that work best in each set of circumstances need to be encouraged. Appropriate public policies should be implemented to accelerate the process and reduce human suffering.

Satisfying basic human needs with modern energy carriers requires relatively small amounts of energy in absolute terms. In regions that do not require space heating, final household energy requirements for satisfying basic needs are estimated to be about 2,000 kilocalories per capita per day, or 0.1 kilowatt per capita in average power provided (80 percent for cooking and 20 percent for electricity; Reddy, 1999). The cooking needs of the 2 billion people not served by modern fuels correspond to about 120 million tonnes of oil equivalent of LPG a year—which equals 1 percent of global commercial energy consumption or 3 percent of global oil consumption. This is less than is currently lost flaring natural gas in oil fields and refineries.

Thus commercial energy requirements for satisfying basic needs

FIGURE 10.1. EFFICIENCY OF STOVES WITH COMMERCIAL AND NON-COMMERCIAL FUELS

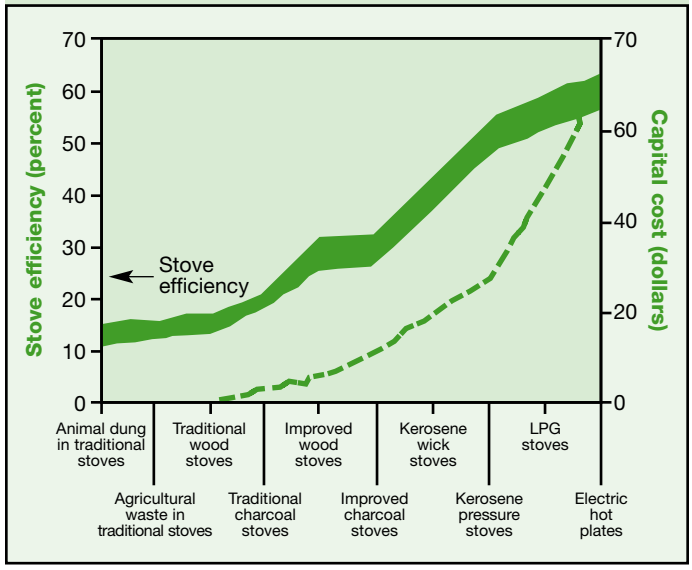

Source: Baldwin, 1987.

in rural areas are truly modest. Yet provision of even these modest amounts of energy to rural areas would offer the potential for enormous increases in amenities, particularly if these modern energy carriers were coupled with energy-efficient end-use devices.[3]

Progress in delivering modern energy to rural areas has been slow. But as will be shown, technical options to provide rural people with access to convenient, affordable energy services are commercially available (or nearly so). This is particularly the case in regions where modern energy carriers, such as biogas or producer gas, can be derived from local biomass and where gathering biomass feedstock can provide opportunity for income generation. The challenge of making modern energy available to the very poorest households is primarily institutional, notwithstanding the economic costs and risks inherent in developing and disseminating untried systems. New financial mechanisms and other innovative policy approaches are needed, as discussed below.

Fuels in rural areas: climbing the energy ladder

The oldest human energy technology, the home cooking fire, persists as the most prevalent fuel-using technology in the world. For much of the world's population, household fuel demand makes up more than half of total energy demand. The energy ladder (discussed briefly above and in chapter 3) is used here as a framework for examining the trends and impacts of household fuel use. As figure 10.1 illustrates, the fuel-stove combinations that represent rungs on the ladder tend to increase in cleanliness, efficiency, and controllability. Conversely, capital cost and dependence on centralised fuel cycles also tend to increase with movement up the ladder.

Shortages of local wood supplies combined with institutional and economic constraints on petroleum-based fuels often lead to household

BOX 10.1. COMPARISON OF STOVE PROGRAMMES IN CHINA AND INDIA

China	India
The programme focused on areas with the greatest need and selected pilot counties with biomass fuel deficits.	The programme was implemented country-wide, resulting in dispersion of effort and dilution of financial resources.
Direct contracts between the central government and the county bypassed much bureaucracy. This arrangement generated self-sustaining rural energy companies that manufacture, install, and service stoves and other energy technologies.	The programme administration was cumbersome, moving from the centre to the state level, then to the district, and finally to the *taluka,* where the stove programme is just one of many national efforts being implemented locally by the same people.
Local rural energy offices run by provincial governments are in charge of technical training, service, implementation, and monitoring for the programmes. These efforts are separately funded and relatively independent.	Lack of a strong monitoring plan was a severe weakness in early programmes. Some improvement has occurred through assignment of the task to university-based technical backup units. Coverage is still incomplete, however.
Stoves are not only suitable for fuel savings and reduction of household smoke, but also are designed for convenience and attractiveness, highlighting the lessons learned from problems in early programmes that stressed only fuel savings.	India has made a wide variety of attempts to integrate efficiency and convenience, which have suffered from the top-down structure of the programme.
Stove adopters pay the full cost of materials and labour. The government helps producers through stove construction training, administration, and promotion support.	Stove adopters pay about half the cost of stoves; the government pays the rest. As a result the producer's incentive to construct stoves is oriented towards the government.
Emphasis has been on long-lived stoves made of ceramic or metal and otherwise designed to be a significant household asset for a number of years.	Many of the stoves have been made from local materials and by villagers without artisanal skills, resulting in short lifetimes in day-to-day household use.

Source: Smith and others, 1993; Barnes and others, 1993; Ramakrishna, 1991a, b.

coal use, which is widespread in Eastern Europe, China, and South Africa. Coal has a higher energy density than wood and so is easier to store. Coal's high energy density also makes it cost-effective to ship over longer distances than wood to efficiently supply urban or rural markets. In these senses, coal is similar to other household fossil fuels. Unlike kerosene and gas, however, coal often represents a decrease in cleanliness relative to wood. Like wood, another solid fuel, coal is difficult to use efficiently in household appliances.

Climbing the energy ladder for cooking can be accomplished using commercially available technologies such as improved cooking stoves and kerosene or LPG. As discussed below, biogas and producer gas are almost at the point of commercialisation, and additional and

cleaner advanced technologies for meeting cooking needs are under development.

> The cooking needs of the 2 billion people not served by modern fuels correspond to about 1 percent of global commercial energy consumption or 3 percent of global oil consumption.

Improved cooking stoves

Since about 1980, several hundred programmes around the world have focussed on developing and disseminating improved biomass cooking stoves in the villages and urban slums of the developing world. These programmes have ranged in size from the introduction of a few hundred stoves by local non-governmental organisations to huge national efforts in China and India that have affected millions of households. The programmes seek to accelerate the natural trend for people to move towards cleaner, more efficient devices when they are available and affordable.

Such programmes have had mixed success. Some have disseminated many improved stoves with significant lifetimes. Others have not. The failures, however, represent progress along a learning curve, and more recent programmes have tended to have higher success rates. In this regard, it is instructive to compare the two largest initiatives, those of China and India (box 10.1).

Over the past 20 years, perhaps 90 percent of world-wide installations of improved cooking stoves occurred in China. From 1982–99 the Chinese National Improved Stoves Programme reported the installation of improved stoves in more than 175 million rural households. These were mainly biomass stoves used for cooking. But in the northern states of China, where temperatures drop during the winter, dual-use stoves for cooking and heating were included. In China improved stoves are affordable, and the government contribution is low. An improved stove in China costs about 85 yuan ($10), and the government contributes an average of 4.2 yuan per stove ($0.84). Part of the success of the programme is attributed to the attention—including well-publicised national competitions and awards—given to improved stove design.

The Indian programme, initiated in 1983, is called the National Programme on Improved Chulhas (cooking stoves). So far, nearly 30 million stoves have been disseminated. A mix of portable (without chimneys) and fixed designs have been approved. The government subsidises at least half of the costs of the stoves, which amounts to 200 rupees ($4.50) per stove. Although dissemination has been impressive, follow-up surveys suggest that less than one-third of the improved stoves are still in use. Some reasons given for discontinuing use are that the stoves did not really save energy, did not eliminate smoke, or broke down. Other surveys found that adopters felt that stoves were consuming less energy and producing less smoke. The mixed perceptions indicate differing levels of success in implementation.

Several lessons can be learned from the two programmes. The greater success in China can be attributed to programme design and implementation, including the factors described in box 10.1. Both programmes now face pressure to reduce subsidies in a more market-based approach. In addition, although both programmes now incorporate monitoring for energy efficiency, neither includes evaluations of the smoke-exposure benefits.

Another commonly cited example of success is the introduction of a more efficient ceramic charcoal cooking stove, the *jiko,* developed in Kenya. At least 700,000 such stoves are now in use in that country, in more than 50 percent of urban homes and in about 16 percent of rural homes. About 200 small-scale businesses and artisans produce more than 13,000 stoves each month. Both the stove itself and the general programme for disseminating it have been adapted for use in a number of other African nations (table 10.1).

The process of research, development, demonstration, and commercialisation that led first to the improved jiko and then to other high-efficiency stoves was seeded by international and local development funds (in contrast to the Indian and Chinese programmes, which were almost entirely organised and funded domestically). Most important, policy-makers decided not to directly subsidise the production and dissemination of these stoves but to provide support to designers and manufacturers.

Because the stoves were relatively expensive ($15) and their quality was highly variable, sales were slow at first. But continued research and increased competition among manufacturers and vendors spurred innovations in both the materials used and the methods of production. An extensive marketing network for those stoves is flourishing, and prices have fallen to $1–3, depending on size, design, and quality. This outcome is consistent with the learning curve theory, whereby the price of a new technology decreases by a uniform amount (often about 20 percent) for each doubling of cumulative sales (chapter 12).

Part of the success of the jiko, however, is due to its use of a relatively high-quality fuel, charcoal. It is much easier to design simple stoves with high energy efficiency for use with such low-volatility solid fuels relative to those that use the unprocessed biomass that is the main source of household energy in the world's

TABLE 10.1. NUMBER OF IMPROVED STOVES DISSEMINATED IN EAST AND SOUTHERN AFRICA, 1995

Country	Urban	Rural	Total
Kenya	600,000	180,000	780,000
Tanzania	54,000	n.a.	54,000
Uganda	52,000	n.a.	52,000
Ethiopia	23,000	22,000	45,000
Rwanda[a]	30,000	n.a.	30,000
Sudan	27,000	1,400	28,400
Zimbabwe	11,000	10,000	21,000
Burundi[a]	20,500	n.a.	20,500
Somalia[a]	15,400	n.a.	15,400

n.a. – Not available.
a. Civil strife has significantly affected stove programmes and reduced the number of improved stoves in use. *Source: Karekezi and Ranja, 1997.*

villages. Charcoal stoves are also inherently less polluting than those burning unprocessed biomass, and thus do not incorporate chimneys. Like other low-volatility solid fuels—such as some coals—charcoal produces fewer health-damaging particles and gases than wood, but it does produce substantial carbon monoxide. Households relying on such low-volatility fuels, therefore, risk overnight carbon monoxide poisoning, which annually causes thousands of deaths world-wide.

In addition, the process of making charcoal from wood is often quite inefficient, leading to heavy pressure on forests in much of Africa to supply urban areas. The inefficiency of charcoal kilns means that the charcoal fuel cycle is probably the most greenhouse-gas-intensive major fuel cycle in the world, even when the wood is harvested renewably, and often it is not. Thus charcoal could not be a sustainable rural energy option in the long run, unless its supply system were to be drastically altered.

Even the best biomass stoves available today do not greatly reduce the health-damaging pollution from biomass combustion, although they may put it outside through well-operating chimneys or hoods. This is certainly better than releasing the smoke inside; but in densely populated villages and slums, it can lead to heavy neighbourhood pollution. Thus even nearby households using clean (or no!) fuels may suffer from high levels of exposure. Therefore, because of health concerns—unless truly clean-burning biomass stoves can be developed at reasonable costs—in many areas, improved stoves are probably not sustainable in the long run. They may continue to play an important interim role in improving the quality of life of the rural and urban poor; but as concluded in chapter 3, the long-term goal should be to eliminate household use of unprocessed solid fuels.

FIGURE 10.2. POST-BIOMASS ENERGY TRANSITION IN THE REPUBLIC OF KOREA, 1965–80

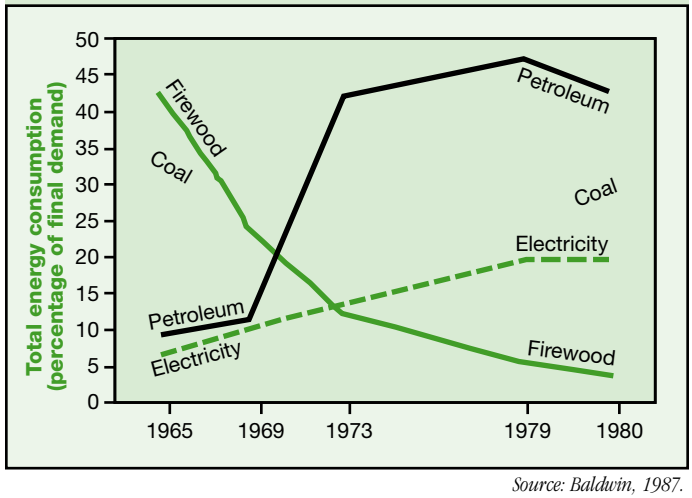

Source: Baldwin, 1987.

Kerosene and LPG actually produce fewer greenhouse gas emissions per unit of energy service than biomass fuels used in traditional ways.

Kerosene and liquefied petroleum gas

In countries that achieved successful rural development during the past 50 years, kerosene and then LPG replaced biomass fuels. Figure 10.2 shows the changing household fuel picture in the Republic of Korea as rural development proceeded in the 1960s. At the start of the period, wood was the chief fuel, but 15 years later it had been replaced almost entirely by petroleum-based fuels. Similar transitions have occurred in other regions as well. Natural gas and town gas (made from coal) have continuing important roles in urban development (but rarely in rural areas, because of pipeline transmission requirements).

As consumers climb the energy ladder, kerosene is usually the first modern fuel to be used, because it is more easily transported and stored than LPG. However some countries—notably China—have restricted the availability of kerosene, thereby encouraging the direct movement to LPG. Kerosene, although substantially superior to biomass in efficiency and cleanliness, is not as desirable as LPG, which burns nearly without pollution in comparison with fuels on lower rungs. Of course, liquid and gaseous fuels pose other risks: For LPG, the most important are fires and explosions; in the case of kerosene, children may suffer poisoning due to careless household storage. Experience has shown, however, that these risks are lower than those posed by biomass fuels.

LPG must be distributed in pressurised canisters that, along with the stove, involve significant up-front investments by households. In addition, both LPG and kerosene require a stable, reliable distribution system running from the refinery to neighbourhood distributors, something that does not exist in many parts of the developing world. The combination of these two factors often prevents LPG from being used by many households that could otherwise afford its daily cost. Indeed, in many developing-country cities, the daily cost of LPG would be less than the cost of shipping biomass from rural areas. Lack of capital for the stove and canister and poor supply reliability, however, prevent households from shifting to LPG.

Despite these problems, LPG programmes have been very successful in most of Latin America, particularly in Brazil, where LPG has replaced all other fuels for cooking—even in many remote rural areas. The main reason for this success was a very dependable system of distribution and replacement of LPG canisters.

A study in Hyderabad, India, found that the simple measure of stabilising LPG supplies by the local government encouraged many urban households to shift to LPG. This is a policy without fuel subsidies that saves money for households and has a beneficial impact on the environment (Barnes and others, 1994). If users have a first-cost constraint, the programme should provide low-interest loans towards initial costs. Subsidies to help households meet the up-front costs for equipment such as stoves and canisters are much more acceptable policies than subsidising fuel. Fuel subsidies alone tend to divert use of fuel to industry, transport, and households that already have stoves, making the subsidies very costly, economically inefficient ways to help the poor.

Because fossil fuels such as kerosene and LPG are non-renewable and their combustion contributes to greenhouse-gas emissions, some may question their role in sustainable energy strategies. However, the quantity of LPG needed to support cooking for the current unserved population of 2 billion is trivial at the global level (see above). Moreover, kerosene and LPG actually produce fewer greenhouse gas emissions per unit of energy service than biomass fuels used in traditional ways (chapter 3).

Nevertheless, instead of relying on fossil fuels with substantial new infrastructure requirements, it is sometimes desirable to produce clean fuels that can be used efficiently from local biomass resources. Biogas and producer gas systems, as well as advanced technology options such as synthetic LPG or dimethyl ether (DME), appear promising in the longer term.

Biogas for cooking

Biogas, a clean-burning methane-rich fuel gas produced through anaerobic digestion (bacterial action in a tank without air) of suitable biomass feedstocks, is the only biomass-derived modern energy carrier for household applications with which there is widespread experience. Biogas can be generated from cattle dung and animal wastes, and with substantially more difficulty, from some crop residues. Although these feedstocks are frequently used directly as cooking fuel, in most areas they are not preferred fuels and are used only when wood is not available. Biogas systems offer multiple benefits. The digester-effluent is usually a good fertiliser, and, if connected to latrines, biogas plants can provide valuable sanitation services. For cooking and other thermal household tasks, it is simple and reasonably efficient to use the gas directly in conventional low-pressure gas burners. Biogas can also provide lighting when used in mantle lamps.

In societies where suitable feedstocks are readily available, small family-sized biogas digesters were thought to have considerable potential. A number of countries initiated programmes—China and India on a large scale. Results have been mixed, especially in the early stages. China's efforts resulted in the construction of 7 million household-scale digesters from 1973–78. But quality control and management problems resulted in a large number of failures. More recently, coordinated efforts have focused on regions thought to be most promising for the technology. Service organisations and biogas services stations have been established. By 1994, 5 million domestic plants were operating satisfactorily. India's experience has been on a slightly smaller scale, but the numbers are still impressive—by the end of 1998, almost 2.8 million domestic plants were installed. India's Ministry of Non-Conventional Energy Sources has identified a potential for 12 million digesters.

Biogas experience in Africa has been on a far smaller scale and has been generally disappointing at the household level. The capital cost, maintenance, and management support required have been higher than expected. Moreover, under subsistence agriculture, access to cattle dung and to water that must be mixed with slurry has been more of an obstacle than expected. However, possibilities are better where farming is done with more actively managed livestock and where dung supply is abundant—as in rearing feedlot-based livestock.

The initial enthusiasm for biogas has thus been somewhat dampened by experience. Because of its requirement for relatively large amounts of animal dung, the niche for household biogas plants is likely to remain small. Poor families do not have access to enough dung, and better-off families with sufficient animals often prefer to purchase fuel and fertiliser rather than spend time gathering dung and managing the often-temperamental digesters. Even so, in the right social and institutional context, and with appropriate technical expertise, the potential for biogas remains significant. These conditions seem to have been achieved in the Biogas Support Programme in Nepal through an innovative financial scheme (box 10.2).

BOX 10.2. BIOGAS IN NEPAL

The principal objective of the Biogas Support Programme in Nepal is to promote the wide-scale use of biogas as a substitute for the wood, agricultural residues, animal dung, and kerosene that presently meet the cooking and lighting needs of most rural households in the country. The rising demand for locally available biomass from a rapidly increasing population has helped accelerate the rates of deforestation, soil degradation, and environmental decline in densely inhabited areas. In addition, use of biomass fuels and kerosene has compromised health and welfare—especially of women and children, who are most often subjected to the smoke and fumes associated with the use of these fuels.

Since its inception, the programme has installed more than 40,000 family-size biogas units benefiting more than 200,000 members of rural households. The programme's target is to install an additional 100,000 units by the middle of 2003. This compares to only 6,000 biogas units installed before the programme. This substantial increase has been achieved while simultaneously reducing the costs and increasing the reliability and efficiency of biogas plants.

A critical element in developing the commercial market for these plants has been the programme's innovative financial engineering and judicious application of consumer subsidies. The subsidy, fixed at three levels, accounted for 35 percent of the total cost of biogas plants in 1998. The objective of the programme is to eliminate dependency on direct subsidies by 2003. The programme has also strengthened institutional support for the biogas market.

At the start of the programme, essentially only one state-owned company, the Gobar Gas Company, was producing biogas plants. By the end of 1998, as a direct result of market development, 38 private companies besides Gobar had entered the business. To be eligible to receive the subsidy provided to farmers, all participating companies must meet strict production quality and service standards for their plants. As a result of the growing competition, technical design modifications, and better quality control measures, the overall cost of biogas plants in Nepal has declined by more than 30 percent since 1992. In addition to the institutional improvements, employment for skilled as well as unskilled labour in rural areas has been generated.

Source: Mendis, 1999.

Producer gas for cooking

An alternative to biogas is producer gas, a mixture consisting largely of carbon monoxide, hydrogen, and nitrogen. Producer gas is generated in a thermochemical conversion process through partial oxidation in air of biomass feedstocks (Stassen, 1995). The basic principles of generating producer gas have been known since the 18th century. Producer gas derived from biomass has been used for domestic and industrial heating purposes, for cooking, for stationary power, and for

Subsidies to help households meet the up-front costs for equipment such as stoves and canisters are much more acceptable policies than subsidising fuel.

motor vehicle applications. (During World War II more than a million gasifier-powered vehicles helped to keep basic transport systems running in Europe and Asia.)

During periods of peace and wide availability of cheap, more convenient fossil fuels, interest in biomass-derived producer gas has been low. The energy crises of the 1970s rekindled interest in producer gas technology, but interest waned again with the collapse of world oil prices in the mid-1980s. Once again, there is growing interest in technology for making producer gas from biomass for cooking, heating, and electricity generation. Power generation applications of producer gas are discussed later in this chapter. Here the focus is on domestic cooking.

Part of the reason for renewed interest in producer gas technology is increasing concern about the adverse health effects of indoor air pollution caused by biomass and coal burned for domestic cooking and heating (chapter 3) and the large role that producer gas used in gas-burning stoves could play in reducing this pollution—the air pollution from these stoves is nearly zero. In typical agricultural regions, the energy generation potential from producer gas is greater than that from biogas, because crop residues tend to be more abundant than dung.[4] And whereas biogas generation is often the preferred energy conversion technology for making use of the energy content of dung, producer gas generation is a far easier approach for exploiting the energy content of crop residues.

In addition, because it is a chemical rather than biological process, producer gas manufacture is not sensitive to ambient temperature, greatly increasing the potential geographic extent of its application. Another reason for renewed interest in biomass-derived producer gas in China is a severe new air pollution problem caused by the burning of crop residues in fields—a consequence of the rising affluence of farmers (see the annex to this chapter). This problem is forcing a search for new productive uses of crop residues.

Several Chinese provinces are making efforts to convert residues into producer gas in centralised village-scale gasifiers and to distribute the cooking gas by pipes to households. For example, the Shangdong Academy of Sciences has developed crop residue gasifiers and centralised gas supply system technology for cooking gas applications, and 20 such village-scale gasification systems are operating in the province (Dai and Lu, 1998). Monitoring and assessment of a village experience in Shangdong Province (case 1 in the annex) shows that current technology has considerable consumer appeal and would be highly competitive if the gas were properly priced. The technology for making producer gas from crop residues promises to be widely deployable for cooking applications, and thus to largely solve the indoor air pollution problem caused by stoves that burn biomass or coal.

One problem posed by current gasifiers used in China is that they produce substantial tars (condensable hydrocarbons that are scrubbed from the gas before delivery to consumers). If disposed of without adequate treatment to groundwater or surface water, these tar wastes would pose significant water pollution problems. Moreover, the option of using crop residues or producer gas for cooking will not solve the air pollution problem in China that arises from burning excess crop residues in the field. The producer gas option is about twice as efficient as direct combustion in providing cooking services, so that only about half as much residue is required for cooking relative to direct-combustion stove systems.[5] At the national level, use of just 60 percent of all crop residues potentially available for energy purposes would be adequate to meet all rural cooking needs.

In addition, the producer gas cooking option poses another public health risk: Typically, about 20 percent of producer gas is carbon monoxide—of which accidental leaks into houses can be lethal. Although some hydrocarbon impurities in the gas impart an odour to producer gas that is usually noticed before a lethal dose is inhaled, occasional accidents are inevitable. Therefore (as discussed below), safe, clean, advanced technological options for producing cooking fuel from biomass should be the focus of research and development.

TABLE 10.2. GLOBAL POPULATION AND ACCESS TO ELECTRICITY, 1970–90 (MILLIONS OF PEOPLE)

Country	1970	1980	1990
World population	3,600	4,400	5,300
Rural population	2,600	3.000	3,200
With access to electricity[a]	610	1,000	1,400
Without access to electricity	2,000	2,000	1,800
Percentage of rural population with access	23	33	44

a. Access includes people living in villages connected to power lines. This does not necessarily mean that most households are hooked up to electricity.

Source: Davis, 1995.

Rural electrification

Electricity is at the top of the energy ladder and is highly efficient and convenient for some specialised cooking appliances, such as rice cookers and microwave ovens. But for many years to come, electricity is unlikely to be practical for general cooking in most rural areas of the developing world. Nevertheless, for lighting, communication, refrigeration, and motor applications, electricity is essential for a satisfactory quality of life. Moreover, electricity is key to improving agricultural productivity through mechanisation and is essential for many rural industrial activities. Considerable progress has been made in rural electrification programmes designed to extend electricity services to isolated villages (table 10.2).

The centralised approach

Between 1970 and 1990, 800 million people in rural areas gained access to electricity. Yet of the 3 billion people living in rural areas of developing countries in 1990, 2 billion were still without access to electricity. This global total masks significant variations between

regions and countries. In particular, China's rapid electrification programme—through which 365 million rural residents gained access to electricity from 1970–90—significantly increased the world total. If China were excluded, current access levels would drop from 44 to 33 percent, or exactly the level of 1980.[6]

The distinction between access to electricity by villages and households should also be noted. India, for example, has an ambitious rural electrification programme, targeting agricultural end use. But while 80 percent of villages have electricity, less than 50 percent of households can afford it.

Several studies highlight an important point for economic success: electrification cannot by itself ensure economic development. It is a necessary but insufficient condition. Electrification works best when overall conditions are right for rural income growth and when it is complemented by social and economic infrastructure development—such as rural water supplies, health programmes, primary and secondary education, and regional and feeder roads. Thus rural electrification contributes to but is not a substitute for other rural development measures.

Rural electrification programmes have typically concentrated on connecting villages and remote areas to a national grid—often owned and operated by a public utility. The tendency has been to extend the grid incrementally, reaching towns and settlements in order of increasing capital costs. Thus remote areas with small populations are likely to be the last to receive electricity. Moreover, many rural areas face high transmission and distribution costs, for several reasons:

- The capacity of power lines is inefficiently used because of low population.
- Densities and demand levels are low.
- Villages may have very peaky (undiversified) demand profiles.
- Line losses tend to be high.

In addition, incremental extension of the grid (rather than extension optimised to minimise losses) causes lines to be strung haphazardly, resulting in greater losses.

The decentralised approach

Because of the problems of supplying grid electricity for small, scattered, peaky loads, decentralised electricity generation is becoming more attractive. With decentralised systems, the high costs of transmission and distribution networks can be avoided. But small-scale, decentralised solutions face other barriers. The decentralised generation technologies discussed below are diesel-engine generator sets, small-scale hydropower, photovoltaics, wind, and small-scale biopower using producer gas. No attempt is made to be comprehensive on the technological opportunities for decentralised electricity generation. Instead, the discussion illustrates key features of different technologies, highlighting advantages and drawbacks for rural development needs.

Diesel-engine generator sets. Diesel generators are common in many remote settlements, either for a single user or as part of a local distribution network. Such systems may be operated by a power utility or, more commonly, by private enterprises. Rural hospitals, government offices, and police stations in remote areas typically have their own diesel generators.

Diesel sets with capacities of 50–500 kilowatts of electricity are widely used in rural Latin America and Asia but have only recently been disseminated in Africa. The electricity produced by diesel sets typically costs $0.30 a kilowatt-hour—two to three times the cost of electricity from grids in urban areas but still cost-effective relative to grid extension. (This cost is typical of the Amazonia region of Brazil, where there are 900 diesel sets with a total generating capacity of 391 megawatts.) The high costs of maintenance and of transporting diesel fuel and lubricating oil to remote places make electricity fairly expensive.[7] Despite these costs, electricity is typically highly valued by local populations because of the enormous improvements in living standards that it brings (box 10.3). But while high-cost electricity may be acceptable for satisfying basic needs in households and for some agricultural and cottage industry applications, lower costs are needed to attract a greater job-generating industrial base to rural areas.

Small-scale hydropower. Small-scale hydropower is a locally available resource that in some regions can be exploited to deliver electricity or mechanical power (for pumping water and other applications) to rural areas. The resource potential for small-scale hydropower is discussed in chapter 5; its technology, costs, and future prospects are discussed in chapter 7. Here the focus is on current activities and the prospects for using small-scale hydropower to address rural development needs.

Small-scale hydropower technology, which is being pursued in about 100 countries, is often divided into three categories: micro hydro (less than 100 kilowatts), mini hydro (100–1,000 kilowatts), and small hydro (1–30 megawatts). By the end of 1994 China alone had 6,000 small-scale hydropower stations with a total installed capacity of 15,650 megawatts, supplying 49 terawatt-hours of electricity (Qui and others, 1996)—29 percent of hydroelectric power generation and nearly 8 percent of rural electricity consumption (Deng and others, 1996). In 1989 China accounted for about 38 percent of world-wide small hydropower (23.5 gigawatts), at which time more than 130 companies manufactured equipment specifically for plants with capacities ranging from 10 kilowatts to more than 10 megawatts. Of the 205 turbines ordered world-wide in 1989, the size distribution was micro hydro, 15 percent; mini hydro, 57 percent; and small hydro, 28 percent (Moreira and Poole, 1993). In China and Viet Nam even sub-kilowatt systems have been sold for household electrification. Such turbines are installed at the end of hose-pipes, with somewhat unreliable but serviceable results. However, the potential market for such systems is limited by the availability of water resources.

On a somewhat larger scale, hydropower plants of 50 kilowatts and more can be used to electrify communities or small regions by establishing mini grids. Costs are highly variable (chapter 7), depending on the site topography, proximity of the site to the main load area, and hydrological conditions.

Small-scale hydropower has one drawback: it is almost always obtained from run-of-river plants that lack the reservoir capacity

to store water. Consequently, severe seasonal variations in power output may occur, depending on a site's hydrology. Thus the long-term viability of small-scale hydropower may depend on backup electricity that is supplied either locally or through the grid (Moreira and Poole, 1993).

Photovoltaics. Photovoltaic technology is cost-effective in providing electricity to rural areas at the very smallest scales (typically less than 100 watts) in areas with no access to grid electricity and where electricity demand is characterised by such low levels and infrequency that even diesel electricity cannot compete (see chapter 7 for details about photovoltaic technology and its economics in such applications). The potential for photovoltaic technology to support rural development arises from the fact that it can be used for household lighting, radios, and television sets, and to refrigerate medicines at rural clinics.

In 1999 global photovoltaic sales totalled 200 megawatts, 10 percent of which was for off-grid applications in rural areas of developing countries. One important obstacle to wider rural deployment of photovoltaic technology is the limited financing available for such small systems (see section below on the time horizon for technological options). Kenya has the world's highest penetration rate of household photovoltaic systems, with more than 80,000 systems in place and annual sales of 20,000 systems. Fifty local and fifteen international importers, assemblers, installers, and after-sales providers serve this market, which developed without significant aid, subsidies, or other support. Although the current market is strong, there is still a tremendous need to standardise equipment, as well as improve batteries, lighting fixtures, and electronic ballasts used in integrated household photovoltaic systems. In addition, possible credit arrangements need to be studied, as do the relative advantages of leasing a system rather than purchasing it.

In 1999 South Africa's power utility, Eskom, entered into a joint venture with Shell Solar Systems to provide 50,000 homes with photovoltaic systems in areas where grid connection is not considered feasible. This three-year programme contributes to a market that is

BOX 10.3. DIESEL ENGINES IN A MULTIPURPOSE PLATFORM PROJECT IN MALI

In Mali a project is under way to introduce, by 2003, 450 multipurpose platforms to provide, at the village scale, mechanical power and electricity through diesel engines to 10 percent of the country's rural population. At least two-thirds of these platforms will be coupled to water and electricity distribution networks. By 2003 rural access to electricity is expected to be more than 3 percentage points higher than urban access. Although the project is based on the use of diesel fuel oil, it is envisaged that in the future pourghere nut oil or some other liquid biofuel will be used.

The engine selected for this project is a 1950s-vintage slow diesel engine (a Lister engine, from India). This engine was chosen because of its low initial capital cost; low prices for its spare parts; its ability to operate without damage on the relatively low-quality diesel fuel typically available in villages; its ease of operation, maintenance, and repair by local artisans (blacksmiths, mechanics, carpenters); and the availability of a network of sellers and servicers for it throughout much of Mali.

It is intended that the engine in a typical platform would power various types of equipment, such as a cereal mill, husker, alternator, battery charger, pump, welder, and carpentry machine. Thus the platforms would reduce many rural women's burdensome tasks (fetching water, grinding cereal); offer them income-generating opportunities and management experience; and, as they become more economically independent, help them improve their social status. Because so many activities would be supported by the platforms, their economic and social benefits would be felt at multiple levels, resulting in an overall empowerment of women. In the pilot phase of the project (1996–98), during which 45 platforms with 14 water or electricity networks were installed, the platforms' availability stimulated the creation, development, and modernisation of artisanal activities in participating villages. The platforms are being operated and maintained on a cost-recovery basis by private enterprise.

By design, the acquisition of a multipurpose platform is a demand-driven process. The initial request has to be made by a recognised, registered women's association at the grass-roots level. International donors are subsidising equipment costs (including the engine, mill, de-huller, alternator, battery charger, and building) at up to $1,500 per module. In situations where the supply of electricity and running water is requested, the contribution of the international donor can be increased by up to $10,000 per module. An equity contribution of at least 50 percent is required of the women's associations. Operation and maintenance costs are borne entirely by beneficiaries.

The mechanical work provided by the engines costs about $0.25 per kilowatt-hour (see table). Notably, more than 70 percent of the cost is for diesel fuel and lubricating oil, which must be imported into the region. If the mechanical work were converted to electricity, the added cost associated with the generator and conversion losses would increase the electricity cost to at least $0.30 per kilowatt-hour. If liquid biofuels produced in the region eventually could be substituted for imported oil, the region's balance of payments would be improved, although costs would probably not be reduced much or at all, because liquid biofuels tend to be more costly than petroleum fuels.

Although this project is interesting in revealing consumer wants, it is in its initial phase of implementation, and only experience will supply information on real costs. Nevertheless, the project shows that there are attractive alternatives to grid extension, that rural electrification does not necessarily mean grid electrification, that decentralised electrification is a serious option, and that entrepreneur-driven participatory development is crucial.

Cost of mechanical work for a diesel engine, Mali multipurpose platform

Cost	Dollars per year	Dollars per kilowatt-hour
Capital[a]	131	0.018
Fuel[b]	1,140	0.138
Maintenance		
Every 100 hours		
Lubricating oil	158	0.022
Other	36	0.005
Every 500 hours	179	0.025
Every 1,000 hours	104	0.015
Every 1,500 hours	74	0.010
Total	1,820	0.233

a. For an 8-horsepower (6-kilowatt) Indian Lister diesel engine with a 7-year plant life costing $600 (excluding the cost of a generator) and operated 1,500 hours a year at 80 percent of rated capacity, on average, so that the annual average capacity factor is 13.7 percent. Assuming a 12 percent discount rate, the capital recovery factor is 21.9 percent a year.

b. For a diesel fuel price of $0.44 a litre and an engine efficiency of 30 percent (higher heating value basis).

Source: Mali and UNDP, 1999.

Household-scale wind turbines (of about 100 watts) offer benefits to wind-rich regions similar to those offered by domestic photovoltaic systems.

believed to exceed 2 million households. Customers pay a monthly rate to lease and use the equipment, which allows a reasonable rate of return to Eskom.

Still another approach to reach a greater portion of low-income rural people was adopted by Soluz. This company developed a system to lease small photovoltaic battery systems to provide high-quality electric services at an affordable price while offering a positive financial return to its investors. In 1993, with assistance from the Rockefeller Foundation, Soluz conducted a pre-feasibility study for a solar electricity delivery company and construction of a company prototype for 200 rural homes in the Dominican Republic. The company installs standalone photovoltaic battery systems on or near rural homes yet retains ownership of the systems. The photovoltaic systems provide lighting and access to information services (through radio and television). Users make regular payments, as determined in the lease agreement, and the company is responsible for maintaining the systems.

In Central America customers pay a monthly fee of $15–20, depending on the size of the photovoltaic system leased. The company has an on-time collection rate exceeding 90 percent. Many customers are small businesses, for whom the provision of high-quality energy services contributes to increased profitability.

But even where appropriate financing is made available, the poorest households often cannot afford photovoltaic systems (box 10.4). In considering measures to support photovoltaic programmes for rural areas, it is important to pay particular attention to the poorest households and to strategies to make the technology available to them.

Although significant in improving the quality of life in rural areas, without major cost reductions, photovoltaic technology will be limited mainly to remote household and other small-scale applications and will not be able to compete in the provision of electricity for manufacturing or even most cottage industrial applications.

BOX 10.4. EQUITY ISSUES RELATING TO PHOTOVOLTAIC TECHNOLOGY FOR RURAL AREAS IN INDIA

Of the 79 million rural households in India without electricity (out of a total of 114 million rural households), 7, 17, and 75 percent of households could afford, respectively, 37-watt (four-light), 20-watt (two-light), and 10-watt (one-light) photovoltaic systems with Grameen-type financing (five-year loans at 12 percent interest with a 15 percent down payment; see box 10.7). Thus it appears that the poorest 25 percent of households cannot afford any photovoltaic purchase, even with financing.

But such findings, which are based on willingness-to-pay considerations, might be overly simplistic. The availability of lighting might be exploited to earn extra income that could make a photovoltaic system affordable for even the poorest household. If, for example, a poor Indian household could weave two extra baskets a night by the light made available by a 10-watt photovoltaic system, the technology would become affordable.

Source: Reddy, 1999; Hande, 1999.

Wind. There are two promising ways to exploit wind power to meet rural energy needs. The first is household units that provide electricity at scales where neither grid power nor mini-grid power from diesel units is cost-effective. The second is village-scale wind-battery-diesel hybrid systems (using wind turbines with capacities typically of 5–100 kilowatts).

Household-scale wind turbines (of about 100 watts) offer benefits to wind-rich regions similar to those offered by domestic photovoltaic systems. Such turbines have been developed, produced, and deployed, for example, in China, mostly in the Inner Mongolian Autonomous Region. The dispersion of houses in this region of low population density (18 people per square kilometre) makes household wind systems a viable option for providing electricity. In Inner Mongolia an estimated 130,000 small-scale (mostly 50–200 watt) wind energy systems have been installed, providing electricity for lighting, radios, television, and small appliances to more than 500,000 people, mostly rural herdsmen (about one-third of the population). About 89,000 of these systems are operating routinely, producing from 8.7 megawatts of installed capacity about 15.7 gigawatt-hours a year (Wu, 1995).

The success of the Chinese programme was achieved through careful planning and the creation of an effective regional and local infrastructure for manufacturing, sales, maintenance, and training. This included the development of a market for individual household systems through various subsidy mechanisms. The government of Inner Mongolia also recognised and allowed for the long gestation period and sustained support needed to create a thriving local industry. The project has also led to technology transfers at many levels—between Inner Mongolia and local, regional, and national organisations within China, as well as with other countries. Replicating the programme would require enough institutional capacity to support such ventures.

Where rural households are clustered in villages far from electric grids that are served instead by diesel-engine generator sets, an alternative option is to deploy wind turbines in wind-diesel or wind-battery-diesel hybrid configurations, which have been installed in many parts of the world (Baring-Gould and others, 1999). In regions where diesel fuel is costly, these hybrid systems can lead to lower electricity costs and less air pollution than conventional diesel-engine generator sets.

Unlike the household-scale wind turbines being developed in China, however, many components of these hybrid systems are based on technology developed in industrialised countries, and costs of imported systems are often prohibitive. But if these systems can be mass produced in developing countries under arrangements—such as international industrial joint ventures—that are conducive to technology transfer, substantial cost reductions are possible (see chapter 7 for an example).

Small-scale biopower using producer gas. Biomass-derived producer gas (see above) can be used to make electricity at scales

Historically, electric utilities have discouraged independent power producers from selling electricity into grids, but this situation is changing as electricity markets are becoming more competitive.

comparable to those associated with diesel-engine generator sets. The potential benefits are:

- The capacity to use locally available biomass as fuel instead of oil imported into the region.
- Lower electricity generation costs than with diesel.
- Increased rural income generation, and possibly rural industrialisation, as a result of the lower electricity cost.

The reciprocating compression-ignition (diesel) engine is the main commercially viable engine available for these applications.[8] When producer gas is used with such engines, it must be supplemented with a pilot oil to assist ignition because mixtures of producer gas and air do not auto-ignite at the pressures and temperatures realised when the gas is compressed. As a result producer gas can typically displace about 70 percent of diesel fuel consumption. When operated with producer gas in the dual-fuel mode, diesel-engine generators have somewhat lower efficiencies and rated capacities (typically about 20 percent lower than when operating on pure diesel fuel).

Producer gas must meet far higher standards for reciprocating engine operation than for cooking or heating (domestic or industrial) applications. The main problem is the propensity of tars formed in the gasifier to condense on downstream surfaces, causing problems such as the sticking of engine gas intake valves. Most early gasifiers generated so much tar that adequate gas clean-up for engine operation was impractical, and tar removal would significantly reduce the potential for power generation from a given amount of biomass feedstock. But in recent years, gasifiers have been developed (notably in India) that generate tars at levels that make engine operation on producer gas acceptable (Kartha and Larson, 2000).

Biomass-derived technology for producer gas, reciprocating-engine generators is commercially ready. In India, for example, the Ministry of Non-Conventional Energy Sources has supported development efforts that have led to technically sound gasifier-engine systems and trial implementation of more than 1,600 such systems with a total installed capacity of more than 28 megawatts (Kartha and Larson, 2000). For engines operated on producer gas and pilot oil, fuel costs are typically much lower than for conventional diesel systems. But capital, operation, and maintenance costs are higher (see table A10.1).

In fact, the savings derived from diesel replacement have to pay for the extra initial capital cost as well as the extra operation and maintenance costs incurred for the gasifier. The technology can be cost-effective, either where diesel fuel costs are very high (for example, $0.35–0.40 a litre or more, as is often the case for extremely remote regions) or, with efficient capital utilisation, in regions where diesel fuel prices are more moderate. If the diesel fuel price is $0.25 a litre, a typical system must be operated at full capacity for 3,000 hours a year to break even with a conventional diesel system. About 6,000 hours of annual operation are needed to realise a cost savings of 25 percent (see table A10.1). It is desirable to seek opportunities for such high rates of capacity utilisation because consumers are likely to be more motivated to adopt the technology if they can realise substantial cost savings. Unfortunately, achieving high rates of capital utilisation is often difficult because local electricity demand is typically low and sporadic but peaky, with very little electric load diversity.

A promising strategy for launching a producer gas, engine-generator technology industry would be to focus initially on market opportunities where the technology could be deployed in large numbers in baseload configurations. This requires that two conditions be satisfied. Biomass supplies have to be adequate for fuelling baseload plants, and the demand for electricity has to be adequate to justify baseload operation. Strong candidate regions for doing this are agricultural regions of China where crop residues are abundant and where grid connections exist (87 percent of the rural population in China is grid-connected), so that electricity generated in excess of local needs can be sold into the grid (Li, Bai, and Overend, 1998). Historically, electric utilities have discouraged independent power producers from selling electricity into grids, but this situation is changing as electricity markets are becoming more competitive (chapter 12).

New technologies that might be commercialised in the near term (5–10 years) offer the potential for electricity generation at costs significantly lower than with current technology. One promising new technology is the microturbine, which might be deployed with essentially the same gasifiers that have been developed to provide producer gas for use with diesel dual-fuel engine generator sets.

Microturbines are gas turbines designed for operation at scales of 50–250 kilowatts of electricity, with electric efficiencies (lower heating value) of 25–30 percent for larger units. Microturbines were originally developed for military and aerospace applications and are now offered by several companies for applications in distributed power and cogeneration markets, mainly for use with natural gas or diesel fuel. Developers expect microturbine use to grow rapidly for such applications in regions where there is competition in electricity markets (chapter 8). The technology appears to be readily adaptable for use with biomass-derived producer gas (Henderick, 2000).

Microturbines are less complex (some variants have only one moving part) than reciprocating engines. They can be fuelled with producer gas without de-rating and without loss of efficiency relative to operation on natural gas or diesel fuel. Most important, they need no costly pilot oil (Henderick, 2000). In regions where crop residues or other low-cost biomass feedstocks are readily available, there are reasonably good prospects that the technology could become widely competitive in grid-connected applications (Henderick and Williams, 2000). Case 2 in the annex describes a potential application of the technology to the trigeneration of cooking gas, electricity, and space heating through district heating in a hypothetical village in northern China.

To illustrate the aggregate potential of this technology, consider

that in China, 376 million tonnes of crop residues a year are potentially available for energy purposes.[9] Committing these residues to trigeneration (case 2 in the annex) could provide enough cooking gas for 230 million people (27 percent of China's rural population) plus 270 terawatt-hours a year of electricity (equivalent to 30 percent of coal power generation in China in 1997) plus hot water for space heating in regions where it is needed (for example, in regions with cold winters).

Several public policy initiatives could facilitate the creation of a viable industry for small-scale biopower technologies. One important measure would be to eliminate or phase out diesel fuel subsidies that exist in many regions. Another would be market reforms that facilitate the sale of electricity into electric grids, coupled with incentives to encourage the extension of electric grids to more rural areas. Notably, the commercial availability of competitive baseload biopower technology could profoundly influence the economics of extending electric grids to rural areas. In contrast to the poor capacity utilisation (and hence poor economics) of transmission-distribution lines sending electrons from centralised power plants to rural areas, high capacity factors (and thus more favourable economics) could be realised if electrons instead flowed to urban centres from baseload village-scale biopower plants.

Finally, demonstration projects are needed to prove the viability of new technological concepts for biopower. Projects are needed for biopower systems based on gasification of alternative crop residue feedstocks, for which tar production rates are higher than for wood chips (Henderick and Williams, 2000). Such projects could involve the use of commercially established diesel dual-fuel engine technologies. Demonstrations are also needed of microturbines in producer gas applications. If carried out together with the above institutional reforms, these projects could lead to commercially viable microturbine-based products for biopower applications in the near term (2005–10).

Leapfrogging to new rungs on the energy ladder

The previous sections have shown that existing and near-term energy technologies have great potential for improving the quality of life in rural areas. But advanced technologies have residual problems that might need to be addressed. For instance, fuels such as LPG are highly desirable for cooking, but making LPG widely available requires considerable infrastructure for distribution, and finding ways to make LPG affordable to the poorest households is a major challenge. Moreover, because LPG is derived from petroleum—a commodity for which price swings can be substantial, as recent experience has shown—price spikes are likely to be burdensome for lower-income households that depend on LPG for their cooking needs.

Local manufacture of clean cooking fuels (such as biogas and producer gas derived from biomass feedstocks) is a strategy for addressing the fuel-infrastructure challenges and price volatility concerns posed by exclusive reliance on LPG. This strategy also provides opportunities for addressing the needs of the very poorest households, because the need to gather typically dispersed biomass feedstocks (such as dung for biogas or crop residues for producer gas) and deliver them to the conversion facility can sometimes make it possible for the poor to monetise their labour and thereby earn income to help pay for these clean cooking fuels (case 2 in the annex).

But today's available gaseous cooking fuel technologies have limitations. Biogas technologies, though well suited for use with dung feedstocks, are not easily applied to crop residues, which tend to be much more abundant. And a persistent concern about producer gas is that it contains carbon monoxide, accidental leaks of which might lead to fatalities. Odourants added to producer gas could greatly reduce the risk of poisoning, but accidents are difficult to avoid completely.

Advanced technologies can make it possible to manufacture synthetic cooking fuels from biomass that are non-toxic as well as clean. A promising approach is to adapt to biomass some of the technologies being developed for fossil fuels—specifically, syngas-based fluid fuels (chapter 8). Strong candidates are synthetic LPG (SLPG) and dimethyl ether (DME), which can be made from any carbonaceous feedstock by catalytic synthesis from syngas (a gaseous mixture consisting largely of carbon monoxide and hydrogen). SLPG (like petroleum-derived LPG, a mixture of propane and butane) and DME are superclean, non-toxic cooking fuels that are gaseous at ambient conditions but can be stored and delivered to consumers as liquids in moderately pressurised canisters. These fuels can be produced from crop residues or other biomass feedstocks through thermochemical gasification to produce the needed syngas. (Case 3 in the annex discusses the potential offered by such technologies for rural regions of China rich in crop residues.)

In addition to the toxicity advantages offered by SLPG and DME, both fuels could be readily transported in canisters by truck or donkey cart to remote, scattered households. Producer gas, by contrast, is a viable option primarily for villages in which houses are clustered closely enough to make pipe transport economically viable. Thus SLPG and DME extend the scope of the cooking fuel markets that could be served relative to producer gas. DME is also a potentially strong low-polluting synthetic fuel for diesel-engine vehicle applications (chapter 8) and might be used as tractor fuel, thereby facilitating the mechanisation of agriculture.

Neither SLPG nor DME is currently produced for fuel applications, but either fuel derived from biomass feedstocks could probably be brought to market readiness by 2010–15 if there were sufficient market interest and a focused development effort. Because neither SLPG nor DME is currently on the market anywhere in the world, a shift from the use of current low-quality fuels to either might be described as jumping to entirely new rungs at the top of the energy ladder (technological leapfrogging).

The time horizon for technological options

Chapters 6–8 and this chapter show that there are abundant opportun-ities for technological change relating to rural energy. Technological change is desirable to the extent that it serves development

needs. Rural development planners can help shape the course of technological change for desirable options, taking into account the time horizons required for development and implementation—demanding more of the longer-term options in addressing societal needs. Options that warrant focussed attention in the near term (that is, implementation in the next 5 years) as alternatives to current technology should offer the potential for immediate improvement. For the medium term (5–15 years), planners should emphasise technologies that can potentially achieve dramatic improvements relative to current technology. To the extent that technologies realisable in the medium term fall short of performance consistent with sustainable development goals, policy-makers should also encourage for the long-term (15–30 years) technologies that are fully consistent with sustainable development goals.

It is also wise to have a balanced portfolio with a combination of near-, medium-, and long-term options, to ensure a continuing flow of improved technologies into rural energy markets. Successes with near-term improvements can help win political support for the development of longer-term options. Some important technological options for rural energy in the near, medium, and long terms are summarised in table 10.3.

Accelerating rural energy development

The preceding sections show that there are many technological opportunities for implementing the goals set forth at the start of this chapter: providing clean liquid or gaseous fuels for cooking and electricity for lighting and other basic household amenities, and making bulk electricity available at low cost for mechanising rural agriculture and promoting rural industrialisation.

Both centralised and decentralised energy technologies and strategies can make contributions to reaching these ends. But new strategies and policies are needed to increase access to these modern energy services and to make modern energy services widely affordable. Coordinated efforts that include the active participation of rural people can accelerate the process.

Integrated rural development

Making modern energy services more readily available is a necessary but insufficient condition for rural development. To be most effective, certain forms of energy (such as grid-based electricity) should be introduced into rural areas only after, or along with, other development inputs or infrastructure components. To achieve this integration, it is essential that there be horizontal communication among all agencies involved in rural development.

Many rural development activities—agriculture, transport, water supply, education, income generation, health care—have energy requirements. Yet the ministries and departments responsible for these activities rarely coordinate or cooperate with the ministry of energy, or with one another, to arrive at the most rational, integrated solution

TABLE 10.3. SOME NEAR-, MEDIUM-, AND LONG-TERM TECHNOLOGICAL OPTIONS FOR RURAL ENERGY

Energy source or task	Present	Near term	Medium term	Long term
Source				
Electricity	Grid or no electricity	Natural gas combined cycles, biomass-based generation using gasifiers coupled to internal combustion engines, photovoltaic, small wind, small hydroelectric for applications remote from grids	Biomass-based generation using gasifiers coupled to micro-turbines and integrated gasifier combined cycles, mini grids involving various combinations of photovoltaic, wind, small hydroelectric, batteries	Grid-connected photovoltaic and solar thermal, biomass-based generation using gasifiers coupled to fuel cells and fuel cell/turbine hybrids
Fuel	Wood, charcoal, dung, crop residues	Natural gas, LPG, producer gas, biogas	Syngas, DME	Biomass-derived DME with electricity coproduct
Cogeneration (combined heat and power)		Internal combustion engines, turbines	Microturbines and integrated gasifier combined cycles	Fuel cells, fuel cell/turbine hybrids
Task				
Cooking	Woodstoves	Improved woodstoves, LPG stoves, biogas	Producer gas, natural gas and DME stoves	Electric stoves, catalytic burners
Lighting	Oil and kerosene lamps	Electric lights	Fluorescent and compact fluorescent lamps	Improved fluorescent and compact fluorescent lamps
Motive power	Human- and animal-powered devices	Internal combustion engines, electric motors	Biofueled prime movers, improved motors	Fuel cells
Process heat	Wood, biomass	Electric furnaces, cogeneration, producer gas, NG/solar thermal furnaces	Induction furnaces, biomass/solar thermal furnaces	Solar thermal furnaces with heat storage

to their energy needs. Decentralisation of rural energy planning may help achieve this. But optimising the allocation of development resources requires attention at the central government planning level as well. In the many places where integrated rural development has been pursued, the availability of affordable modern energy supplies has proven to be a catalyst for economic and social transformation.

Where integrated rural development has been pursued, the availability of affordable modern energy supplies has proven to be a catalyst for economic and social transformation.

The provision of affordable financial services for rural people has long been a prime component of rural development strategies. Originally, these strategies focussed on concessional loans to farmers. More recently, however, this approach has been replaced by much wider financing for rural activities, with lower transaction costs. By creating rural financial markets and integrating them with general financial markets, it may be possible to mobilise substantial domestic savings as the main capital resource for rural people—and to reduce their dependence on concessional outside funds. Where urban-biased financial policies have inhibited the creation of effective rural financial institutions, new policies and strategies should seek to integrate rural and urban financial services and thus promote the greatest financial efficiency and lowest credit costs for rural people.

Involving rural people (particularly women) in decision-making

Above all, planning for rural energy development should have a decentralised component and should involve rural people—the customers—in planning and decision-making. And special attention should be devoted to involving women, because they bear the burden of traditional energy systems and are likely to be the greatest beneficiaries of improved systems. A major driving force for the move towards decentralisation has been the recognition of the limited extent to which benefits have flowed to rural people from the investments already made. More active involvement of rural people (particularly women) and their institutions in identifying rural energy problems, and in formulating and implementing plans to overcome them, would result in more efficient, rational use of resources and more equitable sharing of the benefits of development.

Decentralisation of rural energy planning is wise for other reasons as well. Rural energy systems are based primarily on biomass, a local energy resource. Although historically this has involved direct combustion of biomass for cooking or heating (as this chapter has shown), clean, convenient, modern energy carriers can also be derived from biomass. Consequently, an assessment of the demand and supply flows and of desirable interventions must all also occur on the same geographic scale. Through their superior knowledge of the local situation, local people—women in particular—can be integral parts of the solution.

Strategies for expanding access to modern energy services

Often, policies ensuring that supplies—even from centralised production sources—are reliable and stable can promote the use of modern energy carriers. The Hyderabad, India, example (see above) shows that by the simple expedient of stabilising LPG supplies, the local government was able to encourage many households to shift from biomass to LPG for cooking.

For rural electrification through grid extension, rural cooperatives seem to be a viable alternative to grid extension by the large parastatals that have dominated power generation in developing countries. In Bangladesh financial and technical failures of public power utilities in 1980 led to a government-supported take-over of its parastatals by rural electrification cooperatives. Now numbering 45, the cooperatives have engineered a rapid expansion of grid-based rural electricity supply that serves 1.6 million consumers—as many as the public sector in urban areas. Power outages have fallen dramatically, while revenue collection has improved from 91 to 98 percent, despite higher tariffs. Most important, the cooperatives have fostered an alternative structure to meet a demand that was previously unexpected in such a poor country. They have also demonstrated that consumers have considerable interest in getting access to electricity and are willing to pay for reliable service.

More effective electric grid extension measures can also help promote the wider availability of electricity from local biomass sources by making village-scale biopower-generating technology more attractive to investors. Grid access would make it possible to operate biopower plants as baseload units, thereby increasing capacity utilisation and reducing generation costs per kilowatt-hour. Grid access would enable rural populations to sell into the grid electricity produced in excess of local needs—until local rural industrial capacity could be increased to more fully use the electricity produced this way (case 2 in the annex). Thus a promising new approach would be to couple grid extension in regions rich in crop residues (or other suitable biomass resources) to measures that encourage village-scale biopower generation.

This strategy would also make investments in grid extension more attractive. The availability of baseload biopower on these grids would enhance grid capacity utilisation and make transmission costs per kilowatt-hour much lower than when electrons instead flow from large central power plants to rural areas to serve small, scattered, peaky rural electrical loads.

Policies that make grid access possible are needed to facilitate the launch of such baseload biopower technologies on the market. Policies promoting increasing competition in electricity generation would be helpful. But consideration also has to be given to the fact that, when any new technology is introduced, its cost is higher than that of the established technology it would replace. That remains the case until enough new plants have been built to buy down the cost of the new technology along its learning curve to prospective market-clearing price levels (chapter 12).

One way to pursue technology cost buydown in a competitive electricity market is to require that each electricity provider include in its portfolio a small but growing fraction provided by biopower

or other renewable energy supplies. This requirement would be imposed during a transitional period as new renewable energy industries are being launched on the market. Power generators could either produce this renewable electricity themselves or purchase renewable energy credits that are sold in a credit trading market. Experiments with this mechanism are being conducted in the United States (where it is called a renewable portfolio standard) and in Europe (where it is called green certificate markets). The concept has great promise for developing countries.

A major challenge in extending energy services to rural areas is to find and pursue the least costly mix of energy options (centralised and decentralised, fossil and renewable, end-use efficiency improvements) for a particular region. This might be achieved, for example, through concessions for both cooking fuels and electricity. Concessions grant the exclusive right to provide energy services in exchange for the obligation to serve all customers in the region. They offer the advantage of being able to reduce transaction costs greatly in serving large numbers of small customers, relative to other mechanisms. Concessionaires ought to have the flexibility to choose the least costly combinations of technologies in meeting their obligations. The rural energy concessions recently introduced in Argentina illustrate how the concept might work (box 10.5).

BOX 10.5. A CONCESSION SCHEME FOR RURAL ENERGY DEVELOPMENT IN ARGENTINA

Argentina recently began implementing an innovative rural energy plan to encourage private sector involvement in rural energy services. To begin with, the programme targets eight provinces with 1.4 million people and 6,000 facilities without access. In each province, private companies bid for the right to provide electricity to the people and to the schools, medical centres, drinking water facilities, and other public facilities without access. Solar photovoltaic panels, small wind turbines, micro hydropower, and diesel-driven generators compete on a least-cost basis.

Preliminary analyses show that in most cases renewable technologies will be competitive with diesel generators. A large share of household supply will be through solar photovoltaic home systems. Total investment for all provinces amounts to $314 million, with a 55 percent subsidy from provincial, federal, and World Bank funds to cover initial capital investments. The winning bids will be those seeking the lowest government subsidy per energy hook-up.

In 1996 two concessions were awarded in Jujuy and Salta provinces. In Jujuy, after solving some initial problems with the tariff structure proposed in the bidding papers, 500 of 2,000 new users are now served through renewable sources, and a programme to supply 550 additional users through solar home systems is in progress. By 1998 solar systems were installed in 220 schools in Salta province, which aims to achieve full coverage of public service electrification (including schools and first-aid medical centres) in 2000.

In April 1999 a $30 million loan from the World Bank and a $10 million subsidy from the Global Environment Facility were approved. These funds will help finance the national government's share of subsidies for the first eight provinces to adopt the programme, as well as overcome barriers to the use of renewable energies. Concessions to provide electric power to significant portions of the population within three years were granted in the next six provinces to adopt the programme in late 1999 and early 2000. Eventually, all rural Argentine provinces will participate in the programme.

Source: Covarrubias and Reiche, 2000.

Strategies for making modern energy services affordable

Although policies aimed at widening access to modern energy services are necessary, they are often insufficient to deliver modern energy services to all rural residents. Modern energy technologies are useful only to those who can afford to adopt them. Even the more affluent rural households typically cannot afford to purchase photovoltaic systems, which may be the only plausible electrification option for scattered rural households. Moreover, the very poorest households are unable to pay for even less capital-intensive modern energy options. And such households are the majority in the poorest countries: 37 of the countries listed in the World Bank's *World Development Report 1998/99* had a 1997 GDP per capita below $500 (unadjusted for purchasing power parity).

Historically, energy price subsidies have been used extensively to promote wider use of modern energy carriers. But energy price subsidies are problematic. The welfare objective embodied in such subsidies is often not realised because of their diversion to unintended uses. Typically, there is a disproportionate exploitation of the subsidies by the more affluent, who could afford to pay unsubsidised prices. Such subsidies help explain the poor financial conditions of many parastatal energy companies, and have made continued expansion of energy supplies difficult (chapter 12). Energy price subsidies should be a policy of last resort to deliver modern energy services to rural areas.

When attempting to increase the level of energy services provided, a central question is: what is affordable? There is frequent mention of affordability, but there has been no rigorous quantification of this concept. One might argue that a consumer's current energy expenditures—for example, on kerosene for lighting—are a good indicator of what that consumer is prepared to spend for electric lighting. In some cases, however, the consumer is prepared to spend more for a new technology if it is safer or more convenient.

Policy reforms to make capital resources more readily available for small-scale rural energy investments would be especially helpful in making modern energy affordable to small rural consumers. Various microfinance schemes are being tried (box 10.6), and some are proving quite successful. When the poor have access to microfinance, they are no longer beneficiaries of government and donor largesse but clients with assets, whose preferences and needs must be respected. Microfinance has demonstrated success not only in providing access to energy services for poor households, but also in generating income and alternative economic activities. Microfinance is facilitating access to affordable modern energy technologies for which many people are willing to pay the full cost.

Poor Indian households that currently buy kerosene for lighting could afford electric lighting if energy-efficient fluorescent bulbs were used (Reddy, 1999). An appropriate microfinance scheme could make investment in fluorescent lights a viable option, even for poor households, if total spending on electricity plus debt servicing was less than maximum household spending on energy (about 15 percent). The combination of modern technology and microfinance can thus widen the window of opportunity. Because of the capital-intensive nature of photovoltaic and other renewable energy technologies,

BOX 10.6. ALTERNATIVE APPROACHES FOR FINANCING SMALL-SCALE RURAL ENERGY TECHNOLOGIES

At the smallest scales, many sustainable energy technologies (including small-scale wind and hydropower supplies and photovoltaics for homes) cost a few hundred dollars. Buying them outright is impossible for most rural households in developing countries. But an important minority of households, communities, and small businesses can afford to buy them with credit. The main obstacle to serving this crucial market is the reluctance of banks to manage numerous small loans and to lend without collateral or other guarantees against loan defaults. A variety of innovative approaches are being used to overcome this obstacle:

- **Financing through dealers.** Banks transfer the collateral problem from the end user to dealers by lending to dealers, who in turn lend to purchasers using payment schemes compatible with their income. Dealers must bear the financial risk along with technical risks. This system is best suited to large, relatively high-income rural markets.
- **Financing through energy service companies.** These companies can replace dealers as the financing intermediary. Companies typically require greater efforts to establish higher funding levels, because they provide a more comprehensive installation and back-up service to clients.
- **Revolving funds (with grant support).** A bank takes on the risk of operating a revolving loan fund, usually with start-up capital provided by a grant.
- **Loan aggregation through cooperatives.** To avoid the high costs of servicing many small loans, prospective borrowers form a community association (or enlarge the functions of an existing village or farmer cooperative). Banks lend to the cooperative or lease the energy systems but retain ownership of the equipment in case of payment defaults.
- **Concessional funding for public sector objectives.** The government contracts and pays a local company to provide energy services that meet development objectives, such as photovoltaic lighting for schools. This provides entry capital for the company to offer credit and expand its business to other local markets, such as photovoltaics for households, health clinics, and community centres.
- **Payment for energy services.** Payment for outputs, such as irrigation and drinking water, have been used to fund the recurrent operation and maintenance costs of small-scale energy systems. These cost streams are usually hard to fund, or remain unfunded, when loans target the capital cost.

Most of these approaches demand high levels of local participation and so take time to mature. Participation must start at the concept development stage, so that local people can decide which schemes and parameters are most appropriate.

Source: EC and UNDP, 1999.

BOX 10.7. THE GRAMEEN SHAKTI PHOTOVOLTAIC PROGRAMME IN BANGLADESH

In 1996 the Grameen Bank of Bangladesh, a microlending agency with more than 1,000 branches and 2 million members, initiated a programme of loans for photovoltaic home systems to serve those without access to electricity. The loans are administered by a non-profit rural energy company, Grameen Shakti, and call for a small down payment.

Grameen Shakti's first initiative has been a 1,000-unit project to understand better a number of important issues concerning household photovoltaic systems. These include:

- Technical performance of these systems in rural Bangladesh.
- Acceptance of the systems by the poor.
- Income-generating potential of light in the evening.
- Affordability, factoring in technical improvements and economies of scale.
- The training, monitoring, and evaluation expertise that would be required to replicate this project if it proves successful.

Grameen Shakti expects that 100,000 photovoltaic systems will be operating in rural Bangladeshi homes in 2000. The bank plans to expand this service by offering small loans for wind power and biogas plants. Demonstration projects are under way to determine the most appropriate financing packages for these technologies.

microfinance schemes are especially important to promote their widespread dissemination (box 10.7).

Microfinance by itself is no panacea, however. Two other factors limit the affordability of energy services: the high costs of imported energy products (including high inherent costs and inefficient procurement of small quantities) and the low incomes of the very poorest households. But international industrial joint ventures that manufacture modern energy technology with gradually increasing domestic content can, over time, reduce costs relative to the cost of the same technology if imported (Weise and others, 1995; see also the case study of wind-diesel hybrid technology in China in chapter 7). Such cost reductions lead to expanded market opportunities, which lead to further cost reductions resulting from higher production volumes. The keys to success in creating this kind of virtuous cycle of cost reduction and market expansion are policies that facilitate the formation of such joint ventures and steer them towards the provision of energy services for rural areas (chapter 12).

The very poorest households may need higher incomes as well as microfinance to afford modern energy supplies and end-use devices. Increasing the incomes of the rural poor through macroeconomic policies is an especially daunting challenge and takes a long time. But energy policies that facilitate the introduction of low-cost electricity generation for rural industrialisation could effectively promote income generation.

Especially promising are the possibilities for electricity generation from low-cost crop residues in agriculture-intensive regions. Moreover, village-scale, crop-residue-based biopower technologies offer the possibility of near-term income from gathering biomass and delivering it to conversion facilities. This could help the poor pay for modern energy supplies without having to wait for rural industrialisation opportunities to materialise (case 2 in the annex). A key to making such income-generating activities viable seems to be the opportunity to sell into the grid electricity produced in excess of local needs (see the section above on small-scale biopower).

Pursuing all the above strategies might still leave the very poorest households in some areas unable to afford convenient energy services. If so, subsidies may still be needed. As noted, to stimulate the use of new technologies (such as fluorescent light bulbs), one-time equipment subsidies are preferable to continued price subsidies.

To sum up, sustainable development implies that modern energy carriers need to be made affordable to satisfy the basic needs of all rural residents. Policies are needed that will make pursuing this objective profitable. If a subsidy is needed, it might be provided as an integral part of a new social contract that creates highly competitive conditions in the energy sector (a key element of ongoing energy reforms), complemented by the establishment of a public benefits fund financed with wire and pipe charges imposed on electricity, oil, and gas providers to protect the public interest under new

competitive market conditions (see chapter 12 for a discussion of public benefits funds). Specifically, some fund revenues could subsidise the basic energy needs.

This public benefits fund strategy could be made entirely consistent with a shift to greater reliance on market forces to more efficiently allocate resources. If, for example, an energy concession proved to be the preferred way to deliver modern energy services to a particular rural area, and if the concession was awarded competitively, market forces would be brought into play to find the least costly mix of energy technologies with the least amount of subsidy to satisfy the concessionaire's obligation to provide modern energy services to all.

Through their superior knowledge of the local situation, local people—women in particular—can be integral parts of the solution.

Conclusion

Between 1970 and 1990 rural electrification from grids brought electricity to 800 million additional people. In addition, in the past 20–30 years a number of innovative schemes have been developed to commercialise improved cooking stove, biogas, and producer gas systems; photovoltaics; wind; and so on—with the result that several hundred million people have improved their access to energy. Perhaps as many as 600 million people have benefited from these innovations. Yet despite these efforts to improve energy services to rural areas, the population without access to such services has stayed about the same: 2 billion.

The task is daunting but not hopeless. Technologies can be deployed immediately or in the near term to improve energy services for rural areas. These technologies will lead to dramatic advances in the quality of life for rural populations. These advances can be achieved at costs that are within the means of governments and beneficiaries. They also require quite modest increases in the magnitudes of total energy supplied to the countries involved. They offer attractive options for decision-makers seeking quick political pay-offs before the next popular judgement of their performance. Even more exciting is the possibility of interesting new technologies that might be developed and exploited. All such possibilities would enable rural populations to climb up the energy ladder, leapfrog to higher rungs on the ladder, or even reach new rungs that could be added near the top of the ladder.

New policies are needed to bring the top of the energy ladder within reach of all rural people. Past efforts to deliver modern energy to rural areas have often been ineffective and inefficient. Some recent programmes are showing good results, but more promising new approaches need to be tested to determine if they can address poverty, equity, environmental, and public health concerns in the context of the ongoing global restructuring of energy industries. Much can be done towards these ends without resorting to large subsidies if competitive market conditions are fostered and complemented by measures to protect the public interest. Subsidies should be reserved for situations in which new strategies alone cannot make modern energy widely available. Even then, fuel price subsidies should be avoided if basic needs can be addressed by alternatives, such as subsidised purchases of energy-efficient equipment. Sound policies to accelerate the wide availability of modern energy services in rural areas could lead to even more dramatic improvements in the rural quality of life without creating large demands on public treasuries. ■

ANNEX Case studies of crop-residue-derived modern energy carriers in China

In densely populated countries that are largely self-sufficient in food production and are prolific generators of crop residues, thermochemical gasification of crop residues can provide an attractive means of providing both clean cooking fuel and electricity or combined heat and power (CHP) to satisfy basic human needs and generate additional electricity in support of income generation and rural industrialisation. Prospects in this regard are here illustrated by three case studies for China that illustrate the prospects for providing:

- With existing technology, residue-derived producer gas as a clean cooking fuel at the village scale.
- With medium-term (5–10 year) technology, cooking gas plus CHP at the village scale, with residue-derived producer gas.
- With long-term (10–20 year) technology, both electricity suitable for rural industrialisation and a synthetic fluid fuel for cooking (synthetic LPG or DME derived from synthesis gas; see chapter 8) that is safe as well as clean.

There are three reasons to focus on China in studying this approach to making modern energy carriers widely available in rural areas. First, China satisfies the criteria of being densely populated, self-sufficient in food, and a prolific generator of crop residues. About 376 million tonnes a year (about half the total residue generation rate) are potentially available for energy; the rest is used for paper-making, forage, or returned to the fields to sustain soil quality (Li, Bai, and Overend, 1998). The energy content of these residues is equivalent to 15 percent of the coal energy use in China in 1998.

Second, China has a severe new air pollution problem caused by the burning of crop residues in the field at harvest time, a consequence of the rising affluence of farmers. Traditionally, in poor agricultural communities of China, residues were fully utilised for heating, cooking, and other purposes. But as incomes have risen, growing numbers of farmers have become less willing to gather residues from the fields and store them for use throughout the year—preferring instead to buy coal briquettes or LPG as needed. As a result, excess crop residues that do not readily decay (because they dry out too quickly) for incorporation into the soils have been burned off in the fields to avoid insect infestation problems. The resulting air pollution has been severe—often even closing airports near harvest time. As a response, the government in 1999 banned burning crop residues

near airports, railroads, and highways. The ban will be difficult to enforce, however, unless alternative productive uses of residues can be found.

Third, a key to providing low-cost electricity from crop residues as a coproduct of cooking gas is being able to produce baseload electricity and to sell electricity produced in excess of local needs into the electric grid. In most developing countries, this is not yet feasible because few rural communities are hooked up to grids. But in China, 87 percent of rural households are connected, in comparison with an average of about 33 percent for all other developing countries. Thus China stands out as a strong candidate country for launching small-scale biopower technologies in the market.

Case 1. Cooking with producer gas generated at the village scale

With technology currently available in China, it is feasible to provide clean cooking gas derived from crop residues at the village scale through partial oxidation in air, as illustrated by recent experience in Shangdong Province.[10]

In May 1996 a village-scale crop residue gasification system serving village households with producer gas for cooking went into operation in Tengzhai village (216 households, 800 people), Huantai County, Shangdong Province (the second village-scale gasification system installed in the province), using an atmospheric pressure, air-blown, downdraft gasifier developed by the Energy Research Institute of the Shangdong Academy of Sciences. Researchers at the institute also carried out detailed socio-economic studies of the implications of the technology and of costs in relation to benefits.

The gasifier requires 0.25 tonnes of crop residue per capita to meet the annual cooking needs of villagers. About 12 percent of the residues generated by the village's wheat and corn crops are adequate to meet all its cooking energy requirements. Researchers estimated that, with the producer gas cooking system, cooking time for housewives is reduced from 3.0 to 1.5 hours a day.

In a survey of 30 randomly selected households, the researchers found that this technology was regarded as being as good as or better than coal or LPG (the major technologies displaced) with regard to price, convenience, reliability of supply, environmental impact, and working intensity of housewives (all the issues investigated in the survey) by 97.5 percent or more of all households surveyed for each issue.

The total capital cost for the entire project (with an expected 10-year project life) was 378,000 yuan ($47,000, or $220 a household), a third of which was provided by a government subsidy. The producer gas is sold to villagers at a price that is a third of the market price for LPG on an equivalent-cooking-service-provided basis.[11] At this selling price, the project is not cost-effective, even with the capital subsidy. However, if the gas selling price were raised to two-thirds of the equivalent market price for LPG, the technology would be cost-effective without any capital subsidy, generating an internal rate of return of 17 percent. At this higher gas price, the annual cost of cooking fuel per household would be 360 yuan ($45) a year, about 25 percent less than the fuel cost for cooking with coal.

Case 2. Combined heat and power systems using producer gas generated at the village scale

Although desirable as a way to make an affordable, clean, convenient cooking fuel available to villagers, the strategy described above will not solve the air pollution problem caused by burning excess residues. However, using residues in excess of what are needed to make cooking gas power generation or CHP could solve the problem.

This case discusses the prospects for improving village living conditions through the 'trigeneration' of cooking gas, hot water for space heating, and electricity from a village-scale gasifier that converts crop residues (corn stalks) into producer gas (Henderick and Williams, 2000). The system is designed to satisfy all cooking needs in the village with a clean gas, plus meet all village electricity needs, plus generate much more electricity for sale into the grid, plus generate hot water through waste heat recovery at the biopower plant for distribution to village households through a district heating system that would satisfy all space-heating needs (especially important in Jilin Province, where winters are very cold). For specificity, the analysis is for a hypothetical 100-household village (400 residents) in Jilin Province, where about half the residue generated could potentially be exploited for energy purposes at a rate of about 6.5 tonnes a household per year (Cao and others, 1998).

With currently available biopower technology, electricity could be produced at the least cost with diesel-engine generator sets operated in dual-fuel mode, using producer gas as the primary fuel, plus pilot diesel fuel for ignition purposes (see the section in the main text of the chapter on small-scale biopower using producer gas). Because this technology is more capital-intensive than conventional diesel technology (table A10.1), a high level of capital utilisation (high capacity factor) is often required to reach economically attractive generation costs. Local electricity demand in poor rural areas is often inadequate to make the required high capacity factors feasible. If electricity could be sold into the electric grid, high capacity factors could often be realised.

A microturbine providing 75 kilowatts of electricity, a second-generation small-scale biopower technology (see the section on small-scale biopower using producer gas), was selected for the detailed design of a village trigeneration system. The microturbine is a technology for which the potential generating cost using low-cost residues is low enough (see table A10.1) to make the technology quite attractive for selling electricity into the grid. The energy balance for the village trigeneration system based on the use of this micro-turbine is shown in figure A10.1.

The estimated initial investment (base case) for the system is $1,800 a household, a third of which is for gas and for infrastructure to pipe hot water. It is assumed that the infrastructure investment is covered by a loan from the government at 6 percent interest, and that the rest of the investment is covered by equity capital provided

TABLE A10.1 COSTS OF ELECTRICITY WITH ALTERNATIVE ENGINE-GENERATORS FUELLED WITH DIESEL OIL AND/OR PRODUCER GAS DERIVED FROM CROP RESIDUES

System type[a]	Diesel engine		Spark-ignition engine	Microturbine
	Diesel only	Dual-fuel[b]		
Engine-generator set				
Equipment lifetime (years)[c]	6	6	6	10
Rated power output (kilowatts)	80	100	160	80
De-rated power output (kilowatts)[d]	80	80	80	80
Thermal efficiency, lower heating value (percent)[e]	34	27	21	28
Installed equipment cost (dollars per rated kilowatt)[f]	181	181	362	350
Installed equipment cost (dollars per de-rated kilowatt)	181	226	724	350
Present value of lifecycle capital investment for the engine-generator set (dollars per de-rated kilowatt)[g]	330	413	1,320	463
Total system (including building plus gasifier plus gas clean-up)[h]				
Initial cost (dollars per de-rated kilowatt)[i]	243	680	1,280	850
Present value of lifecycle capital investment for the total system (dollars per de-rated kilowatt)[j]	392	960	1,970	1,070
Operating costs				
Diesel fuel (dollars per hour, at full power output)[k]	5.48	1.65	0	0
Crop residues (dollars per hour, at full power output)[l]	0	0.39	0.66	0.50
Lubricating oil (dollars per hour, at full power output)[m]	0.21	0.42	0.42	0
Labour (dollars per hour during operation, at full power output)[n]	0.12	0.23	0.23	0.23
System maintenance (dollars per year)[o]	1,500	2,800	2,800	3,300
Levelised life-cycle electricity generation cost (cents per kilowatt-hour)				
Total capital cost	0.92	2.26	4.63	2.51
Diesel fuel	6.85	2.06	0	0
Biomass	0	0.49	0.83	0.62
Lubricating oil	0.26	0.53	0.53	0
Maintenance	0.34	0.62	0.62	0.73
Labour	0.16	0.33	0.33	0.33
Total (cents per kilowatt-hour)	**8.5**	**6.3**	**6.9**	**4.2**

a. All costs are in 1998 U.S. dollars. All systems are designed for an electrical output capacity of 80 kilowatts of electricity, and operation at 65 percent average capacity factor, so that annual electricity generation is 456,000 kilowatt-hours. Costs are calculated for a 12 percent real discount rate and a system lifetime of 20 years, so that the capital recovery factor is 0.134. b. Dual fuel refers to operation on producer gas plus pilot oil. It is assumed that producer gas displaces 70 percent of the diesel fuel required for standard operation on diesel fuel only. c. It is assumed that reciprocating internal combustion engines have 6-year (34,000-hour) lifetimes. The 10-year (57,000-hour) lifetime for the microturbine is an estimate by Honeywell. d. Relative to operation on diesel fuel, a diesel engine operated on producer gas plus pilot oil is typically de-rated 20 percent. For spark-ignited engines operated on producer gas, a 50 percent de-rating relative to operation on gasoline is typical. There is no de-rating penalty for microturbines operated on producer gas (Henderick, 2000). e. The assumed efficiencies (producer gas to electricity) for internal combustion engines converted to run on producer gas (21 percent for spark-ignition engines and 27 percent for diesel engines) are representative (Reed and Das, 1988). For the microturbine, 28 percent is representative of Honeywell's 75-kilowatt model (their target is 30 percent). The overall conversion efficiency (crop residue to electricity) is obtained by multiplying these efficiencies by the 70 percent gasifier efficiency. f. The diesel engine capital cost is from Mukunda and others (1993). The spark-ignition engine is assumed to be an industrial gas engine, for which the capital cost is typically twice that of a diesel (McKeon, 1998). Honeywell product literature (1998) estimates year 2003 installed equipment cost at $350–450 a kilowatt for its 75-kilowatt microturbine. g. Present value of the life-cycle capital investment includes the installed equipment cost plus future replacements during the 20-year life cycle, less equipment salvage value at 20 years. h. On the basis of Mukunda and others (1993), capital costs for gasification and gas clean-up are assumed to be $1,160 for the gasifier, $8,700 for the cooling and cleaning system, $11,600 for a control system, and $5,800 for a building ($1,740 if diesel only). For the microturbine, an additional fine filtration cleaning unit costing $20 a kilowatt is assumed. i. The total initial cost includes a 20 percent increment over the installed equipment cost to allow for engineering and contingencies. j. During the 20-year life cycle, the gasifier is replaced three times (6-year life), and the clean-up and control systems are replaced once (10-year life), while the building requires no replacement (Mukunda and others, 1993). k. The cost of diesel fuel is assumed to be $0.25 a litre. l. For rural Jilin Province, China, the cost of gathering corn stalks from the field and delivering them to the trigeneration facility modelled in Henderick and Williams (2000) is estimated to be 45 yuan a tonne ($0.33 a gigajoule), on the basis of data for the province provided by Cao and others (1998). m. On the basis of Mukunda and others (1993), lubricating oil requirements are assumed to be 1.36 grams a kilowatt-hour for dual-fuel engines; for spark-ignition engines the same value is assumed, and half this rate is assumed for conventional diesel engines; microturbines require no lubricating oil. Also on the basis of Mukunda and others (1993), the lubricating oil cost is assumed to be $3.50 a litre ($3.87 a kilogram). n. On the basis of Mukunda and others (1993) for rural India, during the 65 percent of the time the engine is assumed to be operating at full output, labour costs are $0.23 an hour (4 rupees an hour) for two workers for dual-fuel systems—assumed to be the same for spark-ignition engines and microturbines. Labour costs at half this rate are assumed for conventional diesel engines. In addition, it is assumed that these labour cost rates are applicable for 14 hours a week during downtime, for maintenance, preparation, and so on. o. On the basis of Mukunda and others (1993), annual maintenance costs are estimated as fixed percentages of installed building and equipment costs (not including engineering and contingencies) for the diesel, dual-fuel, and microturbine cases. The assumed percentage for diesel and dual-fuel engines is 10 percent; that for microturbines is assumed to be 8 percent. The assumed percentage for the building, gasifier, and gas clean-up is 5 percent; for the control system, 2 percent. It is assumed that the maintenance costs for the spark-ignited engine case are the same as for the dual-fuel engine case.

Source: Based on Henderick and Williams, 2000.

either by an independent power producer or by a villager-owned corporation. (Village corporation financing is plausible because the required capital is equivalent to less than three years of the average savings rate—38 percent of income in 1998—for Jilin's rural population.) For the village corporation option, the average net cash flow to villagers (income from crop residue sales plus revenues to the corporation minus expenses of the corporation) is adequate to cover all expenditures on energy by the villagers for the 20-year life of the system.[12]

The low-interest government loan for piping infrastructure might be justified as a cost-effective measure for avoiding the health costs of indoor air pollution associated with burning solid fuels for cooking and heating. For the hypothetical village, the annual health damage costs avoided would be $4,800 (assuming the average per capita value for all rural China; World Bank, 1997), more than three times the cost savings to the villagers, as a result of having debt instead of equity financing for piping.

Poor households that own no crop residues might earn income to cover energy expenditures by being paid by rich farmers to remove crop residues from their fields (for example, to enable them to comply with the ban on field burning of residues); residue recovery from the farmland of less than five average households would enable a poor household to earn enough income to cover all energy expenditures.

Case 3. Coproduction at industrial-scale of synthetic liquid petroleum gas and electricity from crop residues

The trigeneration technology described above could be improved if the cooking fuel provided were safe as well as clean (for example, producer gas contains carbon monoxide, so the risk of leaks poses a danger). This might be realised through the coproduction, at industrial scales, of electricity and synthetic liquid petroleum gas (SLPG) or dimethyl ether (DME)—synthetic fuels well suited for cooking, the use of which would involve no risk of carbon monoxide poisoning.

A preliminary design of a plant that would convert grain crop residues into SLPG and electricity using a once-through Fischer-Tropsch liquids plant coupled to a biomass integrated gasifier combined cycle (IGCC) plant has been carried out (Larson and Jin, 1999) at plant scales appropriate for Jilin Province, the corn belt of China, which produced 15 million tonnes of corn in 1995 (13 percent of the country's total). The technology would build on advances that are being made for liquid-phase syngas reactors that are being developed for the coproduction of synthetic liquid fuels and electricity from fossil fuel feedstocks (chapter 8).

The design involves 10-megawatt-electric biomass IGCC plants producing SLPG as a coproduct (250 barrels of crude oil equivalent a day). For the corn crop residue densities characteristic of Jilin, residues would have to be gathered from cornfields within a 11-kilometre radius to meet feedstock needs at the plant. Such plants could convert 15 percent of the biomass feedstock to electricity and 28 percent to LPG. Preliminary estimates are that the SLPG produced this way in rural Jilin might be competitive with conventional LPG, once biomass IGCC technology is established in the market (Larson and Jin, 1999). As discussed in chapter 7, biomass IGCC technology has advanced to the point where it is now being demonstrated in various parts of the world, building on the experience that has already brought coal IGCC technology to commercial readiness (chapter 8).[13]

If the technology could be used with all the 376 million tonnes of crop residues per year potentially available for energy purposes in China, it could provide 1.4 exajoules a year of SLPG along with 210 terawatt-hours a year of electricity. This much LPG could meet—in the form of a super-clean fuel—the cooking needs of 560 million people (about 70 percent of the rural population projected for 2010), while generating electricity at a rate equivalent to the output of 2.5 Three Gorges power plants (the Three Gorges plant's output is 18 gigawatts of electricity). And whereas the electricity from the Three Gorges plant would have to be transmitted long distances to most customers, this residue-generated electricity would be

FIGURE A10.1. ENERGY BALANCE FOR A TRIGENERATION SYSTEM BASED ON THE USE OF PRODUCER GAS DERIVED FROM CROP RESIDUES IN A HYPOTHETICAL 100-HOUSEHOLD VILLAGE, JILIN PROVINCE, CHINA

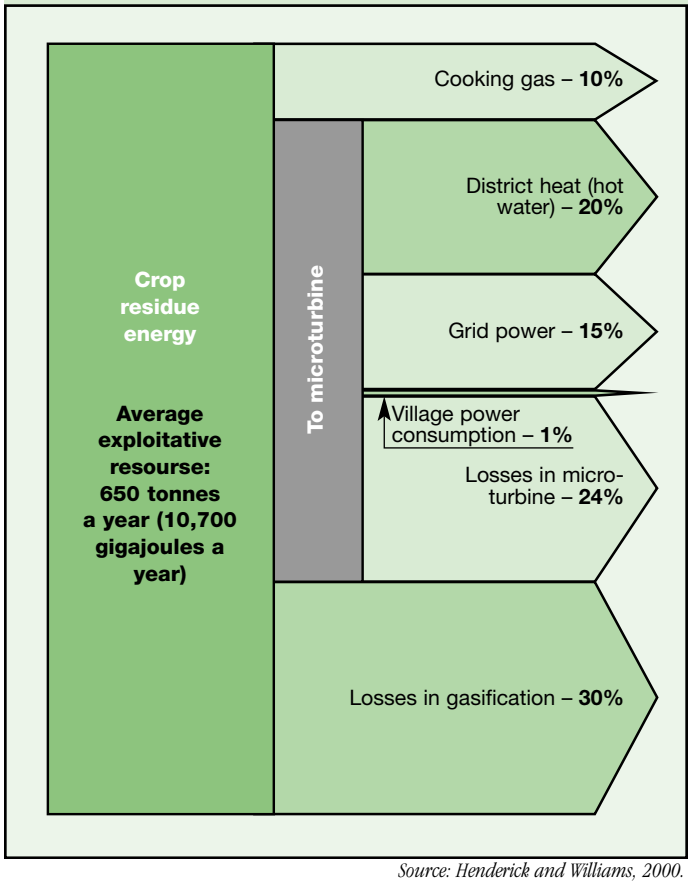

Source: Henderick and Williams, 2000.

produced in 3,400 power plants (each with output of 10 megawatts of electricity), which would typically be located close to the consumers they serve.

As in the case of the village-scale trigeneration system described above, with this technology the very poorest households could pay enough for electricity and clean cooking fuel to satisfy their basic needs by gathering residues from the fields of rich farmers and delivering the residues to the energy conversion plants, thereby monetising their labour.

DME, which is expected to be easier to manufacture as a synthetic fuel than SLPG, would have similar properties as a cooking fuel. Although the technology for making DME is not as far advanced as that for SLPG, either option could probably be commercially ready by 2010–15 with a concerted development effort. The Institute of Coal Chemistry at the Chinese Academy of Sciences is investigating prospects for making DME from coal for cooking fuel applications (Niu, 2000). ■

Notes

1. The amount of time varies widely depending on the availability of biomass. Surveys have shown that in some regions, women spend close to an hour a day collecting firewood, and could spend more than two hours a day in areas where fuels are scarce (World Bank, 1996).

2. As discussed in the next section, many of the technologies associated with the intermediate rungs on the ladder pose greater development challenges than technologies associated with the top rungs.

3. For a family of five, 0.08 kilowatts per capita consumption for cooking is equivalent to 21 kilograms of LPG per month. Assuming that 30 percent of the 0.02 kilowatts per capita of electricity is consumed to support community activities, the remaining electricity would be adequate to support six compact fluorescent light bulbs used for four hours a day in addition to a television for two hours a day plus a refrigerator-freezer with the average energy efficiency projected for new U.S. units in 2001.

4. For example, in China the energy content of crop residues is twice that of animal excrement on large and medium-size farms, and the fraction of crop residues recoverable for energy purposes (about half the total generation rate) is equivalent in terms of contained energy to about 20 percent of China's coal consumption rate (Li and others, 1998; Su and others, 1998).

5. Gasifiers are about 70 percent efficient in converting biomass energy into gas energy, and producer gas stoves are about 50 percent efficient. Thus the overall efficiency of converting biomass into heat energy used in cooking is about 35 percent, which is double or more the efficiency of typical biomass stoves.

6. In China the number without access to electricity in 1996 was only 110 million, less than 13 percent of China's rural population (Dai, Liu, and Lu, 1998).

7. Lubricating oil can contribute as much to the generation cost as natural gas fuel contributes to the generation costs of a modern large combined-cycle power plant—compare tables 10.3 and 8.4.

8. If spark-ignited instead of compression-ignited engines were used for power generation, the need for diesel fuel could be eliminated entirely. But such engines are less efficient and more capital intensive than diesel engines, and they must be de-rated more (about 50 percent relative to operation on gasoline) than compression-ignition engines. As a result or are often not competitive (Henderick and Williams, 2000).

9. This is about half the total residue generation rate. The rest is used for paper-making, forage, or returned to the fields to sustain soil quality (Li, Bai, and Overend, 1998).

10. This case is based on Dai and Lu (1998), Dai and Sun (1998), and Dai, Liu, and Lu (1998).

11. The market price for LPG in the village is 3.3 yuan per kilogram ($8.30 per gigajoule).

12. It is assumed that villagers are paid $0.33 a gigajoule for residues delivered to the conversion facility. It is also assumed that gas is sold for $6 a gigajoule (somewhat less than the LPG price) and hot water is sold for $5 a gigajoule (lower than the gas price to discourage gas burning for heat), and that electricity is sold to villagers for $0.10 a kilowatt-hour (the price they would otherwise pay for grid electricity) and to the grid for $0.05 a kilowatt-hour.

13. Demonstration projects include a Global Environment Facility–sponsored, 30-megawatt-electric IGCC project in northeast Brazil (chapter 7).

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Rural mimeo newspapers

A guide to the production
of low-cost community papers
in developing countries

by Robert de T. Lawrence

Unesco

PREFACE

In developed countries, the small town newspaper has been a powerful influence in the progress of rural communities. It is the focus of local activities, a leader in community affairs and a market place for those who want to buy and sell.

The rôle of the press in the emerging countries can be just as significant, but the problem has been that economic factors have restricted publishing to a comparatively few large urban centres. The overwhelming majority of people in these countries, however, live in rural areas, and for the most part, they never see a newspaper.

The development of broadcasting, jumping as it does the barriers of isolation and illiteracy, has recently brought to many communities news contact with the rest of the nation and with the world at large. But even this is not a substitute for a home town newspaper - local and personal and permanent, and dealing with affairs and people the reader is familiar with.

In the emerging countries, a local paper has all these characteristics, and another important one as well - it is a tool of education. One of the great problems in spreading literacy, is the provision of follow-up reading material. The new literate will soon lose his hard-won skill unless he can practise it. The local newspaper provides opportunity and motivation for reading, and will in due course reinforce the lessons of the classroom and establish the reading habit. In addition, it brings development information, as well as news, which helps improve agriculture, health, living conditions and civic consciousness.

Any system, therefore, which promotes the early establishment and growth of rural newspapers, makes an important contribution to the speed of national development. For this reason the project in Liberia described in this booklet, has attracted wide attention. The fact that thirty mimeo papers grew up within a year - a number of them spontaneously - is an indication of the need and a measure of the success of the method.

In this booklet, we describe in some detail the successful Liberian experiment, and suggest ways in which other countries may organize a similar project through their Information Ministry or other development agency. The third part of the booklet, is a simple "how-to-do-it" guide for the editor/publisher of a mimeo newspaper. It is, in fact, an elementary manual for the journalist who has had no professional experience, and is in a form suitable for reprinting and wide distribution to the staffs of the rural papers.

The mimeo newspaper is, admittedly, a rudimentary form of publishing, technically limited by the capacity of the equipment used. It is none the less significant for all that, and in passing, it should be noted that with skill and care, a professional looking paper can be produced. The important thing, however, is that this method of production enables a means of expression and establishes a small business enterprise, years before it would be economically possible with conventional printing plant. On the basis of the Liberian experience, it is estimated that a paper could be established with an initial outlay of as little as $100, and that it could provide a living for its owner/editor from the outset. This is a beginning from which a publisher and a community might aspire to progress until the time when a printed broadsheet can be produced by a professional staff on a modern printing plant.

This booklet has been prepared for Unesco by Mr. Robert de T. Lawrence, a newspaperman of long experience, who, as a staff member of the U.S. Agency for International Development, was adviser to the Liberian Information Service in 1963. Opinions expressed are naturally those of the author and do not necessarily reflect the views of Unesco. Appreciation is expressed to the Honourable E. Reginald Townsend, Director-General of the Liberian Information Service for information about the project, to which he contributed so significantly. The author wishes to acknowledge also the technical assistance of the following companies: Heyer Inc., Chicago, Ill., Gestetner Corp., Washington, D.C., A.B. Dick Co., Chicago, Ill., Roneo and Modern Duplicator Co., Washington, D.C.

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FOREWORD

The drum beats cease, the banners are taken down, the orator departs, the crowd disperses - and the newly literate man who, with his fellows, has been the centre of attention returns with his proud family to his hut in the village. The months of training are over. The textbook has become a cherished possession, though grimy from heavy and laborious use. Curvy or angular figures have become recognized letters or pictographs and then in turn they have been put together to assert, to question, to plead, or to deny. The hand which was used to labour has learned to trace a name or to record a thought. A man has been changed and, however minutely, so has the whole human community. One of its half billion adult illiterates has found a place at least on the outskirts of a complex culture.

But a skill is lost if it is not practised, and in all the tomorrows after Literacy Day where is that practice to be found? The jungle, the savannah and the tenement have little or no print. For the villager where are the road-signs and guideposts, the printed packages and sheets of directions, the pamphlets and bulletins, the posters and billboards, the newspapers, magazines, or books which constantly reinforce the reading skill of the man who lives in a literate society? Why write a letter if all one's acquaintances are right there in the village? Where are the rewards for reading and writing to be found in a simple agriculture, a tradition-bound family life, under a government based either on oral edict or the deliberations of a village council? Slowly, the painfully-learned skills of reading and writing erode away - to the eventual cost of the individual as he competes in a complex world and of his government which needs his support and understanding.

It has taken centuries to build the literate societies of the world. The non-literate societies cannot achieve a similar status overnight, however much they may wish to do so, for fully functional literacy is harder to accomplish than is often thought by those who have long possessed it. The centuries can perhaps be reduced to decades, however, if the fortunate nations can find useful and economical ways to help those which are less fortunate. One necessity is the perfection of better techniques of literacy training, but there are many other frontiers as well. The improvement of reading and writing must be approached at successively higher levels to reinforce and add to basic skills, until finally the individual is fully equipped to achieve a good life for himself and his family, and the nation is knit together by that sense of the larger community which only print can finally assure.

This present account by Mr. Lawrence reports an imaginative and determined effort to provide simple rural newspapers for the people of Liberia. This modestly-conceived and low-cost venture had a surprisingly warm response and thereby established a pattern of activity which might be repeated elsewhere with a similar success. The press has played a central rôle in the building of all modern complex cultures and its importance will be equally great in those nations which are trying to achieve the maturity which can only result from a universal and functional literacy. A newspaper offers a means of information, entertainment, and the discussion of policy; it advances the economy; it enlarges the horizon of its readers; it spreads the ideas of government leaders and takes the voice of the people back to them; and, less obviously but no less vitally, it helps weave the essential fabric of knowledge, trust, understanding, and aspiration which is at the heart of nationhood.

Cyril O. Houls
Professor of Education
The University of Chicago

PART I

RURAL MIMEO NEWSPAPERS

The case history of a project in Liberia

When the first issue of the Gbarnga Gbele News was published on 29 April 1963 it marked the beginning of a rural newspaper revolution in the interior of Liberia. Before the end of the year there were 30 of these two-columned, brightly titled, neatly mimeographed newspapers covering the entire country, where none had existed before.

In this comparatively short time a major step forward was made in low cost community newspaper publishing with these and other resulting benefits: (1) the literacy programme was stimulated thanks to a steady flow of interesting, easy-to-read, locally produced reading materials; (2) news from every corner of the country came to the newspapers and radio stations of the capital for nationwide redissemination; and (3) printed news became available to most Liberians living in the interior.

The new Liberian newspapers represent the first steps in newspaper production and some of them hold good promise of developing into more sophisticated publications in the foreseeable future. It will be decades before most areas of the interior can afford conventional printing equipment. Meantime the present system will give many years of practical, on-the-job, small town newspaper publishing experience to scores of people, which would not have been possible otherwise.

The project was undertaken because the people of interior towns were anxious to have their own locally produced newspapers, and government agencies such as education, health and agriculture ministries wanted a means of communicating with the local population. Since the level of literacy was about 10 to 12%, there were sufficient literates to read the newspapers and to read to others, thus encouraging literacy training.

The mimeograph method of printing was considered the only practicable one, being simple in operation and requiring no expensive equipment. Professional journalists in industrialized nations might hesitate to call any news publication printed by mimeograph a newspaper. Nevertheless, the perfect mimeo newspaper with three columns per page, justified typing, colourful title heading, using line sketches, "boxes", advertising and good make-up can rival in appearance some examples of more expensive types of printing. Two and even three colours can be used with a little practice. The dictionary describes a newspaper as "a paper printed and distributed at stated intervals, usually daily or weekly, to convey news". Printing is defined as "a mark made by pressure; a line, figure, etc., impressed; an imprint". A mimeographed newspaper would seem then to qualify fully for the "newspaper" definition. How the newspaper is printed, so long as it is clearly legible, makes little difference to people who have none at all.

PLANNING THE PROJECT

Under the leadership of Director-General E. Reginald Townsend the Liberian Information Service (LIS) sponsored the rural newspaper project. About 90% of the nation's population of 1,250,000 lived in the interior, where there were some 28 tribal groups speaking 16 different languages. This presented a problem, but at the same time an opportunity to help overcome it by publishing newspapers in the national language, English.

The original plan called for the establishment of five newspapers published five days each week. There was no supply of trained journalists, but it was hoped that editor/typists with high school education could be found. The bulk of the news was to be gathered from a 30-minute radio newscast each morning at dictation speed. Local news would be gathered the day before - one or two stories, or more, and typed on to the first page of the stencil. The editor would then type the news from the radio directly on to the stencil as received over the air. Stories were to be short with brief headlines, short sentences and paragraphs using only easy words. Page one was to carry an attractive title heading, pre-mimeographed.

Editor/typists with a good command of spoken and written English, would be brought to the capital Monrovia for a training period of two to six weeks. This was to include lessons in writing simple news stories, practice in typing, and learning to run a mimeograph machine. They were also to be given instruction in gathering advertising, newspaper distribution and the care and handling of supplies.

Each newspaper was to be provided with basic printing supplies: a standard typewriter, a crank mimeograph machine, a flashlight-powered short-wave radio receiver, and a stapling machine. It was estimated that the five papers would need in one year, on the basis of four pages per issue, five days a week, and 100 copies per issue: 5,500 stencils and 1,100 reams of paper. It was hoped that a small, battery-powered tape recorder could, in time, be supplied to each newspaper.

PUTTING THE PLAN INTO OPERATION

When the cost of equipment was considered along with problems of starting special radio newscasts, hiring and paying personnel, training, and the time needed to accomplish all this - it was decided to make a more modest and simple start. At Gbarnga, a centrally located town of about 10,000 population, 125 miles in the hinterland, there was a district headquarters and a small LIS information centre. Two men, neither of whom had had any training in journalism, ran the centre, which consisted of a small library reading room, a display board and mimeographing facilities. Fifty miles away at Zorzor was the newly established Rural Teacher Training Institute where teacher trainees from all parts of the country were prepared for their profession, and rural school teachers were given refresher courses. These two locations where educated people were on duty and mimeograph equipment was available were selected for the establishment of the first two newspapers.

The LIS graphics section in Monrovia prepared the art work for the title headings, one reading Gbarnga Gbele News and the other Zorzor Institute News, in lettering about 2 1/2 inches in height and running within a half inch of the border of letter size paper. Some ornamentation and simple sketch work suitable to the region was included, and 5,000 copies of each were printed by offset press in black at the top of letter-size white paper. These provided the title heading sheets for page one.

At Gbarnga on the appointed day the information centre men assisted in gathering news for the first issue. A number of sources were visited, including the District Commissioner's health, agriculture and education offices and short news items were prepared in the form of single column stories of two to three paragraphs. The people interviewed were enthusiastic about the prospects of the news of their offices and operations being printed in their own local newspaper and were encouraged to submit news voluntarily and regularly to the information centre. The regular radio newscasts had been monitored early that morning for national and international news and a few items jotted down to fill out the last page of the 2-page first issue of the Gbarnga Gbele News. However, few of these were used for in a few hours more local news had been gathered than was needed. As the project developed, indeed, less and less radio news was included because local news was comparatively plentiful and the reader demand for it was strong.

Distribution raised a problem owing to the scarcity of transport in the district, but copies were circulated free of charge to government offices, schools, clinics, churches, stores, to various officials and to nearby towns. The first press run was of 300 copies which were distributed by every possible means. Circulation will probably remain a problem for some time to come but it will improve as transport in the interior increases.

The enthusiastic reception of the first newspaper in the area was a considerable encouragement to go forward with the project. The District officials were pleased to have this new means of communicating with the people in the area. The health and sanitation authorities were glad to have a way of getting across their medical messages regularly to a large segment of the population. Education advisers and teachers welcomed this type of locally produced material which would promote literacy training. Agriculturalists, religious leaders, women's groups and others began contributing news and feature stories and spot news provided interest to all readers.

At Zorzor, the Rural Teacher Training Institute was given assistance in forming a staff, gathering and writing news, and printing the first issue of the Zorzor Institute News. Here, among the large number of advanced students and teachers in training, considerable talent was available for collecting, writing and processing the news for a weekly publication of the college type, with professors and instructors on hand to supervise and offer help. News coverage extended to the nearby town of Zorzor but was mainly confined to Institute affairs. Later, when the Zorzor Weekly Kelai, sponsored by a religious literacy training group, began publication giving full coverage of the town news, the Institute newspaper concentrated almost entirely on school news, printed on its own machine.

Both the Gbarnga and Zorzor newspaper editors were asked to exchange copies of each issue regularly so as to be able to reprint, from each other news articles of interest to both districts. Readers in the two areas could thus share knowledge of community development projects and many other useful items of benefit to both. In a small way, this helped bridge the gaps between tribal groups and customs.

Both new newspapers were asked to send ten copies of each issue to LIS: (1) to be placed on public view in the Information Service, (2) to be permanently filed in the Library, (3) given to the radio stations where news items of general interest were broadcast, and (4) to the Monrovia daily newspaper which picked up similar items and reprinted them.

DEVELOPING A RURAL NEWSPAPER SYSTEM

Valuable experience was gained through starting the first two newspapers and it was decided to try to increase the number and provide a basis of support by LIS to help the new publications survive during their early life and prosper through gradual improvement. From a target goal of five originally set for 1963, six times that number began publication.

To encourage the establishment of more newspapers which would serve other large communities and offer a greater geographical spread the following action was taken:

(a) A press release was issued by LIS to the two

Monrovia newspapers and two radio stations describing the project and explaining how simple and inexpensive it would be for other organizations or groups in the interior to start their own papers. The release outlined the support that LIS could give in the way of technical assistance, printing of page one title headings, etc.

(b) The Director-General of LIS was interviewed on radio station ELBC where he described the contribution that rural newspapers could make to economic, social and political advancement throughout the interior where the great majority of the population lived.

(c) Field trips were made to mining companies, rubber plantations and to the Booker Washington Institute. Letters were written to others who had at one time shown an interest in newspaper work and where mimeographing facilities were known to exist. In some cases, the title heading art work was drawn in advance and dummy news typed on the first page to show a prospective publisher what his newspaper would look like.

(d) On two occasions, LIS representatives gave talks to large groups of American Peace Corps volunteers who were about to assume posts in the interior as school-teachers. Aware of the contribution made by rural newspapers to educational and social development in their own country, a number of the newly arrived teachers later supported mimeo newspapers in the communities where they taught.

Within a few weeks, three new newspapers began publication - the Bomi Hills News, Zorzor Weekly Kelai, and the B.W.I. News.

As these additional newspapers came into existence the rôle of LIS in assisting them to grow and take up more effectively their important responsibilities to their communities became clear. Among the steps taken in this direction were:

(a) Assignment of a full-time editorial assistant to the project with duties ranging from news writing to handling supplies.

(b) Preparation of an 11-page mimeographed set of instructions bearing the title, "How to Publish a Mimeographed Newspaper; Helpful Facts on Writing, Editing, Printing and Distributing a Rural Newspaper". It contained sections on what a newspaper can accomplish, planning the staff, equipment/supplies, gathering the news, writing the news story, editing, general publishing information, and advertising/business operations. Several copies were sent to each editor.

(c) An effort was made to cut to the minimum (sometimes through government purchasing channels) costs for printing equipment, paper, stencil and ink supplies.

(d) Two films were secured for loan to the newspaper staffs. One described the small town weekly newspaper editor in an industrialized country and his rôle in community affairs. The other showed the motivation and progress that a newspaper of that type can stimulate.

(e) More attention was given to tailoring the slowly spoken, early morning newscast to the needs of the newspapers. The editors seldom made use of this added service, but it is still believed that enterprising newspapers could expand their news coverage considerably this way. More national and international news, briefly presented for easy understanding, can broaden the knowledge and outlook of people living in the hinterland and make them think in terms of national rather than restricted tribal and regional goals.

(f) LIS press releases providing a good source of continuing news were sent to each editor. These were mailed on a selected basis, keeping in mind that it might take ten days or two weeks for them to reach their destination.

(g) Complete files were kept on each newspaper and careful attention was given to direct correspondence. Each issue, especially at the beginning, was read closely at LIS. If ways of improving the quality of the publication within the capabilities of the editor could be seen he was informed by letter. This tended to develop a warm and friendly relationship.

(h) A popular innovation was the offer to editors of a choice of colours for their title headings. The reds, greens, yellows and blues, in different shades presented a striking appearance when viewed en masse on the public information board in the reception hall of the new LIS building.

EXPANSION OF THE SYSTEM

A quarterly report covering July, August and September 1963 noted a "sharp increase in the number of new rural newspapers...". It was announced that ten more had begun publication during that period, including the Bopolu-Weasua Kpelletun, Ganta News, Tappita Times, Tchien Post, Bolahun News, Salayea Post, Sinoe News, and others.

Excerpts of general news taken from the rural newspapers and sent to the capital city news media were welcomed and printed under the heading of "Around Liberia in Brief". For the first time a steady flow of news was received from the difficult-to-reach interior areas and the large percentage of the population of Monrovia which had originally come from rural towns were pleased to read and hear the news of their former communities.

According to the manager of radio station ELBC his office at one point was "deluged" with letters from listeners asking for more of the rural news contained in the small newspapers. The station manager of ELWA, which also has powerful transmitters covering Central West Africa, wrote, "We at ELWA are vitally interested in these new mimeographed regional news sheets encouraged by LIS all over Liberia... We would like to receive any and all of these direct. We have in mind our coverage of local news in English as well as the broadcasts in seven major dialects..." The newspapers thus served another purpose by making the news available by radio to those who could not read it in the first place.

Although it had not been a part of the original

planning of the project, it became apparent that a nationwide system of news coverage had developed. Heretofore, it had been almost impossible to obtain coverage of important events in the interior owing to transport and communication difficulties, and the problem of finding qualified correspondents to gather and transmit the facts accurately.

The rural newspaper system changed all this. Each newspaper constituted a point of contact for the whole nation and, indeed, became a news source for even the remotest areas. For example, over its world-wide news system the Reuter agency sent out a human interest story about the drowning of a huge elephant in the Cavalla River, deep in the interior on the eastern border adjoining the Ivory Coast. The story came from the Webbo World. In another instance, the Charnga Gbele News published news of the successful birth of quadruplets to a local couple in a special issue. This was one of the top news stories in Liberia for the year, which won the News considerable credit and prestige.

Realizing the potential of this formation of a nationwide news reporting system, LIS announced it to the news media. Newspapers and radio stations were advised that reporters were available in the principal towns and would be on call for special assignments. If, for example, an airplane should crash near Bolahun along the Sierra Leone border, the editor of the Bolahun News could cover the story. Short wave radio communications were within reach of all the newspapers via police posts, government offices, religious missions, etc., and could be utilized.

This development in turn opened up possibilities of a new source of income for the editors. Special correspondent services for the city media earned reasonable reimbursement. For a story of about 300 words, for example, a fee of about $5.00 could be charged - a nice supplement to the community newspaper budget and sufficient to pay the cost of two or three issues. The full potential of the countrywide correspondents system has yet to be realized, but there is every prospect that it will grow in value in many ways. Broader and more accurate coverage of Liberian news from all areas would increase the readership and listenership of Monrovia media and would likewise stimulate the growth and increase the usefulness of the rural newspapers.

SUPPORT FROM RURAL EDUCATORS

A prominent official in the field of education once remarked that in his opinion newspapers were the most important single educational medium of all. The fact that more than half of the rural newspapers are edited by school-teachers and officials also seems to indicate that they are helpful tools of education and top Department of Education officials have strongly supported their development.

Two of the new publications were established primarily for the contribution they would make to literacy training. These were the Ganta News, published by the Ganta Mission Literacy Department, and the Zorzor Weekly Kelai ("Kelai" is the Loma word for "message"). They are performing a valuable function in teaching people to read and write and the interest of their news content provides a strong incentive to learn to read. Those who can read take them home and read to others. The cost is only two or three cents per copy. In many of the large communities they serve, these newspapers are the only reading materials produced there. They thus help to solve one of the worst problems in any literacy programme - the lack of low cost, easy to read, locally produced reading matter.

Dr. D.J. Hays, a veteran education adviser who has been actively associated with community education programmes in many areas, has encouraged the development of the low cost newspapers. In the early days of his work the only village news organ was the "town crier" who called out the news of the village each evening. There was almost no news from outside the village, often reached only by a jungle trail. In a recent letter he stated, "I have been engaged in rural school development in the Liberian interior for nine-and-a-half years and consider the community newspapers the most important education implementing device that has been introduced". He also cited the rôle the newspapers were playing in the process of unification of the numerous tribes with their different languages. The "Unification Programme" has been given one of the top priorities by President William V.S. Tubman.

RURAL NEWSPAPERS AS MONEY EARNERS

For the success of the project, it was necessary that each of the newspapers be self-supporting. There were no funds available at LIS to buy the mimeographing equipment, paper and other supplies for them. Considering their value to community development and education, and their low cost, it would no doubt have been worth while to subsidize them. However, this was not possible, nor was it desirable, in the long run, so long as they were potentially self-supporting. LIS was able to print the coloured title headings and furnish technical assistance without charge, but that was the extent of its support.

One very important long-range objective was to ensure their financial prosperity through good business practices so that in due course they could buy their own mimeograph machines and typewriters. From this basis, they could perfect their printing and journalistic techniques and produce better newspapers. Eventually their increased income and more advanced publishing ability would allow the experienced staff to progress to offset printing. The mimeograph stage, however, was the all-important starting point.

It was found that the profit motive more strongly influenced some editors than others. Opportunities

varied, of course, some newspapers being more favourably located in large towns with sizeable business communities where advertising and direct contributions were easier to obtain. However, all newspapers were encouraged to build up their sales, advertising and other revenues no matter how small their size or low their cost, because a sound financial basis would permit more rapid improvement.

It was suggested that each publisher have a part-time business manager on his staff to collect advertising, handle distribution and do the bookkeeping. The manager would also keep a close watch on supplies of paper, ink, stencils, etc., and see that the orders were placed well in advance thus freeing the editor for his work of news gathering, writing, and printing.

Advertising was surprisingly easy to obtain, even in the smallest towns. The merchants, owners of businesses and other groups welcomed the advent of the community newspapers and the chance of making their products known to a wider public. The cost of advertising varied from 50 cents to one dollar for one insertion of two inch single column ad. Special rates were given for full page, half page, and long running ads. Advertisements were usually "boxed" to distinguish them from the news. Often it was a matter of prestige to advertise in the newspaper or a question of keeping up with competitors. Some newspapers are doing quite well with their advertising income, for instance the Cape Palmas News in which 17 ads at $1.00 each were counted in a recent issue whereas the cost of publishing probably amounted to $2.00 or less for paper and stencils. The editor of the Buchanan Star reported that he was making about $25.00 per weekly issue on ads and copy sales or a total of $1,300 yearly. He is buying his own new mimeograph machine. Sometimes help comes from unexpected sources, as the enterprising school-teacher editor of the Sanniquellie Sun discovered. He had struggled along with an old mimeographed machine found abandoned in a store room. The District Commissioner, learning about his problems and knowing the good work the Sun was performing, bought a new mimeograph machine for the school which was made available to the editor.

The community newspaper can be an active stimulant to the local economy and regular advertising increases store sales. Large special ads, sometimes on coloured paper, published on national holidays and anniversaries also promote sales. News story campaigns over a period of several issues can be used to boost the local economy. In this respect the Gbarnga Gbele News set a good example for other newspapers in the system. The News printed several articles about a forthcoming bazaar to be held by a local women's charity in order to raise funds for the construction of a medical clinic. The bazaar was a great success, with higher attendance and more money donated than had been expected for which the News received a large share of the credit. The job was done in the best tradition of public service journalism and was afterwards cited by LIS as a good example for other newspapers to follow.

ENTERTAINMENT ASPECTS ENCOURAGED

The average reader seeks entertainment as well as information in his newspaper. A good balance between the two in each issue adds a great deal to its popularity and increases sales and expands readership. For these reasons every opportunity was taken to encourage the entertainment aspects and the rural Liberian's love of story telling and his natural ability to do it well provided a store of feature material on which the editors drew heavily.

Each tribal group had its own body of folklore and legends dating back hundreds of years which had been handed down from story teller to story teller. Now this could be preserved in print. For the most part it consisted of colourful anecdotes involving animals, birds and reptiles which in addition to being highly entertaining, convey a moral about truth, honesty and other virtues.

A book of Liberian proverbs was also compiled and published by LIS for free distribution to each editor. This provided a ready supply of "fillers" simply written for easy reading, usually concerned with animals, objects or events known to the people. Not only were they entertaining, but they helped spread the rich and varied national culture.

FEATURE MATERIALS

LIS also helped editors to supplement their straight news content by distributing prepared feature materials. These were specially tailored for the needs of the community newspapers and were sometimes tied to anniversaries and special events. For "Flag Day" for instance, a full page article was produced, giving the history of this celebration.

A brief experiment was conducted using an electronic stencil reproducing machine. Identical stencils of a page of short background articles concerning events in other African countries were produced on the electronic scanner. These were sent to the newspapers, some of which used them, but it was decided that the cost of about $2.00 per stencil was prohibitive except in the case of highly important events. The scanner machine is expensive (about $1,800), although it has the advantage of reproducing illustrations, in particular line drawings.

NATIONAL JOURNALISM AWARDS

Owing to the rapid increase in the number of regional newspapers a sizeable corps of new editors and writers has been built up. Considering that they are making their first venture into the profession they are doing well, although they have had no former training. In order to emphasize to them

the importance of their positions, raise their journalistic standards, upgrade the quality of printing and underscore the importance of the business aspects of newspaper publishing, a plan was devised to present national rural newspaper awards.

Eight prizes were to be given annually to newspapers which excelled in:

(1) news coverage, (2) feature stories, (3) editorials, (4) printing quality, (5) largest number of issues, (6) largest advertising, (7) largest circulation, (8) general excellence.

A rural newspaper, for the purposes of the contest, was defined as one published ten miles or more from the capital city, and which produced at least five issues during the year, printed in the national language.

A committee composed predominantly of journalists would judge the contest after a study of the complete files held at LIS of each newspaper. No newspaper, or editor, could receive more than one prize, so as to ensure a wider distribution of honours.

Most of the awards were to be donated by business firms although some were to be provided by interested government agencies and affiliated bodies. Mimeograph machines, printing supplies and books on newspaper editing and printing were to be awarded to the winners, accompanied by a certificate of merit to be framed and hung on their office walls.

It was planned to run publicity before, during and after the prize giving so as to focus national attention on the importance of newspapers in the national development. It was hoped that the President would hand the prizes to the recipients, and during formal ceremonies he and other senior officials would make speeches emphasizing the need for a strong code of ethics among editors.

The plan for annual, national journalism awards is still under study and has not been implemented to date.

THE "RURAL NEWSPAPER NEWS" - ADVICE TO THE EDITORS

Early in the development of the newspaper system it became apparent that some means was needed of communicating with all the editors on subjects of mutual interest and concern. Analysis of individual newspapers as they came in to LIS revealed numerous minor shortcomings which could be corrected by a word of advice, and on the whole the problems and opportunities were the same everywhere. Therefore the LIS began publishing twice monthly the "Rural Newspaper News" consisting of several pages of mimeographed information of special interest to editors. It provided regular instruction in improving editorial and printing techniques and gave a pat on the back to editors who had used some publishing method particularly well, thus instructing others and drawing attention to the technique. It also provided a way of transmitting special notices and background data to editors. Newspapers were advised to keep a permanent file of these for constant study and reference. All in all, it consisted of a continuing course in journalism and printing.

CONCLUSIONS

As the result of this full-scale field experiment, Liberia possesses a nationwide self-supporting rural newspaper system. There is no reason why other developing and semi-industrialized nations cannot initiate similar programmes. It is stimulating to think what effect hundreds of these low-cost newspapers could have on community development in scores of other nations affecting tens of millions of rural people.

By printing the local and national news, these newspapers are both creating and expressing public opinion. They are educating the communities and providing a substantial boost to literacy training. They act as a means of unifying the people and express their ideals and spirit. They provide an outlet for suggestions for the betterment of rural life, thus stimulating worth-while activities. They promote understanding of other communities, and therefore encourage greater co-operation with their neighbouring towns. They motivate people to more and better work.

It is not necessary for the small entrepreneur in his remote inland town to wait and dream of the day when he might have the several thousand dollars needed to buy conventional printing equipment. The way is now open to break out of the vicious circle of low industrialization and low advertising support which in turn prevents the would-be publisher from buying newsprint and hiring more capable staff. This is not a problem with the Liberian newspapers.

Of course, caution must be exercised in transplanting experimental results across cultures. However, the desire of peoples of all levels of development to have news of their own region is uniformly strong. The communities themselves take pride in having their own newspapers for the first time, and undoubtedly they consider it a mark of prestige. The editor is respected and looked up to by the people in his region. His office provides a place of contact, a focal point, a meeting place from which community projects can be originated and encouraged. He possesses real and potential power for social, economic, and political advancement.

It has been said that no country has ever modernized without dealing with the basic task of communication. The establishment of low cost, self-supporting rural newspapers is one of the most natural, easiest, and fastest means of doing so.

It is entirely within the capabilities of any nation, using the resources on hand, to match or even exceed the accomplishment of Liberia, and do it in the course of one year. The speed with which this can be accomplished is dependent only on how soon the small amount of effort is expended to start the ball rolling.

PART II

ORGANIZING A RURAL NEWSPAPER PROGRAMME

Background and suggestions on how to plan, staff, publish and assist low-cost newspapers in rural communities of developing countries

We have seen in the previous pages the introduction of an idea and certain techniques, which resulted in the establishment of many small newspapers in Liberia. A strong desire for news, information, entertainment and communication with neighbouring areas exists among all peoples, especially those who live in the interior regions of developing countries where no newspapers are published. There may well be hundreds throughout the world who are searching for a way to publish the first small newspaper in their communities. This booklet is intended to show how it can be done.

There are a number of ways of planning establishment of a group of rural newspapers, and they may all work quite well. Although we are dealing with simple basic publishing, a great deal was learned during the Liberian experiment which can be helpful to us now. Part II of this booklet will be divided into two sections: A. how to organize and start the first newspapers, and B. how to encourage them during their early period and assist them to develop and mature.

A. PLANNING AND STARTING THE FIRST NEWSPAPERS

Staff

The newspaper system will probably be initiated and supported by some government agency. Since this is a journalistic enterprise, it is appropriate that the sponsoring agency should be the Ministry of Information, or its equivalent. However, the benefits of the programme lie so predominantly in the field of adult education and literacy training, it would not be illogical if it came under a Community Development Agency.

Whatever the sponsoring agency, it would be an advantage (although not entirely necessary) if it had access to graphics and printing facilities. Although preparation of art work and printing of newspaper title headings can be assigned to commercial houses, it is preferable that it be handled by the agency sponsoring the newspaper project. The same applies to radio broadcasting. In Liberia, one of the two radio stations was affiliated with the Information Service which made it convenient to arrange slowly-spoken newscasts.

In a small country it is suggested that two men be assigned full time to the programme. One should be an experienced newspaperman and the other a trainee or someone with communications media experience.

The chief of the project should possess a broad background of training in journalism. This should include actual experience in the editorial side - news, feature and editorial writing, as well as a knowledge of layout and illustrations - coupled with experience in the business field (advertising, circulation, and simple bookkeeping). Small town weekly newspaper experience is usually a better qualification than experience on a big city daily.

Since about one-third or one-fourth of the project chief's time will be spent travelling in the rural regions he should have access to transportation whenever required. He should be present at the "birth" of each newspaper and should visit each one about twice during the first year of publication.

Equipment and supplies

One of the strong points of mimeo newspapers is that only inexpensive, small, lightweight equipment is needed. It is assumed that the publisher will have a typewriter, stencils, paper, ink, stencil correction fluid, and a mimeograph machine. He may not own the latter, but will be able to borrow one from an education office, rural government post, religious mission, or other organization. This may be found in his own town, or he may have to go 25 or 50 miles on the day of printing to run off the issue.

On his visits, the chief should carry with him a typewriter (a heavy portable that can cut stencils will do), a few stencils, a can of ink, a bottle of correction fluid, one ream of paper, and a stapling machine with a supply of staples. A second typewriter is handy when story writing time arrives. It is also quite possible that one of the smaller supplies may be missing at the time of printing. By having extras, a long trip to the nearest supply centre, probably the capital city, may well be saved.

If possible, the chief may also wish to take with him a light-weight, low-cost mimeograph machine which is the ultimate in simplicity to operate.[1]

1/ One such machine of which the author has experience is the "Lettergraph", Model 24, made by Heyer Inc., 1850 S. Kostner Ave., Chicago, Ill., 60623, U.S.A., costs $34.50. A copy of the original rotary mimeograph developed by Roneo Ltd., London, in 1899; weighs about 15 lbs., hand fed, brush-on-ink, simple parts, can do three colour work. It uses the standard 8 1/2 inch by 11 inch stencil only.

This can be used in the event of a breakdown in the publisher's machine, and can be demonstrated to prospective publishers in other towns on the same trip. Larger, more expensive automatic mimeograph machines can perform better work, but they are more sensitive to severe climates and more complicated to maintain and repair. The smaller one referred to here will print clearly and should give years of good service. Spare parts are inexpensive and can be replaced by the owner with little trouble. Newspaper owners are advised to begin with a machine of this type and then progress to more sophisticated models.

In regard to low-cost equipment, sponsoring agencies can perform a service to rural editors by shopping around for the best buys in printing supplies and machines. These vary a good deal in price and quality. Therefore, it takes an experienced buyer to select the types needed, arrange for special discounts, and advise the rural editors on how they can obtain them. In Liberia, the newspapers were sometimes allowed to buy through the Information Service at government prices. This was often quite helpful to the publishers who operated on modest budgets.

Governments could also assist fledgling newspapers by establishing a revolving fund which would allow new publishers to buy basic equipment and repay the borrowed money in small amounts, monthly, as advertising and other revenues came in. Since a typewriter and a mimeograph machine suffice to establish a publisher in business, such a fund need not be large. For example, $1,500.00 would purchase about ten typewriters and ten low cost mimeograph machines enough to put ten newspapers in business, at a cost of $150.00 each. If each editor was required to repay his loan at the rate of $5.00 per month, this would give the Government $50.00 per month, and in three months time $150.00 would be collected, enough to set up another editor.

Sometimes, it may be practical for a government to fully subsidize one or more newspapers. This may be so if there is an information centre or a similar government project already in operation in the interior. The Gbarnga Gbele News is a case in point. The equipment was already on hand at the Information Service Centre at Gbarnga, and the two employees assumed the newspaper publishing work as an additional duty. The News was highly valued by the Centre, especially in view of the comparatively small amount of time and money needed to publish it weekly.

Sponsoring agencies may wish to investigate the possibilities of purchasing an electronic stencil duplicator for use, centrally, both by the agency and by the newspapers. This machine will prepare a stencil copy of drawings, headlines, type faces, and even photographs, although the latter are not altogether satisfactory. The stencil can then be run on a mimeograph in the desired number of copies. Electronic scanners cost about $1,800.00.

As more newspapers are started and develop their mimeo printing to a higher standard of quality, sponsors may wish to purchase some additional aids to demonstrate to them. Tracing pages by professional artists provide eye-catching illustrations that can be made by anyone. Signature plates and styli give letter perfect signatures with transparent lettering guides, large type headlines and display lettering can be added to stencils easily and quickly. Shading plates give interesting patterns to copy and much can be done to improve the appearance of mimeo printing with different coloured inks and papers.

Planning the first newspaper

It will probably not be difficult to decide where to start the first rural newspaper, because in all developing countries there are some heavily populated centres in need of one. In these towns there are often potential publishers who have at one time or another wished to start a newspaper if only it were economically and technically possible. The problem is how to find these people.

If there is a district government office - for information, community development, etc., - such as, for instance, the Information Centre in Liberia, the best choice is one of these, where basic facilities already exist. Failing this, and if no entrepreneurs can be found through inquiries at the capital city newspaper offices and other likely sources, it is suggested that a survey be made covering any known publications in the interior, and listing all large population centres. The large industries (mining, agriculture, etc.), educational institutes, provincial headquarters, religious centres and literacy training offices can then be approached by letter outlining the idea, explaining the support desired from the sponsor, and enclosing a dummy copy or sample of a small mimeo newspaper.

The "Selling" and public relations techniques will need to be used, especially in the first stages, to get the plan across to the potential publishers. After the first two or three newspapers have been started it will be considerably easier, because copies can be shown as examples for others to imitate and as a demonstration of how simple it is to publish this type of newspaper.

Other sources that should be tapped for the recruitment of entrepreneurs are the conventions, seminars, and other group meetings which are constantly being held in capital cities - possibly an assembly of provincial school principals, a meeting of district chiefs, or a business convention. Arrangements should be made through the proper channels to address these gatherings for thirty minutes or so. Illustrative materials clearly showing the plan and how it can bring social, economic and political benefits to the rural regions should accompany the addresses and will usually bring forth strong leads which can be followed to good advantage.

Publishing the first newspaper

When the publisher has been found and after preliminary conversations about his new enterprise,

a name must be chosen for the newspaper. He may already have made his choice, or he may ask the project chief to suggest one. Usually the title consists of two words, the first being the name of the town, and the second a word denoting news. The question of art work should then be settled. The publisher may want his own artist to design special lettering and ornamentation for the title heading for page one. More probably, however, he will ask the sponsor because art facilities are rare in the interior and this service is one which should if possible be offered free.

To help get the paper off to a good start the sponsor should arrange for offset printing of some 5,000 to 10,000 copies of the title heading at no cost to the publisher in a colour of the publisher's choice. The photo offset negative and original art work are then filed for use when another supply of headings is needed. The importance of free art work and free title heading printing by the sponsor cannot be too strongly emphasized for nothing brightens the newspaper or lends it a professional appearance more than a well-designed coloured title at the top of page one. The publisher, of course, can be expected to pay for the paper stock on which it is printed, about $1.50 per ream of 500 sheets. If an electronic stencil copier is available, it is possible to copy the art work on to a stencil and then mimeograph the title heading. This can be done in colour too, with a little extra trouble. For printing 5,000 or more copies the photo offset method is more practical, and if the sponsoring agency has this printing equipment, as was the case in Liberia, all the better. Otherwise, a commercial firm can be used.

The question of language for the paper is important, and should be discussed with education and community development officials. Generally, the newspaper should be printed in the predominant language of the community, but account must be taken of the language being used for local literacy teaching, and the language in which radio news and supporting material is produced by the sponsoring agency.

When the preliminaries are completed, and publication day arrives for Volume One, issue One - the project chief comes to the town prepared to assist in gathering, writing and printing the news. He may bring his assistant with him both to learn and to help with basic duties. It is strongly suggested that the first issue be restricted to two pages, or to a maximum of three. In this way a small, well-rounded issue (a little national along with local news, a social item, sports story, short editorial, and two or three ads) can be produced in one day. An issue of this size makes the entire operation less complex for the publisher (who is probably also the editor) and at the same time stresses variety of content and demonstrates how a profit can be made. The mimeograph printing operation can also be performed more speedily when there are not too many complications.

Early on the day of the first issue the chief may want to jot down one or two short news items of national interest from the radio broadcast. He might prepare in advance a two or three-paragraph editorial sample dealing with a subject such as cleanliness for health. For the top of page one a brief announcement should be drawn up along the following lines: "this is the first issue of the _____ News, a newspaper which will be devoted to the progress of the community, etc.", it will be published weekly; news items are welcomed from everyone; its staff is composed of the following people.....

The chief should assist the editor in gathering news items by making calls on town governing officials (be sure to mention them by name in stories connected with their duties), schools, clinics, police, religious groups and other news leads. Items from a wide variety of sources, including the sports world and society, are recommended in order to broaden the readership interest. Two or three stores or businesses should be approached to run advertisements at the rate of fifty cents to one dollar per ad per issue, for a one-column advertisement 1-1/2 inches deep. Ads are highly important, both as a source of income and because of the professional appearance they give a newspaper and the service they render to readers.

News gathering and writing of some of the stories should not take more than half of the first day. Articles should be only two to three paragraphs in length, each with its own one-line head. The second half of the day can be spent in completing the writing, cutting the stencils, and printing and stapling, say 300 copies. Several days in advance the adviser should check that all printing supplies are on hand and that the mimeograph machine is in good working order.

In laying out the newspaper, it is suggested that (after the announcement) the first news stories deal with local subjects, with the one or two national items, probably on page two. For the latter, "datelines" showing the name of the city and date should be included. Local items need no datelines. There should be two columns, and when more experience is gained by the staff they can go into a three-column format with "justified" typing (i.e., each line being uniform in width, with all letters lining up on the right hand, as well as the left hand side).

The editor may never have written a news story in his life, but if he has had a high school education or even eight or nine years of schooling, he should be able to learn very quickly to do the type of short news items his newspaper requires. He should be trained to cover the points who, when, where, why, and how in each story, and encouraged to feel that with the experience he will pick up in time his new enterprise will progress. It must be remembered that his readers are not accustomed to newspapers and will not be very critical. The two will mature together, each helping the other.

On page two, it is suggested that a short editorial be placed at the top of the right hand column. Its tone and content will establish an impression of

responsibility and public service. The advertisements should have a border on all four sides to distinguish them from the news copy. In the bottom left hand corner the "masthead" might be placed. This gives the names of the editor and members of his staff. It is a nice prestige device, appreciated by the staff members. Because of the small size of the newspaper, however, it is suggested that the masthead be run only about once a month. A social item dealing with women's affairs and mentioning several names should be included in each issue if possible. There will not be enough room in a two-page issue to include a feature story, but if it goes to three pages one could be used for light entertainment purposes. Features should not be long, one column or less. They are excellent for literacy training and should be written with this in mind. The entire content of the newspaper should consist of short words, short sentences, short paragraphs, making short articles.

An arbitrary number of 300 has been suggested for the first press run. This should, of course, be adjusted to the requirements of the population of the area and the distribution desired. It is wise to print the first issue in about double the number estimated as the normal requirement so as to publicize the birth of the newspaper. The first issue might be distributed free in order to reach a larger public. Future issues, depending on size and popularity, could be priced at the equivalent of one, two, or three cents per copy. At least fifty copies should be taken back to the capital city by the adviser to be sent to the city newspapers, radio stations, libraries and the appropriate government offices, and kept for filing. A good supply should be kept in reserve as examples which can be used to encourage future publishers in other towns to start newspapers. The editor will also need about 25 copies to take care of future requests. Distribution should be made to the leading local government officials, to all the news sources cited above, and to stores and businesses and a fair supply should be sent to the neighbouring towns and villages. A distribution list showing numbers of copies to be sent should be drawn up and will form the basis of a future subscription list. The adviser assists in preparing this and should keep a copy of the list.

Although the amount of money involved is very small at first, the publisher should be impressed in the beginning with the importance of keeping a record of income and expenditures. This need not be complicated, but the books should show date of transaction, description, and amount (debit or credit). Even if the newspaper is published by a rural office subsidized by a national government agency, it is still advisable to accept advertising and subscription money and to be self-supporting. The final objective in a case of this kind should be to turn the business over eventually to a local entrepreneur to be run as a private business enterprise.

Finally, the sponsor should leave a check list of reminders concerning the main steps to be taken in order to publish and distribute the first issue successfully. These points may seem elementary and obvious, but they are all essential for the printing of a well-rounded rural newspaper and certain details may be forgotten. The reminder should include mention of keeping a good level of printing supplies and placing orders at least a month in advance.

Summary

Basic as this type of newspaper publishing may seem to the experienced journalist, still it represents a very long and complicated effort for the beginner. Therefore, he should not be pushed to undertake too heavy a schedule or to produce large issues in the early stages. One should not be too critical of his mistakes, but rather quick to applaud his good points and successes. He should be patiently instructed by a variety of means which will be outlined in the following section.

B. HELPING THE NEWSPAPERS TO GROW AND PROSPER

Once three or four rural newspapers are already being published and perhaps several more are envisaged, the sponsoring agency should assist these newborn community enterprises, not only in order to stimulate their growth, but also because of the potential benefits they can bring to the government and the nation as a whole.

"How to Publish a Low-Cost Rural Newspaper" Guide

Part III of this booklet: "How to Publish a Mimeographed Newspaper - Hints on Writing, Editing, Printing and Distributing a Rural Newspaper", has been prepared for the express purpose of helping the beginner. It contains detailed information on planning, forming the staff, gathering the news, writing the news, editing, and printing. It constitutes a short practical course in journalism and, with close study, a high school graduate (or even someone with less schooling) can learn from it the essentials of publishing a newspaper.

It is suggested that the sponsoring agency revise the contents of Part III, to adapt it to local conditions and publish it in pamphlet form. It can be issued quickly in mimeographed form, or illustrated and printed by offset press with a neat, colourful cover.

"Rural Newspaper News - Information to the Editors"

When copies of the newspapers begin to come in regularly to the sponsoring agency, they should be carefully studied for their general journalistic and commercial quality. The experienced reviewer will always note one or more ways in which improvement can be made and in many cases will also remark how certain difficulties have been handled in a better than average way. These good and bad

points being of common interest to every editor, it may be decided as in the Liberian project, to publish a "Rural Newspaper News - Information to the Editors", thus providing, once or twice monthly, a "feedback" in which news coverage, financial affairs, printing methods, and items tending to encourage esprit de corps are discussed.

The "News" is an excellent medium for reminding and emphasizing and also for getting across new ideas. In fact, it will often be necessary to publish "reminders" of "reminders" as the same mistakes appear more than once. It is important to impress upon the editors the value of keeping a permanent and convenient file of the "News" to which all staff members can refer frequently, for it amounts to a small, continuing course in newspaper publishing.

Republication of news

Reprinting and broadcasting of rural news in the capital city not only provides a valued national service but it has an important effect on the staff of the rural newspapers and the people in rural communities who are pleased at this wide recognition of their newspaper and their town and its affairs. They are interested too in hearing of the progress and problems of neighbouring regions as quoted on the radio and in the press of the capital.

Early steps should therefore be taken to get rural news to the city media by sending copies of the newspapers directly to the media, or selecting and condensing items to be forwarded two or three times weekly.

Correspondence with editors

Special emphasis was placed in the Liberian project on exchange of correspondence as a means of advising the local editors and stimulating their efforts. By developing a close personal working relationship with publishers and editors, the adviser of the sponsoring agency can help solve or even foresee problems. This teamwork begins with his participation in the publication of the first one or two issues and from that stage onward he is considered a friend and guide.

He should take the time to review in detail the first three or four issues of a new publication and point out ways of improvement in his correspondence with the publisher. While doing so, he should make note of points which may be of interest and guidance to other newspapers and should file them aside for publication in the next issue of the "Rural Newspaper News" (or whatever medium he has for reaching all the publishers). By checking copies of each issue of every newspaper, the adviser will know if one of them misses an issue. If this happens, he should write and inquire what the problem is, probably finding that it can be solved by a little advice or some small support and assistance.

Training abroad for rural journalists

Rural weekly newspapers in industrialized nations have progressed to a high professional standard. They have had many decades of experience. However, their basic concepts and goals are identical with those of the rural areas in the most underdeveloped nation. Because of this similarity, it may be useful for one or two of the best editors, after considerable practical experience and some local training, to be given the opportunity to study abroad on a small town weekly, selected because of its general journalistic and commercial soundness. Certainly it would be valuable if the sponsoring agency could train one of its own staff in this way. An employee with some newspaper or journalism experience who studies small town newspapers abroad could make a valuable contribution in organizing, developing and upgrading the rural newspaper system.

It is suggested that training abroad be developed along the following lines:

1. News gathering and news writing - how the community newspaper searches for constructive news which aids social, economic and political growth.
2. Writing of editorials and how to find suitable subjects - The interpretation of news and related information in editorials which clarify important civic issues and point the way to constructive community action.
3. Study of the administrative, editorial, and business office structure of a small town weekly.
4. Experience in the society, sports, obituary and similar departments which add to a newspaper's popularity and usefulness - Conducting interviews and writing stories of these types. Studying their value and use.
5. The conduct of civic campaigns (clean-up drives, fire prevention, voting) should be studied - How to combine the use of news, editorials, advertising, and special issues in sustained campaigns lasting over a period of weeks or months.
6. The production and use of special issues (national holidays, festivals, religious anniversaries, and other special events) - How they bring extra advertising revenues and provide a public service.
7. Circulation and unit sales - Methods of keeping records of subscribers, their addresses and payments. Ways of increasing sales.
8. Techniques of advertising promotion and copywriting, use of graphics, and planning of displays - Study special advertising projects. How to collect ads and keep records.
9. Business operations - Basic bookkeeping techniques.
10. Study, and on-the-job training at one of the manufacturers of mimeograph equipment - The use of multicolours and multicolumns, illustrations, special effects, make-up, and maintenance of equipment.

Inspection visits

At least once or twice the first year, the adviser should try to visit each newspaper. Particularly

during the first year of publishing when so much has to be learned, personal advice may be of great importance. The adviser should travel frequently and should have ready access to all the necessary transport.

Journalism awards

One of the most forceful methods of attracting national attention and encouraging the publishers, is to conduct an annual awards contest, as described in Part I.

Well-planned advanced publicity can draw attention to the need for high ethical standards in the profession of journalism. Formal ceremonies at prize-giving time can feature speeches by high officials drawing attention to the value of rural newspapers in national development. Awards in a wide variety of categories, including printing quality, will help to spread interest in the contest and encourage higher standards of production.

Seminars

A one-week seminar conducted yearly and attended by one or two representatives from each newspaper would be another effective way of training the new editorial and printing staffs. This would be especially helpful if held during the first year or two of the project.

A seminar would afford the opportunity to review the various aspects of production: objectives and responsibilities, planning, staffing, equipping, news gathering, news writing, editing, distribution and printing.

One of the benefits of the seminar, in addition to teaching journalism and printing, would be to bring together the newspaper people who have been operating independently in widely scattered areas in the interior. They could compare their publishing problems and successes and discuss many subjects of mutual interest. Finally, the seminar would serve all the functions of an evaluation conference which is so important in any new programme or project.

Model printing demonstrations and training

The sponsoring agency will undoubtedly have a mimeograph section which performs high grade reproduction work. With a small amount of extra equipment and training, a model printing operation could be set up to train operators sent for short periods from their newspapers. They could learn to prepare illustrations, justify type, use column rules, print in two or three colours, make large decorative lettering for headlines, use styli for special line work, prepare boxed advertising, print on coloured papers. Instruction might also be given in the care of equipment and the making of minor repairs and adjustments.

It may be six months or a year before publishers will wish to attempt the more advanced methods of mimeo printing but some of the more enterprising may have the ambition and capability to start earlier. They should be encouraged to progress as quickly as they like for as they improve the quality of printing they will sell more newspapers and attract more advertising. Then, with added income and printing experience at the mimeograph level, they can graduate after a shorter time into the more expensive and complicated photo offset process.

Technical books

There are several basic books which would be of value to the staff of each newspaper. If these cannot be purchased, the sponsoring agency may wish to contribute them on a slow repayment plan, or as a gift. The publications are: dictionary, thesaurus (a compilation of word variations which suggests different words with the same meaning), Modern News Reporting, 3rd ed., by Warren, Harper & Bros., N.Y. City, $5.50; The Active Newsroom, a manual published by The International Press Institute, Zurich, Switzerland; Techniques of Mimeographing, and How to Plan and Publish a Mimeographed Newspaper.1/

These books are basic ones that cover the low cost publishing field fairly well. It is hoped, however, that the newspaper staff will accumulate other technical books of this type, including some on advertising and editing.

Cartoons and comic strips

As has been stated in another Unesco publication,2/ "The use of comic strips to promote social progress in such fields as hygiene, farming, gardening, household crafts and civics should be encouraged with the aid of governments and interested international organizations. These strips could be reproduced by newspapers on payment of an established fee."

The mimeo printing process lends itself very well to reproduction of cartoons and comic strips in the form of simple line drawings and even the more complicated half-tones can be reproduced with electronic scanners which are capable of copying images on to stencils. If the sponsoring agency has such equipment, it can produce for each newspaper in the country a stencil copy of a cartoon strip designed to promote a high priority government project. The stencils are sent to the newspapers to be printed on their own mimeograph machines.

1/ These last two booklets are published by the A.B. Dick Co., Chicago, U.S.A., manufacturers of mimeograph equipment. They may be obtained by writing the company.

2/ Developing Information Media, In Africa, Unesco, 1962. p. 20 (RPMC/37).

News and information releases

Local news will make up the main content of the newspapers, but this can be effectively supplemented by information and national news releases from the government. This serves two purposes - first, it provides a rural outlet for the printing of national news, thus helping to unify the country and broaden the outlook of locally oriented people; and second, it provides editors with a regular supply of general news to help fill out their columns.

Government press releases can be sent to each of the editors, but these should be reviewed to exclude those which are of no interest to rural readers, either because of content or wrong timing. If possible, lengthy releases should be rewritten to suit the format of the small newspapers. A rural newspaper system of some 20 or 30 newspapers can be an extremely valuable outlet for government information of all kinds - on health, agriculture, education and public works. For articles of particular importance, it is suggested that a printed, eye-catching, red slip marked "Special to Editors" be attached, with an additional explanation that this is a public service story and it would be appreciated if editors would make a place for it in an early issue.

Publicity

The opportunity should be taken frequently to publicize the newspapers, their service to their communities, their educational value, their low cost and simple production, and the prestige and profit they can bring to the owners. This will encourage other communities to start their own. This publicity can be conducted through the capital city press and radio stations, using stories about the progress of the developing newspaper system and its contribution to national progress. A large display board with a relief map of the country, showing examples of the newspapers and where they are published, is another effective way to publicize them. If placed in the sponsoring agency's reception lobby, this will also encourage other government departments to use the newspapers for educational purposes. Publicity is a good morale booster too for the hardworking newspaper staff members who appreciate this recognition. Credit lines, for example, should always be given to the newspapers when their materials are reprinted in the city press or broadcast over the radio.

Summary

When a number of newspapers are established financially, and publishing regularly, the first steps have been taken toward the development of a more professional rural press. Rather than wait decades until expensive printing equipment can be afforded, these intervening years can be used to provide practical experience for scores of editors and reports on low-cost newspapers where they can apply the basic science of good journalism.

These newspapers, although small to start with, are economic enterprises in their own right. They add a whole new segment to the business community. While striving for the welfare and advancement of the community, they will at the same time depend on the community for their existence. The newspaper belongs to its community, and the community should give it constant support.

PART III

HOW TO PUBLISH A LOW-COST COMMUNITY NEWSPAPER

This section can be extracted, edited for local needs, reproduced, and distributed by the sponsoring agency to the staff members of the rural newspapers. It is a simple manual for the use of publishers, editors, reporters, and mimeo printers who have little professional experience.

HOW TO PUBLISH A MIMEOGRAPHED NEWSPAPER

Some hints on writing, editing, printing and distributing a rural newspaper

The purpose of this chapter is to offer the man or woman who wants to start a newspaper the basic information needed to form a staff, prepare the news, and print it at very low cost. It is assumed that the person concerned has never had newspaper experience or schooling in journalism.

Many would-be publishers have never made a start because they thought that it was necessary to have large, expensive, complicated printing machinery. This is not true. The news is just the same, however it is printed. If you do not have the money to pay a large staff to run a large printing press, you can merely take the same news, arrange it in newspaper style, and print it with a very low cost mimeograph machine. Any adult with a few hours training can learn to run the mimeograph. As he gains experience he can perfect his work and make it look more professional.

Plans and preparations

To begin with, it will be necessary to select a small staff, obtain equipment either by purchase or loan, buy supplies, arrange distribution, decide on the format (what the newspaper looks like, two or three columns, etc.), and choose a name.

There are two types of community newspaper: (1) the business enterprise, where a commercial entrepreneur collects advertising and sells subscriptions for the purpose of publishing a newspaper which will make a profit for him; (2) an institutional newspaper, that is, a publication supported by a large school, religious group, information service, mining or agricultural company for example. They are both alike, however, from the journalistic point of view. They cover the news of the town and region, and they may both accept paid advertising. The main difference between the two is that if the business enterprise does not make money it will no doubt have to cease publication. Whereas the institutional newspaper will probably have voluntary unpaid staff, and equipment and supplies may be available without direct cost to the publication.

1. Staff. The size of your newspaper and how often it is published will decide what kind of staff you will need. An editor/publisher, giving his full time to the work, should be able to publish a two-page newspaper two or three times weekly. This would be a commercial newspaper, and he would have to write the copy, get the advertising, print the paper, and see to its distribution. He would need help for the distribution (circulation) work - more, of course, if he printed a two-page newspaper three times a week, than if he published a six-page issue once a week. Later on he might be able to take on a reporter to assist him.

On the institutional newspaper the work will probably be spread out with a number of people helping part time. This would require an editor, reporter, business manager (for advertising, bookkeeping), a circulation manager, and a mimeograph operator.

In the case of a newspaper run by a rural information centre, for example, a two-man staff with some newspaper experience having some additional duties as well should be able to publish a six-page mimeo newspaper weekly without other assistance.

"Correspondents" are people who can send you news, or ideas and facts for news stories, but are not considered regular members of the staff. They may be paid or unpaid. It is helpful to name a correspondent in each nearby village, large business or organization who can send you a small but regular flow of information. These people will probably not be able to write a news story, but they can give you facts such as names, times, places, and happenings which the editor can put into news form. Another reason for having correspondents is that one day you may wish to call on them in a hurry to help you on a story in their area.

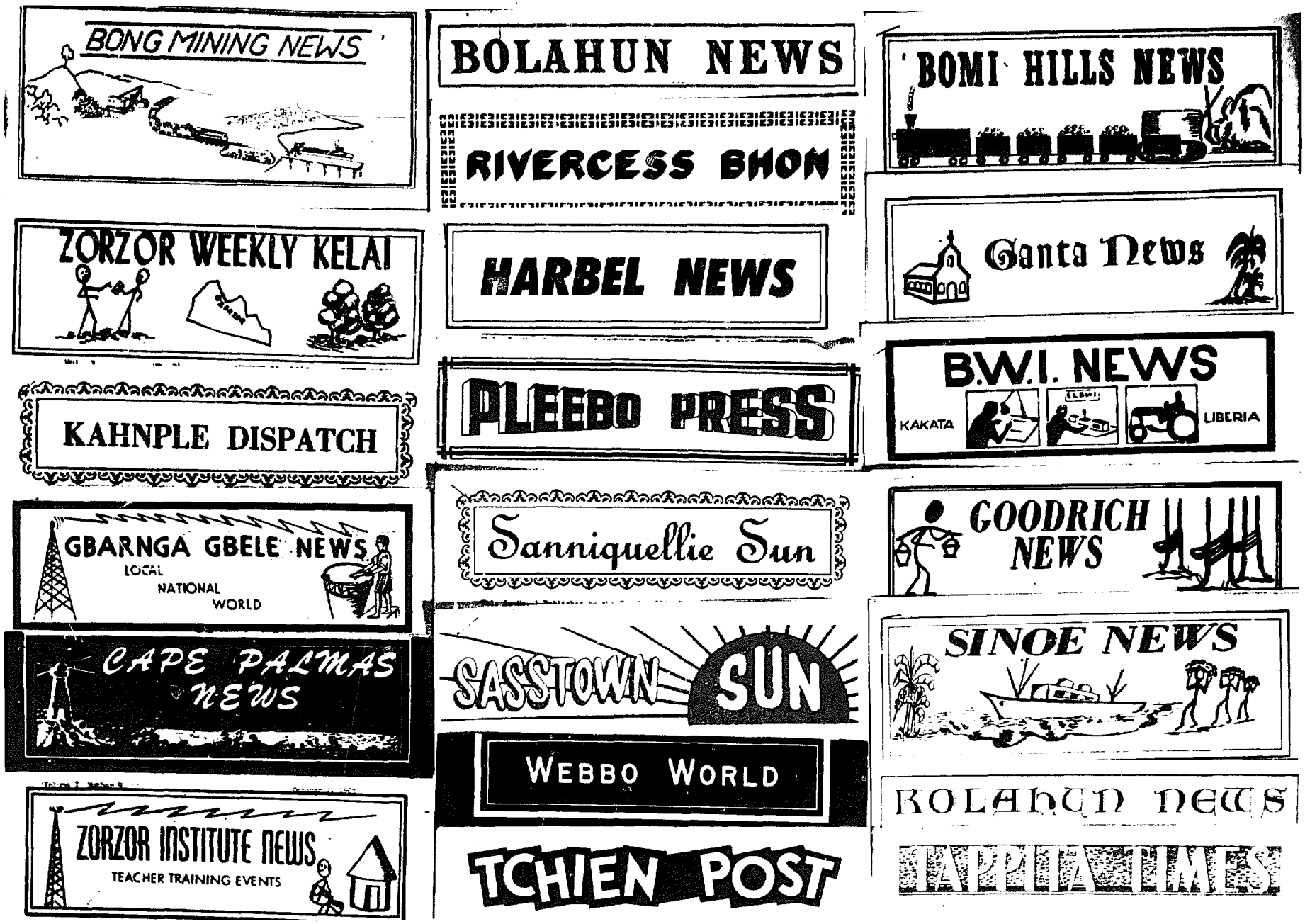

LOW-COST NEWSPAPER TITLE HEADINGS

These twenty-one examples of title headings for low-cost newspapers in Liberia show a wide variation of lettering and ornamentation. The art work sometimes indicates the type of community where they are published – coastal, mining, rubber growing, etc. They were all printed by offset press in various colours. Colourful title headings give a bright, professional appearance to the first page. This increases reader interest and results in more sales.

2. Name. The name of your newspaper should be brief but descriptive of its mission. It is best for the first word to be the name of the town where it is published and where it distributes the greater part of its circulation. You may want to include a local dialect word for news, even if it is printed in another language. For example, the Zorzor Weekly Kelai is printed in English, but the word "Kelai" is the word for "message" in the Loma language. This gives a little colour to the title. It is not always advisable to put the word "weekly" or "daily" in the title because you may want to change the frequency of your publication.

3. When to publish. Unless you have had newspaper experience before, it is best not to publish too large an issue the first time...or to publish it too often and have to go back to a less frequent publication. It is better to start slowly and increase the number of pages and issues as you and your staff gain experience. This is a matter of how large a staff you have. It is not a question of how much news is available. There is always plenty of that about if you are prepared to search for it.

For the institutional newspaper, it is suggested that the first issues should be about four pages weekly. If the town it serves is large (over 5,000) and you have a big enough staff, you may want to publish a larger newspaper.

For the commercial newspaper, the size and frequency must be within the capabilities of the paid staff. For business reasons, it is probably best to publish frequent small issues instead of a few big issues. This will let you print more advertising by the same advertiser and thus increase your income. Whatever frequency of publication is chosen, it is important for your newspaper to appear regularly at the exact date on which it is scheduled. It gives a bad impression if the newspaper is late, or if it does not come out as often as the public expects.

If you decide on a weekly, you must choose the day of the week on which you will publish. In choosing this day, you must know when you can finish collecting news, writing, printing and distributing it. Many editors of weeklies publish on Friday. This is because the news happenings of the week can be printed and reviewed. Storekeepers like to advertise on Friday because people often do most of their buying on Saturdays. Some publishers choose Monday as a publication date. This gives a chance for the editor to review the important news that usually happens on weekends. However, Friday is usually considered the best day. If you publish twice weekly, Mondays and Fridays may be the best days. Publishing days may be determined by mails or other methods of distributing your paper to outlying places.

4. Equipment. A mimeograph machine and an ordinary typewriter are all the printing equipment needed. This has the double advantage of being a very inexpensive and rapid way of printing. If you are printing a weekly four-page newspaper in about 500 copies it should not take more than 1-1/2 to 2 hours to print. Since these few hours each week come to such a small amount of machine time, it may be best to borrow or pay for the use of someone else's mimeo machine.

If you decide to purchase your own machine, it is suggested that you get a simple, hand-operated, non-automatic one. This type will cost less and will be easier to operate and keep in repair. Humid, tropical climates and hot, dusty ones are very hard on all types of automatic equipment. In these countries it is also difficult to have repairs made on fine equipment. If the machine is one of simple construction, it will be much easier to make minor repairs. This kind may cost as little as $34.50.* The more expensive ones cost as high as $800.00.

* Prices mentioned in this chapter are those current in U.S.A.

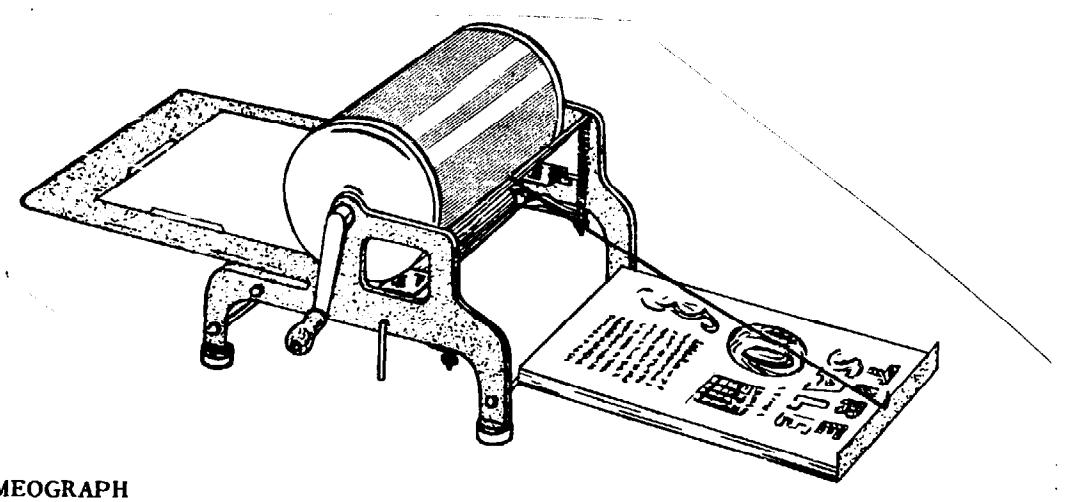

THE SIMPLE MIMEOGRAPH

This machine is similar to the first model constructed about 70 years ago. A cloth pad on the cylinder is soaked with ink and the stencil placed over this. Paper is fed by the left hand and passes between the cylinder and rubber roller as the crank is turned by the right hand. The printed copies fall out on the right. Being simply constructed, there are few working parts to get out of order. When something goes wrong, it is easy to see what the trouble is, and it can usually be corrected by the operator. This one is the "Lettergraph" made by Heyer, Inc., Chicago.

Because of their simplicity, the cheaper machines are also the easiest on which to print two or three colours. This is due to the fact that only the ink pad needs to be changed in going from one colour to another. The drum does not need to be changed. In the larger machines the cleaning is more difficult and the drums will probably have to be changed. Replacement items for the low-cost machine are cheap. For example, the ink pad is only 50 cents. Another advantage is that the small, hand fed machine will use lighter weight paper. The larger machines need a heavier, more expensive type of paper and in humid climates, frequently do not feed well through the automatic devices.

Another type of low-cost printing machine is the so-called "spirit" duplicator. These are not recommended here because they cannot reproduce as many copies per stencil as the mimeograph, and the inks begin to fade sooner. This is important to remember, because your newspaper will be used for many years in the future in the files of libraries and government offices.

A small radio would be useful to receive the national and international news for reprint in your newspaper. An inexpensive battery-powered transistor set will serve your purpose.

Although not absolutely necessary, it is helpful to have a tape recorder so that you can record the radio news; you can then play it back later and write it down on paper. Sometimes the radio news is read rather fast, but a tape recording allows you to play it back over and over until you have it exactly right. Small, battery-powered recorders can be bought for as little as $75.00

5. Supplies. The only supplies needed are paper, stencils, ink, stapling device, and correction fluid. If you have a hand fed machine the 16-pound mimeograph paper can be used. This costs about $1.50 per ream (500 sheets in a ream). The 20-pound paper is heavier and a better grade which holds its shape well in humid weather. It costs about $2.00 per ream. If you wish to print on both sides of the paper, the heavier paper would be better. However, if you get a grade of lightweight paper which is opaque (very white and cannot be seen through) you can print on both sides of this. Coloured paper may be bought for a few cents more per ream. This comes in pale shades of pink, green, blue and yellow and may be used on special occasions.

The stencil is the special paper on which you type or draw pictures for reproduction. They cost about $3.00 per quire of 24 sheets (12¢ a sheet). Ink is about $2.50 per can, staplers $3.50, and correction fluid 50¢ per bottle. Coloured inks cost a little more than black ink.

6. Cost of printing. The cost of paper and stencils for a two-sheet newspaper (four pages if printed on both sides) in 300 copies is about $2.64. This is figured on the basis of two stencils at 12¢ each and 600 sheets of paper ($2.00 per ream of 500). If the newspaper is published weekly, the cost of supplies per year would be 52 times $2.64 which equals $137.28. Twice weekly would amount to $274.56 each year, and so on.

The cost of labour is not included here, though it is important for the commercial publisher to estimate it very closely. Labour costs vary a great deal, of course, and the new publisher must work out his expenses here in relation to his own needs.

7. Income from ads and subscriptions. Keeping in mind that the annual cost of a two-sheet weekly newspaper is about $137.28, we can compare this figure with a rough estimate of what the income might be from sales and advertising. If the newspaper sells for 2¢ per copy and there are 300 copies sold, this would total $6.00 per week. Therefore, 52 times $6.00 equals $312.00 per year for copy sales. Next, we can estimate there might be an average of four small ads in each issue; at $1.00 per ad, this would be $4.00 per week, and 52 times $4.00 comes to $208.00 each year. Thus we see that $208.00 for ads and $312.00 for sales make a total income of $520.00. If we take the cost of supplies ($137.28) from the total income ($520.00) we get an estimated annual return for labour and profit of $382.72.

The above represents a rough idea only of what might be expected. This is based on the experience of other newspapers of this same type. Some of these have run as many as 15 ads in one issue. Another, after being in business a short time, was earning about $25.00 per issue from ads and sales.

A business manager will be necessary on either a commercial newspaper or an institutional one. If the publisher/editor of the commercial newspaper is a good business man he may want to do all the advertising and sales work himself. In which case, if he has a weekly of six or eight pages, he would probably have to turn over some of the editing work to someone else.

8. Distribution. How to get your newspaper into the hands of the reader is a matter that should be discussed and planned at an early stage. After all, this is the final object of publishing. We can call this "distribution", or "circulation" which is the word the big newspapers use. The newspaper must be distributed quickly, while the news is still news. Therefore, at your first planning meeting, draw up a circulation list. This list will always be changing as you add names and places, and as you take off others.

Another reason for planning distribution early is that you need to know how many copies to print. You should not guess at this. If you print too many you waste paper. On the other hand, you do not want to print too few and then have to print more, or worse, not have enough to go round all the people who should get them. For the first two or three issues, you will want to print about twice as many copies as the number planned for regular distribution. For example, print 600 if your distribution list is about 300. This is because you will have many requests that you did not expect. Also, you want to distribute them as widely as possible to let

everyone know about the new newspaper. This will bring you more subscriptions. It will also bring you more news to print. It is a good idea to give free copies to many people, offices and organizations who you think may wish to subscribe later on a regular basis. Also, give them to the stores and shops who may want to advertise.

If you have been helped in starting your newspaper by some government agency in the capital city, be sure to send them about ten copies of each issue. The agency should send them to the radio stations and daily newspapers which will give the name of your newspaper as the source of the news. This will bring national recognition to your town and paper. Later on, you may want to make some arrangement to sell your news to the radio stations and city dailies. The agency will also want to send copies of your newspaper to other places like the libraries, bulletin boards, high government officials, and public information people. If no agency in the capital is associated with your newspaper, it would be a good idea to send copies directly to the radio stations, newspapers, libraries and information services. Your newspaper is writing the history of your part of the nation, therefore, if copies of each issue go to the libraries your paper can be kept there as a permanent record.

If there are other newspapers like yours in towns within about 100 miles around, it would be wise to place them on your distribution list. Ask them to send you their newspaper too. This is usually done without cost to either publisher. Your readers want to know the important news from the region around them, and you can reprint some of the items from the other newspapers. They, in turn, will print some of your news.

Be sure to keep three or four permanent files with a copy of each issue. As soon as they are printed, put them in a file where they cannot be taken out. You and your staff will want to look back many times to see what you have published. It is a good idea to save five to ten per cent (15 to 30 copies of a 300-copy issue) of each issue because you will always have requests and other needs for them. In fact you may have need for them several months and even years afterwards. It is very easy to run off a few extra copies for this purpose at the time, and you will always be glad that you did.

Institutional newspapers especially, will want to exchange copies with like institutions around the country. For example, the publisher of a newspaper for a vocational school will want to send copies to other interested schools. Or a paper published by an agricultural organization will find many interested readers at similar agricultural groups and agencies throughout the nation. This will attract news, advertising and subscriptions.

When drawing up the distribution list of your first issue, keep in mind the following: (a) provincial and town leaders; (b) officials of nearby towns and villages; (c) education officials; (d) agricultural groups; (e) hospitals, clinics, health organizations, doctors and nurses; (f) schools and their teachers; (g) libraries; (h) military units; (i) police stations; (j) public markets (paste or tack on walls and display boards for the most people to see); (k) religious missions and their leaders; (l) large commercial firms (mining, agricultural plantations, etc.); (m) information centres; (n) clubs and youth groups, and (o) stores and shops. Do not forget to make changes in the list promptly and keep it up to date.

Gathering the news

Finding and gathering the news, according to many editors, takes three-fourths of your time, and the other fourth is taken up in writing the story from the information that is gathered. It is therefore necessary to have a good system for getting the news. The editor is responsible for finding the news and preparing it for publication. There are several ways of doing this, and there are several places to go to find the news. Here are some suggestions to consider:

1. Reporters. The editor/publisher of a newspaper of six to eight pages published weekly should be able to assemble the news and write it himself, (as well as undertake the other publishing activities). In the case of the institutional newspaper where several part-time helpers are available, it is a good idea to name two or three "reporters". Reporting has been described as gathering information of interest to other people, and writing it down correctly in a way which makes them understand and remember it. This is the work of getting the news for the newspaper.

What makes a good reporter? He must have a good school education, preferably a high school one. He should have some of these qualifications:

(a) An inquiring mind. A good reporter should seek all the facts about the story he is going to write. He must ask many questions and know the full story of what is happening and why.

(b) Know what is news. He must know what his readers want to read and need to learn.

(c) Tell a story. He should know how to put bits of information together and make them tell a clear story. His facts must be arranged in the right order.

(d) Be well informed. He should know the town, the people, and the area where he is working. He should be a man (or a woman) who knows people in many kinds of work (town officials, clinics, schools, shops, etc.) and likes to talk with them.

(e) Desire for truth. He should check what is told him and be sure that what he writes is based on fact. By printing the truth he will stop rumours.

(f) Want to work. The reporter must not be lazy. He must be ready to work at odd hours and on holidays. A big news event may happen at night and he must be ready to go for the information. He may have to spend off-days and holidays on special stories.

After a little experience, the reporter will know where to go to find his news. The editor can tell him certain places to visit each week. There is always plenty of news wherever there are people. The reporter

must go out and look for it, ask questions, bring the information back and write the story.

Reporters can be given special types of work to do. The editor can name one sports reporter to cover news about games. He can name another to write about the work of local government officials. He could have another reporter to do the stories about agriculture, health and road building. A reporter should learn to type his story but clear handwritten copy should be acceptable.

Don't forget that reporters, and editors too, must "dig" for most of the stories they get. You cannot publish a notice asking for news and expect it to come to you. It is a good idea to invite the people to bring in interesting items, but this does not take the place of a reporter going out and really "digging" the news out of the source.

2. Correspondents. As we have said, a correspondent is a kind of reporter who lives in another town or distant village. It is a good idea to name a correspondent in each of the villages in your area. They may not be able to write well, but if you tell them what kind of news you want they can send in the information and you, the editor/publisher, or a reporter can write it into news story form.

The editor/publisher must keep in close touch with his correspondents and remind them to send in the news. If possible, he should pay them something either for each story or by the month. Or, he can encourage them by putting their names in the stories as being the source of the news. For example, such a story can begin by stating, "According to our correspondent Mr. John Brown in Gello village, there was a bad automobile accident there last week..." The correspondent may be able to use the telephone of some police station in the area to get the news in faster. Otherwise, it can be sent by mail. A correspondent can also do other work like taking care of the distribution of the newspaper in his village. School-teachers or school-principals make good correspondents because they are well educated, and are good news sources as they are in touch with many people.

The people in your town also want to know what is going on in nearby villages and towns, so you should encourage your correspondents to send in a story each week. You will sell more newspapers in the villages too, if the readers there see some of their own local news. Visit your correspondents when you can and let them know what a useful job they are doing.

3. Radio news. The easiest way to get national and international news is by arrangement with the radio station. Your readers will be more interested in the local news, but they will want to know of important happenings in the outside world too. It is a good idea to have two or three national or international news stories in each issue. This kind of information will give your readers a broader outlook and will help them understand better how the social, economic and political progress of their community makes a stronger united nation.

On the morning of the day you publish your newspaper, or the evening before, listen to the radio news. Write down as many facts as you can about two or three stories which are of general interest to your region. The announcer will be speaking too fast for you to copy down everything he says, but you should get enough for short stories of one or two paragraphs. Remember when you write the story to put the name of the city where it came from, at the very start. Your readers will know then that it is not a local story and will not be confused. You should also give "credit" to the radio station from which it was taken by stating the name of the station.

News from the radio should usually be printed after the local news. This is because your readers are more interested in the stories about their town and region than they are about far away places. Sometimes there may be a very important national news story which might go on page one. But if you have one like this you should add to it the ideas of local officials on this subject. This will give it the important local "angle". An example of this would be a story about the president of the country asking farmers to plant more rice. You can then talk with a local leader who will probably make some comment of special interest to the people of the district. This information can be added to the original radio story.

There will probably be times when the editor/publisher has to be away from the town and has not had the chance to write much local news. He knows that he must print his newspaper on the regular publishing day. The problem is how to get enough news to fill out at least a small issue. If he has two or three local stories, and reports from his correspondents, he can complete the rest of the newspaper with news from the radio. He should not print radio material just to fill space, but if he carefully selects stories from the large amount available from two or three newscasts he should have plenty of copy.

We have seen that national and international news is good to educate your readers and broaden their outlook. It should usually be placed in second position to the local news, and it can be used to fill out an issue when there is a shortage of local news. Be careful, however, about errors when you jot down the facts from the fast-spoken newscast.

4. Exchange of newspapers. We have already mentioned the swapping of your newspaper with those published in neighbouring regions. This is a good source of news. Be especially on the watch for stories about road and school building, health campaigns, and other public service stories which will inspire and help the people of your area.

5. Press releases. Most governments have public information offices which publish news stories daily about the operations of the various departments and high officials. These stories are called "press releases" and are distributed to radio stations, newspapers and other news outlets. If there is a ministry of information or similar department in your country you should ask them to send their press releases to your newspaper. They will be glad to do so without any cost to you.

By the time they reach you in your distant town many of them will probably be too old to use. But there will always be some stories related to agriculture, health, education, rural improvement and other government affairs which will be of interest even though a little out of date. You may want to cut down a story to one or two paragraphs instead of using the whole article. The information service will no doubt be prepared to have you do this as long as you do not change the facts or meaning of the story.

If you receive many press releases from the capital city, you may want to publish a weekly page of news from this source. You could prepare a special lettered "standing" heading (one that you use again and again) for the top of the page or column. This could be "Around The Capital", or "News From The Capital". Besides being of interest to your readers, news of this type will help to educate the public about the work of their national government.

Taxes always need a lot of explaining. Without taxes the government cannot operate. For people who have never paid taxes or know little about them, it is hard to understand why they should give part of their money to a far-away government. Your newspaper can do a public service by explaining how taxes can be calculated, when and how to pay, what the money will be used for, and how the public benefits in the form of roads, schools, police protection, etc. Press releases usually give you this information.

Agricultural departments issue press releases containing news for farmers. Information like this may help them to grow better crops, or perhaps advise them on how to get help from the government. Often, farmers do not have the chance to go to school and, therefore, cannot read or write very well. It may be hard for them to understand agricultural notices. You can help them by writing agricultural stories in very simple language. Use short words, short sentences and short paragraphs. For the more important news, you may want to write an editorial to explain it clearly for local understanding.

6. Foreign embassies. These can be a good source of news, because they put out press releases and other information with stories of interest to your country and theirs. For example, a story about someone from your area who is studying in the foreign country. Find out which embassies have information services and ask them to put your newspaper on their mailing list. They will be glad to send releases to you at no cost.

7. Background material. If you ask your government information agency they will probably place you on their mailing list for tests of speeches by top government leaders and other similar materials. This would be in addition to the regular press releases noted before. You may not want to print much of this type of information, but it can be valuable background reading for you. You can file some of it for future reference, like biographies, and use it later. If, for example, the head of the government, or one of his top cabinet members is making a trip to your area you will have the background material to help you write stories about him.

8. Religious news. The staff of religious missions and religious schools are good sources of news. Talk with these people each week and you will nearly always find a good story or two. Ask one of them to be a correspondent for you. Many of your readers will be members of some religious organization and will like to see news of this kind. Missions or other public organizations often conduct fairs and entertainments to raise money for some charitable purpose. The stories or "publicity" the paper can publish in advance of the event, will greatly increase the number of people who will attend. The newspaper in this way can directly help good causes, and will win much goodwill for itself as well.

9. Sports. Most readers are interested in learning the outcome of sports contests. There is nearly always some kind of sporting event going on each week in large towns. One or two stories on sports in each issue will give a nice variety to your news. It will attract young readers too. If you do not have time to cover the sports news, perhaps you would like to find someone interested to be your sports editor. Being a special type of news, sports stories are generally kept together, and not scattered throughout the paper.

10. Foreign teachers. In scores of countries around the world there are now thousands of teachers from other nations working in schools in rural areas. They are well educated and many of them have either worked on school newspapers or have written stories for them. They would probably like to contribute news of school activities to your paper, or serve as correspondents. Visit them and invite their assistance. Newspapers are an aid to education, and educators can help the newspapers.

11. National holidays. Editors of city newspapers always keep a calendar of coming special events, such as annual religious feasts, Freedom Day, United Nations Day, etc.

It is wise to keep a calendar of these holidays and celebrations and plan ahead to print stories about them before they happen. You may wish to ask the officials of the town and province about plans for local celebrations which you can publicize. This is also the time to write a short editorial explaining the meaning behind the holiday... why it was created in the first place and what this occasion means to the local people.

12. Other news sources. You can often find news or news leads if you visit and talk with the people at the following places:

(a) Local government offices... the mayor and his staff members.

(b) Education offices.

(c) Schools.

(d) Police stations... accidents, law-breaking, arrests.

(e) Courts... trials and court decisions.

(f) Medical clinics... births, deaths and health information.

(g) Public markets.

(h) Construction projects... new roads and buildings.

(i) Airports and stations... the news of where travellers came from (neighbouring towns and countries).

(j) Stores... storekeepers hear many rumours, and you can track down the facts for a truthful story.

(k) Agricultural offices and co-operatives.

(l) Women's clubs... social and personal items.

When we review all the sources of news listed here, we can see that a hard working editor/publisher or his reporters should have no difficulty in filling his paper. The people in these offices, organizations and places are always doing something, and what they are doing is of interest to the rest of the public. Develop these news sources by visiting them often and letting them know what kind of information you need. There is no substitute for asking many questions. Soon your news sources will have news waiting for you with the kind of facts you need.

13. Follow-up stories. When an important happening has been reported, it is often of interest to publish another story on the same subject in the next issue of the newspaper. This is called a follow-up story - for example, one about three babies being born to a local mother. This is unusual, something which attracts wide interest, and the public wants to know how the mother and babies are getting on. A second story about a week later may tell about the health of the mother and babies, how much weight they have gained, and perhaps a statement from the father or the doctor. Sometimes the follow-up makes a bigger story than the first. It pays to review each issue of the newspaper a day or two after it comes out to see what stories need to be followed up.

Writing the news story

1. What is news? "News" has been described as anything that interests a large part of the community and which was not known before. It could be a report on something that is going to happen, or has happened. News is intended to interest, inform or entertain the reader. But every story does not attract the attention of every reader. Some of the qualities you may look for in a news story are the following:

(a) Timeliness - must be of interest on the day when it is printed and not previously known. It can be a timely explanation of something that has already taken place.

(b) Interest - a story must be of interest to a large number of your readers. A story of interest to only a very few people is probably not worth publishing.

(c) Nearness - people want to know about things that happen close to their homes or community, or at least have some local significance.

(d) Value - the news item may contain information that is helpful or entertaining...something that will inspire a person to be a better citizen, or to take action that would be good for other people, or for his town.

Let us review these four qualities in a little more detail. News must be timely, because it is good only when it is fresh. The writer should show in his story that something has just happened, or is about to happen. In his first paragraph he will tell when it happened - this week, yesterday, or last night, or a day or date in the near future. For example, "A man was bitten by a snake yesterday..." Or, "A town meeting will be held next Wednesday..."

Interesting can be one of several things. A story can attract the reader if it concerns someone for example who is a high official, or is widely known for some reason. It can be about a famous hero, and on the other hand it may concern a very bad man who has committed a terrible crime. Oddity is a quality which attracts interest. It is not odd that the sun rises in the morning or that water runs down hill, but it would be odd if they did otherwise. A famous newspaperman once said, "When a dog bites a man that is not news, but when a man bites a dog that is news." Conflict is another quality which makes news. This can be a sports contest between two teams, or an argument between two politicians. Where there is action there is usually conflict of some kind. Human emotions are another strong element which can be described as human interest. The baby left on the doorstep of someone's house, or the dog lying by his master's grave, are examples of human interest stories. Thus, important people, oddities, conflict and human interest are qualities that cause interest in the reader's mind.

An accident in front of your home is of far more interest to you than an accident in the next town. The reason for this is because of its nearness. A good news story will generally have a local connexion, something that the reader can feel has some meaning for him, his life, or community. We can describe news as international, national, and local, according to where it comes from. The local news is always the most interesting because the readers already have some idea of what it is about. If someone from your community goes to the capital city and does something important, that would be national news but with special local interest. The most interesting things to every person are his life, family, health, job, neighbours, community, sports and recreations. The newswriter should therefore try to connect his stories with the lives of his readers.

The fourth quality, value, is closely related to timeliness and nearness. "Consequence" can be another term for value and means something of importance to the reader. A story about an increase in town taxes may not be of such moving interest as one about the leopard that killed a dog at someone's back door. But the tax story is of value to a large number of readers. Information about public meetings, government actions, how to cure malaria, or new agricultural methods is important to many people. News of consequence can tell about progress, or happenings which may have a helpful result or show what future progress might be. This is very different from the news story about an accident. The average reader wants news of progress, but the reporter must put together the facts in a way which will make them easy to understand.

2. The summary lead. A news story is different from other kinds of writing. The personal letter may have several topics mixed together in no

special order. A book may begin with a long description of the general scene. But the news story starts with the most important facts followed by the next most important details with the least important at the last. The first paragraph is called the "lead" and it should contain a summary of what the entire story is about. It is sometimes called the summary lead.

Many people do not have the time to read the whole newspaper, so they look from headline to headline to find what interests them the most. When the eye stops at one story, the reader can quickly tell if he is interested in the whole story by reading the first paragraph. This will give him the "gist" of what happened. The reporter must write his story in such a way that the reader gets full understanding at the start. After all, news telling in this way is like a man telling another about an accident, "A car struck a tree on main street this morning and killed two people...". Then the details become less and less important as the story goes on. If the editor is short of space and does not want to print the whole story, he can cut the bottom paragraph or two off and not hurt the meaning.

3. The five W's. The summary lead, in order to give the general idea of the whole story, should contain the who, what, when, where, and why elements. In other words, the first paragraph in your story should tell who it is about, what it was that happened, when it happened, where the action took place, and why it was done. Sometimes the how is added, or takes the place of the why.

Let's say that we have heard there will be a farmers' fair in our town next week to encourage better farming and that two officials of the agricultural office will be in charge. Breaking it down into the five W's we have:

WHO - John Brown and Jack Smith, agricultural officials. (Names make news is an old newsman's rule. Print them whenever you can, but be careful to spell them correctly.)

WHAT - they were placed in charge of the fair. (In a later paragraph you can tell something about the experience of these men.)

WHEN - Here we must remember what makes news. There are at least two news stories in this event. One is a report of what happened at the fair when it is over. The other is a story now to tell your readers about it in advance.

WHY - to encourage better farming. (Later, you can enlarge this part by describing the different methods of better farming.)

WHERE - in our town of Fairville.

Therefore, when we put the five W's together the summary lead looks like this:

"John Brown and Jack Smith, local agricultural officials, were named to be in charge of the Farmer's Fair which will be held next week in Fairville to encourage better farming methods."

If we leave out any of these parts, the reader will wonder about the missing elements. By reading this much, he will learn enough to decide whether to read on further. He will know quickly if the story interests him, instead of going all the way to the end to find out what it is all about.

As we said before, the how may also be included. For example, if the mayor did the naming, the lead could go like this, "John Brown and Jack Smith, local agricultural officials, were named last week by Mayor Jones to be in charge of..." This tells how they were appointed.

"Accreditation" is an important element to include in some stories in the lead. This means that you tell where the story came from. Examples of this are, "...according to an announcement by...", "...it was stated by the President", or, "...the Chief of Police said..." Accreditation gives the reader a little more useful information. It helps him to judge the value of the story by knowing the authority for it. Crediting a story to the source also gives the writer a certain amount of protection. If any of the facts are wrong, the source from which they came will be known. Try to credit your stories to good sources, never to rumours.

The lead is the most important part of the story. It should be clear and as short as possible. When you can, put a little "punch" into it so as to hold the attention of the reader. For example, the above story could have mentioned that it was the first such fair, or the biggest ever planned.

After the lead, there often must be a bridge, or connecting sentence or paragraph, between the lead and the main body of the story. This makes smooth reading between the lead and the body. The bridge might bring in details which do not fit in the lead but are too important to place later on in the body.

The body of the story supports the lead and the bridge by telling the story in detail. It explains and adds more facts that were not included before.

4. Avoid editorializing. This means that the reporter must not put his own views into a story, but instead, he should report the news only as it happened. He must write the news accurately and fairly. He is a reporter, not a judge. His own opinions must not appear in the news columns.

By editorializing, we mean expressing doubt, blame, praise or thanks. While he should quote a truthful source, the reporter may not act as the expert. In other words, do not use the personal pronouns like, "I saw ...," "He told me ..." and "I think that ..." Instead, use "He reported ...", "They stated ...", or "She described...".

In an editorial (to be discussed later) the editor, or someone he appoints, can write his own opinions and use the pronoun "I" or "we" but not in the news story. It has been said that the reporter cannot watch the show and at the same time be one of its actors.

5. Be brief. Space in a newspaper is valuable and should not be wasted. The reader does not want to be tired out by a long account using extra words when a short one would be better. The great majority of your readers are not as well educated as you, and so short words, short sentences and short paragraphs are best. Many of them are just

beginning to learn to read. Brief, clear writing will be better understood and will help them to learn faster.

Eight or nine lines in one column are about right for a single paragraph. This is enough to contain a main thought with some detail. The paragraph is a way of breaking up solid reading matter. A story can be wearisome to the eye if it goes on and on without a break. A point of good writing is to get over the message clearly and brightly.

In a small, two-page newspaper, it would be best to keep all stories short - two to four paragraphs at the most. This will let you include more stories on different subjects which will interest a larger number of readers.

6. Writing style. If you are writing for new literates, or those with limited reading skills, you must write very simply if you are to retain their interest and be readily understood. The key to this type of writing, is to express your ideas clearly, in short sentences with simple words. It is better to use the active voice than the passive.

New or difficult words which may confuse the reader, should be avoided. On the other hand, newspapers can be good teachers if the meaning of words is clear, or clearly explained.

Next to the dictionary, the second most important book for an editor to have is a thesaurus. The dictionary tells you how to spell a word and what it means. The thesaurus gives you other words and phrases that have the same meaning. Let us take the word "book". The thesaurus gives us other words which mean the same thing like volume, publication, novel, paperback and edition. Common words are the words which most people use in talking and in which they think. They are usually short and short words are usually the strongest. Keep your words simple but give a variation when you can do so without losing clarity.

7. Dictionaries. Correct spelling is one of the first duties of the writer. Your newspaper will help teach your readers to spell, therefore your spelling should be perfect. When you have any doubt, look the word up in the dictionary and get it right. A dictionary is one of the first books you should get for your office.

Remember that, as the editor, you are a leader in reading and writing. The readers, especially those just learning to read, will learn to write and spell from what they see in your newspaper. You are setting an example, and that example should be correct. Besides informing the public with news, your newspaper is also educating the public. Keep the dictionary by your side when you are writing. Refer to it often.

8. Names make news. Everyone likes to read names in the news, especially his own. We have already mentioned this earlier, but it is a good point to emphasize. Put as many names in the story as you can. When a school class graduates, put the names of all the students in the story. They and their parents will look for their names and more than likely will save that copy of the newspaper.

Names are the lifeblood of news and nowhere is it more true than in the society story. If there is a big party, festival or funeral, include the names of all the important people, members of the family, etc. The people who went to the affair will want to read about it afterwards. They will look to see if their names are given in the story. Your newspaper will make friends if it uses a lot of names. But if you spell a name wrongly you can make an enemy. So, put many names in your stories, but be sure to spell them correctly.

9. How to write your story. Let us review briefly what we have been trying to say.

Tell everything you know about one event in as few words as possible.

Use simple words, not big ones. Use short, straightforward sentences, not long, hard-to-understand ones. Do not try to be clever. Write in news style.

Say everything important in the lead. Try to keep it less than 25 words.

If you are not sure how to start, here is an easy outline. Just fill in the blanks:

....
(who) (does what) (where/when) (why or how)

Sample: "John Smith was drowned yesterday in Fairville in a boating accident."

With that as a start, go into more details of how and why.

Tell who saw it or who told you. Get his name right. Quote him if you like.

Here are some of the finer points that may help you to smooth and complete your story:

The "Who": Give first and last name, and spell them correctly. Identify the main people and connect them with the story. For example, "Smith was new principal of the Fairville school", and "Fred White, a wood cutter happened to be working nearby at the time of the accident".

The "What": This is the heart of the story. There is never news without action. Use active verbs. Emphasize coming events.

The "When and Where": These are especially important about coming events which the public will go to.

The "Why": This has been described as "the news behind the news". You learn the "why" by asking questions. If you do not get the answers you want the first time, ask other people. Go to the source who knows the most and whom you can trust to give you the truth.

The "How": This often makes the difference between a colourful, page one story and a dull little space filler. The "how" is made up of those lively details that make a story stand out in the reader's mind.

10. The interview. The interview is the most widely used method by which interesting material is gathered. There are good and bad ways of doing this. If it is a big story, you will want to make an outline. To do this, you will have to learn in advance as much about the subject as possible. Review old copies of the newspaper and any

other materials which might be helpful.

Find out as much as you can about the person to whom you will talk. What has he done that makes him worth an interview? Where did he come from, what did he do before? Is he easy to get along with? What does he like and what does he not like?

Make up a list of questions. Think what your readers would like to know about the subject - things that they have not already learned from material written in the past. You may think you can remember what to ask, but if he is an important person and you are new at the job, it is easy to forget. Write down the questions.

When you meet for the interview, try to appear calm. Make him feel that you are sure of yourself. If you show signs of being nervous, and if you have not studied the subject beforehand, you may not get all the information you want. He will look to you to start the questions. If he cuts his answers too short to "yes" and "no", ask him "Why do you think...?" instead of "Do you think...?" This should bring you more details for your story. Call the person by his name often.

At the end of the interview, check your information to make sure it is correct. If you want to quote his exact words, repeat the quote and check with him on the spot, instead of wishing later you had done so. Now is the time to check, not when you have gone back to write your story. With each interview, you will gain new experience in questioning people. Remember, always be well prepared before you sit down to talk.

11. Always review your story. There is no reporter who can do a perfect story the first try. Always re-read what you have written at least once. Test it by these reminders:

(a) Editorializing. A news story gives nothing but facts. Does your story tell your feelings on the subject it covers? If it does, rewrite it until the reader cannot tell how you feel. Leave condemnation or praise for an editorial.

(b) Accuracy. Is there anything you have written which you could not prove? Have you checked all grammar and spelling, especially the spelling of names? Do not forget punctuation.

(c) Completeness. Have you left out any important element in the story? If so, find the person who knows the facts and ask him.

(d) Clarity. Is every sentence clear? Could anything be mistaken, or taken to mean two things?

(e) Brevity. Can you improve the story by leaving out a word, a sentence, or even a paragraph? Do so, if it does not change the meaning.

12. Libel. Before we leave the field of writing, a word of warning should be given about libel. The term libel means the printed untruth that hurts the character or business of a person or a group of people. It may be a lie printed in a newspaper which hurts the government or damages a man's family. Libel can also be the printed truth where it can be proven that the reporter or editor was trying to hurt someone on purpose.

The laws about libel differ from country to country. In general, however, libel is of two kinds: civil and criminal. Civil libel, the most common, are those based on stories which hurt character or business. For example, if you call a man a "drunkard" and thereby hurt his reputation, you may be accused of civil libel. An example of criminal libel can be a case of printing material which encourages the overthrow of the government by force.

Be careful of crime news. If you call a man a murderer before he has been sentenced as one in the law court, you are taking a chance of being libellous and of committing what is called "contempt of court". Here are some words to avoid: gambler, burglar, criminal, drunkard, kidnapper and thief.

The best defence against libel action, if you have printed something objectionable about someone, is to point out its truth. Or, if it was a mistake, say so. If you can prove you made an honest mistake, or that you did not intend to hurt someone, you will probably be safe. It is a good idea to publish a "retraction" as soon as possible. That is to say, admit that a mistake was made, that you did not want to do harm, and that you are sorry this happened.

Therefore, reporters and editors must always be on the lookout for a possible libel in their newspaper. Avoid words which injure people and make sure you state only the truth. The particular laws in your country concerning libel should be studied.

Articles and features

You will want to include in your paper, special articles or readers' opinions which are not strictly news stories. Here are some ideas for features of this kind.

1. Letters to the editor. The editor will receive letters from his readers talking about some article or idea his newspaper expressed, or putting forward some view of their own. They may condemn, praise, ask for more information or give news. If any of these contain interesting or useful facts or opinions they should be printed under a heading "Letters To The Editor". They are usually placed on the same page as the Editorial. When you read the mail, watch for constructive letters of interest to the public. Readers like to know what other readers are thinking.

The publishing of critical letters can add to the strength and reputation of your newspaper. It shows you are not afraid of criticism or to print the truth. If you believe the writer of the letter made a wrong statement, you can print your own views below it. In that way, readers will learn both sides of the question on the popular issues of the day.

Letters can start people thinking and talking about the important affairs of the community. This helps to form public opinion on local and even national matters. In time, this might bring enough pressure to change old customs and bring about new and better ones.

2. Legends and folklore. There are probably several good story-tellers in your town. They may

be old men or women who remember the early history of the country. They can tell the tales that their parents, and their parents before them, passed on down. Everyone likes to hear a good legend or folk tale, especially if it is about his area and places he knows. The facts contained in these can be part of the history of your country which may not have been written before. If it is a long story, you can print part in one issue and the rest in the next issue or two. This will help to make your readers look forward more to seeing the next issue.

3. Editorials. As we have seen, the editorial is the place where the editor can write his own ideas. He should not do this in the news columns because there, only facts are reported, and no opinions expressed. The editorial, usually one column or a half column long, should be marked "Editorial" at the top. The reader will then know he is getting the ideas of the writer and not a news story.

The editorial page has been called the "heart of the newspaper". The editor in his editorials can express the policy of the newspaper. If he publishes news stories about people who boil their water or dig a new well for better health, and then follows these with editorials saying how important this is for the whole community - then, you know that one of the newspaper's policies is to work for the people's welfare. Good editorial policies will make the people like the newspaper and respect the editor.

Editorials can be dull and you should write them only when you have something to say. It is better to miss publishing an editorial one week or two, than to publish one which is not good.

Here are some ideas for editorial subjects: campaigns conducted by the government for improving agriculture, health, education, citizenship, etc.; town improvement or clean-up campaigns, celebrations, important national and international events; community events, self-help projects, etc.

The editorial, therefore, is the place where the editor can "point with pride" and "view with alarm" the issues of the day. This is the place where he can praise and give credit to a person or group for doing a good job. Or, it can be the place where he can write about something wrong in the community which could be corrected or improved.

4. Anniversaries. Marriages, births and deaths have always been good news makers. Here is the place where names are used as often as possible... the names of mothers and fathers, babies, grandparents, and the people who attended marriage or funeral ceremonies.

Births may be reported in short paragraphs, or they may be listed in a special column. A combination of the two could be used - a short story for a birth in a prominent family, the arrival of twins or triplets - followed by the column listing for all births of the past week. Either way, you should include certain basic facts - the names of the parents the name of the child, date of birth, sex.

Deaths may usually be written up in a standard form. If the reporter gets information covering ten questions he will have the facts for the story. Here are the points to be filled in: (a) name? (b) address? (c) age? (d) business? (e) cause of death? (f) how long was he sick? (g) where did he die? (h) names of members of his family? (i) time and place of the funeral? (j) where will he be buried?

5. Feature stories. What is the difference between a news story and a feature story? Both are written about facts, but the feature may be about an event that happened long ago. The news story is more timely and is written mainly to inform the reader. The feature is intended to entertain or instruct more than to inform. Features may be about local history (the legends and folklore we mentioned before), or about persons (a new town official, foreign teacher, or traveller), for example. A feature story can support a news story, because it can bring in additional information on the subject and help to explain the news.

The feature does not have to follow a form like the news story - most important facts first. The feature can begin with a general description and build up to the climax at the last. The lead (first paragraph) sometimes might begin with an eye-catching detail, then, having attracted the reader, fill out with general descriptions.

Features do not give the reader news, but they must give him something that he did not know before. A story about the life of your president may not have any new information. But the fact that he lived for two years in your town while a boy, and the details of that period, would make a good feature. Another example of a feature would be a story about a new dam or big national project. Still another might be about the life and experience of a popular athlete or musician. Or perhaps it will be an explanatory article about a new agricultural technique.

Invite your readers to send in features they have written. Many of them will probably be good for printing, though they will possibly need some editing. Give the writer a "by-line" (put his name at the top of the story. "By John Jones"). This will make him feel proud of his work, and he will no doubt send you more.

6. Women's page. As more and more women read newspapers, it becomes necessary to publish a greater number of stories of special interest to them. The women are a highly important section of your readership and you should remember that their news interests are not the same as those of the men. The housewife is concerned about cooking, home making, child raising, fashions, beauty care, women's clubs, family health, sewing, dressmaking and household improvements. If your newspaper is fairly large (six to eight pages) you may want to have a "Women's Section". Stories on the above topics could be grouped together in this section.

7. Coming events. It may be useful to prepare and publish a list of all the meetings and public events of interest which will take place during the next few weeks. This is an interesting feature in

itself, and should also act as a reminder to the editor to prepare advance stories about them when appropriate, and to ensure that the event is "covered" by his reporter when it takes place.

8. Public service items. Local and national governments always have certain programmes and policies which they wish to encourage the public to take action on. If there is a national shortage of food, for example, there may be a national programme to have every family plant a garden. It is then the job of the editor to help his country and his people by supporting this campaign. As we have already indicated, he can do this in editorials and feature stories.

There are always public service stories to be written, but the editor and reporters must look for them. The press releases that come from the national government should be looked over carefully for this type of story. The editor/publisher in his contacts with the mayor and other town leaders will become familiar with the policies of the local government, and will soon recognize ways in which he can encourage local progress.

On the more important programmes, the newspaper may want to run a "publicity campaign". This means planning a series of news items and articles to be published over a period of time. The editor could plan a campaign on home gardening for instance, to begin about a month before the planting season. This would be the best time to remind the public to buy their seed, where to get it, the cost, etc. An article on preparing the ground could follow. A week or two later, a story about gardens being planted by well-known villagers would keep the subject alive. Prizes might be offered for the best garden, and the newspaper could publicize this. The "power of the press" as it has been called for many years can serve the public in no better way than to lead the people in constructive action. The good results of public service press campaigns will make the editor/publisher and his staff justifiably proud.

9. Weather. The weather is the most popular news subject of all. Everyone likes to know how hot or cold it is, or will be, and what the weather is in other parts of the country compared to local weather.

If there is a weather station in your region, or if you can get reports of national weather by radio or otherwise from the capital city, publish weather stories when you can. Here are some of the facts that you might gather: temperature and rainfall since last issue; weather forecasts; records and comparisons with other years.

10. Year-end reviews. A few weeks before the end of the year, many editors gather facts and figures for a "year-end review" story, or several stories. A "year-ender", as it is sometimes called, tells about the most exciting news that happened during the past year, important community projects that were completed or started, and then goes into what might happen or be done in the coming year. This is a useful type of story, and one so large and important that you may wish to publish a special issue for it.

To gather information for the year-ender, look back through all the old issues of the newspaper to find the outstanding news highlights. Interview officials in agriculture, health, education, police, etc., to find out what their most successful projects were. Find out from the leading town officials what their projects are for the next year. The future part of the year-ender is probably the most interesting to the reader.

If your story is very long, you may want to divide it into two or three sections to run in several issues. Plan your year-ender in advance and have all the facts ready. You might publish it exactly on the first day of the new year in a special issue. Print a number of extra copies, because there will almost certainly be many requests for them later on in the year.

Editing your newspaper

The publisher is the person who owns the newspaper. On a large newspaper in the city he will have assistants to take care of the two main departments - the business side (advertising, subscriptions, bookkeeping, etc.) and the editorial part (news, editorials, illustrations and headlines). The editor is in charge of the editorial section, and under him work the various reporters, sub-editors, artists and photographers. On the small commercial rural newspaper, the publisher will probably be his own editor, reporter, and perhaps business manager too. It is quite possible that he will have the good fortune to have some member of his family assist him. In either case, he will be the editor and will have to "edit" each issue of his newspaper.

1. Checking content. Editing consists of several kinds of work, but the most important of these is to see that each story is correct before it is put into the newspaper. When it is printed, it is too late to make any changes. Therefore, all stories must be edited carefully before they are printed in final form.

While checking a story, the editor must read it slowly to see that grammar, spelling and punctuation are right. Remember what we said about reviewing a story. Check for (a) editorializing, (b) accuracy, (c) completeness, (d) clarity, and (e) brevity. And do not forget about libel.

2. Style. A "style" should be followed for the use and spelling of certain words, capitalization of words, and other usages. For example, you should not write "$5" in one place, "$5.00" in another, and "five dollars" in still another part of the paper. All are correct, but every newspaper should have a style and follow it in each issue. You can probably get a style book from another newspaper, or you can make your own as you go along. Whatever style you choose, be consistent.

3. Futures book. Whether it be called an "assignment book", "calendar" or "futures book", the editor will need some way of remembering

important coming events. He should know everything that is going on in the town. While talking to many people every day, he can make notes of forthcoming news events. When he returns to the office, they should be written in a Futures Book.

After his newspaper has been publishing a year, he can review the old copies for news leads. Much news is seasonal, like agricultural harvests, football seasons and tax payments. They happen at the same time of the year. By spotting them in advance, he can note each event in his Futures Book in a way that will remind him about two weeks ahead.

4. Editorial writing. This is a time-honoured job of the editor. We have already described this in some detail, so let this just be a reminder that you are the "voice" of the town. Try to make your editorial as truthful, useful and instructive as you can. Before you make a judgement, be sure of all the facts. Know both sides of an issue before you state your view. Write fairly, and you will gain the respect of the community. You may sometimes invite the mayor, or other high official, to write a "guest" editorial.

5. Balance. It is the editor's task to see that a proper balance of news is published. There should not be too many of any one type of story. A variation of news brightens the paper and offers something for many kinds of readers. Try and maintain a balance between these kinds of stories: local, national, features, sports, society, political. If you have more of any of these than you need, maybe some can be saved for the next issue.

6. Deadlines. The newspaper should be ready for distribution at the exact time and date scheduled each week. In order to do this, the editor must set certain "deadlines". A deadline is the time that a job must be finished. You will have to set a deadline for all news to be written. Another one for it to be typed for printing, and one for the whole newspaper to be printed and distributed. Whatever these deadlines are, it is important that the editor keep closely to them. He and the newspaper will then gain a reputation for dependability.

7. Writing the headlines. Every story no matter how small, must have a headline to describe and introduce it. There is not as much room to do this as you would like to have. However, one line (two at the most) should be enough. The headline should be eye-catching and attract the interest of the reader. It should give him an idea quickly of what the story is about.

Put action into each headline by including a verb. For example, instead of writing a sports head like "Football Game", it is better to say, "Fairville Footballers Beat Pleebo"...or, in place of "New School", write "New School Opens in Midland Today". As we have said, try to use only one line for each head.

Long stories of one column or more should be broken in half with a sub-head. This is a very small headline and may have only two or three words. Unlike the main head, the sub-head does not always have a verb. Whereas typed main heads should be underlined for emphasis, the sub-head should not be underlined. This will keep it from looking like a main head and thus confusing the reader.

Useful points to remember:
(a) Each headline should be a sentence. It should contain a subject and a verb. It should say the same thing the lead says but in a very few words....it should give a brief summary of the highlights of the story. (b) "Label" heads, like "Football Game", should be avoided. They are inactive and do not tell what is happening. (c) Leave out the "the's" and "and's". Replace "and's" with commas or semicolons. Heads written in capitals ("caps") and small letters (called "lower case") are much easier to read than those that are made up entirely of capitals. Some all-cap heads are good for lead stories on page one and to give a variation with cap and lower case heads. (d) It is much easier to print your headlines even with the left margin ("flush left") than to try to centre them exactly in the column. They look just as well, and some editors even think they look better this way. (e) Do not worry if some lines are shorter than others. The white space caused by short headlines gives the eye relief from the row on row of even type. (f) Be careful of headlines that are too big for your newspaper. Letters half an inch high (if you hand-letter them) are the largest that should be used on a standard size page (8-1/2 x 11 inches).

8. Standing columns? Readers will look forward to getting your newspaper in order to check cinema schedules, radio broadcasting times, notices of church and club meetings, sporting events, and other routine but useful news. They are small items but popular ones. They may be called "standing columns" and the editor must make sure they are brought up to date and included in each issue.

9. Date and volume number. The date and volume number must be changed with every issue. These are usually placed at the top of page one just under the title heading. The first issue is numbered "Volume I, Number 1". This may be shortened to "Vol. I, No. 1". Usually the Roman numerals are used for the volume numbers. The second issue would be "Vol. I, No. 2" and so on. At the beginning of the second calendar year of publication, the first issue should be number "Vol. II, No. 1", and the second "Vol. II, No. 2". It is easy to forget to change the volume number for the new year, so mark it on your calendar as a reminder.

10. By-lines. When a reporter or correspondent turns in a story that is very good, the editor might print the writer's name at the beginning, right under the headline. For example, "By Henry Smith". This is called a "by-line". By-lines encourage writers to work harder for more stories and write them better if they know they will get credit for them. Also, the reporter will be more careful with his facts and figures if he knows his name will be on the story for the public to see. By-lines will make a writer feel more responsibility for what he writes. They are a good device for

introducing members of the staff to the readers. This helps to personalize the newspaper and tends to make a warmer relationship between it and the community. One or two by-lines in each issue are a good idea, but do not put by-lines on every story. You may want to give by-lines to out-of-town correspondents in order to show their stories are not local ones.

11. Fillers. The editor must be planning ahead constantly. One problem he can solve in advance is what to do with the little space left over at the end of some articles which do not go to the exact bottom of the page. To fill this space he needs a supply of "fillers". These are short pieces of about three to six lines in length. Fillers can be slogans (Everybody Plant A Home Garden), clever sayings, proverbs, local facts and figures, reminders, or publicity for some local charity. Several of these should be collected and put in a "filler file". They should not have a time element, because they may not be used for weeks or months.

12. Masthead. This is a small, standing "box" (a straight line on all four sides) placed towards the back part of the newspaper. It contains information like the following: (a) name of editor and staff, (b) name of publisher and printer, (c) how often it is published, and (d) advertising and subscription facts. It may look something like this:

"Fairville News"

John Jones	Editor
Mary Brown	Assistant Editor
Robert Smith	Glenville Correspondent
Robin White	Business Manager (ads)
Harry Tarut	Mimeograph Operator

Published and printed by the Sun Printing Co., Fairville, every Friday. Subscriptions are 20¢ monthly, $2.00 yearly. Advertising rate is 50¢ per column inch.

The business side

1. Keeping supplies. The editor will want to make a weekly check on his printing supplies. He should keep in reserve at least a two months' supply of paper, stencils, ink, stencil correction fluid, staples, pencils and other items necessary for publishing the newspaper. These can be bought only in large cities, and since your town is probably a long way from one, supplies should be ordered a long time in advance. If you ask one of your local merchants, he would probably be willing to stock the items you will need. This might save much letter writing and travelling.

2. Storage of supplies. Stocks of paper should be stored in a cool, dry room and stacked flat. Handle paper carefully so that the corners of the paper and stencils do not become bent or torn. If so, they will not feed properly when they are being printed.

Store stencil sheets so the cartons are on the edge. Do not let them lie flat with heavy objects on them. Keep them out of direct sunlight in a room where there is not too much heat. Also keep ink supplies away from extreme heat. Care of supplies will reduce waste and give you better quality newspapers.

3. Keeping money records. Most rural editors are their own business managers. As such, they need to know how much money is coming in and how much is being paid out. A strict accounting is necessary to show you where the money goes and you may be able to take steps that will save costs. Also, you must know what money is owed to you and collect it.

Instead of storing figures of income and payments in one's head, or on little slips of paper put here and there, it is best to get a record book that can be used for several years. On the left hand side of a double page record all the money received, showing date, person paying, reason for payment, and amount. On the right hand page record all expenditures - date, person, reason and amount. The difference between the totals is the balance. If receipts are more than expenses, that is the profit.

You will also need a book to record all orders for advertising and subscriptions, so that you will know when and where to send out bills. Some of your readers will prefer to pay for your paper, a whole year in advance, and you must remind them when their subscription is due for renewal.

Community newspapers can be good money makers, especially if you work hard to get advertising and sell newspapers. It can be a business just like a store. You are selling news, entertainment and advertising services, and are entitled to payment for them. But editors must be business-like and keep good money records.

4. Advertisements. Without money from advertising, most newspapers could not go on printing. Because of the low cost of mimeo printing, institutional newspapers may not want to bother with collecting and printing ads. But even they will find the extra income very useful. With it they may buy a new mimeograph machine, typewriter, add more pages to the newspaper, and perhaps even pay small salaries for editorial and printing help. It is hoped that the goal of the institutional newspaper will be to train the staff and some day make it a self-supporting, community business enterprise. If so, the experience of handling the business affairs involved in advertising will be valuable.

By printing advertising, you are giving a service to both the readers and the local business people. The average reader wants to know what is being sold where, and where he can get the best value for his money. The merchant finds he makes more money from ads because more people come to his store and his sales are bigger. Not only the shop keepers, but cinema houses, religious groups, and government offices may give you advertising.

Regular visits must be made to advertising prospects. This should be done several days before the newspaper publishes. Some clients may give

you "standing" ads which do not change and are run several weeks or even months without stopping. Some advertisers will come by your office to hand in ads, but if possible, you should have a business manager or make regular visits yourself to every prospect. There should not be a problem, of course, in getting too many ads, because you can always put in extra pages in your newspaper to print them. Do not overlook prospects in nearby towns where the newspaper is distributed. Also, there are many national advertisers in the capital city who may give you ads if you ask them - the ciragette, soft drink, clothing and other companies to name a very few.

(a) What to charge. This will have to be decided by your according to the local business situation and the size of your circulation. Here are some examples of the different types of ads and what other rural newspapers have charged:

(i) For small, one-column, typewritten ads about one-and-a-half inches deep, $1.00 per insertion. If the advertiser wishes to run the ad in, say, six successive issues, you may give him a special rate of $5.00 for the six.

This may give you a standard, a measurement on which you can base charges for larger ads. For example, $1.75 for a three-inch ad. There are about five or six lines in the usual one-and-a-half inch ad. Advertising charges are usually stated as so much per inch or so much per line.

(ii) Half-page, or full-page ads are not unusual. They may be bought by merchants on special occasions. If you hear that a merchant is going to receive a large shipment of new goods, suggest to him the value of announcing this in your newspaper with a full-page ad.

In the standard-size mimeo newspaper, 8-1/2 inches by 11 inches, the columns have about nine inches of type in each. This makes a total of 18 inches of type on one two-column page. In this 18 inches you can put 11 ads that are 1-1/2 inches deep each, allowing some space for border lines. At $1.00 per ad, this would come to $10.00 or $11.00 per page, if you sold the ads singly. You might reduce this price to about $8.00 for a full-page ad, and about $4.50 for a half-page ad.

(iii) Illustrated, or picture ads, are the best. Your readers will see and remember the illustrated ad. But it takes time to draw the picture, and so you should charge more. If a simple three-inch ad brings $1.75, the charge for the illustrated three-inch ad might be about $3.50. Much depends on how much time you have to take in drawing the picture.

If you want to do many illustrated and specially lettered ads, it would be wise to buy the tracing models sold by the mimeograph companies. They give a wide selection to choose from. They are made by professional artists and will add to the good appearance of the newspaper.

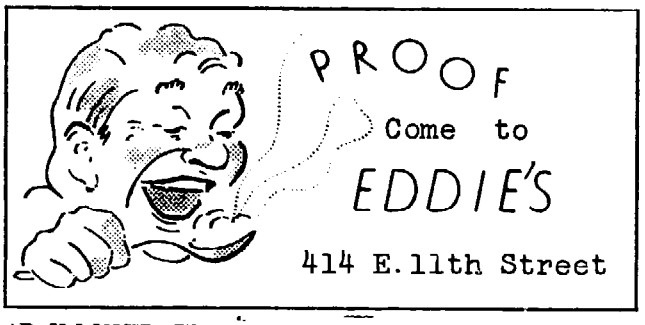

AD ILLUSTRATIONS

A simple line drawing can make an advertisement much more effective. Increased store sales will cause the merchant to advertise more, thereby increasing the income of the newspaper.

A word of advice - treat all your customers the same. Set your prices and make the same standard for each advertiser. When a merchant buys a three-inch ad, make sure that he is given the full three inches, not two-and-a-half. Be business-like and keep good records of your income and payments.

(b) Writing the ad. The merchant may prepare the wording of his advertisement, but is more likely to want you to do it for him. (i) Space is so small that ads must be written in a few words. (ii) Use words that have action. What you write must appeal to the reader and attract his eye. (iii) The ad should contain a "selling" message...make the reader want to go to that store the next day and buy what was advertised. (iv) Vary the content from week to week if possible. (v) Make each ad clear, neat and easy to read.

(c) Ad display. (i) It is important to make the ads look different from the news and other printed matter. The reader does not want to read an ad, thinking that he is reading news. Also, it is better to have the ad look striking. For these reasons, the ad might well be enclosed in a box of "stars" like this; or some other design:

```
*************************************
*                                   *
*                                   *
*      Union National Bank          *
*        Main Street                *
*                                   *
*                                   *
*    Local And Worldwide Banking    *
*                                   *
*                                   *
*  Open A SAVINGS ACCOUNT - 3% Int. *
*                                   *
*                                   *
*************************************
```

It is best not to enclose an ad in straight lines, because these are used to make a news "box" which should be reserved for news or other editorial items. (ii) Ads should have a lot of white space in them. (iii) Do not put ads on the front page. (iv) They should be scattered through the other pages among the stories and other editorial material. An alternative to consider, is to "classify" all small ads, and place them together in a group.

(d) Special advertising issues. One way to bring in extra advertising income is to plan special advertising issues. These go well at times like New Year, and other national or big local holidays.

You can work on this a month or more in advance. Go to the merchants with your plan. Offer special low rates for large spaces. Try to write the ads in a way that will connect them with the special occasion. Get a few stories and features which do not have a close time element, and use them alongside the ads. In this way you can put together and print several pages in advance. Then you will not be rushed on the usual day of printing. Special issues offer an ideal time to use two or three colours in your printing.

Remember, the merchants who support your newspaper should have the best advertisements you can prepare for them. The better value they get from their advertising, the more likely are they to keep on advertising - which is necessary for the future of your paper.

Copy preparation

After the news has been gathered and the stories written and the advertising collected, the hardest part of the work is over. The next step is to arrange the stories in the right order, type them on a stencil and print them. This work is mostly mechanical and can be done well and quickly after a little practice.

"Copy" is the newspaperman's word for the typed or long-hand written story. Clean copy - a story that can be read easily by the person who types the stencil - is necessary so that no errors will be made in re-typing. Here are some simple rules to follow in typing or hand writing the first copy of your story before you put it on the stencil:

1. Write on one side of the paper only.
2. Double space between lines. This will give you room to make corrections or changes.
3. Start the story about one-fourth of the way down the page. This gives room at the top to write the headline later. You may also want to write a note in this space to the stencil cutter.
4. Leave good margins at the bottom, left and right sides. Later, you may want to write a note or make changes in this space. It is also easier for the stencil cutter to read the copy if the page is not too crowded.
5. Indent the start of every paragraph.
6. If the event took place in another town, you should include a "dateline". For example, "HIGH TOWN, July 20 - Local elections will be held soon for the office of..." Note that the name of the town is in caps.
7. As you write, you can save time by crossing out mistakes. Do not bother to rub out wrong words in the first draft of your story. But when you copy on to the stencil it must be perfect.
8. After writing, re-read the story slowly to see that it is correct.
9. Always make a carbon copy to keep in your file. The first copy may be lost. Editors often put the carbon on a nail spike on their desk, so they can quickly refer to it. This is especially helpful if there is a follow-up story later on.
10. When the story is written as outlined above, you are ready to type it on the stencil. This time it will be single spaced (no space between the lines).

The layout

1. Page make-up. When all the news, features, editorial, and advertising copy are in their final form (before stencilling), you are ready to do the "make-up". Make-up is the arrangement of this material the way you want it to appear in the printed newspaper.

Let us suppose that your newspaper will be three pages and will have a two-column format. We might call it the "Fairville News" which will be published weekly. This is the first issue.

Starting at the top of the first page you will have the title "Fairville News" running all the way from the left to the right margin. We will discuss later how the title can be made with special, large letters, and in colour too, if you wish. The title might be from one to two inches deep.

Right under the title heading, there will be one typed line giving information like the following: "Vol. 1, No. 1 Sun Printing Co., Fairville, Nigeria July 20, 1964"

About three-fourths of an inch under this line in the left column you can put the headline for the first story. The most important story should be placed here, because it is in the place where the eye falls most easily when the reader looks at page one. Being an important story, it may have two lines in its headline. It will probably take up about two-thirds of the column. The next most important story should be placed next. The second story will probably be too long to finish on the first column, so you will have to continue it over to the top of the second column. The third most important story comes next. Each story must have a headline and they should all be underlined. There should be no advertising, editorials, sports or features on page one, only the most important spot news.

On page two, top of left hand column, there can be a continuation of the last story on page one, or, a new story can begin here. One or two ads might be put on page two. The top of the right column is a good place for an editorial. The lower left corner on the left column is a good place for the masthead, or, it might be placed on the top of the left column

MAKE-UP

Vol. I Acme Publishing Co. Jonesville, Ark , April 12 No. 2

Mimeograph Papers Can Put Most Important Story in left-hand Column

This Will Give Space To Complete It On Page One

Daily newspapers ordinarily use the right-hand column for their banner story, and the left-hand column for the second best one. However, because of space limitations in a mimeographed paper, it is often advantageous to reverse this procedure.

Reason? A printed paper has a whole column of fine print--500 words of it or more before it runs out of the column. This of course is not possible in a mimeographed paper. Therefore, by starting on the left side, you have as many as three columns in which to tell your most important story.

If your big story should happen to be a fairly short one, you can complete it in the top part of the second column, and leave room for a double-column spread to give weight to the bottom half of the page.

A recent newspaper article in a Boston paper states that scientific research shows that in spite of the fact that editors place their pictures and leading stories on the right side, reader preference is actually for the left side of the page.

Since this subject is apparently quite controversial, it would seem that both approaches to it should be considered and that the preference of the mimeograph newspaper staff should be the ultimate choice.

Put Short Items Of Importance In Boxes

Announcements to which you want to call attention, but which do not have enough news in them to merit a top head, will stand out if you put a "box" around them, and have the typist copy them in lines two spaces shorter than the usual line.

The box is also used for short, breezy human-interest stories.

A Double Column Headline Gives Weight To The Bottom Of The Page

A double-column headline has two advantages. It is easy to write, since it has room for a lot of words in it. This may permit you to work out a clever head that will catch the reader's attention.

The double-column head (known to make-up men as the "d.c.") is also useful in breaking up the masses of small type that frequently occur at the bottom of the page and give it a flat, dull, uninteresting appearance.

----o----

Keep Fillers on Hand

There is nothing more exasperating than a little empty space at the bottom.

USE ITALIC TYPE TO CONTRAST WITH ROMAN FACES

Where two headlines are likely to fall together, either beside each other or one underneath the other, the smaller of the two should be in italic type.

"Italic"is the printer's term for slanting type. He uses "Roman" to designate straight-up-and-down type faces.

Note how the slanting type on the headline to this story contrasts and stands out from the Roman head directly above it.

Now look over in the first column to see how the top head and the secondary head below it (this lower head is known as a "deck") seem to blend into each other, even though they are of different type sizes.

If the boxed item in the middle column had been higher, so that its headline was even with the other two, the effect would have been even more confusing, and the necessity even greater for putting one of the heads in italics. However, in this case the middle head would be in italic, since it would have the greatest need for something to make it stand out from the others which surround it.

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MODEL MAKE-UP PAGE

Make-up is not easy to describe in words, but this model gives an idea of several qualities that help to make the mimeo newspaper look clean and well balanced. Note the justified type, use of three columns, box in the centre, and variation in headline type. See also the little filler at the bottom of the middle column. The small type used for the main story was set on a Vari-Typer machine and not a typewriter. The special headline lettering can be done by anyone using the lettering guides.

on page three. A national story or two might go on page two or three.

Local and national stories of still less importance can be placed on page three, along with sports, social items, meeting schedules and advertising. Feature stories and news items that are not too timely and fillers should be held in reserve to fill out space as necessary. Try not to skip around and type pages out of order or may you have trouble fitting in all your copy.

The make-up described above, is very simple and straightforward. When you have had a little experience, you will probably want to experiment with more complicated and interesting page make-up. You have much more scope for variation and display, if you adopt a three-column format.

In this case, you may wish to have a double column main story on the front page. The heading and the intro. (that is, the first sentence or two of the story) might be typed over a width of two columns, and then the rest of the story appears in the one column size.

A double column story, particularly, will look better if you can hand letter the caption on the stencil, in the way described elsewhere in this booklet. This will enable you to use big letters, and give an attractive display.

The double column story need not necessarily be at the top of the page. It may be in the bottom left or right hand corner.

You might choose, too, to have some special announcement or important small item of news "boxed" for special emphasis. A cartoon or other simple illustration is another way of adding variety and display to the printed page.

It should be noted that all typewriters do not have the same size and shape of letters - for example, some are large, some "elite", some "italic". If you have access to more than one typewriter, therefore, you can get some variety in the appearance of your paper by using different type for various parts of each page.

The main thing to watch in a more complicated page make-up, is the need to obtain "balance" - in other words you do not want all the big letters, or illustrations on the same side of the page, so as to make it look lopsided.

The best way to learn about newspaper display and page make-up, is to examine carefully the front pages of the city newspapers, see how they get variety and balance in their presentation, and then experiment with your own paper. For practice, you could cut out some printed news items of various sizes, and then juggle round the clippings to see how they look.

When planning your page make-up it is best to prepare a "dummy". You take a blank sheet the same size as your newspaper, and rule up the columns and mark the space taken for the title. Then with a pencil, mark on the "dummy" where each item of news is to be placed, occupying one column or two columns, as you may decide. By counting the number of words in each story, and estimating the number of words to one inch on your paper (perhaps 35, but this depends on column width and size of type), you can judge quite accurately how much space each story will occupy. In this way you can plan your whole paper before you start typing the stencil, and you will know if you have enough copy to fill the paper, or have to leave some items out.

2. How to "justify" lines. The word "justify" means to have all the lines even, on the right-hand margin. You can have a good newspaper without justifying the lines. But if you wish some day to make your pages look neater, and your paper more professional, spend a little extra typing time and justify each line. Here is how it is done.

Set the typewriter stops to the width of the column - that is the length of line you want. Then type your story on a sheet of paper - not the stencil. If the line is short, fill out the extra spaces with a slash (/). (See example below.)

After the story is typed, go back and make a tick on each line with a pencil, where you can spread out the words (a space for each slash). Spread the ticks from line to line so that they do not fall together. Then type the stencil, leaving extra spaces where you have placed the ticks.

For example:

```
In preparing copy for
the duplicated newspaper//
it is necessary to set up/
a dummy of the news story/
in this manner. The slant
bars (/) at the end of the
lines indicate the number/
of spaces that must be////
added to each line when///
the copy is typed on the//
stencil.
```

```
In preparing copy for
the duplicated newspaper
it is necessary to set up
a dummy of the news story
in this manner. The slant
bars (/) at the end of the
lines indicate the number
of spaces that must be
added to each line when
the copy is typed on the
stencil.
```

See how much neater that makes the news column? These columns are the width for a three-column newspaper. To start with, we suggest that you use a two-column format. After you have gained experience with the two-column, non-justified format, you may like to experiment with justifying the type on page one of your newspaper. It takes a little extra time, but it improves the appearance a great deal.

Two-column or three-column formats are much better than just straight across-the-page typing, which is more difficult to read. Two columns break up the solid bank of type and makes the newspaper more pleasing to the eye. It looks more professional. It is also easier to write ads for the two or three-column page. You can put rules between the columns - that is vertical lines ruled on the stencil by hand, with a stylus, before you start typing. This is not essential, and you can leave a space equal to 3 or 4 letters, between columns, if you prefer.

Preparing the stencil

The stencil printing process, called mimeographing, uses a special coated sheet of paper on which you type. The stencil is placed on a round cylinder which is coated with ink. The paper to be printed is pressed against the stencil, and the ink from the cylinder goes through the little typed holes of the stencil and on to the paper. This is how your newspaper will be printed - the simplest and least expensive way that is known today.

Stencil paper is bought with a heavy piece of paper on the back to hold it straight. In the package of stencils you will find some soft, loose sheets of paper. These are called "cushion" sheets. The cushion sheet can be used several times, but the stencil can be used only once. Each time you type a stencil, the cushion sheet should be placed between the stencil and the backing sheet. The cushion lets the type cut deeper into the stencil which results in blacker print.

All the trouble taken to gather and write the news is wasted if it cannot be read due to careless stencil cutting. It is therefore important to follow these rules closely:

1. Cleaning the typewriter. It is necessary to clean the typewriter type well before typing the stencil. A well-prepared stencil will give good printing results, but a badly cut stencil will give printing which is hard to read. To make sure your typewriter is clean: (a) use a stiff brush and cleaning fluid to clean the type; (b) chop strokes that scoop out the dirt are better than side-to-side cleaning strokes; (c) be sure the "cavity" letters like "e", "a" and "o" are well cleaned; (d) do not let the cleaning fluid get on the stencil. Dry the type off well before typing the stencil.

2. Adjusting and typing. (a) Do not type on the ribbon when cutting a stencil. Move the ribbon adjustment to the stencil cutting positions which is usually marked on the typewriter by a white spot. (b) Place the cushion sheet between the stencil and the backing sheets and put all three into the typewriter as you would a single piece of paper. Line them up straight. (c) A firm, even typewriting touch is the best and will cut the letters deep enough. Hit the capitals "M", "W" and "E" with a slightly harder stroke. A slightly lighter stroke should be used on "c", "e" and "o" to avoid chopping out little round holes.

3. Illustrations and headlines. You may make picture drawings and large letters for title headings and headlines if you like. This can be done with a ball point pen or the special pen for this work called a "stylus".

(a) Place the stencil on a hard, flat surface; (b) put a piece of cellophane, like the wrapping on a pack of cigarettes, over the stencil where the letter or picture will be drawn. This will keep the stencil from tearing; (c) hold the stylus as if it were a pencil and write or draw through the cellophane on the stencil as you would on a piece of paper; (d) use a pressure which will penetrate the coating of the stencil but will not tear it; (e) where you have lines or letters that meet, it is best to move the stylus towards where the lines meet. Otherwise, the stencil may tear; (f) when you have finished, hold the stencil to the light. If it is not evenly cut, retrace the lines again that need it.

To obtain the best results, trace the drawing or lettering from a copy placed under the stencil. Place it against the window so that light will show through, or on a glass that has an electric light under it. This way, you can see better how to trace the lines.

You can fill in letters or drawings with dots or lines to make them appear more solid, or you can buy devices which help you to get this effect more easily.

The mimeograph companies sell model lettering and drawings that can be traced on to the stencil very quickly. There is a large selection to choose from. They do not cost very much. They also sell lettering and drawings already cut on stencils. To use these, you cut a hole in your stencil the size of the drawing, then paste the stencilled drawing over the hole. The companies are glad to furnish free examples of the lettering and drawings they have so that you can select what you need. They also have lettering guides, different kinds of stylus pens, and many other helpful items to make perfect illustrations. You should write for their free booklets or ask the nearest dealer for them.

Cartoons and other drawings are highly useful in attracting the eye of the reader. You do not have to be an expert artist to draw a cartoon. Just sketch down your ideas on the stencil with a ball point pen. When you have an idea for a cartoon, or if you see some in other newspapers or magazines, write them down or cut them out and store them in a cartoon file. Drawings and special lettering are valuable in writing ads too. We have only briefly discussed the methods for making illustrations, and so it is suggested that you get the free booklets on how to do this.

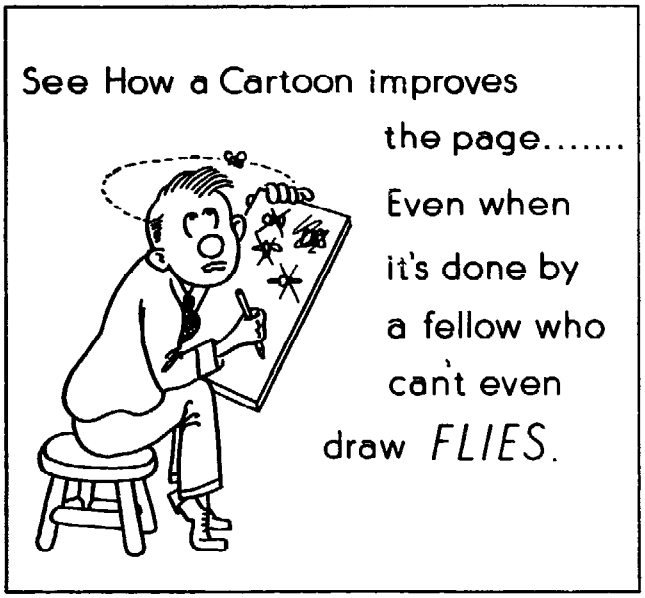

CARTOON DRAWINGS

Cartoon drawings of people are good eye catchers. A simple sketch can tell the story better than many words. The figure should be in action and perhaps saying something.

To save yourself the bother of making a new title heading drawing (or special lettering) for each issue of the newspaper, you will want to print a good supply ahead of time. These can be printed and stored in packs of about one ream each (500 copies). From 2,000 to 10,000 copies can be run on one stencil, depending on the quality of the stencil, how it is handled, condition of the printing machine, etc. It is a good idea to print the title headings in colour to make the first page stand out more brightly. The use of colour will be discussed later. If you desire to have a stock of more than 10,000 headings, you can arrange to have them printed by offset press in the capital city. The charge for this should not be high. By this method a first-class piece of art work for the heading can be reproduced any number of times, and saved for future runs.

4. Making corrections. After typing, re-read each word carefully to find any errors. Do this before you remove the stencil from the typewriter. If you make an error it may be corrected with correction fluid.

(a) Rub the error lightly with the round end of a paper clip or other smooth metal. This presses the stencil coating over the impression; (b) put on a light coat of correction fluid. Let it dry for about 30 seconds or one minute; (c) retype over the exact place to be corrected; (d) try to keep the correction fluid from sticking the stencil and cushion sheet together.

Correction fluid may be used to repair small holes and creases in the stencil. Always have a bottle of correction fluid by your side when you type a stencil. Read and follow the directions on the instruction sheet which comes with every package of stencils.

Printing

There are a number of different companies that make mimeograph machines. They all use the basic method which we have briefly described before.

There are highly automatic machines costing up to $800 each and inexpensive ones at $34.50 which are hand-cranked, hand-fed and simple to operate. For the beginner, we have suggested that a non-electric, inexpensive machine be purchased. No matter what make of machine you have there are certain rules that should be followed. Here are some of the basic ones:

1. Inking the pad. (a) Before putting the stencil on the drum, see that the pad is properly inked; (b) do not put on too much ink or it will drip from the cylinder when the machine is not in use; (d) clean spots of ink from around the machine, especially on those parts where the printed copies will touch them.

2. Putting on the stencil. (a) Tear off the hard backing sheet and throw it away; (b) mount the stencil on to the cylinder, being careful to smooth out all wrinkles. (Note that different machines need different stencil mounts - you must make sure they match.) (c) Run several sheets through the machine to see that the ink comes through all right; (d) if the copy prints too high or too low on the page, make the proper adjustments; (e) turn the crank with a steady, even motion. Do not stop half way on a page, because this will cause blots of ink; (f) when the printing becomes dim, the pad needs more ink. If the first sheets are poorly printed, either the pad is not inked properly, the ink has not yet worked through the stencil, or the stencil was not cut correctly.

3. Colour printing. A second colour in your printing (in addition to black) will attract attention probably more than any other device you can use. Colour gives a striking as well as an attractive appearance, if it is well used. You can have colour in your newspaper no matter what kind of mimeograph machine you use. In most ways, the simpler the machine, the easier it is to have two or three-colour printing. This is because there are fewer changes to make in the equipment of the hand-operated machines than the automatic, electric ones. If you have a coloured title heading stocked in advance, that is a good start.

You may want to plan colour for special issues of the newspaper. A national holiday or other big celebration is a good occasion. It will take a little more work to use a second or third colour, but you will have the time to plan for it in advance. You can even print some of the extra colour work a week or two ahead of the holiday. Colour is also very good for special advertising issues. You might arrange with an advertiser to print his ads in colour for an extra price.

The easiest way to have colour is by the use

of coloured paper. Here are some pointers about coloured paper:

(a) Some companies carry as many as 14 different shades of coloured papers; (b) be careful not to use coloured papers that are too dark, as this makes it hard to read the black type. Light colours are the best; (c) most coloured papers have less "show through" than white papers of the same weight. They are therefore good for printing on both sides; (d) do not overdo the use of coloured papers. Day in and day out, white is the best because it makes reading easier. Use colour for emphasis and variation on special occasions; (e) the cost of coloured papers is only a few cents more per ream than white.

A second way to have colour is by the use of coloured ink and a second printing.

(a) Type the stencil in the usual way, but leave a space where you want the second colour; (b) type a second stencil using just the part that you want printed in the second colour, say red; (c) print the first stencil in the usual way with the black colour; (d) take off the black ink pad and put on a red ink pad; (e) put the second stencil on the cylinder. Print on top of the sheets you have already printed black. The red will print in the open spaces you left on the black sheets; (f) a third or fourth colour can be printed by making stencils number three and four for the same page.

4. Stencil filing. Newspaper stencils should be filed for about six months. You may want to print some of them again. So it pays to keep them in good condition in a safe file as follows:

(a) Remove the stencil from the machine; (b) lay it flat on a sheet of paper and blot it several times with another sheet. This will remove most of the ink; (c) smooth out all wrinkles and lay a plain sheet of paper on top. Place these in a file folder; (d) put a duplicate copy of the printing on the outside of the folder. This will tell you quickly which stencil is inside; (e) do not store near extreme heat.

5. Care of the machine. Printing machinery will give years of good service if it has been well cared for. It will give trouble and produce poor printing within months if it is not cleaned and oiled properly.

(a) When the printing run is finished, remove the stencil from the cylinder. This will keep parts of the stencil from sticking to the ink pad, which will cause light spots because the ink cannot get through; (b) place an oiled paper over the ink pad. This will not stick to the pad and will keep the dust away; (c) keep the machine clean and oiled. (See directions which accompany the machine.) (d) Clean the impression roller once a month. Remove ink with soap and water. Do not use gasoline or other chemicals. Ink and chemicals are bad for the rubber roller. Make sure the roller is dry before using; (e) place the cover on top of the machine. Keep it there always when the machine is not in use.

CONCLUSION

This chapter has set out in very simple form, some of the basic rules and principles for reporting, editing and publishing. It is only an introduction to a very big subject, on which many books have been written.

We have tried to show that it is not hard to start a mimeo newspaper. But this is only the beginning. It is a first big step, but there is much more to learn and much progress to be made toward bigger newspapers and better equipment.

It is hoped that those who have gained an entry into journalism through mimeo newspapers will extend their knowledge and experience and will always uphold the traditions of a great and challenging profession.

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DEPARTMENT OF PUBLIC WORKS

SELF-HELP AND RURAL IMPROVEMENT ROADS

CONSTRUCTION MANUAL

(1976 EDITION)

ADVISORY SERVICE TO LOCAL GOVERNMENT COUNCILS

PUBLIC WORKS DEPARTMENT

LOCAL GOVERNMENT ADVISORY SERVICE

RURAL ROADS MANUAL

SIMPLE ENGLISH VERSION

A CONSTRUCTION AND MAINTENANCE BOOK FOR OVERSEERS

OF RURAL IMPROVEMENT OR LOCAL GOVERNMENT COUNCIL ROADS.

THIS BOOK USES METRIC MEASURES.

WHAT YOU WILL FIND IN THIS BOOK:

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B. Drainage — Page 7
C. Surfacing Material — Page 13
D. Formation of the Road — Page 16
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FOREWORD TO THE SIMPLE ENGLISH

EDITION OF THE ROAD CONSTRUCTION MANUAL

Exactly three years ago the Local Government Engineer of the Department of Public Works produced a comprehensive Manual dealing with the construction and maintenance of Rural Roads. It was issued to the Councils. They read it and asked for more copies. The success of the book made us very happy. Knowing that we have many keen students of our book, we decided to improve on our work. Readers brought to our attention shortcomings of the first edition, making it possible to make improvements. At the same time the localisation of Council Advisors and the knowledge of technical English by Council staff made it apparent to us that while broadening the technical contents of the book, we should also attempt to remove less known technical words and replace them with every day English. Mrs. Rock, the wife of our Local Government Engineer, being a highly qualified teaching expert, came to our assistance. Painstakingly she went sentence by sentence, paragraph by paragraph and turned all the technical paragraphs into correct but non-technical sentences. The result of this excellent work is offered now back to the Councils as the Second Edition of our original Manual.

I am proud to be associated with this book and hope that readers in the far distant areas of our country, far from assistance and advice of professional engineers and experienced road foremen, will be able with the help of this book, get most of the answers they may be looking for in solving the never ending problems of road builders. At the same time I invite all readers to send any constructive criticism and advice they may have so, that if needed, we may be able in time to issue a third edition of the same book brought up to date at some future date.

Good luck.

E. ROBIN SAFITOA
Director of Department of Public Works

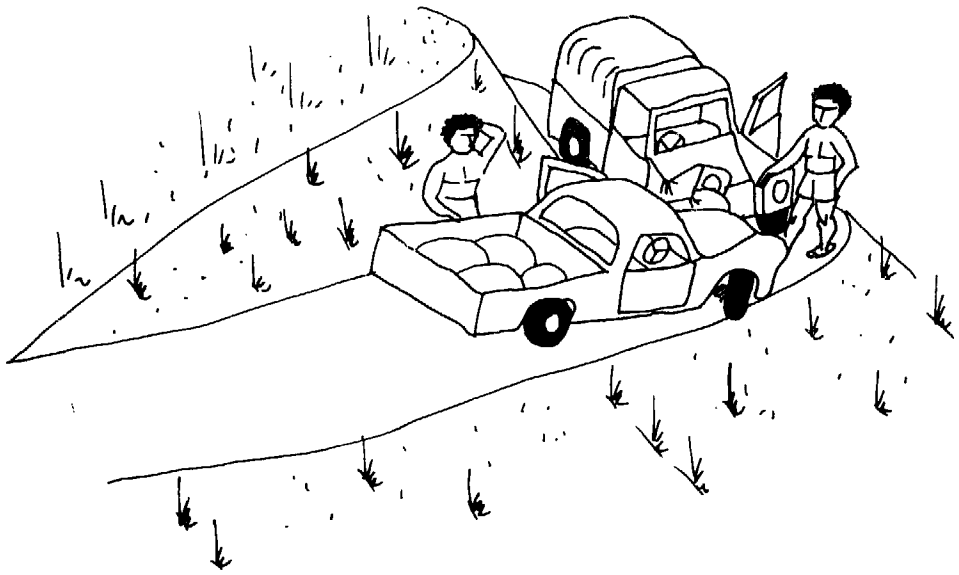

For these reasons, Councils and the people should not try to build too much new road at one time. It is better to build a few kilometres properly, than to try too much and do it badly. Bad roads should be improved in small sections. These are not too hard to get finished. When the old roads have been fixed, new ones can be added to them each year.

Do not waste money. Ask the Local Government Engineer.

It costs a lot of money to improve a road and build permanent bridges and culverts.

If these things are not done the right way, the improvements will not be very good and the money will be wasted. A good council does not want to waste its money or the Rural Improvement money that the Government gives.

Two things will help a Council not to waste money: First, roads should be built in the fashion this Construction Manual talks about. Secondly, a Council can get help from Local Government Engineering field staff in its own District, or write to the

Director,
Department of Public Works,
P.O. Box 1108,
BOROKO.

making the letter "Attention : Local Government Engineer", and ask for technical help. The Local Government Engineer can send surveyors, men who will measure high hills, and who will tell the Council the best place to build a road on a high hill.

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Many roads in Papua New Guinea are not good enough

All round Papua New Guinea there are plenty of roads that have been built by village people. A lot of these roads are no good and others can only be used some of the time. Many months of work, and much of the money of the Government, Councils and people have been wasted on roads not built properly.

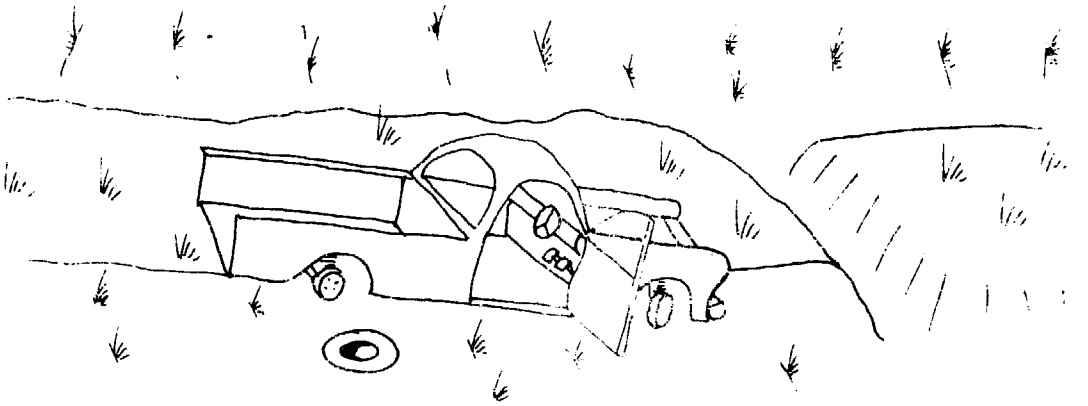

This has often happened because the people building the roads did not know the right way to do the work. The other big trouble has been that there were not enough skilled men, or supervisors, to show the people what to do and stop mistakes from being made. This book, called a Construction Manual, has been written because the Government wants to try to help the people build better roads, and to talk about things that can go wrong when roads are being built.

As well as the need to save money and work from being wasted, there are other reasons why self-help roads should be built better.

Good roads do not need a lot of maintenance.

The first reason is maintenance. When we talk about "maintenance" in road work, the word means work that is done and money spent to fix up a road or bridge when it has been worn or damaged, either from being used or by too much rain. Section 7 of this book is about maintenance. You can read about it on pages 81 to 89. Some money is being given by the Government to help Councils maintain their roads, but Councils will have to help too with their own money and work. There will always be a shortage of money for this work, but roads built properly, the way this book says, will not cost as much to maintain as roads built badly. Bad roads on steep slopes will cost a lot more to keep in use than roads that were well made in the first place.

Good roads are safer

Also, a well-built road is safer than a badly built one, and people are not so likely to get hurt in accidents, or have their cars and trucks damaged, broken or stuck.

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The Local Government Engineer can also send engineers, men who plan bridges and causeways that will go over rivers.

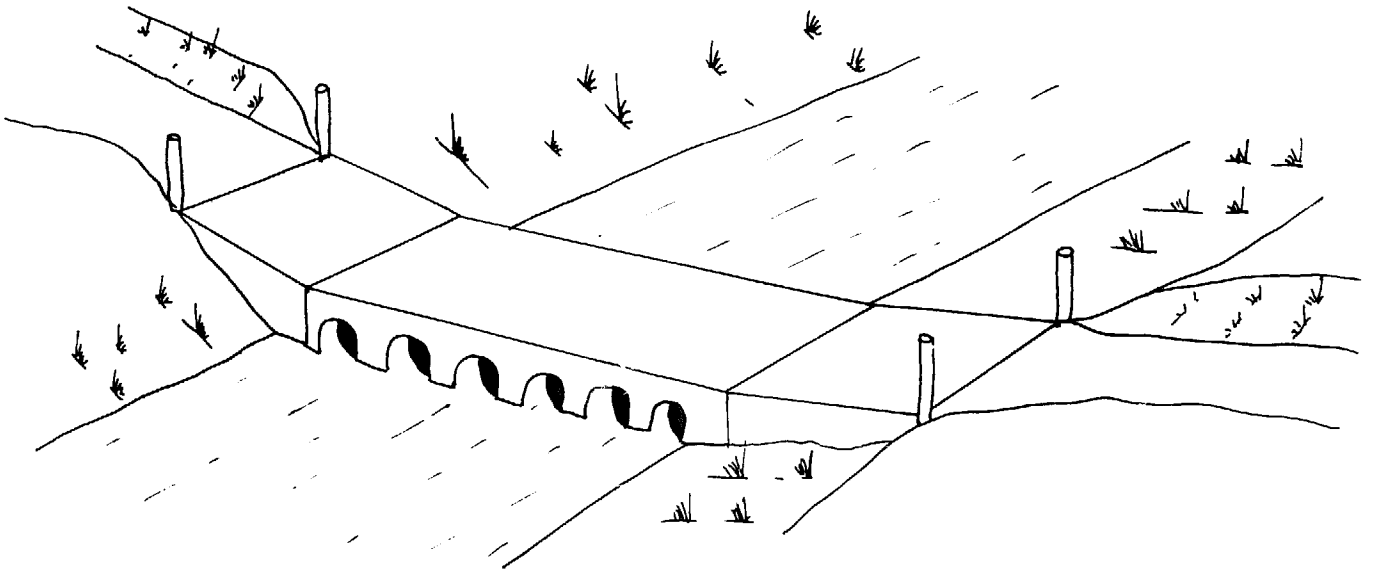

The Council does not have to pay these men for their help. The Local Government Engineer sends them out to help Councils build roads that are being built with Rural Improvement Fund money.

If you want technical help from surveyors and engineers for a job that is not paid for by Rural Improvement Fund money, you will have to wait a while.

<u>It is not good for Papua New Guinea to have bad roads.</u>

Councils can construct new roads.

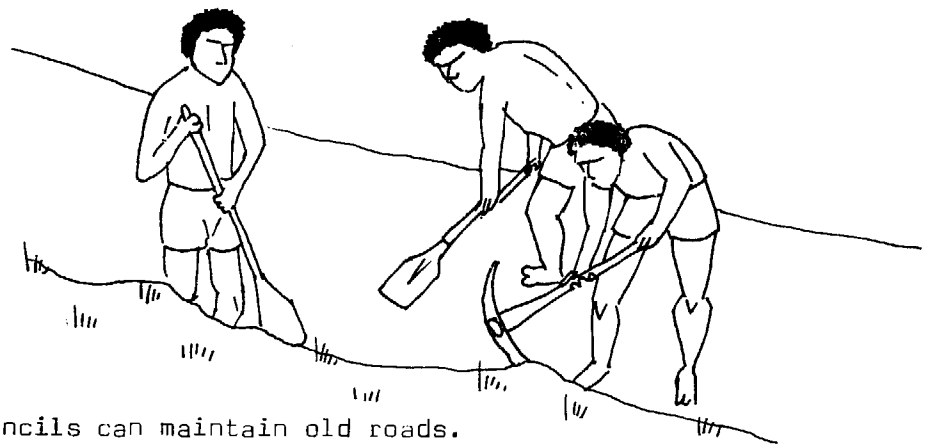

Councils can maintain old roads.

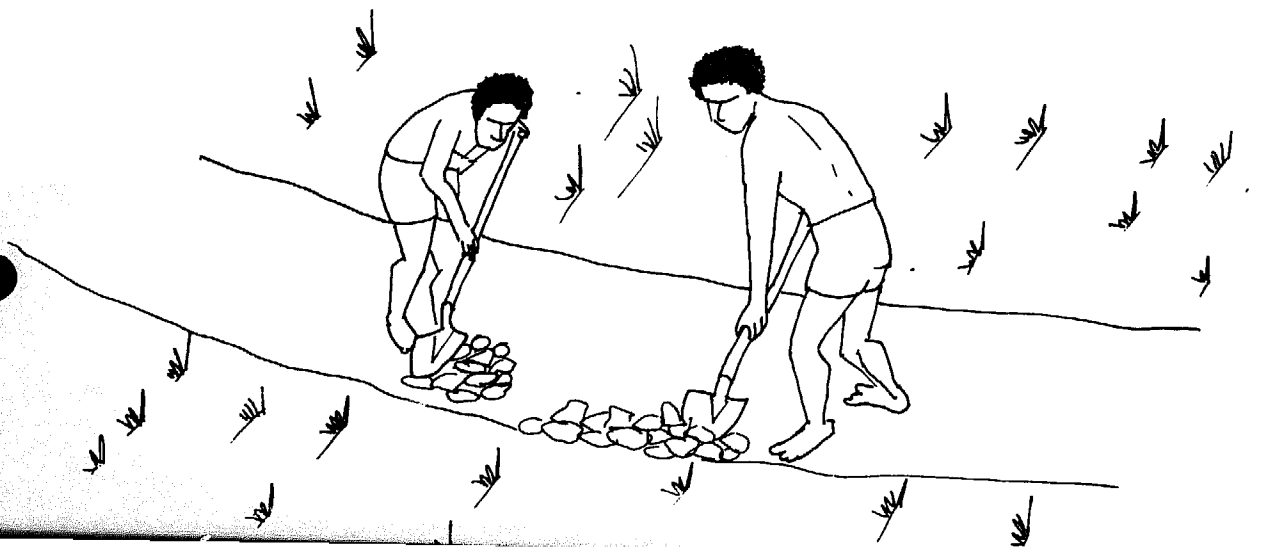

A. GRADIENT

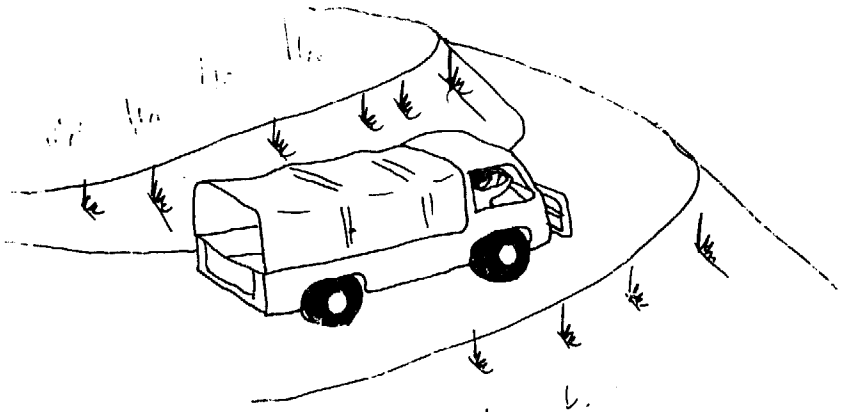

A Truck can easily go up this road because the road is not too steep. This road has a low gradient.

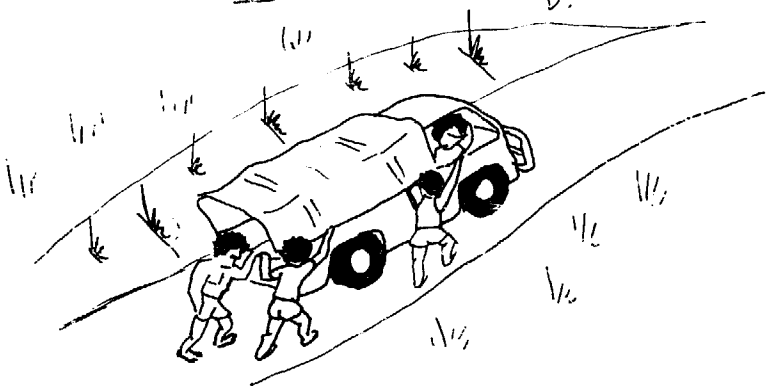

A truck cannot go up this road easily, because the road is very steep. This road has a high gradient.

The gradient of a road talks about the steepness of a road. If your first work on a road follows the right gradient, then you can easily look after the road and improve it later.

There are five reasons why you should not build roads that are very steep.

1. It is hard to improve a steep road. Suppose you want to make a small road bigger. If the road is not too steep you can just make the road wider. You will need some more money and work, but not too much. But if the small road is a very steep road, you cannot make it wider. You have to make a new road that is not so steep. This costs a lot of work and money.
2. Not all trucks can go up very steep roads. Suppose a truck tries to go up a road that has only a little bit of surfacing material on it. An ordinary truck can go up the road if it is not too steep. But an ordinary truck cannot go up the road if it is too steep. You need a 4-wheel-drive truck to go up a very steep road and 4-wheel-drive trucks cost a lot of money.

SECTION 2 : GENERAL TALK ABOUT HOW TO CONSTRUCT ROADS

This book is to help people supervise work on self-help and Council roads. If you have a hard problem that this book does not help you with, men from the Department of Public Works will help you. You can ask the District Works Officer or the District Works Engineer in your own District, or you can write to the Local Government Engineer in Port Moresby. His address is on Page 2.

What are these self-help roads used for?

They are built so that a man can drive a truck to a town or to a Council or Sub-District Office, trade stores, aid post, coffee co-operative, cocoa fermentary, air-strip, wharf, resettlement area, quarry, ferry, mission headquarters or school, or to join a Highway or big road. Papua New Guinea needs a lot of roads like these, but there is not much money.

Four things are important when you build Council roads and Rural Improvement Roads.

These roads should be :

1. Cheap to build
2. Cheap to maintain
3. Safe
4. Open for trucks to use in most weather

How can Councils build roads that are cheap and safe and almost always open for use?

The things that help most have special names. Here are five of these names.

A. Gradient - the steepness of road. You can read about this on pages 6 and 7.

B. Drainage - getting water off the road. You can read about this on pages 7 to 13.

C. Surfacing or Sheeting - putting material on the road to make it stronger. You can read about this on pages 13 to 15.

D. Formation of the Road - how wide it should be and the distance between the drains. Read page 16.

E. Horizontal Alignment - building roads with no sharp bends. Read pages 16 and 17.

We will talk about these things one by one. First we will help you to understand them; then we will help you to learn how to use them to make roads that are cheap and safe and good roads.

Councils can upgrade old roads.

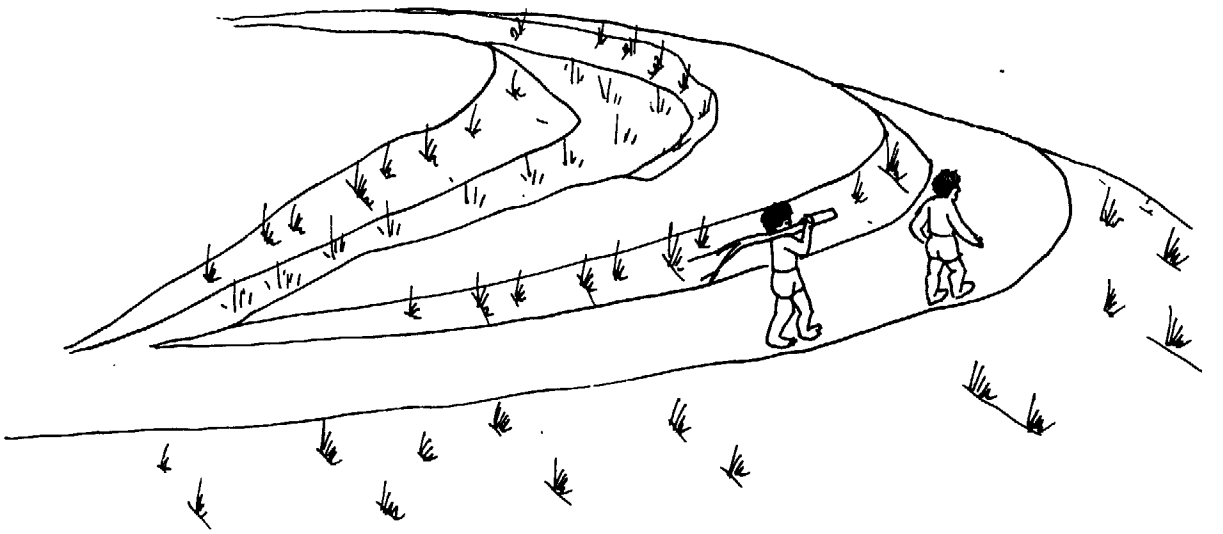

This book will help Council supervisors do these things well
In all this work, Councils need men who have read this Construction Book because it tells them the best way to construct roads, and maintain them and upgrade them. These men must understand this book and do what it says.

3. A truck has to work hard on a road that is too steep and it will damage the road. A truck has to work very hard on a steep road. This has two bad results. The first bad result is that the wheels throw out the loose surfacing material from on top of the road. This is dangerous. The second bad result is that the wheels work hard and they make deep holes and cuts in the road. You have seen the deep cuts that a tractor makes on a road that is steep or soft. The village people or the Council men have to keep on working hard to fix the road. Also, if there is not much surfacing material in that area, you do not want to waste it by fixing up the same roads all the time.

4. Very steep roads are dangerous. When you are going down a steep hill in a truck, you have to go down very slowly. You put on the brake to go slow, and this can make you slide. Sliding downhill in a truck is very dangerous because you cannot control the truck. You might have an accident. An accident like this can easily happen when there is only a little bit of surfacing material.

5. Rain water damages very steep roads more than it damages roads that are not so steep. Why is this true? When it rains, water falls on the road. The water runs off a flat road slowly. The water runs off a steep road very fast. When water runs off fast, it makes holes and cuts in the road and it washes off the surfacing material.

If a councillor wants you to build a very steep road because he says it is a short road, will you be able to tell him why his idea is not a good one? I have given you five (5) reasons why very steep roads are bad. I will say them again now:

1: It is not easy to make a very steep road bigger:

2: Not all trucks can use a steep road.

3: A truck has to work hard on a steep road and the truck damages the road.

4. Very steep roads are dangerous when you go downhill with the brake on.

5. Rain water falls off steep roads very fast, and this damages the road.

B. DRAINAGE

Water is bad for roads.

Here are three reasons why water is bad for roads:

1. When it rains, trucks can get bogged if the water stays on the road.

2. Water that stays on a road makes deep holes and cuts in the road.

3. Water makes the ground near the road soft and loose. When the ground is loose, it can fall on the road and block it.

Can you stop these bad things? Yes, good drainage stops these bad things. Drainage carries water away from the road so that the water does not damage the road.

Here are four ways that good drainage can help you:

1. Good drainage gets the water off the road to the side before the water washes off the surfacing material and before it makes deep cuts along the length of the road.

Three things help you get this good drainage:

(i) First, you should build the road with a curved surface like the one in this picture:

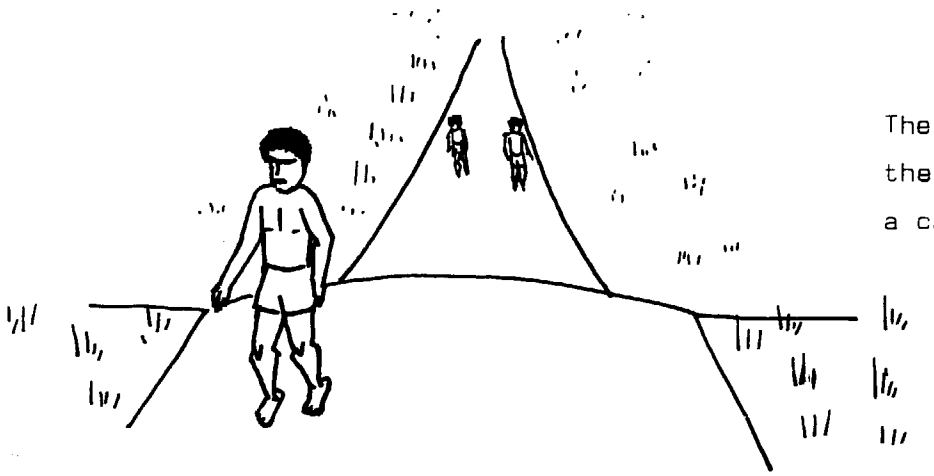

The rain water runs off the road with a curve or a camber like this.

(ii) Secondly, you build side drains. The water runs off the curved road into the drains, like in this picture:

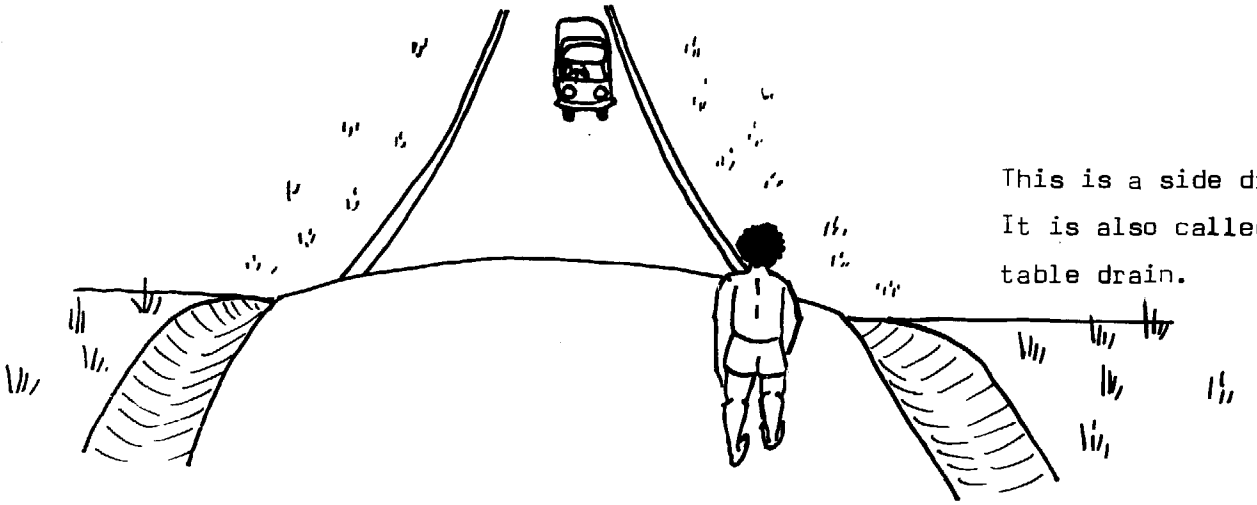

This is a side drain. It is also called a table drain.

You might need more than one catch drain. You might also need a relief drain for very heavy rain.

4. Good drainage prevents potholes before they start. When it rains, holes fill with water. When a truck wheel drops into a hole filled with water, the wheel makes the water splash up hard. The water washes away the ground around the hole. This makes the hole bigger. The hole can become a boggy patch. Good drainage carries away the water so that a hole is not made in the road surface.

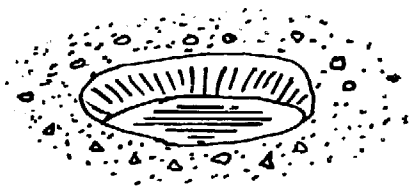

This is a small pot-hole.

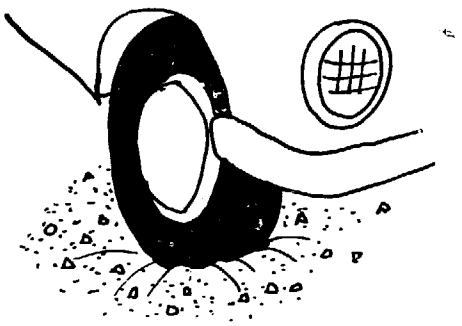

This truck wheel is splashing water out of the pot-hole.

This truck is stuck in the boggy patch that was formed.

Some roads are cut into a hillside in this fashion:

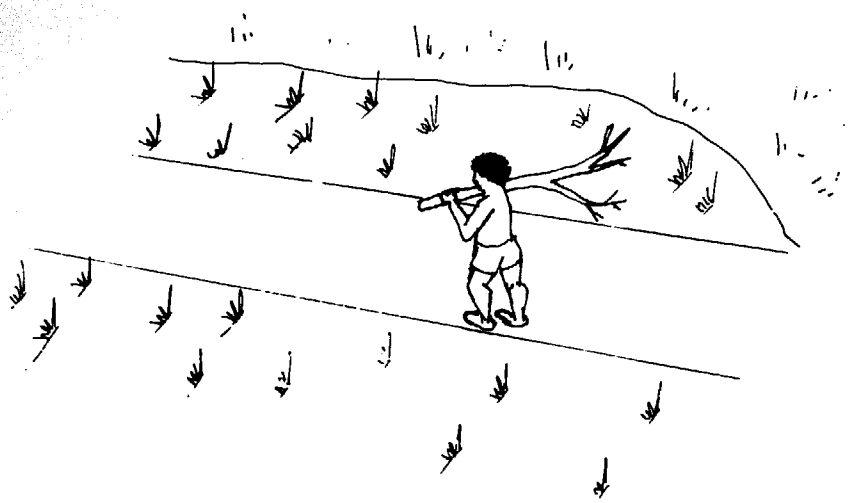

This picture shows a bench-cut road. It is cut into a hillside.

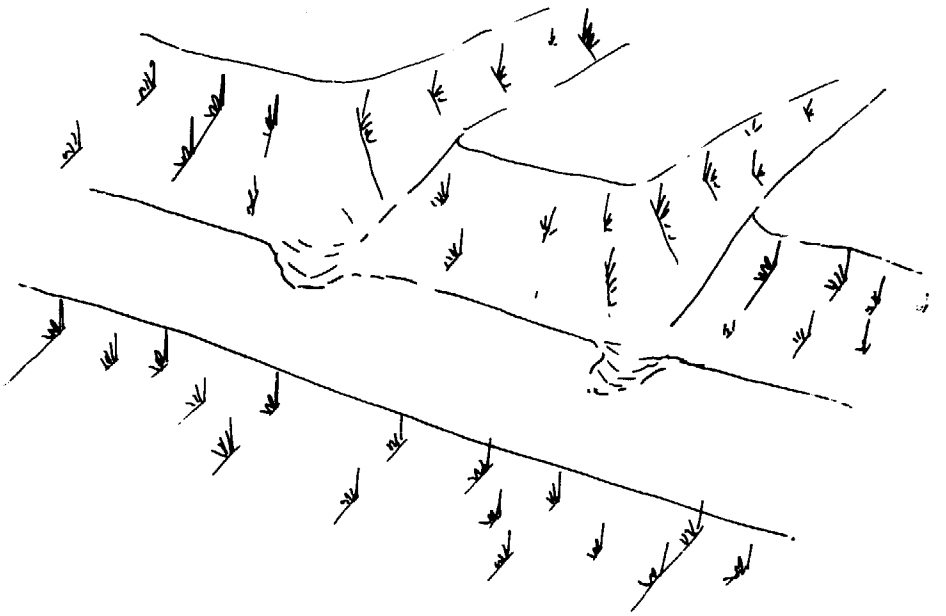

The banks above the road can be washed away. (This is called erosion). The road itself will also wash away.

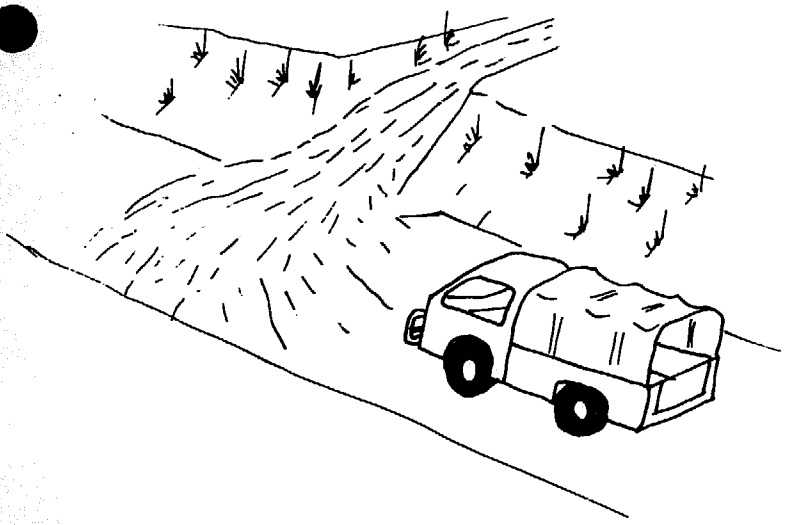

The ground above the road can become loose and slip on to the road. This can block the road. This is called a landslide.

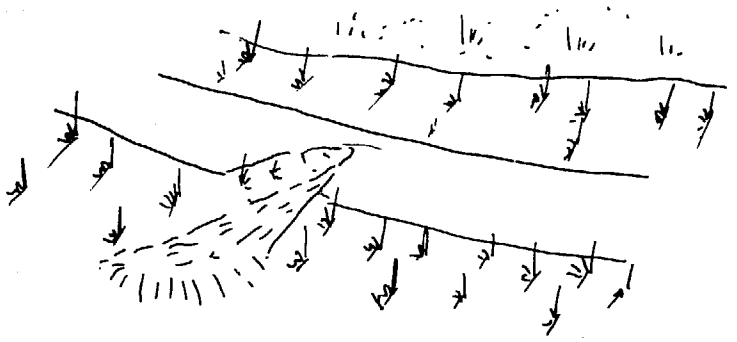

This is a different sort of landslide. The road is loose and has fallen down the hillside.

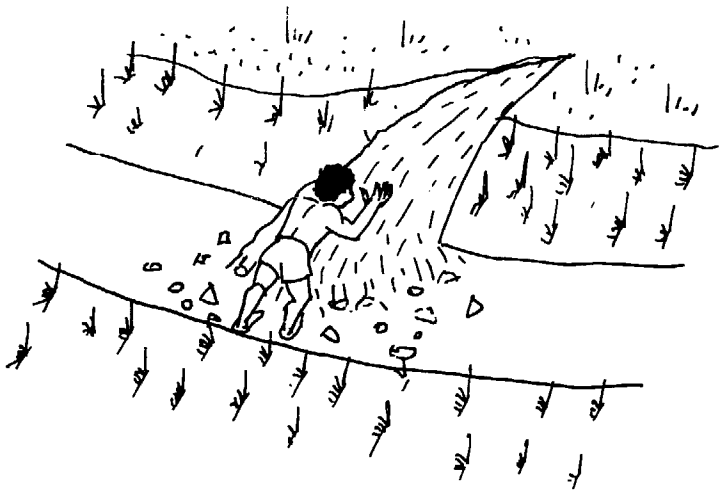

Can you stop a landslide?

No, you cannot stop a landslide, when it has started to slide.

But you can help prevent a landslide. That means that you can help to stop it before it starts. A good road builder will help prevent a landslide by making a catch drain above the road.

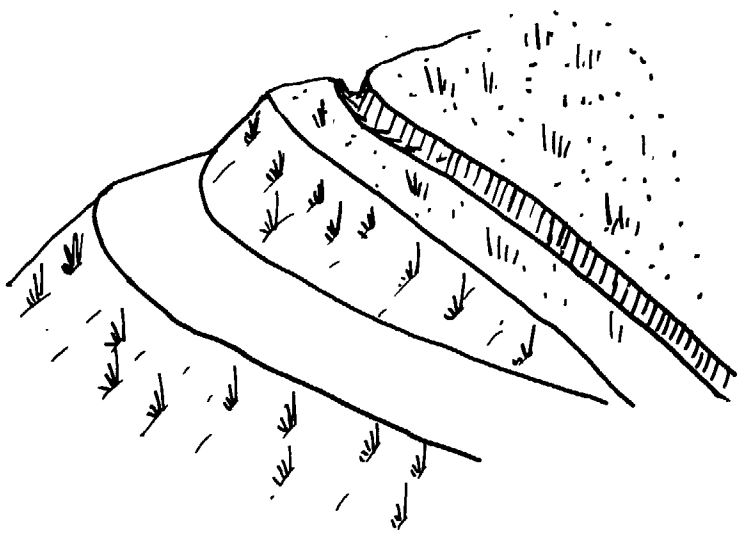

This picture shows a catch drain. A catch drain catches the rain before it gets to the road. The catch drain carries the water away so that the water cannot cause landslides.

(iii) Thirdly, you should build special drains called relief drains to carry away the extra water that falls in the wet season. In the wet season, it rains very hard. There is a lot of water and it quickly fills up the side drains. You do not want the water to stay on the road because it will hurt the road. You want the extra water to run away. You build relief drains going away from the road like the ones in this picture. These relief drains carry away the extra water that falls in heavy rain.

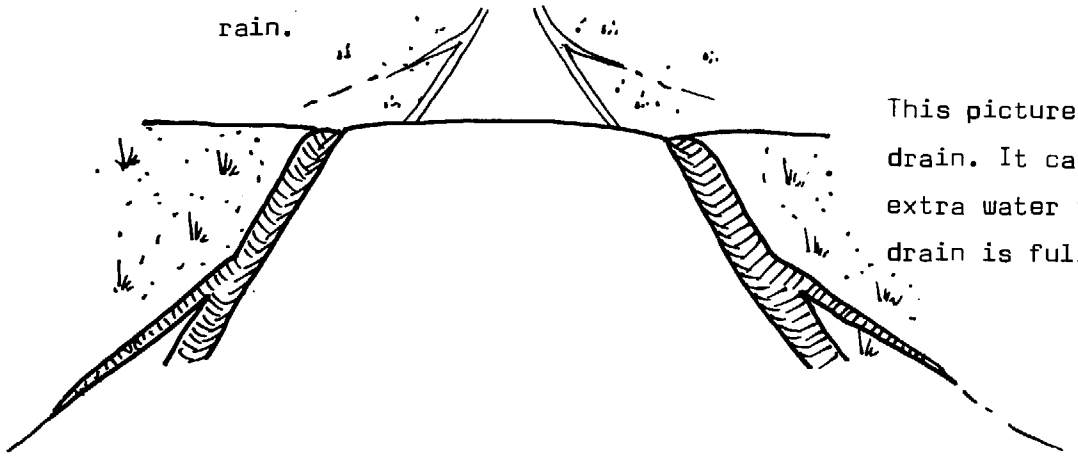

This picture shows a relief drain. It carries away the extra water when the side drain is full.

2. In swampy ground, good drainage keeps dry the ground under the road. When the round is swampy, the ground under the road can be wet. The wet ground under the road can make the surface weak. Heavy trucks can go through the weak road surface and get bogged. Also, the wet ground can make the road bumpy. Bumpy roads are not good for trucks. You can stop these bad things with good drainage.

   If you have to build a road where the ground is swampy, ask the District Works Engineer or the Local Government Engineer. He will tell you the best sort of drainage for your bit of swampy ground. He will tell you the best drains to carry the water away from the road, so that the ground under the road will not be wet, and so the road will not get weak or bumpy.

   This good drainage will mean that trucks will not get stuck on the road, and you will not have to keep fixing the road all the time.

3. Good drainage helps to stop water from causing landslides and washways on bench-cut roads.

   Heavy rain falls down hillsides fast. If there is no special drain, the fast water running down the hill will fall onto the road. This fast water will cause two bad things called erosion and landslides. You can see them in the pictures on page 10.

You should now know four reasons why you need drains for a road:

WATER IS BAD FOR ROADS. DRAINS KEEP THE WATER OFF THE ROADS.

1. Relief drains carry away extra water in the wet season.
2. Good drainage in swampy ground stops the ground under the road From being wet and from making the road boggy and bumpy.
3. A catch drain above a bench-cut road can help stop Landslides and can help stop the banks and the road itself from washing away.
4. Drains stop pot-holes from forming and from getting bigger.

C. SURFACING MATERIAL

1. Surfacing material or "pavement" is the name given to the things you put on a road to make it stronger. Put your hand on top of the table. Now you are touching the surface of the table. The surface of the table is the part that you write on, or put plates on. The"surface" of a road is the top layer of the road where the wheels of a truck drive.

2. What can you use to put on top of roads in your area ?
If you are from the north coast or one of the islands, you might have coronous roads.

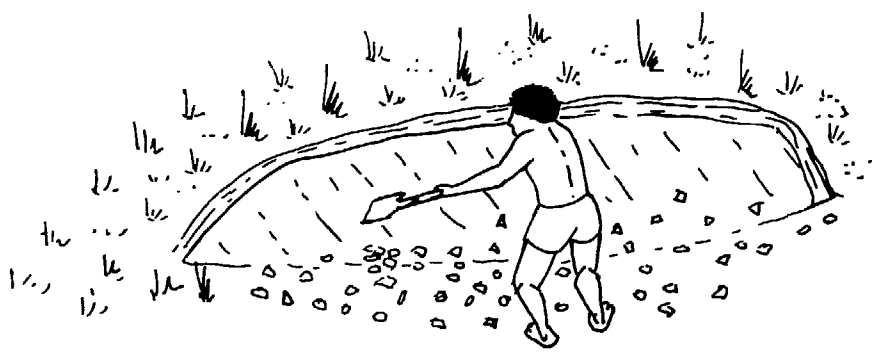

This is a coronous pit. Coronous is white. It is made of sand or coral and sometimes has sheils in it. It makes a good hard surface.

D. FORMATION OF THE ROAD

Formation of the road talks about how wide a road should be, from one side to the other:

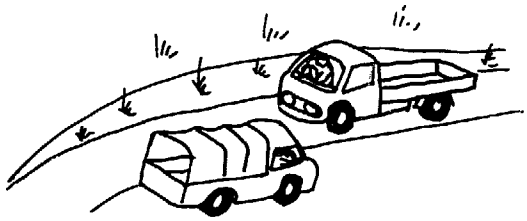

This picture shows a narrow road. Only one truck can use it.

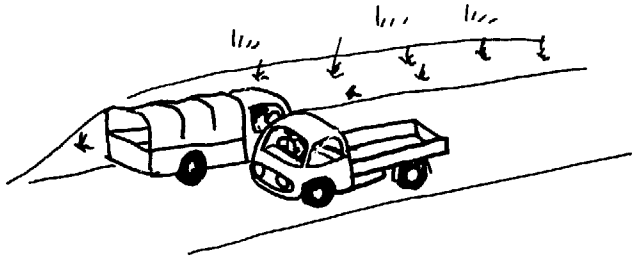

This picture shows a wide road. Two trucks can use it and pass each other.

Formation of the road also talks about the distance between the side drains. Formation of the road is important if there are many trucks using the road. It is not important on a road that is used only a little bit.

E. HORIZONTAL ALIGNMENT

Horizontal alignment means the shape of a road in plan (as you would see it from a place, looking down.)

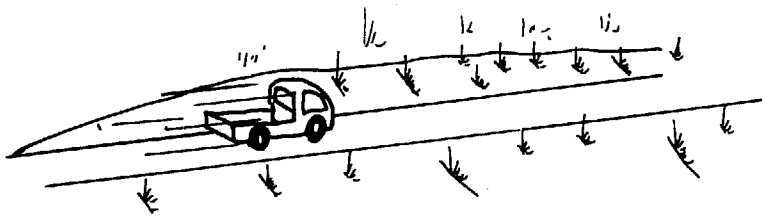

A straight road has good horizontal alignment and cars can go fast.

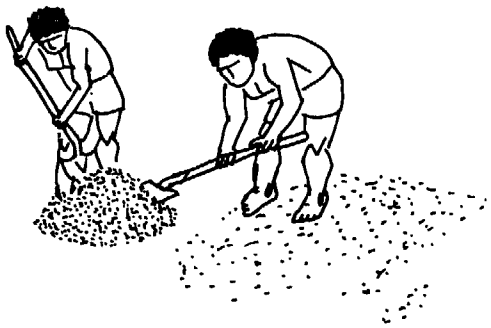

Natural sand from beaches or river beds may be used on your roads. Gravel from ridges or hillside gravel pits can also be used.

We call these "material" because material is a word that you can use for different things like coronous , river gravel, stones, sand. We call them all "surfacing" material because they are used for the surface of the road.

3. <u>When do you use surfacing material</u>?

When you make a road you must have surfacing material. There are three reasons why you must have surfacing material:

1. You need surfacing material to make the road safe and strong.
2. You need surfacing material so that all kinds of vehicles can use the road.
3. You need surfacing material to save maintenance money.

You must have surfacing material, and if the road is not built through rock or natural gravel, you have to cart it onto the road.
You should look in the bush near the road, and ask the people who live there, to find all the places where there is coronous, or river gravel, or other surfacing material.
It costs a lot of money to put surfacing material on a road. It takes a lot of time also. Do not waste the surfacing material on a road that is very steep and curves round a lot if you can build the road in a better place. It is better to build a good line of road, than to do a lot of work putting surfacing material on a bad line of road.

If you are from the highlands, they might use river gravel in your area.

This truck is getting river gravel to put on the roads.

If your Council is a big one, you might have a quarry and a crusher.

This is a quarry. Men blast big rocks or dig up the stones by machines such as bulldozers.

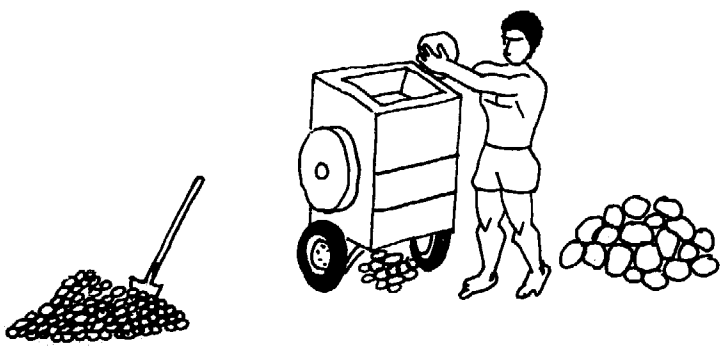

This is a crusher. Big rocks are broken up in this machine, to make gravel, which is a very good surface.

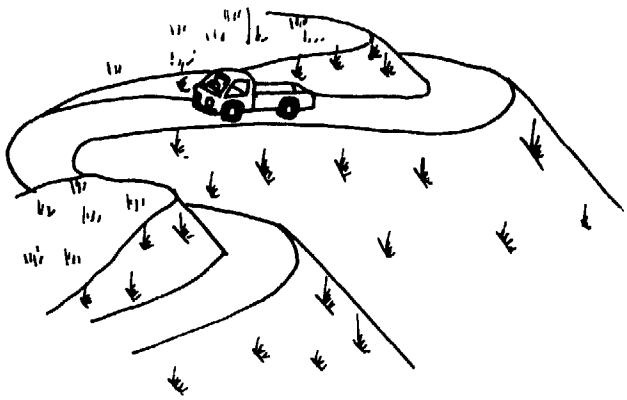

A road with many sharp bends has poor horizontal alignment.

When a lot of fast trucks and cars use a road, you need good horizontal alignment. Most Rural Improvement Roads are rough. Trucks go slowly. Bad accidents are not often caused by fast trucks on these roads. Horizontal alignment is not important on these roads. When you want to build a Rural Improvement Road, ask the Local Government Engineer at Public Works Department for a surveyor. He will show you where the road should go. He will not worry too much about horizontal alignment on a small road. But suppose you want to change a small road into a big road, or suppose you want to start building a new big road. Then the surveyor will be careful about horizontal alignment. Horizontal alignment is important on a big road so that fast cars and trucks do not have accidents. Good horizontal alignment is easy in flat areas. It is also easy in areas that are a little bit hilly. It is not easy in the mountains because the road has to be built up. This is a hard job and it costs a lot of money.

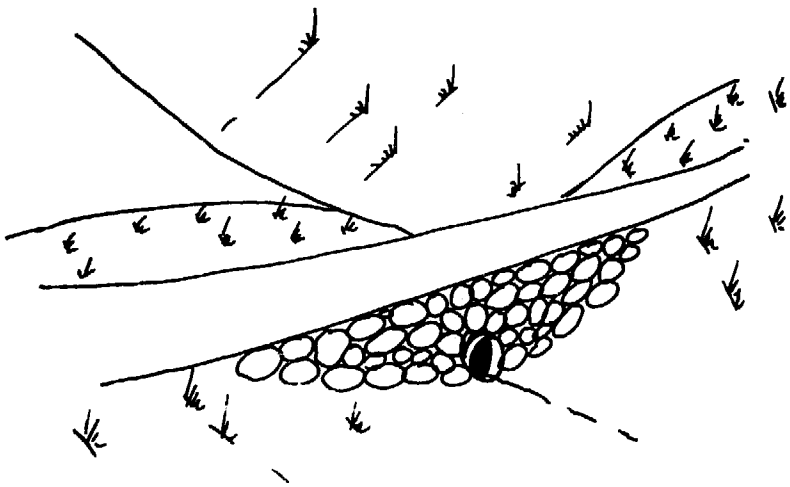

This shows the way you get good horizontal alignment, in the mountains. The road is built up on one side.

Suppose you build a small road that is not too steep. Later on you can make the road wider. This saves a lot of money and work.

F. SUMMARY

On Page 5 we said that there are four important aims for Council roads and Rural Development Roads. Five things help you get these aims.

The four aims are these:

Council roads and Rural Development Fund roads should be:

1. Cheap to build.
2. Cheap to maintain.
3. Safe.
4. Open in most weather.

The five things that you get these four aims are:

1. Good gradient-roads should not be too steep
2. Good drainage.
3. Surfacing material

These 3 things work together. It is a waste to surface a road that is too steep. It is a waste to surface a road that is drained badly.

4. Good road formation - a road has good formation if it is wide enough for the traffic that uses it.
5. Horizontal alignment is important for big roads with a lot of fast traffic.

Now you know what your aims are. You also know what helps you get these aims. In the next part of the book, we will talk about what you do when you are building a new road or making an old road bigger.

1. First you get a surveyor to survey the road.
2. Build the road to the right gradient - not too steep.
3. Put surfacing material on the places where it is needed, especially on the slopes.

If you are improving an old road to make it bigger and better you do three more things:

4. Improve the horizontal alignment so that cars and trucks can go faster.
5. Replace the old bridges and culverts where needed.
6. Surface all the road.

A. THERE ARE DIFFERENT SORTS OF SURVEYS:

1. A survey for roads that are already built. The surveyor may not put in any pegs where the ground is flat or only a little bit steep because he will not want to change it. But the surveyor will want to change the place where the road is too steep in one part. He will measure this part and mark it with pegs, for a new line.

2. A survey for new roads. Usually, the surveyor pegs all the places where the road will be built. The pegs should be put in so that the ground level at the peg is exactly the same as the surface of the road will be built to.

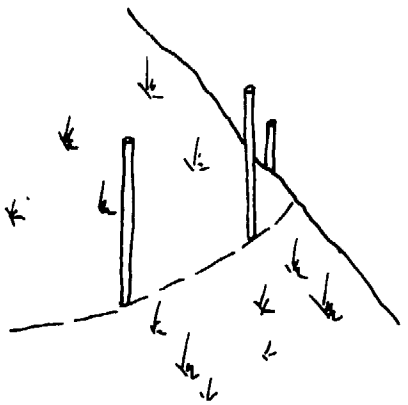

This picture shows a line of pegs where the road will go.

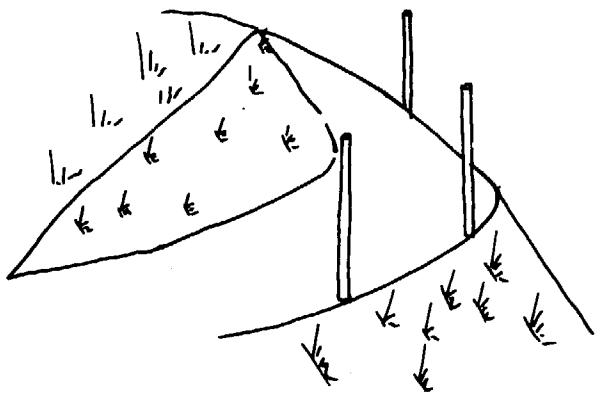

This picture shows the road formation level built to what was said on the surveyors pegs.

Sometimes a hill will have to be cut away below the level of the ground at the peg. These places are called cuts. Here the surveyor will write on the peg a minus sign and the depth of cut. "-1.5" would mean "Cut 1.5 metres below the ground at the peg".

When you build the road along this baseline, the road is in the best place. Papua New Guinea needs many new roads. Papua New Guinea does not have many surveyors and they cost a lot of money. The survey of Rural Improvement Roads is usually quick so that the surveyor can go off to the next job.

The Surveyor leaves pegs in the ground. What are they for?

The pegs he leaves in the ground show where the road should go so that it is not too steep.

Usually, the pegs are bush stakes. These are sticks cut from a tree. The pegs will be painted, if possible. All pegs will have numbers written on them. The numbers are in order - 1,2,3 and so on. Rainwater cannot wash off the numbers. The pegs show where the road should be cut. On a hill, the pegs do not show the place where the centre of the road will be. The pegs show the place where the edge of the road will be:

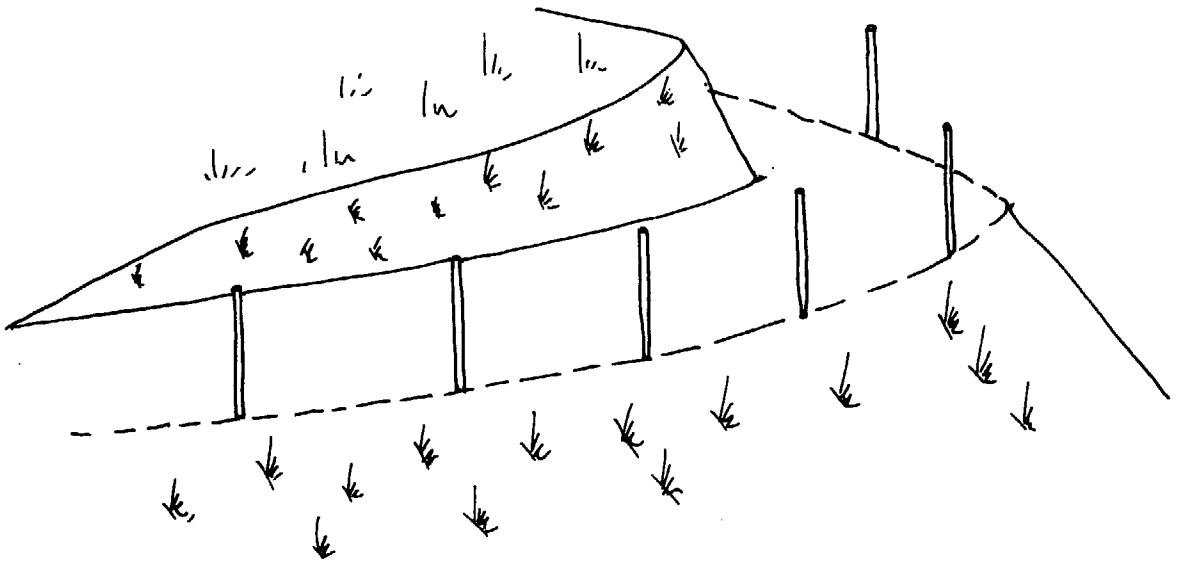

It is very important to leave the pegs exactly where they are. In Section 4 on pages 26 to 32 , you will learn about marking the place where the road will go. Do not move the pegs before the "permanent identification" is made, and you have marked the place where the road will go.

SECTION 3 : SURVEYING A ROAD

First you must survey the place where the road will go. Then you can build the road.

If the ground is flat and hard you do not need a survey to find out where to build the road, but before work starts the Supervisor of the road must make sure the whole road can be built. He must check that there are no land disputes, swamps, cliffs, or other trouble that might stop the road. If you are going to build a road through a swamp or up a hill or mountain, you need help. You can ask Public Works Department in your district for a surveyor, or you can write to the Local Government Engineer at Public Works Department in Port Moresby and he will send a surveyor. To understand more about this see page 2 "Requesting a Survey".

What does the Surveyor do?

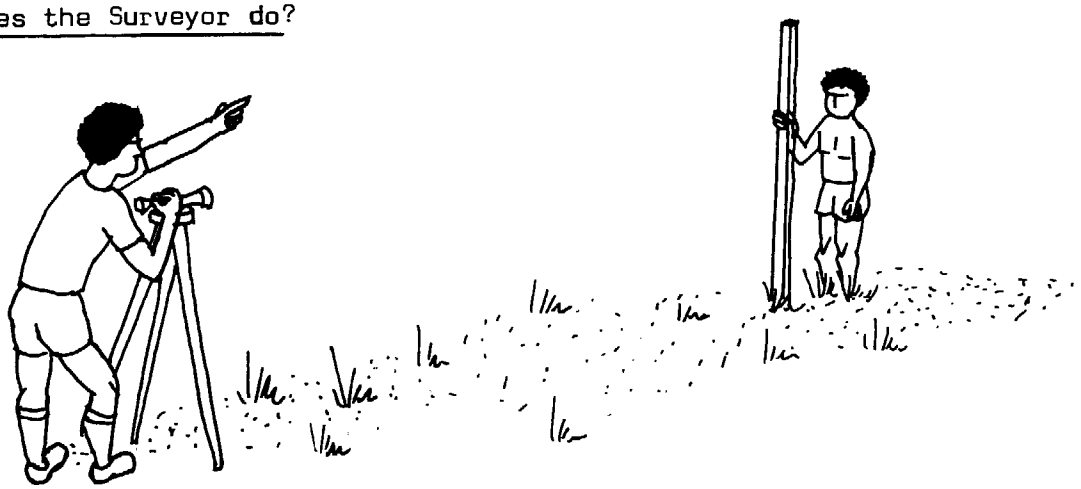

The surveyor will use a special tool or "instrument" to find out where the road should go. He will put markers called "pegs" in the ground that mark the place for the road. If you line up all the pegs you have the gradient line.

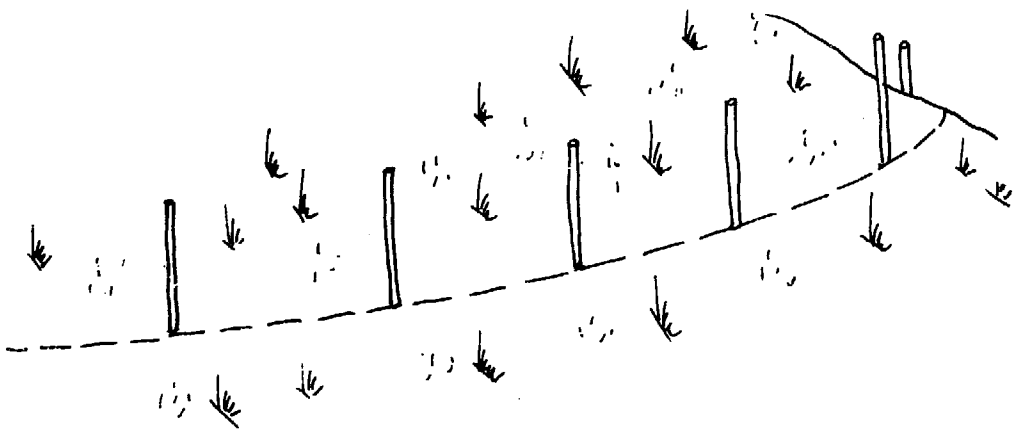

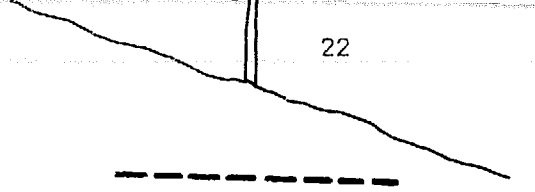

Before cutting.

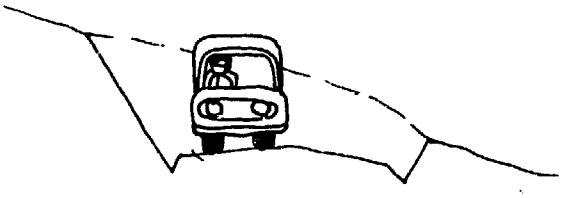

After cutting.

Sometimes you must fill in a hollow, over the place where the surveyor puts the peg. These places are called fills. Here the surveyor will write on the peg a "plus" sign and the height to fill. "+2.2" would mean "Fill 2.2 metres above the ground at the peg".

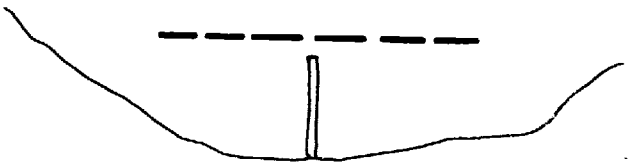

Before filling.

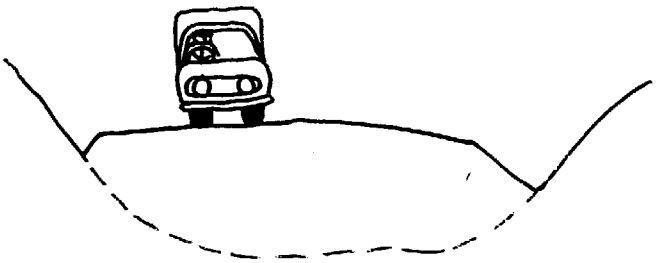

After filling.

In steep ground, the surveyor will measure how far it is between the pegs. The pegs have numbers painted on them that show how far it is to the next peg. The surveyor writes a report about everything, and a copy is sent to the Council, in case you need to check something.

3. <u>A survey in an area that is very steep and broken.</u> The surveyor may not know whether a road can be built there. He will measure very carefully and put in pegs. He will tell the Council or people not to start work. He will take the measurements back to the Local Government Engineer. The engineers at Public Works Department will look at the measurements. Suppose they say it is a place where you can build a road, they will say to work from the pegs, or they may design a special road. Suppose they think it is a bad place for a road, they will tell you not to build in that place.

DO NOT TOUCH THE PEGS before you have a letter from Public Works Department. DO NOT START TO BUILD THE ROAD until you have a letter from Public Works Department. You do not want to waste your money and work by building in the wrong place.

4. A survey for a hairpin bend:

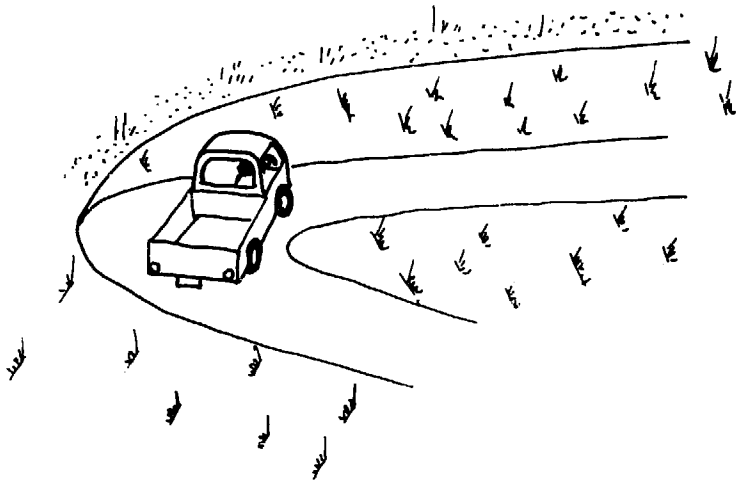

This is a hairpin bend

Hairpin bends are dangerous. The surveyor will try to have no hairpin bends for your road. If the road must have a hairpin bend, the surveyor will peg the place very carefully. You will build the road exactly where the pegs are. Then the hairpin bend will be as safe as the rest of the road. You can read more about hairpin bends from page 46 and 47.

3. THE SURVEYOR'S FIELD BOOK:

The surveyor writes all the useful facts in a field book. These are facts about measurements, directions, details of rivers, villages, tracks and roads along the place where your road will be built. The surveyor sends his field book to Local Government Engineer, Public Works Department. The engineers at Public Works Department will look at all this information. They will send the Council and the Area Authority a copy of the surveyor's report, and a letter that talks about any special problems or things to be done when you build the road. The engineers want you to build a road that is not too steep. They will tell you all the information you need to build the road in the right place. The field book will use the names of rivers, villages, tracks and existing roads to help you find the right place. If the engineer wants to talk about a place in between two pegs, he will give you a measurement from one of the pegs. The picture on the next page will help you to understand this.

SECTION 4 : MARKING THE PLACE WHERE THE ROAD WILL GO

The Surveyor puts marker pegs into the ground. After nine (9) months, these pegs are not good. Why are they not good? In the bush, the grass and leaves cover the marker pegs. Also the water in the ground makes them rot, and they fall apart. In villages, people move the pegs, and children take them to play with.
When the surveyor finishes marking the route with pegs, you must straight away mark the route permanently. Something "permanent" is a thing that lasts a long time, so your marks must last a long time.

A. HOW DO YOU MARK THE ROUTE PERMANENTLY?

Do you put steel pegs instead of wooden pegs in the ground? No, that is no good. Steel pegs do not rot, but they do get covered by kunai and pit pit, then you cannot find them when you want to work on the road.
Do you cut a track to follow the pegs? Yes. This is the best way to mark the route.

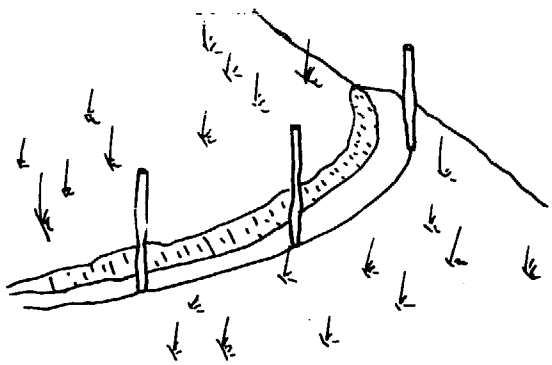

You cut a benched foot-track (called a pilot track) around the line of the survey.

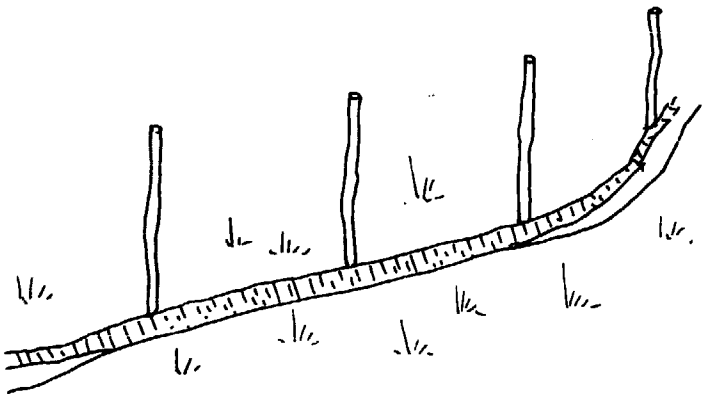

If the road is on flat country, you dig a small trench.

You must cut the track straight away before the bush grows over the pegs.
If the bush grows before you start to cut the track then you must be careful.
A falling tree can break a marker peg.

Suppose a peg has a measurement to show how much you should fill in a hollow. You start to measure from ground level at that peg.

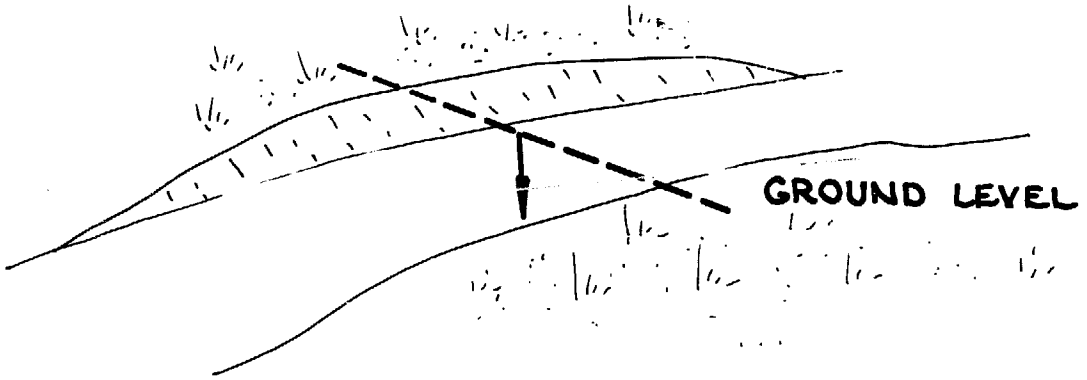

4. When all the road is good, it is a good road. When a road has some bad places, the road is bad. When a road has even one very bad place, the road is very bad road. Follow the pegs very carefully. Do what the surveyors and engineers say you should do. Then you will not have any very bad places on your road.

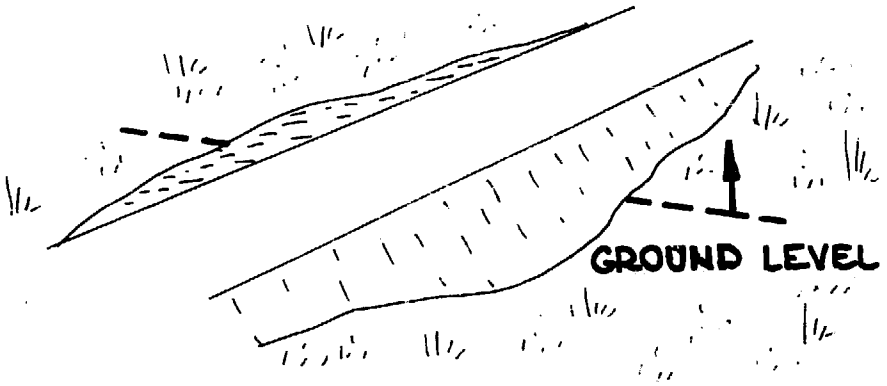

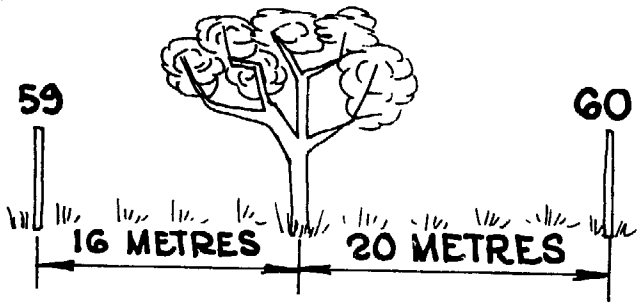

In the field book the engineer would say the tree was at peg 59 + 16 metres or peg 60-20 metres. That means the tree is 16 metres past the peg 59 and 20 metres before peg 60.

C. <u>HERE ARE THE FOUR MOST IMPORTANT FACTS TO REMEMBER ABOUT SURVEYS:</u>

1. Pegs sometimes mark the centre line of the road on flat ground, but on hillsides they usually mark the outside edge.

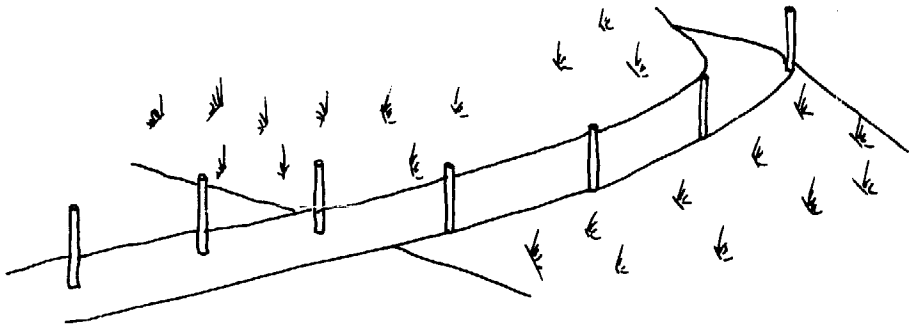

2. Pegs are usually placed so that the ground height or "level" at the peg is exactly the same as the height where the road surface will be.

3. Suppose a peg has a measurement to show how deep you should cut away. You start to measure from ground level at the peg.

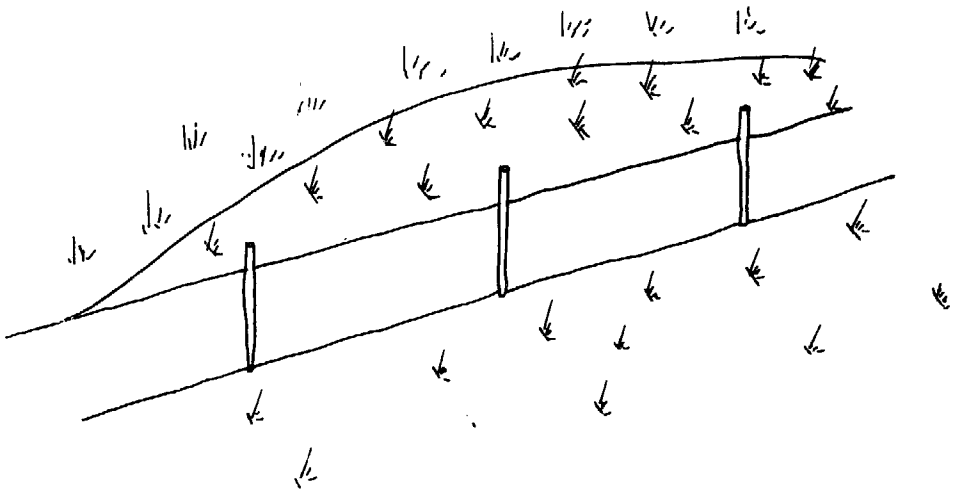

8. HOW BIG MUST YOU MAKE THE TRACK?

You make the foot track 1 metre wide.

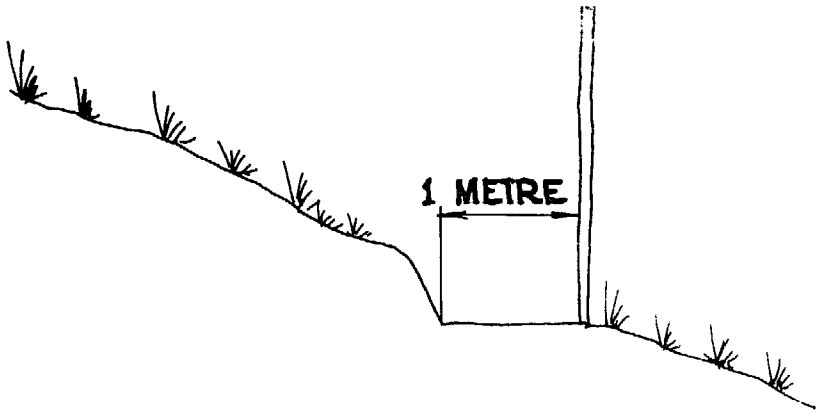

In flat country, you make the trench 1 metre wide and clear away the topsoil.

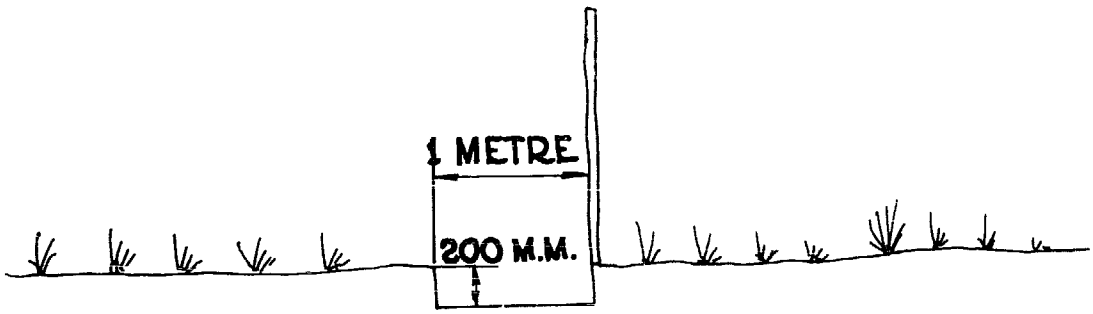

The surveyor puts pegs along the route. You must make the track wider in those places and leave the peg in the ground. Clear of the main track.

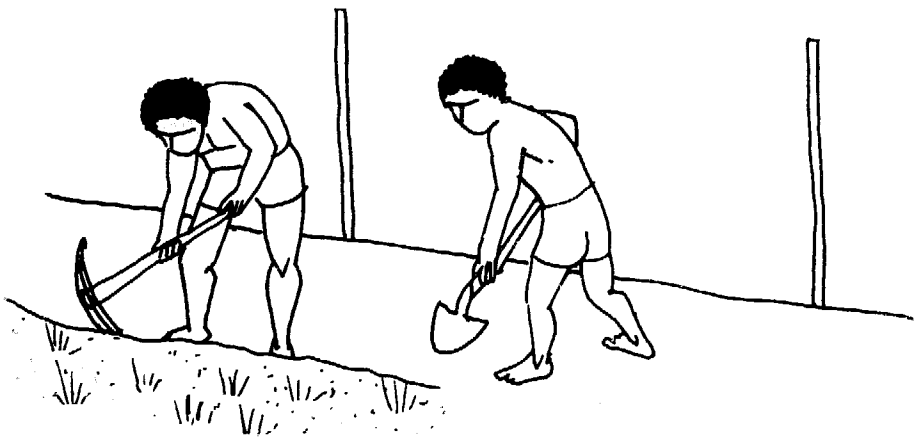

Suppose one peg shows that you must cut or fill in that place. You should get a bigger timber post or steel peg and paint the number on it and also print the height of cut or fill, like the numbers on the bush peg. Then you put this peg well in the ground, where the bush peg was. (Put the peg in so that it will not fall over). You know that you can start to make a road this year but maybe it will take years to finish. The pegs with the numbers must be steel or strong timber to stay there.

C. HOW DO YOU MAKE A BENCHED ROAD TRACK?

You must cut flat into the bank at the same exact place where the peg meets the ground. This is very important.

Now I will tell you how to make the track between pegs. The track should go where the road will go. If the hillside is curving, do not make the track as short as possible between pegs. Suppose you do that, the track could be too steep.

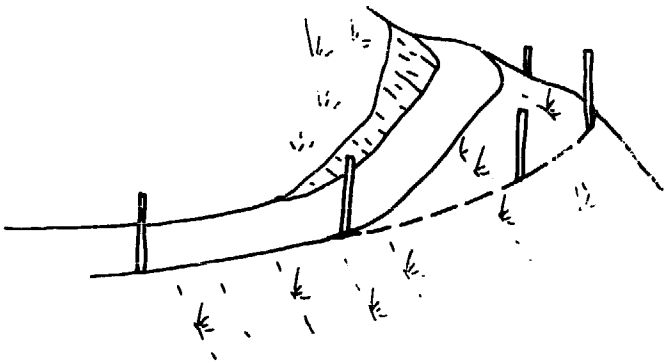

This is bad. The benched track does not follow the line of pegs.

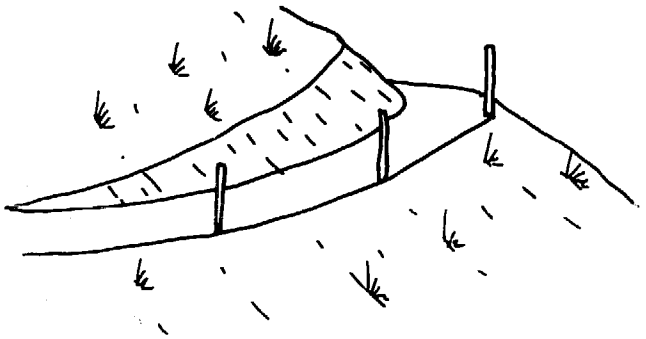

This is good. The benched track follows the line of pegs.

You must supervise the workmen when they cut the track on steep parts of a hillside. Suppose they make a short track that is very steep, you will have trouble when you make the true road.

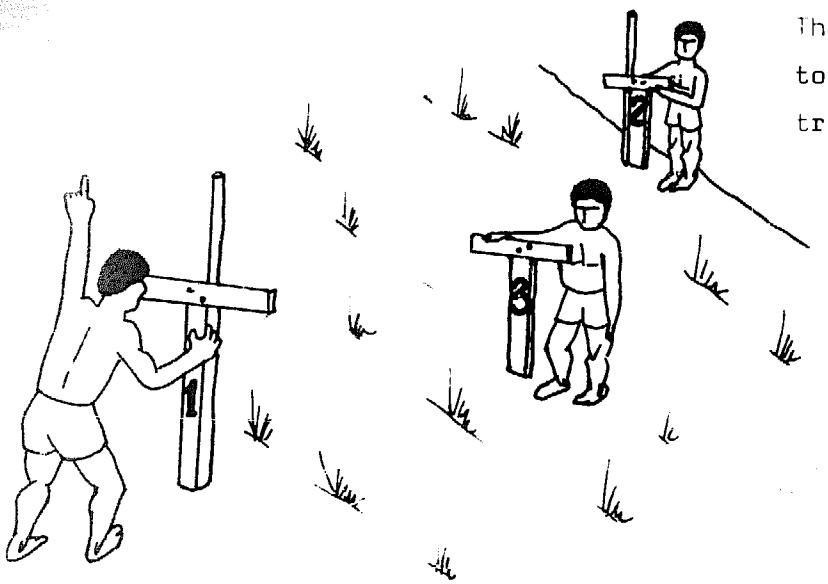

This man can see that rod 3 is too low. He can see where the track should go.

You can put in extra little pegs in the places where the third boning rod shows the gradient line.

E. USING A GRADIENT TEMPLATE:

When working around curved hillsides, it can be difficult to get an even grade, especially when you cannot see between pegs. If you work by eye only, you can be wrong, because slopes of road can look different when seen against different slopes in the background.

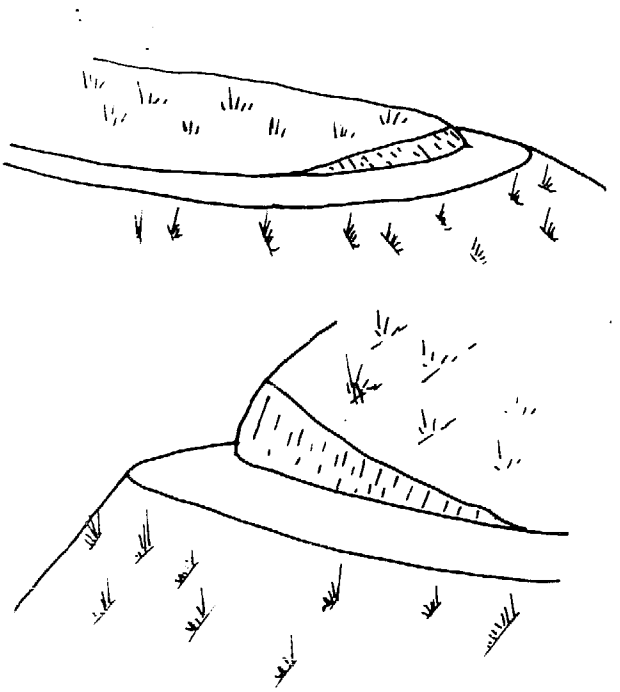

Both of these roads have a grade of 5% but they look different because of the shape of the hills on which they are built.

D. MAKING A GOOD EVEN GRADIENT WITH BONING RODS:

Now, for hillside which are not very curved between pegs, I will tell you one easy way to make the track between two pegs with a good even gradient. You need three (3) pieces of wood. Each piece of wood will be one (1) metre high. Measure them so they are the same. Nail a piece of wood on top of each of them so they look like a "T".

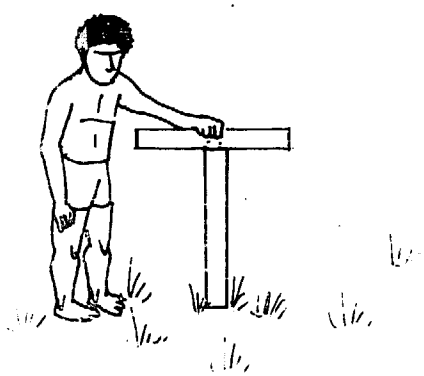

This is called a boning rod.

Put one "boning" rod at formation level at each peg and bend down so that your eye looks from the top of one rod to the top of the next rod. A man can walk along between the pegs with the other rod. He can rest this rod on the ground. Your eye will see if the third rod is very high above your line of sight, or very low below you line of sight.

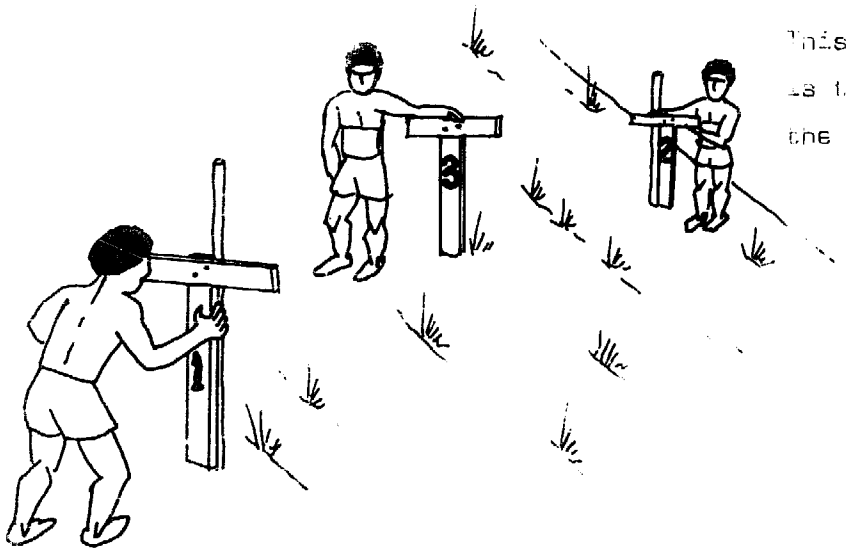

This man can see that rod 3 is too high. He can see where the track should go.

To work round curved ground between pegs, you need a gradient template. This is a wooden frame with a straight edge that can be set at different slopes or grades.

FLAT GRADE

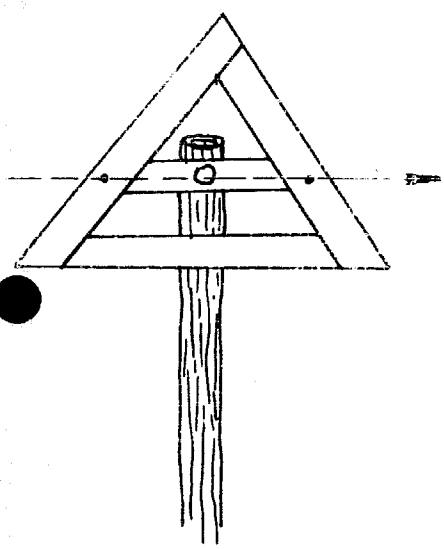

FALLING GRADE

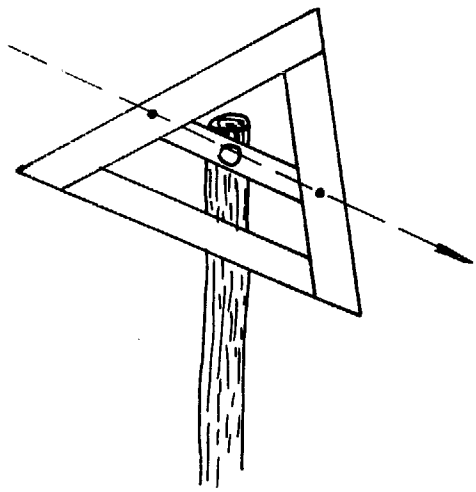

RISING GRADE

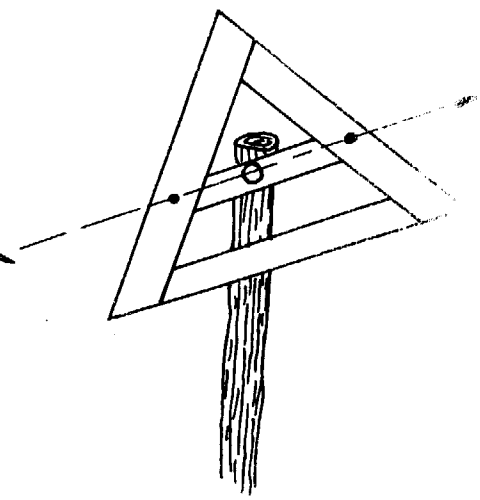

You hang a string with a weight on it from the top corner. The string goes past a mark on the other side showing the percentage of grade or the slope up or down.

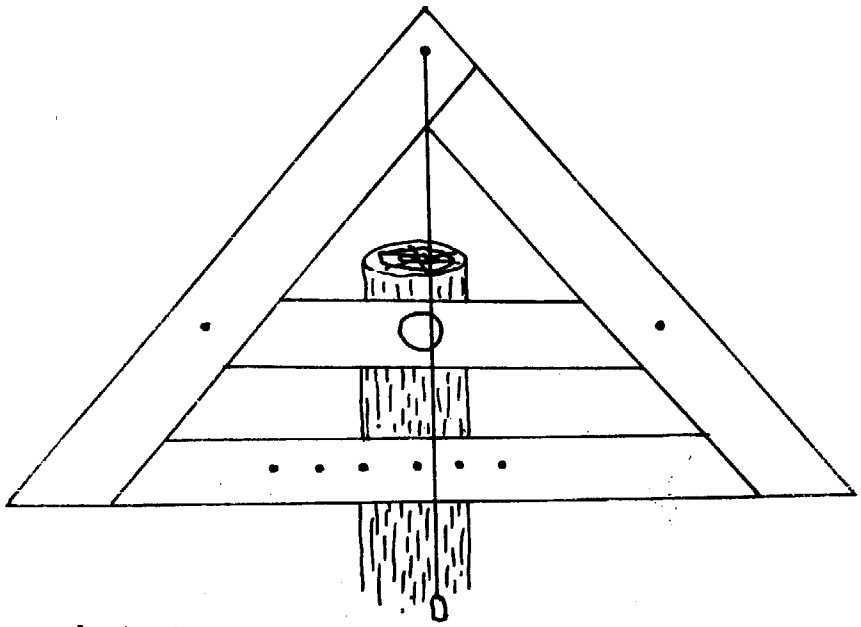

Then you can look along the bottom straight edge, and set the grade that fits properly around the curve between the pegs. Ask the Local Government Supervisor in your District to build you one of these gradient templates.

I want to say again that you should not go from one peg to the next peg in a straight line, when the hillside between them is curved. This is because the track might be too steep.

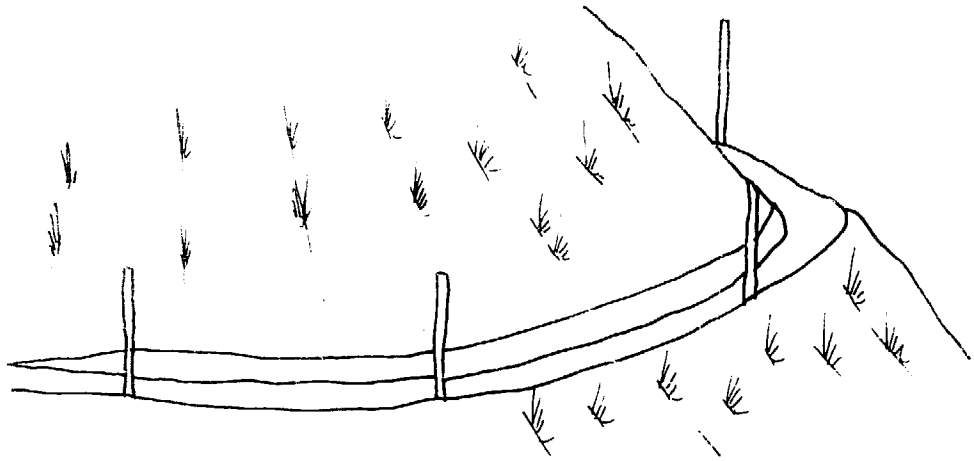

And because the track might need too much fill. (Gully)

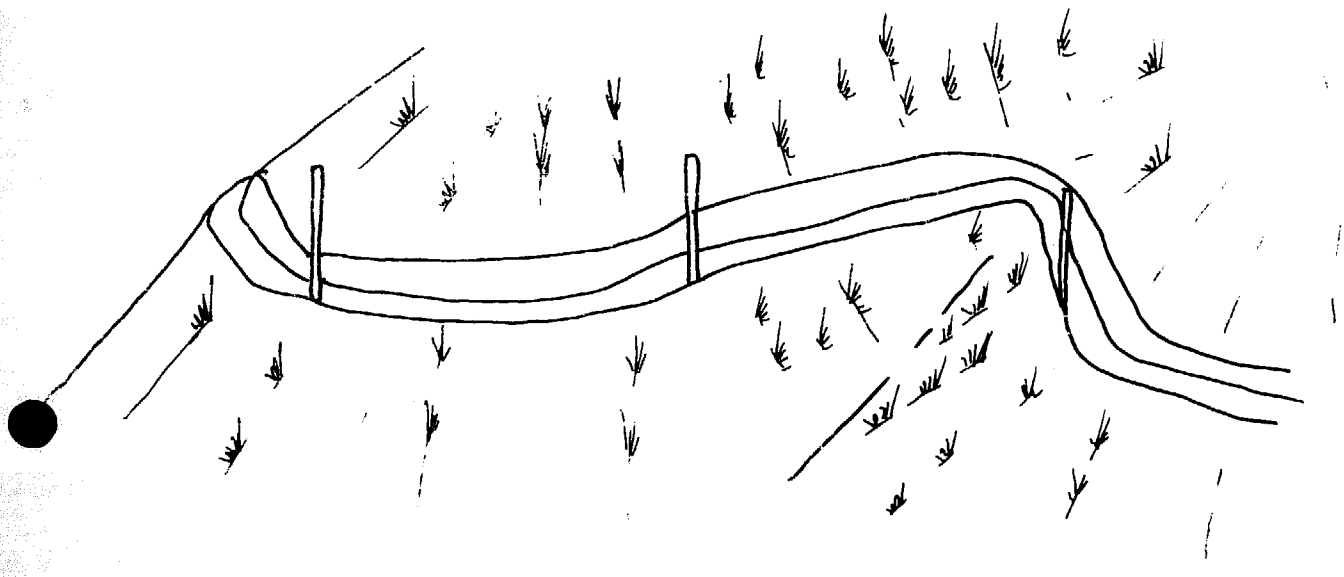

A lot of hard work would be needed to fill that gully in the picture. Also the fill would not be safe. It would sink. A big company like Dillingham's has big machines to make the ground hard and safe. Usually Councils do not have these machines.

You want to keep the track on the correct gradient, not too steep. Suppose the pegs show that you must make a cut or a fill when you make the road. You cannot make this cut or fill for the pilot track. The pilot track will not be on the correct gradient on these sections. But you must put in steel pegs or strong posts with the numbers painted on them. These new steel pegs must go in the same exact place where the surveyor put the bush pegs. When the true road is built, the overseer must look out that the pegs and the numbers on them are used to make the right cut or fill.

SECTION 5 : BEGINNING TO MAKE A ROAD

Now we will talk about what you must do when you begin to make the true road. We will talk about this in four (4) parts:

A. How to begin a bench cut road (read pages 34 to 47).

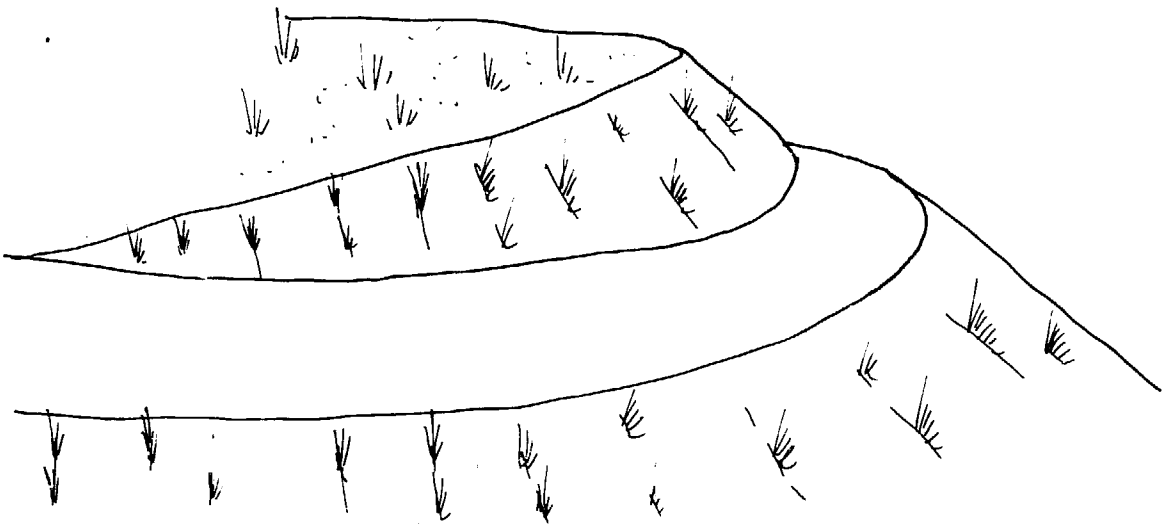

B. How to begin a road on flat country or country that is nearly flat. (read pages 48 to 54).

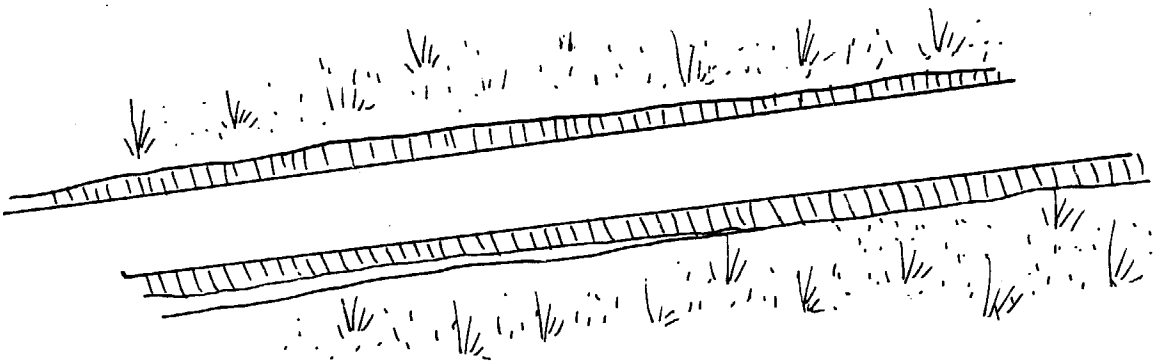

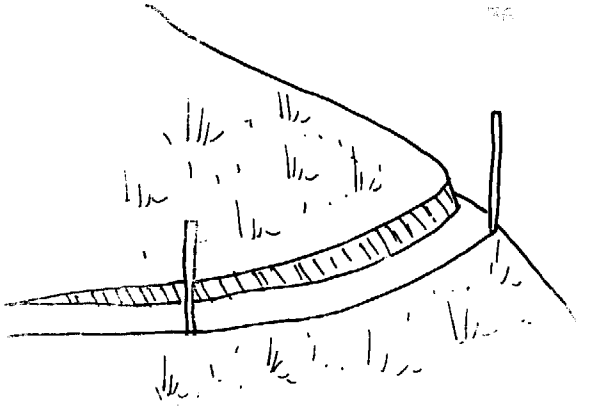

This is a foot track.

It must not be less than 5 metres.

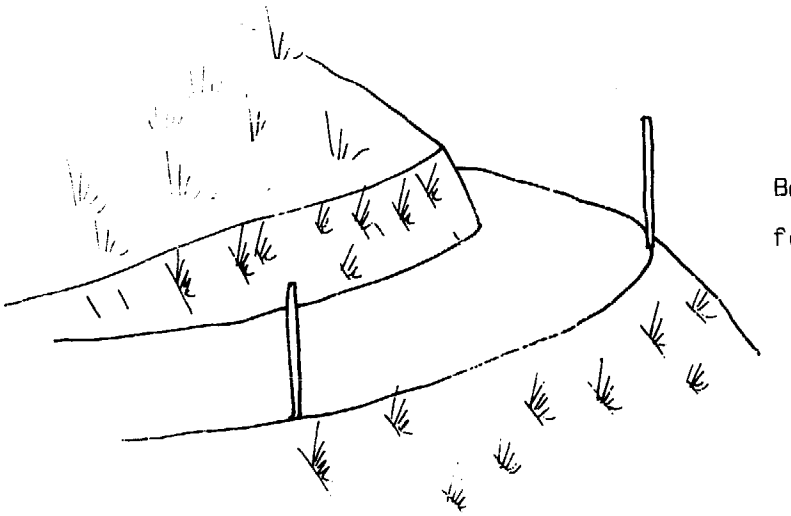

Bench cutting in from the foot track.

Here is a picture showing that the solid bench is five metres wide with a lot of ground dumped down the hill beside the road:

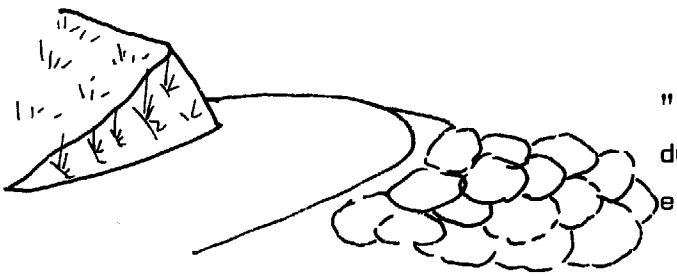

"Spoil" is ground that was dug and dumped over the edge of the bench.

The solid bench must be at least five metres wide. It does not matter how wide the spoil is.

2nd Rule: For unstable country where there is plenty of bush.

Do not cut down big trees. The roots of the trees hold the ground and make the ground more stable. Also the trees stop stormwater from running down the hill fast in big rains. Do not cut the big trees. Cut only the little bit of bush close to the road where it might grow over the road. But read 3rd rule about trees at the top of a cutting.

3rd Rule: For stable and unstable country where there are trees near a cutting.

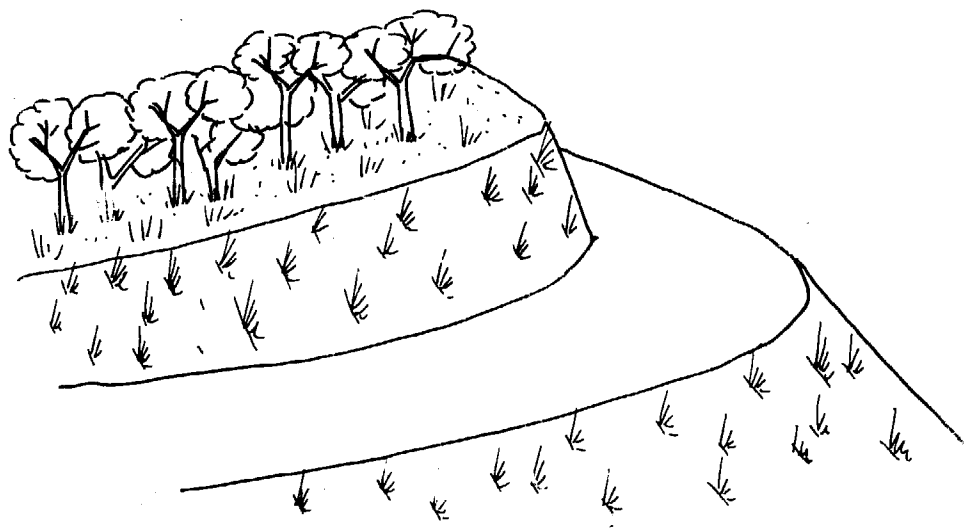

You must cut down every tree that is less than 3 metres from the top. Why? You must cut them down because some of the roots will be cut when you make the cutting, and the trees might fall down.

4th Rule: For unstable country where there is no bush.

Suppose your road goes through country where you can see the landslides have happened. You must plant bush to hold the ground together. Bamboo and Casuarina trees are good to plant in places like this because they grow quickly.

2. Cutting the bench.

Now the bush is cleared, you can start to cut the bench.

(a) How wide do you cut the bench?

You must cut it flat into the hillside from the foot track, for at least 5 metres.

C. How to begin a road that goes through swampy and low-lying country.
(read pages 54 to 59).

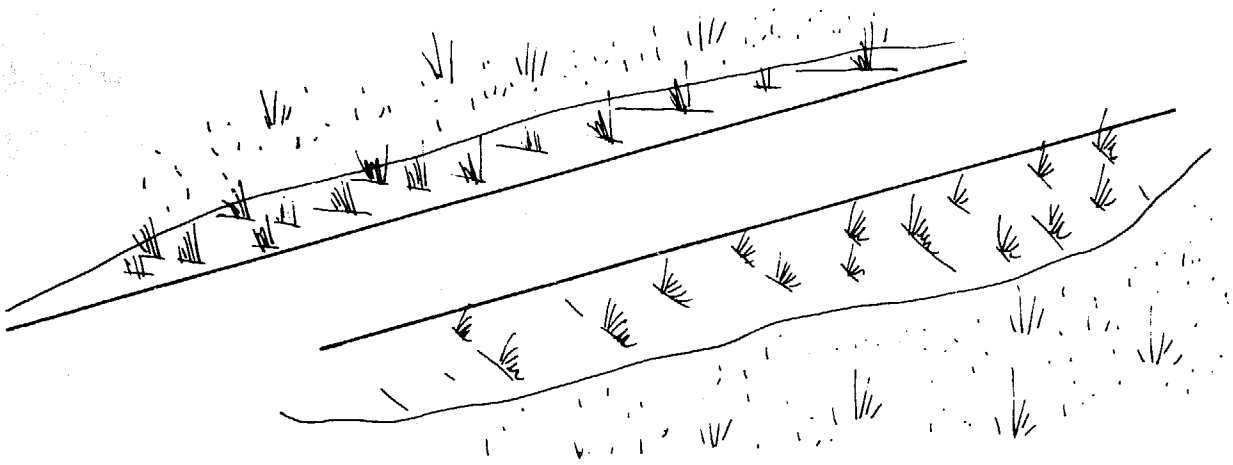

D. Other information about how to begin to make a road.
(read pages 59 to 74).

A. HOW TO MAKE A BENCH-CUT ROAD

1. Clearing the bush.

Firstly, you must clear the bush along the place where the road will go. Why do you do this? You clear the bush so that the sun can shine on the road and make it as dry as possible. BUT suppose the country is not stable - suppose a lot of landslides fall down the hillside in that area. Where the country is not stable, you must leave trees in the ground together to prevent landslides.

There are four (4) rules about clearing the bush:

1st Rule: For stable country where landslides do not happen.

Usually, you can let the sun shine on the road to dry it by clearing a little bit of bush (or overhanging trees) below the road. Above the road you must clear the bush at least 10 metres from the centre line of the road. All big trees that grow less than 30 metres from the centre line above the road, and hang over the road, should be cut down. If you have plenty of workmen you can clear all the bush, big trees and little trees, back to 30 metres from the centre line.

Suppose you cannot make the solid bench five metres wide. You might find a big rock in the hill or something like that.

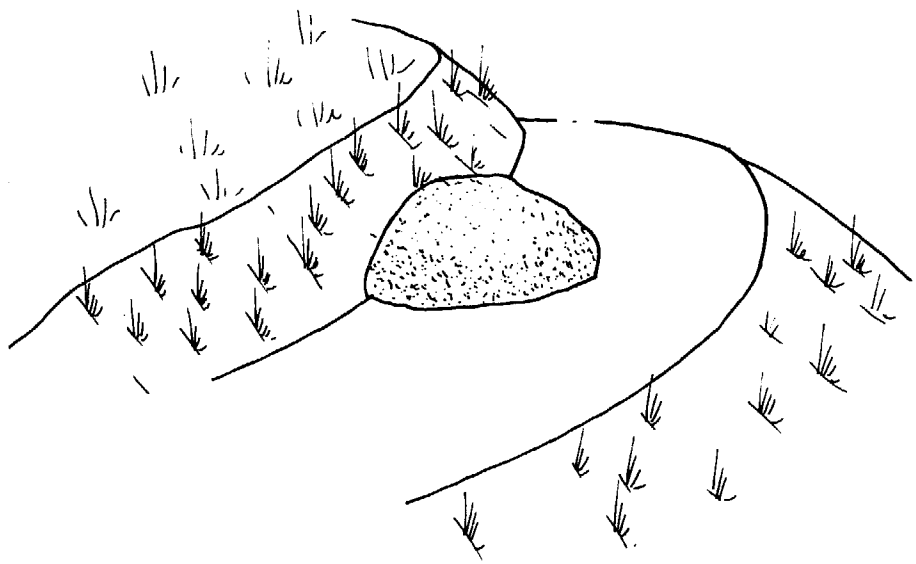

Suppose you meet some kind of trouble like that, you must write to the Local Government Supervisor in your District straight away. He will help you and give you advice. You must not build the road less than five metres wide. This 5 metres is the "absolute minimum".

It is better to build the road 8 metres wide. That is a good measure, called the "preferable" or "desirable" standard.

Will heavy truck use the road straight away when it is finished?

If the big trucks use the road, you should build the better road that is 8 metres wide. A road 5 metres wide will not be good enough. Read Section 6 "Upgrading", and build a road like page 75 says. A road made that way will be a good road for heavy trucks.

(b) Keep the grade or steepness of the road even.

All the time you are beginning to make the road, you must make sure that the grade or steepness of the road between the pegs is even.

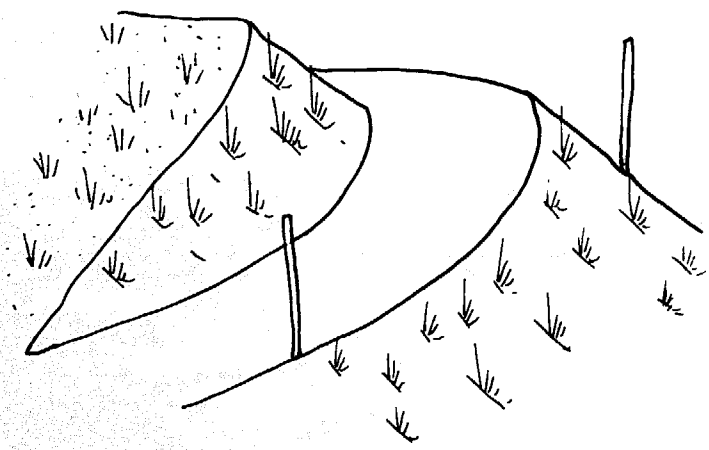

Road with uneven gradients between pegs.

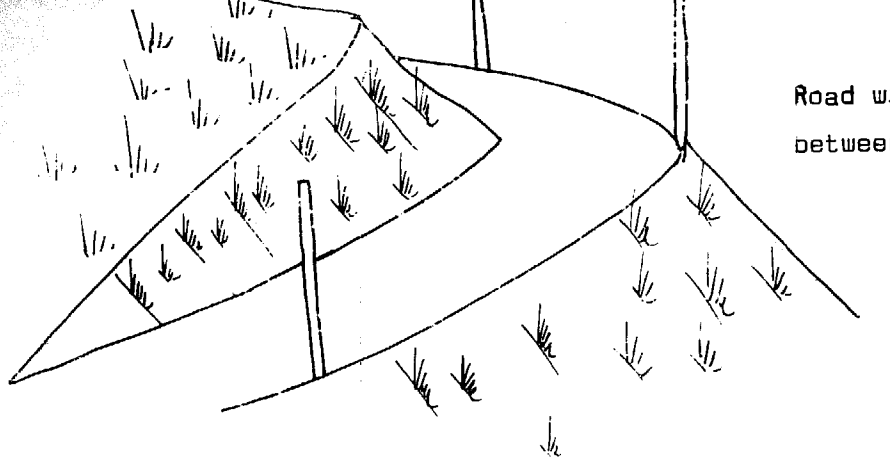

Road with even gradients between pegs.

Usually, the best way to make sure of this is to use boning rods the way I told you on page 29.

Suppose the surveyor's pegs say you must cut in one place. You must cut all around the peg.

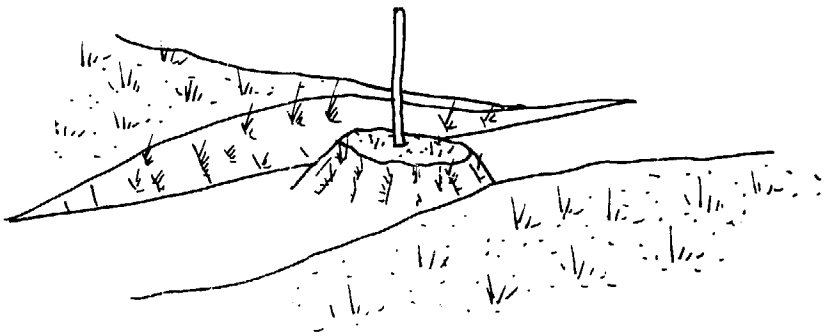

You do not cut the ground where the peg is. The peg stays there until you have cut to the measure. Suppose the peg says -3m. You do not cut the ground where the peg is, but you must cut away the ground all around the peguntil you can measure down 3 metres.

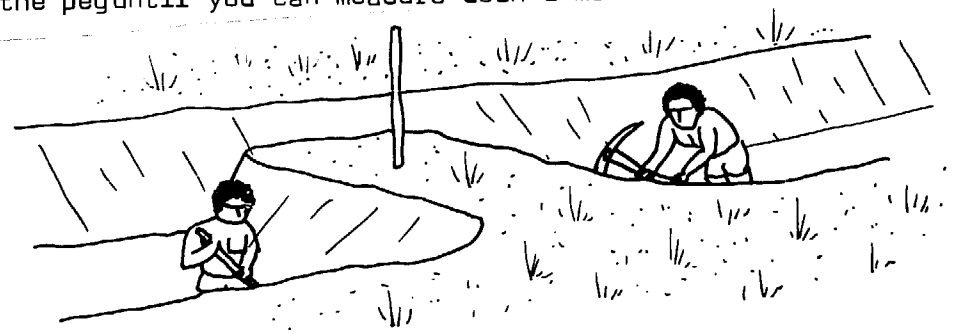

When you can measure 3 metres from the ground level on the peg to the bench, than you can cut away the ground where the peg is.

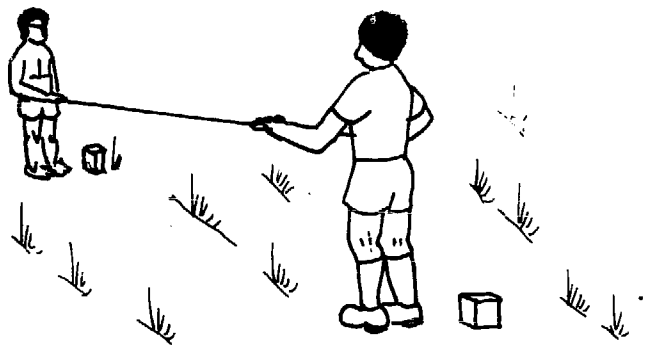

This work has to be done by a surveyor, or by a roads supervisor who knows how to set out pegs for earthwork.

3. Camber and drainage.

Now the first bench has been cut, you must do two things straight away. First, camber the road. Second, cut drainage channels straight away. Why must you do these two things straight away? Because even one heavy rain can spoil you road. One big rain can wash away the top ground of the road and make holes and cuts in the road.

(a) Camber of the Road

If you go the Council Road Overseers Course at Embogo, you will learn how to use the template. With the template, you should set out a camber 1 in 24.

Suppose you do not know how to use a template. You must make the road curve like the road in this picture.

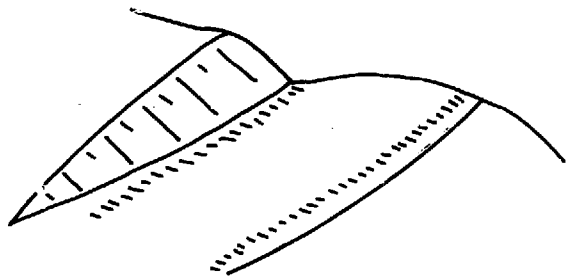

Rainwater can run off this road. The water will not spoil the road.

Suppose you fill to the top of the peg. You must put in a new peg, the place at the top of the peg is the ground level for the new peg. The new peg is measured. Say this measure was 1.3m, again you calculate the measure to the top of the fill. This new measure would be 2.3m - 1.3m = 1.0m. of more fill above the top of the new peg.

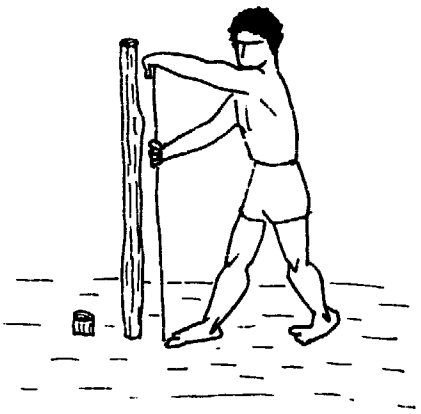

Measure height of new peg: 1.3 m

Fill to the top of this peg.

You fill again to the top of the new peg. Now you must fill 1.0m more from the top of the new peg. Put in one more peg and measure up 1.0m from the top of the peg you have just filled to and put a mark on this new peg.

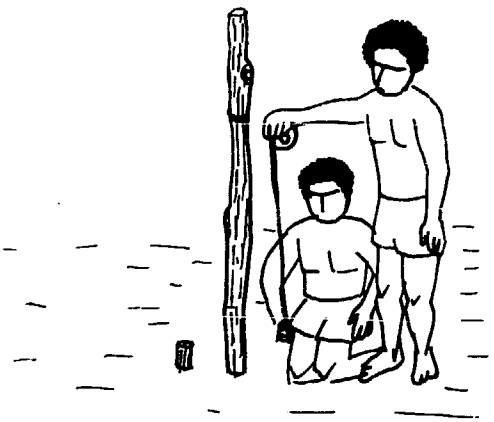

A cut mark on peg.

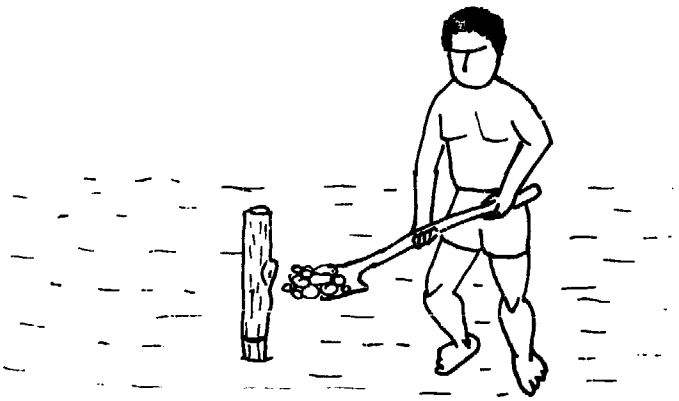

Fill to the mark.

(c) Machine Earthwork

If the cut or fill is being done by machines such as bulldozers, pegs cannot usually be left in this way. They get knocked out by the machine. Extra pegs that are called "offsets", have to be set off the road. You measure from these offset pegs.

Suppose the peg shows that you must fill the place where it stands.

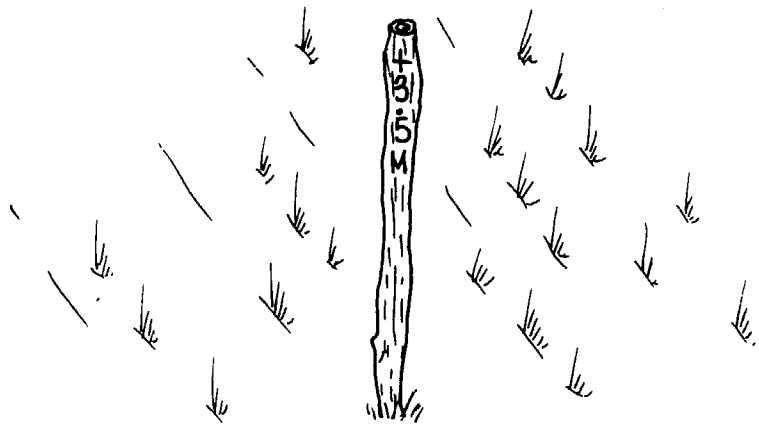

This peg in the picture shows that you must fill that place until you can measure up 3.5m. How can you do that? Suppose you throw ground on the peg, you will cover the peg. You cannot measure from a peg that is covered. So this is what you do: you measure from the ground level of the peg to the top of the peg. Say this measure was 1.2m. You calculate the measure the top of the fill that you want. This measure would be 3.5m - 1.2m = 2.3m. of more fill above the top of the peg.

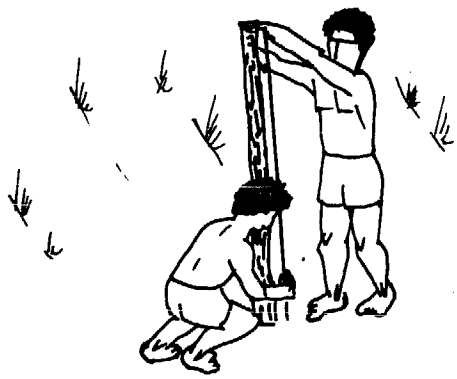

Measure height of this peg.
This measure is 1.2 m.

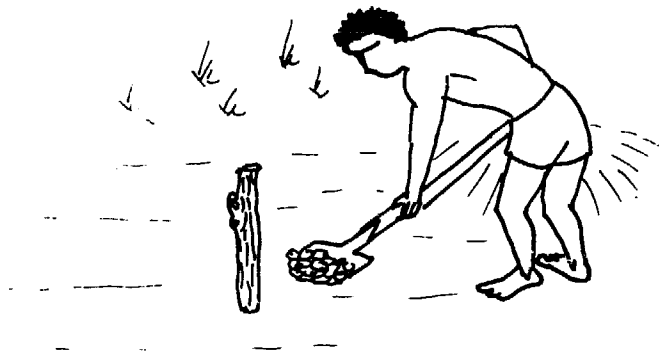

Fill to the top of the peg.

(b) Side drains.

You must hurry up and make drains along the sides of the road. These drains are called side drains. They are sometimes called table drains. You must cut them like the drains in this picture.

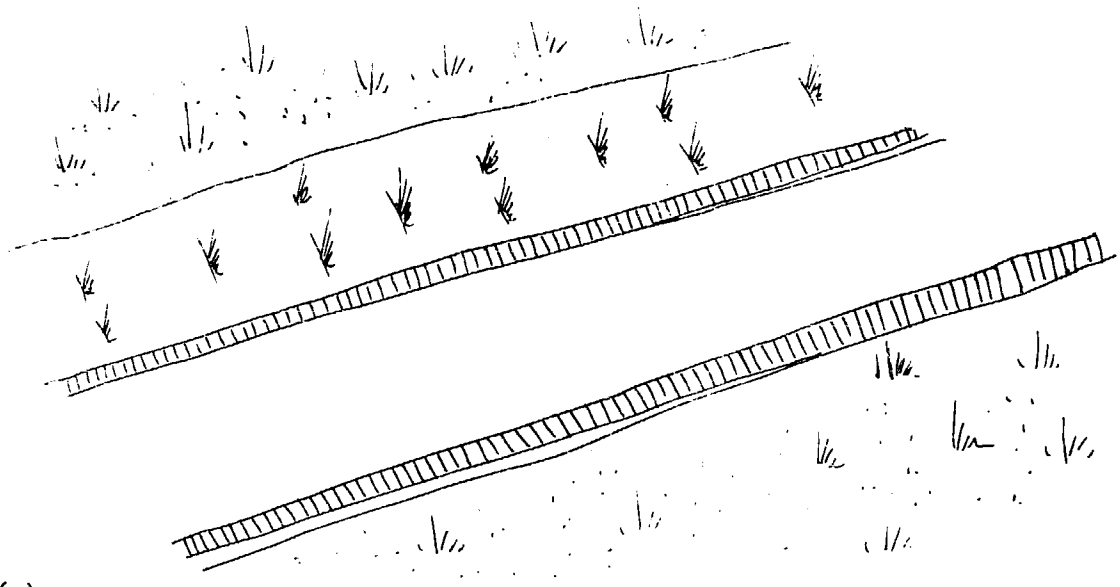

(c) Relief drains.

Also you must cut relief drains to take water away from the side drains.

How many relief drains do you need?

If you go to Embogo you will learn how to measure gradient. When you know how to measure gradient, or steepness of a road, you can use this information to work out how many relief drains you need:

Suppose the gradient is 12%, you must cut a relief drain every 40 metres.

Suppose the gradient is 10%, you must cut a relief drain every 60 metres.

Suppose the gradient is 8%, you must cut a relief drain every 80 metres.

Suppose the gradient is less than 8%, you must cut a relief drain every 100 metres.

If the ground is high on one side of the road, you cannot take away the water in a drain on that side. Then you need to put a culvert under the road. This culvert will take away the water. If you cannot measure gradient, these pictures may help you.

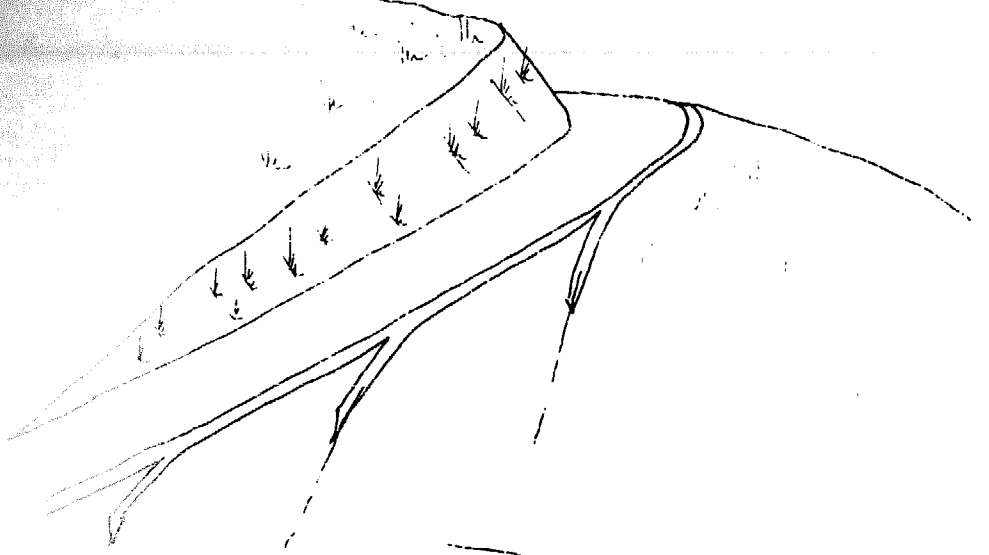

Picture 1.

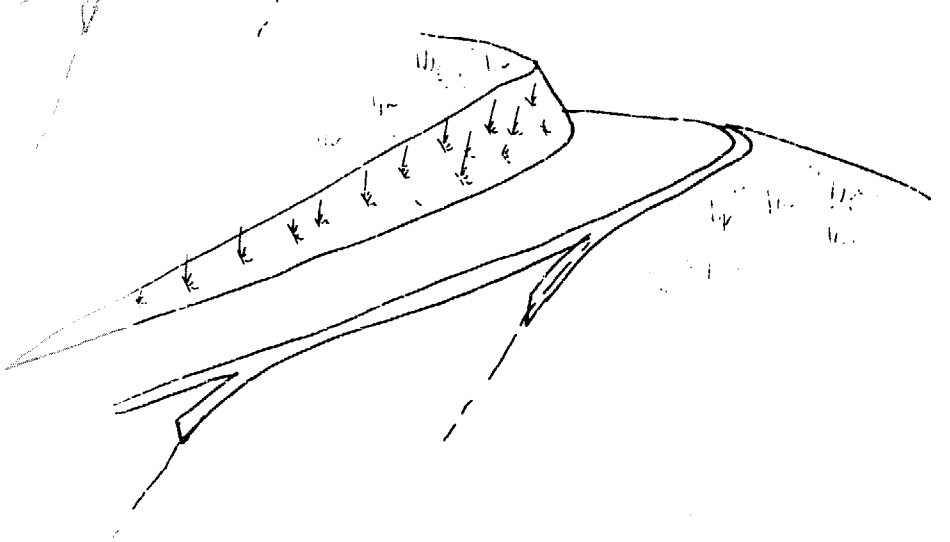

Picture 2.

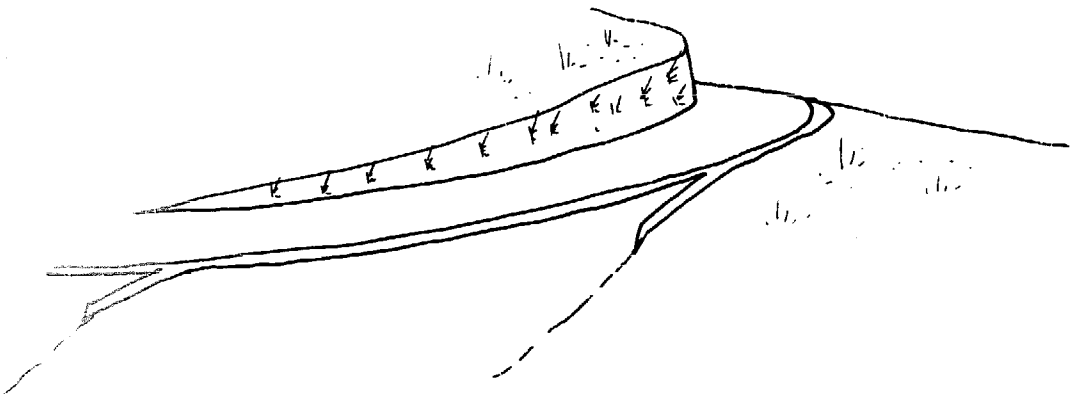

Picture 3.

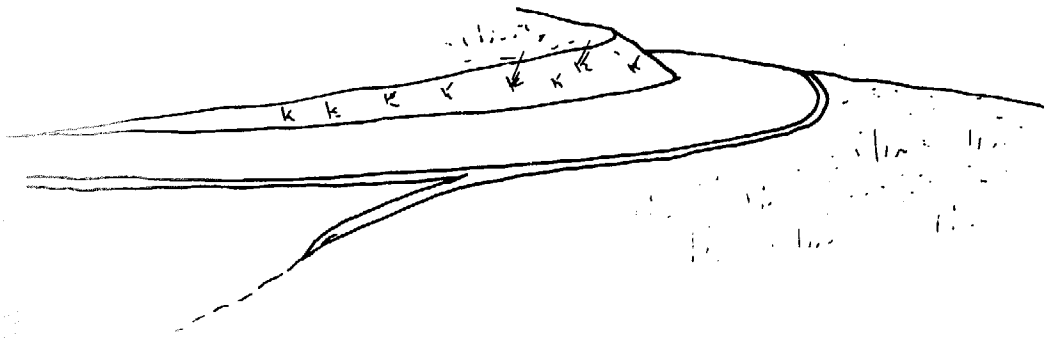

Picture 4.

(d) Catch drains.

When do you need a catch drain?

When a cutting is 3 metres high, or higher, a drain should be dug along the ground above the cutting. This will stop water coming down the hillside onto the cutting.

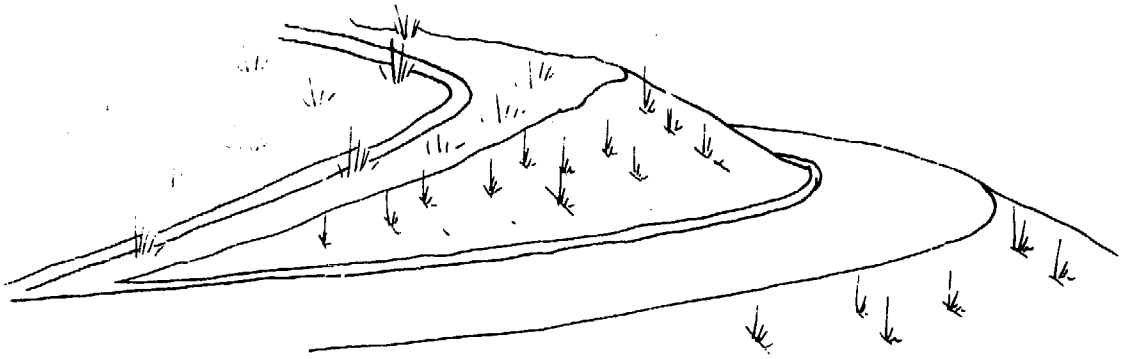

Where do you dig the catch drain?

If the cutting is 3 metres high, you dig the catch drain 3 metres back from the top of the cut. If the cutting is 7 metres high or more, you dig the catch drain 7 metres back.

What would happen if you did not dig a catch drain?

If there was no catch drain, water running down the hillside would wash away the face of the cutting, and could make it all slide down onto the road, like this:

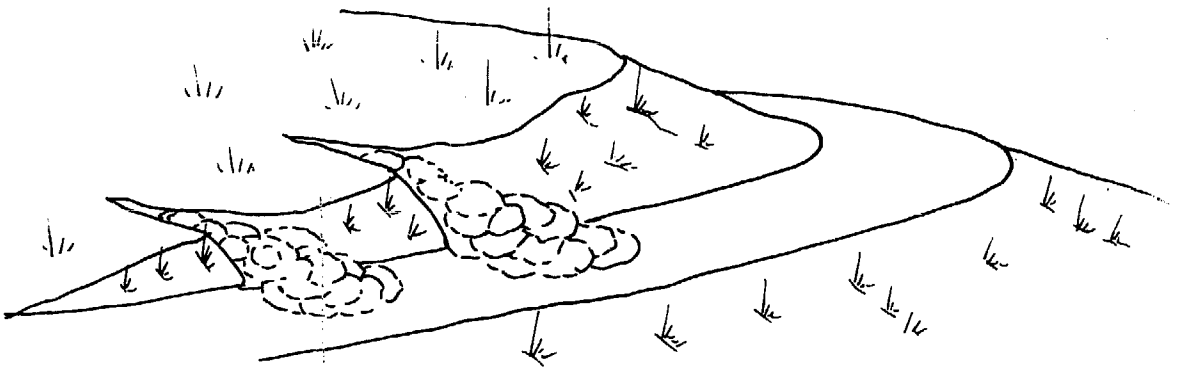

This is important: Now you have cut the bench, cambered the road and cut the side drains, the relief drains and the catch drains. All right. <u>Now the important thing</u>:

When the first heavy rain comes you must go straight away and look at the road. Suppose you see some places where the stones or fill have been washed away. This washaway (also called scouring) means your drainage is not good. You must start to make the drainage good straight away. You must make the camber of the road good again and you must cut more relief drains to keep water away from the road in the next big rain.

4. Batter.

This picture shows what we mean by "batter". Batter means the slope of ground across the road, where it is cut or filled. Batter is measured as so many metres vertical (up and down) to each metre horizontal (on the flat).

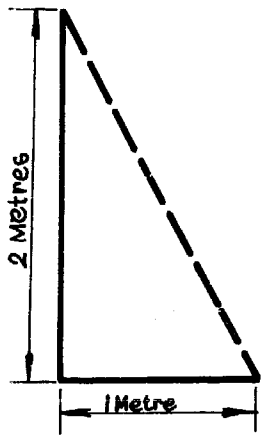

Usually, a cutting should be dug with a batter of 2 to 1, as in the picture. If the batter measures 4 metres up and down, it should be 2 metres on the flat and so on.

But if the road is in very mountainour country, see if the ground is strong enough to stand up at a steeper batter, such as 4 to 1 (nearly vertical).

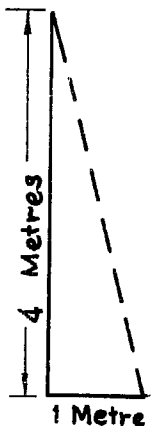

If it will stand up, and the road can be built this way, then a lot of cutting work can be saved.

If the road is built with very steep batters, some parts might fall down. These parts should be quickly cleared so that the drains do not get blocked and make washouts on the road surface. Suppose you have a high cutting, with a cut 7 metres or more, then you must use the right batter, 2 to 1. At every 7 metres of height from the bottom, a step 1.5 metres wide must be formed, then the batter goes on up at 2 to 1.

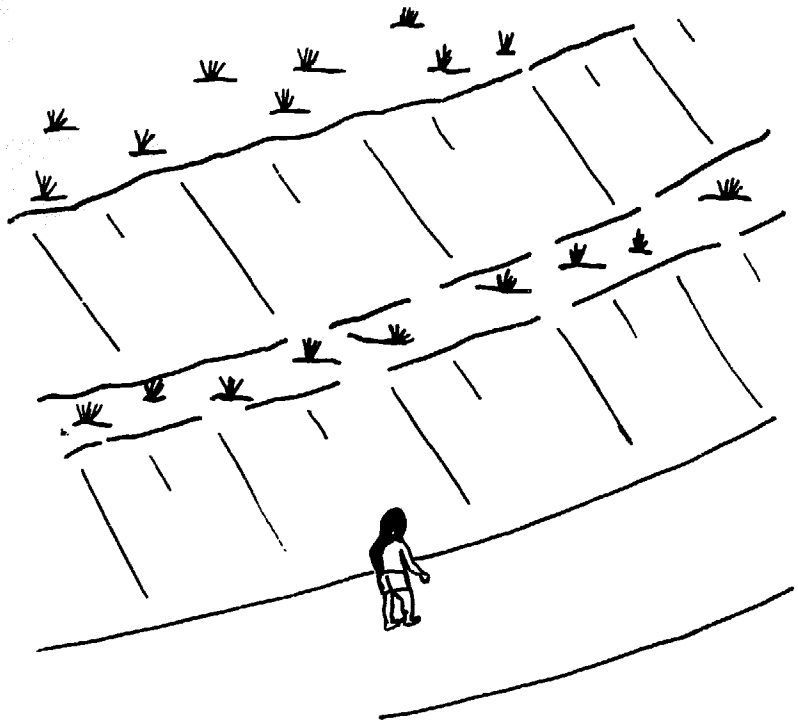

The batter at the bottom of this picture is 3.5m on the flat because the cutting is 7m higher to the step. Then the step is 1.5m wide. Then the top of the cutting is 6m high so the top batter is 3m on the flat.

For cutting batters, especially many high ones, you should use a template like that shown before (page 30).

Hairpin bends.

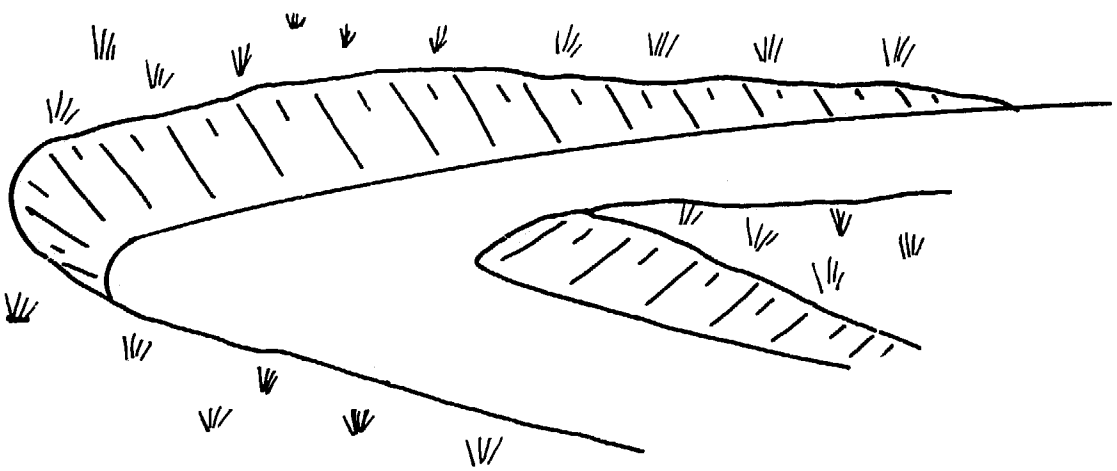

When the surveyor marks the route where the road will go, he tries to have no hairpin bends. Hairpin bends are not good. But sometimes the surveyor has to use a hairpin bend. Then he marks the route very carefully so that a tractor and trailer can get around the bend without stopping. Suppose the tractor is turning round the bend, it goes in a circle of radius 15 metres.

The road at the inside of the bend must be graded smoothly, so there is not a sudden bump in it. This means the outside of the bend must be almost flat. The normal grade of the road does not start again until the road goes straight in the new direction, after the hairpin bend.
Drains must be built carefully round the hairpin bend, so that water does not wash away the pavement.

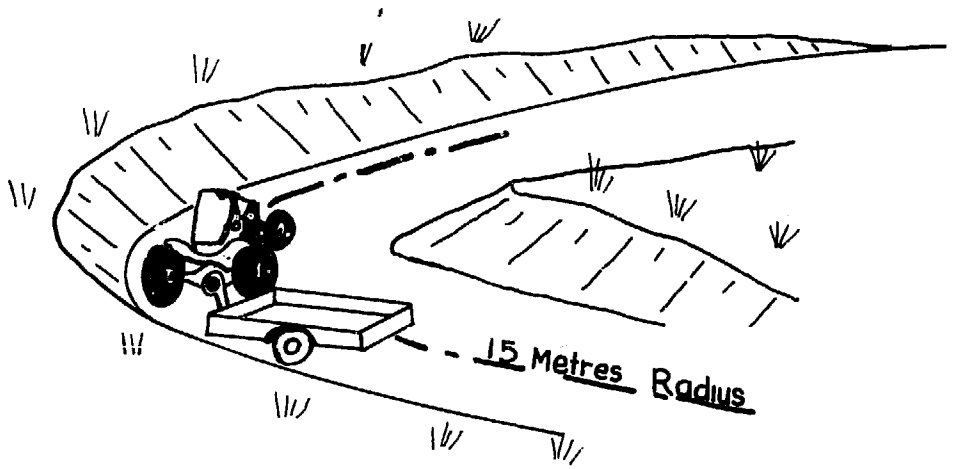

Bench cut roads can give a lot of trouble. They are hard to make properly so that trucks can use them all the time. Also, you have to work a lot to maintain them. BUT you will make the bench cut road as good as possible for trucks, and as easy as possible to maintain, if you construct them as I have told you.

B. HOW TO CONSTRUCT A ROAD ON FLAT COUNTRY OR COUNTRY THAT IS NEARLY FLAT

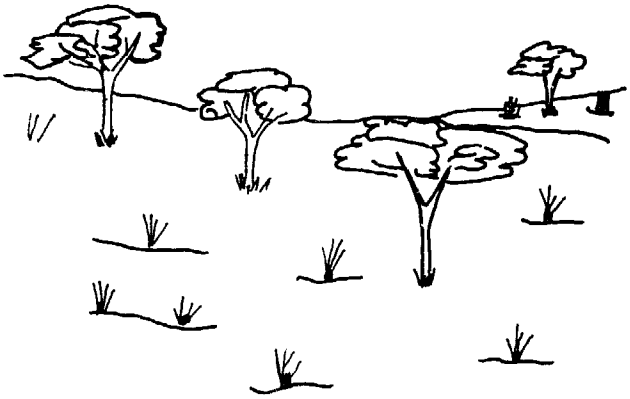

This picture shows country that is nearly flat. Engineers say it has a "very low crossfall".

This section tells you how to construct roads that are not bench cut. A road along the ridge top of a mountain is not bench cut. You will use this section for constructing ridge top roads.

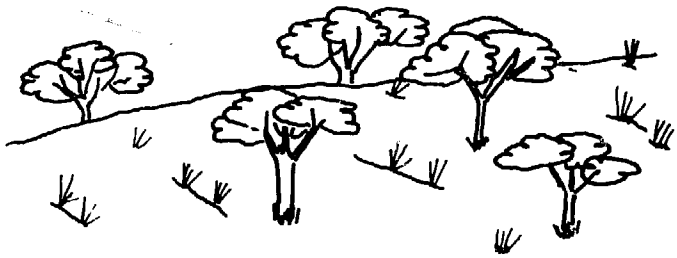

A ridge.

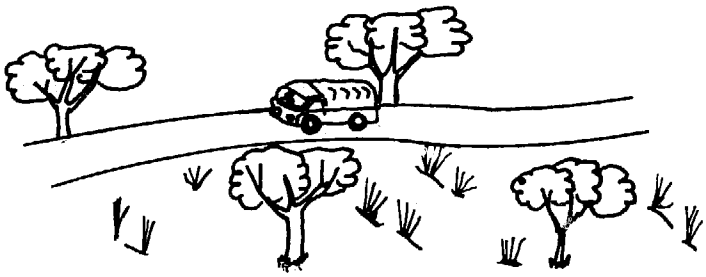

Ridge top road.

1. Clearing the bush.

USUALLY, you clear all the bush for 10 metres from the centre line of the road that you are beginning to build.

You cut down the big trees that are less than 30 metres from the centre line of the road.

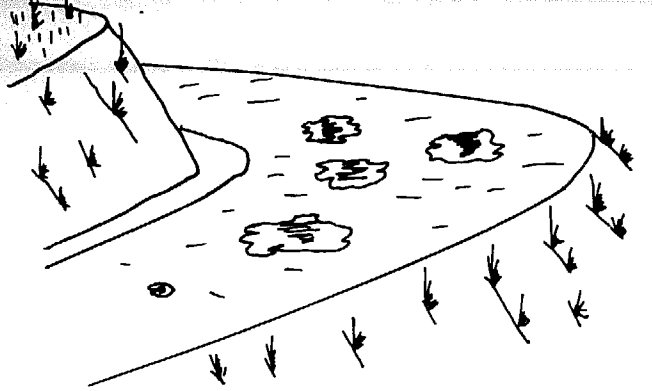

(b) This road is too flat. Water has collected in puddles. The road surface is not good (Read page 12).

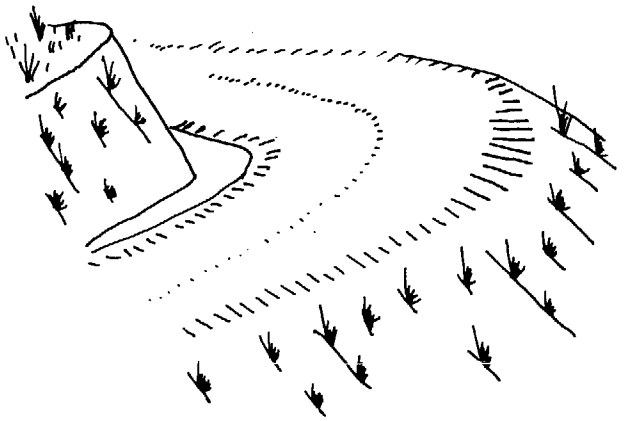

(c) This is a good camber. The storm water runs off easily, water cannot collect in puddles or holes.

4. <u>Formation of the Road - side drains</u>

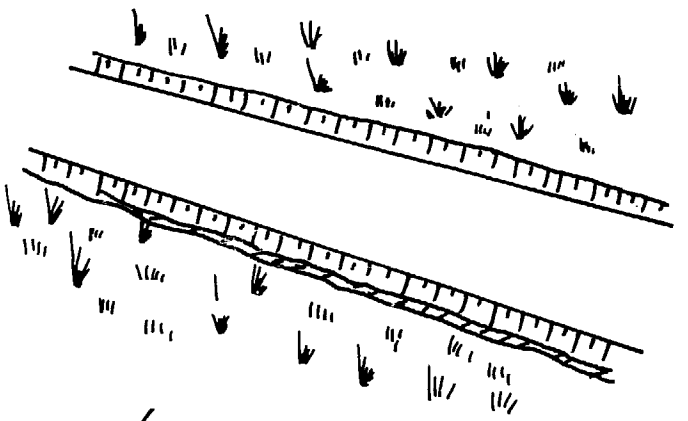

The side drains carry away water that runs off the road. They also carry away water that flows towards the road from the area around.

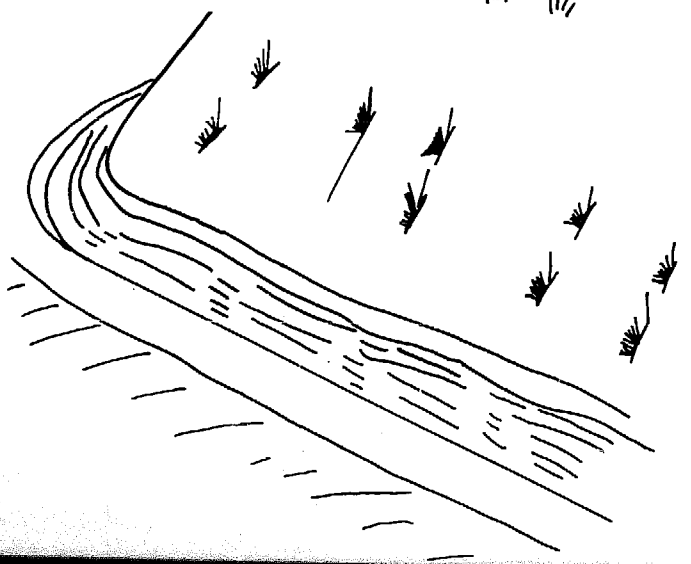

The side drains must be big enough to carry away all this water. (Side drains are also called table drains).

All the topsoil must be taken away from where the road will be.
Do not use topsoil to build up the roadway. Topsoil is too soft. Usually, topsoil is not more than half a metre deep. (500mm).

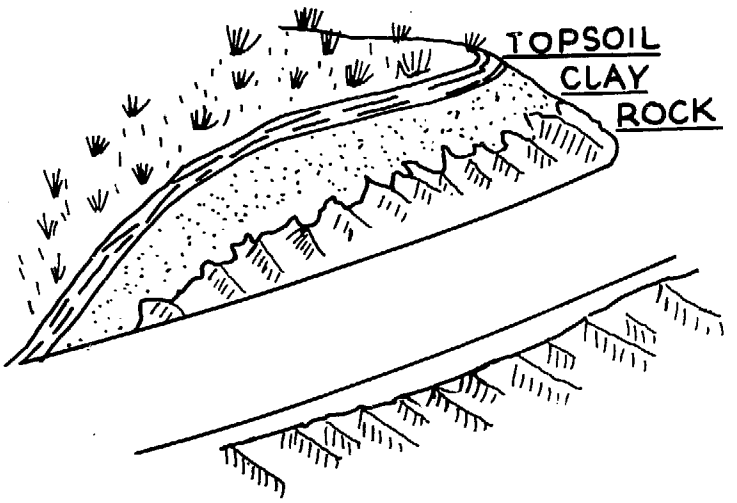

Cross-section of ground.

This picture shows a cutting. On top of the hard ground or rock is some topsoil. Sometimes the topsoil is only 100mm deep.
Sometimes it is 400mm deep. It is not often more than half a metre deep.
If it is less than half a metre deep, you must clear it all away before you begin the road.
Suppose you had to build the road in a place where the topsoil is very deep. What do you do? You cannot clear it all away. You cannot make the road on topsoil. It is too soft. All right, you must carry loam or sand or stone to the place to put on top of the topsoil. You must put on one lot of loam or sand or stone and ram it down very hard. A big Council may have a tractor and roller to ram it down hard. A small Council may have to get all the people to dance on the place to ram the material down hard, or they may use rammers that you can read about on page 66. When one lot of loam or sand or stone is rammed down hard, you must get another layer and ram it down hard. Each layer must be no more than 150mm deep when it has been rammed down. This stone or sand or clay material makes a "pavement" when it is rammed down hard. When you finish making the pavement, the pavement must be 300mm deep or even more deep. The pavement must not be less than 300mm deep.
Rhe road must not be less than 5 metres wide. Suppose you can make the road 8 metres wide, this is better.

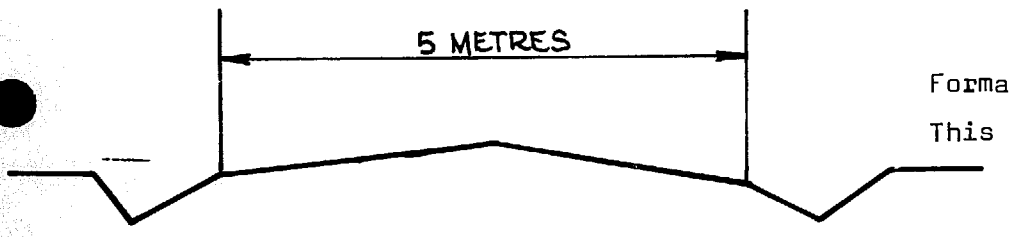

Formation 5.0 metres.
This is good.

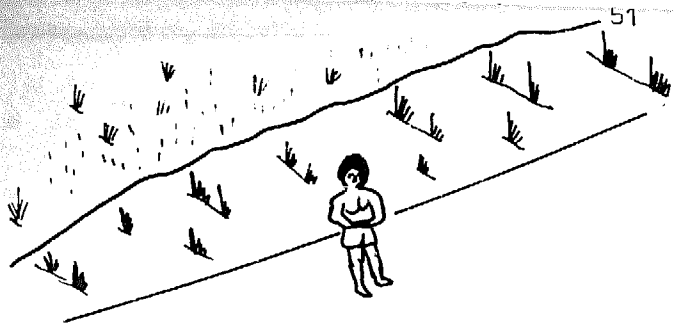

Formation is 8.0 metres.
This is very good.

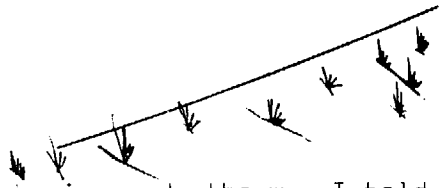

Now you must use boning rods the way I told you on page 29. The boning rods will help you to make the grade evenly between the pegs.

3. <u>Formation of the road - camber</u>

Now you must camber the road straight away, before rain comes. If you go to Embogo Training College, you will learn how to use a template. Use the template to set out a camber of 1 in 24. If you do not know how to use a template you can use these pictures to help you:

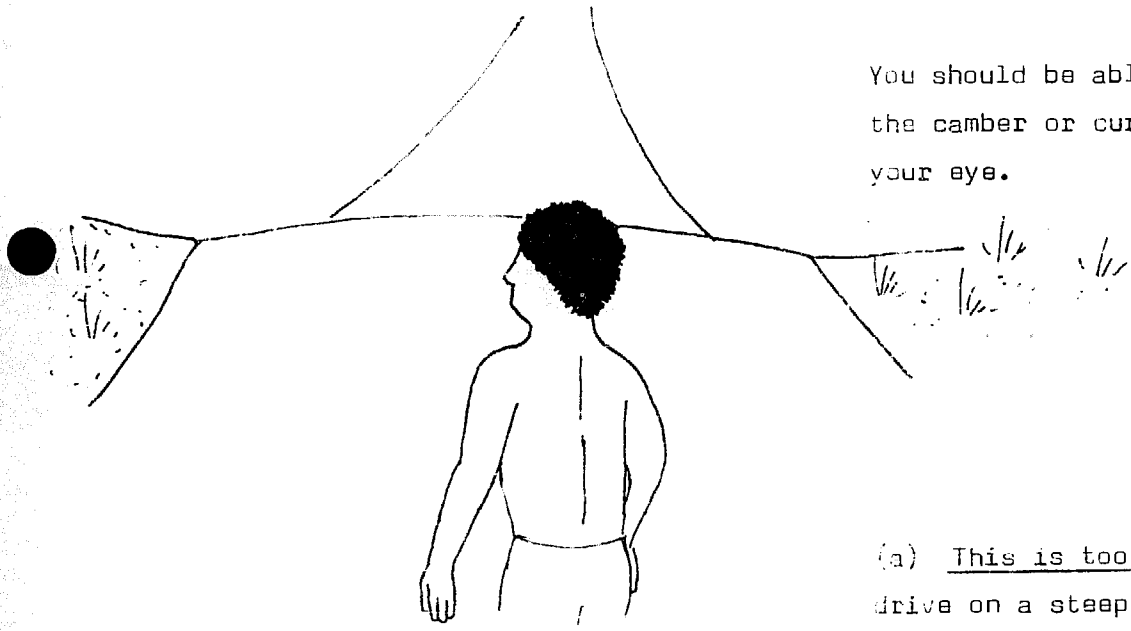

You should be able to see the camber or curve with your eye.

(a) <u>This is too steep</u>. You cannot drive on a steep camber like this. Also the storm water will run off too fast and this will scour the road.

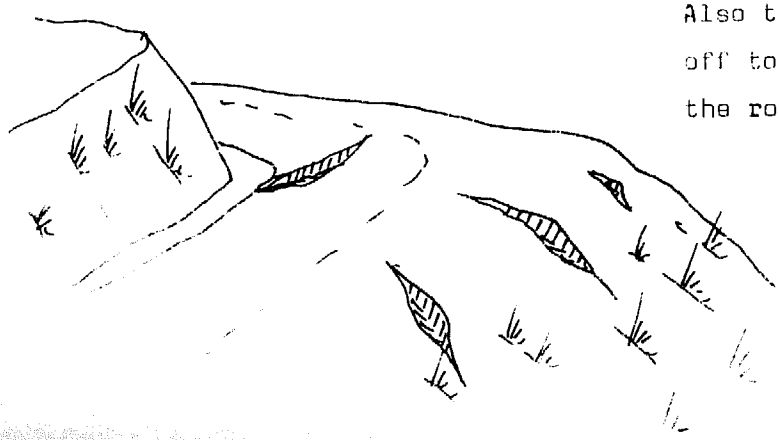

BUT suppose the road is on a razor back ridge, you must not clear trees and bush below the ridge top. If you clear these trees and bush, the ground will become unstable and you will make landslides fall.

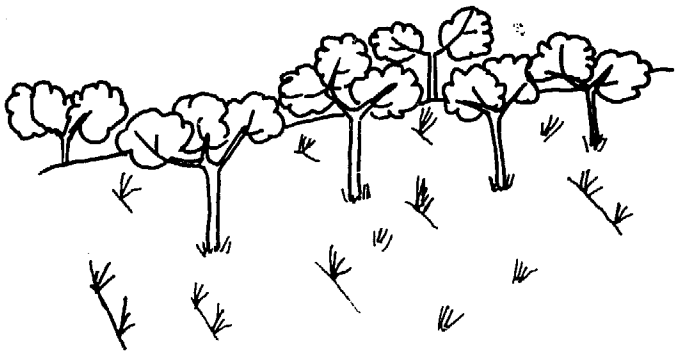

This picture shows a razor back ridge. You must not cut down the bush below the flat top of ridge top where the road will be built.

2. Clearing the topsoil

Next, you have to take away all the topsoil. Topsoil is the soft ground that plants and trees grow in.

These two pictures show where your road will be

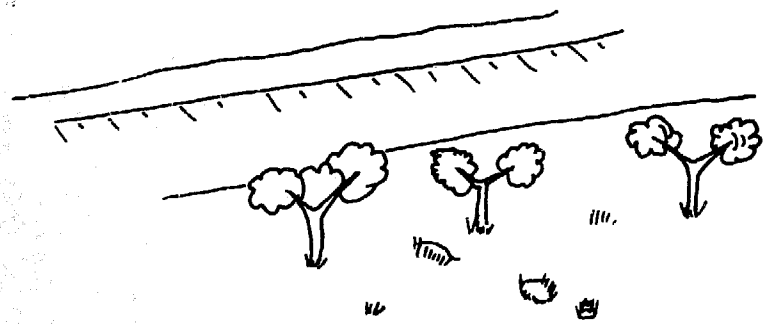

5. <u>Formation of the Road - relief drains</u>

Relief drains help side drains.

How many relief drains do you need? Read page 42 .

Where do you put the relief drains?

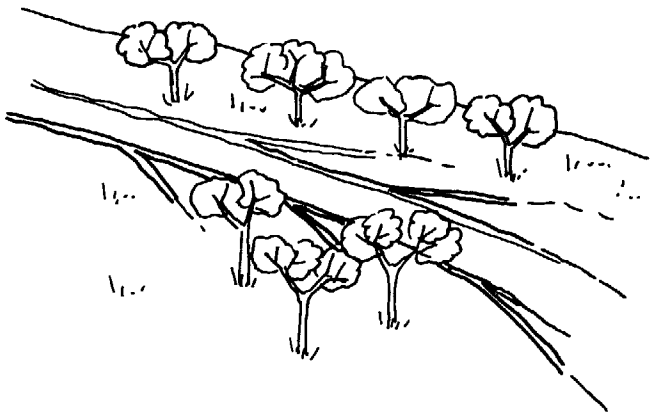

This picture shows where you dig the relief drains.

The relief drains should be at an angle of 45 degrees from the centreline of the road.

What do you do if you cannot get relief drains on both sides of the road? Sometimes the surrounding area makes it difficult to have the relief drains at an angle of 45 degrees from the centreline of the road; then you should follow the natural fall of the ground.

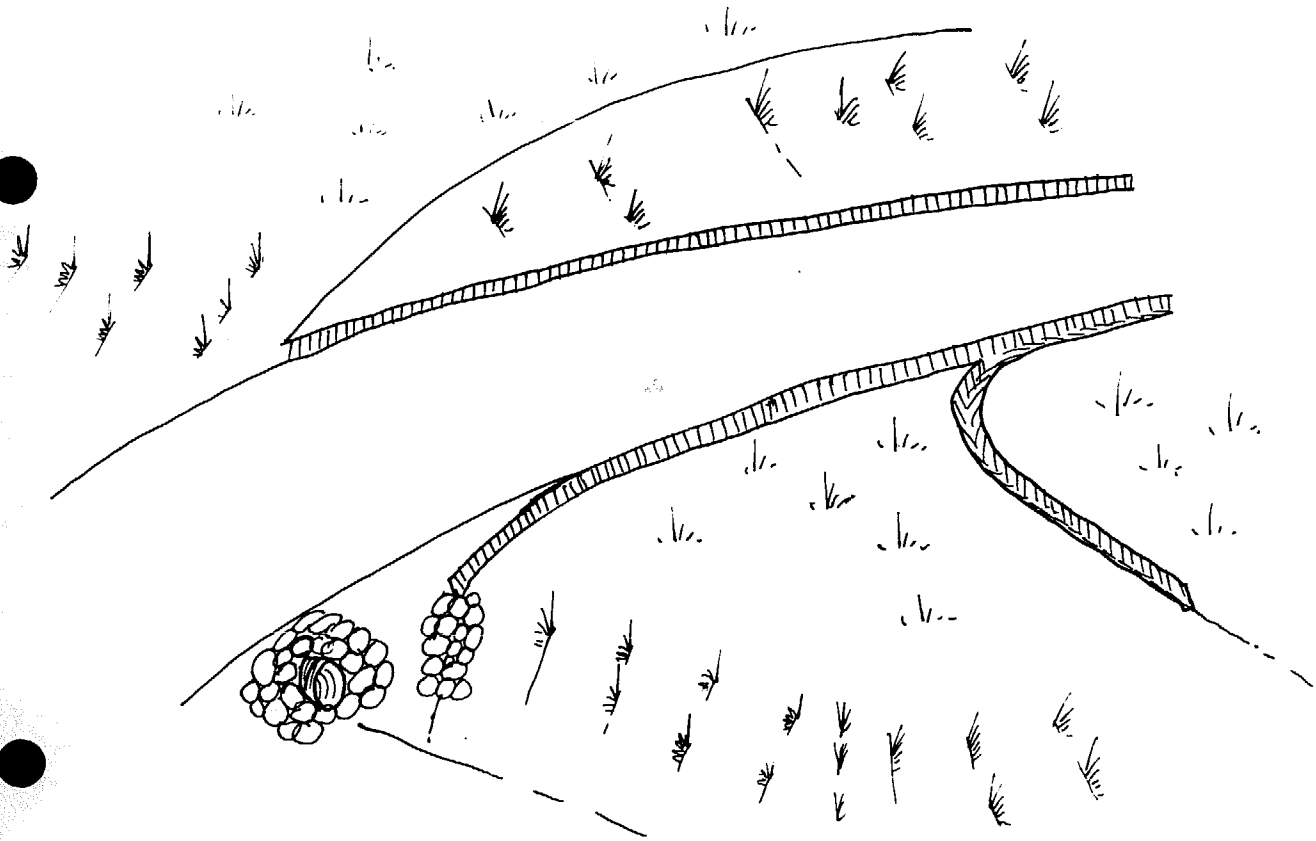

If relief drains cannot be built from one side of the road, because all the ground on that side is higher, then you have to put culverts under the road. The water will go through the culverts and away in the relief drains or the gullies from the other side.

6. Why do all roads need drainage?

People building a road on a steep hill can understand that they must make good drainage for the road, because the road will fall down if they do not make good drainage. People building a road in flat ground cannot understand this so clearly. People building a road in flat country often do not form the road properly or give it good drainage because they think the road does not need good camber and good drainage. This is bad thinking. Many roads in Papua New Guinea cannot be used now, because the people who built them did not make them with good camber and drainage. Suppose you build a road in flat country with good camber and drainage, trucks will always be able to use the road and also you will not have to work hard all the time to maintain it.

C. HOW TO BUILD A ROAD IN SWAMPY COUNTRY AND LOW LYING COUNTRY

1. Roads in swampy country are hard to build and hard to maintain.

Do not build a road in this country if you can build it in a different place. It is hard to build a road through country that is swampy or low lying. Also, it is hard to maintain a road in this country.
Suppose you must build a road in swampy country because all the country in that area is swampy. Then you must try to get the top of the road as far above the ground water-level as you can.

2. What is ground water-level?

(Ground water-level is also called the water table).
If you dig a hole or a well in the ground the level of the top of the water standing in the hole is called the ground water-level. The closer this is to the ground level, the more swampy the country.
Look at the next page and you will see what I mean.

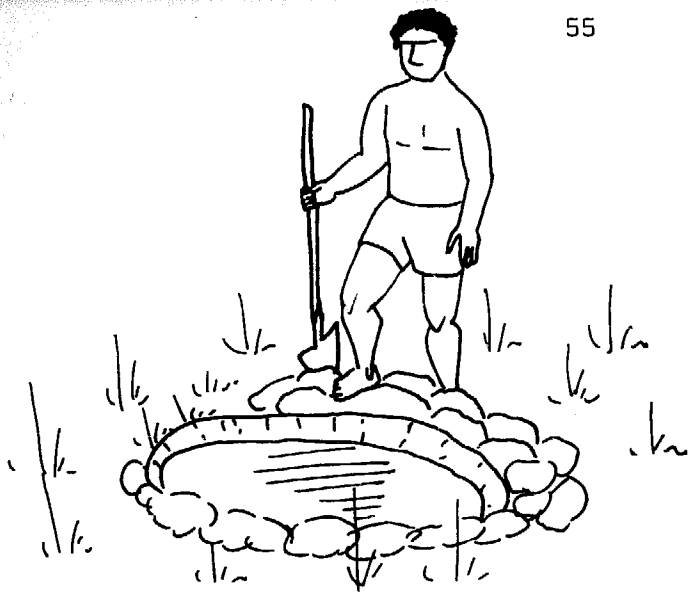

This picture shows the ground water-level in swampy country.

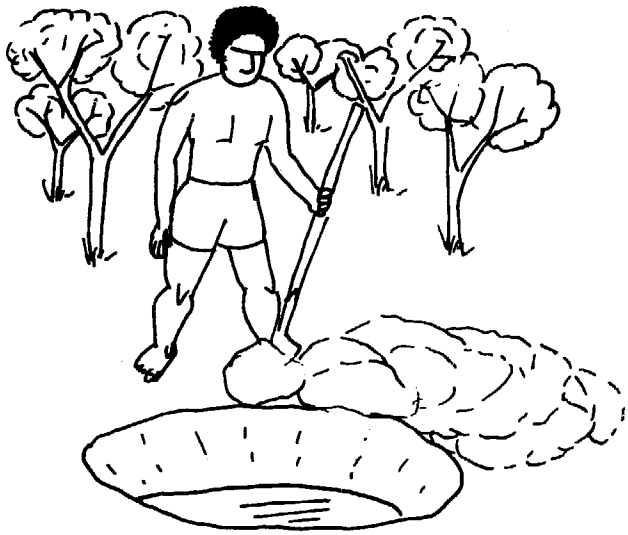

This picture shows the ground water-level in dry country.

How do you construct the road so that the top of the road is above the ground water-level? You do this by constructing big drainage ditches. You also build up the road with the ground that you dig out of the drains. You construct an embankment.

3. <u>How to construct an embankment:</u>

First you clear the bush. You must clear all the bush at least 15 metres on both sides of the centre line of the road so that the sun can get on the ground and dry it as much as possible. You must clear all the big trees for 30 metres on both sides of the centre line of the road.

Second, you make a mat of logs from the bush you cut. You must use trees that measure 100 to 200 mm across the end. This is called the diameter.

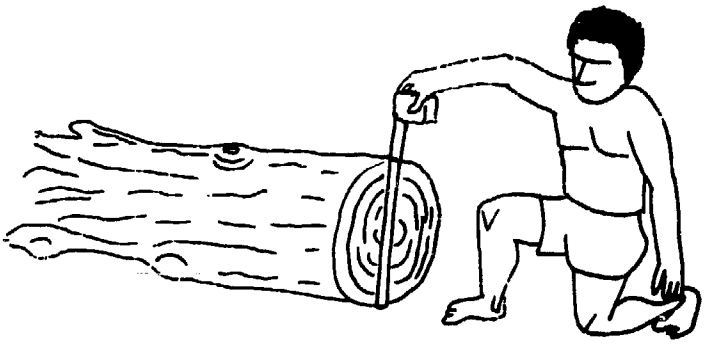

When clearing the bush you must choose good straight pieces of wood. You must cut off the leaves and branches and put the wood down side by side on the place where the road will be.

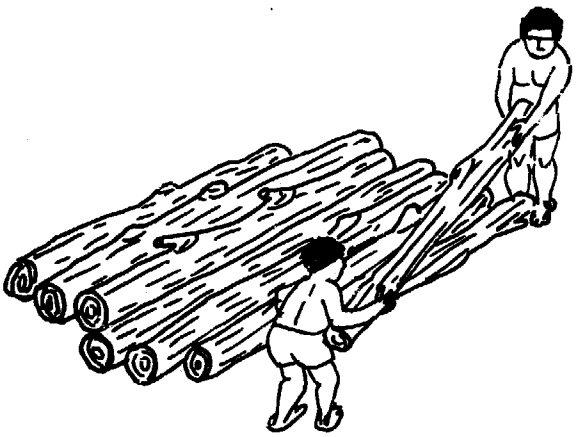

This mat of logs is sometimes called "conduroy".

Third, you must cover these logs of wood with the mud and soil that you dig out of the side drains. If you cover the logs completely, they will not rot or fall apart for many years.
Make sure that the ends of the logs do not stick out. If the ends stick out, the trees will rot and fall apart.

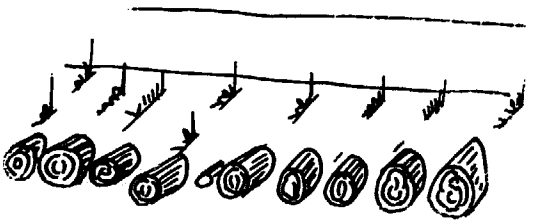

Ends sticking out.
This is bad.

In some areas, these logs may be eaten out by white ants after a few months, unless the logs are below the ground water-level. If this happens, more pavement might have to be put on top of the road to keep its strength.

Fourth you must build up the road with fill.

The place where the road will be must be built up so that the formation level of the completed road will be at least one metre above the ordinary ground level.

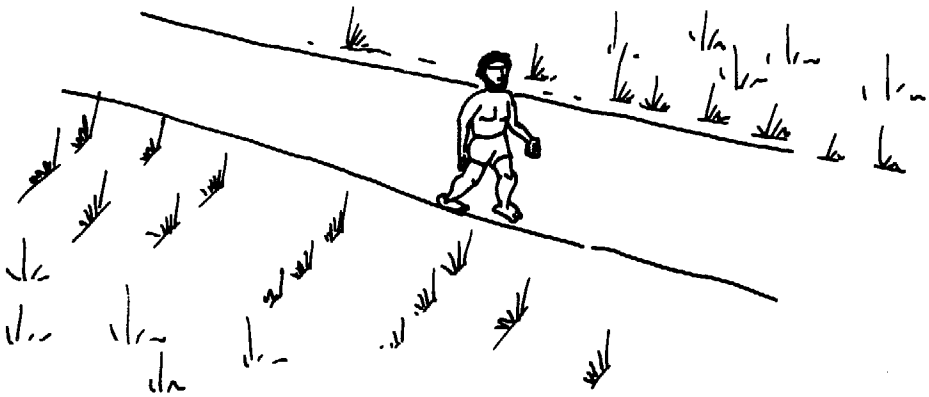

Suppose the ground water-level (or water table) is higher than the ordinary ground level. That means, suppose the place is always swampy. Then the ground-level of the completed road must be one metre above the ground water-level.

How deep should the fill be?

An expert has to look at the area to tell you these things. If you must build your road in a swamp, you must ask the Local Government Supervisor to come and have a look at the place to tell you what to use for fill, and how much to use, and how deep to put it. A road through a swamp is like a bridge over water, or like a causeway to an island. The "bridge" must have a strong deep fill that is not wet. This fill must not let trucks break through the surfacing material and fill to the soft wet ground underneath. It is most important to ram the fill material down hard. (Read page 66 to find out how to ram or "compact" material).

<u>The fill must not be wet</u>.

You cannot compact wet material. If you jump on a heap of ordinary ground it will go flat under your feet. If you jump on wet mud, the mud comes up through your toes and around your feet. The wet mud does not go down flat and hard. In the same way, you cannot ram down wet material for the fill. You must dry out the wet material or build up the fill higher above the ordinary ground level before you try again to compact it and ram it down.

The fill must not be too dry.

Suppose the material you have carried to the place for the embankment is too dry, then you will have trouble. If you jump on dry sand, the sand does not go hard and flat. The sand comes up around your foot and toes. But this is not a big trouble. You can sprinkle a little water on the dry material and then you can compact it and ram it down hard.

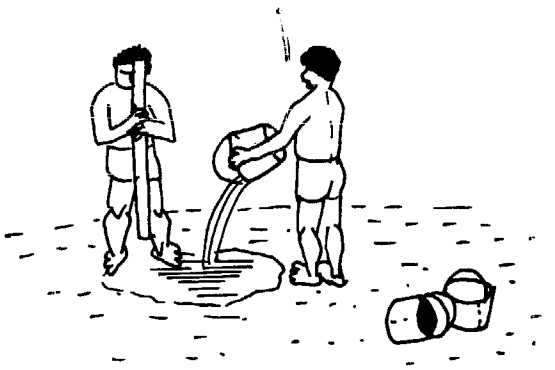

Do not pour on water.
This is not good.

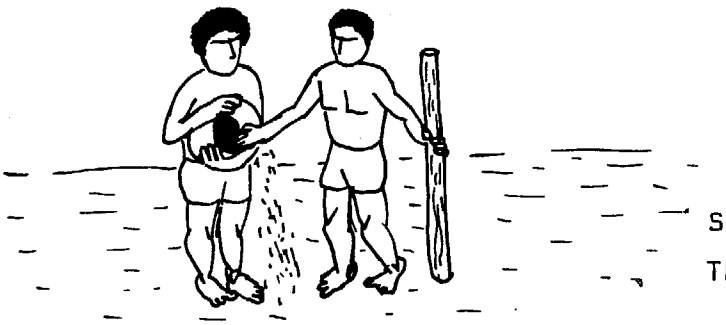

Sprinkle a little water on.
This is good.

Surfacing Material - What do you use? How deep should it be?

You have to ask the Local Government Supervisor to come and see the area to tell you about fill. He will also tell you what to use for surfacing material. He will tell you how deep the surfacing material should be.

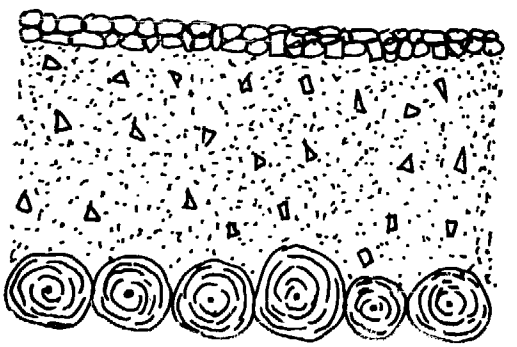

Surfacing material.

You must carry good stone or sand or clay to the place to make this.

Mat of logs covered with mud and ground from ditches or drains.

When you are filling these 2 types of ground, you need to take away the topsoil if the fill is 600mm deep or less. If the fill is more than 600mm deep, you do not need to take away the topsoil.

(iv) <u>You must use good material for fill:</u>

The material must not have any leaves or grass [illegible], either fresh or rotted (rotted leaves and grass are called humus) This means you should not use topsoil for fill except in swamps.

(v) <u>The fill must not be too wet or too dry.</u>

Suppose the fill is too wet or too dry or has leaves in it or humus in it. Then you cannot compact it. You cannot ram it down hard. How do you find out if the fill is too wet or too dry?
Suppose you do not know whether the fill is too wet or too dry. Try it. If you can ram it down hard, it is okay. If it is too wet to ram it down hard, you can leave it loose, and turn it to let all of it dry out. Then you can ram it down.
If it is too dry you can wet it a little bit by sprinkling water on it.

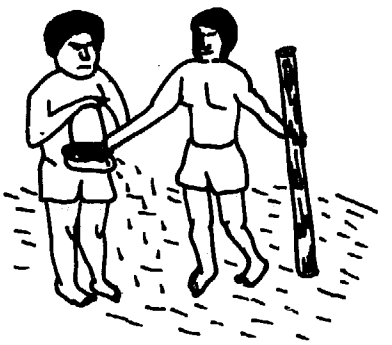

Sprinkle a little bit of water on the ground like I told you about on page 58.

(vi) <u>Put down the fill in layers:</u>

You must put down the fill a little bit at a time. Put down a layer that measures 150mm deep. Then ram it hard. Get poles of wood that measure 50mm across the end. Get a lot of men to use these poles as rammers.
When one layer is compacted and hard, put down another layer 150mm deep, do the same thing again.
See the picture on the next page showing men ramming fill with poles.

First you must keep the steepness (or grades) smooth and even between pegs. You do this with boning rods or a template. Read page 29 to find out how to make boning rods and how to use them. Remember that you must leave the pegs in the ground until the cut and fill are finished.

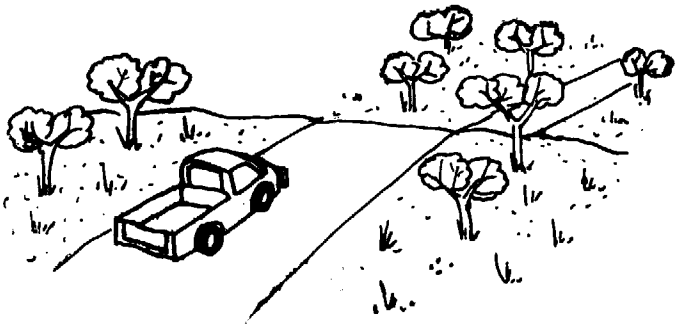

This picture shows curves in the slope of the road. These are called vertical curves.

Now you must construct vertical curves (curves in the slope) at the places where the road has a crest.
You must also construct vertical curves where the road has a dip.

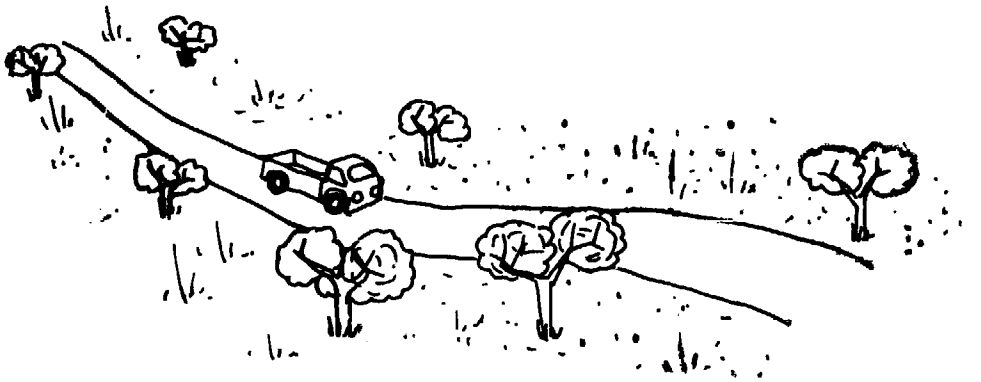

You must look at the way the slope changes, and build a smooth curve. This is not hard work, but the road will be much more safe when you fill in the places where the road suddenly dips, and when you cut away the bumps at the top of the places where the road rises.
But when you fill in the dips, you must not let water collect in a pond behind the fill. If the water seems to collect in a pond, you must cut a drain to let the water run away.
You must use good stone or sand or gravel for the fill. Also, you must ram it down hard. You can read how to ram material on page 66.

2. Horizontal Alignment. Make your road with easy curves or bends.

A good horizontal line means a road that has not got too many sharp bends or curves.

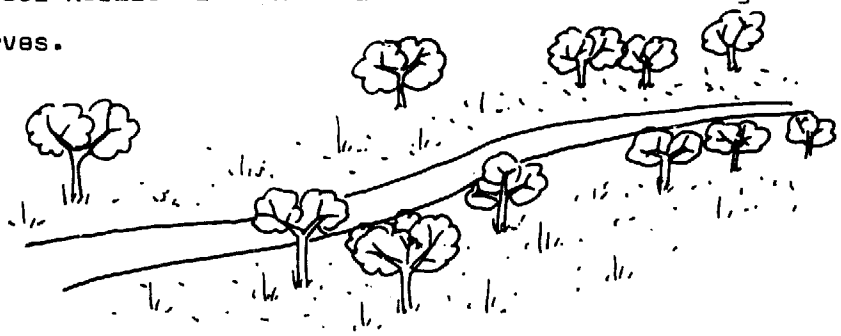

In hills or mountains, you cannot do much about getting a good horizontal line because that would take too much earthwork.

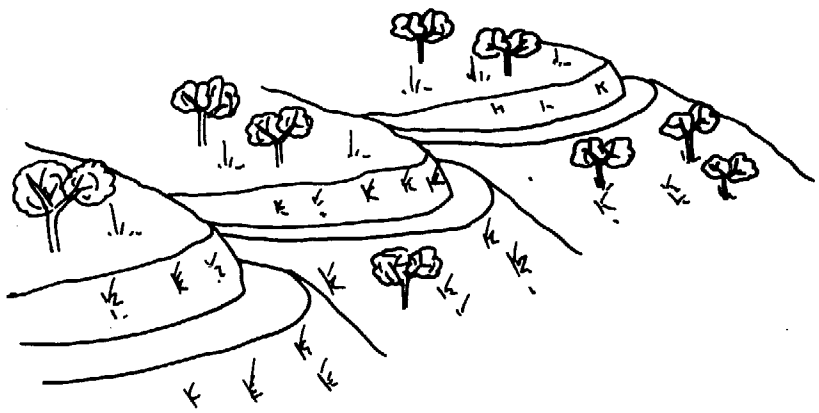

But in flat or easy country, you should try to build the road with a good horizontal line so that cars and trucks can go faster and safer.

Ask your Local Government Supervisor to help you get good easy curves.

The radius of curves should not be less than this.

Desirable standard	-	100m
Minimum standard	-	25m
Hairpin bends	-	15m

3. Temporary Culverts and Bridges

You can read some more about culverts and bridges on pages 90 to 128.

"Temporary" means something that will not last a long time.

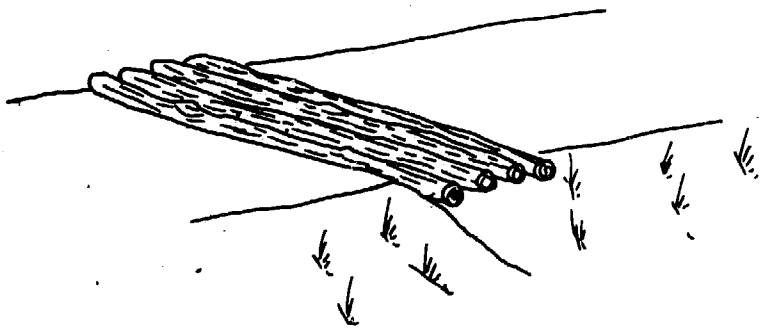

This is temporary bridge over a water course or a relief drain.

You can build a temporary bridge like this by putting logs over the drain. The logs should be about 100mm across the end.

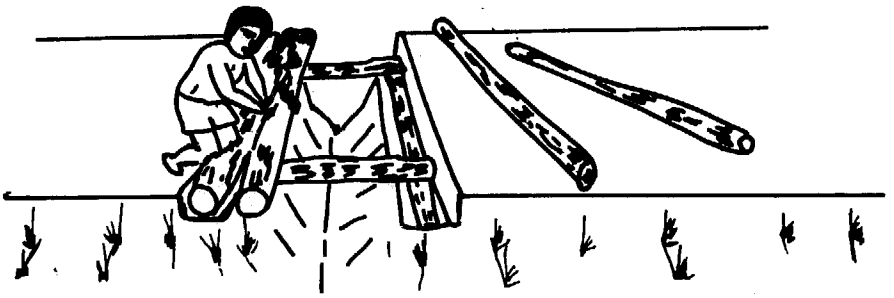

Usually you must cut a sill beam on each side of the drain to hold the short logs so that they do not go down into the banks of the drain or creek.

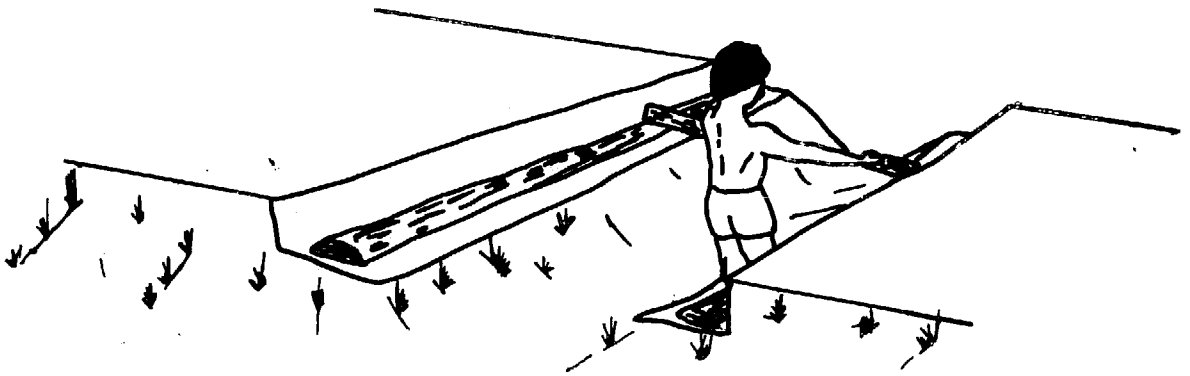

Suppose you want to build a good log bridge, read pages 104 to 119 in Section 8 about "Culverts and Bridges". Suppose you want to build a permanent culvert that will last a very long time. Read page 77 in Section 6 about "Upgrading".

4. <u>Side Drains</u> (these are also called table drains).
   You must look at these regularly, to see if there is any erosion. (Erosion means that earth is washed away by water).
   Suppose you see some erosion.

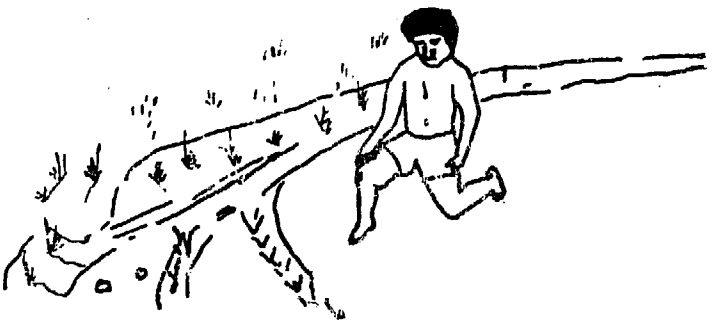

You must stone pitch the drain.

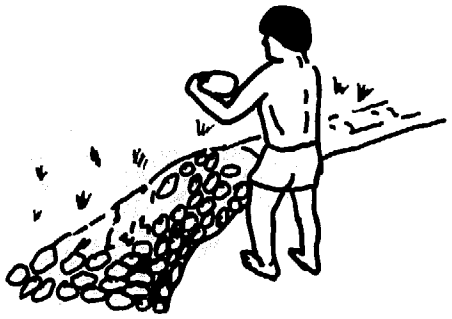

This means to put a lining of stones on the bottom and sides, to stop more dirt from washing away.

Stone pitching is very good to use where there is a lot of clay, because clay erodes easily.

Here is another way to stop erosion as much as possible.

You can "Step" the side drains like this.

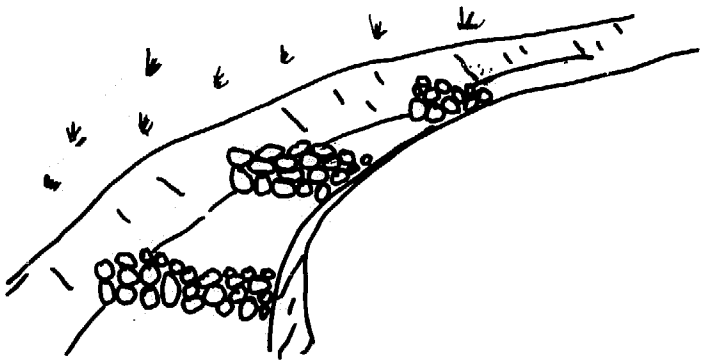

This picture shows a table drain with stone steps to slow the water down and stop erosion.

You make the small dams out of rock. You measure and build each dam 300mm high. The distance between them will depend on how steep the grade of the road is. The distance between each dam might be from 10 to 30 metres. You let the drain fill up with rubbish behind each small dam. This makes the drain not so steep and the water does not flow so quickly. You must dig a small put under each step. Each pit must be 300mm deep. You fill the pit with stones. The water falls on the stones and does not cause erosion.

5. <u>Filling</u>

(a) <u>Do not build a road on top of fill</u>, if you can build it in a different place.

Usually, Public Works Department Engineers do not like Rural Improvement Roads to be built on top of fill. Why not? They do not like Rural Roads built on top of fill because it is very hard to compact the fill properly. You need expert supervisors. You also need special equipment to ram down the fill properly. This equipment needs a lot of money. Also when you fill on a cross-fall slope, the fill may not be stable.

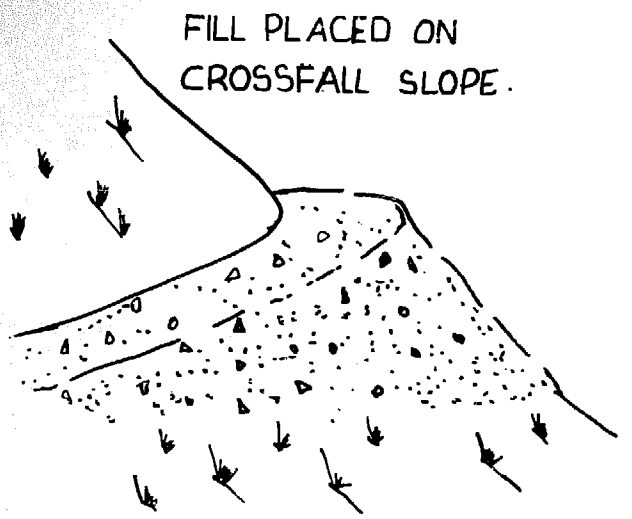

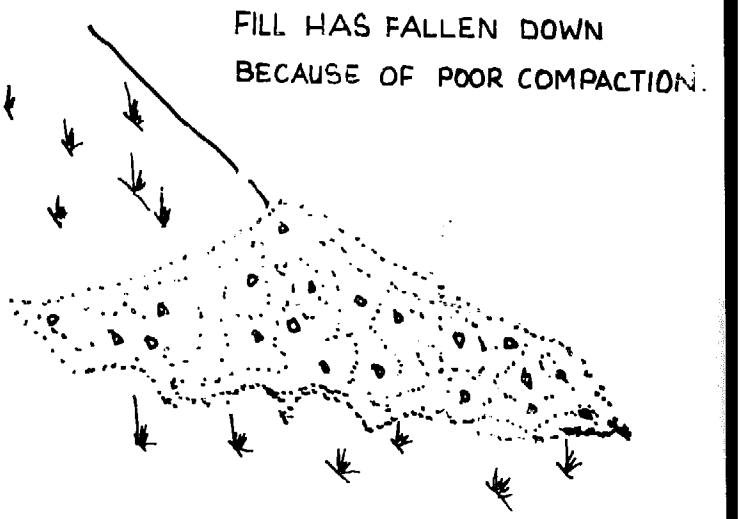

(b) <u>How to fill</u>:

BUT you will need a little bit of fill on your road and now I will tell you the best way to do it.

(i) See where the bottom of the fill comes to.

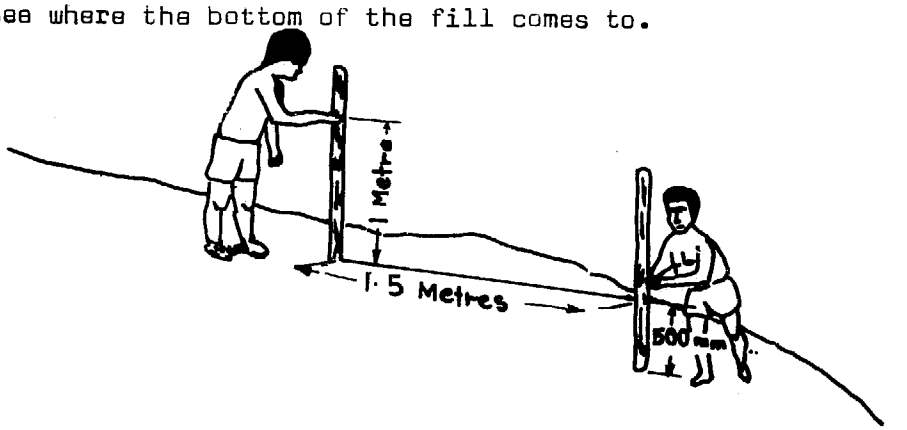

You start at the top outside corner where the fill will come. Work in steps, first down to the ground, then out horizontally, $1\frac{1}{2}$ times that distance, then down to the ground again.

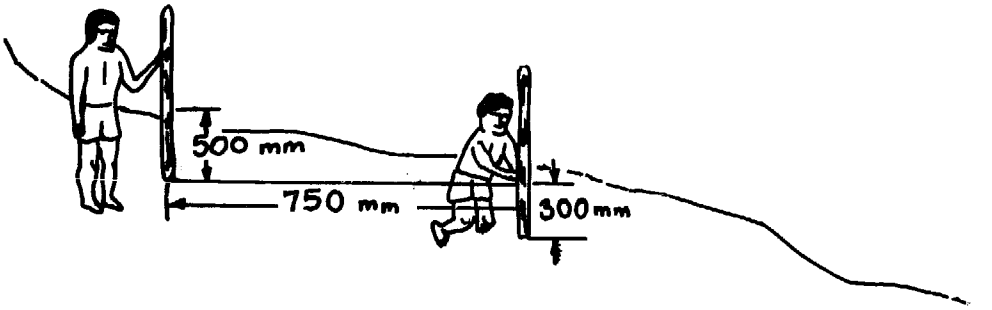

When the last horizontal measurement is on or near the ground (within 100mm), that is where the toe of the batter will be.

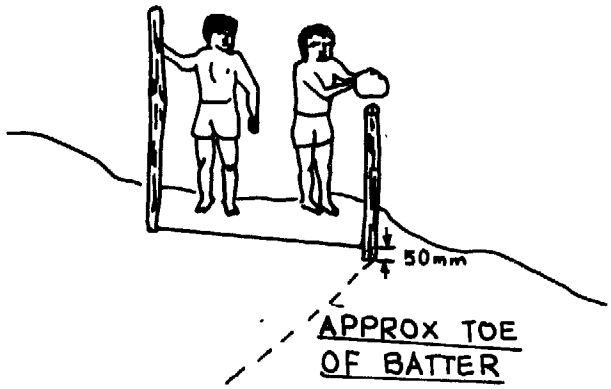

You cannot fill unless the natural slope is less than $1\frac{1}{2}$ to 1.

(ii) Suppose you are filling on a cross-fall.

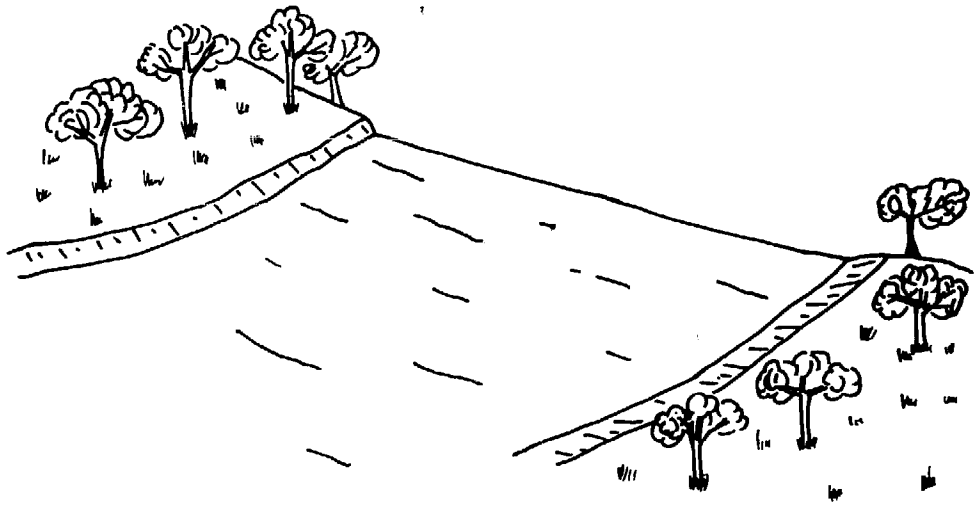

You clear away all the bush and trees and grass and topsoil from the place to be filled.

(iii) Suppose you are filling with no cross-fall or on flat ground.

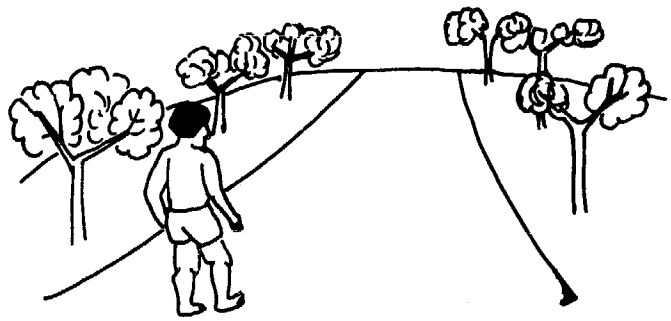

4. Camber on an Embankment road to keep the embankment dry:

You must keep the embankment as dry as possible. To keep it dry, you must form a camber for the road on an embankment. You form this camber from the beginning when you begin to construct the road. Most roads get a camber as the last thing, when the construction is finished. But a road in a swamp does not get camber last, it must have camber from the first mat of logs under the basecourse. You must supervise the road to see that the camber is kept all the time. When the road is finished you can set out a camber of the surfacing material of 1 in 24 if you can use a template. If you cannot use a template, read page 51 .

5. Road stabilizing fabric:

A new way of building roads in a swamp is to use "road stabilizing fabric". This is a thin sheet of strong material like plastic. You buy it in rolls. Each roll is usually about 5 metres wide and 100 metres long. You have to clear the trees and bushes (not the grass). Then you unroll the fabric where the road is to be built. Then, you cover it with 300mm or more of pavement such as sand, to form the road. You need machines (trucks or tractors and trailers) to do this properly.

6. What do you do when you have trouble building a road across a swamp?

There are a lot of different troubles about building a road across a swamp. This information is to help you with most troubles but you may find other troubles. If you have a trouble that this manual does not talk about, ask the Local Government Supervisor or Local Government Engineer for help straight away.

D OTHER INFORMATION ABOUT HOW TO MAKE A NEW ROAD

1. Vertical Alignment - Make your road go smoothly up hills.

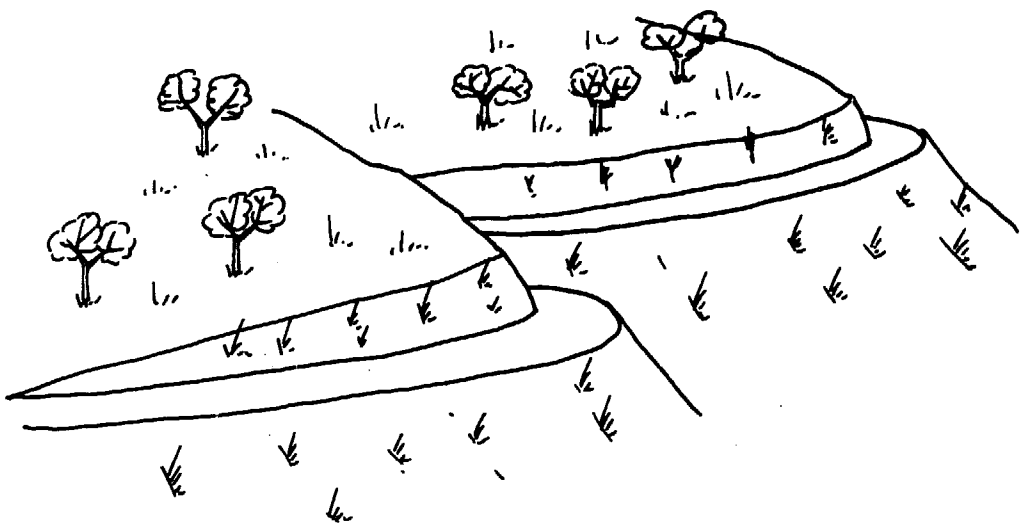

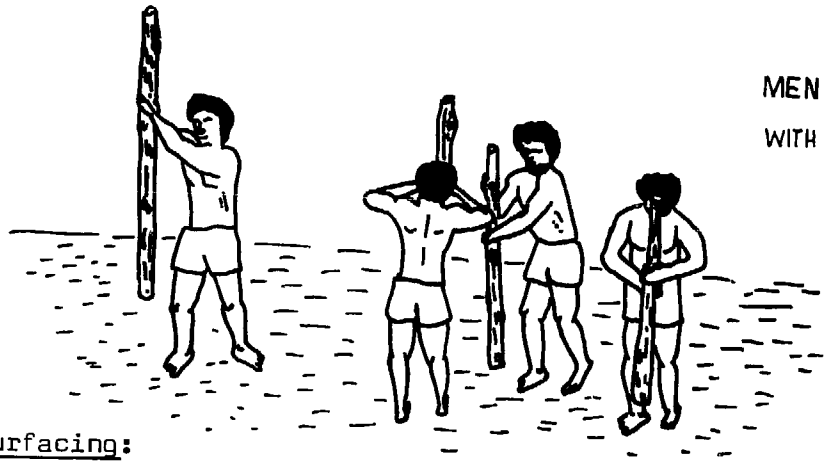

MEN RAMMING FILL WITH POLES.

6. Surfacing:

(a) When you build a road, the first aim is to make a road base that will not break up, when normal traffic uses it. The road base may be fill that you have carried to put on the natural ground. The road base may be the natural subgrade. BUT the road base must not go into holes when trucks run over it. The second aim is to have a surface that the wheels of cars and trucks can grip or hold and drive on, without slipping.

(b) How much surfacing material do you need?

(i) Suppose the subgrade is good. Then you need surfacing material that is 150mm deep before it is compacted. After ramming, the surfacing material should be 100mm deep.

(ii) Suppose the subgrade is not good. You need a lot more surfacing material. Suppose you put down one layer of surfacing material that is 150mm deep before it is compacted. That is not enough. It will quickly be forced into the subgrade by the trucks. Then it is no use as surfacing material. You need to put down a lot of layers.

(iii) Suppose you do not know if the subgrade is good or bad. You cannot always tell if the subgrade is good quality or not good. You must test little sections of the road before you surface all the road. You must put surfacing material on little sections of the road and make a tractor and trailer with a full load go over and over the section. You will quickly see if the surfacing material is strong enough.

The sections of road should be in different parts of the road. One section should be on a steep part, another section not so steep. One section in the shade, another not in the shade. One section on benchcut road, another section on flat ground, and so on.

You must test in dry weather and wet weather.

(iv) Suppose you put on surfacing material but the subgrade will not stand up to normal traffic.

Then you must ask the Local Government Supervisor for help. He will tell you what to do to surface the road. You might have to carry material like stone or sand to the place to make a fill. This is what you do when you build across a swamp. Read about this on page 55.

(v) Suppose your work is to make an old road better.

You call this "upgrading" a road. You can look at the old road and look at the surface. If the surface is in good condition, you know the subgrade material is good. If the surface is in bad condition you know the subgrade material is not good or the surfacing material is not thick enough. BUT think about one thing. The old road may be more steep than the new road. If it is more steep, the trucks work harder on it and the surface will not be in such good condition. The trucks will not work so hard on the new road that you build because it will not be so steep. The subgrade will be too weak for a steep road, might be strong enough for a new road that is not so steep.

(vi) Now here is one important thing: Suppose the road is very steep. (More than 10% grade).

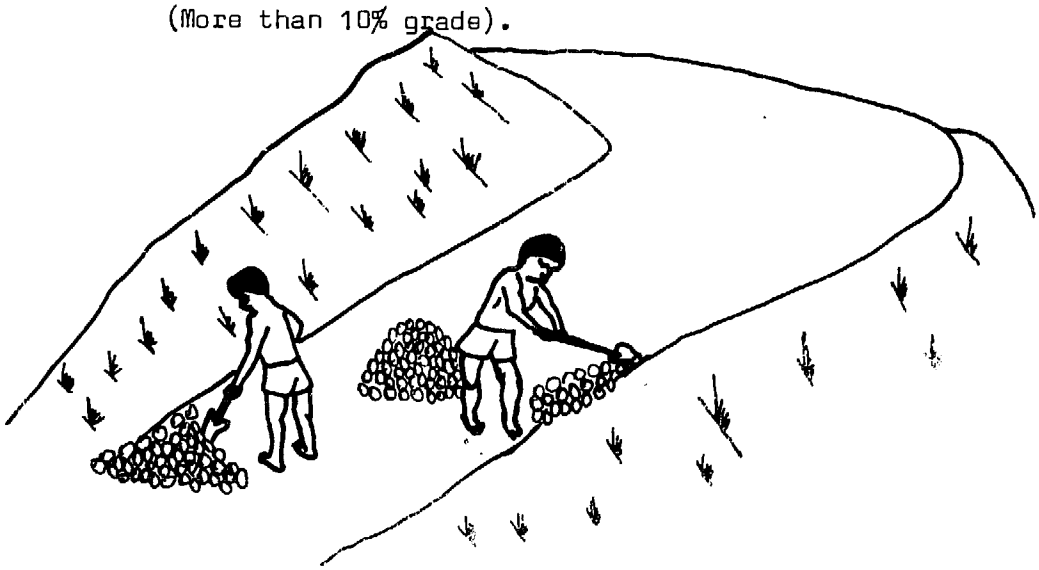

You must put surfacing material on any road that is steep like this. You must surface the road straight away, as soon as they finish the first construction.

You must not let any trucks on the road before the road has been surfaced. Suppose you let trucks drive on a steep road before you have put surfacing material on the road. The trucks will cut up the subgrade and the trucks will make hard work for you to do.

(vii) How much surfacing material on a steep road?

The surfacing material must be deep enough to prevent trucks from cutting up the road surface. Suppose you told the people not to use the road but some trucks and tractors used the road and road is cut up. What do you do before you surface the road? You must take away all loose material. Then you must camber the road again. Then you can put down the surfacing material. The surfacing material must not go on a subgrade that is soft and muddy, because you will need a lot more surfacing material.

(viii) What do you use for surfacing material?

a. The best thing is coronous if you have coronous pits in your area.

b. Hard stone with sharp points is good.

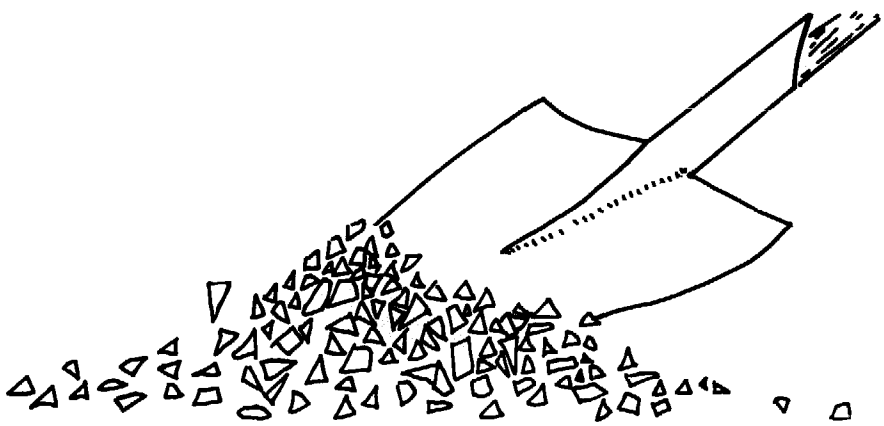

c. Round smooth river gravel is not good because it rolls out of place when trucks go over it.

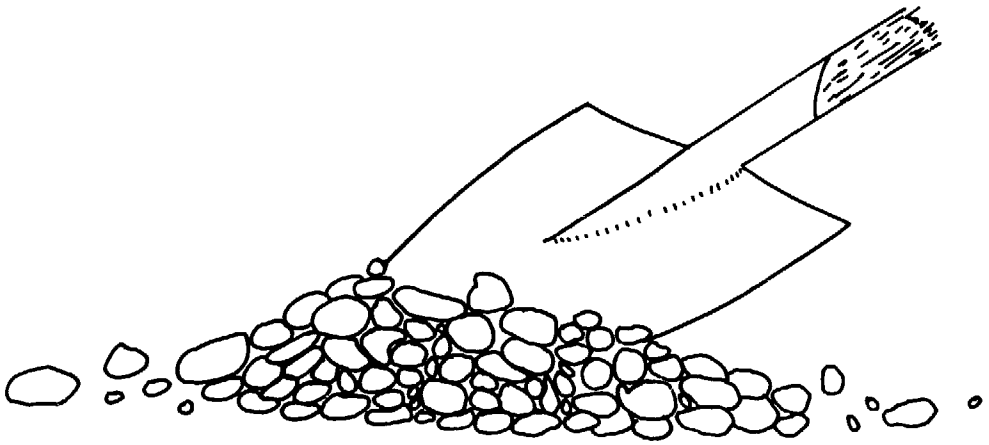

If you have no machinery, stone may have to be dug and broken up by hand tools - picks, spades and sledge hammers.
It is good to use a little sand and clay with the other material. One part of sand and clay in ten parts of other material would be good. (That is, 10% sand and clay).
This helps you compact the surfacing material better, and holds it together.

7. Removing Solid Rock.

It costs a lot of money to buy dynamite, to blast rocks. Also, in remote areas, it is hard to find the proper equipment. Usually, you can break the rock with fire and water. You must build a fire on the rock and keep it burning very strongly for at least four (4) hours. You muse use wood that burns very hot. On the coast, a fire of coconut shells is very good. When the rock is very, very hot you must throw a lot of water on the rock. Buckets and buckets of water. This cold water on the hot rock will make the rock break into pieces. BUT look out that all the people and children stand back from the rock. The rock may explode and hurt them.

8. Razor-back ridges.

In some areas, the road must go along a narrow razor-back ridge.
These ridges may be only 2 metres wide at the top. But your road should be at least 5 metres wide, or better 8 metres wide. What do you do?
You must cut down the top of the ridge.
But first, you must plant a "wall" of planted trees and bamboo on both sides of the ridge.

(a) The ridge should be cut down to where it is at least 8 metres wide.

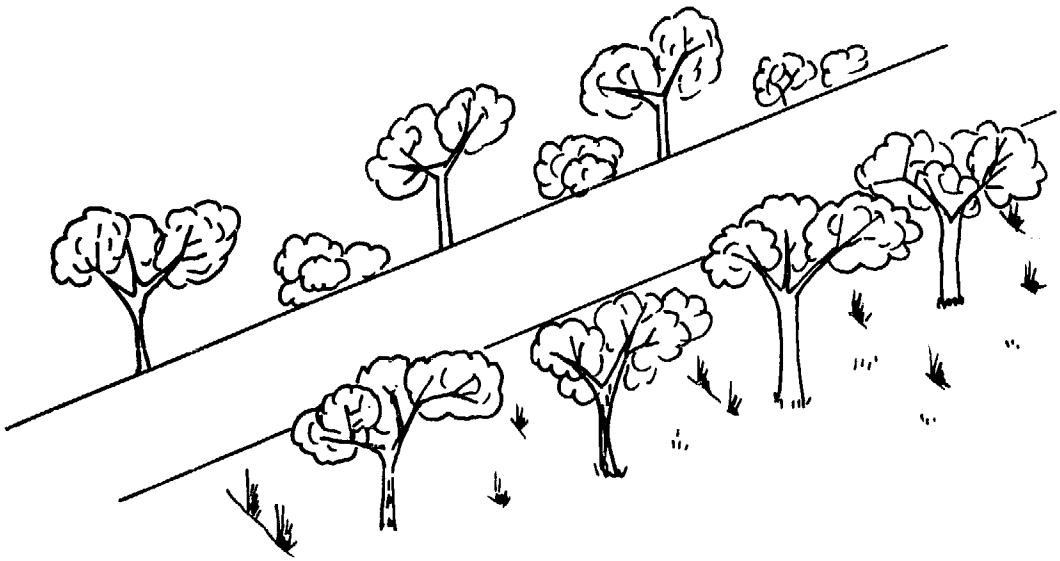

Suppose the 2 sides of the mountain are too steep (more than 1 to 1 slope). You may not be able to cut the ridge down to 8 metres wide, but the solid width must be at least 5 metres wide.

(b) Now you must plant the "wall" of trees and bamboo 4.5 metres on each side from the centre of the ridge. As these grow, the roots of the bush will be like a safety fence for the trucks and tractors. Later you will cut down the ridge. You can pile up clay against the "wall" of bush. This wall will make the formation wider and will give more safety for trucks in trouble. But this extra width will not usually be used, so you must mark the sides of the solid ridge-top with strong posts that can be seen easily.

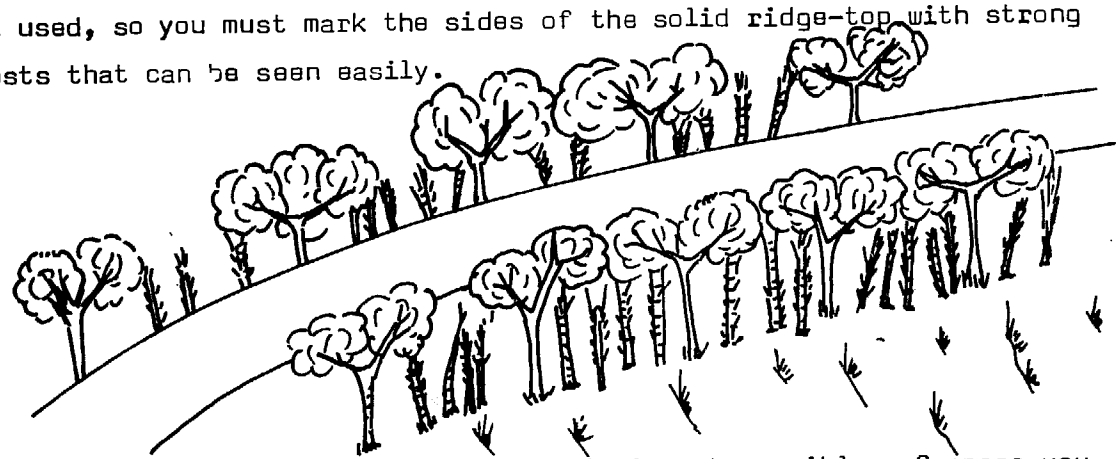

Suppose you think maybe a road like this is not possible. Suppose you think it is not safe. Suppose you are not happy about it. Then you must write to the Local Government Engineer, Soroko for advice and help.

(c) Draining a razor-back ridge

When you drain a razor-back ridge road like this, you must take care that you do not lose any of the road by erosion. The narrow section of road will usually be in a place in the mountains like this:

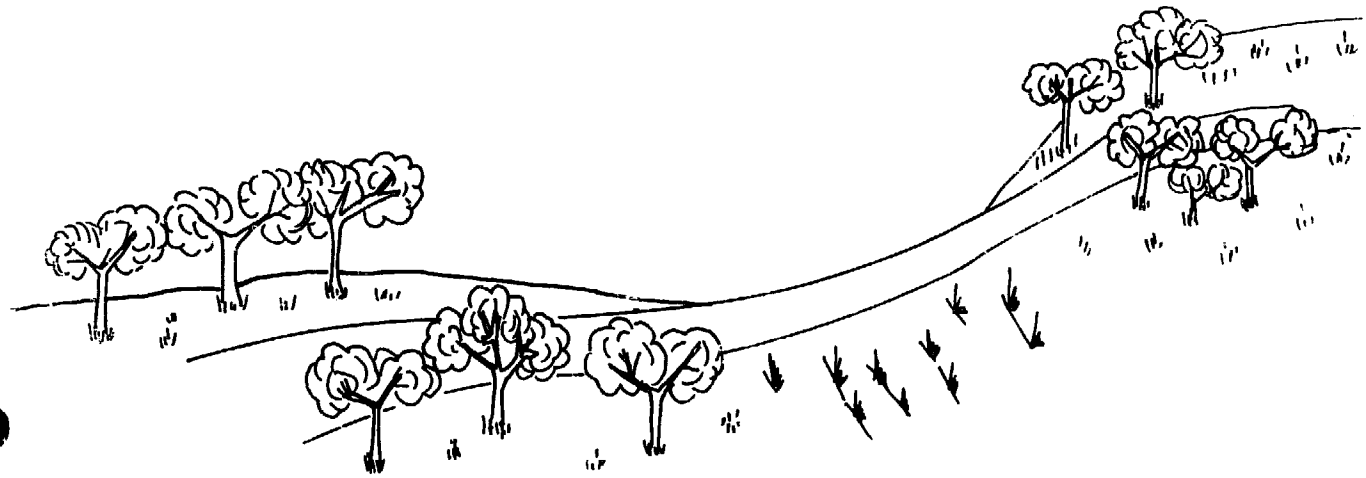

You must make two channels for the water at the two ends of the narrow section so that the water will go over the side of the ridge before the water reaches the narrow section.

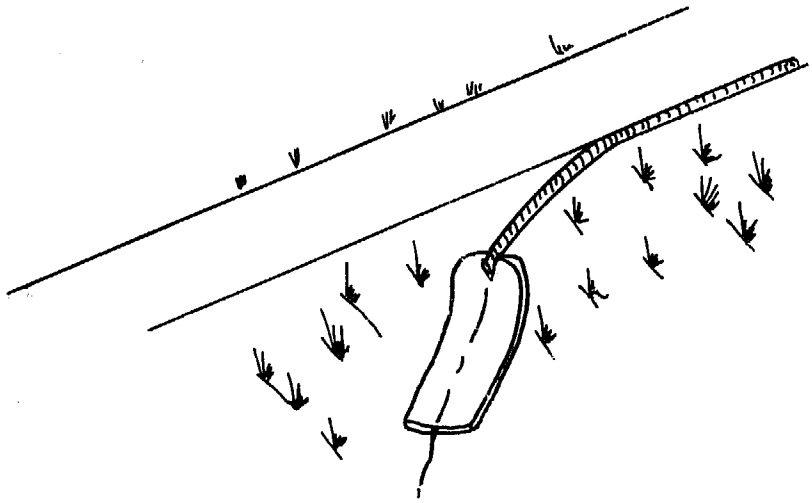

You will probably need to build "aprons" made out of concrete at the places where these relief drains let out the water. These aprons will let the flash-flowing water spread out without causing erosion. You can read page 102 to 104 in Section 8 about "Culverts and Bridges" to learn how to build a concrete apron.

You must always look out for erosion on the narrow ridge top. You must stop erosion straight away if it starts. Some months may pass before drainage and erosion troubles begin to show.

9. When can trucks use the road?

When you begin to construct or upgrade a road, you must decide whether trucks can use the road straight away when the road is finished. If the road is not surfaced, it should not be used until the new earthwork has settled down.

Suppose you decide that trucks should not use the road straight away when the road is finished. Then you must not let even one truck on the road. You must dig a trench across the road or leave a river without a bridge so that no trucks can use the road before you want trucks to use the road. Even one truck can damage a road badly. Suppose one truck uses the road and damages the road. Read page 69 to find out what to do.

10. Construction Management. (What to do with the workmen).

This book is not the right place to advise you how to manage your men. But I will tell you one thing about managing your workmen. Suppose you have a lot of workmen. You should divide them into groups. Each group of men has special work.

The men in Group 1 clear the bush.

The men in Group 2 make the first earthworks.

The men in Group 3 form the road - camber and drainage.

The men in Group 4 construct bridges.

The men in Group 5 surface the road when the initial construction is finished.

The five groups can all work at the same time on different sections of the road. As the group gets good at the special work of the group, you will not need to supervise so much. Do not let the men change around from one group to a different group.

How can workmen make the road the proper width if you are not there to supervise? You can give the labour line a piece of rope with knots or markers that measure distance. Give them one rope that measures the distance from centre line to the outside of the road formation. Give them another rope that measures the distance between the drains.

If a road was not well-built with camber and drainage, it will lose pavement faster. If it was well-built, it will lose pavement more slowly.

Suppose a road is drained, but stays soft and muddy. Then you know that the subgrade is not good enough, or there is not enough basecourse, and you should ask the Local Government Supervisor to help you. The surface material gets worn off all roads. When it is worn off, you must put down a new layer before all the old layer is worn away. This is called resurfacing or "resheeting".

Suppose you do not fix the road and all the pavement wears off. Then the trucks will cut up the road, and the damage gets very bad.

When do you re-surface a road?

On a good hard road with good pavement, you might need to re-surface it after three years. On a bad road with bad pavements, you might have to re-surface it after six months. If the road is steep, it will lose its pavement more quickly.

How do you re-surface a road?

New pavement can be carted and spread by hand, but that is a slow job. If your Council can use tractors and trailers, you can do the job quicker. If your Council can use trucks and a grader, you can do the job quickest and get the best result with these. Graders are best but they cost a lot of money.

Can your Council buy big Equipment?

The Council has to think if it has enough money to do the job by machines. On the more important roads called "feeder roads", the Council gets some money from the Government for maintenance.

3. You must make the camber good again.

A road can get flat and not have a camber. Then the road will have potholes, bumps and bad drainage.

What you do if a short bit of road has lost its camber?

In some places, if the trouble is not too bad, you can just "top up" the road along the middle, and get back the camber.

If a few metres of the road have got soft and have sunk, then you can dig out the soft material, 0.7 metre deep, and fill it up again with good hard stone. You put the new stone in layers 0.15 metres deep, and ram it down.

SECTION 6 : UPGRADING A ROAD

"Upgrading" a road means improving a road. You make it a good road.

A. WHY DO YOU NEED TO UPGRADE A ROAD?

In Section 1, we said that roads that are too steep are bad, for five (5) reasons:

1. Ordinary trucks and tractors cannot use roads that are too steep. Only 4-wheel-drive trucks can use them.
2. These roads are not safe. A truck going down a steep hill might slide and crash.
3. Trucks have to work hard when they go up a steep road. This damages the road.
4. Rain water runs very fast down a steep road. This damages the road.
5. It is hard to improve a steep old road - you have to build a new one. This is called "upgrading".
   You can read about this on pages 76 to 80 .

B. HOW DO YOU UPGRADE A ROAD THAT WAS NOT SURVEYED BEFORE IT WAS BUILT?

1. You must get the road surveyed. Many old roads will be good new roads if you only change the steep sections. Suppose the survey shows that there are two places that are very steep. All right, you can construct 2 new sections of road that are not so steep in those two places. That is enough. Now your road is upgraded enough.
2. Put in temporary log bridges and culverts - a temporary bridge is one that trucks can use for a little time until you build a permanent bridge in that place.
3. Put down some surfacing material. Not very much, just enough so that trucks can use the road but not cut up the surface. Now you must ask the Local Government Engineer in Boroko to send a surveyor to survey the places where you will need bridges and culverts.
4. Next you will construct the new permanent bridge and culverts. At the same time, you will make the horizontal line better. You can straighten some places and make some bends less sharp. Build new culverts and bridges when you do this work.
5. The last thing to do is to construct a good pavement. Read page 67 to find out how to do this.

C. HOW TO CONSTRUCT A ROAD IN VERY STEEP COUNTRY

Suppose the country is very very steep. Then you cannot construct or widen the road like I have just told you on page 75 . That does not matter for most of the road. BUT at the crest of a hill you must construct the road very carefully. You must construct the road so that the pavement is 3.6 metres wide and so that the formation is 8 metres wide. You must construct the road as wide as that for 70 metres, on both sides of the crest of the hill. This makes the road more safe. Trucks will not crash so easily.

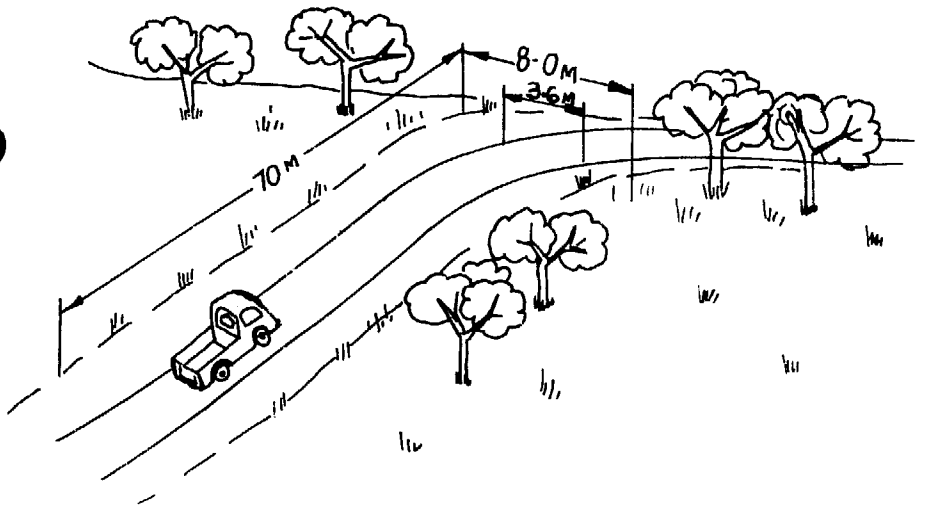

This picture shows the road getting wider near the top of the crest.

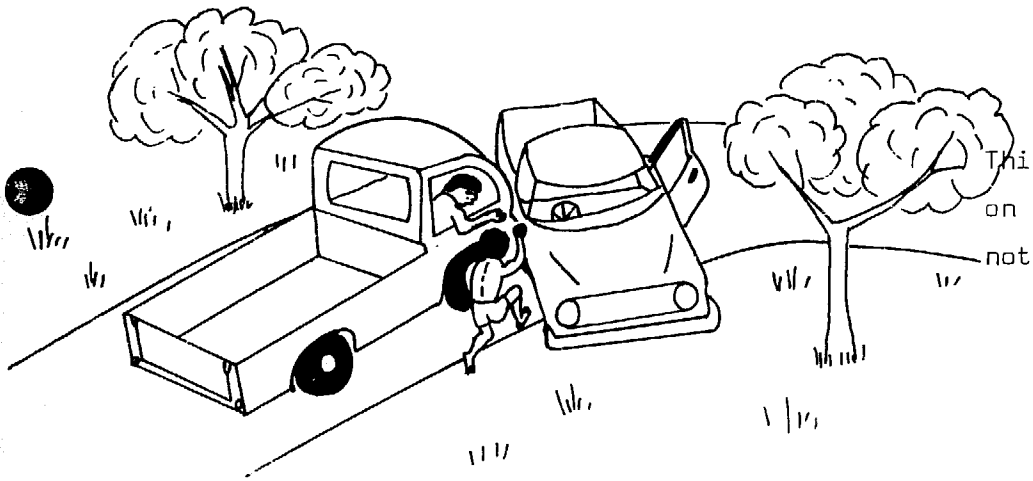

This picture shows an accident on a crest because the road was not built wide enough.

D. NEW CULVERTS

When you improve the horizontal alignment of most roads, you should also make new culverts. You do not need to do this in country with a very little slope.

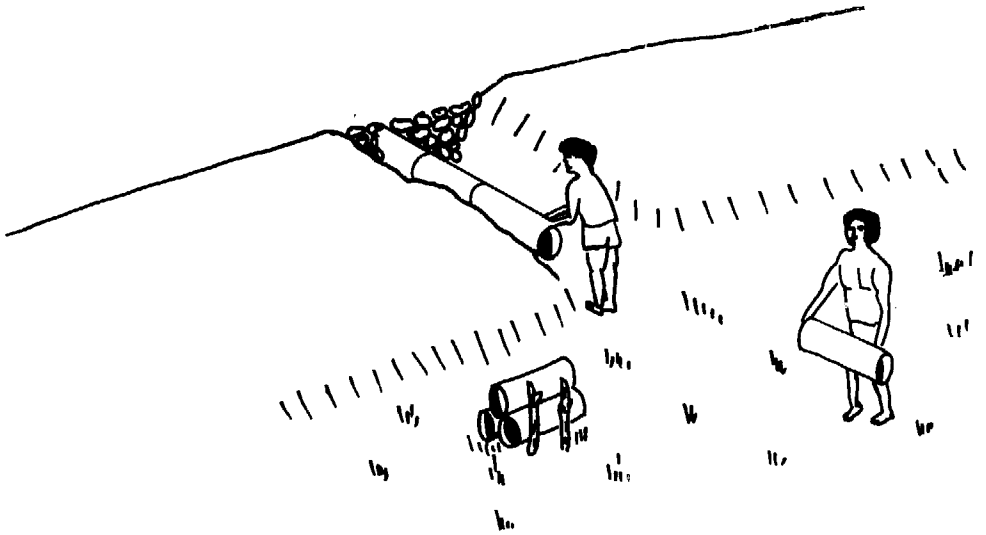

Why do you have to make new culverts for most roads when you upgrade them? Because when you cut back corners and widen the road you dig a lot of ground. It is good to use this ground to fill gullies. You fill the gullies and compact the material like I told you on page 66 .
When you fill gullies in this fashion, the length of the culvert under the fill must be longer than the road is wide. The extra length is 3 times the depth of fill. You must think about this fact when you buy the culverting. For example, if the fill is 3 metres deep, the culvert will be 9 metres longer than the formation width of the road.
If you construct "extended headwalls", the culvert need not be so long. Read page 100 , to find out about "extended headwalls" in the Section about "Bridge and Culvert Construction".

E. MAKE THE CURVES AND BENDS MORE EASY

When you upgrade a road, you must try to make the curves easier than they were before.
They will have a larger radius. That means, they make part of a bigger circle. The trucks will not have to turn around curves so quickly, and there will be less danger of accidents.
See the picture on the next page to show what I mean.

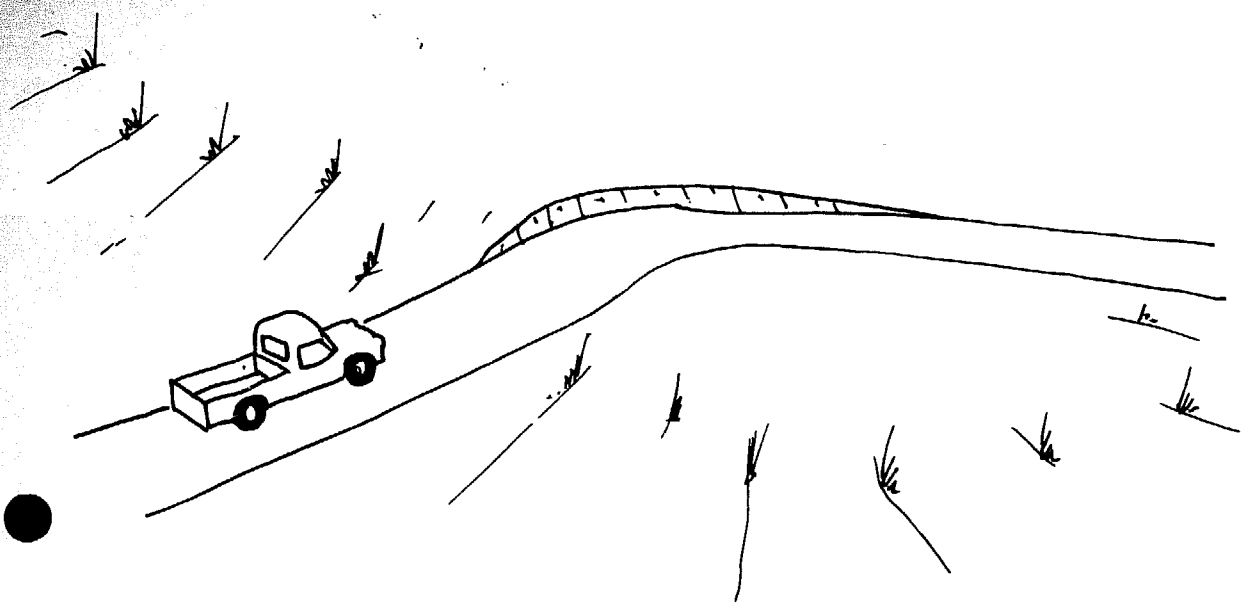

When you construct the curves like this, the road will be shorter. Some of the road will be more steep, and this could be a bad result. But there are good results also. Here are the good results:

1. You will put on surfacing material.
2. The road will be wider.
3. It will take less time to go from one place to another place.

There are three good results and one bad result, so you must be careful. Suppose the road is too steep. Then you cannot use the road and that is no good. When you change the road, use boning rods. I told you about boning rods on page 29. Boning rods help you to make an even grade between pegs. The road will go up smoothly. You use the boning rods between one section of the old road that you do not want to change and the next section of the old road that you do not want to change.

F. WHAT TO DO IN PLACES WHERE THE ROAD GOES ROUND A CORNER

In places where the road goes round a corner, you must do two things. First, you must raise up the outside of the road. This is also called "super-elevation" the road. I will tell you about this later on next page. Second, you must make the pavement of the road more wide.

Why do you raise up the road at corners? When you raise up the road at corners, it makes the road "guide" trucks round the corner.

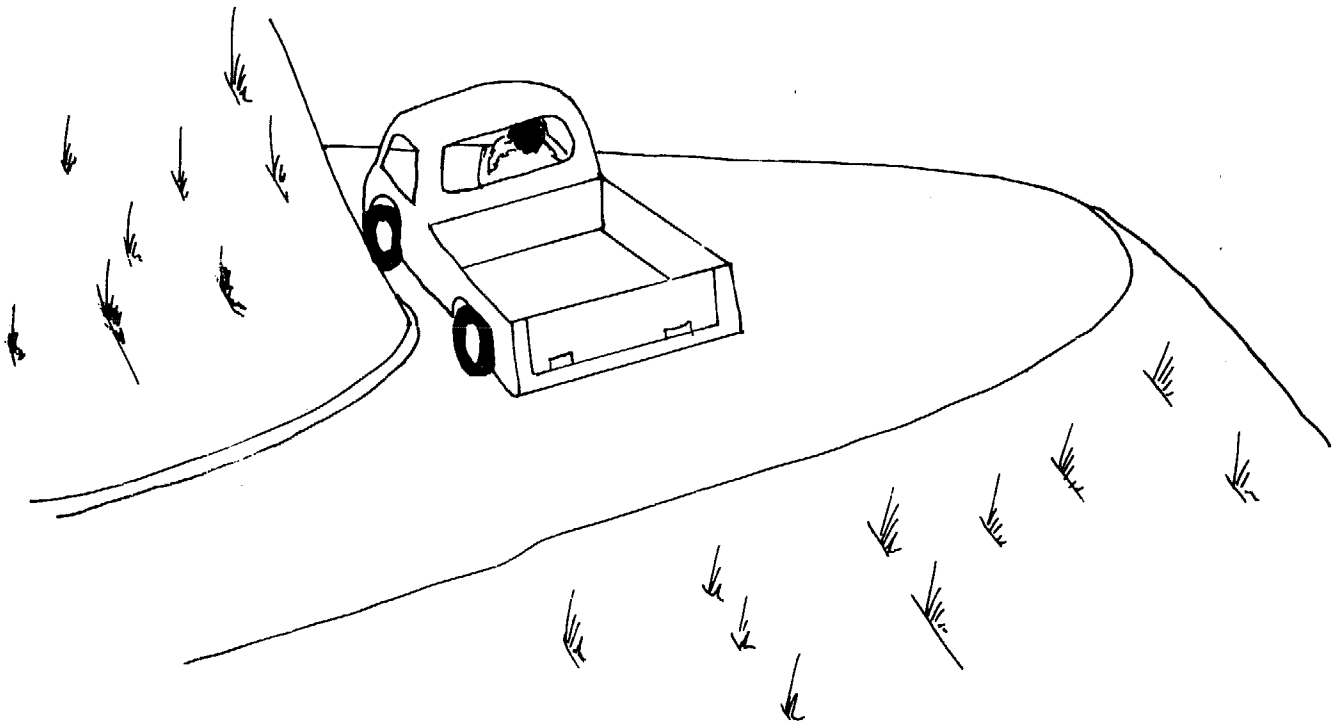

If you do not raise the road at corners, the trucks might slide off the road when they are going fast round the bend.

How do you raise up the road at corners?

You start to raise the outside corner while still on the straight part of the road. On an ordinary road, the surface has a camber both ways of 1 in 24. Still on the straight, you raise the side that will be the outside of the curve, by tilting it round the centre line of the road, until the whole road slopes to the inside of the curve.

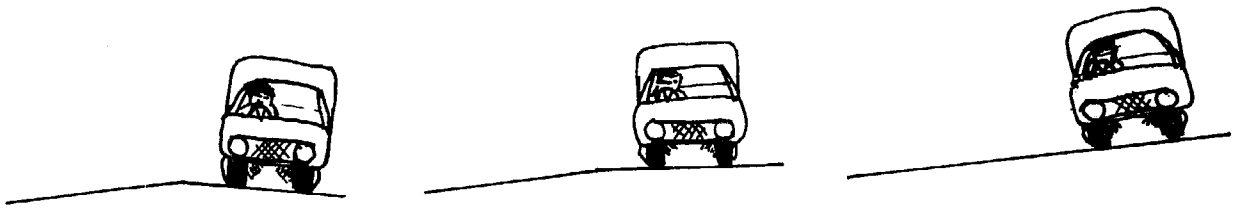

ON STRAIGHT ROAD NEAR TO THE CORNER ON CORNER

Then you raise the whole surface more tilting round the inside edge, until it reaches the right slope, or super-elevation, just where the curve starts.

This goes right round the curve, then after the curve is ended, the surface gradually goes back to the normal camber again. You should use a spirit level and wooden frame (template) to set out this work.

G. YOU MUST MAKE NEW DRAINS WHEN YOU UPGRADE A ROAD

You know that good drainage is very, very important. You must have good drainage or your road will not be good. You can look at the old road and see if the drainage for the old road was good. Read pages 52 to 54, about drainage in Section 5, called "Beginning to Make the Road". You must do the things I told you about in that section to have good drainage. You must set out the camber of the road properly on the straight section of the road when you upgrade a road. You should use a template to set out a camber of 1 in 24.

SECTION 7 : MAINTAINING A ROAD

A WHY DO YOU NEED TO MAINTAIN A ROAD?

ou might have a road that is well built, but you have to keep looking after it, to keep it in good order. This work is called "maintenance". The best way to maintain a road is to keep looking after the road all the time. Then you will see trouble spots when they are small. You can fix them up before they turn into big troubles. Big troubles cost a lot of money and work to fix. The road might break up altogether. You cannot use a road that is not maintained for a long time.

Now I will tell you how to maintain a road. I will tell you how to maintain bridges in the next section.

B WHAT DO YOU DO TO FIX UP OR MAINTAIN A ROAD?

There are three bad things that happen to roads:

1. Roads get potholes.
2. Roads loose the surfacing material.
3. Roads loose camber.

1. You must fix up potholes.

When holes come in the road, they fill up with water, they get soft and make bad bumps. How do you fix them? You dig out all soft material. Then you fill the hole again with good gravel, and pack it down hard. It is a good idea to leave heaps of gravel spread along the road, so the road men can soon fix the potholes.

This is a very good idea in places where the Council has a "road maintenance day" each week.

2. You must put back Surfacing Material

The road might be well built, but it will always loose the surfacing material. This happens because the trucks throw it off the road, or squeezes it down into the mud. Also, the pavement is worn away by sun, rain, wind, animals or people walking on it.

11. <u>Summary</u>:- A List of Important Things.

Here are some important things you must know about the first part of building a road:

1. Pegs show the level of the surface of the road when it is finished. That means the numbers on the pegs show how much to cut or fill from the ground level at the peg.
2. Pegs may not be on the centre-line of the road. They are put in the ground to show the level of the surface of the finished road. They are not put in to show the centre-line of the road.
3. Build an even grade between pegs. Then smooth out any curves at crests or hollows.
4. The surface must have a camber. Also there must be good drains to keep water off the road.
5. Fill has to be rammed down hard.
6. After the road is built, watch it carefully for a year to see if anything goes wrong.
7. Do not change a marked line of pegs, without asking the District Local Government Supervisor.
8. All roads which are steeper than 10% grade must have a hard surface before trucks and cars start to use the road.

If the soft spot is holding water, you may need a new drain, or pipe, or a drain filled with stones. If you cannot fix a very bad place, ask the Local Government Supervisor for help.

What you do if a long part of the road has lost its camber?

If a long part of the road looses its camber quickly, the trouble might be because of three reasons:

(i) Maybe the fill is poor, or not compacted (rammed down).

(ii) Maybe the road is not wide enough, and all the trucks go down the middle and make deep wheel tracks.

(iii) Maybe the subgrade is not strong enough.

The first two troubles were made when the road was built. To fix them you have to rebuild the road properly, as this book tells you. The third trouble is fixed by putting on more good basecourse, and then another layer of pavement.

When a road has become flat, it can be fixed by teams of road workers going along with spades to throw the stones from the edges, back into the middle of the road. If the Council has a grader, the grader does a better job than hand work, but is more expensive. In some places, graders cannot get there at all, and the work has to be done by hand labour.

C OTHER MAINTENANCE JOBS

The road workers have other jobs to do all the time.

(a) After heavy rain, look at the culverts and drains. If any are blocked by dirt, stones, sticks or so on, they must be cleared straight away.

(b) The edges of the road must be kept clear of long grass, bushes and young trees. It is a good idea to leave the grass growing to stop erosion, but it should be kept cut short.

(c) The side drains should be kept clear of growing plants and rubbish. Then water can flow along them and get away.

(d) At any places where the road is starting to slip away, you must put in new fill and see that there is proper drainage.

The rule for all roads is to always look at them, and to always work where it is needed, straightaway. Sometimes, a big job of resheeting must be done, but other jobs can be kept down if you fix the road straightaway when it needs fixing.

D ROAD GANGS ON SECTIONS

When a long road is being maintained by hand, it is a good idea to have men working on it permanently.

If you have tractors and trailers or small trucks, one overseer ("roadmaster") with one tractor and a gang of eight or ten men, can look after about thirty kilometers of road. They should have a camp near the middle of this section of road.

If you have no machinery, it is a good idea to have a "roadman" to look after one smaller piece of road near the place where he lives. This piece might be three to five kilometers long. Then he can walk along his section of road every day with a wheelbarrow and spade and fix up trouble-spots.

E THE GOVERNMENT WILL HELP COUNCILS MAINTAIN THEIR ROADS

Money for Feeder Roads

The Government will help Councils by paying some money to help them look after the more important roads in their area. These important roads are called Feeder Roads.

In October, 1974, a letter was written from the Public Works Department to tell all Councils about this.

This is what it said:

"The President,
Local Government Council.

FEEDER ROAD MAINTENANCE ALLOCATIONS

Dear Sir,

This letter is to tell you about money that may be paid by the Government to help Councils look after and maintain their roads.

CLASSIFICATIONS:

The Government made a law called the Roads Maintenance Ordinance. It said that roads in Papua New Guinea were to be divided into different types, or classifications like this:-

(i) Big roads are called "Highways" or "Trunk Roads". The Government will look after them.

(ii) Middle roads are called "Feeder Roads". Councils can look after them, and the Government will give some money to help.

(iii) Little roads are called "Minor Roads". The Government will not give any money at present, and the Council or the people have to look after them. (Next year, 1975/76, the Government might give some money on the Rural Improvement Programme to maintain these roads).

ROADS BOARDS

Each District has three men called the District Roads Board. They decide what roads will be Highways and Trunk Roads, what roads will be Feeders, and the rest that stay minor roads. These men have now done their work in most Districts, and Councils will soon be told what are the Feeder Roads in their places. You should soon get a letter about this from your Public Works Office in the District.

FEEDER ROADS - COUNCIL MAINTENANCE

Now, Councils will have to decide if they are going to look after their Feeder Roads. If they agree to, the Government will pay a grant of funds to help. If a Council does not agree to look after these roads, then the Government will not pay this money. If a Council says it will not maintain a feeder road, then the District Roads Board will say what to do. Maybe the Government will look after the road, or maybe the road will be left alone and get broken up, and no one will be able to use it.

When a Council agrees to maintain its Feeder Roads, it has to pass a resolution to do this. Then it must sign an agreement with the Government.

AGREEMENT

A copy of the Agreement is enclosed with this letter, for you to look at. The main things it says are:-

1. The Government and the Council make an agreement.
2. There is a list of the Feeder Roads or towns with roads to be maintained.

3. The District Works Engineer or Officer will represent the Government. The Local Government Engineer will advise Councils when they ask.
4. The Council agrees to be responsible for maintaining these roads.
5. Money granted by the Government must be spent on these roads, and books and accounts kept to show this has been done.
6. The Council will employ an overseer (road-master) as soon as it can, to look after this work. His costs can be paid from this grant.
7. Extra money may be given if there is bad trouble with some roads.
8. The Council will take notice of any talk from the District Roads Board or the Government's engineers or other representatives.
9. The Government will hire plant to the Council when it is needed (this is done by the Plant and Transport Authority).
10. The Council has to pay any compensation for people hurt or killed on roads due to maintenance works or mistakes by Council. Insurance should be taken against this.
11. The Government will pay the grant regularly to the Council, without a claim. The grant is not fixed like a contract; it depends on how much money the Government has each year.
12. If there are any disputes, they should be talked over with the District Roads Board.
13. If the Council does not try to do a good job, the Government can stop paying money. But before doing this, the Government will try to help the Council get over any trouble.

SUPERVISION

The Government is worried because there are not enough skilled technical men in the country to properly look after the Rural Improvement Programme and the road maintenance.

We are trying hard to get more men for this work, and hope to be able to supply some men in every District to help look after Council works and maintenance. This does not mean we want to interfere with Councils that can look after their own work, but we want to help Councils that can not. At present, most Councils need this help. We are also trying to help train staff for Councils and where possible will help Councils to get their own staff. A small part of the money granted by the Government for Rural Improvement Funds, may be kept to pay Government staff who will help Councils.

DISCUSSION

Please talk about this letter when the Council has its next meeting so that your Council will be ready to decide about its feeder roads when the District Works Engineer or Officer writes to you. If you have more questions, you can ask him to come and talk to you, or to send one of his road men to do this. Remember he will be in charge of seeing the Council does its job with Government money.

If there are any worries which you cannot agree with, the District Engineer or his staff, you can ask for advice from the Local Government Engineer at Public Works Department Headquarters in Port Moresby.

TOWN ROADS

Councils can also take over the maintenance of roads in towns and Government stations, if they want to and if the District Engineer/Officer agrees. A separate grant would be paid for town roads, and must be spent in that town. If Councils do not want to do the town roads at present, that is all right, and the Government will still look after them.

CONCLUSION

There is a lot of work to be done looking after the country's roads. Councils have the chance to do their share of this work, and help the people in your area by seeing they have good roads. The Government is offering money to help Councils do this work, and the Government will give advice and help with supervision as much as it can.

It is now up to your Council to say if you are going to

do this work.

Yours faithfully,

for: E. ROBIN SAFITOA

Director".

This letter says that the Government will give money to the Councils to maintain Feeder Roads.

Some of the roads in your Council area are Feeder Roads. You can ask your Council Clerk which roads are Feeder Roads.

Your Council must have a Council Meeting. They must think "Will the Council look after the Feeder Roads?" Suppose they say at the meeting that they will look after these Feeder Roads, then they must write their names on a special letter called an Agreement. The Government men will also write their names on the Agreement. Here is what the Agreement says:

<u>What does the Government say it will do?</u>

1. The Government man is the District Works Engineer or District Works Officer.
2. The Government says the Local Government Engineer will help the Councils when they want help.
3. The Government gives the Council a list of the Feeder Roads or Town Roads that they must maintain.
4. The Government will give money to the Council to do this work. The money is called a "grant".
5. The Council does <u>not</u> have to ask for the grant with a "claim form".
6. The Government will give different amounts of money. If there is bad trouble with the road, the Government will give extra money. If the Government has not got much money, the grant will not be so big.
7. The Government will hire machines to the Council, when the Council needs big machines like graders. Plant and Transport Authority hires out these machines.

<u>What does the Council say it will do?</u>

1. The Council says it will maintain the roads that are written in the list of Feeder Roads and Town Roads.
2. The Council says it will use the Government money only on these roads. They will keep books and accounts to show how all the money is spent.

(b) Concrete Pipes: Skid concrete pipes into the trench or roll them into the trench, then shove them together.

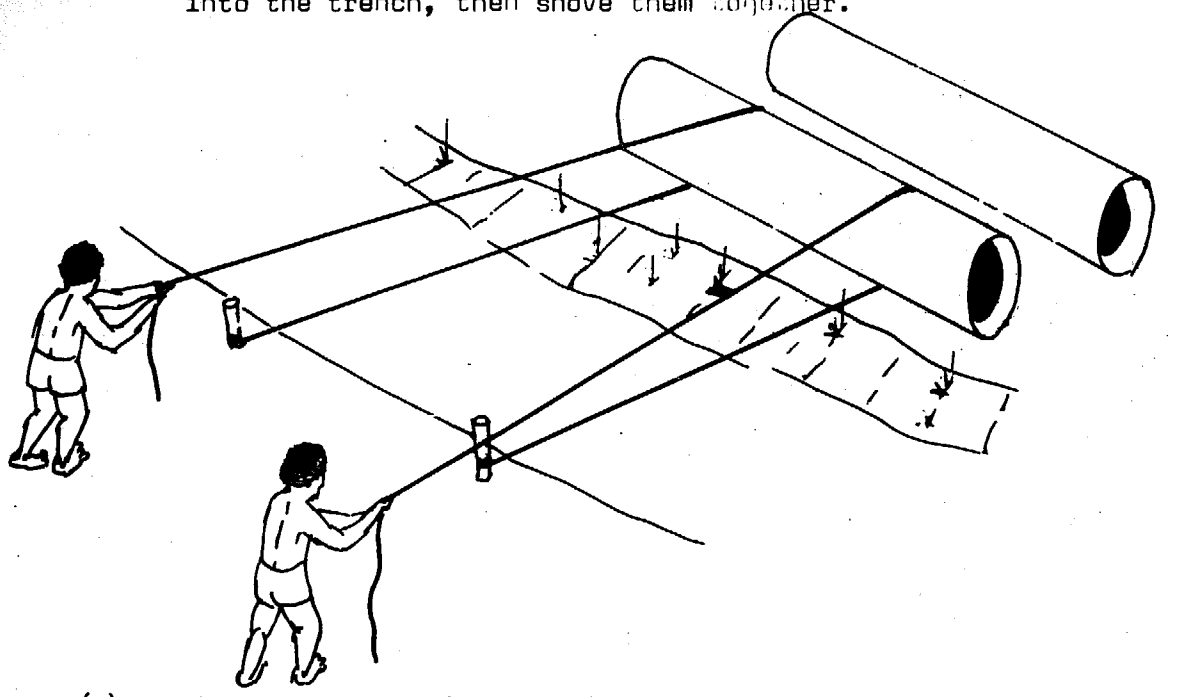

(c) How to lay two lines of pipe:

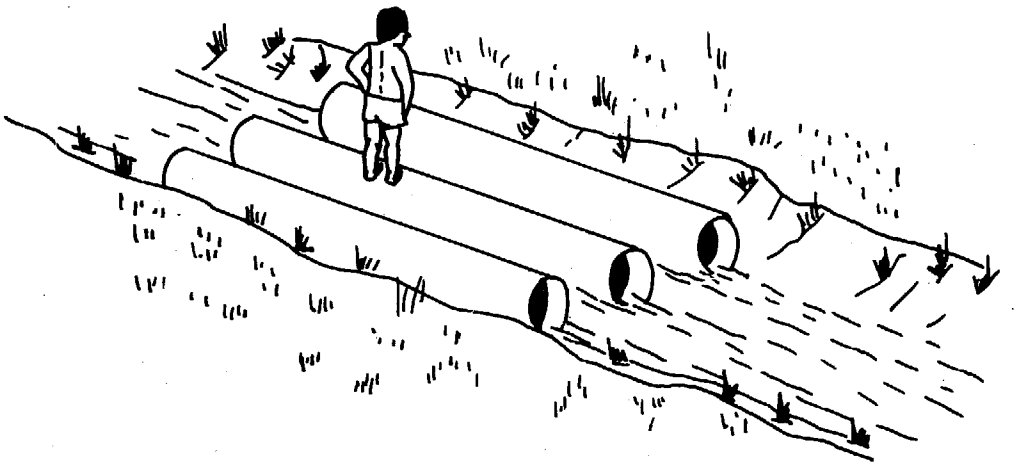

The lines must have a distance between them. The distance should be at least half of the diameter of the pipe, or 0.4m whichever is the bigger.

If each pipe diameter is 900mm., then the clear space between the pipes must be 450mm.

6. How do you backfill a trench round the pipe? You must supervise this very carefully. Suppose you do not do a good backfill, the culvert will be no good and it might get broken. Good ways to backfill are important to all culverts. Good ways of backfill are very, very important with a culvert under deep fill.

SECTION 8 : BUILDING CULVERTS AND BRIDGES

A. CULVERTS

1. What sort of pipe should you use? Usually, corrugated metal pipes are best. When you make a culvert for a Rural Improvement Road, you should usually use a corrugated metal pipe. But concrete ones are better in two cases:

   (i) If you are close to a factory that makes concrete pipes in Papua New Guinea, you should use these concrete pipes. If the factory is less than fifty kilometres from your work, you should use a concrete pipes.

   (ii) If the pipes will be in salt water near the sea, then metal pipes would rust. You should get concrete pipes for flat places where the sea comes in sometimes.

   Concrete pipes are hard to lay properly. But corrugated metal pipes are a little bit hard to lay peoperly. I will tell you how to lay them properly. Also, you must read the directions from the people who make the pipes, and do what they say to do.

2. How big should a culvert be? The District Local Government Supervisor or the Local Government Engineer will tell you how big all the culverts should be if you ask them to come and look at the road. But you yourself, can work out how big a culvert should be. You want to find out the diameter that the culvert should have.

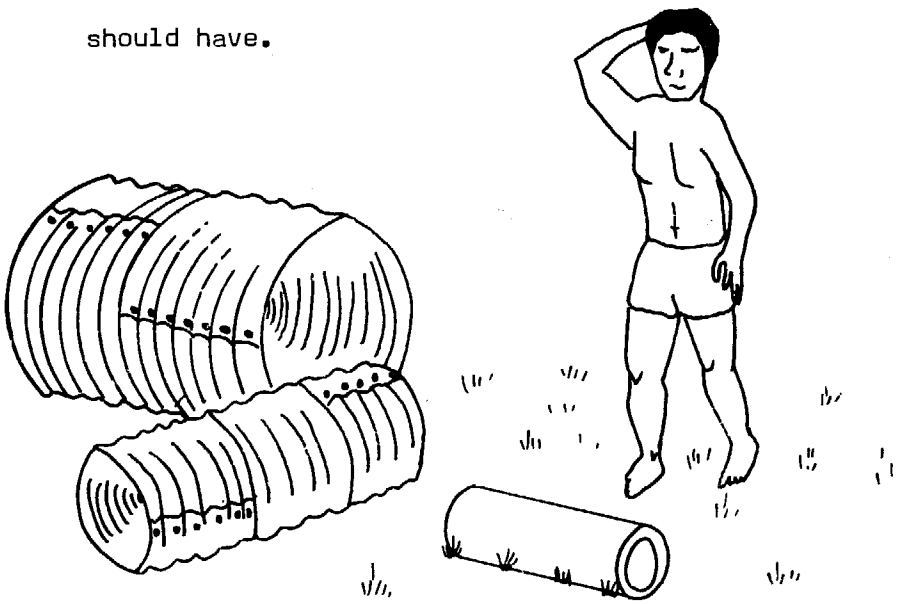

You can work it out like this:

(a) First look at the banks where the water goes. Look for marks that show the highest place it rises to.

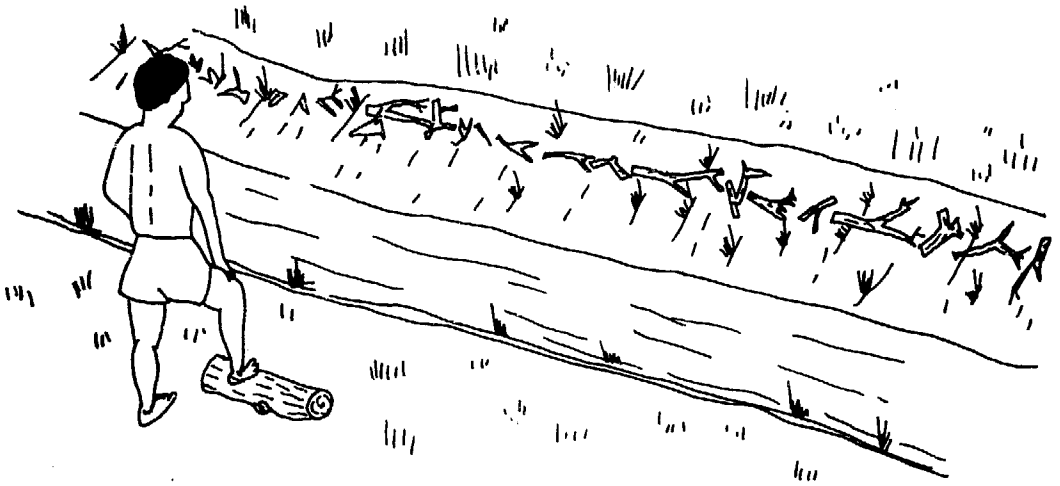

Also, you can ask the Local people how high the water goes. But think about the fact that they may not know, or they may not show you the true place. You want the highest place where the water has ever risen to, not the place it rises to every wet season.

(b) Second, measure three things:

(i) Measure the height from the bed of the stream to the place you find where the highest water has ever risen to. I have marked this place (H) for height on the picture.

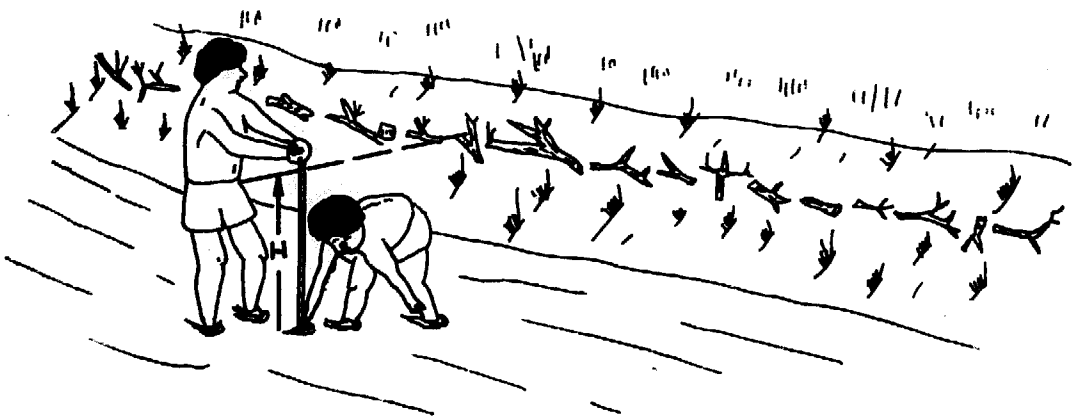

(ii) Measure the distance from one bank of the stream to the other bank at the highest point. I have marked these two places (B) for bank on the picture.

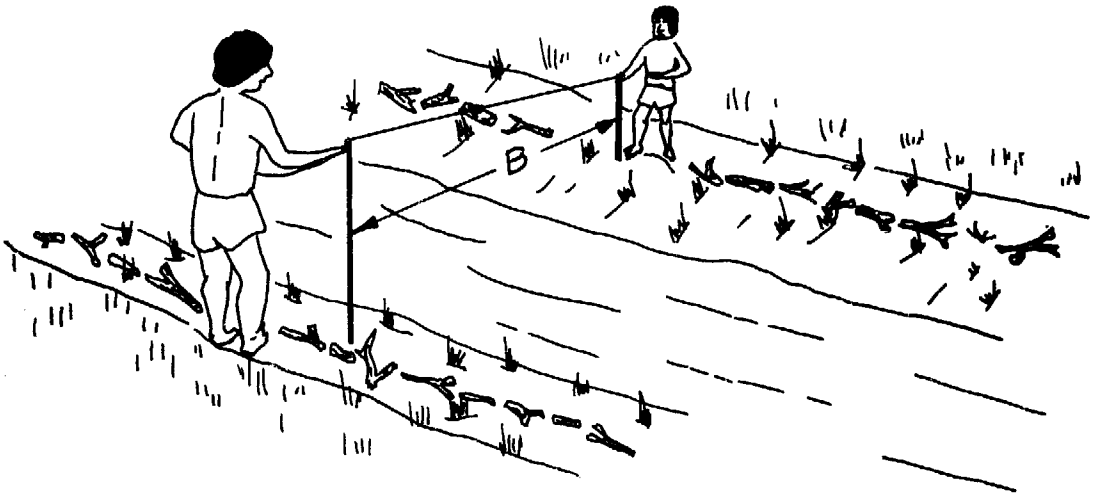

(iii) Measure the width of the stream bed. I have marked this place (S) for stream on the picture.

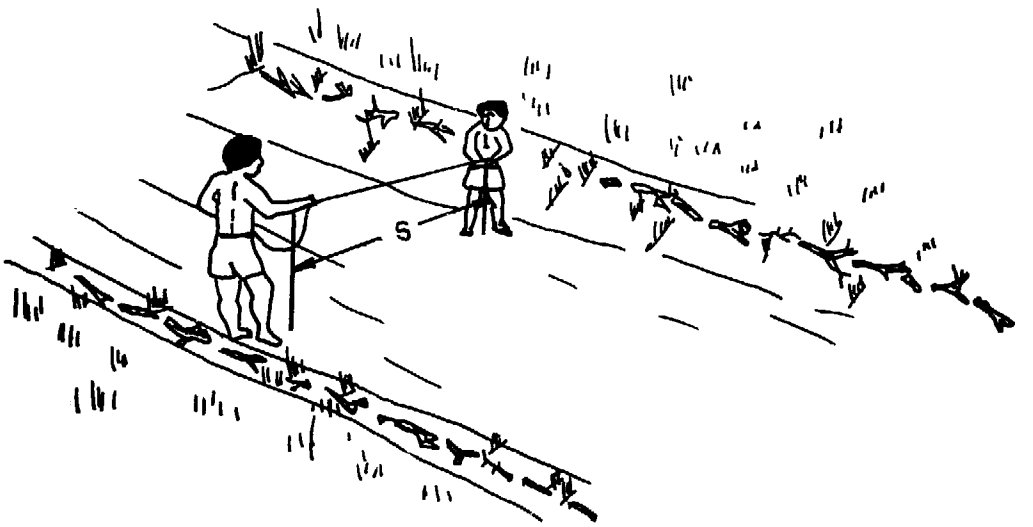

Now you can work out a sum.

You want to know what is called "the area of water way". .

(c) You can work out the area of the water way like this.

(i) Work out half the height. (In our picture the highest point where the water has ever gone was 1.1m. Half that height is 0.55m).

(ii) Measure the width from bank to bank at the highest place. (In our picture, this is 4.7m)
Next, measure the width of the bed of stream (In our picture this is 2.1m).
Add these two measurements together: 4.7m + 2.1m = 6.8m.

(iii) The area equals half the height (0.55m in our picture), multiplied by the width from bank to bank (4.3m), plus the width of the stream bed (2.1m).
Or you can write it like this:

$$\text{THE AREA OF THE WATER WAY} = \tfrac{1}{2}H\ (B + S)$$

Now I will fill in the letters with the measurements from the river in my picture:

$$\text{THE AREA OF THE WATER WAY} = \frac{1.1}{2} \times (4.7 + 2.1)$$

$$= 3.7 \text{ Square metres.}$$

(iv) The area of culvert needed is one half of the area worked out by this sum. That means the area of culvert that you need is half the waterway of the stream when it is in flood.

Area of pipes of different sizes are:-

DIAMETER	300	450	600	750	900	1200	1500	1800
AREA (m^2)	.071	.159	.283	.442	.636	1.13	1.77	2.55

For Council roads, do not use pipes smaller than 300 mm. or larger than 1800 mm. Take the size nearest to the area you worked out by this rule. Or else, you can use 2 or 3 rows of pipes, side by side, adding up to the area you need.

(v) In the picture we worked out that we needed a pipe with an area that was half of 3.7m^2. Half 3.7m^2 is 1.85m^2. Look at the table where it says AREA (m^2) and the nearest number to 1.85m^2 is 1.767m^2, and that is a pipe with a diameter of 1500 mm. You should use a [illegible] mm. size or else three 900 mm pipes side by side.

(vi) If you make headwalls of a strong concrete right across the stream the pipes can be smaller - they can be one-third of the waterway instead of one half.

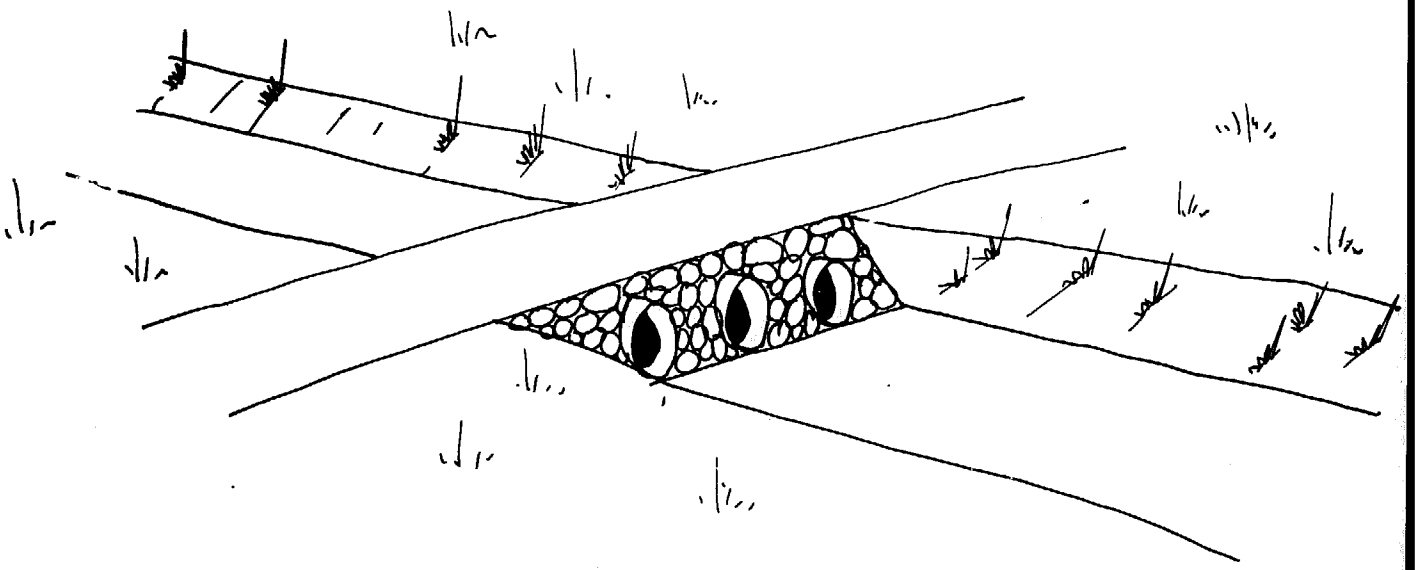

3. <u>How deep should you put the Pipe</u>? For ordinary fill, the top of the pipe should be 1.0m. below the top of the road. But if the fill is good (clay or stone) and is well packed down, you can have less depth, like this:

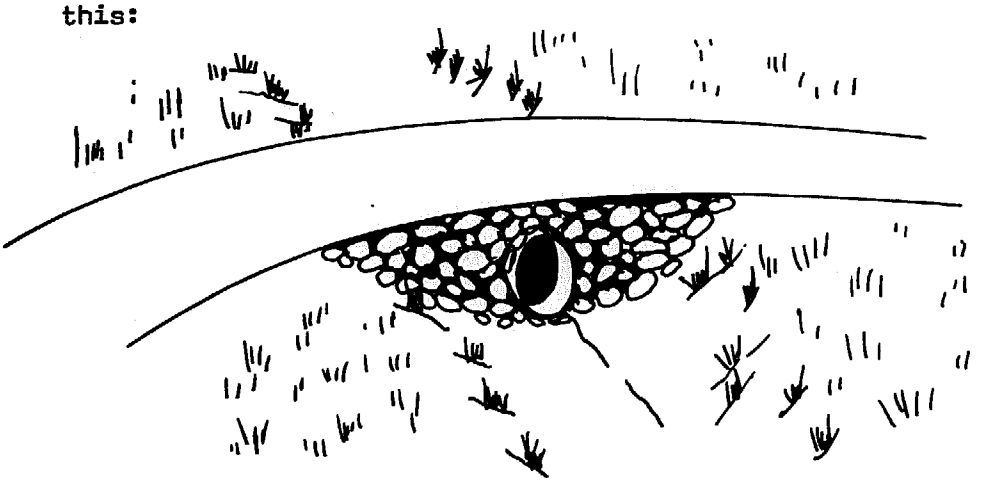

If you use a spun concrete pipe, up to 750 mm diameter, the top should be 0.3 metres below the road.

If you use a spun concrete pipe over 750mm diameter, the top should be 0.6 metres below the road.

If you use a corrugated metal pipe up to 1500 mm diameter, the top should be 0.3 metres below the road.

If you use a corrugated metal pipe over 1500 mm diameter, the top should be 0.6 metres below the road.

This height is measured at the edge of the road. If this height of fill makes a bump in the road, you must ramp the dirt up at a slope of not more than one in 10. Or else, if you use two or three smaller pipes side by side, you might not need a ramp.

4. <u>How to prepare a bed for a pipe:</u> Some streams of water dry up in the dry season each year. Suppose you want to make a culvert for one of these streams, you can do it in the dry season.

Some streams run in the dry season and in the wet season.

What do you do? How can you work with all the water running? You can do one of two things.

Make a wall of sandbags to keep the water away while you dig your trench and lay your pipe.

Here is the second thing you can do:

You can dig a trench for the pipe in ordinary ground. When you have laid the pipe, you can make the stream run through it, and block the place where it ran before.

(a) How to prepare a bed for the pipe on ground: First you must clear the floor of the stream or trench. Take away all loose material like stones and leaves. Take away anything that sticks up and might damage the pipe, things like sharp rocks and roots of trees. Next you grade the floor of the trench, using boning rods (see page 29). Suppose the ground is swampy, you must put down some gravel next. The gravel should be 0.2m to 0.3m deep. This gravel is a foundation for the pipe.

Next you must lay a bed of sand or some material that is very small like that. You must compact it well (read page 66). It must be at least 0.1 m. deep.

(b) How to prepare a bed for the pipe on rock. Suppose you must lay the bed on rock, then you should lay a bed of concrete for the pipe. The concrete should be at least 0.1m deep under the pipe. How wide should the bedding be? It must at least as wide as the diameter of the pipe plus 0.2m. If your pipe is 1 metre across the bedding must be 1.2 metres across(1.0m + 0.2m = 1.2m.).

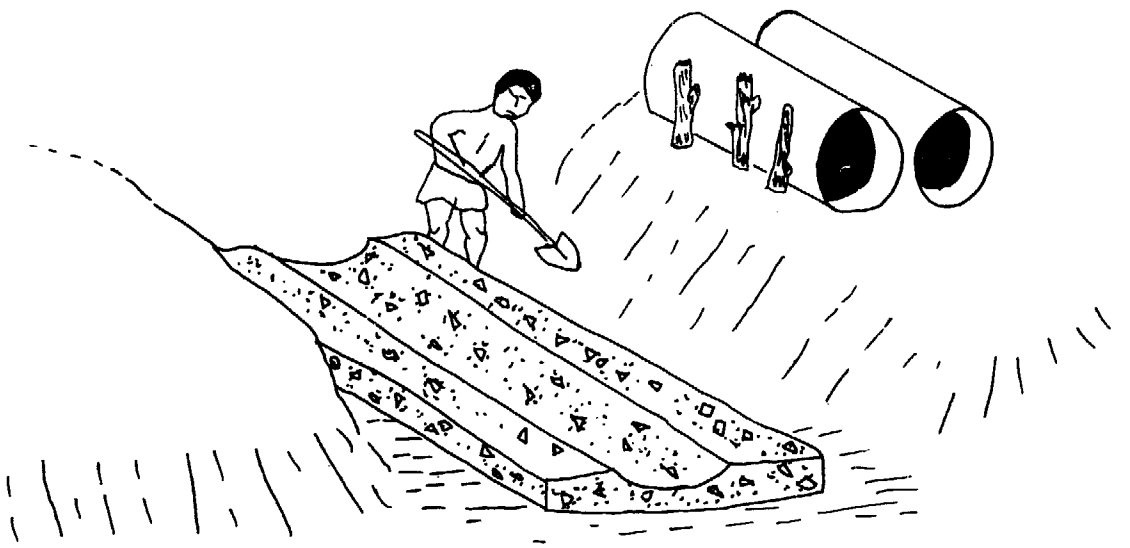

5. <u>How do you lay the pipe</u>?

(a) <u>Corrugated Metal Pipes</u>: You must read the book that comes from the people who make the pipe. That book will tell you how to put together a corrugated metal pipe from the pieces they send you. Suppose you have to put the pipe in a trench. You can put together the pipe on the ground beside the trench and then skid it or roll it into the trench.

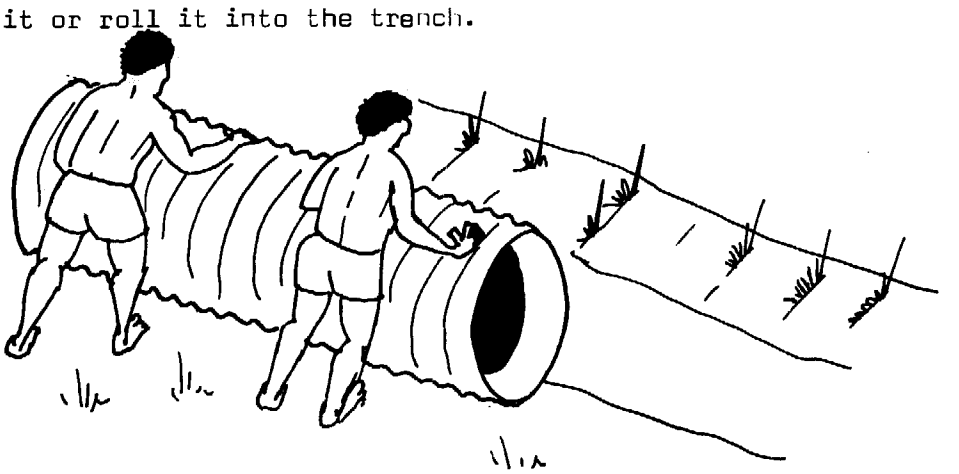

3. The Council says it will get a man called an overseer, or road-master, to look after the work on the roads. They can pay the road-master with some of the Government money.

4. The Council says it will take notice of any talk from its District Roads Board or any of the Government engineers or supervisors. The Council will do what these Government people say they should do.

5. The Council says it will pay compensation to people who hurt or killed on roads because of maintenance work or mistakes that the Council made. The Council must get insurance to pay this compensation.

Suppose there is trouble between the Council and the Government. They must talk about the trouble at the District Roads Board meeting. The Government will try to help the Council get over any trouble. BUT suppose the Council does not try to do a good job, then the Government will not pay the grant money.

Remember, if the Council says it will not maintain the Feeder Roads, then these Feeder Roads will soon get very bad and trucks will not be able to drive on them.

Now, if you work for a Council, you should be able to find out from the Council Clerk, what are the Feeder Roads in the Council's area.

F MINOR ROADS

The Government does not give road maintenance funds for smaller roads. These smaller roads are called minor roads. There can be two types of minor roads:

(i) Council roads:

Suppose the Council says it will maintain a minor road.
The Council must use Council money.
BUT from 1975/76, Councils can also ask for a grant of money from the Rural Improvement Programme, to help with maintenance of these roads. It would come in a one big amount, and the Council would decide where to spend it.

(ii) Non-Council Roads.

Suppose the Council says it will not maintain a road, then the people who live on the road will have to maintain it for themselves. If the people do not maintain it, the road will soon get too bad for any trucks to use it.

First , you must put more sand under the pipes and pack it tight or ram it tight to the height on the picture -

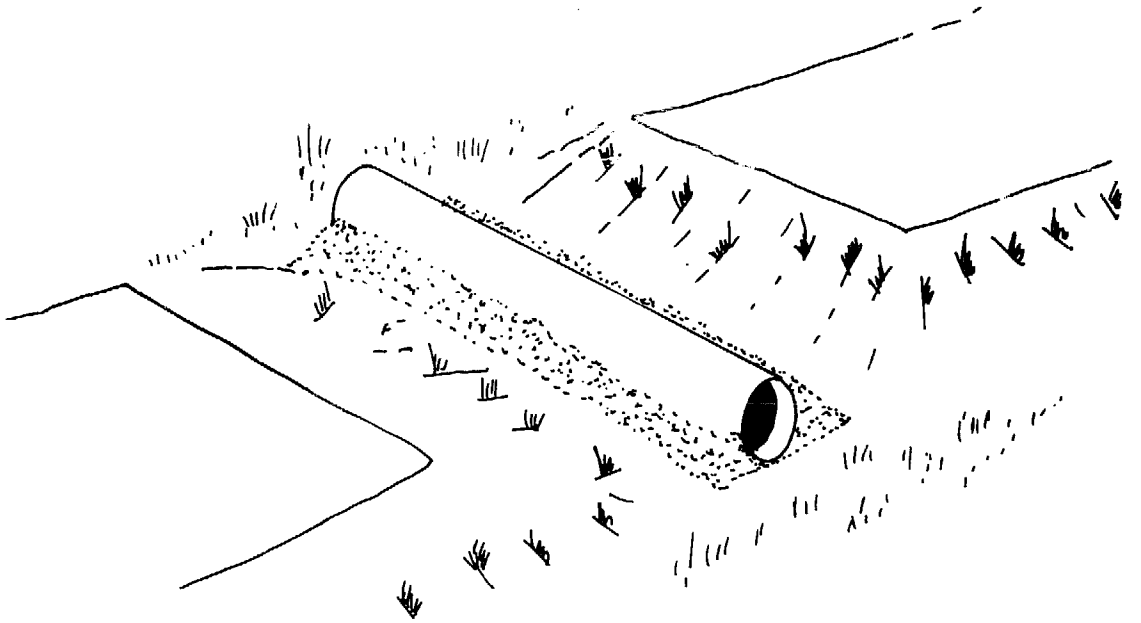

If the pipe is on rock, you must pour more concrete up to the same height.

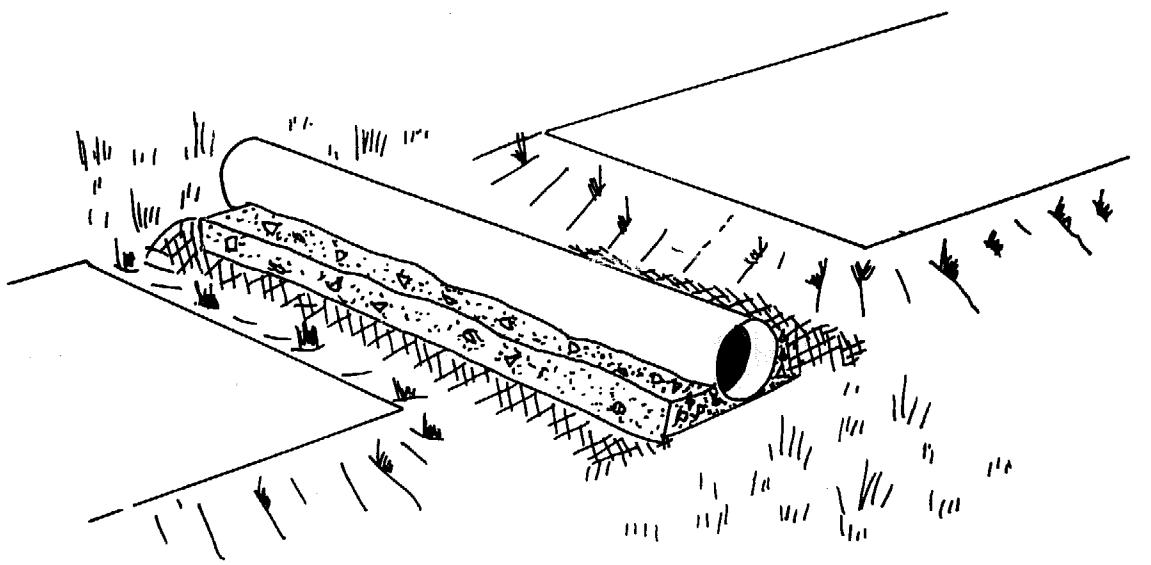

Next you must put down fill. You put down a layer of material 0.2m deep. Then you compact the layer of material (see page 66). Then you put another layer and compact it. And so on. You do this until the compacted fill is at least a quarter of the diameter above the top of the pipe. See the picture on the next page showing this.

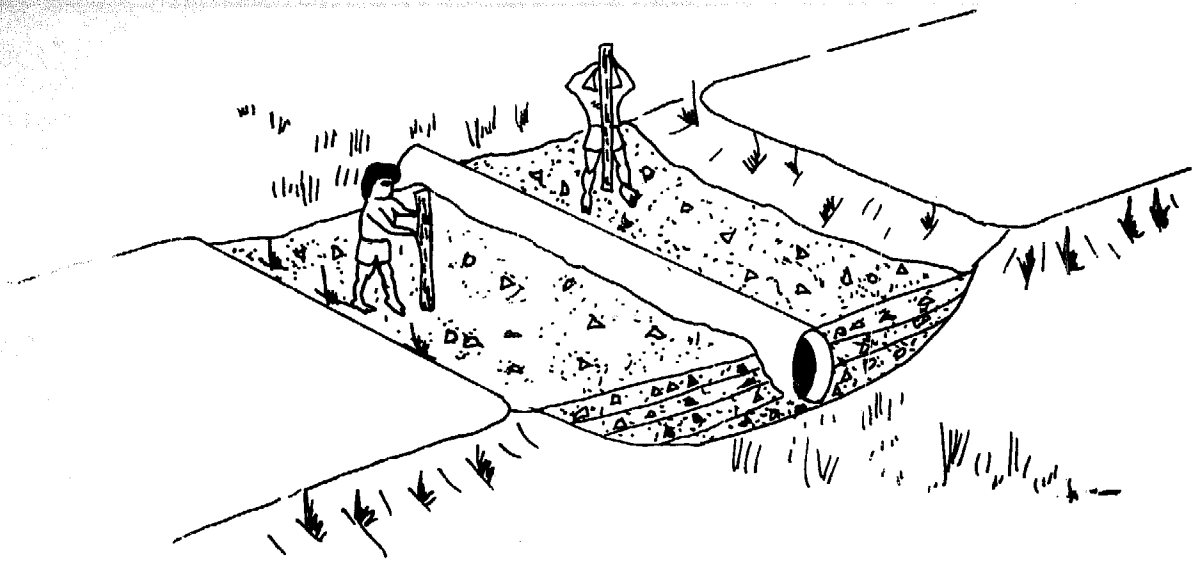

You put down fill and compact the fill until you have compacted fill on both sides of the pipe. The measure of the fill on each side is the same as the measure of the diameter of the pipe.

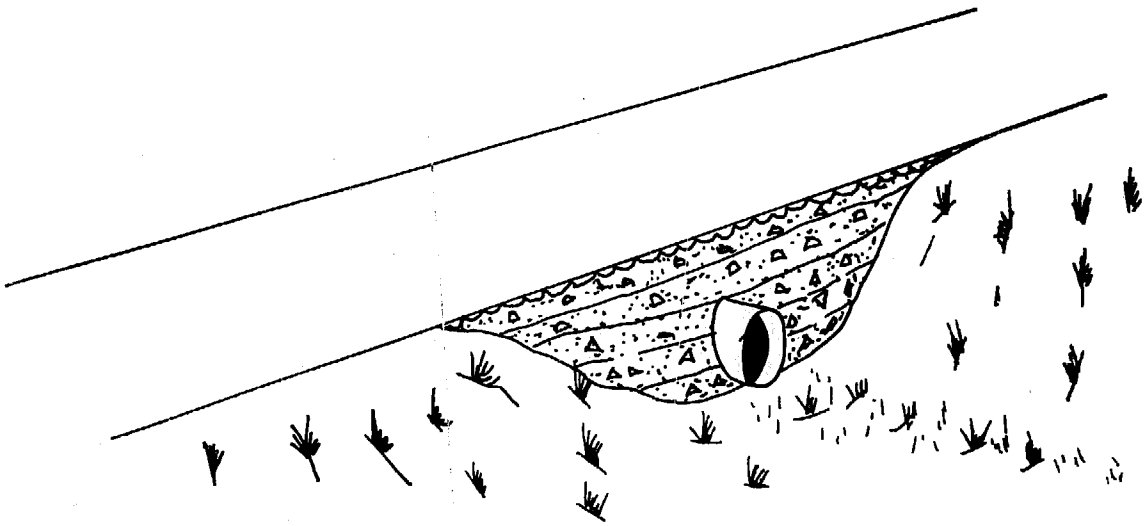

Suppose your pipe is in a trench, you must put down fill and compact it to the sides of the trench.

What material do you need for the fill? The fill material next to the pipe must be good. The material must first have big stones. The stones must not be more than 50 mm. across. You can use sand mixed with a little clay silt from the stream. This is easy to compact. It is very important to use this good fill material close to the pipe. It is very, very important when the culvert is under deep fill. You must supervise this part of the work very carefully. When you have finished compacting this good fill close to the pipe, put down the rest of the fill. It must be well compacted. It must be very well compacted in wide stream beds.

7. Headwalls

Why do you need a headwall?

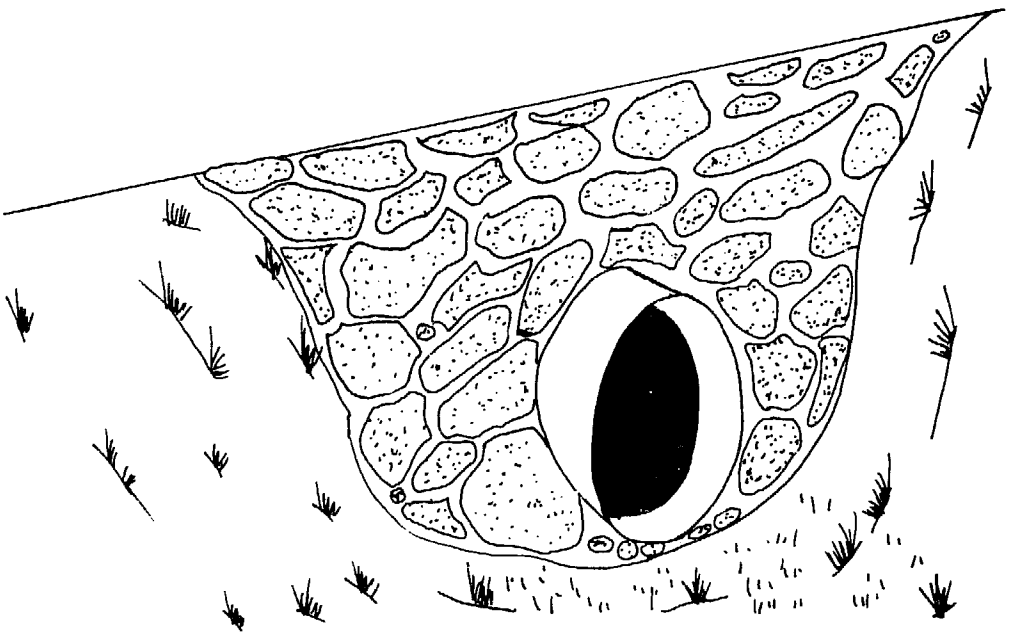

As you can see in the picture an ordinary headwall is made of big stones with cement put all over it to make it strong. This sort of headwall has a big name. It is called "a cement grouted stone pitched headwall". You need a headwall to prevent the fill from scouring or from collapsing. The fill must not scour or get washed out. It must not collapse.

Where must you construct a headwall?

You must construct a headwall at the place where the water goes into the culvert and the place where the water comes out.

See the pictures on the next page for this.

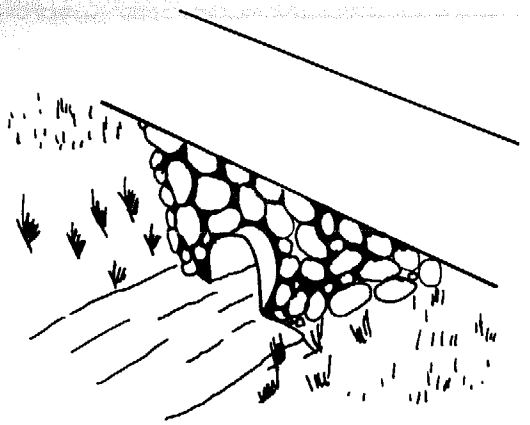

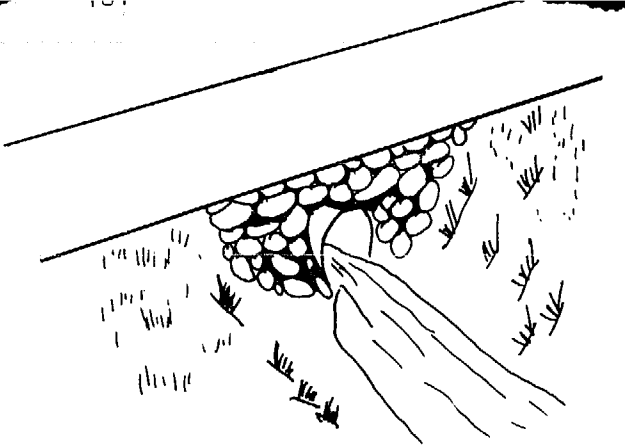

How do you make a headwall? Usually a headwall should go up only to about 0.3m. above the top of the pipe.

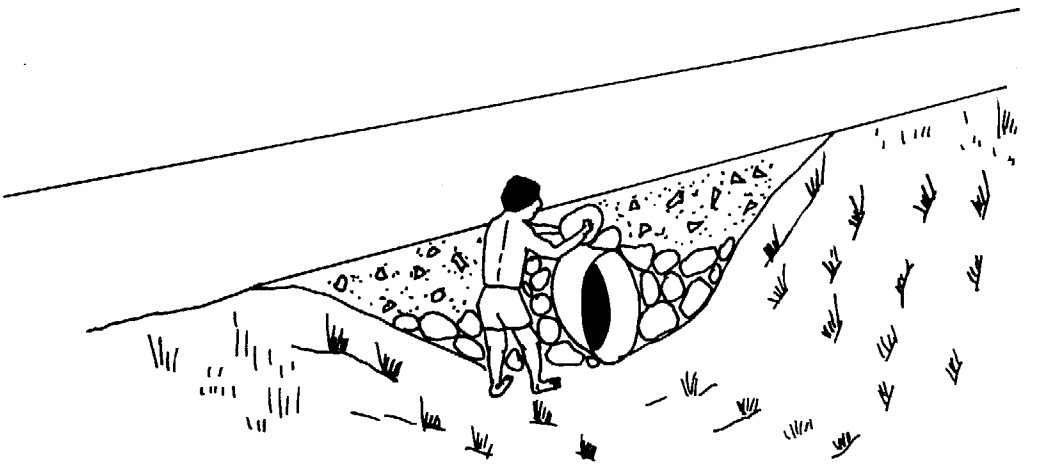

But you can ask the Local Government Supervisor about a special headwall. He may design a special strong, high headwall for your culvert. With a special headwall, the fill slope can be shorter and the pipe can be shorter, too. The Local Government Supervisor may also tell you to use reinforced concrete or wire baskets filled with stones (there baskets are called "gabions"). These ways of supporting the fill cost a lot of money. Do not use them unless the Local Government Engineer advises you to use them.

8. Aprons

How to protect the place where the water flows out of the culvert with a concrete apron. When water flows out of a pipe, it does not spread.

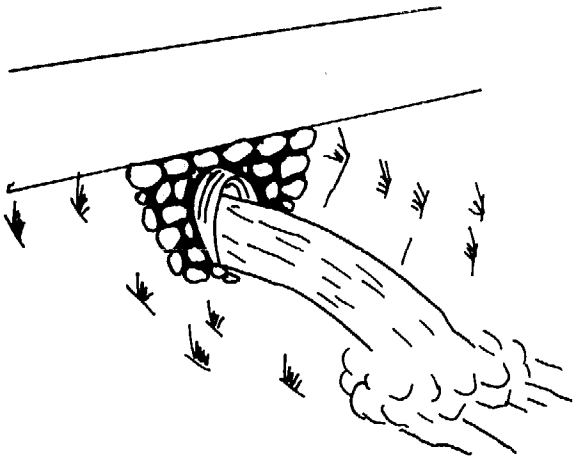

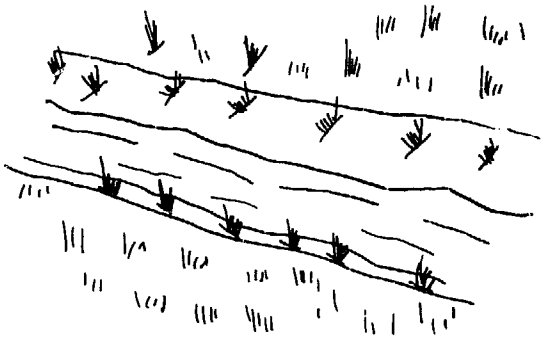

When water slows down it causes erosion. When water flows down a steep hill and then through a pipe it causes a lot of erosion. You must often have a look at the place where the water flows out. If you can see that the water will cause erosion, you must make an "apron" at the place where the water flows out.

An "apron" is a pad of concrete. It is about 0.2m thick. It has this shape.

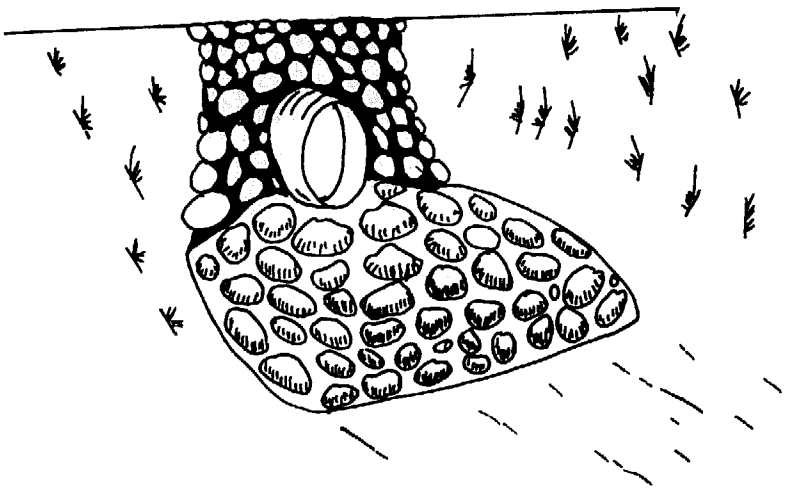

You must make the concrete with a lot of stones in it. The stones will break the flow of the water from the pipe. The stones should be big enough to make the water spread out.

Sometimes the water drops down from the pipe like this:

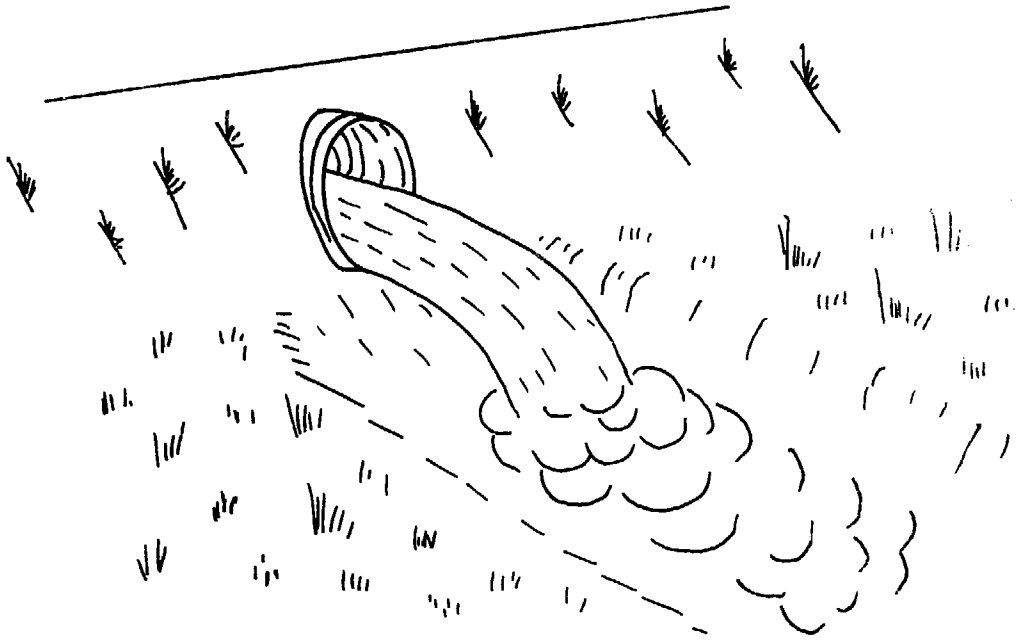

This water falls with a lot of force. It can make the bank collapse. It can wash away the fill under the pipe.

This is very bad. You must place large stones in the pit that the water made under the pipe outlet.

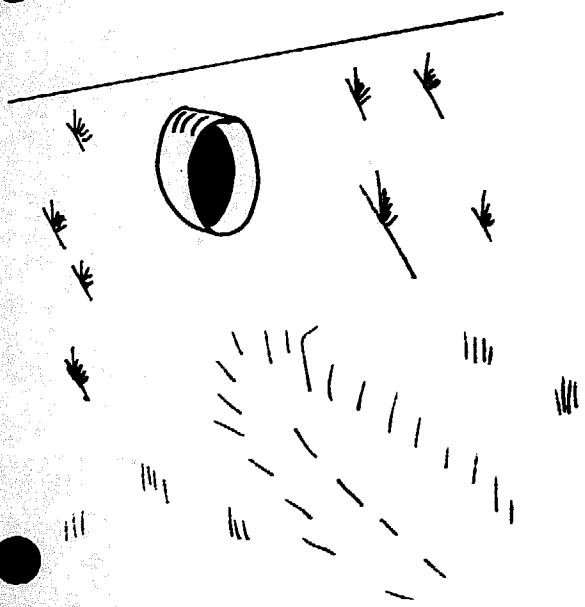

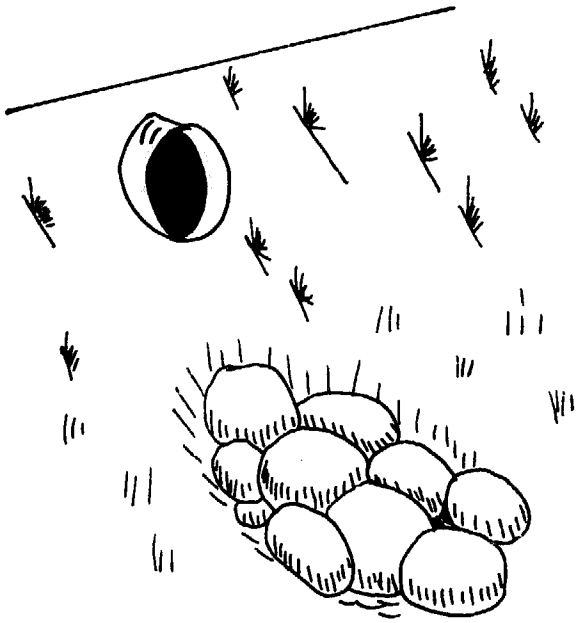

The bark should not be taken off, except if there is fill to be held back. If there is fill the sill-beam must be cut to shape ("stepped") where the stringers rest on it. Walls at the side of the abutments are called wing walls, are shown in the drawing at the back of this book. They are used to hold in the fill so the road does not slip down.

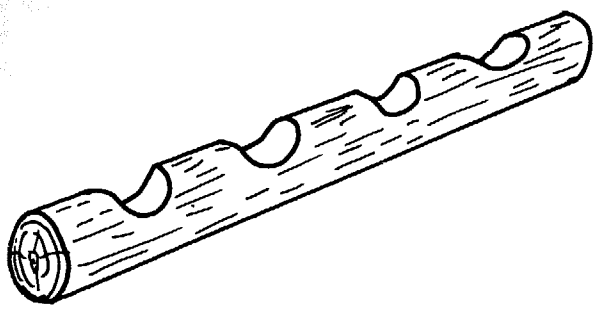

Stepped Sill-beam.

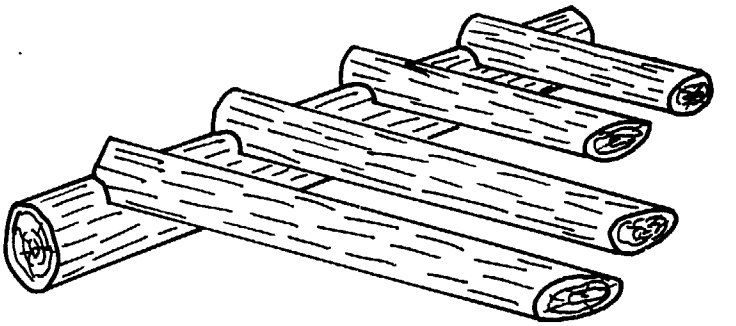

Sill-beam with stringers.

<u>Here are the two types of wing wall that you can use:</u>

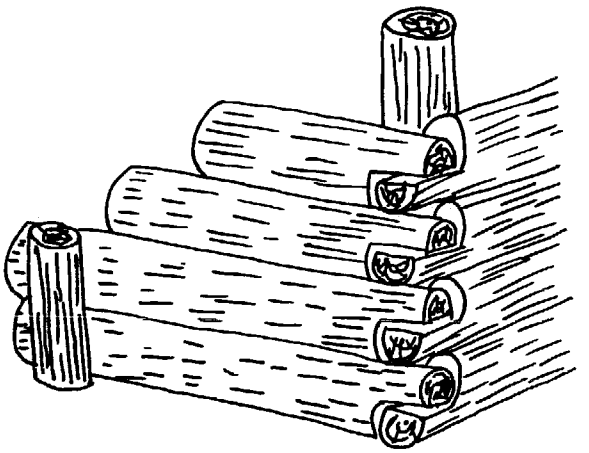

Wing Wall Type W1

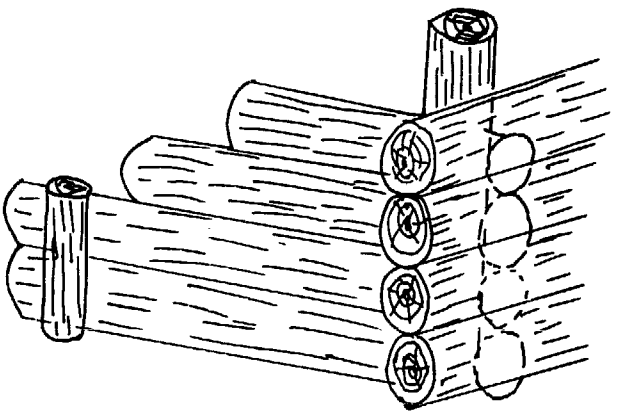

Wing Wall Type W2

These are the same, except W1 is bolted to the retaining wall logs (horizontal); W2 to the piles (vertical).

Bolts must be used for all abutments to keep the structure firm and strong. You can get bolts up to 600 mm. long at Government Stores. Longer ones can be made by threading steel rods in a workshop.

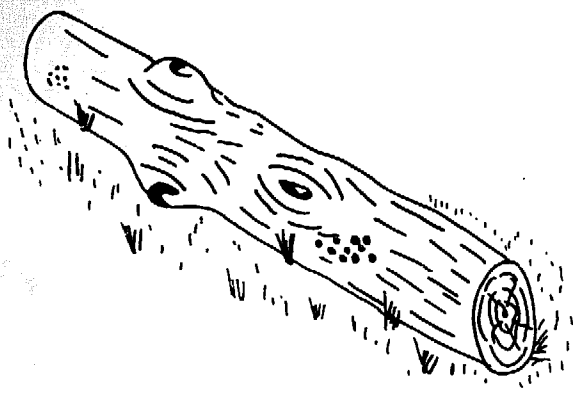

This is a picture of a bad log.

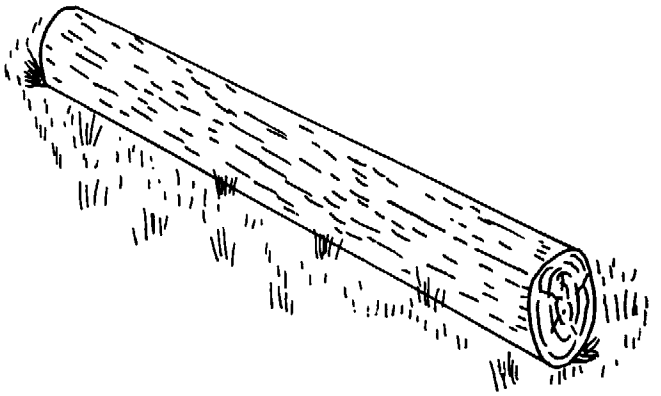

This is a picture of a good log.

3. <u>How big must the timber be</u>?

Strength Group of logs.	Diameter (mm)	250	300	375	450	525	600	675	750	825	900
	Longest spans of logs for different diameters (metres)										
A		3	4.5	6	9	12	15	18	21	24	24
B		–	3	4.5	6	9	12	15	18	21	24
C		–	–	3	4.5	6	9	12	15	18	21

Different strengths of types of wood in Papua New Guinea.

<u>Strength Group A</u>

1. Kwila
2. Kassi-Kassi
3. Hopea - heavy
4. Manikara

<u>Strength Group B</u>

5. Hopea- light
6. Geijepa
7. Heritiera
8. Vitex
9. Garo
10. Hopea - heavy

<u>Strength Group C</u>

11. Yellow Hardwood
12. Dysox
13. N.G. Beech
14. Kamarere
15. Water Gum
16. N.G. Oak
17. Taun
18. Anisoptera

4. How do you measure the log?

The diameter measure does not count the bark. You must measure the thinnest section of the log.

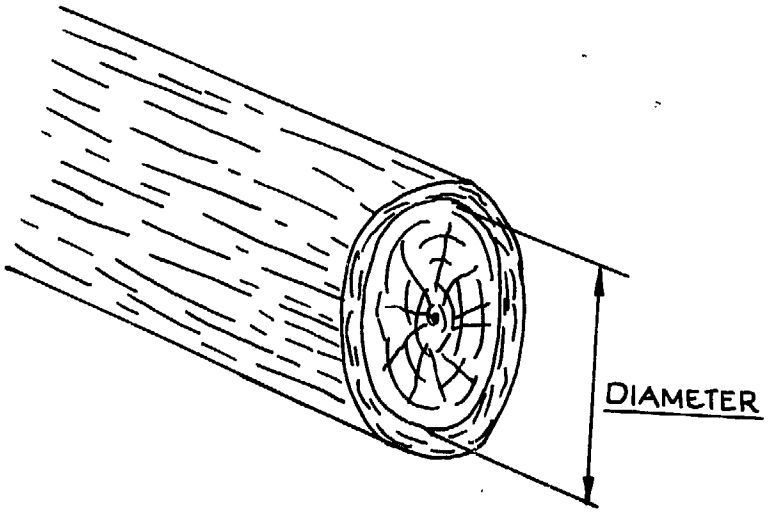

Note: The stringers (mainbeans) must not be smaller than I have told you. Suppose the diameter of the stringer is 10% less than I have written in the list. The bridge will be 30% weaker. Instead of 10 tons, it could carry 7 tons.

The timber for the deck of the bridge is fairly easy to replace. But the stringers and abutment timber is very hard to replace. You do not want the stringers and abutment timbers to rot.

5. How do you prevent timber from rotting?

Try not to disturb the bark on the logs. Also, paint the timber and add creosote or coal tar or sump oil before you start to construct the bridge. You can ask the Department of Forests if they can help you. Sometimes they can help you by treating the timber in a special way by chemicals or in a pressure tank. But they usually cannot do this.

Final test for each log to know if it is a good log: You must get a man to lift up one end of each log. You must hit the log with the back of an axe or with a sledge hammer. A strong log will make a strong, clear sound. A rotten log will make a different, dull sound. You can tell these two different sounds when you have heard them a few times.

6. How high should a bridge be?

Usually a bridge is higher than the place where the river floods to in the rainy season.

The bottom side of the bridge should be 1 metre higher than the highest water level.

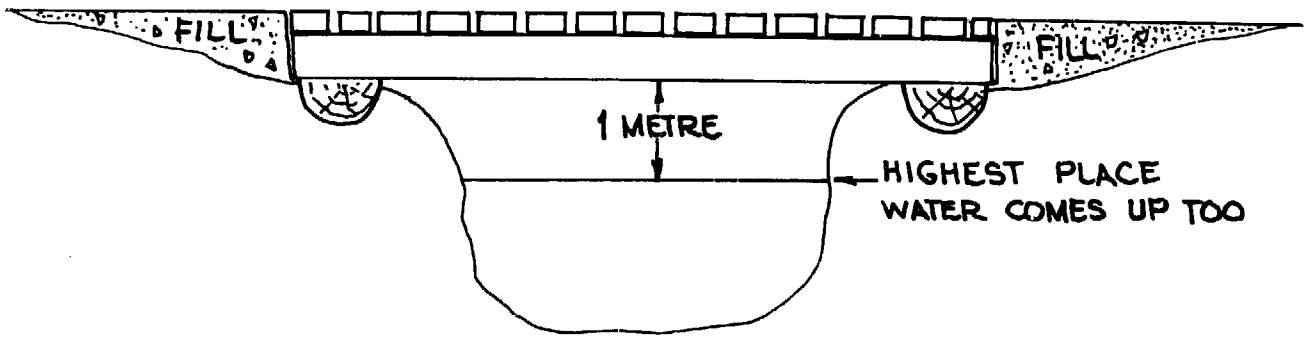

You may have to raise up the road to this height. You call this an approach embankment.

You can read pages 55 to 57 to find out how to construct an embankment. An embankment across a swamp and an approach embankment are made in the same way. Suppose you have to build this approach embankment across a flood relief plain. A flood relief plain is where the water spreads out over flat ground alongside a river in flood.

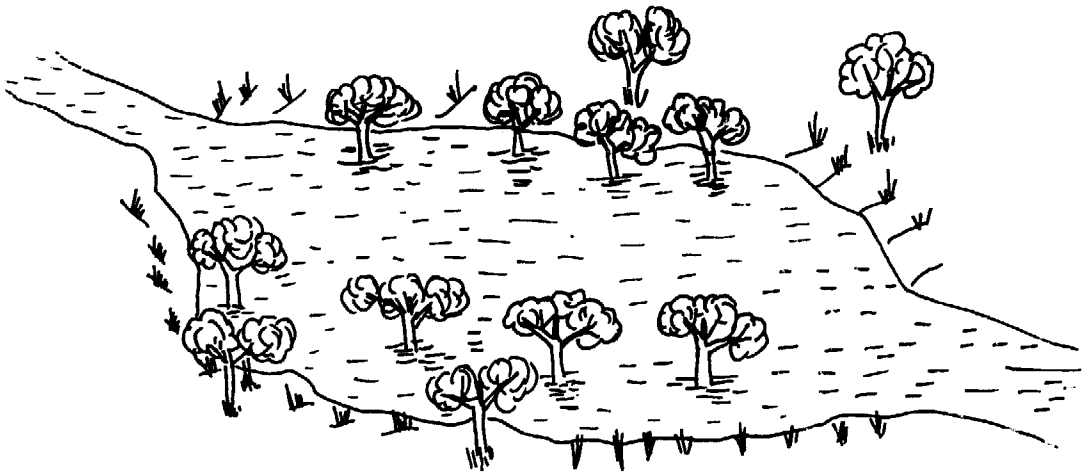

Suppose you stop the flood water from flowing easily. The flood water might erode your bridge or even make it fall down. So you must be careful when you build a road across a flood relief plain. The road must be a low road and you must grade the approach embankment at about 8% to 10% gradient.

7. <u>Abutments</u>:

<u>What is an abutment</u>? It is the foundation, built on each bank, for a bridge to sit on.

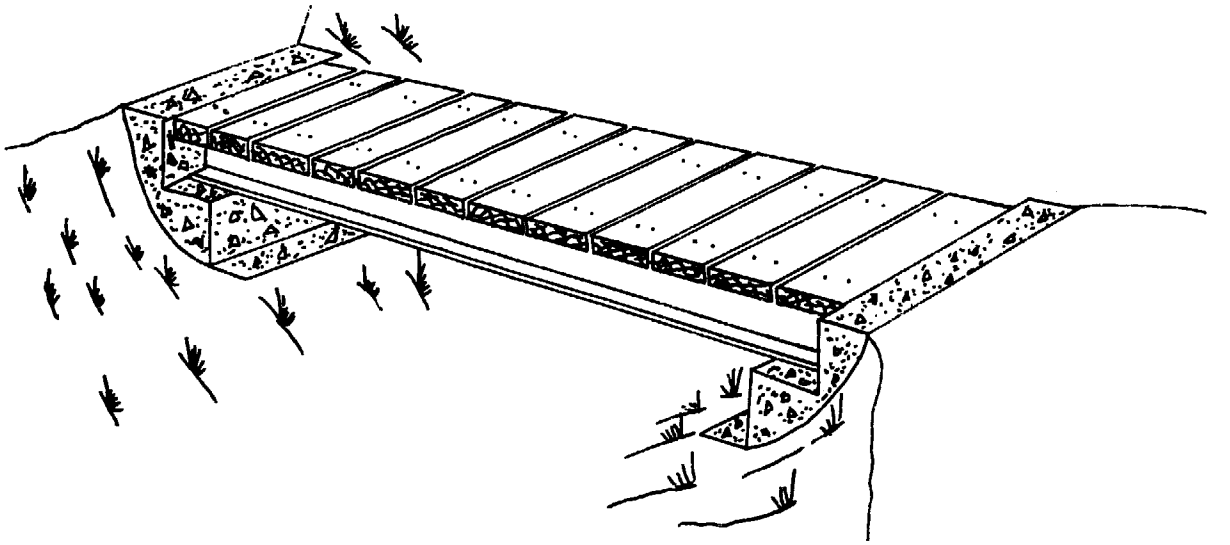

Suppose the abutment to a bridge is badly constructed or suppose it is not big enough. The bridge may break or sink down. Heavy trucks cannot use the bridge. You must construct a good big abutment the way I will now tell you.

(a) <u>Concrete abutments</u> are the best abutments. Suppose you do not have lots of good timber in your area - then concrete abutments are also the cheapest sort of abutment.

(b) <u>Timber log abutment</u>

(c) <u>Gabion abutment</u>

(d) <u>Steel pile abutment</u>

(e) <u>Steel pad abutment</u>

Here are 4 important rules for bridge abutments

Rule 1: Bridge abutments must be stable - they must not shake when a truck goes on the bridge.

Rule 2: Bridge abutments must not break when a heavy load goes on the bridge.

Rule 3: Bridge abutments must be constructed so that the fill behind them does not spill out and so it does not get scoured out.

Rule 4: Bridge abutments must last as long as the stringers without breaking.

Timber abutments for timber bridges: Timber abutments are the cheapest to build and can be replaced sometime in the future when a permanent materials bridge is built.

Here are 3 good sorts of abutments for timber bridges.

Abutment Type A: a retaining wall abutment to go with bridges that are less than 18 m. long.

(Abutment A is NOT good for a longer bridge. It is not stable enough)

The fill behind the abutments must be good material. It must be compacted well (see page 66).

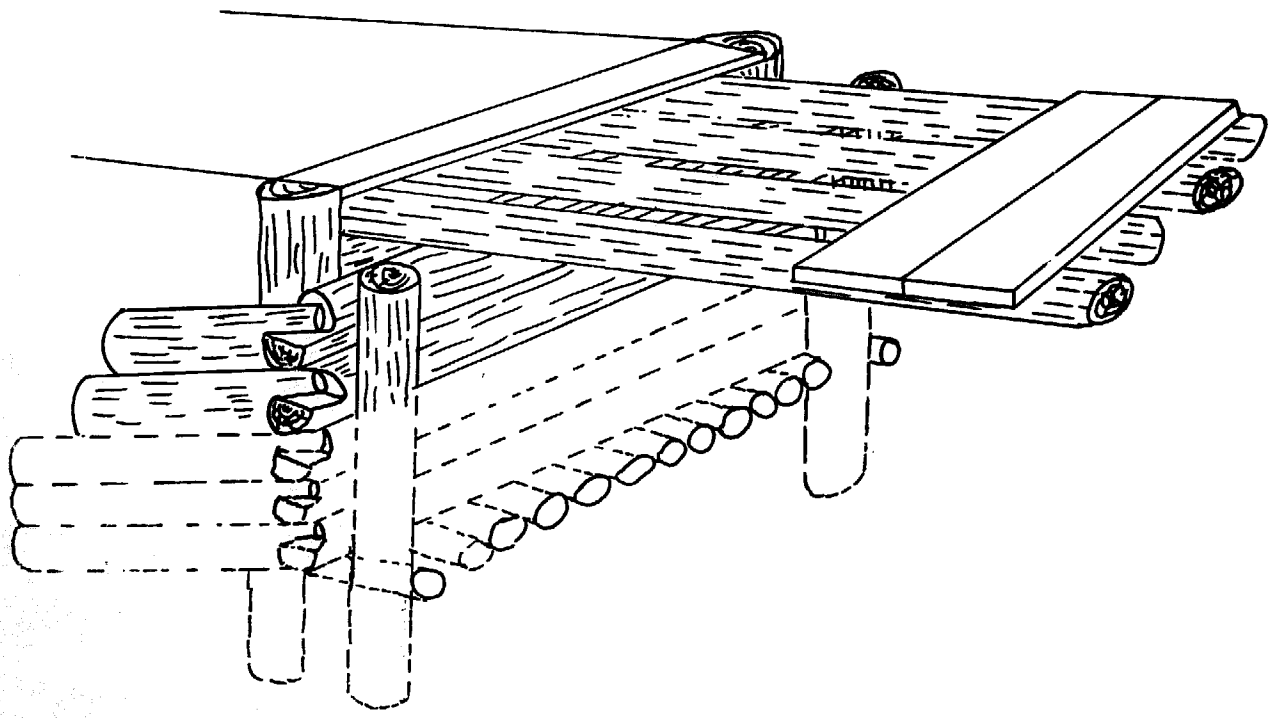

<u>Abutment Type B</u>: a stronger, more stable retaining wall abutment that you can use on bridges 18 metres and longer.

In this abutment you must put stakes close behind the abutment wall to keep in the fill. You can fill behind the stakes in the same way as you fill behind Abutment A.

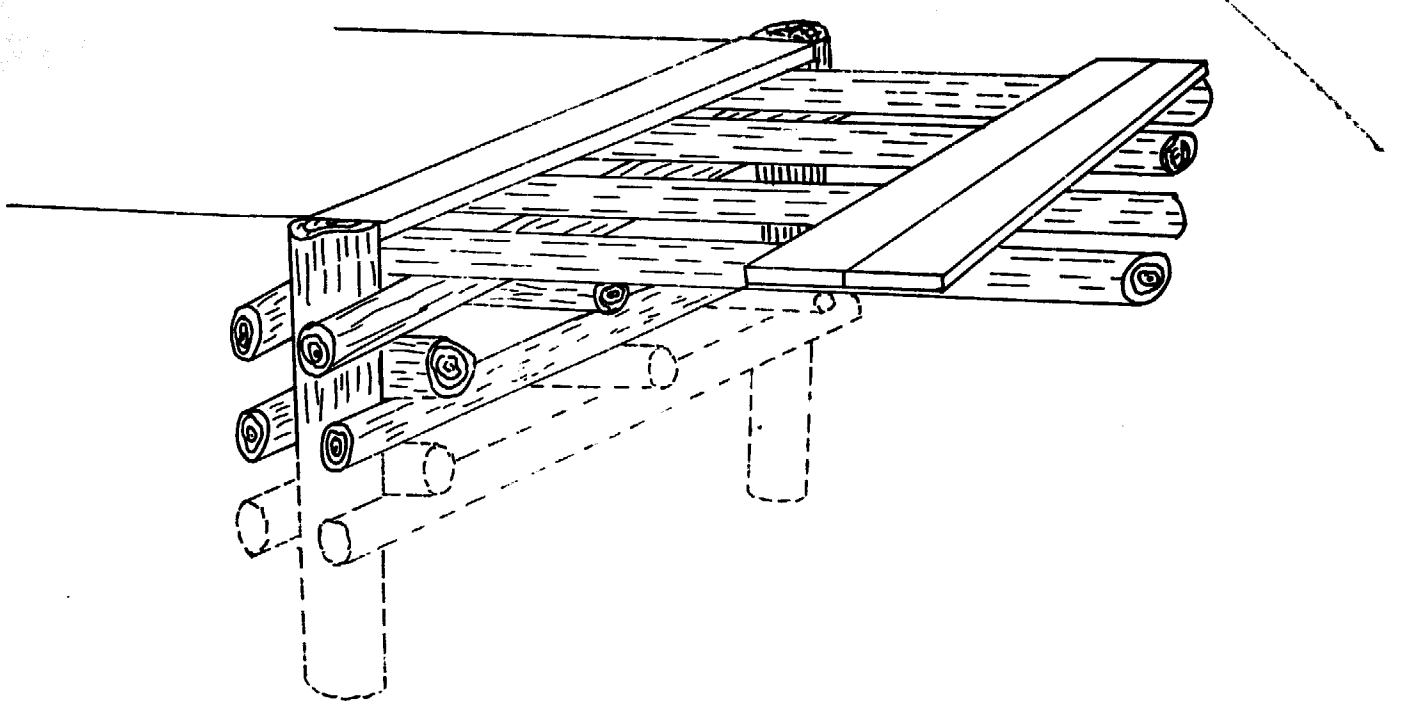

<u>Abutment Type C</u>: a simple piled sill-beam abutment. This is the best sort of abutment.

If you cannot make a concrete abutment, then this is the best abutment to use for a log bridge of any length.

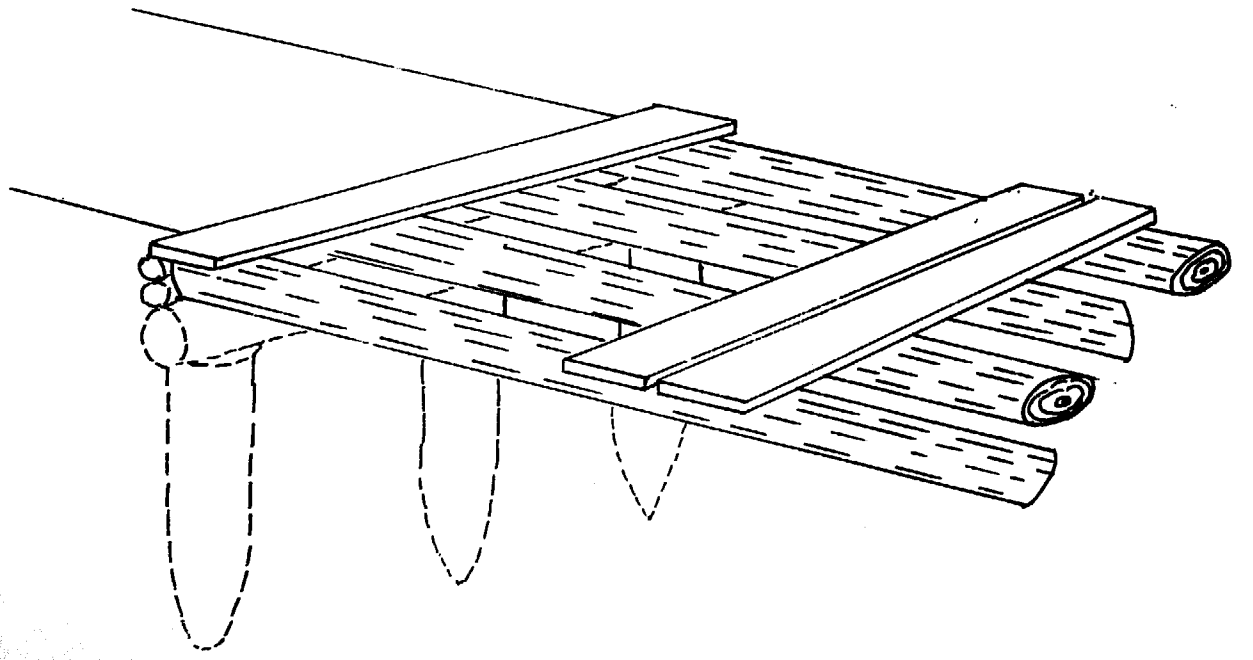

I will now tell you how to construct a piled sill-beam abutment.

First, you dig a trench in the right place for the big beam that holds up the stringers. This beam is called the sill-beam. Suppose the ground at the bottom of the trench is not strong (that is, suppose your foot sinks in when you stand there). Then you should drive three poles (piles) three feet down into the bottom of the trench, (less if the ground gets too hard to hit them in). Then cut off their tops at the bottom of the trench.

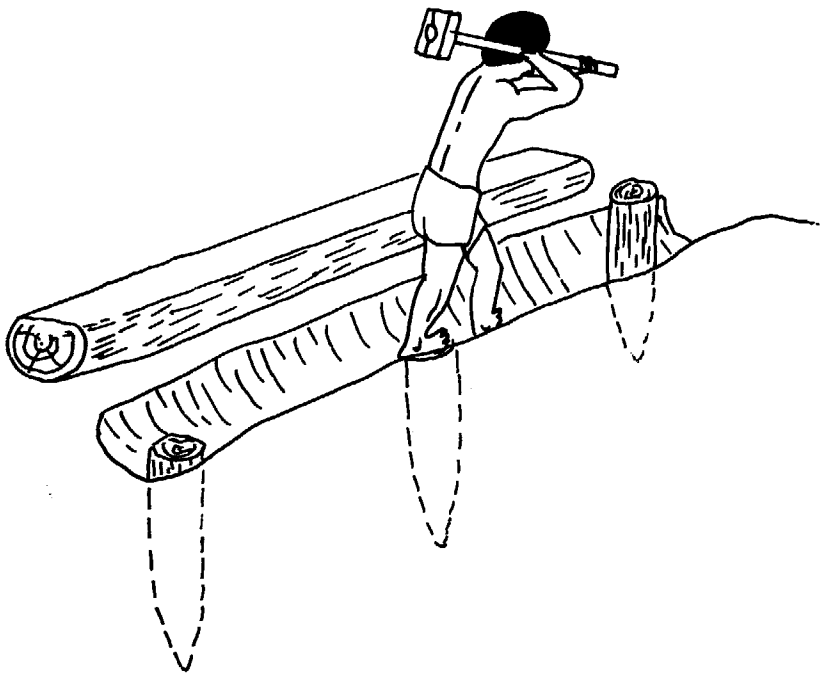

Put the sill-beam in place, pack good fill all round it, then the stringers can be put on top of it and bolted into it with steel bolts or bars.

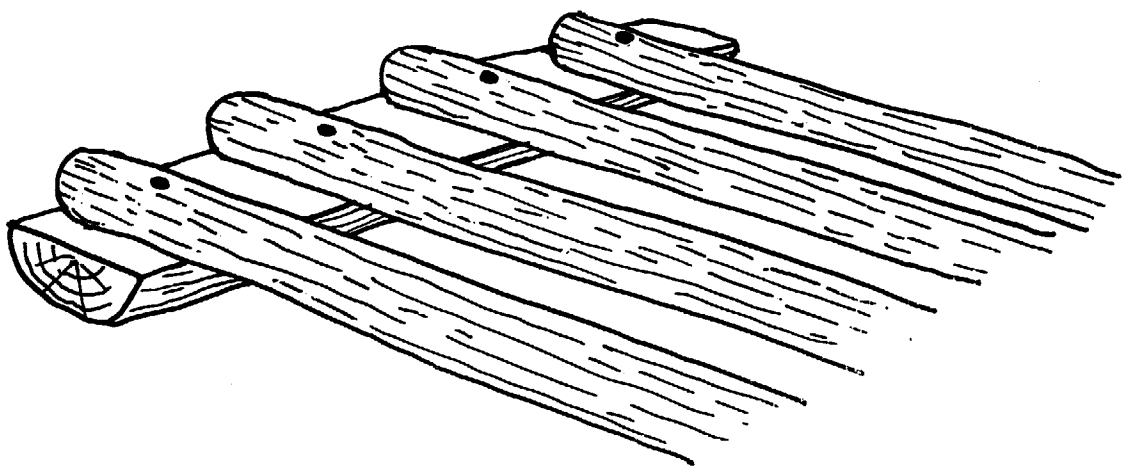

How deep should the stones be in this pit? Suppose the pipe is a small pipe (300 - 900 mm diameter). The stones should be at least 0.3m deep. Suppose the pipe is a big pipe. (1200 - 1800 mm diameter). The stones should be 0.6 m to 1.0 m deep.

How big should the stones be? The stones must not move when water comes quickly out of the pipes. They must not move even when a lot of water comes out in the rainy season. If the pipe is a big pipe, the stones will have to be heavy and strong because the water must not make them move even in the rainy season when a lot of water comes down.

B. TIMBER BRIDGES

1. First words:

I will tell you how to make log bridges out of trees, I will not tell you how to make steel bridges. You need an engineer for steel bridges. A log bridge is a temporary bridge. It does not last for a lot of years. But you must construct a good log bridge because you want a strong bridge, a safe bridge, a bridge that does not cost much to maintain. Also if you live in a place where there is not a lot of timber for bridges, you do not want to waste timber.

2. What timber do you need for bridges?

The most common good timber for log bridges is Tagaruba. This tree has two other names - It is called New Guinea Beech in English and Forestry Officers call it Nothopagurs. Other timbers can be used. Some other timbers that can be usedare Kwila, teak, hopea, ksasi-ksasi, manilkara or other good strong hardwoods. You can ask Department of Forests to tell you about other good timber for log bridges. You must look at each log. Each log must be straight. It must not have twists or knobs or stakes. It must not have insects in it or places where white ants used to live.

Suppose you use bad timber, heavy trucks cannot use the bridge. Also the bridge will not last. See the pictures on the next page that show you what good logs look like.

Stringers with Abutments A and B: You must step the stringers onto the sill-beam and bolt them securely to the sill-beam. These two things are importan. Why must you do this? Because it makes the bridge more rigid or strong. Als it prevents the top of the abutment from being pushed into the stream becaus of heavy weight of the fill behind the abutment. You must protect the wood that has been cut on the sill-beam. You protect it by putting a strip of Malthoid between the stringers and the sill-beam. (Malthoid is a special flooring with tar on it. You will find it in the Government Stores Vocabulary under Class No. 5640). All bolts must be counter sunk. These are sunk so that the tops do not stick out of the wood. See the pictures below showing some Malthoid between the stringers and sill-beam and a counter sun bolt.

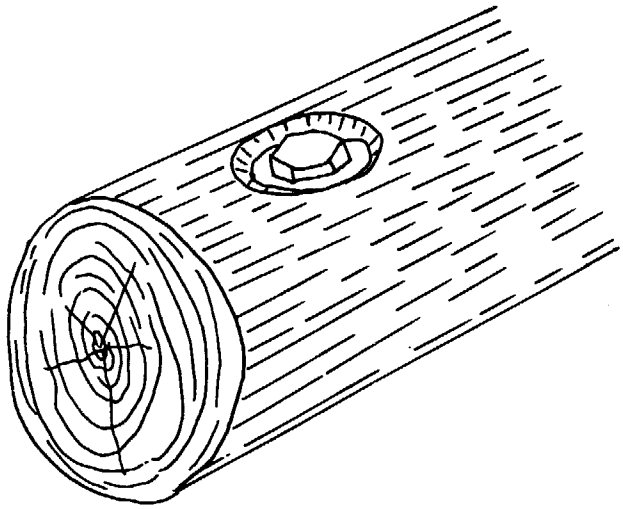

Where bolts have been counter sunk, you must fill the holes with caulking compound or something like tar so that the water will not fill the holes and so the water will not make the timber rot.

Stringers with Abutment C: Usually you do not need to bolt or step the stringer onto the abutment. But suppose you use an Abutment C with a retaining wall abutment, then you need to step and bolt the stringer as I told you before. Do NOT make the abutment piles on the corners of bridges longer, so that you can use them for guide posts. This is very bad. Suppose a truck hits the posts the abutment may be badly damaged. You need separate posts as guide-posts.

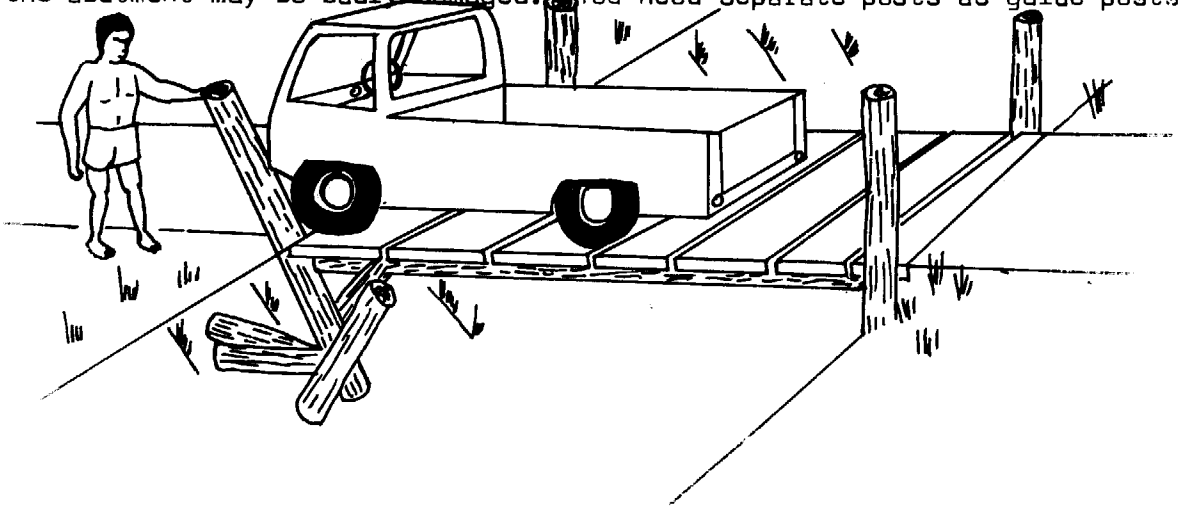

8. Stringers and Decking:

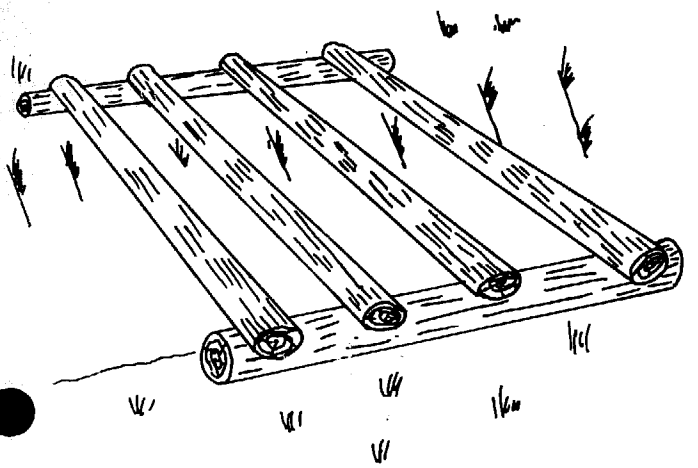

This picture shows 4 stringers on a bridge that is being built.

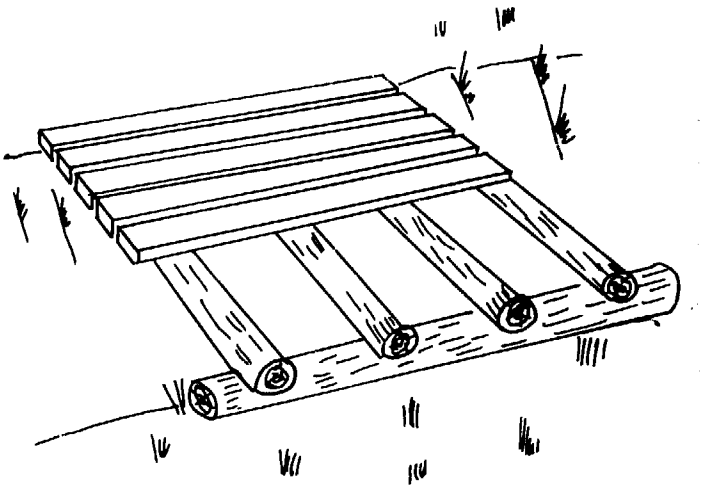

This picture shows the half completed deck on the 4 stringers.

You do not need more than 4 stringers. You cannot make the bridge stronger by using more stringers.

The best sort of decking is sawn timber that has been treated with Creosote or something like that. The decking should be 200 mm x 100 mm. But this is hard to get.

Here is another good sort of decking. Get 200 mm. x 75 mm. decking and spike it to the stringers. Spikes are big nails 6" long or longer. On top of this put 200 mm. x 50 mm. running planks and coach bolt the running planks to the decking.

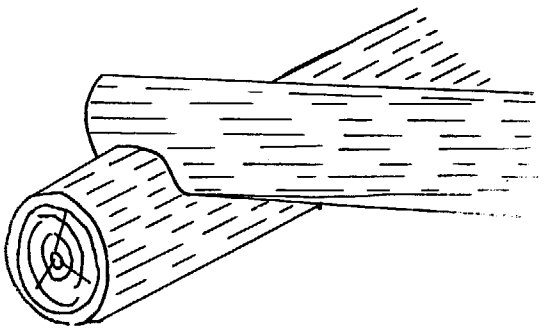

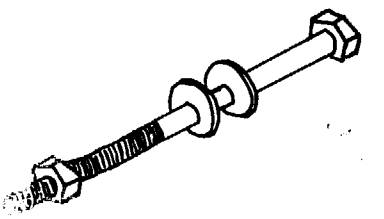

*Do not spike the running plank to the decking. This is very bad. It soon comes loose. The decking must be spiked to the stringers. Use packing where necessary to fill the holes.

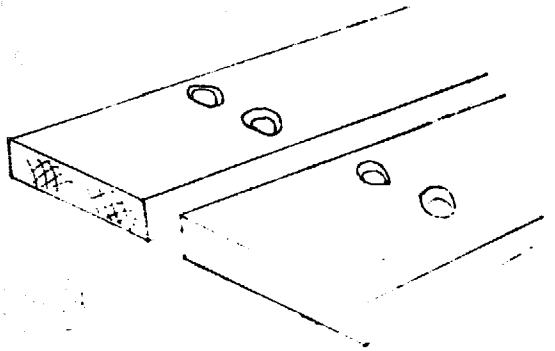

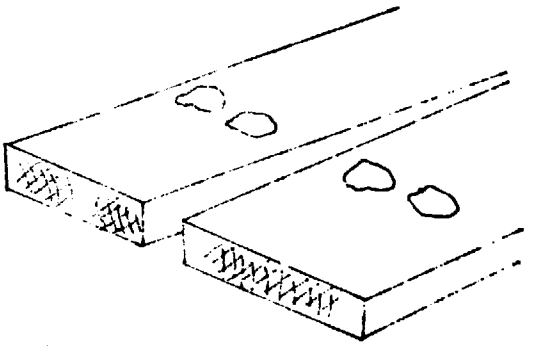

You can flatten the top of the stringer and protect it with Malthoid if you want to.

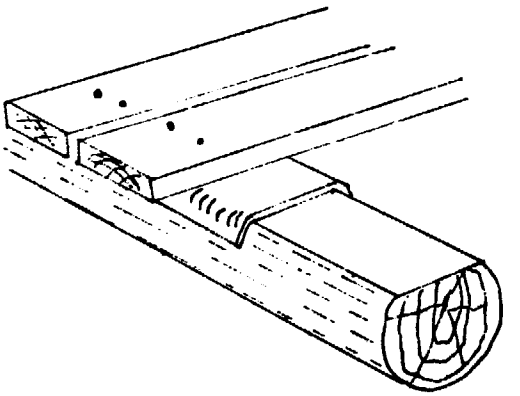

OR: You can leave the bark on the stringers and nail the decking straight onto the stringer.

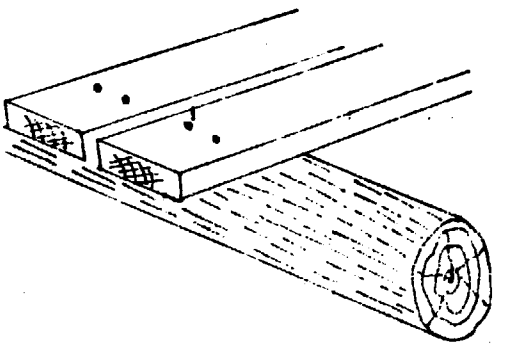

You must not put clay or coronous on top of the decking to make it smooth. Why not? Because they hold water and make the timber rot quickly. Also, they are too heavy and the bridge will not be as strong as I told you before on page 105.

9. <u>Kerbing</u>:

You must spike a kerbing onto the bridge like this:

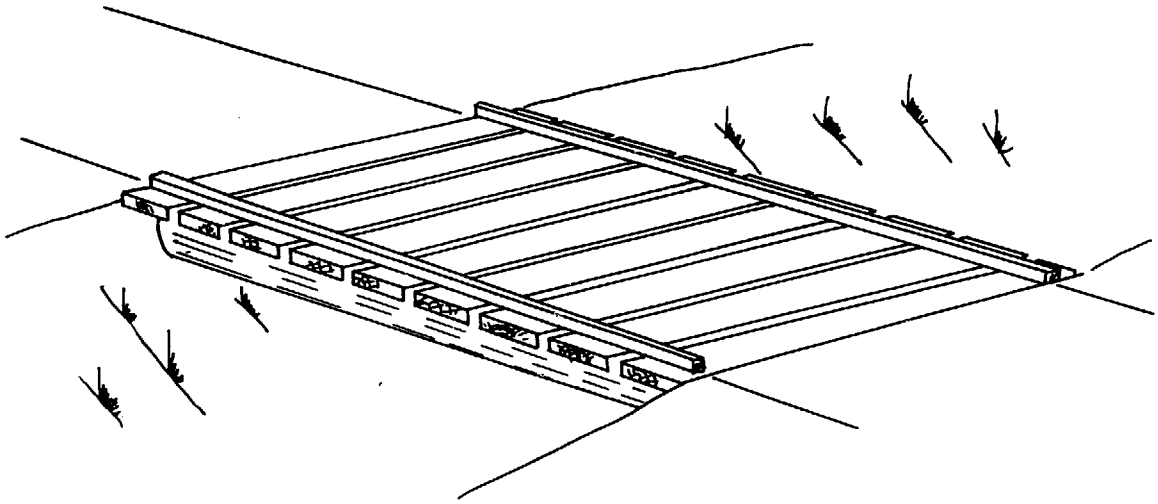

This kerbing is good for 2 reasons. For one reason, it is a safety kerb; it helps trucks not to fall off the bridge into the water. For another reason, the front wheels of trucks cannot shove the decking forward, the way a bulldozer shoves logs forward.

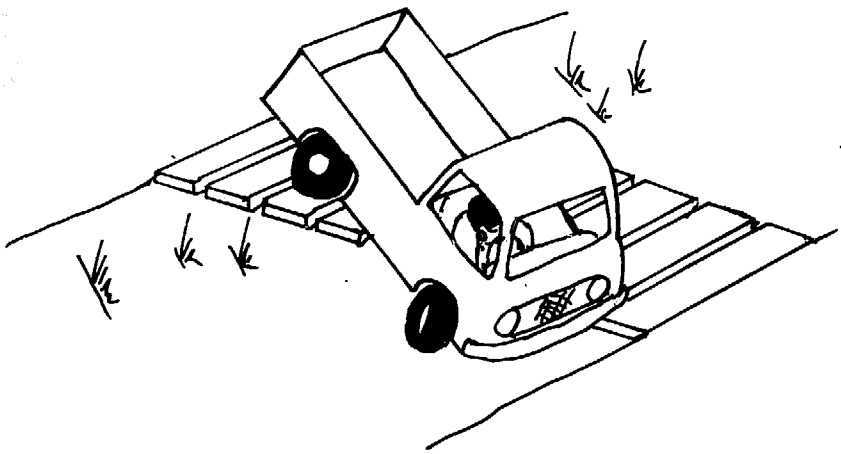

Picture showing truck falling off the bridge.

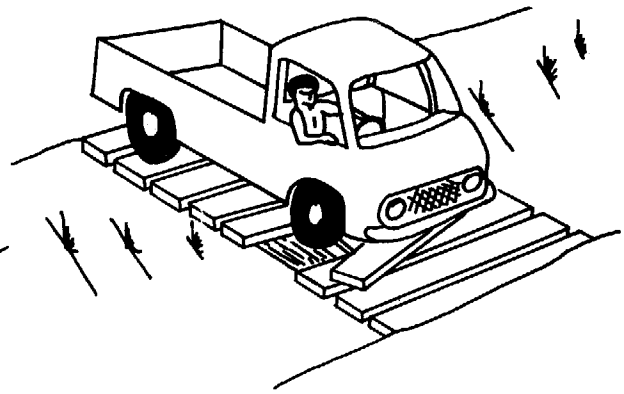

Picture showing truck shoving the decking forward.

10. Guide Posts:

Last, you must put in guide posts. The guide posts should be made of logs about 150 mm. in diameter. You must paint them white. You must not attach them to the bridge or the abutments. You must put one at each corner of the bridge. You must put them firmly in the ground behind the abutments and hard against the outside stringers. Do not forget to put up guide posts. They are important. They are most important where the road coming onto the bridge is not very good.

11. General information about (constructing and maintaining) log bridges:

You must not leave any holes on the bridge or any place where water can collect. If water collects in a hole, it will rot the timber quickly. You must paint the end of each log with a lot of creosote or coal tar or sump oil, and you must make a point at the end of any log that stands up.

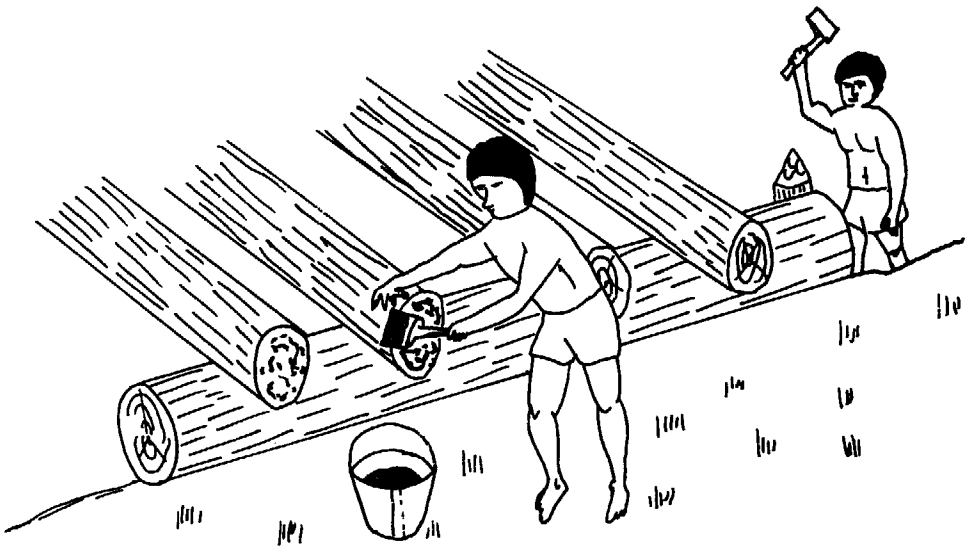

You must fill all holes that are made where bolt-heads are counter sunk. Fill these holes with caulking compound or something like that.

How to maintain the bridge: You must often look around the abutments to see if there is any erosion. The first time you must look for erosion is straight after the first flood. Suppose you find serious erosion and you think it might make the bridge fall down. You must ask the Local Government Supervisor about it. He will tell you what to do.
You must clear away weeds and grass that grow on the abutments. Do not let weeds grow. The abutments must keep dry.

Clear away rubbish that collects around abutments. Rubbish might cause trouble in a flood.
Also, do not let dirt cover the decking of the bridge. Dirt holds water and water rots the timber quickly

<u>How to check the stringers</u>: You must look at the stringer for rot. The first time you look at the stringers for rot is 3 years after the bridge was built.
The second time is 6 months after that and then every 6 months. You can hit the stringer with an axe. If it does not sound clear, get a brace and bit and bore a hole to see how deep the rot goes. This picture shows a stringer with good timber and some rot.

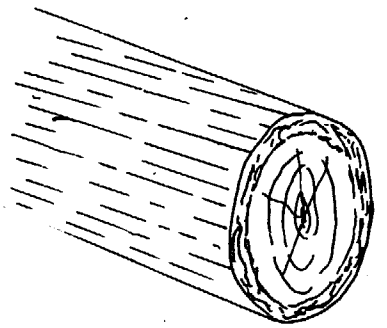

The stringer had to be 600mm in diameter for this bridge. It still looks like 600mm in diameter. But the good timber is only 480mm in diameter.

As soon as the diameter of the good timber is 25mm. less than the minimum diameter, you need for the bridge, you must put up a notice. You must stop heavy trucks from using the bridge, and you must start to get ready to replace the bridge.

12. <u>Summary</u>

Now I will list the most important things I have told you about constructing log bridges.

(a) First, you must select good timber. The timber must not be rotten. You must read the table about diameter of timber and width of the bridge (page 105). The diameter of the timber must be at least as big as the table says.

(b) Second, you must construct strong, stable abutments.

3. <u>Fords</u>:

You can build a simple and inexpensive crossing called a ford if the cost of a bridge is more than the Council has money for. A ford is a place where trucks can safely cross a river and the wheels of the truck run on the bed of the river.

Normally a river bed may look like this in cross section.

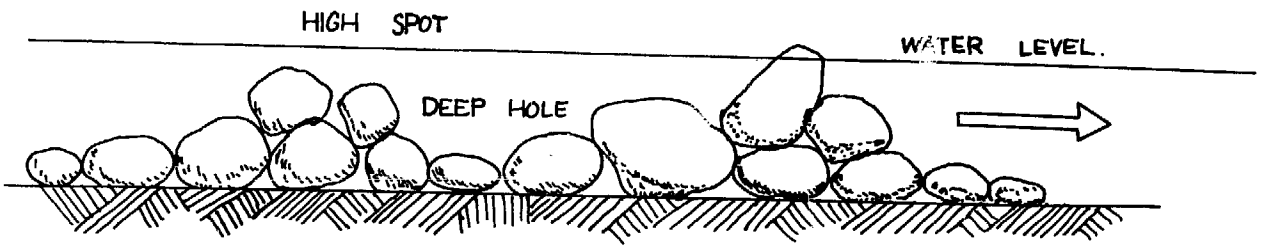

You can see rocks sticking up out of the water and other places are deep holes you cannot see from above. This is bad for trucks trying to cross. To make a better ford you install a round tube of wire screen filled with rock like this. It is held in place by a steel wire.

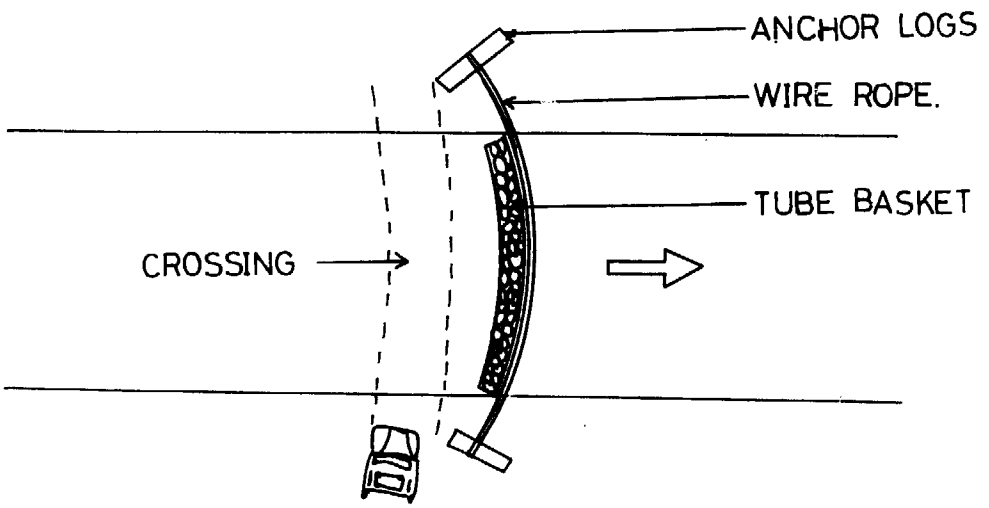

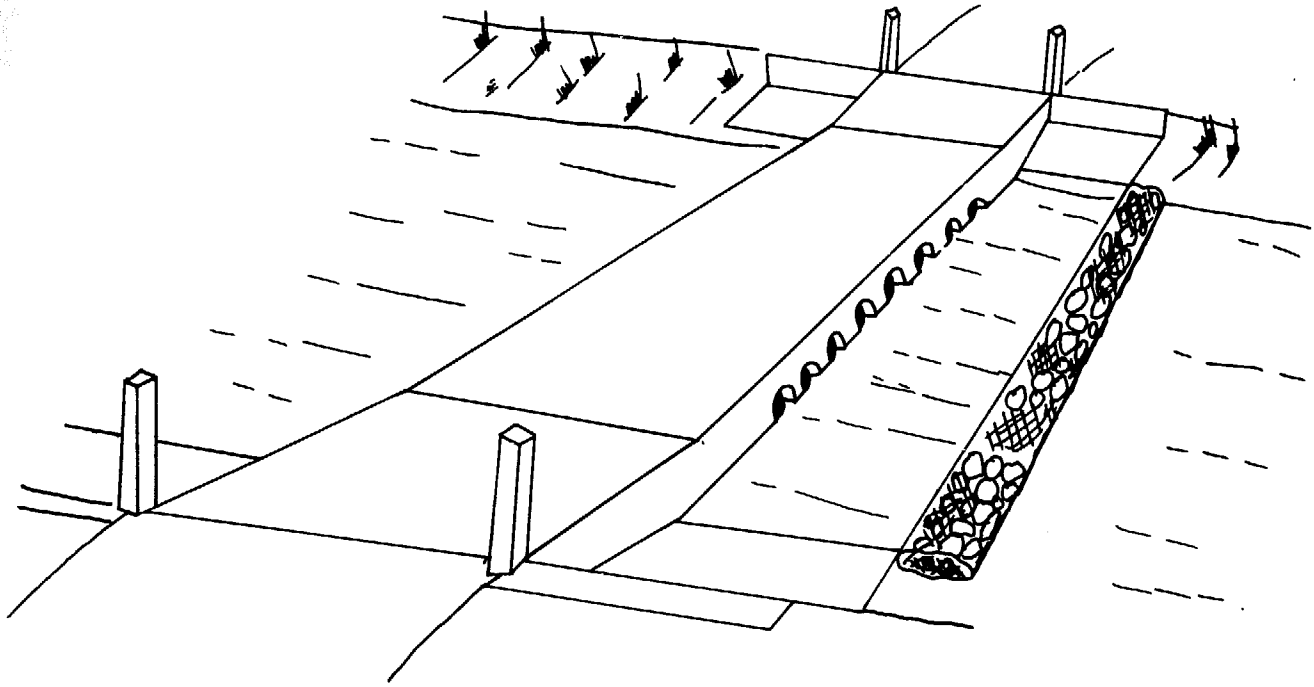

1. <u>What is a good place for a low level crossing</u>?

   (a) Suppose you want to build a bridge over a river or like this: The river bed is firm and does not change much, and is made of sand and gravel.

   (b) The river is usually not more than 0.5 m. deep during the dry season.

   (c) The river may be up to 2.0 m. deep during the wet season.

   (d) This flow of 2.0 m. deep is only for a little time after heavy rain and then the river quickly goes down and is not so deep.

   (e) Big logs and rocks do not come down the river.

All right, suppose your river or creek is like that. Then you can construct a low level crossing.

2. <u>What materials do you need for a low level crossing</u>?

   You may need gabion baskets. A gabion basket is 2 m. x 1 m. x 1 m. in size and is made of wire mesh.

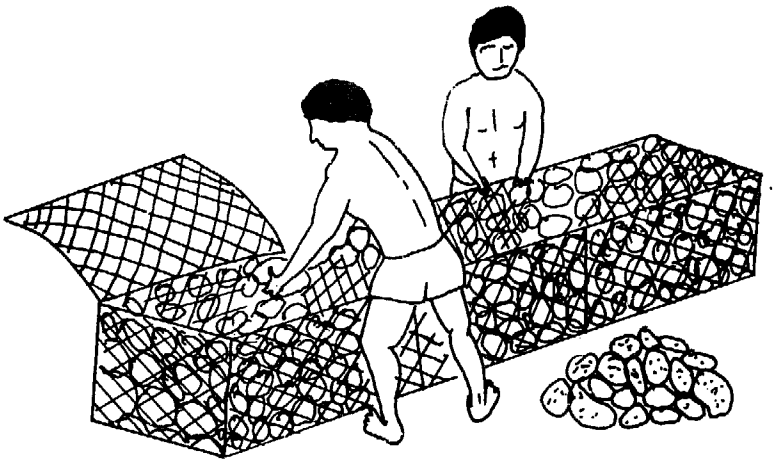

You may need a gabion or "Reno mattress". A reno mattress is 6 m. x 2 m. x 0.29 m. in size and is also made of wire mesh.

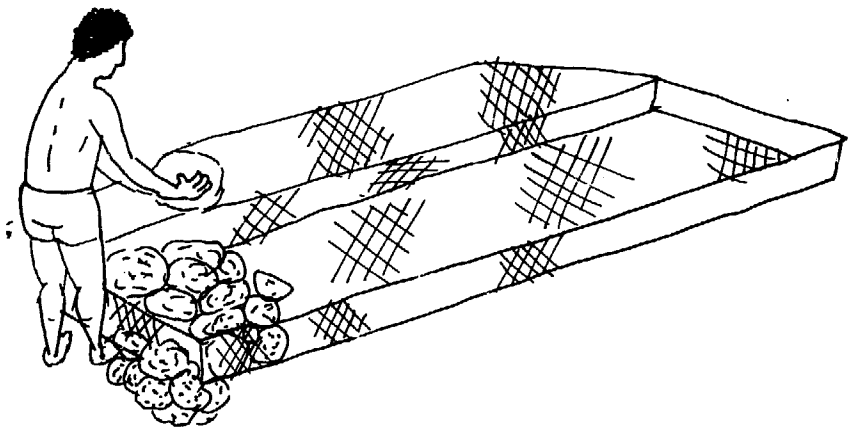

You fill these wire baskets with stones. The stones must be at least 100 m. in diameter. you need a gravel pit or river gravel close to the place for the crossing. You must fill between the baskets. The fill must be good sand mixed with clay or gravel mixed with clay. The fill must not have any dirt or leaves or sticks of wood. It is easy to construct a low lc l crossing.

You must take care that the crossing goes right across the part of the river where the water flows. Do not leave bare ends to get washed away. You must ask the Local Government Engineer to send a surveyor or an engineer to select a good place for the crossing. He will draw a plan, and make an estimate of cost. Then you must get the funds ready and buy the baskets and mattress and take them to the place.

(c) You must not let any of the timber in the bridge or the abutments get wet. You must leave on the bark if you can. You must paint the timber with creosote, coal tar or sump oil before you build the bridge. Suppose you must take off the bark, then you must cover the timber with malthoid (flooring that has tar in it). You must fill all bolt-holes with caulking compound or something like that. You must paint logs that stand up straight.

(d) A log bridge cannot take the same load after it is 3 years old. Suppose you build a bridge the way I have told you, the bridge will take a weight of 10 tonnes. A tractor weighs about 2 tonnes. A tractor and trailer with a load of wet dirt weighs about 6 tonnes. A "5 yard truck" with a load of dirt weighs about 10 tonnes. But after 3 years, the stringers and abutments will start to rot. The bridge cannot take such a big load after 3 years, and you are going to have to start thinking about replacing this bridge with a new timber bridge or a permanent materials bridge.

Multi-span bridges:

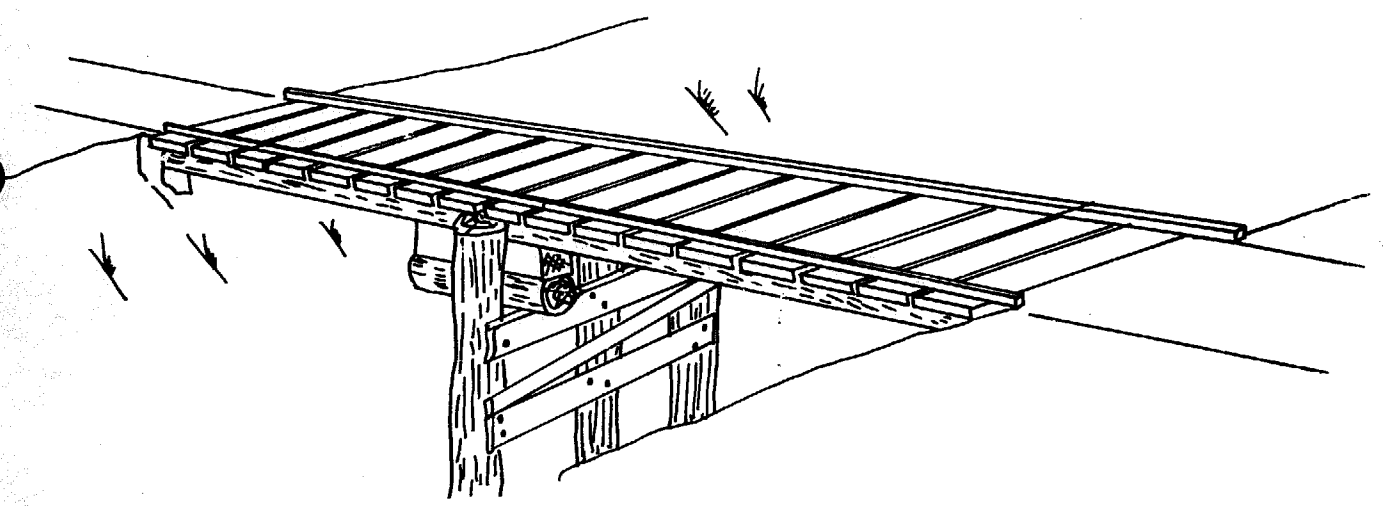

Suppose you cannot get logs stringers that have a big diameter. You can write to the Local Government Engineer. He will help you. His engineers will design a multi-span bridge for you. Do not try to do it yourself.

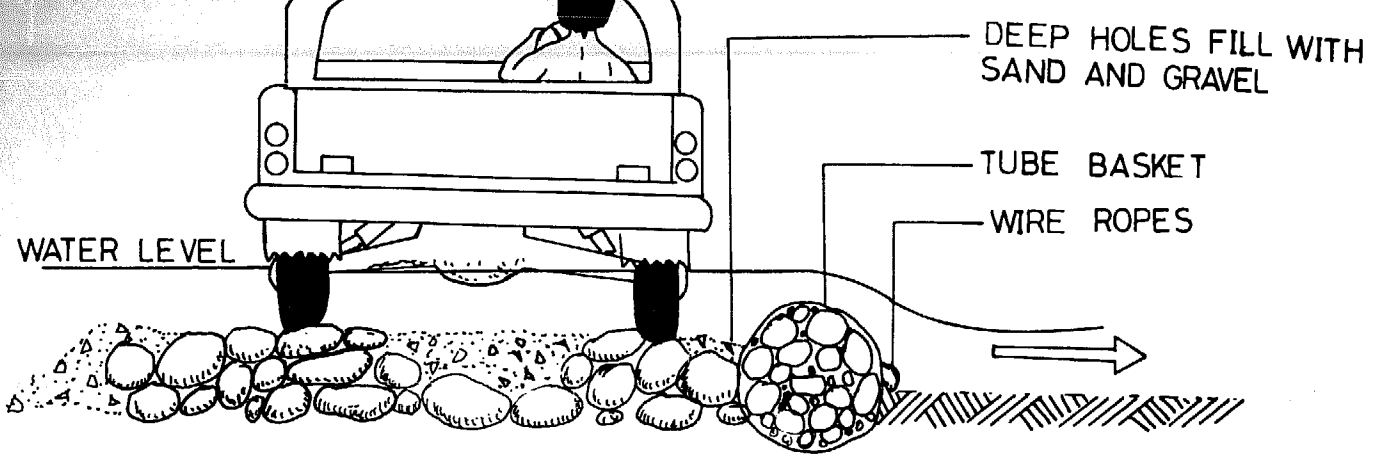

The truck now runs on a layer of sand and gravel bought from up stream by the river but prevented from going further by the presence of the tube basket.

A strong wire rope anchored to a log or concrete block at each bank holds the tube basket in place.

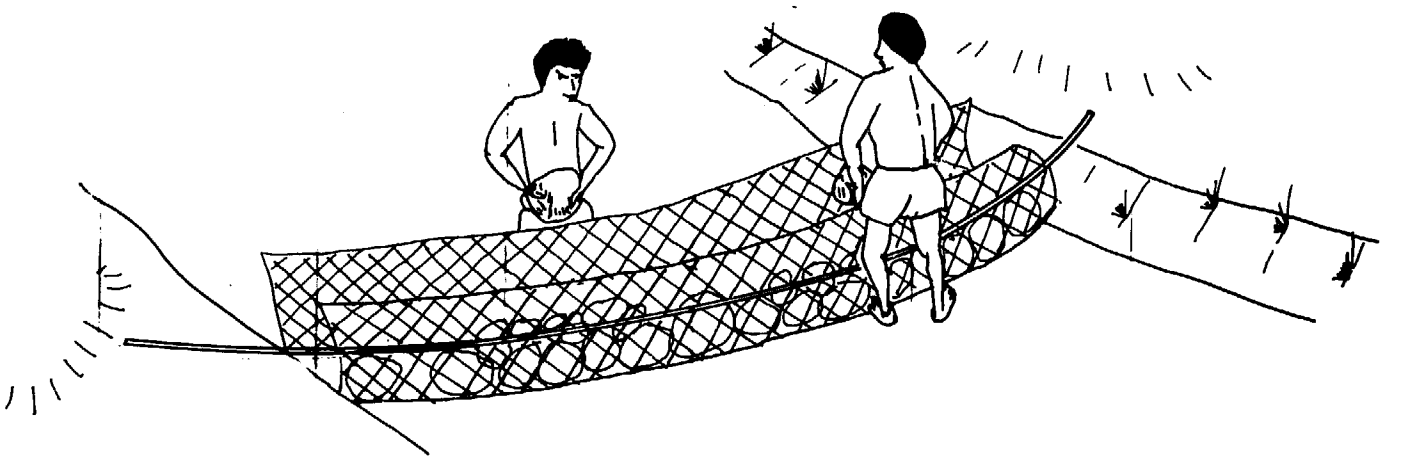

The tube basket can be easily made from a roll of fencing mesh laid out flat on the bed of the creek or river and filled with rock. While filling is going on the outside edge is raised and bent over to form a tube like this. Tie the basket shut at the top. With binding wire 2 or 3 mm thick. Finally attach the steel wire rope.

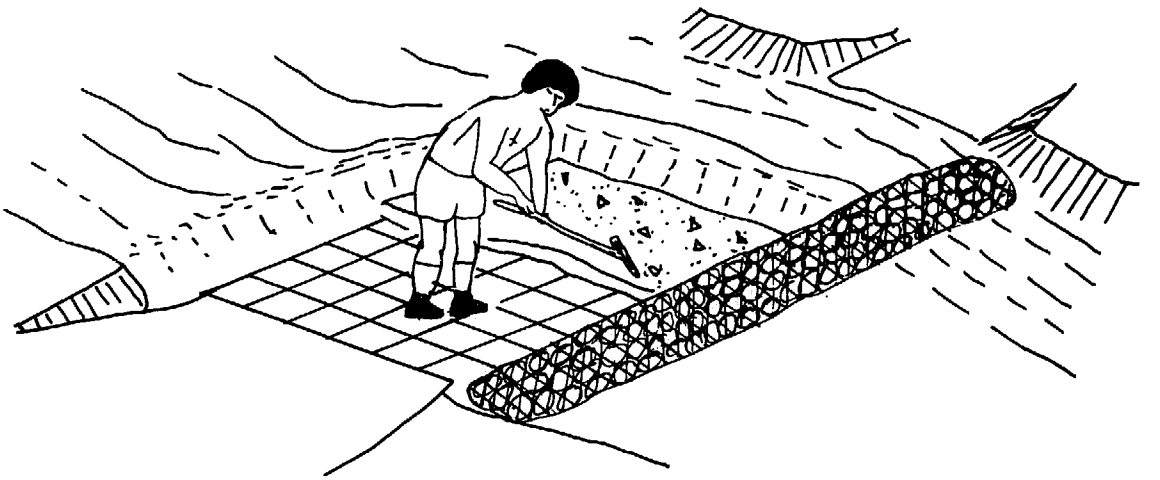

4. Causeways:

A causeway is a series of culvert pipes placed on top of a concrete slab and covered by a concrete deck. If it is built in the proper place it will let the normal river flow pass through the pipes. Flood water will pass over the top and not damage the causeway.
During flooding, the trucks must wait at the side of the road until the water level drops.

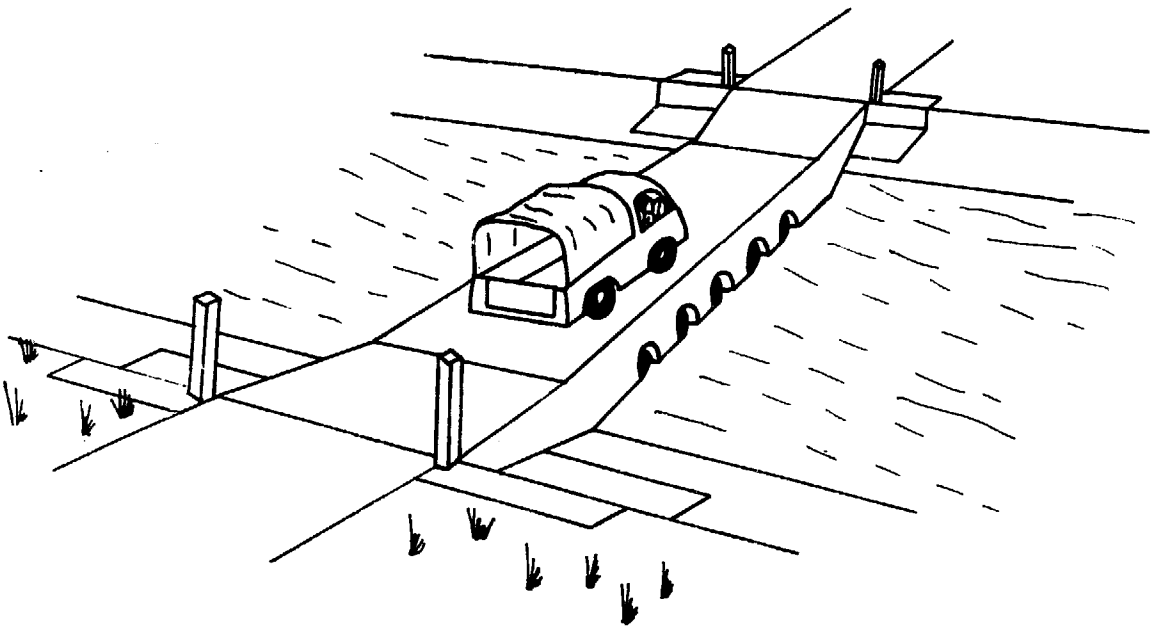

A causeway during normal river flow.

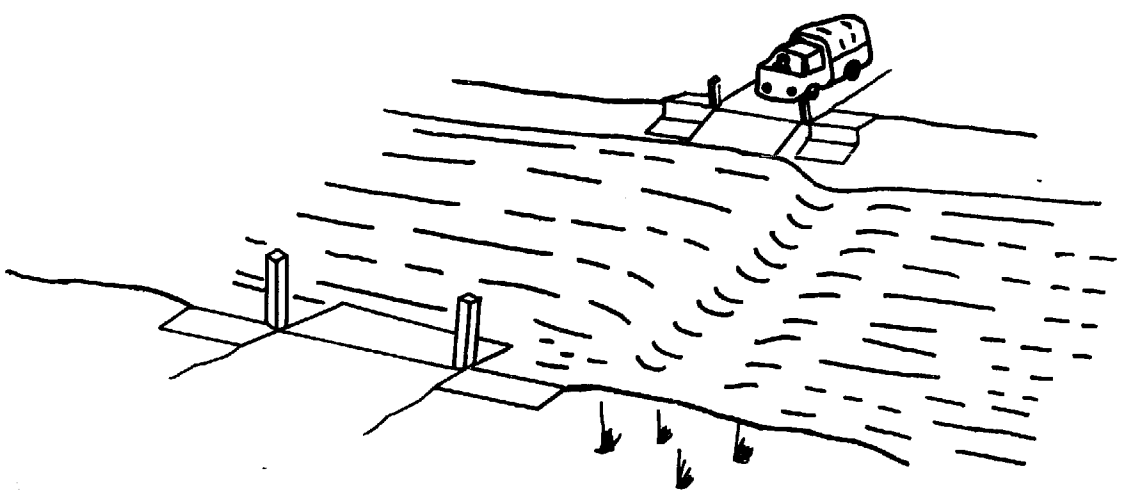

A causeway during flood flow times.

Pipes in a causeway are either corrugated steel or concrete. A design must always be obtained from the Local Government Engineer for there are many places where the causeway will not work properly. For example the water may be moving too quickly or the normal water depth may be too great.

5. Girder Bridges:

This bridge has three steel beams between the abutments, with timber planks on top. The beams are supplied in pieces not more than 6 metres long, and they are bolted together on the job. The span is not more than 15 metres. The bridge can carry loads up to 15 tonnes.

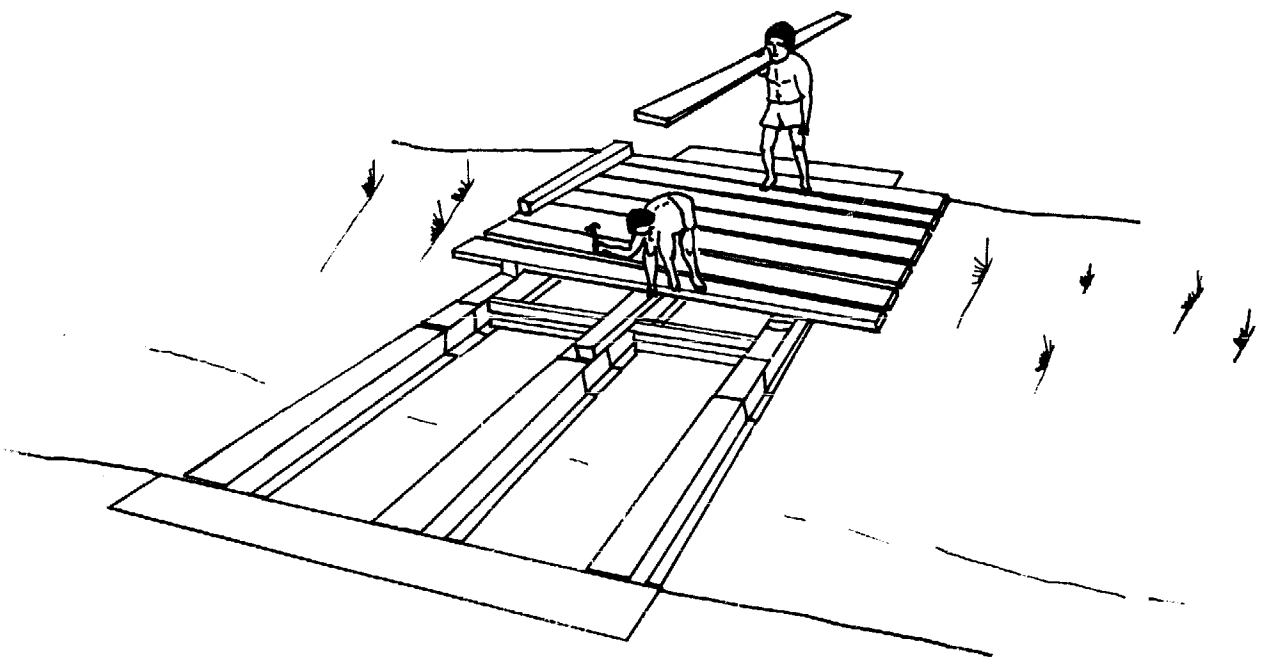

6. Expanded, or latice girder bridges:

These bridges are like the steel beam ones. One thing is different. The beams are made bigger by being cut in two, spread apart, then joined by steel angles. The span is 18 to 27 metres and they have a timber deck. The load is 10 to 15 tonnes. The engineers drawing will show what load you are allowed to put on the bridge.

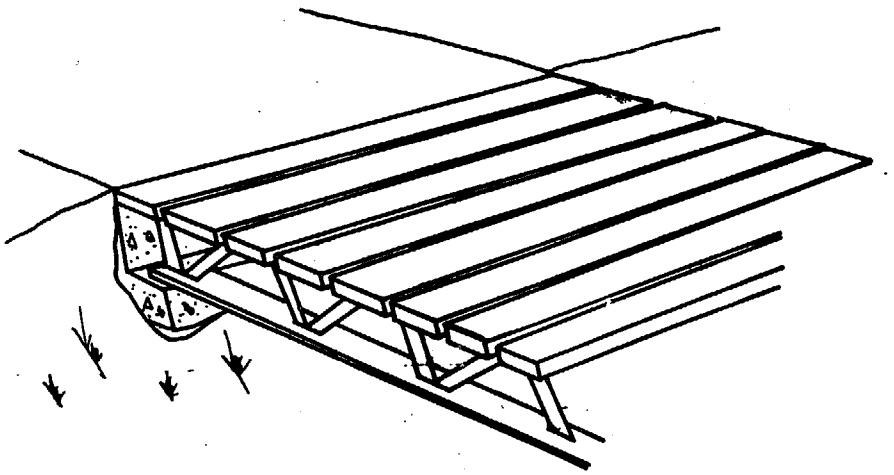

7. Bailey Bridges:

These bridges are made of panels bought from England, with other steel parts. Each panel is 3 metres long. They are joined together on the site. They can be built any length up to about 45 metres. But if they are more than 30 metres, they get heavy and expensive. They have timber decks. They can take loads from 5 to 20 tonnes, depending on the length, and the type of construction used.

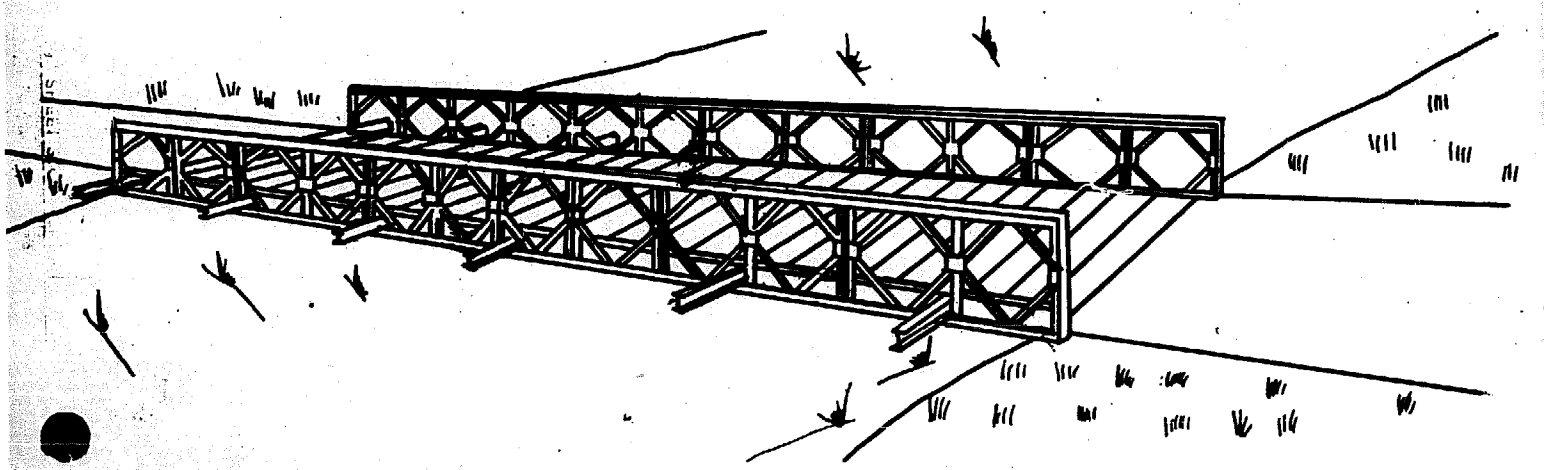

8. Suspension Bridges:

These bridges are hung steel ropes, or cables, which are strung between towers and tied to heavy "anchors blocks" in the ground. The load is 10 tonnes. They can be used for long spans, up to 75 metres.

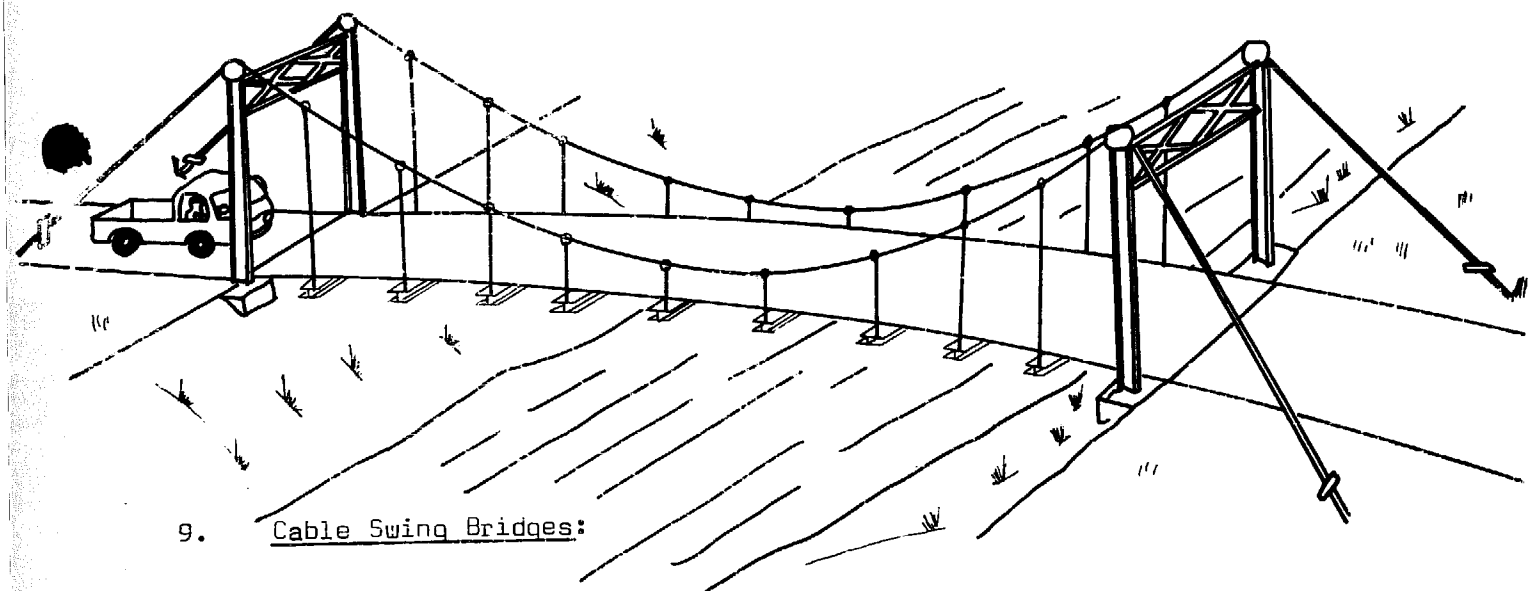

9. Cable Swing Bridges:

These bridges are made of a deck laid straight on a row of wire cables. They are quite cheap, and it is easy to get the materials for them into the Highlands in planes. They cannot take more than about 6¼ tonnes load. They can span about 45 metres.

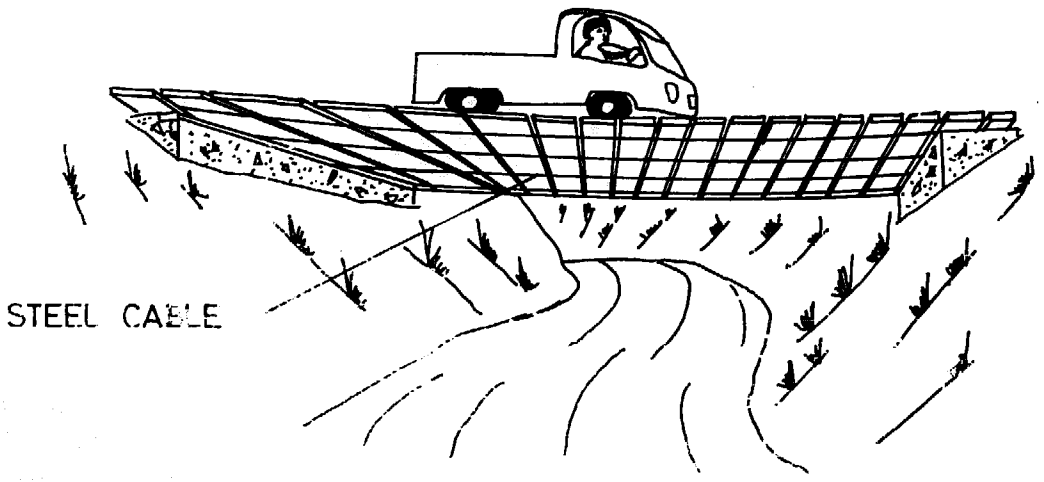

GENERAL NOTES

NEED FOR SURVEY AND DESIGN

Suppose you want to make a river crossing out of permanent materials. First the road must be surveyed. Then the road must be upgraded where it needs upgrading. Then you construct the crossing to go in a place that helps the road.

BUT suppose you want a crossing for a big river. You must get the Local Government Engineer to help you. Big rivers are not easy to bridge. The Engineer will find a good place for a crossing. Then he says where the road will go to lead to the site of the river crossing.

This is important. Why?

It is important because when you have a bridge, the road near it should be good. This should be done at the time the bridge is built. It might be too hard, to fix the road up later on, or it might be impossible to fix it, if the bridge is in a bad place. Wherever you can use culverts, it is better to have culverts instead of bridges. Culverts are stronger than bridges; they are also cheaper and they need less maintenance. Often you can get a better horizontal line using culverts, then you can with bridges.

Bridges, as well as causeways, should be designed by men from the Office of the Local Government Engineer at Public Works Department Headquarters, Boroko. Engineers come and measure the place on the river, draw plans and tell how much it should cost to build a bridge. Councils do not have to pay for this. It is help given by the Government. Even log bridges may be built with concrete abutments, and it is a good idea to have these abutments designed by engineers. Then, you can build permanent bridges on them a few years later when the Council has more money.

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RURAL TANNING TECHNIQUES

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

RURAL TANNING TECHNIQUES

Prepared by the

Agricultural Engineering Branch
Land and Water Development Division

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FAO Consultant

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FOREWORD

This new volume in the Agricultural Development Paper series is intended primarily for agricultural officers and others responsible for the immediate supervision of hides and skins improvement programs, and, in particular, of rural tanneries using local raw materials. It is hoped that the information here presented will reach rural craftsmen through national extension services and, in order to make the book as useful as possible for training purposes, it is fully illustrated.

Rural Tanning Techniques gives a broad outline of selected methods and processes, and describes the tools and equipment required by rural tanneries; it indicates how improvements can be made step by step. It is hoped that even rural tanneries which have been established for centuries may benefit from the information given here. Since research is always going on, new tanning methods will undoubtedly be applied in the future. However, those described in the following pages are proven ones and are used to advantage in subtropical and tropical regions. Some chapters may be of value only for the more advanced rural tanners, but they have been included because they make the publication more suitable for the training courses organized by FAO. A glossary of technical terms is given, and a list of selected references to articles and books from which specialized information may be obtained.

One point regarding the use of this volume should be emphasized. Development programs in hides and skins often do not make a clear distinction between flaying and curing on the one hand and tanning on the other. An improvement program for tanning alone can be successful only when improved practices and techniques for flaying and curing have given positive results.

Such methods are described and illustrated in FAO Agricultural Development Paper No. 49, *Flaying and Curing of Hides and Skins*

as a Rural Industry (Rome, 1955). The present paper, therefore, should be used together with the earlier one.

The following have contributed information, sketches and photographs, and their co-operation is gratefully acknowledged:

Mr. R. Faraday Innes, former FAO Consultant and member of the FAO mission in Libya on hides and skins improvement and tanning

Dr. F. Olga Flint, Department of Leather Industries, Leeds University, United Kingdom

Mr. C. F. Harding, formerly with FAO mission in Libya and Iraq on hides and skins improvement and tanning

Mr. F. H. Hoek, FAO mission in India on hides and skins improvement, carcass and by-products utilization, tanning and leather utilization

Mr. E. Knew, formerly FAO Consultant, now with FAO mission in the Sudan on hides and skins improvement, tanning, leather and by-products utilization

Mrs. Erica Mann, Town Planning Department, Ministry of Local Government, Health and Town Planning, Nairobi, Kenya

Dr. Y. Nayudamma, Director, Central Leather Research Institute, Madras, India

Mr. J. H. Sharphouse, Head of Leather Department, College of Technology, Northampton, United Kingdom

Mr. F. Steiner, formerly with FAO mission in Haiti on hides and skins improvement and tanning

Mr. E. Taussig, FAO mission in the Philippines on hides and skins improvement, tanning, and leather utilization

Mr. G. C. van Hoorn, formerly with FAO missions in Iraq, Libya and Gambia and now with the mission in Turkey on hides and skins improvement, tanning, and leather utilization

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INTRODUCTION

Leather, which has been used by man for many purposes for thousands of years, is remarkable for possessing a combination of properties to be found in no other natural or man-made material. It can be so hard and tough that it requires working with a saw or lathe; yet it can also be as soft and flexible as a fine textile, a fit material for the needlewoman. Leather is not only strong, durable (when properly prepared, it will resist decay for centuries) and flexible; it has a unique porous structure which enables it to "breathe," that is, to permit the passage through it of air and water vapor. It can be easily worked, cut, joined, stitched, embossed, dyed and gilded. When cut, the edge does not fray — a characteristic which for some purposes makes it superior to woven materials. In the hands of a craftsman, leather will yield articles of use and ornament which cannot be produced in any other way.

Leather has been used for clothing for at least 7,000 years. In addition, it has for millenia been made into all kinds of tackle and gear — into ropes and reins, saddles, shields and armor; it has been used for tents, beds and carpets; it has been shaped and molded into cups, bottles, all kinds of water, oil and wine carriers; it has provided boats, sails, writing materials, decoration and ornaments; lanterns have been made of leather; even the floors of ancient Egyptian chariots were made of interlaced leather thongs.

To produce this versatile material, the craft of the tanner is required. How, when and where early man learned to make strong, flexible leather out of dry skins is not known. Nor is the origin of the preserving processes which use the chemical properties of tanning materials. Primitive hunters, killing wild animals for food, must soon have discovered that animal hides and skins gave protection

against cold, rain and thorns. They must also have found that dry hides rot when they get wet.

This would have led to attempts at preservation by scraping off the meat and rubbing in fat, brain and marrow to make the skins softer. Evidence of oil treatment has been found in the tombs of ancient Egypt.

True tanning may have been accidentally discovered by the immersion of raw skins in forest pools where the soaked leaves, twigs, fruit and bark would have given a tannin solution. Or it might have happened that a hide hung over a particular tree became tanned where it touched the bark; thus that part of the hide would have acquired new properties which made it more resistant to decay after subsequent wetting. In this way vegetable tanning materials were no doubt discovered.

Another primitive method of preservation, the use of smoke, was known in China, South America and the extreme north of Europe in prehistoric times, and was later invariably practiced by the North American Indians. The virtue of salt as a preservative has been known for thousands of years, and since some salts contain alum, the value of this mineral, too, as a tanning material was also probably discovered accidentally.

Using primitive tanning methods, anyone can produce some kind of leather. But only an expert tanner can transform dry, harsh hides and skins into fine quality leather, a beautiful material, pleasant and attractive in use and appearance.

During the present century many attempts have been made to produce substitutes for leather, such as impregnated textiles, rubber and plastic materials. Although these products have found wide use in the manufacture of footwear and other articles of everyday use, they have not been able to reproduce the particular properties of leather. The leather trade has taken special measures to popularize leather by disseminating information about the scientific reasons for its individual characteristics; thus, it has been pointed out that the superior insulating qualities of leather, its great capacity to absorb perspiration and its thermostatic properties cannot be duplicated by synthetic products.

Rural tanners, employing family labor and using local raw materials should be able to produce leather cheaply, at prices which will make leather articles available to the poorer classes; they can popularize

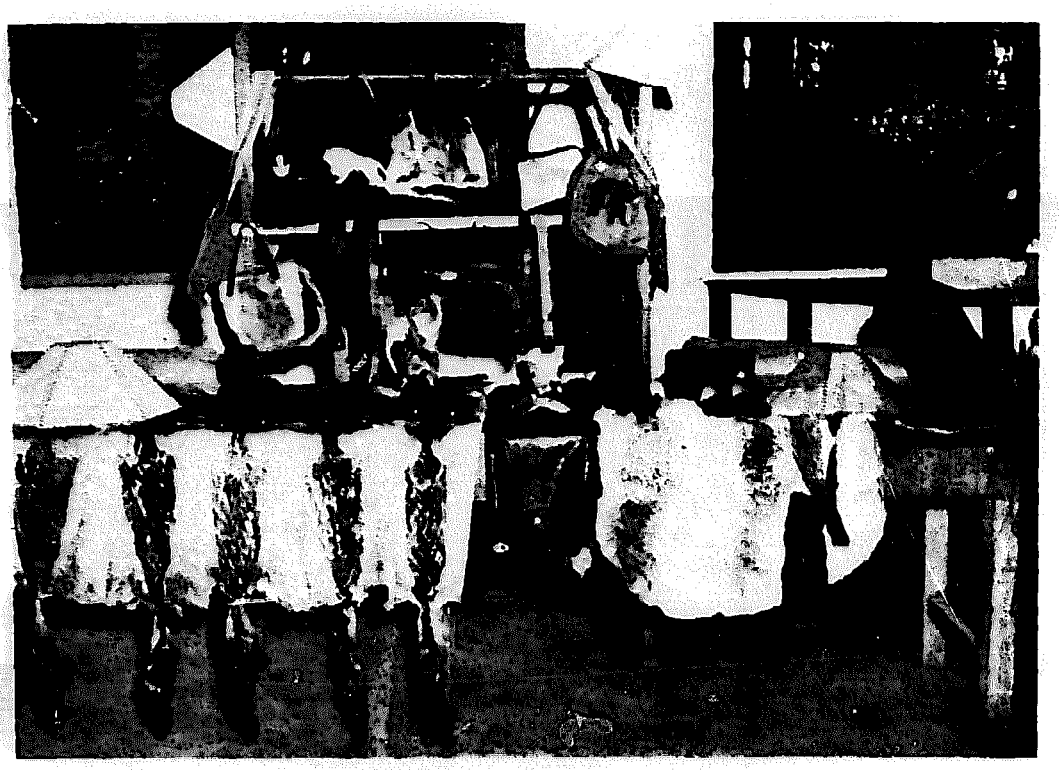

FIGURE 1. – *Leather articles, some of which can be made by rural craftsmen.*
Courtesy Kenya Information Office, Nairobi

FIGURE 2. – *Village tanneries are source of additional income to families.*
Courtesy Kenya Information Office, Nairobi

FIGURE 3. – *Operator engaged in preparing python skin.*

the use of leather as a material which is not only cheap, but also durable and beautiful, a material of which both producer and user will be proud (Figure 1). The production of cheaper leather in villages (Figure 2) will, in turn, encourage a secondary industry manufacturing leather goods of many kinds. Handbags, purses, sandals, slippers, belts, school satchels, cushions and other articles

can be sold not only in the rural community, but also to tourists and on export markets (Figure 3). Such a pair of linked industries will provide a living for many families and thus partly remove their dependence upon agriculture.

In many countries, rural tanning does not exist, even though the necessary raw materials — the hides and skins, lime and vegetable tanning substances — are locally available. This situation is not without advantages. In such areas it should be possible to introduce the industry in a satisfactory manner, free from the shackles of inherited habits, and using improved methods from the beginning.

In other countries where a traditional tanning industry exists, the tanners are often very conservative. However, once a technique has been shown to be better than traditional methods, and, above all, if the resultant product is cheaper and of better quality than that previously obtained, the tanners will be willing to adopt the new technique. The craft of leather making as practiced by rural tanners is frequently an inherited one, and sometimes confined to castes, as in India. The tanners of Northern Sudan and Nigeria are also typical examples of the way in which the family secrets of the trade have been passed on from generation to generation for centuries. From recent observations it is clear that the methods and the indigenous materials employed by the rural tanners have varied very little since ancient times, particularly in some of the less advanced Near East countries.

This static condition of the rural tanner is due to poverty, illiteracy, poor communications and lack of contact with modern scientific tanning methods which, if adopted with appropriate modifications, would greatly improve the rural tanner's working conditions, his position in local affairs and the reward for his labor.

The craft of tanning, inherited from generation to generation, has been based on experience gained by trial and error, although certain phenomena have not always been correctly interpreted. The modern approach is to trace, step by step, the conversion of hides and skins into leather and to understand all the physical and chemical changes involved in tanning. Many factors influence the final quality of the leather, such as the type and quality of the raw materials, the methods and processes employed, the skill of the worker, as well as environmental factors like temperature and climate. A factor of great importance in all tannery processes is the quality

of the water used. Hard water is unsuitable because it interferes with the processes and precipitates dyestuffs. Impure water may contain gelatine-liquefying bacteria and is detrimental to leather manufacture. Without some knowledge of such factors, disappointment and losses may occur. Failure should not, however, lead to discouragement, but to investigation aimed at improvement and better control of the various processes.

The purpose of this volume is not to give instruction in the manufacture of every kind of leather, but to teach rural tanners the fundamental principles and processes of tanning, so that they may be able to find out the reasons for mistakes and failures. Once the basic knowledge has been acquired, other methods may be learned from the many publications which exist. Some are included in the list of selected references given in this book.

It must always be borne in mind, however, that to master the craft of leather making, it is not enough to study books. To acquire skill, the tanner must make a thorough study of the processes involved, by repeated experiments and careful observation. He requires, above all, patience, practice, hard work and experience.

I. RAW MATERIAL - HIDES AND SKINS

Histology

Hides and skins are the raw material of leather. They are tissues of animal body made up of once living cells and their products. A hide or skin has many tissues. The production of leather involves the removal of those tissues which cannot be converted into leather and the treatment of the others in such a way that the final product has the desired properties.

The hide or skin of animals has a very complex and intricate structure. Knowledge of its construction and the complicated chemical and physical reactions and biological changes which occur within the skin before and during the process of leather manufacture enables the rural tanner to view his work with greater understanding and appreciation.

From the histological viewpoint, all mammalian hides and skins are more or less similar in their structure. They consist of three sharply defined layers which are distinct both in structure and origin (Figure 4). The three layers are:

(*a*) the epidermis;

(*b*) the corium or derma;

(*c*) the hypodermis or subcutaneous tissue, which is commonly known as flesh or adipose layer.

THE EPIDERMIS

The epidermis is the outer layer of the skin. It is cellular in structure, and it has several distinct layers of self-reproducing epithelial cells. It has no blood vessels of its own, and the nourishment for

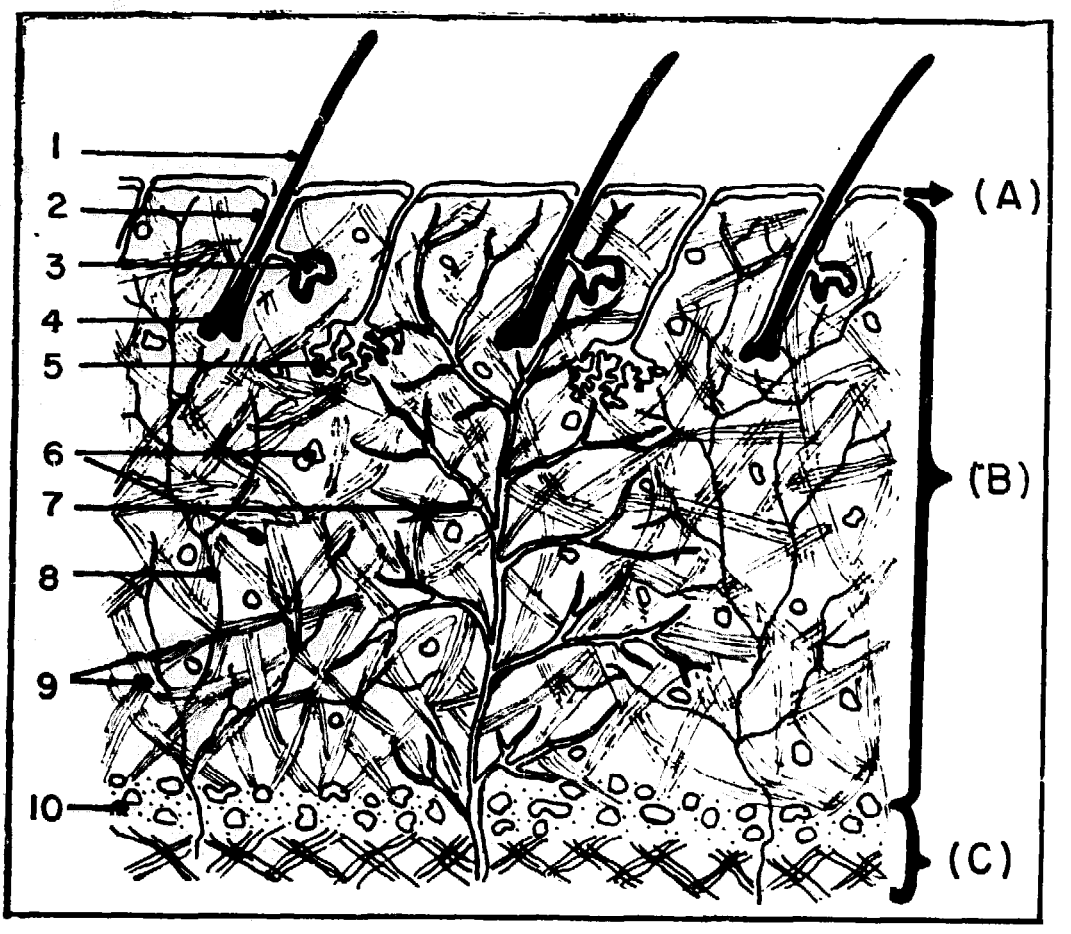

FIGURE 4. – *Enlarged diagrammatic cross section showing main layers of a hide:* (A) *Epidermis;* (B) *Corium or derma;* (C) *Hypodermis.*
(1) *Hair;* (2) *Hair follicle;* (3) *Grease gland;* (4) *Hair bulb;* (5) *Sweat gland;* (6) *Fat cells;* (7) *Blood vessel;* (8) *Nerve;* (9) *Collagen fibers;* (10) *Fat tissue.*

Courtesy Mrs. Erica Mann

the cells is drawn from the blood and lymph of the derma, upon which it rests. The epithelial cells develop not only the epidermis, but also the hair, the sudoriferous and the sebaceous glands. The epidermis is composed of the protein keratin. It belongs to the same group of keratinous substances as nails, claws, hooves, scales and feathers.

The cells of the innermost layer of the epidermis are at all times reproducing new cells. They constantly grow outward and push the older cells in the upper layer. Since the upper layer is deprived of nourishment, it becomes flattened and hardened by dehydration.

In consequence, it dries up in the form of scurf or dandruff, which is more often observed on the scalp.

The cells of the innermost layer of the epidermis contain pigment granules which give color to the hairs and the skin.

The corium or derma

The corium or derma — corium is the Latin for "true skin" — is the main portion of the integument — the natural covering — which is subsequently converted into leather. The derma is composed mainly of connective tissue fibers. Three different types of connective tissues — collagenous tissue, or collagen; elastic tissue, or elastin and reticular tissue, or reticulin — are found in the derma. Collagen constitutes the bulk, and it is the chief leather-forming constituent.

The corium may be further subdivided into two layers: the thermostat, or grain layer; and the reticular layer, or corium proper.

The grain layer is the upper portion of the corium, and it contains hair roots, glands and muscles. It constitutes only a small portion of the corium as a whole. None the less, it varies with the type of skin. As a rule, it is greater on skins and less on the heavier hides. In the grain layer the connective tissue fibers are quite small and fine. They are very compactly felted together without any apparent orderly arrangement.

The grain surface pattern produced by the arrangement of hair pores is distinct for each species of animals. The distinction is shown on the outer surface of leather. Thus, the pattern provides an easy means of identifying leather made from such different skins or hides as goatskin, calfskin, cowhide, horsehide, pigskin and dogskin (Figures 5, 6, 7, 8, 9 and 10).

The reticular layer is composed mainly of interwoven collagen fibers which are arranged in well-defined bundles. The fiber bundles of this layer are relatively much larger than those of the grain. The collagen fibers are straight or wavy threads and they are held in bundles by sheaths made of reticular tissue. They are supposed to be coated with a cement-like substance of interfibrillary proteins which encase the fiber bundles in dry hides. The reticular layer,

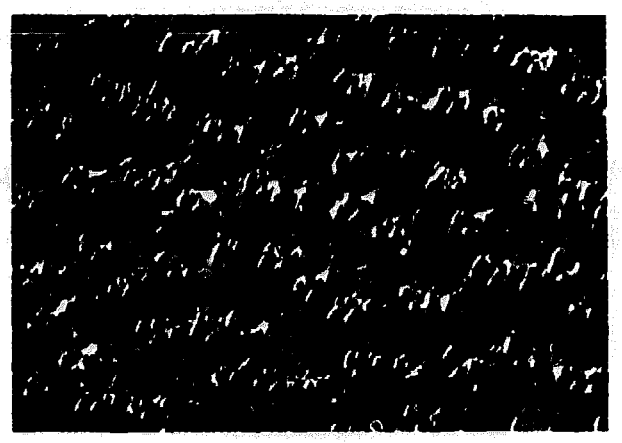

FIGURE 5. – *Photo showing grain structure of glazed goatskin* (× 20).

Courtesy Department of Leather Industries, the University, Leeds

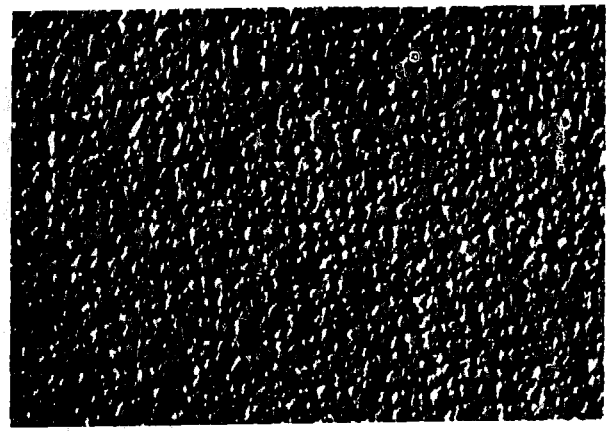

FIGURE 6. – *Photo showing grain structure of calfskin* (× 20).

Courtesy Department of Leather Industries, the University, Leeds

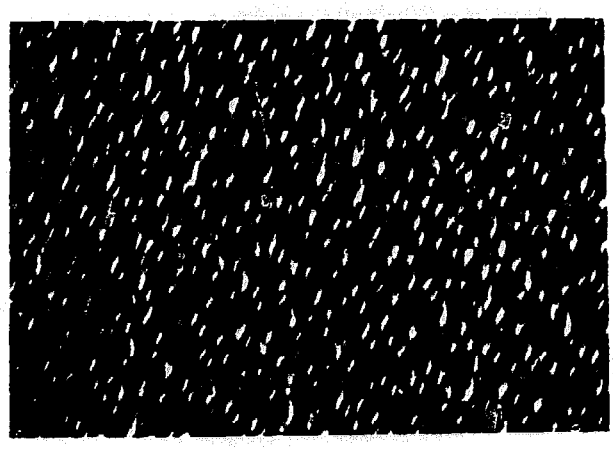

FIGURE 7. – *Photo showing grain structure of cowhide* (× 20).

Courtesy Department of Leather Industries, the University, Leeds

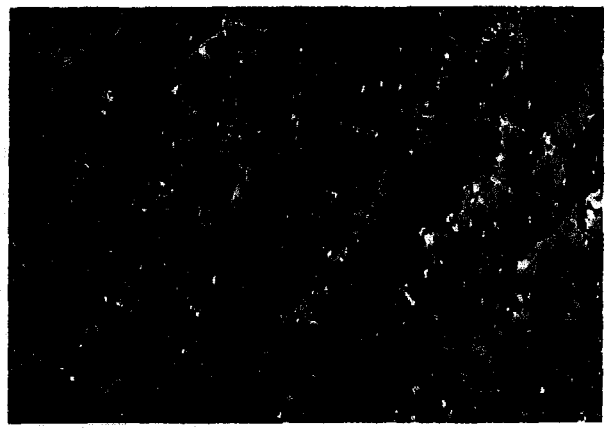

FIGURE 8. – *Photo showing grain structure of horsehide* (× 20).

Courtesy Department of Leather Industries, the University, Leeds

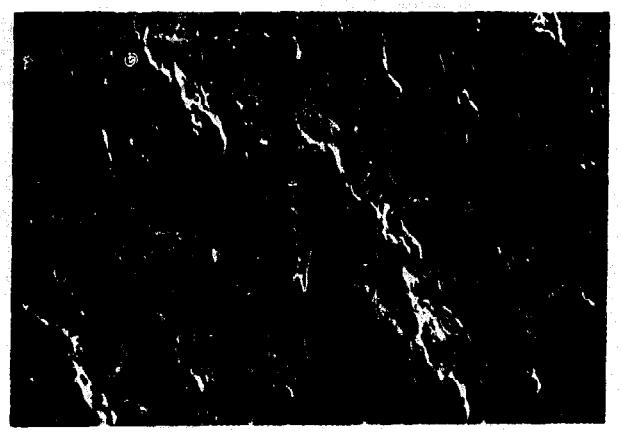

FIGURE 9. – *Photo showing grain structure of pigskin* (× 20).

Courtesy Department of Leather Industries, the University, Leeds

FIGURE 10. – *Photo showing grain structure of dogskin* (× 20).

Courtesy Department of Leather Industries, the University, Leeds

or corium proper, covers about 75 to 80 percent of the total thickness of a hide, and about 45 to 50 percent of the total thickness of a skin.

The hypodermis

The hypodermis, or subcutaneous tissue, is the loose connective tissue which joins the corium to the underlying parts of the body. It consists mainly of collagen and elastin fibers. These are loosely arranged, and they contain the adipose tissue which is the seat of fat deposits. Together, these tissues are what the tanner calls the flesh. It is removed mechanically in the fleshing operation before tanning. A twitch muscle is often appended to this layer.

Fat can be found with the adipose tissue on the flesh side, and the pieces can be large if the flaying has been badly done. It can also be distributed in the center of the corium in discreet fat cells. Then its extent and location depend on the breed of animal, its age and health, the season and the pasturage. In merino sheep, for example, the fat may be 20 percent of the skin weight; in steer hides it may be only 0.75 percent. When the quantities of fat are large, they cause the skins to be objectionably greasy after tanning. The fat cells may be so numerous — for example, in sheep — that they disorganize the corium fiber structure and cause a weakness or splitting of the leather. When such a skin is cured by drying or dry salting, the fat may melt and permeate it, particularly in a hot climate. Then the cure is ineffective. It becomes difficult to wet the skin back.

Water accounts for more than half the weight of a freshly flayed skin, whereas a tanned or a dried skin contains only 14 percent of water. This aqueous phase includes blood and lymph.

Factors influencing quality

Many believe that the tanning process can conceal the defects of raw hides and skins to such an extent that their original quality has no influence on the leather. This is not true. A good leather cannot be made from a bad hide or from a bad skin. On the contrary, tanning may well accentuate the tiniest blemish in some startling

way. The smallest pockmark can produce a hole. A scarcely visible gouge mark can cause the tearing of the entire skin. Every care must always be taken to produce and to select for tanning a raw material which is as free from defects as possible.

Even though dyes and pigments succeed in hiding some blemishes on the surface of the leather, they may accentuate others; or defects may appear once the leather has been used.

Many factors influence the growth and quality of the integument of any animal, whether wild or domestic. The breed and origin of the animal, its mode of life and its food, its general condition, its age and sex and the purpose for which it is bred affect the growth and the properties of the skin during the animal's lifetime. A cow bred for high milk production or a sheep bred for long wool, for instance, will yield a thin hide or skin; for the nutrimental food value has been absorbed by the milk or the wool.

Different types of raw materials are needed for different types of leathers. While a calf skin produces a high quality upper leather with a fine feel, a healthy ox or heifer hide produces only the firmest sole leather for which thickness and a high fiber weave are essential.

Thus the tanner must select his raw hides and skins according to the type of leather which he wishes to produce. He has, unfortunately, little power to control the various defects which influence the quality of raw hides and skins.

These defects are classified into two groups:

(*a*) ante-mortem defects — these are damages caused on the living animal;

(*b*) post-mortem defects — these are damages caused during flaying, curing, storage and transportation.

Ante-mortem defects

The damages may be caused by (i) parasites; (ii) diseases; (iii) old age; and (iv) mechanical means.

The parasites, like the sarceptic mange or the common demodex or demodectic mange (preferably termed *demodicosis*), ticks, lice and warble larvae, produce a pitted and scarred grain surface with

pinpoint holes, depressions, scars and warble holes. These defects greatly reduce the value of the leather.

Any prolonged febrile disease — for example, rinderpest and *trypanosemiasis* — has a substantial damaging and weakening effect upon the fiber structure of the hide. This results in leather of poor quality.

Other diseases caused by bacteria, fungi or virus can produce serious local defects, for heavy lesions bring about irreparable damage. They can be coupled with streptothricosis, ringworm and pox. Some seasonal diseases and nutritional faults severely damage hide and skin.

The hide or skin of any animal which has died of old age, disease or malnutrition, starvation or drought, possesses many defects which lower its quality. An animal which is flayed many hours after the carcass has lain on the ground — for example, a " fallen hide " — may have the underside damaged by putrefaction; the hide may show the discolored patches which are due to congealed blood in the veins. Flaying of a cold carcass and of fallen animals is exceedingly difficult; and, unless exceptional care is taken, there will be many knife cuts. Fallen hides are often of inferior quality. This will be due to poor flaying or to the state of the carcass, which is full of blood because it has not been bled.

Among mechanical damages, the hot iron branding causes irreparable losses. Millions of the world's hides and skins are damaged in this manner. Branding, whether for identification or curative purposes, scars and hardens the corium and renders it quite useless to the tanner.

Scratches from thorns, barbed wire or horns, whether healed or still open, are a very common type of the damage which is visible after tanning. The disfiguration greatly reduces the value of the leather and the extent of its uses. Grain-scratched sheep- and goatskins, for instance, are generally used for suedes. The damaged grain of cattle hides is sprayed and mechanically treated to cover up and eliminate the blemishes. This is sold as " corrected grain " sides. Its commercial value is greatly reduced.

Other mechanical damages are caused by poke mark, goad mark, yoke mark and wounds.

Casting or hitting the animal shortly before death bruises the meat and causes an accumulation of blood over the bruised area.

The smaller blood vessels become ruptured and the flesh side of the fresh hide or skin appears red. This may involve putrefaction during drying or curing.

Post-mortem defects

These defects may be caused by (i) bad handling; (ii) bad flaying; (iii) inefficient curing; (iv) micro-organisms; (v) salt stains; and (vi) insects.

Man-made damage during slaughtering or curing has a pronounced influence on the quality of hides and skins. If carcasses are not bled out properly at the time of slaughtering, blood remains in the vessels and capillaries of the hides and skins. Bacteria then develop more rapidly, and there is putrefaction along the blood vessels. Moreover, the congealed blood in the veins may show up clearly on the grain surface of the leather in an unsightly way.

Rubbed or dragged grain. The dragging of a slaughtered animal over rough ground causes abrasion of the grain surface.

Bad pattern or irregular shape. When the carcass is not opened up correctly, the shape of the hide or skin becomes unsymmetrical. The tanner requires square hides and skins, and these are produced when correct ripping lines are used.

Flay cuts, gouge marks and scores. The use of sharp pointed knives invariably causes this type of damage. It can be avoided and entirely eliminated by the careful use of an improved type of knife which has a curved, convex cutting edge with a rounded tip. The back edge should be concave and blunt.

Drying. This is the simplest method of preserving hides and skins, but improper drying may destroy valuable material. Any delay in drying, either by suspension or on the ground, may cause "hair slip," or even putrefaction.

Hair slip represents relatively mild forms of putrefactive damage, but they may affect the surface of the hide and skin. Ground drying, however, produces the worst raw material; for then hides and skins are usually baked on the outside, while the center is still wet. This provides a ready medium for bacterial action, which invariably causes putrefaction (Figure 11). This type of putrefaction is generally termed "sun blister."

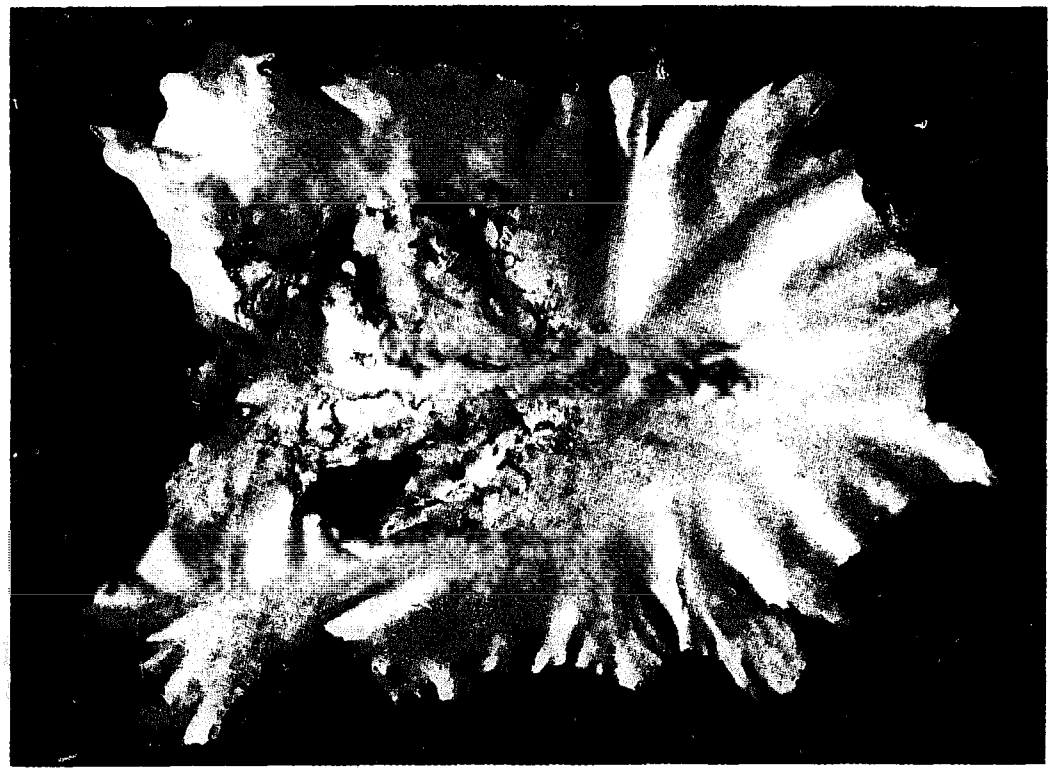

FIGURE 11. – *Skins damaged during flaying and curing by ground drying.*
Courtesy Kenya Information Office, Nairobi

Overdrying of skins may lead to grain cracking, especially when skins are allowed to crumple. A very long exposure to the sun causes the fat in the adipose layer of the skin to escape from its cells into the corium fibers. This makes its removal rather difficult during the process of leather manufacture, and it causes greasy stains.

The shrinkage temperature is 60° C. Raw hide suffers an irreversible shrinkage and damage when it is subjected to this temperature of 60° C for two or three minutes. It will suffer the same damage if it is kept under wet conditions and temperatures above 40° C. for longer periods of several hours. Once the skin is dried — that is, below 14 percent moisture content — it will stand these high temperatures much better.

These temperatures, it should be remembered, refer to the skin itself. They may be different from the temperature of the surrounding air. When the skin is wet, evaporation occurs; it cools the skin and gives it a lower temperature than the air. A wet bulb ther-

mometer reading will give an approximate idea of the skin temperature.

No matter how well the hide or skin has been prepared during flaying and curing, irreparable damage may still be done during storage. Once hide beetles — and, in particular, their larvae — and white ants have obtained access to the goods they can destroy them. A very good protection against the ravages of these insects, however, is the use of insecticides. These may be applied either in liquid or powder form. Recently, a successful preservation of dried hides and skins against attacks of beetles, moths and other insects has been achieved by spraying with a 5 percent suspension of sodium silicofluoride, or dusting with 0.5 percent gammexane powder, or spraying with 0.25 percent solution of sodium arsenite.

Rats and other vermin are also attracted by the fatty nature of hides and skins. They can cause substantial damage by gnawing holes, especially on folds.

Even transport has a bearing on the quality of raw hides and skins. Hides and skins are often loaded singly on to lorry transport and bullock cart, or they are tied in loose bundles. In consequence, any movement makes the surfaces rub together and causes damage, especially to grain, folded edges and corners. The rubbing damage during transportation, the use of baling wire and — worst of all — the wetting from exposure to rain, ruin the goods before they reach the tanner.

Prolonged retention of raw hides and skins in a smoky store leads to the so-called " smoked " goods. Smoking during drying will partly or wholly cause a tanning effect. This tightens the hair and creates difficulties in the liming and tanning processes. Smoke contamination on exposed grain where the hair has slipped before drying may cause discoloration and coarseness after vegetable tanning.

Hides and skins cured by salt may be spoiled if the techniques are inadequate. It is useless to salt goods which are already dry or partly dry, for the salt will not penetrate into the material. Neither can salt be properly absorbed by uncleaned hides and skins which have an excess of flesh. When too little salt is used, hair slip, or even putrefaction, may develop. Storage of salted skins in the wet state — for long periods during hot weather and in air with a high humidity — is dangerous because putrefaction bacteria can become salt tolerant.

Full information on the techniques of salt-curing is found in FAO's Agricultural Development Paper No.49, *Flaying and Curing of Hides and Skins as a Rural Industry*. Common salt, it must be emphasized, has definite limitations as a hide-curing agent. For one thing, putrefaction is not wholly arrested if salted skins are kept in wet conditions both for some length of time and simultaneously at an elevated temperature of 27° C. to 39° C. If the preservation is to be complete, the salt should be mixed with some type of antiseptic, such as sodium fluoride or sodium pentachlorophenate. "Red heat," a discoloration of salted hides and skins caused by bacteria, may lead to putrefaction. Marine salt is likely to be contaminated with salt-loving bacteria which develop "red heat."

The presence of substances, like iron, in the curing salt is harmful. They may lead to indelible stains during curing or in the processes of tanning. In certain parts of the world so-called curing salts contain but little true salt; the main components are insoluble earthy materials. Although exact figures are not available, the total losses caused by avoidable damage to hides and skins in the course of flaying, curing and preservation must amount — even at a conservative estimate — to millions of dollars a year throughout the world.

Damaged stock — the tanner, actual or potential, must realize — produces poor leather. "Good leather," as the old saying goes, "is made only from good hides and skins." In all probability tanning projects will be a complete failure, and all efforts and funds invested in them will be wasted, unless there is, first of all, a forceful drive toward improving the raw hides and skins.

FAO's Agricultural Development Paper No. 49 shows clearly how serious are the losses which can occur during flaying, curing and handling. Its chapter on "Proposed Development Scheme" emphasizes the need for continuous guidance by governments.

Tanning

The art or technique of converting hides and skins into leather is called tanning. Leather is animal hide or skin so treated that it becomes more permanently resistant to decomposition when wet, and supple when dry. By tanning, the easily putrescible hide substance is made resistant to micro-organisms.

There are many different ways of tanning, and a large variety of materials of vegetable or mineral origin possesses the property of being able to "tan." The prospective tanner, therefore, should make a survey of the local indigenous tanning materials, whether it be bark, wood, pods, tubers or leaves, and so estimate future supplies. It is necessary to make sure that the essential tanning materials are available: otherwise failure of supply may well seal the fate of a projected rural industry.

Many vegetable tannins are known. New materials, both mineral and synthetic, are constantly discovered and manufactured. It is reasonable to expect, however, that a suitable vegetable tanning material can be found in the neighborhood and is well known to the inhabitants.

II. LOCAL TANNING EQUIPMENT AND BASIC PROCESS OPERATIONS

Local tanning equipment

The conversion of hides and skins into leather looks like magic to a layman, and it is difficult for a novice to appreciate its complexity. Yet no costly tools nor machinery are needed; nor is a high standard of general education necessary. Successful tanning is based on knowledge, skill and experience; a start could be made on a small scale in, perhaps, a backyard, or in the open air (Figure 12), or preferably in a small building (Figure 13).

Skins

For the beginner, sheepskins are preferable to goatskins; cattle hides should not be used. To avoid loss it is wise to start with damaged skins, preferably small pieces which have little or no commercial value.

Tools

The tools and implements needed are described in the chapters on the particular processes. Most of them can be made by the tanner himself or by rural carpenters and blacksmiths.

Building

At first any shed which protects the worker from the weather and allows him enough light will do.

FIGURE 12. – *General view of typical small rural tannery, Nigeria.*

WATER, LIME AND TANNING MATERIALS

Information on these subjects is given in later chapters.

VESSELS

Iron vessels cannot be used because iron, when in contact with vegetable tanning infusions, gives an " ink " which produces bluish-black spots and stains on the leather. Tin cans quickly become rusty at the seams or wherever there are scratches and dents; and iron is exposed. Vessels made of wood are best, if cheap, for they are long-lasting. Whenever possible, small wooden casks should be used. Larger casks can be cut in half and thus provide two very useful vessels.

Glazed earthenware pots, if they have sufficient capacity and a large mouth, are excellent. Unglazed pots leak and thus they lose much of their contents, but they are improved by a coat of paint containing linseed oil. Pots should not be sunk into the ground. Although this is done in some regions, the practice makes them difficult to clean.

An example of excellent earthenware pots are the *magoors* used

FIGURE 13. – *Rural training center, Bakshi-ka-Talab, Uttar Pradesh, India. In foreground, fleshing and unhairing of hides; in background, lime pits.*

by the Sudanese tanners. They are about 90 centimeters both in diameter and in height. Similar pots are used by the Nigerian tanners (Figure 14) and also in certain regions in the Far East.

At first, aluminium pots may be used, but the cost is prohibitive when more than a few skins have to be handled.

UNHAIRING AND FLESHING KNIVES

In the experimental stage, even a kitchen knife will do, but specially made tools are preferred (Figures 15 and 16).

A BEAM

A log, which has a diameter of about 40 to 50 centimeters and which is made smooth and set at the proper angle, will do for a start. Instead of a beam, a board which is about 40 to 50 centimeters wide and rounded up on the sides can be used. Fleshing, unhairing and scudding can also be done on beams made out of stone.

ADDITIONAL EQUIPMENT

Gradually, when the beginner has mastered the technique and is sure of himself, he can acquire additional equipment, such as draining "horses," a drum, finishing and oiling tables; and he can construct brick, cement or stone vats. More detailed information is given in later chapters.

FIGURE 14. – *Glazed earthenware pots such as these* magoors *are profitably used by tanners in Nigeria and the Sudan.*

Basic process operations

Hides and skins of various animals, such as elephant, horse, buffalo, cow, calf, sheep, goat, pig, reptiles, birds and fish, differ in thickness and grain (Figures 5, 6, 7, 9 and 10). Some have hair or fur, and others have feathers. All are products of the epidermis. The procedure of converting them into leather remains the same. These are the principal processes:

1. The removal of undesirable parts — for example, the epidermis and hypodermis by processes called soaking, liming, unhairing, scudding and fleshing.

2. The preparation of the derma, or " true skin," for tanning by processes called soaking, liming, deliming, bating and pickling, or drenching.

These processes free the derma from epidermis and hypodermis and condition the derma. They are both chemical and mechanical. The liming which helps to soften the epidermis and prepare the derma is a chemical process; the removal of the softened epidermis with a knife is mechanical.

3. Tanning — the absorption of the tanning infusions or solutions which convert the hides and skins into leather.

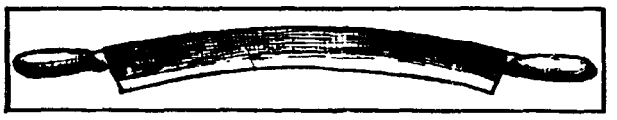

FIGURE 15. – *Sketch of not very sharp unhairing knife with two handles.*

Courtesy Mrs. Erica Mann

FIGURE 16. – *Sketch of fleshing knife with two handles. One edge is concave and used for scraping; the other, convex, is very sharp and used for cutting.*

Courtesy Mrs. Erica Mann

4. Finishing operations, such as oiling and drying, stretching, dyeing, rolling and staking, which are intended to improve the quality and appearance of the leather.

There is no short cut in the tanning processes; nor are there any compromises. Bad soaking, insufficient liming, incomplete tanning and any other neglect become exposed in the finished leather. Its quality suffers greatly if any stage is missed or imperfectly carried out.

The goods pass from one process to the next. It is necessary, therefore, to have a prepared program of work. The right receptacles and chemicals and the right amount of space must be on hand before the operations begin. Even with the smallest skin, thought must be given to each operation.

If the operator has not had any previous experience and wishes to avoid heavy losses, he should experiment with a small piece of hide or skin in a glass jar or any other available receptacle. This will often give him more useful experience than experimenting on a full vat of hides and skins. Each process can be carried out on a small scale before proceeding with proper tanning. In this way losses and disappointment will be avoided, and the basic principles of tanning will be mastered in a reasonably short time.

Since lime, sulphide, wood ash and all tanning materials may lead to dermatitis, the tanner should accustom himself to wearing rubber gloves. Lime is very alkaline. The rinsing of the hands is an elementary hygienic rule.

III. PREPARATION OF HIDES AND SKINS FOR TANNING

Soaking

Figure 17 shows schematically the processes of first converting hides into "pelts." The first step is soaking. Its purpose is:

(*a*) to soften the hides or skins — especially the dried ones and those of fallen animals — so that, in touch and appearance, they resemble skins which have just been removed from freshly slaughtered animals: the fibers absorb the water lost during salting or drying and then swell to their original condition;

(*b*) to remove blood, dung, earth or other impurities which were not removed during curing;

(*c*) to facilitate the penetration of chemicals in later processes, thus producing the light swelling which is called plumping;

(*d*) to remove salt: for salt in the hides prevents swelling and exerts an unfavorable influence on further processes.

The soaking of hides and skins, though apparently simple, presents difficulties. Like all other operations in the tannery, it requires long experience. It is not a good policy to mix different kinds of skins, for instance, sheep and goats. It is also inadvisable to mix suspension-dried with ground-dried goods because the times needed for their soaking are different. The best results are given when separate containers are used for each type of hide or skin. Soaking is quicker in warm weather, when the danger from bacterial damage is very great. In warm weather, therefore, the goods should be

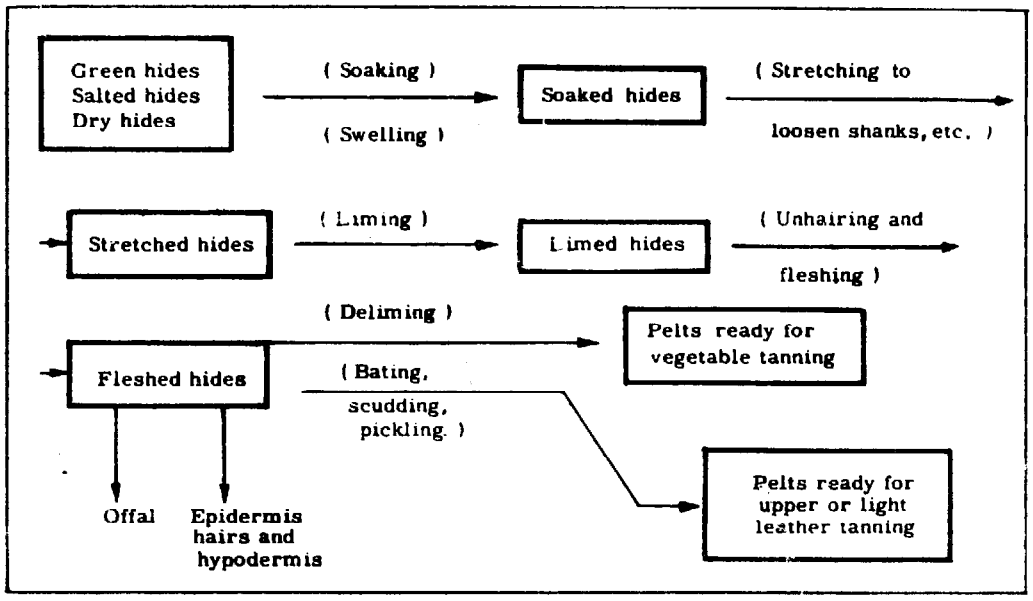

FIGURE 17. – *Flow chart showing subsequent processes to convert hides into "pelts," prior to tanning process.*

frequently inspected and turned. Soakwater containers must always be kept in the shade. The temperature of the soakwater should never be more than 27° to 30° C: for higher temperatures cause a decomposition of the hide. It is easy to soak properly prepared hides and skins, but material which has started to putrefy is dangerous. Once the goods are put in water, the putrefaction continues. It accelerates with increasing temperature.

It is advisable, once progress has been made, to control the soaking process by (*a*) keeping the water as cool as possible, and, in the hot season, by checking the temperatures; and by (*b*) adding a little bactericide.

GREEN HIDES AND SKINS

Hides and skins from freshly slaughtered animals are termed "green." They must reach the tannery within the shortest possible period, and certainly within a few hours. Green material need only be soaked for a short time — a good washing, in fact, is sufficient — before the next process, which is liming, begins.

Wet and dry salted hides and skins

All loose salt should be shaken off before soaking. At least, the first two soaking waters should be changed at short intervals. For the whole of the operation not less than three or four changes should be used, even after the skins or hides feel completely soft.

Dry salted hides are preserved through a combination of two processes — first by salting and then by drying. Though they are more easy to soak than hides which are directly dried, they may well require a soaking period of two days.

Suspension-dried goods

Properly prepared suspension-dried goods cause less trouble than ground-dried goods. Nevertheless, it may take three days before they are uniformly soft. Fresh cool water should be used and frequently changed to prevent the development of an objectionable odor. Bleaching powder should be used as an antiseptic, whenever soaking is to last for more than a few hours. A suitable quantity of bleaching powder is between 1 to 4 kilograms per 1,000 liters of water.

The soaking of very hard hides sometimes needs mechanical or chemical assistance. Mechanical assistance, such as trampling, working over a beam, or kneading, helps the softening. So does the chemical assistance which can be obtained by adding to a good float of water 1 percent of caustic soda which is calculated on the weight of raw skins; for example, 70 kilograms of raw skins, air-dried, require 0.7 kilogram of caustic soda and 1,000 liters of water. The addition of caustic soda also causes a substantial swelling, or plumping, of the goods. To avoid damage to the hides, the caustic soda must be dissolved separately before it is added to the soaking liquid.

Under rural conditions where soda is not available, 1 kilogram of fresh wood ash, "dissolved" separately, or added before the skins are put in, may be used for every 50 liters of water.

Ground-dried goods

The soaking of ground-dried hides and skins is difficult and often risky. In drying, they have been invariably baked on the outside, while the inside is still soft and liable to putrefaction; they will hardly

absorb water. Another factor which prevents ground-dried hides and skins from soaking easily is the subcutaneous fat. This tends to escape from its cells and to run between the fibers, so that the water cannot penetrate. It is, therefore, a bad practice to mix ground-dried goods with suspension-dried goods. They should be soaked separately. The water should be frequently inspected and changed as soon as objectionable odors indicate that putrefaction is starting. Any parts which show extensive damage in the form of holes and any smelly tissue should be cut out and thrown away, so that the putrefaction cannot spread. They must not be thrown near undamaged goods. As for suspension-dried goods, there must be a full use of chemical and mechanical assistance. During hot weather, or when hides show putrefactive patches, it is an advantage to add antiseptics, such as bleaching powder, chlorine, sulphur dioxide, sodium fluoride, sodium hypochlorite and sodium bisulphite. These antiseptics all reduce putrefactive action. The most economic among them are bleaching powder and chlorine. Carbolic acid, cresol and similar tar products must not be used because they have a slight tanning action. The cost of tanning does not justify the treating of material which will lose much of its substance during processing. Rural tanners, for one thing, will not have these chemicals easily available. The tanner should inspect all goods during soaking. He should cut out any parts which show decay. If necessary, he must reject the entire skin or hide. Thus he saves himself time, space, labor and material.

Soaking must continue until the hide or skin has been completely rehydrated or softened, particularly in the butt part (Figure 18). The softer bellies — and even the thicker, but softer, shoulders — will soak back more easily than the butt. If the goods are " broken " over the beam, more attention should be paid to the butt. On the other hand, oversoaking may involve a loss of hide substance. In consequence, there will be a thin, empty leather. It is preferable to stretch partly soaked hides over a saddled beam. This prevents any possible damage to the hide.

Green fleshing — the removal of loose meat and fatty tissue at this stage and before liming — is becoming a common practice. So long as it is done in the proper way, it can greatly help rural tanners wherever flaying is not good. It helps penetration of lime enormously.

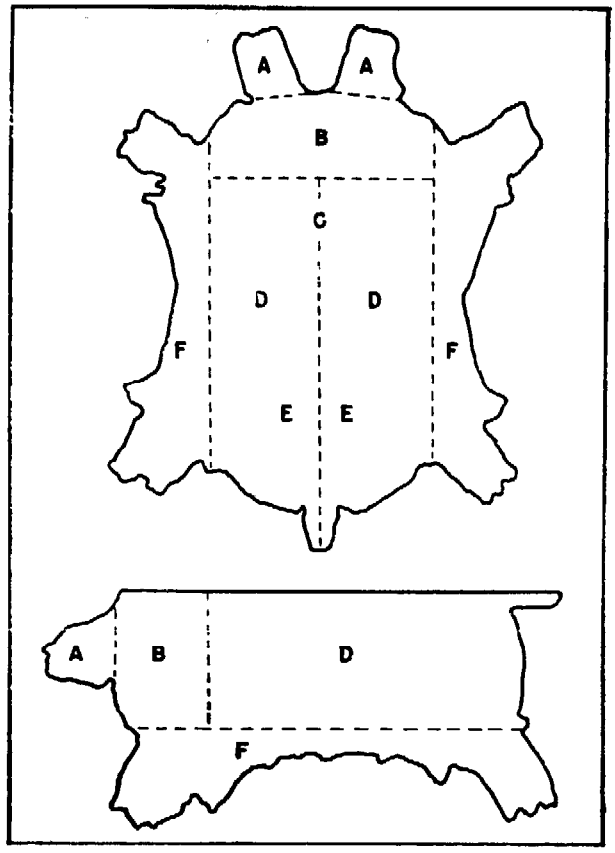

FIGURE 18. – *Sketch to illustrate different parts of a hide, having various thicknesses and strengths and used for various purposes.*

Courtesy Mrs. Erica Mann

A - Cheek
B - Shoulders
C - Butt
D - Bend
E - Crop
F - Belly

Liming

After the hides or skins have been properly soaked, they are ready for "liming." This is so called because one of the chief ingredients of the lime liquors in which hides or skins are immersed is generally milk of lime. Sodium sulphide and hydrosulphide, arsenic sulphide, ammonium salts and even enzyme products, however, are all used in different liming processes.

Wool can be removed by fellmongering, and hair by sweating. Wool sheepskins are invariably fellmongered before liming proper. "Fellmongering" is pasting, or painting, with a fiber brush the flesh side with a mixture of slaked lime and sodium sulphide. The wool is pulled off after the skins have been piled overnight, flesh side to flesh side. The mixture is approximately a 10 percent solution of solid sodium sulphide (fused, containing 60 percent) which becomes about 5 percent by dilution with the lime paste. As an example,

the following mixture is given: 6 kilograms of hydrated lime, 0.5 kilogram of sodium sulphide, 10 liters of water.

In "sweating," the wet hides are piled one on top of the other, or they are hung in a hot and humid room to encourage the bacterial action which loosens the hair. This treatment is difficult to control, and it often damages the grain; it should not be encouraged. Whatever method is used for unhairing, the hide or skin must still be limed to destroy or loosen the epidermis, for this layer keeps the hair or wool attached to the skin. Liming also conditions the derma by removing the "cementing material" — for example, the nonfibrous proteins and mucins which bond and lubricate the fibers. It is far better for the rural tanner to save himself the expense of fellmongering or sweating and to dehair during the essential process of liming.

Lime is made by burning alternate layers of limestone and firewood in special kilns (Figure 19). The product thus obtained is called burnt lime, or quicklime.

If the burnt lime is added to a tub of water, a violent reaction occurs and the burnt lime is converted into a paste called slaked lime. This may be used in tanneries; it is often dried to a powder and sold in bags as hydrated lime.

Figure 20 shows a correct and simple way of slaking lime. The iron drum is two-thirds filled with water at about 60° C. The fresh quicklime is added, and the mixture is well stirred. The temperature rises and the heat developed in the slaking process brings the mixture to the boil, thus producing slaked lime in a very finely divided state. Lime slaked in this manner yields a finer suspension than that slaked in cold water. It allows more lime particles to settle between each hide or skin. The result is a more efficient liming.

The aim of liming is:

(*a*) to destroy or soften the epidermis whereby the hair or wool is loosened;

(*b*) to destroy sweat glands, nerves, veins and blood vessels in the hide substance;

(*c*) to soften and destroy the reticular (interfibrillary) tissues which keep the fibrils together, and to open and plump the fibers and fibrils to facilitate penetration of the tanning materials;

(*d*) to cause swelling and plumping of loose meat and connective tissues on the flesh side and to facilitate its subsequent removal.

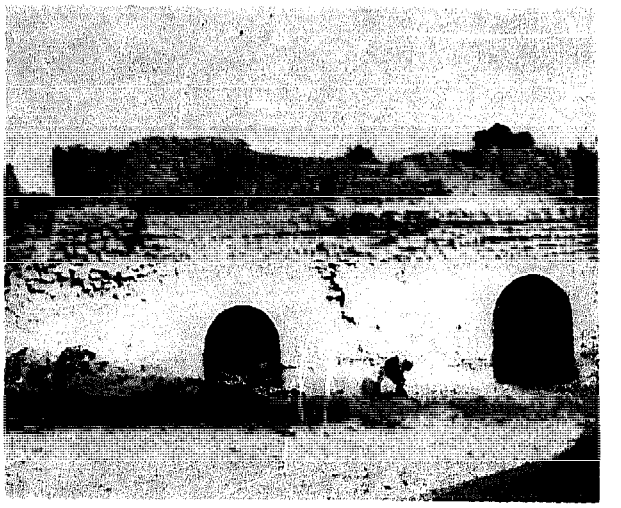

FIGURE 19. – *View of simple lime kiln. Limestone from local deposits is fired by coal and produces a quality of quicklime suitable for building purposes and for use by tanners.*

Lime is only slightly soluble in water. Not more than 13 parts of lime can be dissolved in 10,000 parts of water (25° C.). Thus no damage is done to hides and skins by using excessive lime, for it remains undissolved at the botton of the vat. Gradually, as the skins take up the lime from the water, more lime is taken up by the water itself.

Three types of lime liquors are used in a tannery:

Fresh lime. This liquor is prepared by slaking a weighed quantity of burnt lime separately and adding the required amount of water.

FIGURE 20. – *Slaked lime can be made correctly in iron drums.*

Its concentration can be from 1 to 4 kilograms in 100 liters of water. If it is necessary to strengthen the liquor in a vat, the lime must be slaked first to avoid damage and burns to the skins during the slaking process. Thus strengthening the liquors is done by adding the required amount of the lime which has been slaked separately.

Mellow lime. After one or two packs of hides have passed through fresh lime, it is said to be mellow. This is a lime liquor with mellow or mild action: it is not so caustic as fresh lime, and it causes less plumping. None the less, it attacks the epidermis more vigorously than does fresh lime. Thereby it loosens the hair more rapidly.

Old lime. Lime which has been used many times and has lost its causticity is called old lime. It has feebler plumping powers, but its hair-loosening effect is invariably greater than that of mellow lime liquor. When very old lime smells of ammonia, it is dangerous to use; it should be thrown away.

There are two methods by which fresh, mellow and old limes may be used — the one-pit system and the three-pit system. Both these methods can be used for any type of leather, so long as there is the right degree of mellowness. As a rule, however, sole leather should be limed in fresher limes than those normally used for skins. The goods should be moved once a day and laid flat on the side of the vat. The lime liquor is then vigorously stirred. When the goods are put back, they should be again laid flat, hair side up, before the lime has settled. This prevents the lime content of the liquor from falling as the skins take up lime.

The one-pit system

Used lime liquor is strengthened by adding fresh slaked lime, and the hides are immersed for three days. On the third day, they are removed, and fresh slaked lime is added. After another three days all the lime liquor is removed, and a completely new liquor is prepared from fresh slaked lime. When the hides have been immersed for four days in this new liquor, they are taken out for unhairing. The liquor is then used to start a new batch of hides. The whole process, which takes ten days, is used for thick hides to produce sole leather, harness, and similar types of leather.

To achieve an even and rapid liming, it is advisable to draw the goods out of the vat once, or even twice, every day, to pile them on the rim and then to return them to the lime.

THE THREE-PIT SYSTEM (Figure 21)

Three vats are used. Vat No. 1 contains old lime — that is, lime already used twice. Vat No. 2 contains mellow lime — that is, lime used only once. Vat No. 3 contains fresh lime.

The liming starts in Vat No. 1 and in old lime. The hides are immersed for four days. They are then transferred to Vat No. 2 and to mellow lime for three days. The last treatment is given in Vat No. 3 in fresh lime for three days. There is a daily haul.

When hides have passed through the three vats, the liquor will have changed. The fresh lime will be mellow, and the mellow lime will be old. The old lime will be of no further use and should be thrown away. A further supply of fresh lime will then be made in the empty vat. The vats will then contain the following liquors:

Vat 1 – fresh lime
Vat 2 – old lime
Vat 3 – mellow lime

A new pack of hides, therefore, will be immersed in the vats in the following order:

Vat 2 – old lime
Vat 3 – mellow lime
Vat 1 – fresh lime

The position will change again. The old lime in Vat 2 will be discarded, and this vat will be used for making fresh lime. The order of immersion will then be as follows:

Vat 3 – old lime
Vat 1 – mellow lime
Vat 2 – fresh lime

Figure 21. – *Schematic sketch showing use of lime in so-called "three-pit system."*
Courtesy Mrs. Erica Mann

Different goods require different times in liming before they are ready for unhairing. The correct moment is determined by rubbing the thumb against the lie of the hair. When the hair can be rubbed cleanly off the surface, the goods are ready.

To avoid loss of hide substance, it may be desirable in hot areas to reduce the period of liming, for example one or two days in Vat No. 1, and two days in Vats Nos. 2 and 3 respectively.

After the unhairing, if it has been done by pasting with lime-sulphide paint, it is necessary to lime in fresh lime liquor for about a week. The actual period varies. Goatskins, for example, may be ready for unhairing after a week in lime; yet they may require a further liming after unhairing (Figure 22).

In certain parts of the world, unhairing is done by means of wood ashes. They are mixed with plenty of water, and the skins are immersed in the mixture. After several days — the time depends on the weather and the type of wood from which the ashes are made — the hair becomes loose and can be removed easily. Besides their unhairing qualities, certain ashes have some of the properties of lime liquors.

Smearing the skins with cattle dung or burying them in the earth to remove the hair is very dangerous. It causes hairslip, which is an early stage of putrefaction. The hair of the thin parts, such as the bellies, will become loose, while the hair on the neck and shoulders remains firm. This method must be condemned.

Unhairing, fleshing and scudding

It has already been explained that the epidermis and hypodermis must be removed before the pelt, or corium, is converted into leather. At this stage, the tanner must take the following action:

(*a*) Unhairing — the removal of the hair after liming. In some instances, it should be realized, unhairing takes place in the early stages of liming, while further liming takes place after unhairing.

(*b*) Fleshing — the cutting off of the loose meat and fatty material which is called the hypodermis or, colloquially, "meat" or "flesh."

(*c*) Scudding — scraping off the epidermis as well as the hair roots, glands and lime soaps.

Unhairing

After liming, the hair is loose and can be scraped off easily. This is done with an unhairing knife, which is a two-handled knife curved to fit the beam. The blade is not very sharp; for unhairing is a scraping, rather than a cutting, process (Figure 15).

FIGURE 22. – *Liming vats and workers unhairing on beams.*

Courtesy Kenya Information Office, Nairobi

The unhairing, and also the fleshing and the scudding, operations are performed on a sloping convex table called a beam, the top of which forms an arc. The table is set at an angle of 40 degrees. One end rests on the floor. The other is supported by a kind of leg. so that the top reaches to the waist of the operator (Figures 23 and 24). The skin is laid flat without wrinkles on the beam, hair side up, and the hairs are removed by pushing the knife in the direction of hair growth until a clean grain is visible.

FLESHING

The lime has also caused a plumping of the hypodermis, which is now thick and flabby and can easily be cut off. The removal of the hypodermis is called " fleshing." The knife used for this operation has a very sharp convex outer edge for cutting and slicing, while the inner concave blunt edge is used for scraping and for moving skin or hide round the beam (Figure 16). If these knives are not available, sharpened unhairing knives may be used.

The fleshing knife is used in sweeping movements to slice off any loose pieces. This must be done carefully to avoid cutting into the corium while removing the entire hypodermis. The corium should be left completely smooth, clean and uncut.

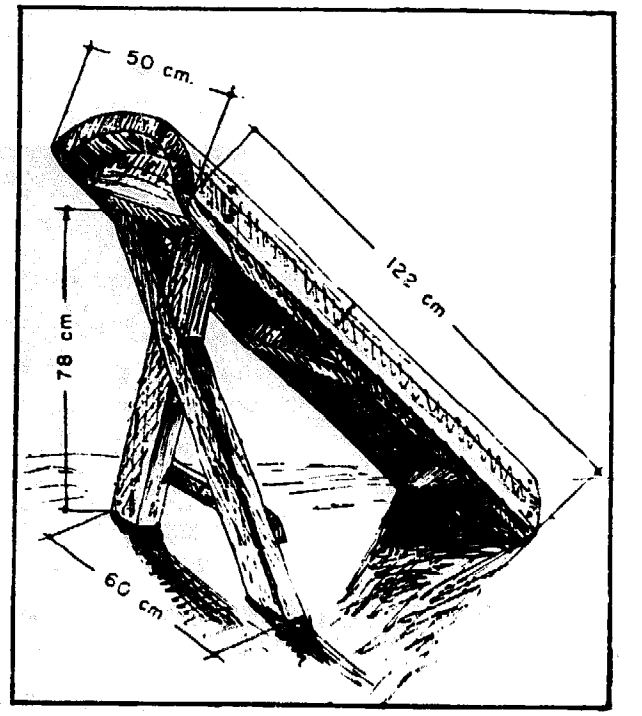

FIGURE 23. – *Sketch of locally constructed beam as used in processes of unhairing, fleshing and scudding.*

Courtesy Mrs. Erica Mann

FIGURE 24. – *Unhairing, as well as fleshing and scudding operations are performed on a beam. For special purposes, scudding is still done manually even in modern tanneries. Photo shows operator de-wooling sheepskin after painting.*

Courtesy Marocchinerie e Scamoscerie Italiane, Turin

Scudding

The hides and skins, when unhaired and fleshed, are then put back into the lime, or limey water, for a further softening of the epidermis. After one day in the lime, they are taken out, put over a beam and scudded.

The skin is laid completely flat and smooth on the beam, grain side up. The operator, as he pushes the blunt knife downwards in the direction of the lay of any remaining hair, needs to use only moderate pressure to squeeze out the hair follicles, glands and dirt.

To obtain a clean surface it is essential to squeeze the smallest hair from the pores. Scudding is a most important action; it must be repeated many times if perfect leather is to be made.

Scudding can be performed not only after liming; it can also be repeated after bating and drenching. These two processes are described later. Even in modern tanneries, scudding for special purposes (Figure 24) is still done by hand; for the skilled worker knows exactly how to adjust the pressure and the angle of the knife and how to maintain that blunt, smooth edge which achieves the best results.

Water vats are often used in the intervals between unhairing, fleshing, scudding and bating.

Rounding and trimming

Rounding is the term for so cutting up the hides usually intended for sole leather that the different parts are tanned separately, and then used, according to their quality and thickness.

Hides are not uniform in fiber structure, substance, nor in thickness. In consequence, it is desirable to divide the hides into three main sections. These are (*a*) the butt, or center part, which consists of two bends, one each side of the spine; (*b*) the two bellies; and (*c*) the shoulder and neck (cheek, face).

These portions are generally used for different purposes (Figure 18). Sole leather is produced from the butt, which requires the longest tanning. The bellies are much thinner. They are normally used for insoles, slipper soles and similar types of leather which need a shorter tanning process.

The shoulders are used for lighter soles, straps or insoles. They represent another type of material, and they are tanned accordingly.

The rounding procedure requires a flat table about 120 centimeters by 180 centimeters in size and a rather heavy type of knife similar to that used for pruning. The hides are folded, grains side out down the back, and lifted on to the table from the neck and tail ends. This is usually done with iron hooks. The rounder's skill is important when he selects the line where he should cut: for it is undesirable to have belly and shoulder pelt attached to the more expensive butt. A reduced butt is also uneconomic. For these reasons, the rounder presses the thin flanks of the pelt with his fingers. In this way he finds the line for the removal of both bellies with one cut. As a rule, the shoulder is removed at a point immediately above the withers, or just behind the hump.

This method of rounding, however, concerns only the more advanced tanners. Later chapters explain that the rural tanner has few vats and must economize in their use. For the rounding of hides for sole leather, therefore, he should follow the simple process of cutting in halves from tail to neck along the ridge of the back.

Cutting, as Figures 25 and 26 show, is best done on a horse. This is made very simply from cut timber. A central groove is cut along its entire length to a depth of about 5 to 6 centimeters, and this allows the knife to move freely during the cutting operation. Two parallel boards will also serve for this purpose if they are fixed 1 centimeter apart.

Trimming is the removal of uneconomic edges, pieces of flesh, and so on.

Deliming, puering and bating

When the epidermis and the hypodermis have been removed, the limed hides and skins are submitted to a deliming process. This means the removal of lime or alkalinity from the hide or skin. Whether the removal is partial or complete depends on the type of leather to be produced.

Limed hides and skins are rendered soft and fallen — a condition termed " flaccid " — by the complete removal of their lime content.

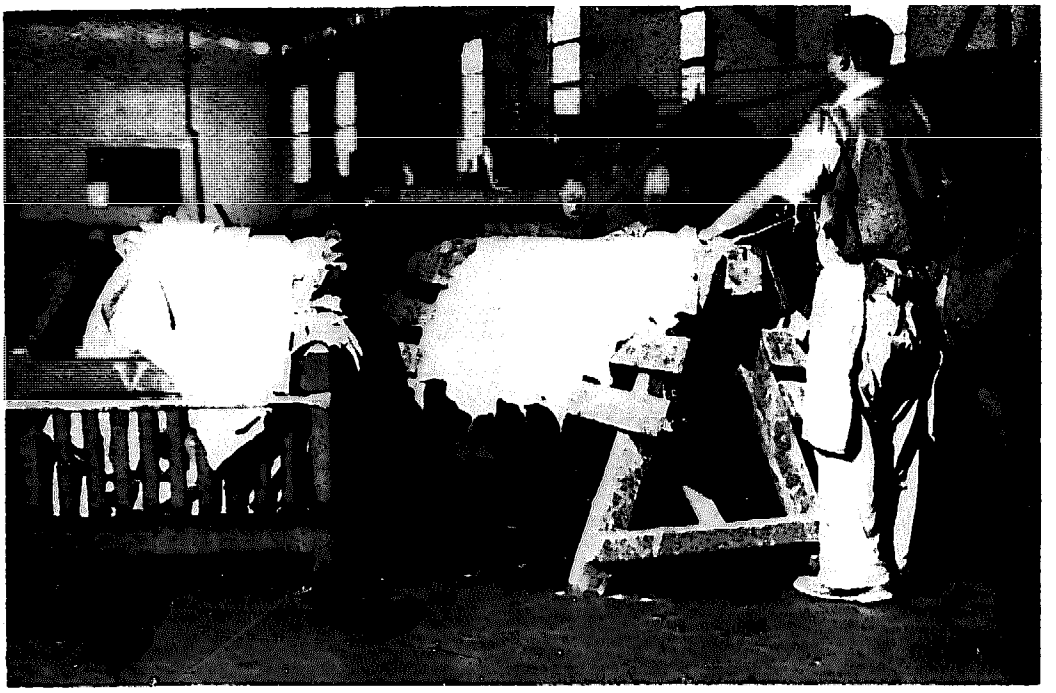

Figure 25. – *Wooden horses made of locally available timber, used to cut hide into sides, and number of other purposes such as draining, piling, dyeing or display of finished product.* Courtesy Kenya Information Office, Nairobi

Figure 26. – *Detail of cutting operation on hide.*
Courtesy Kenya Information Office, Nairobi

A softer leather is obtained from these fallen pelts than from pelts which have been only surface-treated — for example, partly delimed. Unless the lime is removed, the finished leather will be hard; the grain will be brittle and discolored. One method of producing a firmer leather, however, is to leave one third, or two thirds, of the lime in the interior of the pelt as it passes into the tanning process. This is particularly true of sole leather manufacture.

A certain degree of stretch, suppleness and smoothness is desired in shoe upper, gloving, clothing and other light leathers. It cannot be achieved by mere deliming. Stretch or "run" — for instance, in gloving — is obtained by puering or bating. Puering is the treatment of pelts with a warm infusion of dog dung (puer). Bating is a similar process; but here the puer is replaced by hen or pigeon dung, or else by a synthetically produced material, such as the patented Pancreol, Peroly, Cutrilin, Enzo, Oropon, and other similar products. The manufacturers issue instructions on their use. The aim of this paper, however, is to instruct and to guide rural tanners in the use of raw materials which are cheap and readily available in their own locality.

Synthetic bating is a treatment of the skin with a commercially prepared bate made of animal pancreas. This is a gland which produces digestive juices, and it is combined with a deliming agent, such as ammonium chloride.

The actions of puering and bating are similar, but puering is more drastic. It is very important to control the pH value[1] in the puering process. The optimum for tryptic activity is from pH 7.5 to 8.5.

The object of puering or bating is to make the skins ready for the production of soft, smooth and pliable leather. Skins out of the limes are usually plump, and when they are tanned in that condition, they produce firm leather. To ensure a soft pliable leather, however, all plumpness must be removed.

According to an old tanners' proverb, a lambskin cannot pass through a bracelet before puering or bating, but it will readily pass through a wedding ring after one or the other process. The proverb clearly illustrates the action of "falling," for it is the opposite of "plumping," or the swelling caused by the liming process.

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[1] See Appendix on "pH Value in Tanning."

Deliming

Not all the lime is removed by washing limed pelts in running water; and, in any event, it is a prolonged treatment. When vats or pots are used for this process, there must be several changes of water. Trampling the skins with the feet, or wringing by hand, certainly speeds up the washing, but repeated washing under running water and working over a beam with a blunt knife play the major parts in squeezing lime out of the pelt. Sixty percent of lime can be removed by washing, and this is an important economic factor. None the less, the removal of all the lime by water alone is impossible. Prolonged washing may damage the skin or hide mechanically. A light deliming — the use of some acid, followed by puering or bating — removes all caustic lime completely. This method is, therefore, preferable. Complete deliming can also be achieved by ammonium chloride as well as by acid: and it is safer.

Because the effects of puering or bating are very similar, " bating " is now the term used for either process.

Puering and bating

The process of puering is as follows. A paste of 10 percent dog manure in warm water is prepared in a wooden or earthenware utensil, and it is kept unexposed to the air for about a week. It is then thoroughly stirred, passed through a bag, sieve or screen to remove coarse particles and put into a vat of lukewarm water (29°-34° C.). The skins are completely immersed in this solution, which is stirred continuously. The water must not become cold. From time to time, therefore, more warm water is added, or else the whole process is conducted in the sun. As a rule, bating by this method is completed in one or two hours.

Pigeon bate is prepared from 1 kilogram of manure stirred into 100 liters of water, which is heated to 43° C. It is allowed to ferment for at least a week. After this fermentation, the temperature of the bate is raised to 32°-35° C. by adding 200 liters of warm water. It is customary to filter the bate before adding the water. With cold bate the bating may take up to seven hours; but if the bate is kept consistently warm the process can be reduced to about three hours.

The time taken for the bating operation varies, and it is necessary to make periodical tests. This is done by gathering the skin into the form of a bag which contains some of the bating liquor and air. The bag is then squeezed. If the air passes through the pores of the skin, bating is complete. If not, bating should continue.

Another test is to press the thumb firmly against the grain side of the skin. If the thumb impression remains, bating is complete. Only leather which is to be soft should be bated. The grain of bated skins feels very soft and the hair holes remain clearly visible. When properly bated skins are dropped on to a table, they are flaccid — that is, soft and slippery to the touch — and the folds remain close together.

After bating, the goods are scudded again. This is a treatment of the grain side of the pelt with a blunt knife or slate blade. It is done to squeeze out any small particles — called "pigment" or "scud" — which became loose during the bating operation. The skins are then washed in water before they are tanned. A small amount of boric acid is added to the water to ensure neutrality.

Dog or pigeon dung is unpleasant to use and difficult to control. In recent times, it has been replaced by pancreatic juice or minced pancreas.

The pancreas, which the butchers call the "stomach sweetbread," is a gland situated near the liver and the duodenum (Figure 27). It produces juices able to digest meat in the same way that the salivary glands, for instance, produce saliva able to digest starches. This gland is of irregular shape; it has a creamy or reddish color; and it weighs approximately 280 to 340 grams in the ox and 85 to 110 grams in the pig. Ox pancreas juice is weak; goat and sheep pancreas is of medium strength; and pig pancreas is the strongest.

The preparation of minced pancreas for bating purposes is a simple procedure. The gland should be removed from freshly killed animals and, without any previous washing, it should be minced in a meat-mincing machine. As the juices are the most important part of the gland, they should not be lost during the process. Instead, the whole amount should be collected into a pan or plate. If the bate is required at once the pancreas is minced; and to three parts of the pancreas seven parts of ammonium chloride are added. The bating is done by using 3 percent of the pancreas-ammonium chloride mixture calculated on the wet weight of the hides.

FIGURE 27. – *Sketch showing position of ox pancreas in relation to liver, duodenum and gall bladder.*

Courtesy Mrs. Erica Mann

These proportions are for pig pancreas. If goat or sheep pancreas is used, then 50 percent more will be necessary. If ox pancreas is used, the quantity should be doubled. Good results are obtained by mixing two kinds of pancreas — for example, one third pig and two thirds cattle; or one third pig and two thirds sheep.

A steady supply of fresh pancreas is rarely available. The glands, therefore, should be preserved. The cheapest and most efficient method of preserving them is to grind equal parts of fine clean dried sawdust with the pancreas. The mincing should be repeated twice until a homogenous material is obtained. The material should then be placed on a flat tray and exposed to the sun. By continuous turning and mixing it is possible to dry the mass very rapidly. The temperature should not exceed 43° C.; otherwise the bate loses it active properties. Drying in an oven or over a fire renders the bate entirely useless. Once the mixture is completely dry, the addition of 33 percent of ammonium chloride produces a bating material which is long lasting, handy, cheap and clean to use. The beginner, however, finds the preparation of the bate difficult.

The amount of bate which should be used depends on the type of skin, but, as a rule, it does not exceed 0.5 percent of the weight of the pelt. It is always used in water at a temperature of 32° to 35° C. Stirring or paddling greatly assists bating.

Drenching and pickling

Two additional processes are called drenching and pickling. Either may be used after bating to ensure that the pelts enter the tanning liquors in a slightly acid condition. They need not both be used. The rural tanner, however, may find it advantageous to drench after deliming and/or to bate the skins before vegetable tanning. As a rule, pickling is done after bating and before chrome tanning.

DRENCHING

Often an ordinary acid deliming process is described as drenching; it is sometimes called "acid drenching." The real drenching process is one in which the puered or bated pelts are subjected to the action of an infusion of bran or similar substance. The process of drenching is important where natural puers are used. The bran acts as a mechanical "scrubber;" it cleans the dirt brought by the puer from the skin. With pancreatic bates a pickle suffices. The term "drenching" or "acid drenching" is a misnomer; and this is probably due to the frequent substitution of an acid deliming process for a bran drench. In this paper, soaking the skins in a fermented infusion of bran (or flour) and warm water is called drenching, the fermented material is called a drench.

The objects of drenching are:

(*a*) to continue and to complete the removal of lime which began in the washing, puering or bating process;

(*b*) to assist in removing the last remnants of the scud, and any mucoid material which is left after the liming, and to make a whiter and clearer leather;

(*c*) to change the reaction of the pelt from slightly alkaline to feebly acid;

(*d*) to cleanse mechanically the grain of the pelt.

Even when a thorough washing has been followed by bating, some lime may still remain in the pelt. This can be removed by chemical agents.

In commercial tanneries limed pelts are neutralized, and boric, hydrochloric, lactic or acetic acid are normally used. In rural regions it is possible, instead of buying acids, to make them by fermenting the brans of maize, wheat or rice. Any other fermentable cheap material can also be used. Flour, too, can be used, but it is expensive.

The drench is prepared by pouring hot water over bran and by leaving the mixture overnight in a covered vessel and in a warm room. The amount of bran which is needed is calculated on the weight of the skin to be drenched. As a rule, 5 to 10 percent is sufficient — for example, 0.5 to 1 kilogram of bran for 10 kilograms of wet skin. There must be enough warm water to cover the bran and the skins. The skins are stirred occasionally, and they may be weighted down in the drench with stones to prevent their rising to the top. After 24 hours, the process is complete. Keeping the skins in the drench for too long may cause "blister." Therefore, they must be examined periodically.

In certain countries — for example, in the Sudan — small green pods of acacia are used. They are put into warm water and left until some acid is formed by leaching and fermentation. This acid is sufficient for deliming. There are probably many other plants which could be used in this way. They are worth investigating.

To determine when deliming is complete, an indicator is essential. An indicator is a substance which changes color by the action of acid or alkali. The tanner must be acquainted with at least one indicator. Phenol phthalein is, perhaps, the most useful.

If phenol phthalein or any other indicator is unobtainable, the rural tanner may use the green coloring matter from leaves which is called chlorophyll. It gives a well-defined color change with acid and alkali. The coloring matter obtained from mashed tomato leaves also gives excellent results.

A standard solution of phenol phthalein is made by dissolving 1 gram of the solid material in 500 cubic centimeters of strong alcohol; and when the phenol phthalein is dissolved, the solution is diluted with 500 cubic centimeters of distilled water. This stock solution should be poured as required into a small bottle which, like a bottle used for eye drops, is fitted with a rubber teated pipette. The pipette can then be used to deliver one drop at a time (Figure 28).

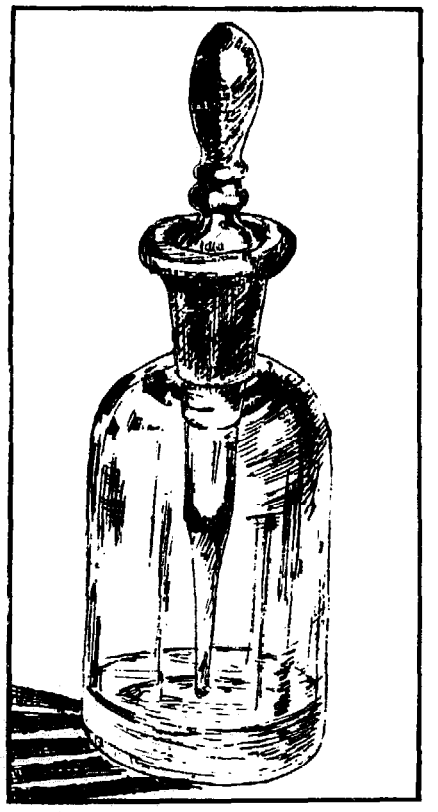

FIGURE 28. – *Sketch of small bottle fitted with rubber-teated pipette (as used for eyedrops) containing standard solution of phenol phthalein.*

Courtesy Mrs. Erica Mann

One drop of phenol phthalein solution on the freshly cut section of the hide or skin will give either:

(*a*) a colorless reaction, which indicates that no alkalinity — for example, no lime — is present; or

(*b*) a pale pink reaction, which shows that a little alkalinity is left; or else

(*c*) a bright red reaction, which shows that much caustic lime remains.

Thus, when the indicator remains colorless, the skins are ready for tanning. When the phenol phthalein turns pink, the skins should remain a little longer in the drench and then be tested again. But when the bright red color remains, it means that nearly all the lime is still present, and probably:

(*a*) the skins were not properly washed before they were placed in the drench; or

(*b*) the drench did not ferment because it was kept too cold; or else

(*c*) too many skins were used for the amount of drench.

For sole leather, complete deliming of hides should not be attempted because this would give a softer leather and make it too light. As a rule, 0.5 percent of boric acid solution used overnight is sufficient deliming for the previously washed hides. If a drench is used, the hide should be immersed for four to six hours to delime both surfaces only.

When these hides are being tested, the cut section will expose the center where lime is still present. Thus the center will give a bright red color with phenol phthalein, while the outside gives a colorless or pale pink reaction.

Drenching, it must be realized, can cause much loss of skin substance by the action of liquefying organisms. If possible, it is safer to dispense with it.

Pickling

The treatment of limed, bated and scudded pelts with a solution of salt and acid is called pickling.

The rural tanner is not likely to pickle skins. This section, however, is included for the benefit of more advanced tanners and for making others familiar with terms and processing techniques which they may encounter later.

Originally the pickling process was applied to pelts to preserve them for transport within the country, or for export. Pickling the pelts before tanning, it was observed, facilitated the penetration of the tanning agents. Thus it speeded up the tanning process.

As a rule, pelts are pickled before chrome tanning. This prevents too rapid a fixation of chromium and ensures an even penetration of the chromium salts. Once penetration is complete, the pH is raised by adding alkali and the chromium salts are fixed.[2]

The amount of chemicals and water used in relation to the quantity of the skin which is treated must be carefully regulated. The quantity of skin is measured by weighing in the limed or bated condition, after fleshing or scudding respectively. The limed weight is about 40 percent greater than the bated weight. This is because of its water-swollen condition, for which allowance must be made.

Fundamentally, the amount of acid should be based on the weight

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[2] See Appendix on "pH Value in Tanning."

of the skins — for example, 1 percent on the limed flesh weight, or 1.4 percent of the bated weight — for its basic purpose is to sour, or to acidify, the skin.

The amount of salt which is used should be based on the amount of water in the pickling bath. If the salt content falls very much below 4 percent on the volume of water (specific gravity 1.028), the acid will cause the skins to swell, and the structure will be weakened. This is prevented by a correct concentration of salt, i.e., not below 4 percent.

As a rule, the skins are immersed in a solution which contains the acid and salt. Normally the solution contains sulphuric acid (of 66 percent strength) and common salt.

The usual method employed for export or storage is based on the weight of the limed skins after unhairing and fleshing. The proportions are 200 percent cold water, with 20 percent common salt (sodium chloride) and 1.5 to 2 percent sulphuric acid. That is, for every 50 kilograms of pelt one requires 100 liters of water, 10 kilograms of salt and 1 kilogram of acid. Immersion should last from four to six hours whenever there is mechanical agitation such as drumming. When the agitation is done by hand, the immersion must continue for a proportionately longer period of time.

For paddling, the quantities are in the proportion of 250 liters of water, 25 kilograms of salt and 2.5 kilograms of acid for 50 kilograms of pelt. Paddling is for 12 to 18 hours; for this gives the pelts plenty of time to get into equilibrium with the pickle liquor. These quantities are right for the rural tanner when he uses a vat without any mechanical means of agitation.

Pickling before chrome tanning should be fairly heavy to ensure

Pickling before chrome tanning should be fairly heavy to ensure
the penetration of the chromium salt. A useful drum mixture based on the pelt weight of the goods may be 1 percent acid, 8-10 percent salt and 70 percent cold water. The drumming should last for two hours.

After sufficient pickling, the pelts needed for storage or export should be drained on a well-covered up horse. Then they should be rolled into bundles — half a dozen pelts in each bundle — and packed in large and well-cleaned barrels. For this purpose, wine barrels are very useful. The pelts can be preserved for a year or two, if they are protected from contact with water. If, however, a further precaution against mold and bacterial action is needed, fungicides and disinfectants such as para-nitro-phenol, beta-naphthol

or santobrite in the proportion of 1 part to 1,000 should be added to the pickle solution. As a fungicide, 0.5 percent beta-naphthol is very effective.

In Europe, it is a common practice to vegetable tan pickled sheepskin in the pickled condition. If the skins are greasy, they are drummed with half their weight of paraffin for two hours. Then they are rinsed in a 5 percent salt solution. Afterwards they are well drained and drummed in 200 percent water and 8 percent salt; and the tan is added directly to the liquor. As a rule, sulphited mimosa extract is used to give 20 percent actual tan. In five to six hours, penetration is complete. All percentages are on the pickled weight.

The skins are then piled, washed off and drummed in 3 to 5 percent sulphonated oil. This gives a pale and even colored tannage. The method can be used just as well with other tanning materials, so long as they are available in a concentrated form — for example, quebracho or myrobalan extract, gambier, or even leaf sumac or tara powder.

The tannage is rapid. It is essential, therefore, to keep the skins agitated, either in the drum or by paddle, or else by other means. Wooden or acid resistant containers must be used. This method is simple, quick and economic in tan.

If traces of iron are present, the leather may suffer from tenderness after a long storage. To counteract this, whitening or powdered chalk can be incorporated after tannage.

An alternative method is to depickle the skins before tannage to neutralize the pickling acid. This is done by working the skins in a 5 percent salt solution with an addition of 1 to 2 percent — on the pickled weight of the skins — of mild alkali: for example, borax, sodium bicarbonate, soda ash, wood ash or sodium thiosulphate (hypo). The skins should finish at pH 5.0 — that is, when they have lost their sour taste. The process is not easy to carry out because the color and grain quality of the leather is very sensitive to the finishing pH. At least five hours — or, for preference, the whole night — are needed.

One of the cheapest depicklers is sodium thiosulphate (hypo). This is quite neutral, and it does no harm when it is used in excess. When, however, hypo is used, sulphur is deposited in the skin, and this is not always desirable. Moreover, sulphurous acid is liberated in the skin, which is still fairly acid.

When all these preliminary operations are over, the prepared hide or skin is white, clean, smooth-grained and free of flesh. The fibrils are separated from each other; and the true derma — the pelt — is ready for tanning.

The pelt may be converted into leather by any one of three types of tanning:

(*a*) vegetable — using tannins derived from the vegetable kingdom, such as barks, leaves, roots or pods;

(*b*) mineral — using chemicals such as chromium, alum, iron salts or formaldehyde;

(*c*) oil — using oils derived from animal or vegetable sources; marine oils such as cod oil, however, are preferable.

IV. VEGETABLE TANNING MATERIALS

General

Tannins are bitter substances present in barks, fruits, pods, leaves, roots or seeds. They are used to convert hides and skins into leather. They come from plant sources, and they are called vegetable tannins. They have different origins, however, and they differ in strength and in character, color, concentration and quality. Thus they produce leathers of different types — hard, soft, light colored, dark colored, heavy or light. These tannins can be used singly or in various combinations to produce different effects.

Although tanning materials are found in all parts of the world, only those which are of commercial importance and are widely used in commercial tanneries — and are thus suitable for rural tanneries — are mentioned in this chapter.

Black wattle, also called *mimosa*, is marketed as a bark which has an average of 35 percent tannin, or else as a solid extract of 63 percent tannin. The wattle originates from Australia. It is extensively cultivated in the Union of South Africa and in Southern Rhodesia; and India has started a planting program. It is also used for dyeing fishing nets, ropes and sails in the Philippines and in other parts of the world. The solution is highly astringent.

Camachile is the bark of the camachile tree (*Pithecolobium dulce*) which grows in Mexico, the Philippines, and southern India. It has about 25 percent tannin.

Chestnut comes from the wood of the chestnut tree in Europe and the United States. It is used principally as a liquid extract (35 percent tannin) or as a powder (70 percent tannin). It gives a firm leather of dark reddish color.

Cutch comes mostly in the form of an extract and is derived from several kinds of acacia (*Acacia catechu*) which grow in India and in Burma. It contains between 35 and 55 percent tannin. It is astringent and produces a dark reddish brown leather. It is also used to dye fishing nets and sails.

Divi-divi comes from the podlike fruit of a small tree (*Caesalpinia coriaria*) which is indigenous to India, South and Central America. These fruits contain tannins up to some 45 percent. Divi-divi is mellow and yields a pale-colored soft leather. It is useful in the early stages of sole leather tanning; for it contains a sugary material which can ferment to form acid.

Gambier is an extract prepared from the leaves and the young twigs of a shrub (*Nauclea gambir*) which grows in Indonesia. It contains up to 40 percent tannin. It is very mellow and it gives a buff-colored leather which discolors when it is exposed to light. Gambier is generally used in combination with more astringent tannins to increase the tensile strength of the leather.

Hemlock is the bark of the hemlock tree (*Tsuga canadensis*) which grows in the United States and in Canada. It gives a red tan and is astringent.

Nut-galls or *oak-galls* are produced by the response of the tree to the action of a wasp which has pierced the young branch or leaf. They contain up to 60 percent tannin and the solution is mellow.

Mallet bark has up to 45 percent tannin, and it comes from the eucalyptus tree (*Eucalyptus* sp.) which grows in Australia. Only the inner layer of the bark is used. The solution is fairly astringent.

Mangrove is the bark of the mangrove tree (*Rhizophora* sp.) which grows in the lagoons or tidal swamps of tropical seas. It contains 35 percent tannin and gives a reddish brown firm leather. It is also sold as an extract containing 62 percent tannin. The solution is very astringent.

Myrobalan comes from the fruit (nut) of a tree (*Terminalia chebula*) which is indigenous to India; it contains from 30 to 40 percent tannin.

of the pith the tanners separate the pulp which is used for tanning. Usually the pulp is not dried separately. The tannin yields a pale, light colored, soft leather. It is generally used in combination with other tannins. The manufactured liquid extract has approximately 45 percent tannin. The solution is mellow.

Oak bark is, perhaps, the oldest tanning material. It is mellow in solution, although it contains no more than 15 to 17 percent tannin. It produces a very bright leather. There is also an oak extract on the market.

Quebracho is derived from a tree (*Quebrachia lorentzii*) which is indigenous to South America and extensively cultivated in plantations. The bark or ground wood, which contains 18 percent tannin, is used; or else a solid extract of 63 percent tannin content is made from it. It gives an astringent solution.

Sumac is derived from dry leaves and small twigs of a shrub (*Rhus coriaria*) which grows in Sicily and in southern Italy. It is marketed as a dry powder, or else in the form of extracts. It gives a very light, pale biscuit-colored leather which is soft, full and plump. The solution is very mellow.

There are many other sumac tannins derived from trees or shrubs of the same family growing in the United States, Spain, South Africa and in other parts of the world. But they contain less tannin.

Tara is the name commonly given to a tanning material which consists of the dried pods of *Caesalpinia spinosa*, a tree or shrub widely distributed in northwestern South America and also grown in many parts of North Africa, especially Morocco.

Tannin content is variable and figures ranging from 35 to 55 percent have been given. The main value of tara pods is in the tanning of light colored leathers, for they impart but little color to the leather.

Valonia is made from the cup of an acorn found on certain species of oak (*Quercus aegilops*) which grow in Greece and in Turkey. It is sold as a liquid which is mellow or as a solid extract — and cups and beard are also commercially available — and it is used extensively to make sole, harness and other heavy leathers.

Vegetable tannins for rural tanners

The advanced tanner will use imported, concentrated and expensive tannins in the form of baled or pressed solid material or in the form of liquid and highly concentrated extracts in barrels. He can afford neither the time nor the space to use tannin-bearing materials which have only a low tannin content. The small rural tanner, however, will certainly want to use easily obtainable materials — particularly for the tanning of light leather — which cost little or nothing, even if the tannin yield is rather low.

It is impossible to enumerate all the tannin-bearing plants, even though many are known and rural tanners have been using them for centuries.

Bark is stripped from trees by a special peeling iron. The stripping is done in such a way that only a part of the bark is peeled off. It does not damage the tree permanently.

In certain parts of the world this is a special trade, and the product is sold to large tanneries. To avoid the deterioration of grassland and soil erosion, however, bark peeling should be controlled.

The gathering of tannin bearing pods, leaves and twigs is a source of income for the rural areas. Collection must be done carefully, and the material gathered must be of the right maturity — that is, when the tannin content is at its highest. The materials must be protected from the leaching effects of rain. They must be free from contamination, and particularly from contamination by soil; for it may contain iron salts which cause a discoloration of the finished leather.

Since the tannin-bearing material may not be available at all seasons, it should be collected and stored for later use. Storage must offer protection against rain, though the material must also be open to the air. To prevent mold growth and fermentation, the material should be turned over from time to time or, better still, laid out in the sun for a day.

Two or more tannin-bearing materials must not be mixed at any preliminary stage, even when they are finally to be used together for tanning.

To the rural tanner of tropical and subtropical Africa and Asia, the acacias are one of the most important tannin-bearing trees.

Several species, such as *Acacia arabica*. *A. nilotica*, and *A. adamsonia*, have supplied pods and bark since immemorial times. They probably explain the origins of vegetable tanning in Africa and Asia. The leather produced by acacia pods is soft, plump, light colored and durable, and it can be readily dyed. Their solutions are mellow. No wonder highly skilled artists appeared in those countries where the acacia is grown. The acacia pods and bark are known variously in the countries where they grow as *babul* (Hindustan), *babar* (Sind), *garad* or *sunt* (Sudan), *babla* (Arabia), *neb-neb* (West Africa) and *gabarua* (Nigeria).

The pods used for tanning are from 10 to 15 centimeters long and 1 centimeter broad, and they have 8 to 10 seeds. Contrary to common belief, the seeds do not contain tannin, which is present only in the pods. The pods should be collected when they are ripe: for their tannin-content reaches the highest level just as they are falling from the trees; it is inadvisable to wait to collect the pods from the ground, for they will then be contaminated with sand, clay, moulds and other undesirable matter. According to the conditions of the soil and the climate, their tannin-content varies from 20 to 30 percent. The material contains an undue proportion of nontans and a high proportion of sugary matter in the seeds. This results in a rapid fermentation of the liquor.

The bark of the *Acacia arabica* does not contain more than 14 percent tannin and is mostly used in northern India under the name of babul bark. The bark from old trees yields a very dark colored tannin. It is best, therefore, to strip from trees which are from five to seven years old. When babul bark is used for tanning, it gives a leather which has a darker color and a tendency to crack and tear; but when it is suitably blended with myrobalan (3:1) or with avaram bark, it can be used with advantage, particularly in sole leather tannage.

Avaram or *turwad bark* (*Cassia auriculata*) and *konnam bark* (*Cassia fistula*) have been used in southern India since time immemorial, and they were the foundation of the crust leather industry. The avaram bark contains from 15 to 17 percent tannin; the konnam bark contains only 10 to 12 percent. Both give a light colored leather: but, like all catechol containing tannins, it darkens when it is exposed to sunlight. The red color difficulty, however, can be solved if tanning is completed with myrobalans. Avaram bark is easily

soluble in water, but a big residue of less easily soluble tannin is often left unleached.

Avaram tanned leather is tough and almost untearable, while the final treatment with myrobalans and oiling increases weight and produces an extremely pale color.

Konnam bark, it is stated, gives a very smooth grained leather and a very pale color. Some tanners mix it with mimosa bark to produce a mellower tannage than is given by mimosa bark alone.

Pomegranate is the dried skin from the fruit of the pomegranate (*Punica granatum*). It gives a pleasant yellow, or red colored, leather. It is extensively used in North Africa and around the Mediterranean.

Besides the black wattle, which, as has been already mentioned, is used commercially for mimosa extracts and bark, at least three other types of wattle — *silver*, *green* and *golden wattle* — are available for the tanner.

The *Eucalyptus* group, so widely distributed over the world, is also a source of good tanning material. Mallet bark, which has been already mentioned, has a commercial importance. Another type of tannin extract called *myrtan* is derived from a plant of this family. A third type of eucalyptus is the red iron bark tree, and tanners can use not only the bark, but also the resinous exudate, which is called kino. This is an excellent, highly concentrated tannin. Many other eucalyptus trees produce similar tannin-rich exudates. *Ximenia*, *Avicennia* and *Bridelia* yield bark which contains 12 to 20 percent tannin.

Tara pods from *Caesalpina tinctora* contain tannin very suitable for sheepskins. They produce soft, nearly white leather. They are used extensively in North Africa.

Bauhinia, the camel foot tree, *Cassio*, the iron wood tree, and *Woodfordia* can all be used as sources of tannins.

Pine bark can be used extensively; it produces a light brown leather and contains sugars which assist fermentation.

The inner bark of a birch tree as well as larch bark can be used successfully.

Another tannin, called *Algarobilla*, comes from a similar plant grown in Central America and the West Indies. The pods have up to 50 percent tannin.

The galls of the tamarisk shrub contain up to 50 percent tannin. Guava, a common fruit-tree, has a bark which gives 30 percent tannin. Its leaves give 10 percent tannin.

Even some of the parasitic plants which grow on trees or shrubs — for example, *Hydnora* — yield tannin.

Tea leaves contain an appreciable amount of tannin. Owing to their high price, however, they cannot be used commercially.

The number of tannin-bearing trees and shrubs is enormous. None the less, the plants vary widely in tannin content; for this is affected by the prevailing climatic conditions, by the soil in which they grow, and by their age.

Once more it must be emphasized that when a tannery is started in a dry area, leaves, twigs or pods should be used rather than bark or roots. The damage done to the neighborhood by a rapid destruction of its trees can be far greater than the benefit derived from a new tannery.

Blends in vegetable tanning as used in India

The Central Leather Research Institute in Madras, India, has given particular attention to the use of blends for the vegetable tanning of hides and skins. Here follows a description of some useful blends.

Some blends for East Indian tanning of skins

Avaram bark is primarily used in the East Indian tanning of skins. Myrobalan nuts are used for topping the avaram tanned skins.

The avaram bark is partly or wholly substituted by konnam bark, babul bark and wattle bark. Other good substitutes are the newer tanning materials like vagai bark (*Cassia marginata*), eyal vagi bark (*Peltophorum ferrugineum*), vel velam bark (*Acacia leucophboea*), kodukkapuri bark or camachile (*Pithecolobium dulce*), hopea bark or iron wood (*Hopea parviflora*) and dhawa leaves (*Anogeissus latifolia*).

The following blends can be used for the East Indian tanning of skins:

Avaram	3	Konnam	2	Babul	4
Konnam	4	Dhawa	1	Wattle	1
Avaram	2	Avaram	4	Avaram	2
Konnam	3	Konnam	1	Babul	2
Wattle	1	Myrobalan	2	Wattle	1
Konnam	2				
Wattle	1				
Myrobalan	2				

Some blends for East Indian tanning of kips

The wattle bark is the main tanning material used in the age-old process of the East Indian tanning of kips.[1] The kips are also "myrobed" after wattle tanning. "Myrobing," incidentally, is the term used by tanners in southern India. It means a treatment with a tanning liquor which has been prepared from myrobalan nuts.

The wattle bark is substituted, partly or wholly, by avaram, konnam and babul bark, myrobalan nuts and wattle extract. Good substitutes are the newer tanning materials like karada bark, also called kodarsi (*Cleistanthus collinis*), goran bark (*Coriops roxburghiana* and other mangrove species), arjun bark, also called kahua (*Terminalia arjuna*), casurina bark, also called casagha pine (*C. equisetifolia*), kodukkapuri, vagai, eyal vagi, vel velam, hopea and dhawa.

The following blends can be used for the East Indian tanning of kips:

Karada	2-3	Karada	1	Karada	1
Myrobalan	1	Konnam	1	Babul	1

Karada, Goran, Arjun or Hopea 3 and Dhawa (Myrobalan) 1

Kodukkapuri	1	Kodukkapuri or Eyal Vagi	6
Konnam	2	Myrobalan	1

[1] See section on "General method of manufacturing East Indian tanned kips as widely practiced in India," in Chapter VI.

Vagai	2	Vagai	3	Dhawa	1
Konnam	1	Arjun	1	Konnam	2
Dhawa	1	Wattle	1		
Goran or Karada	1	Avaram	2		
		Babul	2		

SOME BLENDS FOR SOLE LEATHER TANNAGE

The wattle extract is the main tanning agent used in the East Indian sole leather tannage. It is substituted, partly or wholly, by quebracho extract, myrobalan extract, babul bark and divi-divi pods. Other good substitutes in the tanning of sole leather are karada, goran, eyal vagi, kodukkapuri, hopea and cutch extract.

The following blends can be used in sole leather tannage:

Wattle extract	3			Babul	3-6
Myrobalan extract	1			Myrobalan	1
Karada	3	Cutch extract	3	Eyal Vagi	4
Myrobalan	1	Myrobalan extract	1	Myrobalan	1
Hopea	6				
Myrobalan	1				

For the convenience of the tanner the blends are given on the weight of tanning materials which are to be blended.

One part of wattle bark on a tannin basis is approximately equal to wattle and myrobalan extract (0.5); myrobalan nuts, divi-divi pods and kodukkapuri (1.0); goran, karada, arjun and hopea bark (1.25); shawa leaves and eyal vagi bark (1.5); avaram, babul and vel velum bark (2.0) and konnam and casarina bark (3.0).

V. PREPARATION OF VEGETABLE TANNING LIQUORS

Grinding

Whether the tanning material is intended for use in its natural state, for dusting or for leaching, it must first be broken up by cutting or crushing. Large particles do not allow the tannin to be completely leached out, and it is advisable to use pieces which have been ground as small as possible. The rural tanner who uses small amounts can easily chop or grind the material to the required size.

If acacia pods are used, the seeds are undesirable because their high sugar content causes the tanning liquid to ferment too quickly. These seeds may be removed by riddling or by shaking the pods in a flat basket, thus separating them from the shattered pods.

Good results are obtained by using a wooden pestle and mortar for pounding the leaves, pods or fruit (Figure 29).

Small power-driven mills — in particular, for a group of co-operative organized tanneries — can also be used to advantage.

Leaching

In the tanning vats it is wasteful to use ground bark, leaves or pods, and it is difficult to control and to estimate the strength of the tanning liquor which is produced. Moreover, the rate of tanning with this material is very slow. It is advisable, therefore, to extract the tannins by a process which is called " leaching." This leached liquid or " tan liquor " can be used as and when it is required.

The aim of properly conducted leaching is:

(*a*) to extract the maximum amount of tannins from the tannin-bearing materials; and

(*b*) to prevent any injury to the infusion by contact with lime, iron or heat.

FIGURE 29. – *Pestle and mortar used for pounding acacia pods in Nigeria, to make best use of these tanning materials.*

Continuous production of tan liquor

The most economic and efficient way to make a continuous supply of tan liquor is to use a series of vats built in wood, brick or cement. Wooden casks or large earthenware pots are also useful.

The following rules should be followed:

1 At no stage must the tan liquor come into contact with iron or lime. Thus the vessels used to transfer the liquor, the ladles for stirring and the sieves for straining the liquor must all be made of one of the following materials: wood, earthenware, aluminium, copper, brass or basket work.

2. The water used for leaching must be rain water or soft and clean river water. If necessary, it must be filtered.

3. The bark must be completely covered with water during leaching to prevent oxidation for this causes dark tanning.

4. Although high temperatures assist leaching, boiling water should never be used.

Procedure

Six receptacles are filled with pounded or crushed material. On the first day, water is poured into the first vessel to cover the crushed material completely (Figure 30).

On the second day, the tan liquor which has been produced in the first vessel (A) is poured into the second vessel (B). Fresh water — hot, if possible — is poured over the disintegrated material in the first vessel (A) for its second leaching.

On the third day, the tan liquor in the second vessel (B) is poured into the third vessel (C). The tan liquor in the first vessel (A) is poured into the second vessel (B) and fresh water is poured again into the first vessel (A).

This process is repeated on the fourth, fifth and sixth days. One more vessel is used each day until all the vessels are in use. By this time, the material in the first vessel (A) will have been leached six times.

This material should now be exhausted. The tan liquor in the sixth vessel will be at the strongest because it has passed through all the six vessels. This liquor is now ready, and it is taken to the storage tank (Figure 30).

From the seventh day onwards, a spare vat is necessary when transferring liquors.

Now the battery is in full operation and the principles involved are:

(*a*) fresh material is used to strengthen the strongest liquor;

(*b*) fresh water — hot, if possible — leaches the weakest and nearly exhausted material;

(*c*) the strongest liquor goes to the storage tank; and

(*d*) after having been leached six times, the crushed and spent material is rejected.

In this way the tanner has made each day a definite quantity of strong tan liquor for his storage tank. From this tank he can draw liquor when it is required. He uses it to strengthen other liquor in any of the series.

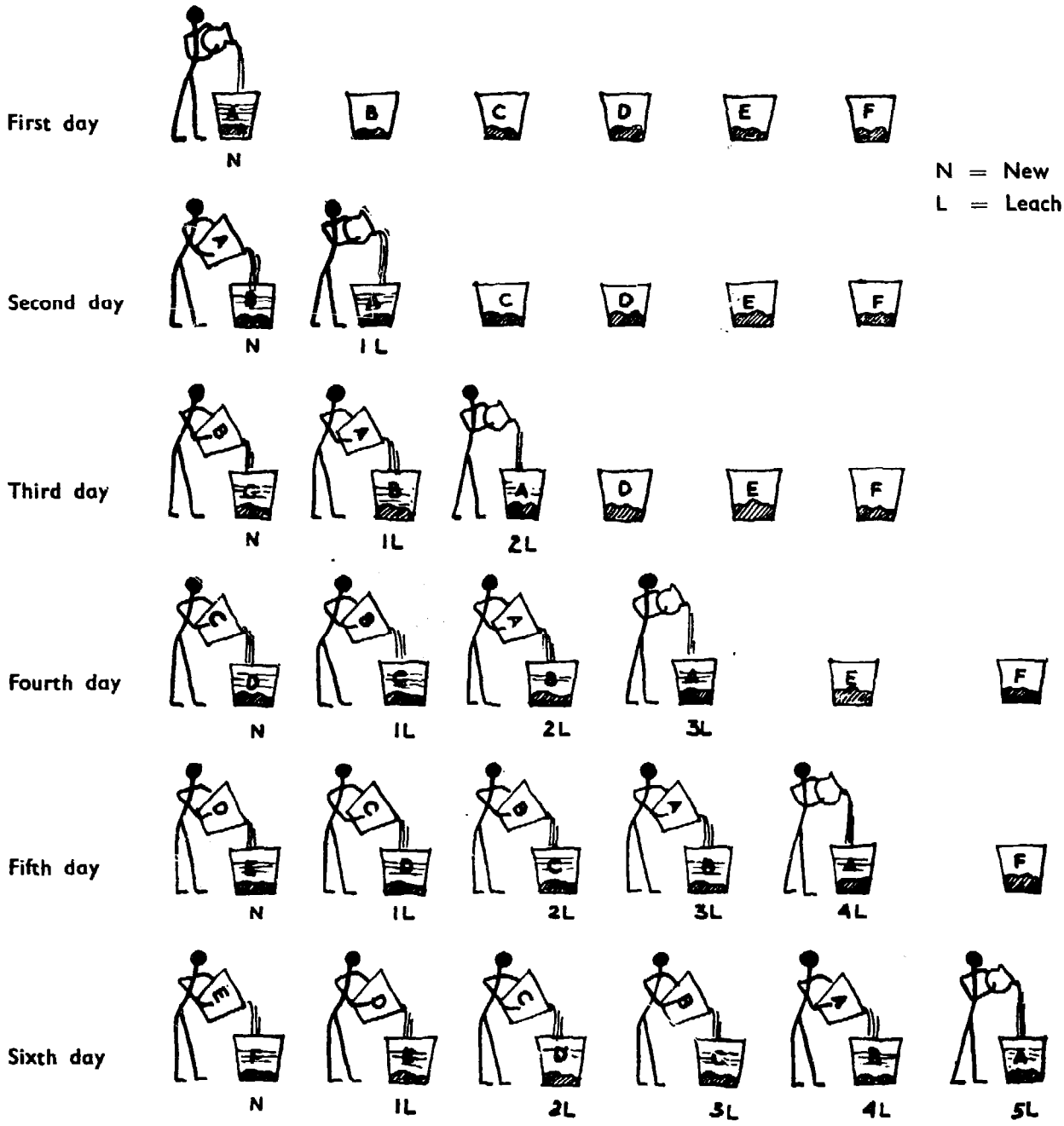
First day
N
Second day
N
1 L
Third day
N
1L
2L
Fourth day
N
1L
2L
3L
Fifth day
N
1L
2L
3L
4L
Sixth day
N
1L
2L
3L
4L
5L
N = New
L = Leach

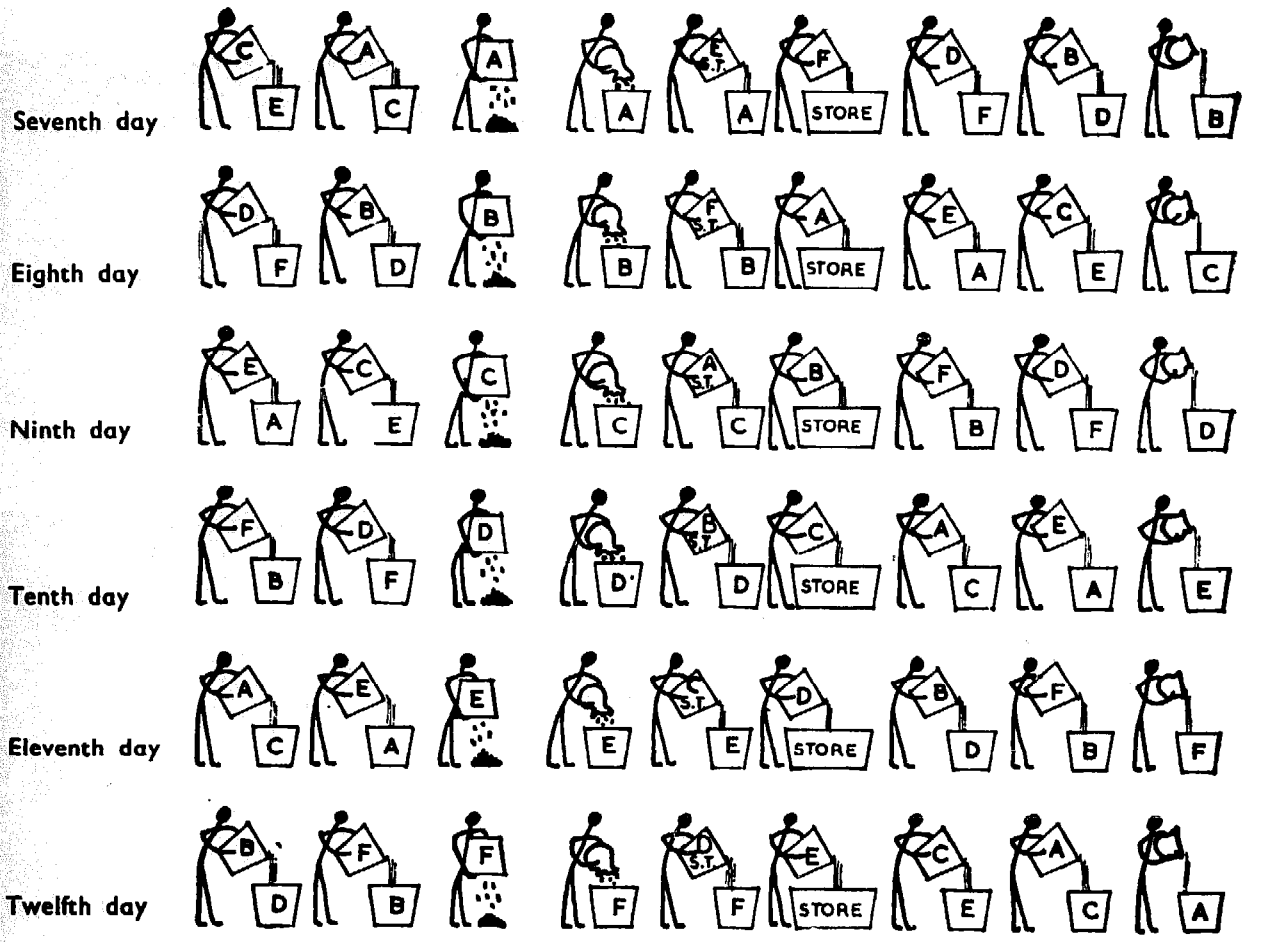

ST = Spare Tank

Thirteenth day like seventh, fourteenth day like eighth, and so on.

FIGURE 30. – *Schematic flow chart for the continuous processing (leaching) of vegetable tanning materials, showing which particular operations are performed in the battery of vessels during the consecutive days the process continues.*

Courtesy Mrs. Erica Mann

Commercial extracts manufacture

Large tanneries — anxious to save the time, installation, space and labor of leaching — prefer to buy concentrated extracts prepared in districts where the tannin-bearing plants grow. As a rule, wattle, cutch, mangrove, myrobalan, chestnut or quebracho extracts are used. They are marketed in two forms — as a thick liquid which contains about 40 percent tannin sold in barrels; or in a solid form which resembles toffee and contains up to 60 percent tannin. The use of tannin extracts saves transport and storage, and it allows the use of tan liquors at high concentrations.

The preparations of extracts in large factories is similar to the methods applied by the small rural tanner. The stages of production are grinding, leaching and concentrating.

Grinding

The material is chopped into small pieces by passing through a power-driven disintegrator or hammer mill.

Leaching

The ground material is put into leaching vats. By passing the liquid from one vat to another it becomes progressively stronger. In modern plants vacuum pans have replaced open vats. The highly concentrated extract is prepared at low temperature and out of contact with air.

Concentrating

In the concentrators most of the moisture is evaporated. At this stage the liquor may be drawn off and sold as a liquid extract which contains 35 to 45 percent tannin; or concentration may continue in large vacuum concentrators until the extract is toffee-like. It solidifies after it has been poured into bags. This solid extract contains up to 65 percent tannin. The application of commercially

prepared extracts is very simple: the required amount of liquor is made up by dissolving the extract in hot water, by passing live steam through it, or by steaming through copper pipes.

Use of the barkometer

Good tanning requires the use of a number of liquors which have increasing strengths. Rough results can be obtained by using different proportions of tannin-bearing materials with varying quantities of water. This method is still used in many countries. It is, however, very inaccurate; for the same tannin-bearing material from different places will yield different amounts of tannin. Waters, too, vary in their leaching properties, which depend on their temperatures and hardness.

A more accurate and easier way of determining the strength — that is, the concentration — of tanning liquids is the use of a barkometer, which is a special type of hydrometer.

A hydrometer indicates the specific gravity of a liquid. It consists of a long glass graduated stem with two glass bulbs. The lower, smaller bulb (Figure 31) is filled with mercury or lead shot. The larger upper bulb serves as a float, for it allows the graduated stem to stand vertically above the surface of the liquid.

When a hydrometer floats in distilled water at 15.6° C., it sinks to the mark 1.000 at the top of the scale. Thus it indicates the specific gravity of water at that temperature. This mark is the definitive standard for determining the specific gravity of other liquids.

For the barkometer used in tanning processes one degree barkometer (1° Bkr.) is by definition equal to a specific gravity of 1.001. Hence, 10° Bkr. equals a specific gravity of 1.010.

Whenever a barkometer is not available, a simple lactometer — an instrument used to measure the specific gravity of milk — can be used. The scale of a lactometer is marked with the same units as a barkometer, but it does not read above 38° or 40° Bkr., and it is unsuitable for the strong tan liquors used for sole leather.

A number of tanners and several textbooks use the so-called Baumé meter instead of the barkometer. The fixed points on the Baumé scale are 0, 10 and 66° Bé. These three fixed points are

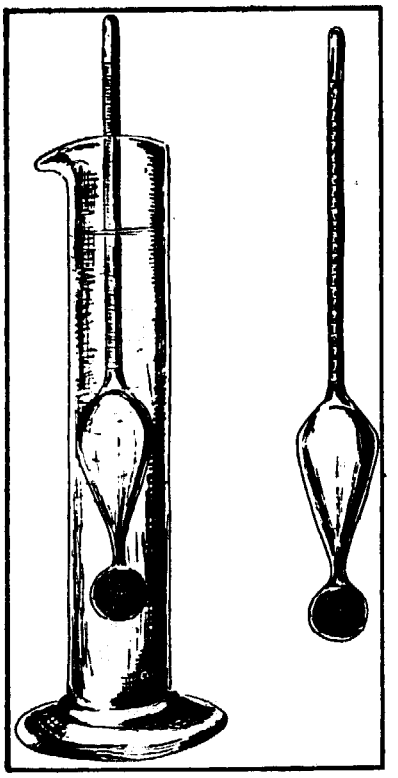

FIGURE 31. – *Sketch of barkometer and measuring glass.*

Courtesy Mrs. Erica Mann

found by floating the Baumé meter in distilled water (at 15.6° C.); in a 10 percent solution of sodium chloride; and in concentrated sulphuric acid (specific gravity 1.84).

Table 1 shows — through the use of any ordinary hydrometer — the conversion from specific gravity to barkometer reading and also to Baumé reading.

The use of the barkometer is very simple. Some of the tan liquor to be tested is put into a cylinder. The barkometer is then immersed and read off (Figure 31).

When the movement of both liquid and barkometer has stopped, the reading of the barkometer should be taken where the curved surface of the liquid touches the graduated stem. This reading varies with the temperature of the liquor. Some barkometers have a thermometer built into them. With others a separate thermometer can be used. The manufacturer of the barkometer encloses a table to compensate the readings for various temperatures when accurate laboratory conversions are required; but for normal tannery readings the use of the thermometer is not necessary.

TABLE 1. – CONVERSION FROM SPECIFIC GRAVITY TO BARKOMETER READING AND TO BAUMÉ READING

Specific gravity (s.g.)	Barkometer (Bkr.)	Baumé (Bé)
1.0007	0.7	0.1
1.0014	1.4	0.2
1.0020	2.0	0.3
1.0027	2.7	0.4
1.0034	3.4	0.5
1.0041	4.1	0.6
1.0048	4.8	0.7
1.0055	5.5	0.8
1.0062	6.2	0.9
1.0069	6.9	1.0
1.0076	7.6	1.1
1.0082	8.2	1.2
1.0089	8.9	1.3
1.0096	9.6	1.4
1.0103	10.3	1.5
1.0110	11.0	1.6
1.0117	11.7	1.7
1.0124	12.4	1.8
1.0131	13.1	1.9
1.0138	13.8	2.0
1.0173	17.3	2.5
1.0209	20.9	3.0
1.0244	24.4	3.5
1.0280	28.0	4.0
1.0316	31.6	4.5
1.0353	35.3	5.0
1.0389	38.9	5.5
1.0426	42.6	6.0
1.0463	46.3	6.5
1.0501	50.1	7.0
1.0539	53.9	7.5
1.0576	57.6	8.0
1.0653	65.3	9.0
1.0731	73.1	10.0
1.0850	85.0	12.0
1.1138	113.8	15.0
1.1578	157.8	20.0

One degree Bkr. is approximately equal to 0.3 percent solids. Thus 1 kilogram of dry extract dissolved in 300 liters of water gives a solution of 1° Bkr.

Other solid materials, however, will also dissolve, though they have no tanning property. They must be fully considered when reading the barkometer or the Baumé meter.

Basic principles of vegetable tanning

The principel of vegetable tanning is that when tannins come into contact with hide proteins, they combine and react together to form leather; and this completely new product is resistant to putrefaction.

Immersing hides directly into strong solutions of vegetable tannins causes the surface to tan so hard that the tannin cannot penetrate into the center. This can be compared to putting bread into a very hot oven, where it rapidly forms a crust, while the inside remains uncooked.

To be successful, therefore, vegetable tanning has to start with a weak liquor and gradually to progress to stronger liquors. This may be achieved in two ways:

(*a*) by passing the skins or hides through a series of vessels, each containing a stronger solution than the previous one; or

(*b*) by strengthening the liquor in the original container by adding more tannin to it.

It is essential first to use mellow tan liquors and to follow them by using astringent tannins.

By astringent is meant a liquor which causes the fibers to contract. Astringent tannins draw together the grain of the pelt and produce hard leather. Very astringent tannins may produce a leather which is untanned inside, because the pores were contracted too rapidly. This causes " case hardening," which is also called " dead tanning." Mimosa and mangrove are highly astringent tannins. Gambier, myrobalan and acacia pods, on the other hand, are mellow tannin, and they produce soft leather.

It should be noted that some modern methods of tannage appear to contradict these postulates, in that good sole or light leather is made by adjustment of the pH of the hides, which are then immediately immersed in strong liquors of 70° to 90° Bkr. with consequent rapid tannage but not casehardening of the surface, although such liquors would be ranked as very astringent. This is a special technique involving the use of strong extracts and it is best to consult the extract manufacturer before embarking on one of these seven-day sole leather tannages.

In the section on " Liming " in Chapter III it was explained that a " mellow " lime is one through which some hides have already passed, so that it has lost some of its sharpness. Tan liquors, which have lost their astringency because some hides have already been tanned in them, are similarly termed " mellow;" for they have a higher proportion of nontans than tans.

VI. TANNING OF HEAVY HIDES

Heavy hides are used for soles, harness and belting; and light hides and calf skins are used for shoe uppers.

In large tanneries completely independent treatment is given to each of these leathers. A tannery may, in fact, specialize in making one product only. Under rural conditions, where the market for a given type of leather is limited, it is better to adopt one simplified treatment for all types of hides. Thus there is a common initial treatment. Later, if sole leather is to be made, the bend will be cut from the side and treated further.

Sole leather

The tanning of heavy hides, especially for sole leather, is a lengthy process. It is sometimes controlled by the laboratory in a large tannery (Figure 32).

Generally speaking, three methods of sole leather tanning exist:

(*a*) pit tanning;

(*b*) combination (mixed) tanning;

(*c*) rapid tanning.

Pit tanning represents the old classical method of sole leather tanning. In the initial stages the pelts are tanned in the normal way; but the process is finished with bark in layaway pits. Though it depends on the tanning material which is available, the process can take up to one and a half years. The finished product is a high quality sole leather. There are now, however, only a very few tanneries

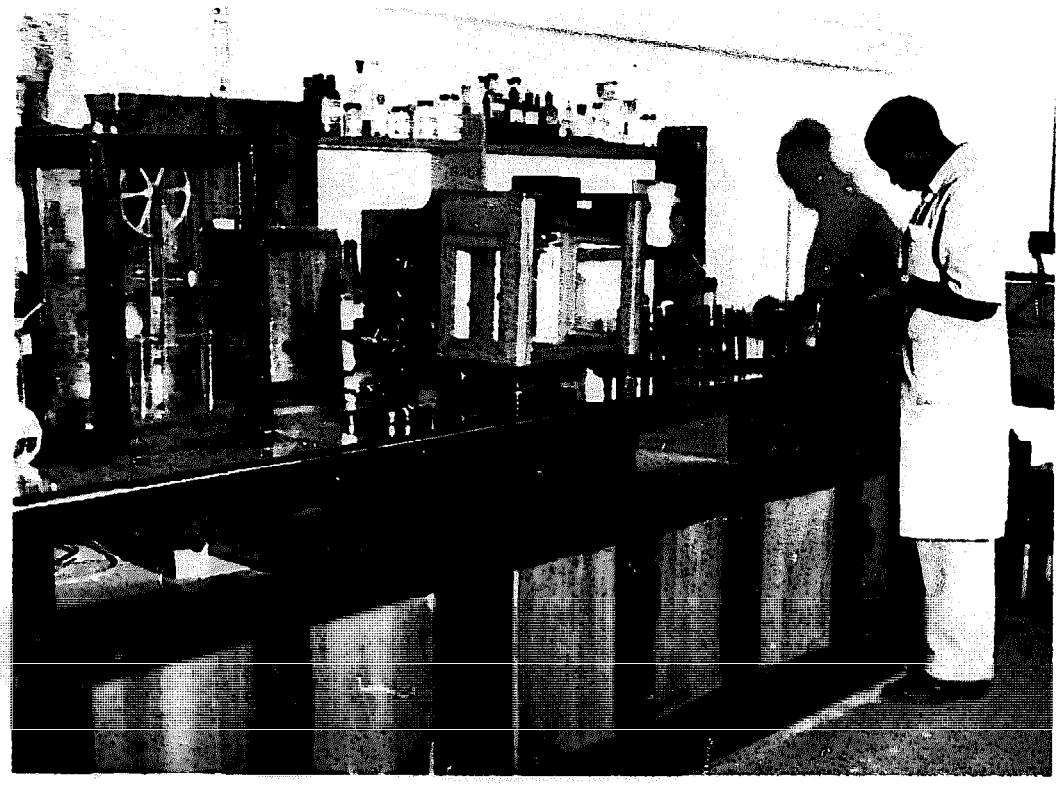

FIGURE 32. – *A testing and control laboratory as sometimes used in large tanneries.*

Courtesy Kenya Information Office, Nairobi

which still use this process. The reason is that the process requires very much labor and a high capital investment. Together they make the product rather expensive.

In the combination (mixed) tanning method, the pelts, in the initial stages, are tanned in the same way as in pit tanning, but the layaway pits are replaced by tanning drums (Figure 33). In some tanneries the finishing is done in hot pits instead of tanning drums.

In the rapid tanning method, after a short period of initial tanning, the process is finished in drums. This is very often followed by retanning (filling).

For a vegetable tanning, the drums should not make more than eight turns a minute, otherwise the hides and the tanning material could become too hot. At the beginning of the operation particularly, one has to be careful and it may be necessary to reduce the number of turns for hides which become hot.

The fundamental idea of pit tanning is universal, but it is natu-

FIGURE 33. – *Rural training center, Bakshi-ka-Talab, Uttar Pradesh, India. Drum tanning.*

rally adapted to tanning materials, climatic conditions and hide supplies in different countries. The consumer in a hot dry climate, it is obvious, demands an article different from the one demanded by a boot maker in the cold mountain districts in Asia or in Europe.

In the tanning of skins, the weight of the leather which is obtained has no importance for the tanner, for this leather is sold by the square foot or the piece, and not by the weight. Crust "East India" tanned skins, however, are sold by weight in London. Sole leather is also sold by weight. For this reason, the tanner aims at the fullest penetration and the maximum combination of all the tanning materials, so that the maximum weight and quality are obtained. Chrome sides and calf for uppers are often sold by piece or by the square foot.

The duration of the tanning process for hides is extremely variable. Many weeks, or even months, are required to achieve complete penetration and fixation of tannins through a thick, heavy hide. Very strong tan liquors are needed, and these, in turn, require skill in their preparation, unless tanning extracts are used. It is a mistake to attempt to make sole leather without proper investment and the necessary patience. Sole leather prepared by primitive tanners is often tanned superficially, while the center is still raw. Although this leather may look nice when it is dry, it starts to rot immediately it comes into contact with water.

When the initial tanning is too rapid, it is extremely dangerous. The outside becomes hard too quickly, it is termed "case hardening"

FIGURE 34. – *Suspender vats as used in large tannery.*

Courtesy Kenya Information Office, Nairobi

or "dead tanning" and this prevents the tannins from penetrating to the center, which remains untanned. Similarly, it is dangerous to use very astringent liquors too early for the sake of speeding up the tanning of sole leather; for this makes the grain drawn and wrinkled. Therefore, the tanning of sole leather must be a slow process. Attempts were made to hasten this process to save time and capital. This was achieved by the following method, which, until a few years ago, was still used in some English tanneries.

First, the butts are suspended for approximately 12 days in vats which contain tan liquors in progressively increasing strengths. These vats are called " suspenders," because the butts are suspended in the liquor on hoops of string fastened to wooden slats which rest on the walls of the vat (Figure 34).

The second operation takes place in other vats which are called " handlers." Here the butts remain for approximately six weeks. The name " handlers " comes from the frequent handling of the

goods. The butts are laid horizontally, grain side up, and they are taken out three times a week while the liquor is strengthened.

The third operation, which is called " dusting," consists in laying the butts in strong tan liquor, grain side up, one on top of the other, with a few handfuls of ground bark between them. This bark keeps the hides apart and replaces and replenishes the tannins taken up by the hides. When the " laying " and dusting are completed, the pack should be totally immersed. In these pits, which are called " layers," the hides remain for four to five weeks.

For the fourth stage — to obtain a good, hard, firm and heavy waterproof sole leather — the butts are transferred to the so-called "hot pits," where they are suspended in strong tan liquors of over 100° Bkr. at very carefully controlled temperatures (40° C.) and acidity.

The process can ruin the leather, unless the behavior of the particular extract is thoroughly known, and unless the conditions of hot pitting are accordingly adjusted.

The conversion of raw hide to finished sole leather is shown in the following timetable.

TABLE 2. – APPROXIMATE DURATION OF EACH PROCESS FOR THE MANUFACTURE OF SOLE LEATHER

Process	Time (weeks)
Soaking, liming, unhairing	2
Suspenders	2
Handlers	6
Layers	5
Hot pit	1
Drying, finishing, rolling	3
TOTAL	19 (or nearly five months)

Even today, despite the availability of highly concentrated extracts, the application of mechanical agitation, and a greater knowledge of the subject, the tanning of sole leather is a relatively slow process, and it takes not less than 12 weeks. In many countries, however, soft, pliable sole leather is required. Here the use of hot pits must be avoided, and the tanning is finished in layers.

Sole and other heavy leather

Without proper vats large enough to accommodate the hides, whether lying down or suspended, sole leather of good quality cannot be expected.

The vats required are:

Suspenders:	8, but preferably 10	
	Length:	1.5 to 2.1 meters
	Width:	1 meter
	Depth:	2 meters or more, according to the size of the hides.
Layers:	2 or 4	
	Dimensions:	as suspenders, or slightly wider to take sides (see below)
	Depth:	1 meter above ground level.

These pits could be built partly above ground level (about 1 meter), but the rest should be sunk into the ground. The vats may be built of brick, stone, concrete or wood, but no iron work or lime must be used; and it is unwise to sink large earthenware pots entirely into the ground (Figure 35).

Besides the making of sole leather, these vats can be used for uppers, harness and other leathers which in large tanneries have their separate vats. In large tanneries, as has been already explained, the bellies and shoulders are cut from the hides after liming and selected for sole leather. The butts are then tanned separately. The rural tanner, however, has little space available. He should adopt a method in which the sides for upper leather, harness or upholstery, and those for sole leather, are initially tanned together.

He can do this by cutting all hides, before they are suspended in the vats, into two halves and by tanning them as sides; the sole leather is tanned as bends and not as butts.

When the shoulders and bellies are tanned through, they are cut off and removed from the tan liquor. The remaining bends are transferred to the layers for a further tanning.

FIGURE 35. – *Vats made by sinking large earthenware pots into the ground. This practice is not recommended.*

Courtesy Kenya Information Office, Nairobi

The whole process is as follows: Sides are hung from sticks or slats by means of short strings, and they are completely immersed into tan liquor in the suspender. The first vat of tan liquor should have a strength of 5° Bkr., the next a strength of 9° Bkr. and so on until the last one, which has a strength of 33° Bkr.

The sides are left for two days in each vat. This makes a total period of 16 days. If they are very thick they should remain in each suspender for three days instead of two. The total period is then 24 days.

By this time the thinner sides for uppers, harness, saddle and upholstery leather should be ready. This can be tested by cutting through the thickest part of the hide to ensure that the actual center has been tanned completely and that no light-colored streak of raw hide remains.

When the shoulders are very thick, and when the hides are intended for harness or upper leather, they may need refleshing and shaving. They should be removed from the suspenders and refleshed on the third and sixth days, until the leather is of even thickness. Refleshing during the tanning operation, however, is not a practice to be recommended; it should have been done in the earlier stage.

The hides are taken out and moved up the series every other day. They are stretched and placed on boards over the vats to drain; and the first — that is, the oldest — vat is left empty and ready to receive fresh goods. While the hides are draining, the liquor is strengthened by rejecting some of the liquor from the first — the oldest — vat and by adding the stronger liquor from the second vat, and so on. Fresh, strong liquor, obtained from leaching, is added only to the last (eighth) vat. The bellies and shoulders in sides from which bends are to be cut for sole leather should also be ready. They should then be cut off, so that the bends are at hand for further treatment.

Whenever hard leather other than sole leather is required — for example, for harness making — the whole side may be treated in the layer vats, but only for one to three weeks.

The bends or sides are now transferred to layer vat No. 1, where they are laid flat, grain side up. A thin layer of ground tannin-bearing material is evenly spread over each — the operation is called " dusting " — and the next placed on top. This operation is repeated until all the sides of the same age have been placed in the layer vat. A piece of timber — or, better still, a piece of string — is placed on top of them to indicate where the batch ends, and a new pile is formed on top of the old one from the next batch. Strong tannin liquor — as strong, in fact, as it is possible to obtain by proper leaching — is poured into the vats until it covers the goods. It is advisable, however, to layer and to dust down in the liquor rather than adding liquor to dusted goods. In this way it is possible to avoid the air pockets which are otherwise difficult to press out from the bulk of the pack.

Twice weekly the sides are taken out of Vat No. 1 and piled into Vat No. 2, so that those which were on top in Vat No. 1 will now be at the bottom.

Once a week, when layering is completed, fresh ground tanning material is dusted over each layer, and the whole of the old material is removed. As the old material will not have been completely leached, it should be mixed with fresh bark and used again in the leaching vats.

According to the tanning material, the strength of the liquid and the thickness of the hide, the sole leather will be sufficiently tanned within three to six months.

General method of manufacturing East Indian tanned kips as widely practiced in India

This age-old East Indian tanning process, by which the largest amount of vegetable tanned leather in India is produced for export, makes use of wet salted cowhides.

These are first soaked in plain water for one to one and a half hours. They are then washed in four or five changes of water, drained well and weighed. After this, they are submitted to the liming process.

To straight lime liquor which has been used once — that is, liquor from which one batch of hides has been taken for fleshing — there is added 25 to 30 percent of slaked lime, based on the weight of the soaked hides. This amount can be added in one lot or in two equal installments during the first liming period — that is, before unhairing the hides. The hides are put in, one after another, hair side up — except for the topmost one, which is put in flesh side up — and they are left in the lime liquor for one hour. They are then hauled; the lime liquor is stirred and the hides are returned to it and left overnight. They are kept in this liquor for eight to ten days. During this period they are hauled every day and the lime liquor is stirred up. On the last day, the hides are unhaired.

They are now relimed in a fresh bath, to which is added 12 to 15 percent of slaked lime, based on the weight of the soaked hides. They remain in this new lime liquor for four days. During this period they are hauled; the liquor is stirred up and the hides are put back every day. This time, however, all hides — with the exception of the bottom one — are laid flesh side up. On the evening of the fourth day, they are taken out of the lime liquor and left overnight in plain water. They are fleshed by hand over a beam on the next day and then weighed. After this, they are washed and trampled in several changes of water, scudded and left in water overnight.

On the following day, they are again washed and trampled and lightly fleshed a second time. After this operation, about 57 grams of sulphuric acid (specific gravity 1.84) per hundred, based on the fleshed pelt weight, are added to the water. The hides are trampled in this for about ten minutes, scudded, washed two or three times, scudded again, washed twice more and scudded once more. They are piled to drain and then trampled for about 15 minutes in a bath

containing 85 to 113 grams per hundred of sulphuric acid and 4 to 5 percent common salt, based on the weight of the pelt (pickling). The hides may now be washed, and they are ready for tanning.

Old bark liquor, to which fresh bark or mixtures of bark and extracts are added, is always used at first. The old bark is removed from the vat; the clear liquor is decanted into another vat, and a very small quantity of bark and extract mixture is added and left overnight. On the following day, the required quantity of bark or bark and extract, containing 8 percent tannin, is soaked in this liquor. This 8 percent is calculated on the fleshed weight of the hides and represents about half the total amount of tannin required for the complete process. The total amount required is 17 percent.

For instance, if a mixture of wattle bark, mimosa extract, konnam or babul — instead of konnam — bark is used, the total amount of tan stuffs required for the first and second tanning should have at least 17 percent tannin, based on the fleshed pelt weight. To yield 17 percent tannin, it must be remembered that wattle bark contains 6 percent tannin; mimosa extract contains 3 percent tannin; and konnam or babul bark contains 8 percent tannin.

When uncrushed konnam or wattle bark is used, it is advisable to cut this into small pieces; big pieces should be soaked in water for a short time first. In any event, barks should be passed through two or three changes of water to remove any adhering dirt. They should then be soaked in liquor, as has been already mentioned, and stirred several times.

The delimed hides are dipped in this liquor one by one; they are moved to and fro for a few minutes, and then they are immersed and pressed down to the bottom of the pit. After five minutes, they are hauled and returned to the liquor. This operation is repeated after 10 or 15 minutes, while the bark is kept at the bottom of the pit and the remaining half is kept at the top of the tan liquor. On the following day, the hides are hauled once in the morning and once in the afternoon and returned to the same liquor. If the hides, when hauled in the afternoon appear to be pulled down too much, they are laid grain sides together into the liquor and bark is sprinkled on the flesh sides.

On the third or fourth day, they are beamed on the flesh side. They are then returned to the same liquor, hauled after ten minutes and returned once more to the liquor with bark sprinkled on the

flesh side. They are kept in this liquor for four days. During this period they are hauled once every day in the manner which has been already described. On the last day, the hides are taken to the second bark liquor.

For this liquor, bark or bark and extract mixtures containing 8 percent of tannin, based on the fleshed pelt weight, is used. The tanning material should be soaked in old liquor for a day or two before it is used.

The hides which have been removed from the first bark liquor are beamed, wrung out and placed, one by one, into the second bark liquor. They are hauled after five or ten minutes and returned, one by one, to the pit, and bark is sprinkled between them.

They stay in this liquor for five days. During this period, they are hauled and returned to the pit once daily, while bark is sprinkled in between them. If, at this stage, the hides appear to be flaccid, they are beamed and returned to the liquor, to which a little bark or extract, or both, is added.

The goods are left in this liquor for another seven or eight days and again they are hauled and put back every day. On the last day, they are kept in a pile in the same liquor; and half the bark is kept at the bottom of the pit or vat, and half is kept on the top. The pile should not be disturbed for 24 hours.

For myrobing, the goods are soaked overnight in hot water, to which is added the required amount of crushed myrobalan of good quality. The amount is calculated to be from 187 to 248 grams for every kilogram of expected leather; and this is, on an average, 45 percent of the fleshed weight of the pelt. On the next morning, this liquor is diluted to the required strength, with cold water.

The hides are rinsed with plain water, wrung out, dipped, one by one, into the myrobalan liquor and placed into another tub nearby. When all the hides are thus dipped, they are left in a pile for five to ten minutes. After this, they are hauled and put back in a pile in either the same or another tub, and the myrobalan liquor is poured over them. On the next morning, the hides are hauled and returned to the same liquor.

On the same day, an amount of crushed myrobalan, equal to the first, is soaked in hot water in a separate tub and left overnight.

The hides are beamed, wrung out and put into this second myrobalan liquor. On the following day, the color of the hides is examined: if they have too much myrobalan color, they should be rinsed with water or with the same myrobalan liquor diluted with water. They are then beamed and oiled.[1] Heavy hides are wrung out first.

The hides are oiled on the grain side — as a rule, with pungam oil — and they are piled one on the other. A thick, syrupy paste is prepared from one part Epsom salts (magnesium sulphate), one part glucose and two parts corn flour. This is applied on the flesh side, and then each hide is hung to dry. When semidry, the hides are piled again and left overnight. Next day they are set out on the flesh side, on a wooden plank or table, with a stainless steel or brass slicker.

If a light-colored flesh side is required, a thin corn flour paste should be applied to it. If more weight is wanted, a thick paste is prepared from one part Epsom salts (magnesium sulphate), one part glucose, two parts corn flour and sufficient water, and it is applied to the flesh side. These pasted hides are set on the grain and hung up until they are semidry. They are then lightly slicked on the grain, folded along the back bone with the grain side in and dried completely. The dry hides are again lightly slicked on the grain to produce a gloss. They are then trimmed and sorted into grades.[2]

Vegetable tanned sole leather by rapid pit tanning process

In this process, as developed by the Central Leather Research Institute in Madras, wet salted local buffalo hides, which weigh from 18 to 23 kilograms each, are soaked in plain cold water for a period of 6 hours after the excess salt has been removed. The hides are then cut into sides which are washed in 4 changes of water. They are trampled during each change.

They are limed in once-used second lime liquor with the addition of 6 percent of slaked shell lime powder. Handle the sides twice. Next day haul them up and add to the same bath 1 percent sodium sulphide (60 percent fused), which has been previously

[1] See Chapter IX.
[2] See Chapters IX and X.

dissolved in hot water. Put the sides in this sharpened lime liquor and haul them the same evening. Afterwards return them to the same liquor. Next day the sides are unhaired and relimed.

In the second liming operation, the sides are put for a further period of two days into a fresh bath, to which has been added 12 percent slaked lime powder and one percent caustic soda.

On the first day the sides are hauled twice. Next day they are hauled only once. They are fleshed, weighed and washed; and then they are left overnight in plain water.

Up to fleshing, the percentages are all based on the wet salted weight.

Next day trample the sides for a period of 15 minutes. Then scud and leave them overnight in plain water. On the following day, the sides are again trampled for a period of 15 minutes. Then they are scudded, washed and delimed with 1.5 to 2 percent of sodium bisulphite, which has been dissolved separately in cold water. This should be added to the bath over a period of 15 minutes if it is done in drums, or 30 minutes if it is done in pits. Drum the sides, or trample them, until the cut section of the butt when tested with a 1 percent alcoholic solution of phenol phthalein shows that one quarter of the total thickness is delimed. When this is so, add to the same bath a diluted solution of formic acid and use 0.75 to 1 percent, or 170 to 227 grams per hundred of sulphuric acid (specific gravity 1.84). Drum the sides, or trample them, until the cut section of the butt shows that one third of the total thickness is delimed. Then the sides are lightly scudded, rinsed with plain water and taken to suspenders.

The vegetable tanning process is as follows: the sides are suspended and tilted several times in an old liquor of 10° Bkr. strength and a pH of about 5 to 5.5.

The procedure is repeated on the following day. When it is completed, the sides are beamed on the flesh side. They are then laid flat in a tan liquor of 20° Bkr. strength: and only mimosa extract is used. They are handled once in the evening, and then as follows:

third day – piled and transferred to 30° Bkr. liquor
fourth day – beamed and put back in the same liquor
fifth day – piled and transferred to 40° Bkr. liquor

sixth day – beamed and put back in the same liquor
seventh day – piled and transferred to 70° Bkr. liquor
eighth day – beamed and put back in the same liquor
ninth day – piled and transferred to 100° Bkr. liquor
tenth day – beamed and put back in the same liquor

On the eleventh day the sides are piled, drained well and dipped in a myrobalan liquor of 60° Bkr. strength. This liquor is prepared a day beforehand by soaking in hot water and by using 25 percent of the powdered myrobalan nuts. On the twelfth day, the sides are hauled and put back in the same liquor. Leave the goods in the same bath for one day more. Now the sides are washed on both sides with plain water and piled for two days, while kept grain to grain and well covered.

In the oiling operation which follows, the sides are first drummed for 15 minutes in a slowly revolving drum with the addition of gum tragacanth paste, using 57 to 85 grams per hundred of the gum. Then add 2 percent of Epsom salts (magnesium sulphate) and drum again for 15 minutes. Then add one percent glucose. Drum for 15 minutes. Then add a mixture of 3 to 4 percent of raw pungam oil and 1.75 percent sulphonated pungam or castor oil. Drum the sides for half an hour. Stop the drum for half an hour, and again drum the sides for another half an hour. Then the sides are removed from the drum and hung to dry. When sammed, the sides are set well and again hung to dry. Again set twice before the drying is complete.

The percentages — from deliming to oiling — are all based on the fleshed pelt weight.

Finally, the dried sides are seasoned and rolled in the usual manner, which involves the use of casein solution, soap, linseed mucilage and gelatine. They are then rolled on and rolled off. The yield obtained is 53 percent, based on the fleshed weight.[3]

For another process of rapid tannage of sole leather, which has also been developed by the Central Leather Research Institute in Madras, wet salted buffalo hides with an average weight of 20 kilo-

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[3] See Chapters IX and X.

grams are suitable. They can be green, wet salted, dry salted, or dry cured. Their weights correspond to the wet salted weight which has been already mentioned. Green and wet salted hides are thoroughly washed in two or three changes of plain water, cut into sides and then put into the liming process. For dry salted and dry hides, the soaking period may vary between 24 to 72 hours, according to the condition of the hides and the efficiency of the soaking agents which are used. The best proportion of soaking agents are 100 grams of caustic soda or 200 grams of sodium sulphide (60 percent fused) for 100 liters of water. It is advisable to add 50 grams of bleaching powder.

Liming is done first in once used liquor, to which are added 10 percent slaked lime and 0.5 percent of sodium sulphide, based on the soaked weight of the hides. The goods are handled and replaced three times a day for four days.

On the fifth day, the sides are unhaired and put into a new lime liquor. This is made up of 10 percent slaked lime and one percent caustic soda and about 400 percent of water, based on the soaked hide weight. The sides are kept in the liquor for four days, and meanwhile they are handled and replaced three times a day.

On the ninth day they are fleshed, washed well and weighed to determine the limed pelt weight. The new lime liquor now used is the once-used lime liquor for the next pack of hides.

The sides are delimed in a pit in which 0.5 percent boric acid, based on the pelt weight, is used. They are kept overnight in the deliming bath. Next morning they are handled again. A fresh amount of 0.5 percent boric acid is added to the bath until one quarter of the thickness of the pelt both from the grain and the flesh side is delimed, as tested by a one percent alcoholic solution of phenol phthalein. At this stage, the sides are ready for tanning.

They are put into the first suspender liquor, which is a mellow one of 7° Bkr. and made from wattle bark or mimosa extract. They are handled in this liquor for the day and kept overnight. Next day they are transferred to the next pit. This contains the second suspender liquor, of which the strength is increased by 2° Bkr. In this way the sides are passed successively every day through 7 suspender liquors. The strength of the liquor of each succeeding pit is higher by 2° Bkr. than the previous one, and the last suspender liquor is of 19° Bkr. There the preliminary treatment in suspenders is completed. From the last suspender, the goods are taken out and

made ready for subsequent operations. Thus the total time of tanning in suspenders is seven days.

The material is tanned in 30° Bkr. liquor in a drum for eight hours. The drumming is intermittent, and the material is left stationary overnight in the drum. The liquor is strengthened to 40° Bkr. on the second day and again drummed intermittently for eight hours. Overnight the material is left stationary in the drum. Thereafter drumming is continued, and the strength of the liquor is increased by 20° Bkr. after every two days. Drumming is intermittent for eight hours each day; and each day the strength is adjusted until the material has been tanned in 80° Bkr. for two days. Total drum tanning from 30° to 80° Bkr. takes six days. The speed of the drum is 4 revolutions each minute. The strong liquor is made from mimosa extract, which was dissolved in a suitable quantity of hot water in a pit. At the end of this period, the tanning is complete. The goods are taken out and horsed up for a day. Further operations follow, and they are now described.

The tanned sides are bleached with a solution of a bleaching syntan, 0.5 percent oxalic acid and 10 percent water, based on the weight of the leather. The duration of bleaching is one hour. The bleached goods are rinsed and treated with a myrobalan liquor.

The sides are handled in myrobalan liquor of 30° Bkr. for two days. The goods are kept for a further period of one day in the liquor, grain to grain and without handling. On the fourth day the sides are taken out, scoured, washed well and then piled up to drain. The goods are next oiled on the grain with pungam oil (3 percent, based on the weight of the goods) and the flesh sides are coated once with a paste made up of 2 parts of flour, 2 parts of Epsom salts (magnesium sulphate), 2 parts of glucose, 1 part of china clay and 4.5 liters of water. They are hung up to be sammed.

The sammed sides are set out twice, either by hand or machine, and dried.

The dry sides are finished on the grain side with a mixture which is 3 parts of casein, 0.75 part of borax, 6 parts of soap, 3 parts of linseed mucilage and 80 parts of water.[4]

The casein is dissolved in hot water with borax, and the linseed mucilage is extracted with boiling water alone. The solution of

[4] See Chapters IX and X.

soap is made with hot water. The three solutions are mixed together. They are applied on the grain side of the leather with a brush and dried.

The sides are now rolled twice — first with light pressure, and then with a heavy pressure.

The leather is now ready for the market. The total period of tanning — from raw to finish — is 26 days. The yield of leather is 55 percent, based on the limed pelt weight.

Rapid East Indian tanning of cowhides

The reader is referred to the section on "Rapid East Indian tanning of sheepskins and goatskins" in Chapter VIII.

The method described in this chapter — notably the pretanning and tanning procedures — can also be applied to wet salted cowhides. There are, however, the following differences.

The soaked hides are put in a lime liquor which contains ½ old liquor, ½ water, 10 percent lime and 1 percent sodium sulphide, based on the soaked weight.

The hides remain in this liquor for three days with daily handling. On the fourth day, they are unhaired and put in a new lime liquor which contains 10 percent lime and 85 grams per hundred caustic soda, calculated on the soaked weight. They are handled for three days. On the seventh day, they are fleshed, scudded and put in plain water overnight. Next day they are again fleshed and scudded and delimed fully with 0.5 percent boric acid, based on fleshed weight. When fully delimed they are scudded, washed with water, trampled twice and pretreated.

One of the two pretreatments which are later described for skins can be used for hides.

The pretreated hides remain in the first bark liquor for five days and in the second bark liquor, according to the thickness of the hides, for five to six days. Tanning materials such as konnam, babul, wattle bark and wattle extract are used. They are blended in suitable proportions, and they contain 16 percent tannin, based on the fleshed weight. They are divided equally between the first and the second bark liquor.

For myrobing, 360 to 500 grams of good quality myrobalans per

kilogram of expected yield are used, and the tanned hides remain in this liquor for two days. Then they are wrung out and beamed. The expected yield is generally 45 percent, based on the fleshed weight.

A solution of Epsom salts (magnesium sulphate) is sprinkled on the flesh side and well rubbed, and the hides are piled for oiling. About 2 percent Epsom salts on the expected yield can be used. The hides are then oiled with pungam oil and hooked. When sammed, they are set well on the grain and folded along the back bone, while the grain side is kept inwards. Again they are dried completely. The dried hides are lightly slicked on the grain to produce a gloss. They are then trimmed and sorted into grades.[5]

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[5] See Chapters IX and X.

VII. IMPROVED RURAL TANNING IN INDIA

Rural tanning has been practiced in India since time immemorial by villagers who belong to the leather-working caste of *Chamars*. For generations, their tanning techniques have been handed from father to son.

It is estimated that village tanners, who are spread out over this vast subcontinent, process annually 8 to 9 million hides and 3 to 4 million skins. They handle both buffalo and cattle hides. The processes which they have developed over the ages are quite different from those used in the large leather factories of India. Large quantities of leather for the manufacture of village footwear and leather goods, for instance, are still turned out today by the so-called "bag-tanning" technique. As a rule, unfortunately, this leather is of poor quality; for it is spongy and overstretched, and it has a low resistance to water.

In the northern state of Uttar Pradesh, special efforts have been made to organize the rural tanners into co-operatives, and many village tanneries have been organized in this way. They are located at suitable distances from the villages and they are a far cry from the old, primitive cottage tannery-cum-living quarters. They are built of permanent materials, such as bricks, and equipped with pits, drums, bark crushers and leaching pits. They have adequate supplies of water, good drainage, oil powered engines and facilities for proper drying and storage.

Operations, such as soaking, liming, deliming, tanning and retanning, are carried out communally under the supervision of trained personnel. The village tanner is able not only to produce quality leather, but also to build up some working capital for still further improvement.

The Central Leather Research Institute in Madras has developed and introduced new techniques to improve the quality of bag-tanned

leather, and it has made this leather more wear-and-water resistant by the incorporation of resins and syntans — that is, any synthetic high molecular compound which is able to tan.

Soaking

Well-soaked hides should contain about 60 percent water by weight. The soaking back of air-dried hides is accelerated by the addition of 1 to 2 kilograms of caustic soda to each 1,000 liters of water.

During the first day of soaking only half this amount is added. The other half is added on the following day to ensure a gradual soaking back of the dried hides. The soak pits should be large enough to take the dry hides in their "full spread;" for, at this stage, folding can cause permanent damage to the goods.

When the hides are considered sufficiently soft to withstand mechanical action, they are worked in a drum for about half an hour. Drumming, it is necessary to point out, must not be carried out for longer periods; for the frictional heat developed during the operation may permanently damage the hides. Drumming in running water is safe as well as effective, but the operational costs may be high. Where water is scarce, it is let in through the hollow axle of the drum and let out through a lattice door, which replaces the normal water-tight door.

As a rule, drumming is followed by what is known as "breaking over the beam." In this operation, the hides are thrown over scudding or fleshing beams, flesh side up, and they are worked all over with firm, but smooth, strokes with the blunt edge of a scudding knife. This helps greatly in softening the hides which are then returned to the soak pits and kept there until they are judged to be soft enough and ready for liming.

They are then removed, piled on the rims of the pits to drain for one hour, and weighed; and their weight is recorded.

Liming

Hydrated lime is becoming more frequently used in the small rural tanneries. It is easier to handle, and when it is packed in smaller quantities in paper bags, it does not deteriorate so quickly.

About 6 percent of hydrated lime, calculated on the weight of the soaked hides, is used. Sometimes, strong alkalies like caustic soda or sodium sulphide are added to the lime liquor; but these should be used carefully, for they cause excessive swelling (plumping) and loss of valuable hide substance. A quantity not exceeding 2 percent, based on the soaked hides weight, improves the liming effect.

In more progressive rural tanneries, however, increasing use is made of a lime — sodium sulphide paste. This involves using 6 kilograms of hydrated lime and 0.6 kilogram of sodium sulphide (60 percent, fused) per 10 liters of water. This paste is generally used for liming light hides and skins, when their hair or wool has to be saved. It is painted on the flesh side, and its concentration permits a maximum of 24 hours of piling. After this time, the hair should be loosened. There should be no excess paste liquor, but ample draining facilities should be available.

Tanneries possessing paddles (Figure 36) lime by keeping the liquor to goods ratio as 4 to 1. Where drums (Figure 33) are used, the ratio may be 2 or 3 to 1. The amount of sodium sulphide (60 percent fused) lies between 2 and 4 percent, while the quantity of lime is about 2 to 6 percent, both based on the weight of drained soaked hides.

If hair is of no value and drums are available, a pack of hides may be drum-limed in a float of 200 percent water, 2 percent hydrated lime, 4 percent sodium sulphide (60 percent fused) and 10 percent common salt, calculated on the " green " or soaked weight of hides. Drumming should be intermittent — that is, one or two minutes every hour — for 24 hours at a speed of 1 to 2 revolutions each minute.

Pit liming in fresh lime liquor for one or two days may follow, but liming should be cut down to the minimum for all upper leathers.

In paddle liming, 5 percent hydrated lime, 3 percent sodium sulphide (60 percent fused) and 20 percent common salt can be used to 400 percent water.

Paddling is done intermittently for 24 hours. Pit liming for one or two days may follow, if this is considered desirable.

Soft and supple leather is obtained by a liming process in which lime is predominant; for sole leather, pasting with sodium sulphide-lime paste followed by unhairing and an additional pit liming is also to be recommended. Painted hides may be washed before pit liming to prevent the sodium sulphide from being moved forward into the lime.

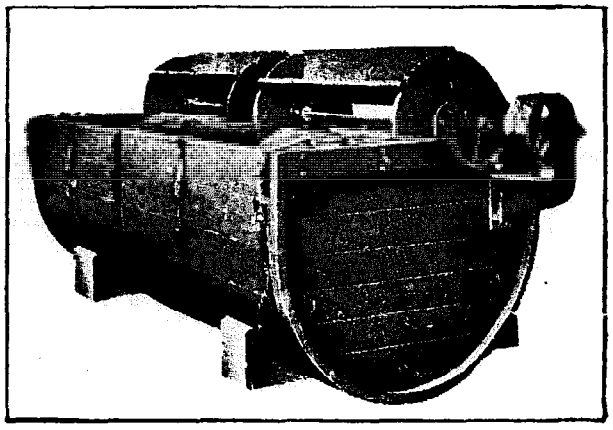

FIGURE 36. – *Paddle used for liming, deliming, and eventually pretanning operations.*

Unhairing and deliming

Most of the hair remains on the hide during the liming process; and unless drumming or other mechanical means are employed to lime and unhair at the same time, human action will be needed. The hide can be placed over a flat stone on the ground or, preferably, over a beam and (Figure 23) worked over with a blunt knife or a proper unhairing knife. Indian rural tanners use a sharp, half-moon shaped knife, which they call a *rumpi* (Figures 37 and 38).

To reduce the plumping effect and to make the pelts more flaccid, the hides are kept in cold water which is softened with a little lime for some time, before cleaning the grain or scudding begins. This also prevents their exposure to the atmosphere, which can cause lime blast.

Scudding is generally carried out before deliming and also, when it is considered necessary, after deliming or bating.

To prevent any formation of lime blast on the hides before deliming, it is a good practice to add some lime liquor to every water vat, if the water is " naturally hard."

Complete deliming is not essential for producing sole leathers by the bag-tanning process, although washing is necessary to remove any loosely adhering lime. The usual period of washing in running water is 30 minutes. After that time, there will still be about 70 percent of the total quantity of lime, calculated on the dry weight of the pelt, left in the hide. To remove this lime, drenching is applied; and the pelts are immersed and left to soak overnight in water at 35° C., which contains bran. They are taken out on the following

FIGURE 37. - *Village tanners in India fleshing hides with half-moon-shaped* rumpi (*see also Figure 38*).

morning if — through the formation of gases in the fermentation process — they are found to be floating on the surface of the liquor.

Another method of deliming is to move or paddle the pelts in water which contains an organic acid, until they are completely delimed and show a neutral cut.

This is more rapid; for one hour's treatment with 1 percent acid based on the limed weight of the pelt may be sufficient. This process can be controlled more effectively, but many rural tanners prefer the former method; for they claim that it produces a fuller and cleaner piece of leather. Moreover, deliming with fermented infusions is cheaper.

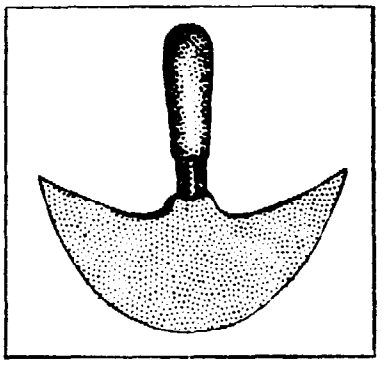

FIGURE 38. - *The* rumpi, *a half-moon-shaped knife widely used in Indian rural tanneries for fleshing operations.*

Bag tanning

An earlier description of the production of sole leather showed that the process is costly in space, equipment and time: to obtain a good product, great skill and patience are needed.

Bag tanning can be used with advantage wherever equipment and funds are in short supply. In this system, the hide is not tanned in a vessel, but is sewn up in the form of a bag, which is filled with bark and tanning liquor and suspended from a beam (Figures 39 and 40). By this ingenious method of using the hide itself as a tanning receptacle, leaching and tanning can be combined in one operation.

In bag tanning only vegetable tanning materials which are easily available in India are used. The most common are listed in Table 3.

TABLE 3. – RAW VEGETABLE TANNING MATERIALS AS COMMONLY FOUND IN INDIA, AND THEIR TANNIN CONTENT

Material	Approximate tannin content (percentage)
Avaram, or tarwar (*Cassia auriculata*)	14-18
Aonla bark (*Emblica officinalia*)	12-20
Babul bark (*Acacia arabica*)	11-18
Dhawa leaves (*Anegeissus latifolia*)	12-20
Gothar fruit (*Zizyphus xylopyra*)	10-20
Goran bark (Ceriops and other mangroves)	18-25
Kahua bark (*Terminalia arjuna*)	12-18
Karaunda leaves (*Carissa opaca*)	8-10
Myrobalan nuts (*Terminalia chebula*)	27-45
Sal bark (*Shorea robusta*)	7-10
Sonari bark (*Cassisfistula*)	10-12
Green wattle bark (*Acacia decurrens*)	24-35

The most important tanning material for the processing of bag-tanned sole leather is a mixture of babul bark and myrobalan nuts in a ratio of 3 to 2.

Other mixtures are also in use, such as babul bark (50 percent), dhawa leaves (20 percent) and gothar fruit (30 percent); or dhawa leaves (20 percent), karaunda leaves (25 percent) and aonla twig bark (15 percent); and so are many other mixtures of local importance.

FIGURE 39. – *Bag tanning as practiced in Indian co-operative rural tannery. The buffalo hides are suspended from a beam, the liquor oozing into a cement vat from which bags are refilled.*

The babul tree is used for timber and fuel in northern India, and its bark has been easily available as a by-product. Unfortunately, many trees have been felled all over the plains; and now bark supplies are short. The recognized types of myrobalans are: Jubbulpores (Js), in the State of Madhya Pradesh; Rajpores (Rs.) and Bimlies (Bs), in the States of Madras and Bombay.

Babul bark is collected by villagers in their spare time from November to March. The best month in which to collect myrobalans is January. Earlier collection gives inferior fruit, and later gathering is unwise.

Fleshy myrobalan nuts with small stones are better than those with bigger stones; for the flesh is rich in tannins, while the stones contain less. It is an advantage, after they have been collected in the field, to crush the dried myrobalan nuts and thus to remove the stones. Adulteration, however, has taught the tanner to be chary. The crushed myrobalan would become more popular, if only adulteration could be more easily detected.

The nuts are highly valuable for fixing the color of hides and skins and, in particular, for the final treatment of the so-called " East

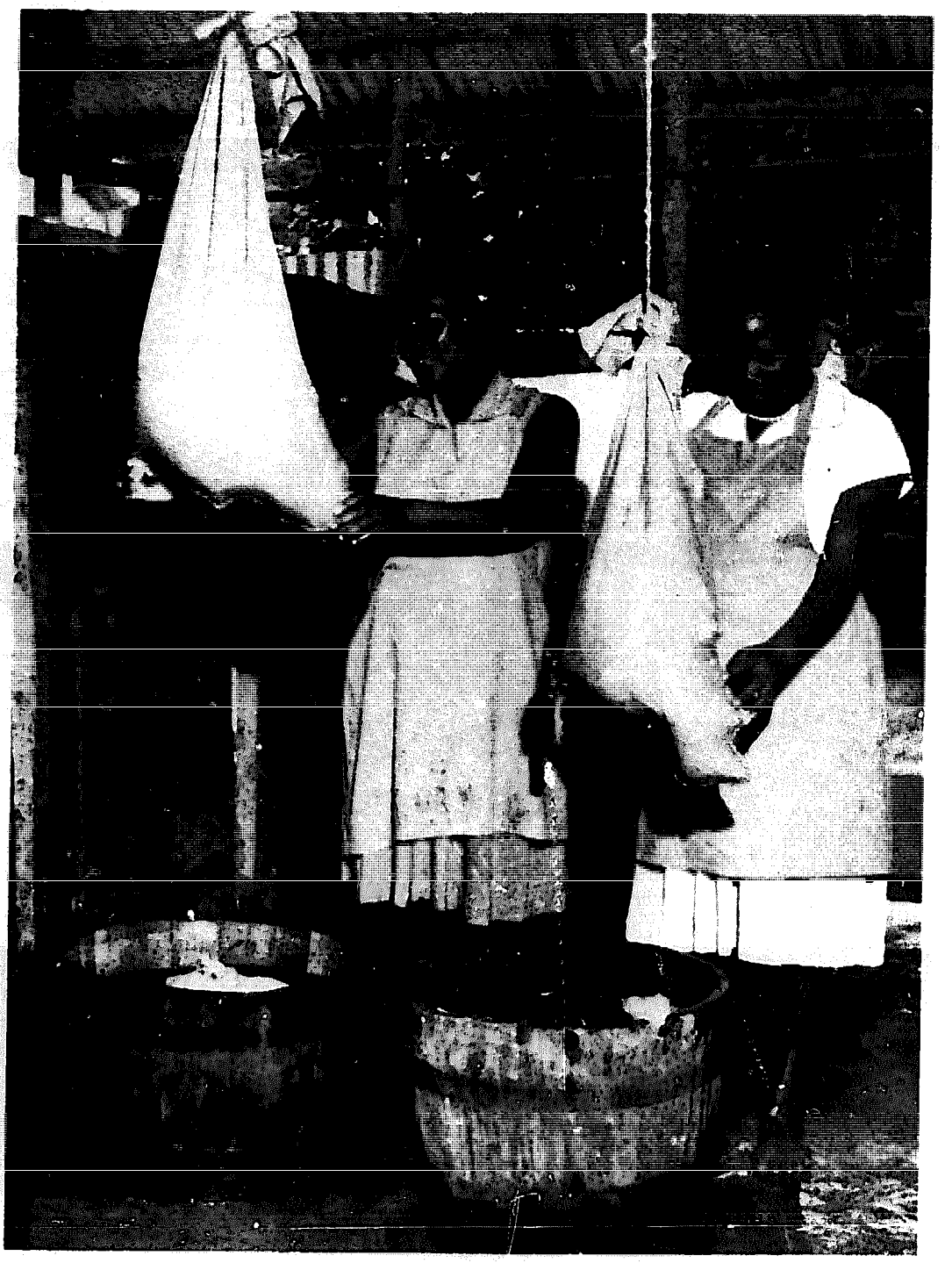

FIGURE 40. - *Bag tanning of goatskins as practiced in village tannery in Africa.*

Courtesy Kenya Information Office, Nairobi

India kips." Myrobalan tanning mixture, however, does not penetrate the hide rapidly. For this reason, it is used in mixtures with other tanning materials.

Babul bark should be removed as soon as possible after the felling of the tree. This can be done in one of two ways:

(*a*) by beating the bark off with a wooden mallet; or

(*b*) by making a single incision along the full length of the log and then — with a 20 to 30 centimeter long bone or spoon-like instrument — by loosening and by prying the bark off, as far as possible, in one piece.

When the bark is left too long on the trunk, the consequences are fermentation and a loss of tannins.

After the bark has been removed, it can be chopped into pieces not longer than 5 centimeters, spread out on the ground, and dried in the sun. For this purpose, the chaff cutter which is found on all village farms can be used. When the bark is to be kept in large pieces, these are placed tent-wise for drying and, for the sake of a sufficient air circulation, the outer side of the bark is made to face the sun. A tanner who owns a bark crusher prefers to buy bark in large pieces: for it is cheaper.

Initial bag tanning

To convert one pelt of about 20 kilograms in weight into bag-tanned leather suitable for the manufacture of shoes, a total of at least 40 kilograms of crushed tanning material is needed. In the initial tanning or *malni*, however, only 10 kilograms of a babul bark-myrobalan mixture — in the proportion of 6 kilograms of bark and 4 kilograms of nuts — is used.

The first *malni* liquor should be 5° Bkr. strong, and the strength is gradually raised to 20° Bkr. The period of this initial tanning process, which ranges from five to ten days, depends on the condition of the pelt, the efficiency of handling and the frequency with which the tanning liquor is strengthened.

The delimed hides are immersed in the tanning liquor and moved continuously. To accelerate this process, they are squeezed out regularly, and a fresh addition of tanning material is made every day.

In more progressive tanneries, the initial tanning process is carried out in paddle vats. The paddle blades are rotated by hand or, when engine power is available, by belt drive; and the regular strengthening of the tanning liquor is done by adding liquor which has been previously prepared in leaching pits.

After this initial tanning, and to accelerate bag tanning, the hides are squeezed out so as to reduce their moisture content.

For bag tanning, it is a definite advantage to leave all hides, buffalo or cow, as complete hides and to pretan them, if necessary, in a folded condition. The folding is done along the backbone line with the grain side in (Figure 41).

They are then sewn into bags with a sharp, strong awl and fibrous string. The stitching starts from the tail towards the hind shanks, which are left open. It continues from the open shanks along the entire hide (Figures 42 and 43). The stitches are at a regular distance from the edge. Great care is needed to ensure that the underlying side or piece of hide does not slip away, for this causes a weak or a broken seam. The size of the stitch varies, according to the thickness of the skin or the hide, from 0.5 to 1 centimeter. The edges are butted together with a so-called " zig-zag " stitch. This method of sewing produces a seam capable of withstanding the load and the pressure which the tanning material imposes.

Leather-sewing machines are not in use. Yet, in an advanced rural tannery, where many hides are handled every day, these machines could create a large saving in time.

When the sewing is completed, the bag is turned grain side out by pulling the hide through the open hide shanks. The bags are then suspended over a collection pit and filled through the open top with vegetable tanning material. In all, about 13 kilograms of babul bark and 10 kilograms of myrobalan nuts — all crushed — are required for this second stage in tanning. The tanning liquor derived from the last solution used in the initial tanning stage is also poured into this opening. The pouring continues until the bag is half full.

The tanning material is leached out inside the bag, and its strength increases gradually to 25° or 30° Bkr. The tanning liquor percolates, and it is collected in the pit below the hanging bags. The level of the tanning liquor in the bags is maintained by filling them regularly — three or four times daily for three days — with the liquor collected

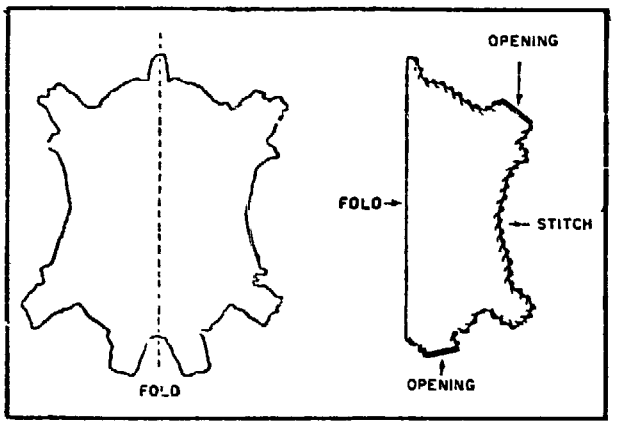

FIGURE 41. – *It is an advantage to leave hides complete, folded down the back line, then to sew edges together.*

in the pit. After three days, the bottom is opened and the top of the bag is sewed up. The bag is inverted and refilled with tanning materials and tanning liquor. Another three days are needed for completing the tanning process. Sludge deposits which show on the grain side are wiped away daily, in order to prevent stains. Then the bottom is opened; the tanning material and liquor are removed; and the adhering tanning material is washed away with the tanning liquor.

Finally, the entire bag is opened by cutting away the fibrous stitching strings: and the leather is washed superficially and piled down.

Unfortunately, leather at this stage is often undertanned and although it may be sold by tanners in need of immediate returns, it does not fetch a good price on the market. In organized rural tanneries a more fully tanned leather is produced by layering the bag-tanned leather in pits. This is often followed by some light extract tanning in drums.

Layering

The opened bag-tanned leather is spread out flat in a pit: sufficient tanning material is dusted in between the pieces: and the whole is covered with a liquor of at least 35° Bkr. and left for a minimum period of seven days.

This layering can be extended by enriching the pit weekly with a fresh tanning mixture, thereby also increasing the yield of the leather. Tanners who wish to allow only one week for layering use about 7 to 10 kilograms of crushed myrobalan nuts for hides weighing 20 kilograms each.

FIGURE 42. – *Bag tanning arrangements, showing how two sides are sewn together to form a bag.*

FIGURE 43. – *Sewing hides together is widely practiced in Indian villages.*

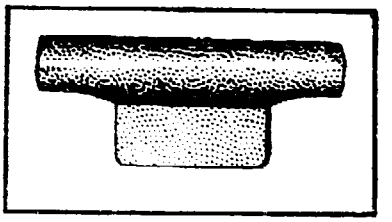

FIGURE 44. – *Setting out tool — stone embedded in wooden handle.*

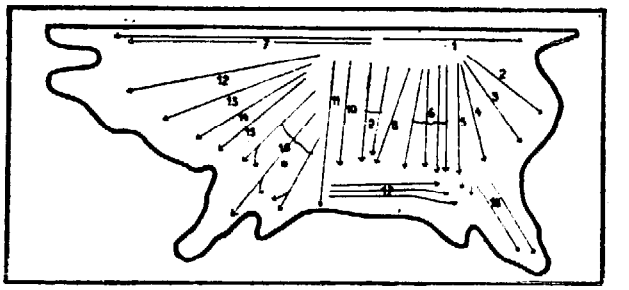

FIGURE 45. – *Setting out manually is practiced on setting table. Sketch shows direction of strokes and scheme of setting.*

FIGURE 46. *Setting leather by hand while still in moist condition, as practiced in advanced and organized rural tannery.*

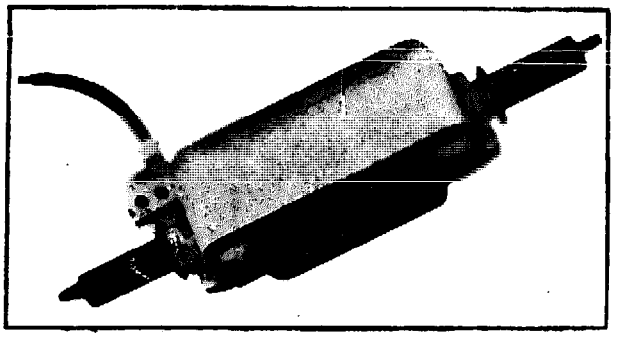

FIGURE 47. – *Self-contained electrically-operated hand-setting apparatus which can be used to advantage in tanneries.*

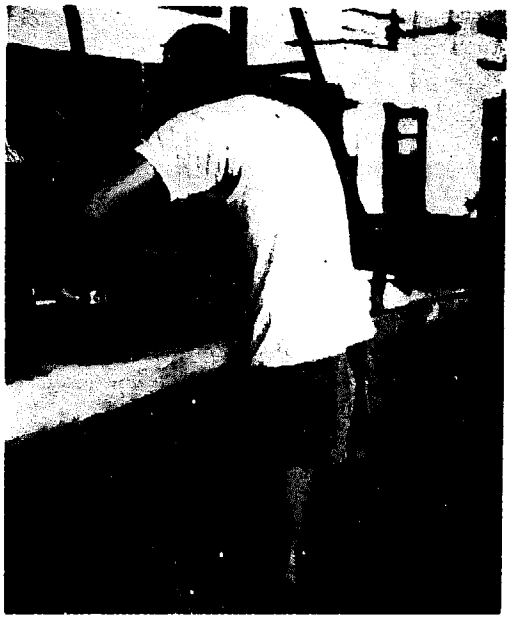

FIGURE 48. – *Worker with self-contained electrically-operated hand-setting apparatus.*

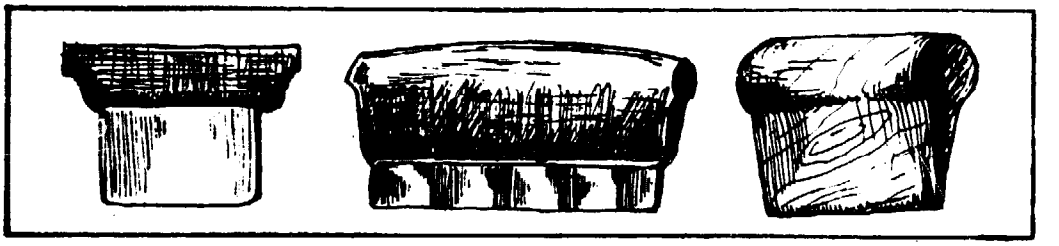

FIGURE 49. – *Sketches of slickers which can be made of brass, steel, glass or hard wood.*

Courtesy Mrs. Erica Mann

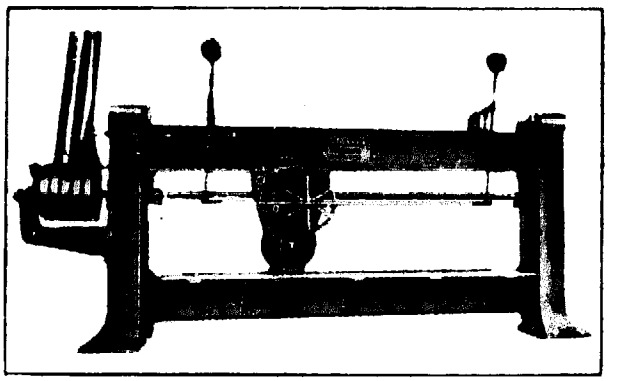

FIGURE 50. – *Sole leather rolling machine with belt drive for heavy sole leather.*

Finishing

The tanned leathers are piled for some period; they are washed and struck out to remove uncombined tans, sludge and so on; and they are hung up for partial drying in the shade.

Care is needed to prevent tanned leathers from becoming hot in the pile; otherwise they cannot be used.

Tanned leathers are first set when they are still in a moist condition. They are then dried again. As soon as a leather has lost about 50 percent of its moisture, another scouring and setting takes place. A scouring stone embedded in a wooden handle is used (Figure 44).

Figure 45 indicates the direction of the strokes and the method of setting (see also Figure 46). In more advanced tanneries, where electric power is available, a self-contained electrically operated hand-setting machine can be used with advantage (Figures 47 and 48).

Later the leather is oiled with a mixture, which has been prepared by adding 250 grams of linseed oil to 7 liters of boiling water. This mixture is cooled down, and 0.75 liters of milk can be added to improve the finish of the leather.

Rural tanners also use sesame oil, which they sprinkle over both the flesh and the grain sides.

After a complete drying, the leather is polished with a tool which is devised to squeeze out the moisture, to compress the grain and to smooth out the wrinkles. This tool is called a "slicker." It consists of a wooden handle, 20 to 25 centimeters long and 2 centimeters thick, into which is set a 60 millimeters wide piece of glass or brass. A less durable slicker can be made entirely of hard wood (Figure 49).

Heavy leather, while still in a slightly damp condition, can be rolled by a small cart which is loaded with heavy weights and which is provided with a brass roller. More advanced rural tanneries use sole-leather rolling machines (Figure 50).

When bag-tanned leathers are treated in the manner which has been described in this chapter, they have not only a better finish; their compactness and their resistance to water and to wear are greatly increased. Accordingly, their value is substantially enhanced.

VIII. VEGETABLE TANNING OF LIGHT LEATHER

Sheepskins and goatskins

As a rule, the rural tanner depends on tanning material which he obtains locally rather than on commercial concentrated extracts. It is difficult, therefore, to give strict rules and recipes for tanning.

The basic principles are given in this chapter only as a guide. They should be modified in the light of results. Tanning of light leather is simple if there is a strict adherence to these two basic principles:

1. to start tanning in weak liquors and gradually increase the strength until the process is completed;
2. to help the tanning mechanically by pulling, turning over and rocking.

Under rural conditions, light leather can be tanned in three different ways:

(*a*) in one pot or vat, in which the original liquor is gradually strengthened; or

(*b*) in several pots or vats, where the skins are transferred from weak to stronger liquor; or

(*c*) in a drum or paddle, in which the process is greatly speeded up.

In one vessel

Sheep- or goatskins should be tanned separately because goatskins require rather longer tanning than do sheepskins. The skins are merely immersed in the pot or vat (Figure 51) in an initial

FIGURE 51. – *Small village tannery where only one vat is used in tanning operation. The skin is suspended from a stick and taken out at least four times a day.*

Courtesy Kenya Information Office. Nairobi

FIGURE 52. – *Small village tanneries can utilize an earthenware pot for skins which are pulled and streched to obtain a uniform penetration of tan liquor.*

Courtesy Kenya Information Office. Nairobi

liquor which does not exceed the strength of 2° Bkr. Each skin should be suspended by at least three strings — one at each hind shank, and one at the tail — from a piece of wood which rests across the top of the vessel. In this way, touch marks called "kisses" are avoided. This method is better than piling crumpled skins into the liquid in a disorderly state; for crumpling causes "drawn grain" — for example, permanent creases in the grain.

At least four times a day the skins should be taken out (Figure 52), pulled and stretched.

Each day a fresh and stronger solution of tannin is added, so that on the second day the strength is 4° Bkr.; on the third day it is 6° Bkr., and so on. This continues until the skins are tanned completely.

In order to see whether the skin is completely tanned all through, the leather is cut with a clean sharp knife on the thickest part, and the cut section is inspected. If the color is uniform throughout, the process of tanning is finished. If a light-colored streak is visible in the center, the tanning is not complete, and it must be continued.

In more than one vessel

Instead of adding increased quantities of tannin to the same vessel, it is better to have a series of vessels of increasing liquor strength. This method is specially advisable for tanners who have more than one or two skins to tan at a time; for it permits a continuous process. The first vat is filled with a liquor of 2° Bkr., the second with a liquor of 4° Bkr.; and the final vat has a liquor of 8° to 10° Bkr. It is sufficient to keep sheepskins for two days in each of these vats, so that they are tanned in eight days. Goatskins, on the other hand, stay for three days in each vat, and they are finished in 12 days. Here again, the more often the skins are taken out, stretched and pulled, the more thorough will be the tanning.

Tanning in a drum or paddle

Almost all the operations performed by the tanner can be done more cheaply, more quickly and better if the goods are stirred or moved continuously. The best way to achieve continuous movement

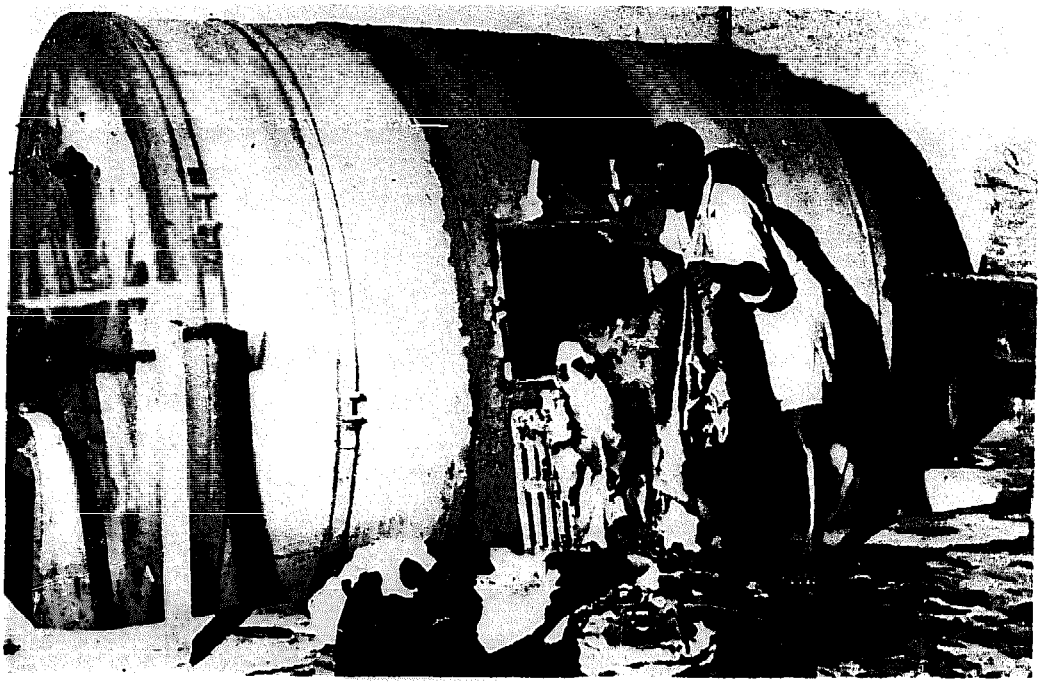

FIGURE 53. – *Power-driven drum as used in large tannery for washing and liming.*
Courtesy Kenya Information Office, Nairobi

FIGURE 54. – *Hand-operated tanning drum made locally from cask and which can be used in rural tanneries.*
Courtesy Kenya Information Office, Nairobi

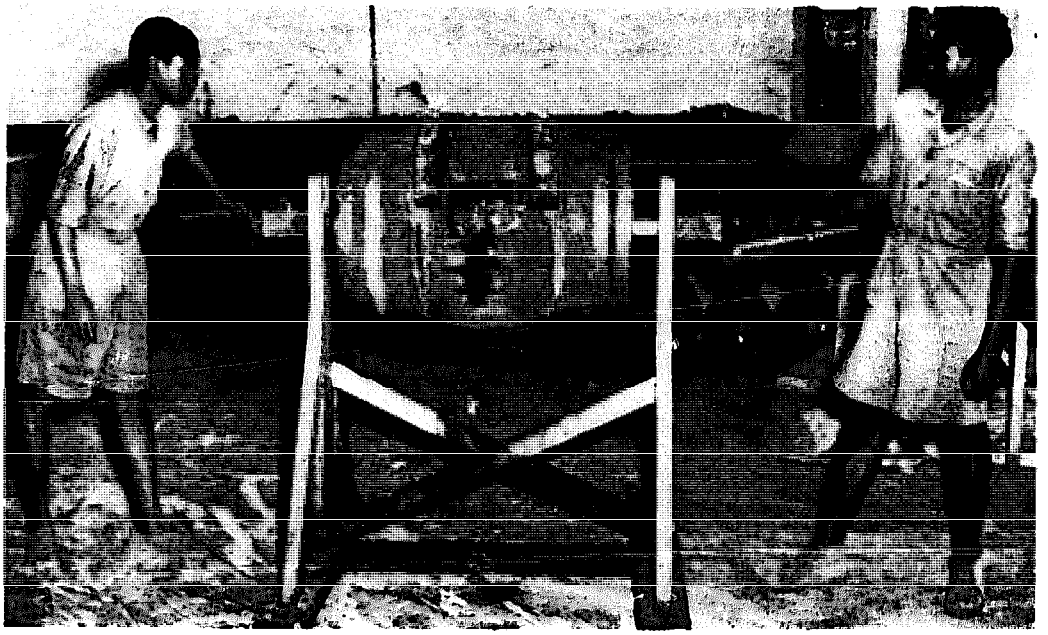

of the goods and the liquor is in a drum (Figure 53) or paddle (Figure 36). Every large tannery has a battery of drums and paddles which are used for nearly all the processes, such as soaking, liming, deliming, tanning, dyeing and fat-liquoring. When a rural tanner cannot afford power, he can certainly make for himself a small hand-operated drum (Figures 54 and 55).

Oil or petrol drums are useless, unless alum tanning only is practised; for iron combines with the tannin, and this causes a blue or a green discoloration. Wooden casks, therefore, should be used. Old sherry or wine casks of 200 to 300 liters' capacity are the best, but the iron hoops must be removed and replaced by wooden or brass ones, or raw leather straps, and fixed with nonferrous nails. An old butter churn, provided there are no iron parts, can be used instead of a drum. The stub axles are fastened to the top and bottom of the cask, and they rest on two crossed legs, as shown in Figure 55.

FIGURE 55. – *Sketch of hand-operated locally made tanning drum.*

Courtesy Mrs. Erica Mann

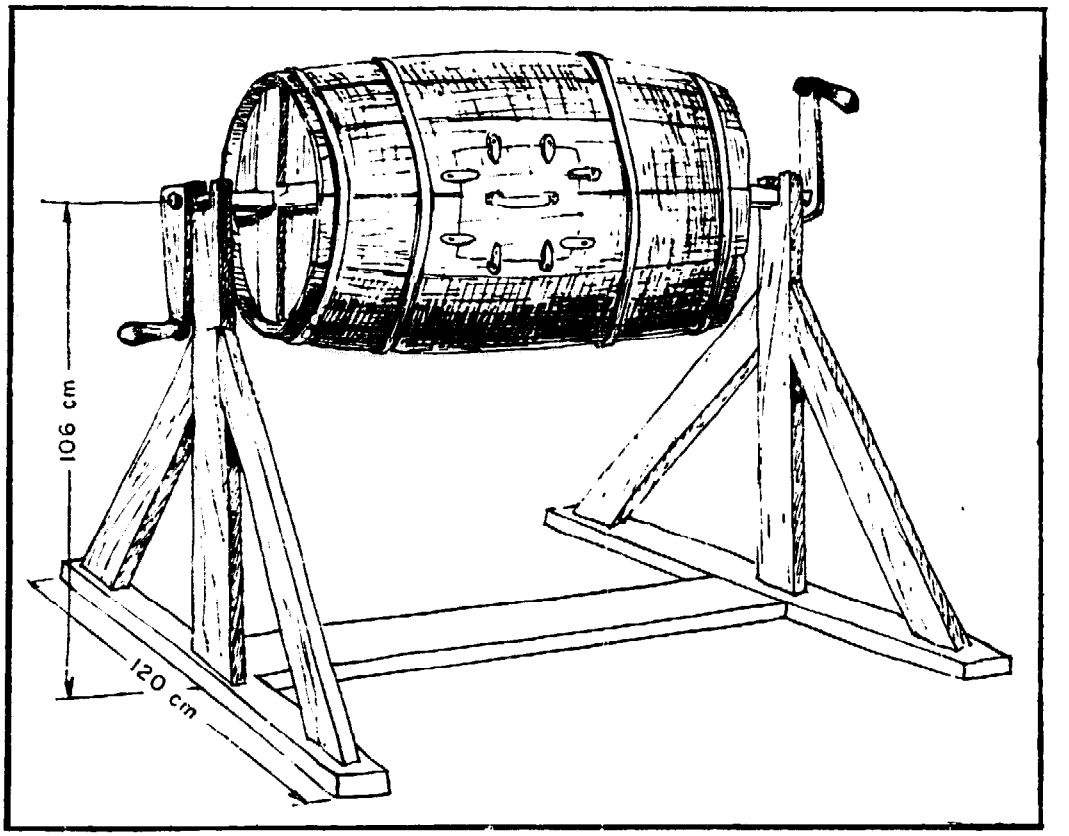

Two handles, one at each end, enable the operators to turn the drum with ease, even when it is full of goods. A removable door as water-tight as possible can be made by cutting a rectangular or circular piece from the body of the cask. The door is fitted with strong wooden fasteners to keep it in place while the cask is rotating. Strong wooden round-ended pegs are also fixed in staggered formation inside on the drum walls. This is done to promote the lifting and the falling of the rotating skins.

The tanning operation is carried out in the following manner.

A stock solution, which contains 5 percent tannin, equal to a strength of 15° Bkr. is made up and divided into ten equal parts. The skins are put into the drum. They are covered with water, and 5 kilograms of salt are added to each 100 kilograms of wet skins. After drumming for a quarter of an hour, the first part of the stock solution is added. Drumming then continues for another 45 minutes, and a further part of stock solution is added. This addition of stock solution and drumming is repeated four times — in other words, until half the stock solution has been used. The skins are then stretched, squeezed out and piled, one on another, over a wooden horse. In the meantime, the sixth part of the solution is added to the liquid in the drum. The skins are then returned to the drum and drummed again. Every 45 minutes, further parts of the stock solution are added until all has been used.

A similar process can be adopted for paddle tanning.

Rapid East Indian tanning of sheepskins and goatskins

The method of tanning sheepskins and goatskins, which is now described, has been developed by the Central Leather Research Institute in Madras.

The wet salted goat- and sheepskins are weighed and put in plain water, with the flesh side up, for two to three hours. When the skins are sufficiently soft, they are cut open and given three to four changes of water. Between each change they are well trampled. The well-soaked skins are then drained and weighed.

Now a paste, which contains one part of sodium sulphide (60 per-cent fused), 16 parts of lime and enough water to make it smooth-flowing, is prepared, and it is applied on the flesh side of the skins.

The painted skins are then piled, flesh to flesh, and covered with gunny.

As a rule, for the wet salted stock of 100 kilograms, a paste composed of 1 kilogram of sodium sulphide, 16 kilograms of lime and enough water to make it smooth-flowing is sufficient. After six hours, or after overnight, the painted skins are unhaired. They are then put into a lime liquor which contains half of old liquor, half fresh water and 5 percent lime, based on the wet salted weight.

The goods remain in this liquor for two days, and they are handled daily. On the third day, the skins are scudded and put in a lime liquor which contains fresh water, 10 percent lime and 57 grams per hundred caustic soda, both based on the wet salted weight.

The skins are handled daily in this liquor, and they remain there for three days. On the fourth day, they are fleshed, and the fleshed weight is taken. The fleshed skins are then trampled well in water. After a scudding, they are put in plain water overnight. On the fifth day, after they have been well trampled they are fleshed, scudded twice and delimed fully with 0.5 percent boric acid, based on the fleshed weight. The cut section is tested with a 1 percent alcohol solution of phenol phthalein. The delimed skins are scudded, washed twice and are ready for the petreatment with commercial sodium acetate and sulphuric acid. The delimed and washed skins are trampled in a pit which contains a minimum amount of water to cover the skins — that is, 100 to 150 percent of water, based on the fleshed weight: 0.75 percent to 1.125 percent sulphuric acid (specific gravity 1.84) is taken and diluted, and the acid is added in three installments at an interval of half an hour; and meanwhile the goods are trampled all the time. The pH of the bath is adjusted to 4.8 to 5, as tested with the indicator paper.[1] The goods are left in this solution overnight, and the pelt is kept well immersed in the liquor.

Next morning, after a good trampling, the pH is again tested to see whether it is constant at 4.8 to 5. If not, the bath is adjusted, and the goods are trampled to attain an equilibrium pH 4.8 to 5. The whole operation can also be carried out in a drum, with one to one and a half hours drumming.

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[1] See Appendix on "pH Value in Tanning."

The following five points need to be emphasized.

1. At no time should the sulphuric acid be added to the goods. The goods should be first removed. The sulphuric acid, which is diluted, is then added and well mixed.
2. As a rule, 0.75 to 1.125 percent sulphuric acid, based on the fleshed weight, is sufficient to attain an equilibrium pH of 4.8 to 5 for delimed goods.
3. It is essential that the pH should be adjusted to pH 4.8 to 5 in the cut section of the skins as well as in the bath.
4. In treating with sulphuric acid, the pH of the bath suddenly goes down, but it increases again as the pelt is neutralized. Repeated additions of the acid are, therefore, necessary to adjust the bath.
5. The pH may be readily tested by using either narrow range indicator papers or a pH meter.

Another pretreatment is given by using calgon, a material to obtain soft water, and sulphuric acid. The delimed and washed goods are trampled in a pit which contains a minimum amount of soft water to cover the skins — that is, 100 to 150 percent water, based on the fleshed weight, 2 percent calgon and 0.75 to 1.25 percent sulphuric acid for a period of two hours. The acid, after it has been well diluted, is added in three installments at an interval of half an hour. The other procedures are the same as in the pretreatment which has been already described, except that there the pH has to be adjusted to 2.3. The five other points already mentioned should also be followed here and the equilibrium pH of 2.3 should be obtained. The cut section of the goods pretreated with calgon should be white. The calgon pretreated goods are repeatedly washed with water free from acid, and two or three changes of water are sufficient.

The whole operation can also be carried out in a drum with one to one and a half hours drumming. Either of these two pretreatments can be followed.

Vegetable tanning carried out in the traditional way and by using the two-pit system. The amount of tanning material required is worked out, as usual, from the expected yield. With avaram bark,

about 1.5 to 3 kilograms of bark per kilogram of expected yield are used, and the quantity is given equally between the first and the second bark tanning operations. With wattle bark, the amount is 1.25 to 1.5 kilograms per kilogram of expected leather yield. Tanning can also be done by using different tanning materials which are blended in suitable proportions.

With avaram, the type of bark which is good colored — that is, with a greenish tinge at the fracture — is rinsed twice with fresh water as quickly as possible. The required quantity of the bark is soaked along with half of old liquor and half fresh water in a pit or tub about 24 to 48 hours before the goods are brought to the tan yard. If wattle bark or extract is used with avaram, it is also soaked together with the avaram bark.

The pretreated skins, which are drained, are then immersed in the liquor. In the treatment of the skins, they are drawn individually once or twice through the liquor, and then they are piled and pressed in the pit. The liquor is then stirred up and the skins are once again drawn through, one by one, and piled in the pit. They are well pressed, while keeping half the bark at the top and the other half at the bottom. The goods are left overnight. On the next morning and in the following evening, they are again hauled and piled to ensure an even color. On the third day, they are worked over the beam on the flesh side with a blunt scudding knife. This sets the grain smooth and flat and gives the skins the required shape. During beaming, care should be taken not to expose the skins for a longer period, if discoloration is to be prevented. Beaming should be such that the goods are free of growth marks, wrinkles and folds. After beaming, the skins are put in the liquor. Here the skins are kept in pairs, grain to grain, and bark is sprinkled between each pair. Some bark is kept at the top and some at the bottom. Sometimes the bark is also sprinkled between each skin. The skins are well pressed inside the liquor, so as to avoid air bubbles and unevenness in the color of the leather. Similar handling is done on the fourth and the fifth days.

On the sixth day, the skins are wrung out, beamed on the flesh side and put in the second bark solution, which is prepared in just the same way as the first one. The goods are handled in the way which has been already described; and here they remain for another five days.

The tanned skins are then wrung out, and bleached in the usual manner; and the skins are trampled in a bleaching syntan for about 15 minutes. For every 100 kilograms of expected leather 1 to 2 kilograms of syntan are used. The bleached goods are rinsed in the same bath by adding more water. They are then beamed on the flesh side. The beamed skins are ready for myrobing.

The myrobalan bath is given in one installment for a total period of two days. On the whole, 360 grams of good quality myrobalan per kilogram of expected leather are taken, and the crushed myrobalan nuts are soaked in hot water (55° to 60° C.) at least 18 hours before they are used. The overnight soaked myrobalan nuts are then trampled. Sufficient cold water is added to extract more tannin from them and also to bring the liquor to a proper dilution (30° to 40° Bkr.), so as to get a yellow color on the flesh side of the skin after it has been dipped in the bath. The skins are dipped one by one in this bath and piled in another empty tub nearby. When all the skins are piled and well pressed, the liquor is poured over them. Care is taken to avoid any formation of air bubbles. The skins are kept in this second tub for a short time. They are then removed one by one, piled in a third tub and well pressed. The liquor is again poured, and the goods are left in it overnight. Next day, another handling is given in the same way. On the third day, the skins are rinsed in the same bath by adding more water; they are beamed on the flesh side and piled for oiling. The final working over the beam is done carefully to obtain the best pattern and the correct moisture content.

The beamed skins are then piled on an oiling table, while keeping the grain up. Each skin is then oiled by sprinkling a good quality of oil — as a rule, this is gingelly oil or ground nut oil — and, if necessary, a little amount of water. The oil is then evenly applied on the grain of the skins. The oiled skins are kept in another pile. They are again rubbed three or four times, and hooked in a cool place. When the skins are in a sammed condition, they are conditioned and piled in a wooden tub and covered with a gunny or palm leaf. They are left overnight to equalize moisture. They are then set twice on a glass or marble table and allowed to dry in a dark cool place. The dried skins are weighed to calculate their yield, and they are piled for a day or two.

As a rule, they are staked and fluffed on the flesh side; they are trimmed and graded in the usual manner.

Their physical characteristics like general appearance, color, feel, fullness, crackiness and tear strength are comparable with the traditional E. I. tanned skins, while the yield is 40 percent on the fleshed weight.[2]

Calfskins

Calfskins, although they are thin, are not easily tanned as those of sheep or goats. Wherever vats are available for the tanning of sides, they should also be used for calfskins. Here follows a simple method for rural tanneries which handle calfskins from animals under six to eight months.

1. Immerse or, better still, suspend the skins in an old liquor of approximately 3° Bkr. and "handle" as frequently as possible. Handling means taking the skins out and carefully stretching, pulling and kneading them. In this way, the moisture is squeezed out, and the calfskin will the more easily absorb further tanning liquor. The skins should be stirred often by hand or with a wooden paddle, so that they do not touch each other for long periods; otherwise the points of contact will be discolored. The skins should remain in the first liquor for one or two days.
2. Transfer the skins to a stronger liquor, or increase the existing liquor to a strength of 6° Bkr., and handle frequently for three days.
3. Strengthen the liquor, or transfer to the next liquor of 9° Bkr., and leave for four days.
4. The last tan liquor should have 12° Bkr., and the skins are left for five to eight days in this liquor until they are colored right through. For thicker skins from older animals, an even stronger liquor will often be required, unless the time for tanning is lengthened by one to two days in each vat. The "kneading" operation, however, must be done with care; otherwise the result may be a distortion of the grain and "loose grain."

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[2] See also Chapters IX and X.

IX. FAT LIQUORING, OILING AND STUFFING

After the hides or skins have been tanned, they require further treatment to improve their quality and appearance. The basic principles of this treatment aim at:

(*a*) removing excess uncombined tannins — in particular, from the grain and flesh surfaces;

(*b*) adding fats and oils to make the goods more pliable and waterproof;

(*c*) softening or hardening the goods as required; and

(*d*) improving the appearance by applying a finish.

Excess tans and non tans, however, are not removed from sole leather, apart from the flesh and grain surfaces, because this would mean a reduction in weight and solidity.

These operations differ according to the type of leather and its future use. In this chapter, therefore, the treatments of light, heavy and sole leathers will be considered separately.

The treatment of sole leather is described first because it is very simple and because it offers a basic method for the treatment of other types of leather.

Sole leather

After the bends are removed from the vats, they require a further careful treatment.

Piling

In order to absorb and fix any uncombined tannins and to lose excess moisture, the bends are piled one on top of the other and completely covered with tarpaulins or wet sacks. They should be left for a minimum of 48 hours.

Scouring

When tannins which contain pyrogallol are used, such as myrobalans and chestnut, a certain amount of " bloom " is deposited inside the leather and on the grain. The bloom and the surface tannins should be removed by " scouring. " This the rural tanner can do by using a sloping table which inclines away from him. The bloom is removed with a stone or slate slicker and well washed off with water. This process should also be adopted for catechol-tanned leather — wattle-tanned leather — but washing both surfaces with water should be sufficient. Without adequate scouring the dried leather will be " off color " and cracky.

Oiling

To prevent cracking and to make the leather more waterproof. the bends are then oiled. The best are cod and sulphonated oils. Another important reason for oiling sole leather is that the oil prevents oxidation of the surface tannins, thereby greatly improving and preserving the color of the leather when it is dry. The tensile strength is also increased.

Drying

The rapid drying of leather by exposure to the sun or to very hot air is injurious; for it causes shrinkage, hardening, cracks and discoloration.

The speed of drying depends on the moisture content, temperature, humidity and circulation of air. To be independent of these factors,

large tanneries use a dark, properly ventilated and heated drying room, where the leather is dried under ideal conditions. Even the rural tanner will need a dark, properly enclosed space where he can dry his leather away from the sun, rain and excessive wind.

After oiling, the bends are transferred to this drying shed and hung on hooks or on two pieces of string.

Setting or striking out

When the leather is half dry, it is taken from the drying shed. Dry grain patches are wetted back and the leather is piled to " samm " overnight (see page 125). Next day the leather is worked on a table with a brass or glass slicker (Figure 49). If the leather is too wet, the grain will not stay " set."

If parts of the bend have dried out during " samming," they should be remoistened, so that the whole piece is damp and soft.

The work should start on the flesh side, so that the surface is smooth, the leather set out and as much moisture as possible removed. A " bottom finish " is now applied to the flesh side by means of a hard brush and then smoothed by hand. The bend is then turned over and the grain side treated with a coat of linseed or any other suitable oil. Afterwards it is hung again in the drying shed.

Rolling

During drying the bends should be continuously examined and only taken down with a little moisture when the " color is up." This minimum moisture is very important; for it allows a binding and firming action when the bends are rolled under pressure. Before rolling, the bends are normally piled overnight to " samm," but the dry edges are first wetted to even out the moisture. Placing heavy weights on top of the pile has obvious advantages.

In a large tannery leather is rolled by a special power-driven machine. Here a brass or stainless steel roller moves under pressure over a smooth surface. The bend is put in between the surface and the roller which, by moving backwards and forwards, rolls the bend flat (Figure 56).

A stone, tennis-court roller can be used under rural conditions, provided it has a very smooth surface. As a rule, however, this does not give sufficient pressure. A more satisfactory way of improving the quality of the leather is to use a section of the trunk of a hardwood tree, 30 to 45 centimeters in diameter, as a block. On this block the leather is laid flat and beaten evenly with a heavy wooden mallet (Figure 57).

Final drying

Final drying now takes place in a more open, but shaded, position, or near a stove, where less harm can be done.

If additional firmness and "finish" (polish) are desired, the bends could be rolled again and then finally dried. Two rollings are termed "rolling on" and "rolling off." "Rolling on" is done with more moisture in the leather than is "rolling off."

Heavy upper and dressing leather

Once the treatment of sole leather is mastered, the work on other heavy leather should present no difficulty.

Piling

The period of piling may be reduced and should not exceed 24 hours, for the leather is normally thinner than sole leather.

Shaving and splitting

A reduction of the leather to an even and predetermined thickness is obtained by hand shaving. As a rule, this follows tanning, and it should be done before any other process. The beam which is used has a flat working surface, and this is inclined at an angle of about 10 degrees off the vertical. The wet "sammed" leather is placed over the beam and held by the pressure of the operator's

abdomen. The shaving knife is double-edged, and it has two handles; one horizontal, and one vertical. The vertical handle moves along the edge of the beam, and thus it gives the operator a guide and support. The blades with turned edges must be extremely sharp before the shaving begins. This very delicate operation requires skill and patience. Those who are unaccustomed to the work may harm the goods rather than improve them. Figure 58 shows a modern shaving machine, as used in large tanneries.

An inexperienced tanner is advised, therefore, not to attempt to shave leather, but to leave the sides unshaved. The shoemaker and the leather craftsman will then be able to select those parts of the sides which are best suited to their particular requirements.

When a hide is hand-shaved, the small pieces of leather shaved off are normally useless to the rural tanners. There are, however, machines which prevent this waste by splitting the hide into two or more even layers and by leaving the grain portion with an even and predetermined substance. The other layers are called " splits " and, as they have less value, they are used for cheap upper leather, linings or similar purposes.

Scouring

The next operation is to wash out all superfluous tan. It is essential that no excess tan is present when leather is subsequently fed with grease; otherwise a " dead " feel will be imparted to the finished leather. At this stage it is necessary to " clean " the grain with a brush and with a weak and warm solution of oxalic acid. Ample scouring with water completes the operation.

Stuffing

Sole leather which has to be firm requires little oiling. Only one or two applications to the grain side are, therefore, necessary. Leather for belting harness, upholstery or uppers, however, must be pliable and soft, and a much heavier application of oil is required. The more pliable the leather has to be, the more fat should be incorporated. Here is a simple recipe. To one third soap, shredded very finely, add a sufficient coverage of water; heat until the soap is dissolved,

FIGURE 56. – *Type of power-driven roller suitable for advanced tanneries.*

Courtesy Kenya Information Office, Nairobi

FIGURE 57. – *Beating sole leather on wooden trunk with a mallet can improve the quality of the leather.*

Courtesy Kenya Information Office, Nairobi

FIGURE 58. – *Modern shaving machine as used in large tanneries.*

add one third tallow and stir continuously until the mixture is homogeneous; to this add one third of any available vegetable oil: take from the fire and continue stirring until there is a uniform mass which resembles soft butter. The completed mixture should be only applied to the flesh side.

When the stuffing is finished, the side is taken off the table, which is then thoroughly cleaned. The grain side of the hide is cleaned — in particular, around the edges — set out with a brass or glass slicker and oiled. The last results are obtained with fish oils, but sesame, groundnut, cotton seed or any other vegetable oil can be used.

Where a very pliable leather is required, stuffing can be repeated after the leather has been hung up for several days to dry. The goods must be brushed with warm water. After they have been evenly wetted and wiped, the stuffing is applied once more.

Drying

After stuffing, the leather is carefully hung in the shed to dry.

Removal of excess fat

When the leather is completely dry, a considerable amount of fat will still be left on the surface. To further the absorption of fat, the leather pieces should be placed, flesh side to flesh side, flat on the floor and covered for 10 to 14 days. After this period of "ageing," the leather is taken out and again spread on the table, and the operator works with a slicker to scrape off any excess fat. This fat should not be rejected, for it can be used with the next bath of stuffing material. It is now, however, different in its composition, for it has lost its low melting constituents.

Softening or boarding

If the leather is still hard, it may be softened or boarded, not by passing over a staking slicker, as is done with light leather, but by working over with a tool called an "arm board," or a "graining board," shown in Figures 59, 60 and 61.

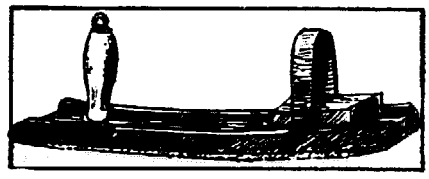

FIGURE 59. – *Sketch of tool called an "arm board" or "graining board."*

Courtesy Mrs. Erica Mann

FIGURE 60. – *Hand-operated graining board covered with cork layer: length 28 cm.; breadth 18 cm.; height 2.5-3 cm.; cork layer 1/2-1 cm.*

Courtesy Marocchinerie e Scamoscerie Italiane, Turin

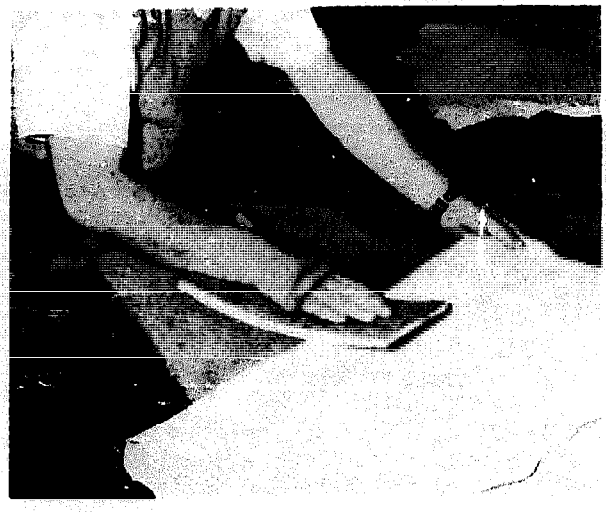

FIGURE 61. – *Operator working with graining board. This operation is called "boarding" or "graining."*

Courtesy Marocchinerie e Scamoscerie Italiane, Turin

PILING

When the skins are taken from the tan liquor, they are piled on a flat table and covered with a tarpaulin or sacks and left overnight to drain.

Washing

Any uncombined tannin must be completely removed; otherwise the skins will be hard and dark. Washing for a few minutes under running water, or at least in a vat with warm water, is strongly recommended.

Fat liquoring

There is a marked difference in the amount of fat required for sheepskins and goatskins. Sheepskins contain more natural fat and may need as little as 2 percent, while goatskins may require double the amount. Goatskins are an exception, and they may be finished like heavy leather by applying a stuffing material to the flesh side prepared from one third soap, one third tallow and one third vegetable oil.

The following method used by the Hausa tanners in Nigeria is recommended; for, although it is primitive, it gives good results.

A few skins at a time are put into a wooden mortar together with groundnut oil and a little water. The skins are gently pounded with a wooden pestle; and, from time to time, they are lifted clear of the oil, returned and pounded again. After fat liquoring the skins are piled, flesh to flesh, and left overnight, or, preferably, for 24 hours.

Drying

Drying should take place in a semidark and well ventilated shed. After the skins are completely dry, they should be left in the shade for two or three weeks to "age."

Staking

Staking is the name given to the process of softening light leather by working it over a kind of slicker. This is a piece of rounded blade which is fixed vertically on the top of a wooden post and called a stake (Figures 62 and 63). The process requires great skill and care.

The operator must feel those parts which are thin and require more gentle treatment if tearing is to be prevented.

The operator puts the leather, flesh side down, on the edge of the blade, which is then worked backwards and forwards with the required downward pressure (Figure 64).

Leather for staking should be slightly damp. With practice the operator will be able to judge the correct condition. Dried out leather may easily tear during this operation.

It is advisable, however, not to soak the leather in water, but to "condition" it by covering it with damp sawdust overnight. This results in an even moisture content (Figure 65), and the process is called "samming."

During staking the skins are slightly stretched. For alum tanned goods, however, fuller stretching is essential to accentuate the whiteness and to bring out the quality of the alum tanned leather. After staking the skins are returned to the shed for final drying. Large tanneries use staking machines (Figure 66).

FINISHING

After being neatly trimmed, the goods are ready for finishing, and the methods are described in Chapter X.

Further details on fat liquoring and stuffing

Although fat liquoring and stuffing have been already briefly discussed, some additional information is now given on these operations, which are delicate and difficult.

Most of the natural fat present in the derma, it has been already stated, is removed by liming and bating. This loss of fat causes the leather, after tanning, to be hard and stiff and to have a tendency to crack. If the tanned fibers are lubricated by oil or fat, they flex easily and the leather is more pliable.

Artificial lubrication with fat or oils is called fat liquoring for light leather such as from sheep-, goat- or calfskins, oiling for heavy sole leather and stuffing for belting and harness.

The purpose of replacing the natural fats by fat liquoring, oiling

Figure 62. – This device, called a "stake," is used to soften leather by working it over the stake.

Courtesy Marocchinerie e Scamoscerie Italiane, Turin

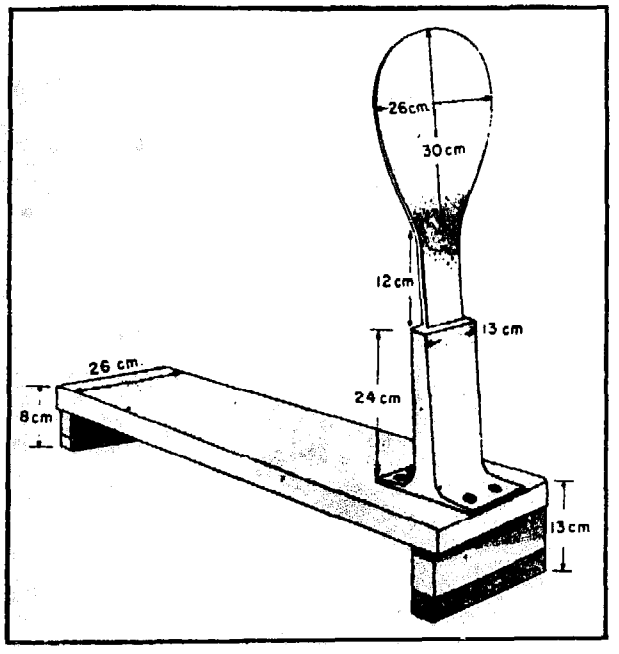

Figure 63. – *Dimensions of the stake in Figure 62.*

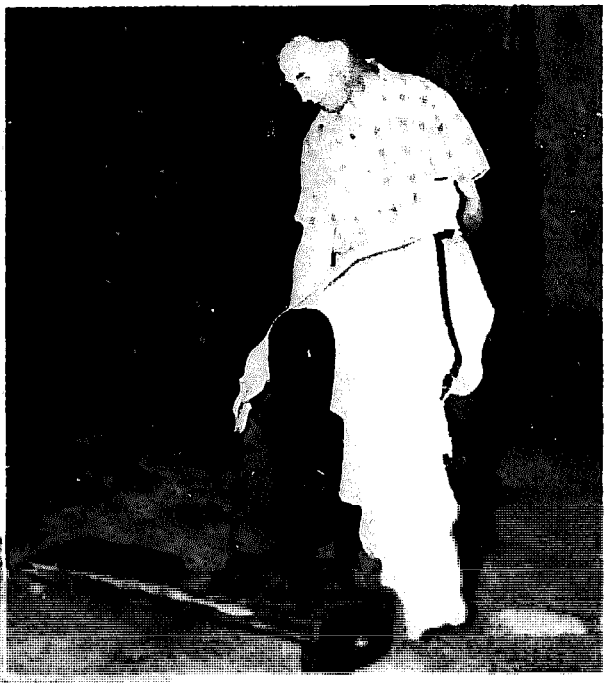

FIGURE 64. – *"Staking operation." Operator working the leather flesh side on the stake over the blade, by pulling backward and forward with required downward pressure.*

Courtesy Marocchinerie e Scamoscerie Italiane, Turin

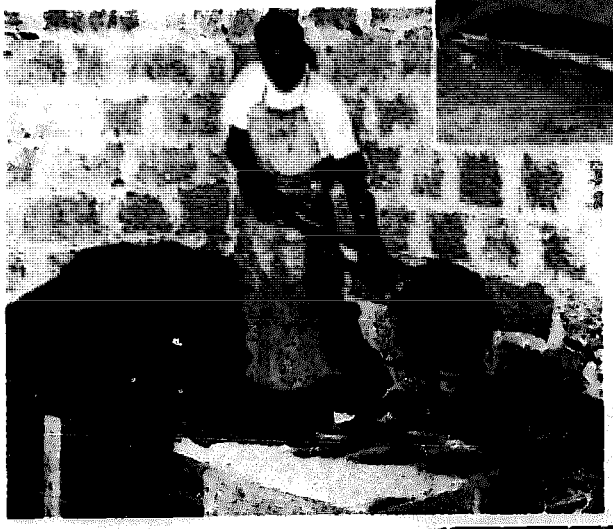

FIGURE 65. – *Upper leather is placed into slightly moist sawdust, to acquire the correct moisture content required for staking operation. This process is called "samming."*

Courtesy Kenya Information Office, Nairobi

FIGURE 66. – *Modern staking machine as used in large tanneries.*

Courtesy Marocchinerie e Scamoscerie Italiane, Turin

and stuffing is to prevent oxidation and so to avoid discoloration of vegetable tanned leather; to protect the grain against overdrying and cracking; to increase the water resistance; to ensure suppleness and softness; and to increase the elasticity — that is, the stretchability — of the leathers.

For fat liquoring and stuffing, many different oils can be used — for example, vegetable oils, such as groundnut, castor, sesame and cottonseed; animal oils, such as tallow, mutton fat, neats-foot oil; and marine oils, such as shark, cod and seal.

Oil used alone can only penetrate the leather with difficulty It is customary, therefore, to use the oil as an emulsion, which is a mixture of oil suspended in the form of tiny droplets in another liquid, still in its insoluble state. Milk is a typical example of an emulsion; for the fat is suspended in the form of small insoluble particles. An emulsion of oil in water can be made with the help of emulsifying agents, such as soap or egg yolk.

Agitation helps to form a more constant emulsion. Thus the fat should always be run slowly into the soap solution, which is constantly stirred.

The correct amount of oil, together with the right emulsifying agent, determines the quality of the fat liquor. The aim is to make a fat liquor which remains as an emulsion for a long time. If the emulsion is badly prepared and insufficiently emulsified, it will separate again into its original components.

The oils most commonly used in large tanneries today are commercially available, and they are called sulphonated oils. These are oils which have been treated with sulphuric acid and have become water-miscible.

It is not intended in this chapter to give the formulae for all types of fat liquor which are used for the different types of leather, but every attempt should be made to use locally produced oils and to try them out as fat liquors. Nowadays, however, modern industry manufactures all kinds of fat liquors, stuffing materials and special oils for the tanner. For large tanneries the use of these products is well worth the expense.

As a rule, a fat liquor is prepared in the following way. First, soap is shredded into a little water. This is heated until it is completely dissolved, and then oil is stirred into the mass. When egg yolk is used instead of soap, the temperature should never exceed

38° C.; otherwise the yolk will coagulate, nd the emulsion will not form.

The amount of fat liquor required is about 2 to 3 percent, calculated on the wet weight of the leather. The process of fat liquoring can take place either in a drum — in a float of warm water (40° C.), which is, as a rule, 300 percent of water on the weight of the skins — or in a wooden mortar, in which the leather is gently beaten with a pestle (Figure 67). If fat liquoring is done in a vessel, the leather is stirred either by hand or with a wooden stick until it has taken up most of the fat.

The average fat requirements of vegetable tanned leathers vary from 10 to 20 percent. For chrome leather they vary from 3 to 6 percent, but this depends entirely upon the type of leather which is needed. At first the fats are taken up only superficially by the leathers, and they are taken up more from the flesh than from the grain side. During further drying, however, the fatty substance is gradually absorbed and evenly spread throughout the leather.

When only a few skins are fat liquored, fair results can be achieved by rubbing in the fat on both sides and then by piling up the skins and by covering them with wet sacks, or a tarpaulin, for at least 24 hours. This method can be used advantageously instead of drumming or trampling in vats.

The following rules must be observed when preparing and using a fat liquor: soft or rain water is used; the leather is thoroughly washed in warm running water for 10 to 15 minutes before the fat liquor is added; after the leather has been taken out of the fat liquor, it is piled and covered with a wet sack for 24 hours before it is dried.

Fat liquoring is difficult, and even the experienced tanner may have occasional failures. Sometimes it happens that the emulsion is " broken " when the fat liquor comes into contact with the leather, and the oil settles in droplets on the leather. This indicates that the emulsion was not well prepared. The failure may also be due to the fact that different types of leather, according to the kind of tannin which has been used, vary in their ability to absorb and to retain fats. The choice of fats is difficult, and before using a new oil or a new emulsifying agent, it is best to test the new fat liquor on a piece of leather or on one skin before proceeding with a large batch.

Heavy leather requires more oil and fat than does light leather.

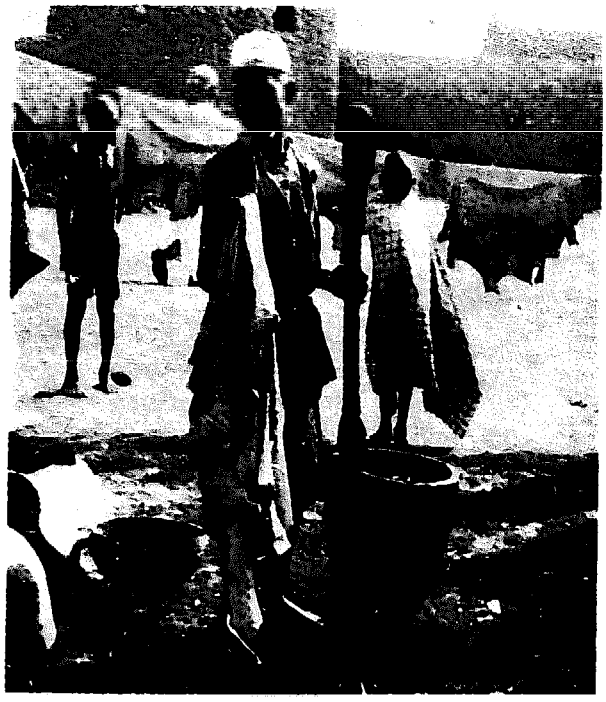

FIGURE 67. – *Fat liquoring, using an oil soap solution, is carried out in wooden mortar in some parts of the world. Leather is beaten gently with pestle.*

FIGURE 68. – *Operator rubbing an emulsion of fatty material and soap into heavy leather with piece of cloth.*

Courtesy Kenya Information Office, Nairobi

Too much oil is, of course, undesirable, for the leather than becomes too soft to be used as sole leather. Sole leather requires only one or two coats of oil. For preference, the coats are mixed with some sulphonated oil, which is applied on both the flesh and the grain side. The stuffing material which is used for heavy leather — that is, for belts, harness and so on — is called "dubbin". As a rule, it is prepared by melting together one part of cod oil and two parts of tallow. Normally, it is first applied to the grain side. Then the leather is turned over and the same mixture is applied to the flesh. After drying, and after laying the goods away for 24 to 48 hours, both flesh and grain are finished by slicking. They are polished by brushing, which evens out the grease.

A "dubbin" for heavy leather, which is used for harness or belts, can also be made by warming a mixture of 1 kilogram of tallow, 1 kilogram of linseed oil and half a kilogram of neats-foot oil. Then 250 grams of soap are boiled in 10 liters of water. When the soap has been completely dissolved, the mixture is added to these ingredients.

If the stuffing material is too solid, it does not enter the leather; if it is too liquid, it runs off quickly. The leather is stuffed by rubbing the emulsion into both the grain and flesh sides with a cloth or with a wool sheepskin pad. The addition of sulphonated castor oil, or fish oil, improves the quality of the leather (Figure 68).

In large tanneries stuffing is done in a "hot drum." This is a slowly revolving and heated drum. It has a hollow axle, through which hot fats — as a rule, a mixture of stearine, tallow and marine oils — are fed into the drum which contains the leather. The heat and the rubbing together produced by the revolutions of the drum encourage the penetration of the oils and fats.

The fat liquored or stuffed leather must be dried slowly in the shade. Generally, as the water evaporates, the fat is absorbed by the leather. Rapid drying in a bright light causes the fat to run off, or else it penetrates the leather only superficially.

X. LEATHER FINISHING MATERIALS

Many finishing materials are on the market, but the rural tanner is advised to use only those which he can obtain locally and prepare himself, such as milk, casein, blood, blood albumen, gelatine, glue and beeswax.

In this chapter finishing materials are reviewed. For the sake of simplicity they are divided into six main groups:

Proteins;
Waxes;
Gums and mucilages;
Resins;
Pigments; and
Miscellaneous, such as sulphonated oils, soaps, metal salts, plasticizers and solvents.

The first four groups are the most important for the rural tanner.

Proteins producing a gloss after glazing

Milk

Milk has been a leather finishing material since ancient times in Egypt. Half a liter of whole milk mixed with the same quantity of water makes a cheap and durable finish. Very good results are obtained by beating the white of one egg into the milk to increase the protein content.

For dark colored leather a good finish can be made by mixing 0.4 liter of milk with 0.3 liter of fresh, defibrinated ox blood and 2.3 liters of water.

Casein

In large tanneries, casein, one of the constituents of milk, is used instead of milk itself. A simple method of making casein is to leave the skimmed milk in a warm place to sour. To hasten fermentation, a " starter " — that is, a little old sour milk — can be added. After the milk has curdled, it is heated to 38°-48° C. to separate the whey. The whey is strained off through a sieve or a porous cloth, and this leaves the curd — the casein — which is washed in two or three changes of rain water — that is, soft water. The washed casein is placed in a triangular cloth bag, and as much water as possible is pressed out. Finally, the wet casein is broken up and spread evenly over a mosquito gauze and exposed to the sun for drying. It is turned repeatedly until it is completely dry. A stock of dried casein can be stored in tightly closed jars, and it will keep indefinitely.

Casein is only slightly water soluble, but it is easily dissolved in the presence of borax. A typical finish can be made from 2 kilograms of casein, 7 kilograms of water and 1 kilogram of borax. The casein must soak for about half a day in cold water. The borax is then dissolved in a little water and added. The whole is heated to about 74° C. for 15 minutes, until a transparent solution is obtained.

This stock solution is made up with water as required at the rate of one part of stock solution to ten parts of water.

Ammonia can be used instead of borax. In that case, 1 kilogram of casein is soaked in 10 kilograms of water for several hours, and then 0.25 kilogram of ammonia and 10 liters of water are added.

Gelatine

Another good finishing material is glue or gelatine, which is applied on the grain side as well as on the flesh side. Glue mixed with starch or whiting is often applied on the flesh side of sole leather to improve the appearance, while a solution of gelatine in water gives a very good finish on the grain side. Gelatine should be prepared in the following way:

1. Collect all fleshing, trimmings and any limed and unhaired hides or skins which have been rejected.
2. Wash in several changes of soft water until all traces of visible lime are removed.

3. Put in a bran; drench overnight, or wash in boric acid solution. Squeeze out by hand as much water as possible.
4. Put in a pot without adding water and place on the edge of a stove, so that the mass will be heated but not brought to the boil.
5. After four hours some "soup" will be seen, and it should be poured off. This is the best and the strongest gelatine bearing liquor, and it can be applied immediately.

A further supply of gelatine soup can be obtained by heating for four hours at the same temperature. This second cooking gives good quality gelatine, but repeated cooking yields only glue. To the second, third and fourth cooking a small amount of water must be added to avoid burning the bottom layer of stock. Fleshings and trimmings, however, produce a far greater yield of gelatine if they receive prolonged liming beforehand.

It is not practical to prepare the dried glue or gelatine at home, and thus the process of drying is omitted. Fresh glue and gelatine should always be used. Where a formula requires the solid material, approximately ten times as much of the liquid is required.

A gelatine finish is prepared from dry gelatine in this way: one part of gelatine is put into a jar, covered with eight parts of water and left for several hours until it absorbs most of the water and swells. This gelatine is put into water in a pan and warmed, but not boiled, until a completely transparent solution is obtained.

Another good flesh side finish for sole leather may be made from 1 kilogram of glue, 1 kilogram of flour, 120 grams of soap and 240 grams of sugar of lead (lead acetate) dissolved in 20 liters of water.

If liquid glue is employed, 10 kilograms of glue soup are used to replace the 1 kilogram of dry glue.

Blood

Blood may be used as finishing material in two forms: (*a*) black blood; or (*b*) blood albumen.

Black blood is used for finishing dark colored leather. Its preparation is extremely simple: collect in a clean, dry vessel — preferably a glass jar — blood from a freshly killed animal, but avoid impurities,

such as stomach contents and hair; beat the blood with a wooden spoon or glass rod until a thick clot collects round the rod; this is fibrin, which should be removed. Cover the bottom of a shallow pan with the residue to a depth of about half a centimeter and expose to the sun; stir from time to time and leave the blood until thick, black, dried flakes are obtained; keep dry in a closed jar.

Blood albumen is used for light colored leather only, and it is made in this way: put the collected defibrinated blood in a cool place and leave for 24 hours; the next day the blood will have two layers, one dark brown and the second reddish-yellow, completely transparent; pour the transparent part into a shallow vessel and dry.

Defibrinated blood and blood albumen may be used fresh without drying, but since blood is not always available, it is useful to have a stock of both.

Egg white or egg albumen

The white of fresh eggs, beaten with twice as much water and strained through mosquito gauze wire, can be applied fresh as a leather finish. Fresh eggs, however, are not always available and, as the whites of eggs may remain when yolks are used for fat liquoring, it is helpful to know how to prepare egg albumen.

To obtain egg albumen, separate the yolk from the white; to one part of egg white add two to three parts of water; beat with a fork until a froth is formed; pass through a mosquito gauze wire to remove all large particles; put in shallow pans to evaporate at a temperature not exceeding 40° C. and stir as described under the drying of blood. If no thermometer is available, this temperature is just above blood heat — that is, a little warmer than lukewarm.

The dried egg albumen looks like whitish scales. To make a finish, one part of this dried powder is put into eight parts of water, well shaken and put aside. After several hours the albumen will be completely dissolved. Do not try to heat or boil blood albumen or egg albumen; for the heat will coagulate it and make it quite useless.

All these products decompose rapidly when they are wet. For this reason, no more than is needed for one day should be prepared.

Stock solution

The decomposition of these protein solutions is caused by bacterial action which makes them thin, smelly and useless as finishes. It may be delayed by chemical preservatives. One percent by weight of beta naphtol will preserve the solutions for a long time. Even if preservatives are used, however, finishing material should not be prepared in large quantities, but only in quantities sufficient for one week.

Application

The application of finishing materials to the leather is a very simple operation. Failures should not occur if the finishing material is fresh, if there is a proper concentration, and if the following rules are observed:

The leather must be perfectly dry and flat before the finish is applied. The finish should be applied with a sponge, brush or cotton wool and evenly distributed; a "flit" pump is also an excellent means of applying finishing materials. After it has been applied, the finish must be allowed to dry before the glazing begins. The surface on which the glazing is to take place must be hard and completely smooth.

Glazing

In large tanneries, special power-operated glazing machines are used. They consist of a glass cylinder fixed at the end of a wooden arm, which moves backwards and forwards. The glass cylinder is usually 13 centimeters long by 5 centimeters in diameter. The operator puts the leather on the bed of the machine and moves it in such a way that all the parts get the same gloss. Glazing not only adds gloss but increases the water-resistant properties; for the heat created by the friction of the glass over the leather coagulates the protein present in the finish (Figure 69).

The small tanner can obtain good results by using as a glazing cylinder a jar or bottle, provided it is round and free from inscrip-

tions, patterns or irregularities. The bottle or jar should be held firmly in the hands, and moved backwards and forwards over the leather (Figure 70). Care must be taken, however, not to turn it in the hands; for sweat would wet the glass and thus prevent the gloss developing. A heavy plate glass slicker would also be a good substitute.

Waxes producing a gloss after brushing

Many waxes are used in finishing operations — for example, montana, carnauba and beeswax.

The use of beeswax only will be described here, because it is easily obtained and cheap. A simple beeswax finish may be made as follows: one part wax, five parts soap, six parts turpentine and six parts water.

The soap is first dissolved in boiling water, and the wax is heated in turpentine until it is completely melted. The two liquids are then put together and mixed until a uniform mass is formed.

A wax emulsion may be prepared from 1 kilogram of soap and 0.5 kilogram of borax. These are boiled, with continual stirring, in the least possible amount of water until the soap has completely melted. To this, 3 kilograms of hot melted beeswax are added, and the mixture is stirred. Then hot water is added, half a liter or so at a time, until the whole mass has absorbed some 20 liters of water.

Waxed leather cannot be glazed, for glazing raises the temperature above the melting point of wax, but a gloss can be produced by brushing.

Gums and mucilages

Of all the gums, perhaps, gum arabic is the most used for leather finishes. Even so, its popularity is limited, for the dried film it produces on the leather surface lacks the flexibility which is normally desired. This gum exudes from the stems and branches of the acacia trees (*Acacia senegal*). It is known as *hashab* gum in the Sudan; and from this source most of the tannery requirements are met.

FIGURE 69. – *Glazing leather on power-operated glazing machine.*

Courtesy Kenya Information Office, Nairobi

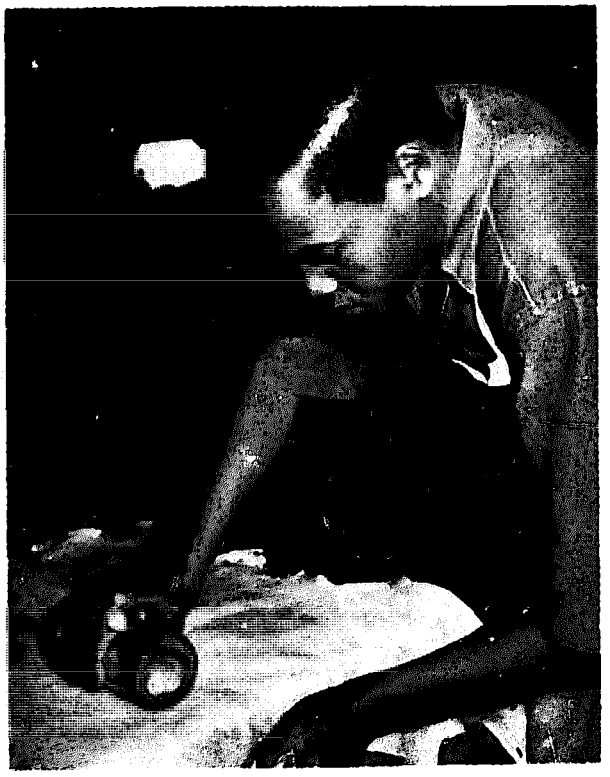

FIGURE 70. – *Glazing by hand, using a jar which is moved backward and forward over the leather.*

Courtesy Kenya Information Office, Nairobi

The hard yellow, translucent "tears" are soluble in water, but solutions putrefy easily. The "tears," however, can be stored for long periods.

Irish moss or carragheen

This is the dried seaweed found along the coasts of Ireland and New England, which can be made into a solution by first washing in cold water to remove the salt and then boiling for about two hours. The solution will set to a jelly, if it contains more than 10 grams per liter. Some other kinds of seaweeds are also suitable, such as Iceland moss and agar-agar.

Linseed mucilage

This material can be prepared by extracting ripe flaxseed in about 40 times its weight of boiling water for approximately two hours and by straining while it is hot. The mucilage is contained only in the shell of the seed, and, to avoid extracting the oil as well, the operation must not be prolonged. This mucilage is often added to other finishes to reduce the brittleness which is experienced with gums.

Resins

Shellac or lac is the only true resin universally used for leather finishes. It is found as a thick crust on small branches of several species of Indian trees, and it is actually a secretion of the lac insect (*Coccus lacca*).

It is collected and macerated with water to extract a brilliant red dye, which is called lac dye. It is afterwards refined by melting and by straining and it is allowed to cool and harden either in moulds or in thin flakes.

Shellac is soluble in alcohol (methylated spirit) or mild alkaline solutions, such as ammonia or borax. When it is used as a leather finish it imparts resistance to washing and wetting. It might well be used to finish dyed leather which is not fast to wet rubbing and perspiration, such as leather for pouffes.

Pigments

These finishing materials are virtually colorless. By the addition of certain pigments, such as carbon black, white lead or zinc oxide, the finish can be converted into a kind of paint, which is called a pigment finish. For such a finish skill is needed as well as special equipment during the preparation, grinding and mixing. It is not advisable for the beginner to attempt it. Later, after having acquired the art of simple finishing, he can try to blend pigment finishes.

In these finishes, the wax emulsion and the casein solution are used either together or separately. A typical formula, when wax and casein are used, is: five parts casein solution, twelve parts wax emulsion, one part sulphonated oil and six parts pigment — for example, zinc oxide or carbon black.

The pigment finish is applied with a pad or a brush. Circular and even strokes are used, so that the thickness of the finish is uniform.

When a pigment finish is completely dry, it should be glazed. If a high luster is required, the surface can be treated with a protein — for example, blood albumen or milk — and then glazed again.

Miscellaneous materials

To enumerate all the materials which are at the disposal of the more advanced tanner is beyond the scope of this paper. A few words may be useful, however, on the advantages of sulphonated oils as a dispersing agent for pigments; on sodium and potassium soaps as emulsifying agents for waxes; on glycerine for keeping rather hard brittle finishes more pliable, as well as on plasticizers, such as castor oil, for use in lacquers; and on linseed oil, which is another excellent plasticizer used in the finish for patent leather.

XI. ALUM TANNING

Where white leather is required, alum tanning should be employed. Although this is not entirely resistant to moisture, the process of alum tanning is widely used where soft, white and pliable leather is to be made by simple methods. The use of alum is known from very ancient times; it may have been introduced in Europe by the Arabs who, for centuries, had employed it as a tanning material.

Alum tanning is suitable for both unhaired skins and fur skins — for example, rabbit, buck or leopard. It may also be used for reptile skins, such as lizards or snake.

The skin must be perfectly soaked in cold water with a little salt to retard bacterial action, and great care must be taken to remove all the hypodermis — especially of fur skins — for flesh and adipose tissues prevent the penetration of the alum salt.

For goods tanned without hair, scudding after depilation must also be perfect; for any remaining hair or follicles will show on the finished white leather.

There are three methods of using alum for tanning: alum can be applied in the form of a solution; in thin paste; or in thick paste.

Whatever method of treating the skins is used, it is important, first of all, to examine their condition of acidity or alkalinity. If they contain lime or alkali. this will make the alum very astringent, and it will give a hard. firm and tinny leather. If, on the other hand, they are too acid, the tannage will be poorly fixed and the leather will be very thin. The right condition is about pH 5.0, which is obtained by drenching free from lime; it is a very slightly acid condition.

Alum solution

This is made by dissolving 10 kilograms of potash alum and 3 kilograms of salt in 100 liters of water. The skins are soaked in this solution for some three days, and there is occasional stirring. After this, they are taken out, dried completely, kept for about three weeks to mature and then placed in moist sawdust before they are staked.

Alum in solution produces a leather which is not very soft. To obtain softer leather, drumming or churning in a thin paste is recommended.

Thin alum paste

Dissolve 3.5 kilograms of potash alum and 1 kilogram of common salt in enough water to make a thin paste. A little soda is added until a slight cloudiness appears. Then approximately 1 kilogram of egg yolk and 2 kilograms of flour are added. Add 110 liters of water and mix thoroughly.

The skins are placed in a drum or churn with this paste and revolved for approximately four hours. Afterwards, some more paste is added. This amount of paste is sufficient to tan 45 kilograms of wet goods. When the second quantity of paste is added, some oil, such as groundnut oil, should also be added. The tanning takes a whole day. The skins should then be left overnight and taken out on the following day.

Thick alum paste

When a drum is not available and the amount of skins to be tanned is not large, a satisfactory alternative method is to use a thick alum paste which is made in this way: dissolve 1.5 kilograms of potash alum and 0.5 kilogram of common salt in a little water, and add 12 egg yolks and 2.5 kilograms of flour. Add water to this mixture to bring the texture to that of thin porridge.

The paste is applied by laying the skins flat on a table and by rubbing the paste evenly into the flesh, while leaving a layer of about half a centimeter on the surface. To retard drying out, the skins are folded inwards. They are rolled and then piled in a cool dark

place, where they are covered with wet gunny and weighed down with a stone. After about five days, the damp or dried paste is shaken off. This process may need to be repeated, according to the thickness of the skins. When a reapplication is necessary, the skins are resoaked in water until they are soft. The paste is applied in the same way as before.

There are many recipes for making alum paste. Most tanners have their own which they find suited to different kinds of leather. Here is a popular recipe.

Dissolve 1.1 kilograms of potash alum and 0.5 kilogram of common salt in a little water. Mix separately 1.8 kilograms of flour, 0.5 kilogram of French chalk or kaolin with 0.7 kilogram of egg yolk and 58 grams of olive oil; and add 5.7 liters of water.

Too much salt always produces moist leather, while softness, fullness and velvety texture can be achieved by adding egg yolk.

The finishing of alum tanned leather requires skill and patience. It cannot be hurried; for the leather should " age " for some three weeks before finishing. Before staking, it is wise to put the leather in moist sawdust overnight; for this simplifies the operation. The wood from which the sawdust is derived, however, must be white and free from tannins. Finishing with pumice stone or sandpaper gives a velvet texture. Should there be fat stains, these can be removed by dusting the area with French chalk, rubbing with bran, or dabbing with petrol on a clean rag or cottonwool.

Alum tanned leather, as has already been mentioned, is not waterresistant. It is thus unsuitable for shoes.

XII. OIL TANNING

Oil tanning is one of the oldest forms of tanning. Our ancestors used stones to rub fatty substances, such as brains, bone marrow, ghee, butter or milk, into hides and skins to obtain a material which resembled leather. The process was simple. The hides or skins were treated with cattle dung, or they were merely bundled and left until a superficial putrefaction had started. After the hair had been loosened, it was removed by rubbing with a sharp instrument. Brain or marrow was then applied to the flesh side and the skins were covered, so that little air could find access. After a week, they were spread out, stretched, pulled and kneaded to soften them. The flesh side was then cleaned of meat with a sharp instrument and rubbed smooth with lime or pumice stone.

Today the process of oil tanning is basically similar, and it still involves kneading, stretching and trampling. Oil tanning is, therefore, a combination of chemical and mechanical processes. Correctly prepared oil tanned leather is durable and washable, and it is considered very healthy to wear. Oil tanned leather with the proper characteristics can be obtained only by using marine oils, such as cod, whale, shark or seal; of non-marine oils, rape oil is claimed to be the best.

Making reims

A typical example of rough oil tanning is the preparation of leather ropes called reims, which are used for ox harness in South Africa. Apart from harness, they may be used to secure animals or as springs for beds, seats and for many other purposes.

Reims are made by a combination of mechanical treatment

(twisting) and chemical treatment (rubbing in oils or fat). Although the making of reims is not regarded as true tanning, it is described here because it is useful for rural tanners, who can sell their produce to farmers.

Hides from suitable animals should be carefully selected — in particular, hides from young oxen or steers. It is possible to make reims with the hair on, but some prefer to remove the hair by one of various depilating methods.

As full liming is not necessary, the hides should only be kept in lime until the hair can be scraped off easily. Alternative methods of unhairing are immersing the hide in water with wood ashes, or leaving the hide in bran for a few days; either method loosens the follicles, and then the hair can be scraped off easily.

The unhaired hide is now cut into 2.5 to 3.5 centimeter wide strips. If very long reims are needed, they can be made by cutting around the hide from outside towards the center. In this way, one reim only is made from the whole hide. The reims are now hung over a branch of a tree, so that the two ends are hanging down. An ox cart wheel, or a heavy stone, or a piece of iron rail is attached to each end. After they have dried a little, the reims are ready for oiling. Good results are obtained by rubbing in marine oils. Equal parts of marine oils and animal oils — for instance, cod or whale with melted tallow or mutton fat — can also be recommended. Penetration of the oils is made easier by winding and unwinding for half an hour. This process of twisting by hand is repeated at least three times daily. The next day the reims can be moistened, and the twisting and untwisting are repeated. After four to five days of this treatment, the oil tannage should be complete.

"Raw hide" leather

This term is used to describe hides and skins which have received a type of fat tanning by working in fatty substances. The mechanical action softens the hide, while the fat renders it waterproof and resistant to decay.

Even today, the following primitive method is used in certain rural areas: a paste is made which contains seven parts of flour, seven parts of beef tallow, two parts of mutton fat and one part

of salt. By adding a little warm water, all the ingredients are mixed together until a paste of uniform consistency is obtained. This is ready for use and it is applied on an unhaired hide or skin.

In certain parts of the world, raw hides are prepared in the following way: properly limed, unhaired and fleshed hides are rubbed, when still wet, with any available oil or fat, or even a combination of both — for instance, 1 kilogram of groundnut oil with 1 kilogram of tallow. They are heated together until a uniform mixture is obtained. This is rubbed into the flesh side of the hide, which is then hung over a wire in a dark, warm room. Before it is completely dry, it is kneaded, worked over and trampled and then put in water for a short period. The wet skins or hides are again oiled and returned to the dark room to dry. The process is repeated several times, according to the thickness of the hides. Oils and fats should be applied only to damp or wet hides; for during the process of evaporation, the fat replaces the water. The flesh side is then smoothed by rubbing with pieces of pumice stone.

Oil tanned leather

This simple method of oil tanning suitable for rural tanneries is recommended.

Properly delimed skins are rubbed with one of the marine oils — for example, cod, shark, whale or seal. The skins are then put into a wooden vat and trampled for three hours until they have a soapy, slippery appearance. Afterwards they are taken out, piled one on top of the other and tightly covered with a tarpaulin. When the pile is opened next day, it will be found that heat has been generated and that a definite odor has been produced by the skins. They are again put into the vat, sprinkled with oil and trampled for another three hours. A second dressing of a mixture of 1 kilogram of cod liver oil and 3 kilograms of soap which is dissolved by heating in 10 liters of water may also be applied.

The skins are now hung to dry in a very small and very warm dark room. After they have completely dried out, they are soaked in warm water, and all the excess oil is squeezed out. The skins are stretched in all directions, kneaded and worked over again until

they are extremely soft and pliable. They are again washed in warm water and hung in the sun to give them a light color. After the skins are dry, they are stacked and finished in the usual manner.

Chamois tanning of sheepskins

Certain oils have been known and used since prehistoric times for their tanning action. Centuries ago, the skins of the Alpine chamois, tanned with oil, were in great demand for clothing leathers.

As the true chamois became scarcer, tanners learned to prepare sheepskins for the leather which is known today as *chamois*; and the process of oil tanning sheepskins is known as *chamoising*.

This tanning method produces very supple, stretchable and soft leather, but it involves much time and labor. Special care has to be taken and it is a good practice to use a ball mill or a machine called "crank," "faller stocks," or "kickers."

Chamois tanning is confined to sheepskin fleshes; and the grains after splitting are tanned and dyed as skivers for fancy leathers.

The "faller stocks" machine (Figure 71) consists of two vertical arms, which swing past each other when the machine is running. Attached to these arms are two cast iron feet, which are made in the shape of steps and which pound and work the leather. The pummeling, or stocking, is occasionally stopped, and then the skins are spread out to cool. They are oiled again and returned to the faller stocks.

The skins receive several treatments with cod liver oil, or with seal, whale, shark or similar oils. The highest quality of chamois, however, is obtained with cod liver oil. Between the operations, the skins are piled up in heaps and covered with canvas. Chemical reactions develop much heat in the heap and it is necessary to turn the skins over occasionally to prevent damage from overheating. The duration of this tanning process is determined by the properties which are desired in the leather.

During piling, the color of the skins is gradually changed into yellow, and this indicates that tannage has set in. Temperature inside the pile, however, should never exceed 40° C.

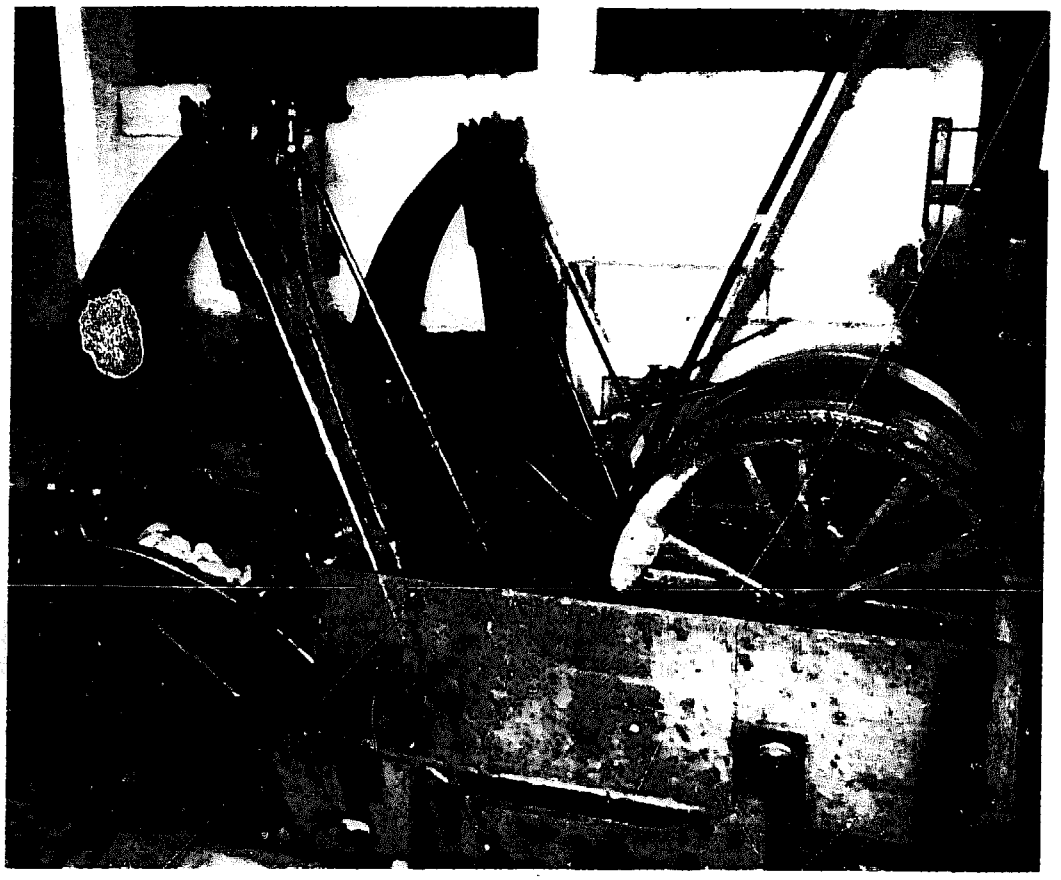

FIGURE 71. – *Crank or faller stock machine as used in oil tanning.*

Courtesy Marocchinerie e Scamoscerie Italiane, Turin

In hot weather, the piling of oil-treated skins is not practiced. Instead, the skins, after treatment with oil, are immediately hung up for drying in a warm humid room, where the tanning action of the oils proceeds. When the tannage is judged complete, the leather should then be drummed in water at about 40° to 43° C., to which soda ash has been added. For example, for one dozen sheepskins, 0.5 kilogram of soda ash is dissolved in water and added to the drums. By this process the surplus oil is emulsified and removed.

The bulk of uncombined oil thus recovered is sold to tanners as a fat-liquoring material under the name of *moellon*. At this stage, the skins are judged for their color, and if they are considered to be too dark, bleaching is done with a solution of 120 grams of potassium permanganate and 20 grams of sulphuric acid (specific gravity 1.84) in 100 liters of water. This process can be advantageously carried

out in a drum. The color of the skins now becomes brown. By a subsequent treatment with sodium bisulphite and one to two percent hydrochloric acid (specific gravity 1.1) in 100 liters of water, the color of the skin gradually changes into white. The best bleach is produced by exposure to sunlight. Bleaching, however, is not essential, unless the skins are to be dyed in pale shades.

An extra amount of cod liver oil is essential. For a dozen skins, for example, 4.5 kilograms of oil are required. Sometimes on 100 parts of finished chamois leather, 100 to 150 parts of oil are consumed.

XIII. TANNING OF FUR, WOOL OR HAIR SKINS

From earliest times, animal furs — among them the furs of bear, fox, mongoose, mole, monkey, lynx, leopard, rabbit, otter, sable, squirrel and antelope — have been used for clothing. Over the centuries, the art of tanning has been gradually developed to the present high standard, but its basic principles have only slightly changed. Several methods are used. Some are described in this chapter.

Correct preparation of the fur skins

It is most important that the fur should reach the tannery without any damage to the hair; for obviously the hair is the most valuable part. Fur skins require greater attention than others; for almost any damage leads to a loss of hair and to bare patches. The flaying knife should be curved with a blunt tip.

Flaying should be started as soon as possible, preferably while the animal is still warm. Casing is the best method, for it does the least damage to the fur. For preference, it is done by hand pulling, and the knife is used only to cut subcutaneous muscles.[1] The greatest care must be taken while flaying around the nostrils, ears and eyes, for these places are easily damaged. With many furs, however, the head is not flayed at all, and the skin is removed only as far as the neck.

Preservation

The finest results are obtained when the furs reach the tannery completely fresh and within four hours of flaying; but, as a rule, these conditions are impossible. The alternative is to use some

[1] See *Flaying and Curing of Hides and Skins as a Rural Industry*, FAO Agricultural Development Paper No. 49, p. 30.

temporary preservatives, such as immersing the skins in a saturated salt solution for a few days.

For longer periods, however, wet salting can be used, and this requires skill.[2] First, the skins should be thoroughly washed to remove any blood. Then, after draining and fleshing, they should be spread on a flat table or on the ground, and fresh medium-grain salt should be rubbed in evenly. Afterwards, the bellies are folded over, so that they touch each other. The skin should then be rolled — with the hair out — from head to tail and the bundle secured with a rope. A skin preserved in this manner will remain fresh, according to the weather, for about ten days. This method is particularly suitable for hunters who are able to deliver the furs to a tannery within this period.

When the skins have to be kept for a longer period, they must be either resalted or dried. This is done in the following manner. The salt which has been left over is shaken off, and all the wrinkles and infolds are carefully stretched out. New fine salt is spread evenly, and it is gently rubbed over the whole surface. An even layer of not more than 0.5 centimeter of salt is left, and the belly part is closed together. The skins are now rolled from the head towards the tail into a round bundle and tied with a string.

Further preservation for periods of longer than five to seven days can be achieved by drying the previously salted skins. The salt is beaten or shaken off, and the skin is merely dried, flesh side out, over a wire in the shade. The fur must be suspended without wrinkles; otherwise putrefaction may occur. Here again, by leaving the flesh side out, the hairs are protected against the bleaching rays of the sun.

Certain types of fur skins are dried on a skeleton frame by inserting a U-shaped piece of wire. Drying must be in the shade, and it is always done with the flesh side out. Drying on a hoop can be carried out easily by bending a green branch to the desired form. Alternately, the skins may be dried on a board by nailing them, while allowing a space of at least 1 centimeter between the board and the skins.

Fur skins are susceptible to heavy damage by insects, but a certain degree of protection can be obtained by the use of dry pyrethrum flowers, naphthalene or chillies, finely ground and spread

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[2] See *Flaying and Curing of Hides and Skins*, p. 70.

over both surfaces. Evenly dusted modern insecticides which contain gammexane or DDT will provide complete protection for up to six months.

Tanning

The aim of tanning is to obtain an attractive and lustrous fur, and the damage which results in bare patches must be avoided. The tanning of fur skins is similar to the tanning of other skins, except that the epidermis, which includes the hair, is not removed; and liming is not practiced because it leads to the destruction of the epidermis.

Soaking, therefore, should be carried out with the utmost care, and the operation is completed as soon as possible to prevent hair slip. Only cold water is used. The soaking period for air-dried fur skins should be longer than that for dry-salted or wet-salted skins. To facilitate the soaking process, 3 to 5 percent salt is added to the water, which should be changed several times. Large skins can be trampled by foot, taken out and worked with a blunt knife over a beam until the hard meat can be removed. Small fur skins can be rubbed by hand until they are completely soft.

For small fur skins, the salt solution is also applied only on the flesh side to prevent any possible damage to the hairs.

Wool skins which, such as lamb, contain fat or grease must first have the fat removed by fleshing. This is followed by washing in several changes of warm water, to which washing soda is added. Apart from this defatting procedure, however, good results are obtained only when the cured skins are brought back to a condition almost similar to their condition immediately after their flaying before curing.

Chrome tanning of fur skins

The preparation of fur skins which are resistant to all kinds of influence is best done through chrome tanning. In the past, chrome tanning was made unpopular through some mistaken idea that it was difficult to produce soft and supple fur skins. Chrome tanning,

it was also found, made the bleaching of the hairs difficult. After bleaching, it often happened that the entire lot of chrome furs was destroyed. These disadvantages and difficulties, however, have all been overcome. At the present time, the best quality fur skin can be produced by this method, even though an inexperienced tanner encounters preliminary difficulties.

Chrome tanning, it must be recognized, is an irreversible process. In contrast to alum tanning, however, chrome tanned fur skins are full, durable, and resistant to moisture and heat. The properties of chrome tanned fur skins are also especially advantageous for the dyeing process. It is now possible to dye all kinds of fur skins by first treating them with chrome.

As a rule, those chrome tanning materials which are applied for ordinary leather tanning — that is chrome alum and other commercial chrome salts — can be used.

Special care, however, is needed to prevent an overtanning of the hairs. The so-called two-bath chrome tanning method should not be followed, because it produces an undesirable tanning of the hairs.

The following chrome tanning methods are recommended:

(*a*) the application of the chrome liquor on the flesh side of the skins only; and

(*b*) the immersion in chrome liquor in a vat or paddle.

The application of chrome liquor on the flesh side is only practiced when the number of skins to be treated is small. The concentration of the chrome liquor is then 30 to 40 grams of chrome salts (with 25 to 30 percent chromoxide) and 60 to 100 grams of common salt for each 1 liter of water.

The concentration of the liquor to be used in a vat or a paddle should be 4 to 6 grams of chrome salt and 30 to 40 grams of common salt for each 1 liter of water; and the ratio of skin to liquor is equal to 1 to 10 or 1 to 20. Paddling should be continuous.

Pickling before chrome tanning is not required, because the fur skins have not undergone any alkali treatment.

An initial tanning with aluminum salts, by which process the skins are brought to a slight acid condition, is beneficial. Chrome salts, which are expensive, can then also be saved.

Initial alum tanning should always be followed by a reduction of the moisture content of the skins; for this facilitates the thinning out of the flesh side.

The bleaching of the hairs with hydrogen peroxide can also be carried out in a more efficient way without damaging the skins. This peroxide bleach should be done before the chrome tanning; otherwise the leather might be completely destroyed.

For initial alum tanning a concentration of 30 grams alum and 50 grams common salt is used per 1 liter of water.

For chrome retanning, chrome alum is being used, and about 15 percent of the shaved initial alum tanned weight is recommended.

For tanneries with drum tanning facilities, the following procedure is recommended :

(*a*) to 100 percent water, add 5 percent common salt and turn for 15 minutes;

(*b*) add 2 percent chrome alum and 7.95 percent sodium carbonate on chrome alum weight; turn for an hour;

(*c*) add 3 percent chrome alum and 10.6 percent sodium carbonate on chrome alum weight; turn for one hour;

(*d*) add 5 percent chrome alum and 15.9 percent sodium carbonate on chrome alum weight; turn for one hour;

(*e*) add 5 percent chrome alum and 15.9 percent sodium carbonate on chrome alum weight; turn for two hours.

(In drumming wool skins, the drum should revolve slowly — say, about twice each minute — and thus avoid any felting of the wool.)

Finally, add 0.4 to 0.8 percent sodium carbonate on the initial tanned weight, dissolve sodium carbonate in 10 to 20 times water, and turn for a further three hours, or until tanned through.

Tanning time differs. Light hides or skins are tanned in about eight hours, while heavy hides take 12 to 24 hours.

On the second day, if a longer tanning time is needed (12 to 24 hours), more sodium carbonate is added.

The chrome tanned fur skins should be horsed up overnight for about 12 hours to ensure a maximum fixation of the chromium. The skins are then washed and neutralized. Washing removes most

of the salts and some of the acid present in the leather The removal of the salts helps to prevent the formation of a salt spew later on, and the removal of free acid mechanically held by the fur and leather ensures that the neutralizing agent is not wasted.

Neutralization of fur skins is carried out in a drum, and the leather to water ratio should be 1 to 20. For neutralization, 10 to 30 grams sodium bicarbonate per liter of water are sufficient, and the drumming is for about half to one hour. Subsequently, the fur skins are thoroughly washed in running water for 30 minutes.

Tanning of hair skins with basic aluminium sulphate

The Central Leather Research Institute in Madras recommends the following process.

Skins which are received in a dry condition are soaked overnight in a 6 percent solution of common salt, to which 0.1 percent carbolic acid, or 1 percent boric acid, on the volume of water is added. The skins are left in the soaking bath overnight. Next day they are rough fleshed, if this is necessary, and again soaked in a fresh soaking bath prepared as before. They are left in the bath overnight until the skins acquire the desired softness. They are then taken out, and the water is allowed to drip off them.

Next they are pickled with 100 percent water, 10 percent common salt and 1 percent sulphuric acid; and these percentages are based on the weight of the soaked skins. They are left in this solution for one or two days. During this time they are hauled up, well drained and put back. The pH of the pickled pelt is about 3.5 to 3.7.

The skins are now piled and tanned in a liquor, which contains 15 percent basic aluminium sulphate, and this is calculated on the pickled weight.[3] Tanning takes from two to three days. It is completed by the addition of soda ash, or hypo, in the quantities needed to raise the pH of the tanning bath. The initial pH of the bath is 3.5 to 3.8, and this is raised to 4.5 towards the end of the tanning process. The addition of soda, or hypo, makes the tanning liquor more basic; that is, more powerful for tanning. To ensure

[3] For the preparation of this solution, see later section of this chapter on "Pickling."

a complete tanning, the skins are left in this soda bath for anotl one or two days.

The completely tanned skins are washed with water to remove the adhering tan liquor from them. The washed skins are horsed up, or piled, for "samming" — in order to remove an excess of water by a slight drying.

The "sammed" skins are fatliquored at a temperature of 45° C. for one hour with a fat liquor of this composition — sulphonated neats foot oil 1.5 percent: neats foot oil 1.5 percent: cod oil 1 percent; castor oil 2 percent and soap flakes 1 percent — or else with any other suitable fat liquor.

The percentages are on the weight of the "sammed" skins. The fat liquor is adjusted to a quantity which does not make the finished skins too greasy.

In the finishing operation the fatliquored skins are "sammed" by drying them in the shade. The dried skins are finally staked to make them nice and soft to the feel.

Basic aluminium sulphate is usually prepared the previous day in the following way: dissolve, in a tub, 31.8 kilograms of aluminium sulphate and 2.3 kilograms of sodium citrate in 68 liters of water. Dissolve separately, in another tub, 7.9 kilograms of soda ash in 23 liters of water. The soda ash solution is added in two or three instalments in the course of an hour and with a good stirring. The solution is left to age overnight. The clear solution has a pH of 3.4.

Fur skin tanning with vegetable and synthetic tanning materials

Vegetable fur skin tanning, if practiced alone, will not produce the same quality leather as that obtained with other tanning materials. Lack of softness, stretchability and suppleness are the main reasons why this tanning method is seldom practiced in fur skin tanning. During vegetable tanning, moreover, the hairs of the skin become more or less colored, while it is also a disadvantage that the dyeing of vegetable tanned fur skins can be carried out in dye solutions only at low temperatures.

The dyeing of chrome tanned skins, however, can be done in a more efficient way; for they can be dyed at much higher temperatures than can vegetable tanned fur skins.

Very good results are also obtained by using a combination of vegetable and synthetic tanning materials, but when a bright and white fur skin is required, synthetic tanning materials alone are preferred. This skin should be first pickled in a solution of sulphuric acid and common salt, followed by draining and centrifugation, and finally it should be tanned in a synthetic tanning solution of 30° to 40° Bkr. Pickling by immersion, however, is recommended only if the fur or hairs are unharmed.

Pickling

Although it is customary to pickle fur skins, certain difficulties must be overcome. Some fur skins are discolored when they come into touch with acids. When, therefore, pickling is applied, care is needed to avoid wetting the fur side.

Pickling of fur skins differs from that of unhaired skins, for they are not immersed in liquor. Instead, they are swabbed with it while they are stretched in a frame or spread on a table. The concentration of the pickle is 3.6 kilograms of common salt and 0.3 kilogram of sulphuric acid (specific gravity 1.84) to 40 liters of water.

Pickling of fur skins has also been done successfully by using a mixture of one part sodium bisulphate and four parts of common salt; and the dry pickle is rubbed into the wet skin.

Tanning

Synthetic tanning materials are used in the following ways:

(*a*) as an initial tanning alone — that is, before the tanning with vegetable material; or

(*b*) blended with vegetable tanning materials in the tanning process; or

(*c*) alone or blended with vegetable materials as a retanning.

To pickled stock destined for drum tanning, the initial tanning is normally applied in the drum. About 4 to 5 percent of a suitable synthetic tanning material, based on the drained and pickled weight of the furs, is used.

The undiluted synthetic tanning material is added directly to the stock in the drum, and 30 minutes of drumming are sufficient for the complete take-up of the tannins. The furs are washed in water to remove excess salt and acid.

The after-tanning in drum, paddle, or pit proceeds rapidly, and a strong vegetable extract solution of 30° to 40° Bkr. can be used for very heavy skins. This type of tanning has proved successful on greasy stocks or on stock hard to penetrate.

Finally, the tanned skins are thoroughly washed, fat liquored and finished in the usual way.

Fat liquoring

If oil is not introduced during tanning nor incorporated in the alum paste, fat liquoring of the fur skins is necessary. The fat liquoring process also follows chrome tanning, neutralizing, washing and draining. The object is to restore the natural fats which were lost during the tanning, and thus to regain suppleness and softness. The fatty matters most suitable for this purpose are generally in liquid form — that is, fish oils, mineral oils and vegetable oils, such as are obtained from rape seed. Glycerine is also used, and it is mixed with oils to facilitate the penetration of the fat liquor. Undiluted egg yolk can also be applied by rubbing in evenly on the flesh side.

To a large extent sulphonated oils are now replacing the conventional oils, for their use results in a better penetration and in a more uniform distribution of the fat. Their emulsions are more stable in hard water.

Fat liquoring is usually applied to the flesh side, and special care should be taken not to contaminate the hairs. After fat liquoring, the fur skins are piled, flesh on flesh, folded together along the backbone line and left in this condition for a couple of hours. They are then hung for drying over poles in well ventilated rooms, where the temperature should not exceed 30° C. The skins should not be allowed to dry out completely, for they should retain enough moisture to facilitate the subsequent stretching, cleaning, degreasing and softening processes. It is a good practice during drying to stretch the skins in all directions.

In the next operation, the fur skins are cleansed thoroughly to free the hair or wool from dirt and other impediments. This process is known as " scouring " and it is carried out with the help of sawdust. Here the skins are left in moist sawdust for 24 hours, or, still better, the sawdust is applied to the hair side before the skins are drummed in a rotating drum for about one hour. The humid sawdust absorbs the dirt and separates the hairs. A thorough scouring effect can be obtained by raising the temperature inside the drum to 35° C. When the skins are greasy, the sawdust is damped with a solvent like white spirit. The skins are degreased by drumming.

When no subsequent dyeing is anticipated, it is a good practice to add some kaolin to the sawdust. This, in addition to the drumming, has a good softening effect. To condition skins which have been overdried, scouring should start with partly wet sawdust followed by drumming in dry sawdust. After scouring, the adhering sawdust is removed by drumming in a lattice drum or in a wire-mesh drum or by gently beating the fur skins with sticks, or by brushing them with a stiff brush.

As a rule, stretching and drumming are not enough to obtain the desired degree of softness. In addition, therefore, the fur skins are stretched over a half-moon shaped staking knife, or knee staking apparatus. In this way, the hide fibers are separated from each other, and softness and suppleness are obtained. For preference, stretching and staking should be carried out between wet sawdust and dry sawdust drumming, and again immediately after dry drumming. The skins should be stretched more in the length than in the width.

The stretching and staking operation calls for skill and patience; otherwise the skin may be torn. Special attention must be paid to legs and neck, for they have a tendency to wrinkle during tanning.

XIV. DYEING AND BLEACHING OF FURS

The dyeing of furs requires skill and knowledge. They can be obtained only after many years of practical experience. The work involves the use of special techniques and "developed dyes," in which an insoluble colored pigment is formed on the fiber. Large dyestuff manufacturers supply precise details on the use of their products.

Killing of hairs

A special treatment — the "killing" of the hairs — is necessary before dyeing because hairs which consist of keratin are difficult to swell. Without pretreatment they have little affinity for dyestuffs.

The penetration of the dyestuff, therefore, should be more than just a superficial coloring. Any natural fat or grease should be removed to ensure an even and thorough dyeing effect.

The effect of swelling the fur or hairs and the emulsification of the fat or grease is obtained by treatment with a weak solution of ammonia, or else of sodium carbonate, which is particularly suitable for soft hair or wool.

For stiff or hard hairs, sodium carbonate or a mixture of soda and ammonia is recommended, while caustic soda is only applied to particularly hard hairy skins. If this process is carried out with the help of a brush, the concentration of the liquor should be higher than when the skins are immersed in liquor.

The concentration of commercial ammonia is normally 22 percent, and the strength of the working solution should not be more than 50 cubic centimeters per liter when brushing. The concentration of sodium carbonate solution should be about 50 grams in one liter of water. Caustic soda solutions vary from 7° to 35° Bkr.

By treating the skins in the liquor, the following concentrations are used: (*a*) 5 to 10 grams of sodium carbonate; or (*b*) 5 to 10 cubic centimeters of ammonia (of 22 percent) in one liter of water. If the two chemicals are mixed together, half of the above quantities should be calculated. The temperature of the solution should not exceed 32° C.

Any concentration which is too strong is detrimental to the hairs, for they will lose their elasticity, suppleness and shape. In extreme examples, the hair shafts and tips curve or dissolve. Moreover, the leather fiber is also affected. Hard and stiff fur skins with cracky grain are the result.

Sometimes hydrogen peroxide and ammonia are used for obtaining a bleaching effect on the hairs. As an example, the following mixture is mentioned: 50 parts of hydrogen peroxide (of 40 percent), 25 parts of ammonia (of 22 percent) and 80 parts of water.

Mordanting process

In this process, use is made of certain salts which help to fix the dyestuff on the hairs by forming an insoluble product. Before the so-called mordanting, the hairs should be washed out thoroughly. Any alkali which is left should be removed, or neutralized, by adding some acid to the liquor. The most common salts used in this process are chrome alum, potassium bichromate, copper sulphate and iron sulphate. These salts produce on the hairs a characteristic of their own — for example, chrome alum produces a reddish blue; potassium bichromate, a dark red-brown shade; copper sulphate, a very dark shade; and iron sulphate, a blue-gray shade.

By combining these salts, a wider range of shades is obtained. Iron sulphate and potassium bichromate, however, should not be used together; otherwise a precipitation follows.

To carry out the process, the fur skins are continuously moved in the salt solution. Its temperature should not exceed 30° C. The duration of the movement depends on the desired intensity, and it varies from 3 to 15 hours.

The concentration is variable and it depends on the kind of fur skins and on the shades which are desired.

For 1 liter of water, the following examples are given:

(*a*) 5 to 10 grams of chrome alum and 10 to 20 grams of common salt;

(*b*) 1 to 2 grams of potassium bichromate and 1 to 1.5 grams of acetic acid (of 30 percent);

(*c*) 1 to 4 grams of iron sulphate with 0.5 to 2 grams of acetic acid (of 30 percent) and 5 to 10 grams of ammonium chloride.

When these salts are used in a mixture, their quantity should be correspondingly reduced. After mordanting, the fur skins are pressed or centrifuged and washed thoroughly with cold water. They are then ready for dyeing.

If the mordanting was too short, or if the solution used was too weak, the shades will not be sufficiently deep. If, however, the fur skins are excessively mordanted, no coloring effect can be obtained at all. When this happens, the fur skin should be treated with acid to make dyeing possible.

For wool dyeing, the wool must be pretreated with sodium hypochlorite. Paddles are used, and the wool skins run for five to ten minutes in water with a temperature of 20° C. to ensure that the wool skins are uniformly soaked back. For every 500 liters of water, about 1 kilogram of sodium hypochlorite is used. It is dissolved separately and added to the paddle over a period of 15 minutes.

After the last addition, the wool skins are paddled for another 20 minutes. Subsequently, hydrochloric acid is added to make the solution acid. About 170 cubic centimeters of hydrochloric acid (specific gravity 1.2) are sufficient for every 500 liters of water.

This addition should be done in portions over a period of 15 minutes. After the last addition the paddling is continued for another 15 minutes.

The wool skins are now taken out and thrown into a new liquor, which consists of 187 grams of soda ash and 187 grams of sodium sulphite crystals for every 500 liters of water. The paddle is again run for 20 minutes.

Gaseous chlorination — another method very advantageous for wool skins — is also recommended.

Bleaching

Natural white colored fur skins have generally an uneven and slighly yellow color. To obtain an even white color they have to be bleached.

Black hair pigments can also be removed by bleaching, so that nearly white fur skins will result from skins which are dark colored by nature. A good bleaching effect can be obtained by treating the hairs with hydrogen peroxide or with the fumes of sulphur dioxide. Extreme bleaching, however, should be avoided, for it has a detrimental effect on the leather properties of the skins.

Certain precautions are therefore essential, and it is a good practice to carry out the fat liquoring process in such a way that the fatty matters or oil penetrate through the entire skin. An initial treatment with formaldehyde also gives a sufficient protection.

Chrome tanned fur skins which are treated with chrome salts should not be bleached, for the bleaching process may destroy the fiber structure of the leather. Bleaching with hydrogen peroxide is also practiced, if the furs are to be dyed. Here the bleaching process should be carried out between the killing, mordanting and dyeing processes. The fur skins are immersed in the bleach liquor, which has a temperature of 32° to 35° C.; and a bleaching effect is obtained after an immersion of two to six hours. The bleaching liquor contains 600 cubic centimeters of hydrogen peroxide (of 3 percent) and 100 cubic centimeters of water, to which some ammonia is added. The pH of this liquor should be continuously checked; for when the alkalinity is too high, it reduces the bleaching effect, and when the pH of the liquor falls below pH 7, no bleaching can be obtained at all.[4]

Sulphur bleaching is also practiced. For this purpose the damp fur skins are hung in an airtight chamber, which is divided into two compartments. The skins are hung in the larger compartment, while sulphur is burned in the other one. Thus the fur skins are exposed to the sulphur dioxide fumes until the desired degree of bleaching is obtained. A check must be made, now and then, to ensure that the burning of the sulphur is regular.

See Appendix on "pH Value in Tanning."

Dyeing

The dyeing process can only be carried out successfully if the pretreatment — that is, killing and mordanting — has been satisfactorily effected. The following factors can also greatly influence the dyeing process:

(*a*) the concentration of the dye bath;

(*b*) the duration of the process;

(*c*) the temperature of the dye bath; and

(*d*) the acidity (or alkalinity) of the dye bath.

Different processes and materials which can be applied are mentioned below.

Natural dyes

There are a number of natural dyes in use — for instance, haematin, fustic or yellow wood, leaves of sumac, gallic acid and others.

Only fur skins mordanted with salts can be dyed with natural dyes. The dyes form insoluble lakes with the salt on the hairs, while the final fixation and shade are developed through the combination of oxygen from the air.

The fur skins are either drawn through the dye bath or remain for some hours in the dye solution at a temperature which does not exceed 45° C. Vegetable dyes have a beneficial influence on the properties of the hairs and the leather, for a certain tanning effect is obtained on both the hairs and the skin.

Soft hairy or woolly skins, in particular, benefit by this treatment. Dyeing with wood dyes is still practiced for high-quality furs, such as the so-called Persian fur skins.

"Development" dyes (also called "diazo" dyes)

There are a number of dyes, which are known commercially, but no further reference to their application is made here.

Synthetic dyes

These dyestuff solutions, which are commercially available, are not discussed in this paper.

Color effect with salts

The principle of producing color effects with salts is based on the use of basic lead acetate. This salt can be changed into lead sulphide by using sodium sulphide, whereby yellow, orange or redbrown shades are obtained. Special nuances can be effected by brushing the hair tips with the lead salt.

Dressing sheepskins for wool rugs

It is easy for a rural tanner to make attractive wool rugs from sheepskins. Preferably, pure white skins should be used.

The best results are obtained from sheepskins which come straight from the butcher. They should be thoroughly washed on both sides with soda and soap in warm water until all traces of dirt and blood are removed. If green skins are unobtainable, the dry skins should be soaked in the same way as other skins. As the next step, the fat must be removed. This is the most important operation, and it should be carried out very carefully. The skins are first stretched on frames similar to those used for the manufacture of parchment (Figure 72).

The flesh side is treated evenly with a paste which is made of Fuller's earth or whiting (calcium carbonate or chalk). The skins are then exposed to moderate heat, near a stove or in the direct sunlight, until they are dry. The fat will soften and pass into the paste. This should be scraped off after a day or two. The process can be repeated when handling very fatty skins.

If a snow-white color is required, the skins can be bleached. The skins are removed from the frames and passed through a bath which contains a weak solution of bleaching powder (chloride of lime), or hydrogen peroxide. They are immediately wrung out and returned to the frame. To have them tanned, alum paste is applied to the

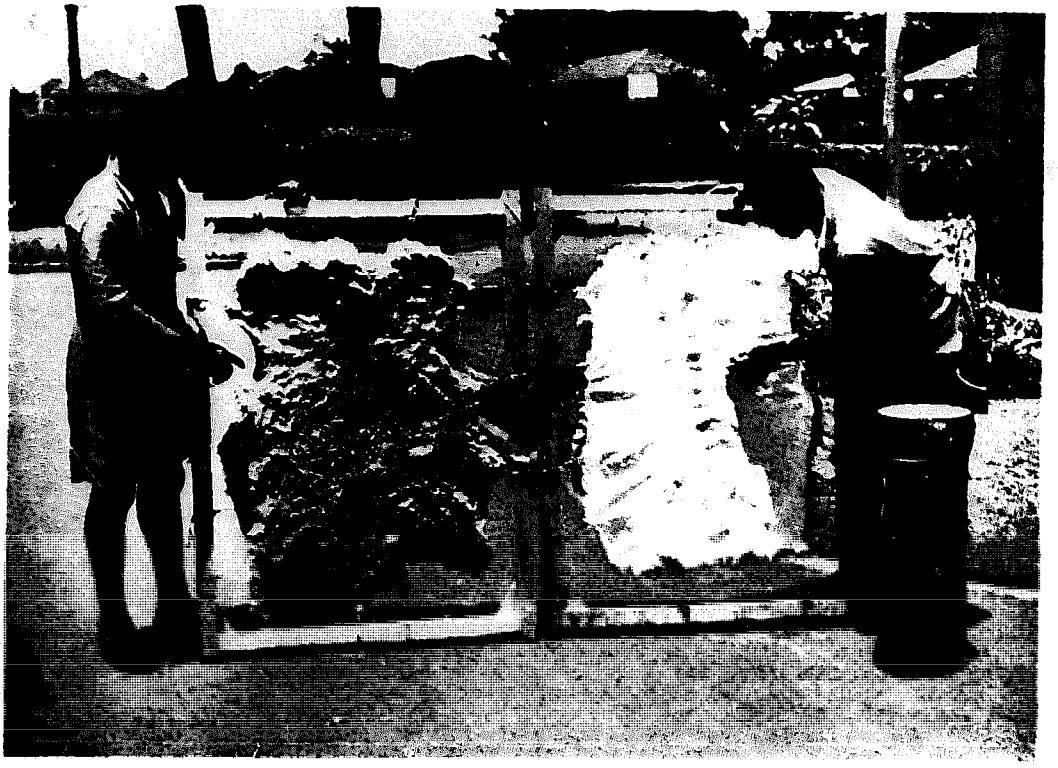

FIGURE 72. – *Dressing of sheepskins stretched in frames. Tanner on right is applying a paste of whiting to degrease skin.*

Courtesy Kenya Information Office, Nairobi

damp skins, on the flesh side only. It must never come in touch with the wool. The frames are put into a dark room: and when the skins are dry, they are taken out, and the paste is scraped off. The skins are again dampened, and a second application of paste is made.

Finally, the skins are finished, according to the methods already described in Chapter XI.

XV. PREPARATION AND TANNING OF REPTILE SKINS

Snakes and lizards

Reptile skins, such as crocodile, alligator, lizard and snake, make very attractive and durable leather; even East Asian frog skins are tanned. Unfortunately, owing to faulty preparation, reptile skins often reach the tanners in too bad a condition to tan. The usual blemishes are cuts, gouge marks, bad shape, scale slip and putrefaction. Damage due to delayed flaying or dragging over rough ground is also common. So is damage due to overdrying or overexposure to the sun, to distortion and overextension, or to the action of beetles after the skins have been dried. Damage due to parasites or ticks may have occurred before death. These skins should not be mixed with undamaged skins; they should be handled separately.

If first-class material is to be obtained, the correct methods must be used to catch and to collect reptile skins.

Preparation of snakes and lizards

The catching and killing of snakes and lizards must be done without damage to the skins. Spearing a python and battering it to death with sticks and stones will not secure a perfect skin.

Flaying should start immediately before decomposition can take place, and proper ripping lines should be used before the removal of the skin begins. Fleshing and scraping off any loose meat, fat or tissue and removing blood must start immediately after the skin has been taken off.

Lizards and snakes are opened down the belly, from the tip of the chin to the end of the tail; they are not opened on the back. Only

iguana and chameleons should be opened along the back; and their legs are cut along the center line on the lower side so as to get the full spread.

Drying

Lizard or snakeskins can be dried either on a frame wire mesh or on a board or plank. The frames are prepared from light poles without the use of nails. They are held together by bark or twines, so that they can be easily adjusted to the size of the skin. Tiny holes are made on the edge of the skin at intervals of less than 10 centimeters to take string. The skin is stretched in the frame, while care is taken not to apply too much tension. Drying on a plank can be done in the following way.

The skin, flesh side up, is nailed to the board or plank with aluminium nails. These are 2 to 3 centimeters long, and they are allowed to remain projecting above the skin. Then the skin is raised from the board and eased up to the head of each nail. This makes a clear space of about a centimeter under the skin, and it allows the air to circulate beneath.

Care must be taken that a direct sun does not scorch the skin. On all occasions, therefore, it is better to dry in the shade.

Salting

Very good results are obtained when salting is used in place of air-drying. Only fine salt should be used for salting lizard and snakeskins, for the crystals of coarse salt can cause damage by piercing into the corium.

If the skin is to be used within a week, one salting is sufficient. When it is necessary to preserve skins for a longer period, however, a further application of salt is sometimes advisable before drying out.

Salting should start immediately after the meat has been scraped from the skin; and the salt is rubbed evenly into the flesh side. The skins are then kept flat, so that the brine can drain off easily. Any excess salt can be removed after 24 hours, and this avoids blood contamination, if the skins were badly washed. The skins can be dried after the first salt has been taken off. They are then said to be "dry salted."

The second salting of wet stock starts the next day. First, the old salt is shaken out. If it has formed a crust, this can be broken by gently rubbing the skin. New clean, fine salt is evenly rubbed into the surface again, and the skin is rolled, flesh side inwards, from tail to head, so that a neat bundle is formed. Throughout the salting, it is essential to keep the stock in a wet condition by covering it with wet bagging.

Lizard and snakeskins, as will be described later, can also be preserved and exported after a light tannage.

Vegetable tannins are used only on skins which are not required to remain white. As a rule, an immersion for two days in tanning liquor made from acacia pods is a sufficient treatment.

Wet salted lizard and python skins are best shipped in wooden casks packed in a similar way to pickled pelts.

Dried goods in bales must be protected against beetles. Sprinkling with naphthalene has been used for many years. The use of modern insecticides in the form of DDT or gammexane powders, however, assures a full protection.

Crocodiles

Few workers realize that crocodile skins must be treated with greater care than lambskins. Prolonged and direct exposure to the sun is injurious to sheep- or goatskins, but even a brief exposure rapidly damages crocodile skins.

Crocodile bellies are valuable. Yet many factors make them susceptible to damage. For this reason, a brief description of the methods used to obtain the best raw material is included in this chapter.

Various methods are employed for capturing crocodiles. They depend on the local conditions and on the skill of the hunter. Whether shooting or netting, harpooning or noosing, drowning with a weight or poisoning, blinding with a torch or pole-axing, trapping or baiting on a hook is the chosen method, a number of rules must be observed. They are now described.

1. The belly part of the skin must suffer no damage. Wounds caused by spears, harpoons or bullets, or any other injuries which occur during the killing and securing of the animal, must be restricted, if possible, to the head and back.

2. Ideally the crocodile should be removed from the water immediately. The carcass should not be left in the water for more than eight hours and certainly not until it "blows" and floats to the surface: for the skins from these carcasses, even though they show no substantial damage during flaying, may be useless to the tanner.

3. The carcass should be dragged out of the water upside down, so that the back, and not the belly, comes into contact with the ground.

4. No time should be wasted between flaying, fleshing and salting. From the moment the carcass has been landed until the skin is salted, speed is essential. This is not only because there is a danger of putrefaction, but also because the skin dries out and hardens rapidly and will resist the absorption of salt.

5. The skin should never be exposed to direct sunlight: for the sun dries too rapidly, and the scales take on an oily, transparent appearance. This condition interferes with tanning. Only the belly part of the crocodile skin can be converted into leather, for the back is covered with very hard bony scales and it is horny. The backs, however, are sometimes used for decorating such articles as handbags and cigarette cases.

Skinning

The hunter should aim at obtaining a properly shaped belly skin — from the snout to the tip of the tail, including the legs (Figure 73).

The basic incisions, which are called "ripping lines," should be made in this way:

Head. Separate the skin on the neck from the body under the hard disc on the top of the neck. Cut downwards inside the jaw, near the jawbone and along the lips until the two cuts meet at the front (see A on Figure 74).

Body. Make two long incisions from the back of the head and along the body. These cuts should start at the initial cut and end at the tail fin. Two rows of scutes should be left on each side (see

B on Figure 74). This is important, because crocodile skins are sold by the width across the belly (Figure 75).

Legs. Each leg should be opened in the following way. Hold the leg firmly at the " wrist " and pull it away from the body; make an incision in the middle of the top of the leg from the main ripping line over the point of the elbow to the "wrist" (see C on Figure 74); cut around the " wrist " as near as possible to the foot (see D on Figure 74). This produces a piece of skin which has light-colored scales surrounded by an even, dark edge. It is most important, when opening up the legs, to cut through the skin over the point of the elbow; otherwise a " pocket " is formed. This defect lowers the price on grading.

Tail. It is possible to get the skin off the tail by working downwards from the main ripping line. It is better, however, to gain access by cutting out a triangle; the line between the hind legs is the base of the triangle, and the tip of the tail is its apex. Remove the triangle, and this will facilitate access to the tailpiece. On large crocodiles, which are over two meters long, the last 15 to 20 centimeters of the skin from the tail can be pulled off. On smaller specimens, however, the skin must be separated with a knife right to the tip.

When flaying, the skin should be pulled away from the body with one hand; for the knife is used only to cut through the connecting tissue. This eliminates damage by cuts and scores.

Fleshing

As soon as the skin has been separated from the carcass, it should be placed on a completely flat surface. Any surplus meat, fat or tissue should be scraped or cut off.

Washing

Blood and dirt interfere with the salting. The skin, therefore, should be thoroughly washed — or, preferably, scrubbed with a brush — while water from above is poured over it.

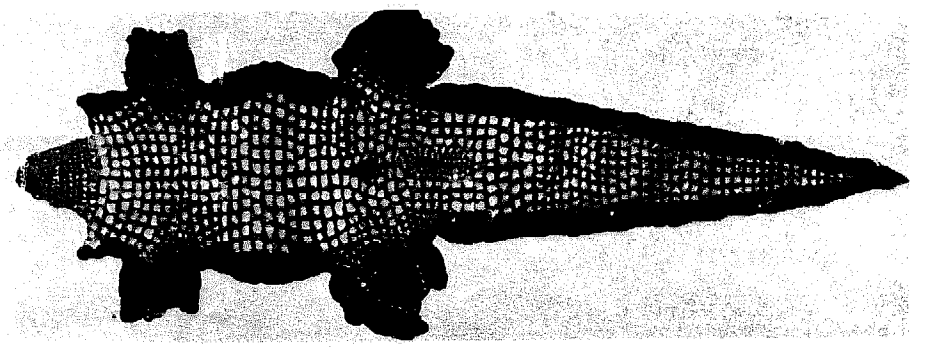

FIGURE 73. – *Properly flayed crocodile belly.*

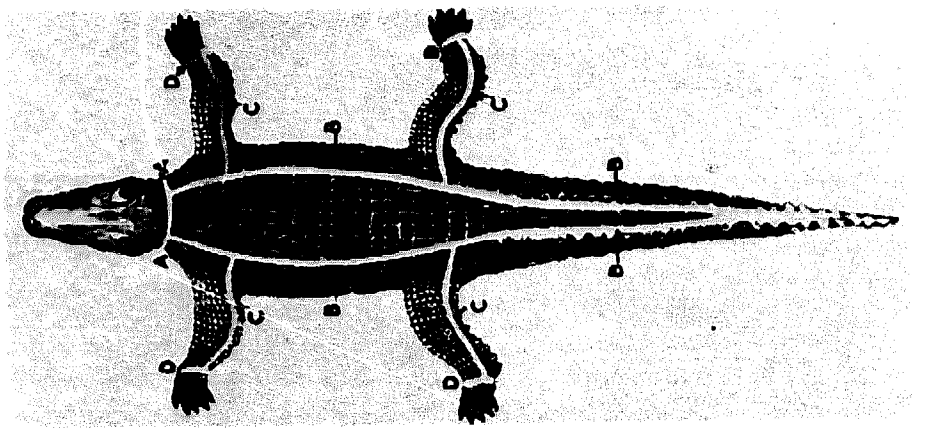

FIGURE 74. – *Proper ripping lines to flay a crocodile.*
Courtesy Kenya Information Office, Nair

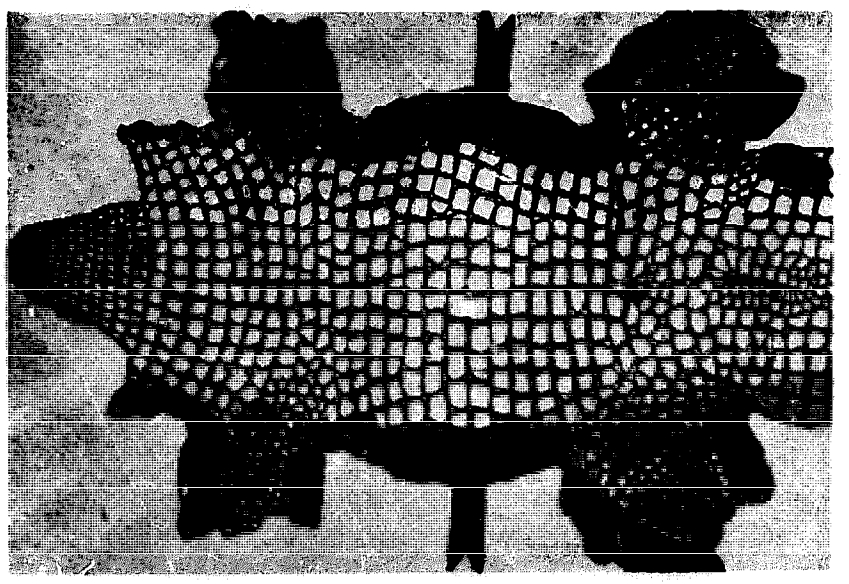

FIGURE 75. – *Crocodile skins are measured across the widest part of the belly.*

First salting

Salting is the most important and intricate operation, and it requires the greatest care. Only fine, clean, dry salt, free from dirt and blood, should be used; for coarse salt does not facilitate penetration. The salt is rubbed very thoroughly and evenly into the wet skin, on the flesh side only.

Draining

By putting the skin in the shade and by draining off the brine, a great part of the skin moisture can be removed immediately after the first salting. The skin can be put over poles or wire, with the flesh side uppermost, until dripping ceases. Great care must be taken that no sunlight beats directly on the skin (Figure 76). If, however, a second salting is anticipated, no drying effect whatever should be allowed to take place.

Second salting

The draining should not take more than one or two hours. The second salting can then begin. This is a repetition of the process used for the first salting; and the same precautions are taken.

Transport

After these two preliminary operations, the skins are taken to a storehouse for final treatment. For transportation, they should be rolled, scales inwards, and there should be a layer of salt between each skin.

Curing

In the curing process, the old salt is completely shaken off. It may be necessary, however, to examine the flesh, and any superfluous salt should be scraped off. On no account should the skin be placed on earth; it should be placed on a concrete floor or wooden platform. This concrete floor or platform is covered with a layer of 3 to 6 centimeters of salt, and the first skin is placed, scale side

downwards, on the salt; the flesh side is covered with a 6 centimeters of salt. Further layers of skins are added in the same way — that is, a layer of skins, flesh up, covered with a layer of salt. In this way a "pack" not more than 60 centimeters high is made. If this height is exceeded, damage through pressure may result.

It takes about three weeks to cure the skins and to prepare them for shipment. As the bottom layer of skins cures more quickly, it is advisable to alter their positions after ten days. This is done by placing the top skin on the floor beside the first pack and by building a new pack with the skins in reverse order. The same salt can be used, provided no red coloring is observed. This should not occur if a preservative has been used.

Packing for shipment

The skins are first removed from the pack, and the salt is shaken off without beating; for beating may damage them.

Each skin is now evenly covered with a little fresh salt. Rubbing is not necessary because cured skins absorb very little additional salt. Each skin is then folded, as shown in the diagram in Figure 77. First, the sides are folded along the lines A and D; then the head is folded in along the line B, and finally the tail along the line C. Sufficient salt should be placed in all the folds of the skin.

The skins can now be packed in clean sacks. They are placed tightly, one on top of the other, until the sack is three-quarters full. The sack is then closed and placed in another sack, which is sewn up. In this way, a double thickness of sacking gives the necessary protection against drying out.

Although this method gives good results, crating, in spite of its higher costs, is to be preferred. Care should be taken that no nails penetrate the crate, which should be well lined with sisal-craft or any other suitable material. The rectangular folded (not rolled) skins are packed very firmly, so that there is no possibility on any movement which might cause damage by friction. They should be so packed that no spaces are left, either in the corners, or at the top, before the lid is nailed down. Up to 450 kilograms of crocodile skins can be packed in this way in one crate. The crate should be strengthened with three or four bands of hoop iron.

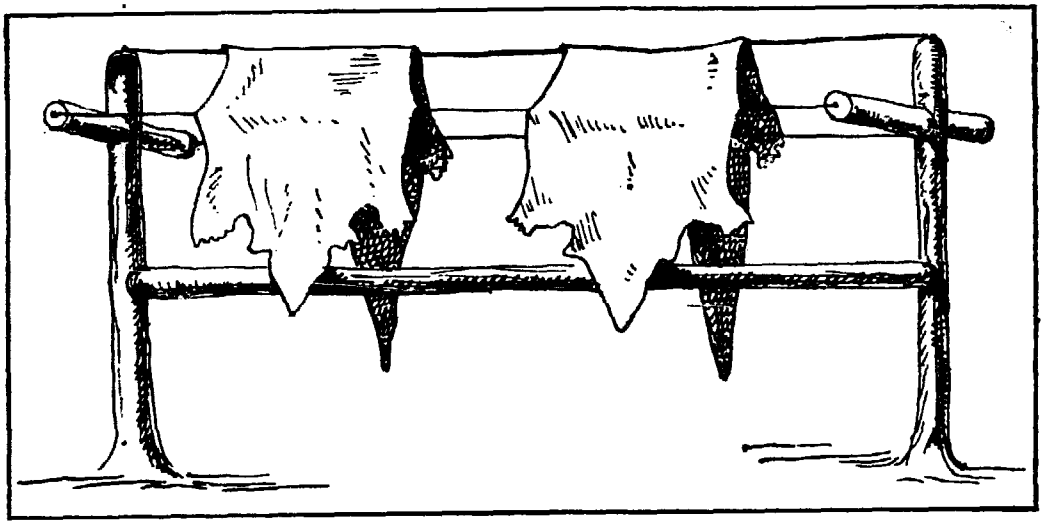

FIGURE 76. – *Draining rack for crocodile skins.*

Courtesy Mrs. Erica Mann

Progress of work at tannery

SOAKING

When the goods reach the tannery, the first step is to inspect and sort them into bundles of the same animal and origin and size. It is inadvisable, for example, to tan python skins and small snake-skins, or crocodiles and iguana, together.

Meat, fat and any loose tissue should be removed while the skin

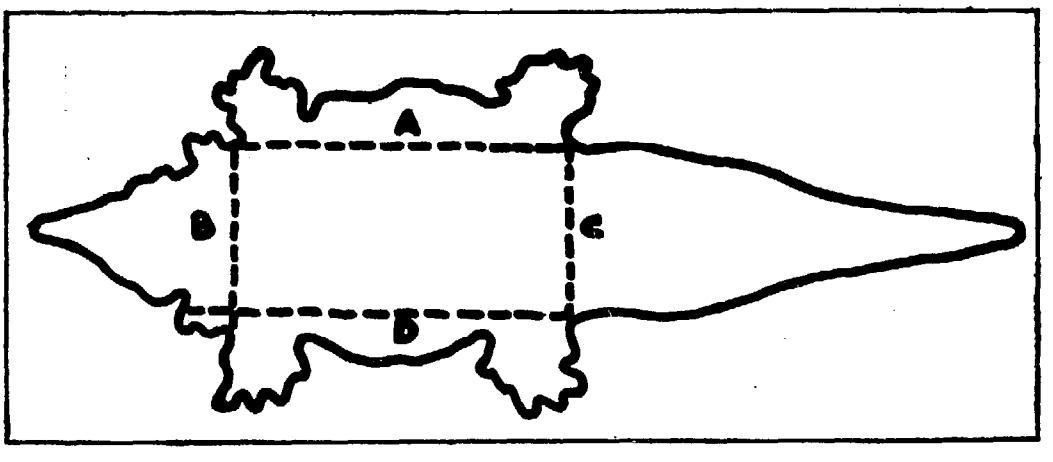

FIGURE 77. – *Proper folding lines for crocodile skins.*

Courtesy Mrs. Erica Mann

is still only partially soaked. If this is delayed until the whole skin becomes soft, putrefaction may begin again and damage the skin. The addition of 0.3 percent washing soda reduces the danger of putrefaction and increases the swelling.

If running water is not available, the goods should be soaked in at least three changes of fresh water. In the first two changes, they remain for only a few hours. They can remain in the third change until they are completely soft.

Skins which are not completely softened after being soaked for 24 hours in a 3 percent solution of washing soda may require careful mechanical " kneading " and further soaking.

Liming

Only those skins which are completely soaked through, including their thickest parts, should be limed. At first, they should be placed in mellow lime and left for half a day. They should then be transferred to a fresh lime which contains 5 percent lime and 800 to 1,000 percent water, calculated on the dried weight of the skins.

It is advisable, while the liquor is being plunged (mixed), to pull the skins out of the lime from time to time and to allow them to drain over the edge of the vat or on draining boards before putting them back for further liming.

Fleshing and scudding

The skins are ready for fleshing and scudding when the transparent membrane on the scale comes off easily. Scudding should be carried out in the direction off the scales, *not against* them. Care should be taken to remove the membranes completely — in particular, from the large squares on the bellies, where they tend to adhere strongly. Fleshing must be complete; for even the smallest amount of meat interferes with the tanning.

Reliming

After scudding and fleshing, the skins should again be immersed in fresh lime liquor, containing 5 percent lime and 7 percent common salt, for not less than five days. They are then ready for rescudding.

These preliminary operations before tanning must be carried out with great care, particularly to avoid scratching the grain during scudding.

Washing

After liming, the skins, wherever possible, should be washed under running water. If small numbers are being treated, each individual skin should be rubbed and wrung, and again washed.

Deliming

Ammonium chloride is a most effective deliming agent. The immersion of washed skins in 2 percent borax or boric acid solution overnight is also practiced. The use of strong acid, such as sulphuric or hydrochloric, is not advised.

Bating

A pigeon or dog manure bate may be used; but, for a better control, pancreatic bates should be employed. It is impossible to state the time that bating should take, but great care is necessary to ensure that the skins are neither overbated nor taken out before the bating is complete.

Drenching

The immersion of skins in fermented bran gives a finer leather. It is worth the extra trouble.

The greatest care is needed to avoid taking the skins out of the drench before deliming is complete. Any lime left in the skins makes the finished goods hard and liable to crack. Thus the use of a phenol phthalein indicator is most necessary.

Alum tanning

Unlike crocodile bellies, which are appreciated as leather in many colors, snake and lizard skins are usually sold in their natural color. Here alum tanning can be followed. This tanning actually accen-

tuates the difference between the white and brown, or black, of the raw skin.

Alum tanning is best divided into two operations: (*a*) tanning proper; and (*b*) fat liquoring.

Tanning

For every 100 kilograms of wet reptile skins, the following ingredients are used: 5 kilograms of alum, 3 kilograms of common salt, 12 kilograms of flour, 1 kilogram of sulphonated oil, and 5 kilograms of china clay. Water is added and the ingredients mixed together until a thin paste which has the consistency of porridge is obtained.

If a drum is available, half the amount of this paste is put in it, together with the skins; and the drum is kept in slow motion for about one hour. Then, from the paste which now remains, a twelfth part is added after every half hour. Within six hours, therefore, the whole amount of the paste will have been used. This procedure, which is called "strengthening," ensures that the ingredients absorbed by the skins are continually replenished. After this operation, the skins are taken out and hung to dry.

Fat liquoring

This starts the next day. A new paste is prepared from the following ingredients for 100 kilograms of wet skins: 3 kilograms of flour, 5 kilograms of oil (olive, groundnut or cottonseed) and 5 kilograms of egg yolk. Water is added and constantly stirred until all the ingredients form a smooth thin paste.

The skins are put back into the drum, together with all this paste, and turned for one to two hours. To avoid the drum rubbing which results in rubbed grain, the skins should not be turned for too long a period. After this operation, the skins are ready for ageing — that is, for hanging in a cool, dark place.

As alum, unlike vegetable tannins, does not stain leather when it is in contact with iron, a steel drum or a butter churn can be used. If neither is available, it is possible to use a simple wooden vat and to trample the skins and the paste with bare feet for the same length of time as is recommended for drumming.

Vegetable tanning

If vegetable tanning is used, the choice of tannin must be carefully considered so as to obtain the required color for the skins. Pure white leather can be obtained only with alum tanning, or with synthetic tannins combined with a bleach: and this process is not easily mastered by rural tanners.

Without bleach it is possible to obtain a whitish leather by using gambier, sumac or acacia pods, for these produce a light colored, flexible leather.

Very light lizard or snakeskins can be tanned quickly by suspension in a barrel of tan liquor. The initial strength should be 1° Bkr., and this can be gradually increased to 5° Bkr. by adding stock solution to the original liquor.

The skins can be tanned in five days. If larger numbers are tanned, it is much better to use five different vats which have the successive strengths of 1° Bkr., 2, 3, 4 and 5° Bkr. The skins are suspended on sticks which rest on the edges of the drums. They are totally immersed in the liquid. For at least the first two days, they are frequently shaken or lifted up and down, and great care is taken to prevent them from touching each other. They are transferred daily from one vat to the next until they reach the fifth and strongest vat. The surface, exposed by a cut through the skin with a sharp clean knife, shows when tanning is completed.

Heavy crocodile bellies require heavier concentrations of liquor and a longer time. The initial liquor strength should be 2° Bkr. The strength is gradually increased by 2° to 10° Bkr., and the skins are left immersed for two days in each liquor. The four initial liquors will be used for eight days. After this, the skins should be transferred to a 15° Bkr. liquor and kept there. As a rule, five to eight days are sufficient in the last and strongest vat (20° Bkr.). Only for exceptionally large and thick crocodile bellies are liquors of concentration higher than 25° or 30° Bkr. required.

Finish

Fat liquoring of vegetable tanned lizard and crocodile skins does not differ from the methods described for other types of leather.

Any oil mixed with sulphonated cod liver oil gives good results. Linseed oil can be used as a top finish for brown or dark colored leather.

The leather should be stretched on a wooden table, fixed by means of nails or pegs, and brushed with linseed oil. As a general rule, lizard and snakeskins should be stretched while they are being dried; they should not be just hung over a wire. This method of stretching ensures a straight undistorted shape.

The tanned reptile skin can be finished by using any of the finishes previously described in Chapters X and XI. A sharp contrast is desirable in snake and lizard skins between the white and black of the natural markings. The finishing materials which are used—such as gelatin or blood albumen — must be transparent and colorless, so as not to obscure the character of the natural markings.

When slicking reptile skins, the action must be with, and not against, the lie of the scales; otherwise damage is done. The edges of the slickers should be perfectly smooth to avoid scratching.

Some tanneries specialize in the production of chrome-tanned crocodile leather. This is a highly complicated process, and one which rural tanners are not encouraged to undertake.

XVI. PARCHMENT AND VELLUM

The art of preparing parchment and vellum is more than a thousand years old. Today, in spite of its simplicity, very few people know how it is done. In the distant past, it was kept a secret in families and in monasteries, and the knowledge was handed on from worker to worker.

The process is simple and cheap; no expensive tool nor machinery is needed; and as there is always a good market for parchment and vellum for bookbinding, lampshades and fancy goods, the art ought to be revised.

Parchment, as a rule, refers to the flesh split of a sheepskin; *vellum* is made from stillborn or very young calves, kids and lambs. Greater care, however, is required in the preparation of vellum, for the raw material is delicate and easily damaged.

Select only the best quality skins, free from scratches, pimples, scabies or other irregularities.

The only equipment needed is a timber frame of 5 × 8 centimeters. This frame, which is called the herse, should be approximately 1.2 meters wide by 1 meter long. Eight holes of 1 centimeter in diameter are drilled in each side of the frame. Thirty-two wooden pegs, similar to those used in a violin, are fitted in these holes. They should be some 12 centimeters long and shaped like a key. A hole of 0.5 centimeter in diameter, 8 centimeters from the pointed end, is drilled through each peg to take a string, or a thin reim (Figure 78).

Parchment and vellum can be made on a simple frame without pegs, by attaching the string to the frame itself, but the quality of the finished product will not be so good as that produced on a frame fitted with pegs.

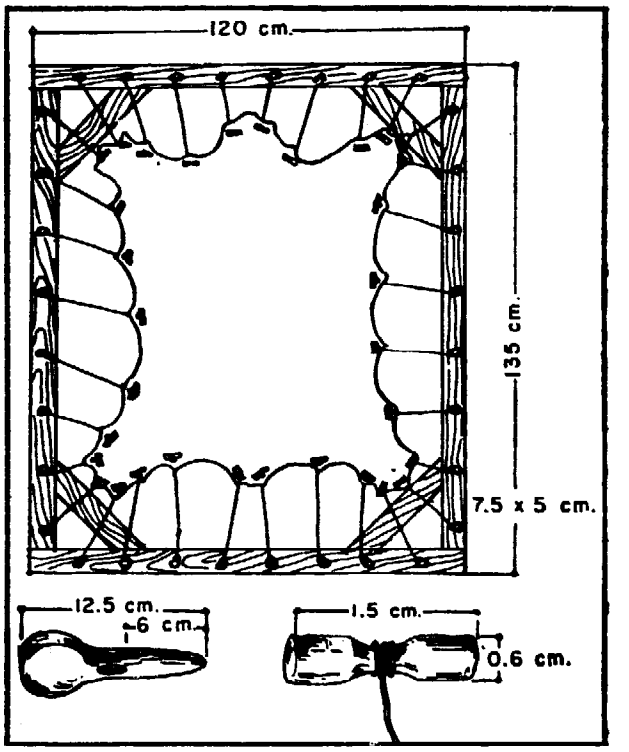

FIGURE 78. – *Frame with pegs and keys used for parchment making.*

Courtesy Mrs. Erica Mann

Liming

The skins are first thoroughly washed, soaked and limed. The liming is the most important step in the process. It must be done carefully and in the following way:

1. The skins are put in mellow lime — that is, lime through which skins have already passed — for a week.
2. They are then immersed in new lime for another week. It is advisable to stir the skins several times daily and to take them out for an hour to drain over the edge of the liming vat or cask before returning them to the liquor.

After 15 days of liming, the skins are ready for unhairing and fleshing. This is done on a beam with a scudding and a fleshing knife as with other hide or skin. Alternatively, it can be done with a knife on a flat table.

The skins should now be washed repeatedly in several changes of water, until they are completely clean and more or less free from

lime on the surface. They should then be wrung out like cloths to remove excessive moisture.

After washing, the skins are ready for lacing and stretching. Small slits or punch holes — 32 in all — are cut evenly round the perimeter. A string or reim is passed through each hole and held in position with a small piece of wood, which is of pencil thickness and called a "toggle." The other end of each string is threaded through the hole in the peg, and the peg is inserted in its hole in the frame. The neck and tail are first secured. Then the skin is stretched and fastened evenly. The lacing is done on alternate sides to obtain an even tension until each reim is attached to its peg. It is customary to stretch the skin more in length than in breadth. By twisting the pegs, the tension can be gradually increased.

Shaving

When the skin has been evenly stretched in the frame, hot water (80° C.) is thrown on it from buckets, while the lacings are kept at their maximum tightness. At the same time, the skin is "fulled," or fleshed, to remove surplus fat and scud, to extend its area and to compact the fiber structure so as to render it nonporous. This fleshing is done with a semicircular knife or with a convex, blunt-pointed skinning knife. Great care must be taken to move the knife parallel to the surface of the skin to avoid gouging.

When the work is finished on the flesh side, small hairs, hair roots and sweat glands on the grain side should be carefully scraped off with the knife until the surface is completely smooth and clean.

Dusting

While the flesh side is still wet, it is dusted evenly and liberally with chalk, talcum or china clay. The powder is rubbed in with a pumice stone which has previously been made flat and smooth by rubbing on a hard stone or a cement floor (Figure 79). When the flesh side is complete, the same treatment is given to the grain side, which needs little rubbing.

The skin is now left to dry. The best results are obtained by

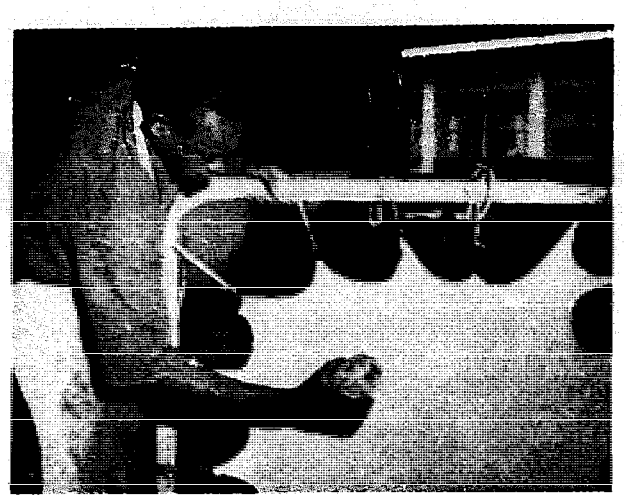

FIGURE 79. – *Operator using pumice stone to prepare parchment.*

Courtesy Kenya Information Office, Nairobi

keeping the skin out of the heat and in a dark room. On no account should the parchment or vellum be exposed to the sun or to the wind: for irreparable damage can be done by what is termed "lime blast."

Finishing

When the parchment is bone dry, it is ready for finishing. While still in the frame, it is laid flat on a table which has been covered with a blanket. For large-scale operations, a table can be padded in the same way as an ironing board. The parchment is rubbed, in circular movements, with the wool side of a sheepskin. Any unevenness or spots should be removed by rubbing with a pumice stone. Grease spots are due to inadequate liming, and they can be removed by rubbing in a 5 percent borax solution with a stiff brush. They are also removed by rubbing in a paste of whiting to the wet skin and allowing it to dry out. If necessary, this operation must be repeated.

If a gloss is needed, the parchment can be coated with the white of an egg, which is rubbed on it with cotton wool.

The parchment is now ready to be removed from the frame. It is trimmed by cutting off all the irregular corners and punch holes. Then it is rolled and stored in a dark, dry place.

XVII. LEATHER DYEING

Leather dyeing, although it has been known since time immemorial, is difficult and tricky. It requires an intimate knowledge of the preparation of leather before dyeing, the application of suitable dyes, the use of mordants and various kinds of after-treatment. Dyeing leather is much more difficult than dyeing cotton because cotton piece goods or thread always absorb the dye uniformly, while the leather dyes differently on shanks, on shoulders or along the backbone.

It is beyond the scope of this Development Paper to mention every dyeing method; only brief descriptions of the more common methods are given in this chapter with the object of helping the rural tanner, while he is still a beginner. Some detailed processes will be explained later for the benefit of the more advanced tanner.

Dyestuffs used for coloring leather are of two types:

(*a*) natural — that is, those derived from plants or animals; and

(*b*) artificial — that is, those prepared synthetically.

Natural dyes

Coloring matters of natural origin are widely distributed. Every part of the globe has its own examples.

Natural dyes were the first to be used. Even though artificial dyes have largely replaced them today, the rural tanner is well advised to start working with natural dyes before attempting experiments with the synthetic dyes.

Natural dyes cannot be used by themselves; for they will not stay on the leather. They must be fixed by means of certain chemicals

which are called "mordants" or "strikers." The same dye will give different colors, according to the mordant which is used.

The best-known natural dyes are:

Logwood — This is the natural dye extracted from campeachy wood, a large tree (*Hematoxylon campechianum*), which grows in the West Indies and Mexico. The dye is extracted by boiling chips of the red-brown wood in water. It is sold as solid or liquid extract and as wood chips.

Logwood gives different colors if it is used with the following mordants:

Logwood and lime water	Dark violet
" " alum	Plum
" " copper sulphate	Dark red
" " dichromate of potash or sodium	Black
" " ferrous sulphate	Violet black

Logwood is generally chosen to produce a black color on vegetable tanned leather when iron salts are used as mordants. First, a 3 percent solution of logwood is applied to the leather; then a solution of 3 percent ferrous sulphate and 0.5 percent copper sulphate is brushed on. If a deeper black is desired, a little ammonia and 0.5 percent fustic — a yellow natural dye extracted from the yellow Brazil wood of the species *Morus tinctoria* — can be added to the solution of logwood.

Fustic — This is known also as Cuba wood and is extensively used as a yellow dye. It is obtained from a tree, *Chlorophora tinctoria*, which grows in Brazil, Mexico, Cuba and Jamaica. It is sold either as liquid or as solid extract, or as ground wood.

The following tints are obtained by using fustic with different mordants:

Fustic and lime water	Orange
" " alum	Bright yellow
" " lead acetate	Yellow orange
" " copper sulphate	Dark green

Indigo blue — The indigo plant (*Indigofera tinctoria*) is grown commercially in India, China, Japan and Indonesia. The dye is extracted from both seeds and leaves; the yield from the leaves is higher than the yield from the seeds. The cut plants are first extracted

in vats under fermentation. The liquid which contains flakes of coloring material undergoes further treatment until it is dried and pressed into cakes.

For dyeing leather, an infusion of indigo with ferrous sulphate and slaked lime is used. After this application the pieces of leather are hung out of doors, where the blue color develops by oxidation.

Cochineal — This is a scarlet coloring material obtained from the dried, ground body of a female insect (*Coccus bacti*) which resembles the ladybird and lives on cacti in Mexico, Central America and Java. Cochineal is used with tin mordants.

There are many shrubs, trees and fruits which yield red dyes, and they are used under a variety of names.

A good example of how a natural dye and mordant can give a brilliant red is the age-old art of dyeing Morocco leather. The process is as follows:

1. The skins are softened in water and stretched out completely flat.
2. Alum, or tin salt, dissolved in water, is applied as a mordant.
3. A cochineal bath is prepared by boiling the scales in water with a little tartar emetic.
4. The skins are immersed for half an hour in this bath, with continous handling, at a temperature of about 43° C.
5. The skins are then taken out, rinsed, drained, laid flat on a table, oiled with linseed oil on the grain side and drained.
6. When the skins are dry, a finish prepared in the following way is applied: 42 grams of shredded soap, 5 grams of lard, and 7 grams of carbonate of soda are boiled together with sufficient water to dissolve them. After the mass has completely dissolved, 42 grams of flax seed decoction are added.
7. The finish is applied lightly with a sponge or cotton wool pad and then allowed to dry. Then the skins are rubbed with a piece of flannel to produce the desired gloss.

Further examples of the use of natural dyes are found in Nigeria. After years of trial and error the Nigerian tanner has learned how to obtain excellent results from local natural coloring matters.

Yellow is obtained from the tuberous rhizome of a shrub which grows abundantly in dry areas. Salt from Lake Chad is used as a mordant. The principal salt responsible for this color is sodium carbonate.

Red is obtainable from guinea corn leaf sheaths. dried and powdered. Lake Chad salt is again used as a mordant. and lime juice provides the necessary acid.

Black is obtained by first dyeing the skins red with guinea corn sheaths and then using as a mordant the smelted and vitrified clay and iron which are obtained from blacksmiths' hearths. This vitric material is mixed with sugar and water.

The Sudanese tanner uses acid produced by the fermentation of dates to obtain a brown or tan color. Red color is obtained from red wood which is imported from Turkey and mixed with alum and some powdered local wood.

Wherever tanning is a home industry. the rural tanner can learn from the cotton dyer or basket and mat worker what local plants yield dyes. He should then experiment with small pieces of leather and use these dyes with different mordants.

Artificial dyestuffs

The tanner divides artificial dyes into three main groups:

Acid dyes are readily soluble in water. and they require no mordant for their vegetable or chrome-tanned leather. Such dyes are: Orange G. Metanil Yellow. Fast Red. Resorcine Brown. Acid Green. Nigrosine. Acid Black-Brown. Naphthol Blue-Black and Naphthalene Leather Yellow. Brown or Red and others.

Basic dyes can be used on vegetable tanned leather. They are favored because of the rapidity of the covering and absorption power. It is. however. essential to give the leather a preliminary treatment because basic dyes are readily precipitated by tannin. The leather. therefore. should be washed. retanned slightly with sumac or any mild tanning material. washed again and then drummed in a solution of titanium potassium oxalate or other salts. such as tartar emetic or lead acetate. This treatment not only precipitates the remaining

tannin which might diffuse out of the leather and interfere with the dyeing; it also effects the final combination of leather and dye stuff and makes the color faster to washing and to light.

If basic dyes are employed for chrome leather in the neutralized state, it is necessary to mordant with a surface retannage and to use vegetable tanning materials, syntans or natural dyes which contain tannin. Afterwards the skins should be washed, drummed in a salt, such as titanium potassium oxalate, washed again and then dyed.

Examples of common basic dyes are: Bismarck Brown, Magenta, Safranine, Methylene Blue, Basic Black, Indine Blue and Rhoduline Yellow.

Direct dyes can combine directly with chrome-tanned leather without the aid of a mordant. They can also deepen the color of vegetable-tanned leather which has been previously dyed with a basic dye, but they have little affinity with vegetable-tanned leather. They will only produce light shades on chrome leather mordanted with tannin.

Diazole Chrome Brown, Direct Blue, Direct Fast Red and Direct Black are examples of direct dyes.

Note — Acid and basic dyes must never be mixed, for they precipitate each other.

Use of dyes

It is impossible to give a comprehensive list of instructions on how to apply dyestuffs to all kinds of leather. Before attempting to dye a whole batch of skins, therefore, the tanner should first try his skill on a small piece of leather about 10 by 20 centimeters.

The manufacturers of dyestuffs supply data on the range of color, solubility, penetration and the light and wash fastness of their dyes and on how to use them.

The amount of dye used depends on many factors — among them are the type of dye, the kind of tanning, the quality of the leather, the method of application and the nature of the water — but it falls between 0.5 percent and 5 percent of the weight of dry leather.

The preparation of leather for dyeing requires patience and skill. The leather must be well washed to remove any excess soluble tannin.

Uneven or spotted vegetable tanned leather, produced by astringent tannins such as mimosa, can be dyed more easily if it is first washed (or "stripped") thoroughly in a mild (1 percent) bath of sodium bicarbonate, sodium carbonate or borax. This leather can then be retanned by using a mellow tannin such as sumac, gambier, or acacia at a strength of 1 to 2 percent in warm water, calculated on the dry weight of the leather. A drum is recommended for these processes, which should not take more than two to three hours. After retanning, the leather is washed thoroughly.

Dyestuffs should never be dissolved in iron vessels, but in wooden, porcelain, aluminium, enamelled or glass vessels; for iron may affect certain colors. The best way to dissolve dyes is first to make them into a paste with cold water and then to add more water and to heat to 70° C., while stirring vigorously. If only hard water is available, basic dyestuffs should first be made into a paste with an equal quantity of acetic acid (of 30 percent strength) before adding the hot water.

Acid dyes are made up for use by dissolving 5 to 20 parts of the dyestuff in 1,000 parts of warm water at 30° to 40° C. The amount of dye used depends on the depth of color desired. Acetic, formic or sulphuric acid is later added to this solution — that is, after the color has been absorbed by the leather. The amount of acid should be slightly less than the weight of dye used — for 2 grams of dye stuff, 1.5 grams of acid. The solution and acid may also be stirred together. As soon as the color becomes uniform, it is ready for use.

Dyeing takes about 30 minutes. If a number of skins are being dyed, the color of the bath will slowly become less intense, because the dyestuff is being absorbed by the leather. For this reason, it is advisable to add the dye in two portions to obtain more even shades before the acid is added.

Vegetable-tanned leathers are often stored in the crust state for prolonged periods. This storage may discolor the grain, spoil its appearance and make dyeing difficult. To ensure that the dyestuffs are evenly assimilated by these leathers, the following procedure should be adopted.

Drum goat and sheep leather first in lukewarm water, or, better still, draw the leather through the water; horse up for about one

hour and drum in a float of water at 30° C. for 30 minutes; and then drain.

This is followed by "stripping" in the same drum, or vat, and using about 1 to 2 percent borax or 0.25 to 0.5 percent soda ash, based on the drained or "sammed" weight for about half an hour. The leather is washed again before it is retanned with a suitable light-colored tanning material.

Basic as well as acid dyes can be used. For delicate and pale shades, however, acid dyestuffs are preferred.

Methods of application

One-tray system

A wooden tray — approximately 1 meter long by 1.4 meters wide and about 20 centimeters deep — is used. As dyeing is only necessary on the grain side, the following method is considered to be sufficient.

Two wet skins of about the same size are "paired" — that is, they are placed flesh to flesh and immersed in the dye. On a small scale, the skins, instead of being "paired," can be folded along the backbone, grain side out.

The skins — not more than a dozen — are piled on the right hand side of the tray and then transferred, one by one, to the left side. When the bottom pair has been placed on the top of the left hand pile, they are once again transferred, one at a time, to the right hand side. This process is repeated for about 10 to 15 minutes until the desired uniform color is obtained. The skins are then taken out, rinsed in warm water and dried.

The dye must be replenished; for it becomes exhausted, or else the following batch of skins will be much paler that the first ones.

Two-tray system

When this method is used, the skins are transferred from one tray to the other, so that those which were on the top in one tray are on the bottom in the other. As a rule, ten to twelve turns are required.

Brush coloring

The easiest method of dyeing is to apply the solution with a brush or pad. The skin to be dyed is laid flat on a smooth table, grain side up, and several applications of the dye are made with a soft brush or pad in even, circular movements (Figure 80).

With basic dyes which require a mordant, brush dyeing is carried out in this way:

1. About a dozen skins are laid, one above the other, on a table, flesh side down and heads towards the left.
2. The skins are moistened with clean tepid water.
3. The mordant is applied with a soft brush to the top skin, first around the edges and then zig-zag across the center.
4. This skin is then placed alongside the pile and the others are treated in a similar way, so that they are built into a new pile. The mordant should be given time to penetrate into the skins.
5. The dye is then applied in a similar manner to the mordanted skin.
6. After one coat of dye has been applied, the skin is put to one side, but not piled; and the next skin is similarly dyed. This is repeated until all skins have received one coat. The process may have to be repeated once or twice.
7. The skins are washed in running water and wrung out.
8. They are then stretched out and dried, either by nailing to a slatted frame or by hanging after slicking.
9. The finish is applied when the skins are dried.

Spraying

Dyes may be applied with a "flit" gun, and then a more concentrated dye solution is used. Great care must be taken to apply the dye evenly to the whole surface by moving the gun smoothly (Figure 81). After one application, the skin is placed to one side and the next skin is treated. A second or third coat may be necessary.

FIGURE 80. – *Operator applying dye with brush.*

Courtesy Kenya Information Office, Nairobi

FIGURE 81. – *Operator spray-dyeing in a small tannery.*

Courtesy Kenya Information Office, Nairobi

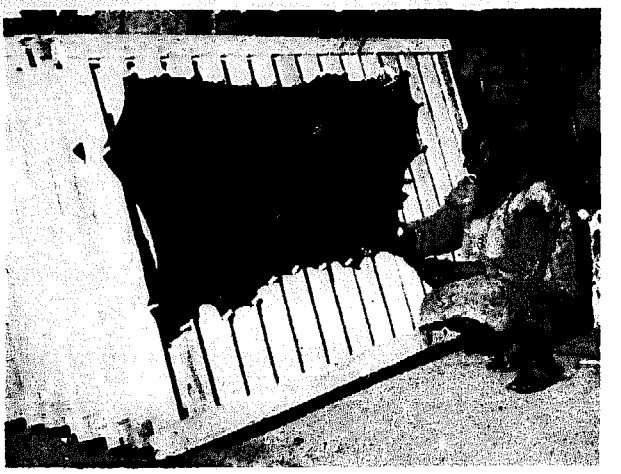

FIGURE 82. – *Operator pegging a tanned side on a frame.*

Courtesy Kenya Information Office, Nairobi

Drum dyeing

Dyeing with acid dyes is a very simple operation, if a small drum is available. The washed skins are put into the drum, which contains hot water at 42° C. The required amount of dye solution is then added in two portions, and the drum rotates for ten minutes for each addition. After this, the required amount of acetic or formic acid is poured in, and the drum rotates for a further fifteen minutes. Then the skins are taken out, rinsed, slicked out and stretched on a board for dyeing (Figure 82).

XVIII. PLANNING A RURAL TANNERY

Once the tanner has acquired sufficient knowledge and confidence to produce quality leather, the time comes to abandon his shed in the backyard and to establish a proper tannery. Either he does this alone or he builds with other tanners a co-operative tannery. Choosing a suitable location for a tannery needs careful thought.

Site

Ideally, a tannery should have a copious supply of suitable water and allow easy disposal of waste (effluents). It should be readily accessible by road or rail; it should be situated as closely as possible to permanent sources of raw materials, such as hides, skins, tannins and lime; and it should also be in an area where skilled labor is available and near a leather-consuming area.

It is unlikely that one site will offer all these advantages. Various factors, therefore, must be considered. It is, for instance, not absolutely essential to have a market for the finished products in the immediate vicinity, for the finished leather is easier to transport than the raw material.

A new tannery should be so constructed that it allows adequate space for the planned output; it should be on high ground to allow for easy drainage and waste disposal; it should be sanitary and provide good working conditions for the laborers; it should allow the continuous flow of materials — it should ensure that hides and skins are so handled through the tannery that all unnecessary movement is avoided. Finally, it should be easy to enlarge the tannery, if the volume of trade increases.

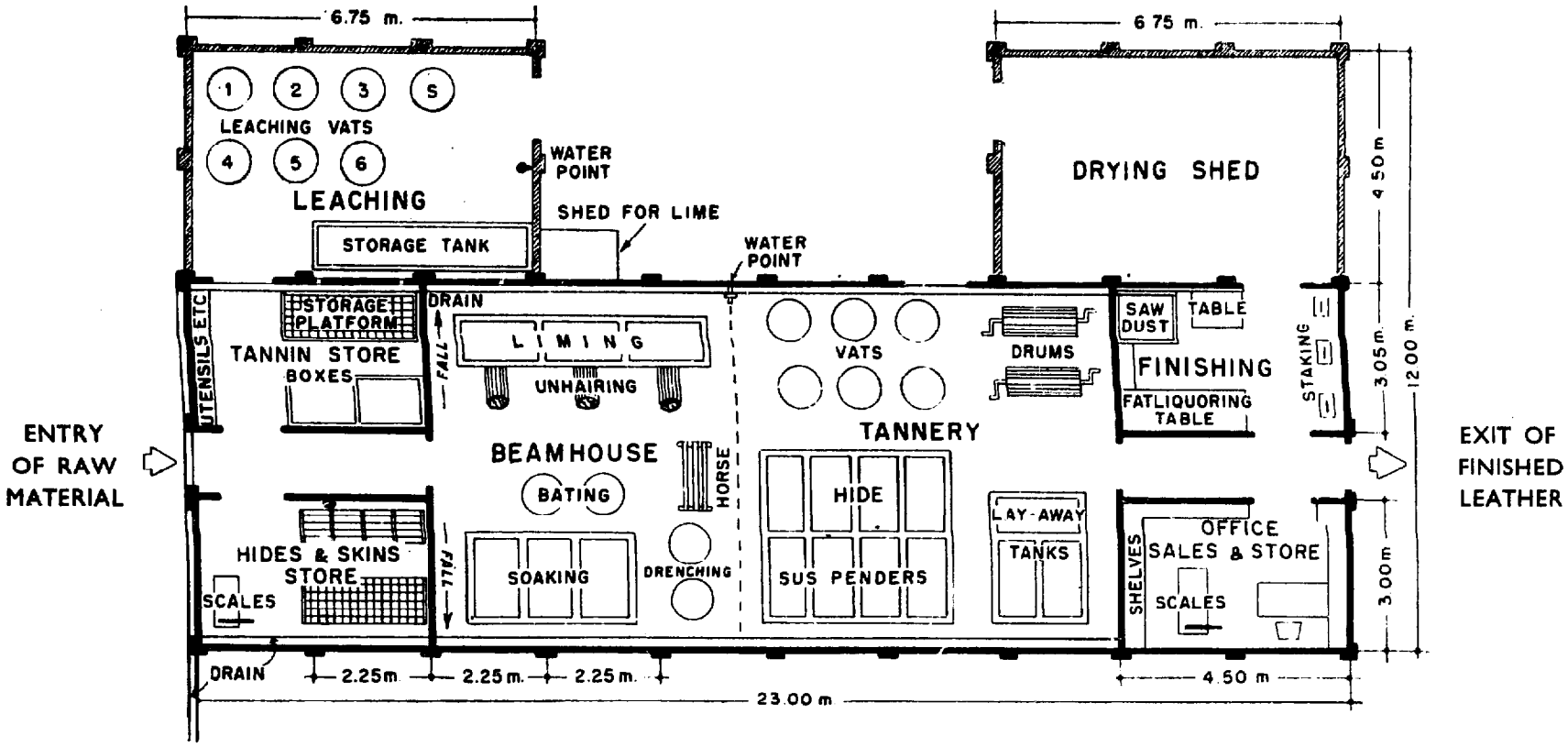

FIGURE 83. – *General sketch plan for a rural tannery. Details need to be adjusted to local conditions and needs.*

Courtesy Mrs. Erica Mann

Size

There are no standard dimensions for a tannery. Its size depends on the output and types of leathers to be produced, the methods of tanning and, naturally, the financial means of the owner. Once the basic parts of the building are planned and the questions of water supply, waste disposal and markets are settled, it is easy to decide upon the size.

A very simple tannery consists of one long building and two "lean-tos." The walls are made of stone, brick or timber 1.2 to 1.5 meters above ground level. The roof should be supported by stone, brick or wooden pillars. The distance between the pillars should be 2.5 to 3 meters, or else they should conform to the regulations which the government of the particular country may have made for this industry. In hot climates, the space above the walls, up to the eaves, should be closed by sheets of metal or by strong wire netting. In cooler climates, the sides of the building may be walled up: but sufficient windows or openings must be left for adequate lighting and ventilation. Light is extremely important in a tannery — first, because most processes require visual inspection and, second, because the growth of moulds in a dark ill-ventilated tannery can present very serious problems.

The following dimensions are suggested for a rural tannery which has an output of 10 to 12 hides and 50 to 75 skins per day (Figure 83). It should be realized, however, that details have to be adjusted to local conditions and needs.

A building 27 meters long and 7 meters wide, divided into:

Stores	6.5 meters long
Beamhouse	6 meters long
Tannery	7.5 meters long
Finishing room and office	6.5 meters long

By working 25 days each month, such a tannery could handle 250 to 300 hides and 1,250 to 1,875 skins each month. This output could be increased substantially if, later on, suitable machinery were installed.

The recommended dimensions of the "lean-to" sheds are 6 meters by 6 meters both for the leaching and drying sheds.

When planning a tannery, allowance should be made for enlarg-

ing the premises, if and when required, rather then starting with a building which is only just large enough. The leaching pits, for instance, should be located close to the suspenders, and provision for the crushing of barks, etc., should be made.

Roof

Corrugated iron roofs are not entirely suitable for tanneries, because iron reacts to the chemicals which are used. The moisture, always present in the tannery, condenses during the night or in cold weather, and dripping from an iron roof will stain the leather and tan liquors. Galvanized corrugated iron sheets, however, are used in large tanneries. Certain paints which are available on the market prevent the corrugated iron from getting rusty. A thatched roof is also troublesome; for the straw and dust which fall from it contaminate dyes and interfere with glazing. Aluminium, asbestos or country tile roofs are the best because they are durable and cool, and they do not spoil the work. There are, however, countries where thatched roofs are not made out of straw, but are woven out (plaited) of different kinds of palm leaves and other strong vegetable material. In many countries this is an old established small rural industry. Mats from vegetable material are also woven, and they could be used as ceilings.

To reduce condensation and increase ventilation, it is advisable to provide a ventilated ridge along the whole length of the roof (Figure 84).

Floors and drains

Floors may be made of stone, brick or concrete. Concrete should be roughened by pressing diamond-shaped weld mesh, or expanded metal, into the wet cement mix. The channels thus constructed drain off the surface water, while providing a firm grip for the feet of the workers.

The efficient removal of liquids from the tannery is essential both for the health of the workers and for the quality of the leather. Sooner or later, slippery and smelly floors, without slopes leading to the

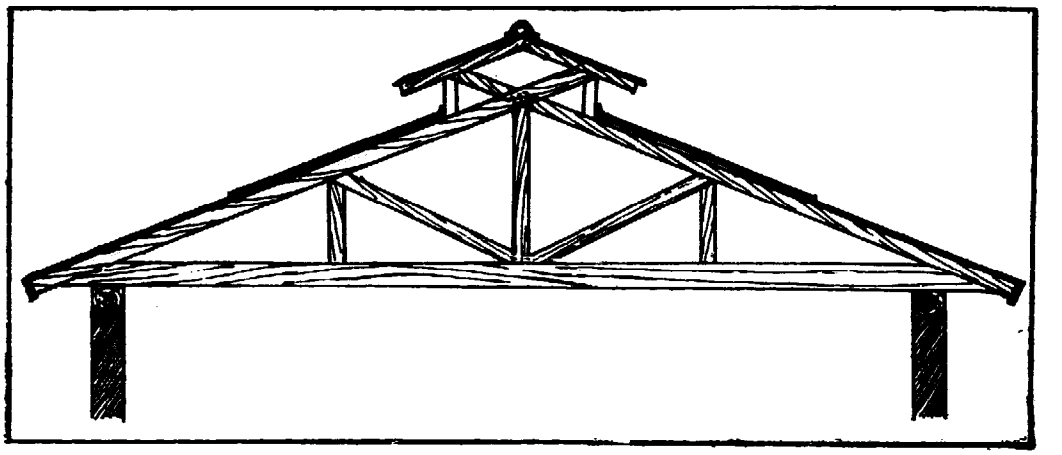

FIGURE 84. – *A possible roof construction, showing open ridge for ventilation.*

Courtesy Mrs. Erica Mann

drains or without drains at all, will cause dissatisfaction or disease among the laborers; they will also cause a lowering in the quality of the products. Many tanneries have still only one main drain, which runs along the center line of the building, and which is covered with an iron grating. It is better to have two drains which run parallel to the long walls of the tannery (Figure 85).

Simple grease traps and screens — or, better still, perforated buckets — should be installed in the drains to trap larger particles before they leave the tannery premises. This waste can be added to a compost heap and thus enrich the fields with nitrogenous material.

Basic sections

Whether the tannery is to be small or large, provision for the following assets is essential (Figure 83):

1. A store for hides and skins;
2. A store for tannins (lime, however, should be stored separately);
3. A lean-to shed for leaching;
4. A " beamhouse," also called " wethouse," for preliminary operations such as soaking, liming, unhairing, bating and drenching;

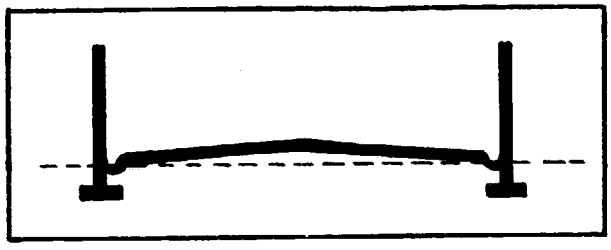

FIGURE 85. – *Cross section of tannery floor showing two drains running parallel to the long walls, as recommended for rural tanneries.*

Courtesy Mrs. Erica Mann

5. The tannery proper;
6. A drying shed;
7. A finishing room; and
8. A store for finished leather, to include an office.

STORE FOR HIDES AND SKINS

The store should be large enough for a two-month production of hides and skins to be tanned. It should also provide for storage of hides and skins which can sometimes be bought at a low price when market conditions are favorable. The store should be weather-proof to prevent spoilage by rain, well ventilated and vermin-proof; it should be fitted with a slatted platform on which the hides and skins are stored, and it should be provided with a platform scale.

STORE FOR TANNINS

As a rule, tannin-bearing materials are collected seasonally. Thus, at certain times of the year, it may be cheaper to buy more than is necessary for immediate consumption and to store the surplus until it is required.

Although this store need not be an elaborate building, full protection from the rain is essential. Tannin-containing materials should be kept on a slatted platform, and the store should be well ventilated to prevent the growth of moulds.

Lime must not be allowed to contaminate the tanning material. It is best kept in a pit or in a large, covered, wooden box, separate from the tanning material and preferably outside but protected from the rain.

Leaching shed

This need not be part of the building itself; for a " lean-to " shed is quite adequate. It must have a stone or cement floor; otherwise it will soon become muddy. This floor should slope inwards, towards the wall of the tannery; it should discharge into the main tannery drain, but not into the effluent drain.

Provision should be made for possible expansion — accommodation, for instance, for large slatted floored wooden vessels or whole batteries of brick, stone or cement vats to produce tanning liquor.

The beamhouse (also called wethouse)

Preliminary operations, such as soaking, liming, unhairing, scudding, bating and drenching, take place in the beamhouse.

It is not possible to recommend a standard size for this building, but there should be enough space for each operation.

As most of the wet work is done in the beamhouse, it is the source of most of the effluents and solid wastes — for example, hair, fleshings and trimmings. It is essential, therefore, that the floor is made of cement, brick or stone. Since the water consumption in this part of the tannery is very high, there must be provision for an adequate and quick water supply.

If cattle hides are to be tanned, preference is given to brick or cement vats. Under rural conditions, vats should be erected above ground level and not built completely into the ground; otherwise draining is difficult. A hole — about 6 to 8 centimeters in diameter and fitted with a wooden tap — should be made at the bottom of that side of the vat which is nearest the drain. The bottom of the tank should slope in the direction of the floor.

The following dimensions are recommended for vats:

(*a*) two or three soaking tanks, each 1.5 meters long by 0.9 meter wide and 1 meter deep; and

(*b*) three liming tanks of the same dimensions as the soaking tanks.

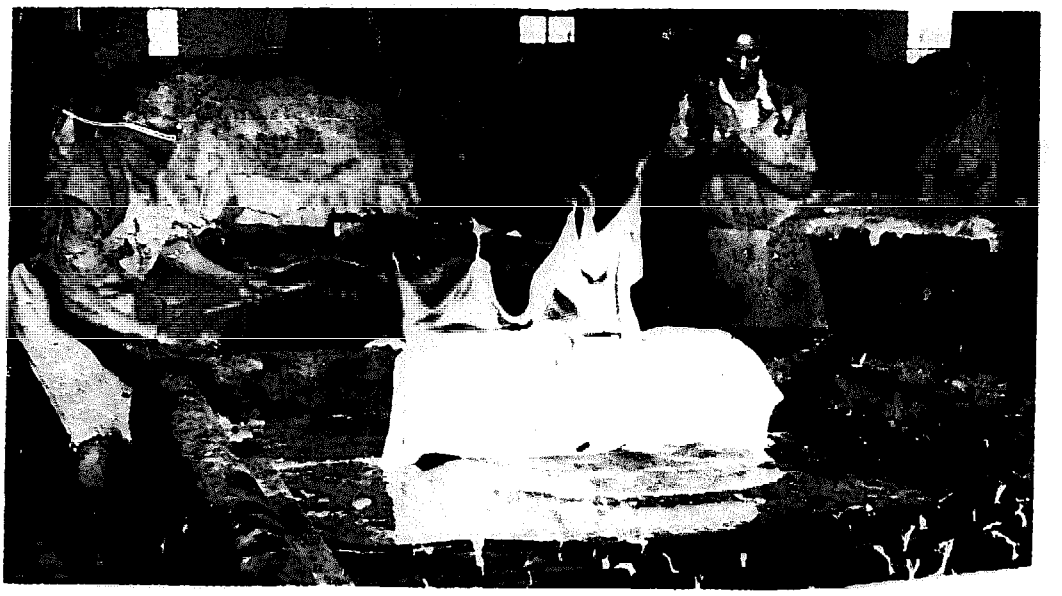

FIGURE 86. – *Moving hides in suspender pits.*
Courtesy Kenya Information Office, Nairobi

FIGURE 87. – *Cross section of vat showing sloping base (witk slope expressly enlarged) toward drain. Side in vat is suspended from a wooden slat.*
Courtesy Mrs. Erica Mann

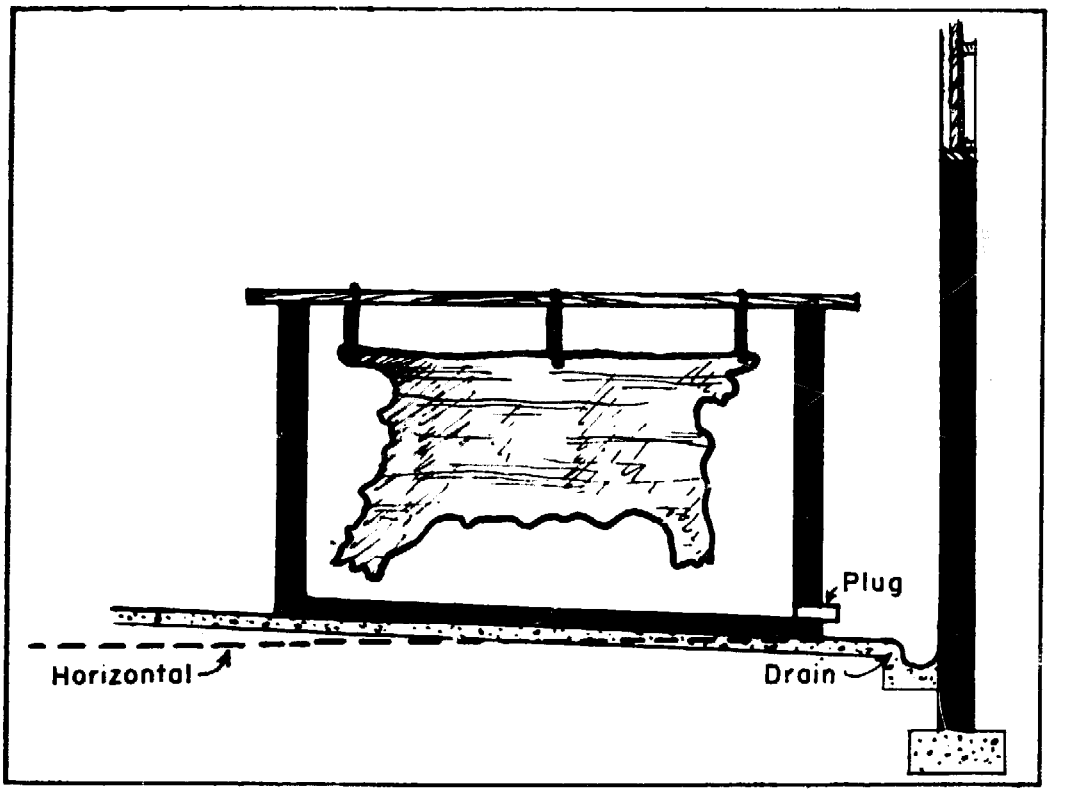

The part of the building where the hides or skins are tanned must be separate from the beamhouse. A clear space should always be left between the two, although a wall is not necessary.

The size of the tannery proper depends on the amount and on the nature of the material to be treated and also on the number of hides and skins to be taken for each soak. If only skins are to be tanned, the tannery need not be a large building. If, however, the tanner intends to handle cattle hides as well, the space must be much larger, and the following vats will be required:

Eight suspenders and handlers — each 1.5 meters long, 0.9 meter wide and 1.5 meters deep (Figures 86 and 87) — and three lay-away tanks of the same dimensions. There must also be enough space for leaching the bark.

The eight suspenders and handlers are interconnected by staggered drainways, which are about 15 centimeters in diameter, at the top of the dividing walls. These drains allow the tan liquor, which is always added to the last suspender, to overflow from vat to vat. They strengthen each vat in turn by an equal volume of mellow liquor, while an equal volume of used liquor is rejected from the first vat, either by overflowing or by draining. The diagram shows how the liquor moves in the opposite direction to the hides (Figure 88). The number of hides which enter the first vat is identical to the number which leaves the last. Thus a continuous and steady flow

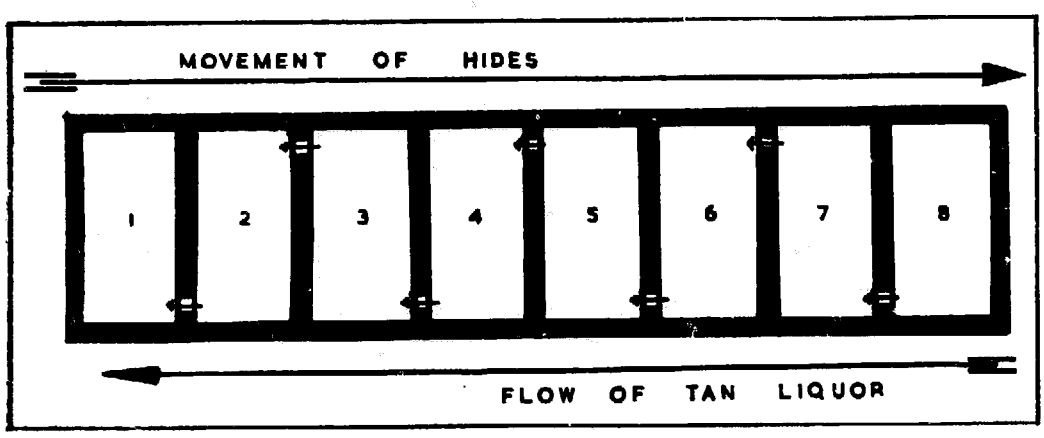

FIGURE 88. – *Sketch showing that hides and tan liquor move in opposite directions and that the vats are interconnected.*

Courtesy Mrs. Erica Mann

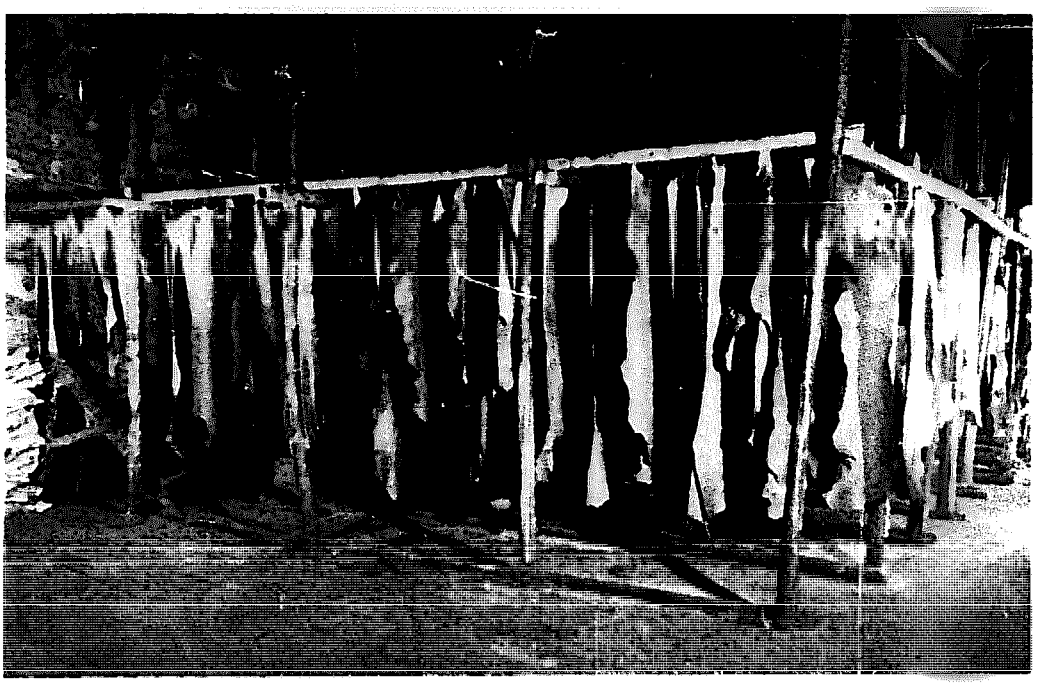

FIGURE 89. – *Interior of drying shed for leather.*
Courtesy Kenya Information Office, Nairobi

FIGURE 90. – *Leather displayed on "horses."*
Courtesy Kenya Information Office, Nairobi

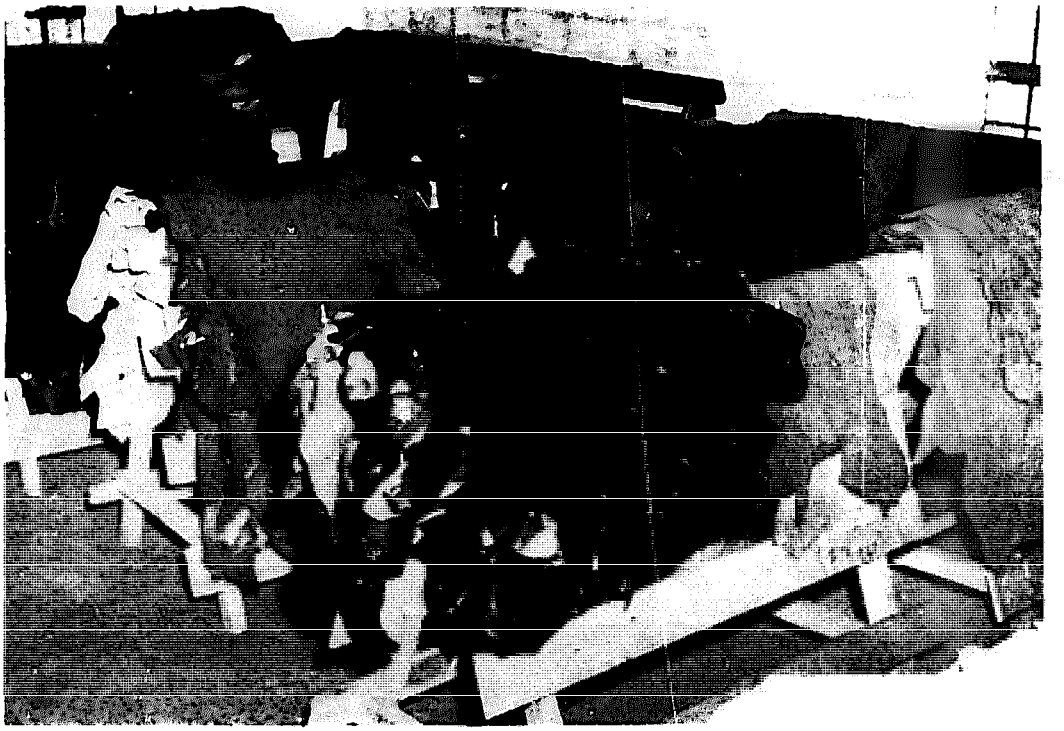

of goods is maintained. When tanning skins, it is better to install paddles, and not hand-driven drums.

One or two tables are needed for scouring, fatliquoring, oiling and stuffing. Each must be large enough to take a hide or skin stretched out completely without any of it hanging over the side.

Drying shed

The forced drying of leather under direct sun or in hot wind, as earlier chapters have stressed, is undesirable. Hence, every tanner must have a drying shed (Figure 89). This need not be an elaborate building, but it must protect the leather from rain, direct sunlight and heat. The drying shed can be a part of the main building. Any shed built of wood or adobe, however, will be adequate.

A leak-proof thatched or country-tiled roof is cheap, cool and satisfactory if sacking is stretched out below to prevent dust and other contaminating particles from falling on the hides. Corrugated iron becomes excessively hot under tropical conditions. If it is used, it should be covered with mats.

The sides of the sheds should be built in such a way that parts of it can be opened to increase circulation of the air. The beams of the roof should not be too high, and they should be provided with hooks made of brass or stainless steel, from which leather can be hung. As there is no effluent or other waste, this part of the tannery does not require a permanent floor.

Finishing room

Staking, dyeing, glazing, buffing and compressor and handrolling for sole leather and sorting are done in the finishing room. Here it is necessary to have shelves and cupboards for dyes and chemicals, as well as several tables and " horses " (Figure 90). It is also desirable to have a box — 1.2 meters long, 1.2 meters wide and 0.3 meter deep — for clean sawdust.

Store for finished leather

Finished leather must be kept on racks in a well-ventilated and dry store. There should be a table on which leather can be spread for measuring. If sole leather is sold, a weighing scale will be necessary. This dry store should also be the tanner's office, where he keeps all his records, invoices and books, for it is the cleanest and driest part of the tannery.

Machinery

Throughout this paper mainly simple hand tools have been recommended, and, in the design for rural tanneries, no provision has been made for machinery. When, however, expansion occurs, when labor becomes more expensive and increased funds are available, a gradual replacement of manual labor by machinery may follow.

XIX. WATER

Water has a primary importance for tanneries. It is essential, therefore, to see that water is available in abundance and that it is also suitable for tanning. It may astonish the rural tanner to learn that water, though considered pure enough for him to drink, is not necessarily suitable for tanning.

A suitable water supply must be given the first consideration. An unsuitable, or insufficient, supply of water interferes with the production of leather in all basic processes. It affects the leaching, soaking, deliming, tanning, fat liquoring and dyeing, and it increases the cost of production by the loss of tannins and by the loss in hide substance. It is disastrous, therefore, to start a tannery before the availability and suitability of the water has been thoroughly tested. It is cheaper to bring all the tanning materials to suitable water rather than to bring the water to the tanning materials. The main conditions to avoid are: (*a*) hardness; (*b*) presence of iron; and (*c*) contamination with sewage, factory wastes, etc.

Hardness

For the purpose of this paper, water can be divided into two categories: hard water, which contains certain salts; and soft water, which is free of these salts.

In hard water, soap lathers with difficulty; but in soft water, it lathers easily.

The salts contained in hard water have a very bad effect on several tanning processes, and, as far as possible, only soft water should be used. Rain water or neutral stream water are the best.

Hardness, which is generally due to the presence of calcium and

magnesium salts, may be " temporary " — that is, it is removable by boiling. On the other hand, it may be " permanent " — that is, it is not removable by boiling.

A simple test can be made to determine whether water is soft or hard:

Two bowls or plates of equal size are required. Rain water is put into one, and the water to be tested is put in the other. With a piece of good toilet soap the hands are washed vigorously for half a minute in one bowl; and the washing is then repeated in the second bowl. If the amount of lather produced in both bowls is more or less the same, the water is soft enough to use. When, however, only a little lather is formed, this water is unsuitable for certain processes in tanning. Soft water, in contact with soap, feels smooth and soft, whereas hard water, in contact with soap, gives a harsh rough feeling.

To see whether the hardness is temporary or permanent, another simple test must be made. If, after boiling, hard water throws down a sediment, it may then lather; and, if so, the hardness was only temporary. Permanently hard water does not lose its hardness when it is boiled. None the less, temporary hard water is also unsuitable for a tannery because boiling all the water is out of the question.

Water can be softened by treatment with lime, lime and soda or by the addition of acids. Patent water softeners can also be used. All these installations are, however, too costly for the rural tanner.

In deliming by washing with water alone, temporary hardness and free carbon dioxide react with lime in the pelt. This forms a precipitate of calcium carbonate on the grain and flesh surfaces, and it is known as " lime blast." This deposit causes uneven bating, uneven coloring in the tan liquors, and dullness in glace finishing. With hard water it is difficult, if not impossible, to make an emulsion for fat liquors; and certain dyes may not dissolve well in hard water.

Iron

Water may be undesirable for reasons other than hardness. Iron in water reacts with vegetable tannins and causes black or bluegreen stains on leather because tannin and iron produce an ink.

Iron may be present in water in the form of dissolved iron, or as "iron bacteria." These bacteria assimilate iron into their bodies; iron water pipes may be dissolved to obtain the necessary iron.

Iron can be removed from water by several processes. The cheapest process is lime treatment or aeration — that is, spraying water into the atmosphere. Although cheap and simple, aeration requires expert advice. Iron in water or iron stains on leather can be put out of action by acid sodium pyrophosphate, which is used in small amounts.

Whenever iron containers are used as storage tanks, they must be thoroughly coated with bituminous paint.

Contamination

Stagnant water, polluted by sewage and containing large amounts of decomposed organic matter, is most unsuitable for tanning; for the high bacterial content causes rapid putrefaction of hides and skins during soaking. Pollution of water with wastes from factories or with mineral oil or paraffin from storage tanks or garages may cause difficulties at every stage of tanning.

Abnormal amounts of mud interfere with many processes. Muddy water can be improved by settling and filtering.

Sources of water

Rain water

Rain water is ideal for all tannery processes. In many areas however, the supply of rain water is unreliable. Wherever possible, the roof of a house, tannery or other building, should be used to collect rain water, which should be stored in underground cement tanks or else in corrugated iron tanks coated with bituminous paint. As impurities tend to settle, the draw-off tap should be at least 15 centimeters from the bottom of the tank. In some areas, rain water is collected in shallow pans built into rocks. As a rule, this water is suitable; but, again, it is rarely available in adequate quantities.

Ponds

The quality of water from ponds, lakes and other stagnant sources depends on such factors as the size and depth of the lake or pond, the proximity of settlements, and pollution with factory effluents. Before it is used, this water should be carefully tested.

Rivers

Wide variations exist in the quality, not only from river to river, but also from point to point in the same river.

As a rule, water should be drawn from upstream of any large town to avoid factory or sewage pollution. Rivers may contain undesirable chemicals leached from the soil. This can happen when, for instance, they flow through limestone.

Mountain stream water is usually the finest river water; it is not polluted and it is as soft as rain water.

Springs

Contrary to common belief, spring water is not always suitable for use in tanneries. It may be very hard or it may contain iron, sulphur, or other minerals which can interfere with the tanning.

Wells

Frequently water from shallow wells is polluted. Deep well water is usually pure and it needs to be tested only for hardness and for iron.

Rural tanners cannot afford complex purification equipment. For this reason, they must be certain of the purity and abundance of the water supply, before they start a project which is so dependent upon suitable water.

A large co-operative tannery could perhaps afford a private deep well or draw its water from a tested township supply. If these two alternatives are impossible, the tannery could use water from a stagnant source — provided the water is soft and free from iron — by filtering out the suspended and decomposed organic matter.

Water can be filtered by passing it through sand. As a rule, this sort of filter is built as a rectangular brick or concrete tank. On the bottom a series of parallel channels support a layer of coarse gravel, on which the sand rests. The tank must be not less than 2.4 meters deep, so that drains and gravel may be 0.6 meter deep and the sand 0.9 meter deep. The remaining 0.9 meter holds the water awaiting filtration. The rate of flow must be adjusted, so that the amount coming in is equal to the amount flowing out. It is advisable to have two such sand filters, for periodically they become clogged and must be cleansed. Antiseptics, however, may also have to be applied when stagnant water is used.

So many factors influence the quality of water for tanning that a qualified person should be consulted before tanning is started in a new area. Where the water has already been used successfully for tanning, no further tests are necessary.

For testing, which must be done in a well-equipped laboratory, two liters of water should be sent for analysis in a clean bottle with a closely fitting stopper, which has been thoroughly rinsed in the water to be analyzed. When taking samples from a river or a well, the bottles should be immersed below the surface of the water with the stopper closed. The stopper is then removed, and the bottle is allowed to fill completely. The stopper should then be returned and fastened, and the bottle packed for dispatch to the laboratory.

It is now clear that the water problem must be solved before the site for the tannery is selected.

Effluents

A quantity of about 1,350 liters of water is required for each 50 kilograms of hides or skins to be tanned. Hence, every tannery has to dispose of large amounts of effluents which are heavily contaminated with tannins, lime and organic waste, such as hair, fleshings, fat, blood, dung and pieces of hide or skin. The organic material will decompose rapidly and produce very unpleasant odors. The hygienic disposal of effluents is as important as the availability of suitable water supplies.

It is most convenient to divert effluents directly into the sea, a large river or an existing sewer.

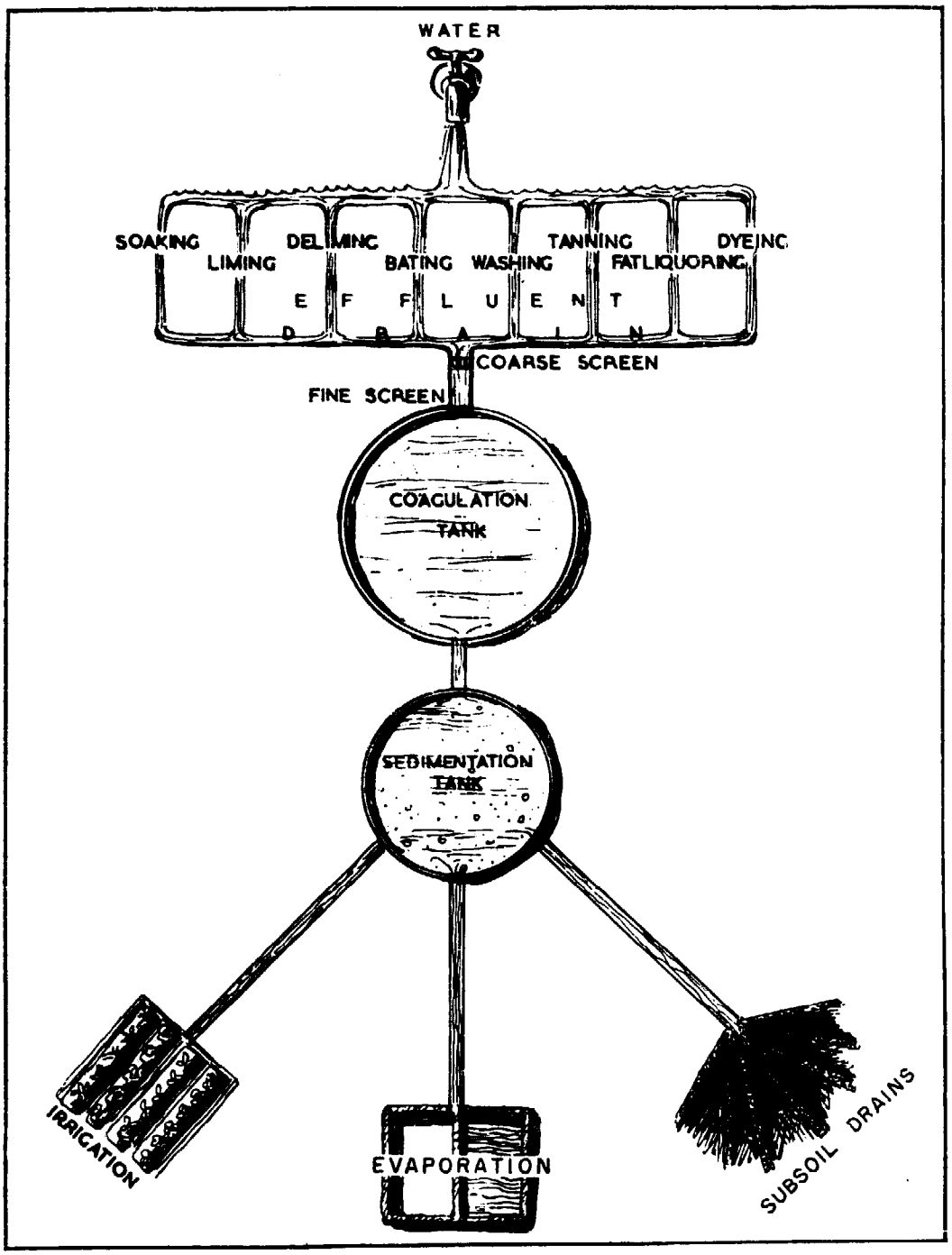

FIGURE 91. – *Sketch of layout of drains, coagulation and sedimentation tanks, and three possible methods of disposing of effluents.*

Courtesy Mrs. Erica Mann

In most countries public health legislation prohibits the discharge of unpurified factory effluents into rivers. Where there is no legislation concerning effluents, the tanner is still advised to be very careful about the disposal of sewage; it is unfair to pollute other people's drinking or washing water and thus to endanger their health.

Under rural conditions, tannery effluents should be eliminated as cheaply as possible. If sewers, rivers or the sea cannot be used, land treatment is a good alternative. This can be done in three ways (Figure 91):

1. Direct flooding of the land by small quantities of used water, which will be lost by evaporation and seepage. As a rule, alternate square beds surrounded by low earth ridges are flooded. This land should not incline more than 0.3 meter in 3 meters.
2. An excellent method, provided the nature of the soil permits it, is to divide the land into ridges, to plant the ridges with crops, and to discharge the effluent along the furrows. Thus the effluent irrigates and fertilizes the crops at the same time. This method gives the tanner an additional income and more than pays for the water which he uses in the tannery.
3. Another method of disposal in light, sandy soils is by subterranean drains. These should be 1.5 meters deep, 0.6 meter wide and filled in to about 15 centimeters below soil level with stones. The stones are then covered with grass or old corrugated iron sheets, and they are topped with soil. Alongside the trenches, eucalyptus (gum) trees can be planted to assist evaporation.

Before any of these methods are applied, the effluents must first be treated. In the first method any sludge in the effluent quickly clogs the pores in the soil, and seepage stops. In the second method, cultivation is rarely successful, because the plants are treated with tannins one day and with lime the next. In the third, the open spaces between the stones quickly become filled with sludge.

A good solution is to have the material precipitated in tanks, in which the tannins and lime are mixed and subsequently settled as sludge in sedimentation tanks. These should be built in pairs to facilitate cleaning.

The rural tanner need not be put off by the use of the word "tank." At first, simple, unlined pits can be used. Later, with the growth of the tannery, more permanent round or rectangular tanks of brick, stone or cement should replace them. The size of both precipitation and sedimentation tanks is directly dependent on the amount of effluent to be handled.

The sludge, consisting of wet solids, is formed at the bottom of the pits, and it must be removed periodically. The disposal of this sludge presents a problem. V-shaped trenches — 0.6 meter wide and 0.3 meter deep — can be dug; the wet sludge can be thrown into these and covered with earth. The rural tanner is better advised, however, to use the sludge to make compost for the land.

He can also use his compost heap to dispose of other tannery waste, such as hair, fleshings and trimmings, household and farm waste and animal manure or night soil.

The tanner should, in fact, start two compost heaps simultaneously, and each should measure about 7 square meters with a distance of approximately 4.8 meters between them. Bricks, stones and any other coarse material are placed on the ground to form a base for the compost heaps and to encourage aeration. Alternate layers of grass, straw, household waste, tannery sludge and offal are placed on top of this base until the heap is about 1.5 meters high. To assist decomposition, the heaps are covered with dry grass. After one month these two heaps are converted into one heap. In the second month, this compost heap can be turned over again. By the third month decomposition should be complete. At this stage the compost should be free from offensive odors and ready for use.

pH VALUE IN TANNING

In the preliminary tanning processes, such as soaking and liming, mainly *alkaline* solutions are used. Solutions of lime, sodium sulphide, caustic soda, ammonia, etc., in water are called *alkaline* solutions. Strongly alkaline solutions *dissolve* hide substance.

For deliming and actual tanning processes *acid* solutions are used. Solutions in water of oxalic acid, formic acid, acetic acid, hydrochloric acid, sulphuric acid, etc., have *acid* reactions. Strong acid solutions destroy hide, cloth and even metals.

In the past, in vegetable tanning processes, the acidity of the solutions was regulated by using raw vegetable materials. These contain sugars, which fermented naturally to produce the necessary acidity. Formerly tanning liquors were tested with the tongue to discover whether they were strongly or weakly acidic.

More exact methods of determining whether a solution is acid or alkaline are now in use, and they enable the modern tanner to regulate the actual tanning process properly. The degree of alkalinity or acidity is indicated by means of a figure which is called the "pH value" (the hydrogen ion exponent).

By definition, a neutral solution — that is, a solution which is neither acidic nor alkaline — has a pH value of 7.0; and pH values which decrease from 7.0 represent solutions of increasing acidity, while values which increase from 7.0 represent solutions of increasing alkalinity. The scale which is used is given schematically in Figure 92.

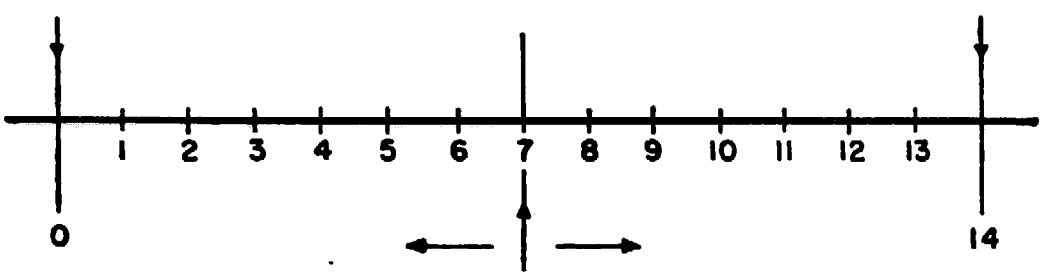

FIGURE 92. – *Scale indicating the pH value of acid, neutral and alkaline solution.*

To determine the pH value of a liquid, indicators are used; and this is the colorimetric method. On the other hand, modern chemical laboratories — those, for example, in large-scale tanneries — use what are called pH meters; and this is the electrometric method. As a rule, the practical tanner finds that indicators are accurate enough to measure the pH value. For this reason, a progressive rural tanner, while he is working in his tannery,

should always carry with him a booklet of indicator papers to test his solutions regularly. This method of measuring the pH is obviously more accurate with colorless liquids than with colored liquids.

Indicators are special substances, soluble in alcohol and/or water. These solutions change in color according to the pH value of any liquid into which they are introduced. Thus it is possible to use the color of the solution as a measure of its pH value.

An example is the use of phenol phthalein, which has been already described.

Papers soaked in these indicator solutions and dried out are sold in book form. They are very helpful for the practical tanner who wants to control his bate liquors, pickle liquors and other colorless solutions. Table 1 shows how the full range of pH values, as used in tannery processes, are covered by a variety of indicators.

TABLE 1. – RANGE OF pH VALUES FOR SOME INDICATORS

Name of indicator	pH range
Thymol blue	1.2 - 2.8
Brom phenol blue	3.0 - 4.6
Methylred	4.4 - 6.0
Brom cresol purple	5.2 - 6.8
Brom thymol blue	6.0 - 7.6
Phenol red	6.8 - 8.4
Cresol red	7.2 - 8.8
Thymol blue	8.0 - 9.6
Cresol phthalein	8.2 - 9.8

It is not necessary for the practical tanner to have all these indicators; for, as Table 2 shows, the approximate pH values of the main processes have a specific pH range.

A regular control of the pH value throughout all the processes, it should be realized, goes far to ensure good results.

The most important indicator papers for the practical tanner are " congo " and " delta " papers. Congo paper has a blue color at a pH value of 3.0, a blue-gray color at a pH value of 4.0, and it remains red at a pH value of 5.0. Delta paper undergoes the following changes in color:

pH 5.0	yellow
pH 6.0	grey yellow
pH 7.0 (neutral)	grey
pH 7.2	slight blue
pH 8.0	blue

Indicator *solutions* can be used to determine the pH of a solution. This is done by adding a few drops of the solution to a sample of the liquid in a test-tube and by observing the change of color. Pieces of pelt can also

TABLE 2. – APPROXIMATE pH VALUES OF A NUMBER OF TANNING PROCESSES

Process	pH value
Soaking (almost neutral)	5 - 7.5
Soaking (alkaline), if alkali is added to assist soaking	9 - 10
Liming (strongly alkaline)	approximately 12.5
Deliming and bating (almost neutral when at the end)	7.5 - 8.5
Vegetable tanning (moderate to weak acid)	3 - 5.5
Pickling (acid)	2 - 4
Chrome tanning	approximately 2 at the start, up to 4.5 towards the end

be tested by using suitable indicator solutions — for example, in the deliming and bating process, by using phenol phthalein; and in the pickling process, by using congo red or methyl orange. Meanwhile, the neutralization of chrome leather can be followed by using brom cresol green, or brom cresol purple, or blue litmas, paper. Table 3 shows the particulars.

TABLE 3. – PROPERTIES OF A RANGE OF INDICATORS

Name of indicator	Color change		pH range applicable
	From	To	
Congo red	blue	red	3.0 - 5.2
Brom phenol blue	yellow	blue	3.0 - 4.6
Brom cresol green	yellow	blue	3.8 - 5.4
Brom cresol purple	yellow	purple	5.2 - 6.8
Phenol phthalein	colorless	red	8.2 - 9.8

There are many more indicators in regular use, but, as a rule, the practical tanner is satisfied with the ones already mentioned. The indicators can be easily bought, either as dry powders or as solutions already prepared for tannery use.

Through suitable mixtures of certain indicators, the color change can extend over a large portion of the pH range. These mixtures are usually called *universal indicators*. One example is the B. D. H. universal indicator. The color changes are: pH up to 3, yellowish green; pH 4, orange-red; pH 5, orange; pH 6, yellow; pH 7, yellowish green; pH 8, greenish blue; pH 9, blue; pH 10, violet; and pH 11, reddish violet.

Appendix 2

TANNERY RECORDS

The only way to control the production, to ensure better quality and to make a profit is to keep records. Leather of high quality is the aim of every tanner, but it is only too easy to forget what kind of chemicals were used, the time needed for different processes and even the quality of the raw material which has been obtained. It is essential, therefore, for a good tanner to keep adequate records.

The record sheet should be pinned on a wooden board, and it should remain adjacent to the hides or skins to which it refers as they move from vat to vat. Details of every stage of production which have any bearing on the hides or skins should be entered on the record sheet.

The hides or skins must be marked in relation to the record sheet. Paint or pencil marks are unsatisfactory, for they will be lost during the various processes, or they will produce stains. The use of an 0.5 to 1 centimeter punch permits a whole range of code marks; one, two or three holes in a row; one above the other; triangles; squares and so on. The marks should always be punched in the same place — for example, on the right fore shank — so that they can be found at a glance. It is actually preferable, however, to mark the hides on both sides of the root of the tail.

The interpretation of these records will give the tanner much experience and will prevent him from repeating mistakes.

Table 4 shows a useful example of a tanning record.

TABLE 4. – EXAMPLE OF A TANNING RECORD

REMARKS AND OBSERVATIONS

STARTING DATE ..... BATCH NO. ..... MARKING .....

TYPE (Goat, sheep, calf, cattle, buffalo, etc.) .....

TOTAL NUMBER .....

WEIGHT (*a*) Raw hide (*b*) Soaked weight (*c*) Limed weight (*d*) Pelt weight (*e*) Wet-leather weight (*f*) Shaved leather weight (*g*) Finished leather weight or area.

	Processing time	Quantity of chemicals used
Soaking	From ..... To	
Liming	From ..... To	
Bating	From ..... To	

Remarks and Observations .....

Drenching From ..... To .....

Remarks and Observations .....

Oiling, Tanning, Fat liquoring or stuffing

From ..... To .....

Remarks and Observations .....

Drying From ..... To .....

Remarks and Observations .....

Finishing operation (Dyeing, fat liquoring, setting, drying, staking, pigment finishing, glazing and ironing)

Finishing Date .....

Quality report (Area or weight)

Date ..... Signature .....

Appendix 3

CONVERSION RULES

To convert:	*Multiply by:*
Centimeters to inches	0.3937
Meters to feet	3.281
Square centimeters to square inches	0.1550
Square meter to square feet	10.76
Cubic centimeters to cubic inches	0.06103
Cubic meters to cubic feet	35.32
Liters to cubic inches	61.03
Liters to U.S.A. gallons	0.2642
Liters to Imperial gallons	0.2203
Grams to pounds	0.002205
Kilograms to pounds	2.205

Centigrade to Fahrenheit

°C	°F
0	32
5	41
10	50
15	59
20	68
21.1	70
25	77
26.7	80
29	84.2
30	86
32.2	90
35	95
37.8	100
40	104
43	109.4
45	113
50	122
60	140
70	158.9
74	165.2
100	212

GLOSSARY

This glossary is compiled from a series of articles entitled "Encyclopaedia of the Leather Trade," by D. Woodroffe which appear regularly in *The Leather Trades' Review*; John Arthur Wilson's *Modern Practice in Leather Manufacture* and the *Glossary of Leather Terms*, British Standard 2780; 1956, published by the British Standards Institution.

ALUM TANNED LEATHER	Leather prepared solely with a mixture of which the essential active ingredient is an aluminium salt. This is often, but not necessarily, alum — for example, alum, salt, egg yolk and flour. The natural color of the leather is white.
ANILINE DYED	Leather which has been dyed by immersion in a dyebath and has not received any coating of pigmented finish.
ASTRINGENCY	This refers to the property of many vegetable tannins in bringing about a contraction, or drawing together, of the pelt fibers, and it varies in its intensity with different materials. Astringency appears to be associated with a high tan to nontan ratio, low acid content and very low salt content of the liquor; for an alteration in any of these factors affects the result. *Mellowness* in a liquor is the reserve, and it refers to one in which the combination rate with hide substance is slow and the penetration rapid.
BABY CALF	Calf skin leather made from small, lightweight skins with a smooth or finely boarded grain surface, free from any artificial surface pattern. The finish is more or less glossy, and it is produced by glazing, ironing or plating.
BACK	The main portion of a hide, obtained by cutting off the two bellies (see Figure 18).

Bag hide — Flexible leather generally embossed with a grain pattern; oat grain is the most usual. Made from cattle hide, usually vegetable tanned, split to a suitable thickness and sometimes hand or machine boarded.

Barkometer — An instrument used for measuring the density ("strength") of tan liquors. In the barkometer scale, one degree specific gravity is divided into 1000 equal subdivisions. Each of these divisions is called a barkometer degree, and it is expressed as X° Bkr. To convert barkometer degree into specific gravity, the former is divided by 1000 and 1 added to the quotient.

$$\text{Specific gravity} = \frac{\text{Degree Barkometer}}{1000} + 1.$$

Conversely degrees barkometer = (specific gravity — 1) × 1000.

Bark tanned — Leather vegetable tanned by means of the tannins contained in the barks of trees. In the process the leather comes in contact with the raw bark.

Bate — Materials which are used for the removal of nonessential proteins like globular, mucins, elastins and residues of keratin by chemically reacting with them and dissolving, along with some fats. They also remove lime from hides and skins. Formerly hen, pigeon and dog dung were used. With dog dung the process was known as puering. Nowadays artificial bates which contain proteolytic and lipatatic enzymes and deliming chemicals are manufactured. These are quite as efficient as dung bate, and they are not obnoxious. Bating renders the final leather soft and supple to the feel and silky on the surface.

Bating — To treat skins with a commercially prepared bate or a bate made from animal pancreas and ammonium chloride.

Beam — An inclined table with a convex working surface. Used for fleshing, unhairing and scudding.

Beamhouse (Wethouse) — Part of tannery where hides and skins are soaked, limed, unhaired, scudded, bated and drenched. It is that part of the tannery where hides and skins are prepared for the actual tanning.

Belly — That portion of a hide or skin which covers the underpart of an animal and includes the upper part of the legs (see Figure 18 and Offal).

Belly grain — The tanned outer, hair or grain side split from a belly.

Belly middle — The middle part of a cattle hide belly (see Figure 19).

Belting butt — The butt portion of selected cattle hides which have been specially tanned, curried and dressed to produce strong, flexible leather with minimum stretch, suitable for the manufacture of machine belting.

Bend — Half of a cattle hide butt, obtained by dividing it along the line of the back bone. Usually applied only to tanned material (see Figure 18).

Bleaching leather — For vegetable-tanned leathers this usually consists of making the color lighter by washing and thus removing the oxidized tannins and insoluble matter from the surface with a solution of soda ash, and then by treating with diluted acid, or by using bisulfited tanning or bleaching extracts. Synthetic tanning materials are also used for this purpose. For chrome-tanned leather it usually consists of making the color lighter by treatment with syntans and sometimes also by precipitating white pigments on the surface of the leather to give it a white appearance.

Boarded leather — Leather which has been softened and its surface lightly creased by folding, grain to grain, and then by working the fold across the leather to and fro by means of hand boarding or a boarding machine.

Box calf — Black calf skin leather with a surface pattern of fine box shaped creases formed by boarding the skin in two directions — neck to tail and belly to belly. Full-chrome tanned.

Box sides — Black leather dressed in the same way as box calf, but made from cattle hides cut down the backbone. The tannage may be full-chrome, semichrome or vegetable.

Bran drench — A warm infusion of bran, in which the puered or bated skins are immersed. The bran contains starch which is converted into organic acids and gases in the skin. The gases, separate the pelt fibers, inflate the pelt and cause it to rise to the surface of the drench liquor; the acids complete the deliming of the pelt, bring about slight acid swelling and effectively check further bating action by acidification. The bran particles help to scour the pelt and remove the scud, leaving the pelt white and clean.

Bridle leather — Strong flexible leather of reasonably uniform thickness with a plain finish and a close shaved flesh. Made from ox or cow hide, vegetable tanned and curried.

Buff leather — Flexible dry leather with a cream or white surface and finished on the grain side with a velvet-like nap. Made from cattle hides, from which the whole of the grain has been removed, and oil tanned.

Buffalo — Leather made from the hides of buffalo cattle, excluding the North American buffalo.

Buffed leather — Leather from which the top surface of the grain has been removed by an abrasive or bladed cylinder or, less generally, by hand. With upholstery leather known as "hand buffed," the buffing process is invariably carried out by means of an abrasive or bladed cylinder.

Butt — That part of the hide which is left after the bellies and shoulder have been removed (see Figure 18).

Butt split — The underlayer split from the butt of a cattle hide.

Calf — In its wides sense, this is leather made from the skins of young or immature bovine animals. In a more limited sense, it is leather made from the skins of those animals of the bovine species which had not been weaned or had only been fed upon milk and which do not exceed a certain weight in the green state; this limit may be 6.8 kilograms, or even higher. The heavier skins of immature milk-fed animals up to 11.3 to 13.6 kilograms in green weight are often termed veals.

Case hide — The skin of a fully grown animal of the bovine species.

Chamois — (*a*) Suede-finished leather made from the flesh of sheep- or lambskins, or from sheep- or lambskins from which the grain has been removed by frizzing. It is tanned by processes involving the oxidation of fish or marine animal oils in the skins. They make use either of these oils solely (full oil chamois) or, first, formaldehyde and then these oils (combination chamois). The U.S. Federal Trade Commission restricts the term "chamois," without any qualifications, to the flesh splits of sheepskins tanned solely with oils.
(*b*) Leather made from the mountain antelope or chamois. This leather is rare.

Cheek — Leather from the cheeks of cattle hides.

Chrome retan — Leather which has been, first, chrome tanned throughout its thickness and, second, further treated or tanned with vegetable and/or synthetic tanning agents. These retanning agents penetrate markedly, but not necessarily completely, into the interior.

Chrome tanned — Leather tanned either solely with chromium salts or with chromium salts, together with quite small amounts of some other tanning agent. This other tanning agent is used merely to assist the chrome tanning process, and not in sufficient amount to alter the essential chrome character of the leather.

Circulators — Circulators, or a circulator round, consist of a series of tan pits which are interconnected. The leathers, or partly tanned butts, are suspended in these pits. As a rule, there are seven pits in a round, and butts are suspended in six of the pits, leaving one to contain tan liquor only. The butts remain suspended in the pits, and the tan liquor is circulated through all seven pits. Additions of extract, acid or salts are made to the liquor in the spare pit — that is, the one in which no leather is suspended. The temperature of the whole tan liquor in the circulator round can be adjusted by controlling that of the tan liquor in the spare pit. The advantages are: (*i*) Frequent handling before strengthening and adjusting the liquors is avoided; there is less hauling of the leather; thus labor is saved and labor

costs are reduced. (*ii*) The tannin penetrates more rapidly. (*iii*) There are no hook scratches caused by too frequent handling of the leather.

COMBINATION OIL — A tannage, or a process of tannage, in which the skin is first tanned with formaldehyde and subsequently treated by the oil process (see CHAMOIS).

COMBINATION TANNED — Leather tanned by two or more tanning agents — for example, chrome followed by vegetable (chrome retan); vegetable followed by chrome (semichrome); formaldehyde followed by oil (see COMBINATION OIL).

CORRECTED GRAIN — Leather from which the surface of the grain has been partially removed by buffing to a depth governed by the condition of the raw material. Upon this leather, a new surface has been built by various finishes (see BUFFED LEATHER),

COW HIDE — Strictly, this is leather made from unsplit cow hides or their grain split, but the term is sometimes applied to similar leathers from any hides of the bovine species. The term must not be applied to leathers from flesh splits.

CURRIED LEATHER — Leather which has been subjected to the currying process.

CURRYING — A series of dressing and finishing processes which are applied to leather after tanning. During these processes appropriate amounts of oils and greases are incorporated in the leather to give it increased tensile strength, flexibility and water-resisting properties.

DELIMING — The partial or complete removal of the lime or other alkali from lime pelts, by immersion in water, a weak solution of an acid or an acid salt. Not more than 60 percent of the lime can be removed by prolonged washing of the pelts in running water only. The remainder of the lime is chemically combined with the pelt and can only be removed by treatment with an acid or an acid salt. Hydrochloric, lactic, boric and acetic acid and sodium bisulphite or ammonium salts are commonly used. Treatment with acids can be dangerous due to the phenomenon called acid or overswelling, especially if

strong acids, such as hydrochloric or sulphuric, are used. To avoid this and to economize in the use of boric acid, it has become a common practice to delime the surface of pelts or butts with a mixture of borax and sulphuric acid. A pit is filled with a 0.25 percent solution of borax; the limed butts are suspended in this, and diluted sulphuric acid is added from time to time until the grain surface has been completely delimed.

Drawn grain — A grain showing an irregular pattern of creases or narrow grooves. It is produced by tanning the skin so that the main thickness has contracted relatively to the grain layer, which is then fixed in a puckered or "drawn together" condition.

Drench — Fermented bran or flour used for deliming skins.

Drenching — Soaking skins in a fermented infusion of bran or flour and warm water.

Dressing hide — Unsplit rough tanned cattle hide, vegetable tanned in a manner giving good tensile strength and mellow feel. Suitable for dressing for harness and straps.

Dubbin — Stuffing material used for heavy leather. This is usually a mixture of fish oil (preferably cod oil) and tallow in suitable proportion.

Dyes (1) Artificial — Dyes prepared synthetically.

Dyes (2) Natural — Coloring matters of natural origin.

E. I. — An abbreviation of East India. A descriptive term applied to crust, vegetable-tanned cowhide (kip), buffalo hide and calf, sheep and goatskin, originating in the Indian subcontinent and tanned in India, mainly in the south, and especially around Madras (see Kip).

Embossed leather — Leather embossed or printed with a raised pattern, either imitating or resembling the grain pattern of some animal or being quite unrelated to a natural grain pattern.

Emulsifying agent — A substance which helps to form an emulsion.

Emulsion — A suspension of tiny droplets of fat in a liquid in which it is not soluble.

Enzymes — An enzyme is a soluble, colloidal, organic catalyst, produced by a living organism. They are not themselves alive. When present, they can increase the speed of certain specific reactions without being affected themselves; only very small amounts are required to bring about these changes. The most important enzyme encountered in leather manufacture is trypsin, which is the active principle in the dog dung bacteria responsible for puering action. Trypsin also occurs in certain plants and moulds. Another source of trypsin is cattle and pig pancreas, which contains some other enzymes besides trypsin. Trypsin is the chief ingredient of tryptic bates, which are enzyme bating materials. Trypsin is also the active principle in the enzyme unhairing process. Epidermis is digested by trypsin. An enzyme papain has also been used for bating purposes. Puering and bating bacteria are effective owing to the enzymes which they form and contain. Enzymes are poisoned by some products but stimulated by others — for example, by ammonium salts. Enzymes are destroyed by heat.

Face — Leather made from the face of cattle hide — that is, a triangular-shaped portion from between the ears and eyes to the nose, excluding the cheek (see Figure 18).

Fall (or fallen) — To deplete or to remove the swelling of limed pelts. It is one of the effects of puering or bating. The bated pelts are soft, silky on the grain and flaccid. This is the condition known as "fallen," and the production of this effect is termed "to fall."

Fat liquor — Is an emulsion of oil or fat in water, and the oil or fat globules in the emulsion are absorbed evenly by leather which is treated with it. The fibers of the leather become coated with the oil or fat, so that the leather is thereby rendered soft.

Fat liquoring — The process of applying emulsified fat to light leather.

Finishing — All operations, such as oiling, dyeing and rolling, which are meant to improve the quality and appearance of the leather.

FULL CHROME (TANNED)	The adjective " full " is sometimes added to chrome tanned to emphasize the fact that the leather is neither semichrome nor combination chrome.
FULL GRAIN	Leather bearing the original grain surface, as exposed by removal of the epidermis, and with none of the surface removed by buffing, snuffing or splitting (see CORRECTED GRAIN).
FUR	The skin of a recognized fur-bearing animal dressed and finished with the hair on.
GLAZING	The operation of producing a bright, glossy or glass-like finish on the grain surface of leather by subjecting it to the action of a machine which rapidly draws, under pressure, a tool of glass, agate or other suitable material across the suitably prepared surface of the leather.
GRAIN	(*a*) The outer, or hair side, layer of a hide or skin which has been split into two or more layers. (*b*) The pattern visible on the outer surface of a hide or skin after the hair or wool has been removed.
GRAIN LAYER	The portion of a hide or skin extending from the surface exposed by removal of the hair or wool and epidermis down to about the level of the hair or wool roots.
GRAIN LEATHER	Leather which has the grain layer substantially intact and finished on the grain side.
GRAIN SPLIT	The outer, wool or hair side, layer of a hide or skin which has been split into two or more layers.
HANDLER	The vegetable tanning process for sole leather consisted of suspender liquors, handler liquors and layers. The first development of modern sole leather tannage includes these same three types of liquors. The handlers or handler liquors comprised those tan liquors which followed the suspender liquors. The handler liquors are stronger than the suspender liquors, and they vary between 15 to 45 degrees Barkometer strength. The butts were hung or suspended in the suspender liquors, but they were laid flat in the handler liquors. On alternate days, the butts were hauled, and piled to allow for

the strengthening of the liquors with extracts or stronger tan liquor. These liquors derived their name from this frequent handling. Nowadays, the handlers have been replaced in modern tanneries by rotors in which the butts are enclosed in a lattice drum, which is half immersed in the pit (see also LATTICE DRUM), or by circulators.

HERSE — A wooden frame used for stretching skins for parchment or vellum manufacture.

HORSE — A portable wooden vehicle on which leather, hides and skins are piled for draining or for transporting from one department to another.

HOT PITS — A series of circulator pits in which very strong tannin extract liquors of about 130 degrees Barkometer are used at 41°C. to 43°C. The leather remains in these liquors for up to one week. It becomes filled with the strong extract liquor, and even crude quebracho extract liquors can be used because of the temperature. They are used to increase the amount of tannin fixed by the leather and also to fill the butts. The hot liquors are contained in a set of circulator pits. These comprise six pits in which the leather is suspended and one pit which contains tanning extract liquor only. This one pit is provided with a closed steam coil for maintaining the temperature. All seven pits are interconnected, so that by controlling the strength, temperature and pH value of the liquor in the seventh pit, these properties are also controlled for all the tan liquors.

HYDRAULIC LEATHER — Leather made from cattle hide which has been so dressed with soft grease that it becomes virtually waterproof.

HYPODERMIS — Loose connective tissue mixed with fatty tissue, joining the skin to the body.

INDICATORS — Substances soluble in alcohol and water which undergo a change in color according to the pH value of any solution into which they are introduced, thus making it possible to use the color of the solution as a measure of its pH value. These indicator solutions can be used to control the pH value of bate liquors, pickle liquors and other colorless solutions.

INSOLE BELLY — Vegetable-tanned hide belly, suitable for insoles for footwear.

KERATIN — The basic substance (proteins) in all horny structures such as the epidermis, hair, nails, horns, claws. They are characterized by great resistance to fermentation (enzymes) acids and alkalies. They are extremely sensitive to reducing agents — for example, sodium sulphide and hydrosulphide — for they are speedily disintegrated by them. Hair is completely dissolved after one hour in a 10 percent solution of sodium sulphide. They are only slightly swollen by acids or alkalies. Thus if any epidermis is left adhering to the pelt after unhairing, it impedes the swelling and plumping of the pelt collagen, and this causes the production of thin, flat leather.

KICKER — Receptacle apparatus used for fur skins processing. Fur skins are pickled and rubbed on the pelt side with cod oil or similar fish oil. They are hung up in a warm drying room to oxidize and dry. The dry pelts are softened in the "kicker," which is a box-like receptacle containing sawdust. Into this box dips a foot-like projection which is capable of being moved to and fro mechanically, whereby any dry pelts can be softened. The movement of the fur skin in the sawdust cleans the hair and gives it a polish.

KILLING — A process applied to wool or fur skins in order to make dyeing of the wool or fur more easy. Killing is often done with soda ash (sodium carbonate), ammonia or ammonia and hydrogen peroxide.

KIP — Smaller type of cattle hide. They are:

(*a*) Hides of fully mature cattle, other than buffaloes, native to the Indian subcontinent; for these are smaller than those of Europe and America.

(*b*) Hides derived from immature European and American animals of the bovine species which have been grass fed and have sizes intermediate between those of calf and full grown cattle.

(*c*) As an abbreviation of the full term "East India Tanned Kip" — or "E. I. Kip" — crust, vegetable-tanned leather, made from cow or buffalo hide originating in the Indian subcontinent and tanned in India, mainly in the south and especially around Madras.

Kiss spot — A light stain or lightly colored portion on vegetable tanned hides or skins caused by the pelts touching each other in the early stages of the tanning process. Movement of pelts in the first tan liquors is designed to avoid this staining. Staining may occur above the kiss mark through the settlement of heavy particles in the tan liquor on to the two grain surfaces. The kiss itself is not a discoloration; for it is the portion which touching has prevented from being colored.

Knee staker — A metal blade set upright on a wooden support, which may be a rigid upright portion of the stand or an upright stake. The skins for staking are worked over the blade. Both hands and knee are used for giving the necessary pressure on the skin. Staking pulls apart the fibers of the skin, which should remain quite soft on drying out.

Lattice drum — Lattice drums are usually designed to rotate in a pit. For washing only, lattice *doors* are used in an ordinary drum. Rotors are lattice drums with the butts fixed to slats inside.

Layaways, Layers or Layer vats — A vat containing relatively strong vegetable tan liquor into which sole leather hides are layed flat after preliminary initial tanning in pits or rocker vats.

Laying away — Storing hides in layer vats for a long time to ensure that they are tanned through; where only weak liquors are available, the hides are dusted with ground raw vegetable-tanning materials to provide a sufficient amount of tannin.

Leaching — Extracting the tannins from the tannin-bearing material by immersion in water.

Leather — A general term for hide or skin, which still retains its original fibrous structure more or less intact, but from which the hair or wool may, or may not, have been removed and hwich has been treated so as not to be putrescible, even after treatment with water. Certain skins, similarly treated, or dressed, without removal of the hair are termed "fur." No product can be described as leather if its manufacture involves breaking down the original skin structure into fibers, powder or other fragments by chemical and/or mechanical methods and reconstituting these fragments into sheets or other forms.

LIME, FRESH	Slacked lime freshly dissolved in water.
LIME, MELLOW	Fresh lime in which some hides have already been limed.
LIME, OLD	Lime used many times.
LIME, CALCIUM OXIDE, BURNT LIME	Is produced by " burning " limestone or calcium carbonate. By this process carbon dioxide is driven off, and the burnt lime or calcium oxide remains. It is usually in the form of white lumps, which react violently with water to form slaked lime or calcium hydroxide.
LIME LIQUOR, LIMING	As slaked lime is very slightly soluble in water, excess gives a milky liquor — usually called a lime liquor — in which the raw hides are immersed to loosen the hair or wool and to swell and plump the collagen fibers of the pelt. Lime liquors also exercise a degree of saponification of the grease in the pelts and loosen some of the " scud " or undesirable ingredients in the pelt.
LIME PAINT	Sodium sulphide solution is mixed with slaked lime, hydrated lime or china clay to form a thin paint which can be applied to the flesh side of sheep, goat or calf skins. Alternatively, one can slake a mixture of burnt lime and red arsenic to yield a paint. The mixtures are so called because they are usually " painted " on the flesh side of the hide or skin. After treatment, the skins are folded down the backbone, or they can be placed, flesh to flesh, in pairs and left overnight. As a rule, the hair or wool is loose next morning and it can be pushed off.
MELLOWNESS	See ASTRINGENCY.
MORDANT	See STRIKER.
MUCILAGE	A soft jelly-like material, such as linseed mucilage, which is obtained by soaking whole linseed in water overnight. Next morning, the water is raised to the boil, simmered for a few minutes and allowed to cool; and the coarse particles strained off through coarse muslin. The thin jelly obtained forms the basis of many "binders" for use in finishing leather. Gum tragacanth and many other substances also yield mucilages.

Nontans — Substances present in a tanning liquor which do not tan, such as sugary matter, gallic acid, soluble mineral salts and other acids.

Oak bark tanned — Leather conforming to the minimum requirements of the Oak Bark Tanners' Association Ltd. — that is, an unadulterated, unbleached leather, pit tanned for not less than five to six months by a process which embodies layering for not less than three months and employs oak bark as a basis of tannage.

Offal — The bellies, shoulders and head portions of cattle hide, which are cut away to isolate the butt (see Figure 18).

Oiling off — Black chrome leathers, in particular, are sometimes "oiled off" — that is, they are given a light coat of mineral oil on the grain side before they are hung up for drying. The oil prevents the grain of the leather from becoming too hard and bone dry. As a rule, warm light mineral oil is employed, but other oils can also be applied. Sole leather is also oiled off for a soft grain and to prevent the vegetable tanning materials from drying on the surface.

Oil tanning — A process of tanning which involves the incorporation of fish or marine animal oils into prepared skins. These oils are subsequently induced to undergo oxidation and other chemical changes in contact with the skin fibers, leading to chemical combination of oil derivatives with the skin.

Pancreatin — Any enzyme product occurring in the pancreatic glands of mammals. Cattle and pig pancreas is the largest source; the pancreas is dried, ground to powder and then added to ammonium chloride and wood flour to give a substitute bating product. Pancreatin contains enzymes, the chief of which for the leather trade is trypsin, a proteolytic enzyme which functions best at pH 8.5 and 35°C. Substitute bates containing pancreatin are often described as "pancreatic" bates, and they have proved entirely satisfactory in bating hides, calf skins and sheep pelts.

Parchment — Translucent or opaque material with a smooth surface, suitable for writing, bookbinding and other purposes, made from the flesh split of

sheep, goat or ass skin, by drying out the limed material without applying any tannage; the material is thoroughly cleansed and degreased and smoothed during the process. As a rule, parchment refers to the flesh split of a sheep skin.

Pasting or painting — The application to the flesh side of raw hides and skins of a lime paint, a mixture of slaked lime, water and sodium or arsenic sulphide or sodium hydrosulphide. The term "pasting" is applied also in drying dyed and fatliquored leather over glass or other suitable plates in the drying chamber.

Pelt — In the leather trade, as opposed to the fur trade, pelt commonly means the hide and skin prepared for tanning by the hair or wool, epidermis and flesh.

Phenol phthalein — A white powder soluble in ethyl alcohol, used as an indicator. Its range of color change is from the pH value 8.3 (colorless) to pH value 10.0 (deep pink, red). It is useful in indicating the extent of the deliming of limed pelts. A drop of phenol phthalein in a 1 percent solution applied to the cut edge of a partly delimed pelt indicates the presence of lime by a deep pink color (see also pH value).

pH value — A measure of the strength of the acid or alkaline reaction of a solution, where 7.0 represents a neutral solution. Values decreasing from 7.0 represent solutions of increasing acidity and values increasing from 7.0 represent solutions of increasing alkalinity.

Pickling — The treatment of bated skins or drenched skins with a solution of salt and acid (sulphuric, hydrochloric or formic) to preserve them, or as a preparation for the tanning operation. Pickling increases the rate of penetration of the tanning so as to prevent drawn grain. Pickling brings the pelt to a nonswollen acid condition which is very necessary as a preliminary to chrome tannage; commonly used before chrone tanning, but not generally in vegetable tanning.

Pigment finished — Leather to the surface of which a finish containing fine pigment particles in suspension has been applied. Sometimes called "doped."

Pit liming — A method in which hides and skins are limed in rectangular brick or concrete pits, varying in size, according to the class of goods to be processed. The smaller pits are used for skins, the larger pits for liming hides. The pits may be sunk from ground level, or they may be built above ground. The raw hides and skins are immersed in lime liquor in the pits for three days. Then the liquor may be strengthened with freshly slaked lime paste (one-pit system) or the goods may be transferred to a pit containing a once-used lime liquor. After a further three days, the goods are transferred to a new lime liquor prepared in the same pit (one-pit system) or to a fresh pit containing a new lime liquor (three-pit system). The pits must be provided with waste exits, or the liquor must be removed by pumping it out of the pits. Pit liming is laborious because the goods must be frequently hauled from the pits to permit the plunging of the liquor in them; for this is necessary to agitate the lime sediment and so to maintain the saturation of the lime liquor. Mechanical devices have been designed for agitating pit lime liquors.

Puering — The treatment of fleshed, limed pelts or grains with a warm infusion of dog dung for 1½ to 5 hours, according to the type of pelt, in order to remove traces of epidermis tissue, short hairs, lime soaps and "cementing substance," to loosen the scud, to deplete the pelts and to complete the deliming, and to increase the stretch and pliability of the finished leather.

Pulling — A term applied to the removal of the wool loosened in fellmongering. The wool is actually pushed off by hand and sorted as it is removed. The operators are called "pullers."

Rawhide belting leather — A leather suitable for the manufacture of high-speed machine belting. It is made from dehaired and fleshed cattle hide by treating it, either as such or after alum tawing (tanning), with vegetable tanning agents so as to leave a central layer untanned. The product is subsequently curried.

Reim leather — A kind of leather for the strap of a bridle obtained from oil-tanned hides.

Rotors — See Lattice drum.

ROUGH TANNED LEATHER	Leather, usually vegetable tanned, which has not been further processed after tanning, but has been merely dried out. The term "rough tanned" is used chiefly in relation to hide leather — for example, tanned strap butts.
ROUNDING	Trimming and cutting the hide into different parts according to the quality and the use to which the leather is to be put.
SAMM (SAMMY)	When wet leather is allowed to dry, it passes through a stage at which it is still damp, but no water can be squeezed out. At this stage, the leather is said to be in a sammed condition. The process of producing this condition in the leather is described as "samming" or "sammying." Sammed leather is in an ideal condition for absorbing grease or fat liquor. Most leather is sammed before it is treated with grease. "Sammed" is, in fact, a contraction for "semidried."
SCUDDING	Removing the scud from unhaired hides and skins; remnants of epithelial tissues, hair pigment, lime soap, etc., left in the grain layer.
SEMICHROME LEATHER	Leather which has been tanned first with vegetable tannin and then retanned with chromium salts.
SETTING OUT OR STRIKING OUT	To smoothen out creases and squeeze out liquor by means of a slicker.
SHAVING	Reducing the thickness of hides after they have been tanned. Reducing the thickness before tanning is called splitting (see SPLIT, SPLIT HIDE).
SHEEP SKIN RUG	A rug made from a woolled sheepskin which has been tanned and dressed.
SHOULDER	That portion of a hide or skin covering the shoulders and neck of the animal, and the leather made therefrom (see Figure 18).
SIDE	Half of a whole hide with offal (head, shoulder and belly) attached. It is obtained by dividing the hide along the line of the backbone.
SIDE LEATHER	Shoe upper leather made from cattle hide sides.

SLICKER	A hand tool used to squeeze out moisture and to smooth the leather.
SOAKING	Immersing hides and skins in water before liming.
SOLE LEATHER BEND	Leather made from the bend region of cattle hides, tanned and finished to be suitable for the outer soles of footwear (see BEND).
SPLIT	The underlayer of a hide or skin, or part of a hide or skin separated by splitting, or leather made therefrom. If the name of the animal from which it originates, or the word "hide" or "skin," or the part of the animal from which it comes is included in the description, then the word "split" must be used as a noun — for example, pig split, hide split, butt split — and not as an adjective — for example, split pigskin (see SPLIT HIDE).
SPLIT HIDE	The outer or grain layer of a hide from which the under, or flesh side has been split to give it a reasonably uniform thickness, or leather made therefrom.
STAKING	To soften light leather by rubbing it over a vertical slicker.
STRIKER	The name often given to a tannin mordant used on leather to develop a particular color. Besides vegetable tannin mordants there are also some metallic salts which are used to "strike" or to develop a particular color. Thus, if tanned leathers are first treated with a vegetable tannin or with fustic, they can be subsequently treated with a metallic salt "striker" — for example, potash alum to strike a rich yellow shade. If other metallic salts are used as "strikers," different colors are produced.
STUFFING	The process of applying hot fats to heavy leather.
SYNTAN (SYNTHETIC TANNING AGENT)	May be defined as any synthetic high molecular organic compound or a mixture of compounds, which is capable of converting animal hide or skin into leather.
TAN	The process or method used to convert raw hides and skins into leather (see LEATHER). There are many different ways of tanning

and a large variety of materials which possess the property of being able to "tan." The process is called "tanning" and the person responsible for it, or in charge of it, is known as a "tanner."

TANNAGE, DEGREE OF — The proportion of combined tannin in a leather expressed as a percentage of the hide substance in that leather.

TANNIN — Normally, the substance or substances in a vegetable tanning material by means of which raw hides or skins can be converted into leather.

TANNING — The process of treating skins or hides with tanning agents, such as vegetable tannins, chromium salts, formaldehyde and fish oils, to produce leather.

TAN LIQUOR — A liquid containing tannins prepared either by leaching or by dissolving concentrated tannin extracts or any vegetable tanning material, such as barks, leaves and fruits.

TENSILE STRENGTH — The force required to pull apart a piece of the leather which has a specific square cross section.

TRYPSIN — See ENZYMES.

UNHAIRING — The removal of the hair or wool from hides or skins which have been treated to loosen the hair or wool. The hair or wool can be loosened by a so-called "liming" process, in which the hides or skins are immersed in an alkaline liquor prepared from slaked lime and water, or from slaked lime, sodium sulphide or hydrosulphide and water. These alkaline liquors hydrolyse and destroy the epidermis, thus loosening the hair or wool. Wool on sheepskins is sometimes loosened by sweating — that is, the epidermis is destroyed by means of a controlled putrefaction process in which the raw skins are hung in damp semi-underground chambers at a temperature of 10°C. to 15°C. After 48 hours in these chambers, the wool is loose and can be pulled off. This is usually called "pulling." Another process makes use of an enzyme to attack the epidermis. The soaked skins are first swollen by soaking them for 48 hours in a weak solution of caustic soda. This treatment is followed by the enzyme process — that is, using 1.5 to

2 percent of the enzyme on the dry weight of the skins in the hair. The enzyme treatment should be at 24°C. to 29.5°C. The epidermis will be loosened and the hair or wool can be removed in 24 hours. The hair or wool is quite undamaged. The process has proved to be popular with glazed goat tanners and with producers of gloving sheep.

UNHAIRING KNIFE — A curved knife with a blunt edge on the inner side. The knife is used to push or scrape off the hair which has been loosened on hides and skins after the liming (and unhairing) process. The knife is also used to scrape the grain of unhaired hides and skins and to work out the scud. The knife is tilted away from the operator and worked on the blunt edge.

VATS — Wooden, brick or stone tanks used for liming, tanning, etc.

VAT, CIRCULATORS — Vats full of strong tan liquor which is circulated by pump.

VAT, HANDLERS — Vats in which butts are laid horizontally, immersed in tan liquor.

VAT LAYERS OR LAY-AWAYS — Vats, similar to handlers.

VAT SUSPENDERS — Vats full of tan liquor, in which heavy hides are suspended from wooden slats.

VEGETABLE TANNED — Leather tanned exclusively with any vegetable-tanning material.

VELLUM — Translucent or opaque material with a smooth surface and suitable for writing, bookbinding and other purposes. It is made from unsplit calf, sheep and other skins, by drying out the limed skin without applying any tannage. The material is thoroughly cleansed and degreased, and the grain surface is smoothed during the process. The best vellum is made from calf (see PARCHMENT).

WHITING — Calcium carbonate or chalk.

NOTE: See also the glossary in FAO Agricultural Development Paper No. 49: *Flaying and Curing of Hides and Skins as a Rural Industry*.

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Rural Transport in Developing Countries

by I. Barwell et. al.

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RURAL TRANSPORT IN DEVELOPING COUNTRIES

Barwell, G.A. Edwards,
J.D.G. Howe and B.H. Vee

RURAL TRANSPORT IN DEVELOPING COUNTRIES

The World Employment Programme (WEP) was launched by the International Labour Organisation in 1969, as the ILO's main contribution to the International Development Strategy for the Second United Nations Development Decade.

The means of action adopted by the WEP have included the following:
— short-term high-level advisory missions;
— longer-term national or regional employment teams; and
— a wide-ranging research programme.

Through these activities the ILO has been able to help national decision-makers to reshape their policies and plans with the aim of eradicating mass poverty and unemployment.

A landmark in the development of the WEP was the World Employment Conference of 1976, which proclaimed *inter alia* that 'strategies and national development plans should include as a priority objective the promotion of employment and the satisfaction of the basic needs of each country's population'. The Declaration of Principles and Programme of action adopted by the Conference will remain the cornerstone of WEP technical assistance and research activities during the 1980s.

This publication is the outcome of a WEP project.

RURAL TRANSPORT IN DEVELOPING COUNTRIES

I. J. BARWELL, G. A. EDMONDS, J. D. G. F. HOWE and J. DE VEEN

A study prepared for the International Labour Office within the framework of the World Employment Programme

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ILO Foreword

Rural transport is one of the most significant means of ensuring that those who live in rural areas have access to markets for their products and to social services. While much has been published — by the ILO, the World Bank and others — on rural access roads, little has been written on alternative means of rural transport. The present volume, edited by Messrs. Barwell, Edmonds, Howe and de Veen, is designed to fill this gap. Research work in support of the volume was undertaken within the framework of the ILO Technology and Employment Programme, and was financed by a research grant from the Swedish Government (Swedish Agency for Research Co-operation with Development Countries — SAREC).

The volume contains a selection of case studies which highlight transport patterns, means and policies. One of the main conclusions of the study is that transport planning in most developing countries takes insufficient account of the needs and requirements of the bulk of the rural population. Only the transport demands of a few large farmers producing for the export markets are captured by conventional transport planning; the transport needs of the rest of the rural population are largely for the movement of small loads over relatively short distances and this is largely ignored. In addition poor credit facilities are a major constraint on the small producer acquiring even simple means of transport.

Within the framework of the United National Administrative Committee on Co-ordination Task Force on Science and Technology for Development, a number of joint activities have been formulated for implementation at the country level in the Third World. Upgrading of traditional transport technology is one such activity for which the ILO has been designated as a lead agency. The present volume is a contribution to this programme — which it is envisaged will also include a selected number of operational projects within the developing countries.

A.S. BHALLA,
Chief, Technology and Employment Branch

Introduction

For more than three decades investment in the transport sector has been a priority for developing country governments. With a few exceptions, roads have accounted for the major part of these investments. The explicit, and often articulated, assumption upon which the decision to allocate such large sums of money to road transport has been made is that road transport and development are inextricably linked. The implicit, and rarely articulated assumption is that the provision of suitable roads will lead to the operation of an adequate level of road transport services. If roads do not actually produce economic development, it has been argued, they certainly play a major role. This belief in the beneficial effects of roads is not wholly unsubstantiated. Clearly the provision of some form of access is vital for the development of the rural economy. Nevertheless, the studies carried out over the last 10-15 years on the impact of highway investment have sounded a cautionary note. George W. Wilson, writing in the concluding chapter of the Brookings Institution studies on transport and development, suggested that* 'A much more sceptical attitude towards transport appears essential and far more attention needs to be devoted to the set of circumstances surrounding expansion of transport capacity'.[1] The suggestion of a more restrained attitude reflected a growing concern that transport, and in particular roads, was only one factor amongst a large number that needed to be integrated for effective development. The concern to see road transport in a wider context partly explains the move towards the evaluation of the social, as well as strictly economic, benefits of road construction.

More recently the argument about the role of transport in development has largely been overshadowed by the practicalities of the situation. The effect of new roads becomes somewhat academic if funds are not forthcoming for their construction. The present economic recession has exacerbated the problem, and it is clear that neither donors nor governments are willing or able to invest large sums in new construction as opposed to reconstruction and

* references in the text are given at the back of the book

rehabilitation. Equally it would seem that previous investment strategies vis-à-vis transport have not been as successful as it was assumed. In particular, recent research [2, 3, 4] has drawn attention to the fact that:

— Few regular transport services operate away from all-weather road networks. However, many people live remote from such networks, and hence lack access to transport services.
— In areas with all-weather road access, motor vehicles are beyond the financial means of the majority of people. Equally, many people cannot afford to use the transport services which do operate.

There is unlikely to be a significant improvement in this situation for the foreseeable future given the limited resources available for expansion of road networks and motor vehicle fleets, and the problems of maintaining existing roads [5, 6] and operating conventional motor vehicles.

It is perhaps the limitation of resources, rather than the dissatisfaction with previous policy, that has led to a consideration of alternative strategies. The use of labour-based techniques in road construction is just one example of the search for low-cost alternatives. One of the major barriers, however, to the formulation of alternative strategies is the paucity of knowledge of the transport needs of rural communities. Their transport needs are assumed to be taken into account within the overall framework of transport provision. The latter usually, however, relates to motorized vehicles on conventional roads.

This book has two related purposes:

1 to improve understanding of the nature of the transport needs of rural people in developing countries and of the extent, and means whereby, they are currently met;
2 to contribute to the development of practical policies to provide transport facilities which will better meet the needs of rural communities.

The core of the book is the series of case studies presented in Chapters 1-10. These cover nine developing countries in Africa, Asia and the Pacific. The studies encompass countries at different stages of development, from those at the most impoverished levels (Bangladesh and Tanzania) to those which have sizeable industrial and market economy sectors, and relatively high per capita incomes (Republic of Korea and Malaysia). They also cover a variety of different agricultural, social and geographic conditions and

include a wide variety of different human, animal and motor-powered means of transport used to meet local movement needs.

The studies offer different perspectives on, and approaches to, the investigation of rural transport. The common, and distinctive, feature which links the case studies is that they examine rural transport conditions and problems from the viewpoint of rural people — small farmers, village households etc. They focus attention on the nature of small farmer and household transport needs, and on the physical and other constraints within which these must be satisfied. Much of the analysis is concerned with what the ILO has defined as the 'local transport system', that is the means whereby the majority of the rural population transport themselves, their families and their goods. A consequence of this focus is that the studies pay explicit attention to the role of simple, low-cost forms of transport and to the transport activities that take place remote from the motorable road network.

The studies [7] did not have a common research framework. They are therefore quite diverse in their coverage: from the analysis of transport needs in the Makete District of Tanzania to the description of one particular mode of transport, the *chee-geh*, in the Republic of Korea. They are all, however, illustrative of the local transport system.

The case studies have been grouped into three parts. The first comprises studies of the travel patterns of rural communities. The seond looks at particular means of local level transport. The studies that form the third part are more concerned with evaluations of transport policy and how it affects rural communities.

In editing the studies, every effort has been made to maintain the balance and perspective of the originals findings. Each study is prefaced by a short introduction to explain the focus and context of the original investigations. A brief assessment of the pertinent findings and implications is provided at the end of each study.

It would have been easy to prejudge the case studies by providing a detailed rationale for the study of the local transport system, but it is our view that the case studies are much more eloquent in providing such a rationale given their diversity and specificity. We have however attempted to draw together the most important lessons from the case studies in Chapter 11. This final chapter reviews the most important findings of the case studies, draws on supporting evidence from other sources revealed in the research associated with the production of this book and discusses the implications of these findings for the development of more effective policies for the planning and provision of local level rural transport facilities.

PART I — TRANSPORT PATTERNS

CHAPTER 1

Smallholder Transport Requirements in Malaysia†

Introduction

Peninsular Malaysia has a relatively high per capita income. In 1981, GNP stood at US$1,840, compared with US$770 for Thailand and US$790 for the Philippines. Income is not equally distributed, however, and the problems of the rural areas of Malaysia are not dissimilar to those of other countries in the region.

The study on which this chapter is based focused on the transport requirements of smallholder agriculture. It was commissioned by the ILO and carried out by J.D. Smith at the Kedah State Economic Planning Unit. It examined the transport requirements of a particular sub-district of the State and provided some ideas on the ways in which the demand could be met.

The study was carried out in 1981. National level data were drawn from existing official publications. Local level data were based on interviews with 184 households and on surveys of traders and other relevant groups, complemented by the findings of previous socio-economic surveys in the study area.

Background

Although per capita incomes are relatively high in Peninsular Malaysia the statistics show that in many rural areas the majority of the Malay population are living at or near the poverty line. The

†The study on which this chapter is based is described in J.D. Smith, 'Transport Technology and Employment in Rural Malaysia' (Geneva, ILO, 1981; mimeographed World Employment programme research working paper; restricted). Exchange rate at the time of the study M$2.38 (Malaysian dollars) = US$1.0.

Government's socio-economic policies aim to eradicate this poverty and redistribute incomes.

The sub-district of Jeneri in the State of Kedah was chosen for the detailed studies (Figure 1). Kedah has a population of about 1.1 million (the population of Peninsular Malaysia is 11,139,000 (1980 census)). Eighty-eight per cent of households in the State of

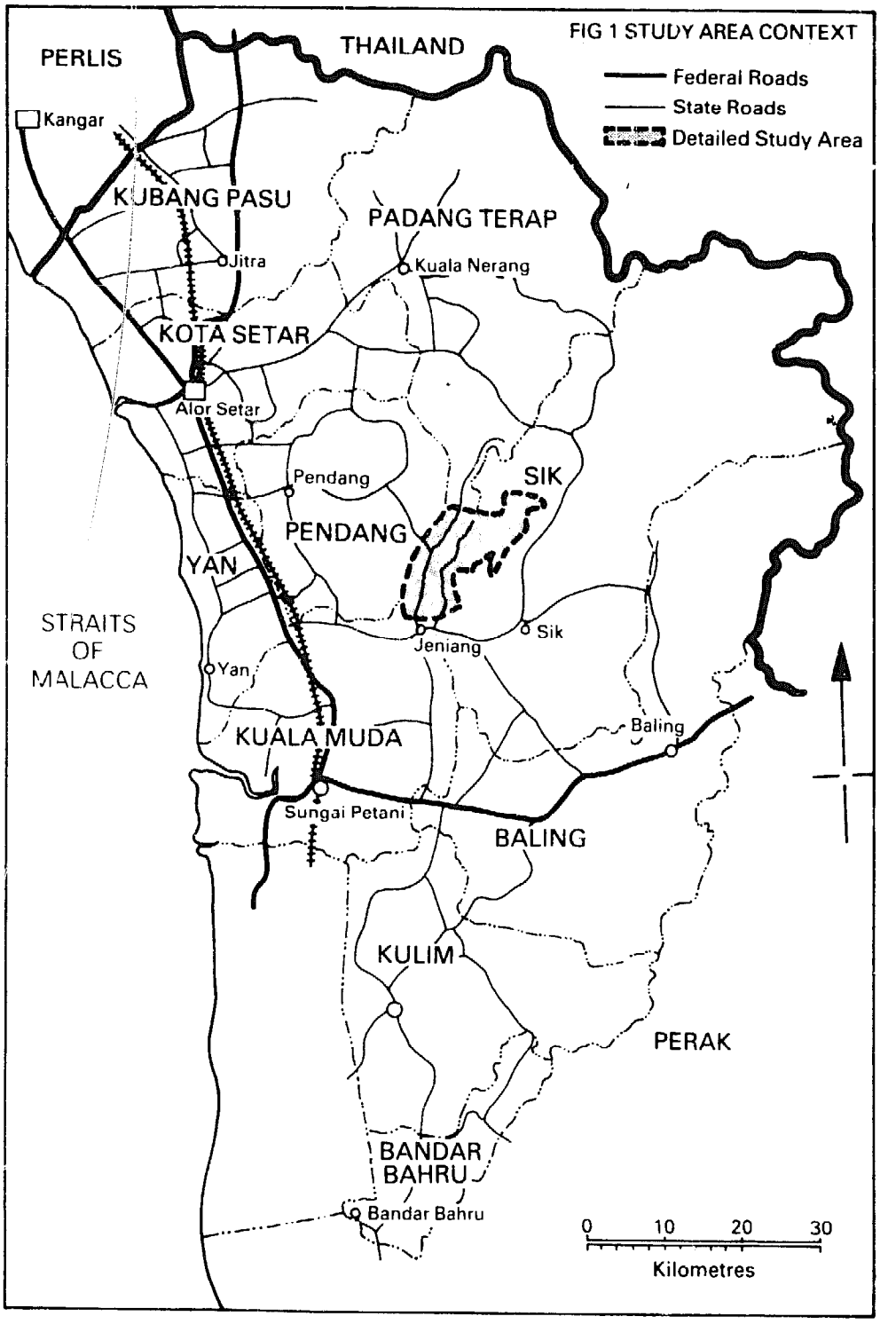

Kedah are in the rural areas and are principally engaged in agricultural activities, 59 per cent of households in the State are considered to be living at or near the poverty line. Jeneri is a poor agricultural area which is less well developed in terms of infrastructure than other areas in the State of Kedah and the peninsula. The population of 9,500 people depend upon farming for their livelihood. Jeneri (Figure 2) lies in the 'central belt' of Kedah State, which represents the greater part of the land area lying between the developed coastal plain in the west and the steep forest areas along the eastern boundary. The main road transport corridor in Kedah State is Federal Highway Route 1 which runs north-south through the coastal plain. From this Highway, several roads run inland to serve the rest of the State. The road network in the inland areas is oriented towards providing access to the more developed coastal plain. The standard and quality of the roads making up the inland network vary significantly depending on various factors but mostly on the state of development of the area concerned. Piped water supply is rare in the inland areas. Apart from some small isolated systems and some small-scale gravity feed systems installed by the Ministry of Health, most rural areas rely on wells and watercourses.

The main crops grown in the Jeneri study area are, in order of importance, rubber, padi (rice) and fruit. At the national level these three crops also represent the major share of agricultural production. This means that the study findings on the total transport demand related to these crops are certainly also relevant at the regional and peninsular level.

The Rural Transport System in Malaysia

Increasing emphasis is being placed on the development of the rural and village road network in Malaysia. Although the total budget allocation for roads has decreased over the period 1976-85, that for the construction and upgrading of rural and village roads has increased substantially. Under the village roads programme, existing tracks are being upgraded to facilitate marketing and processing of agricultural produce, and to provide better access to social amenities. Village roads are below official standards having only a 3 m wide unsurfaced pavement. They are passable by cars in dry weather but are more usually used by motorcycles and bicycles. Future programmes propose upgrading the roads to a bituminized surface standard on the existing alignment and improving drainage. This will allow all-weather use by motorcycles, bicycles and other simple vehicles. The low standard of construction makes these roads less suitable for pick-ups and lorries unlike the rural

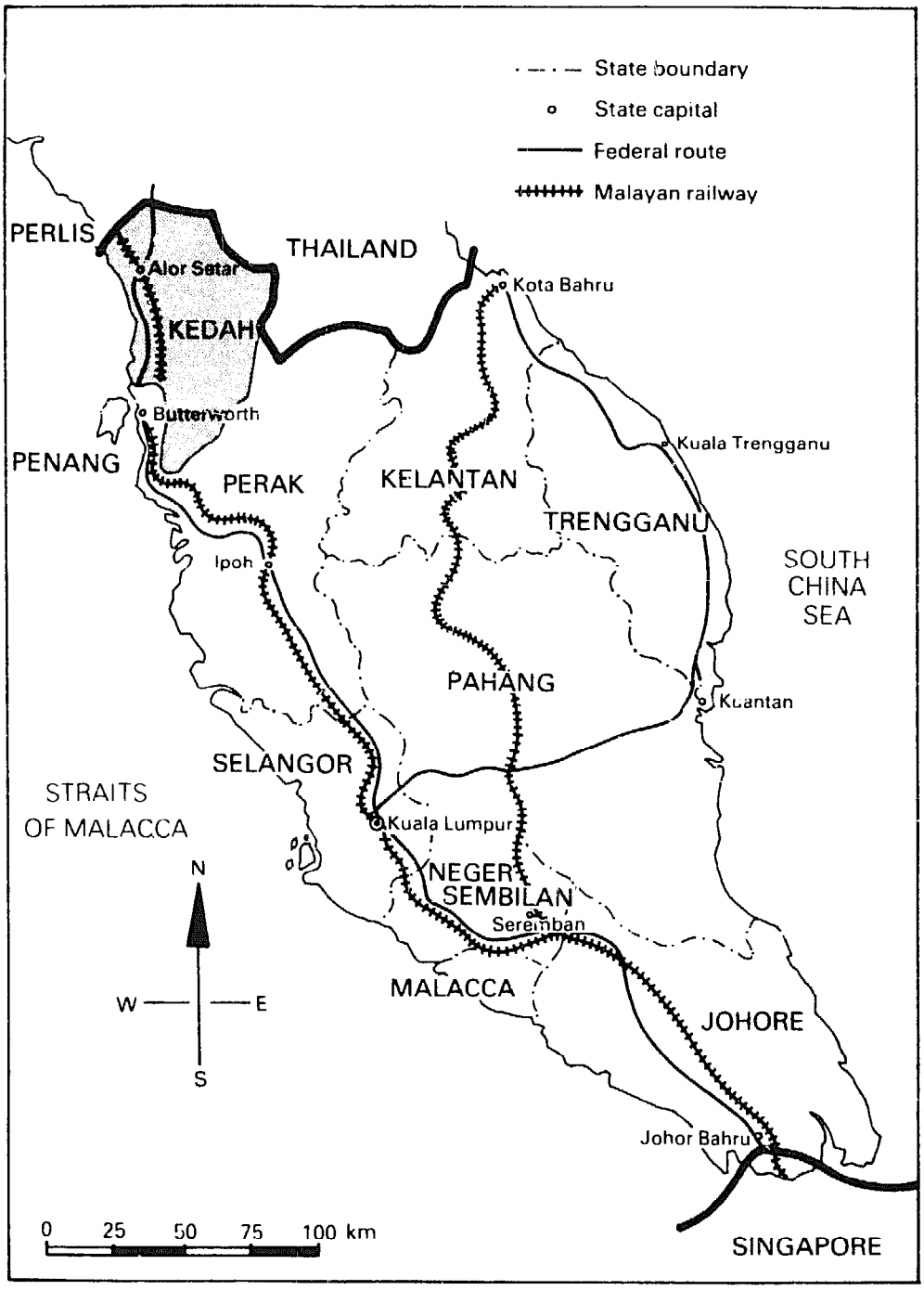

Fig. 2 *Kedah and the Study Area*

roads constructed by the Public Works Department. The latter are of a higher standard, in principle suitable for year-round use by heavy motorized transport.

Table 1 shows the distribution of vehicle ownership in Peninsular Malaysia.

The data indicate the relatively high level of motorization in Malaysia, and show the dominance of 'conventional' motor vehicles, in contrast to the locally developed modes (e.g. the jeepney) found in other Asian countries. They also indicate the limited range (bicycles and tricycles) of simple vehicles available for use by low-income households compared with other countries in the region.

Vehicle ownership and household income

Table 2 shows the level of vehicle ownership by households in the study area based on data from the sample interview survey.

Table 1. Peninsular Malaysia Road Transport

	No. of Vehicles	*Vehicles per 100 population*
Motorized:		
Cars	555,358	5.1
Motorcycles	1,079,020	9.9
Buses	11,589	0.1
Trucks and vans	122,543	1.1
Taxis	12,051	0.1
Others[1]	49,397	0.5
Sub-total	1,829,958	16.8
Non-motorized:		
Bicycles	1,416,000	13.0
Tricycles[2]	12,608	0.1
Sub-total	1,428,608	13.1
Total	3,258,566	29.9

[1] Includes tractors, road rollers and trailers.
[2] Excludes goods-carrying tricycles.

Table 2. Vehicle Ownership by Household

Households with	*No.*	*%*
No vehicle	24	13.1
Bicycle	58	31.5
Motorcycle	42	22.8
Motorcycle and bicycle	49	26.6
Car	4	2.2
Car and motorcycle	3	1.6
Car and motorcycle and bicycle	2	1.1
Boat	1	0.5
Truck/van	1	0.5
Total	184	99.9

The high levels of motorcycle and bicycle ownership are noteworthy. However car and truck ownership is very low in the study area, and is much less than the average for the peninsula.

Household income in the study area is also low. Eighty-nine per cent of the households had incomes lower than M$250 per month, as compared with the average monthly income of M$590 for rural households elsewhere in Peninsular Malaysia. Over 90 per cent of the households in the study area derive their income from the cultivation and sale of agricultural produce. The amount of disposable income is subject to considerable variation because of changes in commodity price levels and agricultural yields.

Other data collected during general household expenditure surveys indicate that between 12 and 16 per cent of monthly household incomes is expended on transport and communications. This means that approximately M$20 to 30 per month will be available for such things as fuel, bus and taxi fares, vehicle repairs or the purchase of new or second-hand vehicles. The survey data confirm this; only 20 per cent of households spent more than M$30 on transport.

A standard bicycle costs around M$160, the best-selling motorcycle — a 70 cc Japanese model — costs around M$1,650 and the best-selling car — a 1,200-1,300 cc Japanese model — costs about M$15,000, of which 35-40 per cent would be required as a deposit. For the majority of the population the cost of a new bicycle represents their total monthly household income or between 6-8 months of their average expenditure on transport. The purchase of

a new motorcycle represents some 10 months total income or nearly 8 years of the average expenditure on transport for the poorest farmers. The M$5,250 deposit for a standard saloon car in the peninsula is clearly out of the range of study area households.

Given the prices of new bicycles and motorcycles, the fact that 60 per cent of the households own a bicycle and 50 per cent own a motorcycle suggests that the majority of purchases were of second-hand vehicles. Various types of informal credit or cash arrangements exist between smallholder and trader and facilitate the purchase of second-hand bicycles and motorcycles. The substantial increase in motorcycle ownership which has taken place over the period 1970-81 can be partly explained by the introduction of new loan schemes by rural credit institutions. The small percentage of car-owning households indicates that, in terms of financial outlay, a vast difference exists between the ownership of cars and motorcycles.

The level of bicycle and motorcycle ownership in the study area suggests that even the low disposable income available for transport is sufficient for the purchase of substantial numbers of (second-hand) bicycles and motorcycles. It also suggests that transport is high on the priority list of rural people with very low incomes and that they are prepared to spend a sizeable proportion of their monthly income to satisfy their movement needs.

Transport for agricultural purposes

The way in which the local population use the transport system is a function of a variety of factors including level of access, cropping patterns, vehicle ownership and the state of the network. In general, however, transport can be divided by location into on-farm and off-farm transport and by function into agricultural and other.

Ninety per cent of the households in the study area are smallholders, of whom 92 per cent grow rubber, 47 per cent padi and 18 per cent fruits. The significance of rubber to the smallholder lies in the fact that it is useful only as a cash crop and as such provides his main source of income. Padi and fruits are grown partly for home consumption.

Table 3 shows that nearly half of the smallholders in the study area have rubber as the only crop and that rubber and padi together account for nearly 80 per cent of the total cultivation.

Table 4 presents data on the on- and off-farm transport requirements for the major agricultural crops produced by smallholders in the study area. The table shows that transport requirements are related predominantly to the production of padi and rubber.

Inputs of fertilizer, seedlings and insecticides are generally provided free of charge by government agencies and are delivered once a year to the farm gate or a local collection point. The average trip lengths (14-20 km) and the total transport requirements per farm (227 kg for padi and 488 kg for rubber) are high. The significant difference between the two major crops is that inputs are used by most padi farmers but only by 25 per cent of rubber farmers.

In terms of transporting agricultural outputs, the requirements for padi and rubber are totally different. Two-thirds of the padi produced is for home consumption and is either processed at home or taken to the nearest rice mill. The average production of padi per farm is 1,285 kg. Padi is harvested once or twice per year and thus gives rise to a requirement for bulk transportation over fairly long distances.

In contrast, smallholders tap rubber for about 200 days per year. The rubber must be collected every one or two days and sold in the form of latex, scrap or sheets. Each type of rubber can be marketed through government agencies or private sector traders. The government agencies provide collection centres and processing services. The private sector competes with the Government by providing the same services with the added flexibility of farmgate collection. The smallholder has the option, based on price levels,

Table 3. Farming Patterns

	No. of smallholder farms	*% Farms*	*Total area (ha)*	*% Total*	*Average Farm Size (ha)*
Rubber only	911	48.3	1,430	19.0	1.6
Rubber and padi	536	28.4	1,287	17.1	2.4
Rubber, padi and fruits	215	11.4	630	8.4	2.9
Rubber and fruits	85	4.5	201	2.7	2.4
Padi only	96	5.1	99	1.3	1.0
Padi and fruits	43	2.3	48	0.6	1.1
Sub-total	1,886	100.0	3,695	49.1	2.0
Non-productive rubber	—	—	2,248	29.9	—
Other[1]	—	—	1,574	20.9	—
Total	—	—	7,517	100.0	—

[1] Includes non-productive fruits, other crops and rubber farmed by non-Jeneri smallholders (probably untitled squatters).

Table 4. Agricultural Transport Requirements by Commodity

Commodity	Quantity (% of total tonnage)	Off-farm: Average trip length/km	Off-farm: % of total tonne/km	On-farm: Average trip length/km	On-farm: % of total tonne/km
Inputs[1]					
Padi[2]	6.8	19.6	17.0	0.15	5.1
Rubber[3]	5.9	14.3	10.8	0.25	7.4
Outputs					
Padi home	27.4	6.8	23.9	0.15	20.6
Padi sale	13.0	18.2	30.2	0.15	9.7
Rubber scrap[4]	38.9	3.1	15.5	0.25	48.8
Rubber sheets	2.2	3.1	0.9	0.25	2.7
Rubber latex	2.6	3.1	1.0	0.25	3.3
Fruits home	1.7	1.8	0.4	0.15	1.1
Fruits sale	1.5	1.8	0.3	0.15	1.1
Total	100.0	—	100.0	—	100.0

[1] Fruits inputs insignificant.
[2] Over 70% of padi farmers use all inputs and 97% fertilizer.
[3] Less than 27% of rubber farmers use any inputs.
[4] All rubber is sold.
[5] Trip length weighted for destinations west and east of River Muda.

Source: Study estimates based on survey data.

of using any purchasing agency for his produce. Thus the main transport need of the smallholders for rubber products is short-distance transport of relatively small quantities from farm to group collection centre.

Table 5 details the modes used for off-farm transport of inputs and outputs. Because they involve bulk transportation over fairly long distances, the movement of inputs is predominantly by truck (78 per cent) and motorcycle (12 per cent). Similarly, marketed padi is transported mainly by truck (70 per cent) and motorcycle (25 per cent). However for movement over shorter distances, the pattern changes. Transport of rubber (from farm gate to first level buyer/dealer) is by motorcycle (60 per cent) and bicycle (25 per cent), and of padi for home consumption by motorcycle (50 per cent), truck (23 per cent), car/taxi (14 per cent) and bicycle (13 per cent). Overall, motorcycles account for 42 per cent of transport of agricultural outputs, trucks 38 per cent and bicycles 13 per cent.

The generally small size of holdings means that on-farm movements are short-ranging as Table 4 shows, from about 0.15 to 0.25 km on average. It has been estimated that on-farm movements amount to only 2.5 per cent of the total tonne/km. However, over 90 per cent of agricultural inputs and outputs (a total of 3,750 tonnes in the study area) are moved on the farm by human porterage. Various methods of head, shoulder and backloading are used, but shoulder poles and yokes are by far the most common. In addition to movement on the farm, transport is also required to travel to and from the smallholding. As Table 6 shows, these journeys are made predominantly on foot and by bicycle. (Note: In this case-study the term 'on-farm transport' is used to refer specifically to movement on the farm land itself. In the remainder of the

Table 6. Mode of Transport to Smallholding by Farm Type (%)

Mode	*Rubber*	*Padi*	*Fruits*
Walk	56.7	73.6	90.6
Bicycle	31.1	20.9	9.4
Motorcycle	10.4	5.5	—
Car/Taxi	1.8	—	—
Total	100.0	100.0	100.0

Table 5. Summary of Off-farm Vehicle Use in the Study Area

Commodity (tonne/km)	*Walk*	*Bicycle*	*Motor cycle*	*Truck*	*Car/Taxi*	*Total*	*%*
Inputs[1]							
Padi[2]	174	133	294	4,138	223	4,963	17.0
Rubber	—	146	600	2,274	152	3,172	10.8
Outputs							
Padi home	—	902	3,494	1,579	1,013	6,988	23.9
Padi sale	—	442	2,212	6,193	—	8,847	30.2
Rubber sale	188	1,232	3,182	320	61	5,084	17.4
Fruits home	105	11	—	—	—	116	0.4
Fruits sale	14	10	73	5	—	106	0.3
Sub-total	481	2,977	9,855	14,509	1,449	29,272	100.0
% of Total	1.6	10.2	33.7	49.6	4.9	100.0	

[1] Inputs transported by modes other than truck represent mainly private sector purchases.

book it is used in a broader sense to refer to movement in and around the village, between village and farm, and on the farm.)

Transport for non-agricultural purposes

Information from the household interviews indicates that significant numbers of passenger trips are made to schools, shops and medical facilities, and for services and repairs. The most important of these, in that they are carried out on a regular daily basis, are trips to school and sundry shopping. Visits to coffee shops, local clinics and fruit and vegetable markets are also significant on a weekly basis. Table 7 gives details of these trips by mode of travel.

For daily trips to school and to the shops, walking is by far the most important mode of transport. Bicycle trips to secondary schools, sundry shops and coffee shops are also important. The latter two will usually be made in non-farmwork time. Secondary and, to a lesser extent, primary school trips would conflict with work trips if school attendance is required during the morning shift in households owning only one bicycle. The proportion of bicycle trips reflects the relatively short average trip lengths and small goods-carrying requirements (from sundry shops) for these purposes. In contrast the heavy use of the local bus system for weekly clinic and market trips, mainly by females, and children's school trips reflects longer average trip lengths, the non-availability of bicycles and motorcycles, the inability to drive motorcycles and the larger carrying capacity requirements for weekly shopping or marketing.

Provision of transport

The study revealed that for on-farm transport human porterage is ubiquitous. The shoulder pole, which is the most common method

Table 7. Daily and Weekly Non-agricultural Trips by Mode (%)

Trip	*Walk*	*Bicycle*	*Motor cycle*	*Car/ Taxi*	*Bus*	*Total*
Daily						
School Primary	60.8	8.8	5.7	2.1	22.6	100.0
School Secondary	38.5	21.1	0.9	—	39.5	100.0
Sundry shop	47.8	18.5	25.8	3.4	4.5	100.0
Weekly						
Coffee shop	18.9	17.6	43.2	8.1	12.2	100.0
Clinic	4.7	4.7	13.6	35.5	41.5	100.0
Market	0.6	2.8	18.6	35.1	42.9	100.0

used, has a long history in Malaysia. Even though increased rural income has engendered a move towards the use of bicycles and motorcycles, the shoulder pole remains an important aid to on-farm transport and almost every smallholder possesses one or more. Whilst the shoulder pole looks simple (Plate 1) it is, in fact, an ingenious device. The pole is flexible and is designed to move in harmony with the carrier. The pole is used to transport small loads (up to 50 kg) over short distances (up to about 1 km), and has the advantage that it can be used over rough ground. Shoulder poles are usually made from hardwood or bamboo and fashioned at home at no cost.

In the study area, 13 per cent of households own no vehicle at all and a further 31.5 per cent only a bicycle. The bicycle therefore is for many the only means of transport and what others aspire to. The bicycle is of significant importance for rural transport of goods and passengers, being used for travel to smallholdings, for the movement of crops and for non-agricultural trips. It is a multi-functional vehicle that can be used by different members of the household. Hitherto only few modifications, notably the fitting of a rear carrier, have been made to the standard design to increase its useful carrying capacity. However, potential may exist for improvements to the goods-carrying capacity of bicycles which could generate additional local employment. The urban location and large size of the major bicycle manufacturers indicates that potential markets for any improved goods-carrying bicycle or tri-cycle would have to be large to warrant their attention. In contrast, the local adaptation or modification of standard designs to suit individual crop and yield requirements could prove sufficiently profitable to warrant the establishment of small-scale workshops and repair facilities.

The motorcycle is the major locally owned mode of off-farm transport. It would seem logical to concentrate efforts on the improvement or adaptation of the motorcycle to conform to transport needs. Presently much of the rubber, having been transported to the collection point on shoulder poles is transferred to the motorcycle (Plate 2). It would be sensible to consider the introduction of locally manufactured motorcycle trailers to provide a more effective means of transporting the rubber.

The conclusions of a survey on the existing levels of employment in the transport sector are of interest. At the national level, there is a general trend away from agricultural employment into manufacturing and other secondary and tertiary jobs. In the transport sector, this is reflected in the increase of the number of workers employed in the manufacture and assembly of bicycles, trishaws

and tricycles by about 480 per cent over the period 1968-80. In 1980, employment in the manufacture and assembly of non-motorized vehicles made up over 11 per cent of total employment in the manufacture of transport equipment, compared to 8 per cent in 1968. It is estimated that non-motorized transport activities provide employment to as many as 25,000 people.

These figures show the growing importance of the sector in terms of employment creation: they also indicate that the requisite expertise is available to meet the demands of an expanded market. However, the geographical distribution of existing firms suggests that future manufacturing of non-motorized vehicles on a medium to large-scale will continue to be concentrated in the urban areas rather than in rural areas. Indeed, according to the 1973 Census there were only four firms employing a total of 42 workers in the manufacture of all types of transport equipment in Kedah as a whole. Small-scale assembly of vehicles can, on the other hand, be carried out in rural areas (as at present) but will usually be done in conjunction with the sale and repair ot bicycles spare parts and accessories.

Support for the entrepreneurial sector

Given the potential demand for bicycles and motorcycles adapted to carry freight, and the fact that local people will spend a considerable proportion of their income on transport, it is worth examining the prospects of government support for the local manufacture of such vehicles.

There is significant government commitment to develop the entrepreneurial sector. The Government provides financial assistance to Malay entreprenuers in the form of low interest charges or high loan ceilings. Official government loans for small-scale activities can be obtained by smallholders using land titles as collateral. Loans can also be obtained through commercial banks, specialized industrialized finance institutions, rural credit institutions and the informal lending sector, including pawnshops.

In line with government policies, substantial portions of commercial bank and finance company lending are allocated to small-scale enterprise development including manufacturing and vehicle repair. However, since there are few commercial banks located outside the major urban centres their services are not readily accessible to the majority of smallholders. The fact that commercial banks prefer to limit their risks by providing low risk, high value loans makes them less accessible to the small-scale manufacturers.

The specialized industrial finance institutions are mainly geared

to the financing of medium and large-scale industrial enterprises. Apart from the formal channels of credit, Malaysia has a system of pawnshops operated by private businessmen but licensed by individual states. The main advantages of pawnshops to small industrialists are their proximity to the grass-roots level of operation, their informality, particularly in terms of collateral requirements and their speed of transaction; the main drawback lies in the high interest rates.

Two other instititutions provide loans or facilities to farmers and entrepreneurs, the Government Development Agencies and rural credit institutions. The latter are undoubtedly the most important source of funding available to smaller farm units such as those found in the study area. Unfortunately, however, in terms of the manufacture, assembly and repair of transport equipment the rural credit institutions have little or no commercial experience or expertise.

A survey of bicycle manufacturers and vehicle repair shops in the study area was carried out to define the difficulties they faced. Finance was only one of the problems identified by manufacturers and certainly not the most important. The supply of raw materials, spare parts and other inputs, and the fluctuating level of demand were identified as more important constraints to the development of the sector. The survey revealed that the majority of transport equipment and related businesses in this area are small family concerns providing mainly repair services to local inhabitants. Most of the Malay traders in this sector did not seem to be operating on a viable basis, and depended on agricultural activities to supplement their incomes.

Summary

Although income levels are low in the study area, smallholders are prepared to spend a considerable proportion of their income on transportation. Since the long distance transport of agricultural inputs and outputs is well-organized and reasonably available, the greatest demand would seem to be for on-farm and short distance off-farm transport of agricultural inputs and produce, and for personal transport. At present the bicycle and motorcycle are used for both these purposes and are within the financial reach of the majority of households, even in the low-income study area.

Head and shoulder loading remain dominant for on-farm transport. Considering the multi-purpose use of the bicycle and motorcycle, the greatest potential for improvements appears to be in increasing the goods-carrying capacity of these vehicles. The local

adaption or modification of standard designs could prove sufficiently rewarding to guarantee the successful establishment of small-scale workshops and repair facilities in the rural areas. However, a number of constraints would need to be overcome before such developments could take place. Access to credit would need to be facilitated, and supplies (e.g. raw materials) would need to be readily available at reasonable cost. Furthermore, training in small enterprise management skills would be required to teach the entrepreneur the basics of organizing and administering his business. Most important, however, would be to identify which types of modifications/improvements would be most useful and to examine the commercial viability of satisfying this demand at the local level.

CHAPTER 2

Rural Transport in India†

Introduction

The bullock cart is one of the major means of transport in India. It is estimated that there are some 15 million carts of which 12 million are in the rural areas[1].

In 1977, the Indian Ministry of Shipping and Transport sponsored a nationwide socio-economic study of animal cart transport. The objective of the survey was to obtain a better understanding of the role and usage of animal carts in rural areas. Separate surveys were carried out in the northern and southern regions of India. The northern region survey, carried out by the National Council of Applied Economic Research (NCAER), covers rural areas in seven Indian States accounting for nearly 50 per cent of the country's rural population. There are estimated to be over 6 million animal carts in use in the region covered by the survey. Data was gathered in 1977-78 by direct interviews with a stratified sample of 1,150 households and 200 cart manufacturers and repairers.

This case study is based on the findings of that survey, and a supplementary survey of 200 households and 30 cart manufacturers carried out in 1980. Data on employment aspects of rural transportation are drawn from separate studies carried out previously by NCAER.

Background

There is a wide spectrum of transport modes in India, ranging from trains and motorized vehicles through many different types

†The study on which this chapter is based is described in the National Council of Applied Economic Research, *Transport Technology for the Rural Areas: India*, (Geneva, ILO, July 1981; mimeographed World Employment Programme research working paper; restricted). Exchange rate at time of study 9.7 Rupees = US$1.0.

Table 8. Road Access to Villages

Population category	Total number of villages	Number of villages: Connected with all weather road	Connected with fair weather road	Not connected with any road
1,500 and above	69,681	37,729	13,949	18,003
1,000-1,500	54,623	22,985	9,816	21,822
Less than 1,000	451,632	107,925	69,062	274,645
Total	575,936	168,639	92,827	314,470

of animal- and human-powered devices to headloading. Motorized vehicles have only recently begun to play a role in rural transportation. This role is at present a minor one and is unlikely to become more significant in the near future. A major reason for this is the low standard and relatively poor condition of the rural road network. Table 8 details the status of the Indian rural road network in March 1978. In this instance 'connected' was defined as being not more than 1.6 km from the road.

Thus 55 per cent of villages have no road access and a further 16 per cent have only a low-standard, fair-weather road connection. The surveys also showed that approximately 75 per cent of all rural goods transport takes place on unsurfaced roads. Another 12 per cent takes place on roads which are only partly surfaced. There is little doubt that this situation will remain as such for a long time to come, as resources for road improvement and maintenance are limited and are unlikely to increase in real terms.[2]

Another important factor limiting the use of motorized vehicles in rural areas is the nature of the transport needs of the majority of the people. The surveys established that about 90 per cent of rural goods traffic relates to the movement of farm inputs, products and equipment. The transport of foodgrains, sugar cane and food accounts for 65 per cent, commercial crops for 8 per cent, and farm inputs, of which manure is the most important, for 16 per cent. The remaining 11 per cent of rural goods traffic relates to the transport of construction materials such as bricks, mud, tinsheets, etc., and fuels such as firewood and dung cakes. Fodder and manure account for two-thirds of the goods transported within the village boundaries. The major goods moved outside the villages are commercial crops and vegetables. The surveys also showed

Table 9. Transportation of Goods in Rural Areas

	Quantity (million tonnes)	*Tonne-km (million)*	*Average trip distance (km)*
Within village	520	842	1.5
Outside village	124	1,064	8.3
Total	644	1,905	1.9

that transport by the household sector dominates rural goods traffic. The household sector accounts for over 80 per cent of rural goods movements in terms of tonne-km, and approximately 95 per cent of the total quantity of goods moved in rural areas. The remainder is transported by commercial establishments and the rural industrial sector. Table 9 shows the quantities moved and average distance of trips made within and outside the village boundaries. This suggests that for agriculture, transport needs are primarily for the movement of small quantities of goods over relatively short distances. The average distance over which goods are transported is approximately 1.9 km. In terms of weight of goods, about 81 per cent are transported within the village limits.

Requirements for longer distance transport are less frequent, at irregular intervals, and often relate to travel for social purposes. It is not surprising therefore that tractors and buses are the only types of motorized vehicles which have had a significant impact on rural transportation. Tractors are within the financial reach of the wealthier people in rural areas and are utilized for a multitude of purposes, of which transport is only one. Buses provide relatively cheap services which cater for the longer distance transport needs of rural people.

By far the most important mode of rural transport in India is the animal cart. Table 10 shows that, in terms of tonne-km, animal carts account for over 68 per cent of the goods traffic in the rural areas. In terms of tonnes moved, they handle 72 per cent of the goods. The comparatively large share of goods handled by headloading and the importance of this mode of transport for shorter trips is also worth noting. However, headloading is used predominantly within the village, while animal carts account for 65 per cent of goods traffic outside the village as well as 72 per cent within. Because animal carts are slow, motorized modes become the most

Table 10. Transportation of Goods by Mode of Transport

Mode of transport	Average trip distance (km)	Transport output: million tonnes	% share	million tonne/km	% share
Headloading	1.5	113	17.7	170	9.0
Bicycle, tricycle	4.5	4	0.5	10	0.6
Pack animals	1.0	2	0.3	2	0.1
Animal carts	2.6	462	71.8	1,307	68.6
Tractor-trailer	5.4	59	9.3	353	18.5
Truck, light commercial vehicle	18.5	4	0.5	64	3.3
All modes	1.9	644	100.0	1,906	100.0

important means of transport for trip distances above 10 km. Tractor-trailer combinations play a significant role for medium-distance trips and account for 7.5 per cent of transport within villages. Trucks are important for long-distance trips but account for only 0.5 per cent of the total quantity of goods transported.

Ownership patterns

Table 11 shows the distribution of vehicle ownership by income group.

Seventy-four per cent of rural households do not own any vehicle. Ninety per cent of these households have incomes of less than Rs6,000 per annum and only 1.5 per cent belong to income groups above Rs12,000. The major reason given for not acquiring a vehicle is simply lack of finance. However, about 30 per cent of the households indicated that they did not need a vehicle, mainly because their landholdings were very small. A very small proportion of the households, 0.2 per cent, indicated that the lack of roads in their area was the reason for not owning transport.

Animal carts are the dominant type of transport, being owned by 17 per cent of the total number of households and used by approximately 48 per cent. Most of the non-owners borrowed the

Plate 1 *A shoulder pole used by a fish farmer in Indonesia*

Plate 2 *A motor-cycle being used to carry rubber in Malaysia*

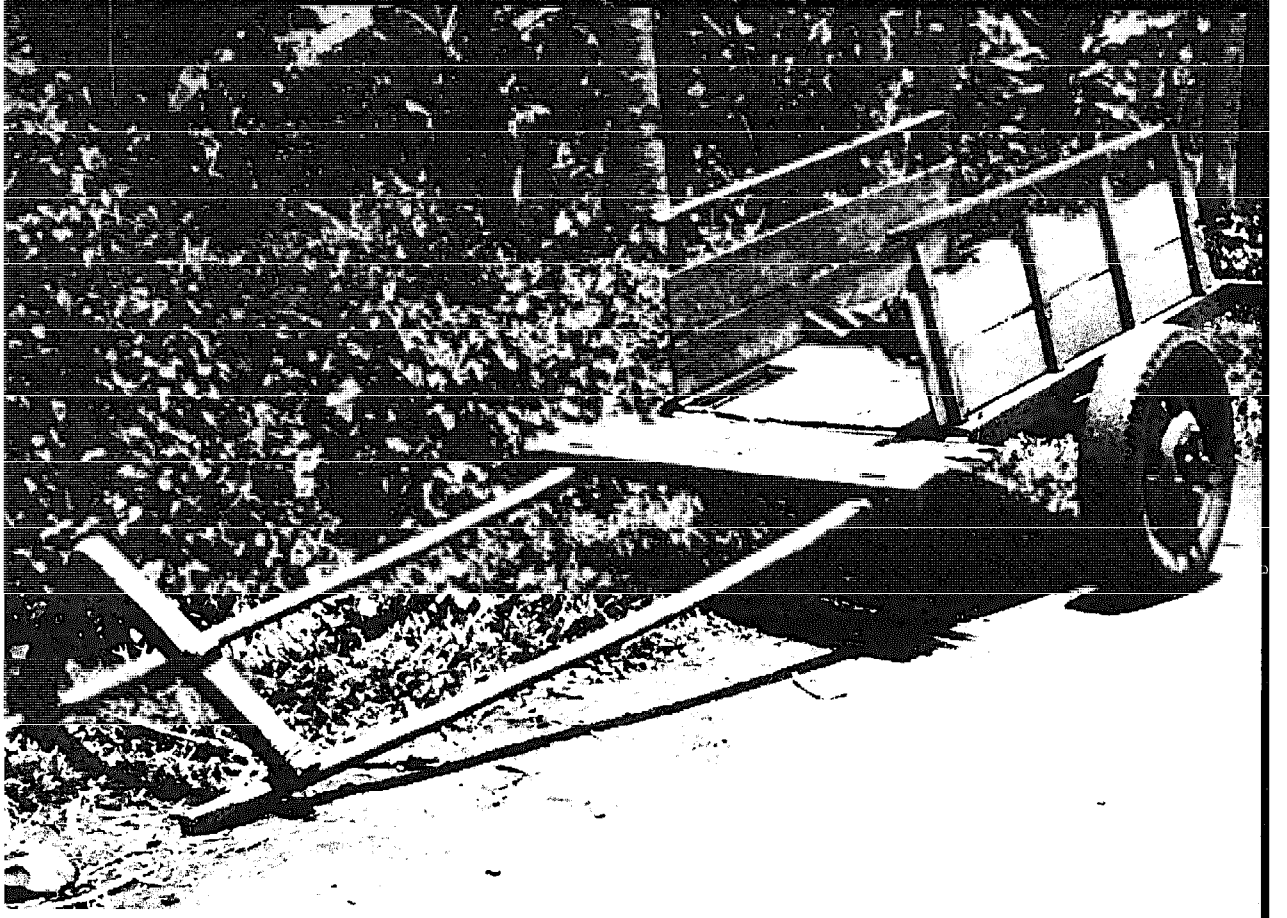

Plate 3 *A modern cart with pneumatic tyres and roller bearings*

Plate 4 *Traditional wooden-wheeled cart drawn by a pair of bullocks*

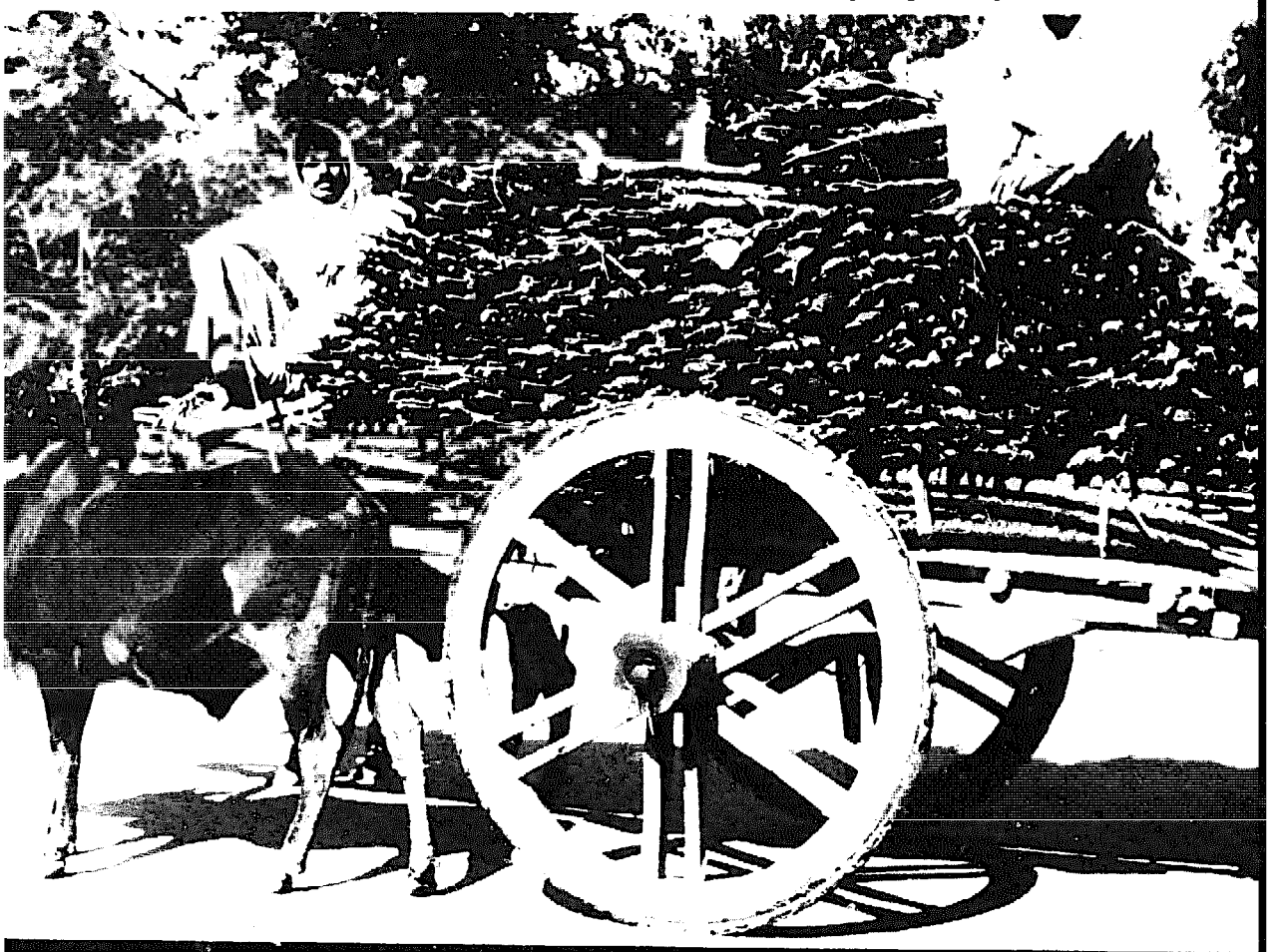

Table 11. Per cent Share of Households Owning Different Vehicles or Using Animal Carts in Different Income Classes

Household income group (Rs.)	*Percentage of households in income group owning*				*Households not owning any vehicles (%)*	*Users of animal carts (%)*
	Animal carts	*Tractors*	*Buses*	*Bicycles*		
Up to 3,000	4.1	—	—	13.1	83.7	39.6
3,001 - 6,000	12.6	—	—	6.9	81.7	41.1
6,001 - 9,000	51.7	4.0	—	8.2	38.0	82.1
9,001 - 12,000	43.7	1.1	6.9	5.4	46.3	65.3
12,001 - 15,000	60.3	5.1	—	1.3	31.5	80.0
Over 15,000	51.4	17.3	—	5.6	31.4	76.7
Total	16.8	0.9	0.4	9.2	74.0	41.6

Note: Aggregate percentages in any income group may exceed 100 as a household may own more than one type of vehicle.

Table 12. Percentage Share of Households Owning Different Vehicles by Operational Holding

Operational holding (hectares)	*Animal carts*	*Tractors*	*Buses*	*Bicycles*	*Not owning any vehicle*
Up to 2.0	3.8	—	—	6.1	91.1
2.1- 5.0	36.0	—	—	16.9	49.0
5.1-10.0	41.6	1.9	0.1	14.3	43.9
Over 10.0	45.0	12.2	6.5	7.6	31.7
Total	16.8	0.9	0.4	9.2	74.0

carts from their friends or relatives without paying any charge. Some 10 per cent of the owners reported charging for hiring out carts. Tractors were not owned by households having an income below Rs6,000 per year and the proportion of tractor-owning households increased sharply at higher income levels.

Ownership of vehicles, with the exception of bicycles, is closely related to the size of landholding—as Table 12 shows.

Characteristics of animal cart use

Given the features of rural transportation in India, the popularity of animal carts is understandable. They can be used on sealed roads, rough tracks and cropland where a significant proportion of movement takes place during the harvest period. Animal power is abundant and cheaply available. The carts are produced and maintained with locally available skills and materials, and can carry a variety of loads ranging from manure to construction materials. Their average speed of 3-5 km per hour is adequate for the uses to which they are put and the distances travelled.

Table 13 shows the percentage distribution of numbers of trips and quantities transported categorized by trip distance. On average, animal carts make 265 trips per year with an average one-way trip distance of 2.58 km. About one trip in six is ouside the village. Eighty per cent of trips within the village are less than 2 km while over 60 per cent of trips outside the village are more than 5 km.

In general, the capacity of carts is under-utilized. On most trips the carts travel empty in one direction and the loads carried vary from a few kilograms to 2 tonnes. The carts are filled to capacity on about 19 per cent of trips and are less than half full on 46 per

cent of trips. However, capacity utilization increases for trips outside the village when carts are fully loaded on 37 per cent of trips and less than half full on only 28 per cent.

Table 14 shows the intensity of cart use according to owners' income level. On average, carts are utilized for a total of 106 days per year, 73 days by the owner and 33 days on hire. Cart usage by the owner increases with income level. However, overall usage is highest at the extremes of income since the poorest owners hire or loan their carts for a substantial proportion of the time.

Animal carts provided an estimated total employment of 458.1 million man-days in Northern India in 1977-78. Ninety-three per cent of it emanated in the rural sector. Cart operation accounted for 90 per cent of the employment, the remainder being in manufacturing and repair. For India, as a whole, the employment due to animal carts is estimated to be in the region of 990 million work-days, and the rural component about 925 million work-days.

Types of animal carts

In Northern India, 78.0 per cent of animal carts are drawn by a pair of bullocks. The remainder are drawn by buffaloes (17.8 per cent), camels (3.8 per cent) and horses/ponies (0.6 per cent). Two different types of cart are widely used, the traditional variety with

Table 13. Percentage Share of Load Trips and Quantities Transported by Trip Distance

Trip distance (km)	*Loaded cart trips*			*Quantity transported*		
	Within village	*Outside village*	*Total*	*Within village*	*Outside village*	*Total*
Up to 0.5	10.0	0.3	8.6	10.2	0.2	8.1
0.6-1.0	41.3	2.6	35.4	41.7	2.4	33.5
1.1-2.0	34.5	5.6	30.2	34.0	7.4	28.5
2.1-3.0	9.5	11.4	9.8	9.4	8.8	9.3
3.1-5.0	3.1	17.8	5.3	2.8	22.9	7.0
5.1-7.5	1.2	18.5	3.8	1.1	24.6	6.0
7.6-10.0	0.2	22.5	3.6	0.4	18.0	4.0
10.1-15.0	0.1	11.8	1.8	0.1	9.1	2.0
15.1-20.0	neg.	5.9	0.9	neg.	3.2	0.7
Over 20.0	0.1	3.6	0.6	0.3	3.4	0.9
Total	100.0	100.0	100.0	100.0	100.0	100.0

large diameter wooden wheels and improved versions with pneumatic tyres and roller bearings (plates 3 and 4). About 24 per cent of the total number of carts are of the improved type.

The traditional carts have certain design deficiencies which result in strain and injury to draught animals, waste draught power and thus reduce carrying capacity, and cause damage to roads. The traditional yoke is inefficient and can cause injury to the animals, the carts are very heavy, the rough bush bearings have high frictional resistance and the narrow, often steel-rimmed wheels cut into road surfaces. The use of pneumatic tyres and roller bearings overcomes some of these disadvantages, allowing greater loads to be carried, eliminating road damage and providing greater comfort for passengers. However, the cost of the traditional cart is lower and, because of its wide availability, it is easy to acquire cheaply second-hand. A disadvantage of pneumatic tyres is that they are prone to punctures and repair and vulcanizing services are not readily available along rural roads.

There are a certain number of marked differences in the utilization of the two types of carts. Improved carts are more intensively used on surfaced roads where they carry 63 per cent of the goods transported. On lower standard roads the traditional carts are more common.

There are estimated to be over 80 million work animals, mostly bullocks, in India, of which about 25 million are used to pull carts. Animal power is cheap, and easy to obtain. As the data show, many animals are not used to haul carts and are therefore idle

Table 14. Intensity of Cart Use by Owners by Income Level

Income class (Rs. per annum)	*Number of days a cart used*		
	Self use	*Hired use*	*Total*
Up to 3,000	48	108	156
3,001 - 6,000	56	39	95
6,001 - 9,000	70	25	95
9,001 - 12,000	92	20	112
12,001 - 15,000	100	6	106
Over 15,000	129	3	132
Average	73	33	106

Table 15. Annual Cart Costs (in Rupees)

	Improved cart	*Traditional cart*
Cost of cart	2,000	1,000
Annual maintenance cost[1]	121	56
Interest on capital (10%)	200	100
Depreciation[2]	125	66
Total annual cost	446	222

[1] Based on survey data.
[2] Based on cart-life of 16 years reported in survey.

when not used for agricultural purposes. Generally, when animals are used to pull carts it is in addition to their usage in agriculture. It is therefore reasonable to assume that their utilization for transportation is at marginal or zero cost. Table 15 details the annual costs for owning and operating animal carts assuming that the owner already has work animals for agricultural purposes which can be used for transportation at zero cost.

An average cart transports 72 tonnes of goods per year. Transport charges for animal carts vary between Rs2.5-3.0 per 100 kg for a fixed distance between the village and the nearest commercial centre. This gives imputed earnings of Rs1,800-2,160. This indi-

Table 16. Percent Share of Households Owning Carts of Different Values by Income Level

	Value of carts (Rs.)				
Income class (Rs)	*Up to 750*	*751 to 1,250*	*1,251 to 1,750*	*Over 1,750*	*All carts*
Up to 3,000	60.1	32.0	6.4	1.5	100.0
3,001 - 6,000	45.5	36.5	12.2	5.7	100.0
6,001 - 9,000	60.5	15.9	15.1	8.4	100.0
9,001 - 12,000	56.9	20.5	12.7	9.9	100.0
12,001 - 15,000	51.5	15.9	18.6	14.0	100.0
Over 15,000	32.0	14.5	29.4	24.1	100.0
Total	53.1	24.3	14.1	8.5	100.0

cates that cart operation is economical given that annual costs range between Rs.222-446 depending on type of cart. However, the economics to the individual owner depend on the utilization of the cart, his ability to make the initial investment, the number of days the cart is hired out and on what basis, and the realistic value that should be assumed for his time when operating the cart for his own purposes.

Table 16 shows that the cheapest carts are most in demand and indicates a positive relationship between the income of the households and the value of the carts owned by them.

Finance for the manufacture and purchase of carts

The Government of India actively supports the development of small-scale rural and cottage industrial units. Such units generate employment, have low capital-intensity and are an effective mechanism for mobilizing resources and skills. It is the Government's policy to reserve the manufacture of over 800 different items, including animal carts to the small-scale sector. Small-scale industry development programmes are carried out by the State Governments. The services provided under such programmes include infrastructural works, technical guidance, training facilities and financial assistance.

The major part of these services is provided directly to small-scale entrepreneurs, of which cart manufacturing and repair units represent a considerable proportion. However, some agencies also provide credit facilities to farmers and agricultural labourers for the purchase of animal carts. Such financial support to the customers of the cart manufacturers greatly facilitates the sales of their products. Under the rules of these agencies the purchase price of the animal carts is remitted directly to the dealer or manufacturer on behalf of the borrower. Certain development programmes provide 25-50 per cent subsidies to small farmers and agricultural labourers for the purchase of animal carts.

There are five major sources of finance for small industrial units: state financial corporations, commercial banks, co-operative banks and societies, District Industries Centres and the 'Khadi and Village Industries Commission'. These institutions provide loans for the purchase of land, buildings, plant and machinery at favourable rates of interest. The amounts advanced and the period of repayment generally depend on the type of manufacturing activity. Various schemes provide for advantageous rates of interest to the educated unemployed and potential entrepreneurs with technical qualifications. Enterprises set up in backward districts usually qualify for lower than normal rates of interest. The Lead Bank

Scheme, which operates in all districts of the country, is of interest. In each district a designated bank, the 'Lead Bank' is given special responsibility for overall economic development. It prepares the credit plan for the district and, with the co-operation of other banks, financial institutions and government agencies, provides loans to different categories of borrowers. In many districts, the lead banks have provided finance to carpentry units (who often include cart manufacture among their activities) and to prospective buyers of pneumatic-tyred animal-drawn carts.

The co-operative banks provide one-year loans to artisans for working capital through primary co-operative societies. The loans are usually granted on the basis of promissory notes and securities from the members. For larger amounts these securities are supplemented by using goods as collateral. The loan applications are scrutinized and approved by a committee of government bank and primary society representatives.

In some states, the co-operative banks provide loans for the purchase of carts and animals. The terms vary from place to place. In one state, the borrower has to create a statutory charge on his land in favour of the primary society if he wants a loan for more than Rs1,000. In others the hypothecation of the cart itself in favour of the primary society is sufficient provided the borrower takes out an insurance policy for the cost of the cart, meets at least 15 per cent of the loan from his own resources, and purchases share capital of the co-operative to the equivalent of 10 per cent of the outstanding loan. The purchase price of the cart is remitted directly to the cart dealer or manufacturer.

During the household survey, 38 banks located near the study areas were interviewed about their policies towards the credit needs of cart manufacturers. Most of the banks provide loans to a maximum credit limit of Rs5,000 on the basis of personal securities. Only a small percentage of the banks resort to the hypothecation of the equipment concerned or to mortgaging fixed assets. The interest rates charged vary generally between 9 and 12 per cent, although cheaper rates (as low as 4 per cent) are available under special schemes.

During the surveys 251 cart manufacturing and repairing units were interviewed. Information was requested on the amount of capital invested, production, labour employed and the problems faced by the units. Over 80 per cent of these units had invested less than Rs5,000 in their business. The investments of the cart repairing units are comparatively smaller, the great majority being less than Rs2,000. Of the 251 units only 17 per cent had borrowed money during the year preceding the survey. Eight of these had

borrowed from moneylenders, even though they charge interest rates ranging between 10 and 60 per cent. The second important source of loans is from banks, but the amounts borrowed are higher (averaging Rs3,720), compared with Rs1,710 from money lenders. Friends and colleagues are another source of capital, providing some 13 per cent of the total loan amount at interest rates ranging between 15 and 24 per cent.

Analysis of the problems faced by cart manufacturers and repairers showed financial difficulties, especially in relation to obtaining loans, to be the major problem. Second in importance is a lack of demand for animal carts. Further problems are the high prices and often the non-availability of raw materials and components. Apparently the relative abundance of credit schemes offering funds at reasonable rates does not result in credit being easily accessible to animal-cart manufacturing or repairing units.

The major obstacle in participating in government-backed credit schemes appears to be the lengthy and bureaucratic approach of the financial institutions responsible. In some cases, the procedures take up to a year to complete. The potential borrowers often have to obtain a large number of certificates from different agencies, especially when they do not have enough land, property or other personal securities to offer as collateral for their loans.

Various units complained about the indifferent attitude, and sometimes corruption, of officials dealing with loan requests. Some potential borrowers are harrassed instead of aided in securing their loans. These problems would appear to be due in large part to the fact that such officials are not well-motivated because they do not stand to gain anything personally. This results in well-intended government policies being effectively thwarted by defective implementation.

These factors force may enterprises, especially the smaller ones, to forgo the loan altogether or to turn to private sources, which means paying higher charges. Furthermore, a large number of self-employed persons or small enterprises are unable to obtain financial assistance as they are not in a position to provide the required down-payments or third party guarantees. Even in those cases when the entrepreneur qualifies for a loan, the time-consuming procedures often cause long delays which could defeat the objective for which the loan was originally required.

Summary

The animal cart is the major means of goods transportation in rural India and, given the limited extent and slow growth of the

surfaced road network, is likely to remain important for a long time to come. However, the survey shows that household income is the main determinant of animal cart ownership. Seventy-four per cent of rural households do not own any type of vehicle, in most cases because they cannot afford one.

As part of the survey the concept of communal use of carts was presented as a means of extending access to those who cannot afford individual ownership. However, the reaction to this idea was generally indifference or scepticism. There is considerable potential for increasing the efficiency of animal carts since the traditional types have certain technical deficiencies. However, the link between income and cart ownership suggests that design improvements which increase cost would not be acceptable to the majority of the rural population. Given the low level of ownership of carts the survey suggests that greater emphasis should be placed on providing some form of transport to the majority rather than improving the existing modes.

There is no lack of schemes to provide finance at economical rates of interest for the manufacture and purchase of carts. However, the cumbersome and lengthy procedures and the requirements for securing loans make them inaccessible to many artisans and potential cart purchasers.

CHAPTER 3

Rural Transport in Northern Nigeria†

Introduction

Over the past decade and a half Nigeria has embarked on a wide range of major infrastructure investments with the aid of its oil revenues. Between 1972 and 1980 the length of paved road in the country increased by 60 per cent. At 13 km per 100 sq km, it has one of the highest road densities in Africa.

The study on which this chapter is based examined the transport demands of the rural population in one area of Northern Nigeria and the way in which these demands were met. It also attempted to evaluate the likely response of farmers to improvements in transport.

The study was in the form of a questionnaire to a sample of households in four groups during two separate periods of the year. It was carried out in 1981 by Dr. O. Adebisi of the University of Zaria.

Background

The area selected for the study was Borno State in the north-east of the country (Figure 3). It is among the least industrially developed parts of Nigeria, but is in the savannah region which extends over more than half the country and provides good agricultural conditions. Farming practices and general living conditions are similar throughout the Savannah vegetation belt. The study was focussed on the town of Potiskum (estimated population 80,000) and covered an area within a radius of 60 km from this centre.

The bulk of Nigeria's agricultural products come from rural areas, but there are now some semi-urban dwellers who engage in

†The study on which this chapter is based is described in O. Adebisi: *Transport Technology for the Rural Areas: Nigeria*, World Employment Programme; (Geneva, ILO, 1982); (mimeographed World Employment Programme, research Working Paper; restricted). Exchange rate at the time of the study ₦ 0.69 (Naira) = US$1.0.

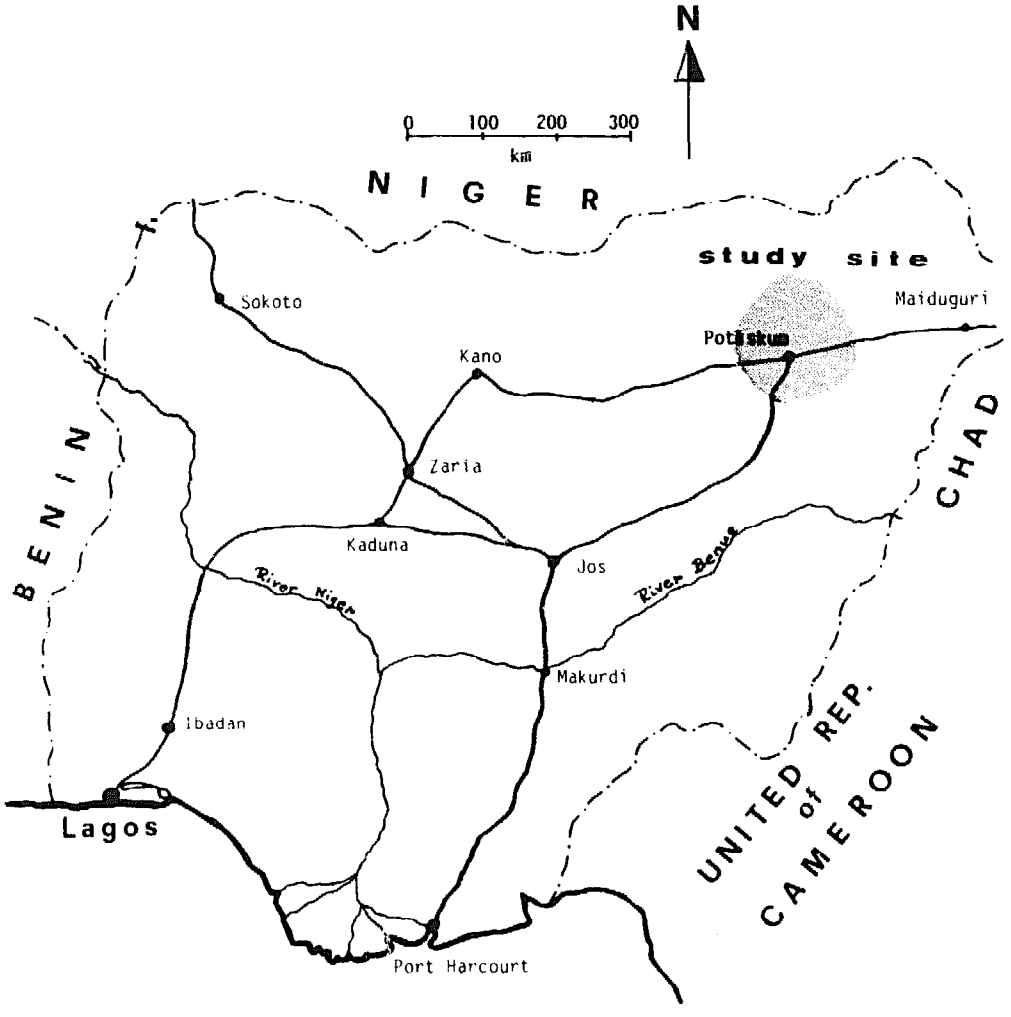

Fig. 3 *Map of Nigergia showing the study site*

farming. For the purposes of the study four types of farming household were defined on the basis of the size and accessibility of the settlements. Settlements were categorized as towns (population greater than 1,000), and villages (population less than 1,000). Accessibility was categorized as good—lying on an all-weather road—and poor—either linked by an unpaved road or not lying on an all-weather road. Settlements were selected for survey so that each of the four categories were approximately equally represented. In each settlement sample households were interviewed, the selection being made with the assistance of field agricultural officers to provide a representative cross-section of socio-economic characteristics. Two interview surveys were made, each with a sample size of 600, the two samples being selected independently. The first survey was carried out in July 1981 during the planting season, the second in October 1981 at the peak of harvest-

ing. This approach reduced the number of questions asked of each household and hence enhanced the prospects of co-operation. Secondly, because questions asked at each stage were directly relevant to the prevailing transportation problems the data derived are likely to be more reliable than those depending upon recall.

Travel patterns of rural farmers

The following five categories of trip were found to be of direct relevance to the study:

1 trips to acquire farm inputs, including fertilizers, seedlings and farming implements;
2 trips to the farm;

Table 17. Travel Demand Characteristics of Farmers Resident in Villages not Lying on an All-weather Road

	Average number of annual person-trips/household				
Travel time (mins)	*Trips for acquiring inputs*	*Trips to farms*	*Trips for domestic needs*	*Trips to markets*	*Recreational trips*
0-5	15	31	22	17	—
5-10	9	418	116	41	1
10-15	8	500	41	17	—
15-20	10	365	13	39	2
20-25	15	—	30	20	1
25-30	5	608	77	28	3
30-60	8	365	18	44	3
60-120	—	—	—	—	3
120-180	—	—	—	—	2
Over 180	—	—	—	—	5
Total	70	2,787	317	206	20
Average travel time (mins)	18	18	17	21	80

3 trips to meet domestic needs — including those made to obtain firewood and construction materials;
4 trips to market to sell crops and to purchase food items;
5 recreational/social trips — including those made in order to participate in customary festivals and marriage celebrations.

In the study area the year consists of four main seasons:

1 the planting season (mid-June to end July);
2 the farming season (July to October);
3 the harvesting season (October to end of November);
4 the dry (off) season (December to June).

Trips to acquire farm inputs tend to be concentrated around the planting season. Trips to the farm are undertaken throughout the year but are more frequent during the farming and harvesting seasons. Domestic trips, except those to meet routine requirements, are concentrated during the off-season. Trips to the market to pur-

Table 18. Travel Demand Characteristics of Farmers Resident in Villages Lying on an All-weather Road

	Average number of annual person-trips/household				
Travel time (mins)	*Trips for acquiring inputs*	*Trips to farms*	*Trips for domestic needs*	*Trips to markets*	*Recreational trips*
0-5	1	898	72	—	—
5-10	2	939	55	20	1
10-15	2	565	172	26	—
15-20	1	423	189	1	—
20-25	1	—	13	2	—
25-30	2	—	1	30	2
30-60	5	—	—	4	7
Over 60	—	—	—	—	—
Total	14	2,825	502	83	10
Average travel time (mins)	25	8	13	19	41

chase food items are made mostly during the farming season while those to sell crops are during the harvesting and off-seasons. Recreational/social trips are normally made during the off-season.

Tables 17-20 give detailed breakdowns, for the four categories of farming households studied, of numbers of trips and travel times for different purposes. Table 21 summarizes the findings.

The average size of the households surveyed was about eight people which implies an average of 1.3 trips per person per day. In interpreting these findings it is important to note that some trips are undertaken for more than one purpose, e.g. a visit to the farm may be used as an opportunity to collect firewood.[1] Thus the breakdown of trip purposes is not precise. However, the results do show that, regardless of the accessibility and population of farmers' settlement, by far the most frequent trips are those to the

Table 19. Travel Demand Characteristics of Farmers Resident in Towns not Lying on an All-weather Road

	Average number of annual person-trips/household				
Travel time (mins)	*Trips for acquiring inputs*	*Trips to farms*	*Trips for domestic needs*	*Trips to markets*	*Recreational trips*
0-5	—	365	1	19	—
5-10	3	521	98	29	2
10-15	1	521	28	16	1
15-20	—	876	16	12	—
20-25	2	1,460	52	—	—
25-30	1	657	1	24	—
30-60	3	624	27	16	2
60-120	2	1,095	101	10	1
120-180	1	—	1	2	1
Over 180	—	—	—	—	1
Total	13	6,119	365	128	8
Average travel time (mins)	44	33	39	25	71

farm. Trips for domestic purposes and to markets come a distant second and third respectively. In terms of frequency, trips to acquire farming inputs are almost insignificant. However, the trips that do take place for this purpose are very important because these inputs constitute invaluable aids to successful farming.

Vehicle ownership patterns

Data on vehicle ownership were obtained from the survey households for the four types of vehicle encountered in the study area:

1 animals — mostly donkeys;
2 bicycles;
3 motorcycles;
4 motor vehicles — including passenger cars, pick-ups and minibuses.

Table 20. Travel Demand Characteristics of Farmers Resident in Towns Lying on an All-weather Road

	Average number of annual person-trips/household				
Travel time (mins)	*Trips for acquiring inputs*	*Trips to farms*	*Trips for domestic needs*	*Trips to markets*	*Recreational trips*
0- 5	6	—	5	39	—
5- 10	7	49	1	78	—
10. 15	7	106	104	63	24
15- 20	—	52	78	1	—
20- 25	—	140	—	—	—
25- 30	—	165	95	—	—
30- 60	—	160	159	—	—
60-120	—	185	146	—	2
120-180	—	161	94	—	1
Total	20	1,018	682	181	27
Average travel time (mins)	8	57	39	8	25

Table 21. Summary of Travel Demand Characteristics

	Farmers resident in			
	Villages remote from all-weather road	*Villages on all-weather road*	*Towns remote from all-weather road*	*Towns on all-weather road*
Average annual number of person-trips per household	3,411	3,433	6,632	1,926
Trips for different purposes as % of total trips				
— Inputs	2.1	0.4	0.2	1.1
— Farm	81.7	82.3	92.2	52.8
— Domestic	9.4	14.6	5.5	35.3
— Market	6.2	2.4	1.9	9.4
— Recreation	0.6	0.3	0.1	1.4

Data on vehicle ownership patterns are presented in Figure 4. There are on average:

1.0 donkey per household
0.9 bicycles per household
0.3 motorcycles per household
0.25 motor vehicles per household

However:

68.1 per cent of households have no animals
31.9 per cent of households have no bicycles
72.8 per cent of households have no motorcycles
84.5 per cent of households have no motor vehicles

Thus, although there are slightly more donkeys than bicycles, the latter is the most widely accessible vehicle with nearly 70 per cent of households owning at least one bicycle. Although donkeys occasionally serve individual households' needs for goods haulage they are, for the most part, hired out on a commercial basis. All households owning animals also own some other form of transport.

A good motorcycle costs about 8 times as much as a new bicycle, and a car in fairly good condition about 50 times as much. The relationship between vehicle ownership and household income has to be analyzed with care since some households own more than one vehicle type and/or operate vehicles commercially. Examin-

back view

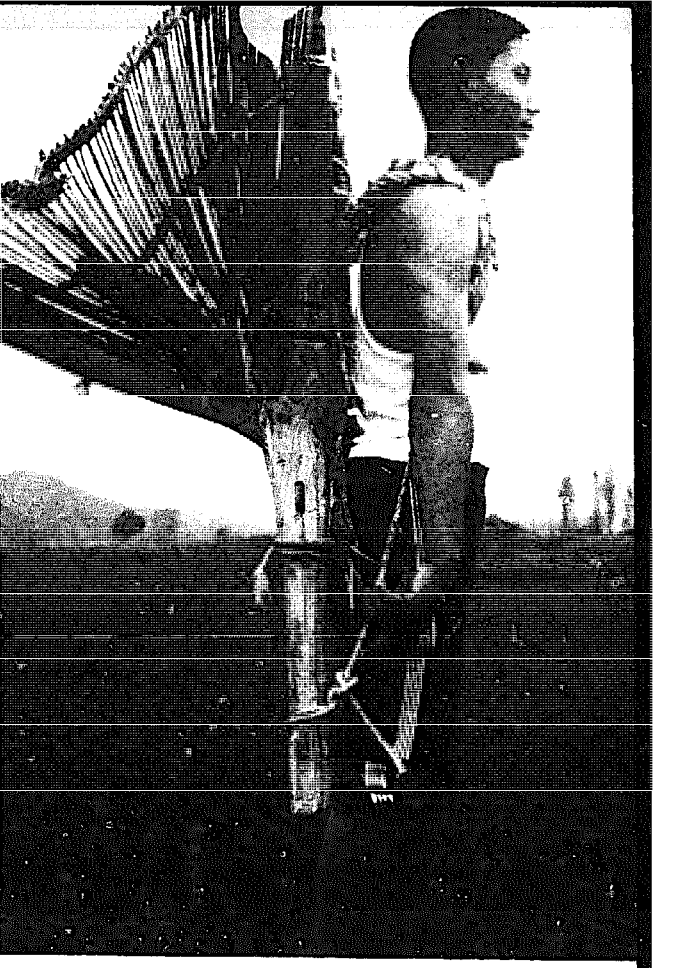

side view

Plate 5 *Traditional Chee-geh*

Plate 6 *The Li-uh-Ka*

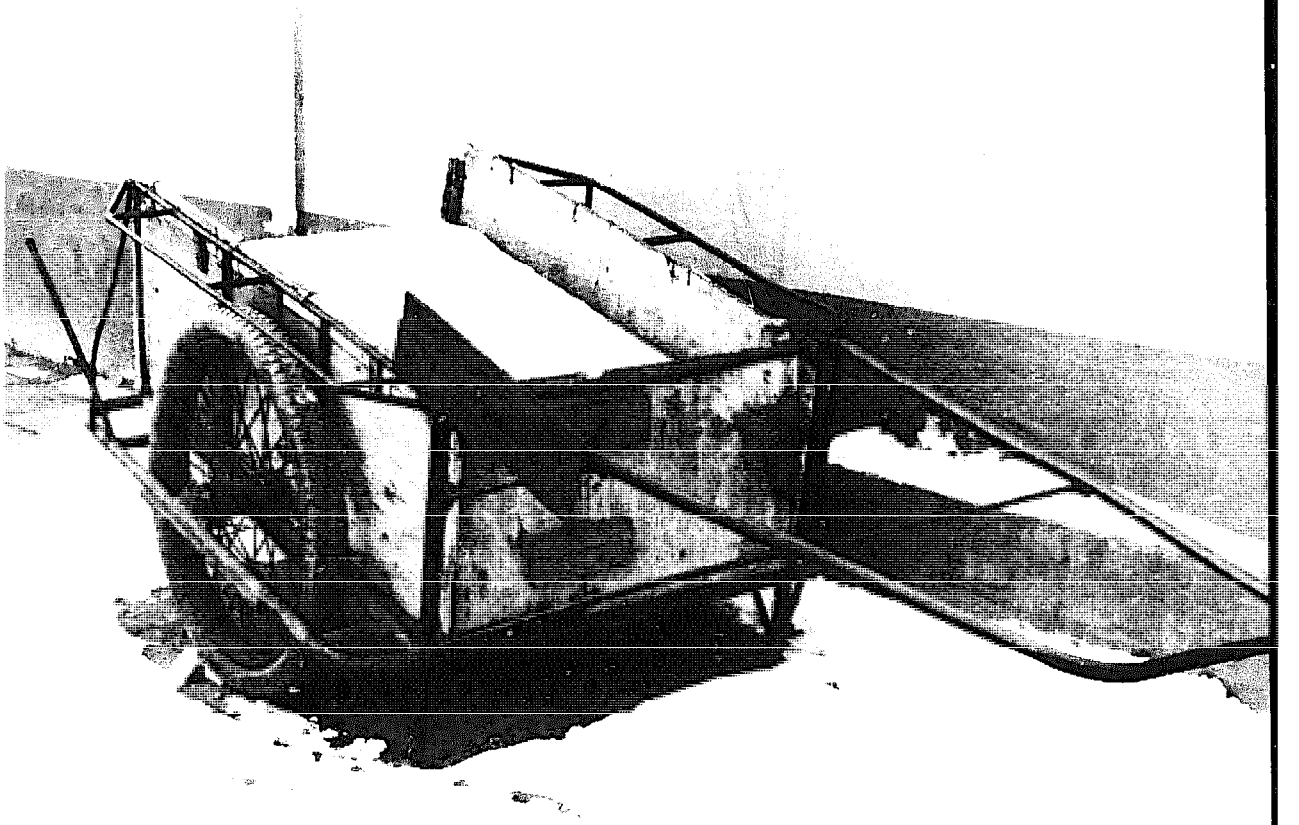

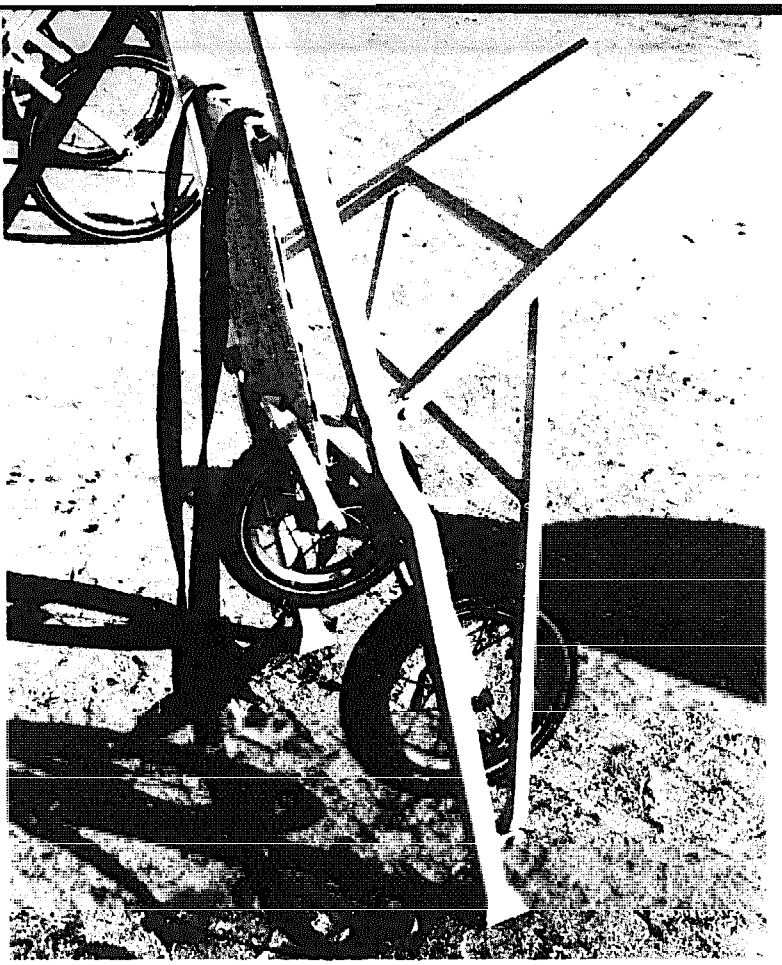

Plate 7 *The improved Chee-geh*

Plate 8 *A recently completed Jeepney awaiting delivery*

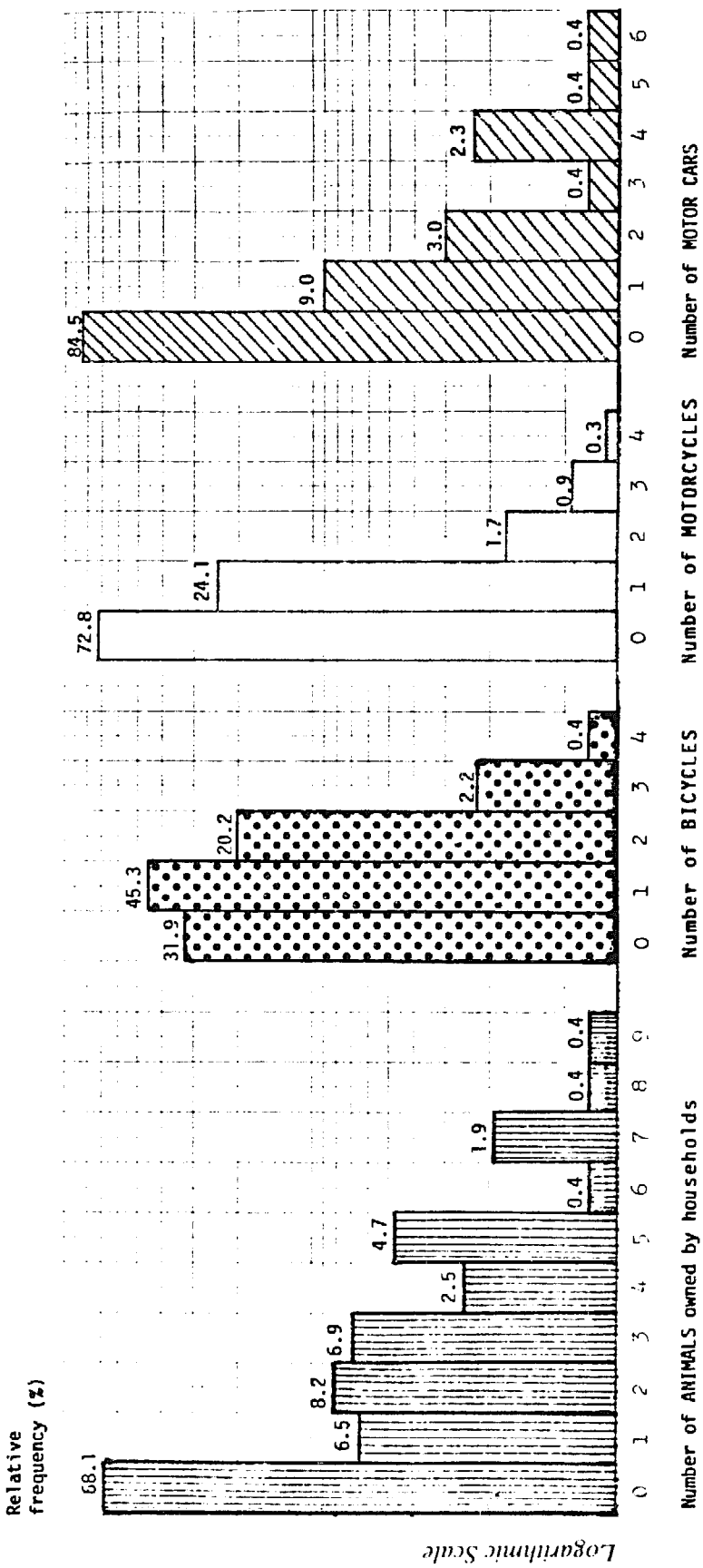

Fig. 4 *Frequency Distribution of Number of Animals, Bicycles, Motorcycles and Motor Cars owned by Households*

ation of the characteristics of households owning only bicycles shows that ownership of this vehicle is strongly influenced by income level. Households owning no vehicle at all have an average annual income of ₦1,335. Households owning one bicycle have an average annual income of ₦2,480, and those owning two bicycles ₦4,550. Households owning more than two bicycles also own at least one other type of vehicle. Another factor which affects vehicle ownership, certainly at the motorized level, relates to the social structure of Nigerian society. The wealth of a rich person is enjoyed, through the extended family system, by less fortunate relations who may not belong to the household. Although the data indicate that most farming households cannot afford to own motor vehicles, some of those owning one motor car have relatively low average incomes. This would be explained by well-to-do relations subsidizing the purchase and maintenance of the vehicle.

No evidence was obtained from the interviews of farmers obtaining loans from the commercial banks. This is hardly surprising since commercial banks have only recently begun to establish branches in rural areas. Furthermore the loan conditions imposed by these banks — good credit rating and property to serve as collateral — are likely to constitute insurmountable obstacles to poor rural households.

The main form of finance available to farming households is soft loans granted through special co-operative banks established by the Federal Government. These banks operate what is in essence a revolving loan scheme and grant loans to registered Co-operative Societies for distribution among their members. The amount of loan granted each year depends on available funds. Societies obtain the loan at the beginning of the planting season and are expected to pay back at the end of the harvesting season. Several Co-operative Societies arrange to sell members' crops collectively and repay the loans before returning the balance from the sales to their members.

The loan scheme is deficient in two ways as a means of financing the purchase of vehicles. The amount given to a farmer is often very small, and inadequate to purchase any vehicle. Second, even if adequate funds are available, the period of repayment is too short for poor farmers to contemplate borrowing an amount sufficient to buy a bicycle, which for them would be a major purchase.

The bicycle industry in Nigeria

Given the importance of the bicycle in rural transport in Nigeria, it is useful to examine the characteristics of the local manufacturing industry.

There are two bicycle manufacturers in Nigeria with a combined capacity of 500,000 units. As Table 22 shows, sales of bicycles declined steadily each year from 1977 to 1980, but rose substantially, though not to former levels, in 1981. More important, the share of the market taken by locally manufactured bicycles declined throughout the period so that by 1981 the industry was operating at only about 40 per cent of capacity. The major reason for this decline was the stiff competition from Indian imports. The import tariff on bicycles is 10 per cent of the total landed cost. At this rate Indian imports are cheaper than the locally manufactured products, though it is alleged that they have been subsidized by up to 50 per cent by the Indian Government. This illustrates the conflict between protecting and encouraging local industry on the one hand and the benefit to the consumer of making bicycles available at the lowest price.

The two bicycle manufacturers are located in major cities and employ about 1,000 people. Some rural households (estimated at less than 5 per cent) provide bicycle repair and maintenance services to supplement their income from farming. The average annual income from these services is ₦250-300.

Transportation and agriculture

Donkeys are used primarily for goods haulage and, as noted earlier, can be hired on a commercial basis. Their speed of travel is slow but they are hardy, resistant animals. However, keeping an animal purely for transportation needs does not, at the moment, make much economic sense. During the dry (off) season when the animal is little used for transport the owners are faced with the difficult task of fetching fodder for their animal The use of animals

Table 22. Details on Sales and Sources of Bicycles Sold in Nigeria

Year	*Total Sales*	*Local manufacture*	*Imports*			
			India	*China*	*Japan*	*Others*
1977	587,000	420,127	74,122	52,335	21,988	18,378
1978	488,000	343,188	77,621	25,697	14,000	27,494
1979	413,000	253,381	94,619	30,000	10,000	25,000
1980	315,000	185,000	57,000	35,000	19,000	19,000
1981	444,000	208,000	156,000	40,000	20,000	20,000

would be more economically attractive if they could also be used for agricultural purposes such as weeding and harvesting.

The bicycle has certain limitations in meeting the transport needs of farming households. Because the rider has to balance the vehicle it is not suitable for use by the elderly or very young, and it cannot be used to carry very heavy loads. However, the bicycle is relatively cheap, and hence widely available.

For trips to acquire farm inputs, all the farmers interviewed except those who own a motor vehicle use some form of public transport. They walk from their residence to the nearest point where they can board a public transport vehicle. Thus such trips involve out-of-pocket expenses for the farmer.

An overall assessment was made of the probable effect of transportation factors on the farmers' productivity. The interviewees were asked to rank, in order of importance, four key factors which had earlier been found [2] to have the most effect on farm productivity:

— *Ability to weed*: since most farmers in the country use hoes and knives to remove weeds the size of a household's total farm holdings is quite often based on its estimated weeding capabilities;
— *Transportation*: of seed to the farm and of the harvest to market;
— *Availability of sufficient land*: because of the complex land tenure system in the country, a household's total farm holdings may be limited by the type and size of land which is available to it;
— *Subsistence farming*: several households merely cultivate enough land to supply their food requirements, particularly if they have other sources of income. The farming output of such households would thus be based on their home consumption needs.

By applying scores to the rankings (i.e. one when ranked first, two when ranked second, etc.), multiplying these by the frequency of ranking, and aggregating the totals, total scores for each factor were obtained (Table 23).

With this method the factor with the lowest total score is the most important. However, the difference in total scores between factors does not indicate the degree of relative importance.

The table shows that transportation is less of a constraint than ability to weed and availability of land. The transport problems faced by farmers vary from one season to another. During the planting season, the main problem faced by farmers who do not

Table 23. Households' Ranking of the Production Factors

Factors		*RANK* 1	2	3	4	*Total score*	*Rank*
Ability to weed	Frequency	73	82	11	7		
	Aggregate score	73	164	33	28	298	1
Transportation	Frequency	8	32	121	12		
	Aggregate score	8	64	363	48	483	3
Availability of sufficient land	Frequency	84	46	30	13		
	Aggregate score	84	92	90	52	318	2
Subsistence Farming	Frequency	6	14	12	141		
	Aggregate score	6	28	36	564	634	4

own motor vehicles is the access time to, and cost of, public transport for trips to obtain inputs. During the farming and harvesting seasons, the trips made are primarily to and from the farm, and indeed these constitute the large majority of all movements by farming households. There are some indications that transport of farm products is not a particular problem for farmers. This appears to be because crops are commonly stored on the farm and transported in smaller quantities as and when required.

Given the view, well supported by interviewees, that existing available vehicles are not suitable to their needs, the surveyed farmers were asked to rank four vehicle attributes in order of importance:

— *Speed*: explained as the ability of the vehicle to convey the user to the destination within a reasonable time.

Table 24. Farmers' Rankings of their Preferences on Vehicles' Attributes

Factors		*RANK* 1	2	3	4	*Total score*	*Overall Rank*
Speed	Frequency	196	54	56	19		
	Aggregate score	196	108	168	76	548	1
Load carrying capacity	Frequency	56	228	29	12		
	Aggregate score	56	456	87	48	647	2
Reliability	Frequency	21	8	226	70		
	Aggregate score	21	16	678	280	995	3
Cost	Frequency	51	37	13	224		
	Aggregate score	51	74	39	896	1,060	4

— *Load carrying capacity*: explained as the capability of the vehicle to carry the user and all his loads;
— *Reliability*: explained as the ready availability of the vehicle at whatever time required;
— *Cost*: explained as the vehicle's capability to render required services with reasonably low total (i.e. both initial and operating) costs.

The results, using the rank scoring method described earlier, are presented in Table 24.

It is apparent that the farmers consider a vehicle's speed and load carrying capacity as its most useful attributes while reliability and cheapness are less important. This implies that the farmers would be willing to pay adequately for good service rather than owning their own vehicle. However, it is important to note that the data was obtained during the first questionnaire and therefore

reflects the farmers' perceptions of effective solutions to their transportation problems during the planting season.

Summary

Economic realities preclude, for the foreseeable future, both the linking of every village and town by motorable road, and the widespread ownership of motor vehicles. However, there is potential for improving transport for farming households. For example, a government service to deliver farm inputs to the village for sale to the farmers would lessen the problems faced during the planting season. This would be an extension of the Government's present role in subsidizing fertilizers and improved seedlings.

The main problem for rural households would appear to be a general lack of individual access to the transport system. Many households do not own any form of transport. The bicycle, although it has certain limitations, is cheap, and simple to operate and maintain, and contributes to meeting the farmers' transport requirements. The provision of loans on terms that would enable poorer households to purchase bicycles would increase the availability of this form of transport. Finally, animals, particularly donkeys, could play a greater role in rural transport but are only likely to be more widely used when a greater proportion of households own them. This is only likely to occur if their use can be extended to weeding and harvesting.

CHAPTER 4

Transport in Two Kenyan Villages†

Introduction

The Kirinyaga District of Kenya is a densely populated, highly fertile agricultural area. Over the last 10 years this District, like many of the other heavily populated Districts of Kenya, has benefitted from the Government's attempts to provide improved access, in particular through the Rural Access Roads Programme.

The study on which this chapter is based was an attempt to compare the effect of contrasting levels of access on two villages in proximity to each other. The study focused on the level of vehicle ownership and on the methods and costs of moving farm produce to market and meeting other transport needs. It was carried out by Dr. Charles Kaira whilst he was at the Institute of Development Studies, the University of Nairobi.

The field work for the study was carried out in 1980. It took the form of a sample questionnaire and interview in the two villages. Certain biases were inherent in the sampling and an attempt has been made to take this into account in presenting the results of the study. The study is important in that it is one of the few that has attempted to identify travel demand at the local level.

Background

This case study is based on the findings of a household interview survey carried out in 1980 in two villages in the Mwea Division of Kirinyaga District in the Central Province of Kenya (Figure 5). Village A has relatively good access to road transport, while the centre of Village B is more than 6 km from the nearest road with a

†The study on which this chapter is based is described in Charles Kaira, *Transportation Needs of the Rural Population of Developing Countries: An Approach to Improved Transportation Planning*, Institut für Regionalwissenschaft der Universität Karlsruhe, April 1983. Exchange rate at the time of study K.Sh.7.4 (Kenya shillings) = US$1.0.

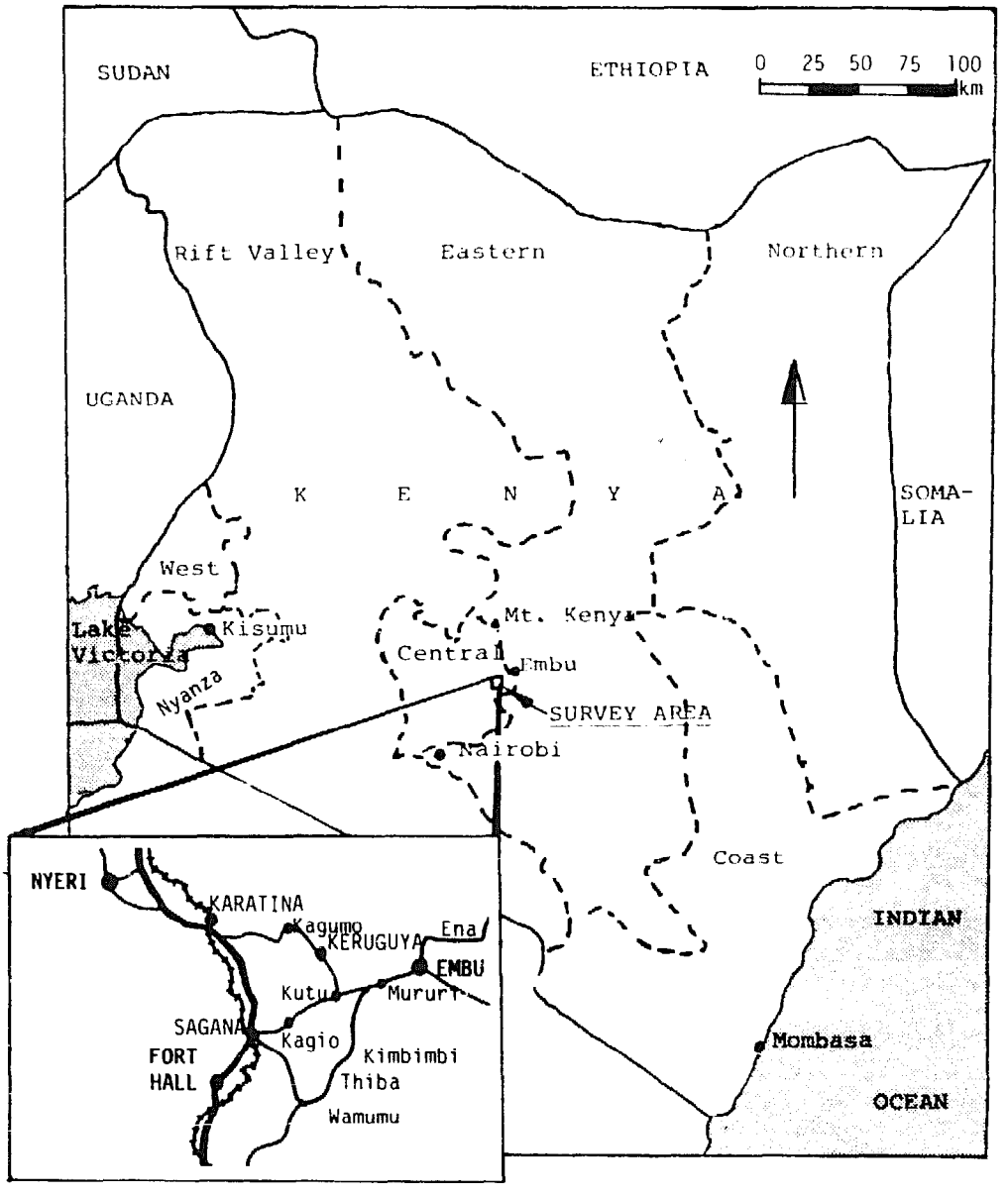

Fig. 5 *Map of Kenya*

dependable public transport service (Figure 6). Sixty-eight per cent of households in Village A, and 99 per cent in Village B are more than 2 km from the nearest market. However, both villages have relatively good access, in comparison with national planning targets, to dispensaries, water sources and primary schools.[1] The 30 per cent illiteracy rate in the area is similar to the national average, while the proportion of permanent dwellings in the two villages is well above the national target of 30 per cent. Formal employment in the area is negligible, and the large majority of households are engaged in smallholder agriculture.

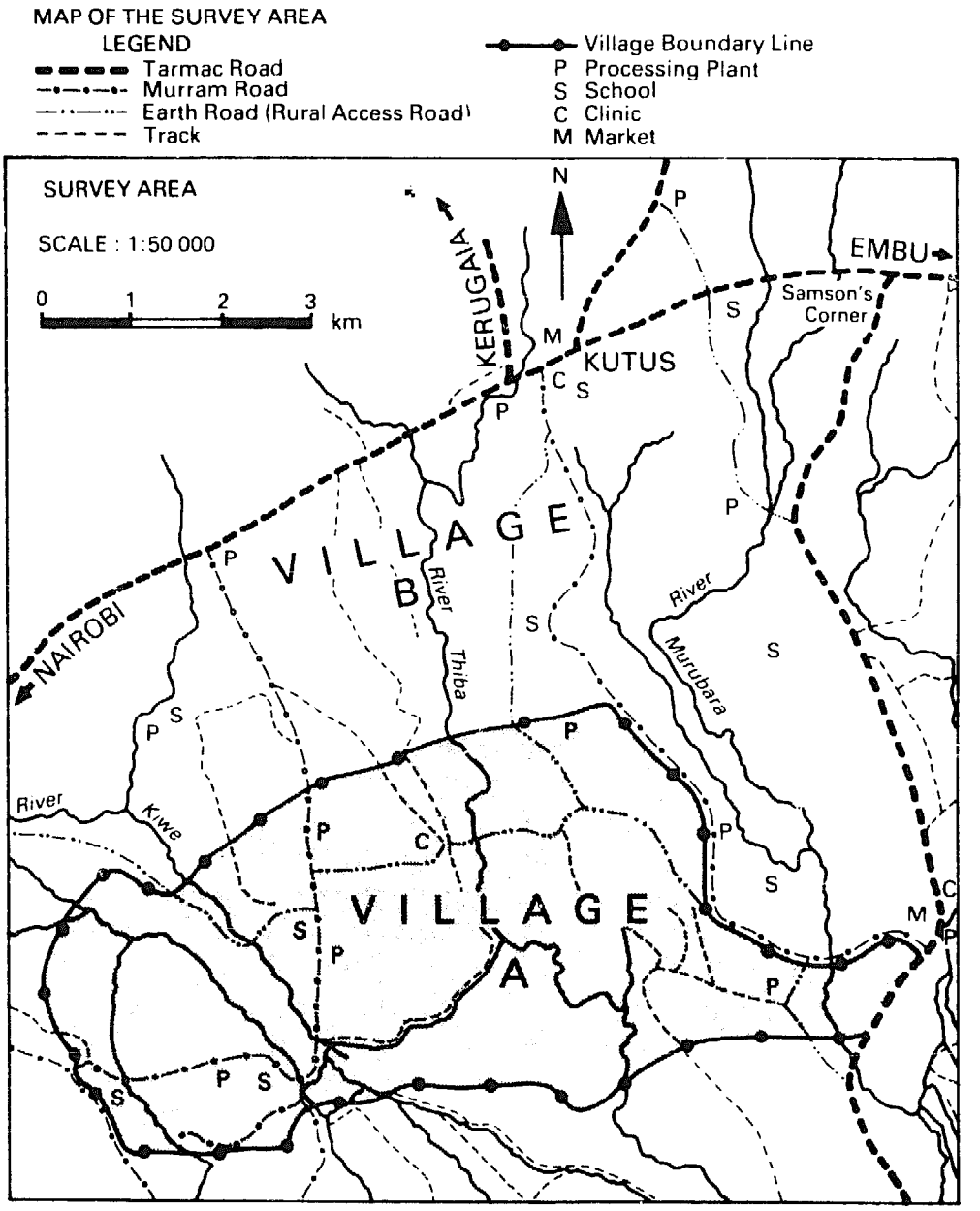

Fig. 6 *Map of the Survey Area*

In Village A, which is densely populated, survey interviews were carried out in every eighth household. In Village B, interviews were conducted with every fourth household. However when, among a set of four sample households, none owned a bicycle or donkey/ox cart, then one household amongst the sixteen which owned such a transport mode was interviewed. This introduces a bias into the sampling procedure but was necessary in order to collect sufficient data about these modes of transport. For similar reasons all households owning motor vehicles were inter-

Table 25. Vehicle Ownership in Sample Households

	Vehicle Category									
	Lorry	Car	Pick-up	Motor cycle	Donkey cart	Ox cart	Bicycle	Wheel barrow	Total vehicles	Number of households sampled
Village A	3	14	12	6	25	19	61	21	161	170
Village B	2	5	9	7	46	18	93	25	205	175

viewed. A total of 174 households in Village A and 176 in Village B were interviewed. There were, on average, 8.6 people per household.

Vehicle ownership

Table 25 details the numbers of vehicles owned by the sample households in the two villages.

These figures have to be interpreted with some caution. Because of the biases in the original sample they overestimate the proportion of animal carts and bicycles in Village B. They overestimate, to a greater extent, the proportion of motor vehicles in the two villages since all households owning these modes were interviewed. However, it can be concluded that the proportion of households owning motor vehicles is small, and that the most commonly owned vehicles are bicycles and animal carts. However, the sample biases prevent any conclusions being drawn on the relationship between vehicle ownership and access to the road network. Similarly, analysis of the relationship between household income and vehicle ownership is not possible because the study only generated data on income from sale of farm products. It is known that earnings from formal employment, and money repatriated by relatives working in towns, are significant contributions to total household income.

Of the bicycles owned by the sample households, about 35 per cent were purchased new, and 65 per cent second-hand. Over 96 per cent were bought for cash. In contrast, 97.5 per cent of the animal carts were purchased new, 87.5 per cent were bought for cash, but about 9.5 per cent were purchased on instalment terms. Table 26 details the cost of new bicycles and animal carts for the period 1976-79. Prices of second-hand bicycles are not available but would be cheaper than new ones and dependent on condition.

Bicycles are purchased new from traders in towns and second-

Table 26. Acquisition Costs for New Bicycles and Animal Carts in K.Sh.

Vehicle category	*Years*			
	1976	*1977*	*1978*	*1979*
Bicycle	650-850	650-850	850-1,200	1,000-1,300
Animal cart[1]	600-1,800	640-1,600	800-1,900	1,200-2,000

[1] Animal cart prices have a wide range because the price depends on the quality of the material (metal or wood) and workmanship.

hand from individuals, while animal carts are made to order by local craftsmen. The dominance of cash purchases reflects the fact that farmers do not normally have access to hire purchase facilities. Even if such facilities are available, farmers do not have the securities required. Analysis of responses to questioning on why households purchased their bicycles or animal carts at a particular time show that availability of cash was the major consideration:

— 80 per cent of the respondents answered 'That is when the household obtained enough money to pay for the vehicle';
— 10.5 per cent answered 'That is when the household realized the value of the vehicle as a general transporter in the household';
— 6 per cent answered 'The household needed another vehicle to replace the old one or to help the existing one';
— 3.5 per cent answered 'The vehicle was needed for business/fieldwork transport'.

Since long life span and maximum utilization of a vehicle depend on its maintenance, the costs of maintaining a bicycle and an animal cart in rural conditions were investigated. In most cases it is the ability to pay which determines whether the vehicle is well maintained during its life span. The average annual cost of maintaining a bicycle in the study area is about K.Sh.220. No statistical difference in the cost of maintenance of bicycles of different ages was found. This analysis is complicated by the fact that it was difficult to determine the age of bicycles purchased second-hand. However, the data shows that, on average, replacement of tyres

Table 27. Cost of Maintaining Animal Carts

Age of cart in years	*Average annual maintenance cost in K.Sh.*
0- 5	190
6-10	280
Over 10	365

and inner tubes accounts for about 50 per cent of total maintenance costs. The design of animal carts is essentially the same whether they are drawn by oxen or donkeys, consisting of a body mounted on the discarded rear axle of a motor car. However the harness design depends on the type of draught animal. The average annual cost of maintaining an animal cart (excluding costs associated with the animal) is about K.Sh.280. There is some evidence that cost increases with the age of the cart, as Table 27 shows.

The major maintenance cost items are replacement or repair of tyres and wooden bodies. This is not surprising as in almost 100 per cent of the cases worn out or retreaded car tyres are used on the animal cart and untreated wood is used for building the body of the cart.

Transport of farm products to market

In the context of subsistence farming, four categories of farm products have been identified:

1 livestock and poultry,
2 dairy products,
3 foodcrops, and
4 perishable products (e.g. fruit and vegetables).

In the survey area, cattle, goats and sheep invariably move to the market under the guidance of an escort walking on foot. Pigs and rabbits are moved by animal cart. Milk, which is the only dairy product in the area, is transported on foot and by bicycle in 70 and 30 per cent of cases respectively. The quantities sold are usually very small (0.5 to 5 litres) and the distances travelled are normally less than 3 km though they may be up to 8 km. Since the sale of milk is a daily task, it is usually the child going to school or a household member going to work who carries the milk. Thus the trip is essentially dual purpose.

The three major cash crops grown in the main season are maize,

beans and cotton, while the most important perishable crop is tomatoes.

Table 28 shows the distribution of sample households by weight of crops sold. As can be seen from the table, 88 and 83 per cent of the households respectively in Village A and Village B sold less than 500 kg of a single cash crop.

Table 29 details the charges for the two main means of hire transport available in the study area, animal carts and *matatu*. (A *matatu* is a share taxi, usually a station wagon or pick-up, with the rear body adapted to carry passengers and goods.)

As far as maize and beans are concerned, the animal cart charges in Village A are generally lower than those of the *matatus* while in Village B the charges for the two modes are similar. The possible explanation is that in Village B *matatus* operate only on market days for the purpose of transporting farmers and their farm

Table 28. Distribution of Households According to Sales by Weight of Cash Crops Grown in the Main Season

Type of crop	*Quantity sold in kilograms*				*Number of households*
	1-100	*101-200*	*201-500*	*Over 500*	
Village A					
Maize	6	9	9	8	32
Beans	17	8	3	1	29
Cotton	32	10	9	1	52
Tomato	2	1	—	3	6
Total	57	28	21	13	119
Village B					
Maize	19	9	17	15	60
Beans	22	5	4	7	38
Cotton	22	18	24	3	67
Tomato	4	3	3	4	14
Total	67	35	48	29	179

Table 29. Transport Charges in the Study Area (K.Sh.)

	Animal cart		Matatu	
	Maize/ Beans	*Cotton*	*Maize/ Beans*	*Cotton*
Village A	13[1] (9-17)[2]	51 (32-58)	26 (20-35)	—
Village B	11 (9-13)	45 (31-60)	13 (9-15)	16 (11-21)

[1] Average
[2] Range

products. However, in Village A *matatu* operation is mainly for passenger transport and operators try to keep away farmers travelling with farm products by imposing a high surcharge on the accompanied goods.

The table shows that the charges for cotton are much higher than for other crops. Cotton is a light but bulky product and therefore the transport cost, expressed in tonne/kilometres, is high compared with maize and beans which are dense.

The transport methods used for the three cash crops are very similar for the two villages. Over 70 per cent of the crops are moved by animal carts, which have low charges and are fairly widely owned in the villages, 17-19 per cent by *matatu* and the remainder by walking. These crops do not spoil easily and are normally sold either to co-operative stores, produce boards or private agencies where timeliness of delivery is not a factor.

In Village B, tomatoes are transported exclusively by *matatu*. In this village, *matatu* charges are comparable to those of the animal cart.

Furthermore, as tomatoes are sold only in the market, time is an important factor. However, in Village A which is nearer the markets and where the *matatu* charges are higher than those of the animal cart, only 20 per cent of the tomato crop is transported by *matatu*.

It is noteworthy that, except for milk delivery, crops are not transported to market by bicycle. This highlights the different roles of bicycles and animal carts, which are the most commonly owned vehicles and are of comparable cost. The bicycle is used for

Table 30. The Share by Weight in Kilograms of Transport of Farm Products to Market by Various Transport Modes

Type of crop	Transport Modes			
	Walking	*Animal cart*	*Matatu*	*Total*
Village A				
Maize	630	8,820	2,100	11,550
Beans	425	2,190	1,045	3,660
Cotton	1,404	5,084	1,190	7,678
Total	2,459	16,094	4,335	22,888
Percentage	10.74	70.31	18.94	100.0
Tomatoes	—	4,080	1,080	5,160
Village B				
Maize	1,735	13,140	4,050	18,925
Beans	205	1,830	1,320	3,355
Cotton	1,502	9,835	400	11,737
Total	3,442	24,805	5,770	34,017
Percentage	10.11	72.91	16.96	100.0
Tomatoes	—	60	8,970	9,030

personal purposes such as travelling to and from work, visiting and shopping, while the animal cart is used as a load carrier.

Trip making by household members

The study included an analysis of the trip making characteristics of the sample households. Five categories of trip purpose were defined:

- work trips related to paid employment;
- shopping/markets;
- leisure activity — visiting, recreation, trips to hospital and church;
- farm activity — going to cultivate, grazing animals and transporting inputs/produce around the farm;

— household activities — washing clothes and bathing at the river bank, water and firewood collection.

Four categories of household members were defined and interviewed — father, mother, son and daughter.

Table 31 details the trips made per person per day. The data have to be interpreted with some caution since they are based on trips made by respondents on the day prior to being interviewed. They therefore do not reflect seasonal variations and in particular:

— exclude school trips as schools were closed at the time of the study;

Table 31. Trips per Person per Day According to Family Status and Trip Purpose

	Family status				
Trip purpose	*Father*	*Mother*	*Son*	*Daughter*	*All*
Village A					
Sample size	95	127	74	64	360
Work	0.24	0.02	0.07	0.02	0.09
Shopping/marketing	0.62	0.23	0.31	0.27	0.36
Leisure activity	0.51	0.36	0.49	0.28	0.41
Farm activity	0.27	0.49	0.57	0.58	0.46
Household activity	0.27	0.29	0.27	0.31	0.29
Total	1.91	1.39	1.71	1.46	1.61
Village B					
Sample size	132	147	89	83	451
Work	0.13	0.03	0.12	0.04	0.08
Shopping/marketing	0.59	0.44	0.28	0.23	0.41
Leisure activity	0.59	0.35	0.53	0.47	0.49
Farm activity	0.59	0.59	0.71	0.35	0.57
Household activity	0.08	0.63	0.21	0.49	0.36
Total	1.98	2.04	1.85	1.58	1.91

— marketing trips are much fewer than would be expected at harvest time;
— interviews in Village A were conducted during the rainy season when the number of trips to collect water decreases.

However the data do illustrate the range of trip purposes and the roles of different members of the household. The survey showed marked variation in the use of transport modes by different members of the household. Mothers or daughters rarely use bicycles, probably on the grounds of custom or life-style. Fathers, who usually control the household cash, make more trips by public transport than other members.

Table 32 shows the modal distributions of all trips in the two villages. What is of significance is the predominance of walking as a means of transport. For shopping and leisure trips, for instance, walking is the most common mode, accounting for 60-80 per cent of trips, the remainder being by bicycle or *matatu*. Over 80 per cent of trips for these purposes are less than 7 km, suggesting that they are usually within the village neighbourhood. The different levels of access to road transport in the two villages have no significant effect on this.

Table 33 shows the distribution of walking trips in relation to farm and household trips. Of particular interest here is the fact that loaded walking trips (head or backloading) account for one in three of all trips and that 95 per cent of those loaded trips are carried out by women and children. About 70 per cent of trips involving carrying a load are for water collection. The usual loads are about 25 kg and the distances range from 0 to 8 km. Both water and firewood collection are female activities. It is apparent that, apart from transport of farm products during harvest, water collection poses the major daily transport problem to the subsistence farmer.

Table 32. Percentage Distribution of Trips by Mode

	Walking	*Animal cart*	*Bicycle*	*Public transport*	*Other*	*Total*
Village A	72.0	1.5	7.5	7.5	11.5	100.0
Village B	71.0	6.0	10.5	7.5	5.0	100.0
Average	71.5	4.5	9.0	7.5	7.5	100.0

Table 33. A Breakdown of Farm and Household Walking Trips According to Family Status

	Family status					
Trip purpose	*Father*	*Mother*	*Son*	*Daughter*	*All*	*%*
Village A						
Sample size	95	127	74	64	360	8
FARM:						
Graze animals	5	1	12	2	20	8
Cultivate	18	58	28	33	137	55
Farm transport[1]	1	3	2	3	9	4
Sub-total	24	62	42	38	166	67
HOUSEHOLD:						
Wash clothes	—	—	—	2	2	1
Bathe	7	1	16	2	26	10
Collect water[1]	1	28	2	12	43	17
Collect firewood[1]	—	7	—	4	11	4
Sub-total	8	36	18	20	82	32
Total	32	98	60	58	248	99
Trips per day	0.34	0.77	0.81	0.91	0.69	
Village B						
Sample size	132	147	89	83	451	
FARM:						
Graze animals	22	15	21	5	63	15
Cultivate	42	57	40	18	157	38
Farm transport[1]	9	14	2	6	31	8
Sub-total	73	86	63	29	251	61
HOUSEHOLD:						
Wash clothes	1	4	1	2	8	2
Bathe	7	—	14	4	25	6
Collect water[1]	—	72	3	28	103	25
Collect firewood[1]	—	15	—	7	22	5
Sub-total	8	91	18	41	158	38
Total	81	177	81	70	409	99
Trips per day	0.61	1.20	0.91	0.84	0.91	

[1] Trips that involve carrying loads.

Summary

The study was intended to show the differences in transport demand related to two levels of access. This it did only to a limited extent. Vehicle ownership was similar as was the amount of cash crops sold. Transport costs did vary although the variation was difficult to ascribe merely to the level of access. On the other hand, the study does say a great deal about the actual demand for travel in the villages in general. Transport for agricultural activity is not dominant, trips for leisure and household activities are equally important. The majority of transport takes place on foot. Trip lengths are short and loads are light and predominantly carried on the back. Each member of the household makes one and a half to two trips per day. The trips for marketing or shopping represent only 20-25 per cent of the total but will generally not be on foot. They take place on animal carts, bicycles or public transport.

PART II — TRANSPORT MEANS

CHAPTER 5

Means of Transport in Western Samoa†

Introduction

Western Samoa suffers from many of the typical problems of Pacific developing countries. A combination of topography, scattered territory, an inability to exploit economies of scale in manufacturing and a relatively poor industrial base restrict the choice of means whereby goods can be moved without relying on imported technologies.

The study upon which this chapter is based was commissioned by the Government with the objective of investigating the most appropriate rural transport technology to meet village agricultural needs in Western Samoa. It was carried out by Ian Barwell in 1980 by means of a detailed survey supported by secondary data.

Background

The country consists of two major islands, Upolu and Savai'i, and five smaller islands, only two of which are inhabited. The capital, and only urban centre in the country, is Apia on Upolu Island. The total population is 160,000, of which 25 per cent live in or around Apia, 50 per cent in other parts of Upolu, and 25 per cent in Savai'i. Thus about 75 per cent of the population of Samoa lives in rural areas. There are about 360 villages on the two major islands with typical populations of 200-500. Most of the villages are situated around the coasts with the cultivated plantations located inland.

The rural economy is predominantly agricultural, crops being

†This chapter is based on work for the Government of Western Samoa by Ian Barwell. At the time of the study 1$ (Samoan Tala) = US$1.14.

produced to meet family requirements with the surplus sold for consumption within Samoa or for export. The Government's development policy recognizes that Samoa will remain a largely rural village-based society and therefore a major objective is to increase production in village agriculture. The major crops grown at present are copra, taro, cocoa and bananas, while fishing is also an important source of food for family consumption and for sale.

The economic situation in Samoa restricts expansion in the use of motor vehicles, and has therefore increased the need to give attention to technologies utilizing local resources. The country has a substantial balance of payments deficit, and foreign exchange controls imposed as a result of this have severely restricted the availability of imported motor vehicles. Petroleum products account for about 8 per cent of the total value of imports, and the operating costs of motor vehicles have risen substantially because of increases in the retail prices of petrol and diesel fuel.

The experience gained since the inception of the Rural Development Programme in 1977 suggested that the horses found in most village communities in the country might be utilized more efficiently to reduce the time and effort devoted to meeting the transportation requirements of village agriculture. In particular, it was considered that the introduction of more efficient means of transport between village and plantation would contribute to increasing productivity.

Transport in Western Samoa

The nature and problem of rural transport in Samoa are conditioned by certain specific characteristics of the country. These include its small size, the nature of the road system, the location of the villages close to the major road network but separate from the cultivated plantations, and the lack of a significant regional marketing structure.

Western Samoa has a fairly good major rural road system. Upolu has sealed roads running along most of the north and south coast, and three cross-island roads of which two are sealed. Savai'i has a coast road running right around the island which is sealed where it passes through villages. Minor 'radial' roads or tracks provide access to those villages not situated adjacent to the major roads and, more importantly, link villages to their cultivated plantations. The current Access Roads Programme is aimed at improving access to inland areas and some 1,300 km have already been constructed or upgraded under the scheme.

It is possible to define two distinct elements of rural transport:

— village-market
— village-plantation

Village-market transport

'Village-market' transport includes all those journeys which involve travel outside the village and plantation area, for example to sell cash crops, to purchase agricultural inputs and household articles, and for social and educational purposes. Such journeys are carried out predominantly using motorized transport.

There are 4,070 motor vehicles licensed for road use in Western Samoa, 3,570 on Upolu and 500 on Savai'i. Thus the average motor vehicle density is about 25 motor vehicles/1,000 population, though in Savai'i the figure is much lower at 12.5/1,000.

There is no publicly-owned passenger transport system, all bus services being provided by private operators. Many of the 150 buses currently licensed are operated by village-based individuals or groups and provide a service to and from the home village. Substantial quantities of accompanied goods are carried by passengers on buses, the average load brought into Apia market being about 80 kg.

The light pick-up of about 1 tonne nominal payload capacity is the most common motor vehicle in the country. There is at least one pick-up owned in most of the villages and it serves as a general purpose carrier of people and cargo. Motor cars and trucks are less commonly owned in villages than pick-ups, and there is only a very limited commercial trucking service available.

While there is a limited amount of inter-village trading, cash crops for domestic consumption are marketed predominantly in Apia, and, to a lesser extent at Salaelologa on Savai'i. The major means of transport for the marketing of cash crops for domestic consumption are the pick-up and bus. A 1976 survey of Apia market[1] showed that 49 per cent of produce was brought to market by pick-up, 33 per cent by bus and the remainder by car. The same modes are used for personal transport to purchase goods, or for social purposes. Export crops are normally sold by the producer at the village to a local trader, who is then responsible for the transport and re-sale of the produce in Apia. The major modes of transport are the pick-up and truck.

Because of the nature of crop marketing, the emphasis of village-market transport is on travel to and from Apia and Salaelologa, often over a considerable distance. This limits the potential application of low-cost forms of transport for village-market jour-

neys.[2] If and when a regional marketing structure develops, the consequent reduction in typical travel distances would increase the potential for these forms of transport.

Village-plantation transport

Village-plantation transport includes all those journeys which involve travel around the area of the village and plantations, and in particular:

— movement of labour, materials (e.g. planting materials, fertilizer) and implements (e.g. digging sticks, knapsack sprayers), from the village to the plantation;
— movement of harvested crops, labour and implements from the plantation to the village; and
— collection of materials for household and social purposes (e.g. firewood, building materials).

The two traditional, and still the most common, methods of transport are walking and the pack-horse. The traditional means of carrying loads when walking is with a shoulder pole, which has the load attached at one or both ends, one person being able to carry up to 25-35 kg.

The most recent survey of the horse population, carried out in 1963, indicated 2,140 village-owned horses distributed equally between Upolu and Savai'i. Discussions suggest that there has not been any substantial change since 1963. While there are several horses owned in most of the villages on the two islands, they are banned by a few communities for social reasons. The horses are used to carry cargo loads, including crops and firewood, and people. Loads of up to a maximum of 135 kg are carried. The harness arrangement consists simply of a rope tied around the horse's neck and mouth. Cargo is carried in low slung burlap panniers, while the rider sits on a burlap cloth sometimes padded with grass. Village horses are small (most are in fact ponies) and are locally bred. While there is considerable variation in the condition of the horses, generally they are not particularly well fed.

People with access to pick-ups use them for village-plantation transport where there are suitable roads. The Government has recently introduced a tractor-trailer hire service. Eighteen tractor-trailer units, with nominal payload capacity of 2 tonnes, are distributed through the two major islands and are available for hire, with operator, at a subsidized rate of $3.20 per hour ($25.60 per day). No detailed analysis of the utilization of these units has yet been carried out, but estimates indicate that they are in use for about two full days per week.

The type of agriculture practised in Samoa, and particularly the emphasis on crops such as copra which yield a substantial weight of produce, results in significant village-plantation transport requirements. Furthermore, the transportation effort involved in clearing, cultivating and harvesting a plantation is increasing as land more distant from the village is brought into production. This has proved necessary because of the declining fertility of land close to the village and in order to increase crop production for domestic consumption by a growing population and for export.

An indication of the transport requirements of village agriculture can be obtained from analysis of the results of a survey of a 'typical copra and cocoa selling farm family' carried out by the Department of Agriculture in 1977.

The family surveyed worked six separate plots of land:

— two old coconut plantations totalling 4.5 ha, intercropped with two acres of cocoa, located close to the village;
— two young coconut plantations, totalling 3.2 ha, 1.6 km distant from the village;
— 0.2 ha taro and taamu plantation, 2.4 km from the village;
— 0.1 ha taro plantation, 4.8 km from the village.

Based on the data given in the survey, the estimated transport requirements for movement of crops back to the village were as given below in Table 34.

Table 34. Transport Requirements of Village Agriculture

	Weight of harvested crop (tonne/annum)	*Transport requirement for movement of crop to village (tonne-km/annum)*
Case 1: existing conditions	46	36
Case 2: all coconuts harvested and moved to village prior to de-husking	65	50
Case 3: increased output of coconuts	94	96

The three cases require some explanation. Case 1 represents the existing volume of transport involved in moving the produce of a typical family farm back to the village. Case 2 is modified by two assumptions:

— that all coconuts are collected from the plantation. At present this is not usually done, a major reason being the effort involved;
— that all husks are brought back to the village. At present a substantial proportion of coconuts are de-husked in the plantation to reduce the weight to be transported. However, the Government is encouraging the export of coir fibre which will give the husk a commercial value.

Case 3 also allows for the increase in crop harvest which will occur when the young plantations on the farm reach maturity. Thus Case 3 represents the volume of crop transport involved if a typical family is to maximize its harvest.

This analysis demonstrates clearly the substantial transportation element involved in moving harvested produce from a typical family farm back to the village. It also demonstrates the additional transport requirement that results from efforts to increase agricultural production through more intensive cultivation of plantations and the use of land more distant from the village. The analysis covers only the movement of harvested produce to the village. This is the major transport requirement in terms of weight of cargo to be moved. However, to this must be added the considerable time and effort involved in travelling to the plantation to clear, cultivate and harvest the land, and the on-plantation transport involved in collecting coconuts.

The modes currently used to meet these transport needs lie at two extremes of the range of possible options. The two traditional modes, walking and pack-horse, are slow and have limited payloads, so that labour productivity is low, though the modes are widely available since the monetary costs involved are also low. Pick-ups and tractor-trailers have much higher payloads and can travel at higher speeds, so that labour productivity is higher. However, pick-ups are very expensive to purchase, and increasingly costly to operate because of rising fuel costs. Consequently they are beyond the means of most rural farming families (availability of pick-ups in rural areas is of the order of 1 vehicle/80-150 people). The hire scheme for tractor-trailers removes the barrier of high investment cost from the farmer but, even at a subsidized rate of $3.20/hr, the cost of using this mode is high. Thus it is logi-

cal to examine the potential for intermediate modes of transport, more productive than the traditional methods, but less costly and therefore more accessible to village families, than motorized vehicles.

Potential for horse-drawn carts

There is considerable potential for animal-powered means of transport. Horses are already widely available, and produce about ten times the power output of human beings. Further, the use of horses as the source of power for transport reduces the human physical effort involved in this activity. The way in which horses are used at present to carry loads on their backs is simple, and requires minimal monetary investment. Village horses change hands for $10-50 though often they are traded for goods or livestock rather than cash. The equipment required for a pack-horse (rope harness, panniers etc.) can be obtained very cheaply. However, except on very steep terrain the power output of a horse is more efficiently utilized by transferring the cargo load from its back to a wheeled cart. Horse-drawn carts can be expected to operate, with a reasonable load, on rising gradients of up to 10 per cent, but not on long continuous climbs. The terrain in most parts of Western Samoa is suitable for horse-drawn carts, particularly since in practice the heaviest loads, harvested crops, will be moved downhill from the plantation to the village rather than uphill. Moreover, the plantation roads being constructed under the Access Roads Programme are generally suitable for use by horse-drawn carts. The areas of the country where the terrain is likely to prove too steep for horse-drawn carts are parts of eastern Upolu and north-west Savai'i.

As noted earlier the village horses are small and are generally not particularly well fed, though they are hardy and disease resistant. The introduction of carts would, initially at least, be aimed at using the horses' energy more efficiently, rather than at substantially increasing the work load demanded of them. In the longer term, efforts to improve the quality of the animals, by the introduction of new breeding stock and better feeding methods, would increase the workload of which they were capable. Under present conditions horse-drawn carts can be expected to carry loads of up to a maximum of about 400 kg plus driver.

Table 35 compares the characteristics of the horse-drawn cart with the traditional modes of walking and pack-saddle horses, light pick-ups and tractor-trailers. It is based on the following assumptions:

— walking — load 32 kg, average speed 4.8 km/h
— horse carrying rider and cargo load — load 57 kg, average speed 6.4 km/h
— horse carrying cargo load with handler walking alongside — load 125 kg, average speed 6.4 km/h
— horse-drawn cart carrying driver — load 400 kg, average speed 4 km/h
— light pick-up — load 1 tonne, average speed on access road 24 km/h
— tractor-trailer — load 2 tonnes, average speed on access road 11 km/h

The cost of acquiring a cart, which gives an indication of its availability to rural families, is much lower than that of a pick-up. It is expected that the purchase of carts would be funded through the Rural Development Programme which would reduce the cost by 50 per cent to about $250. The introduction of the tractor-trailers hire scheme means that there is no 'investment' cost associated with this mode of transport. However the hire charge, at $25.60 per day, is high. The annual cost of owning a cart, allowing for depreciation, interest charges and maintenance, is estimated at about $65, equivalent to two and a half days hire of a tractor-trailer.

Horse-drawn carts offer a substantial increase in transport capacity and reduction in physical effort involved compared with the traditional modes. The saving in effort is important since the

Table 35. Characteristics of Village-plantation Transport Modes

Mode	*Investment cost $*	*Cargo carrying capacity tonne km/hour*
Walking	0	0.15
Horse (cargo and rider)	10-50	0.36
Horse (cargo only)	10-50	0.80
Horse-drawn cart	420-570[1]	2.56
Light pick-up	8-9,000[2]	24.00
Tractor-trailer	0	22.00

[1] Cost of cart, harness and horse.
[2] New vehicle.

effort involved in crop collection and transport is one of the factors that limits harvested output. Based on Case 3 described earlier, it would take 19 man-days to bring the crop to the village by horse-drawn cart, compared with 320 by walking and 102 by pack-horse (the last figure assumes the farmer rides his horse for 50 per cent of the time). Thus compared with the pack-horse there is a time saving of over 80 man-days per annum from the use of a horse-drawn cart for a cost of about $65. The benefit to the farmer depends on how the time is used. As one example, it is estimated that on a typical family farm 10-20 per cent of the coconut crop, with a value of $75-150, is left in the plantation and not harvested.

In addition to carrying crops back to the village, horse-drawn carts would be suitable for the transport of labour, equipment and materials to and from the plantation and for the collection of firewood and building materials. They could also be used for short journeys outside the village on major roads. However in most circumstances they would not be suitable for movement around copra plantations because of the placing of the trees and ground conditions. An alternative horse-drawn method of transport is the sledge, which could be hauled around a plantation more easily than a cart, and would be very cheap to manufacture. However on the surfaces typically found on access roads it is unlikely that a horse could move a significantly larger load on a sledge than on its back.

At present, circumstances in Samoa are very favourable for the introduction of horse-drawn carts. A number of organizations have expressed interest in and support for the concept including the Ministry of Transport and the Department of Agriculture. Several of the large commercial estates have also shown interest in using horse-drawn carts. At present tractor-trailers are used to move produce from the estates, but the operating costs are becoming prohibitive as fuel prices rise. The commercial estates already make considerable use of horses in their operations and have imported breeding stock to improve the quality of their animals which are larger, stronger and better cared for than the village horses.

Summary

The study indicated the potential for the use of an intermediate technology which would both contribute to removing transport constraints and to reducing the need to import the alternative — tractors and trailers. While the investigation indicated that there was considerable interest in their use, the acceptability and

demand for horse-drawn carts among rural families can only be proven by a programme to introduce this form of transport. Thus the study does not prove that horse carts are the most appropriate choice, but it does demonstrate that there is a choice available for exploration.

CHAPTER 6

Improving Traditional Means of Transport in the Republic of Korea†

Introduction

The Republic of Korea is not generally considered as a low-income developing country — it has a GNP per capita similar to Malaysia for instance. Nevertheless, the rural area still provides the livelihood of a large proportion of its population. Given the difficulty of the terrain and the fact that only 20 per cent of the Republic's land is cultivable, the transport system has some unique features. Predominant among these, in the rural areas, is the *chee-geh*, a traditional load carrying frame.

This chapter describes work carried out at Soong Jun University to improve the efficiency of the *chee-geh*. Not only was this of interest in that little work of this nature has been done elsewhere but also because of the methodology adopted. A group comprising academics, artisans and farmers followed the study from conceptual design to the development of a commercially feasible product.

The work was carried out in collaboration with the Georgia Institute of Technology under the overall direction of Dr. Seyeul Kim with a grant from USAID.

Background

The *chee-geh* is a traditional load-carrying frame which is worn on the back and is unique to the Republic of Korea.[1] In spite of the fact that China and Japan have similar terrain and agricultural methods, nothing resembling the *chee-geh* has emerged there.

†The study on which this chapter is based is described in Seyeul Kim: *A Case Study on the Possibility of Improving the Simple Traditional Farm Equipment in Korea with Special Reference to the Chee-geh*. (Taejon, Republic of Korea, Regional Development Institute, Soong Jun University, February 1977.) Exchange rate at the time of the study 480W (Won) = US$1.0.

The evolution of the *chee-geh* in the Republic of Korea is believed to be related to that country's harsh winter climate, predominantly mountainous terrain, fragmented farming land, and narrow and undulating movement routes, all of which favour its use. For many years the people have burned firewood in their 'ondol' (flues that carry the hot gases of a fire — usually the kitchen fire — under the floor of the main rooms) heating systems. Therefore they frequently needed to haul wood to their villages from the mountains, often for long distances. Since 80 per cent of the land is unfarmable mountain terrain, the remaining arable portion is small and comprises numerous irregular pieces of land. There are also many small and large streams. The combination of these factors means that most of the roads and paths between village and field are narrow and winding. There is often little choice but human load carriage on the head or back.

Structure of the *chee-geh*

The traditional *chee-geh* is made mostly of wood, which is readily available from the pine trees growing in rural areas. Because the natural crotches of the trees are used for making the *chee-geh*, its construction is relatively simple (see Plate 5).

Every part of the *chee-geh* looks simple, but it can only carry heavy loads efficiently when it is well-balanced. The basic attachments are a basket and staff. The basket is used to carry loads made up of small pieces (such as fruit and vegetables). For very finely divided loads such as ashes or manure, a piece of matting is used to line the basket and prevent leakage. The staff is used to prop the *chee-geh* when it is standing alone.[2]

The traditional *chee-geh* takes somewhat different forms in different parts of the country, there being variations in the number of crossbars, attachment of the backpad, relative lengths above and below the fork, overall length and curvature of the frame, width of rear extensions and legs, and position of the shoulder strap. These differences between areas are probably due largely to variations in the type of terrain. Where the land is flat it is possible to carry a bulkier load so the upper part of the frame is longer than the lower part. On steep mountain trails loads must be less bulky so farmers prefer a generally smaller version. Frames in use on the plains have long legs to make it easier for the carrier to get it up on to his back when there is no slope in the ground to assist him. In some hilly areas the *chee-geh* is adapted for geater mobility: the lower end of the shoulder strap is attached high up, just below the backpad, and the upper end is attached just above the backpad.

Table 36. Average Yearly Income

Income (1,000W)	*Number of people*	*%*
Below 240	8	6.6
240-360	25	20.7
360-480	22	18.2
480-600	21	17.3
600-720	29	24.0
Above 720	15	12.4
No answer	1	0.8

Thus, although the *chee-geh* seems simple, it has been very carefully modified to suit the physical character of the land and the body structure of the user so that it will be of maximum utility.

Traditional *chee-geh* use

Interviews were carried out with 121 typical farm homes distributed among plains, intermediate and mountainous areas. Analysis showed there to be no significant differences in the responses from the three areas so their results were combined.

Table 36 shows the distribution of income characteristics and Table 37 the distribution of farm sizes among the sample population.

All of the farmers questioned used a *chee-geh* and 95 per cent said that it was necessary for their work. The study also showed

Table 37. Area of Land Cultivated

Area in hectares	*Number of people*	*%*
Very small scale (tenant farming)	7	5.8
Less than 0.3	12	9.9
0.3-0.7	33	27.3
0.7-1.0	34	28.2
1.0-1.3	17	14.0
More than 1.3	17	14.0
No answer	1	0.8

Table 38. Reasons Given for the Necessity of the *Chee-geh* in Farming

Reason	*Number of people*	*%*
Farm paths too narrow for hand cart or ox cart	51	44.3
No way to haul on mountain trails except *chee-geh*	49	42.7
Loads can be carried in fields and (rice) paddies	10	8.7
No hand cart available	5	4.3

(Table 38) that with the lack of adequate farm roads and difficult terrain there was no practical substitute for the *chee-geh*. In terms of most frequently carried loads, barley or rice, firewood, manure and grass were the main items, in descending order of frequency.

An analysis of the ability of farmers to carry various loads showed that 26 per cent could carry between 51-61 kg, and 23 per cent could carry from 71-80 kg. Although there were extreme variations 87 per cent were able to carry maximum loads ranging from 31-80 kg. Surprisingly, load-carrying ability did not seem to vary a great deal between the age of 30 and 60, experience and practice being the deciding factor.

In terms of the frequency of daily use, 26 per cent used it less than 5 times, 27 per cent between 5 and 10 times and 47 per cent more than 11 times a day. These figures emphasize the importance of the *chee-geh's* role in farming.

In terms of distance carried, the largest group, 20 per cent, carried their *chee-geh* between 8 to 10 km per day. This suggested that farmers spend a substantial proportion of their time and strength carrying loads on their backs, as a 10 km journey was estimated to occupy about 2 hours.

Another common form of farm transport is the *li-uh-ka* (metal handcart with spoked wheels). Surveys showed that while the handcart can haul a larger load than the *chee-geh*, and as a wheeled device is easy to use, it is uneconomic for small loads and required two or more people for large loads. Use by women or the old was also difficult. Thirty-one per cent of the farmers interviewed owned a *li-uh-ka*. A significant proportion of farmers (36 per cent) indicated that they could not afford a handcart and

others (15 per cent) that it was unsuited to bad farm roads (Plate 6).

Although farmers were nearly unanimous that use of the *chee-geh* was inevitable because of its 'convenience on narrow, mountain and steep trails and in the fields and paddies' — 98 per cent felt it was still important as a transport device — most (91 per cent) also felt that as a primitive and troublesome device it should be discarded. This ambivalent attitude amoung farmers was the main reason for the conclusion that 'although the *chee-geh* is primitive and inconvenient, because it is absolutely necessary for farming, modern technology must be applied to modernize it'.

Development of an Improved *Chee-geh*

The method of developing an improved *chee-geh* consisted of a series of some eight 'development conferences' spread out over a 16-month period in 1975-1976. Participants in the conferences comprised *chee-geh* users (farmers), manufacturers and academics drawn from technical disciplines. The aim was to develop gradually an improved *chee-geh* based on the synthesis of potential ideas derived from the respective knowledge and experience of the conference participants. Six farmers (two each from lowland, intermediate and mountainous regions), three metal workers with long experience in *chee-geh* and farm-equipment manufacture, two medium-industry machine manufacturers, four professors of mechanical engineering, economics and management, two technical high school teachers (altogether 17 members) constituted the conferences which involved seven model-development meetings, two field surveys and their respective review and analysis meetings.

In order to investigate a wide range of opinions from the farmers especially, a different group of farmers was invited to each conference. Also, in the field tests of the progressively improved models, local community leaders and many influential people of all ages were asked to participate. Their opinions were recorded and immediately after each field test the results were closely analysed and summarized for review at the next meeting.

The conferences aimed at unearthing the participants' 'hidden ideas' through a process of free-association. Ideas presented, opinions and matters of discussion were recorded and then compiled by the conference chairman (research director) for report and re-examination at the next conference. On this basis the participating manufacturers eventually made test models which were field tested. The results of each field test were reported in the following conference, beginning with a close analysis of items pointed

out by the farmers. A next-stage model would then be designed and in this step-by-step fashion, the conference progressed.

In all, six models were produced and tested before a satisfactory improved *chee-geh* resulted. The main feature of the new model was the addition of a pair of wheels (Plate 7) so that it might be pushed or pulled when the condition of the route surface permitted. Thus, the improved *chee-geh* combines some of the utility of the traditional device and the *li-uh-ka* (handcart). Addition of the wheels and construction in steel necessarily made the new model somewhat heavier than traditional *chee-geh*. Prior to finalizing the design, the improved *chee-geh* was subjected to evaluation by 100 farmers, to whom models were loaned for a brief period. They reacted positively to the improved *chee-geh* and gave user criticisms which were utilized in finalizing the design. The trials indicated that the increase in weight did not make the design less convenient since, whenever possible, it was wheeled rather than carried. A separate comparative trial between the new and traditional models — involving the transport of a 60 kg bag of grain over distances up to 3.5 km — indicated that the new model gave rise to significant time savings and productivity increases.

As part of the evaluation, farmers were asked at what price they would buy the improved *chee-geh*. Sixty-eight per cent said they would buy it at about half the price of a *li-uh-ka*, which is about three times the price of a traditional *chee-geh*.

Summary

The work at Soong Jun University shows what can be done when science is applied to the improvement of a traditional technology. The new version was acceptable to the users. Since the development work was completed, a number of potential manufacturers have expressed interest in the making of the new model. Nevertheless, they did not feel sufficiently confident to go into full-scale production without external assistance. As with many 'appropriate technologies' the missing link was the effective marketing of the product.

The concept of the *chee-geh* is one that is applicable to many other countries, and not just those with similar terrain types. The principle is sound and, where wood is not available, other materials such as steel tubing could be used. However, although superficially it seems simple, closer examination reveals that its efficiency results from a number of subtle design features.

CHAPTER 7

Means of Transport in the Philippines†

Introduction

The Philippines is well known for the ingenuity of its people. This is nowhere better reflected than in the diversity of transport vehicles available. These cater for the needs of different levels of society. In addition to conventional motor vehicles, they range from carabao(buffalo)-drawn sleds to the modified jeep known as the 'jeepney'. This case study, commissioned by the ILO, compares the most common forms of transport in one particular area of the Philippines. The objective of the study was to present a description of the transport situation as it pertains to the mass of the population of this particular area. No attempt was made to evaluate the best means of transport, nor to propose changes in policy or procedures which would assist rural transport.

The study focuses on jeepneys, trimobiles (motor-cycles fitted with sidecars), railway skates and *carabao* sleds. The study, carried out by Prof. R.B. Ocampo of the University of the Philippines is based on field interview data obtained in the first half of 1982. A total of 63 informants were interviewed. Thirty-nine of these were vehicle users, drivers, and owners for whom a common interview guide was prepared. The rest were vehicle-body builders and other key informants who were interviewed less formally, but in many cases just as extensively. The interview data were complemented by field observations, and by information from reports on road improvement and agricultural development projects in the study area, an interim report on transport in the region, and a previous evaluation study directed by Professor Ocampo.

Background

Some 70 per cent of the Philippines' 47 million population live in the rural areas. They depend for their livelihood on agriculture

†The study on which this chapter is based is described in R.B. Ocampo: *Rural Transport in the Philippines*, (Geneva, November 1982; mimeographed ILO World Employment Programme research Working Paper; restricted). Exchange rate at time of study P8.2 (Pesos) = US$1.0.

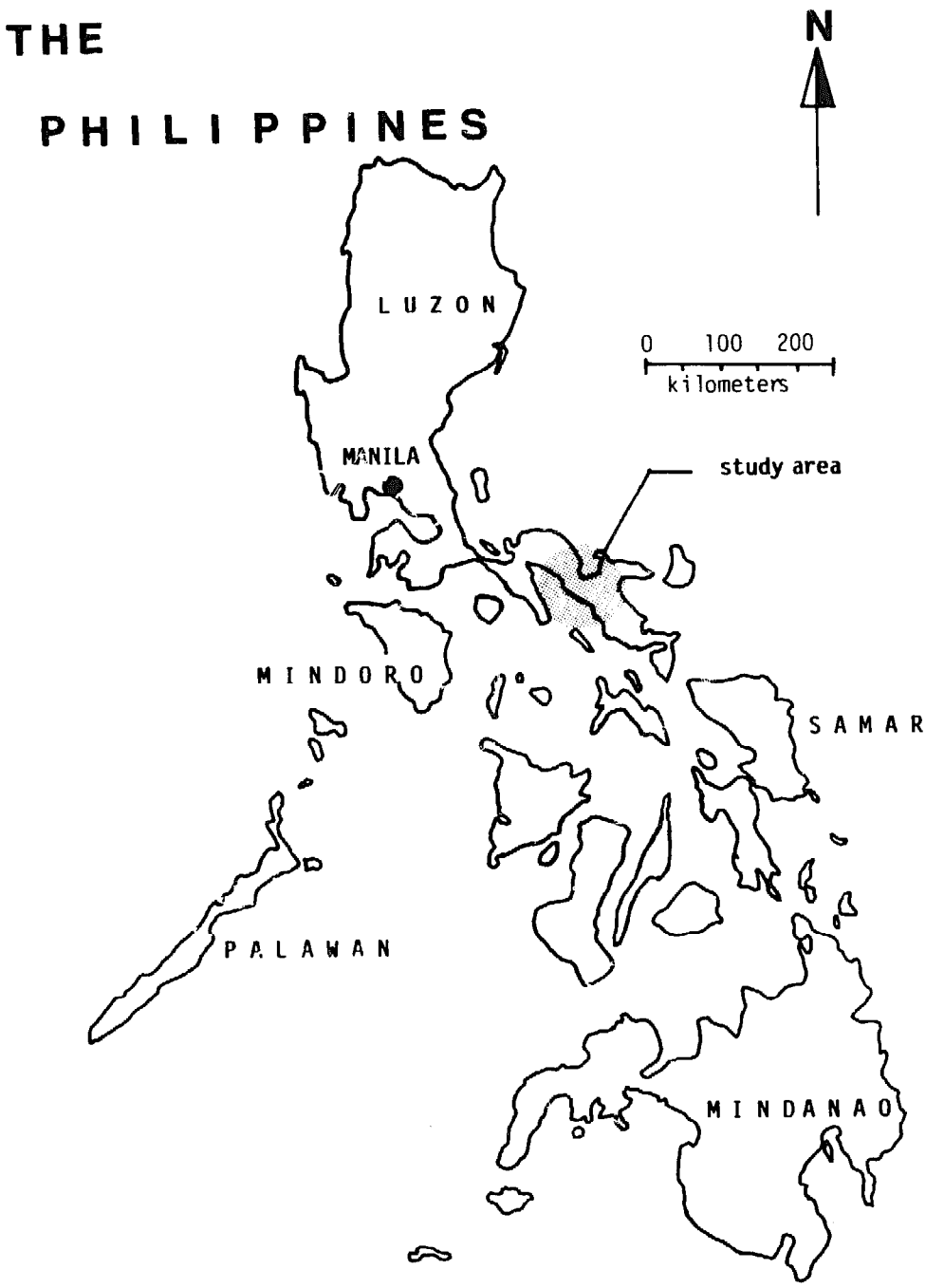

Fig. 7 *The Study Area in the Philippines*

which accounts for 30 per cent of GDP and over 50 per cent of all employment. Whilst the average income level in the Philippines is relatively high at P5,200 per capita, the distribution of this income is by no means even, with a small part of the population accounting for a large proportion of the wealth.

Farming is predominantly concerned with rice and corn for home consumption and coconuts and sugar for export. Less than half of the villages in the rural areas have direct access to roads, and movement of farm produce is initally by head-loading, animal-drawn sleds and carts. The roads to which farmers do have access are generally in poor condition. While there is an extensive system of feeder (*barangay*) roads more than 50 per cent are probably impassable during the wet season (May to November).

The study area is composed of two of the 37 municipalities comprising the Province of Camarines Sur in Southern Luzon (Figure 7). The area stretches across the Bicol Peninsula straddling the Libmanan River, the Maharlika national highway and the Philippines national railway line. The two municipalities, Libmanan and Cabusao, have a total population of 79,000 and cover an area of 38,300 ha. This implies a population density of about 200 people/sq km which is somewhat higher than the national average.

The major economic activity in the area is agriculture from which three-quarters of the population earn a living. The predominant crop is rice although coconuts, sugar cane and fish (on the coast) are of economic importance.

The area is a depressed one with a per capita income of about P1,000 compared with a national average of P5,200. Over 50 per cent of the farms are smaller than 3 ha and crop yields are low by national standards and declining. Rice production is dependent on rain-fed irrigation, and consequently only one crop is grown per year. Moreover, the majority of the farmers are share tenants which reduces the incentive to increase production. Unemployment, at 10 per cent, is high by national standards and underemployment is estimated at 30 per cent. The general picture therefore is of an area which shows the effects, in terms of unemployment, high out-migration and low crop yields, of a general lack of attention to land reform and rural development.

The transport network in the area was also in poor condition until very recently. Many villages had no link to the road network. The lack of an adequate transport system was at least partly responsible for rice being sold as wet paddy at the farm gates for prices as much as 30 per cent lower than dried paddy, and for the restricted use of fertilizers. The major transport movements in the area took place on the 'local transport system' by head-loading, by carabao sleds and carts where the footpaths or canal dykes permitted, by improvised skates on the underutilized railway lines, and by boats on the Bicol River.

The length of the road network has been extended by 50 per cent from 130 to 200 km in the last five years. The extension has

been over the whole range of road types from earth feeder roads to bitumen main roads. It has increased accessibility to large towns outside the area, improved access between the two main towns, Libmanan and Cabusao, and provided road access to villages where it did not exist before.

The increase in road access has had important repercussions. It is still too early to say whether cropping patterns and agricultural output have been influenced by these improvements to the road network.[1] However, there has been a large increase in registered vehicles and traffic movements. Between 1975 and 1980 the number of buses increased by 36 per cent, jeepneys by 39 per cent and trimobiles by 57 per cent, and two new bus lines opened.

Thus, with improvement to the road system the use of motorized transport has increased. To some extent the motorized forms of transport have been brought into competition with the traditional modes. However, the most common motorized modes, jeepneys and trimobiles, are not standard western models but products of Philippine ingenuity like the skates and carabao sleds. There are estimated to be 25-30 jeepneys, 150 trimobiles and 70-100 skates operating in the study area. The numbers of carabao sleds are unknown.

Jeepneys

The jeepneys (Plate 8) evolved from experience with army surplus jeeps after the Second World War. Jeepneys have an extended chassis with a rear passenger compartment. There is a single entrance for passengers at the back and two parallel upholstered benches or seats, plus a side entrance into the driver's compartment. Jeepneys can seat a legal maximum of 16 to 22 passengers but may accommodate as many as 10 more by using the spaces available beside the driver, in the aisles, and on the running board. The rural jeepneys in the study area usually have top load railings and small cargo bars at the rear near the running board so that they can carry freight as well as passengers. Jeepneys are available with petrol or diesel engines ranging from 60-90 hp. The body and passenger compartment of a jeepney are manufactured locally, while the engine and transmission are imported. Some constructors make their own chassis while others use the chassis from a small utility truck. There are no jeepney manufacturers in the study area, although some automotive and welding shops undertake jeepney repairs and servicing.

Six jeepney operators, all using diesel-engined vehicles, were interviewed for the study. The vehicles had been purchased by

their owners between 1974 and 1980, at prices ranging from P36,000 to P42,000 for new vehicles and P30,000 for one second-hand jeepney bought in 1980. The acquisition of the vehicles also entailed registration, insurance and other fees amounting to P1,000-P1,200 per jeepney. The vehicles were paid for partly in cash and partly in instalments over periods ranging from 90 days to 22 months. Down-payments to the manufacturers were made from savings, current incomes, and personal loans. The current minimum price for a new vehicle is P55,000. A down-payment of 40 per cent is normally required, and credit is available to finance purchase from banks or financing companies, although it is becoming more difficult to obtain because of re-payment problems experienced by the institutions.

Of the six informants interviewed, four drove jeepneys owned by other people, one owned two jeepneys and drove one himself, and one owned two jeepneys and employed drivers.

The respondents' jeepneys are in service for 11 to 12 hours a day, starting at 5.00 or 6.00 a.m., and some of them operate seven days a week. Each jeepney has a conductor, and a relief driver for shift work and to allow the main driver to take days off. A driver makes a total of 2 to 3 round-trips (12-18 kms per round trip) during slack or rainy days, and 3 to 5 round-trips during peak periods. Waiting times may vary from 10 to 25 minutes, depending on the level of passenger traffic. A despatcher at each of the two jeepney terminals in the Libmanan city centre controls parking and departures, and collects a terminal fee of P3 to P5 a day per vehicle.

The legal passenger fare for jeepneys is a minimum charge of PO.65, plus PO.13 for every kilometre after the first five. There is a special student rate of PO.50/first 5 km and PO.11/km thereafter. Fares, which have increased with oil prices during the last few years, vary widely according to local practices, and may exceed the legal rates.

There is no additional charge for small baskets or bundles of goods carried by jeepney passengers. However, charges are imposed when cargo attains some minimum size or bulk, or when jeepneys are on cargo-carrying trips. Fifty kilogrammes of palay (unhusked rice) costs P1.00-P1.50 to transport within the area. When a jeepney is operating on hire a unit or 'bulk rate', mutually agreed with the user, is charged for the use of the vehicle and the driver's services. The rate is based on the distance and the load involved, though the opportunity cost rather than the load may be crucial.

The informants interviewed gave figures of P225-P260 for gross daily revenues. Another survey on different routes in 1981 indi-

cates gross daily revenues of P200-P300. Operating costs are 35-45 per cent of revenue, the major daily expense being fuel. Jeepney drivers deduct P10 to P15 a day for operating (oil and wash) and minor maintenance costs which they assume. An allowance is also made for drivers' and conductors' expenses for food and cigarettes. The driver receives 15-25 per cent of the net daily revenue after deducting operating costs, and the conductor 10 per cent. Table 39 gives a breakdown of typical daily revenue, costs and earnings, based on data supplied by informants.

The table shows that typically a conductor earns about P15 per day, a driver about P30 per day, and an owner about P110 per day. Although the drivers may undertake minor repairs themselves, the owners are responsible for major repairs, maintenance and replacement of parts. These costs, plus insurance, registration and loan repayments (if any), must be covered from the owner's earnings. One other important cost item not specifically mentioned by the informants consists of a percentage tax and fixed tax that jeepney operators as well as other public utility owners must pay to the Bureau of Internal Revenue (BIR). The former is a 2 per cent tax on quarterly gross receipts (estimated at a minimum of P72 for

Table 39. Average Daily Revenue and Earnings

		Pesos (P)
Gross Revenue		241
Operating costs		
Fuel	65	
Oil	11	
Meals/snacks	18	94
Net revenue		147
Driver's share of net revenue		29 (20%)
Conductor's share		15 (10%)
Owner's share		103 (70%)[a]

[a] This figure overstates the apparent profitability to the owner, since from his share he must bear the depreciation cost of the vehicle. Depreciation costs, based on a 10-year life, a cost price of P40,000 and 300 working days/year, would amount to about P25 per day. Maintenance and repairs could be expected to account for another P25.

each jeepney every 3 months) while the fixed tax is a flat rate of P100 a year per operator regardless of the number of vehicles that he owns.

Based on interviews with users, jeepneys are used mostly for work-related trips, although social visits, church-going and recreation are sometimes included in trip-purposes. According to jeepney operators, the most frequent passengers are students and schoolchildren, housewives and market vendors. Farmers and government employees are less frequent jeepney passengers.

Jeepney operators perceive an increasing supply of and demand for motorized public transport. The number of jeepneys and trimobiles in the area has grown and people travel more often now than before. This appears to be a consequence of economic and road improvements in the area. However, the major constraint on the frequency of travel is cost, and attempts to increase fares have been strongly resisted. Although demand has increased, jeepney operators report declining net revenues because of growing competition in the sector, and increasing operating and maintenance costs. Compared with other modes available, the major advantages of jeepneys to users are that they are readily available, comfortable, safe, fast, and have a longer range than other modes.

The jeepney operators and drivers do not think that improved vehicle design would reduce prices. While jeepneys could be made larger, more comfortable, and more durable for rural conditions, the costs of manufacture cannot decline, mainly because the costs of materials have steadily grown.

Trimobiles

The trimobile is a local adaptation of an imported technology. It is a motorcycle modified to carry additional goods and passengers by the addition of a side-car (Plate 9). Both new and used Japanese motorcycles with engine capacities in the range of 100 to 125 cc are converted into trimobiles. The local conversion process involves modifying the motorcycle frame for attaching the side-car. The wheels are sometimes reinforced and extra shock absorbers attached to cope with rural road conditions. The side-car consists of a driver cabin, a passenger compartment with a cargo rack above it and an additional cargo rack at the rear. The side-car is of welded construction, from steel bar and sheet. The upholstered seat can accommodate 2 or 3 persons, but metal railings usually supply one or two extra seats in the passenger compartment. Additional passengers can be seated behind the driver or on the cargo rack if it is designed to allow this. The side-car wheel is of

welded construction consisting of a hub, reinforced rim and steel rod spokes. Trimobiles are manufactured by local welding shops in the study area, and on a larger scale by workshops in Naga City. The motorcycle is usually purchased beforehand by the would-be trimobile owner, who then brings it for conversion to a side-car maker.

Nine trimobile operators were interviewed for the study. Most of the study respondents had acquired their trimobiles brand new for prices ranging from P8,500 to P11,000, of which the side-car accounted for P1,000 to P2,000. Registration and other fees were an additional P500 to P1,000. Other vehicles were purchased second-hand for P2,000 to P5,000. In most cases, the owners paid cash for their vehicles. In some instances, short-term credit (2-10 months) was extended by the motor-cycle dealer or the side-car manufacturer for part of the cost. In one case, the owner had borrowed part of the money from the Libmanan Rural Bank. The current minimum price of a new trimobile is about P13,000. Dealers may extend credit to a buyer themselves or arrange credit through a finance or banking institution for the purchaser of the motorcycle. The terms vary from 10-30 per cent down payment and 12-36 months repayment period. Before a buyer is extended credit, an investigation is conducted into his 'character', capacity to pay, and credit record. A comprehensive insurance policy and a chattel mortgage on the vehicle are also required. Collateral such as farmland may be required by a bank. The rural banks very rarely give loans for the purchase of trimobiles.

Of the nine informants interviewed, four drove trimobiles owned by other people, three owned one vehicle each, one owned two vehicles and one owned three. For most of the owners and drivers, the business is their primary or only source of income. Some owners drive their own vehicles, others prefer to hire their trimobiles to drivers who are related or known to them.

Trimobiles operate for 10 to 12 hours a day, starting at 6.00 or 7.00 a.m. and the use of relief drivers is unusual. Operating patterns depend on weather conditions and trip lengths, varying from 3 to 10 round trips a day.

The minimum fare per passenger is PO.6 and increases at a rate of PO.12 per km after the first 5 kilometres. Road conditions are also considered, so that a trip on bad roads to a nearby destination may cost more than a trip on better roads to a more distant place. Cargo fares also vary depending on the kind and quantity of goods carried and the distance travelled. A sack of palay or a bag of fertilizer may cost only the minimum, but fares are greater for remote destinations, e.g. P1.00-P1.50 for 50 kg of palay or rice. As many

as 10 bags of fertilizer or 350-500 kg of palay can be loaded on a trimobile if no passengers other than the cargo owner are on board.

Unlike the jeepney drivers in the area, who get a commission, the trimobile drivers pay a daily 'boundary' or fixed rental to the owners for the use of their vehicles and receive the revenue left over after other daily expenses, including those for fuel, have been met. The gross revenues reported by the trimobile owners and drivers are considerably lower than those reported by jeepney operators and drivers, but their net average revenues are about the same at P26 per day. A typical boundary fee is P17, and running costs average about P19 per day, with fuel taking up at least 75 per cent of the total[2]. From his earnings the owner has to bear the cost of maintenance and spare parts, insurance, registration and depreciation. Trimobile operators are liable to a 2 per cent tax on gross income and a fixed tax of P100 per year, but the Bureau of Internal Revenue experiences difficulties in trying to collect these taxes.

Trimobiles are used mostly for work-related trips — students, school children, farmers and housewives being the most frequent passengers. The predominance of these three groups probably reflects the primarily local clientele of trimobiles. With the new or improved roads, trimobiles have penetrated more isolated areas, enabling their local residents to travel more often by road rather than by railway skate or waterway and to bring goods to or from the market by motor vehicle rather than by head porterage or animal-drawn vehicle. In turn, groups from the cities and outside are better able to visit the peripheral communities. These include midwives, teachers, and other government field personnel with no service vehicles. The major advantages of trimobiles are that they can go to places inaccessible to jeepneys and bring passengers much closer to their destinations.

Trimobile owners and driver-respondents generally share the views of the jeepney operators and drivers about the increasing number of vehicles, frequency of travel by people in the area, economic and road improvements, and growing patronage of trimobiles. According to them, travel and economic life have only improved for some parts of the population. Some roads are still rough and impassable during the rains, and trimobiles are used for internal travel because there are no other alternatives.

The trimobile owners and drivers complain about stagnant or declining levels of patronage and revenues due to growing competition and operating costs. Trimobile driving alone does not provide an adequate income, especially to support a big family, unless

a driver manages to acquire a trimobile of his own. However, there is a general optimism about the future of the business as economic development increases the demand for travel.

Skates

Skates (Plate 10) are used for transporting people and freight on the under-utilized railway lines. A skate is a simple device usually made by the owner, sometimes with the help of a carpenter. It consists of a wooden frame, a bamboo floor, one to four wooden benches on the platform but no roof, and pairs of ball-bearing wheels placed just wide enough apart to fit the railway track. To keep the skate on the track and to minimize friction while the vehicle is in operation, two additional pairs of smaller ball-bearing wheels are installed underneath so that they roll against the side of each rail, and the driver lubricates the wheels with oil every so often. A skate is propelled by foot by the driver, often with the help of an assistant or one of the passengers. A wooden pedal with a rubber pad is tilted down against the rail to slow down or stop the skate.

Although it does not attain great speed, a skate can gain momentum with a heavy load. Otherwise, it is light enough to be carried by a man or two boys so that it can be turned around, 'parked' off the track when not in service or, as often happens, quickly unloaded and carried off the track when the train comes. A bigger skate may be propelled by a small engine (e.g. a 5 hp rice thresher motor) attached to the floor at the rear and connected to one of the rear wheels by a fan belt. These wheels have a larger circumference, and one is thicker to accommodate the belt. An additional foot lever serves to regulate the speed of the vehicle by tightening or relaxing the fan belt as the motor operates. A manual skate seats five to eight persons but can carry as many as a dozen, while a motorized skate with four benches can seat 22 and carry a maximum of 25 passengers. A manual skate may carry as much as 750 kg of palay on a single cargo trip, and a motorized skate can manage 1,500 kg.

Four skate operators, one of whom had a motorized version, were interviewed for the study. All four were owners who drove their own skates but all regarded this as a secondary source of income, their main jobs being farming. The owner of the motorized skate used his engine to drive his rice thresher at harvest time. The operators had built their skates partly to meet their own transport needs as well as for public use. A manual skate costs about P100, and a motorized version up to P2,000.

Skate drivers work 11 to 12 hours a day but are mostly active during the early morning and late afternoon. They normally wait for a full load at the railway station, and unload and pick up passengers along the journey. Skates average 3-4 round trips per day but when demand is high can make up to 6-8 trips. The data obtained from respondents cannot be converted meaningfully into fare rates per passenger/km. For longer journeys, rates appear to be approximately PO.15/km, but are probably higher for short trips. A study of South Luzon [3] in 1981 estimated rates at PO.25/km. Freight rates are based on equivalent passenger space occupied. The skate is not generally claimed to be cheaper than other means of transport.

Operating and maintenance expenses of manual skates are small at about P2 per day. Daily revenues from skate operations appear to be equally low. Daily net earnings range from P7 (single-bench) to P20 (including the motorized skate); gross earnings range from P10 (manual) to P40 (motorized).

Skate-driving does not appear to offer good prospects as a source of income unless it is regarded as a secondary occupation and/or combined with private use. Estimates of the number of skates in the study area vary from 70 to 100, and there is no clear evidence of trends in demand. The skate appears to have certain disadvantages. It is not a fast means of transport, nor is it convenient. Since it has no canopy, the passengers are exposed to sun and wind — no skate runs when it is raining. When two skates meet travelling in opposite directions along the single track, one must yield. There is the obvious safety hazard of having to clear the skate and passengers from the track when a train approaches. However, skates are used by various groups of people, farmers, school children, market vendors and teachers being the most frequent passengers according to the respondents.

The demand for skates may be limited to those living in or having to do with railroad communities that remain inaccessible to road transport, but it is a flexible demand. Skates are easy enough to make and operate, and the investment required is relatively low, so that questions of skills or credit do not appear to be salient in decisions to enter this field, unless a motorized skate is contemplated. Formal regulations on skates are virtually non-existent. Currently, there seems to be grudging official acknowledgement of their necessity for railroad villages.

Carabao sleds

Carabaos are used in the study area for farming. Sleds or wheeled carts are used by carabao owners for transport purposes. The pre-

vailing price of a carabao is about P1,200, but a bigger and healthier one may cost up to P2,000. However, for farmers who own carabaos, a sled provides a means of transport at minimal additional cost. The sled (Plate 11) consists of a flat bed of bamboo strips and wood frame nailed to a pair of bamboo poles, which are attached to another pair of poles harnessed to the yoke on the carabao. The ends of the poles touching the ground serve as the runners, the harness pair moving freely on wooden hinges for turning purposes. The sled is very simple to make and materials are available from bamboo clumps and young trees nearby. The only purchased items required for the sled itself are a length of rope and nails. The wooden yoke, which is also used for the agricultural implements drawn by the carabao, is available ready-made in the market for about P12.

The maintenance cost of the sled appears to be low. The wooden runners wear quickly where they drag on the ground and are repaired or replaced once a week on average, but the rope is replaced only once a year and the yoke may last up to five years.

The sled is used to transport various kinds of farm products, materials, and household needs over short distances on or off the road. Passengers may also be ferried, although the particular design described above is not very suitable for this purpose. (Elsewhere in the country, such as in Central Luzon provinces, the sled is built so that passengers can ride more comfortably. The bed is level and built higher above the ground, and the runners are flat on the ground rather than slanting on their heels.)

Two carabao sled owners were interviewed. In one case, the owner is a share tenant on a coconut farm and uses the sled for his family's transport needs. It is also rented to other farmers to carry their copra, palay and firewood. The rental rate is approximately P2.5 per 100 kg per km. The other informant is a rice farmer and uses his sled exclusively to transport his own palay.

Carabao sleds were used extensively for freight transport in the past, but their numbers have declined in recent years. The number of carabaos also appears to have declined and there is some evidence of the increasing use of power tillers in the study area. As a result of road improvements and the growth of motor transport, carabao sleds now appear to be used mainly in coastal, hilly and other areas not yet accessible by road. However, they can still be observed from time to time on roads in the study area, even along the highway. The utility of the carabao sled on and around the farm suggests that it will probably continue to be used for on-farm transport.

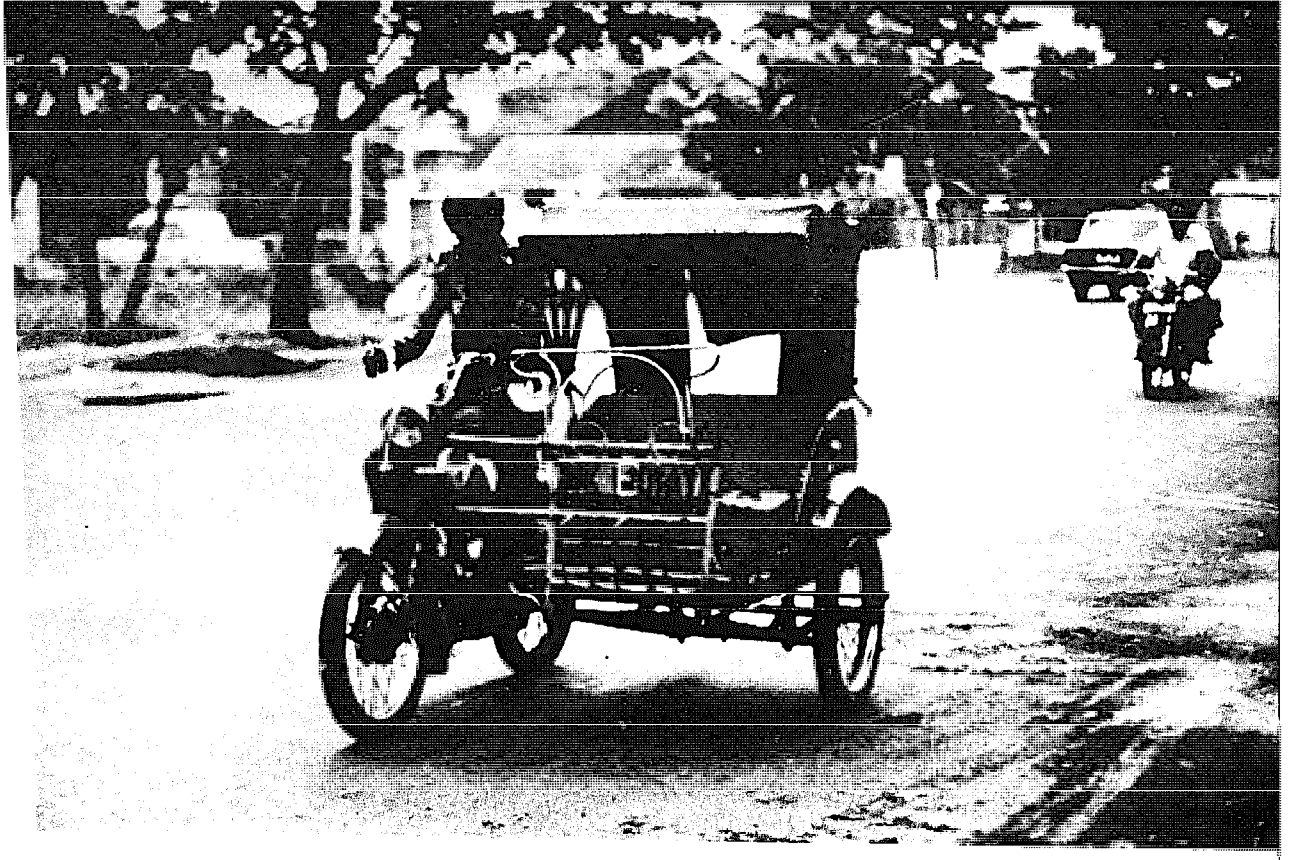

Plate 9 *A passenger carrying trimobile*

Plate 10 *Foot propelled Skate with typical passenger load*

Plate 11 *Carabao Sled Carrying bags of fertilizer along a track*

Plate 12 *The predominant means of transport in Makete District*

Comparison of means of transport

The analysis of the four different means offers some interesting comparisons, a summary of which is presented in Table 40.

In some way, the four means complement each other in their operations and serve the various transport needs of a rural and agricultural community that is still developing internal and external linkages. The jeepneys provide inter-town service for small merchants, farmers, students, employees, and bulk cargo. The trimobiles cater for the intra-town journeys of housewives, market-goers, farmers and school children, especially between the Libmanan town centre and outlying areas. The skates and sleds serve the transport needs of the settlements and farms off the road network. Except for the sled, which is associated with farm work, these modes appear to serve an equally wide variety of clientele and trip-purposes, with farm-to-market journeys as a common denominator. Thus, over time, they have also tended to compete and with the improvements of road links, the jeepneys and trimobiles, which offer a more convenient, faster and wide-ranging means of moving goods and people, have gained ground on the traditional modes. Skates remain a necessary means of transport for railroad-linked communities and sleds are still useful at least as a private vehicle on the farm.

Their salient characteristics invite comparisons between the jeepneys and trimobiles on the one hand, and the skates and sleds on the other. Both motorized, the jeepneys and trimobiles are built and maintained by skilled workers, automotive shops, and supporting enterprises. They are 'operated' (in the legal sense) by owners who are often distinct from the vehicle drivers. Their acquisition, operating and maintenance costs are substantial, and require some form of purchase financing. Since they are for public use, their manufacture, acquisition, and operation are subject to government regulation, although their current legal status is hazy. Table 40 shows that their charges, for passengers and freight, are very similar.

Due to the greater degree of specialization and scale required in their manufacture, marketing, operation and regulation, these modes employ more skilled workers, operators (including distinct 'professional drivers'), entrepreneurs and managers than the skates and sleds do. Between the two motorized modes, the technically more demanding jeepney generates more jobs and income per vehicle than the trimobile does. However, the trimobile appears to have greater potential for local manufacturing, servicing and maintenance activities. There are fewer jeepney-building

Table 40. Transport Mode Comparison

Mode	*Purchase Price (p)*	*Potential load*	*Hire charges (P)*		*Daily income (P)*	
			Passenger	*Freight*[1]	*Driver*	*Owner*
Jeepney	56,000	20-25 passengers	0.13/km	2-4 per tonne/km	20-30	100-110
Trimobile	13,500	5-6 passengers *or* 450 kg	0.12/km	1.5-3.0 per tonne/km	20-35	15-20
Skate Manual	100	5-8 passengers *or* 750 kg	0.15-0.25/km	3-6 per tonne/km	7-20	—
Skate Motorized	1,750	20-25 passengers *or* 1,500 kg	0.15-0.25/km	3-6 per tonne/km	7-20	
Sled	15	—	—	25 per tonne/km	—	—

[1] These figures are interpreted from the study data and should be treated with caution since freight is not usually charged at a rate per kg but on the basis of space occupied or per sack. Rates vary according to route, road condition and distance.

shops and they are confined to Naga City or more remote urban centres, though they serve and depend on a larger market. There are more trimobile shops and a few have been set up in Libmanan. In terms of equipment, capital and skill requirements it is easier and less costly for local shops to extend their activities into trimobile-making than jeepney-building. They also have the incentive of a larger demand for new trimobiles, repair and rehabilitation which ensures a larger volume of work.

Thus, what the trimobiles lack in terms of job-creating capacity per vehicle they compensate for with their greater numbers in the locality where they operate. For example, while they have not hired conductors or despatchers, trimobiles have employed more operators and drivers, many of whom may have no job options. Similarly, what they lack in individual carrying capacity and operating range the trimobiles make up for with their ability to penetrate peripheral or interstitial rural communities less accessible to jeepneys.

Skates and sleds are much easier and cheaper to build and operate. Their manufacture and operation are well within local control in terms of existing skills, resources, and infrastructure. However, they generate not only fewer jobs, but also fewer full-time, permanent ones than jeepneys and trimobiles do, and are more subject to the vicissitudes of weather, demand and operators with other primary occupations. The service that the skates and sleds provide is on the whole more limited in scope, and is more likely to be for personal use than in the case of the two other modes.

Household income seems to be a crucial factor in the demand for the acquisition of jeepneys and trimobles. Because the vehicles are expensive both current income, accrued savings and physical or commercial assets are important. Formal or informal credit may be required to supplement current income for the lumpy investment involved in jeepney or trimobile purchase and amortization. The institutional credit framework is a constraint on vehicle purchases. While trimobile makers extend short-term credit at no interest, this tends to tie down their usually limited working capital. Motor-cycle dealers and financing institutions provide credit, but at high interest rates, and require credit checks and collateral. The latter is usually the vehicle itself but may have to be farm land or a house if the borrower makes no down payment. The risk of foreclosure may be a strong disincentive in a rural setting where land is a precious possession and where share tenancy still seems to prevail despite its official disappearance.

Summary

This study is the only one to focus on for hire and reward transport services. It illustrates the evolution of these services in an area that has undergone significant changes in the scale and pattern of transport. The advancement of the motorized modes at the expense of skates and sleds is what might be expected. However it is noteworthy that the sled, a very simple but useful means of load carrying, remains important for private use by farmers. Of greater significance is the role played by the trimobile which, with its low capital cost and operational flexibility, offers a more extensive and dispersed service than the more conventional motor vehicle, the jeepney, but at competitive charges.

PART III — TRANSPORT POLICIES

CHAPTER 8

Transport in a Rural Community in Tanzania†

Introduction

The Ukinga area of Tanzania forms part of the Makete District which lies in the west of Tanzania. It is an isolated region and efforts to assist its development have been evidently hampered by the lack of transport. The terrain makes any kind of movement slow and expensive. Moreover, in a broader sense, Ukinga is located in a country beset by economic crises not least of which has been the escalating price of oil.

The study was initiated by a non-governmental organization. In defining measures to improve the transport system in the areas, they insisted on a low level approach using local resources. This type of approach they felt could be replicable and sustainable. They stressed the need to include all travel needs and the consideration of 'track' and 'vehicle' requirements as mutually dependent parts of the transport system.

The study, therefore, was more concerned with developing an approach to transport based on a qualitative assessment of the relationship between transport and development. It was carried out in 1981 by Ian Barwell and John Howe of Intermediate Technology Transport Ltd. Since the time of the study the Ukinga area has been formally integrated into the newly formed Makete District.

Background

The approach to the study was constrained by the fact that the field work had to be completed within a period of three weeks. It

†This chapter is based on a study carried out by I. Barwell and J. Howe for the Christian Council of Tanzania. At the time of the study T.Sh.9.2 (Tanzanian Shillings) = US$1.0.

was conditioned by the emphasis on identifying priorities for improvement to the transport system which were sensitive to the requirements of the local people, could be implemented and sustained at low-cost using local resources, and would complement improvements likely to be implemented by the Government.

The field survey therefore focused on:

1 a route characteristics inventory of the roads and tracks in the area;
2 information collection interviews with village groups, church and party representatives in most of the villages in the area;
3 discussions with many government, party, church, medical, education and other community representatives about the nature — magnitude, frequency, type of vehicle or other mode used — of travel needs and difficulties, and to cross-check information on the location of facilities, development prospects and priorities, and attitudes towards community-based initiatives.

The study area

Ukinga is an area in the Livingstone Mountains lying along the south-western border of Tanzania (Figure 8) adjacent to the northernmost shores of Lake Malawi. It lies to the south of the main trunk road — connecting Dar-es-Salaam to Mbeya and the Zambia border — from which it is separated by the almost sheer slope of the Rift Valley. A similar escarpment separates Ukinga from the fertile flat lands on the northern shores of Lake Malawi. On its north-eastern and eastern sides Ukinga merges slowly into the lower, flatter lands of the Njombe area.

Ukinga has a population of some 91,000. In accordance with the nation's policy of *ujamaa*, the vast majority of these people live in villages rather than in scattered houses. This means that there are often wide tracts of empty lands between villages. The population of Ukinga has been growing only very slowly, and much less than the national average of 2.6 per cent per annum. This is because of emigration of the young and the men from the area. The people of Ukinga have a good reputation as hard workers and find it reasonably easy to get work in other regional centres. One of the reasons for initiating the study was to try to accelerate economic and social development so as to put a brake on this process. There are no major towns in Ukinga and the whole of the population can be described as rural. The main population centres tend to be situated along the Njombe-Bulongwa road and include Tandala, Iwawa

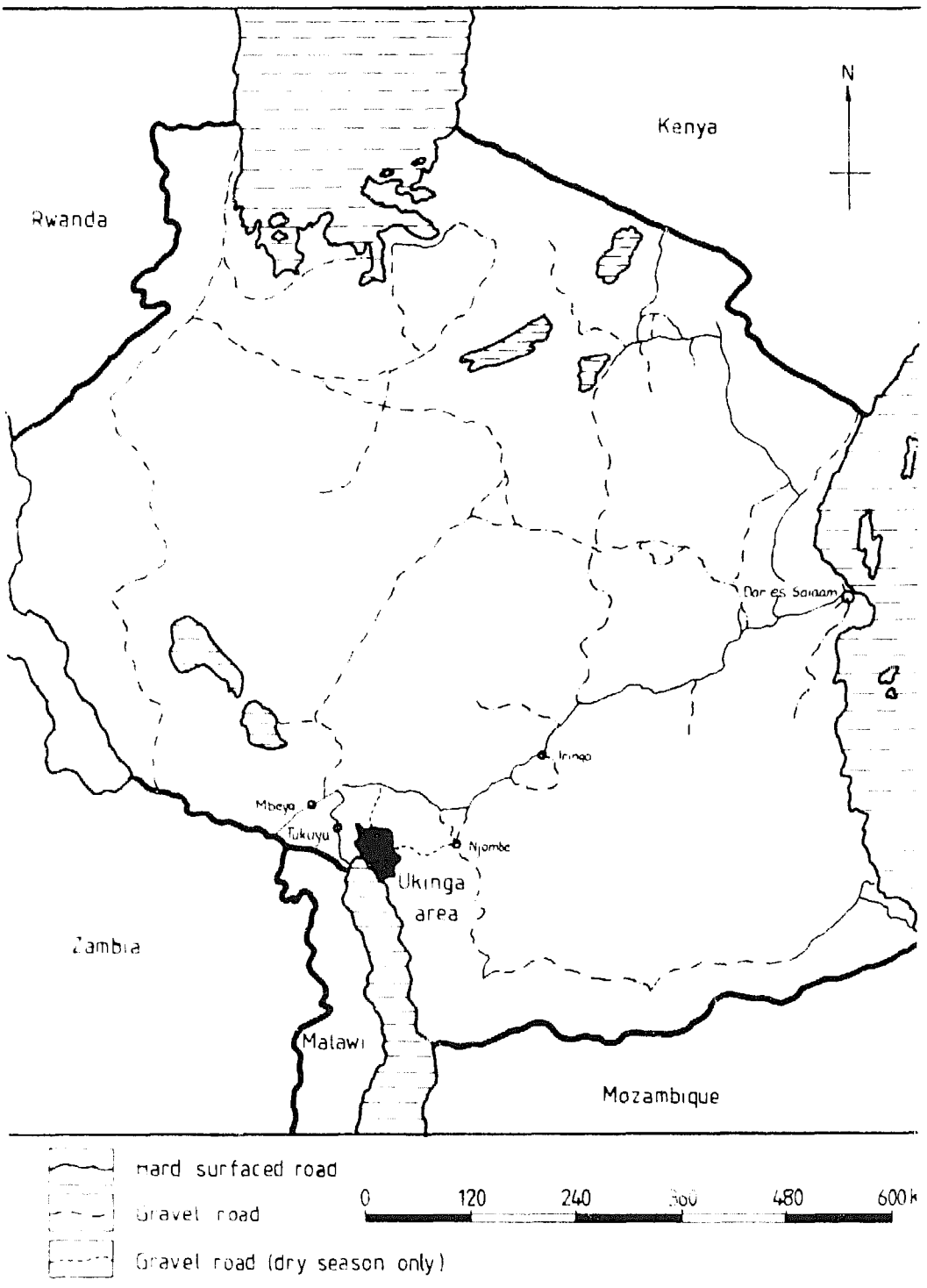

Fig. 8 *Tanzania*

and Bulongwa itself (Figure 9). There are hospitals near Tandala and Bulongwa.

Administratively Ukinga falls within the District of Makete which, in turn, is a part of Iringa Region. Ukinga is at the extreme western edge of the region and in the past has suffered by virtue of its location. Until 1979 it was part of Njombe District but in an attempt to speed up development and direct resources to Ukinga the separate District of Makete has been created, the headquarters of which are located at Iwawa.

The altitude of Ukinga, which varies from 1,500-2,200 metres above sea level (with the highest parts in the west, overlooking the Rift Valley) is a major determinant of the climate. The high temperatures which would be expected by virtue of its location at about 9° south of the Equator are modified to such an extent that Ukinga has a climate very similar to that of the world's temperate zones.

The long period of rainfall from November to May means that the predominantly earth-surfaced roads are often impassable for six months of the year. The muddy roads caused by the long rainy period (the rain tends to fall steadily over extended periods, rather than as short, sharp tropical rainstorms) are a major communications problem. It is extremely difficult for vehicles to pass unless they have 4-wheel-drive; it is, of course, equally difficult to use simple vehicles such as bicycles or handcarts.

Social and economic aspects

Ukinga's location caused it to be neglected by earlier authorities and this is reflected in the lack of facilities and infrastructure. There is nowhere locally to obtain capital equipment, spare parts or administrative material. Such items may be obtained either in Njombe or Iringa (about 300 km away).

Government facilities are being expanded but it will be some years before they are fully operational and able to play a dominant role in the development of the District. Private sector facilities are minimal. There are few shops or other services and only the most basic commodities can be bought. Crucially, there are no garages with repair facilities or fuel supplies, although the Government plans to build one to meet its own requirements and to provide a limited service to the private sector so as to cover running costs. The contribution of the church to development infrastructure — in the form of medical facilities, shops, mills and water and electricity projects, etc. — is important and likely to remain so.

Ukinga's lack of development infrastructure is exacerbated by its remoteness and the difficulty of any form of communication

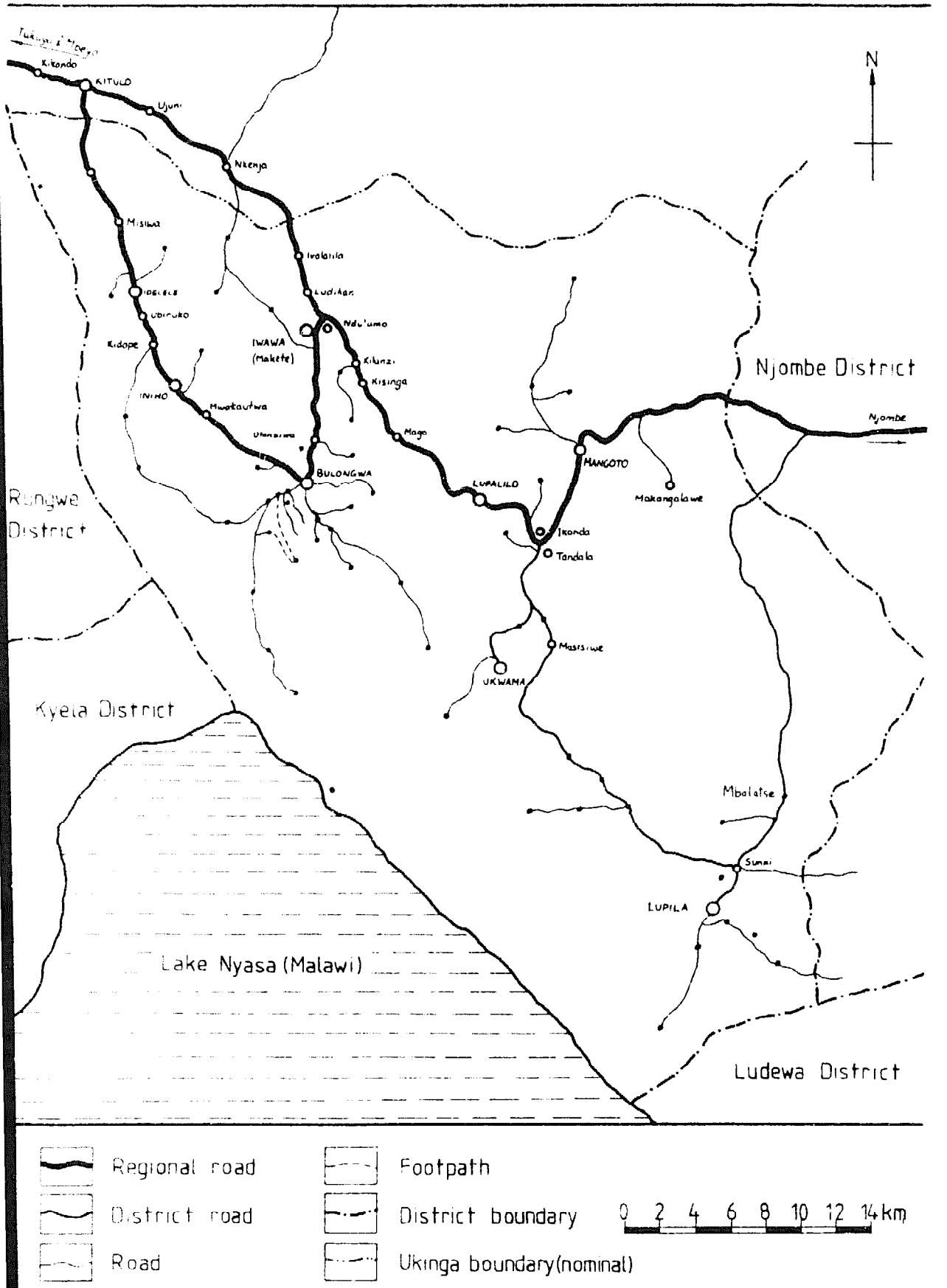

Fig. 9 *Ukinga Area (Makete District)*

with the outside world and within the District. It is about 100 km to Njombe — the former district centre which offers better private sector services than those available within Ukinga — by a predominantly dry season road. Bus services from Njombe to Ukinga are suspended in the wet season. Mbeya, the nearest regional centre, is about 90 km away, but the road is of a poorer standard than that to Njombe and there is no bus service at all. It is noteworthy that all manufactured goods, particularly building materials, have to come into Ukinga via the Njombe/Mbeya connections.

The Ukinga area does not have a telephone service and communication from Makete District to other parts of Tanzania is via the police radio network and limited to emergencies only. The effect of poor communications within the District is most evident in the concern of villages about access to hospital facilities at Bulongwa and Tandala. This consistently emerges as one of their major reasons for wishing to improve transport services. The mobile clinics are highly regarded and undoubtedly do valuable work, but the number of places served is limited and the service is frequently disrupted by the state of the road network. Villagers are forcible in expressing their need of quick access to a hospital in emergency situations.

The counterpart to Ukinga's lack of development infrastructure and remoteness is that it is an area of considerable economic potential. Because of its geography, the fertility of its soil and the hard-working and enterprising nature of its people, a wide range of temperate and tropical produce can be grown; the area is also suitable for sheep and cattle farming with associated wool and dairying activities. Pyrethrum is the only major cash commodity being actively developed. Under a World Bank project[1] improvements are to be carried out to about 50 km of Regional road and 10 km of District road in Northern Ukinga. The Tanganyika Pyrethrum Board (TPB) is to be provided with twelve 7-tonne trucks for transport from buying centres to main stores; five 4-wheel-drive station wagons to reach villages inaccessible by truck; and 21 motor cycles for TPB field staff.

There is said to be considerable scope for coffee in the areas aroung Ipelele, and some villages in the centre and extreme south of Ukinga. The first would benefit from the route improvements to be carried out on behalf of the TPB.

There is considerable scope for the export of food crops, but obstacles to this are typified by those with fruit and potatoes. The Ukinga area could produce considerable quantities of temperate fruits: apples, pears, peaches, etc. These are obviously perishable

and easily damaged, and the harvest period coincides with the rainy seasons when travel is most difficult. Proposals for a fruit cannery have been discussed but the difficulty is that, given the absence of other commodities suitable for canning, the plant will be idle most of the year rendering the investment uneconomic. Potatoes could also be grown on a large scale but, given their bulk and low value, they require a sophisticated marketing and transport system if they are to be exploited successfully.

Another feature of the agricultural economy is the role played by the villages in the south-west of Ukinga close to the escarpment. They are centres for the trade, via the escarpment of the Livingstone Mountains, with the villages of the Lake Malawi plain and Kyela District. Ukinga obtains rice, bananas, sugar cane, cassava, ground nuts, oranges and fish via Tukuyu. In return it trades wheat, potatoes, peas, beans, cow and dairy products. All of this trade is on foot with headloading as the only means of goods carriage.

The last feature of Ukinga's economy worthy of note is the range of skills to be found in such activities as carpentry, basket weaving and hoe handle and grass slasher manufacture, etc.

Transport in Ukinga

Very little of the economic potential of Ukinga is realized, to the detriment of its people and of Tanzania, since the area could make a contribution to reducing the country's existing food deficit. Undoubtedly, a major reason for this situation is the extremely poor state of Ukinga's transport system. It also greatly limits the extent and frequency of welfare and other services. Essentially there are two main problems: the scarcity of vehicles and the poor conditions of the roads.

Vehicles

With the exception of the limited deliveries to the regional and district trading shops, pyrethrum collections by the TPB, and the bus services from Njombe[2] which operate only in the dry season, Ukinga does not have any organized passenger or goods distribution services. The hiring of, or visits by, commercial vehicles from outside of Makete District are rare events. There are no locally owned and operated motor vehicle services available to the public except for those provided informally, and on a very limited basis, by the church. Because of the tough road conditions traders from outside Makete are unwilling to penetrate the area. Local vehicle ownership is virtually non-existent and appears constrained by a

combination of factors additional to the poor road conditions and lack of repair facilities and fuel supplies. Among these are the national shortage of motor vehicles, the difficulty of raising the necessary foreign exchange and the locally depressed economic conditions.

Motor vehicle imports are controlled by the State Motor Corporation and allocated to each Region by the central government. An allocation committee, under the Regional Development Director (RDD), decides the distribution of vehicles within each Region. The Iringa RDD stated that at the last meeting of his committee there were 300 applications for 35 vehicles. One of these vehicles was allocated to an individual from Makete because of the rarity of applications from the District and because it was felt that he would 'serve the people'.

Theoretically, the Government will give priority and assistance to the application of village groups for a vehicle, providing the villagers have first raised a proportion of the money required. In practice few seem able to do this because of the difficulty of turning surplus produce into cash.[3] Headloading and walking are the main means of movement. Journeys by these means to Tukuyu ($1\frac{1}{2}$ days), Mbeye (2-$2\frac{1}{2}$ days) and Njombe ($2\frac{1}{2}$-3 days) for special supplies, such as building materials, and to sell produce are not uncommon. Bicycle, handcart and wheelbarrow ownership are rare so movements around the farm and within the village also rely on headloading and walking (Plate 12).

Roads

The Regional, District, and Village road systems are as depicted in Figure 9. Whilst the alignment of most of the Regional road system is of a reasonable standard given the terrain, the surfacing renders travel difficult in the rainy season. The Regional class road from Bulongwa to Kitulo via Ipelele, and most of the District road system, is in a barely motorable condition and travel is slow, dangerous and very costly. Most of the surface is seriously eroded and much of the alignment substandard, being tortuous, narrow and with sections of gradient in excess of 15 per cent. This group of roads requires major engineering to re-align substandard sections and reconstruct the formation: drains, culverts and bridges also required reinstatement. The Village road system has been constructed almost entirely by voluntary labour and is a significant testimonial to the determination and enterprise of the Ukinga people. Notwithstanding this, the system is in poor condition. The roads have not been built according to basic engineering principles and few have any positive drainage. Many are narrow and unac-

ceptably steep. Most are unsurfaced and eroded (Plates 13, 14 and 15).

The lack of vehicles combined with the poor condition of the roads contributes significantly to Ukinga's social and economic problems. Church, health and school programmes are maintained only at great difficulty and expense, and services cannot be extended to all those that require them. Fruit rots on the trees and potatoes in the ground and stores. Many people are discouraged from producing more by the certain knowledge that the surplus cannot be sold.

Whilst it is considered important not to overemphasize the benefits, social and economic, that could be expected from improvements in Ukinga's transport, they are none the less real and it appears unlikely that they could be achieved by other means. It is possible to envisage non-transport ways of overcoming some of the current demands for movement, but they cannot be eliminated: some examples illustrate this.

The water supply project at Utengule will minimize personal movements associated with obtaining water for household and other community needs in the village. However, diesel fuel for the pumps will have to be brought in from Iwawa and headloaded down a steep valley to the pumping station. All building supplies for the project have been headloaded a distance of 8 km. In a similar way, the creation of more village health centres might reduce the need for the services of the mobile clinics. However, supplies would have to be delivered to the centres and seriously ill people will still need access to hospital. The latter will require adequate roads and vehicles to use them. More generally, a simple telecommunications network could greatly reduce the need for personal travel. Action in this sector is clearly a government prerogative and with all Makete's other development needs such a network seems unlikely to materialize for some years to come.

Improvements to the transport system in Ukinga

The deficiencies in Ukinga's transport are such that movement needs are only likely to be satisified by a package of improvements.

Essentially, four types of improvement are desirable:

1 Encourage the use of low-cost vehicles for the movement of loads around the village (firewood, water, manure, building materials, etc.) and, where appropriate, of produce to market. This will:

— allow substantially larger loads to be moved, compared with headloading, reduce the time and effort involved and stimulate marketing within the District;
— improve employment since there is potential within Ukinga for the use and local manufacture of several such vehicles.

2 Stimulate the local ownership and operation of goods/passenger-carrying motor vehicles. This will:
— assist the people of Ukinga to move their crops to the profitable markets of Mbeya and Njombe;
— improve personal mobility;
— assist the import of essential goods (e.g. building materials) into the District;
— improve access to local facilities.

3 Upgrade District and Regional class roads to improve all-year-round access. This will:
— permit all-year-round passenger and goods access from Njombe and Mbeya to the major centres of Ukinga;
— improve access for government, church, party and medical vehicles between major centres of Ukinga.

4 Upgrade Village class roads to improve all-year-round access. This will:
— improve access to government, party and church organizations and to medical facilities;
— in conjunction with 2, assist in movement of crops to profitable markets.

The four improvements are inter-related and to effect some and not others would reduce the benefits that could be expected. For example, the upgrading of a village road alone will be unlikely to have economic benefits unless the connection to a focus of activity is direct, or via District/Regional roads offering a similar level of access.

The benefits of locally owned and operated motor vehicles will obviously be greater if they are introduced together with improved feeder and main roads. (At present the benefits of locally owned motor vehicles are limited by the fact that access to many places is difficult or impossible in wet weather and because vehicle operating costs are high.) If Regional roads are improved, traders from surrounding Districts might travel into Ukinga to buy produce; the use of local vehicles will ensure:

— control over the marketing of produce, particularly its timing;
— that the profits from marketing are retained in the area;

— the availability of transport for the import of goods and for local welfare and social purposes.

The present District administration is young and still lacking essential facilities, services, personnel, materials and equipment. Because of financial and resource constraints, the role of the Regional and District authorities in implementing these improvements is likely to be limited to upgrading of the Regional and District class roads. The recurrent budget and resources available to the District Works Engineer are inadequate for other than limited maintenance to the District class road system.

Low-cost vehicles

The particular conditions of the Ukinga area — terrain, smallholder-based agriculture giving rise to relatively small consignment sizes, inadequacy of the transport system and the expense of providing for extensive movement by motor vehicle — make it a very suitable location for the use of low-cost vehicles. A great deal of time and effort is devoted to transport, especially if household requirements are taken into consideration. The most basic movement demands are the carriage of water and firewood to the village, sometimes from considerable distances and frequently over steep or broken terrain. Farmed land is often remote from the village and both inputs and outputs have to be moved between them. Cargoes are headloaded long distances up and down the escarpment: from Ukinga to Tukuyu, Mbeya and Njombe; and from the villages to major markets in Makete. Whatever is done to improve the road system and to make motor vehicles more widely available, it is apparent that much transport will continue to take place on the tracks and footpaths that criss-cross Ukinga.

Given the effort the people are prepared to put into carrying loads on their heads, there is potential for introducing non-mechanized vehicles to utilize this effort more efficiently and to reduce the time and the arduousness of this transport element. Since we are primarily concerned with low-cost vehicles for own-use by the poor, then cost, scarcity of fuel, complexity and the difficulty of obtaining spare parts all argue against mechanized transport. The existing use of non-mechanized vehicles in Ukinga supports this approach. Even in mountainous villages several bicycles are found in use. Whilst such a vehicle is not well suited to the terrain and few journeys can be accomplished without pushing the bicycle part of the way, its use clearly indicates that it is regarded by the people themselves as better than the alternatives: walking or headloading. Similarly, isolated examples of crude wheelbarrows of all-wood

construction are seen in Ukinga. Again their use, however inefficient, indicates they are preferred to the alternatives of human carriage. Neither bicycles nor efficient wheelbarrows are readily available in Njombe, Mbeya or Iringa, much less in Ukinga.

The use of animals removes, or reduces considerably, the human effort required to move loads. Substantial loads can be moved even across difficult terrain. It would be feasible for two persons to control a train of ten or more pack-carrying donkeys on any of the trading routes traversing the escarpment separating Ukinga from the Lake Malawi communities. Such a train could move substantially more than the humans involved: each animal, depending on breed and condition being capable of moving 3 to 6 times the weight to be carried by a human. The people of Ukinga are used to dealing with animals, but not with work animals, so a learning process would be involved in their introduction.

It is considered that there is potential within Ukinga for the use of several types of low-cost vehicles:

— *chee-geh* and shoulder pole;
— wheelbarrows and handcarts;
— animal transport (sledge, pack animal and cart);
— cycle panniers and trailers (including those for evacuating patients to hospital in the absence of motor transport).

Most of these vehicles could be manufactured locally, and indeed should be to ensure availability.

Local operation of motor vehicles

There are in Ukinga no locally owned and operated vehicles whose services the public can use. The reported hiring, by individuals in Ukinga, of vehicles from Njombe or Mbeya is unattractive because of the difficulty of arranging cargo in both directions with consequent increased hire costs. To overcome the difficulties this situation imposes, the introduction of a pilot vehicle hire scheme is proposed. This has both long and short-term objectives:

1 *long-term* — to improve the access of villagers to motor transport so that they can market their crops more effectively and obtain goods more easily which have to be purchased outside the Ukinga area.

2 *short-term* — to evaluate the demand for and viability of a commercial transport service;
— to demonstrate the viability to village groups, entrepreneurs and financing institutions.

Plate 13 *A major road in Makete*

Plate 14 *Many roads also act as rivers*

Plate 15 *The main access to a village*

It is recognized that such a scheme will be a risky venture since, with the terrain and road conditions, operating costs will be high. Also if the scheme fails it would be more difficult for anyone else to launch a similar venture. However, the potential returns are also very high. A sack of apples (80-100 kg) retails for T.Sh.150 in Bulongwa, but (headloaded) T.Sh.750 in Mbeya. Similarly, the respective prices for a bag of wheat are said to be T.Sh.250 and 600.

It is recommended that initially the service be confined to a single vehicle such as a long-wheel-base 4-wheel-drive pick-up or a 3-tonne pay-load light truck selected from a list of 12 makes to which the Government has announced future imports will be restricted. It is proposed that the vehicle should be operated on a fully commercial basis so as to cover costs, including allowances for maintenance and depreciation. Pricing of services might also be such as to generate a surplus for future expansion of the scheme if it should prove successful.

Upgrading village roads

Most villages in Ukinga are accessible by motor vehicles although the quality of the routes serving them vary from those giving access only with extreme difficulty to a few providing for near all-year-round movement. The majority of these routes have been constructed, and are maintained, by village self-help efforts. Few all-weather roads have resulted because of:

- lack of knowledge about the techniques of earth road construction and maintenance;
- inadequate provision of culverts and bridges;
- lack of suitable crushed rock or gravel surfaces in places where indigenous soils become easily waterlogged.

Village roads in the area are low on the Government's list of priorities. In the prevailing economic climate it is considered most unlikely that funds will become available for the maintenance of Village class roads. Consequently they are only likely to be improved if present self-help efforts can be redirected and made more effective in establishing and maintaining roads which can withstand the local climatic conditions.

The most important single requirement in upgrading existing village roads is to improve their drainage since the prevailing problems centre on the waterlogging or erosion of the surface due to the uncontrolled flow of water. More specifically, it will be necessary to provide:

1 all roads with a cambered running surface and side drains;
2 lead-off drains where appropriate;
3 culverts to conduct concentrated water flows across the road;
4 spot improvements on naturally water-logging soils and very steep gradients by provision of crushed rock or gravel surfaces;
5 protection measures in side and lead-off drains;
6 selected clearing of brush and trees from the roadside to permit the surface to dry out after periods of rain;
7 for the diversion, before the side or lead-off drains are reached, of potentially erosive water flows from footpaths crossing the road formation;
8 selected widening of the road formation particularly in mountainous areas;
9 selected re-alignment to reduce gradients or the length of route; and
10 safe bridges for major streams and rivers.

To achieve these objectives it will be necessary to educate villagers in improved methods of construction and maintenance, and in some cases to supplement their efforts by technical personnel skilled in the:

1 construction and maintenance of a good road formation comprising the running surface, side and lead-off drains;
2 execution of erosion protection measures;
3 widening and re-aligning of road sections;
4 construction of culverts and bridges; and
5 excavation and crushing of rock and gravel.

The majority of these technical personnel should be recruited from and trained in the Ukinga area.

The emphasis on re-directing village self-help efforts implies that upgrading will be by labour-based rather than the normal equipment-intensive method. Such a policy is eminently suited to local conditions because:

1 of the tradition of road construction and maintenance and the availability of labour;
2 of existing acute difficulties in obtaining construction plant, fuel and spare parts;
3 the terrain — most of the roads are in hilly or mountainous side-cut — will make the operation of bulldozers and graders hazardous and extremely expensive;

4 most of the direct benefits of the investment will stay in Ukinga in the form of wages rather then be exported immediately in the form of equipment purchases;
5 it should inculcate the necessary skills to enhance the standard of future road maintenance.

Any external assistance for the upgrading of village roads should be supplementary to, rather than a replacement for, the existing voluntary system. Thus, it is not proposed to pay village labour for road work other than in exceptional circumstances. The major reason for this is the need to safeguard the future maintenance of the upgraded roads without any external assistance. Experience elsewhere suggests that if villagers were to become accustomed to being paid for work on roads it is unlikely that the tradition of voluntary maintenance will survive. However, it would be necessary to pay skilled labour during their employment on the project.

To implement village roads upgrading programmes it is proposed to set up a unit which would operate a mobile team to provide technical support to villages in improving their roads. It is proposed that the Unit should enter into a covenant with village leaders, or the leaders of a group of villages as appropriate, for the upgrading of the road linking the village(s) to a market centre of the Regional/District road system. Under the terms of the covenant the Unit would undertake to:

1 plan the improvement of the route and conduct all necessary surveys;
2 provide an estimate of material and labour requirements;
3 train selected villagers — to act as local 'gang leaders' — in basic construction skills;
4 provide any specialized tools and equipment as necessary;
5 provide overall skilled supervision;
6 undertake and provide skilled labour for the more difficult operations such as surveying and setting-out, rock crushing, haulage of material, culvert and bridge construction;
7 provide rock and timber, if unavailable from village resources, and other non-local materials, e.g. cement, wire gabions, etc.

In return the village(s) would be required to provide free of charge:

1 the labour required for an agreed duration and starting time;
2 materials such as rock and timber for bridges/culverts, if feasible, from village resources; and
3 to give a guarantee for the road's subsequent maintenance.

Summary

This chapter is the only one in the book which presents a comprehensive programme to overcome the transport problems of a specific area. In fact, the proposals made are a practical reflection of the theme of the book. That is, that any proposal to improve transport in the rural areas must take into account the actual demand, the resources available and the sustainability of the actions proposed. Whilst more roads would indeed help the people of Ukinga, it is quite clear that the economic conditions in Tanzania will allow only a marginal increase in government expenditure for road construction. It is therefore important to look for alternatives which can complement the limited road network available. In the case of roadworks a scheme similar to the one proposed for the Ukinga area was operating very successfully in Afghanistan[4], illustrating that alternative approaches of this nature are certainly a feasible proposition.

Since the time of the study, both the Government and the donor community have shown great interest in this project. It is hoped that it will be implemented in the near future.

CHAPTER 9

Bangladesh Rural Transport Study†

Introduction

Rural transport facilities in Bangladesh are extremely poorly developed. The Planning Commission has estimated that 80 per cent of the 68,000 villages have no direct access to mechanized transport facilities.[1] For the major part of their travel the rural population rely on non-motorized means such as rickshaws, bullock carts, country boats, and bicycles. This study was initiated by the Government to investigate the present and likely future needs for rural transport. The distinctive feature of the study was its focus on the role and consequences of rural transport improvements in relation to rural development. In particular, the study was one of the few to have raised doubts about the causal relationship between transport and development.

A sample of five *thanas* (administrative units) was used, although certain biases relating to farm size and accessibility were included. In selecting the *thanas*, an attempt was made to take account of seasonal and geographical variations. The study was carried out between 1975 and 1977.

Background

The inspiration for this study came from two sources. The first of these was the Bangladesh Transport Survey completed in 1974. This concentrated on the main inter-district arterial transport system and its results incorporated numerous assumptions about the movement of goods in rural areas. There remained a need to investigate the transport of agricultural commodities from farm gate to primary and secondary markets: these movements occur

†This chapter is based on the study carried out by the Planning Commission of the Government of Bangladesh with advisory services from the Overseas Development Group of the University of East Anglia, United Kingdom.

before the arterial system is reached. Secondly, considerable rural development work has been carried out in Bangladesh since the early 1960s involving the introduction of irrigation, fertilizers and high-yield varieties of seeds, and resulting in a considerable increase in agricultural production. Consequently, there has been an increased demand for transport of both agricultural inputs, in the form of fertilizers and diesel oil for irrigation pumps, and of outputs as a result of a considerably increased volume of marketable surplus. In most development proposals and feasibility studies, it has been assumed that the existing rural transport systems can cope with this increased demand although little detailed information about these present systems is available. In particular, it is not known whether they are a real limitation to development efforts.

The study was devised to find out the present methods of rural transport, their costs, capacity to absorb the increased traffic consequent upon development programmes, variations within the country and between seasons in rural transport methods, and how the agricultural commodities get from the farm gate to the arterial transport system. The study also examined the movement of goods between farmers and traders and the extent to which rural transport is a constraint upon rural development. Two specific objectives of the study were to establish:

1 present and likely future methods of rural transport and how they might feed into the arterial network;
2 an appropriate methodology by which rural transport considerations can be included within overall rural development planning.

Study approach

Bangladesh exhibits considerable geographical and seasonal variations and the collection of information on rural production, consumption and transport to illustrate this variety would be nearly impossible. The approach used was to select five *thanas* (administrative units), from the 415 that comprise Bangladesh, as study areas (see Figure 10). The study areas chosen were selected to take account of the seasonal and geographic differences in Bangladesh and the different levels of rural development that are already found. In addition to normal base data collection, observations and interviews were conducted at a sample of the different 'levels' of rural markets; interviews were also conducted with a further sample of farmers.

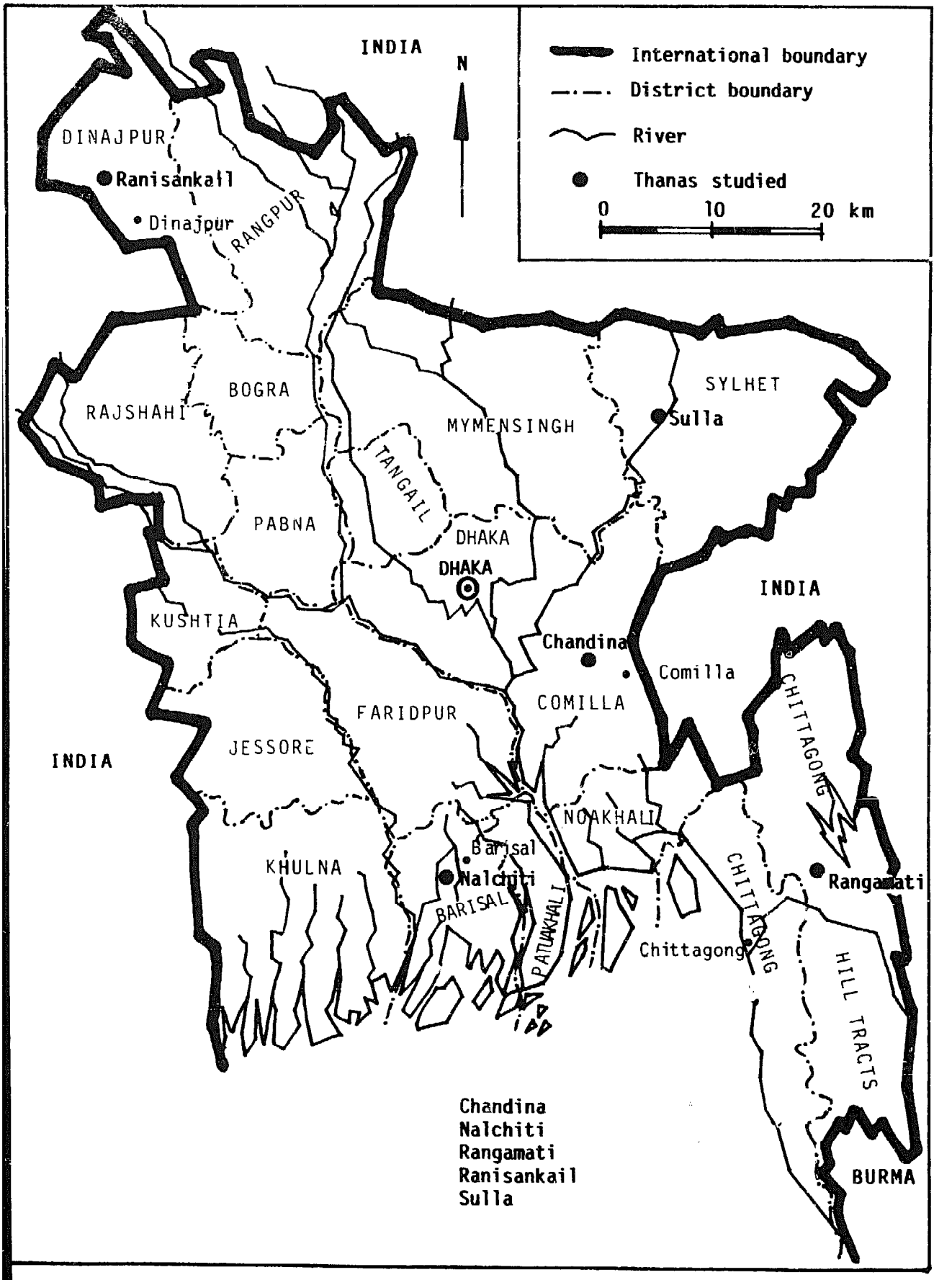

Fig. 10 *Location of Thanas studied*

The study methodology gave rise to two biases in the results. First, the size of the survey team itself led to transport and accommodation problems and this meant that only in exceptional circumstances was it possible to include areas of the country at considerable distances from main roads.[2] Second, the method of selecting farmers for interview also biased the results. The bias derived from the assumption that the surplus food in any area of Bangladesh is produced and marketed by the large farmers, and thus it is they that have the greatest call on the transport facilities in an area. It was, as a consequence of this assumption, thought important to ensure that a representative sample of these large farmers were selected. In the light of the material collected in the study it now appears that the small farmers, because they sell and buy paddy and rice, are also heavy utilizers of the transport facilities. Their vastly superior numbers means that a more representative sampling method would have been desirable. The deliberately biased sample taken of large farmers was made less representative by the method which had to be chosen to select the farmers to be interviewed in each size group. Because of the shortage of time it was not possible for the investigators to visit each farmer in his home. This would have involved long journeys, on foot in many cases. Rather the local Union[3] Council officers were notified in advance of the survey, its purpose and the desired nature of the sample of farmers. The farmers thus selected were asked to be available at the union headquarters on the appropriate day. This undoubtedly biased the sample towards the 'developed' farms and the larger ones in each size group. In the last *thana* to be studied the sampling frame was changed and in each union of the *thana* two villages were selected, one close to a main road and one more distant from good transport, and a 10 per cent sample of all farms within these villages was studied.

Findings of the study

The main points to emerge from the study can be summarized as follows:

1 The small farmers have a need for frequent marketing of small quantities of goods. This is reflected in the purchase of about as much rice or paddy as is sold and in the generally small loads carried to market by farmers over very short distances. These sales immediately after harvest are necessary partly to repay debts (see 6 below) and partly because of a lack of suitable storage (see 2 below).

2 A lack of suitable storage on farms and of credit for farmers are the main reasons why paddy has to be sold shortly after harvest rather than kept for use later in the year. In one of the study areas between 30 and 40 per cent of the paddy is sold within two weeks of harvest either to repay debts or because of lack of storage. Prices are lowest after harvest because of the resulting glut. Small farmers are particularly short of storage. Improving storage, perhaps on a village rather than a farm level, would reduce the necessity to buy and sell the same products at different times of the year. In one area, for example, the small farmers sell 17 per cent of their harvested paddy (mostly directly after the harvest) and they re-buy the equivalent of 26 per cent later in the year. Improved storage would also spread the sale of paddy over a longer period of time. Both these developments would reduce the strain on rural transport facilities available for producers who have a genuine surplus.

3 Dissatisfaction expressed with the state of transport in rural areas is, at least in part, a result of a lack of vehicles, especially country boats[14], which therefore ties the small farmer to the local market where he is in the hands of a very limited number of traders and receives a low price for his paddy (see 7 below and Table 41).

4 Fertilizer distribution benefits the large farmers. This is partly because access to the fertilizer supplies through the important markets is easier for the large farmer who has his own transport, and partly because the large farmer is financially in a better position to make the unofficial payments necessary to obtain these resources.

5 Access to irrigation pumps and irrigation water is similarly limited to the large farmers.

6 The role of traders in the marketing of rice and other products and in the provision of credit to farmers is of the greatest importance. Most farmers are in the hands of a very small number of traders when selling in the local markets. These traders advance money to buy inputs and food before harvest in return for a share of the paddy at harvest time. This share is 'bought' at a price that ensures a very high interest rate to the trader. Without this credit many farmers would be forced to sell their land or, if they are sharecroppers, to move to cities where ration supplies are more readily available, or to find work as labourers on farms or food-for-work programmes. Access to government credit is time-consuming and difficult. Credit agencies are often at a considerable distance and mak-

ing these journeys may absorb up to 25 per cent of the credit applied for.

7 Rice procurement favours the large farmers and traders. Access to the limited number of procurement centres is relatively easy for these groups and, because of their larger volume of rice for sale, also relatively cheaper. As long as rice marketing is tied to the provision of credit, the government rice procurement programme will have limited effects on the small farmers who are obliged to sell to the traders who provide the credit.

8 Production, storage, marketing and credit form a closely connected quartet and development work and investment should not consider one without an assessment of its impact on the other three.

9 Rural transport is difficult over much of Bangladesh but it does not at present provide the only constraint to agricultural development. The vast majority of Bangladeshi farmers cultivate very small acreages and the constraints limiting their increased production are associated with unequal access to resources (particularly credit and agriculture inputs) and tied marketing arrangements with traders where competition is limited. To improve rural transport alone in this situation is likely to provide greater advantages to the larger farmers and to the traders, both groups having their own transport (bullock carts and country boats). Transport development should be conceived as part of an overall rural development package aimed at improving conditions for small and large farmers.

10 Present rural transport is slow and labour-intensive but there are few commodities for which speed is essential, and rural labour supply is abundant and growing. Most transport infrastructure improvements, while providing employment during their construction, reduce the total labour requirements in the transport sector in the long run. Agricultural improvements of all sorts have in the past encouraged a concentration of land holding in fewer hands and an increase in the number of share-croppers and landless labourers. *Improvement of transport facilities alone is likely to accelerate this trend by providing further advantage to bigger farmers.* Transport demand is at present highly seasonal and the peak demands could be reduced and levelled out by improvements in credit and rural storage. Some paddy is sold at the same time as the sale of small amounts of perishable goods such as vegetables and eggs. However, if the need to sell crops, especially paddy, directly after harvest can be reduced through local storage

Table 41. Country Boat Ownership (%) in Relation to Size of Holding (ha)[1]

Survey area	Operational holding (ha)		
	0-1.6	1.6-4.0	+ 4.0
1	Little used except in some areas in the wet season only		
2	36	N/A	76
3	18	46	60
4	Little used anywhere in survey area		
5	55	75	95

[1] Ownership is not only a function of size of holding (wealth) but also of location. Bangladesh is subject to seasonal flooding. In some cases this is extreme and all land transport ceases for several months: boat ownership is virtually essential to survival; in other areas — for example, the north-west — little, if any, flooding occurs and land transport dominates. Many coastal and some inland areas of Bangladesh are only accessible by water.

and credit availability, the capacity of the existing rural transport facilities should, with some improvements, be adequate to cope with increased agricultural output. Small farmers rarely employ labour, relying on that of their families, and any reduction in marketing time would be a net gain to the productive employment of that family.

11 In areas where the cropping ratio is high and the scope for further increase in productivity is limited, the main need for improved speed of travel is for the movement of skilled and experienced manpower. Because, under existing arrangements, this is in short supply for health care, family planning, agricultural extension services, etc., the few people who are available have to be mobile and have quick access to rural areas. They cannot be based in dispersed locations without a substantial increase in their numbers. Thus, the movement of manpower into rural areas, rather than an improvement in the movement of goods out, may provide a justification for rural road construction and other transport improvements. In this case, the detailed priorities for road construction and improvement become fairly obvious: first, access to the *thana* headquarters or major population centre and from there, access into the interior of the *thana*, probably by means of a spine road or routeway more or less down the centre.

The study findings suggested that the transport of goods and freight does present a problem in the rural areas of Bangladesh. Nevertheless, they also reveal that the conventional response to this problem — the provision of transport infrastructure — may not be appropriate. In the first place, lack of transport is only one of a large range of obstacles that impeded development. Providing it will not, automatically, lead to development. Moreover, other solutions to the problems posed by lack of transport may be more cost-effective and may benefit a larger number of the population. The reallocation of services, the provision of storage for paddy, better credit facilities, access to simple vehicles would all help to solve problems which are presently seen to be the fault of transport. Unlike most of its predecessors, and many of its successors, this study did not assume that the solution to the lack of transport was necessarily the provision of roads. Indeed it suggested that there could be other, more cost-effective, ways of solving the problem. This naturally led to a reassessment of appraisal methodology.

In Bangladesh, as in many parts of the world, the assessment of the benefits of transport improvements has been based on the estimation of the savings to existing users of the transport facility and an allowance for the benefits generated by the investment. As far as user savings were concerned the levels of traffic were such that the benefits so derived were unlikely to justify anything but the most meagre investment. The study indicated that the most likely generated traffic benefits would result from an increase in agricultural production.

The evidence suggested that such effects were likely to be small. For most crops, transport costs represent only a small proportion of the market price. Therefore, reductions in transport costs alone would offer little incentive to increase production. Similarly, transport costs represent only a small part of the cost of farm inputs such as fertilizer (approximately 5 per cent for urea) and therefore transport cost reductions are unlikely to lead to significant increases in use of these inputs. Probably one of the few situations where transport improvements would have a dramatic effect on production would be where new land can be brought into cultivation or where the cropping ratio can be substantially improved. Such situations are rare in most parts of Bangladesh. Generally speaking, the benefits to generated traffic are likely to be fairly low and unlikely to significantly alter the conclusions reached on the basis of normal traffic unless other obstacles to increased output can be overcome.

The general conclusion therefore was that, whilst transport was

one of the constraints to development, large investments in transport *alone* could not be justified because:

— other constraints would still effectively limit development;
— road improvements would merely benefit the minority élite who were able to take advantage of the investment.

Summary

The study findings argued strongly for the assessment of alternative ways to solve the transport problem. In subsequent work, the Planning Commission has described one element which merits serious consideration — the local transport system. The study noted that one of the serious constraints was the lack of access to even the most simple vehicles. If attention were focused on this, the local transport system might be able to play its proper role as a complement to the national system. In Bangladesh, 50 per cent of the population are more than 10 km from the recognized transport network. Non-motorized transport, and in particular head and shoulder loading, dominates rural transport. In the riverine parts of the country, simple boats driven by oars and muscle power are the only means of transport. The Planning Commission has estimated that non-motorized transport accounts for more than half of freight and passenger movements in rural Bangladesh. As far as transport is concerned therefore, it would appear that investments in improving the quality of non-motorized vehicles would be equally profitable as investments in road improvements.

The work carried out by the Planning Commission and its advisers is of particular interest because it eschews the conventional formula that investments in rural transport will result in rural development. It accepts that transport is one of the constraints to development but must be viewed in conjunction with the other identified constraints. Equally transport is understood to have two distinct and complementary elements: the national system, upon which previous attention has been focused, and the local transport system, which has been generally ignored.

CHAPTER 10

Transport for Small Farmers in Kenya

Introduction

For the final case study we return to Kenya. Charles Kaira's study, described in Chapter 4, was concerned with a detailed comparison of transport patterns in two villages. This study is concerned more with general transport policy and how it affects small farmers.

In Kenya, there are over 1.5 million small farms, most of which are less than 5 ha. The study was carried out by John Howe as part of a general evaluation of how transport planning in Kenya affected these farmers. Whilst it is somewhat dated, having been carried out in 1976, it does provide a sound description of how transport constrains the development of small-farmer agriculture.

Background

The study is based on a short-term field investigation carried out in 1976. The investigation drew upon published statistics, data drawn from other studies and surveys, and information obtained from informal interviews with farmers, transporters, local government officials and other key informants.

Study findings

All small farmers in Kenya need transport for the production and marketing of crops and livestock, and household activities. However, the survey revealed a wide variety in the specific transport requirements of different farmers, depending on the crops grown, number of livestock owned, size of farms, distance to market outlets, and the range of inputs used. This variety is reflected in Table 42, which summarizes the findings regarding frequency of trips, trip purposes, typical loads, distances and pathway conditions associated with the different transport requirements. The figures suggest that most important needs can be characterized as the movement of small loads (10-150 kg units) over relatively short distances (1-25 km). On-farm the range of loads is likely to be the same, but the typical distances are shorter (1-13 km).

Table 42. Transport Requirements of Small Farmers

Group involved	*Trip purpose*	*Frequency*	*Load*	*Distance*	*Conditions*
All small farmers	On-farm transport connected with subsistence: transport of food products from plot to dwelling	Daily	Very small 10 kg	Very short 1 km	Off-road
All small farmers above subsistence level	On-farm transport connected with commercial farming: transport of products and inputs from fields to storage area	Follows agricultural schedule: varies with crops	Depends on yields, increases with acreage under cultivation or grazing	Increases with acreage: 1-2 km	Off-road
All small farmers	Gathering of water and fuel from areas near farm	Probably daily	50 kg water and 30 kg firewood	Depends on available supplies: 2-13 km quoted	Primarily off-road
All small farmers above subsistence level	Trips to local market: transport of surplus products from farm to market and purchased products back from market to farm	Daily, twice a week or weekly; depending on market schedule	Depends on yield, acreage, transport capacity: 15-150 kg	Up to 25 km: average 5-15 km	Part off-road, part on-road
All small farmers producing cotton, coffee, tea or pyrethrum	Transport of cash crops to collection points, depots or buying centres	Depends on harvesting schedule, perishability of product	Depends on yields, acreage, transport capacity	5-10 km average	Part off-road, part on-road
All small farmers producing milk, maize and food crops not sold at farmgate	Transport of surplus food products to collection points, depots, or cooling centres	Depends on harvesting schedule, perishability of product; daily for milk	Depends on yield, acreage, transport capacity	5-25 km average	Part off-road, part on-road
All small farmers using purchased inputs such as fertilizers, chemicals, special seeds	Transport of inputs from buying centre or stores	Follows agricultural schedule; varies with crops	Increases with acreage; minimum 50 kg bag	5-25 km average	Part off-road, part on-road
Most small farmers	Trips to major towns for special goods or services	Probably once a month on average	Usually small: 30 kg	Up to 50 km	Primarily on-road

On-farm transport

On-farm transport is required for a variety of tasks related to crop production and household needs. Movement of seeds, fodder, fertilizer and other inputs, as well as movement of harvested crops, is required each season as part of normal farming operations. Also, firewood and water must be gathered from areas surrounding the farm for the household. Since the farmer must follow a fairly rigid schedule to obtain desired yields, it is important that on-farm transport should not be so time-consuming as to delay important operations.

The degree to which on-farm transport becomes a bottleneck depends on the pool of labour available, the size of the fields and their position relative to dwellings and storage areas, and the abundance of supplies of water and fuel. Although traditional methods such as headloading and, in some areas, animals have been adequate in the past for on-farm movements, the introduction of new inputs and high-yielding seed varieties is beginning to strain the available transport capacity. While loads and distances are manageable for some tasks, such as milking cows or gathering food for meals, other on-farm transport tasks are very time-consuming, particularly the gathering of fuel and water. It has been estimated that women and children in the rural areas spend an average of three to six hours per day gathering water for home use. In cases where additional water is required for crop spraying or livestock, on-farm transport is even more burdensome and can contribute to lowered yields by interfering with the timeliness of farm operations, if headloading is the only form of movement.[1]

Transport of inputs to the farm

An important requirement of the farmer, related to crop production, is the transport of inputs from market outlets to the farm. The most important purchased inputs used on small farms in Kenya include fertilizer, insecticides for crops in storage and in the field, and seeds. Use of these purchased inputs has always been high in the large farm areas, but only recently have they been promoted among smallholders, and the distribution network is relatively thin and underdeveloped.

Of the two main distribution channels for inputs, the Kenya Farmers Association Limited (KFA) has the most comprehensive coverage. In the early 1970s, over half of total KFA sales went to smaller farmers. However, because of fixed margins for stockists, which do not include transport costs, smaller and less commercialized farmers in remote areas were effectively excluded from access to inputs sold by KFA agents. In response to the need of

some of these farmers, the co-operative movement began to play a role in input distribution through a new merchandising branch of the Kenya National Federation of Co-operatives (KNFC). Distances to KFA and co-operative stores generally range from 5-25 km on average, but there is considerable variation depending on the effectiveness of the distribution network in the area. The loads involved vary with the acreage of crops under cultivation. For some inputs such as fertilizer, however, a 50 kg bag is the minimum quantity available, and this is too heavy to be carried any distance by headloading. The problems small famers experience in obtaining inputs are therefore due in part to lack of appropriate transport alternatives as well as the limited network of KFA and KNFC distributors. These transport and distribution problems have had serious consequences in some areas; the failure to obtain needed inputs at the correct time has been an important factor holding down yields among smallholders.

Transport of outputs for marketing

Another important requirement for the smallholder is the transport of agricultural products to market for sale. The market outlets available to the small farmer in Kenya include local market places, itinerant traders, co-operative marketing societies, and official agents of statutory authorities such as the Maize and Produce Board.

As yields increase on existing farms, as new lands are opened up for cultivation, and as improved inputs are accepted by small farmers, transport requirements increase. A typical smallholder participating in the Integrated Agricultural Development Project is expected over a four-year period to increase his annual output from 5.5 tonnes to 12.6 tonnes. Most of the increase in production will be for sale and will require transport to a market outlet.

For major export and cash crops such as coffee, tea, passion fruit and pyrethrum, collection services are well organized by co-operatives and traders, and collection points in many areas are within a reasonable distance of the farmer. In tea growing areas, for example, roads constructed specifically to serve the tea industry allow efficient collection services which require farmers to travel no more than 5 km to collection points.

For farmers growing foodcrops however, few market outlets are available. Although the Maize and Produce Board has a number of agents who purchase produce on their behalf, there are too few of these agents to provide a marketing outlet within easy reach of most farmers. Co-operative collection services for minor food

crops such as pulses, potatoes, peas, sorghum and millet are virtually non-existent. Although there are over 200 multi-produce co-operative societies in Kenya which handle these food crops, many do not consider the provision of collection services to be one of their functions. Among those co-operatives who provide limited collection services, there seems to be a general lack of transport capacity and a shortage of buying centres.

For many small farmers growing foodcrops, then, the only market outlets available are the local market places and the private traders. Most local market places operate on a regular schedule and are within 5-15 km of small farmers. In areas where agricultural potential or population density is low, the farmer may have to travel longer distances to get to the market place. Although the aggregate amount traded in these market places is quite large, individual trading generally involves small amounts.

Farmers who produce a large surplus of food crops often sell to itinerant traders as well as in the market place. Since the traders operate pick-ups which can penetrate many areas, these farmers only have to transport their goods a short distance to the roadside. However, there are reports that prices offered by the traders are extremely low and many smallholders would like to seek other market outlets, but have no alternative transport. Farmers growing low-value, bulky, perishable foodcrops such as potatoes are particularly dependent on itinerant traders since they lack the transport capacity to carry large, heavy loads to the local market place for sale.

In the Meru and Embu regions, for example, problems with transport limited the cultivation of areas which had a high agricultural potential. The higher zones of the Meru region are among the most important potato producing areas of the country. Yields are very high (18-22.5 tonnes per ha) and a relatively small plot can be an excellent source of cash earnings. However, most of the potatoes are harvested over a relatively short period and, with no storage facilities, large quantities must be transported promptly to the market to avoid spoilage. Indeed, it is a matter of record that in most normal years the farmers have been dependent on traders who circulate among them offering low prices related more often to the farmers' transport difficulties than to actual values. For example, in one area it was reported that farmers were selling potatoes at the farmgate for K.Sh.25-40 per bag as against a selling price of as much as K.Sh.150-200 per bag, in the capital. As typical round-trip transportation costs from the area to the capital are no more than K.Sh.8-10 per bag, the income to the trader from sale of the produce is substantially higher than that to the farmer. How-

ever, it does relieve the farmer of the need to negotiate supply and delivery of the produce to buyers in the capital.

Limited milk production by smallholders is a common example of agricultural yields held back by transport constraints. Although the services collecting and transporting milk to the creameries appear to be efficient, movement of milk from the farms to collection points has proven to be a time-consuming activity which limits production in some regions (Nakuru, Kericho, Meru and Embu). Because there is a lack of cooling facilities on small farms, the milk must be transported daily by bicycle or by hand to the nearest collection point. Throughout Kenya, this lack of transportation and storage produces a pattern of selling only the morning milk, while the evening production is consumed at home, fed to calves, sold among any interested neighbours, or simply wasted. Officials estimate that in some areas as much as 10-30 per cent of the milk yield may be wasted. A serious constraint to increased production results since the farmer realizes that increasing overall yields will also raise the amount of evening milk for which he has no cash market. In certain areas the Agricultural Finance Corporation has established a maximum loan limit for dairy cows until the problem of collecting evening milk is resolved.

Transport modes used by Kenyan smallholders

A variety of transport methods are used by small farmers to meet their requirements. Headloading is by far the most common method, being used for on-farm transport, gathering of fuel and water, and trips to and from marketing outlets. Surveys some years ago showed that over 90 per cent of rural trips were on foot, 4 per cent by bicycle and just 2.5 per cent by motorized transport.[2,3] Wheelbarrows and animal-drawn carts or sledges are also used by some farmers for on-farm transport and gathering of water and fuel supplies, but only in a few areas are they common.

Transport by tractor and trailer is relatively rare in small farm areas. Tractor hire services provided by entrepreneurs and the Government are generally confined to ploughing, which is more profitable. The tractors available are mostly 50-60 hp units which have relatively limited transport capability despite their high power output.

Motorized road vehicles are available to small farmers in the form of buses, *matatus*, and small pick-up trucks available for hire. While buses and *matutus* are used widely by small farmers for longer trips, the pick-up trucks for hire provide services only indirectly through private traders and co-operative collection services. These entrepreneurial services are filling many of the

important transport needs of smallholders, but only for those located close to the main roads.

Costs and charges for transport

Table 43 gives a summary of estimated costs and charges of the different forms of transport used by farmers. Many of these figures must be treated with caution since the evidence upon which they are based is fragmentary. It is clear that for buses and *matatus* the unit cost is dependent upon the distance travelled: the shorter the distance, the higher the unit cost. Although some of the figures are imprecise, the main conclusions are fairly robust.

1 For short-distance trips, which are the norm for most smallholders, charges can exceed costs by a factor of 10 or more if bus, taxi, or ox-cart are used.
2 For short-distance trips, the cost of most primitive forms of transport — donkeys and headloading — is relatively very expensive. This is partly because of their slowness. However, costs of these modes are critically dependent upon the value assumed for operator time. A value of K.Sh.3 per day was used, which was the lowest quoted wage rate for rural labour.
3 For journeys from the roadside to market, *matatu* transport is probably the most expensive to the smallholder. It also appeared to be one of the most common.

Table 43. Summary of Rural Goods Transport Costs and Charges[1] (July 1976 prices)

Means of goods movement	*Cost K.Sh./tonne km*	*Charge K.Sh./tonne km*
Lorry	0.3	2
Bus	0.4-0.7	1-80
Matatu	0.5-0.6	1-100
Tractor and trailer	1.6.-6.0	2-13
Ox-cart (2 oxen)	0.8	2.3-13.9
Donkey	5.6	18-42
Bicycle	1.6	NA[2]
Headloading	17	31-63

[1] A range of values is given for costs because of uncertainty in the data and doubts about average load factors, availability of return loads etc. The range of values for charges is because rates are dictated by bargaining and what the market will bear. Usually charges are per bag, giving very high rates for short distances.

[2] Not operated for hire.

4 Ox-carts offer the potentially lowest cost of transport to the smallholder for on-farm and farm-to-roadside goods movement, although this is dependent upon the load factor assumed.

In considering these conclusions it is vital to bear in mind that of equal, if not more, importance to transport costs and charges are:

— the choice available to the farmer; and
— what he can afford to buy for himself where conventional services are not available.

If there is no sensible alternative, the fact that a particular mode of transport is costly is largely immaterial. In the study area, lorry services were uncommon because of the generally scattered and small consignments offered by smallholders. Buses were largely confined to the main roads and few tractors and ox-carts were engaged in transport for hire. This probably accounts for the high charges *matatus* were able to command: in many cases they were the only service available.

If conventional transport services are scarce or expensive, and the marketing and co-operative organizations are unable to organize collection and delivery for the smallholder, he must fend for himself. The critical factor in improving the transport available to the smallholder then becomes affordability. The very low unit costs of movement that lorries and pick-ups can achieve are immaterial to the farmer who cannot afford such vehicles. An ILO survey in 1972 showed that most smallholders' net incomes from farming were limited to K.Sh.4,000 or less.[4,5]

In general, expenditure on transport averaged 3 per cent of total expenditure and for the majority of small farmers this would amount to less than K.Sh.100/annum). These figures indicate that the purchase of the cheapest conventional motorized vehicle (pick-up, K.Sh.40,000) was beyond practical consideration. Even oxen (K.Sh.420-600 each), an ox-cart (K.Sh.1,000-1,500), a bicycle (K.Sh.850) or a wheelbarrow (K.Sh.300) would have represented a significant investment. At present levels of development simple vehicles may be the only means of transport the majority of smallholders can afford to own.

Summary

The survey indicated that transport is indeed a major problem for small farmers. Not, however, in the sense that would be immediately detectable by standard methods of economic appraisal. For, in fact, transport charges account for a very minor part of the sell-

ing price of crops. It is in its effect as an inhibitor that the lack of suitable transport is evident as a constraint to development of smallholder agriculture.

The forms of transport available to the small farmer are simple and low cost. They are also capable of carrying small loads over short distances. Policies in relation to agricultural production however tend to be in conflict with this type of transport. New varieties of seed and the attendant fertilizers imply increased transport demands. In general, the distribution system does not reach the small farmer and the inputs are packaged in such a way that they are too big to be transported by the means at his disposal. As far as outputs are concerned, the transport facilities for major export crops are available. However those for minor food crops such as potatoes, sorghum and millet are virtually non-existent. Many small farmers are therefore dependent on traders who can dictate the price.

PART IV — SUMMARY

CHAPTER 11

Conclusions and Policy Implications

The case studies have illustrated the argument set out in the Introduction that a local transport system exists; that in many communities it is thriving; that economic and social development could not take place without it; and, paradoxically, that it has been generally ignored by planners. This local transport system is complementary to the national one and takes over where the other leaves off. It seems clear that the local system merits a great deal more attention than it has been given hitherto. These studies are a first step in that direction.

Given the variety of climatic, social and political conditions encompassed by the studies, it is perhaps rather surprising that there is a considerable degree of commonality in their findings and that there are general conclusions to be drawn from them. In the following sections, we have attempted to identify the major findings and, in so doing, lay the basis for a reorientation in the approach to rural transport planning.

1 Access to the transport system

The fact that the majority of the rural population of developing countries do not have direct access to a recognizable road is a clear enough indication that transport planning has not been explicitly concerned with people and their transport needs. In the Philippines, for example, less than half the rural villages were said to have access to the road system. In Bangladesh the situation is worse with 80 per cent of the villages having no direct access to mechanized means of transport. Evidence from other sources shows that in India (1978) about 70 per cent of villages did not have all-weather road connections, and 55 per cent of villages were not connected to any type of road.[1] Also, in a comparatively wealthy country such as Egypt, 32 per cent of villages were connected to larger villages, and thence the road network, only by footpaths.[2] Although not quantified, lack of road access was

clearly a significant aspect of the studies in Nigeria, the Republic of Korea, Tanzania and Western Samoa. Moreover, it was clear from most of the studies that the majority of rural communities would, for the foreseeable future, be dependent upon footpaths and tracks, rather than engineered roads, for the bulk of their movement needs despite the best efforts of the respective governments to extend the road network.

The correlation between quality of route and the existence and reliability of public transport services (observed previously in the Philippines, Sierra Leone, Tunisia and India[3]) was confirmed by the study in Tanzania: for six months of the year (the rainy season) services simply cease. The evidence also suggests that the poor make only infrequent use of public transport services. In the Philippines, for example, the people using hire-and-reward passenger services have incomes at or about the median income level.[4]

The situation described above has not arisen, one should hasten to add, because of the callousness or insensitivity of planners. It is a natural result of an exaggerated concern with economic rather than socio-economic development. Thus, in Kenya, roads related to the exploitation of export crops are well established. On the other hand, roads serving small farmers working to sell surplus food crops were less well developed. In Tanzania, the perceived demand was for roads to exploit pyrethrum; the actual demand, as established by the study, included a real desire for better access to health facilities.

As many of the case studies show, the local transport system used by the majority of rural people is, of necessity, complementary to the 'national' transport system. It has not developed because of any rational planning. What is evident is that this part of the transport system is not well understood by government planners and their international advisers, whose perception of rural transport is exemplified by lorries laden with crops for sale and vehicles taking busy officials about their business. For the rural inhabitants, on the other hand, the local transport system is the means to simplify the attainment of basic needs such as food, clothing, shelter, education and health.

2 The characteristics of local level transport

The studies provide valuable information on the nature of local level transport in terms of travel demand patterns, vehicle ownership, modal distribution and frequency.

The studies show that it is important to differentiate between on-farm and off-farm transport. The former comprises movements related to domestic needs, such as water and firewood gathering,

smallholder cultivation, grazing of animals and transport of farm inputs and outputs. On-farm transport generally takes place away from a recognized road. Off-farm transport comprises trips to the market, to visit friends or to reach certain social amenities, for example, schools and health clinics. Off-farm transport relates more to the conventional perception of transport in that at least some of it takes place on a recognizable road and, sometimes, with a motorized vehicle.

2.1 The purpose of local level transport

Evaluation of rural transport is conventionally focused on off-farm transport and, in particular, on the increase in agricultural production that is produced by the construction or improvement of a road. The evaluation therefore assumes that rural transport demand is mainly related to agricultural production and that trips for agricultural purposes are predominant.

The studies reveal a somewhat different picture. In the first place, people in the rural areas are more mobile than has previously been assumed. The evidence from the studies suggests that each member of a rural household will make at least one and sometimes two recognizable journeys each day. Secondly, the studies show that trips related to the marketing of agricultural production are in the minority; an important minority indeed, but other trips make up the majority of rural transport.

Kaira's detailed analysis of local level transport in Kenya, for example, shows that only a minority of trips were related to shopping or marketing. Trips for leisure, for farming activities and for household tasks, such as water and wood collection, were of equal if not greater importance. In Nigeria, trips to the market represented less than 10 per cent of the total.

The Kenya study indicated that, apart from transport of farm products during harvest, it is water collection that poses the primary daily movement problem to the subsistence household. The majority of trips involving the carriage of a load are for water and wood collection. A recent study in Southern and East Africa confirmed that in an average family of six or seven, one person's sole job is to collect firewood.[5]

Long distance trips in Kenya were described as being 'compulsory' visits to facilities unavailable in the village, such as hospitals and shops. A World Bank study in Mexico[6] found that out-of-village trips were approximately evenly divided between work-related travel and general purpose (shopping/business/social) visits, though in the more remote areas work-related travel predominated. A village level study in Tanzania[7] described travel for

non-economic (social or medical) purposes as being 'relatively important' with familial ties providing the major reason for social trips.

2.2 *Length and loads transported*

Table 44 summarizes the data available from the studies. In general, the conclusion of the Kenyan study can be applied to all the studies. That is, the transport needs of the rural population can be characterized as the movement of small loads over relatively short distances.

Trips of less than 7 km comprise the majority in Kenya, Malaysia, India and Western Samoa. As one would expect, on-farm trips are generally short. However even in India, where 'on-farm' was understood as being within the community, the average trip distance was 1.5 km. Off-farm trips were generally longer but few were over 12 km long.

The evidence regarding the average size of loads is more limited but suggests that most trips are concerned with relatively small loads of between 25 and 50 kg. Other, indirect evidence from the studies seems to support this. Thus, even where crops are being transported, each household has relatively little to transport — 500 kg of each crop per year in Kenya. Again in Kenya, water and wood collection comprised a considerable proportion of the journeys made. These would generally amount to loads of 30-50 kg per trip.

2.3 *Modes of local transport*

The predominant means of transport in the rural areas of developing countries is on foot. Even in a country as relatively prosperous as Malaysia 70 per cent of all on-farm trips, 60 per cent of all school trips and 50 per cent of shopping trips were on foot. In Kenya, over 70 per cent of all trips were on foot. The same level can be deduced in India, where over 70 per cent of households do not own any form of transport.

Walking remains the major means of movement for short journeys, and for some longer ones, with loads carried on the head (Kenya, Tanzania), the back (Republic of Korea) and the shoulder (Malaysia). It is noteworthy how even very simple load-carrying devices, such as the *chee-geh*, have subtle design features adapted to local conditions. There are also, for example, a variety of versions of the shoulder pole, referred to in the Malaysian study, for different applications. The dimensions and material of the pole are usually such that it is flexible and moves in time with

Table 44. Length and Loads of Rural Transport

	Kenya	*Malaysia*	*India*	*Bangladesh*	*Western Samoa*	*Republic of Korea*
Typical distance of transport	90% of trips <7 km	75% of trips <7 km	90% of trips <5 km	Most trips <12 km	Most trips <5 km	Most trips 10 km
Average on-farm distance	0.8 km	1 km	1.5 km			
Average off-farm distance		10 km	8.3 km			
Loads transported	70% of trips <25 kg			Most trips <50 kg	Most trips <80 kg	30-80 kg

the carrier's walking rhythm, thus cushioning his shoulder from the load. There is limited evidence (Tanzania) of the use of wheelbarrows for load carrying. In China[8], wheelbarrows of a different configuration from that found elsewhere are used extensively for the movement of goods in rural areas.

The studies illustrate the widespread popularity of the bicycle throughout the developing world as a means of personal transport, and a load carrier. A variety of locally made attachments are fitted to bicycles to facilitate the carrying of different loads. The studies make limited mention, through the references to tricycles in Malaysia and pedal rickshaws in Bangladesh, of adaptations of the bicycle to increase its load carrying capacity. In China and Indonesia, the back wheels of the bicycle are strengthened to increase the load carrying capacity. In some French-speaking countries, two-wheeled trailers are commonly towed behind bicycles. This reflects practice in some parts of Europe, including Switzerland, where bicycle trailers are one of the methods used by the Post Office to deliver letters and parcels.

The studies illustrate the range of ways in which work animals can be used for transport — as pack animals (donkeys in Nigeria), to pull sledges (buffaloes in the Philippines) and to haul carts (bullocks in India). The use of animals for transport obviously complements agricultural practices based on the use of animal power. It is also worth noting that the consideration of animals for transport has generally developed as a by-product of the renewed interest in the use of animals in agriculture.

The Philippine study describes a low-cost motorized means of transport, the motor cycle and sidecar. In Malaysia, motorcycles are used to carry agricultural produce and the study proposes the use of trailers to increase their capacity. In Asian countries where two-wheeled (single axle) tractors have been adopted in agriculture, they are also widely used, with a trailer attached, for transport. In parts of Greece simple, low-cost three-wheeled diesel-engined vehicles have become popular amongst small-scale farmers.

The studies reflect the diversity of transport modes that exist in the developing world. Moreover, they indicate the extent of the use of low-cost forms of transport. This is the case in countries such as India, with low per capita incomes and very low motor vehicle ownership levels; in China which has adopted an official policy of emphasizing the use of non-motorized modes to meet local level rural transport needs; and even in petroleum producing and exporting countries such as Indonesia.[9] The popularity of these forms of transport results from the fact that they suit local

requirements and because, being low-cost, they are affordable. It is obvious that the purchase of a car or pick-up is quite beyond the means of most rural people in most developing countries. Low-cost vehicles are more widely affordable, and hence available. Personal ownership of a low-cost vehicle gives the user the capacity to meet a range of transport needs, and provides a degree of control which is not possible when he has to depend on a hire service. However, the benefits of low-cost vehicles are not restricted to those who own them. The Indian study illustrates the extent to which bullock carts are hired out to village people who do not own a cart, most commonly on a non-cash basis. The trimobiles in the Philippines offer a transport service which in terms of charges is at least competitive with the more conventional vehicles. Furthermore, trimobiles provide a more flexible, widely dispersed service, operating in areas where there are no jeepneys, because they can be used in poor route conditions. Being small and low-cost, they can operate profitably in areas where there is insufficient demand to justify using a jeepney.

Despite the extent of their use, low-cost forms of transport are largely ignored by conventional transport planning with its focus on the national system of engineered roads and conventional motor transport services. Low-cost vehicles lack official 'visibility' and are to a large extent excluded from vehicle statistics. Yet the clear implication from the case studies is that low-cost vehicles and the local transport system to which they belong must be an important element of any transport policy aimed at meeting the needs of rural communities.

2.4 Vehicle ownership

The studies emphasize the low levels of vehicle ownership, and several reported on the income constraints on people's ability both to purchase vehicles and to pay the fares charged by the transport services that were offered. The results from India confirmed earlier findings of the very low level of vehicle ownership. Some 74 per cent of households do not own any form of vehicle, with only some 17 and 9 per cent owning respectively an animal cart or bicycle. At the lowest levels of income, however, the studies show that it is the bicycle which most people would aspire to rather than animal carts. The study in Malaysia reported 13 per cent of households as owning no vehicle at all and a further 32 per cent as owning only a bicycle. In the Nigerian study 32 per cent of the households owned an animal used for transport, and 68 per cent a bicycle: only about 27 per cent of households had some form of motorized transport. Another Indian study indicated that nearly

40 per cent of rural households spend no money on travel or transport.[10]

Even where money is available to purchase motorized vehicles there are other constraints on their acquisition. In the Tanzanian study it was reported that there were more than eight applicants for every motor vehicle on offer. This is a notable example of what is becoming an increasingly common problem for many of the poorer developing countries: foreign exchange limitations on the supply of (imported) motor vehicles. The same constraint applies to the import of spare parts and fuel. The implication is that for these countries the development of efficient non-motorized means of movement that utilize, exclusively or mainly, indigenous resources will necessarily become a major priority.

The inability to obtain credit was, however, the most commonly noted constraint to the acquisition of any type of vehicle, motorized or non-motorized. The study in Kenya attributed the high proportion of second-hand and cash-purchased vehicles as being due to this factor. It is significant that in India well-intentioned government efforts to provide finance specifically for vehicle purchase were being frustrated by defective implementation, principally excessively bureaucratic procedures and indifferent loan administrators. A similar picture emerges from the study in Malaysia, although there had been some impact as far as the development of motor-cycle repair shops. In Nigeria, commercial loans were out of the question for small farmers and the government credit scheme was too limited and too restrictive. The implication here is not that credit schemes don't work. Rather they need to be more flexible to respond to the demand.

3 Towards a more rational approach

In the Introduction we suggested that this book served two main purposes. One was to improve understanding of rural transport needs, the second was to move towards the definition of practical policies to meet these needs. Naturally, these two objectives are inter-related — to develop effective policy one needs a clear definition of the transport demand. The studies go some way to providing this and the conclusions can be summarized as follows:

1 The majority of transport movements in the rural areas are unrelated to agricultural marketing and are made for a whole range of other activities.
2 For most small farmers, the major transport need is for efficient means of transporting small loads over relatively short distances.

3 Short-distance trips within and around the village or community make up the routine transport movements of rural households. Long-distance trips outside the community are much less frequent.
4 Trips for social and welfare activities are a significant proportion of these longer trips made outside the community. The siting of essential services thus influences the nature of rural transport.
5 There is a large range of low-cost means of transport. Many of them are specifically adapted to the locale where they exist. Equally, many of them could be adapted for use in other parts of the world. In nearly all cases, they could be improved. The existence of these means of transport is generally unrelated to the development of a conventional rural road network. It can, however, be argued that in some cases they have developed in response to the lack of conventional roads.

These conclusions seem to suggest that conventional transport planning does not fully address the scope of the problem. The planning and development of rural transport facilities is currently dominated by the provision of engineered roads. Rural transport is planned as if the end of a road into a rural area were the end of the transport system. The road element, however, is only one part of the transport system. Moreover, as the studies show, the majority of rural personal and goods movements do not take place on a road system in the generally accepted sense. Viewed from the perspective of the rural household, the road system is a long way down a transport chain that starts in their field and home. The local level transport system, with which they are familiar, is the other part of the system of which we know too little. Over the past years strenuous efforts have been made to expand the size of the rural road network. Special attention has been paid to reducing construction costs so as to make the money go further. In particular, it has been shown technically and economically feasible to construct roads using labour-based techniques thus reducing the cost and putting money into rural areas. There is no doubt that a more extensive rural road network would be beneficial to development in most developing countries. Nevertheless, the hard fact is that the resources available for the expansion and improvement of rural road networks are limited and in the current difficult economic situation, most governments find the greatest difficulty in maintaining the existing network.

The studies, themselves, particularly those in India and Nigeria, reflect the financial impracticability of providing road access to the mass of the rural population. If it is assumed, as has been the case

to date, that this is the only means by which local level transport can be improved, then, of course, the conclusion is a depressing one. If, on the other hand, it is recognized that conventional road transport is only the final link in the whole rural transport system, there is less reason for discouragement although present policies must be reoriented to incorporate the local level system.[11] There must necessarily be a move towards greater emphasis on socio-economic factors in transport appraisal and greater efforts to understand the nature of local level transport needs. Policies related to the local transport system could be defined so as to result in interventions that will bring about improvements in the level of the basic social and economic services of the community and/or region. These interventions should be low-cost and sustainable.

The conclusions imply that, if we are to address seriously the transport needs of the rural population, changes of attitude and of policy will be necessary. Perhaps the most fundamental change required is that footpaths and tracks and simple methods of movement are recognized as legitimate and essential elements of the rural transport system and equally worthy of attention as engineered roads and motor vehicles. The provision of rural transport facilities needs to be viewed in terms of overcoming the constraints and alleviating the problems faced by rural households. This also means that it will be necessary to place an economic value on improvements in the local transport system and that methodologies for doing this must be developed.[12, 13]

The starting point for the planning of rural transport improvements should be the analysis of specific local level movement needs at the rural household or community level. This analysis should not be restricted to the needs of agricultural production but should include the whole range of economic and social activities. Unless subsistence movement requirements are identified and plans made to meet them more efficiently than at present, there is likely to be a serious limitation to the contribution that some family members can make to productive farming and thus to the most likely source of future household wealth. Hitherto there have been few development programmes that have included an element of investment specifically for measures to reduce the drudgery associated with the movement element of subsistence tasks.

Analysis of the range of transport needs should lead to the identification, from a range of possible measures, of the most effective way of utilizing scarce resources to overcome critical transport constraints An important consideration would be the location and supply of social and welfare services which can signifi-

cantly influence the longer distance transport requirements of communities. The trade-offs between the cost of providing additional social/welfare facilities and that of moving community members to existing service points ought to be an inherent part of any local level development appraisal.

Present policies which emphasize the provision of infrastructure should be broadened to include the possibility of constructing and improving tracks and paths to allow the more efficient operation of low-cost means of transport. Such facilities lend themselves to construction and maintenance by local labour.

A crucial aspect of the more comprehensive approach outlined here is a greater public sector involvement in the vehicle element of rural transport. It may seem incongruous to suggest that the public sector, i.e. government, becomes involved in what is essentially a private sector activity. In terms of national development however such involvement could be quite rational. Previously governments (and aid agencies) have been concerned with investing public funds in road construction to facilitate social and economic development. What is suggested here is that it is in the public interest to facilitate the purchase and use of low-cost vehicles. There is at present no individual capacity in the rural areas to develop these low-cost modes of transport. It will be necessary therefore to promote the transfer of successful low-cost vehicle technologies between countries and, in some cases, even within the same country. Although such transfers do take place through the private sector, they are usually concerned with technologies that are relatively high cost and likely to attract the interest of organizations familiar with international practices and trading. Since many of the potentially most useful technologies are low-cost and offer more limited profit potential, they are most likely to appeal to the small businessman who, paradoxically, cannot be expected to discover and exploit them unaided. This is clearly a situation in which international development agencies and governments should intervene to demonstrate possibilities and thus stimulate local interest and manufacture.

The provision of technical and financial assistance for the local manufacture of efficient low-cost vehicles and of improved traditional devices is an obvious sphere of activity for government and aid agency-sponsored small industry support organizations.

Finally, but of crucial importance in facilitating widespread availability of low-cost vehicles, there is a need to establish innovative credit schemes that provide the modest amounts of finance needed for their purchase, on terms that do not preclude participation by small farmers.

4 Transport and development

The studies illustrate the important role of transport in rural life and in economic and social development. The Kenyan, Tanzanian and Samoan studies provide specific evidence of inadequate transport as a constraint on agricultural production and marketing and indicate how this problem becomes greater with the need to increase farm outputs. However, perhaps the most valuable aspect of the studies is that they show the important role of the local transport system in meeting the people's movement needs and how, for many communities, major transport constraints exist at the local level. The picture which the studies provide of the importance and nature of local level transport needs is very different from that implied by the structure and focus of past rural development investments with their emphasis on long-distance motorized means of movement.

The rationale for conventional rural transport planning is, and has been, economic. It would certainly be irresponsible to propose an alternative approach which was purely social in emphasis and which did not take account of the economic facts of life. It is our contention, however, that the approach outlined above does make economic sense. Improvements to the local transport system would not merely provide access to essential social services. They would also reduce the drudgery of, and the time spent on, basic domestic and farming activities. Consequently, more time and effort could be put into productive, income-generating activities. Moreover, the size of investments required to effect an increase in productivity and output would be relatively small compared with other infrastructure investments. More important, the investments would be more manageable and would be within the control of the people who would benefit from them.

Whilst the economic rationale for low-cost transport investments remains to be proven,[12] the indications from the studies are that a more rational approach to rural transport planning is not only socially desirable but economically viable.

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Chapter 2

1 N.S. Ramaswamy: *The Management of Animal Energy Resources and the Modernization of the Bullock-cart system* (Bangalore, Indian Institute of Management 1979).

2 The Government has initiated a Programme (Minimum Needs Plan) to progressively 'connect' villages by all-weather roads as follows:

— villages with 1,500+ population by 1990;
— villages with 1,000-1,500 population, 50 per cent connected by 1990; and
— 50 per cent of the above programme to be completed by 1985.

Such a programme would involve construction of nearly 250,000 km of road costing Rs34,000 million (US$3,500 million in 1978 prices) and in 1990 would still leave over 60 per cent of all villages, mainly those with less than 1,000 population, without an all-weather road connection. The connection of all villages would require construction of nearly 1.3 million km of road and cost Rs180,000 million (1978 prices) or approximately US$20 billion. (Source: Government of India, *Report of the National Transport Policy Committe*, May 1980.)

Chapter 3

1 The numbers of trips made for recreational/social purposes appear to be very low. However this is probably a result of the wording of the survey questionnaire. The relevant question referred specifically to trips to attend festivals or celebrations. No information was sought on other recreational trips.
2 From a literature survey of factors influencing agricultural outputs of Nigerian farmers, and from discussions with Government Agricultural Field Officers and a cross-section of the farmers before the questionnaires were actually prepared.

Chapter 4

1 Government of Kenya: *Development Plan 1979-84*, Parts I and II. (Nairobi, 1979).

Chapter 5

1 K.G. Wright: *Food Marketing within Western Samoa: The Primary Produce Component*, Economic Analysis and Planning Division working paper, (Department of Agriculture, 1976).
2 It is noteworthy that the bicycle is quite rare in the rural areas, and is certainly not the important means of rural transport that it is in many African and Asian countries. Typical travel distances are quite high, and the humid,

high-rainfall climate and undulating terrain in many rural areas are not conducive to cycling.

Chapter 6

1 Backloading devices however do exist in other mountainous areas of the world such as Switzerland and Nepal.
2 The staff is fundamental to one of the *chee-geh's* main features, its self-loading capability. The load that a person is physically capable of carrying on their head or back is much greater than can normally be lifted in position unaided. (On Asian construction sites where headloading in baskets, or metal pans, is the preferred method of moving sand, mortar, etc. it is normal to employ a loader). The staff enables the *chee-geh* to be propped up whilst it is loaded by the carrier who then 'climbs into' the shoulder harness and departs unaided. The staff is carried as a balancing aid and to enable the carrier to stop on route for a rest: the *chee-geh* is simply propped with the staff and the carrier can then 'climb out of' the harness.

Chapter 7

1 It is estimated, however, that per hectare yield has tripled in areas which have been provided with improved access and pump irrigation.
2 Depreciation costs for a trimobile costing P13,000 would be P7-9 per day, leaving P8-10 for maintenance, repair and taxes.
3 *National Transportation Planning Project: Interim Report on Southern Luzon*, (Manila, 1981).

Chapter 8

1 World Bank: *Staff Appraisal Report, Tanzania Pyrethrum Project*, (Washington, March 1980; mimeographed).
2 Twice a week to Lupila; four times a week to Bulongwa.
3 A group of villages south-west of Bulongwa have been saving to purchase a 7-ton truck. The contributions required are:

— Individual T.Sh. 150
— Village council T.Sh. 3,000
— School T.Sh. 500
— Church T.Sh. 250

Between one-third and one-half of the total cost of T.Sh.300,000 has to be saved before a loan can be raised through the Ministry of Rural Development. Another scheme has been initiated under the Ward Secretary in which Kijombo village is located. Individual contributions are just T.Shs.20, but only T.Shs.2,800 has been saved and morale is admitted to be low.

4 G. Glaister: 'The Self-help Approach, Afghanistan', in G.A. Edmonds and J.D.G.F. Howe (Eds.): *Roads and Resources: Appropriate Technology in Road Construction and Maintenance in Developing Countries*, (ILO, Geneva, 1980)

Chapter 9

1 Government of Bangladesh: Country Paper prepared for the ESCAP meeting on the improvement of non-motorized transport, (Bangkok, 8-14 March 1983.)
2 The biases this gives rise to have only recently been acknowledged and are eloquently described by R. Chambers 'Rural Poverty Unperceived: Problems and Remedies' in *World Development* 1980.
3 A 'union' is an administrative division of a *thana*.
4 These non-mechanized boats are the most important form of rural transport in riverine areas of the country.

Chapter 10

1 For example, 2-3 tonnes of water are required during the year to spray 0.5 ha of cotton — a formidable amount if headloading is used for transport.
2 Ministry of Transport and Communications: *Trends in Road Use in Kenya*, (Nairobi, July 1971)
3 This is supported by the evidence from Kaira's study in Chapter 4.
4 ILO: *Employment, Incomes and Equality in Kenya*, (Geneva, 1972).
5 This figure is dated, and does not give a complete picture because since that survey money earned by family members working in towns has become a significant element of rural household incomes. A more recent survey revealed an average total family income in the smallholder sector of K.Sh.5,000-7,000 (US$590-830).

Chapter 11

1 Report of the National Transport Planning Committee, Government of India, May 1980.
2 El-Hawary, M.A. and El-Reedy, T.Y. *Rural Roads and Poverty Alleviation in Egypt*, (Geneva, ILO, 1982).
3 Carapetis, S., Beenhakker, H.L. and Howe, J.D.G.F.: The Supply and Quality of Rural Transport Services: A Comparative Review. *World Bank Staff Working Papers No. 654*, Washington D.C., 1984.
4 *Philippine Islands Roads Feasibility Study: Final Report (general text)*, Ministry of Public Highways: (Manila, 1980)
5 Hall, D.D.: 'Biomass for Energy: Fuels Now and in the Future', in *Journal of the Royal Society of Arts*, July 1982. No. 5312, CXXX, page 457-471.
6 Cook, C.: *Rural Mobility and Communications in Mexico: Interim Report*, (Washington D.C., World Bank, March 1981 (mimeographed).
7 Van der Wees, G.: *Mobility, Transportation and Economic Development in Rural Areas of Developing Nations: Perspectives from Tanzania*, (Seattle, University of Washington, November 1978).
8 Bureau of Highways of Ministry of Communications. *China Non-Motorized Vehicles*, People's Republic of China, 1983.
9 Thorburn, C., Darrow, K. and Stannky, B.: *Teknologi Kampungan: A Collection of Indigenous Indonesian Technologies*, Appropriate Technology Project of Volunteers in Asia, June 1983.
10 Madhavan, S.: *Rural Transport in Karnataka with Special Reference to Kanakapura, Bangalore District, India*. Research Working Paper No. 7, School of Social Sciences and Business Studies, Polytechnic of Central London, July 1980.
11 Edmonds, G.A.: 'Towards More Rational Rural Road Transport Planning', in *International Labour Review*, (Geneva, ILO) Vol. 121, No. 1, Jan.-Feb. 1982.
12 Howe, J.D.: *A Conceptual Framework for Defining and Evaluating Improvement to Local Level Rural Transport in Developing Communities*, September 1983, (Geneva, mimeographed).
13 Kaira, C.: *Transportation Needs of the Rural Population in Developing Countries,* (Institut für Regionalwissenschaft de Universität Karlsruhe, April 1983).

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W. Owen, *Strategy for Mobility*. (Washington, DC, The Brookings Institution, 1964).
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W. Owen, *Distance and Development*. (Washington, DC, The Brookings Institution, 1968).
B.S. Hoyle (ed.), *Transport and Development*. (London, Macmillan, 1973).
R. Hofmeier, *Transport and Economic Development in Tanzania*. (Munchen, Weltforum Verlag, 1973).
World Bank, *Comparative Evaluation of Selected Highway Projects*, Operations Evaluation Department Report No. 349. (Washington, DC, 1974).
P. Blaikie, J. Cameron and D. Seddon, *The Effects of Roads in West Central Nepal*. (Overseas Development Group, University of East Anglia, 1977).
G. van der Wees, *Mobility, Transportation and Economic Development in Rural Areas of Developing Countries: Perspectives from Tanzania*. (Seattle, University of Washington, November 1978).
I.J. Barwell and J.D. Howe, *Appropriate Transport Facilities for the Rural Sector in Developing Countries*. (Vienna, UNIDO, and Geneva, ILO, 1979).
S. Madhavan, *Rural Transport in Karnataka with Special Reference to Kanakapura, Bangalore District, India*, Research Working Paper. (School of Social Sciences and Business Studies, Polytechnic of Central London, July 1980).
J. Bugnicourt et al., *Transports en Sursis?* (Enda Dakar, Senegal, March 1981).
C. Cook, *Rural Mobility and Communications in Mexico: Interim Report*, Transportation and Water Department. (Washington, DC, World Bank, March 1981).
World Bank, *The Road Maintenance Problem and International Assistance*. (Washington, DC, December 1981).
G.A. Edmonds and J.J. de Veen, *Road Maintenance: Options for*

Improvement. (Geneva, World Employment Programme, ILO, August 1982, mimeographed).
R.B. Ocampo, *Low-cost Transport in Asia: A Comparative Report on Five Cities*. (Ottawa, Canada, International Development Research Centre, 1982).
S. Carapetis, H.L. Beenhakker and J.D.G.F. Howe, The Supply and Quality of Rural Transport Services: A Comparative Review. *World Bank Staff Working Papers No. 654*, Washington, D.C., 1984.
I.J. Barwell, G.K. Hathway and J.D.G.F. Howe, *Guide to Low-cost Vehicles for Rural Communities in Developing Countries*. (Vienna, UNIDO, October 1982).
J.D.G.F. Howe, *A Conceptual Framework for Defining and Evaluating Improvement to Local Level Rural Transport in Developing Communities*. (Geneva, ILO, September 1983; mimeographed).
World Bank, *Transportation Sector Strategy Support Paper*. (Washington, DC, 1983).
J.D.G.F. Howe and P. Richards (eds.), *Rural Roads and Poverty Alleviation*. (London, I.T. Publications, 1984).

This book suggests that conventional rural transport planning has been almost exclusively concerned with motorised transport, and with roads designed for its use. Whilst this has no doubt resulted in more effective identification of rural road needs, it has ignored the local-level transport systems which provide the means of mobility and access for the mass of the rural population.

The nine case studies – from Malaysia, India, Nigeria, Kenya, Samoa, Korea, The Philippines, Tanzania and Bangladesh – deal with transport patterns, means and policies and provides a very different picture of rural transport. They show that mobility in the rural areas is provided by a wide range of low-cost forms of transport, and that 'the road' is already a long way down a transport chain which starts on the farm or smallholding. The writers have attempted to draw together the main elements of these case studies to suggest that there is a need to broaden the scope of rural transport planning to encompass the totality of transport demand. In this way, a more rational investment of resources could result in more productive uses of time and energy in the rural areas.

Ian Barwell and John Howe are Directors of Intermediate Technology Transport Ltd. Geoff Edmonds and Jan de Veen are employed by the International Labour Organisation to investigate and promote appropriate policies and approaches to rural transport.

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The Intermediate Technology Development Group was founded in 1965 by the late Dr E.F. Schumacher. The Group, an independent charity, helps to introduce technologies suitable for rural communities in developing countries. The Group is also active in assisting small-scale industry in the UK.

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Appropriate Technology in Rural Development: Vehicles Designed for On and Off Farm Operations

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Washington, DC 20433 USA

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Regional Development Unit
Transportation Department
World Bank
Washington, D.C. 20433
USA

April 1978

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April 1978

FOREWORD

While an increasing number of low standard rural access roads or feeder roads are being constructed in developing countries, little attention is being given to the type of vehicles best used on them. The absence of appropriate means of low cost rural transport is in many cases a constraint to development and forces farmers to rely on headloading or other equally expensive methods for transporting farm produce and inputs. While vehicles commonly used in industrialized countries may be suitable for long and medium haul transport on primary and secondary roads in developing countries, such vehicles are not particularly suited to short distance transport on low standard rural roads, due to size, heavy axle loads, and the low-volume transport requirements of rural communities. There is thus a need for vehicles which are not only within the means of the rural population, but are also well adapted to the kind of daily agricultural and transport tasks facing small farmers.

The Transportation Department is studying the transport needs of rural communities with a view to encourage the development and adoption of more appropriate vehicles for rural transport. As a first step, information on vehicles already produced and sold commercially throughout the world was collected as well as information on various prototype vehicles. Many of these vehicles are wholly or in part designed and constructed in developing countries and are making use of local resources and labor.

Since this information was collected with difficulty from many diverse and scattered sources, and much could be of interest to those concerned with rural development or rural transport, it has been compiled in this reference document.

Organization

The document consists of summary descriptions of vehicles. The vehicles range in level of sophistication from simple animal-drawn carts to small trucks able to carry several tons of goods. Many are not manufactured solely for road transport purposes, but may be used for farming applications as well. Also included are various types of small tractors which while primarily intended for agriculture may also serve as light transport vehicles.

Vehicles have been classified as follows:

NON-MOTORIZED VEHICLES

1. Animal or Motor Drawn Carts and Cart Assemblies

2. Pedal Vehicles

MOTORIZED VEHICLES

3. Transport Vehicles: On-Road Goods and People Carriers

4. Transport Vehicles: On/Off Road Goods and People Carriers (All Terrain Vehicles)

5. Multi-Purpose Vehicles (Agriculture and Basic Transport)

6. Farm Vehicles: Single Axle Tractors

7. Farm Vehicles: Three and Four Wheel Riding Tractors

8. Products of Local Ingenuity

Selection Criteria

The criteria used for determining which vehicles to include in the publication were: (i) relatively low purchase price, (ii) reasonably simple maintenance and repair requirements, (iii) satisfactory performance under varied temperature ranges as well as soil and climatic conditions, (iv) low fuel consumption, and (v) a wide range of transport and agriculture uses. All vehicles which, on the basis of information provided by manufacturers or designers, appeared to satisfy most of these criteria were included.

Some vehicles were both designed and manufactured in developing countries. Others were designed for use in developing countries but manufactured elsewhere. Still others were judged appropriate for use in the developing world while not actually designed with this purpose in mind.

Information supplied by the manufacturers on particular vehicles has not been verified by the World Bank. Those wishing further information on particular vehicles should contact the manufacturer directly. Prices have been listed (when available) in US dollars, and vehicle specifications in metric units. Export prices may change as a function of both real changes in purchase prices and fluctuating exchange rates. Also, delivered prices will depend on local taxes, customs duty, cost of freight, etc.

This initial survey is by no means exhaustive or complete. It is quite likely that many vehicles which should be included in a publication of this sort are not, due to lack of relevant information. It will therefore be greatly appreciated if readers who know of other suitable transport or

farm vehicles would complete the summary forms at the back of this document and return them to:

Regional Development Unit
Transportation Department
World Bank
Washington, D.C. 20433
USA

Information on field testing or actual experience will also be helpful.

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NON-MOTORIZED VEHICLES

1. ANIMAL OR MOTOR DRAWN CARTS AND CART ASSEMBLIES

Six carts are described in this section; four are designed for use with draught animals and two may be pulled either by a draught animal or motorized vehicle. In addition, one manufacturer supplies pneumatic wheel assemblies and brakes for use with carts of any design.

Two of the manufacturers market fully assembled carts in the price range of US$191-795. A third manufacturer sells carts in kit form (US$903) which can be constructed using simple tools and a welding set. The remaining three carts are designed for construction in developing countries using local labor and resources. Plans and descriptions of required materials are available.

SISCOMA's Animal-Drawn Carts

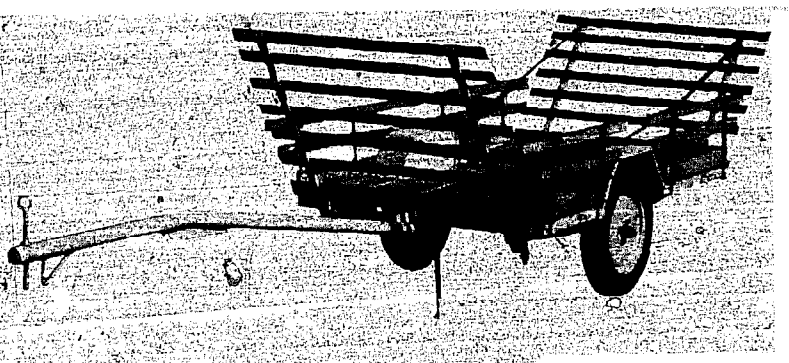

SISCOMA
BP 3214
Dakar
Senegal
Telephone: 223-75
Telex: 585 "SISCOMA-DAKAR"

Description:

Donkey Cart

- Full square axle (35 x 35 mm) in A.60 steel.
- 1 set of two tapered roller bearings on each spindle.
- Useful load of 400 to 500 kg.
- Pneumatic tires for on-farm use (135 x 13).
- Floor dimensions 1600 x 920 mm.

Horse Cart

- Full square axle (40 x 40 mm) in A.60 steel.
- 1 set of two tapered roller bearings on each spindle.
- Useful load 1000 kg.
- Equipped with 2 harness shafts.
- Pneumatic tires for on-farm use (165 x 14 or 155 x 15).
- Floor dimensions 2000 x 1150 mm.

Ox Cart

- Full square axle (45 x 45 mm) in A.60 steel.
- 1 set of 2 tapered roller bearings on each spindle.
- Useful load of 1500 to 1700 kg.
- Equipped with a central harness pole.
- Floor dimensions 2490 x 1500 mm.
- Choice of flooring in either wood or sheet metal.
- Pneumatic tires for on-farm use (185 x 14 or 600 x 19).

Ferlo Type Ox Cart for Forage

- Full square axle (45 x 45 mm) in A.60 steel.
- 1 set of 2 tapered roller bearings on each spindle.
- Useful load 1500 to 1700 kg.
- Floor dimensions 2500 x 1500 mm.
- Equipped with high sides.
- Pneumatic tires for on-farm use (185 x 14 or 600 x 19).

Mouride Type Two Axle Cart

- Swivel front axle.
- Full square rear axle (45 x 45 mm) in A 60 steel.
- 1 set of 2 tapered roller bearings on each spindle.
- Useful load 1500 to 1700 kg.
- Floor dimensions 2490 x 1500 mm.
- Pneumatic tires for on-farm use (185 x 14 or 600 x 19).

Comments on Maintenance, Productivity, "Appropriateness," etc.: These various models have been manufactured since 1961; designed cooperatively through collaboration with Senegal's Department of Agriculture and the farmers themselves, tested by the Machinery Division of the National Agricultural Research Center at Bambey; the cart's hub and bearing assembly is attached to the axle by means of a pinned castle nut and is sealed with a dust-proof cover; exported to several West African countries; specific modifications to the basic models have been made at the customer's request in order to adapt them to local needs; also, some models can be modified for hitching to a small tractor.

Cost and Present Status (as of 10/25/77):

	Ex-Factory price, net of tax and duty
Donkey Cart	US$191
Horse Cart	US$234
Ox Cart	US$369
Ferlo Type Ox Cart	US$641
Mouride Type Two Axle Cart	US$795

Total production of all kinds of carts for 1977/78 - approximately 20,000 units.

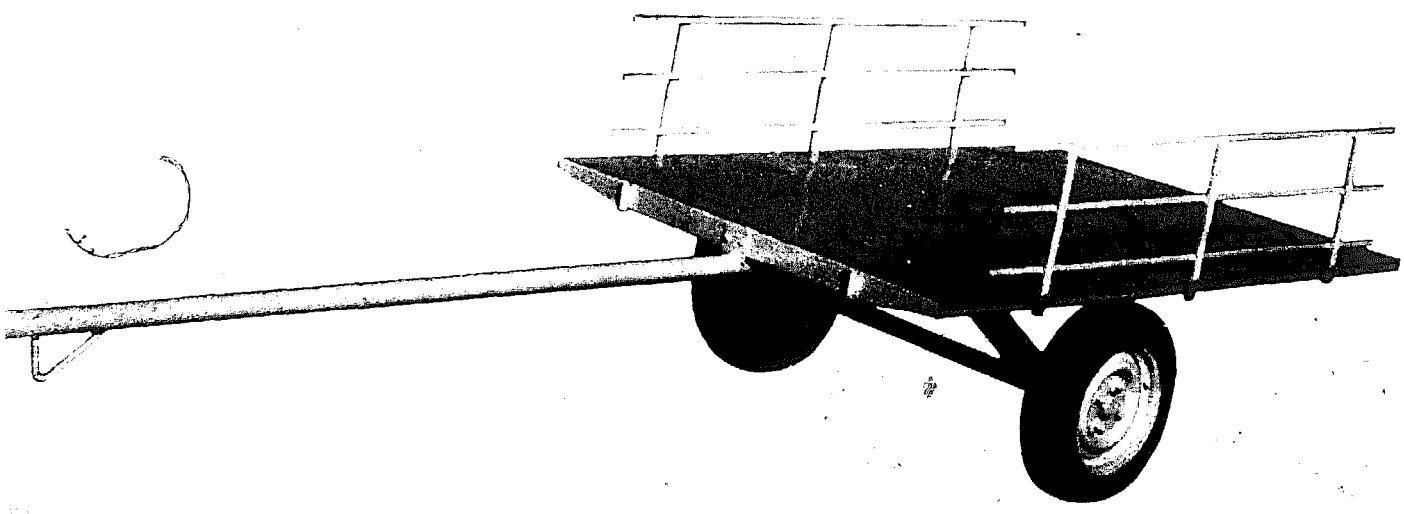

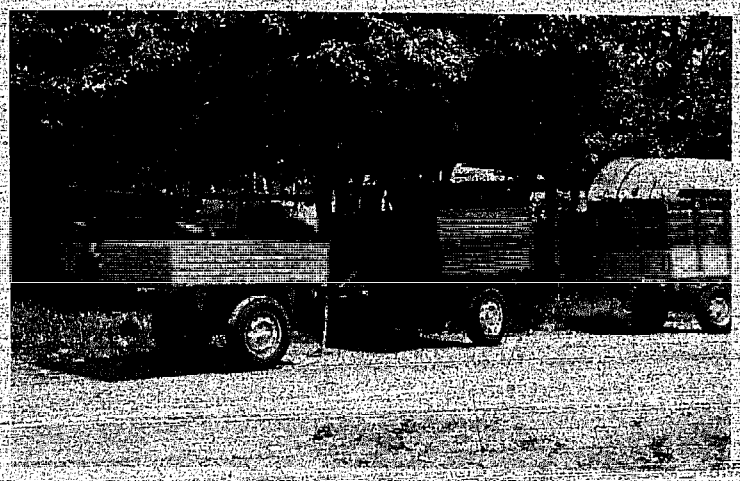

Trailers ALAS

Industrias Alas Ltda.
Cra. 3 Oeste #4-50
Barrio El Penon
Cali
Colombia, S.A.
Telephone: 861323-731397-731061

Description: A light trailer designed for heavy work on village roads; built with pressed sheet metal; heavy duty suspension.

Specifications

weight	- 131 kg
length	- 1.45 m
width	- 1.3 m
height	- 1.0 m
wheel base	- 1.1 m
ground clearance	- .27 m
payload	- 500 kg

Comments on Maintenance, Productivity, "Appropriateness," etc: May be pulled either by engine power or animal power; maintenance consists of periodically oiling the wheel bearings; appropriate for many types of hauling; expected life is five years.

Cost and Present Status (as of 2/20/78):

Trailer	US$750.00
Draft Horse Shaft	70.15
Jib for the Draft Horse Shaft	23.98

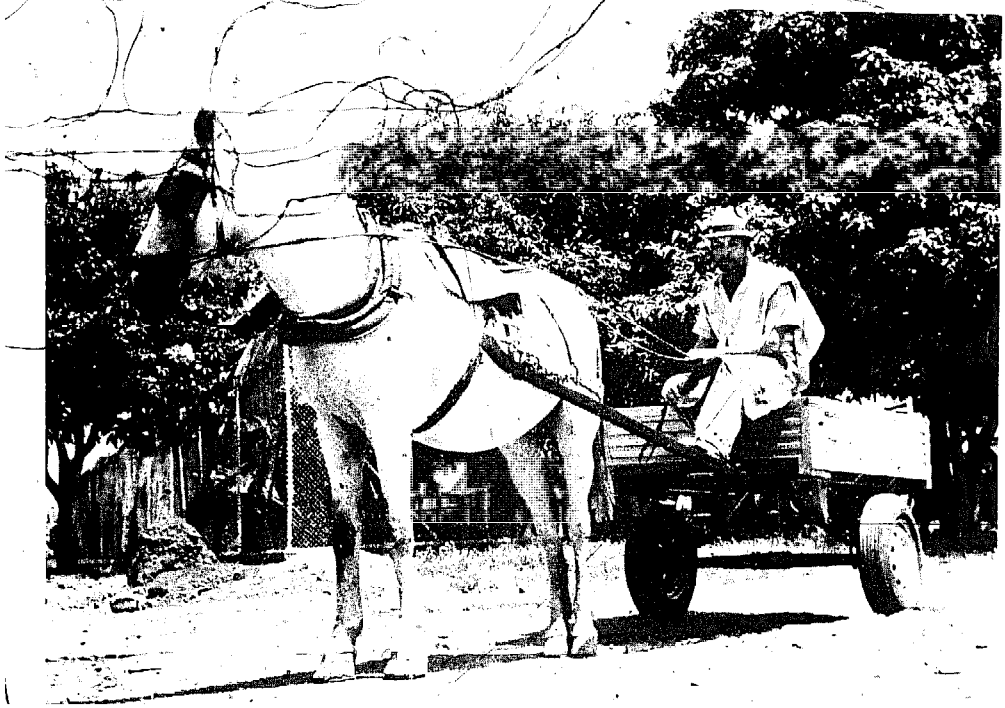

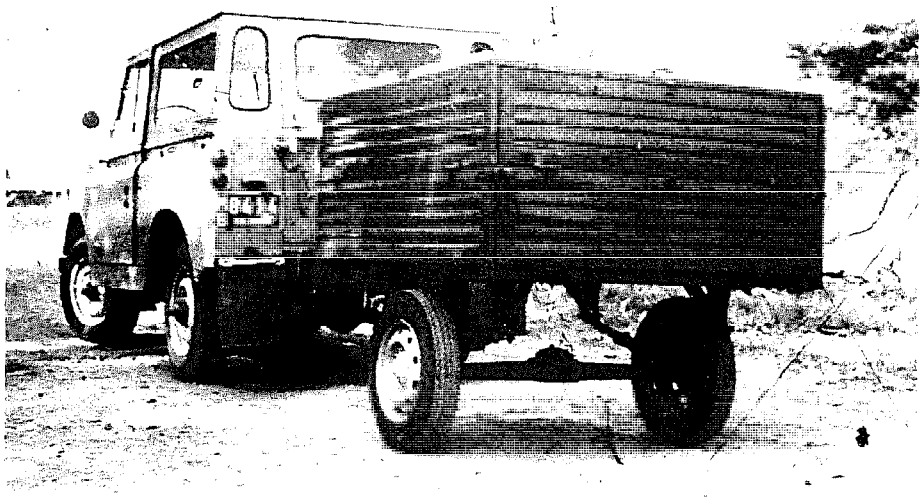

Kit Trailer # 35NTW

Weeks Trailers Ltd.
Ferry Road
Hessle
North Humberside HU13 ODZ
England
Telephone: 0482 - 649171
Telex:: 52612
Cable: 'Weeks' Hull.

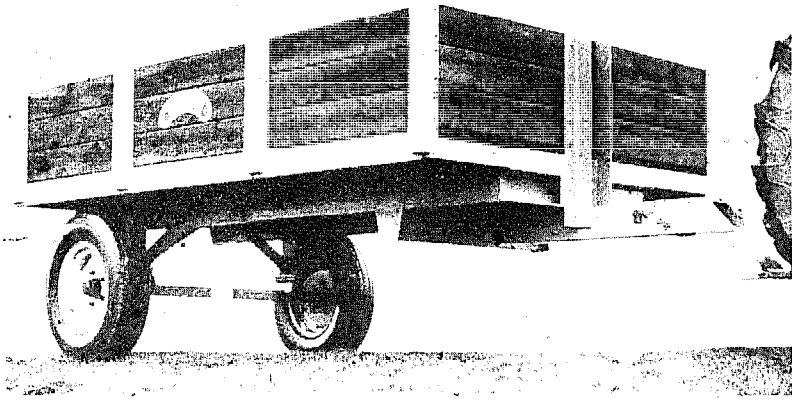

Description: Agricultural trailer which utilizes the packing case as the trailer's body and uses local labor in assembly.

Specifications

weight	-	600 kg
overall length	-	4.16 m
width	-	1.83 m
ground clearance	-	.33 m to axle and towing hitch level
height of trailer sides	-	.45 m
payload capacity	-	3,500 kg

Comments on Maintenance, Productivity, "Appropriateness," etc.: Kit trailer is especially designed for assembly using local labor; because of 'easy stage' construction method, only simple hand tools and welding set are required; used in over 40 countries.

Cost and Present Status (as of 2/17/78): US$ 903 net F.O.B. U.K. Port

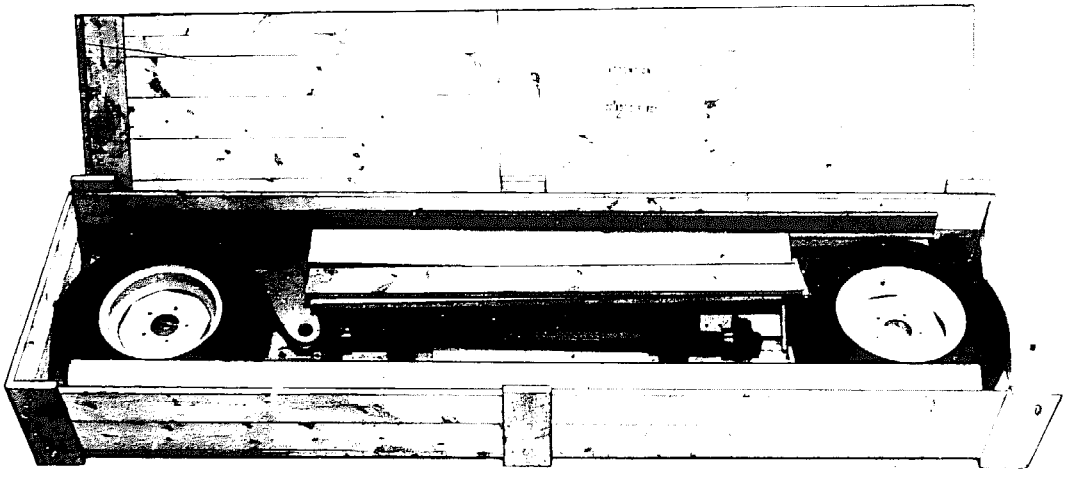

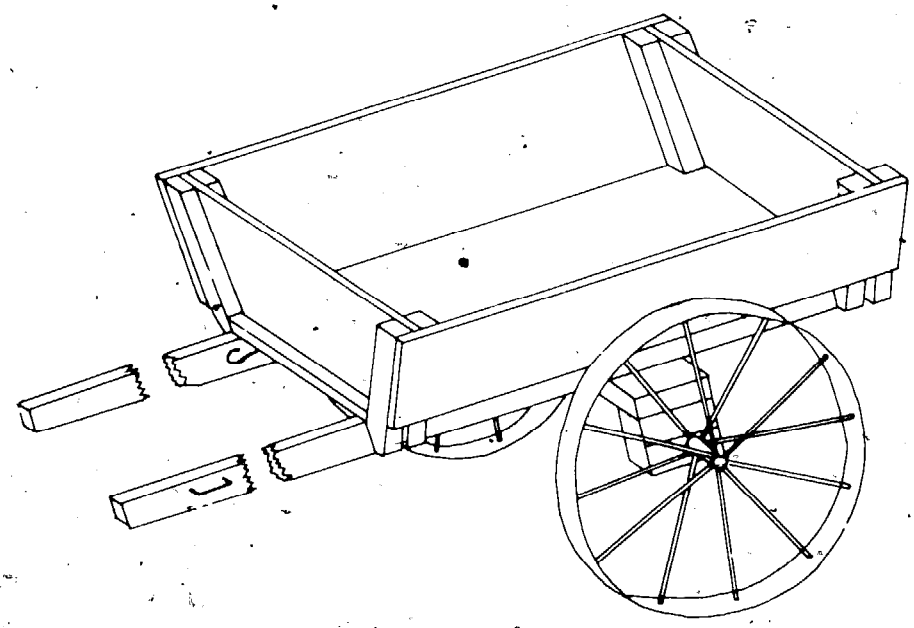

Cart (for one draught animal)

Intermediate Technology
Publications Ltd.
9 King Street
London WC2E 8HN,
England
Telephone: 01-836-6379

Description: Pulled by a single ox or donkey; payload-318 kg; the wood-block axle bearings fitted underneath the cart body are oil-impregnated by soaking in hot oil before drilling and assembly; the front and back boards of the cart body are removable; the cart shafts can be made of tubular metal pipe instead of timber if extra-strength is found necessary.

Comments on Maintenance, Productivity, "Appropriateness," etc.: Designed for local construction.

Cost and Present Status (as of 7/77): Developed by J. Wirth, engineer at TAMTU (Tanzania Agricultural Machinery Testing Unit), Tanzania; more complete drawings and description of the materials required can be obtained from Intermediate Technology Publications Ltd.

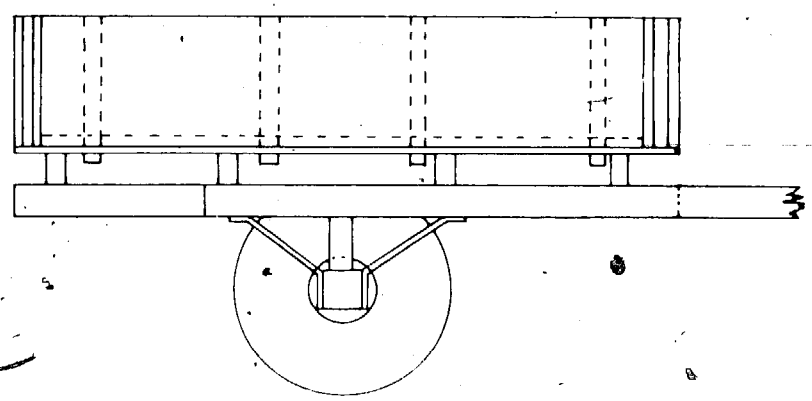

Ox-Cart (using old car wheels)

Intermediate Technology
Publications Ltd.
9 King Street
London WC2E 8HN,
England
Telephone: 01-836-6379

Description: Pulled by two-oxen; this cart makes use of the front wheels from an old car or lorry; the wheel mountings are welded on to a box-section axle, fabricated from angle iron; (a car rear axle, complete with differential can be used, but this would add unnecessary bulk and weight to the cart); this cart chassis and body are constructed of wood and all parts are bolted together; the body side and end boards are made of planks 19 mm in thickness, and are detachable.

Comments on Maintenance, Productivity, "Appropriateness," etc.: Designed for local construction.

Cost and Present Status (as of 7/77): Developed by Rev. L. H. Robertson, Mlanje, Malawi; more complete drawings and description of the materials required can be obtained from Intermediate Technology Publications Ltd.

Wananchi Ox-Cart

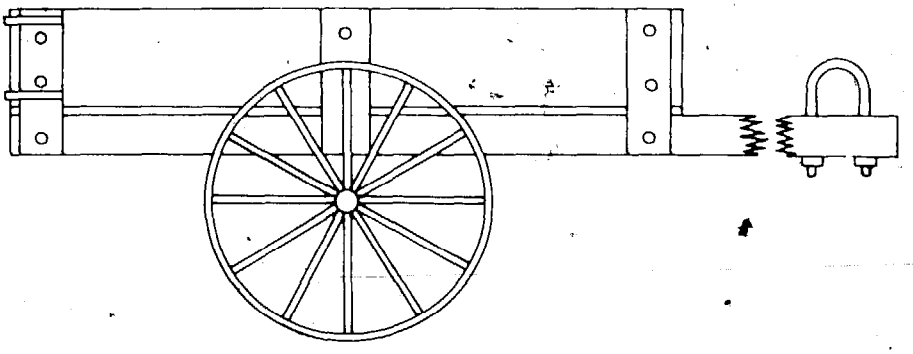

Intermediate Technology
Publications Ltd.
9 King Street
London WC2E 8HN,
England
Telephone: 01-836-6379

Description: Pulled by two-oxen; payload-636 kgs.; an important design feature of this cart is the wood-block axle bearings-each bearing is made of two pieces of wood, impregnated by soaking in hot oil, the axle bearing hole, 38 mm diameter, is drilled centrally through the blocks; each wheel assembly is an integral unit, the wheel spokes are welded to the axle shaft.

Comments on Maintenance, Productivity, "Appropriateness," etc.: Designed for local construction; this bearing design facilitates ease of maintenance and renewal of the bearings by carpenters in rural areas.

Cost and Present Status (as of 7/77): Originally designed by Rev. V. Swenson of Singida Mission and later developed further at TAMTU (Tanzania Agricultural Machinery Testing Unit), Tanzania; more complete drawings and description of the materials required can be obtained from Intermediate Technology Publications Ltd.

Dunlop Pneumatic Tire Equipment
for Animal Drawn Vehicles

Dunlop India Limited
Dunlop House, 57B
Mirza Ghalib Street
Calcutta-700 016
Post Office Box No. 9023
INDIA

Telephone: 24-9641/49
Telegraph: COVERS

Description: Pneumatic plain, ribbed pattern tire assemblies, including axle, 2 tires, hubs, and optional cast iron brake drums and lined shoes; pressed steel disc wheels under-coated to resist erosion; various tire sizes (5.00-19 to 8.00-19); plys, and axle lengths; complete instructions for various appropriate cart designs available on request.

Specifications

ply ratings	- 6 pr, 8 pr, and 10 pr
hub design	- standard or heavy
axle section	- 40, 50, 56, and 60 mm
gross load per axle	- 1,340 - 3,320 kg
weight of complete assembly (without brakes)	- 56.3 - 131.65 kg
standard track widths	- 1,370 mm and 1,525 mm

Comments on Maintenance, Productivity, "Appropriateness", etc.: These tire assemblies are designed to be used in place of iron tires on animal drawn carts, thus minimizing rolling resistance and allowing a low loading height which lowers the center of gravity of the loaded cart; carts with pneumatic tires travel some 25% faster than iron-tired carts; also, a pneumatic tired cart will remain mobile in soft or marshy ground and do less damage to road surfaces. This wheel assembly encourages buyers to construct an appropriately designed cart out of locally available materials.

Cost and Present status (as of):

2. PEDAL VEHICLES

The two pedal vehicles included are of the three-wheel type and are designed to carry a rider plus goods or passengers. Neither is provided with a prefabricated box or cabin for carrying purposes. Such additions could easily be made locally. Plans for various load carrying designs can be obtained.

One of the three-wheelers is presently in the prototype stage. It was designed for manufacture in the developing countries. The second is manufactured only in the US and sold commercially throughout the world. Both are built for use under rough conditions.

OXTRIKE

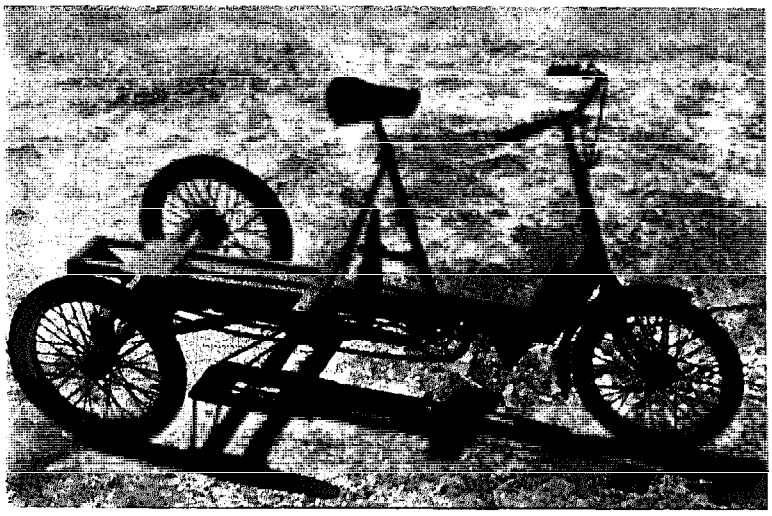

S. S. Wilson
Department of Engineering
Science
University of Oxford
Parks Road, Oxford OX1 3PJ
England
Telephone: 59988

Description: Two-wheels in the rear are driven by a simple differential mechanism based on two standard sprockets and freewheels; standard 3-speed gearbox; band brakes on each rear axle; front wheel and fork are standard carrier bicycle type, able to carry heavy loads; rear wheel of the chopper type; payload: 2 passengers or 150 kg.

Comments on Maintenance, Productivity, "Appropriateness," etc.: Since design is based on standard bicycle components and chassis is made from sheet steel of 1.6 mm thickness, they can be built locally in small workshops from kits of parts as is common practice in India; designs include rickshaw, multi-use body, box-van body, hopper body, and water cart; requires roads with reasonably level surfaces; its scope can be extended by addition of a small motor; pedal carts and cycle rickshaws are used on a large scale in India, China, and Southeast Asia.

Cost and Present Status (as of 5/77): Prototype.

Adaptable Tricycle with
Platform-Model ADP

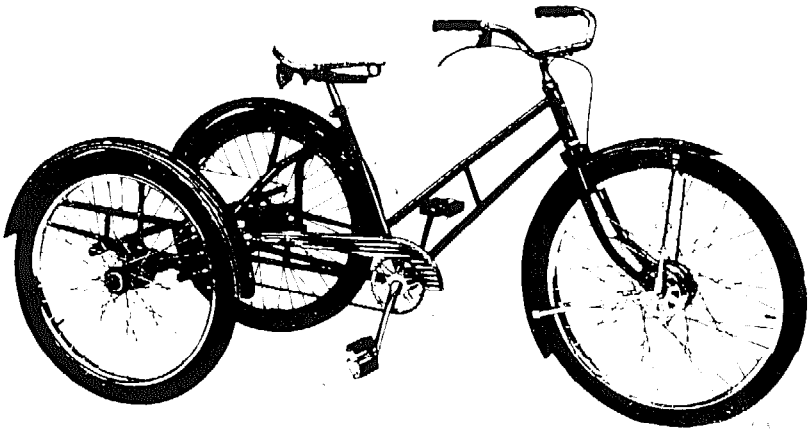

Worksman Trading Corp.
139-151 Banker Street
Brooklyn, N.Y. 11222
Telephone: 212.388.5710
Telex/Cable: WORKCYCLE - NEW YORK

Description: (1) Chassis-heavy gauge steel tubing 2.56cm-16 gauge, 2.26cm solid steel axle, axle width-.8m; (2) Wheels-heavy duty ball bearing wheels-.66m front & .61m rear, hand controlled drum brake on front wheel, free-wheeling on rear axle, available with 3 solid tire puncture proof wheels, rear coaster brake available, (3) Equipment-vinyl padded seat, chromium handlebars, and heavy duty mudguards.

Comments on Maintenance, Productivity, "Appropriateness," etc.: This adaptable tricycle line is used in many large manufacturer facilities throughout the world; setup and maintenance instructions are provided to assist owner in securing the maximum service from the cycles.

Cost and Present Status (as of 3/1/78): ADP Model-US$232, list price when ordered in quantities of 7 or more; all prices are F.O.B. factory Brooklyn, N.Y.

Other models include:	(list price for quantities of 7 or more)
Middleweight Adult Tricycle	US$ 228
Standard Delivery Tricycle (Cabinet size: 67cm x 92cm x 67cm)	US$ 285
Utility Tricycle (Platform: 87cm x 77cm-over the wheels)	US$ 239
Ice Cream Tricycle	US$ 615

Cost and Present Status (as of 5/15/77): ADP Model-US $218, list price when ordered in quantities of 7 or more; all prices are F.O.B. factory Brooklyn, N.Y.

Other models include:	(list price for quantities of 7 or more)
Middleweight Adult Tricycle	US $190
Standard Delivery Tricycle (Cabinet size: 67cm x 92cm x 67cm)	US $273
Utility Tricycle (Platform: 87cm x 77cm-over the wheels)	US $230
Ice Cream Tricycle	US $570

MOTORIZED VEHICLES

3. TRANSPORT VEHICLES: ON-ROAD GOODS AND PEOPLE CARRIERS

Seven vehicles are described in this section. Five are light three-wheeled vehicles powered by engines ranging from 5 hp to 15 hp. Prices range from US$700-1,700. Three-wheeled vehicles of this type have been used increasingly in South Asia and the Middle East in recent years. They are versatile, carrying as many as seven or eight people and up to 750 kg, and travelling at speeds up to 60 km per hour. Low fuel consumption keeps fuel costs down, and simple design of vehicle components permits easy maintenance. All but two of these vehicles are at least in part manufactured in South Asian countries. One of the three-wheelers is manufactured in Crete, a country which has evidenced increased production of low-cost three-wheeled vehicles.

The remaining two vehicles are small, standard four-wheel pickup trucks (42.5 and 77 hp) which cost from US$3,100-3,600. One is manufactured in Thailand and sold only in local markets. The other is marketed through distributorships in several developing countries. Sheet metal fabrication and generally assembly are performed locally, while mechanical components (engine, transmission, etc.) are imported.

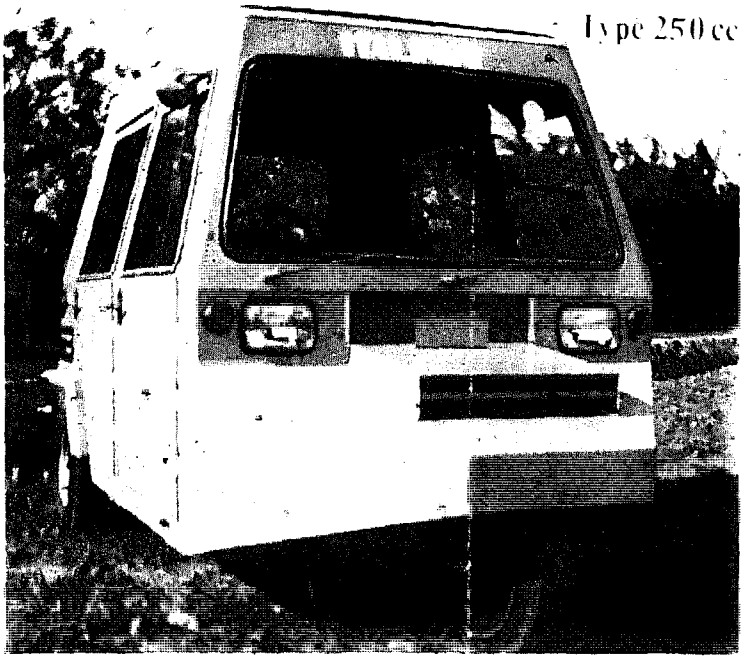

Super Helicak-250cc

Italindo
Jalan Jenderal A. Yani-Bypass
Jakarta, Indonesia
Telephone: 81514
Telex/Cable:

Description: 2 cylinder, 2 cycle, centrally mounted 12 HP Italindo engine; electric starter; fuel is regular gas mixed with 3 to 4 percent SAE 40 oil; transmission -- automatic 4 speeds forward and one reverse; all steel body; coil springs with double-action oil shock absorbers; hydraulic expansion-type brakes and hand brake.

Specifications:

weight	-	engine	- 12 HP
length	-	speed	- maximum - 50 km/h
width	-		- cruising - 35-45 km/h
height	-	fuel capacity	-
wheel base	- 1.96 m	fuel consumption	- 15 km/l
track	- 1.23 m		

payload capacity - 3 passengers (150 kg) plus 20 kg of cargo in area beside the driver's seat

Comments on Maintenance, Productivity, "Appropriateness," etc.:

Cost and Present Status (as of): Super Helicak-250cc - US $

Also available 6 HP engined Super Helicak-125cc US $

MEBEA Goods Transport
Threewheeler Type No. 206

Mediterranean Engine Brand
Enterprises Association S.A.
P.O. Box 30
Kifissia
Athens
Greece
Telephone: 822.6060/822.2539
Telgrams: MEBEA ATHENS
Telex: (21) 5827

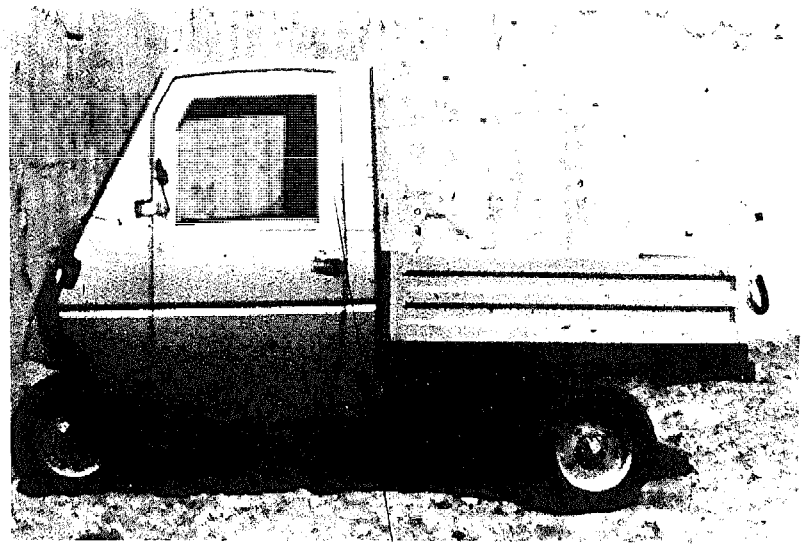

Description: Three-wheeled goods transport vehicle with 50cc or 135cc ZUNDAPP engine, 4-speed or 5-speed, single cylinder, 2-stroke, 5.6 SAE-hp at 7,700 rpm, air-cooled; runs on a 25:1 petrol to oil mix; all steel tubular and sheet metal chassis; hydraulic and hand brake on rear wheels, mechanical brake on front wheel; start by manually operated hand lever; BOSCH flywheel type electrical system.

Specifications

weight	- app. 189 kg.	engine	- 5.6 SAE-hp
length	- 2.63 m	speed	- avg. of 55 km/h
width	- 1.2 m	fuel capacity	- app. 5 litres
ground clearance height	- 1.0 m (without cabin)	fuel consumption	- app. 27 km/litre
payload capacity	-		

Comments on Maintenance, Productivity, "Appropriateness", etc.: Used in Greece for over 20 years for light transport tasks; two engine sizes appropriate for different uses; also, enclosed or open driver's cab available.

Cost and present status (as of):
(135 cc engine model available soon)

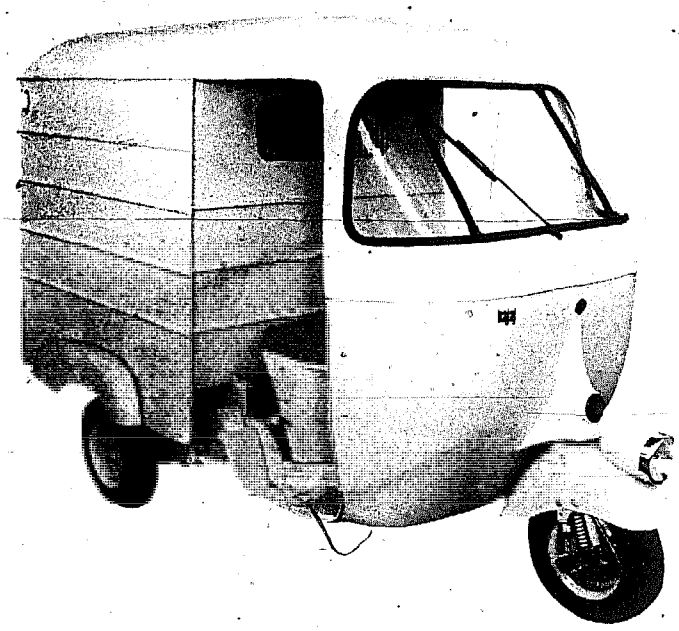

Bajaj Three Wheeler Chassis; Autoriksha, Pickup Van and Delivery Van

Bajaj Auto Ltd.
Akurdi, Poona-411 035
Maharashtra,
India
Telephone: 82551/83011
Telex : PN 0145-308
Cable : AUTORIKSHA

Description: 3 wheeled vehicle which comes in 3 styles for passenger/freight transport: autoriksha, pickup van, and delivery van; midmounted engine, two stroke, single cylinder, 5.7 hp (at 5000 RPM) 150 cc, air cooled engine running on petrol and oil mixture; rear wheel driven, four forward, one reverse gear; pedal operated hydraulic rear brakes, hand operated mechanical brake for front wheel, parking brakes on rear wheels.

Specifications

weight	- 260 to 290 kgs	engine	- 5.7 hp at 5000 RPM
wheel base	- 1.65 m	speed	- 0 to 55-60 km/hr.
ground clearance	- .02 m	fuel capacity	- 11 litres
payload	- 310 to 500 kgs	fuel consumption	- 26± 5 km/litre

Comments on Maintenance, Productivity, "Appropriateness," etc.: Low cost road vehicle which is in use in the Middle East, South East Asia and Africa; three different styles suited to various uses; drive away chassis is available for fitting locally fabricated bodies; optional equipment includes electric windshield wiper and battery.

Cost and Present Status (as of 1/78): F.O.B. Bombay prices of basic models.

Drive away chassis	- app.	US$625
Autoriksha	- app.	US$705
Pickup Van	- app.	US$705
Delivery Van	- app.	US$784

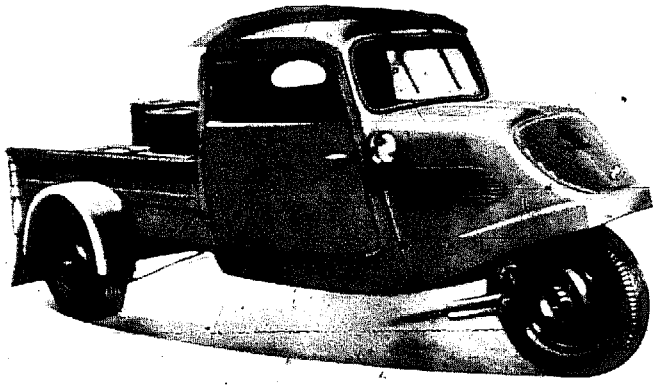

Tempo 3-Wheeler Pick-Up Truck

Bajaj-Tempo Ltd.
Bombay-Poona Road
Akurdi Poona 411 035
India
Telephone: 82281
Telex/Cable: 0145-352/TEMPOWORK

Description: 2 cylinder, 2 stroke, 15 HP petrol engine designed by Henschel AG of Stuttgart, Germany; steel tubular chassis with cross members; the entire drive unit i.e. engine, gear box, and chain case is mounted on the front wheel; gear-box -- 4 forward, 1 reverse gear; front wheel drive; brakes -- hydraulic brakes on all 3 wheels and independent mechanical hand brakes on 2 rear wheels; suspension -- rear axles have independent suspension assisted by dual coil springs and telescopic shock absorbers; steering -- adjustable worm and segment.

Specifications:

weight	-	engine	- 15 HP
length	- 3.57 m	speed - maximum	- 60 km/h
width	-	fuel capacity	- 12 l
height	- 1.55 m	fuel consumption	- 12.4 km/l
wheel base	- 2.87 m		
track (rear)	- 1.37 m		

payload capacity - 750 kg

Comments on Maintenance, Productivity, "Appropriateness," etc.: Entire power unit can be dismounted within 1 hour; expected life under normal use on good and bad roads is about 6 to 8 years or 150,000 kms; petrol and oil must be mixed in 40:1 proportions; runs well on rough roads but cannot operate in conditions where 4-wheel drive is essential; other models include delivery van, refuse truck, water and kerosene tanker, ambulance, and autorickshaw; as a autorickshaw, designed to carry 7 passengers but known to carry up to 20.

Cost and Present Status (as of 7/5/77): PICK-UP model - US $1,394 (this price is ex-works without excise duty and without the mark-up by the dealer); is manufactured in collaboration with the German firm Vidal & Sohn Tempo Werk; have been manufacturing this vehicle since 1959 and the maximum quantity ever produced in one year was 3,500; the investment required to initiate the production of this vehicle is not prohibitive for some developing countries.

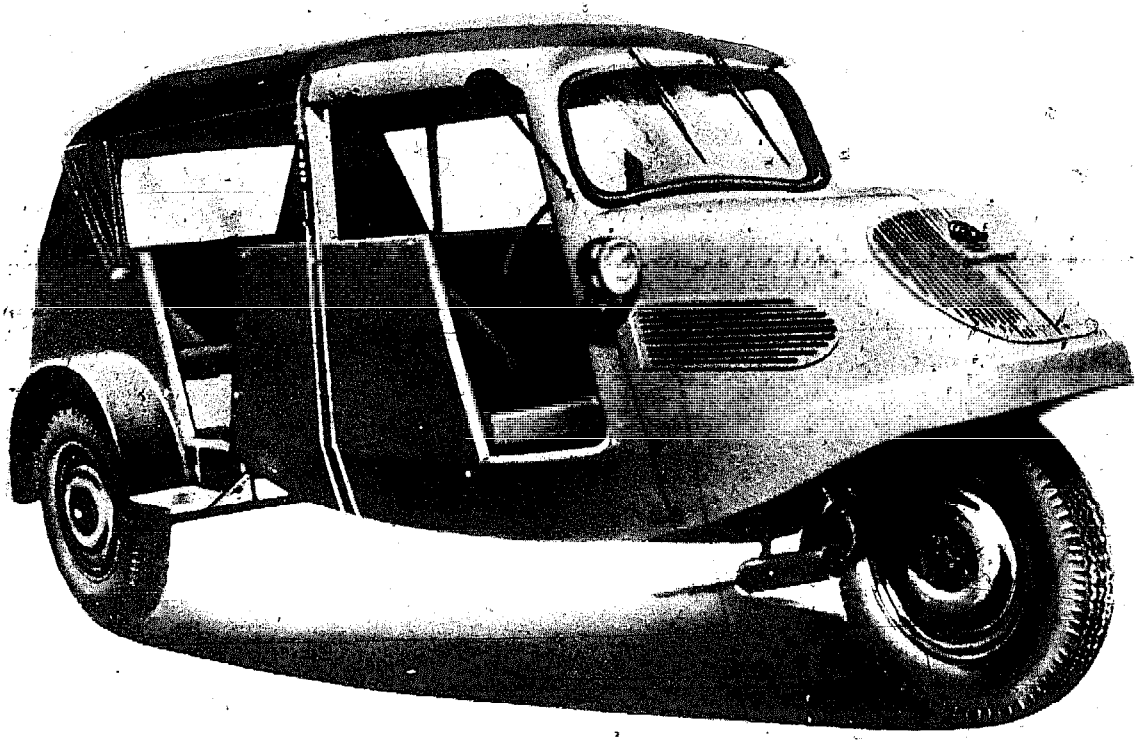

Krishi Auto-Rickshaw

Krishi Engines Limited
A-7 Unit, Sanatnagar.
Hyderabad-500018
India
Telephone: 269306
Telex: CARE 015-372 ESTATE

Description: Compact 7-seater including driver; powered by a water-cooled, 4 stroke, single cylinder, 5 HP diesel engine; 4 speed gear box; hydraulic braking system; self-starting facility with a 12V battery.

Specifications:

weight	- 600 kg	engine	- 5 HP
length	- 2.75 m	speed--maximum	- 45km/h
width	- 1.15 m	fuel capacity	- 7 litres
height	- 1.68 m	fuel consumption	- 17 km/l

payload capacity - 7 people

Comments on Maintenance, Productivity, "Appropriateness," etc.:
Tested for use in urban areas and country roads.

Cost and Present Status (as of 6/30/77): US $1,700

BASIC TRANSPORTATION VEHICLE

B.T.V. Operations Group
Bedford Commercial Vehicles
Vauxhall Motors Ltd.
P.O. Box No. 3,
Luton LU2 OSY
England
Telephone: 0582 21122
Telex: 82131 VAUXGM (G)

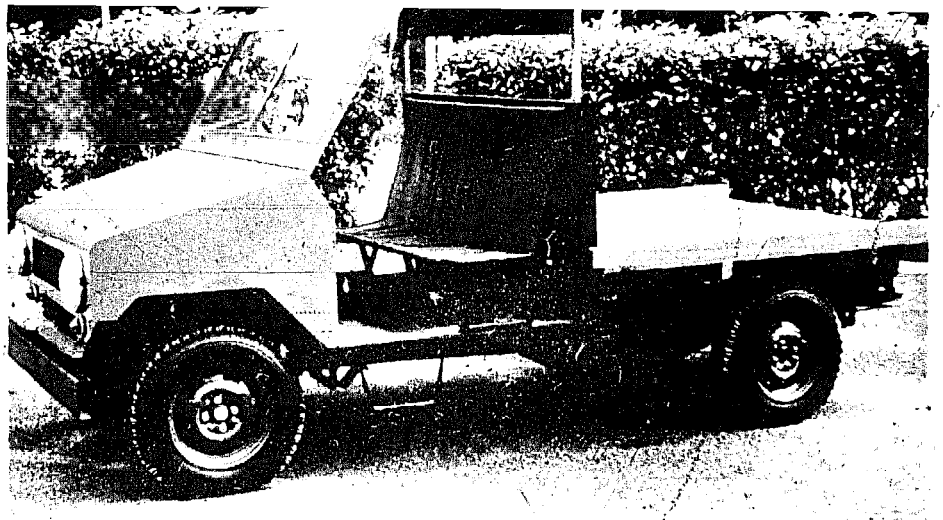

Description: Water-cooled, 4-cylinder petrol engine of 42.5 hp; 4-speed synchromesh transmission with floor mounted gear lever; two-wheel drive; rack and pinion steering; dual circuit hydraulic service brakes.

Specifications

weight	- 1,321 kg	engine	- 42.5 HP
length	- 3.6 m	speed (maximum)	- 97km/h to 105km/h
width	- 1.6 m	fuel capacity	- 36.5 litres
height	- 1.7 m	fuel consumption	- 8-9 km/l
wheel base	- 2.3 m		
track front	- 1.20 m		
track rear	- 1.22 m		
wheel clearance laden	- .1 m		
payload capacity	- 551 kg; cab takes a 3-man seat		

Comments on Maintenance, Productivity, "Appropriateness," etc.: It is capable of easy conversion to an owner's specific needs; since it utilizes Vauxhall mechanicals (i.e., engine, transmission, drive line, etc.), in conjunction with locally fabricated sheet metal and local assembly, all mechanical components are proven in quality and reliability to the extent that they have been common to vehicles in the current Bedford range; distributorships have expanded to include some twenty countries in Africa, the Far East, Central and South America since the vehicle was introduced in Malaysia, Portugal, Ecuador, and the Phillipines in 1973.

Cost and Present Status (as of 4/25/77): Distributed in over twenty countries in an approximate range of US $3,100-3,600; in some small markets, it is possible to economically produce less than 200 units a year.

5.

Singha Siam

Siam Motors Co., Ltd.
865 Rama 1 Road
Bangkok
Thailand
Telephone: 2529830
Cable: Siamo Bangkok
Telex: Siamo TH2655

Description: Gasoline, water cooled, 4-cycle, overhead valve, 4 cylinder, 77 hp Datsun engine; 4 speed column shift; recirculating ball steering; dual circuit hydraulic brake system.

Specifications

weight	- 960 kg	engine	- 77 hp
length	- 4.28 m	speed	- max. 120 km/hr
width	- 1.54 m	fuel capacity	- 45 l
height	- 1.64 m		
wheel base	- 2.54 m		
payload capacity	- 1000 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Designed for transportation of goods, passengers, etc., in rural areas and on construction sites; assembled locally with a body that can be modified into cargo truck or mini bus.

Cost and Present Status (as of 3/78): Sales only in local market at a retail price of US$3,750.

Also Available: Datsun 1200 AX mini truck - 69 hp engine; production has just begun and is around 40 units per month; retail price - US$3,600.

4. TRANSPORT VEHICLES: ON/OFF ROAD GOODS AND PEOPLE CARRIERS (ALL-TERRAIN VEHICLES)

The nine vehicles included in this section are designed to operate under difficult ground and climatic conditions. Most carry only one or two passengers and a half ton load. Engines range from 7.5 hp to 35 hp. Prices vary from US$280-480 for a three-wheeled, 8 hp trail bike that comes in kit form, to a 28 hp cross-country carrier (payload capacity up to 1,830 kg) for US$6,000.

While none of these vehicles were specifically designed for use in developing countries, several are presently either in limited use or being tested in these countries. All the vehicles are built to withstand and negotiate marshy or rough terrain and inclines.

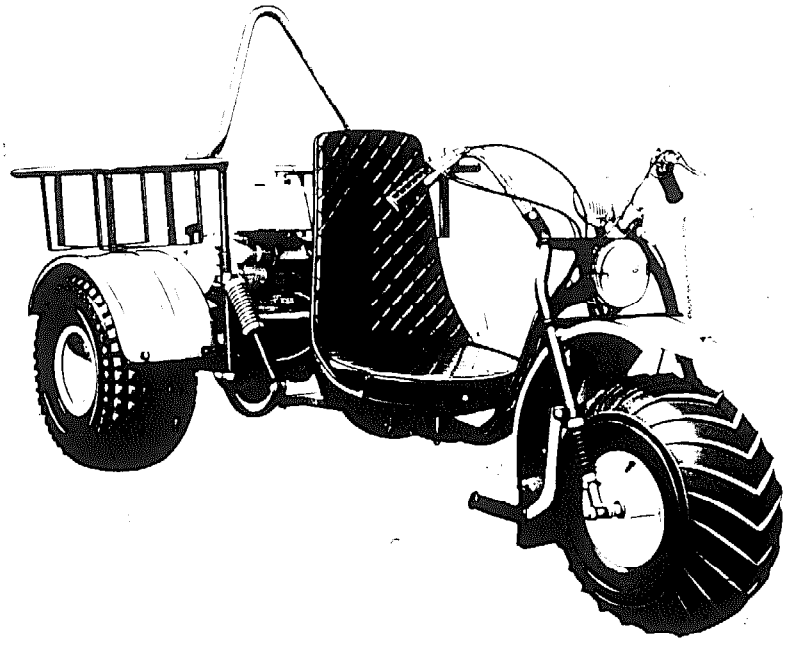

SST-821 Super Tryke

Heald, Inc.
P.O. Box 1148
Benton Harbor, Michigan 49022
USA
Telephone: 616-927-1366

Description: 8 hp, Tecumseh 4-cycle engine; transmission - Comet Torque converter; frame type-single member, right angle pivot attached to rear frame assembly with spring damped shocks; hand operated band type brakes.

Specifications:

weight	- 114 kg	engine	- 8 HP
length	- 2.0 m	speed--maximum	- 65km/hr
width	- 1.2 m	fuel capacity	- 4.5 l
height (at handle bars)	- 1.0 m	fuel consumption	- 10.6km/l
wheel base	- 1.4 m		
ground clearance	- 15 cm		

payload capacity - 2 passengers if double seat ordered or a total load of 275 kg

Comments on Maintenance, Productivity, "Appropriateness," etc.: Every part comes ready to assemble in a kit - by following the step-by-step instruction sheet the machine can be assembled in 6 to 12 hours using normal tools.

Cost and Present Status (as of 7/6/77): SST-821 Super Tryke - US $540.60

Also available:	Price Range (US$)	
5 HP & 8 HP Trail Bikes	$279.95 -	$479.95
10 HP & 20 HP Trykes	$659.95 -	$699.95
10 HP Tractor	$699.95	-
Dump Cart (300 kg payload)	$179.95	
8 HP & 10 HP Trucks	$999.95	$1,099.95

total load capacity - 365 kg
payload - 227 kg
bedsize - 1.1 m x 1.0 m x .3 m
(also electric model powered by three, 12 volt batteries available 9/77)

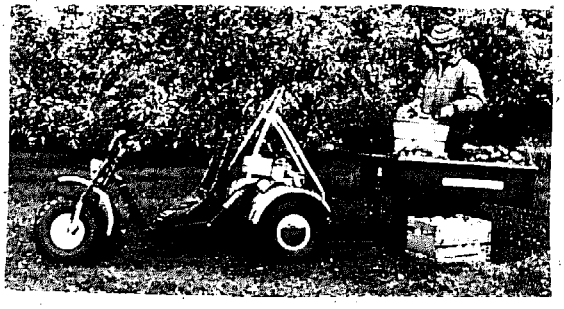

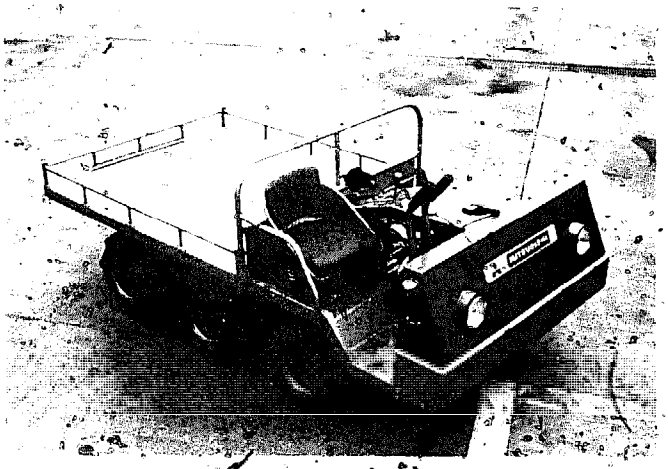

All-Terrain Vehicle - Model AT 52

Mitsubishi Heavy Industries Ltd.
Engine & Equipment Division
5-1 Marunouchi 2-chome, Chiyoda-ku
Tokyo, Japan
Telephone: Tokyo (212) 3111
Telex: J22282, J22443
Cable: Hishiju Tokyo

Description: Air cooled, 2 cylinder 18-26 HP diesel engine, haul [illegible] rectangular tubular steel frame with heavy front bumper plate; 4-speed constant mesh transmission with 3 forward and 1 reverse gear; dry single plate clutch; independent disc brakes on rear wheels; 3-point hitch, hydraulic system, rear P.T.O. and tool bar (optional).

Specifications

weight	- 390 kg	engine	- 7.5 HP
length	- 2.52 m	speed (maximum)	- 14.9 km/h
width	- 1.27 m	fuel capacity	- 16 litres
height	- 1.11 m	fuel consumption	- app. [illegible] /HP/h
ground clearance	- .2 m		
wheel base	- .58 m x 2		
payload capacity	- 500 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: It is suitable for off-road conditions such as inclined terrain, muddy ground, and sandy soil; low maintenance requirements; feasibility study has been carried out in Malaysia, Brazil, Guatemala, and Philippines.

Cost and Present Status (as of 8/77): Model AT 52 - US$2,500, FOB Japan; annual production is 2,500 units.

Also Available: Model AT 81A (8 wheel drive all terrain vehicle with 11 HP engine and payload capacity of 1000 kg) - US$3,500, FOB Japan.

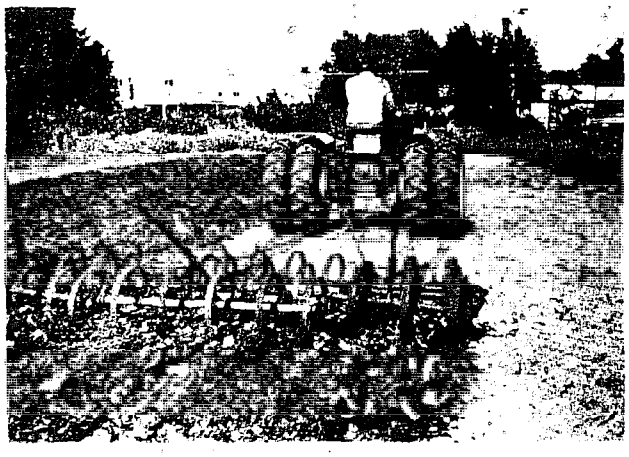

Leyland Moke

Leyland Australia
Box 346 PO
Bondi Junction
NSW 2022
Australia
Telephone: 387-0233
Cables: LEYAUST
Telex: 20222

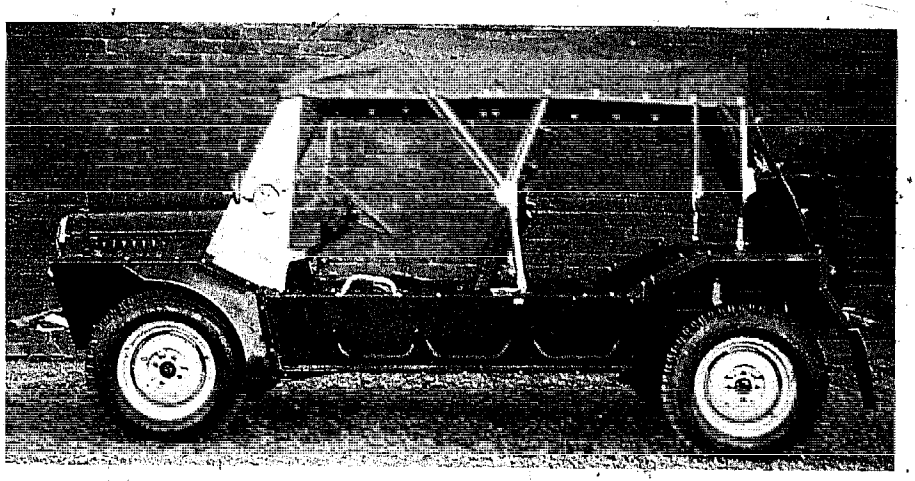

Description: All steel welded buckboard; four cylinder, OHV engine; single plate clutch - hydraulically operated; four forward speeds and one reverse speed; hydraulic brakes; rack and pinion steering; suspension-cone springs and tubular shock absorbers.

Specifications

weight	- 998 kg	engine	- 998 cc
length	- 3.23 m	speed	- 7.6 km/h to 26.9 km/h
width	- 1.45 m	fuel capacity	- 27 l
ground clearance	- .20 m	fuel consumption	- 15 km per litre
height	- 1.60 m		
wheelbase	- 2.09 m		
maximum vehicle load	- 240 kg		
maximum towing weight	- 400 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Light on/off road passenger and goods vehicle that negotiates rough terrain due to large wheels (325 mm) and high ground clearance (200 mm); may be purchased fully assembled, partially assembled, or fully knocked down.

Cost and Present Status (as of 1/78):): FOB Sydney, Australia:

Fully assembled (1-9 units) - app US$2,500
Partially to fully knocked down (1-9 units) - app. US$2,273-2,388

Slight reduction in prices for purchase of larger batches of vehicles.

QUARTER HORSE - QH-14 / QH-10

Promark Products Corportation
of Ohio, Inc.

P.O. Box 738
Norwalk, Ohio 44857
419/668-3721

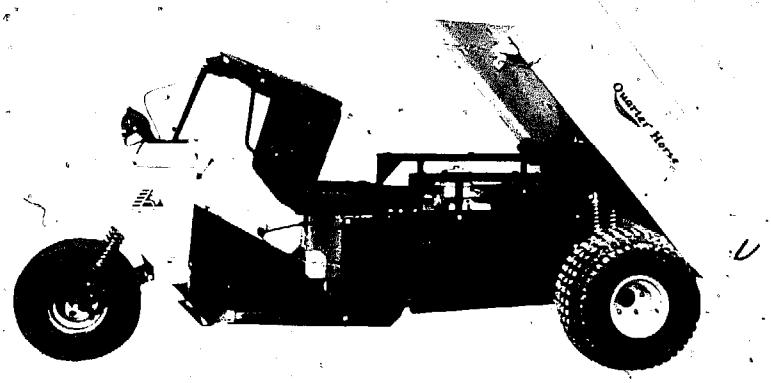

Description: 10 HP Briggs & Stratton or 14 HP Kohler, 4 cycle - cast iron industrial engine; automatic transmission, "torque sensitive" type; gear driven, completely sealed "Transaxle" differential with forward and reverse transmission; independent suspension (all wheels with adjustable double shocks); hydraulic disc brakes (self-aligning); wide oval flotation tires; dump bed - standard (in 2 sizes - easily removed); hitchplate - standard (takes most standard tow-behind accessories).

Specifications

Weight	-	333 kg	Engine	-	10 HP or 14 HP
Length	-	2.8 m	Speed	-	19.3 - 38.6 k/h
Width	-	1.4 m	Fuel Capacity	-	12.3 litres
Ground Clearance	-	12.8 cm	Fuel Consumption	-	17 km/l
Dump Bed Size	-	.31 cu m			
Payload Capacity	-	225 kg and 2 passengers			

Comments on Maintenance, Productivity, "Appropriateness," etc.: Was designed and built for the agricultural market but performs equally as well as a grounds maintenance or industrial vehicle; can do almost any light job on a farm - such as checking irrigation systems, transporting milk, fogging insects, hauling, fertilizer, dirt, firewood, water, people, tools; can perform under muddy conditions.

Cost and Present Status (as of 11/1/77): QH14 - US$ 2,599.00
QH10 - US$ 2,299.00

Implements:

12.3 Liter Auxiliary Gas Tank	- US$ 41.95
Utility Blade (Manual Lift)	- US$199.95
Cab (Fibreglass with doors)	- US$650.00

Terra VW

Terra Sales & Service Ltd.
Ferguson Place
P.O. Box 1430, Rotorua
New Zealand
Telephone: 82-012

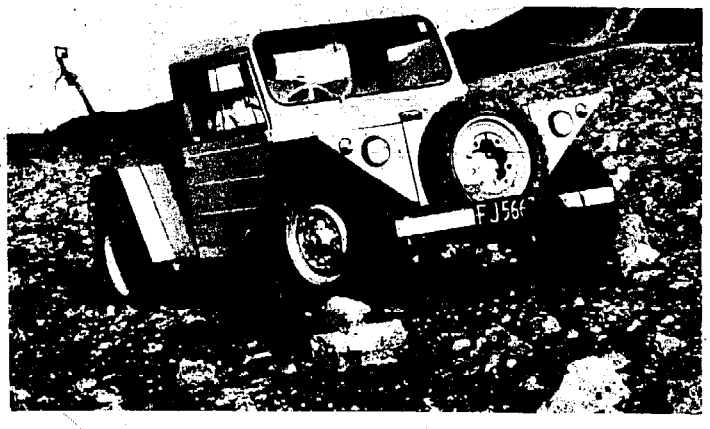

Description: Engine, transmission, suspension, steering and brakes from Volkswagen 1200 saloon; frame and body built up from angle iron welded into safety-cage unit; all-independent torsion bar suspension.

Specifications

weight	-		engine	-	
length	-		speed	-	up to 88 km/h
width	-		fuel capacity	-	
height	-		fuel consumption	-	9 km/l to 11 km/l
wheel base	-				
ground clearance	-				
load capacity	-	300 kg			
pick-up tray dimensions	-	133 cm x 108 cm x 33 cm			

Comments on Maintenance, Productivity, "Appropriateness," etc: Used by farmers, surveyors, and works operators in various parts of New Zealand; designed for off-the-road conditions; uses standard Volkswagen basic components; power unit is mounted close to the rear driving wheels, giving traction over rough ground, wet grass, mud, and firm sand.

Cost and Present Status (as of 10/77): US$2,660.

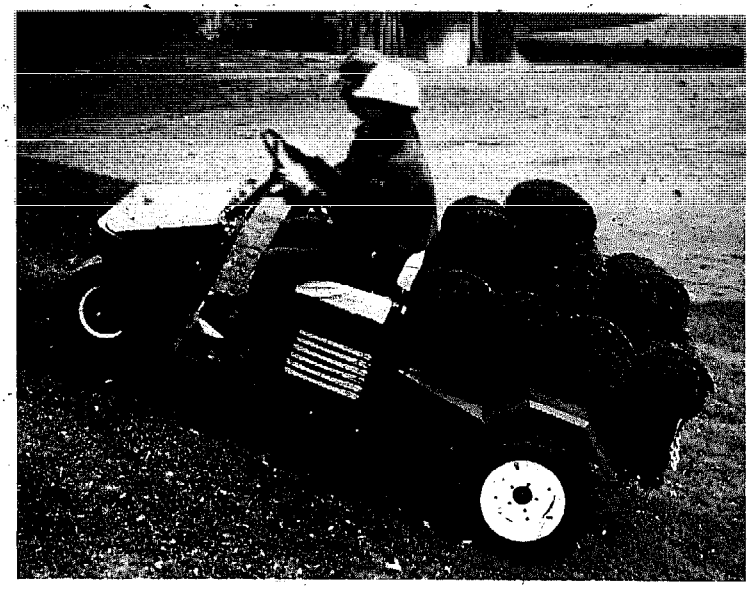

Workmaster

TORO
8111 Lyndale Avenue South
Minneapolis, Minnesota 55420
Telephone : (612) 888.8801
Telex/Cable: 29.0463

Description: Two wheel drive, three wheeled vehicle for hauling goods and people; two passenger seating capacity with a Kohler Model K3215 air-cooled, 4 cycle, 14 hp, gasoline engine; hydrostatic variable speed transmission, single foot pedal for instant forward and reverse; 12 volt battery; trailer hitch in rear, steel construction box, 1.15 m long, .875 m wide, and .25 m deep; hydraulic drum brakes on the rear wheels, mechanical parking brake.

Specifications

weight	- 436 kg (empty)	engine	- 14 hp.
length	- 2.69 m	speed	- 0-24.15 km/h
width	- 1.45 m	fuel capacity	- 23.5 liters
height	- 1.17 m	fuel consumption	-
wheel base	- 1.93 m		
ground clearance	- 0.08 m		
payload	- 454.1 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Short turning radius (3.35 m), travels over a variety of terrains; standard size box carries existing engine driven top dressers, sprayers, mowers, and other maintenance equipment.

Cost and Present Status (as of 9/77): US$3,148.

Passe Par Tout (P.P.T.)

Valquentin Industries, Ltd.
13204-126 Avenue
Edmonton, Alberta,
Canada T5L 3E1
Telephone: (403) 454-6862

Description: Lightweight, twin tracked industrial tractor, available with Kohler 4 cycle, 16 hp, 1 cylinder engine, splash lube system or Onan 4 cycle, 16.5 hp, 2 cylinder, pressurized lubrication engine; excellent for off-road personnel carrier or small tractor for inaccessible areas; pedal and parking brakes, 2 forward speeds and one reverse, drawbar pulls 2204 kg.

Specifications

weight	-	474.6 kg	engine	-	16 or 16.5 hp
length	-	2.44 m	speed	-	0-32.2 km/hr.
width	-	1.21 m	fuel capacity	-	15.15 litres
height	-	0.62 m	fuel consumption	-	1.97 l/h under load
wheel base	-				
ground clearance	-	0.27 m			
payload	-	454.1 kg			

Comments on Maintenance, Productivity, "Appropriateness," etc.: Broad range of applications due to vehicle's size and versatility; track life approx. 5 years. Successfully arctic tested and marketed in many countries. Range of implements and optionals include Safari Cabs, 1361 kg winch, and several smaller winches; also works well as personnel carrier over swamp etc.; helicopter and pickup truck transportable.

Cost and Present Status (as of 2/78): Model 500-16h.p. Kohler engine US$4,699.75

Model 520-16h.p. Onan engine /Roll Bar & aluminum firewall only US$5,161.75

Roll-bars, Safari Cab, Grille guard, winch, etc. vary from $200.00-$500.00

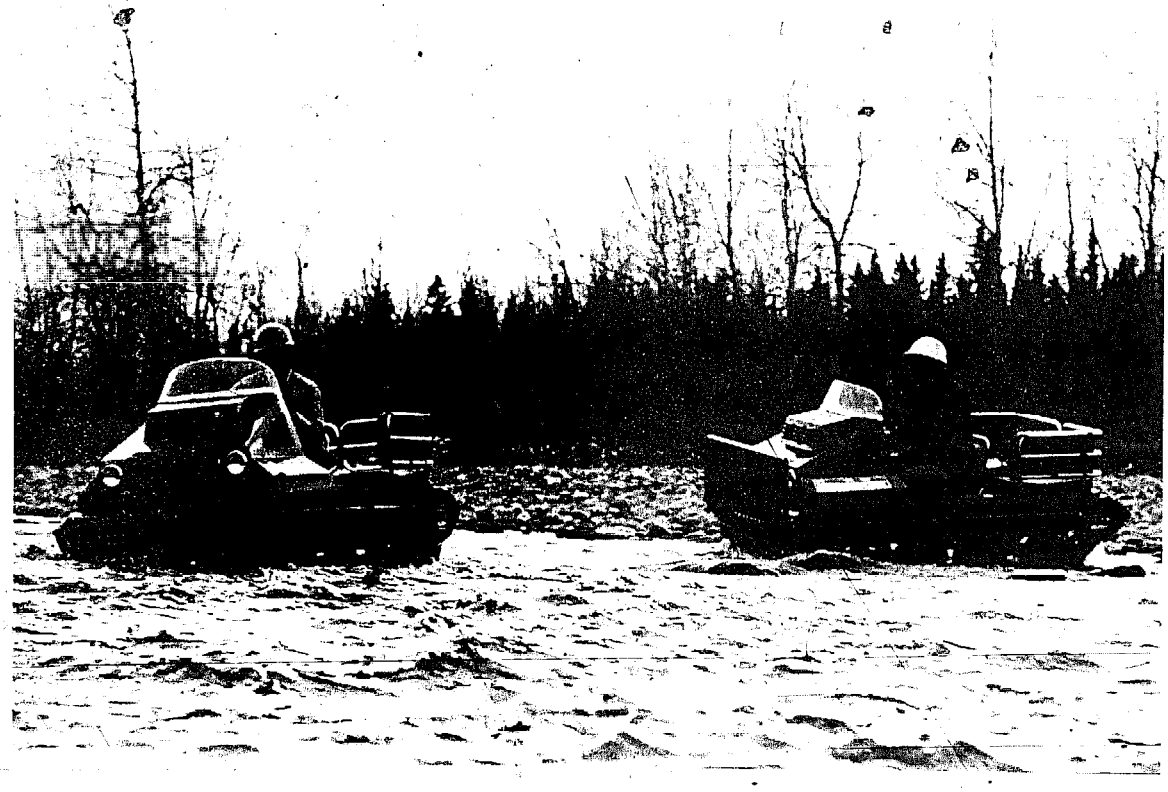

Terri 30

Velsa Oy
61300 Kurikka
Finland
Telephone: 964-52100
Telex/Cable: 72-139/Velsa

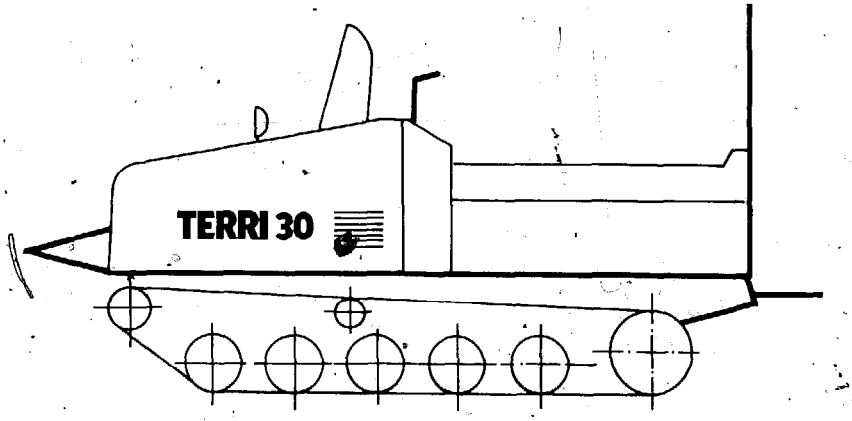

Description: A track-driven work and transport vehicle: 2-cylinder, 2-stroke air-cooled 35 H.P. gasoline Kohler engine; electric and manual starting device; transmission-gear box with two forward speed ranges and reverse; mechanical disk brakes; steering and control are done equally simply by means of a steering rod and hand-accelerator; has a frame-mounted winch.

Specifications:

weight	- 550 kg	engine	- 35 HP
length	- 2.8 m	speed	- 3km/h. to 40km/h
width	- 1.4 m	fuel capacity	- 21 litres
height (with protective frame)	- 1.4 m	fuel consumption	- 6-7 l/h
track	- .5 m		
payload capacity	- one passenger		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Can work in the most varied types of terrain-both in winter and in summer-such as uncleared forest country, marshy bogs, deep snow or water-covered ice; suitable for most demanding transportation tasks of forest management i.e. transporting felled trees to the roadside, forest fertilization, transporting seedlings, clearing roads in winter and for inspection trips of power lines etc, in inaccessible locations; exerting only a pressure of about 30g/cm^2 against the ground means it can be used in bogs and quagmires where other machines cannot go.

Cost and Present Status (as of 7/77): Terri 30-US $5,000

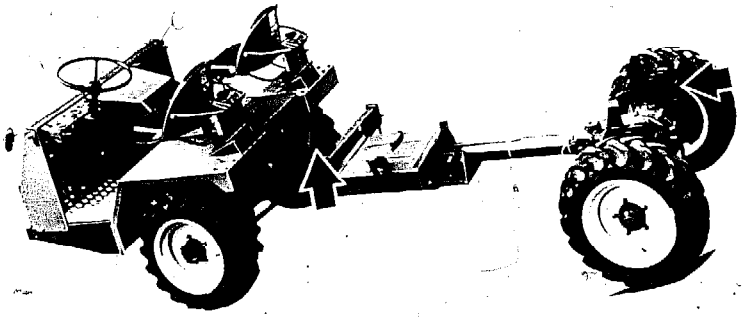

Bucher Transporter - 1500

Bucher-Guyer Ltd.,
Engineering Works
8166 Niederweningen
Zurich, Switzerland
Telephone: 01-856 03 22
Telex: 53199 bgnwg ch

Description: Transporter (cross-country carrier) with many practical combinations for pulling, powering, transporting and working; 4 wheel drive whereby the front wheel drive can be disengaged and a differential lock in the rear axle; 4 cylinder air-cooled 28 HP Lombardini diesel engine; transmission - 6 forward speeds and 2 reverse; auxiliary P.T.O. drive; dual circuit hydraulic brakes on all 4 wheels.

Specifications

weight	- 1070 kg	engine	- 28 HP
length (chassis)	- 3.90 m	speed	- 2.8 km/h to 25.4 km/h
width	- 1.50 m	fuel capacity	- 45 litres
height	- 7.32 m	fuel consumption	- 3.5 l/h
ground clearance	- 0.79 m		
wheel base	- 2.40 m		
track	- 1.24 m		
payload capacity	- 1830 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.:
Adaptable to all kinds of tools such as tipping body, self-loading forage box, manure spreader, liquid manure tanks, winch, crane, hydraulic system with 3 pt. hitch, etc.; twisting chassis provides good adhesion in broken terrain and in sandy and swampy conditions; the "Transporter" will climb hills with an incline of 45°; all mechanical components are agriculturally proven and tested in many countries; the engine needs to be serviced normally like any diesel engine; in the gear box and final drives, the oil has to be changed once yearly; there are few wearing parts; production started in the early 60's, and since then, every year necessary technical changes and novelties have been built into the machines.

Cost and Present Status (as of 7/31/77): Transporter 1500 - commercially produced in Switzerland for about US$6,000.

Also Available: 3 other models including the TR 2500 which has a 40 HP Leyland diesel engine and a payload of 2780 kg and is produced for about US$8,000.

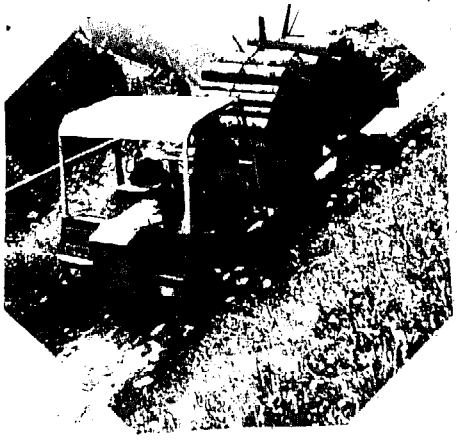

5. MULTI-PURPOSE VEHICLES (AGRICULTURE AND BASIC TRANSPORT)

The eight vehicles in this section range from a simple two-wheeled riding tractor with optional farm implements to a fairly sophisticated small truck which performs a variety of farm tasks. These vehicles all have a broad range of possible uses, from simple road transport tasks to a variety of farm jobs. They vary in cost from US$1,150 to US$3,350. Engine power ranges from as low as 8 hp to 75 hp. These vehicles have grade capabilities from 28 degrees to 45 degrees and as much as 9 ton pulling capacity.

Of the vehicles included in this section, three were designed for assembly in developing countries. The remainder are manufactured in the US or Europe. Three of the manufacturers reported use of their vehicles in developing countries.

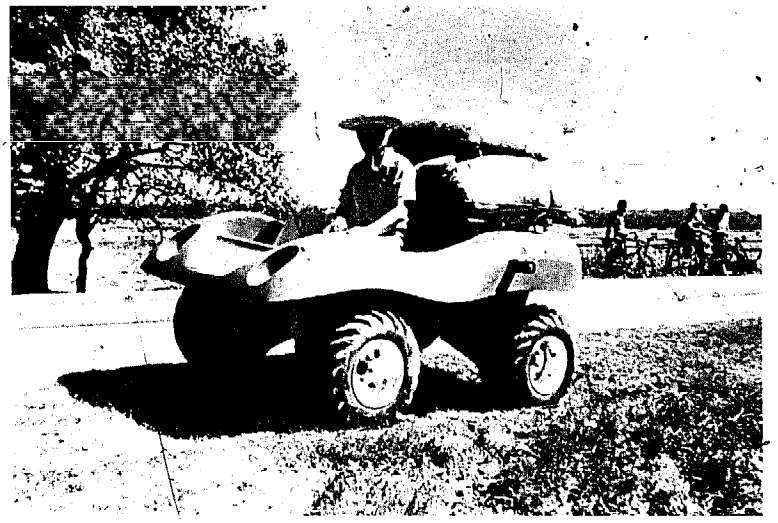

Small Farm Vehicle

Ray Wijewardene
Farming Systems Engineer
I.I.T.A.
Oyo Road, P.M.B. 5320
Ibadan, Nigeria
Telephone: Ibadan 23740
Cable: TROPFOUND, IKEJA

Description: Four-wheel-drive vehicle that can be used as a transport vehicle and also perform agricultural tasks like tilling, mowing, compaction, etc.; 14 HP gasoline engine (another version uses an electric battery); power take-off is available; body is made of plywood.

Specifications

weight	- 182 kg	engine	- 14 HP

Comments on Maintenance, Productivity, "Appropriateness," etc.: High clearance permits easy off-the-road usage; can work in various off-roa conditions such as soft soil by fitting an idler wheel and tracks, and boggy land by installing a third wheel on each side along with tracks.

Cost and Present Status (as of 6/76): Prototype stage; development work abandoned since 1971; US $1,500 (1970 prices).

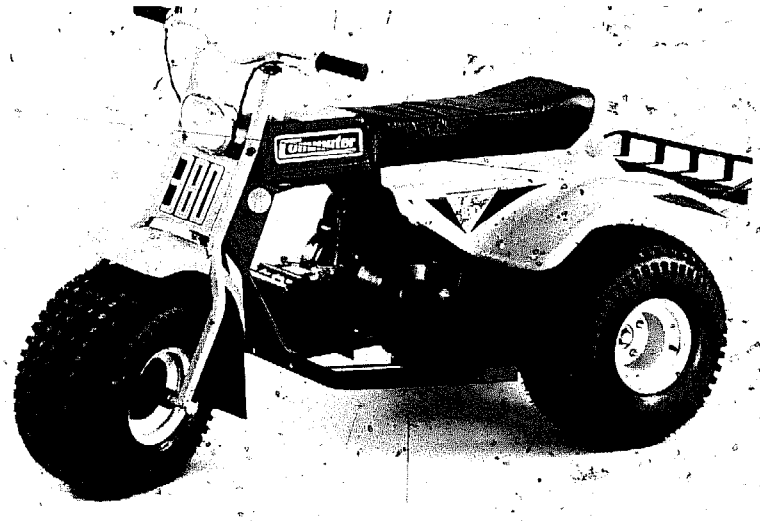

COMMUTER TE-380

Commuter Industries Inc.
Highway 151 East
Cascade,
Iowa 52033 U.S.A.
Telephone: (319) 852.3208

Description: Three wheel, all terrain cycle; 8 hp cast iron Kohler engine; electric start, fourstroke, single cylinder, fan-cooled; transmission, automatic torque converter; final drive-transaxle.

Specifications

weight	- 135 kg	engine	- 8 HP
length	- 2.1 m	speed	- .5km/h to 50 km/h
width	- 1.0 m	fuel capacity	- 6.36 litres
ground clearance	- .225 m	fuel consumption	- 1.36 l/h
wheel base	- 1.25 m		
height over seat	- .825 m		
height over handle bars	- 1.1 m		
load capacity	- 200 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: The Commuter with its cast iron engine and transaxle drive is designed to withstand hundreds of hours of trouble free use; the only regular maintenance that must be performed is changing the engine oil and servicing the air cleaner; the Commuter is used for all types of farm work such as crop spraying, irrigation, herding livestock, pulling trailers, etc.

Cost and Present Status (as of 6/1/77): COMMUTER TE-380, Retail, United States US$1,149.00

ROKON MOTOTRACTOR (SCOUT MODEL)

Rokon, Inc.
160 Emerald Street, Keene
New Hampshire 03431
USA
Telephone: 603-352-7341
Telex: 928451

Description: Two-wheel drive; 10 hp Chrysler engine - two-stroke, single cylinder, gas and oil mixed, fan-cooled; transmission-automatic torque converter into 3 speed range selector with built in power take off; front and rear disc brakes.

Specifications:

weight	- 93 kg	engine	- 10 HP
length	- 1.88 m	speed	- .8km/h to 65km/h
width	- .77 m	fuel capacity	- 10 litres
ground clearance	- .36 m	fuel consumption	- up to 14km per liter in transport mode; 1.7l/h while ploughing
height over seat	- .74 m		
height over handlebars	- 1.02 m		
fording depth	- .59 m		
wheel base	- 1.25 m		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Its range of implements include all purpose trailer (.34 cu m with a recommended payload of 227 kg), 750 watt alternator, York rake, moldboard plough, double gang harrow, soil cultivator, and attachments for crop spraying and irrigation pumping; over 10,000 models have provided transportation in difficult terrain and conditions over various areas of the world; grade capability - 45 degree slopes; usage of the agricultural implements has just begun in such countries as Indonesia, Colombia, Philippines, Iran, Brazil, New Zealand, and Mexico; using the moldboard plough, the rate of work is approximately 12½ hours per hectare; daily maintenance requires lubricating the chains and cleaning the air filter as well as keeping the tires properly inflated; a major overhaul inspection should be made after 1,000 hours; the life expectancy of the tires is 3-5 years.

Cost and Present Status (as of 11/7/77): Rokon Scout-US$ 1,570.00

Ranger model also available-US $ 1,675.00. Specifications same as Scout except 25mm higher due to larger implement tires mounted on 17 l. aluminum storage tank wheels.

Implements:

3-Point Hitch 3PH-I	$175.00
Left Side - PTO Kit PTO-II (for driving peripheral equipment; 7000rpm)	Std. Equip.
Mototractor All Purpose Trailer APT-I (.34 cu m)	
York Rake YR-I	$260.00
Moldboard Plow MBP8-I (plowing depth: 10-13cm, width of cut: 21 cm)	$125.00
Double Gang Disc Harrow DH2-I (width of cut: 1.1m, depth of cut: 10cm)	$140.00 (per gang)
Spreader SP-I	$162.80
Soil Cultivator SC-I (adjustable depth)	$150.00
Agri-Fogger AF-I (45 l tank; fogging done at speeds up to 10km/h)	$435.00
Agri-Sprayer AS-I (225 l tank with horizontal or vertical spray booms)	$625.00
Rapid Hose Lay Unit RHL-I (manual rewind; capacity: 300m of 1.3-3.8cm hose)	$395.00
Electric Broadcaster Seeder (34 kg. capacity)	$125.00
Tri-Trak (3rd wheel Attachment)	$195.00

Roadmac CUB Transportation Vehicle

Road Machines (India) Private Ltd.
31 Chittaranjan Avenue
Calcutta 700 012
India
Telephone: 23-0099
Cable: ROADMACH

Description: Air-cooled, manual start, single cylinder 8.5 hp diesel engine; synchromesh transmission with floor mounted gear lever; two wheel drive; rack and pinion steering; dual circuit hydraulic service brakes.

Specifications

weight	- 895 kg	engine	- 8.5 hp
length	- 2.45 m	speed	- 20 km/h
width	- 1.34 m	fuel consumption	- 1.5 litre/h
height	- 1.42 m		
wheel base	- 1.61 m		
payload capacity	- 1,000 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: An all-purpose machine for construction, agriculture and irrigation work; implements include water pump, plough, small generator, and it can pull a trailer with a 1000 kg payload; chassis constructed with locally fabricated steel and assembled locally; all mechanical components are motor vehicle units; maneuverable in difficult ground conditions and grade capability of 28 degrees; working since its introduction in 1973 in S.E. Asia, Middle East, and India.

Cost and Present Status (as of 1/78): US$2,200. Implements vary from US$100 to US$900.

Also Available: Roadmac Lioness - 16.5 hp engine, payload of platform tray - 2000 kg; can pull a trailer with a 1365 kg payload: US$3,000.

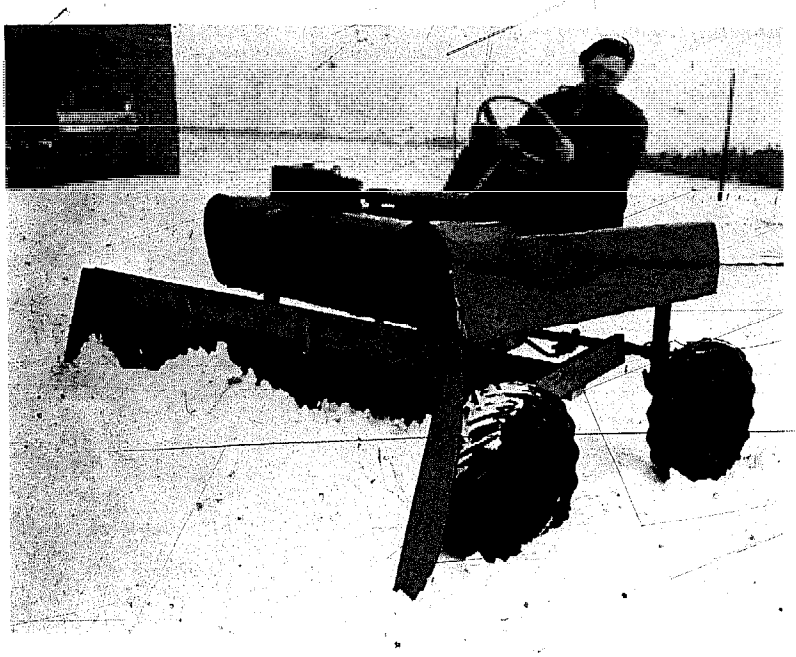

QUADRACTOR

Traction, Inc.
Box 90
N. Troy, Vermont 05859
USA
Telephone: (212) 533.4043
Cable: NYC

Description: 1 cylinder, 4-stroke, 8 hp Briggs and Stratton engine powered tractor; four wheel drive with powered vertical axles; powered suspension system; four wheel cable steering through full 180 degrees; 12 volt electrical system; 72:1 gear reduction, 2 forward 1 reverse gear.

Specifications

length	- 233.7 cm
width	- 127.0 cm
weight	- app. 227 kg.
height (at back seat)	- 147.3 cm
wheel base	- 157.5 cm
tread (at outside of tires)	- 157.5 cm
payload capacity	- 317 kgs carrying app 1 ton pulling
engine	- 8 hp
speed range	- 0-12.9 km/h
fuel capacity	- 3.79 litres
ground clearance	- 78.8 cm

Comments on Maintenance, Productivity, "Appropriateness," etc.: Under development and testing since 1969, this uniquely designed tractor went into production in early 1978; the vehicle has been designed to maximize traction and minimize weight, thus minimize energy wasted driving the weight of the vehicle itself; flexible steel and alloy frame; vehicle may be lowered up to 17.8 cm on one side to allow efficient functioning on steep side grades; climbs a forward grade of up to 42 degrees; functions in up to 78.8 cm of water, thus appropriate for use in rice paddies; wheel assemblies hermetically sealed; maintenance is simple and requires few tools. A full range of accessories are available from the manufacturer, including a winch plus drawbar equipment (2,000 lb load capability), mower (172.7 cm swath for lawns 213.4 cm for haying), rototiller (91.4 cm swath); plow (25.4 cm x 30.5 cm furrow at 3.22 km/hr standard soil), and logging attachment

which carries up to 2 tons across level ground.

Cost and Present Status (as of 2-1-78):

cost of basic Quadractor - app. US$ 2,900.00 (F.O.B. East Coast port)
cost of additional engine to power attachments other than winch - app. US$200.00
price of accessories furnished on request.

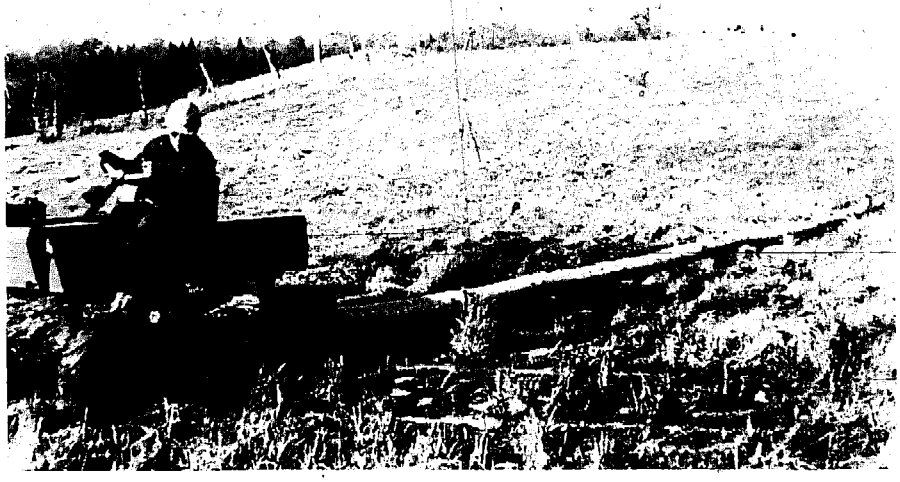

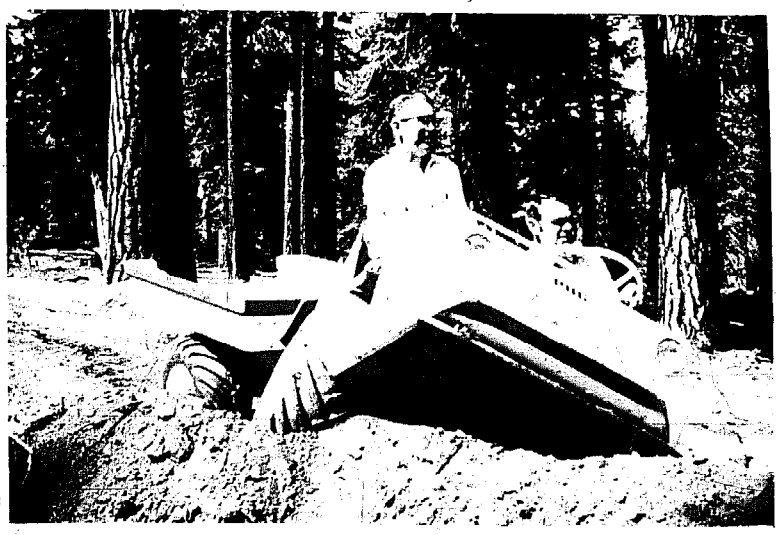

PUG

Bruce Manufacturing, Inc.
7450 France Avenue So.
Minneapolis, Minnesota 55435
USA
Telephone: 612-927-4545
Cable: Pug Minneapolis

Description: 4-wheel drive utility vehicle for farming, ranching, and a multitude of industrial uses; powered by a 4 cycle, 1 cylinder, air-cooled 16 HP Briggs and Stratton engine which unleashes more torque and power traction per horsepower than any other vehicle now being commercially produced; is constructed with separate front and rear sections with individual differentials and the sections are joined by a special universal joint which permits each body section to twist and turn freely while keeping all four wheels in constant traction with the ground; two-speed automotive type transmission with variable speed torque converter; a hydraulically operated dump body can be easily mounted; automotive type steering sector; hydraulic brakes.

Specifications:

weight	- 455 kg	engine	- 16 HP
length	- 3.56 m	speed--maximum	- 40km/hr
width	- 1.30 m	fuel capacity	- 9.1 l
height	- 1.20 m	fuel consumption	- 1.5 l/h
wheel base	- 1.68 m		
ground clearance	- 20.5 cm		
payload capacity	- 909 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Climbs 45 degree hills, fords streams and swamps; can carry 909 kg payload over rough and hilly terrain and obstacles; can pull up to 9000 kg; designed for such farm uses as tilling, mowing, hauling, grading, spraying, and fertilizing; as a personnel carrier, has room for 6 adults in rear plus driver and passenger up front.

Cost and Present Status (as of 2/1/77):
(these are retailed prices; wholesale would be approximately 25% less)

4 wheel-drive Pug	- US $2,950
Hydraulic P.T.O. Assembly	- US $ 195
Grader Blade Assembly	- US $ 295
Draw Bar Hitch	- US $ 6.50

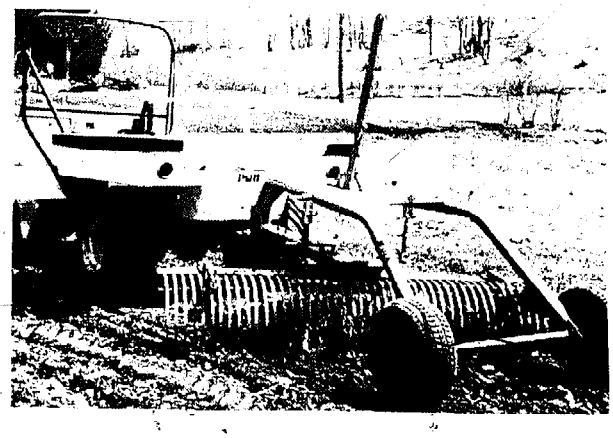

MOTOCHAR XR

Ets LABOURIER & Co
39330 Mouchard (Juro)
France
Telephone: 16 (84) 73.83.14
16 (84) 73.80.06
Telex: 360303

Description: Citroen M 28/1 petrol engine of 28 HP, maximum speed of 25 KM/h; gearbox: 3 forward, 1 reverse; two wheel drive; Rack and pinion steering; the brakes are hydraulic on rear wheels; one man cab or optional 3 man cab.

Specifications :

weight	- 900 kg	engine	- 28 HP
length	- 2.88	speed	- 25 Km/h
width	- 1.55 m	fuel capacity	- 40 liter
ground clearance	- 0.45 m	fuel consumption	- 7 liter/h
payload of vehicle platform	- 1,365 Kg		
payload of trailer	- 2,273 Kg		

Comments on Maintenance, Productivity, "Appropriateness." etc. The Citroen set (engine, gear box and transmission) is available worldwide; the other mechanical parts are of simple design and are rugged; grade capability : 40% slopes; possible implements : irrigation set, tip wagon, water pump.

Cost and Present Status (as of 4/1/78) : Produced and sold in France since the beginning of 1977 at about US$3,350.

Cost and Present Status (as of): TS2210 Tractor US $
Also available are models ranging from 13 HP to 35 HP

Implements:

SR1320 Rotary Hoe (standard tilling width-1.3 m)	US $
Bottom Plow	US $
Disc Harrow	US $
Puddling Rake	US $
Trailer	US $
Land Leveler	US $

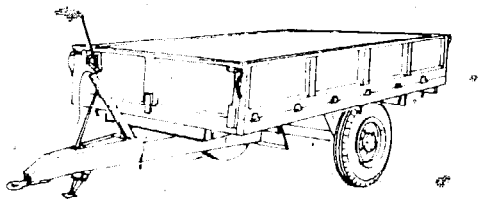

6. FARM VEHICLES: SINGLE AXLE TRACTORS

Descriptions of fifteen single axle tractors are included in this section. Prices vary from US$390 for a very simple 6 hp hand tractor to US$2,310 for a sophisticated 18 to 21 hp machine.

Single axle tractors are not only used for light farm tasks such as mowing, ploughing, tilling, and pumping water for irrigation, but also in place of draught animals for transport purposes. When attached to small carts, these machines can pull as much as 1,000 to 1,500 kg. Some single axle tractors are designed with removable engines that may be put in vehicle chassis more suited for on-road transport.

The single axle tractors described in this section are manufactured and used throughout the world. All parts save the engine could quite feasibly be fabricated locally in developing countries.

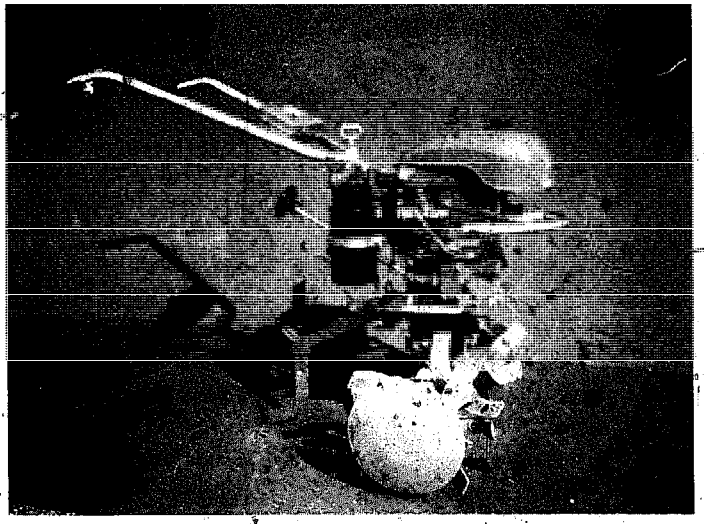

Motozappa S

F. M. di Franceshi &
Masina s.d.f.
Via A. Sarti N.4
Budrio, Bologna
Italy
Telephone: 80.11.89

Description: F. B. Minarelli, single cylinder, 6 hp or 7.5 hp, two stroke cycle engine with forced air cooling; gearbox - 3 forward speeds and reverse speed by request; adjustable handle bar.

Specifications

weight	- 90 kg	engine	- 6 hp or 7.5 hp
length	-.90 cm	speed	-
width	-.45 cm	fuel consumption	- 2.3 kg/h
height	-.60 cm		
payload capacity	- 90 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc: Work width from 10 cm up to 20 cm; power take-off for the application of pumps and cutter bar; designed for olive groves, mountainous cultivations with steep slopes, and gardening; implements include: plough, rubber wheels, iron wheels, trailer.

Cost and Present Status (as of 8/26/77): Commercially produced in Italy at about US$566 and distributed in Greece, Egypt, Yugoslavia. Several other models available with prices ranging from US$390 to US$1,137.

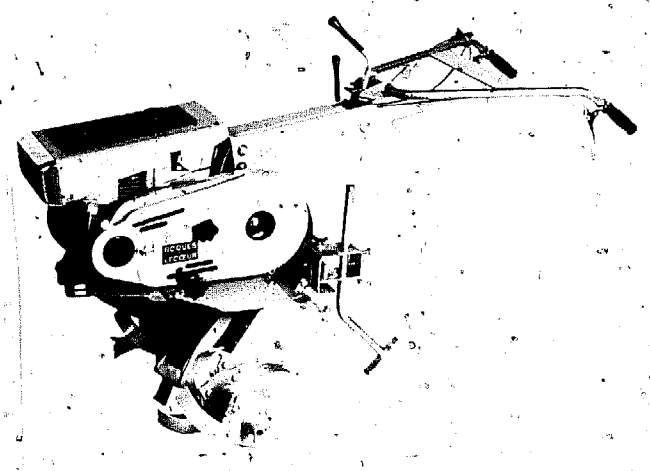

RLX 950 Tiller

Roques & Lecoeur S.A.
78690 Les Essarts Le Roi, France
Telephone: 483-92-44
Telex: 600827

Description: Power pack for multipurpose agricultural work; 4 cycle, one cylinder 5 HP Briggs & Stratton engine (capacity - 205 cc); chain drive transmission - 3 speeds forward and 3 speeds reverse.

Specifications

weight	- basic power pack - 75 kg complete with wheels, weights, and 17.9 cm plough - 250 kg	engine	- 5 HP
		fuel capacity	- 2.4 litres
		fuel consumption	- 1.1l/h
width	- .85 m (with tiller)		
height	- .75 - .80 m		
payload with trailer	- 750 kg.		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Attachments include plough, tiller, furrower, rake, trailer - easily convertible from one to another; additional accessories include pumps, circular saws, etc; handlebars may be adjusted to suit the size of the user.

Cost and Present Status as of 10/77): RLX 950 Tiller - US$564.00*

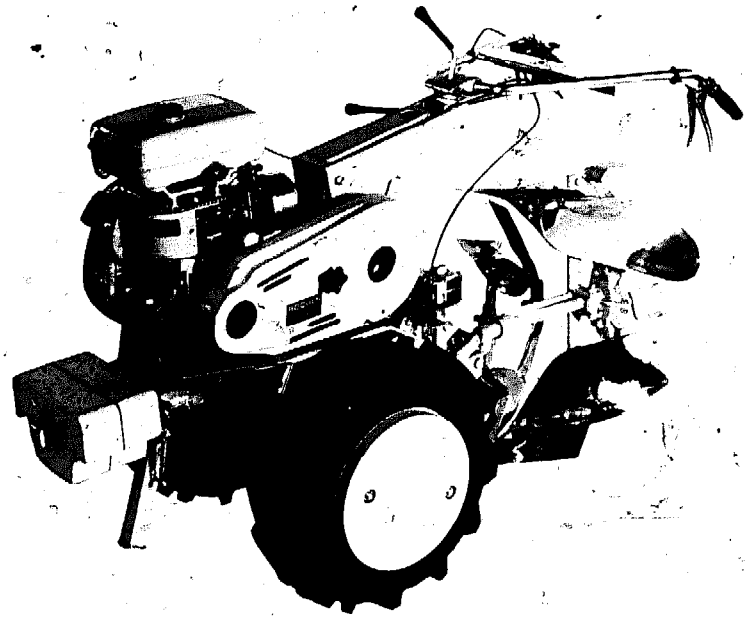

Also Available:
RLX 970 Tiller (7 HP Robin engine, capacity - 250 cc) - US$819.00*

*This price includes no attachments, only the basic power pack.

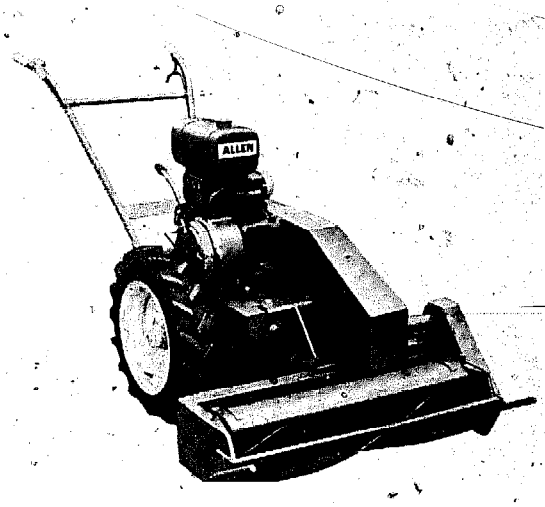

Allen Mayfield 8

Allen Power Equipment Limited
The Broadway
Didcot
Oxfordshire, OX11 8ES
England
Telephone: (0235) 813936
Telex: 837326

Description: Two wheeled tractor unit with 8 hp, 4 stroke Kohler engine; three forward speeds; recoil starter; adjustable handlebars.

Specifications

weight	- 114 kg	engine	- 8 hp
length	- 1.5 m	speed	- 2.4 k/h to 6.6 km/h
width	- .7 m	fuel capacity	- 5.7 l
height	- 1.1 m	fuel consumption	- 1 l/h
payload capacity with trailer	- 600 kg		

Comments on Maintenance, Productivity, "Appropriateness", etc.: Implements include: 920 mm scythe, 820 mm rotary, 770 mm cylinder mowers, spraying equipment (113 l tank), cultivator, ridger, plough, bulldozer blade, and trailer seat; mowing rate varies from .2 ha/h to .7 ha/h.

Cost and Present Status (as of 8/18/77): Tractor unit - net export price, US$810. Implements vary from US$50 to US$234.

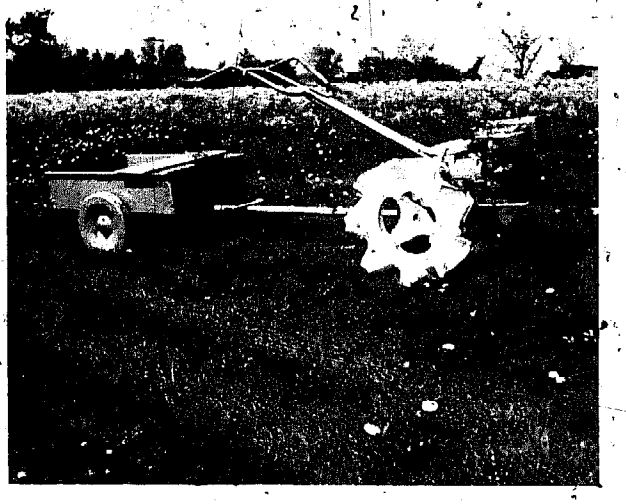

INTEC 77 Tractor

Dowding Tool Products, Inc.
8950 Narrow Lake Road
Springport,
Michigan 49284, U.S.A.
Telephone: (517) 543-0980

Description: Air-cooled, 4 stroke, single cylinder, 7 HP Briggs & Stratton gasoline engine (diesel option to be offered); cast iron transaxle housing encloses double disc dry clutch, 3 stage gear reduction, and power take-off shaft; hand started; cast iron zig-zag tread wheels; adjustable handlebars.

weight	- 156 kg	engine	- 7 HP
with wheel weights & dual wheels	- 272 kg	speed	- 2.9 km/h to 4.0 km/h
length	- 1.83 m	fuel capacity	- 3.6 l
width	- .60 m to .71 m depending on wheels	fuel consumption	- 2 l/h
height	- 1.09 m		
wheel base	- 1.95 m		
ground clearance	- .23 m		
payload with cart (65 cm x 100 cm)	- 272 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Farm implements include 19 cm bottom moldboard plow, 8 blade 100 cm disc harrow, 5 sweep toolbar cultivator, middlebuster, rotovator wheels and drag tooth, 1 row planter-fertilizer unit, (irrigation pump under development);maintenance is primarily limited to changing engine oil and cleaning foam air filter every 25 hours; transmission life should average 2000 hours of field use with only periodic checks on oil level; a few easy-to-do daily

service steps are recommended to prolong life of tractor; requires 20 hr/hectare for plowing 15 cm deep and 4 hr/hectare when discing; external tractor parts and implements are rugged and adaptable for local manufacture; 300 tractors of this design have been in use for 5 years in Jamaica and Ecuador; (this tractor was originally designed and sold by Ford Motor Co.)

Cost and Present Status (as of 8/77): Currently produced in USA, joint manufacture being considered in Colombia and Jamaica.

Basic tractor	US$924.00 FOB factory
Plow	US$ 92.88
Toolbar implements	US$155.95
Disc harrow	US$ 70.00
Rotovator package	US$137.20
Planter unit	US$200.00
Cart	US$ 95.00

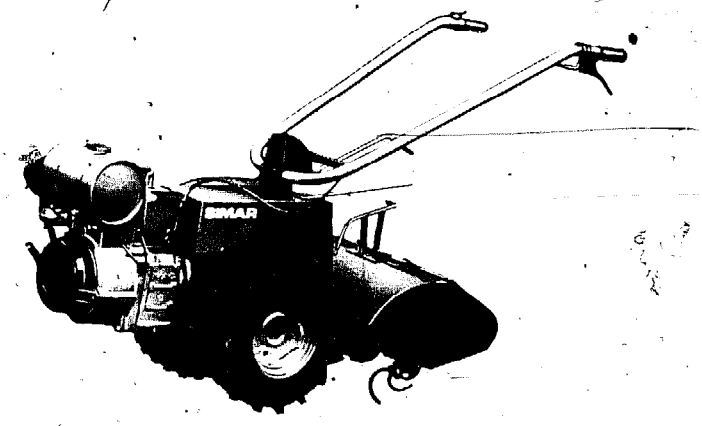

SIMAR Two-Wheel Tractor - 320 D

SIMAR
1 Chemin de la Marbrerie
1227 Carouge
Geneva, Switzerland
Telephone: (022) 42-23-66
Telex: 28-95-91 Sima
Cable: Simar Geneve

Description: Single axle multipurpose walking tractor with air-cooled, single-cylinder four-stroke 7.5 HP engine; transmission - 4 forward and 5 reverse speeds, all synchronized, entirely mounted on ball bearings with oil seal on all shafts including the power take-off; power take-off rotates in both directions at constant rpm; quick coupling for fast assembly of all implements without tools; on request - recoil starter; handlebars - vertically and laterally adjustable; handlebar and controls - reversible 180 degrees without need of tools.

Specifications

weight	- 100 kg	engine	- 7.5 HP
length	- 1.650 m	speed	- .75 km/h to 8.00 km/h
width	- .58 m		
height	- 1.02-1.60 m	fuel capacity	- 4 litres
wheelbase	- .185-.225 m	fuel consumption	- .7 to 1.2 l/h
ground clearance	- .12 - .22 m		
payload with trailer	- 400 kg		

Comments on Maintenance, Productivity, "Appropriateness", etc.:
More than 18 tested and time-proven implements such as several miller units of different widths and depths (with springs and tines or rigid tools), lawn mowers, front mowers with mulching bar, reversible plough, hoe, potato digger, riding sulky and trailer with riding seat for road transportation; needs little maintenance and has a long life duration; over 50,000 units built since 1918 and a great number of those built before 1940 are still in service. Exported regularly to 15 countries on several continents.

Cost and Present Status (as of 3/1/78):
Basic 320 D model - US$1,150 ex-works.
Implements ranging from US$100 to US$600 ex-works.

Also Available:
Model 220 - 5 HP engine and weight - 60 kg.
Model 420 - 10 HP engine and weight - 150 kg.

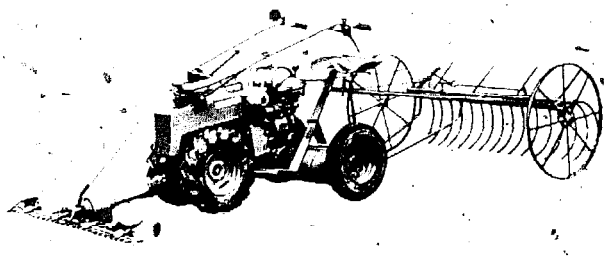

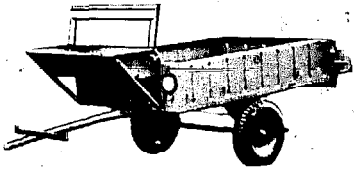

Pasquali Motorcultivators
(941 and 946)

Motocultores Pasquali, S.A.
Poligono Industrial "Can Jardi"
Calle Haendel, s/n
Apartado Correos 132
Barcelona
Spain
Telephone: (34-3) 299 09 00
Cable: MOTOCULTORES

Description: 14 and 18 hp motorcultivators, 1-cylinder, air cooled, diesel engine; 9 forward speeds, 3 reverse; hand start; may be easily converted to 4-wheel articulated tractor.

Specifications

weight	340-350 kg	engine	14 and 18 hp
length	2.00 m	speed	0.6 to 25 km/h
width		fuel consumption	1 l/hr
height	0.85 m	fuel capacity	
wheel base			
payload capacity	1,500 kg (with trailer extension)		

Comments on Maintenance, Productivity, "Appropriateness", etc: The single-axle cultivators are easily converted to double-axle, articulated tractors, or a double-axle transport vehicle with a heavy duty platform bed; the transport vehicle seats one and pulls up to one and one half tons on a 45° slope; design and conversions are simple, little maintenance required; full range of implements available; exported to 19 countries in Europe, South America, and Africa.

Cost and Present Status (as of 6/77):

14 hp model 941 - US$1,288 F.O.B.
18 hp model 946 - US$1,331 F.O.B.

Also Available: 14 and 18 hp articulated 4-wheel diesel tractors, 2.20 m long, 1.06 m in height, factory single-axle tractor conversions:

14 hp model 941/603 - US$2,194 F.O.B.
18 hp model 946/603 - US$2,237 F.O.B.

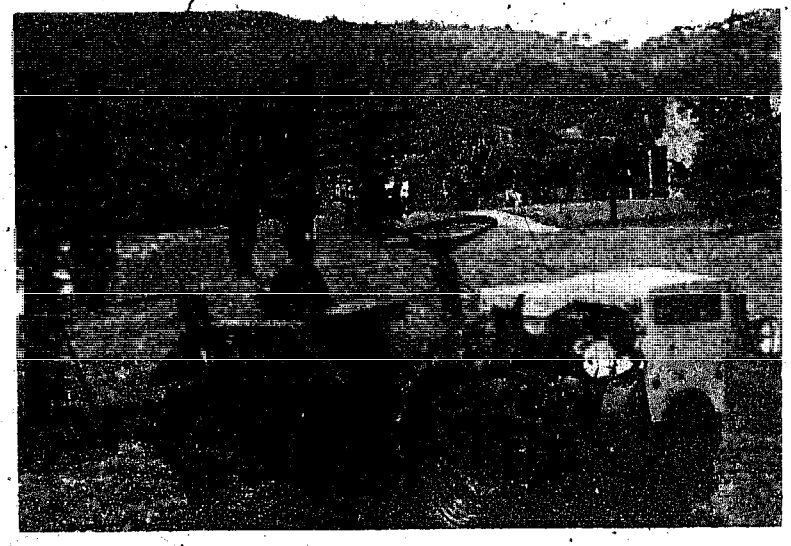

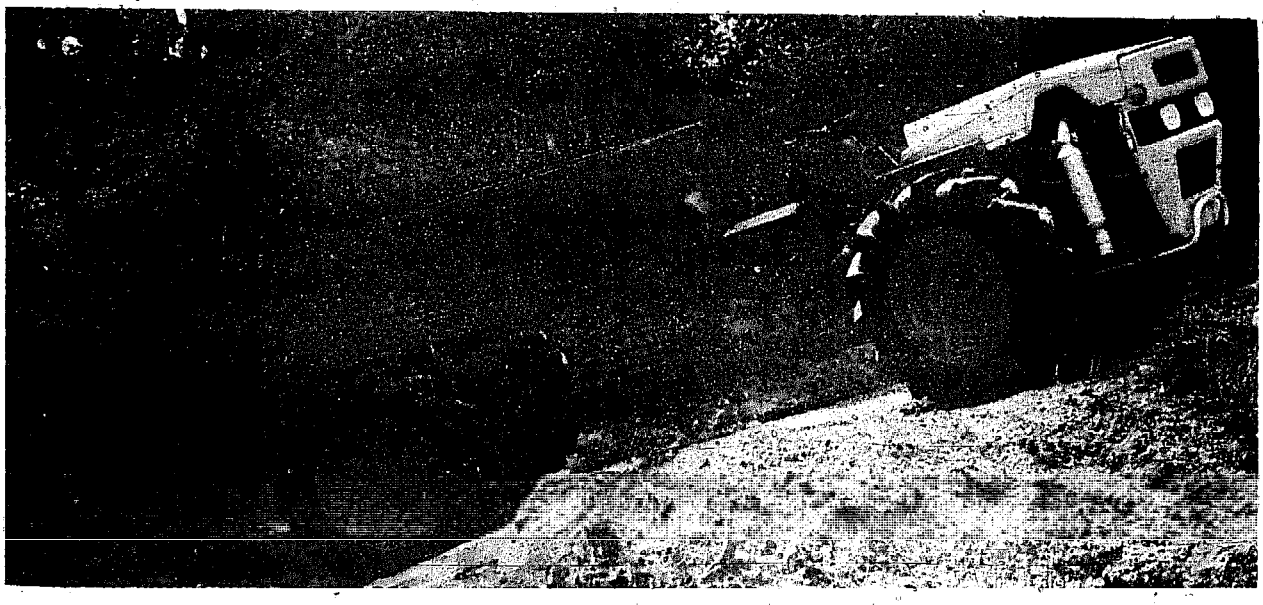

Krishi Power Tiller

Krishi Engines Ltd.
A-7 Unit, Sanatnagar
Hyderabad-500018
India
Telephone: 269306
Telex: CARE 015-372 ESTATE

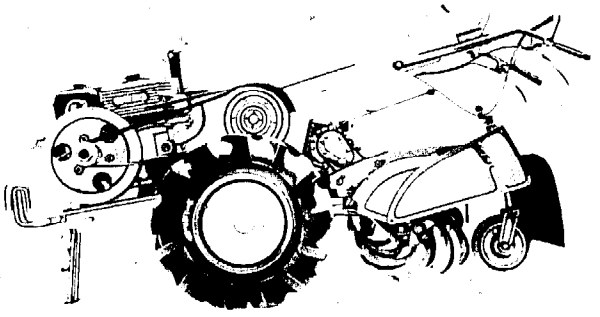

Description: Model NV-700; center drive rotary, equipped with a 7 HP, water-cooled, 4 stroke, single cylinder diesel engine; tilling width-61 cm; tilling depth-15.2-17.8 cm; number of blades-18; operating speeds-4 forward, 2 reverse; maximum blade speed-240rpm.

Specifications:

weight	- 340 kg	engine	- 7 HP
length	- 1.85 m	speed	- 1.5km/h to 21km/h
width	- .76 m	fuel capacity	- 6 litres
height	- .99 m	fuel consumption	- 210 gms./B. H.P. Hr.
ground clearance	- .23 m		
payload with trailer	- 1,500 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Equals 4 pairs of bullocks in work output; design incorporates local materials; production and assembly operations are simple to provide easy operation and maintenance without the need for complicated tools and fixtures; expected life is around 10 years; the tiller's effectiveness in puddling operations has resulted in intensive marketing in rice growing areas of neighboring states.

Cost and Present Status (as of 6/30/77): US $1,300; estimated economic level of production is 600 tillers per annum.

Implements:

Mouldboard Plow-field capacity is 17-20 hrs/hectare with average depth of 15-20 cm
Reversible Plow-field capacity is 17-20 hrs/hectare with average depth of 15-18 cm
Cultivator-field capacity is 7-10 hrs/hectare with average depth of 8 cm
Disc Harrow-field capacity is 7-10 hrs/hectare with average depth of 8-10 cm after two cross and length-wise operations
Riding Sulky-field capacity is 5-7 hrs/hectare with effective puddling operation
Ridger-vee and trapezoidal ridges can be made
Ferti-Seed Drill-used for sowing crops and application of fertilizer
Various blades and wheels are available

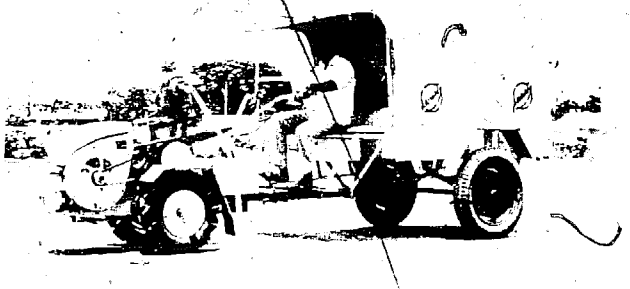

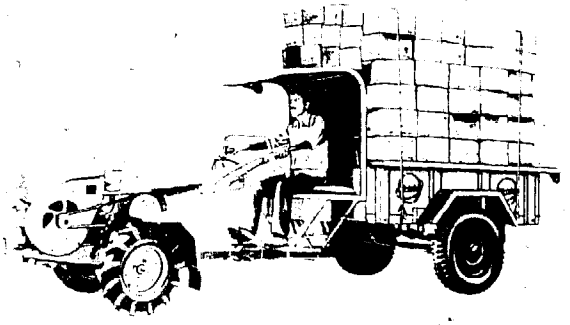

Also available:

Hippo Hauler - US $1,750
2 wheel trailer attached to the model NV-700 power tiller; various sorts of bodies-high steel walls, wire mesh, canvas covering, or even a 1,500 liter water tank--can be built on the chassis, thus making it adaptable to meet several farmers needs; weight-500 kgs; payload-1,500 kg; speeds-1.5 km/h to 21 km/h; fuel consumption-17 kms/l; ground clearance-22 cm; gradient when fully loaded-1 in 10.

Super Special 130 Motorcultivator

Goldoni S.p.A
Via Canale 3
41012 Migliarina di Carpi
Modena
Italy
Telephone: 0522-699240
Telex: 53023 Goldoni

Description: Single axle motorcultivator with diesel or gasoline, air-cooled 13 hp engine; gearbox - 4 forward and 2 reverse speeds with differential lock; 2 power take-off shafts - one with speeds of 3,000, 1,393, and 740 rpm and the other with 934 and 575 rpm; independent and simultaneous brakes with rubber wheels; rotary tiller width - adjustable to 35, 46, 57, 68 or 80 cms.

Specifications

weight	- 236 kg	engine	- 13 hp
length	- 1.80 m	speed	- 1.37 to 11.19 km/hr
width	- .60 m	fuel capacity	- 5.5 litres
height	- 1.15 m	fuel consumption	- about 180 grs. per hp/hr
payload capacity with trailer	- 1,000 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Its range of implements include: rotary cultivators, trailers with differential, spraying and centrifugal water pump, pulled fibreglass tank, ploughs, side mower, circular saw, and rotary lawn mower; presently being used in Ghana, France, Ecuador, Algeria, Switzerland, Spain, USA, Portugal, Yugoslavia, Greece, Turkey, Tunisia, Libya, Egypt, Jordan, Costa Rica; capacity of work with plough: depth 15/20 cms, width 20/25 cms. 900 sq/mts. per hour; capacity of work with rotary cultivator: width 80 cms, 1,200 sq/mts per hour.

Cost and Present Status (as of 1/23/78):
Super Special 130 with rubber wheels - US$1,351.00.
Implements vary from US$37.76 to US$845.25.

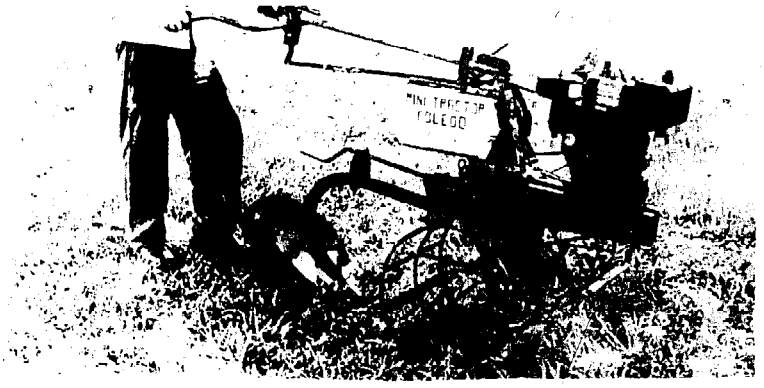

Toledo Mini-Tractor

Taller Toleda Ltda.
No. 36-26 Carrera 8a-A
Cali, Colombia
Telephone: 401220-441737

Description: 7 HP Briggs & Stratton gasoline engined tiller that performs such operations as plowing, puddling, cultivation, and hauling; is constructed from standard drive components and simple structural sections-four main parts: main frame, transmission, handlebar, & engine; handlebar adjusts forward and back to permit operation with towed implements; to change from field speed to transport speed or vice-versa, the operator simply slips a V-belt from one set of pulleys to another.

Specifications:

weight	- 112 kg	engine	- 7 HP
length	- 2.0 m	speed (maximum)	- field - 4.3 km/h
width	- 1.2 m		- road - 11.5 km/h
height	- .96 m	fuel capacity	-
		fuel consumption	- 4 l/h

payload of trailer -

Comments on Maintenance, Productivity, "Appropriateness," etc.: Tiller is lightweight so three men can lift it out if the tiller bogs down; attachments can be changed in seconds without the use of tools; high ground clearance makes it well-suited for wet, muddy fields; constructed according to IRRI (Int'l Rice Research Inst.) design; built mainly from local materials; the solid construction, the sealed bearings and the transmission box results in low maintenance needs; oil in the chaincase lubricates all moving parts; plowing wet soil (one pass) - .5-.8 ha/8hr-day, harrowing flooded soil (one pass) - 1.0 ha/8hr-day; implements include blade, harrow, towbar, turf cutter, pump, heavy-terrain and light-terrain hauling tiles, cultivator blades, and weights.

Cost and Present Status (as of 6/20/77): Toledo Mini-Tractor - US $1,400 (including trailer)

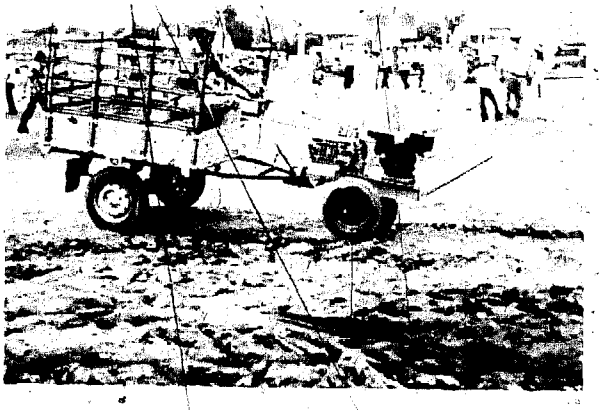

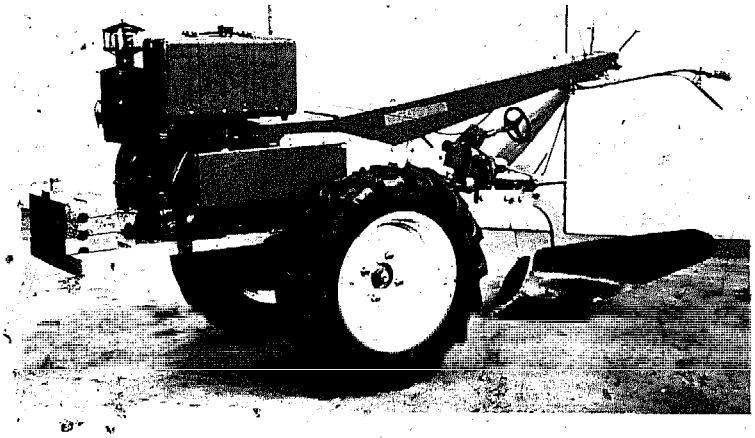

TR Tractor

Bouyer S.A.
Boite Postale No. 7.
54510, Tomblaine, France
Telephone: (28) 29-26-62
Telex: 960484 F

Description: Air-cooled and hand started, one cylinder, 4 stroke engine from 10 to 16 HP; transmission - mechanical gearbox, 6 forward speeds and 3 reverse; 3 independent P.T.O. (260 rpm, 685 rpm, 1590 rpm); vertically adjustable handlebars.

Specifications

weight (without front and wheel weights)	-	260 kg	engine	-	up to 16 HP
length	-	2.32 m	speed	-	.48 km/h to 8.61 km/h
width	-	.60 m	fuel capacity	-	10 litres
height	-	.95 m	fuel consumption	-	1 l/h
ground clearance	-	.16 m to .25 m under axle, .345 m to .43 m under engine			
payload with trailer	-	1000 kg			

Comments on Maintenance, Productivity, "Appropriateness", etc.:
Oil regenerator and oil bath air filter specially designed for hot climates; suited for work in dry and wet cultures; range of implements includes 3 types of plough, rotovator with different skids, puddling equipment, tool carrier, ridger, potato harvester, spring tine cultivator, irrigation pump, tipping trailer (with brakes), special spraying equipment, drills, sickle mower, back mower; simple design reduces maintenance and makes eventual repairs easier; sold in Tunisia, Morocco, Ivory Coast, Mali, Niger, Senegal, Upper Volta, Chad, Cameroon, East Africa Community, Nigeria, Egypt.

Cost and Present Status (as of 8/77): TR Tractor - US$1,550 (ground unit)

Also Available:

MT 80 Tractor - designed for tropical tilling in small and medium size plots; air-cooled, 4 stroke, one cylinder 8 or 10 HP diesel engine; tractor weight with tropical cultivator - 690 kg; speed - up to 17 km/h.

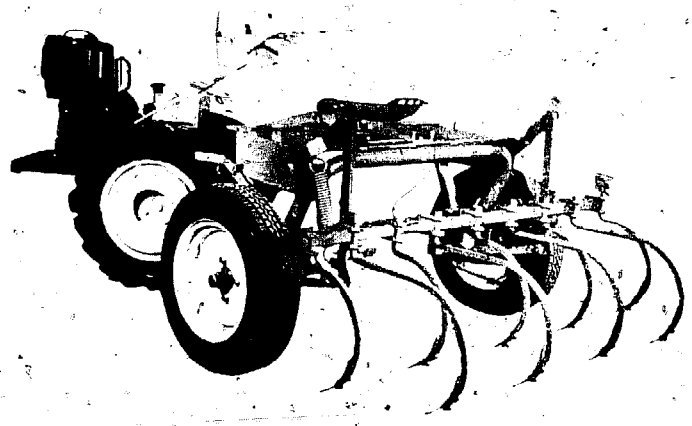

Mitsubishi Power Tiller CT85

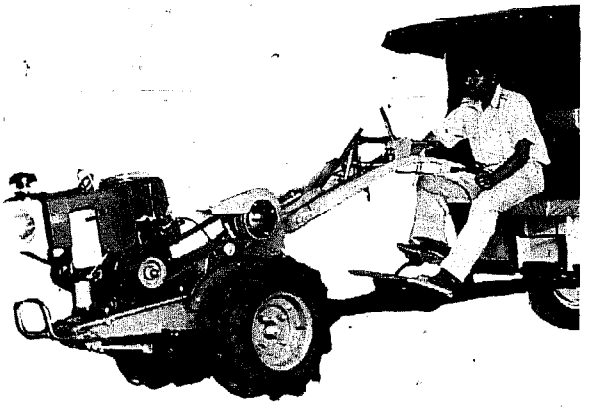

V.S.T. Tillers Tractors Ltd.
P.B. No. 4801
Whitefield Road, Mahadevapura P.O.
Bangalore 560 048, Karnataka State
India
Telephone: 58205, 58206, 58207
Cable: POWERTILER - Bangalore 560048

Description: Two wheeled drive; 8 to 10 hp, air cooled, four stroke single cylinder diesel engine; 6 forward speeds, 2 reverse speeds, 4 rotary speeds; track adjustable between 65 cm to 100 cm; multiple plate dry disc brake - internal expanding metallic shoe type; turning by side dog clutch arrangement; manual start.

Specifications

weight	- 345 kg	engine	- 8 to 10 hp
length	- 230 cm	speed	- 9 km/h to 22.0 km/h
width	- 67 cm	fuel capacity	- 8 liters
height	- 120 cm	fuel consumption	- between 1.0 to 1.5 l/h
payload capacity with trailer	- 1,500 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc: Range of implements include: rotary with 16 blades, reversible moldboard plough, 5 tine cultivator, furrower, dry land leveller, trailer, high volume sprayer, water pump - 75 mm x 75 mm, grass cutter, ground nut/potato harvester, rotary plough, multi-purpose thresher, auger; multipurpose machine suited for working on small farms and transportation on undulating terrains; designed for use in wet paddy fields with knee deep water and designed to suit tropical conditions; tested extensively at the Government of India Tractor Training and Testing Station, BUDNI; dry rotary tilling - .8 to 1.0 ha/8 hr, wet puddling - up to 1.2 ha/8 hr, ploughing - up to 6 ha/8 hr, pumping - 440 l/m at 1,200 rpm; six to ten times more productive than a pair of bullocks.

Cost and Present Status (as of 1/9/77):
Mitsubishi Power Tiller CT85 with rotary, US$1,550.
Mitsubishi Power Hauler (tiller with trailer) US$1,850
Manufactured in collaboration with Mitsubishi Heavy Industries Ltd. of Japan.

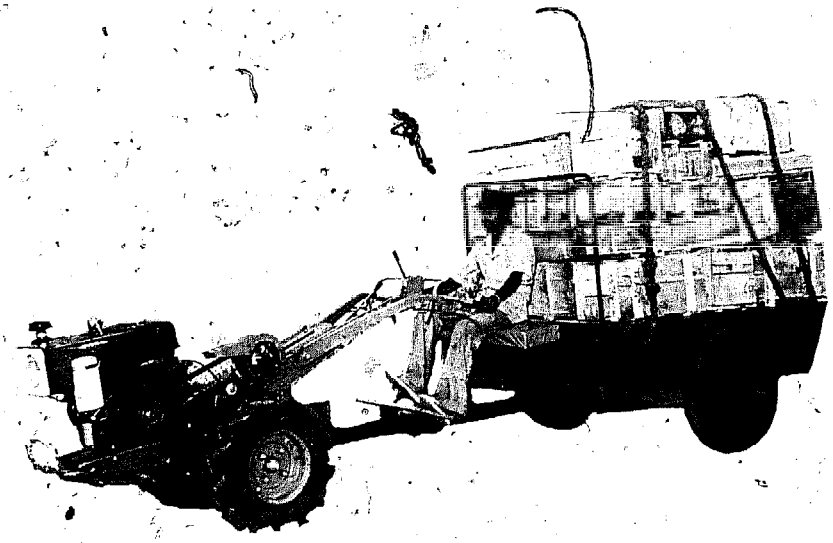

Diamond Hand Tractor

Bingkil Muntijul, Jl
Semarang 62-64
Surabaya,
Indonesia
Telephone: 44273

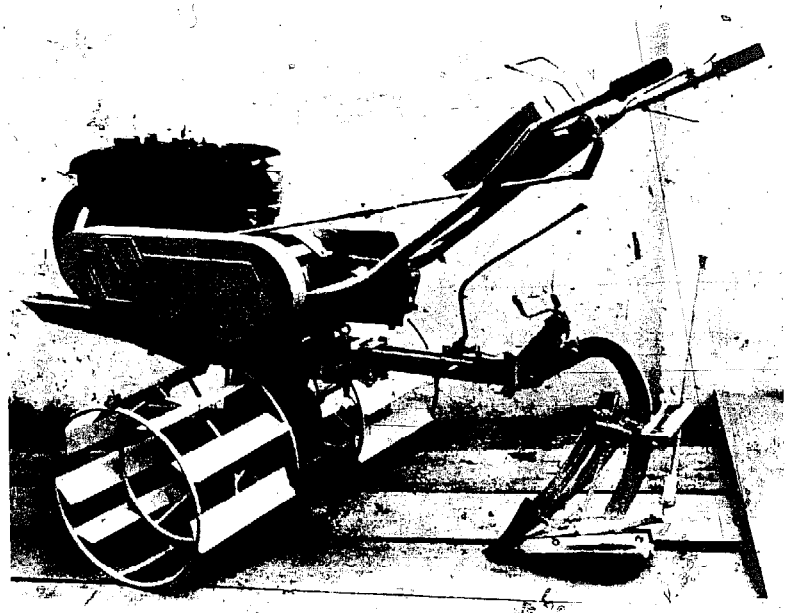

Description: Hand directed two-wheel tractor, 7 hp Honda engine, choice of gasoline or diesel; cord pull starter; hand-operated fuel lever and clutch for forward and stop only; optional mini trailer unit which may be attached to standard hitch.

Specifications

weight	- 126.5 kg	engine	- 7 hp
length	- 2.4 m	speed	-
width	- 1.1 m	fuel capacity	-
height	- 1.32 m	fuel consumption	- 1 litre/hr or 24 litre/ha
wheel base	-		
ground clearance	-		
payload capacity with trailer	-		

Comments on Maintenance, Productivity, "Appropriateness," etc.: May be attached to specially designed cart for carrying goods or people, attachments include leveling rake and moldboard plow; designed to be appropriate for road conditions in developing countries such as Indonesia; similar to vehicle used in Philippines, with minor modifications for soil and climatic differences.

Cost and Present Status (as of 8/14/77):

Hand tractor with diesel engine: US$1619
Hand tractor with gasoline engine: US$1143
Mini trailer: US$429

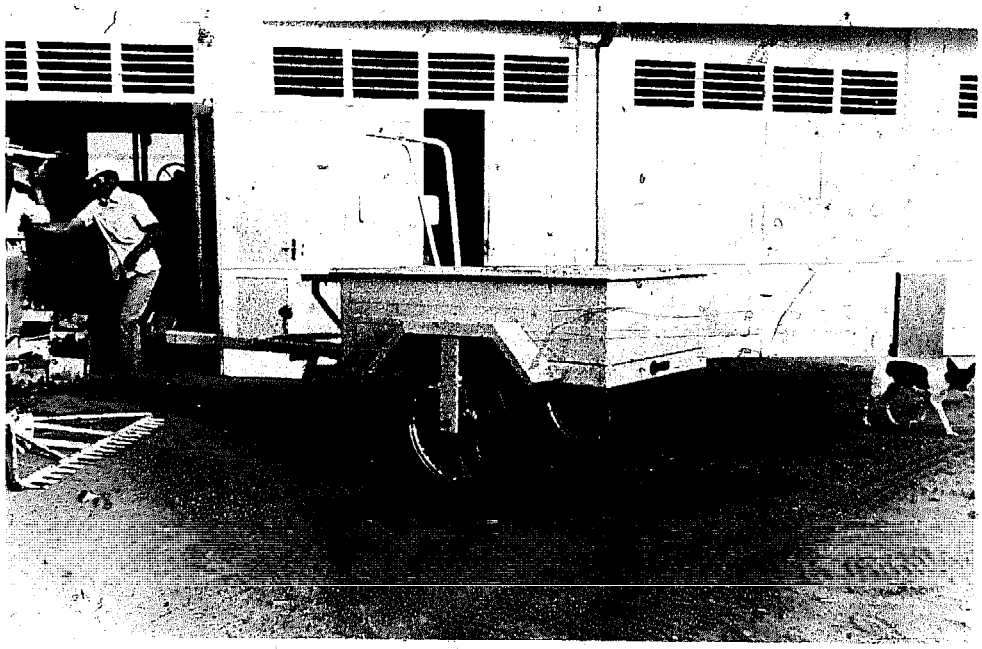

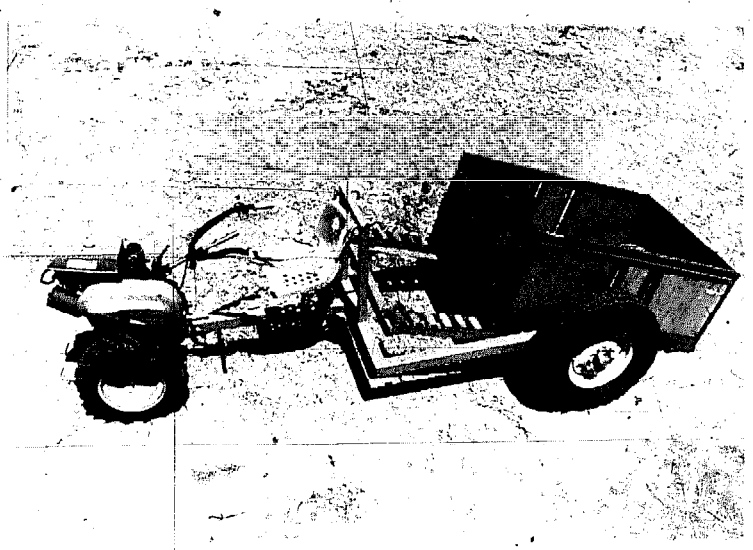

Roller Bed Carrier

Ramat David Metal Works
Post Ramat David 30093, Israel
Telephone: 065-66111

Description: Single-axle trailer which unloads by sliding pallets and containers rearward on rollers; suitable for many agricultural uses; available in a wide range of weights and sizes:

weights	-	from 500 kg to 10,000 kg
lengths	-	from 1.60 m to 6.00 m
widths	-	from 1.50 m to 3.00 m

The smallest trailers come equipped with a single-axle tractor with a capacity of between 6-24 HP and a speed of up to 10 km/h; the biggest trailers are pulled by standard tractors.

Comments on Maintenance, Productivity, "Appropriateness," etc.: Maintenance and operation of the single-axle trailer are simple, and the roller bed carrier is also of simple design and construction; the small tractor can perform many other agricultural tasks not related to hauling, and in combination with the roller bed carrier it becomes a versatile and inexpensive low-maintenance farm machine.

Cost and Present Status (as of 8/77): 6 HP single axle tractor with a roller bed carrier which has a payload of 700 kg - US$1,900.

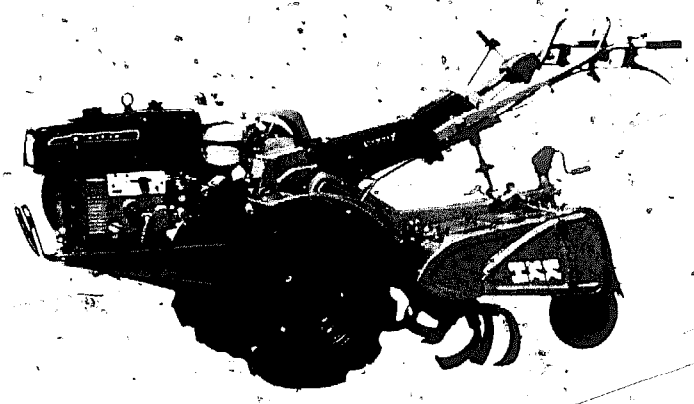

Suzue Power Tiller - LAC-90

Chuo Boeki Goshi Kaisha
CeCoCo Agricultural & Small
Industrial Center
P.O. Box 8, Ibaraki City
Osaka, Japan
Telephone: Ibaraki 0726-22-2441 3
Cable: CeCoCo Ibaraki

Description: Center drive, equipped with a 8-11 HP water-cooled diesel engine and a rotary hoe set; tilling width-54 to 73 cm; number of tilling blades-18 to 22; speeds-6 forward, 2 reverse and 4 steps for rotary work; the levers of speed change, PTO speed, and clutch are located on the handles.

Specifications:

weight	- 350 kg	engine	- 11 HP
length	- 2.2 m	speed	- (max. speed on the road) 15km/h
width	- .7 m		
height	- 1.1 m	fuel capacity	-
		fuel consumption	-

payload with trailer - 500 kg

Comments on Maintenance, Productivity, "Appropriateness," etc.: Any engine can be loaded on the engine frame in compliance with the buyer's wishes; handle is adjustable up and down so to agree with a worker's physique; wide range of implements available.

Cost and Present Status (as of 10/77): Suzue Power Tiller LAC-90 US$2,080
Also available LEC-50 model tiller (5-7 HP engine) US$1,800
(F.O.B. Kobe, Japan)

Implements:

Ridger	US $36
Reversible Plow	US $84
Trailer with saddle, pneumatic wheel, hitch bar and brake	US $580
Self-priming centrifugal pump	US $450

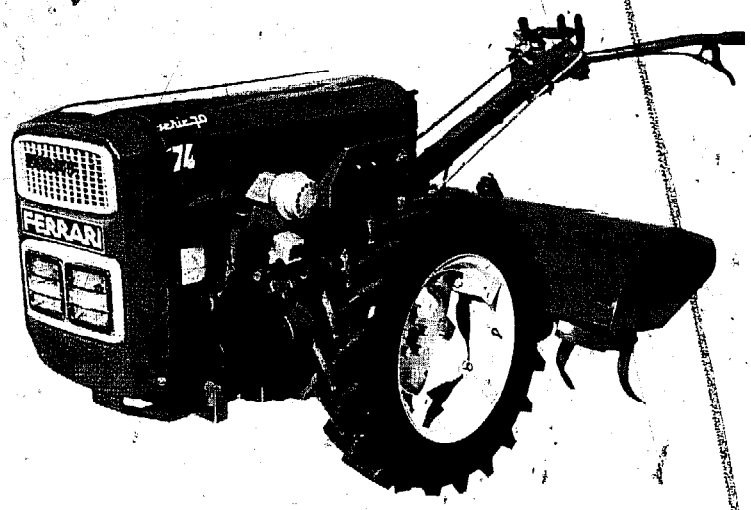

Ferrari 74 Motor Cultivator

Ferrari S.p.A.
Officine Meccaniche
42045 Luzzara
Reggio Emilia
Italy
Telephone: (0522) 835113/216
Telex: 53144 Fermac

Description: Air-cooled, single cylinder, 18-21 hp diesel engine; electric or jerk starting; gearbox - 6 forward and 3 reverse speeds; clutch - dry single plate type; two P.T.O.s - 550-640 rpm and 800-930 rpm, one synchronized for towing trailers with driving wheels; adjustable steering handlebar; variable track - according to type of tire, wheel, and spacer assembly - minimum of 560 mm and maximum of 970 mm; drum type brakes.

Specifications

weight (with tiller)	- 430 kg	engine	- 18-21 hp.
length	- 2.30 m	speed	- .9 km/h to 15.4 km/h
width (with tiller)	- 1.00 m		
height	- 1.00 m		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Designed to handle a broad range of agricultural and other operations such as ploughing, mowing, irrigating, spraying, towing, etc.; its central articulation makes handling easier.

Cost and Present Status (as of 1/1/78): app. US$ 2,310.
Several other models available, ranging from 7 to 14 hp.

7. FARM VEHICLES: THREE AND FOUR WHEEL RIDING TRACTORS

Thirty-one tractors are described in this section. Six are prototype vehicles, currently being tested in developing countries. Five of these could be assembled in local shops using imported mechanical parts and locally fabricated bodies. The remaining twenty-five tractors are manufactured and used throughout the world in both developing and industrialized countries.

The tractors are powered by engines ranging from 7 hp to 30 hp, and are priced from approximately US$1,500-4,886. Most have a payload capacity of about one half ton, although several models can carry as much as two and one half tons.

While this type of tractor was designed for general farm tasks such as ploughing, tilling, and the like it is often used for off-road transport. The tractors can be easily hitched to a cart for this purpose.

Mouzon-Le Lous Row Crop Tractor

Mouzon
B.P. 26
60250 Mouy, France
Telephone: 456-56-18

Description: 7 to 10 HP engine, either gasoline or diesel; transmission - 3 forward and 3 reverse gears; simplified hydraulic lifting.

Specifications

weight	-		engine	-	up to 10 HP
length	-		speed (ploughing)	-	4 km/h
width	-		fuel capacity	-	
height	-		fuel consumption	-	
wheel base	-				
ground clearance	-	.60 m			
payload with trailer	-	800 kg			

Comments on Maintenance, Productivity, "Appropriateness," etc.: Although power is limited to 10 HP, its weight and mass balance enables it to plough even in hard conditions with a one furrow plough; features all tools necessary for drag-chain tilling; traction power is equivalent to two strong oxen.

Cost and Present Status (as of 8/77): Prototype.

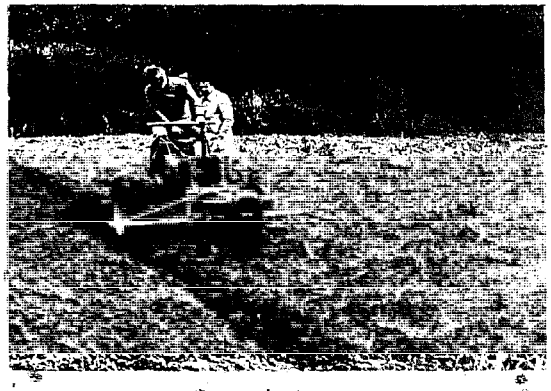

One-Wheel-Drive Tractor

National Institute of Agricultural Engineering
Wrest Park, Silsoe
Bedford, U.K.
Telephone : Silsoe (0525) 60000
Telex/Cable :

Description : Small three-wheel tractor; 2 cylinder, 9.5 hp diesel engine; mechanical transmission.

Specifications :

wheel base	- 1.68 m	engine	- 9.5 hp
wheel track	- 1.53 m	speed	- maximum 12 km/h

Comments on Maintenance, Productivity, "Appropriateness," etc.:

Prototype testing trials were stopped in 1964 because of lack of interest in African countries.

Costs and Present Status (as of):

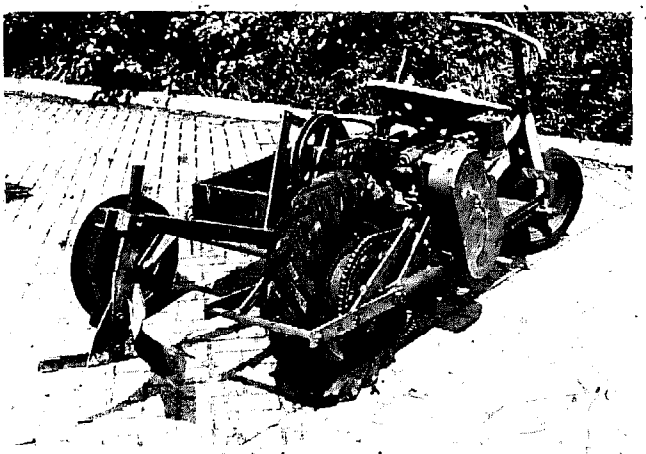

Three Wheel Riding Tractor

Department of Agricultural
Engineering
State University of Agriculture
Mansholtlaan 12
Wageningen, The Netherlands
Telephone (08370) 82980/19110/19143

Description: Air-cooled, hand started, 4 stroke, one cylinder 7 HP Briggs & Stratton gasoline engine; transmission - V-belt and chain drives; wheel arrangement results in only 2 tracks; bicycle type of steering; main frame is made of 3.8 cm pipe; speed is changed by transferring the V-belt from one pulley to the other; simple band brake; drawbar behind the driving wheel with a central hole for hitching a trailer.

Specifications

weight	-	approx. 320 kg	engine		- 7HP
length	-	2.40 m	speed:	field operations	-4 km/h
width	-	1.19 m		transport	-10 km/h
height	-	1.00 m	fuel capacity		-3.8 litres
wheel base	-	.90 m			
ground clearance	-	.335 m			

Comments on Maintenance, Productivity, "Appropriateness," etc.: This tractor was designed to provide a suitable replacement for bullock power in India; implements to be used with this tractor will be improved bullock-drawn implements; engine can be taken out for running stationary machines like a water pump and thresher; can be manufactured in a small smithy and welding shop; engine, tires, bearings, belts, chains and different materials for

the construction of the tractor are available in India; the major operations in the manufacturing process are cutting, welding and drilling; turning operations are required on two shafts, three axles and housings; construction is very simple and familiar to bicycle repair shops; these shops can open and assemble the tractors without any instructions; the shops are very common in India and can play a major role in the first stage of its popularization; the tractor is designed to replace two pairs of bullocks.

Cost and Present Status (as of 8/77): Prototype; certain improvements have been suggested after which manufacturing could be undertaken.

15-20 HP Tractor

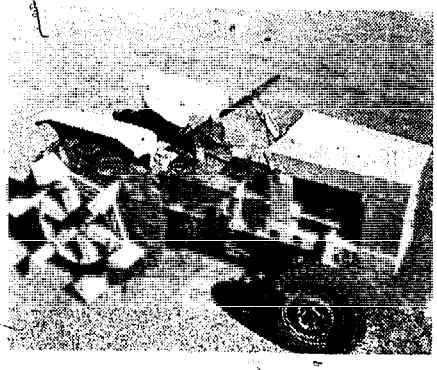

IRRI-PAK Agricultural Machinery Program
73-A, Satellite Town
Rawalpindi,
Pakistan
Phone: 42193

Description: four-wheel tractor powered by 15 to 20 HP diesel or gasoline engine; requires standard automotive components such as gear transmission, differential, transfer box, steering gear box, wheels and brake assemblies.

Comments on Maintenance, Productivity, "Appropriateness", etc.: The tractor is designed to utilize readily available automotive parts to facilitate local production in developing countries; a prototype tractor with jeep components was recently received from the Philippines; interest in local production is under evaluation.

Cost and Present Status (as of 1/78): prototype

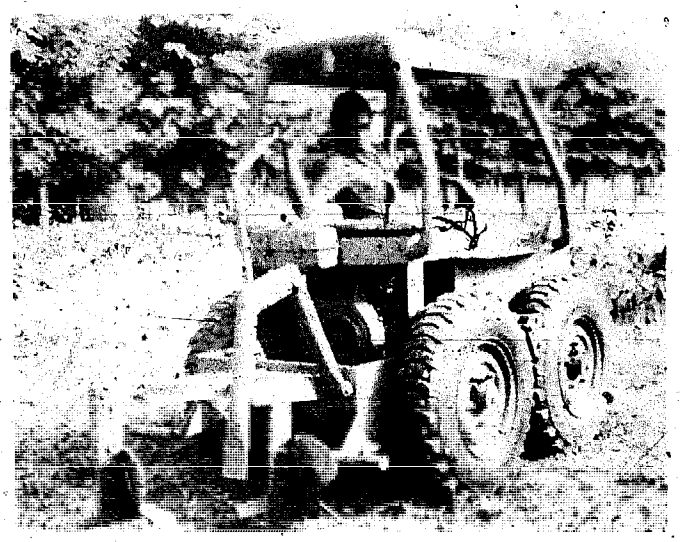

Pangolin CD26

Le Bureau de Developpement
Industriel
B.P. 4196
Abidjan, Ivory Coast
Telephone: 22-78-81, 32-42-86
Telex: Burdevi 793 R.C.I.

Description: Air cooled, 26 HP diesel engine; gear box-axle -- 3 forward synchronized gears and 1 reverse; drive-rollers are sandwich-mounted between the front and rear wheels to provide 4-wheel drive; steering--through 2 levers independently actuating the right or left hand brake, if one brake is applied, both corresponding wheels and their track are blocked; brakes--through fluid master cylinder; suspension--none, the axles are fixed and rigid and no articulation; power take-off--through pulley wheels at back of engine; tracks--articulated, 35mm pins in plastic sleeves (locally made); chassis--self-supporting with 2 safety hoops and rugged sheet metal roof.

Specifications:

weight	- 800 kg	engine	- 26 HP
length	- 1.8 m	speed	- 2km/h to 14km/h
width	- 1.24 m		
height (with roof)	- 1.74 m	fuel capacity	-
wheel base	- .7 m	fuel consumption	-
ground clearance	- .42 m		
track	- 1.0 m		
payload capacity			

Comments on Maintenance, Productivity, "Appropriateness," etc.: Constructed by village artisans and can thus be repaired by artisans in remote areas; the engine-gear box is imported, already assembled, from Ets. Jacquet (France), and the chassis, tracks and 6 hubs are made locally; production tasks are limited to simple welding and carpentry and can be performed in a workshop equipped with a reciprocating saw, welding equipment, oxyacetylene cutter, grinding machine, portable drilling tools and hand tools, mixed production is possible with a plant in a major city and small workshops in the rural areas; various implements can be

attached, i.e., single-share plow, twin-share plow, minibulldozer blade (height-.4m and width-1.25m), in the development stage are a small land clearer and a light gyro-crusher.

Cost and Present Status (as of 7/77): Prototype--since work began on the vehicle in January 1974, there have been several improvements to the original design; under the auspices of IDB (Le Bureau de Developpement Industriel), five newly constructed prototypes are being tested at Katiola, Ivory Coast; the testing program is examining different engines, methods of traction, and various agricultural and special implements; these three other models have also been introduced: (1) RD16 (16 HP engine and weight-600 kg), (2) RD26 (26 HP engine and weight-650 kg), and (3) RE28 (28 HP engine and weight-650 kg).

AFCOM Tractor

AFCOM
Route de Vridi
B.P. 11670
Abidjan, Ivory Coast
Telephone:
Telex/Cable:

Description: 4 stroke, 2 cylinder, air-cooled 15 HP diesel engine; electric start; transmission - 4 forward and 1 reverse gear, speed-reducing gearbox; power take-off - 1500 rpm; hydraulic foot brakes; the front load pan can easily be tilted forward.

Specifications

weight (with platform)	- 870 kg	engine	- 15 HP
length	-	speed	- 3.6 km/h to 13.0 km/h
width	-		
height	-	fuel capacity	-
wheel base	- 1.75 m	fuel consumption	-
ground clearance	- .55 m		
payload of front load pan	- 900 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Implements include plough, cultivator, seeder, and trailer; recorded ploughing times: medium ploughing - 6 hr/ha, deep ploughing - 12 hr/ha, weeding - 2 hr/ha, ridging - 3 hr/ha.

Cost and Present Status (as of 8/77): Prototype.

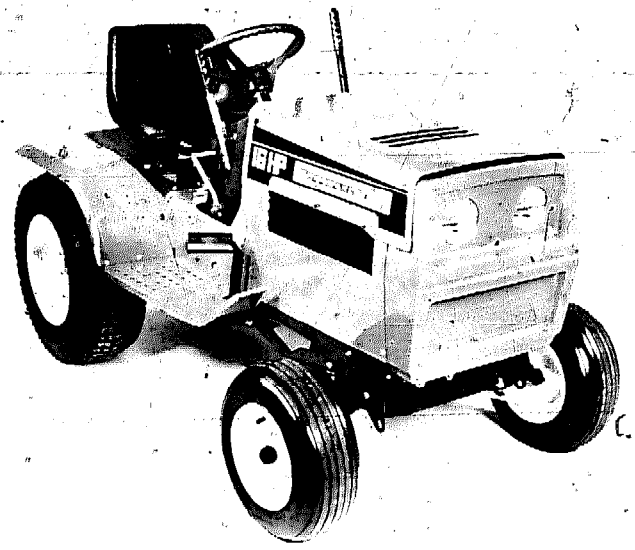

16 HP Transaxle Compact Tractor

MTD PRODUCTS INC
5389 West 130th Street
Cleveland, Ohio 44111
Telephone: 216-267-2600
Telex: 980-635

Description: Air cooled Briggs & Stratton twin cylinder gasoline engine; 12 volt electric battery start with dual circuit alternator; 4 speed cast iron transaxle with automatic over drive--16 speeds forward and 4 speeds reverse; 2000rpm PTO points at front, middle, and rear; adjustable rear wheel spacings; disc brakes.

Specifications

shipping weight	- 386 kg	engine	- 16 HP
length	- 1.82 m	speed	- .8km/h to 17km/h
width	- 1.04 m		
height	- 1.09 m	fuel capacity	- 13.6 l
ground clearance	- 0.20 m	fuel consumption	- heavy load - 3.78 l/h light load - .95 l/h
payload of dump cart	- 450 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.:
Accepts all category "0" type implements; currently being studied for agricultural use on small farms by Nigerian government.

Cost and Present Status (as of 7/77): 16 HP Transaxle- approximately US $1,500.00 F.O.B. Cleveland without attachments.

Implements:

Moldboard Plow (30cm)	US $ 130.00
Rotary Tiller (102cm)	US $ 358.00
Tandem Disc Harrow	US $ 190.00
Cultivator	US $ 85.00
Angle Dozer Blade (138cm)	US $ 139.00
Water Pump	US $ 280.00
Mower (128cm)	US $ 257.00
Dump Cart (.3 cu m)	US $ 85.00
5 kw Alternator	US $ 408.00

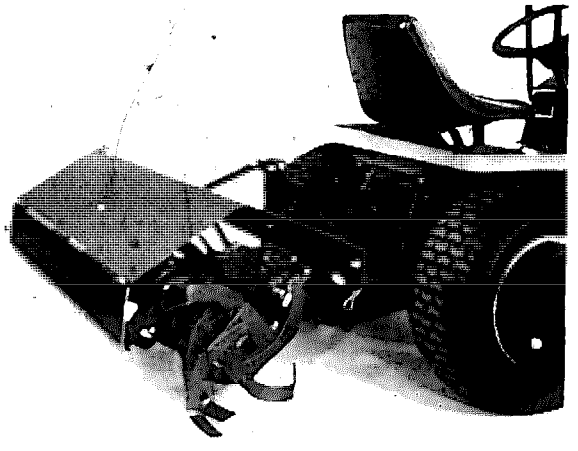

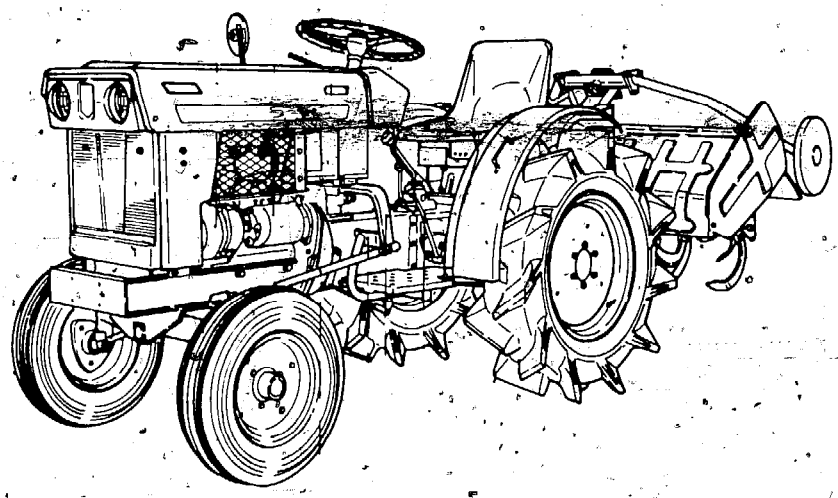

ST-1300 TRACTOR

Satoh Agricultural Machine
Mfg. Co., Ltd.
Hibiya Kokusai Bldg., No. 2,
2-chome
Uchisaiwai-cho, Chiyoda-ku
Tokyo, Japan
Telephone: (03) 508-7927
Telex: TOK 222-2567
Cable: Satohzoki Tokyo

Description: 4 cycle, water-cooled, 2-cylinder 13 HP diesel engine; transmission--6-forward and 2-reverse speeds with a differential lock; 3-speed power-take-off (517, 762, 1,249 rpm); hydraulic system directly driven from the engine; brakes-internal expanding.

Specifications:

weight	- 470 kg	engine	- 13 HP
length	- 1.89 m	speed	- 1.01km/h to 12.34km/h
width	- 1.0 m		
height (to top of steering wheel)	- 1.12 m	fuel capacity	-
wheel base	- 1.22 m	fuel consumption	-
ground clearance	- .26 m		
payload with trailer	- 350-500 kg		

Comment on Maintenance, Productivity, "Appropriateness," etc.: Dry paper element air cleaner is superior in filtration of fine particles of dust to protect the engine; wide variety of implements.

Cost and Present Status (as of 3/12/76): ST-1300 TRACTOR - US $1,512

Implements:

Single Moldboard Plow (width-31 cm, depth-26 cm-31 cm)	US $242
2 Rows Reversible Plow (width-46 cm, depth-15 cm-26 cm)	US $226
Rotary Tiller	US $289
3 Point Linkage Assembly	US $ 91
Trailer (payload-350 to 500 kg)	US $464

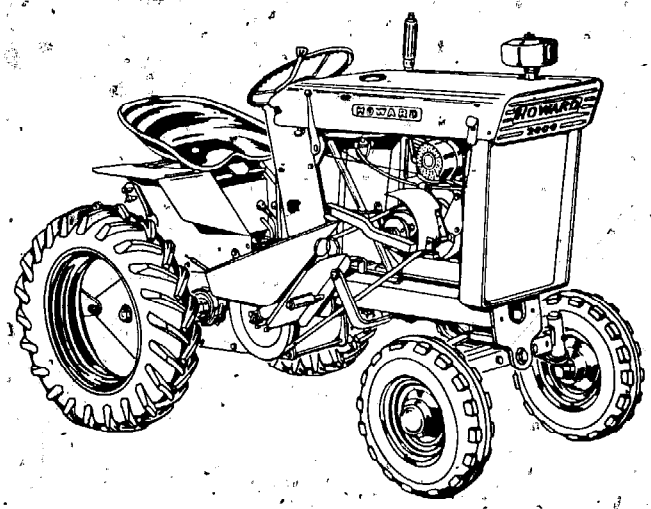

HOWARD 2000 Diesel

Howard Rotavator Pty. Ltd.
P.O. Box 82
Parramatta N.S.W. 2150
Australia
Telephone: 630.1231
Telex/Cable: AA21328/ROTAHOE Sydney

Description: Horizontal, 4 cycle, single cylinder air-cooled petrol engine, 14 HP, with electric start and 12 volt battery, alternative condenser cooled, Yanmar 7 HP diesel engine; crank handle starter; transmission-four forward speeds and two reverse speeds are achieved with high and low ratio on 1st, 2nd, and reverse gears; rack and pinion steering; external band type brakes; power take off operated at 1426rpm.

Specifications:

weight	- 408 kg	engine	- 7 HP
length	- 1.77 m	speed	- 1.66km/h to 9.14km/h
width	- .7 m to .9 m	fuel capacity	- 8.1
height	- 1.1 m	fuel consumption	- .76 l/h

payload with trailer - 800-1000 kg

Comments on Maintenance, Productivity, "Appropriateness," etc.:
Handles all aspects of cultivation in a dry land farming situation; versatile with over 20 attachments; engine sits on the frame using 4 bolts and can be simply removed to be used as a power unit in a boat, irrigation situation, etc.; tank capacity gives 4-5 hours of operation under full load; normal oil changing and greasing maintenance is all that is required and a major overhaul is at about 2,000 hours under normal work conditions; currently marketed successfully throughout the Pacific Islands and the Arabian Gulf countries.

Cost and Present Status (as of 10/1/77): 2000 Diesel-US 1,900

Also available:	Price Range (US$)
Howard 2000 gasoline (Briggs & Stratton 14 HP engine)	$1,900
Special airfield and industrial models	Price on application

Implements:

Rotavator side drive (53.35 cm)	$ 492
Twin Spindle Rotary Mower (109.22 cm)	$ 445
Spray Kit with pump (1.905 cm)	$ 409
Mower (71.12 cm)	$ 300
Dozer with Linkage (0.91¼ m)	$ 97
Front Tipping Bucket	$ 127
Mouldboard Plough (20.32 cm)	$ 125
Toolbar with 5 spring tynes	$ 114
Cart with tipping tray	$ 215

All implements with Quick Hitch attachment (no tools required)

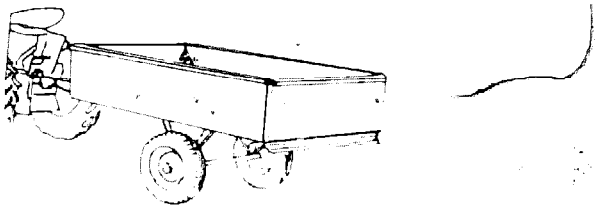

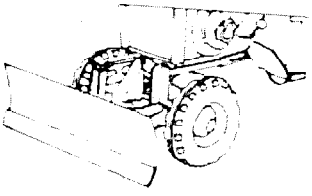

AGRO-UTIL Model "A"

Agro-Util
Div. Kalamazoo International Inc.
PO Box 271 - 70 Van Buren Street
South Haven, Michigan 49090
USA
Telephone: 616-637-2178
Telex: 729452 JENJEN SHAV
Cable: JENJEN

Description: 4 wheel agricultural tractor, 14 horsepower air-cooled gasoline engine; smaller engine available for substitution; standard equipment includes: three point hitch, 18.9 liter fuel tank and individual rear disc brakes; automotive type steering, electric start, 4 speeds forward, 1 reverse, belt-design drive system.

Specifications

weight	- 408.237 kg	engine	- 14 hp
length	220.98 cm	fuel capacity	- 18.93 l
width	- 116.84 cm		
height to hood	- 109.22 cm		
wheel base	- 152.4 cm		
payload capacity capacity	- 1 ton		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Specifically designed for use in developing countries by small farmers to increase crop production; simple and safe to operate; maintenance is minimal and requires little or no mechanical background; simple parts package available as option; high profile for crop clearance; design allows shipment in semi-knocked down form for reduced shipping cube; drive system makes substitution of engines in size and power range of the tractor very simple; some available accessories and implements include plough, disc harrow, furrower, cultivator, irrigation pump, two-ton capacity trailer, planter, feedmill grinder, wheel weights, spare parts package, plus others; primary applications: plowing, discing, cultivating, spraying, pumping for irrigation, feed grinding, hauling, off road transport - designed for small to medium size farms; practical features: most notable features found in this size and price range are 3-point hitch for versatile use of more implements,

jumbo fuel tank with 18.9 liter capacity, individual rear wheel disc brakes for turning, easy accessibility to engine output for belt power take-off, front grill is removable and a double sheave is provided as standard equipment.

Cost and Present Status (as of 1/12/78):

Model "A" Tractor - US$1,999 single unit net price.

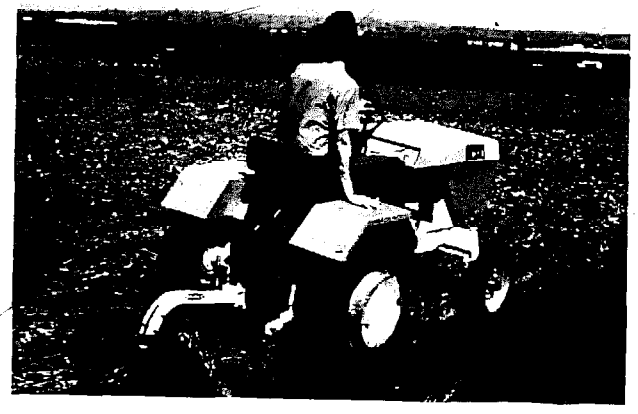

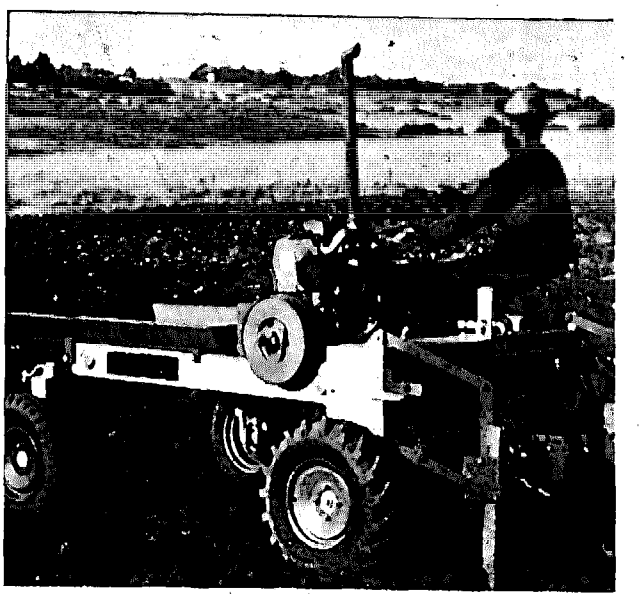

TINKABI TRACTOR

National Industrial Development
Corporation
P.O. Box 450, Manzini
Swaziland
Telephone: MBA 3391/2/3
Telex: SAX 52

Description: Air-cooled and hand started twin cylinder diesel engine of 16 hp; hydrostatic drive transmission which controls speed, direction, and braking through a single-hand lever.

Specifications:

weight unballasted	1,050 kg	engine	16 HP
overall length	2.5 m	speed	8km/h
overall width	1.8 m	fuel capacity	
ground clearance	.6 m	fuel consumption	less than 1.5 litres an hour under normal farm use
wheel base	2 m		
wheel track	1.7 m		

payload capacity - 500 kg, can be increased to 2,000 kg with the addition of a trailer

Comments on Maintenance, Productivity, "Appropriateness," etc.: Its range of implements include a plough, planter, cultivator, ridger, harrow, water pump, irrigation set, circular saw, cotton sprayer, hammermill and electrical generator; between service intervals of 250 hours or 6 months, whichever is earlier, the operator needs only fill the fuel tank, keep the tires inflated, and tighten all nuts and bolts; under dry soil conditions, using the Tinkabi single furrow 30 cm moldboard plough, the rate of work is up to 2 hectares a day at 20 cm deep; extensive testing has been carried out in Tanzania, Zambia, Swaziland, U.K., South Africa, Lesotho, Botswana, S.W.A., Mozambique, Kenya and U.S.A.; the work requirements of the Swazi farmer were met under test conditions.

Cost and Present Status (as of 5/77): Commercially produced in Swaziland at about US $2,000.

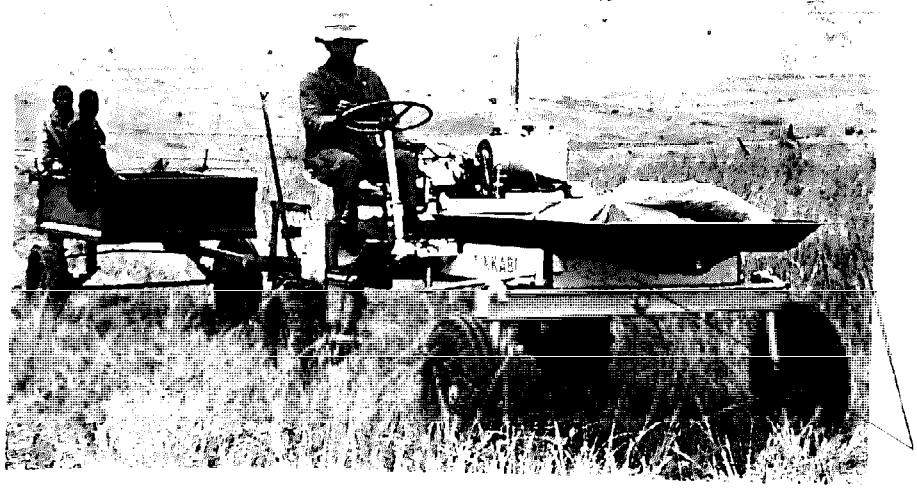

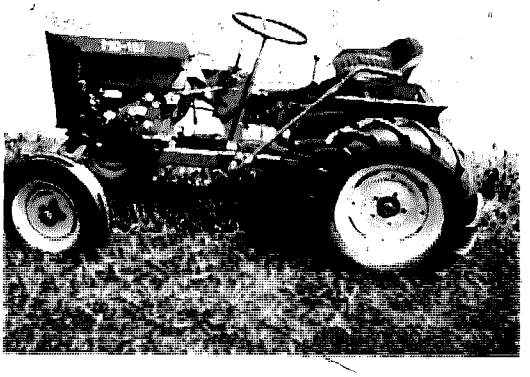

Self-Helper

Self Help Foundation
P.O. Box 186
Highway #3 East
Waverly, Iowa 50677, U.S.A.
Telephone: 319-352-4483

Description: Two wheel drive, three speed transmission, 41 x 20 cm agricultural grip tires; crank start, 7 h.p. diesel engine; rack and pinion steering; foot and hand braking.

Specifications

weight (dry)	- 385 kg	engine	- 7 hp
length	- 2.06 m	speed	- up to 8.8 km/h
width	- 1.1 m	fuel capacity	- 8 litres
height	- 1.04 m	fuel consumption	- approximately 1 l/hr for farming operations
wheel base	- 1.41 m		
ground clearance	- 36 cm		
payload with trailer	- 1360 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: The tractor and implements are designed to need only small wrenches and lubricants to maintain and repair; it has been designed to be easily adapted to local assembly; the following agricultural implements are available: moldboard and disc plows, small and large seed planters, disc harrows, cultivators, sickle bar mower, rotary mower, furrower, hiller, root chisel, irrigation equipment, three leveling blades (front, middle, rear mounted), row crop and fruit tree sprayers, and 1,360 kg trailer; serves as a power source for electrical generators, circular saws, hammer mills, stone mills, and chicken plucker; plows up to 2 hectares a day; pulls a 30 cm plow 18 cm deep at 5.6 km/h in hard plowing in second gear; being used in Central and South America, Africa and Asia.

Cost and Present Status (as of 7/1/77): Commercially produced in the United States at about US$2,100.

G-14 Tractor

Bolens
Port Washington
Wisconsin,
USA

Description: 4 cycle single overhead valve Tecumseh 14 HP engine; Bendix flywheel type electric starter; transmission-6 speeds forward and 2 reverse-with the push of a lever; disc brakes; steering-bevel gear sector and pinion.

Specifications:

weight	- 300 kg	engine	- 14 HP
length	-	speed	-
width	-	fuel capacity	- 5.7 l
height	-	fuel consumption	-
wheel base	- 1.08 m		
ground clearance	- .18 m		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Bolens tractors and equipment are tested under such conditions as the soft and sandy soil of Florida and the rock-hard adobe clay of Texas; also certified by the Outdoor Power Equipment Institute; Bolens has several other models of tractors ranging from 8 HP to 19.5 HP and varied implements such as front end loaders, terra-blades, etc.

Cost and Present Status (as of 9/15/75): G-14 Tractor US $ 2,296 (with 1.07 m mower)

Implements

Dump Cart (.2 cu m)	US $139
Rotary Tiller (.84 m)	US $546
Moldboard Plow (31 cm)	US $136
Cultivator	US $ 85
Disc Harrow (8 blades)	US $ 90

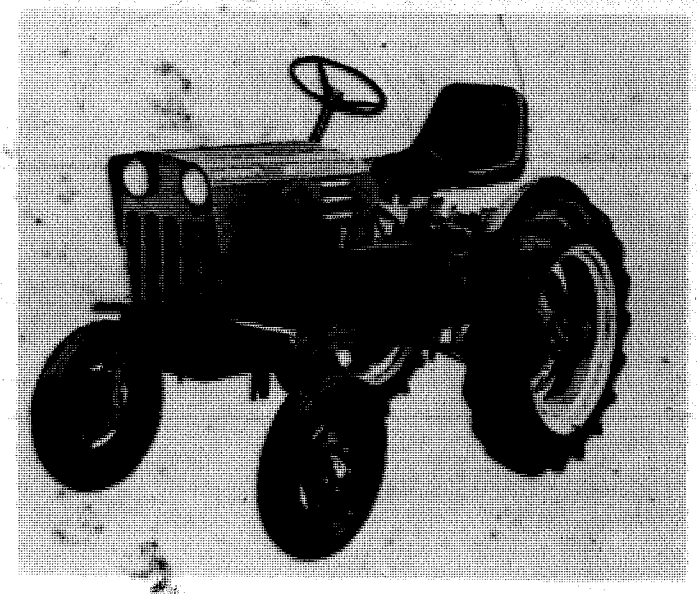

Power King Tractor, Model 1614

Engineering Products Co.
PO Box 1510
Waukesha, Wisconsin 53187
USA
Telephone: 414-547-5558

Description: Air-cooled 14 hp gasoline engine tractor has all-gear drive including automotive clutch, transmission and differential; drop-axle design for maximum crop clearance; 176:1 reduction in 1st gear for high wheel-torque; individual rear wheel brakes; 3-point rear tool hitch with manual or hydraulic lift available.

Specifications

weight	- 467 kg	engine	- 14 hp
length	- 2.36 m	speed	- 2.7 to 9.2 km/hr
width	- 1.05 m		
frame clearance	- 0.49 m		
height	- 1.38 m		

Comments on Maintenance, Productivity, "Appropriateness", etc.: In use over 30 years, exported on a limited basis to a number of countries; all gear drive provides maximum work output per installed horsepower and per liter of fuel; high gear ratio; available attachments include 1.22 m snowblower, 1.22 m x .45 m bulldozer-snowplow, 1.22 m V-snowplow, log splitter for up to .66 m long logs, front end loader that lifts up to 295 kg, 1.98 m high with adequate rear weighting - different style bucket attachments; also, .3 m wide moldboard plow, .4 m wide disk harrow, tandem disk harrow, corn and bean planter, seeder-fertilizer, weed-insect sprayer, hay rake, rotary tiller, heavy duty cultivator, spring-tooth cultivator, straddle-row cultivator, tool bar, hiller, and furrower.

Cost and Present Status (as of 1-1-78):

US domestic list price with manual lift: US$ 2,524 F.O.B. Waukesha, WI
with hydraulic lift: US$ 2,752 F.O.B. Waukesha, WI

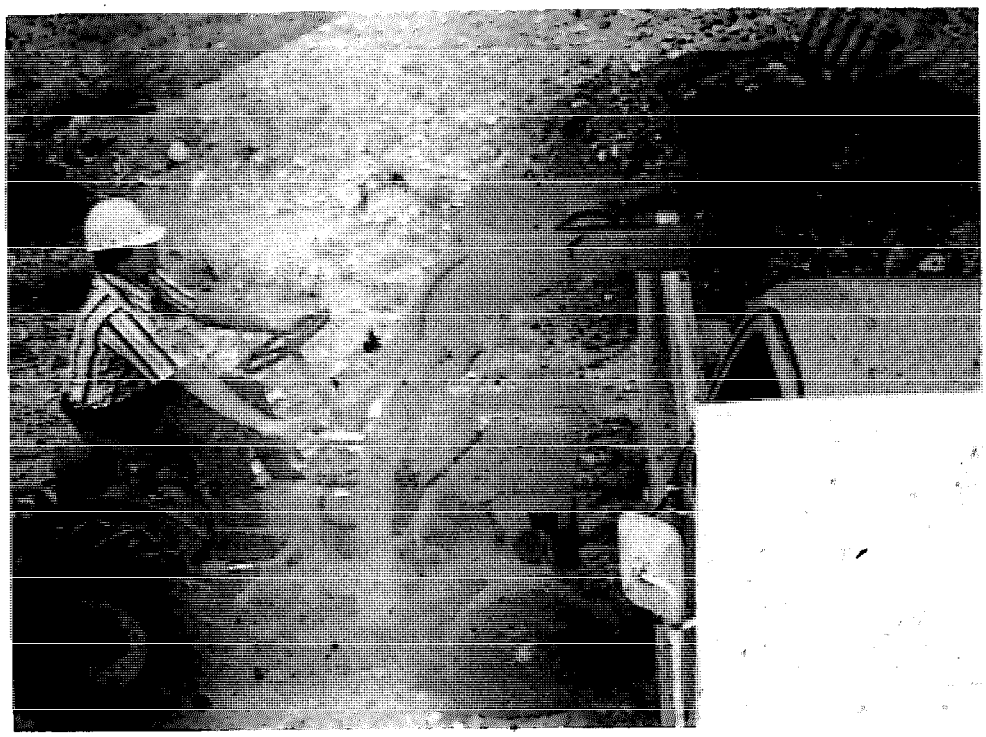

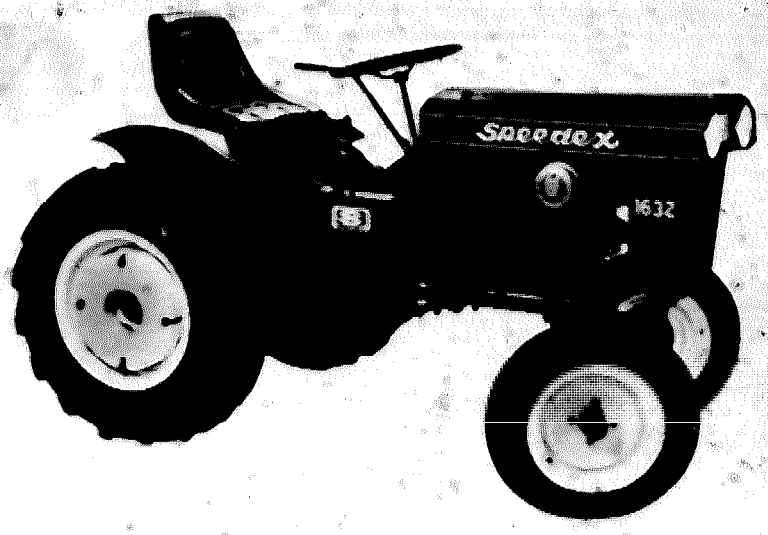

Speedex Model 1632 Tractor

Mechtron International Corporation
2140 W. Washington Street
Orlando, Florida 32805
USA
Telephone: 305-843-9880

Description: 16 hp Kohler cast-iron engine; 3 forward speeds; primary drive-belt; equipped with dual independent rear wheel brakes; category "0" 3-point hitch is standard.

Specifications

weight	-	377 kg	engine	-	16 hp
length	-	2.121 m	speed	-	3.30 k/h to 10.96 k/h
width	-	1.067 m	fuel capacity	-	11.4 l
height	-	1.092 m			
wheel base	-	1.372 m			
ground clearance	-	35.6 cm			

Comments on Maintenance, Productivity, "Appropriateness," etc.: Designed for small farms.

Cost and Present Status (as of May 1977): US$2,540.

Implements

Plow	-	25.6 cm	US$190
Disc set	-	14 blades	US$161
Cultivator	-	rear mount	US$190
Furrower	-		US$ 21
Dump cart	-	163 l without sideboards	US$131
	-		

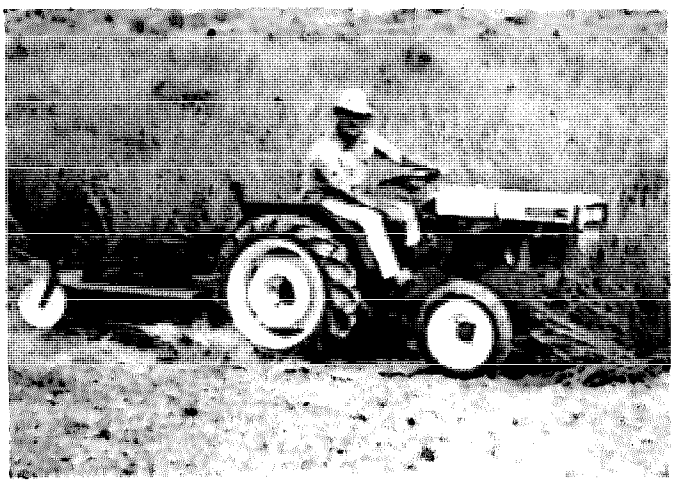

AGRALE 4100

AGRALE S.A.
Tratores e Motores
Estrada Federal BR 116, Km 125
C.P. 1311 95100, Caxias do Sul, R.S.
Brazil

Telephone: (0542) - 21.35.00 and (0542) 21.35.15
Telex/Cable: 0542.156

Description: Four stroke, air-cooled, 16 hp diesel tractor; BOSCH 12V electrical system with starter and generator; heavy duty differential lock gear box with 7 forward gears and 3 reverse; dry plate, spring loaded clutch, power takeoff; foot operated brakes, directional, individual, or conjugated in the rear wheels; lock lever for parking, lifting system driven by a hydraulic pump coupled directly on the front mounted P.T.O. of the engine.

Specifications

weight	- 950 kg.	engine	- 16 hp
length	- 2.30 m	speed	- 1.16 to 13.25 km
width	- (between axles) 1.10 m	fuel capacity	-
height	- 1.16 m	fuel consumption	-
payload capacity	- 1.5 tons		
ground clearance	- .22 m		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Developed and marketed in Brazil for use on small farms; tested by the Brazilian Ministry of Agriculture under varied soil and climate conditions; numerous attachments available including a disk plow, harrower, rotary cultivator, furrow plough, mower and cart.

Cost and Present Status (as of 2/6/78): (F.O.B.) packed : US$ 2,678
unpacked : US$ 2,585

Prices of attachments furnished on request.

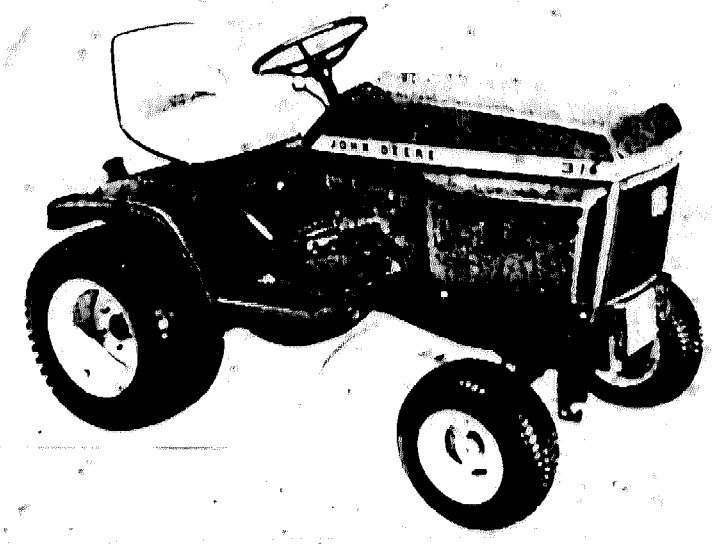

316 Tractor

John Deere Horicon Works
220 East Lake
Horicon, WI 53032
Telephone: (414) 485-4411

Description: 16 hp tractor, fully enclosed single-cylinder, 4-cycle, air cooled engine, gasoline driven; single lever hydrostatic drive with front, center and rear hydraulic lift, dual levers; individual braking system on rear wheels operated independently by dual foot pedals; automatic key start with safty features; many optional attachments available.

Specifications

weight	347 kg	engine	16 hp
length	1.753 m	speed	.8 to 10.5 km/hr.
width	1.079 m	fuel capacity	17.034 litres
ground clearance	.156 m	fuel consumption	5.8 litres/hr
height	1.118 m		
wheel base	1.168 m		
payload capacity with trailer	Depends on trailer, ballast on tractor, and whether trailer has brakes.		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Implements include 1.68 m and .965 m mowers, 1.372 x .0457 m front blade, snow thrower, rotary tiller, 3-point and integral hitch, and front mounted PTO attachments; no information on present international usage.

Cost and Present Status (as of 8/1/77):

Manufactured in USA
Retail priced at US$2795
Price of implements vary from US$280 to US$695

Also Available: Model 214 - 14 hp. engine, standard mechanic lift (hydraulic or electric optional), weight 334 kg. - US$2195.

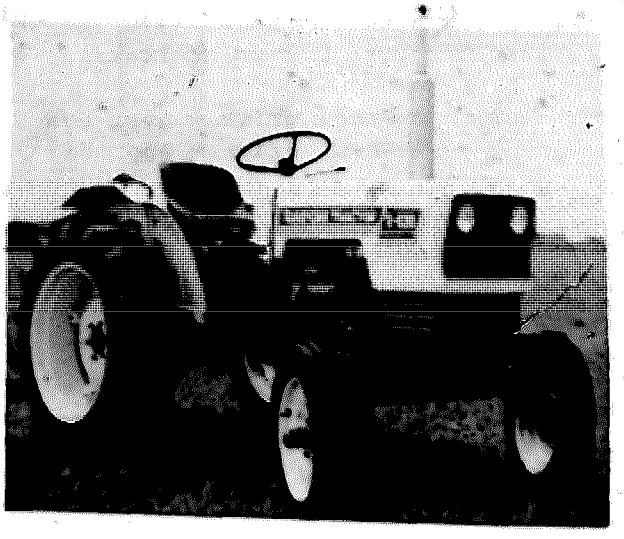

Satoh Tractor Model S63D (Bull)

Satoh Agricultural Machine
Mfg. Co., Ltd.
Hibiya Kokusai Bldg., No. 2, 2-chome
Uchisaiwi-cho, Chiyodo
Tokyo,
Japan
Telephone: Tokyo 508.7927
Cable: "SATOHZOKI" Tokyo
Telex: TOK 222.2567

Description: 2 cylinder, 4 cycle, water-cooled, 25 hp diesel engine tractor; 2 wheel or 4 wheel drive; dry single disc clutch with 9 forward and 3 reverse speeds, differential gear, differential lock; multi-speed rear P.T.O., 3-point category 1 linkage and permanent drawbar; water-proof internal expansion drum type brake with parking brake; 12-volt 70 AH electrical system.

Specifications

weight	- 910/970 kg (2 wheel and 4 wheel drive)
length	- 2.45 m
width	- 1.265 m
height	- 1.975 m
wheel base	- 1.524 m
ground clearance	- .41/295 m (2 wheel and 4 wheel drive)
payload capacity	-
engine	- 25 hp
speed range	- 1.26 km/h to 18.41 km/h
fuel capacity	- 20 litres
fuel consumption	-

Comments on Maintenance, Productivity, "Appropriateness", etc.: Complete manual provided with maintenance instructions; implements include rotary tiller and front P.T.O.

Cost and Present Status (as of 10/77):

Ex-godown, Japanese port: 2-wheel drive-app. US$ 2,800
4-wheel drive-app. US$ 3,200

Also Available : Model 5370 (Beaver) - 15 HP diesel engine, 2 and 4 wheel drive, category 0 3-point linkage, 6 foreward speeds, 2 reverse, priced at :

2-wheel drive - app. US$ 1,770
4-wheel drive - app. US$ 2,033

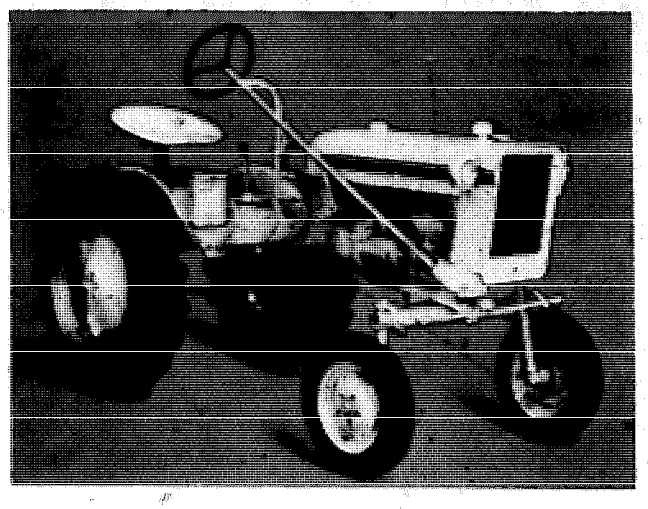

International Cub Tractor

International Harvester
Agricultural Equipment Division.
401 N. Michigan Avenue
Chicago, Illinois 60611
USA
Telephone: 312-670-2000

Description: IHC-60, 4 cylinder, 15 HP, liquid-cooled gasoline engine; electrical starter; transmission-selective sliding spur type gears; 1900rpm power take-off; band type brakes; steering-worm and gear with center point control; touch control hydraulic system-engine mounted 10.61/m pump delivers live power whenever the engine is running.

Specifications:

weight	- 653 kg	engine	- 15 HP
length with hitch	- 2.5 m	speed	- 5km/h to 14.8km/h
width	- 1.5 m	fuel capacity	- 28.4 l
ground clearance	- .5 m	fuel consumption	- 3.46 l/hr
height (to top of steering wheel)	- 1.6 m		
wheel base	- 1.8 m		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Major contributing factor in the mass conversion of mule and horse power to tractor power in the USA during the 50's; due to Cub's offset design, you see everything straight ahead easily without having to lean to the side-great for working in row crops; manual hand lift is available in lieu of the hydraulics for less cost and easier serviceability; air-cooled diesel engine could be fitted in lieu of the gasoline engine.

Cost and Present Status (as of 7/14/77): Cub-US $2,970

Implements: (wholesale prices)

54A middle mounted blade	US $207.75
Model C-3 center mounted rotary cutter (cuts a 1.5 m swath)	US $262.50
L-38 disk harrow (1.2 m or 1.6 m sizes)	US $225.75
144 cultivator (handles row widths from .9 m to 1.4 m)	US $274.05
L-194 one bottom Fasthitch moldboard plow	US $200.83
22 sicklebar mower (has a 1.5 m cut)	US $213.75
#1200 flat bed trailer (payload-550 kg)	US $266.25

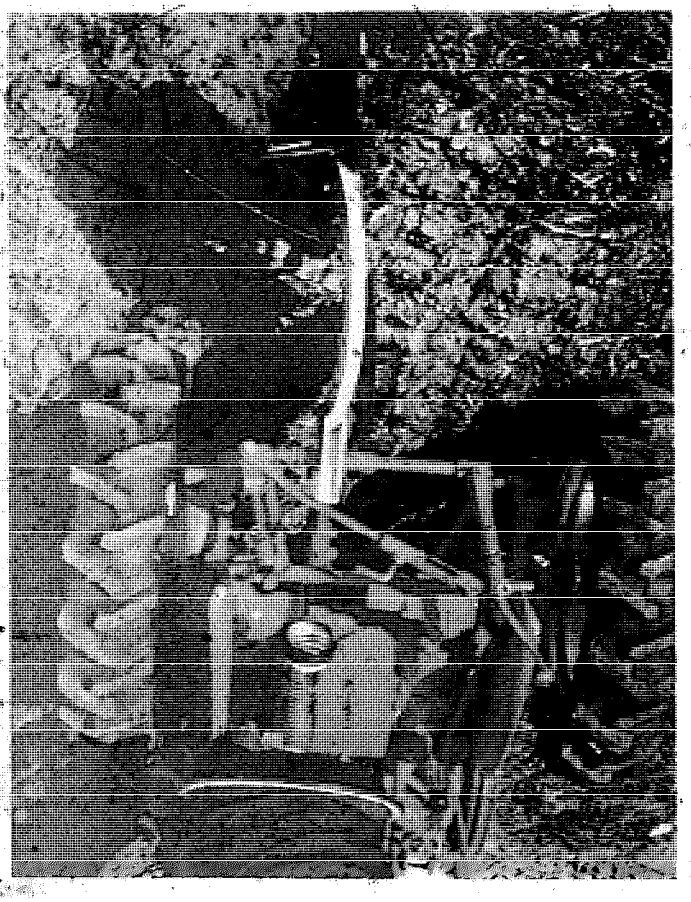

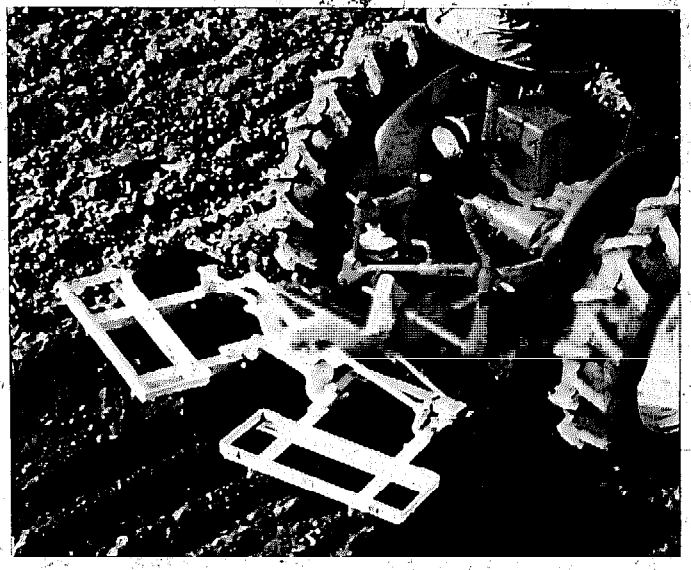

ARIENS TRACTOR

The Ariens Company
655 West Ryan St., Brillion
Wisconsin 54110
USA
Telephone: 414-756-2141
Telex: 26-3490

Description: Single cylinder, 4-cycle, fan cooled, electric start, 10-14 hp gasoline engine; rear wheel drive; 4 selected speeds forward and reverse speed; enclosed gear transmission and differential with belt clutch; drum brakes on each rear wheel; manual lift on 10 hp model and hydraulic lift on 14 hp model; 540 rpm front P.T.O. and 3250 rpm rear P.T.O.

Specifications

weight	-	385 kg	engine	-	10 or 14 hp
length	-	1.57 m	speed	-	2.2 k/h to 8.7 k/h
width	-	.86 m	fuel capacity	-	
height	-	1.00 m	fuel consumption	-	
wheel base	-	1.09 m			
payload with a trailer	-				

Comments on Maintenance, Productivity, "Appropriateness," etc.: Its range of implements includes trailers, rotary tiller, mowers, 3,000 or 5,000 watt generator, front loader, front dozer blade, plough, disc; thousands of units operating in USA, Canada, Europe and Australia.

Cost and Present Status (as of 10/77):

Manufactured in United States
Exported FOB factory
Approximate export retail price range - US$2,999 - US$3,799

Also Available:

12, 14, 16 and 18 hp engine models with hydrostatic drive.
Approximate export retail price range - US$3,999 - US$4,999

8900-D Agria

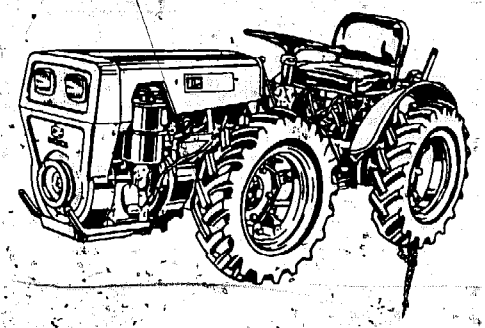

Agria Hispania, S.A.
Amorebieta (Vizcaya)
Spain
Telephone: 673-04-50
Telex/Cable: 32448 Agria E

Description: Articulated tractor equipped with a 4 stroke, 1 cylinder, air-cooled, 20 HP diesel engine; transmission-12 speed gearbox; differential-on both axles with lock and automatic release; steering-globoid, worm gearing; brakes-independent front and rear; lift-hydraulic with lifting capacity of 1500 kg; 4 wheel drive with possibility of disconnecting front section; PTO shaft-4 speeds from 540 to 1000rpm.

Specifications:

weight	- 950 kg	engine	- 20 HP
length	- 2.43 m	speed	-
width	- .81 m	fuel capacity	-
height	- 1.00 m	fuel consumption	-
ground clearance	- .24 m		
payload with driving trailer	-		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Trailer can be mounted on tractor with 4 bolts; a driving trailer with synchronized gears is also available; smaller tires are available which reduce the ground clearance to .20m.

Cost and Present Status (as of 6/30/77): 8900-D Agria - US $3,076

Also available:

Model Number		
9900	Articulated Tractor (30 HP engine & weight-1150 kg)	US $3,560
1900ED/20	Two Wheel Tractor (18 HP engine & weight-420 kg)	US $1,373
7000	Motorhoe (9 HP engine & weight-115 kg)	US $ 708
3000 EL	Motorhoe (7 HP engine & weight-47.5 kg)	US $ 410

All of these have a varied range of implements such as plows, cultivators, hoeing attachments, and trailers-with and without traction.

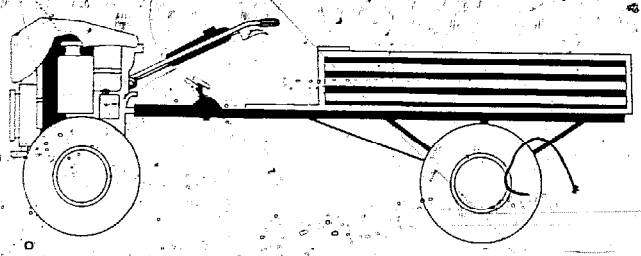

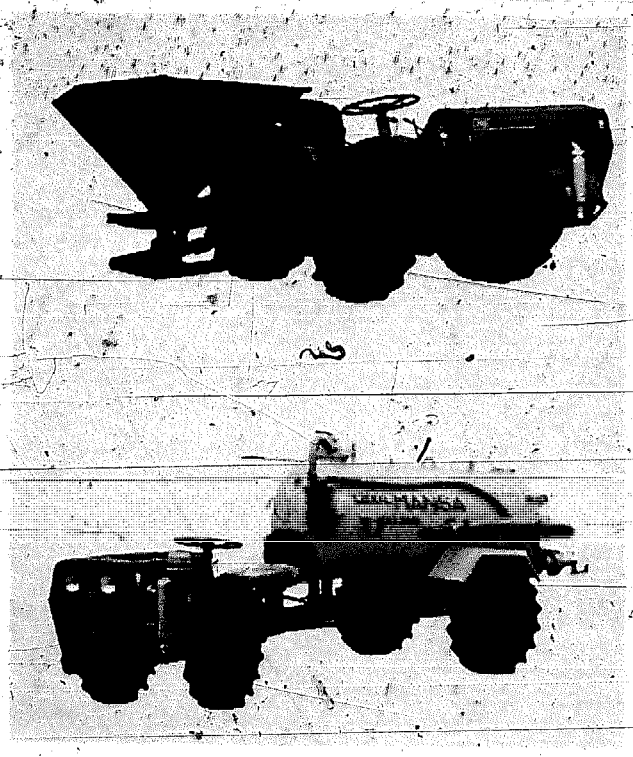

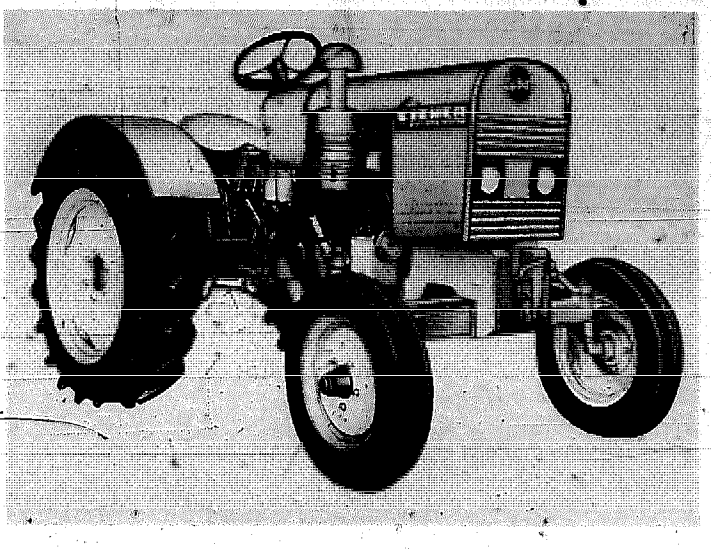

Eicher-Goodearth Tractor

Eicher Tractors India Limited
Deepak, 3rd Floor
13 Nehru Place
New Delhi 110024
India
Telephone: 633612
Telex/cable: TRACEICHER

Description: Air cooled 26.5 hp diesel tractor at 1650 rpm, single cylinder, four stroke, 6 forward and one reverse speed, foot operated expanding type brakes, independent for left and right rear wheels (with coupling latch to hand operated parking brakes), manual start, self starter optional; 495 rpm P.T.O.

Specifications

weight	- 1,559 kg	engine	- 26.5 hp (SAE)
length	- 2.90 m		- 24.0 hp (DIN)
width	- 1.53 m	speed range	- 2.03 km/hr to 24.70 km/hr
ground clearance	- .38 m		
height	- 1.66 m	fuel capacity	- 34.00 liters
wheel base	- 1.76 m	fuel consumption while plowing	- 1.5 to 2.5 liters/hr.
haulage capacity	- 9 tons, level road, 5-6 tons in fields		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Simple design, low fuel consumption, low maintenance cost; matching implements include mouldboard plow, disc plough, offset disc harrow, paddy puddler, cage wheel, paddy disc harrow, ridger, tiller and land leveller.

Cost and Present Status (as of 2/1/78):

Export price US$ 3,385 E.O.B. Indian port.

Price of implements - ranging from US$150 to US$420.

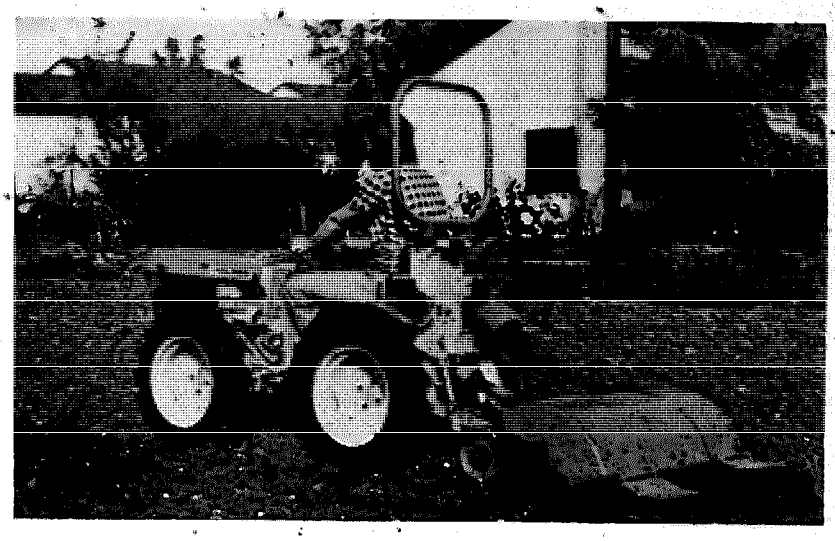

Gultitrac A18

Gebruder Holder GmbH & Co.
P.O. Box 66
D 7418 Metzingen
West Germany
Telephone : 07123-1331
Telex : 07245319

Description: Four-wheel drive, articulated tractor; complete electrical system and hydraulic equipment; 18 hp air-cooled four-stroke diesel engine, 6 forward and 3 reverse gears, four-wheel drive via 2 differentials, diff-lock; articulated steering acting on all four wheels, two independent braking systems, i.e., foot and hand brakes acting independently on all four wheels, three-point linkage.

Specifications

weight	- 900 kg	engine	- 18 hp SAE (12 kw)
length	- 2.28 m	speed	- .5 k/h to 20 k/h
width	- .74 m/.98 m	fuel capacity	- 6.5 liters
height	- 1.06 m	fuel consumption	- 254 g/kwh
wheel base	- 1.12 m		
ground clearance	- .25 m		
payload with trailer	- 830 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Designed for maneuverability in smallest spaces, i.e., narrow row cultivations, weight distribution permits a small ground pressure; most suitable for vineyard and nurseries; implements include rotary cultivators (70-100 cm working width), rear-mounted mower (120 cm), full-turn and border ploughs, tractor-mounted sprayer, and trailer.

Cost and Present Status (as of 1/78): Approximately US$3,500.

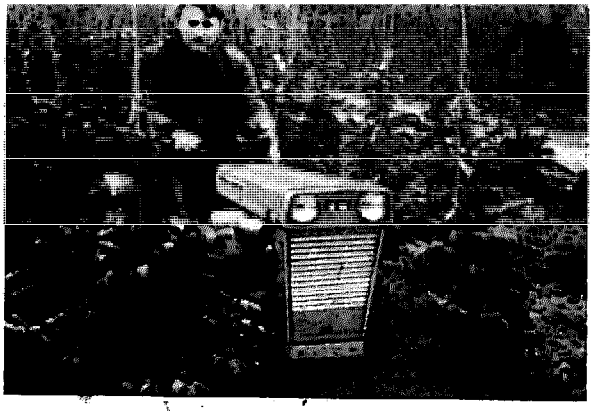

Buffalo Tractor

Waverly Tractor Company
Sleeping Giant - Hwy. 3 East
Waverly, Iowa, U.S.A. 50677
Telephone: 319-352-3130

Description: Air cooled, two cylinder 18-26 HP diesel engine; gasoline engine is also available; hand start; hydrastatic drive (full testing on the hydrastatic model is not complete at this time), or 4-speed constant mesh transmission, 3 foreward, 1 reverse; hydraulic 3-point hitch; independent rear wheel disc brakes.

Specifications

weight	-	715 kg	engine	-	18-26 HP
width	-	1.422 m	speed	-	up to 12 km/h
height	-	1.397 m	fuel capacity	-	22.7 litres
wheel base	-	1.676 m	fuel consumption	-	under normal farm use, about 1.8 l/h

Comments on Maintenance, Productivity, "Appropriateness," etc.: Its range of implements include a plow, planter, cultivator, disc harrow, chisel point or sub-soiler; between service intervals of approximately 6 months, the operator need only fill the fuel tank, keep the tires inflated and tighten all nuts and bolts; under dry soil conditions using a 41 cm moldboard plow, the rate of work is up to 3 1/2 hectares a day at 20 cm deep; basic design has been field tested in North and South America, Africa and the Caribbean area for over 14 years; a full set of drawings will be made available so one can assemble his own Buffalo tractor.

Cost and Present Status (as of 8/77): Commercially produced in Waverly, Iowa, U.S.A. ranging from about US$3,600.

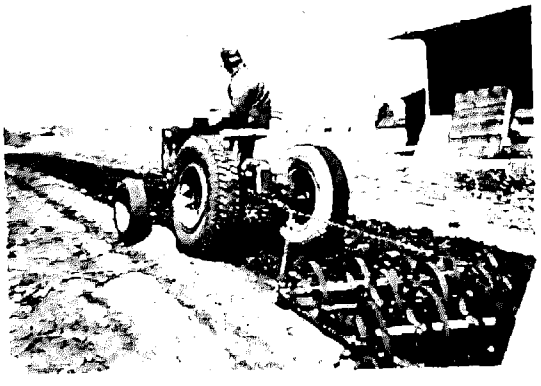

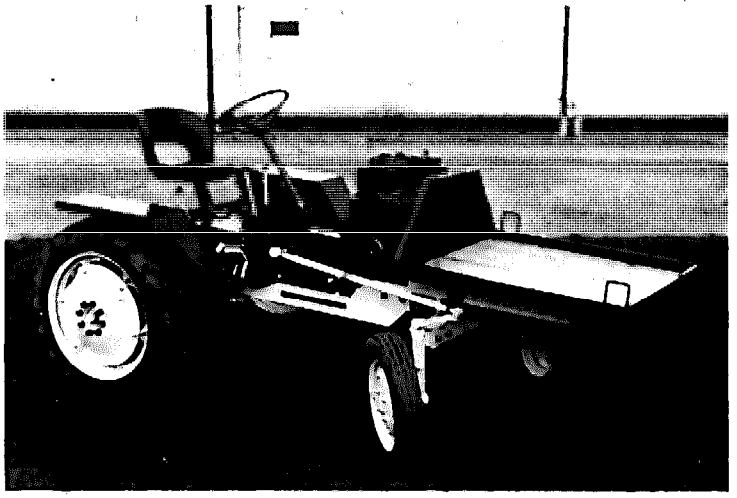

TE Tractor

Bouyer S.A.
Boite Postale No. 7
54510, Tomblaine, France
Telephone: (28) 29-26-62
Telex: 960484 F

Description: Air-cooled, one or two cylinder, 4 stroke, diesel engine from 15 to 25 HP; hand starter is standard - optional electrical starter; mechanical gear-box with 6 forward speeds and 3 reverse, differential lock with automatic disengaging; drum brakes - independent for ploughing or coupled for operating on roads; power take-off - 1000 rpm.

Specifications

weight	- 1100 kg	engine	- up to 25 HP
length	- 3.10 m	speed	- 1.48 km/h to 15.75 km/h
width (with minimum tread)	- 1.80 m	fuel capacity	- 31 litres
height	- 1.50 m	fuel consumption	- max. 2 l/hr. plowing
wheel base	-		
ground clearance	- .56 m		
payload of front load pan (1 m x 1.1 m)	- 500 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.:
Its range of implements includes a double furrow plough, cultivator, ridger, disc-harrow (width - 1.30 m), flail-mower, four row seeder, and also in the near future a 500 l sprayer, rear rotavator, flour mill, and two-disc plough; maintenance - farmers are required to tighten units and bolts regularly; sold in Tunisia, Morocco, Greece, Ivory Coast, Mali, Senegal, Upper Volta, Chad, Cameroon, East Africa Community.

Cost and Present Status (as of 8/77): TE Tractor - US$3,800 (ground unit)

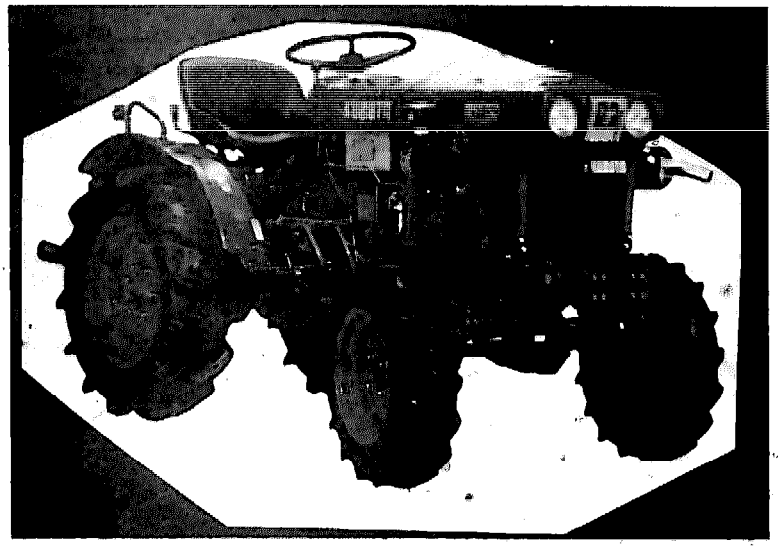

B7100 Tractor

Kubota Ltd.
22-2 Funade Mati Naniwaku
Osaka
Japan
Telephone: 06-648-2111
Telex: 7810-526-7785

Description: 16 hp, 4 cycle, 3 cylinder, water-cooled diesel engine; 4 wheel drive; front and rear P.T.O. shafts; hydraulic lifting system: 6 forward and 2 reverse speeds; independent rear brakes.

Specifications

weight	- 475 kg	engine	- 16 hp
length	- 1.99 m	speed	- .98 km/h to 13.02 km/h
width	- 1.01 m	fuel capacity	- 15.5 l
ground clearance	- .24 m		
height	- 1.14 m		
wheel base	- 1.24 m		
payload capacity with trailer	- 499 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Accommodates a variety of implements for tilling, cultivating, ploughing, loading, etc.

Cost and Present Status (as of 9/1/77):
B7100 - US$3,895.
Also available:
L185FP model - 2 wheel drive, engine - 17 hp, weight - 725 kg, price - US$4,050
L245DTP model- 4 wheel drive, engine - 25 hp, weight - 910 kg, price - US$4,895

Universal "serie 200"

Goldoni SpA
Via Canale 3
41012 Migliarina di
Carpi (Modena)
Italy
Telephone: 0522-699240
Telex: 53023 GOLDONI

Description: 4 stroke, air-cooled diesel engine from 28 to 38 hp; four-wheel drive with central articulation; three point hydraulic lift (maximum lifting capacity - 700 kg); 2 P.T.O. shafts, one of which can by synchronized for a trailer with differential; electrical start and light installation with 12 volt battery: gear box with 9 speeds - 6 forward and 3 reverse; drum type brakes on four wheels; differential on both axles; mechanical or hydraulic steering; track adjustable without wheel track expanders.

Specifications

weight	- 945 kg	engine	- 28 to 38 hp
length	- 2.45 m	speed	- 1.2 km/h to 21.0 km/h
width	- .94 m	fuel capacity	- 16 litres
ground clearance	- .21 m	fuel consumption	- about 180 grs per hp/h
height	- 1.12 m		
payload capacity with trailer	- 2,500 kg.		

Comments on Maintenance, Productivity, "Appropriateness," etc: Its range of implements includes: rotary cultivators, trailer, spraying and centrifugal water pump, fibreglass tank, ploughs, front hydraulic implements, side mower, circular saw bench, post-hole auger, etc; used in various conditions on plains, hill-sides, and other difficult terrains; has been exported to many different countries throughout the world; capacity of work with plough: depth 30/35 cms - width 30/35 cms - 1600 sq/mts per hour; capacity of work with rotary cultivator: width 115 cms - 2400 sq/mts per hour.

Cost and Present Status (as of 1/1/77): From US$4,886.00 for the 28 hp. to US$5,886.00 for the 38 hp; Cost of implements varies from US$52.55 to US$1,905.10.

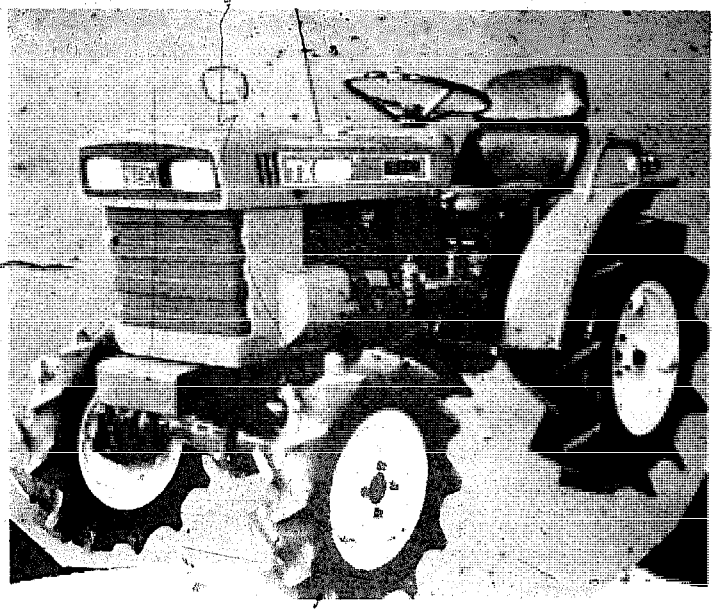

TS2210 ISEKI Tractor

Iseki Agricultural Machinery
Mfg. Co., Ltd.
Overseas Department
1-3, Nihonbashi, 2-chome,
Chuo-ku, Tokyo, 103 Japan
Telephone: 03-271-1271
Telex: 222-2821
Cable: ISEKIRICE TOKYO

Description: Water-cooled, 4-cycle, 2-cylinder 22 HP diesel engine; speed operation can be conducted through selection of 9 forward and 3 reverse speed transmission and 4 speed power take-off; implement lift has independent hydraulic system; differential lock is standard; ball-screw type steering system;

Specifications

weight	- 930 kg	engine	- 22 HP
length	- 2.51 m	speed (travelling)	- 1.37 km/h to 14.5 km/h
width	- 1.28 m		
height	- 1.32 m	fuel capacity	- 20 l
wheel base	- 1.56 m	fuel consumption	-
ground clearance	- .35 m		

payload with trailer -

Comments on Maintenance, Productivity, "Appropriateness," etc.: 4-wheel drive is available; many implements which will perform the following type tasks--plowing and tillage, harrowing, puddling and leveling, ridging and weeding, fertilizing and seeding, harvesting, transporting, and light road maintenance.

Agria 4800 L Tractor

Agria-Werke GmbH
D7108 Moeckmuehl
West Germany
Telephone: 06298/5061
Telex: 0466791

Description: Air-cooled, 4-stroke single cylinder 19 hp diesel engine; gearbox - 6 forward and 6 reverse speeds, differential lock; rear P.T.O. - 825 rpm, independent of gear speed; hydraulic lift; segment-gear steering; wheel and steering brakes; electric start.

Specifications

weight	- 600 kg	engine	- 19 hp
length	- 2.25 m	speed	- 1.2 km/h to 16.5 km/h
width	-	fuel capacity	-
ground clearance	- 25 cm	fuel consumption	-
height	- 1.10 m		
payload capacity with two wheeled trailer with spring suspension	- 1000 kg		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Designed to fill the gap between the range of operation of the two-wheel tractor and the conventional 4-wheel tractor in agriculture, horticulture, orchards and vineyards, and also in the trades and municipalities sector; agricultural operations include: rotary hoeing and cultivating with working widths of 90 and 110 cms, ploughing in all kinds of soil, spraying - 100 l tank and boom adjustable from 70-130 cms, and mowing - rear mounted sidemower with width of 120 cms.

Cost and Present Status (as of):

Also available: Agria 2700 Two-Wheel Tractor - 13 hp, four stroke, diesel engine; weight - 270 kg; two P.T.O. shafts; speeds - 1.2 to 19 km/h; gearbox - 6 forward and 3 reverse speeds.

19-1/2 HP Power Max

Simplicity Division of Allis-Chalmers Corp.
500 N. Spring St.
Port Washington, WI 53074
USA
Telephone: (414) 377-5450
Telex/Cable: SIMPWAS

Description: 19.5 horsepower tractor with 12 volt electrical system and hydraulic front, center and rear power lifts; two cylinder air cooled Onan CCKB engine, hydrostatic transmission; individual disk brakes located on differential output shafts; three point linkage, three forward speeds and three reverse speeds.

Specifications

shipping weight	- 589.7 kg	engine	- 19.5 hp
length	- 2.11 m	speed	- 6.76 km/h to 16.75 km/h
width	- 1.27 m		
height at steering wheel	- 1.22 m	fuel capacity	- 14.38 litre
wheel base	- 1.42 m	fuel consumption	-
ground clearance	- .381 m		
payload	-		

Comments on Maintenance, Productivity, "Appropriateness," etc.: Designed for all season versatile performance; can be matched with up to 20 attachments which include a sickle bar (1.52 m), front end loader (.19 cubic m, 295 kg capacity), dozer blade (1.52 m), rotary tiller (1.22 m), grader (1.52 m) cultivator (1.37 m), moldboard plow, and optional PTO. High clearance (381 mm) with drawbar removed. Most suitable for small farms.

Cost and Present Status (as of _____):

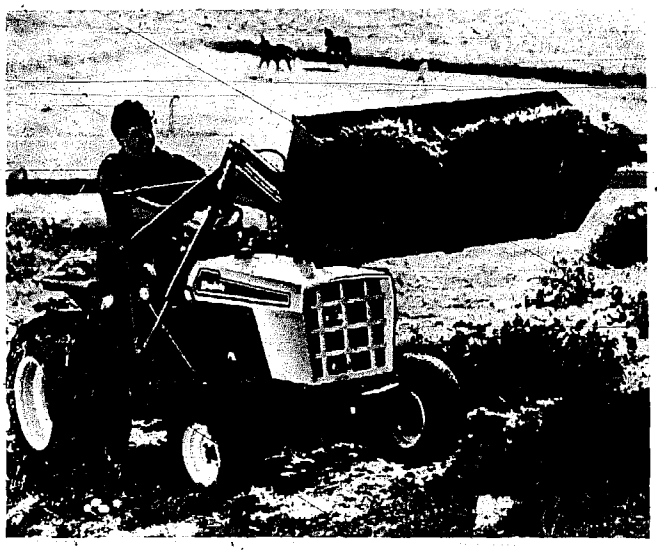

Motoagricola 35/DT A

SO.GE.M.A. S.p.A.
Zona Ind. Nord "Regnano"
06012/Citta di Castello/
Perugia
Italia
Telephone: 075/852270,
853609, 852731, 854690
Telex: 66074 Nardi

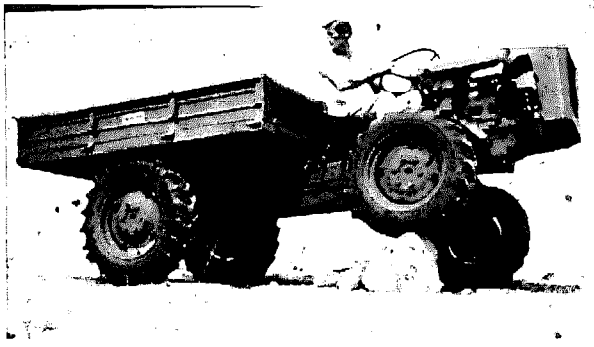

Description: 4-wheel drive tractor with reversing gears and with 3-point draft-controlled universal lift; 4 stroke, 2 cylinders, air-cooled, 30 HP diesel engine; foot brake and hand brake; transmission-8 forward and 8 reverse gears.

Specifications:

weight (including lift)	-	1,430 kg	engine	-	30 HP
length	-		speeds	-	1.63km/h to 20km/h
width	-		fuel capacity	-	
height (to steering wheel)	-	1.52 m	fuel consumption	-	
ground clearance	-	.44 m			
variable track:					
front end	-	1.24m-1.32m			
rear end	-	1.20m-1.48m			
distance between axles	-	1.85 m			
payload dump body (190cm x 150cm x 35cm)	-				

Comments on Maintenance, Productivity, "Appropriateness," etc.:
Capable of handling steep and muddy terrain, narrow and winding roads; the following tasks can be performed :

(1) hauling -- dump body which is located over rear wheels is easily tilted by removing only a front pin, ribbed steel is used for the platform and pressed steel for the sides;

(2) plowing -- a transversal off-setting system permits complete tilling ;

(3) hoeing -- rotary hoe has working width up to 116cm and can reach a depth of 12-18cm, where hoeing has to be done simultaneously between plant rows and individual plants, possible to attach a hoe operated by a 3-position oil-powered feeler;

(4) seeding -- single-seed and single-germ drills are available in 1,2,3, and 4 row types and have independent adjustable components;

(5) transplanting -- transplanter is equipped for watering each seedling as it is planted;

(6) cultivating and ridging -- rotary cultivator has adjustable width and working depth;

(7) irrigating -- various types of pump can be attached for sprinkler and flush irrigation;

(8) spraying -- large tanks (800-1000 liters) can be mounted;

(9) reaping -- hydraulically operated cutter bars can be mounted in back, at the sides, and in front of the tractor;

(10) sawing -- power take-off can drive circular and belt saws and winches for dragging logs;

(11) loading -- a mounted revolving rear loader is oil-powered; and

(12) road maintenance and other operations -- both bulldozer blade (width-1.5m & height-.5m) and angledozer blade (width-1.65m & height-.5m) are attachable in front.

Cost and Present Status (as of): 35/DT A - US $
Also available is the 35/DT B model which is designed for hilly terrain and has a lower ground clearance of .29 m.

8. PRODUCTS OF LOCAL INGENUITY

This section contains photographs of an assortment of vehicles or carts built or assembled locally in a number of countries in the developing world. Vehicle designs reflect the availability of local resources and craft expertise. Examples of both motorized and non-motorized vehicles are included. While mechanical parts (such as engines, gear boxes, etc.) and pneumatic wheel assemblies are usually imported or purchased second-hand, the bodies of the vehicles are invariably fabricated locally.

KENYA: Locally fabricated handcart.

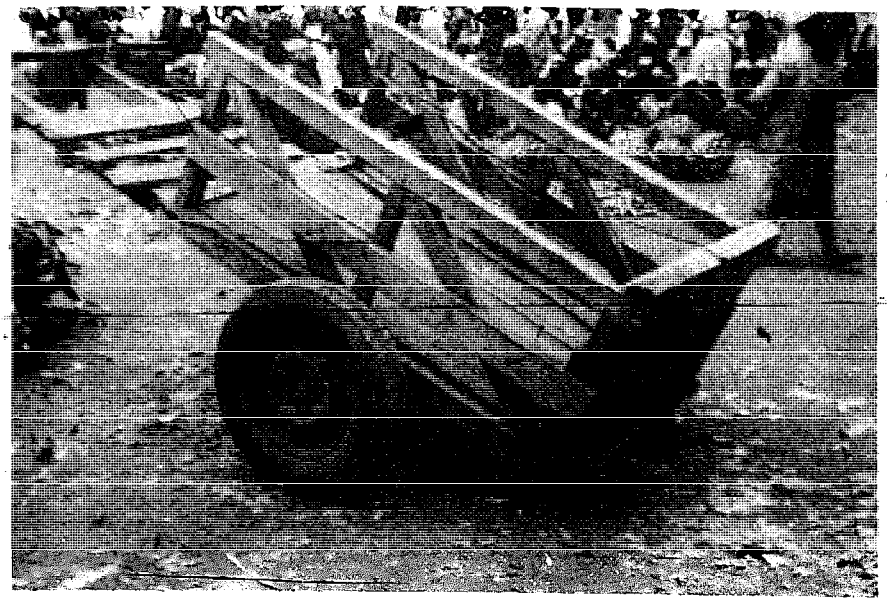

KENYA: Factory made ox-cart.

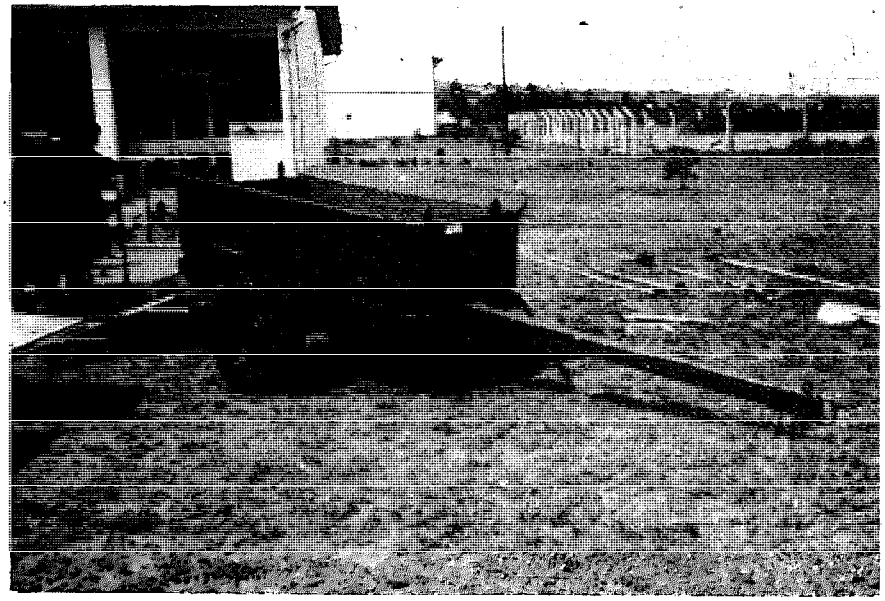

KENYA: Bicycle trailer.

KENYA: Locally fabricated industrial handcart.

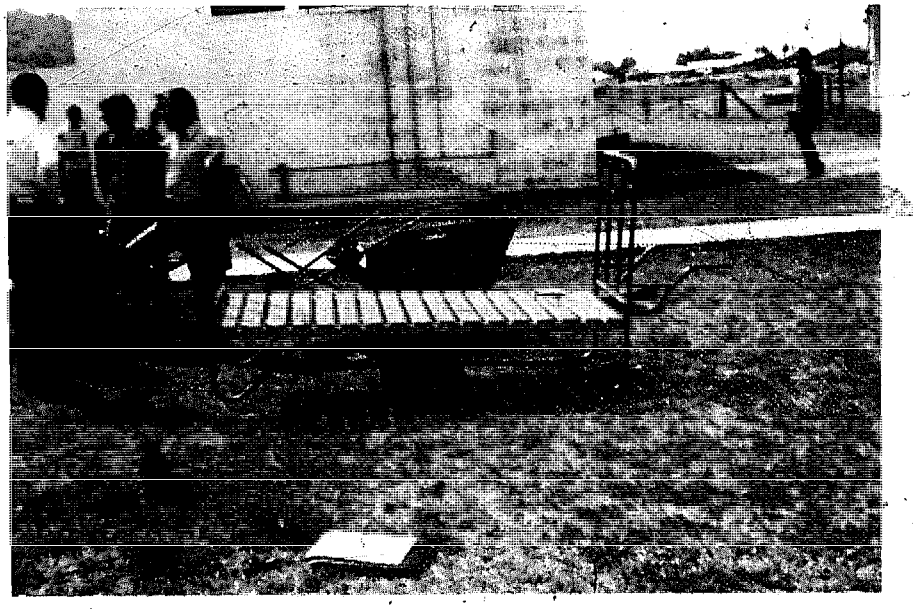

CHINA: Large-wheel wheel barrow with single wheel centered under the load.

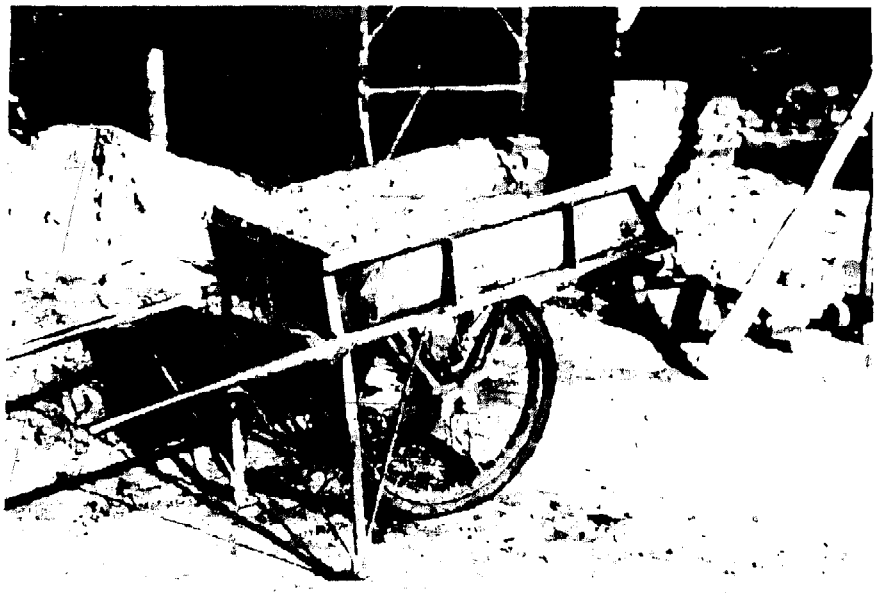

CHINA: Four wheel pushcart.

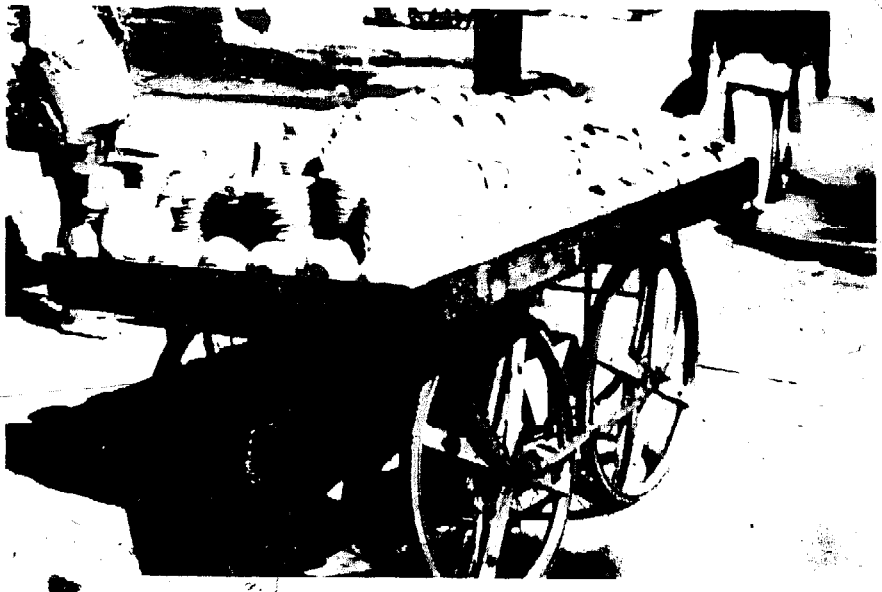

INDIA: Tri-cycle for hauling goods.

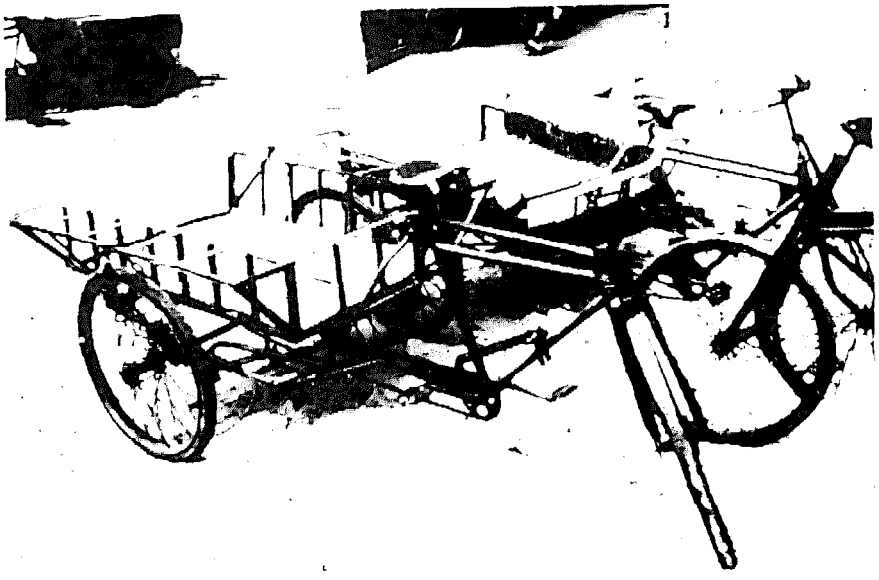

CHINA: Mono-cycle pulling single-axle cart.

KENYA: Small truck made from spare vehicle parts.

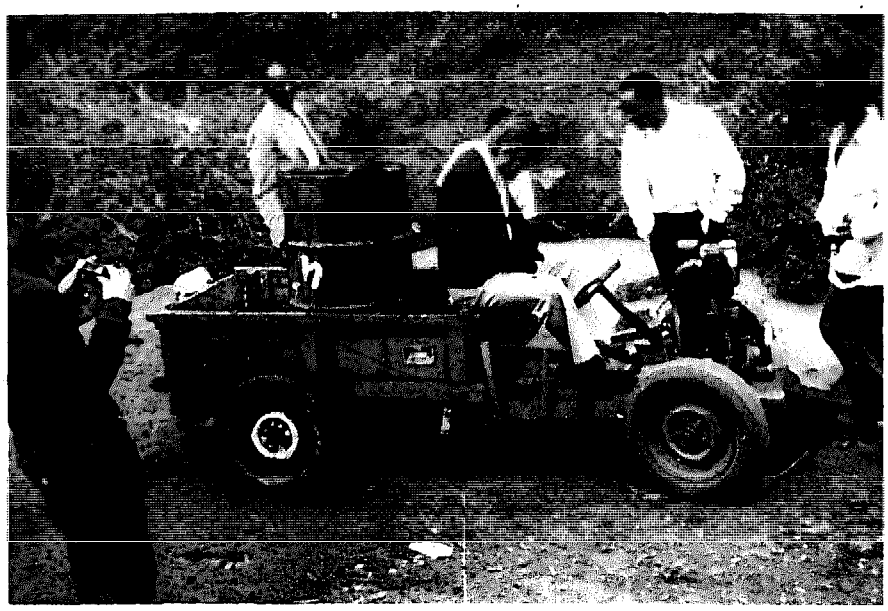

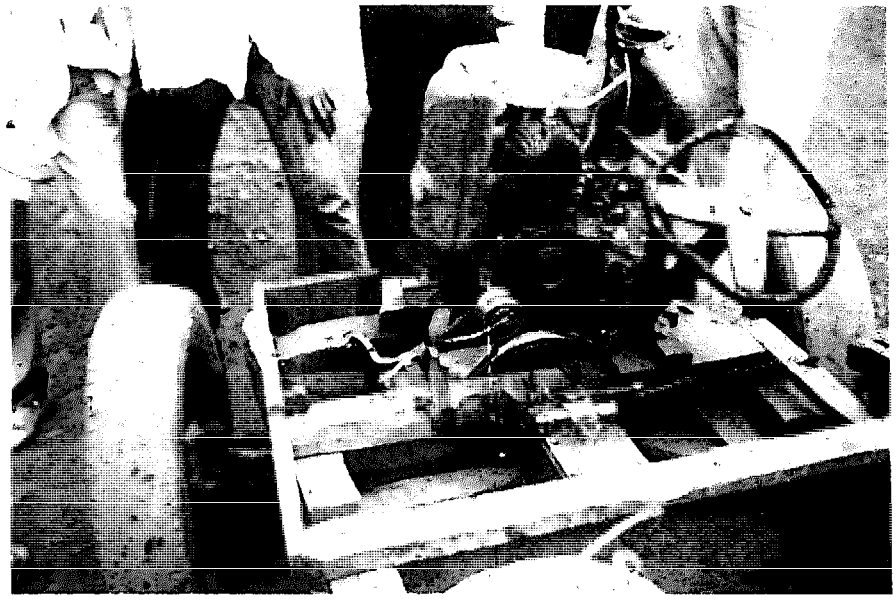

KENYA: Locally constructed cart pulled by single-axle tractor.

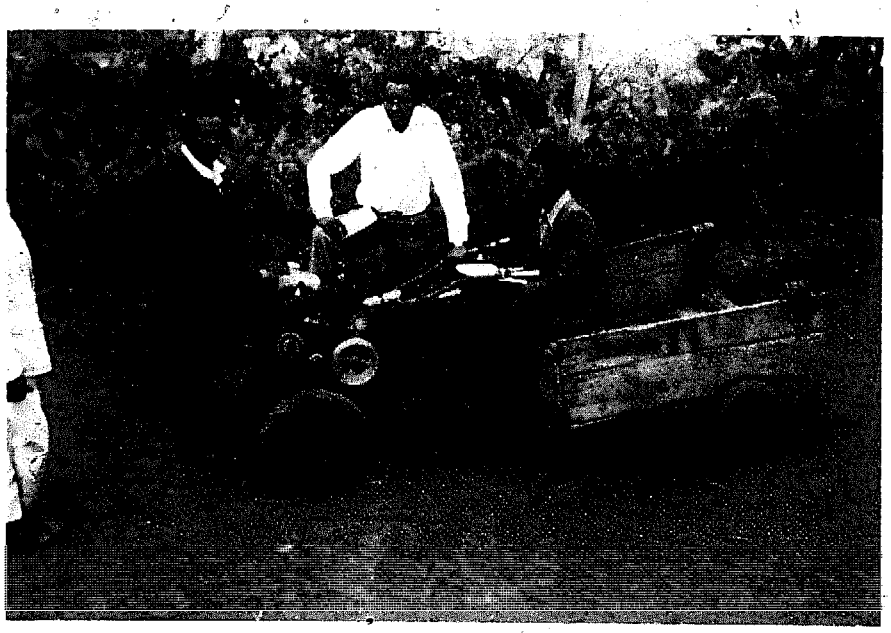

INDIA: Locally fabricated cart pulled by single-axle tractor.

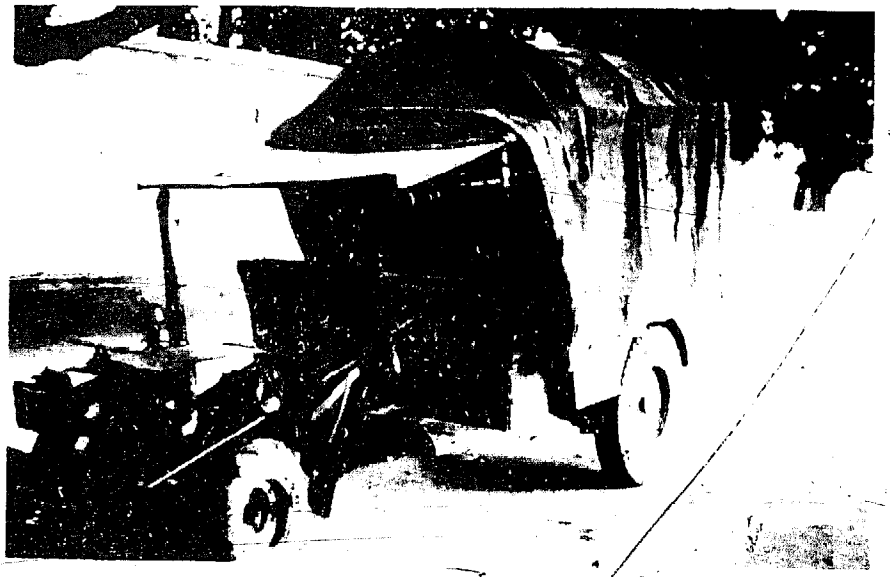

CHINA: Three-wheel vehicle constructed from basic motorcycle parts and local materials.

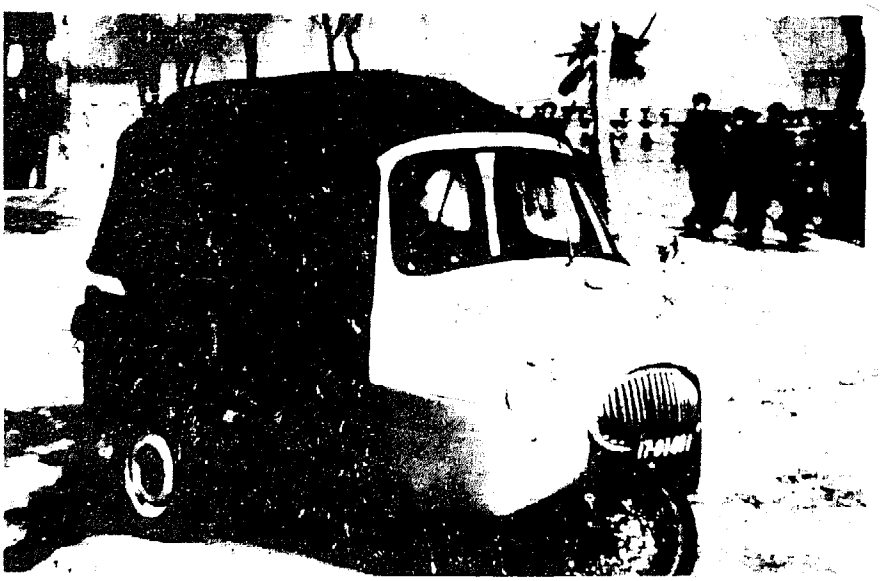

INDIA: Local three-wheeled taxi:

INDIA: Cart pulled by single-axle tractor.

TAIWAN: Three-wheel truck with single cylinder engine and flywheel

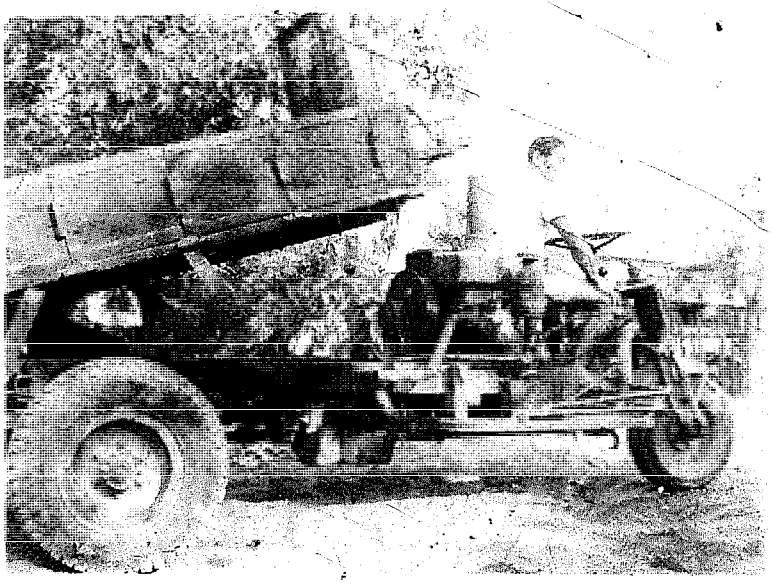

PHILIPPINES: Locally fabricated truck

VEHICLE SUMMARY SHEET

Vehicle Name:

Company Address:

Telephone:
Telex/Cable:

Description:

Specifications

weight	-	engine	-
length	-	speed	-
width	-	fuel capacity	-
height	-	fuel consumption	-
ground clearance	-		
wheel base	-		
payload capacity	-		

Comments on Maintenance, Productivity, "Appropriateness", etc.:

Cost and Present Status (as of _____):

VEHICLE SUMMARY SHEET

Vehicle Name:

Company Address:

Telephone:
Telex/Cable:

Description:

Specifications

weight	-	engine	-
length	-	speed	-
width	-	fuel capacity	-
height	-	fuel consumption	-
ground clearance	-		
wheel base	-		
payload capacity	-		

Comments on Maintenance, Productivity, "Appropriateness", etc.:

Cost and Present Status (as of _____):

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CANADA

IDRC-TS25e

Rural Water Supply in China

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Rural Water Supply in China

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Foreword

China has made substantial progress toward meeting the basic water supply and sanitation needs of its vast population. Integration of health care and community involvement with water supply and sanitation delivery has been an important element of these efforts. The pragmatic approach of the Chinese led to the publication of a number of simple didactic manuals on water supply that have been widely distributed throughout the country. These manuals are the primary source of information available in China's rural areas on water supply techniques.

This translation is a composite of five of these manuals: *Potable Water Supply in Rural Areas* (Public Health and Epidemic Prevention Station, Hebei Province. 1976. People's Health Press); *Waterworks Design and Construction for Rural Areas* (Shanghai Academy of City Planning and Engineering. 1978. Chinese Building Industry Press); *Digging and Repairing Wells* (Design Department of the Beijing Hydraulic Power Station. 1972); *Well Repair and Damage Prevention* (Hydraulic Power Ministry. 1975); and *Quality Standards for Domestic and Potable Water Supplies* (Ministry of Health. 1976. Chinese Building Industry Press).

The original translation from Chinese was carried out by Lee Thim Loy, engineering consultant, Malaysia, and Peter Phoon of the Civil Engineering Department of Ohio State University. The manuals were obtained during visits to China by Ariane van Buren, International Institute for Environment and Development, and Geoffrey Read, UNDP Global Project GLO/78/006 Technical Advisory Group. The latter's visit was supported by the British Filtration Society. Ariane van Buren undertook editorial rewriting and assembly of the book. Final editing was by Amy Chouinard, graphics by Wendy Moriarty, technical editing by Geoffrey Read and Michael McGarry.

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Chapter 1

Potable Water

Water and Health

Water is essential for life; not only is it required for consumption, bringing with it micronutrients such as iron, and fluoride, but also it is required for personal hygiene. Clean, potable water is needed as drinking water and for washing, bathing, laundering, dish washing, and general cleaning. Water that has been contaminated by disease-causing organisms can transmit disease.

Numerous investigators have illustrated that bacterial and viral diseases can be spread through use of contaminated water. This is a result of pathogenic bacteria and viruses originating from fecal contamination of water sources whether it be through excreta being washed into rivers, seeping into groundwater, use of excreta as fertilizer in agriculture, or improper methods of washing night-soil buckets. Infectious diseases transmitted through water are termed water-carried diseases. Once contaminated, a water source can infect all drawers of water from that source. Consequently, an epidemic of the water-carried disease may occur within a relatively short time, affecting not only public health but also production. Water or food that has become contaminated by pathogens may spread bacterial diseases, including typhoid, cholera, childhood diarrhea, and other gastrointestinal infections; viral diseases, such as infectious hepatitis, infantile paralysis, and infectious conjunctivitis; and parasitic diseases, like schistosomiasis, amebiasis, and giardiasis.

Where rivers, ponds, and shallow groundwater are the major sources of water supply as in southern China, pathogens are introduced into the water by infected persons using the water source for washing or defecation. Of all diseases affecting rural populations, those that are water-related are the most important. An outbreak of water-borne disease is evident when a cluster of cases suddenly appears, especially of persons using a common water source. Improving the quality of drinking water, disinfecting it, and abstaining from drinking untreated water are essential in prevention of water-carried diseases.

Lack or excess of certain trace elements in water causes endemic diseases that are not infectious but are widespread in areas where the water is affected; the most common endemic afflictions due to water quality are fluorosis and goitre. Chemical poisoning does not occur naturally except in areas where trace elements are excessive. People may be poisoned by water that has been polluted by human activities, especially those that produce industrial waste such as mercury, cadmium, chromium, arsenic, and organic phosphates. At present, industrial development in China is increasing; wastewater and solid wastes are augmenting other forms of water pollution. Preventing industrial pollution is essential for protection of water supplies in both urban and rural areas.

Water Quality Criteria

Maintaining adequate water quality is essential for protection of the public health. Physical characteristics of water quality can be measured with laboratory equipment or can be assessed by sight, smell, and taste. Turbidity is cloudiness caused by soil, sand, organic matter, and mineral salts in the water. Where water is contaminated by soil, sand, industrial wastewater, domestic wastewater, or suspended solids, its turbidity will be high. Unpolluted water has no colour; brown is indicative of decomposing organic matter; a dark-yellow may be caused by iron or manganese. Colour in water normally indicates some kind of contamination.

Unpolluted water is odourless so that any smell normally indicates contamination. For example, water polluted by excreta emits characteristic odours. Where industrial pollution occurs, chemical odours such as those of petroleum or benzene will be emitted. Similarly where water has a taste, it contains extraneous chemicals. High concentrations of chlorides cause a salty taste, magnesium sulfate a bitter taste, and calcium sulfate an astringent effect. Water temperatures

remain relatively constant within any season. Sudden rises in temperature indicate industrial waste discharges and are therefore very significant in identification of water pollution.

Table 1 presents water-quality standards for domestic and potable water supplies in China.

Good water does not contain chemicals in harmful quantities. The concentrations of chemicals in water are an important indicator of water quality. Also, natural water is slightly basic, with a pH ranging from 7.2 to 8.6. If water is contaminated by acidic or alkaline pollutants, its pH will change accordingly. Overly acidic or alkaline water will affect people and will damage crops irrigated with it.

Dissolved solids in the water can be detected as precipitates after evaporation. The quantity of dissolved solids depends largely on the amount of dissolved minerals that are in the water. The maximum amount of dissolved solids acceptable in potable water is 1000 mg/l.

The hardness of water indicates its calcium and magnesium salts content. The terms "hard water" and "soft water" are used to describe high or low hardness. People can get used to the hardness of water with no serious health effects; however,

Table 1. Water quality standards for domestic and potable water supplies.[a]

Parameter	Limit
Physical property	
Colour	Not more than 15° and not visually offensive
Turbidity	Not more than 5°
Tastes and odours	Not offensive
Visible solids	None
Chemical property	
pH	6.5–8.5
Hardness (CaO)	Not more than 250 mg/l
Iron	Not more than 0.3 mg/l
Manganese	Not more than 0.1 mg/l
Copper	Not more than 1.0 mg/l
Zinc	Not more than 1.0 mg/l
Volatile carbolic	Not more than 0.002 mg/l
Anionic detergent	Not more than 0.3 mg/l
Toxicological content	
Fluoride	Not more than 10 mg/l; recommended 0.5–1.0 mg/l
Cyanide	Not more than 0.05 mg/l
Arsenic	Not more than 0.04 mg/l
Selenium	Not more than 0.01 mg/l
Mercury	Not more than 0.001 mg/l
Cadmium	Not more than 0.01 mg/l
Chromium (hexacovalent)	Not more than 0.05 mg/l
Lead	Not more than 0.1 mg/l
Bacteriological content	
Total colony count	Not more than 100/ml
Coliform	Not more than 3/ml
Residual chlorine	After treatment, not less than 0.3 mg/l for the next 30 minutes. In piped supply systems, concentration at the end of the network should not be less than 0.05 mg/l.

Source: Ministry of Health, People's Republic of China, 1 December 1976.

[a]Quality of private (small) water systems should comply with the toxicological limits of these standards. If the qualities of other items cannot be adequately met, the responsible authority should start a mass campaign of sanitation to improve the public health environment, adequate measures should be adopted for water treatment, and the quality of the supply should be continually improved.

Editor's note: These standards are drawn from a separate document (TJ20-76) approved by the Ministry of Health and the Basic Construction Committee and published by the Chinese Building Industry Press, Beijing. The document is translated and presented in Appendix 4. The degree to which they are enforced throughout China is not known. The Chinese Health Ministry's water quality standards reflect the difficulties in maintaining an effective surveillance system in rural areas and China's level of industrial development. China's pragmatic approach is illustrated in its standards for bacterial contamination. They are far less stringent than Canada's water quality criteria guidelines. China does not include pesticides, radionuclides, nitrilotriacetic acid, or trihalomethanes — a reflection of the complexity of analysis needed for these and the degree to which the Chinese see them as priorities.

people accustomed to soft water who are suddenly given hard water to drink get stomach troubles and, shortly thereafter, indigestion or diarrhea. This is a common complaint in persons traveling in a new area, not acclimatized to the water. Also, hard water may change the taste of food and tea; increase the amount of soap required for washing; or damage skin, especially delicate facial skin. Overly soft water also has effects; for example, research in recent years has found that use of soft water is linked with prevalence of vascular diseases.

Chloride is an indication of the salinity of water. Salinity is caused by several compounds, although sodium chloride (ordinary salt) is the most common. The amount of chloride in natural water depends on the geology of a region. Coastal regions usually have water with high chloride concentrations, whereas concentrations are usually low in mountainous areas. However, the chloride content within one source in a particular area is usually quite consistent. An abnormal increase in chlorides suggests that the water is contaminated by human or animal excreta, domestic wastewater, or industrial chloride-containing wastewater. A high chloride content makes the water not only salty to taste but also unpleasant to use. Furthermore, it affects secretion of gastric juices and, eventually, digestion.

Like chloride, sulfate is normally present in water, and the amount depends on the geology of the area. Some sulfates, such as magnesium sulfate and sodium sulfate, cause diarrhea; therefore their concentrations must be kept low.

Iron is an essential trace element for the human body. However, at high concentrations, it gives water a bad taste and a reddish colour. It also is aesthetically undesirable because it colours cloth and turns tea and rice black. Copper is another essential trace element for humans. Natural water contains very little copper. High concentrations in drinking water produce an abnormal, generally unacceptable, taste, and excessive accumulation of copper in humans causes chronic poisoning.

Drinking water is a person's major natural source of iodine. Iodine is necessary for the production of thyroxine in the thyroid gland, and lack of it is the main cause of goitres. People need 120 μg of iodine every day to ensure proper physiologic functioning. Where iodine in water is less than 10 mg/l for a long time, people are likely to suffer from goitre. High iodine content is an important criterion in the selection of a water source and is a major factor in goitre prevention. Fluoride is essential for human bones and teeth formation and is found in small amounts in teeth, bones, and hair. Evidence shows that in areas where the fluoride in water is less than 0.5 mg/l, the occurrence of tooth decay is more frequent. Most sources contain some fluoride, and, in fact, many contain too much, causing damage to normal teeth and bone growth. Teeth become brittle, and their crowns may break off where the fluoride concentration is higher than 1.5 mg/l. With concentrations higher than 4 mg/l, chronic poisoning occurs, bone structure is seriously damaged, and bones become brittle. It is desirable to determine the fluoride content carefully in water that is for human consumption.

The many harmful substances that frequently pollute drinking water are divided into two major categories: organic matter containing nitrogen and carbon, such as human, animal excreta and decayed animal, plant matter; and chemical waste from industry. Due to the development of industry in China, discharges of industrial wastewater, solid wastes, and air pollutants are on the increase. In some countries such pollution has become a serious problem, but through the policy of "prevention first," the Chinese are trying to control pollution from the start and have made significant achievements.

The major sources of nitrogen compounds in water are animal excreta and decaying animal bodies. Nitrogen compounds include protein, nitrate, nitrite, and ammonium salts; they are the products of protein decomposition. The presence of various nitrogen compounds and their levels of concentration are good indicators of direct or indirect contamination by excreta.

When water contains proteins and organic nitrogen compounds, but no ammonia, it is freshly contaminated and has not yet reached the stages of ammonification and nitrification. However, if ammonia, nitrites, and nitrates are present, the water is being continually contaminated. Water that contains only nitrites and nitrates may have been contaminated previously and is reaching recovery. High nitrite and nitrate concentrations in water may also indicate that the water has flowed over areas with high nitrate contents. Under these circumstances, part of the nitrate may be oxidized to nitrite. Careful investigation and surveys are needed to determine water quality if nitrogen compounds are being used as indicators. Furthermore, nitrite is harmful to human beings. In high concentrations, it combines with the erythrocytes in blood and impedes the transmission of oxygen. In general, the maximum acceptable concentration of nitrate and nitrite in water is 10 mg/l.

Dissolved oxygen is an important criterion for the identification of organic contamination. Surface water that is exposed to air has considerable oxygen dissolved in it, but groundwater has only

small amounts. If the water is contaminated, its dissolved-oxygen content is low, and sometimes even exhausted, because of the oxygen consumption of microorganisms and the oxidation of pollutants.

There are numerous harmful substances in industrial wastewater and solid wastes, for example: phenols, cyanide, arsenic, mercury, chromium, cadmium, lead, toluene, aldehyde, petroleum, tar, sulfides, organic phosphorus, and chlorinated hydrocarbons. Normally, the most harmful and common contaminants are phenols, cyanide, arsenic, mercury, and chromium, which are found in the wastes of many industries, including coking, oil refining, chemical manufacturing, plating, and organics synthesis. Industrial waste can be widespread and can easily pollute surface water sources, such as rivers and lakes. Because such pollution can eventually lead to the poisoning of people and animals, its early detection is essential.

Phenols are widely used in coking, petroleum, paper, synthetic resin, and other industries, from which they can contaminate drinking water. Not only do these wastes smell unpleasant, but they react with chlorine used in water purification and produce a more pungent odour. The phenol-chlorate produced by the reaction makes the water completely unacceptable for drinking. Water that contains phenols can create chronic health problems, e.g., anemia, headaches, dizziness, and other illnesses. In China, the maximum acceptable concentration of phenol in waste discharges is 0.5 mg/l, and surface water should not contain more phenol than 0.01 mg/l.

Cyanide is a highly poisonous substance that causes cells to lose their ability to dehydrogenate and oxidate; it can also affect internal respiratory functioning and cause serious poisoning. Arsenic is a trace substance in nature and harmless within its natural range of concentrations; however, industrial discharges often include arsenic levels that are poisonous. The arsenic affects the nervous and digestive systems and causes vascular problems. Mercury is another highly poisonous substance that is damaging to the nervous system and can cause fetal poisoning. The maximum acceptable concentration of mercury in surface water is 0.005 mg/l. Chromium is also poisonous; it is widely used in plating, printing, dyeing, and hide-processing industries and is discharged in their wastewaters. When a body of water is contaminated by chromates, it becomes yellow and unacceptable for drinking. High intake of chromium affects normal oxidation and may cause anemia. The maximum acceptable amount in surface water in China is 0.1 mg/l.

Polluted water is an important medium for the transmission of infectious diseases, especially intestinal diseases. Understanding the role of water will help prevent the spread of those diseases. The following are criteria that indicate the pathogen content of water:

- Total bacterial count is the number of bacteria in a litre of water as determined under certain laboratory conditions. Clean water does not usually contain more than 100 bacteria/ml (24 hours incubation at 37 °C). In contrast, polluted water, such as that contaminated by excreta, may contain more than several hundred thousand per millilitre. The numbers of bacteria in water are therefore a good indication of its quality. There are two basic types of bacteria — pathogenic (disease-causing) and nonpathogenic. It is difficult to isolate and enumerate the pathogenic ones, but a high total count suggests the presence of pathogens. Thus, an estimation of the total bacterial count in the water gives a basic indication of the danger of spreading infectious diseases. The total bacterial count is a principal criterion for water quality in China; the maximum acceptable total colony count is 100 bacteria/ml.
- The *Escherichia coli* or coliform index is defined as the number of *E. coli* in a litre of water as determined under certain laboratory conditions. An estimate of *E. coli* densities can determine the direct or indirect contamination from excreta and the possibility of other excreta-related pathogens being present. Coliform organisms do not usually cause disease. However, pathogenic organisms coexist with them in small numbers and are difficult to isolate. Therefore, the enumeration of coliform organisms is an important epidemiologic tool.

Coliform organisms normally exist in the intestinal tract and, when discharged into water, are more resilient than other pathogens. A low coliform count in water suggests the absence of intestinal pathogens; high coliform count indicates that the water was recently contaminated by excreta, the existence of intestinal pathogens is likely, and the water is unsafe.

Testing water quality is relatively complicated, but if there is any doubt concerning the quality, samples should be taken immediately and brought to the public health authorities.

Water Quality Control

Prior to liberation, the people of China lacked even adequate food and clothing; it was pointless to promote sanitation. Lack of water and sanitation was an acute problem, water-related diseases were endemic in the population, and mortality among the rural people due to communicable

diseases was very high. Since that time and especially as a result of the increasing numbers of barefoot doctors, there has been a continuing improvement in rural health. Water-supply protection and quality maintenance have become the responsibility of the barefoot doctors. Their duties include:

- Educating the people in water quality control: explaining the importance of clean water and counteracting illiteracy, superstition, and poor health practices. Following the policy of emphasizing prevention, barefoot doctors stress the interrelationship of health, production, and sanitation; disinfection and water supply improvement; communal action in guaranteeing the quality of the water supply;
- Providing advice in selection of the best source of water: it is their responsibility to conduct initial surveys of alternative sources including gathering hydrologic and geologic data, information on sanitary conditions in the surrounding areas, and analyses of soil and water quality;
- Improving the drinking water supply by protecting and treating the water using methods discussed in chapter 4; and
- Conducting drinking-water surveys as an essential step in maintaining the quality of the water.

Water Source Investigations

Potable water investigation for rural areas includes monitoring, site observation, community meetings and participation, consultations with old peasants in the area with experience of local problems, and laboratory examination.

The investigations for a well should cover the topography of the site, the location, the well life, the number of users, the maximum service radius, and the seasonal volume. A knowledge of all these items is essential in rural water management.

In northern China the main source of supply is groundwater; in southern China it is surface water. A stone-built well in northern China can have a life of about 250 years. If its age is more than 300 years, the foundation and the sealing material may be damaged and the water quality subsequently affected. Old wells should therefore be carefully maintained.

The maximum service radius is defined as the maximum distance between the well and any one of the users. This should be considered not only for the convenience of the users but also for water-quality hygiene. Investigations have indicated that the total bacterial count in water supplies increases with the distance between the well and household. The service radius of a well should be no greater than 300–400 m. It is uneconomic to have the service radius too small because of the costs in construction.

The number of users should be carefully estimated. If a well serves too many people, the water will be too rapidly withdrawn; sand and other settled materials will be disturbed; and the turbidity, total bacterial count, and coliform count will be increased.

A good well should have a solid foundation, an impervious apron, platform, lip, and cover. It has been proved that the structure of the well has an important effect on the water quality. The structure and the materials used for a well should therefore be essential items of detailed investigation. The well should be sealed against the entry of, and possible contamination from, shallower water. The lip and platform should be reasonably high, and the cover should be effective. These are the most important structural aspects preventing contamination.

In areas where a well exists, sources of contamination and their distance from the well should be investigated carefully, including the number and size of latrines, manure pits, dirty-water ponds, sewage, and garbage pits. The quantity and nature of pollutants and the degree of possible contamination should be estimated. Items for investigation include what equipment is used to draw water (e.g., buckets), whether the well is privately or publicly used, and whether there are any rules or regulations for maintenance, management, and cleaning. In other words, water-quality investigation consists primarily in understanding the likelihood of contamination. Physical criteria are usually only judged by the human senses. However, a water sample can also be sent for analysis.

The method of disinfection should depend on the local conditions and available resources. To prevent epidemics, it is essential to investigate the effectiveness of disinfection in killing pathogens and viruses. The occurrence and spread of infectious diseases should be investigated from the information supplied by local people.

For newly built wells, the hydrogeologic conditions, the depth of the water-bearing layer, the soil conditions, and the well structure should also be investigated. For other sources (rivers, lakes, reservoirs, ponds), methods and items of investigation are quite similar; that is, they include assessment of the general situation, structure and equipment of water intake, surrounding hygienic conditions, usage and management of the source, the possibility of contamination and pollution discharged upstream, and quality and quantity of the source water. Knowing these, one can improve the water source and its quality.

Chapter 2

Source Selection and Protection

Water in nature is continuously recycling. The hydrologic cycle includes precipitation (snow, hail, sleet, and rain), which reaches the ground surface and eventually becomes streams, from which part will be evaporated. The streams go into rivers, lakes, seas, reservoirs, etc., which become surface water supplies. Water that percolates into the ground, known as groundwater, also becomes a source of water supply. Groundwater can be classified as shallow and deep. A spring is the discharge of groundwater from an aquifer. An understanding of the characteristics of water quality from the various sources enables one to make a better decision in source selection.

Surface Water Sources

The common characteristics of surface water are that it contains few minerals, is not very hard, is usually large in volume, and is convenient for many people. It is, however, easily contaminated, and its turbidity and total bacterial counts are high. It is also difficult to protect.

These characteristics all apply to rivers, although the diluting and self-purification capacities of rivers are also very high. River-water quality varies with the season and precipitation; it also varies with the rate of flow. During the dry season, the turbidity is usually low, but the degree of hardness and salt content, high. During flooding, turbidity and total bacterial counts are high, whereas the degree of hardness and the salt content decrease. Wastewater from domestic or industrial discharges may pollute the river and exceed its capacity for dilution and self-purification. In such cases, not only does the quality deteriorate, but the danger of disease increases.

Lakes are slow-moving, so the water they contain is retained for long times. Suspended solids settle to the bottom, and the result is low turbidities and bacterial counts. Photosynthetic organisms grow in lakes during the summer when solar radiation is greatest, thereby seriously affecting the water quality. During the autumn, these algae die, producing a distinctive odour and colour. Thus, lake-water quality changes with seasonal variation and precipitation but to a much smaller degree than does river water. Reservoirs behave similarly to lakes, but generally the water has a higher mineral content.

Pond water termed "dead water," cannot purify itself as easily as it is contaminated, and contamination can be serious, especially in inhabited areas. Ponds commonly have an odour, as the water contains large quantities of organic matter and bacteria. In summer, aquatic weeds and plankton worsen the water quality.

Groundwater Sources

Shallow groundwater is replenished from surface water sources that are relatively nearby. Because such water only travels a short distance, natural filtration is limited, and the quality of the water may be poor. Shallow groundwater can easily become contaminated if there is any source of pollution on the surface or in the ground. Both quality and quantity are clearly affected by the surrounding environment.

Deep groundwater is generally replenished by a source further from the collection site. Due to the long distance it travels, through natural filtration in water-bearing soil strata, deep groundwater has low turbidity and can usually meet health standards for drinking and domestic use. However, deep groundwater may contain various kinds of salts and can be very hard. Some sources of deep groundwater have a high concentration of iron, fluoride, and magnesium. Most of those sources contain few bacteria, certainly fewer than surface water.

Source Selection

China is a socialist country; the water resources are the property of the people. Sources are selected according to political as well as economic and technological benefits. The following characteristics are pertinent in source selection:

- Abundance. The source must fulfill the requirements of consumption — the selection taking the weather and the local patterns of water use into account. For example, people in southern China use more water than those in the north, and there are seasonal differences in water consumption.

The quantity of water must satisfy not only current consumption but also future demands. Water should be available during both dry and rainy seasons. Therefore, when the source is being chosen, hydrologic and hydrogeologic studies should be strictly and accurately carried out. If a water source is selected during the rainy season, when water is abundant, it may be unable to meet the demands during the dry season. The variation is large, especially in mountainous and semi-mountainous areas where water may be not available at all during the dry season.

- Quality. The water should be odourless, colourless, and tasteless; it should not contain harmful amounts of chemicals or be contaminated. For these reasons a full investigation should be undertaken before a water source is chosen. The water should have good physical characteristics and should be hygienically safe. Where water treatment consists of just adding chlorine, the coliform count should not exceed an average 1000/l of raw water. The levels of toxic substances in water must be lower than those indicated in Appendix 4, as present waterworks technology is not able to reduce the concentration of those chemicals. High concentrations of fluoride or negligible levels of iodine — the latter indicated by a high prevalence of goitre in a locality — are not acceptable in the selected source. For the small, simple waterworks the best source is one in which the quality of the untreated water is as close as possible to the required standard.

- Hygienic environment. The source should be easy to protect from contamination. Wells should not be drilled near rubbish piles, dung pits, graveyards, or in undesirable soils, as they could affect the water quality.

Groundwater should be used where available, and surface water only considered as an alternative where no groundwater is available or drilling is extremely difficult. No physical connection is permitted between water used for agriculture or aquaculture and that for drinking purposes.

Water collection, purification, and transmission facilities are interdependent. For example, when the raw water is of poor quality, it is costly and difficult to purify, and maintenance and management are more complex. Similarly, if collection is difficult, construction and pumping costs increase. The source thus affects the investment required for the whole system. If there are several potential sources available, each should be assessed from technical and economic viewpoints before one of the alternatives is selected.

Once the source has been decided upon and the waterworks built, the system must be carefully protected from contamination, a side-effect of human activities.

Dung contamination is caused by seepage from latrines and by rainwater and irrigation washing over the ground's surface, especially in areas where dung is used as fertilizer on the field. It is a major contributor to the spread of infectious diseases. Therefore, wells should be drilled at elevated, slightly sloped sites. An impervious apron, a cover, and a rim should be constructed for the well. There must be no rubbish piles, dung pits, or cattle pens within 30 m of the well. Laundering and the washing of night-soil buckets should be prohibited within 3 – 5 m. The structure for the well should be made of watertight material, such as brick, stone, or concrete.

If a surface-water source (lake, reservoir, or pond) is used, an area around it should be protected as a water-catchment area, with no latrine, dung pit, or other polluting agent allowed near the shore. Laundering, washing night-soil buckets, and discharging wastewater into the water should be prohibited, as should swimming and fishing. If river water is used, the site for drawing water should be upstream of any wastewater discharge or docking facilities. Similarly, all wastewater or solid-waste discharge should be prohibited upstream of the chosen site.

The dangers from contamination by industrial wastes are increasingly being recognized, and prevention of industrial pollution is a priority. The most effective measure is the treatment and reuse of wastes within the industry, with the purpose of minimizing the harmful chemicals discharged. Industrial wastewater should be discharged into a drainage system not into a source of water supply.

To protect domestic and drinking-water supplies from contamination, the standards laid down in Appendix 4 are a good reference.

Chapter 3

Source Improvement

Source protection and improvement are permanent methods of ensuring the water quality against bacterial, harmful chemical, and other pollution. In contrast, disinfection is a continuing task that does not deal with the cause of pollution. In China, where emphasis is put on prevention, techniques for improving water sources are preferable to disinfection, and they should be part of the barefoot doctors' curricula. They begin with the collection of information on hydrologic conditions and source characteristics. The following are simple methods that improve surface water, spring water, and groundwater supply systems.

Improving Surface Water

Surface water is exposed to the atmosphere and is therefore easily contaminated; it is not as good as water from other sources. In fact, in many areas, wells have been drilled (especially deep wells) to replace surface-water sources — a practice that is recommended but not always possible. The other alternative is to improve the surface-water source.

One method is to build a natural infiltration well (Fig. 1) near a river or pond that contains potable water. The only prerequisite is that the subterranean strata be able to transfer water or that a water-bearing stratum exists so that the river or pond water filters into the well and is purified by the sand stratum.

Another method is to construct a sand-filter well (Fig. 2–4), for which there are many designs. The basic principle is utilizing sand to filter water. The water is purified by the operation of two mechanisms: the small openings between the grains of sand do not permit undesirable substances to pass through with the water and a biological layer on the sand, which is created by microorganisms, absorbs many of the undesirable substances.

When newly constructed, the well may not filter satisfactorily, especially if turbidity is high; however, when the biological layer has been created, the water quality improves.

The size of particles affects the effectiveness and rate of filtration. If the grains are too small, the filtration may be good but slow and will require a large surface area. Large grains increase the filtration rate but with poor results. The particle size used in the filter should reflect the turbidity of the raw water. Riverbed sand is usually satisfactory, once the larger particles are picked out and the tiny ones removed with a wicker basket and fine sieve.

The thickness of the filter also has an important affect on filtration. It is usually between 0.5 and 1.0 m thick but should be thicker if the sand in the bed is coarse, thinner if the sand is fine. The filtering bed area is calculated from the consumption and filtration rates. According to the design promoted by the Public Health and Epidemic Prevention Station in Hebei province, if the particle radius is 0.3–0.5 mm, the bed should be approximately 0.8–1.0 m deep, the filtration rate being 0.1–0.3 m/h (i.e., 0.1–0.3 m^3 of water through 1 m^2 of filter area per hour) (Table 2).

When the height of the filtering well is calculated, besides the depth of the bed, a supporting layer and a distance between the sand and the top

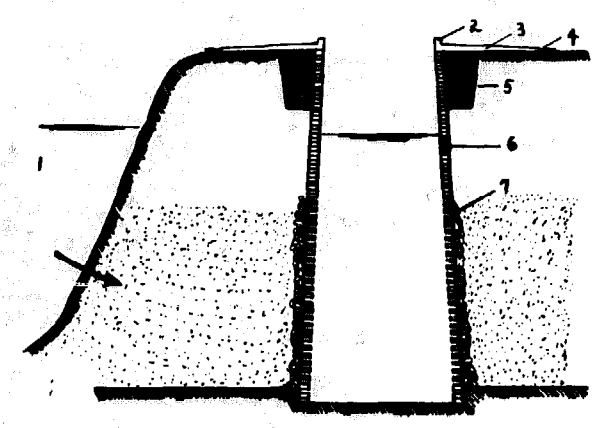

Fig. 1. Natural infiltration well (1, river water; 2, lip; 3, impervious apron; 4, ditch; 5, clay; 6, seal; and 7, pebbles or broken brick).

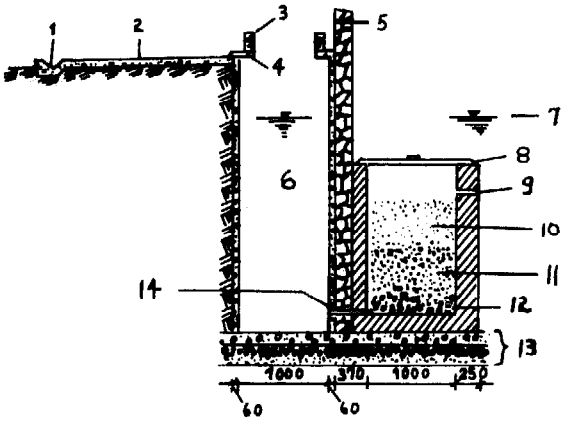

Fig. 2. Sand-filtering well (1, ditch; 2, impervious apron; 3, lip; 4, corner platform; 5, protection wall; 6, treated water tank; 7, flood-season level; 8, cover; 9, water intake; 10, fine sand; 11, coarse sand; 12, pebbles; 13, foundation; and 14, inlet).

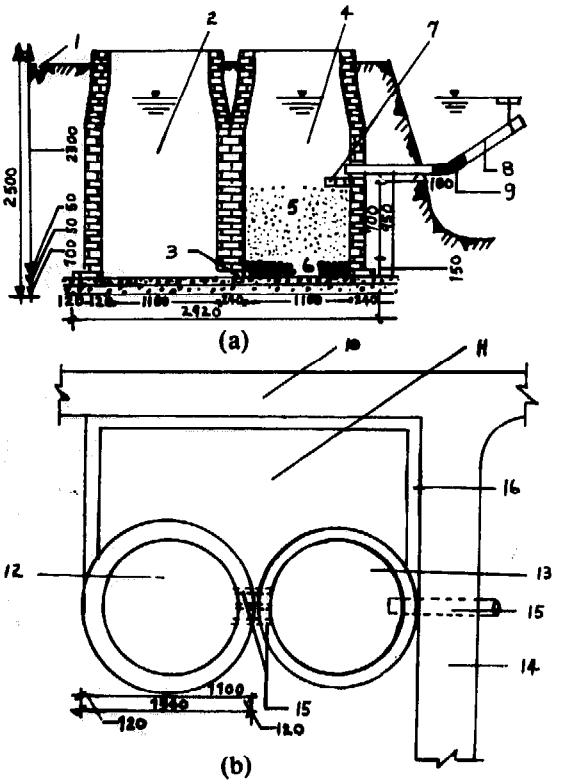

Fig. 3. Sand-filtering well: (a) the cross section (1, ditch; 2, pure-water tank; 3, water inlet; 4, sand-filtering well; 5, coarse sand; 6, pebbles; 7, stepping brick; 8, intake pipe, bamboo; and 9, rubber joint); (b) the plan (10, earth; 11, impervious apron; 12, pure-water tank; 13, sand-filtering well; 14, earth; 15, water inlet; and 16, ditch).

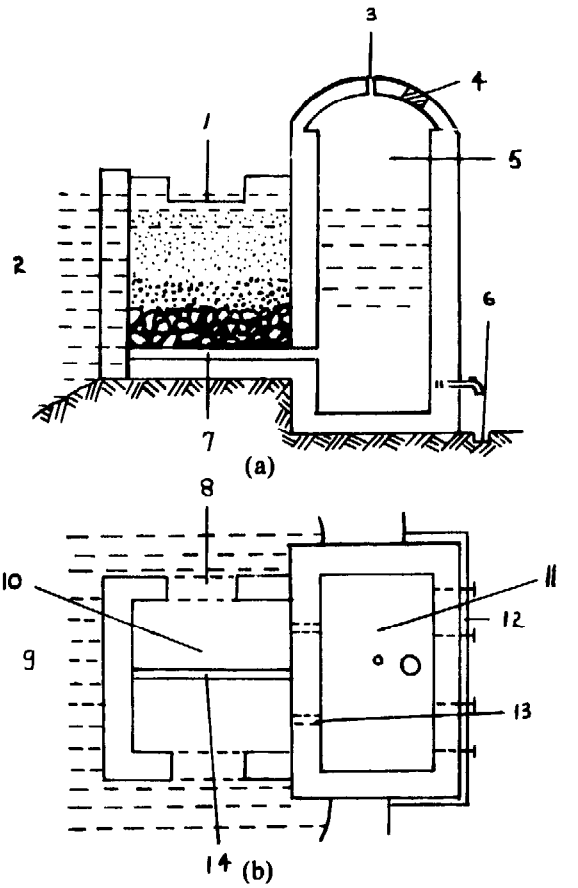

Fig. 4. Sand-filtering well: (a) the cross section (1, intake, 55 mm higher than the sand surface; 2, source; 3, vent; 4, entrance; 5, pure-water tank; 6, ditch; and 7, drain); (b) the plan (8, intake; 9, source; 10, sand-filtering well; 11, pure-water tank; 12, ditch; 13, drain; and 14, drain).

should be taken into account. The supporting layer could be 0.15–0.3 m thick. The water above the sand surface will exert pressure on the bed and help to increase the filtration rate. After a period of operation, the openings in the sand filter become blocked and the filtration rate decreases; 5 cm of sand is taken off the surface layer, washed, and replaced. If the filtration rate does not then recover, all the sand must be removed and thoroughly washed; this should be necessary only after the filter bed has been in use for a relatively long time.

Surface Water Collection

For surface water schemes, intake structures can be either fixed or movable. The fixed intake conduit is usually placed beside a reservoir or in a

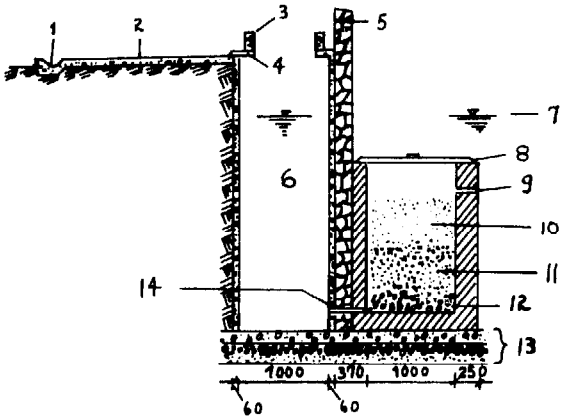

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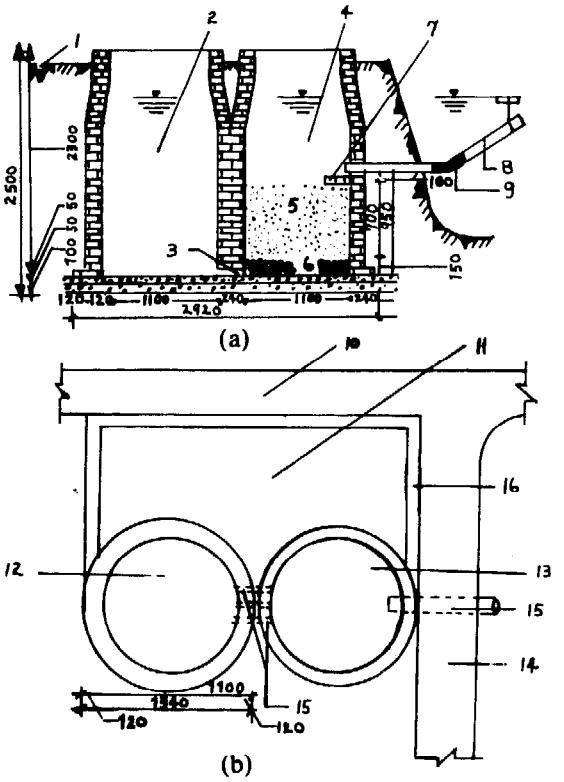

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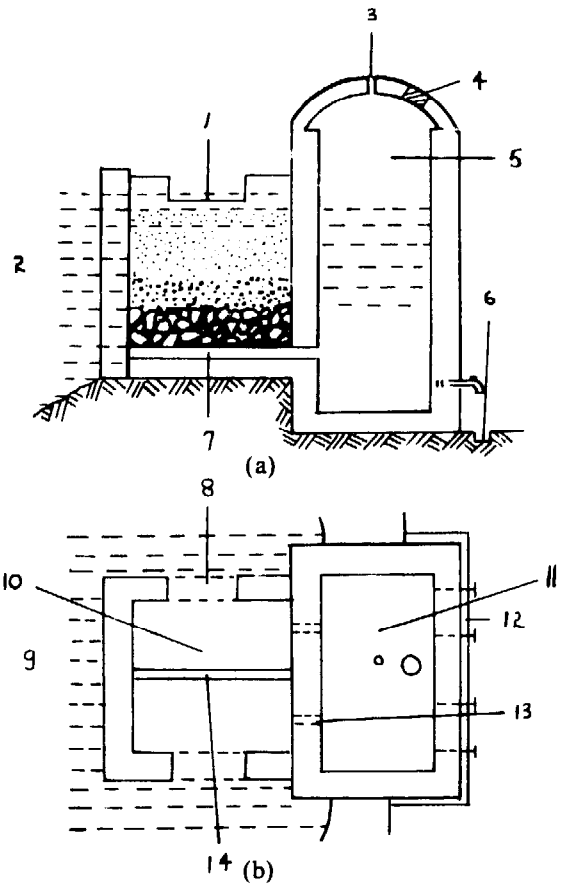

Fig. 4. Sand-filtering well: (a) the cross section (1, intake, 55 mm higher than the sand surface; 2, source; 3, vent; 4, entrance; 5, pure-water tank; 6, ditch; and 7, drain); (b) the plan (8, intake; 9, source; 10, sand-filtering well; 11, pure-water tank; 12, ditch; 13, drain; and 14, drain).

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Surface Water Collection

For surface water schemes, intake structures can be either fixed or movable. The fixed intake conduit is usually placed beside a reservoir or in a

Table 2. Data for filter and pure-water well design.[a]

Households (no.)	Filter tank: Tank depth (mm)	Filter tank: Diameter (mm)	Filter tank: Filter area (m^2)	Treated water tank: Well depth (mm)	Treated water tank: Diameter (mm)	Treated water tank: Max. water content (m^3)
30	2300	1000	0.785	2300	1000	1.5
40	2300	1100	0.95	2300	1100	1.8
50	2300	1200	1.13	2300	1200	2.15

[a]The calculation is based on summer water consumption (20 litres/person-day) with five persons per household.

riverbed. If the slope of the reservoir or riverbank is steep, and the geologic structure good, the intake conduit can be built right into the bank, or if the mainstream is far from the bank and the water quality near the shore unsatisfactory, the conduit is usually built right into the riverbed, provided the bed is flat and stable.

If the intake conduit is movable, it is placed on a boat or cable car so that water can be collected even where the water level varies between 10 and 35 m. The water level should not fall or rise more than 2 m/h, and the shore should be reasonably sloped (10°–30°). There should be no solid objects floating on the water and no risk of collision by boats. In other words, the sites chosen for movable conduits should be safe and easy to manage (Fig. 5).

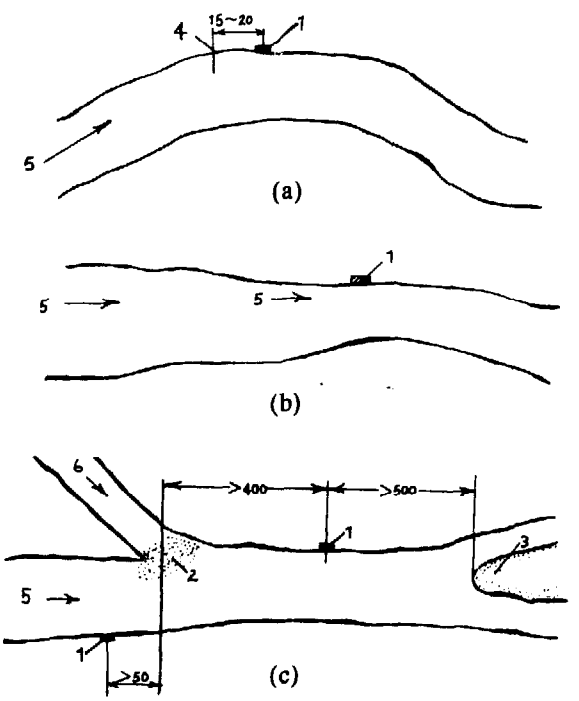

Fig. 5. Collection sites for surface water (1, intake siting; 2, accumulation [sludge, sand, etc.]; 3, island; 4, heading point; 5, mainstream) in (a) a winding river, (b) a straight river, and (c) a branched river with island.

Where the river is winding, the direction of the mainstream should be carefully investigated and the catchment should be sited downstream where the water is deep (Fig. 5a).

If the river is fairly straight, the intake should be sited as close as possible to the mainstream; a narrow section of the river may be optimal (Fig. 5b). However, some hydraulic effects may occur after the intake structure is built, and the shape of the river may change.

If there is a sandy island in the middle of the river, the collection point should be sited at least 500 m away (Fig. 5c, right), and if the island is at the mouth of one of the branches, the collection point might be better sited upstream in the other branch (Fig. 5c, left).

Uncontaminated spring water is suitable for drinking, but it must be protected from contamination. The greatest emphasis should be placed on improving the surrounding environment. Any pollution source within 30 m — latrines, cattle pens — should be removed. A sealed enclosure should be constructed of brick, stone, or concrete, and a tap should be installed (Fig. 6).

If the spring water is abundant, it can be transmitted to the community by a system combining a pure-water tank and a pipeline (Fig. 7). It will be sanitary, convenient for the users, and easy to maintain.

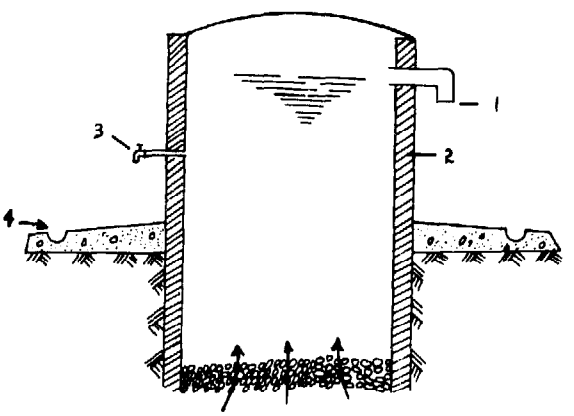

Fig. 6. Sealed spring (1, overflow; 2, tight wall; 3, tap; and 4, ditch).

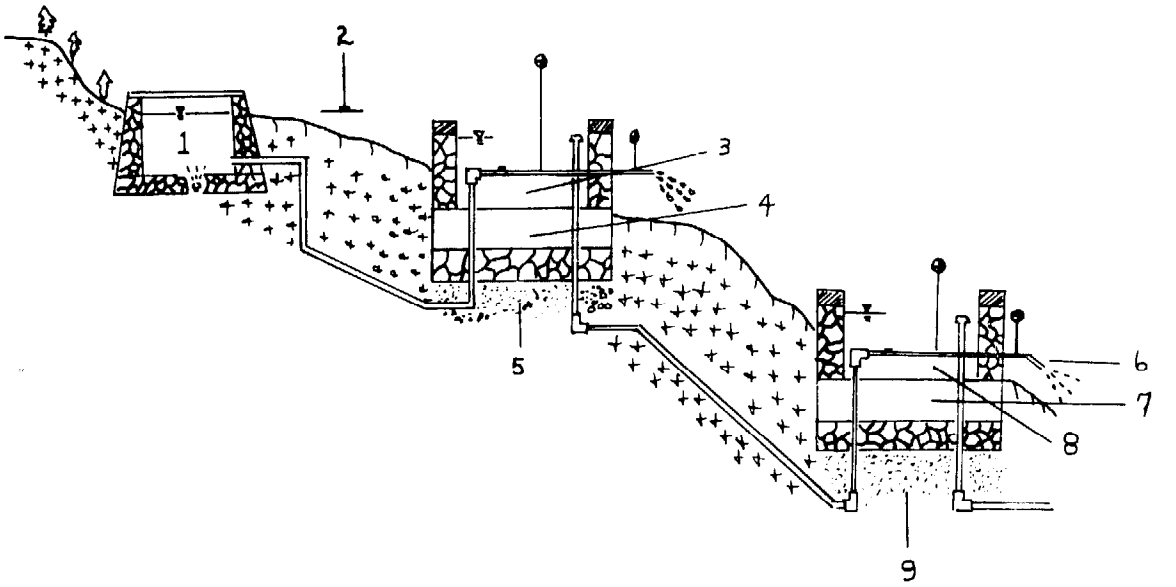

Fig. 7. Transmission of spring water (1, source enclosure; 2, 7.5 m; 3, pure-water tank; 4, concrete; 5, sand; 6, tap; 7, concrete; 8, pure-water tank; and 9, sand layer).

In the mountainous areas of Fujian and Guangdong provinces, spring water is abundant and does not need treatment. Also, it is easily transported by gravity to the community — a cheap and convenient water supply. The pipeline may be bamboo, concrete, porcelain, clay, or plastic.

If bamboo is used, it should have its "skin" taken off, the nodes pierced with a sharp tool and scraped, and then it should be thoroughly cleaned several times in water so that the water piped through it doesn't acquire an odour. Burying the bamboo pipeline will make it last longer; a lifespan of 2–3 years is normal. Sections of either concrete or porcelain pipelines should be joined with a mortar of cement : sand (ratio 1 : 2). If the joints do not seal well, sodium silicate or potassium silicate should be added to the mortar.

Spring water for drinking purposes should be

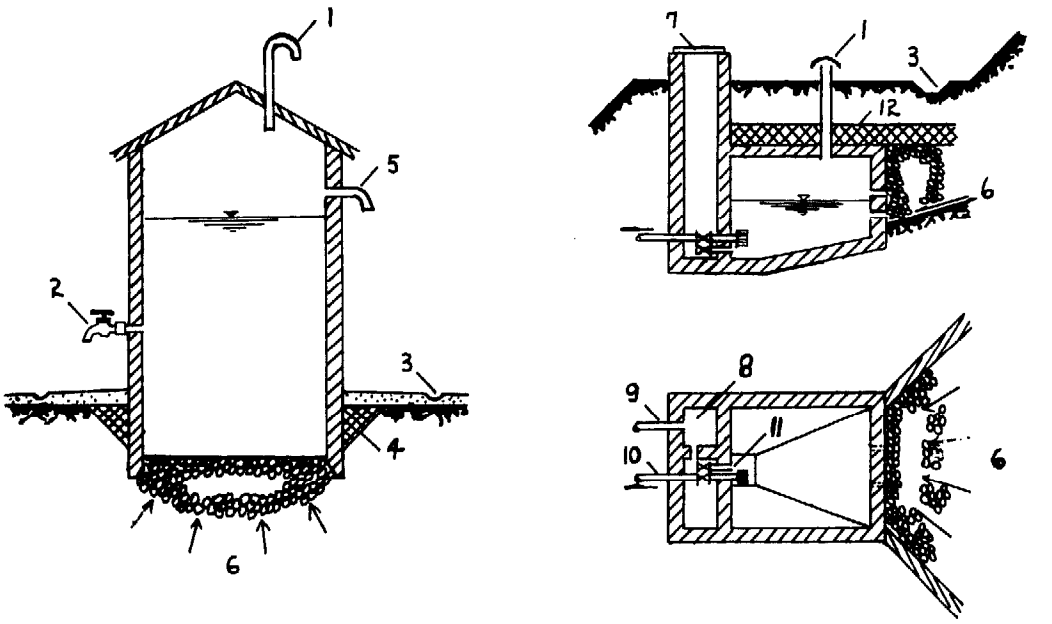

Fig. 8. Spring house (1, vent; 2, tap; 3, ditch; 4, soil filler to strengthen the structure; 5, overflow; 6, spring water; 7, cover; 8, settled sludge compartment; 9, sludge discharge; 10, supply pipeline; 11, discharge pipe for tank cleaning; and 12, clay).

far from pollution sources but near enough to users to be convenient. The discharge point of a spring can only be found by site investigation and visits. Long-time residents are the best experts on how and where to look for a spring.

Most communities in mountainous areas are small and scattered, so the piping structure should be simple, low cost, and convenient. A "spring house" (Fig. 8) is sometimes desired, and it can be built with local materials, near the point of use. Bricks, blocks of stone, and concrete are the common building materials.

The steps to collect water and protect it from pollution are to:

- Install a watertight cover with a vent that opens downward and with a screen that prevents insects from entering;
- Design all entrances so that pollution is minimized; for example, an entrance should not be too close to the ground;
- Ensure walls are impervious; clay should be used as a seal on the outside of the wall to a thickness of 0.3–0.5 m;
- Construct a slanted, impervious apron around the house to prevent polluted water from seeping in;
- Build a "spring house," which is a sealed enclosure, on impervious bedrock; the site is important for maximum water collection; and
- If water is to be taken directly from the spring house, provide a tap or a public bucket.

The Hondi production team in Fujian province uses a spring house to collect its water. The water is then transmitted through 450 m of pipe (a shortened version in Fig. 9), the last 50 m of which is porcelain with an 80-mm diameter, into a village storage tank, built of hewn-stone blocks, with a capacity of 12 m^3. Four taps have been installed in two sides of the tank. A lever valve permits a large volume of water to be drawn in just a few seconds. Bathroom and laundry facilities are located next to the tank.

The Qile production team in Guangdong province also uses a spring house but uses bamboo to transmit the water to the village (Fig. 10). The junctions between sections of bamboo were sealed with tar and reinforced with cement mortar on the outside. The pipeline was buried but marked with stakes for ease in maintenance.

Groundwater Collection

Structures for groundwater collection depend on the depth and thickness of the aquifer, on hydrologic conditions, and on the quantity of water required. Collection can be divided into two categories: drilled, dug wells, and infiltration galleries (Table 3). In rural areas with scattered populations, other well types — built of bamboo or with a spring house — are used for groundwater collection.

Hydrogeologic conditions generally determine where a groundwater collection facility should be installed. It should be sited where water is abundant and as near as possible to the major users. Other factors, e.g., the capital available for engineering and construction; people and means available for operation, management, and maintenance; should also be considered. Furthermore, the possibility of contamination should be taken into account, and the replenishing source and its path of flow should be estimated. Sources for domestic and drinking-water supply should be located upriver from towns, cities, inhabited areas, and industrial areas.

The Bamboo-Built Well

A bamboo well uses the simplest equipment for collecting subsurface percolating water and shallow groundwater. In the Shanghai suburban area, where the groundwater table is high (usually less than 1 m below ground surface), the bamboo well is used for single-family water supply (Fig. 11 and 12). It is inexpensive, easy to make, and the material (bamboo) is available everywhere. A bamboo-built well is usually installed indoors (kitchen) to minimize the possibility of contamination and to maximize the life of the well.

Kitchen Well

The kitchen well is another simple structure for drawing subsurface percolating water or shallow groundwater (Fig. 13). It is named for its location in or near the kitchen. The advantages of a kitchen well are that it is inexpensive and easy to build, usually only 3 m deep and requiring no more than 2–3 work days. The materials needed for construction are 300–400 bricks and a short section of concrete pipe with an internal diameter of 400 mm; the total cost is only 20–50 yuan. Because the kitchen well is installed in individual houses, it is convenient to use and maintain and is little susceptible — if at all — to contamination during seasons when fertilizer is used in fields.

The minimum space between the well and cattle pens or latrines is 5 m. If the sanitary conditions in the kitchen are poor, strict rearrangement of connections and disposal is required before the well is built.

Before construction of the well, the building materials should be washed. After construction, the first few draws of water should be discarded;

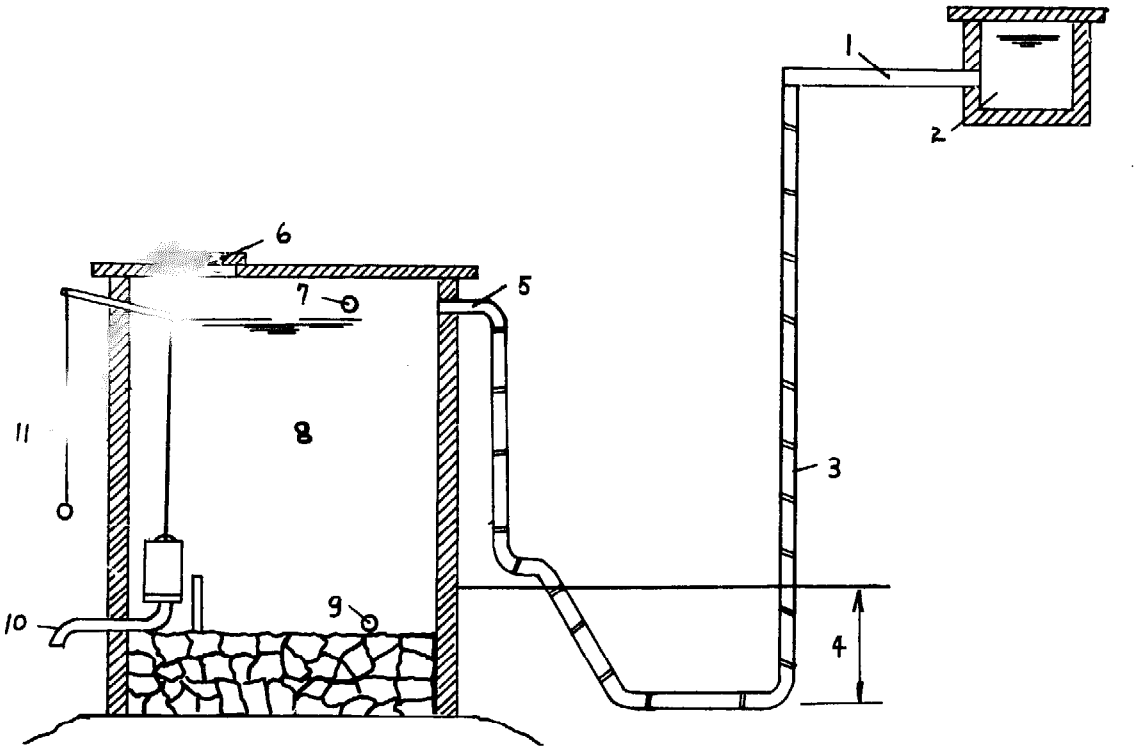

Fig. 9. Diagram of Hondi production team's spring water system (1, triangular channel; 2, spring water; 3, porcelain pipe; 4, buried portion of pipe 1 m underground; 5, inlet; 6, access for repairs, adjustments, etc.; 7, overflow; 8, storage tank; 9, pipeline to supply; 10, outlet; and 11, pull that releases valve for water discharge).

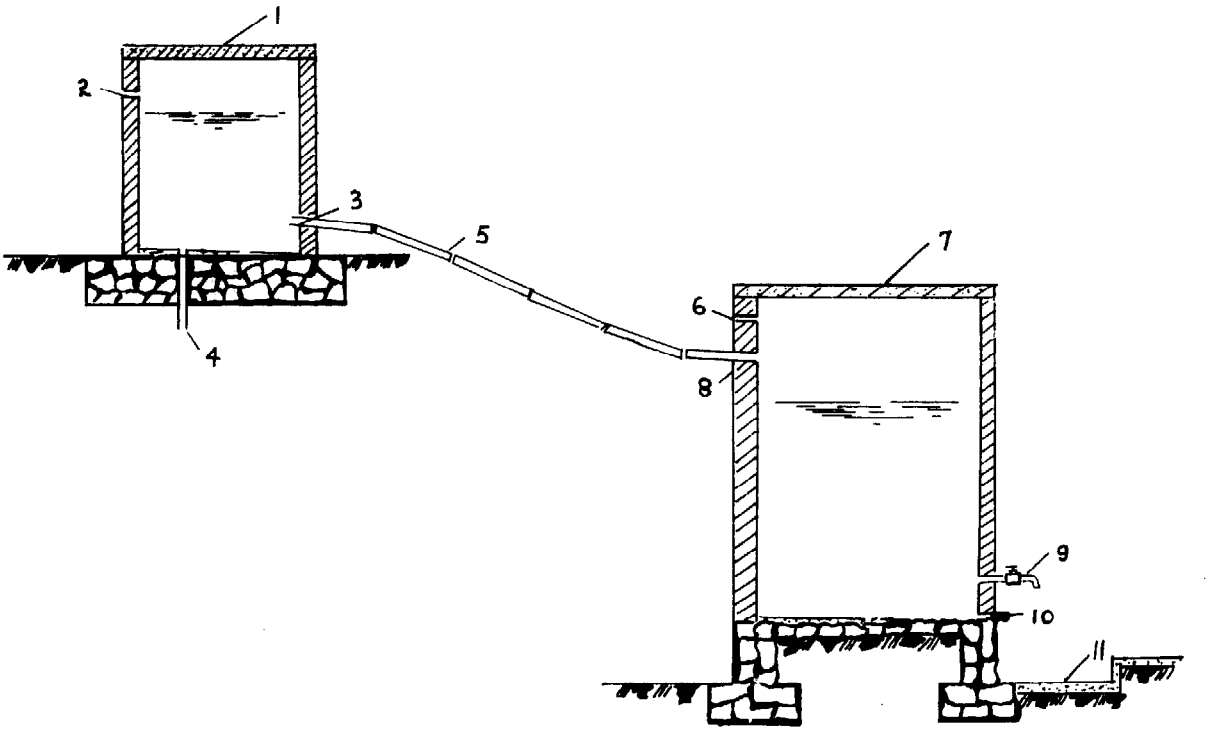

Fig. 10. Diagram of the Qile production team's spring water transmission (1, source-protecting tank; 2, overflow; 3, outlet; 4, spring-water inlet; 5, bamboo pipeline; 6, overflow; 7, storage tank; 8, inlet; 9, tap; 10, sludge discharge; and 11, ditch).

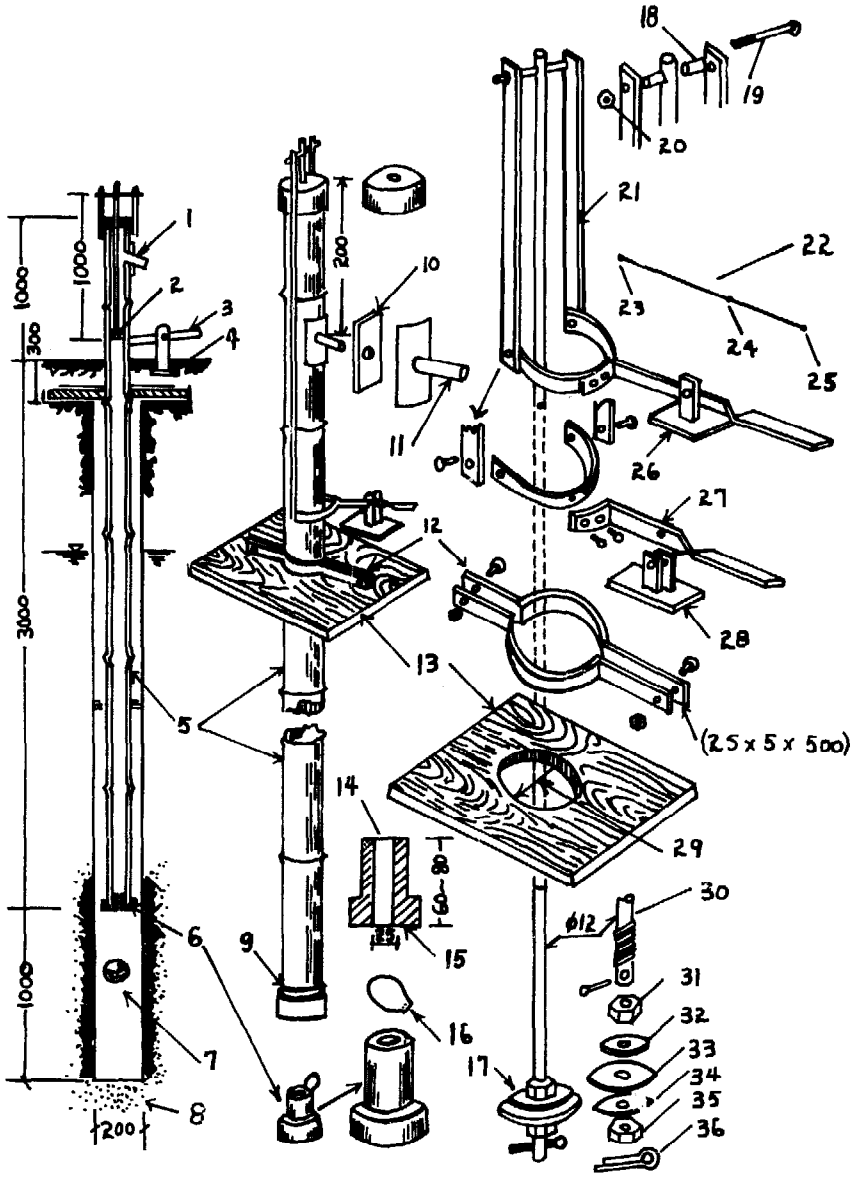

Fig. 11. Bamboo-built well (1, steel tap; 2, piston; 3, pedal; 4, supporting plate; 5, bamboo; 6, unidirectional valve; 7, water storage; 8, sand layer; 9, galvanized wire; 10, rubber gasket; 11, 30-mm-diameter steel tap; 12, fitted frame; 13, wooden plate; 14, hole; 15, unidirectional valve; 16, rubber piston cover; 17, piston; 18, 10-mm-diameter jacket; 19, long bolt; 20, nut and retainer; 21, link: 20 × 3 mm steel plate, length: 900–1000 mm; 22, lever; 23, loading; 24, supporting joint; 25, force; 26, supporting plate; 27, flat steel bracket for pedal, 30 × 5 × 200 mm; 28, steel plate; 29, diameter decided by the external diameter of bamboo pipe; 30, lever; 31, nut; 32, retainer; 33, rubber washer; 34, retainer; 35, nut; and 36, pin 3 × 20 mm).

then the water can be used. Drilling more deeply into the ground produces more and better water. The diameter of the body of the well, especially at the bottom, can be reduced as a cost-cutting measure.

The Sealed, Dug Well

The sealed, dug well prevents pollution or contamination from the use of buckets. Of the many designs for this type of well, the most frequently used are the draw well with hand pump (Fig. 14), draw well with waterwheel (Fig. 15), and draw well with windlass (Fig. 16). For the first two, the water surface should not be more than 5–6 m underground, or drawing water will be difficult. If the hand pump is difficult to use, it can also be modified so that the piston of the pump is under water. This modification causes the piston to push the water up rather than using a

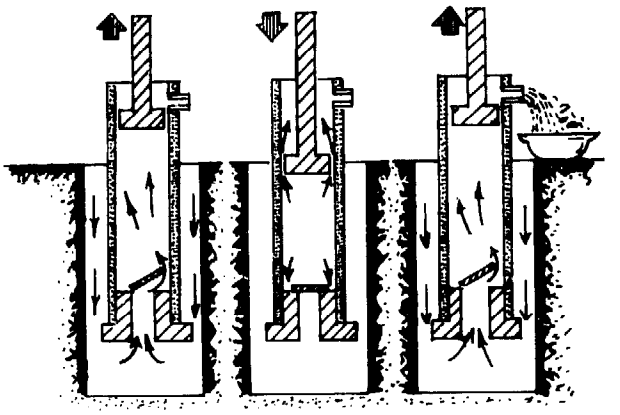

Fig. 12. The bamboo-built well in operation.

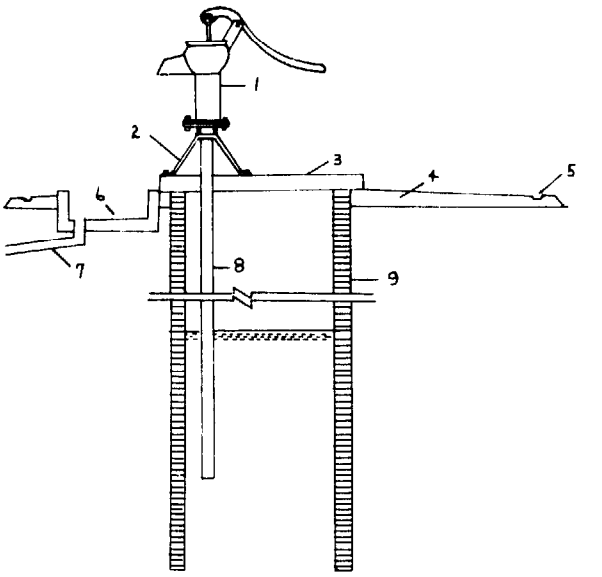

Fig. 14. Draw well with hand pump (1, hand pump; 2, supporting frame; 3, cover; 4, impervious apron; 5, ditch; 6, position for bucket; 7, ditch; 8, intake pipe; and 9, seal).

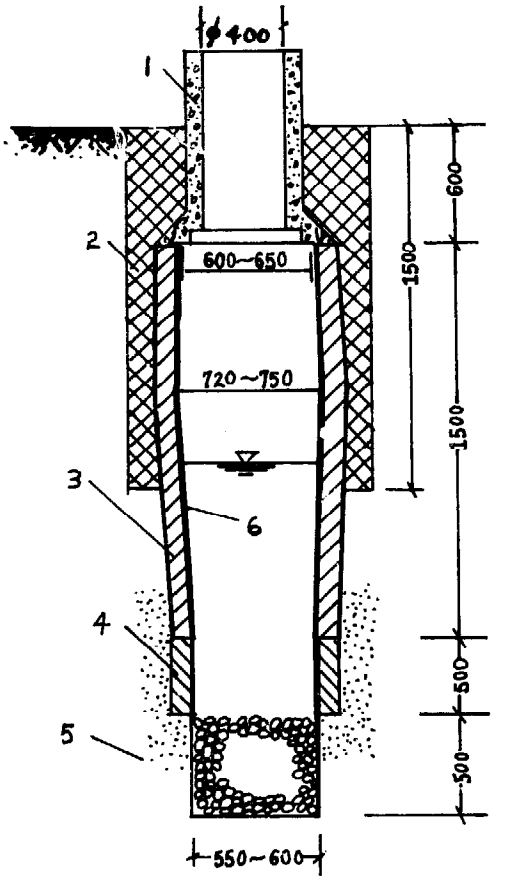

Fig. 13. Cross section of the kitchen well (1, cement pipe; 2, clay stabilization; 3, brick wall sealed by cement; 4, brick without cement; 5, sand; and 6, polished cement mortar).

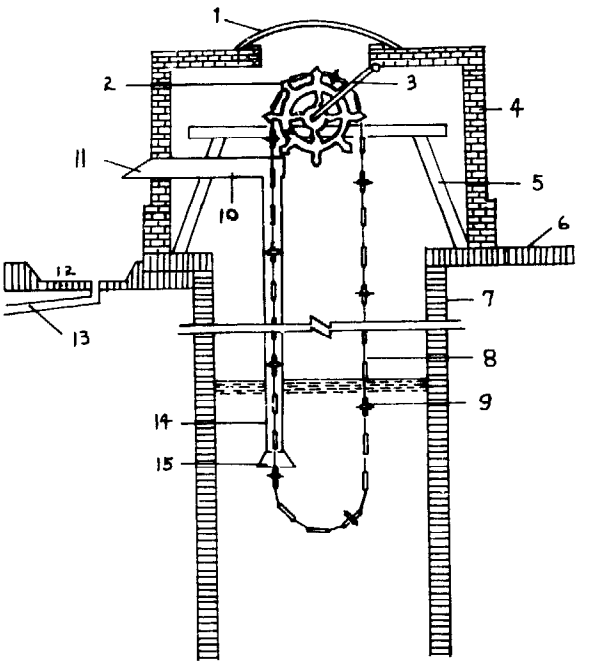

Fig. 15. Draw well with waterwheel (1, entrance; 2, wheel; 3, handle [for turning]; 4, tight seal; 5, frame; 6, impervious apron; 7, well seal; 8, iron chain; 9, leather washer; 10, trough; 11, outlet; 12, position for bucket; 13, ditch; 14, intake pipe; and 15, bell).

Table 3. Groundwater collection technologies.

Category	Scale	Well depth	Hydrogeologic conditions: Aquifer depth	Aquifer thickness	Characteristic	Production
Drilled well	Diameter of well 50–1000 mm but usually 150–160 mm.	20–1000 m, but usually less than 300 m	Dependent on pumping capacity, no maximum	Usually thicker than 5 m, or a multiple water-bearing stratum	Suitable for sand, gravel, or pebble stratum	Generally 500–6000 m^3/day for a single well; maximum 20 000–30 000 m^3/day
Dug well	Well diameter, 2–12 m but usually 4–8 m	Less than 30 m, usually 6–20 m	Very shallow, usually less than 12 m	Generally 5–20 m	In-flow and percolation are good; percolation index should be higher than 20 m/day; suitable for sand or gravel stratum	Generally 500–10 000 m^3/day; maximum 20 000–30 000 m^3/day
Infiltration gallery	Pipe diameter 0.45–1.5 m but usually 0.6–1.0 m	Greater than 10 m but conventionally 4–7 m	Very shallow, usually less than 2 m	Very thin, usually 4–6 m	In-flow and percolation are good; suitable for the middle sized or coarse sand stratum, or gravel, pebble stratum	Generally 15–30 m^3/day-m; maximum 50–100 m^3/day-m

vacuum. If the well is deep, the windlass should be used.

A windlass carries the water up in a round-bottomed bucket and lets it out through a trough. Some designs use a large stone as an anchor at the well bottom and two lengths of wire extending from the stone to the top as a track. The bucket travels between wires through two holes on both sides of the bucket and can thus move steadily up or down. A stophook is placed at the top, which causes the bucket, once it reaches the top, to tilt and pour the water down the trough.

A tight seal for a well with a windlass or waterwheel can be made of wood, brick, or concrete. Only the end of the trough and handle are outside the well. Improvements for existing wells include cleaning the bottom by withdrawing the slurry and introducing a layer of sand, moving cattle pens, and filling in latrines and rubbish or manure pits within 30 m. Also, the walls of the well should be sealed and an impervious apron built, 20–30 cm aboveground. The apron should be sloped, and a ditch should be made at the outside edge so that no polluted water flows into the well. All these measures are essential for well protection.

Small-Mouthed Well

The traditional well has a big opening and shaft, which are difficult and costly to repair or rebuild; it is easily contaminated and hard to protect; therefore, a small-mouthed well is recommended where the water table is high enough (Fig. 17).

The small-mouthed well has a shaft 20–25 cm in diameter, the opening is even smaller, with a diameter of 15–20 cm. The well shaft can be made of bamboo, earthenware pipe, concrete pipe — whatever is locally available. A layer of pebbles or sand should be laid on the bottom of the well, and it should be cleaned periodically. A sloping impervious apron should also be built

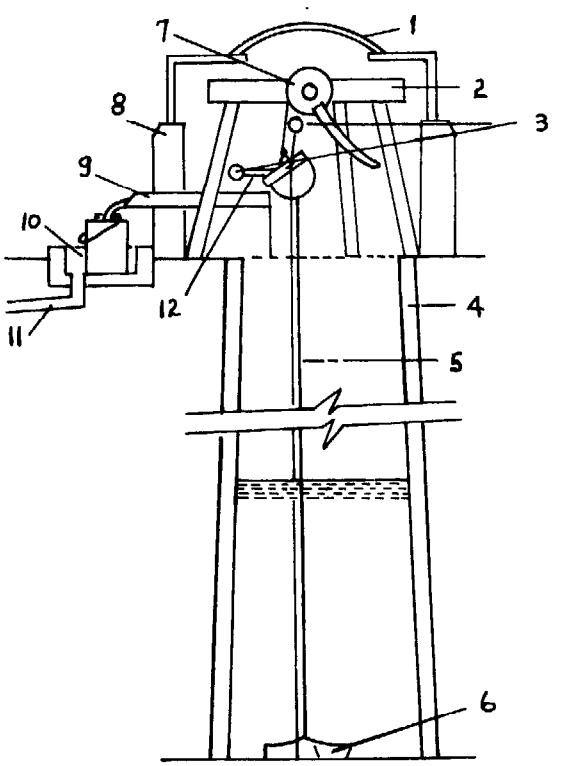

Fig. 16. Draw well with windlass (1, entrance; 2, frame; 3, fixed shaft; 4, seal; 5, track; 6, fixed stand; 7, windlass; 8, tight seal; 9, trough; 10, position for bucket; 11, ditch; and 12, stop hook).

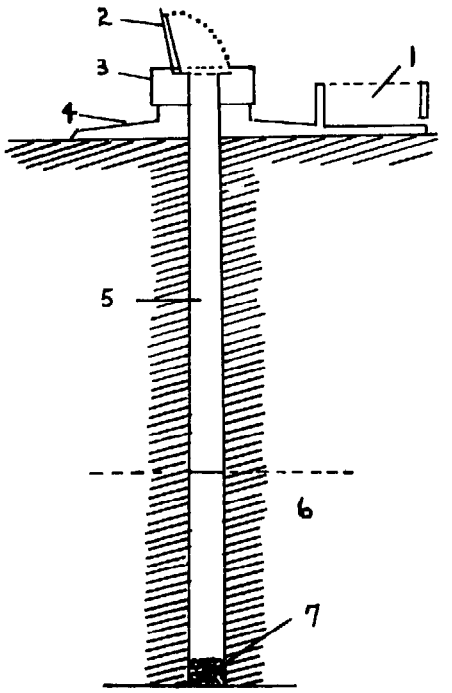

Fig. 17. Cross section of a small-mouthed well (1, tank; 2, cover; 3, lip; 4, impervious apron; 5, well body; 6, water-bearing layer; and 7, pebbles or sand).

around it. A curved, iron spade can be used to drill a small-mouthed well. The spade should be approximately 30 cm long (Fig. 18) with teeth on both sides. The shaft handle is a horizontal rod, fixed to the apparatus with cord; its length will depend on the height of the water table but is usually about 7 m. The other end of the cord can be tied to the spade to prevent it from dropping into the well.

A person holds the spade in position, pushing downward on the handle, while two other people push the horizontal rod to make the shaft rotate. At the same time, water is added to the hole to make some of the soil into slurry, which will cause the soil to stick to the spade and come out easily when the spade is withdrawn. The soil is removed in this way after the shaft is rotated several times. When the groundwater appears, the hole is drilled another 2 m deep; then the water is pumped out until it becomes clear.

The water-intake device for a small-mouthed well can be a long bucket with a piston valve at the bottom (Fig. 19). Water enters the bucket through the valve and is poured out when the string is pulled. Alternatively, a hand pump can be installed on the well.

The advantages of a small-mouthed well are that it is easy to construct and maintain. It can be installed in the yard or kitchen and is easy to use and protect.

The Driven Well

The driven well (Fig. 20 and 21) is suitable where the water table is high, the quantity of water is abundant and sand layers do not contain large rocks that could obstruct the pipe as it is being driven down. Bamboo or steel pipes can be used for the driving pipe. A steel pipe should be 2.5–5 cm in diameter; bamboo should be young stems (as old ones break easily), 7–8 m long, with a diameter of 1.5–2.0 cm (measured at the base). Both steel and bamboo pipes should be pierced 1 m from the lower end with 30–40 fine holes (0.3–0.5 cm in diameter) for water intake; these holes should be 3–4 rows, 6–10 holes per row. When bamboo is used, all the nodes should be broken except the one at the bottom. The slender part of the bamboo should point downward with wire wrapped around the end to prevent breakage. If steel pipe is used, the lower end should be made into a diagonal point.

Before the pipe is driven into the ground, a hole with a diameter of 30 cm should be drilled as deep as possible, then water poured in to soften the soil. Two or three people will be needed to insert the steel pipe perpendicular to the ground surface. A

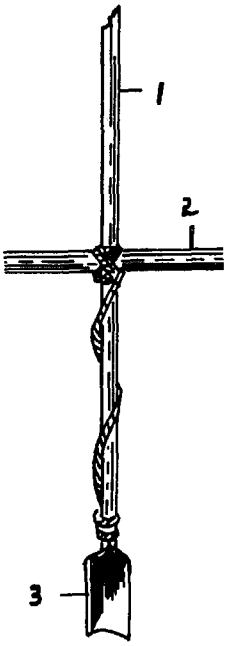

Fig. 18. Long-handled spade used in small-mouthed well (1, handle; 2, horizontal rod; 3, spade).

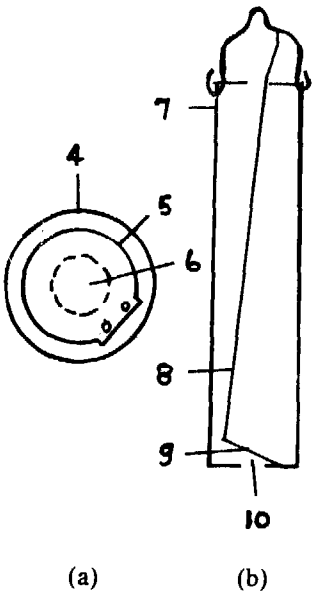

Fig. 19. (a) piston valve (seen from below) (4, bottom of bucket; 5, rubber valve; 6, water intake or outlet) and (b) bucket with piston valve (7, water-intake bucket; 8, string; 9, rubber valve; and 10, water intake or outlet).

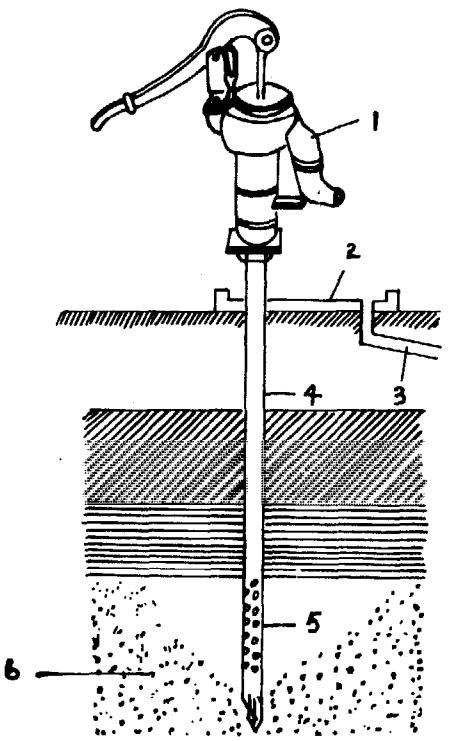

Fig. 20. Steel-pipe driven well (1, hand pump; 2, groove; 3, ditch; 4, steel pipe; 5, water-intake hole; and 6, water-bearing layer).

horizontal rod can be attached (as for the spade Fig. 18) to rotate it when the resistance becomes great.

One person should hold the pipe while it is being inserted to keep it straight and to assess the condition of the soil. Experience shows that if insertion is easy and noiseless, the earth is soft, perhaps loess with a little water in it; if insertion is difficult and the earth sticks to the pipe, it may be clay. If insertion is difficult and produces a scratching sound, the soil is probably sand. The louder the sound, the larger the sand particles, and the more the water contained in the layer. If there is a gravel stratum, the water should be plentiful, but the shaft may wobble and should be held firmly while being driven in. After the pipe is driven into the ground to an appropriate depth, 0.5 m of pipe should be above the ground surface for the hand pump installation. Water should be withdrawn until it comes out clear. If bamboo is used, a steel pipe should first be used for driving and then be replaced with the bamboo. A hand pump can be homemade with waste steel pipe and sheet. The advantage of a driven well is that it is easy to install and convenient to use.

Riverbed Percolation Well

A riverbed percolation well is a kind of wide-mouthed well, suitable for areas where the riverbed allows good percolation. In the mountains, the water level is usually low during the dry season, sometimes so low that the bed can be seen. A riverbed percolation well is suitable for this hydrologic condition, because it allows water to be collected by a drain beneath the surface of the riverbed by the well.

The site on the riverbed should be stable, with good water that is flowing rapidly. The section of river should be straight, and percolation through the riverbed should be good. The construction material is usually brick, stone rubble, or precast concrete blocks; however, local materials are recommended. The rate at which water enters the well is increased if an inlet is built into the wall of the well. It can be horizontal (Fig. 22a) or inclined (Fig. 22b).

A horizontal inlet is easy to make and is commonly used. It is usually a cylindrical hole with a diameter 100–200 mm; sometimes it is rectangular (100 × 150 to 200 × 250 mm). Inclusion of a galvanized wire screen will prevent loss of filter media.

An inclined inlet is usually circular with a diameter of 50–150 mm (maximum 200 mm).An inclined hole facilitates changing the filter media but is susceptible to blockage. The incline should

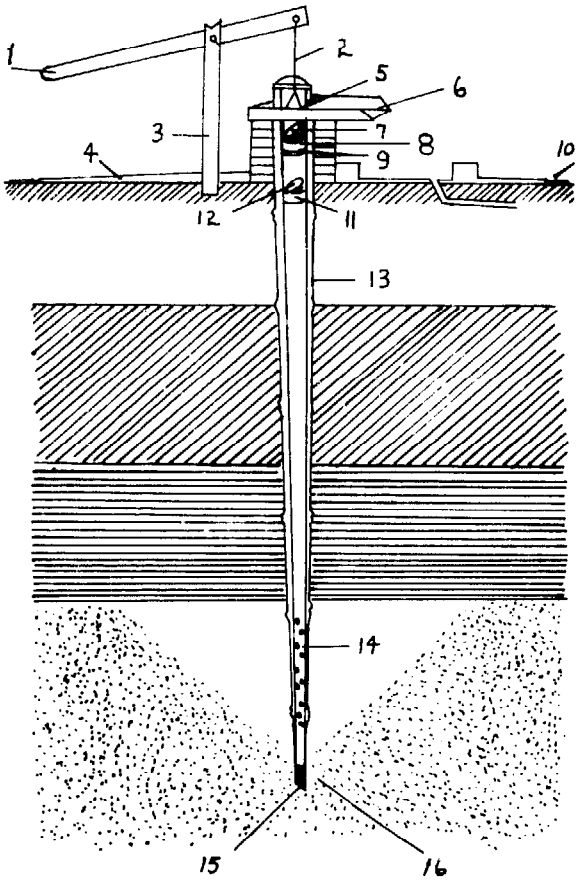

Fig. 21. Bamboo-pipe driven well (1, handle; 2, pull rod; 3, supporting post; 4, impervious apron; 5, outlet; 6, trough; 7, piston valve; 8, piston; 9, rubber gasket; 10, ditch; 11, piston supporter; 12, piston valve; 13, bamboo; 14, water-intake hole; 15, cork; and 16, wire).

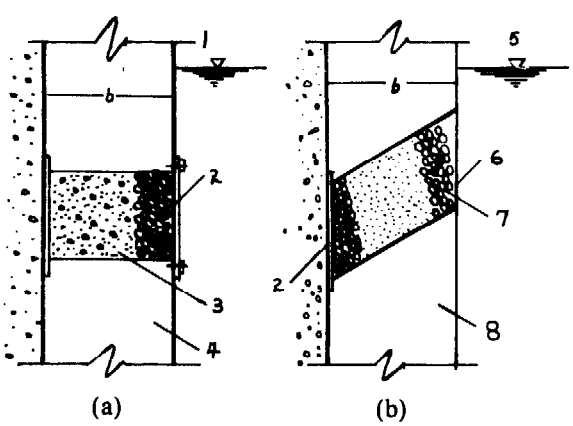

Fig. 22. Inside-view of (a) a horizontal inlet (1, inside the well; 2, galvanized wire screen; 3, filter media — sand, pebbles; and 4, wall seal) and (b) an inclined inlet (5, inside the well; 6, screen, if inlet is less than 500 mm; 7, stone; and 8, wall seal).

not be greater than 45°, and a screen is usually put at both ends. The filter at the bottom is mainly to prevent sand from getting into the well. Usually there are three to four layers, 200–300 mm thick each, with the size of grain increasing from bottom to top. If the grains of sand in the riverbed are large, two layers of filter and a total thickness of 400–600 mm may suffice (Table 4).

On top of the well, a cover with a vent should be fitted. The vent pipe should be 1–2 m higher than the water level during the flood season. An example is a riverbed percolation well in Guangdong province, with an external diameter of 5 m and a depth of 4 m (Fig. 23). The well wall is a precast-concrete ring in two short sections, each 2 m high. The concrete ring was sunk to the required depth by dredging the sand from the bed. At the bottom, a 0.4-m layer of stones was used as a seal. Above that, 2–4 mm of medium grain sand and 4–8 mm of fine sand were placed, topped by a filter of three layers, 200 mm each, with grain diameters of 10–20, 20–40, and 40–80 mm respectively.

This well started to provide water in 1969 with an output of 1500 m^3/day and did not stop until 1975. The sand in the well was then cleaned and production resumed.

Deep Well

In the suburban areas of Shanghai, some communes use deep groundwater for their water supply. This water meets the drinking water standards and treatment is unnecessary. These communes (Caoxing, Zhangjiang, and Zhuanqiao) each use a system with one well and one storage tower. Well depth is more than 200 m, and output

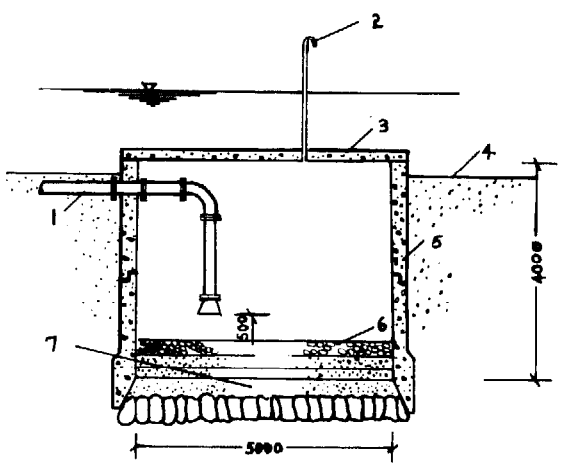

Fig. 23. Cross section of a riverbed percolation well (1, water-intake pipe; 2, vent, 50 mm in diameter; 3, concrete cover; 4, riverbed; 5, precast concrete ring; 6, pebbles; and 7, sand).

Table 4. Grain diameter and layer thickness for bottom filter.

Riverbed material	First layer		Second layer		Third layer	
	Grain diameter (mm)	Thickness (mm)	Grain diameter (mm)	Thickness (mm)	Grain diameter (mm)	Thickness (mm)
Medium-grain sand	2–4	300	10–20	200	50–80	200
Fine sand	4–8	200	20–30	200	60–100	200
Gravel	15–30	200	50–150	200	–	–

is 60–80 m^3/h. The effective volume of the storage tank is 50 m^3, at 25 m above the ground. The waterworks provide water continuously. When the demand is less than pumping-station capacity, excess water is stored in the tower; when the demand is greater than capacity, the storage tower and pump together supply the water required. When the consumption is low at night, the pumping station stops working and the storage tower alone supplies the community.

Infiltration Galleries

An infiltration gallery is a horizontal water-collecting facility laid in a riverbed (or riverbank or island in the river). Water is collected through

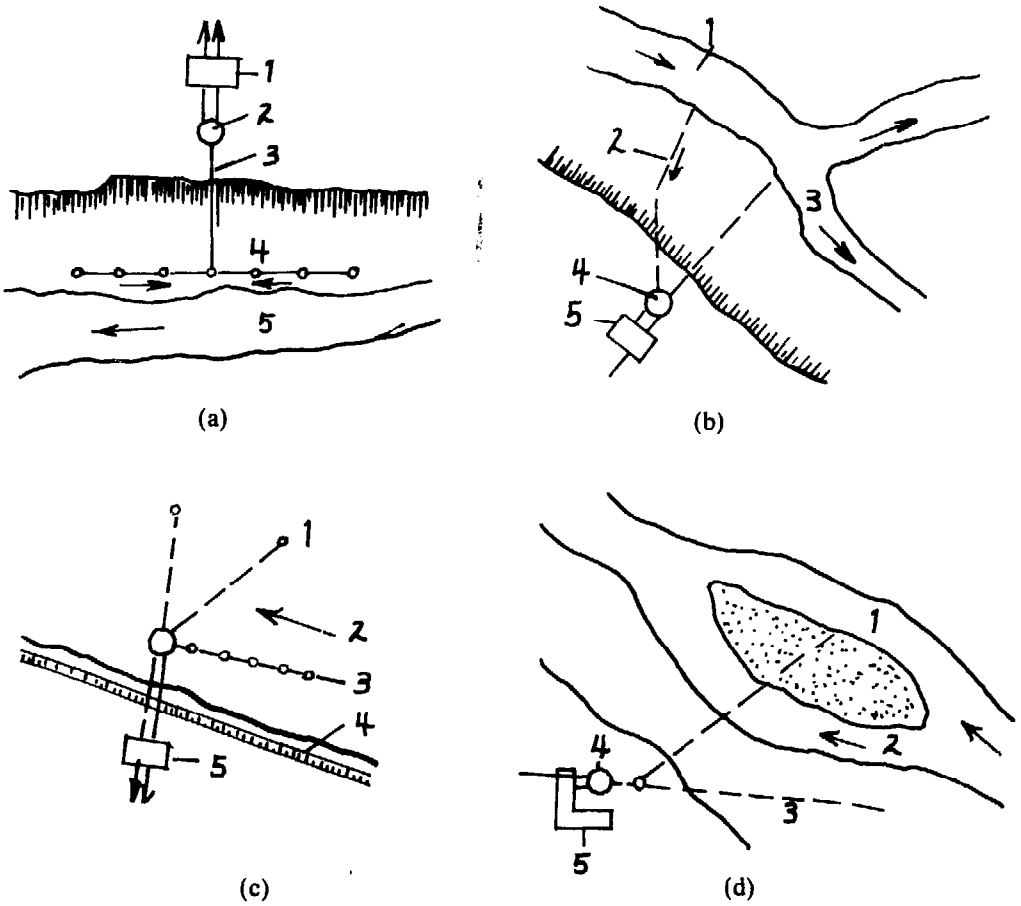

Fig. 24. Infiltration galleries (a) parallel to the river, beneath the riverbank (1, pumping station; 2, water-collecting tank; 3, pipeline; 4, infiltration galleries; and 5, river); (b) perpendicular to the river, beneath the riverbank (1, river; 2, infiltration galleries; 3, branch stream; 4, water-collecting well; and 5, pumping station); (c) perpendicular to the river, beneath the riverbed (1, older infiltration galleries; 2, river; 3, newer arch-shaped galleries; 4, riverbank ; and 5, pumping station); and (d) parallel and perpendicular to the river, beneath the riverbank (1, river; 2, branch stream; 3, infiltration galleries; 4, water-collecting well; and 5, pumping station).

holes in the gallery or pipe or through gaps between pipe sections.

Infiltration galleries intercept and collect the water below the riverbed. This method of collection is relatively efficient and the resulting volume of water is large. In addition, some purification occurs, although the amount depends on the original tubidity of the raw water. If a structure for artificial filtration is installed, about 70% of the suspended solids, 70–90% of the bacteria, and more than 70% of the *E. coli* can be filtered out. The choice of a site for an infiltration gallery greatly affects the water output. The flow of water should be rapid, with enough force to prevent sediment from settling on the bed. The chosen section of river should be straight with inverted banks, and the site should be as close to the mainstream as possible. The water-bearing layer should be thick with no impervious layers within it. The river should have a stable bed, with relatively clean water and little variation in water level. There are four possible configurations (Fig. 24) for infiltration galleries:

- In the first, the galleries are parallel with the river (or at a slight angle) (Fig. 24a); this is suitable for places where the water-bearing layer is thick and groundwater is abundant. The riverbed should be stable and the water of good quality. This arrangement collects the water filtering into the river and groundwater from the riverbank.
- In the second and third arrangements, the galleries are perpendicular to the river beneath either the riverbank (Fig. 24b) or the riverbed (Fig. 24c). The latter is appropriate when there is a thick water-bearing layer and little water under the bank. The percolation of the bed should be good and groundwater abundant. The galleries are placed beneath the riverbed in areas where the rivers are shallow and iced over during winter or where the water-bearing layer is thin and the percolation is low.
- The combination of parallel and perpendicular galleries (Fig. 24d) suits areas where the groundwater is abundant and the water-bearing layer is thick. This arrangement permits collection of groundwater from both the riverbank and the riverbed as well as percolation water all at the same time.

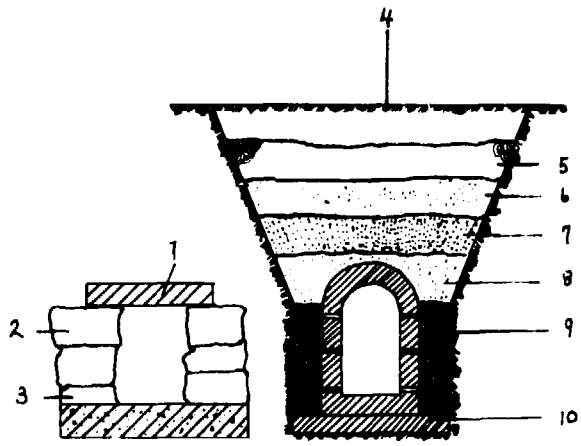

Fig. 25. Materials used in infiltration galleries (1, stone plate; 2, stone blocks; 3, openings, slits, or gaps; 4, surface soil; 5, clay; 6, fine sand; 7, coarse sand; 8, infiltration-sand layer; 9, pebbles; and 10, foundation).

A reinforced concrete pipeline is usually used. If the volume of water is small, steel pipes can also be used. Other locally available materials, such as stone, stone and mortar, or brick (Fig. 25), are also widely used. Sand-filter layers are generally made around the infiltration galleries. The number of layers and their thickness depend on the size of particles in the water, but three to four layers should be sufficient. The total thickness should be 800 mm, with each layer 200–300 mm. The top layer is the thickest but with the finest grain; the layer nearest the galleries should contain grain that is larger than the openings in the gallery piping. There must be no clay, glass, or weathered rock in the layers; therefore, the original sand from the riverbed should be thoroughly washed before being put back as filling.

Chapter 4

Water Treatment

Filtration

Of the many kinds of filters there are two major types based on the filtration rate: slow filters and rapid filters (this publication covers only the former).

Slow filters have a filtration rate of 0.1–0.3 m^3 water volume/m^2 filter area-hour for water below 50 mg/1 turbidity. The inflowing water may be untreated. Water with high turbidity must be pretreated, usually by sedimentation and possibly by coagulation (p. 31).

The disadvantages of a slow filter are its low filtration rate and low capacity; also, it is difficult to clean. Its main advantages are that it removes bacteria very effectively, produces water of high quality, has a simple structure, and can be built with local materials. For these reasons, slow filters are still widely used for treatment in water-supply installations.

The following slow filters are small, simple to operate, and inexpensive. Even though the quality of water produced after treatment with these filters cannot meet national quality standards, there is still value in using them in rural areas in southern China, as they do improve domestic water and, hence, reduce water-related infections.

Pond-Side Filter

The pond-side filter consists of two parts, the filter and the treated water tank. There are three types, depending on the direction of water flow: vertical (Fig. 26), horizontal (Fig. 27), and vertical/horizontal. In the vertical filter, the water flows into the upper part of the filter, through the sand, and out the bottom. In the horizontal filter, water flows through the sand horizontally; as its name implies, the vertical/horizontal filter is a combination of the two. The filter and the treated water tank are connected. Walls can be made of concrete or cemented brick. The bottom of the filter consists of channeled, porous blocks. There are three or four layers of sand, including the foundation layer: the top layer is fine sand (0.3–1 mm diameter), 800–1000 mm deep; the next layer down is coarse sand (1–2 mm), grains 100–150 mm deep; the next is pebbles (2–8 mm), 100–200 mm; and the bottom is stones (8–32 mm), 100–200 mm. The filter tank is 2–3 m high and the total depth of sand layers is 1.2–1.5 m. Thus, above the sand, a space 0.5–1.5 m is available for inflowing-water storage.

Slow pond-side filters are widely used in rural areas of Nanning prefecture, Guangxi province, Guangdong province, and Hebei province.

The filtration rate is based on 0.1–0.3 m/h flow rate. Based on the current water consumption in rural areas, 40–80 1/person-day, every m^2 of filter will be able to supply water to 60–120 people, provided the waterworks runs 24 hours a day. Because demand peaks at certain times, storage should be approximately 50% of the total volume of daily consumption.

The data obtained by the Department of Health and Epidemic Prevention in Fusui county from seven pond-side filters for production brigades indicate the effectiveness of the system: the degree of coloration was reduced from an average 24.5 to 9.8 (60%); the turbidity (mg/1) from 88.8 to 7.7 (91.2%); the oxygen demand (mg/1) from 10.53 to 3.73 (64%); and the total bacterial count/ml from 4486 to 246 (96.3%).

Tests made by the Department of Health and Epidemic Prevention of Guangdong province also indicated that using the filter significantly reduced colour, turbidity, iron (Fe) and magnesium (Mg) content, total bacterial count, and *E. coli* count. Reductions in turbidity and bacterial count were 93.91% and 90.33% respectively.

In areas where ponds are used as the source for water supply, measures to protect the water include prohibiting (1) the washing of clothes and other items in the pond and (2) the use of private buckets to take water directly from the storage tank, which should be tightly covered. When algal growth occurs, particularly in summer, the addition of bleaching powder may be necessary. Also,

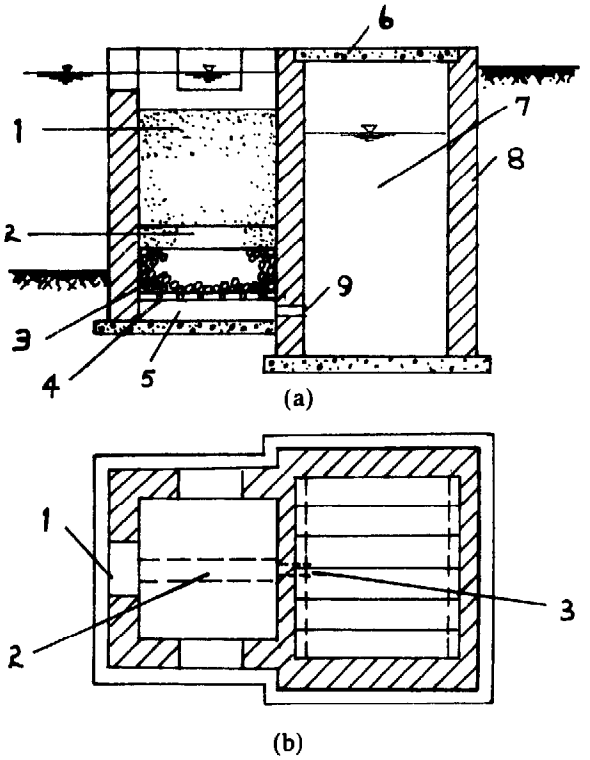

Fig. 26. A vertical pond-side filter: (a) the cross section (1, fine sand; 2, coarse sand; 3, pebbles or stones; 4, channeled, porous stone; 5, main drain; 6, cover; 7, storage tank; 8, wall; and 9, drain) and (b) the plan (1, influent; 2, main drain; and 3, drain).

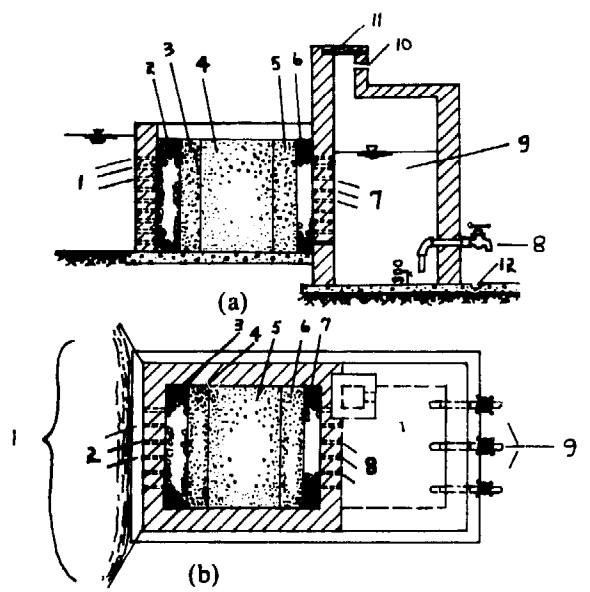

Fig. 27. A horizontal pond-side filter: (a) the cross section (1, drain; 2, pebbles or stones; 3, coarse sand; 4, fine sand; 5, coarse sand; 6, pebbles or stones; 7, drain; 8, tap; 9, storage tank; 10, vent; and 11, cover) and (b) the plan (1, source; 2, drain; 3, pebbles or stones; 4, coarse sand; 5, fine sand; 6, coarse sand; 7, pebbles or stones; 8, drain; and 9, taps).

fish may be put into the pond as a monitor of water quality and harmful contamination.

Depending on the quality of the raw water, periodic cleaning of the 100–200 mm fine sand on the filter surface is needed. The sand is withdrawn and washed about every 1–2 months. The frequency of this washing is determined by the turbidity of the raw water. When the difference between inflow and outflow (head loss) is greater than 1 m or when the treated water is unsatisfactory, washing is necessary. All the sand should be washed every 1–2 years.

Sources of water are selected for their convenience for the users, but a more important criterion is that the raw water be unpolluted and of good quality. Thus, there should be no latrines, manure piles, or grazing areas nearby. Also, experience has shown that using private buckets to take water directly from a water source seriously pollutes the water; effective protection is provided by the installation of hand pumps or taps. In Guangxi, the data from 11 storage tanks showed that the total bacterial count was reduced by 96.2% when hand pumps or taps were used, whereas only 54% reduction was achieved when private buckets were used. Ventilating the storage tank reduces any odours in the water.

Nabu production brigade in Guangxi province has a population of 535 116 households. The brigade's water-treatment installation is a combined horizontal/vertical pond-side filter (Fig. 28). The tanks are stone. The primary (horizontal) filter is 1.5 m wide, and the secondary (vertical) filter is 2.0 m × 2.5 m. There are eight taps at the bottom of the storage tank. The raw water has 25.0° coloration, 100 mg/l turbidity, 5.79 mg/l oxygen demand, and a total bacterial count of 4000/ml. Using the pond-side filtration system, the brigade improves those figures to 10.0°, 6 mg/l, 5.03 mg/l, and 120 bacteria/ml respectively.

In another commune in Guangxi province, a horizontal filter was built out of bricks with the filter in front and the storage tank behind. The taps were placed at the front end of the storage tank. Elsewhere, long, tunnel filters have been constructed of stone and filled with sand. They have functioned well, but the shape has made it difficult to wash the sand.

Washing the sand is labour-intensive and time-consuming. Usually, 5–7 work days are required for a single washing, although this can be reduced by use of a backwash tank (Fig. 29). The steps in using a backwash facility are to close the drain between the storage tank and the filter; open the valve to let the wash water come up through the filter;

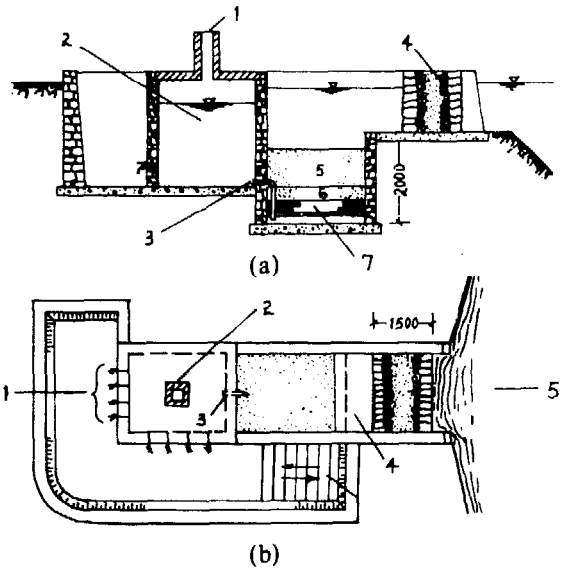

Fig. 28. Horizontal/vertical pond-side filter used by Nabu production brigade: (a) the cross section (1, vent; 2, storage tank; 3, drain; 4, primary filtration; 5, fine sand; 6, coarse sand; and 7, stones or pebbles); and (b) the plan (1, taps; 2, vent; 3, steps; 4, bridge; and 5, source).

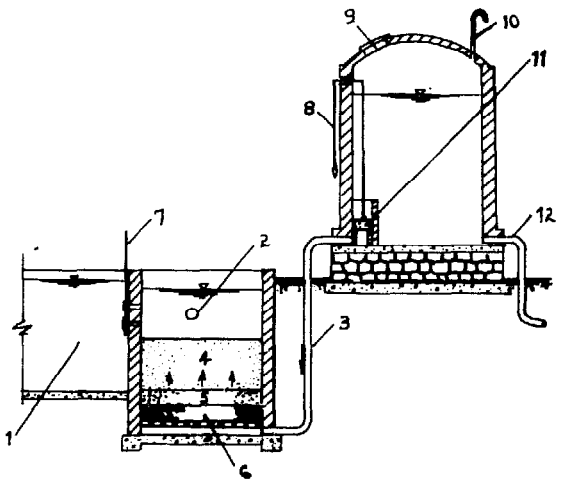

Fig. 29. Simple backwash for slow sand filter (1, sedimentation tank; 2, wash-water outlet; 3, backwash-water inlet pipe; 4, fine sand; 5, coarse sand; 6, pebbles; 7, inlet control sluice board; 8, hand pull; 9, maintenance access; 10, vent; 11, valve; and 12, distribution pipeline).

rake the sand surface to a depth of 200–500 mm; as the wash water becomes clean, stop the backwashing; and, finally, open the drain again for filtering.

The backwash water-storage tank is usually placed 3–4 m higher than the filter system on the bank of the pond. It should have a diameter of 3–4 m, a depth of 2.5–3.5 m, one or two ventilation holes, and a 0.5 m-diameter maintenance access. When backwashing is in progress, the water depth in the backwash tank should be kept at least 1 m deep, and the connecting pipe should be large enough to guarantee satisfactory backwashing. The wash-water outlet should be at least 0.5 m above the sand surface so that the risk of sand losses is minimized.

Riverbank Filter Wells

People living near rivers have designed riverbank filter wells (Fig. 30) to improve the water quality. This type of well has proved to be both economic and efficient. It consists of a pure-water basin and a filter and is constructed near the bank of a river; its method of operation is similar to that of the pond-side filter. A substantial number of such wells have been built in Guangdong province.

The site for a riverbank filter should be an area where the water is deep and swift-flowing. If the well is constructed in a "dead corner," weeds and other suspended solids will enter the filter. The site should be accessible: within 50 m of the area served. The soil should be suitable for construction, and no latrines, stables, excreta storage, or compost heaps should be within 30 m of the site.

The well has a surface area 1.0–1.2 × 1.0 m and a depth of 1.6–2 m. There are one to three inlet holes in the upper part of the filter, and the bottom of the filter has one to three drains, 15–30 mm in diameter, connecting it with the pure-water storage. Sand for filtration is often taken from the river. The three filter layers (including a supporting layer) are the lower layer, 100–200 mm thick, composed of pebbles (grains of 10–30 mm in diameter); the middle layer, 150–200 mm

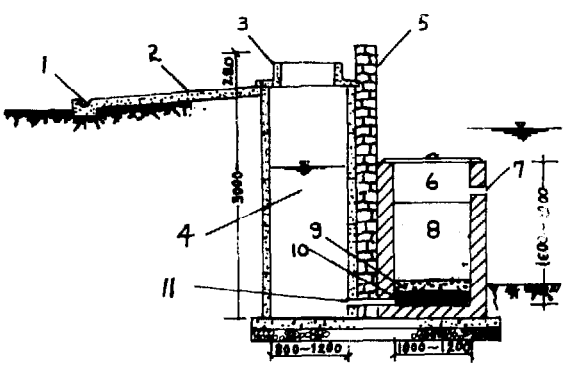

Fig. 30. Riverbank filtering well (1, drain; 2, impervious apron; 3, wall; 4, storage well; 5, protecting wall; 6, filter tank; 7, inlet; 8, fine sand; 9, coarse sand; 10, pebbles; and 11, drain).

thick, of coarse sand (3–10 mm in diameter); and the upper layer, 800–1000 mm thick of fine sand (0.2–2.0 mm in diameter). The diameter of the pure-water storage well reflects the number of users; a 0.8–1.2 m-diameter well can supply 100–200 people (approximately 20–40 households). The well is usually 3 m deep.

Both the pure-water well and the filter can be built of brick or stone; silicate bricks of dimensions 900 × 200 × 380 mm are also used. The materials cost roughly 200 yuan[1].

Water treated by riverbank filtration wells is palatable, without taste or odour. Although it may not conform to national water quality standards, it is a vast improvement on the raw water. According to the statistics provided by Tanbai commune in Guangdong province, where a filtering well was built in 1973, the number of cases of intestinal-tract infections declined by 41.67% from the figures in 1971.

Maintenance procedures for riverbank filter wells are similar to those for pond-side filters. The well should be covered and the bucket used for water extraction should be public property. Regulations should be established to avoid contamination. The surface sand (top layer) should be washed every 2 weeks; the entire filter media and the bottom of the storage well should be washed every 3–5 months; washing is simplest when the water level in the river is low.

Coagulation

A simple process of water purification is sedimentation in which solids settle to the bottom of a container holding turbid water. However, to remove all or even most of the solids, the process takes a very long time. One method to speed up the operation is chemical coagulation of the solids.

The basic concept is to use chemicals (coagulants) to create the conditions for particle conjunction or flocculation. Alum — $Al_2(SO_4)_3 \cdot 18H_2O$ — is the most common coagulant used in China; it reacts in the water to form an aluminum-hydroxide floc. According to the experience of the Shanghai waterworks with alum, the optimum pH for reduction of colour is 4.5–5 and for reduction of turbidity, 6–8; optimum water output is obtained at pH 6.5–7.5. Ferric chloride ($FeCl_3 \cdot 6H_2O$) is also used as a coagulant. It is effective but may corrode metal and concrete. Ferrous sulfate ($FeSO_4 \cdot 7H_2O$) is also used.

[1]Editor's note: costs cannot easily be translated into other currencies because wages in China are low but are supplemented by various allowances and social services.

Chemicals can be fed into water by a solution-feed machine or a dry-feed machine. Practical results show that 10–25% less chemicals are needed if the dosage is introduced into the water before it is pumped through, because thorough mixing will occur by the rotating blades of the pump. The only disadvantage is that the chemicals may corrode the pump over a long period of application.

Disinfection

Water quality improves once the source is improved and protection measures are applied, but there will still be some microorganisms in the water. Investigations have shown that improved wells reduce the total bacterial count by 60–80%; a slow sand filter reduces the total bacterial count of surface water by approximately 90%. To kill the pathogens and bacteria still in the water and prevent the occurrence of water-borne diseases, it is essential to disinfect the water; this is especially true during summer when outbreaks of such infectious diseases are at a peak.

Methods of disinfection are either physical or chemical. Boiling water is one of the former. Most people in rural areas customarily use only boiled water for drinking — a policy that should be more widely promoted. Chemical methods involve the addition of chemicals like chlorine and iodine. Chemical disinfection is effective but leaves an odour in the water. In China, chemical disinfection is now only used in areas with epidemics of intestinal infectious diseases.

Chlorine as an element is a gas with a powerful oxidizing ability. Bleach is made up of chlorine and lime (calcium hypochlorite). It is a white powder with a pungent odour that affects both eyes and nose. Its chlorine content is usually 25–35%. "Refined bleaching powder" is another chlorine compound; it contains 60–70% chlorine.

Bleaching powder, when added to water, produces hypochloric acid (HOCl), which can kill bacteria. The chlorine that comes from bleaching powder in this way is called free, available chlorine. The concentration of bleaching powder required for disinfecting water is usually expressed as the concentration of free, available chlorine.

Besides killing bacteria, chlorine oxidizes some organic and inorganic matter contained in water. Part of the chlorine is consumed in this way, so highly polluted water needs considerable amounts of chlorine for effective disinfection. Different sources and even the same source vary in quality; therefore, the amount of chlorine required should be determined before each application. The exact quantity should be used (Table 5).

Table 5. Bleaching powder consumption of different water sources.

Source of water	Chlorine requirement (mg/l)	Bleaching powder consumption[a] (g/m^3)
Rainwater	0.5–1.0	2–4
Deep-well water	0.5–1.0	2–4
Shallow-well water	1.0–1.5	4–6
Spring water	1.5–2.0	6–8
Turbid river water	2.0–2.5	8–10
Pond water (in a good environment)	2.0–2.5	8–10
Pond water (in a poor environment)	2.5–3.0	10–12
Lightly polluted stored water	2.0–2.5	8–10
Heavily polluted stored water	2.5–3.0	10–12

[a]Bleaching powder with 25% chlorine content.

The treated water should contain a certain amount of residual chlorine (appendices 1 and 2), but excessive amounts produce a strong smell. Generally 0.2–0.5 mg/l will be satisfactory, although heavily polluted water in summer requires more residual chlorine and water in winter needs less.

Well Chlorination

The steps in well disinfection with chlorine are to (1) calculate the water volume in the well (water volume [m^3] = diameter^2 [m^2] $\times$ 0.8 $\times$ depth [m]); (2) determine the bleaching powder required; (3) add a little water to the powder to form a paste and then dilute it; (4) allow any undissolved solids to settle; (5) pour the liquid into the well; and (6) mix the well water. Disinfection takes about 30 minutes, after which time the residual chlorine is measured. When a well is heavily used, the water should be monitored for residual chlorine twice a day, perhaps more often in summer. Table 6 lays out the bleaching-powder consumption for different water depths and well diameters.

In some areas, the plastic-bag chlorinator (Fig. 31a, b) is used for well chlorination. The bleaching powder is placed in a plastic bag in which small openings have been made to allow the chlorine to diffuse. Although this method is simple, its use must be complemented by frequent checks of the residual chlorine. A plastic bag 20 $\times$ 15 cm can hold 300–500 g of bleaching powder. In the bag, there are two rows of small openings, 0.3–0.5 cm in diameter, the upper row above the bleaching powder, the lower row in the powder-containing part. The number of openings depends on the volume of water in the well: 1–2 m^3 of water requires 12 openings on each side of the bag, whereas 3–5 m^3 water needs 13–18 per side. Using these sizes should maintain the residual chlorine at 0.05–0.50 mg/l for 9–15 days. Once the bag is installed, the openings are checked from time to time in case they become blocked.

As an alternative, a bamboo chlorinator (Fig. 31c) is sometimes used. A piece of bamboo about 5–6 cm in diameter, 50–60 cm long with 3–4 small holes (0.5–0.6 cm in diameter) in its wall is filled with 0.5 kg bleaching powder and used the same way as the plastic bag, in the same arrangement, although no flotation rod is necessary. This tool requires little space in the well and maintains the residual chlorine level at approximately 0.2–0.3 mg/l.

Storage-Tank Chlorination

Chlorine solutions for storage-tank chlorination usually need 2–5% free, available chlorine. When a 3% chlorine solution is used, then 5 ml (roughly half a tablespoon) is needed for every 25 litres of water. In areas where the plastic-bag chlorinator is used for chlorination of storage tanks, it is generally 10 $\times$ 4 cm — a bag that will contain 20 g bleaching powder — with three holes (0.3 cm in diameter) on each side, perpendicular to the bottom, 2 cm apart, starting at 1.5 cm from the bottom. The mouth of the bag is tied with an elastic band. Placed in the storage tank, the bag sinks eventually, and the chlorine is diffused. One such bag maintains the residual chlorine at 0.01–0.1 mg/l for 10 days.

Bleaching powder is sometimes combined with ammonia salts — the reaction forming chloramines. Although disinfection takes longer with chloramines than with free chlorine (1 hour as opposed to 30 minutes), the chloramines are stable in water, are effective longer, and do not give off as strong an odour as chlorine.

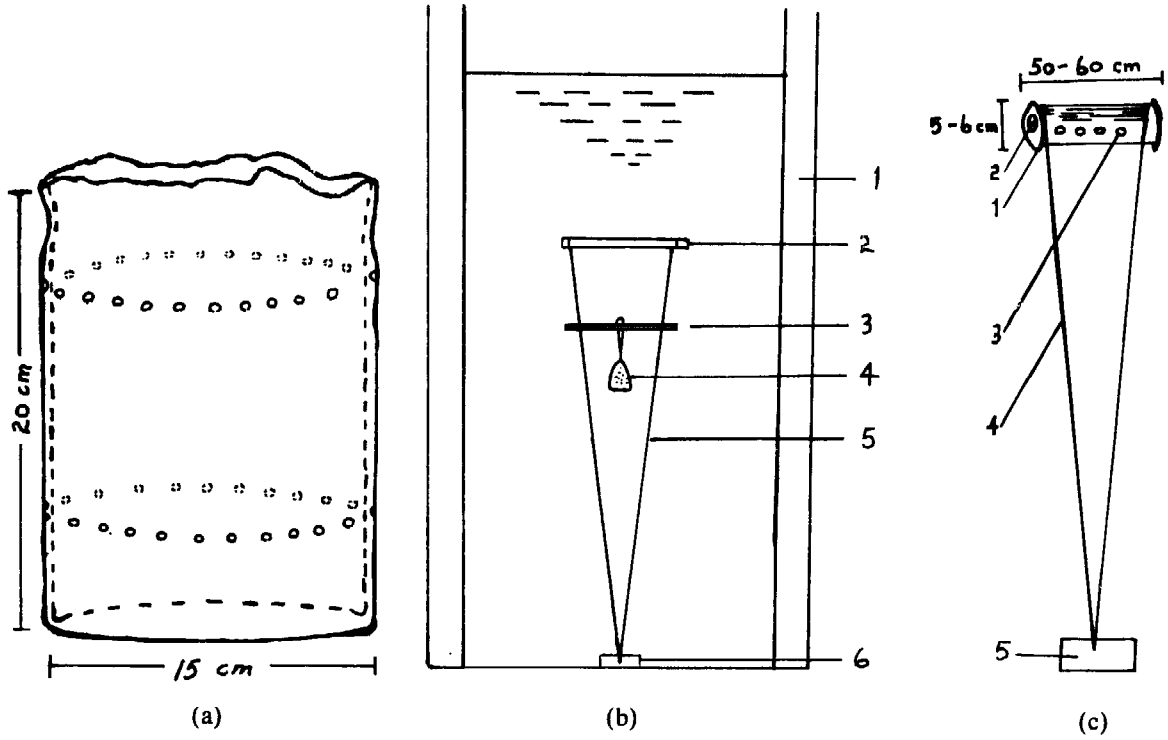

Fig. 31. Two low-cost chlorinators: (a) the plastic-bag chlorinator; (b) in position in the well (1, well wall; 2, floating wooden rod; 3, thin rod; 4, plastic bag; 5, wire; and 6, stone or brick); and (c) the bamboo chlorinator (1, node; 2, opening; 3, hole; 4, wire; and 5, stone).

Table 6. Relationship between the depth, diameter of the well, and the consumption of bleaching powder.[a]

Water depth (m)	Bleaching powder (g) for wells with diameters: 0.5 m	0.8 m	1.0 m	1.5 m	2.0 m
1	1.6	4.1	6.4	14.4	25.6
2	3.2	8.2	12.8	28.4	51.2
3	4.8	12.3	19.2	43.2	76.2
4	6.4	16.4	25.6	57.6	102.4
5	8.0	20.5	32.0	72.0	128.0
6	9.6	24.6	38.4	86.4	153.6
7	11.2	28.7	44.8	100.8	179.2
8	12.8	32.8	51.2	115.2	204.8
9	14.4	36.9	57.6	129.6	230.4
10	16.0	41.0	64.0	144.0	265.0

[a]The required chlorine is 2 mg of bleaching powder containing 25% free available chlorine for each litre of treated water.

Usually a ratio of 4:1 chlorine to ammonia is required for chloramine to be produced, but it can vary. In practice, it has been found that if ammonia is put into the water first and then chlorine, the disinfection lasts longer. If the operation is reversed, some of the chlorine is lost. Ammonium sulfate containing 25% ammonia is commonly used, but ammonium chloride, which contains 32% ammonia is also used. For example, a well with 2 m^3 of water requires 1.5 mg of chlorine per litre of water. If chloramine is to be used instead of chlorine, the required quantities of chlorine and ammonia for a 4:1 ratio are: bleaching powder (20% chlorine) $([2 \times 1.5]/20) \times 100 =$ 15 g and either ammonium sulfate $([1.5/4]2/25) \times 100 = 3$ g or ammonium chloride $([1.5/4]2/32) \times 100 = 2.3$ g. Both ammonium nitrite and ammonium nitrate are poisonous and, therefore, are not used.

Defluoridation

In natural water, fluoride concentrations sometimes exceed 1.5 mg/l and need to be reduced. Effective and simple methods of defluoridation are being investigated, but at present one of three chemical methods is generally used:

- The aluminum oxide method. Burning aluminum at 400–600 °C produces aluminum oxide, which has a high surface area where ion exchange can take place. The aluminum oxide is mixed with the sand used in filtration, and it reacts with the fluoride ions in the water. The filtration rate is

altered according to the concentration of fluoride but generally approximates 2.5 m/h. When treated, if the water still contains more than 1.5 mg/l of fluoride, alum is added and will revitalize the media. This method can reduce the concentration of fluoride from 8.0 mg/l to below 1.5 mg/l, suitable for community water supplies.

- The aluminum chloride method. Alkaline aluminum chloride (0.5 mg) mixed with 1 litre water for 30 seconds reduces the fluoride concentration from 7.0 mg/l to below 1.0 mg/l, suitable for individual or community water supplies.
- The aluminum sulfate method. For every milligram of fluoride ion per litre water, 100–200 mg/l aluminum sulfate are needed for defluoridation. When the raw water has a fluoride concentration greater than 8 mg/l, use of aluminum sulfate alone is not very effective.

Chapter 5

Water Supply Configurations

There is a long history of waterworks in China. People knew the technique of drilling a well to obtain water 4000 years ago. Clarification of water by alum flocculation — still used today — was initiated in China more than a thousand years ago. Since the establishment of the People's Republic of China, great emphasis has been put on the provision of water supplies. All the cities have their own water supply, and many small towns now have water-supply networks. For example, in Zhejiang province more than 90% of the towns have water-supply systems. More encouraging is the fact that many communes and production brigades have been constructing their own systems.

Because water management is directly related to people's health, the Department of Health and Epidemic Prevention is very concerned with water-quality control in rural water supply. Since 1960, for instance, a series of water-treatment works have been constructed in the suburbs of Shanghai as part of the project for schistosomiasis prevention; to date (April 1977), more than 60 waterworks have been built in the Shanghai suburbs alone. In addition, many people who live far from cities or towns have gained access to an adequate water supply. For example, in the Guangxi Zhuang Autonomous Region, Wuming county, several simple water-supply works were constructed after 1967; now 25% of the population of this county is provided with adequate water. Before Liberation, the people of this region only had access to raw surface water. In Jiliang county, Guangdong province, through the use of local methods and local resources in water-scheme construction, more than 110 production brigades now have their own systems, supplying more than 300 000 people.

Since 1965, when Chairman Mao called on the nation's health and medical services to "put the emphasis on the rural areas," the development of water supplies has made considerable progress toward ensuring people's health and, especially, preventing acute water-related infections. For example, in the suburban areas of Shanghai, such diseases were 72.6% lower in 1975 than in 1965.

Water treatment is a means to rid water of water-borne pathogens and harmful substances. Further, it reduces turbidities, colour, taste, and odour to acceptable levels. Water-treatment works should fulfill requirements of quantity, quality, and pressure. Intake works must supply a sufficient quantity of water, whereas the treatment plants improve the water quality. The distribution system moves the treated water to the consumers while maintaining a minimum pressure in the system (Fig. 32).

The sizes of waterworks vary greatly in China; Fig. 33–40 are flowcharts of some systems that are common in southern China and the Shanghai area.

In rural areas, generally, users are scattered over a large area, and rural households are widely dispersed. However, this situation is likely to change with the recent increase of "socialist villages" and the revolution in agricultural production. Currently, the population of a production brigade is 400–800 and that for a commune located in a town is usually between 3000 and 5000. Production brigades use almost all their water for domestic consumption; even in towns where communes are located, more than 60–70% of the water is for domestic consumption. In rural villages, people live together and engage in the same sort of work; therefore the water demand varies greatly during the day, peaking at certain times.

Short periods of breakdown in supply seldom cause serious problems, especially in southern China where surface water is easily accessible. For this reason, it is rarely necessary to have a full-time staff to run rural waterworks. Generally, the leaders of each community run the water-supply system, as well as engaging in the activity of production. There is no clear division of labour, and when the waterworks are being built or extended, most of the community helps; people working for other water-treatment works may also

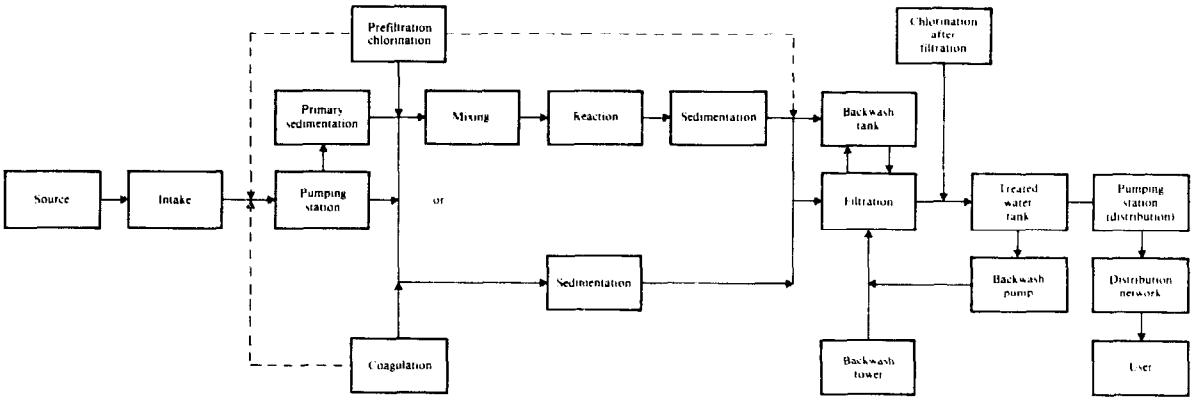

Fig. 32. Surface-water supply.

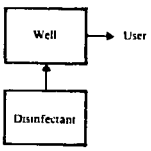

Fig. 33. Suitable system for dispersed populations, each well serving just one or a few households.

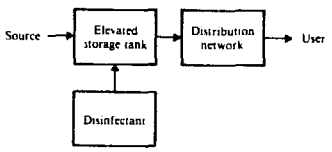

Fig. 34. Suitable system for spring water located at an altitude high enough for gravity feed.

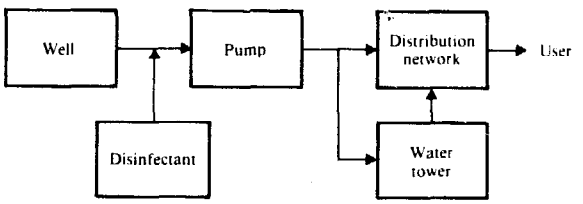

Fig. 35. Suitable system for drilled wells where the water quality is good.

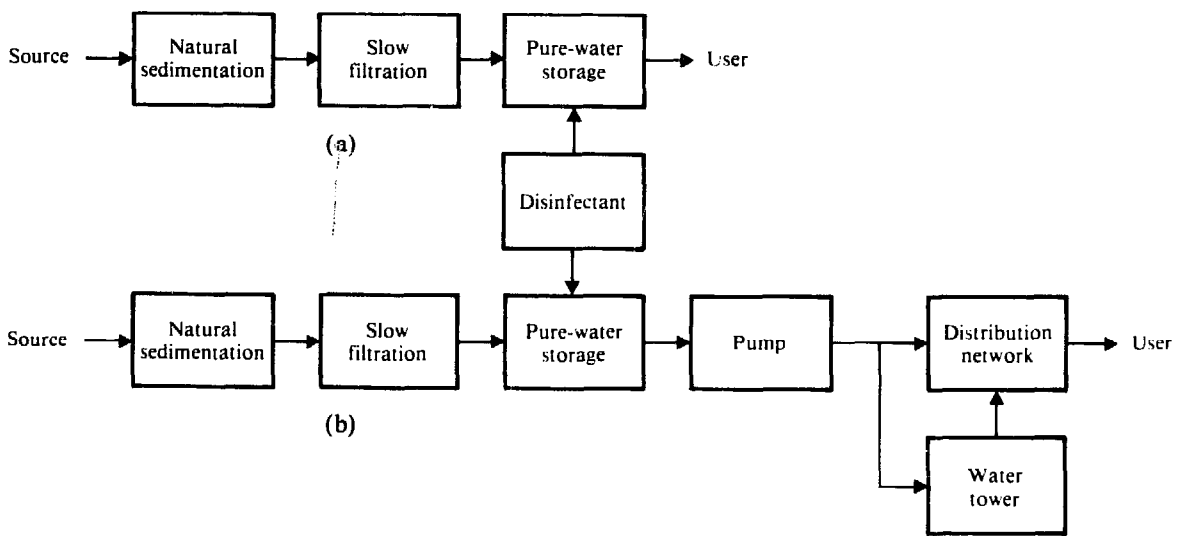

Fig. 36(a) and (b). Suitable systems for surface water: a natural pond usually used for primary sedimentation.

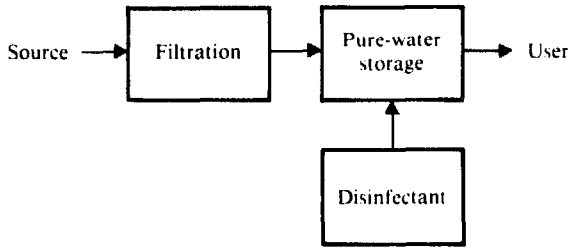

Fig. 37. Suitable system for good surface water, the filtration plant near or next to the source.

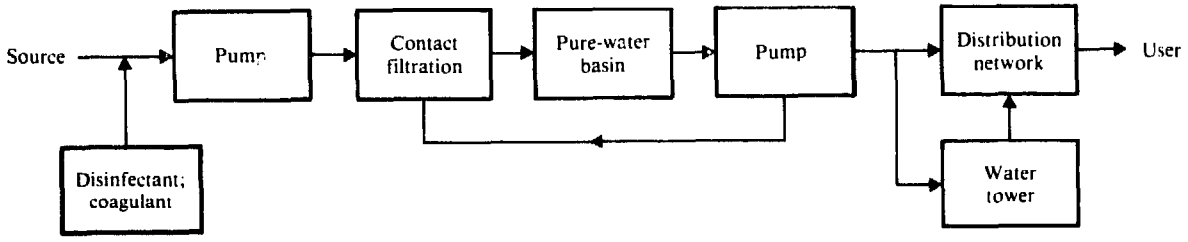

Fig. 38. System suitable for surface water with turbidity less than 100 mg/l.

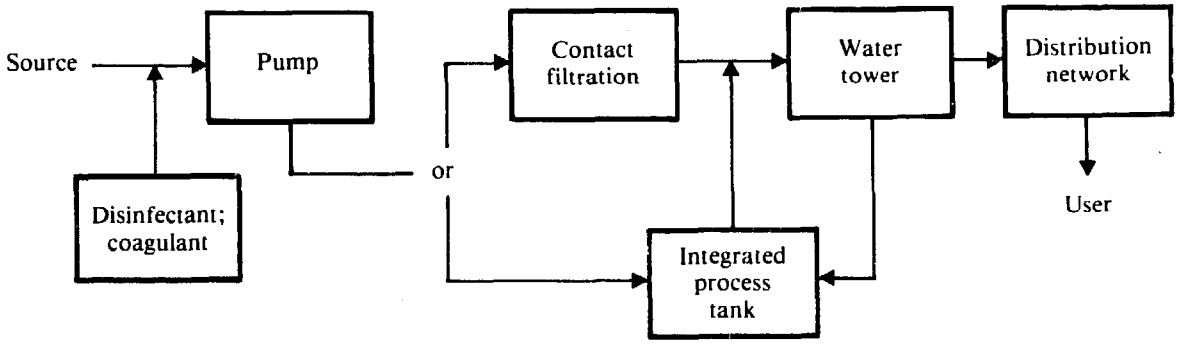

Fig. 39. System for surface water; it includes either an integrated process tank for surface water with a turbidity below 500 mg/l or a direct filtration unit for water with a turbidity below 100 mg/l.

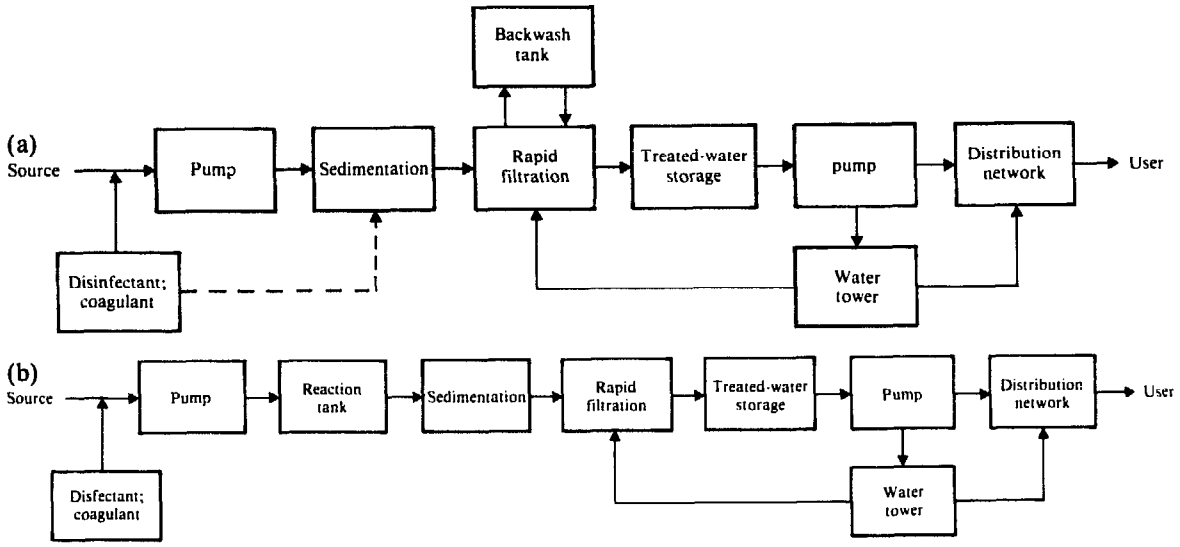

Fig. 40(a) and (b). The most complex systems used in rural China for water supply; turbidity is usually less than 3000 mg/l.

assist. Still, construction, which is based on local methods and materials, sometimes takes a long time.

The communities are encouraged by public health authorities to build as simple and reliable a system as possible. The output of the waterworks is usually less than 24 hours' supply, and storage tanks are generally required. The distribution networks follow a branching pattern.

In construction of the waterworks, the first task is to decide how much water is required, because every component of the system is defined by the volume of water to be supplied. Because China is a huge country encompassing different climates and cultural patterns, water consumption varies greatly across its length and breadth. Water in rural areas is mainly for domestic supplies, and the quantity is estimated on that assumption (Table 7). According to production statistics from 60 waterworks in the Shanghai suburban area, approximately 70–80 litres/person-day are required. In Guangxi province, an estimated 50–60 litres/person-day is assumed for simple waterworks in rural areas. The authority in Fujian province recommends 20–30 litres/person-day for short-term supply and 30–60 for long-term supply.

Besides varying within any day, water consumption in summer is greater than in other seasons, and demand in southern China is greater than in northern China due to differing living customs, climatic conditions, etc.

Table 7. Domestic water demand standard for residential areas.[a]

Outdoor standpipe, no indoor sanitation facilities; with wastewater disposal system.

District (no.)	1	2	3	4	5
Maximum daily consumption (l/person-day)	20–35	20–40	35–55	40–60	20–40
Average daily consumption (l/person-day)	10–20	10–25	20–35	25–40	10–25
Hourly variation coefficient (peak factor)	2.5–2.0	2.5–2.0	2.5–2.0	2.5–2.0	2.5–2.0

Indoor taps, but no sanitation facilities or bathroom; with disposal system.

District (no.)	1	2	3	4	5
Maximum daily consumption (l/person-day)	40–60	45–65	60–85	60–90	45–60
Average daily consumption (l/person-day)	20–40	30–45	40–65	40–70	25–40
Hourly variation coefficient (peak factor)	2.0–1.8	2.0–1.8	2.0–1.8	2.0–1.8	2.0–1.8

Indoor taps, with indoor stanitation facilities but no bathroom.

District (no.)	1	2	3	4	5
Maximum daily consumption (l/person-day)	85–120	90–125	95–130	95–130	85–120
Average daily consumption (l/person-day)	55–90	60–95	65–100	65–100	55–90
Hourly variation coefficient (peak factor)	1.8–1.5	1.8–1.5	1.8–1.5	1.8–1.5	1.8–1.5

Indoor taps, with sanitation facilities and bathroom.

District (no.)	1	2	3	4	5
Maximum daily consumption (l/person-day)	130–170	140–180	140–180	150–190	140–180
Average daily consumption (l/person-day)	90–125	100–140	110–150	120–160	100–140
Hourly variation coefficient (peak factor)	1.7–1.4	1.7–1.4	1.7–1.4	1.7–1.4	1.7–1.4

Indoor taps, with sanitation facilities, bathroom, and central hot water supply.

District (no.)	1	2	3	4	5
Maximum daily consumption (l/person-day)	170–200	180–200	185–215	190–220	180–210
Average daily consumption (l/person-day)	130–170	140–180	145–185	150–190	140–180
Hourly variation coefficient (peak factor)	1.5–1.3	1.5–1.3	1.5–1.3	1.5–1.3	1.5–1.3

[a]Consumption in small public facilities is included, but consumption in sprinkling on roads, in extensive planting projects, and in major public facilities in cities is not. The climatic conditions, distribution system, inhabitants' customs, etc. differ according to locality and cannot be ignored. Applicability to other districts is possible if the climatic conditions, inhabitants' customs, etc. are similar.

Source: Outdoor water supply design regulation (TJ13-74 Preliminary).

The daily coefficient of variation is defined as the maximum daily demand (volume) divided by the average daily demand (volume). According to estimates, the daily coefficient of variation for cities and towns ranges from 1.1–2.0 to approximately 2–4; it is sometimes even greater in rural areas. From the daily coefficient of variation and average daily consumption, the maximum daily volume can be calculated and used as the basis for the various parts of the structure. The maximum volume of daily supply for a waterworks is equal to the number of users × average consumption per person-day × daily coefficient of variation. For example, a commune with a population of 3000 consuming an average 50 litres of water per person-day and having a daily coefficient of variation of 3.0 needs a maximum volume of daily supply of 450 m^3/day (3000 × 50/1000 × 3). Thus the waterworks in this commune should be able to provide 450 m^3/day. However, this calculation excludes factors such as leaking, and the actual consumption would probably be greater than that calculated. Any industrial water consumption also has to be added to the calculation's result.

The use of water in a community fluctuates every hour in the day. The ratio between maximum hourly use and average hourly use during the day is defined as the hourly coefficient of variation. This coefficient for cities and towns may range from 1.3 to 2.5; for communes it may range from 4 to 6. The hourly maximum consumption determines the diameter of the main distribution pipe, the capacity of pumps, etc. The maximum hourly consumption is equal to the maximum daily consumption average per hour × the hourly coefficient of variation. If the commune in the last example had an hourly coefficient of variation of 5, then its maximum hourly consumption would be 93.75 m^3/h (450/24 × 5).

Chapter 6

The Well Site

When rain and other forms of precipitation fall on the ground, a portion becomes surface water that flows along the ground into rivers and is eventually discharged into the sea; another portion evaporates due to the heat of the sun and is returned to the atmosphere; and the remainder percolates into the ground and accumulates in the water-containing layer, forming underground water (Fig. 41). Underground water can be classified as groundwater, artesian groundwater, and perched water.

Groundwater

Groundwater is the water that collects above the first stable impervious layer of rock. It can move freely, and its surface is known as the groundwater surface. Generally there is no pressure in groundwater; it is supplied mainly by rainwater or the percolation of rivers or lakes. Because groundwater is mainly affected by rain, the level fluctuates greatly, rising during the rainy season and dropping during drought. Groundwater can be used for irrigation in areas where it is plentiful. However, in some places it is scarce and should not be used for irrigation. Village water supplies are often taken from groundwater (Fig. 42).

Groundwater is generally stored in a permeable soil layer. The space between soil particles makes the layer permeable and allows for good water storage.

Artesian Groundwater

Artesian groundwater (Fig. 43) is stored in a water-containing layer sandwiched between and confined by two impervious layers. Geologic variations are such that the upper and lower impervious layers are not continually horizontal. Pressure differentials are located in the water at various locations and form what is known as water heads. If, when a well is drilled, the water flows freely to the surface under pressure, the well is

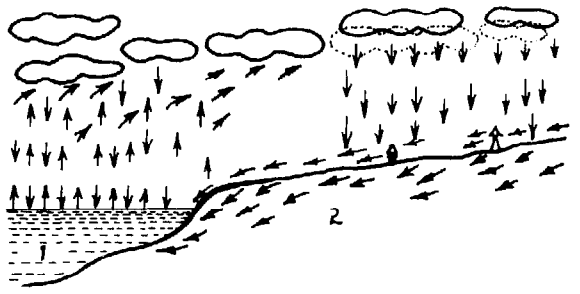

Fig. 41. Relationship between rain, surface water, and underground water (1, sea; 2, mainland).

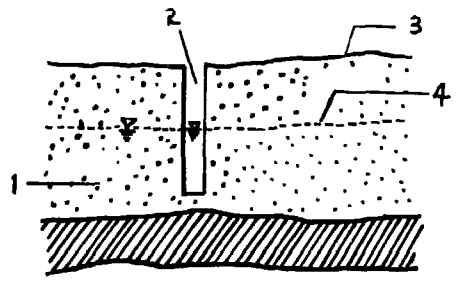

Fig. 42. Structure of the groundwater layer (1, groundwater; 2, well; 3, ground surface; and 4, groundwater level).

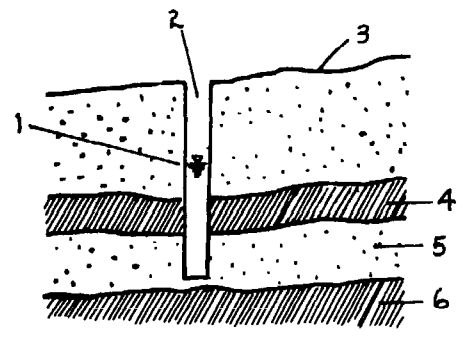

Fig. 43. Structure of an artesian groundwater layer (1, water level; 2, well; 3, ground surface; 4, impervious layer; 5, artesian groundwater; and 6, impervious layer).

known as an artesian well (Fig. 44). If the water rises but does not reach the ground surface it is termed subartesian water.

There is one other type of nonartesian groundwater: water that is sandwiched between two impervious layers but does not fill the water-containing layer. This water moves freely and will not rise when a well is drilled into the layer. Most water used for agricultural irrigation is artesian groundwater; the supply varies in different areas, sometimes coming from very far away.

Perched Water

Perched water exists above a sectional impervious layer. It is not widely distributed and is seasonal. It is not discussed in detail here because it is not significant in the drilling of wells for irrigation (Fig. 45).

The Search for Underground Water

Searching for underground water is relatively complicated, especially in mountainous areas, where the work is affected by topographic conditions and geologic structure. However, there is an important principle that can be followed: underground water is similar to surface water, having a tendency to flow to low-lying areas. An investigation can be carried out in various areas having different topographic and geologic conditions to find the source of underground water and its point of discharge and, thus, to determine the best location for a well.

Underground water can usually be found in valleys or basins in areas where the surrounding topography is relatively high because all the underground and surface water in the area flows toward the central valley or basin. If there is an impervious layer beneath the basin or if there is no discharge point for the underground water, an underground reservoir is formed at the centre of the basin.

In an area surrounded on three sides by mountains (Fig. 46), the valley should have large quantities of water because the surface water in streams and underground water flow toward the outlet of the valley.

Underground water can also be found in marshy land where a number of valleys meet. However, the catchment area must be large to provide enough water. If the catchment area is not sufficient — even if the topographic characteristics are ideal — the supply of underground water will not be abundant.

A well that must be drilled in front of a mountain should be located on the alluvial cone (fan) at the valley outlet because most of the alluvial cone consists of sand and gravel layers, with large spaces between particles and, thus, good storage conditions for underground and surface water flowing down the mountain. Away from the alluvial cone, even if water is found, it will not be abundant (Fig. 47).

A search for underground water in a mountainous area should normally be carried out in areas where limestone is abundant and where the geologic structure is relatively matured, such as a fault-fractured zone. As a result of the earth crust's movements, the rock layers have broken and shifted, and the underground water in the water-permeable layer has been cut off. As the layers break, different widths of fractured zones are formed, and the voids in the rocks are thereby increased. As the voids increase, all the underground water that has been cut off in the water-permeable layer flows to the fractured zone and forms a water-containing zone (Fig. 48). Thus, underground water is found in crevices of limestone areas or in underground caves.

If rocks, such as granite, penetrate the water-containing layer, they form a water-retaining wall so that underground water can also be found where the rock wall begins (Fig. 49).

Underground water also generally exists in flat plains, although the amount varies. Areas with plenty of underground water are usually old routes of rivers or areas that have been flooded at some time; these are very permeable and form a good passage for underground water (Fig. 50). To find old river routes or previously flooded areas, one must depend upon local people, who know the history of the area.

Searching for water and drilling wells are undertaken by local inhabitants because they are familiar with the area, available building materials, etc. Water plants (reeds, cow's hair grass, *Scirpus maritimus*) and water animals (frogs and snails) serve as indicators of underground water, as do abnormal phenomena after weather changes such as, in summer, cooler temperatures in one area than in the surrounding areas; in winter, frost in crack lines of the earth or water vapour in the morning; and in dry weather, earth that appears to be damp when all around the ground is cracked and white.

Rational Planning for Wells

Underground storage capacities are always limited, and if they are exceeded by installed

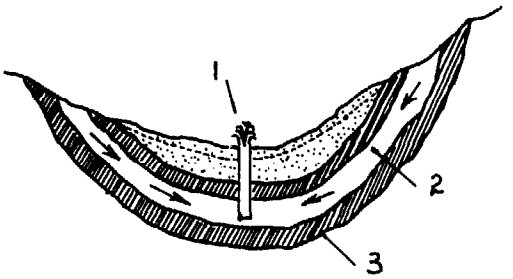

Fig. 44. Structure of an artesian well (1, well; 2, water-containing layer; and 3, impervious layer).

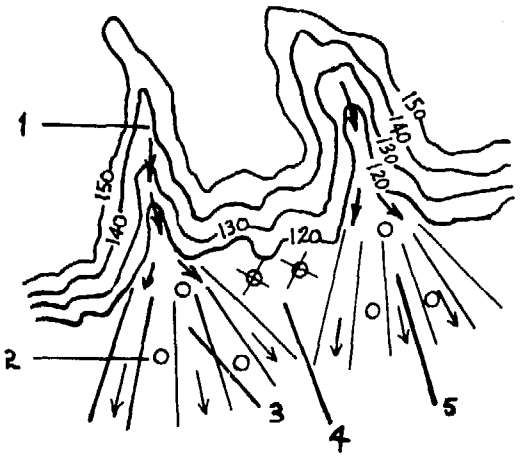

Fig. 47. Location of well on the alluvial cone (1, flow direction of the underground water; 2, suitable well location; 3, alluvial cone, fan; 4, unsuitable well location; and 5, alluvial cone, fan).

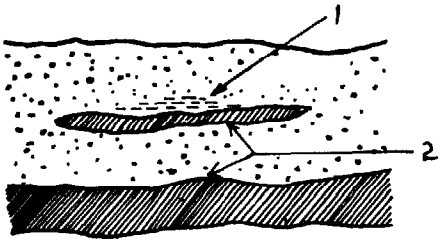

Fig. 45. Perched water (1, perched water and 2, impervious layers).

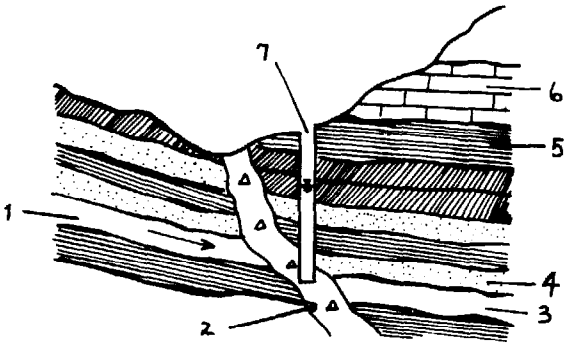

Fig. 48. A fault-fractured zone (1, water-containing layer; 2, fault-fractured zone; 3, water-containing layer; 4, sandstone; 5, shale; and 6, limestone).

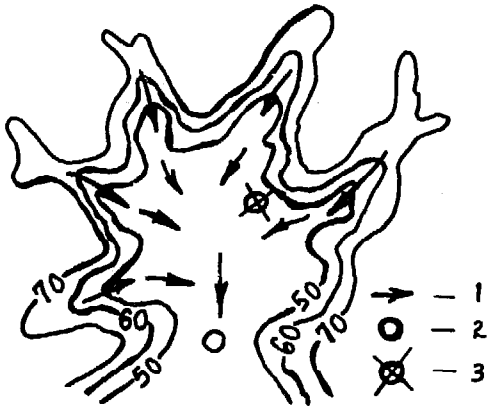

Fig. 46. Location of a well at a valley outlet (1, flow direction of the underground water; 2, suitable location for well; and 3, unsuitable location for well).

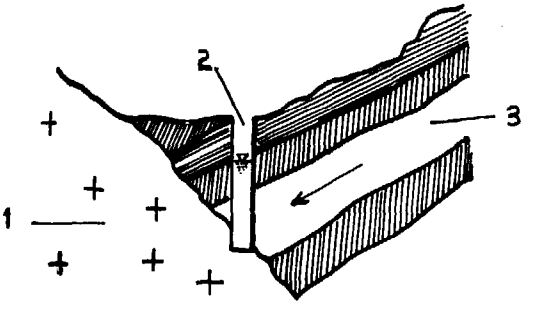

Fig. 49. Granite cutting off the water-containing layer (1, granite; 2, well; and 3, water-containing layer).

Table 8. Characteristics of percussion-drilling machines.

Name, model no. of drilling machine	Production unit	Machine suitable for soil layers	Drilling diameter (mm)	Practical maximum drilling depth (m)	Lifting capacity of reel (t)	Cable standard (mm)	Outer dimensions (length × width × height) (mm)	Weight of main machine (kg)	Power (kW)	Electric motor revolution (rpm)
CJ-700 model percussion drilling machine.	Liaoning Haicheng Agricultural Machinery Factory	Sand; clay; cobble; loose, scattered soil layer; thin slate layer	700	100	1.5–2	18.5	5200 × 1400 × 2300	1400	14	1450
Good-harvest model percussion drilling machine	Hebei Kuan Agricultural Machinery Factory	Loamy soil; gravel soil; sand; loose, scattered soil layer	500	120	1.5	6 × 19 + 1 − 17	1920 × 1280 ×1630	1300	10	1480
150-metres cable percussion drilling machine	Hebei Kuan Agricultural Machinery Factory	Loose, scattered soil layer; thin layer of sandy gravel, sandy cobble	500	150	1.3	6 × 19 + 1 − 17	2030 × 1370 × 1623	1300	10 or 14	1450-1500
Dash and grab drill	Henan Nayang Agricultural Machinery Factory	Sandy soil; cobble; clay; "ginger" rock	1100	33	1.5	12.5–15.5	–	800	7	1500
YKC-30 model percussion drilling machine	Henan Loyang Mine Exploration Machinery Factory	Loamy soil; sandy loamy soil; clay; sand layer; sandy cobble; sandy gravel; weathered rock; half-weathered rock; bedrock, etc.	Last-drill diameter 400	200-250	2.0	–	–	13000	40	–
YKC-22 model percussion drilling machine	Henan Loyang Mine Exploration Machinery Factory	Loamy soil; sandy loamy soil; clay; sand layer; sandy cobble; weathered rock; half-weathered rock; bedrock; etc.	Last-drill diameter 400	150-210	1.3	–	–	7000	28	–
YKC-20 model percussion drilling machine	Henan Loyang Mine Exploration Machinery Factory	Loamy soil; sandy loamy soil; clay; sand layer; sandy pebble; sandy gravel; weathered rock; half-weathered rock; bedrock, etc.	Last-drill diameter 400	120-170	1.0	–	–	5000	20	–

Table 9. Characteristics of rotary drilling machines.

Name, model no. of drilling machine	Production unit	Drilling diameter (mm)	Practical maximum drilling depth (m)	Type of bore head	Machine suitable for soil layers	Boring rod standard (mm)	Cable standard (mm)	Boring rod revolution (rpm)	Power	Maximum weight of drilling machine (t)
ZW-500 counter-circulation well-drilling machine	Province of Jilin Machinery Factory	500	120.5	Tri-wing bore head	Yellow soil; clay; sand; gravel; loose, scattered soil strata	127 × 4.5	Main reel 12.4, secondary reel 9.3	50	NB8 model, 55 hp	–
Anti-drought 66 model manpower rotary drilling machine	Nei Monggol Paotou Agricultural Machinery Factory	1100; 950; 700; 450;	80 (bore diameter 500 mm)	Deer's horn driller	Sandy soil; sandy loamy soil; loamy soil; clay; sandy gravel; cobble smaller than 100 mm	70 × 10	15 × 6 − 1	5	–	–
Twin-well drilling machine	Agricultural Implements Factory; District of Pucheng, Province of Shanxi	700-1100	190 (bore diameter 1100 mm); 120 (bore diameter 700 mm)	Bottom all open	Sand; gravel; cobble less than 50%, diameter smaller than 100 mm	76 × 8	15.5	8	–	–
Sufung 66 model manpower drilling machine	Hardware Factory; District of Fung, Province of Jiangsu	1000-1100; 650-700	67 (bore diameter 650 mm)	Rocket drill	Sandy loamy soil; clay	76 × 8	12.5	–	–	–
R-T65 rotary manpower drilling machine	Agricultural Implements Factory; Province of Shandong	800; 700; 690; 600; 540	101 (bore diameter 450 mm)	Knife's rack driller 110°	Clay; sand smaller than 150 mm; cobble layer	70 × 7	12.5	3-4	–	–
Red-star 300 model drilling machine	Exploratory Machinery Factory; Province of Henan	560	Alluvial stratum 300; Bedrock 250	–	Bedrock; alluvial layer	114	12; 19.5	21; 43; 61; 83 (turning dish revolution speed)	40 kW	10
SPO-30 model drilling machine	Mine Exploration Machinery Factory, Shanghai	500	300	–	Medium-, fine-particle layers	89 × 70 × 6500	6 × 19 + 1 (20, 19.5)	4; 7; 128 (clockwise, counter-clockwise turning dish revolution speed)	Electric engine 40 kW; diesel engine (65 hp)	Main machine weighs 2.3; tripod weighs 5.3; subsidiary implements weigh 4.0
300-metre drilling machine	Machinery Factory District of Pa, Tienchin, Province of Hebei	500	300	–	Clay; sand; weathered shale; clayey, sandy gravel; cobble	73 × 9	–	40 (turning dish clockwise, counter-clockwise)	Concentrated moving power 40 kW	13.2
500 model drilling machine	Agricultural Implements Factory District of Failai, Province of Hebei	500	500	–	Clay; sand; weathered shale	73 × 9	–	65 (turning dish revolution speed)	Concentrated moving power 40 kW	9.8

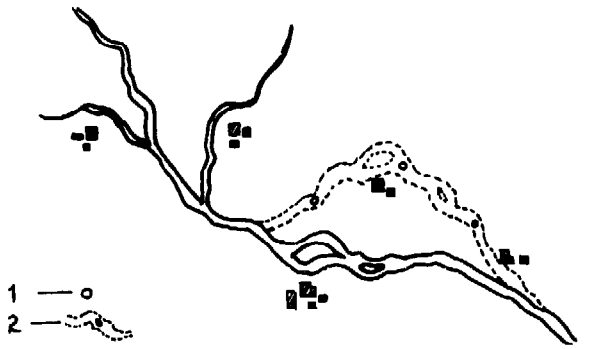

Fig. 50. Layout of an old river route (1, well position and 2, old river route).

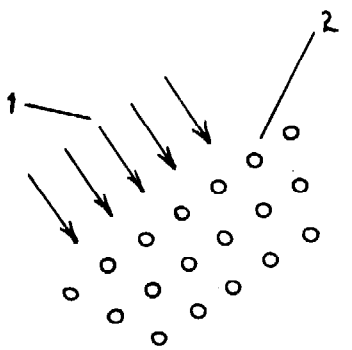

Fig. 51. Arrangement of wells on underground water site (1, flow direction of the underground water and 2, well locations).

pumping capacity, the underground water level drops, the amount of water discharged from the well decreases, and the well may fail. At worst, the underground water level drops to such an extent that the well has to be abandoned. Therefore, in developing and using underground water supplies, one must carefully plan the distribution of wells, the distance between them, and their depth.

Planning must be carried out by a hydrologist and geologist who are familiar with local conditions. An integrated search is carried out on the basis of hydrologic and geologic information or data from existing wells. When hydrologic and geologic data are lacking, a few test wells can be drilled initially and the number increased after observation. If the test wells are arranged in rows, they must be located along the direction of flow of the underground water (Fig. 51).

The location of wells, the distance between them, and their depths should be based on the capacity of the underground-water supply and on the potential effects of lowering the underground-water level. Other items that must be considered are agricultural plans, the level of mechanized cultivation, drainage systems, crop distribution, water and electrical supplies, and transportation during well construction.

The distance between adjacent wells is especially important because interference between wells should be avoided. For example, in an area where there is only one water-containing layer consisting of coarse aggregates such as sandy gravel and rock, wells discharging 3000–4000 m^3/day should be separated by a distance of 300–350 m; in an area where there are several water-containing layers consisting of coarse and medium particles (e.g., coarse and medium sand), wells discharging 2000–3000 m^3/day should be 400–450 m apart; and, finally, in an area where there are a number of water-containing layers of medium, fine, and powder-sized particles, wells discharging 1000–2000 m^3/day should be 500–550 m apart. Single water-containing layers are fairly rare; most areas contain several layers that are best utilized by a combination of deep and shallow wells. This setup ensures that all the water is not taken from one water-containing layer.

Once the location for a well has been decided, the shape of well and the type of drilling machine are selected on the basis of the geology of the area, financial constraints, available construction materials, and personnel.

Usually, wells are 30–150 m deep, although some exceed 200 m in depth. Drilling equipment primarily consists of mechanically and manually driven rotary bores and percussion drilling machines (Table 8 and 9).

The rotary bore is normally used for deep wells in bedrock, in areas where underground water is not abundant in the shallow layers of rock, or in an area where the underground water must be extracted from a deep layer. In riverbeds, where groundwater is abundant, wells are generally dug by hand, and because the workers must climb into the hole to dig, these wells tend to be large.

In mountainous areas, the underground water is normally relatively deep because of the thickness of the covering layers. For this reason, rotary bores and percussion drilling machines are generally used to dig the well, although manually excavated wells are possible if safety measures are followed. In flat or plains areas where water-containing layers are numerous, either manual or mechanical devices can be used for the drilling. The walls or casing for the well can be iron, concrete, cement/gravel, asbestos/cement, or brick pipe. A large-diameter, power-driven rotary bore should be used when the underground water is deep, and the casing of the well should be either cast-iron or concrete pipe.

Chapter 7

Percussion Drilling

Site Investigations

The well-drilling unit sends personnel to a site to carry out investigations and to make necessary arrangements that include:

- A study of the construction site, topography, roads, bridges, etc., to determine the route for transporting the drilling machinery and to arrange for any necessary repairs on roads and bridges;
- A study of local water supply so that adequate water is available during construction work and drilling;
- The preparations for excavation of the slurry discharge pit and its discharge path;
- A study of the electrical supply and the capacity of the transformer to ensure the power requirements of the drilling rig;
- An investigation of the quality of soil; and
- Arrangements for accommodation of the construction workers.

Then, the construction crew are briefed on the tasks to be done.

Drilling Technique

When the drilling machinery has been sent to the field, it is installed on the site and leveled. The mast is raised, and the towline pulled tight and anchored. Every part of the drilling machine is examined carefully, especially the wheel on top of the mast, and all turning parts are oiled. Then, the machinery is given a test run, the bit allowed to move up and down several times as a check on the functioning of the bit and the brake. Using the stationary position of the bit as the centre of a circle, the crew excavate the opening of the well, install a protective pipe, and cover the well opening with planks.

Boring or Drilling

After commencing drilling, all the workers must concentrate on the operation, use their hands to hold the cable so that they can feel the changes of soil-layer characteristics and avoid accidents. The well opening must be covered with protective planks during drilling; otherwise workers or tools may fall into the well hole. Small holes must be drilled in the middle two covering planks for the cable and for regular observation of any changes of position in the cable. Also, the covering planks must be stationary so that the drilling machine is kept in a horizontal position, producing a perfectly perpendicular hole.

The bore-bit should be measured during drilling as an indication of the degree of wear and tear on it and the need for repairs. The hole must be kept circular and vertical during drilling. Every 20 m it must be checked; measurements should be taken on the length of the bore-rod and the angle of deviation of the hole; if there is any deviation, it should be rectified immediately. Whenever drilling is stopped, the drilling machine should be lifted slightly or taken from the hole so as not to become buried.

The well diameter should be wide enough to accommodate filter materials after the pipe casings have been lowered into the well (the thickness of the filter materials should not be less than 10 cm). The angle of deviation for the finished well should not exceed one in a thousand (e.g., if the well is 100 m deep, the deviation should not exceed 10 cm).

Soil samples should be taken during drilling when, through the cable, one can feel that the soil layer has changed. Sampling and recording are important tasks in well drilling. How does one perform them? The old method of sampling is to use a sand-extracting bucket or the bore-bit to bring up the rock and sand samples for examination. However, this method is not accurate, especially in sand, when samples are taken from the water-containing layer. Water washes away the fine particles, leaving only the coarse sand. Thus, the sample is misleading and could result in a wrong judgment.

Now, the sampler shown in Fig. 52 is commonly used. It is lowered to the bottom of the hole

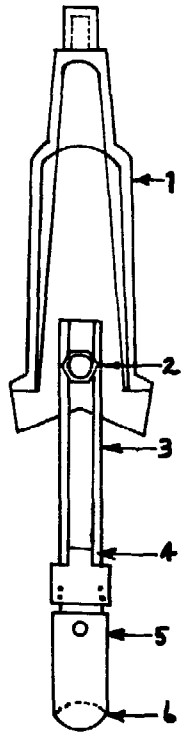

Fig. 52. Soil sampler (1, bore-bit; 2, screw; 3, percussion-sliding tube; 4, impact receiver; 5, water-discharge outlet; and 6, cutter).

so that the sampler's cutter touches the soil layer where the sample will be taken; the bore-bit's cutter is connected to the impact receiver of the sampler; it then hammers the sampler several times and lifts it up. This method of sampling is more accurate than the old method because the sand or rock sample is intact. Samples should not weigh less than 1.5 kg; they should be taken at 4-m intervals in the nonwater-containing layers and at 1-m intervals in the water-containing layer. The samples should not vary more than 10 cm in depth.

At each layer, a soil sample should be taken and its description recorded. It should be stored in a wooden box and be identified by a number, description, depth, thickness, etc. The drilling log (Table 10) should record a description of the soil, the depth and thickness of each characteristic; it should be drawn to scale and should follow standard geologic symbols (Fig. 53). The drilling log should be kept current as the work progresses.

Soil samples are the most reliable means available to monitor drilling; however, distinguishing a soil sample, as well as classifying it, is a subjective process; it can be made as consistent as possible if the people performing it are aware of existing standards in discrimination and terminology.

The clay group includes clayey sand, sandy clay, clay, loess and loessy sand, artificial soil, planting soil, peat, and silt.

Clayey sand: Mainly sand, this type of soil, when rolled between a person's hands, feels very sandy; also it can be rolled into a 3-mm thick rod, though sometimes the rod is difficult to form. Water seeps out when this type of soil is saturated, and it can be easily crushed; when dry, it forms a lump, albeit a very fragile one, and in water, it disperses.

Sandy clay: Mainly clay, this type of soil feels slightly sandy when rubbed between a person's hands; it can be rolled to form a 1–2-mm thick rod; after being cut with a knife, this type has a cut surface that is slightly smooth and bright. It is very hard when dry.

Clay: This type of soil does not feel sandy at all; it can be rolled into a long rod having a diameter smaller than 0.5 mm. After being cut with a knife, this type has a cut surface that appears very bright. It is very hard when dry.

Loess and loessy sand: When rolled between a person's hands, this type of soil has a floury texture, rather than a particle-like texture. Having a greater void in structure, it loosens easily.

Artificial soil: This type of soil has been disturbed by human beings; it is mixed with construction rubbish, broken brick, tile, etc.

Planting soil: This type of soil is topsoil and contains plant roots.

Peat: This type of soil is black, has a high moisture content; when rubbed between a person's hands, the decomposed part of peat will squeeze out between the fingers; its volume is reduced when it is dried.

Silt: Grey-black in colour, this type of soil resembles decomposed peat, but it contains some minerals and has a distinct smell. It is hard when dry.

The sand and rock group comprises boulders, bulk rock, pebbles, debris, conglomerate, gravel, coarse sand, medium sand, fine sand, powdered sand, and ginger rock.

Boulders: This type of soil mainly consists of rounded rock fragments having a diameter greater than 200 mm and a weight exceeding 50% of the total soil sample.

Bulk rock: This type mainly consists of subangular rock fragments having a diameter greater than 200 mm and a weight exceeding 50% of the total soil sample.

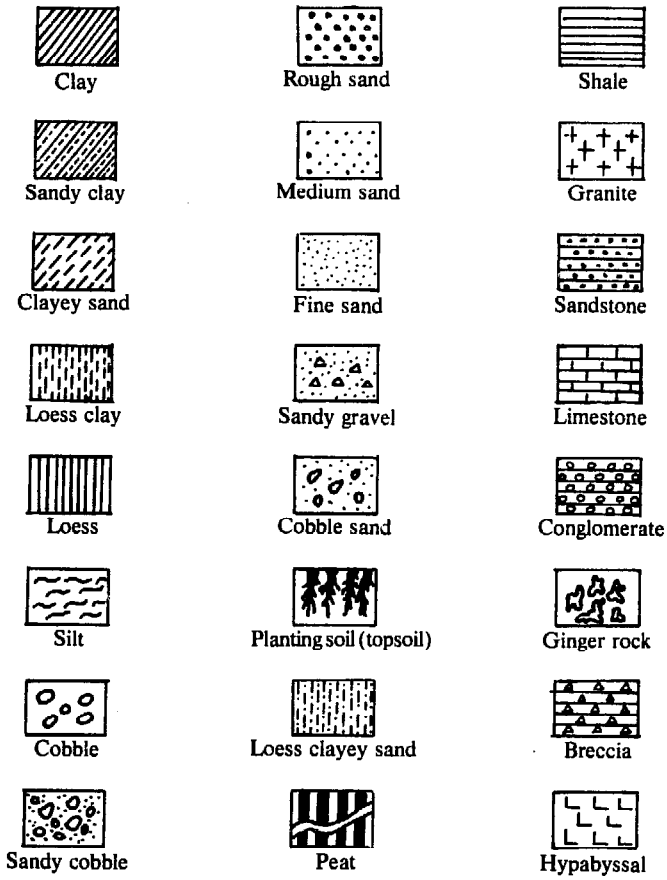

Fig. 53. Geological symbols.

Pebbles: This type mainly consists of rounded rock, with a diameter greater than 10 mm and a weight exceeding 50% of the total soil sample.

Debris: This type mainly consists of subangular rock, with a diameter greater than 10 mm and a weight exceeding 50% of the total soil sample.

Conglomerate: This type mainly consists of rounded and subangular rocks having a diameter greater than 2 mm and a weight exceeding 50% of the total soil sample.

Gravel: This type is made up of rocks with a diameter greater than 2 mm and a weight exceeding 25% of the total sample.

Coarse sand: The diameter of the constituents is greater than 0.5 mm and their weight exceeds 50% of the total sample.

Medium sand: The diameter of the constituents is greater than 0.25 mm, and their weight exceeds 50% of the total sample.

Fine sand: This type of soil has 70% or more of its weight composed of particles with a diameter greater than 0.1 mm.

Powdered sand: This type of soil has less than 70% of its weight made up of particles with a diameter greater than 0.1 mm.

Ginger rock: The shape of this type resembles green ginger.

Slurry is a mixture of water and clay. Using slurry while drilling prevents cave-in, suspends debris, and allows safe penetration of sand layers. Proper use of slurry ensures safe drilling; however, if slurry is used excessively, it hinders washing of the well and adversely affects the quantity of well discharge. Therefore, the consistency of the slurry must be varied according to the characteristics of the soil layer. The quality of the slurry is a reflection of specific gravity, density, viscosity, amount of sand, cohesiveness, stability, and permeability. Although permeability

Table 10. Sample of drilling log sheet.

Depth to layer (m)	Thickness of layer (m)	Water-containing layer	Geological symbol	Structure of well tube	Filter materials (mm)	Depth (m)	Filter pipe	Description
0.50	0.50							Top soil
8.00	7.50							Yellowish brown clayey sand
13.00	5.00				4–6			Gray clayey sand with decomposed wood debris
19.00	6.00							Gray clayey sand
29.00	10.00							Yellowish brown clay
32.50	3.50							Fine sand
42.00	9.50					44.51		Yellow clayey sand
45.00	3.00				2–3			Fine sand
48.30	2.60					48.58		Sandy gravel
61.60	14.00				4–6			Gray clay
74.10	12.50				3–4	74.81		Sandy cobble
75.60	1.50							Clayey sand
85.10	9.50				4–6	81.91		Gray clayey sand
86.80	1.70							Medium sand
92.10	5.30				2–3	89.45		Sandy cobble
94.00	1.90				4–6			Yellow clayey sand

Serial no.	65-2-05	**Underground water layer (m)**	11.5	**Method of joining**	Screw joint
Drilling unit		**Type of drilling machine**	YKC-20	**Date of construction**	2 January 1968
Location	50 m north of Chan Village	**Method of drilling**	Percussion	**Sand content**	
Well diameter at opening (mm)	500	**Type of well pipe**	Cast iron	**Method of well washing**	Piston

must be measured in a laboratory, all the other parameters can be measured in the field. Specific gravity, viscosity, amount of sand, and cohesiveness should be measured frequently, but if the workers find it too troublesome to determine the viscosity, the specific gravity (the ratio of the slurry's weight to the weight of the same volume of water) can be used as a control for other parameters. Specific gravity can be measured easily, i.e., a hydrometer is dipped into the slurry and the reading taken. The specific gravity of ordinary soil is constant between 1.1 and 1.5, whereas in a sandy-cobble layer or artesian groundwater layer, it is calculated as an average of overall conditions and is generally higher than 1.25. The requirements for slurry are briefly:

- When the slurry's specific gravity is 1.1, the amount of sand it contains should not exceed 5%, and the viscosity should not be slower than 17 seconds; the viscosity meter is shown in Fig. 54;
- The well hole should always be filled with slurry to a level not lower than 0.5 m from ground level. If drilling is stopped, the bore-rod should be moved up and down several times every hour as a means to maintain a uniform concentration of slurry throughout the hole; if necessary, fresh slurry should be added. In a layer where the slurry tends to leak or in an easily collapsible layer, the specific gravity of the slurry should be increased, and the duration of drilling interruptions should be shortened; in fact every possible means should be used to bore quickly through that layer. Unless there is a special need, dry clay or clay balls should not be allowed into the hole;
- In a fine sand layer, the slurry's viscosity should be 18–20 seconds; in medium sand, 20–22 seconds; in coarse sand 22–24 seconds; and in gravel, cobble, or fault layers, 24–28 seconds;
- When testing equipment is not available, one can usually estimate sand content by fingering and handling a sample of the slurry; it is considered suitable when no sand can be felt. One can also test viscosity by using a smooth pole; if very little adheres to the pole, the slurry is considered suitable; and
- When there is a thick layer of clay inside the hole, the slurry can be made in the well itself, water being poured into the hole and being mixed by the movement of the drilling machine. However, after the clay layer has been bored through, the new layer must be tested and slurry added accordingly.

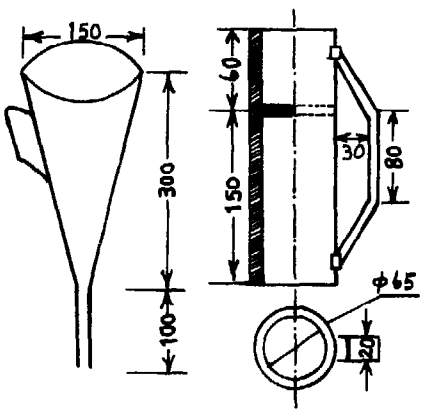

Fig. 54. Viscosity meter; the partition in the centre should be calibrated to indicate the 200 ml and 50 ml levels; φ = diameter.

Sieve Analysis

Sieve analysis of the sand sample taken from a water-containing layer can be carried out in the field; it is necessary in determining the correct terminology and in selecting the right filter pipes and filter materials. After drying the sand sample taken from a water-containing layer, one must carry out sieve analysis. There are several commonly used sieves for particle diameters greater than 10 mm; for diameters 10–2 mm, 2–0.5 mm, 0.5–0.25 mm, and 0.25–0.1 mm and for diameters smaller than or equal to 0.1 mm.

The sieves should be constructed so that they can be stacked — the largest-diameter mesh on top — and can be interlocked and shaken without loss of the sample.

The sample should weigh about 1 kg. After the sieves have been stacked, the sand sample is poured into the top sieve, the one with the largest holes. The interlocked stack of sieves is then covered and shaken vigorously. Finally, the particles retained by each sieve are weighed and recorded (Table 11). The results of sieve analysis should be kept as a permanent record of the well.

Well Casings

There are many types of pipe that can be used as casing for a well. The common ones are steel, cast iron, plastic, asbestos cement, clay, brick, and concrete. The suitability of a particular material is determined by the soil characteristics and the financial resources available. The materials all have a fixed strength and porosity (about 15–35%); the smaller the pipe diameter is, the lower the porosity.

After the drilling is completed and before the casing is lowered into the hole, the well should be measured with a hole-testing apparatus that is 50 mm smaller than the internal diameter of the well. This check is to ensure the hole is circular and vertical. A steel ruler is ideal for measuring the diameter.

Table 11. Sample results of sieve analysis.

Sample no.	Sampling depth (m)	Visual description of soil	Distribution (% total weight) of particles with diameters (mm): ≤0.1	0.1–0.25	0.25–0.5	0.5–2	2–10	≥10	Sieve analysis description
1	25	Fine sand	10	50	30	10	–	–	Fine sand
2	34	Medium sand	5	25	45	20	5	–	Medium sand
3	38	Medium sand	4	16	10	65	5	–	Coarse sand
4	42	Cobbly sand	5	15	50	10	15	5	Gravel medium sand
5	57	Sandy cobbles	–	3	7	30	45	15	Coarse sandy gravel

Attention should be paid to the arrangement of the casing and the well-screen pipes; their locations and lengths should tally with the geological symbols of soils on the drilling log (Table 10) and should be arranged in the order in which the pipes will be lowered. The drilling log should provide an accurate picture of the lengths and types of soil layers and, thus, should be a guide to the types and lengths of pipes required. It also indicates the need for filter materials as well as their type and depth.

The filter pipe and filter materials used should suit the conditions of the soil layers. In coarse, aggregate layers such as medium sand, coarse sand, sandy cobbles, or sandy gravel, it is not advisable to wrap the filter pipe with coir bark (fibrous leaves matted together), coppermesh, or similar materials. However, in fine and powdered sand layers where the filter materials will not prevent the fine particles from entering the well pipe, a thin layer of coir bark can be wrapped around the outer face of the filter pipe.

The well pipes should meet quality standards; substandard pipes should never be used in wells. All the pipes — well-wall pipes, filter pipes, the settling pipe, and the foundation — should be placed near the hole in the order they are to be lowered. When cast-iron pipe is being used, a circular pipe-testing instrument 5 mm smaller than the internal diameter of the well pipes should be passed through the pipes as a check on whether a piston can be used to wash the well.

The slurry inside the hole must be replaced before the pipes are lowered; the concentrated slurry is pumped out while clear water is being added. The water level should not be lower than 0.5 m from the ground surface; this level must be maintained until all the filter materials have been added. Replacing the slurry with clear water is sometimes tricky because of the risk of cave-in, especially of the easily collapsible layers.

A "straightness-supporting device" (Fig. 55), usually wooden, is tied securely to the base, middle, and upper portions of the pipe, so that the well stands straight in the centre of the hole, and an even thickness of filter materials can be placed around the pipe. The clearance between the straightness-supporting device and the hole wall should be 20–40 mm.

If a screw-joint, cast-iron pipe is used, then the screw joint must be cleaned with a steel brush and the pipe hoop must be tested on the two joined pipes. If the pipe is of another type or the joining method is different, all the components of the joint must be properly prepared. If either a cement pipe or a concrete pipe is used, a suitable composition of joint materials by weight would be 43% bitumen, 43% cement (no. 300 or no. 400), and 14% salt. The method of preparing the materials is to place the bitumen in a pot, heating until it melts and then adding the cement and salt. The mixture is then boiled to pastry consistency and applied to the end of the pipe that has been brushed clean. The ends of the two pipes are aligned, pressed firmly together, and secured with thin, flat strips of bamboo tied around the outer wall of the pipe. The bamboo strips prevent the pipe from going awry when it is lowered into the well. This method is dependable and saves time.

Before lowering the pipe, workers place a pipe-lowering wooden support at the opening of the well and drive in four pieces of fixed wooden piles so that it will stay symmetrical to the opening of the well.

The fixed wooden piles are four pieces of rounded timber, 2 m long and not less than 25 cm in diameter (Fig. 56). An iron hoop with a groove should be fastened to the middle of each piling to protect the timber.

A steel cable is used in pipe lowering; diameters of 12.5 mm, 14 mm, and 15.5 mm are suitable and one end should have a loop. Fig. 56 indicates an iron hook is also necessary, but it is common to use a steel bar with a diameter of 20 mm, a length of 30 cm, with a circular hook at one end.

There are two common methods for pipe lowering: one is to use a pipe stopper to hold the pipe while it is being lowered. This method is suitable for cast-iron pipe, which is lowered in stages. The other method is suitable for cement, concrete, and asbestos cement pipes. The preliminary steps (Fig. 57) are to place the cables for

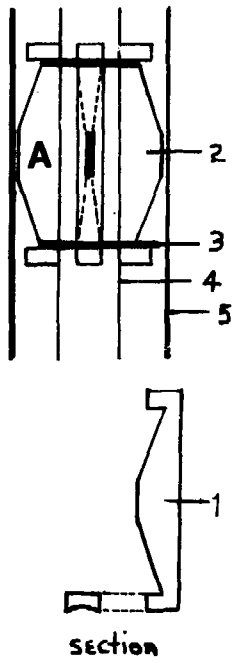

Fig. 55. A straightness-supporting device (1, section A; 2, straightness-supporting device; 3, galvanized wire tie; 4, well pipe; and 5, hole wall).

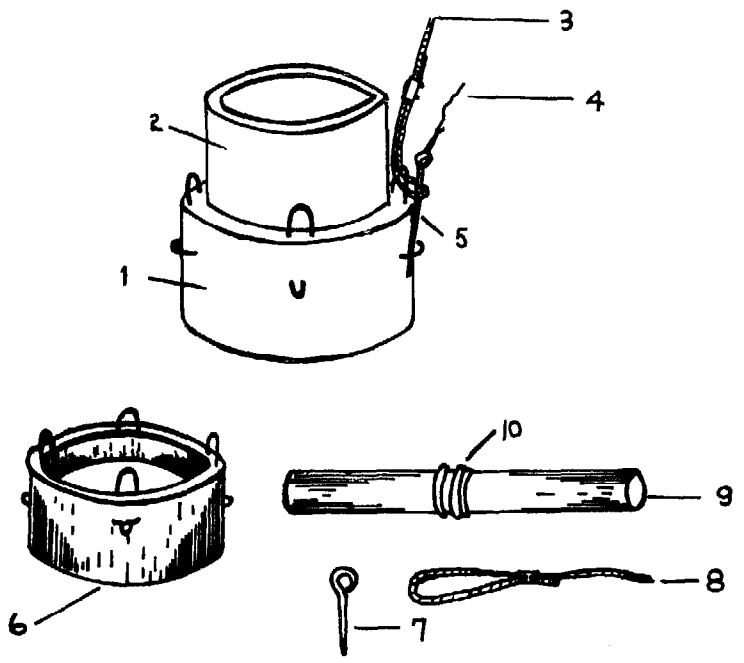

Fig. 56. Pipe-lowering tools (1, base; 2, well pipe; 3, main pipe-lowering cable; 4, secondary cable; 5, hook; 6, base; 7, iron hook; 8, cable; 9, pipe-lowering fixed wooden pile; and 10, groove form iron hoop).

lowering the pipe at the opening of the well, wind one end around the groove of the iron hoops on the fixed wooden piles as a means of control, fix the steel cable loops onto a base with the iron hooks, suspend the base securely over the opening of the well, place the well pipe (usually the sand settling pipe first, the filter pipe next, and finally the well-wall pipe) on the base, fasten the joints with galvanized wire to hold on thin, flat strips of bamboo. Next, the cable is slowly released until the whole pipe is lowered to the bottom of the well.

After all pipes have been lowered into the well, the clearance between the wall of the pipe and the hole must be filled with filter materials that prevent sand getting into the pipe. The choice of filter materials depends on the particle-size of the sand sample taken from the water-containing layer (Table 12). The diameter of the filter materials should generally be 8–10 times greater than the particle sizes in the water-containing layer. The reason is that the physical arrangement of the filter particles is similar to a layer of filter mesh (Fig. 58). The layer of filter particles prevents sand particles in the water-containing layer from entering the pipe and allows the water to flow through. Therefore when selecting filter materials, one must choose well-rounded gravel, not rock debris or other materials. Substandard foreign elements and soil should be removed and should definitely not exceed 10–15%. If the particle sizes of the filter materials are not correct, or there are a lot of foreign elements and soil, then the filter materials will not function properly.

The amount of filter materials should be calculated according to the formula: $\pi(R^2 - r^2)\,h$, where R = well-hole diameter; r = outer diameter of well pipe; h = depth of well hole; and $\pi = 3.1416$. This amount plus 15% should be sufficient.

The opening of the pipe should be covered before filling so that no filter materials enter the well pipe. The materials should be added continuously, gradually, and evenly around the well pipe. If the materials become blocked or arched, an iron bar can be used to pry them loose but the well pipe should not be moved at all. The depth of the filling should be measured periodically, and suitable filter materials (Table 12) should be placed at each water-containing layer. The height of the filter materials should reach 0.7–5.0 m above the height of the water-containing layer. If the water-containing layers penetrated by the well hole are not much different from one another, mixed filter materials can be used. The advantage of mixed materials is that they eliminate the need for repeated measurements and they speed up the process considerably.

In an area where the upper and lower layers are freshwater-containing layers, the space between

Table 12. Relationships between diameter of sand particles in the water-containing layer, filter materials, and filter pipe spacing.

Corresponding sand-particle size in water-containing layer (mm)	Filter materials (mm)	Filter pipe spacing (mm)
0.10–0.15	1.0–1.5	0.75–1.00
0.15–0.25	1.5–2.5	1.00–2.00
0.25–0.50	2.5–4.0	2.00–3.00
0.50–0.75	4.0–7.5	2.00–4.00
1.00–1.25	7.5–12.0	5
1.25–2.00	12.0–18.0	5–7
>2.00	18.0–20.0	7–10

the well wall and the hole should be filled to ground level with filter materials. This procedure facilitates the adding of filter materials if the original material should settle naturally or during well repairs. If the water in the upper layer is undesirable (e.g., saltwater), it should be completely sealed with clay after the filter materials have settled. The seal should begin from 1.0 to 5 m below the layer.

Well Development and Water Testing

Well washing (for well development) is one of the important steps in well-drilling techniques and a key to achieving a good well. It should be done immediately after the filter materials have been added to the hole. Common methods for well washing use a piston, compressor, extractor, or the combination of a piston and a compressor. The purposes of well washing are to remove soil stuck on the wall of the hole, to remove the slurry, to remove any soil in the water-containing layer, and to remove the fine particles in the water-containing layer that are adjacent to the filter materials; this procedure allows the filter materials and the particles in the water-containing layer to arrange themselves naturally and, hence, to form a good underground, water-filter layer. The piston method is applicable to wells in which screw-joint or welded-joint iron pipe has been installed; this method is second only to the combined piston and compressor method. The advantages are that it is highly efficient and that it is thorough, ensuring a good well discharge. Within 2–3 hours washing, the piston method removes the soil stuck on the wall of the well hole and within two or three shifts removes the slurry that has penetrated into the water-containing layers as well as the fine particles. The thoroughness of the method means maximum water discharge. Other methods never achieve this. For example, a well that was being washed by the compressor method only achieved a discharge of 1600 m^3/day whereas when the well was rewashed by the piston method, the final discharge was 2500 m^3/day (under the same water-level condi-

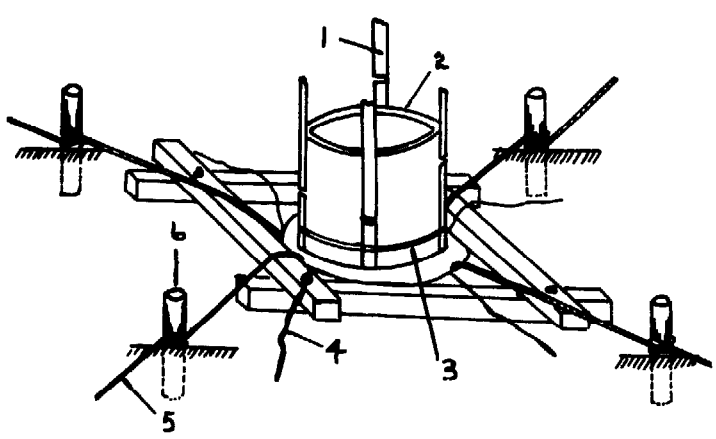

Fig. 57. Pipe-lowering technique (1, thin, flat strips of bamboo; 2, well pipe; 3, galvanized wire tie; 4, secondary cable; 5, main pipe-lowering cable; and 6, wooden pile).

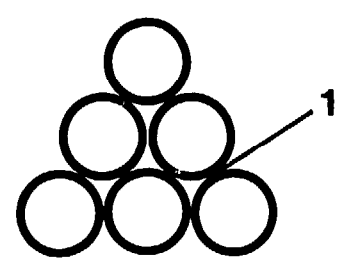

Fig. 58. Arrangement of filter materials (1, space between particles).

tions and at the same depth), an increase of 900 m^3/day.

The piston is made of wood with a groove in the centre, a water outlet in the upper portion, and a water inlet in the lower portion; it is circular in cross section and looks like a date stone (Fig. 59). It is divided in half, and when in use, is fixed on a heavier pulling rod (diameter 50 mm). A rounded piece of iron is welded underneath the "stop ring," weighing down the piston and increasing its speed of descent. A tire or a strip of rubber 8–10 mm smaller than the diameter of the well pipe is nailed in the groove in the middle of the piston. Another piece of rubber is nailed on the top of the water inlet to act as a valve. When the piston ascends, the valve covers the water outlet; when the piston descends, the valve at the water outlet will be pushed aside by the rushing water. The piston should be submerged in water for no fewer than 24 hours prior to being used; this step ensures that the wood does not swell inside the well pipe and become lodged. The ascending speed of the piston should be between 0.5 m/s and 1 m/s. Washing should begin at the upper-most water-containing layer, and the piston should be gradually worked downward. The process should be properly monitored, as it is not advisable to wash the well for extended periods. For fine sand layers, the washing should be carried out until all soil has been removed, the slurry has been cleared, and just a little sand from the water-containing layer gets into the well pipe.

The compressor method is based on pneumatic pressure. The tools are a compressor, water pipe, and air pipe. The two pipes are submerged in the well. The ratio of the depth of air pipe to the total length of the water pipe (the submerged ratio) should be 60–70%. If the submerged ratio is too small, the well will not be completely washed; likewise if the submerged ratio is too high, the compressor may be damaged.

The compressor commonly used has a capacity of 9 m^3/s. The water pipe normally has a diameter of 10.2–12.7 cm, and the air pipe has a diameter of 3.2–3.8 cm. There are two arrangements: concentric and parallel (Fig. 60). How the air pipe is lowered into the well is determined by the characteristics of the compressor, e.g., when a 6 m^3/s compressor is used, the air pipe is lowered into the well up to 60 m. Well washing should be carried out from the upper water-containing layer, and from one layer to the next, finally the well should be washed over its entirety several times.

The extractor method is used when other facilities are not available or when the type of pipe used is not suitable for other methods. The extractor takes up mud and turbid water from

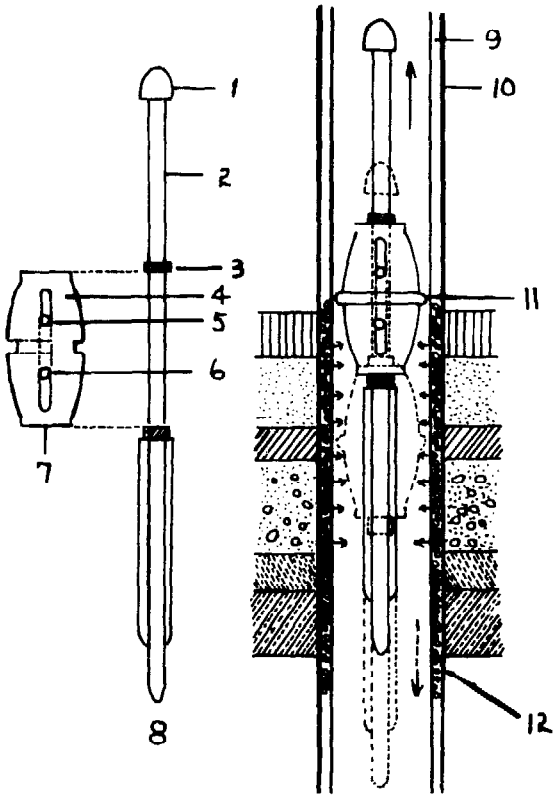

Fig. 59. Piston method of well washing (1, lifting ring; 2, 50-mm round iron bar; 3, stop ring; 4, wooden piston; 5, water outlet; 6, water inlet; 7, wooden piston; 8, pulling rod; 9, well pipe; 10, well wall; 11, tire or rubber strip; and 12, filter material).

inside the well and thereby ensures that the water keeps flowing into the well from the water-containing layer, washing away the stuck soil and clearing the well pipe. This method is very easy to carry out but not very efficient.

The combined compressor and piston method is the best, as it has the advantages of efficiently washing the water-containing layers with the piston and following up with the compressor to clean out any residual dirt. This method is not only fast but also very efficient.

The high-pressure pump method is suitable when there is a large clear-water source adjacent to the well site and when none of the other facilities for well washing are available. A high-pressure pump, however, needs to be complemented by a sand extractor. The method is to pump clear water at high pressure into the well. The pump is made stationary first; then a water-discharge pipe is lowered into the well to clean the walls, the turbid water rising to ground surface via the well pipe. The walls of the well will be cleaned if this procedure is repeated several times. In fact, the clear water can be reused if a

sedimentation pond is excavated next to the clear-water source and the sand is allowed to settle in it. Washing should be done from the top portion of the well down, and the sand extractor used to remove the sand in the bottom of the well.

Water Testing

After washing the well, one must test the water to find out whether the well has been thoroughly washed and also to determine the water discharge as an indicator of the type of pump needed. Water testing is normally carried out with a 90°, V-notch, water-testing box (Fig. 61). The box must be properly placed prior to testing.

Measuring a fluctuating water level is best done with an electric water-level meter (Fig. 62), which uses an electrometer as a measuring device and a dry-cell battery as the source of electricity. One end of a series connection wire is connected to the well pipe or stuck in the ground, and the other end is attached to the measuring head that records the water level. Both the height of the water that flows through the V-notch and the fluctuation are measured. The corresponding water discharge can be found in any standard tables for V-notch wiers. It is better to repeat measurements several times so as to arrive at an average.

Well examination can be done incrementally, item by item, or simultaneously. The former involves examining the important items separately during the construction process and finally putting the well into operation after washing and water testing, whereas the latter is carried out upon completion of construction and under the recommendation of the construction unit. The water is tested and the well is put into operation. Normally, the former method is adopted, because it provides an opportunity for the well users to understand each important item and to monitor the procedures.

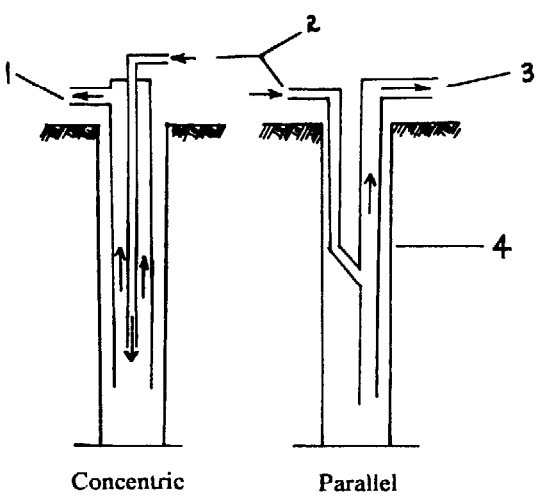

Fig. 60. Air and water pipes in the well (1, water pipe; 2, air pipe; 3, water pipe; and 4, well pipe).

Elements that do not comply with the requirements should be pointed out and rectified. Any problem that raises disagreement should be discussed and resolved. Single examination should only be undertaken if recommended by the construction unit. Whichever the type of examination, it must be carried out in the field by staff from both the construction unit and the users. The construction unit must recommend the items for examination and their quality requirements.

Quality Standards

The steps in examination are to:

- Check all soil samples and sieve analysis results;
- Ensure that the deviation of installed pipe length and well-hole depth is less than 0.2% and the inclination of the well is less than one in a thousand;
- Measure the well-hole diameter and the thickness of filter materials, which should comply with the requirements (normally the thickness of filter materials is 10 cm);
- Make certain that the well pipe is right at the centre of the well hole and that the opening of the pipe is horizontal;
- Determine that the deviation between the filter and the corresponding water-containing layer is less than 0.5 m;
- Establish that the proportions of filter pipe and filter materials and of filter materials and the sand particles in the water-containing layer are correct (Table 12);
- Compare the quantity of filling materials used with that calculated; the difference should not be greater than 5%;
- Check that the seal against undesirable water-containing layers is strong and secure;
- Ensure that all the well pipes have been lowered into the well safely without any cracks or disconnections;
- Measure the sand content with a sand-content measuring cylinder (Fig. 63) after well washing (the amount should be less than 1/10 000 and the water, crystal clear); and
- Ensure that the sodium contents of irrigation water are not greater than 1 g/l Na_2CO_3 (sodium carbonate), 2 g/l NaCl (sodium chloride), and 3 g/l Na_2SO_4 (sodium sulfate) (standards for areas where a water shortage exists can be less stringent).

Upon completion of the well, the construction crew should hand over to the well-operating crew

a final diagram of the geological symbols together with the soil samples, retaining copies. The construction crew should also give the operating crew information about the pump setup and depth of the underground chamber that must be excavated.

Troubleshooting

During construction, failures may occur in the machinery parts or inside the well hole due to either natural factors or human negligence. Failures or obstructions in the machinery can be detected, and, depending on the seriousness of the damage, the machinery will have to be either repaired or removed. Failures inside the well hole can only be detected in the ensuing phenomena. Although there are many failures that cannot be handled properly, and therefore force the well to be abandoned, there are many that can be corrected by the construction workers.

For different types of drills, there are normally salvage tools that are specifically designed to deal with incidents inside the well hole; the main requirement is that the cause of the incident be calmly and correctly analyzed and the location and the depth of the problem measured accurately. Then, a suitable method can be found to deal with the problem. Some common problems during compression drilling and how to deal with them are noted below.

A common incident in percussion drilling is that the drill becomes lodged; if not properly handled, this problem results in serious losses. The main reason the drill sticks inside the hole is that the drilling tool is substandard or needs repair. Other possibilities are that the machinery is being improperly operated by workers trying to speed up drilling; the well hole is not circular; or the diameter of the well hole has become smaller because of a soft soil layer or a rock outcrop inside the well hole. When the upper portion of the drill is stuck, the main causes are a noncircular hole, rock outcrop, reduction of the well-hole diameter, or drill expansion. When dealing with this problem, workers must not force the drilling tool; instead, a secondary windlass should be used to drive the percussion rig slowly. When the bore-bit moves, it should be rotated to an angle that will allow it to be pulled up easily. As an alternative, reverse percussion can be used to break the rock outcrop or any other blockage before the drill is lifted. When the bore-bit is out of the hole, both the bore-bit and the well hole can be repaired. When the lower portion of the drill is stuck, the reason is that the lower portion of the bore-bit has worn more rapidly than the upper portion. When it penetrates to the bottom of the hole, it gets caught in the rock layer. When this happens, a windlass should not be used. Instead, the cable should be pulled tight and shaken vigorously to loosen the drill, or else a jack may be used to raise it. If these methods are unsuccessful, a small amount of dynamite can be used to blast and crack the rock. Once the bore-bit is released, it should be repaired.

A cave-in is a serious occurrence in percussion drilling, the drill always becoming buried. The main reasons for a cave-in are improper use of slurry, lack of slurry, and a running sand layer. A cave-in can actually be foreseen; danger signals are a large piece of earth dropping into the hole, the slurry suddenly rising to the mouth of the well

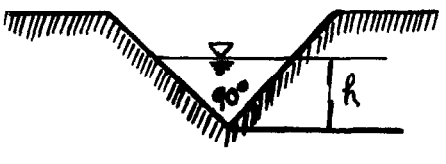

Fig. 61. 90°, V-notch wier.

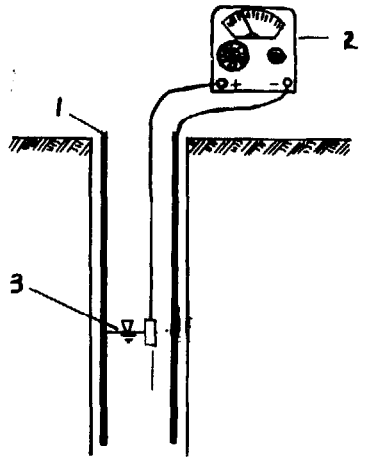

Fig. 62. Water-level measurement (1, well pipe; 2, electrometer; and 3, fluctuating water level).

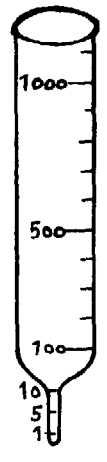

Fig. 63. Sand-content measuring cylinder.

hole, or the slurry suddenly leaking away. When such phenomena have been detected, the drilling tool should be raised immediately, and an investigation of the situation conducted. If the upper part of the hole caves in, a casing should be installed and completely sealed with clay, or the concentration and viscosity of the slurry should be increased. If the lower part caves in, large amounts of clay should be added so that the specific gravity and the viscosity of the slurry are increased. Also, if the hole starts to leak excessive amounts of slurry, the specific gravity and the viscosity of the slurry should be increased.

Another common problem is the broken bit. When the drill breaks or falls into the hole, a straightness-supporting hook or other tool should be used to stand the bore-bit up; then a catch with a hook or a cable loop should be lowered into the well hole, to pull out the tool for repairs. If the drilling tool has a lifting ring, then a hook can be used to lift it.

Many other incidents can occur inside the well hole, and the methods of handling them vary; if the construction crew takes time to analyze the problem carefully, a suitable salvage tool or procedure can usually be found.

Chapter 8

Manual Well Drilling

The principles of manual and mechanical well drilling are similar, as are the basic requirements of the well, but there are different tools and personnel requirements. The three main manual methods are pot drilling, percussion drilling, and hand digging with caison sinking.

Pot Drilling

A "pot-drill" is a manual rotary drilling machine, suitable for use in clayey soil, sandy soil, sand, and sandy-cobble and sandy-gravel layers where the diameter of the cobble is not greater than 50 mm and the amount of cobble not more than 30%. This tool drills quickly, especially in clayey soil and sandy soil; it is also suitable for flat plains areas where the water-containing layer is shallow.

The diameter of the well opening is determined by the diameter of the "pot-head" on the drill, of which two types are commonly used. A large pot-drill will produce a well with a diameter 1.0–1.1 m and a depth of 30–40 m. A small pot-drill can produce a well with a diameter of 0.55 m and a depth of 60–70 m.

The main components of the "pot-drill" are a boring rod, intermediate rod, pot-head, and bore-bit. The boring rod (Fig. 64) is a steel pipe having a wall thickness of 8–10 mm, a diameter of 70–80 mm, and a length of 4 m. On one end is welded a trapezoid male thread, and on the other, a trapezoid female thread (Fig. 64). Because the boring rod encounters great torsion in the course of drilling, it must be made of strong materials, and the welding must be firm and straight.

The intermediate rod (Fig. 65) is made of no. 45 steel with a diameter of 70–80 mm and a length of 2 m; two surfaces are planed at a fixed distance. The intermediate rod is connected to the boring rod with a screw joint, and a pushing rod (Fig. 66) is placed on top and held so that the force is transferred to the pot-drill portion.

The pot-head consists of a frame, a mud-guard tube, a clutch, the body of the drill, valves, cutters, and upper and lower hole-expanding cutters. The mud-guard tube is a steel pipe with a diameter of 95–105 mm; a clutch is welded to its lower end (Fig. 67). The boring rod is inserted into the mud-guard tube, and the pot-head can move up and down the boring rod. During drilling, the pot-head is seated at the bottom of the well; the boring rod is rotated clockwise, a motion that engages the clutch with the "clutch catch" on the bore-bit, so that the pot-drill will rotate. When the drill is lifted up, the boring rod should be rotated counterclockwise to release the pot-head from the catch of the bore-bit; then the pot-head can be lifted out from the well with a windlass. The frame is made of thin steel plate welded on both sides of the mud-guard tube in symmetric locations. The body of the drill, upper and lower hole-expanding cutters, cutters, and valves are all fixed on the frame. The body of the drill is formed by two pieces of half-circular steel plate that are joined together on the frame by hinges, screws, and nuts. In different soil layers, cutters with various angles are used. Generally the large pot-drill should be 15–20°, and the small pot-drill 25° or 30°; they should be used together with the "cow's horns" cutter. Cutters with a small angle are used to drill the hard and clay layers, and those with a large angle are used to drill the loose layers. A "cow's horns" cutter is used to drill the gravel and cobble layers. The cutters should be made of relatively hard steel, for example, manganese steel no. 65, which is durable. The cutters are fixed on the frame by a screw, so that they can be replaced easily. A valve is installed inside the cutter, where soil is brought in, made of thin steel plate and inlaid with thin India rubber; it prevents the trapped soil from falling out. The valve is attached when a sand layer is being drilled and taken out when a clay layer is being drilled. The upper and lower hole-expanding cutters are fixed on the frame to enlarge the well hole; their functions are to reduce the friction between the body of the pot-drill and the wall of the hole, to reduce the diameter in a loose layer, and to prevent the hole from caving in

Fig. 64. Boring rod.

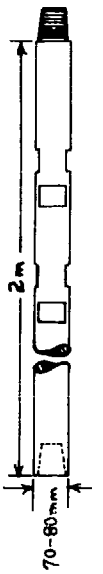

Fig. 65. Intermediate rod.

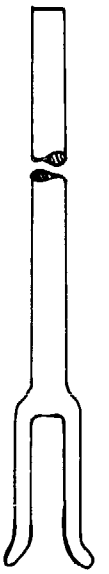

Fig. 66. Pushing rod.

when a temporary vacuum is formed by the lifting of the pot-head.

The bore-bit facilitates the pot-head's soil penetration. There are two types of bore-bits, spiral (Fig. 68) and fish-tail (Fig. 69). The former is used in sandy-loam soil, sand, and cobble-sand layers, and the latter in clayey-soil layers.

Once the pot has filled with soil, it must be lifted and the soil poured out. The claw is one suitable tool for lifting; when lowered into the well along the boring-rod, it grabs the pot-head and lifts it up (Fig. 70). Sometimes, the pot-head is connected to the cable of a windlass (Fig. 71), which is a very convenient tool for lifting and lowering. The windlass is either manually or electrically driven, at low speeds of revolution; it is commonly used for lifting and lowering the pot-head and the boring rods.

In manual operations, scaffolds (Fig. 72 and 73) are needed; a suitable structure for the pot-drill and windlass is made up of four intersectionally bound, 8 m long deal (crytomeria) poles; the vertical distance from the centre is not less than 5 m, and the lower end of each deal pole is buried 0.8 m underground. An awning frame is installed 2.5 m aboveground with a stopping ring on one side, poised above the centre of the well. Protecting planks (two) are placed over the opening of the well, and a second stopping ring is placed in their centre. A pulley is tied at the intersection of the scaffold, and a ground pulley is fixed between two adjacent poles, the structure forming a lifting system with the windlass. The top pulley, ground pulley, stopping ring of the awning frame, stopping ring of the well opening, and the cable of the windlass are along a vertical plane (Fig. 72).

To operate the setup, 12–15 persons are needed, with a leader responsible for the construction work. Four persons are responsible for lifting and lowering the pot-head, removing the soil at the well opening, and preparing to insert the pushing rod into the intermediate rod and rotating it. One person is responsible for closing and opening the stopping ring at the awning frame, two persons supply the slurry, two persons operate the wind-

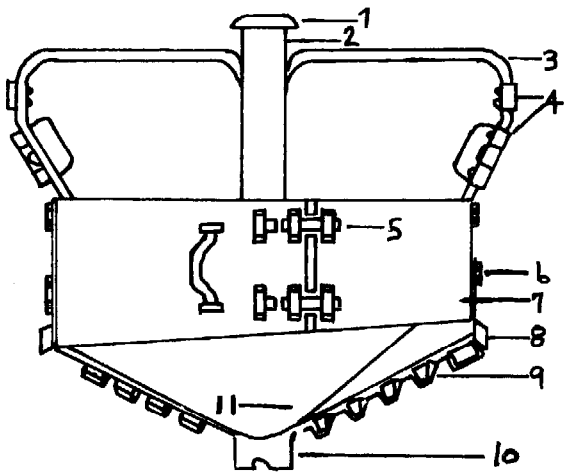

Fig. 67. Large pot-drill (1, flange; 2, mud-guard tube; 3, frame; 4, upper hole-expanding cutters; 5, screw and nut; 6, hinges; 7, the body of the drill; 8, lower hole-expanding cutters; 9, cutters; 10, clutch; and 11, soil inlet).

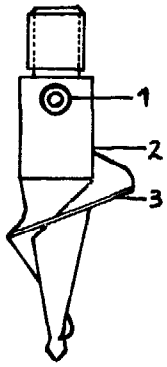

Fig. 68. Spiral bore-bit (1, clutch catch; 2, sharp-cone body; and 3, spiral cutter).

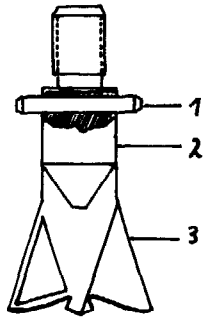

Fig. 69. Fish-tail bore-bit (1, clutch catch; 2, sharp-cone body; and 3, fish-tail cutter).

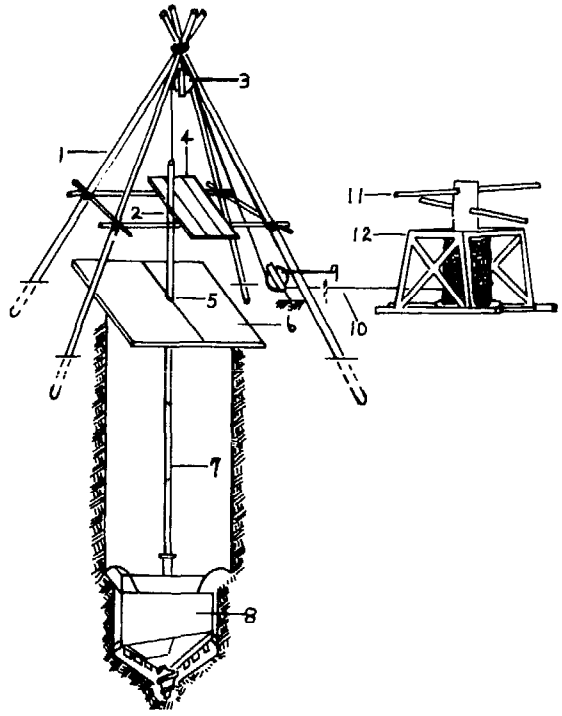

Fig. 72. Scaffold for a pot-drill (1, scaffold; 2, stopping ring at the awning frame; 3, top pulley; 4, awning frame; 5, stopping ring at the opening of the well; 6, door at the opening of the well; 7, boring rod; 8, large pot-drill; 9, ground pulley; 10, steel cable; 11, windlass pushing rod; and 12, manual windlass).

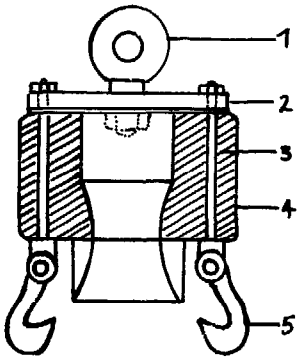

Fig. 70. Claw hook (1, lifting ring; 2, lifting body; 3, lifting rod; 4, supplementary weight; and 5, claw hook).

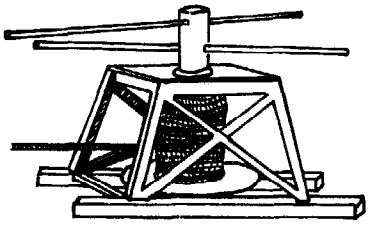

Fig. 71. Manual windlass.

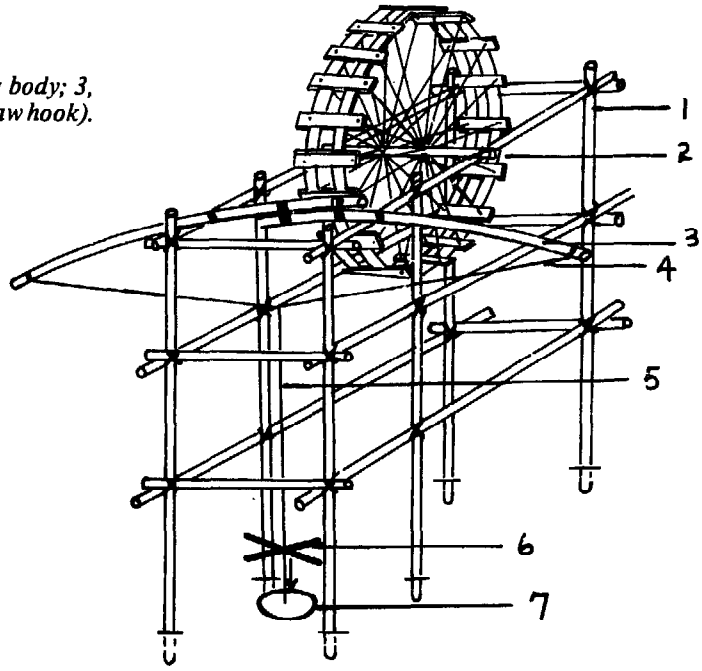

Fig. 73. Scaffold for percussion drilling (1, scaffold; 2, wheel; 3, bow; 4, bow string; 5, lifting rope; 6, press stick; and 7, well opening).

lass, and one person records the information about the soil layers. All take part in pushing the pot except one or two who remain with the windlass; when lifting the pot, all take part in pushing the windlass except one person who remains at the opening of the well.

With this setup, there are several matters requiring special attention:

- Slurry should be kept inside the well at a level not lower than 0.5 m below the well opening;
- The screw joint of the boring rod must be properly protected and kept clean when in use. Faulty boring rods should be rejected, and the number of people rotating the pot should not be more than 8–10; otherwise the risk of breaking the boring rod is high;
- The angles of the pot-drill cutters should be varied according to the type of soil being drilled;
- The pot-head should be lifted and lowered at a uniform speed. It should not be pushed by force, reversed, or shaken; instead, it should be lifted up slightly, changed to another angle and rotated again. If the bottom of the pot becomes slippery and will not advance any deeper, the cutters should be changed to a larger angle;
- Whenever the drilling is stopped, the pot-head should be lifted 2–4 m from the bottom of the well; this measure prevents it from being buried;
- The pot-head should be rotated clockwise so that the boring rod does not fall off;
- When the pot-head is being pushed or rotated in a shallow layer, it should be pushed and filled quickly; in a medium-depth layer it should be pushed and filled slowly; in a deep layer it should be pushed slowly and filled halfway. In other words, the rotating speed and degree of filling must be changed according to the soil layer.

Manual Percussion Drilling

Scaffold drilling is one type of manual percussion drilling and is extensively used in China for deep wells. The structure is simple and easy to make, and the operation can be easily controlled.

The structure consists of a wooden scaffold, a wheel, thin-flat strips of bamboo, bore-bit, bow, bailer, and protective casing at the well opening (Fig. 73).

The wooden scaffold is made of six vertical poles and three layers of horizontal poles. Each vertical pole is 20 cm in diameter, 7 m high, 6 m being aboveground and 1 m being buried.

The wheel comprises the axis, spokes, and stepping planks. The wheel is 4.2 m in diameter; around it thin, flat strips of bamboo are fastened. The axis is made of two steel rods with diameters of 50 mm and lengths of 2.5 m. The wheel has two sets of spokes and two parallel supports for stepping planks. One set of spokes is 14 steel rods 16 mm in diameter; each spoke is slightly longer than the wheel's diameter and a ring is fastened at its centre to fix it to the axis of the wheel. Both ends of the spoke are provided with screws so that the stepping planks can be fixed on top. There are 14 stepping planks, each 1.2 m long, 12 cm wide, and 12 mm thick, their length equal to 7% of the circumference of the wheel; they are joined firmly to the spokes, forming the circumference of the wheel.

The bow should be made of newly felled elm with a diameter not smaller than 20 cm and a length of about 10 m. The bowstring should be steel cable or thick, strong, elastic hemp rope.

Thin, flat strips of bamboo, 50 mm wide, have both ends trimmed to a square joint that allows extension (Fig. 74). They are connected to the bore-bit and facilitate lifting of the drilling tool.

Generally an extractor-type, hollow-valve bore-bit is used. It is made of steel pipe 2.5 m long, with a diameter 200 mm; a strong, bell-mouthed cutter is welded to the bottom of the pipe; a handle joint to the upper part of the pipe. A valve is fixed to the cutter. The welding is with "flying wings" with supplementary heavy reinforcement on the perimeter of the steel pipe (Fig. 75).

The bailer is an iron plate, 5.7 mm thick, rolled and welded to form a 2.5 m long cylinder with a diameter of 250 mm; the bottom of the bailer encases a valve cutter, and the top is welded with a handle joint.

A protective casing made of timber or iron plates, with a diameter of 50–60 cm and a length of 2 m, is used to protect the well opening.

First, the protective casing is placed firmly inside the excavated well opening. The bowstring faces the centre of the well opening; the bore-bit with the thin, flat strips of bamboo is hung by rope on the bowstring. Two intersection sticks are tied on the lifting rope, and then slurry is poured into the well and the bore-bit lowered. Pressing the sticks causes the percussion, and the bore-bit rebounds by the force of the bow. The bore-bit should be rotated during percussion so that the hole being drilled is made circular and vertical. When the slurry becomes concentrated and makes percussion and rebound difficult, the bailer is used to remove the soil. If the thin, flat strips of bamboo are not long enough, several can be connected together by the "square-joint" and made secure with an iron hoop. The wheel is used to bail soil and to lift and lower the bore-bit. Lifting and lowering must be carefully controlled, and the person who steps on the wheel must prevent the

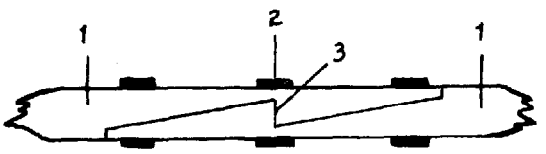

Fig. 74. Joining of thin, flat strips of bamboo (1, slim, flat strips of bamboo; 2, iron hoop; and 3, square joint).

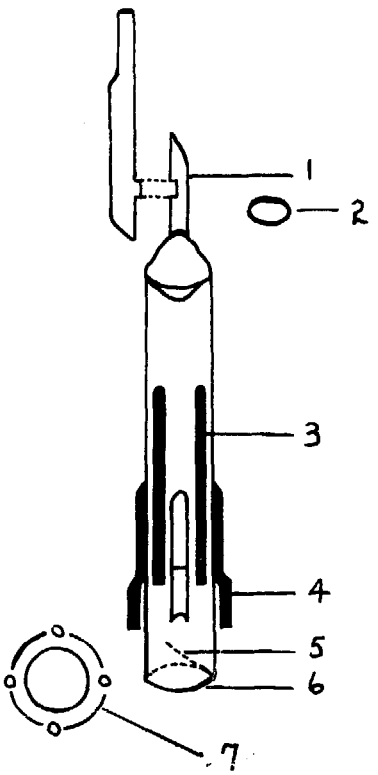

Fig. 75. Bore-bit, (1, joint; 2, hoop ring of the joint; 3, supplementary heavy reinforcement; 4, "flying wings"; 5, valve; 6, bell-mouthed cutter; and 7, view from below).

wheel from running out of control when the well is deep. The section on troubleshooting in chapter 7 is equally applicable to manual percussion drilling.

Matters requiring special attention are that:

- The bowstring needs to be tightened periodically, as its elasticity decreases during use;
- The valve at the bore-bit must constantly be kept flexible; otherwise it will have to be replaced or repaired;
- The cutter and "flying wings" need to be monitored for wear or damage; their dimensions should comply with the standard, and if they become damaged, they should be repaired, welded, or replaced; and
- The wheel and the hoops on the thin and flat strips of bamboo should also be examined regularly; the wheel loosens through use, and the hoops wear out. If these items are not properly maintained, the bore-bit will fall and the thin and flat strips of bamboo will break.

Hand-Dug Well: the Caisson-Sinking Technique

Well sinking is a safe construction method for large-mouthed wells; construction is simple and suitable for a single, water-containing layer close to the surface. The main tools needed are a windlass, pulleys, and a tripod (Fig. 76). The windlass consists of a frame, steel cable reel, electric motor, and handbrake.

There are two pulleys (Fig. 76b), one fixed on the tripod and one fixed near the opening of the well, forming a lifting system with the windlass. The tripod, as the name indicates, is three poles whose diameter is not smaller than 20 cm, tied intersectionally; it stands over the well opening to form a lifting system with the windlass.

The well pipe should be a 125–150 mm thick, double layer, circular steel-reinforced concrete pipe, 1.5–2.0 m in diameter. The filter pipe should be the same type of pipe with small holes as water inlets (Fig. 77).

Bitumen cement is the joint material to be used between pipes, and supporting plates are used to hold them in position (Fig. 78). The joint material is composed of 43% bitumen, 43% cement, and 14% salt The method is to drill a hole in the side of two pipes 11 cm from the ends to be joined so that the distance between the two holes, when aligned, is 22 cm. Then, after the bitumen mixture has been applied and the pipes placed in position, the supporting plate is bolted to both pipes. Usually the procedure is to attach a supporting plate on each side of the pipes. The supporting plates are 7–8 mm thick, iron, 30 cm long, and 7 cm wide. The holes on the iron plate (Fig. 79) should be slightly larger than the diameter of the screw (2.0–2.5 cm). The screw is 225 mm long or may be made from 250 mm of round steel (Fig. 80); the thread should be 8 cm long. The digging consists of seven persons: an operator, a commander, two to push the windlass, and three to work inside the well. If the progress is fast, the number of persons pushing the windlass and those working inside the well can be increased.

Before well construction begins, a pit deep enough for a length of well pipe should be hand dug at the well opening; then the bottom filter pipe with water inlets should be lowered into the well by chain-block and placed in a horizontal position. The second filter pipe is then lifted by chain-

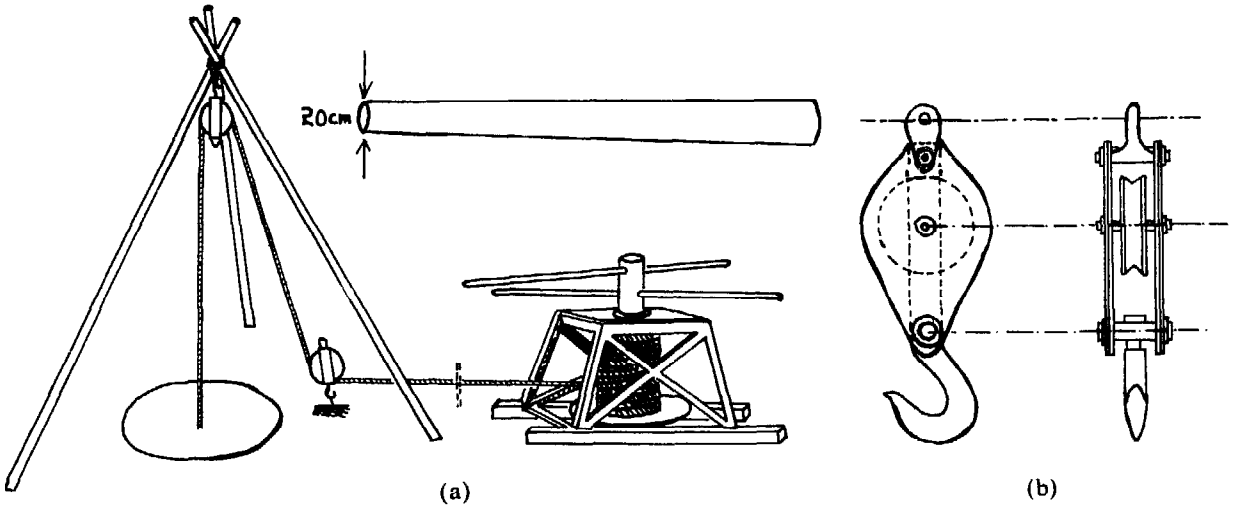

Fig. 76. Tools for caisson-sinking technique: (a) tripod and its arrangement in a well field and (b) pulley.

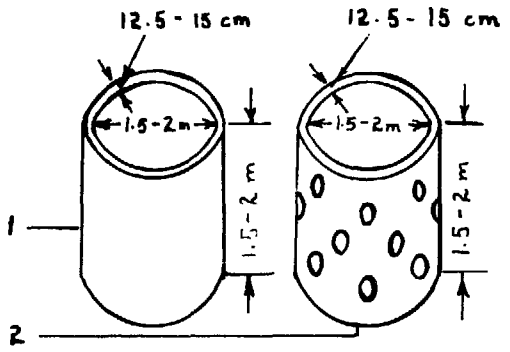

Fig. 77. Well pipes for large-mouthed well (1, solid pipe and 2, filter pipe).

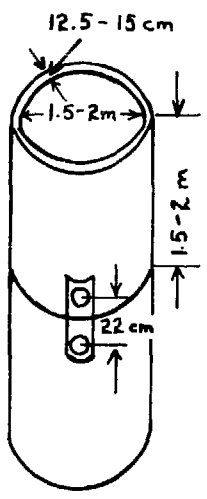

Fig. 78. The joint between the two well pipes.

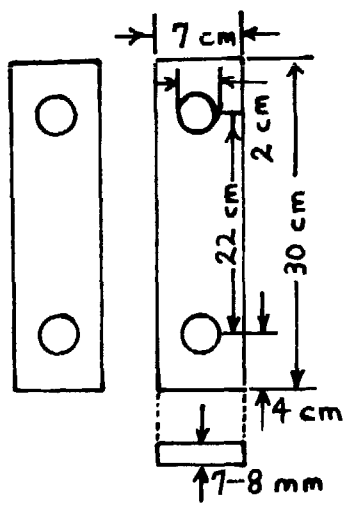

Fig. 79. Supporting plate.

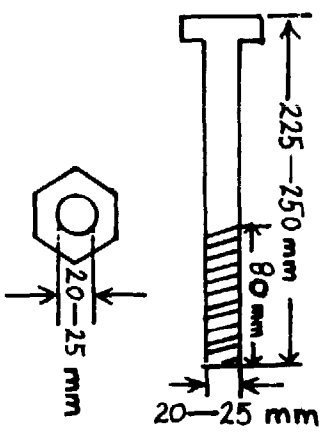

Fig. 80. Screw and nut for pipe joint.

ock, a layer of joint materials applied to its end; then lowered onto the first filter pipe, supporting plates being attached appropriately (generally six and eight pairs of supporting plates are used for wells having a diameter of 1.5 m and 2 m, respectively). The screw's thread end should face inside the pipe when the screw is being inserted so that the external pipe wall is smooth and friction during lowering is minimized. Once the pipes are joined, workers should get inside the pipe and begin excavation. It is extremely important that excavation be carried out evenly all around the pipe, so that the pipes stay relatively level as they sink and strain on the joints is minimized. When groundwater is encountered, it should be pumped out before excavation is continued; all the soil layers should be recorded in a drilling log as the work progresses (see chapter 7).

Advantages

Because the well-sinking method uses precast well pipes, it is not necessary to support the wall of the well. Cave-in does not occur during construction, and the people working inside are safe. The method is labour-saving compared with others using brickwork. Penetration through running sand layers is relatively simple, and in an area where the water is deep underground, the workers can dig as deep as 60 m.

This method should be employed in a dry season when the underground water is at a minimum, as this makes work easier and guarantees the water discharge upon completion.

When the well is completed, a pump stage should be constructed 1.5 m higher than the highest water level and the pumping equipment installed on it.

Chapter 9

Well Repairs and Damage Prevention

Due to their poor quality and improper maintenance and operation, some well pipes become disconnected; damage is caused by sand, and siltation occurs. The discharge from the wells becomes markedly reduced, and some even have to be abandoned. To regain water output and further agricultural production, workers not only must build new wells but must repair and maintain old damaged wells. A standard procedure has been established for checking, repairing, and preventing well damage. In China, more than 100 damaged wells have been renovated, all regaining their original capacity.

The methods of repair and prevention are economic and simple, and they produce good results. They have been popularized widely in China and are fully accepted by the people.

Well Inspection

According to field surveys, the causes of damage to open-mouthed, concrete wells are poor design and construction, improper maintenance and operation, and improper diagnosis and handling of problems (see chapter 7). Some of the common manifestations of the three causes are:

- An air pocket forms next to the well wall and causes the pipe to collapse; the construction fault is that (1) the diameter of the hole is much larger than that of the well pipe, (2) the thickness of the gravel filling layer is less than 10 cm, or (3) the gravel filler has been added too quickly and, hence, has created obstruction; when pumping is under way, sand enters the well and the external filler moves to produce the air pocket;
- Part of the pipe sinks and becomes disconnected; this indicates that (1) the final drilling did not reach an impervious layer of clay, (2) the well hole was not cleared before the well pipes were lowered, or (3) the pipe does not reach the bottom of the hole;
- The joints open or crack when pumping begins; possible causes are that (1) the well hole is not straight, (2) the well pipes are not round, (3) the joint is not properly reinforced, or (4) the quality of the clay rings is poor; and
- The water discharge is minimal, or siltation is apparent in the water; these problems probably reflect (1) an incorrect proportion between the particle sizes of the filter pipe aggregates or the gravel filling layer and the particle sizes of the water layer, (2) irregular filter materials such as kiln dregs or brick being used as filler, or (3) the well not being covered or protected by a pump house or well platform so that stones, bricks, or mud have been thrown into the well or have been washed into it by heavy rains.

The most common mishandling of a problem is the use of some object, such as a cone, to remove sediment or to knock down obstructions in the well. This approach to the problem of blockage or siltation often results in broken pipes.

Abrupt changes, for example, a discharge of brackish water, an extensive blowout of sand, or a decrease in water quantity, indicate that the well pipe has broken; the pump must be switched off immediately before the well wall collapses. In such circumstances, the pumping facilities should be taken from the well and the damaged well pipe examined carefully. The steps are to insert a measuring rope and determine the height of siltation inside the well, an approximation of the location of damage. When the pipe breaks, the gravel filler becomes damaged because during pumping water feeds continuously from the water-containing sand layer into the well and brings with it sand particles. The particles settle until they reach the height of the breakage.

A more accurate and immediate checking method is to use a soil-receiving container (Fig. 81). The soil containers are firmly joined in series at 1 m intervals by a measuring rope. The containers are made of no. 8 galvanized wire that has been bent into a circle and gauze that has been sewn securely to the wire ring in a cone shape. The diameter of the container is 2–3 cm smaller than the internal diameter of the well pipe so that it can

be easily lowered into the well. A heavy weight is hung at the bottom of the measuring rope, a small piece of brick is placed inside each soil-receiving container so that the measuring rope remains parallel to the well pipe and the soil receivers are kept upright and stable. First, the soil-receiving containers are lowered into the well, then a rubber suction pipe is installed, and the pump is switched on for 3–5 minutes, the sand particles in the water-containing layer immediately flowing into the well. Then, the rubber pipe and soil-receiving containers are withdrawn and their contents examined. Sediment in a soil-receiving container means there is a break somewhere above that container.

If the level of silt has already reached the break, this method cannot be used. The well must be cleaned or washed before the examination. A pressure hose is used to wash out the sediment. A 3-inch (7.5-cm) diameter rubber tubing connected to a 20-mm diameter steel pressure hose (Fig. 82) is lowered to about 300 mm above the sediment. Then, the water is pumped out. The pressure will scatter and wash out the sediment as the water flows out of the well. As the depth of sediment is reduced, the pressure should also be gradually reduced, especially near the area where the break is thought to have occurred. After the hose has been lifted up, water has to be reintroduced into the well to keep up the pressure until the examination with soil-receiving containers and the repair of the well pipe have been completed.

If damage in the well pipe is only a crack or a few small holes, then repair work can be carried out at once. However, if the well pipes have become disconnected then a pipe-knocking instrument has to be used to bring the pipes into correct position before any repair work can be done. To indicate the nature of damage, a guiding instrument (Fig. 83) is used. This instrument is a 4-m long rod with lantern-shaped bamboo bows fixed to both ends; the diameter of the lantern shape must be 3–4 cm smaller than the internal diameter of the well for easy insertion. During examination, the guiding instrument is lowered gradually into the damaged portion. If it passes through without obstruction, the implication is that the side of the well pipe is broken; if its pathway is obstructed, the well pipes are probably disconnected. The pipe-knocking instrument (Fig. 84) can be used to bring the pipes into line. The pipe-knocking instrument is similar to the guiding instrument except that the two bamboo-bow circles in the latter are replaced by an elliptical piece of wood, tightened by a screw. Its function is to knock, repeatedly along the length of the well until the pipes are brought into their correct position.

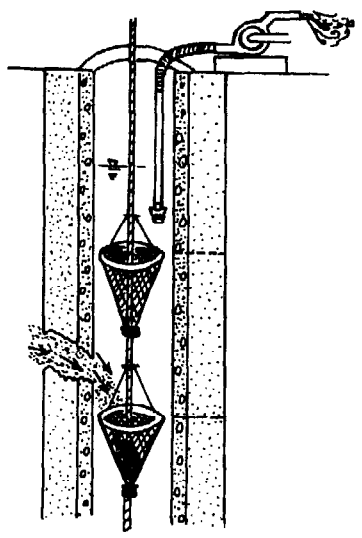

Fig. 81. Soil-receiving container: a tool to locate damage in a well pipe.

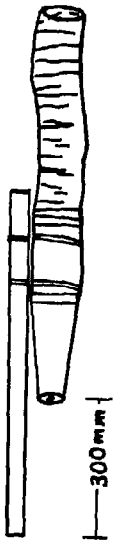

Fig. 82. Pressure hose.

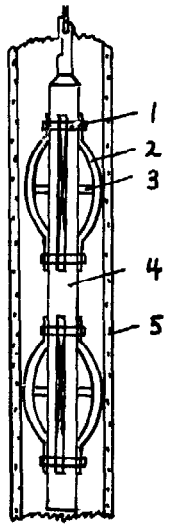

Fig. 83. A guiding instrument (1, galvanized wire fastening; 2, bamboo bow; 3, supporting pole; 4, core; and 5, well pipe).

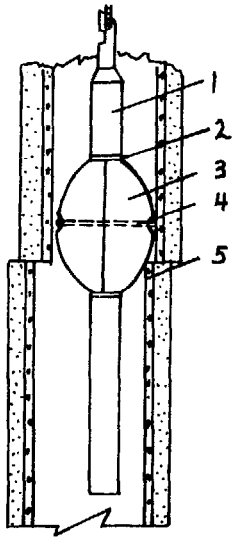

Fig. 84. Pipe-knocking instrument (1, core; 2, galvanized-wire fastening; 3, knocking pole; 4, screw; and 5, well pipe).

Well Repair

Repairing a damaged well consists of placing a repair pipe in the well; this procedure seals the broken hole, stops the sand from coming in, and restores normal water supply. The structure, shape, and material of the repair pipe depend on the structure and type of the well as well as the location and type of damage. The three types of materials used are plastic, sheet metal, and bamboo-

strip matting (coir). The three types of repair pipe are fixed-diameter, variable-diameter, and bell-mouthed. Its structure can be either fixed or movable.

There are two main parts to the repair pipe, the seal and the support. The seal is provided by two bamboo-mat bowls, one attached to each end of the repair pipe; the support is a mechanism in the middle of the repair pipe, a holder, that supports and stabilizes the pipe.

The bamboo-mat bowl (coir bowl or head) is designed according to the shape of the well; it can be either fixed or movable (expansive or contractive). A bowl with a fixed diameter is used in damaged wells that have the same diameter throughout, whereas a movable bowl is used for repairing damaged wells that have a larger diameter at the upper end. The fixed-type bowl is made from three or four layers of bamboo-strip matting. The width of the bowl is 20 cm, which consists of one expansive bamboo ring wrapped with a layer of plastic cloth that protects the bamboo sheet and increases its smoothness. The construction of the movable bowl is similar, but the upper bowl is fixed and the bottom bowl expands and contracts. The bottom bowl is made of three layers of bamboo-strip matting sewn into one piece with string, the upper end tied firmly with galvanized wire and the lower end pressed hard with iron sheet; the inner ring is supported by two bamboo rings. The iron sheet ring is 10 cm wide, and its diameter is slightly bigger than the outer diameter of the repair pipe so that it can move vertically. Two poles are fixed symmetrically to the iron ring. A rope is fastened to the upper ends of the two poles. At the bottom of the iron ring, a supporting plate is attached with two galvanized wires. When the poles are lifted, the iron ring moves upward, the supporting plate forces out the holders, and the diameter of the bowl enlarges and seals up the opening between the repair pipe and the well pipe (Fig. 85). The support or holder is a 2–3-mm thick black iron sheet forming a 12-cm long teeth-shaped iron claw. According to the length and weight of the repair pipe, the claw is either fan-shaped or bat-shaped, nailed directly onto the repair pipe, three teeth facing up and two teeth facing down, in order to increase the stability. This shape is suitable for short (e.g., 2–2.5 m), light sheet-iron repair pipes. Another type of holder is an iron claw nailed to both ends of a bamboo bow. This holder uses four pieces of 80-cm long by 4-cm wide bamboo sheet that are formed into bows. The rough surfaces of the bamboo sheet are smoothed; the sheet is soaked for an hour and heat is applied at the centre so that a bow can be formed. The centre of each bow is

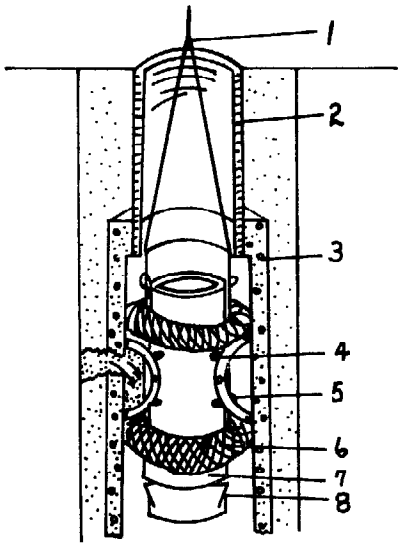

Fig. 85. Repairing a narrow well (1, rope; 2, iron pipe; 3, cement pipe; 4, iron-claw fixer; 5, pole; 6, expanding–contracting bowl; 7, iron ring; and 8, supporting plate).

tied with no. 10 galvanized wire firmly onto the repair pipe. This holder is suitable for 2.5–3 m repair pipes. At the base of the expansive and contractive part of the holder, small springs made of no. 12 steel wire are fixed all around to squeeze the repair pipe to the inner wall of the well.

Unlike standard plastic repair pipes, the sheet iron and bamboo matting pipes are made by hand. The sheet-iron pipe is steel rolled into the form of the repair pipe. Based on the type of well and the position of damage, the repair pipe is a uniform diameter, a variable diameter, or bell-shaped (used to repair the holes in concentric pipes, variable pipes, and wide-mouthed pipes respectively) (Fig. 86).

Bamboo/palm coir repair pipe is made from several old discarded cart hub rings, which provide the internal support, and 4 cm-wide bamboo pieces that are nailed 1 cm apart onto and around the hub ring. The number of rings depends on the length of repair pipe; their diameter depends on the internal diameter of the damaged well. The repair pipe is wrapped with a plastic cloth, five layers of bamboo, and another layer of plastic cloth, all of which is firmly tied with no. 20 galvanized wire. This type of pipe is cheap, and the materials are easily obtainable; it is suitable for repairing large-diameter brick and cement pipes.

After clearing the sediment in the well, examining the position and characteristics of damage, selecting the structure and shape of repair pipe, workers can begin installing the repair pipe and

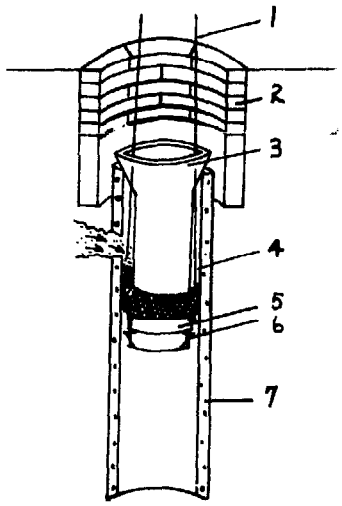

Fig. 86. Repairing a wide-mouthed well (1, rope; 2, brick pipe; 3, bell-mouthed sheet-iron repair pipe; 4, pole; 5, iron ring; 6, supporting plate; and 7, cement pipe).

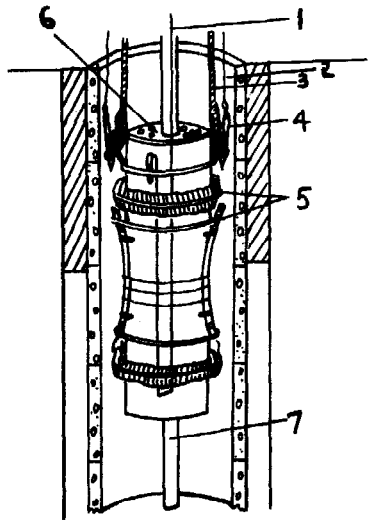

Fig. 87. Lifting and lowering the repair pipe (1, rope-cutting [no. 10] galvanized wire; 2, wire; 3, insert wire; 4, insert; 5, rope; 6, wooden cover; and 7, boring rod).

doing the renovation. The method and tools for the installation (Fig. 87) are:

- Pipe-lowering tool, which is a boring rod longer than 4 m with steel wire attached to the top and T-shaped wooden covers attached to the upper half to press the pipe down. Holes in the wooden covers reduce the buoyancy when the water is being replaced. More than 30 cm of pipe must be pressed down.
- Pipe-releasing insert, which resembles a cone, 1 cm wide × 10 cm. A rope is connected to the pipe by means of this insert. When the repair pipe has been lowered to the damaged area, the insert is pulled out and the rope released.
- Rope-cutting (no. 10) galvanized wire, which is used to lower the pipe. Before installing the repair pipe, workers must ensure that the rope tying the bamboo-arc ring to the bamboo-matting bowl and the iron claw holder is tight so that the external diameter of the repair pipe is minimized and the pipe can be easily lowered into the well.

After the repair pipe has been placed in position, all the ropes have to be cut so that the repair components expand and fulfill their purpose. The ropes are cut with a piece of no. 10 galvanized wire, longer than the depth of the installation, with one of its ends connected to the insert and tied firmly at the opening of the repair pipe and the other end passing through all the ropes that have to be cut and extending out of the well. Pulling the galvanized wire cuts the ropes; then the bamboo-arc ring in the bamboo-matting bowl and the iron claw of the holder will expand so that the repair pipe is squeezed against the inner wall of the damaged pipe (Fig. 88). After the repair pipe has been installed, a pressure hose is used to wash out all the sediment. Because of improper repairs or discovery of new holes below a repair, sometimes a repair pipe must be lifted and further repairs done. The tools and technique for lifting the repair pipe are comparatively simple: a crimped hook is used for lifting; it is made of a boring rod (32 mm diameter) with a trapezoid-shaped knife fixed at the bottom (Fig. 89). Holes are drilled at both ends of the knife and steel wire attached; the knife is bolted at its centre to the boring rod. The apparatus is lowered into the well, one of the steel wires being pulled so that the knife is nearly vertical and is able to pass through the repaired area completely; then the other steel wire is pulled so that the knife is horizontal and can act as a lift for the repair pipe.

Well-Construction Technique

The quality of a well depends on its construction, maintenance, and use, and there are several key elements that should be emphasized. These include:

- The diameter of the excavated hole, which must be based on the thickness of the well pipe and the water-filtering layer; generally, it must be 20 cm greater than the outer diameter of the well pipe so that the water-filtering layer is the correct thickness.
- The soil layer at the bottom of the hole, which must be a hard, solid, impervious layer to

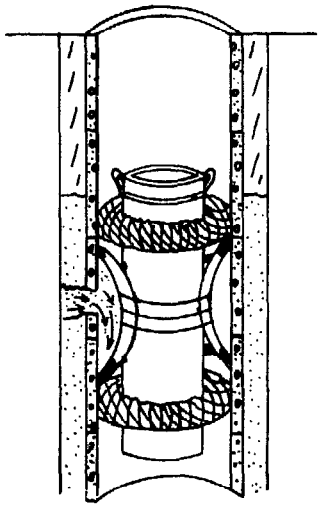

Fig. 88. Installed repair pipe.

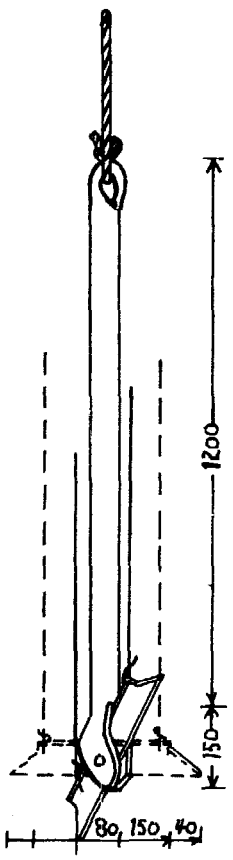

Fig. 89. Crimped hook for lifting repair pipe (unit = mm).

prevent the well pipes from settling, disconnecting, or sliding out of line.

- The particle size of the aggregate (gravel) for a multiporous, concrete, filter pipe, which should be 16–20 times the average particle size of the sand in the water-containing layer, whereas the average particle size of the gravel-filter layer should be 8–10 times as great.
- The well shape and diameter of the well pipe opening, which depends on the type and standard of water-pump facilities; in some cases, the upper portion of the well has a larger diameter than does the lower portion, and they are joined by an adapter. In such cases, a deep-well pump with a large capacity can be installed.
- The quality of the multiporous filter pipe, which must be strong enough to withstand pressure and at the same time porous enough to allow water to pass through; the mouth of the pipe must be horizontal and circular; good strong adhesive bitumen, sand, slurry, and clay improve the strength of the well pipe and thus prevent disconnection, opening, sliding out, and breakage.
- The standards and performance of the filter layer, which must be appropriate to the water-containing layer; the gravel filling must be 2–5 m higher than the filter pipe and must be added consistently, slowly, and continuously.
- The timing of well washing, which should be immediately after construction has been completed; while the well is being washed, the pump must be operated at a higher rate than that used for normal pumping, and washing must continue until the turbid water turns clear. Whenever sediment occurs inside a well, the washing should be repeated.
- The contents of the pump house, which must include all the facilities necessary for maintaining the pump.
- The special washing of the multiporous filter pipe, which is accomplished with a wire brush (Fig. 90) and a water-jet (Fig. 91); this is not

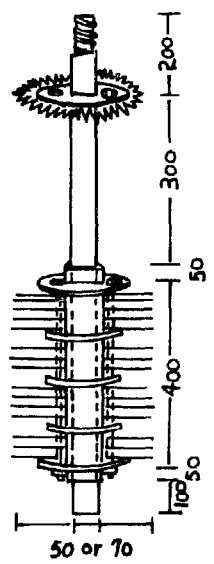

Fig. 90. Steel-wire brush (unit = mm).

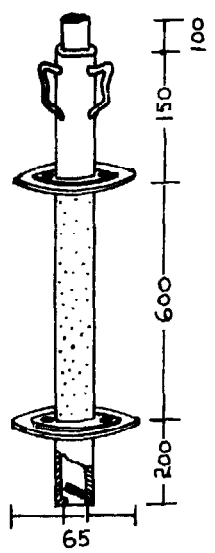

Fig. 91. water-jet (unit = mm).

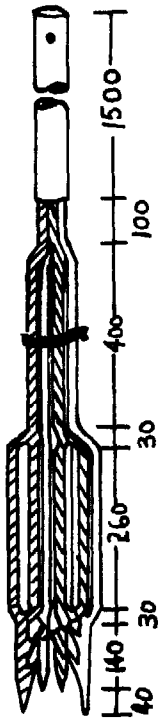

Fig. 92. Brick-salvaging equipment (unit = mm).

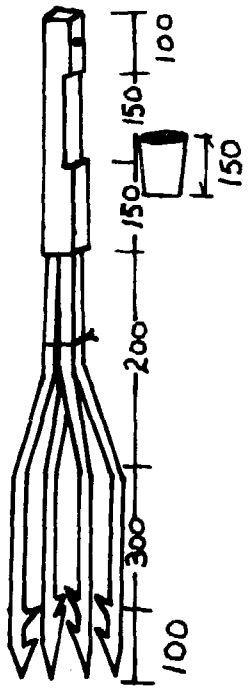

Fig. 93. Fork-and-hook instrument (unit = mm).

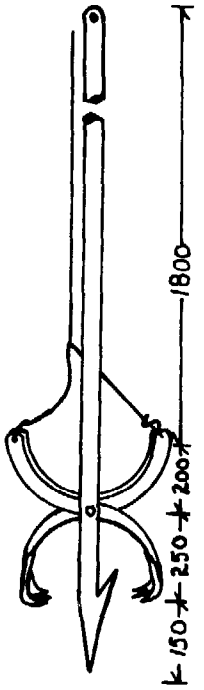

Fig. 94. Piercing rod (unit = mm).

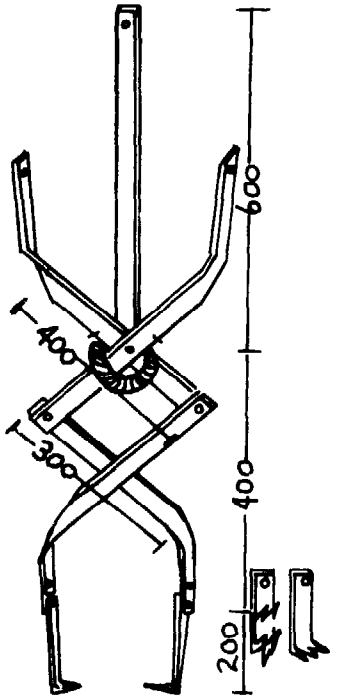

Fig. 95. Multipurpose hook (unit = mm).

always required, but when washing is delayed or is improperly done, the clay wall of the well hole hardens, and particles in the water-containing layer sift into the porous spaces of filter pipe, leading to a reduction or cessation of water output. The wire brush used is made of flanged pipe onto which steel wire has been fixed. At the upper part of the brush, the flanged pipe has a rubber gasket. A boring rod is attached to the brush. The apparatus moves up and down, brushing the inner wall of the well. The water-jet is used after the brush; it is attached to a 3-inch (7.5-cm) rubber tube and, when operating, washes the surface of the filter pipe, forcing water through the pores and washing out all settled particles.

Salvaging Tools

Frequently in the use of a well, bricks fall into the well and sink to the bottom or get stuck between the pipe and the well wall. They can be removed with specially designed brick-salvaging equipment, fork-and-hook instrument, and piercing rod (Fig. 92–94).

Brick-salvaging equipment consists of a boring rod welded to four steel bars. The central portions of the bars are bent to form a drum that can hold the brick. At the ends there are hooks to prevent the brick from falling out again. The instrument is lowered into the well with a pulley fixed at the well opening, and the steel wire is gradually moved into a vertical position so that the brick can be scooped into the drum and lifted. The impact of the brick-salvaging equipment sometimes causes a few bricks to be pushed into the corners at the base of the inner well wall, reducing the efficiency of salvage. Then the piercing rod and fork-and-hook instrument provide help. When bricks land at the joint between big and small well pipes, piercing equipment should be used because other instruments may damage the edge of the pipes. The size of the brick-salvaging equipment and fork-and-hook instrument is dependent upon the internal diameter of the well pipe. If the bricks are covered by sediment, then they have to be removed after well washing.

The multipurpose hook (Fig. 95) is made of four 40 mm × 12 mm flat iron bars joined by a movable shaft. The multipurpose hook is opened by impact and held closed by a spring. Several types of hooks can be attached to it as required. When the upper steel wire is attached to a rubber suction hose, the multipurpose hook can be used to withdraw most odds and ends that drop into the well.

Chapter 10

Experiences in Repairing Wells

In well construction, maintenance, and use, as in many endeavours, there is a large gap between theory and practice, in which any number of problems may occur. A knowledge of some specific problems that have beset others and how they were handled can provide insight into problem-solving and can sometimes save needless work. In Henshui district of Hebei province there has been considerable experience in well repair; some of the details are especially noteworthy.

For instance, after deep-well pumps had been installed on some of the 8-inch (20-cm) diameter, concrete-pipe wells, it was found that the vibration and friction of the suction and discharge pipe damaged the well pipe. As a result, underground saltwater or sand particles were able to enter the well. The first thing to do was to determine the location of the damaged pipe.

The single-electrode method was used. The way it works is that an electric current is passed along the sides of the well pipe and measured. The value measured at a hole is higher than at any other place along the pipe. This method is especially good at detecting a disconnected pipe or a large hole. In the well situated 100 m northwest of Xia village, this method showed that the well was damaged at a depth of 13–13.2 m (Fig. 96). This is the depth of the deep-well pump head — the damage being caused by the vibration of the head during pumping.

The components used in the single-electrode method include a single electrode, a potentiometer (model UJ-18), a battery, a galvanometer, and a ground electrode. The single electrode is made of wood; it is hollow and three groups of galvanized wires are wound around it: the centre group for creating a barrier. A triple cable is inserted through the centre of the electrode and each of the three lines is connected with one group of the galvanized wires (Fig. 97). The battery supplies the electric current; the potentiometer measures the current on the electrode; and the galvanometer registers changes due to differences in the conductor (well wall). The ground electrode completes the circuit (Fig. 98), offering least resistance if it is a metal plate connected to a wire and placed inside a waterfilled hole adjacent to the well.

The method is to lower the single electrode into the well pipe, record readings from the potentiometer of the electric current at different depths from the bottom to the top, plot, on a graph, the depth as the ordinate and the electric current as the abscissa to form a curve showing the variations in electric current. Once the circuit is on, the three groups of electrodes on the single electrode have the same electric potential; the upper and lower barrier electrodes prevent the electric current from flowing either up or down from the centre electrode, so that it can only discharge horizontally. During the measurement, the electric current passing through the broken part of the concrete pipe is greater, its measured value is

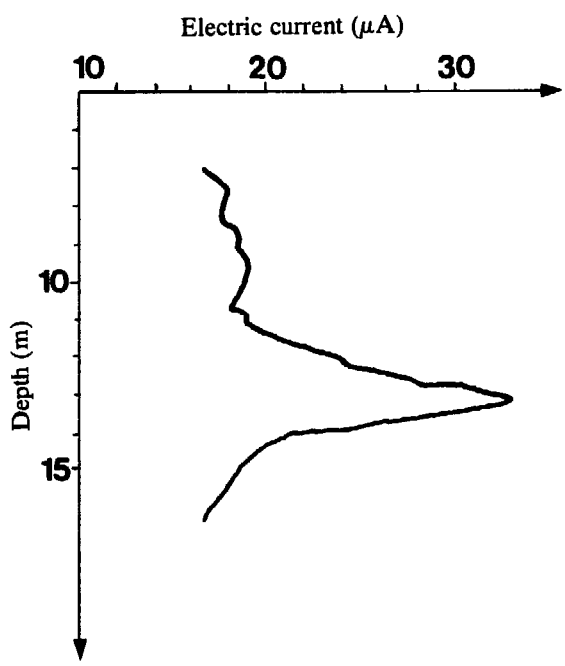

Fig. 96. Curve showing the damaged well pipe at Xia village.

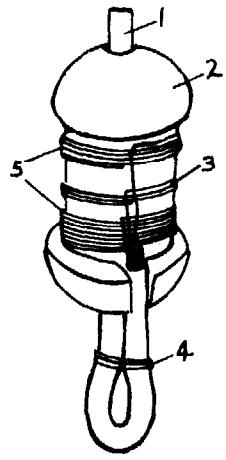

Fig. 97. Single electrode (1, electric cable; 2, wooden electrode; 3, measuring electrode; 4, galvanized wire; and 5, barrier electrodes).

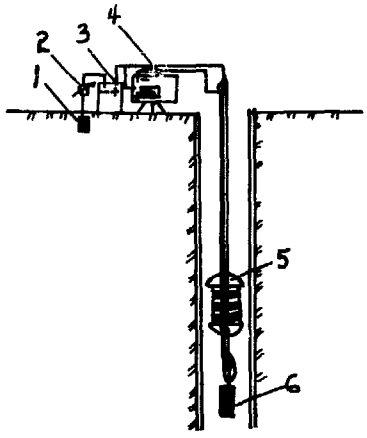

Fig. 98. Connections for single-electrode method (1, ground electrode; 2, galvanometer; 3, battery; 4, potentiometer [model UJ-18]; 5, single electrode; and 6, weight).

higher, and the damage in the pipe can be located from the curve.

Matters requiring special attention are the electric potential of the electrical supply, which should be kept constant during the measurement; the ground electrode, which should not be moved during the measurement; and the single electrode, which should be rubbed clean after use.

Another method of locating damage in a well pipe is the electrical measurement method, which was invented by an investigation group of the Chi district. The basic principles are similar to those of the single-electrode method — to create an electric field and then to use a potentiometer (model UJ-18) to detect the changes in resistance in the concrete pipe. In a concrete-pipe well, the resistance of the pipe is greater than that of the ground layer so that the electric current along an undamaged pipe is consistent but abnormal where there is damage.

The main facilities needed in this method are a potentiometer (model UJ-18) to measure the electric potential difference and the electric current inside a well pipe; a battery (36–72 volt) to supply electricity; and a stepping electrode system (four electrodes, A, B, M, N). Electrodes A, M, and N are lowered into the well. The electric field is formed by the electrical supply electrode A and the ground surface electrical supply electrode B; this is used to measure the electric potential difference between electrodes M and N and the strength of the electric current from the supply (Fig. 99).The method of operation is to connect the circuit (Fig. 100), lower the electric cable to the boundary between salt- and freshwater, raise the cable and carry out measurements at half-metre intervals, record the electric potential difference and the electric current value, and calculate the resistance (K [V/I], where K = coefficient of insulation or 2.26, V = electric potential difference, and I = electric current). The last step is to plot, on a graph, the depth as the ordinate and the resistance as the abscissa. A substantial change in resistance marks the location of the damage.

Some other methods of locating damage have been invented by the well-repairing groups in the Chi district and the Chauchiang district and have proved successful. When turbid water appears in a normally functioning well, workers in these areas first visually examine the pipe above the water level, using a flashlight (most efficient at night). If no damage is detected, it is assumed that the damaged area is below the water surface. The position of such damage is judged from the pipe of the deep-well pump, i.e., the highest part of the pipe that carries turbidity is the location of the damage. To determine this, workers use a simple sieve technique; when a fine-mesh sieve the diameter of the well is placed in the well and raised slowly, it will filter out the turbidity as soon as it is raised above the damaged area. The sieve is simple to construct. In the Chinese districts where it is used, the sieve is a flange, having a diameter smaller than the internal diameter of the well pipe, that has been welded onto a drilling rod and surrounded by a palm-matting net (Fig. 101) whose outer diameter is the same as the internal diameter of the well pipe. It is lowered into the well by galvanized wire; then a submersible pump is lowered to just above it. The pump and sieve are raised simultaneously, the submersible pump being operated while being lifted. When the sieve is above the damaged area, the water pumped out

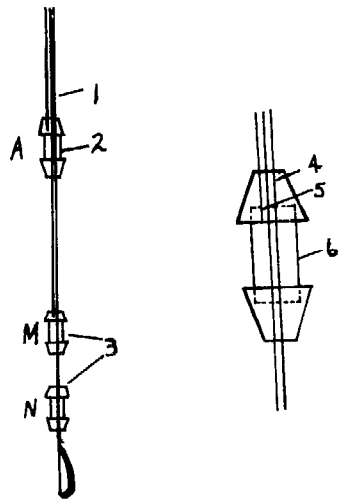

Fig. 99. Electrode system for the electrical measurement method (1, triple cable; 2, electrical supply electrode (A); 3, measurement electrodes (M and N); 4, high-voltage insulating rubber cloth; 5, cable connecting the lead electrode; and 6, lead cell).

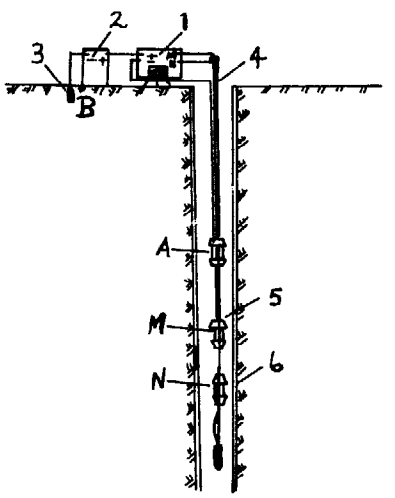

Fig. 100. Circuit connections for detection of damaged areas in a well pipe (1, model UJ-18, potentiometer; 2, battery; 3, ground electrode; 4, cable; 5, electrode system; and 6, well pipe).

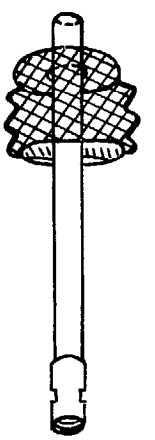

Fig. 101. Sieve made of palm matting.

will suddenly become clear. Repeating this process several times reveals the exact position of the damage.

Realigning Pipes and Replacing Damaged Ones

In the development of irrigation for agriculture, many areas have found centrifugal pumps inadequate and have had to replace them with deep-well submersible pumps. The deep-well pumps used in China are often almost as large as the internal diameter of the well pipe; if the well pipe is slightly bent, the deep-well pump cannot be lowered. The bent portions must be straightened or exchanged for pipe of a larger diameter. Also, sometimes, the well pipes are damaged during the installation of the deep-well pump and need to be repaired.

To straighten bent pipes, the people of Chi district have invented a method using a hollow cone to drill holes around the well. The procedures are to excavate a working pit around the well pipe, with a diameter of 2.5 m and a depth of 3–4 m (Fig. 102), build a rectangular wooden scaffold above the pit, and tie a wooden bow (made of elm or date wood, 4–5 m long) on the scaffold, with a bowstring made of hemp rope or no. 8 galvanized wire (Fig. 103). The next step is to install, at the bottom of the working pit, a 1-m high protective casing around the well pipe (20-cm pipe needs a 50–60 cm-diameter casing, and 30-cm pipe needs a 80 cm-diameter casing) (Fig. 102). Once these preparations have been made, the final steps are to drill holes with a hollow cone (Fig. 104) around the well pipe until the lowest part of the bent pipe is reached (Fig. 105), then to drill around the pipe so that the joints between pipes are movable, and, finally, to lower, while rotating, different pipe-straightening devices, such as a big bamboo rod or a deep-well pump, into the bent pipe (Fig. 106). The people of Chi district have found that the length of the drill can easily be extended by the addition of sections of pipe or sticks of wood. Sticky clay is used to seal around the well pipe, and the pipe-straightening device is withdrawn 3–5 days later.

Matters requiring special attention are that:

- Water should be maintained inside the well during drilling, so that a cave-in does not occur; if a running-sand layer is encountered, slurry should be introduced.
- Drilling should not be too forceful; otherwise there is a risk of breaking the wire or damaging the well pipe.
- The hollow cone should be supported vertically by hand or allowed to lean against the pipe while being lowered.
- When the deep-well pump pipe is being used to straighten the well pipe, the flanges of the pump pipe should not be adjacent to joints of the well pipe.
- Once the pipe-straightening device has been lowered into the well pipe, it should be moved once a day to ensure it does not become lodged inside.

Drilling holes with a bore-bit is also a means to straighten a bent pipe. The main equipment is a wooden straightening device, diesel engine, windlass, slurry pump, bore-bit, and boring rod. The wooden pipe-straightening device is a round stick 18 cm in diameter, 4.8–8 m long so that its length is 2–3 m longer than the bent portion of pipe (Fig. 107).

The procedure is first to connect a 20-cm-diameter bore-bit to a boring rod; next to drill three holes on the vertical plane of the well pipe. The manual rotary drilling method is used, water being pumped via a high pressure tube in the boring rod to the bottom of the holes. The holes are dug to the depth of the bent pipe. The drilling loosens the soil, and the resistance of the soil layers is reduced. The third step is to lower the wooden pipe-straightening device into the well, twisting it continuously so that the pressure straightens the bent pipe. When the well pipe has been straightened, the holes outside the well pipe are filled or sealed with clay, the pipe-straightening device is withdrawn, and the well can be used again.

Sometimes, a pipe must be replaced — the damaged pipe removed first and the new one lowered. One method to prevent running sand from entering the well while the pipe is being replaced is to fill the well with beans contained in 30-cm-long bags whose diameter is the same as the internal diameter of the well pipe. The beans absorb water, and stuff the well. To be effective, this operation should be conducted 24 hours before the pipe is lifted, and the depth of the bean filler should be 1.5 times that of the pipe to be replaced. As in pipe-straightening, soil resistance is reduced if four to six holes are dug around the well pipe; a 16-cm-diameter sharp bore-bit (Fig. 108) is a size suitable for the drilling.

In some areas of China, a crescent-shaped, pipe-lifting tool (Fig. 109) is connected to a boring rod and is lowered into the well. A guiding boring rod, not more than one and a half times as long as the depth at which pipe replacement is needed, is also lowered into the well and left there when the damaged pipe is withrawn. It marks the location of damage. From a new well, the number of pipes that can be lifted in one session is much more than that from an old well. If sand and silt enter the well when the pipe is withdrawn, a 55-cm-diameter, fishtail bore-bit (Fig. 110) can be used to expand the well hole; it will also remove the bamboo strips and other miscellaneous objects inside the well. A 28-cm-diameter cylinder-type, bore-bit may facilitate the joining of the pipes; connected to a straightness-supporting device (Fig. 111), it comes in contact with the pipe inside the well and clears

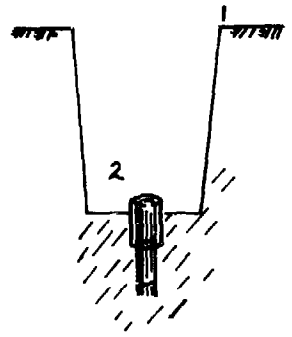

Fig. 102. The working pit and protective casing (1, working pit and 2, protective casing).

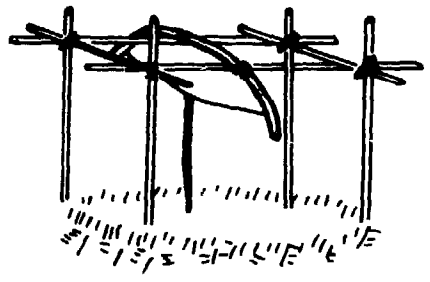

Fig. 103. The working scaffold.

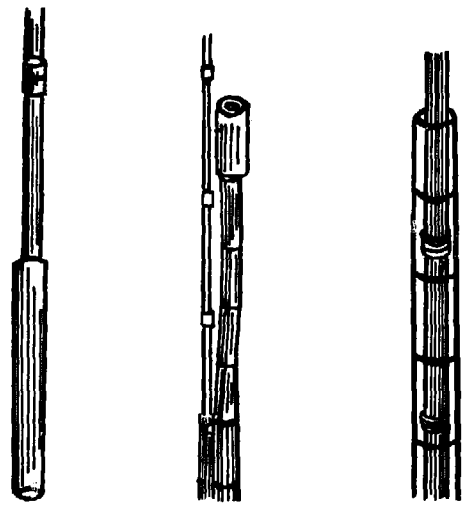

Fig. 104. Hollow cone. *Fig. 105. Hollow cone driven to bottom of bent pipe.* *Fig. 106. Pipe being used to straighten well pipe.*

Fig. 107. Wooden pipe-straightening device.

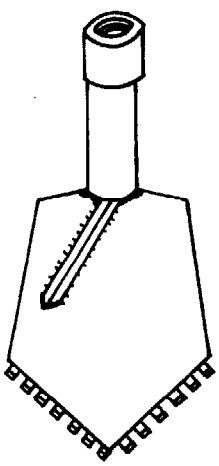

Fig. 108. Sharp bore-bit.

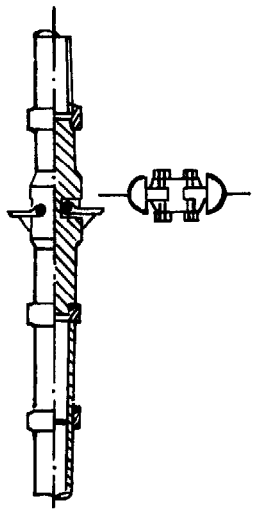

Fig. 109. Crescent-shaped, pipe-lifting tool.

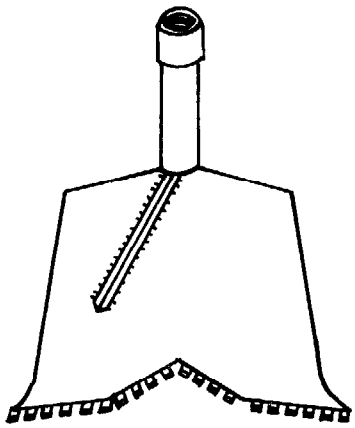

Fig. 110. Fish-tail bore-bit.

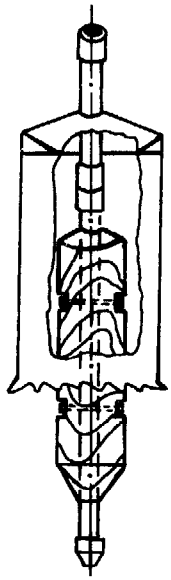

Fig. 111. Cylinder-type bore-bit connected to the straightness-supporting device.

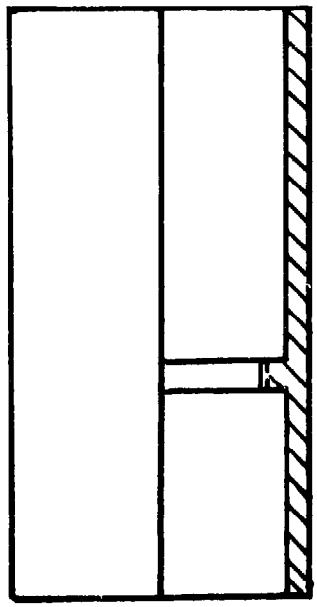

Fig. 112. Reverse screw joint.

the outer surface of the well pipe to a depth of 50 cm, removing all the bamboo strips and miscellaneous objects existing around the mouth of the pipe inside the well.

An iron joint is fixed to the first new pipe that is to be lowered into the well — for concrete pipe, a reverse-screw joint (Fig. 112) and for a cast-iron pipe, a nonscrew joint (Fig. 113). After the pipes are joined, the holes around the well should be filled and sealed with clay.

Sometimes the new pipe is lowered before the damaged one is extracted. This method is possible when a large-diameter well pipe is to replace a small-diameter pipe. As in all other methods, the first step is to locate the damaged area. Then the well is filled with slurry. Next, a 2.5-m-long boring rod is tied to a base plate by palm coir and driven down 3–5 m lower than the damaged pipe. A manually operated scaffold with a suspended hollow cone (Fig. 114) provides the support for the boring rod. The cone is lifted and lowered by galvanized wire.

Well Sealing against Saltwater Entry

In Henshui district, there is generally a saltwater layer (salinity exceeding 2 g/l, often called "bitter water"); the freshwater is often 30 m but may be 200 m lower. Even partial, shallow freshwater layers are covered by a thick layer of

saline water. Sealing off the saline layer, therefore, is the key to guaranteeing good water in the well.

The three main reasons for saltwater entry into a well are that the saltwater layer is not sealed properly with clay (when pumping begins, air pockets outside the well pipe form and allow passage of the saltwater); that poor-quality concrete pipe has been installed or the joints between pipes have not been properly sealed; and that the filter materials exceed the boundary of both fresh- and saltwater so that the latter percolates into the well. The procedures for treating a well in which saltwater has occurred are the same as those for preventing the entry of the saltwater. Sealing can be either external or internal to the well pipe.

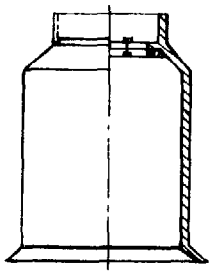

Fig. 113. Nonscrew joint.

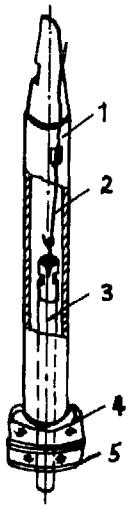

Fig. 114. Apparatus for large-diameter pipe lowering (1, hollow cone; 2, two galvanized wires; 3, boring rod; 4, palm coir; and 5, base plate).

External Sealing

The external sealing method was invented by the well-drilling team of the Chi district and has been used in 18 wells that were contaminated by saltwater. The well-repairing groups of Woo-i district are using this method as well. The steps in the method are to define the saltwater layer; then, use a 33–50-cm diameter, fishtail bore-bit to drill four to six holes around the well pipe on a diagonal to it (the centres of the holes being 50 cm away from the edge of the well pipe and reaching 1–2 m deeper than the saltwater layer); next, flush out the holes with clean water; fill them with clay balls or broken clay lumps, about 2 cm in diameter; and, finally excavate a trench 1.5 m deep and 2 m in diameter around the well pipe, fill it with water, and maintain the water level for 2–3 days to allow the soil layer around the pipe to settle firmly. The trench is then refilled with dirt, and, after 7 days, the well is ready for use.

Matters requiring special attention are the diameter of the bore-bit, which should be at least 33 cm; the distance between the drilled holes and the well pipe, which should be no more than 50 cm; the direction of the holes, which should be diagonal and not parallel; and the type of equipment used to drill the holes — a manually operated scaffold with a suspended hollow cone or a hand-operated auger is suitable because these tools operate at low speeds, are more sensitive to changes in soil layers, and thus are unlikely to damage the well pipe.

Internal Sealing

The well-repairing group of a drilling team in Fu district invented a method of sealing the inside of the well pipe with a plastic pipe and preventing the entry of saltwater. This method is suitable for use in a nonporous pipe in a deep well, when the intrusion of saltwater is caused by improper packing of filling materials, loose joints, or horizontally displaced pipes.

The sealing pipe is approximately 6–9 cm smaller in diameter than the original pipe and is 4, 6, or 8 mm thick. It is 10 m longer than the depth at which saline water is entering the well.

The preparatory steps are to ensure there are no obstructions inside the well; to attach a sealing mechanism to the plastic pipe; and to install a one-way valve within the sealing pipe. Lowering a 108-mm-diameter, 100-mm-long steel pipe into the well is a means to detect obstructions that must be cleared by a steel bore (Fig. 115).

A seal against the entry of saltwater is provided by coir fastened around the plastic pipe by galvanized wire (no. 10–12). About 1.5 kg of good quality (soft, tight) palm coir is sufficient; the end product is a plastic pipe with two coir bowls attached, one near the top and one near the bottom (Fig. 116). Making the coir bowls is simple; three layers of palm coir are wrapped evenly around the pipe and tied firmly by the root with three rounds of the wire. Then the coir tip with the coir root is folded, tied with three rounds of galvanized wire, and fixed to the plastic pipe with four screw nails. Once the coir root and tip are folded, the bottom is formed by hand into the shape of a bowl. The lower end of the bowl is firmly tied with three rounds of wire. Finally, two no. 8 galvanized wires are tied to the bottom of the lower coir bowl and fastened firmly to something outside the well.

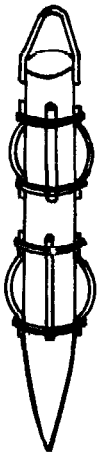

Fig. 115. Steel bore.

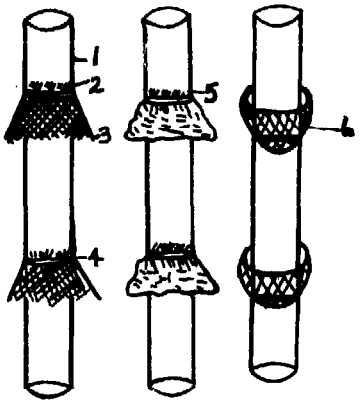

Fig. 116. Forming the coir bowls and attaching them to a plastic pipe (1, plastic pipe; 2, coir root; 3, coir lip; 4, wire; 5, place where the coir lip and the coir root will be folded; and 6, coir bowl).

This final step allows the plastic pipe to be lifted without damage to the sealing mechanism.

The final step in preparation is to install a one-way valve in the pipe. Because the well pipe becomes smaller after the plastic pipe has been lowered into the well, a suction pipe cannot be lowered into the well, and pumping must be carried out directly from the opening of the plastic pipe. Thus, a one-way valve must be installed in it before it is lowered into the well pipe. One method is to heat one end of a plastic pipe and use a round bar to push the one-way valve 0.5 m into the pipe; the diameter of the valve should be 3 mm greater than that of the plastic pipe so that, when the pipe cools, the valve will be firmly fixed. It is of paramount importance that the valve is not inclined inside the pipe.

Installing the plastic pipe is next. The method is to lower the plastic pipe into the well pipe; fill the space between the upper and lower coir bowls with clay. If more than one section of plastic pipe is needed, then only the uppermost section has a one-way valve, and each new section is heated along the bottom, supported by a wooden piston or bowl, and while still hot, inserted 10 cm into the previous section of pipe. The joints are secured by four wooden screws. When all the pipes have been lowered, 50 kg of wet clay balls and 50 kg of dry clay lumps are inserted between the well pipe and the plastic sealing pipe; the clay settles on top of the upper coir bowl and forms a clay layer approximately 2 m thick (Fig. 117). Pumping is not resumed until at least 10 hours later.

Matters requiring special attention are the distribution of the clay, which should be even and continuous; the quality of the clay both in wet balls and dry lumps, which must be pure, the balls 8–12 mm across and the lumps about 10 mm across; the plastic pipe's descent into the well, which should be slow and steady, the pipe being twisted and rotated by hand; the joints between pipe sections, which must be tight; and the screws within the joints, which must not be allowed to protrude into the well.

Since March 1972 the Fucheng district has repaired six deep wells with this method, achieving good results (Table 13).

Silt and Sediment Removal

At times, wells do not produce enough water, or they have a good discharge at the beginning but the discharge steadily declines until it is negligible. The reason is that sand or rocks have blocked the water inlets. The silt or sediment inside the well must be removed. Of the numerous methods currently used in China to deal with siltation, only three are really satisfactory: blowing out the silt through a sealed pipe, removing the silt with two pumps, and cleaning out the silt with a well-washing tool.

The equipment for blowing out silt through a sealed pipe (air-pump method) (Fig. 118) comprises a compressor and air pipe that forces air under high pressure into the well, a sealed pipe, either plastic or iron, that has a wall thickness of

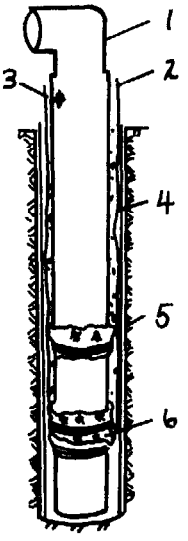

Fig. 117. Internal seal with plastic pipe (1, bend of water pump; 2, galvanized wire; 3, one-way valve; 4, clay ball; 5, upper coir bowl; and 6, lower coir bowl).

Table 13. Comparison of salinity in wells before and after repair.

Team	Depth of leak (m)	Depth of internal sealing (m)	Salinity before repair (g/l)	Salinity after repair (g/l)
Holi	130	140	9	1.2
Shihchuang	20	30	3	0.9
Siliu	110	120	6	1.6
Liunan	120	130	5	0.8
Chautun	70	100	7	0.7
Yangsan	40	70	5	1.2

5 mm and a diameter of 100 mm, a pipe-holding tool, and a T junction.

First, a scaffold is erected and a winch attached so that the sealed pipe can be lowered into the well to 1 m above the silt surface. The upper part of the sealed pipe is connected with a T junction, and an iron pressure cap and a circular rubber washer are mounted on the vertical outlet of the T junction to cover the upper opening of the sealed pipe. The air pipe is connected to the vertical opening of the junction so that water and sand can flow out through the horizontal outlet. A pressure tube connects the compressor to the air pipe. When the compressor is switched on, air under high pressure enters the sealed pipe and forms air bubbles in a water–air mixture. The specific gravity of this mixture decreases as the bubbles increase, and its volume gradually expands; the water level inside the sealed pipe rises until it reaches the T-junction outlet; water flows out, bringing up sand and silt from inside the well. The sealed pipe is lowered gradually until all the silt inside the well is removed, and the water being pumped from the horizontal outlet is clear.

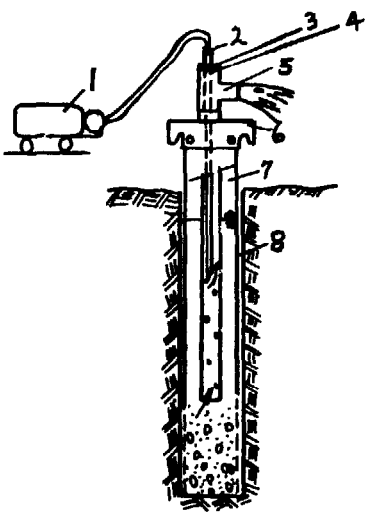

Fig. 118. Blowing out silt through a sealed pipe (air-pump method) (1, compressor; 2, air pipe; 3, pressure cap; 4, washer; 5, T junction; 6, pipe-holding tool; 7, sealed pipe; and 8, well pipe).

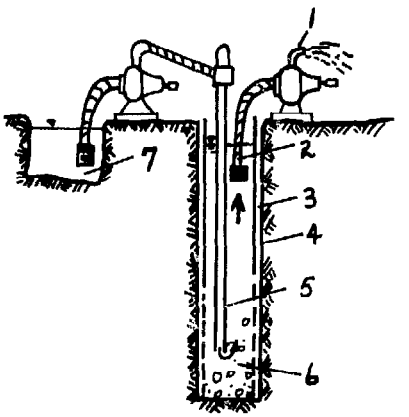

Fig. 119. Cleaning out the silt with two pumps (1, centrifugal pump; 2, suction pipe; 3, well pipe; 4, well wall; 5, delivery pipe; 6, silt and sand; and 7, reservoir).

Practical experience has shown this method to be efficient and time-saving, requiring only 1–2 days. Although it is generally used in deep wells, it is also applicable to shallow wells. Since autumn 1971, Woochiang district has used this method to clear 187 silted wells, after which 175 began to function properly (93%); 156 were silted with sand and 19 with filter materials. For example, a 260-m-deep well built in 1969 was silted with filter materials to a depth of 110 m; there was no discharge whatsoever. The damaged pipe was repaired, and the silt-blowing method was used to clear the filter materials. The well now produces enough water to supply a 5-inch (13-cm) pump.

Matters requiring special attention are the depth to which the sealed pipe is lowered, which should be far enough away from the silt surface so that the water flows freely but close enough so that silt is extracted; the depth to which the air pipe is inserted into the sealed pipe, which should be only enough to ensure good air pressure; and the straightness of the well pipe — if the pipe is not perfectly straight, this method cannot be used.

Clearing the silt with two pumps is a method invented by the peasants in Lauyang district; it uses a 4-inch (10-cm) centrifugal pump, which sends clean water into the bottom of the well through a 3.5-cm diameter water pipe, and another 8–10-cm centrifugal pump to pump out the well water (Fig. 119).

The pumping of clear water brings up the silt from the bottom of the well. The sand is washed up within the range of the suction head of the second centrifugal pump, which pumps it out. The delivery pipe is gradually lowered, as the sand is continuously being pumped out. It is important that the air-delivery pipe is not too near the silt surface; otherwise, the pipe opening may become blocked. Ideally, it should be 30–40 cm away from the surface of the silt. Substituting a slurry pump for the clear-water pump or slurry for the clear water is more efficient, as the water pressure and its capability to bring up silt and sand are increased.

This method is suitable for shallow or medium-depth wells. The operation is easy, and the installation is simple. Normally, three or four people can carry out the task; compared with the labour required to erect a scaffold and a hollow cone to bail out the silt, the method is labour-saving, and the risk of damage to the well pipe is low. It usually takes 2 days to clear 20–30 m of silt. This method has been used in Lauyang district to clear 54 wells, the deepest of which was 184 m, and the results were good. In Anping district, a similar method was used to clear more than 30 wells.

Clearing silt with a well-washing tool was invented by the well-repairing unit of Gin district. Operation is easy and the structure simple. It produces good results in shallow wells. The equipment consists of a jet gun, "jet head," wire ring, and control device (Fig. 120). Also, a scaffold, pulley, a rubber tube, a centrifugal pump, and several sections of pipe are required.

The jet gun is two pieces of steel pipe welded together, the upper one with a diameter of 110 mm and the lower one with a diameter of 76 mm. The jet head is a piece of 60-mm-diameter steel pipe welded on the lower end of the jet gun. The main nozzle is the lower end of the jet head, having a diameter of 60 mm. There are 10–15 small holes or nozzles 15 mm in diameter on the upper part of the jet head.

The control device is two 60-mm-diameter steel pipes welded on the middle of the jet gun, at an angle such that the whole apparatus is narrower than the well diameter. The control device is a support to prevent the jet head from burrowing into the silt. The preparatory steps are to excavate a water-recirculation drain and two water-storage ponds away from the well; erect a well scaffold with a pulley on top to lift a rubber tube; connect a water-delivery pipe (10 cm in diameter and the length of the well) to the jet gun and the discharge pipe of the centrifugal pump; and fasten the cable of the winch onto the wire ring on the jet gun through the pulley. Dry clay is mixed with water to form a slurry that is pumped through a rubber tube attached to the well-washing tool. The sediment is brought up by the buoyant force of the slurry. The rubber tube is lowered continuously into the well as the work progresses. Once the bottom of the well is reached, the well is washed with water until clear.

Matters requiring special attention are the well-washing tool, which should be firmly joined to the rubber tube; the nozzles, which should be free from obstruction; the speed with which the rubber tube is lowered, which should be slow and continuous; and the sand and silt settling on the water-recirculation drain, which should be removed periodically.

This method was employed in Chin district in more than 20 wells, and the results were very good. It has also been used to wash the walls of the wells; the water spurting out through the small nozzles cleans the filter pipe and increases the well's discharge. In one case, a 39-m-deep, "pot-drilled" well was supplying only enough water for an 8-cm pump; this method took 2 h to clear the well, and now the discharge is sufficient to supply a 10-cm pump.

Salvaging Equipment

Sometimes due to negligence during construction, pumping facilities are not properly installed, and during use, the pump's intake pipe, suction pipe, or some other part falls into the well. Or due to poor maintenance at the well opening, rocks, bricks, tiles, and tools occasionally fall into the well. Tools to salvage such equipment have evolved from practical implementation. One tool is designed especially to salvage the intake pipe of a centrifugal pump. It is made according to the special features of a water-pump intake pipe, i.e., the upper part is small and the lower part is large.

The tool consists of a rounded steel bar and movable hooks (Fig. 121); a handle is welded to the upper part of the bar and is connected to a cable; the lower part of the bar is sharp, and the middle has a rectangular groove. Two movable hooks are fixed to two small pivots in this groove such that the hooks can be moved up and down on the pivots. A rubber band is attached to the lower ends of the hooks and pulled tight so that the

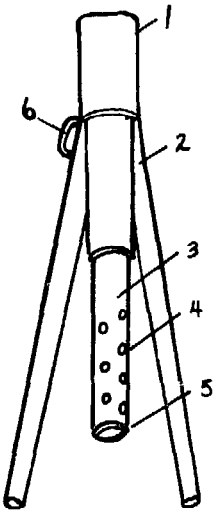

Fig. 120. Well-washing tool (1, jet gun; 2, control device; 3, "jet head"; 4, small nozzle; 5, main nozzle; and 6, wire ring).

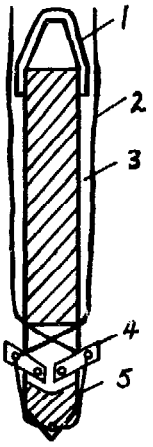

Fig. 121. Salvage tool for a water-pump intake pipe (1, handle; 2, guiding cord; 3, steel bar; 4, movable hooks; and 5, rubber band).

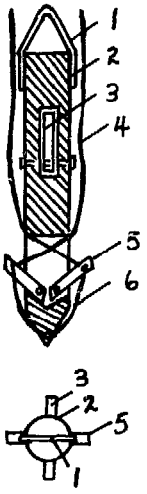

Fig. 122. Rubber-tube salvage tool (1, handle; 2, rounded steel bar; 3, movable hooks; 4, guiding cords; 5, movable hooks; and 6, rubber band).

hooks are extended outward. Each hook is tied to a guiding cord and folds up when the cord is pulled.

The tool is gradually lowered on a cable into the well. When the sharp end of the bar enters the upper part of the intake pipe, the two movable hooks fold up because of the pressure from the internal wall of the pipe. When the salvage tool reaches the lower part of the intake pipe, the rubber band pulls the movable hooks outward. Because the width of the extended hooks is greater than the internal diameter of the upper intake pipe, the pipe is lifted when the salvage tool is withdrawn from the well. If the intake pipe is lodged inside the well, the salvage tool is withdrawn without the intake pipe, the guiding cords being pulled so that the hooks fold back into the groove.

This tool has been extensively used in China, salvaging more than 20 centrifugal pump intake pipes in Hensui district, 4 in Fu district, and 12 in Shen district. The operation generally takes 1–2 h. Another tool used in China is the rubber-tube salvage tool. The basic structure is similar to that of the water-pump, intake-pipe salvage tool. The only difference is an additional pair of movable hooks (Fig. 122). Both pairs of hooks are fixed on the rounded steel bar. This tool has been used by Hensui district to salvage six rubber tubes.

If wire or cable falls into the well, it can be salvaged with a piece of rounded steel bar that has had three hooks welded to its centre (Fig. 123). The position of the cable inside the well is determined first; then the hook is lowered into the well on a wire. When the hook has caught the cable, it should be lifted immediately, bringing the cable with it. This hook has been used by the well-repairing group in Fu district to extract a 180-m-long steel cable.

The spiral salvage tool is mainly for pincers, axes, hammers, bricks, etc. It is a rounded steel bar reinforced by a spiral bar wound five times around it (Fig. 124). When used to salvage equipment in a 200-mm-diameter well pipe, it usually has an upper diameter about 100 mm and a lower diameter about 180 mm. The spiral salvage tool is lowered into the well on a boring rod and is

Fig. 123. Hook for salvaging wire and cable.

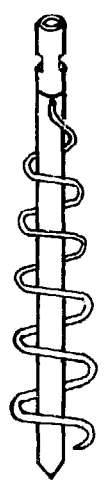

Fig. 124. Spiral salvage tool.

Fig. 125. Piercer.

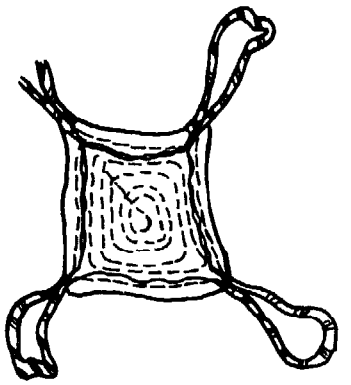

Fig. 126. Canvas sack.

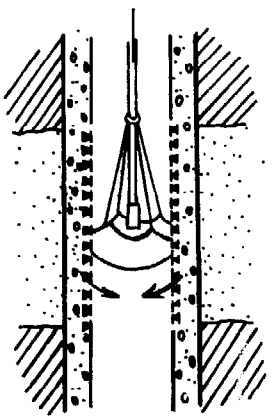

Fig. 127. Canvas-sack well washing.

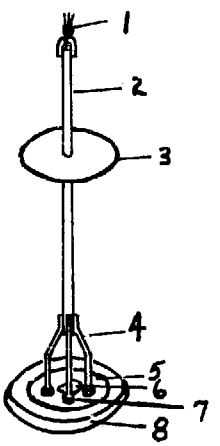

Fig. 128. Piston (1, steel wire; 2, boring rod; 3, rubber ring; 4, iron bar; 5, circular iron plate; 6, valve; 7, female thread; and 8, rubber mat).

manipulated so that the object enters the spiral from the bottom. The boring rod is rotated carefully until the object is cramped firmly by the spiral reinforcement bar.

A piercer (Fig. 125) breaks bricks and rocks that have fallen into the well into pieces so that they settle to the bottom. It is a rounded steel bar with one end sharpened to a point and topped with a screw. The piercer is attached to a boring rod and lowered into the well via a scaffold. It is rotated so that it bores through any obstructions.

Increasing Well Capacity

Some wells have no damaged pipes, no sand inside, yet still give insufficient discharge to supply a pump. The reasons are mainly improper handling of the slurry during construction, incomplete or delayed washing (developing) of the well after construction, and leaving the well in disuse for a long time, in which case the slurry clogs up the filter pipe and fills the voids in the sand layer so that water cannot enter the well. Two methods have been designed to deal with these problems and have achieved good results. One is the canvas-sack well washing method, which has been used successfully by the well-drilling team of Shen district for more than 80% of poorly discharging wells. The only disadvantage is that the canvas sack wears out quickly.

The canvas sack comprises three square pieces of canvas that are bigger than the internal diameter of the well pipe. These are stitched together, one on top of another; two pieces of rope are sewn to the corners of the canvas so that they form an "X" (Fig. 126). The ropes are attached to a short boring rod, which is raised and lowered repeatedly until the well is washed.

As it is lowered, the canvas sack folds together under the resistance of the water and opens when it is being lifted; the water on top of the sack forms a vacuum under the sack for a short time, and the water in the water-containing layer rushes into the vacuum through the filter materials, bringing a lot of sand with it. The process is repeated until the well's discharge is improved (Fig. 127).

Matters requiring special attention are the quality of the canvas sack and the hemp ropes, which should be reliable; the position of the boring rod, which must be in the centre of the canvas sack; the speed at which the boring rod is lowered, which should be slow; and the speed at which the rod is lifted, which should be fast.

The well-repairing group of Lauyoung district has increased well discharge by installing a valve piston on a boring rod and using it to remove

slurry and sand particles from the well. The principles are similar to those in the canvas-sack well-washing method. The method is suitable for wells with a good sand layer but not for horizontally displaced well pipes.

The piston consists of five layers of thin rubber sheet formed into a circular rubber mat with a diameter of 3–4 cm larger than the internal diameter of the well pipe and sandwiched between two circular iron plates, the upper one 14 cm and the lower one 16 cm in diameter. A valve is installed at the centre. Three 1.5-cm-thick, 0.5-m-long iron bars joined by a screw joint at one end form a tripod to hold the iron plates. The other ends of the bars are welded to a 5-m-long boring rod, and an iron ring is welded on the top. A rubber ring is fixed on the top portion of the boring rod and just below the iron ring (Fig. 128). A frame is made from four pieces of 14-cm-thick and 1-m-long rounded sticks; an iron plate is attached at the centre of the frame to support a pulley mounted directly over the well. The additional equipment needed is a windlass to lift and lower the piston; an intermediate unit to control the revolution speed; and a 10-hp diesel engine or electric motor to drive the piston via the intermediate unit and the windlass. When the piston is moving, the water inside the well becomes turbid; then the piston is stopped and the turbid water is pumped out. These procedures are repeated until the water is clear and the discharge sufficient.

Matters requiring special attention are the alignment of the pulley, the cable, and the piston, which must be straight; the lifting speed for the piston, which must be maintained at 0.1–1 m/s; the type of well pipe, which must be porous (filter pipe); the cable, which should be checked for weakness regularly; and the number of layers in the piston's rubber mat, which may be modified if the piston is difficult to move or moves too freely.

From June 1972 to November 1972, the well-repairing group of Lauyoung district used this method to repair 40 wells.

Chapter 11

Well-Repair Methods in Shantung Province

In Shantung province, modified well-repairing instruments have been successfully developed. They have proved to be good quality, highly efficient, economic, and simple. To date, more than 100 wells have been repaired.

The three-headed probe (Fig. 129) is a tool used by the well-repairing group in Shantung province to locate damage in a well and to find out its cause. Formerly the singled-headed probe was used, but it often bypassed the damage, was difficult to operate, and was not efficient. The three-headed probe was devised after much testing, improvement, and modification. It consists of three probe heads, each topping a series of two sliding cylinders, and two probe springs. The probe heads and cylinders are mounted on a frame attached to a rod; a rope connected to the apparatus controls its spring action. The sliding cylinder with the probe fits inside the second sliding cylinder. The use of more than one sliding cylinder allows the apparatus to accommodate a range of well-pipe diameters. The spring action pushes the probe head into damaged areas, the probe head being automatically pushed into a hole or disconnected joint by the spring. Thus, the depth of damage can be easily recorded. If the probe can only be moved to a limited degree, the damage is a hole; if it can be turned completely, the pipes have been disconnected. The sliding rope is pulled tight so that the probe head is contracted into the sliding cylinders and the search for additional damage can be resumed.

Bamboo and Coir-Bark Casing

A bamboo and coir-bark casing has been found useful in well-wall repairs. It is more effective than normal casings that reduce the cross-sec-

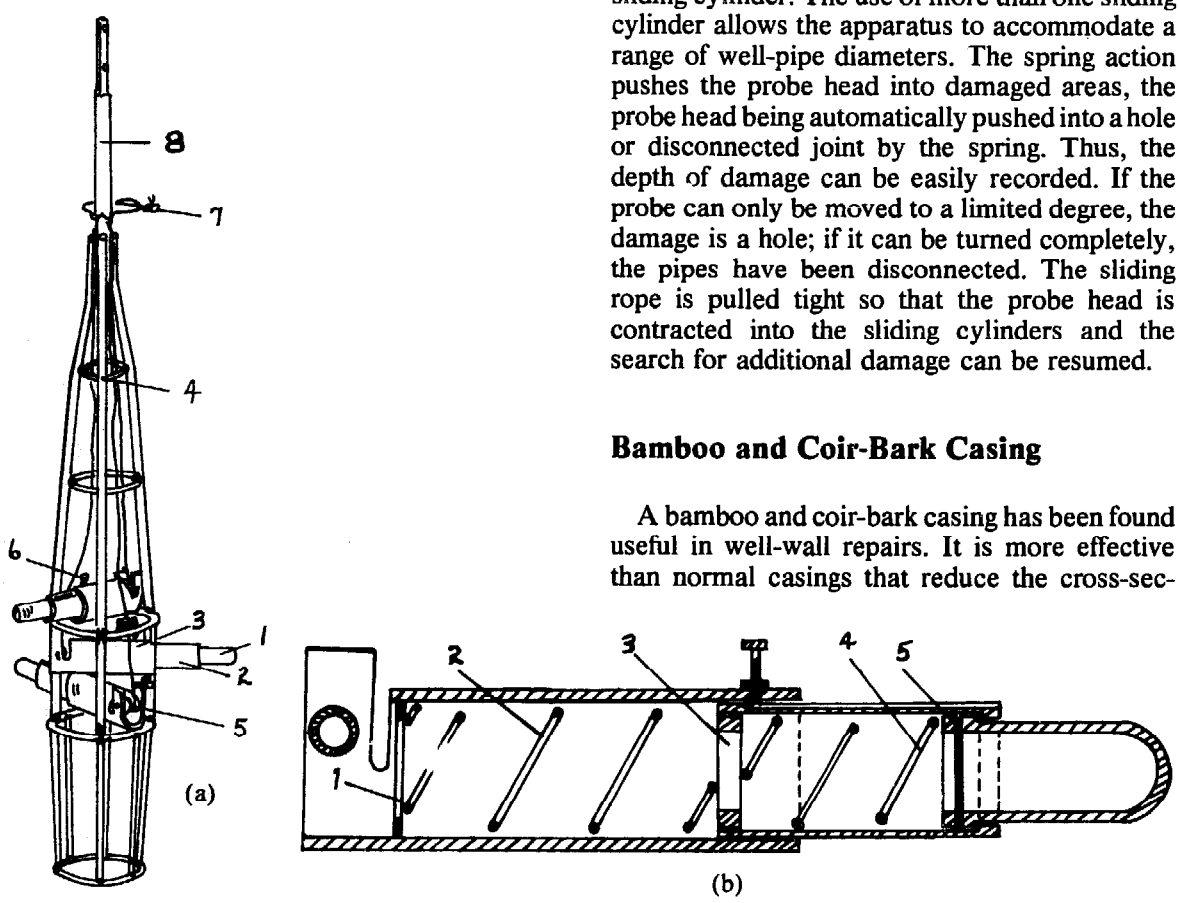

Fig. 129. Three-headed probe (a) apparatus (1, probe head; 2, first-layer sliding cylinder; 3, second-layer sliding cylinder; 4, probe frame; 5, pulley; 6, fixed screw; 7, sliding rope; and 8, operating rod) and (b) cross section of probe head (1, second-layer stopping ring; 2, second-layer sliding cylinder spring; 3, screw-joint stopping ring; 4, first-layer sliding cylinder spring; and 5, probe head insert).

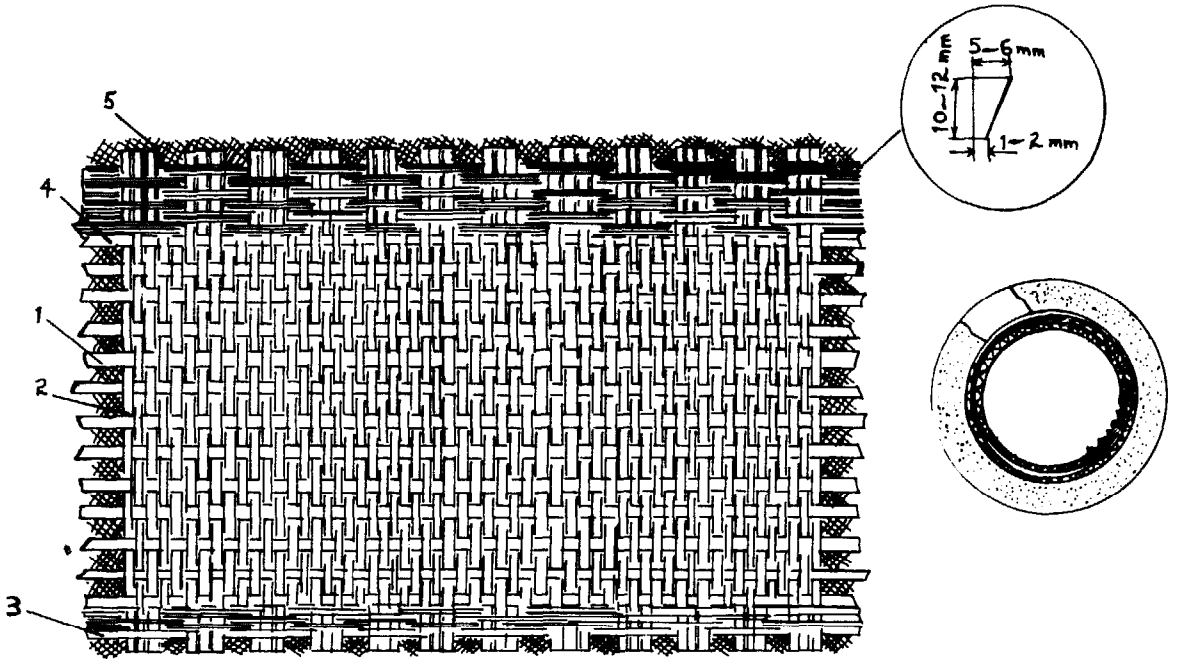

Fig. 130. Bamboo and coir-bark casing (1, horizontal bamboo strip; 2, vertical bamboo strip; 3, flat bamboo plank; 4, trapezoidal bamboo plank; and 5, coir bark).

tional area inside a well and, therefore, the water flow. It is flexible, expanding and assuming the required shape once it has been lowered into the well. It has been modified and improved during use and has proved durable.

The steps in making the bamboo and coir bark casing are to calculate the area of casing needed to repair the well pipe (this figure is calculated from the well diameter and the depth of damage); arrange 1.5–2-cm-wide bamboo strips so that they are horizontal and vertical like a knitted mat the size of which is equal to the area of casing needed; at one end of this skeleton, attach six trapezoidal bamboo planks (upper base 1–2 mm, lower base 5–6 mm, height 10–12 mm) and at the other end attach four flat bamboo planks (width 10 mm, thickness 3–4 mm); finally, reinforce the matting with two or three layers of coir bark, attached with string or galvanized wire (no. 20). This forms the planar surface of the casing. It is soaked in water for 1–2 h before being used so that it is pliable and then is rolled to form the casing. One end of the bamboo strips is matched with the "teeth" formed by the trapezoidal bamboo planks. The bamboo strips can slide in only one direction, the casing being allowed to expand but not contract; when the casing expands, it is wedged against the well wall (Fig. 130). Installation can be carried out with the help of a well-repairing device — a specially made tool that operates like an umbrella (Fig. 131).

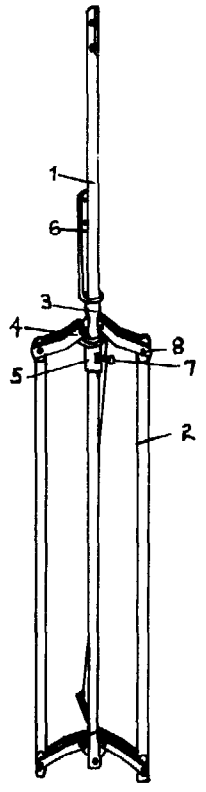

Fig. 131. Well-repairing device (1, pulling rod; 2, casing-support frame; 3, expanding and contracting sliding case; 4, prop arm; 5, prop-arm supporting case; 6, supporting rod; 7, supporting-case screw; and 8, prop-arm screw).

The well-repairing device is contracted and the protruding bamboo strip at one end of the bamboo and coir-bark casing inserted into the device. The casing is rolled tightly around the frame and tied with string; galvanized wire (no. 12) is attached to the string and will be used later to sever the string. The well-repairing device is contracted and lowered into the well, one end of the wire being kept at the well opening. When the device is at the level of well damage, the wire is pulled sharply so that the string is severed and the casing installed. Then, the well-repairing device is contracted and withdrawn.

The three-headed probe, well-repairing device, and the bamboo and coir-bark casing are simple devices. They can be made easily and inexpensively.

Iron Sealing Pipe

The iron sealing pipe (Fig. 132) has proved suitable for repairs of leaks in wells, takes little time to install, and is both economic and simple to produce. It is made from a 1–1.5-mm-thick iron sheet rolled to form 10–12.5-cm-diameter pipes, the joints of which are connected by rivets; bitumen is applied to areas where leakage may occur. The 10–15-m-long iron pipe is lowered into the well, with a tripod, and both the lower opening of the bottom valve and the upper part of the iron pipe are sealed. This method is very popular and is inexpensive.

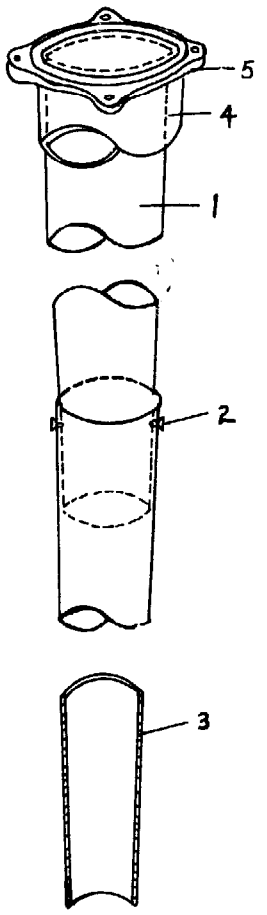

Fig. 132. Iron sealing pipe (1, iron pipe; 2, rivet; 3, bitumen; 4, original pipe; and 5, original plate).

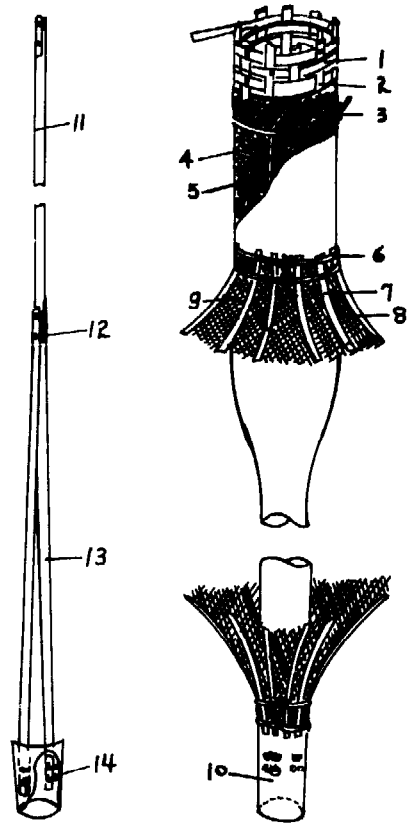

Fig. 133. Conical bamboo pipe (1, horizontal bamboo strips; 2, vertical bamboo strips; 3, coir bark; 4, externally wrapped horizontal bamboo strips; 5, externally wrapped vertical bamboo strips; 6, galvanized wire [no. 10]; 7, coir bark [bamboo strip]; 8, coir bowl [coir bark]; 9, wire [no. 20]; 10, conical iron pipe; 11, pulling rod; 12, screw; 13, guiding prong; and 14, insert ring).

Conical and Hollow Bamboo Pipes

If horizontal displacement in well pipes exceeds 8 cm and the well continues to be used, silt will enter the well pipe and directly affect the discharge of the well. The conical bamboo pipe is an economic and simple solution to the problem.

The conical bamboo pipe (Fig. 133) is 3.5–4 m long, is composed of bamboo strips, and has two pieces of galvanized wire (no. 10–20) as rein-

forcement. The diameter of the pipe is based on the degree of horizontal displacement. On both ends of the pipe, bamboo bowls are attached, facing opposite directions. For installation, a conical iron pipe, 1–1.5 mm thick, made from sheet metal is fixed inside the bamboo pipe with galvanized wire. Then, a guiding prong is placed in an insert ring, and an insert prong is connected to the pulling rod, which will deliver the pipe to the position of displacement. When siltation occurs at joints of well pipes or at holes, a hollow bamboo pipe can be used for repair, giving good results. Made of 4-m-long bamboo strips, the pipe's diameter is about 12 cm; the outer part of the pipe is wrapped with two or three layers of coir bark and tied with thick bamboo. The 4-m-long bamboo pipes are joined by 1-m-long iron pipe (tied with no. 10 galvanized wire) so that the total length of the pipe is equal to the depth of the well. The whole length of the pipe is reinforced by galvanized wire (no. 10–12).

The bottom part of the pipe is attached to iron pipe, 1.1–5 mm thick; two symmetrical insert rings are suitable. The guiding prongs pass through the insert rings and connect to the pulling rods; this apparatus is lowered into the well, and the pulling rods are withdrawn. This method of repair costs about 50 yuan.

Appendix 1

Determining Residual Chlorine

Potassium Iodide Colorimetry

The reagent for potassium iodide colorimetry is starch–potassium solution: 2 g soluble starch (or normal starch) is dissolved in 100 ml distilled water, boiled, and allowed to cool to room temperature; 8 g potassium iodide (KI) is added, and the mixture is agitated until the KI is thoroughly dissolved. The solution should be stored in the dark.

The procedure is to add five or six drops of the solution to a 100-ml sample of water disinfected with chlorine (e.g., bleaching powder) and mix carefully. Blue indicates residual chlorine; light blue indicates the appropriate chlorine content.

Append. Table 1. Relationship between smell, colour, and residual chlorine in DPD colorimetry.

Residual chlorine (mg/l)	Smell of chlorine	Colour
0.1	Slight	Light yellow
0.2	Easily detectable	Yellow
0.5	Obvious	Yellow
0.7–1.0	Strong	Deep yellow
>20	Strong	Brown

Dimethyl-Paraphenylene-Diamine-Hydrochloride (DPD) Colorimetry

The reagent for dimethyl-paraphenylene-diamine-hydrochloride (DPD) colorimetry is a solution of 10 ml hydrochloric acid, 90 ml distilled water, and 0.1 g DPD.

The procedure is to add three to five drops of the solution to a 5-ml water sample. Yellow indicates residual chlorine (Append. Table 1).

Appendix 2

Determining the Chlorine Required

If adequate chlorine is added as treatment for water, there should be residual chlorine in the water. A test for residual chlorine should be run (Appendix 1) but not until at least 30 minutes after the chlorine application. One method of determining how much chlorine is needed is to compare the effects of adding different amounts of chlorine to small quantities of the water to be treated and then to extrapolate the amount that provides suitable residual chlorine to the amount of water to be treated.

The equipment needed is five 100-ml beakers (or porcelain bowls), five glass rods, 100-ml measuring cylinders, 10-ml graduated pipettes, and droppers. The procedure is to dilute 1 ml of 1 : 100 (w : v) bleaching solution (1 g bleaching powder : 100 ml distilled water) in enough distilled water to make 100 ml; line the beakers on the table and label them (e.g., 1, 2, 3, 4, 5), each containing a 100-ml sample of water; with a pipette, add 2, 3, 4, 5 ml of the bleaching solution into beakers 2, 3, 4, 5, respectively; agitate with glass rods, and drop three drops of starch–potassium iodide solution (Appendix 1) into each beaker and agitate. Within 5 minutes, the chlorine will have liberated the iodine from the solution, and the treated water will be blue. The amount (ml) of bleaching powder solution added to the beaker with a light-blue solution is the amount of bleaching powder in g/m^3 one needs to treat the drinking water. For example, if a light-blue solution is obtained when 4 ml of bleaching powder solution (1:10 000) is added, then 4 g bleaching powder is required to treat 1 m^3 water. If the free available chlorine in the bleaching powder is 30% by weight, then the chlorine required is 1.2 g/m^3, ($4 \times 30\%$), or 1.2 mg for each litre of water.

Appendix 3

Determining Water Quality

Some methods have been developed to test water quality in rural areas where no laboratory or equipment are available. These include tests on colour, odour, taste, temperature, settleable solids, and pH. Pure water is colourless, odourless, and tasteless.

If water placed in a white container is yellowish, it may contain a large quantity of decayed organic matter. A reddish yellow suggests a high iron concentration, and blue suggests a high hydrogen sulfide concentration.

If a sample of water shaken in a stoppered bottle has an odour, it should be heated to 60° C in a water bath and smelled again. If it still emits odours, the source should be further investigated before being used.

To test for taste, one heats a sample of water to 60 °C in a water bath, then tastes it. If the water contains a high quantity of organic matter, its taste may be sweet; a high concentration of sodium chloride will produce a salty taste; hard water will have an astringent effect.

Water temperature is often a good indicator of contamination. Any sudden change in temperature suggests that the water is contaminated.

A test for settleable solids is to let a sample of water stand overnight, pour the water, with care not to disturb the sediment, into another bottle, heat the water in the new bottle to 100 °C, let it stand till cool, and then observe the sediment. The second sediment is the partially soluble mineral sediment and is indicative of water quality.

Another test is to drip a few drops of sample water onto white paper and let them dry. The less the trace of watermarks, the better the quality of water.

If the pH of sample water is outside the range 6.5–9, the water may be contaminated.

Appendix 4

Quality Standards for Domestic and Potable Water Supplies[1]

These standards are an edited version of the *Quality Regulation for Domestic and Potable Water Supplies*, which was published in 1959 by the Ministry of Health and the previous Ministry of Building. The new standards apply from 1 December 1976.

The standards are controlled by the Ministry of Health; technical aspects will be explained by the Health Department of the Chinese Medical Institute.

In this edition, a section on general provisions has been introduced; it illustrates the purposes, significance, and application of the standards. Also, a section on the quality requirements for water supply has been added, and it stresses the importance of selection of a water source in urban and rural developments, providing for both long-term and short-term requirements.

All units are advised to review the results and problems in executing these standards. Comments would be appreciated for the benefit of future editions.

General Provisions

The reason for establishing these standards (Table 1) is to put into effect a policy of "prevention first," to guarantee that the quality of domestic water supply fulfills the health requirements and thus to protect our people's health.

In applying these standards, water supply authorities, planning authorities, design authorities, etc. should insist on self-reliance and on a combination of traditional and Western methods. These standards should be competently adopted and seriously adhered to. Health departments at all levels should examine and supervise the application of these standards.

When new waterworks are built or when existing works are being expanded or rebuilt, responsible departments should advise on source selection, should check planning and design, and should approve schemes with care.

Source selection, quality examination, and management of individual supplies are carried out by production teams or residential committees. All such units should encourage people to participate in protecting the water sources and in preventing contamination.

These standards are applicable to both rural and urban domestic water supplies and both individual (including private installations) and piped supply systems (Table 1).

For piped supply systems, besides the necessary treatment plant, disinfection facilities should be installed, regardless of the source. For systems that transmit groundwater to the user directly without treatment, equipment should be installed to remove grit and turbidity if necessary. Facilities for water storage, transmission, and distribution must be carefully protected from contact with sewerage networks.

The raw materials used for treatment plant construction and chemicals used for water purification should not contaminate the water supply.

Independent, private water supply systems should not be connected to the urban water supply systems. In special cases when it is necessary, such a connection should be approved by the authority of health and water supply. The connection point should be carefully situated and effectively made; even more effort than otherwise should be put into maintenance, management, and protection of the water.

In a piped supply system, the authority should put considerable effort into the management of the facilities for water collection, purification, storage, distribution, and transmission. Rules and operation regulations should be established, regarding effective control of overflows, disinfection, cleaning, waste discharge, examination, and testing so that the water quality is guaranteed.

[1]These standards were published and distributed in China in 1976 under the auspices of the Ministry of Health, Ministry Series 139 and an abridged version has also been made available, Hygienic and Health Series 310.

In rural areas, greater emphasis than in the past should be placed on the hygienic control of domestic water supply. Hygienic regulations should be laid down for wells, riverbank filtering wells, sand filters, simple water supply systems, and springs. Adequate measures should be adopted for proper maintenance and management.

Source Selection

In selecting sources, both long term and short term, authorities should consider village developments and city planning. Current data on quality, hydrology, and hydrogeology must be taken into account. Sanitation and cleanliness around the water catchment area and the surroundings and the absence of endemic diseases are important criteria. The source should be sufficient in quantity and quality and be easy to protect. Groundwater should be used in preference to other supply sources. The water catchment site should be upstream from city or industrial development.

The quality of raw water for domestic supplies is determined by:

- The number of *Escherichia coli* in the water, which should be fewer than 1000/litre on average if chlorination is the only disinfection available; the number of *E. coli* can be 10 000/litre on average if both purification and disinfection processes are available;
- The physical and chemical quality, which should conform to the standards (Table 1);
- The toxicological levels, which should conform to the standards (Table 1);
- In areas where goitre is endemic, the iodine concentration; and
- The presence of harmful substances not included in the quality standards (Table 1).

If the source quality does not conform to the standards and if there is no alternative, the project should be approved by the department of health of the province, city, or autonomous region. Alternative treatment methods should be considered in association with the department so that the quality of the water can be improved.

Source Protection

The source for domestic water supply should be in a protected area. For piped supply systems, the protection measures and the size of the area should follow the requirements for:

Surface Water

- Within a radius of 100 m of the catchment point, no boating, swimming, fishing, or other activities that could contaminate the water are permitted. The boundary should be clearly marked.
- Within 1000 m upstream and 100 m downstream of the catchment point, no industrial or domestic wastewater should be discharged into the source; within the protected area, no solid waste material may be dumped, and no harmful chemicals may be stored; use of the protected area as a harbour for loading or unloading refuse, excreta, or toxic chemicals is not permitted; no industrial or domestic wastewater may be used for irrigation in the area; no residual or highly toxic chemical may be used on fields that drain into the protected area; and no grazing is permitted.
- No residential areas, livestock, or husbandry areas; seepage latrines; seepage pits should be constructed or planned within 10 m of pumping stations, sedimentation tanks, or final water tanks at waterworks or private installations.
- Good hygienic conditions and tree planting should be planned.

Groundwater

- The size of the area protecting a catchment depends on hydrogeologic conditions, method and structure of the catchment, and sanitary conditions of the surrounding areas. Protection measures should be carried out as for surface water.
- Within the effective areas of an individual well or a group of wells, no industrial or domestic wastewater should be used for irrigation and no residual or highly toxic chemicals should be used; no seepage latrines, seepage pits, or solid waste dumps may be constructed; no drainage of wastes should be allowed; and no disruption of deep soil strata should be permitted. If the water-bearing stratum is not exposed at the surface or is not recharged by adjacent surface water, the size of the protected area can be reduced somewhat. Protection limits for a water-catchment facility, the effective radius, and water-quality protection methods for groundwater should be studied and determined by the water-supply authority in conjunction with hydrogeologic and public health departments.
- For the area around water-treatment works, the requirements for surface water sources should be met.

Private water supplies from groundwater should be protected from pollution due to seepage latrines, seepage pits, excreta pits, refuse heaps, and solid

waste heaps, none of which should be within 20–30 m of the well. Adequate sanitation systems should be constructed.

When the construction, expansion, or reconstruction of a piped supply system or a private water system is undertaken, the design unit should fulfill all these requirements. When starting the final design, the planners should submit details of the protected area, protection measures, and completion guidelines for the project to the local health authority for approval.

For the protection areas of existing piped supplies and waterworks, consultation should be made with the local health authority and a plan submitted for improving the environment. After approval by the local government body, the plan should be completed in due course. For private water supplies, depending on the circumstances, the health authority may identify the protected area required.

Beyond 1000 m from the catchment point of a surface water source, any discharge of industrial and domestic wastewater should fulfill the requirements of the *Industrial Three-Wastes* [liquid wastes, solid wastes, and gaseous wastes] *Discharge Preliminary Standard* and the *Industrial Design Sanitary Standard*. Any wastewater from health, medical, scientific, and veterinary facilities that may contain pathogens must be fully disinfected before being discharged. The quality of water that is artificially recharged into groundwater should not be lower than the standard of drinking water, or it will decrease the local groundwater quality.

In addition to establishing a protected area around water sources, the environmental protection, health, and water supply authorities should monitor industrial and domestic wastewater discharges, wastewater irrigation, and cases of infection and accidental pollution. If water pollution occurs, it should be reported to the responsible body and to the water authorities so that they may take the necessary measures for protecting water sources.

Water quality should be examined according to the *Domestic Water Quality Testing Methods*. For urban piped supply systems, a water-quality laboratory must be set up, responsible for examining raw water, treated water, water ready for supply, and water in distribution networks. For large or medium-sized enterprises that have their own water supply systems, specialists within the organization should be given responsibility for their own water examination. For other units with independent water supply systems, the local government authority should appoint a testing unit to take the responsibility for water-quality examination, and the local health authority should take samples for water-quality tests.

For private water supply or rural piped supply systems, the quality should be examined by the local health department or the commune sanitary station.

For domestic water supplies, samples should be taken from places where water is frequently withdrawn, and the results of analyses should be comprehensive. For urban piped supply systems, one sample should be taken for every 20 000 people being served by the system. If the population served is more than 1 million, the number of samples may be fewer, but for a service population under 200 000, the number of samples should be more. A reasonable proportion of samples should be taken from the service connection, the end of the distribution network, the older part of the distribution network — anywhere the supply may become contaminated.

Sampling should be carried out at least twice a month at all sampling points, more often if possible. In general, bacteriological and physical criteria should be examined regularly; according to the local situation and requirements, chemical and toxicological criteria should be selectively examined. Sampling points and selective items of examination should be studied and chosen by the water-supply authority associated with the local health department.

For private supplies and piped supply systems in rural areas, sampling points, the number of samples, and items for examination should be decided by local authorities, and the results of examination should be submitted to the local health department.

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Water

Supply in Developing Countries

Proceedings of a workshop on training held in Zomba, Malawi, 5-12 August 1980

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Rural Water Supply in Developing Countries

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Foreword

The 1980–1990 decade has been chosen by the United Nations as a period when a special effort will be made to overcome the lack of adequate water supply and sanitation facilities for large sections of the populations of the less-developed world. The manpower resources to realize these goals are minimal in most countries.

The regions of East and Southern Africa are areas where the scarcity of adequately trained personnel is acute and there is a lack of information on newly developed low-cost technologies.

In August 1980, two workshops were held: one in Malawi on water supply and another in Botswana on sanitation. Full delegations from Ethiopia, Tanzania, Malawi, and Botswana attended. Selected representatives from Kenya, Swaziland, Zambia, Lesotho, and Mozambique were also invited to participate.

The regional workshops were not intended to be an end in themselves but were planned to be followed by small, national training workshops carried out by the participants in their own countries. The aim of the workshops was to further disseminate the information on low-cost technologies and discuss the implementation of curricula changes and training needs recommended at the regional meetings.

These proceedings include papers presented at the first meeting, summaries of the resulting discussions, descriptions of the field visits, resolutions, and action plans. It is hoped that, through wide dissemination, the influence of this training workshop will spread beyond the countries of the attending delegates.

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Participants

K. Achamyeleh Head, Planning and Research, Ethiopian Water Resources Authority, P.O. Box 1008, Addis Ababa, Ethiopia

Aseged Mammo Research and Development Engineer, Mechanical Engineering Department, Addis Ababa University, Addis Ababa, Ethiopia

Richard Carothers Research Associate, Department of Mechanical Engineering, University of Waterloo, Waterloo, Canada

C.H. Carr Groundwater Geologist, Department of Lands, Valuation and Water, Private Bag 311, Lilongwe 3, Malawi

A.T. Chibwana Senior Supervisor, Department of Lands, Valuation and Water, Box 97, Mulanje, Malawi

Ron Droste Assistant Professor, Department of Civil Engineering, Water Engineering Group, University of Ottawa, Ottawa, Canada

Joshua Gecaga Lecturer, Department of Civil Engineering, University of Nairobi, P.O. Box 30197, Nairobi, Kenya

Wanjiru Getechah Staff Development Officer, Directorate of Personnel Management, P.O. Box 30050, Nairobi, Kenya

Michael Graham Head, Technical Editing Unit, International Development Research Centre, P.O. Box 8500, Ottawa, Canada

S.K. Ichung'wa Provincial Head, Western Province, Ministry of Water Development, P.O. Box 235, Kakamega, Kenya

K. Jellema Wells Engineer, Department of Lands, Valuation and Water, Private Bag 311, Lilongwe, Malawi

G.A. Kamwanja Lecturer, Department of Engineering, The Polytechnic, University of Malawi, Private Bag 303, Blantyre 3, Malawi

J.A.K. Kandawire Head, Department of Psychology, Philosophy, and Sociology, Chancellor College, University of Malawi, P.O. Box 280, Zomba, Malawi

James Kanyenda Assistant Research Officer, Christian Service Committee, P.O. Box 949, Blantyre, Malawi

Yussuf N. Kashoro Project Manager (Shallow Wells), Ministry of Water, Energy and Minerals, P.O. Box 147, Shinyanga, Tanzania

H.R. Khoviwa Technical Officer, Department of Lands, Valuation and Water, Private Bag 311, Lilongwe 3, Malawi

M.M. Kivugo Principal, Water Resources Institute, P.O. Box 35059, Dar es Salaam, Tanzania

Lesetedinyana Lesetedi Senior Health Inspector, Ministry of Health, P.O. Box 258, Gaborone, Botswana

Michael G. McGarry Associate Director, Health Sciences Division, International Development Research Centre, P.O. Box 8500, Ottawa, Canada

Gilbert John Maikano Civil Engineering Technician, Department of Water Affairs, Private Bag 0029, Gaborone, Botswana

E.S. Malindi Assistant Chief Agricultural Development Officer, Agricultural Development Department, Box 30134, Lilongwe 3, Malawi

Patrick Marcello Head, Groundwater Division, Department of Lands, Valuation and Water, Private Bag 311, Lilongwe 3, Malawi

L.W.C. Munthali Senior Boreholes Maintenance Officer, Department of Lands, Valuation and Water, Private Bag 311, Lilongwe 3, Malawi

Michael Musie Head, Training Service, Ethiopian Water Resources Authority, P.O. Box 1008, Addis Ababa, Ethiopia

J. Kuthemba Mwale Lecturer, Department of Education, Chancellor College, University of Malawi, P.O. Box 280, Zomba, Malawi

A. Mzee Chief Maintenance Engineer, Ministry of Water, Energy and Minerals, P.O. Box 9153, Dar es Salaam, Tanzania

Fredy Ndhlovu Senior Works Inspector, Department of Water Affairs, P.O. Box 329, Francistown, Botswana

T.H.B. Nkana Wells Programme Officer, Department of Lands, Valuation and Water, P.O. Box 17, Dowa, Malawi

Mandlenkosi Robert Z. Ntshangase Head, Construction Department, Swaziland College of Technology, P.O. Box 69, Mbabane, Swaziland

Yohane M.Z. Nyasulu Regional Health Inspector, Ministry of Health, P.O. Box 95, Lilongwe, Malawi

Lars Nyberg Chief Training Officer, Department of Water Affairs, Private Bag 0029, Gaborone, Botswana

M.N. Opondo Panel Leader, Wind Energy Technical Panel, Department of Mechanical Engineering, University of Nairobi, P.O. Box 30197, Nairobi, Kenya

Lindsay Robertson Principal Water Engineer (Rural), Ministry of Community Development, Private Bag 8, Lilongwe, Malawi

Eric J. Schiller Associate Professor, Department of Civil Engineering, Water Engineering Group, University of Ottawa, Ottawa, Canada

R.C. Shikwe Deputy Secretary/Director of Administration, Ministry of Water Development, P.O. Box 49720, Nairobi, Kenya

O.C. Sibale Chief Water Resources Supervisor, Department of Lands, Valuation and Water, Private Bag 311, Lilongwe 3, Malawi

A.M. Singini Water Engineer (Rural), Department of Lands, Valuation and Water, Private Bag 8, Lilongwe, Malawi

R.M.A. Swere Director for Manpower Development, Ministry of Water, Energy and Minerals, P.O. Box 9153, Dar es Salaam, Tanzania

Tsehaye Haile Head, Public Relations Service, Ethiopian Water Resources Authority, P.O. Box 1008, Addis Ababa, Ethiopia

The Development of Self-Help Gravity-Piped Water Projects in Malawi

L.H. Robertson[1]

Malawi covers 95 000 km², including a number of mountains which are the sources of perennial rivers and streams. Of the total population of 5 million, 420 000 live in the rural areas of Mulanje. These people are served by 2700 village taps, which they themselves have installed by laying 2000 km of piping. The total cost has been K2 million (K1 = U.S. $1.2484), an average of K750 per tap unit and a cost of K5 per head of population.

The majority of people get their domestic water supply from shallow wells or streams. When these dry up during the dry season, water has to be carried long distances.

With the growth of population and the increase in cultivation, rivers and wells dry up earlier in the year. Water supply, therefore, becomes more and more of a problem. As the population becomes more dense, the health hazard from polluted rivers becomes greater.

Technical Background

The design objective of the project is to pipe pure mountain water, by gravity systems, from mountain streams to villages on the fertile plain.

The design criteria are: (1) 27 litres per person per day; (2) one tap to approximately 160 people; and (3) a design flow of 0.075 litres/s at each tap (when all taps are open).

All taps are public standpoints; water must be carried away (which limits consumption); and the water is free, so it is used by everyone.

Population figures are obtained from census maps. The layout and details of villages are obtained from aerial photographs. Alignment of pipelines is determined from 1:50 000 ordinance survey maps and profiles are plotted for each line.

The overall design capacity, as well as considering the existing population, takes into account the food production capacity of the soil, and is based on the (estimated) maximum population which the land can support.

From these data, required flows and pipe sizes can be calculated and the network designed.

The full range of pipe sizes is used: 12–90 mm PVC, and the larger sizes, 100–250 mm asbestos cement.

Pressures used are up to 10 atmospheres (10.3 kg/cm²). A suitable site is chosen to ensure that the header tank is at the proper elevation, the intake being high enough to feed this tank. For large projects, the main pipeline will feed a number of branch line tanks, which will then be header tanks for the branch line systems, as well as providing night storage, thereby enabling the main line to be utilized throughout the night.

Because the streams used for water supplies come from mountain forest reserves, the only purification methods employed are screening and sedimentation. Work is now being carried out to introduce

[1]Principal Water Engineer (Rural), Ministry of Community Development, Lilongwe, Malawi.

slow-sand filtration. This would greatly increase the number of rivers which could then be utilized and would extend the scope of this program.

Management and Planning

Development of Project Management

As a result of the first two pilot projects in 1968 and 1969, four things became apparent:

(1) The villagers and their leaders, having seen the possibilities, wanted more of these projects. They had become convinced that water could flow long distances through pipes (without the use of an engine) and that government was able to assist through the provision of pipes and expertise. Thus, the credibility gap between government and the villagers was bridged.

(2) Although it was essential to start with a small pilot project, until the people were convinced of its merits, it would become necessary to expand the project to cover a larger area in a comprehensive manner. This might involve as many as 100 000 people in one project.

(3) If projects of this size were to be attempted there must be proper technical supervision. Although the digging and backfilling of all the pipelines could be done using self-help labour, the actual laying and jointing must be done to a high standard and there are many aspects of the job which require the supervision of a technical assistant.

(4) The project leadership and organization would have to be such that it could maintain enthusiasm over a prolonged period (2 years), between the start of a project and the completion, when taps are turned on in the villages.

Project Leadership and Committees

The key to the success of these projects is the involvement of the whole community, and the setting up of an organization that can handle the large amount of work that has to be done and ensure that everyone does his share.

The first step is to hold a public meeting to announce the project. At this meeting all leaders are present: member of parliament, chiefs, and party leaders. The chief will ask his people if they want the project and are willing to work for it. In this way, the self-help commitment is established from the start. The meeting then appoints a project committee to organize the work.

The project committee has the support of the chiefs and all the leaders and people. It is, therefore, able to control the work that has to be done and to overcome any problems which may arise. It is important that these committees are not appointed by the government, but that they derive support from the people, chiefs, and party leaders.

For a large project, there will be a number of section committees within the main committee, which will be responsible for the different sections of the pipeline system.

Finally, there will be a village committee in each village to oversee the construction of the tap site and apron with soakaway pit, etc. This committee will be responsible for the cleanliness of the tap surroundings and for the maintenance of the tap (replacement of washers, etc.).

With this type of organizational structure, it will be clear to the people that the government's role is to assist the people with the installation of their project. This is very different from the government putting in a project for the people. It is now widely recognized that participation by the people is essential for the success of rural projects and that when a committee is given responsibility, it responds to the trust given to it.

It is, however, necessary for the project management to spell out the specific tasks that have to be done: digging of the pipeline, excavation of the tank site, collection of building stone, or digging of river sand. It is also essential that lines are marked out before digging starts. The technical assistant is the vital link between the project and the people.

Technical Assistant

The technical assistants are carefully selected for their practical experience and suitability for working with people in the field. They are trained in all the necessary skills, mainly through in-service training. They become very proficient at their work and are respected by the people. They are also personally involved in the success of their section of the project and become highly motivated.

Weekly staff meetings and annual refresher courses help to maintain high standards and build a strong team spirit. These also provide an opportunity for discussions and exchange of ideas on the problems of management in the field.

The Role of the Engineer

The necessary support for the field staff is provided by the project engineer, who has previously designed accurate and easily interpreted plans for the project. He is responsible for the coordination of the work, for setting out standard procedures, for programing the work to fit in with the seasons, for supplying pipes and other materials, and for solving all the technical and other problems which may arise in the field. In this way, he ensures that the whole project goes ahead with a momentum that can maintain the local enthusiasm.

In addition to being competent, the engineer should have a high degree of motivation, with qualities of leadership and sound judgement, which will enable him to evolve appropriate management techniques suitable for the rural project situation.

Conclusions

The basic principles which have contributed to the success of these projects can be summarized as follows:

(1) The system has evolved as a response to a real need.

(2) The community has been involved in the project at all levels and through the whole cycle of planning, implementation, and maintenance.

(3) As a result of this involvement and because of its basic importance to the success of the program, a sense of pride and ownership in the project is generated within the local community.

(4) Rural communities have always been conservative and cautious of innovations until the innovations have been shown to be appropriate to rural conditions. It has been possible to gain the confidence of the rural communities, through successful demonstration, and to involve them in a technical program of development, which then generated confidence for further projects.

The success of this project did not, of course, happen overnight, but has taken 10 years of patient understanding and persistent hard work from dedicated field staff.

Mulanje Tour

A field trip, which was an integral part of the workshop, gave the participants the opportunity to observe the Mulanje gravity-fed rural water supply system. This tour included visits to view all of the main components that make up the system: village tap outlets, storage tanks, the laying of pipes, and the intake system located high on the slopes of Mulanje Mountain. The tour involved not only visits to the sites, but at each location village committees and workers were present to explain and to show how they had built and continue to maintain their system. The tour was climaxed by a visit to a working site where village men and women were busy laying PVC pipes in the ground.

One feature that became clear was that in constructing this extensive rural water supply system, the water authorities worked with the existing tribal infrastructure, i.e., rather than trying to bypass traditional values they sought to work within them. The role of chiefs was not reduced, but was considered important in assisting with the organization of the people and the planning of work schedules.

In designing the water system, the physical constraints imposed by the environment were carefully considered. It was estimated that even with the most efficient agricultural practices, the land could not support more than 300 people/km^2. This, therefore, became the design density for the water standpipes. The amount of water allotted was 6 gallons (27 litres) per person per day. In view of the limited amount of water available on the mountain there were no plans to increase this limit. Also, any increase in water consumption would tend to go to a privileged few and develop inequalities among the villagers.

Originally, this water scheme used much self-help labour. Where the task was large and complex, however, as in building concrete storage tanks, it was eventually found to be more efficient to contract this work out to competent local masons. In addition, as development proceeded it was considered that self-help labour would become more difficult to obtain, so that with time more professional, paid skilled labour would be used. The use of local personnel and committees, however, would probably continue to be more efficient for constructing small-scale local tanks, keeping the standpipe area clean, and repairing taps and washers.

Education of the users was stressed. The villagers had to be convinced of the superiority of the piped water system in order to (1) operate and maintain it carefully and (2) continue to use it in preference to less hygienic sites (e.g., pools, temporary rivers) that become available during the rainy season.

Rainwater Catchment in Botswana

Gilbert J. Maikano[1] and Lars Nyberg[2]

The Republic of Botswana, with an area of 561 800 km^2, lies at the centre of the Southern African Plateau, at a mean altitude of 1000 m above sea level. The climate is continental and semi-arid, with an average annual rainfall of 450 mm. The rainfall is erratic and unevenly distributed, ranging from 300 mm in the southwest to 700 mm in the northwest. Over 90 percent of the rain falls in the summer months between November and April, although some light rains occur as early as September. The country lacks perennial surface water, except in the northwest and a few springs, dams, and pools in the east. Mean maximum and minimum temperatures vary according to region, but the former seldom rises above 30°C and the latter seldom falls below 5°C.

About 84 percent of the land surface is covered with Kalahari sand, which supports low savanna-type vegetation. Rainfall is normally held in the top few metres and is largely lost through evaporation. Only 5 percent of Botswana has the combination of adequate rainfall and suitable soils necessary to provide for arable agriculture.

The population is estimated at 857 000, about 80 percent of whom live on the eastern side of the country, where there are suitable soils and sufficient rainfall to permit arable agriculture. About 15 percent of the population lives in towns and the remaining 85 percent lives in large villages, rangelands, and cattle posts. A peculiarity of life-style in Botswana is that most people have more than one home, i.e., the main village or town, where people reside from July to September; the rangeland area, where people reside from October to July; and in some cases, the cattle-posts area, where people stay for various lengths of time. This pattern of living makes it difficult to provide potable water to all the communities all the time.

One of the main constraints to productive arable agriculture is the lack of water, both for human consumption and animal watering, during the time prior to the main part of the rainy season. This causes plowing to begin late, which results in poor crop yield.

Rainwater Catchment Concept

Lack of water at the beginning of the rainy season has brought about the introduction of the rainwater catchment. It was felt that if water from the first light rains could be collected and stored, it could then be used for human consumption and draft-animal watering prior to the heavy rains; thus, plowing could begin earlier, resulting in a better crop yield.

Feasibility Studies

With cheaper alternative sources of water supply not available, the construction of rainwater cisterns becomes justified. This is particularly true at the beginning of the plowing season, when there are no other sources of water in many parts of Botswana.

[1]Civil Engineering Technician, Department of Water Affairs, Gaborone, Botswana.

[2]Chief Training Officer, Department of Water Affairs, Gaborone, Botswana.

At Pelotshetlha, in the Southern District of Botswana, an integrated farming pilot project has engaged farmers in a new and alternative rainwater harvesting scheme. Advantage is taken of a traditional grain-threshing floor, which is used as a rainwater-collecting surface. The floor is surrounded by a low mud wall and is plastered with a mixture of clay and cow dung that provides a smooth, relatively hard surface. Plastering is done annually at the beginning of the crop-harvesting season.

These floors, which are common all over the country, slope gently toward one corner, where a small hole is usually made to allow the waste out. Under this pilot project, a shallow basin connected to a rainwater cistern by a short length of PVC pipe has been provided. This basin acts as both a collecting and sedimentation device.

The cistern is entirely underground, but has a brick curb to exclude surface runoff and to provide a bearing surface for a cover. In the initial cisterns, the cover was constructed of lengths of tree trunk. Because it is not easy to find long lengths of tree trunk, the width of these initial cisterns was restricted to 2 m. Also, because the surfaces of tree trunks are uneven, gaps occurred in the cover and permitted dust to enter the cisterns. This type of cover has, however, been found effective enough to provide shade against the sun and, thus, prevent algal growth in the water.

The cistern itself was waterproofed by a thin layer of cement plaster applied on a chicken-wire mesh that was pegged along the sides during plastering. The finishing plaster was smoothed over to render the surface waterproof. To date, no evidence of seepage loss has been noted.

Design and Construction Options

These initial rectangular cisterns have been criticized because the rectangular shape is structurally less strong due to differential stresses that will, in time, cause the plaster to crack at the corners and on the long sides, which are 8 m in the larger of the current cisterns. Also, the surface area to be plastered is about 25 times greater in a rectangular cistern than in a circular one of the same capacity. Thus, plastering costs are higher.

It is now recommended that circular tanks be used and that the rectangular ones be monitored to determine if they crack. If they do, they can be replastered and checked before the next rainy season. If the rectangular tanks fail, either they will be backfilled and circular tanks will be dug nearby, or an attempt will be made to convert them to an elliptical shape.

The roofing of circular tanks can take the form of precast concrete slabs incorporating a hole for drawing water in the same manner as for hand-dug protected wells. The slab can be cast in portions to facilitate handling, which can be eased through the use of pulleys. As tank size increases, the covering slab thickness will also increase. It can vary from 2 cm at the edge to 7.5 cm at the centre. The slab can be reinforced by five strands of barbed wire in the thick slabs and two strands in thinner ones.

Another alternative being tested is a domed cover, which is cast on a mound of earth that is carefully shaped and whose size is calculated to be larger than the outside diameter of the tank. The height of the centre of the dome varies with diameter (i.e., about 40 cm for a 10 m^3 tank and increasing to 1.5 m for a 25 m^3 tank). A well-shaped chicken-wire mesh is then pegged to the mound and plastered with cement mortar, which is then allowed to set for 5 days. In the case of domed covers, the hole for the dipping bucket should be toward the side so that people do not have to climb the dome to draw water. When the dome is set, it can be carefully lifted on poles and mounted on the tank.

Selection of Size

Table 1 gives the dimensions and estimated costs of four tanks ranging from 10–25 m^3 in capacity.

Operation and Maintenance

As mentioned earlier, the plastering of the traditional threshing floor is done annually

Table 1. Estimated costs (pula) of underground rainwater tanks of four different capacities (m^3). In all cases tank depth is 2 m.

	10 m^3		15 m^3		20 m^3		25 m^3	
	Quantity	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Diameter (m)	2.52		3.09		3.57		3.99	
Floor area (m^2)	5		7.5		10.0		12.5	
Total plastered area (m^2)	20.8		26.9		32.4		37.5	
Man-days 1.27 m^2/day at P4.00/day	16	64	21	84	25	100	30	120
Supervised man-days (P12.5/day)	4	50	5	63	6	75	7	88
Cement bags (P2.84/bag)	7	20	9	26	11	31	13	37
Wire mesh (P1.44/m^2)	21	30	27	39	32	46	38	55
PVC inlet pipe		10		10		10		10
Contingencies, at 10% for transport		22		27		31		36
Transport of materials		50		50		50		50
Farm improvement grant		20		20		20		20
Total estimated cost		266		319		363		416
Cost per m^3 stored		26.6		21.3		18.2		16.6

Note: P1=U.S.$1.29.

at the beginning of the harvesting season. This is the only extensive maintenance required for the floor other than sweeping it time and again so that the first rain can find it clean and free from loose dust. The fact that the threshing floor will be used for collecting water means that all possible pollutants must be kept away from the floor.

Some silt will, obviously, be carried in the water and this may necessitate the provision of a simple slow-sand filter, which will require renewing of the filtering material once a year. By introducing a slow-sand filter the bacteriological content of the water will also be reduced.

The cistern will require cleaning before the beginning of the next rains. Plastering of the tank and cover may have to be done as cracks are noticed.

The entire unit must be fenced to prevent damage by livestock, particularly after the people return to their villages. The fencing itself is not a new innovation, nor is it expensive. It is common to have homesteads fenced with tree branches and gates blocked using newly cut branches at the end of the harvesting season.

Water must be drawn by bucket through the manhole and a trough should be available for watering livestock.

Water Quality

It has been feared that because the catchment area is plastered with a mixture of clay and cow dung, that nitrate and bacteriological pollution would be a serious problem. A sample taken from one of the existing tanks at Pelotshetlha showed a nitrate concentration of 1 ppm. The parameters tested were: nitrate 1 mg/litre; pH 7.2; conductivity 211 mmho; total dissolved solids 190 mg/litre; and chloride 8 mg/litre.

Further chemical and bacteriological tests of the water will be conducted, particularly because pathogens may also be found as a result of the use of cow dung. Such monitoring will be done while water from the previous rains is still in the tanks and also after the tanks have filled from the next rains.

Rainfall Analysis

Rainfall data for Pelotshetlha over the last 10 years were used to calculate the amount of water it should be possible to obtain with a catchment area of 150 m^2. Consumption figures of 20 litres per person per day for a community of 7 persons and 60 litres per ox per day for 6 oxen were used and the calculated water demand was 0.5 m^3 per day.

As mentioned earlier, the aim is to encourage early plowing by providing people and cattle with a safe water supply.

Today, people rely on water from pools. The oxen are often in poor health and as a result, when the first heavy rains come in November, plowing takes a long time.

Table 2 gives the amount of water that can be collected using water catchments and the earlier dates on which land preparation can begin as a result.

Table 2 indicates that an average of 17 days can be gained for land preparation before the start of plowing. (Normally, plowing begins with the first rainfall of >25 mm.) The following rainwater catchment data indicate the amount of rainfall it was possible to obtain in three different areas: Kanye: average, 8.0 m^3; 0–5 m^3, 4 years out of 19; 5–10 m^3, 10 years out of 19; > 10 m^3, 5 years out of 19. Mahalapye: average, 6.2 m^3; 0–5 m^3, 11 years out of 20; 5–10 m^3, 3 years out of 20; > 10 m^3, 6 years out of 20. Ghanzi: average, 3.4 m^3; 0–5 m^3, 15 years out of 20; 5–10 m^3, 4 years out of 20; >10 m^3, 1 year out of 20.

User Education

The experiments on rainwater catchment have been publicized in *Agrinews*, a bulletin

Table 2. Normal starting date for plowing vs. possible starting date of land preparation through the use of water catchments.

Normal starting date for plowing	Amount of water collected before plowing begins (m^3)	Possible starting date of land preparation with water catchment tank	Time gained (days)	Year
13 November	10.9	22 October	22	1971
7 November	5.6	7 November	0	1972
30 November	23.0	19 October	42	1973
18 November	9.0	5 November	13	1974
12 November	8.1	6 November	6	1975
7 November	19.9	14 October	24	1976
23 November	11.4	6 November	17	1977
29 November	13.7	6 November	23	1978
1 November	21.5	20 October	12	1979

of the Ministry of Agriculture. Agricultural demonstrators continuously take farmers in their areas of operation to Pelotshetlha to show them the rainwater catchment project run by the integrated farming pilot project. It is hoped that these measures, as well as others in the future, will prepare the farming community to accept and maintain these devices.

Today, the pilot project has about 10 underground tanks built and more are under construction. In all, it is hoped to have 80 completed by the end of 1980.

Conclusions

From rainfall statistics it is possible to state that in areas around Kanye and Mahalapye there is no need to construct tanks larger than 12–15 m^3. In the dry Ghanzi area, the tank volume can be reduced to 8 m^3. Before the heavy rains start in November, the average amount of rainwater it is possible to catch on a 150 m^2 threshing floor in these three areas is: Kanye, 8 m^3; Mahalapye, 6.2 m^3; and Ghanzi, 3.4 m^3.

Usually, the farmer is expecting enough rain for plowing in November and after the rain he takes his oxen out to the land. With the introduction of rainwater catchment tanks he can move with his family and oxen to the land 2–3 weeks earlier and be able to prepare for plowing so that he can start as soon as the rain comes.

In this way, the possibility exists that the farmer will be supplied with water during his entire stay at the land and when he comes back to the land for harvesting, his tank, in most cases, will again be filled with rainwater, which will last for a long time.

The quality of the water, although still not satisfactorily investigated, is a definite improvement over the water collected in pools, which is often contaminated by excreta from animals.

Shallow Wells and Hand Pumps

Teged Mammo[1]

At present, there is a general lack of potable water in rural parts of Ethiopia. There are a number of ways of supplying such water: engine-driven pumps, from boreholes, shallow wells, springs, rivers, lakes, etc.

Of the many alternatives, springs are widely regarded as the cheapest source of clean water, if they are available. Rivers and lakes are few, and streams last only during or just after the rainy season, after which time they are too turbid to be used as a source of potable water.

Another source of potable water is hand-dug wells. In rural Ethiopia, one of the local craftsmen is always the well digger. At present, however, most hand-dug wells are improperly constructed and use primitive water-lifting devices such as buckets and inner tubes that are unhealthy and time consuming. The use of hand pumps would facilitate the withdrawal of water from these wells.

In a country like Ethiopia, where there is a tremendous demand for hand pumps and a shortage of funds for importing foreign goods, a plausible hand pump has to be inexpensive and reliable to be imported.

This report, apart from a short section on wells, is essentially a comparison of some hand pumps that are in use in Ethiopia, both imported and locally designed and manufactured.

[1]Research and Development Engineer, Mechanical Engineering Department, Addis Ababa University, Addis Ababa, Ethiopia.

The project is financially and technically supported by the International Development Research Centre (IDRC) and the United Nations Development Programme/ United Nations Industrial Development Organization (UNDP/UNIDO), and implemented through the Ethiopian Water Resources Authority (EWRA).

The designing and manufacturing were carried out in the Mechanical Engineering Department, Faculty of Technology, Addis Ababa University. This research is essentially a continuation of research on hand pumps and windmills that took place at Addis Ababa University during the "Development through Cooperation Campaign," which spanned the years 1974–1976.

Wells

Selection of Well Sites

According to the EWRA Central Region, and presumably in general, almost all water points are established at the request of the local population. When the request arrives, a team is sent to determine what type of water-point design will satisfy the local demand, as well as be most economical to implement.

The team first considers the possibility of springs in the vicinity. If none are available, it must then consider shallow or deep hand-dug wells or perhaps boreholes with engine-driven pumps. Wind-powered water points are not, as yet, available.

Construction

When the most economical water-point design is a hand-dug well, a work crew is sent to camp near the site. Presently, a major problem exists with the supplying of construction and other support equipment to the work crews. As much as 50 percent of the crew's productive time can be lost trying to purchase and ship materials and handling per diem requisitions.

Technical difficulties are less of a problem. For example, if the soil is too loose, it will cave in before the casing is lowered. A temporary wooden frame, therefore, must be made as digging proceeds. Another problem with loose soil is that it keeps falling into the water, making frequent cleaning of the well necessary. In one location in Awara Melka, 200 km southeast of Addis Ababa, the aquifer material contained a lot of pumice which is much less dense than water. These rock particles were suspended in the water and were sucked into the hand pump that had been installed. After a month of operation the piston and foot valve were both stuck.

There is now a standard well design developed by the Central Region for use by the EWRA. The United Nations Children's Fund (UNICEF) and the Evangelical Church Mekane Yesus (ECMY) are two of the well "suppliers" to this project with their own standard designs. These designs are affected by the pump type to be used, the terrain, and the degree of cleanliness required of the water (e.g., UNICEF well covers have no manhole).

This particular project doesn't deal with well digging or construction directly, but requests wells to: (1) have studs cast in the concrete to match the holes in the pump stands being used and (2) be easily accessible from the main road and within a 200 km radius of Addis Ababa. In areas beyond this boundary, maintenance and follow-up are carried out by local residents. Eventually, all manufacturing (except for pistons and foot valves), installation, and maintenance of pumps will be carried out by the regions themselves. Currently, there are no hand pumps installed in boreholes in the Central Region and very few elsewhere.

Hand Pumps

In the EWRA Central Region (where more than two-thirds of the pumps are installed to date) there are three categories of hand pumps being used. The following list gives the category and the types of pumps used within each: (1) imported: (a) Consallen, (b) mono (myno); (2) semi-local: (a) Boswell; and (3) local (EWRA/IDRC): (a) BP, (b) BPL, (c) type C, (d) type D. This list doesn't include all hand pumps that are in use in the Central Region, but is a collection of those hand pumps which are closely connected to the EWRA and, hence, this project.

Consallen

These hand pumps were installed when the United Kingdom was giving aid to the EWRA Central Region. They are installed mainly in the Maki area about 130 km south of Addis Ababa, and have a 2, 2.5, or 3 in. (5.1, 6.4, or 7.6 cm) piston and cylinder (depending upon the depth of the well); a 1.25 in. (3.2 cm) riser PVC pipe; steel pump rod; and steel pump stand with lever. The piston has rings and is running in a stainless steel cylinder. The foot valve consists of a rubber sealer against a slotted or perforated steel body. Unless foreign particles are introduced, the sealer is quite effective. The riser pipe is connected with a PVC flange to the pump stand.

When operated, because of the tight fit between the piston and cylinder, the pump feels heavy, even at low pumping heads. Also, the riser pipe snakes, particularly at faster pumping speeds. Consequently, the PVC flange at the pump stand breaks and repeated failures of the 1.25 in. (3.2 cm) riser pipe at the threaded connection were experienced. Foot valve leakage was not acceptable in many cases, after some time of operation. Except for the flange connection in the stand, the part of the pump above ground stands up to a lot of mishandling.

Mono

This is a rotary positive-displacement pump. The piston is a solid steel helix

running in a matching rubber cylinder. There may or may not be a foot valve because the fit of the piston and cylinder is very tight. The transmission shaft is steel and is guided by rubber bearings in the riser pipe. Pumping is accomplished by rotating the arms that are on opposite sides of the pump stand. A bevel-gear pair transmits the torque to the pump rod (transmission shaft), which has the piston attached to its other end.

This pump is normally regarded as the best type as far as reliability and ease of pumping are concerned. The only maintenance problem is oil loss at the seal of the gearbox bearings. The United Nations Children's Fund, which is importing and installing this type of pump, leaves a quantity of oil with a person living nearby to fill up the gearbox once a month or as required. The newer version of the mono pump, the myno pump, will have double O-rings at these points in the gearbox to reduce oil leakage. If, however, there is a considerable loss in the height of the static water level (drought), parts which rely on water for lubrication, such as the starter in the mono pump, could suffer heavy wear and tear. The greatest problem with this type of pump is its cost, which is presently about U.S.$1200.

Boswell

In the past, this pump was imported in its entirety. Now, the only imported parts are the pump rod, piston, and cylinder. The Boswell pump is basically a piston pump with a distinctive, above-ground structure. The piston and foot valve both possess leather cup seals to minimize leakage. The cylinder is brass-lined, galvanized steel pipe. The foot valve can be withdrawn without taking up the 2 in. (5 cm) galvanized steel riser pipe by screwing the lower end of the piston into the foot valve. The pump rod is galvanized steel.

There are many varieties of this pump, but generally the pump stand is always offset from the riser pipe. The lower arm is very long (about 2 m, with a relatively small mechanical advantage of 3.3) and the pump stand is relatively high.

Installation of this pump is difficult because the stand and riser pipe are offset. As a result, alignment of the pump rod end of the lever with the "stuffing box" (the above-ground portion of the riser pipe) is never perfect. The pump rod upper end normally scrapes the wall of the riser pipe. The stops which limit the up and down strokes of the handle are frequently worn away. The piston cup seals expand when immersed in water and pumping is very heavy, even at low heads, just after installation. By the time pumping is no longer heavy, the cup seals have worn down and are almost ready for replacement. Unscrewing of the piston from the pump rod has been experienced.

The pump stand, piston, and cylinder are the major problem areas of this pump. In agreement with UNICEF and EWRA staff, it was decided that an attempt be made to modify the Boswell pump in this project. The tentative plan was to (1) have the stand screwed directly onto the riser main by using the type BPL pump stand designed by this project for this purpose (with a mechanical advantage of 4 and a maximum stroke of 20 cm); (2) redesign the leather cup seal to reduce piston–cylinder friction, but keep volumetric efficiency reasonably high; and (3) have pins drilled through parts of the piston to prevent it from working itself loose.

The pump stand is being manufactured at the Society of International Missionaries (SIM) workshops at the rate of 120 per year. It is planned to manufacture 160 per year by extending the SIM and/or the Oxfam workshop at the EWRA.

The pump rod, piston, cylinder, and foot valve are still being imported at a cost of U.S.$100 per pump. The pump stand is being made locally for Br370 (U.S.$178) and the 2 in. (5 cm) galvanized steel riser pipe is locally purchased.

Local EWRA/IDRC Pumps

This project is working on three types of hand pumps: types B, C, and D. Type B pumps are further subdivided into types BP and BPL. They consist of a piston, cylinder, and foot valve submersed in water. Type BP

(Fig. 1) uses plastic (PVC) riser pipe and a direct-acting handle operating in a bicycle-pump fashion. It is designed for shallow-well pumping (up to 20 m depth). Type BPL (Fig. 2) is the same as type BP below the well apron, but employs above-ground leverage and is designed for use in deeper hand-dug wells (depths up to 35–40 m). Type C (Fig. 3) is an inertia pump in which the water column and riser pipe are suspended on a spring and oscillate at the natural frequency of vibration of the system. Type D is also an inertia pump in which only the water column is oscillating.

Type C (Fig. 3)

These pumps have pipes that are suspended on a spring on the well apron. The foot valve is at the other end and pumping is accomplished by oscillating both pipe and water in the pump. The pump is self-priming, has very few parts, and has

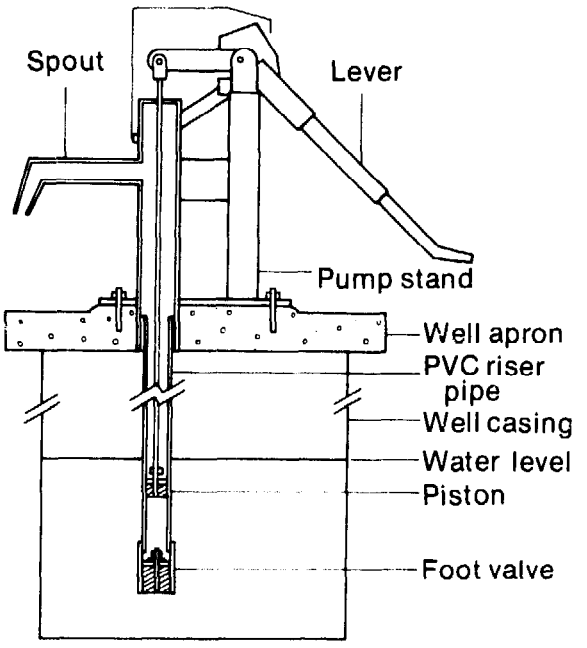

Fig. 2. Type BPL pump assembly.

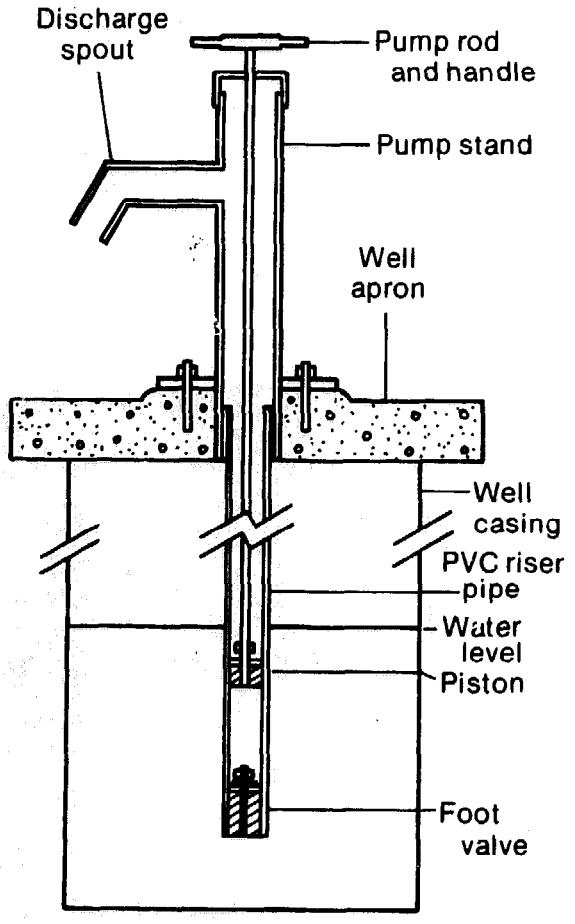

Fig. 1. Type BP pump assembly.

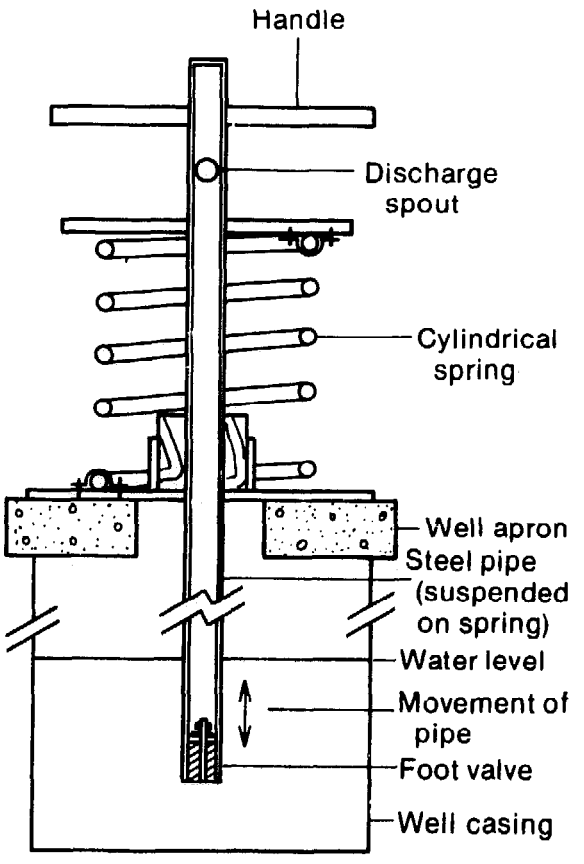

Fig. 3. Type C pump assembly.

high efficiency. It can, theoretically, be used with very high heads, and is relatively easy to pump. Collection of water is accomplished via a flexible hose attached to the discharge spout. Development of this pump has been slow due to the emphasis placed on other pump types. The main problem with this pump is that the required spring characteristics are demanding. The operating speed, i.e., the natural frequency of vibration of the system, must be 1.5–2 Hz. On wells with heads of up to 14 m, induced stress in the spring wires is 3000–5000 kg/cm^2. Because the springs are not readily available locally, facilities for the manufacturing of the springs will be necessary if the pump is to be used. Another problem which must be solved involves obtaining the steel needed to make the springs, because it is not available locally. It will be necessary to overcome these difficulties if the type C pump is to be successful.

Type D

This pump has a stationary pipe in which the water oscillates at its natural frequency. Excitation is accomplished by a piston and cylinder arrangement on the top. At the other end of the pipe is a foot valve.

Because the pipe is stationary, induced stresses are relatively low. The fact that the pump head (cylinder and actuating piston) could be arranged offset from the well makes this pump attractive as a sludge pump (dewatering pump). This pump is not self-priming, however.

Experiments on this pump were temporarily stopped due to a foot valve problem (it would not tolerate muddy water). When the foot valve problem was finally solved, priority was then given to type C pump development and later, based on a consulting report from the University of Waterloo, toward the type BP pump. The BP pump has since been used as a sludge pump as well, which led to further delay in the development of the type D pump. More information on the type D pump will become available in the future when efforts will be geared away from the type BP pump, which is now in a relatively advanced stage of development.

Type B

This pump consists of a pipe at the end of which is a foot valve. The lower end of the pipe serves as a cylinder. The piston is submerged in the water at the end of a pump rod. The piston has a valve incorporated in it. A type A pump, which was the same as the type B pump, except that it had no valve in the piston, was discarded early in the project in favour of the type B pump.

Experiments on the type B pump were first started using galvanized steel pipe for the riser pipe and cylinder. It was found, however, that the surface of these pipes was too rough, resulting in an inefficient system and considerable wear on the piston. It was then decided to line the bottom metre of pipe (the cylinder) with thin PVC pipe.

The type BP pump (Fig. 1) as it stands now, has a pump stand made of galvanized steel pipes that are welded and painted. The riser pipe is PVC (1.5 or 2 in. (3.8 or 5.1 cm)) and screws directly onto the stand. The joints between the pipes are made using steel couplings and at the end is a foot valve. The pump rod consists of pipes cement welded by bell ends, and at the lower end is the piston. This type of pump is designed for pumping from depths up to 10 m with the 2 in. (5.1 cm) (BP50; Fig. 4) riser pipe and from depths up to 20 m with the 1.5 in. (3.8 cm) (BP40) riser pipe. Lower heads (1–4 m) could be handled with 3 in. (7.6 cm) or 2.5 in. (6.4 cm) pipe, but these sizes are not produced locally. The handle is made of wood and is clamped onto the 0.5 in. (1.3 cm) PVC pipe/pump rod. There is no mechanical advantage on the BP50 and BP40 versions, which decreases pump stresses and cost while making pumping more difficult.

Installation of both the BP and BPL pumps is not time consuming; 3 h are sufficient for two technicians and a helper to completely install a BP40 or BP50 pump. In one instance, installation was completed in 1.5 h. The BPL pump would take about 5 h to install because the pump rod has to be measured exactly, and the steel rod and 0.75 in. (1.9 cm) PVC pipe/pump rod joined on-site. The following are some the problems experienced with this pump that have now been solved.

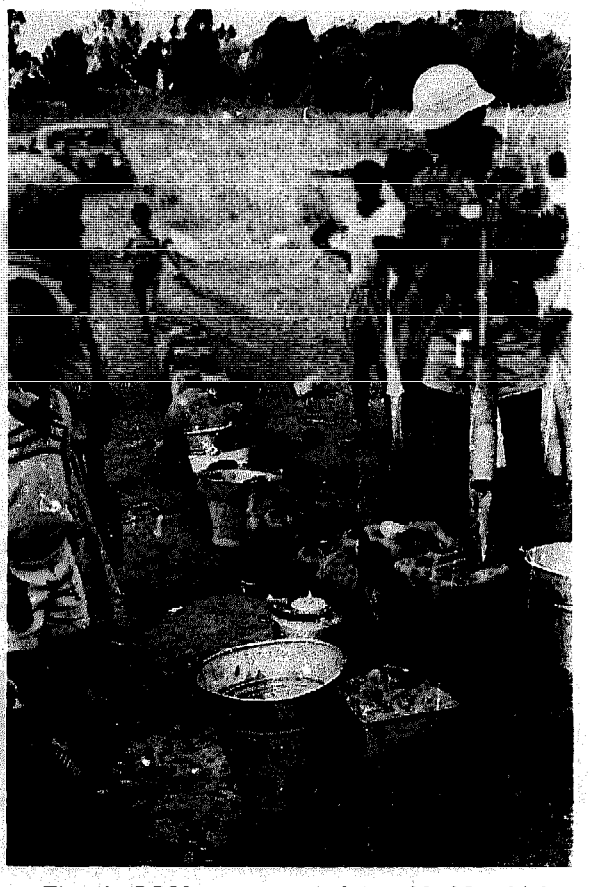

Fig. 4. BP50 pump supplying 20–25 m³/day from a depth of 3 m to the town of Assossa (pump installed in August 1979).

Pump stand. The most frequent problem with the pump stand involved the pump-rod guide, which was also serving as a crude stuffing box. The wood which was used had to be boiled in oil to make it a more durable bearing surface. When fastened with screws and/or when it was in contact with the handle during pumping, the guide would break and the pieces would go down into the riser pipe. To avoid the screws that initiated most of the cracks, the "cap" idea was started. The impact of the handle was still breaking the wood, however, so it has now been replaced with polyethylene, which has to be imported.

Another problem involved children putting material in the spout opening, which caused heavy piston and cylinder wear and eventual sticking. To eliminate the problem the spout, which was straight originally, was designed to face downward to make it more difficult for children to put material into the opening.

In one instance, the base plate cracked and the pump stand and riser fell down. To remedy this problem, ribs were welded onto the base plate to reinforce it.

Pump rod. Within 1 week of the installation of the first pump, the pump rod was broken about 30 cm below the handle. Although thin-walled steel tubing was added to reinforce the pump rod, this too was breaking, just below the lower bolt that attaches the pump rod to the handle. As a result, present pumps have at least 1 m of pump rod reinforced with a solid steel bar. To avoid drilling holes in the pump rod it is now clamped to the handle by friction only. A better solution to this problem, however, would be to use a solid nylon bar which is strong enough, but is lighter and can be welded to the PVC pipe. Nylon of this nature will be manufactured locally some time in the future. The pump rod stop (which prevents the rod from being pulled out all the way) was frequently becoming detached. Now, a bell-end joint on the pump rod about 50 cm below the handle also serves as a stop.

Riser pipe/cylinder. This is the major problem at present. Because the 2 in. and 1.5 in. (5.1 cm and 3.8 cm) pipes received from the local factory were not consistent in their dimensions, had wavy internal surfaces, a high out of roundness rate, and an uneven wall thickness, longitudinal cracks in the pipe developed after a few weeks of operation. After being approached on the matter, the management of the factory that had been providing the pipes pledged to supply pipes of better quality.

In a couple of instances, the riser pipe failed at the root of the thread coupling it to the pump stand. Currently, a design change is under way that avoids threaded connections (stress concentration). Because plastic couplings are not locally available, standard steel pipe couplings are used for the other connection.

Because the largest high pressure pipe produced by the factory is 2 in. (5.1 cm) in diameter, it is used in the lower head pumps

(1–4 m) (2.5 or 3 in. (6.4 or 7.6 cm) pipes would give higher discharges).

Cylinder. The last metre or so of riser pipe also serves as the cylinder. Field tests have shown that loss of volumetric efficiency has been mainly due to wear on the PVC cylinder rather than on the polyethylene piston. Thus, it is now envisaged to have the last metre of the riser pipe consist of a detachable unit, which can be replaced when it wears down (every 6–12 months, depending on the amount of usage and type of pump). It is more critical on the BPL type pump with its short (20 cm) stroke.

Piston. The piston also becomes a serious problem on the BPL type pump. Longer pistons (two coupled together) were unsuccessful in decreasing the rapid loss of volumetric efficiency. A design change to a piston with rings, after the preliminary IDRC (University of Waterloo) design, and which can easily be installed and withdrawn in the riser/cylinder, is under way. No changes in design are immediately planned on the pistons of the BP50 and BP40 pumps. However, there may be slight changes when the units go into mass production.

Foot valves. The centrally-pinned type design was abandoned early in the project in favour of the present design, in which the sealing rubber flapper is free to move up and down on a central stem (brass bushing). Because the steel washers adjacent to the brass have shown a tendency to corrode, the bushing is made of steel. The 1.5 in. (3.8 cm) foot valve was troublesome because it had little sealing area. Now, all foot valves are of the 2 in. (5.1 cm) type, with an adaptor/coupling for use on 1.5 in. (3.8 cm) pipes. This foot valve is now very effective in sealing and highly tolerant to foreign particles. There have been no further foot valve problems since the last modification, except once, when excessive amounts of floating pumice were sucked into the pump.

Cost Comparisons

Prices quoted in Table 1 are from the people who import the pumps. In the case of the local pump (type BP), the figures are taken from Aseged and Jensen (1979).

Conclusions

With respect to costs, spare parts, and backup, the best pump is the type BP pump for heads of up to about 20 m. However, the robust pump-stand design of the Consallen and overall reliability of the mono pump are desirable. In these respects, the type BPL

Table 1. Price breakdown of various pump types.

Pump type	Price (Br) (1 Br = U.S.$0.48)	Approximate amount of foreign currency in price (%)	Remarks
Consallen	900[1]	100	
Mono (myno)	2480[1]	100	Myno with double oil seal will be slightly more expensive than mono
Boswell	860[2]	40	25 m head
BP50	185[3]	20	8 m head
BP40	220	20	16 m head
BPL	450	20	25 m head, with similar piston as in BP50

[1]Consallen and mono pump prices are for the pump stand, piston/cylinder assembly, and pump rod only.
[2]Stand, BR370; riser (5.1 cm × 25 m), Br300; piston, foot valve, and pump rod, Br207.
[3]Labour cost for type BP pumps assumed at Br5/h.

pump requires further development.

It has also been shown from field tests, however, that no hand pump is maintenance free. Routine inspection and maintenance cannot be done by the EWRA because it does not have the manpower, organization, or sufficient funds.

Therefore, in order for any hand-pump program to be successful, the participation of the community is imperative! Maintenance should be carried out at the village level, with only marginal involvement from a central government body.

Aseged, M. and Jensen, K. 1979. Research and development in water pumping technology in rural areas. Interim Technical Report, Polyethylene/PVC Hand Pump. Addis Ababa, Ethiopian Water Resources Authority.

Shallow Wells Project, Shinyanga Region

Y.N. Kashoro[1]

Shinyanga Region is one of the 20 regions in Tanzania south of Lake Victoria. It has an area of about 50 000 km^2 and is divided into four districts (Shinyanga, Maswa, Bariadi, Kahama) and one subdistrict (Meatu). It has a population of 1 325 000, who are settled in 684 villages.

The region has a semi-arid tropical climate, with an average annual rainfall of 700–1000 mm. The rains start in mid-October and end in early May. The elevation in the region varies between 1500 m above sea level (asl) in the Bariadi District and 1100 m asl in some parts of the Kahama District. The majority of the region has an undulating landscape. The temperature is fairly constant throughout the region, with highs ranging from 28°C in March to June to 32°C in October and lows varying from 15°C in June and July to 19°C in October to December.

Shinyanga Shallow Wells Project

The Shinyanga shallow wells project started in October 1974 in response to recommendations of the Shinyanga water master plan survey, which was carried out in 1973. In the survey report it was recommended that 2000 shallow wells be constructed in the Shinyanga Region as a quick and inexpensive method of serving most of the population in the region. This was followed by a bilateral agreement between the United Republic of Tanzania and the Kingdom of the Netherlands, whereby it was agreed to set up a construction unit to construct 700 shallow wells and in the course of construction to train Tanzanians to man the project. This task was accomplished in June 1978 and the project was turned over to the Tanzanians. Table 1 shows the present distribution of shallow wells throughout the region.

Selection of Well Sites

Requests and applications for well construction come from the villages to the districts and, finally, to the region. At the district level, the applications are compiled in order of priority, the most needy villages being first. These lists of villages are then sent to the regional development committee with a copy going to the regional water engineer. The regional development committee decides which district or part of the region should be started first, bearing in mind that concentration in one particular area could be cheaper and construction could progress more rapidly.

Table 1. Shallow-well distribution throughout the Shinyanga Region.

District	No. of wells	No. of villages	Population served
Shinyanga	365	115	109500
Maswa/Meatu	262	80	78600
Bariadi	222	52	66600
Kahama	145	50	43800

[1]Project Manager (Shallow Wells), Ministry of Water, Energy and Minerals, Shinyanga, Tanzania.

Knowing the villages and their priorities, a hydrogeologist studies aerial photos, maps, and all available data to locate possible seepage areas, riverbeds, old riverbeds, possible valleys, vegetation, etc. This is followed by a visit to the village, at which time he contacts the village chairman and others from whom he can seek information such as where the village is currently obtaining its water supply during the dry season and where, within the area, water might be found. A reconnaissance survey is then made of the village to locate potential sites for shallow wells based on accessibility, soil suitability, and population within the village. A study of the geology of the area is important for locating recharge areas and possible aquifer locations. Rainfall and evaporation data are also useful for determining potential water supplies in an area. Based on all of this information a survey plan is then made.

Surveying of Well Sites

After a thorough investigation, potential well sites are marked and a survey is carried out to determine if water is present and, if so, its quality and quantity. Two methods of drilling are used in the surveys depending on the material being penetrated: hand drilling methods are used in soft material and in hard material a mechanical drill is employed. Hand drilling can easily go down to a depth of 10 m in sand, loam, and other loose materials, whereas mechanical drilling is capable of penetrating hard weathered and cemented materials and normally continues until the water table is reached. If, during drilling, the soil tends to cave in or collapse, a casing is used. When the aquifer is reached, its thickness is measured and a pump test is carried out to determine the yield of the well. Water samples are also taken at this time to determine water quality. In the Shinyanga Region, high fluoride and salt contents are the main hazards to the potability of groundwater, particularly in East and Central Shinyanga District and Maswa. These factors influence the health of consumers. Efforts are made during site selection, however, to avoid such pollution problems.

Well Construction

In Shinyanga there are three methods used for constructing wells: hand-dug wells, hand-drilled wells, and mechanically-drilled or dug wells.

Hand-Dug Wells

This type of well is constructed using traditional methods of digging a hole with a hoe or pickaxe. After reaching the aquifer, the hole is lined with concrete rings and covered with a concrete cover. Hand-dug wells become very expensive if the depth goes beyond 10 m. This is mainly a result of the need to use dewatering pumps during their construction and the cost of lifting soil from the well, which is time consuming and very laborious if hard layers are encountered. Using this method, one well sinker with four self-help labourers can dig two 7 m deep wells per month. This method of producing wells is appropriate in cases where it is felt that it is important to leave some knowledge of construction techniques at the village level.

Hand-Drilled Wells

Hand-drilled wells are drilled by using a 25 cm auger turned by two self-help labourers. When the hole has reached the required depth, it is lined with slotted 15 cm diameter PVC pipe casing and gravel-filter packing is applied around the outside of the pipe. This method is the cheapest method for drilling wells for hand pumps, but is only applicable in sand and soft materials where it is not difficult to drill with such an auger. One foreman and eight self-help labourers can drill two wells per week using this method.

Mechanically Drilled Wells

Where the aquifer is deeper or the material is harder and cannot be penetrated by hand drills, a percussion rig is used. The borehole is cased with slotted 15 cm diameter PVC pipe with gravel-filter packing around the outside of the pipe. This method, with some modification, could be used as a quick method of constructing inexpensive shallow wells. One foreman, four rig-crew members, and three labourers can produce one well per week. This method is the only

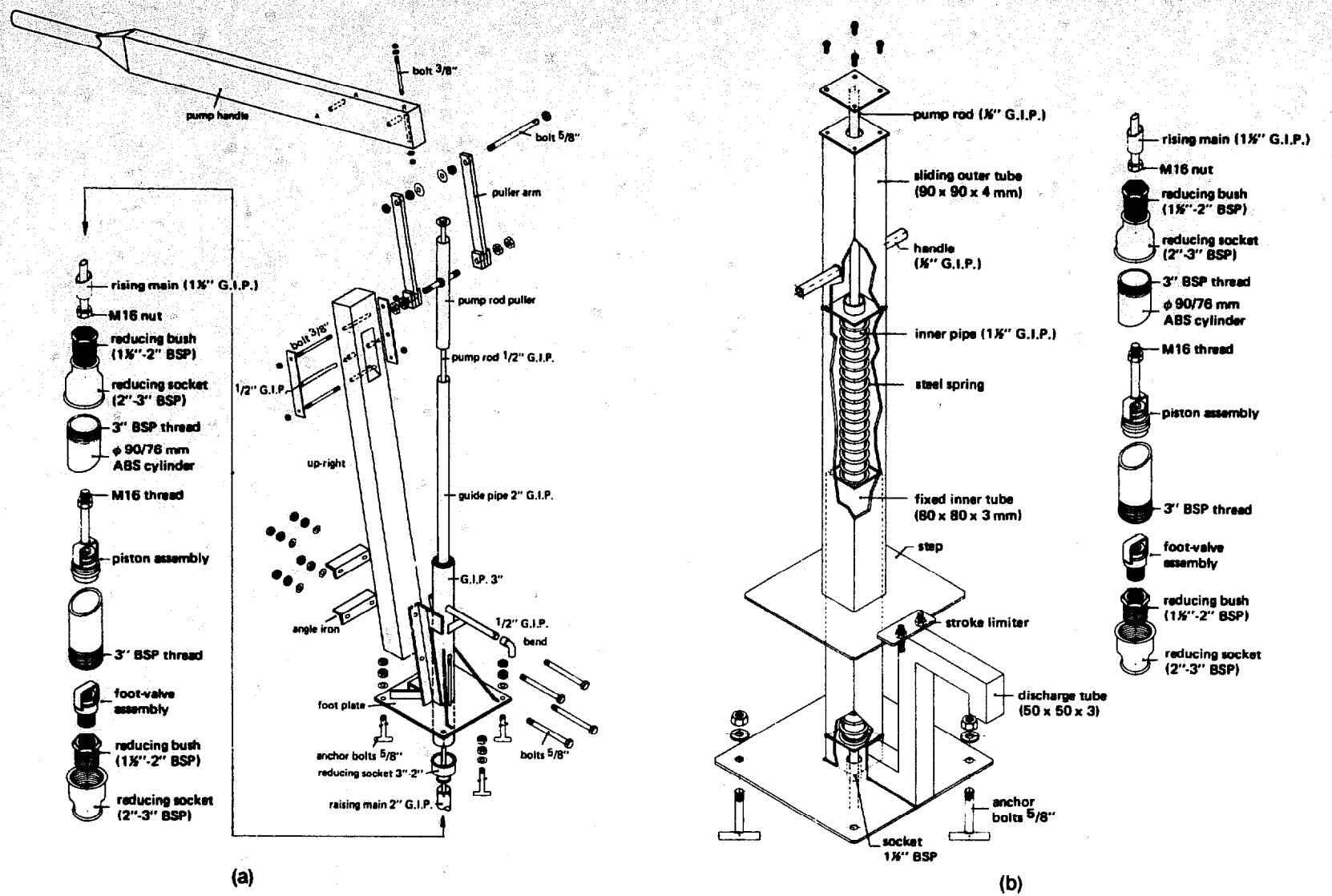

Fig. 1. (a) Shinyanga pump; (b) Kangaroo pump (reproduced from Shallow Wells, 2nd ed., 1979, pp.126, 130, DHV Consulting Engineers, P.O. Box 85, Amersfoort, The Netherlands).

Table 2. Well-inspection report, June 1979–May 1980.

District	No. of wells	Total inspected	No. of repairs	Low recharge wells	Dry wells, November 1979	Wells polluted/ disinfected
Shinyanga	365	400	120	80	15	30
Bariadi	212	300	50	10	3	4
Maswa	152	200	30	5	10	7
Meatu	110	95	20	3	5	5
Kahama	145	310	46	6	3	24
Total	984	1305	266	104	36	70

one practical in cases where many wells must be produced in a short period of time. Its main disadvantage, however, is that it does not involve the community nor leave any drilling expertise in the community.

The Shinyanga Pump

The Shinyanga pump (Fig. 1a), which is an improvement of the United Nations Children's Fund (UNICEF) and Uganda pumps consists of four main parts: pump stand, wooden upright and handle, rising main and pump rod, and pump cylinder and piston. After taking the necessary measurements, the pump is installed and the rising main and pump rods are cut, threaded, and screwed together with the pump cylinder. The pump is then lowered into the well and the wooden uprights and handle are bolted together on the pump stand.

With the exception of the cylinder and piston, the rest of the pump is fabricated in a Shinyanga workshop. The workshop has the capacity to manufacture 35 pumps per month. Since June 1978 about 200 pumps have been sold to other regions in Tanzania.

The Kangaroo Pump

This pump (Fig. 1b) was designed to try to minimize maintenance by avoiding the use of hinge points requiring periodic lubrication. The head of the pump incorporates a spring which is compressed by pushing on a foot plate. As the spring recoils it produces the energy for the pumping stroke. Water can be pumped from a depth of 6 m with a 4 in. (10.2 cm) cylinder, 10 m with a 3 in. (7.6 cm) cylinder, and 20 m with a 2 in. (5.1 cm) cylinder. Because there are no hinges and wear on the pipes is minimal, a maintenance-free period of 10 years has been estimated for this design.

Maintenance of Shinyanga Shallow Wells

When construction is completed, the well is turned over to the village chairman, together with a certificate of well ownership. Two people are then selected and trained to maintain the well. If repairs to the well are required, a form is filled out and sent to the district maintenance officer, who is housed in the office of the district water engineer. Most of the villages now understand this system. However, due to a lack of transportation and an increasing number of breakdowns, the district maintenance officer cannot always cope with all of the requests for repairs which are received. By employing a maintenance officer at the divisional level, as the number of well repairs increases, this problem may be reduced. Apart from this, regular inspections are carried out at wells to determine their condition. Water level checks are also carried out. Pollution and chemical fluctuations are monitored as well (Table 2). In Shinyanga, unless improperly installed, the Shinyanga pump normally has a 2 year maintenance-free period. Women and children, being the most common users, look after their pumps well, because they know that a breakdown means walking a long distance to obtain unclean water. As a result, nobody tampers with the pump.

Shallow Wells Program in Malawi

T.H.B. Nkana[1]

The aim of the shallow wells program in Malawi is to assist villages in obtaining their own protected wells, which can provide a plentiful supply of disease-free water.

The program operates within the Groundwater Section of the Department of Lands, Valuation and Water (DLVW). Office personnel include engineers and administrators, field personnel include project supervisors and assistants, and labour is provided by the rural people on a self-help basis. Tools, cement, slabs, pumps, and technical expertise are provided by the DLVW. Funding for the program comes primarily from the Christian Service Committee of the Churches of Malawi (CSC) and the United Nations Children's Fund (UNICEF).

Areas suitable for water supply from wells are those with perennially high water tables. This condition is met in the plateau areas and particularly in the dambo areas of the Central Region. Fortunately, areas suitable for wells rarely overlap with those suitable for gravity-fed water schemes, so that much of Malawi can be serviced with one of these two water-supply systems.

In 1975, a pilot project was started in the District of Lilongwe, where 30 wells were constructed and pumps were installed. Due to the success of the project, the program was expanded into the neighbouring districts of Dowa, Ntchisi, Kasungu, and Dedza, all of which are in the Central Region. Five hundred wells had been constructed by the end of 1979 and the program continues to grow.

Until recently, the wells constructed were relatively shallow, averaging 6 m in depth; were installed with a PVC pump; and had a correspondingly low head. Currently, an experimental project is under way to test and develop both construction and pump design for wells ranging in depth from 10–15 m.

Implementation

Well construction is implemented through village action groups or development committees, organized in a manner similar to those village committees responsible for gravity-fed piped-water schemes. To achieve the high level of motivation and strong unified leadership required of the village authorities, the project assistants may take these leaders on a tour of completed wells and wells under construction. These tours are particularly effective because the village leaders have the opportunity to discuss with their fellow village leaders, who are already in the program, the relative merits and costs of the project. At this point, the prospective village leaders for the project are able to decide to what extent they wish to participate in the program. Meetings involving the whole village are then arranged, at which time the project assistant can explain the program to the entire community, obtain popular support for it, and elect a working committee responsible for the tools and materials such as cement, slabs, and pump

[1]Wells Programme Officer, Department of Lands, Valuation and Water, Dowa, Malawi.

fittings required for both construction and maintenance.

Where strong program leadership exists within the rural community, it is possible to set up a program subcentre through which a complete system of protected wells can be constructed for the surrounding area. The advantages of working through a subcentre are great, both from the point of view of stable organizational structure and the abundance of wells to set the precedent as the program spreads from one village to the next. Currently, there are six fully functioning subcentres.

Execution

The preliminary tasks of well construction are carried out by the community under the leadership of the village committee. These tasks include: (1) provision of 1000 bricks for lining the well; (2) collection of sand and gravel for mixing cement; (3) digging a 1 m diameter hole to a depth of 6 m; and (4) transportation of cement and slabs to the site (not always necessary).

In the past, lining of the well was done by a project assistant, but now local builders do this on a contract basis. Generally, "dambo" clays are self-supporting, so only the top 1 or 2 m of the well are lined to prevent the entry of surface waters. The slab is positioned by the builder, with the assistance of the community. The builder then plasters the apron and drainage channel. Finally, the project assistant delivers the pump and assists the village committee with its installation.

Maintenance

Each village committee is responsible for the maintenance of its own well. Routine duties and repair capabilities include: (1) removal of the pump and cleaning of pipe cylinders and foot valve; (2) detection of pipe cylinder, foot valve, and plunger wear and replacement of foot valve and plunger, where possible, in Mark II and III pumps; (3) tightening of the nuts securing the pump to the slab; (4) replastering of the apron and drainage channel with fresh cement; (5) removal of sediment and debris from the apron and drainage channel; and (6) prevention of slab misuse, such as the washing of dishes and clothing. Any replacement of parts or repairs that cannot be handled by the village committee are referred to the local project assistant.

Training

Project assistants are recruited at the 8th year level of education and given a 2 week course in the skills and techniques used in well construction and community motivation. Local builders employed for well construction are trained in well siting; soil types; building techniques; and Mark I, II, and III pump assemblies and maintenance.

Mark Series Well Pumps

K. Jellema[1]

The hand pump is probably the most important contribution made by the government to the community in support of the wells program. Often, it is the pump that makes people enthusiastic about the program and, consequently, willing to dig a well on a self-help basis. When the people see how a pump on an existing well facilitates the drawing of water and improves water quality, it speaks for itself, encouraging the spreading of the program.

Mark Series Pumps

Pump design in its early stages was governed mainly by criteria such as investment costs, ease of installation, and local availability of parts. Later, the emphasis shifted toward factors related to maintenance and pollution control. It is now felt that the skills and resources required to make repairs, as well as the cost of worn-out parts, are of more importance than the initial investment costs.

There is another factor which influenced pump design. Being a program oriented toward assisting village communities, the response of the rural people was often so encouraging that pump production could not keep up with demand. Shortage of imported materials sometimes prompted the designer to follow solutions which might not be the best but would, at least, allow pump production to continue.

[1]Wells Engineer, Department of Lands, Valuation and Water, Lilongwe, Malawi.

Design Modifications

The pump used in shallow wells was developed completely as a result of field research; no laboratory testing was carried out at all. This resulted in a considerable number of modifications, both to the pump-stand assembly and the "in-well" parts. Four pump stands have been in use since 1975, all of which operate on the "bicycle pump" principle (Fig. 1). Because pumping heads are usually less than 5 m, there is no need for lever-type pump stands and the accompanying "hinge" problems. A bicycle-type pump has the additional advantage of high plungers without seals (cup leathers or piston rings). Badly worn plungers still function satisfactorily when operated at high pumping rates. The advantages of a PVC pump pipe were realized soon after the first Mark I pumps were installed. No corrosion, lower investment costs, and a smoother surface are the obvious benefits of a PVC pump pipe.

Design modifications to the plunger and foot valve (in-well pumping mechanism) were more extensive than those to the pump-stand assembly (Tables 2, 3). Further modifications were introduced as a result of an International Development Research Centre (IDRC) sponsored international pump-research project. For example, the plunger was changed from a perspex disc to a PVC disc with a polyethylene sleeve because there is little friction between PVC and polyethylene. Thus, nearly all of the resulting wear occurs on the polyethylene part, which is cheap and easily replaced.

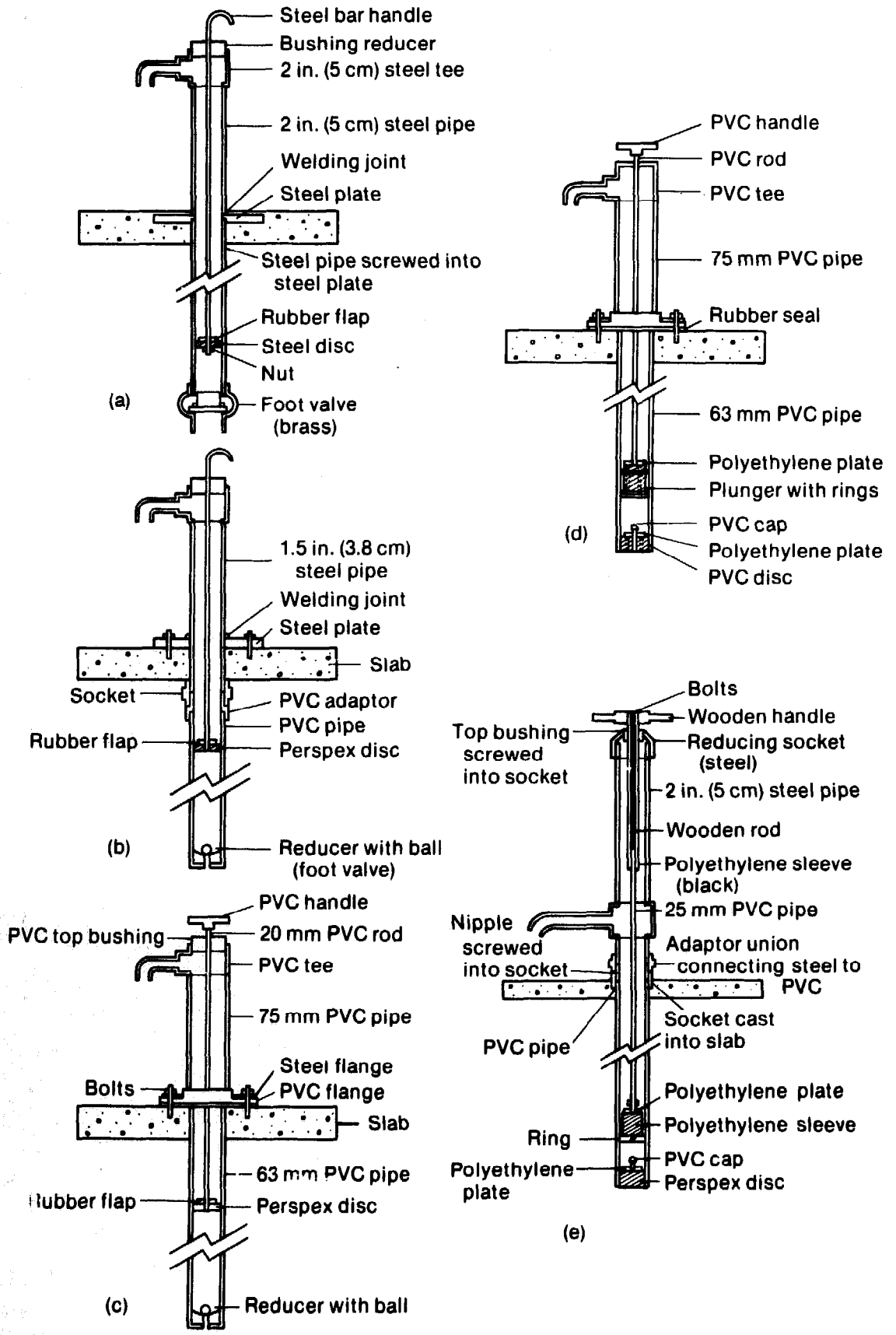

Fig. 1. Mark series well pumps: (a) Mark I; (b) Mark II; (c) Mark III; (d) Mark IV; and (e) Mark V.

Table 1. Modifications incorporated into the Mark V pump.

Pump type	Problem	Solution used in Mark V pump
Mark I–IV	Splashing water at the top bushing	Lowering the outlet tee and extending the outlet pipe away from the well head creates storage above the outlet, resulting in decreased leakage
	The pump had to be removed for measuring water levels in the well or when adding chlorine	A small socket (1 in. (2.5 cm)) is cast in the slab and closed with a plug that can be unscrewed for inspection
	Wastewater and dirt enter the well through small gaps between the flange and slab	The pump stand is screwed into a 3 in. (7.6 cm) socket that is cast into the slab. The resulting seal stops dirty water from entering
Mark II	The steel pipe of the pump stand is connected to the PVC pump pipe by means of a PVC adaptor with internal threads. Rust and frequent dismantling spoil the PVC threads	A special fitting, called an adaptor union, connects the pump pipe to the stand. This union has no PVC threads, only a PVC collar that holds the pump pipe
	Plunger inspection and checking for foot-valve leakage requires lifting of the entire pump	The PVC pump stand features a retractable plunger. In the case of the Mark V pump, the plunger can be withdrawn after the pump stand is unscrewed from the adaptor union
Mark II–III	Bouching as a result of foot valve closure	The plate-valve stroke of the foot valve should be as small as possible. At present, a valve stroke of 5 mm is used. A further decrease, however, might be feasible
Mark III–IV	The top part of the 20 mm PVC rod wears out in 1–2 years. When replacing the rod, a new handle is also required	The stronger 25 mm class 16 PVC pipe is protected against wear by a 1 in. (2.5 cm) polyethylene pipe that can be replaced by taking the bolts out of the handle
	Replacing the top bushing results in the cutting of the PVC pump rod	After removing the wooden handle, the top bushing can be screwed into the socket
	The PVC flange on this PVC pump head cracked due to excessive forces and/or aging of the PVC as a result of exposure to ultraviolet light. Repairs included a complete new pump-stand assembly	A pump stand made of galvanized pipe and fittings is very strong and all parts can be replaced if necessary

Table 2. Pump-stand assembly.

Mark series	Standpipe	Handle	Rod	Fixture	Top bushing
I	2 in. (5.1 cm) steel	Steel bar		Loosely to slab	Reducer
II	1.5 in. (3.8 cm) steel	Steel bar		Flange and bolts	Reducer
III/IV	75 mm PVC	PVC tee	20 mm PVC	Flange and bolts	PVC plate
V	2 in. (5.1 cm) steel	Hardwood	25 mm PVC	Screwed into 3 in. (7.6 cm) socket	Polypro-pylene

Table 3. In-well pumping mechanism.

Mark series	Pump pipe	Plunger body	Plunger valve	Foot valve
I	2 in. (5.1 cm) steel	Steel disc	Rubber flap	Brass
II	63 mm PVC	Perspex disc	Rubber flap	Reducer with ball
III	63 mm PVC	Perspex disc	Rubber flap	Reducer with ball
IV	63 mm PVC	PVC disc with polyethylene rings	Polyethylene plate	PVC disc
V	63 mm PVC	PVC disc with polyethylene sleeve	Polyethylene plate	PVC disc

Table 1 lists the problems experienced and the resulting solutions that were incorporated into the Mark V pump. Field testing of the Mark V pump only started in June 1980, so it is too early for an evaluation of its field performance. However, the following problems are anticipated: (1) The 25 mm PVC rod is reinforced with a hardwood rod 1 m long. Consequently, the rod is less flexible than that of the Mark III/IV pump. As the rod becomes bent, due to extensive pumping, it will touch the inside of the steel pump stand. The resulting wear of the 1 in. (2.5 cm) polyethylene pipe might be unacceptable. (2) Installation of the pump requires a 24 in. (61 cm) pipe wrench. Wrenches of this size are difficult for field assistants to carry on a bicycle. Fortunately, once the nut of the adaptor, which is welded to a 3 in. (7.6 cm) pipe end, is screwed into the socket, there is no need to unscrew it because the pump pipe can be lifted through the nut. (3) Replacing the polyethylene sleeve on the plunger requires the use of solvent cement. This means it can only be done by a field assistant, not by the pump attendant. Further experimentation will be carried out to overcome this problem.

The Ndowa Pump

J. Kanyenda[1]

Concurrent with the development of the Mark V pump, a hand pump suitable for use with heads of up to 10 m was being developed by the Christian Service Committee of the Churches of Malawi (CSC). It is called the "ndowa" pump, which means paid pump. The cost of materials for a 6 m long ndowa pump is approximately U.S.$60. This price is significantly lower than the least expensive imported pump, which costs U.S.$300 in Malawi. Overhead and labour costs for the ndowa pump are lower because production techniques do not require diverse or elaborate machinery. Furthermore, the pump has been designed so that the parts most susceptible to wear are inexpensive and easily replaced.

Pump Stand

The ndowa pump, like the Mark pump series, is based on a bicycle pump type action, which requires no lever. The pump stand is made of 2 in. (5.1 cm) galvanized pipe and fittings, and the pump pipe is a 50 mm class 10 PVC pipe. The plunger can be retracted through the standpipe after the reducing socket, which holds the bushing, is unscrewed. The outlet tee, which is situated just above the slab, is welded to a 2.5 in. (6.4 cm) pipe end. A 2.5 in. (6.4 cm) socket is cast into the slab and the pump stand is screwed into this socket. This system of anchoring the pump stand to the slab provides better protection against the entry of contaminated surface water into the well than the conventional system of using bolts and a flange. A long outlet pipe is usually screwed into the outlet tee and this pipe is supported at the end by a pillar, thereby keeping wastewater away from the well head and reducing the chances of contamination.

In-Well Mechanism

A 50 mm pump pipe is screwed into the galvanized tee of the pump stand by means of a reducing adaptor bushing. Because the plunger is retractable, the bushing, with male PVC thread, does not need to be unscrewed for maintenance inspection. The advantage of the 50 mm pump pipe, compared with a 36 mm pipe, is that the former is more flexible, facilitating installation and removal for maintenance in deeper wells. However, smaller plunger area allows water to be pumped from deeper wells without exceeding the maximum permissible force on the handle, which is approximately 15 kg.

Another feature of the ndowa pump is the large 32 mm pump rod with an internal air chamber. Water enters the pump rod through the plunger on the downstroke, compressing the air in the rod. During this stroke, part of the water is forced through the outlet due to the displacement of the air within the large rod. Expansion of the air in the pump rod takes place during the upstroke and forces additional water up into the pump pipe. These two phenomena create

[1]Assistant Research Officer, Christian Service Committee, Blantyre, Malawi.

a steady outflow of water and, at the same time, reduce the required lifting force on the pump rod and, therefore, the effort required from the user.

In the ndowa pump, both the plunger and foot valve are of unusual design. The main plunger body has a polypropylene adaptor, which slides around the 32 mm pump rod. Its movement controls the opening of the holes in the pump rod. The stroke is limited to 6 mm by an end cap and a socket, which are solvent cemented onto the pump rod. The adaptor used is a standard adaptor filed down to fit inside the pump pipe.

In the foot valve, a 1 in. (2.5 cm) polypropylene adaptor is screwed into a 50 mm to 1 in. (2.5 cm) PVC reducing bushing and solvent cemented into the end of the pump pipe. The moving part of the foot valve consists of a short piece of 25 mm PVC pipe. The pipe has holes in it and a cap at each end. The end cap on the lower end is perforated with small holes. The valve stroke is about 6 mm.

Pump Design Recommendations

Hand pumps will always require maintenance, which can be expensive. The expense can be reduced, however, if pump design is based on the following criteria:

(1) Parts which wear out quickly should be inexpensive and replaceable by the village pump attendant. Worn-out parts should be easily detected and should only cause less satisfactory operation, not total pump breakdown. Replacement parts should be available from stores nearby.

(2) Field assistants should be familiar with simple methods of checking the condition of plungers and foot valves. If the state of operation of these parts is not up to a minimum standard, they should be replaced by the field assistant (preventive maintenance).

(3) Major pump problems should be reported to authorities through established channels. Where feasible, the faulty pump or part should be taken to the nearest workshop for repair.

(4) Field assistants should have easy access to replacement parts, a small workshop, and technical advice.

(5) Wells that cannot supply sufficient water at all times are hard on the pump. Because users are required to use greater force on the pump, the resulting wear is considerably increased. Attempts snould be made to increase the yield of such wells or to decrease demand by providing more wells in the area.

Water Pumping by Wind Energy in Kenya

M.N. Opondo[1]

A survey was carried out from 15–30 May 1980 in Kenya to collect information on the present use of wind energy for pumping water. The findings from the survey indicate that wind energy has been used for over 100 years in Kenya to power well-designed and durable windmills manufactured by Southern Cross, Australia; Aeromotor and Dempster, U.S.A.; and Climax, England. Today, only a few of these windmills remain (Fig. 1), having been replaced by diesel engines. With the demand for oil and other fossil fuels continuing to increase, however, it has become necessary to look for alternative sources of energy. Thus, wind-energy technology has been revived.

Since 1973, industrialized countries have concentrated on the development of windmills with rotors of up to 100 m in diameter for generating electricity in the megawatt range, which can be fed into national electricity supply grids. In developing countries, on the other hand, windmill technology was new to many scientists, research facilities were inadequate, and manpower was limited. Because this is still the case, the feasible application of this technology is confined to the use of windmills for pumping water and generating electricity in the 1–10 kW range.

The main objective in these countries is to reduce the need to purchase foreign materials to supply energy by developing methods of producing energy that utilize local resources. Thus, windmills would be produced from locally available materials. This led to the construction of several types of windmill rotors, e.g., in Kenya, a

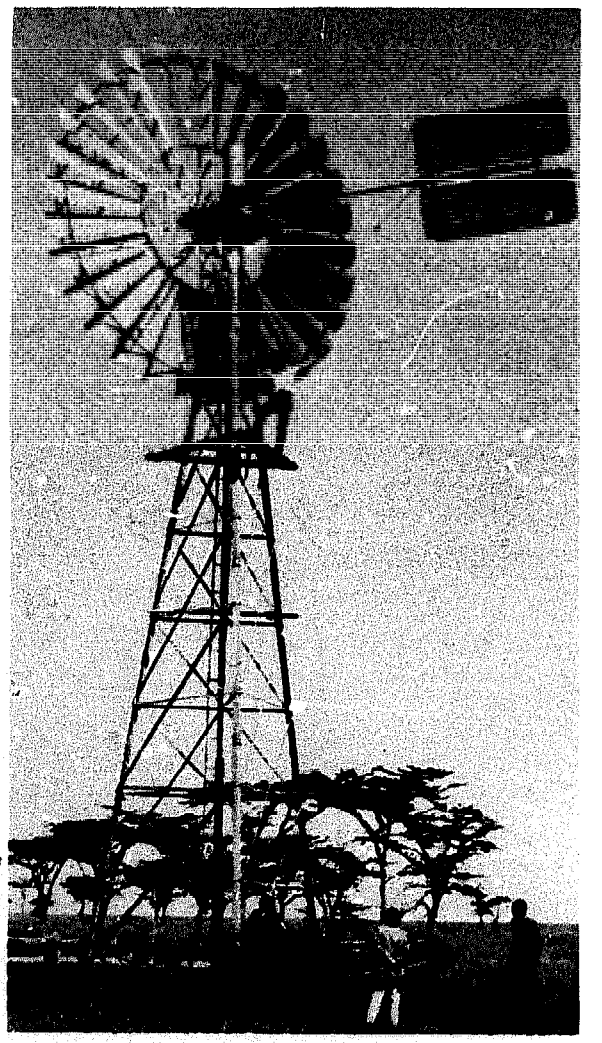

Fig. 1. Southern Cross windmill with a rotor diameter of 21 ft (6.4 m), installed more than 30 years ago.

[1]Panel Leader, Wind Energy Technical Panel, University of Nairobi, Nairobi, Kenya.

windmill was produced in 1976 with bamboo arms and sheet-metal blades (Fig. 2); another, the Cretan sail windmill, had a cloth sail and bamboo arms (Fig. 3). The VITA windmill was produced by the volunteer in technology assistance program based in Maryland, U.S.A., for use in developing countries. These windmills, however, were generally less efficient than the imported models.

As a result, a second stage of windmill development followed, leading to improved machines, e.g., the Kijito windmill, manufactured by Bobs Harris Engineering Ltd. (Fig. 4); the Mbita windmill (Fig. 5), an improved version of the Cretan sail windmill; the KIE (Kenya Industrial Estate) windmill, manufactured by Plough and Allied Products in Kisumu; and Carl Jensen's design, installed in Kisumu through the KIE (Fig. 6). There is, therefore, a wide variety of windmills, and it is difficult to accommodate them all in large-scale installations. Because all of these products are at the research and development stage, careful technical scrutiny is required before any one of them can qualify for large-scale use.

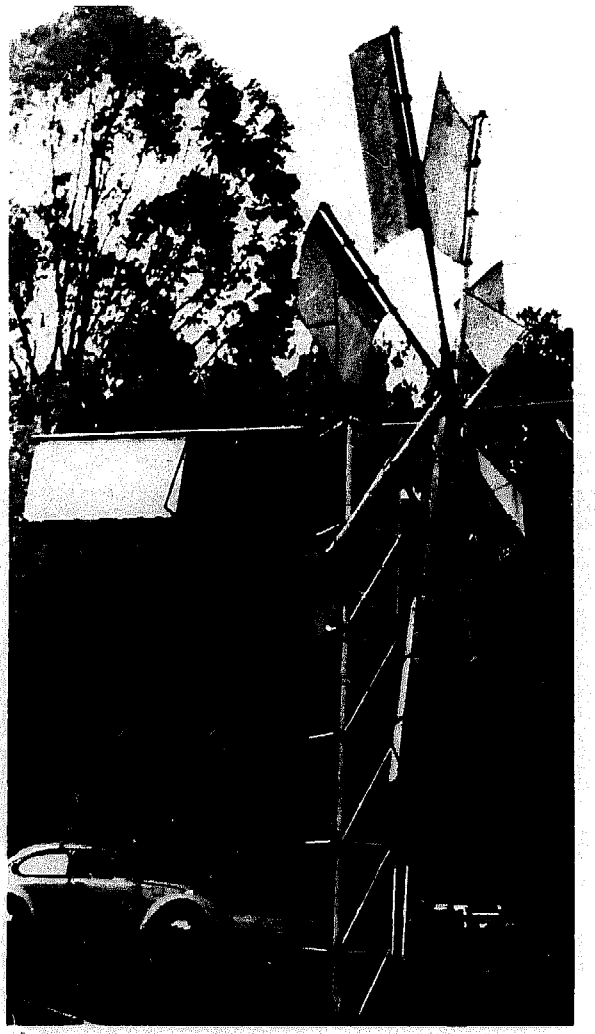

Fig. 2. A rotor with sheet-metal blades and bamboo poles made in 1976.

Fig. 3. A Cretan sail windmill with bamboo poles made in 1976-1977.

Wind-Power Devices

The criteria for identifying a good windmill are: (1) it should have at least 30 percent conversion efficiency; (2) it should be durable, with a lifetime of at least 20 years; (3) it should be affordable by low-income communities; and (4) it should be effective in conserving foreign exchange.

A windmill can only convert a portion of the kinetic energy available in the wind blowing through the area swept by its rotor into mechanical or electrical energy. Kinetic energy (E) is given by the formula

$$E = 0.5\ \rho A V^3$$

where ρ = density of air; A = area swept by the rotor; and V = mean wind velocity.

Fig. 4. The Kijito windmill.

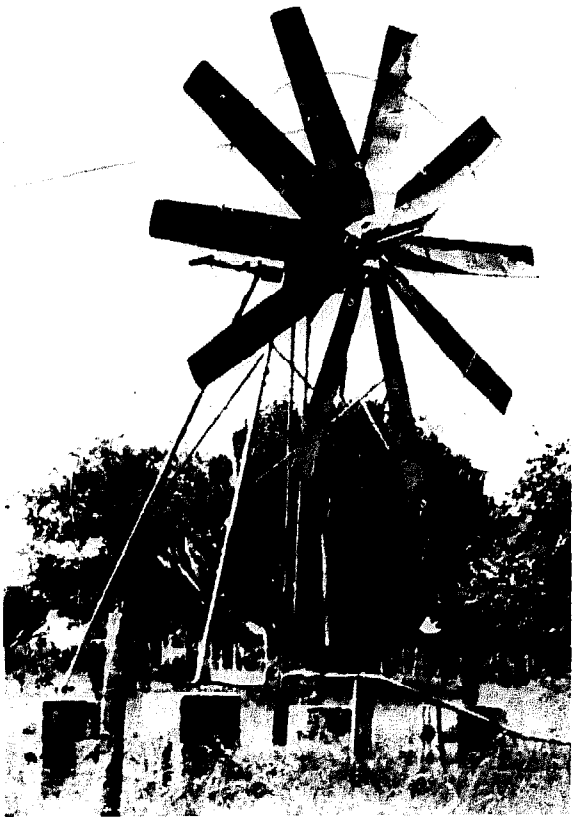

Fig. 5. Front view of a Mbita windmill with twisted blades.

Theoretically, a windmill of ideal aerodynamic efficiency can convert approximately 59 percent of the kinetic energy into useable energy. It is difficult to design a windmill approaching 50 percent efficiency. The best windmills presently known can only reach 30–40 percent efficiency. The efficiency of conversion is known as the coefficient of performance (Cp). The power available from a windmill, therefore, is given by the formula

$$P = 0.5\,\rho\, Cp A V^3$$

Kijito Windmills

The Kijito windmill has evolved from the Intermediate Technology Development Group (ITDG), London, prototype design. Its Cp can reach 30 percent. The Kijito windmill has a swivel-head rotor that always turns into the wind, thereby preventing damage from high-speed winds, and its blades are moulded from fiberglass, which gives them a good aerodynamic profile and makes them efficient.

The maintenance requirements of these windmills are minimal. They require only monthly lubrication inspections. The manufacturer, therefore, feels that there is no need to train servicemen to look after them, because the chances of failure are minimal. It is recommended that in case of major problems, repairs are best carried out by experts from the production unit. The largest rotor available with the Kijito windmill is 7.3 m in diameter. It has 24 blades and its rated pumping capacity is 220 m^3/day from a depth of 250 m in a wind with an average speed of 5 m/s.

Despite their good performance, Kenyan wind-energy technical experts feel that Kijito windmills have not yet satisfied the standards required of windmills destined for widespread use in the rural sector of a developing country, i.e., the price of these windmills is higher than the price of some of the alternative windmill designs; a large

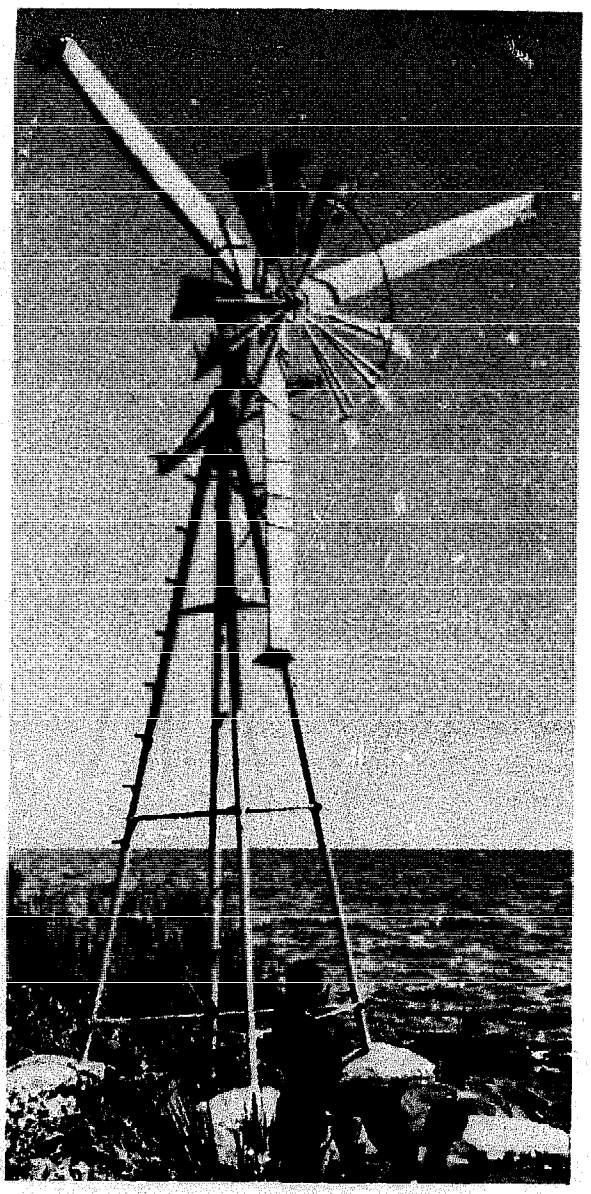

Fig. 6. The Carl Jensen design.

proportion of the materials used to construct the windmill is imported; and the design itself has not been successful in all cases (e.g., the fiberglass blades have been known to break off after only 4 years of use, due to the effects of weathering). Because the Kijito windmill is still a new product, there is room, through continued research and development, to modify the design to meet the standards of windmills used in developing countries.

Mbita Windmills

The windmills at Mbita, on the shores of Lake Victoria in South Nyanza, are of excellent design, produced by a Dutch engineer (Herman M. Carlsen, Mbita Catholic Mission). The blades are made of galvanized sheet metal and have good aerodynamic efficiency. Very little material is imported for making these windmills. A 6 m diameter rotor, used for deep-well pumping, would cost U.S.$2300. In the production unit, where the windmills are made, trainees are engaged in all aspects of the fabrication and construction of the machines. Training in the use of these machines is readily available to all interested persons.

These windmills have operated successfully under the stormy conditions of the lake region for about 2 years, and further improvements are being made in their design as more ideas develop from field tests. A subsidy program is being considered to encourage and enable prospective users to install them. The Mbita windmills have, therefore, made remarkable advances towards realizing success in rural water supply.

The CITC Cretan Sail Windmill

The production of the CITC Cretan sail rotor has been abandoned because of its poor aerodynamic properties. The only achievement has been the construction of a tower which costs U.S.$370. It is envisaged that a Mbita wind rotor and a CITC windmill tower could be assembled together to achieve a very cheap water-pumping device, and collaborative work between the respective organizations is highly encouraged.

The KIE (Kisumu) Windmill

Plough and Allied Products have produced a machine comparable to the Mbita windmill costing approximately U.S. $2300. The organization is also willing to participate in training prospective users. In collaboration with academic institutions, Plough and Allied Products is attempting to develop methods to reduce the cost of producing its product. It is also anxious to have the government, particularly the

Ministry of Energy, participate in their wind-energy development work.

Water Pumps

Water pumps have followed the same trend as windmills. For many years metal pumps were produced cheaply in commercial sectors. Today, commercial pumps are quite expensive, and scientists have produced a wide variety of alternative designs. The choice of a hand pump is often not critical, because even an inefficient pump can deliver adequate water for consumers' demands. The power requirement for a water pump is given by

$$P=\xi \sigma QH$$

where ξ = the efficiency of the pump

σ = specific weight of water

Q = flow discharge rate

H = height to which the water is raised

The difficult task usually arises when a windmill is to be properly matched to a pump.

Windmill Size

When deciding on the most appropriate size of windmill for a particular use, it is necessary to carefully match the windmill to the water pump and to ensure that the wind-power potential matches groundwater potential.

To match the windmill to the pump, such factors as average wind speed, rotor diameter, performance efficiency, water demand (pump capacity), and well depth must be considered. These factors can be accounted for by using mathematical equations to calculate the best pump and windmill combination to meet the needs of the consumer.

Consumer needs and windmill size, however, must also match the groundwater potential of the area. The collection and analysis of meteorological data on wind regimes are used to calculate the amount of power that can be harnessed and, therefore, the size of windmill and pump needed to meet the water demand. If this demand is found to be higher than the groundwater potential calculated from geological data, then supplementary sources, such as rainwater storage, must also be considered.

Operating Characteristics and Design Details

The requirements and design parameters of a good windmill have been highlighted in the foregoing discussion. Scientists, however, are not yet satisfied with the performance of even the best windmills currently available. Many attempts are in progress aimed at increasing performance but the problem that arises is that as performance is increased so is the level of sophistication. An example is shown in Fig. 6, where the windmill has a starter rotor containing shorter blades and a larger drive rotor consisting of three blades with flaps on the tips to prevent the blades from rotating too quickly. In developing countries, although the achievement of high efficiency is also of paramount importance, greater priority is given to the designing of machines which are durable and not dependent on imported materials for their construction.

Construction, Production, and Installation

Because research and development work is time consuming, it will be necessary to continue using the windmills that are currently available until improved designs can be developed. Collaborative work among organizations involved in manufacturing wind-powered devices is, therefore, desirable and should continue. In Kenya, prototypes of new designs can be constructed at the KIE (Kisumu) and CITC, Nairobi. Manpower training takes place at Mbita, KIE, and CITC. Trainees are instructed in the construction of windmills and how to repair them in the field.

Financing

The production and installation of commercial windmills is self-financing because there are organizations that finance enterprising industries. The financing of users, on the other hand, is a major limitation to large-scale windmill use, because very few people can afford windmills individually. On a communal basis, convincing all of the people in a community to purchase a windmill jointly is not easily accomplished. Although the use of windmills in rural areas should be promoted, the problem of a shortage of financing must first be solved. Training of farm technicians to install and maintain these machines will also require substantial funding, carefully planned to produce fruitful results. It should be noted that research and development are an essential part of these programs and that funding of well-planned research programs should be encouraged.

Conclusions

The use of wind energy for pumping water has reached the stage where it can be exploited on a large scale in Kenya, and the four manufacturing organizations mentioned earlier, which have brought this technology to a useable stage, are appreciated. Methods of assisting the manufacturers in the installation of windmills on a large scale should be outlined and put into practice. Because all of the present manufacturers need to modify their products to suit local requirements, they should receive research and development support. Prospective manufacturers should also be given technical and advisory support to enable them to enter the industry. In order to make the water supply program successful, manpower training in the construction and maintenance of windmills will be necessary.

The survey team is grateful to the Ministry of Energy for sponsoring the survey trips and making the early stages of wind-energy research in Kenya a success. It is hoped that this support will continue, thereby enabling the team to achieve its ultimate goal. Gratitude is also extended to Miss Elizabeth Efiketi for preparing the text for reproduction and presentation.

An Assessment of Water-Pumping Technologies Using Locally Available Energy Resources, Botswana

R. Carothers[1]

Problems with Respect to Water Supply

Botswana is a dry, semi-arid country with little or no surface water throughout most of the year. Rainfall is erratic and although a number of rainwater catchment dams have been constructed, about 75 percent of the people and livestock depend on groundwater as a source of water supply. In some areas water is close enough to the surface to allow for the construction of shallow wells, but in most cases the drilling of boreholes is required. In the eastern part of the country it is possible to find water at depths of 25 m or less, but the national average is 100 m and increasing as new boreholes are drilled. Because of the depths of the boreholes and the demands placed on them, power sources superior to hand pumps often become necessary for withdrawing water from wells.

The original pumping systems installed throughout Botswana used reciprocating pumps driven by diesel engines. In the days before high fuel costs these could supply water reasonably cheaply, but they suffered from maintenance problems. The saline nature and high grit content of the water in many boreholes caused excessive wearing of pump seals. Because of a shortage of trained maintenance crews, repairs could take up to several months. Also, the diesel power plants have been the source of a variety of faults in the past. Recently, government and many private borehole operators began using mono pumps. These can supply water from deep boreholes with less pump-related maintenance problems. As a result, the government prefers to continue using mono pumps.

The rising price of petroleum-based fuels has added a new economic element to the problems facing water supply systems. During 1979 the price of diesel fuel in Botswana doubled and further increases are expected during 1980. A directive from the president's office has recently involved government ministries in the search for suitable wind pumps that could be used both for government and private borehole operations.

During a survey carried out in 53 neighbouring villages, the Rural Industries Innovation Centre (RIIC), which is located at Kanye in the southern part of Botswana, found that problems related to water supply were by far the main concern of village dwellers. The search for suitable water-pumping technologies led the RIIC to investigate the possibility of using local energy resources including biogas, solar radiation, and wind energy. Because of previous pump-related maintenance problems, it was proposed that new systems be designed to operate using the mono pump.

[1]Research Associate, Department of Mechanical Engineering, University of Waterloo, Waterloo, Canada.

Windmills for pumping water were a possibility, but it was not known how suitable these would be under Botswana's windy climatic conditions. A limitation of commercial windmills was that they would be unable to operate the mono pumps. Perhaps other options would offer greater benefits. Cow dung, in plentiful supply in the cattle fields, could be fermented in biogas plants to produce a substitute for diesel fuel. Advances were being made in technologies for harnessing solar radiation and it could be that these would work well under Botswana's clear, sunny skies. To compare these different methods, the RIIC decided to undertake a program of testing wind, biogas, and solar pumping techniques. The intention was to study each alternative to determine what difficulties, including maintenance problems, might arise and to determine, in economic terms, which option could provide water at the lowest cost. To carry out the economic comparisons it was necessary to refer all costs to a unit pumping capacity that was the same for each pumping technique. In this report all costs have been referred to a unit pumping capacity of 1 kW-h/day. In terms of the amount of water pumped per day, 1 kW-h/day is equivalent to pumping 36 m^3 from a depth of 10 m; 18 m^3 from 20 m depth; 7.2 m^3 from 50 m depth; and 3.6 m^3 from a depth of 100 m.

An Assessment of Alternative Pumping Techniques

As a means for comparison, an attempt was made to determine the present-day value of all costs for a standard diesel engine on a per unit pumping capacity basis. It is worth noting that the analyses for the diesel engine and other options are specific to costs occurring in Botswana at the present time.

The Diesel Engine

A study carried out on behalf of the Government of Botswana (Department of Water Affairs 1975) produced a cost breakdown for the installation and operation of a diesel engine over a 20 year period. An updated summary of this study is given in Table 1. These results are, if anything, overly optimistic in favour of the diesel engine, particularly in the assumption of a 20 year operating life.

Biogas/Diesel Pumping

Although the maintenance problems associated with diesel engines would still remain, it is possible to develop an alternative energy source, using locally available resources, to fuel existing diesel engines. At the RIIC, biogas digesters have been constructed in which a mixture of 60 percent methane and 40 percent carbon dioxide (biogas) is produced through the anaerobic fermentation of cow dung and water. This biogas can be fed into a diesel engine after only minor modifications to the engine and will replace 85 percent of the diesel fuel. There are, however, technical problems associated with supplying sufficient biogas for the engine throughout the year. The rate of gas production decreases during the colder winter months. To supply sufficient biogas to replace 85 percent of the diesel fuel during this period, the biogas digesters must be made considerably larger than those supplying gas during the warmer months of the year. This requires higher investment costs. It is this "worst case" that has been used in the economic analysis shown in Table 2. The economic outlook improves, however, if the biogas plant provides 85 percent of the fuel for 8 months and 42.5 percent of the fuel for 4 months. Although fuel costs increase, they are offset by reduced investment and as a result the costs per kilowatt hour per day pumping capacity decrease.

There are other economic factors that favour the use of a biogas/diesel pumping system. The 85 percent saving in fuel equates to a similar saving in foreign expenditures, whereas the cost of establishing the biogas digesters involves mainly labour and, therefore, contributes positively to the national economy. Another advantage of the biogas/diesel pumping option is that it can be designed to supply

Table 1. Operating costs for a diesel engine (based on 1980 rates).

Technical data	
Engine	ST 1 (4.5 kW (6 hp))
Borehole depth	115 m
Demand	600 head of cattle
Annual hours of operation	3036
Years of operation	20
Fuel consumption (litres/year)	3656
Cost data	
Engine	P1460 (P1.00 = U.S.$1.27)
Fuel	P0.42/litre (middle rate for stationary engine, January 1980)
Energy delivered per day	21.6 kW-h (assuming 8 h of operating time per day and pump/transmission efficiency of 60%)
Operating costs	
Engine	P1460
Fuel	P13418
Repair and maintenance scheme (Department of Water Affairs 1975)	P6582
Spare parts	P616
Overhaul	P877
Total	P22953
Cost per kW-h/day pumping capacity	
Based on 1980 diesel prices	P1063
Allowing for 5% per year inflation in the price of diesel fuel	P1522

fuel for larger diesel engines which are required when pumping water from very deep boreholes.

Solar Pumping

In considering the use of solar radiation as an energy source for pumping water, it is necessary to determine the amount of solar energy available and to evaluate the technologies that could be used to capture this energy.

Botswana is fortunate in having abundant solar radiation, being situated within one of the world's few areas that receives more than 3200 h of sunshine annually. In addition, the intensity of the radiation is high, ranging from 0.7 kW/m^2 in winter to 1.2 kW/m^2 in summer (the mean level of solar radiation throughout the year is approximately 5.4 kW-h/m^2/day). It is interesting to note that at this rate the solar energy falling on 4 m^2 would be equivalent to that delivered (during 8 h of operation) by the 4.5 kW (6 hp) diesel engine discussed earlier. Unfortunately, the technologies for capturing this energy are expensive and are generally felt to be uneconomic at present for pumping water. Nevertheless, research aimed at developing solar pumping equipment is continuing. A photovoltaic panel that converts solar radiation into electrical energy which is then used to power an electric motor and pump is one type of pump being considered. Another possibility involves the vaporization of a heavy organic liquid which causes the transfer of a liquid mass in a rocking-beam arrangement. Both of these pumps, however, require further development to reduce their cost of operation.

Wind Pumps

As in the case of solar pumping, consideration of wind pumps as a means of providing water requires a knowledge of both the energy available and the performance characteristics of the wind pumps being considered. In practice, there

Table 2. Operating costs of a biogas/diesel pumping station (based on 1980 rates).

Technical data (for engine, borehole, and other data see Table 1)	
Biogas plant (summarized from McGarry 1980)	
Gas yield/kg dung	0.050 m^3/kg
Gas production rate (winter, 17°C)	10% of digester volume per day
Gas production rate (summer, 27°C)	30% of digester volume per day
Consumption rate of biogas by engine	0.9 m^3/kW-h
Diesel equivalence of biogas	1 m^3 of biogas = 0.25 litres of diesel fuel
Operating costs	
Case 1. Biogas plant providing 85% of fuel throughout the year	
Engine	P1460
Fuel	P2013
Repair and maintenance (Department of Water Affairs 1975)	P6582
Spare parts	P616
Overhaul	P877
Total	P11548
Cost per kW-h/day pumping capacity	P535
Cost for biogas plant per kW-h/day of delivered energy	P650
Total operating costs per kW-h/day pumping capacity	P1185
Case 2. Biogas plant providing 85% of fuel for 8 months and 42.5% of fuel for 4 months. (The engine and maintenance data are the same as case 1, except fuel prices increased to P3891.)	
Total	P13426
Cost per kW-h/day pumping capacity	P622
Cost for biogas plant per kW-h/day of delivered energy	P430
Total operating costs per kW-h/day pumping capacity	P1052
Cost per kW-h/day pumping capacity	
Assuming 85% of fuel replaced by biogas throughout the year	
Based on 1980 diesel prices	P1174
Allowing for 5% inflation in real terms for diesel fuel	P1242
Assuming 85% of fuel replaced by biogas through 8 months and 42.5% replaced through 4 months	
Based on 1980 diesel prices	P1040
Allowing for 5% inflation in real terms for diesel fuel	P1171

are complexities in evaluating both of these parameters.

Wind Monitoring

The energy available from the wind depends on the cube of the wind speed , i.e., doubling the wind speed means that the available energy increases by a factor of eight (2^3). As a result, equipment capable of measuring only average wind speed over a given time interval, when used to predict

available wind energy, can introduce large errors. In response to this, equipment has been developed to measure and record instantaneous wind speed, thus providing a frequency distribution of the wind speed and allowing a more accurate prediction of the energy available to be made.

The Filippini Rotor and Mono Pump System

The mono pump presents some serious technical difficulties when operated by wind. Its high starting torque and high operating speed (revolutions per minute) require that the transmission of the wind pump be specially designed to overcome these problems.

A three-stage transmission was used to achieve the high pump speed required and a clutch mechanism was designed to overcome the starting problems. This system also allowed for easy hand operation of the pump if there were prolonged periods with no wind or if the wind rotor required repairs.

The choice of the Filippini rotor (Fig. 1) as a means of driving the mono pump also solved one additional problem. The mono pump requires a rotary drive, whereas most conventional (horizontal-axis) wind rotors operate reciprocating pumps. The vertical-axis feature of the Filippini rotor allowed for the coupling of the rotor and pump with a straightforward V-belt drive system.

It can be shown that the efficiency of a wind-pump system decreases for wind speeds above the minimum level required for the wind pump to operate. By selecting a pumping rate per rotor revolution that corresponds with wind speeds that provide maximum energy, maximum efficiency of the system will be achieved. This is illustrated in Table 3.

The optimization of the Filippini wind pump has been made easier because the clutch mechanism allows the unit to start at the minimum operating wind speed. Wind pumps that do not have a clutch will usually require a wind speed higher than the minimum operating wind speed before they will actually start. If these speeds are significantly different, then allowances for

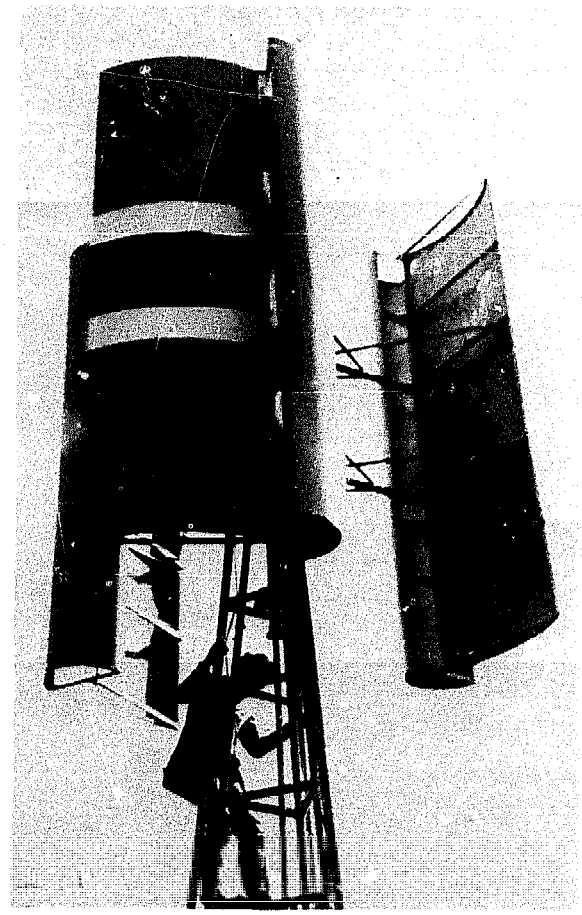

Fig. 1. Filippini rotor at the Ramonedi site.

this need to be made in predicting the amount of water that will be delivered in a particular wind regime.

Although the Filippini rotor has been successfully matched with a mono pump, it must still be classified as an experimental wind pump. Further work to develop a high-wind protection system for the rotor and to refine the clutch mechanism will be necessary before production can begin.

The Experimental Horizontal-Axis Rotor

The horizontal-axis wind pump that was originally designed by the Intermediate Technology Development Group (ITDG) of the United Kingdom is currently being field tested in several countries. Figure 2 shows one version of the unit that is already in commercial production in Kenya. The ITDG design used in Kenya is well made but expensive when compared with other locally manufactured wind pumps and imported

Table 3. Operating costs of Filippini rotor/mono pump system.

Technical data	
Filippini/mono pump system optimum efficiency	11%
Energy delivered per day (winter, starting/min. running wind speed = 15 km/h)	1.6 kW-h/day
Energy delivered per day (winter, starting/min. running wind speed = 20 km/h)	2.5 kW-h/day
Available energy per m^2 of sweep area	3.59 kW-h/m^2/day
Sweep area	11.7 m^2
Cost data	
Rotor and tower (cost estimate based on prototype)	P1500
Operating costs	
Wind rotor and tower	P1500
Spare parts	P252
Total	P1752
Cost per kW-h/day pumping capacity	
With starting/min. running wind speed = 15 km/h	P1095
With starting/min. running wind speed = 20 km/h	P701

Fig. 2. Intermediate Technology Development Group rotor as produced in Kenya.

commercial models. Part of the high costs is attributable to moulded fiberglass blades, which are specific to the Kenyan rotor.

The ITDG design, as built in Botswana, incorporates all-metal blades, as in the original concept. However, because the transmission was intended to drive reciprocating pumps, major modifications are required to run the rotary-drive mono pump. Efforts are under way to obtain a suitable right-angle drive gearbox that will be able to handle the torque loads.

As with the Filippini rotor, a clutch will be necessary in the transmission to overcome starting problems. The inclusion of a clutch will have additional advantages in reducing construction costs. With a clutch, the rotor will be able to start without a load and as a result will require only six blades. The 24 blades of the normal rotor are needed only in starting. A rotor with fewer blades will run faster, thereby requiring less step-up in the transmission to meet the high pump speed (revolutions per minute) requirement,

and will normally operate with a greater overall efficiency. The rotor in its present stage is shown in Fig. 3.

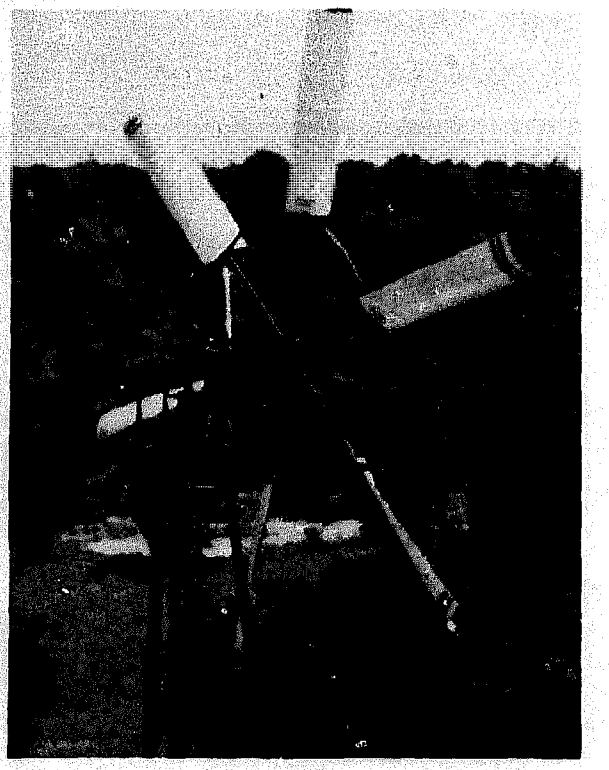

Fig. 3. Intermediate Technology Development Group rotor as produced in Botswana.

Because the ITDG rotor in Botswana has not yet been connected to a pump, data on the performance and costs per kilowatt hour per day pumping capacity are not available.

Commercial Windmills

The manufacturers of commercial windmills do not specify the performance of their windmills over a range of operating wind speeds. It is not possible, therefore, to accurately predict the energy delivered under actual wind conditions. It is, however, possible to predict the output under idealized conditions, where all of the available energy occurs at the minimum operating (maximum efficiency) wind speed for the windmill. On this basis, the costs per kilowatt hour per day pumping capacity have been estimated for a Climax and Southern Cross wind pump (Table 4). Thus, under idealized wind conditions it is possible to compare one windmill against another, but it is not realistic to compare the windmills against other pumping options. Better data will become available as the Government of Botswana monitoring program continues to develop.

Summary

In comparing power sources (in economic terms) that make use of locally available energy resources, with the existing diesel engine, it appears that both the biogas and wind-pumping options are practical alternatives. The use of biogas as a supplementary fuel becomes particularly attractive due to the probability of further increases in the price of diesel fuel. The use of wind as a power source for pumping water seems to be the best economic choice even now, provided that the wind pumps are properly matched with local wind regimes. Solar pumps would be impractical at the present time, but would become the least expensive option in the future if the price of photovoltaic equipment continues to drop as predicted.

There are other economic factors to consider. The biogas and wind systems will involve local costs (if the wind pumps are produced locally), which will contribute to the domestic economy. The use of biogas or wind for pumping, on the other hand, requires a higher initial investment than that required to use the diesel engine. Where capital funds are in short supply, therefore, the diesel engine as a power source could be the most economic short-term choice.

When comparing the alternatives, the diesel engine and the biogas option are the most similar. Both can be operated at any time by the user and neither require large storage facilities nor backup systems. They can also meet large pumping demands when these occur. Both of these systems, however, have the maintenance problems associated with the use of the diesel engine. The biogas system, although providing considerable fuel savings, also introduces the need to operate the biogas digester and requires the collection of dung.

Table 4. Operating costs of commercial windmills under idealized wind conditions.

Southern Cross - Seneschal, 7.5 m diameter	
Technical data	
Southern Cross windmill	
overall efficiency	15 31% ?
(inaccuracies arise because testing procedures are not specified in manufacturers published data)	
Energy delivery per day	24.6 - 49.1 kW-h/day
Available energy per m^2 of sweep area	3.59 kW-h/m^2/day
Sweep area	45.6 m^2
Cost data	
Windmill rotor and tower	P5700
Operating costs	
Windmill rotor and tower	P5700
Repair/maintenance scheme (Department of Water Affairs 1975)	P2870
Total	P8570
Cost per kW-h/day pumping capacity under idealized wind conditions	P175 - P348
Climax No. 12, 3.7 m diameter	
Technical data	
Climax windmill overall efficiency	8 - 17% ?
(inaccuracies arise because testing procedures are not specified in manufacturers published data)	
Energy delivery per day	3.2 - 6.4 kW-h/day
Available energy per m^2 of sweep area	3.59 kW-h/m^2/day
Sweep area	10.5 m^2
Cost data	
Windmill rotor and tower	P1640
Operating costs	
Windmill rotor and tower	P1640
Repair/maintenance scheme (estimated)	P700
Total	P2340
Cost per kW-h/day pumping capacity under idealized wind conditions	P366 - P731
Cost per kW-h/day pumping capacity under idealized wind conditions	
Southern Cross - Seneschal	P175 - P348
Climax No. 12	P366 - P731
Filippini rotor	P380

Note: The values in this table should be taken as approximate.

Wind pumps can deliver in the range of 1–20 kW-h/day of useful energy, which would be equivalent to pumping 3.6–72 m^3 of water from a depth of 100 m each day. This would make them useful to supply small to medium water demands. In general, they require less frequent and less sophisticated maintenance. Wind pumps, however, require larger storage facilities or backup systems (manual operation in the case of the Filippini wind pump) to allow for extended calm periods. Locally produced wind pumps can be matched more effectively to domestic wind regimes and preferred pumps. Also, the decision to produce wind pumps locally boosts the level of expertise within the country that can be applied to future maintenance needs and in training others in the selection and use of wind-pumping systems.

Implications for Training

As imported energy costs continue to rise, it seems inevitable that Botswana will turn more toward locally available energy resources for the pumping of water. It will be necessary to maintain an up-to-date assessment of the available energy resources and the technologies that may be used to apply these to pumping water. There will also be a need for field personnel to carry out basic energy assessments for individuals or groups, and to recommend the most appropriate pumping systems. Additional skilled and semi-skilled manpower will be required to design, manufacture, and maintain biogas or wind-powered pumping systems.

In Botswana, progress toward meeting some training needs has been made, as new windmills are being manufactured at Kanye and Gabane, with work also starting in Serowe. Biogas pumping systems have also been developed and tested at the RIIC site in Kanye. The Government of Botswana evaluation program of commercial windmills will be a means whereby the skills necessary to assess the wind energy resources available could be developed. This program, along with the tests of experimental wind pumps and biogas systems, could be used to develop future training materials and programs. These could then be used to equip extension staff with the knowledge and support materials necessary to play an essential role in advising local groups or individuals as to the most suitable pumping system for their needs.

Department of Water Affairs, Government of Botswana. 1975. Borehole preventative maintenance study. Volume II.

McGarry, B. 1980. Biogas pumping, Botswana. Kanye, Botswana, Rural Industries Innovation Centre.

Simple Water Treatment Methods

J. Gecaga[1]

Water quality must satisfy two requirements: it must be safe to consume and it should be attractive to use. A study among the Masai of Kenya showed that they preferred using a rain pond rather than piped water, which is exceptionally good, coming underground from Kilimanjaro's rain forest. Making water potable may be realized by judicious selection of the source or by purification after recovery. For good health, the quantity available must be adequate.

The agency responsible for controlling water quality should oppose vigorously the use of treatment processes which the community concerned cannot afford to procure, operate, and maintain with its meagre financial resources. Modern equipment designed to minimize maintenance problems is expensive and requires skill in its operation. On the other hand, equipment which is less costly needs constant maintenance and repair. Sufficient attention must be given to the cost effectiveness of the designs and materials selected. Too often, cheap materials used to minimize initial costs lead to early failure in service and a loss of supply for protracted periods while replacements are obtained and installed. These failures are not confined to the more complex systems with motorized pumps. Throughout the developing world thousands of hand pumps are unserviceable and research is being carried out to discover the reasons and improve designs. Field investigations in Kenya showed that out of more than 20 slow filters constructed, none of them were functioning properly. This explains, in part, why a careful study, based on engineering and economic analyses, may have to be made to compare, in doubtful situations, the relative merits of long pipelines bringing in untreated water from distant springs, artesian wells, or infiltration galleries. When such studies cannot be made, experience shows that, whenever possible, it is wise to make a larger investment in order to eliminate operational and maintenance problems.

Among the factors to be considered are the following: (1) amount of funds available; (2) cost of construction of different designs for the same projects; (3) cost of operation (gas, oil, chemicals, personnel); and (4) useful operating life for each proposed design.

When considering treatment systems, it should be realized that one treatment may be able to perform various functions. For example, slow-sand filtration contributes to clarification and removal of iron and pathogenic organisms. Conversely, the same result can be attained by different treatments, as in the case of the removal of suspended matter, which may be accomplished by sedimentation as well as by filtration.

Plain Sedimentation

Plain sedimentation in natural or impounded reservoirs is useful for the removal of gross turbidity and for a

[1]Lecturer, Department of Civil Engineering, University of Nairobi, Nairobi, Kenya.

reduction in bacteria, particularly pathogenic bacteria. It can be effective either alone or in combination with slow-sand filtration or chlorination.

Generally, plain sedimentation will have the following effects:

(1) Reduction in turbidity. The efficiency of sedimentation in the reduction of turbidity is dependent upon the nature of the suspended material and the settling time allowed. Before a decision is reached regarding the use of this treatment process, it is necessary to study the nature and characteristics of the suspended matter in the untreated water. The quantity of suspended matter varies a great deal in most tropical surface waters. For example, suspended solids in the Tana River can range from 10.3–2792.8 mg/litre and at the Kamburu dam from 15.9–284.2 mg/litre.

(2) Reduction in bacteria. Simply holding water in a reservoir will reduce the total number of bacteria. This is particularly true of pathogens, which do not usually find water a suitable environment for growth. The more adverse the conditions for bacterial growth, the less growth will occur, e.g., as in water with low pH.

(3) Storage. Any reservoir or tank constructed primarily for accomplishing sedimentation also provides space for storage. Ample storage helps to guarantee a continuous supply of water, which is a fundamental objective.

Basins for plain sedimentation can be constructed as simple dug basins with an overflow rate of 1–10 m/day.

Aeration

Aeration is sometimes necessary to accomplish the following:

(1) To control tastes and odours. When tastes and odours are caused by dissolved gases, such as hydrogen sulfide, aeration is necessary. It can also be effective, perhaps to a lesser degree, when odours and tastes are caused by decomposing organic matter, chemical wastes, or secretions from microorganisms.

(2) To precipitate iron and manganese. Iron is more common in natural waters than manganese. A chemical examination of the untreated water will reveal the nature of iron compounds in the water. Usually, the iron is in the form of ferrous bicarbonate or ferrous sulfate. Upon contact with free oxygen (0.14 ppm O_2 for each part per million of iron oxidized), ferric oxide will be formed. The reaction takes place at a pH of 7.0 or more. This compound is insoluble and will settle out.

(3) To expel carbon dioxide. Excessive amounts of CO_2 make water aggressive and cause it to dissolve the exposed iron in the water pipes of the system. Aeration can be useful for the removal of CO_2, which escapes into the air.

Methods of aeration may be classified into three broad groups: waterfall aerators, bubble aerators, and mechanical aerators. Under rural conditions it would normally be uneconomical to provide pumping solely for the purpose of aeration. It might be possible, however, to combine the aeration process with pumping from the source to a storage area. In a gravity system, ample head may be available to provide for aeration.

Waterfall aerators may be constructed as spray aerators with upward or downward water outflow, as multiple tray aerators, or cascade aerators, the latter having the advantage that the loss of carbon dioxide can be kept to a minimum. Spray aeration requires an elaborate pipe distribution system to deliver the water to the various nozzles, making its construction rather expensive. Multiple tray aerators offer the cheapest and simplest construction, requiring little space and performing an excellent job both with regard to oxygen absorption and removal of undesirable gases. Cascade aerators require more space and are more expensive to construct, but should be used when the water recovered is in carbon dioxide–bicarbonate equilibrium, meaning that the loss of carbon dioxide would result in the precipitation of calcium carbonate.

In every case, however, preliminary studies with a small pilot experimental plant are recommended. In this way, a definite idea can be obtained regarding the efficiency of the aeration process under a given set of

circumstances before any large expenditure on construction of aeration structures is made. Figure 1 shows a typical aerator.

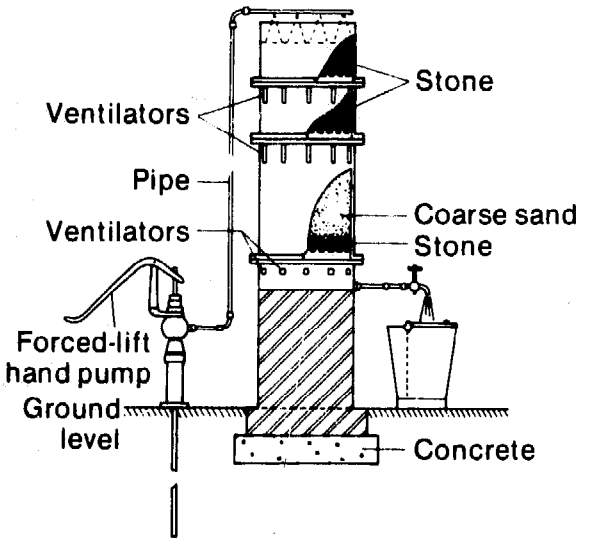

Fig. 1. National Environmental Engineering Research Institute (NEERI), Nagpur, India, iron removal unit.

Slow-Sand Filtration

Huisman and Wood (1974) claim that "no other single process can effect such an improvement in the physical, chemical and bacteriological quality of normal surface waters." Slow-sand filters have a high degree of efficiency in the removal of turbidity, tastes, and odours. Furthermore, no chemicals are used. Some additional advantages of this method for developing countries are: (1) the cost of construction is low, particularly when manual labour is used; (2) simplicity of design and operation means that filters can be built and used with limited technical supervision; (3) importing of material and equipment can be negligible, and no chemicals are needed; (4) power is not required if a waterfall is available on site, because there are no moving parts nor requirements for compressed air or high-pressure water; (5) variations in rainwater quality and temperature can be accommodated provided turbidity does not become excessive; and overloading for short periods is not harmful; (6) water is saved (an important matter in many areas) because large quantities of washwater are not required; and (7) sludge, which is often a major problem with water treatment by more sophisticated methods, is less troublesome.

Application

Slow-sand filters are most practical in the treatment of water with turbidity below 50 mg/litre (expressed as SiO_2), as this permits a longer filter run, although untreated water turbidities of 100–200 mg/litre can be tolerated for 2–3 days. The best purification by slow-sand filtration occurs when the average turbidity is 10 mg/litre or less. When higher turbidities are expected, slow-sand filtration should be preceded by some type of pretreatment, such as plain sedimentation, storage with microstraining for algae removal, rapid "roughing" filtration, and sedimentation preceded by chemical coagulation and followed by rapid filtration.

Design of Slow-Sand Filters

Untreated water. Turbidity should be less than 50 ppm for the water applied to the filter; higher turbidities can be accommodated for short periods.

Filter loading. The rate of filtration should be 0.1–0.2 m/h. The lower the rate of filtration, the more effective will be the treatment.

Filter sand. It should be uniform, with a uniformity coefficient of about 2.00 and not greater than 5.0, and free of organic matter. The effective size should be 0.15–0.35 mm. The finer the filter sand, the more efficient will be its filtering action, but the quicker it will clog, thus increasing operating costs. For proper functioning of the purification process, a minimum filter thickness of 0.6 m should be provided. Because the top layer (10–20 mm) of the filter bed will have to be removed regularly during operation, a new filter should be provided with a filter bed 1 m thick (range 1–1.4 m) so that the bed will not have to be refilled more than once every few years.

Filter gravel. It should be graded so as to prevent the penetration of sand and yet provide for the free flow of water toward the underdrains. The following minimum depth

of graded gravel is acceptable: a 15 cm layer passing an 80 mm screen but held on a 10 mm screen; a 5 cm layer passing a 25 mm screen but held on a 10 mm screen; a 5 cm layer passing a 10 mm screen but held on a 5 mm screen.

Underdrainage system. This is required for three purposes: support for the filter media, collection of the filtered water, and uniform distribution of the filtration rate. The simplest form of underdrainage system consists of lateral drains spaced less than 4 m apart, and a main drain. Filter bottoms are sometimes gently sloped downward from the midpoints between the laterals. The laterals usually consist of porous or perforated unglazed tiles, glazed pipes laid with open joints, or perforated pipes of asbestos cement or polyvinyl chloride, covered with layers of gravel. The main drain may be constructed of pipes or made from concrete.

Filter control. Generally, filter control is accomplished by means of a system of hand-operated valves to regulate the filtration rate and the depth of water over the filter. A simple filter control system is shown in Fig. 2.

Continuous operation. It is important that maximum precautions be taken to ensure continuous operation and to maintain the water level above the sand. This is necessary to protect the layer of silt that builds up on the surface of the sand and the slime film that coats the sand grains near the top of the filter. These deposits help considerably to increase the efficiency of filtration.

Filter cleaning. Cleaning is accomplished by very carefully scraping (5–8 cm) sand from the top of the filter. This done, the filter is put back into operation. The dirty sand is placed in a washing box for cleaning and reuse. This process can be repeated until about 40 percent of the sand is removed. At this time the cleaned sand is returned to the filter to the original level.

Sand-washing. In rural areas this job is normally done by hand. The sand is agitated in a box with water running through it at a low velocity in order to wash out the fine particles. As the process goes on, the washing water becomes clearer as the sand is cleaned. The sand can then be stored and is ready for replacement on the filter.

Rapid-Sand Filtration

The term rapid-sand filtration implies a water treatment process which includes coagulation sedimentation, filtration, and disinfection. The design of the basic units of a conventional water treatment facility is well documented and, therefore, will not be discussed here.

Chlorination and Disinfection

The disinfection of potable water is almost universally accomplished by use of gaseous chlorine compounds. Chlorine and

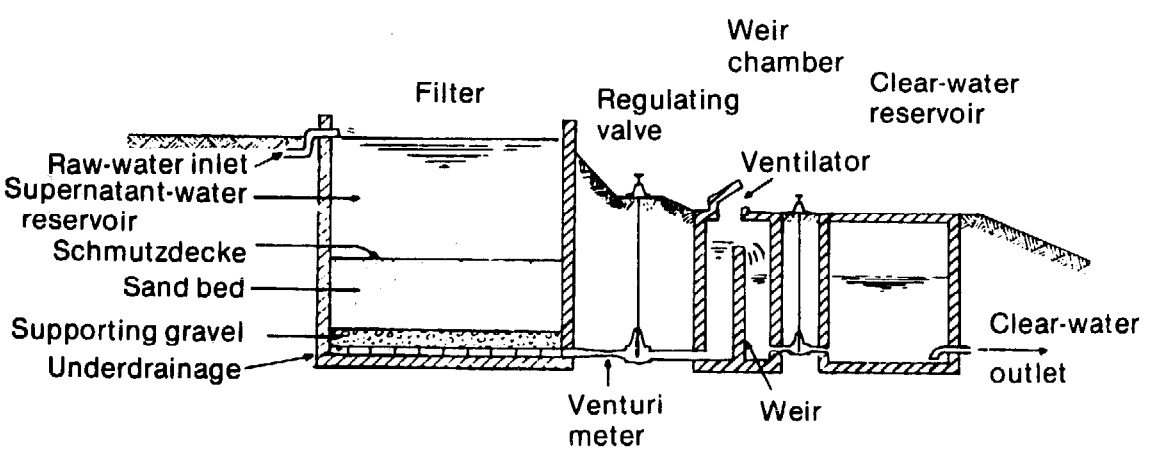

Fig. 2. Slow-sand filter (after Huisman and Wood 1974).

chlorine compounds, such as chloride of lime or calcium hypochlorite, are relatively cheap, readily available, and provide a disinfectant that has prolonged action.

The object of chlorination of potable waters is the destruction of bacteria through the germicidal effects of chlorine. There are several important secondary uses for chlorination, such as oxidation of iron, manganese, and hydrogen sulfide; destruction of some taste- and odour-producing compounds; control of algae and slime organisms in treatment plants; and as an aid to coagulation.

The requirements for effective chlorination are met when the chlorine dosage is sufficient to react with the organic matter, ammonia, iron, manganese, and other reduced substances and at the same time leave sufficient excess or residual chlorine for disinfecting purposes. Also, the concentration of residual chlorine should compensate for the deleterious influence of any prevailing high alkalinity, low water temperature, or short period of contact.

For urban water supplies, chlorine is often applied as a gas, but for rural schemes a solution made from bleaching powder is more convenient. Figure 3 is a simple but reliable device for discharging a batch-mixed chlorine solution into a tank or open conduit. Figure 4 is an example of simple chlorination pots which can be used for wells and storage tanks.

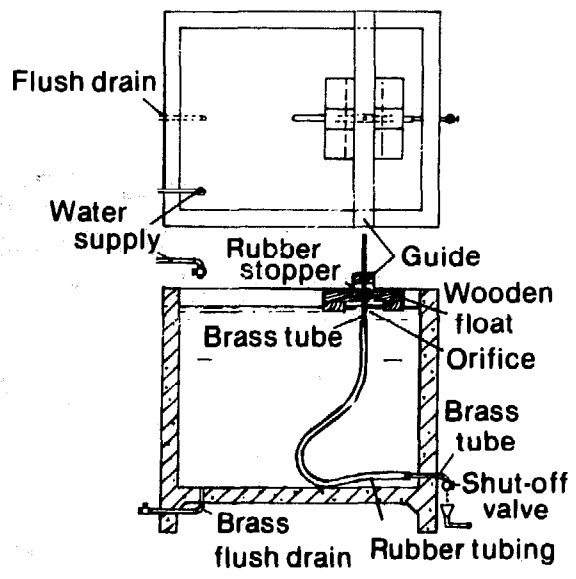

Fig. 3. Plan and cross-sectional views of equipment used for discharging a batch-mixed chlorine solution into a tank or open conduit (modified from Wagner and Lanoix 1959, p. 182). Note: Brass material may be replaced by plastic.

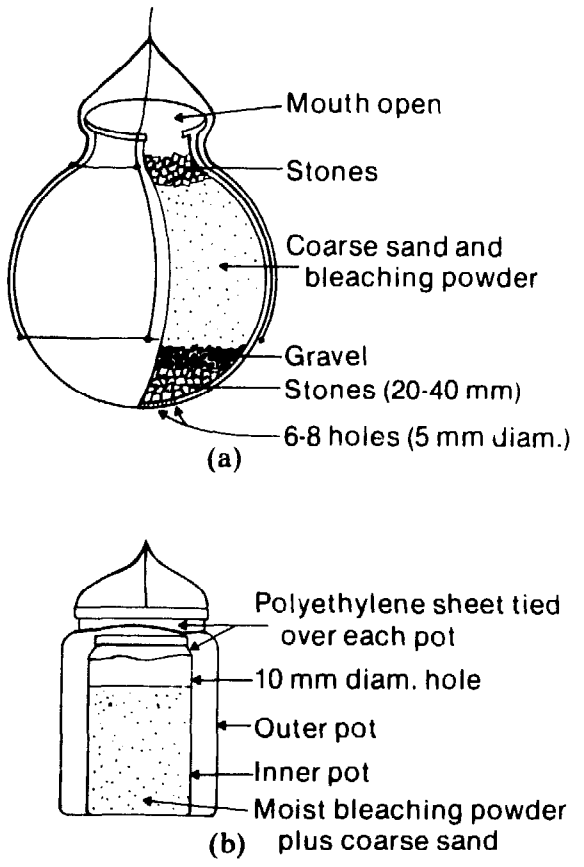

Fig. 4. Chlorination pots used for wells and storage tanks: (a) single-pot system; (b) double-pot system.

Fluoridation

Minute concentrations of fluoride in water consumed by children during the period of tooth formation have been found to reduce dental cavities by as much as 60–65 percent. The concentration of fluoride that accomplishes this varies with the rate of water consumption (the range is 0.6–1.7 mg/litre). Fluoride compounds used for controlled artificial fluoridation are sodium silicofluoride, sodium fluoride, fluosilicic acid, and calcium fluoride. Fluosilicic acid is always used as a solution and is convenient for use by communities without treatment plants. Calcium fluoride, as naturally mined fluorspar, can be dissolved in an alum

solution and added to water with alum to effect simultaneous coagulation and fluoridation.

Defluoridation of Water

When water supplies contain excessive fluorides, the teeth of people using the water become mottled with a permanent black or grey discolouration of the enamel.

At present, three defluoridation methods have proved possible. The first two methods employ insoluble granular media, such as activated alumina or bone char, which remove the fluorides as the water percolates through them. The media are periodically regenerated by chemical treatment when they become saturated. In the third method, the fluorides are removed along with magnesium through the use of settling basins and then discarded. Research is currently under way in Kenya to find cheaper and simpler methods of defluoridation.

Conclusions

In an article discussing long-range planning for water service in the U.S.A., Dr Abel Wolman of Johns Hopkins University, Baltimore, has said "Adequate water service, at a reasonable price, is an attainable objective. If it has not yet been attained, it is only because the skilled workers in this field have not seen fit to define the objective, to delineate the principles which control its implementation, to devise the structure for administration and management, and to establish the fiscal principles which might safely and wisely provide the sinews for the project." The author of this paper believes that this objective can also be met in developing countries provided that the principles outlined above are adhered to. In the field of water treatment, I believe that it is a bit naive to imagine that only simple treatment facilities like slow-sand filters will have a significant impact on all of the varied water supply programs in developing countries. Water engineers working in these countries need to keep abreast of current water supply technology to be able to make rational decisions in this very important field of national development.

Huisman, L. and Wood, W.E. 1974. Slow sand filtration. Geneva, Switzerland, World Health Organization (WHO).

Wagner, E.G. and Lanoix, J.N. 1959. Water supply for rural areas and small communities. Geneva, Switzerland, World Health Organization.

White, G.F., Bradley, D.J., and White, A.U. 1972. Drawers of water, domestic water use in East Africa. Chicago, Illinois, University of Chicago Press.

Technology: Discussion

The discussions of the papers in the technology section were characterized by debate on the different options available.

The discussion was often detailed and technical. It was clear that some of the low-cost renewable technologies were not simple but could be quite sophisticated. The discussion on wind-power pumping was a case in point. Wind-power potential, blade design, tower design, drive mechanisms, matching the windmill to the water pump, and groundwater characteristics were some of the many features considered. It was clear that in the case of wind-power pumping devices research and development was still actively going on, even while units were being installed.

There was a constant debate about the choice between high-cost, capital-intensive devices that require minimum maintenance and low-cost, locally made technologies that often require careful, extensive maintenance. The imported steel pumps used in Tanzania were compared with the locally made plastic models used in Malawi and Ethiopia. This issue also was raised when imported windmills were compared with locally made models.

The discussions were also characterized by debate on the various options that are now available in the renewable energy technologies. A great variety of hand pumps are being developed. Various simple methods of slow-sand filters, honeycombed concrete filters, and other simple treatment methods were discussed. It became clear to trainers that a variety of options had to be included in any training curriculum to allow technical personnel to be familiar with the wide range of technical choices available. It was making known this increase in the number of options available for rural water supply that was one of the goals of the workshop.

Kenya presented a brief description of the rooftop rainwater catchments that are being constructed there. The roofs are usually made of corrugated iron and the cisterns are locally-made using concrete. At present, this is one of the most successful technologies at the local level of development.

Role of Operation and Maintenance in Training (with Emphasis on Hand Pumps)

Aseged Mammo[1]

The Ethiopian Water Resources Authority (EWRA), like its equivalent organization in most developing countries, has the immense task of supplying clean water to the country's rural population. To do that, however, it must overcome many shortcomings: organizational, financial, and human to name but a few.

Training at the EWRA is geared toward alleviating the shortage of skilled manpower, its most pressing need at present. To achieve that goal, the EWRA's training programs cover all relevant positions from pump attendant to postgraduate courses outside of Ethiopia.

This report will look at the training of field personnel who are involved with the maintenance of engine-driven rural water points. Comparative analyses of the operation and maintenance of hand pumps installed in various regions of the country will be discussed in detail. Thus, it is suggested that the reader be acquainted with the designs of some hand pumps currently used in Ethiopia as described by the author in a report presented earlier in these proceedings.

Engine-Driven Pumps

Of the numerous water points made by the EWRA in rural Ethiopia, the most scattered, costly, and relatively "fragile" are the diesel-powered deep well and submersible pumps used in boreholes. Training at the EWRA concentrates on providing skilled and semi-skilled labour for borehole drilling and the maintenance and operation of pumps installed within these boreholes.

There are four levels of training for rural water supply operation and maintenance. The relatively short course for pump attendants covers diesel engine operation, daily maintenance of the engine and pump units, and writing reports on their performance. The course for plumbers and welders deals with the installation, maintenance, and repair of equipment for water supply and piping networks in rural areas. Field mechanics are trained as "maintenance mechanics," and they make up a mobile unit responsible for routine inspections and subsequent preventive maintenance on units in the field. The course covers diesel and gasoline power plants, deep well "mono" and submersible pumps, hand pumps, and cutting and welding. The fourth course, designed to train mechanics to overhaul the equipment at regional levels in the field, is yet to be started.

Status of Hand-Pump Maintenance

Compared with motor-driven pumps, hand pumps are cheaper, simpler, more numerous, and serve a much smaller community per pump. They are widely

[1]Research and Development Engineer, Mechanical Engineering Department, Addis Ababa University, Addis Ababa, Ethiopia.

scattered and in many cases access to them is difficult, even by four-wheel drive vehicles. If they fail, the people using them just open the manhole cover and use the inefficient and unsanitary, but reliable, bucket at the end of a rope. Therefore, efforts by the EWRA to train mechanics to perform routine inspections and maintenance on all hand-pump installations becomes unrealistic.

The following is a short description of the status of some hand pumps with respect to training at the EWRA. The pumping elements of the mono pump are basically the same as those of an engine-driven pump, thus making the hand pump version very expensive but reliable. This pump is, therefore, included in the syllabi of the maintenance and overhaul mechanics' courses. The other unit is a hand piston pump. A demonstration model (Boswell pump) can be found at the training centre. This design is rather inefficient but is included in the syllabus as an introduction to all hand piston pumps and as a possible "heir" to the imported versions (although part of it is still imported) because some of the stands are being manufactured at the EWRA's premises.

Comparative Analysis of Pumps and Users

Maki

In this area, 130 km south of Addis Ababa, are found the mono, Consallen, Boswell, and EWRA/International Development Research Centre (IDRC) type pumps. These hand pumps have been in use here for some years now. Installation and maintenance on the mono and Boswell pumps are carried out by the United Nations Children's Fund (UNICEF), on the EWRA/IDRC pumps by this project, and on the Consallen pump, at one time, by the Central Region. Since the United Kingdom government stopped providing direct aid, however, the Consallen pumps have been neglected. The problem is aggravated by the fact that the level of water in the wells drops during periods of drought, in some cases completely drying up the well. This is a result of inadequate information on water depth when the well was originally developed. Abuse of pumps by the local population is relatively minor.

Awara Melka

The only pumps found in this area are of the EWRA/IDRC type, the first of which was installed in May 1979. Since that time, 10 pumps have been put into operation within 25 km of the town. The people of this area are largely nomadic herdsmen and training them is of little value. Abuse of the pumps is exceptionally high. In one instance, about 6 mm of steel were worn away from the handle of a type BPL hand pump in less than 3 months of operation!

The need for water in this semi-arid region, 200 km southeast of Addis Ababa, is immense. Engine-driven water points are not necessary because the area is scarcely populated. The only time pumps in this area are kept in proper working order is when a village chief is willing to take care of them. A fence is constructed around the water point to keep cattle away and the key to the door lock remains in the nearby chief's hut overnight. Attempts to fix the pumps by the user have so far resulted in worsening the situation.

Maintenance is carried out by research crews only, because the well digging crews do not have the tools required to deal with the pumps. It is difficult for the research crews to work in this area, however, because it is normally very hot and dusty, and access is often limited to four-wheel drive vehicles. At two sites, the temperature of the water in the dug wells was 50–70°C. Without a proper well-draining pump the digging could not continue. Furthermore, it is not possible to install any type of hand pump under these conditions.

A short-term solution may be to train the well digging crews in the installation and maintenance of these pumps, and station them permanently in the area. However, a lasting solution will come only when the nomadic Afar people are settled. Until then, wells employing buckets as water-lifting

devices are the only realistic option. Designs to keep wells more sanitary during operation should also be developed.

Assossa and Hosanna

In these two areas, which are located 800 km west and 250 km southwest of Addis Ababa, respectively, wells for EWRA/IDRC pumps were prepared by the Evangelical Church Mekane Yesus (ECMY). The wells are relatively shallow, 1-6 m, in most places. In the Assossa area, the traditional lift pumps with piston and cylinder above the well, and mono pumps have been installed, in some cases more than 10 years ago. The immediate surroundings of most of the pumps in both areas are heavily populated. However, there is little pump abuse.

In Assossa and Hosanna, as well as any other area where the ECMY produces wells, it is now agreed that they (ECMY) will provide the installation and maintenance with their own development crews. Initially, installation was carried out by the research crew. The ECMY technicians have received no formal training, but some relatively novel aspects (e.g., cementing of bell-end joints) were demonstrated and/or explained to their field personnel in letters. Feedback to and from the research crew is in 2 or 3 months. In two cases, pump stands that were sent for installation in Assossa would not fit into the well covers. These pumps are now being used for well draining during the digging of new wells. The ECMY has so far solved all of its field problems without the help of the EWRA.

Goba (Robé)

This new settlement area, 250 km south of Addis Ababa, is a prospective candidate for hand-pump installation. The United Nations Children's Fund has dug about 20 wells and installation will be carried out, in part, by the research crew. All subsequent installation and maintenance will be the responsibility of the settlement's craftsmen.

At present, this arrangement seems to be the most suitable for a hand-pump program. The "villages" concerned will be virtually self-sufficient to the extent of producing spare parts from local materials. Manufacturing of the pumps by the research crew and preparation of the wells by UNICEF are well under way.

Conclusions

This report has attempted to point out that all hand pumps, unlike engine-driven pumps, cannot be installed and maintained by a central government unit. These numerous pumps can only be successfully handled at the small community level.

Based on the experience of the hand pumps installed by the EWRA/IDRC research project, it was found that the more successful programs were located in those areas where maintenance was carried out from within the community itself. Continued research, until an economical and robust local pump is produced, should be encouraged.

In view of all this, Ethiopia now has a considerable advantage over many other developing countries because most of its rural population comes under well-organized peasants' associations. Taking care of pumps installed to supply cleaner water to a community should be a relatively straightforward procedure.

Operational Maintenance in Malawi

L.W.C. Munthali[1] and G.A. Kamwanja[2]

If the government's efforts to upgrade the standard of living in rural communities by supplying them with potable sources of water are to be realized, then operational maintenance of these systems is of vital importance. The success of these efforts depends upon the operational maintenance organization. Unfortunately, this branch of rural water supply is the weakest link between the organizers/planners and the users. This is due to several factors: (1) unrealistic assumptions made by the organizers when setting up the operational maintenance network; (2) difficulty in identifying which sector of society will shoulder the operating and maintenance costs; and (3) manpower-training difficulties due to funding, organizational, and planning problems.

This paper will attempt to outline the present state of operational maintenance in Malawi and focus attention on possible solutions. The three major rural water supply systems in Malawi to be discussed are: the gravity-fed scheme; the shallow wells program; and the borehole program.

Gravity-Fed Scheme

Responsibility for the maintenance of a piped-water project is divided between the main project committee and their subcommittees and the village committees, all of which are established prior to the installation of the project. The project committees are responsible for reporting failures in the pipeline and intake, whereas the village committees report on the taps. A few people within the project area are trained by the field assistant in methods used to mend and join PVC piping, to repair breaks in the line, and how to clean each of the screening, sediment, and storage tanks.

There are two problems with this maintenance system: (1) the people trained to maintain the system are not employees and as a result they may leave the area without notifying the main committee or training a replacement; and (2) the people who monitor breakdowns in the system have to travel long distances to report any problems and to collect materials at the project subcentre to repair the system.

Shallow Wells Program

One of the major problems with this program is that the PVC pump is still being modified by the research branch of the program. As a result, no fully field-tested pump is available. The first pump was a Mark I pump, which has undergone modifications through the Mark II, III, and IV series. It is being modified further into a Mark V model. The result of such diversity in this experimental pump is that it requires a large and varied stock of spare parts.

In this program, maintenance is carried out by an action committee in the village

[1]Senior Boreholes Maintenance Officer, Department of Lands, Valuation and Water, Lilongwe, Malawi.

[2]Lecturer, Department of Engineering, The Polytechnic, University of Malawi, Blantyre, Malawi.

that owns the well. Because the pump is simple in design, it can be easily maintained using spanners and requires little expertise. The committee is also aided by a project assistant.

The main faults of the PVC pump are the wearing out of the PVC plunger, washers, and the cylinder. The PVC pump has an advantage over the borehole pump, however, because it needs no lubrication. Also, because it serves a small community it is not as overused as the borehole pump.

One of the problems of maintaining the pump is that it is assumed that the self-help spirit in the rural communities, generated during the project, can be perpetuated indefinitely. The other problem is that no funds or funding agencies are identified for operational maintenance and as a result the program tends to deteriorate as spare parts dwindle and are not restocked.

Borehole Program

Of the 300 boreholes drilled annually, 250 are fitted with hand pumps to supply water to rural communities. There are several types of hand pumps being used as the government tries to find one which is durable and inexpensive. Unfortunately, this has been difficult to achieve because the most durable pump is also the most expensive. The pumps used are: Climax, Goodwin, Bush pumps, Limani mono pumps, and National pumps. The first two pumps are supplied from Britain and the last two pumps from South Africa. Only the Bush pump is locally made. The diversity of pump types has further aggravated the problem because it requires that parts for all pump types be stocked. Of all of these pumps, only the Climax pump is durable enough to withstand prolonged usage; but again, it is the most expensive pump. Conversely, the cheapest pump, the Bush pump, is also the weakest pump, requiring maintenance more often. The other pumps are relatively durable but require more attention than the Climax pump.

The most common causes of borehole-pump breakdown are: (1) The number of people using the borehole as their only source of water is much too large; sometimes as many as 500 persons. The result of this heavy usage is premature breakdown. (2) Poor workmanship by maintenance crews due to inadequate training. This is primarily the fault of planners. (3) Use of low-cost pumps. This results in increased maintenance and frequent breakdowns, which makes the use of cheaper pumps a poor choice economically. (4) Waters aggressive to mild steel, resulting in frequent replacement of parts. (5) User mishandling because of a lack of knowledge on how to operate the pump. (6) The failure of the community to develop a feeling of ownership of the pump and to realize the importance of clean water results in neglect of the pump, followed by breakdown. (7) The borehole maintenance units are too few to maintain all of the boreholes. This results in long periods without servicing. Because they are few, the units can only respond to breakdown calls. This also results in inefficiency. (8) Incorrect gravel packing, resulting in silting and leakage in the cylinder due to the abrasive nature of the sand.

Maintenance Organization

There are 20 units strategically located throughout the country to service and maintain 4000 pumps. Each maintenance unit operates a 5 ton truck that has a winch and mast mounted at the back for lifting the pump head. A borehole pump is serviced after it is reported broken down. A member of the community reports the breakdown to the district council which, in turn, reports to the maintenance unit of the Department of Lands, Valuation and Water in that particular district.

The maintenance section is headed by a senior wells maintenance officer who is both the administrative and technical head of that section. His deputy is a technical officer. These two people supervise three regional foremen who are the field officers controlling the 20 units. Each unit is divided into four subunits. The wells maintenance

assistant heading each unit organizes trips to each subunit. He leaves his base and establishes a temporary working base in the subunit with the highest number of broken-down pumps. This reduces the amount of travelling that would otherwise be required. As he works in one subunit, pump breakdowns accumulate in the other subunits. He then moves to the next subunit with the highest number of broken-down pumps. The regional foreman makes sure that the units meet all operational requirements and supervises the overall program.

Recommendations

During the organizational stage, operational maintenance of the project must be considered and, if possible, included in the early phases of the project with the intention of improving its organization with time.

Training should be considered in terms of the following questions: (1) What part of the system can successfully be maintained by the rural communities, taking into account their literacy? (2) Could the rural communities themselves organize and fund that maintenance, and/or if it must be handled by the government, what is the best approach to achieving this end to include community involvement? (3) Who is best suited to training the rural communities? Could the field staff who installed the system together with the rural community provide the training?

It is, therefore, envisaged that any training program for operational maintenance must involve mainly the field assistant and the users. Thus, the program must be geared toward these two groups.

Role of Operation and Maintenance in Training

S.K. Ichung'wa[1]

It is the policy of the Kenyan government to provide piped water to every household by the year 2000. The government is trying to achieve this goal in two ways: through the construction of national water projects for domestic use and livestock development and through the construction of small water supplies through implementation of the national motto "harambee" (self-help).

The Ministry of Water Development (MWD) has decentralized services and every provincial headquarters has full maintenance facilities. The system goes down to the district level. The district headquarters also has full maintenance facilities. This is where operational work is generally carried out.

At the moment, Kenyan engineers, in collaboration with Canadian engineers, are undertaking the training of operational staff in western Kenya. Most of the training is on-the-job in nature. This is a quick method of transferring technology from one country to another. The main purpose, however, is to strengthen operational and maintenance capabilities.

Training of Operation and Maintenance Staff, Ministry of Water Development

The current practice for the selection of candidates for training as inspectors requires that the individual should have passed the East African Certificate of Education (EACE) examination ("O" level) division III or above. The candidate should also have indicated an interest in working with the MWD. Applicants meeting the minimum requirements are invited for interview by the Public Service Commission.

Having passed the interview, they are selected to undergo a training program at the MWD training school, Nairobi. The candidate is enrolled in the preselection course that commences in July of each year. This course provides exposure to many facets of the MWD operation curriculum and syllabus, which comprises the following subjects: administration, accounting, purchasing, stores, hydraulics, hydrology, drilling, water law, water treatment, construction, sewerage, mechanical work, drawing, and pipe work.

On the basis of the student's performance in these subjects, as well as in the individual's course assignments to various sections of the MWD, a person is selected for further training.

During field training, the trainee inspector gains experience in all areas of the work of the provincial MWD organization, but is permitted or encouraged to specialize in one discipline, either construction or operation and maintenance.

Training Programs

Water Supply Inspectors

After the 6 month preselection course at

[1]Provincial Head, Western Province, Ministry of Water Development, Kakamega, Kenya.

the training school, those chosen for training as water supply inspector trainees undergo a 2 year training period in the field. This is on-the-job training consisting of different activities such as supervision of construction, administration, and water treatment in different districts within the province to which the person is posted. During this period, the trainee's capability is assessed and confidential forms are completed by his direct supervisor and sent to the principal of the training school.

After this period in the field, the trainees return to the training school in Nairobi for a final 3 month revision course and thereafter take their final examinations. Success in these examinations leads to a final posting as inspectors of water supply in the provinces as well as in the districts.

Engineering Assistants

Candidates wishing to train as engineering assistants are also selected after the 6 month preselection course at the MWD training school. They must have done well in the preselection examination held after the 6 month training period. While the inspector trainees are being sent out to receive on-the-job training in various districts, the selected engineering assistant trainees are sponsored for further training at the Kenya Polytechnic for eight terms of 3 months each.

Before commencing the course at the Kenya Polytechnic, the chosen candidates are first posted to various sections within the province, for 4 months, to familiarize themselves with the many facets of the MWD organization. During this period, the trainee is under the direct supervision of a qualified person who has been in the field for many years.

At the end of 4 months of on-the-job training in the field, the trainees then start their first term at the Kenya Polytechnic. The first stage consists of three consecutive terms of classroom instruction, which comprises the theoretical and practical aspects of mathematics, surveying, elementary quantities, civil engineering construction, hydrology, hydraulics, soil mechanics, and services. The students then take an intermediate examination and thereafter they are again posted for 4 months of on-the-job field training at various locations within the provinces. Upon completion of the on-the-job training, the successful candidates return to Kenya Polytechnic for three consecutive terms, after which they take the final ordinary diploma examinations and are then posted to provinces and various sections at the ministry's headquarters as water engineering assistants. The entire course lasts for 2.5 years, six terms at the college and two terms of on-the-job training.

Candidates who have served for a number of years and done well at the ordinary diploma level can apply to attend a further 3 year course at the Kenya Polytechnic to obtain a higher diploma. This in-service course also consists of eight terms in a sequence similar to that of the ordinary diploma course.

Skilled Tradesmen

Fundamental to the needs of the MWD is a mixture of skilled tradesmen in a number of different disciplines. The skills involved may be directly related to the function of the ministry, i.e., pipe fitters, plumbers, plant mechanics, carpenters, masons, or welders.

The scheme currently being implemented by the MWD to meet its requirements for skilled personnel is the appointment of subordinate staff personnel as "apprentices."

The apprentice is assigned to and works under the supervision of a certified tradesman. The effectiveness of adequate on-the-job training is only as good as the qualified tradesman makes it, and is totally dependent on the particular jobs that the tradesman and his apprentice are called upon to deal with.

Opportunities for formal technical training are offered via apprenticeship and learning programs for persons entering the employment market with differing academic qualifications. For technical apprenticeship the student requires an EACE, form II is required for craft apprenticeship, and the Certificate of Primary Education (CPE) is required for the learning program. The

foregoing training opportunities fall under the jurisdiction of the Ministry of Labour through the Directorate of Industrial Training.

Skill-development courses are also offered both to upgrade skills and provide short-term relief for skilled-staff shortages. At the present time, the MWD makes use of these training opportunities, but only on a limited scale, even though these opportunities represent a long-term solution to the countrywide shortage of technical personnel. A thorough analysis is required to determine the future technical manpower requirements of the ministry. These requirements could require constant annual revision in the light of current development.

Operators

The candidates are usually recruited directly from school and should hold an EACE division IV or above. These people are appointed as operator trainees grade II. Those persons holding the CPE and having completed the Kenya junior school examination (KJSE) can be appointed as operator trainees grade III.

The operator trainee is assigned to and works under the close supervision of a qualified water supply operator. During this on-the-job training, the operator trainee should be able to learn the overall operation and maintenance of pumps and engines used for supplying water. He should also be able to learn simple water treatment methods. In the office, the trainee is taught general office organization, meter reading, repair of broken pipe work, and connection and disconnection of water meters.

After some time, the trainee can be recommended for the 2 month water operator course at the MWD training school in Nairobi. At school, the operator learns about the operation and maintenance of pumps, engines, and motors used in water supply systems, and details about pipe fitting, administration, and the principles of water treatment. Following this course, the operator trainee may be assigned the duties of full operator or he may be appointed to assist another operator. Periodically, the operators are invited to attend refresher courses at the MWD training school.

Apprenticeship Training

One option in training technical personnel which the MWD has not sufficiently utilized is the apprenticeship training program offered by the Ministry of Labour at the industrial training centres in Kisumu, Nairobi, and Mombasa.

(1) Technical apprenticeship: The candidates are usually recruited directly from school or from agencies such as "Employment Exchange" and the "Directorate of Industrial Training." The minimum educational qualification for entry is the EACE, with credits in English, mathematics, and appropriate science subjects. The training of these apprentices is usually carried out at a postsecondary institution such as Kenya Polytechnic and includes practical fieldwork.

(2) Craft apprenticeship: The minimum educational qualification for entry is form II secondary vocational/technical school or equivalent. Suitably qualified holders of the national trade test grade II may be considered for entry in a craft apprenticeship program at an advanced level. The director of industrial training is responsible for the operation of the scheme and the first 6 months of the training are considered to be a probationary period. The craft apprenticeship program is organized into five stages and is spread over a 1 year period. It consists of a combination of theory and practice plus on-the-job training, supervised by personnel from the training institution.

Upon completion of each craft course, the training institution submits to the employer progress reports on the performance of the apprentice. Upon successful completion of the apprenticeship course, the institution issues a nationally recognized certificate of apprenticeship.

Conclusion

These training programs are part of a well-planned master water plan developed by the Kenyan government for the entire country. As a result of these programs Kenya has a considerable operation and maintenance staff.

A Sociological Approach to Water Development

J.A.K. Kandawire[1]

This paper attempts to stimulate some thought regarding two questions: (1) What must someone involved in training people in the development of rural communities understand about the communities themselves? (2) What methods of persuasion should be used to obtain the cooperation of rural communities when introducing new techniques for the development of rural water supplies? These are not new questions and they are raised here not to give new answers but to highlight sociocultural problems.

Three important aspects of the problem of rural development are leadership, organizational framework, and cultural conservatism. How these three aspects can be connected will be shown when describing, in general terms, what is happening in Malawi in the field of rural water development. In this regard a brief outline of the general organizational framework in Malawi will be given. It will include an explanation of the way Malawi uses the approach of self-help in the development of rural water supplies; the problem of traditional health practices, with special reference to traditional culture in Malawi; and an attempt will be made to suggest a sociopedagogical approach to rural water development. This approach involves "group discussion" and "community self-survey" as aids in training for technological innovation in the development of rural water supplies.

[1]Head, Department of Psychology, Philosophy, and Sociology, Chancellor College, University of Malawi, Zomba, Malawi.

Leadership and Organizational Framework in Malawi

The government of Malawi realizes that the success of the rural water supply program depends upon an ideal combination of the central and local government systems, in which rural communities can have an adequate measure of representation and participation in determining the character, extent, and direction of development (SDSECA 1971). For this reason, it formed an integrated department through which to plan and execute the program of rural water supply. The department in question brings together three different water supply programs: gravity-piped water, shallow wells, and boreholes. These were brought together under the newly created Department of Lands, Valuation and Water (DLVW) within the office of the president and cabinet (OPC) in July 1979. The spirit of "self-help" governs the formation of the department as will be shown by the way it relates to rural communities, thus forming an ideal organizational framework. Prior to the formation of the DLVW, water-related functions were scattered throughout 14 departmental or subdepartmental units distributed throughout six ministries.

The creation of the DLVW means that water is now regarded by the government of Malawi as a high priority and that lines of communication between rural communities and those responsible for the provision of technical knowledge related to water supply are simplified. These lines pass through the

district development committee (DDC), which is very important in district administration because it provides a direct link between the central government and rural communities, or through the management of agricultural development projects. Requests for assistance originate in villages and are sent to the DDC through councillors. Each DDC discusses a number of project proposals of different kinds, all of which are related to rural development, and submits to the OPC a request for funding (CSC 1974). After funding has been established, the DLVW is directed by the OPC to begin work on the project.

The DDC is made up of the district commissioner, who is also its chairman; the district chairman of the Malawi Congress Party, League of Malawi Women, and League of Malawi Youth; the district council chairman; members of parliament from the district; the district medical officer, ADMARC official; and technical officers of other departments such as Community Development, the DLVW, and the Ministry of Agriculture and Natural Resources. Traditional leaders are not members of the DDC although literate ones may be co-opted. These leaders play their role in area action groups (AAG). Party leaders operating below the district level sit on this committee together with their chiefs. The AAG is responsible for forming work committees, establishing work responsibilities, and undertaking the actual labour. However, the practice is to form a special project committee for a major project such as a piped-water project. This project committee is divided into branch committees which are further divided into village committees.

Technical staff of different ranks sit on committees appropriate to their rank. For instance, water development assistants sit on village committees, project supervisors sit on branch committees, and project managers sit on the main project committee. In this way, the central government is represented at the grass-roots level just as rural communities are represented in the DDC, which would otherwise be dominated by officials. This organizational framework is ideal for a rural development approach that stresses the involvement of potential beneficiaries in the rural development program. Using the community development principles, rural communities can participate in the entire program cycle of planning, construction, and maintenance. The organizational framework also makes a clear distinction between the role of community organization and that of the DLVW headquarters, as well as its field staff. The DLVW provides technical support to rural committees, whereas community organization provides all the labour and organization required to successfully complete a safe water project.

This relationship enables the beneficiaries to take the first step toward the development of rural water supplies. They identify the need and then ask for assistance from the government through the appropriate channels already described, i.e., requests from villages are routed either through the DDC or through the Ministry of Agriculture and Natural Resources.

The involvement of the whole community in the development program presupposes that people in the community are aware of their problems and that they will make an effort to solve the problems through self-help methods. Yet, in reality, not all such people may be aware of, and willing to solve, their problems because of some cultural barriers. The organizational framework outlined here can be used as a channel through which rural communities can be taught to understand sociocultural problems of development. In Malawi, such sociocultural problems, insofar as they may affect the development of rural water supplies, can be discerned from the works of Marwick (1965), Mitchell (1966), and Wilson (1963).

Cultural Barriers in Malawi

This section will provide an outline of the contrast between the scientific explanation for problems such as disease and the traditional explanation based upon the systems of belief held by the Chewa, Yao,

and Nyakyusa peoples. For example, with regard to drinking water, health experts say that water is the carrier of germs which cause diseases such as typhoid and cholera. It follows that the outbreak of these water-borne diseases can be prevented at the source by providing clean water to people. In contrast, the explanation for such diseases in much of traditional Africa is based on beliefs in the power of witchcraft and sorcery, ancestral spirits, and sex taboos.

To take Chewa beliefs in sorcery as an example, it is said that sorcerers in that society cause different types of misfortune among people and that these sorcerers usually attack their matrilineal relatives (Marwick 1965) with whom they have quarreled. This is also true of the Yao people, who believe that sorcery operates between people who are linked by kinship ties and this means that sorcerers kill matrilineal relatives by magic (Mitchell 1966). The point to be emphasized here is that it is only quarreling matrilineal relatives who believe that one is practicing sorcery and magic against the other, and that such conflicts usually lead to group segmentation (Mitchell 1966).

Patrilineal Nyakyusa also believe that illness among them is caused by "witches," "murmuring," and "the breath of men." They further believe that witches are certain people among them who have pythons in their bellies, and these pythons are believed to give power to witches to harm others as well as cattle (Wilson 1963). What motivates witches to harm others, it is said, is their greed and lust for human flesh and the milk from cows. To obtain these valued foodstuffs, witches are believed to go to their victims in dreams during the night. "The breath of men," on the other hand, is believed to be used by villagers to punish wrong-doers in society (Wilson 1963). For example, a son who insults his father in the presence of his father's neighbours thereby insults the entire age-group of his father who murmur in response to the insult. Similarly, a daughter-in-law who looks at her father-in-law shocks the age-group of her father-in-law who then murmur against her. These murmurs are what Wilson calls "the breath of men," which are believed by the Nyakyusa people to bring onto wrong-doers, or their children or cattle, some prolonged illness.

Sorcery among the Chewa and Yao people can be prevented by the immediate settlement of differences between quarreling matrilineal relatives (Marwick 1965; Mitchell 1966). Nyakyusa people, on the other hand, are protected against witchcraft by their village headmen (Wilson 1963). A Nyakyusa village headman is given this power at "the coming out ceremony" when the country of an old chief and his village headmen is formally handed over to his two eldest sons and their respective headmen to administer (Wilson 1963). During this ceremonial occasion, all new village headmen are treated with medicines to give them the power to see and fight witches through the medium of dreams at night.

Beliefs in the power of ancestral spirits over living members of their lineages also exist. Among the Chewa people, the belief is that lineage spirits manifest themselves in the form of illness in a living member. This occurs when the living members do not make regular offerings to the spirit, when the rituals performed following the death of the spirit are performed incorrectly, or when the spirit's name has not been passed on to a successor (Marwick 1965). A similar belief is also held by the Yao (Mitchell 1966) and Nyakyusa (Wilson 1963) peoples.

An example of the beliefs in taboos is that which forbids a man to commit adultery when his wife is expecting a baby. It is believed that failure to observe this taboo causes harm to the wife. The Chewa people refer to this as *mdulo* (Marwick 1965) and the Yao people call it *ndaka* (Mitchell 1966). Similar taboos are imposed on close relatives or mourners who have lost a kinsman, and on relatives of boys and girls who are being initiated into adulthood.

These systems of belief and others constitute cultural barriers which may limit the extent to which rural communities participate in developmental projects, such as water supply projects, designed to benefit the rural community. People in rural

communities need to appreciate the scientific relationship between water and disease. This could be accomplished through some form of informal adult education program. It is only when the people understand why they are participating in a water project that they will appreciate the value of clean water in the prevention of disease.

Sociopedagogical Approach

It has been suggested earlier that the organizational framework outlined thus far can serve as a channel through which people can be made aware of cultural problems. This point is made here based on the assumption that people's awareness of their own problems, and their attempts to solve these problems through self-help methods, will modify their attitudes toward new technical innovations. The proposal here is that this change should be brought about through the development of mature and able local leadership (SDSECA 1971). A committee structure is ideal for this purpose. This section considers how the committee structure can be used to achieve this educational goal. It advocates the use of organized group discussions aimed at developing constructive mental attitudes and healthy social relations among members of the group (UNESCO 1958). An organized group discussion has rules which enable one to focus the discussion on a specific goal. Six such rules will be mentioned here: group composition, the need for a democratic and peaceful atmosphere, material arrangements when preparing for the discussion, launching and developing the subject, choice and preparation of the subject, and the need for flexibility (UNESCO 1958).

In order for a group to be compatible it must satisfy two requirements: it must be composed of people of differing origin and social status, so as to have a variety of opinions (UNESCO 1958); and it must not be too large or too small, 7–20 people being a workable size (UNESCO 1958).

Ensuring orderly guidance of the discussion and a democratic atmosphere within the group is the responsibility of the organizer of the group. As such, the organizer is supposed to ensure that the group discussion leads to the sharing of ideas among participants and not to the imposition of the organizer's own decisions on the group (UNESCO 1958). The need for a peaceful atmosphere is closely related to the need for a democratic atmosphere in that a properly conducted meeting is one that discourages polemics and reconciles opposing views, thereby ensuring peace and maximizing the benefits of having different opinions expressed by members of the discussion group.

The arrangements to be made when preparing for the discussion should ensure that a spirit of equality among members of the group prevails. A classroom situation that puts one person in an authoritarian position is not recommended for adults, but rather a relaxed atmosphere such as a circular or oval arrangement that ensures that all participants exchange ideas freely.

With respect to launching and developing the discussion, a democratic atmosphere reassures participants that the person who is launching the discussion is their equal. Likewise, the latter feels the same about his colleagues and in this way he is not likely to use an authoritarian tone, which usually frustrates discussions. In such a situation the group leader can easily bring a runaway discussion to order, but to be able to do this he should be quick to step into the discussion whenever he sees that it is not developing well.

The choice and presentation of subjects to be discussed by the group should reflect the personal interests of group members. Furthermore, only one subject should be discussed at a time (UNESCO 1958). Relating the subject matter to people's interests has the advantage of ensuring that all members of the group may contribute to the discussion.

All of these rules are presented here to serve only as guides. Their application to specific situations should be governed by the principle of flexibility. What is important is the achievement of the adult education goal

at which the group discussion is aimed. Another method which can be used to achieve this goal is the community self-survey.

The community self-survey has been defined as "some kind of specific research method whose own character is derived from its socio-pedagogic aim" (van de Lest 1962). As a sociopedagogical method, the community self-survey has to be conducted by the people facing the problem they wish to solve. The procedure adopted in community self-surveys must be simple enough to enable someone with an elementary form of education to follow it.

The scientific procedure which social scientists follow begins with a general problem and proceeds to the reformulation of the problem. This is followed by enquiries, data collection through interviews, and then data analysis leading to interpretation.

Experts in methods of social research advise that the first step in reformulating a research problem is to make the problem concrete and explicit (Selltiz et al. 1965). This step requires that a set of questions related to a central problem be formulated (Goode and Hatt 1952), and that "the content of questions should particularly be suited to obtaining information about what the respondents know, believe or expect, feel or want, intend to do or have done, and about their explanations or reasons for any of the preceding" (Selltiz et al. 1965). It is advised that a preliminary list of questions should be submitted to experts, both in the field of the problem and in related fields, for their comments (Goode and Hatt 1952). In assessing these data, the reliability and validity of the information collected from respondents must be considered.

After deciding on the type and form of questions to be asked, the next problem is deciding who should be interviewed. The solution to this problem depends upon whether questions are aimed at obtaining objective factual information or subjective information based on people's beliefs and feelings. The selection of people to collect the information may also pose a problem depending upon the level of their literacy and the complexity of the interview schedule.

Once data have been collected, the next step is to process them in order to find out whether the responses can be used to answer the research questions. If the data collected actually relate to the problem being studied, interpretation should not present too great a problem in spite of the fact that the people interpreting the data have a low level of literacy and may not have been exposed to a social science study of this nature in the past.

Conclusions

This paper has attempted to explain what a person involved in training people in the development of rural communities should understand about such communities and what methods should be used to obtain the cooperation of the people in the community. It has been suggested that in addition to understanding those cultural aspects that tend toward conservatism, people involved in the training should also understand the sources of group divisions within the society, because problems of community organization usually arise from group divisions which may or may not be based on cultural differences. It has also been suggested that by trying to understand the cultural aspects of a community, attention should be drawn to the way the social structure is defined, because it is through the structural principles that groups of people, as well as their leaders, can be identified.

Leadership in this paper has been treated together with the organizational framework based on an example from Malawi. When explaining the Malawi organizational framework no attempt was made to expose its possible weaknesses. The following are a few such weaknesses which come to mind.

(1) There is the separation between the DDC and the management of special agricultural development projects. This conceals differences in the operation of the principle of self-help. Special agricultural development projects receive heavy monetary input, whereas projects which fall under the DDC umbrella receive

comparatively little aid. As such, the latter type of project is more dependent upon local participation than on outside help. Nevertheless, in both cases agricultural extension workers who have been exposed to self-help principles, community development workers who claim to be experts in promoting self-help activities in rural areas, and health assistants are all used to influence participation from the rural communities.

(2) There is a difference in the nature of the water programs for special agricultural development areas and those for other areas. Boreholes and shallow wells are used in special agricultural areas, by individuals who hire government services at their own expense to drill a borehole, and by communities that submit a request to have a borehole drilled. On the other hand, a piped-water program involves a very large group of people and is never an individual's concern. Hence, the nature of the water program can influence the extent to which community participation in it can be achieved.

(3) The sociopedagogical approach as a method of persuading people to cooperate with water development assistants can be complemented by a community self-survey. It has been suggested here that people in the local communities should choose the subject, formulate the problem, collect data, arrange, and interpret it. In the same way as they are assisted by officers who are trained in technology, they should also be assisted in all stages of carrying out such research by a well-trained social scientist.

(4) This last problem involves extension services in rural areas. If agricultural extension workers, public health workers, community development workers, and water development assistants do not adopt a common approach to rural development, there is bound to be confusion in the field. This confusion can be minimized if the DDC takes great interest in bringing about some collaboration among these groups. The DDC can discharge this duty reasonably well if an interministerial committee in Lilongwe, in which all of the ministries represented in the field participate, gives the DDC its strong support.

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The Role of Operation and Maintenance in Community Rural Water Supply Training

A. Mzee[1]

Mankind cannot live without water. To survive, the equivalent of at least three pints of water per day must be taken into the body in the form of foods or liquids. This is only a small portion of our water needs, however, because water is needed for cooking, cleaning, and washing; water is also essential for agriculture and livestock; for practically all industrial processes; for use in hospitals; as a source of power; for cooling and for numerous other uses.

It is for this reason that nations are concerned with the exploitation and utilization of their water resources. It is for the same reasons that colossal amounts of money are being spent to implement water projects and programs in developing countries to meet the needs of the rural populace. Unfortunately, in a number of cases the expected returns from these projects are not fully realized. Most of the water projects that are commissioned become partially or fully inoperative. Where do things go wrong, or, more precisely, what is the reason for such a state of affairs? Could it be due to finances, equipment, systems, or the people themselves? Whatever other reasons are advanced, the operation and maintenance personnel seem to be the main cause of the problem. It is their inability, due to a lack of proper training, to carry out their various responsibilities effectively that is the root of the problem. There is, therefore, a strong relationship between the performance of water projects and training in the field of operation and maintenance. In the water sector, one cannot talk of training without including operation and maintenance needs. In this paper, an attempt is made to discuss training requirements for proper operation and maintenance of community water supply projects run by public institutions.

Operational and Maintenance Management Requirements

In the management of community rural water supplies, it is generally accepted that operation and maintenance functions are better managed if they are decentralized. However, in doing so the chain of technical communication in terms of information flow, instructions, data and records must be streamlined, coordinated, and maintained from top to bottom. For instance, it should be possible for the village mechanic or operator to pass on information regarding an abnormal breakdown to his local district or regional (provincial) branch and finally to the headquarters of his institution, which in turn should either seek further technical advice elsewhere or provide appropriate assistance in the shortest possible time. Because maintenance problems are highly technical and unpredictable, no one isolated functional unit can solve all the problems. For a water project to continue to give the

[1]Chief Maintenance Engineer, Ministry of Water, Energy and Minerals, Dar es Salaam, Tanzania.

expected performance, timely maintenance is essential.

The success of a rural water supply program or project is hinged on how effective the program is operated and maintained. Operation and maintenance is a permanent feature of the program and its continuity depends on the existence of systematic and comprehensive working principles built on past history and experiences. Normally, such principles are developed when maintenance service is based on specified sequences of operation that can be chosen to suit a particular condition and circumstance. In general terms, the sequences consist of the standard activities given in Fig. 1.

To develop such a program, sound knowledge of the duties and responsibilities of the operation and maintenance unit is required. However, such a system should be supported by the availability of balanced resources in terms of finances, manpower, materials, facilities, and transportation on the one hand, and on the other, be under the proper supervision of maintenance and cost conscious technically disciplined personnel capable of working in accordance with professional ethics and with a sense of commitment to public service. To keep the morale of such personnel high there must be attractive service schemes and fair methods of providing rewards and incentives. Finally, because the efficiency of operation and maintenance is based on fast decision making and quick action, an operation and maintenance setup must at all costs avoid cumbersome formalities and unnecessary administrative bureaucracy.

How Training Should be Carried Out

Every water project that is completed requires competent personnel for its continued operation and maintenance. A shortage of such people suggests the need for

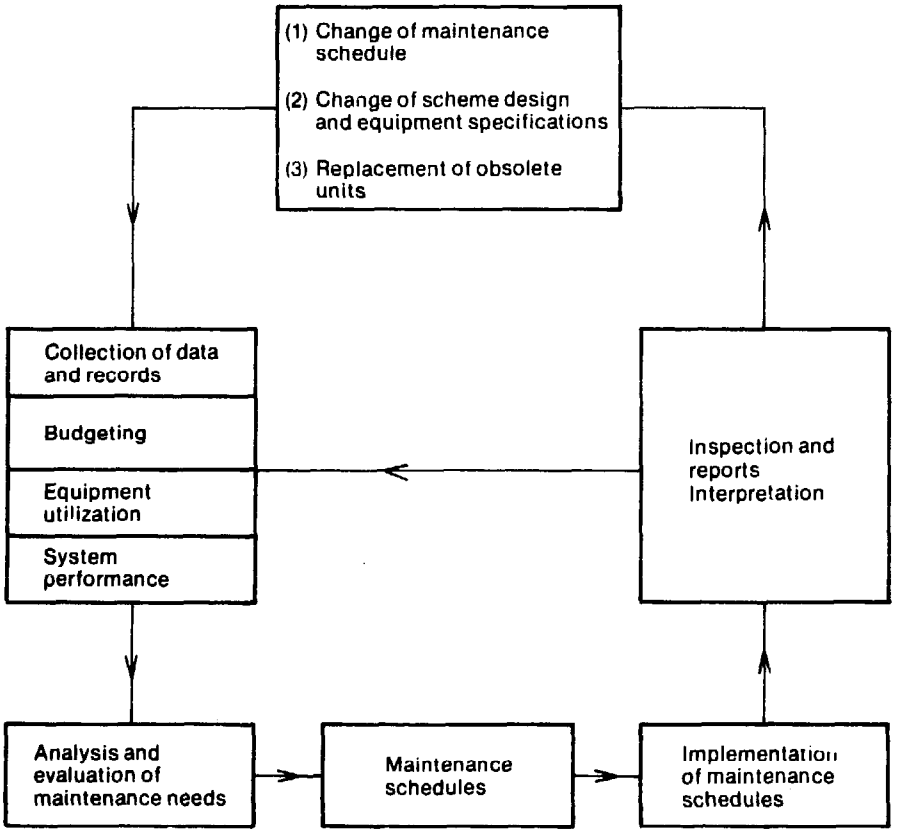

Fig. 1. Maintenance service for water supply programs.

training at all levels and in all fields of water supply maintenance. The training of additional personnel must be commensurate with the number and type of water projects under consideration. In preparing training programs for operation and maintenance personnel it is important to know and define the objective of the training, be it at the village, craftsman, technician, or engineering level. Is it for meeting additional needs, improving the quality of the personnel, upgrading already competent personnel, or introducing new techniques? It should aim at training people who can do the work and provide the required services. It should by no means be intended to create knowledgeable people who cannot be put to use as soon as it is practically possible. For this reason, training programs for operation and maintenance are more meaningful if classified in terms of formal, in-service, and informal training.

Formal training equips the candidate with the basic academic qualifications necessary for working in a given discipline. This is acquired as general education, mass education, or workers' education. It does not possess special requirements as far as operation and maintenance are concerned. The individual abilities of the trainees, however, determine the speed at which they can translate theory into practice. Experience shows that it is better to start by assuming that all trainees are of equal ability when preparing for the in-service training.

In-service training is perhaps the most important part of training insofar as operation and maintenance are concerned. It is during this stage that maintenance consciousness is instilled. After in-service training, one is able to assess the potential of the would-be operation and maintenance personnel. Apart from the trainees themselves, the prerequisites for good in-service training include availability of work, facilities, experienced personnel to work with (preferably with equivalent academic qualifications as the trainee), and a comprehensive training schedule. Insofar as operation and maintenance are concerned, it does not mean much to assign a trainee to a counterpart. The nature of in-service training in operation and maintenance is such that one has to actually do the work in order to learn. Furthermore, there are no tailored solutions to operation and maintenance problems.

The in-service training should start with a short orientation course, during which time the trainees should be introduced to the various functions of the organization, the duties of the position, rules and regulations, current practices, communication and information systems, etc. It is useful at this time for the trainees to discuss the in-service training schedule that they will follow. This schedule will include topics such as general maintenance; design, installation, and performance of water supply systems; safety; records management; and materials and manpower management.

At the end of in-service training, the trainees should undergo practical objective testing. For instance, the training could lead to the professional registration of an engineer or an upgrading trade test in the case of a craftsman. In-service training without a time limit, goal, and benefit is likely to be frustrating, vague, and lax. As mentioned earlier, in-service training is the responsibility of the Operation and Maintenance Department. However, to ensure that a homogeneous level of training is maintained it must be checked, inspected, and coordinated by formally trained instructors. Such instructors should be capable of evaluating the operation and maintenance needs relevant to the formal training in the academic institutions. The schedule should be prepared by operation and maintenance personnel who should also be responsible for its execution on a rotational basis. The schedule covers those areas of operation and maintenance relevant to the trainees that have immediate application or are already in use. At the end of the in-service training, efforts should be made to measure its success. An important indicator is the ability of the trainee to apply the theory in a practical work situation. In reality, the productivity of operation and maintenance personnel begins with the end of in-service training. It is at this time that reliable independent work can be expected.

The novice operation and maintenance worker has much to learn before becoming competent in the work. During this time, and after, the operation and maintenance worker must constantly update his knowledge by attending informal training sessions at a water supply demonstration training centre. The demonstration centre, if properly utilized, is of particular assistance for the administration of upgrading tests and the introduction of new work methods to the craftsmen and operation and maintenance personnel. Here trainees can easily comprehend the working principles of water schemes and see how a water supply project should ideally be run. The centre should be designed to meet engineering standards and be supervised by experienced field officers.

Choosing the Correct Level of Technology

As mentioned earlier, effective maintenance service is based on specific sequences of operation selected to suit particular conditions and circumstances. It is worth mentioning here that such a selection, as a rule, is governed by the level of technology available and the type of technology mix used in the development of the water supply. Because it is not always feasible to use a particular level of technology, and because the level of technology available is of fundamental importance in facilitating operation and maintenance activities, the selection of various water supply technologies to be used must take these facts into consideration. It is clear, however, that the presence or absence of other resources and the desire to meet demands completely overshadow the need to use appropriate technology to facilitate operation and maintenance. Any attempt to satisfy all of these conditions is likely to complicate matters and cause undue delays. The logical compromise is systematic training. Those who advocate intensive use of hand pumps, windmills, and the like as appropriate technology to facilitate operation and maintenance have yet to provide workable alternatives where such technologies are not feasible. Without political bias or inner motives the people should be required to adapt to the technology used in the development of water resources and not vice versa. With technology developing, cultural and traditional bonds must be broken to accommodate the newly developed innovations. This is where training instructors face the challenge of technological development of the country as a whole.

Understandably, community rural water supplies are better managed if the beneficiaries are involved in the supervision of the project. Their participation can either be in kind or monetarily. Villagers can be expected to protect, operate, and even supervise the projects. Such involvement can have detrimental effects if not considered in the technology, design, and equipment selection. Simpler and less sophisticated projects and equipment should be used at the expense of obvious advantages, and appropriate training should be given to the beneficiaries. In practice, however, the technology used is normally of such a level that operation and maintenance requires a formally qualified and trained employee who expects to be inspected, supervised, advised, and rewarded. The training programs for beneficiaries must, therefore, be selective and distinct.

Conclusions

When preparing a training program for operation and maintenance of a community water supply, consideration must be given to the prerequisites of a good operation and maintenance system. The training objectives should be clear and practical. The training should be carried out under conditions which permit monitoring and control of the end results and it should take into consideration the technologies in use and type of people being trained. Lastly, the training should be recognized, appreciated, and rewarded.

The Role of the Ministry of Education in the Training of Future Users of Rural Water Supply Systems

J. Kuthemba Mwale[1]

This paper will attempt to show how the Ministry of Education educates future users of rural water supply systems, what problems the schools face in this process of education, and what measures have been taken in order to remedy these problems.

Some suggestions have been made regarding the role that rural water supply personnel could play to consolidate the knowledge that rural water supply users have gained in school. This has been envisaged in the form of extension work and adult education, which have to form a necessary instrument for educating the rural community.

It is essential that the user of rural water supply systems should be educated in the maintenance and care of the water supply because even a system that is well maintained by technical staff can be nullified by negligent, poorly educated users.

It is logical and appropriate to utilize the existing infrastructure for educating the people, i.e., the Ministry of Education through its school system. The primary school system is particularly useful for this purpose due to the large distribution of schools within the country (e.g., the average distance between primary schools is approximately 3 miles (4.8 km)).

The primary school system educates future users in two major ways: directly in schools and indirectly through the integration of school and community. In the schools, future users of rural water supplies are taught the protection and care of water supply systems, i.e., methods of purifying water and an elementary introduction to germ theory.

Both theory and practice are taught at the primary level. For example, teachers may teach purification and care of water by actually bringing a pot of water into the school, boiling it over a wood fire, and then sieving it. Through this practical demonstration, teachers emphasize that this is what the pupil should do to prepare water for drinking at home.

The thinking behind the indirect method of educating the population, through the integration of school and community, is that those who have received formal school education and have gained a knowledge of hygiene will influence and persuade their neighbours in the community through daily encounters, visits, and discussions to learn about hygiene.

In most cases, this integration of school and community begins very early. School children participate in adult projects such as digging wells and constructing covers or shelters for these wells. There is also the latrine-construction project that schools embark on, which spreads into the community through the participation of schoolchildren in village projects.

It should not be assumed from the system

[1]Lecturer, Department of Education, Chancellor College, University of Malawi, Zomba, Malawi.

described here that the whole process is smooth and easy. There are four major problems that the schools face when educating the future users of rural water supply systems. There are problems arising from the discrepancy between traditional society and educated groups about germ theory; some teachers lack competency in teaching health education; there is a scarcity of educated people in rural areas; and there is a lack of knowledge in handling rural people by the few educated individuals living in the rural community.

It is not easy for the rural community to understand and accept that the diseases they suffer from are caused by microorganisms such as bacteria and viruses. It requires some degree of education to enable them to understand and accept the germ theory as we understand it ourselves.

Even in the schools, not all of the teachers are competent enough to handle all of the health education topics. This results in confusion and/or misunderstanding on the part of the pupils. In rural areas there is very little to attract the educated children to live there. A large number leave the rural community in search of paid employment elsewhere. This reverts the community to urban and semiurban centres.

Even if these individuals stayed in the rural areas, their impact would not be felt much because they have no skills in handling and persuading adults toward better health. Also, by the nature of the society, children may not teach adults for it is looked upon as impudence or rudeness for a youth "pretending" to teach his elders.

The problem of a lack of competence of some teachers in handling health education subjects has been approached practically through a cooperative system in which the schoolteachers invite health officers to the schools to lecture on health education topics.

This has helped, although in some cases it was observed that these health officers gave too much and too advanced content to the schoolchildren. This results in the teachers having to simplify the content to suit the level of the children.

Rural settlement schemes have helped to bring back into the rural community some of the educated people to help educate their neighbours. These schemes have aided in the spread of hygiene knowledge in the rural areas. Some rural individuals have learned simple methods of purifying and caring for water and the use of pit latrines. However, there is still a need to educate the rural community about the causes, prevention, and cure of diseases and the skills of dealing with elders.

This is one area where rural water supply personnel could take over the role of educating the rural community in the maintenance and care of water supplies and health education. This could be done through the existing structure of village committees, district committees, and area development committees, with the extension worker as the teacher.

The rural water supply personnel should, apart from knowing the construction, maintenance, and care of rural water supply systems, also know the structure, organization, and social dynamics of rural communities. Such knowledge should enable them to be comfortable in the rural community and competent at their work.

They should be able to understand the cultural systems of beliefs and traditions of the people they are to work with. This might enable them to influence the people and persuade them to change their attitudes toward clean water supplies, causes of diseases, and the use of pit latrines.

In conclusion, it should be emphasized that there is a great need to educate the future user of rural water supply systems if he is going to benefit from them. This education should not end after primary school but should continue in the form of adult education and extension work by government extension workers and literacy teachers. It is important that the rural water supply personnel should take over the role of educating the rural water supply user from the point where the Ministry of Education stopped, to guarantee continuity and relevance of the knowledge to their health.

Health Education in Rural Areas

Y.M.Z. Nyasulu[1]

A community that has traditionally relied upon dambo wells and streams for its water supply may not readily accept a different water supply without resistance. A new water system implies changing the attitudes of the people and may mean changing their values as well. This paper will try to focus attention on the health aspects of rural water supplies and the training of health personnel in rural areas.

The introduction of clean water supplies should be accompanied by simultaneous sanitation and health education. It has been shown and clearly demonstrated that provision of clean water supplies does not automatically result in a decrease in the incidence of water-related diseases and that little impact on health status can be anticipated unless the introduction of new water systems is accompanied by programs in proper excreta disposal and health education.

Common Diseases

Health problems and disease patterns found in Malawi are similar to those of many other developing countries. Using hospital statistics as a rough indicator, it appears that diseases such as measles, malaria, and gastroenteritis are the main causes of death, with the largest mortality falling within the under-five age-group. The crude birth rate is 50.5, with most women bearing 7.7 children during their reproductive years. The crude death rate is 28.2, and the estimated infant mortality is 142 per 1000 live births. The 1977 census indicates an annual growth of 2.92 percent.

Diarrheal diseases are listed as the third major overall cause of death, but they are the foremost cause of death among the water-related diseases. Diarrheal diseases also play a role in the cycle of malnutrition and infection, which weakens and often kills young children in Malawi. Unlike schistosomiasis and malaria, the diarrheal diseases have several transmission routes, and the primary transmission routes of some viral diarrheal diseases have not yet been conclusively established. Most of these illnesses, however, are water- or food-borne or transmitted by contaminated hands or flies. These diarrheal diseases are classified as (1) fecal-oral, (2) waterborne, or (3) water-washed illnesses.

One such diarrheal disease, which has received considerable attention in Malawi since late 1973, is cholera. The Ministry of Health (MOH) has been successful in controlling outbreaks and minimizing deaths. The 1973 epidemic had the positive side effect of drawing attention to the need for expanded sanitation and health education efforts and to the importance of clean water supplies. In the Mulanje Mountain area, which is served by rural piped-water systems, no more than one cholera case per village was reported in 1974, as opposed to the average of 20 cases in villages without water systems.

[1]Regional Health Inspector, Ministry of Health, Lilongwe, Malawi.

Among the more common water-related illnesses are typhoid, paratyphoid, skin and eye diseases (such as scabies and trachoma respectively), and onchocerciasis, a water-related insect vector disease that can cause blindness. It is important to note that experience with water-related diseases in many countries has demonstrated the importance of a multiple-intervention approach. The best results are achieved by combining the provision of clean water with safe excreta disposal and hygiene and sanitation education. The reasons for this are clear: (1) many water-related diseases have more than one route of transmission; and (2) improper excreta disposal can contaminate what might have started as a clean water supply.

Relationship Between Pollution and Gravity-Fed Water Supplies

In Malawi, the gravity-flow water systems have not yet been affected by much, if any, fecal pollution because the water is piped from areas that have no human habitation or cultivation. This lack of pollution was demonstrated during the cholera epidemic referred to earlier, in which villagers using the water systems were well protected. Unfortunately, it is not safe to assume that these rural piped-water schemes will protect the population from other water-related diseases nor that the water schemes will stay unpolluted indefinitely unless proper sanitation measures are introduced. Health education efforts must be aimed not only at protecting new or existing water schemes, but also personal hygiene, avoidance of lakes or streams harbouring schistosome-infected snails, and proper waste-water disposal to avoid anopheles mosquito breeding areas.

Health Education

Through the Ministry of Health (MOH) there is a national sanitation program involving several cadres of health personnel. The director of this health inspectorate program is the health superintendent at MOH headquarters in Lilongwe. The health superintendent reports to the secretary of health on the need for public health regulations. These health programs in each of the three regions (North, Central, and South) are coordinated by regional health inspectors who supervise the district staff and liaise between the ministry and the district staff. There are 52 health inspectors assigned to the 24 districts throughout the country, with the larger districts being subdivided into areas and managed by several health assistants who are normally assigned to health subcentres. The district health inspectors supervise and work with the health assistants. They submit a report to the regional health inspector on all field activities. There is a total of 134 health assistants scattered throughout the districts, with the actual distribution determined by the location of health subcentres and adequate housing.

Health inspectors are trained for 3 years after "O" levels (equivalent of 10th grade) at the Malawi Polytechnic; a constituent college of the University of Malawi in Blantyre. The training program began in 1966, but was discontinued in 1969 due to saturation of the job market. Plans are now under way to reopen the program because vacancies have developed in the MOH. Health assistants are given 2 years of training after junior certificate (JC) level at the School of Hygiene in Zomba. Both health inspectors and health assistants are expected to focus their attention primarily on water-supply protection, disease surveillance, promotion of pit latrines, environmental cleanliness, and hygiene education. Health assistants work directly with the people in the community and help them to identify their health problems. They are responsible for urging villagers to construct pit latrines and for providing the relevant technical guidance. They work together with the surveillance assistants and report to the district health inspector. There is no government subsidy program for pit-latrine construction; rather health assistants concentrate on using affordable materials. Ministry of Health officials estimate that

approximately 40–50 percent of households in Malawi have latrines.

To assist with health education and disease surveillance at the village level, the MOH employs approximately 220 "surveillance assistants" on a daily-wage basis. The workers were originally hired to work in the cholera-control program, but now they are given 3 months of in-service training by health inspectors in order to function as general health promoters. The number assigned to each district ranges from 6–14 depending upon the areas which were most seriously affected by the cholera outbreak. The surveillance assistants reside in the village with the people where their duties include pit-latrine construction, water protection, disease control, water chlorination, and immunization programs. They report to the health assistant on a weekly basis.

The health inspectors have encouraged the formation of village health committees to help hasten the sanitation and disease-control programs. These committees consist of the village headmen and others selected by the people. The members of the committee are taken to training centres to attend a course that emphasizes the methods by which diseases are transmitted. The diseases discussed are the common communicable diseases such as cholera, bilharzia, malaria, measles, tuberculosis, diarrhea, dysentery, and others. For example, the committee members learn how bilharzia is transmitted. When a person who is infected with bilharzia urinates in stagnant water containing small water snails, the schistosome eggs will hatch and enter the snail (Kacilombo) where they will grow and reproduce. Small fish-shaped organisms (Kakolidoli) then leave the snails in search of a person or warm-blooded animal. This training allows the village health committee members to understand the life cycle of the bilharzia disease in order that it can be explained to other village inhabitants. Although such organisms have been observed in the past, their association with disease has not been understood.

Once the association between water and disease is understood, then steps can be taken to prevent disease. For example, committee members have learned that bilharzia can be prevented by (1) never washing or bathing in infected waters; (2) never urinating in water; (3) constructing and using pit latrines; and (4) ensuring that persons with the disease receive proper medical treatment.

Thus, the training received by the village health committee enables its members to understand the methods of disease transmission and how to prevent it. When the training course is completed, in 3-4 weeks, the committee members return to their village where they can teach other members of the community what they have learned.

In addition to the group of health workers described above, who are the main cadres for water and sanitation education, the MOH maintains a small health education unit (HEU) at its headquarters. The HEU is headed by a health education specialist, who supervises visual aids and graphic arts assistants, a newsletter editor, and a Peace Corps health educator. The HEU staff produce a variety of educational posters, daily radio programs, and a newsletter called "Moyo." In addition, the health education specialist conducts in-service health education seminars for a variety of MOH personnel because the ministry believes that all health workers must participate in educating the public.

With respect to special water-related disease-control programs, the MOH has a small bilharzia (schistosomiasis) unit that is working on control programs on several irrigated estates in the three regions of the country. Limited use of molluscicides, treatment, and health education is carried out; however, the program is seriously constrained by a lack of adequate funds. The malaria-control program consists of prophylactic drugs routinely given to preschool children and antenatal patients at maternal and child health (MCH) clinics. Some spraying is carried out in urban areas as well.

Problems

There is a general realization by both MOH officials and Department of Lands, Valuation and Water (DLVW) rural water supply officials of the need for greater coordination between the groups introducing new water schemes and the personnel responsible for health and sanitation education. At the local level, some coordination is achieved informally; health inspectors are invited to give health education talks at tap-dedication ceremonies. However, there is lack of coordination over time between pit-latrine construction, community sanitation surveillance, and new water schemes.

In addition to the problem of coordination, another reported problem within the MOH sanitation program has been the difficulty of providing adequate transportation for district health inspectors and health assistants. The MOH cannot afford to provide, or to absorb, the cost of vehicles for all its personnel. Health inspectors have been encouraged to purchase their own motorcycles and to use them officially on a mileage reimbursement basis. The amount reimbursed, however, is low and apparently very difficult to change, which serves as a deterrent to personal ownership.

A final constraint is one of insufficient knowledge about the sociocultural aspects of health-, water-, and sanitation-related behaviour of rural people. Because health education is really an exercise in changing or reinforcing certain kinds of behaviour, it is important to know what people do and how they can be positively influenced. Even when planners do know the characteristic and behavioural patterns of rural people, they may not understand how to motivate and influence them. Health education campaigns can become more effective and more persuasive if they incorporate the social and cultural values of the people.

Recommendations

The MOH has the organizational structure and experience for handling health and sanitation programs regarding water supply. Personnel of the DLVW may utilize the existing structure through coordination, cooperation, and consultation. However, in the training of rural water supply personnel, health and sanitation should be taught at all levels with varying emphasis to prepare them for their future partnership with the MOH.

The Role of Women in Rural Water Development in Kenya

W. Getechah[1]

It is the Kenyan government's policy to provide piped water to every household by the year 2000. The government is trying to achieve this goal in two major ways: (1) through its efforts to construct what are known as national water projects to provide water for domestic use and for use in other economic activities such as raising animals and spraying coffee; and (2) under the national spirit of "harambee" (pulling together), the government encourages the people to contribute as much as they can toward community water projects, so as to induce further contributions by either the government or foreign aid donors. It is this latter case that is of interest because the contribution of women is an integral part of the community effort to bring running water closer to the home.

In terms of national water development, the self-help element is very small, but it has, nevertheless, made an impact in rural areas in particular and these efforts have brought clean water to thousands of households. This paper is an attempt to assess and portray the very important role of the rural woman in Kenya in community water development.

Why Should Women be Involved?

In traditional African societies, fetching water from the river was one of the many tasks relegated to women. The trend toward modernization has not relieved rural women of this task. Indeed, at a time when more men are drawn into urban areas in search of more lucrative employment, the woman's energies are spread over an increasing variety of tasks, some of which were formerly performed by men, such as animal husbandry and even house building.

The burden of fetching enough water for the household cannot be exaggerated. According to studies carried out by the United Nations Economic Commission for Africa, the carrying of water is the most strenuous physical burden of all the tasks performed by African women. It is estimated that one-sixth of all the energy expended by women in rural areas is used for carrying water. In some cases, a single water fetching trip lasts 4 h or even a day!

Assuming that an average woman carries 4 gallons (18.2 litres) of water per trip, she would definitely not be able to fetch enough water for domestic consumption as well as other household requirements such as feeding the animals and spraying coffee. It is, therefore, not surprising that women have spearheaded much of the efforts to bring water closer to the home. Not only would plenty of clean water at home enhance the rural socioeconomic activities but also the woman's energy would be channelled to many other neglected areas.

Because women are the main beneficiaries of water projects, they have been a major instrument in creating an awareness and in

[1]Staff Development Officer, Directorate of Personnel Management, Nairobi, Kenya.

translating this awareness into programs. They have assisted in mobilizing support for the projects, raising the initial capital, and in most cases contributed most of the labour.

Women's Contribution

The role of women in rural water development can only be discussed in the context of self-help input into community water projects, and to a lesser extent into government-assisted water projects. According to the Ministry of Water Development, many water projects, even current government-assisted ones, started on a self-help basis. This means that women have had to assist in the initial phase of nearly every project.

The involvement of women in rural water projects is characteristic of the impact which women's groups have made in an effort to upgrade living conditions in rural Kenya and also to alleviate their water-carrying burden, as indicated earlier. Furthermore, this involvement in rural transformation is a result of the current sociopolitical conditions that prevail in most rural areas of Kenya. The following are a few of these conditions:

(1) As mentioned earlier, the prospect of a regular, well-paying, and "prestigious" form of employment has increasingly drawn more men into urban areas, often leaving women as the sole head of the household. Self-help efforts that called for household contributions subsequently found women involved in all sorts of social and economic activities.

(2) In the absence of water projects, the task of fetching water falls exclusively on the woman; hence, her enthusiasm to have water pumps erected and maintained in a serviceable condition.

(3) In rural areas, women seem to have a higher sense of organization than men. It is easier to enlist their labour than that of men and their loyalty to and enthusiasm for the project seem to last longer.

(4) Due to the traditional African attitude towards work and the colonial experience of forced communal labour, many men consider it degrading for them to engage in communal work and this attitude has reduced the men's contribution towards self-help labour to the minimum. Men feel more appropriately employed when they are engaged in money-earning occupations.

The major factors involved in the successful erection and maintenance of a water supply project are capital, labour, materials, and management and maintenance skills. In view of the prevailing conditions of poverty, ignorance, and lack of technical know-how among rural women, the women tend to leave the more technical tasks, such as management and maintenance of machinery, to the men, whereas they (the women) tackle the bulk of the nontechnical work such as digging trenches and carrying building materials. After the idea of a project has been conceived and accepted by the community, the women's groups are often the driving force that keep up the momentum.

Raising the initial capital is the first step in a new project. Quite often this sum has to be paid by the woman if she is the head of the household. The 1969 Kenyan census indicated that one-third of rural households is headed by women (ECA/ATRCW 1975), and other studies have indicated an even higher proportion.

The ability to make cost estimates, keep books and records, and negotiate for outside financial assistance is rare among rural women. Although many aid organizations have insisted that project committees must include a female secretary or treasurer, these offices are almost exclusively held by men.

Maintaining the pumps and piping systems is a second area where the men's contribution is vital. Training in this area is given mainly to men. It is strongly felt, however, that training in the maintenance of water systems should also be extended to women.

Case Studies

The following two case studies will illustrate the role of women in community water projects. The focus is on the self-help input of the project.

Karweti Water Project

The Karweti water project is located near Githunguri in Kiambu District in the Central Province of Kenya. The local community, particularly the women, had for a long time felt the need to have piped water near their homes. Karweti is a very hilly area and the women used to spend hours fetching water for domestic needs, for cattle to drink, and for use in spraying coffee. The inability of the women to carry enough water up the steep hills often imposed a limit on the number of cows a household could keep or how much coffee they could grow.

The driving force behind the launching of this project was a local woman who was a community development worker. Although she had no problem mobilizing the overenthusiastic women, she recognized the women's financial and management inadequacy to handle such a project unaided by their menfolk. Her next task, therefore, was to sell the idea to the men. She was able to get about 200 households to enrol as members of the project. Initially, every member, usually the head of a household, contributed KSh 300, and the community, mainly the women, dug the trenches and moved the construction materials. Every member now pays KSh 10 each month to buy diesel fuel for the pump and to pay the pump attendant whom the project committee has employed. The project is managed by a committee of nine members of which four are women. The chairman and secretary of the committee are men and the treasurer is a woman.

Kihara Water Project

The Kihara water project is located near Gatundu in Kiambu District in the Central Province of Kenya. The idea of a water project in this locality developed out of an attempt by a women's group called Mabati Women to instal water tanks in every member's home to store the water caught on the roofs of houses.

The group approached a government minister for financial assistance and he suggested that a water pump would be more appropriate because it would provide water to more people and on a more reliable and regular basis. The 32 members of the Mabati Women's group then acted as the nucleus around which the local community channeled their efforts. Money was raised on a household basis and the digging of trenches and laying down of pipes were mainly carried out by the women of the area. The women have remained the operational and management core of this project. Although five of the nine members of the project committee are men, the chairman, secretary, and treasurer are women.

The benefits that the above two communities derive from having piped water in their homes are many. The most important benefit is that the woman no longer has to spend hours transporting water. It is possible now to have a cleaner home as well as keep more cows and grow more coffee. Also, a successful project fills the community with pride and provides the impetus to embark on other projects.

Conclusions

The above are but the highlights of how Kenyan women are assisting in rural water development. Although the women are making a substantial contribution, their potential has not been fully exhausted and they could do a lot more if their educational level was upgraded.

Teaching the women to be literate and training them in skills such as bookkeeping, project management, and project evaluation would go a long way toward intensifying their contribution toward rural projects. Equipping them with the above skills would also make them more self-reliant. In Kenya, the adult education and extramural departments are two examples of government attempts to eliminate illiteracy nationally.

Since 1976, the Ministry of Water Development has recruited an average of five women each year to attend its training school (total enrollment approximately 150 students). The proportion of women to men is very small largely because girls graduating from high schools lack the necessary

background in science subjects, and also many girls are not inclined to become water technologists. However, with the gradual correction of the imbalance in educational opportunities offered to girls and boys, and the change in attitude, more and more girls will present themselves to be trained as water technicians in the future. Of the handful of the women who have completed the course successfully, most opt to become water laboratory technicians or water bailiffs. The principal of the water school is hopeful that with the change in attitudes all fields of water technology will be infiltrated by women.

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Community Participation in Rural Water Supply Development

Tsehaye Haile[1]

Public (community) participation, an indispensable social component of rural water supply programs, has sparked considerable discussion in many rural development forums. There are few ideas that have been more popularized and idealized than that which is usually referred to as community participation.

The success of rural water supply programs depends on the extent to which society is considered during the planning stages. Genuine and unfailing involvement of the intended beneficiaries right from the initial stages ensures the success of village water supply systems. Enthusiastic community participation can play a significant role in developing and increasing community awareness, a sense of responsibility, and pride of ownership toward the village water supply system, resulting in success and a high level of performance of the system.

In general terms, community participation implies development to be achieved with and by the people, not just for the people (EEC/APC 1979). Participatory rural development has received a great deal of attention in recent years in development literature, national plans, political platforms, and in the lending programs of most donors. Since the 1960s, interest in promoting participation of the lowest income groups through rural development programs has gained wide acceptance.

Rural development is generally understood as a means of improving the living standards of the low-income population residing in rural areas. As stated by Lele (1975) "improving the living standards of the subsistence population involves mobilization and allocation of resources so as to reach a desirable balance over time between the welfare and productive services available to the subsistence rural sector."

Mass Participation in Rural Development in Ethiopia

In an effort to materialize the objectives of the ongoing national revolutionary development campaign, the rural masses of Ethiopia are undertaking multidimensional rural development activities. The rural development undertakings, which are enthusiastically being carried out jointly or separately by the peasants' and urban dwellers' associations, will with all certainty lay the groundwork for the task of socialist construction which revolutionary Ethiopia has launched.

Although crude mutual cooperation in the sense of working together has existed in Ethiopia for years, the rural mass of the country had no chance to organize themselves during the prerevolutionary era. With perhaps a few exceptions, the

[1]Head, Public Relations Service, Ethiopian Water Resources Authority, Addis Ababa, Ethiopia.

past landlord-dominated Ethiopian leadership had been apathetic toward, if not at odds with, the concept of mass participation in rural development.

Today in Ethiopia, the revolutionary government unreservedly encourages and supports the rural masses to take part in developing the rural economy. Since the enactment of the fundamental rural land proclamation in March 1975, several thousand peasants' associations, based on socialist principles, have been established at village, subdistrict, regional, and national levels under the All Ethiopian Peasants' Association (AEPA). One of the major functions of the peasants' association, in addition to safeguarding the gains of the revolution, is to work collectively and to speed up socioeconomic development by improving the quality of the instruments and level of productivity.

Each of these associations serves an area of 800 ha. Although these organizations are new (only 5 years old), they are a potential focal point of rural development and are of national as well as local significance. They are familiar with the problems and needs of their areas and are able to express local demands for a wide range of services based on the actual needs of the rural population. In towns and larger villages, urban dwellers' associations play a similar role.

Community Participation in Rural Water Supply Development in Ethiopia

As mentioned earlier, sporadic community participation in rural water supply development has been witnessed in several rural parts of Ethiopia during the prerevolutionary era. Since the 1974 revolution, however, community-initiated self-help water supply schemes have become more common.

At the national level, the Ethiopian Water Resources Authority (EWRA), the principal government institution vested with general water resources and rural supply development responsibilites, has recently prepared a community participation promotion document pertaining to rural water supply works. The objectives of the EWRA community participation projects are: (1) to utilize effectively the resources of the consumer by encouraging the community to invest either cash or labour in the construction, operation, and maintenance of water supply projects, thereby indicating that further government funding should be used to increase water supply facilities in other areas or for additional work in the same area; (2) to ensure the success of village water supply systems and reduce the chances of systems failing as a result of misuse, vandalism, or a lack of maintenance; (3) to ensure that rural water supply is given due social consideration and is appropriate to the needs and desires of the villagers and to increase the usage or consumption rate of improved water by the community; (4) to eliminate the paternalistic approach to development and encourage communities to depend upon and pool together their potential manpower and financial resources in order to be self-reliant instead of becoming passive government aid handout recipients; (5) to develop and increase community awareness, a sense of responsibility, and pride of ownership on the part of the villagers toward the water system; (6) to promote and encourage community run and initiated self-help water supply schemes to enable the country to fully or partially meet the United Nations Water Supply and Sanitation Decade objectives; and (7) to help promote water use and health education programs (EWRA 1980).

Areas and Scope of Community Participation

It is fundamental to any successful water supply scheme that the people concerned be involved in as many stages as possible in the entire process. If due consideration is not paid to social aspects when planning, the risk is high that the water supply system will either not be used or it will be misused. It is essential, therefore, that a high degree of

community participation in rural water supply works is applied. In principle, communities should participate in the planning, construction, operation, maintenance, and evaluation phases of rural water supply projects.

Planning Phase

Until recently, social factors were almost completely ignored in rural development planning. Planning emphasis was mainly on the physical aspects, whereas the social aspects, i.e., how the project was related to the lives of the people, were left out in many cases. The input from the community at the planning stage should deal mainly with the identification of community needs and priority setting, the choice of suitable technology, and the siting of the supply points in a way that is acceptable to the community.

The social aspect of rural water supply development calls for a thorough investigation and adequate knowledge of local conditions. Information on problems felt by community, community resources, experience, and preference are prerequisites for joint planning of rural water supply programs.

It is essential that social considerations regarding the siting of the water supply are taken into account together with technical considerations. There must be communication between technicians and the community on the most appropriate site of communal facilities. This calls for considerable background information and knowledge about the community's needs and attitude toward the new system.

Construction Phase

After participating in the choice of system and technology, the community is also expected to contribute in the actual installation of the facilities. During the construction phase, the degree of community participation is greatly influenced by the type of technology being used. In cases where sophisticated technology is applied, community participation is generally low. To promote community involvement in rural water supply development the EWRA is intending to adopt simple technology such as spring protection and shallow hand-dug wells. However, even in areas where the exploitation of groundwater resources requires sophisticated drilling equipment and deep borehole schemes, village participation in the form of free labour contribution for digging pipeline trenches, the construction of earthworks associated with pump platforms, or installation of public stand posts, etc., can be significant.

Operation and Maintenance Phase

Operation and maintenance of the rural water supply is a crucial part of the program. Generally, the community is willing to contribute and associate with the system if the service is satisfactory. The community should have a clear understanding of the contributions expected from it after the completion of the system and of the increased public health benefits from the improved system. Upon completion of a water supply system, an explicit and formal agreement specifying the community's and agency's responsibilities with respect to operation and maintenance tasks must be established. According to the EWRA community participation promotion document mentioned earlier, the routine day-to-day operation and simple maintenance, pump attendants salaries, lubricants and fuel would be the community's responsibility (EWRA 1980). Pump attendants would be appointed from and by the community and trained in maintenance techniques free of charge by the EWRA. After training, pump attendants go back to their respective communities to operate and maintain village water supplies.

Evaluation Phase

It is essential to any development activity that continuous follow-up is carried out in order to avoid repeating mistakes and to adjust the approach where possible. The people who know the most about how the project is functioning are the community

people themselves. They can play a vital role in providing feedback and in pinpointing the difficulties and the successes of the water supply system for both technical and social aspects.

Promotion of Community Participation

Nowadays, community participation in rural development projects is gaining wide acceptance. During the last two decades, it has become more and more widely accepted that it is futile to implement rural development programs without the participation of the intended beneficiaries, the rural poor (EEC/APC 1979).

There are no universal techniques for involving community people in rural development. Each country has its own set of parameters and problems requiring a solution of their own. If the initiative for the water supply comes from the people themselves, the process of involving them may be easier. Local organizations and cooperative societies are favoured as the most appropriate forms of group action on the part of the people. In rural Ethiopia, all necessary base organizational frameworks are laid down. The peasants' associations, women's associations, and youth organizations are playing instrumental roles in mobilizing mass participation in rural development.

To gain meaningful community participation in rural water supply development, preparation is under way to establish "village water committees" as subcommittees to the rural development committee or as an independent and integral committee within the framework of the local peasants' associations. Village water committees will be made up of five persons, of which at least two will be women. One of the prime objectives of these committees will be to promote community participation at the planning, construction, operation and maintenance, and evaluation phases of a rural water supply scheme.

Trained community participation promoters will be deployed to the rural areas to carry out motivational and community organization activities. The promoters will monitor all community participation and provide feedback for planning and evaluation purposes.

The Role of Women in Rural Development in Ethiopia

It is generally agreed that rural women should be actively involved in shaping the future of their societies for the betterment of all concerned. However, the diversity and importance of the economic and social roles played by women in rural life in most developing countries has often not been appreciated in the past by development planners. Measures to involve women in all phases of rural development cannot be isolated from the overall development strategy. Development programs which do not involve women fail to realize their full potential (UNICEF 1977).

In Ethiopia, the voices of rural women are now being heard by the revolutionary government. Before the revolution in Ethiopia women were underrepresented in government institutions. Today, the opportunity exists for women to use rural services that can make their lives easier as well as provide more skills and knowledge and promote development of an effective infrastructure through which women can express their needs and increase their self-reliance. Women are organizing their association from the local level to the regional level. Efforts are also under way to establish a national women's association that would give them more influence when participating in economic, social, and political struggles. Such organizations would increase their political consciousness and confidence and enhance their pride in whatever role they play.

There is a noticeable trend in Ethiopia that is providing a greater opportunity for women to participate in rural development. Today, in addition to their household duties, rural women in many parts of Ethiopia are working side by side with their male counterparts on environmental

sanitation, road cutting, reforestation programs, cooperative farms, and other rural development projects including rural water supply development.

Water Consumption (Usage) Pattern

No scientific investigation on household water consumption and the social use of water has been conducted in Ethiopia. However, from scanty enquiries and studies it appears that household use of water varies tremendously. Several factors affect the amount of water withdrawn by individual households. Some of these factors are the size of the family, distance from the water source, income level, education, cultural heritage, character of the water supply, cost of obtaining water as measured by energy or cash expenditure, climate, and terrain.

The EWRA design standard for rural consumption indicates 20 litres per day per capita. The actual daily consumption in most areas, however, barely exceeds 10 litres per day per capita. In some localities the consumption is as low as 5 litres per day per capita. Table 1 gives the results of a water consumption rate survey of 70 households comprising 391 people in the Hararghe administrative region of eastern Ethiopia.

Choice of Water Source

The manner in which people choose between alternative water sources and the criteria they use to do so are largely determined by distance and price factors. Quantity and reliability are of lesser importance.

In most parts of rural Ethiopia, people use whichever source they consider to be the best at the time. They turn to their second choice when the first one is not available. In some places, distance seems to be more of a determining factor than price. People will not usually walk further to an EWRA water supply if there is an alternative source nearer their home, even though that alternative source is dirty. Despite the fact that the EWRA water is free in most parts of the country, consumers usually use it only after nearer sources have dried up. In some places people use poor quality water from ponds and unimproved shallow wells even though an extra 10 min walk could take them to an improved water source.

Seasonal variation of water consumption is a major factor affecting water use from EWRA supplies. This is mainly due to people using alternative sources during the wet season rather than variations in individual consumption.

Water Use in the Household

In Ethiopia, only 4 percent of the total rural population, the rural population making up about 90 percent of the country's total population of 30 million people, have access to improved water supplies. There are no scientific studies illustrating the social use of water. However, water is generally used for consumption, hygiene, and to a lesser extent for amenities. In the household, water is also used for cooking, washing utensils and clothes, bathing children, and for watering animals. During the dry season, most rural people, particularly the poor, wash themselves and their clothes infrequently, if at all. However, during the wet season, people use considerable quantities of water at the source, predominantly for washing clothes and for personal hygiene.

Perception of Water

People in rural areas have a different perception about water. Their general outlook is different from their urban counterparts who are usually more concerned with quality as well as quantity. In many rural communities in Ethiopia, people pay little attention to the quality of water. They are prepared to drink unclean water. For most rural people, any water is safe to drink. The health impact of an unimproved water supply is not noticed. In most localities, the same source of water, be it ponds, dug wells, or springs, is used for human consumption, washing, bathing, and for watering livestock. This problem is also compounded by poor storage of water when it reaches the home. Water may be

Table 1. Consumption rate survey of 70 families in Hararghe.

Site	No. of households	No. of persons	Total daily consumption (litres)	Average daily per capita consumption (litres)	Average distance (km)	Water source
Jara	3	27	147	5.4	20	Stream, dry season
Tuluguled	3	20	168	8.4	Nil	Use their own cisterns
Kocher	3	12	98	8.2	1.5	Improved spring
Lugo	3	14	160	11.4	0.7	Improved spring
Chinahassen	4	25	149	6.0	0.7	Improved spring
Babile	6	25	165	6.6	1.1	River and shallow well
Barjok	4	17	95	5.6	3	Spring
Erer area	3	15	162	10.8	1	River and riverbed
Harar area	3	13	139	10.7	1.7	Stream
Midegalola	7	40	256	6.4	1.8	EWRA well
Byoweraba	3	13	126	9.7	0.67	EWRA well
Deder area	4	13	165	12.7	0.6	Unimproved source
Jijiga town	5	38	515	13.6	0.44	Municipal public fountain
Hameresa	3	18	210	11.7	0.2	Public fountain
Mieso	2	12	150	12.5	0.7	Municipal public fountain
Mechara	2	13	210	16.2	0.4	Stream from a spring
Jijiga area	4	28	310	11.1	15.5	Nomadic centre carries in large containers on camels
Tuluanot	1	5	40	8.0	2	EWRA well
Gebi Gebu	1	3	14	4.7	4	River and riverbed
Kuni	1	5	45	9.0	0.8	Spring
A. Teferi	1	5	36	7.2	0.9	Spring
Awaday	1	10	105	10.5	0.2	From an individual with a house connection
Kobo (town)	1	6	80	13.3	—	Water vendor
Kobo (area)	2	14	90	6.4	1	Spring

reasonably acceptable and potable at the source, but due to poor and unclean storage it usually becomes contaminated. This poor perception of water has greatly contributed to the deteriorating state of health in the rural areas of the country. Over 70 percent of the prevalent diseases in rural Ethiopia are caused by poor water supply and sanitation.

It is recognized that the only possible way to change the attitude, as well as the consumption pattern in the rural community, is by intensification of water education. In order to avoid the main cause of surface water contamination, i.e., from waste disposal, methods of handling excreta and solid waste must be part of water education. At present, there is a water education project being carried out at the primary school level. The emphasis of the project is on the education of children and women. Such water education programs could result in bringing about changes in attitudes toward the use of water within the household.

The impact of health and water education in transforming family behaviour and attitude toward water use largely depends upon the degree of cooperation between the community, schools, and home. To impart and transfer the desired knowledge, the health education curriculum must be community oriented and less academic in content.

In countries like Ethiopia, where the rural majority has little or no access to rural social services such as schools and health stations, water education programs using the medium of schools suffer from limitations. Well-organized, broader approaches in the form of national water and sanitation campaigns are required for transferring meaningful knowledge and lasting changes regarding the water perception of the rural masses. A concerted effort to persuade people to adopt the use of improved water supplies would undoubtedly result in a great impact and change of attitudes.

One useful and suitable method of reaching the rural masses, particularly women, would be the effective use of mass media such as radio programs. In Ethiopia, there is a weekly health program transmitted through the radio voice of revolutionary Ethiopia. The content of the program is general environmental sanitation, of which the proper use of water both in the household and at the source is one aspect. In addition to radio programs, the use of local and traditional media such as the street announcer, locally produced printed matter, lectures, exhibitions, drama performances, puppet shows, etc., may provide easier accessibility (WHO 1979).

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Operation and Maintenance: Discussion

There were lengthy and diverse discussions on training for operation and maintenance of rural water supply projects. Everyone agreed upon the importance of this topic. The following points were made:

Firstly, it is necessary to have a clear, well-defined operation and maintenance program. One can then outline a training schedule to meet the needs of the program.

The need to decentralize maintenance procedures and training was emphasized. This requires in-service training by experienced persons in the field. It is also useful to have orientation courses in workshops before sending technician students into the field for in-service training.

Operation and maintenance training are very important when dealing with the smaller-sized plastic hand pumps. This maintenance can often best be carried out by the local village people. It is important, however, that they have a sense of "owning" their pump and being truly responsible for it.

It is crucial to involve women in the training process for operation and maintenance at the village level, but there are obstacles in the way of this development. Some cultures are not yet ready to accept women as maintenance technicians. Unfortunately, women are often too busy with other chores to engage in this new task. If the pump breaks down, however, the task of obtaining water will usually fall to the women. Sometimes there are communication problems between male technicians and the women in the village whom they would teach. These can be problems of language or of social custom. Technicians are often too busy with their technical tasks to set aside time for the training of village women. In spite of all these difficulties, women have often done a very commendable job of keeping the pump site clean and there is considerable pressure for them to be able to participate in higher levels of pump maintenance. The change will begin when women enter more of the training programs related to rural water supply.

There was a fairly extensive debate concerning whether or not rural water should be provided free of charge. Malawi and Tanzania provide water free to rural communities and cited the following reasons: A charge for the water may cause people to use nearby polluted water sources during the wet season because they are "free." Also, the rural peasantry cannot afford to pay large tariffs so the cost of collecting the money may be more than the money actually received. Because the villagers, in most cases, contribute much of the labour for the construction and maintenance of the system, they are, in fact, providing a form of payment.

Kenya, on the other hand, instituted a multi-level payment system depending upon the ability of the community to pay. It was hoped that this method would cut down on the wastage of water and help reimburse some of the operational costs of the system. This was considered necessary because although donors often contribute funds for capital assistance, rarely are operation and maintenance costs funded externally.

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Ethiopia found that it was not effective to charge the rural population individually but communities could be charged and then the community would decide upon the method of payment by its members.

Finally, some specific suggestions for operation and maintenance training were:

(1) Maintenance centres, including training centres, are best established in a decentralized manner, in the regions.

(2) Leaflets should be written in the local language to explain the parts, construction, and maintenance procedures for the new, simple plastic pumps being manufactured.

(3) Water operators at the village level need broad training to cope with the diversity of problems they are likely to encounter.

(4) The need for operation and maintenance training is very much a function of the durability of the equipment, e.g., countries that opt for the lower-priced plastic hand pumps will need a well-run network of decentralized and diversified maintenance depots.

(5) Development of rural water supplies brings about the need for more careful coordination in maintenance, operation, and training. With the creation of the Department of Lands, Valuation and Water, maintenance crews may soon be trained to deal with groundwater, gravity, and shallow well hand pump systems. These previously came under the authority of different departments. Thus, in Malawi, the future may require a more versatile, more broadly educated maintenance person in rural areas.

Manpower Surveys in Ethiopia

K. Achamyeleh[1]

Rural water supply development is a field requiring the combined technologies of most disciplines of engineering. Professional personnel such as hydrogeologists, civil engineers, sanitary engineers, mechanical engineers, and electrical engineers are indispensable. At the subprofessional level surveyors, geology assistants, engineering assistants, draftsmen, construction foremen, drillers, mechanics, welders, and electricians are needed.

In economic and social development, the key factors that govern the pace of progress are natural resources, capital, and skilled manpower. In developing countries, where priorities for the allocation of scarce financial resources are based mainly on economic projects that are considered directly and immediately productive, rural water supply development suffers from the chronic problem of lack of financing. As a result, it is difficult for this sector to compete with other sectors to obtain the technical manpower required. Thus, in many cases the sector is forced to develop its own skilled manpower at all levels through training, mostly with external assistance. Training for water supply development, therefore, becomes essential for most countries.

In the case of Ethiopia, two factors may be cited as the major obstacles hindering the natural development of manpower in the water supply sector.

(1) General shortage of skilled manpower: The prevailing general shortage of skilled technical manpower in the country makes it difficult to acquire new staff because stiff competition among employers is created. The usual result is that water agencies cannot offer as attractive employment conditions as other similar organizations. This state of affairs is detrimental to the intentions of a water agency to expand its manpower to meet an accelerated program such as the International Drinking Water Supply and Sanitation Decade. To improve this situation, government has started allocating graduates from institutions of higher education to various organizations on the basis of priorities.

(2) Less attractive system of employment: The water sector in Ethiopia has less attractive salary scales than most other competing organizations. Furthermore, there is no rational system of promotion as yet. Thus, the water sector has not attracted an adequate number of qualified staff. These factors coupled with others make special training necessary in order to obtain additional manpower.

Prior to deciding on training, a thorough assessment of existing and available manpower should be carried out. The extent of manpower deficiency at all levels and for all categories should be defined. This assessment or survey should aim toward providing knowledge on: (1) type, number, and qualifications of all key personnel at all levels employed in the water development agency; (2) the type and qualifications of skilled manpower available for employ-

[1]Head, Planning and Research, Ethiopian Water Resources Authority, Addis Ababa, Ethiopia.

ment; (3) the manpower available within the country for further training; and (4) technical training institutions within the country and their capacity.

All information pertaining to the availability of manpower outside the agency is normally established during the search for prospective employees. Where rural water supply and all water-related development are centrally coordinated, which is the case in Ethiopia, information can be obtained easily through the central institution (e.g., in Ethiopia from the Commission for Higher Education and the Ministry of Labour). Upon completion of the manpower survey, deficiencies at the various levels can be determined and planning and organization of training programs to eliminate the deficiencies can begin.

Scope of Survey

The survey should provide adequate information on the number and type of manpower engaged in water-development activities. In assessing available manpower, one should carefully determine the type of staff at all levels, standard of education and training, and current performance. Information on prevailing systems of employment should also be gathered.

Given that a detailed development plan has been prepared and that this plan contains comprehensive information on all the inputs required for its realization, one would then assume that a forecast of skilled manpower requirements at all levels has also been made. A manpower survey would provide information on the availability of manpower from regular sources. The survey would also establish whether or not there is a deficiency of manpower and if so, would supply indications of where these deficiencies lie.

It is not so simple to make an accurate forecast of manpower requirements. At best these forecasts are only guides. Nevertheless, on the basis of acquired experience, and where such experience is lacking on the basis of normal engineering assumptions, standards for manpower requirements must be established. From such standards, and in relation to the targets set in the development plan, the number and categories of personnel required for rural water supply development activities are derived.

The types of activities would vary depending upon the system of water supply selected. The most common systems for rural water supply in Ethiopia are boreholes, hand-dug wells, spring improvements, ponds, and cisterns. The individual components of activities that are carried out at various stages are: siting, surveying, designing, drilling, test pumping, pump installation, construction and distribution of reservoirs, and construction of wells and spring improvements. Also, maintenance and repairs of water supply installations are activities which come at a later stage but for which an estimate of manpower must be made. Projections of manpower requirements are made on the basis of assumed standards for each of these activities.

Future Projections and Training Plans

In Ethiopia, rural water supply, urban water supply, and hydrometeorology are under one authority. Programs of manpower development are centrally carried out for all three subsectors.

Having made projections of manpower requirements to fulfill planned targets for all categories, one must now identify the source from which all the manpower in excess of what can be obtained from known sources should be obtained. An assessment of the capacity of existing national institutions and a forecast of the likely number of new graduates that may be attracted to the water development sector, based on past experiences or extrapolation of experiences, should also be made. The balance of manpower required to implement the plan will have to be obtained through training.

Training may take the form of upgrading the skills of existing staff or training new recruits. For lower level technicians, the type of training needed to upgrade

employees may be different from that required to train new recruits. One can set the minimum academic standard for new recruits but this may not be possible for existing personnel who compensate for their lack of formal education with job-related experience. Generally, upgrading courses for existing personnel may require more of the theoretical aspects, whereas the recruit courses may emphasize practical application. Evidently, priority needs to be given to the more specialized categories such as drillers, pump operators, and hydrometeorology technicians. The requirements of training, duration, and curriculum will change depending upon the type of personnel available within the country for training. The survey should, therefore, attempt to provide as much accurate information as possible on all aspects of available manpower.

Recommendations

Prior to the planning of training programs, a comprehensive survey of manpower in the field of water supply is essential. The manpower survey should provide complete information on all aspects of manpower including: (1) availability of manpower in all categories and at all levels; (2) standards of training and education; (3) conditions of employment and performance; and (4) existing institutions for training within the country. If a water-development plan has been prepared with a manpower-requirement forecast, manpower requirements should be determined by comparing the forecast with available manpower. If there is no long-term development plan, the survey may establish the needs of manpower on the basis of current activities and annual plans.

Manpower Surveys in Tanzania

R.M.A. Swere[1]

It is common, in many organizations, to make plans for the future without first assessing the present situation. This often leads to doing things that are not necessary or useful. What should be done before making any plans is to determine what resources are available. It is then possible to determine whether or not the presently available resources are sufficient for a particular purpose. Having obtained information on the present situation, one can accurately plan the action to be taken to reach a required target.

Similarly, with respect to manpower, taking stock of the people available in a given area or organization is essential if any manpower planning is required. Such an exercise, commonly known as a manpower survey, consists of taking stock of the people available in terms of quantity and quality.

There are several methods of conducting a manpower survey. The method employed varies with the type and organization of the institution being dealt with. Surveys in Tanzania are commonly conducted by a team of interviewers, departmentally, or through correspondence.

Survey Conducted by a Team of Interviewers

This method of conducting a manpower survey is used extensively in Tanzania. It is also, in the opinion of the author, the method which provides the most accurate results in comparison with the other methods. It involves a group of people selected and trained to carry out the survey. Generally, the survey consists of a questionnaire, which contains all the questions to be asked and provides spaces for answers to the questions.

The training normally takes 2–4 weeks depending upon the complexity of the survey. Techniques of approaching people, the psychology of getting answers from people, and a knowledge of the information required are very important and must be taught thoroughly if accurate results are to be obtained. Upon completion of the training, the surveyors are sent into the field, each one to their respective area, to carry out the survey. The disadvantage of this type of survey is that it is the most expensive method.

Survey Conducted Departmentally

A departmental survey is the cheapest type of survey and can be carried out conveniently within the office where the people who are to be interviewed are employed. Questionnaires are sent to the officer in charge of an organization along with a request for those people from whom information is required to respond to the questionnaire. In this type of survey the officer in charge is required to verify, in each case, that the information supplied is correct. The officer in charge may also be

[1]Director, Manpower Development, Ministry of Water, Energy and Minerals, Dar es Salaam, Tanzania.

required to comment or supply certain information about each person who has completed the questionnaire. The accuracy of the data supplied and the time taken to conduct the survey depend upon the importance the officer in charge attributes to the survey.

Survey Conducted Through Correspondence

When the survey involves selected people who are scattered over a large area, it becomes convenient and cheaper to write to the people involved and ask them to provide the information required. This is normally done only when representative information is required. In this case, it is not necessary to interview each person in the particular group. The questionnaire is sent either to the specific (named) person or to anonymous people. If the questionnaire is being sent to a specific person, then it is addressed to that person's mailing address. In cases where the questionnaires are sent to unspecified people, they are distributed randomly through post office box numbers, house numbers, or through other means of communication. The disadvantages of this method are that the information received may not be very accurate or a reply may not be received at all.

Information Collected and its Significance

There may be many alternate methods of collecting manpower information in use in other countries, particularly in developed countries. In Tanzania, however, the most commonly used methods are those described here, with departmental surveys being utilized most within the water sector. Currently, another survey is being organized with the assistance of the World Health Organization and the International Reference Centre for Community Water Supply. This survey will employ the use of interviewers.

Although every manpower survey may have its own purpose and the specific information required may vary from one survey to another, there is a certain amount of general information required when carrying out any manpower survey. This information consists of name, age (birth), sex, marital status, basic education, training, profession, date of first employment and designation, various employment to date, date and nature of present employment, reasons for changing employment (i.e., previous employment), membership in professional bodies (institutions), present duties, persons you report to in the organization, the number of people reporting to you, and your future plans. In addition to the information supplied by the person being interviewed, the supervising officer is required to comment on the person responding to the questionnaire.

The above information is supplied by the employee. There is also information that must be supplied by the organization. The information generally required from the organization includes the name of the organization, type of business, date of establishment, organizational structure, total number of employees by grades, total number of vacant posts, number of employees undergoing training (and fields) within the organization and outside, posts designated for those persons receiving training, number of people leaving the organization during a specified time period, number of people joining the organization during a specified time period, reasons for leaving (retirement, expulsion, resignation, transfer), and staff development programs (training programs, promotions, insurance schemes, pension schemes, and other incentives) available.

To complete a manpower survey, information about the nature and extent of activities carried out by an organization is required. An analysis of the tasks carried out by each cadre of people is essential. From this information it is possible to determine what skills are involved in performing certain tasks and the manpower required to complete the tasks within a specified time

period. It is then possible to determine the total manpower required, in terms of skills and qualifications, within the organization. In addition to information about current activities, an organization's future activities should also be surveyed.

All of this data can then be analyzed to provide the following information about a given organization: the total number of people employed; the number of people at various categories (levels) of education; the number of trained (in different skills) employees; the number of people leaving the organization per specified time period; the number of people currently required by the organization; the number of people with various skills (training) currently required by the organization; the future manpower requirements (in terms of number and quality); and the present surplus or deficit of manpower within the organization.

Having obtained this information, it is then possible to begin filling any gaps in present or future manpower requirements. In cases where employees' skills are below those required for the tasks they are performing, additional training will be necessary. Similarly, if there is a shortage of personnel within an organization, it would be necessary to recruit people from the market and train them. In such cases, the organization is said to have a "training need." Where people can be employed from the market, a training need does not exist. In cases where a training need exists and the training is likely to take a long time, temporary recruitment measures from abroad are taken to enable the organization to function.

In 1976, a manpower survey was carried out for technicians working in the water sector throughout the country. This survey was carried out through departmental heads. Questionnaires were prepared and dispatched to the regional water engineers' offices with a request that the questionnaires be completed and returned to the ministry's headquarters within a month from the date of issue. Several points of interest were observed from this particular survey: not all questionnaires were completed and returned within the specified time period; some questionnaires were completed incorrectly; some questionnaires were not completed and, therefore, not returned at all; and the questionnaires which were completed incorrectly and those which were not completed at all were completed after a second request to do so was made. These observations revealed some of the disadvantages of the departmental method of conducting a manpower survey. The survey revealed that (1) the head of the office must be interested enough in the surveys so as to persuade those people being surveyed to complete the questionnaire correctly and on time; (2) the people being surveyed must understand the purpose and the importance of the survey; otherwise, they may get the impression that the survey may result in dismissals; and (3) the questionnaires should be simple enough to enable those persons completing them to do so with ease and without making errors.

Conclusions

It is important to remember that regardless of the method used to conduct a survey, the people involved in it should be made aware of its purpose so that accurate results are obtained. It is also recommended that where training is being organized and/or where recruiting of additional staff is being planned, surveys of available manpower should first be carried out to determine exactly what training is needed and what type and number of additional personnel are required.

Planning and Organizing Training in Ethiopia

Michael Musie[1]

This paper will attempt to explain how planning and organizing of training are carried out within the Ethiopian Water Resources Authority (EWRA).

Structure

The EWRA has a general manager under whom there are offices that have advisory functions. Some of these are the Planning and Programing Department, Training Department, and the Legal Department. As well, there are four operational agencies: Urban Water and Sewerage Agency, Land and Water Studies Agency, Water Well Drilling Agency, and Rural Water Supply Agency. Other than noting their existence, these agencies will not be discussed further in this paper.

Functions

The main tasks of the Planning and Programing Department are to prepare a short- and long-term investment plan, follow up its implementation, and evaluate and report accordingly. One other important task entrusted to this department is the preparation of a manpower study in the short term and a projection of the future manpower needs to meet the targets set in the physical plans of projects.

The main function of the Training Department is to follow up and implement the training requirements indicated by the manpower survey, both in the short and long terms.

In short, study of manpower needs is carried out in the planning office and implementation of training programs is carried out within the Training Department.

Matching Training Needs with Manpower Surveys

As far as the EWRA is concerned, training is carried out at three levels. At the professional level, most training is carried out in foreign countries and applies to fields such as hydrogeology and civil, mechanical, sanitary, and hydraulic engineering. Training at the subprofessional level deals mainly with engineering aids (technicians) and takes place at the local university. The third level concerns the training of maintenance mechanics, overhaul mechanics, plumbers, welders, drillers, electricians, hydrometeorological technicians, and pump attendants. This training is carried out in the EWRA headquarters temporary workshop. At all levels, the actual training is carried out after the manpower survey has been completed and a plan of operation has been clearly established.

Organizing for Training

Selection

Postgraduate students are selected by the

[1]Head, Training Service, Ethiopian Water Resources Authority, Addis Ababa, Ethiopia.

EWRA Training Department and committee appointed by the general manager. The criteria used are qualifications, job performance, and general attitude toward future service. Selections for civil and mechanical engineering candidates, who will study in India, are made by the Ethiopian Higher Commission for Education in collaboration with the Training Department. Selections of engineering aids and other technicians are made by the EWRA. Pump attendants are selected by peasants' associations.

Accommodation

Professionals studying abroad are accommodated in boarding colleges. Engineering aides are paid a monthly allowance of about U.S. $75. This is to cover their out-of-pocket expenses and accommodation costs. Technicians are paid about U.S.$120 per month to cover their living costs.

Location

Training is carried out in four locations: postgraduates are currently trained in The Netherlands; civil and mechanical engineers are trained in the Indian universities of Roorkee and Calicat; engineering aides are trained in the Technology Faculty of Addis Ababa University; and technicians are trained in the temporary workshop at the EWRA headquarters. The curricula are determined by the respective heads of the departments.

Management

The overall management and organization are carried out by the Training Department, which is staffed and equipped to meet training needs.

Using Local and Outside Training Resources

Professionals are trained in foreign universities. For postgraduate studies in The Netherlands, the European Economic Community (EEC) has granted a sum of about U.S.$140/month. Civil and mechanical engineers are trained through the assistance of the Swedish International Development Authority (SIDA) and the Canadian International Development Agency (CIDA). Currently, there are 76 such students, at a cost of about U.S.$3000 per student per year. Another 80 students will begin studies in October 1980.

Engineering aides (technicians) are trained in collaboration with the local university. The curricula are designed to suit the needs of the EWRA. Financing for this program is made possible through the assistance of the United Nations Children's Fund (UNICEF). Technicians are trained locally in the EWRA workshop through financial assistance from the United Nations Development Programme (UNDP) and by the International Labour Organisation (ILO). Recurrent expenses are met by the Ethiopian government and UNICEF. Trainees allowances are paid by UNICEF.

A new training centre is to be constructed in Awassa. The construction costs are expected to be of the order of U.S. $800 000. The construction is to be financed by West Germany and the EEC. After completion of the building, West Germany will provide instructors, the Ethiopian government will provide local instructors and pay recurrent expenses, and UNICEF will continue to pay for board and lodging of the trainees for the next 3 years.

Evaluation of Training

Training is normally evaluated through reports from departmental and section heads where the trainee is assigned to work or through field visits by the training staff. The evaluation is normally followed by adjustments in the curricula or additional training.

Future Plans

Beginning in September 1980, 20 additional engineering aides will commence

a 2.5 year training period at Addis Ababa University. Another 80 students (25 mechanical engineers, 55 civil engineers) will begin classes before October 1980. The engineering students will receive 4 years of training at Indian universities, leading to a Bachelor of Science (B.Sc.) in their respective fields.

The training centre for water works personnel, being constructed in Awassa, is expected to be completed by February 1981. Initially, the centre will be staffed by expatriates. In preparation for eventually taking over the training program, however, six Ethiopians will begin 15-24 months of study in technical fields in December 1980. Upon completion of the studies, these people will take over the training duties at the centre that were formerly held by the expatriates.

Planning and Organizing Training in Tanzania

R.M.A. Swere[1]

Training is an area that should receive high priority in every independent African country today due to the lack of training during colonial times. If there was any training at all during that time period, its sole purpose was to maintain colonial rule.

When African countries gained their independence, most of them found that they had few properly trained people. For the most part, those few people who had training were trained in clerical duties, interpretation, and junior administration. Training in technical fields had been very much neglected. As a result, when independent African governments came into power they had to mount massive training programs for their people. In some countries the training was carried out without proper planning, resulting in a surplus of trained personnel in certain fields and a deficit in others.

It has now become apparent that proper planning is necessary before any training program can be implemented. A training program should be worked out in response to a "training need" that has evolved from a properly designed manpower planning program. Without proper planning, training may not serve its intended purpose.

A training program can be national in nature or specific to the needs of an organization, ministry, or any other institution. Regardless of the organization, however, the program must be based on a known requirement.

A manpower survey leading to manpower planning is the key to a successful training program. Upon completion of the manpower survey, an organization is able to compare its requirements with its present staff. If the comparison indicates that more trained people are required, then a training need is said to exist.

Having established a training need, it is then possible to organize and implement a training program to fulfill that need. In countries like Tanzania, where the resources needed for carrying out a training program are limited, extensive planning is required before any training can begin. The conditions of sufficient training facilities, adequate funding, and suitable trainees must all be satisfied before training commences.

Because training facilities are limited, facilities for training in a specific field may not be readily available within a country. The first step toward organizing a training program, therefore, is to assess the availability of the training facilities within the country. Where facilities are inadequate, the possibility of improving existing facilities should be considered before considering construction of a new facility. The alternative to this is to assess the availability of the required training facilities in neighbouring countries.

In preparing training facilities within a

[1]Director, Manpower Development, Ministry of Water, Energy and Minerals, Dar es Salaam, Tanzania.

local institution or department, the availability of training space, training apparatus, and instructors must be considered. It may also be necessary to prepare a curriculum if one has not been prepared.

Depending upon the nature of the training, the training space does not have to be elaborate; protection from the weather and cleanliness are the main criteria. Training of mechanics, plumbers, and pump operators can conveniently be carried out under these conditions.

Training apparatus should include all of the materials required to conduct a given course. For example, a mechanic's course would require spanners, screwdrivers, overalls, used pumps, and motor vehicles. If the situation allowed, audiovisual aids, model pumps, and motor vehicles prepared for training purposes could be obtained. Similarly, training apparatus for other areas of study should be listed and obtained before training begins.

The availability of instructors is an important factor to be considered before training starts. If instructors are not readily available, people from relevant fields could be selected to act as instructors on a full-time or part-time basis. It would be beneficial for these people to attend a short course on teaching methods before they begin teaching. A number of countries offer short courses on training instructors. If they are not offered within a country, a request to attend such a course in a neighbouring country should be made.

At the Dar es Salaam Water Resources Institute a program to train instructors is being prepared with the assistance of the International Labour Organisation (ILO). The instructors trained here will be dispatched to the regions to conduct the training of craftsmen under the regional water engineers. When the program is completed and in full operation it will be open to trainees from neighbouring countries.

Preparation of a curriculum is another important task in establishing a training program. In this regard, the manpower survey, which indicated a need for training, can also be used to establish the subject matter to be covered in the program. Training programs that have already been established may not necessarily meet the specific training required. In such a case a special curriculum must be worked out.

In developing a curriculum for a specific purpose, the duties to be performed and the skills required must be analyzed and discussed with the supervisors of the work to be done and the people currently doing the job. This is essential to ensure that the syllabus being developed meets the required purpose.

Having secured training facilities, or even while efforts to locate training facilities are being carried out, the funds required for carrying out the training program should be sought. This is normally done after a cost estimate is worked out. In governments where funds are allocated on an annual basis, as in Tanzania, the funds required for a specific year of implementation should be included in the annual estimate.

At times, the costs of training become large, particularly higher education training within or outside the country. In such a case it may be difficult to obtain the necessary funds within the annual government allocation. If this happens, training is likely to be jeopardized and possibly delayed to a later date. A problem such as this may be solved by asking for financial assistance from another country or financing agency. Often there are donor countries and other international agencies that are ready to help finance a worthwhile training program.

Currently in Tanzania, a number of training programs are being financed by various international agencies. In particular, two training programs that should be noted are (1) a 4 year program involving 159 students financed by the Swedish International Development Authority and leading to a degree in civil engineering and (2) a program designed to train technicians that is being financed by the Swedish International Development Authority and the World Bank.

Sometimes it is not enough to have adequate training facilities and funding. It is also essential to have the right trainees for

the program. The candidates selected for training must possess the necessary qualifications for a particular course.

Once training facilities and funding are made available and the trainees have been selected, the training program can begin. If possible training courses should be offered within the country requiring the trained personnel. This will ensure that the program will focus on problems and solutions as they relate to that country. Only where there is no alternative should a course be attended in a foreign country.

Upon completion of the training program, graduates should be placed in relevant positions. Often, in countries where manpower shortages are still significant, such as in Tanzania, graduates are placed in positions that are not relevant to their fields of training. As a result, it is not possible to get the maximum benefit from the training received by the graduate because it is not being applied. Another disadvantage of improper job placement is that it is not possible to evaluate the training program because the training is not being applied.

Graduates who are placed correctly, on the other hand, should be evaluated so as to determine the success of the training program. The feedback should be conveyed to the training institution concerned for adjustments, if necessary, in the course being conducted. The evaluation is also essential to determine whether or not the graduates have obtained sufficient training for the jobs they are performing.

The exercise of designing, executing, and evaluating training programs and determining training needs should be carried out on a continuous basis by the training officer in an organization. In Tanzania. for example, more than 60 different types of on-the-job training are being conducted departmentally. Before training begins, the syllabus is determined and the necessary equipment and instructors are acquired. The training for a particular field is broken down into three grades corresponding to the grades of employment of the junior technicians, i.e., water technician grades III, II, and I.

The organization of this training is such that the instruction and daily management of the training are carried out at each of the regional water engineers' offices. Quality inspection is carried out by the training section of the ministry in conjunction with the Water Resources Institute. Examination and testing are done by the Water Resources Institute.

The evaluation of current training programs has revealed a need for improved instruction and examination of the subject matter and improved supervision of the programs. The syllabi have also proved insufficient, leaving out a significant amount of important material.

Plans are presently under way, with the assistance of various donors (United Kingdom, ILO, International Reference Center for Water Supply, World Bank), to improve the programs by providing expertise, funding, and equipment. Plans are also being made to improve training for instructors, to update the present system of testing trade men, and to establish a special wing at the Water Resources Institute that will be responsible solely for the supervision and monitoring of the training programs.

The Planning and Organization of Training for Water Development in Kenya

R.C. Shikwe[1]

Historical Development

Institutional Framework

Water is scarce, yet vital to life and development. Its management, therefore, attracts many agencies and organizations. At different points in time, the responsibility for the management and development of Kenya's national water resources has been shared between various organizations, government ministries, local authorities, and parastatals. Each organization has concerned itself with one aspect of water use or another. Such uses include water supply for human and livestock consumption, irrigated agriculture, and hydropower generation. Prior to 1964, public water supplies were the responsibility of the Ministry of Works and the African Land Development Organization (ALDEV) in urban and rural areas respectively.

In 1964, the Ministry of Works and the ALDEV were combined to form the Water Development Department of the Ministry of Natural Resources. In 1968, the department was transferred to the Ministry of Agriculture and made a division. In 1972, its departmental status was restored. Finally, in November 1974, it became the Ministry of Water Development. The ministry has the overall statutory responsibility for the conservation, control, and apportionment of national water resources under the Water Act (Cap 372), Laws of Kenya. It is also responsible for water development and supplies, control of water catchments, and water quality and pollution control.

The Development of the Rural Water Sector

Concurrent with the changes in the institutional framework for the management of national water resources, the development of the rural water sector was also receiving attention. The experience of the first decade of independence and the performance of the first two 5 year national development plans had proved that the achievement of development-plan targets in other sectors, such as education, health, power, agriculture, and industry, depended upon the availability of adequate water supplies. The frequent shifting of responsibility for water management between ministries was, in effect, a reflection of the government's attempt to develop the water sector.

Toward the end of the first national development plan period in 1970, a national goal of providing water to the entire population by the year 2000 was set. This was an ambitious 30 year plan to be implemented through multiphased programs and projects. The most important of these was the rural water supply program. The objective of the program, currently in its fourth phase, is the improvement of water supplies available to people living in rural

[1]Deputy Secretary/Director of Administration, Ministry of Water Development, Nairobi, Kenya.

areas, who account for 90 percent of the national population. It is anticipated that the fifth phase of the program will commence during the current development plan period (1979-1983); to be followed by others in the series until the entire population is served by the year 2000.

Training Objectives and Policies

The formulation of national training objectives and policies has been conditioned by the need for relevance to prevailing circumstances. During the 1960s, after independence had been gained, there was a need to find human resources to replace departing expatriates. Therefore, the training emphasis was quantitative. The 1970s were a decade of training for development. The challenge then was to equip practicing managers and administrators with the appropriate concepts, skills, attitudes, and techniques required to enable them to play an effective role in national development. The emphasis, accordingly, shifted to qualitative training. The 1980s are destined to be a decade of "fine tuning" to achieve excellence, commitment, dedication, devotion, and loyalty in "service to the nation."

Despite the changes in the emphasis, objectives, policies, and strategies, certain deep-rooted traditional attitudes and concepts toward training still persist. According to these attitudes and concepts, training is synonymous with employment. Selection and admission to preservice training is interpreted as direct employment or reduction in unemployment because it absorbs potential job seekers from the streets into training institutions. Furthermore, successful completion of a training course is viewed as a passport to an automatic promotion. Thus, there is a definite need to uproot such attitudes by developing a new philosophy.

Planning for Training

Training within any organization aims at developing the competence and capability necessary for the effective performance of the activities entrusted to the organization. This involves inculcating and imparting relevant skills to the individuals comprising the work force of the organization. In planning training programs for rural water supplies, it is, therefore, logical to start with the identification of the nature and magnitude of the activities involved, followed by determination of the relevant skills required for their effective execution. Certain parameters within the Kenyan rural water sector situation are relevant in computing this information. These include the time factor, hydrology, hydrogeology, geography, and demography. For example, there are 20 years remaining in which to supply potable water to the entire population by the year 2000. The population, currently at 15 million, is increasing at 3.5 percent annually. The land area to be covered is approximately 570 000 km^2, two-thirds of which is arid or semi-arid land (ASAL) with a sparse human population of pastoral communities but large livestock and game populations. The other one-third of the land area, endowed with abundant rainfall and surface water, is densely populated.

From the foregoing, the following conclusions may be drawn: firstly, that the use of both surface water and groundwater resources is imperative; secondly, that the development of the water sector must involve the investigation of the availability and location of the water resources, particularly in the ASAL areas; the assessment of water quantity and quality; the planning and design of water projects; the construction of water schemes; and the operation and maintenance of completed water supplies. These are multidisciplinary activities calling for a wide range of technical and scientific skills. The key technical skills involved are civil, electrical, mechanical, environmental, and sanitary engineering. Scientific skills are required in chemistry, biology, hydrology, and geology. The support of administrative services in accounting, personnel, and supplies and the skills of economists, sociologists, demographers, and systems analysts are also required. All of these skills are required at all

levels of specialization, i.e., professional, subprofessional, technician, and craftsman.

Manpower Projections

Long-term planning for training requires manpower projections over appropriate time horizons. These may be over 1, 2, or 3 years but more appropriately in relation to the 5 year national development plan. The Ministry of Water Development (MWD) is currently preparing the national master water plan, which has prepared manpower projections for the water sector over 10, 20, and 30 year time horizons. The first decade (1978–1988) is also covered by a management study project on the MWD. The two studies make the manpower projections for the first decade fairly reliable for purposes of planning training programs for rural water supply.

The projections are based on MWD programs and the activity levels required to achieve the national goal as set for the year 2000. The MWD's capability to absorb financial expenditures was assessed on the basis of its performance during the first decade of the rural water supply program (1969–1978). This has been used to establish an engineer/expenditure ratio and an engineer/technician ratio. The projections for engineers were made on the basis of anticipated investment. The numbers in other categories of manpower were computed as ratios of the higher categories, e.g., four technicians for every engineer.

Manpower Surveys

The objective of a manpower survey is to determine the actual manpower available in terms of quantity and quality. It is the next step after manpower projections in planning training programs. The difference between manpower requirements and manpower availability indicates a training need if the difference cannot be eliminated through direct recruitment. An in-depth survey, conducted in February 1978, of existing MWD manpower in all grades showed a total staff of 5500. This number is expected to increase to 12 700 by 1983. Although some positions will be filled through redistribution of existing staff or direct recruitment, a training need has been established for engineers at the professional level, engineering assistants at the subprofessional level, water inspectors at the technician level, and water operators/pump attendants at the craftsman level. Training needs for other disciplines vary, but overall, the need for major training within the MWD has been established.

Organization for Training

As mentioned earlier, the development of the rural water sector did not begin until the 1970s. Training for the sector is, therefore, a recent undertaking. The various phases described in the historical development of training objectives and policies are not relevant to rural water supply. When the MWD was created in 1974, there was a training gap of a decade between the MWD and the rest of the service or other sectors. This gap had to be bridged within a few years if the sector was to catch up with other industries and make its contribution to the national economy. Crash training programs appeared to be the obvious solution.

Training, however, is an expensive undertaking. It was imperative to minimize costs by avoiding the creation of new training programs in new training institutions. The objective was to realize savings on infrastructure, which could then be used for the actual training. The MWD, in line with the rest of the government, pursued the policy of making maximum use of existing facilities by avoiding duplication, gaps, and idle periods within the national training system. The MWD, therefore, continues to plan and organize its training programs within the existing national network, utilizing existing facilities at other institutions. Through improvements, improvisations, modifications, additions and extensions to buildings, and training programs within existing training institutions, the MWD has been able to provide both qualitative and quantitative training without having to construct new

facilities. The emphasis placed on on-the-job training and the planned introduction of mobile training units will further ensure decreasing expenses for the infrastructure.

The following are summaries of training programs given within each of the institutions utilized by the MWD for the training of its staff. In addition to the common skills taught at these institutions, the MWD has had specific courses, peculiar to water development, given at the University of Nairobi, the Polytechnic, and the Harambee Institutes of Technology.

The University of Nairobi

This is the highest institution of learning within the republic. It combines both formal education and training and caters to the whole economy. The various courses offered in the Faculties of Engineering and Science are relevant to the water sector's manpower requirements and are regarded as professional training. Courses in civil, electrical, environmental public health, and mechanical engineering as well as chemistry, geology, hydrology, and surveying are offered.

The university is required to produce manpower with motivation and the necessary skills to enhance national development. Certain courses, however, may not be available at the university due to high costs or insufficient demand for them. To overcome this, overseas fellowships and scholarships have been utilized. To meet the requirements of the MWD, for courses in water and sanitary engineering given at the University of Nairobi, the policy of using existing facilities was invoked. This led to the introduction of a special 1 year postgraduate diploma course in water and wastewater engineering. It was made possible through a tripartite collaboration between the University of Nairobi, the MWD, and the Norwegian government through the Norwegian Agency for International Development (NORAD). The undergraduate program of study for the degree of Bachelor of Science (B.Sc.) in civil engineering was examined with a view toward determining its suitability and relevance to the peculiar needs of water development. It was concluded that the program was too general in nature for the purposes of water development engineering. In its place, a supplementary course in water related subjects, stressing practical application, was recommended. To begin with, a 1 year postgraduate diploma was considered appropriate, with an allowance for future modifications.

This approach can be extrapolated to other disciplines. For example, the need for a similar postgraduate course in hydrology, within the Faculty of Science, was revealed as a result of a review of the undergraduate B.Sc. program offered by the Department of Geography.

The Kenya Polytechnic

This is an institution of further education that caters to people leaving form 4. Before being admitted, trainees must first be employed in industry and commerce in order to obtain employer sponsorship to undertake training programs relevant to their employment. The objective is to acquire relevant skills, thus making the trainees more competent in the performance of their duties. The training programs lead to both professional and subprofessional qualifications.

The MWD utilizes the facilities at the Polytechnic for training its technical subprofessional personnel in selected disciplines. The MWD's trainees attending the Polytechnic must first undergo a 6 month preselection course at the MWD staff training school. Individual preference and performance in the preselection course determine selection and admission to the Polytechnic. Since 1971, the MWD has sponsored students for the following courses: ordinary diploma in water engineering (the first 6 months of this course are given at the MWD staff training school; the remainder at the Polytechnic); building (draftsmanship); science laboratory technician; land surveying; mechanical engineering; motor vehicle technician; and higher diploma in construction (structural engineering).

The Staff Training School

This is the MWD's own and only training institution. It was started in 1965 on a small scale but served the entire public water sector as it was then under the Ministry of Works. It has steadily expanded over the years to its present size and status, with an annual enrollment of 185 into 3 year training programs. The main course programs begin in July of each year, with a common 6 month preselection course.

The school has the responsibility of training subprofessional and technical staff for the MWD. The former, to some extent, is accomplished on an agency basis by the Kenya Polytechnic. The school has trained students from Swaziland, Sudan, and a number of local authorities. Between January and June, in-service, refresher, and upgrading courses are offered. Because the present site has been fully developed and the school still remains overcrowded, plans for the construction of a Water Resources Training Institute on a new site are being developed.

The Industrial Training Centres

These centres implement the national industrial training scheme established under the Industrial Training Act (Cap 237), which regulates the training of apprentices. Its aim is to promote, develop, and regulate systematic and standardized training for apprentices and other indentured learners. It operates on the premise that skills are not inherent but have to be learned. Lack of formal training denies workers the opportunity of acquiring skills to enable them to progress.

Apprenticeship training is designed to provide specialized skills and knowledge geared to the specific needs of the country's industries. It benefits the employer by developing skilled workers; the apprentice by providing the opportunity to acquire the skills necessary for advancement in the trade of their choice; and the country by accelerating its development. The skills acquired under the scheme are relevant and common to many industries. The MWD has utilized these centres without the necessity of having to request that special courses be arranged.

The Harambee Institutes of Technology

Kenya has a self-help activity called the Harambee movement. It is responsible for a large part of the development within the rural areas. The rural water sector has received double benefits from the movement. Firstly, directly through the construction of self-help water schemes and, secondly, through the movement's latest expression in education in the form of the establishment of a number of institutes and colleges of science and technology, collectively called the Harambee Institutes of Technology. There are 15 such institutes in Kenya.

These offer technical training at the technician and craftsman levels. It has been possible, by the construction of additional facilities through donor assistance, to convert three of these institutes into suitable training institutions for purposes of rural water development. The additional facilities provided by the MWD include hostels, workshops, accommodations for instructors, tools, and equipment. Among the leading donors in this new area of training are the Danish International Development Agency (DANIDA), the Canadian International Development Agency (CIDA), and the Swedish International Development Authority (SIDA). The three institutes will turn out 360 trained water operators per year.

The Kenya Water Resources Training Institute

The manpower projections and surveys already carried out have established beyond doubt that the greatest quantitative training needs are within the subprofessional and technician cadres. The two main institutes for training these cadres are the Polytechnic and the staff training school. They cannot cope with the requirements for operation and maintenance as more complex and larger schemes are completed. To meet this demand and because the MWD's staff train-

ing school cannot be expanded any further, it is planned, through World Bank assistance, to establish the Kenya Water Resources Training Institute on a new site.

The Kenya Technical Teachers College

The need for the training of instructors is obvious. The present staff training school, the proposed Water Resources Training Institute, the on-the-job training, and the proposed mobile training units all need personnel trained in the art of imparting their skills to others. These will be deployed as technical teachers or instructors. The Kenya Technical Teachers College at Gigiri in Nairobi is the appropriate institution for this purpose.

The Kenya Institute of Administration and Government Training Institutes

The above summary has only outlined training programs for technical personnel at all levels. The MWD also needs nontechnical manpower with administrative skills in accounting, personnel, supplies, clerical, and secretarial duties. Even technical officers who occupy supervisory and managerial positions need training in administrative skills.

The Kenya Institute of Administration at Kabete is the main government institution responsible for the training of top executives and middle cadre administrative staff. Two government training institutes at Maseno and Mombasa and a secretarial college at Nairobi cater to the other cadres.

Overseas Fellowships

It is Kenyan government policy to train locally within the Kenyan environment in order to give training a practical orientation and relevance. As stated earlier, however, certain courses may not be offered locally. This necessitates overseas training. Sanitary engineering is a case in point where the MWD has to seek overseas fellowships. However, unless donor sponsorship is forthcoming, this type of training, because of the expense involved, must be reduced to the very minimum and cater to qualitative training only.

Towards a New Philosophy on Training

Manpower and Water as National Resources

Human beings and water are both taken for granted, yet they are also the two most valuable resources in any nation. Total absence of either can bring to an abrupt end the processes of development, civilization and life itself.

The achievement of national development is not conditioned by the endowment of natural resources and capital only. The availability of manpower with appropriate skills and attitudes to exploit and convert these resources effectively for the national benefit is an imperative condition. Training, therefore, concerns itself with this very important process of imparting and developing the appropriate skills in individuals to enable them to perform tasks related to national development. With regard to national development, training should be viewed as the development of the most important national resource, the human resource. The developed manpower becomes a tool or agent for other development efforts. Manpower training should, therefore, take on a new meaning and a new rating value. For the individual, training is the method and means by which one's potential can be developed to the fullest extent.

Water, on the other hand, is the forerunner of development. Human activities, in a given setting, presuppose the availability of sufficient and reliable supplies of water of good quality. Training for water development should be given a high priority rating in the allocation of national resources for development. This will ensure its availability both as a catalyst and as a factor of development in other fields of human endeavour.

Training Programs and Organizational Climate

There is a growing awareness and acceptance of the need for comprehensive and enhanced training programs. Such programs must be multifaceted and multiphased, covering all levels of specialization from craftsmanship to professionalism. It is important that skill levels be advanced on all fronts so that progress in one sphere is not negated by the inability of other spheres to adapt their activities to changed conditions. The needs of organizations change; technologies change also. In this process, training must be a continuous activity lasting an entire career. It will normally start with induction; continue with on-the-job instruction; and should, from time to time, include specifically designed courses to meet increased responsibilities or adaptation to new technologies. It is at this juncture that training for rural water supply differs from urban water supply in the need for orientation towards, and emphasis on, simpler and cheaper technologies contrasting with the sophistication of urban water supplies.

It should be policy to employ people in meaningful work that provides motivation, challenge, and an opportunity to develop by offering well-defined opportunities for advancement. This requires hiring and promoting individuals on the basis of talent and competence. It also requires providing relevant training opportunities at the appropriate time so that advancement becomes reality, and when one still has much of their working life ahead of them. It contrasts sharply with a situation where training is merely part of employment. Thus, organizations must be flexible, up-to-date, and capable of planning for change. The chronic shortage of particular skills in a given organization may be attributed to the inadequacy of the organization itself. Although the fact of a nationwide shortage of skilled manpower is recognized and accepted, it is the duty of each organization to strive to make itself competitive in attracting and recruiting whatever scarce manpower is available. It should be noted, however, that it is one thing to recruit, but quite a different thing to retain the recruited manpower. Here, the organizational climate and conditions of service are critical. The challenge facing training for rural water supply is whether or not trained manpower can be retained in a rural working environment when the urban environment can offer more attractive working conditions, e.g., better salaries, housing, education, and health facilities.

Conclusions

The purpose of this paper was to advocate "low cost" as a major objective of planning and organizing training for rural water supply. The Kenyan method is an example of one way the objective can be achieved. It makes maximum use of existing facilities within the national training network, thereby reducing expenses by avoiding creation of new training facilities within the infrastructure. Implied in this is the sharing of common facilities among sectors, which can be extended to an entire region. Infrastructure in this context means and includes physical facilities and training aids or materials. Training programs, course structures, and contents are conditioned by the anticipated working environment. These include the equipment and technologies used. Thus, the author's advocacy for low cost or reduced expenses on training infrastructure applies equally to low-cost technologies for rural water supply.

The low-cost objective, by saving on expensive infrastructure, allows scarce financial resources to be used on the training itself. Lastly, a resource that is often overlooked, but is used effectively in this approach, is that of time. Through the use of existing facilities and instructors, the delay in implementing a training program, while facilities are being constructed and instructors are being trained, is avoided.

Proposed Curriculum for Rural Water Supply Personnel

J. Kuthemba Mwale[1]

This paper will discuss the need to train rural water supply personnel, the content of the training program, methods of teaching and evaluating the training, and the resources required for carrying out the training program.

The countries participating in this workshop have identified the need to provide trained and competent personnel to cope with the problems associated with rural water supply. Manpower surveys have been used to establish whether or not a training need exists and, if so, the nature of training required, i.e., training additional personnel or upgrading the skills of existing personnel.

Contact and routine consultation with other countries and organizations helps individual countries to realize the training needs of their rural water supply personnel. The type and level of training required by water supply personnel can constitute a problem for developing countries. Three types of training have been identified: basic, in-service, and advanced.

Basic training is that training tailored specifically for new recruits in the profession. It should include orientation to the trade, basic knowledge of rural water supply systems, their maintenance and care, and an elementary knowledge of the structure and organization of the rural communities within one's country.

After individuals have gained some confidence in their job, in-service training should begin. Such training should teach the individual how to resolve problems encountered in the field and how to operate efficiently.

Advanced courses should be designed for those people who have proved themselves efficient at their job and show promising abilities that could be developed through an advanced training course.

The three existing levels of rural water supply personnel are field assistants, field officers, and engineers. The basic training discussed above should be given to all of these groups but at different levels of difficulty.

The field assistant is the front-line worker who transfers the technological information from the engineers to the users in the rural community. For this reason, field assistants should have some knowledge of the structure and organization of the community in which they work, in addition to their technical skills.

A field officer supervises field assistants in the process of transferring technological information and, therefore, must be able to construct and operate the rural water supply systems. The field officer is the middleman between the engineer who designs the water supply systems and the field assistant who brings technological information to the users.

The engineer is a professional officer and decision-maker, who is at the top of the

[1]Lecturer, Department of Education, Chancellor College, University of Malawi, Zomba, Malawi.

hierarchy of water supply personnel. The engineer should be competent in designing water supply systems and supervising their implementation through the technical officers. Knowledge about the rural community would help the engineer to understand why some projects or schemes are resisted and others are accepted.

The Department/Ministry of Water Affairs should be directly responsible for all training of rural water supply personnel, whether the training is provided within or outside the country. Training centres should pool all available information on shallow wells, boreholes, pumps, and all other aspects of rural water supply. This would provide trainees with a broad knowledge of water supply systems, thereby enabling them to utilize their country's resources to the fullest extent. An awareness of successes or failures in other countries may also be of benefit when organizing water supply programs.

The content of the training courses and how they should be taught are areas of great concern. Rural water supply personnel should be taught design, construction, and maintenance of water supply systems. Because water supply is a very technical area, such subjects as natural sciences, mathematics, geography, earth sciences, meteorology, and biology could be relevant.

Organization, management, and some personnel training and supervision should accompany the technical training. Organizational training includes the art of administering staff and equipment and a knowledge of the individual's place and role within the organization. Management and personnel training provides information on handling, understanding, and placing junior personnel in suitable and appropriate positions and recommending them for promotion or dismissal when the occasion arises.

It is felt that some knowledge of rural community structure and organization should be included in the curriculum. Such knowledge will help the rural water supply personnel to feel comfortable among the rural people with whom they will work. The rationale behind this is that one can positively influence others more easily if they are able to identify with them.

The question of how the curriculum should be taught, however, remains unanswered. One method would be to teach theory in the classroom and practical application in the field and in workshops. The exact proportions of time devoted to theory and to practice would depend upon the level of the personnel and the type of training. For example, more time would be devoted to the theory required for basic engineering training than that required for a field assistant.

Workshops, seminars, and relevant discussion meetings should be encouraged as a productive method of teaching. Students have often indicated, for example, that they pick up more information during such sessions than from classroom lectures.

Staff motivation should be a built-in mechanism that should not only keep people on the job but also encourage them to be efficient, competent, and productive. Some motivation techniques that have been suggested include accrediting all courses of training that an individual undergoes, monetary incentives, improved status, and increased responsibility. It should be possible, for example, for individuals to move from the technical assistant level to a higher level when all that is required is for them to prove that they are capable of being trained to fill the higher position.

Training programs can be realized only when there are adequate resources. These resources include qualified instructors; suitable equipment and materials, such as buildings and machinery; and enough funds to finance the training program. It has been pointed out earlier that the responsibility for training should fall in the hands of a national body that deals with water affairs. This does not mean, necessarily, that such a body will meet all of the needs or assemble all of the resources required for the training.

In such a case, outside organizations may be of assistance to training programs. Through interregional cooperation such organizations guarantee exchange of personnel, experience, and other resources.

Finally, methods of evaluating training programs, beyond examinations based on course content, must be considered. Evaluation of a training program should also involve the graduate's needs and level of development. This will reveal whether or not adjustments or changes are necessary in the training program.

There should also be an evaluation of the community's response to the products and how, in their view, the training course should be run. This should be followed up because it may provide feedback that may reveal some of the weaknesses and strengths of the curriculum and the teaching methods.

In conclusion, this paper has attempted to provoke some thought on the question of a curriculum for a rural water supply training program. The curriculum and methods of implementation proposed herein, and the questions raised and suggestions offered are intended as guidelines to encourage the development and implementation of better curricula.

Training of Workers for Piped-Water Schemes in Malawi

H.R. Khoviwa[1]

Malawi is blessed with abundant water resources. The average rainfall is 1145 mm, ranging from a minimum of 635 mm, to a maximum of 2896 mm. Runoff averages 17 percent, and gross water availability, based on a population of 6.0 million, is estimated at 9000 litres per capita per day. Water supply during the dry season (May–November) is eased by natural storage provided by lakes, swamps, and dambo areas. Several major rivers and numerous mountain streams flow year-round. Malawi is, therefore, in a favourable position, in terms of available water resources, to respond positively to the challenge of providing clean water and adequate sanitation.

Malawi has made remarkable progress during the past several years in providing safe water supplies to the rural population. The sources of supply are piped-water (gravity) systems, protected shallow wells, and boreholes. Piped-water systems offer the most convenient service because water is provided through multiple communal taps.

Organization

The rural piped-water program is administered and technically supported by the Rural Water Supply Section (RWS) of the Department of Lands, Valuation and Water (DLVW). It is implemented by extension workers and self-help labour. The extension workers consist of 60 water foremen and water operators who are, in turn, supervised by the regionally-based project engineers. The levels of supervision are office staff, headed by the principal water engineer of the RWS; and field staff, consisting of the project engineer, water supervisor, water assistant, water foreman, water operator, and village-level self-help labour.

The actual number of water assistants, foremen, and operators assigned to a region at any one time depends upon the number of rural piped-water subprojects being implemented in that region. The field staff, consequently, is transferred from region to region as required.

Ten trainees are recruited annually, and employed at the lowest level of water operator (ungraded). After an initial interview, trainees are given a combined selection/training course for 2 weeks. Once selected and employed, water operators can be promoted to increasingly higher ranks (up to the rank of water foreman) by completing 1–3 years of on-the-job training and attending upgrading courses offered at the Ministry of Works and Supplies (MWS) training centre at each level. The best and the brightest of water foremen, in turn, can then be promoted to the highest ranks of field and head office staff

The self-help labour concept advocates that the communities served should be involved at every stage in the development process. The members of the community should regard the project and the resulting

[1]Technical Officer, Department of Lands, Valuation and Water, Lilongwe, Malawi.

supply as their own and should be motivated to build and maintain it accordingly.

This is achieved through Malawi Congress Party and government leaders meetings with the prospective users to determine their collective wishes and commitments. Thus, from the time of identification of a suitable project, with respect to the supply areas, the local people participate to the fullest extent of their capabilities until the completion of the project.

Training

Training in the gravity scheme is carried out at three levels: the technician, field assistant, and user levels.

Technician Level

Students graduating at the diploma level of engineering from the Polytechnic, one of the colleges of the University of Malawi, have been trained for 3 years in civil, mechanical, and electrical engineering. Graduates taken into piped-water schemes to fill the position of water supervisor are those who have specialized in civil engineering.

The new graduate undergoes a 2 week induction course and then is sent to supervise an on-going project. Here, the graduate will work closely with the project engineer who designed the project to implement the design. This involves supervising the construction of the intake weirs and the sedimentation and storage tanks, and the laying of the pipeline to the distribution tanks and villages. This requires working closely with the field assistant who translates instructions into a properly constructed design. After 6 months of on-the-job training, the trainee is given a project to design and execute.

Field Assistant Level

The field assistant is taken from the junior certificate level of secondary education, after 10 years of education. His position in the scheme is that of a water operator. Initially, the field assistant is assigned to an experienced field assistant and only when the trainee proves competent is he given a project to work on independently. If, after independent project work, the trainee continues to exhibit competence, he may be promoted to the position of water foreman or water assistant.

Because the success of the project depends upon community input as well as proper engineering design, the field assistant's role of linking the people to the engineers is one of the most important in the project. The field assistant is trained for 2 weeks in aerial photograph interpretation, map reading, community organization, and leadership in preparation for both the technical and social aspects of the job. In the field, the field assistant is expected to convene meetings for the community, organize the community into action committees, mark out the network of pipelines on the ground, mobilize the community through the action committees to dig trenches for the pipeline, and at the same time supervise the digging itself. Here, the field assistant's job training includes use of various types of tools and how to work with different types of pipes.

User Level

When a project is planned for an area, the local leaders are approached to assess and encourage their willingness to participate in the project to improve their water supply. The leaders approached are the chief and the chairman of the local Malawi Congress Party branch, who are the key people in any village. These leaders work closely with the field assistant who starts teaching them community organization. The leaders are asked to call meetings at which the field assistant can acquaint the community with the aim, scope, and logistics of the project. At this stage, the community must be convinced enough of the ease of water collection and health benefits that the project will bring, that they will be motivated to join in the project work. Village committees and committee leaders are then selected. They decide within the limits imposed by technical needs, the water-

point sites and, hence, the pipe routes, and they provide the unskilled labour, such as pipe trenching and sand collection for the installations.

For the overall project, there is an elected committee which organizes the labour and within this there are area or village groups with their own specific tasks and programs. The work is supervised by trained government officers and assistants.

Upon completion of the project, the committees are instructed in the simple requirements of maintenance and are then expected to carry out their own maintenance, except for occasional visits by the department's area supervisor or when emergency assistance is required (e.g., damaged intake).

Problems and Recommendations

The basic problem with training at all levels, except the users' level, is that too much must be learned on the job, which reduces both learning and job effectiveness. Formal training by the organizers of the project is quite intensive, but it still does not provide enough time to prepare for the varied roles to be played while in the field. In particular, the field assistant's formal training is inadequate for the technical work given to him by the technician. The field assistant must be able to explain and demonstrate the work to people with absolutely no technical training.

It is recommended that the RWS produce a training manual to expand and standardize training at all levels, as well as to underline the responsibilities of each position.

A group of employees needs to be incorporated into the organization to monitor and assess the effectiveness of the completed scheme on a continuing basis. This would provide more reliable maintenance, repairs, and information for the improvement of future schemes.

Views About Water Supply and Training at the Department of Water Affairs, Botswana

Gilbert J. Maikano[1] and Lars Nyberg[2]

Botswana is a country where no perennial lakes exist. In the eastern part of the country, all of the rivers are ephemeral in nature and flow only after heavy rains. Flooding is erratic and during some years there are no floods at all. The seasonal flow of these rivers, however, provides a good source of recharge to the sand deposits of the riverbeds and to the dams, which are utilized as a source of water for urban centres in this part of the country.

In the northwestern part of Botswana, the Okavango delta surface water is readily available. In the largest part of the country, the Kalahari Desert, there is virtually no runoff and there are no rivers or lakes, apart from pans containing water temporarily. Any rainfall in this area would either be absorbed by the Kalahari sand or it would evaporate. It has been estimated that plant roots can reach most of the water retained in the sand (due to high capillarity) and groundwater would, therefore, not be replenished, except locally and infrequently.

There is a long-standing tradition of keeping cattle by the Tswana people. The environment in Botswana is well suited to raising cattle and there are few diseases which restrict or limit production. With a small human population of approximately 850 000 inhabitants and a proportionally large cattle population of over 3 million, the export of beef is very important (approximately 25 percent of national exports).

Essentially, most families have three places of residence: the home village, the lands area, and the cattle post. The lands area, usually situated several hours walk from the village, is where the farmer grows his crops. The cattle post may be situated several days walk from the village and is often far into the Kalahari Desert. As the name implies, the cattle post is an area where the cattle are kept and is located near a borehole.

Water Supply

There are about 5000 registered boreholes and perhaps another 2000 unregistered boreholes. The average depth of a borehole is about 100 m and often boreholes are 150–200 m deep. It has been estimated that 75 percent of human population and livestock are dependent upon groundwater. In rural areas, all water supplies are dependent upon groundwater.

Initially, drilling of boreholes was carried out by the Drilling Branch of the Department of Geological Surveys in Lobatse. This branch was drilling for both government and private organizations. Because it could not keep up with the number of boreholes required, some private farmers decided to employ private drillers, mainly from South Africa. In most cases it was found that these farmers were cheated

[1]Civil Engineering Technician, Department of Water Affairs, Gaborone, Botswana.

[2]Chief Training Officer, Department of Water Affairs, Gaborone, Botswana.

by the drillers, who did not file their "completion certificate" and did not send samples of the aquifer material to the geological survey for analysis. They inconvenienced the government by not forwarding information of the geological formations of the areas they were drilling in and cheated the farmers by giving them false results of the well yield. In many cases the boreholes went dry. This was all due to a lack of facilities in the government sector to meet drilling demands. As facilities were improved, however, private drilling was discouraged. At present, there are still some private drillers but they are well monitored by the Drilling Branch, which is now part of the Department of Water Affairs.

Today, drilling is carried out by the Drilling Branch mainly for rural water supplies. It follows the design and construction methods developed by the Department of Water Affairs. All of the rural areas are under the supervision of district councils, except for major villages. The projects are classified into three divisions, i.e., WB17, major villages, run by the Department of Water Affairs after completion; WB26, rural water supply for populations of between 500 and 5000; and WB30, small villages with populations of less than 500. The WB26 and WB30 projects are run by the district councils after completion. The district councils also provide private connections at a fee of P110 (U.S.$150) and a meter charge of about 50 thebe (U.S.$0.70) per cubic metre; checked at monthly intervals.

Training

Within the Department of Water Affairs there is a Borehole Repair Service Division (BRS). This division is a service organization for both district councils and owners of private boreholes. The repairs and overhauls of diesel engines are extremely centralized. Steps are now being taken to begin decentralization. Considering that there are 29 different kinds of diesel engines in operation and also a variety of pumps, highly qualified borehole mechanics (field assistants) are needed. Unfortunately, there has been no training of borehole mechanics since 1975, except for a short course carried out recently. There is also a need to train pumpers. With 7000 boreholes, there are perhaps 7000 pumpers in Botswana; most of them illiterate. The original intention was that borehole mechanics would train pumpers, but this has failed to materialize.

Since 1975, almost all training within the Department of Water Affairs has been at the technician level. One course for civil engineering technicians (3 years duration) and one course for hydrologists (2 years duration) have been carried out. Two courses for drilling foremen (5 years duration) are currently in full progress and another course for civil engineering technicians is planned to start in 1980.

The civil engineering technician course given between 1975 and 1978 was the first technical course of its type given in Botswana. The course was divided into four parts: preselection period (theory) (1 year); on-the-job training (1 year); revision course (0.5 year); and specialization course (0.5 year) and was conducted to meet the needs of the Department of Water Affairs. Upon completion of the course, the 11 candidates were posted in the Design Section, Water Pollution Section, Water Supply Division, and Water Law Section of the Department of Water Affairs. At present, four of the graduates, who were awarded scholarships, are studying abroad to obtain a Bachelor of Science in civil engineering.

Since 1979, there has been a Polytechnic in Botswana. The Polytechnic is conducting City and Guild's courses. There are now 17 trainees attending from the Department of Water Affairs, all of them studying mechanics. There is still no civil engineering course available. Botswana has no university of technology.

It seems to be difficult to apply low-cost appropriate technology in Botswana with regard to water supply. However, the Department of Water Affairs has recently bought 8 windmills and 20 handpumps (gasoline pumps). There is no doubt that problems with repairs to diesel engines are considerable. Today, two-thirds of all diesel

engines are sent to the Republic of South Africa for overhaul and repair. Hopefully, appropriate technology together with more training are the tools required to eliminate this situation.

Conclusions

With regard to water supply, it should be noted that Botswana is a large country with a small population, a large number of cattle, and limited water supplies. It has a tripartite system of rural life that has been forced to use advanced technology for water supply. In spite of a high potential for industrial development, based on an abundance of mineral resources, there is a considerable lack of technicians and engineers. This has resulted in an economic and technical dependence upon the Republic of South Africa. In an effort to become more self-reliant, Botswana would be interested in sending trainees to other countries such as Ethiopia, Kenya, Tanzania, Malawi, and Swaziland to develop the technical skills they require.

Training of Water Technicians in Tanzania

M.M. Kivugo[1]

Training of water technicians in Tanzania started a long time ago in the form of on-the-job training. In 1957, a small group of in-service trainees was selected to undergo short courses related to water resources development. Subjects taught included mathematics, building construction, technical drawing, surveying, river gauging, irrigation, and water supply.

In 1971, the Government of the United Republic of Tanzania decided to embark on a 20 year program of rural water supply; envisaging supplies of clean and potable water within easy access to every Tanzanian household by 1991. (Tanzania was, thus, a decade ahead of the United Nations Water Decade.) The execution of this massive program of water-supply schemes demands a vast force of technical manpower, the bulk of which is made up of middle-level technicians. In order to create this category of technical manpower in a relatively short time, the Water Resources Institute was set up in 1974, under the Ministry of Water, Energy and Minerals.

Development of the Water Resources Institute

With the completion of the first few buildings in 1974, the institute commenced with an initial enrollment of 32 students in that year. As further construction of classrooms and hostel facilities continued, the yearly enrollment increased to 62 in 1975, 82 in 1976, and has continued at the equilibrium level of 120 since 1977.

Although the institute has been serving, essentially, national needs, the interests of neighbouring countries are not forgotten; as evidenced by the fact that 12 students from countries outside Tanzania have, so far, been admitted to the institute (one from Botswana in 1975, two from Sudan in 1976, and nine from Burundi in 1979).

The present objectives and functions of the institute can be summarized as follows: (1) to conduct training programs leading to the full technician certificate in water resources engineering, with particular emphasis in hydrology, hydrogeology, and water supply; (2) to arrange and provide opportunities for ministerial in-service and upgrading courses; (3) to act as ministerial examining body for various courses conducted by the regional water engineers in the country; (4) to arrange and provide facilities for seminars and conferences on matters related to water development; and (5) to provide consultancy services to the different technical departments of the ministry and other interested national institutions as required.

The Full Technician Certificate Training Program (FTC)

The institute offers a 3 year, full-time, residential course leading to the full technician certificate in water resources engineering. To qualify to join the institute

[1]Principal, Water Resources Institute, Dar es Salaam, Tanzania.

directly from school, a candidate must pass the national form IV examination or equivalent and have credits in mathematics, physics, and chemistry and/or engineering subjects. Special entrance arrangements do exist for employees of the Ministry of Water, Energy and Minerals.

The course combines theoretical instruction, laboratory, and practical work as well as on-the-job training (field training). Each academic year consists of three terms: the first term runs from mid-May to the end of July, the second term from the beginning of September to the end of November, and the third term starts at the beginning of January and continues to the end of March. The first 2 years of the present FTC progam deal with basic subjects in civil engineering, with the third year providing more specialized training in subjects dealing with water resources engineering, centring primarily on hydrology, hydrogeology, and water supply. In the second term a period of 17 weeks, beginning in August and continuing until the end of November, is spent on intensive practical on-the-job training in the field, under the direct supervision of the regional water engineers. The field training is an integral part of the curriculum of any engineering course and, therefore, cannot be overemphasized. A system of close liaison between the institute and field staff of the ministry has been developed for the purpose of this program through field visits by institute staff. In the third year, a period of 4 weeks at the beginning of the third term is allotted for students to work on practical project assignments, either individually or in small groups.

Upon graduating from the institute, the graduates are absorbed essentially as senior water technicians into the water sector of the Ministry of Water, Energy and Minerals. Graduates who have taken the works option (water supply) are deployed to work on investigations, design, construction, and operation and maintenance of water supply schemes; those with the hydrology option work on hydrological problems as well as meteorological data observation, collection, compilation, and analysis; and those who have taken the hydrogeology option work on exploration for groundwater and drilling and construction of wells.

In 1977, the institute took another step forward by introducing a 3 year laboratory water technician course, with an annual maximum enrollment of 15 candidates. Entry requirements are the same as for the FTC course. Upon completion of the course, the graduates are posted as senior water technicians in charge of water quality testing at major water supply plants within the country. They will also man proposed zone water laboratories.

In-Service and Upgrading Courses

The institute also runs short-term in-service courses for craftsmen. Such courses include draftsmanship, surveying, motor and pump mechanics, building construction, and drilling and well construction. The institute will be able to handle at least 60 candidates in this program at any given time. Course duration varies from 1-6 months. More in-service and upgrading courses are conducted during the period when the FTC students are away, undergoing fieldwork or during vacations.

Review and Verification of Regional Training

To facilitate the in-service training programs of the ministry, regional on-the-job training is encouraged. An on-the-job training syllabus for water technicians has been worked out. The institute coordinates the program for training craftsmen in different trades such as carpentry, masonry, plumbing, and pump mechanics and carries out periodical evaluation of the courses.

The Curricula

As mentioned earlier, the teaching program consists of a common core of basic science and civil engineering subjects during the first 2 years, followed by branching out

into the three options in the third year, i.e., civil engineering works (as applied mainly in water-supply schemes), surface-water hydrology, and hydrogeology (groundwater hydrology).

The present curriculum, worked out in 1974, is an adaptation of the courses required for the full technician certificate at the Dar es Salaam Technical College, which itself was patterned after the curricula of the City and Guilds Institute, London.

The relative proportion of students allowed to choose the works, hydrology, and hydrogeology options is maintained at 50, 25, and 25 percent respectively; roughly based on the demand for technicians in these disciplines under the ministry.

The institute is presently busy trying to review the current training program. It is felt that some courses, particularly the course for the hydrogeology option, are unbalanced, with as much as 70 percent of the total time devoted to the study of civil engineering subjects, whereas hydrogeology and related subjects make up only a small part of the overall program. Tentative proposals for a revised curriculum have already been worked out. Under the new proposals, the hydrogeology option is separated from the other options in the first year, whereas the branching out of the other two options takes place at the end of the second year of study as at present. The subjects, their relative emphasis, and the sequence in which they are taught are all sought to be modified so as to make the whole program more intensive and effective.

Program Features

The Water Resources Institute in Dar es Salaam is the only institute in Tanzania providing facilities for training technicians in water resources. It is directly administered by the Ministry of Water, Energy and Minerals and functions as a centre for producing middle-level technical manpower for the ministry. Candidates, once admitted into the FTC course, are, effectively, employees of the ministry, with the exception of students from outside Tanzania. At the same time, the FTC course of the institute is recognized by the Ministry of National Education and the final examination for the award of the certificate is conducted and evaluated by the National Examination Council.

As the preservice training centre of the Ministry of Water, Energy and Minerals, it is the duty of the institute to offer a program which imparts enough theoretical knowledge to the students while preparing them fully for the practical skills that will be demanded of them when they enter service as technicians of the ministry. On the other hand, as an instrument of national technical education, the institute has not only the responsibility of producing technical manpower suited to national needs, but also of promoting technical education per se; in other words, of making the training program a link between secondary school and university levels of technical education, so as not to deny opportunities of advanced education to students.

Training Program for Technical Officers in Malawi

G.A. Kamwanja[1]

The aim of this paper is to try to identify the specific training programs or curricula necessary to train the intermediate engineer, of the technical officer grade, in the rural water supply program in Malawi. It cannot be emphasized enough that developing nations must take great interest in the development of the rural population in order to ensure an even distribution of development throughout the country.

Sources for the Recruitment of Intermediate Water Engineers

If any training program is to be successful, it is essential that an appraisal be made within the country concerned of possible sources of manpower supply, i.e., schools and colleges from which interested agencies can recruit trainees for their courses.

After completion of secondary education in Malawi, students attend the University of Malawi to study subjects such as technology and business at the Polytechnic; agriculture in Lilongwe; and education, arts, and science in Zomba. It would seem inevitable, therefore, that any organization wishing to recruit and train water engineers should look upon the Polytechnic as its primary source of recruits. The students attending this college pursue a general diploma course in engineering, with emphasis on electrical, mechanical, and civil engineering. Courses leading to a degree in engineering were started at the Polytechnic in October 1980.

The proposed training program is based on the understanding that the hierarchy of the engineering structure is such that at the top is the water engineer, of professional level; followed by the assistant water engineer, of technical officer grade; technical assistants; and the users. The training envisaged here is, therefore, that of the technical officer who once trained will supervise and work with technical assistants in the execution of designated projects, and at the same time will assist and train the users in maintaining the water supply installations after the completion of the work.

To ensure that a minimum of wastage is experienced during and after training, the prospective candidates should be recruited on a trial basis before starting the actual training. Those students showing potential for further studies after training should be encouraged and opportunities should be made available for further training to the professional level.

Training Objectives and Staff Development

The training objectives should reflect the basic established policy, i.e., to provide the rural population with potable water. Such

[1]Lecturer, Department of Engineering, The Polytechnic, University of Malawi, Blantyre, Malawi.

training should be geared toward learning the principles that will enhance the desired goals. The training of engineers should satisfy the following broad objectives: (1) At the end of the course, the students should be able to apply the principles related to water supply with the appropriate technology to suit a particular environment. (2) They should be able to plan, manage, and liaise with staff at the junior level and with the users in the care and maintenance of the water supply.

Depending upon the extent of the training program envisaged under the rural development program, it would seem economical in the long term to establish a National School of Water Engineering, under which the nation would pool together all of its water resources personnel and expertise to develop and train students for involvement in the program.

It would be difficult for the Polytechnic to incorporate water-supply courses under the present diploma scheme without jeopardizing the character of the present course, which is general in nature. Furthermore, this would set a precedent for other departments to seek such special treatment. Certainly, the expertise available within the Polytechnic should be utilized, perhaps through the presentation of special courses at seminars, specifically arranged to cater to specialist groups.

Due to a shortage of trained personnel, local residents with previous knowledge in water supply should be recruited as field instructors; the advantage being easy communication, particularly when dealing with the users.

Criteria for Choosing Appropriate Technology

Today, one finds arguments throughout developed and developing countries about what is good for the developing nations insofar as technology is concerned. Some people still argue that teaching in developing countries should be geared toward those subject areas that are relevant to the country in question. Although this is true to some extent, one still finds that there comes a time when the rudimentary technology becomes inadequate, perhaps due to the fact that it cannot meet the demands put upon it, and as a result an advanced technology must take over. Because of this, it is important that the intermediate engineer be knowledgeable in modern technology on the one hand, and the local technology on the other.

The concept of applying principles learned in one subject area to new situations implies that the subjects taught to technical officers should be broad in nature.

The following guidelines could be used when discussing appropriate technology for the rural water supply program: (1) the choice of technology should be one that would facilitate a significant improvement in the quantity of water; (2) the technology should be as low as possible in cost without jeopardizing the effectiveness of the improvements sought; (3) the technology should facilitate operation and maintenance by users without demanding a high level of technical skill; (4) the technology should make as much use as possible of locally available materials, thereby decreasing reliance upon imported materials; (5) where possible, the technology should encourage the growth of local manufacturing of necessary equipment and parts; (6) the technology should be compatible with local users' values, attitudes, and preferences; and (7) the technology should encourage and facilitate community involvement and participation.

Maintenance Centres and Users' Guide

It is generally found that many self-help projects fail in developing countries after they have been completed, mainly because of a lack of commitment on the part of the users to report any problems that arise. As a result, completed projects deteriorate and fail, making the whole exercise a waste of time and resources. It is, therefore, suggested that the Department of Lands, Valuation and Water should consider the idea of dividing each district into centres and

at the same time seek to employ someone from the user groups. Such a person would be indentified from the action groups as reliable and would have worked together with the technical officers and assistants, as well as other local personnel on the self-help basis, throughout the entire project. This person would be left with a small workshop facility and maintenance tools, such as spanners and pipes, and would be responsible for dealing with any problems reported by the users within a given area. Depending upon the gravity of the problem reported by the users, this person would be responsible for referring the problem to the district water department office.

Syllabus

The following syllabus is suggested for a 1 year course in rural water supply engineering. The course is divided into three modules of 4 months duration, with the first module being conducted in the classroom, the second module in the field, and the third module in the classroom again.

The full-time period in the field is incorporated into the course in order to give the student first hand on-site experience and at the same time give the student an opportunity to learn and to try to identify problem areas within the existing system in hopes of improving the system for the future.

Module One

The topics covered in module one include: the importance of water to humanity; sources of rural water supply (sources of water supplies in Malawi include gravity-fed systems, boreholes, and shallow wells); feasibility studies; information analysis and recommendations; water installation systems for natural gravity systems and pressure systems; and types and principles of operation of pumps

Module Two

For the duration of the second module the student is assigned to a work project in order to gain practical on-the-job experience.

Module Three

The topics covered in module three include: water treatment methods, i.e., removal of minerals and odours and the addition of water softeners; sedimentation techniques; sand filtration; care and maintenance of water systems; public health as related to water supply; project planning and management; resource selection and allocation; and public relations and government procedures, including government regulations and conditions of service; project reporting and communication; education for users; and organizing rural projects and the importance of local party leaders in community development.

The International Water Technician's Course, Swaziland College of Technology

M.R.Z. Ntshangase[1]

Origin and Development

The international water technician's course was first established in 1976 at the instigation of the general director of the Water and Sewage Board in Mbabane, with the objective of providing staff with a basic all-around knowledge of public health, with specific emphasis on water- and sewage works. Since then, the course has become an integral part of the program offered by the Swaziland College of Technology in Mbabane, thus allowing full advantage to be taken of the facilities offered by other departments and sections on the campus. Moreover, strong support has been received from the World Health Organization and some development agencies since the establishment of the course.

Initially, it was thought that the course (of 4 years duration) would consist of 2 years of theoretical training separated by a period of 2 years of practical work in the water branch. Although only the first year of theoretical training (part I), has been given to this point in time, it has been decided to reduce the interval for practical training to 1 year, so as to provide sufficient time for the practical training without adversely affecting the continuity of the theoretical content of the course. At the beginning of the 1981 academic year, the second year of theoretical training (part II) is expected to start for the first time.

Since its beginning, the course has been attended by students from Botswana, Lesotho, and Swaziland. The designation of 1981-1990 as the "International Drinking Water Supply and Sanitation Decade" by the United Nations will certainly promote the success of this course.

Table 1. International water technician's course curriculum.

Subject	Part I	Part II
Mathematics	•	•
Hydraulics	•	•
Chemistry	•	
Biology	•	
Water and sewage technology	•	•
Distribution and collection	•	
Drawing	•	
Design		•
Laboratory practice	•	•
Mechanical operation and maintenance	•	•
Electrical operation and maintenance	•	•
Building practice	•	
Plumbing	•	
Surveying (land)		•
Management and administration	•	•
Measurement and specification		•
Hygienics and first aid	•	

[1]Head, Construction Department, Swaziland College of Technology, Mbabane, Swaziland.

Objectives of the Course

The original objective of the course, as mentioned above, has not changed. The course is expected to prepare staff for progression to middle-level posts in the water industry, i.e., assistant waterworks operators; waterworks and sewage-works operators in charge of plants with conventionally designed treatment; supervisors; inspectors of works; and clerks of works. Table 1 indicates the courses given to prepare the students for these positions.

Admission Requirements

The minimum requirements for admission to the course are a Cambridge overseas school certificate (COSC) or equivalent, which includes courses in chemistry, biology, and mathematics; a City and Guilds of London Institute (CGLI) certificate in general construction; or a special recommendation by the sponsoring organization.

Examinations, Promotion, and Award of Diploma

Students' progress and levels of achievement are assessed on the basis of individual assignments and written examinations throughout the course. In addition, reports are requested from the employers to which students are assigned during the practical period. These reports are taken into account in the overall assessment of the students' progress.

Promotion to part II of the course is subject to the satisfactory completion of both part I of the course and the practical period.

To qualify for the award of the diploma, students are required to complete the entire course, including the practical period, to the satisfaction of the authorities of the Swaziland College of Technology.

Training of Civil Engineers in Kenya

J. Gecaga[1]

The Department of Civil Engineering is one of the oldest departments within the University of Nairobi, with records dating back to 1956, when it was then part of the Royal Technical College of Nairobi. The 3 year Bachelor of Science (B.Sc.) program that is offered forms part of the professional engineer's education (which consists of a university course plus 3 years or more of apprenticeship and training). A B.Sc. is the basic acceptable academic qualification required for registering as a graduate engineer with the Kenya Engineers Registration Board. The industrial training of graduate engineers is carried out by industry. The primary employers of civil engineering graduates include the Ministry of Works; the Ministry of Water Development; municipalities; and consulting and contracting firms. Since the establishment of the degree course, the department has produced over 600 graduates up to 1979; over half of them Kenyans. The current average annual output is between 50 and 60 graduates.

Due to an acute shortage of specialists in the fields of water supply and sewage disposal, the department has embarked upon the following postgraduate programs: a Master of Science (M.Sc.) program in environmental health engineering and a postgraduate diploma program in water and wastewater engineering. Postgraduate work in other areas has been carried out mainly through research and the writing of a thesis. Several postgraduate programs involving coursework, examinations, and preparation of a thesis are planned for the future in other disciplines.

This paper will examine some of the design criteria and constraints in the development of civil engineering training programs in developing countries, with particular reference to Kenya. Emphasis will be placed on the training of professionals in the fields of water supply and sewage disposal.

Undergraduate Curriculum

The design of undergraduate engineering curricula has received considerable attention within Europe but there appear to be few criteria for the design of curricula within developing countries. If curricula are designed on purely educational criteria, then little attention need be paid to any difference that may exist between industrialized and nonindustrialized countries. If, however, engineering graduates are expected to play a major role in the technological development of developing countries, then curriculum design must be subject to engineering as well as educational criteria. Thus, it is important to examine the relevant engineering industry and the directions it may take within the next 5–10 years.

It is worthwhile to examine the type of engineering education given at universities. In general, engineering curricula are modelled after those found in Europe. When the Department of Civil Engineering was

[1]Lecturer, Department of Civil Engineering, University of Nairobi, Nairobi, Kenya.

started in Nairobi, it was, in fact, offering external degrees of the University of London. Since that time, the format has not changed significantly. In general, little attention is given to design, i.e., the creation of structures to fulfill a function. The implicit objective of university courses seems to be the production of researchers. The appointment and promotion of staff is based upon research criteria and it is almost impossible to appoint experienced engineers because they seldom have research qualifications. The objective is, naturally, to emphasize the importance of research to the role of the university. As long as this continues to be the primary objective, it will be very difficult for engineering faculties to take into account the needs of the engineering industry when designing their curricula. It is worthwhile, therefore, to examine the differences between science and technology and the application of research-oriented motivations to the needs of developing countries.

The objective of science is the furtherance of knowledge. Its methods are analytical and its central theme is research. The end product is a research paper. after which the scientist has no further responsibility. A good research paper, adding to existing knowledge, brings kudos to all concerned, even if the knowledge is of no practical value.

Technology, on the other hand, is concerned with designing, constructing, and maintaining objects that will serve the people. The methods are synthetic, in the main, and the central theme of technology is design. The technologist is also concerned with the economics, utility, and management of projects. The technologists responsibility ends when the project is completed and functioning properly.

This means that the motivation of a technologist is quite different from that of a science and engineering graduate who is given a largely analytical education and emerges with the approach of a scientist. If adequate industry does not exist to reeducate these graduates, this attitude will remain and the engineering graduates will find it difficult to execute projects. The civil engineer in a developing country covers a wider range of subject matter (because there are few specialists) but generally in less depth (because there is less sophistication) and must possess considerable knowledge about materials (because the supporting industries providing these materials are usually very poor in terms of quality control). Designers in developing countries, therefore, if they are to use locally available skills and maximize the use of local materials with poor quality control, must take this into account when designing projects. This is more difficult and time consuming than creating designs for use by highly skilled technicians using good-quality materials. It is probably for this reason that overseas consultants prefer to use international contractors and imported materials, if possible.

The analytically trained graduates currently emerging from universities cannot execute projects without sound practical training and it seems fairly certain that facilities capable of providing such training are inadequate and are decreasing in number. The long-term consequence will be poorly trained engineers, considerable wastage of money, and probably, an increasing number of unemployable graduates.

Current Method of Producing Professional Engineers

The student who is admitted to the Department of Civil Engineering at the University of Nairobi is exposed to a reasonably wide and sound analytical engineering education. During vacation periods, the student may or may not be able to obtain employment within engineering firms. In recognition of the need for practical training in engineering education, the 4th practical training term was introduced to act as a basis upon which future practical training could be developed. Due to a lack of facilities and staff, however, this objective has not been achieved.

After successful completion of the degree course, the graduate engineer joins industry

to receive practical training. In some cases the graduate undergoes well-organized and well-supervised practical training; in other cases the training may be haphazard or nonexistent. Regardless of the quality of the practical training received, the graduate's immediate goal is to pass the professional interview for registration or for corporate membership in a professional body in the shortest time possible. In many countries, including Kenya, the shortest period during which the graduate is expected to have acquired the necessary practical experience for registration is 3 years.

Because this method of producing professional engineers has been operating in Kenya for some time, it is possible to determine the degree of its success. In this method the employer is responsible for providing the necessary practical training and developing the graduate engineer according to the requirements of the industry. In some cases, however, the employer may not be equipped to provide adequate training facilities and an effective continuous assessment system to ensure proper utilization of the training period. As a result, cases of graduates who have spent 3 years in the field and cannot produce a technical drawing they can call their own are quite common.

Integrated Engineering Training

In general, integrated engineering training may be achieved by either incorporating the practical training component into the undergraduate course, thereby lengthening the duration of the degree course, or by introducing academic sessions during the postgraduate training period.

Introduction of Practical Training into the Undergraduate Course

In this system of engineering education, practical training is considered as an integral part of the undergraduate program. After a certain period of academic training, students are assigned to industries to receive practical training. Guidance and supervision are undertaken by staff from the university and industry. The practical training is assessed and considered as part of the degree course. The practical training periods are organized such that the training is related to the subjects already covered in the academic course. The length of the practical training periods allows for sufficient coverage of practical aspects of the academic subjects already covered.

The advantages of this method are: (1) undergraduates undergo a streamlined practical training program where close supervision, proper guidance, and assessment of the quality of training are ensured; (2) each undergraduate has the opportunity to get involved in a variety of schemes; and (3) the graduate is able to adjust to the requirements of industry relatively quickly due to the experience gained during the practical training period.

The disadvantages of this method are: (1) the length of time required to obtain the degree would be increased, thereby implying that the time (and hence financial) input toward producing a graduate would be high; (2) it is difficult to find industries with suitable practical training facilities and training officers; and (3) undergraduates are normally concerned with passing their examinations and, therefore, tend to view the practical training exercises for their academic value rather than how they relate to future practical applications.

Introduction of Academic Sessions into the Postgraduate Training Period

In this system, the undergraduate undergoes the usual academic training in the university and after graduating joins industry for practical training. During the practical training period, the graduate would attend courses offered by institutions either during evenings or for full-time periods, each of which may last several weeks. These courses would normally be designed to expose the graduate engineer to the latest techniques of the profession. The courses may be general or specialized in nature.

The advantages of this method are: (1) the graduate engineer is more professionally mature at this level of training and appreciates the necessity of acquiring new

techniques; and (2) the graduate is able to appreciate and discuss case studies more easily as a result of having been involved in similar projects during the practical training period.

The disadvantages of this method are: (1) not all graduates are likely to have the same experience base; (2) many industries would not be anxious to part with graduates for extended periods of time once they have started being productive; (3) organization for such courses is difficult because experts from many fields would normally be required for the courses to succeed; and (4) because examinations, based on course material, cannot be given easily, there is a likelihood of laxity developing on the part of the graduates.

Specialized Training in Water Supply and Sewerage

In 1970, the Kenyan government established a goal of bringing the benefits of a safe water supply, sufficient to meet the requirements for livestock and domestic consumption, to the entire population by the year 2000. By 1977, about 30 percent of the entire population had access to an improved water supply. The total water development expenditure in the current development plan (1978/79–1982/83) is estimated at K£200 million (U.S.$548 million). Although this target may not be achieved, it shows the government commitment to this basic infrastructure.

The ministry's total manpower requirements, excluding casuals and trainees, are projected to increase from 7800 to a staff of 14 110 over the same period. The key cadres in which there will be major increases are engineers, geologists and hydrologists, accountants and personnel staff, water inspectors, water bailiffs, surveyors, and many subordinate staff categories including, in particular, patrolmen, pump attendants, water operators, drivers, artisans, clerks, storemen, water guards, and mechanics.

Courses Offered Within the Department of Civil Engineering

Undergraduate Courses

During the undergraduate program previously described, the following basic courses are offered as components of the B.Sc. degree: hydrology and public health engineering; and public health engineering II, which includes microbial processes, chemical processes, and physical processes as related to water supply.

Postgraduate Courses

The department is currently running two courses in the field of water supply and wastewater disposal: a 2 year M.Sc. course was started in 1976 and a 1 year diploma course in water and wastewater engineering was started in 1979. There are 17 students currently registered in the two courses.

Ongoing Research

With the assistance of several donor agencies, the department is involved in the following research activities: slow-sand filtration; stabilization ponds; defluoridation; and solar distillation. Both staff and students participate in the research work.

Conclusions

In designing a curriculum for both undergraduate and postgraduate studies, it is essential to make a thorough appraisal of the country's level of technology and its specific requirements in terms of manpower. Failure to do so may result in the training of personnel who contribute very little to the technological development of the country, in spite of the relatively large financial investments required for university education. Also, efforts should be made to incorporate practical training into all levels of university education because the graduates are, in most cases, expected to become productive very soon after graduation.

Training: Discussion

Planning and Organizing

The discussions on planning and organizing for training centred mainly on the subject of manpower development surveys. These surveys in the water supply and sanitation sector usually include the following information: (1) present training capacity and output; (2) manpower needs of the present and projected needs for the future; and (3) proposals to expand training programs to meet any difference between manpower requirements and available manpower. Thus, manpower development surveys define the need for enlargement of training programs.

In most countries manpower surveys have already been carried out. Some of the main issues discussed in this regard were:

(1) To what degree should countries seek outside assistance in carrying out manpower surveys? It was agreed that the best solution would be to conduct these surveys locally to meet locally defined needs, although outside assistance may be useful at the beginning.

(2) How does one evaluate the efficiency of a manpower survey? Evaluation is an extensive undertaking, long term in nature, and it is often a neglected exercise.

The question of bonding candidates who leave the country to study was also discussed. There are difficulties in enforcing this, but such a procedure is necessary to restrict the brain drain from developing countries.

User Education

It was agreed that it is important to know the composition and cultural interrelationships within a community before one can intelligently plan a user education program.

The villagers' education should depend upon communal participation of the adults as this approach will likely be compatible with their traditional African methods.

Some participants felt that traditional beliefs should not be allowed to stand in the way of bringing new technologies into a village; others felt that participation by the villagers, whether in training or maintenance activities, could be overdone. The villagers may either be too busy with other volunteer efforts or may want to spend more time on activities planned by themselves.

The role of women in the user education process was again debated. It was stated that studies have shown that women are no less intelligent than men and are, therefore, capable of learning about rural water supply operation and maintenance or any other subject. Cultural conditioning, however, often prevents women from participating in training programs. The answer seems to be to make educational opportunities available to women at all levels. The role

of the Ministry of Education is indeed crucial in the education of the future users and maintainers of water systems, but one shouldn't expect the children to quickly change the thinking of their parents. Parents are not likely to change their way of thinking based upon what their children learn in school — at least not immediately.

It was agreed by all that user education was crucial. If one gets clean pure water from a rural water supply system and it is then stored or used in an unsanitary manner, the main purpose of the new system is lost.

Workshop Resolutions

The workshop resolutions given below are the result of deliberations in the working groups, discussion in the plenary session, editorial revision, and final approval by working group chairmen.

It will be seen that these resolutions do *not* contain specific revised curricula. As the workshop progressed, more realistic goals evolved. In the first stages of planning these workshops, an overall curriculum revision was envisaged. This later was reduced to proposed revisions of portions of curricula. At the workshop, it was realized that detailed curriculum revision requires extensive time and discussion with one's colleagues in one's country. Therefore, rather than present a superficial attempt at curriculum revision it was decided to present guidelines for curriculum revision, which could be taken back to the individual countries to assist in the training program reviews that would have to be tailored to each individual country.

General Resolutions

(1) Having reviewed the existing curricula, it has been realized that they are urban water supply system oriented. Further realizing that the world is currently in the midst of a serious energy crisis and that practically every nation is trying to use renewable energy resources, it is recommended that the following technologies identified in this workshop should be introduced and emphasized in the training programs: (a) gravity-fed systems; (b) rainwater catchment systems; (c) shallow well/hand pumps; (d) wind-power pumping; and (e) simple water treatment methods.

(2) Realizing that not all technical disciplines are offered at the different training centres, and that some countries do not have an adequate number of instructors, it is recommended that student exchange programs be promoted. In addition, curriculum development should be carried out with regional cooperation.

(3) Foreign entry requirements such as the City and Guilds should be discouraged in favour of formulating specific requirements tailored to national conditions.

(4) Whereas international assistance to this sector has been mainly for equipment, at the expense of training personnel, the time has come to recognize support for training programs as a necessary component of donor assistance programs.

(5) Upgrading courses should be set up, preferably in the national water institutions, for special training in the water sector.

(6) A curriculum is not a static thing and should be flexible in order to accommodate the changing level of technologies.

(7) Opportunities for women to enter training programs should be increased at all levels.

(8) Health education should be a component of technical training at all levels.

User Education

(1) Users are all the people in the community who depend upon the water supply system, including the water attendant, who is responsible for general maintenance, and the local water management committee. Education programs aimed at users should reflect the general concerns of the community. Specifically, they should provide information on the health and economic benefits that water systems can provide.

(2) The water attendant should be given a working knowledge of the pumping system and should assist in educating the community.

(3) A water committee should be set up at the local level and have overall responsibility for the water system. This committee should provide leadership training, project management, simple maintenance and community education, and oversee the protection and cleanliness of the system.

(4) Teaching methods should include lectures, demonstrations, and discussions. Participation of schools, churches, and existing educational groups should be encouraged. Normally, the water attendant and the water committee will be trained by a technical assistant. The community as a whole can then be trained by the committee with the aid of the technical assistant and water attendant.

(5) Regular community evaluation based on visits, interviews, and follow-up research is required to assess the community's state of knowledge of the water system, hygiene, and general health. Based on the results of these surveys, modifications should be made to improve the content of the training program and the methods being used.

Technical Assistant Level Training

(1) A technical assistant is a skilled craftsman or mechanic who performs a specific practical job. Training should be given by the technician and should emphasize practical knowledge, as well as providing some theoretical input. At the same time, the technical assistant should be provided with information on community development.

(2) The duration of training should be as short as possible while still producing a competent and practical worker. The length of this training period should be evaluated periodically and amendments made to increase effectiveness as required.

(3) Entrance requirements should be carefully tailored to the knowledge required for successful training and the training should be specific to the job the person will do when the training is completed.

(4) Because of the specific nature of the training required, the following points should be emphasized in various programs: (a) drilling: drilling techniques, geological formations, pump testing, knowledge of machines and tools, administration; (b) shallow wells: well siting, geological formations, well construction, pump installation, community participation, administration, well hydraulics; (c) pump attendant: pump operation, fault identification and repair, preventative maintenance; (d) gravity-fed schemes: plumbing, construction work, welding, water treatment, community organization, hydraulics, map reading, leveling, tools; (e) plants: plumbing, mechanical work, installation techniques, tools, welding and soldering; (f) electrician: installation of electric

pumps, welding, plumbing, tools, fault identification and repair; and (g) liaison officer: health aspects, simple water technology, community development, extension and communication.

Technician Level Training

(1) The role of a water technician is to supervise construction, carry out equipment testing, and organize operation and maintenance of a water scheme.

(2) Water technicians must have a thorough knowledge of water hygiene to avoid waterborne diseases.

(3) Within the existing curricula in technical institutes, it has been noted that subjects such as political science, general studies, and management are being taught. Within these subjects, technicians should learn the social, cultural, and economic factors that influence the life of water consumers in a community.

(4) To ensure proper practical training, the teachers themselves must be involved in the supervision of on-the-job training during the course.

(5) Safety precautions during construction, maintenance, and operation should be stressed during the training of technicians.

Engineering Level Training

(1) The role of an engineer is to apply the principles of science. This involves applied research, design, and field supervision.

(2) Facilities for the training of manpower to work in the fields of water and wastewater should be expanded to meet increasing demands.

(3) A 4 year undergraduate course would seem to be necessary to cover all of the broad aspects of water and wastewater engineering.

(4) Teachers in the university should keep in touch with current practices and be involved in actual field project design.

(5) It is desirable to set up and strengthen postgraduate (Master of Science (M.Sc.)) level courses in environmental health engineering. The syllabus of this program should include (a) water-related diseases; (b) social organization and management; (c) economics and planning; and (d) low-cost sanitation methods as an alternative to traditional sewage treatment. Training at this level should be carried out at African institutions.

(6) Applied research in relevant technologies should be encouraged and supported by national governments. Research facilities should be strengthened.

Country Action Plans

Whereas the workshop resolutions give guidelines for revision of training programs, the follow-up action plans present specific plans for action. These were the result of deliberations by the country groups. They were formally presented on the last day of the workshop.

Ethiopia

(1) The resolutions of the workshop will be presented immediately to the Ethiopian Water Resources Authority (EWRA).

(2) Through the mechanism of the EWRA, efforts will be made to ensure that all resolutions relevant to Ethiopia are implemented.

(3) Effective communications will be made with the proper authorities at the University of Addis Ababa (engineering and engineering-aide education) and the Ministry of Health and Ministry of Education (user education) concerning implementation of workshop resolutions.

(4) As most training in other areas of rural water supply training is carried out within the EWRA, useful resolutions such as emphasis on low-cost renewable energy technology, sanitation, community participation, and user education will be accommodated as much as possible in the training curriculum.

(5) The EWRA has had plans to establish a Community Participation Promotion Unit. These plans were reinforced as a result of this workshop when practically all working groups, in one way or another, emphasized the need for making water systems as socially acceptable as possible to users. Therefore, plans to implement this unit on a pilot scale in one or two regions, and expanding it to other regions depending upon initial success, will be carried out. Some of the initial activities needed for this unit are (a) develop a training curriculum; (b) train community participation promotion workers; and (c) define work roles of everyone involved. The setting up of this unit indicates Ethiopia's desire to put strong emphasis on community participation.

(6) Ethiopia hopes to continue to study other countries' experiences in order to learn from them.

(7) Ethiopia seeks increased cooperation with international agencies to accelerate the rate of rural water development.

Kenya

(1) Kenya's first follow-up action will be to report the results of the workshop to the higher authorities in the Ministry of Water Development.

(2) As a result of this workshop, Kenya hopes to put increased emphasis on wind-power water pumping.

(3) Kenya hopes for International Development Research Centre (IDRC)

assistance in training instructors for its M.Sc. program in environmental engineering at the University of Nairobi.

Tanzania

(1) Tanzania plans to pursue a revision of the curriculum of the Water Resources Institute to include low-cost renewable energy technologies.

(2) It is planned to include a training program in the existing shallow wells program in Tanzania.

(3) Tanzania plans to hold a national workshop to discuss the above training programs.

(4) Village contractors training: The Tanzanian delegation intends to formulate a policy paper proposing the concept of implementing small water schemes by trained village contractors. A training program will likely be necessary for village contractors.

(5) The delegation endorses the preparation of training manuals to give guidance about the operation and maintenance of simple technology schemes.

(6) Refresher courses should be instituted to train graduates from the Water Resources Institute.

Malawi

(1) Malawi hopes to convene a national workshop as soon as possible. It is hoped that as a result of this national workshop a national action group will be formed to persuade government to revise training curricula to be more appropriate.

(2) Malawi also plans to set up a Water Training School to train personnel who will work within the Department of Lands, Valuation and Water.

Botswana

(1) Botswana has recently purchased 8 windmills and 20 hand pumps and plans to set up a training program in these technologies. There is a possibility of sending two trainees to Kenya for about 1 month to participate in a proposed IDRC sponsored project there in wind-power pumping. Additional training could be coordinated with the Rural Industries Innovation Centre (RIIC) at Kanye.

(2) Botswana also hopes to conduct a manpower survey within the Water Affairs Department. This will serve as a basis of future training activities within the sector.

Some of these action plans, particularly those of Ethiopia, Tanzania, and Malawi, represent resolutions that were in the planning stage before this workshop. The workshop has given additional momentum to the training emphasis in these countries. Thus, the workshop should be seen as part of the process to place new emphasis on training in low-cost technologies, operation and maintenance, and community participation.

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Rural Water Supply in Nepal: Concrete Course
Technical Training Manual No. 3

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RURAL WATER SUPPLY NEPAL

TECHNICAL TRAINING MANUAL no. 3

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* *
* CONCRETE COURSE *
* *
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CONCRETE COURSE

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CONCRETE COURSE

1. General

1.1 Definition

Concrete is a mixture of:

- aggregates (sand, gravel)
- adhesive (cement)
- water

1.2 Types of concrete

There are many types of concrete which can be grouped, for example, according to the raw materials or to the quality.

For our purpose we can seperate three different types of concrete, according to their use:

- lean concrete
- non-reinforced concrete
- reinforced concrete

As non-reinforced and reinforced concrete have the same mixture of aggregates, cement and water, the difference is explained as follows:

Concrete alone has a very high compression strength but a low tensile strength. So concrete which is exposed to tensile stresses has to be strengthened with steelbars. These have a very high tensile strength.

Take for example a slab of a spring collection chamber:

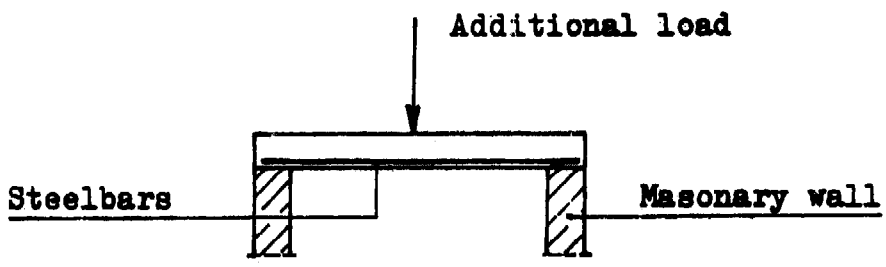

Due to dead load and additional loads such as people, earthfill, snow etc. the slab will get tensile stresses at the bottom. So in this place we must put some steel-bars into the concrete.

The number, diameter, length and position of the bars is a matter for the design engineer or the engineer - in - charge of the project.

1.3 Application of concrete

I. Lean concrete: To make a clean and completely horizontal base for concrete and masonry constructions.

1. Example: Storage tank wall - foundation.

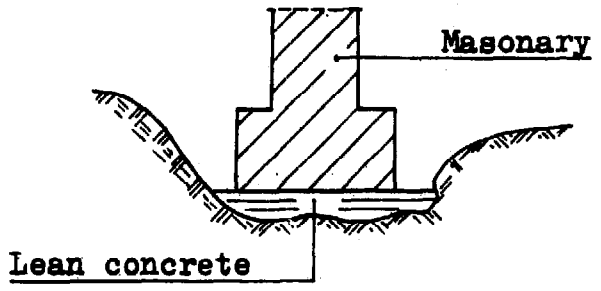

2. Example: Foundation of a spring collection chamber.

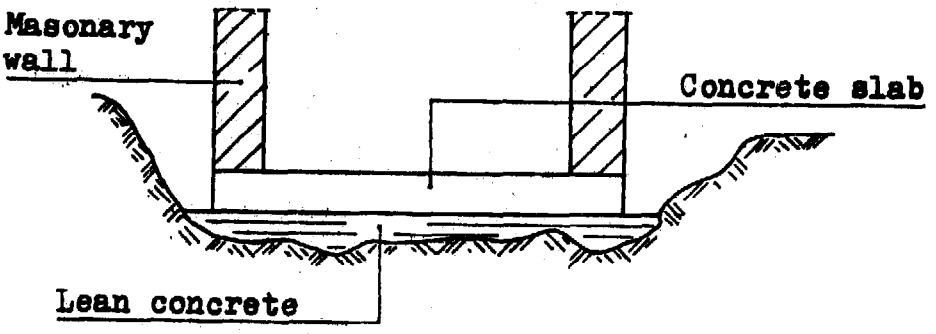

II. Non-reinforced concrete: To make foundations, floors small staircases, walls etc. All concrete constructions which are not exposed to high tensile stresses.

Example: Floor of a storage tank

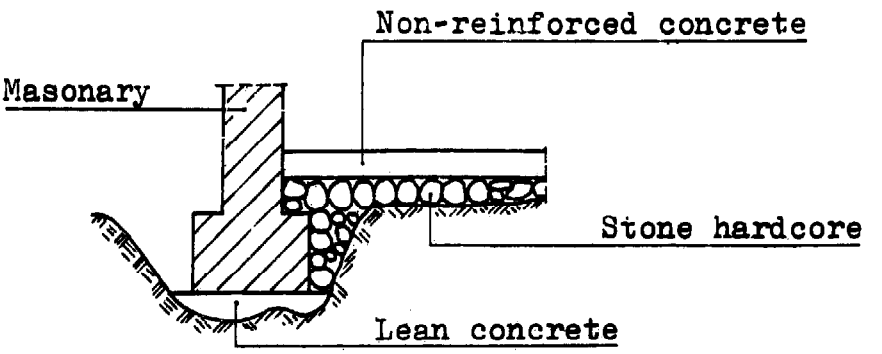

III. Reinforced concrete: To make all kind of concrete constructions such as slabs, walls, bridges, etc.

Example: Slab of a spring collection chamber

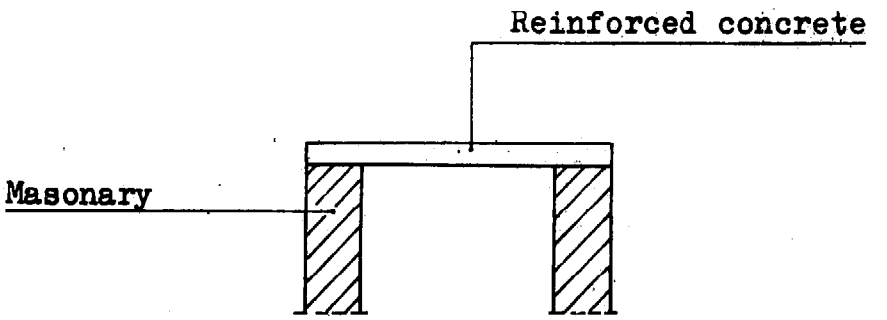

Note: The decision to use reinforced or non-reinforced concrete is a matter for the engineer,and it should be shown on the site drawings.

2. Materials

2.1 The aggregates

2.1.1 Origin and extraction

Natural materials

Rubble sediments in rivers and lakes. Due to long transport in the rivers, gravel and sand are ground round,and bad materials have already been eliminated. They are also washed so that in many cases they are ready to be used for making concrete.

Crushed materials

Pieces of rocks and big stones broken in stone breakers or by hand.

This material must be washed and sorted out. It is important to remove all the dust which arises by crushing; stone with cracks should be eliminated. To obtain a high strength the crushed material should be mixed with river sand.

2.1.2 The form of grains

The compressive strength of each grain must be higher than the strength of the finished concrete. The ideal form of gravel is round for river gravel and cubic for crushed gravel. Do not use weather-worn stones,slate and flat stones.

2.1.3 Impurities

If aggregates are dirty and contain grass leaves, wood, humus, silt, clay etc, they have to be washed, but particular attention should be paid not to wash away the fine sand aggregates. Gravel and sand containing impurities cause heavy loss of strength in the finished concrete.

Simple methods for field tests:

Fist test

The hand filled with the aggregates to be tested is to clench and then to open again. If the material is clean it should not stick together in a lump. When the material is rubbed between the hands, they should remain almost clean.

Bottle test

A clear bottle filled up to 2/3 with material and the remaining space with water is to be shaked vigorously. After about 30 minutes of settlement, there should be no dirt or silt on top of the material.

2.1.4 Grading or gradation

In properly made concrete, each particle of aggregate is completely surrounded by cement paste. The better the distribution of the particle sizes, the better all spaces will be filled and the denser and stronger the finished concrete will be.

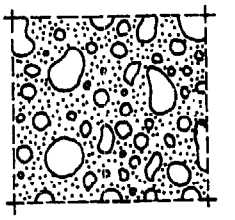

The most common composition is 3 parts gravel and 2 parts sand.

To find out the proper composition, it is recommended to make testing mixtures on site. The following table should give an idea of a good gradation.

Table of gradation

	Ø	Range of grains			
	mm	0-8	0-15	0-30	0-60
Dust	0.0-0.1	8-14	5-10	3-7	2-5
Fine sand	0.1-1	15-21	16-15	7-11	5-7
Medium sand	1-4	38-37	23-26	13-18	9-14
Coarse sand	4-8	39-28	24-21	16-15	9-10
Fine gravel	8-15		37-28	21-19	13-14
Medium gravel	15-30			40-30	22-20
Coarse gravel	30-60				40-30

Proportions in % of weight (dry aggregates)

2.2 Cement

2.2.1 Introduction

Cement is a product of minerals which are burnt and then pulverized. If water is added it becomes a binding paste which first sets (becomes firm) and then hardens for an indefinite period. The setting and hardening are brought about by chemical reaction between the cement and the water. This process is called hydration.

On the world market there are a lot of different adhesives available. But in Nepal, and also in other countries, only portland cement is used to date. Therefore the following chapters give a brief description of this portland cement.

2.2.2 Manufacture

The raw materials, limestone and clay, are extracted from quarries and crushed into pieces of the size of a fist. After this, the raw materials are mixed with hydraulic compound, granulated and burnt at a temperature of 1500°C. This burning produces a clinker which is cooled and pulverized into fine powder with a small amount of gypsum added to regulate the setting time. This powder is the finished portland cement.

2.2.3 Hydration

Hydration of the cement is divided into two processes: The setting stage and the hardening stage.

Setting

This chemical process which radiates heat, starts at a certain time after the water has been added and it lasts till the mass is solid. The time of beginning and the duration of this process varies mainly according to the temperature. At a temperature of 18°C the setting starts after about 2.5 hours and lasts 7 hours. If the temperature falls to 0°C, no setting process takes place. In the tropics, where temperatures of 30°C often occur, the same cement may change to a quick setting one.

During the setting time the material must not be disturbed, as this would diminish its strength considerably.

The setting time can be checked on site, by a very simple method:

> The concrete is scratched with a fingernail or a piece of soft wood.

If it flows together again, the setting has not yet started, if the scratch remains, the setting is in process, if no scratch can be seen on the concrete, the setting stage has finished and the hardening stage has already started.

Hardening

Theoretically portland cement never stops hardening and therefore the end of the process cannot really be determined.

For practical work it is sufficient to know how long it takes a structural part to attain the required strength.

2.2.4 Shrinkage

All adhesives, including portland cement, are subject to shrinking during the setting and the hardening process.

The shrinkage must be counteracted by keeping the mortar or the concrete wet.

2.2.5 Storage of cement

Cement should not be stored longer than three months. Otherwise the strength will be reduced to approximately 75% of the original value. If cement is allowed to absorb any moisture, it will set more slowly and the strength will be drastically in decreased.

In storing cement, especially sacked cement, the warehouse or shed should be as airtight as possible. All cracks in the roof and walls must be closed. The floor should be above ground to protect cement against dampness. Sacks should be stored close together to reduce the circulation of air, but at least 50 cm away from walls, and with not more than 10 bags per pile.

On smaller sites, where there is no shed or other building available, the sacks may be placed on a raised wood platform. A waterproof tarpauline should be placed over the pile to protect the cement against rain. The tarpaulin should extend over the edges of the platform. If the cement is hard due to moisture, it can not be used.

2.3 Water

The water must be clean. Drinking water is always suitable for making concrete. If it is not possible to use drinking water it must be certain that the water is not polluted by:

- soil particles
- mud
- dirt
- oil
- soap, etc

It is important to use only clean water for making concrete and mortar.

3. Making and handling of concrete

3.1 Mixture

3.1.1 The amount of aggregates

Experiments have shown that the portion of gravel and sand which is used in mixing 1 m3 finished concrete is not always the same. Normally 1400 liters of aggregates are needed to make 1 m3 of finished concrete.

3.1.2 The amount of cement

The amount of cement for a certain mixture is given in liters or kilograms.

1 bag of cement = 50 kg = 40 liters

For the different types of concrete we need the following amount of cement per m3:

lean concrete	: 150 kg = 120 liters
non-reinforced) reinforced) concrete	: 300 kg = 240 liters

The quantity has to be increased if the aggregates do not correspond to the requirements described in chapter 2.1.4.

3.1.3 Amount of water used in concrete

The amount of water to be used depends on: the aggregates; on the consistency of concrete wanted; and on the amount of cement.

It should be noted that the total amount of water in a mixture is equal to the added water and the natural moisture of the aggregates.

The proportion of water to cement is called:

$$\text{water-cement ratio} = \frac{\text{water (in kg)}}{\text{cement (in kg)}}$$

The water-cement ratio has a direct influence on:

- workability
- density
- strength

The best results for density and strength are achieved by using a mixture with a water-cement ratio of:

0.4 for lean concrete
0.5 for non-reinforced and reinforced concrete

Note: Each litre of extra water used demolishes the effect of 2 to 3 kg cement.

Natural moisture of aggregates:

	Sand	Gravel
	liters/m3	liters/m3
Dry season	25-30	5-10
Rain and sun mixed	70-80	25-35
Rainy season	160-170	70-80

3.1.4 Measuring the ingredients for hand mixing

The following table shows volume ratios.

	Type of concrete	
	Lean concrete	Non-reinforced and reinforced concrete
Cement : sand : gravel	1 : 4 : 7	1 : 2 : 3
Cement : sand + gravel	1 : 25	1 : 12

3.2 Mixing

3.2.1 Equipment

Hand mixing does not need much equipment but a lot of manpower.

A batch to be hand mixed should not be larger than about 0.5 m3. Concrete should never be mixed on soil. A platform has to be built, with boards, metal sheets, stones or concrete. It should be level to prevent water or fluid material from flowing off the platform.

3.2.2 Procedure of mixing

Measure the amount of aggregates used for the batch, put it onto the platform in a layer, and spread the cement over it. Mix together until it is uniform in colour.

For addition of water, the material is sprinkled gradually while it is turned over another 3 times, that is, until it is uniform in consistancy.

3.3 Transporting concrete

If mixed concrete is transported there is a tendency for the larger aggregate particles to segregate by settling to the bottom. To avoid this, ready mixed concrete should not be transported over long distances and if it has to be, the transport container should be adequate. There should be no leakage, so that none of the cement milk is able to flow off.

3.4 Casting concrete

3.4.1 Preparation of the formwork

Before any concrete is placed, the forms must be cleaned of all rubbish and carefully checked for strength, tightness and proper alignment. The forms should be wet the day before casting and again before the work starts. If this is not done, the boards will absorb a high amount of the cement milk, which is necessary to bond the aggregates.

3.4.2 Placing of concrete

Concrete has to be placed in layers or strips of maximum 15 - 20 cm width.

Placing in layers is correct

Placing heaps is wrong (causes segregation)

Each layer has to be cast before the former layer has started setting.

3.4.3 Casting concrete inside standing water

The depth of the water should not exceed 20 cm, as this would demand a pump and a water tight formwork.

The amount of cement has to be increased by at least 50 kg/m3 finished concrete.

The concrete has to be consolidated immediately after placing.

It is not possible to cast concrete inside flowing water.

3.5 Consolidating concrete

3.5.1 Why consolidating ?

If concrete is simply poured into a form and left to harden without further treatment, the product will contain a number of defects:

- Large number of bubbles entrapped in the material.
- Inadequate coverage of coarse aggregates.
- Small or intricate form spaces are not completely filled.
- Reinforcing steel is not solidly bonded to the concrete.

3.5.2 Hand - vibrated concrete

The concrete layers should not be thicker than 15 to 20 centimeters. Those layers have to be stamped vigorously especially at the edges and the corners until the water rises up to the surface.

If the work is interrupted for more than 2 hours, the last layer has to be roughened before new casting can go on.

3.5.3 Consolidating with vibrator

Proper consolidating is only possible with vibrators. But these engines are heavy and expensive. From the transportation point of view therefore, it is not practical to use vibrators in the hilly regions of Nepal.

3.6 Curing concrete

3.6.1 Drying out

As mentioned in the chapter on cement, concrete hardens as a result of the hydration of the cement by water. Fresh concrete contains more than enough water to hydrate the cement completely, but if the concrete is not protected against drying out, the water, especially near the surface, will drop below the amount required for complete hydration.

3.6.2 Shrinkage

Rapid drying-out causes a decrease in volume, which starts at the surface of the concrete mass while the centre of the mass is still wet. This causes a surface tension which the fresh concrete is not able to absorb. The results are reticular cracks all over the surface.

The more water and cement are used the more the concrete shrinks.

3.6.3 Curing

The procedure called curing is designed to prevent surface evaporation of water during setting and hardening stages.

Curing starts as soon as possible without damaging the surface. Curing is brought about by keeping the concrete surface continuously wet. Depending upon the structure and the means available this may be done by:

- Sprinkling or flooding
- Covering with jute bags, grass and leaves which should be wet continuously. Min. coverage 5 cm.

Highly strained concrete should be kept moist for at least 14 days.

3.7 Removal of forms

Forms should be left in place until the concrete has hardened enough to hold its own weight and any other weight it may be carrying.

The surface must be hard enough to remain uninjured and unmarked when care is used in stripping the forms. The engineer in charge of the project should tell how long the formwork should remain in place.

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RURAL WATER SUPPLY NEPAL

TECHNICAL TRAINING MANUAL no. 5

CONSTRUCTION DESIGN COURSE

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CONSTRUCTION DESIGN COURSE

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CONSTRUCTION DESIGN COURSE

Preface

The objective of a water supply system is to collect, on a continuing basis, a sufficient quantity of pure water to satisfy the daily physical needs of all the human consumers in a district and their animals and deliver it to them in the most convenient way possible at the most convenient location.

There are therefore three major elements or processes to a water supply system, which will be dealt with in turn in the course. They are:

- Establishing a source of water.
- Ensuring the quality of the water (maintenance.)
- Arranging storage and distribution.

This course covers the constructions necessary for accomplishing all these processes. In designing the installations of a water supply system we should also bear in mind the need to repair and maintain the installations themselves as part of an ongoing process of water supply.

1. THE WATER SOURCE

1.1 Spring Catchment - General Points

The Spring Catchment is the term we use for the place where water is gathered in sufficient quantity to form the basis of a water supply. Some of these types of sources are:

- Water bearing soil
- Existing streams or rivers
- Rock fissures, which allow underground water to be released on the surface.

The type of spring catchment installation to be built depends on three factors: the topographical situation, the structure of the ground and the type of source.

Here are some general points which should be considered before, and during, the construction of a spring catchment installation.

a. The catchment area should be clearly marked on the terrain with mark - pillars.

b. This intake-area, as it is called, should be declared a protected zone during building and after completion to minimise factors which may cause pollution.

c. No attempt should be made to change the spring's natural flow. If there is any obstruction the water will try to find way around it, and the spring may get dirty. The free flow of the water must be guaranteed during the construction.

d. The installation has to be built carefully, to prevent the possibility of leakages and water pollution whether by accident, negligence or even malice.

e. The constructionof the catchment installation, and its depth, will depend on several considerations. Some of these are:

   - geological considerations - the type of rocks and terrain in the district,
   - the type of matter or soil which covers the water bearing earth,
   - hygiene consideration

f. The spring catchment should be built right up to the impermeable stratum, which should not be broken.

g. Plastering near a spring should be avoided.

1.2 The Catchment Area

As we said before, the intake area should be declared a protected zone. Unless they are directly working on the project people should be prohibited from entering it, and actively prevented from doing so. Within this area there should be no farming, building or other activities.

As a preparation for building, the boundaries of the area should be marked on the ground by stones or concrete pillars, and the direction of the flow of water from the catchment installation itself should also be marked in this way.

It is a good idea to plant grass over the installation after it has been completed, and to keep it short by cutting it regularly. Trees can be planted to provide shade, and protect the water, but they should not be closer than 10 metres to the catchment installation itself. This is so that their roots do not grow to interfere with the source.

Drains should be constructed to divert or drain off any surface water that collects within the area, so that there is no possibility of pollution from this source.

Refer to page 4 for the relevant diagram.

1.3 Spring Catchment Installation

There are three elements which comprise a spring catchment installation: (see page 4).

a. The catchment itself made by perforated pipes within a trench or by a dry wall channel.

b. The supply pipe to the inspection chamber.

c. The inspection chamber. This consists of an entrance basin for the spring water and an operation chamber. Its purpose is to help in controlling the water's quantity and quality. Sometimes it can also serve as a sedimentation chamber, but it should not be confused with the storage tank.

FIGURE 1.1

Spring catchment – general arrangement

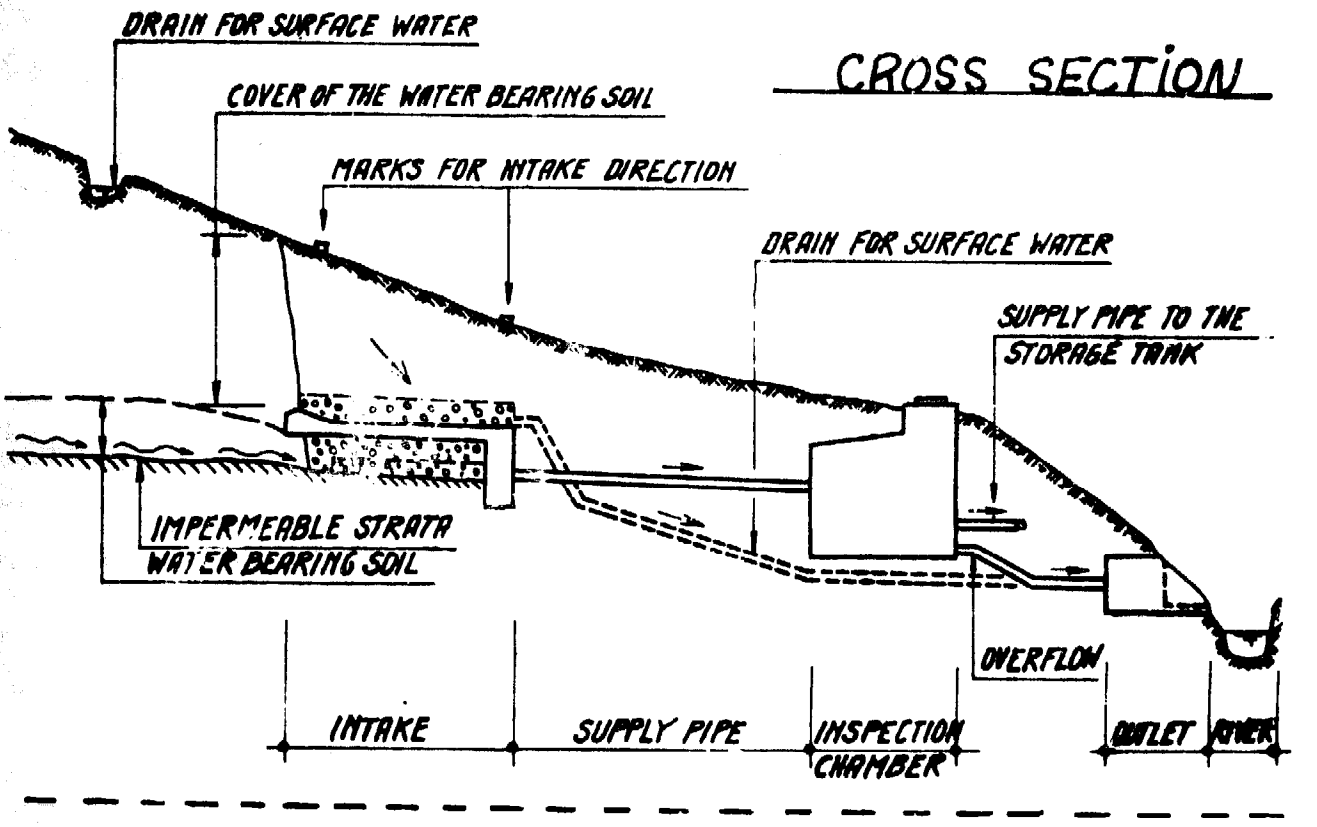

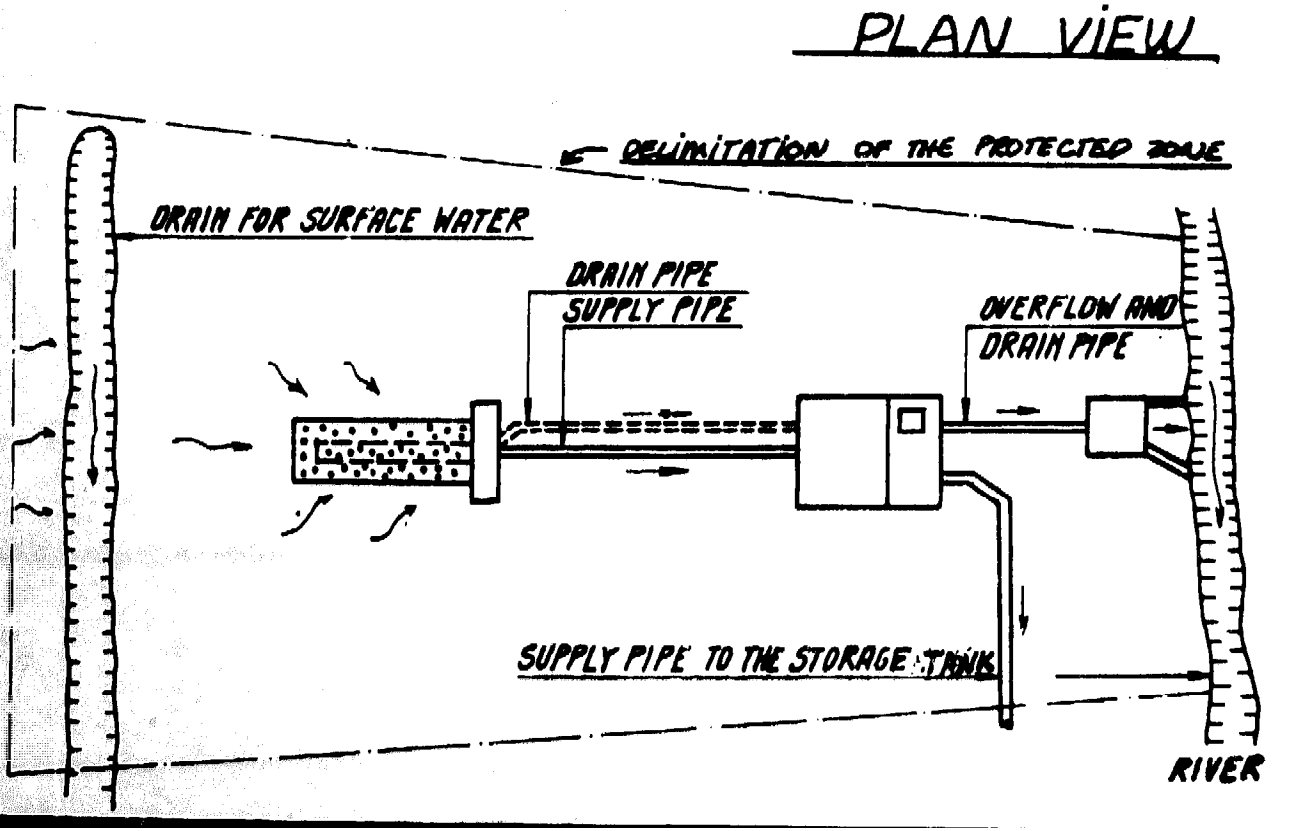

1.4 Trench Catchment

The simplest type of water catchment installation is a trench, containing a perforated pipe, which allows water from water bearing soil to seep into the pipe, through the perforations, and collect there. Alternatively a dry-wall channel can be built, (i.e. a channel constructed without the use of cement which would make it water-tight). This will function in the same way. For many situations in Nepal this is the best method, as it can be constructed using local materials without having to bring in special pipes.

The diagrams on pages 6 and 7 give more details. The sectional elevation Type 1 shows a cross section of a catchment installation using a drywall channel. Type 2 shows a cross section using perforated pipe. The plan shows the overhead view.

Some points to remember

- The distance between the trench and any trees in the area should be large enough to ensure that no roots can enter the catchment.
- The cross section of the catchment drain or dry wall channel should be large enough to ensure that the amount of water drained off is the maximum possible. If it is too small it will obstruct the natural flow of the spring or water-bearing soil.
- A small dam or barrage (10) should be constructed below the lowest water outlet. This marks the end of the catchment trench and the beginning of the supply pipe to the inspection chamber. The barrage should be built into the impermeable stratum, as well as into both side-walls of the trench, to prevent the water from finding a way around it.
- If perforated pipe is being used, the sides of the ditch around it and the first 30cm. above the pipe should be filled with gravel. The size of the gravel - its minimum diameter - should be related to the size of the holes in the perforated pipes. If a dry wall channel has been adopted as method of catchment it should be roofed with slabs, with gravel around the sides, the size of the gravel again being related to the size of the spaces in the dry wall. People should be forbidden to walk on the gravel during construction.
- The drain or dry wall channel and the layer of gravel need a watertight cover of concrete which extends on both sides, 10 to 20cm. above the walls. Surface water reaching this cover should be drained off at the dam.
- It is important to construct the catchment trench itself very carefully, because it will no longer be accessible after completion of the work. This is because the hole will be filled with layers of backfill, (12) to protect it from above.
- The supply pipe material will need to be resistant to corrosion.

FIGURE 1.2

Intake-details

Sectional Elevation

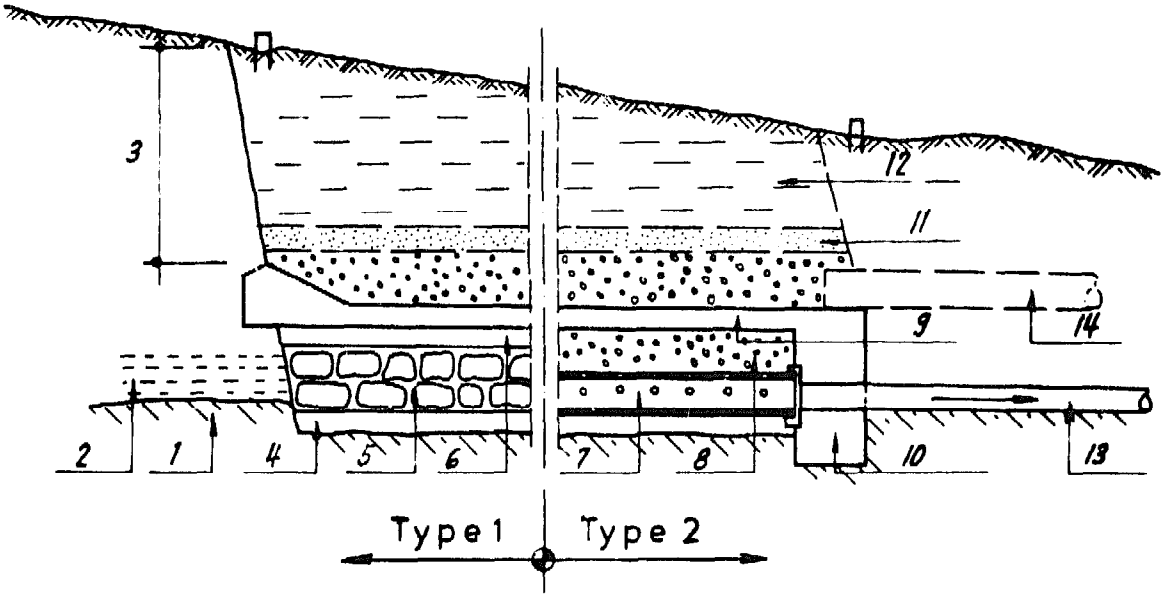

1 IMPERMEABLE STRATA
2 WATER BEARING SOIL
3 COVER OF WATER BEAR. SOIL
4 BED PLATE
5 DRY WALL
6 SLABS
7 PERFORATED PIPE
8 GRAVEL
9 WATERTIGHT COVER
10 DAM
11 PERMEABLE MATERIAL
12 IMPERMEABLE BACK FILL.
13 SUPPLY PIPE
14 DRAIN FOR SURFACE WATER

Plan

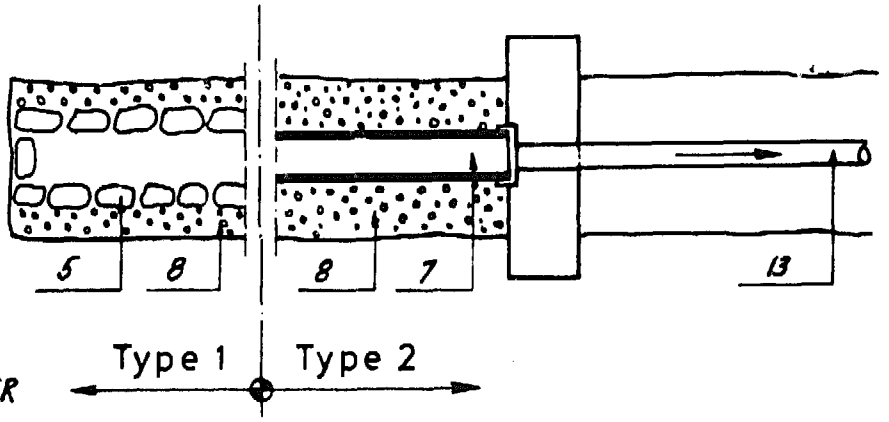

Cross section type 1

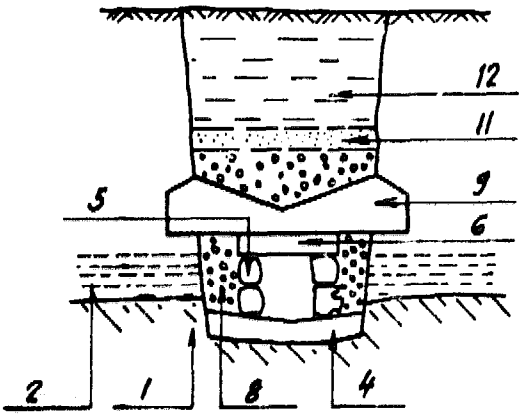

Cross section type 2

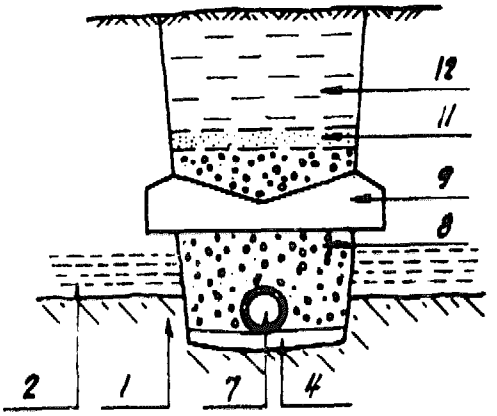

FIGURE 1.3

Intake across a slope - details

Sectional elevation

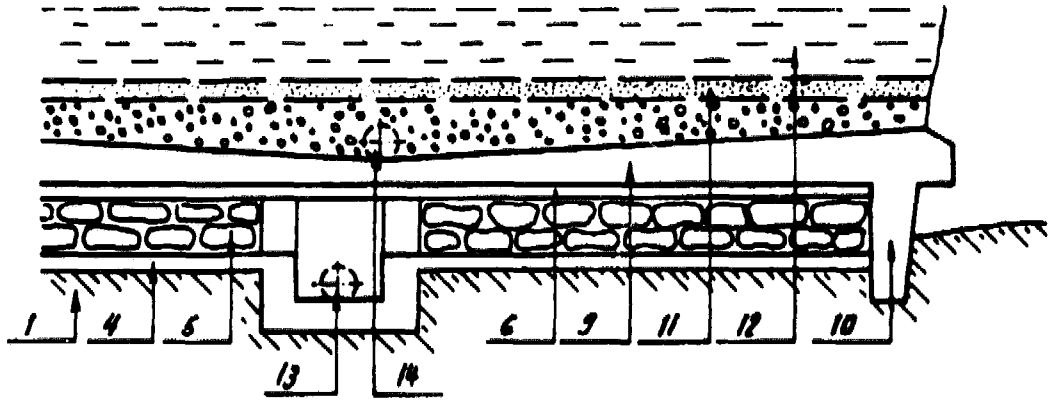

1 IMPERMEABLE STRATA
2 WATER BEARING SOIL
3 COVER OF WATER BEARING SOIL
4 BED PLATE
5 DRY WALL
6 SLABS
7 PERFORATED PIPES
8 GRAVEL
9 WATERTIGHT COVER
10 DAM
11 PERMEABLE MATERIAL
12 IMPERMEABLE BACKFILLING
13 SUPPLY PIPE
14 DRAIN FOR SURFACE WATER

Plan

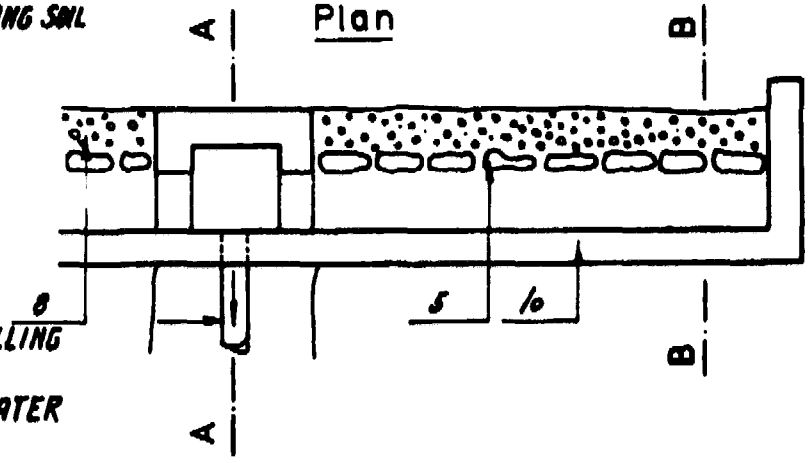

Section A-A

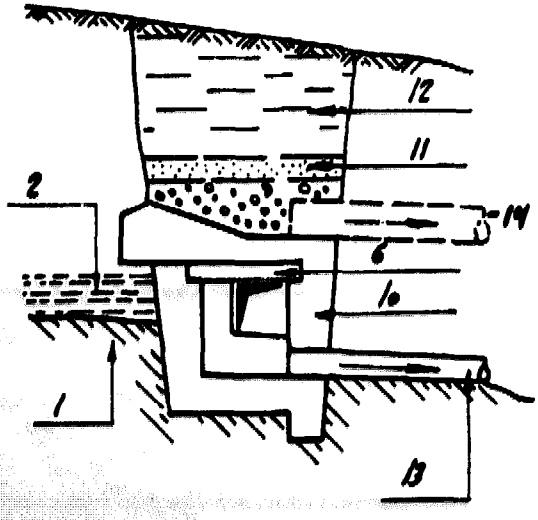

Section B-B

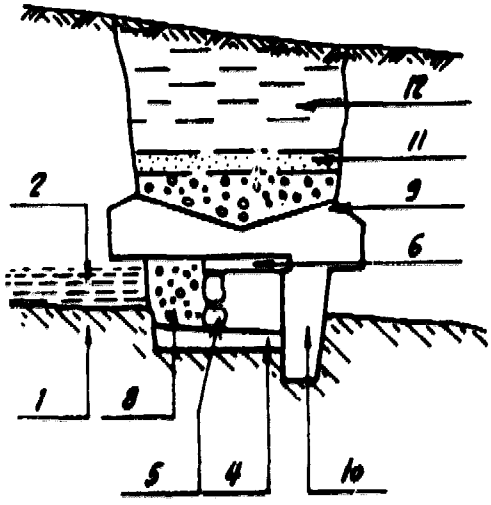

1.5 Small Spring Catchment

This method is suitable for areas where there are small springs - perhaps several of them in close proximity. To be feasible the flow of water from a single spring should not exceed 1 litre per second.

It is a simple construction, consisting of several small trench - catchments made with stone masonry, so that there is a catchment channel for each place where water is coming from the soil. The maximum length of a channel branch should be 20mm. If it is more than 20m. a collection chamber (or control chamber) should be built.

The following sketches show the design of this type of catchment installation. The measurements on the diagram are in centimetres.

FIGURE 1·4

SMALL SPRING CATCHMENT

GENERAL ARRANGEMENT

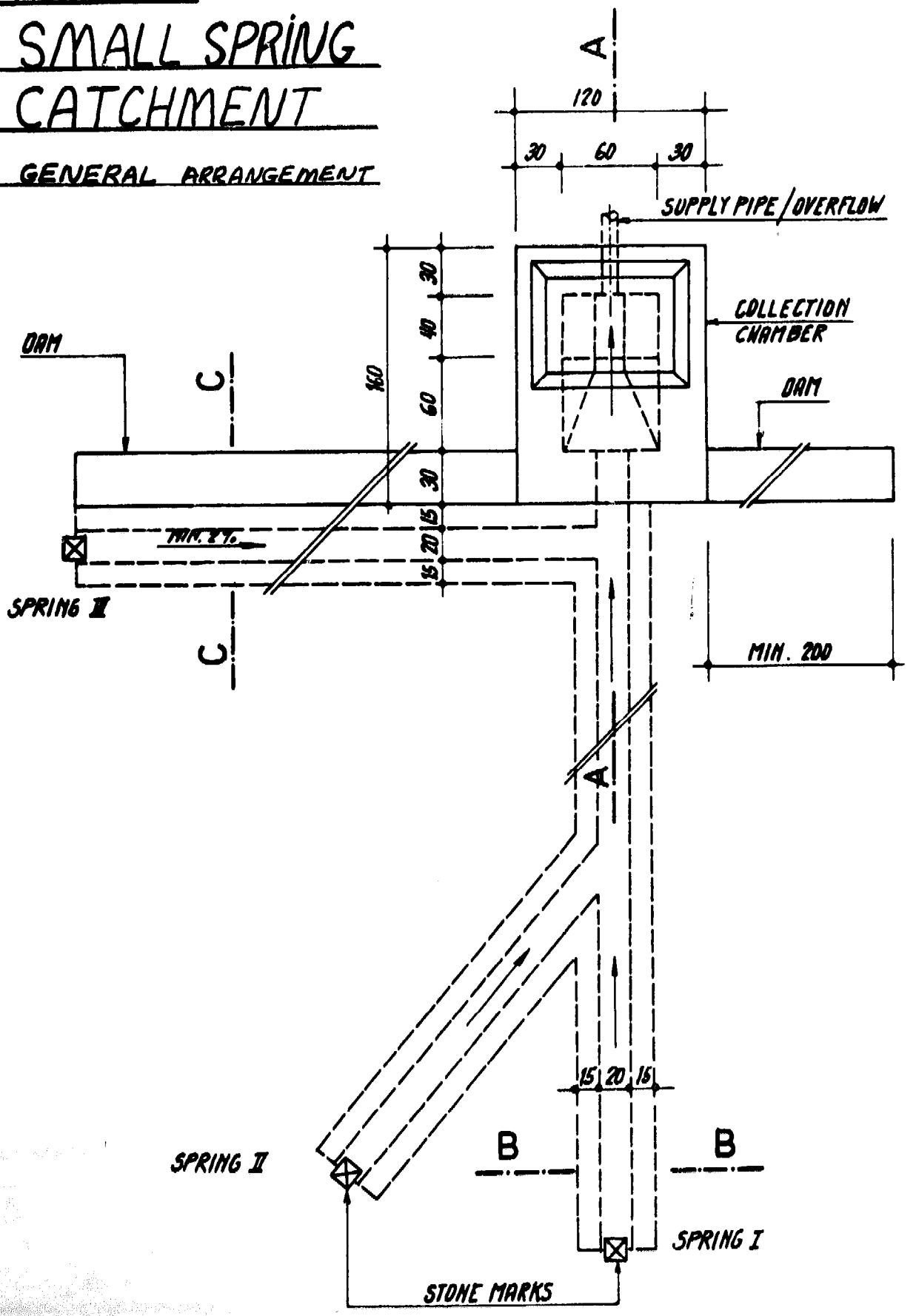

FIGURE 1.5 SMALL SPRING CATCHMENT — DETAILS

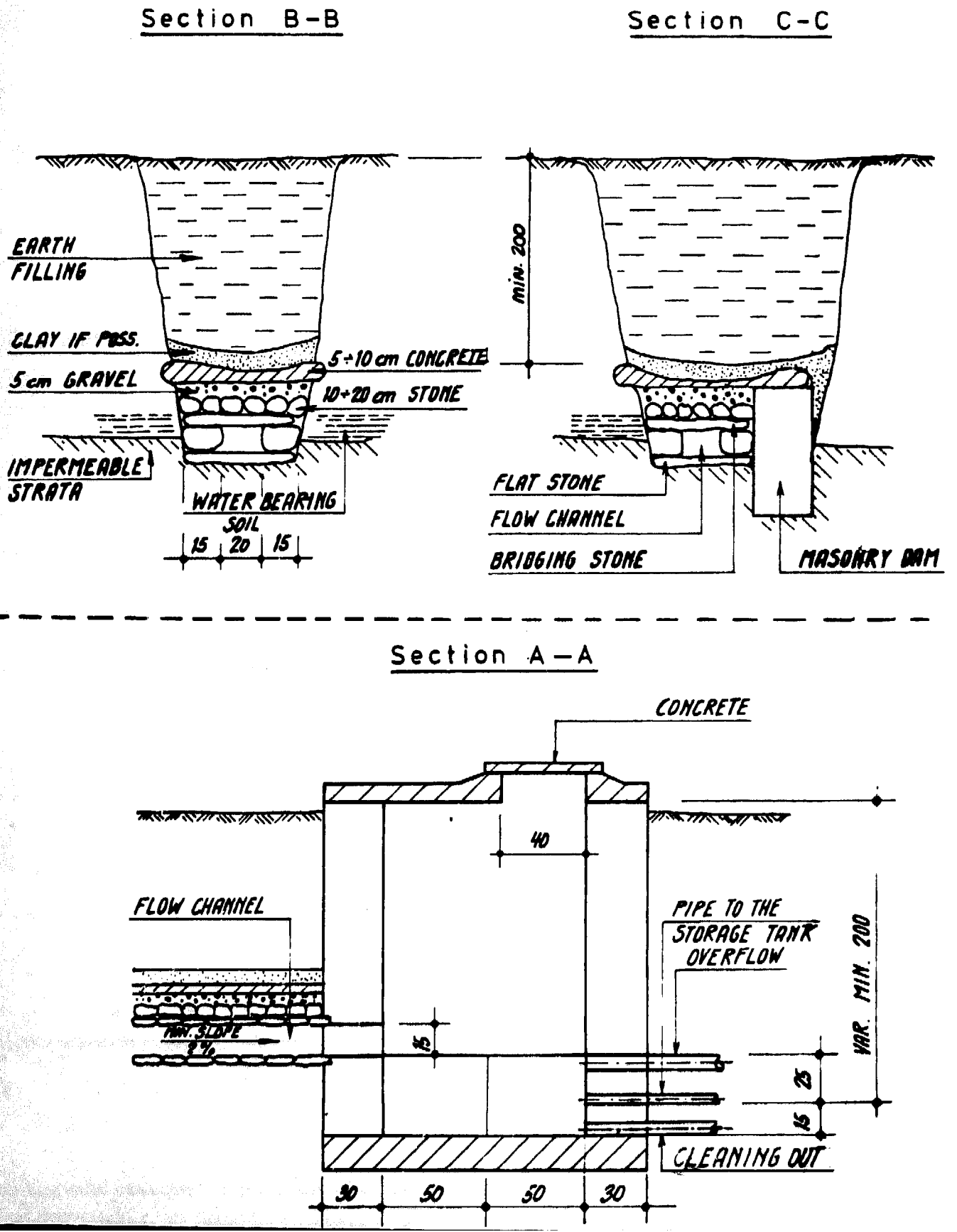

FIGURE 1·6 – DETAILS OF FITTINGS USED IN FIGURE 1·5

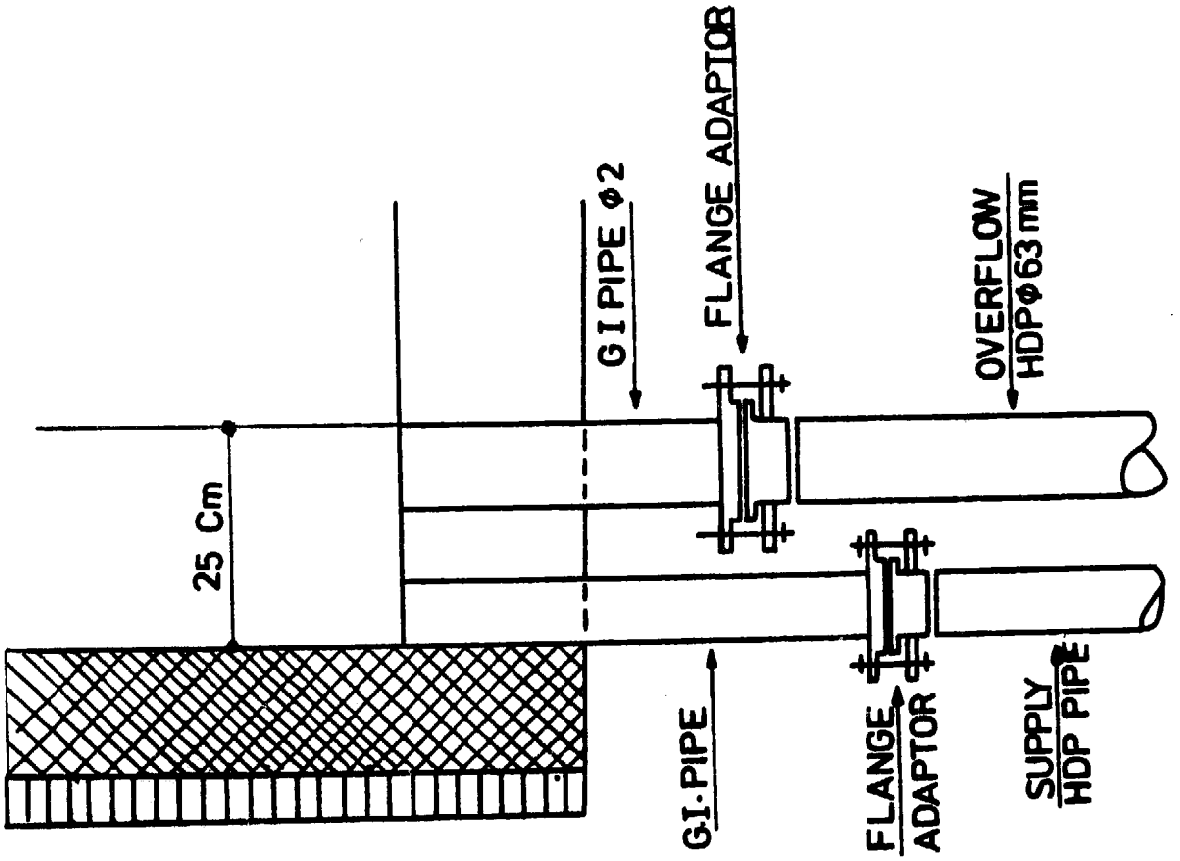

1.6 Small Stream Catchment

In certain cases, especially in high, rocky country, the possibility of trapping water from one spring does not exist. Often in these cases, water comes from between rocks at places which are distant from each other, and at each spot the yield of water is very small. To ensure an adequate quantity of water for a supply therefore, we must first direct all the available water into a stream. In other cases water seeps out of the ground over a large surface area, for example a river bed. Here, too, there is no specific spot at which to trap the water.

In such cases, a small stream catchment installation must be built. This consists of the following elements:

- A dam across the stream.
- A spillway at the dam.
- An intake chamber.
- Protective walls on each side of the intake chamber.
- A cleaning out valve.
- A supply pipe with control valve.

For details of this, look at the diagrams on pages 13, 14, 15 and 16. Study them and ask the instructor if anything is unclear to you.

When a project uses this type of water source, we recommend that a sedimentation tank and slow sand filters be built to ensure the quality of drinking water is up to standard. There may be impurities in the stream water.

FIGURE 1·7

SMALL STREAM CATCHMENT DETAIL

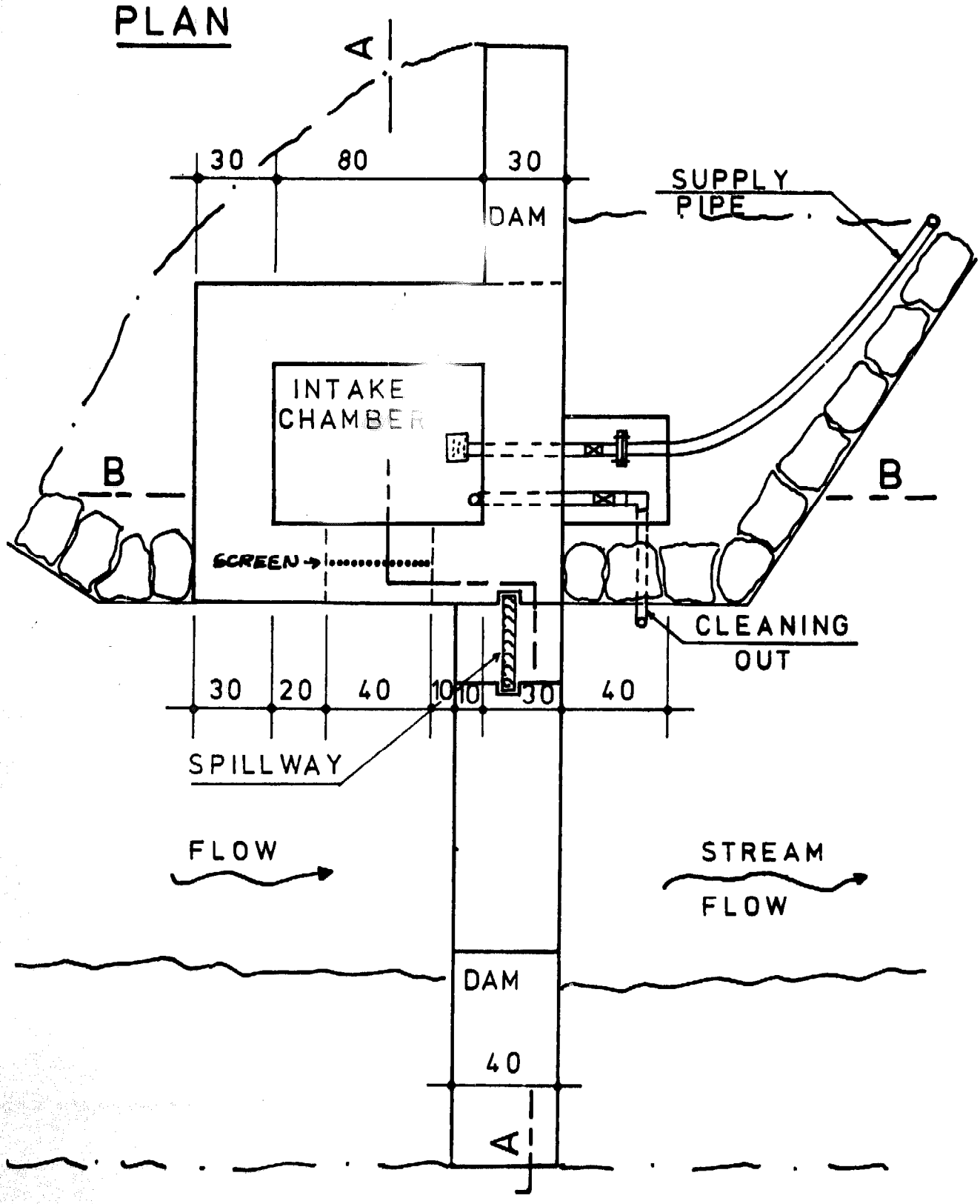

FIGURE 1·8

SMALL STREAM CATCHMENT DETAIL

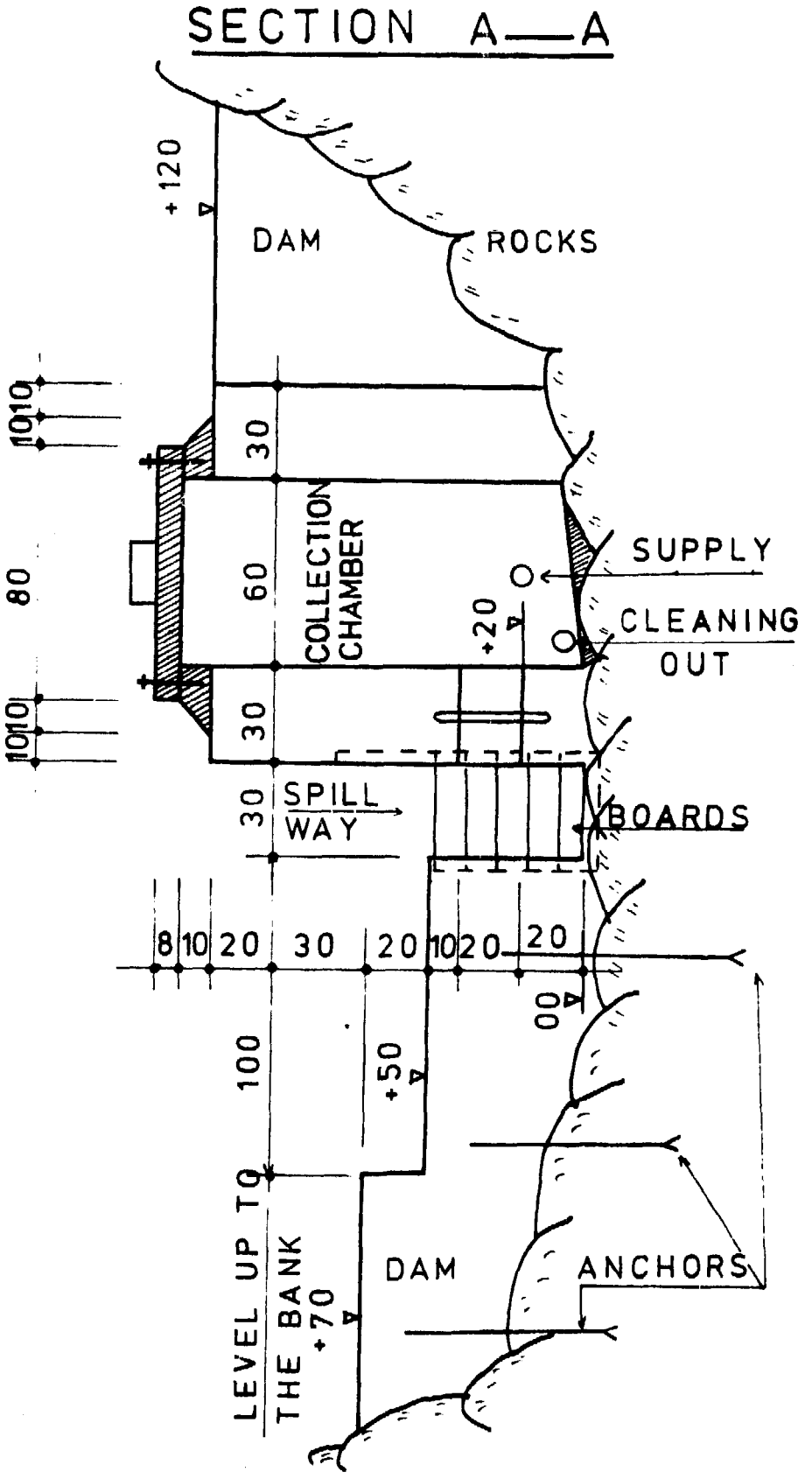

FIGURE 1·9

SMALL STREAM CATCHMENT DETAIL

SECTION B—B

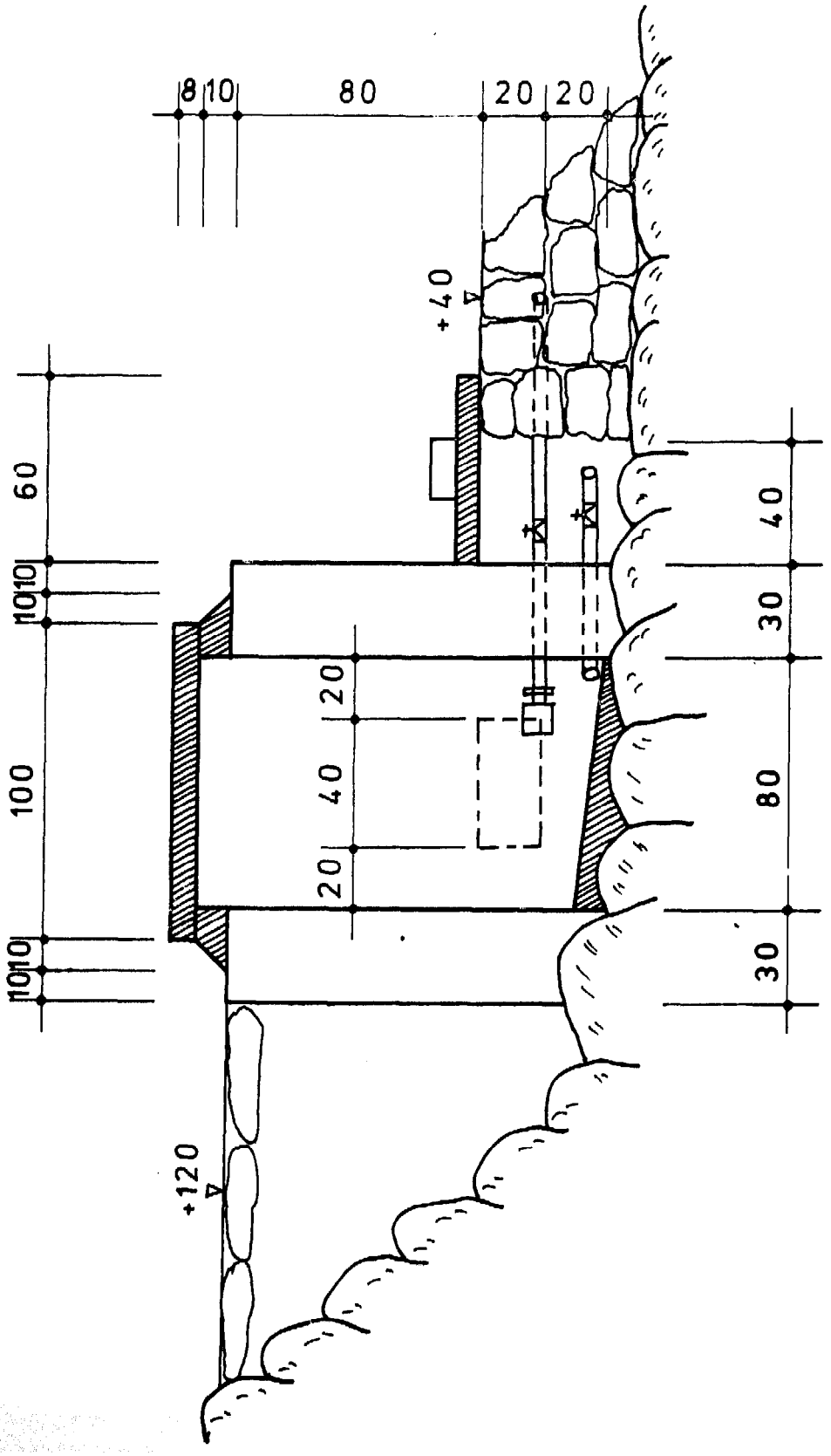

FIGURE 1.10

SMALL STREAM CATCHMENT INSTALLATION DETAILS

OUTLET

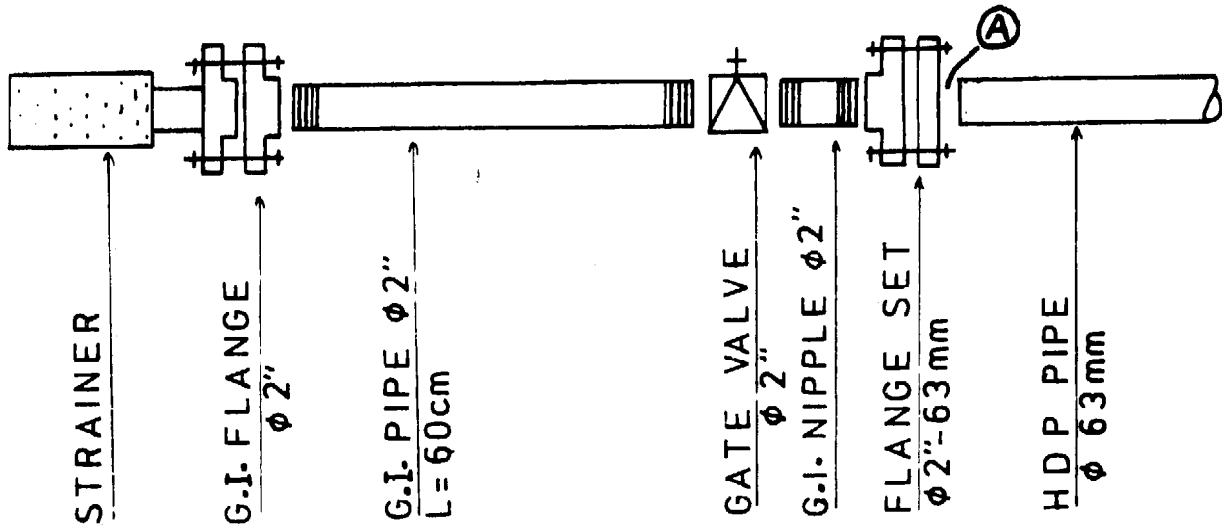

NOTE: IF THE DIAMETER OF THE PIPELINE IS SMALLER THAN THE OUTLET DIAMETER, A HDP REDUCER SHOULD BE USED AT POINT (A)

CLEANING OUT

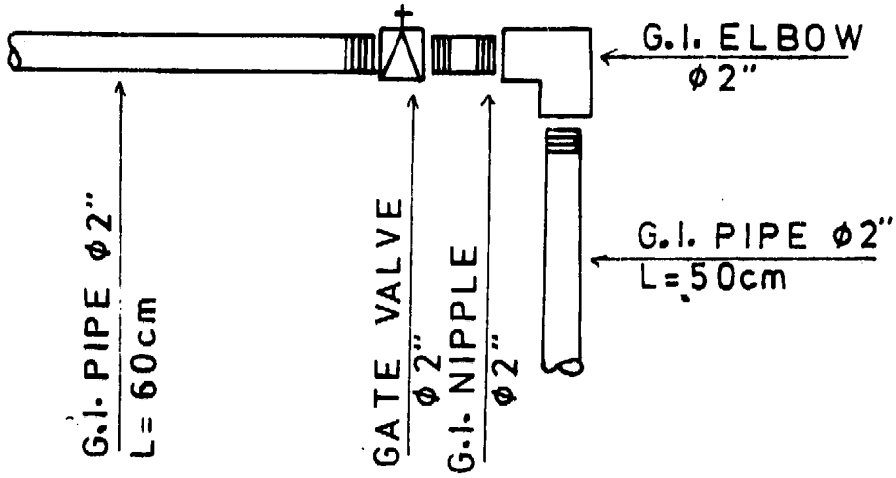

1.7 Inspection Chamber

The function of an inspection chamber is to control the quality of the water before it is stored or distributed. It consists of an entrance basin, where water collects, and an operation room.

It is important for hygienic reasons that timbers (wood) are not used as building materials and that no timber is left in the catchment installaiton or inspection chamber. The timber will get rotten and will become a breeding place for insects and micro-organisms leading to pollution of water. Concrete and stone masonry are the most suitable building materials for a long-lasting spring catchment installation and inspection chamber.

The inspection chamber should be built at a level lower than the spring, so that there is no obstruction to the flow of water. (See page 4)

If there are two or more catchment trenches, each spring catchment installation will need its own entrance basin, from which the water flows into a collection basin. It should be possible to drain each basin so that a single spring, if necessary, can be cut off from the supply. (See page 9)

The chamber should be ventilated, if possible in combination with a drain pipe or an entrance. It should not be built too small, since sufficient room should be allowed for all installations. This is especially important for future maintenance. Enough space should be allowed to swing a wrench easily for valve changing.

The inflow pipe must be 20cm. above the highest possible water level in the entrance basin. The dimensions of the overflow pipes and drains must be large enough to enable the total capacity of the spring to be drained off, without restricting the flow of water from it.

Ventilators and manholes should be placed in the operation room. They should not he located directly above the water. They should be 50cm. above ground-level with footsteps down at 25cm. intervals. Manhole covers should be locked to prevent unauthorised persons from prying them open. It is advisable to cover the chamber (excluding the entrance) so that the water is not influenced by the outside temperature. All openings (including the overflow and the manhole) have to be constructed in such a way that the possibility of pollution is prevented and so that there is no chance for small animals to enter into the chamber.

Corners and edges have to be rounded and the structure has to be waterproof inside and outside. For details of the fittings for an inspection chamber, see the storage tank diagrams (pages 36, 37, 41, 42, 43 and 44).

FIGURE 1·11

Inspection chamber with manhole – details

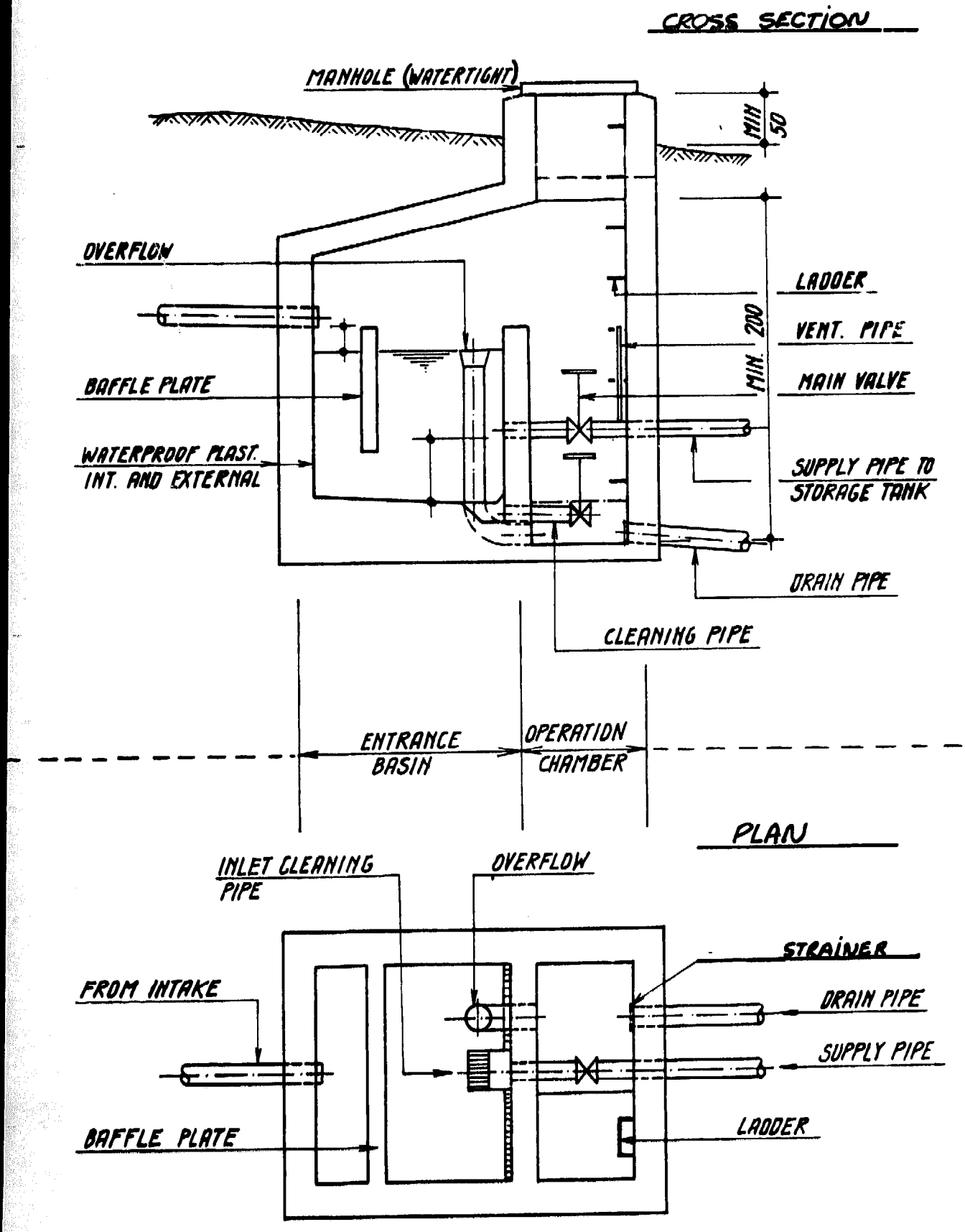

FIGURE 1.12

Inspection chamber with door-details

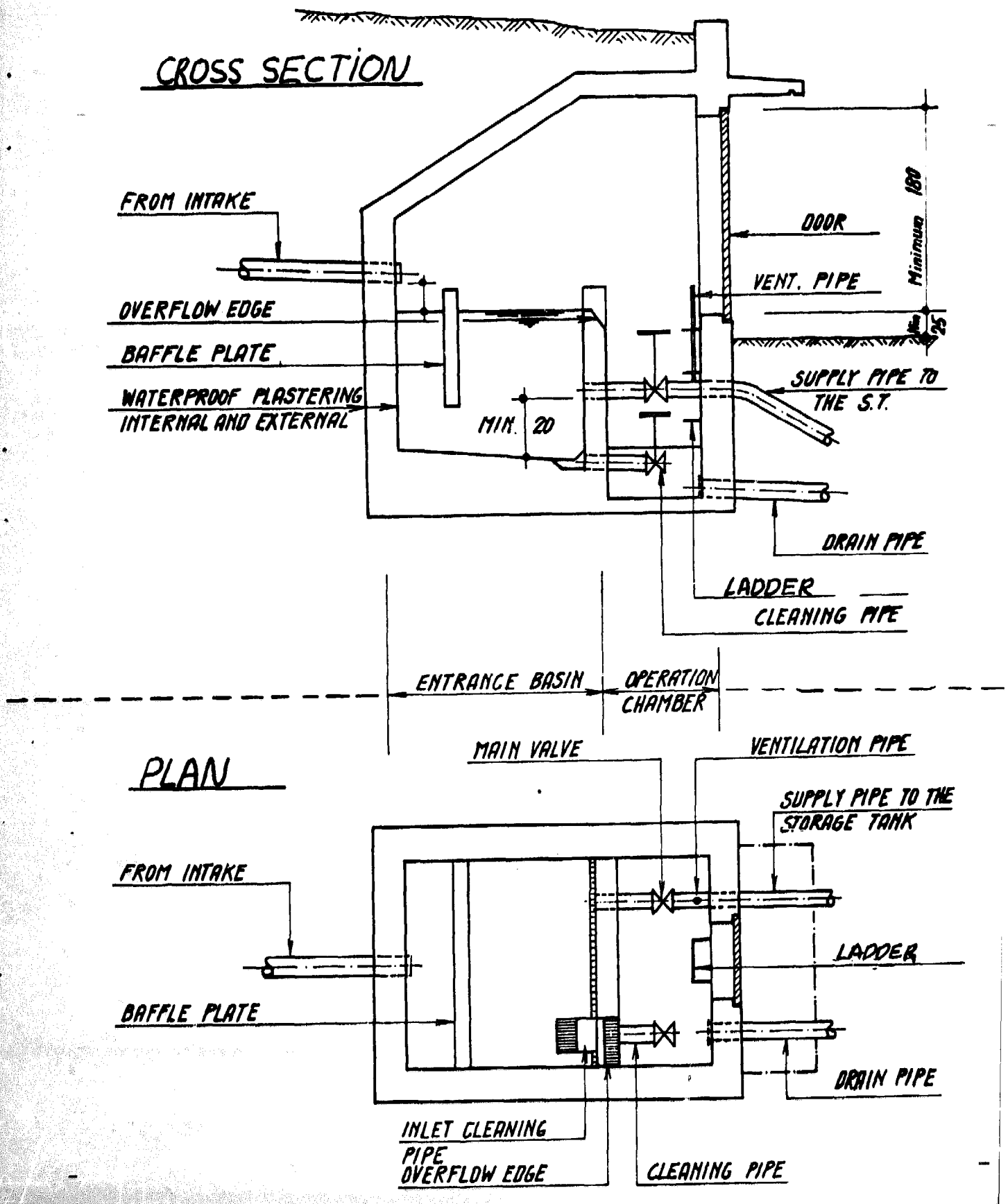

FIGURE 1.13

Inspection chamber for several intakes - details

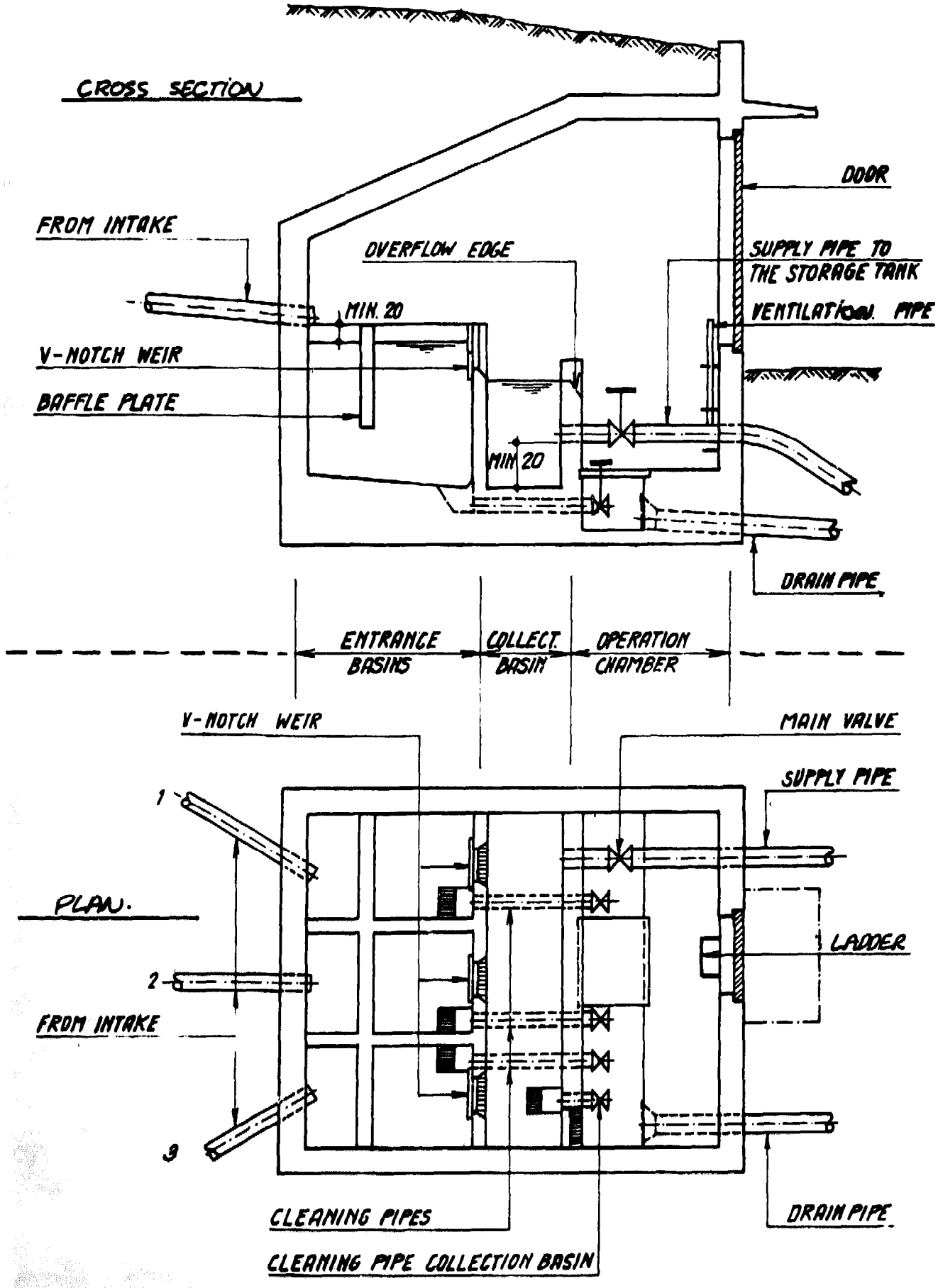

2. WATER QUALITY

2.1 Water Treatment In The Rural Situation

Having dealt with the installations relating to establishing a water source, this section of the course will deal with the installations which ensure that the water is as pure and clean as possible.

It should always be the policy of the responsible people, in charge of water supplies, to restrict the use of water treatment under rural conditions to those cases where such treatment is absolutely essential, and to those where correct plant operation and maintenance can be secured and supervised.

Projected water supply schemes should be studied carefully, looking at the engineering and economic considerations, so that the relative merits of different schemes can be compared. For example a scheme requiring water treatment must be compared with projects in which long pipelines bring water from a spring which is far away. It would be better to make a large investment at the beginning of a project, using a long pipeline, than to design a scheme in which there will be treatment costs and operational and maintenance problems.

In any case rural water supplies should be designed to safeguard and maintain the quality of the natural water selected, and if a catchment installation is correctly built there should be no need for elaborate treatment.

In many cases if the inspection chamber is constructed with a long basin, sedimentation will occur there. In other cases, however, a special sedimentation basin or chamber will need to be constructed. The objective is to attain the WHO standard for drinking water supplies without elaborate installations or treatment.

2.2 Filtration

Filtration is a process which purifies water of particles or bacteria remaining after the process of sedimentation. The first part of a filter is a bacteriological bed. Bacteria live on this bed and feed on other bacteria in the water passing through the bed. Thus they form a natural, organic process as a result of which bacteria in the water are digested, decomposed and disposed of. There are three main types of filters:

- slow sand filters with slow water velocity during filtration
- rapid sand filters with rapid water velocity during filtration
- pressure filters, contained in pressurised steel vessels, with rapid water velocity during filtration.

2.3 Sedimentation and Methods

Sedimentation is the removal of suspended particles by gravitational settling. It takes place in a special tank, designed for this purpose. In the basin, or tank, large particles of sand have time to settle at the bottom, and thus be eliminated from the water flowing above. Particles originally enter the water because they are washed into it by rain, especially during the heavy rain of the monsoon.

During the course we will be considering only one kind of sedimentation process, "plain sedimentation". There are, however, two other kinds, and all these are briefly described below.

Plain sedimentation - In plain sedimentation impurities are separated from the fluid by gravitation and aggregation, and they sink to the bottom of the special tank. Later this sediment can be cleaned out. "Aggregation" describes the natural tendency of particles to gather together. Plain sedimentation can be most effective when the temperature of the water is high enough to reduce the viscosity of the water, permitting suspended solids to settle out of it more easily.

Coagulation - In the coagulation process chemical substances are added to the water to induce aggregation. These chemicals cause fine suspended matter, large molecules and colloidal substances to settle. By colloidal we mean dissolved substances or compounds.

Chemical Precipitation - When chemical precipitation occurs chemicals are added to precipate dissolved impurities out of solution in the water, by changing them into insoluble substances. Various factors affect the speed of sedimentation. Some of these are:

a. The settling velocity. This is related to the mass, shape and density of the particles themselves and the mass, density and viscosity of the water.

b. The drag force. This is related to the shape of the particles and the velocity, mass and density of the water.

c. The concentration of suspended solids in the water.

For sedimentation to occur the speed of the water (its velocity) must be reduced. Therefore the water should move very slowly through the tank. Inside, the water surface should look quite still, and no disturbance of the flow should be seen. The slower the water the more particles will settle, especially smaller particles.

2.4 Elements of Tank Design

Since sedimentation efficiency depends to a greater extent on the design of the tank itself, we should remember the following points:

- The inlet and outlet should be constructed so that the water travels the longest possible distance. Avoid a straight path between inlet and outlet, as shown on the diagram below. A straight inlet creates an equally straight flow to the outlet and this reduces the overall efficiency of the sedimentation tank.
- It is important to achieve a uniform flow of water over the longitudinal section of the tank. Agitation of the water in the tank, caused by the circulation of the water, should be prevented.

WRONG INLET OUTLET POSITION

FIGURE 2.1

CROSS SECTION

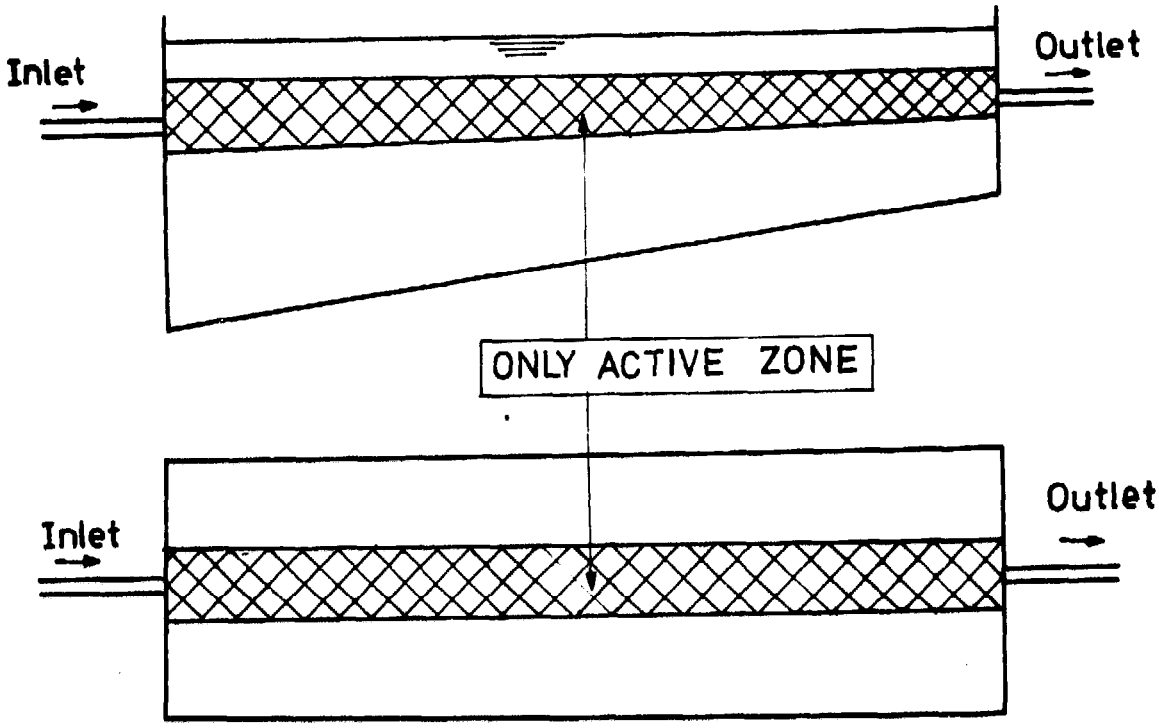

PLAN

Tank Shape

The dimensions of the tank are important as a relation exists between the surface area and the tank's efficiency. The greater the surface area the greater the sedimentation which will occur. The overseer in charge of the project will generally calculate the correct dimensions. The bottom of the tank should be sloping to enable it to be kept clean. Three types are shown below, all sloping.

Minimum slope = 3 degrees
Maximum slope = 8 degrees

There are two types of sedimentation tanks, circular and rectangular. Rectangular tanks are easier to construct and so this type of tank is the subject of the designs found in the following sections:

Look at them. Ask the teacher any questions you have. Make sure you understand all the functions of each element in the installation. For details of the fittings of a sedimentation tank look at the fittings for storage tanks (section 3.3) and for break pressure tanks (section 4.2).

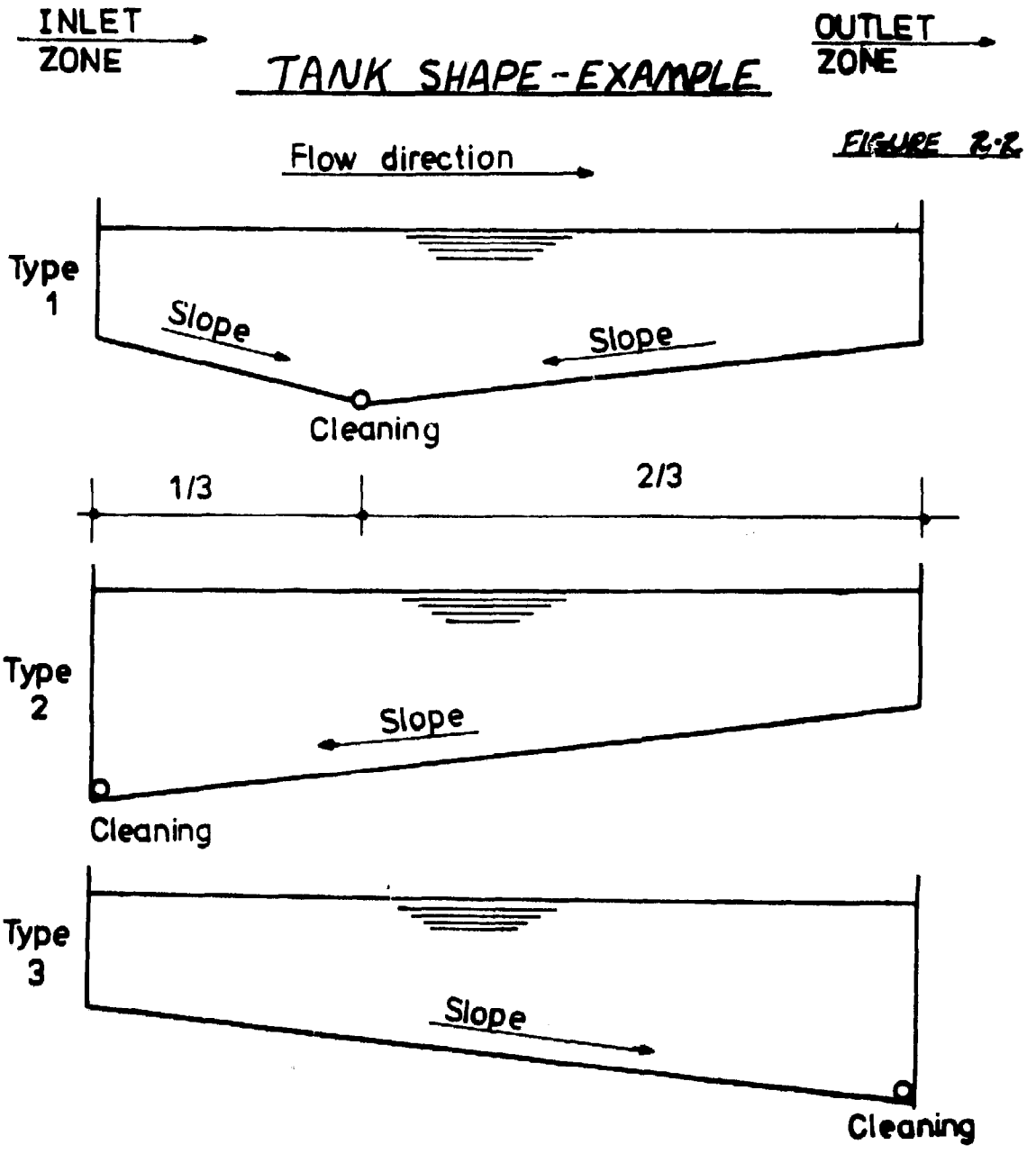

INLET PLAN VIEW

FIGURE 2.3

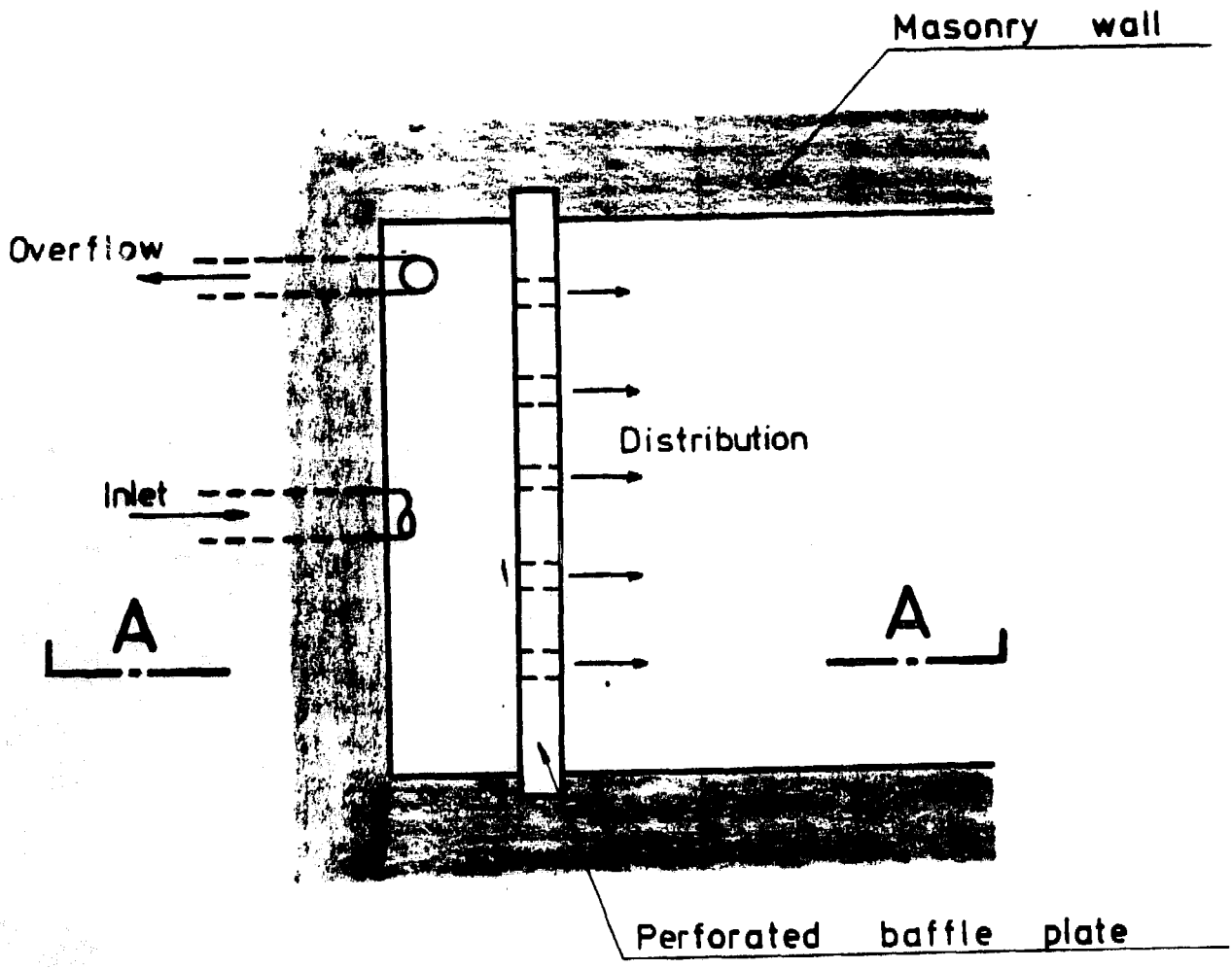

INLET CROSS SECTION A-A

FIGURE 2.4

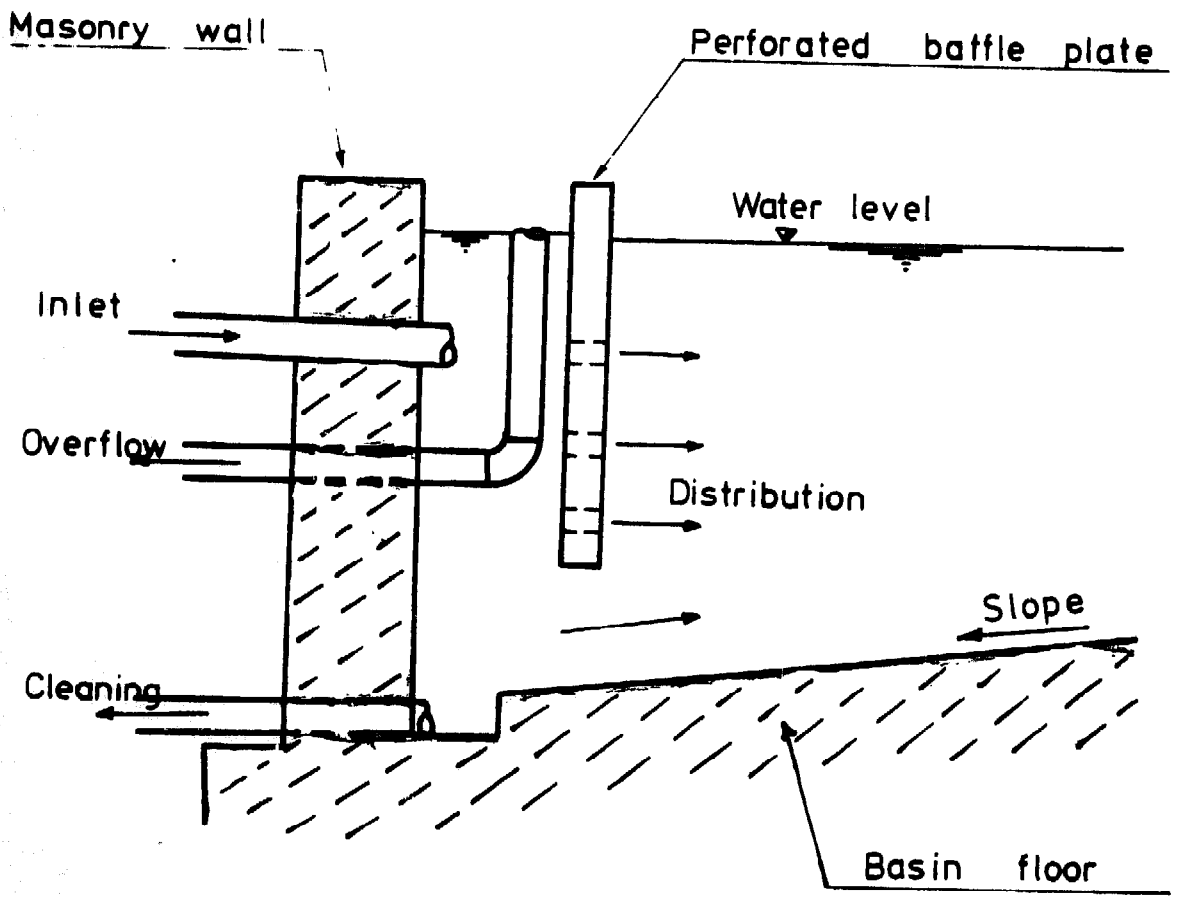

OUTLET CROSS SECTION

FIGURE 2·5

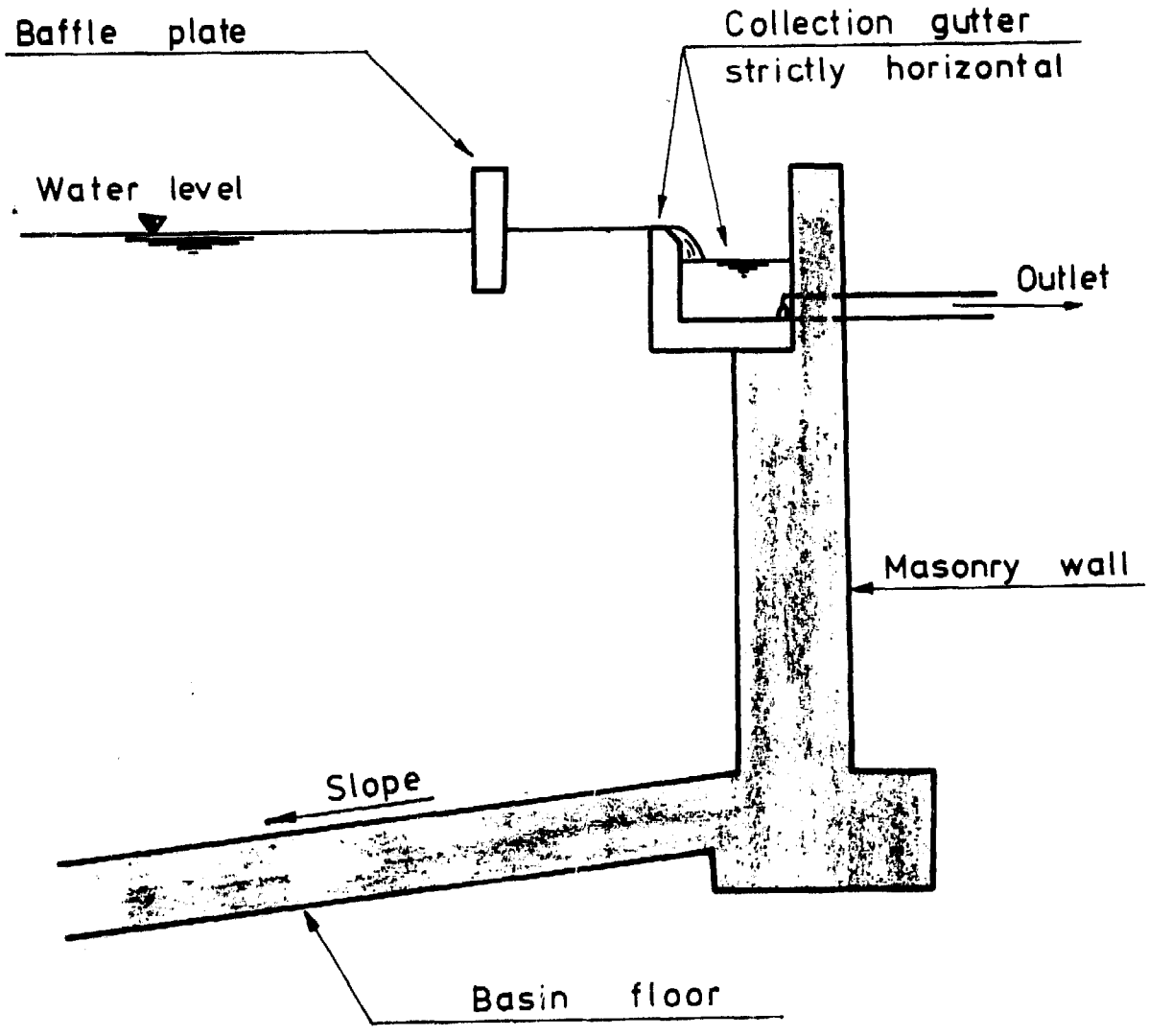

SEDIMENTATION TANK DETAIL

FIGURE 2·6

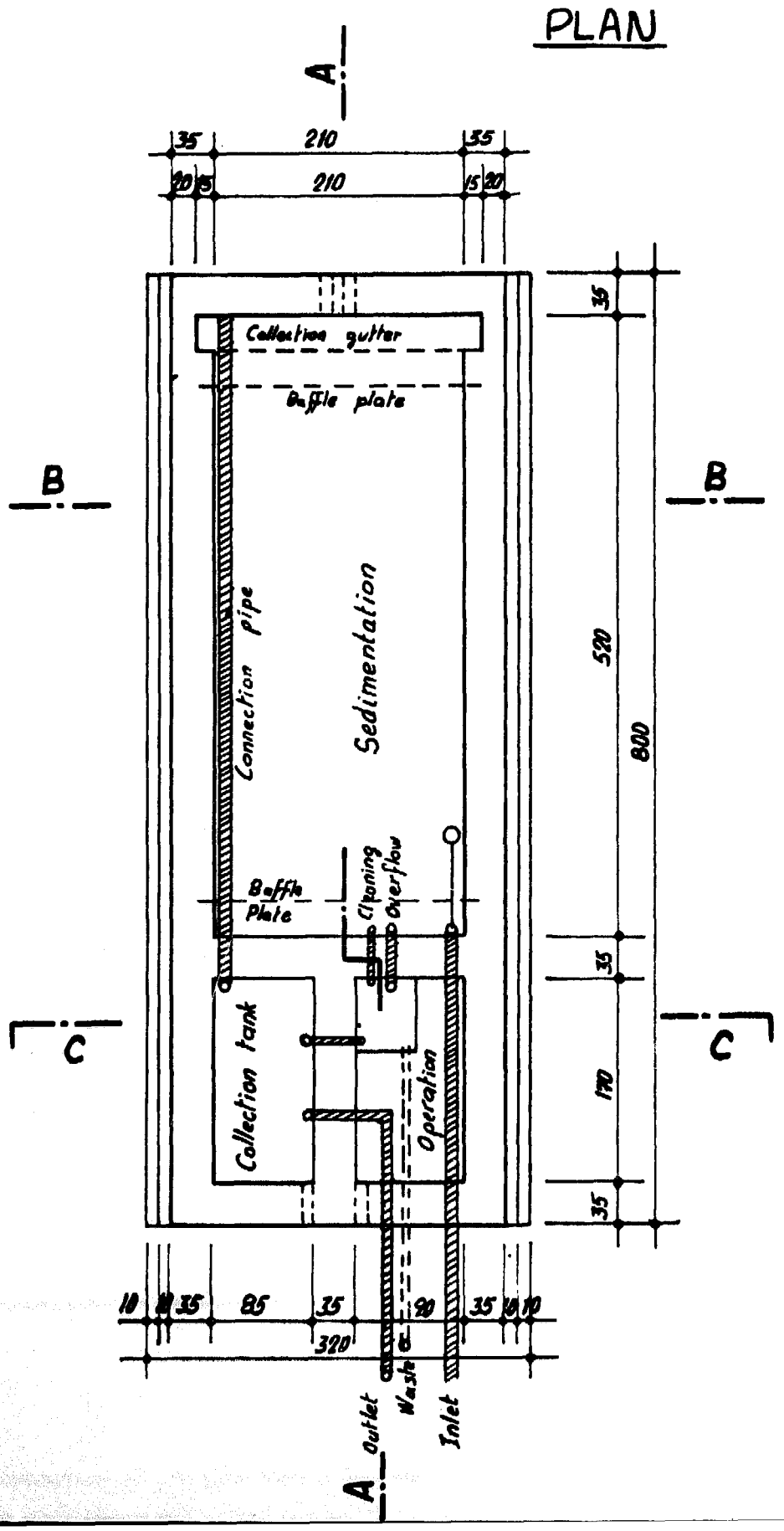

SEDIMENTATION TANK DETAIL

FIGURE 2.7

SECTION A—A

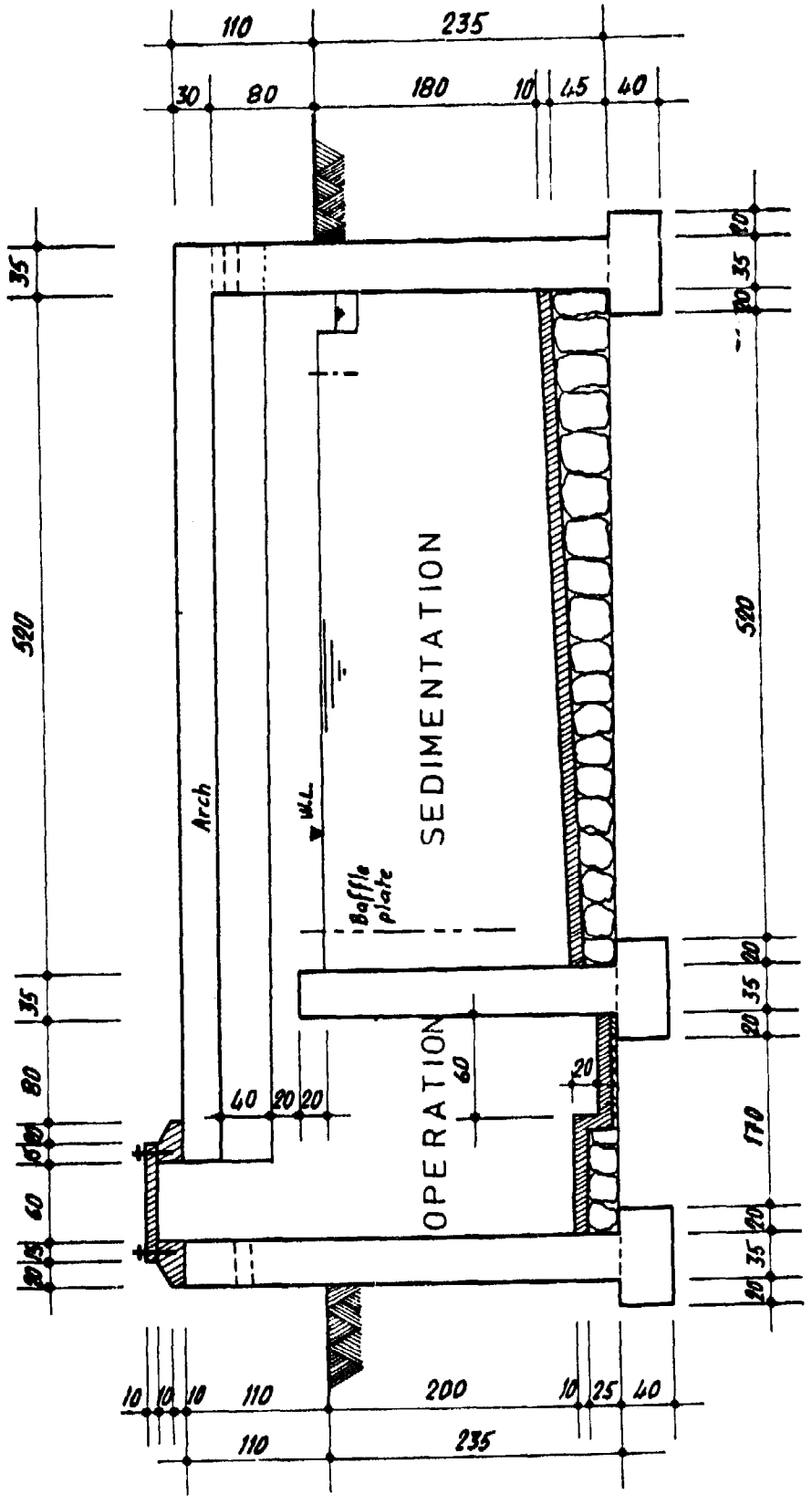

SEDIMENTATION TANK DETAIL

FIGURE 2·8

CROSS SECTION B—B

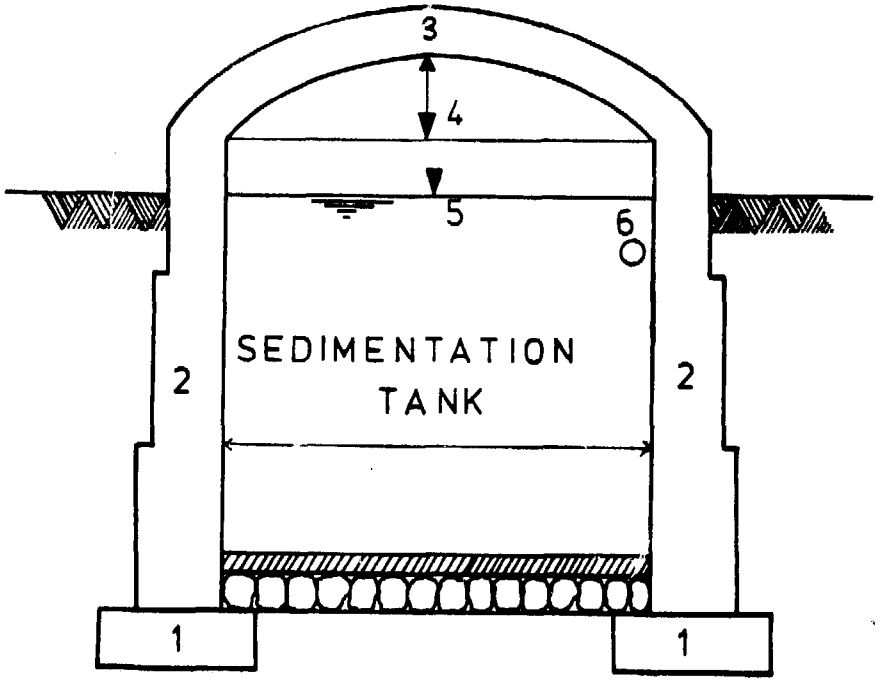

1-STONE MASONRY FOUNDATION
2-STONE MASONRY WALLS
3-STONE MASONRY ARCH
4-ARCH RISE
5-WATER LEVEL
6-CONNECTION PIPE

LEGEND:

Concrete

Hard core

Masonry

SEDIMENTATION TANK DETAIL

FIGURE 2.9

SECTION C—C

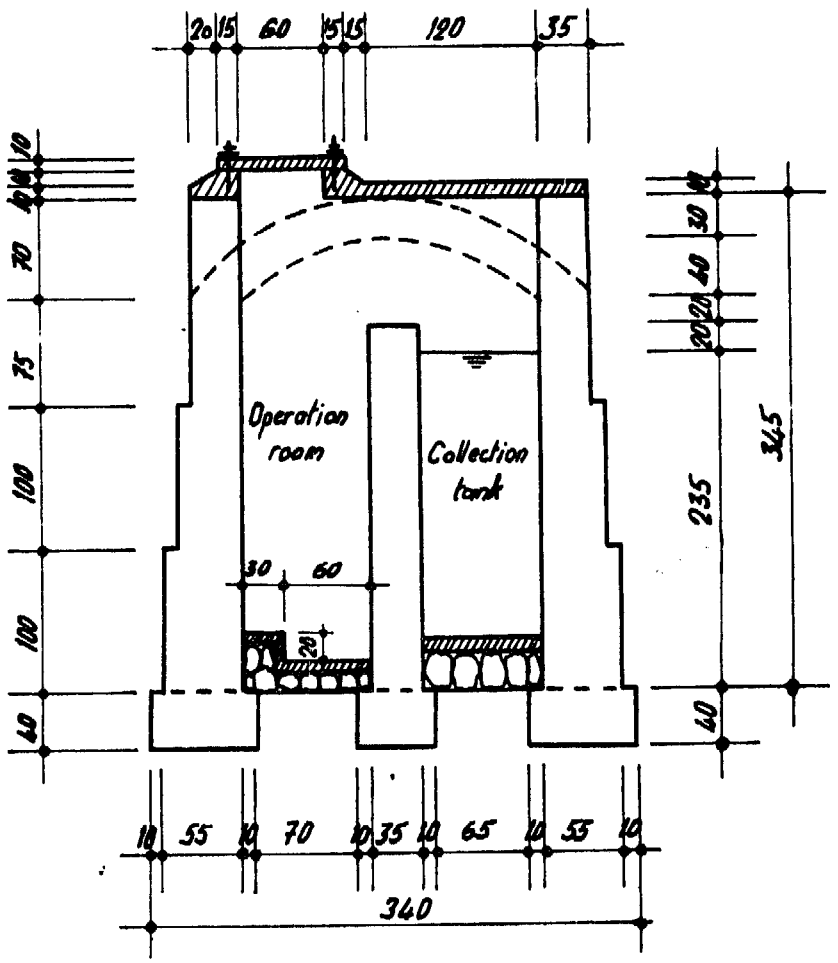

CONCRETE

STONE (HARD CORE)

STONE MASONRY

3. STORAGE TANKS

3.1 General Points, and Hygienic and Operational Requirements

A storage tank should always be constructed in a water supply system, for the following reasons:

a. To plan for variations in the rate of consumption at different times during the day. The spring will be producing water continuously during 24 hours, but the time during which water is distributed is only about 13 hours, with a high demand in the morning and evening.

   The typical pattern of draw-off in a Nepalese village is as follows, although local customs cause variation in consumption:

From	To	% of daily demand
5 am	8 am	40%
8 am	4 pm	20%
4 pm	6 pm	30%
6 pm	5 am	10%

b. To enable the pipe line from the catchment area to the storage tank to be cleaned without stopping distribution to the village.

c. To enable the diameter of the pipe-line from the catchment to be reduced.

The capacity of a storage tank is influenced by two main factors.

a. The need to cover the peak demand periods.

b. The need is to provide a reserve of water to cover break-down of supply, or normal interruptions due to maintenance work.

Hygienic Requirements

Water in the tank should be protected against external influences, and a good circulation of water ensured. Ventilation should be provided, but any doors or entrances must be insect proof.

Operational Requirements

An operation chamber as well as the storage room has to be provided. The supply must continue during cleaning work. Therefore tanks bigger than 38 cubic meters should have two independent chambers each with an overflow capable of draining all the incoming water. Each chamber has to be provided with a cleaning outlet to allow complete draining.

3.2 Siting the Tank

A site for the storage tank should be chosen which is as close as possible to the area where the highest consumption will occur. The tank should be between 20m. to 50m. above the area which will be supplied, although this elevation difference is only valid for pipelines which have a working pressure rating of 6kg./sq.cm. or less. In such cases, if the head difference exceeds 60m. break pressure tanks will be necessary.

3.3 Design and Capacity

Storage tanks are constructed square or rectangular. Stone masonry storage tanks are more economical if built in a circular shape. The following designs, however, are all for square tanks $9m^3$ or $22m^3$.

For rural water supply in Nepal storage tank size has been standardised as follows:

- Storage tank $2.5m^3$
- Storage tank $9m^3$
- Storage tank $16m^3$
- Storage tank $22m^3$
- Storage tank $30m^3$
- Storage tank $38m^3$

The water depth in tanks less than 100 cubic meters should not exceed 2m. by 2.5m.

Pages 34 through 44 describe storage tank design and give details of fittings used.

FIGURE 3·1: STORAGE TANK $9m^3$ DETAILS

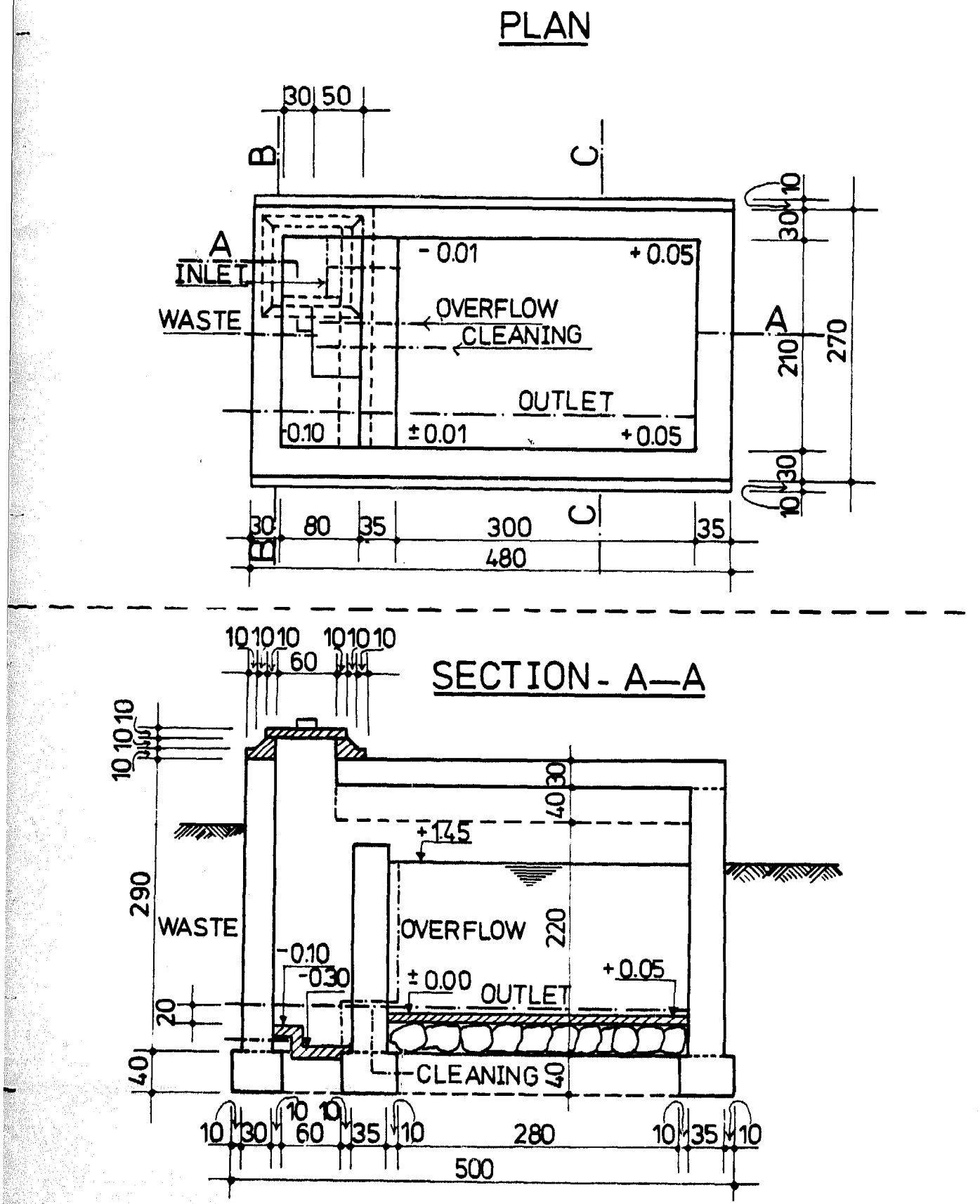

FIGURE 3·2 – STORAGE TANK 9m^3 DETAILS

SECTION - B–B

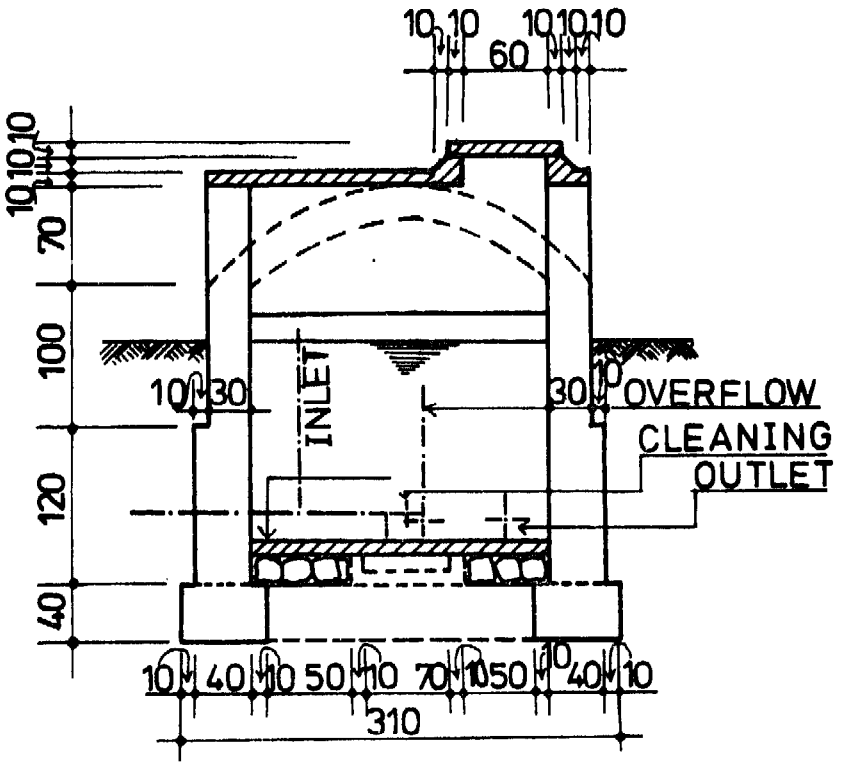

SECTION - C–C

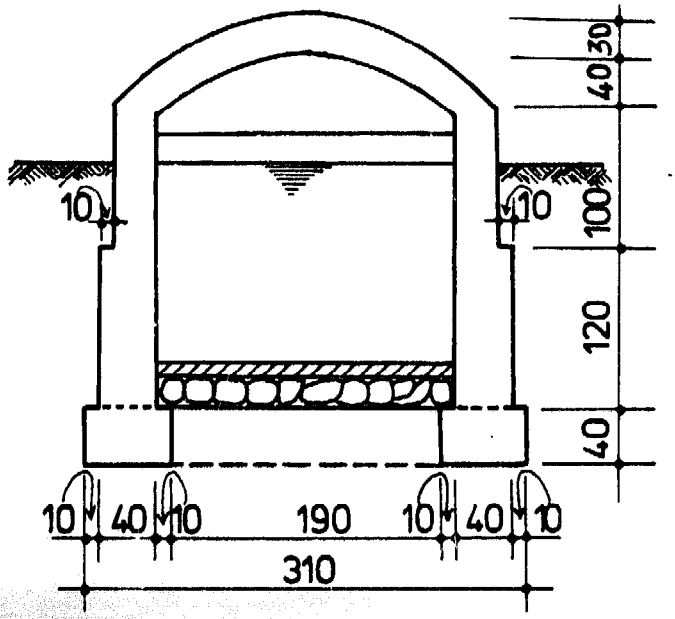

FIGURE 3.3 – TANK, 9M³ INSTALLATION DETAILS

INLET

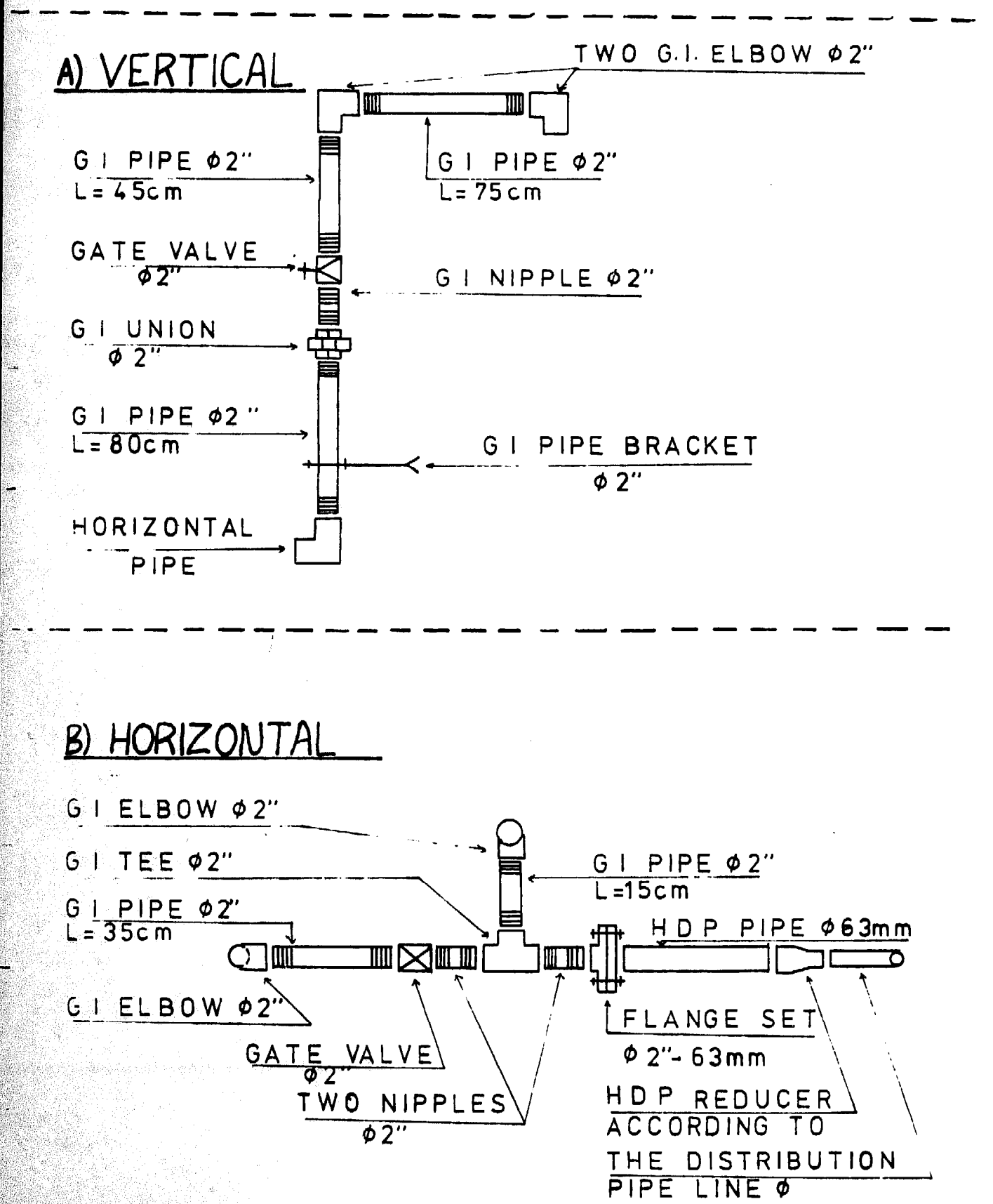

FIGURE 3.4

TANK 9m3 INSTALLATION DETAILS

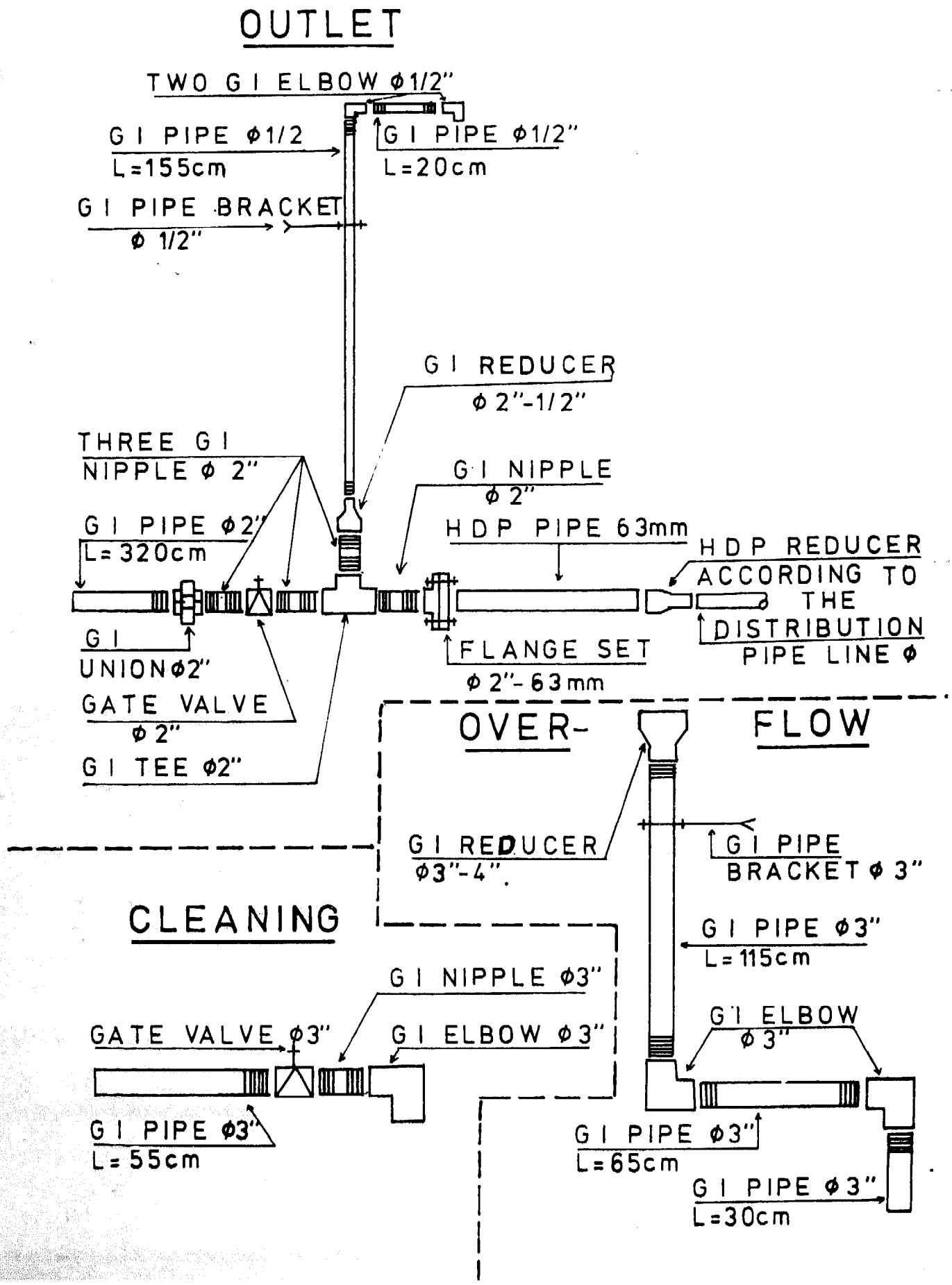

FIGURE 3·5

STORAGE TANK 22m³ DETAILS

PLAN

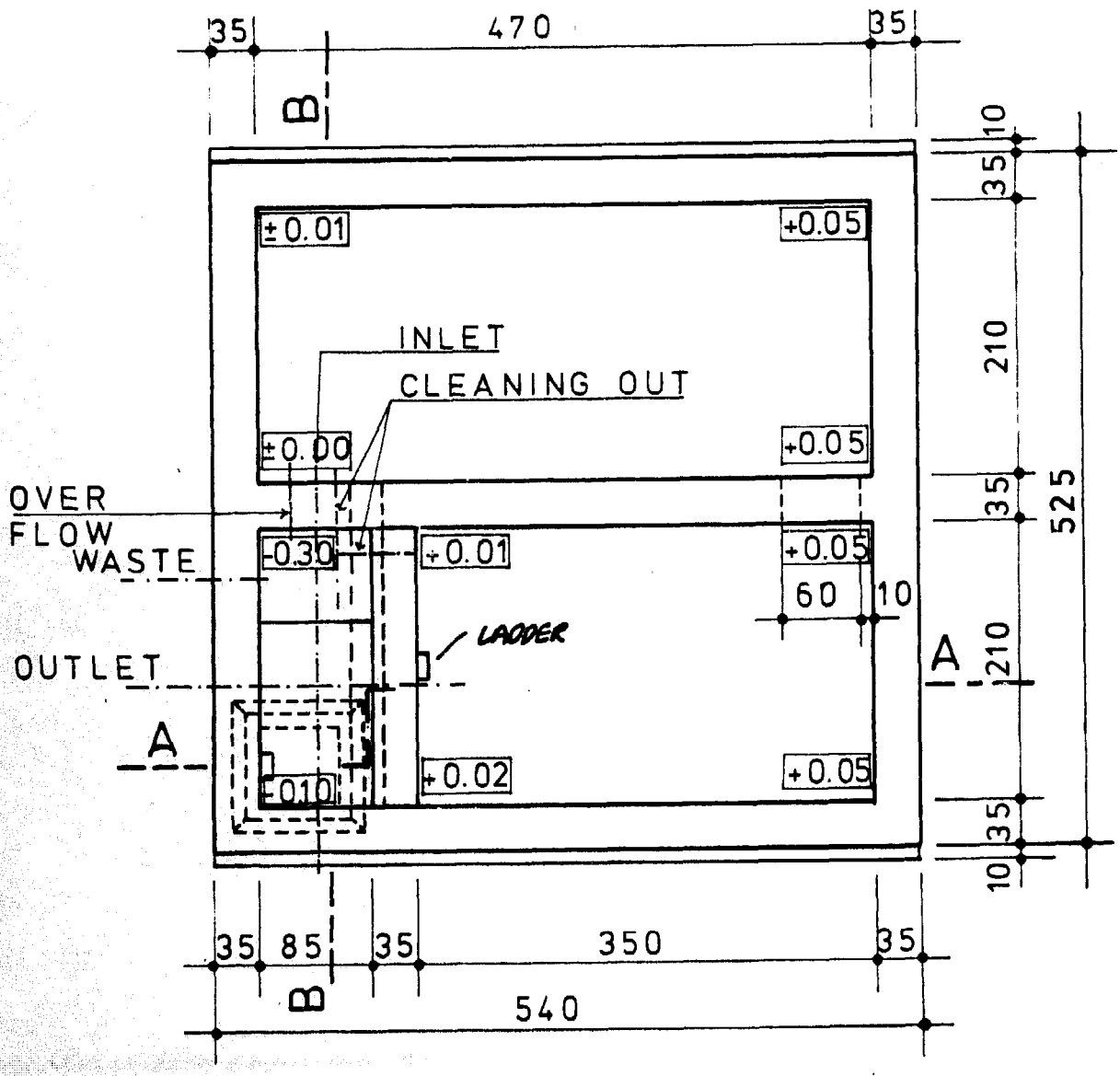

FIGURE 3.6

STORAGE TANK 22m^3 DETAILS

SECTION A—A

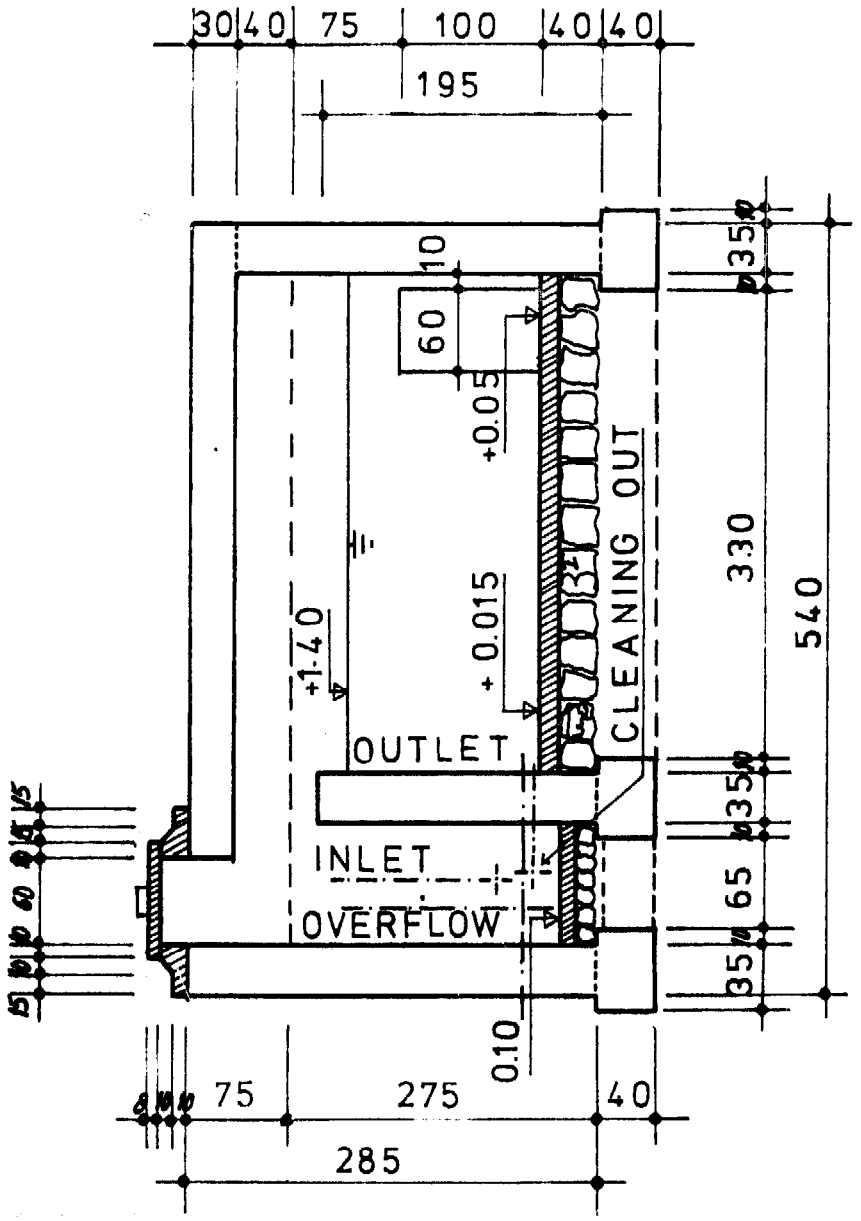

FIGURE 3.7

STORAGE TANK 22m^3 DETAILS

SECTION B—B

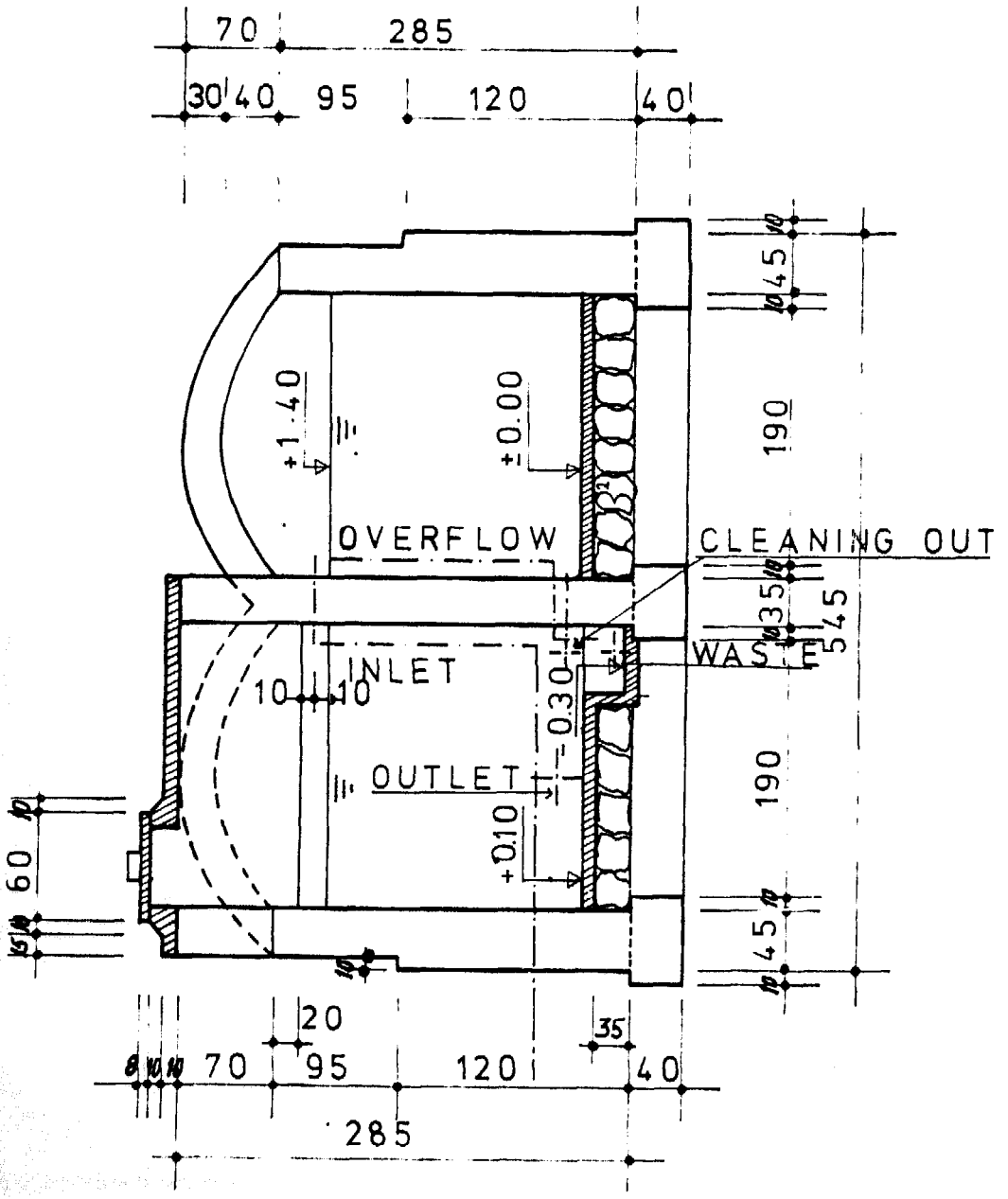

FIGURE 3·8 – TANK 22m^3 INSTALLATION DETAILS

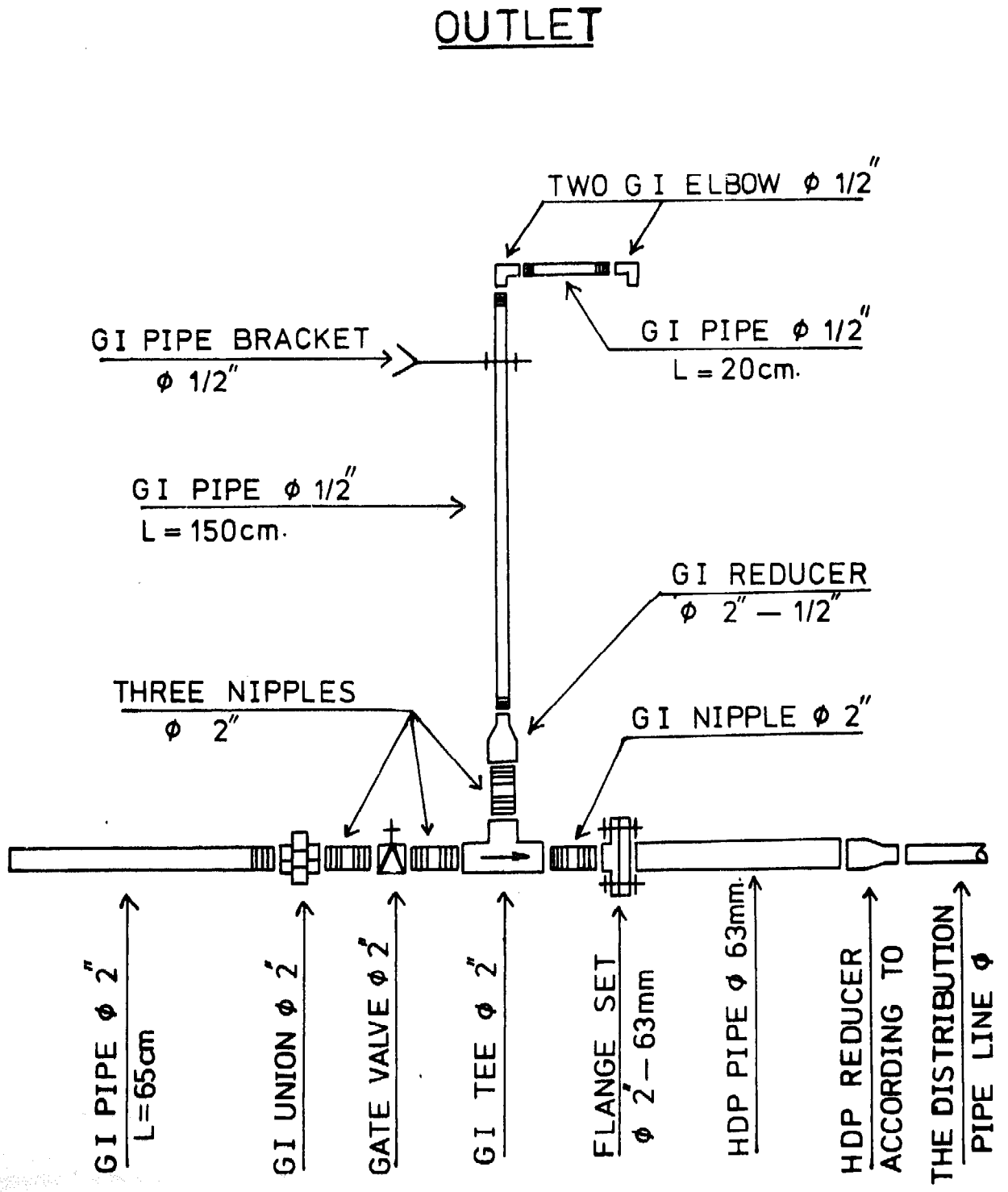

FIGURE 3.9-TANK 22m^3 INSTALLATION DETAILS

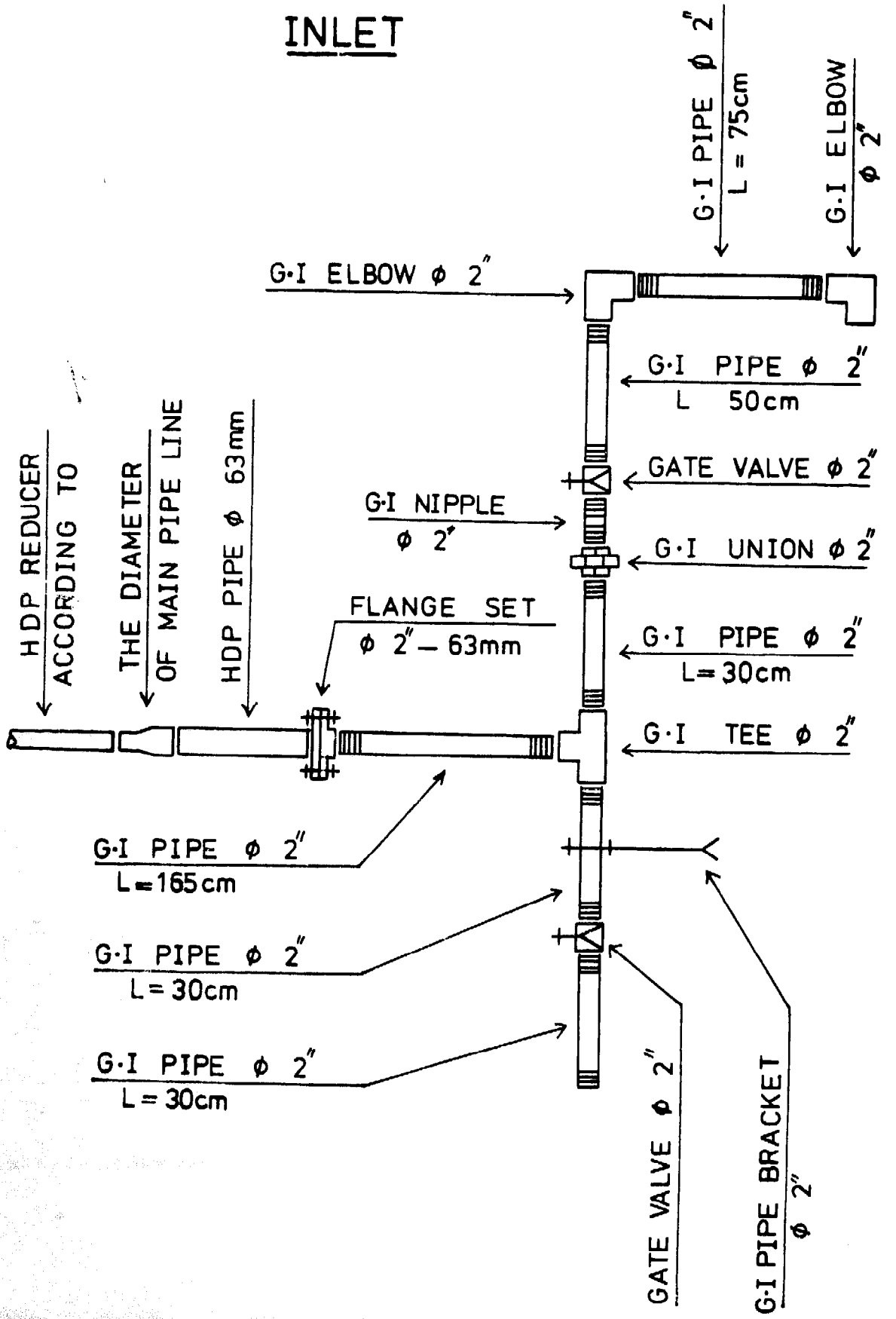

FIGURE 3·10—TANK 22m^3 INSTALLATION DETAILS

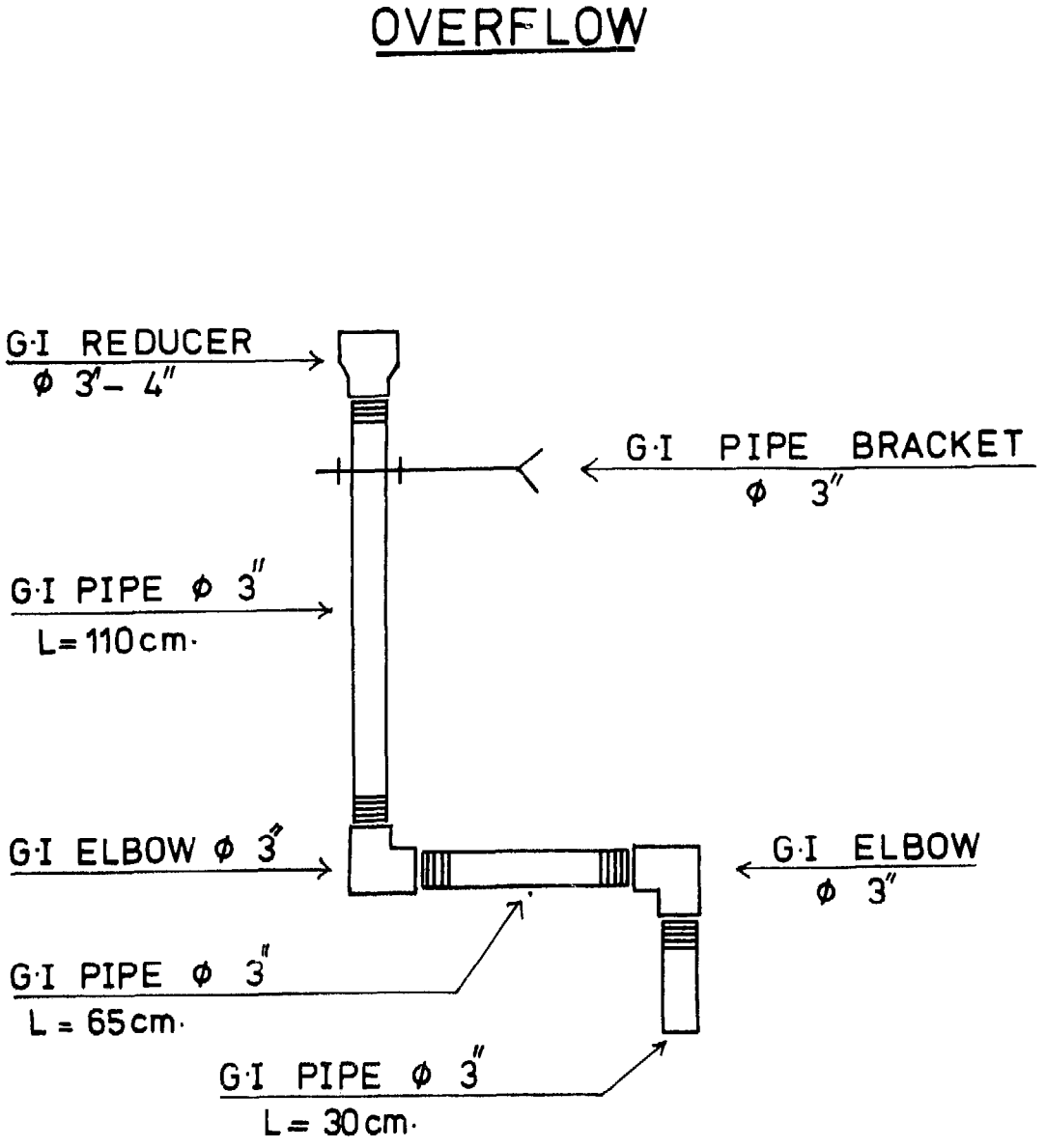

FIGURE 3.11 – TANK 22 m^3 INSTALLATION DETAILS

CLEANING

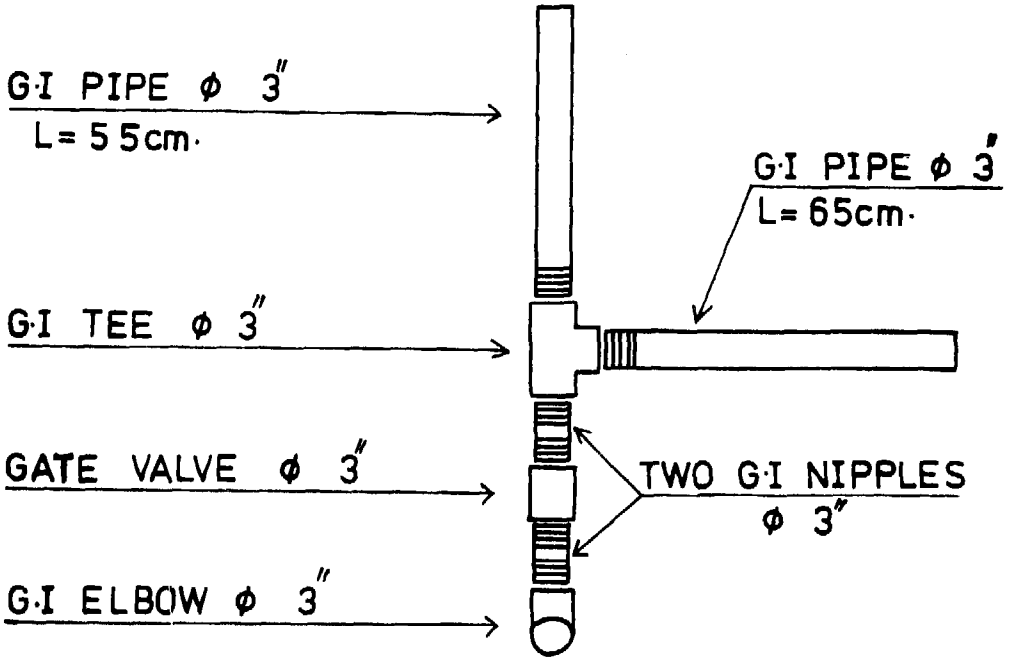

4. PRESSURE REDUCING INSTALLATIONS

4.1 Pressure Reducing Pipe

When pressure is too high a pressure reducing pipe can be built. But this should be only done if it is certain that valves cannot stop the pressure in the main. There are two main kinds of pressure reducer.

a. A special reducing valve,

b. A construction made from a piece of steel pipe of very small diameter. The length can be varied according to need. This will bring the pressure down to the required value. The exact length and diameter of the small pipe will be given by the engineer in charge of the project.

This second solution is recommended in Nepal, because the special valve needs a high quality of maintenance and spare parts which are not available here. Look at the diagram on pages 47 and 48 for details of the design of a pipe like this.

4.2 Break Pressure Tank

A break pressure tank, or interruption chamber, is built in order to bring the water back to atmospheric pressure. This means that the water pressure (hydraulic gradient) will be reduced to zero.

A stone or concrete baffle plate should be located in front of the inflow pipe. This disperses the energy of the water as it comes in under pressure. The plate should be built in such a way that it will be easily removable. The inlet can also be built with a float valve to ensure that water is not wasted. This valve will eliminate the need for a baffle.

As the design on page 49 shows, access to the break pressure tank should be made through the operation chamber, and not from a man-hole directly over the tank. Access from a point directly over the water surface could cause water pollution. GI pipes and fittings should be used as inflow and outflow pipes to and from the tank.

An overflow system with the capacity to remove the maximum quantity of water which is likely to overflow should be included. The overflow water should be disposed of in such a way that it will not cause soil erosion.

The location of the tank and its technical specifications will be given by the engineer in charge of the project. Details of the tank and its fittings are given on pages 49 through 53.

FIGURE 4·1 – PRESSURE REDUCER

SECTION

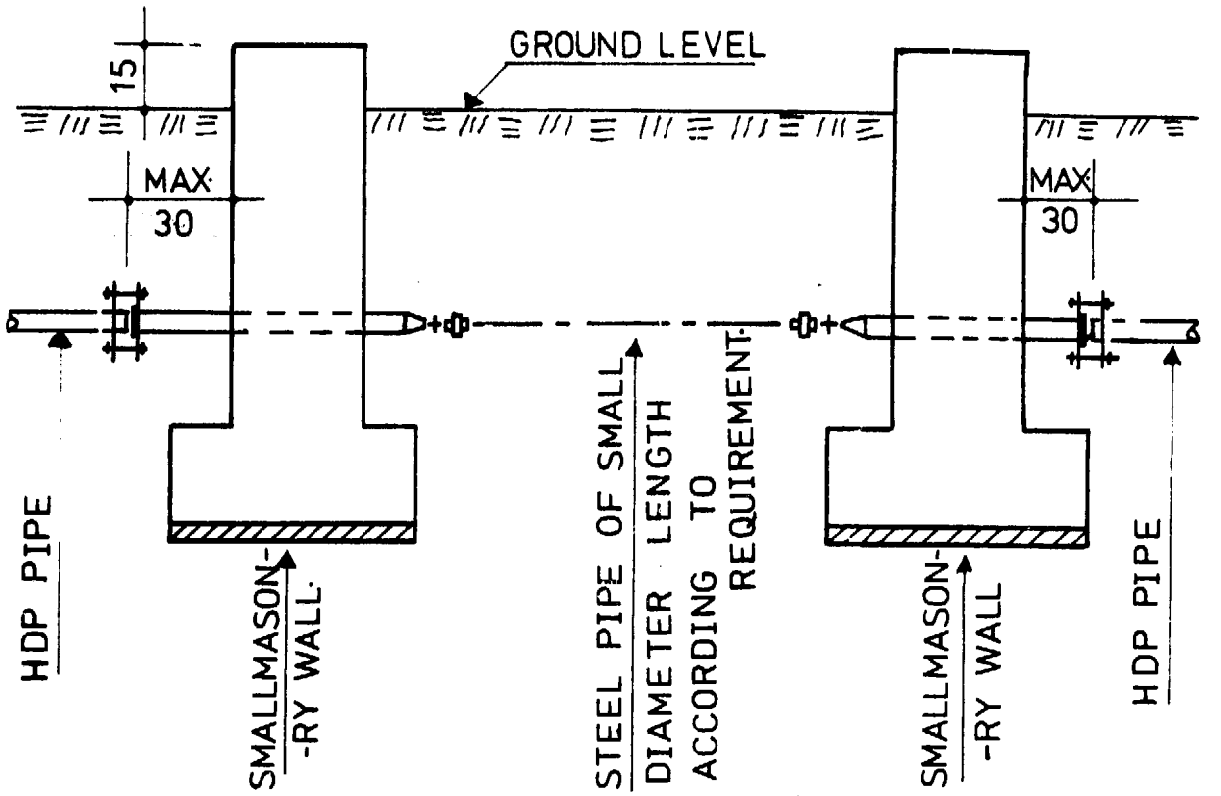

PRESSURE REDUCER

FIGURE 4.2

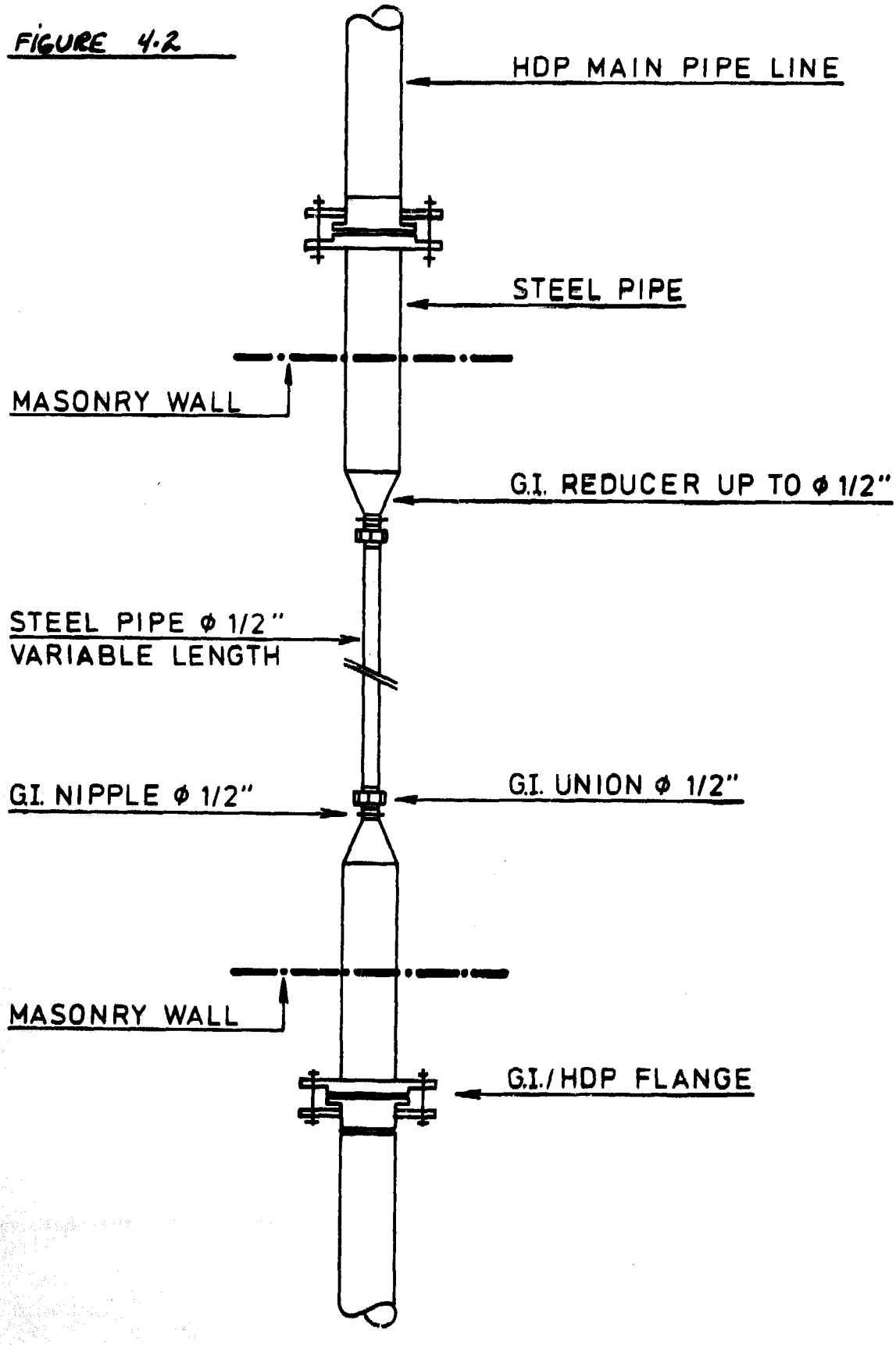

BREAK PRESSURE TANK DETAILS

FIGURE 4.3

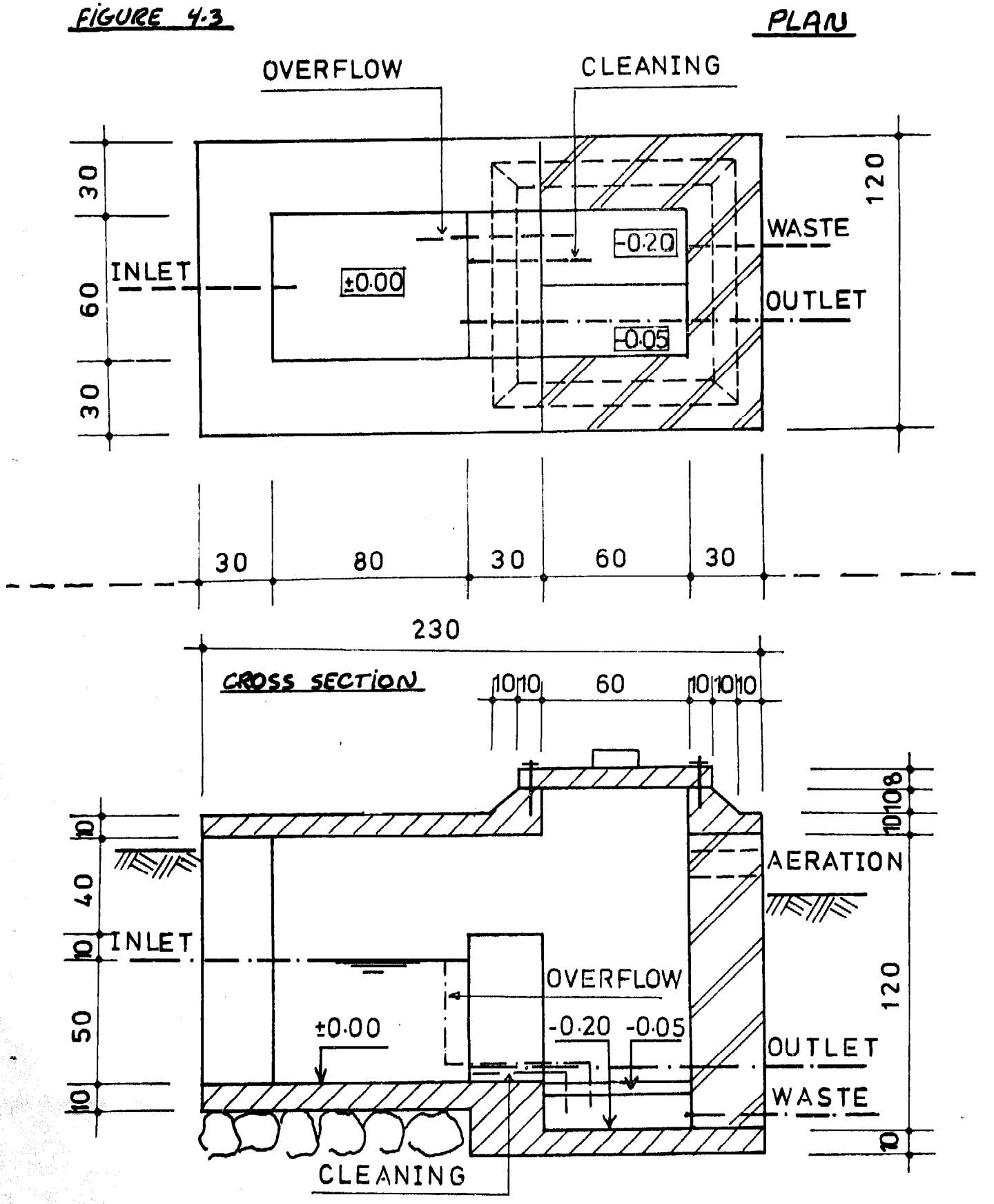

REMARK INLET INSTALLED WITH FLOAT VALVE

FIGURE 4.4 – BREAK PRESSURE TANK DETAILS

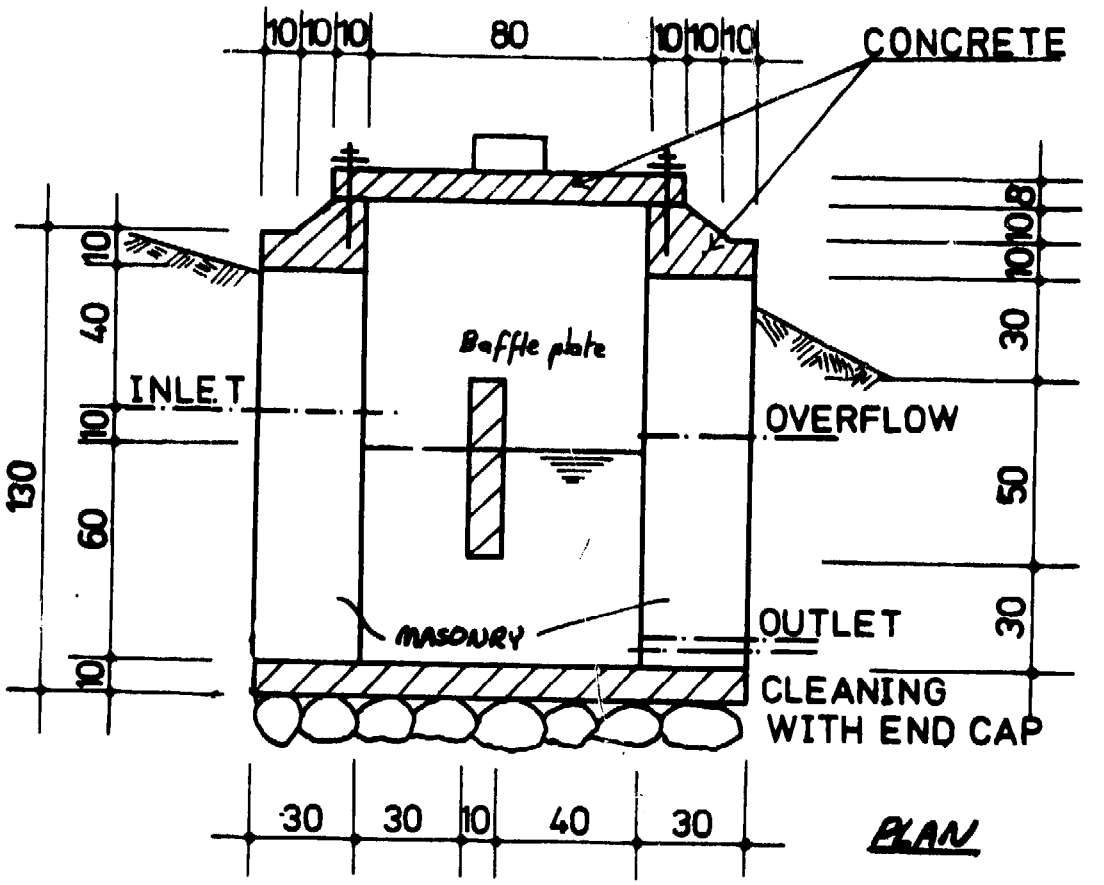

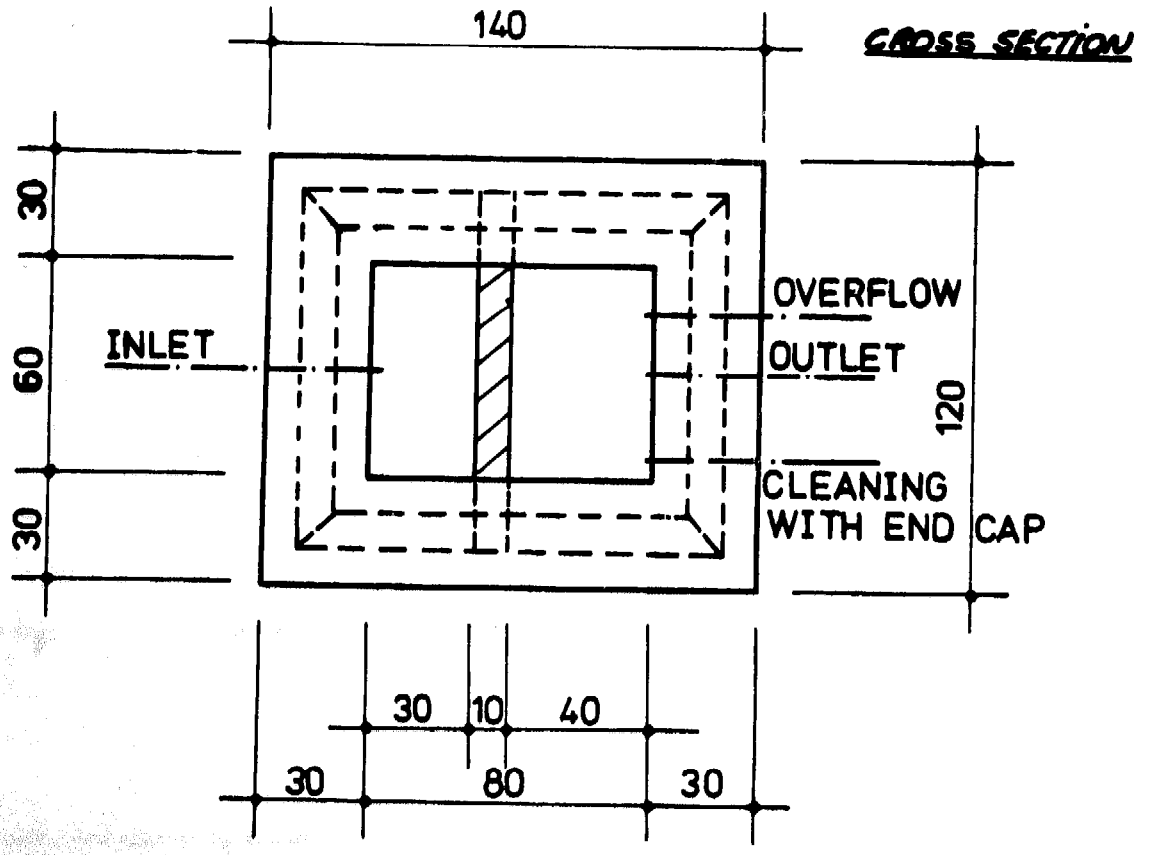

FIGURE 4.5 — BREAK PRESSURE TANK INSTALLATION DETAILS

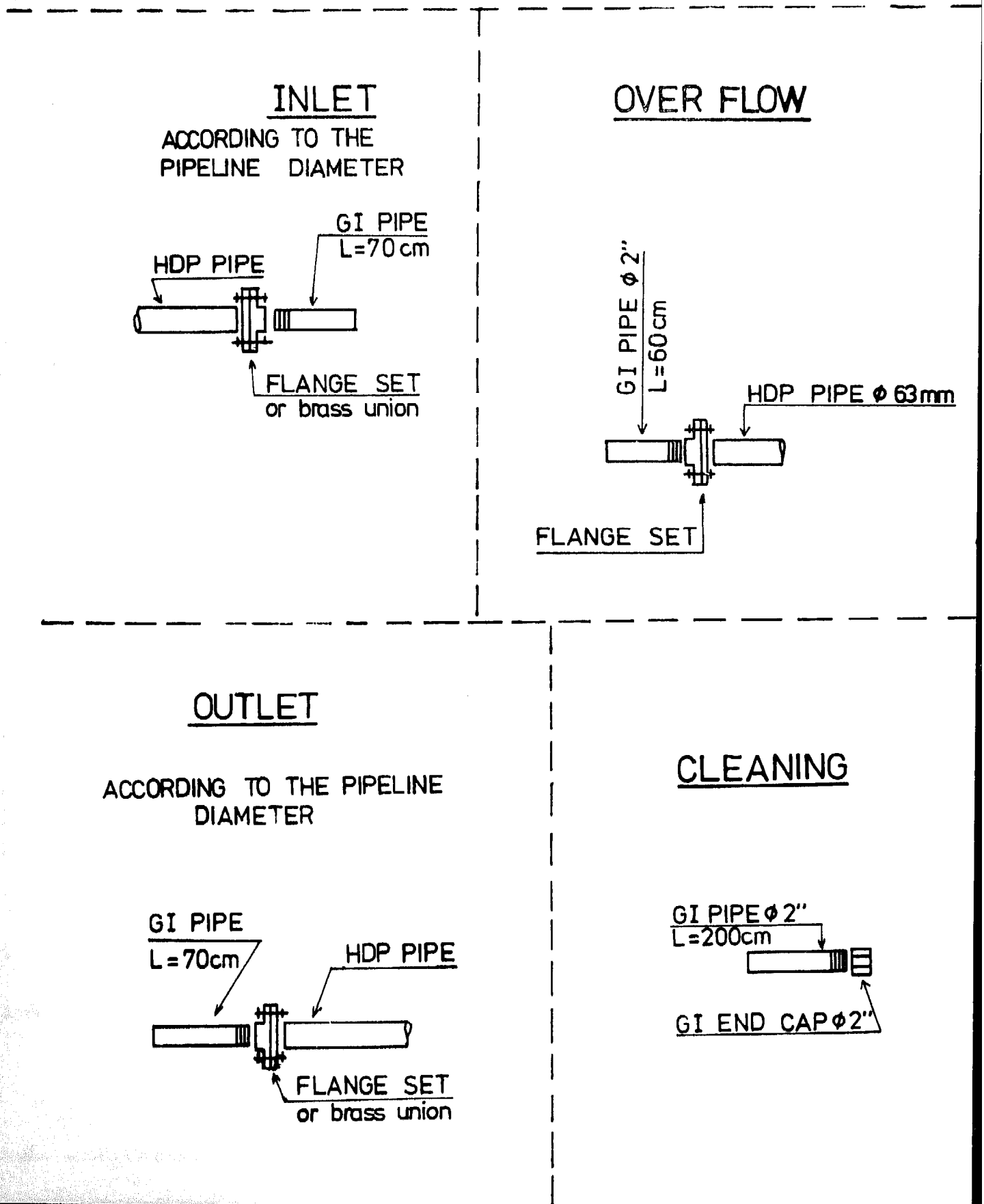

BREAK PRESSURE TANK INSTALLATION DETAILS

FIGURE 4-6

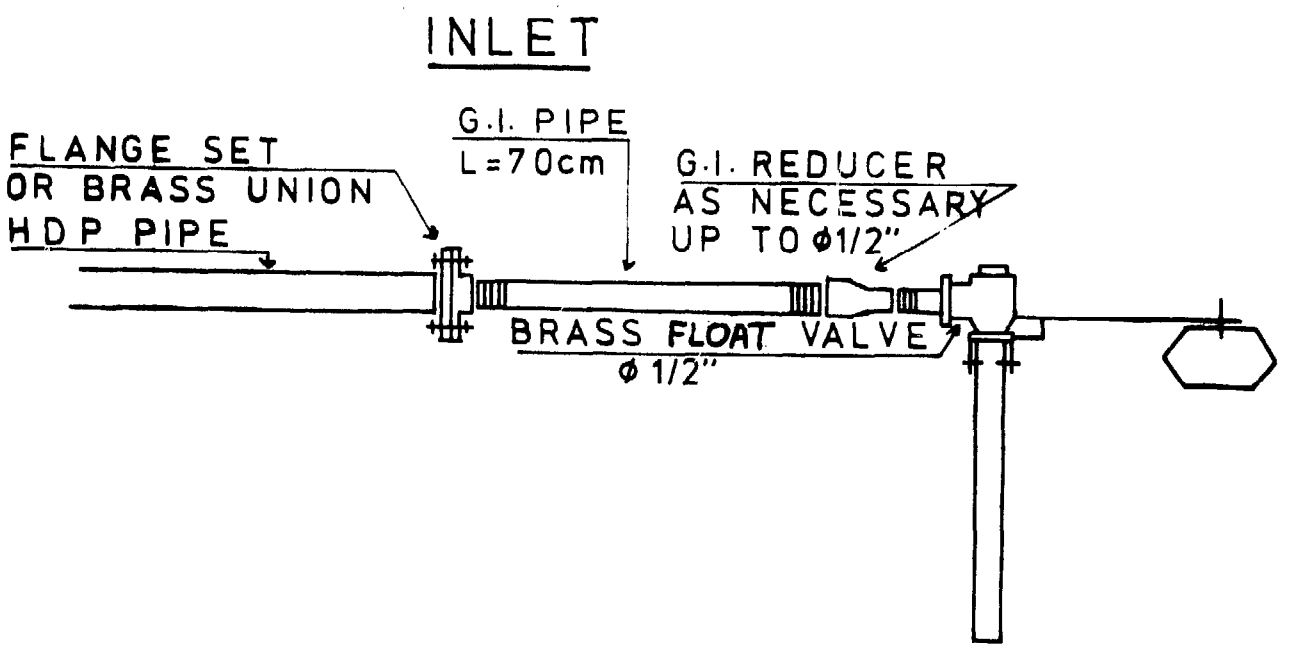

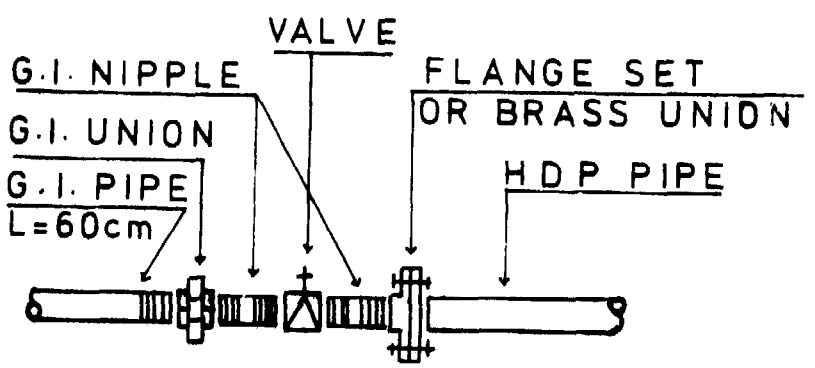

FIGURE 4.7 — BREAK PRESSURE TANK INSTALLATION DETAILS

OVERFLOW

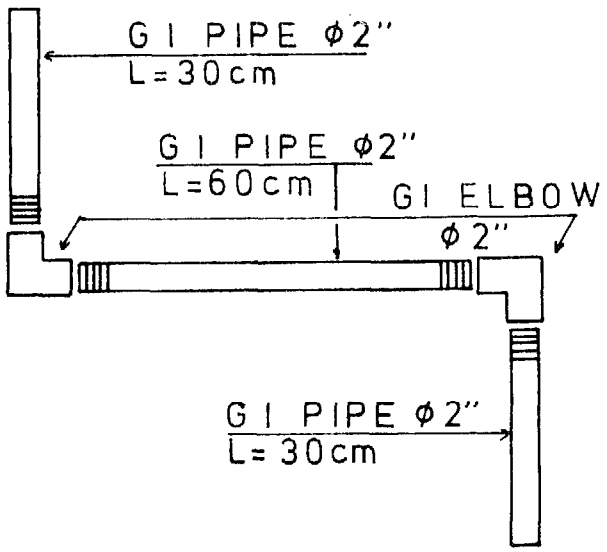

CLEANING

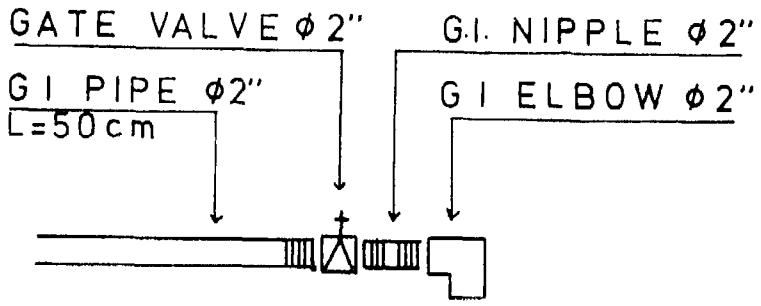

5. DISTRIBUTION: THE PIPELINE

5.1 General Points

The aim of the pipeline is to transport the water safely, without introducing contamination, to the different places of consumption. There can be several problems in trying to fulfill this aim, arising from air pockets, pressure, velocity of water and the need to control the water. Pressure problems have been dealt with. The other subjects will now be dealt with in turn.

There are four different kinds of distribution pipe. Each has a different function.

a. Supply main - This is the main pipeline bringing the water from the source to the storage tank. In village water schemes in Nepal, the water flows by gravity.

b. Distribution main - This is the main pipeline bringing the water from the storage tank to the village for distribution.

c. Ring main - This is a distribution pipeline which joins two distribution mains to form a ring system. The advantages of constructing a ring main are that it reduces the need for large diameter for the distribution main. It maintains pressure well, gives a good flow of water, and avoids stagnation of water in the dead end of the distribution main. It also gives more flexibility to the distribution system, for example when repairs are necessary.

d. Service Pipe - This is an individual supply line laid in the ground, going to a stand pipe, a house or a farm.

There are three further requirements for a distribution pipeline. These are as follows:

- It must convey the required quantity of water
- It must be capable of withstanding considerable force resulting from water pressure and movement of the soil which surrounds the pipe.
- It must be durable, that is, be long lasting and tough.

5.2 Air In the Pipeline

Water always carries air bubbles and the presence of air in the pipeline can cause serious blockages of water flow, even when a pipe has a big diameter. Air-blocks can happen for the following reasons:

a. Where the static gradient is lower than 5 meters. (See the diagrams on pages 56, 57 and 58 for an illustration of this).

b. At high points in the pipeline.

c. If there is no air outlet after the storage tank outlet.

d. If the pipe is too large. The pipeline should not be bigger than either the size of the inflow or the source of the water supply. If it is, tanks will become empty very quickly, then when the top of the outlet pipe is not covered with any water, air will be sucked into it. This reduces the capacity of the pipeline until inflow to the tank becomes bigger than outflow again. Then the water level in the storage tank gradually increases until it is level with the pipeline, and water flows out again. Since the capacity of the outflow remains greater than inflow the process repeats itself again and again. Then the caretaker will have to be constantly opening airvalves to release the accumulated air.

FIGURE 5·1 – PIPELINE PROFILE

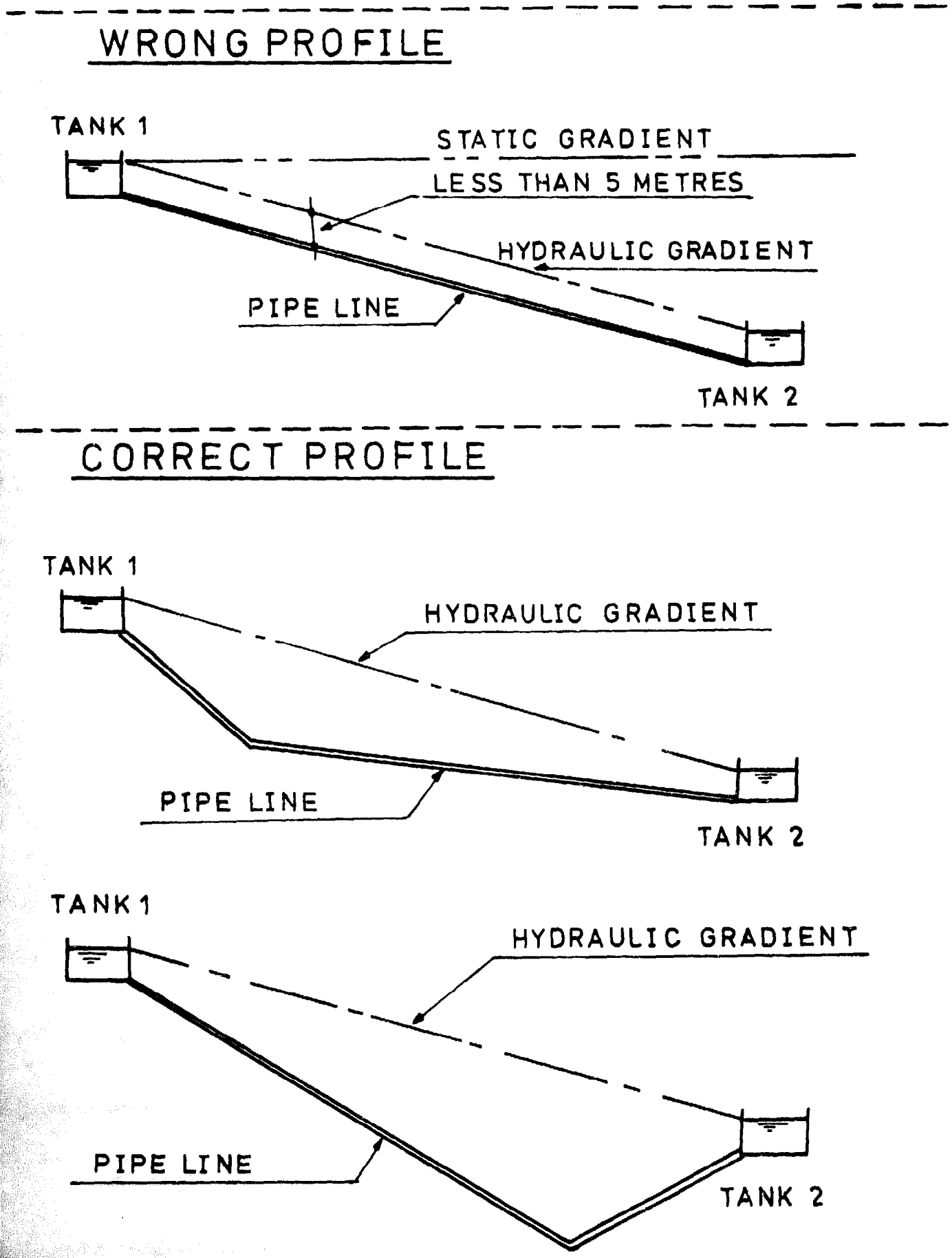

FIGURE 5·2 — PIPELINE AERATION

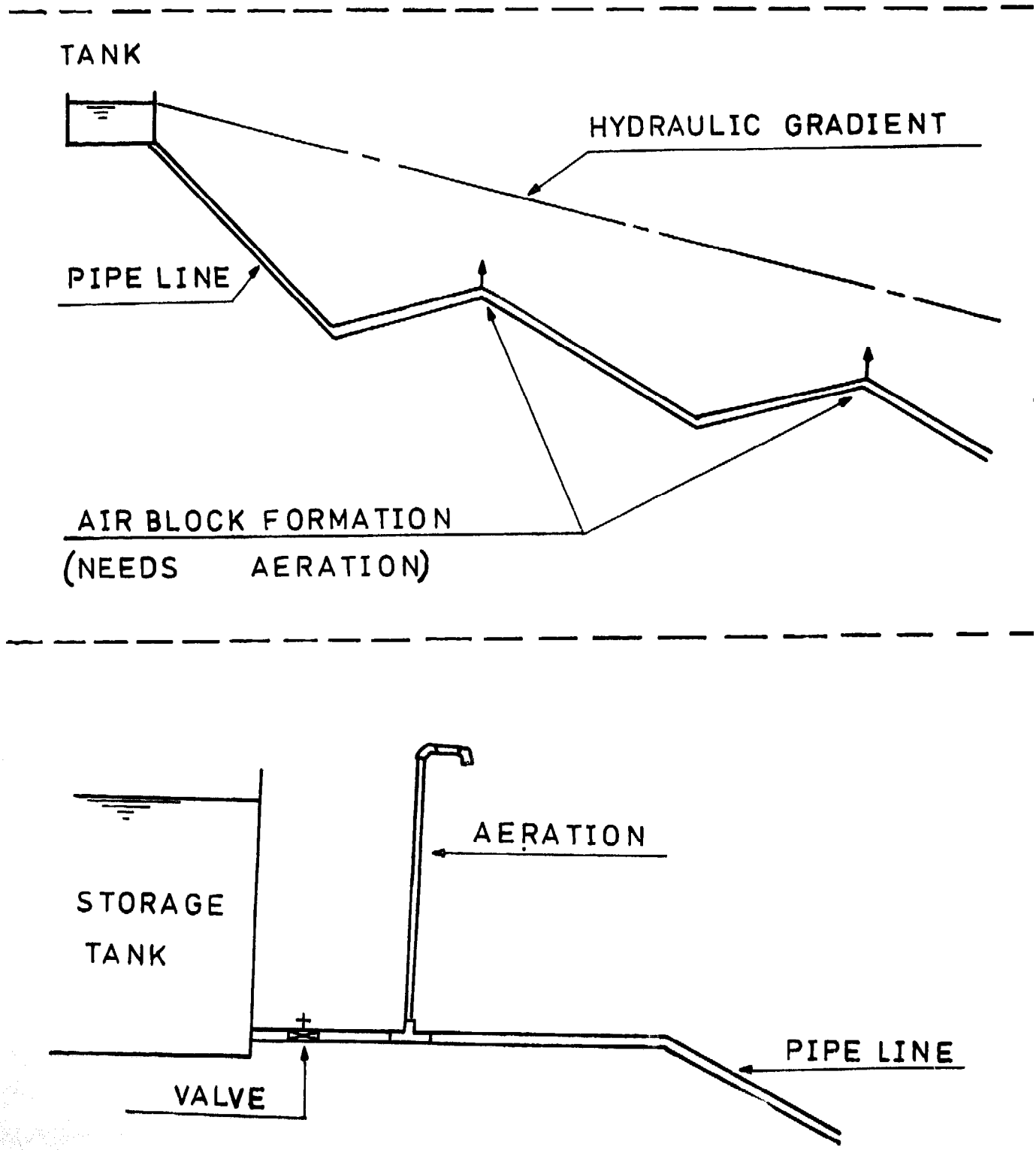

AIR VALVE INSTALLATION DETAILS

FIGURE 5·3

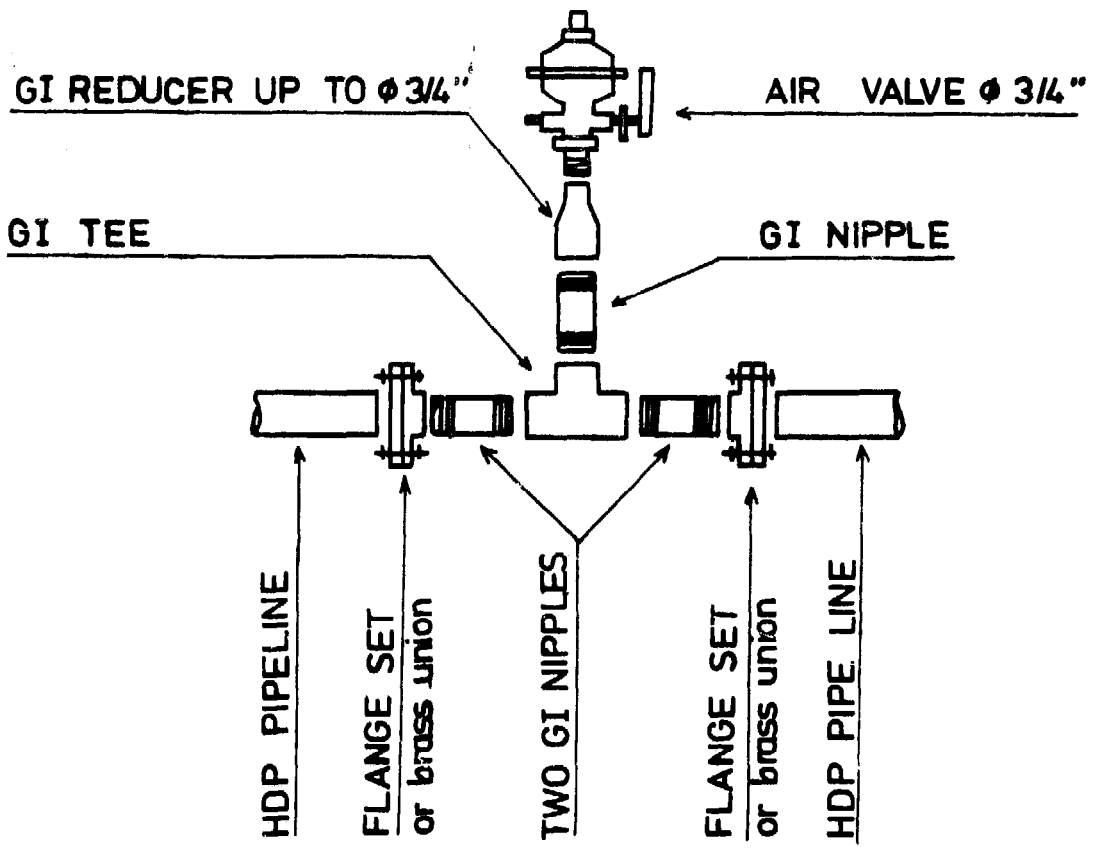

NOTE: IN ORDER TO MAKE THE AIR-VALVE FIT THE PIPELINE, ONE OR MORE G.I. REDUCERS MAY HAVE TO BE USED.

5.3 Chambers for Valve and Tap Connections

Valves are used to control the flow of water. They should be located in a special chamber, which is referred to as a "valve box". They will be installed at intervals along a pipe line and at branches in it.

Look at the diagram on page 60 for drawings of a valve chamber. The details on pages 61 and 62 show how pipe-line connections are constructed, using valve boxes.

Stand pipes are connected to the main distribution pipe-line by small diameter pipe called a "service pipe". (See page 63). A stopcock should be fitted to the service pipe to allow the water to be controlled at the stand pipe. This stopcock should be installed directly after the connection from the distribution main.

This stopcock and the connection fittings are protected in a valve box which is referred to as "tap connection chamber". (See page 63).

VALVE CHAMBER

FIGURE 5·4

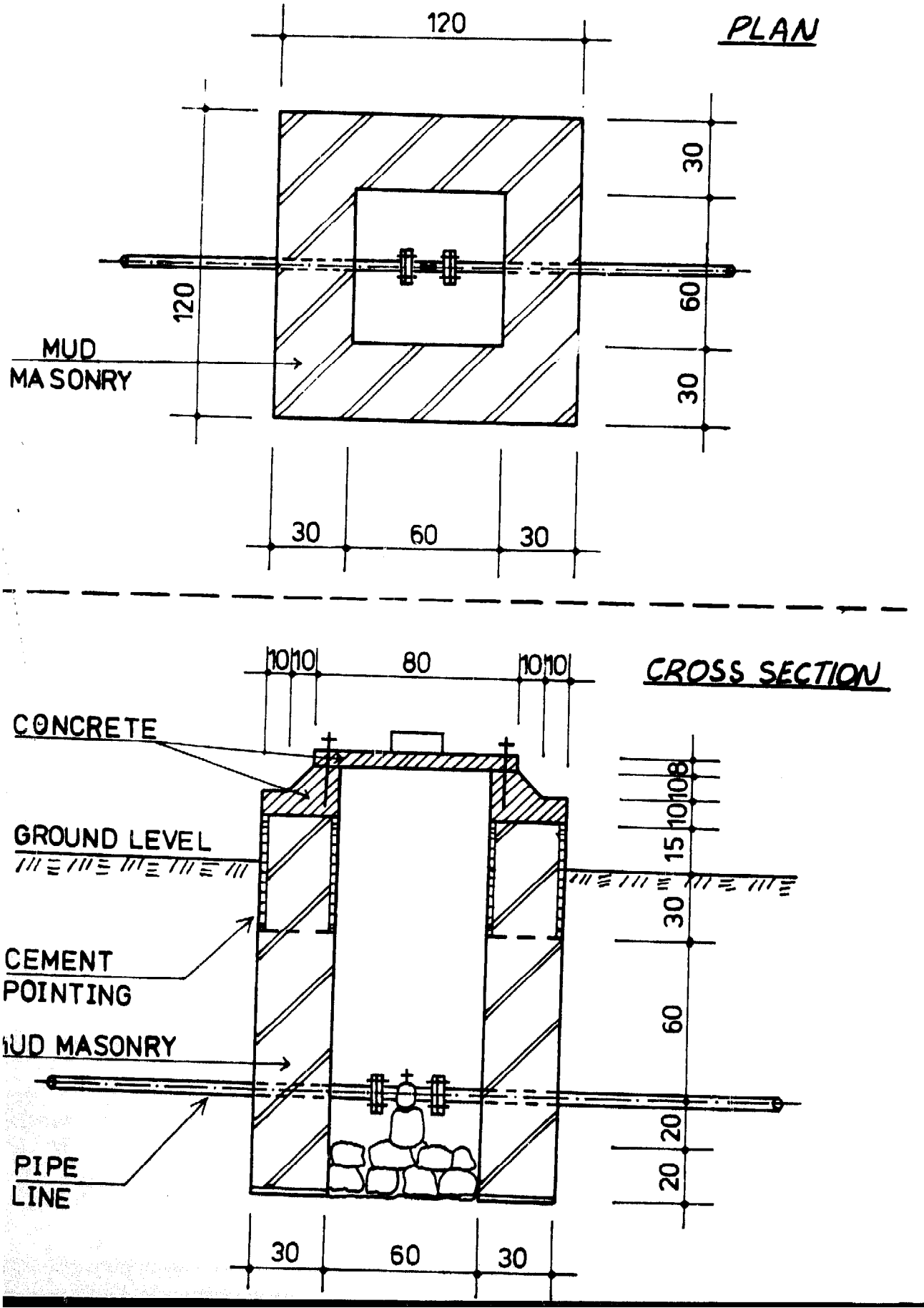

MAIN FLOW CONTROL VALVE INSTALLATION DETAIL

FIGURE 5·5

FOR PIPE LINE Ø32 mm

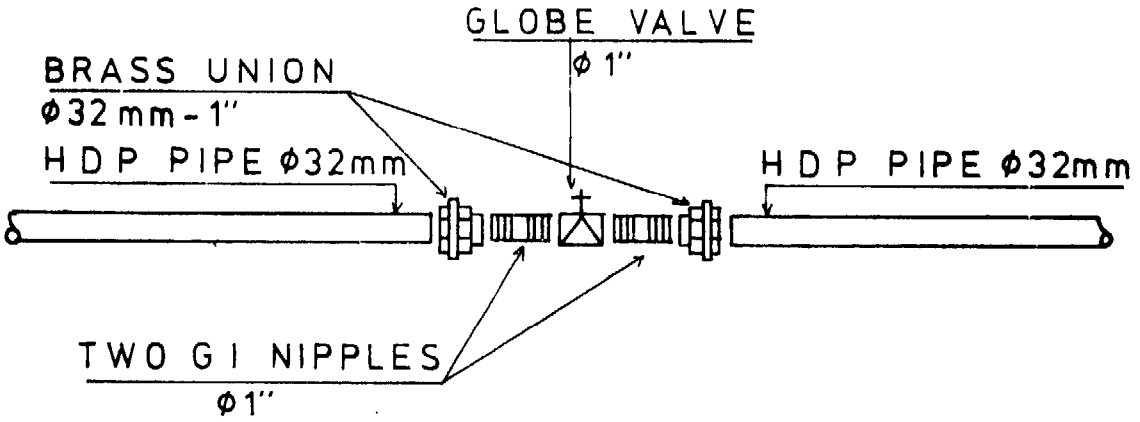

FOR PIPE LINE
Ø50 AND 63mm

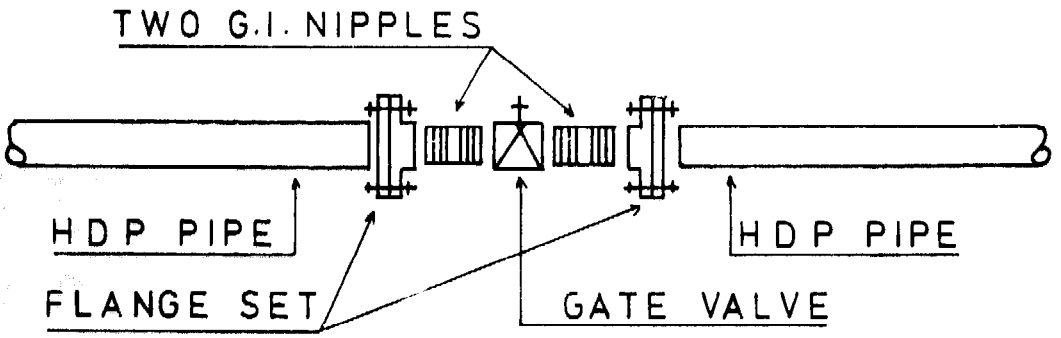

PIPE LINE MAIN CONNECTION INSTALLATION DETAIL

FIGURE 5·6

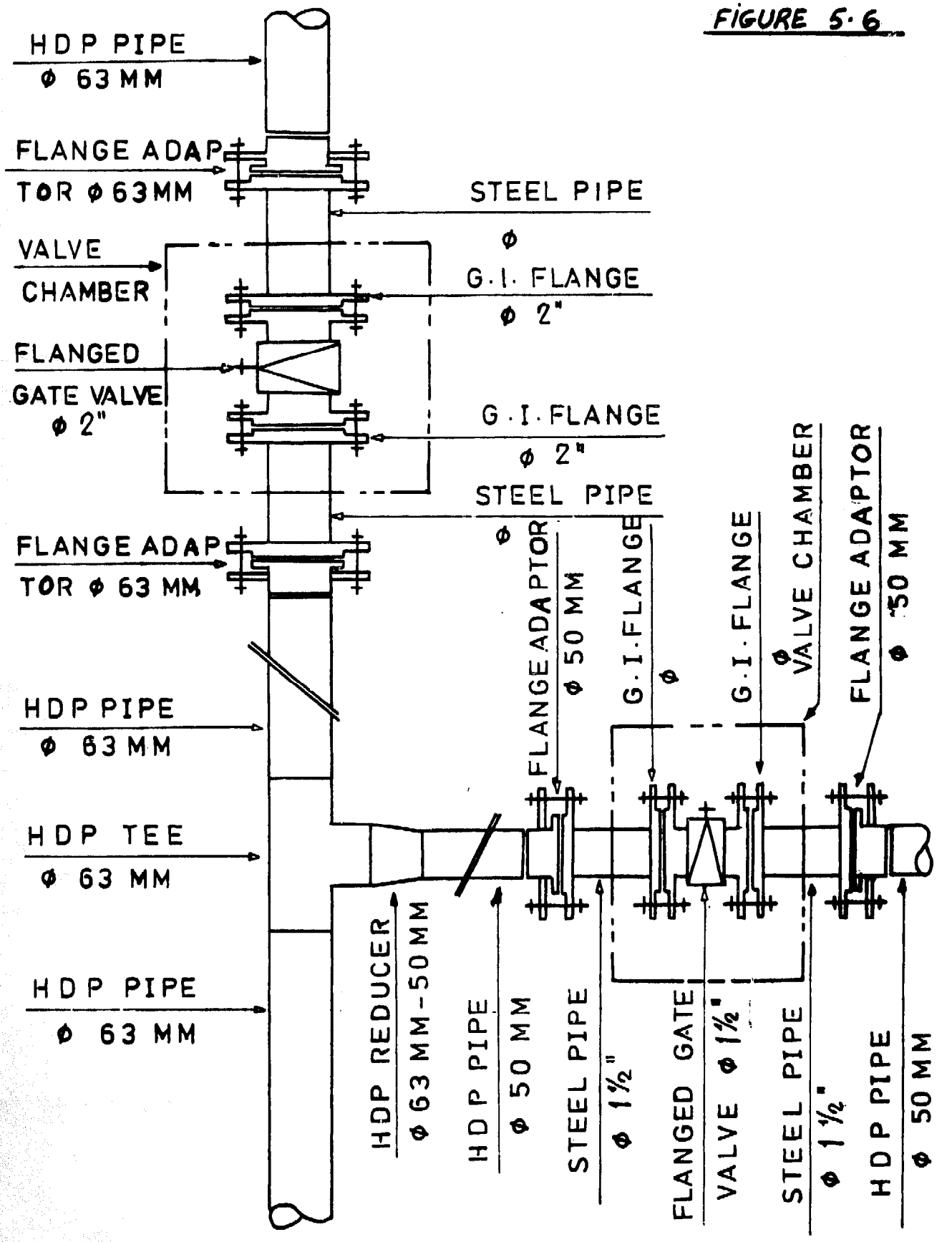

TAP CONNECTION CHAMBER

FIGURE 5·7

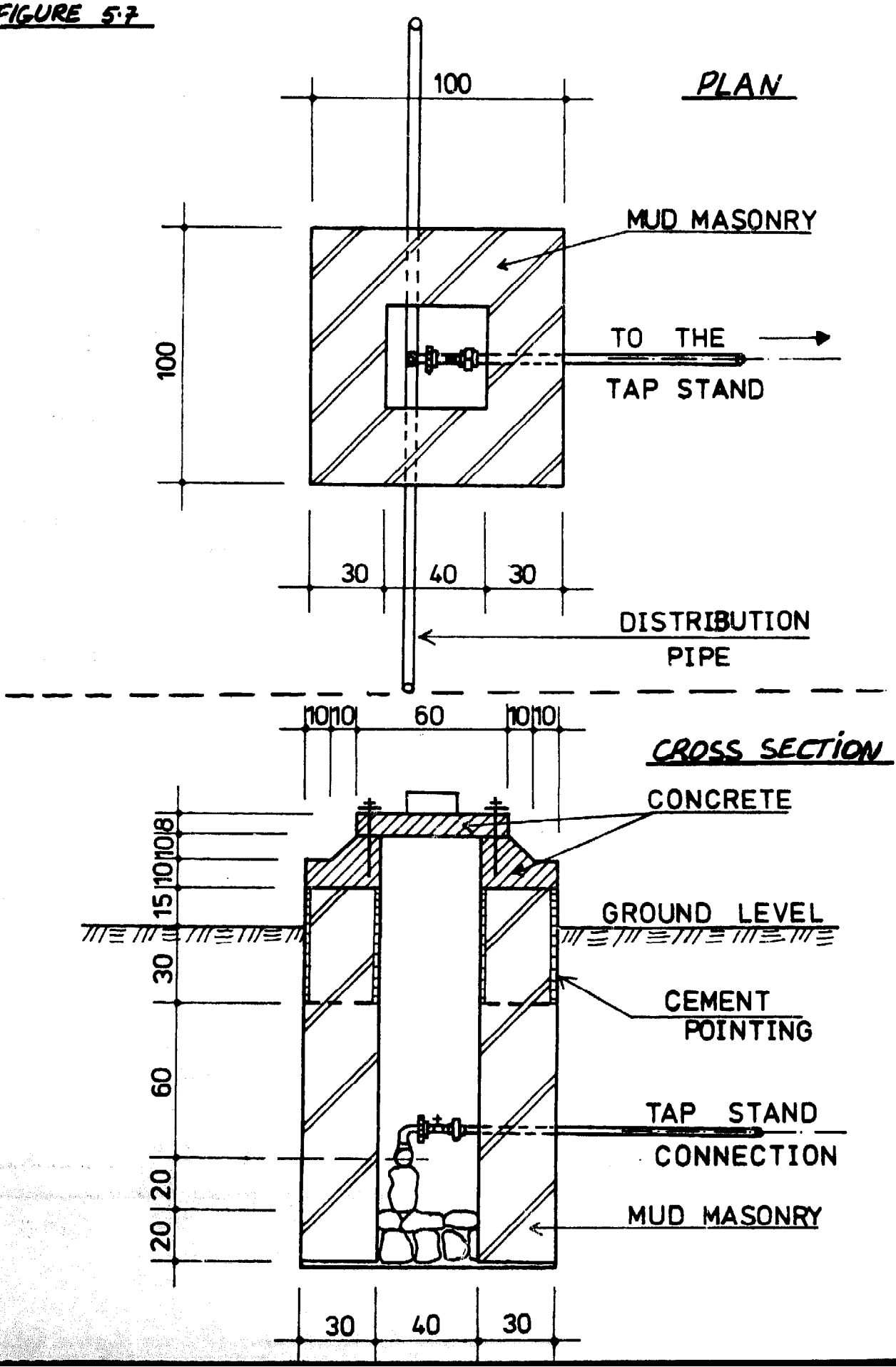

5.4 Pipeline Passing Through Walls

When pipe passes through a wall, as in the installations shown, stress may affect and damage the pipe. The construction details given below show how to fix the pipe, so that the chances of this hapening are minimized.

HDP pipes can only be used through the walls if there is no water behind the walls. For example:

- Valve chamber walls
- Tap connection chamber walls
- Operation room outside walls.

Special attention should be paid to avoiding leakages where pipes are inside a wall and are connected under the water level.

Cleaning Pipe and Overflow Pipe - The pipe used is steel. It is fixed rigidly in the wall. The part of pipe in the wall should be scraped before insertion. Diagram A.

Outlet and Inlet Pipes - The pipe used in the wall is steel. It is fixed rigidly in the wall as above. The HDP pipe after the joint will take all the stress because of its flexibility. Diagram B.

Sedimentation tank - As in Diagram A and B.

Pressure reducing pipe - Identical to the inlet and outlet shown in Diagram B.

Break pressure tank - As in diagram A and B.

Valve Chamber - HDP pipe will be fixed directly inside the chamber walls for all diameters of pipe. (See page 63).

FIGURE 5-8 — PIPELINE PASSING THROUGH WALLS

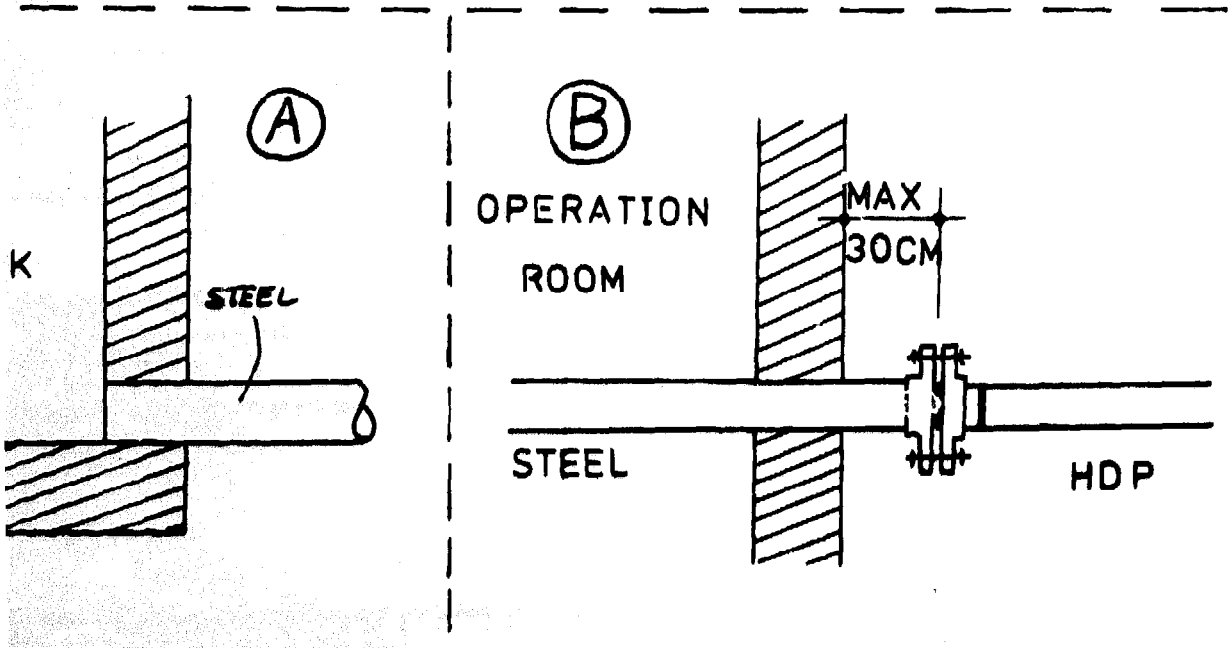

5.5 Velocity of Water and Pressure Loss

The velocity of water in a supply main should not be more than 2.5m. per second. The velocity in a distribution main should not be more than 1.5m. per second. If the velocity is too high it will damage pipes, taps and valves.

Whenever water flows in a pipe there is continuous loss of pressure along the pipe in the direction of the flow. This loss is due to friction between the water and the inside surface of the pipe. A pipeline should therefore always be laid on a downward slope to carry water to its destination. This "head loss", as it is called, is a function of the diameter of the pipe, its quality and the quantity of the water flowing in it.

5.6 Laying HDP Pipe, Trenching and Embankment

Laying pipe - Before laying HDP pipe it is important to remove from the trench all rocks and stones. The pipe should be layed on a bed of good inorganic soil. Here are some important points to watch for.

- The coil of HDP pipe should be put into the trench and unrolled in the direction of the water flow. Care should be taken that the pipe does not become buck-bended as it unrolls, because this will make weak points in it and later it will break under pressure.
- When the pipe bends or turns make sure a good long line is allowed with a radius big enough to prevent the pipe being bent and weakened.
- If the trench is on a slope the coil should be unrolled very slowly. There should be enough people to hold the coil as this is being done, so that it does not get damaged in the process.

Trenching - The minimum width of the trench should be 50cm. for HDP pipeline with a diameter under 100m. A trench which is too wide will increase the earthload on the pipe. Pipe should be buried in the ground at a suitable depth (approx. 90cm.) in order to protect it from erosion, action damage from traffic above it, chemical action, weathering by the sun, rain or frost, and to prevent vandalism. The depth for a pipeline under a road should be 150cm. The pipeline should be laid along the straightest possible course. Road crossing should be done at right angles to the road and avoided wherever possible. Lengths of pipeline should be laid with a gradual rise to high points of about 2% to 5% so that air can be released through air valves (pages 56 and 57), and with a gradual fall to low points. Cleaning-valve outlets should be fixed at these low points for emptying that portion of the line. Flat lengths of pipeline - those laid parallel to the hydraulic gradient - should be avoided since they will give air lock problems. The bottom of the trench should be straight and rocks and stones should be cleared away.

Embankment - Where soil cannot be excavated, or only excavated to a small depth, pipe should be protected by an embankment of earth instead of by burying it. The outside base of the embankment should be fixed into the original ground stone. These stones have the effect of lining up the new edge with the ordinary ground and preventing erosion. The earth around the pipe should be well compacted. The top and sides of the embankment should be planted with grass to stabilise the soil or other ground cover. (See below)

A - Pipe
B - Soil free of sharp pebbles, stones and organic matter. Well compacted
C - Soil free of stones and organic matter, compacted in layers of 10cm.
D - New grass cover or other stabilization.
E - Stones fixed into the original ground - to provide continuity with it.

FIGURE 5·9 — EMBANKMENT

CROSS SECTION

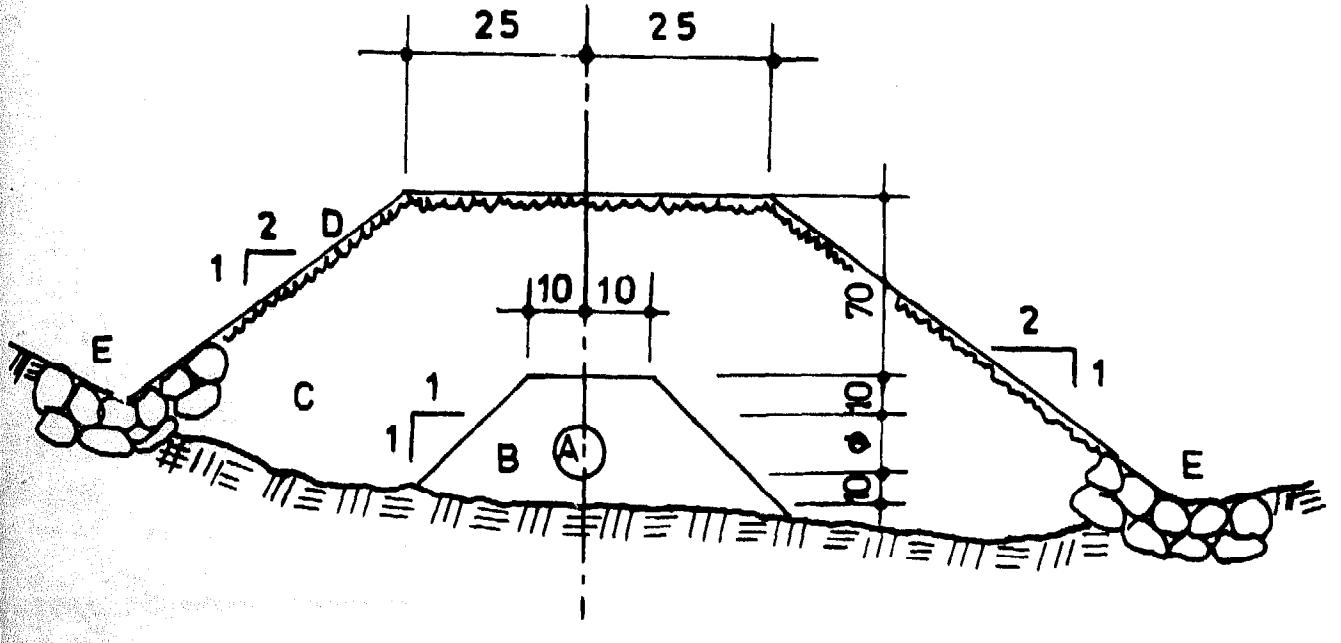

5.7 Backfilling and Tamping

Backfilling and tamping have a big influence on the life of the pipeline, so this should be done very carefully. The first backfilling materials must be soft, inorganic and free of stones, lumps or rocks. Backfill should be laid in layers of 10cm. each. Layers should be laid until a level 30cm. above the top of the pipe has been reached. After this bulk backfulling of the remaining part of the trench may take place, using excavated materials which are free of rocks and stones. Since some settling will occur, the trench when filled should be made into a mound large enough to avoid it becoming a conduit for rain water or surface run off. Look at the diagrams on pages 68 and 69 for step by step illustrations of backfilling.

The diagram on page 70 shows how to proceed when the pipe is laid beneath a road.

a. Where pipe is laid at a depth of 1.20 metres or more, proceed as with normal backfilling shown on pages 68 and 69.

b. Where pipe is laid at depths of 1 metre to 1.20 metres, the pipe should be laid on a sand bed and be covered with at least 30cm. of sand. The remaining backfilling is done as normal.

c. Where pipe is laid at a depth of less than 1 metre, the pipe should be laid on a sand bed and covered by 20cm. of sand. In addition a concrete slab should be laid, as in the diagram, to disperse the load above the pipe caused by traffic. The backfilling above the slab should be done as normal.

FIGURE 5·10·1 — LAYING A PIPELINE : TAMPING & BACKFILLING

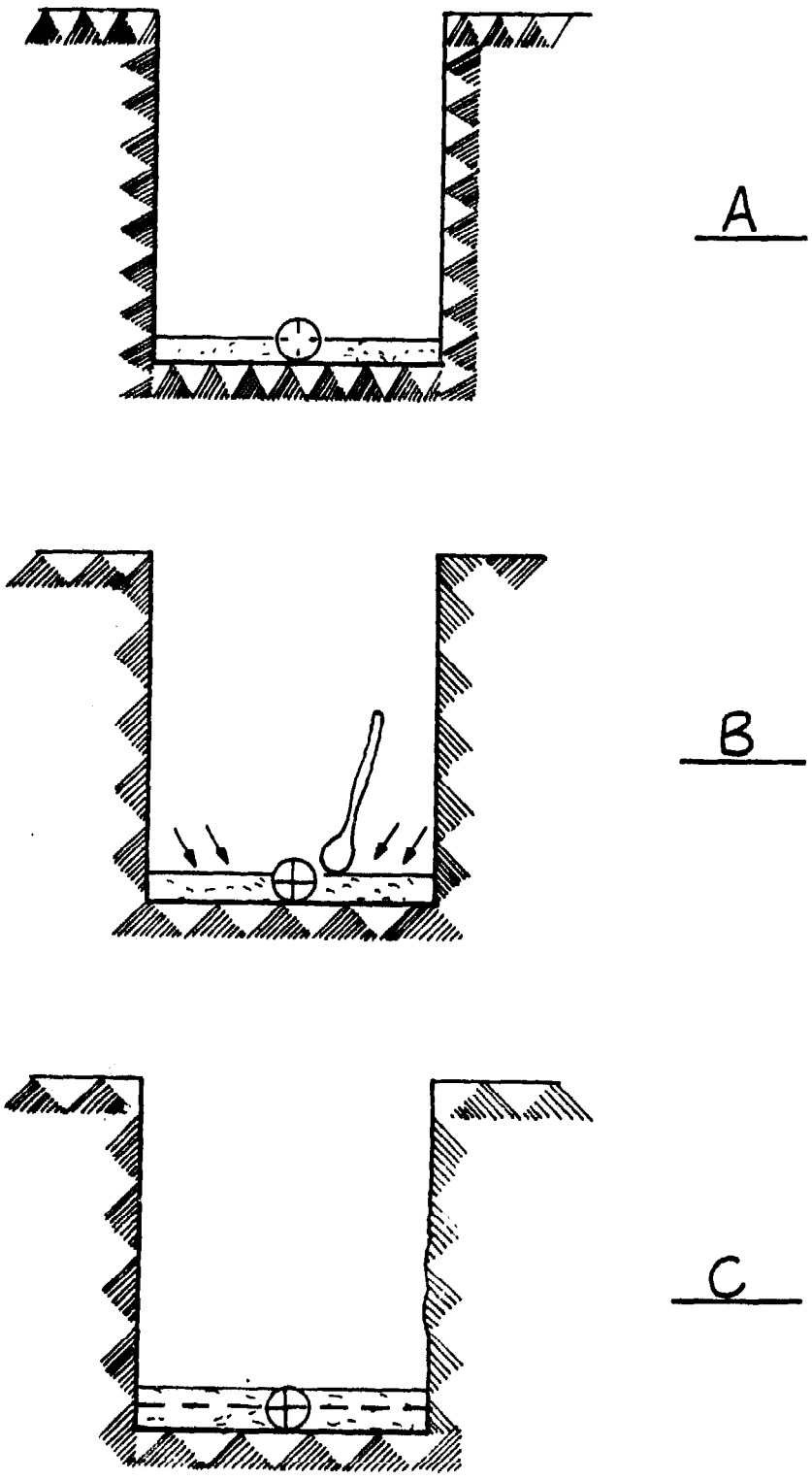

FIGURE 5·10·2 — TAMPING & BACKFILLING

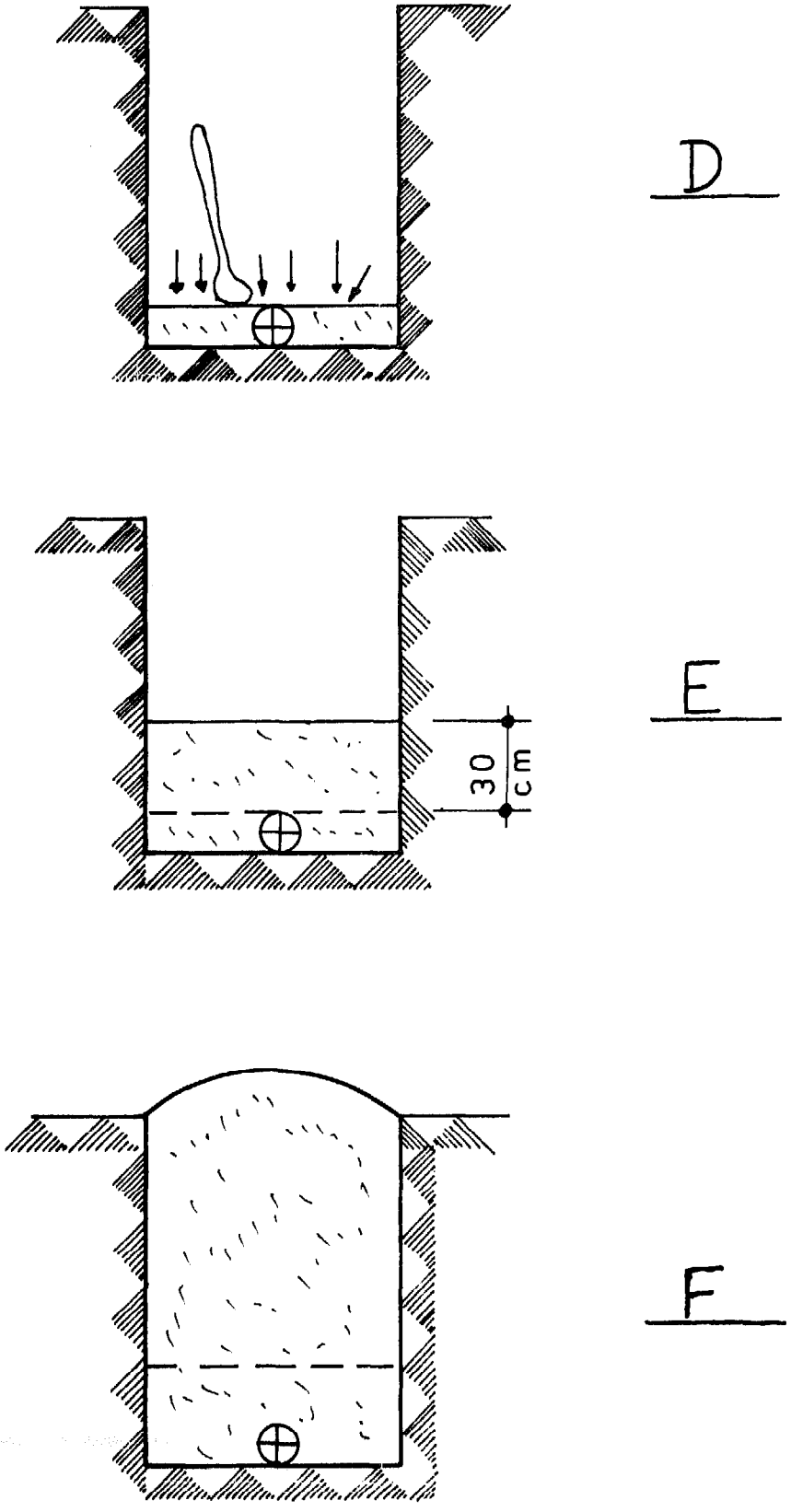

FIGURE 5.11 — LAYING A PIPELINE UNDER A MAIN ROAD

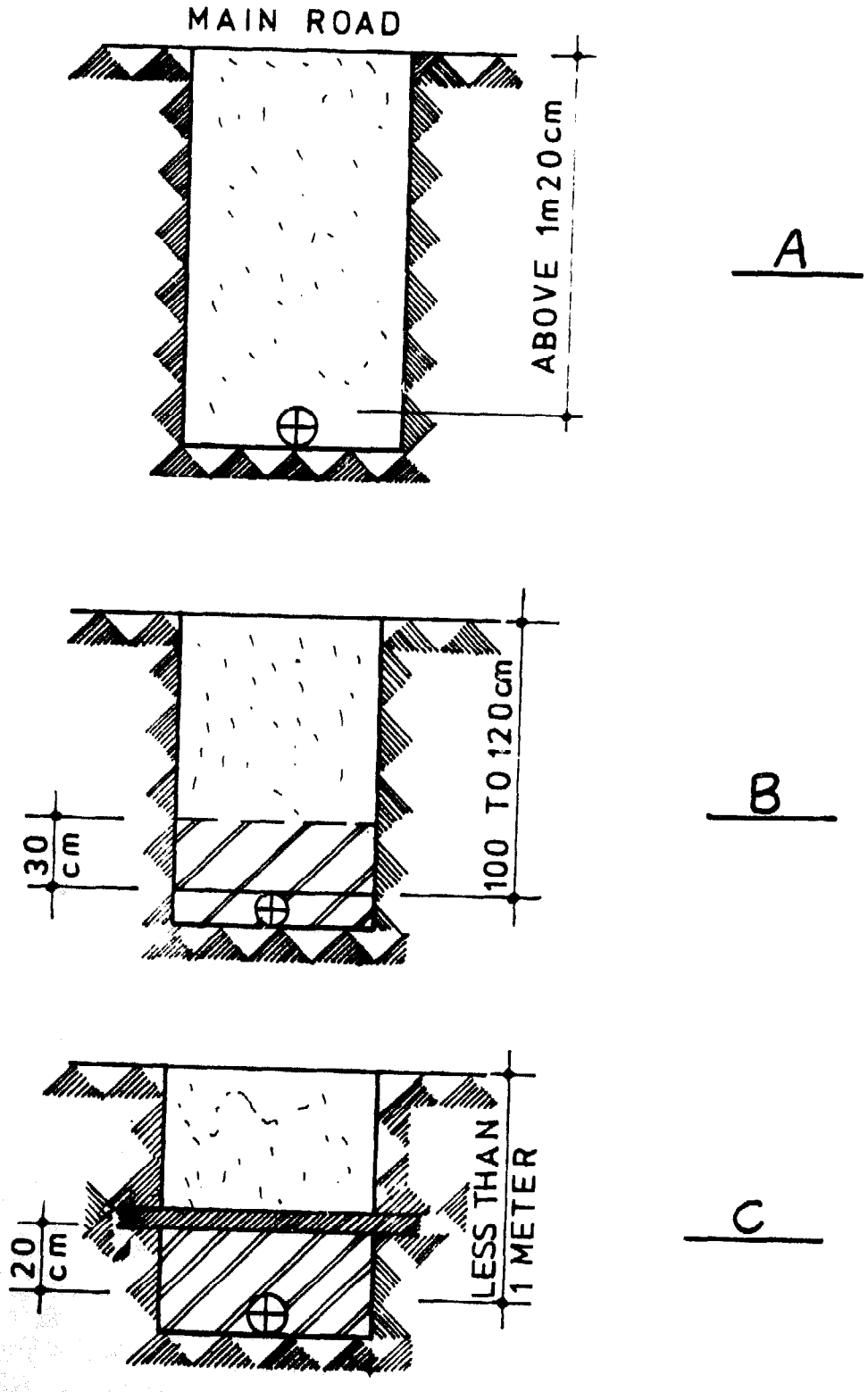

5.8 Pipeline Testing

After laying pipe, but before backfilling, the pipeline should be tested. Here are some points to remember about this.

- All HDP pipe joints should be checked when cool, after butt-welding, by hand testing i.e. bending gently and looking at them closely.
- All service pipes and fixed fittings should be checked with a hand-pump pressure test, before beginning construction of masonry standpipes.
- After completing storage tank pipelines and stand pipes the system should be put under water pressure. Each welded joint, fitting and pipeline connection through a wall should be carefully checked by hand as above.
- Repairs should be done as necessary. After the first test there should be a second test, carried out with the same attention as for the first, to check that all repairs are satisfactory. Trenches should not be filled until both tests have been successfully completed. They should be filled only if the whole system has been shown to contain no leakages.

5.9 Marking The Pipeline

Immediately after backfilling, the pipeline should be marked with permanent signs otherwise, it might be difficult to find the pipeline later by relying on memory alone. It may necessary to know the route in order to do maintenance or repair work.

Marks should be placed at the following points:

a. At branches
b. At changes in direction
c. At changes of size
d. At valve boxes,
e. At every 200 meters in straight runs in good terrain, and
f. At every 50 meters in straight runs in bad terrain.

Note that diagram B (page 72) shows a small piece of pipe buried in the mark. This is used to indicate the diameter of the pipeline at that point. Notches should be cut into this piece of pipe to indicate the direction of the pipeline. Marks are usually burried on one side of the pipe axis (diagram A, page 72). If the marks were directly over the pipe two things could occur: they might be removed, lost or not correctly replaced when repair work was done; the backfill might sink, taking the mark with it and covering it up.

All marks from source to storage tank to village should be numbered in sequence. This is very important. A small stone masonry construction with a concrete top is recommended. This should rise at least 15cm. above the ground and be well fixed in place. These points are illustrated in diagrams A and B below.

FIGURE 5·12 — MARKING THE PIPELINE

A. WHERE MARKS SHOULD BE PLACED

EXAMPLE

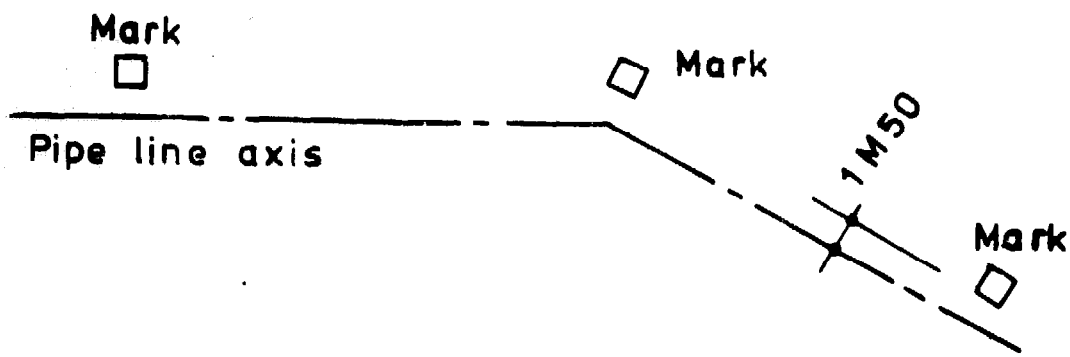

B. WHAT MARKS SHOULD LOOK LIKE

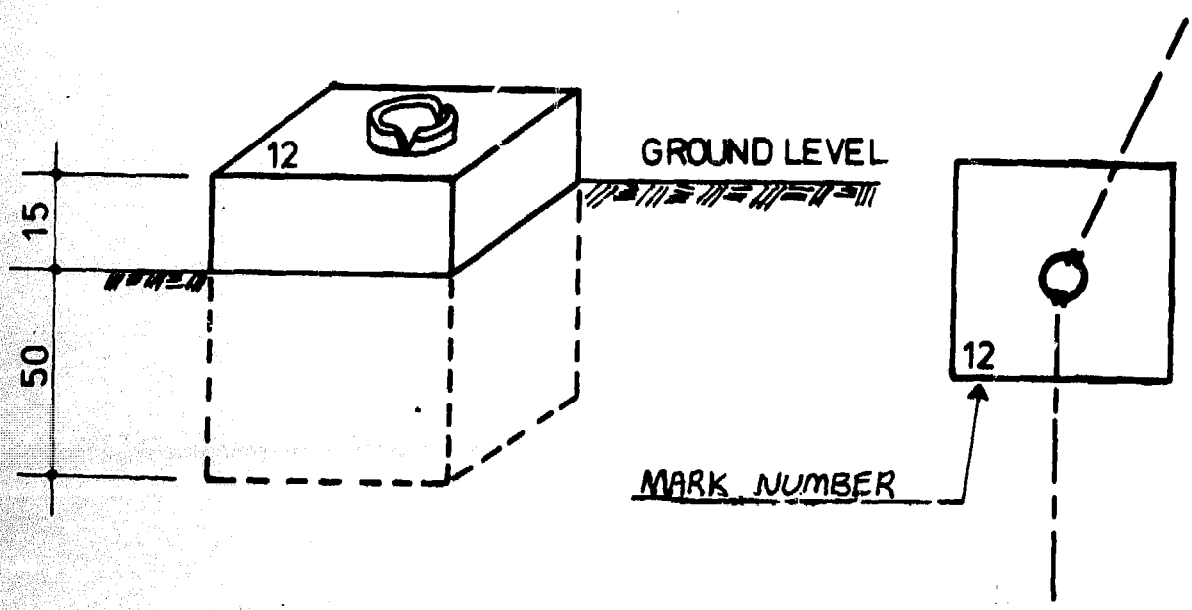

5.10 Finishing and First Chlorination

It is as important to finish the trench properly as it is to correctly lay the pipe. Ground surface over a new trench should be restored to its original condition or improved if possible. This will minimise erosion of the fresh soil and it is especially important for steep slopes which will present greater problems of erosion. Alternatively, one can pave the disturbed area with stones. To do this place long flat stones across the path of the pipe. This will break the flow of the surface water.

After completing the project, the tank and the pipeline must be cleaned and disinfected with a chlorine solution in order to prevent pollution of the drinking water.

Chlorine should be mixed with water from the storage tank and should stay in the pipeline for at least three hours. The strength of the chlorine solution, that is, the quantity of chorine put into the water, will be worked out by the engineer in charge of the project.

FIGURE 5·13 — CLEANING OUT INSTALLATION DETAIL

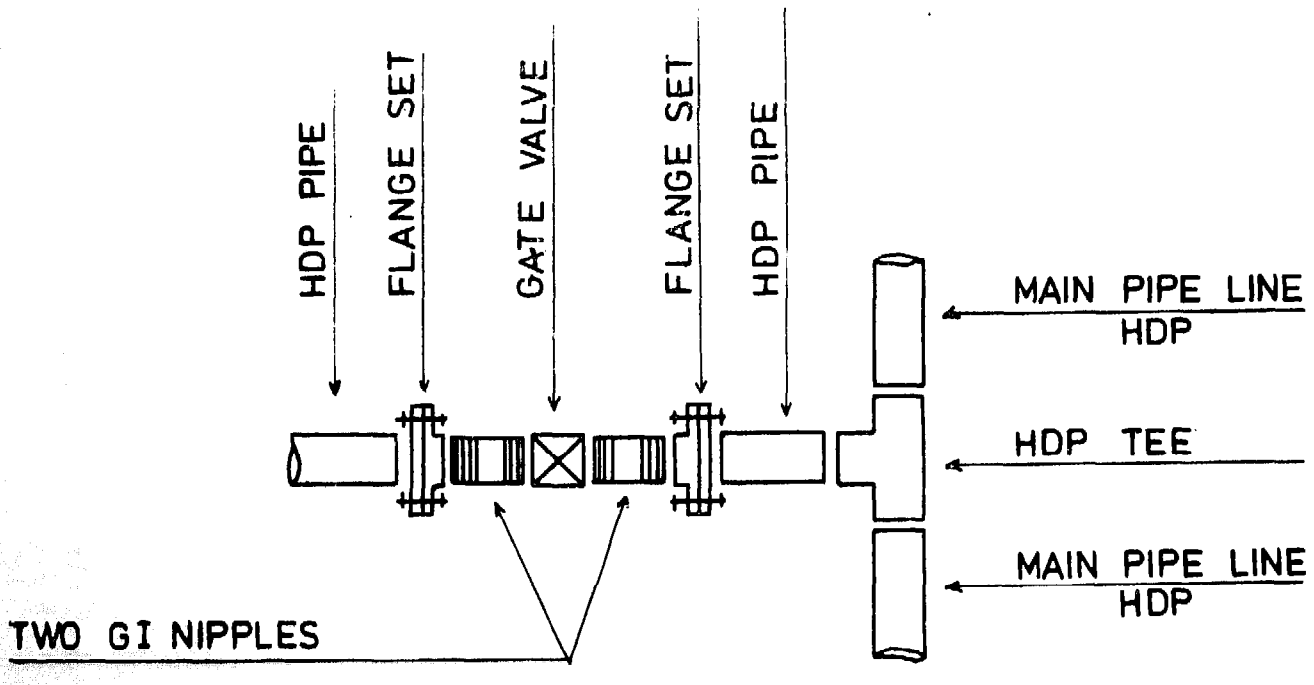

REMARK: ALL FITTINGS ARE ACCORDING TO THE PIPE LINE DIAMETER

6. STAND PIPES, TAPSTANDS AND PUBLIC FOUNTAINS

6.1 General Points

Stand pipes should be built wherever it is most convenient for the villagers to collect water. Two considerations should be remembered when building them.

The first are technical considerations such as the need for cleaning valves in the pipeline, or air valves. The second is the concentration of population in the village. One tapstand should be built for every 150-250 persons.

The design should also take account of the following points all of which apply to the local situation in Nepal.

a. There should be a hole under the tap through which water can drain.

b. Waste water should be used for cattle or small gardens. There should be a waste pipe to bring the water to a pond. This pond should be at least 50m. from the stand pipe to prevent pollution. It should be constructed at the same time as the stand pipe itself.

c. There should be enough space around the drainage hole to allow people to wash clothes on the tap stand floor.

d. The tap stand floor should be built with big, flat stones pointed at the joints.

e. The sides of the stand pipe pillar should be built in such a way that there will be a flat surface on which baskets, loads or gagros can be placed. These surfaces should be done in dry masonry.

f. The tap should be at a height of about 1.20 meters.

g. The faucet (tap) should be at 25mm. from the pillar, to allow a wide-rimmed gagro to be filled with water.

6.2 Construction

Designs for stand pipes and details of fittings are shown on the following pages. These conform to the general points mentioned earlier.

There are three designs shown:

- Public tapstand (pages 76, 77 and 78)
- Bazar tap stand (pages 79, 80 and 81). These are built in areas where there is not enough space to build a public tapstand.
- Public fountains. (Pages 82, 83 and 84). These are erected in areas of high population density. Water distribution is from two taps located one on either side of the post.

Details of required fittings are given on pages 85, 86 and 87.

FIGURE 6.1 – PUBLIC TAPSTAND DETAILS

PLAN 1:20

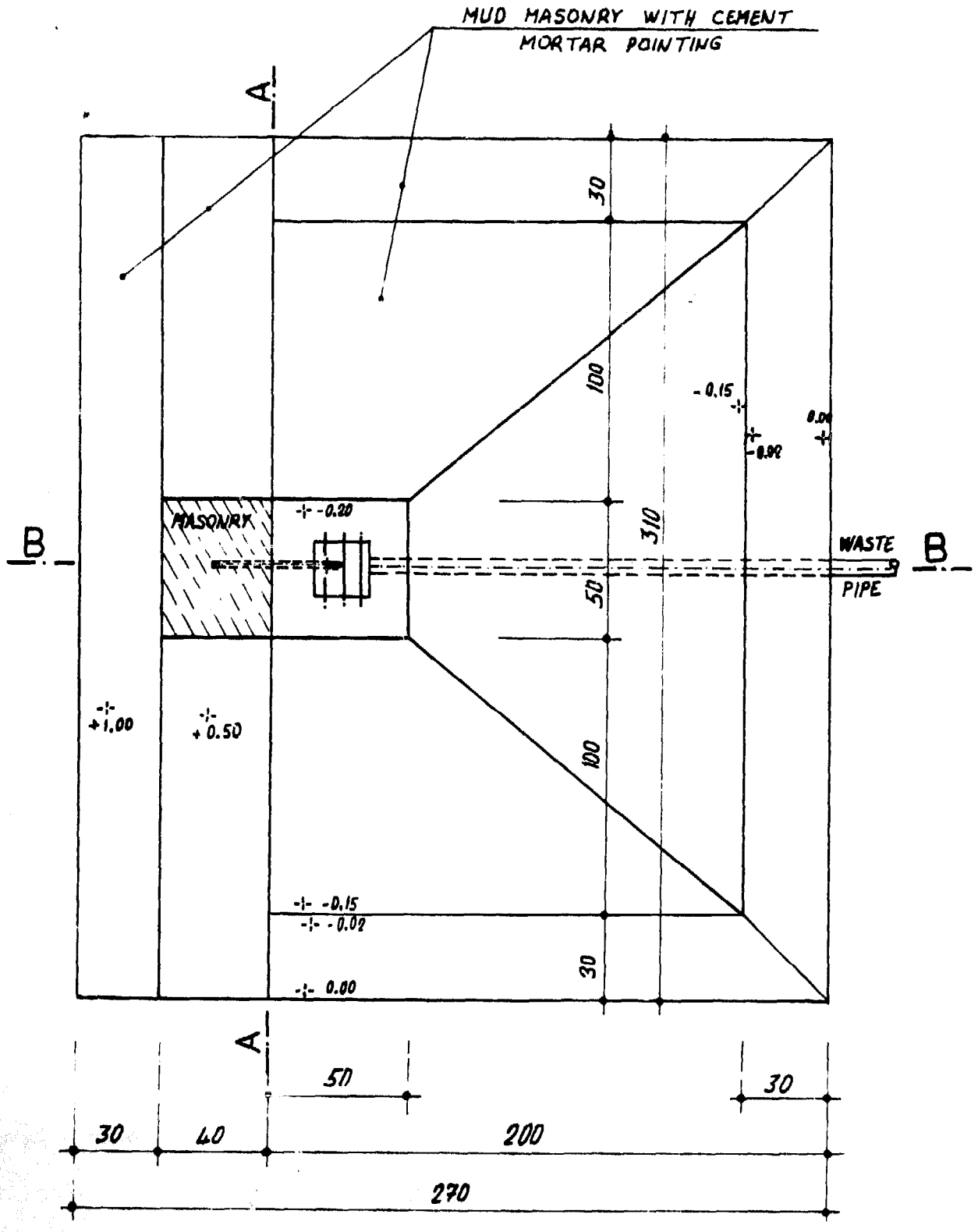

FIGURE 6.2 – PUBLIC TAPSTAND DETAILS

SECTION A-A 1:20

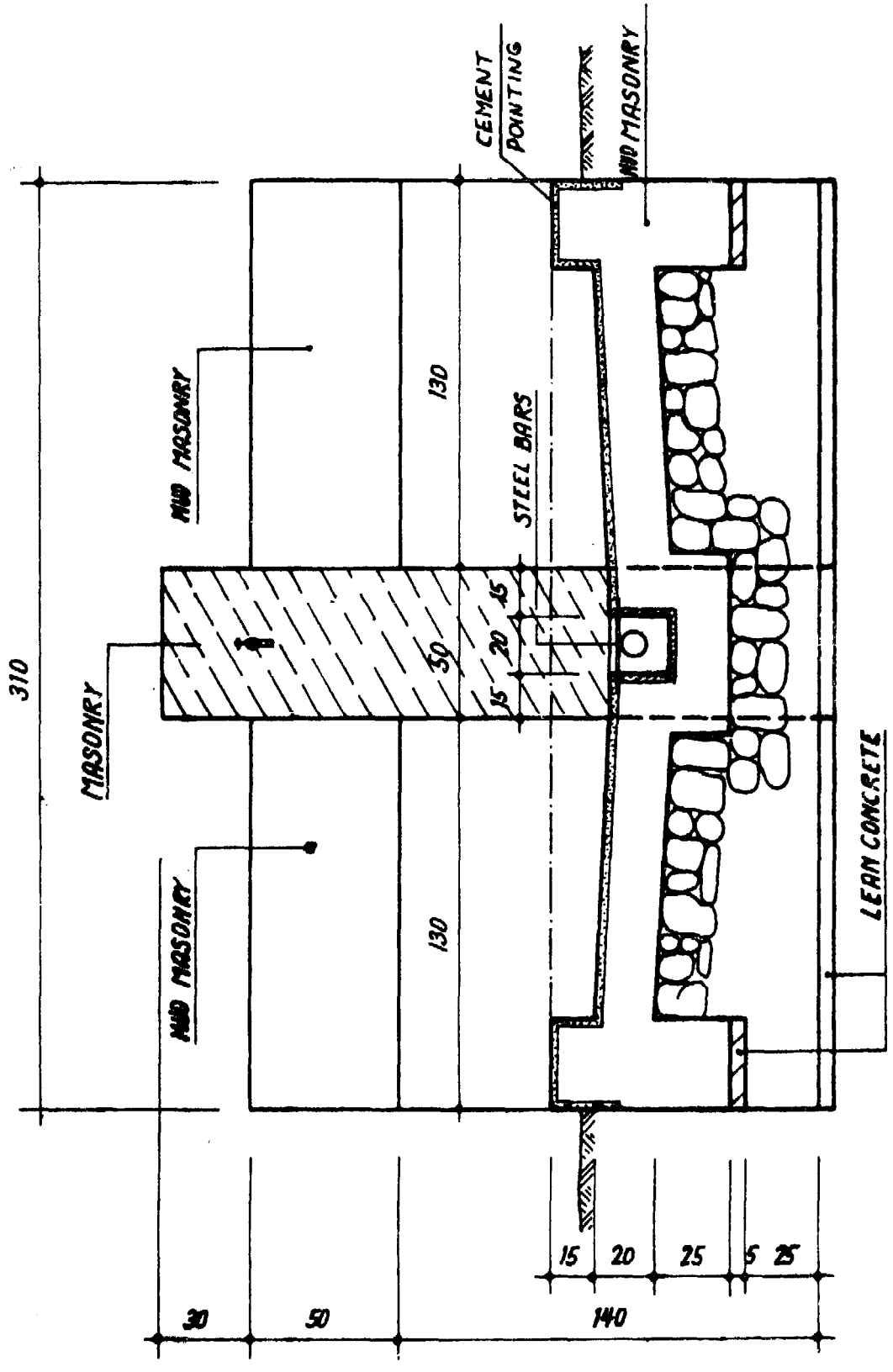

FIGURE 6:3 — PUBLIC TAPSTAND DETAILS

SECTION B-B 1:20

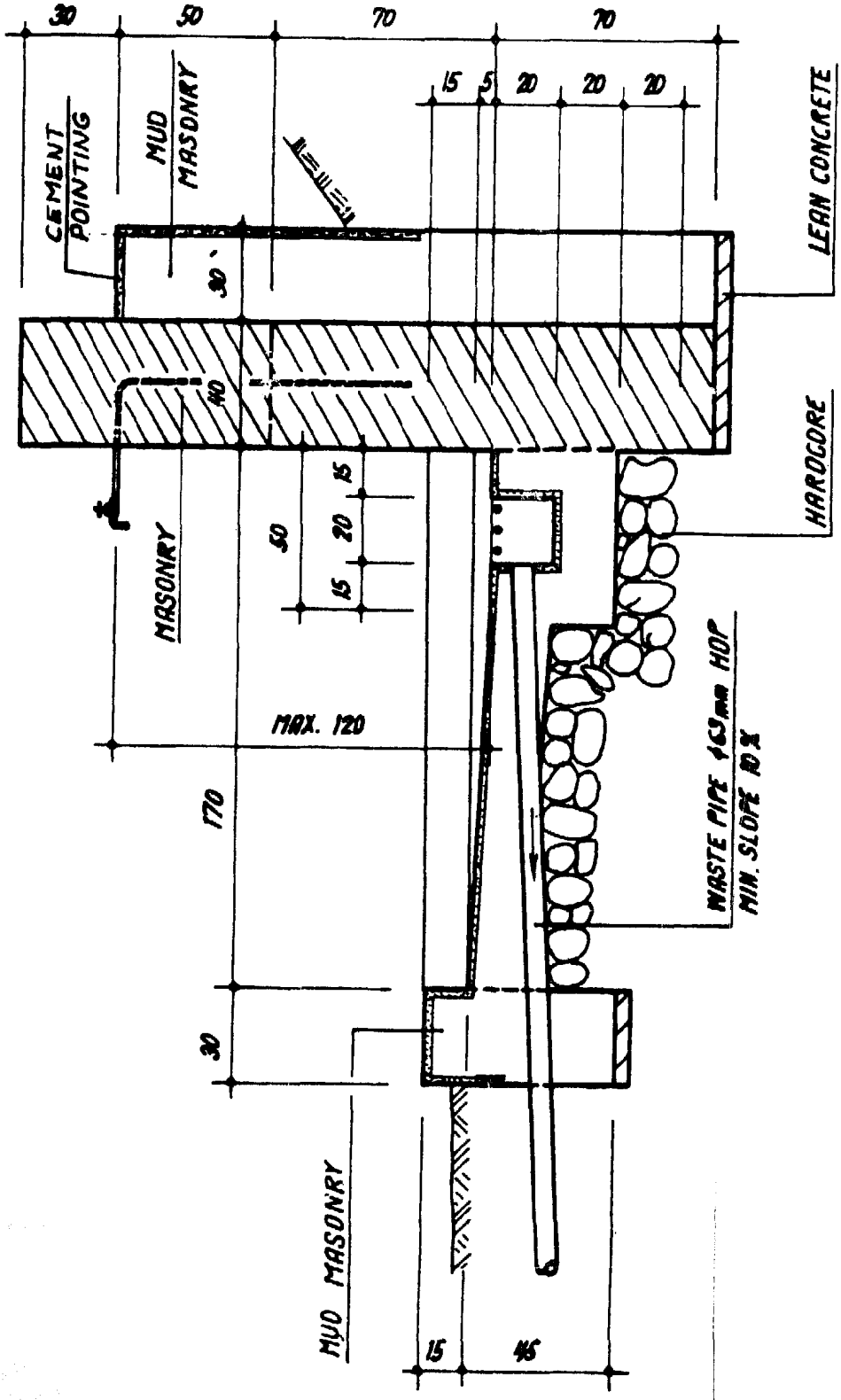

BAZAR TAPSTAND DETAIL

FIGURE 6·4

PLAN

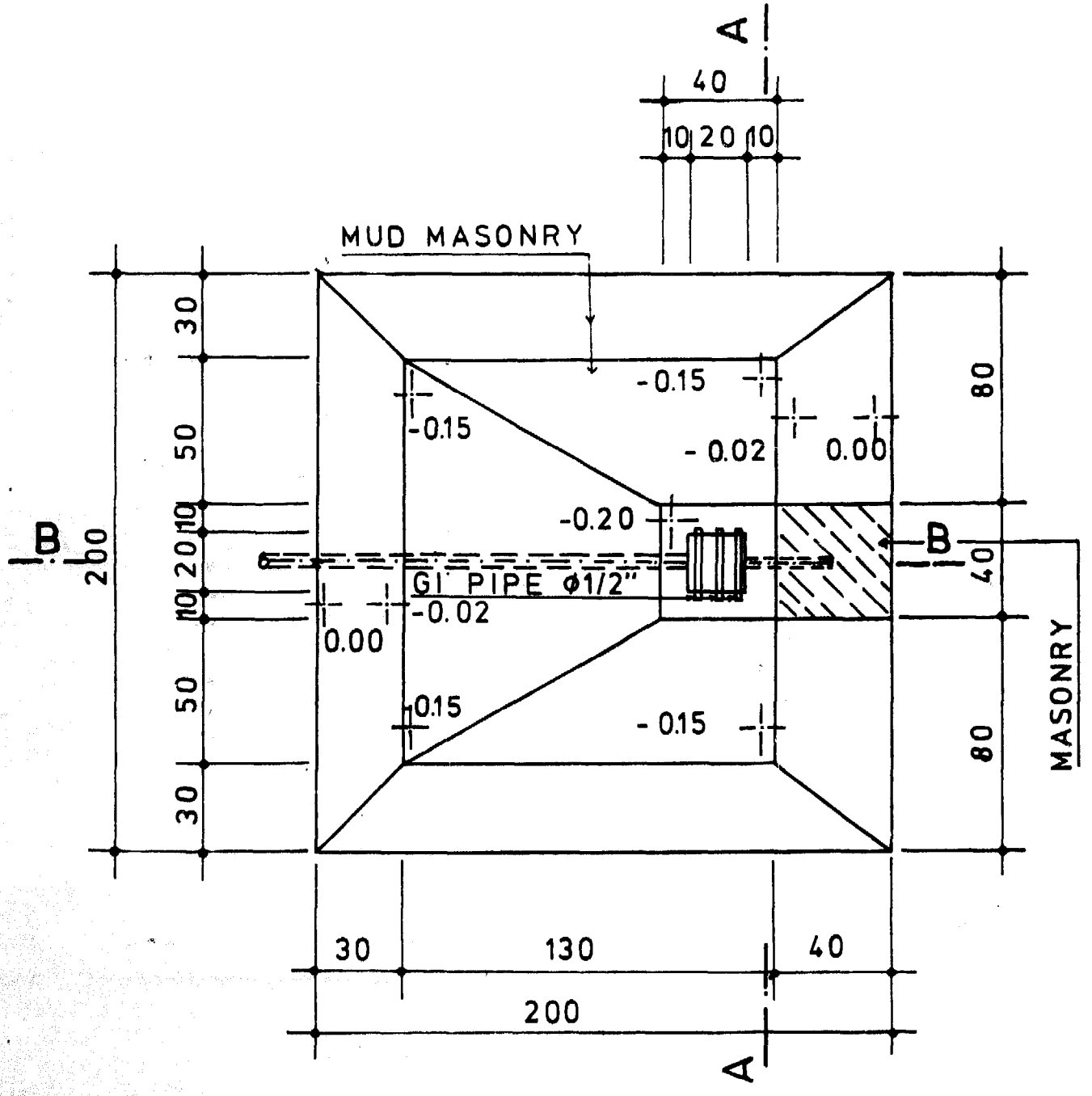

BAZAR TAPSTAND DETAIL

FIGURE 6·5

SECTION A—A

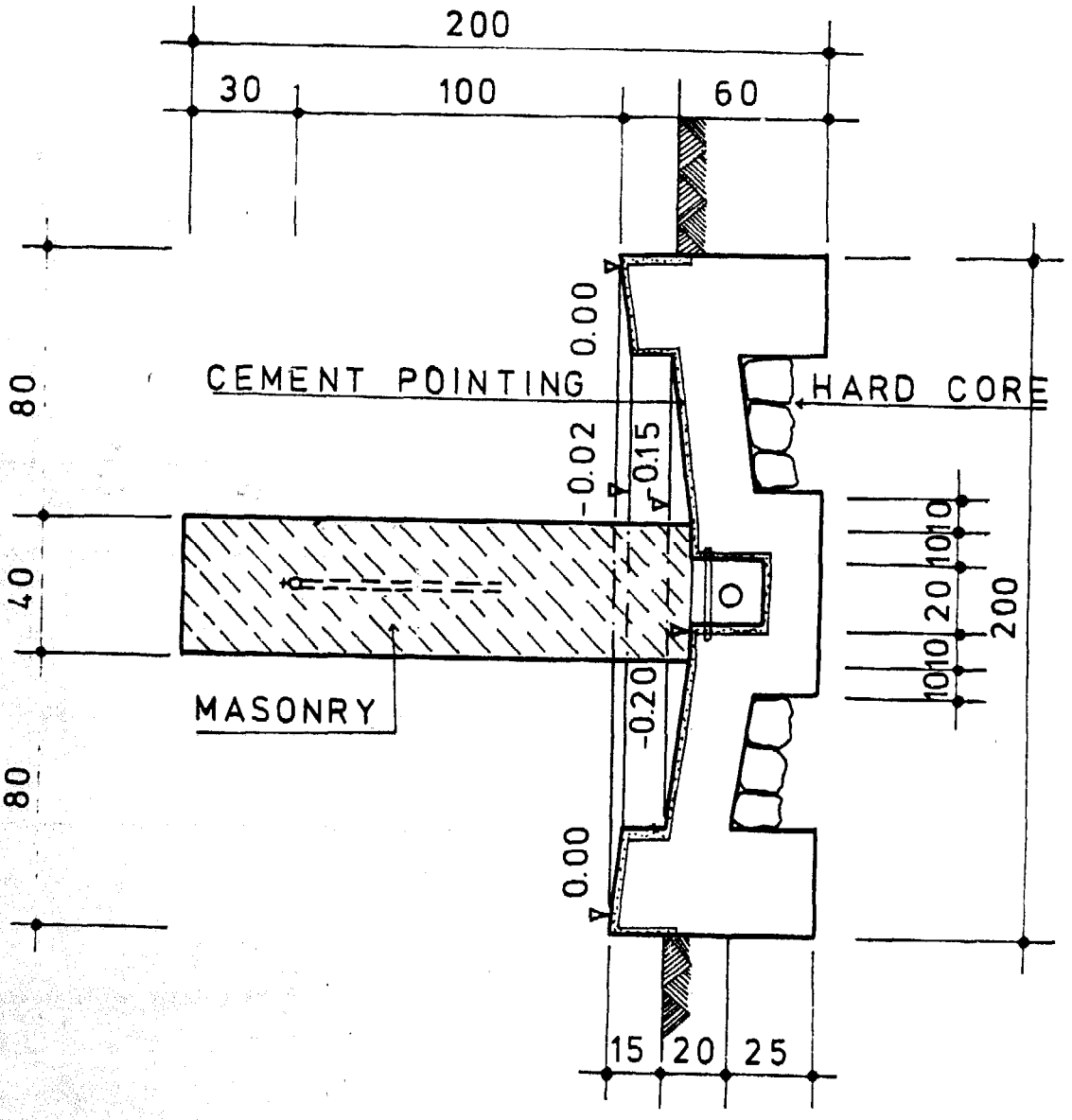

BAZAR TAPSTAND DETAIL

FIGURE 6·6

SECTION B—B

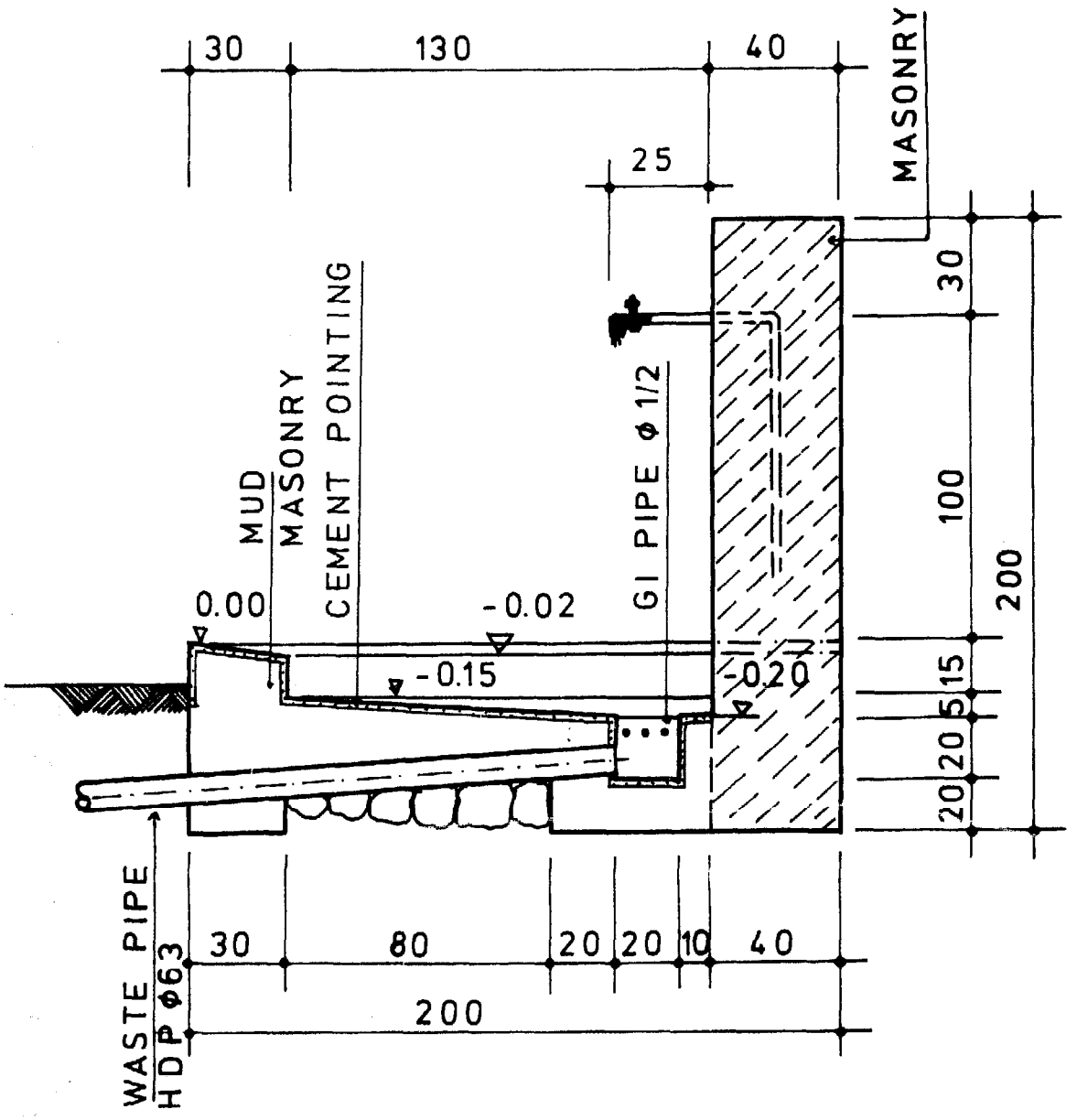

PUBLIC FOUNTAIN DETAIL

FIGURE 6.7

PLAN

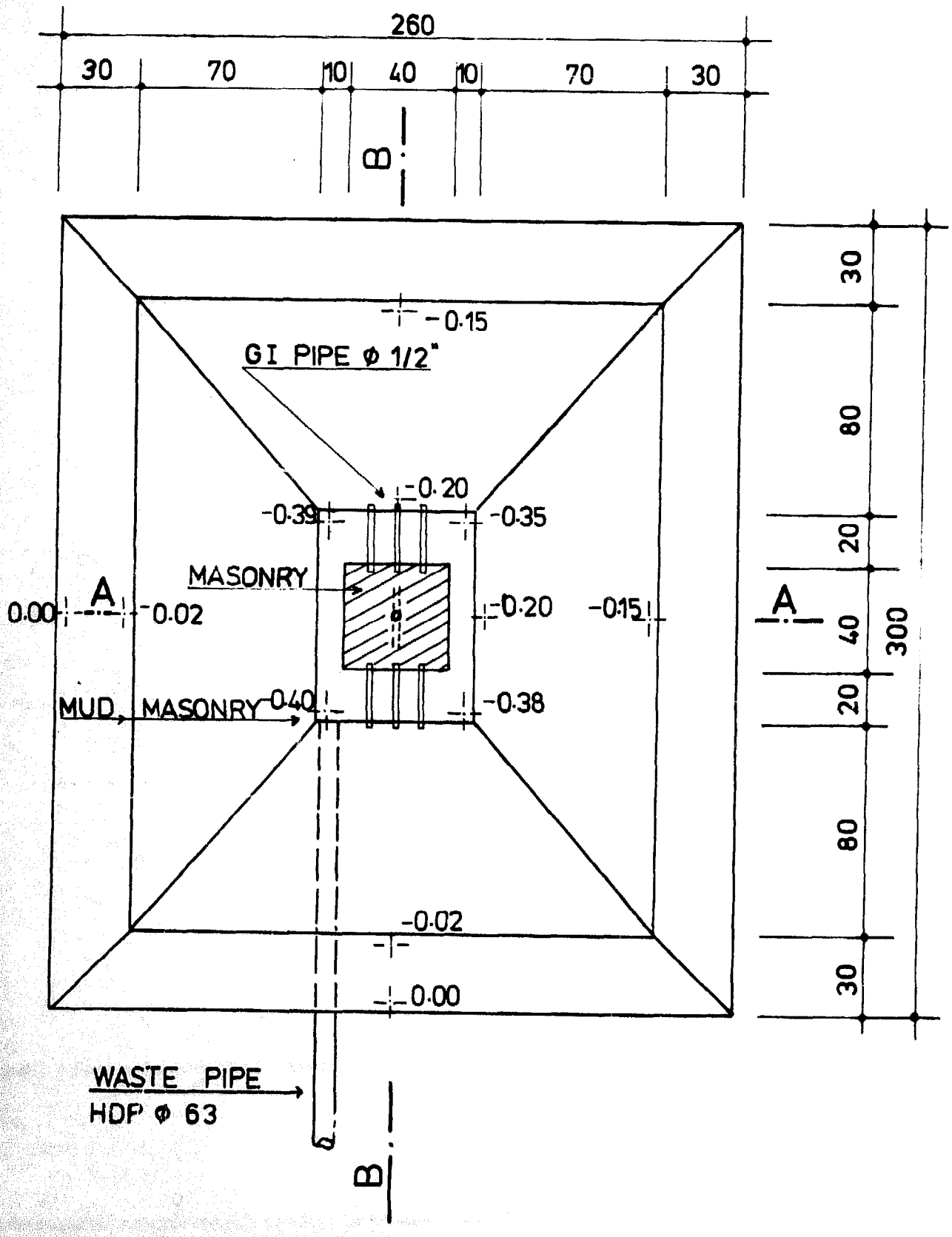

PUBLIC FOUNTAIN DETAIL

FIGURE 6·8

SECTION - A - A

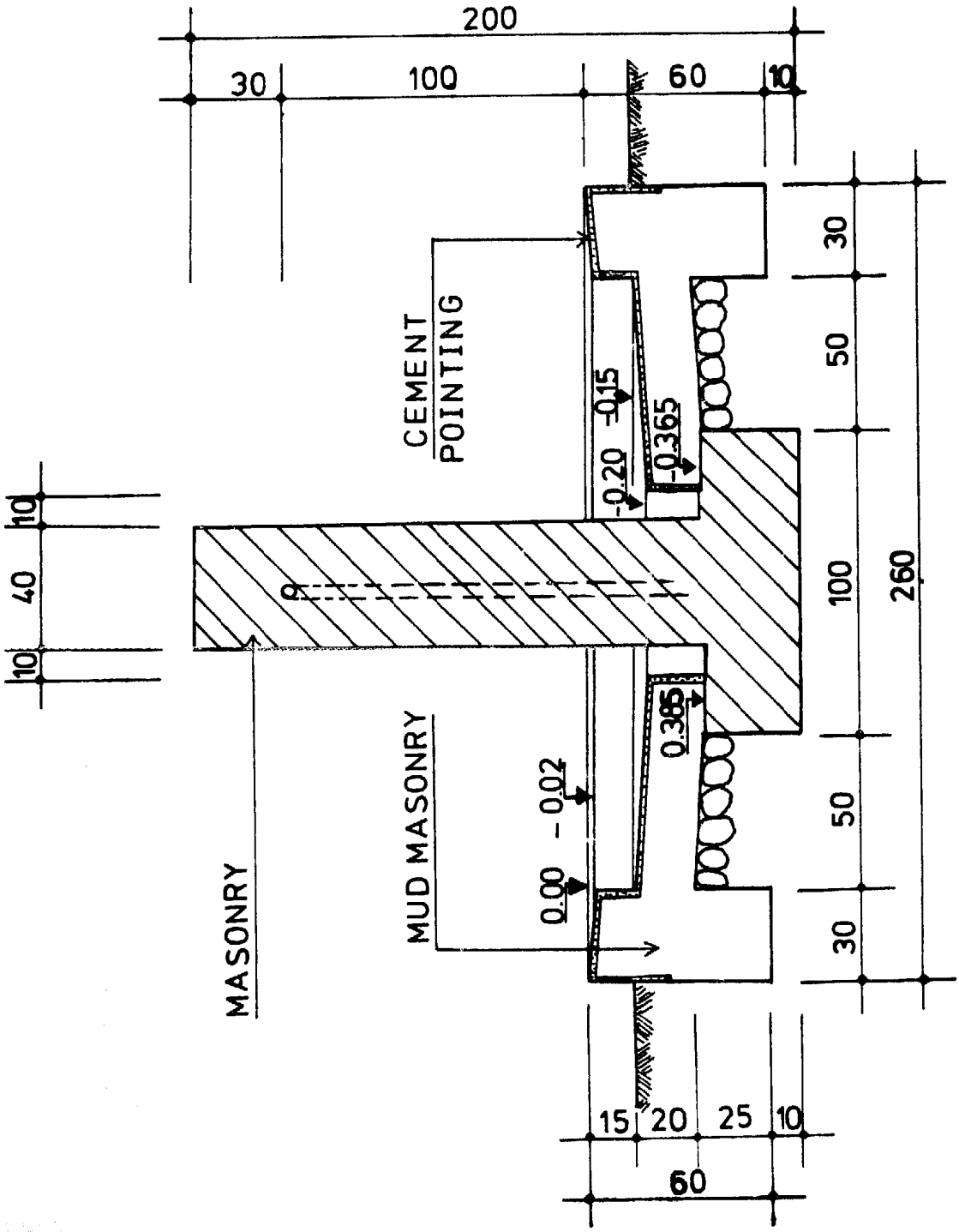

PUBLIC FOUNTAIN DETAIL

SECTION B-B

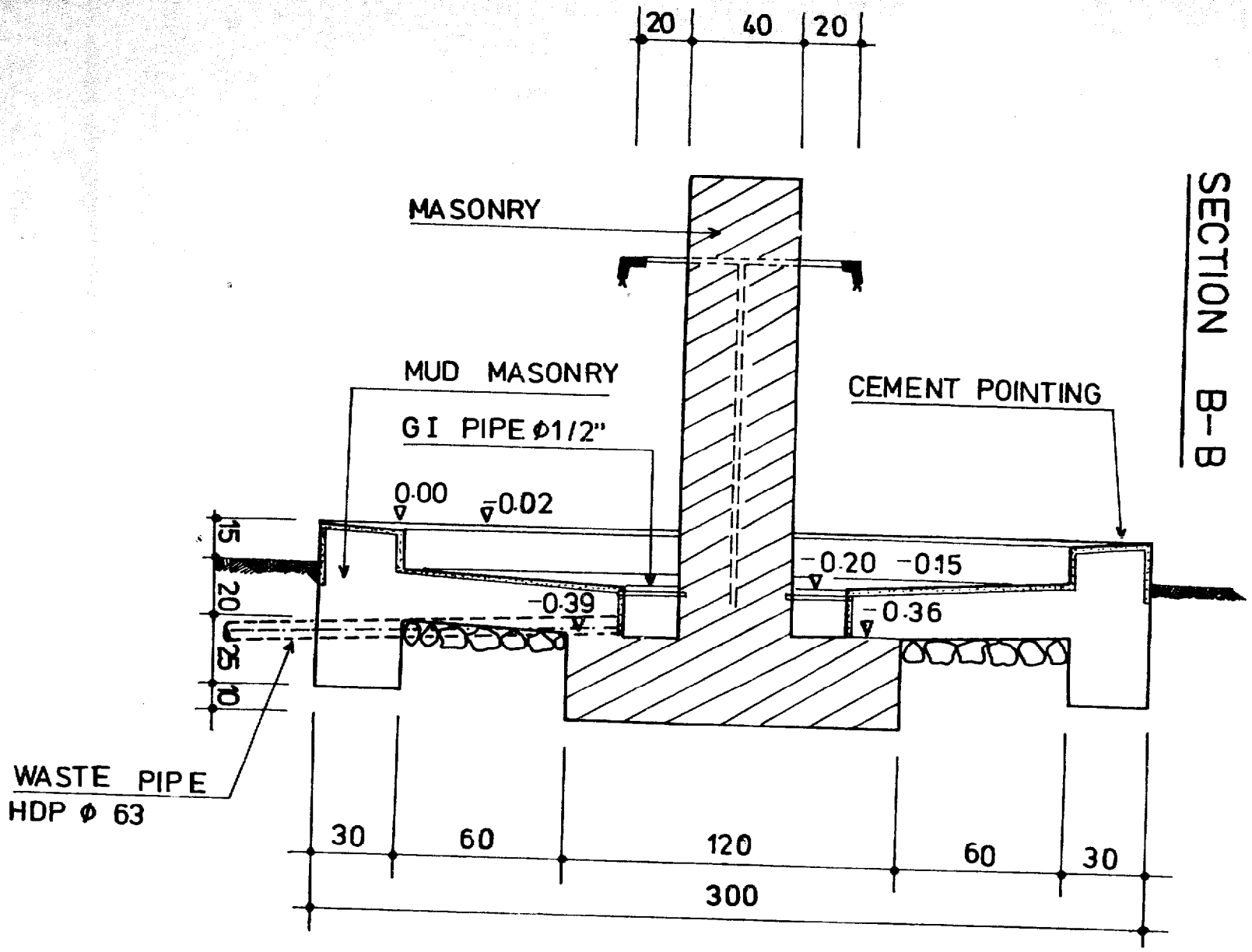

FIGURE 6.9

TAP STAND INSTALLATION DETAIL

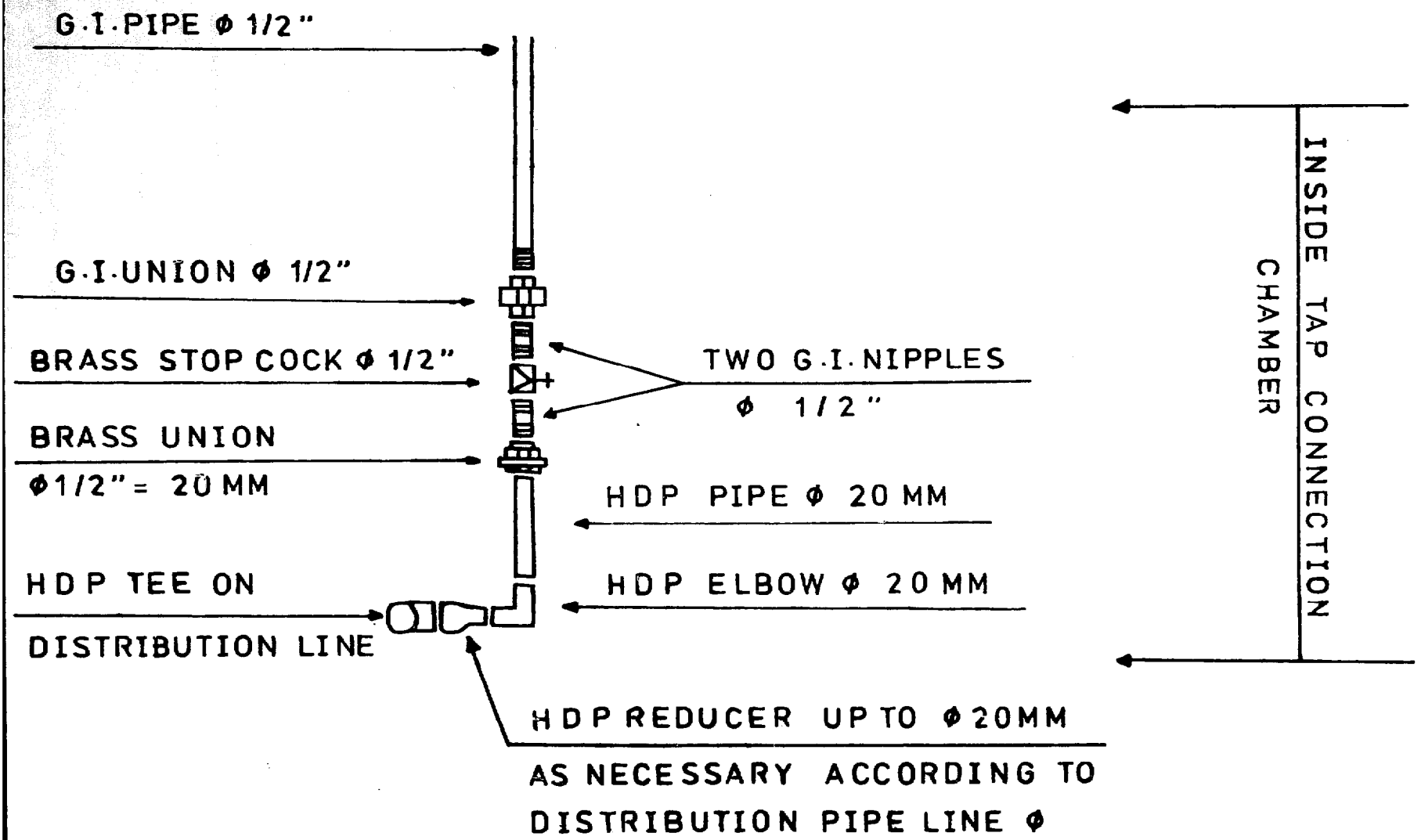

FIGURE 6.10

TAP STAND INSTALLATION DETAIL

FIGURE 6·11

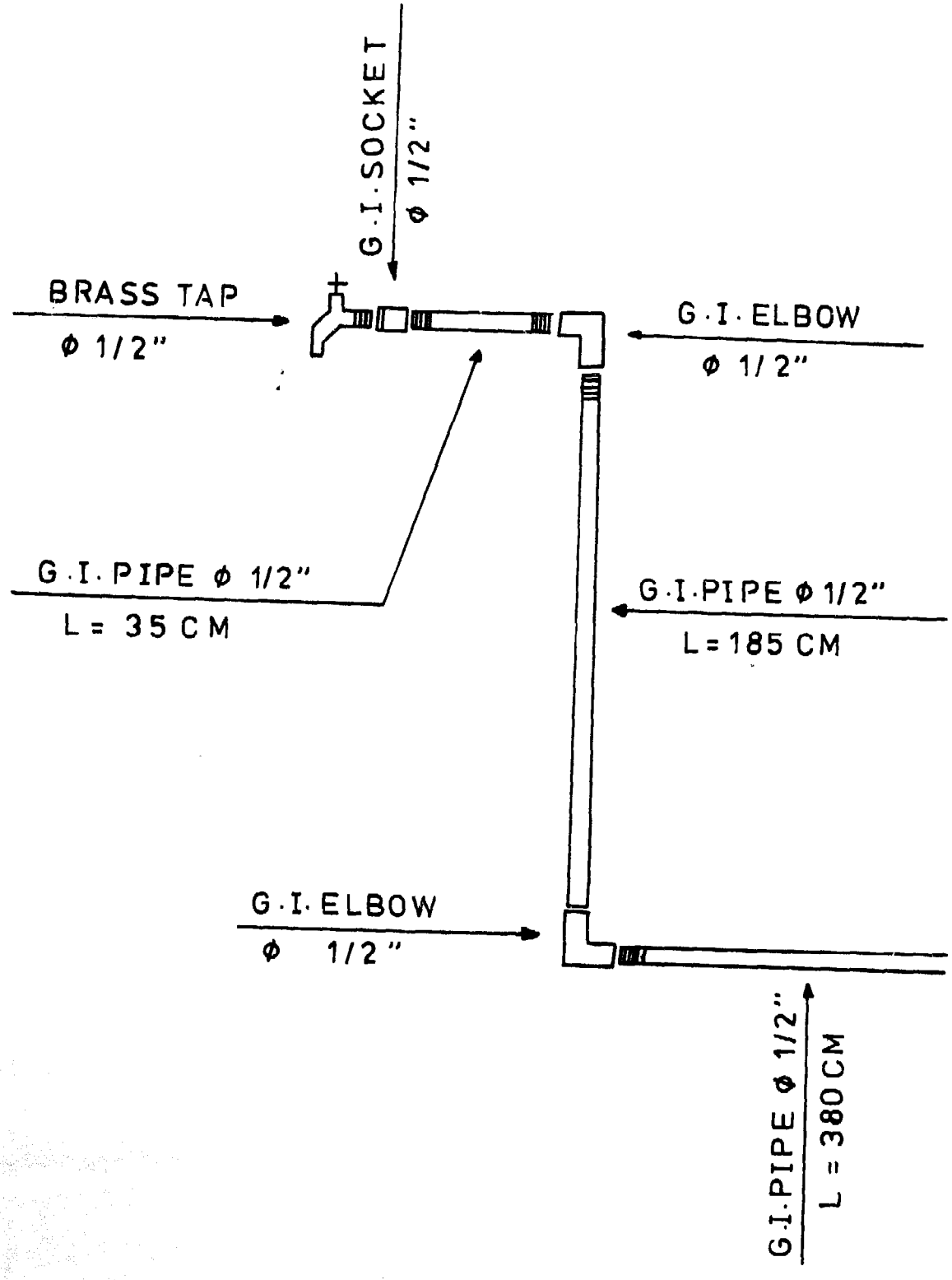

PUBLIC FOUNTAIN INSTALLATION DETAIL

FIGURE 6·12

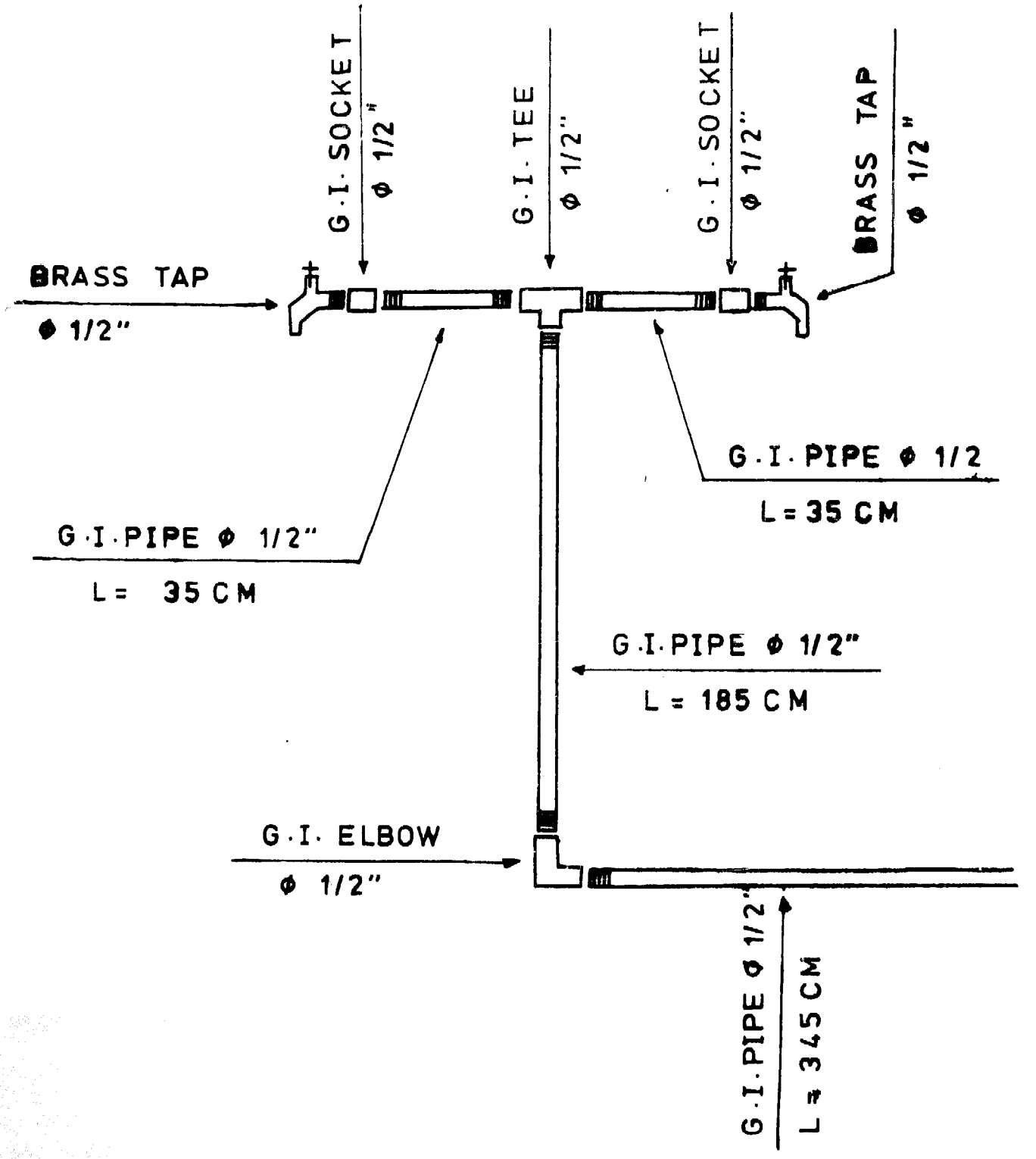

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RURAL WATER SUPPLY NEPAL

TECHNICAL TRAINING MANUAL no. 1

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* *
* HYDROLOGY-WATER CYCLE COURSE *
* *
****

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UNICEF - United Nations Children's Fund

Kathmandu 1977

HYDROLOGY - WATER CYCLE COURSE

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HYDROLOGY - WATER CYCLE COURSE

1- Definition and hydrologic cycle

Hydrology is the science of distribution and behaviour of water in nature.

Hydrology is a part of climatology. The cycle of water (hydrologic cycle) is without beginning and end and consists of the following:

Precipitation

All water from the atmosphere deposited on the surface of the earth as either rain, snow, hail or mist.

Surface run off

The water which is derived directly from precipitation and passes over ground into water courses. It is the precipitation less the losses from infiltration and evaporation.

Evaporation, transpiration

Combined loss of water from land and water-surface by evaporation and vegetation transpiration.

Percolation

The term percolation describes the passage of water into, through and out of the ground. Infiltration is the entrance of the water into the ground and its vertical movement down to the ground water table, while percolation (or ground water flow) is applied to the movement of water after it has reached the ground water table.

HYDROLOGIC NATURAL WATER CYCLE

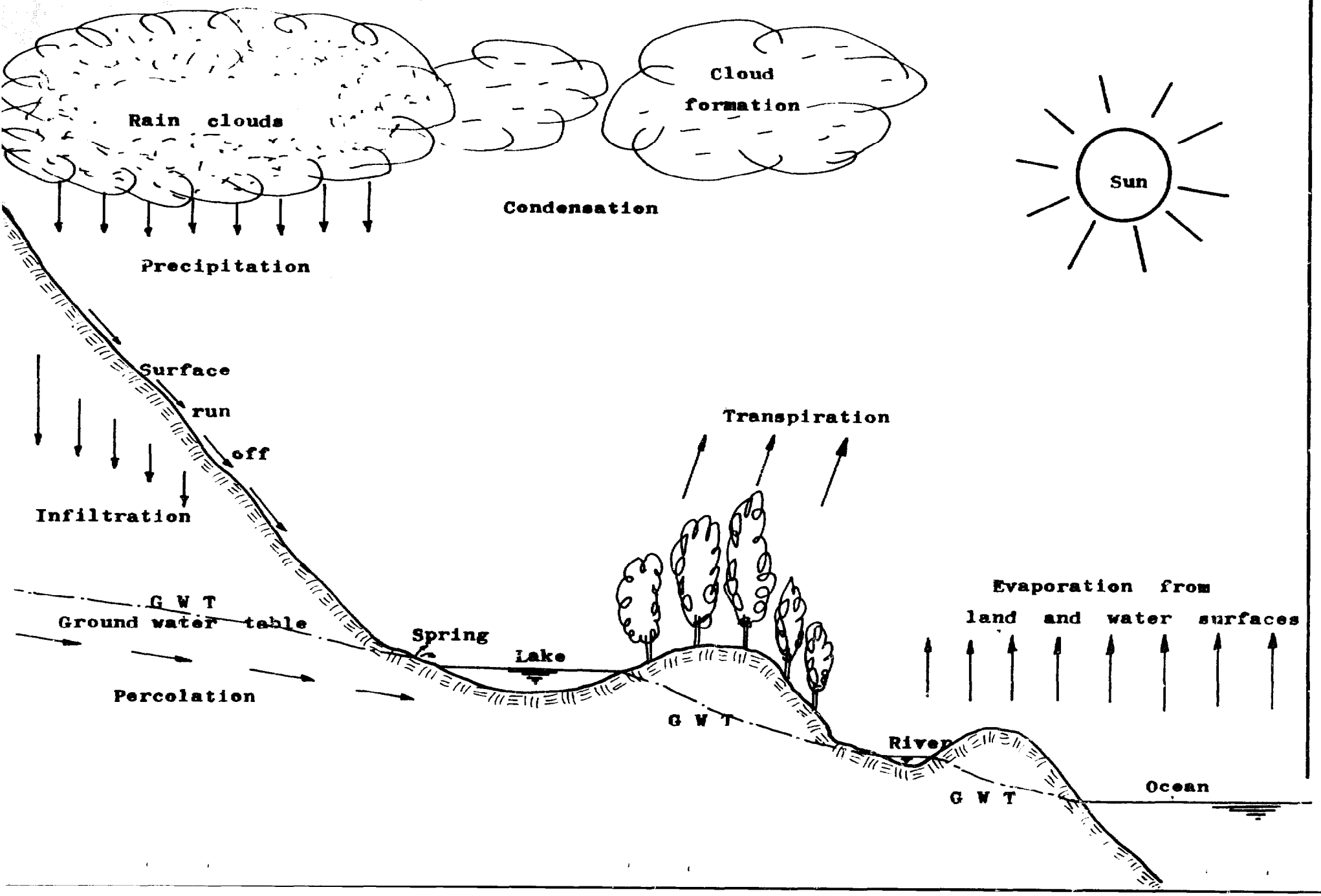

2. Climate

Concerning the year, the main climatic features in Nepal, Gandaki Zone, are as follows:

- The raining season of the year, from April to September (monsoon)

- The dry season of the year, from October to April.

3. Quantity and variation of rainfall in Gandaki Zone, Nepal

Rainfall quantities can be mapped as for example the following diagram for Pokhara town rainfall in 1975.

The rainfall varies greatly throughout the year and also from one year to the other as well as from one station to another.

Rainfall table for the year 1975

Stations	Rainfall amount in mm													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Annual	Max. in 24 hrs.
Khudibagar	63	55	24	140	235	677	923	555	620	154	00	3	3449	111 25 April
Pokhara	38	37	42	118	446	704	1177	650	1096	259	00	00	4767	171 1 July
Shyangja	29	37	32	123	401	654	1033	562	748	210	00	00	3829	195 3 August
Kunchha	32	71	23	41	272	603	740	452	604	85	00	00	2923	158 25 July
Bandipur	17	24	1	40	340	341	553	329	122	21	00	00	1788	102 27 July
Gorkha	24	30	15	63	176	188	343	250	285	22	00	00	1396	60 21 June
Chaparkot	38	20	33	107	210	674	472	472	609	11	00	00	2646	236 30 June
Lumle	51	59	50	29	285	910	1719	1120	897	232	4	00	5356	188 1 July
Chame	28	46	13	1	2	90	262	128	126	42	18	00	756	61 1 July
Lamachaur	64	41	36	117	271	979	1261	783	1229	368	00	00	5149	175 5 Sept.

Rainfall amount in milimeters

POKHARA RAINFALL IN 1975

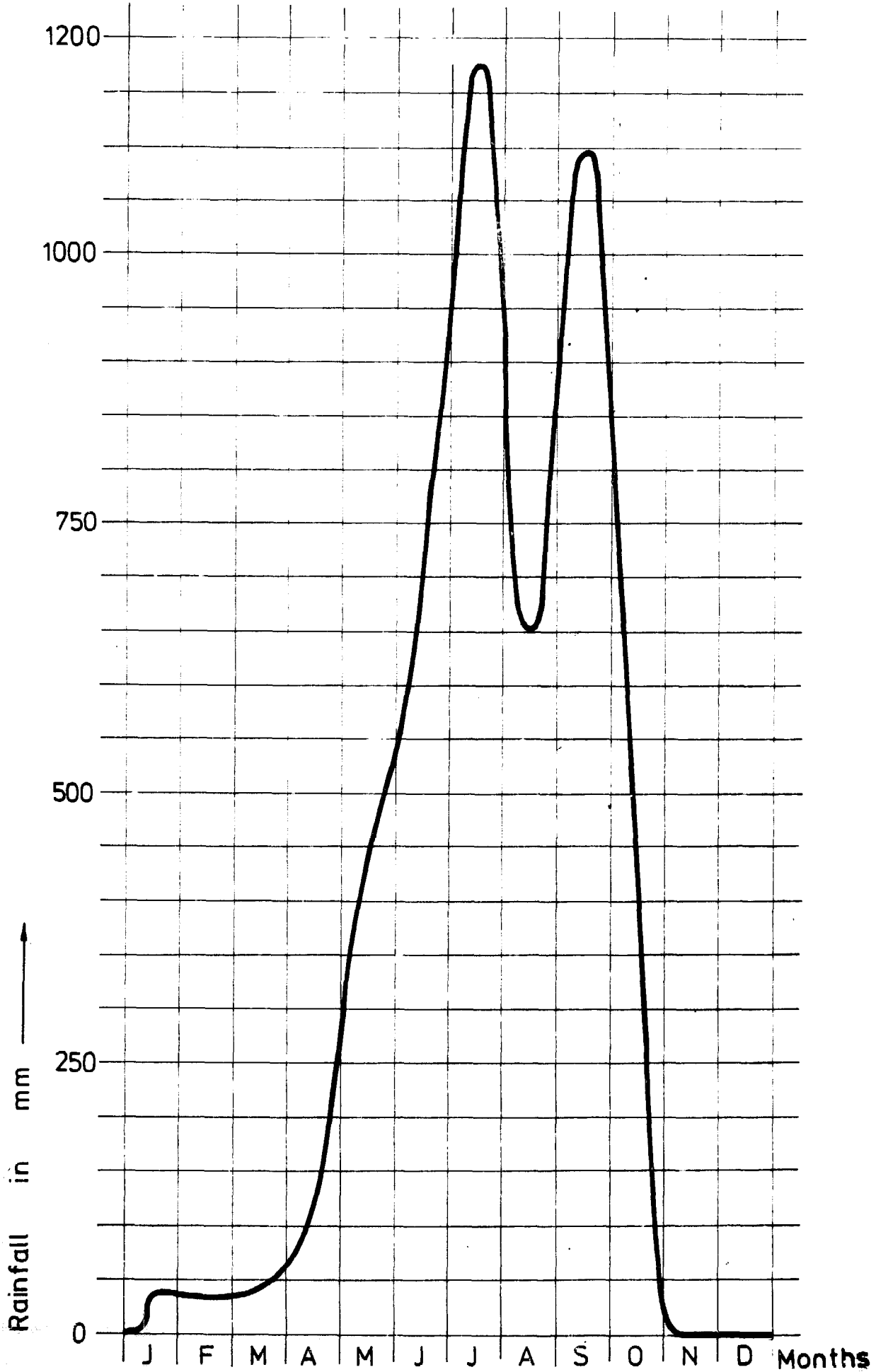

4. Rainfall, run off and infiltration

The quantity of water running from an area into streams and finally into the sea is not the same as the rainfall.

The quantity of rainfall will be shared into:

- direct evaporation
- transpiration through vegetation
- infiltration
- run off

Infiltrated water

It forms the ground water and through its natural filtration it can be used directly as drinking water, only as far as protective, measurements for catchment are adopted.

The characteristics of the yield of a spring depend on the type of soil and sub-soil. From rocky area the quantity of water will directly depend upon the rainfall. Surface springs will also dry up shortly after the monsoon and supply again after the first rains.

Springs from deep porous and water-holding covers, or from far distant catchment areas, are more regular, but their lowest supply quantity does not correspond with the lowest rainfall.

Run off

Similar characteristics can be found in streams. Rocky areas provide flood and low water according to the rains. Porous and water-holding soils supply the streams with underground water and the quantity may still decrease after the first rains. Quantity of water may also varies because of the snow when the melting time arises.

5. Drainage in Gandaki Zone

River	Comes from	Drains	Separates	Runs into or forms
Gandaki River	Tibet	East of Gorkha Distt.	Gorkha & Dhading Distt.	Trisuli river
Trisuli River	Tibet	Central region of Gandaki Zone	Dhading & Nuwakot Distt.	Budhigandaki River
Marsyangdi River	Manang Distt.	Manang & Lamjung Distt.	Gandaki Zone in the middle	Budhigandaki River
Modi River	Annapurna Mountains	Middle part of Gandaki Zone		Budhigandaki River
Seti River	Machhapuchare Mountains	Kaski Distt.		Modi River
Kaligandaki River	Tibet	Western region	Gandaki from Dhaulagiri & Lumbini Zone	Mix with Budhigandaki & forms Narayani River
Modi Stream	Machhapuchare Mountains	West of Gandaki Zone	Kaski & Parabat Distt.	Kaligandaki River
Andhi Stream	South of Pokhara	Syangja Distt.		Kaligandaki River

Important lakes in Gandaki Zone

In Pokhara is the Fewa lake which is partly used for hydro-electric purpose with the help of a dam at the lake outlet.

Near Pokhara there are also

two lakes : Begnas lake

Rupa lake

In the north - west of Manang district is located the Tilchi lake

DRAINAGE IN GANDAKI ZONE

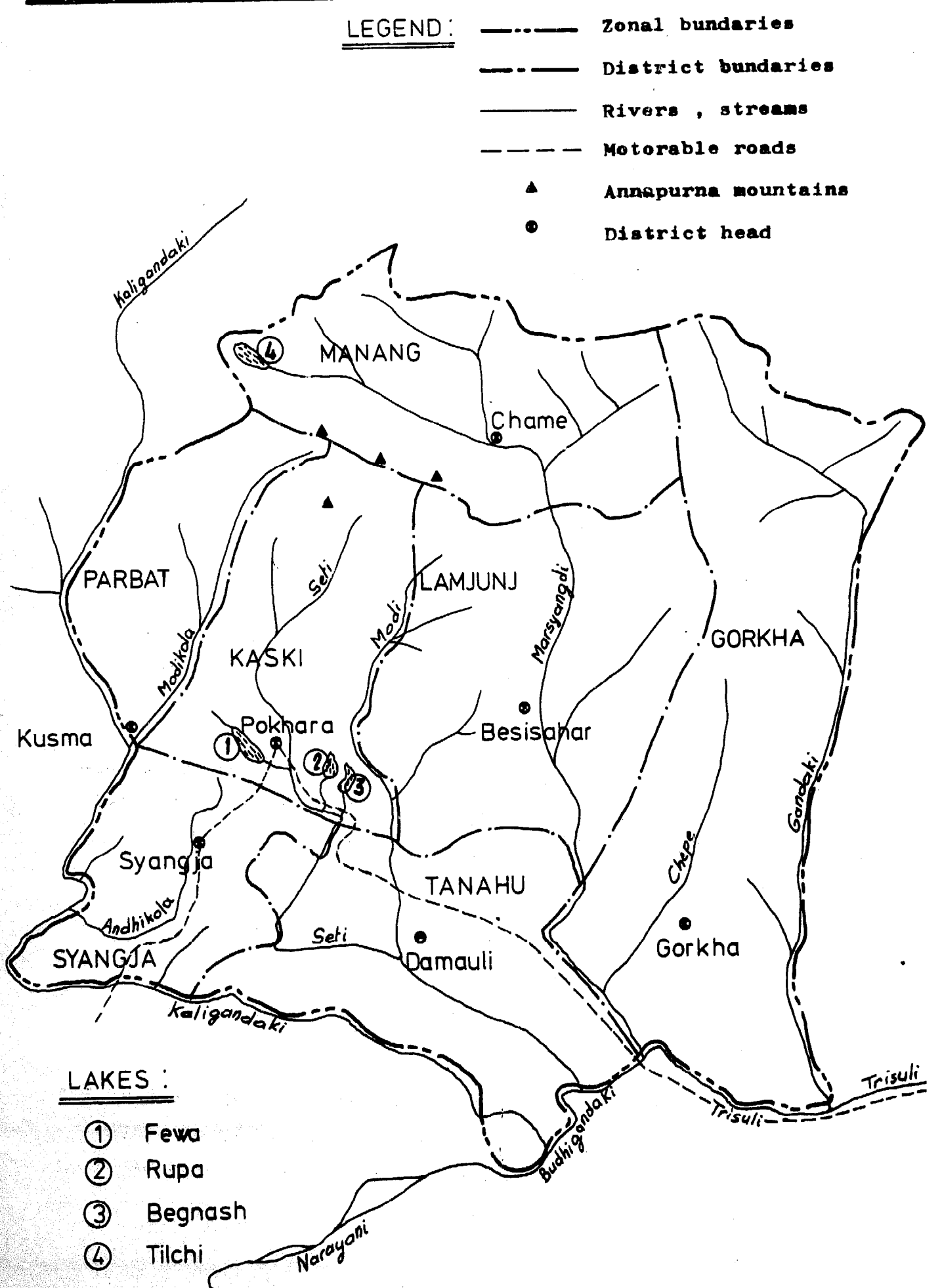

6. Water sources

6.1 Importance of water

The water is very essential for :

- life
- health and sanitation
- as raw material for food production
- farming
- cattle

The water conservation and the sanitation are important to everyone.

6.2 Ground-water

The ground-water is the water which by percolating through the ground reaches the ground water table. The quality of the ground-water depends on:

a) The thickness of the stratum which covers the water-bearing soil, this is important because of indirect contaminations like waste water, latrines and fertilizers, etc...

b) The porosity of the sub-soil which influences the natural filtration process.

The quantity of ground - water depends on :

a) The intake areas. It is important to realise that the topographical basin does not necessarily correspond with the geological or hydrological drainage area.

b) Annual rainfall percolation. This depends on the nature of the intake area. (kind of vegetation like forest, farm, bush, grass field, etc..)

c) Perviousness of the ground. This depends on the kind of material, stratification and its homogenety.

d) Storage capacity of the ground. This depends on the same factors as perviousness and the intake area.

6.3 Springs

If ground-water leaves the ground without artificial help, we call it spring-water.

Spring - water is usually the best water quality. Whenever a water supply is planned, first investigation should be made with possibility to use a spring.

The quality and the quantity of the spring depends on:

a) Intake area

b) Annual rainfall percolation

The continuous flow of a spring depends on the following points :

a) Thickness of the stratum covers

b) Perviousness of the ground

c) Storage capability of the ground

Example of a spring influence by a single rainfall: This spring will not have a constant flow:

- A thin stratum covers the water bearing soil
- The saturated stratum has a great perviousness (cracks and fissures)
- The water - bearing soil has little storage capability (few pores which could be filled with water)

Example of a spring influenced only by annual rainfall. This spring will have a good continuous flow volume :

- A thick stratum covers the water - bearing soil
- The saturated stratum has a small perviousness.
- The water - bearing soil has a big storage capability

Variation of ground water table and position of springs according to season .

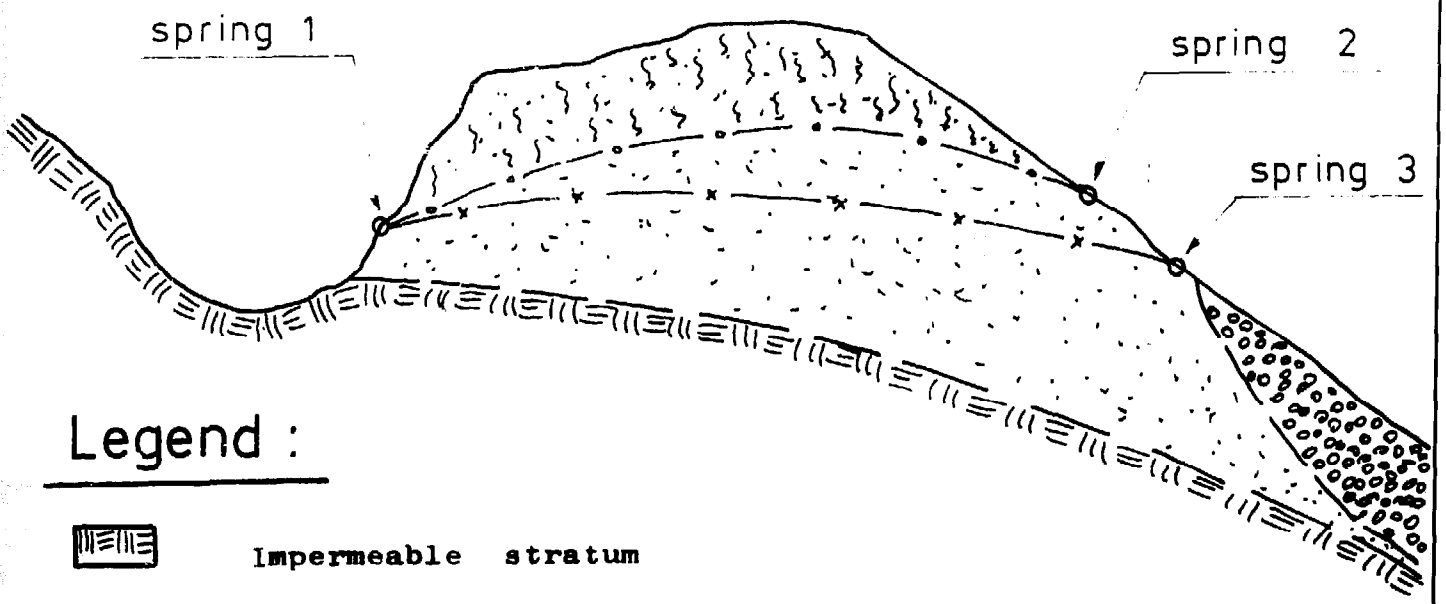

Legend :

Impermeable stratum

Saturated stratum

Clays

—o— Wet season water table

—x— Dry season water table

Remarks :

SPRING 1 : Wet season = large flow
Dry season = small flow

SPRING 2 : Wet season = normal flow
Dry season = dry (no water)

SPRING 3 : Wet season = normal flow
Dry season = normal flow

VARIOUS TYPE OF SPRINGS

Type 1.

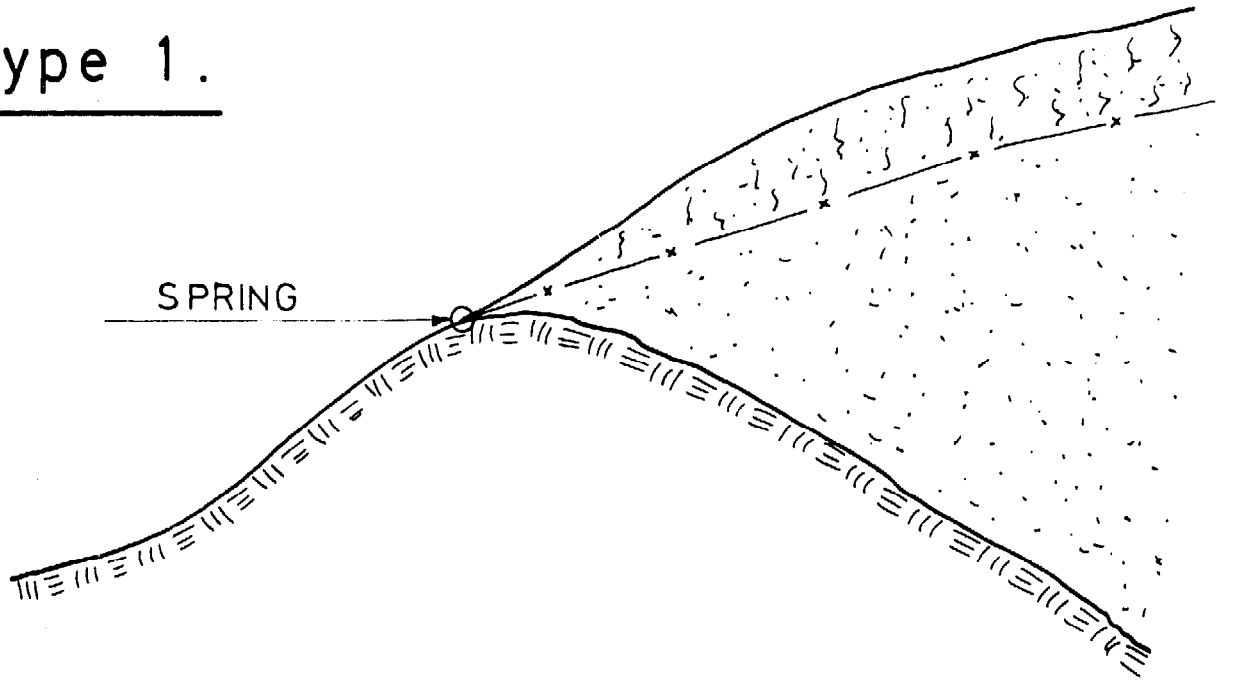

Type 2.

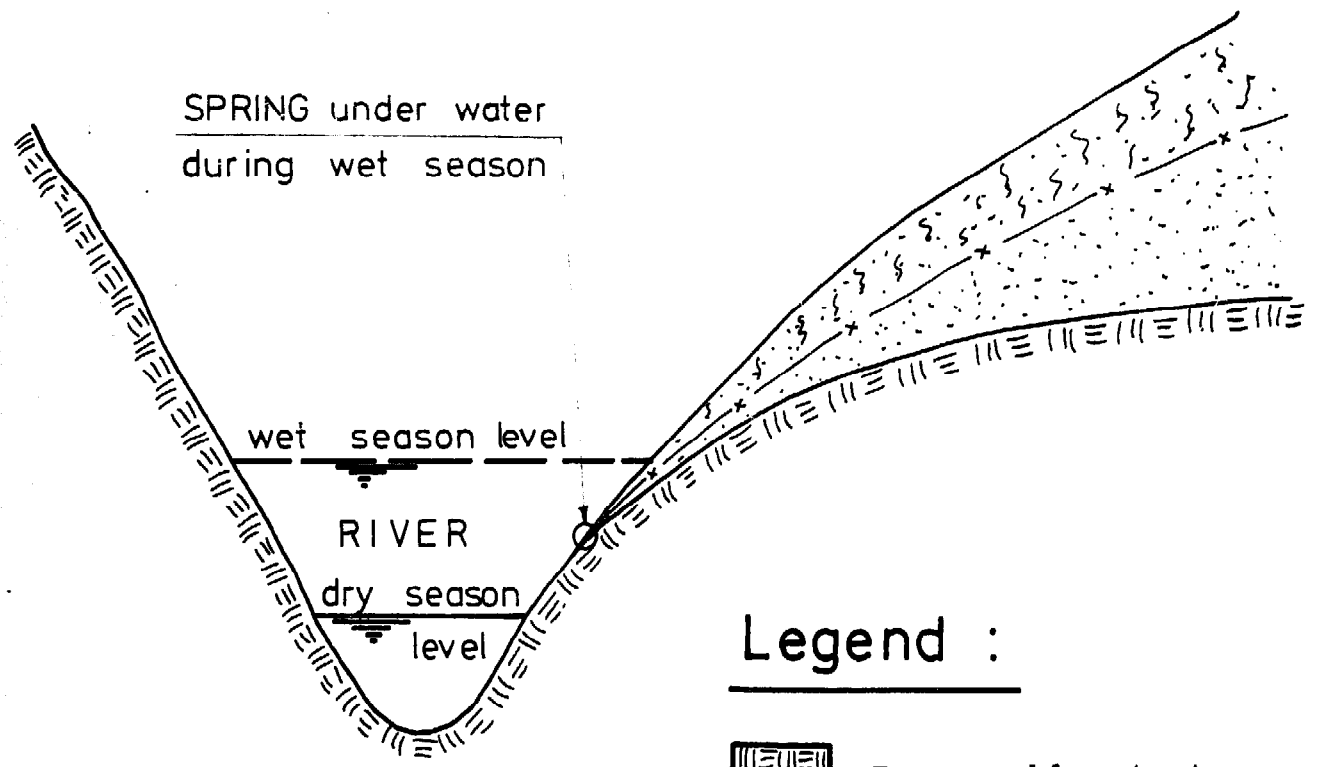

Legend :

Impermeable stratum

Saturated stratum

Ground water table

Type 3.

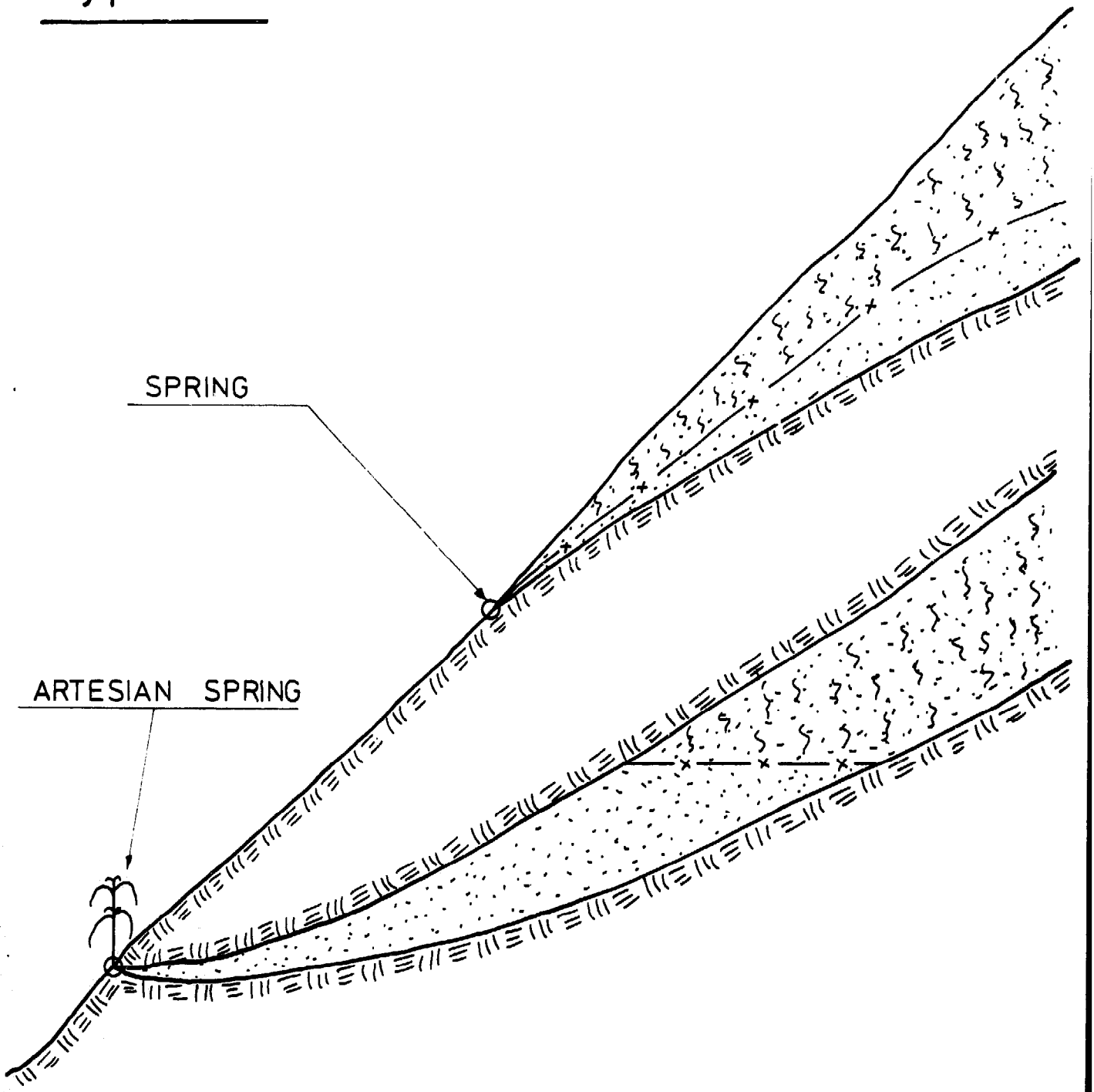

LEGEND :

Impermeable stratum

Saturated stratum

Pervious stratum

Ground water table

6.4 Wells

A well is a round hole dug in the ground up to a certain distance in the saturated stratum.

Wells make it possible to use the underground water for economic applications as for water supplies or irrigation purposes.

The quality of the water obtained from a well depends on :

a) The thickness of the stratum which covers the water - bearing soil.

b) The porosity of the sub-soil.

The quantity of water obtainable from a well depends on :

a) The intake area

b) The annual rainfall percolation

c) The perviousness of the ground

d) The storage capability of the ground.

The different types of wells are as follows:

a) The shallow well which draws the water from the permeable stratum between surface and the first impermeable stratum.

b) The deep well which draws the water from a deep saturated stratum unaffected by surface impurities.

c) The artesian well which has the similar characteristics as the deep well except that it taps water under pressure which will bring the water to the surface under its own head.

TYPE OF WELLS.

a = shallow well

b = deep well

c = artesian well

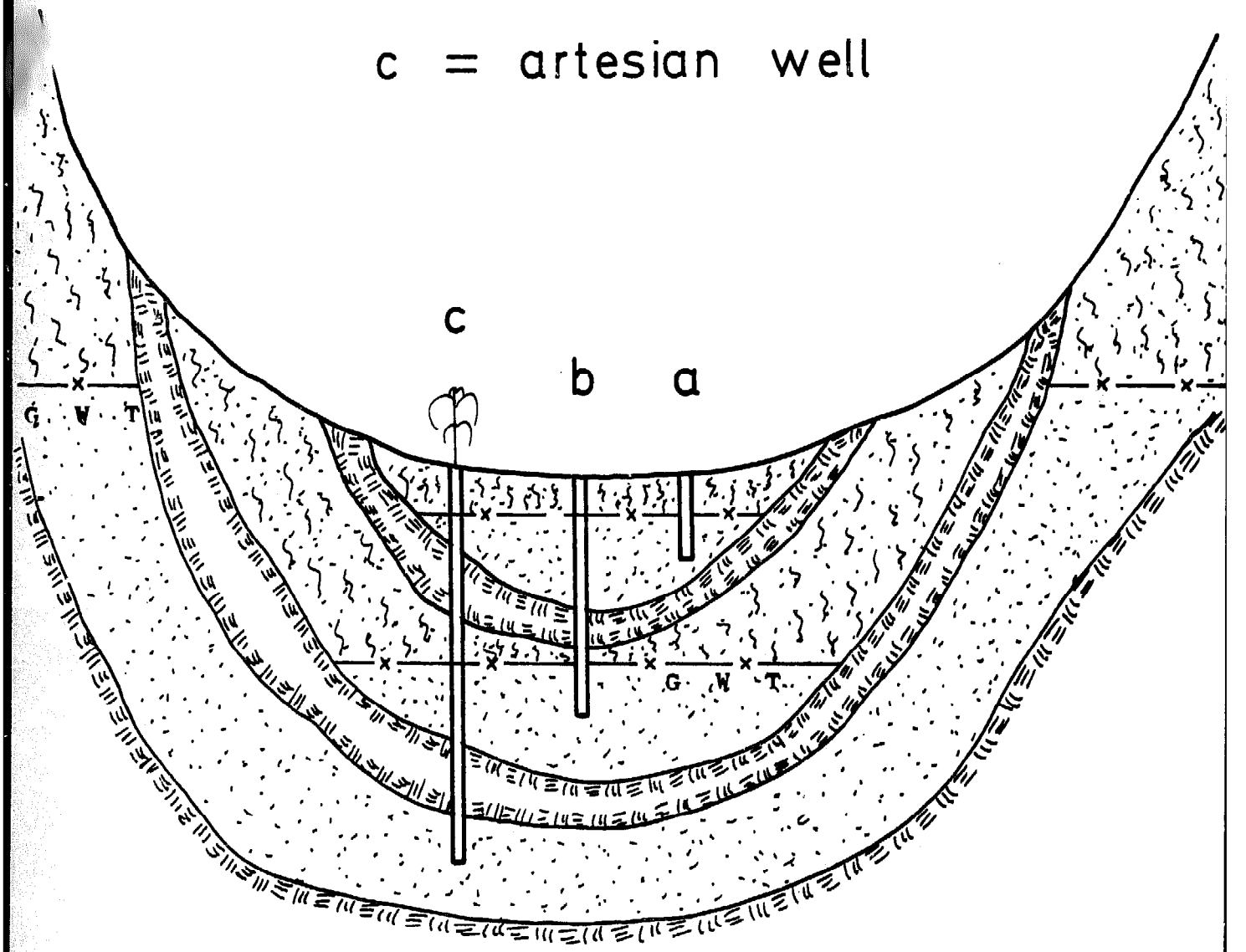

Legend :

- Impermeable stratum
- Saturated stratum
- Pervious stratum
- Ground water table

6.5 Rivers

The run-off water or stream -flow is the water which is gathered into rivulets, brooks, streams or rivers.

The volume and variation of run-off are influenced chiefly by the rainfall and its distribution by the size, shape, cover and general topography of the catchment area, by the nature and condition of the ground.

The melting of the snow also influneces the flow of rivers.

For drinking purpose, the water of rivers should be treated by sedimentation and filtration. Chemical products, (chlorination) can be added for elimination of bacteria. It will be the same for lake water.

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RURAL WATER SUPPLY NEPAL

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PIPE AND FITTINGS COURSE

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Kathmandu 1978

PIPE AND FITTINGS COURSE

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PIPE AND FITTINGS COURSE

1. Preface

The purpose of this course is to give foremen a brief introduction to the types of pipe and fittings most commonly used in the construction of community water supply systems in Nepal. The following types of pipe are presently used:

- HDP (plastic) pipe for distribution pipelines
- GI for service pipes in tanks and for stand pipes

Pipe and fittings made from several other types of materials, for example asbestos and PVC, are available on the world market but these are not described here as their use in Nepal is at present limited.

2. HDP pipe and fittings

2.1 Introduction

2.1.1 Materials

HDP is an abbreviation for high density polyethylene. The liquid gas ethylene is the basic material for the production of polyethylene. Ethylene is produced from either petroleum or coal.

Density: 0.95 gm/cc (lighter than water)
Colour : Black
Permissable temperature range: -30°C to + 50°C

2.1.2 Advantages of HDP pipe

- Simple joining procedure (see chapter 2.4).
- It is possible to make fittings, such as tees and bends, out of pipe.
- Low transport cost due to light weight. Compared to GI pipe, HDP is about seven times lighter in weight.
- The fact that HDP pipe is flexible reduces the cost of installation in difficult hilly areas.
- HDP pipes have a smooth internal surface which means low pressure loss due to friction.
- Polyethylene is exceptionally resistant to inorganic chemicals and to many organic chemicals as well.

2.1.3 Disadvantages of HDP pipe

- HDP cannot be joined to metal by welding. This means the need for special fittings.
- HDP can easily be damaged, so it is recommended that HDP pipe be used only when the pipe is not exposed to the open air. Connecting HDP directly to a masonry or concrete wall should be avoided.
- Coils of larger pipe are difficult to carry because of their size.

2.2 Standard supplies of HDP pipe and fittings

2.2.1 General

HDP pipe and fittings are available in various sizes and types. From time to time it is necessary to change or substitute one or more of the items provided in order to suit changing conditions. For further information on materials described under this section please refer to the booklet entitled "UNICEF Standard Supplies, Rural Water Supply Programme, Nepal". This booklet is updated from time to time to include any changes made.

Firms which manufacture HDP pipe and fittings use the outer diameter to indicate size. Inner diameter is used to indicate GI pipe size. The following table gives the equivalent GI and HDP pipe sizes:

GI (in inches)	HDP (in millimetres)
½	20
1	32
1½	50
2	63
3	90

2.2.2 Pipe

The dimensions and technical specifications of the pipe can differ depending on the supplier's country. To date, all HDP pipe used in Nepal has been manufactured according to DIN (German) specifications, but in future pipe purchased in India will be according to ISI (Indian Standard Specifications). The only major difference between them is that the pipe wall thickness is greater for ISI than for DIN.

Normally, only four sizes of HDP pipe are used in Nepal. These are 20mm. (outer diameter); 32mm; 50mm and 63mm. The usual pressure ratings are 10 kg/sq.cm. for 20mm pipe and 6 kg/sq.cm. for the other three sizes. (A pipe with a 10 kg/sq.cm. rating can withstand water head pressures of up to 100 metres; 6 kg/sq.cm. represents a water head pressure of 60 metres).

When required, however, it is possible to obtain HDP pipe in other sizes (e.g. 90mm). It is also possible to obtain the larger sizes suitable for 10 kg/sq.cm. pressure ratings.

Pressure ratings show the maximum pressure the pipe can withstand. In designing a water system, care should be taken to ensure that the water pressure inside the pipe will never exceed the pressure rating for that particular size of pipe.

2.2.3 Fittings

Fittings are used to join the pipe. Different types of fittings are used to suit different needs. Fittings now available are:

A - Flange sets
B - Brass unions
C - Equal tees
D - Reducers
E - Pipe caps

Elbows can be manufactured in Nepal from pipe, and reducing tees can be made by welding reducers to equal tees.

A. Flange sets

A flange set consists of five parts:

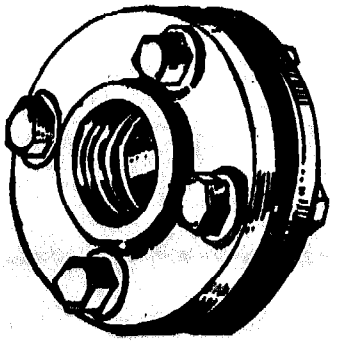

1 - Threaded flange
2 - Unthreaded (plain) flange
3 - Flange adaptor
4 - Rubber gasket
5 - Nuts, bolts and washers.
Flange sets are used as described under section 2.5.2

The threaded flange is for joining to the GI pipe; the flange adaptor is for joining to the HDP pipe.

B. Brass unions

A brass union of this type consists of five parts:

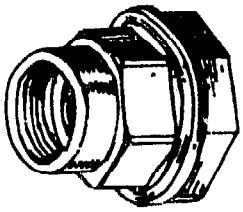

1 - The union body
2 - Brass ring
3 - Brass expansion plug
4 - Neoprene ring
5 - Neoprene gasket. Brass unions are used as described under section 2.5.3

The female-threaded socket is for joining to the GI pipe. The male-threaded socket is for joining to the HDP pipe.

C. HDP Equal tees

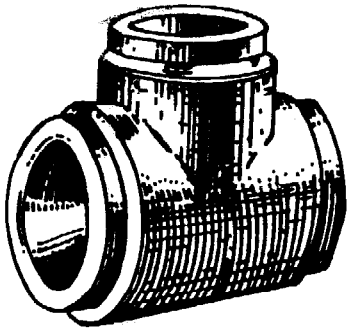

Three equal diameter openings at 90° to each other. These are used in adding branch lines to the main line. Where a reducing tee is required, one or more reducers are welded to one of the tee openings.

D. HDP Reducers

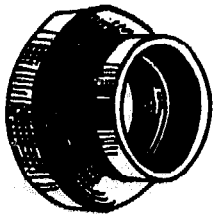

Used in joining two lengths of pipe of different sizes. The larger pipe is welded to the larger reducer end; the smaller pipe to the smaller reducer end.

E. HDP Pipe caps

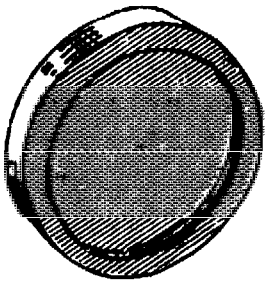

Where a 90° elbow is required, a cap can be welded to one of the ends of an equal tee. Caps can also be used in blocking lines, when required, and in manufacturing HDP screens for tank outlets.

2.3 Handling of HDP pipe

2.3.1 Transport

HDP pipes are normally transported in coils. Any possibility of external damage, for example from sharp stones or glass, should be avoided.

2.3.2 Storage

HDP pipe coils should be laid horizontally, and stored in the shade. Polyethylene pipes should not be stored near fertilizers, insecticides or other strong chemicals. The pipe should never be exposed to fire or excessive heat.

2.3.3 Pipe coils

The pipe which is extruded in a straight length is mechanically wrapped around a coil former and bound together into a rigid transportable coil. When the binding is cut from the coil, the pipe will tend to revert to a straight pipe. Care should be taken to control this movement for 50mm diameter pipe and above, as the uncoiling force can be of a considerable magnitude. (HDP pipe can also be provided uncoiled and cut into lengths if so required).

2.4 Joining HDP to HDP

2.4.1 General

HDP pipes are joined by a process called "Butt-Welding". When HDP plastic is heated to the correct temperature it becomes molten and solidifies again after cooling. A properly welded joint is as strong as the pipe itself. This joint has the same life expectancy and corrosion resisting properties as unwelded pipe.

2.4.2 Tools for "Butt-Welding".

The following tools are required:

- Heating plate
- Blow torch or other source of heat (see appendix 1)
- Thermochrome crayon
- Hacksaw (with blades)
- Scraper or knife

Other very helpful tools are:

- Mould)
- Mitre box) - see appendix 2
- Hand mitre saw)

2.4.3 Welding procedure

a) Hold the pipe in the mitre box and cut it to the desired angle. Care should be taken to prevent movement of the pipe while cutting so as to prevent any change in the profile of the surface.

b) Remove fibrous material with a scraper or knife to obtain a smooth surface. Care should be taken that the trimming of the pipe ends is complete over the entire pipe circumference. After trimming nothing should be allowed to touch the newly exposed faces.

c) Check the joint for neat contact and true alignment. At no point of the joint should there be a gap of more than 0.5mm.

d) Heat the clean plate a short time. Put marks with the thermochrome crayon on it and continue with heating. During the heating the colour of the marks will change from white to brown. When the marks are dry and brown, the plate has the right temperature of 220°C and the heating plate must be removed immediately from the blowtorch. It is very important to weld with the correct heating plate temperature. Every new joint needs the same procedure.

e) Hold the pipe ends on the two sides of the hot plate and press them gently until a low rim of melted material is formed.

f) Remove the heating plate and without delay bring the pipe ends into contact under light but firm pressure. At no time should excessive pressure be applied. Keep pressure on the joint until it has cooled. It is recommended that contact with cold water not be used in speeding up joint cooling.

g) Every joint has to be checked by bending and good visual control. An internal water pressure test will be carried out after the pipe has been welded into a line. (See water supply construction course).

Summary of Butt-Welding

1. Rules

Clean straight cut (pipe end)
Clean welding plate
Heating plate temperature 220°C

2. Form of the Butt-Weld under various welding conditions

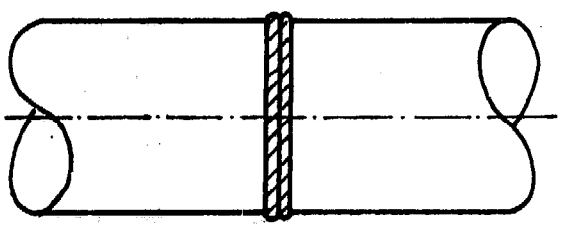

Correct

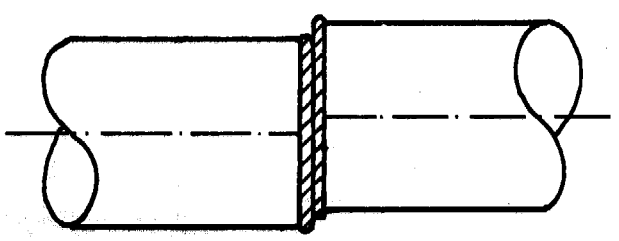

Wrong: Out of axial alignment

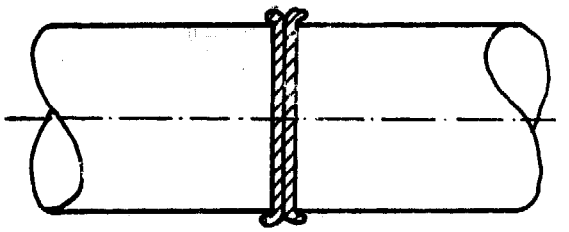

Excessive pressure at the start of the welding procedure

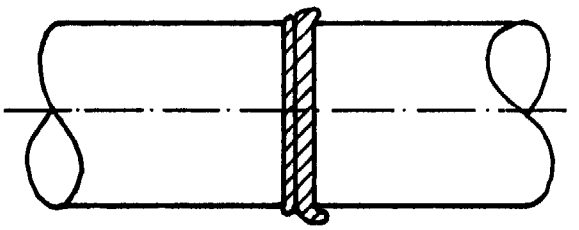

Uneven heating of the two pipe ends

2.4.4 Making fittings locally

Usually the HDP fittings are prefabricated but in certain cases, for instance repairs, some fittings can be produced at the site.

On the following pages the procedures for making different fittings are illustrated.

1. BRANCH 90°

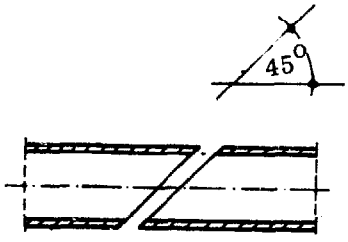

1. cut

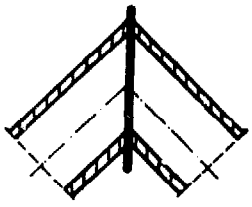

2. check

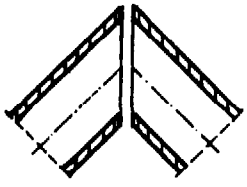

3. file and check

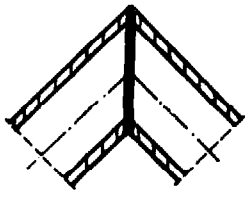

4. Weld

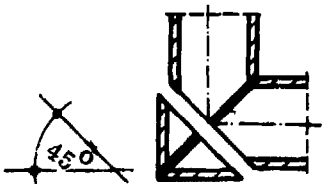

5. Cut

6. Cut another piece

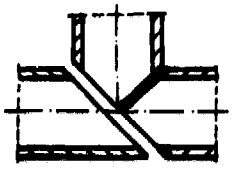

7. File and Check

8. Weld

2. BRANCH 60°

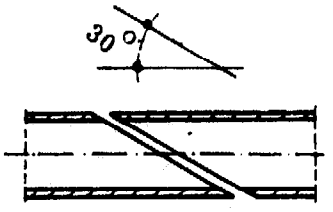

1. Cut

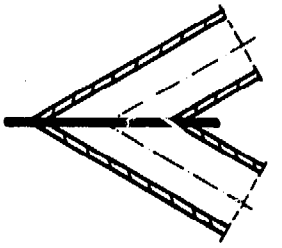

2. Check

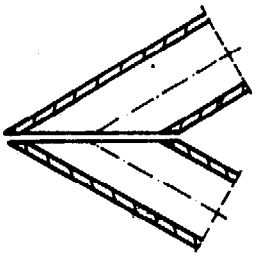

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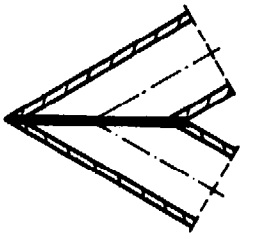

4. Weld

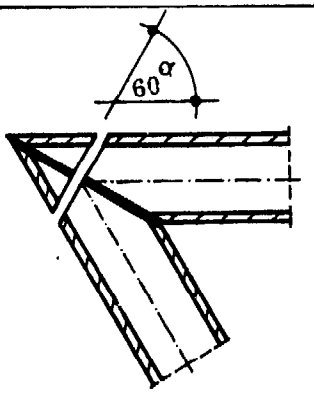

5. Cut

6. Cut another piece

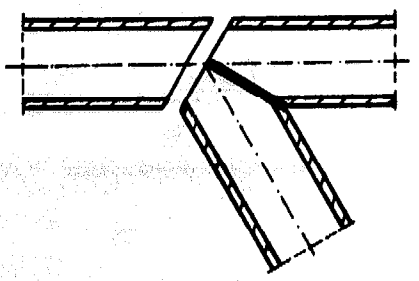

7. File and Check

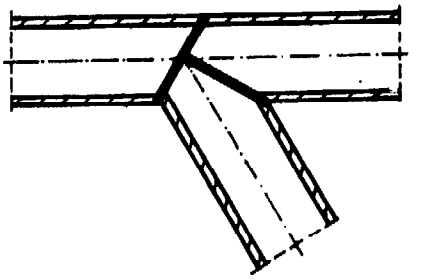

8. Weld

3. BRANCH 45°

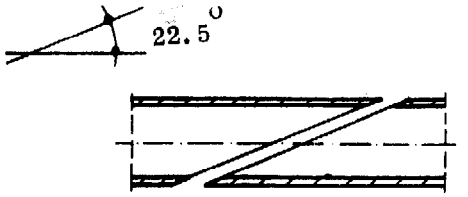

1. Cut

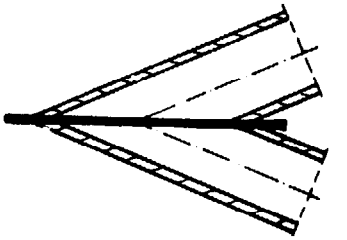

2. Check

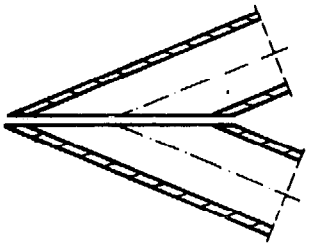

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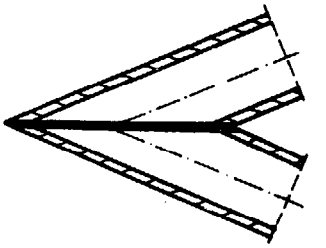

4. Weld

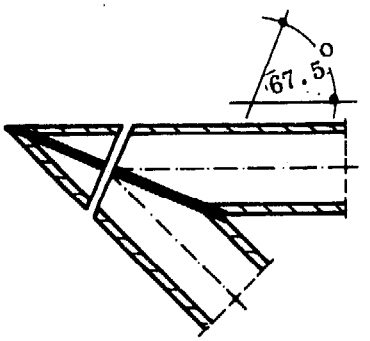

5. Cut

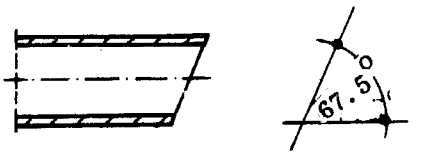

6. Cut another piece

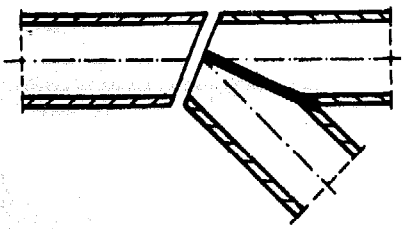

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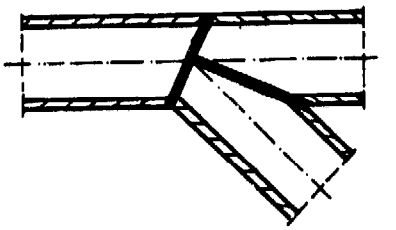

8. Weld

4. ELBOWS AND BENDS

Elbow 45°

2 pieces with 11.25° cut
1 segment piece 2 x 11.25° cut

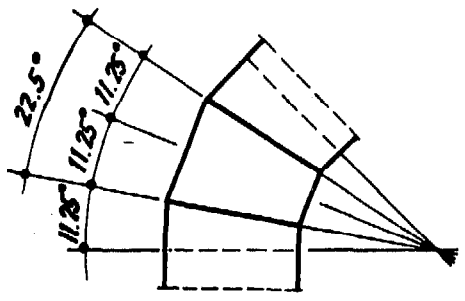

Elbow 90°

2 pieces with 15° cut

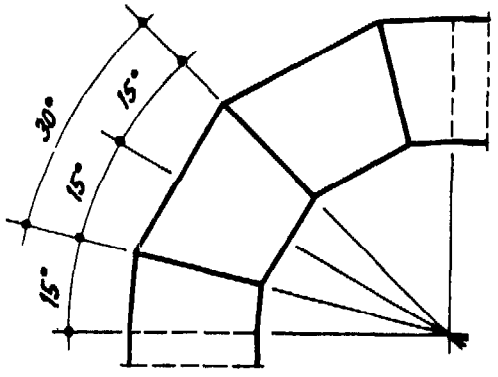

2 segment pieces 2 x 15° cut

Bend 45°

2 pieces with 5.6°
3 segment pieces 2 x 5.6°

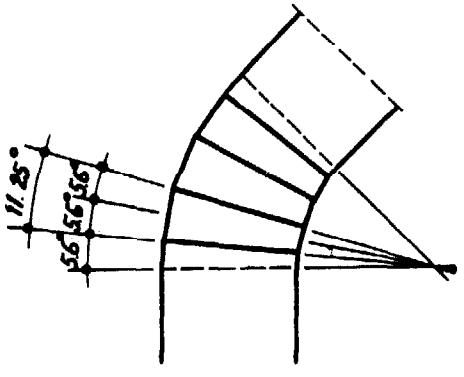

Bend 90°

2 pieces with 7.5°
5 segment pieces 2 x 7.5°

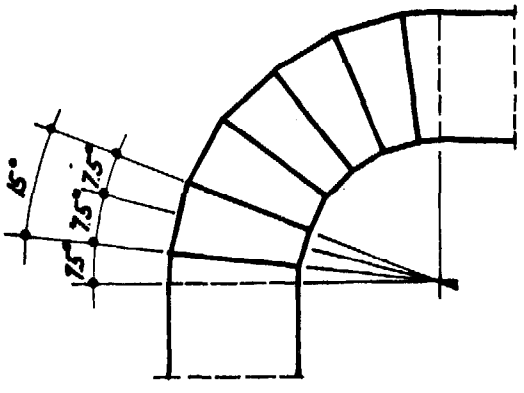

Not recommended

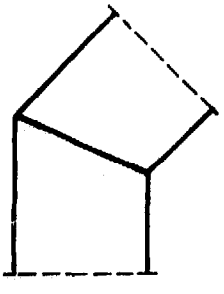

Wrong

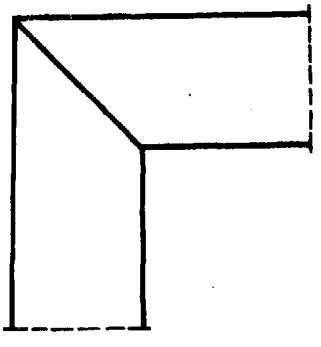

5. ENDCAP

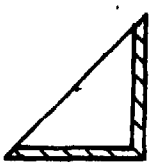

Take the left-over segment of a 90° branch of the same diameter as the pipeline

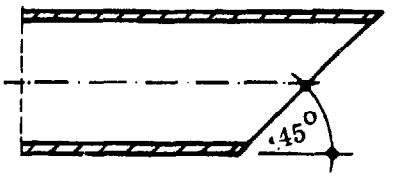

Cut a 45° angle on the pipe line

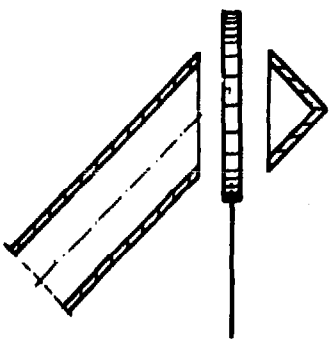

Heat both pieces on the welding plate

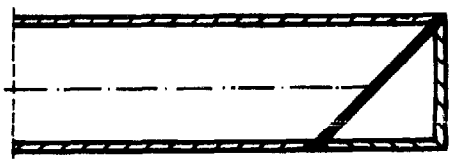

Weld them together

6. CONICAL REDUCER

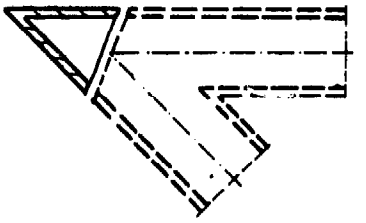

1. Take a segment of a 45^0 branch

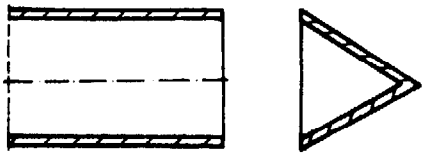

2. Check to ensure that the diameter of the segment is the same as that of the larger diameter pipeline

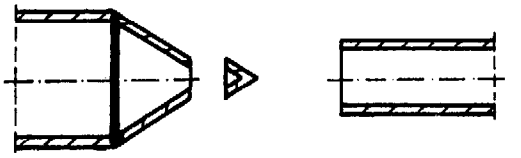

3. Weld the conical piece to the pipe with the larger diameter

   Cut off the pointed end; this small segment has to be smaller than the diameter of the smaller pipe to be joined.

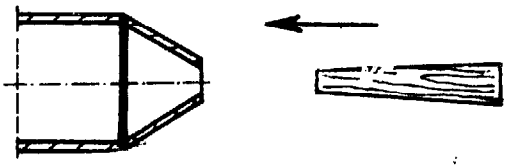

4. Heat the end lightly and push a conical piece into it.

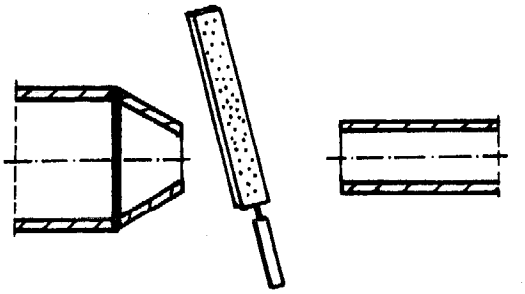

5. After cooling file the end of the reducer down to the diameter of the smaller sized pipe

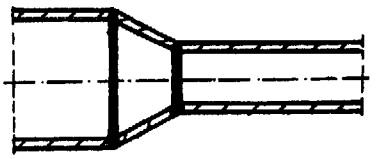

6. Heat both pieces on the welding plate and weld them together

2.5 Joining HDP pipe to GI pipe or GI fittings

2.5.1 General

HDP cannot be joined to metal by butt-welding, but there are several other methods of making such a joint. The two methods for which fittings are provided are joining with flanges and joining with unions.

2.5.2 Using flanges

In making a flanged joint a flange set is used (see 2.2.3). A flange set has one threaded flange, one flange which is not threaded, a plastic flange adaptor, a rubber gasket and nuts and bolts to hold these together. First, the set is disassembled by removing the bolts. Second, the threaded flange is screwed onto the GI pipe. Third, the unthreaded flange is slid onto the HDP pipe. Fourth, the HDP pipe is welded to the flange-adaptor. Fifth, the gasket is replaced and the flanges are bolted together again.

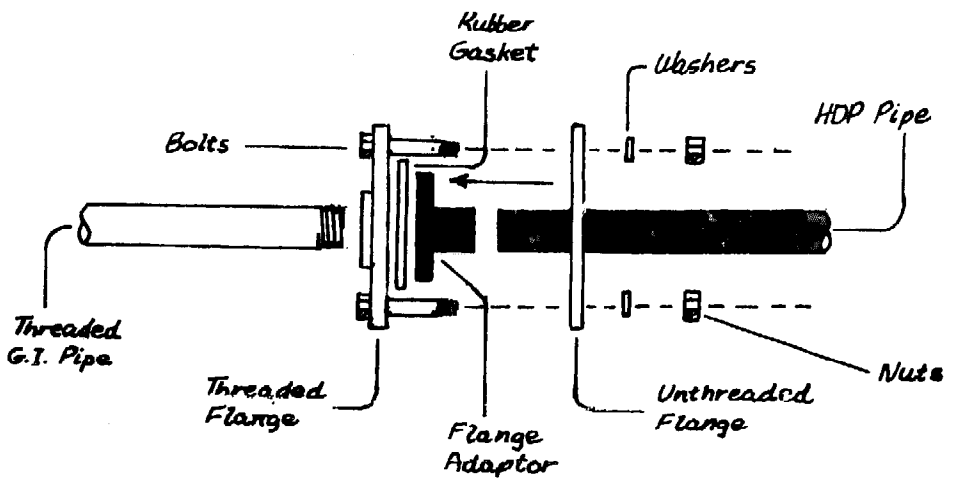

2.5.3 Using brass unions

For making a union joint a brass union is provided (see 2.2.3). A brass union of this type consists of 5 parts:

a) The union body which has female threads on one end and male threads on the other
b) A brass ring, with female threads
c) A brass expansion plug
d) A neoprene ring
e) A neoprene gasket

First, the female-threaded end of the union is screwed onto the GI pipe. Second, the brass ring is unscrewed and slid over the HDP pipe. Third, the neoprene ring is also slid over the pipe. Fourth, the end of the HDP pipe is heated until it becomes soft. The most practical way of doing this is to place the pipe end directly in a flame, but in using this method care must be taken to ensure that the pipe is not over-heated or made to burn.

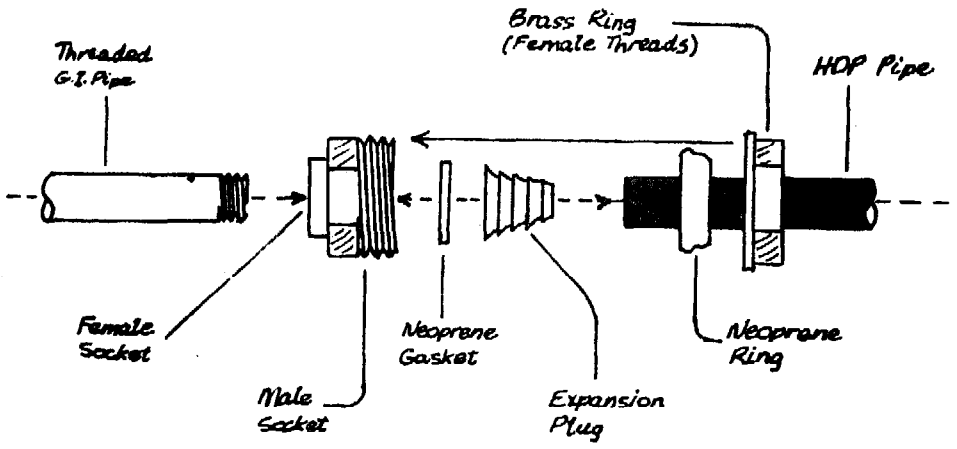

Fifth, the expansion plug is inserted into the HDP pipe, small end first. The nozzle should be pushed in until its large end is even with the pipe end, but not further. This must be done while the pipe end is still warm. Sixth, the neoprene gasket is placed in the union socket which has male threads. (Note that with certain types of brass unions a gasket is not necessary). Seventh, the brass ring is screwed tightly onto the union. With a union joint no butt-welding is necessary.

APPENDIX 1: OPERATING A BLOW TORCH

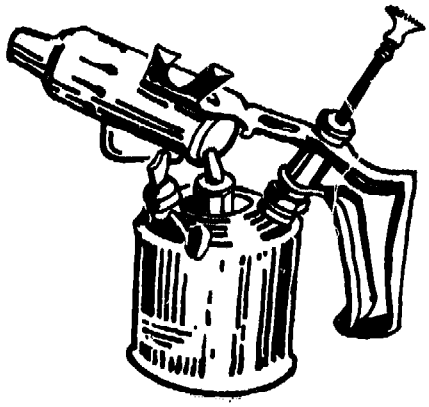

The blow lamp is a portable kerosene torch used to produce intense local heat, for melting metals, heating metals and soldering. The blow torch can also be used in welding HDP pipe and fittings.

Operating a blow torch

1. Fill the tank to 3/4 with kerosene. Use a funnel with a filter so that dirt will not flow into the tank and block the outlet.
2. Open the air valve.
3. Fill the oil cup with kerosene.
4. Light the kerosene in the oil cup. Leave the burning match in the cup.
5. Let the kerosene almost burn out.
6. Close the air valve.
7. Pump the air pump 15 to 20 times.
8. After pumping the torch should start burning. If it goes out, repeat the above operation.
9. Pump more if a more intense flame is required.
10. To decrease flame intensity open the air valve slightly to lower the air pressure.
11. If the flame smokes or fluctuates, clean the outlet with a cleaning needle.
12. To put out the flame open the air valve all the way.

APPENDIX 2 : *Mould and Mitre Box*

MOULD FOR STRAIGHT PIPE WELDING

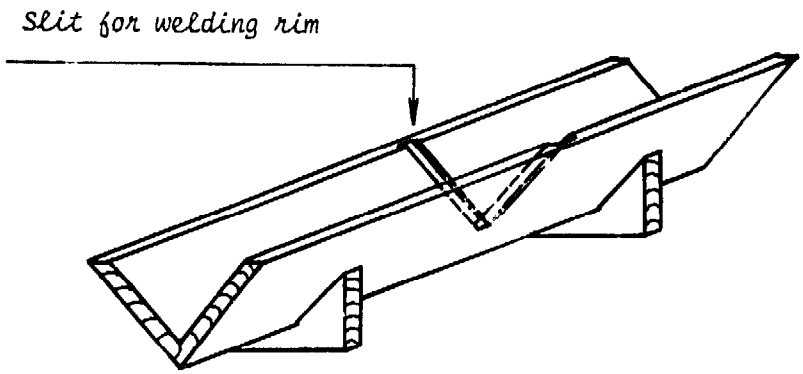

MITRE BOX

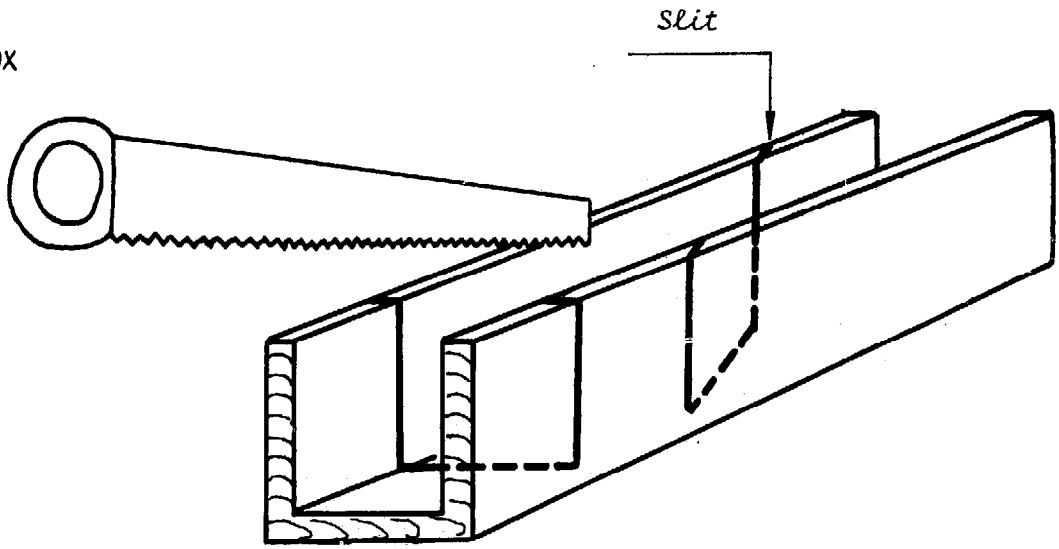

MOULD FOR BRANCH (WELDING AND CUTTING)

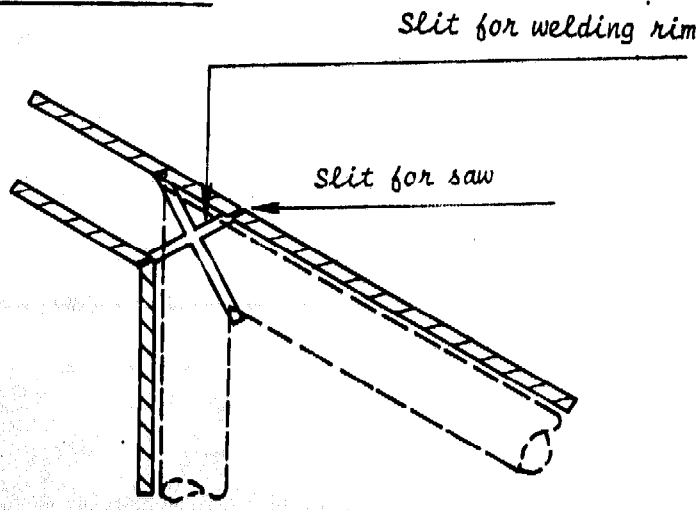

3. GI pipe and fittings

3.1 Introduction

3.1.1 General

Galvanised iron pipes are used as service pipes in crossing rivers, in tank installations and pressure reducers. This is possible because of the rigidity and high pressure rating of GI pipe. GI pipe and most of the fittings are usually locally available in the bazaar. The abbreviation GI is short for "Galvanised Iron".

Density : 7.85 gm/cc.
Colour : Grey-galvanized.

3.1.2 Advantages of GI pipe and fittings

- Mechanical strength and high pressure rating.
- Locally available.
- Cement will adhere to the metal after the galvanisation has been removed. This makes it possible to use the pipe in concrete structures such as reservoirs.

3.1.3 Disadvantages of GI pipe and fittings

- No possibility of making fittings locally.
- High loss of water pressure due to internal friction.
- Low resistance to chemical corrosion as compared with HDP or other plastic pipe.
- Higher cost than HDP or other plastic pipe.
- Heavy weight.

3.2 Standard supply of GI pipe and fittings

3.2.1 General

The following sections give a brief description of each GI item normally used in constructing water supply systems of the gravity-flow type. (Refer to section 2.2.1 for pipe size description).

3.2.2 Pipe

GI is an abbreviation of "Galvanised Iron", a term broadly used to describe metal pipe of the type commonly utilised in the installation of gas, water and steam conduits. Although such pipe is normally made of mild steel, it is nevertheless widely referred to as GI.

It is possible to procure such pipe without the galvanisation, but it is usually galvanised (coated with an thin layer of zinc) to prevent otherwise rapid rusting of the pipe. For this reason, GI pipe should not be bent. If this is done the galvanisation will crack and the pipe will begin to rust at that point. If a bend is required, an appropriate fittings (e.g. an elbow) should be used.

GI pipe is normally delivered in single lengths of 6 metres each. Each length should have a socket screwed to one end.

The pipe is manufactured in three categories according to its weight and pressure-bearing capacity. The categories are: 1-light (formerly Class A); 2-medium (formerly Class B); 3-heavy (formerly Class C). The category most readily available in hardware stores in Nepal is of the light grade. Medium and heavy grades can also be purchased but for those grades an advance order is generally required.

The three tables given below described the basic characteristics of each grade of pipe.

a) <u>Light grade</u>

INSIDE DIAMETER (INCHES)	OUTSIDE DIAMETER (mm)	WALL THICKNESS (mm)	WEIGHT (kg/m)	RECOMMENDED WORKING PRESSURE (kg/sq.cm.)
½	21.2	2.0	0.95	10.6
1	33.5	2.7	2.01	10.6
1½	48.1	2.9	3.25	8.8
2	59.9	2.9	4.11	7.0
3	88.3	3.3	6.81	7.0

b) <u>Medium grade</u>

INSIDE DIAMETER (INCHES)	OUTSIDE DIAMETER (mm)	WALL THICKNESS (mm)	WEIGHT (kg/m)	RECOMMENDED WORKING PRESSURE (kg/sq.cm)
½	21.4	2.7	1.22	21.1
1	33.8	3.3	2.44	21.1
1½	48.4	3.3	3.61	17.6
2	60.2	3.7	5.10	14.1
3	88.8	4.1	8.47	14.1

c) Heavy grade

INSIDE DIAMETER (INCHES)	OUTSIDE DIAMETER (mm)	WALL THICKNESS (mm)	WEIGHT (kg/m)	RECOMMENDED WORKING PRESSURE (kg/sq.cm)
½	21.4	3.3	1.45	24.6
1	33.8	4.1	2.97	24.6
1½	48.4	4.1	4.43	22.1
2	60.2	4.5	6.17	17.6
3	88.8	4.9	10.10	17.6

Important note: In calculating the recommended working pressure, a safety factor of 4 is included in order to allow for occasionally high water pressure which results from surge pressure, water hammer etc. within the pipe. Under working conditions which are generally free of exceptionally high pressures which result from surging, or other such causes, the pipe can be used under pressure conditions up to 4 times the recommended working pressure. This applies to all three grades. For example, this could mean that 1" light grade pipe could be safely used under pressures of up to 42.4kg/sq.cm.; 2" heavy grade pipe could be used under pressures of up to 70.4kg/sq.cm. provided that intermittently very high pressures as described above are not expected.

3.2.3 Fittings

Most GI fittings are normally made of either medium or heavy grade mild steel. Certain types, such as sockets, are sometimes made of light grade mild steel, and this should be kept in mind while designing a system as such fittings are not as durable as those of medium or heavy grade mild steel. One way of getting around this would be to bring spare fittings to the village. For example, if 10 elbows are required for a certain system, 15 could be brought to the work site. This would allow for spares and for replacements in case some of the parts were found to be defective.

On the following pages, the most commonly used GI fittings are described.

BEND

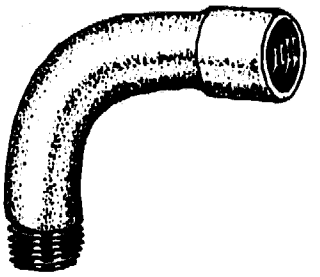

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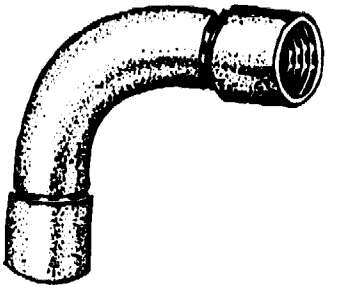

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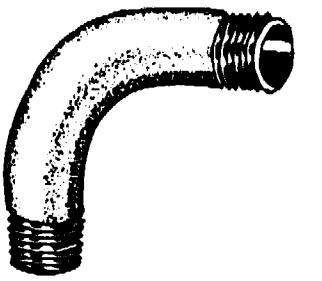

ELBOW

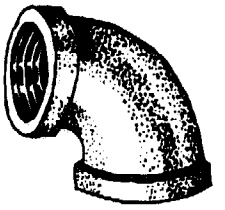

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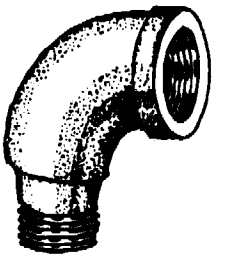

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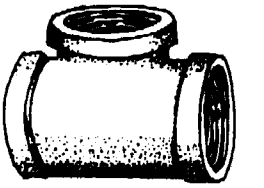

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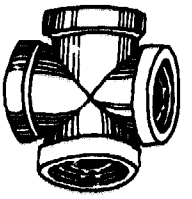

REDUCING SOCKETS

REDUCING BUSHES

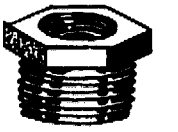

SOCKET

HEXAGON NIPPLES

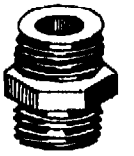

PLUGS

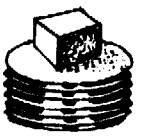

CAPS

BACK NUTS

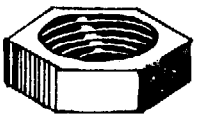

FLANGE OVAL

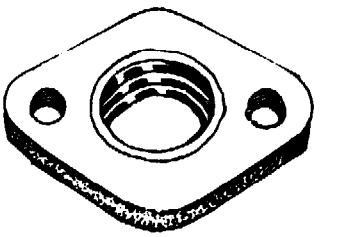

FLANGE ROUND

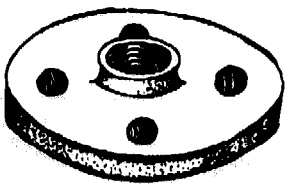

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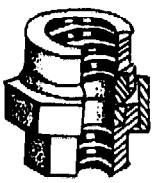

NIPPLE

3.3 Handling of GI pipe

3.3.1 Transport

GI pipes are heavy. They should be treated carefully. If the galvanisation is damaged, the pipe will start to rust.

3.3.2 Storage

GI pipes have low resistance to chemical corrosion, so it is better to store them above ground level by using supports or other means.

3.4 Joining of GI pipe

3.4.1 Tools

To work with GI pipes, the following tools are required:

- Pipe wrench
- Shifting spanner
- File
- Hacksaw (with baldes)
- Die set
- Plumber's table with vice
- Hammer
- Chisel
- Tape and pencil
- Spirit level

3.4.2 Thread cutting

Measure and mark the length of pipe to be threaded and cut the pipe with the hacksaw. In cutting the pipe, even strokes should be used as hasty, irregular strokes rapidly wear out the teeth. The saw blade must be kept straight. After the pipe has been cut, a die set is used to thread the end of the pipe. A properly cut pipe-end makes the pipe easier to thread.

a) Use the set of teeth which corresponds to the diameter of the pipe to be threaded.

b) Put oil on the end of the pipe which is to be threaded.

c) Fix the machine in such a way as to place the guiding teeth on the pipe.

d) Begin the thread cutting. There has to be a sufficient quantity of oil on the surface to be threaded during the entire cutting operation.

e) The length of thread to be cut varies with the diameter of the pipe according to the table given below. The threads have to be cut in three working operations.

f) Clean the thread and test it by fitting a socket on the threaded pipe end.

Internal pipe diameter (inches)	Length of thread to be cut (mm)
½	13
1	17
1½	19
2	24
3	30

-Many of the locally available die sets are of low quality, and added care should be taken in using such sets. These sets have no guiding teeth, no fixed point for the cutting teeth and they are difficult to use in threading large diameter pipe.

3.4.3 Water-tight joints

Although several types of materials can be placed on threads to make the joint water-tight, only dry hemp and non-poisonous joint paste (putty or animal grease) should be used. Because paint becomes very hard when it dries, it is not recommended as joint paste.

a) To guarantee water-tightness the threads have to be roughened with an old hack-saw blade so that the hemp will remain in the thread.

b) Turn the hemp in a clockwise direction, starting at the beginning of the thread (end of the pipe), covering the entire thread with hemp.

c) Put joint paste on the thread hemp. Ensure that no hemp, oil or joint paste remains inside the pipe.

d) Fix the fitting on the pipe by hand and tighten with a pipe wrench until reasonably tight. If turned too tight, the fitting may stretch or crack.

e) Cut off the visible hemp with an old hacksaw blade by moving it counter-clockwise.

The conical form of threads contributes to water-tightness. If a lot of hemp comes out of screwed fittings, it means that the hemp was not fixed correctly.

Tools must always be kept clean, especially the teeth of pipe wrenches.

4. Miscellaneous valves

4.1 Gate valve

Gate valves are normally used in situations where a full pipe flow is required but where it is occasionally necessary to shut off the flow completely. Gate valves should not be used in controlling flow. In other words, gate valves should not be left partially open - they should either be completely open or completely closed. The gate of the valve is wedge shaped and this gate cuts off the flow when the valve is closed and the gate is lowered into a groove cast in the body of the valve.

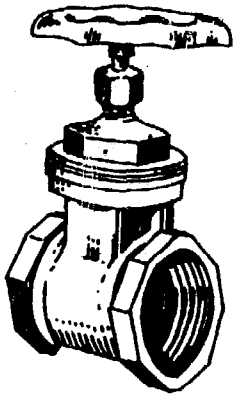

The valve opening is usually of the same diameter as the inside of the pipe to which it is fitted and the valve, when completely open, offers very little resistance to water low. Gate valves which are left shut for a long time tend to stick shut, after which great force is required to get the gate off the sealing. Similarly, valves which have been left open for a long time may not close properly because of dirt collected in the gate groove which prevents proper lowering of the gate. If a gate valve has not been opened or closed for years after that time it may not be possible to operate it at all.

These problems can be avoided by regularly opening and closing the valves.

4.2 Globe valve or stop cock (corporation cock)

These valves derive their name from the valve body which is globe-shaped. Globe valves are normally made only in smaller sizes. The body of the valve is cast so that the water must pass through a horizontal opening in the valve seat. A plug, a diaphragm or a jumper can then be forced down into this opening by a screwed handle for shutting off or controlling flow.

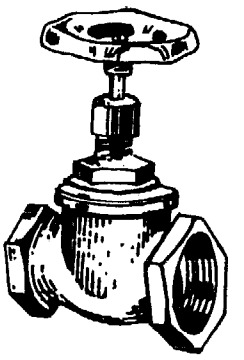

Globe valves have to be installed in such a way that the force of the incoming water is pressing upwards on the valve seat.

The friction loss of water flowing through such valves is quite high.

4.3 Tap (faucet)

Taps are used at the water collecting point to fully open, partially open or completely shut off the flow of water. Many types of taps are available (automatic control, manual control, etc.) and all of those can be made of a variety of materials (brass, iron, steel, etc.).

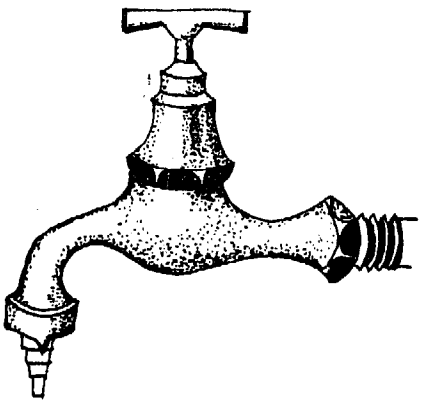

The tap most commonly used in rural areas of Nepal is a manually operated, brass tap with male threads suitable for fitting to a 1/2" socket. Another type, called the "Jayson Waste-Not" tap, closes automatically when water is no longer required. The Jayson tap can be purchased in local hardware shops.

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RURAL WATER SUPPLY NEPAL

TECHNICAL TRAINING MANUAL no. 2

****
* STONE MASONRY COURSE *
****

Prepared And Published By

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SATA - Swiss Association For Technical Assistance

UNICEF - United Nations Children's Fund

Kathmandu 1977

STONE MASONRY COURSE

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STONE MASONRY COURSE FOR RURAL WATER SUPPLY

1 - MATERIALS

1-1- sand

1-1-1- Pit sand

It is a product of weathered rocks or of volcanic deposits.

Derived from	contains	good elements missing	Quality for water work
Granitic rocks	- coarse grains - medium and fine sand - dust	none	good
trachytic rocks	- fine sand - dust - clay aggregates	- medium sand	acceptable after washing
lateritic soils	- coarse sand with large, medium and fine grains		can not be used for water work because is water absorbant
Volcanic deposits	- coarse and sharp edged grains - few medium grains	- fine grains - very fine grains	acceptable only after adding fine grains

1-1-2- River sand

It is an alluvial material which is moving from one place to be deposed some where else according to the quantity of water in the stream or river.
The characteristics of the sand are not the same as the surronnding materials, but a mixture of local and foreign particles. The sand from very big river is the best because the weak particles (as laterite) are eliminated.

1-1-3- For the construction

The sand should be clean, there fore washed, but without removing the fine particles. The quality of the sand can be checked with the white bottle test. The granulation of the sand should be mixed between 0 to 5 mm diameter with the following proportions:

Diameter of sand grains	percent
0 to 0,5 mm	20 %
0,5to 2 mm	35 %
2 to 5 mm	45 %

1-1-4- For pointing

The sand should be verry clean (only river sand if possible).
The grannulation should be mixed between 0 to 3 mm diameter with the following proportions:

Diameter of sand grains	percent
0 to 0,5 mm	30 %
0,5 to 2 mm	50 %
2 to 3 mm	20 %

1-2- Cement

The cement should not be hard.

1-3- Water

The water should be clean and not polluted by:

- soil particles
- humus
- mudd
- dirt
- natural oil
- vegetable oil
- soap

1-4- Stones

1-4-1- Quality of the stones

The stones should be good, therefore the following stones cannot be used:

- surface stones
- stones with cracks
- weather-worn stones
- small stones (min. side 20 cm)
- plain stones (min. thickness 12 cm)

1-4-2- Dressing of stones

1-4-2-1 Surfaces of the stone

The following list gives the surfaces of a stone which needs to be cut and shaped.

Face	This is the exposed surface of a stone in elevation
Returned face	This is the exposed surface to the side elevation.
Bed	This is the top or the bottom of a stone
Joints	Those are the surfaces prepared to meet surfaces of other stones.

The stones are classified according to their different purposes:

- linestones
- cornerstones
- archstones

1-4-2-2- Linestones

Cut out the sides to form the beds and the joints.
The beds should be as such that they can keep the stone when laid without support.
If the joints and the beds are shaped, the face can now be produced.
Lay the stone down with the intented face up and cut off the high parts with a chisel, or with a club hammer, to a plain surface. Use a straight edge to check the surface.

The maximum plain of the surface for a shaped stone should not be more than 4 mm.

CROSS SECTION

The form of the stone should be as near as possible to a square stone .

CROSS SECTIONS

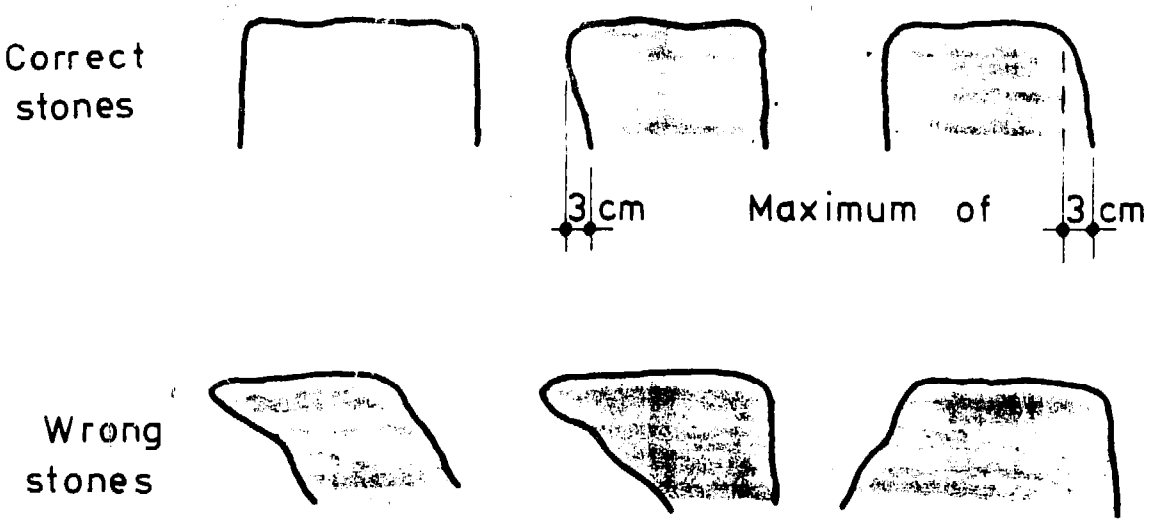

Example of a linestone .

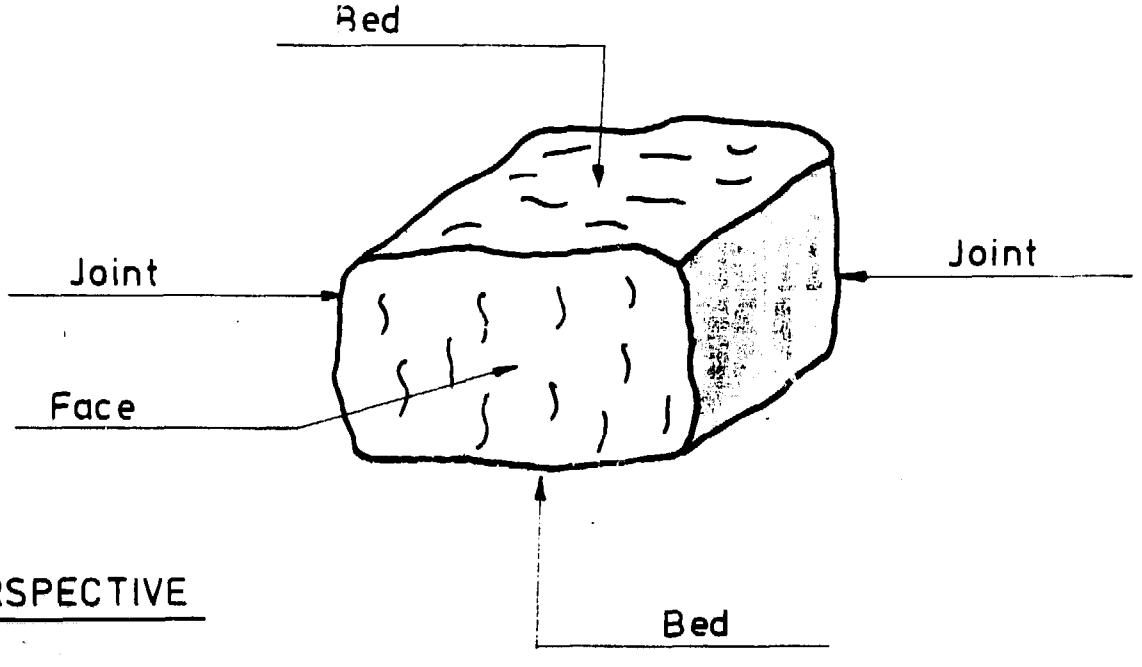

PERSPECTIVE

1-4-2-3- Cornerstones

They are the stones placed at the external angle of a building and prepared to bond with other stones in the wall in each directions. The corner stones are very important and must have good arrises. The two faces of a cornerstone must be squared to each other.

Example of a cornerstone

PERSPECTIVE

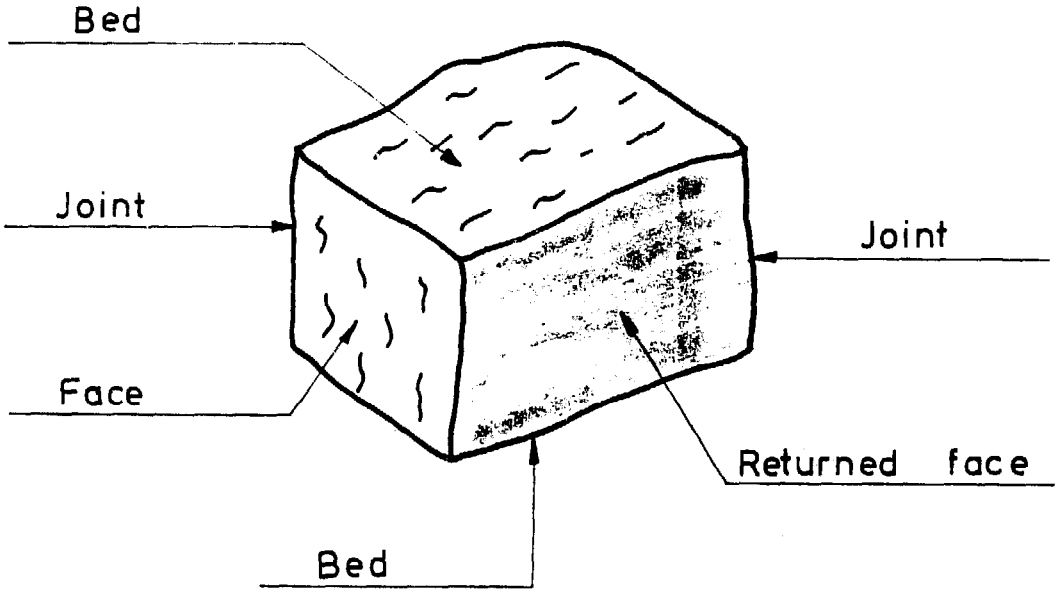

Preparation of a cornerstone

Select one stone which approach to a cube. Cut first the beds and the joints and give particular attention to the returned face. If the joints and the beds are well prepared, lay the stone with the intended face up, shape it and make sure that it is straight by using the straight edge.
Then shape the returned face by chiseling and squaring it to the face.

Care must be taken not to damage the arrises.

1-4-2-4- Archstones

Unlike the cornerstones the archstone is shaped like a wedge and is more difficult to shape than any other stone, because it has to be shaped to specific measurements and dimensions according to the arch size.

Example of an archstone

PERSPECTIVE

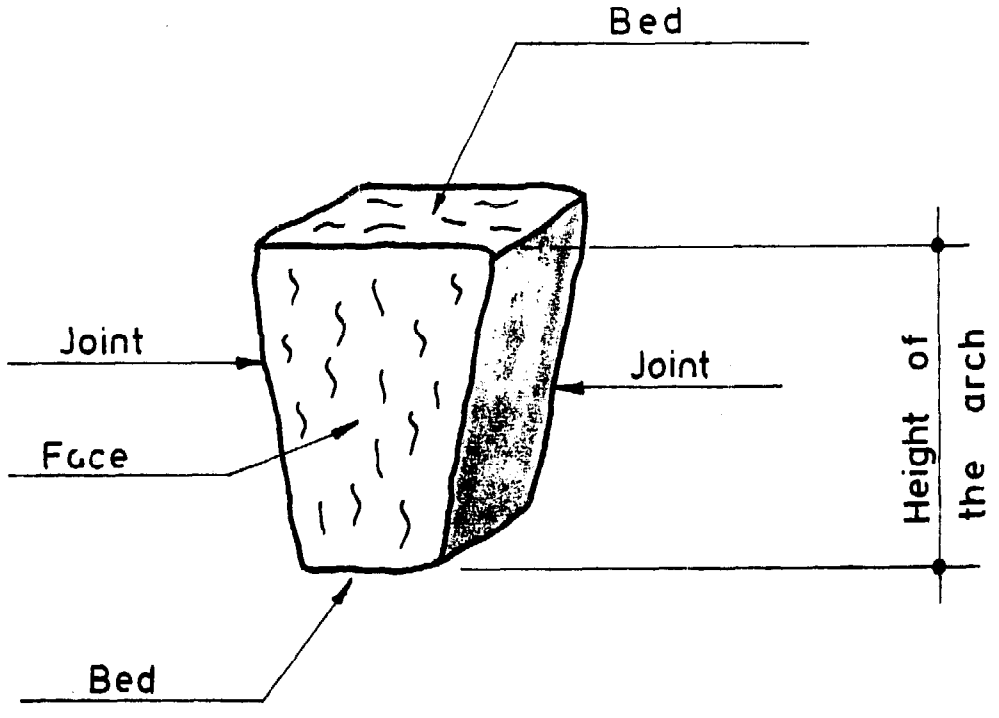

Preparation of an archstone

Select a good stone, which by size approach to the desired stone. First cut out the beds to the required height of the arch. Then cut the joints and form the wedge by giving special attention to the dimensions required. Finally cut out and shape the face. Check the face with a straight edge.

1-4-3 Quantity for dressing

For indication the following table shown the number in quantity of stones to be shaped in one working day by a mason.

Type of stones	Hard stones black-blue	White stones
LINESTONES 1 face shaped	45 to 60	60 to 75
1 face + 2 beds shaped	15 to 17	17 to 20
CORNERSTONES 1 face + 1 return face + 2 beds shaped	9 to 12	11 to 15
ARCH STONES All faces shaped	6 to 9	9 to 11

1-5- Mortar

1-5-1- Generalities

Mortar may be defined as a material composed of fine aggregate and cementing materials which form a hardened mass after mixing with a suiatable proportion of water.
Good mortar is necessary for good workmanship and good performance.
It must bind the masonry units into a strong wall.
The strength of the bond depends on various factors:

- The amount of adhesive used
- The type and quality of sand
- The rate of suction of the masonry units
- The surface texture of the mortar binding area
- The water retentivity of the mortar
- The quality of the workmanship.

1-5-2- Mixing place

For a precise building construction, it is necessary to build only one mixing slab.
For big projects the mixing slab should be in concrete and placed in the way that it can serve easily all places of the job site.
For small projects the mixing slab should be transportable to reach the maximum near of the construction.

1-5-3- Mixtures Quantities

Proportions table

Part of building	sand	cement
Foundation of construction under water level	4	1
Normal foundation	5	1
Heavy construction	4	1
Pressured walls	4	1
Other walls	5	1
Normal pointing	4	1
Exposed pointing (steps, water channels, floors, spillway, dams)	3	1

The above quantities are valid for a good construction sand as described before.

The best way will be to do different mixtures (sand - cement) with the available sand for each job site. Those mixtures will be set in cube - elements, 4 cm by 4 cm by 16 cm, which will be tested with hammer, not before 28 days after mixing. The mixture which presents the best resistance will be chosen.

1-5-4- Preparation

- Mixing of the sand and cement as dry mixture
- Adding of water to the dry mixture for quantities to be used within half an hour only.
- Protection of the mortar against rain and sun.
- The consistancy of the mortar should be in the way that itdoes not flow out of the trowel.
- Remark
  As the setting action commences soon after watering and mixing, the mortar should be used at once. Any subsequent disturbances will reduce the strength
  Cement mortar should never be retempored if not used within 1½ hours after its watering and mixing.

1-6- Materials quantities for one finished cubic meter of stone masonry for different constructions

Building description			Cement in bags	sand in m^3	Uncut stones in m^3
Stone masonry walls					
Design	Height	Thickness			
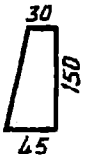	up to 1,5 m	45 to 30 cm	2,5 to 3	0,40	1,5
	More than 1,5 (max 3m)	70 to 30 cm	2 to 2,5	0, 35	1,2 to 1,5
Stone arches					
Lenght of spans					
1,2 to 1,8 m			2,5	0,40	2
1,8 to 2,5 m			3	0,40	2,5

2- Tools

The mixing slab and the showels should be cleaned before mixing the mortar.
The trowel and the straight edge should be washed before using for masonry work.

Every evening all the tools should be carefully washed.

3- Construction

3-1- Generalities

The classification of stone masonry construction varies according to the kind of Stones used, the surface finish and the type of bonding.

For water work the best masonry work will be a squared uncoursed masonry with various size of stones.

As we know it is difficult to find squared stones, so we also can use the uncoursed rubble masonry (unsquared) with well shaped stones.

SQUARED UNCOURSED MASONRY

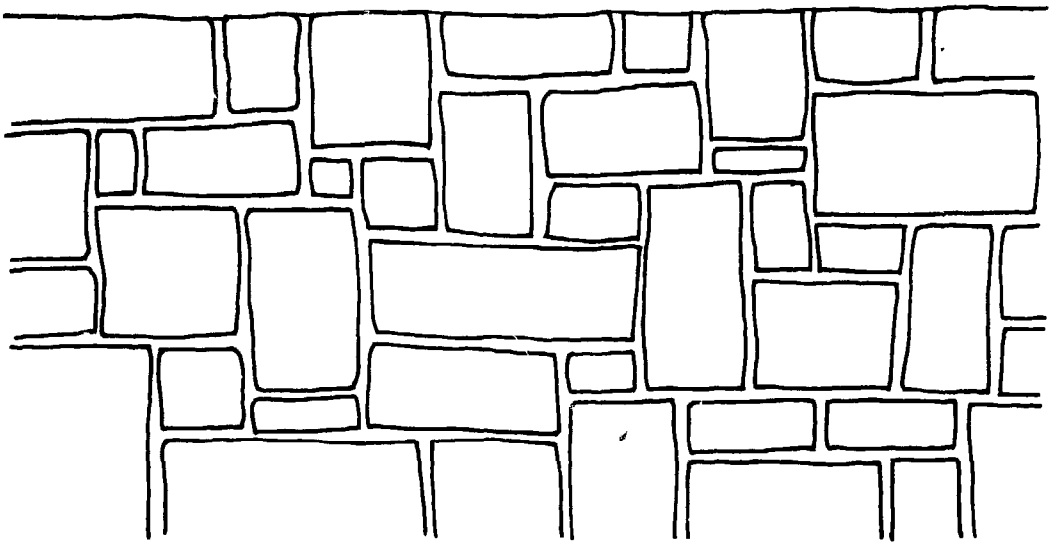

UNCOURSED RUBBLE MASONRY

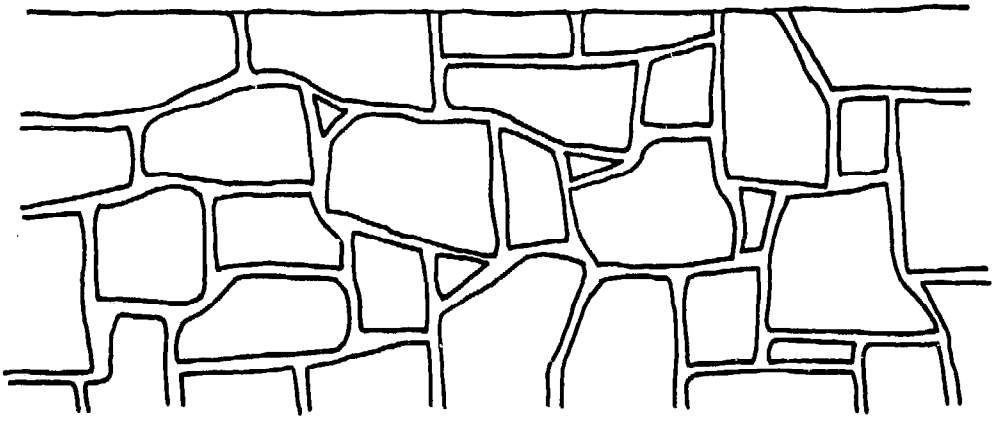

3-2- Conditions for a good construction in stone masonry

a - The normal procedure need two masons working one at each face of the wall.
b - All the stones (especially the dirty) should be brushed with hard iron brushes.
c - All the stones should be washed before use.
d - All the stones have to be wet before laying them into mortar to insure a good connection with the mortar in the wall.
e - Never used stones with cracks.
f - The bottom (or footing course) should be laid with largest and straight stones since the stability of the wall depends largely on the bearing of stones on the ground.
g - First the corners of the walls should be built up to a height of about one meter, making sure that outer and inner faces are plumbed and squared.
h - The corners must be of large stones, that will bond the two walls together in the best to resist of strain. The binding of stones should require special attention.

TOP VIEW

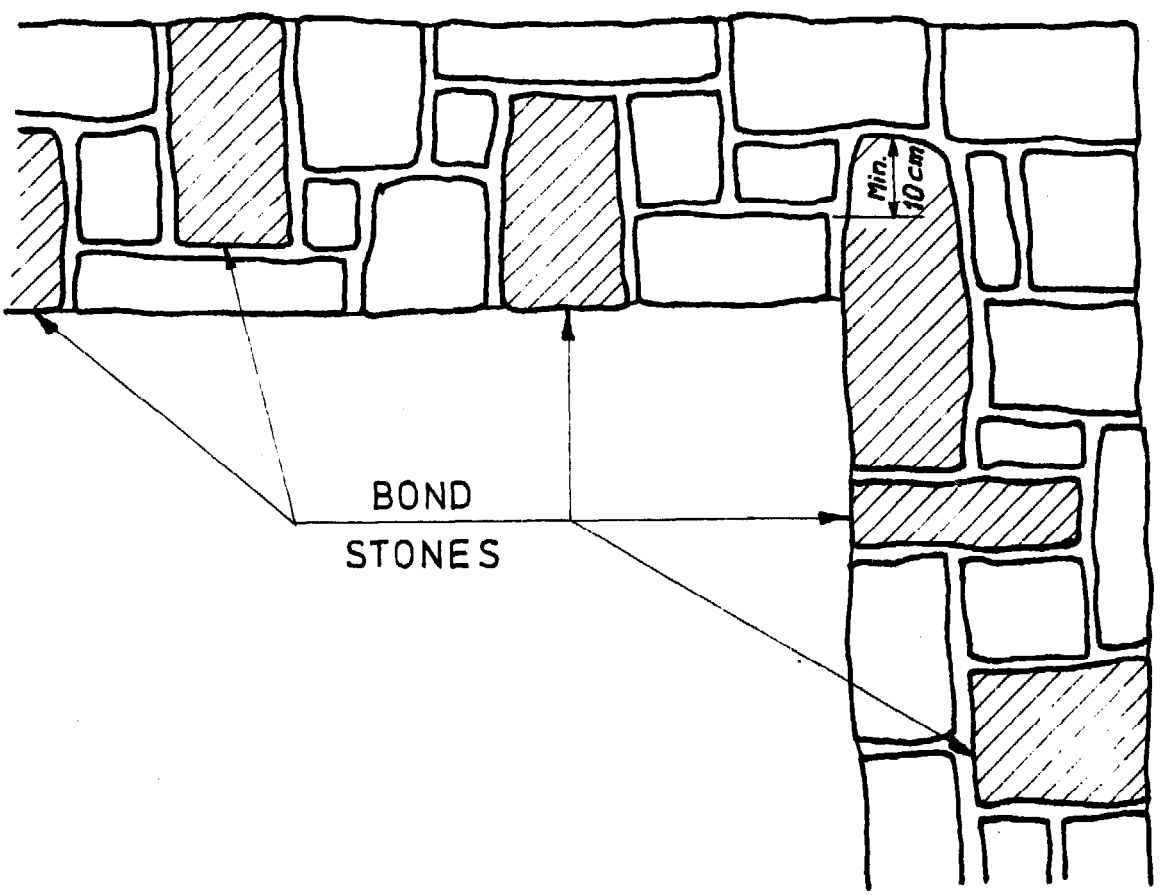

i - When the corners are up, the building can continue by fixing two lines in and out side the wall to guide the masons during laying of stones. The lines are 2 mm away from the face of the wall. The stones should be checked for alignement with straight edge and spirit level.

j - Broken pieces of stones (spalls) can be slipped under the shaped stones to help for a good bed seating.
The wall should NOT be built by forming the outer parts in good masonry and then filling the middle part with mortar and spalls (see "wrong" drawing below).

CROSS SECTIONS

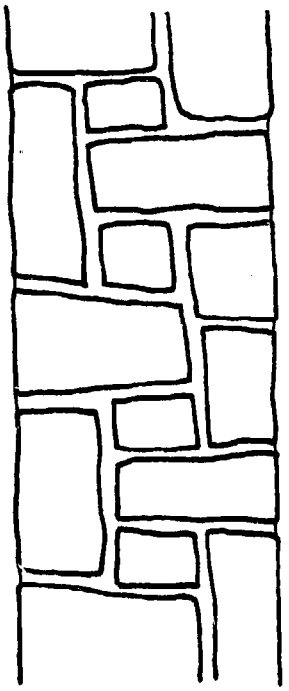

Correct

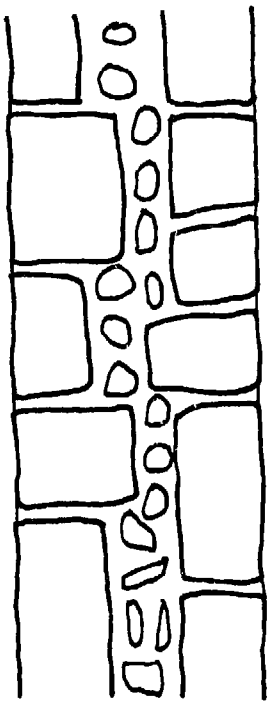

Wrong

k - Special attention should be paid to the bondstones. They should be crossing on the two plans, vertical and horizontal. The lap (or difference) should not be less than 10 cm. For water work the stone masonry should never be laid in courses. (very important)

TOP VIEW

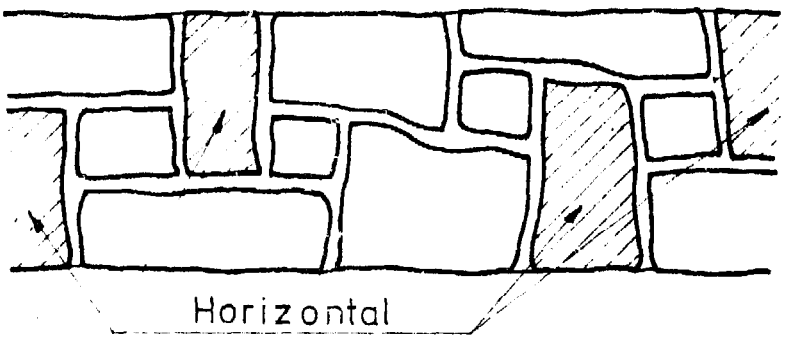

l - A long stone needs a uniform bedding. If the stone is too long, it should be broken and laid as two stones.

m - It should never be a stone crossing all the wall face to face.

n - Spread the mortar, force the stone to its bed with power, maintain a perfect face alignment on the wall. The joint in mortar between two stones should <u>not</u> be bigger than 2 cm to 2,5 cm and never less than 1 cm to 1,5 cm.

o - Two stones can <u>never</u> touch each other.

p - After building up the wall stages, at the end of the day, all new erected masonry should be cover by wet paper or any similar wet materials, to prevent the construction (especially the joints) against rain or too fast drying by sun and air.

q - A masonry work should be wet for at least 3 or 4 days after completion.
Water should be spilled on it.

3-3- Special attention to the bonding

In stone masonry for water work it is important to secure a good vertical and horizontal bonding.
In bonding the following rules should be strictly observed:

a - Bondstones should extend about 2/3 of the wall thickness.

b - The lap should not be less than 10 cm.

c - The largest stones should be used for the lowest part of the wall.

d - It should not be continous joints, vertical or horizontal.

3-4- Details of stone masonry foundation

a - A foundation should start on a firm, uniform strong sub-soil. It should not be started on grass, black fertile soil, filled up materials and mud.

b - Under any foundation there should be a layer of lean concrete (min 5 cm) before starting with the masonry.

c - A minimum depth of 40 cm of foundation should be built in the actual ground in place. Backfilling should appear after and cannot be taken for the minimum depth of foundation.

d - All differences of level in a stone masonry foundation should be erected verticaly.

e - If the foundation is wider than the wall, the top of the foundation should be made with big shaped stones without topping coat.

CROSS SECTION

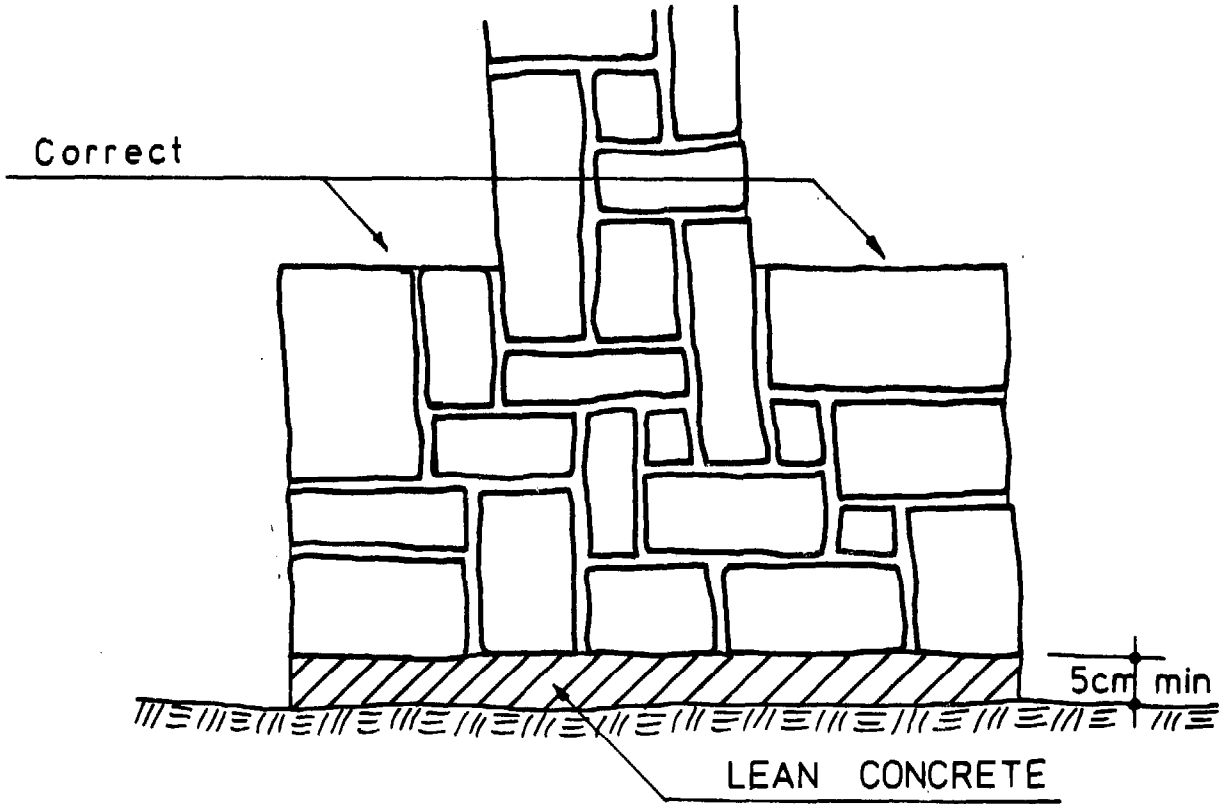

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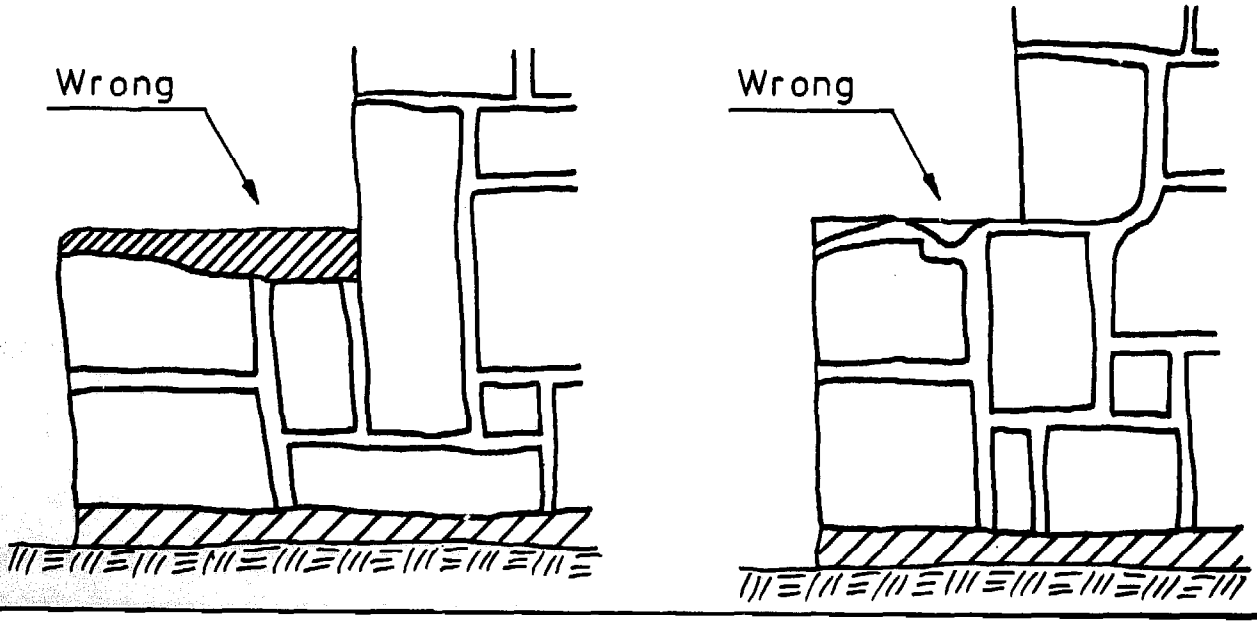

3-5- Details of stone masonry walls

a - The maximum thickness of the bottom of a stone masonry wall should be 60 to 70 cm because wider walls cannot be constructed with two lines.

b - The minimum thickness of a stone masonry wall should be 30 cm.

c - The height of walls should be reduced in area of black soil or swampy places.

d - The top of a normal stone masonry wall should be built with shaped stones with good pointing.
Never should it be with topping coat.
(see drawings below)

CROSS SECTIONS

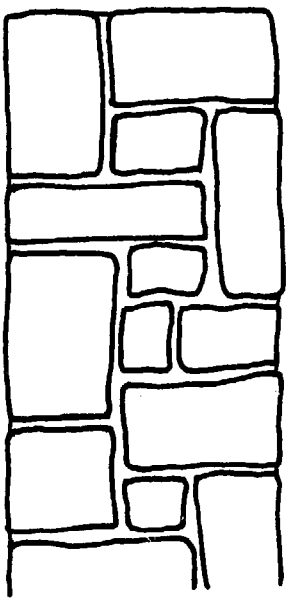

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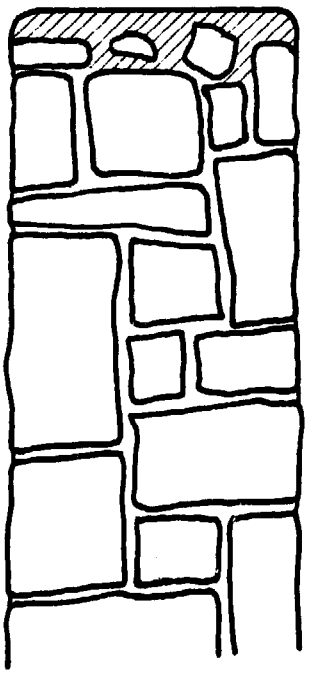

Wrong

e - The top of dry stone masonry wall (protection or retaining wall) should be built with shaped stones on the two sides, with mortar and joints pointing as from at least 40 cm below the ground level (in place or future).

CROSS SECTION

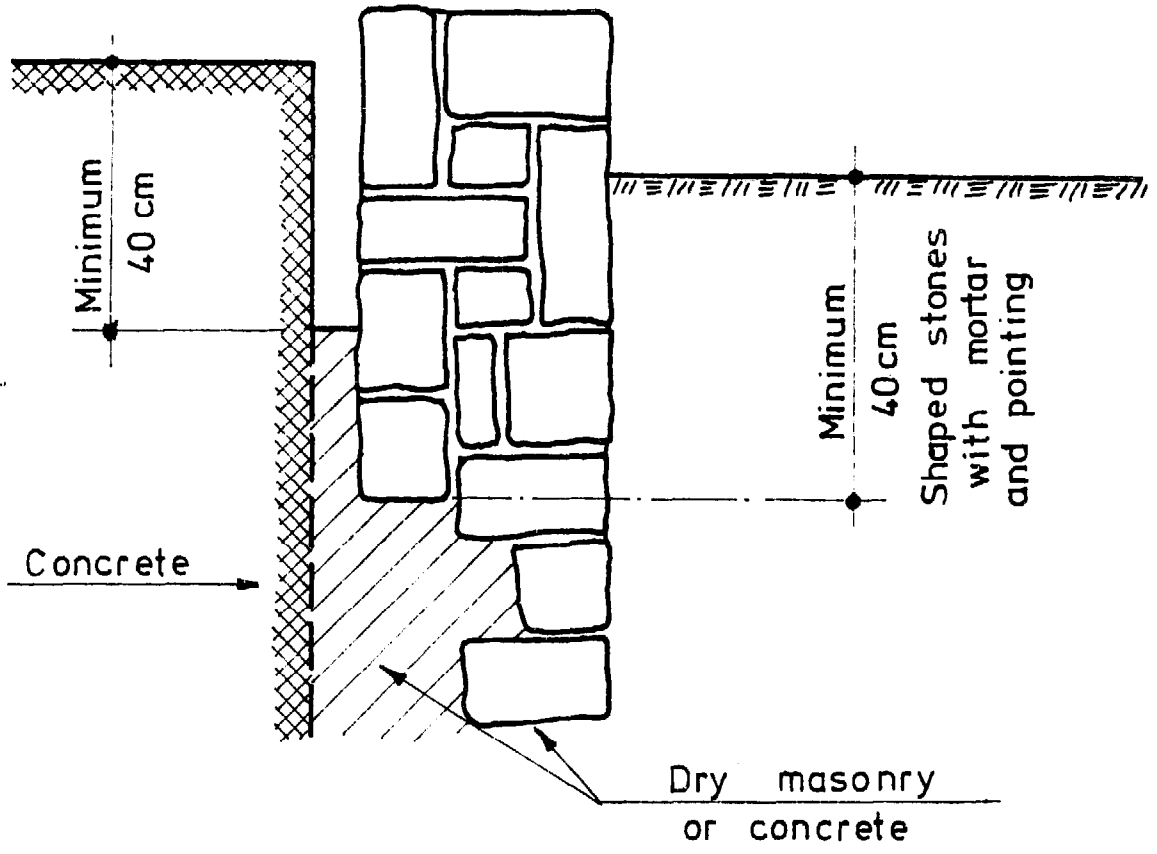

f - For a bevel wall on the top of a chamber or at an entrance of a chamber, the wall can be reduced to 15 cm thick.

3-6- Details of stone masonry pillars

a) For a single pillar the minimum dimensions should be 40 by 40 cm.

b) A special attention should be paid to the cross jointing of the different courses.

c) The cornerstones should be enough big to cover at one side more than the half of the pillar.

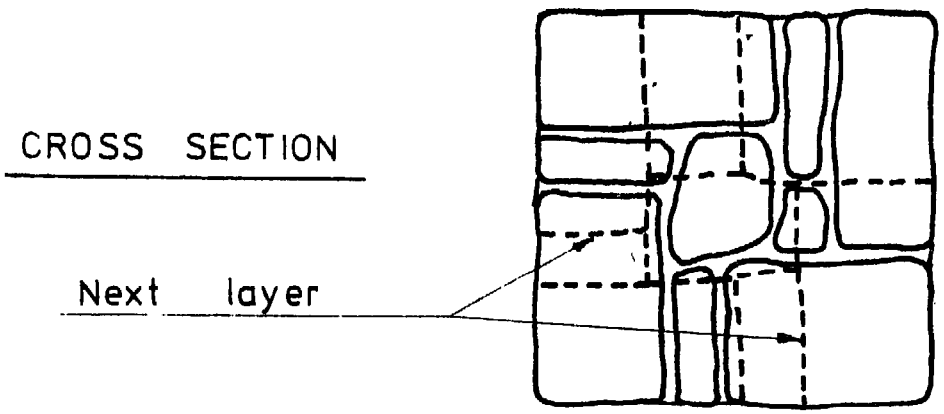

3-7- Details of stone masonry arch

a - The thickness of a stone arch cannot be less than 20 cm.

b - The front arch stones each side of the building should be especially shaped precise according to the size of the arch (thickness) and to the angle of the arch rise.

c - The front face arch stones should be built in the way that it will be started on the two sides to be finished together on the arch Key stone in the middle (coping stone).

d - The top of the supporting walls should be built in the line of the arch, before starting to place the arch stones.

e - The biggest stones should be used on the lowest part of the arch slab.

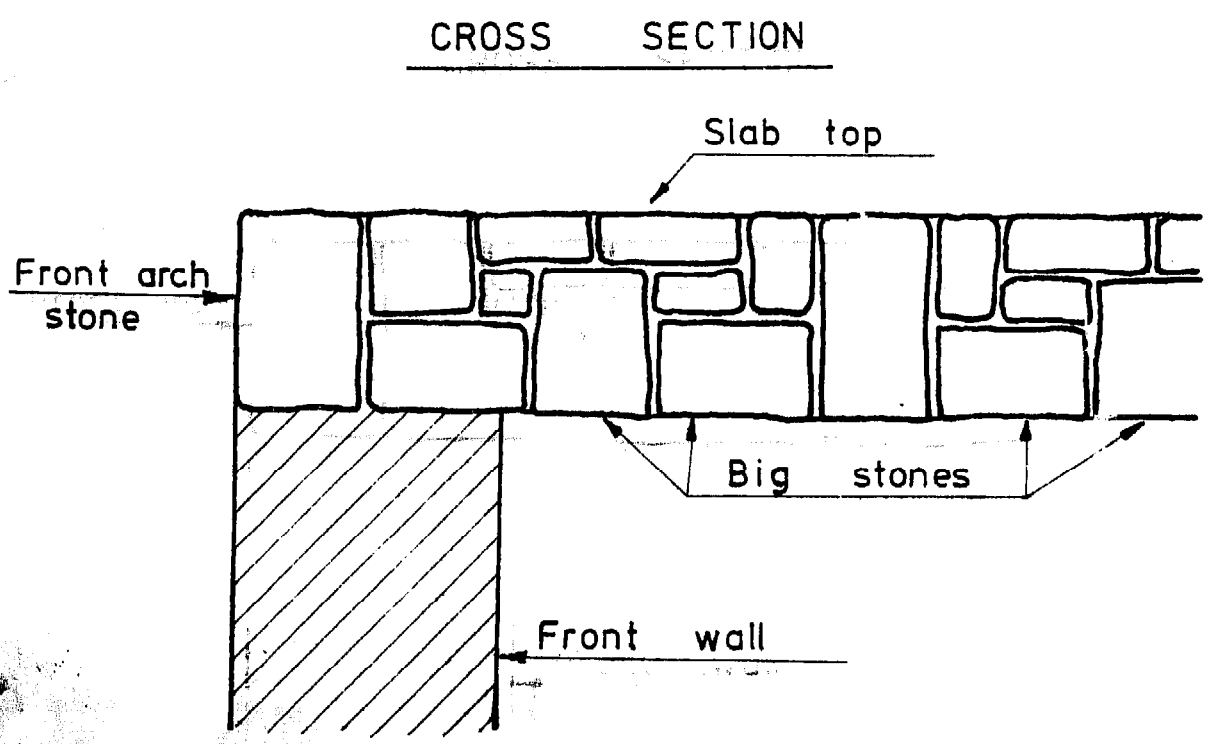

f - The water level in the tank should be at least 20 cm lower than the line of the arch rise.

g - Table for the arch rise

Distance between the two walls	Arch rise	Arch slab thickness
1 m to 1 m 50	25 cm	20 cm
1 m 50 to 2 m	35 cm	25 cm
2 m to 2 m 50	45 cm	30 cm
2 m 50 to 3 m	55 cm	35 cm

h - A pre- fabricated formwork will be installed under the arch slab for the construction.

Example of an arch in stone masonry .

FRONT SECTION

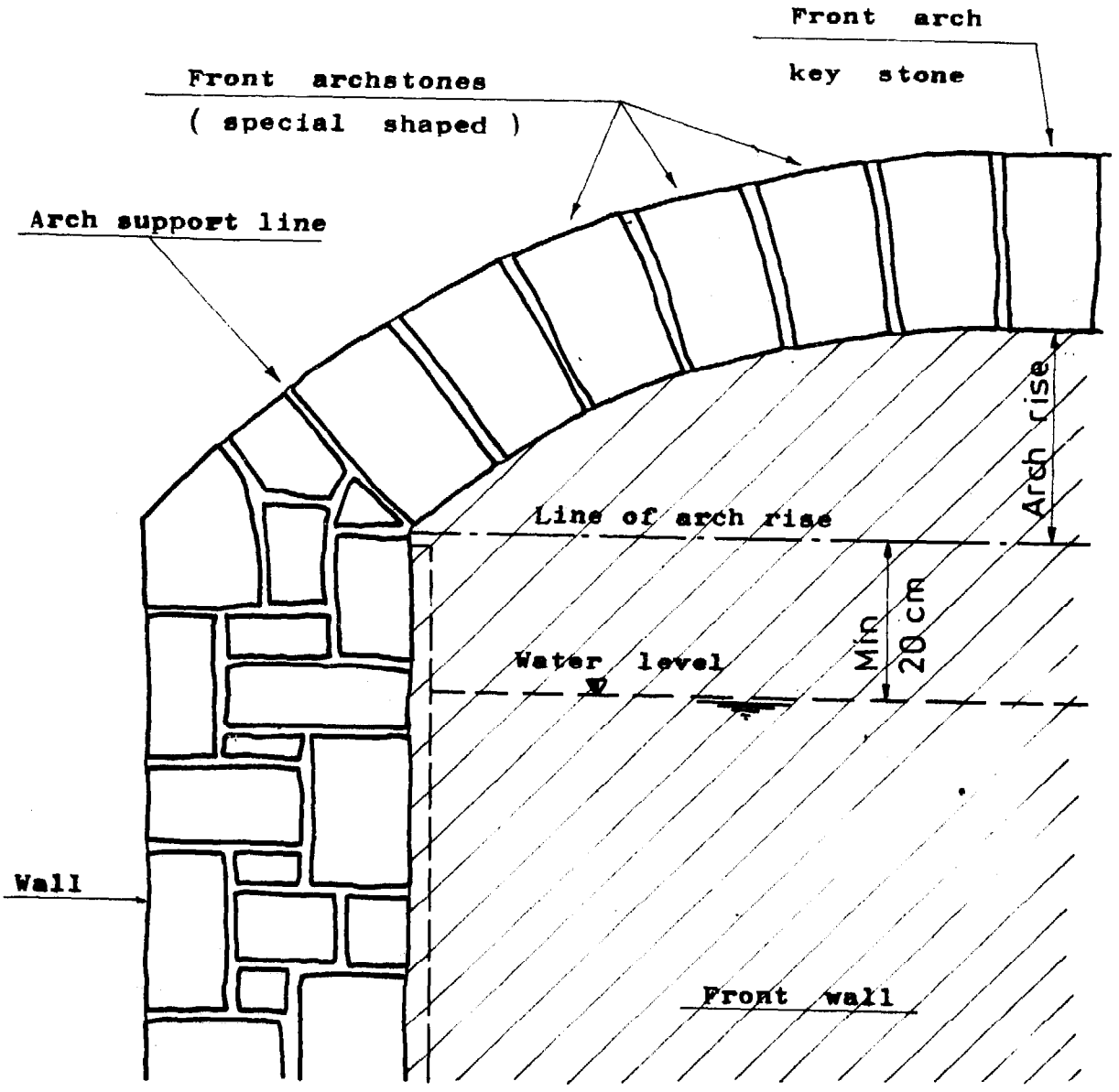

Example of an arch in stone masonry .

CROSS SECTION

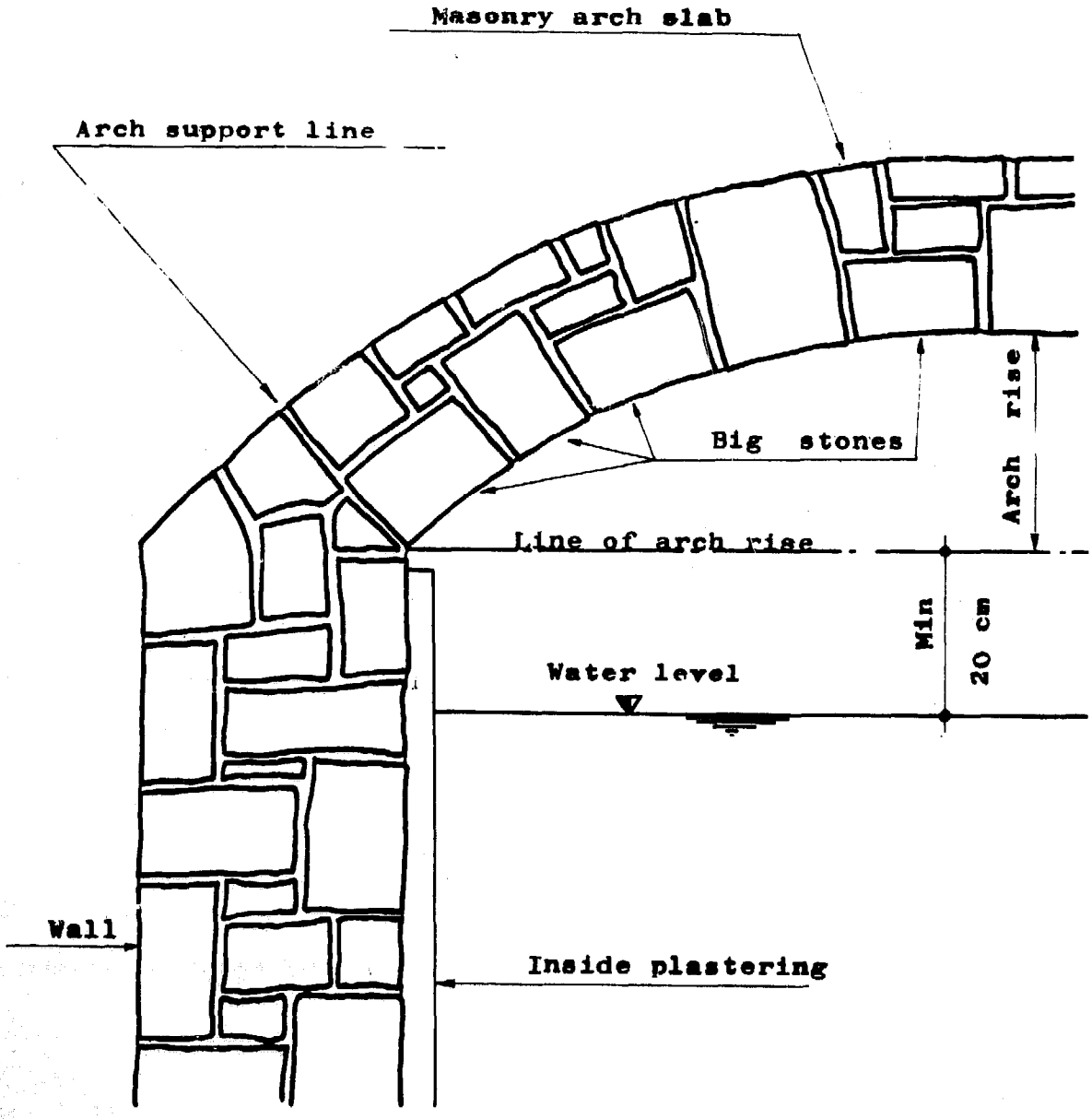

3-8- Connection between stone masonry wall and concrete slab

a - The joint between the wall and the slab should be washed before concreting, and never at all it should be paper between.

b - The junction can be as follows:

CROSS SECTIONS

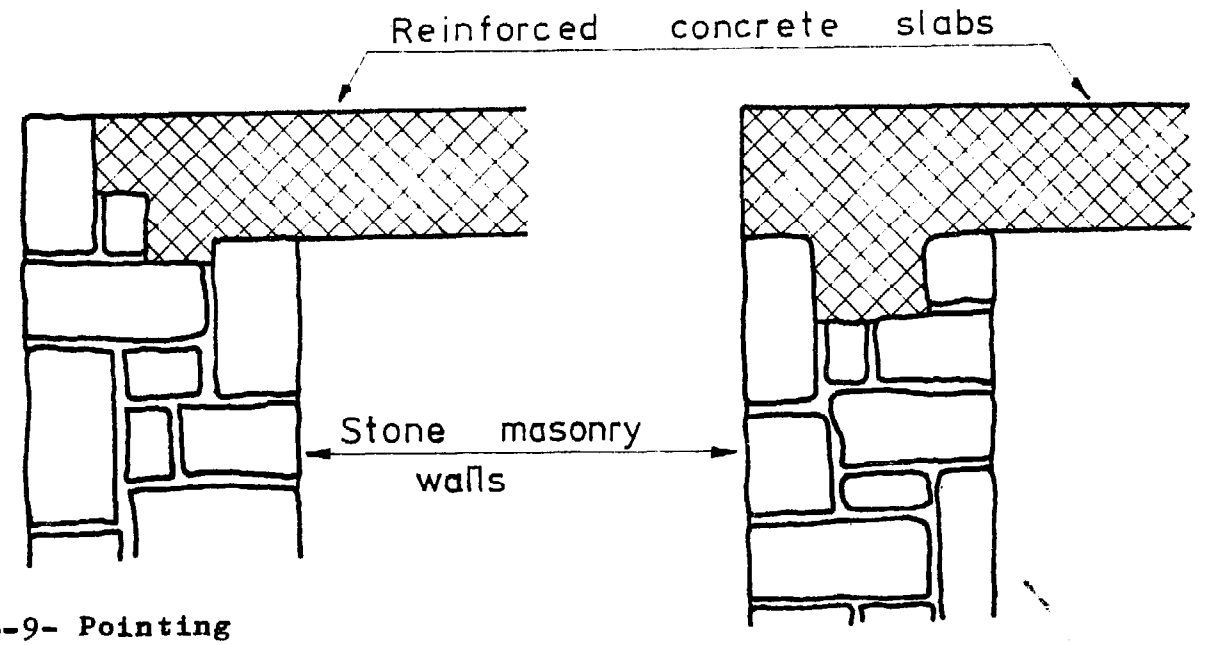

3-9- Pointing

a - The pointing should not be done on the face of the stone.

CROSS SECTIONS

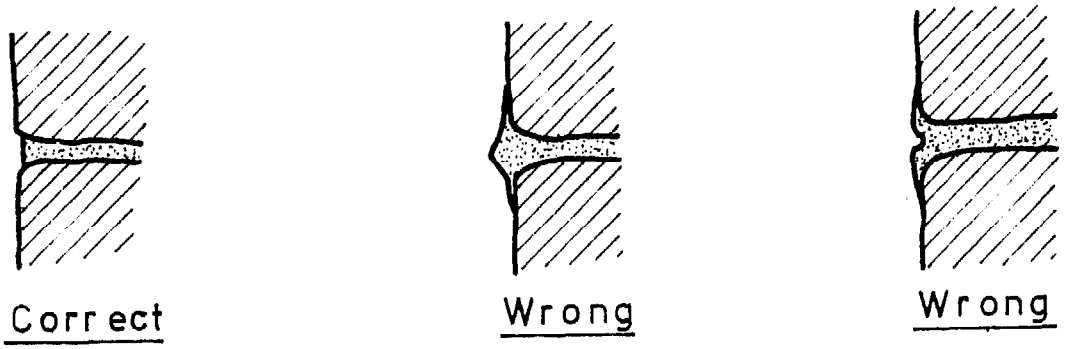

b - Before pointing, all joints should be brushed and wet by watering.

c - The best time for pointing will be four days after completion of the stone masonry wall, part after part.

d - The pointing should also be done for the inside walls with the same precautions.

e - The pointing should be protected against sun and rain for at least one whole day.

4 - Inside storage tank plastering

4-1- Generalities

Plastering is the process of covering walls with a substance which still plastic when applied and which will later become hard. Plastering may be carried out in one, two, three or four coats, depending upon the required quality.

4-2- Preparations and precautions

To obtain a good connection between the stone masonry wall and the plastering, the following rules should be considered:

a - All loose particles have to be removed.

b - Dust should be wipped out.

c - Moss and other organic specimens have to be eliminated (with iron brushes)

d - The surface should be wet the day before and only moisty before the plastering takes place.

e - Plastering should be strongly protected against sun and rain destruction.

f - A hot wall cannot be plastered.

4-3- The different coats

For a waterproof construction the plastering should be made in four coats:

- spatterdash
- floating coat
- setting coat
- cement paste

In certain cases it can be necessary to applied a waterproof paint at the end.

4-4- Spatterdash

It is a wet, rich mixture of cement and cleaned sand.

Proportions: 1 cement for 1½ sand

Thickness: 2 to 4 mm

Application: It is thrown with the trowel, hard onto the wall in two different times with a lap of 6 hours between the two. The first application, covering the whole surface, provides a key and reduces the suction of the next coat. The period in between allow the first application to set. The second application gives the first seal of the plastering.

Remarks

Do not use a straight edge, a patter or a finishing trowel. The spatterdash should remain rough. Before the next coat is applied the spatterdash should remain at least for twenty four hours (24).

4-5- Floating coat

It is a plastic mixture of cement and cleaned sand.

Proportions: 1 cement for 3 to 4 sand

Thickness: 2 cm (20 mm)

Application: The mixture (plastic consistance) is thrown onto the spatterdashed wall with the trowel and screeded with a straight edge only, to insure a good connection with the next coat.

Remarks

Do not use a patter or a finishing trowel.
The finishing surface should not be too smooth.
It is recommended to use screeds (small lintels with thickness of the coat) to insure a plumb and straight surface.

4-6- Setting coat

Setting coat or finishing coat is a mixture of cement and fine sieved sand. The sand grains should not exceed 2 mm.

Proportions: 1 cement for 2 to 3 sand

Thickness: 1 to 2 mm according to the size of the grains. (Not thicker than the largest grain).

Application: Usually it is applied the day after floating coat in one operation all over the surface to be plastered. The consistance should be slurry. It is applied by putting the mixture on the patter and pressing it onto the wall, while moving it upwards in zig-zag motion.

Remarks

Application should start on a corner of the wall. Circular strokes must be used, always in the same direction, to produce an uniform surface. If the plaster becomes too dry, it should be lightly sprinkled with water to maintain the plastictity of the material as long as it is manipulated.

4-7- Cement paste

It is pure cement mixed with water.

Thickness: 1 to 2 mm

Application: The paste is trowelled on the wall with a finishing trowel up to a smooth finish, while sprinkling water if necessary.

Remarks: This cement paste should never be exposed to the sun or let it dry to quickly, because of shrinkage cracks.
The cement paste should be kept wet for at least three days, by sprinkling water and use of paper or leaves.
The best way will be to filled the tank with water as soon the cement paste start to become enough hard.

4-8- The corners

It is very important to bench well all the corners, between walls and walls, between walls and floor.
It is recommanded to use a bottle.

4-9- Water proof paint

If a water proof paint is applied on the wall, it should be done in two coats.
The first coat to close all the pores of the plastering.
The second coat as a waterproof finishing.
A waterproof additif can also be mixed together with the cement for the plastering.

ANNEXE

DIAGRAM OF THE BOTTOM WALL THICKNESS FOR STONE MASONRY BASINS AND STORAGE TANKS

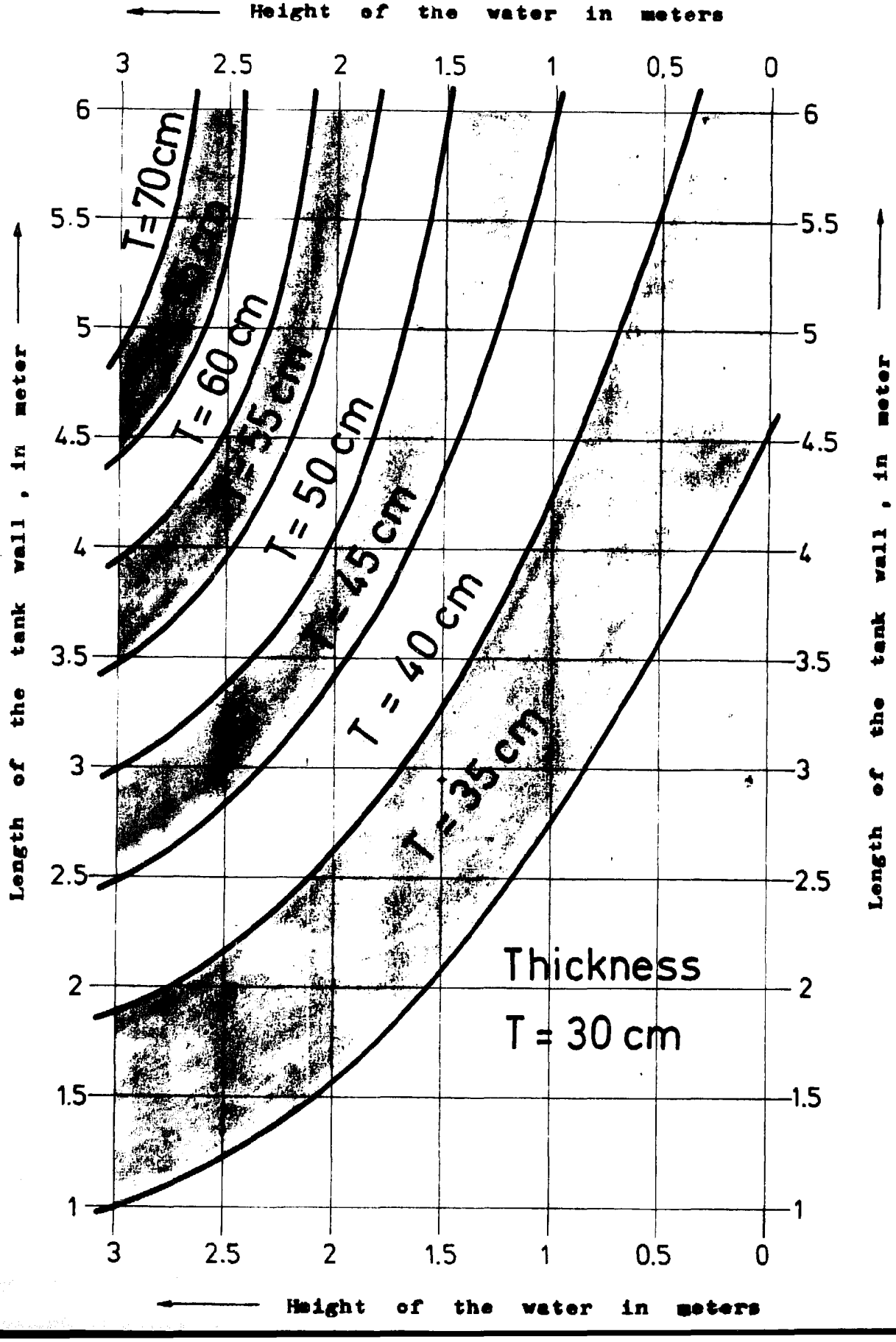

Russian Morse code

From Wikipedia, the free encyclopedia

The **Russian Morse code** approximates the Morse code for the Latin alphabet. To memorize the codes, mnemonics are used, called "melodies" (напевы).

A "melody" for a morse code for a character is a phrase which is sung (hence the name): the syllables with vowels а, о, ы correspond to dashes and sung long, the other syllables and the syllable "ай" correspond to dots and sung short. The "melodies" differ among various schools.

Table & Melody

Russian character	Latin character	Morse code	"Melody"
А	A	· –	ай-даа
Б	B	– · · ·	баа-ки-те-кут
В	W	· – –	ви-даа-лаа
Г	G	– – ·	гаа-раа-жи, гаа-гаа-рин
Д	D	– · ·	доо-ми-ки
Е	E	·	есть
Ж	V	· · · –	жи-ви-те-таак
З	Z	– – · ·	заа-каа-ти-ки, заа-моо-чи-ки
И	I	· ·	и-ди
Й	J	· – – –	и краат-коо-ее, йес-наа паа-раа
К	K	– · –	каак же таак?, каак-де-лаа
Л	L	· – · ·	лу-наа-ти-ки
М	M	– –	маа-маа
Н	N	– ·	ноо-мер
О	O	– – –	оо-коо-лоо
П	P	· – – ·	пи-лаа-поо-ёт, пи-лаа-ноо-ет

Р	R	· – ·	ре-шаа-ет
С	S	· · ·	си-ни-е, си-не-е, са-мо-лёт
Т	T	–	таак
У	U	· · –	у-нес-лоо
Ф	F	· · – ·	фи-ли-моон-чик
Х	H	· · · ·	хи-ми-чи-те
Ц	C	– · – ·	цаа-пли-наа-ши, цаа-пли-хоо-дят
Ч	ö	– – – ·	чаа-шаа-тоо-нет, чее-лоо-вее-чек
Ш	ch	– – – –	шаа-роо-ваа-рыы
Щ	Q	– – · –	щаа-ваам-не-шаа
Ъ	ñ	– – · – –	ээ-тоо-твёр-дыый-знаак, твёёр-дыый-не-мяяг-киий
Ы	Y	– · – –	ыы-не-наа-доо
Ь	X	– · · –	тоо-мяг-кий-знаак
Э	é	· · – · ·	э-ле-ктроо-ни-ки
Ю	ü	· · – –	ю-ли-аа-наа
Я	ä	· – · –	я-маал-я-маал
1		· – – – –	и-тооль-коо-оо-днаа
2		· · – – –	две не-хоо-роо-шоо
3		· · · – –	три те-бе-маа-лоо
4		· · · · –	че-тве-ри-те-каа
5		· · · · ·	пя-ти-ле-ти-е
6		– · · · ·	поо-шес-ти бе-ри, шеесть по-ка бе-ри
7		– – · · ·	даа-даа-се-ме-ри, сеемь сеемь хо-ро-шо, даай-даай-за-ку-рить
8		– – – · ·	воо-сьмоо-гоо-и-ди
9		– – – – ·	ноо-наа-ноо-наа-ми
0		– – – – –	нооль-тоо-оо-коо-лоо
period		· · · · · ·	сеть сети сеть сети
comma		· – · – · –	
colon		– – – · · ·	

semicolon	– · – · –	
Parenthesis	– · – – · –	
Apostrophe	· – – – – ·	
Quotation mark	· – · · – ·	
-	– · · · · –	
/	– · · – ·	дрообь здесь пред-стаавь-те
?	· · – – · ·	вы ку-даа смоо-три-те?
!	– – · · – –	гаа-даа-ли три браа-таа
Hyphen	– · · · –	рааз-де-ли-те-каа
Error/redo	· · · · · · · ·	хи-ми-чи-те хи-ми-чи-те
@	· – – · – ·	

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Categories: Morse code | Russian language | Cyrillic alphabet representations

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Russian oven

From Wikipedia, the free encyclopedia

A **Russian oven** or **Russian stove** (Russian: Русская печь) is a unique type of masonry stove that first appeared in the 15th century.[1] It is used both for cooking and domestic heating in traditional Russian, Ukrainian and Belarusian households.[2] The Russian oven burns firewood or wood manufacturing waste.[2][3]

Typical Russian oven in a peasant izba. Oven's tools in the right side. Photo from Belarusian State Museum of Folk Architecture and Everyday Life.

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- 1 Construction
- 2 Design
- 3 Fuel
- 4 Uses
- 5 In Russian culture
- 6 See also
- 7 References

Construction

A Russian oven is designed to retain heat for long periods of time. This is achieved by channeling the smoke and hot air produced by combustion through a complex labyrinth of passages, warming the bricks from which the oven is constructed.[2][3]

A brick flue (Russian: борова) in the attic, sometimes with a chamber for smoking food, is required to slow down the cooling of the oven.[2]

Design

The Russian oven is usually in the centre of the log hut (izba). The builders of Russian ovens are referred to as "stovemakers" (*pechniki*). Good stovemakers always had a high status among the population. A badly built Russian oven may be very difficult to repair, bake unevenly, smoke, or retain heat poorly.[2][4][5]

There are many designs for the Russian oven. For example, there is a variant with two hearths (one of the hearths is used mainly for fast cooking, the other mainly for heating in winter).[2][4]

Fuel

Various types of firewood can be used, for example birch or pine. Aspen is the least efficient for heating a Russian oven because the amount needed is twice that of other woods.[2]

Uses

Besides its use for domestic heating, in winter people may sleep on top of the oven to keep warm.[2] The oven is also used for cooking, for example, to bake pancakes or pies. The porridge or the pancakes prepared in such an oven may differ in taste from the same meal prepared on a modern stove or range. The process of cooking in the Russian oven can be called "languor" — holding dishes for a long period of time at a steady temperature. Foods that are believed to acquire a distinctive character from being prepared in a Russian oven include baked milk, pastila candies, mushrooms cooked in sour cream, or even a simple potato.[2] Bread is put in and taken out from the oven using a special wooden paddle on a long shank. Cast iron pots with soup or milk are taken out with a two-pronged metal stick.[2][6]

Usage of the Russian oven etched by John Augustus Atkinson (1803)

As well as warming and cooking, the Russian oven can be used for washing. A grown man can easily fit inside, and during World War II some people escaped the Nazis by hiding in ovens.[2][3][6][7] In former times the oven was used to treat winter diseases by warming the sick person's body inside it.[2][3][6][7]

In Russian culture

The Russian oven was a major element of Russian life and consequently it often appears in folklore, in particular in Russian fairy tales. The legendary hero Ilya Muromets was able to walk after 33 years of incapacity after being laid on a Russian oven. Emelya, according to the legend, was so reluctant to leave it that he simply flew and rode on it.[8][9] Baba Yaga according to the legend baked lost children in her oven. Often in those fairy tales the oven received human characteristics. For example, in "The Magic Swan Geese" a girl meets a Russian oven, and asks it for directions. The oven offers the girl rye buns, and subsequently, on the girl's return, hides her from the swan geese.[10][11]

See also

- Masonry heater
- Timeline of Russian inventions and technology records
- List of cooking appliances

Wikimedia Commons has media related to ***Russian oven***.

References

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Categories: Russian inventions | Masonry | Baking | Fireplaces | Ovens | Russian culture | Residential heating appliances

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